EARSeL 2015

9th EARSeL SIG Imaging Spectroscopy workshop

14-16 April 2015 I Luxembourg

Programme & Abstracts

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY

LIST

Universität Trier

with the financial support of:

Contents

Welcome to Luxembourg!

We are very pleased to welcome you to the 9th EARSeL Workshop on Imaging Spectroscopy. Since the start of this workshop series in 1998 in Zurich, the idea of using light as a diagnostic source of information has been picking up momentum and turned into an exciting and challenging field of research. Taking measurements in many, narrow spectral bands will be possible from space in a few years, and has just become feasible from remotely piloted airborne systems. At the same time the latest imaging spectrometers measure not only in the traditional visible and near-infrared regions, but now also cover fluorescence and the thermal- and mid-infrared regions. The advances being made in spectrometer measurements and analytical techniques allow us today to explore numerous applications that previously nobody had thought of.

After eight successful workshops, the opportunity to be the host of this prestigious event was jointly given to Trier University and Luxembourg Institute of Science and Technology (LIST, former CRP - Gabriel Lippmann). Concerning the workshop program we have tried to find a balance between science, technology, and applications. Please enjoy the keynotes, presentations, posters and exhibition booths. The idea is to interact and socialize with the international imaging spectroscopy community and to enjoy your stay in Luxembourg.

We wish to thank the conference sponsors, scientific committee, student volunteers, and members of the organizing committee, for all their efforts to make this workshop a success.

Thanks for joining our workshop. Have fun!

Martin Schlerf and *Thomas Udelhoven*
Co-chairs 9th EARSeL IS Workshop

Venue

The EARSeL workshop will be held at the prestigious Neumünster Abbey Cultural Exchange Center. The Abbey is dedicated to hosting cultural events and conferences, and houses an exhibition gallery with many sculptures. Neumünster Abbey (28, rue Münster, L-2160 Luxembourg City, Luxembourg) is located in the Grund area below the Old Town, at the base of a dramatic fortified escarpment. Situated in one of Luxembourg's historic quarters, which are registered on the UNESCO world heritage list, Neumünster Abbey is the ideal location for this workshop.

Nearby attractions include the Chemin de la Corniche, a pedestrian path that offers splendid views across the river canyon towards the mighty fortifications of the Wenzelsmauer (Wenceslas Wall), the Bock Casemates, an arrangement of rock galleries and passages initially carved by the Spaniards during the 18th century, and the Luxembourg City History Museum. Besides this, the cafés, bars, and restaurants in the scenic Grund quarter and behind the Royal Palace offer original dining and drinking options.

Highlights outside Luxembourg City comprise the enchanted Müllerthal for hikes into woodlands and rocky canyons, the historic city town of Echternach, and famous Vianden Castle. The city of Trier lies about 40 km north-east of Luxembourg City, and is the oldest city in Germany, founded in 16 BCE, and known for its well-preserved Roman and medieval buildings (including the Porta Nigra, Imperial Baths and Trier Cathedral).

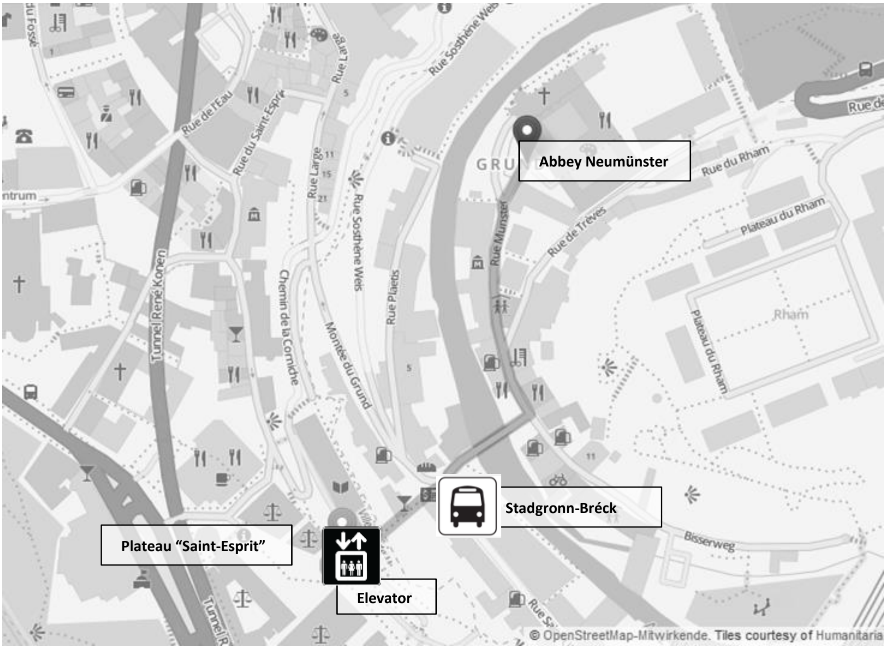
Organizing Committee

- Heide Bierbrauer, EARSeL Secretariat, Münster, Germany
- Henning Buddenbaum, University of Trier, Germany
- Véronique Carrère, Université de Nantes, France
- Alexandra Dobrowolski, Luxembourg Institute of Science and Technology, Luxembourg
- Uta Heiden, German Aerospace Centre, Germany
- Klaus-Ulrich Komp, EARSeL Vice-Chairman, Münster, Germany
- Miriam Machwitz, Luxembourg Institute of Science and Technology, Luxembourg
- Franz Ronellenfitsch, Luxembourg Institute of Science and Technology, Luxembourg
- Martin Schlerf, Luxembourg Institute of Science and Technology, Luxembourg
- Thomas Udelhoven, University of Trier, Germany

Scientific Committee

- Clement Atzberger, University of Natural Resources and Life Sciences, Austria
- Eyal Ben Dor, Tel Aviv University, Israel
- Joachim Hill, Trier University, Germany
- Lucien Hoffmann, Luxembourg Institute of Science and Technology, Luxembourg
- Patrick Hostert, Humbold University Berlin, Germany
- Freek van der Meer, University of Twente – ITC, The Netherlands
- Jose Moreno, University of Valencia, Spain
- Andreas Mueller, German Aerospace Centre, Germany
- Michael Schaepman, University of Zurich, Switzerland
- Andrew Skidmore, University of Twente – ITC, The Netherlands
- Ben Somers, KU Leuven, Belgium
- Sindy Sterckx, VITO - Flemish Institute for Technological Research, Belgium

Map of location



By bus: At the central train station – take line 23 which leaves from lane n°5 every hour from 8:19 am to 7:49 pm at 19 and 49 minutes past the hour, then at 8:35 pm, 9:35 pm and the last bus is at 10:35 pm – get off at the “Stadgronn-Bréck” stop, the shuttles terminal – cross the small bridge opposite and take a left on to rue Münster. The Abbey of Neumünster is located at the end of the street.

By foot: At the plateau “Saint-Esprit” in the city centre of Luxembourg a public elevator gives access to the Grund quarter. When leaving the elevator, go straight on, cross the small bridge ahead, then turn left into the rue Münster. The Abbey of Neumünster is located at the end of the street.

Practical Information

Registration Desk

- at the Icebreaker
- Tuesday to Thursday from 8 am – 4 pm

Poster

Please put up your poster during the registration time or morning coffee break on Tuesday. Posters will remain on the boards for the entire workshop. We have special poster sessions from Tue to Thu at 12pm were you should stand by your poster.

Presentation

Please upload your presentation to the computer in the respective seminar room before the start of your session (in the morning at 8:30 or during coffee/lunch breaks). Personal laptops cannot be used.

Oral presentations last 15 minutes, including 3 minutes for discussion and changeover to the next speaker. Keynote presentations last 30 minutes, including 5 minutes for discussion and changeover to the next speaker.

WIFI

User: Free
Password: sekpekig

Phone

Reception Abbey Neumünster: +352 / 26 20 52 – 1

Luxembourg City Tourist Office
30, place Guillaume II, Phone: +352 / 222809
Mon–Sat: 9 am – 7 pm / Sun: 10 am – 6 pm
http://www.lcto.lu/en

Social events

Monday, 13 April 2015, 19:00 – 21:00

Icebreaker at Neumunster Abbey Cloister and Garden

Tuesday, 14 April 2015, "free evening"

Recommendations nearby:

- Urban Bar & Kitchen (international pub with salads, wraps, burgers, sandwiches, 2, rue de la Boucherie)
- Café des Artistes (lovable, atmospheric café, 22, Montée du Grund)
- Scott's Pub (Snacks and Pizza, 4, Bisserweg)
- Konrad Café & Bar (lots of organic food, 7, Rue du Nord)
- Ukulele (very nice Thai food, 57, Rue de la Tour Jacob, Grund)
- Mesa Verde (vegetarian and seafood, 11, rue du St. Esprit)
- Wine Republic (excellent wine, great food, 4, Rue de la Loge)

Wednesday, 15 April 2015, 17:00 – 23:30

Conference Dinner

17:15 Departure by bus from Neumunster Abbey to Remich

18:00 Caves St Martin Wine Cellars

19:30 – approx. 22:30 Cruise on the Moselle and Dinner

Approx. 23:30 Return at Luxembourg City

Programme overview

Tuesday, 14/Apr/2015			
8:00am-9:00am	**Registration** Location: Nic Klecker Space		
9:00am-9:30am	**O1: Greetings** Location: Robert Krieps Auditorium		
9:30am - 10:00am	**Keynote 1: Mike Rast, ESA: Sentinel-2: Optical High-Resolution Mission for Copernicus** Location: Robert Krieps Auditorium		
10:00am - 10:30am	**Keynote 2: Michael Schaepman, RSL Zurich: The Spectroscopy of Things: From Traceability to Tracing** Location: Robert Krieps Auditorium		
10:30am-11:00am	**CB1: Coffee Break** Location: Nic Klecker Space		
11:00am-12:00pm	**O2-Sen: Next generation of IS sensors** Location: Robert Krieps Auditorium		
12:00pm - 12:45pm	**P1A-Sen: Poster: Next generation of IS sensors** Location: Nic Klecker Space	**P1B-For: Poster: Applications in Forestry** Location: Nic Klecker Space	**P1C-Eco: Poster: Ecosystem Services and Disturbances** Location: Nic Klecker Space
12:45pm-2:00pm	**LB1: Lunch Break and Continuation of P1A/P1B/P1C** Location: Nic Klecker Space		
2:00pm	**GROUP PICTURE, outside**		
2:15pm - 2:45pm	**Keynote 3: Nicholas Coops, UBC Vancouver: Linking Canopy Spectroscopy with Stand Architecture to Estimate Vertical Patterns of Light-Use Efficiency** Location: Robert Krieps Auditorium		
2:45pm-3:30pm	**O3-For: Applications in Forestry** Location: Robert Krieps Auditorium		
3:30pm-4:00pm	**CB2: Coffee Break** Location: Nic Klecker Space		
4:00pm-5:15pm	**O4-Eco: Ecosystem Services and Disturbances Part 1** Location: Robert Krieps Auditorium		

<table>
<tr><th colspan="5">Wednesday, 15/Apr/2015</th></tr>
<tr><td>9:00am
-
9:30am</td><td colspan="4">Keynote 4: Eyal Ben-Dor, TAU Tel Aviv: Recent Advances in the Image Spectroscopy for Soil Science Applications
Location: José Ensch Room</td></tr>
<tr><td>9:30am
-
10:15am</td><td colspan="2">O5A-Soi: Soils and Minerals Part 1
Location: José Ensch Room</td><td colspan="2">O5B-Eco: Ecosystem Services and Disturbances Part 2
Location: Edmond Dune Room</td></tr>
<tr><td>10:15am-
10:45am</td><td colspan="4">CB3: Coffee Break
Location: Nic Klecker Space</td></tr>
<tr><td>10:45am
-
12:00pm</td><td colspan="2">O6A-Soi: Soils and Minerals Part 2
Location: José Ensch Room</td><td colspan="2">O6B-THy: Thermal Hyperspectral Remote Sensing of Vegetation
Location: Edmond Dune Room</td></tr>
<tr><td>12:00pm
-
12:45pm</td><td>P2A-Soi: Poster: Soils and Minerals
Location: Nic Klecker Space</td><td>P2B-Tec: Poster: New Analytical Techniques
Location: Nic Klecker Space</td><td>P2C-Bio: Poster: Retrieval of biophysical properties
Location: Nic Klecker Space</td><td>P2D-The: Poster: Thermal Infrared Spectroscopy
Location: Nic Klecker Space</td></tr>
<tr><td>12:45pm-
2:00pm</td><td colspan="4">LB2: Lunch Break and Continuation of P2A/P2B/P2C/2D
Location: Nic Klecker Space</td></tr>
<tr><td>2:00pm
-
3:15pm</td><td colspan="2">O7A-Ret: Retrieval of biophysical properties Part 1
Location: José Ensch Room</td><td colspan="2">O7B-Tec: New Analytical Techniques
Location: Edmond Dune Room</td></tr>
<tr><td>3:15pm-
3:45pm</td><td colspan="4">CB4: Coffee Break
Location: Nic Klecker Space</td></tr>
<tr><td>3:45pm
-
4:45pm</td><td colspan="2">O8A-Ret: Retrieval of biophysical properties Part 2
Location: José Ensch Room</td><td colspan="2">O8B-The: Thermal Infrared Spectroscopy
Location: Edmond Dune Room</td></tr>
<tr><td>5:00pm-
11:30pm</td><td colspan="4">CD: Conference Dinner</td></tr>
</table>

Thursday, 16/Apr/2015				
9:00am - 9:30am	**Keynote 5: Jose Moreno, U. Valencia: Observing land surface dynamics in very high spectral resolution: theory, methods and applications** Location: José Ensch Room			
9:30am - 10:15am	**O9A-Flu: Remote Sensing of Vegetation Fluorescence Part 1** Location: José Ensch Room		**O9B-Enm: Latest EnMAP Developments** Location: Edmond Dune Room	
10:15am-10:45am	**CB5: Coffee Break** Location: Nic Klecker Space			
10:45am - 12:00pm	**O10A-Flu: Remote Sensing of Vegetation Fluorescence Part 2** Location: José Ensch Room		**O10B-Cal: Imaging Spectrometers Instrument and Data Calibration** Location: Edmond Dune Room	
12:00pm - 12:45pm	**P3A-Flu: Poster: Remote Sensing of Vegetation Fluorescence** Nic Klecker Space	**P3B-Enm: Poster: Latest EnMAP Developments** Location: Nic Klecker Space	**P3C-Pro: Poster: Image Processing Methods** Location: Nic Klecker Space	**P3D-Wat: Poster: Water Applications** Location: Nic Klecker Space
12:45pm-2:00pm	**LB3: Lunch Break and Continuation of P3A/P3B/P3C/3D** Location: Nic Klecker Space			
2:00pm - 3:00pm	**O11A-Pro: Image Processing Methods Part 1** Location: José Ensch Room		**O11B-Dro: Remotely Piloted Aircraft Systems (RPAS) based hyperspectral remote sensing of vegetation** Location: Edmond Dune Room	
3:00pm-3:30pm	**CB6: Coffee Break** Location: Nic Klecker Space			
3:30pm - 4:30pm	**O12A-Pro: Image Processing Methods Part 2** Location: José Ensch Room		**O12B-Sca: Scaling and Uncertainty** Location: Edmond Dune Room	
4:30pm-5:00pm	**CC: Closing Ceremony** Location: José Ensch Room			

Detailed Programme

Tuesday, 14/Apr/2015	
8:00am-9:30am	**Registration** Location: Nic Klecker Space
9:00am-9:30am	**O1: Greetings**: **Joachim Hill (Trier University), Lucien Hoffmann (LIST Luxembourg), Bogdan Zagajewski (University of Warsaw, treasurer of EARSeL), Andreas Müller (DLR, chairman of the EARSeL Special Interest Group)** Location: Robert Krieps Auditorium
9:30am-10:00am	**Keynote 1: Michael Rast, ESA: Sentinel-2: Optical High-Resolution Mission for Copernicus Spectroscopy**, Chair: T. Udelhoven, M. Schlerf, Robert Krieps Auditorium
10:00am-10:30am	**Keynote 2: Michael Schaepman, RSL Zurich: The Spectroscopy of Things: From Traceability to Tracing,** Chair: T. Udelhoven, M. Schlerf, Robert Krieps Auditorium
10:30am-11:00am	**CB1: Coffee Break** Location: Nic Klecker Space
Oral	**O2-Sen: Next generation of IS sensors (page 28)** Chair: Andreas Müller, Michael E. Schaepman, Location: Robert Krieps Auditorium
11:00am - 12:00pm	**1-Sysiphe System: a state of the art airborne hyperspectral imaging system. Initial results from the first airborne campaign** Laurent Rousset-Rouviere *et al.*, ONERA, France; **2-The high-end airborne hyperspectral imaging system HySpex ODIN-1024** Søren Blaaberg, Trond Løke *et al.*, Norsk Elektro Optikk AS, Norway **3-High-resolution temperature and emissivity mapping (HiTeSEM): A satellite sensor concept for hyperspectral thermal remote sensing** Thomas Udelhoven *et al.*, Trier University, Germany **4-The HyspIRI Preparatory Airborne Campaign: 14 Investigations using Spectroscopy and Thermal Measurements from 6 Large Diverse Areas measured for 3 Seasons over 3 Years** Robert O Green *et al.*, Jet Propulsion Laboratory, United States of America
Poster	**P1A-Sen: Next generation of IS sensors (page 87)** Chair: Ils Reusen, Location: Nic Klecker Space
12:00pm - 12:45pm	**1-HySpex Mjolnir-1024 – a new high performance small form factor VNIR hyperspectral camera** Trond Løke *et al.*, Norsk Elektro Optikk AS, Norway **2-PentaSpek – A ground based hyperspectral system for the estimation of vegetation parameters** Holger Lilienthal, Julius Kühn-Institut, Germany **3-EUFAR – European Facility for Airborne Research: Easy and Open Access to the Airborne Research Facilities and Expert Knowledge** Stefanie Holzwarth *et al.*, German Aerospace Center (DLR), Oberpfaffenhofen, Germany **4-Hyperspectral imaging spectrometer SPEKTROP - first measurements** Miroslaw Rataj, Michal Krupinski *et al.*, Space Research Centre of the Polish Academy of Science

Poster	**P1B-For: Poster: Applications in Forestry (page 90)** Chair: Sandra Dotzler, Location: Nic Klecker Space
12:00pm - 12:45pm	**1-Detection of Vegetation Stress using VNIR and SWIR Field Imaging Spectroscopy** Henning Buddenbaum *et al.*, University of Trier, Germany **2-Early detection of drought stress in Beech stands using hyperspectral airborne data** Sandra Dotzler *et al.*, University of Trier, Germany **3-Above Ground Biomass Estimation with Airborne Hyperspectral and Lidar Data in Temperate Spruce Forest** Olga Brovkina *et al.*, University in Brno, Czech Republic **4-Tree Species Classification in a Central European Floodplain Forest: with AISA DUAL Airborne Data Using Machine Learning Algorithms and Spectral Variable Selection.** Ronny Richter, Daniel Doktor *et al.*, University of Leipzig, Germany **5-Tree species classification of Karkonoski National Park using APEX hyperspectral data** Edwin Raczko, University of Warsaw, Poland **6-Optimizing Temporal Sampling for Broad Leaf Species Classification in Laboratory Spectroscopy** Geoffrey Quinn *et al.*, Department of Geography, University of Victoria, Canada **7-Monitoring forests phenology by remote sensing techniques: Merits and limitations** Alexandra Shtein, Arnon Karnieli *et al.* Ben Gurion University, Israel

Poster	**P1C-Eco: Ecosystem Services and Disturbances (page 94)** Chair: Anna Jarocinska, Location: Nic Klecker Space
12:00pm - 12:45pm	**1-Assessing the influence of seasonal dynamics of canopy interception storage on the urban water balance using remote sensing and field validation.** Charlotte Wirion *et al.*, Vrije Universiteit Brussel, Belgium **2-Hyperspectral method of assessment studies of heavy metals in plants** Marlena Kycko *et al.*,University of Warsaw, Poland **3-Hyperspectral Simulation of an Arctic Landscape with ISDASv2** H. Peter White *et al.*, Natural Resources Canada, Canada **4-Random forest classification for flower mapping using hyperspectral data** Richard Kyalo *et al.*, icipe, Kenya; **5-Spectral identification of biological soil crusts in the Northern Negev** Ittai Herrmann, Arnon Karnieli *et al.*, Ben-Gurion University of the Negev, Israel **6-Hyperspectral image data for classification of tundra vegetation in the Krkonoše Mts. National Park** Lucie Kupková *et al.*, Charles University in Prague, Czech Republic **7-LiDAR and spectral imaging for coastal dune vegetation characterization in Western France** Antoine Ba *et al.*, Laboratoire Planétologie et Géodynamique, Nantes **8-Applications of point and imaging spectrometry to studies of plant functional diversity** John A. Gamon *et al.* **9-Mapping of overburden substrates for post-mining re-cultivation using imagery spectroscopy** Miroslav Pikl *et al.*, Global Change Research Centre AS CR, Czech Republic **10-Assessment of hyperspectral images for vegetation classification of Polish mountain M&B Reserves** Adriana Marcinkowska-Ochtyra *et al.*, University of Warsaw, Poland **11-Field hyperspectral techniques for evaluating the phenological changes and biophysical state of forests of M&B UNESCO Karkonosze Mountains Reserve** Martyna Wietecha *et al.*, University of Warsaw, Poland

	13-Vegetation condition of non-forest communities in Karkonosze Mountains based on APEX hyperspectral images Monika Kacprzyk *et al.*, University of Warsaw, Poland **14-Fusion of hyperspectral field data and multispectral satellite images to assess vegetation condition: case study Tatra Mountains** Adrian Ochtyra *et al.*, University of Warsaw, Poland **15-Near Field Remote Sensing of Light Use Efficiency and Plant Stress** Eva van Gorsel, Dale Hughes, CSIRO, Australia **16-STARS - Monitoring smallholder farming in sub-Saharan Africa and South Asia from an UAV perspective** Rolf A. de By *et al.*, ITC - University of Twente, Netherlands **17-Applications of Near Infrared Hyperspectral Imaging for crop disease detection** Damien Vincke *et al.*, Walloon Agricultural Research Center, Belgium **18- LAI retrieval from heterogeneous meadows using PROSAIL model based on field measurements** Anna Jarocinska *et al.*, University of Warsaw, Poland
12:45pm- 2:00pm	**LB1: Lunch Break and Continuation of P1A/P1B/P1C** Location: Nic Klecker Space
2:00pm	**GROUP PICTURE, outside**
2:15pm - 2:45pm	**Keynote 3: Nicholas Coops, UBC Vancouver: Linking Canopy Spectroscopy with Stand Architecture to Estimate Vertical Patterns of Light-Use Efficiency** Location: Robert Krieps Auditorium, Chair: Henning Buddenbaum
Oral	**O3-For: Applications in Forestry (page 30)** Chair: Henning Buddenbaum, Nicholas Coops, Location: Robert Krieps Auditorium
2:45pm - 3:30pm	**1-Non-destructive estimation of foliar carotenoid content of tree species using merged vegetation indices** Fabian Fassnacht *et al.*, Karlsruhe Institute of Technology, Germany **2-Condition of dominant arborescent species of Bialowieza National park in Poland** Karolina Orlowska *et al.*, University of Warsaw, Poland **3-Development of a Spectral, Structural and Site Specific Feature Data Base for Mapping of Tree Species in the Bavarian Forest National Park** Carolin Sommer, Stefanie Holzwarth *et al.*, German Aerospace Center (DLR), Germany
3:30pm- 4:00pm	**CB2: Coffee Break** Location: Nic Klecker Space
Oral	**O4-Eco: Ecosystem Services and Disturbances Part 1 (page 33)** Chair: Anatoly Gitelson, Bogdan Zagajewski, Location: Robert Krieps Auditorium
4:00pm - 5:15pm	**1-Ecosystem service mapping using imaging spectroscopy: Where do we benefit from ecosystems?** Daniela D.M. Braun *et al.*, Remote Sensing Laboratories, University of Zurich, Switzerland **2-A tale of bees, flowers, and spectral data – mapping plant pollination traits with imaging spectroscopy** Hannes Feilhauer, FAU Erlangen-Nürnberg, Germany **3-Discriminating invasive plant species, Polypogon monspeliensis and Phoenix dactylifera, in arid wetland ecosystems of Australia using Multiple Endmember Spectral Mixture Modelling** Davina Cherie White, Megan Mary Lewis, The University of Adelaide, Australia

	4-Application of the HySpex imaging spectrometer in a laboratory set-up for the automated qualification and quantification of microplastic particles from natural water samples Mathias Bochow *et al.*, Helmholtz Centre Potsdam - GFZ, Germany **5-PROSAIL model in simulating reflectance from field measurement and APEX reflectance on heterogeneous mountain non-forest communities – first results** Anna Jarocinska *et al.*, University of Warsaw, Poland

Wednesday, 15/Apr/2015		
9:00am-9:30am	**Keynote 4: E. Ben-Dor, TAU Tel Aviv: Recent Advances in the Image Spectroscopy for Soil Science Applications,** Chair: Andreas Müller, Eyal Ben Dor, Location: José Ensch	
Oral	**O5A-Soi: Soils and Minerals Part 1 (p. 37)** Chair: Andreas Müller, Eyal Ben Dor Location: José Ensch Room	**O5B-Eco: Ecosystem Services and Disturbances Part 2 (p. 40)** Chair: Matthias Bochow, Hannes Feilhauer, Location: Edmond Dune
9:30am - 10:15am	**1-Soil imVisIR – Quantification of soil organic matter fractions in undisturbed soil profiles** Markus Steffens *et al.*, TU München, Germany **2-Imaging Spectroscopy and Accurate Prediction of Highly Weathered Soils Properties: The Influence of Fractional Vegetation Cover** Marston H. D. Franceschini *et al.*, Wageningen University, The Netherlands **3-Spectral analysis of airborne hyperspectral images of soil-hydrocarbon mixtures to retrieve total petroleum hydrocarbon content** Vincent Lever *et al.*, ONERA, France	**1-Remote sensing analysis of the state of trampling alpine grasslands in the Tatra National Park.** Marlena Kycko *et al.*, University of Warsaw, Cartography and Remote Sensing, Poland **2-Comparison of methods for hyperspectral change detection of pioneer vegetation in a post-mining landscape in Eastern Germany** Henning Gerstmann, Cornelia Gläßer *et al.*, University of Halle, Germany **3-Characterization of Soil Erosion Stages Using Airborne Hyperspectral Data and Lidar Derived Morphometric Parameters in a Mediterranean Agricultural Area** Robert Milewski *et al.*, Helmholtz-Zentrum Potsdam GFZ, Germany
10:15am-10:45am	**CB3: Coffee Break** Location: Nic Klecker Space	
Oral	**O6A-Soi: Soils and Minerals Part 2 (p. 43)** Chair: Thomas Jarmer, Freek van der Meer, Location: José Ensch Room	**O6B-THy: Thermal Hyperspectral Remote Sensing of Vegetation (p. 46)** Chair: Andrew Skidmore, Roshanak Darvishzadeh, Location: Edmond Dune
10:45am - 12:00pm	**1-Evaluation of the potential of a lightweight VNIR snapshot imaging spectrometer for rapid soil diagnostics** András Jung *et al.*, University of Leipzig, Germany **2-Spectral Feature Analyses Versus Statistical Multivariate Approaches: Expected Accuracy for the Quantitative Determination of Surface Soil Properties**	**1-Species discrimination using emissive thermal infrared imaging spectroscopy** Gilles Rock *et al.*, Trier University, Germany **2-Changes in Thermal infrared spectra of plants caused by temperature and water stress** Maria Buitrago *et al.*, University of Twente, Netherlands

	from Hyperspectral Airborne and Simulated Enmap Images Sabine Chabrillat *et al.*, German Research Centre for Geosciences, Germany **3-Hyperspectral analysis and mapping of iron and steel work by-products** Michael Denk *et al.*, Martin Luther University Halle-Wittenberg, Germany **4-Quantification of Soil Organic Carbon with Hyperspectral Imaging Data – A case study from Saxony-Anhalt, Germany** Christine Jung-Dahlke, Martin Sauerwein *et al.*, University of Hildesheim Germany	**3-Thermal Hyperspectral Remote Sensing for Pre-Visual Water Stress Detection** Max Gerhards *et al.*, Luxembourg Institute of Science and Technology, Luxembourg **4-Estimation of Leaf Area Index from Hyperspectral Thermal Data** Elnaz Neinavaz *et al.*, ITC, University of Twente, The Netherlands **5-Fusion of Thermal Infrared Hyperspectral image and visible RGB image for Classification** Wenzhi Liao *et al.*, Gent University, Belgium

Poster	**P2A-Soi: Soils and Minerals (page 106)** Chair: Véronique Carrère, Location: Nic Klecker Space
12:00pm - 12:45pm	**1-Assessing the Limits of Spectral Parameters Estimation Using Spectral Derivative and the Modified Gaussian Model (MGM): Application to Soil Spectra** Maïwenn Lothodé *et al.*, University of Nantes, France **2-Potential of hyperspectral imagery for geoarchives mapping and process analysis in southern Africa** Robert Milewski *et al.*, Helmholtz-Zentrum Potsdam, GFZ, Germany **3-Soil clay content prediction from Vis-NIR airborne hyperspectral data by transferring laboratory calibration models** Maroua Nouri, Irstea / UMR ITAP, France **4-Digital soil classification and elemental mapping using imaging Vis-NIR spectroscopy: Quantification of stagnic properties in Luvisol profiles under Norway spruce and European Beech** Stefanie Kriegs, Markus Steffens *et al.*, Lehrstuhl für Bodenkunde, TU München, Germany **5-Regionalization of uncovered agricultural fields based on soil texture type estimation** Martin Kanning *et al.*, University of Osnabrück, Germany **6-Mineral classification of Makhtesh Ramon in Israel using hyperspectral VNIR-SWIR and LWIR remote-sensing data** Eyal Ben Dor *et al.*, Tel Aviv University, Israel **7-SpecTour – Impacts of variability in spectral measurement setups on mineral absorption features** Michael Denk, Cornelia Glaesser *et al.*, Martin Luther University Halle-Wittenberg, Germany **8-Visible and infrared hyperspectral survey of volcanic lava flows on Tenerife (Canary Islands, Spain)** Long Li *et al.*, Vrije Universiteit Brussel, Brussels, Belgium **9-Hyperspectral system analysis for geophysical applications: the ASI-AGI project** Malvina Silvestri *et al.*, Centro Nazionale Terremoti, Italy
Poster	**P2B-Tec: New Analytical Techniques (page 112)** Chair: Peter Roosjen, Location: Nic Klecker Space
	1-Impact of data transformation on LU/LC classification using noisy Hyperion data Florian Beyer *et al.*, University of Osnabrueck, Germany **2-Evaluation of literature indices for determination of crop properties for ground and airborne hyperspectral detection** Frank Liebisch *et al.*, Institute of Agricultural Sciences, ETH Zürich, Switzerland **3-The application of ICA-based algorithms to hyperspectral remotely sensed data for the land cover identification**

	Seloua Chouaf *et al.*, University of Science and Technology Houari Boumediene, Algiers, Algeria **4-Remote monitoring of insects of economic importance based on the spectral analysis of their wing-flap** Ilyas Potamitis *et al.*, Technological Educational Institute of Crete, Greece **5-Use of NIR-HIS and dichotomist classification tree based on SVMDA models in order to discriminate roots and crop residues of winter wheat** Damien Eylenbosch *et al.*, Gembloux Agro-Bio Tech, University of Liège, Belgium **6-Non-invasive documentation of historical painting – hyperspectral approach** Eva Matouskova *et al.*, Czech technical university in Prague, Czech Republic **7-Anisotropic reflectance effects in optical multi-angular laboratory and hyperspectral airborne measurements** Peter Roosjen *et al.*, Wageningen University, Netherlands **8-The integration of aerial-based LiDAR and Hyperspectral data for the seismic vulnerability assessment of historical heritages** Antonio Costanzo, Malvina Silvestri *et al.*, Centro Nazionale Terremoti, Italy
Poster	**P2C-Bio: Retrieval of biophysical properties (page 118)** Chair: Daniel Doktor, Location: Nic Klecker Space
	1-Relationship between spectral resolution and the accuracy of biomass estimation through a data assimilation approach Christian Bossung, et al., Trier University, Germany **2-Remote estimation of gross primary productivity in C3 and C4 crops: from close range to satellites** Anatoly Gitelson *et al.*, Israel Institute of Technology, Israel **3-Identification of spectral bands related to leaf biochemistry with a multi-method ensemble approach** Hannes Feilhauer *et al.*, Geography, FAU Erlangen-Nürnberg, Germany **4-Extraction of plant physiological status from hyperspectral signatures using machine learning methods** Daniel Doktor *et al.*, Helmholtz Centre for Environmental Research - UZF, Leipzig, Germany
Poster	**P2D-The: Thermal Infrared Spectroscopy (page 121)** Chair: Wenzhi Liao, Location: Nic Klecker Space
	1-Hyperspectral and thermal remote sensing application in an integrated crop breeding programs Chadrashekhar Biradar *et al.*, International Center for Agricultural Research in Dry Areas (ICARDA), Jordan **2-Optimized calibration and radiometric processing of MCT based LWIR push-broom hyperspectral imager** Hannu Holma *et al.*, Specim, Spectral Imaging, Finland
12:45pm-2:00pm	**LB2: Lunch Break and Continuation of P2A/P2B/P2C/2D** Location: Nic Klecker Space

Oral	**O7A-Ret: Retrieval of biophysical properties Part 1 (p. 49)** Chair: Clement Atzberger, Wouter Verhoef, Location: José Ensch Room	**O7B-Tec: New Analytical Techniques (p. 53)** Chair: Luis Guanter, Daniel Schläpfer Location: Edmond Dune Room
2:00pm - 3:15pm	**1-Remote estimating C3 and C4 crops biophysical characteristics** Anatoly Gitelson, Israel Institute of Technology, Israel **2-Mapping tropical biodiversity using spectroscopic imagery : characterization of structural and chemical diversity using 3-D radiative transfer modeling** Jean-Baptiste Feret *et al.*, Irstea UMR TETIS, France **3-Estimating leaf and canopy chlorophyll content of a potato crop using Sentinel-2 data** Jan Clevers *et al.*, Wageningen University, Netherlands **4-ARTMO's Global Sensitivity Analysis toolbox to quantify driving variables of leaf and canopy radiative transfer models** Jochem Verrelst *et al.*, University of Valencia, Spain **5-Early indication of plant stresses by changes in vegetation indices and fluorescence** Maria Matveeva *et al.*, Forschungszentrum Jülich GmbH, Germany	**1-Rigorous parametric co-registration of Airborne Hyperspectral and LIDAR intensity data using ray tracing techniques – towards a fusion of Hyperspectral and LIDAR data** Maximilian Brell *et al.*, GFZ German Research Centre for Geosciences, Germany **2-New science data processing for the Next Generation Airborne Visible InfraRed Imaging Spectrometer (AVIRIS-NG): atmospheric correction, validation, and real-time analyses** David Ray Thompson *et al.*, JPL, California Institute of Technology, USA **3-The Analysis of Variance in High Resolution Imaging Spectrometers and its Application to Object Based Classification** Knut Olaf Niemann *et al.*, University of Victoria, Canada **4-On the use of class-probabilities for mapping vegetation-cover fractions in natural environments with EnMAP data and machine learning** Stefan Suess *et al.*, Humboldt-Universität zu Berlin, Germany **5-EnMAP-Box Cross-Language Integration: making Python, R and Matlab Libraries available for Remote Sensing Image Analysis** Andreas Rabe *et al.*, Humboldt University Berlin, Germany
3:15pm- 3:45pm	**CB4: Coffee Break** Location: Nic Klecker Space	
Oral	**O8A-Ret: Retrieval of biophysical properties Part 2 (p. 57)** Chair: Jan Clevers, Lammert Kooistra, Location: José Ensch Room	**O8B-The: Thermal Infrared Spectroscopy (p. 60)** Chair: Robert O Green, Thomas Udelhoven, Location: Edmond Dune Room
3:45pm - 4:45pm	**1-Hyperspectral synthetic scene simulator for the assessment of fluorescence retrieval with ESA's FLEX/Sentinel-3 tandem mission** Carolina Tenjo, Jorge Vicent *et al.* University of Valencia, Spain **2-Evaluation of leaf area index and dry matter predictions for crop growth modeling and yield estimation based on**	**1-First Results from NASA's Hyperspectral Thermal Emission Spectrometer (HyTES)** Michael Abrams *et al.*, NASA/Jet Propulsion Laboratory, USA **2-Airborne Thermal Infrared Hyperspectral Imaging for Mineral Mapping** Marc-André Gagnon[1], Eric Guyot[2] *et al.* [1]Telops, Canada; [2]Telops, France; **3-Visible to Thermal Infrared Emission Spectroscopy of Samples with Singular**

	field reflectance measurements Heike Gerighausen *et al.*, Julius Kühn-Institut (JKI), Germany **3-Leaf Area Index derivation from hyperspectral remote sensing data based on radiative transfer model inversion in heterogeneous grassland** Sarah Asam *et al.*, EURAC Research, Bolzano, Italy **4-Combining physiological parameters, hyper-spectral proximal sensing and partial least squares regression (PLSR) analysis to monitor wine vine water status** Tal Rapaport *et al.*, University of the Negev,Israel	**Spectral Features** Maria Mira *et al.*, Edifici B. Universitat Autònoma de Barcelona, Spain **4-An Overview of Plume Tracker: Mapping Volcanic Emissions with Interactive Radiative Transfer Modeling** Alexander Berk, Spectral Sciences, Inc, USA
5:00pm	**Conference Dinner**	

Thursday, 16/Apr/2015		
9:00am-9:30am	**Keynote 5: Jose Moreno, U. Valencia: Observing land surface dynamics in very high spectral resolution: theory, methods and applications**, Chair: Elizabeth Middleton, Alexander Damm, Location: José Ensch Room	
Oral	**O9A-Flu: Remote Sensing of Vegetation Fluorescence Part 1 (p. 62)** Chair: Elizabeth Middleton, Alexander Damm, Location: José Ensch Room	**O9B-Enm: Latest EnMAP Developments (p. 64)** Chair: Joachim Hill, Patrick Hostert, Location: Edmond Dune Room
9:30am - 10:15am	**1-Mapping sun-induced fluorescence (SIF) for mechanistic stress responses of vegetation using the high-performance imaging spectrometer HyPlant** Uwe Rascher *et al.*, Forschungszentrum Jülich, Germany **2-Monitoring the evolution of plant photosynthetic performances using ground sun-induced fluorescence measurements** Micol Rossini *et al.*, University of Milano Bicocca, Italy **3-Using plant chlorophyll fluorescence for a better prediction of GPP and canopy carbon exchange** Sebastian Wieneke *et al.*, University of Coloversity of Cologne, Germany	**1-Overview of the technical and scientific status of the EnMAP imaging spectroscopy mission** Luis Guanter *et al.*, Helmholtz Center Potsdam, GFZ, Germany **2-On the use of land cover fraction maps derived from simulated EnMAP data for characterizing urban morphology** Akpona Okujeni *et al.*, Humboldt-Universität zu Berlin, Germany; **3-The Potential of Pan-Sharped EnMAP Data for Assessing the Leaf Area Index of Wheat** Bastian Siegmann *et al.*, University of Osnabrueck, Germany
10:15am-10:45am	**CB5: Coffee Break** Location: Nic Klecker Space	

Oral	**O10A-Flu: Remote Sensing of Vegetation Fluorescence Part 2 (p. 67)** Chair: Jose Moreno, Jochem Verrelst Location: José Ensch Room	**O10B-Cal: Imaging Spectrometers Instrument and Data Calibration (p. 71)** Chair: Andreas Hueni, Karim Lenhard Location: Edmond Dune Room
10:45am - 12:00pm	**1-Global monitoring of chlorophyll fluorescence with spaceborne atmospheric sensors** Luis Guanter *et al.*, GFZ Potsdam, Germany **2-Using Multi-angle Spectral Observations of Solar Induced Fluorescence (SIF) and the Non-Photochemical Reflectance Index (PRI) to Estimate Stress Responses, Biophysical Properties and Gross Primary Production in Corn Crops** Elizabeth Middleton *et al.*, NASA/Goddard Space Flight Center, USA **3-The impact of BRDF and adjacency effects on the accuracy of fluorescence retrievals from space** Wouter Verhoef, University of Twente - Faculty ITC, Netherlands **4-On the relationships between solar-induced fluorescence and net photosynthesis of the canopy: a SCOPE modeling study** Jochem Verrelst *et al.*, LEO, University of Valencia, Spain **5-Relationships between sun-induced chlorophyll fluorescence and gross primary production across ecosystems: insights from observational and modeling approaches** Alexander Damm *et al.*, Remote Sensing Laboratories, University of Zurich, Switzerland	**1-Recent Developments in Atmospheric Compensation and Radiometric Processing of Imaging Spectroscopy Data** Daniel Schläpfer *et al.*, ReSe Applications, Switzerland **2-APEX Instrument and Data Calibration** Andreas Hueni *et al.*, University of Zurich, Switzerland **3-Improvements to the calibration of a NEO HySpex VNIR-1600 sensor** Karim Lenhard *et al.*, DLR, Germany **4-Towards open access to time series of in-situ data, drone-based images, airborne hyperspectral images and satellite images collected at the BELAIR sites** Ils Reusen *et al.*, VITO, Belgium **5-Mixel camera prototype – testing the performance of the light mixing chambers** Andrei Fridman *et al.*, Norsk Elektro Optikk AS, Norway
Poster	**P3A-Flu: Poster: Remote Sensing of Vegetation Fluorescence (page 122)** Chair: Uwe Rascher, Nic Klecker Space	
12:00pm - 12:45pm	**1-Sun-Induced Fluorescence as an early indicator for drought stress: a case study in Brazilian soybean varieties** Anke Schickling *et al.*, IBG, Plant Sciences, Forschungszentrum Jülich, Germany **2-Effects of chlorophyll fluorescence on the retrieval of biophysical parameters and leaf traits from leaf reflectance measurements** Benjamin Dechant *et al.*, Helmholtz Centre for Environmental Research (UFZ), Germany	
Poster	**P3B-Enm: Poster: Latest EnMAP Developments (page 123)** Chair: Sebastian van der Linden, Location: Nic Klecker Space	
12:00pm - 12:45pm	**1-EnMAP-Box 2.0 – an overview of the concept and available applications** Sebastian van der Linden *et al.*, Humboldt-Universität zu Berlin, Germany **2-Assessment of soil degradation in Costa Rica using reflectance hyperspectral and simulated EnMAP imagery** Sarah Sophia Malec *et al.*, DLR-DFD, Oberpfaffenhofen, Germany	

Poster	**P3C-Pro: Poster: Image Processing Methods (page 125)** Chair: Jennifer Susan Adams, Location: Nic Klecker Space
12:00pm - 12:45pm	**1-Comparing the Effect of Preprocessing Transformations on Methods of Land-Use Classification Derived From Spectral Soil Measurements** Offer Rozenstein, Arnon Karnieli *et al.*, Ben-Gurion Univeristy of the Negev, Israel **2-STORE-Simulator of TOa RadiancE for new hyperspectral missions** Malvina Silvestri *et al.*, Centro Nazionale Terremoti, Italy **3-A Protocol for Optimum Usage Of Handheld Spectroradiometers in Airborne and Satellite Applications: The Ocean Optics USB2000+ Case** Xavier Pons *et al.*, Edifici B. Universitat Autònoma de Barcelona, Spain **4-Materials and Geometry ror the Empirical Radiometric Calibration of an Airborne Imaging Spectrometer** Geoffrey S. Quinn *et al.*, University of Victoria, Canada **5-Inter-Instrument Registration for the Sysiphe System** Sophie Fabre, Laurent Rousset-Rouviere, ONERA, France
Poster	**P3D-Wat: Poster: Water Applications (page 129)** Chair: Anita Sabat, Location: Nic Klecker Space
12:00pm - 12:45pm	**1-Investigation of heavy metals distribution in suspended matter and macrophytes of the Selenga river delta using airborne hyperspectral remote sensing** Mikhail Tarasov *et al.*, École Polytechnique Fédérale de Lausanne, Switzerland **2-UAV based multispectral imaging over a lagoon with corals in Reunion Island** Harold Clenet *et al.*, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland **3-Application of AISA hyperspectral image for hydrodynamic model verification** Bogdan Zagajewski *et al.*, University of Warsaw, Poland **4-The use of AISA images to water analysis in Zegrzynskie Lake** Anita Sabat *et al.*, University of Warsaw, Poland
12:45pm- 2:00pm	**LB3: Lunch Break and Continuation of P3A/P3B/P3C/3D** Location: Nic Klecker Space

Oral	**O11A-Pro: Image Processing Methods Part 1 (p. 74)** Chair: Jan Hanuš, Sindy Sterckx, Location: José Ensch Room	**O11B-Dro: Remotely Piloted Aircraft Systems (RPAS) based hyperspectral remote sensing of vegetation (p. 77)** Chair: Stephanie Delalieux, Pablo J. Zarco-Tejada, Location: Edmond Dune Room
2:00pm - 3:00pm	**1-Geometric and Atmospheric Processing of APEX Hyperspectral Data** Kristin Vreys *et al.*, VITO, Belgium **2-MODTRAN®6: A Major Upgrade of the MODTRAN Radiative Transfer Code** Alexander Berk *et al.*, Spectral Sciences, Inc, USA **3-Georeferencing Method for Airborne Scanner Image Without Exterior Orientation Parameters** Iscander Latypov[1], Olga Brovkina[2] [1]Center for Ecological Safety of Russian Academy of Science; [2]Mendel University in Brno, Czech Republic;	**1-Remote sensing of vegetation physiological condition using micro- and nano hyperspectral cameras on board lightweight RPAS** Pablo J. Zarco-Tejada *et al.*, Consejo Superior de Investigaciones Científicas (CSIC), Spain **2-Combining hyperspectral RPA and multispectral satellite imagery to increase spectral-temporal detail for precision agriculture applications** Lammert Kooistra *et al.*, Wageningen University, Netherlands **3-Hyperspectral remote sensing of crop properties with Unmanned Aerial Vehicles** Dragos Constantin *et al.*, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

	4-Standards for the validation remotely sensed albedo products Jennifer Susan Adams, Joint Research Centre (JRC), Italy	**4-High resolution vegetation monitoring with a novel compact hyperspectral camera system** Stefan Livens, Bavo Delauré *et al.*,VITO, Belgium **5-UAV hyperspectral image frame cameras: from camera categorization to quality assessment** Helge Aasen *et al.*, University of Cologne, Germany
3:00pm-3:30pm	**CB6: Coffee Break** Location: Nic Klecker Space	
Oral	**O12A-Pro: Image Processing Methods Part 2 (p. 81)** Chair: Kristin Vreys, Allan Aasbjerg Nielsen, Location: José Ensch Room	**O12B-Sca: Scaling and Uncertainty (p. 84)** Chair: Martin Bachmann, Stefanie Holzwarth, Location: Edmond Dune Room
3:30pm - 4:30pm	**1-Optimal Iterated Two-Class Separation in Hyperspectral Data** Allan Aasbjerg Nielsen *et al.*, Technical University of Denmark **2-Advanced dimensionality reduction and active learning for imaging spectroscopy biophysical parameter retrieval** Jochem Verrelst *et al.*, University of Valencia, Spain **3-Decoupling Feature Redundancy Reduction and Feature Ranking for Hyperspectral Data** Matthias Held *et al.*, HU Berlin, Germany **4-Airborne Imaging Spectroscopy at CzechGlobe** Jan Hanuš *et al.*, CzechGlobe - CVGZ AV ČR, Czech Republic	**1-Hyperspectral data for scaling ecosystem traits from point to landscape** Enrico Tomelleri *et al.*, EUR.AC, Italy **2-Derivation of chlorophyll content on different scales at a validation-site for airborne and satellite products** Maximilian Lange *et al.*, Helmholtz Centre for Environmental Research -UFZ, Germany **3-Estimating the uncertainty in ground reflectances resulting from radiometric and spectral calibration.** Martin Bachmann *et al.*, DLR-DFD, Germany **4-Analyzing Uncertainties in simulated Canopy Reflectance through exhaustive Comparison with in-situ measured Optical Properties** Martin Danner *et al.*, LMU München, Germany
4:30pm-5:00pm	**CC: Closing Ceremony, Martin Schlerf (OC, LIST), Thomas Udelhoven (OC, Trier University), Andreas Müller (DLR, chairman of the EARSeL Special Interest Group on Imaging Spectroscopy)**, Location: José Ensch Room	

Abstracts

Keynote presentations

Sentinel-2: Optical High-Resolution Mission for Copernicus

Rast, Michael [1]; Hoersch, Bianca [1]; Spoto, Francois [2]; Martimort, Philippe [2]; Colin, Olivier [1]; Gascon, Ferran [1]

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Keywords: Sentinel-2

Copernicus is a joint initiative of the European Commission (EC) and the European Space Agency (ESA), designed to establish a European capacity for the provision and use of operational monitoring information for environment and security applications.

Within the Copernicus programme, ESA is responsible for the development of the Space Component, a fully operational space-based capability to supply earth-observation data to sustain environmental information Services in Europe.

The Sentinel missions are Copernicus dedicated Earth Observation missions composing the essential elements of the Space Component. In the global Copernicus framework, they are complemented by other satellites made available by third-parties or by ESA and coordinated in the synergistic system through the Copernicus Data-Access system versus the Copernicus Services.

The Copernicus Sentinel-2 mission provides continuity to services relying on multi-spectral high-resolution optical observations over global terrestrial surfaces. Sentinel-2 will capitalize on the technology and the vast experience acquired in Europe and the US to sustain the operational supply of data for services such as forest monitoring, land cover changes detection or natural disasters management.

The Sentinel-2 mission will offer an unprecedented combination of the following capabilities:

- Systematic global coverage of land surfaces: from 56°South to 84°North, coastal waters and Mediterranean sea;
- High revisit: every 5 days at equator under the same viewing conditions with 2 satellites;
- High spatial resolution: 10m, 20m and 60m;
- Multi-spectral information with 13 bands in the visible, near infra-red and short wave infra-red part of the spectrum;
- Wide field of view: 290 km.

Frequent revisits and high mission availability require two identical Sentinel-2 satellites operating simultaneously. The orbit is sun-synchronous at 786 km altitude (14+3/10 revolutions per day) with a 10:30 a.m. descending node. This local time was selected as the best compromise between minimizing cloud cover and ensuring a suitable sun illumination. It is close to the Landsat local time and matches SPOT's, allowing the seamless combination of Sentinel-2 data with historical images to build long-term time series. The two satellites will work on opposite sides of the orbit.

The 13 spectral bands span from the visible and the Near Infra-Red to the Short Wave Infra-Red featuring:

- 4 bands at 10m: the classical blue (490nm), green (560nm), red (665nm) and near infrared (842nm),
- 6 bands at 20m: 4 narrow bands in the vegetation red edge spectral domain (705nm, 740nm, 775nm and 865nm) and 2 SWIR large bands (1610nm and 2190nm),

- 3 bands at 60m mainly dedicated for atmospheric corrections and cloud screening (443nm for aerosols retrieval, 940nm for water vapour and 1375nm for cirrus detection).

The Sentinel-2 Ground-Segment is composed of the Flight Operations Segment (FOS) and the Payload Data Ground Segment (PDGS).

The FOS (Flight Operations Segment) is responsible for all flight operations of the Sentinel-2 spacecraft including monitoring and control, execution of all platform activities and commanding of the payload schedules. The PDGS (Payload Data Ground Segment) is responsible for payload and downlink planning, data acquisition, processing, archiving and downstream distribution of the Sentinel-2 satellite data, while contributing to the overall monitoring of the payload and platform in coordination with the FOS.

The systematic activities of the PDGS include the coordinated planning of the mission sub-systems and all processes cascading from the data acquired systematically from the Sentinel-2 constellation.

Vis-à-vis its users, the ground segment features:

- A scalable data access and distribution system to cope with the high data volumes and the large user demands;
- User-services providing automated user-registration capabilities, on-line access to tools, user manuals, and up-to-date news on the mission main events and performance.

The data from the Sentinel-2 mission will become available on a free and open basis, and dedicated data access schemes with online easy access will be offered in response to the needs of the various user communities.

Sentinel-2 is scheduled for launch in June 2015. The presentation will give a status report on the Sentinel-2 mission preparation, and outlook for the operations Phase, together with a quick review of the other Copernicus Sentinels and further Contributing Missions.

The Spectroscopy of Things: From Traceability to Tracing

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Keywords: Spectroscopy

Our ability to assess dispersion of light is founded in physical optics and its origin is traceable back to 1011 AD (Ibn Al-Haytham: Book of Optics) or 1704 (Isaac Newton: Opticks), depending on viewpoint. The potential to use imaging spectroscopy as a diagnostic source of information has emerged gradually with the advances of technology since the early 1980s. In a continual interplay of advances in modelling quality as well as spectrometer measurements with high SNR, imaging spectroscopy has developed to be a commodity. Nowadays, it allows to explore new applications previously unknown.

I will present a variety of new findings and insights based on the ability to trace imaging spectrometer measurements to relative/absolute calibration standards, as well as to model them. These include the ability to forward and inversely model spectroscopy data, propose updated approaches to in-situ data collections, and linking those to integrated services. Besides the ability of spectroscopy to quantify constituents in a variety of the Earth' spheres as well as in biochemical cycles, spectroscopy is increasingly used to identify molecular pathways in the Earth System. I discuss examples from ecological genomics, phylogenetics and isoscapes. Finally, I will present pathways and options for high-fidelity spectroscopy in the near future.

Linking Canopy Spectroscopy with Stand Architecture to Estimate Vertical Patterns of Light-Use Efficiency

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Keywords: GPP, TLS

Remote sensing of terrestrial carbon absorption, or gross primary production (GPP), in a repeatable and consistent manner remains a key goal to comprehensively understand the role of vegetation within the global carbon cycle. To meet this goal on a landscape level or global scale, accurate remote sensing of photosynthetic light-use efficiency (LUE) is required to understand photosynthetic downregulation and environmental constraints to plant photosynthesis. The past decade has seen advances in detecting both leaf- and canopy-level physiological stress behaviours using the photochemical reflectance index (PRI), a narrow-waveband normalized difference index that relates LUE to a xanthophyll-induced absorption feature at 531 nm. To date, however, much of this research has occurred using top of canopy measurements, while our understanding of the vertical distribution of LUE within the crown is limited. In this study, model photosynthetic behaviour of vegetation using accurate measurements of vertical canopy structure obtained from terrestrial Light Detection and Ranging (LiDAR) data.

We then demonstrate how LiDAR stand reconstructions can then be used to predict proportions of shaded and sunlit canopy which are then linked to predictions of LUE. We apply the approach over a mature Aspen study site located in central Saskatchewan, Canada utilising full-waveform LiDAR data provided by the Echidna terrestrial laser scanner system and canopy spectra obtained by the AMSPEC II spectro-radiometer. We produce a range of LUE vertical profiles, for different stand structures across the growing season and discuss advances and limitations to the approach.

Recent Advances in the Image Spectroscopy for Soil Science Applications

Ben Dor, Eyal

Tel Aviv University, Israel

Keywords: Imaging spectroscopy, soil, Remote Sensing

Combining soil science and Imaging spectroscopy (IS) is a promising tool for studying soil properties. Going from point to image spectrometry is not only a journey from micro to macro scales, but also a long stage where problems such as dealing with data having a low signal-to-noise level, contamination of the atmosphere, large data sets, the BRDF effect, crust and more are often encountered. In this presentation we provide an up-to-date overview of some of the case studies that have used IS technology for soil science applications. Besides a brief discussion on the advantages and disadvantages of IS for studying soils, the following cases are comprehensively discussed: soil degradation, soil mapping and classification, soil genesis and formation, soil contamination, soil water content, and soil swelling. We review these case studies and suggest that the IS data be provided to the end users as real reflectance and not as raw data and with better signal-to-noise ratios than presently exist. These limitations serve as a barrier that impedes potential end-users, inhibiting researchers from trying this technique for their needs. A review of the forthcoming IS missions (air and space) and their affiliation to soil mapping is provided especially for open mines close by area. Also a brief description on the effort done worldwide to gather many potential users into one group is reported. The paper ends with a general call to extend the utilization of the IS technique into soil science and applications.

Observing Land Surface Dynamics in Very High Spectral Resolution: Theory, Methods and Applications

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Keywords: Fluorescence, very high spectral resolution

Imaging spectrometers have been operating over several decades now, becoming a key tool to map the dynamics of land surface processes due to the unique capabilities to measure the chemical composition and structural properties in a quantitative way, contrary to more qualitative approaches. The role of the “high” spectral resolution has been essential. This paper reviews the journey of imaging spectrometers over the last 25 years from spectral resolutions of about 10 nm to resolutions in the order of 0.1 nm available today. It is not only technological improvements in sensors and data quality, but better calibration and data processing schemes, and particularly the advance on the scientific understanding of the signal, what has made possible more advanced science and new applications from such data.

While at the beginning it was considered that a spectral resolution in the range 5-10 nm would be more than enough to observe dynamical surface phenomena, soon became evident that new phenomena would be observed if the spectral resolution would be increased. Two elements had a key role: the realisation that vegetation reflectance is highly dynamical due to the complex variable chemistry, and the fact that what was considered as “reflected” radiance was masked by an “emitted” component, namely vegetation fluorescence emission. The decoupling between fluorescence emission and actual reflectance is essential to properly look at the dynamical processes, because both reflected / emitted dynamics are different and somehow complementary.

Obviously, higher spectral resolutions imply more critical data processing, spectral calibration and compensation of atmospheric effects, but the derived information about the surface become quantifiable in terms of better physically defined processes. Multi-pigment composition of vegetation, and the dynamical changes in reflectance as varying such pigment composition (light absorption as a function of variable chemistry and structure), allow the study of processes in a way impossible with any other remote sensing technique. But the aspect where higher spectral resolution becomes more essential is for the determination of fluorescence emission, which gives information about the actual photosynthesis being made by the plants (as opposed to the potential photosynthesis that can be derived when only chlorophyll content is available) and also informs about stress conditions in the plants beyond those that can be observed with reflectance when damages are already irreversible.

Three main pillars have made possible the recent advancements in the usage of imaging spectrometer data with such high spectral resolution:

First, the development of a proper theoretical framework to understand the signal, developing models able to represent not only the radiometric signal variability but also the coupling between radiometric signal and the underlying physical, chemical and biological processes that determine the observed dynamics, ultimately making possible the usage of imaging spectrometer data into dynamical surface models by mean of data assimilating techniques.

The second pillar have been the advances in data analysis and information extraction techniques, particularly in the treatment of instrumental and atmospheric effects, the ability of decoupling between reflected and emitted components and the exploitation of the actual reflectance signal in a proper quantitative way (i.e., model inversion approaches by using adequate advanced models).

Finally, the third pillar has been the appreciation in the last years of the usefulness of the additional information derived from high spectral resolution imaging spectrometer data, as compared with other techniques --particularly vegetation fluorescence-- into advanced scientific understanding of global carbon/water cycles and impact on vegetation of global environmental and climatic changes, but also on new emerging applications related to better management of agricultural and forestry resources in the context of growing population where food availability and food security issues are essential. The quantification of actual plant photosynthetic rates and the ability for early detection of plant stress and diseases open doors for new operational applications.

This paper provides a review of the achievements made in the last years for such three pillars and points to preparation for the promising future that comes ahead.

O2-Sen: Next generation of IS sensors

Sysiphe System: a state of the art airborne hyperspectral imaging system. Initial results from the first airborne campaign.

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1: ONERA, France; 2: NEO, Norway; 3: FFI, Norway; 4: DGA, France

Keywords: Remote sensing, infrared, multispectral, hyperspectral, airborne, SYSIPHE, SIELETERS, thermal infrared, spectroscopy, Fourier transform

SYSIPHE is an airborne hyperspectral imaging system, result of a cooperation between France (Onera and DGA) and Norway (NEO and FFI). It is a unique system by its spatial sampling—0.5m with a 500m swath at a ground height of 2000m—combined with its wide spectral coverage from 0.4µm to 11.5µm in the atmospheric transmission bands.

Its infrared component, named SIELETERS, consists in two *high étendue* imaging static Fourier transform spectrometers, one for the midwave infrared and one for the longwave infrared. These two imaging spectrometers are closely similar in design, since both are made of a Michelson interferometer, a refractive imaging system, and a large IRFPA (1016x440 pixels). Moreover, both are cryogenically cooled and mounted on their own stabilization platform which allows the line of sight to be controlled and recorded. These data are useful to reconstruct and to georeference the spectral image from the raw interferometric images.

The visible and shortwave infrared component, named Hyspex ODIN-1024, consists of two spectrographs for VNIR and SWIR based on transmissive gratings. These share a common fore-optics and a common slit, to ensure perfect registration between the VNIR and the SWIR images. The spectral resolution varies from 5nm in the visible to 6nm in the shortwave infrared.

In addition, the STAD, the post processing and archiving system, is developed to provide spectral reflectance and temperature products (SRT products) from calibrated georeferenced and inter-band registered spectral images at the sensor level acquired and pre-processed by SIELETERS and Hyspex ODIN-1024 systems.

SYSIPHE was flown for the first time in September, 2013. Initial results are shown.

The high-end airborne hyperspectral imaging system HySpex ODIN-1024

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Norsk Elektro Optikk AS, Norway

Keywords: Hyperspectral imaging, HySpex, resampling, remote sensing, SYSIPHE

HySpex ODIN-1024 is a next generation airborne high-resolution VNIR-SWIR hyperspectral camera developed by Norsk Elektro Optikk AS (NEO). Being designed as a single intrument, HySpex ODIN-1024 has near perfect co-registration between VNIR and SWIR. This is achieved by employing a common fore-optics architecture integrated in one instrument rather than having two individual VNIR and SWIR instruments. In SWIR the across-the-track resolution of the instrument is 1024 pixels, while for the VNIR the user of the instrument can choose between a resolution of either 1024 or 2048 pixels. In addition to high resolution the optical design of the camera enables low smile- and keystone distortion as well as high sensitivity achieved through low F-numbers of F1.64 for VNIR and F2.0 for SWIR. Resampling is used to correct for smile- and keystone distortion in the VNIR spectral range. The HySpex ODIN-1024 system has integrated real-time processing functionalities for hyperspectral image processing and in addition an onboard-calibration subsystem monitors the stability of the camera when subject to environmental changes. HySpex ODIN-1024 has been developed within the French-Norwegian SYSIPHE project. The partners in SYSIPHE are the French aerospace laboratory ONERA, NEO, and the Norwegian Defence Research Establishment (FFI). In SYSIPHE, ONERA developed the hyperspectral imaging instrument, SIELETERS. While ODIN-1024 is sensitive in VNIR and SWIR, SIELETERS covers the MWIR and LWIR spectral ranges. When combined in SYSIPHE, ODIN-1024 and SIELETERS constitutes a unique hyperspectral imaging system with a spatial resolution of more than 1000 pixels covering the atmospheric transmission bands over a broad spectral range going from visible to LWIR. FFI has developed a general software framework for real-time processing, which during SYSIPHE has been adapted for HySpex ODIN-1024 by NEO in collaboration with FFI. During SYSIPHE further real-time software has been developed, and real-time algorithms for real-time detection, classification, and georeferencing have been implemented by NEO. We will present an overview of the performance of the ODIN-1024 system including examples of data acquired during the first flights. The chain for postprocessing of data will be described and, moreover, we present the methods used for the calibration and characterization of the system.

High-resolution temperature and emissivity mapping (HiTeSEM): A satellite sensor concept for hyperspectral thermal remote sensing

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Keywords: hyperspectral, thermal remote sensing, food security

HiTeSEM (High-resolution Temperature and Spectral Emissivity Mapping) is a preparatory study, funded by the German Aerospace Center (DLR) that aims at preparing the floor for a future spaceborne hyperspectral thermal mission. Up to now this spectral region in Earth observation is mainly used to measure surface temperature. Nevertheless, the spectrally dispersed signal between 8µm and 12 µm can provide information about abundances of key rock and soil forming minerals as well as the status of vegetation. HiTeSEM aims at closing the research gap still hampering utilization of the thermal infrared data at reasonable spectral and spatial resolution and focusses on surface-solid Earth interactions to assess natural and human-induced changes. Land surface temperature (LST) and spectral emissivity (LSE) of the Earth are the basis for the extraction of sensitive variables in geology, pedology, vegetation monitoring, and biosphere-pedosphere interaction. Towards this end, HiTeSEM will enable the research community to evaluate the potential of emissive spectroscopy methodologies in Earth observation to answer a series of key science questions related to global change, human health, and food security. Relevant target variables include soil mineral composition, soil organic matter (SOM), surface moisture availability, evapotranspiration and stomatal/surface conductance. These are key indicators for soil productivity and plant stress in sensitive regions and can be used to govern and adapt land use practices under challenging ecological and climatic conditions. In urban remote sensing HiTeSEM is expected to furnish important information to define thermal models, which implies knowledge of the surface material composition by means of spectral emissivity retrieval. The methodological challenge of HiTeSEM lies in the development of a robust high performance temperature emissivity separation (TES) technique to allow optimum pre-processing of the measured thermal radiance signal at the sensor level.

The above science goals define the technical baseline for the proposed mission, namely a system composed of a thermal infrared spectrometer covering the spectral region of 8 – 12.5 µm with ~75 spectral channels, a swath width of 50 km – 100 km, and a ground IFOV of 60 x 60 m^2 (TIR, hyperspectral) and 20 x20 m^2 (TIR, broadband). The retrieval of emissivity spectra requires low noise equivalent temperatures, in the order of 0.05 K @ 300 K.

The HyspIRI Preparatory Airborne Campaign: 14 Investigations using Spectroscopy and Thermal Measurements from 6 Large Diverse Areas measured for 3 Seasons over 3 Years

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Keywords: Imaging Spectrometer, Thermal Infrared, HyspIRI

HyspIRI is a NASA Decadal Survey mission in pre-formulation with a global mapping imaging spectrometer (380 to 2510 nm at 10 nm) and thermal infrared multi-spectral instrument (8 bands between 4 and 12 microns) as well as a real-time processing and broadcast capability. In preparation for HyspIRI, in 2011 NASA selected 14 science investigations to advance science and applications readiness as well as demonstrate Level 1 and Level 2 data processing readiness. This HyspIRI preparatory airborne campaign has completed its second year with collection of simultaneous imaging spectrometer and thermal infrared measurements over 6 large areas of the western United States in three seasons. These large areas data sets capture diverse surface types including the coastal zone, mountains, forests, deserts, agricultural lands, urban areas, etc. The 14 investigations span the following topics: (1) ecosystem composition, function, biochemistry, seasonality, structure, and modeling, (2) coastal ocean phytoplankton functional types, habitat, (3) urban land cover, temperature, transpiration, (4) surface energy balance, (5) atmospheric characterization and local methane sources, (6) surface geology, resources, soils, hazards. This paper presents and overview and current results from this unique campaign from the science and applications as well as the Level 1 and Level 2 processing perspectives. In addition, the current status of the space mission is presented along with recent advances in instrumentation and implementation options for HyspIRI.

O3-For: Applications in Forestry

Non-destructive estimation of foliar carotenoid content of tree species using merged vegetation indices

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Keywords: carotenoids; non-destructive assessment; leaf optics; reflectance; angular vegetation index

Leaf pigment content is an important indicator of plant status and can be used to assess the vigor and photosynthetic activity of plants. Spectral information gathered from laboratory, field and remote sensing-based spectrometers has been applied to nondestructively assess total chlorophyll (Chl) content of higher plants with adequate accuracies. However, the precise estimation of carotenoid (Car) content with nondestructive spectral measurements has so far not reached comparable accuracies.

In this study, we examined the potential of a recently developed angular vegetation index (AVI) in combination with spectrometer data to estimate total foliar Car content of three tree species. From an iterative search of all possible band combinations, we identified a best candidate AVIcar. AVIcar showed quite close but essentially not linear relation with Car contents of the species under examination. The index showed increasing sensitivity to high Car content and a lack of sensitivity to low Car content for which earlier proposed vegetation indices (VI) performed better. To exploit the advantages of both VI types, we developed a simple merging procedure, which combined the AVIcar with two earlier proposed carotenoid indices. The merged indices showed close linear relationship with total Car content and outperformed all other examined indices. The merged indices accurately estimated total Car content with a percental root mean square error (%RMSE) of 8.12 % and a coefficient of determination (r^2) of 0.88. These findings were confirmed with simulated data created by the radiative transfer model PROSPECT 5. For these artificial data, the merged indices again showed a quasi linear relationship with Car content. This leads us to the conclusion that the proposed merged indices have a general ability to accurately estimate foliar Car content.

It is desirable to further examine the ability of the proposed merged indices to estimate foliar Car content of other plant species and to conduct further investigations on the potential limitations of the index on other spatial scales.

Condition of dominant arborescent species of Bialowieza National park in Poland

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Keywords: Bialowieza, fluorescence, spectral reflectance, condition, vegetation indices

Being one of the most significant Polish reservoirs of nature, Bialowieza National Park is the only Polish natural property enlisted by UNESCO as World Heritage site. The Park is located in north - eastern part of the country, along the Polish-Belarusian border. It covers area of 10 517 ha, of which 5725 ha are under strict protection. Bialowieza Park is a mixed forest of a primaeval character, distinctive for its immense biological diversity and a remnant of Central European lowland forests area. Regular, non damaging monitoring of its condition is extremely important to inspect potential threats and to preserve the habitat in its natural state.

The study shows an attempt of using remote sensing techniques and equipment to investigate condition of dominant arborescent species of Bialowieza National Park. The measurements took place in different vegetative periods, which were May, July and September of 2014, inside the borders of the Park. Eight test polygons on possibly homogenous areas have been selected. The dominant species were - deciduous: hornbeam, oak, alder, birch and coniferous: spruce and pine. During each campaign following measurements has been acquired: spectral reflectance curves (using ASD FieldSpec 3 spectrometer with a Plant Probe), chlorophyll fluorescence values measured in a non-adapted and dark adapted state (using OS1p Chlorophyll Fluorometer), radiation surface temperature (using infrared noncontact thermometer IRtec MINIRAY 100) and measurements of pigments content, including chlorophyll level (using Dualex chlorophyll meter).

The measurements were used to evaluate the condition of each of the species by calculating vegetation indices (among many others NDVI, SR, ARVI, PRI, SAVI), assessing whether species photosystem was stress-affected and determine if the specie is under water stress. The values have been analyzed to determine which data present statistically significant changes between different vegetative periods and to estimate correlations between direct parameters describing health conditions of plants and those derived through remote sensing based indices.

The research was conducted as part of the WICLAP Project, funded from Polish-Norwegian Research Programme.

Development of a Spectral, Structural and Site Specific Feature Data Base for Mapping of Tree Species in the Bavarian Forest National Park

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Keywords: tree species, feature data base, Random Forest

Forest inventory is one of the main tasks for the maintenance and management of a forest environment. The Bavarian Forest National Park is a unique area of forests that developed with low anthropogenic interference into a landscape with remnants of a primeval forest. Thus, there is a high interest of the National Park authority to investigate the composition and development of the forest ecosystem. Conventional forest inventories are time-consuming and mainly focus on the economic value of a forest. Our goal is to develop advanced techniques based on hyperspectral remote sensing in combination with other remote sensing and in-situ measurements for species mapping that meet the demands of the National Park and emphasize the ecological value of a forest. These advanced techniques need to be adapted to the heterogeneous appearance of the forest comprising larger standing and lying deadwoods as well as lack of larger pure species stands.

Previous studies showed that the combination of hyperspectral and LiDAR data can bevery effective and accurate for tree species classification. However, the quality of classification is limited by different factors, e.g. high intraspecies spectral variability and interspecies spectral similarity. Objective of this study is to develop a feature data base for improved tree species mapping using image based spectral information, LiDAR based structural information like tree height, terrain information as well as botanical information.

The study is based on airborne hyperspectral data acquired simultaneously with both the HySpex-VNIR 1600 and HySpex-SWIR 320i sensors on 22nd and 27th of July 2013. A total of 29 lines were collected and two mosaics, which cover in total 65% of the National Park, were generated. Additional high resolution orthophotos and Full Waveform LiDAR data, including a Digital Surface Model, Digital Terrain Model and a Digital Canopy height Model, were provided by the National Park. Individual tree crowns as well as clusters of tree crowns from 14 different tree species were located and identified during a field survey in November 2014. By overlaying the pre-selected and field-demarcated tree canopies with the hyperspectral data and LiDAR height models, the tree species spectral and structural libraries were created and used as one input for the analysis. In addition, a spectral library consisting of ASD tree crown measurements provided by the Institute of Forest Management of TUM was included for validation purposes.

The potential and limits of tree species mapping will be elaborated by analyzing the feature data base with Principal Component Analysis to identify the most appropriate bands for species discrimination and Random Forest as classification model. Different input parameters and predictor datasets, consisting of spectral and structural data about tree species, will be investigated to ascertain which variables enhance the Random Forest classification model.

This work aims at building a model transferable to an area wide mapping of tree species based on the needs of the Bavarian Forest National Park. It reveals the requirements for tree species mapping and shows which spectral/spatial features and data composition generate the best results.

O4-Eco: Ecosystem Services and Disturbances Part 1

Ecosystem service mapping using imaging spectroscopy: Where do we benefit from ecosystems?

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Keywords: Imaging spectroscopy, APEX, Gross primary production, Ecosystem services

Humans rely on indispensable goods and services provided by ecosystems, e.g., flood protection, climate regulation, and provisioning of food or fresh water. Profound modifications of biological or physical processes in ecosystems due to environmental changes influence biogeochemical cycles and consequently affect the quantity and quality of ecosystem services (ES) as well as human well-being.

Monitoring changes of ecosystem functioning and related ES is essential since they allow assessing the complex feedbacks between human impacts on ecosystems and related consequences to humans benefiting from ecosystems. Further, ES maps provide additional information for decision-making in landscape planning, land management and conservation. However, this knowledge is missing due to a lack in continuous and detailed ES mapping approaches as most of them are based on discrete land cover data in combination with in-situ measurements, expert knowledge or literature research.

Remote sensing, in particular imaging spectroscopy (IS), can overcome the problem of discrete ES mapping. However, the majority of current RS research is limited to purely quantitative biogeophysical estimations of ecosystem variables neglecting the next step of estimating ES based on them. We demonstrate the capability of IS data to map ES by applying the ES cascade approach (Haines-Young and Potschin 2010) that assesses ES based on ecosystem processes. We particularly focus on ecosystem carbon uptake due to plant photosynthesis (gross primary production, GPP) as one of the most important processes within terrestrial ecosystems and (i) quantify GPP-related service provisioning in terms of climate regulation, food and timber supply, and (ii) evaluate the spatial distribution of GPP-related ES.

Airborne Prism Experiment (APEX) imaging spectroscopy data was used to assess GPP at landscape level continuously covering a land cover gradient from semi-natural ecosystems to urban areas for Zurich (Switzerland) and its surrounding region. GPP was estimated for selected land cover types (forest, grassland and crops) from APEX data following an approach of Gitelson *et al*. (2006) that utilizes the close relationship between GPP and the total chlorophyll content of vegetation and the incoming photosynthetic active radiation PAR_{in}. The resulting land cover specific continuous GPP maps were used in combination with mechanistic models to estimate the aforementioned productivity-related ES.

Our resulting ES maps demonstrate the high spatial heterogeneity in the provisioning of three different ES. By considering the trade-offs between the quantified ES and by relating ES supply to biodiversity data, additional information is provided to evaluate the importance of ecosystems. Those make spatially explicit ES maps a valuable complementary input for land management, land use planning and conservation.

REFERENCES

Gitelson, A.A., Viña, A., Verma, S.B., Rundquist, D.C., Arkebauer, T.J., Keydan, G., Leavitt, B., Ciganda, V., Burba, G.G., & Suyker, A.E. (2006). Relationship between gross primary production and chlorophyll content in crops: Implications for the synoptic monitoring of vegetation productivity. *Journal of Geophysical Research D: Atmospheres, 111*

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. In D. Raffaelli, Frid, C. (Ed.), *Ecosystem Ecology: A New Synthesis* (pp. 110-139). Cambridge: Cambridge University Press

A tale of bees, flowers, and spectral data – mapping plant pollination traits with imaging spectroscopy

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Keywords: ecosystem functioning, grassland, plant traits, vegetation

Imaging spectroscopy is a powerful tool to map and monitor functional ecosystem properties. In particular leaf traits such as the specific leaf area, leaf biochemistry, or structural properties of the canopy are frequently targeted. In contrast, our current knowledge on remote sensing of flowering and pollination traits is very limited.

This study thus addresses the following questions for an extensively used mosaic of grasslands and mires in Southern Bavaria, Germany:

- How are pollination traits distributed across the occurring vegetation types?

- Are pollination traits in the study site correlated with optical traits that account for a characteristic spectral signature?

- Can we map spatial patterns of pollination traits with imaging spectroscopy?

To answer these questions, 100 vegetation records were sampled across the study site. Pollination traits of the occurring species were extracted from trait data bases. Simultaneously, imaging spectroscopy data were acquired with the airborne sensor AISA Dual. After preprocessing, these data covered the spectral range from 530 nm to 2340 nm in 274 spectral bands with a spatial resolution of 2 m x 2 m pixel size on the ground. The data sets were analyzed using ordination techniques and Support Vector Machine regression. The results show that correlations between optical and pollination traits exists and enable a detailed mapping of the related functional vegetation patterns.

Discriminating invasive plant species, Polypogon monspeliensis and Phoenix dactylifera, in arid wetland ecosystems of Australia using Multiple Endmember Spectral Mixture Modelling

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Keywords: Wetland management, invasive species, multiple endmembers, MESMM

The arid wetland ecosystems of central Australia support a number of rare and relic endemic flora. These iconic wetlands are fed by the Great Artesian Basin one of the largest groundwater aquifers in the world. These wetland ecosystems are facing threats from invasive species,annual beard grass (*Polypogon monspeliensis*) and date palms(*Phoenix dactylifera*), which out-compete and displace the endemic flora and fauna and consume large volumes of groundwater. This situation is compounded by current and projected future groundwater extractions for mining operations. Our research focuses on Dalhousie Springs Complex, a significant site for conservation and biodiversity within Australia and internationally. The complex covers approximately 19,000 ha, situated in the remote north of South Australia. Its extensive wetlands are fed by the largest groundwater flows in the Australian arid zone, and support dense stands of white tea tree (*Melaleuca glomerata*) and Common Reeds (*Phragmites australis*) with sparser communities of rushes and sedges (*Baumea* spp., *Cyperus* spp., *Sporobolus* sp.).

This paper evaluates Multiple Endmember Spectral Mixture Modelling (MESMM) for discriminating the extent and distribution of the invasive species annual beard grass and date palms within wetland vegetation using HyMap imagery. HyMap imagery was acquired in September 2014 to capture the greatest contrast between the invasive plants and other wetland vegetation species, particularly Common Reed (*Phragmites australis*). The HyMap imagery comprises 126 wavebands of approximately 15 nm bandwidths over the 450 – 2,500nm range, a 3 m ground sampling distance, and swath width of 1.5 km. The imagery was provided as a georegistered, colour-balanced mosaic, radiometrically corrected using the ATCOR algorithm. Four waveband (visible, near-infrared), mosaicked UltraCAM aerial photography was acquired concurrently at 15 cm resolution, with a 1 m digital elevation model (DEM) product. The aerial photography provided additional detail of the on-ground sample sites, and the DEM was used to terrain-correct the MESMM. Field spectra were collected in October 2014 using an ASD FieldSpec Pro. Spectra recorded included annual beard grass (photosynthetic, senesced and mixed), date palm (shaded and non-shaded), white tea tree (leaves and flowering), and salt couch grass (photosynthetic and sensed). Spatial locations of field measurements were recorded with GPS. Spectral libraries of multiple endmembers (derived from field spectra and image reference polygons) were created, comprising reflectance signatures representing within-species variation of the invasives and species of possible spectral confusion (salt couch grass and white tea tree). The most representative were selected using Endmember Average RMSE, Minimum Average Spectral Angle and Count Based Endmember selection.

Preliminary results indicate that it is possible to discriminate annual beard grass from salt couch grass and date palms from white tea tree. The collection of pure spectra representing within-species variation of the invasive plants assisted with their discrimination from other wetland vegetation, improving on previous mixture tuned matched filtering analyses to map their abundance, extent and distribution.

Application of the HySpex imaging spectrometer in a laboratory set-up for the automated qualification and quantification of microplastic particles from natural water samples

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Keywords: plastic debris in aquatic ecosystems, microplastics, close-range imaging spectroscopy, identification and differentiation of polymers

Recently, plastic debris has received increased attention as it has been detected in aquatic ecosystems across the world while posing risk to the biota. Once plastic litter enters natural environments, various degradation pathways cause the formation of tiny fragments down to the micrometer and nanometer scale, facilitating their consumption by aquatic organisms. Those so-called secondary microplastics (< 5 mm) persist in the environment due to their stability. Moreover, so-called primary microplastics that are engineered for applications in several personal care products, such as toothpaste or facial scrubs enter aquatic ecosystems mainly via sewage treatment plant effluents.

In order to identify sources, sinks and pathways of plastic litter different workflows have been established (Hidalgo-Ruz *et al*. 2012). According to Hidalgo-Ruz *et al*. (2012) the most reliable method for identifying and quantifying microplastic particles from waters and sediment samples is by using spectroscopy. Most studies use Raman micro-spectrometers or Fourier transform infrared (FT-IR) micro-spectrometers whereas a third technique, short-wave infrared (SWIR) spectroscopy, is well established in the recycling industry and used for the automated separation of different plastic types (Eisenreich 2000). Compared to the other methods SWIR imaging spectroscopy has the potential of fast processing while being completely automated whereas its drawback is the relatively large pixel size (e.g., 230 µm for the HySpex SWIR-320m-e sensor using a 30cm close-up lens compared to some tens of micrometers for FT-IR micro-spectrometers and some nanometers for Raman micro-spectrometers).

In this study we use the HySpex SWIR-320m-e sensor in a laboratory set-up for the detection and identification of microplastic particles that were extracted from natural water samples by filtration onto glass fiber filters. An automated spectral feature-based algorithm is used for particle detection followed by an image segmentation algorithm to enable automatic counting of particles. Finally, we compare different classification methods for their ability to distinguish different plastic types commonly found in natural samples (e.g., PE, PP, PS, PET). Moreover, synthetic filters are prepared using different particle sizes, colors and transparency levels for each plastic type to assess possible limits of the approach by classification assessment using confusion matrices.

Eisenreich N, Rohe Th (2000): Infrared Spectroscopy in Analysis of Plastics Recycling. In: Meyers RA (ed.) Encyclopedia of Analytical Chemistry. John Wiley & Sons Ltd., Chichester, UK, Vol 9, S 7623–7644.

Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M. (2012): Microplastics in the marine environment: a review of the methods used for identification and quantification. Environ Sci Technol. 46(6): 3060-3075. doi: 10.1021/es2031505

PROSAIL model in simulating reflectance from field measurement and APEX reflectance on heterogeneous mountain non-forest communities – first results

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Keywords: RTM, PROSAIL, non-forest communities, APEX, field measurements

Monitoring of vegetation cover, especially in mountain and protected areas, is an important indicator of local and global changes, because it shows interactions of different abiotical components, which shouldn't be interrupted by anthropopressure .

The aim of the study was to check the possibility to use Radiative Transfer Model to simulate the reflectance of very diverse mountains non-forest communities. Radiative Transfer Models are physically based models which describe the interactions of radiation with the object. Models are often applied to vegetation modelling. After successful inversion of the model it is possible to retrieve biophysical variables.

The analyses were conducted in Karkonosze Mountains (Giant Mountains) in the Krkonoše National Park in Czech Republic and in Karkonoski National Park in Poland. Non-forest mountain heterogeneous communities were analysed in the researches: meadows ecosystems (20 polygons), alpine swards (8 polygons), synanthropic communities (7 polygons) and dwarf shrubs (2 polygons).

The PROSAIL model was tested to simulate the reflectance on canopy level. PROSAIL was previously used to model the grasslands biophysical variables quite successfully, but the analysed ecosystems are more homogeneous.

During field measurements in August 2013 were collected reference spectrum using ASD FieldSpec 3 and biophysical parameters as input parameters to the model for 37 polygons. Also APEX images were acquired with spectral reflectance 288 bands in range from 400 to 2500 nm. On APEX images was done radiometric, geometric, atmospheric and topographic correction.

Then, PROSAIL model was used to simulate the spectrum on each polygon. Parameterisation was done based on acquired biophysical parameters. Than simulated spectral reflectance were compared with reference spectrum. The accuracy was tested based on two different dataset: firstly, using reference spectrum from field measurements and secondly, using spectral reflectance acquired from APEX images for each polygon. To check the accuracy were calculated RMSE values for whole spectrum 400-2500 nm and at specific ranges: 400-600, 400-800, 800-1500 and 1500-2500 nm.

The results showed that the PROSAIL model can be used for simulation reflectance of mountains non-forest communities, but it is necessary to make adjustments in the model. Quite small errors in modelling were noticed in visible light (both ranges 400-600 and 400-800 nm), the biggest in the near infrared. Worse results were noticed based on APEX data. Proposed parameterization makes possible to retrieve biophysical parameters like pigment content. Analysed plant communities are very diverse, with different structure and density cover. Probably that is why the model is not successful enough in modelling the reflectance.

O5A-Soi: Soils and Minerals Part 1

Soil imVisIR – Quantification of soil organic matter fractions in undisturbed soil profiles

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Keywords: Soil, soil organic matter, chemical composition

Organic matter (OM) is an important soil component controlling many chemical and physical properties ranging from nutrient and pollutant sorption to aggregate stability and water holding capacity. Advanced techniques and sophisticated methods have been developed to characterise and separate qualitatively different fractions of soil organic matter (SOM). Despite its importance and the technical progress, two main deficiencies still constrain the comprehensive analysis of OM quantity and quality in soils: 1) Most of the techniques (e.g. solid state 13C NMR spectroscopy or fourier-transformed infrared spectroscopy) are destructive so that the sample is lost after the measurement; and 2) SOM quantity and quality generally show a heterogeneous spatial distribution across many scales which is not considered in an adequate way in most studies since the analytical techniques require substantial amounts of soil material impeding the sampling of small structures. Therefore, a fast imaging technique that measures SOM quantity and quality in a non-destructive way with a high spatial resolution on the pedon scale is required.

We sampled two different sites in a semiarid steppe in Inner Mongolia, China - one continuously grazed site and the other ungrazed since 1979, with both classified as calcic Chernozems. Longterm grazing is expected to decrease carbon contents and the most pronounced particulate organic matter (POM) fractions. Stainless steel boxes ($100\times100\times300$ mm^3) were used to sample undisturbed soil profiles. Two hyperspectral cameras recorded the visible, near and short wave infrared reflectance (400 to 2500 nm in 416 bands) of the profiles with a ground sampling distance of 63×63 µm^2 per pixel for VisNIR and 256×256 µm^2 per pixel for SWIR. This procedure was repeated over three vertical slices at a lateral distance of 25 mm through the soil boxes. After each image recording the profile was divided into ten equal squares (each 50×50 mm^2) and mixed samples were extracted from each square to a depth of 5 mm. We used three image processing approaches to spectroscopically identify and quantify different SOM fractions and validate these results with density fractionation, which is a standard lab approach to separate SOM fractions with different degrees of decomposition and chemical compositions. We show the potential of laboratory imaging VisNIR-SWIR spectroscopy for the qualitative and quantitative mapping of SOM fractions on the pedon scale.

Imaging Spectroscopy and Accurate Prediction of Highly Weathered Soils Properties: The Influence of Fractional Vegetation Cover

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Keywords: reflectance spectroscopy, hyperspectral, pedometrics, soil properties, fractional vegetation cover

Imaging spectroscopy (IS) can provide spatially continuous information with a high density and imagery obtained can be used to assess soil properties, as performed using laboratory or field-based spectroscopic approaches. These methods are fast, require little labor and may reduce the amount of laboratory waste produced when compared to conventional methods (only soil sampling and wet-chemistry analysis). However, predictions of soil properties based on IS can have poor accuracy specially when soil reflectance mixes with these of other targets, such as photosynthetically and non-photosynthetically active vegetation. Therefore, in this work the performance of data obtained by an airborne hyperspectral sensor (ProSpecTIR-VS; AISA Eagle-Hawk, Specim) is evaluated, concerning the quantification of physical and chemical properties of highly weathered soils (i.e. Oxisols). The study area is located in Brazil (geographical coordinates 22°48'13S and 47°06'44W, Datum WGS84) and 89 soil samples (0-20 cm depth) are collected in 6 fields over this area (a total of approximately 2 ha) in order to evaluate the following soil properties: pH, organic matter (OM), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), aluminum (Al), potential acidity (H+Al), sum of bases (SB), cation-exchange capacity (CEC), base and aluminum saturation (V% and m%, respectively), clay, sand and silt contents. A methodology to assess the soil spectral mixture is adapted and a progressive spectral dataset selection procedure, based on bare soil fractional cover, is proposed and tested. Satisfactory performances are obtained specially for the quantification of clay, sand and CEC using airborne sensor data (R^2 of 0.77, 0.79 and 0.54; RPD of 2.14, 2.22 and 1.50, respectively), after spectral data selection is performed; although results obtained for laboratory data are more accurate (R^2 of 0.92, 0.85 and 0.75; RPD of 3.52, 2.62 and 2.04, for clay, sand and CEC respectively). Most importantly, predictions based on airborne-derived spectra for which the bare soil fractional cover, in contrast to vegetation cover, is not taken into account show considerable lower accuracy, for example for clay, sand and CEC (RPD of 1.52, 1.64 and 1.16, respectively). Therefore, hyperspectral remotely sensed data can be used to predict topsoil properties of highly weathered soils, although spectral mixture of bare soil with vegetation must be considered in order to achieve an improved prediction accuracy.

Spectral analysis of airborne hyperspectral images of soil-hydrocarbon mixtures to retrieve total petroleum hydrocarbon content

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Keywords: hydrocarbon, soil, mixture, contamination, PLS, reflectance spectroscopy, hyperspectral images, airborne simulation

This study aims at producing total petroleum hydrocarbon content (TPH) map from airborne hyperspectral images of bare soils in the 0.4-2.5µm spectral domain. Existing methods, such as Kühn's Hydrocarbon Index [1] or Allen & Satterwhite's Normalized Difference Hydrocarbon Index [2], are not able to produce reliable quantitative maps, in particular for their not accounting for soil type. Indeed,

recent laboratory studies have shown that spectral response dynamics of soil-hydrocarbon mixtures strongly depend on some soil parameters – namely texture, mineralogy, moisture, organic matter.

To this end, more elaborated methods have recently been developed out of laboratories sample spectra. They use multivariate methods to build predictive models from a population of samples observed in controlled, laboratory conditions, in both 0.4-2.5µm [3,4] and 3-12µm [5] spectral domains. These models have been successfully applied to oil spill site samples collected on ground. However, this method has not been applied on a data set acquired by an airborne or spaceborne sensor.

In this paper, we aim at evaluating the impact of our method taking into account atmospheric effects and instrument noise and its spectral resolution. To this end, an end-to-end simulator is used to simulate the at-sensor radiance from a given on-ground spectral reflectance. Then, the corresponding signal is noised and processed to compensate for atmospheric effects [6]. Finally, our method is applied to retrieve the TPH content. The results are then compared to the initial dataset to evaluate the impact of the instrument and the atmosphere correction on the performances of our method. Two different spectral libraries from the literature are jointly used, Winkelmann's [7] and Okparanma's [3], corresponding to an amount of 150+928 spectra. The results are presented and the performances analysed.

References:

1. Kühn, F., Oppermann, K. & Hörig, B. Hydrocarbon Index - an algorithm for hyperspectral detection of hydrocarbons. *International Journal of Remote Sensing* **25,** 2467–2473 (2004).

2. Allen, C. S. & Satterwhite, M. B. Reflectance spectra of three liquid hydrocarbons on a common sand type. SPIE DSS (2006).

3. Okparanma, R. N. & Mouazen, A. M. Combined Effects of Oil Concentration, Clay and Moisture Contents on Diffuse Reflectance Spectra of Diesel-Contaminated Soils. *Water, Air, & Soil Pollution* **224,** (2013).

4. Schwartz, G. *et al*. Quantitative Assessment of Hydrocarbon Contamination in Soil Using Reflectance Spectroscopy: A 'Multipath' Approach. *Applied Spectroscopy* **67,** 1323–1331 (2013).

5. van der Meijde, M. *et al.* Detection of hydrocarbons in clay soils: A laboratory experiment using spectroscopy in the mid- and thermal infrared. *International Journal of Applied Earth Observation and Geoinformation* **23,** 384–388 (2013).

6. Miesch, C. *et al.* Direct and inverse radiative transfer solutions for visible and near-infrared hyperspectral imagery. *IEEE Transactions on Geoscience and Remote Sensing* **43,** 1552–1562 (2005).

7. Winkelmann, K.H. On the applicability of imaging spectrometry for the detection and investigation of contaminated sites with particular consideration given to the detection of fuel hydrocarbon contaminants in soil. (Brandenburg University of Technology, 2005).

O5B-Eco: Ecosystem Services and Disturbances Part 2

Remote sensing analysis of the state of trampling alpine grasslands in the Tatra National Park.

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Keywords: spectrometric measurements, alpine grasslands, fluorescence, trampling, plant stress

Alpine vegetation is susceptible to various types of stress factors. In the alpine environment, the main stressors include too high light intensity, lack of water, changing atmospheric conditions or trampling caused by increased tourist traffic. Too much stress causes irreversible cellular changes leading sometimes to death of plant cells. Studies in non-invasive manner may be accomplished by remote sensing and fluorescence methods.

During the field research spectrometric measurements were performed using a spectrometer ASD FieldSpec 3, bio-radiometric measurements of chlorophyll content (CCM-200), radiation temperature of plant surfaces (ts), thermodynamic air (ta) (pyrometer IRtec), energy storage of photosynthetically active radiation (AccuPAR) and the projection surface of leaves (LAI, LAI-2000 Plant Canopy Analyzer).

Spectrometric measurements allowed to acquire spectral characteristics of tested species of alpine grasslands and calculation of vegetation indices. The indices can present the status of the plant parameters, among others, chlorophyll, carotenoids, the amount of light used in the process of photosynthesis, or the water content in the plant. Conducting bio-radiometric measurements allowed to verify the information acquired from the spectrometer, as well as too see whether there is a correlation between bio-radiometric measurements and vegetation indices. Chlorophyll fluorescence gave information about the state of the photosynthetic apparatus, including the dynamics and the course of the processes of photosynthesis.

The objective of this kind of merged research method was to estimate the proportion of energy used by plant for photosynthesis (photochemical extinction) and emitted in the form of heat (no photochemical extinction) and on this basis to estimate how efficiently the energy of light radiation was consumed by PSII in this process. Correlation of fluorescence (t1/2; Fv/Fm) with the values of the indices allowed to properly identify the state of the plant cell and the impact of stressors on the vegetation. Correlation results from the spectrometer and the results of measurements of bio-radiometric for the studied species varied depending on the construction of vegetation.

The study was performed on vegetation of Polish mountains - sections Kasprowy - Beskid. The measuring points were located in a buffer zone of 5 meters from the trail (covering areas of the most damaged vegetation)and in a buffer above 10 meters (areas of non-damaged, reference vegetation).

The study showed statistically significant differences in the indices between the same species in the analyzed two buffers. In addition, it was observed that the vegetation located on the trails produces less of the light reaction products, showing that influence of stress does not damage completely plant cells. State of the vegetation located 5 meters from trails can be rated as good, however stressor in the form of trampling significantly reduces its condition.

The research was conducted in Assessment of vegetation damages using remote sensing (AVeReS) project granted by The European Space Agency (ESA Contract No: 4000107684/13/NL/KML)

Comparison of methods for hyperspectral change detection of pioneer vegetation in a post-mining landscape in Eastern Germany

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Keywords: pioneer vegetation, hyperspectral, change detection, HyMap

Many landscapes in Germany have been formed by mining activities and the consecutive recultivation processes. Several open-pit mines have been closed in the early 1990s and thus had to be recultivated to allow a post-mining use of these landscapes. Approaches and processes to restore the former dumpsites and mines are for instance flooding, reforestation or natural succession. These actions require a continuous monitoring. In-situ sampling on dumpsites is often expensive and time-consuming, or the sites are not accessible due to security risks. Remote sensing is a possible alternative to allow vegetation succession monitoring on these sites. Especially hyperspectral data with its high geometric and spectral resolution allows the detailed discrimination of different land cover types and change when multi-temporal data is used. However, operational methods for hyperspectral change detection are still rare.

To evaluate the potential of remote-sensing-based monitoring of pioneer vegetation on former mining sites, we compared simple post-classification comparison with different image change detection methods that have been especially designed for hyperspectral data. Change detection accuracy as well as sensitivity on alternating data quality and change types were compared for all methods. The algorithms were applied on a time series of hyperspectral HyMap data acquired in 1998, 2000, 2003 and 2009 to monitor pioneer vegetation changes on a dumpsite near Bitterfeld-Wolfen in the German federal state of Saxony-Anhalt.

During the mining activities, the surface layers have been completely degraded and the ground water table has been decreased artificially and re-rose after mining has been stopped. Thus, the area is characterized by very dynamic vegetation development of spontaneous succession, increasing soil moisture and flooding.

First, seven land cover classes (deciduous and conifer trees, species-rich and species-poor xerothermic grasslands, vegetation-free areas, water bodies, vegetation affected by water logging) were distinguished in each of the HyMap data sets using a Support-Vector-Machines (SVM) classification algorithm. Then, post-classification comparison was applied as one standard approach for image change detection. Next, three more sophisticated change detection algorithms that use multivariate statistics (Multivariate Alteration Detection / MAD, Covariance Equalization, Chronochrome change detection) have been applied.

The resulting change maps have then been investigated for correlations with the ground water level.

The results show that post-classification comparison is the most uncertain method because it accumulates the inevitable errors of two individual classifications, which are caused by noise, geometric effects and the high spectral similarity especially of the two grassland classes.

All algorithms detected changes caused by flooding or establishment of trees on former grassland areas.

Chronochrome change detection turned out to be highly sensitive on geometric inaccuracies, while MAD and Covariance Equalization are more robust approaches. The MAD algorithm was proven to be the best algorithm to detect small-scale changes of vegetation composition caused by spontaneous growth of pioneer plants on former bare soils. Covariance equalization allows the detection of plant-physiological changes caused by rising ground water and thus soil moisture before the ground water table exceeded the surface.

Characterization of Soil Erosion Stages Using Airborne Hyperspectral Data and Lidar Derived Morphometric Parameters in a Mediterranean Agricultural Area

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Keywords: soil, erosion, LiDAR, DTM, curvature

This research focuses on a rainfed agricultural area within Central Spain close to Toledo and Madrid, in which airborne hyperspectral (SPECIM AisaEAGLE & AisaHAWK) and LiDAR (Leica ALS50 (II)) data have been obtained. The region is under the influence of a Mediterranean climate and the selected study area has extended rainfed cultivations that are on soils affected by land management practices such as tillage and overlapped by water erosion processes. .In this gently undulating landscape, erosion processes lead to soil loss in the higher parts of the hill (summits, shoulders and backslopes) and to an accumulation of coarse-textured soil materials at the footslopes, which leads to a decline in soil fertility and productivity. This can be observed in the field where the topsoil (A horizon) is removed and the subsurface (B and C) soil horizons are exposed, which differ in physical and chemical properties, such as their color, pH, texture, structure or consistence, and coarse fragments, iron oxides, calcium carbonate and/or clay minerals content. The appearance of surface erosion features related to soil properties of the exposed underlying horizons represent different soil erosion and accumulation stages.

The goal of this study is to determine the potential of soil spectroscopy at various spatial scales linked with terrain information for the characterization of soil erosional and depositional stages associated to different surface properties. Optical remote sensing techniques from the field to the airborne scale such as soil spectroscopy and imaging spectroscopy can provide support in the identification of these surface properties based on the analysis of the soil spectra within the Visible -Near InfraRed (VNIR, 400-1000 nm) and Short Wave InfraRed (SWIR, 1000–2500 nm) regions. In these regions, major soil chemical components such as clay minerals, organic matter, iron oxides, or calcium carbonate, interact with the electromagnetic radiation and produce characteristic spectral absorption features in soil spectra that can be used to infer soil properties. The identified soil compositions can be related to erosion and accumulation stages and described in terms of their spatial distribution and variability.

The soil surface composition of the different soil erosion and accumulation stages can be complex due to the interaction of the erosion processes and the variability of lithology and landforms within the study area. Therefore, the hyperspectral analysis is accompanied by a geomorphological assessment. This includes morphometric variables derived from a digital terrain model based on the acquired LiDAR data which are related to topographical situations and used to crosscheck the optically derived soil erosion stages. Preliminary results are presented for different spatial scales from field and remote sensing analyses over selected test sites chosen as representative of the main soil types in the area, and of the main erosion and accumulation stages that could be observed. Results show that the identification and mapping of different soil horizons related to soil erosion and accumulation stages as well as slope and curvature analyses can be achieved and are consistent with the soil erosion models implemented for agricultural areas of southern Europe.

O6A-Soi: Soils and Minerals Part 2

Evaluation of the potential of a lightweight VNIR snapshot imaging spectrometer for rapid soil diagnostics.

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Keywords: snapshot spectroscopy, non-scanning, hyperspectral RPAS imaging, spectral mapping, ground truthing

RPAS based hyperspectral remote sensing is facing several technological challenges and demands innovative spectral imaging solutions. The snapshot spectral imaging both in size and performance seems to be a promising alternative to scanning imagers. This study describes how readings of the UHD 285 hyperspectral snapshot camera (Cubert GmbH, Ulm, Germany; camera with non-scanning snapshot technique in the nominal spectral range from 450 nm to 950 nm) could be utilised and enhanced for rapid soil detection and analysis. The UHD series represents a pioneer technology for RPAS and numerous feasibility studies have been initiated in Germany to figure out the potential of the technology for RAPS platforms and applications. We started in soil analysis and will extend our approach to vegetation studies next. To understand the limits and capabilities of the snapshot imaging system a controlled lab based measurement series was conducted. In our experiment the proximally sensed hyperspectral images are compared to 1D spectroradiometric data (ASD FieldSpec 4 Wide-Res, Analytical Spectral Devices, Boulder, Colorado), both acquired in the lab using raw, sieved and grinded soil samples. We then use partial least squares regression (PLS) as statistical calibration method to estimate soil organic carbon (OC), hot-water extractable carbon (HWE-C) and nitrogen (N) from the recorded spectral data. The results that we obtained in a first analysis from the camera data without micro-shadow removal were acceptable (with coefficients of determination (R^2) between 0.62 and 0.84 in the cross-validation), but only with crushed samples and when combing PLS with CARS (competitive adaptive reweighted sampling) as spectral variable selection technique. In case of high spatial and spectral resolution the proximal image measurements are strongly influenced by the micro-shadows caused by the soil surface roughness. The shadowed pixels show a small signal-to-noise ratio and thus a low information content. Our preliminary results show that R^2 values could be enhanced by 5-15% by removing these micro-shadows, which is relevant especially for in-field studies with rough soil surfaces and without soil sample preparation. Based on our results we propose a workflow for an optimised multivariate calibration of the studied soil properties from acquired image data optimized for a snap-shot imaging spectrometer.

Spectral Feature Analyses Versus Statistical Multivariate Approaches: Expected Accuracy for the Quantitative Determination of Surface Soil Properties From Hyperspectral Airborne and Simulated Enmap Images

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Keywords: hyperspectral, digital soil mapping, EnMAP satellite, spectral feature analysis, statistical multivariate regression

Soil spectroscopy based on laboratory, field, and airborne data has been shown to be a proven method for the quantitative prediction of key soil surface properties such as Soil Organic Carbon (SOC) content, clay, carbonates, and iron oxides. Different approaches have been successfully applied in local areas under clear sky and field conditions such as soils are exposed at the surface, reduced vegetation cover, homogeneous roughness and water content. In general, two main approaches have been used for soil property determination in airborne studies: 1) multivariate statistical methods such as Support Vector Regression (SVR) and Partial Least-Square Regression (PLSR), 2) physical analyses of

spectral reflectance such as continuum, slopes, and spectral feature analyses. Both types of methodologies present different conditions of use in terms of ground-truth requirements and transferability, as well as different a priori expected performances which make them use on a per case se. With the upcoming launch of the next generation of hyperspectral satellite sensors (e.g. EnMAP, HISUI, HyspIRI, HypXIM, PRISMA, SHALOM), a great capability for the production of high quality soil maps over spatially extensive areas is appearing. In the frame of the preparation for the EnMAP satellite mission to be launched in 2018, a central question at the forefront of research is the demonstration of the potential of the upcoming sensor system for surface soil properties mapping including the expected accuracy. In particular, to fulfil the entire potential of soil spectroscopy for orbital utilization, a best practice way still needs to be developed associated with a deeper knowledge on the selection of spectral extraction methodologies to be applied that are best adapted for certain soil properties and sensor characteristics.

In this paper, airborne imaging spectroscopy data from several test sites are used to simulate EnMAP satellite images at 30 m scale. Two types of soil algorithms that were recently released for free are applied on an 'operational' basis reducing manual interaction to the minimum: The physical extraction of spectral features based on the HYperspectral Soil Mapper (HYSOMA) software interface (www.gfz-potsdam.de/hysoma), and the SVR and PLSR statistical multivariate procedures implemented in the EnMAP Box (www.enmap.org/box) and in the Unscrambler® X software (www.camo.com, only PLSR). Finally, quantitative soil maps are derived based on field calibration, and results are compared with ground-truth validation data. Different performance indicators are computed to evaluate the prediction capabilities for quantitative SOC, clay, iron oxide mapping at airborne and EnMAP scale. The results show variable outcomes with soil prediction model accuracy varying from very good (R2 ~0.85-0.90) to medium-poor (R2<0.4) depending on algorithms used, soil property in question, and the test site. In general, the results show the high potential of upcoming spaceborne hyperspectral missions for soil science studies. Nevertheless, high care must be used and further studies are needed to clarify for the user best-practice methodologies and availability of associated operational and repeatable algorithms that are suitable for each application.

Hyperspectral analysis and mapping of iron and steel work by-products

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Keywords: reflectance spectroscopy, hyperspectral imaging, terrestrial laser scanning, raw material, heap, dump, outcrop

The importance of raw materials and their availability for industry and the economy is an ongoing issue affecting society. To reduce imports and the unpredictability associated with the global market, international and national initiatives have been launched to exploit new resource deposits, with special focus on identifying and exploring pre-existing anthropogenic metal stocks and the development of recycling strategies for those materials. These stocks include former dump sites of secondary products and residue from metallurgical smelting processes, such as slags, sludge and ashes from the iron and steel industry, which can bear economically important quantities of metals and other materials. However, in many cases the historic treatment and deposition of such materials on dumpsites is not well-documented or known, resulting in uncertain distributions of materials.

In this study, aiming for the detection of economically important materials, an innovative combination of laboratory reflectance measurements, hyperspectral imaging and laser scanning has been applied to explore and analyse iron and steelwork dumpsite materials. The dumpsite, which is located in Thuringia, Germany, is part of an electric steelworks with a long history of iron and steel production.

Since limited information about the reflectance properties of relevant materials is available, a spectral library of different iron and steelwork by-products has been generated based on a wide variety of samples. This has been carried out using systematic full range spectrometer measurements (350-2500 nm) in the laboratory to characterize the spectral responses. In a second step, the spectra have been analysed for absorption features and linked to results from chemical analysis and X-Ray diffraction (XRD). To map and classify the spatial distribution of materials with varying raw material contents, close range hyperspectral images of an exposed cross-section with multiple layers of slags and sludges from earlier iron and steel production phases were acquired using a HySpex SWIR-320m (1300-2500 nm). In addition, integration of 3D terrestrial laser scanning data combined with conventional digital imagery is used as a spatial framework for the hyperspectral data, allowing novel fusion products for processing and validating spectral results.

The results show that hyperspectral methods are suitable tools that can be used to distinguish and analyse industrial by-products from iron and steel production. The application of close range terrestrial imaging at the dump site indicated that the spatial distribution of several by-products associated with different metal contents could be successfully mapped. This has the potential to improve the assessment of existing raw material stocks for potential recycling or reuse, as using hyperspectral imaging aids the separation of layers of contrasting metal content.

Acknowledgements:

The presented research is part of the project REStrateGIS and funded by the German Federal Ministry of Education and Research (BMBF, funding code 033R103B) and embedded within the r³-initiative. Additional travel costs are covered by the German Academic Exchange Service and the Research Council of Norway through the bilateral DAAD PPP programme (project 225192).

Quantification of Soil Organic Carbon with Hyperspectral Imaging Data – A case study from Saxony-Anhalt, Germany

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Keywords: soil organic carbon, hyperspectral imaging

Background: Soils are sources and sinks of organic carbon and therefore a key component of the carbon budget (Smith 2008). Carbon sequestration in the pedosphere and biosphere effects several fields such as climate change (greenhouse effect), ecosystem services (food security, energy security and water scarcity) or nature conservation aspects (Lal *et al*. 2012). The observation and documentation of changes in soil organic carbon (SOC) in the topsoil of cropland can provide a more accurate understanding of the terrestrial carbon budget. The case study is located in Saxony-Anhalt in Germany. The two fields are characterized by intensive agricultural use. The aim of the study is a further development and application of the analysis of hyperspectral data for the quantification of soil carbon in arable land using airborne hyperspectral imaging data (AISA EAGLE/HAWK (DUAL)).

Methods: The study uses ground truth information and hyperspectral data for the geostatistical modelling approach. Ground truth data is modelled by means of principal component regression (PCR) and regression boosting (RB). Model components are selected by stepwise variable selection. The models fitted to the two fields are first validated internally by cross validation within each field. In addition, the model from field 1 is validated on field 2, and vice versa. The goodness of fits are decribed by the coefficients of determination R and the root mean square error.

Results: In both fields, the PCR and RB models can improve prediction accuracy compared to that of the best individual hyperspectral channel, yielding and correlation coefficients R^2 of 0.78 and 0.81,

respectively. Validation of the model from the one field in the other field did not yield a significant correlation between true and predicted soil carbon ($R^2 = 0.26$), while is opposite direction did ($R^2 = 0.38$, $p < 0.01$). With this we show the moderate transferability of models between training field and test field, which can be helpful for further research.

References

Lal, R., Lorenz, K, Hüttl, R.F, Schneider, B.U. & J. v. Braun (2012): Terrestrial biosphere as a source and sink of atmospheric carbon dioxide. In: Lal, R, Lorenz, K, Hüttl, R.F, Schneider, B.U. & J. v. Braun [Eds.]: Recarbonization of the Biosphere. Ecosystems and the Global Carbon Cycle. Dordrecht, Heidelberg, London, New York.

Smith, P. (2008): Land use change and soil organic carbon dynamics. Nutrient Cycling in agroecosystems 81(2), 169-178.

O6B-THy: Thermal Hyperspectral Remote Sensing of Vegetation

Species discrimination using emissive thermal infrared imaging spectroscopy

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Keywords: Hyperspectral Thermal Infrared, Species Discrimination, Temperature and Emissivity Separation

Discrimination of plant species in the optical reflective domain is hampered by the similarity of their reflectance spectra. In the Thermal Infrared (TIR), plants were often considered featureless. Recently, distinct emissivity features have been detected using directional-hemispherical reflectance measurements in the laboratory. This study explores, if the accurate discrimination of a plant species is possible using a faster and more flexible technique, namely emissive thermal infrared imaging.

Hyperspectral thermal infrared images were collected using a passive emissive imaging spectrometer (Telops Hyper-Cam LW) in the 7.7 to 11.8 µm region at 40 nm spectral resolution (@10µm) over 56 plants of eight different species. The images were radiometrically calibrated and subjected to temperature-emissivity separation (TES) using the spectral smoothness approach. The emissivity spectra retrieved were compared to lab reference spectra. The spectra were used for species discrimination using a random forest classifier. For comparison, the same samples were collected in the VIS-SWIR spectral domain.

For six of the eight species the emissivity spectra measured by emissive TIR imager show very good agreement to the laboratory reference spectra (Nash-Sutcliffe-Efficiency Index > 0.70). In species classification, TIR data (OAA=89%) outperformed VNIR data (OAA=69%). Reducing the number of bands had a significant impact on the classification accuracy (OAA=89% for FWHM of 3.33 cm^{-1} OAA < 50% for FWHM > 125 cm^{-1}). Finally, the reduction to the 5 ASTER TIR bands (OAA=85%) caused no severe loss in discrimination power, suggesting that even TIR systems with moderate spectral resolution are useful for plant species discrimination.

These results largely confirm those obtained from lab DHR measurements and demonstrate that emissive TIR imaging offers the possibilities for fast and spatial measurements of plant emissivity spectra with accuracies comparable to laboratory measurements.

Changes in Thermal infrared spectra of plants caused by temperature and water stress

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Keywords: thermal infra red, vegetation, temperature stress, water stres, FTIR, spectroscopy

Stress in plants generates changes in leaves from decreasing water content to changes in the internal composition of the leaf, the structure of the plant and the community. Although the physiological changes are known, the effect of these changes on the thermal properties of plants, and the spectral detection by remote sensors has not been demonstrated yet.

This research shows the results of a series of laboratory experiments where plants were subjected to water and temperature stress, and the spectral changes in the thermal infrared (TIR) signatures were recorded. Two plant species (European beech, *Fagus sylvatica* and Rhododendron, *Rhododendron sp.*) were selected as proxies for deciduous and evergreen plants, respectively. Five individual leaves of each plant were tracked through the treatment process, and the spectral emissivity was measured at the beginning and the end of each treatment.

The results show that both species, when exposed to water and temperature stress, have significant depletion of Leaf Water Content (LWC) and significant spectral changes in distinct sections of the thermal infrared, compared to plants with optimal growing conditions.

All plants under stress suffered desiccation and showed changes in the Mid-Wave Infrared region (MWIR: 3-6 µm) of their spectra. Beech showed significant LWC loss and an overall decrease in emissivity (7.1% of the spectral contrast) in the MWIR. Rhododendron showed an overall increase in emissivity (4.0% of the spectral contrast) in the MWIR region. These spectral dissimilarities in the MWIR region, known for a strong positive correlation with LWC from studies of fast dehydration, suggests the long term stress in this study must be causing leaf adjustments other than LWC that cause the opposite spectral response for Rhododendron.

In the Long-Wave Infrared (LWIR: 6-16 µm) the spectral response is known for have a closer connection with microstructure and biochemistry of the leaves. Also here we observed an increase in emissivity for rhododendron, which may be linked to changes in the composition, texture, thickness or water distribution in the cuticle. We propose more detailed measurements of these morphological changes to analyze their effect on LWIR emissivity.

Thermal Hyperspectral Remote Sensing for Pre-Visual Water Stress Detection

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Keywords: Thermal Infrared, Hyperspectral, Water Stress

Today, agriculture consumes more than 70 percent of the worldwide fresh water. As it is well known, water stress is one of the most critical abiotic stressors limiting plant growth, crop yield and quality concerning food production. Stomatal aperture directly controls plant transpiration, which is negatively correlated with plant temperature. Since stomatal closure is a first response to plant water deficit, thermal remote sensing offers the capability to detect plant water stress pre-visual (‘before seeing’, e.g. changing leaf color) by using temperature-based indices, such as the popular crop water stress index (CWSI).

Considering spectral emissivity and the possibility of an advanced temperature and emissivity separation (TES), we hypothesis that using a hyperspectral thermal infrared imaging system (Telops HyperCam-LW) temperatures and therefore, water stress can be derived more accurately in comparison to a broadband thermal camera (Fluke Tir1) with the assumption of a constant emissivity value (e.g. ε=0.95 for vegetation).

During 15th and 30th July 2014 an outdoor water stress experiment on single potato plants (n=60) was conducted under (semi-) controlled conditions. Twowater treatments (n=30 each), non- and fully-irrigated, were conducted during the end of flowering and the beginning of tuber initiation, when water consumption is highest. Hyperspectral thermal measurements (Telops HyperCam-LW) were taken from a tripod at a height of approx. 2 m, in order to minimize atmospheric disturbance and to ensure the use of a spectral smoothness TES-approach. Co-registrated thermal broadband images were taken using Fluke Tir1. As a plant physiological reference for water stress detection, stomatal conductance measurements using an ADC LCi porometer were performed on every fifth plant (n=12). Considering that clear sky weather conditions are needed to achieve comparable datasets, seven non-continuously points of measurement (DOY: 197, 198, 199, 204, 205, 206, 212) were collected during this 2 week period.

Preliminary results show, that water stress occurred from DOY 199 onwards according to stomatal conductance measurements with significantly different values for watered and non-watered plants (t-test, p = 0.04 at 95% conf. level, n=12). Applying a simple temperature based index (T_{canopy} - T_{air}) derived from Fluke Tir1, control and treatment could be significantly separated starting the next date (DOY 204; p = 0.01 at 95% conf. level, n=12). Regarding the highly accurate temperatures and temperature-based indices derived from hyperspectral images we expect to detect water stress at the minimum from DOY 199. Traditional (VNIR/SWIR) based indices seem to have a more limited detection of water-deficit stress at later dates.

Based on the findings of this experiment further studies at field- and airborne scale will be conducted to demonstrate the applicability of the approach at larger scales.

Estimation of Leaf Area Index from Hyperspectral Thermal Data

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Keywords: Thermal infrared, Emissivity, Leaf area index, Vegetation biophysical parameter

Vegetation leaf area index (LAI) is a key biophysical variable related to photosynthesis, transpiration and productivity. The importance of hyperspectral data in the visible, near-infrared and shortwave infrared have been previously highlighted and they have been successfully used to estimate LAI. Recent studies have shown that hyperspectral data in the mid-wave and thermal infrared contain absorption features related to various vegetation components. However, little is known about the mid-wave and thermal infrared properties of vegetation at canopy level. Therefore, the aim of this study was to analyze the effect of biophysical parameters such as LAI on plant emissivity at canopy level. The study takes advantage of using a dataset collected during a controlled laboratory experiment. Various LAI were destructively acquired for four species in several steps. The plants spectral emissivity was measured by using MIDAC (M4401-F) illuminator FTIR spectrometer. Linear regressions were used to model the relationship between the emissivity of individual wavelength and leaf area index. Cross validation were used to assess the obtained relationships. The spectral analysis of the obtained results indicated that the emissivity of plants varies with the variation of LAI. The results of study suggest the importance of hyperspectral thermal data for estimation of vegetation biophysical variables.

Fusion of Thermal Infrared Hyperspectral image and visible RGB image for Classification

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Keywords: Thermal Infrared, Hyperspectral image, multi-resolution, data fusion

Recent advances in remote sensing (RS) sensor technology have led to the increased availability of multi-sensor and multi-resolution data from the same geographic area on the Earth's surface. In particular, hyperspectral (HS) images have the potential to provide detailed descriptions of the spectral signatures of ground covers, however they typically feature spatial resolutions of circa 1-4m. Meanwhile airborne visible RGB images may offer detailed spatial information at the *cm* level of the same surveyed area. Many techniques have been developed to fuse multi-sensor and multi-resolution RS imagery. To enhance the low spatial resolution of HS/multispectral (MS) images to the same spatial size of high resolution RGB/panchromatic (PAN) images, some of these approaches employ the so-called component substitution methods or their generalizations. Others model PAN images as a linear combination of the ideal MS bands, and restore an ideal high-resolution MS image by utilizing different regularization. Recently, some researchers combined non-linear PCA (NLPCA) and Indusion to enhance the spatial resolution of a HS image by fusing a PAN image. Their method first applied NLPCA to project the original HS data into a lower feature space, then enhanced the derived nonlinear PCs by the Indusion process; and finally retrieved the high spatial resolution HS data by inversing NLPCA. However, these approaches either suffer from spectral distortions or from high cost on computational time to yield satisfactory solutions.

We proposed a image fusion framework by using guided filter in PCA (principal component analysis) domain. Instead of using component substitution which may cause spectral distortions, our approach uses a high resolution RGB image to guided filter the super-resolution of low spatial resolution HS image. By guided filtering the super-resolution process, our approach can not only preserve the spectral information from the original HS image, but also transfer the spatial structures of high resolution RGB image to the enhanced HS image. To speed up the processing time, our method first uses PCA to decorrelate the HS images and separate the information content from the noise, we use cubic interpolation and guided filter to only enlarge the first few PCA channels and preserve the structures of RGB image.

Experimental results on fusion of a low spatial resolution Thermal Infrared HS image and a high spatial visible RGB image of the same scene from the 2014 IEEE GRSS Data Fusion Contest show effectiveness of the proposed method. Compared to the methods using cubic interpolation and component substitution, our proposed method has more than 10% improvements in overall classification accuracy. Moreover, our approach won the Best Paper Challengeof the 2014 IEEE GRSS Data Fusion Contest: http://cucciolo.dibe.unige.it/IPRS/IEEE_GRSS_IADFTC_2014_Paper_Contest_Results.htm.

O7A-Ret: Retrieval of biophysical properties Part 1

Remote estimating C3 and C4 crops biophysical characteristics

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Keywords: reflectance, absorbed radiation, leaf area index, pigment content, satellites

The quantification of absorbed photosynthetically active radiation (fAPAR), pigment contents (chlorophyll, Chl, carotenoids, Car, anthocyanin, Anth), green leaf area index and biomass, yield of vegetation brings objective measures of the size and the functionality of its photosynthetic components. Canopy Chl content is well suited for quantifying canopy level nitrogen (N) content. Chl is a physically sound quantity since it represents the optical path in the canopy where absorption by Chl dominates the radiometric signal. Thus, Chl and other pigment absorption provides the necessary link between remote sensing observations and canopy state variables that are used as indicators of N status as well as primary productivity. Success in estimating Chl content using remotely sensed data may provide equally accurate measures of N content, CO_2assimilation, RuBP carboxylase activity, radiation use efficiency and other biophysical characteristics that are necessity for accurate and reliable phenotyping.

This study presents the principles, techniques and practical methodologies for accurate, rapid remote estimating of such crop biophysical characteristics as fAPAR, green LAI, Chl, Car, Anth, N, water content, yield and GPP using simple few bands radiometers and video cameras. Firstly, relationships between reflectances in visible and NIR ranges of the spectrum and biophysical characteristics were established. Secondly, optimal spectral ranges were identified and the models allowing accurate estimation of biophysical characteristics were developed. Finally, the performance of developed techniques for irrigated and rainfed maize and soybean, C3 and C4 crops with contrasting canopy architectures and leaf structures, was tested during ten years over a wide range of leaf area index in Nebraska, US. Then, developed methods were applied for wheat, potato, rice and grasslands in other countries and climatic zones showing high accuracy and reliability of estimating crop biophysical characteristics.

Mapping tropical biodiversity using spectroscopic imagery: characterization of structural and chemical diversity using 3-D radiative transfer modeling

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Keywords: tropical biodiversity, radiative transfer modeling, CAO AToMS, HYPXIM, DART

The accelerating loss of biodiversity is a major environmental trend. Tropical ecosystems are particularly threatened due to climate change, invasive species, farming and natural resources exploitation. Recent advances in remote sensing of biodiversity confirmed the potential of high spatial resolution spectroscopic imagery for species identification and biodiversity mapping. Such information bridges the scale-gap between small-scale, highly detailed field studies and large-scale, low-resolution satellite observations. In order to produce fine-scale resolution maps of canopy alpha-diversity and beta-diversity of the Peruvian Amazonian forest, we designed, applied and validated a method based on spectral variation hypothesis to CAO AToMS (Carnegie Airborne Observatory Airborne Taxonomic Mapping System) images, acquired from 2011 to 2013. There is a need to understand on a quantitative basis the physical processes leading to this spectral variability. This spectral variability mainly depends on canopy chemistry, structure, and sensor’s characteristics. 3D radiative transfer modeling provides a powerful framework for the study of the relative influence of each of these factors in dense and complex canopies. We simulated series of spectroscopic images with the 3D radiative model DART, with variability gradients in terms of leaf chemistry, individual tree structure, spatial and spectral resolution, and applied methods for biodiversity mapping. This sensitivity study allowed us to determine the relative influence of these factors on the radiometric signal acquired by different types of sensors. Such study is particularly important to define the domain of validity of our approach, to refine requirements for the instrumental specifications, and to help preparing hyperspectral spatial missions to be launched at the horizon 2015-2025 (EnMAP, PRISMA, HISUI, SHALOM, HYSPIRI, HYPXIM). Simulations in preparation include topographic variations in order to estimate the robustness of image processing methods for mountainous ecosystems.

Estimating leaf and canopy chlorophyll content of a potato crop using Sentinel-2 data

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Keywords: Remote sensing, Chlorophyll content, PROSAIL, Vegetation indices, Sentinel-2

Chlorophyll content both at leaf and canopy level is an important variable because of its crucial role in photosynthesis and in understanding plant functioning. Remotely sensed data have shown to provide reliable estimates of chlorophyll content, particularly at the canopy level since remote sensing obtains an integrated signal over a certain area (basically the size of the resolution cell). In particular sensors providing observations in the red-edge region have shown great potential in estimating chlorophyll content, e.g. for agricultural crops. In this respect an important system for agricultural applications is ESA's Sentinel-2 equipped with the Multi Spectral Instrument (MSI). This sensor captures the red-edge region with 15-nm wide spectral bands at 705 nm and 740 nm, in addition to the traditional bands at, e.g., the red (665 nm) and NIR (783 nm and 865 nm). Spatial resolution will be 20 m for the red-edge bands and 10 m for the red and NIR bands.

In this study we tested the hypothesis that canopy chlorophyll content and leaf area index (LAI) can be estimated directly from vegetation indices, and subsequently a combination of these estimates can be used to derive leaf chlorophyll content. Various indices can be used and were tested for deriving LAI. For example, good results were obtained with the SAVI family of indices, like the Optimized Soil-Adjusted Vegetation Index (OSAVI). For estimating canopy chlorophyll content in particular indices using red-edge bands have shown good results, which was confirmed in the current study. An example of such an index is the Transformed Chlorophyll Absorption in Reflectance Index (TCARI), using red-edge bands instead of the ones in the original version of the TCARI. Subsequently, this leads to the hypothesis that the ratio TCARI/OSAVI, adapted to red-edge bands, can be used for estimating chlorophyll content at the leaf level.

The above hypothesis was tested using simulations with the PROSAIL radiative transfer model and field radiometry measurements in five consecutive years (2010-2014) for potato crops. Experimental fields with potato crops were located in the South of the Netherlands. Plots of 30 by 30 m were designed with different nitrogen fertilization levels. On a weekly basis in-situ field measurements of biomass, leaf area index and leaf chlorophyll content were performed. In addition, spectral measurements were performed with a 16-band Cropscan Multispectral Radiometer with bands located close to the Sentinel-2 bands. Using PROSAIL also a sensitivity analysis was performed towards the optimal spectral bands to be used in such a TCARI/OSAVI index combination. Results showed that good estimates of both leaf and canopy chlorophyll content are feasible using the Sentinel-2 satellite. This was also tested using RapidEye images of the study area, although RapidEye has one red-edge band less than Sentinel-2 will have. Still, this paper presents a proof-of-concept for estimating both leaf and canopy chlorophyll content using Sentinel-2 data. Results confirm the importance of the red-edge bands on Sentinel-2 for agricultural applications, in particular in combination with its high spatial resolution of 20 m.

ARTMO's Global Sensitivity Analysis toolbox to quantify driving variables of leaf and canopy radiative transfer models

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Keywords: global sensitivity analysis, radiative transfer models, ARTMO, driving variables

In this contribution, ARTMO's new global sensitivity analysis (GSA) toolbox is presented. ARTMO (Automated Radiative Transfer Models Operator) is a modular software package that consists of a suite of radiative transfer models (RTMs) and retrieval toolboxes. In ARTMO, models at the leaf scale (PROSPECT-4,-5, DLM, LIBERTY), canopy scale (SAIL, INFORM, FLIGHT) and integrations of multiple

scales (SLC, SCOPE) are brought together. RTMs have long proven useful tool for the development of spectral indices or applied in inversion strategies. At the same time, they have been applied in all kinds of sensitivity studies, e.g. in order gain improved insights in radiation-vegetation interactions, or in view of the development of new imaging spectrometers (e.g. FLEX).

Essentially, sensitivity analysis (SA) evaluates the relative importance of each input variable in a model, and can be used to identify the most influential variables affecting model outputs. SA can be applied to RTMs to identify the key determinants of outputs such as fluorescence, reflectance, etc. Less influential variables can also be identified and be safely set to default values under relatively wide ranges of conditions. In general, SA methods can be categorized as either local or global.

Unlike local SA, global SA explores the full input variable space. The contribution of each input variable to the variation in outputs is averaged over the variation of all input variables, i.e., all input variables are changed together. In general, variance-based SA methods aim to quantify the amount of variance that each input variable contributes to the unconditional variance of the model output. The most popular variance-based methods include the Fourier Amplitude Sensitivity Test (FAST), the Sobol' method, and a modified version of the Sobol' method proposed by Saltelli *et al*. (2010). In the Sobol' technique, these amounts, caused either by a single variable or by the interaction of two or more variables, are expressed as Sobol' sensitivity indices.

Within ARTMO's modular framework, we have developed a GSA toolbox that makes use of Saltelli's method. This method has been demonstrated to be effective in identifying both the *main sensitivity effects* (first-order effects) (the contribution to the variance of the model output by each input variables) and *total sensitivity effects* (the first-order effect plus interactions with other input variables) of input variables. Various sampling techniques are provided (uniform, extreme, exponential, normal, Sobol), though Sobol' quasi-random sampling technique is preferred. This sequence helps to distribute the sampling points as uniformly as possible in the variable space to avoid clustering, and increases the convergence rate. Therefore, the use of these sequences enhances the convergence of the Monte Carlo integrals.

The GSA toolbox allows to quantify and visualize the relative contribution of input variables to RTM output variables along the spectral domain (for spectral output, e.g. reflectance) or as bar charts (for fluxes e.g. FAPAR). A variety of results shall be presented to demonstrate its utility. For instance, the driving variables that determine canopy-leaving fluorescence fluxes as well photosynthesis shall be quantified.

Early indication of plant stresses by changes in vegetation indices and fluorescence

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Keywords: Sun Induced Fluorescence, Vegetation Stress, Plant Stress, HyPlant, Vegetation Indices

Photosynthesis dynamically adapts to changing environmental conditions. Extreme environmental conditions such as high temperature and water limitation directly reflect in the photosynthetic performance as vegetation stress. To monitor photosynthesis dynamics at large vegetation scales, indicators of stresses in vegetation extracted by non-invasive techniques can be used.

Spectral reflectance indices such as NDVI and PRI have been tested to provide rapid and non-invasive estimation of photosynthesis at regional scales. Unfortunately, these indices lack sensitivity to short-term vegetation physiological changes. Alternatively, a passive retrieval of sun-induced chlorophyll fluorescence (SIF) using high performance imaging spectroscopy has been suggested. SIF emission is closely related to the status of photosynthesis and therefore has the potential to track adaptation of this process to changes in environmental conditions and plant status. Although SIF emission represents a weak signal in comparison to the reflected radiation, recent research provides evidence that SIF can be measured by exploiting solar and atmospheric absorption lines using high performance spectrometers.

In this contribution, we present the design and first results of an experiment that aimed to evaluate the capability of the new remote observable SIF and common reflectance based indices to detect plant stress. In the experiment, carried out in June and July 2014 in Latisana (Italy), we treated homogeneous lawn plots to provoke different level of stress in plants. In particular, we applied the herbicide (Dicuran) in different concentrations to four plots, three other plots were treated with the anti-transpirant Vaporgard; while three remaining plots were not treated and used as control. Diurnal variations in SIF and surface reflectance were evaluated for period of two weeks, using the high performance imaging spectrometer *HyPlant*. HyPlant is a dedicated fluorescence spectrometer and allows measuring radiance in the wavelength range between 400 nm and 2500 nm with a high spectral resolution of 0.26 nm between 670 nm and 780 nm. Data was recorded for spatial resolution of 1 meter per pixel.

Airborne data was calibrated and validated using high resolution top of canopy measurements of reflectance and SIF. Vegetation indices and SIF were calculated for treated and non-treated areas and compared with corresponding ground measurements. Additional measurements of CO_2 and H_2O fluxes using chambers and an eddy covariance tower to monitor photosynthetic activity were performed.

First results show contrasting responses of emitted SIF and vegetation indices for plant stress: SIF strongly increased after the treatment with Dicuran followed by a slow decrease down to the initial values. The Meris Terrestrial Chlorophyll Index (MTCI) showed a clear decrease after the herbicide treatment. We conclude that SIF is a promising new observable sensitive to plant stress which provides complementary information to commonly used remote observables origin form reflectance spectroscopy. We suggest a combined use of SIF and reflectance spectroscopy to establish reliable approaches for rapid, early, and non-invasive plant stress detection.

O7B-Tec: New Analytical Techniques

Rigorous parametric co-registration of Airborne Hyperspectral and LIDAR intensity data using ray tracing techniques – towards a fusion of Hyperspectral and LIDAR data

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Keywords: Sensor fusion, Hyperspectral, LIDAR, geometric alignment, co-registration

Combining LIDAR and hyperspectral data refers to utilize the LIDAR based Digital Elevation Model (DEM) and the spectral information of the hyperspectral sensor. Both gridded data products are usually generated in separated preprocessing workflows. The orthorectification procedure of hyperspectral data is usually the only overlap of both workflows. However, the separation of both discretized data entities leads to a substantial loss of information and does not exhaust the full capabilities of the contrasting sensors.

A fundamental fusion of hyperspectral and LIDAR sensor characteristics utilizes geometric as well as radiometric synergies.

One of the key aspects for a proper sensor fusion is the ideal geometric alignment of LIDAR and Hyperspectral data. This study reports a geometric alignment approach focused on the co-registration of Airborne Hyperspectral and LIDAR data based on their respective intensity information. A rigorous parametric alignment procedure that co-registers the hyperspectral intensity images to the adopted LIDAR intensity images is developed. This is realized by an automated and adjustable tie point detection algorithm incorporating all adjacent flight stripes and intensity information overlaps. The iterative geometric alignment optimizes flight attitude parameters but does not require additional resampling steps. It is based on ray tracing procedures to overcome the grid inherent discretization and to ensure the highest geometric accuracy as well as the highest resolution. A ray tracing approach also establishes capabilities for further advanced radiometric and spectral sensor fusion. The generic and systematic data fusion approach results in offset free true ortho mosaics generated from high resolution hyperspectral image data. The intensity based geometric alignment is exemplarily realized for the hyperspectral sensor Hyspex and for the LIDAR sensor LMS Q680i.

New science data processing for the Next Generation Airborne Visible InfraRed Imaging Spectrometer (AVIRIS-NG): atmospheric correction, validation, and real-time analyses

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Keywords: AVIRIS-NG, Atmospheric Correction, Real Time Processing

NASA’s Next Generation Airborne Visible Infrared Imaging Spectrometer (AVIRIS-NG) is a VSWIR mapping instrument that measures the 380 to 2510 nm interval at 5 nm spectral sampling, sub-meter spatial resolution, and high Signal to Noise (SNR). Flights conducted in 2014 have validated AVIRIS-NG reflectance retrievals over varied targets in Southern California, including wilderness, urban, agricultural and coastal environments. AVIRIS-NG’s high sensitivity has tested atmospheric correction modeling assumptions, and in some cases has required new refinements to preserve fidelity of the retrievals. This presentation focuses on new elements of the AVIRIS-NG data pipeline, with demonstrations of new data products generated at timescales of seconds to hours. At acquisition, real-time onboard analysis is enabling AVIRIS-NG to coordinate experiments to observe transient phenomena, such as methane plumes from oil and gas infrastructure. Real-time reflectance processing has also been demonstrated and validated against multiple ground targets. At the archive, we are employing a new atmospheric correction method to map absorption due to water in vapor, solid, and liquid forms. This improves the accuracy of vapor estimates and the associated surface reflectance over vegetated terrain. Development is ongoing, but AVIRIS-NG has already proven a useful platform for validating and demonstrating new atmospheric correction methodology in preparation for future orbital instruments.

The Analysis of Variance in High Resolution Imaging Spectrometers and its Application to Object Based Classification

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Keywords: high resolution, object-oriented, variance, imaging spectroscopy

A challenge to tree species classification through high spatial resolution imaging spectroscopy is the high degree of variability within, and between, object reflectance for the same species and between species. This variability is the natural consequence of several factors including internal constituent composition and distribution, surface geometry, 3-D structure (including gap structure and LAI), illumination, and object size/scale. The practical consequence of this high variability is the reduced capacity for consistent characterization and classification of targeted objects. High-density LiDAR datasets provide an ability to spatially resolve objects of interest accurately. These LiDAR datasets

have provided the community with the opportunity to more confidently sample imagery, which are more spatially generalized. For forestry applications, lidar integrated imaging spectrometer datasets are capable of resolving tree crown objects, which can then be used to address questions about within object variation relative to the between object variation. Characterizing the within and between object variability lays the foundation for object characterization and classification.

To address this issue we have developed a research project that can be broken into a sequence of specific questions:

1. How can albedo-based sampling strategy optimize an object-based (individual crown) classification?
    1. Within crown reflectance variability: How do the properties of the reflectance (ie S/N and Albedo) vary over a crown surface?
    2. How does the reflectance vary between crowns of the same species?
    3. How does the reflectance vary between species?
2. How is this affected by spatial resolution?
3. What is the result of the interaction between spatial resolution and crown size?

To support this research project airborne datasets were collected from two forest stands in coastal British Columbia, Canada. These forests are either old-growth, or second growth, conifer stands composed primarily of western red and yellow cedar (thuja plicata, chamaecyparis nootkatensis), western hemlock (tsuga heterophylla), sitka spruce (picea sitchensis) and balsam/amabilis fir (abies amabilis). The differing species all exhibit various crown shapes and sizes and all exist within a broad social context within the forest environment.

The data collected included visible/near infrared (VNIR) airborne imaging spectrometer (AIS) data, discrete, high density, multiple return LiDAR data, and 15-20 cm RGB aerial photography. The AIS data were collected at 1 and 2 metre spatial resolutions. The AIS data were orthorectified through INS (inertial navigation system) and LiDAR data. The lidar data were used to define individual tree crowns and as a sampling tool to guide the AIS spectral extraction.

On the use of class-probabilities for mapping vegetation-cover fractions in natural environments with EnMAP data and machine learning

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Keywords: class-probabilities, support vector machines, imaging spectroscopy, EnMAP, natural environments

Remote sensing is a valuable technique to characterize natural and semi-natural ecosystems, which play an important role for conserving biodiversity and for providing essential ecosystem services. With the advent of the satellite mission EnMAP, frequent and area-wide land-cover mapping of natural environments by means of high quality imaging spectroscopy data will become possible. At the same time, the ground sampling distance of 30m will strongly pronounce mixing of land-cover types within single pixels. Quantitative approaches that are capable of coping with the high spectral dimensionality and spectral mixtures are, therefore, needed to make best use of the information content of future EnMAP data acquired over such spatial heterogeneous environments. Particularly, methods from machine learning have received increasing attention in the remote sensing community and performed well under similarly challenging conditions. Recently, the difficulties in deriving quantitative training information for machine learning based sub-pixel mapping approaches could be solved by integrating synthetically-mixed data into the training of support vector regression models (*Okujeni et al., Remote Sens. Environ., 137: 184-197, 2013*) as well as during parameter selection process for kernel-based probabilistic classification (*Suess et al., IEEE Geosci. Remote Sens. Lett., 11[2]: 449-453, 2014*).

This study demonstrates the value of the probability output of a support vector classification model for quantifying shrub-cover fractions in a natural environment in Portugal. Maps are derived along a spatially and spectrally heterogeneous landscape gradient of shrub encroachment based on simulated EnMAP data. To tune the model's class-probability output with respect to an optimized fraction representation, synthetic spectral mixtures representing gradual transitions from shrub to non-shrub were included into parameter selection. The resulting shrub-cover fractions are accurately mapped (RMSE ~19.3%) and of similar accuracy to those from two different support vector regression approaches, i.e., the first one trained based on spatially aggregated shrub-cover fractions from a high resolution reference map (RMSE ~20.9%) and the second one trained based on synthetic mixtures from pure spectra (RMSE ~23.1%). In addition, results reveal that the discrete class outputs improve through incorporating synthetic mixtures into parameter selection compared to the regular support vector classification implementation. Findings show that class-probabilities can be effectively used for mapping vegetation-cover fractions in natural environments with EnMAP data and adapted machine learning approaches. We briefly illustrate the concept of integrating synthetically-mixed training data and present maps including a comprehensive accuracy assessment.

EnMAP-Box Cross-Language Integration: making Python, R and Matlab Libraries available for Remote Sensing Image Analysis

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Keywords: EnMAP, Toolbox, Algorithms

The EnMAP-Box is an image processing environment designed to process hyperspectral remote sensing data and particularly developed to handle data from the upcoming EnMAP (Environmental Mapping and Analysis Program) sensor. The focus of development is on easy-to-use graphical user interfaces (GUI) for the management and visualization of hyperspectral data and the provision of state-of-the-art applications for the processing of such high dimensional data. Further it provides a rich application programming interface (API) for a comfortable development and integration of new developments, including implementations in various common programming languages. In that sense, the EnMAP-Box serves as a platform for sharing and distributing algorithms and methods among scientists and potential end-users.

The EnMAP-Box itself is programmed in the Interactive Data Language (IDL) and can be integrated in the ENVI menu structure. Recent work on the application programming interface focuses on integrating applications written in Python, R or MATLAB. This so called hubAPI is open source and offers an easy integration of full image-to-image processing chains, rather than creating a GUI for algorithm parameterization. The typical workflow for implementing new applications foresees 1) the collection of user inputs, like filenames and parameters, via the standardized GUI from the hubAPI, 2) data input either via provided API procedures or (user defined) external libraries like GDAL, 3) calling external applications and generation of results and 4) displaying resulting images and reports for further analysis within the EnMAP-Box GUI.

During our presentation we illustrate the concept for integrating external applications in the EnMAP-Box and show brief examples for users how easily they can include their own developments into the EnMAP-Box and, this way, current ENVI versions. We also present a full-blown application for mapping sub-pixel fractions from simulated EnMAP-data from Berlin, Germany, using the very common SciPy Toolkits for machine learning (e.g. for classification, regression, clustering, dimensionality reduction). Results show both the simplicity and flexibility offered by the EnMAP-Box in combination with external libraries.

O8A-Ret: Retrieval of biophysical properties Part 2

Hyperspectral synthetic scene simulator for the assessment of fluorescence retrieval with ESA's FLEX/Sentinel-3 tandem mission

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Keywords: Scene simulation, hyperspectral, vegetation fluorescence, radiative transfer, FLEX, mission simulator, SCOPE, MODTRAN

ESA's Fluorescence Explorer (FLEX) mission is a candidate for the 8th Earth Explorer whos objective is to produce global maps of sun-induced vegetation chrlorophyll fluorescence. Within the frame of the FLEX mission activities, the simulation of synthetic images is necessary to develop image processing and retrieval strategies as well as to evaluate the mission performance.

Despite synthetic scene simulators have been developed in the past, their functionality and flexibility to create user-defined scenes is limited by their architecture, design and implementation. In addition, the simulation of high spectral resolution scenes that include the vegetation fluorescence emission is a feature not incorporated in other scene simulators.

This paper introduces a scene simulator specifically designed for reproducing the FLEX mission concept, which includes: 1) high spectral resolution signal; 2) simulation of vegetion fluorescence emission; 3) multi-sensor capabilities (for FLEX and Sentinel-3 instruments). This developed scene simulator has, in addition, the flexibility to generate realistic synthetic scenes by configuration of the surface and atmosphere.

The developed scene simulator is integrated within ESA's FLEX End-to-End Mission Performance Simulator (FLEX_E) software and it is being used for the assessment of the mission performance, including sensor/platform configuration and retrieval algorithms.

Evaluation of leaf area index and dry matter predictions for crop growth modeling and yield estimation based on field reflectance measurements

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Keywords: leaf area index, biomass dry matter, field spectroscopy, hyper- and multispectral remote sensing

Yield estimations are an important source of information for food security and the assessment of the agricultural market situation, on a national and a European scale. Further, they are a valuable data base for site-specific farming. Remote sensing has the potential to offer essential supplementary information to conventional agricultural statistics and precision farming. Depending on the applied image data spatially and spectrally differentiated information over large areas can be provided. Leaf area index (LAI) and above ground biomass dry matter (DM) are two biophysical key variables for the assimilation of remote sensing data in crop growth models. High prediction accuracies of these parameters are a vital prerequisite for sophisticated yield estimations. Therefore, this study examines LAI and DM prediction performance with respect to the spectral configuration, the spectral pre-processing technique, and the composition of the data base.

The data set consists of more than 300 reflectance measurements of various crop types (winter cereals, sugar beet, potato) which were acquired during field campaigns in Lower Saxony and Saxony-Anhalt in Germany between 2011 and 2014. Canopy reflectance was recorded with field spectrometers ranging from 350nm to 2500nm on plots of 0.25x0.25m². Thereafter, crop parameters

(LAI, DM, biomass fresh matter, height, phenology) were determined for each sample plot using destructive and non-destructive techniques. The quantitative relationship between canopy reflectance and crop parameters was established by means of partial least squares regression. Statistical models were set up with respect to the spectral range and resolution, the spectral pre-processing technique, and the homogeneity of the data set.

The effect of the spectral configuration was tested for four satellite sensors: RapidEye, Landsat-8, Sentinel-2 and EnMAP. Pre-processing techniques applied comprised normalization, absorption and standard normal variate transformation. The nature of the data set was analyzed in terms of crop type, sampling region and time of acquisition. For individual fields, reflectance was acquired in addition with a ground-based mobile system (PentaSpek, 400nm-925nm). From the same day, simulated EnMAP image data were available for these fields allowing for a spatial assessment of the crop parameters.

Splitting the entire data set into a calibration and validation data set, R^2 for the validation data set varied from 0.75 to 0.78 (LAI), and from 0.85 to 0.87 (DM) if reflectance measurements were applied. Root mean square error ranged between 0.62 and 0.71m^2/m^2, and 1.64 and 1.81t/ha respectively. A stratification into local data sets according to date of acquisition and sampling region partially increased prediction performance. There was no general pre-processing method of choice but results pointed out that the technique should be chosen with respect to the sensor and the parameter of interest. Models based on hyperspectral information performed generally best, but promising results were achieved with multispectral configurations too. The best model was applied to the data acquired with the ground-based mobile system and the simulated EnMAP image. The resulting maps displayed a similar pattern of the intra-field variability and a good absolute agreement.

Leaf Area Index derivation from hyperspectral remote sensing data based on radiative transfer model inversion in heterogeneous grassland

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Keywords: Leaf area index (LAI), radiation transfer modeling, HySpex, RapidEye, grassland

The Leaf Area Index (LAI) is a key parameter controlling biophysical exchange processes in the vegetation canopy. Automated LAI derivation from remote sensing data is only feasible based on physical modeling as it is independent from field measurements, and the increasing number of spaceborne, airborne and UAV-based imaging systems provides manifold opportunities for high spatial and temporal resolution and potentially more accurate LAI estimates in the future. However, the use of hyperspectral remote sensing data in an inverted radiation transfer model has only been analyzed in a small number of studies. Further, physical LAI derivation in heterogeneous, semi-natural ecosystems such as grasslands has been largely neglected.

In this study, LAI is derived for heterogeneous alpine grasslands from airborne hyperspectral data using an inverted radiation transfer model. HySpex data have been recorded on August 13, 2012 in the Bavarian alpine upland south of Munich (Germany), covering about 40 km^2. The HySpex data comprise the spectral range of 400 - 2500 nm in 336 bands. Contemporaneous grasslands LAI in situ measurements (n = 22) have been conducted in the study area for validation purposes. LAI is derived from the HySpex data using the PROSAIL model and a look-up table inversion approach as implemented in the ARTMO toolbox. The model is parameterized based on field measurements of the chlorophyll, water, and dry matter contents, as well as of the leaf angle distribution. For LAI derivation, a range of optimization strategies is evaluated in order to increase the accuracy and robustness of the LAI mapping algorithm. First, the number of spectral bands used and the distribution of these bands

across the spectrum determine the amount of available spectral information as well as the uncertainty potentially biasing the result. Further, the level and structure of noise added to the simulated spectra should account for signal disturbances and simplifications of the PROSAIL model. During inversion, the type of cost function and the number of model results used in a multiple solution sample influence the performance of LAI derivation. The combination of these regularization strategies achieving the highest accuracies is determined. Additionally, a RapidEye scene acquired on the same day over the study area is used for LAI derivation using the same parameterization and inversion settings in order to assess the accuracy loss that could be attributed to the reduced spectral and spatial resolution.

Combining physiological parameters, hyper-spectral proximal sensing and partial least squares regression (PLSR) analysis to monitor wine vine water status

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Keywords: Grapevine, drought, physiology, hyperspectral, PLSR

The development of high quality wine grapes in Mediterranean-to-semi-arid environments relies on the use of deficit irrigation (DI) techniques, which are best regulated through leaf physiology measurements. However, the latter are often intrusive and – in light of the spatial biotic and abiotic variability within a vineyard – may also be time- and cost-inefficient. Since visible (VIS)-to-shortwave infrared (SWIR) imaging spectrometers are sensitive enough to detect relevant physiological changes, such instruments can potentially offer a faster, cheaper and non-destructive alternative for DI monitoring. Nonetheless, full-expression of this spectral advantage requires the isolation of the most physiologically-correlated wavelengths from a broad, noisy and auto-correlated hyper-spectrum. This can be efficiently done with the partial least squares regression (PLSR) technique, as this statistical tool is able to relate numerous and highly-collinear predictors to an immeasurably-smaller number of predictees. In this study, stress-induced changes in Cabernet Sauvignon leaf water potential (Ψ_l), stomatal conductance (g_s) and non-photochemical quenching (NPQ) were correlated to spectroscopic narrow-band datasets with PLSR, under greenhouse conditions. The experiment yielded three grapevine water indices (GWIs) – based on specific, opposing VIS (530-550 nm) and SWIR (1500 nm) reflectance patterns – which were both strongly-related to the physiology parameters and able to differentiate between non-stressed (g_s > 0.15 mol H_2O m^{-2} s^{-1}), lightly-stressed (0.05 mol H_2O m^{-2} s^{-1} < g_s < 0.15 mol H_2O m^{-2} s^{-1}) and moderate-severely stressed (g_s < 0.05 mol H_2O m^{-2} s^{-1}) vines. These successful results can be explained by the combination of uncoupled, important physiological mechanisms, which underlies each of the GWIs but cannot be found in many traditional – so-called universal– indices. As was demonstrated in a greenhouse experiment of a second growing season, the empirical grapevine models may also be applicable at the canopy-level, from a few meters height – showing convincing separability in the face of high humidity. Furthermore, when tested under the field conditions of a third growing season, the GWIs efficiently-differentiated between customary irrigation regimes of commercial vineyards, whereas traditional indices could not. In conclusion, the GWI formulations of this study – which are very promising for Cabernet Sauvignon DI control – exemplify the potential of combining physiological parameters, hyper-spectral proximal sensing and the PLSR technique. Moreover, in light of the fine spectral distinctions between and within grapevine cultivars – l*et al*one among plant species – the importance of this combination becomes even greater.

O8B-The: Thermal Infrared Spectroscopy

First Results from NASA's Hyperspectral Thermal Emission Spectrometer (HyTES)

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Keywords: hyperspectral, thermal infrared, airborne

The Hyperspectral Thermal Emission Spectrometer (HyTES) is an airborne imaging spectrometer developed by JPL and currently configured on a Twin Otter aircraft (it will also fly on NASA's ER-2 in 2015). The instrument has 256 spectral channels between 7.5 and 12 micrometers in the thermal infrared, and 512 spatial pixels cross-track. HyTES has a 50 degree full angle field of view; with the relatively low flight altitude of the Twin Otter aircraft (1000m), the instrument provides a wide swath with high spatial resolution of approximately 1.5 m. The available spatial and spectral resolution of HyTES represents a significant advance in airborne TIR remote sensing capability. The TIR wavelength range enables a wide range of remote sensing applications, including the detection of atmospheric trace gases (such as SO2, NH3, H2S, and N2O). The current performance, overall science objectives, and recent trace gas observations of the HyTES instrument will be presented, highlighting results from the 2014 flight campaign over targets in the western United States. The role of HYTES in JPL's overall thermal infrared observation program will be described, focusing on transitioning instruments to spaceborne, orbital instruments.

Airborne Thermal Infrared Hyperspectral Imaging for Mineral Mapping

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Keywords: Thermal Infrared, Hyperspectral, Imaging, Mineral, Airborne, TES

Minerals such as silicates, aluminosilicates (feldspar), magnesium silicates (serpentine) and olivines are among the most commonly encountered in the environment. Airborne mineral mapping of these minerals using conventional visible-near infrared (VNIR) and shortwave infrared (SWIR) sensors can be very challenging since the Si-O bounds are featureless or exhibit very weak spectral features in these spectral ranges. The fundamental vibrations associated with most functional groups found composing the different ores mostly occurs in the thermal infrared (TIR, 8-12 µm) spectral range. In order to illustrate the benefits of thermal infrared hyperspectral imaging for mineral mapping, airborne surveys were carried out over an open-pit mine in the Thetford Mine (Canada) area. The results show how the high spectral resolution provided by the Telops Hyper-Cam airborne platform system facilitates efficient temperature emissivity separation (TES) and atmospheric correction in order to give thermodynamic temperature information and spectral emissivity datacubes. The chemical maps of lizardite, serpentinite and quartz derived from the emissivity data are presented.

Visible to Thermal Infrared Emission Spectroscopy of Samples with Singular Spectral Features

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Keywords: hyperspectral reflectances, ground measurements, gypsum, quartz, salt, calcite, FTIR spectroscopy, USB2000+

Evaporitic dunes, such as those from White Sands or from the Salar of Uyuni, as well as large desert areas, are interesting and particular in spectral features so that they are usually used as reference sites

for calibration of multispectral and hyperspectral airborne sensors for being extensive radiometrically homogeneous areas. On the other hand, to accurately calibrate satellite data, field measurements concurrent to the platform overpass are necessary. Nevertheless, synergy between spectral measurements acquired at ground level with different instruments is as difficult as unusual. This study aims to measure visible to thermal infrared spectra of several samples using two field spectroradiometers: the Ocean Optics USB2000+ (0.2–1.1 µm) and the FTIR D&P Model 102 (2–16 µm). Comparisons with equivalent laboratory spectra available online helped to correctly set and validate the measurement protocol applied to measure reflectances and emissivities with both instruments.

To obtain visible-near infrared spectra, a series of measurements of target leaving radiance, sky radiance and radiance reflected by a reference panel were carried out, besides measurements under dark conditions to quantify noise. Similarly, to retrieve thermal spectra it was measured the target leaving radiance, the radiance reflected by a diffuse reflectance panel and the radiance from a black body at different temperatures. The suite of samples was chosen for *1)* their particular spectral features, *2)* the existence of large areas in the world with abundance of these materials, and/or *3)* their importance for the assessment of thermal emissivity of soils. We focused on a sandy soil rich in gypsum sampled in White Sands (New Mexico, USA), the world's largest gypsum dune field encompassing 400 km^2; salt which could characterize the Salar of Uyuni (Bolivia), the largest salt flat in the world, which comprises up to 10,000 km^2, as well as the Jordanian and Israeli salt evaporation ponds at the south end of the Dead Sea, or the evaporation lagoons in Aigües-Mortes (France); a sample of powdered quartz, omnipresent in most of the arid regions of the world such as the Algodones Dunes or Kelso Dunes (California, USA), of about 700 km^2 and 120 km^2, respectively; and a sample of powdered calcite, which amount are key for the modeling of thermal infrared spectral emissivities of bare soils, along with soil moisture, organic matter and quartz contents.

The good consistency observed between our measurements and laboratory spectra of similar samples indicated the validity of the protocols. Further, our study showed the high precision and accuracy achieved by in situ spectra of real covers (instead of laboratory measurements over microscopic portions of samples). Our field measurements reproduced very well *1)* the high spectral contrast of gypsum in the thermal infrared, which emissivity decreases from 0.98 up to 0.70 around 8.6 µm, *2)* the broad absorption band of salt in the infrared (low emissivity at wavelengths lower than 16.7 µm), *3)* the weak absorption feature of the quartz Reststrahlen bands (low emissivity between 7.7 and 9.7 µm, and near 12.6 µm), and *4)* the absorption features near 2.4 µm, 11.4 µm and 14.0 µm characteristics of calcite.

An Overview of Plume Tracker: Mapping Volcanic Emissions with Interactive Radiative Transfer Modeling

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Keywords: Radiative Transfer, Thermal Infrared, Volcanic Emissions, Remote Sensing, MODTRAN

Infrared remote sensing is a vital tool for the study of volcanic plumes, and radiative transfer (RT) modeling is required to derive quantitative estimation of the sulfur dioxide (SO_2), sulfate aerosol (SO_4), and silicate ash (pulverized rock) content of these plumes. In the thermal infrared, we must account for the temperature, emissivity, and elevation of the surface beneath the plume, plume altitude and thickness, and local atmospheric temperature and humidity. Our knowledge of these parameters is never perfect, and interactive mapping allows us to evaluate the impact of these uncertainties on our estimates of plume composition.

To enable interactive mapping, the Jet Propulsion Laboratory is collaborating with Spectral Sciences, Inc., (SSI) under a NASA Advanced Information Systems Technology Program Grant to develop the

Plume Tracker toolkit. Plume Tracker integrates (1) retrieval procedures for surface temperature and emissivity, SO_2, NH_3, or CH_4 column abundance, and scaling factors for H_2O vapor and O_3 profiles, (2) a RT modeling engine based on MODTRAN, and (3) interactive visualization and analysis utilities under a single graphics user interface.

The principal obstacle to interactive mapping is the computational overhead of the RT modeling engine. Under the NSA grant, we have achieved a 300-fold increase in the performance of the retrieval procedures through the use of indexed caches of model spectra, optimization of the minimization procedures, and scaling of the effects of surface temperature and emissivity on model radiance spectra. In the final year of the grant, we implemented parallel processing to exploit multi-core CPUs and cluster computing, and optimize the RT engine to eliminate redundant calculations when iterating over a range of gas concentrations. These enhancements have resulted in an additional 10 – 15X increase in performance. In addition to the improvements in performance, we have improved the accuracy of the Plume Tracker retrievals through refinements in the description of surface emissivity and use of vector projection to define the misfit between model and observed spectra. The presentation will include results fromvalidation efforts based on analysis of recent measurement data.

O9A-Flu: Remote Sensing of Vegetation Fluorescence Part 1

Mapping sun-induced fluorescence (SIF) for mechanistic stress responses of vegetation using the high-performance imaging spectrometer HyPlant

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Keywords: sun-induced fluorescence, FLEX, HyPlant, vegetation stress, photosynthesis

Variations in photosynthesis that are not related to greenness of vegetation cannot be measured by traditional optical remote sensing techniques and still cause substantial uncertainties in predicting photosynthetic CO_2 uptake rates and monitoring plant stress. Several activities were underway to evaluate the sun-induced fluorescence signal on the ground and on a coarse spatial scale using space-borne imaging spectrometers. Intermediate-scale observations using airborne-based imaging spectroscopy, which are critical to bridge the existing gap between small-scale field studies and global observations, are still insufficient. Here we present validated maps of sun-induced fluorescence in that critical, intermediate spatial resolution, employing the novel airborne imaging spectrometer *HyPlant*. *HyPlant* has an unprecedented spectral resolution, which allows for the first time quantifying sun-induced fluorescence fluxes in physical units according to the Fraunhofer Line Depth Principle that exploits solar and atmospheric absorption bands. Fluorescence maps show a large spatial variability between different vegetation types, which are not detected with classical remote sensing approaches.

It could be shown that different crop types largely differ in emitting fluorescence that is related to the activity of the photosynthetic machinery and allows separating annual and perennial C_3 and C_4 crops and grasses. Additionally, it could be shown in different case studies that the two peak feature of sun-induced fluorescence emission is related to (i) the total absorbed radiation by photosynthetically active chlorophyll (far-RED peak) and (ii) the functional status of photosynthesis and vegetation stress

(RED peak). Thus, the dynamic changes of the two peaks of fluorescence code for structural and functional variability within canopies. Sun-induced fluorescence thus can be used to better understand and to monitor the dynamic adaptations of the photosynthetic machinery of plants to the ever changing environmental conditions. Sun-induced fluorescence thus constitutes a novel and highly relevant remote sensing signal to understand and manage our natural and managed ecosystems in times of global change and to facilitate a sustainable use of plants and plant resources.

Monitoring the evolution of plant photosynthetic performances using ground sun-induced fluorescence measurements

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Keywords: fluorescence, PRI, vegetation, stress

Plants subjected to biotic or abiotic stress factors can respond with adjustments in their biochemical and physiological processes. These adjustments are often accompanied by changes in reflectance, transmittance, and absorbance at leaf and canopy level.

This contribution aims to understand how optical signals linked to plant physiology changes after the application of two different chemical agents: an herbicide blocking the electron-transfer mechanisms in the photosynthetic apparatus (Chlortoluron) and an anti-transpirant chemical known to reduce plant transpiration (Vapor Gard) by sealing the stomata. The chemicals have been applied on 9 grass plots with different concentrations. Three plots have been kept not-treated and used as control. Canopy high resolution spectral measurements and CO_2 fluxes have been collected daily on the same sampling area in each plot for the entire duration of the experiment to monitor the temporal evolution of the stress effects.

Spectral measurements have been used to estimate the sun-induced chlorophyll fluorescence in both the red (SIF_{687}) and far-red region (SIF_{760}), the Photochemical Reflectance Index (PRI) linked to the xanthophyll-related heat dissipation and several traditional vegetation indices related to canopy greenness and chlorophyll concentration. SIF_{687} and SIF_{760} were estimated with spectral fitting methods spectrally modeling the radiance collected with very high resolution spectrometers in the oxygen absorption O_2-A and O_2-B bands.

The applied treatments induced a variation of plant photosynthetic functioning modulated according to the level of herbicide concentration. Both SIF_{687} and SIF_{760} measured in Chlortoluron-treated grass plots were significantly higher than in the control plots. The highest dose caused fluorescence values to double in less than 3 hours while the reflectance signal at the same time was not affected confirming that the increase in fluorescence emission was only related to variations in the plant functional status not associated to changes in pigment content and composition. F_{687} and F_{760} values of treated plots decreased steeply in the following days. Fluorescence decline was accompanied by a decrease in chlorophyll content. Grass photosynthesis began to decline immediately after the herbicide application and continued in the following days. This result implies that fluorescence was negatively correlated to plant photosynthesis in an early phase of stress reaction and then the relation became positive in the following days. Thus the translation of fluorescence values to photosynthesis is not straightforward in this experiment. Lower doses affected fluorescence signal similarly but with a different temporal dynamic in both the initial rise and the recovery. Chlortoluron also caused an initial increase of PRI values followed by a gradual decline associated to the degradation of the pigment pool.

The application of the anti-transpirant agent only slightly affected fluorescence emission and PRI probably because the photosynthetic system was not directly compromised.

Sun-induced chlorophyll fluorescence allowed to monitor the temporal dynamics of plants' functioning and recovery after the application of temporarily blocking photosynthesis agents. Further studies are ongoing to better understand the effects of stress on the fluorescence signal and the link to heat dissipation and photosynthesis.

Using plant chlorophyll fluorescence for a better prediction of GPP and canopy carbon exchange

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Keywords: Sun Induced Fluorescence, photosynthesis, light use efficiency, gross primary productivity

Photosynthesis is the most important exchange process of CO_2 between the atmosphere and the land-surface. Spatial and temporal patterns of photosynthesis depend on dynamic plant-specific adaptation strategies to highly variable environmental conditions e.g. light, water, and nutrient availability. Therefore, an accurate quantification of photosynthetic CO_2 uptake, commonly referred to as gross primary productivity (GPP), is a key parameter to monitor plant performance.

Hyperspectral reflectance techniques often failed to quantify actual photosynthetic light use efficiency (LUE) and only allow measuring pigment content and canopy structure. One promising approach for obtaining global estimates of plant photosynthesis is the use of Sun Induced Chlorophyll Fluorescence (SIF). SIF has been proposed as a direct indicator of plant photosynthesis, and several studies have demonstrated its relationship with vegetation functioning at leaf and canopy level.

In this presentation we summarize the results from several remote sensing projects where SIF was used to quantify the functional status of photosynthesis and LUE from the level of single leaves to the field. Based on Monteith (1972) and Van der Tol *et al*. (2014) models we used remotely sensed SIF flight lines and ground measurements of LUE and SIF yield to estimate GPP. The results from these studies demonstrated high potential of remotely sensed SIF for better understanding of spatial and temporal patterns of GPP and CO_2 exchange between the land and atmosphere.

O9B-Enm: Latest EnMAP Developments

Overview of the technical and scientific status of the EnMAP imaging spectroscopy mission

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[5]; Doerffer, Roland [6]; Krasemann, Hajo [6]; Xi, Hong Yan [6]; Mauser, Wolfram [7]; Hank, Tobias [7]; Locherer, Matthias [7]; Rast, Michael [8]; Staenz, Karl [9]; Sang, Bernhard [10]

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Keywords: EnMAP, mission overview, instrument description, science programme

The Environmental Mapping and Analysis Program (EnMAP) is a joint venture of a consortium of German Earth Observation Research Institutions. The DLR-Agency is the project manager, the GFZ in Potsdam has the scientific lead, OHB-Systems AG is the industrial prime for the sensor and bus, and the DLR-EOC is responsible for the ground segment. EnMAP is designed for the retrieval of bio-, geochemical and physical parameters characterising the Earth surface for applications such as agriculture, land-use, water systems, soil science, and geology.

The core payload of the EnMAP satellite is a prism-based imaging spectrometer covering the 420-2450 nm spectral window with 242 contiguous spectral bands. Spectral resolution ranges between 6.5 and 10 nm in the visible and near-infrared and between 8.5 and 12 nm in the shortwave infrared, with threshold signal-to-noise ratios of 500 and 150, respectively. The ground sampling distance is 30 m and the swath is 30 km. The mission is now in phase D (construction), with launch planned for mid 2018. The expected mission lifetime is 5 years.

Recent activities related to the mission consolidation have been focused on the support of industrial developments and the final consolidation of the mission concept. A scene simulator generating EnMAP-like data under realistic conditions has been implemented. It enables the definition of optimal instrument configurations for radiometric, spectral and geometric parameters as well as the evaluation and profiling of data-processing algorithms. In terms of the development of the EnMAP scientific programme, a software environment for the interactive processing of EnMAP data is being jointly designed by the Geomatics lab of the Humboldt University of Berlin and the GFZ. Tools for calibration, pre-processing and the derivation of higher-level biophysical products are to be included in this software (available on http://www.enmap.org/).

In this contribution we will provide an overview of the mission status including both technical developments and preparatory activities for the implementation of the EnMAP scientific program.

On the use of land cover fraction maps derived from simulated EnMAP data for characterizing urban morphology

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Keywords: imaging spectrometry, EnMAP, urban land cover, support vector machines, urban morphology

The rapid expansion of urban population constitutes a great challenge for the 21st century. Earth is increasingly urbanized and the pressure on natural and human systems is mounting. With the forthcoming hyperspectral satellite mission EnMAP, frequently and globally sampled high quality imaging spectrometer data will become broadly available. This will create novel opportunities for deriving improved descriptions of urban surface properties relevant for disciplines involved in urban environmental research or urban planning. Particularly information on the amount and spatial distribution of different impervious, pervious, and vegetation types are important indicators for exploring and managing impacts of urbanization. Moreover, delineating urban morphological types with respect not only to the biophysical land cover but also to the functional land use characteristics plays an important role for urban planners and modelers. This study demonstrates the potential of the EnMAP mission for providing profound information on urban morphology from detailed urban land cover fraction maps. A simulated EnMAP scene at 30 m resolution and support vector regression combined with synthetically mixed training data are used for quantifying land cover along Berlin's urban-rural gradient. Results demonstrate the value of EnMAP data for accurately mapping *vegetation*, *impervious* and *soil* surface types (MAE < 12%, $R^2 > 0.8$) according to the well recognized VIS framework. Moreover, EnMAP data allows for extending VIS by the more detailed sub-components *roof*, *pavement*, *low vegetation* and *tree* (MAE between 7.3% and 21.0%; R^2 between 0.52 and 0.84). Comparisons to equivalent fraction maps derived from a Landsat-like multispectral image underscore the merit of EnMAP for urban mapping. When represented both as transects along the urban gradient and as density graphs at the urban block scale, the original and extended VIS fractions clearly reveal the possibility for automated classification of different urban structure types / peri-urban land uses, e.g., different residential block developments, industrial zones, parks, allotment gardens, agricultural land use and forest areas. These relationships between land cover maps and urban morphological types demonstrate the value of EnMAP-based mapping for describing functional characteristics of urban areas.

The Potential of Pan-Sharped EnMAP Data for Assessing the Leaf Area Index of Wheat

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Keywords: EnMAP, aisaEAGLE, Ehlers Fusion, Partial Least Squares Regression, LAI

The leaf area index (LAI) is one of the most important structural plant parameters and a key variable in climatological, meteorological, ecological and agricultural modelling. Especially in agronomical modelling the LAI serves as an indicator of the current biotic and abiotic conditions of plants and as an important input parameter for yield estimates, since it is significantly influenced by yield-limiting and -reducing factors such as plant diseases and mismanagement.

During two field campaigns conducted in an agricultural region northwest of Koethen (Saxony-Anhalt, Germany) in May 2011 and May 2012 the LAI of 70 plots (each with a size of 0.25 m^2) distributed over two fields (one field per year) was non-destructively measured. In both years hyperspectral imagery of the test site was acquired by the airborne scanner aisaEAGLE (430-900 nm) in parallel to field campaigns.

Afterwards, EnMAP data (Environmental Mapping and Analysis Program) were simulated from the aisaEAGLE data sets of both years to investigate the potential of EnMAP to estimate the LAI. Due to the problem of validating derived products from EnMAP data because of the medium spatial resolution (30 m GSD), the Ehlers Fusion" algorithm was applied to improve the spatial resolution of the data while preserving the spectral properties. Therefore, spatial information extracted from aisaEAGLE panchromatic data (3 m GSD) were fused with spectral information of the simulated EnMAP data. As a result, data sets were generated with the spectral characteristics of EnMAP and a distinctly improved ground sampling distance.

Subsequently, reflectance spectra of the image pixels corresponding to the geographic location of the different wheat plots were extracted from the fused EnMAP data and a partial least squares regression (PLSR) model was calibrated for LAI prediction. The same procedure was repeated for the aisaEAGLE data and the results of both models were compared. Afterwards, the models have been applied to the fused EnMAP- as well as to the aisaEAGLE image data of the fields to assess the spatial distribution of the LAI.

The leave-one-out cross-validated (cv) PLSR model built with the fused EnMAP data (r^2_{cv}=0.74, $RMSE_{cv}$=0.73) showed a distinctly lower model performance compared to the result achieved from the aisaEAGLE data (r^2_{cv}=0.87, $RMSE_{cv}$=0.52). However, the predicted LAI based on fused EnMAP data was consistent to LAI values measured in field and reflected the spatial distribution of the investigated fields.

The results clearly indicate the potential of pan-sharped EnMAP data for a fast and reliable spatial assessment of LAI. In addition, the method demonstrated that temporal closely acquired EnMAP data and satellite data with a higher spatial resolution can be combined to provide improved spatial predictions of plant parameters which is highly demanded by many applications in precision farming.

O10A-Flu: Remote Sensing of Vegetation Fluorescence Part 2

Global monitoring of chlorophyll fluorescence with spaceborne atmospheric sensors

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Keywords: chlorophyll fluorescence, atmospheric missions, carbon cycle, global scale

Space observations of the sun-induced chlorophyll fluorescence (SIF) electromagnetic signal emitted by plants in the 650-850nm spectral range hold the promise of providing a new view of vegetation photosynthesis on a global basis. Global retrievals of SIF from space have recently been achieved from a number of spaceborne spectrometers originally intended for atmospheric research. Despite not having been designed for land applications, such instruments have turned out to provide the necessary spectral and radiometric sensitivity for SIF retrieval from space as well as a short revisit time, with the main shortcoming of a coarse spatial resolution.

The first global measurements of SIF were achieved in 2011 from spectra acquired by the Japanese GOSAT mission launched in 2009. The retrieval takes advantage of the high spectral resolution provided by GOSAT's Fourier Transform Spectrometer (FTS). SIF retrievals from GOSAT-FTS spectra are performed at two narrow spectral windows at 757 and 770 nm containing a number of solar Fraunhofer lines, which have been demonstrated to be sensitive to SIF in-filling. Unfortunately, GOSAT only provides a sparse spatial sampling with individual soundings separated by several hundred kilometers. Complementary, the Global Ozone Monitoring Experiment-2 (GOME-2) instruments onboard MetOp-A and MetOp-B enable SIF retrievals at 690 and 740 nm with a continuous and global spatial coverage. GOME-2 measures in the red and near-infrared (NIR) spectral regions with a spectral resolution of 0.5 nm and a pixel size of 40x80 km2. Most recently, another global and spatially continuous data set of SIF retrievals at 740 nm spanning the 2003-2012 time frame has been produced from ENVISAT/SCIAMACHY. This observational scenario will be completed by the first fluorescence data from the NASA-JPL OCO-2 mission (launched in July 2014) and the upcoming Copernicus' Sentinel 5-Precursor to be launched in early 2016. OCO-2 and TROPOMI offer the possibility of monitoring SIF globally with a 100-fold improvement in spatial and temporal resolution with respect to the current measurements from the GOSAT, GOME-2 and SCIAMACHY missions.

In this contribution, we will provide an overview of existing global SIF data sets derived from space-based atmospheric spectrometers and will demonstrate the potential of such data to improve our knowledge of vegetation photosynthesis and gross primary production at the synoptic scale. We will show examples of ongoing research exploiting SIF data for an improved monitoring of photosynthetic activity in different ecosystems, including large crop belts worldwide, the Amazon rainforest or boreal evergreen forests.

Using Multi-angle Spectral Observations of Solar Induced Fluorescence (SIF) and the Non-Photochemical Reflectance Index (PRI) to Estimate Stress Responses, Biophysical Properties and Gross Primary Production in Corn Crops

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Keywords: multi-angle, fluorescence, PRI, corn, plant stress

Corn (maize) is an essential crop for global food security” and is provided nitrogen (N) fertilization to enhance growth and yields. In major corn growing belts, such as in the USA, management of large agricultural tracts could benefit from information about the crop’s relative health status that potentially could be obtained through monitoring from satellites. One such satellite observation exercise using coarse resolution (~20 km^2) GOMES-2 data (Guanter *et al*. 2014) related a retrieval of far-red chlorophyll fluorescence to the local Gross Primary Production (GPP) derived from eddy covariance flux towers. In that study, an assumption of surface isotropy was made for the surface signal. In our current ground-based study, we examine the assumption of isotropy in a research cornfield located at the USDA-Agriculture Research Service in Beltsville, MD, USA. Multi-angle high spectral resolution (≤0.3 nm) observations were made in the visible through near-infrared spectrum in multiple years from specialized pole mounted spectroradiometers. These directional observations were obtained in the solar principal plane at seven view zenith angles (VZAs: nadir, 0^o; ±30^o; ±45^o; ±60^o), or alternatively with three view zenith angles (VZAs: 30^o, 45^o, 60^o) acquired around the solar azimuth plane at eight relative view azimuth angle locations (VAAs: 0^o, 45^o, 90^o, 135^o, 180^o, 270^o, 315^o), plus nadir (VZA=0^o). The directional reflectance and fluorescence emissions were measured at different growth stages for experimental plots provided a range of N application regimes, and adjacent to an eddy covariance flux tower. Measurements were made in a typical growing season (adequate precipitation, moderate temperatures), and in a summer with drought (high ambient temperatures >32^o C mid-day, low precipitation amounts). From these measurements, the Photochemical Reflectance Index (PRI) and solar induced chlorophyll fluorescence (SIF) in the two atmospheric telluric oxygen absorption bands (O_2-B, O_2-A) centered at 687 nm (SIF687) and 760 nm (SIF760) were retrieved. The anisotropy of these spectral variables was quantified and examined as a function of N level, growth stage, and environmental conditions. The PRI expressed the greatest anisotropy and was useful for separating among the N treatments under strongly expressed drought stress in 2012, which induced leaf roll that altered canopy structure. The SIF760 also expressed substantial anisotropy, whereas the SIF687 could be considered isotropic. Consequently, the red/far-red SIF ratio (SIF687/SIF760) also expressed anisotropy. The spectral indices were related to top of canopy pigment levels and carbon:nitrogen concentrations, and to Gross Primary Production (GPP) and photosynthetic Light Use Efficiency (LUE). They were also compared with simulated results produced by the SCOPE model.

The impact of BRDF and adjacency effects on the accuracy of fluorescence retrievals from space

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Keywords: vegetation fluorescence, retrieval, BRDF, adjacency

The simultaneous retrieval of a vegetation canopy's fluorescence (F) and its top-of-canopy reflectance (R) from high spectral resolution top-of-atmosphere (TOA) radiance spectra is possible thanks to the smoothness of the spectra of both the canopy's reflectance and its fluorescent radiance. Spectral fitting methods and the Fraunhofer Line Discriminator (FLD) method exploit this relative spectral smoothness to retrieve F and R by modelling these as smooth mathematical functions like low degree polynomials, spline functions, et cetera. The FLD method is based on this idea by focusing on the in-filling by fluorescence of gaseous absorption lines in the terrestrial and the solar atmospheres. For telluric Fraunhofer lines, there are however two effects which interfere with the correct retrieval of fluorescence, namely (1), the fact that differences in atmospheric photon path length, in combination with surface BRDF and adjacency effects, may cause an apparent in-filling, or its opposite, leading to overestimates or underestimates of canopy fluorescence, and (2), the curve-of-growth effect, which is related to the finite band width of the spectrometer, and which causes the in-filling to be underestimated for space-borne imaging spectrometer data. The first effect does not occur for a uniform Lambertian earth surface, and it will be stronger if the target is strongly non-Lambertian or if it has a strong contrast with its surroundings. The second effect is always present and it depends mainly on the spectral characteristics of gases in the terrestrial atmosphere. This contribution will focus on the severity of both mentioned effects for the accuracy of fluorescence retrievals from space and on ways to correct for these effects or to avoid them. This is achieved by means of high spectral resolution simulations based on the atmospheric model MODTRAN and the model SCOPE for the simulation of canopy non-Lambertian fluorescence and reflectance.

On the relationships between solar-induced fluorescence and net photosynthesis of the canopy: a SCOPE modeling study

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Keywords: FLEX, fluorescence, global sensitivity analysis, SCOPE, modeling

In preparation of ESA's Earth Explorer 8 candidate mission FLEX (FLuorescence EXplorer), a Photosynthesis Study (PS) has been completed that aimed to quantitatively link fluorescence to photosynthesis based on model and experimental data. One of the objectives of PS was to develop a prototype inversion algorithm to retrieve photosynthesis from simulated sun-induced fluorescence (SIF) observations. Another objective was to develop biochemical models into an existing soil-vegetation-atmosphere-transfer (SVAT) model. The model 'Soil-Canopy-Observation of Photosynthesis and the Energy balance' (SCOPE) has been selected as baseline model, because it has the ability to simulate the effects of irradiance, vegetation structure and physiology on SIF and photosynthesis. During PS, SCOPE has been extended with various biochemical models (TB12-D, TB12 and MD12) and delivers a wide range of outputs (e.g., fluxes, reflectance, fluorescence). The targeted flux for this study is *Net photosynthesis of the canopy*" (NPC), which is important for carbon cycle and climate change research.

In order to enable estimating NPC from optical data, a hybrid retrieval strategy that feeds SCOPE simulation outputs into a machine learning regression algorithm has been pursued. With such approach the ability of reflectance and sun-induced fluorescence (SIF) data to retrieve NPC for various

canopy configurations has been analyzed. Specifically, the predictive power of FAPAR and SIF wavelengths (e.g. its two peaks) and derived SIF products were evaluated.

To ensure simulating canopy configurations that impact NPC, prior to the regression analysis key variables driving NPC variability were identified. This was done through a global sensitivity analysis (GSA). A GSA is an excellent method to quantify the relative importance of each input variable to model outputs (e.g., NPC), and can help set safe default values for less influential variables. We made use of Saltelli's method, which has been demonstrated to be effective in identifying both *first-order effects* (the contribution to the variance of the model output by each input variables) and *total sensitivity effects* (the first-order effect plus interactions with other input variables) of input variables. Identified key variables were: maximum carboxylation capacity (Vcmo) at the biochemistry scale; chlorophyll content at the leaf scale; leaf area index at the canopy scale; and CO_2 concentration in the air, incoming shortwave radiation and air temperature at the micrometeorological scale.

With these key variables various canopy configurations were simulated, thereby ranging one or multiple variables at the biochemical, leaf and canopy scale. It let to the following general findings:

1) Vcmo is the key variable that drives SIF-NPC relationships. Other biochemical variables degrade these relationships, but their impact is spectrally invariant.

2) Leaf or canopy variables also contribute to SIF-NPC relationships, but these relationships degrade when moving towards the NIR.

3) Most successful SIF wavelengths predicting NPC is not to be found at the top of the emission peaks but rather on the slope in between both peaks.

4) Stronger relationships were obtained when exploiting only two wavelengths which are located at both peaks (e.g. O_2-B and O_2-A).

5) Strongest relationships are achieved when exploiting all wavelengths of the full broadband SIF profile.

Relationships between sun-induced chlorophyll fluorescence and gross primary production across ecosystems: insights from observational and modeling approaches

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Keywords: gross primary production, sun-induced chlorophyll fluorescence, airborne based spectroscopy, photosynthesis models, APEX

Sun-induced chlorophyll fluorescence (SIF) is a radiation flux emitted from chlorophyll molecules and considered an instantaneous indicator for the functional status of plant photosynthesis. Using SIF opens new perspectives to assess actual photosynthesis at ecologically relevant scales and provides an alternative approach to study the terrestrial carbon cycle. Recent studies demonstrated the reliability of measured SIF signals and showed significant relationships between SIF and gross primary production (GPP) at ecosystem and global scales. Despite these encouraging results, understanding the complex mechanisms involved in the relationship of SIF and GPP remains challenging before SIF can be finally utilized to constrain estimates of GPP.

In this study, we present one of the first experimental assessments of the relationship between SIF and GPP and its transferability across structurally and physiologically contrasting ecosystems using high spatial resolution imaging spectroscopy (IS) data. We use multi-temporal IS data acquired with the airborne spectrometer Airborne Prism Experiment (APEX) as well as eddy covariance flux tower data to estimate SIF and GPP of grassland, cropland and forest. We use simulations of the photosynthesis model SCOPE to confirm experimental results and to interpret apparent confounding factors such as structural interferences or temporal scaling effects.

Based on observed ecosystem specific and asymptotic relationships between SIF and GPP grassland (R^2 = 0.92, rRMSE = 9.1%), cropland (R^2 = 0.71, rRMSE = 2.1%) and mixed forest (R^2 = 0.60, rRMSE = 15.9%) we conclude that SIF provides a new promising observational approach to assess terrestrial GPP across ecosystems, but requires a deeper understanding of the factors influencing it at the leaf, plant and ecosystem levels. In particular structural and temporal scaling effects are critical for relating small scale and global assessments of GPP using SIF. We consider our results as crucial to help bridging the gap between mechanistic understanding at the level of leaves or individual plants and large scale studies focusing on the usage of SIF at a global scale.

O10B-Cal: Imaging Spectrometers Instrument and Data Calibration

Recent Developments in Atmospheric Compensation and Radiometric Processing of Imaging Spectroscopy Data

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Keywords: atmospheric correction, BRDF, radiometric compensation, ATCOR, BREFCOR

The goal of atmospheric compensation of imaging spectroscopy is to provide accurate measurements of surface reflectance information which is either be provided as bihemisperical reflectance (i.e. spectral albedo) or as hemispherical directional reflectance. The methods to determine these quantities from the at-sensor radiance measurements have been in development for more than 30 years so far and the process has undergone substantial improvements recently. Currently, a transition from standard atmospheric correction using empirical assumptions to an integral, model based radiometric processing is ongoing. This changing paradigm and the related developments in the ATCOR atmospheric compensation model are outlined in this paper. Such pure radiometric modeling and processing relies on high quality data calibration, a topic which is not covered by this paper even though it is a crucial precondition.

The atmospheric compensation part requires knowledge about the state of the atmosphere. Image based methods have been available for many years now. Recently, substantial progress has been made in haze detection and correction. For improved aerosol detection, new approaches are currently being tested which will allow for more reliable aerosol characterization of high resolution data. Processed image samples and simulations illustrate these advanced capabilities.

On the ground level, the description of illumination is about to be revised. Methods originally developed for satellite imagery are no longer appropriate for high spatial resolution airborne imaging spectroscopy data. New approaches are implemented which rely on image based shadow detection in combination with updated formulations for the illumination field. Such improvements will allow for information extraction even from completely shaded areas.

A topic which only has been adressed recently is the correction for BRDF influences on the data. This bi-directional effects are to be corrected on both the incident direction and the observer side. While the major focus has been put on the latter, the currently used BREFCOR method for correction of BRDF effects is about to be expanded to the application in terrain, where the incidence direction is taken into account in a similar way as the observer BRDF.

Finally, the spectra are to be made comparable to ground reference spectra and modelling results. Smallest spectral variations during data acquisition, radiative transfer model errors in atmospheric gas absorption, and errors in the employed solar irradiance spectrum can lead to significant spectral noise for hyperspectral imagery. Applying spectral recalibration in combination with polishing routines are shown to improve the comparability of the radiometrically corrected data to the ground measurements and to modelled spectra.

The overview on the current state of developments outlines the solved questions as well as open issues which need to be addressed in future developments of radiometric compensation.

APEX Instrument and Data Calibration

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Keywords: Calibration, Data Processing, Sensor Characterisation

ESA's Airborne Imaging Spectrometer APEX (Airborne Prism Experiment) was developed under the PRODEX (PROgramme de Développement d'EXpériences scientifiques) program by a Swiss-Belgian consortium and entered its operational phase at the end of 2010 (Schaepman *et al*., 2015 (in print)).

Detailed laboratory based instrument characterisations and calibrations were carried out in parallel to numerous flight campaigns over the past six years. In due course, the instrument knowledge has greatly increased and resulted in gradually refined sensor models that increased the accuracy of radiometrically calibrated level-1 data. This contribution summarises the current calibration procedures in the APEX Calibration Home Base (Gege *et al*., 2009), the calibration coefficient extraction algorithms employed within the APEX Calibration Information System (Hueni *et al*., 2013a, Hueni *et al*., 2013b) and the dataflow of the APEX level-1 processor (Hueni *et al*., 2014, Hueni *et al*., 2012).

The APEX level-1 data are the basis for the generation Hemispherical-Conical Reflectance Factors and hence a detailed understanding of the underlying calibration processes is crucial for the successful application of higher-level processes. The information presented in this contribution is thus of value to both calibration scientists and APEX end-users. Consequently, users having obtained data at the start of APEX flight operations may consider ordering reprocessed data to further improve their previous results.

Gege, P., Fries, J., Haschberger, P., Schötz, P., Schwarzer, H., Strobl, P., Suhr, B., Ulbrich, G., Vreeling, W. J., 2009. Calibration facility for airborne imaging spectrometers. ISPRS Journal of Photogrammetry & Remote Sensing 64, 387–397.

Hueni, A., Lenhard, K., Baumgartner, A., Schaepman, M., 2013a. The APEX (Airborne Prism Experiment - Imaging Spectrometer) Calibration Information System. IEEE Transactions on Geoscience and Remote Sensing 51(11), 5169-5180.

Hueni, A., Schlaepfer, D., Jehle, M., 2014. APEX: Radiometry Under Spectral Shift Conditions. In: Proceedings IGARSS, Quebec.

Hueni, A., Sterckx, S., Jehle, M., 2013b. Operational Calibration of APEX. In: Proceedings IGARSS, Melbourne, VIC, pp. 4423- 4426.

Hueni, A., Sterckx, S., Jehle, M., D'Odorico, P., Vreys, K., Bomans, B., Biesemans, J., Meuleman, K., Schaepman, M., 2012. Operational Status of APEX and Characteristics of the APEX Open Science Data Set. In: Proceedings IGARSS, Munich, pp. 5009 - 5012.

Schaepman, M., Jehle, M., Hueni, A., D'Odorico, P., Damm, A., Weyermann, J., Schneider, F. D., Laurent, V., Popp, C., Seidel, F. C., Lenhard, K., Gege, P., Küchler, C., Brazile, J., Kohler, P., Vos, L. D., Meuleman, K., Meynart, R., Schläpfer, D., Itten, K. I., 2015 (in print). Advanced radiometry measurements and Earth science applications with the Airborne Prism Experiment (APEX). Remote Sensing of Environment.

Improvements to the calibration of a NEO HySpex VNIR-1600 sensor

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Keywords: Calibration, stray light, bathymetry, characterization

A HySpex VNIR-1600 sensor, built by NEO and operated by German Space Agency (DLR), was extensively characterized at DLR's Calibration Home Base (CHB) facility and at Physikalisch-Technische Bundesanstalt (PTB) PLACOS setup over the course of two years. The generated data significantly extends the characterization performed by the manufacturer, thus allowing to enhance the original raw data calibration method.

The improvements concern radiometric characterization, using a well-calibrated radiometric standard, keystone and smile optical distortions, radiometric nonlinearity and spatial and spectral in-band stray light. Since descriptions of the first two measurements were already published, this talk will focus on the nonlinearity and the in-band stray light.

This extensive effort in characterization was undertaken as data from this instrument will be used to validate satellite data and to simulate hyperspectral images of the German EnMAP mission. In particular the contribution of stray light is assessed on the example of a hyperspectral scene of lake Starnberg.

Towards open access to time series of in-situ data, drone-based images, airborne hyperspectral images and satellite images collected at the BELAIR sites

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Keywords: data acces, in-situ, drone, APEX, satellite

The BELAIR project, initiated in 2013 and funded by the Belgian Science Policy (Belspo), is targeted at developing Belgian test sites on behalf of Belgian and international research communities which may be used as calibration and validation site for new Earth Observation missions, data and products. In BELAIR three study sites were defined each focusing on one or more thematic research topics: HESBANIA for agriculture and horticulture (including a JECAM site and the ICOS Lonzée tower), SONIA for forestry and urban research and LITORA for nature reserves and water quality at the Belgian coast.

In the summer of 2013, the BELAIR teams (13 Belgian research institutes, universities and administrations) joined forces and instruments and collected in-situ measurements, images acquired from drones, hyperspectral airborne (APEX) images and satellite images for reaching their thematic research objectives. Before the BELAIR 2013 campaign, APEX was calibrated at the calibration home base at DLR and the radiometric and spectral performance of the field spectroradiometers of all partners verified at the dark room facility at VITO. Measurement protocols for field spectroradiometer measurements were provided to all partners involved. All BELAIR 2013 data are archived at the BELAIR server.

The HESBANIA-horticulture team is studying perennial fruit orchards for a better management, the HESBANIA-agriculture team is studying potato and grain crops monitoring for abiotic and biotic stresses and HESBANIA-soil is studying soil organic carbon in the cropped fields. The SONIA team is studying water and energy transfer in urban areas (of Brussels) and forests (Zoniënwoud en Kersselaerspleyn). The LITORA team is studying water quality in the harbor of Zeebrugge, sediment in the Yzermonding and biodiversity in nature reserves Het Zwin en Laege Moere.

Currently the BELAIR 2013 data are used by several PhD and MSc students of Belgian universities and partners who collected the data, but to stimulate the use of BELAIR 2013 data and to foster joint

research, all images collected from drones, APEX images and in-situ data will be freely available to the entire research community from February 2016 onwards. To easily access the data an INSPIRE compliant BELAIR GEOPORTAL is currently being developed and will be available from the BELAIR website (http://belair.vgt.vito.be).

Another BELAIR campaign was organized in 2014 at the HESBANIA and LITORA sites and new BELAIR campaigns at the three BELAIR sites are planned for the coming years. The presentation will give an overview of the BELAIR results, show how to access archived BELAIR data and elaborate on future BELAIR plans.

Mixel camera prototype – testing the performance of the light mixing chambers

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Keywords: hyperspectral camera mixel keystone misregistration

A mixel camera is a new type of push-broom hyperspectral camera where the raw sensor data can be mathematically restored to its original keystone-free form, even if the keystone of the camera optics is large. This is possible because of an array of light mixing chambers located in the slit plane. The accuracy of the data in the restored hyperspectral datacube depends on the performance of the mixing chambers – more specifically, how well they mix the incoming light. A mixel camera prototype has been built and extensively tested.

We will present the prototype and the test procedures, show the measured light distribution at the output of the mixing chambers, and discuss how the measured imperfections in the light mixing affect the quality of the restored hyperspectral datacube.

O11A-Pro: Image Processing Methods Part 1

Geometric and Atmospheric Processing of APEX Hyperspectral Data

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Keywords: hyperspectral, atmospheric correction, automated processing, APEX

The Central Data Processing Center (CDPC) from the Flemish Institute for Technological Research (VITO, Mol, Belgium) hosts a complex infrastructure dedicated to the collection, archiving, processing and distribution of remotely sensed data. This paper focuses on the processing and quality of products obtained by the CDPC using as an example hyperspectral data acquired by the Airborne Prism EXperiment (APEX). APEX is an airborn spectrometer developed by a Swiss-Belgian consortium on behalf of ESA and currently jointly operated by VITO and Remote Sensing Laboratories (RSL, Zurich, Switzerland).

The APEX instrument delivers hyperspectral imagery, with a high spectral and spatial resolution, which is well suited for land-cover mapping and for the assessment of important structural and (bio)physical characteristics of vegetative and non-vegetative spaces within several research fields. APEX imagery is also used in calibration/validation activities for future spaceborn Earth Observation missions (e.g., Sentinels).

Since the acceptance of the instrument by the European Space Agency (ESA) in 2009, many APEX flights have been performed throughout Europe, providing data to Belgian and European researchers, institutes and agencies, such as ESA, European Facility For Airborne Research (EUFAR), Belgian Science Policy (BelSPO), among others.

To ensure high quality of the final products, VITO adopts a two-fold approach: 1) targets high quality of the data itself and 2) constantly maintains and improves the operational processing chain. On the one hand, in support of the data quality, recurrent full geometric, radiometric and spectral characterization of the instrument is performed. On the other hand, the standard operational procedures benefit from intensively tested and validated computational methods.

Processing of the APEX imagery comprises several steps, ranging from initial spectral/geometric and radiometric calibration (Level 1 processing) to atmospheric/geometric correction and resampling to a user-requested projection system (Level 2 processing). Thus, the processing is always adapted to the user needs, who can opt between a plethora of final products and settings: radiance/reflectance datacubes, georeferenced/non-georeferenced images, *land reflectance/water leaving reflectance*, various projection systems of the georeferenced data (*e.g.*, geographic, UTM, Lambertian 72), etc.

In this contribution, we present the general APEX processing procedures, with emphasis on the Level 2 processing. Examples of final reflectance spectra obtained in heterogeneous scenes and comparisons to ground-truth signatures are provided for illustrative purposes. The high correlation of the APEX spectra and the ground-truth ones shows the high quality of the CDPC output. For specific research problems, new data can be acquired upon request at any time.

MODTRAN®6: A Major Upgrade of the MODTRAN Radiative Transfer Code

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Keywords: MODTRAN, Remote Sensing

The MODTRAN6 radiative transfer (RT) code is a major advancement over earlier versions of the MODTRAN atmospheric transmittance and radiance model. This version of the code incorporates modern software architecture including an application programming interface, enhanced physics features including a line-by-line algorithm, a supplementary physics toolkit, parallelization options and new documentation. The application programming interface has been developed for ease of integration into user applications. The MODTRAN code has been restructured towards a modular, object-oriented architecture to simplify upgrades as well as facilitate integration with other developers' codes. MODTRAN now includes a line-by-line algorithm for high resolution RT calculations as well as coupling to optical scattering codes for easy implementation of custom aerosols and clouds.

Georeferencing Method for Airborne Scanner Image without Exterior Orientation Parameters

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Keywords: rectification, hyperspectral scanner, airborne

One of the main processing steps of evaluating remote sensing data is the georeferencing or rectification of the acquired scanner data to a local coordinate system. Since in most applications of thematic analysis, a rectified data set is required, there is a need for an effective performing the rectification especially for overlaying the data with existing data sets or maps and using them for change detection analysis. Currently, a Direct Georeferencing Method which has ability to provide data for high accuracy mapping is successfully used for various kind of airborne data. But it happens when exterior orientation parameter didn’t obtain and rectification was demanded. In this study, a georeferencing method is shown to achieve an accurate geocoding of airborne pushbroom type

hyperspectral image acquired without parameters from global positioning system and inertial measurement unit devices.

The airborne hyperspectral image was acquired by AISA Eagle sensor with the spatial resolution of 5 m for the territory of forest site in Beskydy Mountains of the Czech Republic. *The number of spectral bands was 65 in the spectral range of 400 to 970 nm. The image radiometric and atmospheric corrections were preceded the georectification procedure. Radiometric correction of the hyperspectral images was performed using CaliGeo 4.6.4 (Spacim) software and ENVI 4.4. Atmospheric correction was done in ATCOR4 6.0 (ReSe Applications Schlaepfer). Geo*rectification algorithm of the hyperspectral data consisted of two procedures.

The first procedure was alignment where each row was shifted to maximize the correlation coefficient with previous row. To achieve the subpixel accuracy, correlation coefficients calculated with sinc-interpolated rows. This procedure allowed to compensate the distortions caused by aircraft roll motions. To avoid the effect of illumination a luminance value was determined from a user-defined range in the calculation of the correlation coefficient.

The second step was the geometric correction of aligned images for reference (control) points. Mathematically, the problem is formulated as a building of two-dimensional projection from the map to the aligned image. We investigated the quality of the display of affine, bilinear, polynomial and piecewise bilinear mapping (or grid). The best result was obtained by using the piecewise bilinear mapping. Constructing piecewise bilinear mapping was based on the minimization of the maximum modulus of the derivative of two-dimensional mapping in condition of matching the coordinates of control points. Derivative of modules was calculated in nodes of a uniform square grid with steps of 16, 32 and 64.

Accuracy of rectification was assessed by points discrepancy between target image and source hyperspectral image. X-coordinate accuracy was in the range of 0.44...1.31 meters (RMSE=1.1) and Y-coordinate accuracy was in the range of 0.56...1.09 meters (RMSE=1.05).

Standards for the validation remotely sensed albedo products

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Keywords: Vegetation, Albedo, In-situ, Uncertainty, Validation

Land surface albedo is important component of the Earth's energy balance, defined as the fraction of shortwave radiation absorbed by a surface, and is one many Essential Climate Variables (ECVS) that can be retrieved from space through remote sensing. To quantify the accuracy of these products, they must be validated with respect to in-situ measurements of albedo using an albedometer. Whilst accepted standards exist for the calibration of albedometers, standards for the use of in-situ measurement schemes, and their use in validation procedures have yet to be developed.

It is essential that we can assess the quality of remotely sensed albedo data, and to identify traceable sources of uncertainty during process of providing these data. As a result of the current lack of accepted standards for in-situ albedo retrieval and validation procedures, we are not yet able to identify and quantify traceable sources of uncertainty. Establishing standard protocols for in-situ retrievals for the validation of global albedo products would allow inter-product use and comparison, in addition to product standardization. Accordingly, this study aims to assess the quality of in-situ albedo retrieval schemes and identify sources of uncertainty, specifically in vegetation environments.

A 3D Monte Carlo Ray Tracing Model will be used to simulate albedometer instruments in complex 3D vegetation canopies. To determine sources of uncertainty, factors that influence albedo measurement uncertainty were identified and will subsequently be examined:

1. Time of day (Solar Zenith Angle)

2. Ecosytem type
3. Placement albedometer within the ecosystem
4. Height of albedometer above the canopy
5. Clustering within the ecosystem

A variety of 3D vegetation canopies have been generated to cover the main ecosystems found globally, difference seasons, and different plant distributions. Canopies generated include birchstand and pinestand forests for summer and winter, savanna, shrubland, cropland and citrus orchard. All canopies were simulated for a 500x500m area to best represent in-situ measurement conditions. Preliminary tests have been conducted, firstly, identifying the spectral range required to estimate broadband albedo (BBA) and secondly, determining the hyper-spectral intervals required to calculate BBA from spectral albedo.

Final results are expected to be able to identify for the factors aforementioned, given a specified confidence level and within 3% accuracy, when does uncertainty of in-situ measurement fall within these critera, and outside these criteria. As the uncertainty of in-situ measurements should be made on an individual basis accounting for relevant factors, this study aims to document for a specific scenario traceable uncertainty sources in in-situ albedo retrieval.

O11B-Dro: Remotely Piloted Aircraft Systems (RPAS) hyperspectral remote sensing

Remote sensing of vegetation physiological condition using micro- and nano hyperspectral cameras on board lightweight RPAS

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Keywords: unmanned vehicles, UAV, RPAS, hyperspectral

This work presents current progress in physiological condition monitoring using lightweight hyperspectral imagers on board Unmanned Aerial Vehicles (UAVs). Recent studies have demonstrated that nano- and micro-hyperspectral cameras carried by lightweight remotely piloted aircraft (RPAS) enable the generation of several narrow-band spectral indices related to crop physiological condition, canopy temperature, as well as the quantification of the chlorophyll fluorescence emission linked to plant photosynthesis. Work conducted with three different fixed-wing platforms for this purpose will be presented, ranging between 2 and 5-m wingspan to fly autonomously at altitudes between 50 and 500 m AGL with endurance time to cover up to 1500 ha per flight. The miniaturized thermal cameras used in the experiments yield pixel resolutions between 20 and 50 cm depending on the flight altitude, and are calibrated in laboratory. The micro-hyperspectral imager flown acquires between 260-360 spectral bands and 3 to 6 nm FWHM imagery depending on the acquisition mode used, obtaining 30 cm spatial resolution in the 400–1000 nm spectral range. Radiometric calibration, atmospheric correction and imagery ortho-rectification methods are conducted using commercial solutions and software developed at QuantaLab – IAS – CSIC laboratory. The results obtained using these miniaturized cameras demonstrate that sun-induced fluorescence and narrow-band indices show good relationships with physiological indicators such as stomatal conductance, stem water potential (SWP) and leaf photosynthesis. The indices calculated are related to xanthophyll, carotenoids, anthocyanins, and chlorophyll *a+b* absorption using optical indices such as PRI, TCARI, red edge, as well as with new narrow-band indices. For operational purposes, automatic object-based image analysis methods applied to the hyperspectral imagery will be described, enabling the generation of thematic maps of nutrient levels and water stress in orchards and vineyards at individual crown level without soil and background effects in less than 24 hours. The methods here presented demonstrate the feasibility for imagery acquisition using lightweight hyperspectral cameras in the context of precision agriculture.

Combining hyperspectral RPA and multispectral satellite imagery to increase spectral-temporal detail for precision agriculture applications

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Keywords: RPA, Spectral-Temporal Response Surfaces, vegetation indices, interpolation, crop properties

Precision agriculture applications require detailed crop status information at high spatial resolution and at highly-frequent time intervals to characterize crop growth anomalies. Satellite based remote sensing systems are capable of providing regular observations with increasing spatial resolution up to 5-10 m. However, these multi-spectral systems often lack spectral detail in especially the red-edge region of the reflectance spectrum to characterize plant health status related to nutrients or pests and diseases. A recent development in precision agriculture is the use of Remotely Piloted Aircrafts (RPA) equipped with hyperspectral camera's which are capable of acquiring very-high resolution images both in the spatial and spectral domain with flexible timing of data acquisition. However, economic and operational considerations may limit the number of high-resolution RPA images available. Therefore it would be of interest to develop methods that combine hyperspectral data with additional satellite observations of a lower spectral resolution to provide a complete representation of the temporal dynamics of spectral reflectances during the growing season.

In this study we present the concept of Spectral-Temporal Response Surfaces (STRS) to provide continuous reflectance spectra at high temporal intervals. This research presents a novel STRS methodology which uses Bayesian theory to impute missing spectral information in the multispectral imagery and introduce observation uncertainties into the interpolation process. The STRS method is used to combine multispectral satellite imagery (from Formosat-2) with hyperspectral imagery acquired with a RPA for an experimental potato field. The novel STRS method is compared to two earlier published STRS methods: a direct spectral-temporal interpolation of the original data, and a direct interpolation along the temporal dimension after imputation along the spectral dimension. To evaluate the accuracy of the three STRS methods, image based spectra derived for the three methods are compared to field measured canopy reflectance spectra, Leaf Area Index (LAI), and canopy chlorophyll for 24 plots in the experimental potato field. The results indicate that the novel Bayesian STRS approach has the highest correlation (r=0.953) and lowest RMSE (0.032) to the field spectral reflectance measurements. Although the OSAVI obtained from all methods had similar correlations to field data, the MCARI obtained from the Bayesian STRS outperformed the other two methods. A correlation of 0.83 with LAI and 0.77 with canopy chlorophyll measurements was obtained, compared to correlations of 0.27 and 0.09 respectively for the directly interpolated STRS. This observation is very important for future STRS applications. As MCARI is a vegetation index based on wavelengths outside the extent of Formosat-2 imagery, these results indicate that constructing a STRS can accurately extrapolate a limited number of hyperspectral measurements to daily observations during an entire growing season. In applications such as precision farming, it could help bridge the gap between sensor capabilities and data requirements.

Hyperspectral remote sensing of crop properties with Unmanned Aerial Vehicles

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Keywords: hyperspectral imaging, UAV, RPAS, precision farming, agriculture

Aerial hyperspectral remote sensing technologies provide effective methods for the exploration and study of the earth surface. The recent progress in miniaturization of imaging and processing modules enables use of low-cost Unmanned Aerial Vehicles (UAV) as sensor carriers. They offer a great potential for local area remote sensing applications, such as for agricultural, forestry, mining industry and hydrological applications. For agriculture in particular they will allow non-destructive detection of plant biophysical and chemical properties with a high spatial and temporal resolution relevant for precision farming and for agricultural research.

We present a case study conducted over the Field Phenotyping Platform (FIP) at the ETH Zürich research station for plant sciences at Eschikon, Lindau, as collaboration between EPFL TOPO laboratory, Gamaya company and the ETHZ Crop Science Laboratory. The aim of this case study was the determination of crop properties and phenotypes as related to spectral characteristics by using a novel Hyperspectral Imaging (HSI) snapshot camera developed by Gamaya.

Gamaya provides turnkey UAV-optimised hyperspectral imaging solutions for industrial applications. The developed cameras are capable of sensing up to 100 spectral bands in visible and near infrared spectra. In this study a model with 16 bands in the visible range was used. In particular, the snapshot imaging mode allows for the use of modern image processing-based techniques for the geometric registration of HSI data.

The UAV deployed during this study was a custom made hexacopter with Pixhawk autopilot. The unit allows for execution of manual and automatic flights as well as a tight integration with the imaging system. The cameras were integrated together with an embedded computer assuring a proper triggering and synchronization of all the components. Moreover, the camera sensor head was accompanied by Global Navigation Satellite System and Inertial Navigation System (GNSS/INS) constituting a compact all-in-one remote sensing system. The navigation and imaging systems were synchronized to provide precise position and orientation information for each acquired image that in turn speeds up the processing. In addition, the precise knowledge of exterior orientation parameters allows creating seamless orthomosaics and multispectral maps without the need of establishing ground control points which significantly reduces the time and resources. Particularly, this approach is required over areas with homogeneous or dynamic terrain, for example crop fields or water surfaces.

We extracted the spectral data from a set of 34 plots (4 m^2) including a range of different crops (soybean, sunflower, maize and buckwheat) were plant properties were determined. We calculated nine spectral indices reported for visible range. The spectral indices were related to leaf nitrogen, chlorophyll and total pigment concentration (in mg g^-1), canopy cover (fraction of plant per area %), leaf area index (m^2 m^-2) and spad (leaf greenness). For each of the mentioned traits good to very good relationships were identified and are reported in this contribution. Further we show the applicability of the camera and UAV setup for identification of phenotypic differences in winter wheat trial with more than 200 genotypes.

High resolution vegetation monitoring with a novel compact hyperspectral camera system

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Keywords: hyperspectral camera, RPAS, vegetation monitoring

Worldwide, great effort is spent on agricultural field experiments. The effects of fertilizers, cultivation methods, treatments and seed varieties are tested through comparative trials on adjacent plots. The results are of immediate interest to farmers. Field trials are also vital to gather important scientific information, e.g. to assess the performance of new traits, and to gather environmental safety data required by regulatory authorities to evaluate commercial product approvals. Performing field trials requires an accurate and continuous monitoring of small scale fields which is time consuming, labor-intensive and therefore very expensive.

Recently, the development of Remotely Piloted Aircraft Systems (RPAS) has allowed faster and more cost-efficient collection of aerial imagery on a local scale. We present a compact hyperspectral camera system which is small and light enough to be operated on RPAS. The system is very similar to a standard RGB camera. To achieve hyperspectral imaging, standard broadband RGB filters are replaced by thin film interference filters which transmit many narrow spectral bands spread over a wide spectral range. These filters are deposited directly onto the image sensor using the same semiconductor infrastructure as used for the image sensor. This e.g. allows pixel level alignment of the filter with the sensor. The spectral bands are arranged per line, with groups of 5 adjacent lines on the sensor having the same spectral response. Filters were deposited on a 2 Mpx high sensitivity CMOS image sensor, covering a spectral range of 470nm to 900 nm with narrow band filter responses (FWHM 5nm to 10 nm).

We have built such a hyperspectral camera system and complemented it with a customized processing chain. A unique aspect of the system is that it captures 2D images with different spectral responses along image lines. We are able to perform accurate photogrammetry on sets of images collected during flights and produce high quality hyperspectral images of complete areas as well as derived products, including digital surface maps.

We have demonstrated the functionality of camera and processing in various test flights. Flying the system at 60m altitude and optics with 18.5 mm focal length, a very a high spatial resolution of 2,5 cm is achieved. This spatial resolution allows very detailed local vegetation monitoring in which individual crops can be detected. Combined with detailed hyperspectral information, very detailed monitoring of experimental fields is feasible.

Experimental imagery was collected over various test sites. One particular field trial was executed over a strawberry test field in cooperation with PCfruit (research station for fruit growing). The field exhibits different varieties and fertilization strategies. The hyperspectral data was processed and analyzed. It clearly reflects the variations over the field, even at small scale. This clearly illustrates the potential of the hyperspectral camera system.

UAV hyperspectral image frame cameras: from camera categorization to quality assessment

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Keywords: RPAS, UAV, UAS, hyperspectral, data processing, image frame, snapshot camera, crop surface model

Hyperspectral remote sensing has shown great potential to derive information about the biophysical and biochemical parameters of agricultural crops as well as to detect environmental stress or plant diseases. Traditionally, hyperspectral data is acquired with field spectrometers, airborne sensors or satellites. Recently, hyperspectral sensors have been shrinking in size and weight and have thus become feasible for use onboard of UAVs. Additionally, new sensors have become available which capture hyperspectral image frames (IF) sequentially or with one exposure.

In the first part of our presentation we would like to suggest a common terminology to structure the different kinds of the upcoming hyperspectral IF cameras. The first category refers to the type of spectral data the cameras record: here we divide in multispectral cameras (MS) and hyperspectral cameras (HS). The second category refers to the way the images are acquired: here we divide the cameras into image-frame (IF) and snapshot (S). If all bands are synchronously captured, e.g. within the same exposure or for multi-camera systems triggered at exactly the same time ideally with the same integration time, the full IC is recorded without scanning and the cameras are referred to as snapshot (S) cameras. Else, if bands or band packaged are recorded sequentially or unsynchronized as two dimensional images frames, we refer to them as image frame (IF) cameras.

In the second part, we briefly introduce our automated processing chain to derive volumetric hyperspectral data. We use the concept of crop surface models – a 2.5D representation of the plants canopy to monitor plant growth – and incorporate hyperspectral information for each pixel. This is done inherently without co-registering the two types of data. Additionally, the processing chain implements methods of quality assessment. We demonstrate the final data product from a field-campaign conducted with our hyperspectral imaging UAV system equipped with a novel HSS camera. The results show that important plant parameters like chlorophyll, LAI, biomass and plant height can be well estimated. Moreover, we show the importance of quality information within the data product.

O12A-Pro: Image Processing Methods Part 2

Optimal Iterated Two-Class Separation in Hyperspectral Data

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Keywords: canonical discriminant analysis

This paper gives an iterated extension of canonical discriminant analysis (CDA) for separation between two groups or classes in multi- or hypervariate data. We show that the iterative extension greatly enhances the separation between classes in a case with 110-band HyMap data covering part of the Sokolov mining area in the Czech Republic. Below three spectral bands of the original data (red 848 nm, green 1.781 nm and blue 681 nm) and the iterated canonical variate that based on an initial training area gives the optimal separation (in the CDA sense) between waterand everything else” are shown.

References

R. A. Fisher, The utilization of multiple measurements in taxonomic problems,*Annals of Eugenics*, vol. 7, pp. 179–188, 1936.

T. W. Anderson, *An Introduction to Multivariate Statistical Analysis*, John Wiley, New York, third edition, 2003.

T. Cocks, R. Jenssen, A. Stewart, I. Wilson, and T. Shields, The HyMap airborne hyperspectral sensor: The system, calibration, and performance," in *Proceedings 1st EARSeL Workshop on Imaging Spectroscopy*, Zürich, Switzerland, 6-8 October 1998, pp. 37–42.

Advanced dimensionality reduction and active learning for imaging spectroscopy biophysical parameter retrieval

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Keywords: machine learning, active learning, feature extraction, ARTMO

With forthcoming super-spectral Sentinel-2 and Sentinel-3 missions, as well as the planned EnMAP, HyspIRI, PRISMA and ESA's candidate FLEX imaging spectrometer missions, an unprecedented data stream for land monitoring will soon become available to a diverse user community. The expected vast data stream will require enhanced processing techniques that are accurate, robust and fast. One of the major problems with these data streams is the large amount of data that has to be processed. Over the last few years machine learning regression algorithms proved to be powerful for retrieving biophysical variables. However, for many of them their powerful performances goes at a computational cost. This problem is even more significant when using simulated data that can easily scale up to several thousands of samples corresponding to different parameter selections. Simulated data created in this way might be redundant, as slight parameter variations might produce very similar spectra. In order to have these algorithms trained by large (hyperspectral) datasets, we need intelligent approaches that reduce data without losing informative, expressive power.

Data reduction can essentially take place at the two data dimensions: (1) in the spectral domain, i.e. by making use of feature extraction and dimensionality reduction techniques, and (2) in the sampling domain, i.e. by selecting the most informative samples through active learning (AL) techniques.

In this contribution, we present two new modules within our ARTMO's machine learning algorithms (MLRA) retrieval toolbox. ARTMO (Automated Radiative Transfer Models Operator) embodies a suite of leaf and canopy radiative transfer models (RTMs) and multiple retrieval toolboxes (see http://ipl.uv.es/artmo/). The MLRA retrieval toolbox offers a suite of MLRAs that enables to estimate biophysical parameters based on either experimental or simulated data. The newly developed feature extraction module encompasses a variety of principal component analysis (PCA) techniques (both linear and nonlinear, kernel feature extractors). The newly developed active learning module encompasses 6 different AL techniques (3 based on uncertainty and 3 based on diversity).

The utility of these data reduction techniques shall be demonstrated based on experimental and simulated hyperspectral data (e.g. CHRIS, HyMap) and biophysical parameters such as leaf area index (LAI) and leaf chlorophyll content (LCC). We will also show that these techniques not only enable to predict biophysical parameters at a reduced computational time, but also deliver improved accuracies as compared to the full datasets. Cross-validation sampling techniques will be applied to ensure the generation of robust results.

Decoupling Feature Redundancy Reduction and Feature Ranking for Hyperspectral Data

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Keywords: dimensionality reduction, feature clustering, hyperspectral data, support vector machine classification

The high information redundancy in hyperspectral earth observation data can limit the performance of supervised learning algorithms. Traditional feature forward/backward selection approaches successfully link the steps of feature selection and subsequent classification/regression. However, they pose a computationally expensive task and impede the identification of most relevant spectral features/segments due to quasi arbitrary selection of highly correlating, neighboring spectral bands. We therefore propose to decouple the reduction of redundancy from the ranking of features.

This is achieved in three steps. First, an unsupervised and computationally inexpensive clustering of spectrally correlating neighboring features is performed, leading to feature clusters where each cluster only contains highly redundant features. Second, representatives of each cluster are extracted. Finally, the representatives' relevance is determined by an SVM-based feature forward selection.

The quality of the approach is demonstrated on two imaging spectrometer datasets from Berlin. In an urban land cover classification problem using a 3.6 m HyMap scene and a support vector classifier, the approach generates well-interpretable spectral clusters and maps with accuracies comparable (± 2% F1 accuracy) to a more processing-intensive full sequential feature forward selection. For quantifying urban land cover fractions using a simulated 30 m EnMAP scene and support vector regression combined with synthetically mixed training data, the inherent feature reduction poses an effective way to reduce processing time during model training while the quality of fraction maps is maintained (ΔMAE = ±2%; ΔR^2 = ±0.05).

In this study we show that unsupervised feature clustering approach presents a possibility for the analyst to learn about the inherent correlation structure of the dataset. Using the subsequent ranking of each cluster for a supervised classification or regression problem reveals manifold important information, e.g. on the relevance of certain wavelength regions.

Airborne Imaging Spectroscopy at CzechGlobe

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Keywords: imaging spectroscopy, hyperspectral data, processing chain, lidar

Ecosystems, their services, structures and functions are affected by complex environmental processes, which are both natural and human-induced and globally changing. In order to understand how ecosystems behave in globally changing environment, it is important to monitor the current status of ecosystems and their structural and functional changes in time and space. An essential tool allowing monitoring of ecosystems is remote sensing (RS). Many ecosystems variables are being translated into a spectral response recorded by RS instruments. It is however important to understand the complexity and synergies of the key ecosystem variables influencing the reflected signal. This can be achieved by analyzing high resolution RS data from multiple sources acquired simultaneously from the same platform. Such a system has been recently built at CzechGlobe - Global Change Research Centre (Academy of Sciences of the Czech Republic).

CzechGlobe has been significantly extending its research infrastructure in the last years, which allows advanced monitoring of ecosystem changes at hierarchical levels spanning from molecules to entire ecosystems. One of the CzechGlobe components is a laboratory of imaging spectroscopy. The laboratory is now operating a new platform for advanced remote sensing observations called FLIS (Flying Laboratory of Imaging Spectroscopy). FLIS consists from an airborne carrier equipped with passive as well as active RS systems. The core instrument of FLIS is a hyperspectral imaging system provided by Itres Ltd. The hyperspectral system consists of three spectroradiometers (CASI 1500, SASI 600 and TASI 600) that cover the reflective spectral range from 380 to 2450 nm, as well as the thermal range from 8 to 10 um. Together with the hyperspectral system full-waveform laser scanner Riegl-Q780 is mounted (the laser scanner is being operated in cooperation with the AdMaS project). In 2014 the installation of the hyperspectral scanners was completed and the first flights were carried out with all sensors.

The new hyperspectral imaging system required adaptations in the data pre-processing chain. The established pre-processing chain (radiometric, atmospheric and geometric corrections), which was tailored mainly to the AISA Eagle instrument operated at CzechGlobe since 2004, has been now modified to fit the new system and users needs. Continuous development of the processing chain is now focused also on joint processing of hyperspectral and laser scanning data.

In this contribution we will introduce FLIS and the data pre-processing chain in details and show the first hyperspectral images acquired in 2014.

O12B-Sca: Scaling and Uncertainty

Hyperspectral data for scaling ecosystem traits from point to landscape

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Keywords: UAV, hyperspectral, PROSAIL

An accurate and spatially explicit estimation of ecosystem traits such as leaf area index and chlorophyll content is of fundamental importance for biogeochemical modeling. In this perspective remotely sensed spectral information has been shown to be a powerful tool for investigating ecosystem traits and their dynamics. Unluckily the availability of remote sensed hyperspectral data is still limited. On the other side hyperspectral imaging technology for near surface sensing has been recently quickly developing. Instruments are becoming much lighter allowing for being transported on unmanned aerial vehicles (UAV). UAV imagery is spatially limited but offers more flexibility compared to satellite based sensors allowing for specific and high-resolution scenes acquisition. In this context the use of spectral information for inverting radiative transfer models is a widespread approach to estimate biophysical parameters from earth observation data and its application to near surface sensing is offering new opportunities for spatial explicit estimates of ecosystem traits. In the present study we apply an inverted radiation transfer model to two grassland sites with differing management regimes. The objective was to derive ecosystem traits and to provide insights on scaling effects by using multiple spectral measurements techniques addressing different spatial scales. The application is to link point to landscape scale estimates through a better understanding of the scaling effects. For addressing this objective this we made use of a handheld field spectrometer and an UAV-borne imaging Fabry-Peroth interferometer for characterizing the sampling plots. The PROSAIL model parameters were then calibrated by using a Monte Carlo approach. We applied the same method using modis reflectances for the pixels surrounding the experimental plots. The accuracy and reliability of the estimated ecosystem traits with the different methods were then further compared to direct measurements. This allowed to assign uncertainties to the satellite based estimates. Our approach showed the importance of taking in account the spatial variability of ecosystem biophysical properties addressing scales ranging from plot to landscape.

Derivation of chlorophyll content on different scales at a validation-site for airborne and satellite products

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Keywords: chlorophyll, scales, hyperspectral, grassland, geostatistic

This project describes the set-up of a validation test-site for airborne optical-reflective imagery and for validation of satellite products, especially for Sentinel-2. This test-site should serve for a robust retrieval of biophysical parameters, such as phenology, LAI and chlorophyll content etc. We installed multispectral 4-channel and hyperspectral sensors at eddy-flux measurement sites monitoring two different vegetation types, grassland and deciduous forest. Spectral measurements are taken with dual-field-of-view systems continuously and automatically. Radiances and irradiances are measured in order to derive diurnal and seasonal reflectance dynamics. Measurements also include a RGB-camera for visual inspection and to easily derive phenological changes.

In a first step, the above described hyperspectral ground measurements and ASD field spectrometer measurements at the grassland test-site are used to derive chlorophyll content via a model-inversion. Results are scaled by geostatistical methods to landscape level. Airborne hyperspectral imagery is used to compare chlorophyll patterns at landscape level. The images are taken between 12 am and 1 pm with a 2 m spatial resolution and are radiometrically, geometrically and atmospherically corrected.

Our first results show a high correlation between ground- and airborne based chlorophyll patterns. Here we present our measurement concept and technical set-up as well as first results.

Estimating the uncertainty in ground reflectances resulting from radiometric and spectral calibration

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Keywords: Radiometric calibration, atmospheric correction, uncertainty, monte-carlo approach

Within the FP7 EUFAR project, the Joint Research Activity HYQUAPRO was aiming at the harmonization and standardization in the pre-processing of airborne hyperspectral data. One part of this research was to develop methodologies for the estimation of uncertainties related to various steps in the pre-processing chain.

Within this oral presentation, the methodological approach and the results for estimating the uncertainties in ground reflectances related to (1) spectral and (2) vicarious radiometric calibration are shown.

First, the typical uncertainty related to the spectral calibration of the HyMap whiskbroom sensor is addressed. Using datasets from Germany and from Costa Rica, the spectral reflectance near narrow-band absorption features of atmospheric gases is used to check for spectral shifts. For multiple targets in each scene, the corresponding wavelength shift is calculated using ATCOR4. When using multiple targets and multiple scenes, slightly different shift values occur. After the removal of outliers, the standard deviation of these shifts can be directly used to derive the uncertainty probabilistic distribution function (PDF). Next, within the Monte-Carlo approach, multiple realities of spectral calibrations are created using the PDF. Based on 100 of these simulated spectral calibrations, ATCOR4 was running repeatedly for the German test scene, and for one flight line in Costa Rica. Finally, the resulting uncertainty in retrieved ground reflectance was analyzed based on various targets within these 100 atmospherically corrected datasets. By using this approach, it is possible to propagate the uncertainty in spectral calibration to a typical uncertainty value in ground reflectance.

Second, to estimate the uncertainty of radiometric in-flight calibration, the HyMap scene Kaufbeuren/Germany from 2007 was used. Following a similar approach, first the PDF related to the

vicarious (ground-based) radiometric calibration is retrieved. For this scene spectro-radiometric reference measurements for 4 targets were taken with an ASD spectrometer. Using each of these measurements, a radiometric re-calibration was conducted following the approach implemented in ATCOR4. In a next step, the differences between the 4 calibrations and an additional regression-based calibration are analyzed in order to derive the PDF. Since all these calibrations can be considered as possible", the variation can be used as the PDF. As before, 100 realizations of the radiometric calibration PDF were generated, and ATCOR4 was running 100 times on the Kaufbeuren dataset. Finally, the resulting relative uncertainty in ground reflectance was calculated for multiple targets within these scenes.

To summarize the results,the uncertainty in reflectance related to the radiometric in-flight calibration is rather low (usually Also the spectral in-flight calibration using the proposed approach produces consistent results, but some outliers do occur. Generally, the uncertainty is highest in the 1st and 4th spectrometer of HyMap (~ 0.2 nm), and significantly lower in spectrometers 2 and 3 (~0.1 nm). Since the spectral bandwidths of HyMap ranges between 15 – 20 nm (FWHM), the uncertainty in spectral in-flight calibration is not highly important in this case.

Analyzing Uncertainties in simulated Canopy Reflectance through exhaustive Comparison with in-situ measured Optical Properties

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Keywords: Agriculture, EnMAP, field campaign, PROSAIL, phenology

Today, agricultural crops need to be grown efficiently, feeding a continuously growing world population from limited resources. Remote sensing is widely considered a valuable tool, contributing to that topic by monitoring farmland and providing input data for crop growth models. Thereby, spatial information on crop status is crucial for an accurate description of yield formation processes. A stable retrieval of biophysical variables from satellite data must rely on most advanced Earth Observation systems, such as the future hyperspectral mission EnMAP. Physically-based retrieval approaches, such as the inversion of canopy reflectance models, make the best possible use of this advanced data. However, invertible models only take a limited number of parameters into account and thus may show large uncertainties.

The presented study therefore investigates the accuracy of one of the most widely applied canopy reflectance models (PROSAIL). In order to isolate the contribution of different canopy variables to the spectral signature, a comprehensive field campaign has been carried out throughout the growing season of 2014, considering a sampling strategy defined to match the ground resolution of the future EnMAP (GSD 30m) and to account for sub-pixel-heterogeneity. The experiment was carried out on two test sites, a winter wheat and silage maize field located in Hallbergmoos, near Munich.

As of November 2014, 17 field days for wheat and 18 for maize have been realized with 589 measured spectral signatures of canopy, individual leaves and soil background. A total of 1850 in-situ measurements of selected parameters were recorded parallel to these spectral observations. The in-situ data can be classified into directly taken biophysical parameters (Leaf Chlorophyll, Leaf Area Index, Average Leaf Inclination Angle (ALIA), Leaf Mass per Area, Brown Pigment Factor, Soil Brightness, Canopy Height, Phenology) and into secondarily determined parameters which were derived from in-situ spectra (Leaf Carotenoids & Equivalent Water Thickness). Important auxiliary parameters (e.g. Canopy Height, Illumination Geometry) complete the measurements. These parameters were used as input for the PROSAIL model. Thus, vegetation spectra were simulated based on the in-situ measured optical properties. Simulated canopy spectra subsequently were compared to the previously measured ones. Deviations between modelled and measured canopy reflectance were significantly reduced by accounting for the effect of non-green leaf reflectance. Remaining deviations were considered to represent the sum of model uncertainties and measurement errors.

The results of the comparison will be presented, giving insights into the error ranges that will have to be expected when comparing modelled and measured spectral signatures. For winter wheat, the RMSE ranges from 3.4 to 10.7 with a mean value of 6.6 [% reflectance]. Errors for the prediction of silage maize signatures are lower by nearly a factor of two (average RMSE = 3.6). First analyses have identified the measured ALIA as a major error source that increases with density of the canopy. Consequently, wheat is affected in particular. Information on spectral uncertainty is especially important if the comparison of measured and modelled spectral signatures shall be used for the spatial assessment of the performance of land surface models.

Poster: Next generation of IS sensors

HySpex Mjolnir-1024 – a new high performance small form factor VNIR hyperspectral camera

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Keywords: HySpex, Mjolnir, hyperspectral, VNIR, UAV

HySpex Mjolnir-1024 is the latest camera designed and built by HySpex team at Norsk Elektro Optikk. The combination of high spatial resolution (1024 pixels) and spectral resolution (200 channels, 3nm per channel), high light throughput (F1.8) and high stability makes this camera a good candidate for a wide range of applications, including demanding scientific tasks. The camera covers 400-1000nm wavelength range and has a FOV of 20 degrees. The optical design is based on our high-end ODIN-1024 system.

The system contains a hyperspectral camera, data acquisition unit, IMU and GPS. With the total weight of less than 5kg, this system can be used on a wide range of UAVs. The ground station software has the possibility to show real time location of the UAV, plot the flight path of the UAV and show where along the flight path it has acquired images. A user also gets real time INS solution and will be able to control all the acquisition parameters of the camera, such as integration time and framerate. The system can be automatically triggered from the UAVs FMS, but can also be controlled manually. In order to provide real time visual feedback to the user, a serial link can be used to send low-resolution preview and quality control graphs down to the ground station. Even more real time data can be send via a videolink if available.

In this presentation, we will discuss the performance and stability of the camera, and give an overview of the complete system consisting of hyperspectral camera, computer, navigation system and software. We will also present the methods used for calibration and characterization of HySpex Mjolnir-1024.

PentaSpek – A ground based hyperspectral system for the estimation of vegetation parameters

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Keywords: ground based, vegetation, plsr, hyperspectral, breeding

Time critical applications as well as small size parcels often hamper the usage of remote sensing in plant breeding and agriculture research. However, there is an increasing need for non-destructive estimation of plant parameters during the vegetation period for a variety of agricultural applications.

Hyperspectral remote sensing allows for determining plant parameters like leaf area index, biomass, pigment concentration and nutritional information with a high level of accuracy. But high costs and changeable weather conditions in Central Europe often prevent an operational use of hyperspectral remote sensing at present.

The ground based hyperspectral system *PentaSpek* was developed by the Julius Kühn-Institute to make hyperspectral remote sensing available to agricultural field research. The system consists of five similar spectrometers with a spectral range of 400 - 925nm and an effective bandwidth of 5nm, resulting in 84 spectral bands. Incoming radiation is constantly measured by one spectrometer which serves as spectral reference for the four downwards observing spectrometers. Reflectance computation is done on-the-fly by correcting the observing with the spectral reference spectrometer. This setup considerably increases data acquisition times since changes in radiation due to clouds can be compensated. The system also enables measurements under cloudy sky. The system is equipped with a real time kinematic Global Positioning System (RTK-GPS) to locate the spectral measurements with an accuracy of 2.5cm.

The *PentaSpek* has been tested in rye breeding, where over 5000 parcels have been measured per year. Based on 225 reference spectra, partial least squares regression for the parameters fresh biomass (FM), dry biomass (DM), leaf area index (LAI) as well as chlorophyll content (SPAD) with coefficients of determination (R^2) of 0.92 (FM), 0.94 (DM), 0.91 (LAI) and 0.78 (SPAD) respectively could be established. All models showed a ratio of performance to deviation (RPD) above 2 indicating stable regression models. The high temporal resolution (e.g. nine measurements per site in 2013) allows for tracking the development of the different plant parameters over time. This information is very useful to describe the behavior of a specific phenotype to environmental conditions (e.g. drought stress) and can help breeders in plant selection.

Beside the application of *PentaSpek* in small scale applications like agricultural research, the system can also be used as an online sensor in operational farming. In 2011 *PentaSpek* measurements have been performed together with a hyperspectral airborne (AISA DUAL) campaign. The resulting maps displayed a similar pattern of the intra-field variability and a good absolute agreement.

EUFAR – European Facility for Airborne Research: Easy and Open Access to the Airborne Research Facilities and Expert Knowledge

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Keywords: airborne, imaging spectrometers, transnational access

The European Facility for Airborne Research, EUFAR, is an Integrating Activity of the 7th Framework Programme (FP7) of the European Commission with funding covering the period 2014-2018. The current EUFAR follows three previous contracts under FP5, FP6 and FP7, and currently represents a consortium of 24 European institutions and organisations involved in airborne research. 18 small and medium size aircraft equipped with a multitude of different sensor systems are available to the European scientific community through transnational access. The following hyperspectral cameras are available through EUFAR to researchers, who do not have access to a corresponding research infrastructure in their home country:

- AHS
- aisaFenix
- aisaOwl
- APEX

- CASI
- HySpex VNIR
- HySpex SWIR
- TASI

Transnational access is not the only aspect of EUFAR, which is of high interest for the hyperspectral research community. EUFAR also offers Education and Training opportunities for the next-generation researchers. Early-stage researchers have the chance to take part in EUFAR training courses including a flight campaign and to join already planned flight campaigns. EUFAR also offers the platform to exchange knowledge and promote best practice in airborne research through Expert Working Groups, of which several relate to issues of hyperspectral remote sensing (e.g. hyperspectral data processing, hyperspectral applications for soil, calibration and validation). One research activity within EUFAR deals with the development of methodologies and tools for the integrated use of airborne hyperspectral imaging (HSI) data and airborne laser scanning (ALS) data in order to produce improved HSI and ALS products.

This poster will give an overview of all activities taking place within the EUFAR project showing the possibilities for researchers to get involved in Europe's biggest network of airborne Earth Observation.

Hyperspectral imaging spectrometer SPEKTROP - first measurements

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Keywords: SPEKTROP, hyperspectral sensor

SPEKTROP is hyperspectral imaging spectrometer for remote sensing applications designed and built in Space Research Centre of the Polish Academy of Sciences (CBK PAN). The aim of constructors was to minimize the size and the weight of spectrometer system and therefore SPEKTROP is dedicated to measurements from different platforms. It may be used on board of UAV (unmanned aerial vehicle), airplane and helicopter. The system consists of TMA (Three Mirror Anastigmat) telescopes cooperated with CCD detectors matrix, front-end electronic module, controlling unit with data collecting and processing unit. The system is equipped (optionally) in antivibration and stabilization modules. Images are registered in spectral range 400 - 1000nm divided into 200 spectral bands with spectral resolution 3nm. Field of view of the system is around 4,5 deg for current CCD (possible 15 deg by replacement of another CCD array). The maximum speed of image frames collection is 100 frame per second.

In 2012 system SPEKTROP was adapted to work on ultra-light plane platform - monoplane SONEX. The first flights were dedicated for system configuration. During these flights one of the first SPEKTROP acquisitions were performed over the area of Piotrków Trybunalski. In the next stage of the project planes Voulcanair and Cessna with the professional photogrammetric mount were used to carry out measurements in close surrounding of Modlin airport. Results of these measurements are presented.

Poster: Applications in Forestry

Detection of Vegetation Stress using VNIR and SWIR Field Imaging Spectroscopy

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Keywords: Dryness, Beech, Proximal Sensing, Chlorophyll, Water content

In the light of changing climate, drought stress is expected to occur in central Europe more frequently than in previous decades. During the drought episode in the late summer of 2003, it became obvious that stress phenomena are distributed quite heterogeneously both in space and time. In order to investigate the reaction of trees to drought stress with a high temporal, spectral, and spatial resolution, we conducted an experiment on exposing young European beech (*Fagus sylvatica* L.) trees to dryness stress and observing them with field imaging spectroscopy. Five year old beech saplings were planted into pots (three trees per pot, 20 pots in total) and randomly assigned either to well-watered or to drought-stressed group. Both groups were watered until mid-summer, then the drought-stressed group was cut off from water supply for four weeks. During this time, equivalent water thickness (EWT) of the leaves and leaf chlorophyll content (LCC) were measured regularly. Leaf reflectance and transmittance was measured using an ASD FieldSpec spectroradiometer equipped with a leafclip.

In addition, we recorded field imaging spectroscopy data using a HySpex VNIR-1600 and a SWIR-320m-e camera mounted to a 3.8 m high platform three times during the experiment. Up to three pots were recorded in each image; each imaging day 8 VNIR and 8 SWIR images were recorded. The VNIR images are about 4600 x 1600 pixels with 160 bands from 414 to 990 nm. The SWIR images contain about 1200 x 320 pixels with 256 bands from 967 to 2500 nm. Spectra of the tree pots were extracted and used with reference data measured during the drought experiment to train PLS regression models of EWT and LCC. Both properties can be estimated using only the VNIR sensor, but EWT estimation gets considerably better using SWIR data as well. Like expected, LCC estimations with SWIR data alone do not work satisfactorily. The models were applied to the images on a pixel-by-pixel basis to create maps of these properties with a spatial resolution in the millimetre range. As an additional validation of the values extracted from imaging spectroscopy with PLS regression, PROSPECT reflectance model inversions of the ASD leaf spectra were used. These showed that the mapped values were in the correct range of values and that the regression models gave sound results. Observing drought-stress in young trees with field-based imaging spectroscopy in the VNIR and SWIR region is a promising technique. Changes in leaf and canopy reflectance can be examined at a very high spatial resolution that even makes intra-leaf examinations possible.

Early detection of drought stress in Beech stands using hyperspectral airborne data

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Keywords: hyperspectral, European Beech, water stress

The recently published IPCC report underpins that temperatures and length, frequency, and intensity of warm spells or heat waves might increase over all of Europe. Reliable information about the climate sensitivity of important tree species is therefore of importance for maintaining forest productivity. Especially the drought tolerance of European beech (one of the economically most important species in Germany) has already been the subject of various empirical studies and modelling approaches.

Although revealing potential adaptation abilities and site limitations on large spatial scale, results are not necessarily supporting site-specific decision-making.

As in most of Europe, the summer of 2003 was one of the hottest and driest on record in SW Germany, and climatologists suggest it provided a realistic idea about future climate scenarios. The analysis of a seasonal time series of Landsat imagery revealed that Beech stands in the Donnersberg region in Rhineland-Palatinate, Germany, exhibited substantial differences of drought stress symptoms, depending on species and site conditions such as slope, aspect and soil depth. Additionally, dehydration experiments under laboratory and greenhouse conditions have demonstrated that hyperspectral measurements are capable of detecting early stress symptoms on leaf and plant level.

Since climate conditions during spring and early summer 2014 were even warmer and drier than in 2003 it was decided to conduct an airborne experiment to analyse the early detectability of drought symptoms in the Donnersberg region. On 3 July 2014 a cloud and gap free image mosaic was acquired with a HySpex hyperspectral imaging system (covering the full range from 400 to 2500 nm). With a special focus on European Beech (Fagus sylvatica L.) our research addresses whether hyperspectral imaging permits an early detection of water stress in comparison to conventional multispectral data, and whether the spatial distribution of stressed and unstressed stands is related to site conditions. Regionalised information on soil moisture regimes and tree species distribution (available from the State Forest Administration) served as reference for the statistical analysis of hyperspectral indicators (such as PRI, NDWI, MSI etc.).

Above Ground Biomass Estimation with Airborne Hyperspectral and Lidar Data in Temperate Spruce Forest

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Keywords: airborne, hyperspectral, LiDAR, biomass, forestry

Recently estimation of forest aboveground biomass (AGB) has received increasing attention from remote sensing community. Different remote sensing tools have shown a potential to derive some categories of forest attributes related to the AGB. Among these airborne laser scanning (ALS) has been numerously reported as a suitable data source for estimation of AGB due to its ability to estimate forest structure properties. In contrast, imaging spectroscopy has been considered so far as a tool with low predictive value for biomass estimation when used alone. A combined use of ALS and hyperspectral (HS) data has been reported in only a few studies and there is no uniform agreement on the predictive power of ALS and hyperspectral data fusion for estimation of the AGB.

In this study we tested the hypothesis that there is no synergic effect between information from HS and LiDAR on accuracy of estimation of forest above ground biomass on a plot-level scale.

We used two categories of airborne data and one set of field inventory data to test the hypothesis for spruce forests in the Beskydy Mountains of the Czech Republic: 1/ airborne hyperspectral (AISA Eagle scanner, 5m pixel size, 0.40 – 0.89 µm, 64 bands); 2/ ALS data (Riegl LMS-Q680i, near IR-*wavelength*, 1 point/m^2); 3/ field measurements of tree height, diameter at breast height, age, species composition and other stand parameters using Field-Map technology. We derived average tree height and crown density for each forest plot from LiDAR data, and averages of eight vegetation indexes for each plot from hyperspectral data. We applied field data for calibration and verification of the models.

We developed three models based on the metrics from airborne data and field measurements. The first one uses crown density and AGB from allometric equations for a single tree. The second model uses averaged plots' tree height and AGB estimates from field data on a plot level. The last model is an extension of the second one by addition of Red Edge Normalized Vegetation Index – ($NDVI_{705}$) from HS data.

The models were validated against AGB from field measurements for the plot-level.

Our findings show there are statistically significant differences (p^2 = 0.71, RMSE = 17.9 %) and the third (R^2 = 0.79, RMSE = 15.3 %), and between the second (R^2 = 0.72, RMSE = 13.9 %) and the third (R^2 = 0.79, RMSE = 14.8%) models, respectively. This indicates that there is a synergic effect of HS information on LiDAR information for biomass estimation at plot-level in spruce forest.

Tree Species Classification in a Central European Floodplain Forest: with AISA DUAL Airborne Data Using Machine Learning Algorithms and Spectral Variable Selection.

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Keywords: PLS-LDA, Random Forest, machine learning, Competitive Adaptive Reweighted Sampling (CARS), tree species classification

Anthropogenic interventions in natural watercourses e.g. river regulatory measures, extensive embankments and drainage of agricultural and pasture lands, have caused serious changes in Leipzig’s floodplain forest. Due to the water loss and the related lowering of the groundwater level the former floodplain district dries out more from year to year, leading towards a shift in species composition and a loss in biodiversity. To counteract this trend, revitalisation strategies for the former watercourses were developed. The objective of this study is to provide a remote sensing based monitoring system to predict effects from the rewetting on tree species composition, functional diversity and ecosystem services. One main goal of our pilot study presented here was to use the machine learning algorithms Random Forest (RF) vs. Linear Discriminant Analysis based on Partial Least Squares (PLS-LDA) for a supervised classification of 10 tree species within Leipzig's structural- and tree species-diverse floodplain forest; for these classification approaches we used airborne hyperspectral image data (AISA DUAL system) with 2 m ground resolution. To reduce the spectral variability and to exclude shaded parts of the tree crowns from the image, a spectral mixture analysis using shadow as one endmember was performed in preparation of the classification. The generation of calibration and validation sets from ground truth data was conducted using conditioned Latin hypercube for a stratified random sampling procedure. Furthermore, normalisation techniques were compared for a pixel- and an object-based approach. The minimum number of bands leading to an optimal separation of the tree species was identified using iterative bootstrap-validation and the Competitive Adaptive Reweighted Sampling (CARS) variable selection strategy. Preliminary results indicate significantly better results for the PLS-LDA than for the RF approach, with overall accuracies around 69 %. Highest class-specific producer accuracy (98 %) was achieved for *Populus balsamifera* L. with a corresponding user accuracy at about 89 %.

Tree species classification of Karkonoski National Park using APEX hyperspectral data

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Keywords: Tree species, SVM, ANN, classification

288 band APEX (Airborne Prism Experiment) hyperspectral data were used to classify six chosen tree species of Karkonoski Pational Park (M&B reserve of the UNESCO, SE Poland). Classified species were: beech, alder, birch, spruce, pine and larch. Algorithms employed in this work were SVM (Support Vector Machines) with linear kernel and artificial neural networks. Results from two mentioned classification algorithms will be compared. Furthermore successfully trained neural networks will be

used to classify additional scene that didn't took part in training process. To reduce training and classification times for ANN 40 best bands will be selected after achieving satisfactory accuracy of SVM classification. For comparison purposes three types of data were used: images without atmospheric correction and two that used for atmospheric correction high resolution DTM (Digital Terrain Model) and DSM (Digital Surface Model) respectively. Such approach will allow us to measure overall accuracy change of classification depending on type of data. Atmospheric correction has high impact on classification results in areas characterized by very diverse topography such as mountainous areas. Research area covers area located in the north part of Karkonoski National Park near Szklarska Poręba village.

Optimizing Temporal Sampling for Broad Leaf Species Classification in Laboratory Spectroscopy

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Keywords: species identification, senescence, imaging spectroscopy

Given optical collection campaigns are dependent on cloud free sky conditions, there is little control over temporal sampling for remote sensing, especially in the wet Canadian Pacific Northwest climate. Thus, remote sensing for forestry applications are commonly subjected to data that are collected at various times during the growing season. Vegetation can have species-specific phenologies, which have a direct impact on the expression of reflectance responses. This is especially the case when dealing with broad leaf deciduous species, which may have different pigment types and different timing for the onset of senescence. From the perspective of tree species classification, species-specific phenology may offer an optimal temporal sampling for maximum species discrimination. This study was devised to address species differences in spectral reflectance and pigment concentrations throughout the senescence process.

Five broad leaf deciduous species were selected and sampled through six dates from mid September (pre-senescence) through late October. Species sampled included: bigleaf maple (acer macrophyllum), red maple (acer rubrum), Garry oak (quercus garryana), northern red oak (quercus rubra) and southern catalpa (catalpa bignonioides). At each sampling date two specimens per species, three samples per specimen were taken for a total of 180 samples. For each sample, reflectance measurements were made in a darkroom and with a constant geometry with a full range ASD Fieldspec Pro spectroradiometer. Samples were rotated to three different orientations to capture anisotropic effects. In addition, leaf tissues were processed for pigment contents by traditional spectrophotometric means.

Stratified by collection date, species separability was qualitatively assessed through reflectance and first derivative spectra and quantitatively through traditional ND classifiers (clustering and spectral angle mapper). This study will present variations in species classification accuracy attributed to sampling time through senescence. The efficacy of classification will be contrasted with foliar pigment concentrations to determine if the source of species discrimination can be attributed to species-specific senescence phenology (timing of chlorophyll degradation). In addition, we will compare these findings to airborne imaging spectrometer data collected over the sample site.

Monitoring forests phenology by remote sensing techniques: Merits and limitations

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Keywords: phenology, NDVI, NDWI, MODIS, multi-spectral camera

Phenology is the study of recurring life-cycle events that are initiated and driven by environmental factors. Valuable information about ecosystem responses to climate can be derived from time series analyses of selected variables such as green-up, maturity, senescence and dormancy. Numerous techniques have been used to observe the effect of climate on phenology, however remote sensing provides the only way to observe and monitor phenology over large scales and at regular intervals. Spectral indices such as the normalized difference vegetation index (NDVI) and normalized difference water index (NDWI) from MODIS instrument were used in this research for monitoring vegetation responses to climate variables. The aim of this research is twofold: (1) to study the phenological behavior of four forests situated along a climatic gradient in Israel, as a response to three main climate variables (precipitation, temperature and radiation) during the last 14 years; (2) to explore the performance of a multispectral camera to assess a year-around phenological cycle. Specific objectives are as follows: (1) Examine the influence of drought years on the phenological response of the forests under study; (2) Examine the hypothesis that more relevant information on forest phenological response to climate can be retrieved by using two indices (NDVI and NDWI) rather than a single one; (3) Comparing the ability of multi spectral camera to monitor phenological events with that of conventional RGB camera. Four forests that are located along a rainfall gradient in Israel were chosen as research sites (Yatir, Carmel, Jerusalem, and Galil), while the multi spectral camera was situated in Ramat hanadiv. Preliminary results from time series analysis in Yatir site showed the highest response (R^2=0.84) of forest's NDVI to accumulated precipitation in the last 96 days and air temperature at the previous 16 days. In Carmel site all three climate variables showed significant high correlations with vegetation indices. Best fit model for NDVI index in Carmel included summed precipitation of 112 days and temperature in the previous 16 days (R^2=0.87). These simple models explain the variations in forest's greenness and might potentially predict the response of NDVI to changing climate variables. In Ramat Hanadiv site NDVI change was evident both for the whole plot level and individual species. Further work in this site will focus on relations with physiological and climatic data.

Poster: Ecosystem Services and Disturbances

Assessing the influence of seasonal dynamics of canopy interception storage on the urban water balance using remote sensing and field validation.

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Keywords: urban green, vegetation indices, canopy interception storage, seasonal dynamics, hyperspectral imagery

Global warming and population growth will put huge pressure on the quality of urban ecosystems. Urban green contributes to soil formation, flood and heat regulation, and therefore highly supports the livability in our cities. A detailed characterization of urban green is crucial to estimate the influence of vegetation on the water balance in urbanized catchments. As the vegetation cover changes along the year, it is also important to account for the impact of seasonal dynamics on the hydrological processes. However, despite the fact that some studies clearly indicate that both the coverage and the influence of urban green on the water balance are often underestimated, the characterization of the vegetation is usually simplified and/or generalized.

Imaging spectroscopy and aerial hyperspectral remote sensing have increased the resolution and capabilities of categorizing the biophysical properties of urban green in space and time. Therefore, a remote sensing based characterization of hydrological processes such as interception, depression storage, infiltration and evapotranspiration can increase the accuracy of hydrological modelling and improve water regulation and policy making for cities.

In this study, a remote sensing based methodology is presented to quantify the influence of seasonal dynamics of interception storage on the urban water balance. The *Leaf Area Index* (LAI) for trees and the *Poacea Abundance Index* (PAI) for grass are analyzed to gain better understanding of their relation to the interception storage capacity of urban vegetation. Further, the potential of APEX hyperspectral imagery (2m resolution) to extrapolate the interception capacity at catchment level (30m resolution) is shown.

Results from the upper Woluwe River catchment in Belgium indicate that the RS based canopy interception storage is up to 25% higher than the original literature values, resulting in an increase of the cumulative interception rates by 10%. Further, results from local field measurements demonstrate a strong correlation between the actual grass coverage and the PAI (R^2 = 0.89). Thus, a remote sensing based characterization of both grass and tree cover in urban catchments is recommended to evaluate the interception storage of urban green.

The results seem to vary with rainfall intensity as well as with seasonal dynamics. It is clearly seen that the canopy interception storage is lowest in leafless conditions by the beginning of the year, slowly increases until reaching its maximum in spring, then keeps the same storage capacity level until autumn and quickly decreases again until it reaches the initial values by the end of the year.

In summary, remote sensing based methods enable a detailed characterization of the seasonal and spatial variations of urban green and the seasonal dynamics of canopy interception on the urban water balance.

Hyperspectral method of assessment studies of heavy metals in plants.

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Keywords: photosynthesis, fluorometer, detection heavy metals in plants

The main driving force of photosynthesis is light absorbed by photosynthetic pigments. It can be registered by hyperspectral detectors and analysed by chlorophyll absorption and fluorescence. Chlorophyll fluorescence can provide information about the amount of light energy used in photochemistry and heat dissipation. Such analyses can allow for observations of physiological changes in plant vegetation. It can be registered by remote sensing detectors, e.g. field, airborne and satellite detectors.

The aim of this study has been tested hyperspectral remote sensing methods with biometrical fluorescence measurements for detection heavy metals in plants. Biomonitor Plant Stress Meter fluorometer and ASD FieldSpec 3 spectrometer (spectral range is 350-2500 nm) were used to measurements. The studies were conducted in the laboratory on the pea seedlings, which grew in different conditions and were given the lead. It was in 4 variants of the medium: control; Full Knopp medium + Pb; Full Knopp medium without P + Pb; H_2O + Pb. The spectral reflectance curve of control pea seedlings is similar to the pea's given Knop medium which inhibits the action of lead. The most destructive interaction of lead was observed when the plant was growing in the water. Spectrometric measurements allowed to calculate remote sensing indices, which were compared with minimal (F_0) and maximal (F_m) level of fluorescence and half rise time ($T_{1/2}$) from F_0 to F_m.

The fluorescence intensity depends on the quantity of chlorophyll molecules currently in the excited state (the so-called closed energy traps, unable to accept electrons). Reducing ratio of F_v/F_m indicates that a considerably less photosynthetic light reaction products. The main driving force of photosynthesis is light absorbed by photosynthetic pigments. Chlorophyll fluorescence can provide information about the amount of light energy used in photochemistry and heat dissipation.

Spectral characteristics as well as vegetation indices were analyzed by statistical test ANOVA, which showed a significant relationship between photosynthetic parameters measured by spectrometer and fluorometer. The highest correlation was observed between the indicators and the value of fluorescence ratios obtained for SIPI and the PRI group Light Use Efficiency which is characterized by the light energy used in photosynthesis. The decline in F_v/F_m ratios of leaves adapted to the darkness indicate the reduction of photochemical efficiency of the photosynthetic apparatus as a result of photoinhibition, induced by environmental stress factors.

The effect of heavy metals on lead is also evident in the values of remote sensing vegetation indices, indicators. The measurements of fluorescence at different light intensity is also confirmed by the intensity of the changes that occur in the plant peas when it was grown on Knop medium without phosphorus (reduced emission of heat to the plant could retain its photochemical activity) and in the case where the peas were grown in water completely stop of photosynthesis process and cell death is visible.

Changes in vegetation caused by stress or by treading elevated levels of lead in the environment can be recorded using hyperspectral remote sensing methods and a fluorometer.

Hyperspectral Simulation of an Arctic Landscape with ISDASv2

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Keywords: Canadian Arctic, geological exploration

The Canadian Arctic, rich with mineral resources and delicate ecosystems, is a complex landscape of exposed rock, lichen and tundra vegetation. Remote, illuminated by a low elevation sun and snow-free for short periods annually, this region is a challenge to map and explore. Imaging spectrometry (hyperspectral remote sensing) has shown potential to exploit spectral features associated with select mineral and biota as indicators in this environment, demonstrating applicability in geological exploration and habitat monitoring. With a suite of space borne hyperspectral sensor soon to be positioned to regularly acquire imagery over this region, methodologies to exploit hyperspectral imaging as one tool in arctic exploration is now required.

To evaluate space borne hyperspectral imagery for northern environments, the Imaging Spectrometry Data Analysis System (ISDASv2) can be used. ISDASv2 is being developed to provide a robust system allowing for the simulation of space borne imagery from airborne or field data. This includes simulating the effects known sensor characteristics (spectral/spatial resolutions, spectral curvature, keystone, noise, etc.) and atmospheric influences to the recorded signal. Once derived, the simulated imagery can be independently processed to at-surface reflectance. This allows for the evaluation of methodologies for information extraction and their sensitivities to sensor design. In this short demonstration study, an arctic environment scene is simulated for various existing and proposed sensors and the potential for detection of spectral features associated with select surficial constituents is evaluated.

Random forest classification for flower mapping using hyperspectral data

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Keywords: Random Forest, Flower Mapping, Hyperspectral Data, flower mapping

In recent years, managing honeybees have taken a major concern in several parts of the world. Specifically, attention has been paid to factors that threatening honeybee's health such as parasites, pathogens, abiotic stressors and changes in land use practices that wipe out flowering plants. The health of landscape for beehive production is mainly assessed for provision of the necessary resources for honeybees, in particular nectar and pollens which is offered by melliferous plants. Knowledge on density and diversity of melliferous plants as well as floral cycle and intensity is therefore important for honeybee's health and beehive quantity and quality. However, the highly dimensional hyperspectral data present problems that Hughes pheromones occur when number of field samples is smaller than the number of spectral features. In additions, the dimensionality of hyperspectral features might not be captured in a linear projection. We therefore attempted to map flowering melliferous trees in savannas in one of Kenyan beekeeping site using airborne Asia EAGLE hyperspectral data captured during two different dates; at the maximum period of flowering in December 2013 and at the beginning of floral period in January 2014. Using a random forest which is a nonlinear classification methods that produce variable selection by-product during the learning process account as efficient algorithms to delineate flowering trees and other vegetated and non-vegetated classes in savannas environment specifically in Kenyan beekeeping site with classification accuracy of up to 90%. For the white flowers and 84% accuracy for yellow flowers.

Spectral identification of biological soil crusts in the Northern Negev

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Keywords: Biological soils crusts, NDVI, PLSDA, Hyperspectral

Biological soil crusts (BSCs) are important components of arid and semiarid ecosystems. Monitoring BSCs spatial distribution is needed in order to better understand these ecosystems. The yearly phenological cycle of photosynthetic activity in the northern Negev can be divided to three stages: BSCs; annuals; and perennials. These elements are greening one after the other with some overlapping. The aim of the current study is to spectrally identify the greening of BSCs before covered by vegetation. Three treatments were applied: removing vegetation; removing BSCs; and control. Multispectral satellite images (Kompsat3) as well as hyperspectral ground level measurements (400-1000nm) were obtained in the northern Negev. The dates of spectral measurements were from dry season to dry season while obtaining data closely after the first rainfall event of the winter of 2013-2014. Spectral data of the two spectral resolutions were analyzed by partial least squares discriminant analysis (PLSDA) in order to explore difference between the treatments. The normalized difference vegetation index (NDVI) was calculated to assess phenology. The average total accuracy of classification for ground data sampled to satellite bands was 80% and for the images it was 76%. The average of NDVI values per treatment and date allows BSCs identification right after the first rainfall event as well as the annuals peak. Therefore, it can be concluded that: greening of BSCs can be identified based on the first significant rainfall event of the season [>5mm]; and classification of greening BSCs and bare soil as well as covered by dry vegetation is possible.

Hyperspectral image data for classification of tundra vegetation in the Krkonoše Mts. National Park

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Keywords: APEX, AISA DUAL, Neural Net classification, SVM, tundra, vegetation, the Krkonoše Mts. NP, the Czech Republic

The contribution is focused on the classification of the tundra vegetation in the Krkonoše Mts. National Park (the Czech Republic). Two types of hyperspectral image data were used for the

classification – APEX data from August 2012 (spatial resolution 2.4 m, spectral resolution 288 bans) and AISA DUAL data from June 2013 (spatial resolution 1 m, spectral resolution 498 bands). The aim was to compare and evaluate the validity of the two different types of hyperspectral data and different classification methods (e.g. Spectral Angle Mapper, Neural net, Support Vector Machine) for tundra vegetation classification. Classifications was processed on the level of vegetation associations and also on the level of particular species important for the area (several meadow species, Pinus mugo, Vaccinium sp. and Calluna vulgaris). Neural Net classification was found as the most accurate one, as it gives the most accurate results for APEX data as well as for AISA DUAL data (the overall accuracy 90 %, Kappa coefficient 0.88). The resulting accuracy of the classification (the overall one and also for some classes) reached better results than were those mentioned in the literature. Influence of the acquisition date on the classification accuracy was also proved in the case of some vegetation classes. The maps of tundra vegetation created in the framework of the project will be used for management and protection of valuable areas of alpine tundra in the Krkonoše Mountains National Park.

LiDAR and spectral imaging for coastal dune vegetation characterization in Western France

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Keywords: Spectral imaging, LiDAR, coastal dunes, vegetation mapping, spectral mixing

Open beaches and coastal dunes are key environments for preservation of the inland man-made facilities, either for social or recreational purposes. As several storms hit the coast of Western France the last few years and threatened the human coastal goods, it is necessary to understand the structure and dynamics of those environments, especially in the actual context of global warming. Since the vegetation is an essential feature of the coastal system as it allows to maintain the dune position but also plays an important part in the global ecological landscape, this contribution presents a method to characterize the coastal dune vegetation in Vendee, Western France. A focus is made on the Tresson dune which vegetation evolution has been monitored for over a decade. Over the dune, bare sand and almost 20 species of low vegetation can be found, constituting a zonation from the dune foot to the most inland part of the grey dune.

To map this dune, a coupled airborne data set of LiDAR remote sensing and hyperspectral images have been acquired together (with a Leica ALS 70-HP and HySpex VNIR-1600 + SWIR-320m-e) during the same survey in late 2013 summer. However LiDAR data and hyperspectral images still have to be registered so that each pixel of the images has corresponding 3D information (longitude, latitude, height (m)). This type of study requires first to set the hyperspectral data to be able to compare them to ground-truth. So field spectra have also been acquired (ASD FieldSpec 3) as ground-truth data of the dune vegetal species for different seasons since 2012.

Since the dune vegetation is mostly made of small footprint mosses or plants (~cm), it is necessary to introduce the concept of mixing while using remote sensing data with a 1 m x 1 m pixel size. The method used in this study is first to subdivide the dune in sub-areas of homogeneous vegetal associations. These are: Woodlands, mobile and transition dunes, grey dune with Tortula ruraliformis and grey dune with Hypnum lutescens, easily classified with a Spectral Angle Mapper (SAM) of a set of leave color indexes.

A field observation of the simple or intimate species associations, within each sub-area, was necessary to identify the different type of mixing (linear or non-linear) and their true endmember (isolated or spectrally indistinguishable group of species). Then a Fast Constrained Least Squares (FCLS) method allows to unmix the spectral information in order to retrieve the contribution of a limited number of true endmembers within a pixel.

Finally when the endmembers and their contributions are known for each pixel, the co-registered LiDAR data can be used to provide spatial information of the dune dynamics at the sub-pixel level using the associated 3D points cloud (density 6 pts/m²).

Applications of point and imaging spectrometry to studies of plant functional diversity

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Keywords: imaging spectrometry, functional types, optical types, carbon flux, biodiversity

A new class of small, inexpensive imaging spectrometers are enabling novel experimental applications at intermediate sampling scales from a variety of platforms (drones, robotic motion systems, and pan & tilt units). Similarly new methods for creating synthetic image cubes from non-image data provide new views of old topics. These developments provide new opportunities for low-cost, simple experiments that have been difficult to do from traditional satellite, airborne or field sampling. Here, we present initial findings using small VIS-NIR imaging spectrometers as well as dual channel point spectrometers mounted on automated carts (tram system) and light aircraft. Early results demonstrate the power of these approaches for topics ranging from ecosystem carbon flux monitoring, to biodiversity assessment. These sampling protocols and technology allow an integrated analysis of plant functional diversity based on the concept of optical types. Recent examples from this work and the related informatics needs, including the handling of point spectrometer data within spectral information systems (e.g. SPECCHIO) and the processing chain for the imaging spectrometer data will be discussed.

Mapping of overburden substrates for post-mining re-cultivation using imagery spectroscopy

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Keywords: hyperspectral, airborne, soil, toxicity, mine

Open pit coal mining has a severe impact on ecosystems in the mining area. In many cases, overburden material becomes the parent substrate for soil development. These substrates differ substantially from recent soils. They often have extreme pH and can contain high concentrations of heavy metals and or high salt content reflected in high conductivity. The substrates often lack recent organic matter (RSOM) but may contain fossil organic matter (FOM) of various origins.

In the study we illustrate the possible application of airborne imaging spectroscopy to map post mining substrates having various types of potential toxicity or even to directly predict the toxicity of post mining sites and estimate content of fossil and recent organic matter.

We used two post mining sites in this study. The first one is a brown coal-mining district in the North-West of the Czech Republic, the second one the Lusatian lignite mining district near Cottbus (Eastern Germany).

The mapping of overburden substrates is based on evaluation of following data categories: 1/ laboratory chemical and ecotoxicological analyses of substrates; 2/ laboratory and 3/ field spectral measurements of substrates; 4/ airborne AISA Eagle imagery data.

Spectral angle mapper was trained on field ASD measurements and used to classify soil substrates from the hyperspectral image.

Partial least squares was used to develop calibration models between reflectance and total organic carbon (C_{tot}) and recent carbon (C_{rec}) content in soil substrates.

The results show that using multiple regressions with forward selection was able to predict pH of overburden substrates from laboratory spectroscopic data successfully. The regression equation explains more than 80% of data variability. The attempt to explain toxicity the same way was much less successful - the regression explained only 23% of data variability.

Classification of individual overburden substrate types from airborne hyperspectral data using spectral angle mapper gives overall classification accuracy of a 71.18 %.

Near infrared spectroscopy combined with partial-least squares methods provides accurate estimates of RSOM and total organic carbon in soil samples from post-mining area. This method might therefore offer a simple, rapid, and low-cost alternative to expensive and time-consuming radiocarbon dating.

Assessment of hyperspectral images for vegetation classification of Polish mountain M&B Reserves

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Keywords: APEX, DAIS7915, classification, mountain vegetation communities

Identification of vegetation communities is a very important issue for monitoring, especially in high mountain areas. Specific adaptations of such vegetation can be observed as different relationships between leaf characteristics, as green and red pigment content, plant tissue structure, waxes, cuticles, etc. Registration of the electromagnetic spectrum in many narrow bands of electromagnetic radiation allows the use remote sensing for vegetation studies. This is particularly important for areas that are difficult to access.

The aim of the study was to identify 25 non-forest vegetation communities of the part of Karkonosze National Park and 39 communities of the part of Tatra National Park in Southern Poland. On both areas following types of vegetation are present: cryptogamic plant communities on scree – initial phase, epilitic lichen communities, scree communities, snow-bed communities, subnivale swards, alpine swards, peaty and boggy communities, avalanche meadows, tall herb communities, grassland communities after grazing, subalpine dwarf scrub communities, willow thicket, mountain-pine scrub on silicate substrate, mountain-pine scrub on calcareus substrate, montane spruce forest and lakes. These areas are not characterized by exactly the same vegetation communities belonging to these types of vegetation. Tatras are higher mountains, the highest peak in Poland is 2499 meters a.s.l. (Rysy) and in Karkonosze it is 1603 m a.s.l. (Sniezka). Although Karkonosze are not as high as Tatras, they are characterized by harsh climate, their vegetation floors are up to several hundred meters lower than in other high mountain, as Tatras. Both areas are undergoing a significant transformation (in the Eastern part of Tatras are observed large areas of dying forests, in Karkonosze is a rapid regeneration of vegetation after the disaster of acid rain from the '80s.).

The analyses were based on APEX and DAIS 7915 hyperspectral images. As reference materials were used the vector maps of vegetation communities in Parks. For classification of Karkonosze were used the Support Vector Machines algorithm and for Tatras – the fuzzy ARTMAP neural networks. The different sets of spectral bands (all of original and reduced used Minimum Noise Fraction transforms) were tested, for APEX it was 30 MNF bands and for DAIS 7915 – 20 MNF bands. Finally, the classification accuracy was obtained using the verification polygons obtained using the terrain information.

An overall accuracy for both classified areas reached about 85-89% (the higher value is for classification of Tatras using fuzzy ARTMAP). The best classified were large and spectrally homogenous vegetation communities, as e.g.in Tatras – *Empetro-Vaccinietum* comm. or typical alpine grasslands, in Karkonosze – communities from *Rhizocarpion alpicolae* alliance and from *Artemisietea vulgaris* class. The worst classified were complex and mixed communities and also very small which were difficult to find in the terrain (e.g. *Peucedanum ostruthium* in Karkonosze). It appears, that reduction of dimensionality of the hyperspectral images didn't change significantly accuracies, and the best results were achieved for spectral bands of all ranges.

Our result allows concluding that the hyperspectral data and presented methods enable to identify a large number of units at high accuracy for most of them.

Field hyperspectral techniques for evaluating the phenological changes and biophysical state of forests of M&B UNESCO Karkonosze Mountains Reserve

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Keywords: hyperspectral technoques, spectral properties, vegetation, forest ecosystems, fluorescence, Karkonosze Mts

Field hyperspectral data allows to obtain very precise information concerning vegetation condition. Due to many narrow ranges of the electromagnetic spectrum, it is possible to get detailed information on plant physiology (e.g. pigments content, water content, light use efficiency).

The aim of the study was to gain and compare spectral properties and biophysical parameters of forests of M&B UNESCO Karkonosze Mountains Reserve during one growing season in 2014. The research focused on two dominant forest species: spruce and beech. Field campaign includes measurements in May, June and August on 12 research polygons.

Values of spectral reflectance were collected, using ASD FieldSpec 3 spectrometer (spectral range is 350 – 2500 nm) with the Plant Probe and the Leaf Clip. Biophysical parameter were: Chlorophyll Index, Flavonol Index, Anthocyanin Index and Nitrogen Balance Index (NBI) measured using DUALEX SCIENTIFIC+™ tool, fluorescence of chlorophyll (F_v/F_0, and F_v/F_m) measured with the OS1ppr and the thermodynamic air temperature (ta) and radiometric temperature of vegetation (ts) using IRTEC MINIRAY.

In addition to spectral properties, the spectra have enabled the calculations of a wide range of remote sensing vegetation indices, which were divided into followings groups: Broadband Greenness (e.g. NDVI, ARVI), Narrowband Greenness (e.g. $NDVI_{705}$, VOG1), Leaf Pigments (e.g. CRI1, ARI1), Light Use Efficiency (e.g. PRI, SIPI), Canopy Nitrogen (NDNI), Dry or Senescent Carbon (e.g. NDLI, PSRI) and Canopy Water Content (e.g. WBI, MSI). Pivotally, a vegetation index aims to define a simple relationship between the reflectance measured by a sensor in particular wavelengths and the parameter directly characterizing a plant or a vegetation stand. In the study indices were compared with biometrical measurements, using the Pearson and Spearman correlation. Spectral characteristics as well as vegetation indices were analyzed with the ANOVA statistical test to detect any significant changes over the growing season.

The studies have provided the information on the general condition of selected forest communities and the assessment of the phenological changes and biophysical state of forests in Karkonosze

Mountains. The general results can be outlined as follows: spectral signatures of each research polygon were characteristic for plants in good condition; the qualitative and quantitative analysis of photosynthetic pigments showed significant differences between analyzed species; some of remote sensing groups of indicators reached significantly different values in particular periods of growing season (e.g. Narrowband Greenness, Canopy Water Content); the correlation between the indicators and biophysical parameters was disparate for each species.

Vegetation condition of non-forest communities in Karkonosze Mountains based on APEX hyperspectral images

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Keywords: non-forest communities, Karkonosze, APEX, vegetation condition, vegetation indices

Remote sensing tools can be used to analyzing vegetation. Due to non-contact character, these methods are particularly useful in areas that are protected or hard to reach like mountains. In addition, mountains vegetation has different structure and specific adaptation for the climate.

The aim of the study was to analyze the condition of mountain grasslands in Karkonosze based on field measurements and APEX hyperspectral images. The study area includes Karkonosze Mountains, located on Polish and Czech border (with Karkonosze/Krkonoše National Park). The main test areas were located near Velka Upa, Mala Upa, Pec pod Sněžkou, Śnieżka and Szrenica Mountain. In the researches were studied non-forests communities. The research area is diverse with different types of non-forest vegetation communities: meadows ecosystems, alpine swards, dwarf shrubs and synanthropic vegetation. There is visible anthropogenic impact on the environment.

Two kinds of data were used in the analysis: hyperspectral images and biophysical field measurements. First of all, during the field measurements were collected biophysical parameters (Leaf Area Index, fraction of Absorbed Photosynthetically Active Radiation, Chlorophyll Content Index) and values of spectral reflectance using ASD FieldSpec FR 3. The measurements were done in August 2013 on 40 research polygons divided into two classes: grasslands communities (33 polygons) and synanthropic communities (7 polygons).

Secondly, APEX hyperspectral images with spectral reflectance 400 to 2500 nm were used. APEX images were initially processed by radiometric, geometric, atmospheric and topographic correction. On APEX images were located field measurements polygons, obtained spectral reflectance and basing on them were calculated vegetation indices (mNDVI 705, CAI, NDNI, PRI, WBI, ARI1, TCARI). Afterwards, were calculated relationship between values of biophysical parameters acquired during field measurements and vegetation indices. Also were defined regression equations between parameters and indices separately for grasslands and synanthropic communities.

Simultaneously, was done classification Support Vector Machines to distinguish 5 classes: grasslands communities, synanthropic communities, background of image, forests and anthropogenic area. Classification was required to divide analyzed communities into two classes (grasslands and synanthropic communities), which had the best correlation, and mask other areas.

Finally, were prepared maps of vegetation condition, distribution of vegetation indices and biophysical parameters (LAI, CCI, fAPAR). Using maps of spatial distribution of vegetation indices and biophysical variables was done Decision Tree classification of vegetation condition of non-forest communities.

Based on the vegetation indices was estimated vegetation condition of mountainous non-forest communities in Karkonosze and were defined correlation between vegetation indices and biophysical parameters. The results showed that the non-forest vegetation communities in research area are in good condition. Condition and values of biophysical parameters were better for synanthropic communities (average value of LAI is estimated at 5,16; fAPAR 0,93; WBI 1,00 and mNDVI 705 at 0,48).

Fusion of hyperspectral field data and multispectral satellite images to assess vegetation condition: case study Tatra Mountains

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Keywords: vegatation condition, Tatras, Landsat OLI, classification, field measurements

The main purpose of the project is to develop an algorithm to assess and classify of vegetation condition using multispectral Landsat OLI images and hyperspectral and biometrical field data. The study area is located in south Poland, it covers the mountain area protected by Polish Tatra National Park. Vegetation and landscape of this region are very valuable and unique for that reason this Park is enlisted on UNESCO M&B program. In Tatras, there are vertical zones with different microclimate and vegetation communities. Lower parts (lower and upper montane belts) are mainly covered by spruce stands, in upper (subalpine) belt dominant species is dwarf pine. Above dwarf pine belt there is alpine belt with montane meadows. The highest parts are in subnivale belt.

Two types of data were used in project field measurements and Landsat OLI image. During the field works, which were carried out in August 2013, measurements on 120 polygons were done in lower and upper montane, subalpine and alpine zones. On each polygon were collected following data: spectral characteristics (using ASD FieldSpec 3 spectrometer), amount of photosynthetic active radiation (AccuPAR ceptometer; in forest this measurement weren't taken), Leaf Area Index (LAI-2000 Plant Canopy Analyzer) and coordinates (Trimble GeoXT GPS receiver). In forests instead of LAI-2000 Plant Canopy Analyzer the hemispherical photographs were taken to obtain Leaf Area Index. Based on spectral characteristics of measured vegetation a following vegetation indices (VIs) were calculated: Normalized Difference Vegetation Index, Simple Ratio Index, Soil Adjusted Vegetation Index, Optimized Soli-Adjusted Vegetation Index, Wide Dynamic Range Vegetation Index, Atmospherically Resistant Vegetation Index, Green Normalized Difference Vegetation Index, Enhanced Vegetation Index, Plant Senescence Reflectance Index, Normalized Pigment Chlorophyll Ratio Index, Visible Atmospherically Resistant Index, Normalized Difference Infrared Index and Moisture Stress Index. The same set of VIs were also calculated using atmospherically corrected Landsat OLI image (beginning of September 2013). Atmospheric correction was done using ATCOR 3 software. In next step VIs derived from satellite data and from field works were correlated. VIs characterized by the highest correlation were used as input to classification. Obtained values of VIs based on Landsat image were correlated with biophysical parameters of vegetation as APAR and LAI. Based on correlation results regression equation was obtained which allowed to produce maps of spatial distribution of APAR and LAI.

Collected ground truth data were used as reference information about vegetation condition to create patterns to classification. 40 of measured polygons were also used for create verification patterns to assess the accuracy of vegetation condition classification. To classify vegetation condition were used Support Vector Machines classifier and data sets consist of Landsat OLI bands, VIs, LAI and APAR. In this step three classes of condition were distinguished for forests and non-forest vegetation: vegetation in poor condition or dead plants, medium condition and good condition. The overall accuracy for non-forest and forest communities was about 96 % and 86%, respectively.

Generally vegetation in Park is in good condition, only in case of forests there are patches of poor condition caused by bark beetle.

Near Field Remote Sensing of Light Use Efficiency and Plant Stress

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Keywords: near field, carbon uptake, flux tower, hyperspectral, thermal

Climate variability - and associated water availability and heat extremes - is one of the most important manifestations of the climate system for society. The response of vegetation to these changes is one of the largest uncertainties in projecting climate, carbon sequestration and water resources.

We want to be able to observe how vegetation responds to environmental stresses. We want to relate the stresses to the light use efficiency of the plants, the resulting fluxes and ultimately changes in structure and biogeochemical properties. This can only be done by combining flux measurements with remote sensing data and modeling.

We have developed a unique near field remote sensing system that allows data acquisition at unprecedented temporal, extreme spatial and hyperspectral resolution. The instruments include an upward looking Ocean Optics USB2000 spectrometer with a cosine diffuser and – mounted on a pan tilt table - a Headwall Hyperspec® VNIR line scanner and a thermal imager, the FLIR SC655. With the spatial resolution we can target unmixed pixels and due to the hyperspectral resolution we can get direct measures of the actual light use efficiency by looking at the proportion of absorbed radiation that is dissipated as heat and not used for electron transport in photosynthesis (Photochemical Reflectance Index PRI) or by capturing the fluorescence signal emitted during photosynthesis. Having thermal information will allow us to relate the light use efficiency to environmental stresses. We have mounted the remote sensing system on top of our 70m tower at the TERN OzFlux tower Tumbarumba, in Bago State Forest, NSW, where we continuously measure carbon uptake and loss of the forest with the eddy covariance method allowing us to combine the remotely sensed data with the measured fluxes. In this presentation we will give an overview of the remote sensing system and show first results from the acquired datasets.

STARS - Monitoring smallholder farming in sub-Saharan Africa and South Asia from an UAV perspective

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Keywords: STARS, UAV, agriculture, multi-scale

Remotely sensed imagery has comprised a sound source of information for agricultural mapping over the past decades; monitoring smallholder agriculture specifically requires very-high spatial resolution imagery during the crops growth season. The Spurring a Transformation for Agriculture through Remote Sensing (STARS) project aims to investigate the potential of remote sensing to assist smallholder farmers in sub-Saharan Africa and South Asia. In developing countries, monitoring smallholder agriculture during the growing season is challenged by the large heterogeneity in crop varieties, substrate, environmental conditions and variable management practices as well as by the small size of the plots, their fuzzy boundaries and the frequent use of inter-cropping and mixed cropping practices. In this setting, monitoring crops during their subsequent development stages calls for remotely sensed data which have both high spatial and high temporal resolution, which is not currently available. STARS is an ongoing effort to collect data at different spatial scales from *in-situ* measurements, via Unmanned Aerial Vehicle (UAV) narrowband imagery, to very high-, high- and medium-resolution satellite imagery. STARS main objective is to analyze the spectral information of this multi-scale dataset and establish information flows to support smallholder productivity growth and economic development.

UAVs play a key role in this project as they provide information at a transitional scale between the well-studied *in-situ* data and the (very) high spatial resolution satellite imagery. Furthermore UAVs offer the possibility to fly on demand at critical times and designated places. In STARS, we work with Visible/NIR multispectral cameras mounted on fixed-wing eBee and with mini-MCA (Tetracam Inc.) and thermal cameras mounted on octocopters. For the mini-MCA, we used 10nm bandwidth spectral filters (Andover Corporation) to maximize the compatibility between the UAV images those provided by Worldview and Rapideye. Although with only six bands, the camera cannot be considered hyperspectral, its narrow bandwidth is a typical characteristic of hyperspectral systems. For the study areas, biweekly UAV acquisitions offer detailed temporal information on crop development and early warning signs of crop failure throughout the growing season. UAV data with such a fine temporal and spatial resolution, coupled with extensive *in-situ* measurements and complemented by very high resolution satellite imagery, provides the source for establishing a publicly available spectro-temporal and textural crop signature library. This poster presents the specific research objectives and the preliminary results of the project.

Applications of Near Infrared Hyperspectral Imaging for crop disease detection

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Keywords: NIR Hyperspectral Imaging, Agriculture, crops, diseases, Chemometrics

The aim of this work is to demonstrate, through different practical applications, the performance of Near Infrared Hyperspectral Imaging (NIR-HSI) to detect diseases affecting crops. Different diseases are targeted, including *cercospora* leaf plots on sugar beet leaves (*cercospora beticola*) or ergot bodies (*Claviceps purpurea*) in wheat grains. Such diseases represent major issues in terms of yield losses as well as food and feed safety issues.

The present studies are focused on the detection of the infection at laboratory level using a NIR-HSI camera active in the 1100-2400 nm spectral range combined with a conveyor belt. Depending on the disease symptoms, different parts of the plants are scanned (*e.g.* leaves, cereal grains or cereal ears). Then, based on reference NIR spectral libraries, different chemometric tools can be applied such as Principal Component Analysis (PCA) for data exploration and Partial Least Squares Discriminant Analysis (PLS-DA) or Support Vector Machine (SVM) for classification purposes. According to the objectives pursued, models can be applied in cascadein order to remove background and untargeted parts of the plant (*e.g.* limb, veins and hydric stress) prior to the detection of the disease itself. Eventually disease predictions are displayed in false color on the images in order to provide a mapping of the contamination on the different plant parts.

The results obtained in this work forecast promising new applications using NIR hyperspectral imaging directly in the field to detect diseases at ground level and with a higher spatial resolution compared to airborne or satellite platforms.

LAI retrieval from heterogeneous meadows using PROSAIL model based on field measurements

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Keywords: RTM, PROSAIL, LAI, meadows, field measurements

Vegetation analysis is an important problem in a regional and global scale. Two approaches are used to retrieve biophysical variables using remote sensing data: statistical and modelling. In modelling a physically based model is used to represent the photon transport inside leaves and canopy. Radiative Transfer Models are physically based models which describe the interactions of radiation with the object. Models are often applied to vegetation modelling. After successful inversion of the model it is possible to retrieve biophysical variables. In the same time, inversion is very complex process due to ill-posed problem.

The main objective of this study is to retrieve LAI values from heterogeneous meadows using PROSAIL model based on field measurements. To the study was used look-up table inversion. All analyses were done on heterogeneous meadows. All of the analysed meadows were extensively used and located on a flat area. All analysed meadows can be defined as diverse and has at least four different species. The Radiative Transfer Models are generally more efficient for homogeneous ecosystems, with uniform structure. RTM are rarely used to model the reflectance from meadows. However, the PROSAIL model was used to retrieve biophysical parameters from grassland, especially chlorophyll, water content and Leaf Area Index.

Parameterisation of the PROSAIL model and inverse was based on field measurements. The analyses were done on 50 polygons in 2010 located in centre of Poland on Mazowsze region. During field measurement were acquired model input parameters: Leaf Area Index using LAI-2000 Plant Canopy Analyzer (as a reference data), other parameters to set the values of other input PROSAIL parameters (chlorophyll content, fresh biomass, dry matter content, Average Leaf Angle, canopy height and also date and time of measurement) and spectral reflectance using ASD FieldSpec 3 FR. PROSAIL was adjusted based on collected data (input parameters like pigments and water content were adjusted).

The next step was the selection of input data to the PROSAIL inversion. To reduce the size of look-up table were analysed changes in input parameters to estimate the best set of parameters for all polygons. It was statistically analysed, which input parameters have the greatest impact on the modelling of LAI. It was determined, in which wavelengths LAI changes cause changes in the value of reflectance. Next was checked, which other input parameters are affecting the selected ranges of spectrum. Finally, were chosen datasets to generate look-up table and based on that inversion of PROSAIL was done. Acquired values of LAI were verified using values acquired during field measurements.

During the analysis were determined ranges of spectrum, where LAI has the biggest influence on simulating reflectance: mainly near infrared. Also, some parameters (like pigments content) have little influence on the retrieval of LAI. The inversion result was LAI values for all polygons. Conducted studies showed that it is possible to retrieve Leaf Area Index values from hyperspectral data. There were noticed some errors, which are probably related to the heterogeneity of analysed communities.

Poster: Soils and Minerals

Assessing the Limits of Spectral Parameters Estimation Using Spectral Derivative and the Modified Gaussian Model (MGM): Application to Soil Spectra

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Keywords: Derivative, Modified Gaussian Model, Curve Fitting

The reflected sunlight spectrum of a surface measured with a spectrometer often contains absorption bands, and the wavelength positions of these bands are directly related to the composition of the absorbing species within the material. Reflectance spectra of solid surfaces can be modeled as a series of absorption bands (specular component) superimposed on a background continuum (diffuse component). The central wavelength position at which absorption bands are detected is of most interest since these wavelengths are indicative of the mineral types present on the surface. Since the mineral constituents are typically in intimate association with one another the reflectance spectra of mixtures are typically a complex result from the combination of the spectral characteristics of the constituents. We use a nonlinear deconvolution method in order to isolate individual absorption bands and to adjust the continuum. This method called Modified Gaussian Model (MGM), has been used successfully since the 90s to model spectra of mafic minerals. But the MGM needs a starting set of inputs (band center position, depth, and full width at half minimum) for the fitting process, therefore acquiring some a priori knowledge and making it difficult to apply to hyperspectral images. In this study, we attempt to automatize the band center detection using spectral derivatives. Different derivation methods exist: high order (second, fourth and fifth derivatives) and low order (first and second derivatives). We use low order derivatives because of the sensitivity to noise when increasing the derivative order. Depending of the noise level the number of band centers may increase and distort the result of the fitting process leading to overfitting. We developed a simple method to avoid overfitting while improving the Root Mean Square Error. We used a simulated spectra modeled as a sum of Gaussian superimposed on a linear continuum, in order to assess the limitations of the algorithm. We first simulated spectra with a high spectral resolution (1 nm). Then we convolved the spectral data to six different possible hyperspectral instrument configurations (AVIRIS, APEX, ENMAP, HySpex-VNIR, HySpex-SWIR and HYMAP). These results are first tested against the original data without additional noise constraints. Then different Signal-to-Noise Ratio (SNR) values are simulated to test the impact of noise on the algorithm. Testing the algorithm on synthetic spectra demonstrated that despite the derivative sensitivity to noise, the MGM could identify band parameters with a good accuracy, even with a low SNR. The method is tested on laboratory spectra for validation in a natural environment.

Potential of hyperspectral imagery for geoarchives mapping and process analysis in southern Africa

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Keywords: hyperspectral, paleo-environmental analyses, Hyperion, sediment mapping

A remote sensing approach in the BMBF collaborative project Geoarchives – Signals of Climate and Landscape Change preserved in Southern African Geoarchivesfocuses on the use of recent and upcoming Earth Observation Tools for the study of climate and land use changes impacts on the landscape ecosystem in southern Africa. In particular, it aims at demonstrating the potential and constraints of applied hyperspectral remote sensing imagery with its extended spectral coverage and high spectral resolution for the identification and mapping of sediment features associated with palaeo-environmental archives. In the area of the Molopo River valley (RSA), Tsauchab river valley (Naukluft Mountain, Namibia), and Kalahari region (salt/clay pans), high-resolution geoarchives of interest have been identified that were created within the time span of the most recent decades and centuries. Laboratory/field spectroscopy and hyperspectral remote sensing imagery at local and regional scale is used to analyze different geoarchives and landscape formation based on geochemical and physical parameters. In particular, parameters of interest are iron, carbonates, clay, salt, organic matter content and fractional vegetation cover. High-spectral resolution optical remote sensing can provide support in the characterization of these parameters based on the analysis of the surface spectra within the Visible -Near InfraRed (VNIR, 400-1000 nm) and Short Wave InfraRed (SWIR, 1000–2500 nm) regions. In these regions, major chemical components of the sediments interact with the electromagnetic radiation and produce characteristic spectral absorption features that can be used to infer its properties. Although these techniques are well established for surface sediment characterization at laboratory and field scale, the potential of current (Hyperion) and upcoming sensor such as the EnMAP satellite is still to be demonstrated.

Several airborne and EO-1 satellite Hyperion images have been recently acquired over the different test sites in the dry season. The Hyperion images were pre-processed including destriping, atmospheric and geometric correction to derive geocoded reflectance images. The remote sensing acquisitions were linked with local observations using field spectroscopy as well as surface sampling for laboratory geochemical characterization. In this paper, we will present preliminary results consisting of 1) the spectral characterization of the different geoarchives of interest at field scale associated with variable sediments mineralogy and texture, and 2) mineralogical spectral detection and mapping using the HYSOMA software developed at GFZ (HYperspectral SOil MApping) and the USGS MICA software based on hyperspectral imagery from laboratory scale (HySpex) to airborne and spaceborne scale. In the field spectra, mainly variable content in iron in different form (total iron content, iron oxide) and smectitic clay minerals are detected. Depending on locations, some additional carbonate minerals (e.g. calcite) and/or smectite/illite layers, also salt minerals (e.g. gypsum), and some magnesium-related minerals could be detected. These preliminary findings may be confirmed with chemical laboratory characterization. At remote sensing scale, sediments mapping based on the analysis of the imagery shows variable amount in iron-oxides, clay, and carbonates minerals. No/very little organic carbon compound was detected. Further work is focused on the quantitative analyses of the spectroscopic data linked to surface processes.

Soil clay content prediction from Vis-NIR airborne hyperspectral data by transferring laboratory calibration models

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Keywords: hyperspectral image, transfer calibration, laboratory model, standardisation, model update, repfile

Until now, the prediction of the soil clay content from Vis-NIR airborne hyperspectral images was based on regression models calibrated from spectra extracted from these same images. This approach is costly (field work) and produces moderate performances of prediction. We proposed to replace this approach by a regression model build on Vis-NIR Laboratory spectra. This new and original approach required the establishment of calibration transfer methods between laboratory data and airborne hyperspectral data.

To test this approach, we operated in an optimal context: we used a laboratory database including 147 soil samples extracted on the area covered by the Vis-NIR hyperspectral image (watershed of La Peyne in France), therefore representative of the soil background of the image, associated to clay contents measurements. A set of 147 laboratory spectra were acquired for crushed and dried samples of this soil. Moreover, 96 spectra of bare soil were extracted from the hyperspectral image. The goal was then to build a calibration model on the laboratory database and to transfer this model on the image database using several transfer methods.

To do so, among the 147 laboratory data, two-thirds (115 spectra) were used for the calibration of the laboratory model. The laboratory model was calibrated by a PLSR approach. Among the 96 spectra of the image, one third has been set aside for the validation of the final model. The remaining two thirds of image spectra were used as standardsto transfer the laboratory model. The performances of each method were evaluated according to the quality of the prediction results of the clay content (R^2_{val} and SEP). These prediction results were compared to prediction results provided by a classical image calibration model (the model is constructed and tested using the spectra extracted from image: R^2_{val} = 0.72, SEP=42g/kg). In this work, three calibration transfer methods were tested with and without taking into account the pedological stratification of soil: updated model, standardization approach and Repfile model.

Thanks to these transfer methods, we have succeeded to improve the prediction performances, compared to those provided by the direct application of the laboratory calibration model on the image without transfer, and even compared to those provided by the classical image calibration model. In addition, taking into account the soil stratification in the selection of samples in the transfer models ensures the best prediction results especially with two methods: Repfile and updated model. The Repfile and updated model provided performances of prediction better than those obtained from the classical image model respectively using only 30 (R^2_{val} = 0.77, SEP=35g/kg) and 20 standards (R^2_{val}= 0.79, SEP=33g/kg).

According to our study, the laboratory calibration model can be used to predict properties of the soil from a hyperspectral image. Using standards extracted from the image ameliorate the prediction results compared to the classical image model and ensure the success of the transfer. The establishment of such approach allows creating a spatial mapping of soil properties with reduced costs using spectral databases lab available.

Digital soil classification and elemental mapping using imaging Vis-NIR spectroscopy: Quantification of stagnic properties in Luvisol profiles under Norway spruce and European Beech

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Keywords: Soil profiles, soil classification, elemental mapping, supervised classification

Imaging Vis-NIR spectroscopy is a novel technique in soil science that can determine quantity and quality of various chemical soil properties with a hitherto unreached spatial resolution in undisturbed soil profiles. We have applied this technique to soil cores in order to get quantitative proof of redoximorphic processes under two different tree species and to proof tree-soil interactions at microscale. Due to the imaging capabilities of Vis-NIR-spectroscopy a spatially explicit understanding of soil processes and properties can be achieved. Strong spatial heterogeneity of the soil core can be taken into account.

We took six 30 cm-long rectangular soil columns of adjacent Luvisols derived from quaternary aeolian sediments (Loess) in a forest soil near Freising/Bavaria using stainless steel boxes (100×100×300 mm). Three profiles were sampled under Norway spruce and three under European beech. A hyperspectral camera (VNIR, 400–1000 nm in 160 spectral bands) with spatial resolution of 63×63 µm² per pixel was used for data acquisition. Reference samples were taken at representative spots and analysed for SOM quantity and quality with a CN elemental analyser and for iron content using dithionite extraction followed by ICP-OES measurement.

We compared two supervised classification algorithms i.e. Spectral Angle Mapper and Maximum Likelihood using different sets of training areas and spectral libraries. As established in chemometrics we used multivariate analysis such as partial least-squares regression (PLSR) in addition to multivariate adaptive regression splines (MARS) to correlate chemical data with Vis-NIR-spectra. As a result elemental mapping of Fe and C within the soil core at high spatial resolution has been achieved. The regression model was validated by a new set of reference samples for chemical analysis.

Digital soil classification easily visualizes soil properties within the soil profiles. By combining both techniques elemental balances at microscale and detailed soil mapping become feasible.

Regionalization of uncovered agricultural fields based on soil texture type estimation

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Keywords: hyperspectral data, regionalization, soil texture type, support vector regression, decision tree

The determination of soil texture types across agricultural areas is an important information to deduce soil condition and soil properties. The soil texture type is an indicator for the capability to store water and therefore crucial for the fertility. It can be described as a combination of sand, silt and clay fraction. In the presented study the results from laboratory analysis were combined with hyperspectral image data to estimate the distribution of soil texture types across an agricultural area to combine regions with similar soil properties to uniform classes.

Therefore, 41 soil samples were taken in May 2011 from two agricultural fields near Koethen (Saxony-Anhalt, Germany). The percentages of sand, silt and clay for each sample were determined in the laboratory. Additionally, hyperspectral image data of the area were acquired on May 10th, 2011 by the airborne scanner aisaDUAL(400-2500 nm).

The three soil texture parameters and the inherent spectra were subsequently used to calibrate cross-validated (leave-one-out) regression models with Support Vector Regression(SVR), resulting in a very robust model for sand (R^2 = 0.942) and moderate models for silt and clay (R^2 = 0.670 and R^2 = 0.759, respectively). Afterwards, the regression models were used to estimate the percentage of the different parameters for each pixel in the hyperspectral image data. A decision tree, based on an established soil texture type classification scheme, was developed and applied to determine the soil texture type for each pixel in the image. The method provided accurate results in form of homogenous and reasonable regions without abrupt changes between the classes.

The developed method is very useful to determine the soil texture types across an agricultural area. Additionally, the approach could also be expended with other soil parameters like organic carbon or iron concentrations, which can further help to improve the identification of soil regions.

Mineral classification of Makhtesh Ramon in Israel using hyperspectral VNIR-SWIR and LWIR remote-sensing data

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Keywords: Mineral mapping, Hyperspectral remote sensing, VNIR-SWIR spectral region, LWIR spectral region

Makhtesh Ramon in the Negev desert in southern Israel, the largest erosion crater in the world with a total area of about 200 km^2, is one of the most interesting and powerful sites for HRS sensor calibration worldwide, consisting of a variety of geological units.

Remote sensing techniques have been acknowledged as a powerful tool for earth environmental studies. Using both optical and thermal hyperspectral remote-sensing data is well-recognized for mineral mapping studies. In this study we examined the potential of this method for geology mapping in the Makhtesh Ramon area. Accordingly, airborne data acquired with the AisaFENIX hyperspectral sensor in the optical region and AisaOWL hyperspectral sensor in the thermal region over Makhtesh Ramon were analyzed. Major minerals could be identified by analyzing the atmospheric corrected data in the VNIR-SWIR (0.4-2.4 µm) spectral region and by locating similarities in day and night at-sensor radiance spectra in the LWIR (8-12 µm) spectral region, using an in-situ surface for estimating the atmospheric transmittance. The analysis resulted in the classification of calcite, dolomite, kaolinite, gypsum, quartz and other silicates. The classification was found to be in agreement with the mineralogy of selected rock samples which were collected from the study area as derived from laboratory XRF, EDS and XRD analyses. The resulting mineral map of the major minerals in the surface was found to be in agreement with the geological map of the area.

SpecTour – Impacts of variability in spectral measurement setups on mineral absorption features

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Keywords: spectral laboratory measurements, experimental setups, mineral absorption feature analysis, SpecTour

The current hyperspectral research landscape is characterized by a growing market of field and laboratory spectrometers and other equipment as well as an increasing number of users. The simultaneous lack of standards concerning experimental setups and measurement protocols lead to a rising variety of measurement setups and user specific protocols and raises the question of the comparability of results from different institutions.

Against this background, in 2009 the SpecTour project was launched with the purpose of giving an overview of the current test patterns in the hyperspectral research community and to analyse the comparability of individual measurement results[1]. The experimental framework of the SpecTour includes a box with four reference panels as well as a chlorite rock sample that is sent to each participant in a collaborative study. The philosophy behind SpecTour is just measure as you always do. At the present date 32 institutions with over 50 different test arrangements participated on the national and international level.

The focus of this study is the evaluation of the results from the chlorite measurements. Chlorite has characteristic absorption features in the shortwave infrared (1.3 – 2.5 µm) that can be used for the spectral identification of the mineral. Therefore, the precise determination of band positions and shapes is important. The absorption features of the chlorite spectra were parameterized (positions of the absorption minima and shoulders, absorption depths), statistically analyzed and afterwards correlated with measurement parameters.

The comparison of the results between the different participating institutions as well as the measurement series of the same participants show that the majority of the measured spectra allow the spectral identification of the mineral. Nevertheless, the results of some participants showed impairments affecting the qualitative spectra which were mainly caused by influences of the background material, the light sources and sensor information of their noise.

[1] Jung, A.; Götze, C.; Gläßer, C. (2012): Overview of Experimental Setups in Spectroscopic Laboratory Measurements – the SpecTour Project. In: PFG, 4, pp. 433-442 (DOI: 10.1127/1432-8364/20/0129).

Visible and infrared hyperspectral survey of volcanic lava flows on Tenerife (Canary Islands, Spain)

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Keywords: field spectroscopy, hyperspectral remote sensing, Hyperion, Tenerife, lava surface

Spaceborne hyperspectral remote sensing has been used in the volcanology, yet its application is still constrained by the coarse spatial resolution of the image data. A better understanding of the spectral characteristics of volcanic surfaces requires field spectroscopy. For this reason, two field spectroscopy campaigns were carried out on Tenerife (Spain) in November 2013 and September 2014 with anASDFieldSpec 3 to document the reflectance spectra of different types of volcanic surfaces.

In total, 48 sites distributed over different types of volcanic surfaces were measured, most of which focused on lava flows. Lava surfaces differ in age, roughness, weathering level and coverage by vegetation and lichens. We compared the field spectral data after pre-processing and found that reflectance spectra of lava are controlled by various factors: (1) Old lava surfaces in general tend to have higher reflectance than fresh lava surfaces. (2) Smooth lava surfaces usually have higher reflectance than rough lava surfaces but the spectra are similar in shape. (3) Growth of vegetation (dominantly green ferns) contributes to a red-edge effect in the lava spectra. (4) Lichen coverage causes a gradual increase in the visible and near infrared region of spectrum. (5) Chemical weathering changes the composition of the lava surfaces inducing a decrease in the shortwave infrared part of the spectrum.

In addition to observations of spectral data, efforts were also made to investigate the comparability of field-based hyperspectral data and Hyperion hyperspectral imagery. Agreement between the satellite and field measurements is significant although the former is sensitive to atmospheric correction and purity of satellite pixels. Hence we provide solutions for improving the comparability.

Hyperspectral system analysis for geophysical applications: the ASI-AGI project

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Keywords: Hyperspectral data, simulation, remote sensing

In the last decades the technological development of imaging spectrometersboth on airborne and spaceborne platforms has increased the scientific interest of image spectroscopy for a number of applications and in particular in geophysics with regards of interaction between Earth interior surface and surface-atmosphere phenomena. ASI-AGI (Analisi Sistemi Iperspettrali per le Applicazioni Geofisiche Integrate) is part of the projects selected in the frame of the Italian Space Agency (ASI) hyperspectral mission PRISMA (PRecursore IperSpettrale of the application mission). PRISMA project is conceived as a pre-operational and technology demonstrator mission, focused on the development and delivery of hyperspectral products and the qualification of the hyperspectral payload in space. Considering the spectral range covered by the PRISMA sensor (0.4-2.5 microns, 30 m pixel) and the contemporaneous acquisition of panchromatic camera at 5m pixel resolution, a number of products are being developed for scientific applications in particular they will regard the thermal structure of lava flows and forest fires, volcanic gas emission (CO2, CH4) and surface material classification based on spectral analysis and development of data fusion techniques. Moreover the proposed activities will include systematic measurements on a calibration/validation test sites: (Mt. Etna) and a large calibration site located in the Algeria desert. ASI-AGI project focuses on geophysical and geological applications such as improving the scientific understanding of natural phenomena as volcanic activity and forest fires and developing innovative techniques based on PRISMA image spectroscopy characteristics combining an hyperspectral and a panchromatic data.

Poster: New Analytical Techniques

Impact of data transformation on LU/LC classification using noisy Hyperion data

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Keywords: Hyperion, LU/LC classification, data transformation, MNF, PCA

Accurate LU/LC classification still represents a major challenge for multispectral and hyperspectral remote sensing. Hyperspectral satellite imagery becomes more and more important, due to the existing systems (Hyperion, ChrisProba) and coming sensors (PRISMA, EnMAP).

The present work investigates the impact of Minimum Noise Fraction (MNF) and Principal Component Analyses (PCA) for classifying several agricultural classes from Hyperion imagery. The well-established Maximum Likelihood classifier (ML) was compared to the recently established Support Vector Machines (SVM). The agricultural study site is located in North Israel (Haifa area). The region is characterized by small and vast fields with several different crops. A field campaign was conducted in June 2013. Crops such as barley, cabbage, chickpea, cotton, corn, sorghum, orchard, pumpkin, watermelon and additional fields such as fallow, green fallow and harvested field with a high amount of crop residues were mapped.

Bad bands were excluded from Hyperion data leaving a total number of 101 spectral bands for classification. Due to the relatively coarse spatial resolution of the satellite data in relation to the small-sized fields, the required minimum number of pixels per training area turned out as a limitation for ML classification. To overcome this limitation MNF and PCA were applied for band reduction with local and total image noise estimation (shift differencing approach). On the basis of these four transformations classifications with ML and SVM were applied starting with the first MNF / PCA band stepwise increasing the number of bands, in order to indicate the improvement or trend of overall accuracies (OAA) by adding additional information. Regarding the OAA, SVM performed 3 – 5 % better than ML in almost all cases. The accuracy assessment indicated in most cases that the spectral separation between crops often required six or more bands to achieve accuracies over 70 %. This is mainly due to the fact that the spectral shape of green vegetation is often very similar and thus, the differences are appearing in later bands of MNF and PCA data. The PCA-based classifications in general reached higher OAA in the first five bands compared to MNF. However, with more than 6 bands PCA classifications showed an asymptotical behavior at about 80 %, whereas the OAA of MNF-based classifications still increased. The highest accuracies reached 86.29 % with MNF without shift differencing approach / SVM and even exceeded the SVM classification of the untransformed raw data set (101 bands) by almost 10 % (OAA 77.3 %).

Evaluation of literature indices for determination of crop properties for ground and airborne hyperspectral detection

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Keywords: spectral indicies, precision agriculture, plant properties, phenotype

Remote sensing approaches, in particular imaging spectroscopy, are currently used to detect land use and cover, status and functional changes of ecosystems vegetation and crop lands. Additionally, proximal remote sensing methods are applied in precision agriculture or breeding research. The remote detection of biophysical and biochemical plant properties and plant phenology from different levels of distance are important tools for precision agriculture and agricultural research. However, studies reporting spectral indicators for plant properties often focus on a certain remote sensing level, a selection of tools or spectral indices (SI).

In this study we evaluate a set of 120 spectral indices reported in literature for determination of either biophysical or biochemical plant properties in a hyperspectral data set containing two levels of remote sensing and the nine major crops: winter wheat, maize, barley, potato, soy bean, sunflower, rape seed, sugar beet, temporal and permanent grassland. Hyperspectral data were derived by ground ASD measurements and with the Airborne Prism Experiment (APEX) imaging spectrometer over a range of different locations in Switzerland including farmers' fields and agricultural experiments. The study was conducted in five measurement campaigns in 2013 and 2014. Plant properties on the ground were determined in 4 m^2 plots, and comprised leaf nitrogen, chlorophyll and total pigment concentration (in mg g-1), canopy cover (fraction of plant per area %), leaf area index (LAI, m^2 m^{-2}), spad, leaf water content (g $100g^{-1}$), height (cm), fresh and dry biomass (g m-2). Details on some measurements and sample preparation can be found [1]. N concentration was analyzed with CHNS analyzer (Hekatech, Germany), height was measured as the average of 5 point measurements with a ruler and fresh and dry biomass was determined gravimetric on a subset of 1 m row length before and after drying.

In this contribution we report the best correlations of spectral indices for remote detection of the above mention crop properties in general (all crops combined) and crop specific. For example: including all crops in the relationship between LAI and the SI the highest coefficient of correlation was found for the SLAIDI (0.64***) and MCARI1 (0.61***), which were developed for the detection of LAI. However, species specific relationships revealed that often other Sis, sometimes even SIs that were designed for other purposes, were superior. For some examples the identified relationships will be studied in detail as regression functions. Differences between remote sensing levels and band width regarding SIs as plant property indicators will be discussed with regard to measurement and analysis procedures. Spectral indices could also be used for other promising applications like crop type recognition, stress detection, and phenology status description. Combined with modeling approaches they could deliver crop yield estimations.

[1] Liebisch F., Küng G., Damm A., Walter A. (2014) Characterization of crop vitality and resource use efficiency by means of combining imaging spectroscopy based plant traits, Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing, IEEE International, 24-27 June, Lausanne, Switzerland.

The application of ICA-based algorithms to hyperspectral remotely sensed data for the land cover identification

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Keywords: Remote Sensing, Hyperspectral Images Processing, Land Cover Classification, Independent Component Analysis, Feature Extraction, Band Selection

The remotely sensed hyperspectral products are known as being closely related to a very large volume that is not only due to the spatial extent of the observed area but also due to the important spectral dimension which generally reaches few hundreds of narrow, contiguous and often overlapping spectral bands. In addition and when the spatial resolution is medium or low, another phenomenon called the hyperspectral mixture is observed. It can be defined as being related to the presence of different materials within a unique spatial cell of resolution. Thus, the collected response is resulting from the combination of the spectral responses associated to all the components elements. The cited properties make the direct exploitation of the collected hyperspectral data difficult to perform, the reason why processing is needed.

The Independent Component Analysis (ICA) is a statistically based method that has been developped to successfully answer the need of the blind sources separation and then was extended to many other applications such as the features extraction or selection. Thanks to its recognized success when dealing with multidimensional data, the ICA is a suitable candidate that matches the hyperspectral data characteristics.

Many algorithms developed on the basis of the ICA have been proposed in the literature and many are the ones that could be adapted to the hyperspectral data processing. Our work focuses on the feasibility and the conditions of the implementation of such algorithms to obtain new interesting observations of the images scene where only specific and pertinent content is likely to appear making possible the extraction, the localization, the quantification and the identification of the pure elements (independent sources) called endmembers those are present within targeted areas.

Therefore, comparative studies are presented considering the application of the developped algorithms on datasets acquired by sensors embedded on different platforms (both airborne and spatial), with different specifications (mainly spatial resolution, spectral resolution and dimension) and representing zones of different natures (geological, wetlands, urban, mixed).

Our experiments have exploited the MATLAB programming tools for the ICA Toolbox creation, the ENVI software commands for visualization, classification and validation, and finally subsets of remotely sensed images acquired by Hyperion EO1 satellite, AVIRIS, ROSIS, and SpecTIR airborne sensors over distant regions over the world.

Remote monitoring of insects of economic importance based on the spectral analysis of their wing-flap

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Keywords: electronic insect trap, McPhail trap, precision agriculture

In this work we describe a novel, fully operational stand-alone system for remote monitoring of insects of economic and social importance.

We modify typical plastic traps into electronic ones. Insects fly-in the box-shaped traps that hang from trees in response to chemical signals they receive from inside the trap. As they fly-in, an opto-electronic sensor composed of an array of phototransistors that acts as a receiver and an infrared led on the opposite site of the circular entrance guard the entrance. As the insect flies in its wings interrupt the flow of infrared light from emitter to receiver. In this work we show:

a) The signal of the wing-flap received is of very high SNR and resolves the fundamental frequency of the wing-flap as well as several overtones up to 2 kHz.

b) The analog signal of the wing-flap recording received from the opto-electronic sensors is directed to a microprocessor embedded in the trap that analyses the spectrum of the recording. The aim is to extract the fundamental frequency and the way the energy is distributed on the overtones of the recording. We show that this information extracted from a 50-100 msec duration flight is enough to reveal species identity of the entering insect.

c) The detection results of all entering insects are accumulated on per-day basis and an SMS with the results is emitted from the trap to base. The SIM card and the GSM antenna are embedded in the microprocessor hardware. Therefore the recognition results and counts can be emitted as far as to another continent with minor cost.

d) We give details on the hardware implementation of the insect recognizer based on the integration of different Arduino shields. We also present detection and recognition results for a large number of insect events and calculate detailed scores for various insect species.

This work emphasizes the hardware implementation of the hardware classifier performing the signal processing tasks and the opto-acoustic sensor responsible for the detection/counting. We give all necessary implementation details needed to construct all systems. We believe that once optimized the opto-acoustic sensor and the standalone recognizer has the potential to revolutionize the way insect monitoring is carried out for a series of insects with large economic impact (either positive or negative) such as fruit flies, bees and mosquitoes.

Use of NIR-HIS and dichotomist classification tree based on SVMDA models in order to discriminate roots and crop residues of winter wheat

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Keywords: NIR-HSI, SVM discriminant analysis, root system, crop residues decomposition

Monitoring of both crop residues decomposition and root system development is important to improve agricultural practices. In this study, NIR hyperspectral imaging was used to discriminate roots and crop residues of winter wheat (*Triticum aestivum* L.) and soil. This technique has been proposed as an alternative to the tedious hand sorting commonly needed with the soil coring method in studies on roots and crop residues (Eylenbosch *et al*., 2014). Organic matters collected after washing of soil cores have to be separated before quantification and characterization. Sorting is time-consuming and depends on operator subjectivity (Plaza-Bonilla *et al*., 2014).

Dichotomist classification trees based on successive Support Vector Machine Discriminant Analysis (SVMDA) models were used to predict spectral nature of pixels on hyperspectral images (Fernández *et al*., 2004). Images were acquired with a push-broom imaging system working in the range of 1100-2500 nm and combined with a conveyor belt.

Our study highlighted the importance to carefully select pixels intended for models construction. A sufficient number of pixels have to be selected to have a high variability of spectra (Lebot, 2012) and care must be taken to select spectra of shadow separately to increase sensitivity of predictions. In our case, spectra of the conveyor belt, on which samples were laid under NIR camera, have been combined with spectra of root shadow in a single class (background).

Pixels coming from the background and soil particles were well predicted. Mean percentages of correctly predicted pixels were respectively 100% and 98.4% (± 1.0%). For root sampled during the growing seasons, 97.7% (± 0.9 %) pixels were well predicted. Prediction of pixels of dead roots and crop residues was more difficult. Central area of crop residues was always well predicted but most pixels located on the edge were predicted as roots. Only 79.4% (± 4.7%) pixels of crop residues were well predicted. Use of model pattern recognition should allow to better predict pixels of crop residues and to better separate them from roots.

References:

Eylenbosch, D., Fernandez Pierna, J. A., Baeten, V., Bodson, B., 2014. Detection of wheat root and straw in soil by use of NIR hyperspectral imaging spectroscopy and Partial Least Square discriminant analysis, in: proceedings of the ESA XIIIth Congress, Debrecen, Hungary, pp. 237-238.

Fernández Pierna, J. A. , Baeten, V., Michotte Renier, A., Cogdill, R. P., Dardenne, P., 2004. Combination of support vector machines (SVM) and near-infrared (NIR) imaging spectroscopy for the detection of meat and bone meal (MBM) in compound feeds. J Chemometr. 18, 341-349.

Lebot, V, 2012. Near infrared spectroscopy for quality evaluation of root crops: practical constraints, preliminary studies and future prospects. J Root Crops. 38, 3-14.

Plaza-Bonilla, D., Álvaro-Fuentes, J., Hansen, N. C., Lampurlanés, J., Cantero-Martínez, C., 2014. Winter cereal root growth and aboveground–belowground biomass ratios as affected by site and tillage system in dryland Mediterranean conditions. Plant Soil. 374, 925-939.

Non-invasive documentation of historical painting – hyperspectral approach

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Keywords: Hyperspectral, cultural heritage documentation, painting, VNIR, SWIR

Documentation of cultural heritage is crucial for its identification, interpretation, protection and future restoration processes. Non-invasive methods are important in the documentation procedure as they do not harm the object investigated and maintain its existing condition and shape. Hyperspectral imaging is one of these methods and can provide unique information, documenting a historical object in an innovative way. Hyperspectral imaging of historical paintings and documents produces results regarding colour, material and chemical composition of an historical object.

The Department of Geomatics, Faculty of Civil Engineering, at Czech Technical University in Prague has been involved in several cultural heritage documentation projects in last few years. New Modern Methods of Non-invasive Survey of Historical Site Objects is the University's current project. This paper outlines the possibilities of documenting paintings using a VNIR hyperspectral sensor, SWIR VGA camera and SWIR spectrometer. A new mobile set-up for the VNIR hyperspectral sensor will be introduced and tested on a 16th century oil painting on wood painted by an unknown author in this analysis. The analysis will provide more information about the painting's origin and will display this historical artwork in a new light. Painting explorations were performed at the university laboratory with the kind permission of its owner - academic painter Mr. Martin Martan.

Anisotropic reflectance effects in optical multi-angular laboratory and hyperspectral airborne measurements

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Keywords: reflectance anisotropy, unmanned aerial vehicle, goniometer

Anisotropic reflectance effects due to changing viewing and illumination geometries are a commonly known source of error in remote sensing data. Reflectance anisotropy has been studied for several decades under laboratory conditions using goniometer systems, which allow for highly controlled observation configurations. Until now, not much research has been done on the scaling of anisotropic reflectance effects observed under laboratory conditions and effects that are observed in field conditions. In this research, we investigated the anisotropic reflectance behavior of a sugar beet crops using an unmanned aerial vehicle (UAV) and a laboratory goniometer system. During the summer of 2014, we programmed the UAV to fly several flight patterns over a sugar beet field, trying to capture as much of the reflectance anisotropy as possible. Subsequently, some sugar beet plants were collected and measured using a laboratory goniometer system. In order to simulate a similar illumination geometry as during the field measurements, we placed 1000 Watt halogen lamp in the laboratory at a similar zenith angle as the sun zenith during the UAV measurements, namely 30°. The preliminary results of the data analysis show an increased proportion of reflectance in the backscattering direction and a decreased proportion of reflectance in the forward scattering direction in the solar principal plane in the red and near infrared part of the spectrum. We observed a similar pattern in the laboratory measurements, however with a difference in forward and backward scattering of a greater magnitude. Possibly the diffuse illumination that is present at field conditions and absent in the laboratory reduces the magnitude of the observed anisotropy patterns. The data analysis is ongoing and hopefully provides a proof of concept for a laboratory and UAV based vegetation anisotropy measurement campaign during the growing season of 2015.

The integration of aerial-based LiDAR and Hyperspectral data for the seismic vulnerability assessment of historical heritages

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Keywords: Hyperspectral images, LiDAR, Historical heritages, Seismic Vulnerability

In the recent years, the monitoring of cultural heritage has become an operational issue concerning both the material control analysis and the structural health monitoring of the heritage itself in order to identify ad-hoc indicators for both seismic vulnerability assessment and mitigation purposes. This task is particularly relevant when considering historical, monumental and architectural buildings or historical city centers located on seismic areas, whose protection is strictly related to their surrounding environmental context as well as to their artistic, urban, social and security values. Within such a framework, aerial-based active and passive remote sensing instruments have demonstrated their powerful capabilities for providing high-resolution, multi-bands, extensive, timely and repetitive measurements of existing historical centers within urbanized seismic areas in order to gain meaningful parameters for improving and supporting both urban-planning and post-hazard management activities. Based on this rationale, in this paperwork the value-added information and the operational benefits carried out by combining airborne Hyperspectral images and Light Detection and Ranging (LiDAR) measurements are provided for the seismic vulnerability assessment of historical centers. On the one hand, airborne LiDAR measurements have been processed through classical signal processing techniques to provide the ground digital elevation model (DEM), as well as the building height and shape of the observed area. On the other hand, airborne hyperspectral images have been acquired by IPERGEO sensors, IMSpectorV10E and IMSpectorN25E for VNIR (wavelength range between 400 and 1000nm subdivided into 503 bands) and SWIR (1000-2500nm into 203bands) respectively, and properly processed through a supervised classification algorithm to provide spectral and structural information about each building over the whole interested area. The thematic maps carried out by active and passive remotely sensed measurements are combined within a Geographic Information System (GIS) to provide value-added indicators able to describe the seismic vulnerability of the observed area. Preliminary but meaningful experimental results, gathered for the historical center of Cosenza city (Calabria region, Italy), allow demonstrating the powerful capabilities and the full benefits of both the used remote sensing instruments and the proposed approach for both seismic assessment and mitigation purposes. The present work is supported and funded by Ministero dell'Università, dell'Istruzione e della Ricerca (MIUR) under the project PON01-02710 MASSIMO- Monitoraggio in Area Sismica di SIstemi MOnumentali

Poster: Retrieval of biophysical properties

Relationship between spectral resolution and the accuracy of biomass estimation through a data assimilation approach

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Keywords: crop growth model, data assimilation, hyperspectral, Sentinel-2

Crop growth models (CGM) are widely used to predict biomass and yield or simulate the crop growth under different conditions like changes in climate. CGMs are mostly designed as point models and a large number of parameters have to be defined to simulate biomass development with reliable results. These approaches lack transferability from a field to a regional scale. The assimilation of remote sensing data can help to overcome this limitation. A particle filter was used to assimilate the data into

the CGM APSIM in combination with the radiative transfer model ProSAIL and the method was already published (Machwitz *et al*. 2014). An ensemble of APSIM outputs is used as input parameter for ProSAIL to calculate corresponding spectra. According to the probability of each spectra in comparison to the measured data, weights are calculated. The weights are multiplied with the APSIM biomass outputs to generate an updated estimation with respect to the spatial information from the remote sensing data. In this study the particle filter was used to assimilate airborne hyperspectral image data of HyMAP and APEX acquired in Luxembourg in the year's 2010 and 2011. The spectral bands of the sensors are highly correlated due to the hyperspectral narrowband characteristics of the sensors. Consequently, a reduction of the spectral bands was undertaken. The reduction of spectral bands was carried out by using the autocorrelation matrix, as well as the correlation between spectra and biomass (n=93) without changing the bandwidth of each channel. In the region of short wavelength the models and measured spectra showed good agreement while wavelength above 1200nm have been underestimated by PROSAIL. A comparison of the selected bands of the HyMAP dataset with operational multispectral satellites was carried out. The dataset was resampled to the spectral resolution of Landsat-8 and Sentinel-2 to analyze the suitability of the spectral resolution for the crop growth modeling with data assimilation. The results confirm the usefulness of both sensors for biomass prediction with the presented data assimilation approach. The spectral channels and bandwidth corresponds with the most significant wavelengths derived by the correlation analysis for biomass estimation. Low loss of estimation accuracy compared to the HyMAP input has been reported.

Remote estimation of gross primary productivity in C3 and C4 crops: from close range to satellites

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Keywords: gross primary production, crops, remote sensing, chlorophyll, Landsat, MODIS, Sentinel-2

In this study, a simple model for estimating crop gross primary production (GPP) was developed and tested. Using the product of a chlorophyll-related vegetation index, retrieved from close range hyperspectral data, Landsat (30m) and MODIS (250 m) data, and potential photosynthetically active radiation (PAR). The latter of which is the incident irradiance value under conditions of minimal aerosol loading and represents the seasonal changes in hours of sunshine (i.e. day length). This model, which may be based entirely on satellite data, was tested for GPP estimation in both maize and soybean, C3 and C4 crop types that differ in leaf structure and canopy architecture, under different crop management and climatic conditions. When using Landsat data, the model brings results at high spatial resolution, and when employing MODIS data, it brings results at high temporal resolution. The model was capable of estimating GPP accurately for the two crops in both irrigated and rainfed field in three Nebraska AmeriFlux sites during growing seasons 2001 through 2010. Validation for the same crops was done over Illinois, Minnesota and Iowa AmeriFlux sites. The developed model was successfully applied to measure GPP in vegetation (crops, grasslands and deciduous forests) where total chlorophyll content is closely tied to the seasonal dynamic of GPP

Identification of spectral bands related to leaf biochemistry with a multi-method ensemble approach

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Keywords: biochemistry, leaf level, regression, spectral feature, vegetation

Statistical models are frequently used to identify spectral features that allow for a robust assessment of biochemical and biophysical vegetation properties. For this purpose, ensembles evaluating the range of agreement of multiple different models are believed to return more robust and reliable results than the application of one model alone. Here, we we extend the ensemble idea from a multi-model to a multi-method approach and test an ensemble of regression techniques for the quantification of leaf chlorophyll, leaf dry matter, and leaf water content. We evaluated if the multi-method ensemble is able to improve the robustness of the band selection process compared to the outcome of a single technique alone.

The multi-method ensemble consisted of Partial Least Squares (PLSR), Random Forest, and Support Vector Machine regression models. For the tests, we used one artificial and five measured data sets of leaf level spectra and corresponding information on leaf biochemistry. PLSR models optimized for the goodness of fit, an established approach for band selection, were used as benchmark to evaluate the performance of the ensemble approach.

The results showed that the ensemble is able to provide a band selection with higher consistency across the tested data sets than the reference approach. Due to the selection characteristics of the methods within the ensemble, the ensemble selection was rather narrow and restrictive but in good agreement with known absorption features published in literature. We conclude that analyzing the range of agreement of different model types is an efficient way to select a robust set of spectral bands related to the foliar properties under investigation. This may help to deepen our understanding of the spectral response of biochemical and biophysical traits.

Extraction of plant physiological status from hyperspectral signatures using machine learning methods

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Keywords: Hyperspectral Data, Vegetation Status, Random Forest, PROSAIL, crop

This study tests whether the impediment to derive vegetation parameters from hyperspectral signatures at consistently high levels stems from their high dimensionality, (changing) environmental factors such as illumination conditions, or the uncertainty of in-situ measurements. Therefore, vegetation parameters are extracted from a unique combination of three independent datasets: simulated signatures, laboratory and field measurements covering a complete vegetation period combined with respective in-situ measurements. Consquently, applicability of machine learning methods like randomForest (RF) for deriving the plant physiological status from hyperspectral signatures is investigated. Based on PROSAIL simulated data the potential of this approach, which is able to represent also non-linear relations and interactions between variables, can be demonstrated.

First, vegetation parameters are extracted from hyperspectral signatures simulated with the radiative transfer model PROSAIL. Second, transferability of these results with respect to laboratory and field measurements is investigated. In-situ observations of plant physiological parameters and corresponding spectra are gathered in the laboratory for summer barley (Hordeum vulgare). Field in-situ measurements focus on winter crops over several growing seasons. Chlorophyll content, Leaf Area Index and phenological growth stages are derived from simulated and measured spectra.

RF performs very robust and with a very high accuracy on PROSAIL simulated data (Cab: $R2 = >0.98$ / LAI: $R2 = >0.9$). Furthermore, it is almost not affected by introduced noise and bias in the data. When applied to laboratory data, prediction accuracy is still good (Cab: $R2 = 0.94$ / LAI: $R2 = 0.80$ / BBCH: $R2 = 0.91$), but not as high as for simulated spectra. Transferability to field measurements is given with prediction levels as high as on laboratory data (Cab: R2 = 0.89 / LAI: R2 = 0.89 / BBCH: R2 =~0.8). Wavelengths for deriving plant physiological status based on simulated and measured hyperspectral signatures are mostly selected from appropriate spectral regions (both field and laboratory): 700-800 nm regressing on Cab and 800-1300 nm regressing on LAI.

Results suggest that prediction accuracy of vegetation parameters using RF are not hampered by the high dimensionality of hyperspectral signatures (given preceding feature reduction). Wavelengths selected as important for prediction might however vary between underlying datasets. The introduction of changing environmental factors (soil, illumination conditions) has some detrimental effect but more important factors seem to stem from measurements uncertainties and plant geometries. Despite shortcomings when simulating crop hyperspectral signatures at certain phenological growth stages this study could still demonstrate the usefulness of a radiative transfer model like PROSAIL to assess statistical approaches on simulated hyperspectral data: When testing against simulated signatures the truth is already known, i.e. one is able to discriminate between randomForest performance and measurement uncertainties or changing environmental conditions.

Poster: Thermal Infrared Spectroscopy

Hyperspectral and thermal remote sensing application in an integrated crop breeding programs

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Keywords: Hyperspectral, thermal infrared, crop breeding, high-throughput screening

Optimum yield of the agricultural crops can be achieved by screening the best genotypes for specific growing conditions. The successful screening of the desired traits require enormous field measurements at the both breeder plots as well as farm trials which is exhaustive, time consuming and often some measurements qualitative in nature. However, recent advances in remote sensing technology, portable platforms and processing algorithms have been shown to provide relatively accurate, consistent, simultaneous and non-destructive measurements of large breeding plots and farm trials for quantifiable-characterization of plants at low cost in relatively less time. The aim of this research is to develop and evaluate hyperspectral and thermal infrared imaging sensors based high-throughput screening (HTS) of the plants for specific traits. The in-situ spectral measurements at leaf and canopy are aligned with regular plant measurements and wet-lab chemistry to develop and validate the spectral models/algorithms for the rapid HTS. This is undergoing research. The various traits associated with bio-physical and bio-spectral properties of the plants will be further explored for potential agricultural applications such as mapping crop varieties, nutrient uptake, yield gaps, agro-biodiversity and genetic resourcs, etc.

Optimized calibration and radiometric processing of MCT based LWIR push-broom hyperspectral imager

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Keywords: Thermal, Hyperspectral, Data processing, Atmospheric correction, MCT, pushbroom

The airborne hyperspectral imager AisaOWL has been used in data collection since 2008. Instrument utilize MCT (Mercury Cadmium Telluride) based technology detector array and push-broom measuring technique. LWIR (Long Wavelength Infrared) detectors have characteristics that determine specific needs for the data processing. Quality of this processing is the key to make initial raw data first a valid radiometric data to enable good quality emissivity data at the last processing phase. These processing steps may be called as pre-processing preceding the application oriented final processing phase.

The aim of this paper is to describe the main aspects of thermal data pre-processing specifically with AisaOWL hyperspectral sensor. Pre-processing is divided in three logical steps: radiometric correction, blinking pixels correction and non-uniformity correction. Details of the pre-processing are driven by MCT detector characteristics together with optical properties of the hyperspectral imager.

Good quality of the radiometric data is the basis for atmospheric correction and emissivity temperature separation from thermal data. The procedure and examples of calibration and pre-processing of Specim's AisaOWL sensor are presented in the paper.

Poster: Remote Sensing of Vegetation Fluorescence

Sun-Induced Fluorescence as an early indicator for drought stress: a case study in Brazilian soybean varieties

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Keywords: sun-induced fluorescence, drought stress

Sun-induced fluorescence (SIF) is a weak signal emitted from the core of the photosystems. It is therefore directly related to stress induced limitations of the photosynthetic efficiency and thus shows a large potential to be an early indicator for plant stress. SIF can be derived in the atmospheric oxygen absorption bands (e.g. O_2-A and O_2-B bands) using high resolution spectrometers.

Within this communication we present the results of a drought stress experiment conducted in Londrina, Brazil. More than four different soybean varieties are grown under water limiting conditions. Previous lab experiments showed different stress resistances of the four varieties to water limiting conditions using state of the art plant physiological and destructive structural measurements.

High resolution spectrometers measurements at leaf and close canopy level are used to non-invasively detect drought stress. Classical vegetation reflectance indices and SIF measurements are combined with thermal canopy measurements to detect drought stress in vegetation canopies and to compare the drought stress resistance of the four different soybean varieties.

This experiment is a first experiment that will be repeated with different species in the future. In the future improved non-invasive drought stress indicators will be tested by imaging data that are recorded by *HyPlant*, a novel high performance airborne imaging spectrometer. *HyPlant* will be used to map SIF by exploiting its high spectral resolution in the window between 670 and 780 nm characterized by a full width at half maximum of 0.26 nm in the atmospheric oxygen absorption bands. In addition, its second module provides data for calculation of reflectance between 400 and 2500 nm.

Effects of chlorophyll fluorescence on the retrieval of biophysical parameters and leaf traits from leaf reflectance measurements

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Keywords: chlorophyll fluorescence, hyperspectral remote sensing, biophysical parameter retrieval, leaf reflectance, photosynthesis

Chlorophyll fluorescence has been studied intensively in recent years but its effect on vegetation reflectance has mostly been neglected. The Kautsky effect leads to a sudden increase of the contribution of fluorescence to leaf reflectance if the measuring light is more intense than the ambient light. This effect is particularly pronounced in leaves that were adapted to low light conditions but measured with high power light sources. When measuring outdoors, the ambient light level for each leaf is different which leads to a different contribution of chlorophyll fluorescence to each leaf reflectance measurement. The fluorescence contribution to leaf reflectance is, in our opinion, not negligible for the retrieval of biophysical parameters from leaf reflectance spectra because even though the fluorescence contribution to observed leaf reflectance is small in *absolute* terms, it can be considerable in *relative* terms in an important part of the spectrum, the so-called red-edge. Depending on the parameter or leaf trait to be retrieved, it is possible that the fluorescence contribution is a form of noise which masks the real value of reflectance or that it actually contributes useful information to the retrieval.

This study investigated the effect of chlorophyll fluorescence on the retrieval of important parameters of photosynthesis, i.e. Vcmax Jmax, and specific leaf area, as well as chemical leaf traits such as nitrogen content from leaf reflectance. Both, photosynthetic response curves and the reflectance of several hundred leaves from 40 different European tree species were measured. Using the Farquhar, von Caemmerer, Berry photosynthesis model, Vcmax and Jmax were determined. Reflectance was measured in the range of 400–2500 nm with two different protocols: firstly with the standard protocol, which estimates ”apparent reflectance” and secondly using a long-pass filter to exclude the contribution of chlorophyll fluorescence which is a method to estimate ”true reflectance”. This approach allows the separation of the commonly measured apparent reflectanceinto its two components, i.e. ”true reflectance” and the contribution of chlorophyll fluorescence. The preliminary results indicate that the fluorescence contribution to reflectance measurements, amplified by the Kautsky effect, is indeed important when estimating biophysical parameters from leaf reflectance measurements. This is apparent in the photosynthesis parameters as well as in the related chemical traits. It is therefore recommended to measure both, “apparent” and “true reflectance”, or alternatively apparent reflectanceand spectrally resolved chlorophyll fluorescence, which can also be examined on the canopy scale or on larger spatial scales with remote sensing methods.

Poster: Latest EnMAP Developments

EnMAP-Box 2.0 – an overview of the concept and available applications

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Keywords: EnMAP, image processing, data analysis, classification, regression

New possibilities for spaceborne environmental monitoring will arise with the launch of EnMAP. Imaging spectroscopy data of unprecedented quality and global coverage will be available for multi-temporal or comparative studies of arbitrary ecosystems, or for synergistic use with data from Landsat-8, the Sentinels and other sensors. Such analyses require sophisticated data processing approaches, for which the provision of latest developments from computer science in useful and standardized frameworks is desirable. Furthermore, the constant exchange and improvement of adapted methods within the imaging spectroscopy community is desirable. The development of the cost-free and open-source EnMAP-Box within the EnMAP preparatory mission activities was driven by the aim of offering latest applications to all users and a platform for the exchange of new algorithms to developers. All existing applications follow a standardized framework that builds up on the application programming interface hubAPI, which provides high-level dialogues and data I/O routines in IDL that enable external developers to easily include their own developments. After several years of development the EnMAP-Box Version 2.0 offers a rich set of advanced applications for classification (SVC, IVM, RF), regression (SVR, PLSR, RF), unmixing approaches (ISMA, synthMix-SVR) as well as a range of EnMAP specific algorithms, e.g. preprocessing, masking or similar, and application driven indexing tools. By bridging to applications written in Python, R or Matlab, the hubAPI offers users the integration of most existing data analysis approaches. We present an overview of the applications that are directly delivered with the Version 2.0 of the EnMAP-Box and show a set of successful mapping examples.

Assessment of soil degradation in Costa Rica using reflectance hyperspectral and simulated EnMAP imagery

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Keywords: HyMap, EnMAP, Endmember extraction, Spectral unmixing, Soil degradation

The drivers of soil degradation can be described through a number of functions that directly impact soil properties, such as climate variables, the terrain characteristics, vegetation cover, land management and time. In tropical regions where the prevailing climate regime causes severe rainfall events, land cover as well as land management can greatly impact soil conditions. The risk of soil degradation can be linked to the surface relative fractional cover of photosynthetic-active vegetation (PV), non-photosynthetic-active vegetation (NPV) and bare soil. The aim of this study is to investigate the potential of hyperspectral HyMap imagery and simulated Environmental Mapping and Analysis Program (EnMAP) imagery to map areas prone to soil degradation. The vulnerability to soil degradation is determined in two distinct study sites in Costa Rica characterized by different land use intensity. The first being the dry tropical forests within the Guancaste Conservation Area and a second region characterized by spatially extensive coffee plantations southwest of San Jose City of Costa Rica. Both areas can be described by moderate to high topographic relief and a tropical to subtropical climate with a dry season between December and April and a rainy season from May to November. The assessment of soil degradation is based on bi-directional reflectance function (BRDF) corrected image mosaics generated from 15 m spatial resolution airborne hyperspectral HyMap imagery, 30 m simulated EnMAP satellite imagery and additionally, geomorphological properties like aspect and slope derived from a resampled 15 m Digital Elevation Model (DEM). Field data for the given cover types was limited for both study regions. Thus, in a first step representative class spectra for PV, NPV and bare soil were extracted directly from the image using the spatial spectral endmember extraction tool (SSEE). This tool derives multiple spectra for each class that are spectrally similar, but spatially independent, which allows for a good representation of the intra-class variability. In a second step the resulting multi-representative class spectra were input into the Multiple Endmember Spectral Mixture Analysis (MESMA) algorithm to estimate the cover fractions of PV, NPV and bare soil across both study regions. Next, aspect and slope were linked to the relative fraction cover of the three classes. Both, surface cover and terrain information are used as input for a GIS-based approach to detect areas that are prone to soil degradation. Lastly, the methodology developed for the airborne HyMap data was

subsequently applied to the simulated EnMAP imagery to facilitate an assessment of the potential of upcoming hyperspectral satellite missions for soil degradation analysis. With the launch of EnMAP vast regions (potentially 30x5000 km of imagery per day) can be made available to the scientific community to derive useful information about Earth Surface processes. This will offer the possibility for remote evaluations of soil degradation on a large spatial scale where sufficiently large amounts of field data are not available.

Poster: Image Processing Methods

Comparing the Effect of Preprocessing Transformations on Methods of Land-Use Classification Derived From Spectral Soil Measurements

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Keywords: Generalized least squares weighting (GLSW), land-use changes, partial least squares discriminant analysis (PLS-DA), preprocessing transformations (PPTs), random forests (RF), soil spectroscopy

Advanced classifiers, e.g., Partial Least Squares Discriminant Analysis (PLS-DA) and Random Forests (RF), have been recently used to model reflectance spectral data in general, and of soil properties in particular, since their spectra are multivariate and highly collinear. Pre-processing transformations (PPTs) can improve the classification accuracy by increasing the variability between classes while decreasing the variability within classes. Such PPTs are common practice prior to a PLS-DA, but are rarely used for RF. The objectives of this paper are twofold: to compare the performances of PLS-DA and RF for modeling the spectral reflectance of soil in changed land-uses with different treatments and to compare the effects of nine different PPTs on the prediction accuracy of each of these classification methods. Differences in six physical, biological, and chemical soil properties of changed land-uses from the northern Negev Desert in Israel were evaluated. Significant differences were found between soil properties used to classify land-uses and treatments. Depending on the dataset, different PPTs improved the classification accuracy by 11-24% and 32-42% for PLS-DA and RF, respectively, in comparison to the spectra without PPT. Out of the PPTs tested, the Generalized Least Squares Weighting (GLSW) based transformations were found to be the most effective for most classifications using both PLS-DA and RF. Our results show that both PLS-DA and RF are suitable classifiers for spectral data, provided that an appropriate PPT is applied.

STORE-Simulator of TOa RadiancE for new hyperspectral missions

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Keywords: Hyperspectral data, simulation, remote sensing

In the frame of the Italian Space Agency (ASI) Hyperspectral Mission PRISMA (Precursore IperSpettrale della Missione Applicativa), the Istituto Nazionale di Geofisica e Vulcanologia (INGV) is coordinating the scientific project ASI-AGI (Analisi Sistemi Iperspettrali per le Applicazioni Geofisiche Integrate) to develop specific algorithms and products for various geophysical applications. The PRISMA project is conceived as a pre-operational and technology demonstrator mission, focused on the development and delivery of hyperspectral products and the qualification of the hyperspectral payload in space. The ASI-AGI project has the following main objectives: 1) improving the scientific understanding of natural phenomena and in particular geophysical phenomena: volcanic activity and tectonic processes, forest fires; 2) development of innovative techniques based on image spectroscopy and focused on the PRISMA system characteristics that operates an hyperspectral camera and a panchromatic camera. In

the ASI-AGI project a PRISMA data simulator to test the specific algorithms during the developing phases of the PRISMA mission has been developed. STORE (Simulator of TOa RadiancE) is an image satellite sensor simulator developed to generate a simulated hyperspectral data. Its input is a set of parameters in terms of reflectance, sensor features, atmospheric profiles and topographic information in terms of DEM offering the capability to generate a synthetic image. For this paper we have chosen Mt. Etna as test site, due to several ground campaigns performed in the last 10 years. Hyperion data have been used to test STORE itself. The results encourage us to consider STORE as an opportunity to simulate the top of atmosphere radiance (and the at-sensor radiance if sensor spectral response function is known) acquired by new sensors for future missions. Next steps of STORE development will regards the simulation of TOA ASI-PRISMA sensor.

A Protocol for Optimum Usage Of Handheld Spectroradiometers in Airborne and Satellite Applications: The Ocean Optics USB2000+ Case

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Keywords: USB2000+, ground measurements, integration time, hyperspectral and mustispectral images, product validation

Handheld spectroradiometers are often used to provide valuable information for the synergy work with Remote Sensing imagery. Nevertheless, users of these instruments often have to face a lack of details about its optimum usage in the manufacturer's operational manual. Moreover, scientific documents were these instruments have been used often also skip to provide operational details although they can be crucial to obtain the best data. This study aims to set a best practice protocol for the operation of a handheld spectroradiometer operating in the visible and near infrared wavelengths, and applied to measure reflectances. The protocol, which can vary depending on the application, was validated under two case studies: 1) the calibration of two airborne hyperspectral sensors (CASI-550 and AISA EAGLE II), and 2) the enhancement of the radiometric (atmospheric and topographic) correction of Landsat images.

We focused on the Ocean Optics USB2000+ spectroradiometer, covering wavelengths from 200 to 1100 nm with an optical resolution of 0.3-10.0 nm, equipped with fiber-optic extension cables of 25 degrees field of view angle. A succession of measurements of target leaving radiance, sky radiance and radiance reflected by a reference panel were carried out, besides measurements under dark conditions to quantify noise. The reference panel used was a pure white Polytetrafluoroethylene (PTFE) calibration panel (30×30 cm; 2 cm thick). Collection and treatment of data was done using a portable computer and the SpectraSuite® software. Concurrently to field measurements, hyperspectral data from CASI-550 and AISA EAGLE II, visible and near infrared airborne sensors were acquired during a field campaign in the 15th of March 2013 over a selected study area with natural and artificial targets in Banyoles (Catalonia, Spain). Basic radiometric processing of the images was made using the manufacturer's software, while geometric and atmospheric correction by ICGC software. Measurements followed different spectral configurations and images were acquired with very high spatial resolutions (ranging from tens of centimetres to several meters). A second set of field measurements were made under clear-sky, concurrently to Landsat acquisitions (30 m spatial resolution) over several homogeneous land cover areas at the surroundings of Barcelona (Catalonia, Spain). Geometric and radiometric (atmospheric and topographic) correction of Landsat images was done using MiraMon®.

Our study showed that three key aspects have to be considered to obtain accurate and precise data with this type of instruments: 1) the initial decision on the measurement units (i.e., digital counts or radiances), 2) the protocol for the establishment of the optimum integration time depending on the target and the spectral range, and 3) the necessary number of samples to take in order to assure the accuracy and representativity (true mean and variance, etc.) of the measurements. The good consistency observed between our field measurements and hyperespectral data acquired by CASI-550 and AISA EAGLE II indicated the validity of the protocol for airborne sensors calibration purposes. Moreover, results showed how the use of in situ spectra of real covers (instead of laboratory measurements) acquired simultaneously to satellite data helped to validate the radiometric correction model applied to Landsat imagery.

Materials and Geometry ror the Empirical Radiometric Calibration of an Airborne Imaging Spectrometer

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Keywords: calibration, target, goniometer, BRDF

High spectral resolution sensors capture variations in atmospheric absorption features, enabling the retrieval of the amount of the energy attenuating compounds. Such constituents mask energy interactions with surface features. The inversion of radiative transmission models is a widely applied approach to account for the atmosphere. The applications community has reported on residuals in physically modeled surface reflectance. Consequently, empirical calibration and validation methods are still employed. The consistency of target responses translates to the stability of empirical correction coefficients. In support of an AIS-ALS (airborne imaging spectrometer & airborne laser scanner) study, laboratory and ground based studies were conducted to identify appropriate calibration materials and to radiometrically rectify airborne data.

With an ASD Fieldspec Pro spectrometer, laboratory spectra were collected from a variety of potential target materials. A laboratory-based goniometer was used to vary the observation azimuth and zenith angles with 10° increments. This approach was used to demonstrate the diffuse and specular character of the materials. Ideal targets are diffuse, spectrally featureless and well separated radiometrically. Calibration targets were evaluated qualitatively, through median reflectance geometry surfaces, and statistically, through a nonparametric one-way ANOVA. Radiometric separation was evaluated through target medians while a nonparametric coefficient of variation was used to represent spectral invariance.

An airborne campaign deployed Specim's AISA-Eagle (350-1000nm) imaging spectrometer along with an integrated discrete lidar system and 30cm aerial photography. Flight parameters targeted a nominal 1.3m square pixel ground resolution. Six flights, with varying headings, were collected over the targets to capture variations in bidirectional reflectance. A ground campaign was conducted concurrently with the airborne flights. Two ~5x4m targets were deployed and survey grade GPS and radiometric field measurements were collected using an ASD Fieldspec Pro portable spectrometer. A multi-sensor integration/calibration was performed for the airborne system (timing, reference frames). Inertial navigation system (INS) data and unrectified radiance spectra were extracted. Observation geometries were derived from the INS data, while the surface normals were resolved by generating a 0.5m resolution lidar DSM (digital surface model). The variation in collection geometry and spectral responses were evaluated against laboratory-based observations with similar illumination and observation geometries.

Results suggest plant-based and synthetic textiles are not spectrally invariant. Of the materials assessed and in agreement with other research, surfaces of latex paints produced the best results. These samples were well-separated radiometrically and spectrally invariant in the specified range.

However, some paint formulations were highly anisotropic. The airborne study validated the orthorectification-processing stream and demonstrated that the observed variations in target responses were caused not by BRDF, but by target-background mixture fractions. This study revealed that the flight parameters used produced dissimilar scales for along and across track directions. The result of which is that ground features, including calibration targets, are more finely sampled in the across track dimension than along track.

Inter-Instrument Registration for the Sysiphe System

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Keywords: Hyperspectral, mutli-sensors, image registration

Sysiphe is an airborne hyperspectral imaging system with a spectral range from 0.4µm to 11.5µm and a spatial resolution of 0.5m at a ground height of 2000m. Sysiphe includes two components : the infrared hyperspectral instrument Sieleters covers the spectral range [3-11.5µm] and the visible and shortwave infrared reflective hyperspectral instrument Hyspex ODIN-1024 is related to the [0.4-2.5µm] spectra domain. The STAD, the post processing and archiving system, is developed to provide spectral reflectance and temperature products from calibrated georeferenced and inter-band registered spectral radiance products provided by each instrument. The STAD is decomposed in many processing modules including the inter-instrument registration module. This one allows to generate a georeferenced radiance product covering the whole spectral domain with the georeferenced radiance products related to each hyperspectral instrument used as input.

Image registration is the process of transforming an image into the frame of the other image. In this case, the reference image is Hyspex ODIN-1024 radiance image and the Sieleters radiance image is the target image projected in the reference space. The problematic of registration is then related to the very high spatial resolution (0.5m) and the distinct spectral range covered by each instrument.

The proposed method operates in the image domain and is an intensity and feature-based method. It finds correspondence between image features such as points, lines, and contours and compares intensity patterns in images via correlation metric. The transformation model used to relate the target image space to the reference image space includes linear transformations (translation, rotation, scaling) used to model local geometric differences between images. The defined transformation model is applied on the target image by using a robust and reliable resampling tool that involves the extraction and interpolation of gray levels from pixel locations in the target image and their relocation to the approximate matrix coordinate location in the rectified image corresponding to the reference space. The registration method is automatic and can be used to register spectral radiance images or spectral reflectance and emissivity images (before or after the atmospheric compensation).

In this paper, the registration method and the associated resampling tool are described. The performance is analyzed by using simulated data set provided by real data acquired by an airborne hyperspectral instrument different from the Sysiphe system. Finally, preliminary registration results obtained with real data set acquired by the Sysiphe system are presented.

Poster: Water Applications

Investigation of heavy metals distribution in suspended matter and macrophytes of the Selenga river delta using airborne hyperspectral remote sensing

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Keywords: turbudity, hydrology, hyperspectral remote sensing, ultralight aircraft, ground sampling

The Leman-Baikal project is an international Swiss-Russian research initiative in the fields of physical limnology, geochemistry and hydrology of aquatic geosystems. The three-year framework of the project includes three consecutive data acquisition campaigns taking place in the area of the Selenga river delta on lake Baikal in the Russian Federation during the summer months of 2013-2015.

The main methodological principle of the project is constituted by simultaneous collection of airborne wide-area Hyperspectral Imaging (HSI) and ground point-based data. In particular, a specially developed remote sensing platform based on the Headwall Photonics MicroHyperspec VNIR sensor (250 bands, 400-1000 nm) was utilised as the main instrument. The platform was deployed using an Air Creation Tanarg 912S ultralight aircraft.

The purpose of the ground-truthing team was to collect samples of water, suspended matter and aquatic vegetation. Different parameters of water were measured in the field such as pH, Total Dissolved Salinity and turbidity. In addition, the concentrations of dissolved and suspended heavy metals were obtained from the collected samples as part of detailed analysis in the laboratory in Moscow. In previous studies it has been found that certain plant species accumulate different types of heavy metals. In this case macrophytes were taken in some sampling points to identify species composition and amount of heavy metals in it.

Additionally, the reflected spectral response at each sampling point was registered with two spectrometers, the OceanOptics USB 2000+ and SkyeInstruments SpectroSense2+. This spectral data can be used for the sake of atmospheric correction of hyperspectral data. Also it will provide etalon spectrum for identifying vegetation species.

The data management system HypOS was developed at the Geodetic Engineering Laboratory (TOPO) at EPFL, to process the raw data into calibrated. The calibration process include geometric, radiometric, atmospheric correction, orthorectification and georeferencing.

After the two years (2013 and 2014) of data acquisition on lake Baikal we have amassed over 15 TB of airborne HSI data, covering an area in excess of 2000 sq. km; around 60 points of spectrometry and 200 in situ sampling sites. Preliminary results were produced using HSI data obtained in 2013. Based on the points of ground-truthing measurements and images in the visible region of the spectrum the relationship of turbidity to the image pixel values was modeled.

The spectrometry data obtained in 2014 can provide more accurate model of turbidity in the Selenga river as well as possibility of classification of land and water vegetation types. In the nearest future we are planning to make a turbidity map for the whole Selenga river delta and nearby lake area and the main aquatic species map in the delta area. Concurrently analysis of maps, water and vegetation samples will be used in investigation of heavy metals fluxes distributions in the Selenga river delta and it inflow to the lake Baikal.

UAV based multispectral imaging over a lagoon with corals in Reunion Island

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Keywords: drone, multispectral, lagoon, corals, mapping

The understanding and preservation of coral reefs is a key environmental issue regarding their high ecological values. In the context of climatic change and coastal erosion, it is actually critical to map and monitor their evolution. As most of corals are found in clear and shallow water, remote sensing is a perfect tool that could be used to achieve the objectives at both a high spatial resolution and over large extents. In this context, a field campaign was done in September 2014 over the lagoon of Plage de l'Ermitage, Saint Gilles, Reunion Island. This site is of particular interest because it shows blatant signs of erosion and sudden flooding happened during heavy swells associated with storms and cyclones. Human impacts growing on the shoreline and on river basin in the recent decades have also affected the functioning of the coastal sedimentation.

The UAV deployed was a custom made hexacopter with Pixhawk autopilot [1]. The unit allows executing manual and automatic flights as well as a tight integration with the imaging system. The sensor payload is composed of a novel Gamaya [2] 2MP, 16 band, snapshot hyperspectral camera spanning the 470-650nm range and a single channel 5MP infrared camera integrating the 830-950nm range. The cameras were managed by an embedded computer assuring proper triggering and synchronization of all the components. Moreover, the camera sensor head was accompanied by a miniature SBG GNSS/INS [3] (Global Navigation Satellite System/Inertial measurement unit), thus constituting a small all-in-one remote sensing system. The navigation unit was precisely synchronized with the cameras and provided position and orientation for every exposure. This approach allows creating seamless spectral maps without the need of establishing ground control points. Acquired data was processed and projected in a specially developed application based on NASA's WorldWind SDK.

Here we will test the efficiency of the camera for mapping in coralian context, and we will compare the results with images produced from previous hyperspectral data acquired at a lower spatial resolution, but higher spectral resolution, and *in situ* spectra and measurements. Preliminary analysis of the dataset based on spectral principal component analysis shows good discrepancy between corals and sands. We will extend the image processing using several other processing techniques, both supervised and unsupervised.

[1] Pixhawk, Accessed 14.12.2014, https://pixhawk.ethz.ch/

[2] Gamaya (previously VISNX), Accessed 14.12.2014, http://www.visnx.com/

[3] SBG Systems, Accessed 14.12.2014, http://www.sbg-systems.com/products/miniature-inertial-systems-overview

Application of AISA hyperspectral image for hydrodynamic model verification

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Keywords: AISA, hyperspectral image classsification, SVM, Secchi disk, CFD hydrodynamic model

Aims of the presentation is an analysis of confluence of two major Polish lowland rivers Bug and Narew in in the artificial Zegrze Reservoir. Bug discharging to the reservoir deposit large volumes of sediments transported as a bedload and in water column. Water flow at the confluence of the rivers is controlled by the discharge and suspended sediments concentration. Structure of the velocity field has been obtained from two-dimensional hydrodynamic model CCHE2D. Geometry of the channel has been measured by echo-sounding, and boundary conditions are known from hydrological observations. The results of model are displayed in the form of velocity vector map and suspended sediment scalar values. It is relatively easy to verify the results of model calculations for the velocity field, but sediment concentration pattern is difficult to evaluate. The AISA hyperspectral image was acquired by MGGP Aero aircraft on 5/08/2013 and then geometrically and radiometrically corrected. The atmospheric correction was conducted with at-surface reflectance measurements using ASD FieldSpec 3 spectroradiometer. Than were calculated hyperspectral indices to estimate water parameters: Secchi Disk Depth (SSD), Turbidity, chlorophyll-a content, Total Suspended Solids (TSS), Dissolved Organic Matter (DOM), Total Phosphorus (TP), phytoplankton. Apart from that were calculated vegetation indices (Red Edge Normalized Difference Vegetation Index) to estimate chlorophyll content. The acquired maps of spatial distribution of water properties were compared with field measurements of water properties.

The use of AISA images to water analysis in Zegrzynskie Lake

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Keywords: AISA, water properties, lake, hyperspectral indices

Water properties are changing quite quickly. Monitoring lakes properties is an important issue, because of the pollution. Traditional measurements are time-consuming and that is also expensive. This is a reason, why remote sensing techniques are very useful in water monitoring. Also using hyperspectral images it is possible to analyse water properties.

The aim of the study was to evaluate hyperspectral images to water properties analysis. In the study AISA image was acquired. Analyses were conducted in Poland on Zegrzynskie Lake, which is an artificial lake. Zegrzynskie Lake was created in 1963 as at the confluence of two major lowland rivers Bug and Narew. The lake is located approximately 30 km north from Warsaw and is one of the water sources for the city. Water flow at the confluence of the rivers is controlled by the discharge and suspended sediments concentration.

Hyperspectral image was done using AISA Eagle with spectral resolution 129 bands from 400 to 1000 nm. The image was acquired on August 3rd, 2013. During field measurements were acquired spectral reflectance values using ASD FieldSpec 3 on reference polygons of spectrally flat objects (concrete, sett and water). Also on August 5th, 2013 water parameters (Secchi disk depth, electric conductivity and chemistry) in 13 locations were collected.

Data were atmospherically corrected using Empirical Line algorithm. The field measurements from 4 polygons were compared to the values from AISA image and based on that the correction was conducted. Than were calculated hyperspectral indices to estimate water parameters: Secchi Disk

Depth (SSD), Turbidity, chlorophyll-a content, Total Suspended Solids (TSS), Dissolved Organic Matter (DOM), Total Phosphorus (TP), phytoplankton. Apart from that were calculated vegetation indices (like Red Edge Normalized Difference Vegetation Index) to estimate chlorophyll content. The acquired maps of spatial distribution of water properties were compared with field measurements of water properties.

Based on the estimated indices were estimated water properties of Zegrzynskie Lake. Hyperspectral image makes possible the visualisation of selected river water optical properties related to sediment transport.

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