Interactive comment on “Atmospheric winter conditions 2007/08 over the Arctic Ocean based on NP-35 data and regional model simulations” by M. Mielke et al.

M. Mielke et al.
Klaus.Dethloff@awi.de
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Answers to anonymous referee 2

Atmospheric winter conditions 2007/08 over the Arctic Ocean based on NP-35 data and regional model simulations by Mielke et al.

We thank the reviewer for careful reading the manuscript and useful comments.

1. Model runs
A regional climate model (RCM) generates from lower-resolution lateral boundary conditions, dynamically consistent high resolution atmospheric fields. Laprise (2008) showed in ensemble simulations with a RCM, that beside the forced component as a result of prescribed sea-surface and lateral boundary conditions, departures from the ensemble mean, the so called free component appears on spatial scales below 1100 km due to internally generated variability. In this way, RCMs are capable of generating regional and meso-scale features absent in the driving fields. This is the added value of the presented HIRHAM simulations on climate time scales. We believe therefore, that the comparison of forecast mode and climate model simulations against single station data makes sense, although the assessment of regional model quality is an unsolved issue. Laprise, R., 2008, Challenging some tenets of Regional Climate Modelling, Meteorol. Atmos. Phys., 100, 3–22, DOI 10.1007/s00703-008-0292-9

On monthly time scales the atmospheric model in climate mode forget about the initial state, but the different initial states interact with the lateral boundary conditions and induce different free components on spatial scales below 1100 km. In a large integration area during continuous integrations over the whole winter a phase state divergence with a decoupling of the lateral forcing from the interior solution can occur. This can be partly avoided by monthly reinitialisations as done in our model simulations. Another way would be to apply nudging techniques as suggested by von Storch et al. (2008). Von Storch, H., H. Langenberg, and F. Feser, 2000, A spectral nudging technique for dynamical downscaling purposes, Mon. Wea. Rev., 128, 3664-3674.

Page 11868, LN 13-18: Here we changed the text to: “The HIRHAM clima run is the only ensemble member which reproduces the two distinct circulation states shown in Fig. 10. All other ensemble members with the same initialization as HIRHAM clima are not able to reproduce the two local maxima in the frequency distribution of net LW. The HIRHAM b10 run with the same initialization as HIRHAM clima indicates a weaker second maximum.”

2. Use of monthly means/synoptic situations
We computed the atmospheric temperature profiles for the two different surface net long wave radiation conditions and describe the results in the new Figure 10 b. These profiles and further results described...
in the additional Fig. 16 indicate that the Arctic atmosphere is a complex system with nonlinear interactions and complex feedbacks between planetary and baroclinic circulation systems and temperature and cloud cover changes in the lower atmosphere and Arctic PBL.

New Fig. 10 b. Vertical temperature (K) and relative humidity (%) profiles for a) net LW circulation state below 30 Wm\(^{-2}\) and b) net LW circulation state above 30 Wm\(^{-2}\) averaged over NDJFM. The results are described in the text as follows. “The two radiative circulation states differ in their vertical structure. The net LW radiation state above 30 Wm-2, connected with higher pressure is drier and colder (ca 3 K at 900 hPa) than the state below 30 Wm-2.”

3. Explanation of model biases Our sensitivity experiments using different stability functions emphasize the importance of nonlinear interactions between the Arctic PBL, synoptical and planetary scales with the potential to induce changes in the vertical feedbacks of the PBL column with respect to surface energy budget, vertical fluxes and clouds.

We recomputed the Figs. 13-15 by including the HIRHAM f12 simulations and computed area averaged results (rectangles indicated by white lines in Figs. 13-15) in the new Fig. 16. Exemplarily we show here the newly computed Fig. 14.

This has been described in the text in the following way: “The increased vertical stability in the model simulations does not show an influence on synoptical time scales 1-3 days, but leads to reduced planetary-scale variability on time scales of 2-10 and 10-20 days in all winter months.”

New Fig. 14. Pan-Arctic distribution of baroclinic-scale variability on time scales from 2–10 days expressed as filtered temporal standard deviation of 6 hourly mean sea level pressure (hPa) for November 2007 (upper row) until March 2008 (lower row) and December, January and February in between. From left to right ECMWF operational analyses, HIRHAM f12 simulations, HIRHAM clima simulations with b = 5, and HIRHAM b10 with b = 10.

New Fig. 16. Area mean (rectangle indicated by white lines in new Figs. 13-15) of the synoptic and planetary-scale variability on time scales 1-3 days, 2-10 days and 10-20 days for December 2007 (left), January (middle) and February 2008 (right). The results are based on filtered standard deviation of 6 hourly mean sea level pressure (hPa). Red column-ECMWF, Grey column-HIRHAM f12, Green column-HIRHAM clima with b5, Blue column-HIRHAM b10.

With respect to the suggestion of the impact of surface conditions we added the following sentence on page 11864, LN 9: A reduction of sea ice thickness from 2m to 1m reduces the temperature correlation coefficient between model simulations and the NP-35 observations at 1000 hPa from 0.58 to 0.55 and at 500 hPa from 0.74 to 0.66.

On P11869, L20 we added: Turbulent mixing is determined by the surface roughness, the thermal stratification and the vertical wind shear.

4. Clarity of presentation We deliver the requested information in the text.

Relative humidity is always w.r.t. ice.

Fig. 7 is based on 12 hourly NP-35 data and 6 hourly model output.

To count inversions, we applied the definition of Kahl (1990), which we cite now in the manuscript. The inversion height is the depth of the inversion. Kahl, J. D., 1990, Characteristics of the low-level temperature inversion along the Alaskan Arctic coast, Int. J. Climatol., 10, 537-548. The wind speed in the LLJ maximum has to exceed the threshold value of 12 m/s and a minimal wind speed gradient of 8 m/s in the range from the surface to the height of LLJ.

Specific comments:

5. We changed this to: The impact of internal atmospheric dynamics on the . . .

6. We cite the paper Persson et al. (2002) in the introduction on page 11857, LN 13.
systems. Arctic clouds are very often associated with higher near-surface temperatures, but warmer air mass advection and stronger winds contribute to near-surface warming. Under very stable conditions the warm-air advection connected to cyclone passages could reduce the vertical stratification and might result in increased surface sensible heat flux. This changes the surface energy budget and the surface temperature and the outgoing long wave radiation which again impacts on the vertical stability. At the same time the wind changes due to cyclone passages could impact on the wind speeds in the boundary layer and impact on downward turbulent mixing which impact on the stratification. The relations shown in Fig. 12 reflect these conditions with respect to both wind and temperature and show a more pronounced nonlinear variation of \( Ch \) for more stable stratification.

The computation of the sensible heat fluxes is described in the Supplementary Fig. Fluxes.

The intermittent turbulence which is visible in Fig. 12 shows differences between the \( Ch \) dependence for the two net LW states. For the high pressure state this dependence is more nonlinear. The transitions from strongly stable stratified PBL to well mixed convective PBL and intermittent turbulence over the Arctic Ocean are either due to cyclone effects or ice cracks and open leads due to surface heterogeneities and couldn't described by the RCM simulations, where a constant sea ice thickness has been assumed.

21. On page 11871, L16 we changed the sentences to: Significant temperature differences between observations and the simulations occur near the surface due to biases in the ABL vertical mixing parameterization, in the treatment of surface processes, sea ice thickness and cloud cover. Additionally the partitioning between stable and near-neutral conditions in the winter ABL in the model simulations could be erroneous.

22. On page 11871, L25 we changed the sentences: HIRHAM simulates too many elevated inversions compared to the NP-35 data, which could be partly connected with the poor simulations of vertical cloud layers. The energy budget at the surface and the whole ABL structure are strongly dependent on cloud-radiation processes, but the HIRHAM cloud simulations are biased and no cloud measurements have been carried out on NP-35.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 11855, 2014.
New Fig. 10 b. Vertical temperature (K) and relative humidity (%) profiles for a) net LW circulation state below 30 Wm$^{-2}$ and b) net LW circulation state above 30 Wm$^{-2}$ averaged over NDJFM.

New Fig. 14. Pan-Arctic distribution of baroclinic-scale variability on time scales from 2–10 days expressed as filtered temporal standard deviation of 6 hourly mean sea level pressure (hPa) for November 2007 (upper row) and March 2008 (lower row) and December, January and February in between. From left to right: ECMWF operational analyses, HIRHAM f12 simulations, HIRHAM clima simulations with b = 5, and HIRHAM b10 with b = 10.
New Fig. 16. Area mean (rectangle indicated by white lines in new Figs. 13-15) of the synoptic and planetary-scale variability on time scales 1-3 days, 2-10 days and 10-20 days for December 2007 (top), January (middle) and February 2008 (bottom). The results are based on filtered standard deviation of 6 hourly mean sea level pressure (hPa). Red column-ECMWF, Grey column-HIRHAM f12, Green column-HIRHAM clima with b5, Blue column-HIRHAM b10.

The turbulent sensible heat fluxes have been calculated with the following algorithm, based on the parameterization of Zilitinkevich (1970). Sensible heat fluxes \( H \) are calculated very similar to HIRHAM as:

\[
H = - \rho c_p \kappa \left( \frac{U_*}{T_*} \right) \nabla T
\]

where \( U_* \) is the wind speed scale, \( T_* \) is the temperature scale, \( \rho \) is air density, \( c_p \) is specific heat capacity, \( \kappa \) is the Karman constant. The gradients for stable conditions are based on Monin-Obukhov similarity theory, similar to the used model parameterization.

\[
\nabla L = \frac{1}{\beta} \left( \frac{\Delta T}{\Delta U} \right)
\]

\( L \) describes the Monin-Obukhov-length, \( \beta \) is the temperature gradient, \( \Delta T \) is the temperature gradient, \( \Delta U \) is the wind speed gradient, \( z_0 \) is the roughness parameter.

Fig. 3.

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Fig. 4.

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