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Multi-method long-term analysis of atmosphere-ocean-ice interactions in Arctic polynyas

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Polynyas in the Arctic occur in several areas throughout the winter season. These open-water and thin-ice covered areas interact with the atmosphere via large heat and moisture fluxes and have a strong impact on the atmospheric boundary layer. On the other hand, they are strong ice production areas with associated brine release, which is an important driver for the ocean circulation and vertical mixing of the ocean column. Thus the quantification of the heat fluxes and associated sea ice production in Arctic polynyas is of vital interest.

We analyse surface heat fluxes and sea ice production using remote sensing methods and numerical simulations with atmospheric and sea-ice/ocean models. We use MODIS thermal infrared data (MOD/MYD29 Col.6) at a high resolution of 1-2 km and a surface energy balance model to estimate surface heat fluxes and thin-ice thickness (TIT). These data are then used to derive polynya area (TIT<0.2m) and ice production for the winter seasons 2002/2003-2016/2017. The energy balance simulated by the regional climate model COSMO-CLM (CCLM) with 15 km (C15) offers the second method to compute ice production. The polynya area in C15 is prescribed by sea ice concentration data from passive microwave satellite measurements (AMSR-E, SSMI/S, AMSR2). C15 was run with nesting in ERA-Interim data in a forecast mode, while atmospheric data from C15 and ERA-Interim were used for the MODIS retrievals. The third method relies on simulations using the Finite Element Sea ice-Ocean Model (FESOM). FESOM is run on a global grid with a resolution of about 9 km for the Arctic with atmospheric forcing from ERA-Interim. While the first two methods do not account for the ocean heat flux, this term is simulated by FESOM.

The three methods are intercompared for the main Arctic polynya areas with a focus on the Laptev Sea and North Water polynyas. The main difference between CCLM and the much coarser reanalyses is the missing or insufficient representation of polynyas and their interaction with the atmospheric boundary layer. The analysis of surface energy balance components shows the sensible heat flux as the largest contributor to ice production. Therefore differences in the parameterizations of this flux in the different methods can be accounted partly for the differences in ice production. However, the differences in polynya area are most important. Overall, FESOM simulates a smaller ice production than CCLM. For the Fram Strait area this can be explained by a relatively high ocean heat flux. In general, larger polynya areas are found by the MODIS retrievals due to the high resolution and therefore an increased ability to resolve narrow bands of open water and thin ice. On average, about 10% of the ice production in the Arctic results from polynyas.