THE HIGH RESOLUTION LIMITED AREA VERSION OF THE GLOBAL ENVIRONMENTAL MULTISCALE MODEL AND ITS POTENTIAL OPERATIONAL APPLICATIONS

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1. INTRODUCTION

The Canadian Meteorological Center (CMC), the Meteorological Research Branch (MRB) and the Regional Offices of the Meteorological Service of Canada are collaborating on a project to develop and evaluate the performance of a 2.5 km resolution version of the Global Environmental Multiscale Model (GEM).

The aim of this project is to develop a high resolution operational model that offers a better representation of local conditions (orography, vegetations, etc), physical processes (cloud micro-physics, radiation, etc) and dynamical organization of weather systems at all scales (from the synoptic scale to local scale) than the current operational regional model (at 15 km resolution; Mailhot et al. 2005).

This paper provides a summary of the findings to date and offers some of the strengths and weaknesses of the GEM-LAM model at 2.5 km resolution.

2. MODEL SETUP

The GEM model is a two time step implicit semi-Lagrangian grid-point model, with a latitude-longitude C-grid staggering in the horizontal and an unstaggered vertical grid. The model has the option of functioning at hydrostatic and non-hydrostatic modes. For a complete description of the hydrostatic formulation of the model refer to Côté et al. (1998), and for the non-hydrostatic version refer to Yeh et al. (2002).

The GEM model is available both in the Limited Area (GEM-LAM) version and in the Variable (GEM-VAR) resolution version (see Gravel et al. 2004). The Canadian operational regional model GEM at 15 km horizontal resolution (GEM 15) is a GEM-VAR while the 2.5 km resolution (GEM 2.5) is GEM-LAM. For a complete description of the GEM 15 see Mailhot et al., 2005.

The GEM 2.5 has the following features and parameterizations:

- Non-hydrostatic with 58 vertical sigma-pressure hybrid coordinate levels up to 10 hpa. The time step is 60 seconds. The number of grid points over a domain of interest is 560 X 494.

- The geophysical fields are generated based on global high-resolution databases, such as the 1-km resolution U.S. Geological Survey vegetation data (see Bélair et al., 2003). The topographic field generated on the domain of interest is filtered using a 2 delta-x filter.

- A surface modeling system based on a mosaic approach with four types of surfaces: vegetated land with ISBA (Interactions between Soil-Biosphere-Atmosphere) scheme, open waters, sea ice with a thermodynamic ice model and glaciers and ice sheets (see Mailhot et al., 2005).

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- The turbulent fluxes of momentum, heat and moisture are based on predictive equation for moist turbulent kinetic energy (MoisTKE) (see Mailhot et al., 2005).

- A shallow convective scheme (Kuo-Transient), to represent overshooting cumulus cloud activity (see Bélair et al., 2005).

- A fully explicit micro-physical condensation scheme (Kong and Yau, 1997), with no deep convection parameterization.

Currently two GEM 2.5 windows are run daily, on an experimental status, one over Southern British Colombia and the other over Southern Ontario/Quebec regions of Canada (see Figures 1a and 1b). The models generate a 24 hour forecast starting at 12 UTC every day. They are assessed and evaluated daily by the regional representatives and operational forecasters. Current assessments are based on subjective comparisons of the 2.5-km models against actual observations and against the regional GEM 15. Work is also underway to develop an objective evaluation strategy.

The GEM 2.5 windows are initialized using the 12 hour forecast from the 00 UTC GEM 15 run. The needed lateral boundary conditions are also provided by the GEM 15 forecast at each hour.

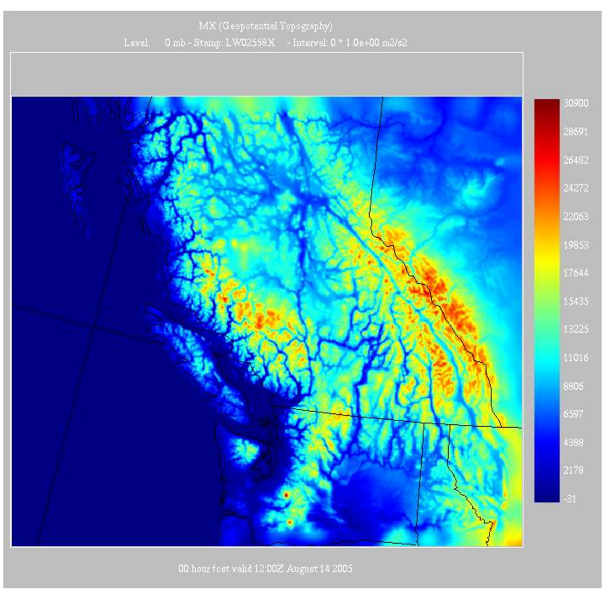

Figure 1a. Topography in the domain of southern British Colombia at 2.5 km resolution.

3. CASE STUDY

Subjective comparisons between Gem 15 and Gem 2.5 have revealed that at the synoptic scales the two models show a great deal of similarities to one another, such as the development and the

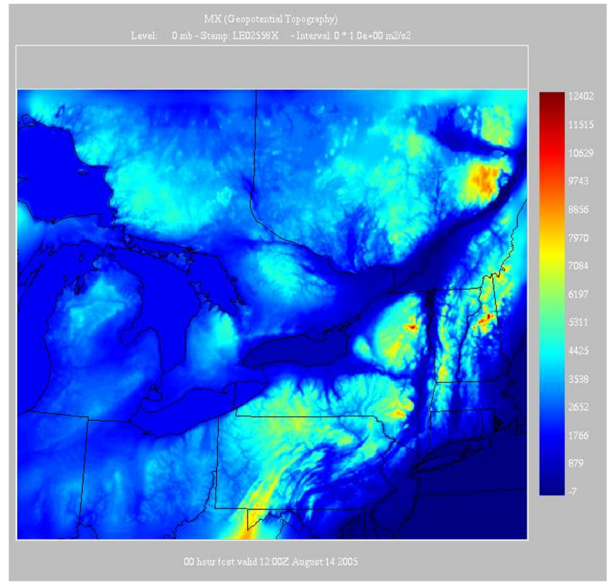

Figure 1b. Topography in the domain of southern Ontario and Quebec at 2.5 km resolution

movement of the weather systems, the general area of cloud formation and precipitation, etc. Perhaps this comes as no surprise since the regional model is the driver of the Gem 2.5. However they show significant differences at smaller scales. Comparisons have shown that the small scale features produced by the GEM 2.5 appear to be more realistic when compared to available observations. Case studies have revealed that the interaction of the larger scale weather features with the underlying lower boundary conditions (e.g. the Lakes, the topography) is in part responsible for the seen contrasts. Further the presence of a more detailed orography of the GEM 2.5 was shown to provide a better forecast of diurnal orographic circulations, such as lake breezes, katabatic and anabatic winds, etc. in the areas where the orography is better resolved. The use of the explicit micro-physical condensation scheme (and no convective parameterization) at GEM 2.5 also play a significant role especially in unstable airmasses and orographic areas.

Some of the contrasts discussed above can be demonstrated from the 02 August 2005 significant weather event that occurred over southern Ontario, Canada. It is during this event that an international airline (AF358) crashed while attempting to land at the Toronto Pearson International Airport (without any casualties fortunately) (information obtained from http://www.cbc.ca/story/canada/national/2005/08/03/plane-fire-readers-050803.html).

3.1 *02 August 2005 storm*

Southern Ontario (Figure 1b) is characterized by generally flat to gently rolling topography. The most significant topographic feature is the Niagara Escarpment which runs roughly north-south from the western end of Lake Ontario to the southern end of Georgian Bay. The eastern face of the Escarpment elevation changes of 100 to 400 m with the greatest slopes at the southern end of Georgian Bay.

On 02 August 2005 a northwesterly flow was advecting cooler air in mid-levels over southern Ontario. Figure 2a is a mesoanalysis at 15 UTC produced by the Research Support Desk (RSD) at the Ontario Storm Prediction Centre (OSPC). Surface winds are generally light and the directions appear to be determined mainly by lake breezes and topographic features; lake breeze positions are shown by dashed lines. These charts are used by the forecasters at OSPC to identify likely areas for convective initiation on days were synoptic forcing is weak and mesoscale factors are likely to predominate. On this day forecasters expected lake breezes and topographic features to serve as a focus for convection. In the image one can see that convection has already begun where the Niagara Escarpment meets Georgian Bay. It appears that it was triggered by a weak shortwave in the northwesterly flow interacting with topographically driven local circulations.

A series of convective storms developed and moved southward parallel to the eastern face of the Escarpment culminating in a severe thunderstorm which affected Toronto Pearson International Airport (YYZ) at 20 UTC (Figure 2b). At that time a wind gust from the north was measured at 61 km/h; winds speeds of up to 80 km/h were reported unofficially. Heavy rain and intense lightning were also reported; 36.2 mm of rain was recorded at Pearson and 28 mm at a nearby station. The 12 hour accumulated radar reflectivity echoes (Figure 3), obtained from the King City radar located 50 km north east of YYZ, showed maximum local precipitation centers of 52 mm. While the storm was affecting the airport, the

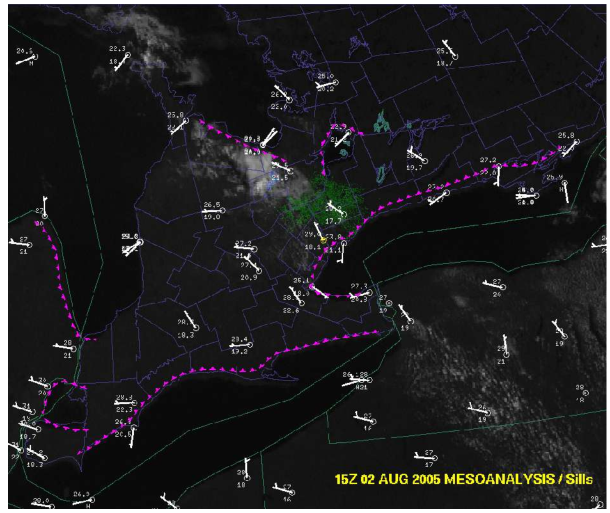

Figure 2a. Mesoscale analysis valid at 15 UTC 02 August 2005 over southern Ontario showing surface observations, orogarphically forced convergences (dashed lines), and clouds in grey (from visible channel of GOES).

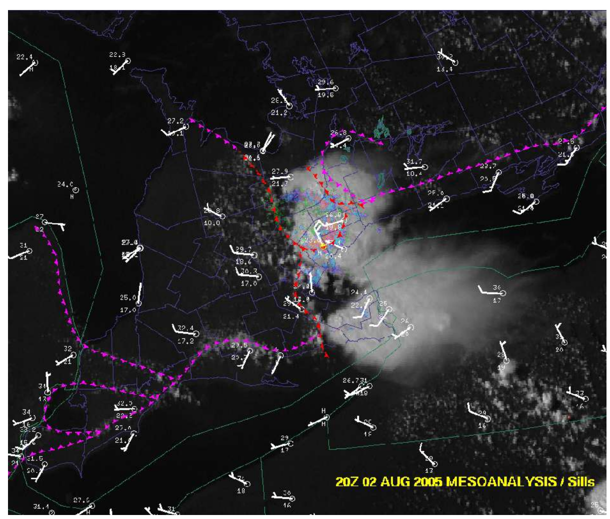

Figure 2b. same as Fig. 2a but at 20 UTC 2 August 2005.

Air France flight 358 crashed at the landing. At the time of this writing, however, there is no report clearly indicating the direct impact of the weather to the aircraft's missed landing.

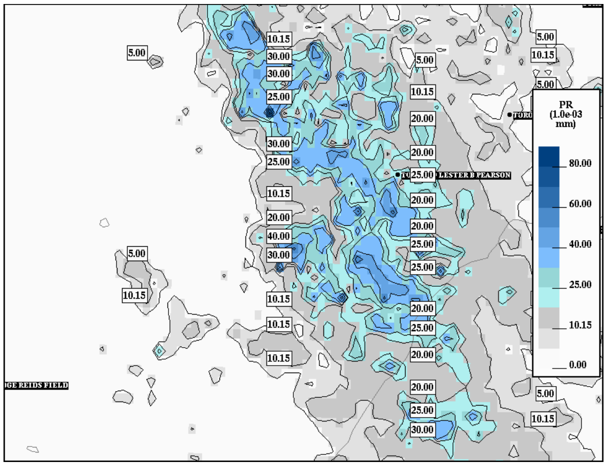

Figure 3. King City radar 12 hr accumulated radar echoes at 00 UTC 03 August 2005.

3.2 GEM 15 VERSUS GEM 2.5

Figures 4 and 5 show total outgoing infrared radiation (a surrogate for model forecast cloud cover) and surface wind barbs at 18 UTC for GEM 15 and GEM 2.5 respectively. Both models have similar cloud cover areas but there is much more detail in the GEM 2.5. The cloud cover is also similar to the actual cloud cover from Figure 2b, but it must be noted there is a 2 hour time difference. It can also be seen that the general areas of wind convergence, away from the clouds are well-correlated to the apparent orography of the two models. More pronounced wind convergence zones are seen in relation with the more detailed orography of the GEM 2.5. Even though we don't have enough observations to verify those winds but since the orography is closer to reality at GEM 2.5 one may expect a more realistic wind pattern from the higher resolution model. Comparison of Figures 4 and 5 to Figure 2b shows that the severity of convection is more apparent in GEM 2.5 than the Gem 15. Further when the models cloud activities are followed in a time sequence (not shown), the evolution of the convective process is better seen and is more correlated to the local topography in GEM 2.5 than in GEM 15. Also the maximum winds generated by the GEM 2.5 for the storm just north of the Lake Ontario were of the order of 60 km/h while in the GEM 15 they were around 20 km/h. As shown in Figures 6 and 7, GEM 15 and

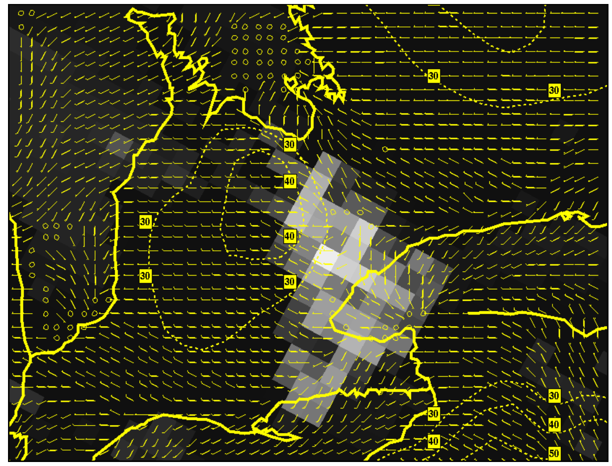

Figure 4. Total outgoing infrared radiation fields in grey, surface winds barbs in knots and local topography (hatched lines in decameters) for Gem 15 at 18 UTC

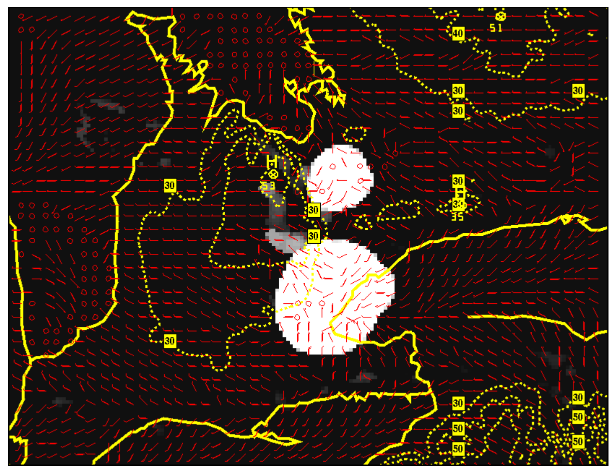

Figure 5. same as Figure. 4 by for GEM 2.5

GEM 2.5 produced rainfall amounts of 5 to 10 mm over the Toronto Pearson airport with considerably higher amounts within 50 km to the west. The maximum precipitation produced by GEM 15 and GEM 2.5 were 31 and 46 mm respectively. It can be noted that the orientations and amounts of the precipitation produced by GEM 2.5 is closer to the actual total reflectivities detected by the King radar (Figure 3) than that produced by GEM 15. However, there is an apparent spatial mismatch in addition to the temporal difference discussed above. Preliminary assessments suggest that the initial conditions are mostly responsible for those spatial and temporal differences.

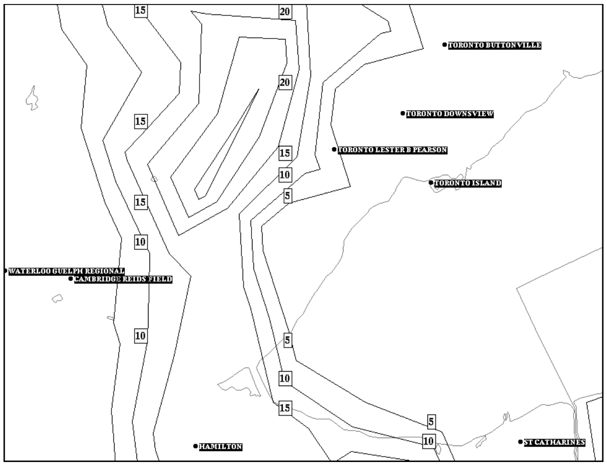

Figure 6. 12 hour accumulated precipitation produced by GEM 15 (intervals are at 5,10,15,20,25,30,40,50,60,70,80).

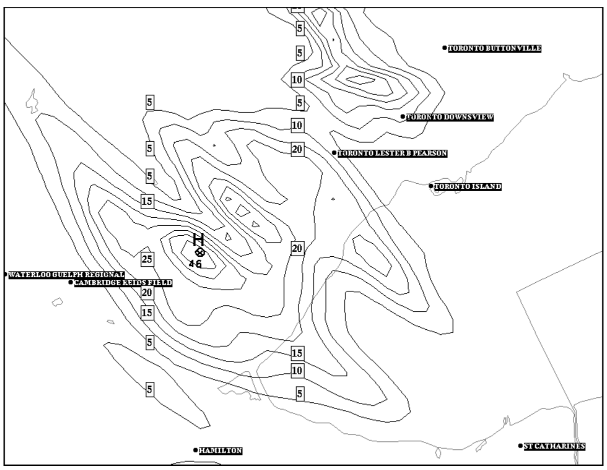

Figure 7. same as Fig. 6 but for GEM 2.5.

4. SUMMARY AND OUTLOOK

A summary of the setup and performance of a 2.5 km resolution version of the GEM-LAM model that is run operationally at CMC on an experimental status has been presented. The availability of the high-resolution forecasts on two limited-area windows allows a critical evaluation over those regions by forecasters with a good knowledge of the local weather characteristics.

The 02 August 2005 weather event over southern Ontario was discussed to demonstrate the typical similarities and differences between the forecast of GEM 15 and GEM 2.5 in relation to the observation. As was shown, since the GEM 15 is the driving model, in the synoptic scale the two models had a lot of similarities in the overall location and timing of the weather system. The differences were in the local scale. The GEM 2.5 showed more similarities to the existing observation. The more detailed orography of the higher resolution model had a large impact. Further the use of the explicit micro-physical condensation scheme (and no convective parameterization) played a significant role.

Having discussed the above, the subjective comparisons of many weather events forecasted by the GEM 15 and the GEM 2.5 in relation to the available observations have shown that, since the large scale weather phenomena impacts the smaller scales, once the GEM 15 mishandles a weather event the GEM 2.5 will follow the same pattern. On the other hand if the GEM 15 does well the GEM 2.5 adds value in relation to orography and convection. Since a lot of significant weather phenomena are related to the local orography and convective processes, the GEM 2.5 has the potential of being a strong tool for operational applications.

Work is also in progress to develop an objective evaluation strategy to better assess the strengths and weaknesses of the GEM-LAM model at 2.5 km resolution. Eventually, there will be a gradual extension of the high-resolution model forecasts to other regions of Canada.

5. ACKNOWLEDGEMENTS

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