THE NEW VERSION OF THE CANADIAN OPERATIONAL GEM REGIONAL MESOSCALE MODEL

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1. OVERVIEW OF NEW MESOSCALE SYSTEM

A regional version of the Global Environmental Multiscale (GEM) model has been operational for numerical weather prediction in Canada for some time. The last operational implementation of the regional version of the GEM model took place on 15 September 1998. It combined an increase in horizontal resolution (~ 24 km) with the Fritsch-Chappell convective scheme that resulted in significant improvements to the summertime QPF (Bélair et al., 2000). The operational model is run at the Canadian Meteorological Center (CMC) twice a day for 48 hours over North America and the adjacent oceans. The initial conditions at 0000 and 1200 UTC are provided by a regional data assimilation system (RDAS), with 12-h cycles using trial fields from 6-h regional integrations and a three-dimensional variational technique.

With the availability at the beginning of 2001 of two NEC SX-5 supercomputers, work began to prepare a new version of the mesoscale modeling system. The main changes to the mesoscale modeling system include an increase in both the horizontal and vertical resolution and major improvements to the physics package. The plans are to increase the number of vertical levels to 43 levels (instead of 28) and the horizontal resolution to 15 km in the uniform domain over North America. The modified physics package includes a new surface modeling system, an improved formulation of the cloudy boundary layer, changes to the convection and explicit schemes, together with revisions to the cloud radiative optical properties. Several changes to the current RDAS are also underway (see Chouinard et al., this volume).

2. THE NEW PHYSICS PACKAGE

The improved version of the physics package that has been developed for the mesoscale forecasting system is also being tested for a new mesocale global version of GEM.

2.1 *Surface processes*

The new surface modeling system aims at an improved treatment of surface processes, using a mosaic-type approach for vegetated land with possible snow pack, for ice-free and ice-covered oceans and lakes, and for glaciers.

A modified version of the ISBA (Interactions Soil Biosphere Atmosphere) scheme is used over land with special attention to the physics of snow to improve its wintertime performance (for details, see Bélair et al., this volume). The new system uses a high-resolution dataset to generate the needed geophysical fields (vegetation types, soil properties,…). A sequential assimilation method based on model error feedback of low-level air temperature and humidity has been developed to generate the soil variables (soil temperature and soil moisture at two levels).

Over sea ice, the surface temperature is obtained from a multi-level thermodynamic sea ice model based on a modified version of the model of Semtner (1976). Its main features comprise a snow cover on top of the ice, heat conduction through snow and ice, thermal inertia of the snow and ice layers, and a parameterization of albedo, conductivity and heat capacity (following Ebert and Curry, 1993 and Flato and Brown, 1996). The effects of leads in ice are also considered.

The sea ice model has been tested in stand-alone mode using datasets representing the climatology of the Arctic and from the SHEBA field campaign to simulate the annual and diurnal cycles over sea ice. In both cases, fairly good agreement with observations was obtained using a 3-layer version of the thermodynamic sea ice model (the uppermost of which may be snow).

2.2 *The cloudy boundary layer*

An improved formulation of the cloudy boundary layer, using a unified moist turbulence approach following the strategy of Bechtold and Siebesma (1998), has been developed. This formulation is appropriate for a low-order turbulence model such as our TKE scheme and allows a general description of stratiform clouds and shallow non-precipitating cumulus convection regimes using a single parameter Q_1 representing the normalized saturation deficit. Statistical relations appropriate to the various boundary-layer cloud regimes were obtained by Bechtold and Siebesma (1998) based on observations and large-eddy simulations, that permit to define the subgrid-scale cloud fraction and cloud water content in terms of Q_1 only. Preliminary tests with this formulation on a case of Arctic boundary-layer clouds over a polynya observed during FIRE.ACE indicated much improved performance of the model.

2.3 *Condensation schemes*

An optimized version of the Kain and Fritsch (1990; KF) deep convective scheme is now being evaluated as a replacement to the Fritsch-Chappell (FC) scheme. The main improvement over the FC scheme comes from the one-dimensional entraining/detraining plume model for the updrafts and downdrafts, and from more detailed microphysics (including glaciation effects).

An explicit cloud scheme with mixed-phase (MXP) microphysics (Tremblay and Glazer, 2000) is being tested to replace the current Sundqvist scheme. The MXP cloud scheme was developed to incorporate more detailed microphysics into mesoscale models. The MXP scheme uses only one prognostic variable, the total cloud water content, making it simple enough to be used in an operational environment, yet it discriminates between the solid, warm, and supercooled liquid phases.

The explicit microphysical processes include condensation or evaporation of cloud droplets, evaporation of rain, ice nucleation, deposition or sublimation of ice particles, sedimentation, and ice melting. Sedimentation includes thresholds with values of the liquid water and ice content of 0.1 g m^{-3} and 0.01 g m^{-3}, respectively, to model the onset of precipitation. Homogeneous nucleation freezing of supercooled cloud droplets and raindrops at temperatures below - 35° C is also considered. For mixed-phase clouds in which both warm and cold microphysical processes are active, the partition between liquid and ice is based on a diagnostic equilibrium relation for the ice fraction within saturated updraft in the cloud. This equilibrium solution expresses the steady-state balance between riming, vapor deposition, production of vapor excess by adiabatic cooling, and mixed-phase sedimentation. The adiabatic cooling process depends on the vertical velocity representing an explicit forcing of microphysical processes by the model dynamics.

2.4 *Cloud optical properties*

Revisions to the cloud optical properties have been made in order to improve cloud-radiation interactions. The revised broadband solar and infrared parameters (extinction coefficient, single-scattering albedo, asymmetry factor) are based on the models of Hu and Stamnes (1993) for cloud water and Fu and Liou (1993) for ice crystals. The effective radius of hydrometeors, a crucial parameter for the cloud optical properties, now varies between 2.5-60 µm for cloud droplets, and 20-150 µm for ice particles depending on the mass and temperature. The lower values of effective radius used in the current scheme generally resulted in too much solar attenuation by clouds.

3. CURRENT STATUS

Due to the large number of modifications proposed for the new mesoscale forecast system, it was decided to proceed in two steps for its parallel testing and operational implementation at CMC. First, only the new surface modeling system together with its sequential assimilation of surface variables, without any changes to the model resolution, was put in parallel runs at CMC during the summer 2001 and was implemented in September 2001.

Verifications showed that the new surface modeling system greatly contributes to improve the representation of temperature and humidity fields, mostly at lower levels, and to improve the diurnal cycle of surface air temperature and the objective precipitation scores (cf., Bélair et al., this volume).

The rest of the changes (increased horizontal and vertical resolutions, new condensation package, and revisions to cloud optical properties) will be put subsequently in parallel runs. Preliminary tests of the impact of those changes have recently begun. Current plans are for operational implementation early in 2002.

4. REFERENCES

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