AN ETA MODEL PRECIPITATION TYPE MINI-ENSEMBLE FOR WINTER WEATHER FORECASTING

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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.

In this study, a mini-ensemble of Eta model precipitation type solutions is used 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 Eta 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."

The Eta model post processor uses a precipitation type algorithm discussed 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 the ground is reached. 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 snow for a sounding like shown in Fig.2.

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2. METHODOLOGY

Raw model profile data is gathered for over 1000 stations with the Eta 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://wwwt.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. 1. For those unable to click on the stars due to browser issues, the 6-digit station identifier can be entered on the main page where a list of available stations is located.

NORTHEAST METEOGRAM LOCATIONS

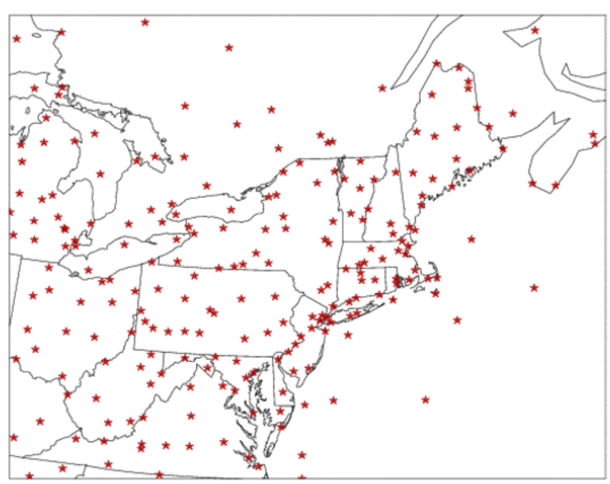

Fig. 1. Map of available stations in the northeast U.S. region. The domain is broken down into nine regions.

The station data is passed through 3 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. 2, 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 algorithm (Ramer 1993). This scheme 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.

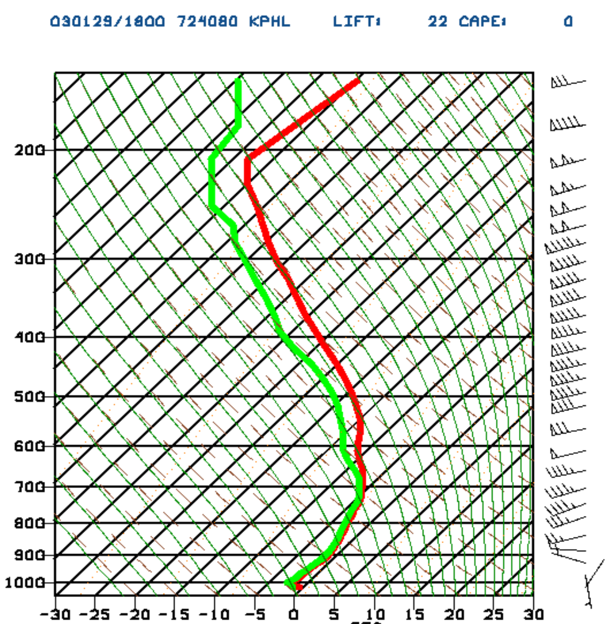

Fig. 2. 6-hr Eta forecast sounding for Philadelphia, PA valid 1800 UTC 29 January 2003.

The final piece of the puzzle is the explicit percentage of frozen precipitation from the Eta 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 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 these products has been performed. All of the following comments are therefore subjective and represent what the authors have observed and the feedback provided by various users.

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. 2 is a model forecast valid for 1800 UTC on 29 January, 6 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 authors that the Ramer algorithm can often be

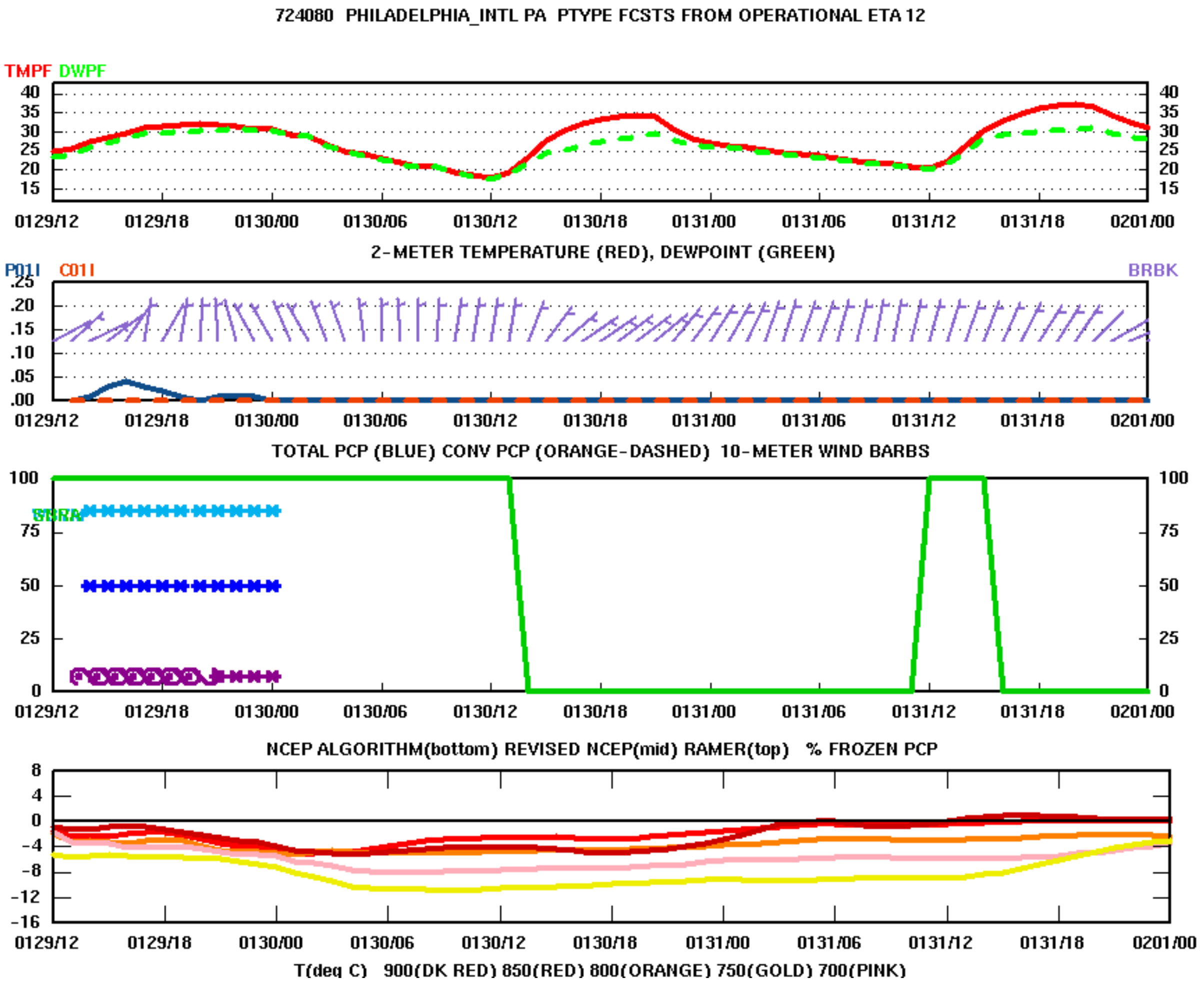

Fig.3 Set of precipitation type meteograms for Philadelphia, PA from the 1200 UTC Eta cycle 29 January 2003.

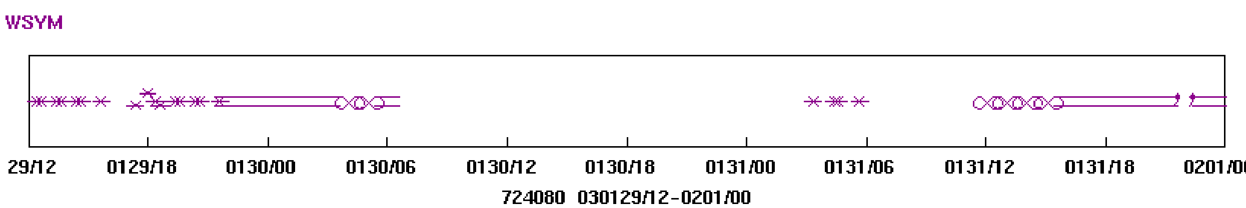

Fig. 4 Observed weather symbols from Philadelphia observations, valid for the same time period as Fig. 3.

used to "break the tie" between the two versions of the NCEP algorithm, with high confidence gained if 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 Eta 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 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. .

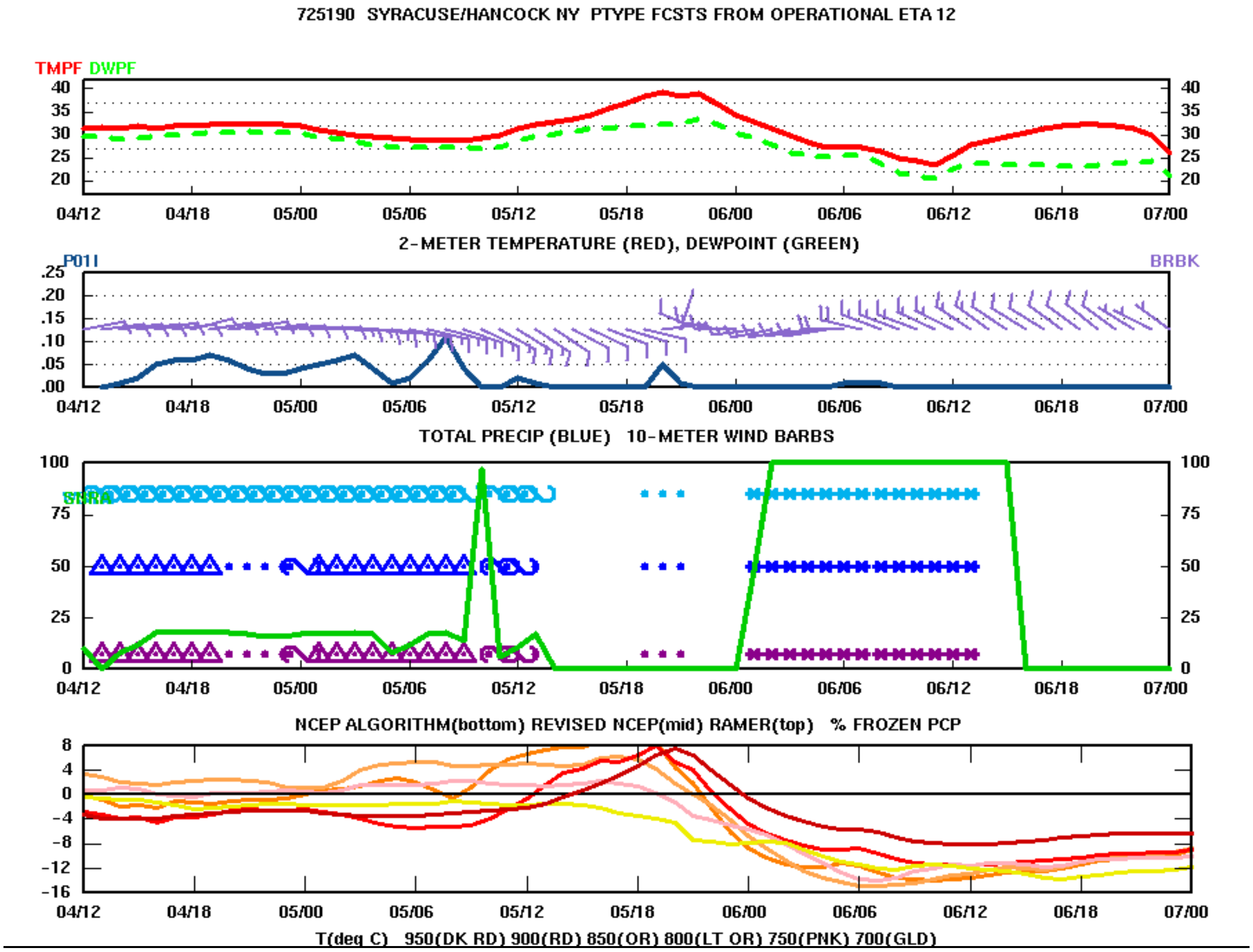

Fig. 5. Set of precipitation type meteograms for Syracuse, NY from the 1200 UTC Eta cycle 04 April 2003.

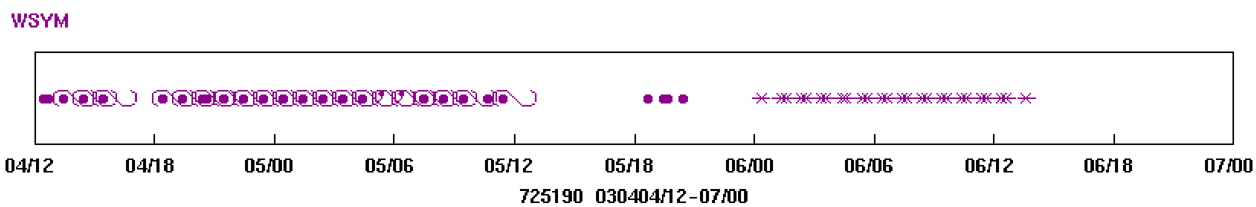

Fig. 6. Observed weather symbols from Syracuse observations, valid for the same time period as Fig. 5.

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.

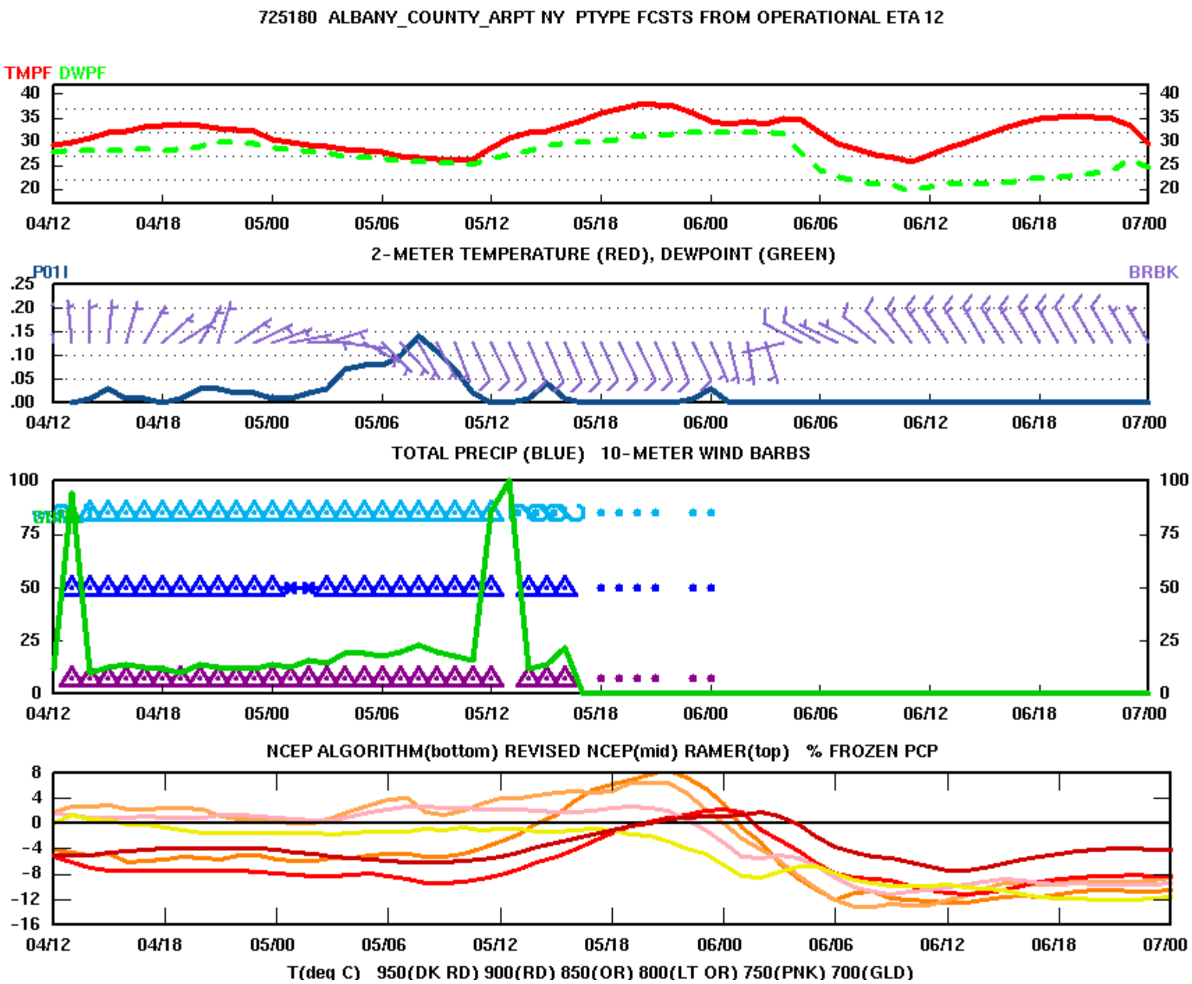

Fig. 7. Sample set of precipitation type meteograms for Albany, NY from the 1200 UTC Eta cycle 04 April 2003.

4. CONCLUSIONS

A web site is available to assist in precipitation forecasting from the Eta model. The NCEP algorithm's forecasted precipitation type is displayed along with an alternate version of the scheme designed to have a higher bias towards snow to balance the operational version which has a bias towards freezing rain and ice pellets. The Ramer algorithm and the model's percentage of frozen precipitation from the grid-scale microphysics comprise the final two members of the mini-ensemble.

The strengths and weaknesses of this product are currently being assessed. It is easy to identify cases in which the operational algorithm is an outlier due to its intentional high bias towards freezing rain and ice pellets. Otherwise, experience in viewing the products suggests that one should treat these forecasts as one would treat the output from any other ensemble. Confidence in a particular solution can be higher if all the members are in agreement, but minority outcomes can not be altogether discounted.

It should be emphasized that the skill of this mini-ensemble is directly tied to the accuracy of the forecasted temperature profiles in the model. This ensemble makes no attempt to account for the initial condition uncertainty which inevitably leads to errors in the thermodyamical predictions which obviously increase with forecast length. This product has little use if the forecaster has reason to believe that the model temperature profile is incorrect; this product, however, is limited to the first 60 hours of output for which it is hoped that these errors are generally small. Forecast soundings should always be inspected when making a precipitation type prediction, but disagreement within this mini-ensemble for a particular event should be a signal to the user that an extra-close inspection is essential.

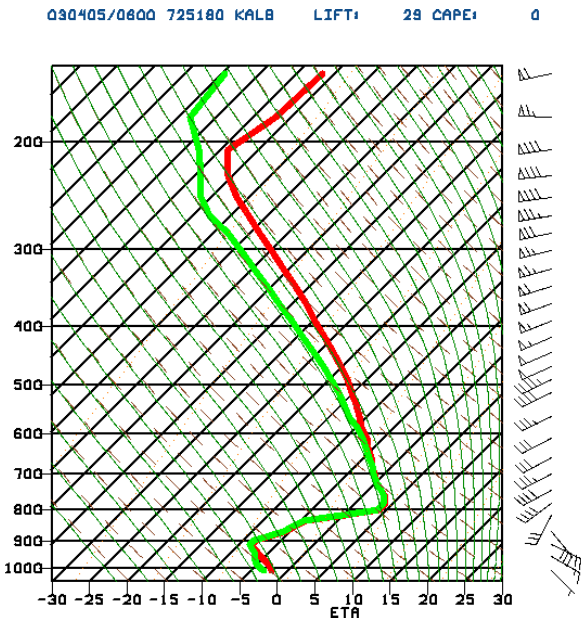

Fig. 8. 6-hr Eta forecast sounding for Albany, New York valid 0600 UTC 5 April 2003.

5. REFERENCES

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