2.49 The WRF Microphysics and a Snow Event in Chicago

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1. Introduction

Mesoscale meteorological models are increasingly being used in NWS forecast offices. One important performance aspect of these models is the parameterization of the ice phase microphysics. Such parameterizations can affect the model output of precipitation during the winter months. The precipitation forecast are important for duration, estimation of the amount of snow and the location of large amounts of snow in a 3 to 48 hour forecast time frame. This study examines various ice phase microphysics schemes or parameterizations and how they affect the model forecast of precipitation amount. The day chosen for this study was December 8, 2005, when there were very good measurements of a significant snowfall that impacted northeast Illinois and northwest Indiana. This study will be a part of the decision process for selection of a microphysical scheme when the model, such as the WRF model, is run operationally in the National Weather Service (NWS) Chicago forecast office.

The Weather Research and Forecasting (WRF) model (Wang et al, 2005) will be used in this study. This model will be the operational mesoscale model that is run locally in the NWS Chicago forecast office.

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The Advanced Research WRF dynamic solver (ARW) (Skamarock et al, 2005) is part of this modeling system.
The model is run every 6 hours operationally and is initialized by the initial data tiles from the North American (NAM) 12 kilometer model run at the National Center of Environmental Prediction, Environmental Prediction Center. Description of the WRF ARW model can be found in Skamarock et al (2005). At the Chicago forecast office the model output includes forecasts of wind, precipitation, and clouds which are used in forecasts for the aviation and marine communities in northeast Illinois and northwest Indiana. The model was set up and runs using procedures and scripts provided by the Science and Operations Officer (SOO) Science and Training Resource Center (Rozumalski, 2004).

2. The Event

On December 8, 2005 a snowstorm occurred over northeast Illinois, producing up to 25.4 cm of accumulation in parts of the Chicago metropolitan area (Labas, 2006) (Fig 1). Some units are in inches, (2.5 cm is 1 inch) on some of the figures. This reflects the operational orientation of this study. Observations at the Chicago Midway Airport indicated visibility was reduced occasionally to .2 km in part due to the large snow flakes. These snow flakes were evident in the television video of a Southwest Airlines jet that skidded off the runway that evening (personal observation). Very reliable observations of snow amounts were collected following this event from cooperative observers and the airport observers. The isolated nature of snow maxima makes this case a good one for study of the WRF-ARW model.

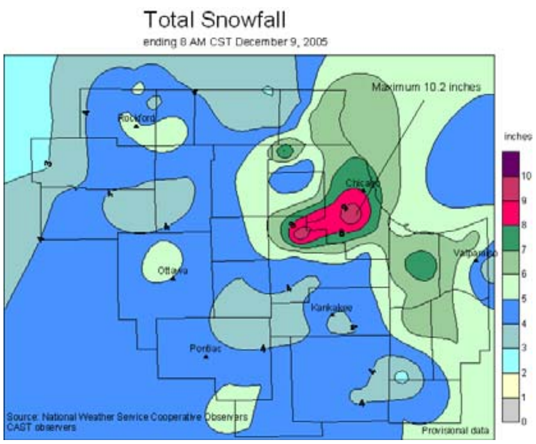

Fig 1 Total 24 hour snowfall in inches. (Labas, 2006)

Figure 2 is a reflectivity image from the WSR88D radar at the Chicago Forecast Office at 2315 UTC. The white areas are 30 to 35 dBz returns.

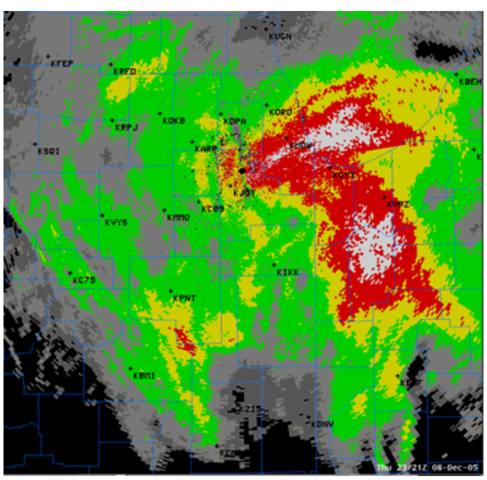
Fig 2 2315 UTC Reflectivity Image. (Labas, 2006)

3. Methodology

The WRF-ARW model was run for a 9 hour forecast starting at 18 UTC. The snow storm simulated in the model produced large snow amounts very similar to those observed within the period of 00 UTC to 03 UTC. In this preprint article the amounts will be shown as liquid. A ratio of 25.4 cm to 2.54 cm of snow to liquid is assumed in this case.

This is assumed because of the nature of the snow that fell.(personal observation) The model domain covers the Chicago Weather Forecast Office forecast area of responsibility over northeast Illinois, northwest Indiana and all of Lake Michigan (Fig 3). The model was initialized with the NAM 12 km tile data. The WRF ARW grid spacing was 10.5 km for this case.

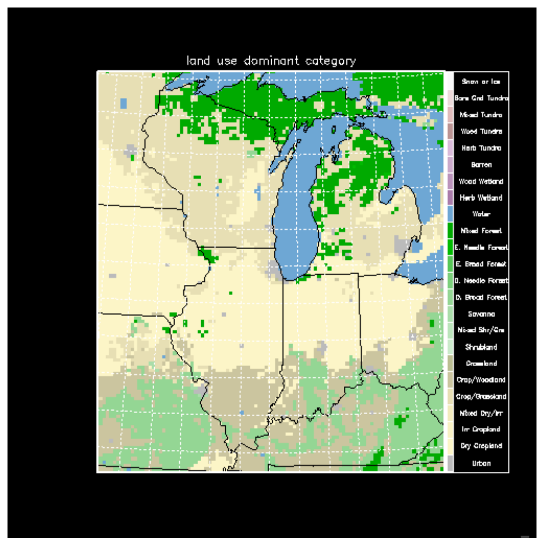

Fig 3 Land use and domain

The following microphysics schemes were tested; Purdue Lin (PL), WRF Single moment 3 class (WSM3), WRF Single Moment 5 class (WSM5), WRF Single Moment 6 class(WSM6), the Eta Grid-scale Cloud and Precipitation Scheme, also known as the Ferrier scheme (FER), and the Thompson et al Scheme (TH). These microphysical schemes are briefly described in the document by Skamarock et al (2005). The model forecast of 9 hour accumulated liquid precipitation for each model run using the above microphysics schemes was examined. A qualitative comparison of the accumulated liquid precipitation with the total snow fall amounts and radar data of heavy snow was occurring was performed. The location of the maximum amount of precipitation is what is important in this case study. Since the entire atmospheric column (not shown) was significantly below freezing, we assume that all the precipitation was snow.

4. Results

Using the PL scheme the WRF ARW model produced a band of higher precipitation over southern Lake Michigan by 03 UTC (Fig 4). The model simulated maximum was over the northwest Indiana shores. The axis of maximum precipitation extended west into southern Chicago.

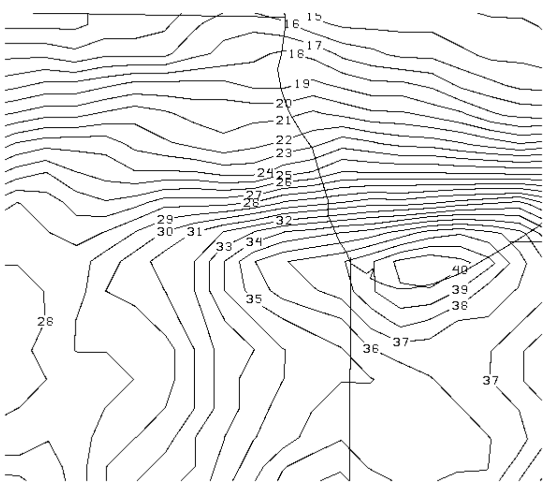

Fig 4 Accumulated Precipitation in inches x 10^2 from the PL scheme.

The WSM5 scheme output depicted the accumulation maximum about 25 km further north into Lake Michigan than the forecast maximum using the PL scheme (Fig 5). The axis of maximum precipitation was nearly coincident with the observed maximum over Midway Airport in Chicago.

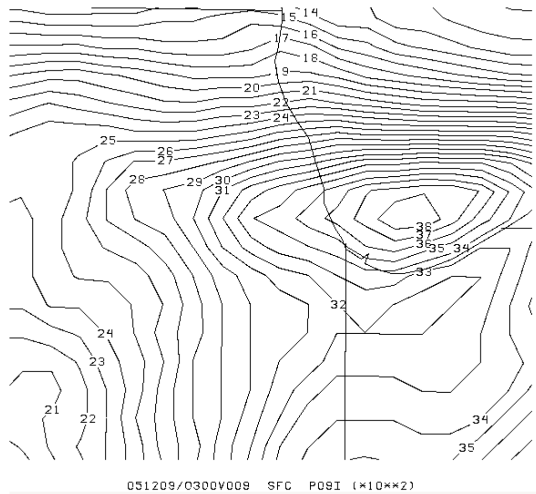

Fig 5 03 UTC Accumulated precipitation from the WSM5 Scheme.

The WSM3 (Fig 6) scheme produced similar results as the WSM5. The maximum was near the same location as the WSM3 scheme. The axis of maximum precipitation was further north than the WSM5 scheme and lines up better with the observed maximum snowfall in Chicago. The WSM3 scheme produced a sharper maximum center over Lake Michigan Both schemes may produce these results because of the number concentration of ice nuclei derived from the ice mixing ratio (Hong et al, 2004). The model may have produced more ice water content over Lake Michigan in this run and the WSM5 run (Heymsfield 1990).

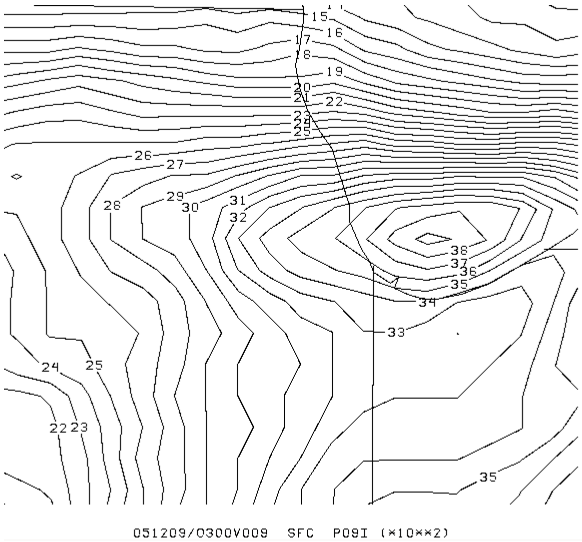

Fig 6   03 UTC Precipitation Accumulation WSM3

The output from the model with the WSM6 scheme is seen in Figure 7. The model output maximum precipitation was near the same location as the WSM3 scheme and WSM5 scheme.   The axis of maximum precipitation extends west into Chicago and lines up closely with the observed snow fall axis.

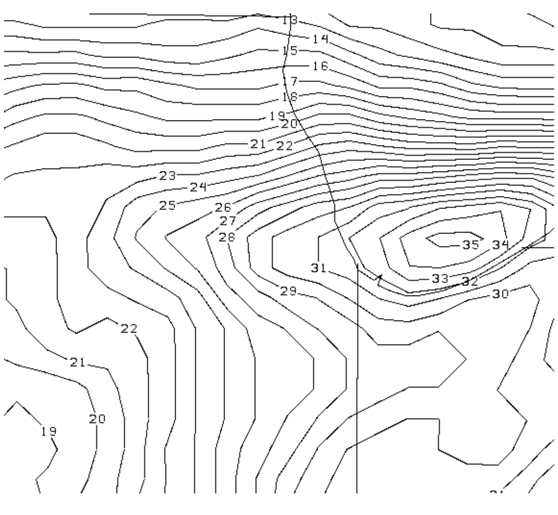

Figure 7   03 UTC Precipitation accumulation W SM6

The Thompson scheme is shown in Figure 8. The model output accumulation precipitation maximum was about 15 km further west than the other schemes. The axis of maximum precipitation produced by the model was less pronounced inland than the previous model runs. The Thompson scheme kept most of the forecast precipitation over the lake.

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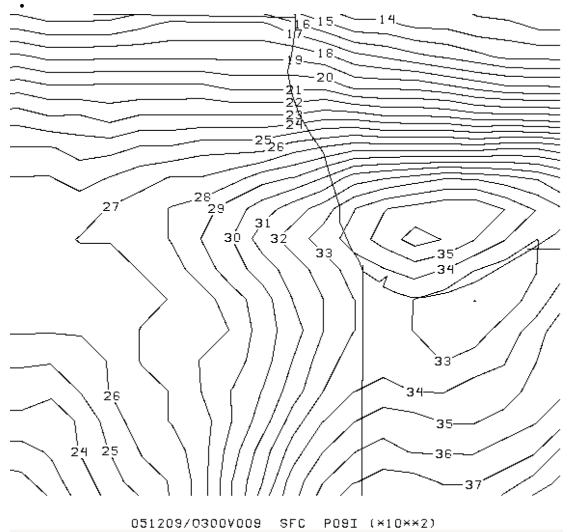

Figure 8   03 UTC Precipitation Accumulation Thompson

The Ferrier scheme is shown in Figure 9. The WRF ran in the shortest time, about 70 minutes compared to around 120 minutes from the other schemes. The results were similar to the WSM5 and WSM6 schemes in location of maximum center of precipitation over Lake Michigan. An axis of maximum precipitation was produced and extended west into Chicago. The axis was sharper and nearly coincident with the maximum observed precipitation.

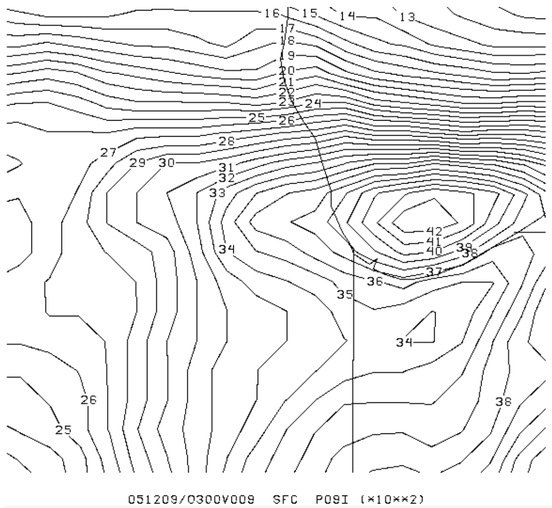

Figure 9 03 UTC Precipitation Accumulation Ferrier

Figure 10 is the PL scheme on a 6 km grid. The PL scheme produced excellent result with this grid spacing. However the run time of the model was more than 2 hours for a 24 hour forecast on the computers in the forecast office. This is a major consideration in the forecast operations. One could speculate that the smaller grid size may allow for better resolution of convective elements or banding of the snow.

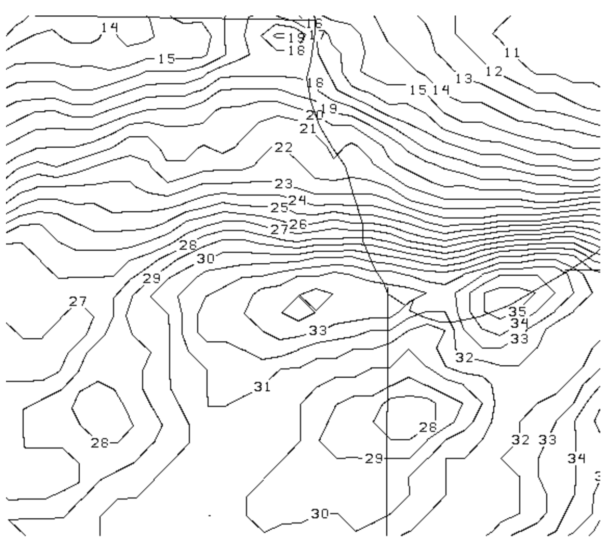

Figure 10 03 UTC precipitation accumulation PL 6km grid

5 .Summary and Conclusion

Model runs with the different microphysical schemes produced precipitation amounts that were roughly in the same areas. The maximum amounts were over southern Lake Michigan just north of the Indiana shoreline. The forecast amounts were close to the areas were the snow fell. This is seen on radar data for example (Figure 2 for example).

There were differences in the westward extent of the maximum precipitation. The maximum center of precipitation was produced further north in the lake by the models using the WSM3, WSM5, WSM6, Thompson and Ferrier schemes than the model using the PL scheme. None of the model runs actually caught the 25.4 cm snow amounts in Chicago. The model in the 6 km grid and using the PL scheme produced a precipitation maximum almost coincident with the observed snow maximum in Chicago, but not in magnitude. A test of all the microphysical schemes with the model in the 6 km grid will be done in the future to see the results and to check model run time. The WRF model output maxima using the different microphysics schemes may have been over the lake because mesoscale and synoptic scale dynamics may have provided the lift and lake based moisture to produce the maximum precipitation over Lake Michigan. The only direct observations were from WSR88D radar at KLOT. (Figure 2 for example). There was snow occurring over Lake Michigan through 03 UTC. Whether the model and the schemes were affected by the Lake and its relatively warm waters will also be investigated in future test runs of the WRF-ARW. There may have been increases in ice water concentration due to the availability of more moisture over Lake Michigan. There were strong updrafts and there was significant mid level moisture (Labas, 2006). This was noted in the WRF model from the model output of vertical velocities and low level humidity (not shown). That was a factor in the forecast models producing the precipitation that they did. There will be future tests of the same microphysical schemes in the smaller grid spacing such as 6 km. But grid spacing and model runtime will have to be considered in setting up the WRF ARW model for operational runs at this time. The PL and the WSM3 scheme seem to be the choice for our operational use of the WRF ARW.

6. Acknowledgements

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7. References

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