P3.15 CLOUDS AND PRECIPITATION FROM A GLOBAL NWP MODEL

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1. INTRODUCTION

In an effort to improve medium-range weather forecasting in Canada, a mesoscale version of the Global Environmental Multi-scale (GEM) model is now being developed at the Meteorological Research Branch (MRB) in collaboration with the Canadian Meteorological Center (CMC). The proposed configuration (**GEM-meso**) has twice the horizontal resolution and doubles the number of levels in the vertical compared to the present operational configuration (**GEM-op**). Major changes to the physical parameterizations are also proposed; namely to the vertical diffusion in the boundary layer as well as to the shallow and deep convective parameterizations.

Before operational implementations, any new model undergoes an extensive objective and subjective evaluation. The objective evaluation generally consists of rms and bias statistics of the wind, geopotential height, temperature and dew point depression as compared to the global synoptic network of radiosondes. Precipitation over North America is evaluated by comparing the model accumulations to the observed accumulations from the synoptic surface stations as well as from the SHEF (Standard Hydrologic Exchange Format) surface network. These evaluations have revealed significant improvements of most verified variables over most regions of the globe, in particular over Asia and the Tropics. However, given the scarcity of these types of observations over vast regions of the globe (e.g. oceans and the southern hemisphere), efforts have been made to make use of existing data sets which offer a more uniform and global coverage.

Two series of 132 hour simulations were conducted spanning the winter season of 2001-2002 and the summer season of 2002. These simulations were analyzed with special emphasis on determining the physical realism of the global-scale distribution and variability of precipitation, humidity, cloud cover, cloud water content as well as on top of atmosphere and surface radiative fluxes. This is accomplished by comparing the model output to observations provided by GPCP (Global Precipitation Climatology Project), ARM (Advanced Radiation Measurement Program), CERES (Cloud's and the Earth's Radiant Energy System), the CAVE (Ceres ARM Validation Experiment) surface network and SSM/I and TRMM satellites.

In this conference paper, the dynamical and physical configurations of the proposed model are first briefly described. Preliminary results of the study described above are then given.

2. DYNAMICAL CONFIGURATION

The GEM model (Côté et al. 1998 a, b) has been in operational use for short, medium, and long-range weather forecast at CMC since 1998 (1997 for short range). The attributes of the uniform resolution **GEM-op** model as well as those of the proposed numerical (or dynamical) configuration are listed in Table 1. The main differences are related to the horizontal and vertical resolutions. The uniform horizontal grid spacing is decreased from 0.9^o to 0.45^o, whereas the number of levels goes from 28 to 58. Most new levels were added in the lowest two km and near the tropopause level. The timestep is decreased from 45 to 15 min In both configurations, the model top is at 10 hPa.

TABLE 1

	Current	***Proposed***
Model	**GEM-meso**	**GEM-op**
Horizontal resolution	0.9^o	0.45^o
No. of vertical levels	28	58
Timestep	45	15

Other aspects with limited impacts on the meteorological response of the model were also modified. For instance, the numerical "computational" poles are now collocated with the geographical poles instead of being located in the Pacific and Atlantic oceans (i.e., the integration grid was rotated).

3. PHYSICS PACKAGE

Practically every aspect of the condensation and convection package is being revisited for this new version of the global forecasting system. Our aim is to include condensation and convective parameterizations which are more appropriate for mesoscale resolution. The configuration of this new physics package is very similar to what is proposed for the short-range regional forecast version of GEM (resolution of 15 km over North America). This new physics package allows the representation of four distinct types of clouds; deep

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convective precipitating clouds (subgrid), shallow convective non-precipitating clouds (subgrid), boundary layer non-precipitating cumulus and strato-cumulus clouds (subgrid) as well as stratiform precipitating clouds (subgrid or grid scale). Bélair et al (2004) have investigated the impact of the improved representation of boundary layer and shallow convective clouds resultant from this new physics package. They have found an improved realism of the cloud distribution associated with a mid-latitude large scale weather system over the Pacific Ocean.

The parameterizations that differ from the current operational configuration are briefly described below.

3.1 Boundary-layer cloud scheme

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. In this formulation (Mailhot and Bélair, 2002), the vertical diffusion associated with boundary layer turbulence is done on the conservative variables. This formulation 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. These relations permit to define the subgrid-scale cloud fraction, the flux enhancement and the cloud water content in terms of Q_1 only.

3.2 Kuo Transient shallow convective scheme

The Kuo transient shallow convection scheme is a modified version of the Kuo scheme for deep convection. This scheme, specifically made to represent shallow and intermediate cumulus activity, was developed and tested by C. Girard and his colleagues (see Bélair et al. 2004, Mailhot et al. 1998). The shallow cloud model is driven at its base by turbulent boundary layer fluxes, i.e. the humidity "accession" is given by the tendencies from the vertical diffusion scheme.

3.3 Deep convection

The Kain and Fritsch (KF, 1990) scheme is proposed for the implicit condensation related to convective activity. In this scheme, the intensity of parameterized deep convection is proportional to the convective available activity (CAPE). Based on Fritsch and Chappell (FC, 1980), deep convection is triggered only if low-level upward motion is sufficient to overcome the convective inhibition, i.e., the negative energy between the lifting condensation level and the level of free convection on a log p - skew T diagram. The main improvement over the FC scheme comes from the one-dimensional entraining/detraining plume model for the updrafts and downdrafts introduced in KF (1990), and from more detailed microphysics.

4. PRELIMINARY RESULTS

4.1 Precipitation

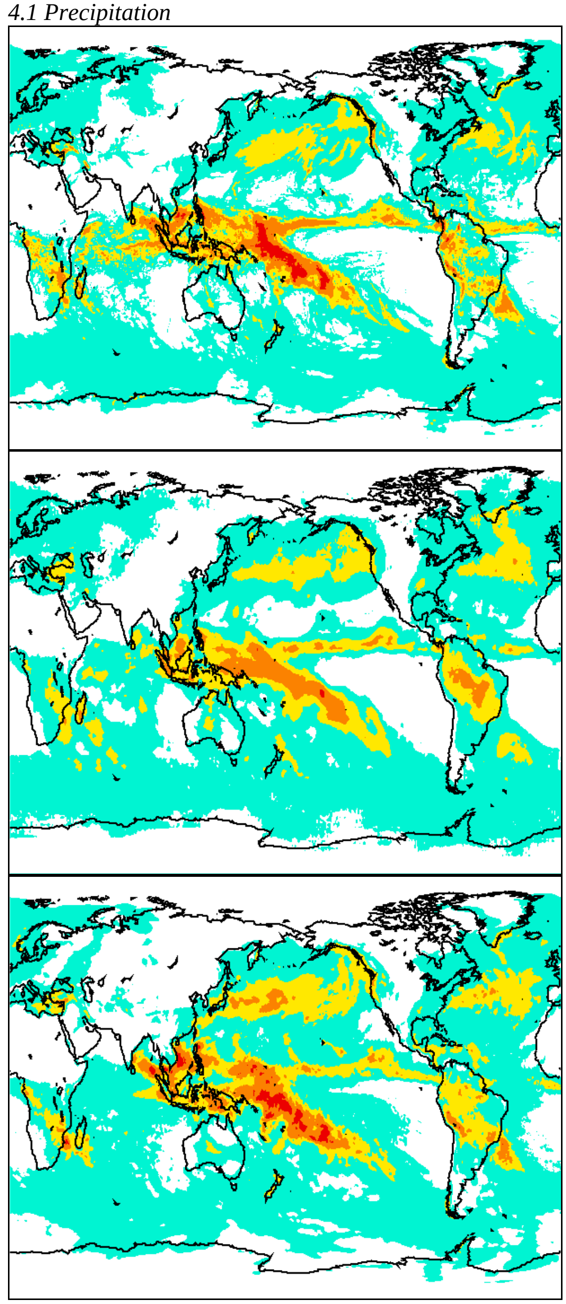

Figure 1: Monthly precipitation for December 2001. Top panel: GEM-meso, middle panel: GPCP, bottom panel: GEM-op. Contours from 0-1, 1-5, 5-10, 10-20, 20-50 mm/day.

The Global Precipitation Climatology Project (GPCP) combines data from polar orbiting and geostationary satellites as well as from rain gauge data to produce global lat-lon maps of precipitation estimates (Hufmann et al. 2001). Several products of different resolutions are available: monthly averages at 2.5 by

2.5°, daily averages at 1 by 1° and 3 hour averages at 0.25° resolution. For this study, we have mostly made use of the 1 by 1° product. Côté et al. (2003) showed 40 month long time series of monthly average precipitation over various geographical domains. The output of the **GEM-op** model was compared to the GPCP data. This study showed that the **GEM-op** model has a clear tendency to over-estimate the precipitation accumulation, in particular over the oceans. The first objective of the current study is to verify whether this problem persists within the **GEM-meso** model. Fig. 1 shows lat-lon maps of monthly averages of precipitation for both models as well as from the GPCP data. Several improvements in the **GEM-meso** model (top panel) are apparent. The areas with very low precipitation accumulation in the subtropical high pressure regions of the eastern Pacific and eastern Atlantic compare better to what can be seen in the GPCP analysis (middle panel). Furthermore, the ITCZ over the equatorial Atlantic of the **GEM-meso** model is very similar in intensity to that of the GPCP analysis, whereas it is very weak in the **GEM-op** model.

However, several features of the **GEM-meso** model can be identified that could be improved. Namely, the areas of strong precipitation over the North Atlantic and over Brazil.

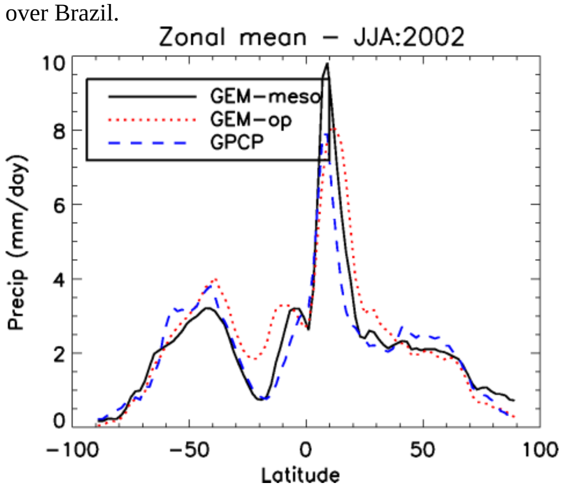

Figure 2: Zonal mean (averages over 2°) of precipitation over the period June to August 2002.

A more quantitative comparison of the precipitation fields is provided in Fig. 2. This figure shows a seasonal (June to August 2002) zonal average of precipitation. This figure confirms that the strong precipitation associated with the upward branch of the Hadley cell circulation as well as the low precipitation associated with the downward branch is much better represented in the new model. However, an over-estimation in the peak of the ITCZ can also be seen. Fig. 3 shows the time series, for the NH summer and winter seasons, of the global (top and bottom panel) average precipitation as well as the average precipitation over the West Pacific area for the NH summer season. The **GEM-meso** model shows a significant improvement in the global average of precipitation for both seasons. An examination of such time series over various geographical domains has led us to conclude that the over estimation seen in the tropical latitudes (Fig. 2) can be mostly traced to the West Pacific area as shown in the middle panel of Fig. 3.

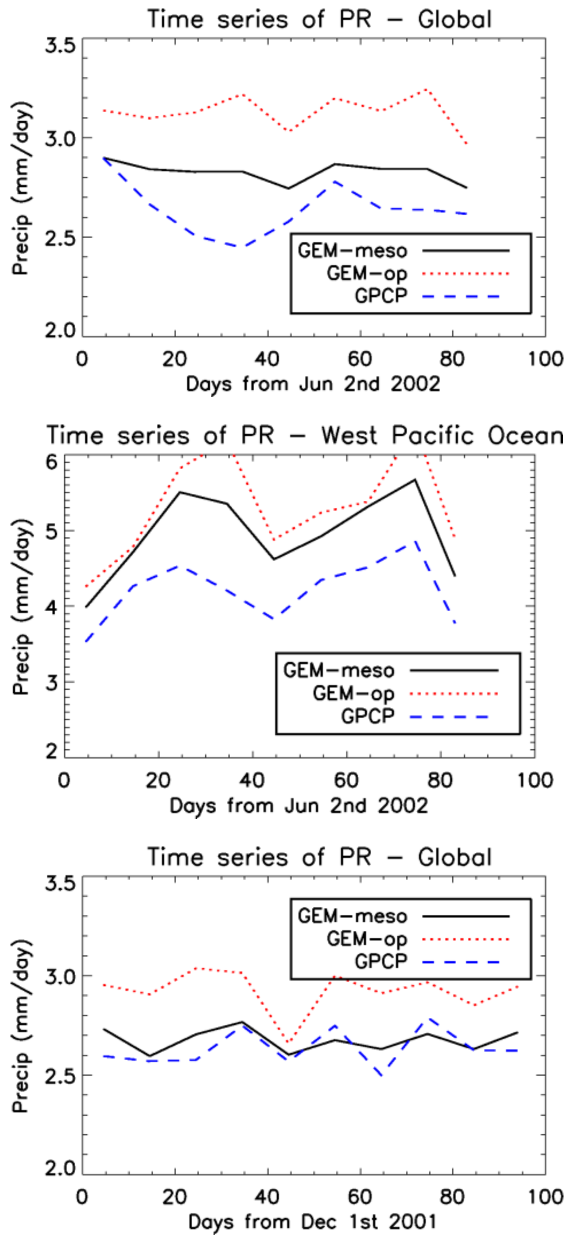

Figure 3: Time series (10 day averages) of precipitation over geographical domains. Top panel: global average for NH summer season. Middle panel: average over West Pacific ocean area (120W-200W) for NH summer season. Bottom panel: global average for NH winter season.

4.2 Precipitable water

The model precipitable water (PW-vertical integration of the specific humidity) was evaluated using data from the SSM/I instruments carried onboard a series of polar orbiting satellites. This data was processed by Remote Sensing Systems (RSS) to provide monthly global maps (only over oceans) of PW (Wentz, 1997) from each SSM/I instrument (F13, F14, F15 for 2001-2002).

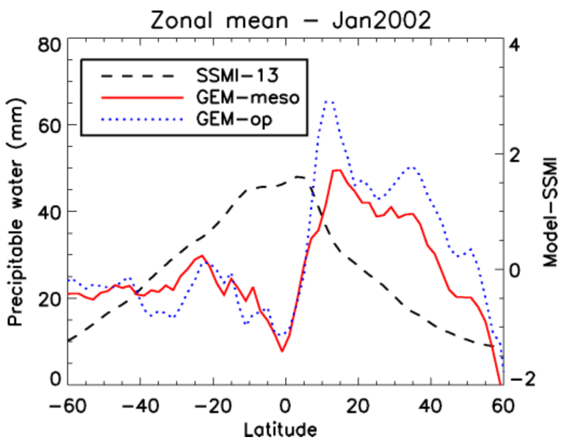

Figure 4: Zonal mean of precipitable water for January 2002.

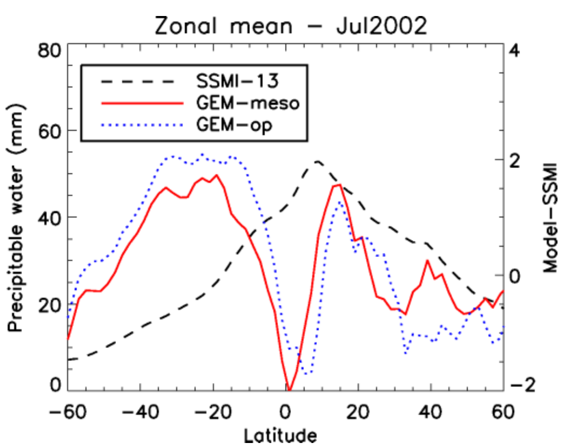

Figure 5: Zonal mean of precipitable water for July 2002.

Figs. 4 and 5 show zonal means (over oceans) of the observed PW (left y-axis) as well as the model PW, from which the observed value was subtracted (right y-axis), for the months of January 2002 and July 2002 respectively. Only the observations from the F13 satellite are shown. The three satellites available for this time period generally agree within less than 0.5 mm. It can be noted that for both models, the strongest biases are positive and are found in the winter hemisphere. Furthermore, the bias for the **GEM-meso** model is generally less that that of the **GEM-op** model.

4.3 Integrated cloud liquid water

The SSM/I instruments also allow the retrieval of the vertically integrated cloud liquid water content (IC). This data was also obtained from RSS has global (excluding land) monthly maps. Fig 6 shows the zonal mean (over oceans) of IC for the month of December 2001. It can be seen that the **GEM-meso** provides a significant improvement in this quantity over the whole globe and in particular over the tropical regions. This is also true for every month of the period under study (not shown). Fig. 7 compares both the total and liquid integrated cloud water content from both models. As can be seen, the difference between the two models cannot be explained by a difference in the liquid versus solid partition of the condensate but is rather due to a significant increase of the cloud condensate in the tropical regions of the **GEM-meso** model.

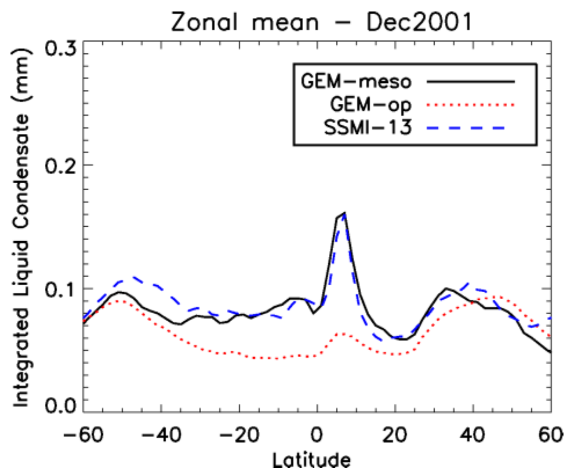

Figure 6: Zonal mean of the vertically integrated cloud liquid water content for December 2001.

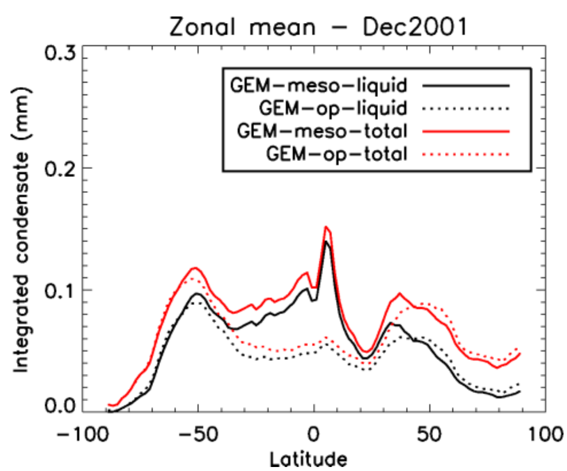

Figure 7: Zonal mean of the vertically integrated cloud liquid water content for December 2001.

5. CONCLUSIONS AND FUTUR WORK

In this paper we have focused on evaluating and comparing the large scale features of the proposed

GEM-meso model to the current operational NWP **GEM-op** model in terms of precipitation, precipitable water and integrated cloud water condensate. It was found that the proposed model provides improved precipitation fields (reduced biases and improved position of ITCZ), reduced biases of precipitable water and significantly improved integrated cloud liquid water in the tropical regions.

This is the first part of a study which also aims at evaluating the variability of the variables mentioned above as well as the biases and variability of the cloud spatial distribution, the outgoing longwave radiation at the top of the atmosphere and the longwave and shortwave radiative fluxes at the surface. Some of this future work will be presented at the conference. Furthermore, work is still needed to understand the weaknesses identified and to provide focused guidance for the efforts that will follow to correct these weaknesses.

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