Circumpolar polynya characteristics in the Arctic between 2002/2003 and 2014/2015 as derived from MODIS thermal infrared imagery and ERA-Interim reanalysis

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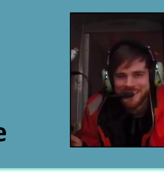


INTRODUCTION

Thin ice regions - Polynyas and Leads

- Enhanced interactions Ocean ←→ Atmosphere
- Most heat loss at the surface balanced by ice growth
  → "ice factories"
- Heat loss sensitive to ice thickness

Motivation:

- Long-term monitoring and quantification of pan-arctic polynya- and lead- dynamics and resulting ice-production in the framework of the Laptev Sea Transdrift project (2013-2016)

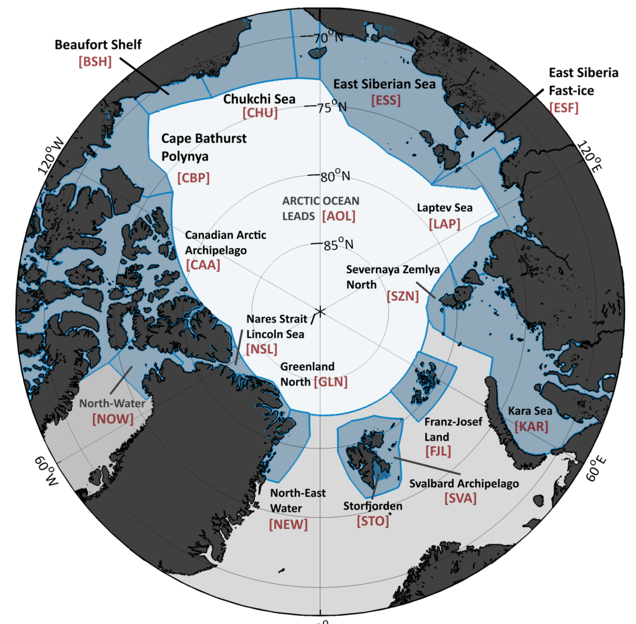


Figure 1. Map of all investigated areas of interest located in the Arctic, north of 68°N. The applied polynya masks are marked in blue, enclosing the typical location of each polynya in wintertime.

METHODOLOGY

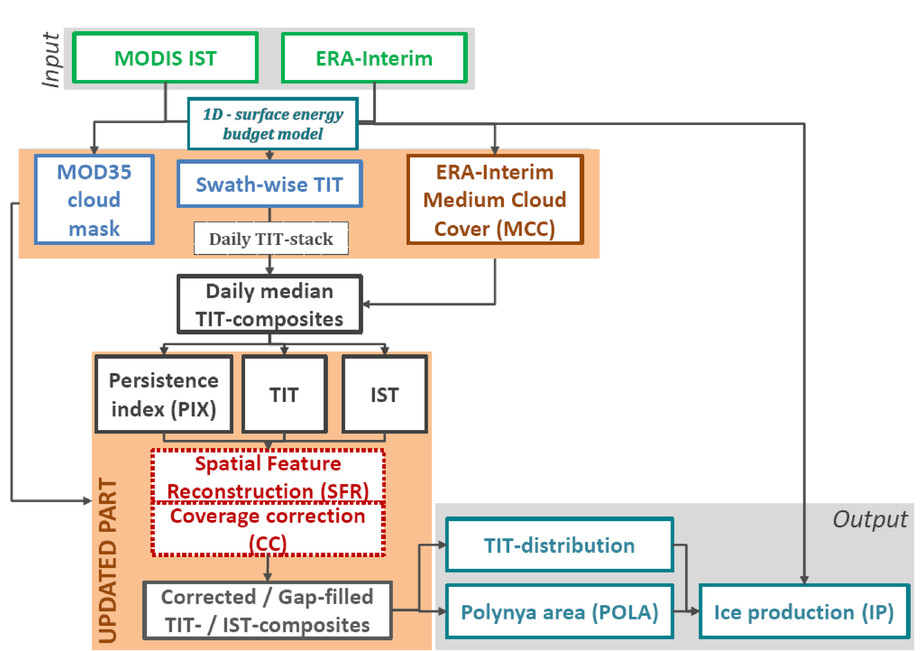


Figure 2. Schematic overview on the current version of the MODIS thin-ice thicknesses retrieval scheme, based on Paul et al. (2015b) and Preußer et al. (2015a). The most recent updates are highlighted in orange and are mainly aimed towards an additional cloud-cover treatment.

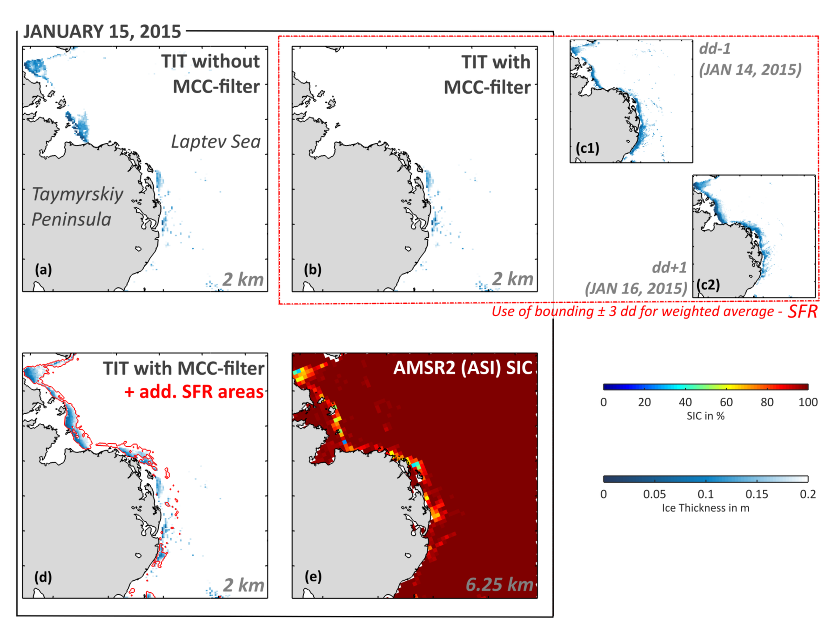


Figure 3. Different stages in the MODIS thin-ice thickness (TIT up to 0.2 m) processing chain for a single exemplary day (January 15, 2015). Panels (a), (b), (c1/c2) and (d) feature a subset (north-western Laptev Sea) from daily pan-Arctic TIT composites. Thereby, (a) shows TIT without any cloud-treatment besides the MOD35 cloud mask and (b) the resulting TIT distribution after applying the ERA-Interim medium cloud cover (MCC) filter. Two bounding days with a better coverage of TIT are presented in panels (c1) and (c2) as a reference for the highest relative contribution in the spatial feature reconstruction (SFR) algorithm. The resulting spatial distribution of TIT after application of SFR is shown in panel (d), with new additional / reconstructed areas (up to 20 cm) marked in red. A comparison with Advanced Microwave Scanning Radiometer-2 (AMSR2) ASI sea-ice concentrations (Spreen et al. 2008; University of Bremen) from the same date is given in (e). The respective grid-resolution is given in the lower right corner of each sub-panel.

Thin-ice thickness frequencies 2002/2003 – 2014/2015

NOV DEC

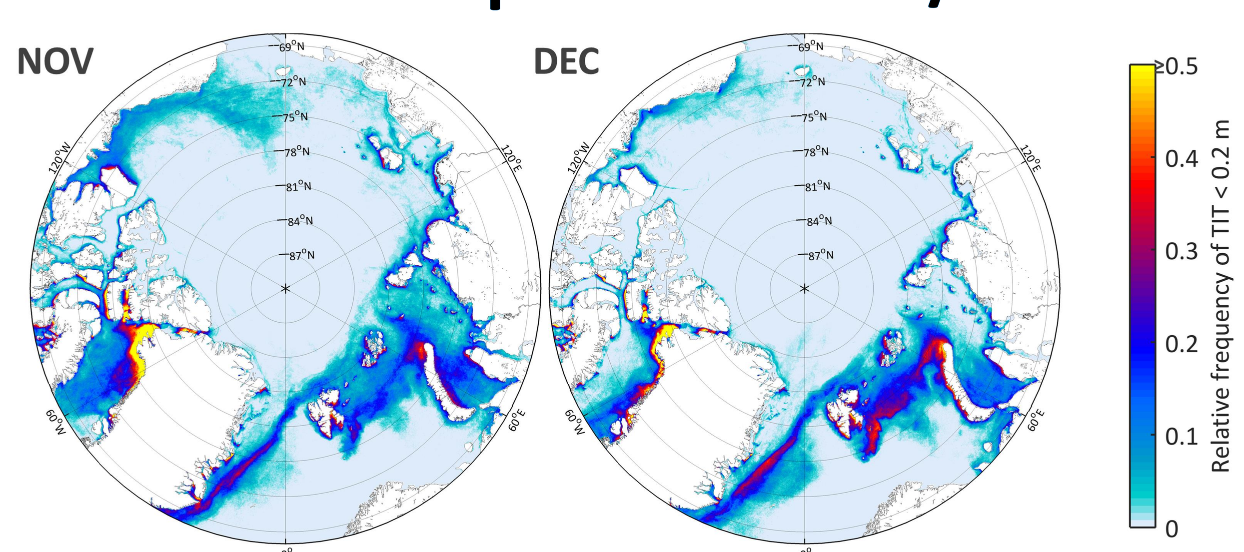
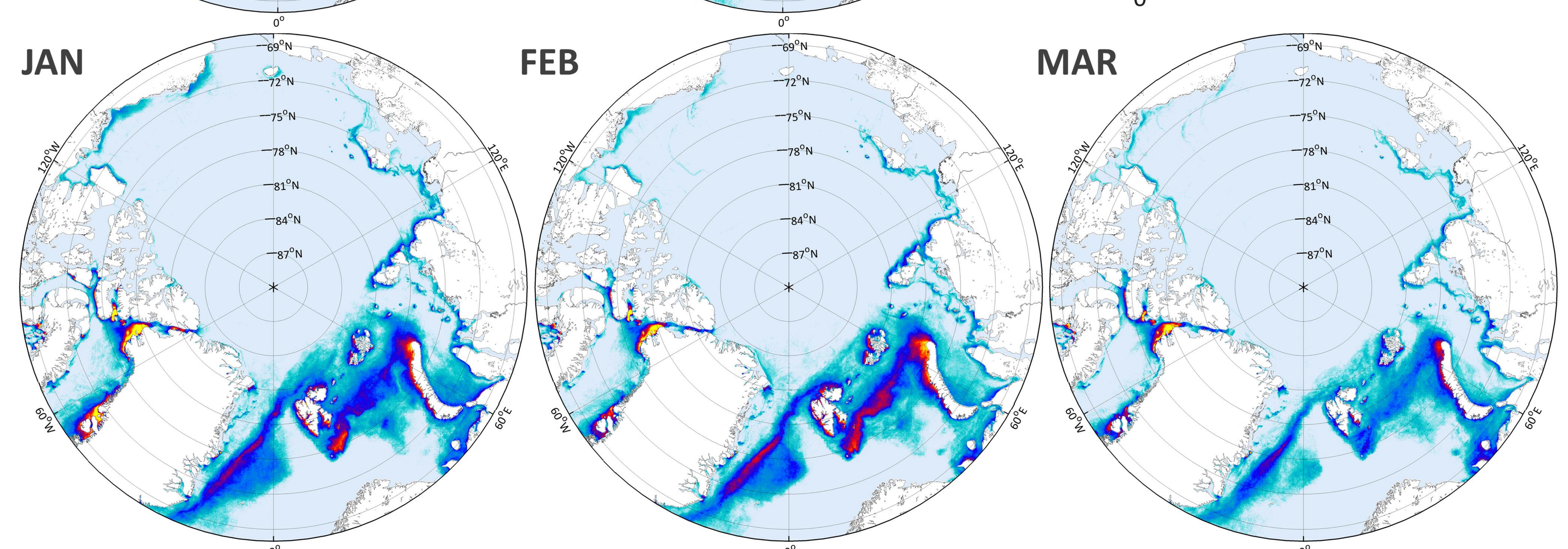


Figure 4. Average wintertime (November to March) frequencies of TIT ≤ 0.2 m in the Arctic between winters 2002/2003 and 2014/2015.

JAN FEB MAR

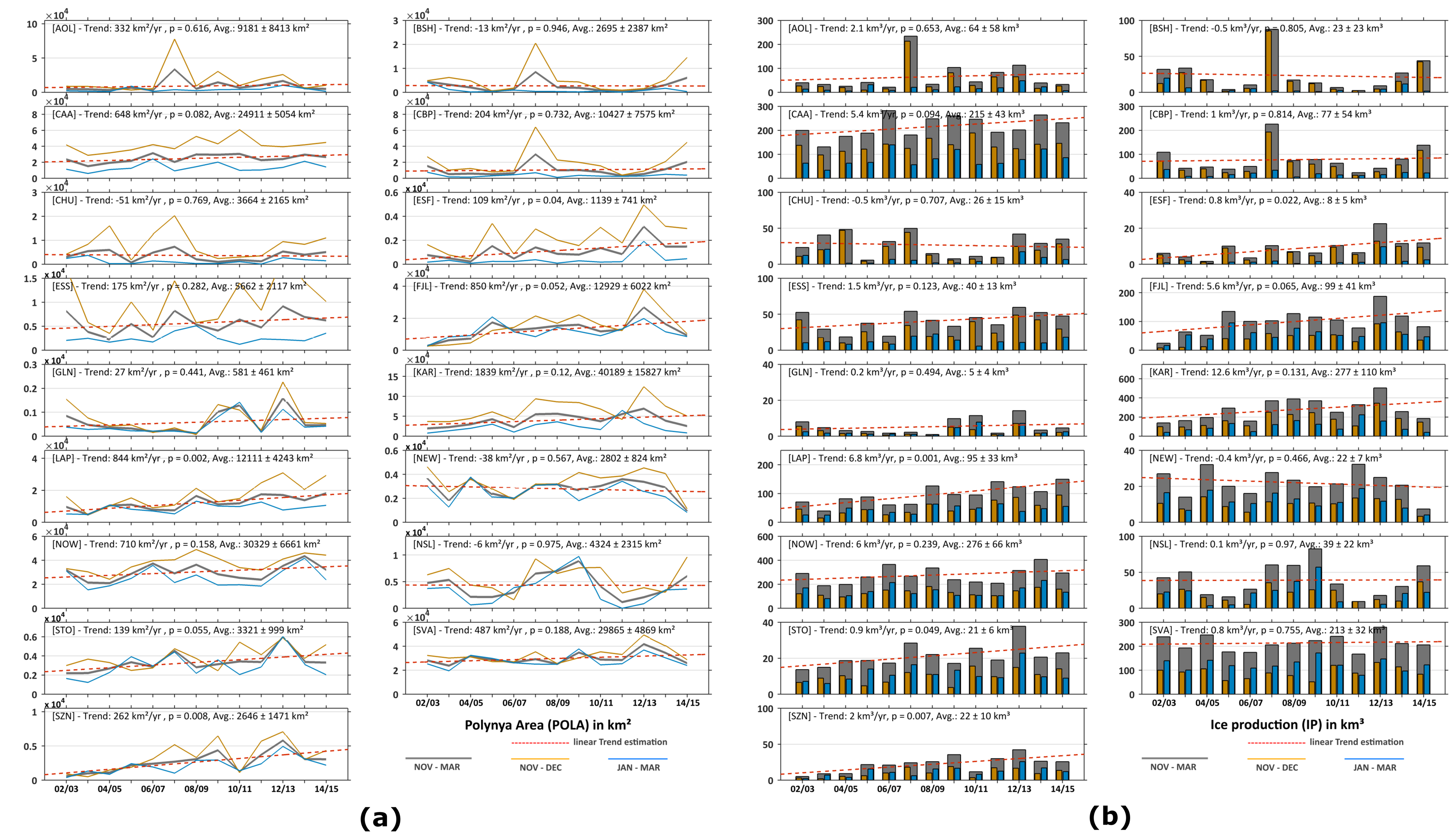


Interannual variability Polynya Area (POLA) and Ice production (IP)

Figure 5. Regional time series of (a) the annual average Polynya Area (POLA; TIT ≤ 0.2 m) in km^2 and (b) the annually accumulated ice production (IP) in km^3 for 2002/2003 to 2014/2015, together with a seasonal comparison (Nov.-Dec. vs. Jan.-Mar.) and a linear trend estimation.
The estimated linear trend (in (a) km^2/yr and (b) km^3/yr), its p-value and the interannual average POLA / IP are additionally listed in each sub-panel.

It shows, that:

- Largest average wintertime POLA and IP are found in the **NOW and KAR areas →** connected to long-term increase.
- The **interannual variability** in all regions is generally pronounced, but **increases for smaller polynya regions** like the NSL, NEW and ESS.
- Concerning **seasonal differences**, it appears that some regions (e.g. NEW, GLN, LAP, SZN) have the tendency towards **larger POLA during the freeze-up period** since approximately 2006/2007 to 2007/2008.
- **Late freeze-up in winter 2007** in the Beaufort Sea area extended until mid-December, leading to extraordinary high IP values in the BSH, CBP and AOL regions.
- Majority of polynya regions shows **overall positive (up to 126 km³ per decade → KAR) or no trends in wintertime ice production**, and only three regions indicate a slight decrease over the last 13 years (BSH, CHU, NEW).



Ice production in Arctic polynyas and leads (Avg. 2002/2003 – 2014/2015)

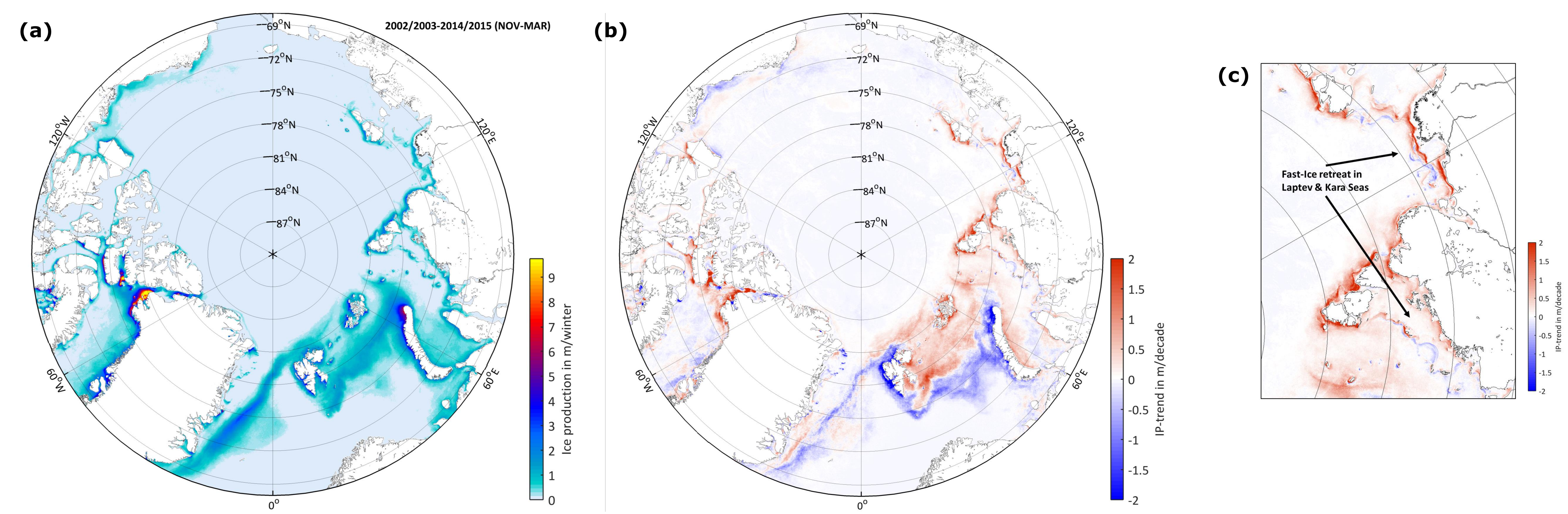


Figure 6. (a) Average (2002/2003 to 2014/2015) accumulated ice production (in m per winter) during winter (Nov.-Mar.) in the Arctic, together with (b) decadal trends (in m per decade) of wintertime (Nov. – Mar.) ice production, calculated by applying a linear regression on the annual accumulated IP per pixel. (c) shows a close-up on the Laptev and Kara Sea region, highlighting changes in the fast-ice regime over the 13-yr record.

CONCLUSIONS & OUTLOOK

- Established comprehensive 13-year dataset of **gap-filled thin-ice thickness and ice production in 2km resolution**
- Average total IP in Arctic polynyas: **1444 km³ per winter** (+ add. 65 km³ from detected leads)
- Distinct **hemispheric contrast** regarding POLA/IP trends (eastern vs. western Arctic)
- High-resolution MODIS data increases the **capability to resolve small / narrow thin-ice features**
- Outlook: **Sub-pixel statistics** from field campaign LEAST (Lead and ABL study in the Transpolar System - *March 2014*) and more detailed **comparison to lead-product from Willmes and Heinemann (2016)**

References

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