FORECASTING

THE MAGIC CHART FOR FORECASTING SNOW AMOUNTS

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ABSTRACT

One of the major challenges for meteorologists is accurately predicting the amount of snowfall, especially for a major storm. A form of the magic chart was initially experimented with at the NWS Forecast Office at Milwaukee to attempt to pinpoint where the heaviest snowfalls would occur during synoptic-scale storms. During the 1987–88 snow season, a modified form of this chart was used at the NWS Training Center to forecast not only where the heaviest snowfall would occur, but also the amounts during 12-hr periods. The appropriate moisture supply must be expected before the chart is useable. The magic chart is a combination of a 12-hr period 700-mb net vertical displacement (NVD) prog by NMC's Trajectory Model, and a 12-hr prog of the 850-mb temperature field by the NGM. The initial results from one snow season were surprisingly accurate. The physical reasoning behind this approach is also given.

1. INTRODUCTION

During the past several decades, weather forecasters have been struggling with the problem of predicting as accurately as possible the amounts of snowfall from major synoptic systems. More recently, as NMC forecast models improved, some of their output have been applied to this challenge, employing unique approaches. Essentially, the best techniques locate approximately where the heaviest snowfalls would likely occur. Development of a method that predicted actual amounts of heavy snow remained elusive.

It is obvious that a reliable technique for forecasting actual snowfall amounts with a high degree of accuracy, would benefit society. This paper presents the results of a technique known as **THE MAGIC CHART** for forecasting snow amounts, so-named because it is easy to use and works "like magic." Initially, the chart was a modification of the approach tried at the NWS forecast office at Milwaukee (2) for identifying the areas of heaviest snow. Partially by accident, it was discovered that the modified approach did more than locate heavy snow areas; this forecasting scheme actually succeeded in predicting the actual amounts of heavy snow with surprising accuracy.

2. METHODOLOGY

Any weather forecasting scheme must be based on sound physical reasoning. Therefore, a forecasting scheme for snow amounts must be logically developed, based on physical principles.

The magic chart is based on the following assumptions:

1. This approach does not apply to mesoscale snowstorms such as topographical/frictional convergence types and lake-effect snowstorms;
2. Adequate moisture must first be available or forecast to be available,
3. The LFM and its subset, the Trajectory Model, are accepted as being reasonably reliable for the first 24-hr projection, and the NGM for the first 12 hr.

The Steps of the MAGIC CHART Procedure

1. Call up AFOS chart 7WG, which is the 12-hr net vertical displacement, in millibars, for air that will arrive at the 700 mb level 24 hr after initial time. (This displacement is for the 12 to 24 hr time-period after initial time.)
2. Overlay AFOS chart 82T, which is the 12-hr 850-mb temperature prog from the NGM.
3. Where the greatest net vertical displacement (NVD) overlays the temperature region between −3°C and −5°C is where the heaviest snowfall is likely to occur using the following guidance for the time-period 12 to 24 hr after initial time:

NET 12-HOUR VERTICAL DISPLACEMENT	12-HOUR SNOWFALL
20 mb to 40 mb	2″ to 4″
40 mb	4″
60 mb	6″
80 mb	8″
100 mb	10″
120 mb	12″
140 mb	14″
>140 mb	>14″

4. The above procedure works with a mature or developing synoptic low-pressure system but only after determining that adequate moisture will be available for 12 to 24 hr after initial time for that region where the NVD overlays the −3°C to −5° C area. Adequate moisture means temperature-dew point spreads of no more than a few degrees at 850 mb and 700 mb, or a 1000-500 RH of about 90% or greater.

3. EXPLANATION OF FIGURES 1 AND 2:

The presentations overlay AFOS charts 7WG and 82T. Where the −3°C to −5°C temperature band overlays the highest NVD band, is where the heaviest snowfall is predicted for that 12-hr period.

In Figure 1, the −3° to −5°C temperature zone that lies within the +040 isoline of NVD is the area where about 4 in. of snowfall can be expected in the 12-hr period from 0000 to 1200 GMT Wednesday, February 10, 1988. Warmer temperatures lead to a snow/rain transition zone and then to rain; therefore, −3°C is the warmest allowable temperature in this forecasting scheme. Colder temperatures than −5°C lower the amount of moisture (saturation mixing ratio) the air can hold; therefore, the same NVD would yield a lower snowfall

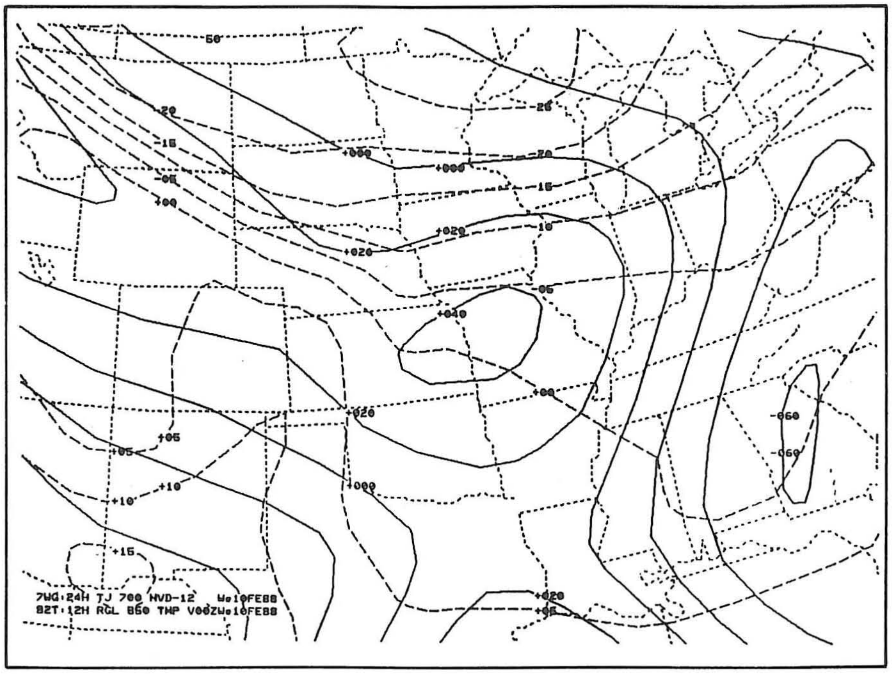

Fig. 1. Two to four in. snowfall forecast for northern Missouri.

amount. In this case, 4 in. was the representative snowfall over northern Missouri during this time period.

In Figure 2, the $-3°$ to $-5°C$ temperature band overlays an essentially $+120$ to $+140$ mb 12-hr net vertical displacement for air that will be at 700 mb 24 hr after the initial time. In this case, 12 in. to 14 in. of snowfall can be predicted for central Illinois during the 12-hr period of 0000 to 1200 GMT Tuesday, December 15, 1987. The actual snowfall during this period for the region was about 13 in. This particular storm was followed from the Plains to the Northeast, employing the magic chart technique. For example, in the prior 12-hr period, the $-3°$ to $-5°C$ area coincided with a $+120$ area over northern Missouri. Thus, 12 in. of snowfall was predicted. The observed snow amounts that fell were from 11 in. to 13 in.

Eight major synoptic storms were followed, using the magic chart to forecast snow amounts. There were several forecasts during the life-cycle of each of these storms. The magic chart was successful in 100% of these cases. This author believes that some of this was due to nothing more than luck. When the magic chart fails, which it undoubtedly will in some cases, the reasons why must be determined. In all of the storms in 1987–88 for which the magic chart approach was used, the LFM and NGM were reliable for the 12- and 24-hr forecasts.

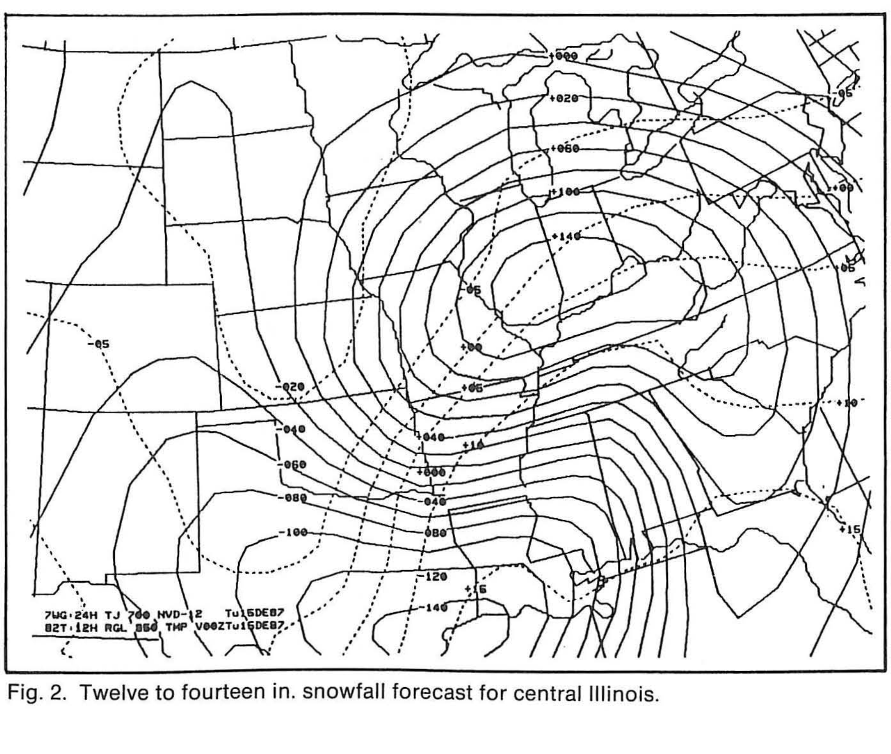

Fig. 2. Twelve to fourteen in. snowfall forecast for central Illinois.

If a model does not have an acceptable diagnosis and prognosis of the weather, then obviously the magic chart cannot be used. The forecaster needs to determine the level of competence of the models' forecasts—sometimes not an easy task.

The meteorological rationale for the magic chart approach needs to be explained, because the technique appears to work exceptionally well, even though it has been applied in this way for only one snow season.

4. METEOROLOGICAL REASONING

This can best be described by a question and answer format:

Question: This method is questionable. Isn't it just another rule-of-thumb scheme?

Response: Try it for a couple of winters to assess it yourself. It works for the area between the Rockies and the East Coast. For the Western Region, a 700-mb temperature threshold seems appropriate and more research and case studies are needed to determine appropriate values. As with all rules-of-thumb, understand the physical reasoning behind it so that you know when to use it and when to suspect it. Also, this approach was presented in a recent talk in Fairbanks, Alaska, suggesting that the technique is not limited to the lower 48 states.

Question: What is the physical rationale for this procedure?

Response: For the heaviest snowfall in a developing or mature synoptic low-pressure system, we are looking for the highest available moisture amounts occurring simultaneously with the greatest synoptic-scale lifting, in a region where the temperature regime is sufficiently cold for snow.

The higher the temperature, the higher the saturation mixing ratio, at the same pressure. Therefore, we are analyzing for the highest moisture content occurring with the highest possible temperatures that are still cold enough for snow. Thus, the 850-mb temperature ribbon of −3°C to −5°C is the choice temperature zone because, if saturated through a deep layer, it would contain the highest volume of moisture (compared with lower temperatures in saturated air). The −3° to −5°C zone also is normally cold enough for snow.

We also want that area to coincide with the strongest synoptic-scale lifting; lifting implies low-level convergence. A strong lift implies strong low-level moisture convergence. If the air being lifted is moist, then the stronger the lift the greater the likelihood of higher amounts of precipitation.

Keep in mind that the temperature-dew point spread must be no more than a few degrees at both 850 and 700 mb before this procedure is useable.

Question: How did you equate the 700-mb NVD values with the snowfall amounts?

Response: This project began as an experiment with meteorological interns doing daily forecasting exercises in the Forecaster Development Course at the weather service's in-house training academy. We noticed that within the −3°C to −5°C band, the heaviest snowfall amounts occurred with the strongest NVDs. During the 1987–88 snow-season, we followed eight major synoptic storms that fit the conditions described earlier for using this method. In each of these storms, two to four 12-hr periods were followed and forecasts made. To our amazement, the technique worked in every forecast episode, for forecasting where the heaviest snow would fall in that 12-hr period as well as accurate amounts. It is a rather nice coincidence that the snowfall amounts correspond to the NVD amounts (e.g., 60 mb relates to 6 in. of snowfall, 80 mb relates to 8 in. etc). For NVDs above 120 mb, it is preferable to forecast "in excess of 12 in." rather than try to pinpoint the value precisely.

Question: The magic chart as herein proposed uses output from the trajectory model but the temperature prognostication from the NGM. Is it not inconsistent to use the NGM rather than the LFM, because the trajectory model is essentially a 3-layer subset of the LFM?

Response: At first impression, it would seem logical to overlay the trajectory model's NVD with the LFM temperature prog. However, in doing this, we found that the forecast snow amounts were slightly displaced, whereas the NGM's temperature forecast had greater accuracy. In dealing with a 12-hr 850-mb temperature forecast, it is true that most of the time the LFM and NGM forecasts should be essentially identical. However, with a large-scale low-pressure system typically undergoing major development, the 12-hr NGM apparently does a better job at delineating the thermal field in the area of that system, compared with the LFM's performance.

Question: What caveats should be kept in mind when using the magic chart?

Response: The magic chart works only when the moisture in the area of concern is forecast to be deep; thus, temperature-dew point depressions through 700 mb should ideally be no more than about 3°C. Moreover, the magic chart is used only for large-scale low-pressure systems and does not include local effects such as orographic, frictional convergence, and lake effect.

Keep in mind, also, that the NGM is still being modified and tweeked, whereas the LFM is not being changed because the MOS equations are based on the LFM. However, it is inconceivable that any good modification of the NGM would harm the 12-hour 850-mb temperature prog.

Finally, the magic chart works only when the 12–24 hr 700-mb NVD prog from the trajectory model is accurate and when the 12-hour NGM 850-mb temperature prog is accurate. If you suspect a forecast problem with either model, do not use the magic chart.

5. RECOMMENDATIONS

Try the magic chart for forecasting the area of greatest snowfall potential, and experiment with forecasting the amounts. It would be prudent not to base official snowfall projections on this procedure unless the magic chart works for your area and the staff knows when to use it.

More seasons of verification are necessary to uphold or dispute the conclusions of the original findings. Moreover, Western mountainous areas would need a scheme developed based on 700-mb temperature forecasts, rather than on 850 mb. Therefore, we need many more case studies to fully substantiate this approach.

NOTES AND REFERENCES

1. Peter R. Chaston is in charge of the Meteorology Program at the NWS Training Center in Kansas City. Previously he was the Meteorologist-in-Charge at the NWS Office at Rochester, NY, and has been stationed at various other NWS offices in the Eastern Region. Chaston received his M.S. in Meteorology from the University of Wisconsin while on a NOAA Fellowship. He is current President of the Kansas City Chapter of the AMS.

2. Sangster, W., and E. Jagler, 1985: NWS Central Region Technical Attachment 85-1, January.