JP3.3 THE USE OF THE GEM FORECAST MODEL AT VERY HIGH RESOLUTION DURING ELBOW 2001

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1. INTRODUCTION

The Effects of Lake Breezes On Weather (ELBOW) 2001 was conducted in southwestern Ontario during June to August of 2001. Its purpose was to study the role of lake breezes in triggering convection and, in particular, the strong convection which can result in hail, heavy rain and tornadoes. A mesoscale network was installed to supplement the regular surface network. On intensive observing days serial radiosondes were launched from 3 sites, mobile observations were taken and the NRC Twin Otter flew transects on a line similar to that of the radiosondes. The project is discussed in more detail in Sills et al. (2002).

As part of its support to the project, the Canadian Meteorological Centre provided special runs of the GEM (Global Environmental Multiscale) model with a horizontal grid spacing of 2.5 km. These model runs were used in conjunction with the regional GEM model and other mesoscale models to plan activities during the project.

Mass et al. (2002) reviewed the efficacy of increasing the horizontal resolution in numerical weather prediction models based on a two-year real-time experiment in the Pacific Northwest. They found clear benefits in increasing resolution where orographic flows or diurnal circulations are important. They also found that higher resolutions benefited when larger-scale features interacted with smaller-scale terrain features. However, they warned that there was little evidence that smaller grid spacing improved convective forecasts at specific locations due to timing and position errors.

We will use case studies to illustrate some of the strengths and weaknesses of using the GEM model at 2.5 km and discuss some implications for severe summer weather forecasting.

2. MODEL USE DURING ELBOW

CMC provided GEM forecast output at 3 horizontal resolutions for use in ELBOW. The standard GEM Regional was used for longer-range planning and larger-scale features; HIMAP and GEM2.5 were used for short-range forecasts of lake breezes and convection. We also consulted high-resolution models run by NWS Detroit (meso-eta) and Buffalo (MM5) and NOAA Forecast Systems Laboratory (RUC).

GEM Regional (Côté et al, 1998) is a variable grid, finite element model with a constant grid-spacing of 24 km over North America. HIMAP is a version of GEM with a 10 km grid-spacing provided for two areas. The HIMAP West grid is centered over the Canadian Rockies and the HIMAP East is centered over the Windsor-Quebec corridor. They were run twice a day based on the 06 hour GEM Regional forecast, GEM2.5 is a non-hydrostatic version of GEM, with no convective parameterization scheme and a Kong-Yau condensation scheme (see Erfani et al., 2001). It was run once a day from the 06 hour GEM Regional forecast based on 0000 UTC analysis.

The region of 2.5 km grid-spacing used in ELBOW is shown in Figure 1. The horizontal grid-spacing increases by 10% for each grid length away from the central region.

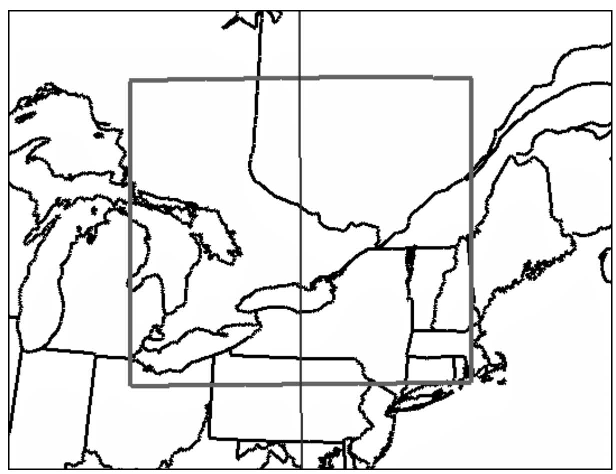

Figure 1. GEM2.5 grid for ELBOW. The horizontal grid spacing was 2.5 km within the inner box.

Forecast fields included: surface winds with vertical velocities and precipitation rate, boundary-layer height and surface air temperature, accumulated precipitation and 850 hPa wind, surface dew point temperature and 925 hPa wind, buoyant energy and vertical wind shear, and surface lifted index and other fields. HIMAP forecasts were available at 3 hr intervals out to 30 hours while GEM2.5 was available at hourly intervals out to 24 hours. In post-project re-runs, we have produced forecast maps for intervals as short as 15 minutes for GEM2.5.

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Both HIMAP and GEM2.5 clearly showed lake breeze effects in several fields. In particular, both showed typical diurnal cycles in the low-level winds. The stability fields showed the stabilizing effects of the lacustrine air in regions where winds were onshore.

Because of its higher resolution, GEM2.5 showed greater detail in the stability fields. The Oak Ridges Moraine is a ridge running parallel to the Lake Ontario shoreline about 30 km to the north. Lake breeze lines tend to align along the Moraine. In many cases, GEM2.5 showed a narrow line of greater instability along the Moraine that HIMAP failed to show.

During ELBOW, we had access to other high-resolution models, which at times showed significant differences from GEM2.5. Together we used them as a poor man's ensemble (Stensrud et al., 1998)

3. CASES

Summer 2001 was drier and warmer than usual in southern Ontario. This was favorable for lake breeze development but there were relatively few severe weather events (see Sills et al., 2002) for more details. In this section, we describe three cases to illustrate the performance of GEM2.5 during ELBOW.

4 July 2001 - Supercell

At 1200 UTC on 4 July 2001, a cold front supported by a vigorous short wave lay across northern Lower Michigan. It was expected to reach the ELBOW project area by 1800 UTC. A moist southwesterly flow at the surface and strong drying in the mid-levels suggested potential for the development of severe thunderstorms.

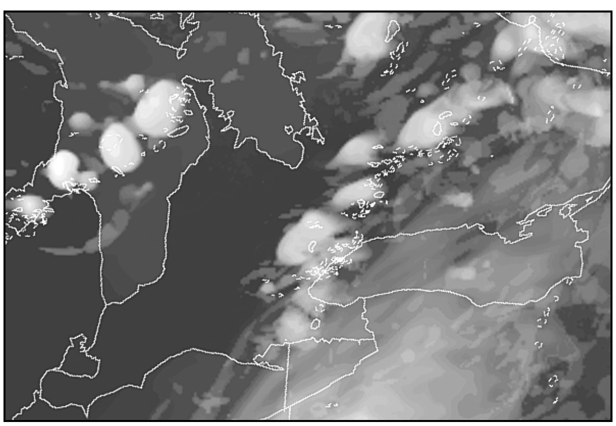

Figure 2a. Total outgoing longwave radiation from GEM2.5 at 1800 UTC 4 July 2001.

Figure 2a shows the GEM2.5 forecast of total outgoing longwave radiation, a proxy for an infrared satellite image, at 1800 UTC. This line of 'clouds' had formed rapidly in central Lake Huron about 1700 UTC. By 1900 UTC, the GEM2.5 forecast showed the line of clouds approaching the east coast of Lake Huron. The solid black lines indicate sinking motion and the dashed lines show rising motion. Several forecasters noted a similarity between this GEM2.5 output and the development of a line of supercells on 31 May 1985. The rapid development and the ascent/subsidence couplets also support this idea. Erfani et al. (2002) demonstrated GEM's ability to forecast supercell structures in their study of the 14 July 2000 Pine Lake Alberta tornado. We will be looking at the GEM2.5 output in more detail to verify this hypothesis.

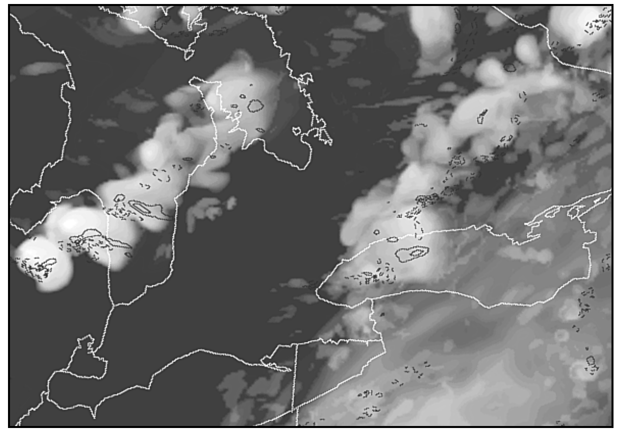

Figure 2b**.** Total outgoing longwave radiation from GEM2.5 at 1900 UTC 4 July 2001. The solid black lines show rising motion and the dashed black lines show sinking motion.

By 1900 UTC, forecast cells over Lake Huron were weakening and those over of Michigan 'Thumb' were becoming dominant. By 2000 UTC, the forecast cells which had formed over Lake Huron had dissipated.

In fact, a line of thunderstorms did develop when the cold front interacted with the lake breeze on the west coast of the Michigan Thumb. However, they formed earlier and further to the southeast than in the model; no thunderstorms developed over Lake Huron.

Figure 3 is a GOES-8 visible image at 1902 UTC when the cold front was along the southeast coast of Lake Huron. There was a large cell with an out flow boundary. The Exeter radar showed a mesocyclone with this storm 25 minutes later. Two ELBOW mobile teams observed a strong gust front about this time. Since no damage was reported at this location, it is likely that no tornado formed. However, there was wind damage elsewhere and two boaters drowned in southern Lake Huron when their boat capsized.

In the WNW flow behind the cold front, several lines of cumulus formed. Some of these lines appeared to originate from peninsulas on the western shore of Lake Michigan. These lines persisted for several hours and developed significant thunderstorms but the GEM2.5 forecasts showed no such developments. In fact, according to the Toronto Forecast Office (RCTO) severe weather log, small tornadoes developed on these lines, apparently where they intersected with the Lake Erie lake breeze line.

In this case, GEM2.5 correctly indicated strong development on the cold front, but the timing and location were incorrect. The forecast fields were suggestive of a supercell which did occur. However, it missed the smaller-scale, less strongly-forced thunderstorms in the cold air behind the front.

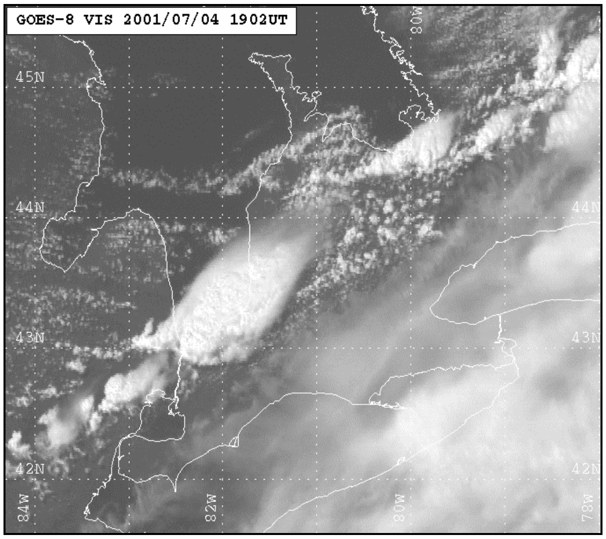

Figure 3. GOES 8 visible image 1902 UTC 4 July 2001.

22 July 2001 - Backbuilding storms

The regional GEM analysis at 0000 UTC on 22 July showed a moderate southwest flow over southwestern Ontario. No precipitation was indicated for the next 24 hours. The GEM2.5 forecast (Figure 4) showed thunderstorms developing in several areas. In particular, it showed model thunderstorms developing at the southeast end of Georgian Bay and a new storm then developing on the southwest flank of the first. The model predicted this process would continue for several hours, with storms moving south toward Lake Ontario, then SW along the Lake Ontario lake breeze line and

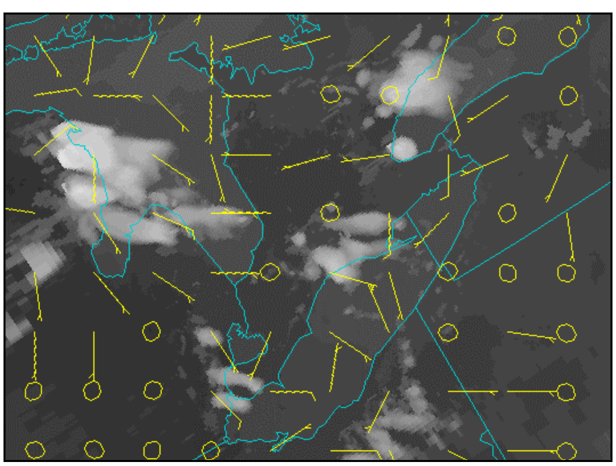
Figure 4. GEM2.5 total outgoing longwave radiation 2000 UTC 22 July 2001.

west on the Lake Erie line.

Figure 5 shows the GOES8 visible image at 2002 UTC. Comparing with Figure 4, the thunderstorms in northern Lower Michigan were well forecast in location and timing. The storms at the west end of Lake Ontario were correctly forecast in location but the timing was off by about 90 minutes. In both areas, local topography appears to have played a role. Thunderstorms forecast to develop in the ELBOW area between Lakes Huron and Erie in fact did not develop (alas).

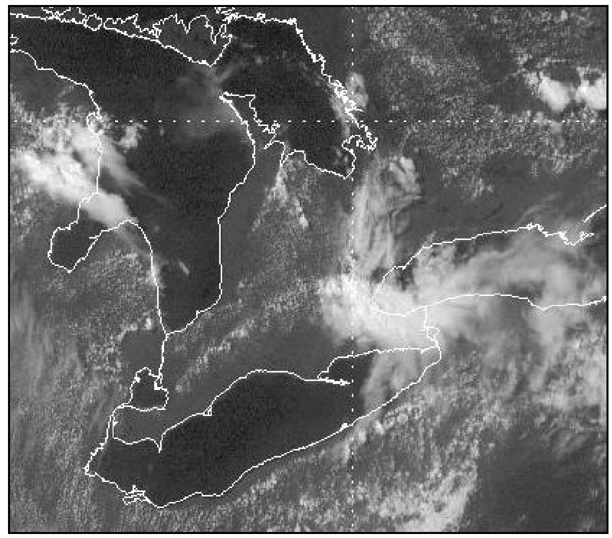
Figure 5. GOES8 visible image 2002 UTC 22 July 2001.

Figure 6 shows the GEM2.5 forecast vertical velocity field at approximately 950 hPa and surface winds for 2100 UTC. The model showed strong easterly winds at the west end of Lake Ontario and strong rising motion on the southern flank of the storm. The RCTO severe weather log recorded damaging winds, large hail and flash flooding in this area.

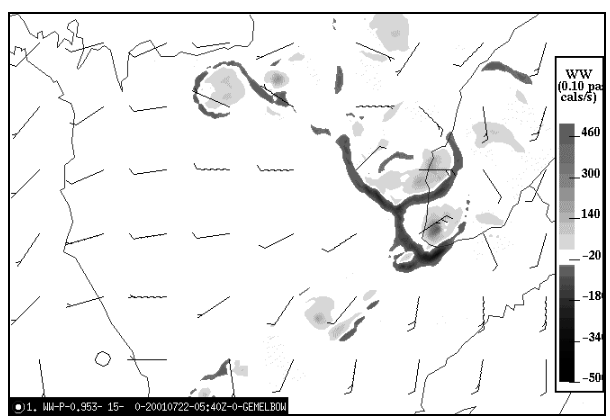

Figure 6. GEM2.5 vertical motion at eta level 0.953 and surface winds at 2100 UTC 22 July 2001.

In this case, GEM2.5 was highly successful in forecasting an unusual sequence of events, but the timing was inaccurate.

30 June 2001 - Failed bow echo?

In this case, there was a westerly flow ahead of an approaching cold front. The GEM2.5 6h forecast (VT 1200 UTC) (not shown) indicated a cold front extending from southern Quebec to northern Lower Michigan with a band of precipitation along the length of the front. By 2000 UTC (Figure 7), the model indicated that the precipitation band would segment into bow-like structures such as the one in southern Lake Huron. Judging by the wind field, the cold front at this time would still be in northern Lake Huron. The wind field and the bowed shape suggest a squall line and possibly a bow-echo storm in this event.

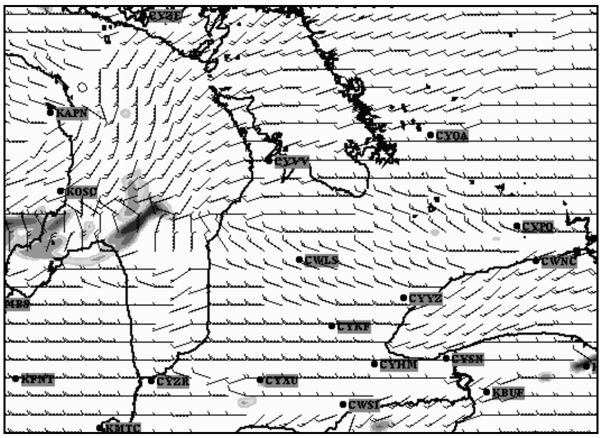

Figure 7. GEM2.5 forecast surface winds and precipitation valid at 2000 UTC 30 June 2001.

Radar and satellite data (not shown) showed that the clouds and precipitation along the front did become segmented but did not move out ahead of the front. In particular, a strong cell developed in central Michigan and moved into Lake Huron in about the location shown in the GEM2.5 forecast. However, its timing was more consistent with the apparent position of the cold front. Crook (1996) discussed the sensitivity of severe storm development to small changes in low-level temperature and humidity. It is possible that the real atmosphere in this case was slightly less favorable to the development of severe thunderstorms.

4. DISCUSSION AND CONCLUSIONS

GEM2.5 correctly captured features in the wind field and stability parameters associated with lake breeze circulations. In general, most significant convection occurred in areas where GEM2.5 forecast precipitation. However, in some areas where GEM2.5 forecast thunderstorms, only fair weather cumulus developed. In other cases, the sequence of events was correctly forecast but timing was inaccurate. On a given day, GEM2.5 performed well in one area but poorly in a nearby area. GEM2.5 predicted structures often linked with severe weather and in some cases these verified, especially the backbuilding thunderstorms of 22 July.

In agreement with the conclusions of Mass et al. (2002), we found that GEM2.5 performed best when there was strong synoptic or topographical forcing or both. On days with weak forcing, convection that developed in the wrong place or at the wrong time corrupted subsequent forecast maps with spurious outflow boundaries.

The GEM2.5 model run proved useful during ELBOW. Our post-analysis study suggests that such models are useful to severe weather forecasters if used with caution. In particular, GEM2.5 may give severe weather forecasters a "heads up" by forecasting the possibility of events such as back-building thunderstorms.

GEM2.5 was considered to be a success and it will be used experimentally in southern British Columbia in fall of 2002. During 2003, GEM2.5 will be available experimentally for various locations across Canada.

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