A Case Study of a Polar Cold Air Outbreak Using the Lokal-Modell of DWD

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Introduction

During polar cold air outbreaks, very cold air flows over the pack ice, across the sea ice edge, and finally over the open ocean. Over the pack ice, the flow is characterized by a shallow boundary layer capped by a strong inversion. Over the open ocean, a strong convective boundary layer is formed and an organized convection is developed in the form of cloud streets for several hundreds of kms from the sea ice edge (fig.1).

A satisfactory simulation of such a weather situation requires, among others, an adequate parameterization of processes in the ABL and appropriate sea surface temperatures. For a case study, the quality of an LM simulation and its sensitivity with respect to different ABL treatments are discussed. The results are compared with aircraft observation data from the ARTIST campaign (Hartmann *et al.*, 1999).

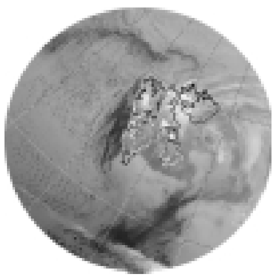

fig. 1: Satellite picture from 4th April 1998 for the situation of a polar cold air outbreak in the Svalbard region.

Model Simulation

Model: Lokal-Modell (LM) of DWD; version 2.18 (Doms and Schättler, 1999)

Horizontal mesh size: 0.0625^o x 0.0625^o (approx. 7 x 7 km)

Number of grids points in the horizontal: 161 x 233

Number of vertical levels: 35

Initial state, surface temperature and time dependent boundary conditions are taken from EM analyses and forecasts.

Simulation period: 04 April 1998 00UTC + 48 hours.

3 EXPERIMENTS based on different ABL parameterizations.

Expt 1: TKE closure(level 2.5) of Mellor and Yamada,1982; in the surface layer, resistance is calculated using TKE scheme.

Expt 2: As in Expt.1 except empirical stability dependent profile functions used for transfer coefficient in surface layer (Louis, 1979).

Expt 3: As in Expt. 2 but diagnostic TKE closure (level 2.0) of Mellor and Yamada (1982).

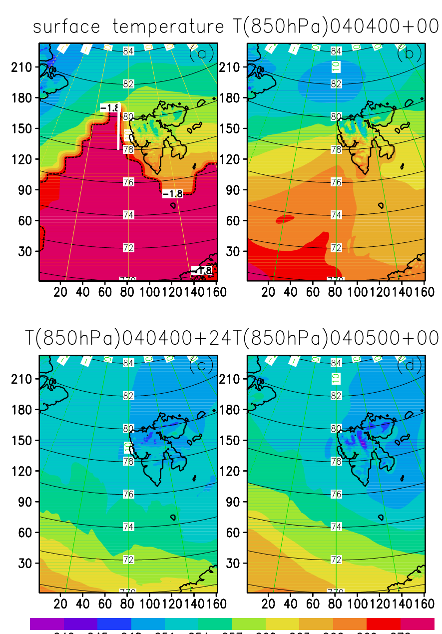

fig. 2: a) Analysis of surface temperature Ts. Ts of ocean is kept constant during simulation. b) Initial temperature distribution at 850 hPa level. c) Same as in fig. 2b but for 24 hour simulation. d) Same as in fig. 2c but data from EM analysis. Thick white line west of Svalbard indicates the ARTIST flight trajectory. Axes are labeled as model grid points.

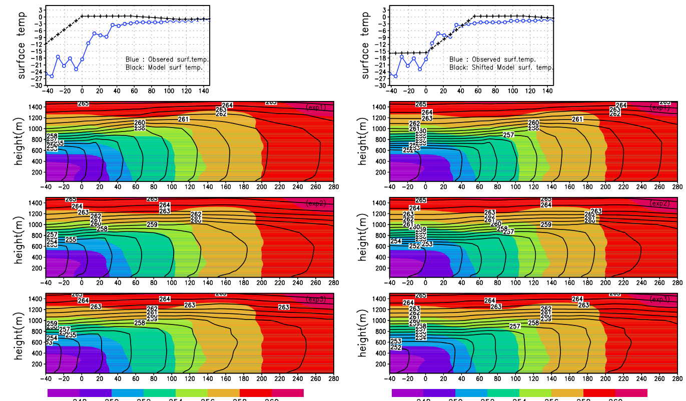

fig. 3: Left panel; Top figure shows the sea surface temperature distribution along the ARTIST flight track (marked in fig.2) on 5th April 1998, 1200 UTC taken from observation and simulation. Bottom panels depicts the vertical cross section of observed (shaded) and simulated (contours) potential temperature (K) for the three experiments. Right Panel; Same as in left panel, but for model data shifted for better coincidence of sea-ice temperature. Distances given in km with respect to the observed sea-ice edge.

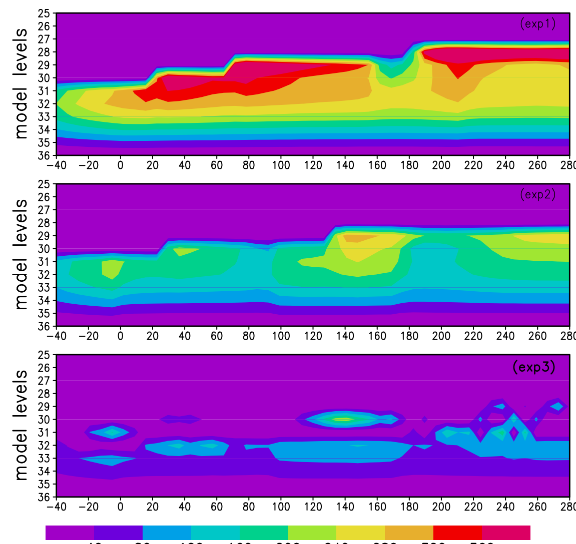

fig. 4: Vertical cross section of turbulent exchange coefficient for momentum, K_m (m^2s^{-1}), on model half levels for the three experiments.

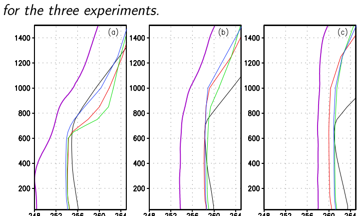

fig. 5: (a) Vertical profiles (height in meters) of model simulated potential temperature (K) at 00 hrs.(black), 12 hrs.(red), 24 hrs.(green), 36 hrs.(blue) and observations corresponding to 36 hrs.(pink) at the sea-ice edge. (b) Same as in fig. (a) but for 100 km south of sea-ice edge. (c) Same as in fig. (a) but at 200 km south of sea ice edge.

Conclusions:

- As compared to the observations, simulations show
  - warmer ABL over ice and up to about 200 km south of sea ice edge,
  - weaker southward increase in temperature,
  - weaker southward increase in boundary layer height.
- Differences are among others, due to differences in the sea ice temperature
  ⟶ correct sea ice temperature analysis required!
- The surface transfer scheme (expts. 1,2) affects the results stronger than the turbulence scheme (expts. 2, 3).
- The surface transfer scheme affects the turbulent exchange coefficients in the entire boundary layer.
- Strong impact of – preset minimum values for K_m, K_h, – convection parameterization (not shown here).

References:

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Louis,J.F., 1979: A parametric model of vertical eddy fluxes in the atmosphere. *Boundary-Layer Meteor.*, 17, 187-202.

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