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WINTER FORECAST PERFORMANCE OF AN OPERATIONAL MESOSCALE MODELLING SYSTEM IN THE NORTHEAST U.S. – WINTER 2002-2003

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1. INTRODUCTION

We examine the winter season forecast performance of an operational mesoscale modelling system dubbed *Deep Thunder* over the northeast United States. Model skill is compared with significant snowfall events during the 2002-2003 season as well as considering the operational availability of such results.

The *Deep Thunder* system has been running operationally since January 2001 at the IBM Thomas J. Watson Research Center in Yorktown Heights, NY with focus on the New York City metropolitan area (Treinish and Praino, 2004). Figure 1 shows the domain configuration for the 4 km and 1 km nests, with the boundary of the latter marked in red on this terrain map. Locations of National Weather Service Metar reporting stations used for verification purposes are shown in white. Selected airport (IATA) locations and municipal centers are indicated in black.

In order to characterize the model's winter seasonal performance, we focus on the December 2002 through April 2003 time period. This particular winter season offered several interesting opportunities to study the model's performance for coastal storms and heavy snow in the northeastern United States. We will present qualitative results of the study of seven major snow events impacting the New York City metropolitan region.

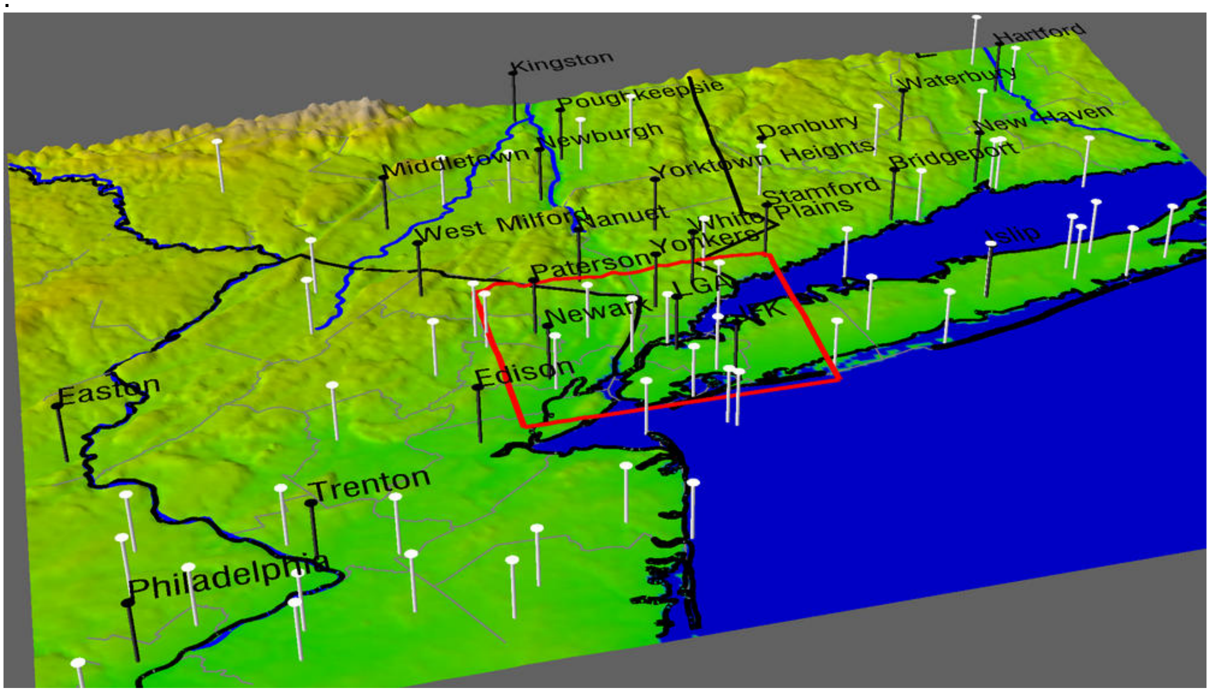

Figure 1. Inner Model Nests and Metar Reporting Stations

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2. METHODS AND DATA SETS

Verification of individual events focused primarily on total snowfall accumulation, precipitation onset, and precipitation ending times with verification against surface observations. Snow accumulation is a derived model variable. Currently, two methods are used, a 'wet' and a 'dry' algorithm. Wet snow is derived from snow estimates from the model microphysics, based upon several layers, including the surface. The dry algorithm uses only surface temperature to determine the ratio between snow amount and liquid precipitation. It is a piecewise linear function, which is built from the information in Table 1. The ratio of liquid precipitation to snow tends to be lower for the wet versus the dry algorithm.

Verification against actual snowfall accumulation was accomplished using snowfall totals reported by the Northeast River Forecast Center and NWS snow spotter (co-op, skywarn, and other) reports. Snowfall measurement is particularly problematic and is highly dependent on the technique used. The associated uncertainties are significant and can be difficult to quantify. Precipitation onset, duration and ending verification is limited by the available observations in the forecast domain.

For the region covered in this study there are 55 Metar reporting stations. The limited number of observation sites in the model forecast domain introduces potential uncertainty in verification as a result of limited sample size and dataset geographic distribution. There are also variations in reporting times as well as precipitation sensor limitations which are potential error sources when using this data for verification. Additional mesoscale model verification issues are discussed in detail in Colle, et al, 2003, Davis and Carr, April 2000 and de Elia and Laprise, 2003.

3. QUANTITATIVE EVALUATION OF SPECIFIC EVENTS

Seven winter storm events are evaluated for model performance in total snowfall accumulation as well as precipitation onset and ending times for selected locations in the 1 km nest. The sites were chosen based on the availability and continuity of observations for verification. Results are summarized in Table 2. The table shows the model prediction and observations for precipitation onset and ending time as well as total snowfall accumulation for LaGuardia (LGA), Newark (EWR) and White Plains (HPN) airports for the seven events studied. Precipitation start times tend to exhibit some negative bias as a result of the model microphysics spin-up time during execution.

Observed results are derived from metars which also introduce bias by virtue of observations being nominally on one hour intervals. Precipitation onset errors are predominantly negative (17 of 21 cases) with the model lagging the actual precipitation start. The mean difference between model precipitation onset time and observed onset time is approximately four hours with some of this due to the aforementioned microphysics spin-up time.

Precipitation ending time errors also show a negative bias, lagging the observed end of precipitation in 15 of 19 cases examined. The mean difference between model and observed ending time for precipitation is about three hours. Utilization of a dry snowfall algorithm described earlier resulted in over-prediction of total snowfall in 16 of the 21 cases examined. Mean error was 4.2 inches.

Table 1. Dry Snowfall Algorithm Liquid to Snow Conversion Ratios

Snow:Liquid Ratio Range	**Temperature Range (^{o}C.)**
15:1	< -5
15:1 - 10:1	>= -5, < 0
10:1 - 5:1	>= 0, < 1
5:1 - 1:1	>= 1, < 2
1:1	>= 2, < 4
0	> 4

Table 2. Model Prediction and Observed Results

Location	Model Forecast Available	Model Precipitation Start Time	Model Precipitation End Time	Model Snow Total	Observed Precipitation Start Time	Observed Precipitation End Time	Observed Snow Total
LGA	1400Z 12/05/02	12/05/02 1400Z	12/06/02 0800Z	14”	12/05/02 1239Z	12/06/02 0251Z	7.0”
LGA	1400Z 12/25/02	12/25/02 1000Z	12/26/02 1000Z	5”	12/25/02 0419Z	12/26/02 0551Z	6.1”
LGA	0300Z 01/03/03	01/03/03 1500Z	01/04/03 0400Z	1”	01/03/03 0408Z	01/04/03 1351Z	7.0”
LGA	0300Z 02/07/03	02/07/03 0500Z	02/07/03 2100Z	9”	02/07/03 0153Z	02/07/03 2018Z	5.3”
LGA	0300Z 02/17/03	02/17/03 1300Z	02/17/03 2300Z	25”	02/16/03 2328Z	02/18/03 0047Z	16.5”
LGA	1400Z 03/06/03	03/06/03 1300Z	03/07/03 0200Z	8”	03/06/03 0951Z	03/06/03 2351Z	3.4”
LGA	0900Z 04/07/03	04/07/03 1600Z	04/08/03 1200Z	1”	04/07/03 1351Z	04/07/03 1339Z	5.5”
EWR	1400Z 12/05/02	12/05/02 1500Z	12/06/02 0500Z	14”	12/05/02 1209Z	12/06/02 0051Z	7.0”
EWR	1400Z 12/25/02	12/25/02 1000Z	12/26/02 0900Z	7”	12/25/02 0351Z	12/26/02 0551Z	3.0”
EWR	0300Z 01/03/03	01/03/03 1400Z	01/04/03 0300Z	0”	01/03/03 0417Z	01/04/03 1400Z	1.0”
EWR	0300Z 02/07/03	02/07/03 0500Z	02/07/03 2100Z	8”	02/07/03 0427Z	02/07/03 2030Z	5.7”
EWR	0300Z 02/17/03	02/17/03 1300Z	02/17/03 2300Z	26”	02/16/03 2051Z	02/18/03 0149Z	22.1”
EWR	1400Z 03/06/03	03/06/03 1300Z	03/06/03 2300Z	7”	03/06/03 0846Z	03/07/03 0012Z	3.3”
EWR	0900Z 04/07/03	04/07/03 1600Z	04/08/03 1200Z	3”	04/07/03 1308Z	04/07/03 1246Z	4.4”
HPN	1400Z 12/05/02	12/05/02 1500Z	12/06/02 0700Z	15”	12/05/02 1356Z	12/06/02 0156Z	6.0”
HPN	1400Z 12/25/02	12/25/02 1500Z	12/26/02 1000Z	6”	12/25/02 0556Z	12/26/02	8.5”
HPN	0300Z 01/03/03	01/03/03 1500Z	01/04/03 0700Z	3”	01/03/03 0556Z	01/04/03 1019Z	3.0”
HPN	0300Z 02/07/03	02/07/03 0500Z	02/07/03 2100Z	10”	02/07/03 0356Z	02/07/03 1956Z	6.5”
HPN	0300Z 02/17/03	02/17/03 1300Z	02/17/03 0100Z	20”	02/17/03 0238Z	02/17/03	17.0”
HPN	1400Z 03/06/03	03/06/03 1300Z	03/07/03 0200Z	9”	03/06/03 0952Z	03/06/03 2356Z	6.7”
HPN	0900Z 04/07/03	04/07/03 1600Z	04/08/03 1200Z	12”	04/07/03 1556Z	04/07/03 0714Z	3.3”

4. QUALITATIVE CASE STUDIES

In addition to the previous quantitative evaluation, qualitative comparisons were made for the seven events studied. These results are potentially more extensive in geographical coverage as they rely on visualization techniques for determination of model predictions. Qualitative verification is limited by available observation and other data available within the forecast domain. For the seven cases studied, we have observed good model skill in the prediction of timing, location, and intensity.

For example consider the nor’easter that impacted the New York City metropolitan area on December 25 – 26, 2002. A low pressure area from the Mississippi Valley moved northeastward and rapidly redeveloped along the North Carolina coast by early on Christmas morning. The storm dramatically deepened as it tracked northeast along the Atlantic coast and reached just south of eastern Long Island by late Christmas night.

A sample of the *Deep Thunder* results is illustrated in Figure 2. The model forecast period was from 1200 UTC on 12/25 to 1200 UTC on 12/26. The model products were available at approximately 1700 UTC on 12/25. Figure 2 is a snapshot from an animation sequence of the two-dimensional visualization created as part of the model products. It details the predicted total snowfall accumulation using the dry snowfall algorithm for a portion of the 4 km model grid. The map is shown overlaid with the location of cities as well as state, coastline and county boundaries. The map is color contoured by forecasted snowfall where the lighter colors indicate heavier accumulations.

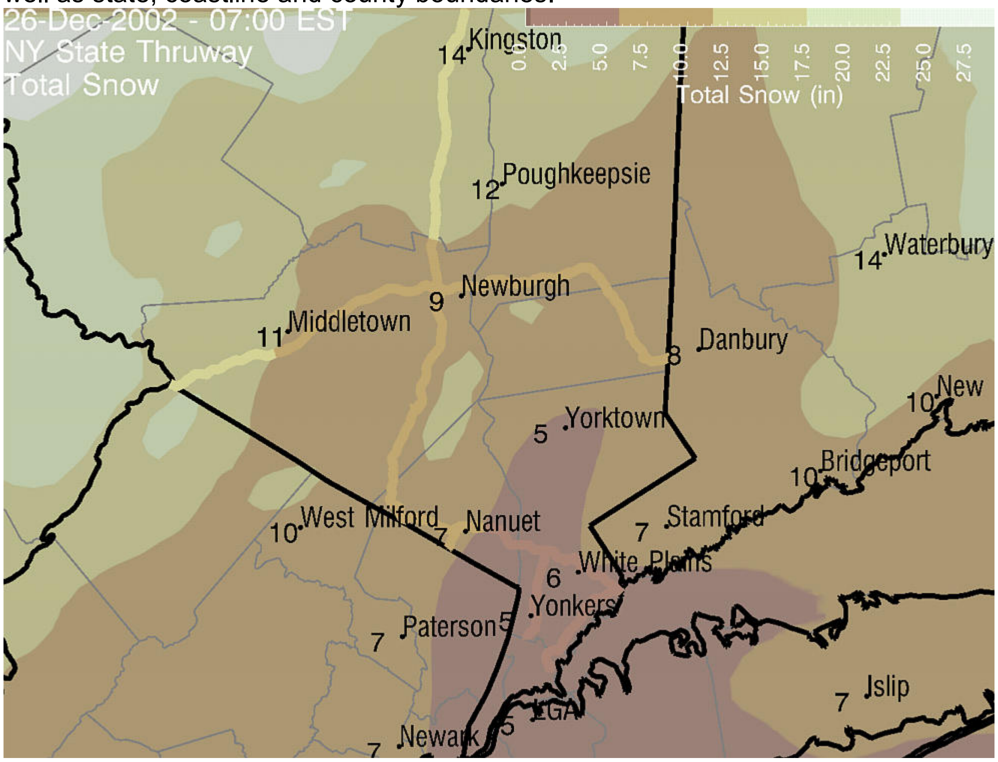

Figure 2. ***Deep Thunder*** **Predicted Snowfall**

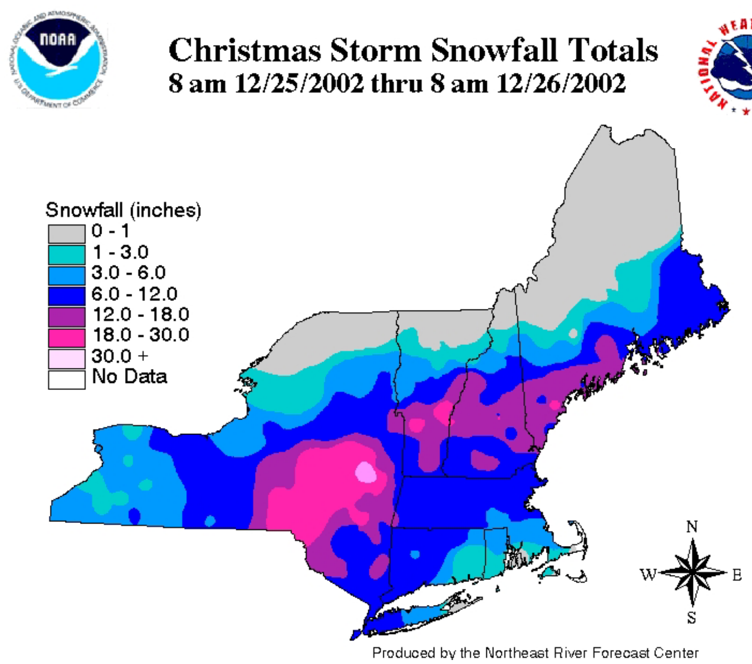

Figure 3. Estimated Snowfall Totals

Figure 3 is an estimated snowfall accumulation map for the storm event from the NWS Northeast River Forecast Center. There is good agreement between the model predicted and observed snowfall both in geographical distribution and total accumulation.

A second case is the President's Day blizzard of February 17 - 18, 2003. This storm was the most significant event of the winter in the northeast. Low pressure developed in the Tennessee Valley and tapped into moisture from the Gulf of Mexico. At the same time, a strong arctic high was building southward from eastern Canada.The low pressure area rapidly redeveloped off the North Carolina coast, then tracked northeast, and was east of Cape Cod by early on February 18.

The model run examined for this event was the 0000 UTC forecast cycle on 2/17/03. Model results and products were available at 0500 UTC (midnight EST) on 2/17. Figure 5 shows the predicted total snowfall accumulation using the dry snowfall algorithm for the 4 km model grid. Figure 6 is the estimated snowfall accumulation map from the NWS Northeast River Forecast Center.

As in the previous event there is good agreement between the model predicted and observed snowfall both in geographical distribution and total accumulation.

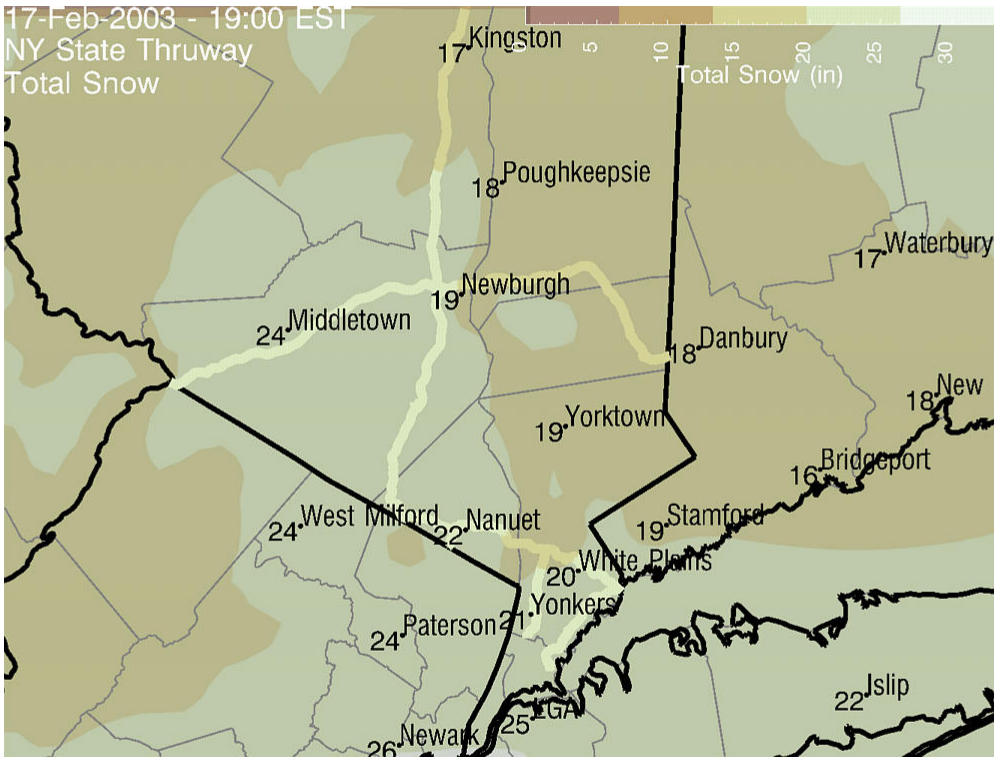

Figure 4. ***Deep Thunder*** **Predicted Snowfall**

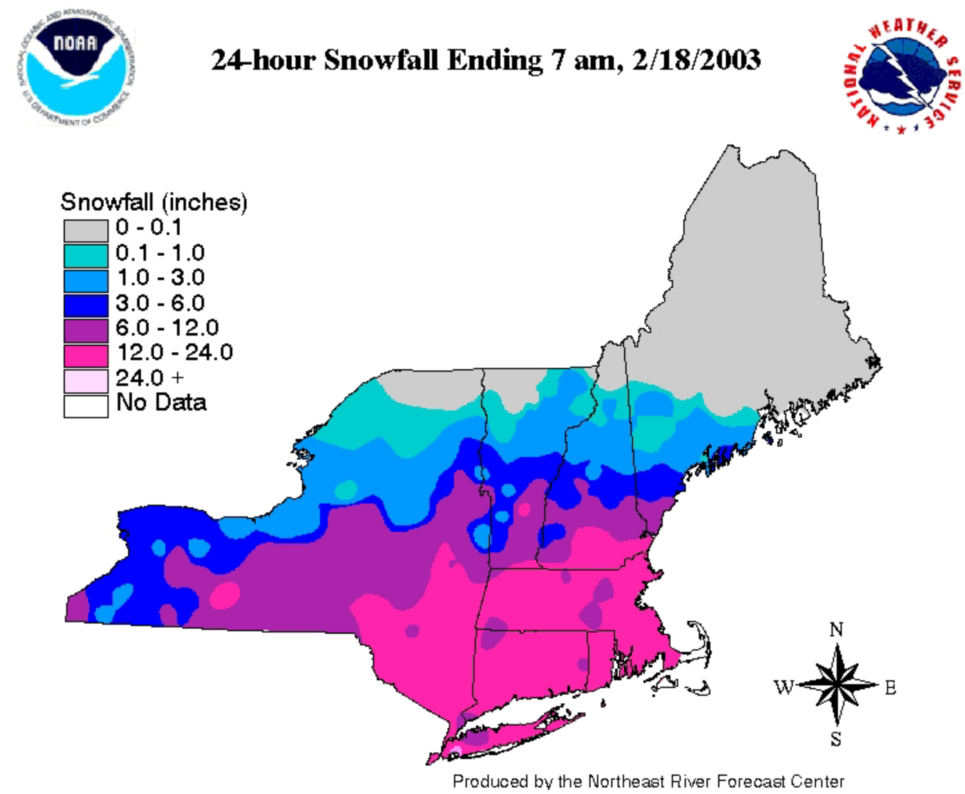

Figure 5. Estimated Snowfall Totals

5. DISCUSSION AND FUTURE WORK

Overall results for the seven events studied were good. *Deep Thunder* demonstrated skill in the regional scale prediction of winter season storms. In many cases the model predictions were available considerably ahead of other forecast data with regard to total storm impacts (snowfall, precipitation onset and ending). While there appears to be a weak positive bias in snowfall accumulation for the dry snow prediction algorithm, the wet snow prediction algorithm has a stronger negative bias. Both of the algorithms have the potential for improvement and will be the focus of future work.

Precipitation timing performance shows a negative bias overall for model predicted onset and ending. It is presumed that data assimilation of observational data would improve performance in this area.

Future work will focus on more robust automation of statistics for verification as well as the aforementioned data assimilation for improved overall model forecast performance.

Computational system issues are also an area of focus in order to improve throughput and provide added capability.

A continued focus is the customization of model products for weather sensitive business operations. Metrics related to end user application of model data which as complementary to the standard meteorological verification benchmarks will also be addressed.

6. ACKNOWLEDGEMENTS

This work is supported by the Mathematical Sciences Department at the IBM Thomas J. Watson Research Center.

7. REFERENCES

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