Ice production and salt rejection of Laptev Sea polynyas, using model and remote sensing data

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Abstract

The Laptev Sea polynyas in the Siberian Arctic are well recognized as strong ice producers [1, 2] and may play a critical role with regards to sea ice volume changes in the Arctic. These flaw polynyas were studied during two seasonal cycles (2007 – 2009) by the Russian-German research project "Laptev Sea System" [3]. A focus was set on an investigation of the contribution of the West New Siberian (WNS) and Anabar-Lena (AL) polynya to saline bottom water formation using a polynya flux model.

The model is calibrated and validated by comparing simulations with observations made during TRANSDRIFT (TD) XIII expedition in April 2008. During this field campaign, the WNS polynya opened for a period of 6 days (April 27 –May 2, 2008). In the meantime, the ice dynamic was closely monitored with satellite and airborne instruments, while moorings deployed along the fast ice edge recorded oceanographic interactions.

The model simulation of the opening event in 2008 is driven with 6-hourly analysis data from the global numerical weather prediction model of the German Weather Service GME [4]. The GME data are in reasonable agreement with in-situ measurements in the Laptev Sea [5] and can be utilized for our study. The ice drift algorithms are tuned to polynya width information extracted from ENVISAT SAR imagery. The determination of open water width is not straight forward, since the backscatter signatures inside the region of open water and the consolidation zone can be very inhomogeneous and vary with climatic conditions. Under uncertain situations, meteorological data, thermal information from AVHRR and/or spatial information from high resolution TerraSAR-X scenes [6] were used to aid SAR image interpretation.

AVHRR derived thermal ice thickness data [7] reveals that the model is well tuned and applicable to this region. Results could also be confirmed by a comparison of helicopter-borne ice thickness measurements [8] made across and along the WNS polynya with modelled thin ice thickness distribution [3].

As opposed to other flux models, our model considers dynamic thickening of thin ice, by assuming the difference between pack ice drift and new ice formation to result in compression. This hypothesis is tested by comparing modelled thin ice compression with quantitative information on rafting and ice concentration extracted from aerial photos using a simple classification procedure. The good agreement between simulated compression and rafting observations shows that the presented approach is a good approximation to determine the distribution of compression along the polynya [9].

After successful validation, the model is applied to a stronger and almost consistent period of ice export in winter 2004, lasting for 51 days (February 10 –April 1, 2004).

Total modelled ice production in the polynya region amounted to 65 Mt for 51 days. The amounts of ice formation and salt rejection were largest under the extensive thin-ice zones of the polynya and only minor in regions of open-water. According to our calculations, a convective mixing event that extends down to the seafloor therefore requires a weakly stratified upper water column at the onset of the event. In the Laptev Sea, the surface hydrography strongly depends on the atmospheric circulation during summer, controlling the distribution of freshwater from river discharge. Thus, an increased probability for saline bottom water formation is given only, if prevailing western winds during summer push surface waters eastwards, leading to a less stratified water column in the polynya area in fall.

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