Polar lows over the Nordic and Labrador Seas: Synoptic circulation patterns and associations with North Atlantic Winter Weather Regimes.

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Due to their relatively small scale, polar lows (PLs) are generally not well represented in reanalyses. Nevertheless, reanalyses are a valuable tool to study their typical synoptic environment. Using several available datasets of PLs (Table 1), the synoptic environment prone to their outbreaks and their evolution are first investigated in this study.

Synoptic circulation during polar low outbreak.

Figure 1 displays standardized composite anomalies of several atmospheric fields estimated from ERA-Interim reanalysis, for PL formation days over the Norwegian and Barents Seas. The geopotential at 500hPa (Z500), the difference between the sea surface temperature and the 500hPa air temperature (SST-T500), the near surface wind, and the potential vorticity (PV) at 300hPa present significant anomaly patterns over large areas centered over the genesis zones. A similar study conducted on several PL datasets over the Norwegian, the Barents, and the Labrador Seas show that PLs formations are always associated with local minimum geopotential, decreased static stability and positive PV anomalies suggestive for stratospheric intrusions. There are nevertheless some geographical specificities for the low-level wind: in the Norwegian Sea, PLs are associated with a northerly flow, while they are bound with a northeasterly flow in the Barents Sea, and a westerly one in the Labrador Sea.

The time evolution of Z500 standardized anomaly for PL cases over the Norwegian and Barents Seas is shown on Figure 2 from for days before PL outbreak day to four days after. A weak, but significant, structure exists over the north of the Barents Sea four days before the key day, gradually intensifies and expands over the whole Barents Sea first, then over the Norwegian Sea spreading towards Iceland, until the PL formation day and the day after. Then the negative anomaly decreases, the maximum of amplitude progressively slides to the south, the westward extension reduces, and finally the anomaly disappears 4 days after the key day. A similar study realized on other field shows that a tropospheric environment specific to the PL formation exists on an approximate 8 days window centered on the PL life days. The PL outbreak day corresponds to a sudden intensification of anomalies, particularly in terms of wind and PV (not shown).

Weather regimes and polar lows.

The relationship between PLs and weather regimes (WRs) is then investigated. WRs are defined over the North Atlantic-Europe domain for winter months from 500hPa geopotential height daily anomaly patterns, correspond to preferred and/or recurrent quasi-stationary atmospheric circulation patterns produced by the interaction between planetary-scale, and synoptic-scale atmospheric waves and have a typical 8-10 days lifetime, similarly to PLs associated large-scale anomalies. For each PL of several considered PL lists, we have determined the regime during which the PLs occur. The distributions are shown on Figure 3, in blue for the Norwegian and Barents Seas lists, and in orange for the Labrador Sea ones. PLs forms preferentially during specific WRs: from 1999 to 2011, a period for which the detection of PLs is the most accurate, PLs are mostly observed over the Norwegian and the Barents seas when the Atlantic ridge (AR) and the negative phase of North Atlantic Oscillation (NAO) regimes are excited, whereas their probability to occur is reduced by half for the positive phase of NAO and the Scandinavian blocking (SB) regimes. Complementary analyzes suggest that, when PLs form during the two NAO+ and SB PL-repellent regimes, anomalous associated large-scale circulation that are characteristic of those regimes are much weaker and displaced compared to average, especially for SB where the blocking high is less pronounced and shifted southward. Over the Labrador Sea, more than half of the PLs occurred during NAO+ and are almost absent during NAO-.

The extension to additional observational cases and different time periods spanning from 1971 to 2011 lead to similar conclusions and confirm the relevance of the approach and the robustness of our findings.

This study corroborates the idea of a continuum of polar lows over the Norwegian and Barents Seas, while, over the Labrador Sea, a vast majority of polar lows form under similar conditions.

Table 1. Characterization of PL databases used in this study.

	Period	Approximate area	Total PL number	PL number for N-M	Wind criteria
Noer et al. 2011	1999-2011	20°W-55°E/65°N-77°N	156	134	Gale force
Ese et al. 1988	1971-1983	10°W-55°E/65°N-75°N	74	45	/
Wilhelmsen 1985	1978-1982	16°W-44°E/64°N-76°N	33	27	Gale force
Businger 1985	1971-1983	20°W-20°E/65°N-75°N	52	35	/
Kolstad 2011	2000-2009	60°W-30°W/55°N-65°N	63	19	Near gale force wind speed
Parker 1997	1977-1994	62°W-43°W/52°N-66°N	121	72	/

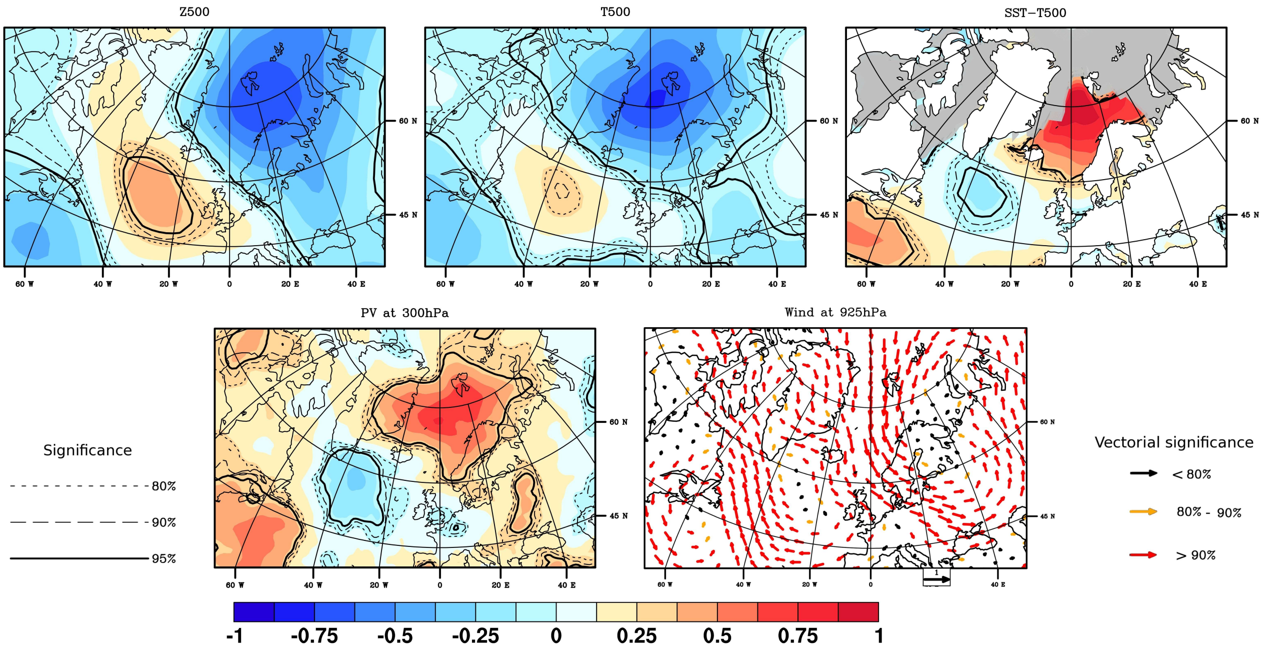

Figure 1. Composite standardized anomalies of T500, SST-T500, Z500, PV at 300hPa, and wind at 925hPa in winters months (October-March) for PL formation days from Noer's list. Grey areas correspond to maximal monthly sea ice extent from 1979 to 2007. The significance level is indicated.

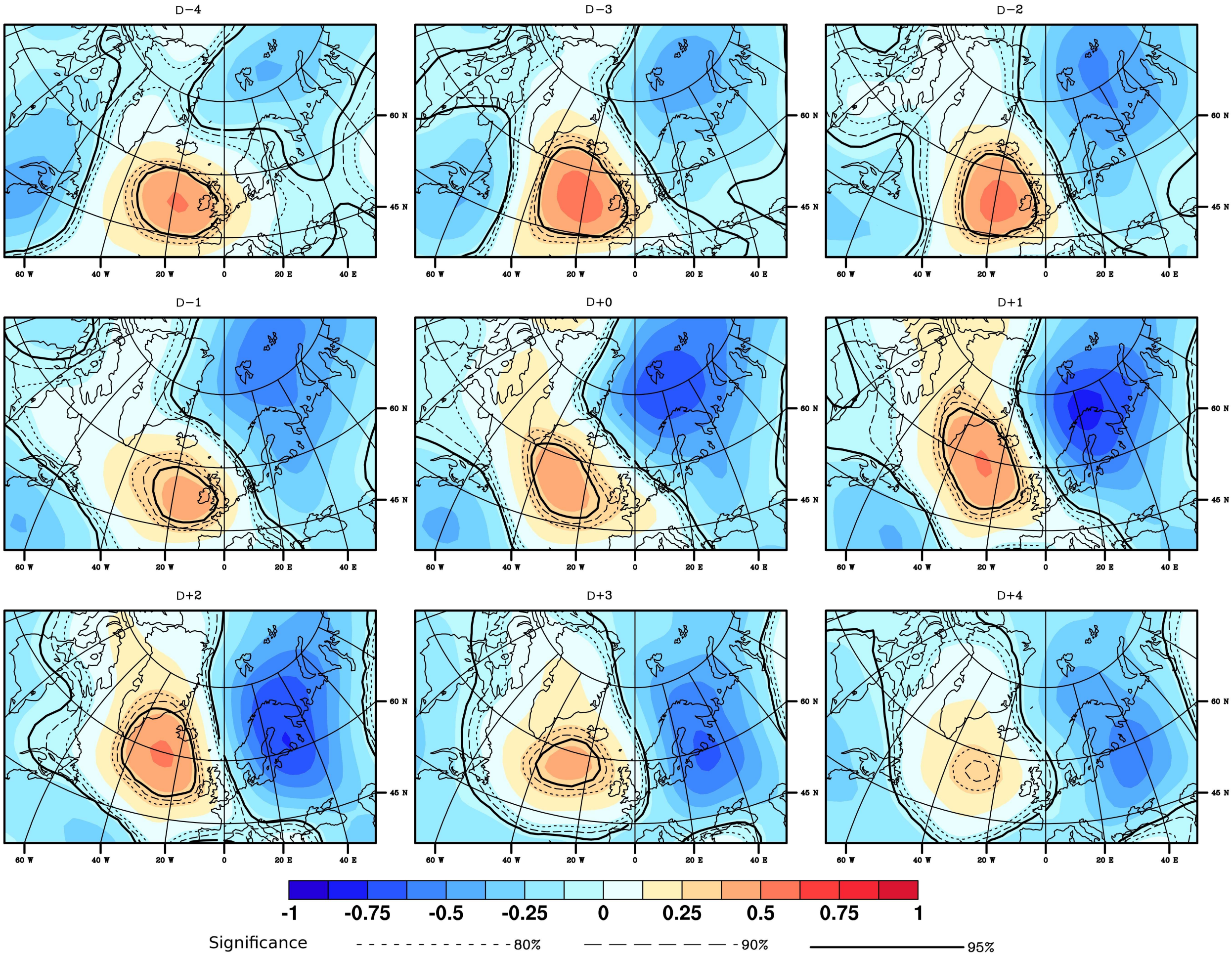

Figure 2. Evolution of the Z500 anomaly field from 4 days before PL formation day to 4 days after, for winter months (October-March), from 2000 to 2011.

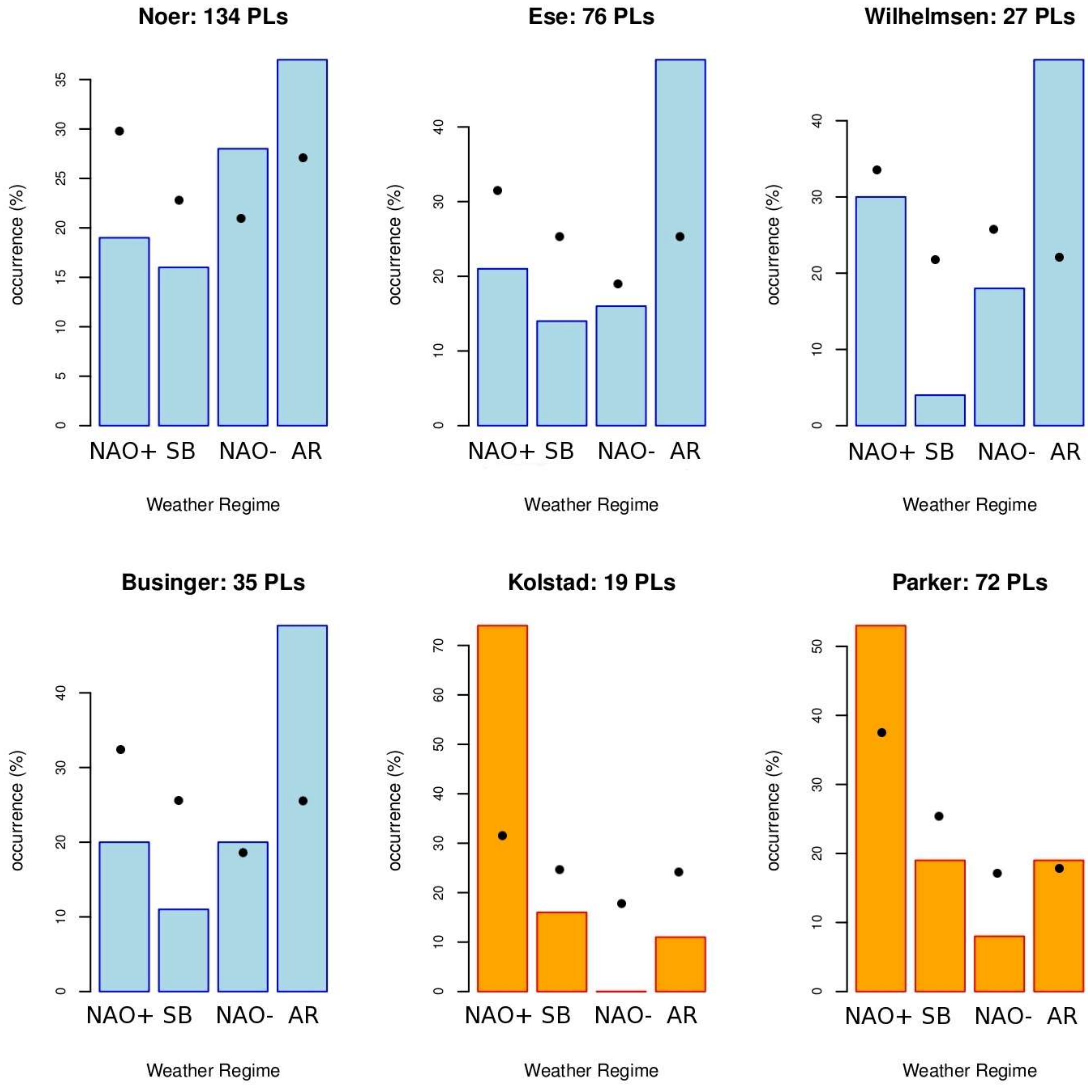

Figure 3. PL cases distribution according to the regime corresponding to PL formation days, for cases over Norwegian and Barents Seas (in blue) and for cases over the Labrador Sea or close to the southern coast of Greenland (in orange): Noer's cases (1999-2011), Ese's cases (1971-1983), Wilhelmsen's cases (1978-1982), Businger's cases (1971-1983), Kolstad's cases (2000-2009), and Parker's cases (1977-1994). WR occurrences during corresponding periods are indicated by black dots.