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IMPACT OF SNOW COVER ON NGM FORECAST TEMPERATURE

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I. Introduction

This report was written in response to a memo from Jim Kaplan at the WSFO in Denver in which he brought to our attention an NGM forecast with significant low level temperature errors in the western U.S. Jim suggested that there may have been too much radiational cooling in the model. After looking into the situation it was determined that there may have been too much snow cover in the Rockies which could lead to excessive radiational cooling in the lowest layers of the model. To test this hypothesis two reruns of the NGM were made: first with the snow cover removed under the 'C' grid and then with the physics package turned off. Turning off the physics package will result in the NGM reverting to the version run prior to 23 July 1986.

II. Background

When a grid volume of the NGM is covered with snow there are two immediate results: the surface albedo is increased and the <u>skin temperature will not go above freezing</u> (see TPB #363 for background on the physics package). The increase in surface albedo results in a decrease in the amount of solar radiation available for raising the skin temperature through the surface energy budget. Cold skin temperatures over snow covered ground will affect the model sigma layer temperatures through two mechanisms:

- exchange of sensible heat between the first sigma layer and the skin
- long wave radiational cooling of the first layer.

The exchange of sensible heat between the first sigma layer and the skin will generally be small when the skin temperature is below the first sigma layer temperature (stable boundary layer). The second affect, long wave flux divergence in the first layer, can be quite large. A 10 degree temperature difference between the skin temperature and the first sigma layer temperature can produce an instantaneous long wave cooling tendency of about 10 degrees per day. This degree of cooling will not be realized due to other compensating affects in the model but significant cooling of the first sigma layer can result when the skin temperature drops below the temperature of the first sigma layer. The skin temperature of snow covered grid volumes can become quite cold in a very realistic manner; however, if the model has snow where none exist in the real world then significant low level temperature errors are likely to occur.

We have seen instances in the past where the snow cover analysis used by the NGM has had some problems. The areal coverage of the snow has been too large and there has been a southwestward displacement of the snow cover. Both of these problems were caused by interpolation inconsistencies between the snow cover analysis grid and the NGM's computational grids and were rectified in early December. However, the snow cover analysis is performed only once per week and when significant snowfall or melting has occurred between analyses there are likely to be errors in the low level temperature forecast from the NGM.

III. Results

The case brought to our attention was 25 October 1986 at 12Z. The snow cover used by the NGM on this day is shown in Fig. 1 (shading indicates no snow cover). Note the large snow covered area in the Rockies. The 48 hour forecast of first sigma layer temperatures for the operational run, the run with no snow cover and the run with the physics package turned off are shown in Figs. 2, 3 and 4, respectively. The 48 hour forecast of 850 mb temperatures are similarly shown in Figs. 5, 6 and 7. The verifying 00 hour forecast valid for 27 October 1986 at 12Z for the first sigma layer and 850 mb temperatures are shown in Figs. 8 and 9.

When interpreting these results one should keep in mind that the NGM's analysis, the Regional OI, analyzes temperatures for the model's sigma layers as defined by the pressure at the terrain height of the model. The NGM's terrain was developed to be consistent with the resolution of the 'C' grid and is smoother than the real orography. Rawinsonde locations in the Rockies are situated in valleys which are not resolved by the NGM's terrain. Therefore the model's orography is generally higher than the real world orography at the rawinsonde locations. This difference in terrain heights will lead to low level temperatures in the analysis which may not closely resemble the low level temperatures in the rawinsonde reports. In addition, the analysis may not draw completely for details in the rawinsonde data because the first guess is given some weight. Because of these two characteristics of the system, low level inversions may not be fully captured by the analysis. The model, with its comprehensive treatment of physical processes, will often try to develop realistic thermal structures. This leads to a situation where the NGM's forecasted low level temperatures may actually be better than the verifying ROI analysis, especially with respect to low level inversions.

Examination of the figures listed above reveals that the area with snow cover in the Rockies is significantly colder with snow cover than without. For the reasons mentioned above, we believe that the snow covered area in the NGM was too large in the Rockies. The run with the physics package turned off is warmer than the operational run and the no snow cover run as expected. Recall that radiation cools the atmosphere to compensate for heat release from other diabatic processes. The NGM does have a cold bias caused by the radiation (as do almost all models including NMC's Global Spectral).

IV. Conclusions

We have seen that the snow cover can have a large effect on the low level temperature forecast from the NGM. Recent improvements in the procedures for interpolating the snow cover analysis to the NGM's computational grids should help prevent the reoccurrence of the excessively cold low level temperatures experienced in the 25 October 1986 case. There still remains two deficiencies in the snow cover analysis: the analysis is performed one per week, and the horizontal resolution is very low compared to the resolution of the NGM's 'C' grid.

We would like to thank Jim Kaplan for bringing this forecast to our attention.

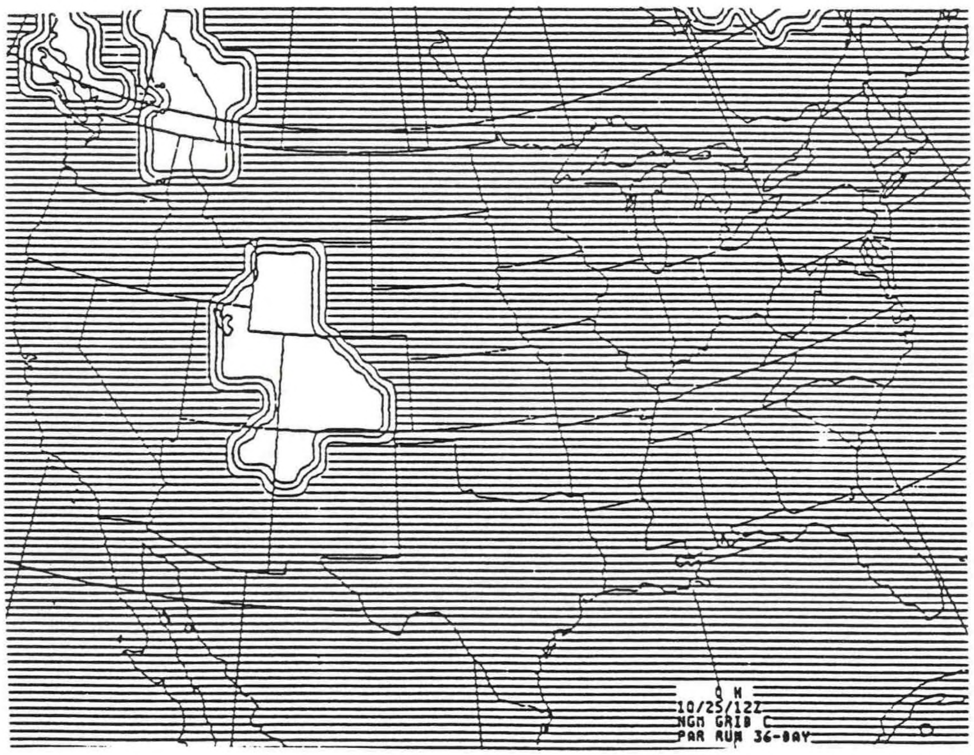

Fig. 1 Snow cover analysis on the NGM's 'C' grid for 25 October 1986. Shading indicates areas of no snow cover.

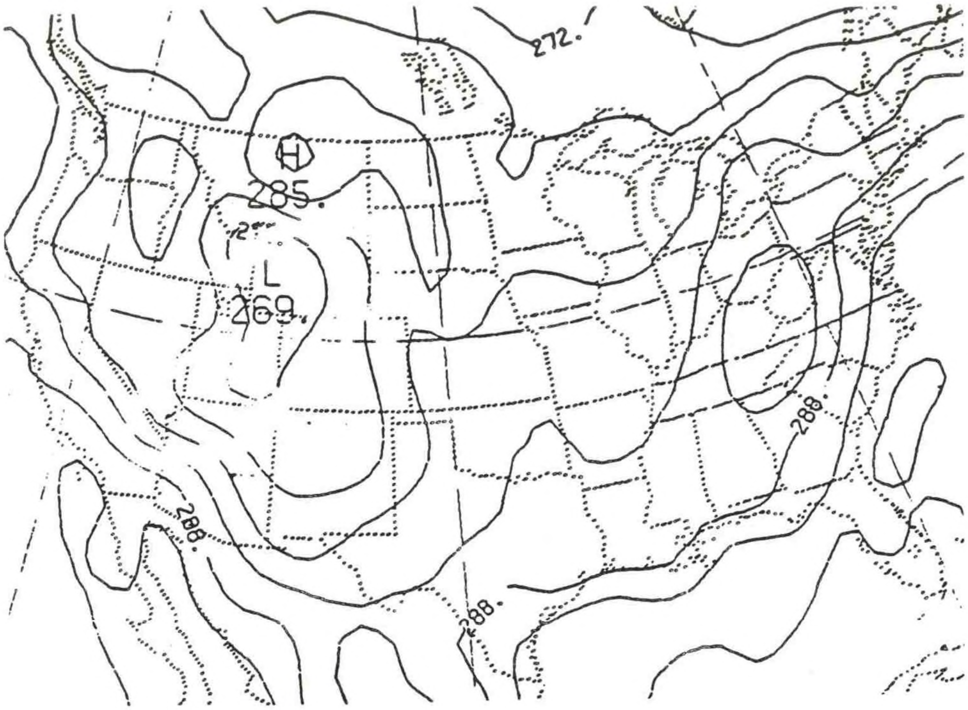

Fig. 2 48 Hour forecast first sigma layer temperatures from the operational NGM initialized on 25 October 1986.

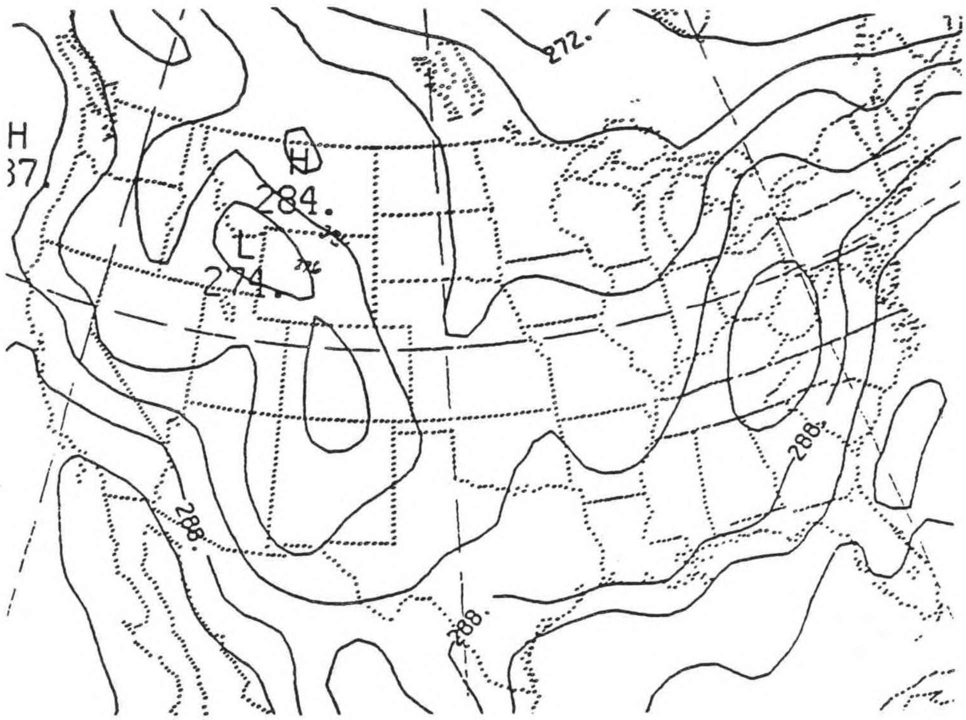

Fig. 3 48 Hour forecast first sigma layer temperatures from the NGM with no snow cover initialized on 25 October 1986.

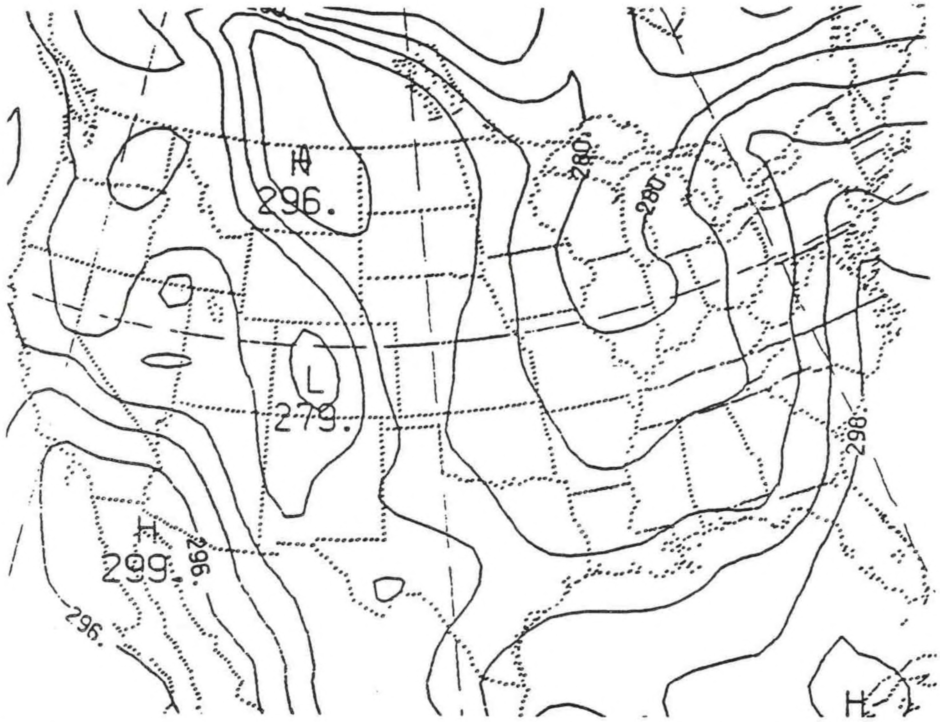

Fig. 4 48 Hour forecast first sigma layer temperatures from the NGM without the physics package initialized on 25 October 1986.

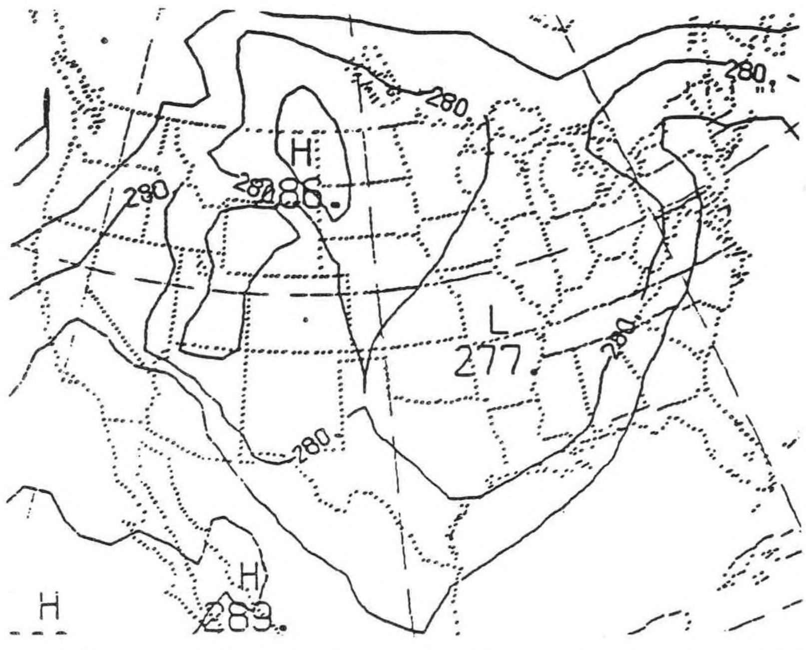

Fig. 5 48 Hour forecast 850 mb temperatures from the operational NGM initialized on 25 October 1986.

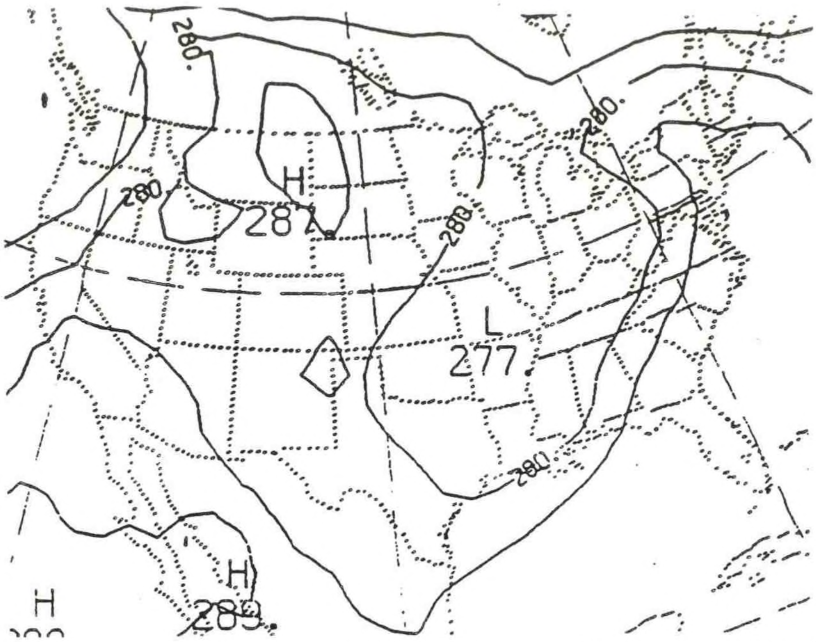

Fig. 6 48 Hour forecast 850 mb temperatures from the NGM with no snow cover initialized on 25 October 1986.

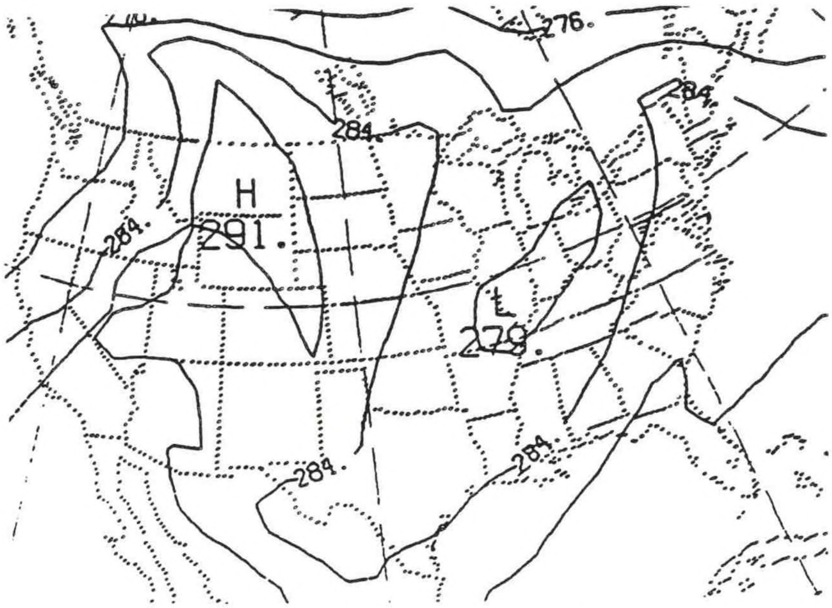

Fig. 7 48 Hour forecast 850 mb temperatures from the NGM without the physics package initialized on 25 October 1986.

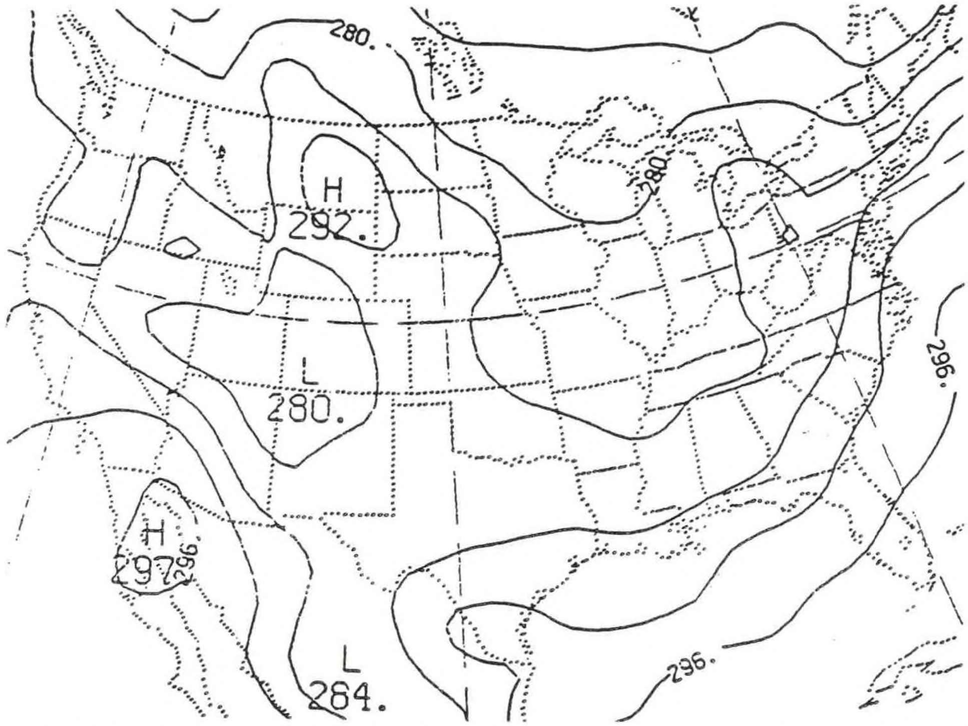

Fig. 8 00 Hour forecast first sigma layer temperatures initialized on 27 October 1986.

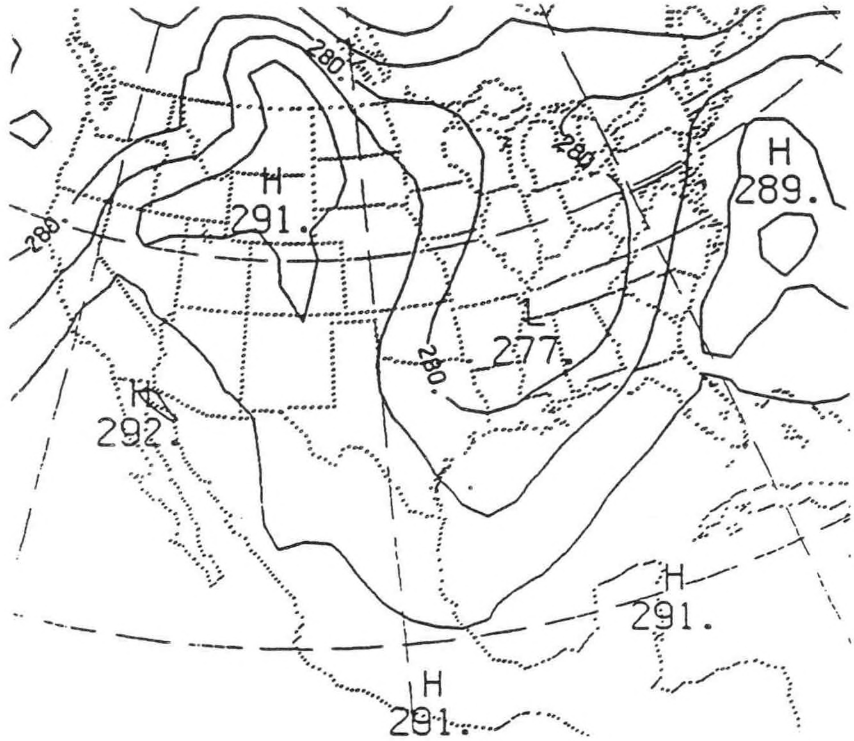

Fig. 9 00 Hour forecast 850 mb temperatures initialized on 27 October 1986.