8A.6 AN OVERVIEW OF PRECIPITATION TYPE FORECASTING USING NAM AND SREF DATA

Geoffrey S. Manikin
NCEP/EMC/Mesoscale Modeling Branch Camp Springs, MD

1. INTRODUCTION

A frequent forecasting problem associated with mid-latitude late fall, winter, and early spring cyclones concerns the type of precipitation that will fall. As noted in Cortinas (1999), sophisticated algorithms are now used to take advantage of high-resolution model output. Even if the predicted thermodynamic profiles are accurate, however, there will be cases in the algorithms struggle to determine whether rain, freezing rain, ice pellets, or snow is most likely.

The operational NAM (formerly Eta) model post processor uses a precipitation type algorithm developed by Baldwin and Contorno (1993), hereafter the NCEP algorithm. It examines the vertical temperature structure to be encountered by a falling hydrometeor to diagnose a single type when it reaches the ground. It identifies layers with temperatures above freezing and ones with temperatures at or below freezing by computing the area between 0°C and the wet-bulb temperature. The entire decision tree approach will be not discussed here, but it is important to note that this algorithm will not diagnose snow if the area in the sounding between -4°C and the wet-bulb temperature is greater than 3000 deg. min.

The result of this area check is that soundings with a deep saturated layer with a temperature between 0 and –4°C will likely not generate an answer of snow. The scheme intentionally over-predicts ice pellets and freezing rain, viewing these two types as more dangerous winter weather. The initial studies performed when constructing the algorithm showed several cases in which the observed vertical temperature profile had no values above 0, yet freezing rain or ice pellets was observed, likely due to supercooled water processes. The goal of the scheme is to have a higher probability of detection of a frozen event. The NCEP algorithm will determine freezing rain for a sounding like shown in Fig.1.

Another popular algorithm is the Ramer (Ramer 1993), which is based on the ice fraction of precipitation reaching the ground. This code

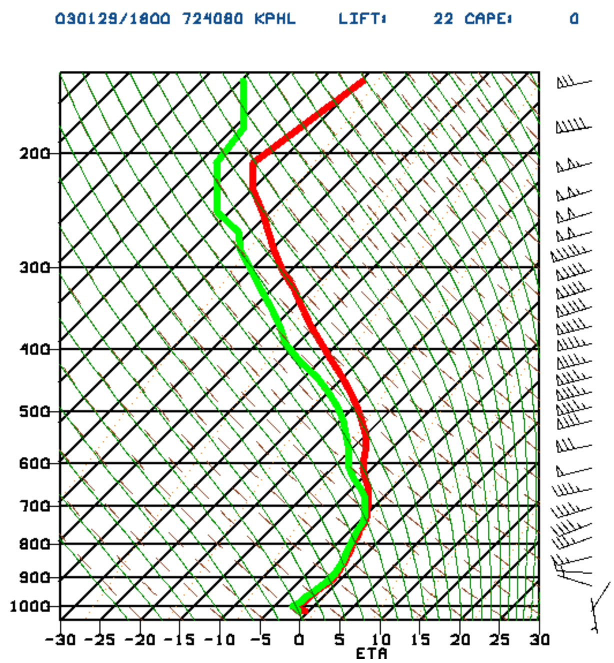


Fig. 1. NAM forecast sounding for Philadelphia,. PA valid 1800 UTC 28 January 2003.

assumes that a hydrometeor will melt or freeze depending upon the wet-bulb temperatures it encounters during its descent. An ice fraction is computed during the descent, and the value is used with the wet-bulb temperature at the lowest model level to determine the precipitation type. It should be noted that this algorithm occasionally makes the determination that it is unable to reach a decision. The code used for this experiment assigns ice pellets as the outcome in this scenario, as it must choose one, and this option is thought to come closest to representing the idea of a mix.

The Bourgouin algorithm (Bourgouin 1992) is somewhat similar to the NCEP algorithm, as it determines whether enough energy is available in the environment to melt or freeze hydrometeors. It computes the areas bounded by 0ºC and temperatures in the profile above freezing and below, and the magnitudes of these melting and freezing energies determine precipitation type. Various thresholds are used to construct requirements for energies in layers aloft and based at the surface in the decision process.

Corresponding author address: Geoff Manikin, NCEP/EMC, 5200 Auth Road, Room 204, Camp Springs, MD 20746. geoffrey.manikin@noaa.gov

2. NAM PRECIPITATION TYPE METEOGRAMS

Due to forecaster concerns about the biases of the NCEP scheme, a mini-ensemble of NAM model precipitation type solutions was developed in 2003 to assess the range of possible outcomes. Unlike most true ensembles, this one does not rely on different model integrations run with different initial conditions or convective schemes or some other modification to create unique solutions. Instead, it applies different post-processing techniques to the single high-resolution operational NAM model run. Three precipitation type algorithms run on the identical thermodynamic profile and an explicit field from the model microphysics are brought together to form this "mini-ensemble." Raw model profile data is gathered for over 1000 stations within the NAM model domain. These are essentially all of the stations at which model station time series bufr data is generated (tropical sites are omitted). The data is for the grid point (specified as land or water) nearest to the station; no interpolation is performed. The locations can be viewed at the web site for this project: http://www.emc.ncep.noaa.gov/mmb/precip_type A sample regional map showing locations in the northeast with clickable stars linking to the plots for the individual stations is shown in Fig. 2. For those unable to click on the stars due to browser issues, the six-digit station identifier can be entered on the main page where a list of available stations is located.

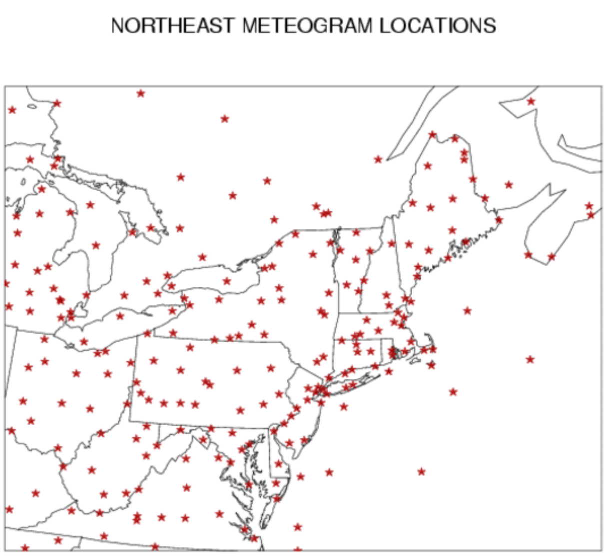


Fig. 2. Map of available stations in the northeast U.S. region. The domain is broken down into nine regions

The station data is passed through three different precipitation type algorithms. The first is the current version of the NCEP algorithm. The second is a modified version of the same algorithm. Instead of the –4°C area check, it computes the area in the sounding with a wet-bulb temperature greater than 0°C. If this area is more than 500 deg. min., then snow is not possible. In the example in Fig. 1, snow will be predicted because there is no area with a temperature above freezing. This version of the scheme attempts to balance the frozen precipitation bias of the regular version by having a bias towards snow. The third scheme is the Ramer

The final piece of the puzzle is the explicit percentage of frozen precipitation from the NAM grid-scale microphysics. This value groups together snow and sleet (frozen) and rain and freezing rain (both considered non-frozen). It will not distinguish between snow and sleet; nor will it distinguish between rain and freezing rain. It is a percentage, not a probability.

A sample set of meteograms generated by this mini-ensemble is displayed in Fig. 3. The most important traces are the second and third. The second displays wind direction and hourly amounts of total precipitation. The third then shows the predicted precipitation type from the NCEP algorithm (purple, bottom symbols), the revised NCEP algorithm (dark blue, middle), and the Ramer algorithm (light blue, top). (Note: precipitation types are generated when even just a trace of precipitation is generated by the model.) The percentage of frozen precipitation is the solid green line with the value axis on both sides. The first and last meteograms are more cosmetic, providing some information to give a quick view of the thermal profile. The predicted 2-meter temperature and dew point values (Fahrenheit) are shown on the top meteogram, and predicted temperatures (Celsius) every 50 hPa between 700 and 950 hPa are displayed at the bottom. Again, this is not the complete vertical profile and is intended to be merely a snapshot.

3. INTERPRETATION

Precipitation type is not yet part of the EMC verification data base, so no verification of any of the meteograms has been performed. All of the following comments are therefore subjective and represent the feedback provided by various users and observations of the author..

In Fig. 3, precipitation is predicted to fall at Philadelphia over an approximately 10-hour period at the beginning of the cycle. The NCEP algorithm predicts freezing rain. The revised NCEP and Ramer algorithms predict snow. The sounding in Fig. 1 is a model forecast valid for 1800 UTC on 29 January, six hours to the right of the start time on the bottom axis of Fig. 3. Inspecting the sounding shows that this is certainly a case in which the operational algorithm is predicting freezing rain because there is a deep layer in the profile with a temperature between –4 and O°C. The snow prediction with the alternate area criterion in the revised version confirms this, and the same prediction from the Ramer gives more confidence the snow is more likely. The 100 value for the percentage of frozen precipitation is a final voice of agreement for snow.

The verifying observations from Philadelphia are shown in Fig. 4 and show that only snow fell at this location, consistent with the majority prediction from the mini-ensemble. It is the opinion of the author that the Ramer algorithm can often be used to "break the tie" between the two versions of the NCEP algorithm, with high confidence gained if

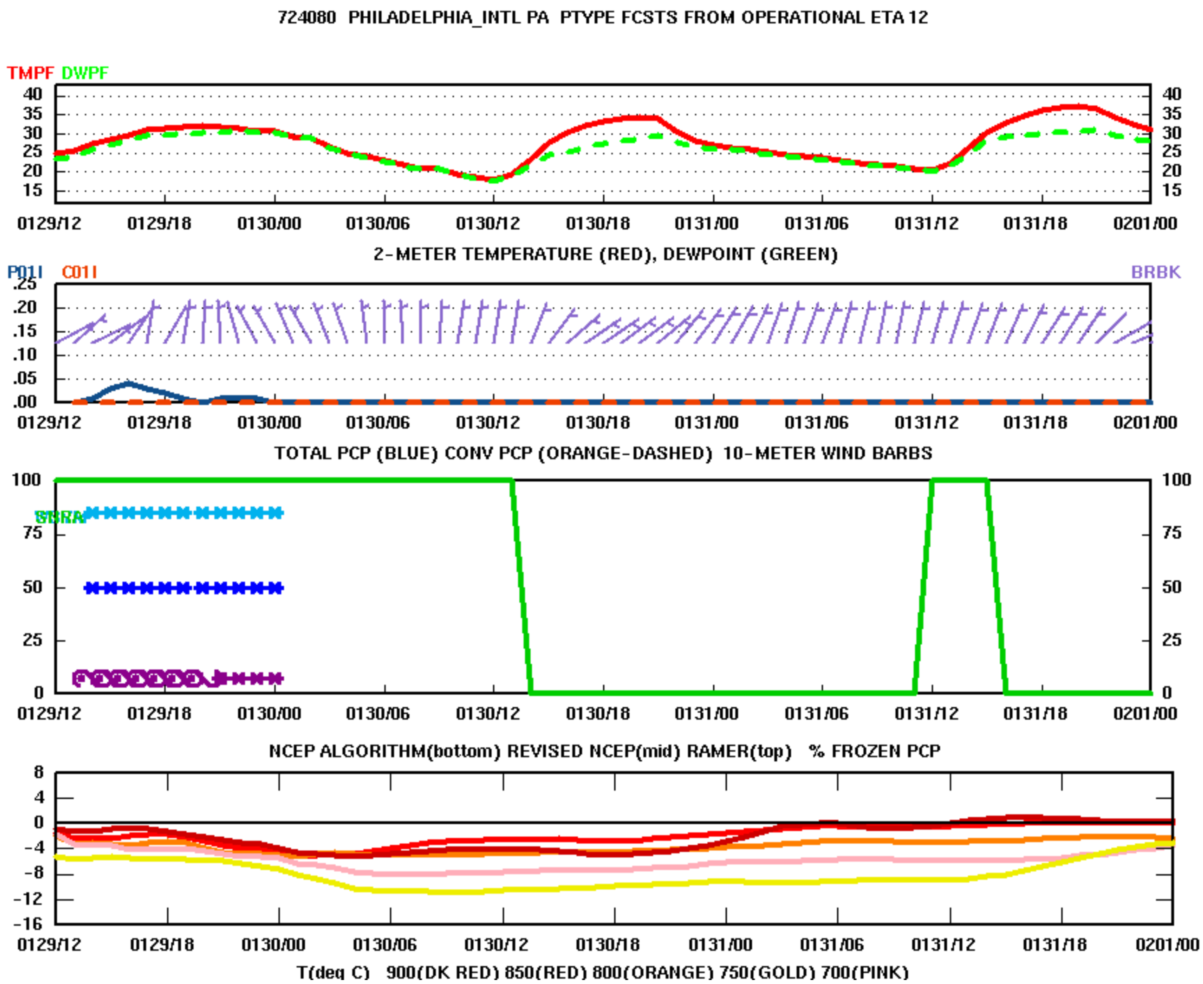


Fig.3 Set of precipitation type meteograms for Philadelphia, PA from the 1200 UTC Eta cycle 29 January 2003.

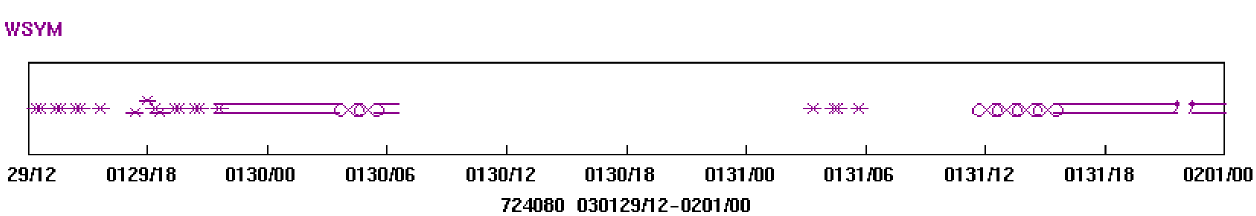


Fig. 4 Observed weather symbols from Philadelphia observations, valid for the same time period as Fig. 3.

the percentage of frozen precipitation value is consistent with the majority of the algorithms.

Fig. 5 shows another set of meteograms, this one for Syracuse, New York from the 1200 UTC NAM cycle of 4 April 2003. In the first 12 hours, there is significant disagreement within the ensemble. Both versions of the NCEP algorithm point to a primarily ice pellets event, with some freezing rain and even rain mixed in. The Ramer algorithm, on the other hand, calls for an ice event. The percentage of frozen precipitation is low, arguing against ice pellets being the dominant precipitation type. While drawing a deterministic conclusion for the type likely can not be done, freezing rain would have to be considered as a bigger threat than the NCEP algorithm would suggest, and the observations shown in Fig. 6 indicate that this was primarily an ice event in Syracuse. .

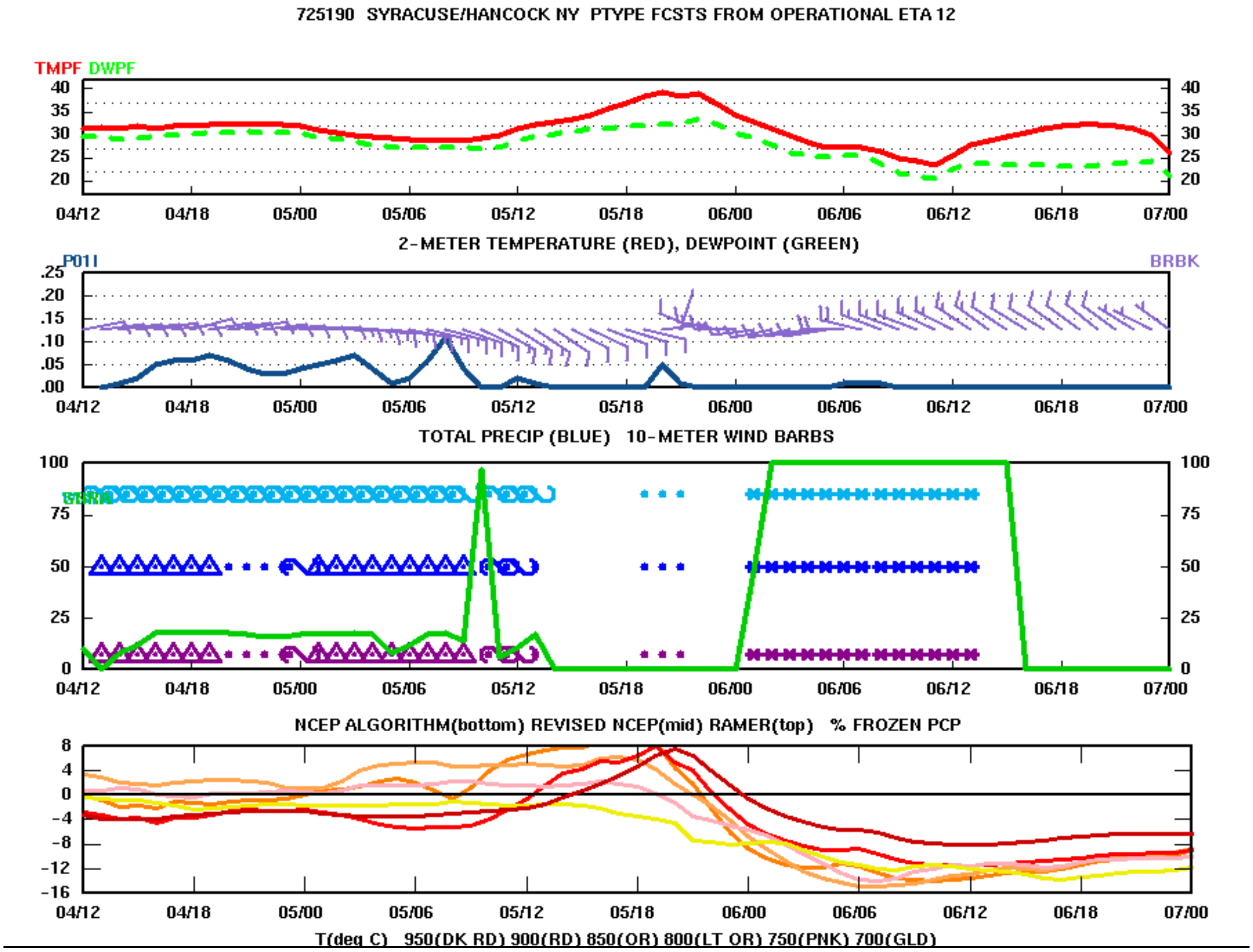


Fig. 5. Set of precipitation type meteograms for Syracuse, NY from the 1200 UTC NAM cycle 04 April 2003.

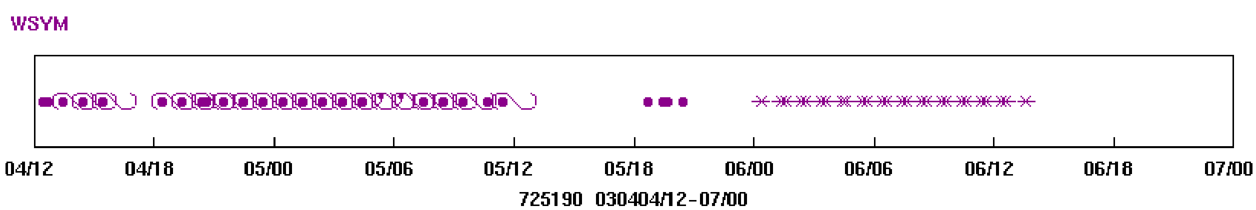


Fig. 6. Observed weather symbols from Syracuse observations, valid for the same time period as Fig. 5.

One problem with the percentage of frozen precipitation variable is that it, in effect, can have a low bias towards detection of ice pellets. Fig. 7 shows a set of meteograms for Albany, NY, for the same event as in Fig. 5. Each of the algorithms agrees that ice pellets are the likely precipitation type for much of the event, yet the percentage of frozen precipitation is less than 20. The forecast sounding for 0600 UTC 5 April (Fig. 8) shows a classic profile for ice pellets; a falling snowflake encounters a warm layer and then passes through a deep cold layer on its path to the surface where it remains colder than the freezing point. The low percentage comes from the fact that the microphysics do not allow full freezing of the melted hydrometeor until the temperature is colder than –5°C. The sounding shows that while the near-ground layer with a temperature below 0°C is deep, the layer with the temperature colder than –5, where re-freezing would occur, is shallow. As a result, only partial freezing occurs, making the percentage a small but non-zero number.

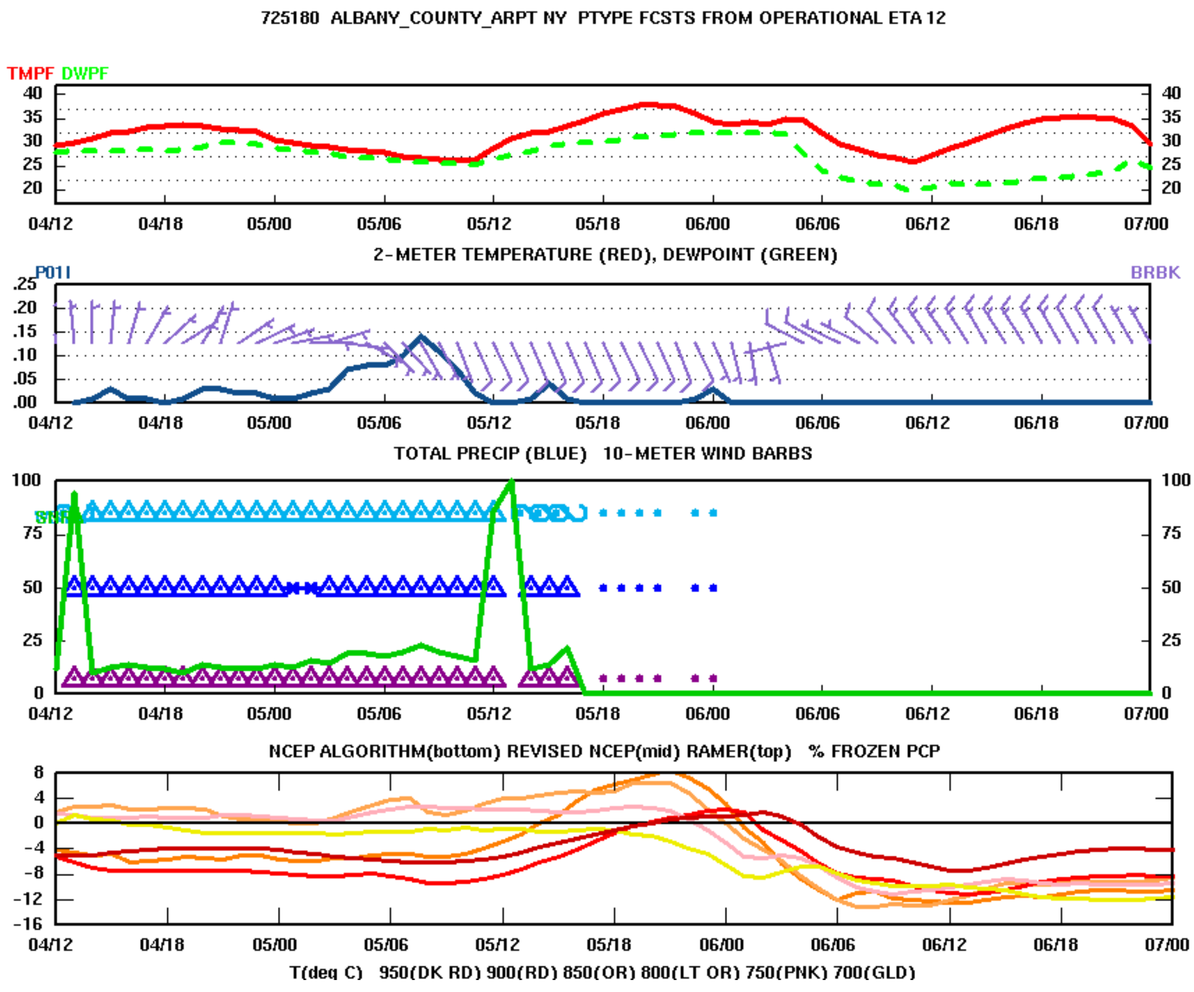


Fig. 7. Sample set of precipitation type meteograms for Albany, NY from the 1200 UTC NAM cycle 04 April 2003.

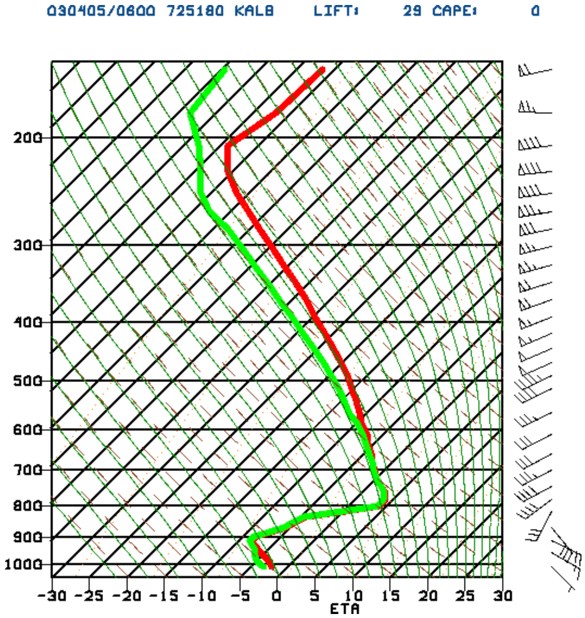
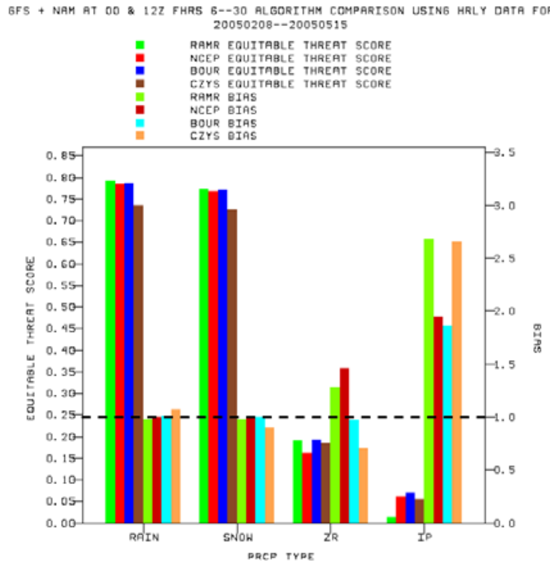


Fig. 8. 6-hr NAM forecast sounding for Albany, New York valid 0600 UTC 5 April 2003.

4. WINTER 2005-06

Several changes are planned to precipitation type guidance for the EMC model suite in the winter of 2005-2006. For the operational NAM, the post processor has been modified to add the revised NCEP, Ramer, and Bourgouin algorithms, and code to generate a precipitation-type "look-alike" product explicitly from the microphysics will be developed. This will give five solutions for precipitation type for each run, and the dominant precipitation type will be determined. At this time, EMC does not intend to output the solution from all 5 algorithms, but we will likely continue to generate the four output fields (categorical rain, snow, ice pellets, freezing rain) from the NCEP algorithm and add the same four fields for the Ramer algorithm.

The choices for algorithms are based on results obtained by NCEP's Hydro-meteorological Prediction Center (HPC) obtained in the winter of 2005-06. The results shown in Fig, 9 compare data obtained from running several of the algorithms already discussed as well as the Czys (Czys et al. 1996). The high bias for freezing rain and ice pellets of the NCEP algorithm is clearly shown, and it is present for the Ramer as well. Needing to eliminate one of the four schemes, the low equitable threat rain and snow scores for the Czys scheme made it the best candidate to not be included, but the choice was not easy and is still being evaluated.



Fig, 9. HPC verification scores for various precipitation type algorithms for the winter of 2005-06. For each type, the first four bars are skill scores with the left-side scale; the second four bars represent bias with the right-side scale.

The alternate precipitation type algorithms will also be applied to the Short-Range Ensemble Forecasting system (SREF, Tracton et al. 1998). Five precipitation type solutions will be available for all 15 members. (The microphysical scheme in the Regional Spectral Model (RSM) members differs from the NAM members, but a precipitation type can still be generated.) This raises an interesting issue when computing a dominant precipitation type for the entire ensemble. Consider the following scenario in which a five-member ensemble is run, and all precipitation type algorithms determine that either rain or snow will occur:

	SNOW	RAIN	DOMINANT
MEMBER 1	3	2	SNOW
MEMBER 2	3	2	SNOW
MEMBER 3	2	3	RAIN
MEMBER 4	3	2	SNOW
MEMBER 5	0	5	RAIN
	-----	------	
TOTAL	**11**	**14**	

In this situation, one has two options in determining the dominant type for the ensemble. If one first determines the dominant type for each member and then sums up the five answers in the far right column, snow would be the dominant type based on a 3-2 victory. If, however, one instead sums the 25 individual solutions (5 answers for 5 members), then rain is the dominant type on the basis of a 14-11 win.

The initial strategy at EMC is to use the former approach. The choice is muddied by the mixing of variability due to different algorithms and variability due to different model solutions. For example, in the above example, it is likely that the lack of consensus within the solutions for each of the first four members is due to different algorithms acting differently on thermodynamic profiles very close to the critical thresholds. On the other hand, the fifth member is likely an outlying warm solution. The danger of the second method is giving too much weight to a solution that is a synoptic outlier. EMC is currently opting to sum up the dominant types for each member (note: a precipitation type solution is only generated when the model generates non-zero precipitation at a grid point), but it should be noted that the issue is still being discussed at the time of this writing.

5. CONCLUSIONS

EMC will enhance its precipitation type output in the winter of 2005-06. Alternate schemes will be used to offset the know biases of the NCEP algorithm. Dominant precipitation type output will be available for the operational NAM and SREF, and some of the output from the individual schemes may be available for the NAM.

For those unable to view the new output, the station time series NAM meteogram site will be maintained. It should be emphasized that the skill of this mini-ensemble as well as the skill of additional precipitation type fields in the NAM is directly tied to the accuracy of the forecasted temperature profiles in the NAM. It does not attempt to account for the initial condition uncertainty which inevitably leads to errors in the thermodyamical predictions which obviously increase with forecast length. These products have little use if the forecaster has reason to believe that the model temperature profile is incorrect. Forecast soundings should always be inspected when making a precipitation type prediction. The SREF should be used to resolve uncertainty with regards to synoptic evolution.

6. REFERENCES

Baldwin, M. E., and S. P. Contorno, 1993: Development of a weather-type prediction system for NMC's mesoscale Eta model. Preprints, *13th Conf. On Weather Analysis And Forecasting*, Vienna, Virginia, Amer. *Meteor.* Soc., 86-87.

Bourgouin, P., 1992: Criteria for determining precipitation types. Preprints, *4th Workshop on Operational Meteorology. Whistler, BC,* AES/CMOS, 460-469.

Cortinas, J. V., and M. E. Baldwin, 1999: A preliminary evaluation of precipitation-type algorithms for use in operational forecasting. Proceedings, *6th Workshop on Operational Meteorology,* Halifax, Nova Scotia, Environment, Canada, 207-211.

Czys, R. R. Scott, K.C. Tang, R. W. Przybylinski, and M. E. Sabones, 1996. A physically-based, nondimensional parameter for discriminating between locations of freezing rain and ice pellets. *Wea. Forecasting*, 11, 591-598.

Ramer, J., 1993: An empirical technique for diagnosing precipitation type from model output. Preprints, *5th Conf. On Aviation Weather Systems*, Vienna, Virginia, Amer. Meteor. Soc., 227-230.

Tracton, M.S., J. Du, Z. Toth, and H. Juang, 1998: Short-range ensemble forecasting (SREF) at NCEP/EMC. Preprints, *12th Conf. On Numerical Weather Prediction, Phoeni*x Arizona, Amer. Meteor. Soc., 269-272.