Large Eddy Simulations of the Arctic atmosphere around the MOSAiC drift track

Daniela Littmann, Wolfgang Dorn, Hélène Bresson, Marion Maturilli, and Markus Rex

Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Potsdam, Germany

Motivation

To study small-scale processes in the Arctic boundary layer, a model with high resolution is a helpful tool. Here we apply the large eddy model configuration of the icosahedral non-hydrostatic model, ICON-LEM [1], for the first time over a domain in the central Arctic, set up around the MOSAiC drift track with horizontal resolutions between 50 m and 800 m. ICON-LEM uses a comparably simple scheme to describe thermodynamic processes over sea ice, originally developed for numerical weather predictions in mid-latitudes [2]. The performance of this scheme in the central Arctic is still unclear, but might play a key role for a realistic simulation of surface fluxes and the exchange between the surface and higher layers.

Model description

Figure 1: Triangle grid of the ICON model [3].

With the extension to Large Eddy Simulations (LES), the icosahedral non-hydrostatic model (ICON) gets the ability to resolve small-scale processes, which normally need to be parameterized in climate simulations and numerical weather forecasts [1]. ICON-LEM is driven at its lateral boundaries by analysis data of the German Weather Service (DWD), interpolated to the chosen ICON-LEM domain using the Limited Area Model of ICON (ICON-LAM) as intermediate downscaling tool.

Model domain and sensitivity experiments

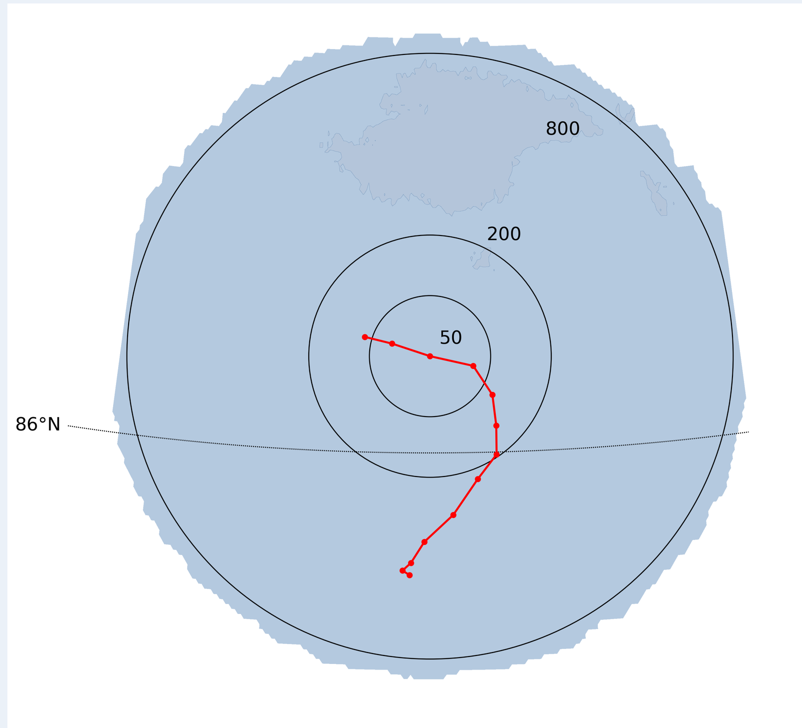

Figure 2: Nested model domains for different model resolutions and the MOSAiC drift track during a storm event from 16 to 19 November 2019 (red line).

The model domains are set up with radii of 10 km, 35 km, and 100 km around the MOSAiC drift track and grid spacings of 50 m, 200 m, and 800 m. Sensitivity experiments were carried out as to different values of sea-ice thickness ($h_{ice} = 0.5$ m, $h_{ice} = 1.0$ m, $h_{ice} = 2.0$ m) with sea-ice fraction $fr_{seaice} = 1.0$ and as to different values of sea-ice fraction ($fr_{seaice} = 0.8$, $fr_{seaice} = 0.9$, $fr_{seaice} = 1.0$) with sea-ice thickness $h_{ice} = 1.0$ m.

The Arctic boundary layer in ICON-LEM

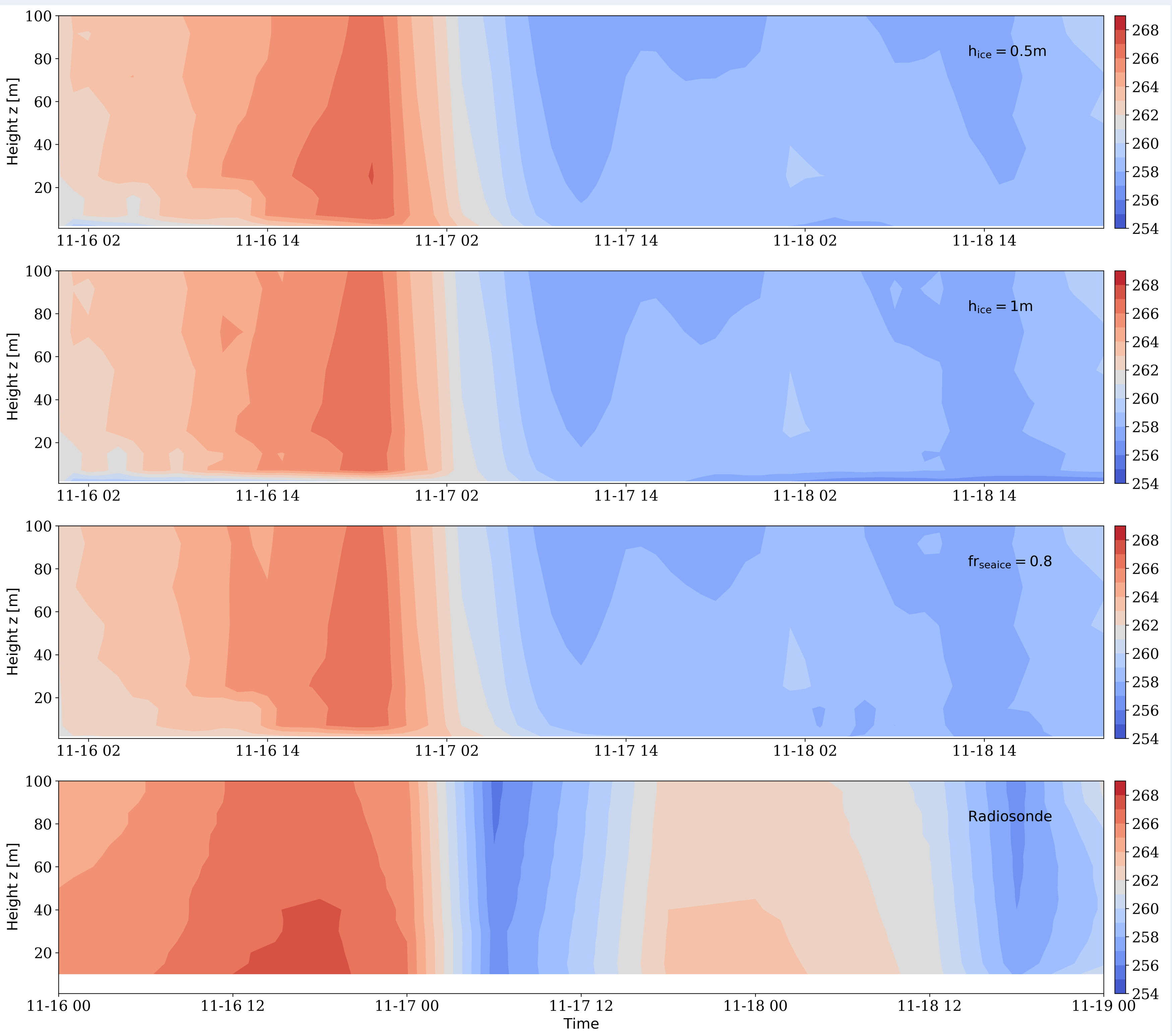

Figure 3: Temporal evolution of the temperature in the lowermost 100 meters during the storm event from 16 to 19 November 2019 from ICON-LEM simulations with different sea-ice conditions (upper three panels) and radiosonde data from the MOSAiC expedition (lower panel).

The radiosondes from the MOSAiC expedition were launched on the ship deck of the Polarstern. The measurements of temperature in the lowermost atmosphere got effected by the ship's own presence. Still the comparison of the preliminary radiosonde data to the model's ability to resolve different weather conditions is sufficient. A first analysis indicates that

- the observed storm event at the first day is reproduced with reasonable timing, but the cold air advection after the storm passage is weaker (this holds true independent from the resolution and the surface conditions),
- the observed second storm on the following day is not reproduced, but only slightly indicated in all simulations,
- higher resolution in ICON-LEM does not lead to a better agreement with the observations.

Different sea-ice conditions does not significantly affect the simulation above the surface layer, but only the surface layer itself, indicating a model deficiency in terms of the vertical exchange.

Within the surface layer, thinner sea ice and lower sea-ice fraction lead to higher temperatures compared to thicker sea ice and higher sea-ice fraction as one would expect.

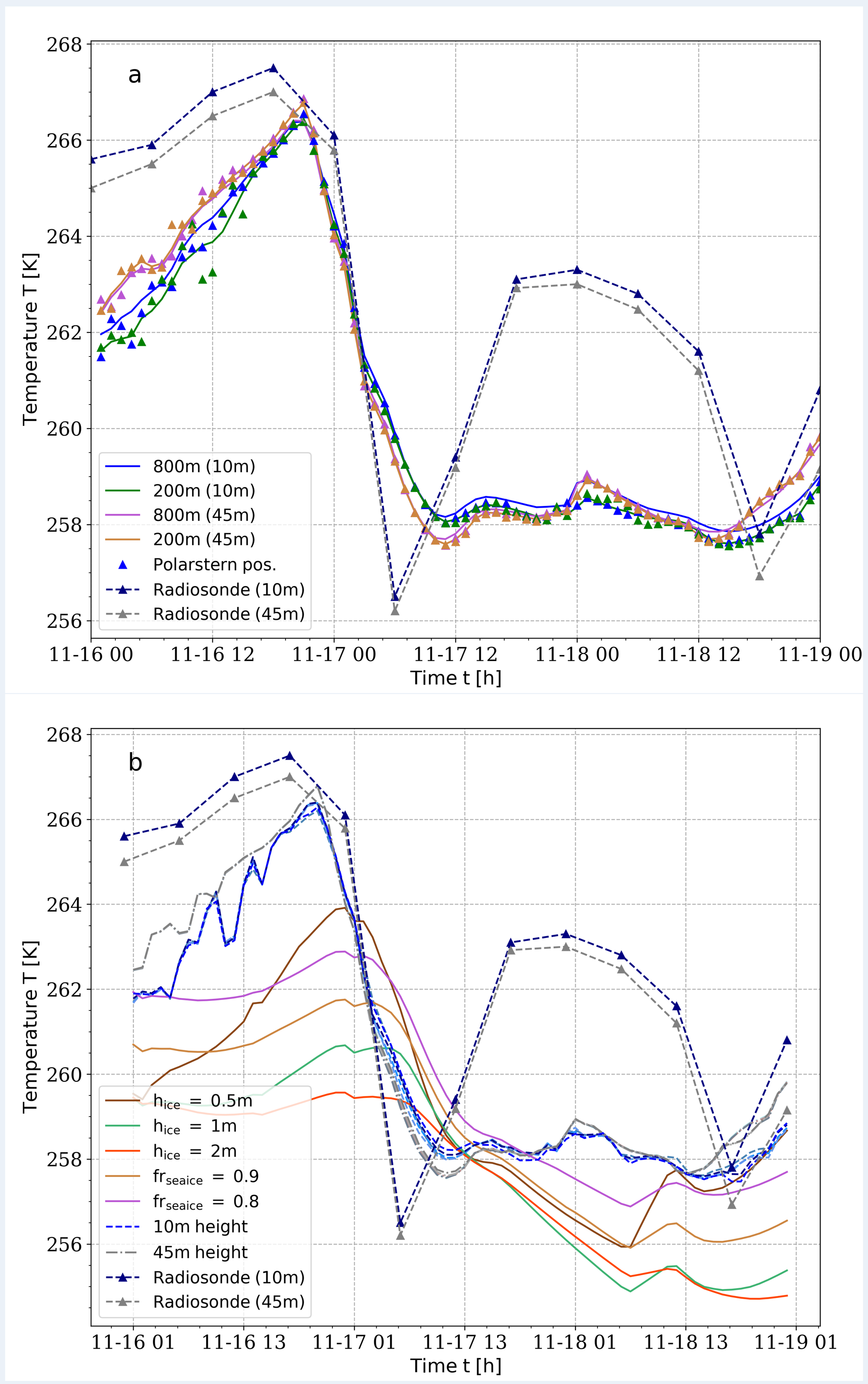

Figure 4: Temporal evolution of the temperature at 10 m height and at 45 m height, during the storm event from 16 to 19 November 2019 from ICON-LEM simulations with different resolutions (top) and sea-ice conditions at the surface (bottom), each in comparison to preliminary radiosonde data (dashed blue for 10 m height and dashed grey for 45 m height in both figures) from the MOSAiC expedition.

Outlook

- Investigation of the reasons for the unrealistically low vertical exchange between the surface layer and upper layers (e.g. by targeted modification of the exchange coefficients or transfer functions).
- Comparison of the simulation results to near surface observational data from the MOSAiC expedition.
- Further experiments with respect to snow cover and spatially differing patterns of sea-ice fraction and thickness.
- Evaluation of surface variables, particularly sensible and latent heat fluxes, against measurements from MOSAiC.
- Evaluation of the surface energy budget.
- Further investigation of particular storm/weather events that occurred or will occur during the MOSAiC expedition.

References

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[3] G. Zängl, D. Reinert, F. Prill, M. Giorgetta, L. Kornblueh, and L. Linardakis (2014): ICON User's Guide, *Deutscher Wetterdienst (DWD)*.

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Daniela.Littmann@awi.de