Impacts of Laptev Sea polynyas on sea ice production and the atmospheric boundary layer

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1. Motivation

Arctic flaw polynyas are considered to be highly productive areas for the formation of sea ice throughout the winter season. In addition, heat and moisture fluxes are strongly modulated by open water fractions associated with polynyas, having important consequences e.g. for the atmospheric boundary layer and ocean processes. Our geographical focus is on the Laptev Sea area of the Siberian Arctic (Fig.1, Fig.2), which is a key area for arctic sea ice production (Dmitrenko et al. 2009).

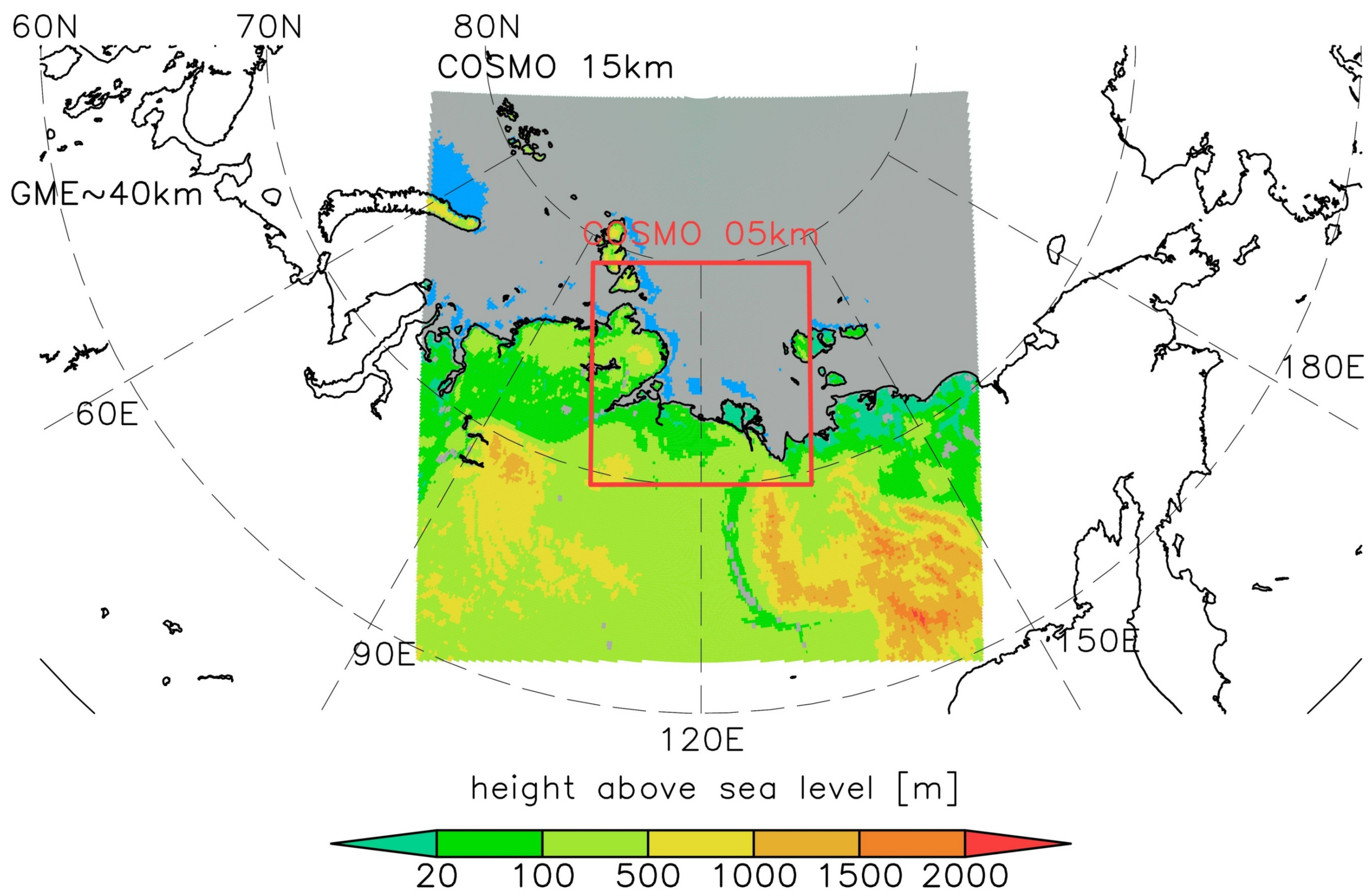

Fig.1: Model domains of COSMO 15 km and COSMO 5 km covering the Laptev Sea. The underlying map shows altitude over land. Polynya areas for 10 January 2009 are shown as blue areas.

2. Models and methods

We present results of dynamical downscaling using simulations of the NWP model COSMO (15 and 5km resolution) for the Laptev Sea of the Siberian Arctic. COSMO is the non-hydrostatic operational weather prediction model of the German Meteorological Service (Deutscher Wetterdienst, DWD). COSMO is forced by ERA-Interim data (ECMWF, 2002-2009) and GME data (DWD, 2007-2009), and the sea ice module of Schröder et al. (2011) is used to simulate the sea ice surface temperature. Sea-ice concentration is taken from AMSR-E passive microwave satellite data with about 6 km. Polynya area is either assumed to be open water or covered by 10 cm thin ice.

While the resolution of reanalyses and most regional climate models is too coarse to include the impact of polynyas on the atmosphere, our data allows for studies of the boundary layer modification and associated large-scale impacts. Using the energy balance equation we are able to estimate the potential ice production for the polynyas.

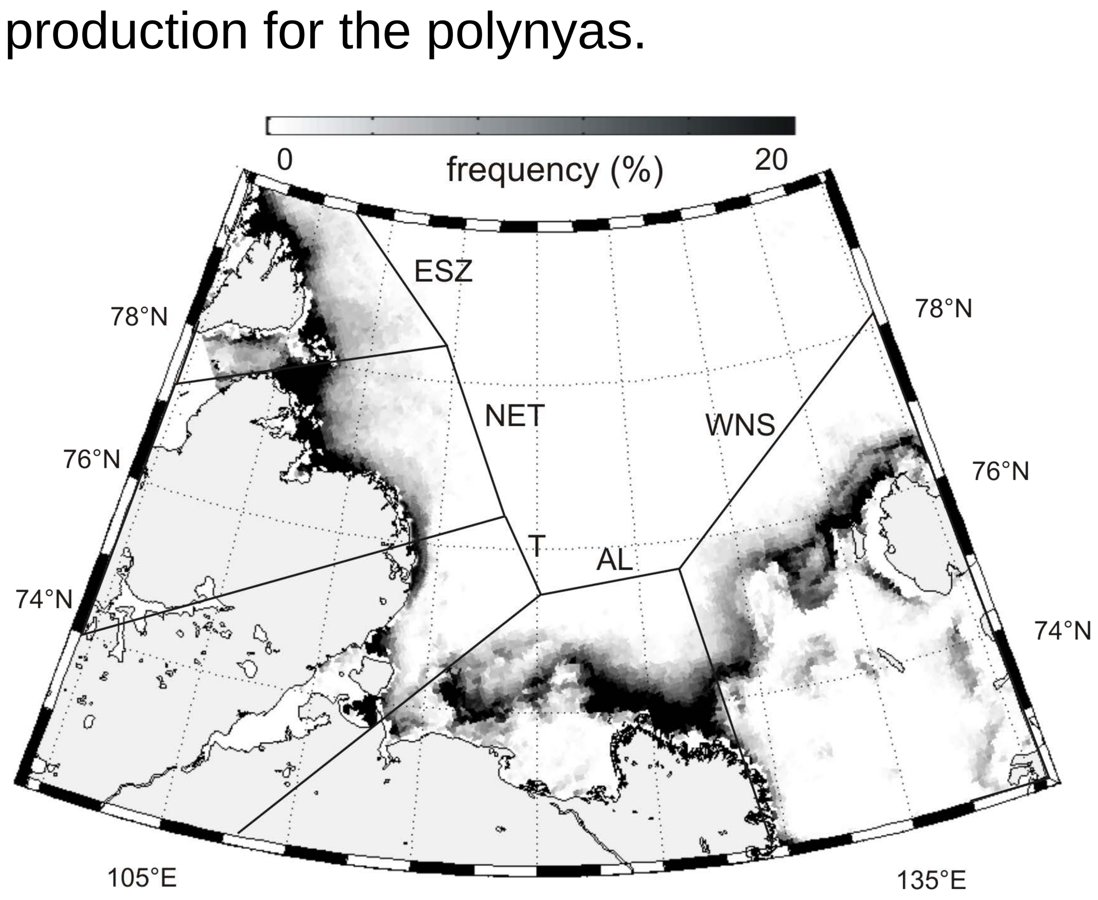

Fig.2: Map of the Laptev Sea showing polynya frequency (Nov-Apr, 2002-2008) and the polynya sub-areas of the East Severnaya Zemlya (ESZ), Northeastern Taimyr (NET), Taimyr (T), Anabar-Lena (AL) and the Western New Siberian (WNS) polynyas (from Willmes et al. 2011).

Acknowledgements

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3. Polynya effects on the ABL

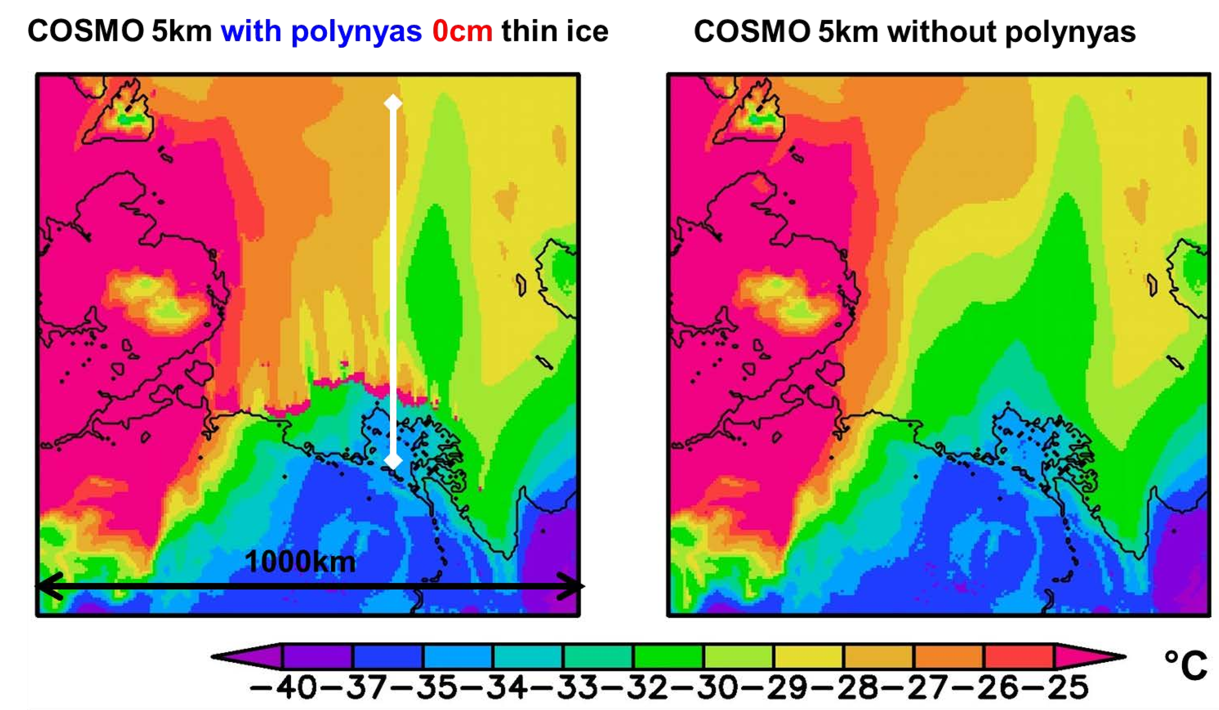

Fig.3: 2m temperature for 0700UTC 4 Jan 2008 (COSMO forced by GME). Left: open water polynyas; right: run without polynya. The white line marks a cross-section.

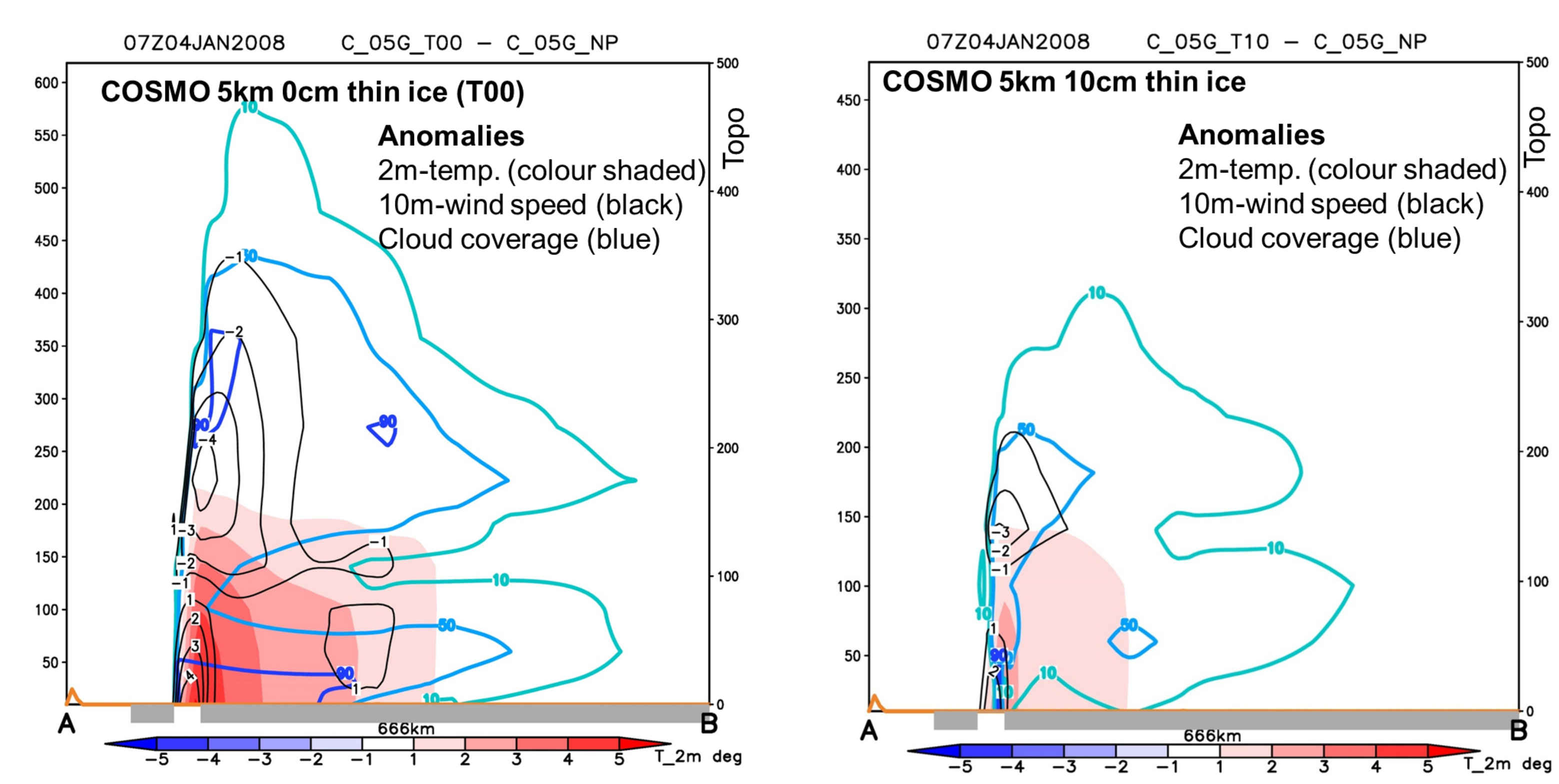

Fig.4: Cross-section along the line marked in Fig.3 for differences between the runs with and without polynyas: temperature (colour shaded), wind speed (black isolines very 1 m/s) and cloud coverage (colour isolines 10, 50, 90%). Left: open water polynya, right: polynya with 10cm thin ice.

4. Comparison with forcing data

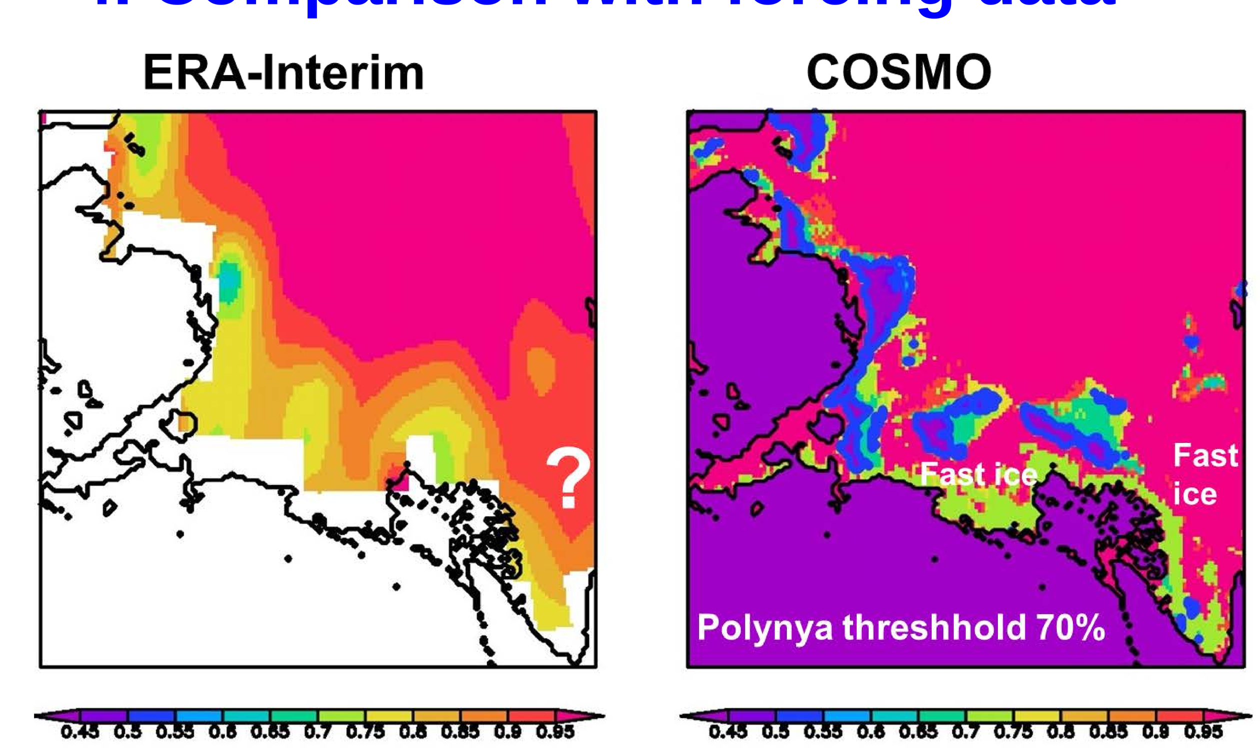

Fig.5: Sea ice concentration for 8 Jan 2009. Left: ERA-I; right: COSMO. A threshold of 70% is used in COSMO to define the polynya area. In ERA-I, fast ice areas are incorrectly represented as areas with ice concentration of 75-90%, and polynyas are smoothed out.

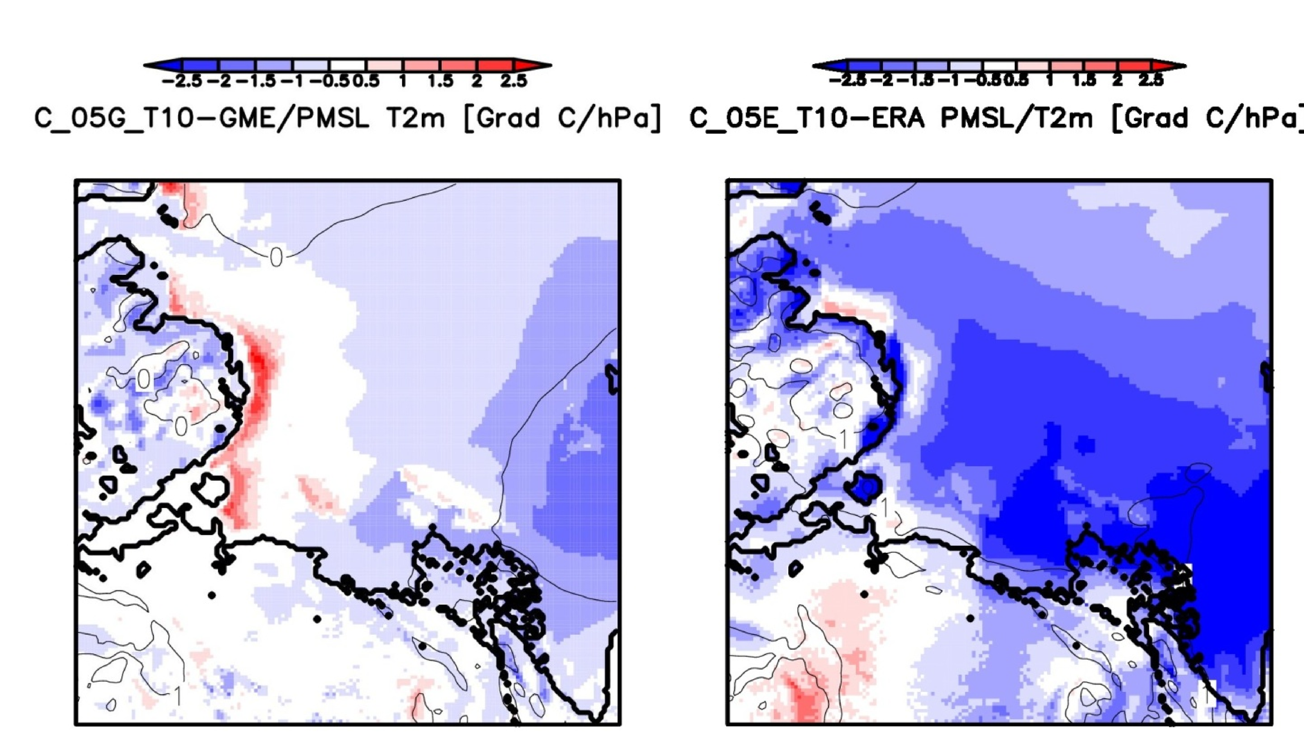

Fig.6: Mean January 2009 anomalies of sea level pressure (isolines, every 1hPa) and 2m temperature (colour shaded) for COSMO-GME (left) and COSMO-ERA-I (right). The area is completely sea ice covered in GME, while sea ice concentration for ERA-I is shown is underestimated in fast ice areas and in a broad belt along the coast, which explains partly the warm bias of ERA-I with respect to COSMO (polynya areas in COSMO are covered by 10 cm thin ice).

5. Ice production in Laptev polynyas

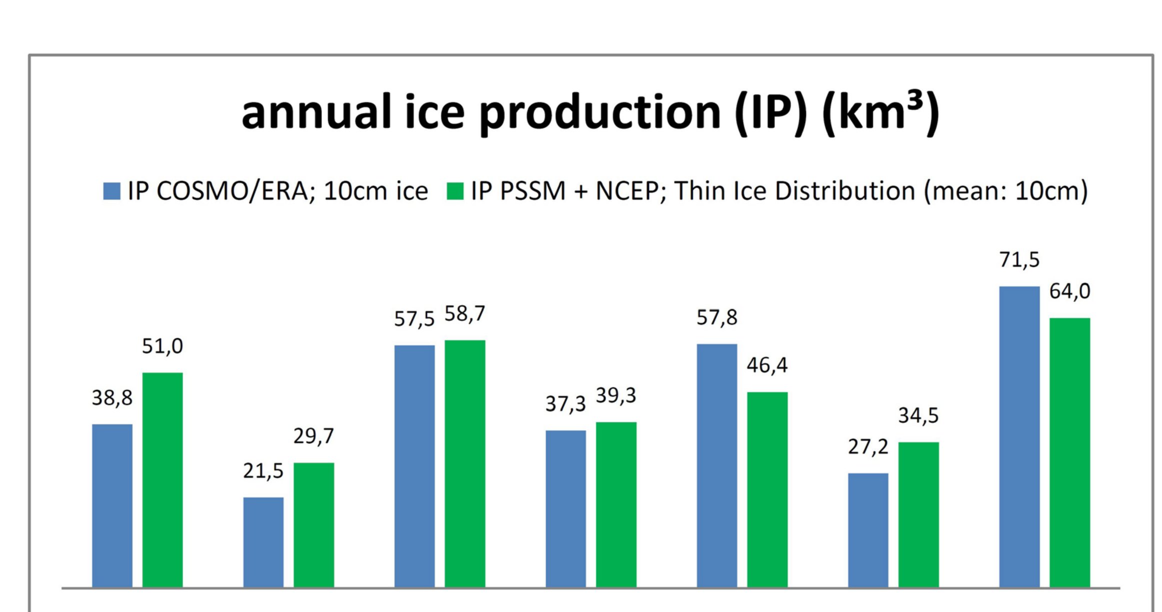

Fig.7: Ice production for Laptev polynyas for winters 2002-2009. Blue: COSMO nested in ERA-Interim, green: satellite-based estimate after Willmes et al. (2011). The mean for COSMO is 39.3 km³/a , and the mean satellite estimate is 46.2 km³/a. This is equivalent to about 5-10% of total Laptev sea ice production, and is much lower than previous studies (e.g. Tamura and Ohshima (2011) estimate 152 km³/a for 1992–2007).