A first version of the ice model for the global NWP system GME of the German Weather Service

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A first version of the ice model for the global numerical weather prediction system GME (cf. Majewski et al. 2002) of the German Weather Service (DWD) is developed. The model accounts for thermodynamic processes only (detailed descriptions of several dynamic-thermodynamic ice models and further references can be found at `http://stommel.tamu.edu/~baum/ocean_models.html`). A distinguishing feature of our model is the treatment of the heat transfer through the ice. Most currently used ice models carry the heat transfer equation that is solved on a finite difference grid where the number of grid points and the grid spacing differ with the application. We use the integral, or bulk, approach. It is based on a parametric representation of the evolving temperature profile within the ice that is conceptually similar to a parametric representation of the temperature profile in the seasonal thermocline in the ocean or lakes. The essence of the concept (Kitaigorodskii and Miropolsky 1970) is that the dimensionless temperature profile in the thermocline can be fairly accurately parameterized through a "universal" function of dimensionless depth, where the temperature difference across the thermocline and its thickness are used as the relevant scaling parameters. We use this concept to parameterize the temperature profile within the ice.

The ice thickness $H(t)$ and the temperature difference $T_s(t) - T_f(t)$ across the ice are utilised as appropriate scales of depth and temperature, respectively. Here, $T_s(t)$ is the temperature at the air-ice interface, and $T_f(t)$ is the temperature at the ice-water interface that is equal to the freezing point. Then, the temperature profile $T(z,t)$ within the ice is represented as $[T(z,t) - T_f(t)] / [T_s(t) - T_f(t)] = \Phi(\zeta)$, where Φ is a dimensionless universal function of dimensionless depth $\zeta = z/H(t)$ referred to as the "shape function". Notice that the assumption about the shape of the temperature profile within the ice is either explicit or implicit in many ice models developed to date. Using the above parameterization of the temperature profile, the heat transfer equation is integrated over z from the lower side to the upper side of the ice to yield the equation of heat budget of the ice layer. The evolution equation for the ice thickness is developed by considering the heat balance at the air-ice interface and at the ice-water interface. The result is the ice model that consists of two ordinary differential equations for the two time-dependent quantities, $T_s(t)$ and $H(t)$. Upon integration of the heat transfer equation over the ice layer the exact knowledge of the shape function is no longer required. It is not $\Phi(\zeta)$ per se, but the so-called shape factor $C_I = \int_0^1 \Phi(\zeta) d\zeta$ that enters the model equations. The shape factor may either be estimated independently, using empirical data on the temperature distribution within the ice, or be considered as adjustable tuning parameter. Its major effect is to control the thermal inertia of the ice layer.

The above ice model is implemented into GME and the test runs are performed, using $C_I = 1/2$ and a constant sea water freezing point $T_f = -1.7°\text{C}$. The model is currently set up in a way that (i) the ice covers the entire GME grid box, and (ii) no ice is created in the GME grid box over the forecast period if this grid box has been set ice-free during the initialisation. As an example of the forecast sensitivity, Fig. 1 shows the surface pressure over Greenland and part of North Atlantic. Results with the new ice model show somewhat more structure in the pressure field, apparently as a result of the air-ice interaction. This

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interaction is lacking in the operational GME ice model, where the ice surface temperature is set to a climatologically mean value and is kept constant over the forecast period.

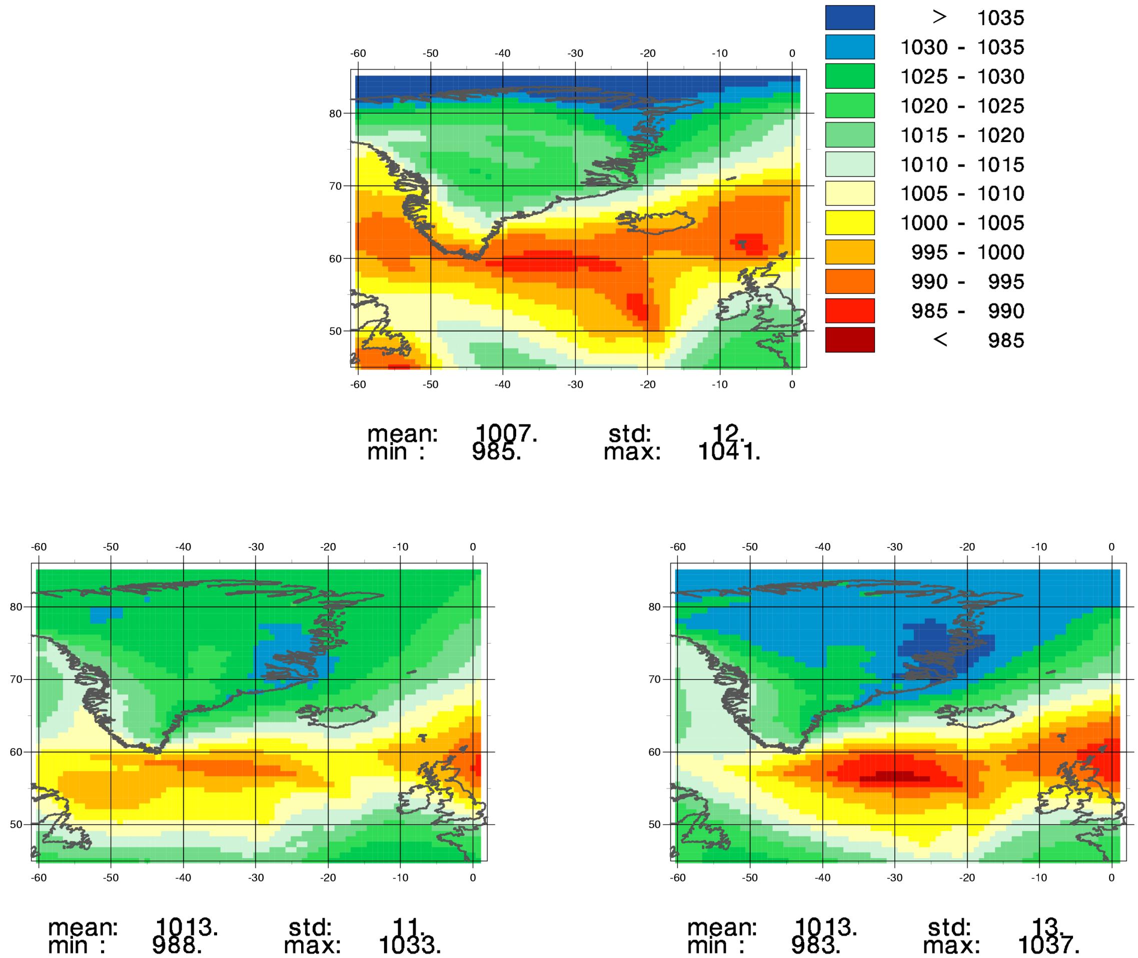

Figure 1. The 12 UTC 01.03.2003 GME analysis, upper panel, versus 168 h GME forecast of the surface pressure produced with the operational ice model, lower left panel, and the new ice model, lower right panel.

In the new model, provision is made to account for the snow layer over the ice. The snow is treated in the same way as the ice, i.e. through the use of a temperature-profile shape function and the integral heat budget of the snow layer.

Acknowledgements. The work was partially supported by the EU Commissions through the project INTAS-01-2132.

References

Kitaigorodskii, S. A., and Yu. Z. Miropolsky, 1970: On the theory of the open ocean active layer. *Izv. Akad. Nauk SSSR. Fizika Atmosfery i Okeana*, **6**, 178–188.

Majewski, D., D. Liermann, P. Prohl, B. Ritter, M. Buchhold, T. Hanisch, G. Paul, W. Wergen, and J. Baumgardner, 2002: Icosahedral-hexagonal gridpoint model GME: description and high-resolution tests. *Mon. Weather Rev.*, **130**, 319–338.