JP2.2 A CASE STUDY OF A WAKE LOW IN NORTHERN ILLINOIS AND THE WRF PREDICTION OF THE WAKE LOW

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A wake low occurred in northern Illinois and southern Wisconsin, during the morning of May 30, 2008. The surface wind was 45 to 55 mph (22 to 28 m/s) with gusts to 65 mph (33 m/s). The wind was not forecasted or expected. Forecasters had to quickly issue wind warnings as the strong wind was occurring. We hope to find ways to predict wake lows of this strength so to give forecasters some lead time or anticipation of wake low development. The Weather Research and Forecasting (WRF), Advanced Research WRF (ARW) model is used as a local operational model at the National Weather Service (NWS) Forecast Office, Chicago/Romeoville Illinois. This study is about some WRF model tests to see what changes can be made to the WRF ARW grid spacing, convective scheme and what initialization times could improve the forecasting of wake lows.

Method

We used the WRF Environmental Modeling System (EMS) version 3 (Rozumulski, 2009) as our test model. s.

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We ran four test runs. At 06 UTC initialization time one run was using an 11.7 km grid spacing and the other run using a 3.4 km grid spacing. At 12 UTC initialization, one run was using a 11.7 km grid spacing and the other run was using a 3.4 km grid spacing. The time period of the WRF model runs were a 15 hour run with initialization at 06 UTC and a 12 hour model run with initialization at 12 UTC. We wanted to investigate the initialization effects on the wake low production, and the effect of grid spacing. The 3.4 km grid spacing model run was without the Kain and Fritch convective scheme (Kain and Fritsch, 1990). We let the model build the thunderstorms. The 11.7 km model runs included the Kain and Fritch convective scheme like the operational WRF ARW model at NWS Chicago. We examined the mean sea level pressure forecasts and forecast soundings at Madison Wisconsin, at 15 UTC. This time would be the time that forecasts would be available using our current Office WRF ARW model set up. All our models were initialized with the North American Meso (NAM) model analysis at 12 km grid spacing from 06 UTC or 12 UTC.

Synoptic Setting and Gravity Waves

At 15 UTC an area of wake low intensification was in the warm sector of a cyclone system that was centered in western Wisconsin (Fig 1).

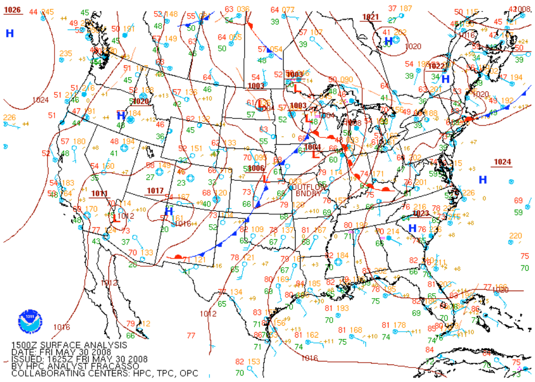

Figure 1 Surface map at 15 UTC May 30, 2008 from NCEP/HPC

A warm front was located along Lake Michigan. The region was in warm air advection. At 850 mb (Fig 2), there was a 50 knot low level jet streak in central Wisconsin. The wake low development region was on the anticyclonic side of this jet and there was horizontal shear south of the jet maximum.

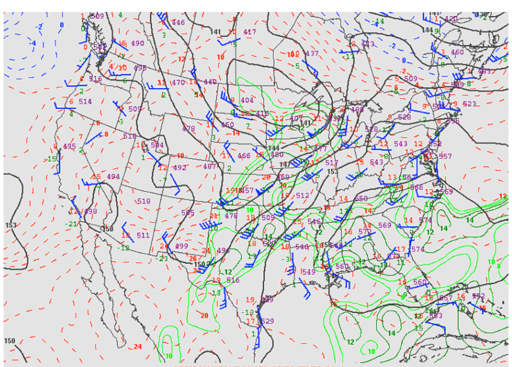

Figure 2 850 mb analysis 12 UTC May 30, 2008

The 250 mb analysis (Fig 3) shows diffluence over the Wisconsin and Illinois border. This area was also under the anticyclonic shear side of the 250 mb jet streak.

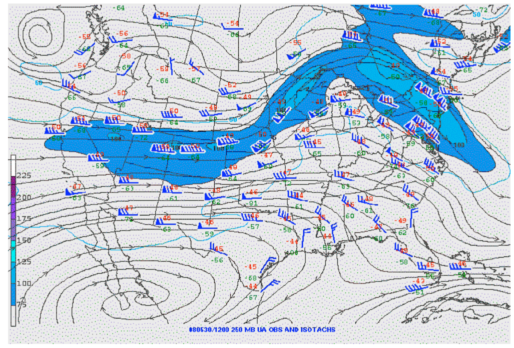

Figure 3 250 mb analysis 12 UTC May 20, 2008 from NCEP/SPC

Bosart and Seimon (1988) have noted these conditions with gravity waves in one of their cases. A 12 UTC sounding at Green Bay Wisconsin is shown in Figure 4. This sounding shows an inversion around 900 mb. The inversion layer seems to have the properties for gravity wave propagation. It is stable and thick enough and there was a good reflector on the top of moist warmer air. This is almost a layer that is conditionally unstable. With the low wind speed of around 5 meters per second, this region could be a good location for gravity waves (Lindzen and Tung, 1976). This wake low may be associated with a gravity wave.

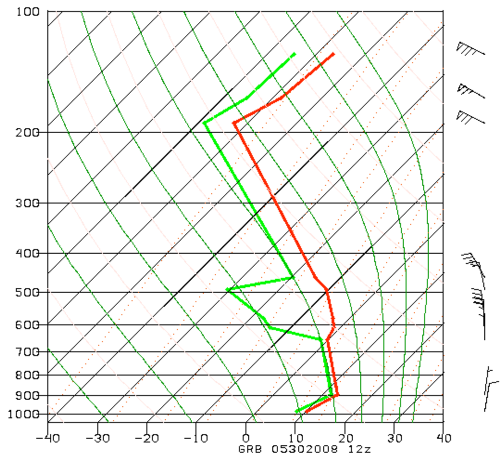

Figure 4 Sounding at Green Bay Wisconsin at 12 UTC May 30, 2008 (wind speed in meters/second)

Surface analysis and plots of altimeters at various stations are shown in figure 5. This was a gravity wave propagating southeast into Illinois. Gaffin (1999) found a gravity wave associated with a wake low in central Missouri.

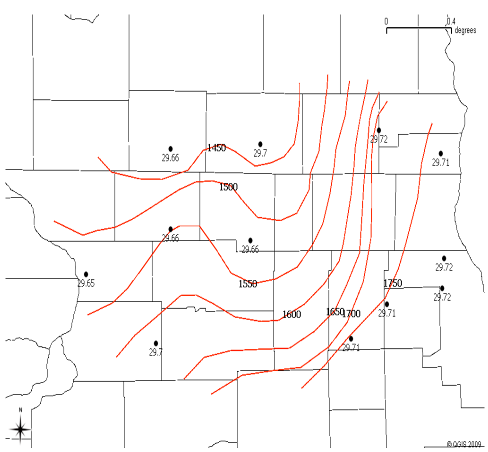

Figure 5 Gravity Wave propagating through Illinois 30 May 2008. Times of the wave are in bold letters and the lowest altimeters are in light letters.

We will look for the ducting inversion in the sounding forecast from the WRF model output.

The wake Low

The 15 UTC surface map (figure 6) show the 3 hour pressure falls. The WSR88D radar reflectivity from the NWS Chicago shows the line of showers and thunderstorms that was moving southeast (Figure 7). This is one hour prior to the strong wind in Rockford and a well defined wake low. There was a band of pressure falls greater than 4.0 mb across northern Illinois and southern Wisconsin north of the line of showers and thunderstorms.

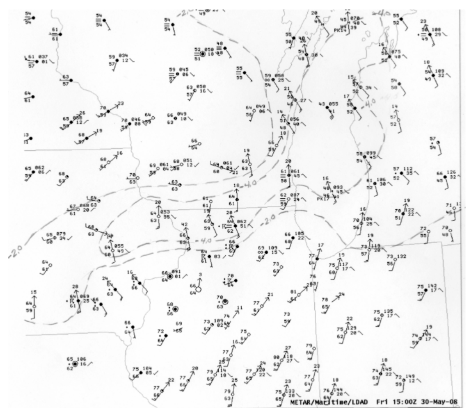

Figure 6 Surface 3 hour pressure falls of 2 mb and 4 mb only at 15 UTC, May 30, 2008

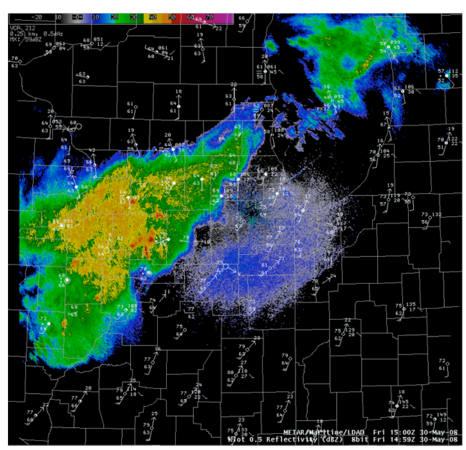

Figure 7 Reflectivity from the WSR88D radar at the Chicago/Romeoville WFO at 14:58 UTC May 30, 2008 with 15 UTC surface Observations.

Figure 8 shows the wake low nearest to the time of maximum wind. A low was just over the Rockford area at 16 UTC. Again, this low was north of the line of showers and thunderstorms (Figure 9). This low formed rapidly and in a location just behind an enhanced stratiform area of rain. This is a typical place for wake lows to form (Johnson and Hamilton, 1988).

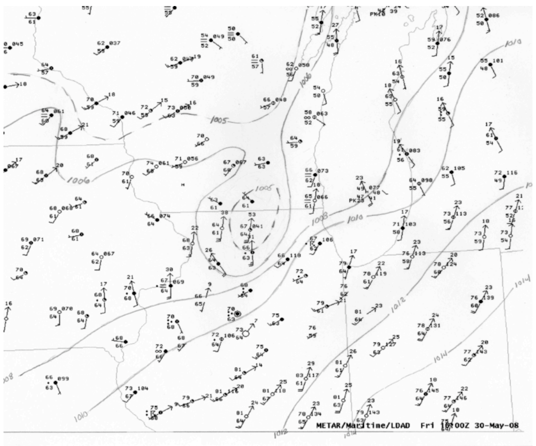

Figure 8 Mean Sea level Pressure analysis at 16 UTC, May 30, 2008

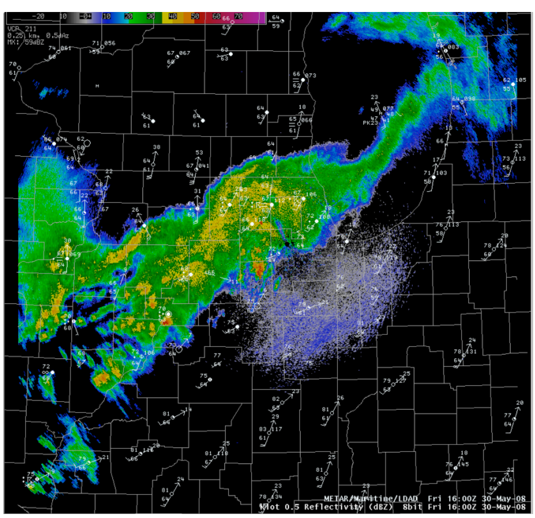

Figure 9 Reflectivity at .5 degree elevation at 16 UTC may 30, 2008 from the Chicago WSR88D radar and surface observations at 16 UTC

The WRF runs.

The following are soundings from the initialization data at 06 UTC (Figure 10) and 12 UTC (Figure 11). The soundings are the same for each 3.4 and 11.7 grid spacing, since the soundings are for a point. We chose Madison Wisconsin, which was close to the wake low and still on the warm side of the front and the anticyclonic side of the upper level jet streak.

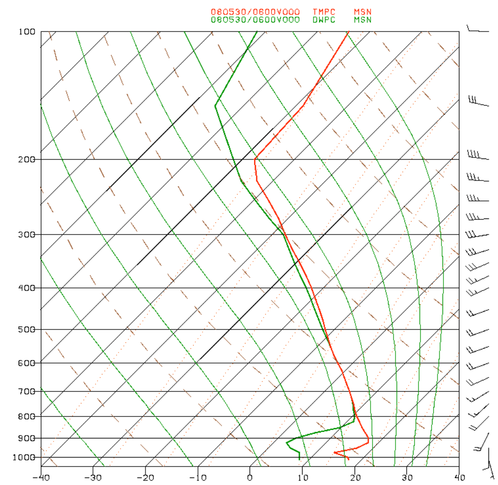

Figure 10 Initial sounding for the WRF models over Madison Wisconsin from the 06 UTC NAM model grids.

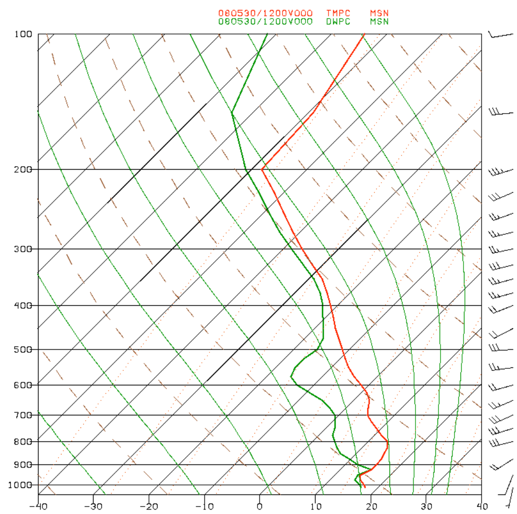

Figure 11 Initial sounding for the WRF model over Madison Wisconsin from the 12 UTC NAM model grids.

An inversion was present in both soundings. However the 12 UTC model runs started with more moisture below 900 mb. The 06 UTC model started with a nearly saturated layer above 800 mb and nearly dry below. This difference may have affected the outcome of the subsequent model atmospheric profiles in each of the model runs.

Figure 12 is the 15 UTC mean sea level pressure forecast from the WRF 06 UTC run on a 3.4 km grid spacing. Along the Wisconsin and Illinois border there is a diffuse pressure pattern, no low development. A very weak trough extends into northeast Iowa.

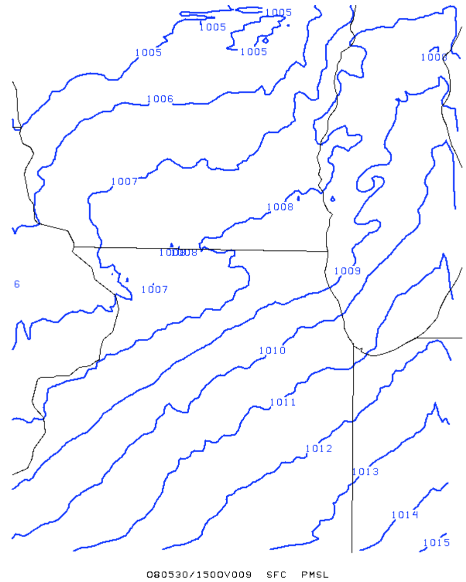

Figure 12 Mean Sea level pressure forecast for 15 UTC from the 06 UTC 3.4 km WRF model run.

Figure 13 is the 15 UTC mean sea level pressure from the 06 UTC 11.7 km WRF run. A weak trough extends to Lake Michigan. This would alert forecasters that a trough may exist at that forecast time but nothing of a wake low.

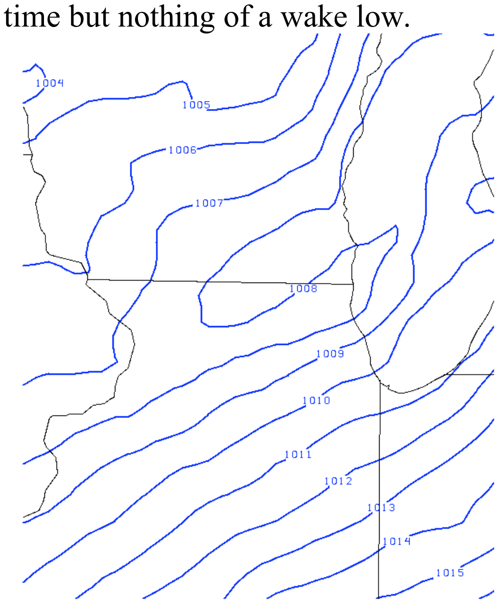

Figure 13 15 UTC mean sea level pressure forecast from the 06 UTC 11.7 km WRF model run.

The following forecast soundings are for Madison Wisconsin which was near where the wake low occurred yet still in the warm air sector. The sounding at 15 UTC from the 06 UTC, at 3.4 km run is shown in figure 14. In this sounding there was a very weak subsidence inversion. There may not be enough of a top reflector for gravity waves (Lindzen and Tung, 1976)

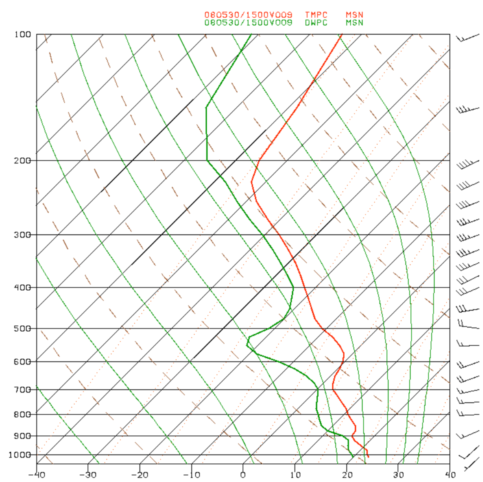

Figure 14 Forecast sounding over Madison Wisconsin valid at 15 UTC

The next figure 15 is a forecast of the mean sea level pressure valid at 15 UTC from the 12 UTC model run on the 3.4 km grid spacing. The surface trough is stronger now and has been displaced north into Wisconsin more. A low is forecast in extreme northwest Illinois, displaced a little to west of the actual wake low.

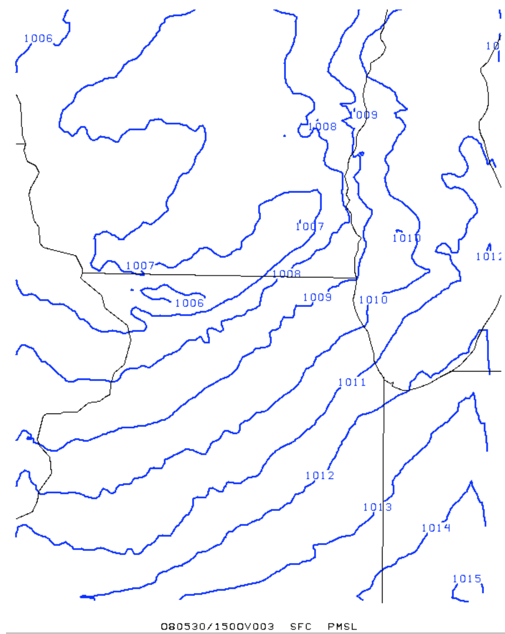

Figure 15 Mean sea level pressure forecast valid at 15 UTC from the 12 UTC 3.4 km WRF model run**.**

Then follows the surface mean sea level pressure forecast from the 12 UTC model run with 11.7 km grid spacing. In this case the wake low is pronounced but forecast location is a little further north. The closed 1006 mb line was just north of Rockford.

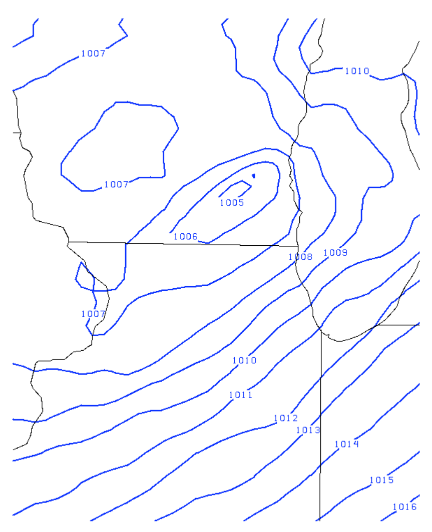

Figure 16 Forecast mean sea level pressure from the 12 UTC 11.7 km WRF model run.

The forecast sounding from 12 UTC valid for 15 UTC follows figure 17. A subsidence inversion was forecast above 850 mb. The layer below was moister than the 06 UTC model runs.

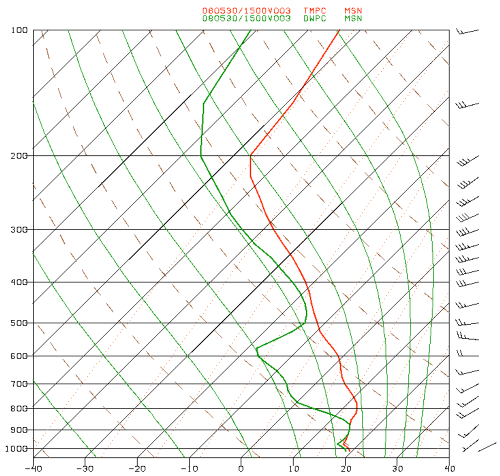

Figure 18 Forecast Sounding over Madison from the 12 UTC WRF model runs.

With a stable layer above 850 mb this was a better duct for gravity waves to propagate.

Summary

The initialization of the WRF model was important to the development of the wake low. The 06 UTC initialization WRF model runs at both 11.7 km and 3.4 km grid spacing increased the moisture below 800 mb and decreased the moisture above 800 mb. The layer below 900 mb was destabilized and a small inversion was created at 900 mb. This subsidence inversion was more pronounced with the 12 UTC model run with 3.4 km grid spacing, than the 12 UTC model run with the 11.7 km grid spacing. The low level duct and the reflector on the 12 UTC model run soundings provided better ducting for a gravity wave. Both 06 UTC and 12 UTC model runs forecasted convective rain as seen in the precipitation forecasts. The 12 UTC WRF forecast area of convective rain fall {in mm }for 1 hour up to 16 UTC (Figure 19), was close to the location where the actual showers and thunderstorms occurred.(Figure 9).

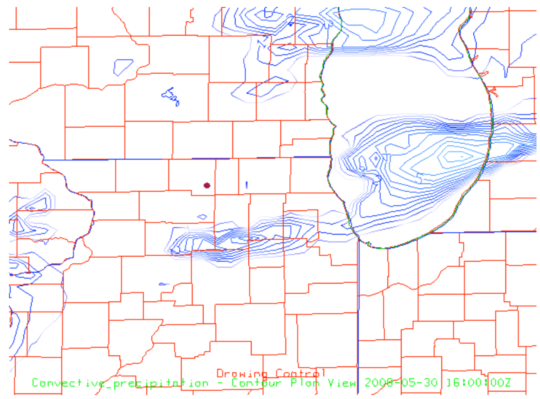

Figure 19 Convective rain in mm from 12 UTC 11.7 km WRF run.

The 06 UTC WRF forecast area of convective rain (Figure 20), was north of the actual showers and thunderstorms.

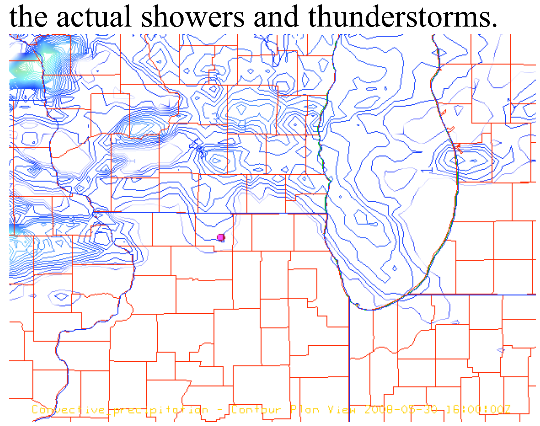

Figure 20 Convective rain in mm from the 06 UTC 11.7 km WRF run.

Conclusion

The initialization of the WRF model had an effect on the outcome. The change in grid spacing affected the forecast surface pressure and the location of the wake low. The gravity wave length may be resolved or not well resolved by different grid spacing The differences in the mean sea level pressure forecast may be a result of the cumulus scheme. Our 3.4 km grid spacing model runs did not use a cumulus scheme. The 11.7 km grid spacing runs used the Kain and Fritsch cumulus scheme. We examined cross sections to see how the model forecast temperature changes in the vertical and moisture changes (not shown). We will examine these changes with regard to microphysics. In this test we kept the same microphysics scheme. The production of precipitation and the forecast location of precipitation in the model forecast played a role in the location of the forecast wake low. The importance of surface analysis in forecast operations was demonstrated here. The forecast mean sea level pressure gradient was small in all the cases. Forecasters would have to be aware of the weather if they would take note of this WRF model's forecast of a wake low. We will examine that aspect in future studies.

References

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