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USING MID-LEVEL THICKNESS PATTERNS AND WARM AIR ADVECTION TO FORECAST HEAVY SNOW

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1. Introduction

Forecasting heavy snow has always been a challenge to forecasters. They have to rely on a variety of techniques to make quality forecasts. Many of these techniques require choosing a path for the surface low and/or 500 mb vorticity maximum. In the age of multiple numerical models, determining the actual path of a feature, such as a 500 mb vorticity maximum, becomes difficult because the models often provide divergent solutions. Many times, reasons to select one model over another are hard to justify.

Not only do solutions differ from model to model, but consistency from run to run for the same model is often lacking. The answer, sometimes, is to select a forecast field which tends to be conservative with time and is consistently well forecast by the numerical models. One such field is the mid-level thickness pattern (the 850-700 mb thickness). In this paper, the use of the mid-level thickness prognosis in successfully forecasting the heavy snow in southern Minnesota on January 19, 1988 is demonstrated. A more thorough discussion of the mid-level thickness prognosis can be found in Umpenhoffer (1968).

2. The Mid-Level Thickness Pattern for the January 19, 1988 Snowstorm

Experience has shown that the location of the 1520-1540 m band of the mid-level or 850-700 mb thickness often correlates well with heavy snow bands that eventually fall in Minnesota from weather systems coming out of the southwestern United States (Umpenhoffer, 1968; Naistat, 1983). This preferred thickness band is one of two variables often used in forecasting heavy snow in Minnesota. Fortunately, the mid-level thickness, once the air mass become saturated, moves very little if at all. Let's review what the mid-level thickness pattern did during the January 19, 1988 snowstorm.

In examining the 36 and 48 hour forecasts from both the Regional (RGL) and the Aviation (AVN) from 0000Z, January 18, 1988 it was seen (not shown in this paper), that the 1530 m mid-level thickness contour was predicted to push northward into southern Minnesota, and then stall there. (The 1530 m line is used since graphically subtracting the 850 mb contours from the 700 mb contours when using 30 m intervals directly yields a 1530 m contour.) The key point is this: EVEN THOUGH THE RGL AND AVN MODELS FORECAST DIFFERENT SURFACE AND UPPER AIR PATTERNS, THE MID-LEVEL THICKNESS FORECASTS FROM BOTH OVER THE UPPER MIDWEST WERE SIMILAR.

An examination of the 12-hour RGL thickness forecast valid at 1200Z, January 19, 1988 showed the favored 1530 m line pushing into southern Minnesota (see Fig. 1). The AVN mid-level thickness forecast for the same time essentially showed the same pattern as that depicted by the RGL even though different surface and upper level patterns were expected. The 24-hour RGL forecast verifying at 0000Z, January 20, 1988 showed the key 1530 m thickness stalling along a FRM-MSP line (see Fig. 2). The AVN mid-level thickness forecast for the same time (not shown), although showing different surface and upper air forecasts, again showed the same thickness pattern as that depicted by the RGL!

Even more striking was the fact that although the RGL was inconsistent from run to run on its forecast position of the surface and upper air features, it's mid-level thickness forecast remained unchanged. This was also true of the AVN runs as well!

The conservative nature of the mid-level thickness prognosis allowed Minneapolis (MSP) forecasters to "zero-in" on the potential for a significant snowfall in southern Minnesota as early as 0900Z on January 18, 1988. Of course, the mid-level thickness prognosis only gives the thermally favored location for possible heavy snow. To properly assess the amount of snowfall, a dynamic technique needs to be used as well. For this storm, MSP forecasters relied on B. J. Cook's empirically derived Snow Index.

3. The B. J. Cook Snow Index for the January 19, 1988 Snowstorm

The Cook Snow Index is well documented elsewhere (Cook, 1980). Very briefly stated, given that 700 mb warm advection is occurring, the average snowfall in inches to be expected will be about one-half of the 24 hour forecast of warm advection in degrees C at 200 mb. The advection is measured from the 200 mb warm core to the 200 mb cold core, but this distance should not exceed 14 degrees latitude.

Strong 200 mb warm advection became evident over the southwestern United States as early as 0000Z, January 18, 1988 (not shown). By 0000Z, January 19, 1988 (see Fig. 3), the intensity of the 200 mb warm advection suggested a potential for a snowfall averaging five inches (10 degrees of warm advection divided by 2). The author has noted that the absolute difference (in this case 10) often yields the maximum amount. By 1200Z, January 19, 1988 (see Fig. 4), the area of 200 mb warm advection was moving towards southern Minnesota. The Cook index suggested that six (average) to 12 inches (maximum) of snowfall could be expected.

4. A Composite Forecast of Heavy Snow on January 19, 1988

Using either the mid-level thickness prognosis or the Cook Snow Index independently can easily lead the forecaster into forecasting too much snow, too soon, and in the wrong area. It is by combining these techniques that

Fig. 1. 12-Hour RGL forecast from 0000Z, January 19, 1988 of the 1530 m contour of the 850-700 mb thickness field.

Fig. 2. 24-Hour RGL forecast from 0000Z, January 19, 1988 of the 1530 m contour of the 850-700 mb thickness field.

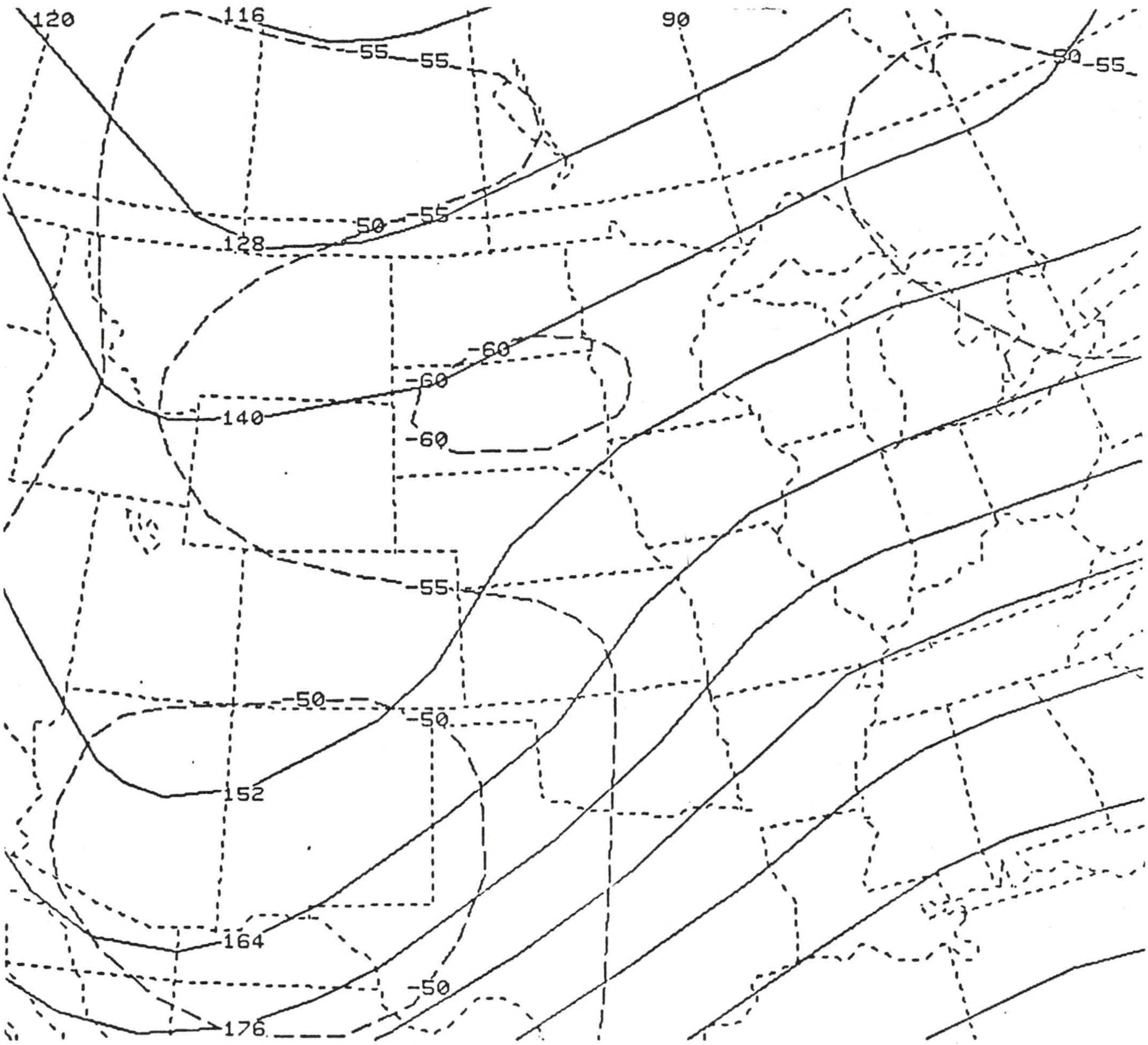

Fig. 3. Observed 200 mb height contours (solid) and isotherms (dashed) for 0000Z, January 19, 1988.

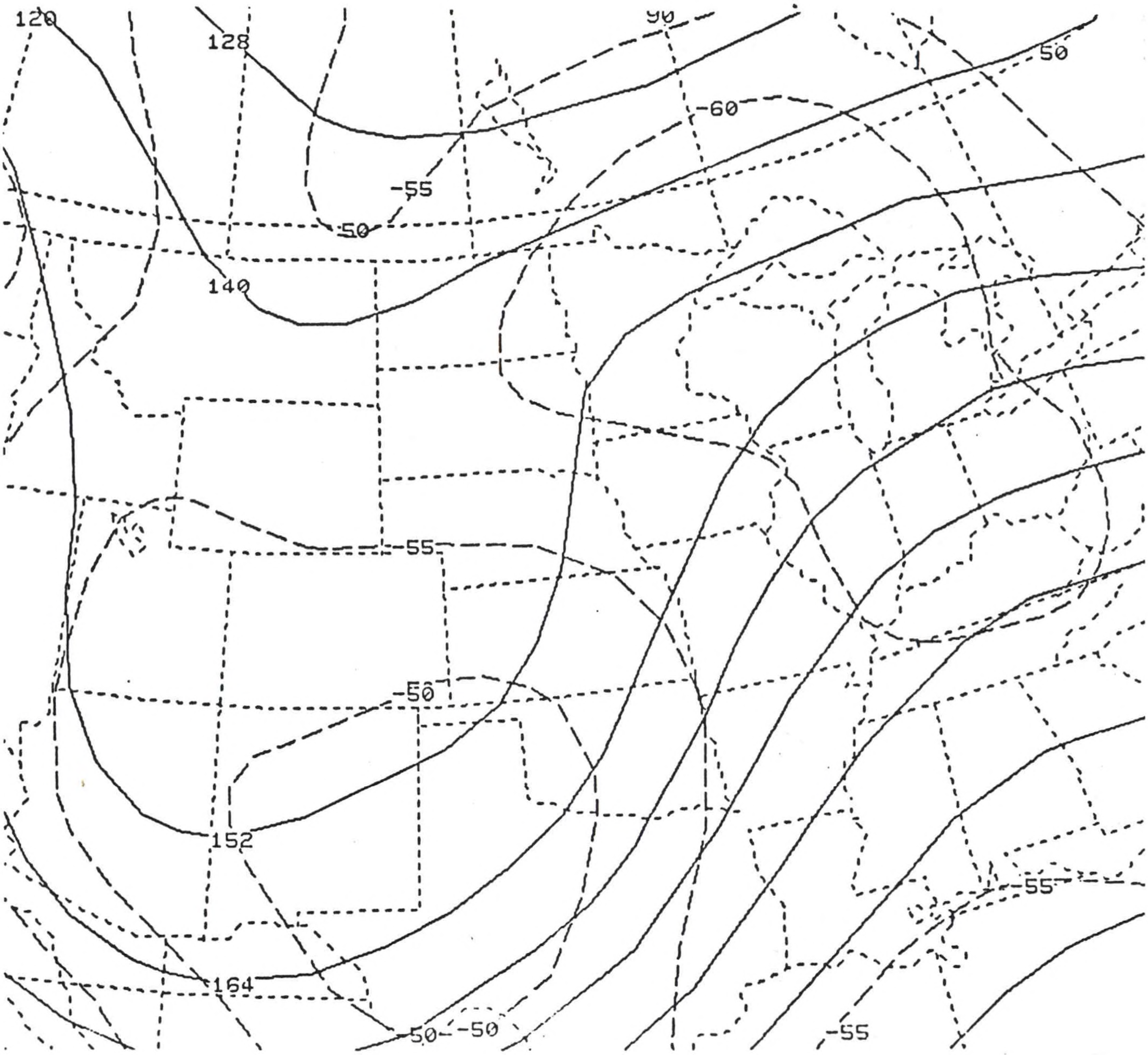

Fig. 4. Observed 200 mb height contours (solid) and isotherms (dashed) for 1200Z, January 19, 1988.

confidence and accuracy can be substantially enhanced. Let's examine what actually transpired. At 1200Z, January 19, 1988 the strong 200 mb warm advection was moving into Minnesota (see Fig. 4). Previous AVN and RGL mid-level thickness forecasts had basically verified well for 1200Z, January 19, 1988. The observed mid-level thickness pattern for 1200Z, January 19, 1988 is shown in Fig. 5.

Both indicators pointed strongly to forecasting heavy snow for the south half of Minnesota in the late morning update at 1600Z on January 19, 1988. Despite the RGL, and AVN models having yo-yo'd on the strength and position of the upper air and surface features, the forecaster was in a good position to issue a detailed and reasonably confident forecast of heavy snow. The salient features were detailed in the Minneapolis state forecast discussion (SFD) at 1550Z:

H2 WAA VERY POWERFUL. -48 at AMA to -62 AT STC AT 12Z. THIS SUGS SNOWFL AXIS OF 7 INCHES ACROSS SRN MN THIS AFTN AND TNGT. MID LVL THICKNESS BAND OTG TO MSP AT 12Z WILL TILT WITH TIME (MOVG EWD ACRS SWRN MN BUT REMAING STNRY OVR MSP). THESE 2 PARAMETERS ARE THE BEST HVY SNOW FALL INDCTORS. ON JAN 20, 1982 WITH THESE 2 INDCTORS POINTG TO HVY SNW AT MSP...17 INCHES FELL...ALTHO THE SFC LO TRACKED OVR TN. ISSUG WSW TO COVER HEAVY SNOW AREA AND LATER THE BLOWG SNOW. ISSUG WXD AS BUFFER ZN JUST N OF WSW. JUST SAW 93S...SUPPORTS OUR REASONG.

In point of fact, the warning discussed in the SFD was issued in between receiving the 19/12Z Early (ERL) model output, which failed to predict heavy snow, and the MOS output which also failed to predict heavy snow at MSP. The RGL guidance arrived after the forecast and while doing a good job, did not have the heavy snow far enough north.

5. What Really Happened

Fig. 6 shows the observed snowfall for the January 19-20, 1988 snowstorm in Minnesota. In southern Minnesota the snow fell between 1800Z, January 19, 1988 and 0600Z, January 20, 1988. Incredibly six to 12 inches of snow fell across southern Minnesota (don't expect results to be this good all the time!) just as the superposition of the mid-level thickness prognosis and Cook Snow Index suggested. The eight to 12 inches of snow that fell in west central Minnesota was a combination of two to four inches falling between 1200Z, January 19, 1988 and 1200Z, January 20, 1988 AND a blast of snow that fell there between 0600Z and 1200Z on January 19, 1988. This heavy snowfall resulted from a combination of a smaller area of 200 mb warm advection that grazed west central Minnesota that night and upslope flow.

6. Summary

Rather than trying to choose the "right model" to forecast heavy snowfalls, forecasters can sometimes benefit from looking at more conservative model parameters such as manually derived thickness fields. In the case described in this

Fig. 5. Observed 1530 m contour of the 850-700 mb thickness at 1200Z, January 19, 1988.

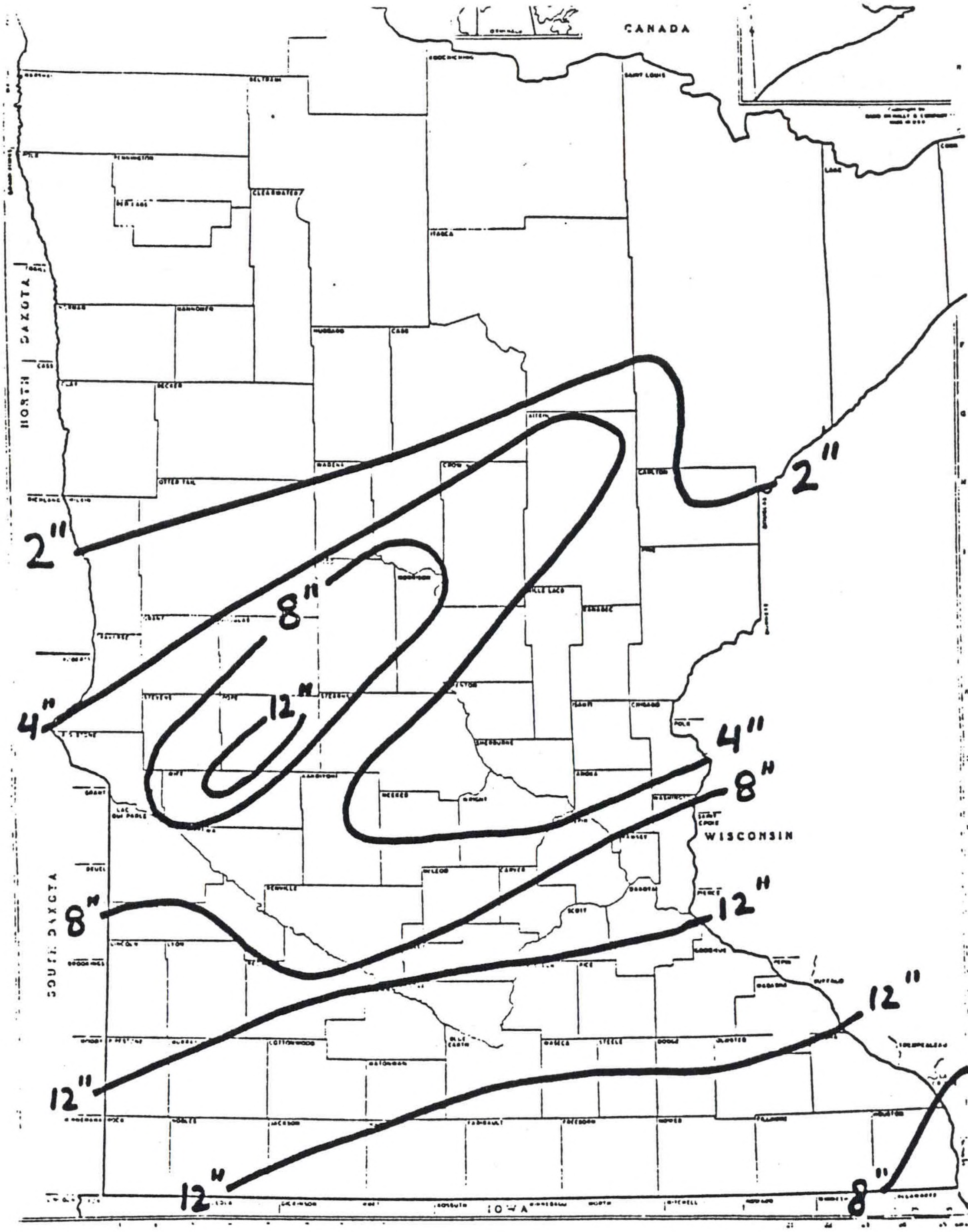

Fig. 6. Observed snowfall over Minnesota from 0600Z, January 19, 1988 to 1200Z, January 20, 1988.

paper, the forecast was based on a simplistic (but accurate) line of reasoning. In review:

A. The 850 mb field was graphically subtracted from the 700 mb field on all available model runs to yield a mid-level thickness prognosis. The 1530 m value of the mid-level thickness was located. It was forecast to change little from run to run, even though other features were forecast to vary considerably.

B. When the 1530 m line finally arrived in Minnesota, forecasters had the mind set to "go with the warning, if need be." All that was needed was a good assessment of possible snowfall. This was obtained from the Cook Snow Index.

7. References

Cook, B. J., 1980: A Snow Index Using 200 mb Warm Advection. Nat. Wea. Dig., 5.

Naistat, R. J., 1983: Heavy Snow Forecast Checksheet (unpublished). Available from National Weather Service Forecast Office, Minneapolis, MN.

Umpenhoffer, C. M., 1968: Low level thickness charts. Det. 42, 7th Weather Wing (MAC), Kansas City, Missouri. Unpublished report available from National Severe Storms Forecast Center, Kansas City, MO 64106.