Implementation of a tile-approach for the energy balance over fractional sea ice in COSMO-CLM

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1. Introduction

We extended the latest version of COSMO-CCLM (5.0_clm1) with the sea-ice module of Schröder et al. (2011) and implemented a tile-approach for the radiation and turbulent heat fluxes over fractional sea ice. This module was already succesfully applied in previous studies (Ebner et al., 2011; Bauer et al., 2012).
To analyse the effects of a tile-approach we performed a case study in the Laptev Sea (Fig. 1). We compare the surface temperature, the energy balance and vertical cross-sections from a reference run without a tile-approach and a sensitivity run with the tile-approach activated and assume that the subgrid-scale ocean fraction is covered with 2 cm thin ice.

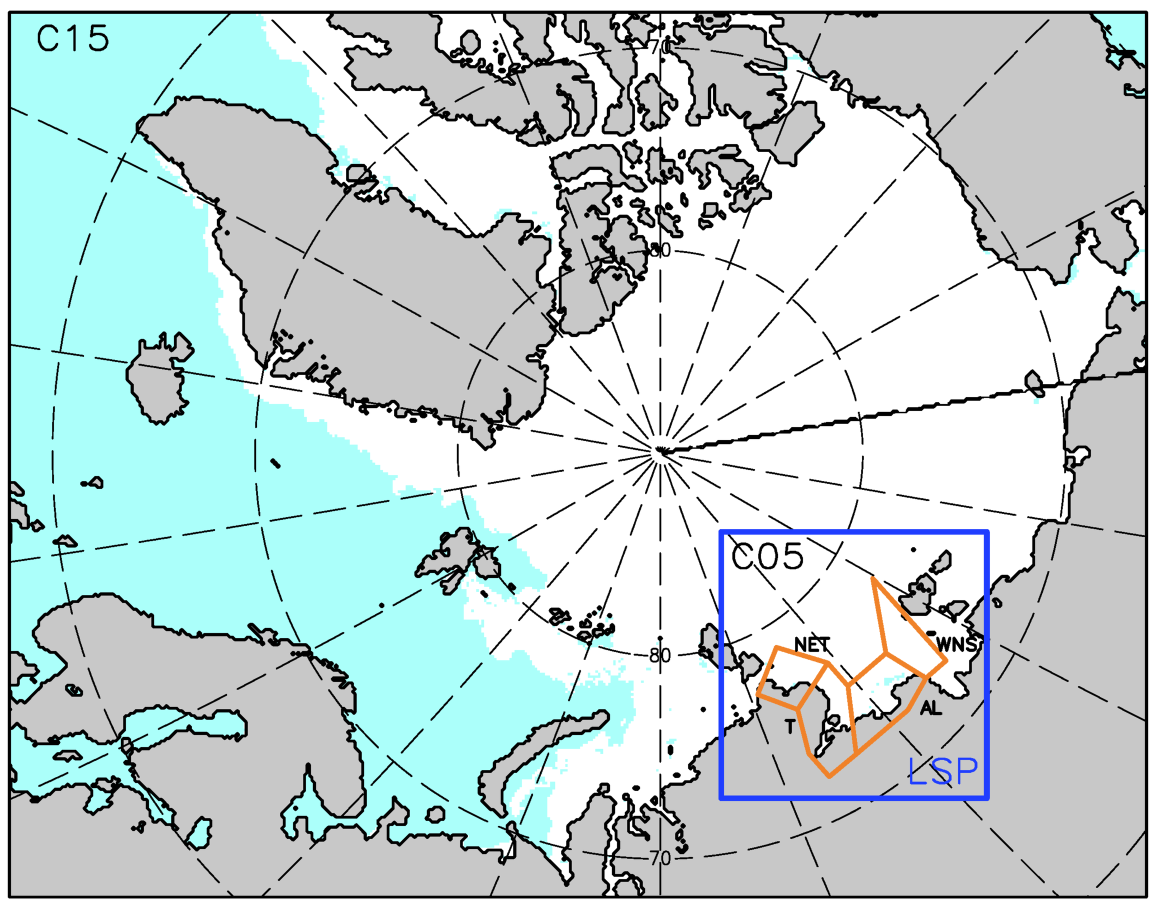

Figure 1: COSMO-CLM model domain for the whole Arctic (C15, 15 km resolution) and the study area of the Laptev Sea (C05, 5 km). The sea-ice extent on 05.01.2008 is shown in white. The orange polygons show four polynya masks from Willmes et al. (2011): north-eastern Taimyr polynya (NET), the Taimyr polynya (T), the Anabar-Lena polynya (AL) and the western New Siberian polynya (WNS).

2. Model and data

- COSMO-CLM_5.0_clm1 forced by ERA-Interim
- simulation period: 05.01.2008
- Runge-Kutta 3rd order, 450×350 (C15), 260×260 (C05), 42 vertical levels, dt=120 s (C15), 60 s (C05)
- surface layer parameterization of Mellor & Yamada (1974), with stability dependent vertical fluxes (Louis, 1979)
- prescription of AMSR-E sea-ice concentration (daily)
- daily sea-ice thickness from PIOMAS data set (Zhang & Rothrock, 2003)
- 10 cm thin ice assumed if ice concentration ≤ 70 %
- 2 cm thin ice assumed for subgrid-scale ocean fraction
- Køltzow sea-ice albedo scheme (Køltzow, 2007)

New modifications:

- NEW: tile-approach for radiation and turbulent heat fluxes over fractional sea ice
- NEW: namelist switch **ltile** (T/F), with options **itype_tile**:
  - **0**: ocean fraction not covered with thin ice, constant TS_OCEAN $= -1.7\,°C$
  - **1**: allow a maximum of 10 % open water per grid box
  - **2**: subgrid-scale ocean fraction covered with thin ice (tit_ocean=2 cm), TS_OCEAN =prognostic

  and **tit_ocean** (subgrid-scale thin ice)
- NEW: variables:
  - Subgrid-scale ocean/ice temperature (TS_OCEAN)
  - Polynya mask (POLYNYA_MASK)
  - ice growth (DH_ICE)

Remote sensing data:

- AMSR-E ice concentration (Spreen et al. 2008) (Δx =6.25 km interpolated to 5 km)

Two-layer thermodynamic sea-ice module

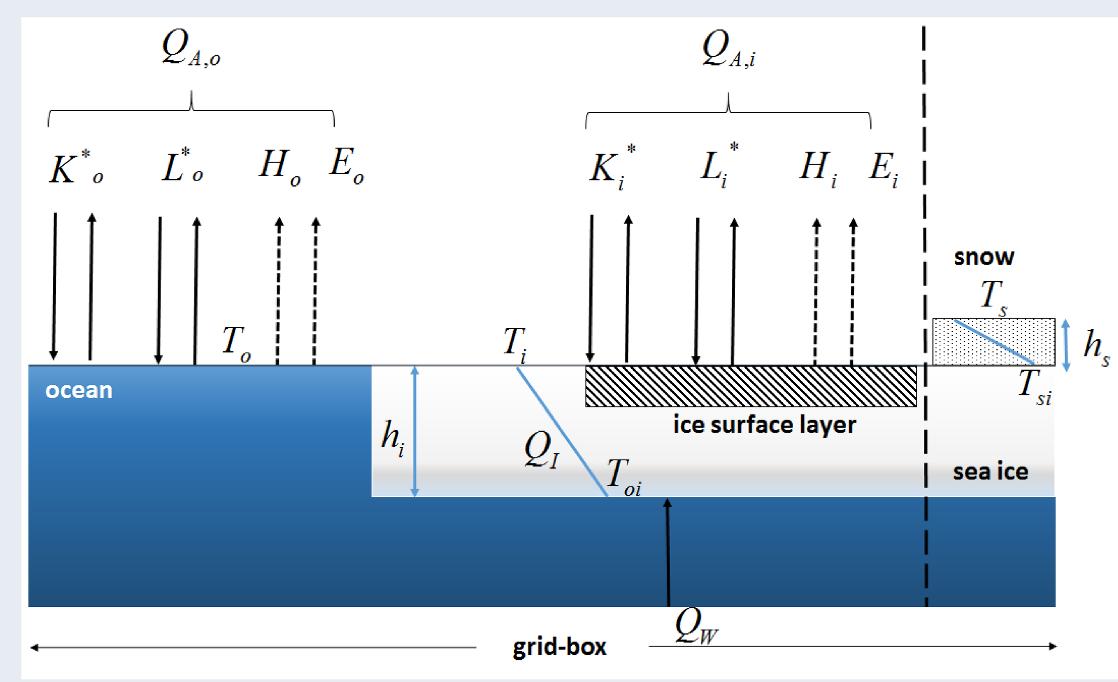

Figure 2: Scheme of the two-layer sea-ice module of Schröder et al. (2011) based on Mironov et al. (2012) and extended with a tile-approach for the radiation and turbulent heat fluxes.

3. Case study: 05.01.2008 Laptev Sea

- Fig. 3 shows open polynyas ($\leq 70\%$) along the fast ice edge in the Laptev Sea (05.01.2008). The mean sea-ice concentration in the polynya is about 30 %.
- These polynyas opened up due to strong offshore winds (up to 20 m/s) directed from southeast to northwest.

Surface temperature:

- Fig. 4 shows a comparison of the surface temperature (instant fields at 15 UTC) and the 10 m wind field.
- Without a tile-approach a polynya signal is already visible (-24-20 °C), which is about 5-10 °C warmer than the vicinity.
- With a tile-approach, the polynya is about 10 °C warmer than in the reference run, caused by the relative warm temperature of the 2 cm thin ice. Furthermore, warm air is advected downstream over long distances.

Energy balance:

- Fig. 5 shows the energy balance at 15 UTC. In both simulations is the energy balance strongly negative ($< -200\,\mathrm{Wm}^2$) over the polynya.
- With a tile-approach, relative warm air is advected downstream (Fig. 6) which causes the turbulent flux of sensible heat (H) to switch sign and contributes to a positive energy balance (red and orange coloured areas in Fig. 5).
- Convection develops over the polynya (Fig. 6) and low level clouds forms where cold air from offshore hits this relative warm and moist air (see green contours). The warm air advection downstream causes a thermal internal boundary layer to develop
- Long bands of low level clouds form downstream the polynya to distances of about 600 km (Fig. 5)

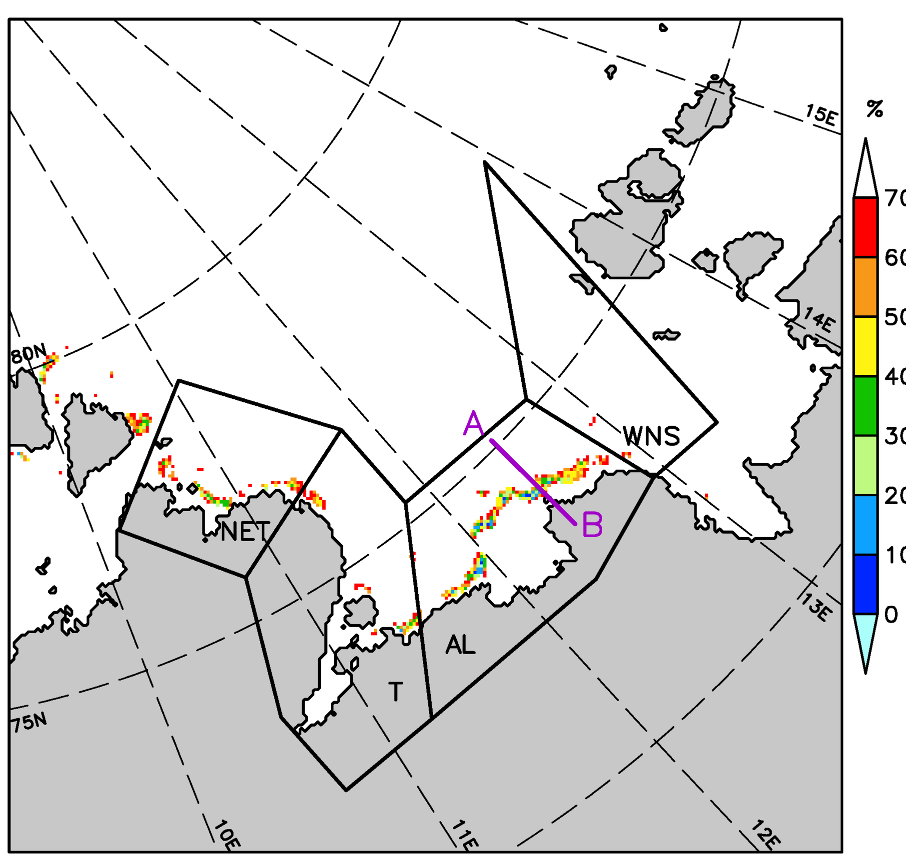

Figure 3: Sea-ice concentration on 05.01.2008 interpolated from AMSR-E data onto the CCLM grid (5 km). Superimposed are four polynya masks (black polygons, see Fig 1) and the path of the cross-section A → B (purple line). The distance of the cross-section is 214 km.

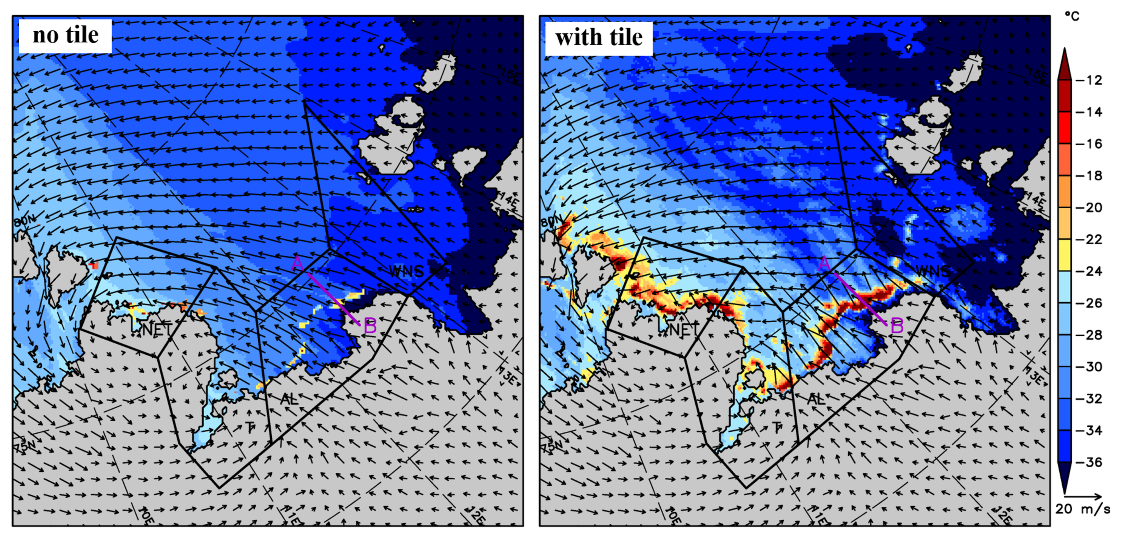

Figure 4: Comparison of the surface temperature on 05.01.2008 15 UTC of a simulation without (left) and with a tile-approach (right) in the Laptev Sea. The arrows indicate the 10 m wind field (vector every 8 grid boxes). Superimposed are four polynya masks (black polygons, see Fig 1) and the path of the cross-section A → B (purple line).

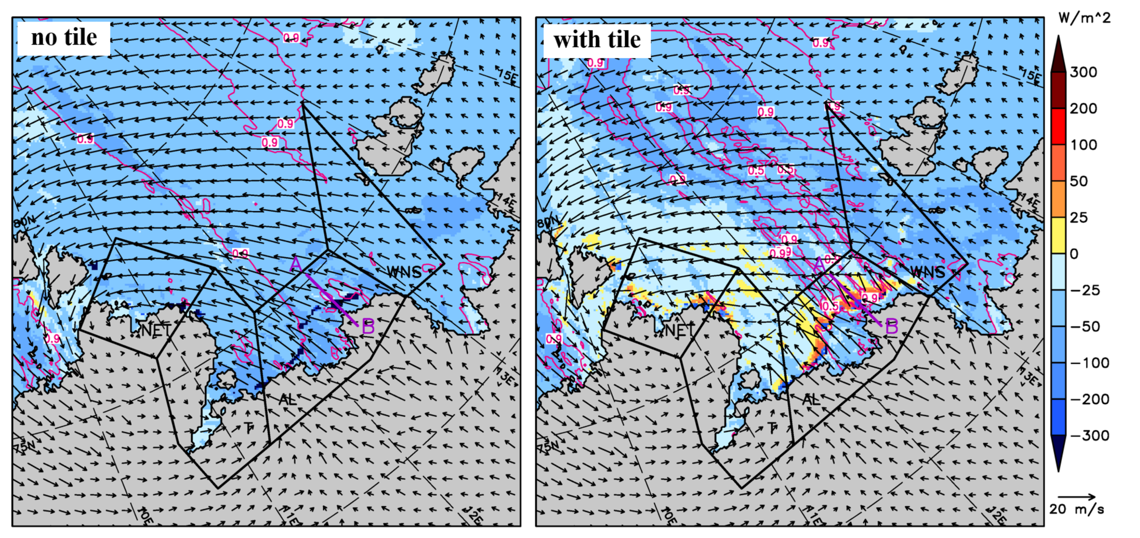

Figure 5: As in Fig. 4 but for the total atmospheric energy flux density: $Q_A = K^* + L^* + H + E$. The purple contour lines show the low cloud coverage [0,1], first contour line is 0.5.

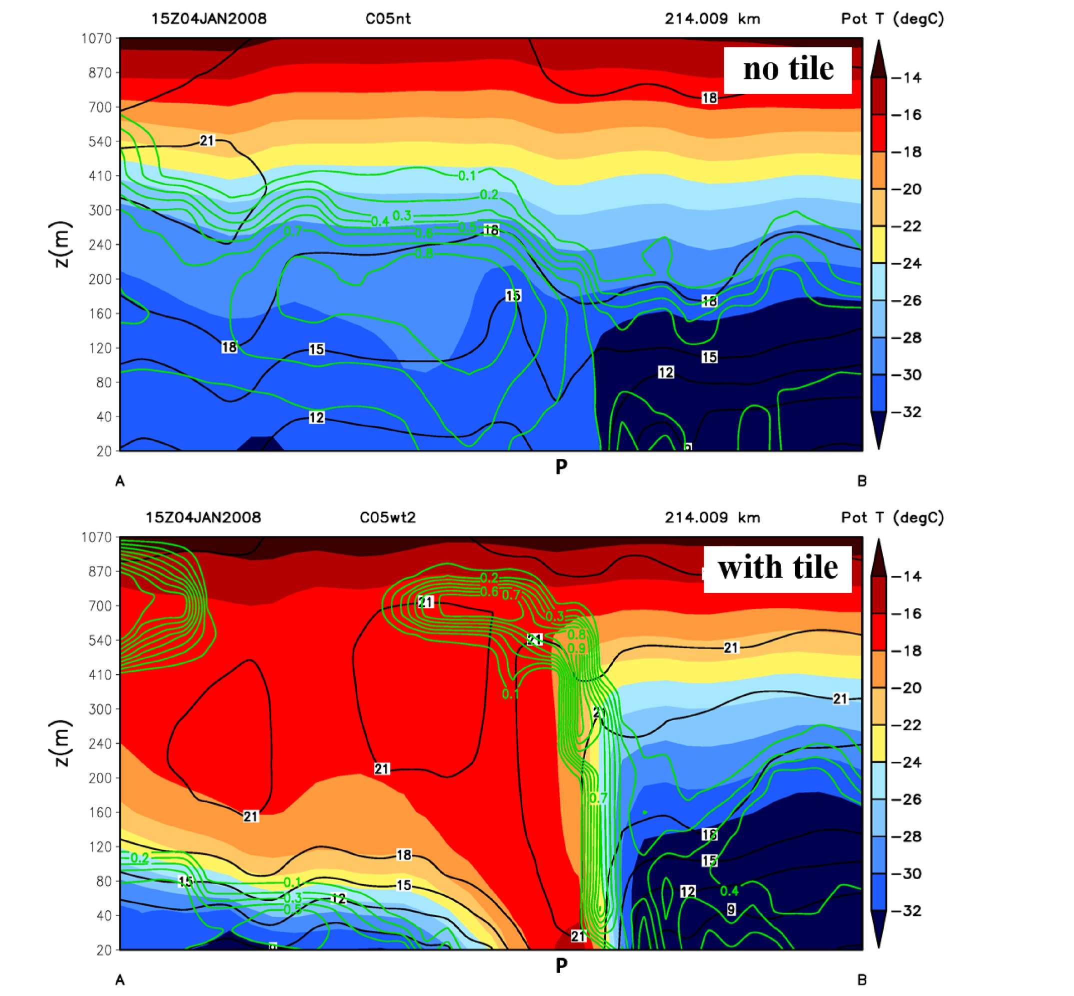

Figure 6: Vertical cross-section of the potential temperature (shaded), the wind speed (black contour lines) and the cloud area fraction (green contour lines) up to 1 km height. P marks the position of the Anabar-Lena polynya. See Fig3 for the path of the cross-section.

4. Conclusions

Achieved:

- Implementation of a tile-approach over fractional sea ice for the radiation and turbulent heat fluxes with several options (new namelists and variables)

Effects

- Tile-approach causes distinctly warmer surface temperatures over fractional sea ice ($\approx +10°\mathrm{C}$)
  - Development of strong thermal boundary layer
  - Convection sets in over relative warm polynyas
  - Low level clouds form
  - Warm air advection downstream

Outlook:

- extend simulation period to one winter 2007–2008 (Nov.–Apr.)
- extend tile-approach for momentum flux
- analyse the effect of a tile-approach on the growth of new sea ice

Acknowledgements

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CLM community

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