NOAA TECHNICAL MEMORANDUM NWS NSSFC-2

A SUBJECTIVE ASSESSMENT OF MODEL INITIAL CONDITIONS USING SATELLITE IMAGERY

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November 1978

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ABSTRACT

Even though numerical models have made great strides forward in recent years, their accuracy is limited by initialization. The forecaster has available high quality satellite pictures which enable him to qualitatively evaluate circulation systems. Using satellite imagery it is frequently possible to recognize regions where there is an initialization problem. When such an area is identified, the numerical forecast can be substantially improved upon. A detailed analysis of the development of the damaging storm that struck Southern California on February 10, 1978 is presented. With this storm there were serious initialization problems. Also, the appendix will include several more cases where satellite imagery is used to improve on the computer models initial analysis.

1. INTRODUCTION

In general, the quality of a forecast from a numerical model will be no better than that of the initial data input into the model. The current Limited Fine Mesh Model (LFM II) is no exception. It can produce a high quality forecast given a good initial analysis. However, its performance is limited by the intrinsic inaccuracies of its initialization.

Brown (1978), the Chief of the Development Division of NMC, pointed to the initial analysis problems as one of the major causes of the poor performance of the LFM-II during the winter season of 1977-1978. He noted that, "the meteorological conditions which existed last year (1976-1977) were considerably different from those experienced this year (1977-1978). Last year the ridging over the west blocked the movement of major storms from the Pacific area across the west coast of the United States. Storms over the U.S. were often located 48 hours earlier over regions where the data are relatively good (Gulf of Alaska, Alaska, western Canada). This year, however, the major storm track has been directly from the Pacific where the data are sparse. This leads one to suspect that the forecast skill to 48 hours over the United States was more sensitive to analyses errors in the eastern Pacific than was the case".

He further states that, "this problem may have been compounded by NMC's lack of manual data monitoring this year (1978), manual data monitoring was used with the LFM-I last year. The elimination of this monitoring step provided for an earlier availability of LFM-II products".

Thus, it is recognized that a problem exists in the eastern Pacific Ocean where there is only one upper air sounding site at the weather ship located at 50°N 145°W. There are available along the primary air traffic routes quality high level wind and temperature observations from the airlines. These are currently being used as input to the model runs at 250 mb. However, the analysis techniques result in only a slight influence of this data below middle tropospheric levels.

The availability of around-the-clock high quality satellite pictures has resulted in an increasing ability to qualitively evaluate circulation systems from cloud motions. Using this qualitative evaluation it is frequently possible to recognize regions where there is a significant error in the LFM-II initialization. When such regions are identified, the subsequent model forecast must be treated very cautiously. The forecaster must subjectively apply dynamic concepts and judiciously modify the model output to account for the errors in initialization.

During the first three months of 1978, several systems were initialized poorly over the eastern Pacific Ocean. In each case, a synoptic satellite interpretation would have revealed the existence of problem regions in the initial analysis. Knowing of the location of large initial errors, the forecaster could most probably have made a marked improvement in the quality of the forecast.

One example of the predictable effects of an initialization error is presented in detail, several other cases during the January-March 1978 period have been examined and are in the appendix.

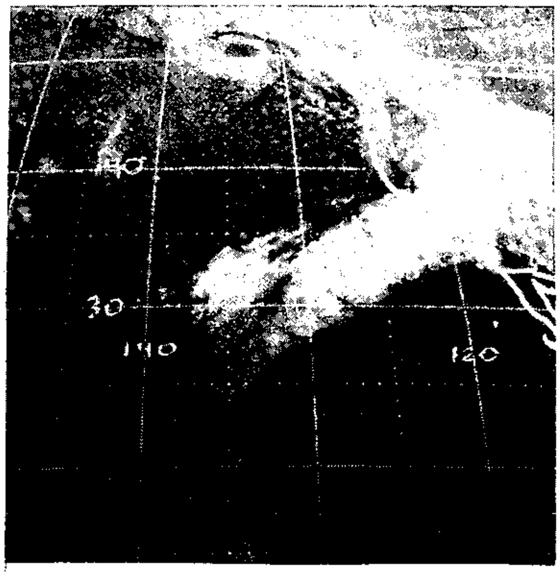
2. CASE STUDY - SIGNIFICANT DEEPENING OFF SOUTHERN CALIFORNIA COAST

On February 9-10, 1978, a rain and wind storm struck Southern California. It was described as one of the most destructive to ever strike the area. Damage due to flooding and winds was in excess of 50 million dollars with 20 lives being lost. Thirteen persons were killed in a flash flood in the mountain resort community of Hidden Springs. Also, a tornado (quite rare in Southern California) struck Huntington Beach early on the morning of the 10th destroying 23 trailers, injuring 6 people and causing $3 million in damage. This was the most costly tornado on record for California.

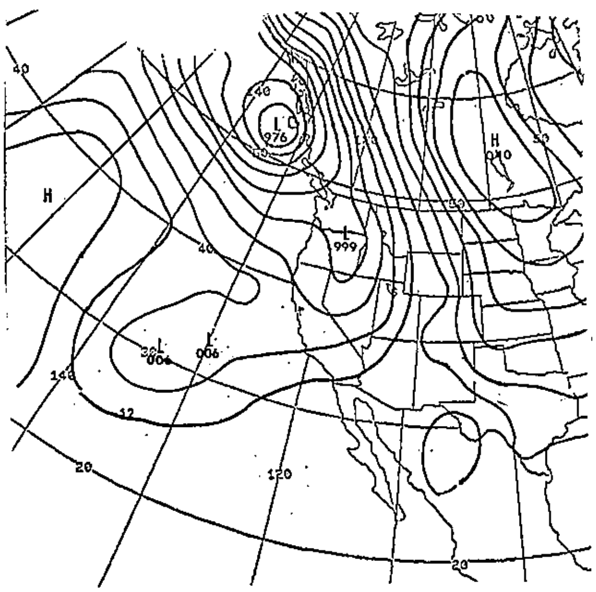
Comparing the 1200 GMT, 9 February satellite imagery (Fig. 1) with the initial LFM-II surface (Fig. 2) and 500 mb analysis (Fig. 3) reveals a well occluded low located near 50°N 135°W. This feature is well placed by the LFM-II.

A frontal zone, well marked by a cloud band, extends from the low southeastward into the Pacific northwest and then southwestward offshore thru south-central California to a wave located near 130°W. A well defined cloud mass associated with positive vorticity advection (PVA) was centered just upstream from the surface wave near 135°W. This cloud feature had about a 2 day history up to this point in time.

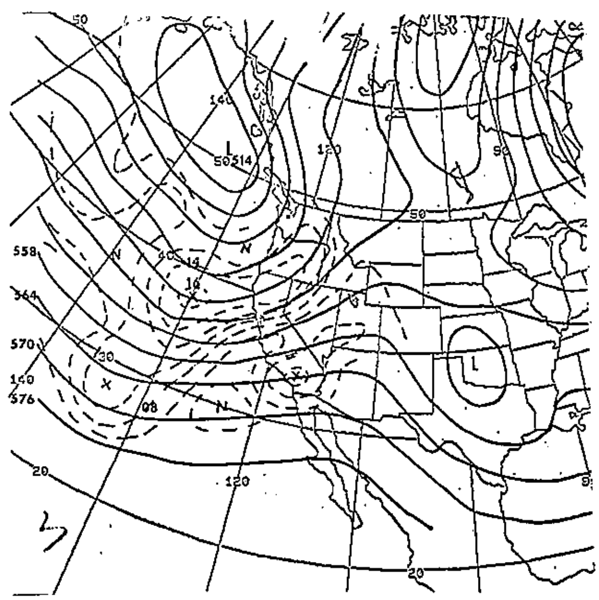
The LFM-II initialized a strong vorticity max at 38°N 130°W which was not supported by the satellite imagery. A secondary weaker vorticity max was initialized near 28°N 134°W which was well south and somewhat east of the PVA clouds. The surface wave at 32°N 130°W was positioned in a zone of NVA.



1. GOES infrared satellite imagery for 1200 GMT 9 February 1978.

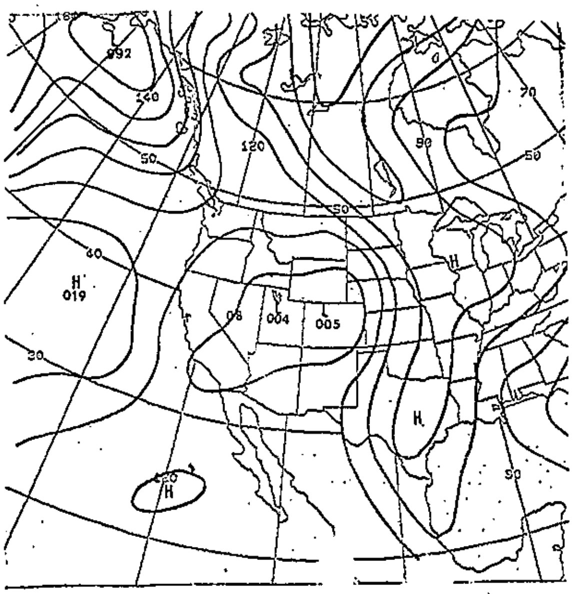


2. LFM II initial surface analysis, 1200 GMT 9 February 1978.

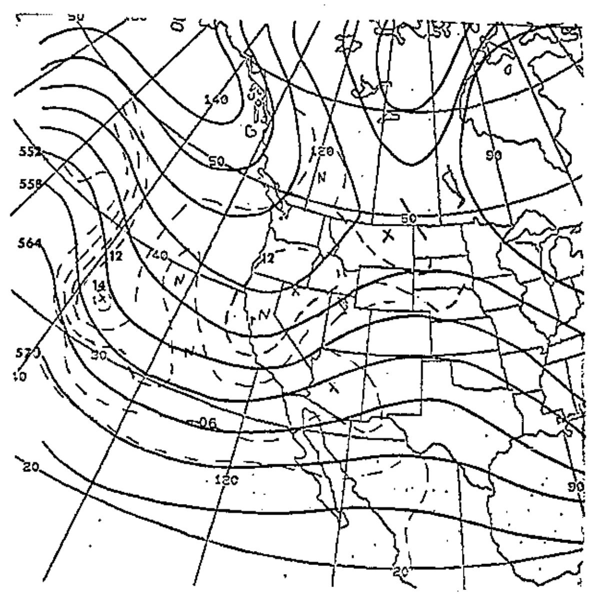


3. LFM II initial 500 mb analysis, 1200 GMT 9 February 1978.

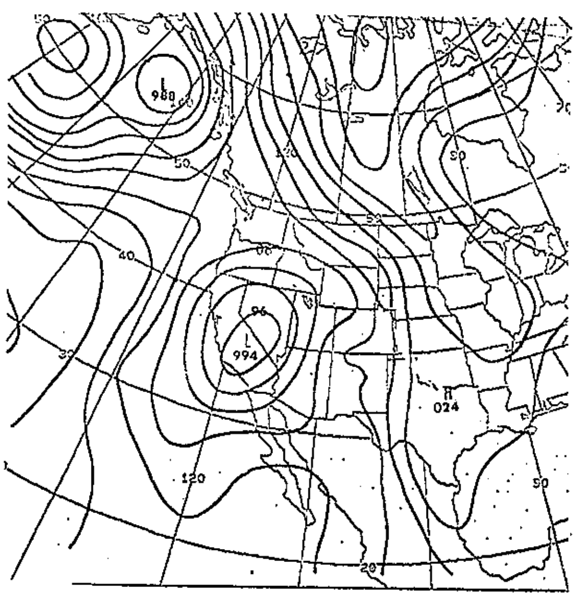
Based on the satellite photo a single well-defined vorticity maxima could have located at 31°N 137°W with PVA eastward to 130°W. This is an excellent example of what is referred to as a vortex development along a frontal band (Anderson *et al.*, 1974). A frontal wave develops with the approach of an upper level vorticity maxima on the cold side of the front. The surface position of the wave is near the spot where the curvature of the rear edge of the frontal band changes from concave to convex and the associated clouds are the widest. The vorticity maximum is located just to the rear of the comma shaped cloud. These clouds are related to the upward motion induced by positive vorticity advection.



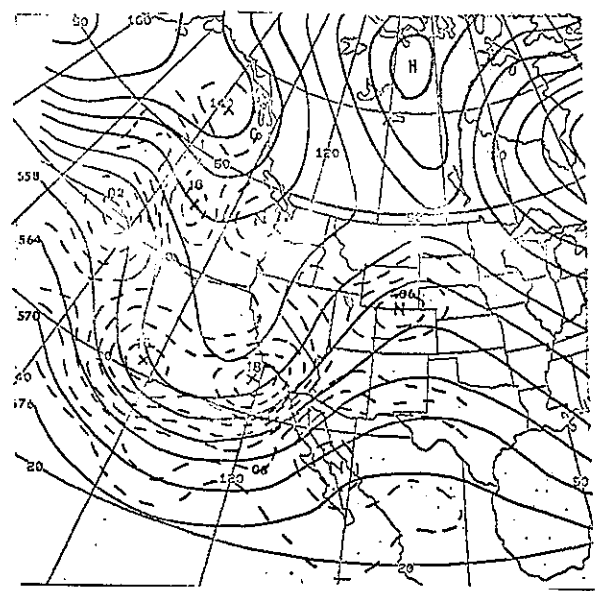
4. LFM II 24-hour surface prog, valid 1200 GMT 10 February 1978.



5. LFM II 24-hour 500 mb prog, valid 1200 GMT 10 February 1978.

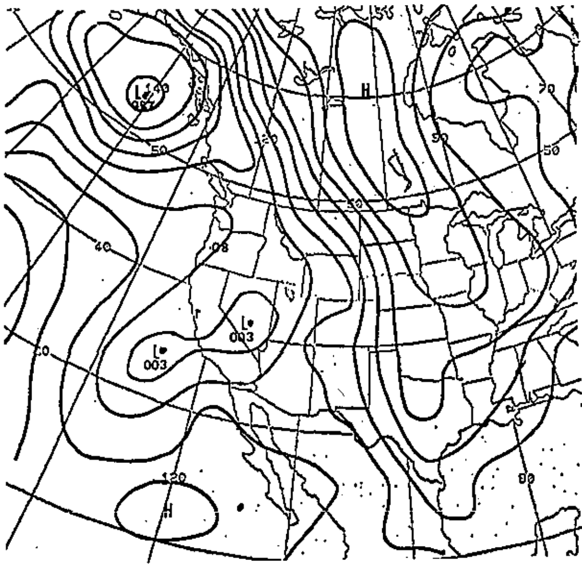


6. LFM II initial surface analysis, 1200 GMT 10 February 1978.

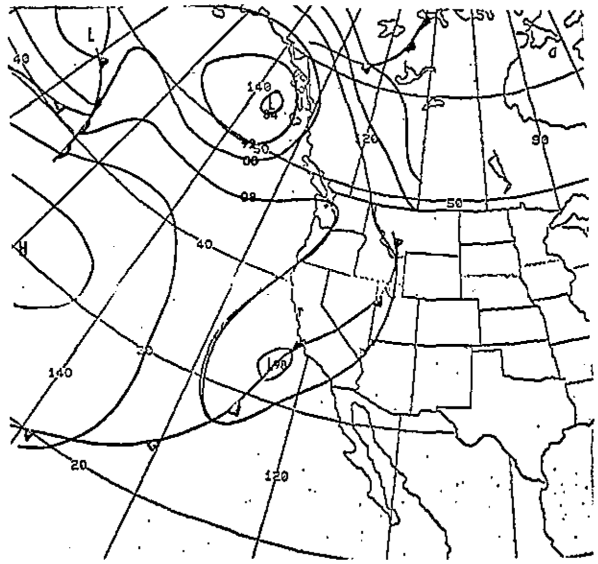


7. LFM II initial 500 mb analyses, 1200 GMT 10 February 1978.

By using the satellite imagery in this case one could infer a strong region of PVA approaching the surface low. Cyclogenesis should be anticipated. On the other hand, as already noted, the LFM-II positioned the wave in the NVA region and its 24-hour forecast (Fig. 4 and 5) showed very little deepening. The verifying charts are given in Fig. 6 and 7.



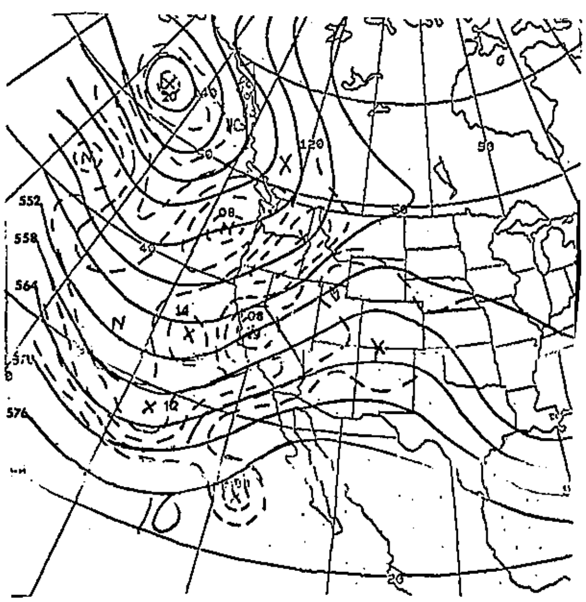
8. LFM II initial surface analyses, 0000 GMT 10 February 1978.



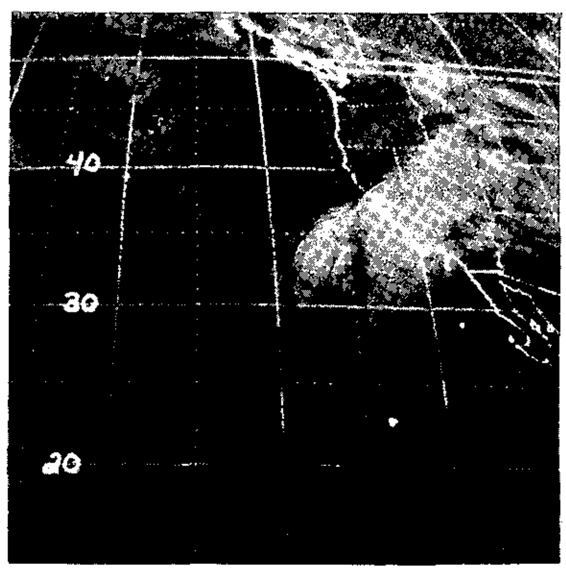
9. Hemispheric surface analyses, 0000 GMT 10 February 1978.

The 0000 GMT 10 Feb. run of the LFM-II was still having initialization problems with the same storm. In the LFM-II surface analysis (Fig. 8) the offshore low was not deep enough. The hemispheric surface analysis (Fig. 9) ran at a later time when more data is available, indicates the low center is 5 mb deeper.

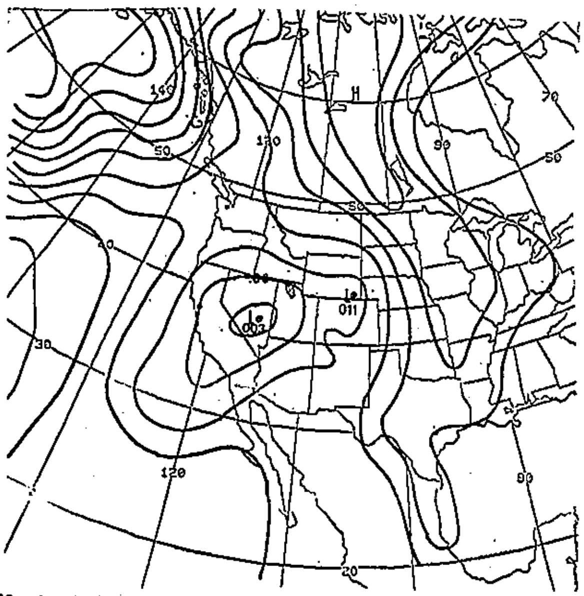
However, just a comparison of the LFM-II 500 mb analysis (Fig. 10) and the 0000 GMT 10 February satellite imagery indicates the existence of an inconsistency. The satellite imagery suggest continued strengthening in the PVA area to the west of the surface low. The PVA induced clouds are located from 36°N to 31°N and 125°W to 129°W, while the LFM-II initialized PVA is well to the east of the region. Not only is the analyzed PVA mostly east of 125°W, but it is broken into two separate areas with the weaker zone located south of 30°N.



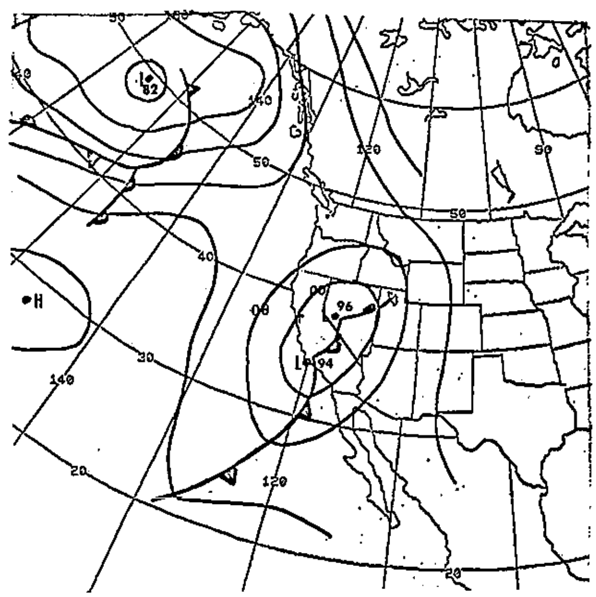
10. LFM II initial 500 mb analyses, 0000 GMT 10 February 1978.



11. GOES infrared satellite imagery for 0000 GMT 10 February 1978.



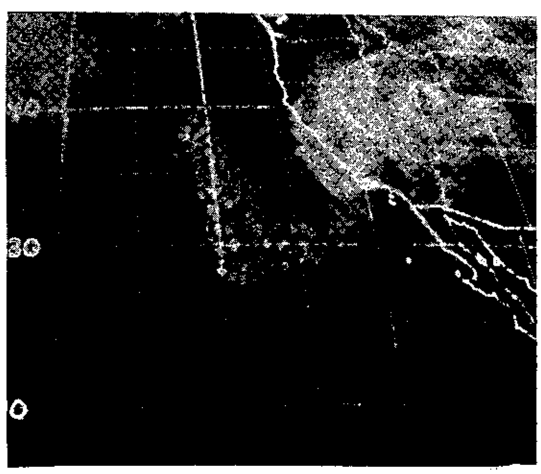
12. LFM II 12-hour surface analyses, valid 1200 GMT 10 February 1978.



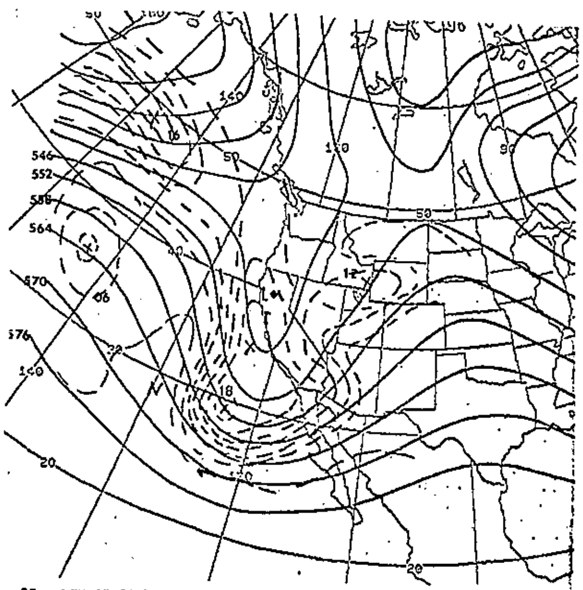
13. Hemispheric surface analyses, 1200 GMT 10 February 1978.

Since the model started with the PVA region already passed the surface low, its 12-hour surface forecast (Fig. 12) calls for no deepending with either rapid eastward movement, or redevelopment of the low, positioning it in central Nevada. This prognosis is quite erroneous. The verifying surface analysis (Fig. 13) shows a much deeper low (994 mb) still positioned along the Southern California coast. The 1200 GMT satellite imagery (Fig. 14) shows the 12-hour intensification of the storm and confirms the low position just offshore.

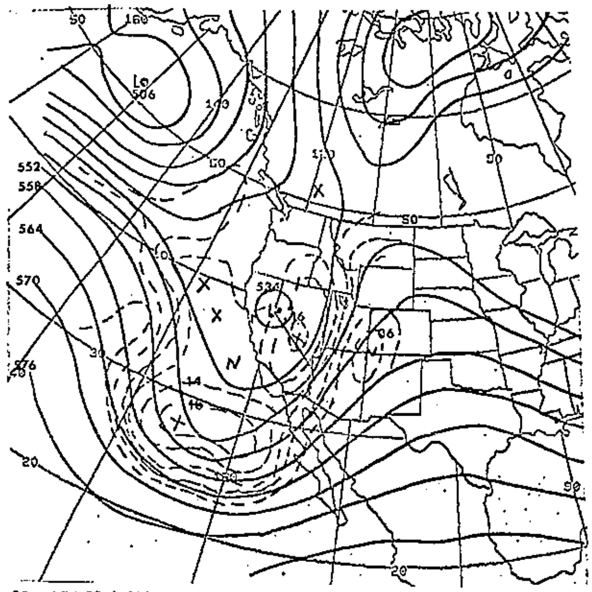
After 24 hours, the LFM-II 500 mb forecast (Fig. 15) looks for a weak vorticity center to be located at 30°N 123°W. The verifying 500 mb analysis at (Fig. 16) shows a strong vorticity maxima moving northward into southern Nevada. In agreement with this, the LFM-II 24 hour surface prognosis (Fig. 17) moved the system too fast; this can be seen by noting the observed surface pattern (Fig. 18).



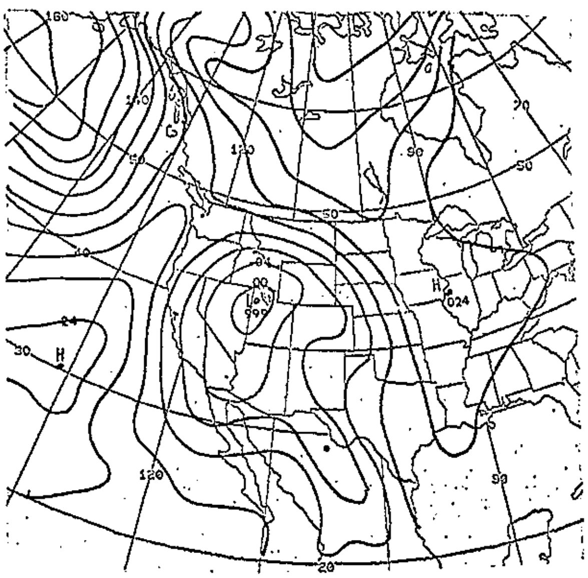
14. GOES infrared satellite imagery for 1200 GMT 10 February 1978.



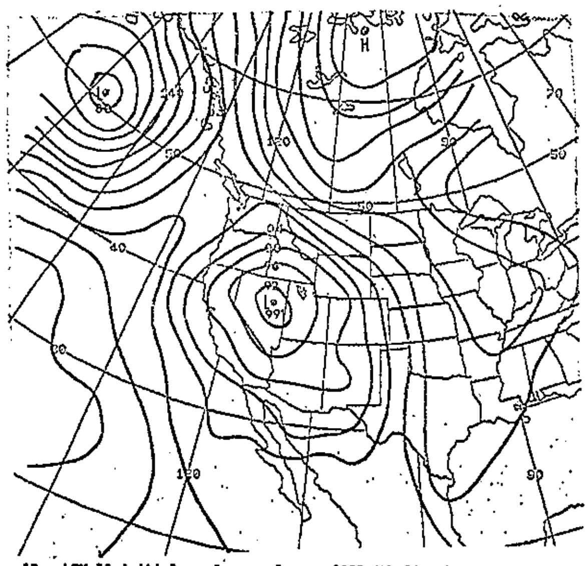
15. LFM II 24-hour 500 mb prog, valid 0000 GMT 11 February 1978.



16. LFM II initial 500 mb analyses, 0000 GMT 11 February 1978.



17. LFM II 24-hour surface prog, valid 0000 GMT 11 February 1978.



18. LFM II initial surface analyses, 0000 GMT 11 February 1978.

This sequence clearly illustrates the problems of initialization in data sparse regions. The persistent PVA area indicated, via satellite imagery, was not noticed by the model initialization scheme. Thus, a significant atmospheric disturbance was mishandled by the LFM-II and the quality of its forecasts suffered. A forecaster recognizing the inconsistencies between the model and the real world could have improved upon the model forecast.

3. CONCLUSION

While the forecasts produced by the LFM-II are generally superior to those produced manually, the forecaster must use the numerical output as guidance rather than as the actually anticipated atmospheric flow patterns. This example, amplified by those documented in the appendix dramatically illustrate that in regions of sparse or questionable data, subjective modification to the objective forecast can be quite fruitful. The initial conditions sensed by the model must be analyzed in light of existing data and dynamic concepts.

If satellite imagery indicates errors in the model's initial analysis, the forecaster is in a position to qualitatively modify the numerical forecast fields. Such an assessment of the consistency between the modeled atmospheric conditions and the true one often has the potential of greatly enhancing the quality of the final forecast.

4. ACKNOWLEDGEMENTS

Thanks to Drs. Joe Schaefer and Richard McNulty for their many helpful suggestions.

5. REFERENCES

Anderson, Ralph K., *et al.*, 1974: Application of Meteorological Satellite Data in Analysis and Forecasting. ESSA Tech. Report NESC 51.

Brown, John A., 1978: On LFM-II Performance, NWS-NMC Tech. Attachment No. 78-1, 10 pp.

Western Region Headquarters Scientific Services Division, 1977: Poor Analysis and Effect on the LFM-PE should be better. NWS-WR Tech. Attachment NO77-22, 6 pp.

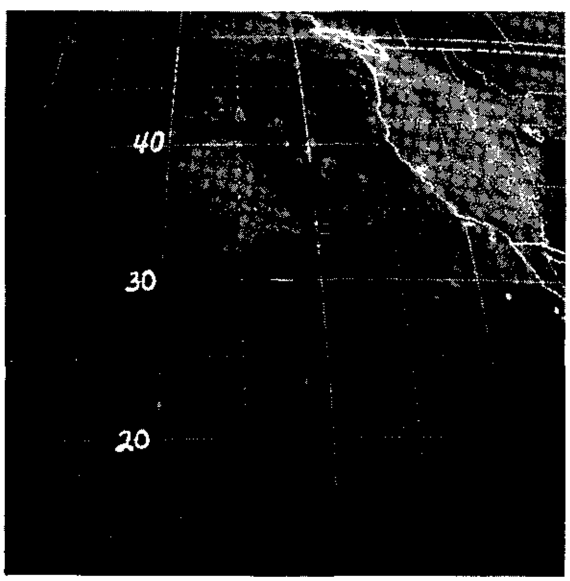
6. APPENDIX

1200 GMT 9 JANUARY 1978

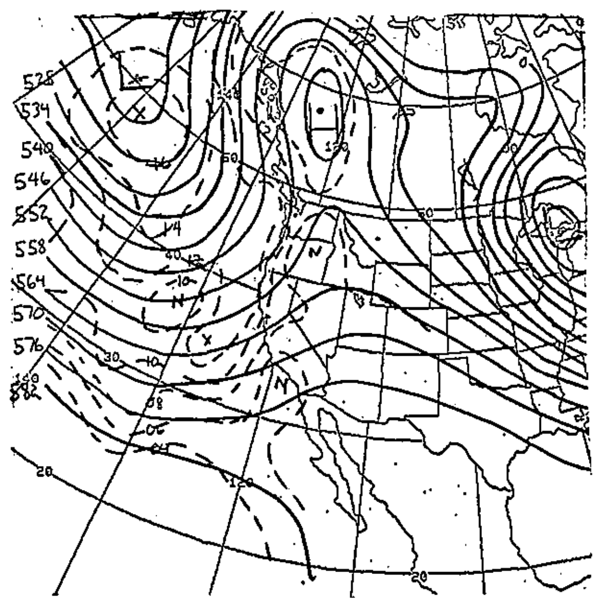
At 1200 GMT January 9, 1978, a well defined PVA area was indicated on satellite imagery south of 40°N along 135°W. A vorticity maximum was located near 35°N 138°W. The LFM II initial 500 mb analysis had a very flat vorticity field with no significant PVA over the Pacific Ocean off the West Coast. There was no indication of any vorticity center on the analysis in the area of the satellite observed PVA.

The 24-hour LFM II 500 mb prog was correct in indicating southeastward development of a vorticity center toward Southern California. However, a much stronger center along with a closed circulation was observed off Southern California by 24 hours. Due to the greater amplitude than initialized for, it was slower. This greater amplitude resulted in more ridging downstream over the Rockies. This increased ridging quite possibly shunted the vorticity maxima that was north of Montana at 1200 GMT January 9th faster toward the southeast to a position over eastern Iowa rather than the 24-hour LFM II position over eastern Montana.

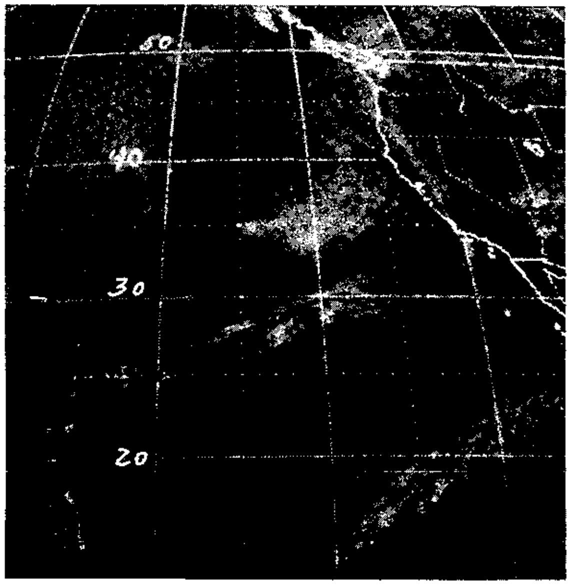
At the surface, a cyclonic flow pattern was observed by 24 hours with a 1004 mb low offshore Southern California rather than the LFM II predicted 1012 mb low over Los Angeles with little associated cyclonic circulation.



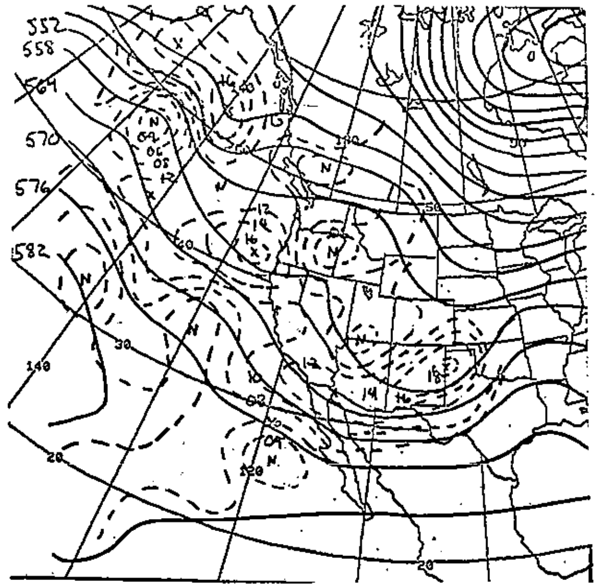
GOES infrared satellite imagery for 1200 GMT 9 January 1978.



LFM II initial 500 mb analysis, 1200 GMT 9 January 1978



GOES infrared imagery for 0000 GMT 11 March 1978



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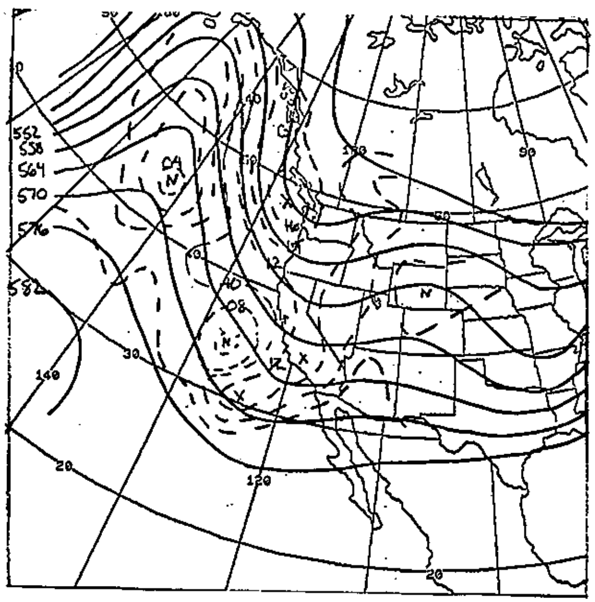
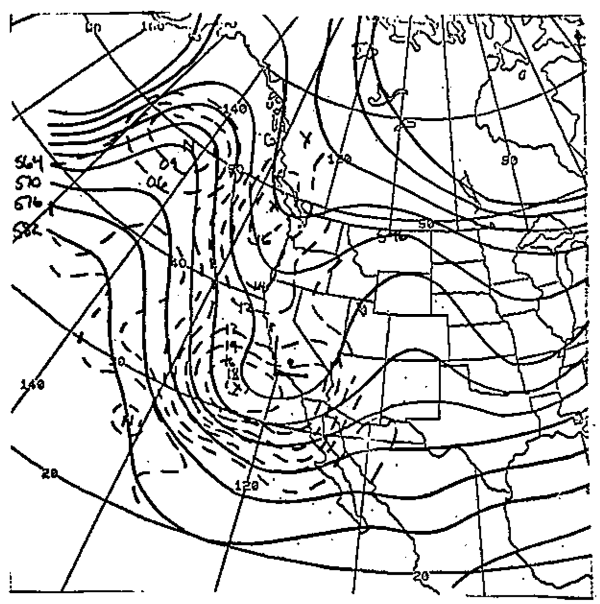


LFM II 24-hour 500 mb prog, valid 0000 GMT 12 March 1978



LFM II initial 500 mb analysis, 0000 GMT 12 March 1978

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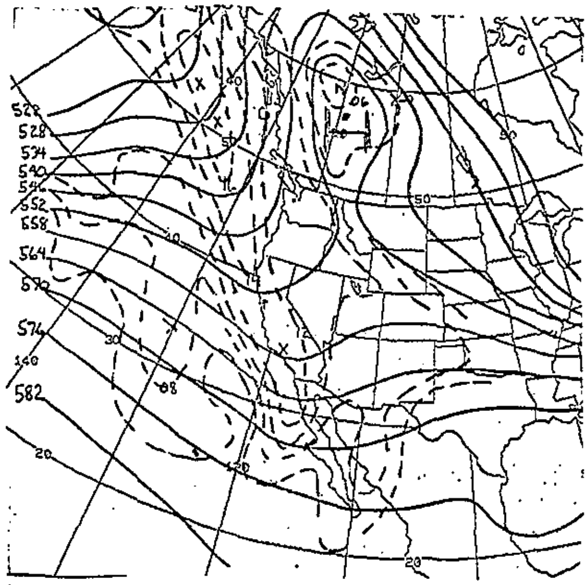
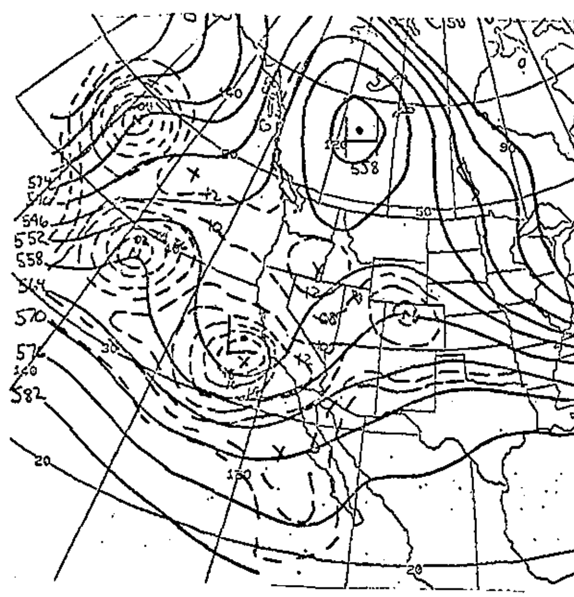
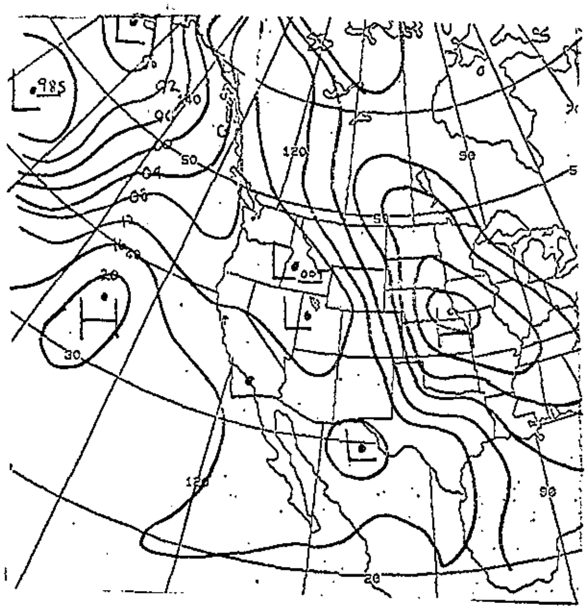
PAGE 11 SHOULD BE PAGE 20.



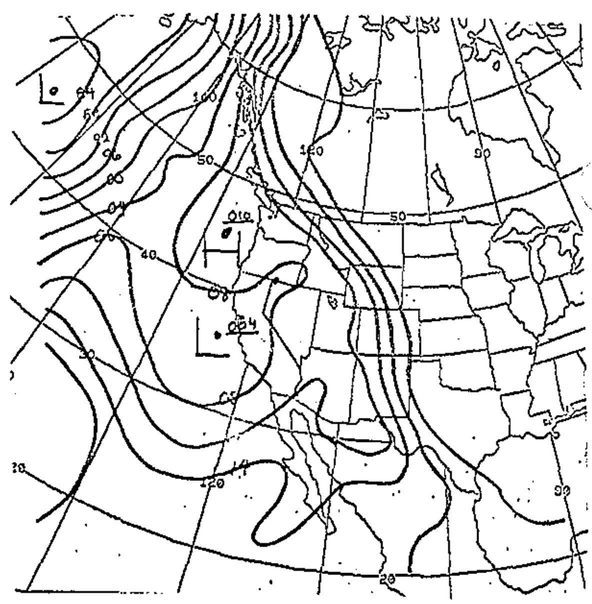
LFM II 24-hour 500 mb prog, valid 1200 GMT 10 January 1978



LFM II initial 500 mb analysis, 1200 GMT 10 January 1978



LFM II 24-hour surface prog, valid 1200 GMT 10 January 1978

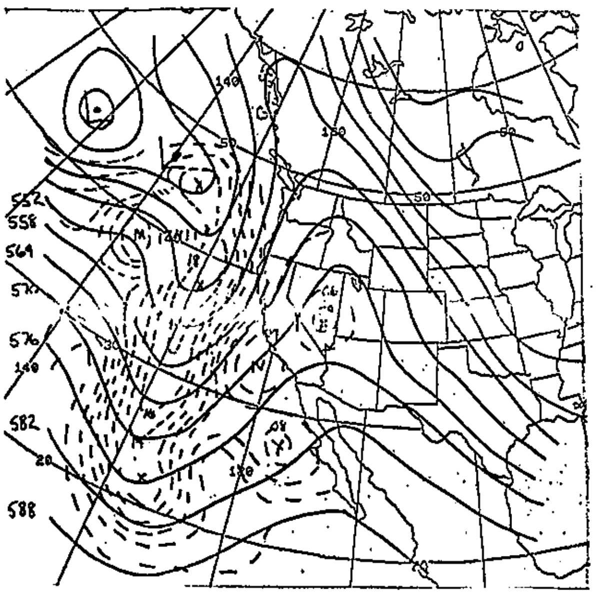


LFM II initial surface analysis, 1200 GMT 9 January 1978

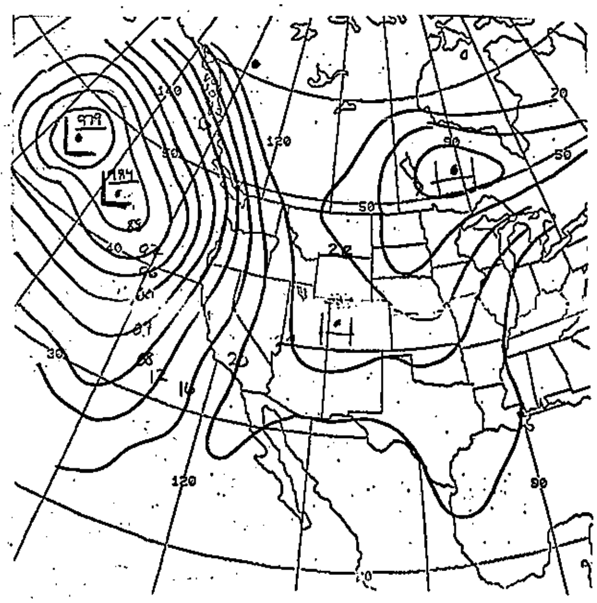
0000 GMT 14 January 1978

On January 14, 1978, the 0000 GMT satellite imagery indicated a well-defined circulation center near 41°N 144°W implying a well developed surface low and associated vorticity center. The initial LFM II surface analysis had two surface lows, one 4 degrees north and the other 4 degrees northeast of the satellite circulation center. Also along 140°W where the back edge of the PVA cloudiness was located the LFM II 500 mb analysis initialized a surface ridge. At 500 mb the two initial LFM II low centers were north and north-east of the satellite center with no significant PVA, while the satellite imagery suggested PVA down to 35°N.

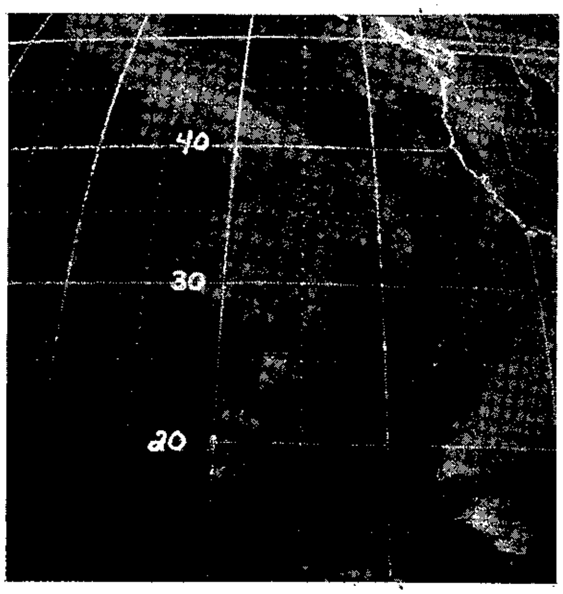
The 24-hour LFM II prog forecasted at 986 mb low, located about 500 miles northwest of the actual deep 973 mb low off the southern Oregon coast. There was a 24 mb pressure error at 39°N 130°W. At 500 mb a strong trough and PVA area was just offshore northern and central California whereas no PVA was indicated on the 24-hour 500 mb prog.



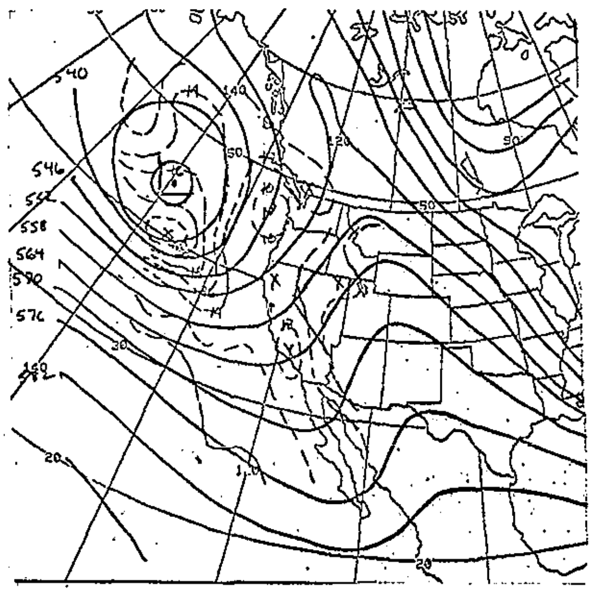
LFM II initial 500 mb analysis, 0000 GMT 14 January 1978



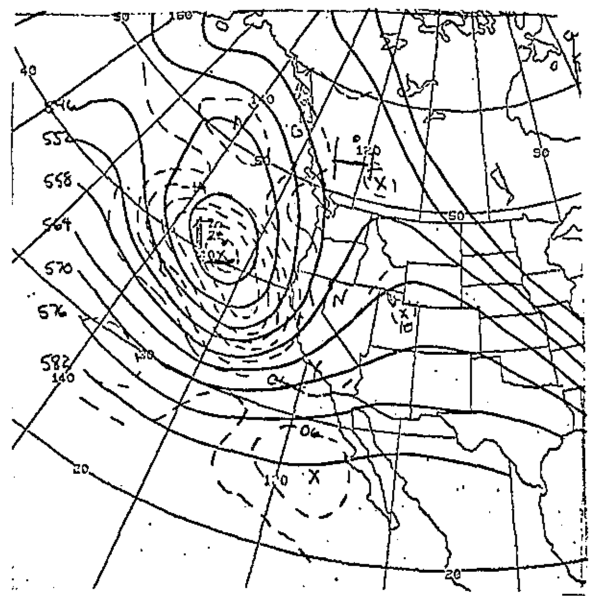
LFM II initial surface analysis, 0000 GMT 14 January 1978



GOES infrared satellite imagery for 0000 GMT 14 January 1978



LFM II 24-hour 500 mb prog, valid 0000 GMT 15 January 1978



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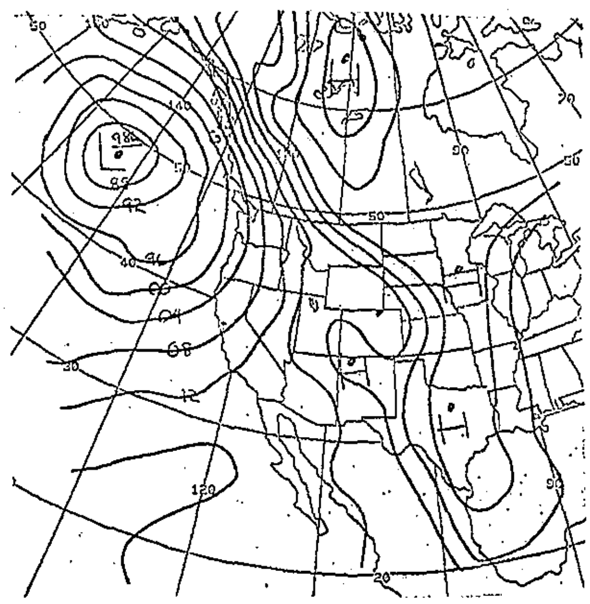

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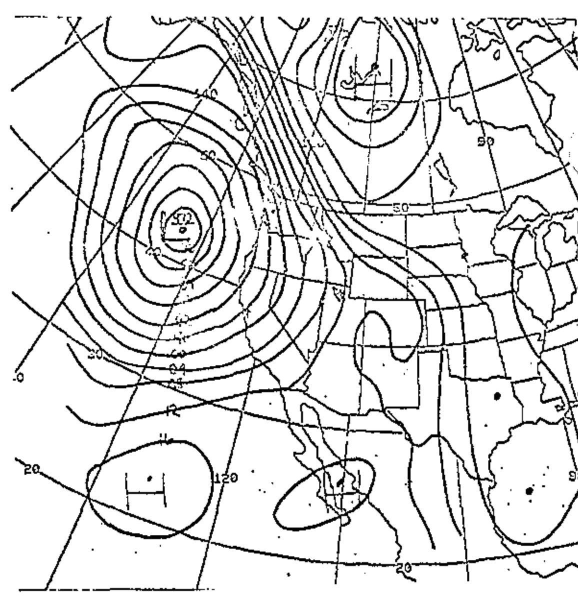


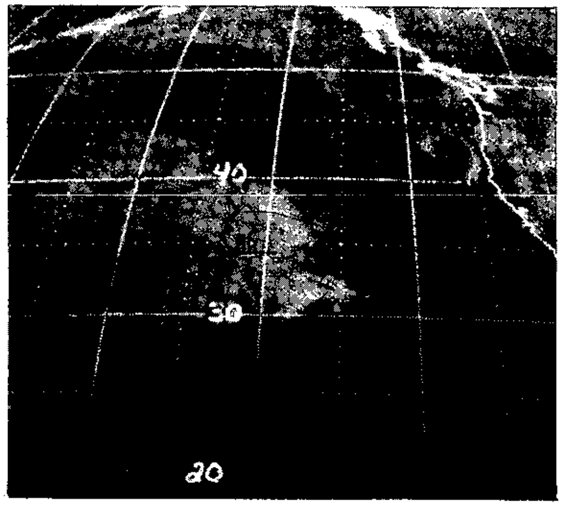
LFM II initial surface analysis, 0000 GMT 15 January 1978

0000 GMT 17 January 1978

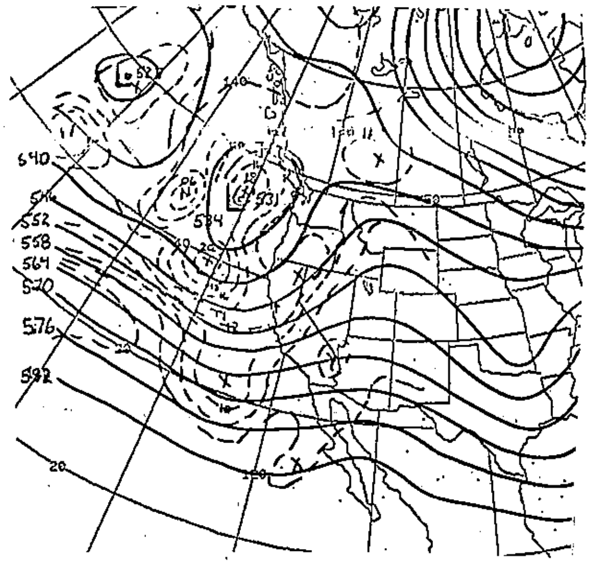
Both the satellite imagery and the final surface analysis show a deep well developed storm located near 35°N 155°W. Even though the storm was just off the edge of the 0000 GMT 17 Jan. initial LFM II analysis, the surface pressure pattern on the charts western edge implies much weaker circulation around the low than observed. Also, the 500 mb initialization had much less amplitude than the satellite imagery supported.

The 24-hour LFM II prog valid 0000 GMT 18 Jan. of a low of 999 mb at 37°N 140°W was acceptable on the location but more than 20 mb to high on the storms central pressure.

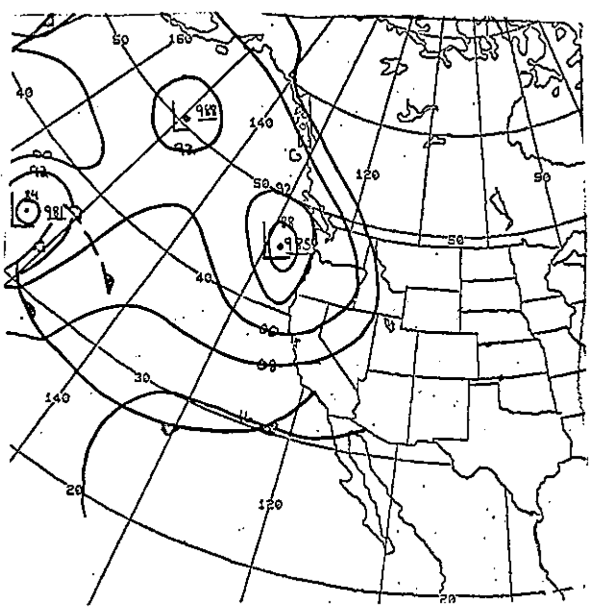
As a result of the underforecasting the deep low offshore, the 24-hour LFM II prog also lacked amplitude downstream with more deepening of the trough into the southwestern U.S.



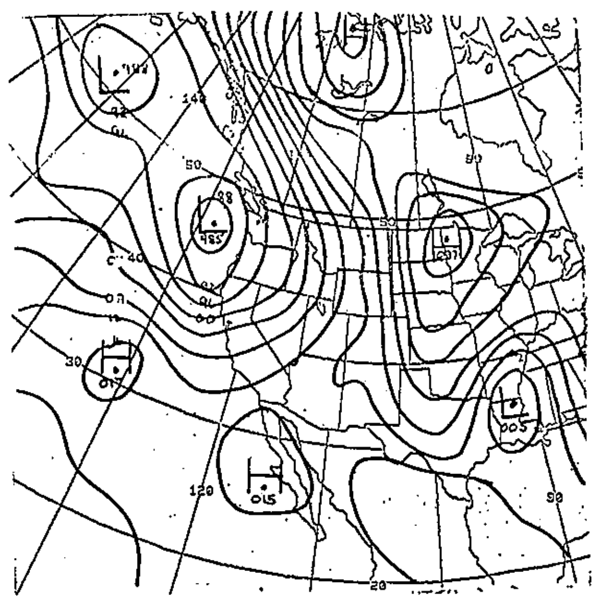
GOES infrared satellite imagery for 0000 GMT 17 January 1978



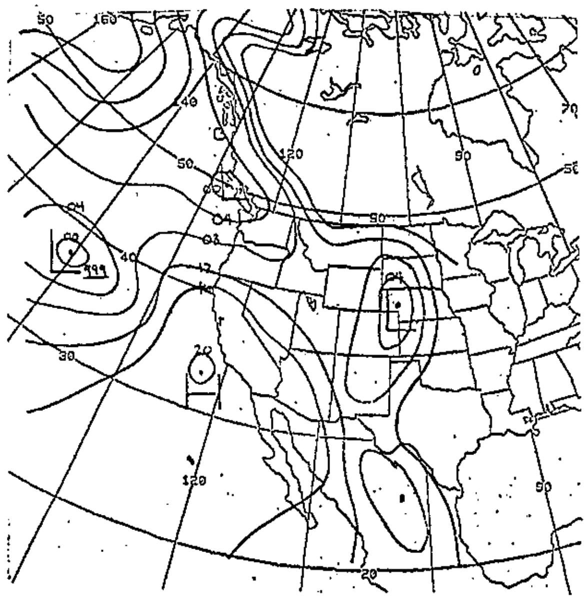
LFM II initial 500 mb analysis, 0000 GMT 17 January 1978



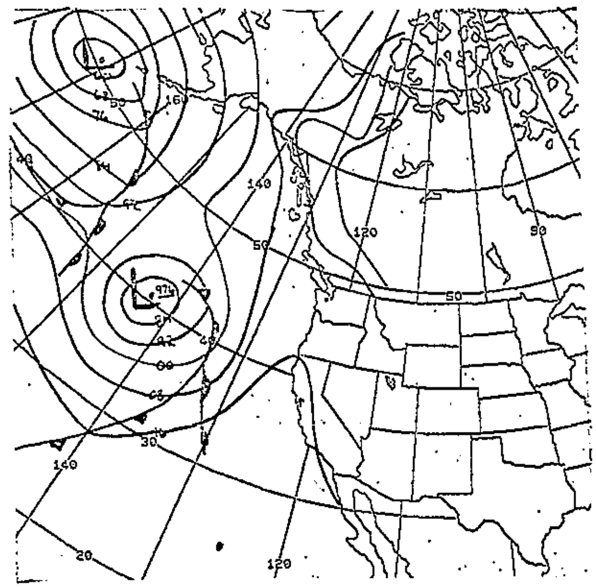
Hemispheric surface analysis, 0000 GMT 17 January 1978



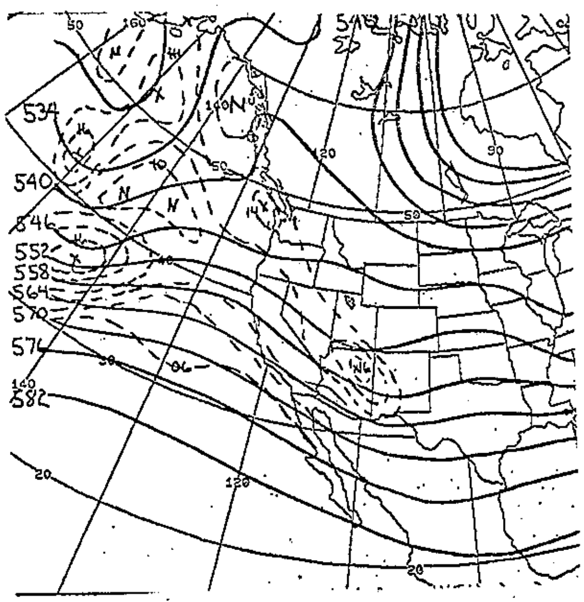
LFM II initial surface analysis, 0000 GMT 17 January 1978



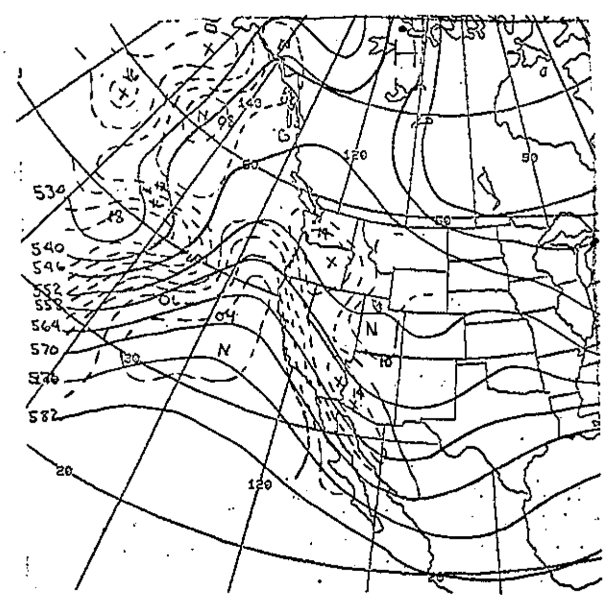
LFM II 24-hour surface prog, valid 0000 GMT 18 January 1978



Hemispheric surface analysis, 0000 GMT 18 January 1978



LFM II initial 500 mb analysis, 0000 GMT 18 January 1978



LFM II 24-hour 500 mb prog, valid 0000 GMT 18 January 1978

1200 GMT 10 March 1978

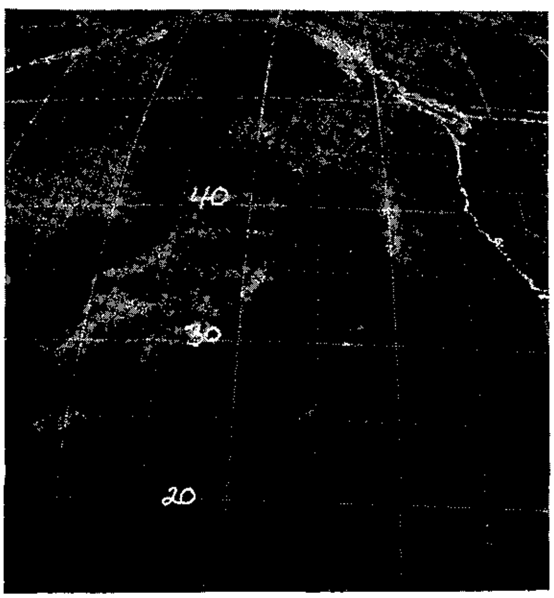
The initialized LFM II 500 mb analysis at 1200 GMT 10 March had a very weak vorticity maxima near 40°N 136°W while the 7 level PE indicated no vorticity maxima or trough at all in the area.

The satellite imagery indicated a possible vorticity center at 0600 GMT 10 March near 43°N 140°W. The 1200 GMT photo was not available but at 1700 GMT this feature was still well defined near 43°N 135°W. Aircraft reports that were requested around 1700 GMT which are plotted on the photo indicated a very sharp negative tilted trough at about 30,000 feet with south-southwesterly winds ahead and strong north-northwesterly winds behind. The LFM II 500 mb analysis showed no amplitude at all in that area. The 100 kt plus north-northwesterly winds were at considerable variance with the west-southwesterly flow at 500 mb in the same area on the 1200 GMT initial LFM II.

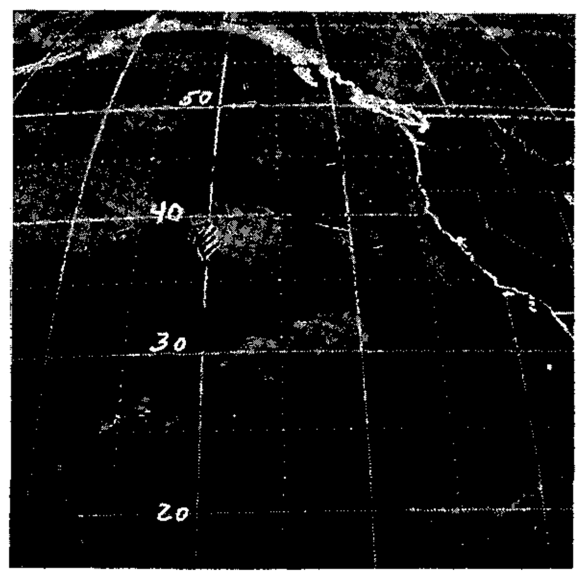
The initial weak trough on the LFM by 24 hours was dropped south-southeastward to off the Southern California coast with another trough upstream near 39°N 132°W ahead of a rapidly developing ridge. On the 7 level PE 24-hour prog, very little detail was evident in the west-northwesterly flow over the western U.S.

On 1200 GMT 11 March a strong vorticity maxima and possible upper closed low were located west of San Francisco dropping southeastward. This was the same system that was evident on the cloud photo near 43°N 140°W at 0600 GMT 10 March.

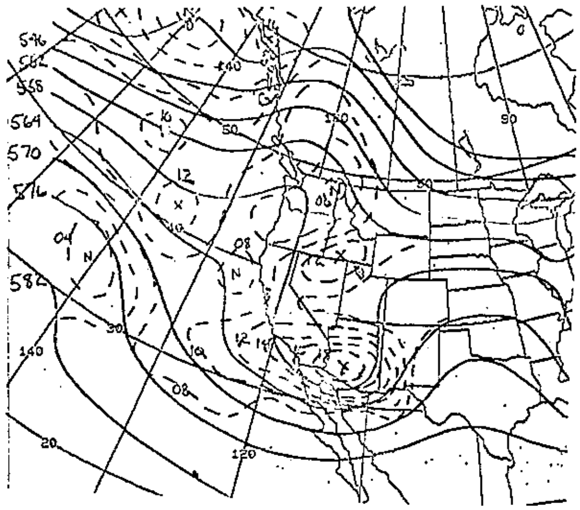
This trough brought considerable unexpected rainfall to Southern California, up to 1½ inches at San Diego.



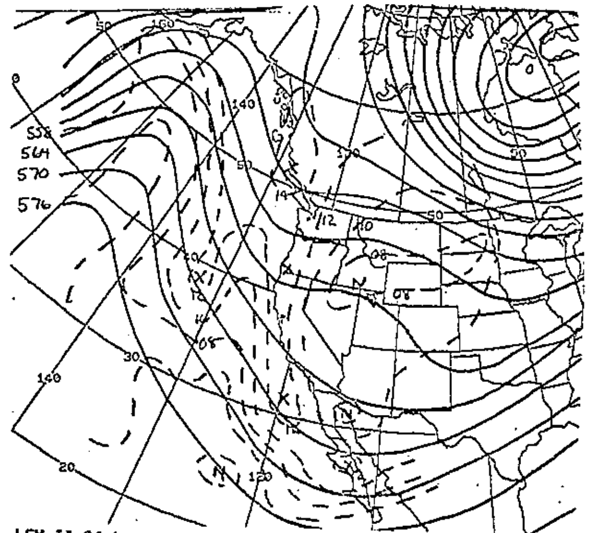
GOES infrared imagery for 0600 GMT 10 March 1978



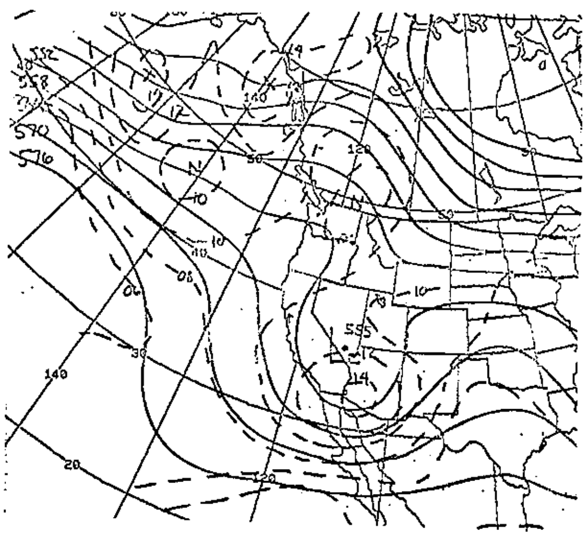
GOES infrared imagery for 1700 GMT 10 March 1978



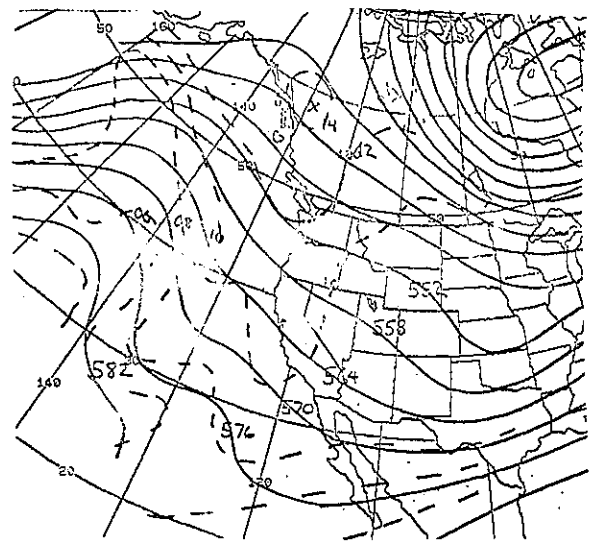
. LFM II initial 500 mb analysis, 1200 GMT 10 March 1978



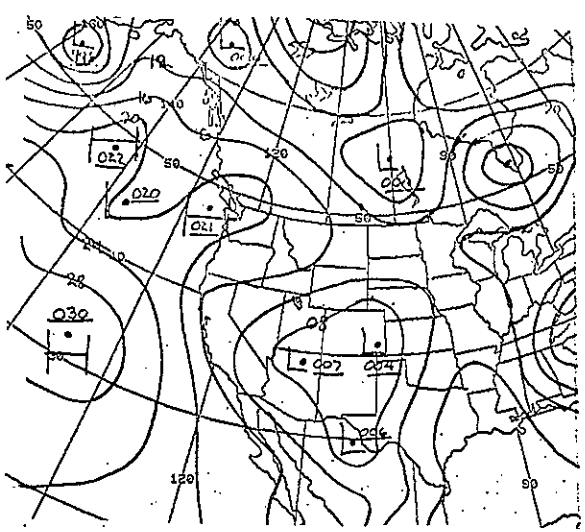
LFM II 24-hour 500 mb prog, valid 1200 GMT 11 March 1978



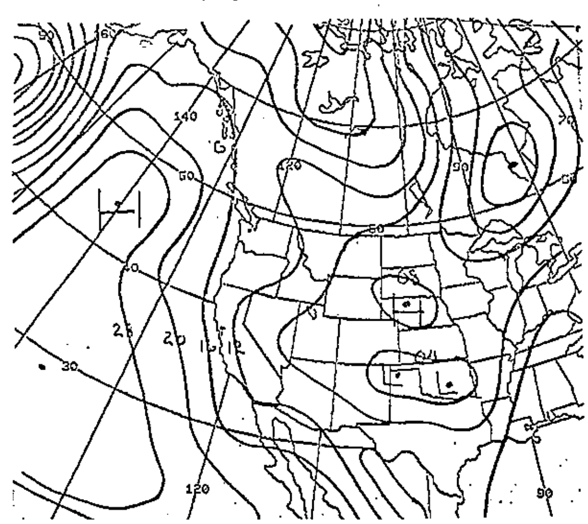
PE 500 mb initial analysis, 10 March 1978



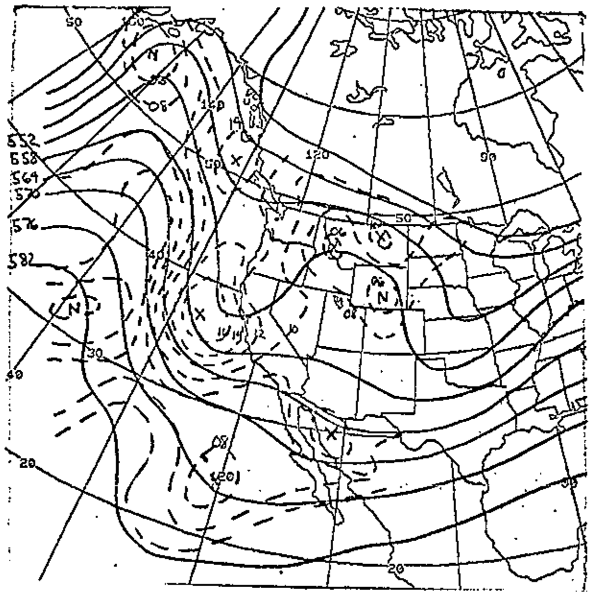
PE 24-hour 500 mb prog, valid 1200 GMT 11 March 1978



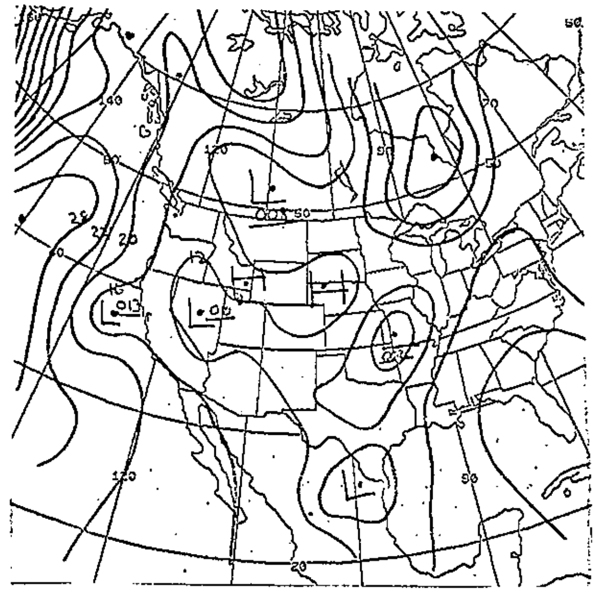
LFM II initial surface analysis, 1200 GMT 10 March 1978



LFM II 24-hour surface prog, valid 1200 GMT 11 March 1978



LFM II initial 500 mb analysis, 1200 GMT 11 March 1978



LFM II initial surface analysis, 1200 GMT 11 March 1978

0000 GMT 11 March 1978

Initialization continued to be a problem with the preceeding trough off the West Coast. The satellite at 0000 GMT 11 March showed an intensifying vorticity center near 41°N 131°W moving southeastward. The initial LFM II 0000 GMT 11 March 500 mb analysis had a vorticity center near 42°N 127°W but the analysis did not take into account the southerly 500 mb winds at Medford and Salem, Oregon suggesting a possible closed circulation offshore. Bad SIRS data at 51°N 140°W erroneously induced a trough on the LFM II 500 mb analysis. The satellite imagery showed no support for a trough in that area.

The 24-hour LFM II 500 mb prog deepened the trough over the southwestern U.S. in response to the strong upstream ridging. However, only a weak vorticity center was progged thru Southern California. In fact, a closed low was located near Los Angeles by 0000 GMT 12 March with 500 mb heights as much as 120 meters lower than forecasted and a much stronger vorticity field.