National Weather Service

Technical Procedures Bulletin

Series No. 300

Subject: MORE EFFICIENT LFM BY APPLYING FOURTH ORDER OPERATORS

Meteorological Services Division, Silver Spring, MD 20910

MARCH 31, 1981

OA/W111x1/AFS

Dr. Dennis Deaven of Atmospheric Modeling Branch, Development Division, National Meteorological Center, describes a newly developed version of the Limited-area Fine-mesh Model (LFM) which employs fourth-order finite differencing and averaging operators. The LFM equations are solved on a 1/2-bedient grid rather than on the 1/3-bedient grid which is now being used operationally. However, because the new version uses fourth-order rather than second-order operators, truncation error is actually reduced. Furthermore, the new program is entirely core-contained in the computer and saves about 25 minutes in clock time per cycle or about 50 minutes per day.

Objective and subjective evaluations of forecasts produced by the LFM II and the fourth-order version, run in parallel, clearly demonstrated that the quality of the forecasts was not degraded. In fact, there are indications that the quality of the forecasts might, on occasion, even be improved because the truncation error of the new version is lower than that of the operational LFM.

Duane S. Cooley
Chief, Technical
Procedures Branch

U.S. DEPARTMENT OF COMMERCE National Oceanic and Atmospheric Administration

MORE EFFICIENT LFM BY GOING TO THE FOURTH ORDER

1. INTRODUCTION

The large number of grid points in NMC's operational Limited-area Fine-mesh Model (LFM II) precludes the placement of all of the grid points in the computer's memory at the same time. Instead, vertical slabs of grid point values are moved in and out of fast core memory during each time step. Although the input-output (I/O) algorithm is designed efficiently, the clock time required for integrating the model is sometimes much greater than the time used by the central processing unit (CPU). This low ratio of wall to CPU time is caused by contention between jobs that are executing simultaneously; I/O requests on the same channel must wait their turn in the queue.

Modifications to the operational LFM have overcome this problem with contention. The new version runs entirely within the computer's fast core memory and is identical to the operational model in every respect with the exception of horizontal truncation. The new version needs about 20 minutes of CPU time to produce a 48-hour forecast; the operational version about 35 minutes. In terms of clock time, the new version requires about 27 minutes to produce a 48-hour forecast compared to 50-90 minutes for the operational model. The modifications have therefore saved at least 25 minutes in clock time per regional cycle, or 50 minutes per day.

2. THE MODIFICATIONS

The number of grid points in each horizontal layer has been reduced from 79 x 67 (5293) to 53 x 45 (2385) to permit the model to reside entirely within the fast core memory. In addition, the horizontal grid interval has been increased from 127 km to 190.5 km (true at 60°N on a polar stereographic projection). This is the same interval that was used in the LFM I. Truncation error in the new version is reduced to levels lower than that of the LFM II in spite of the increased grid spacing, by introducing finite differencing and averaging operators that are accurate to fourth order.

Figure 1 illustrates the truncation error (ratio of the amplitude of the finite differencing derivative to the analytic derivative) for the LFM I, LFM II, and the new in-core fourth-order version. Note that the truncation error for all wavelengths of approximately 500 km or longer is smaller in the in-core version than the truncation error of either of the two other models. The prediction of any quantities whose amplitude or phase is dependent upon truncation error will be as good or slightly better because waves having lengths shorter than about 400 km are damped and discarded in the operational LFM.

All other numerical aspects of the in-core version are identical to the operational model.

3. EVALUATION OF PARALLEL CASE STUDIES

Thirteen 48-hour LFM II and fourth-order forecasts, all run in parallel, were evaluated subjectively and objectively. Four of the 13 were subjectively verified by NMC's Forecast Division. Although differences between the parallel forecasts were noted, those differences were small; neither version out performed the other, and in the opinion of the evaluators, the numerical guidance produced by both models was of the same quality.

Figures 4-7 replicate the LFM II and fourth-order 24-hour forecasts valid at 12Z 10 February 1981 for mean sea level and 500 mb; Figures 2 and 3 replicate the verifying analysis for those forecasts. Although not identical, the forecasts would yield the same numerical guidance. Certainly the large scale features of each forecast are nearly identical.

Precipitation forecasts were also evaluated subjectively and objectively. Threat scores and biases for four of the forecasts are shown in Table 1.

Table 1. Biases and Threat Scores

Date	Forecast Period	Fourth-Order LFM		LFM II	
		Bias	Threat	Bias	Threat
2/5/78	24 hours	1.71	36	1.43	42
2/6/78	36 hours	1.25	59	1.00	60
2/19/79	24 hours	1.00	45	.88	50
2/20/79	36 hours	1.00	41	.75	31

Overall, the skill of the quantitative precipitation forecasts (QPF) was about the same for the two models. These forecasts must be closely monitored after the fourth-order version is implemented, however, before the actual skill of the new model can be determined. An accurate evaluation of QPF skill requires many more case studies than were used here.

4. SUMMARY

Objective and subjective evaluations of forecasts produced by the LFM II and the fourth-order version, run in parallel, clearly demonstrated that the quality of the forecasts was not degraded. In fact, there are indications the the quality of the forecasts might, on occasion, even be improved because the truncation error of the new version is lower than that of the operational LFM. Therefore, because the fourth-order LFM resides entirely within the computer's fast core memory, the savings of about one hour in clock time realized per day more than justifies the implementation of the in-core model operationally.

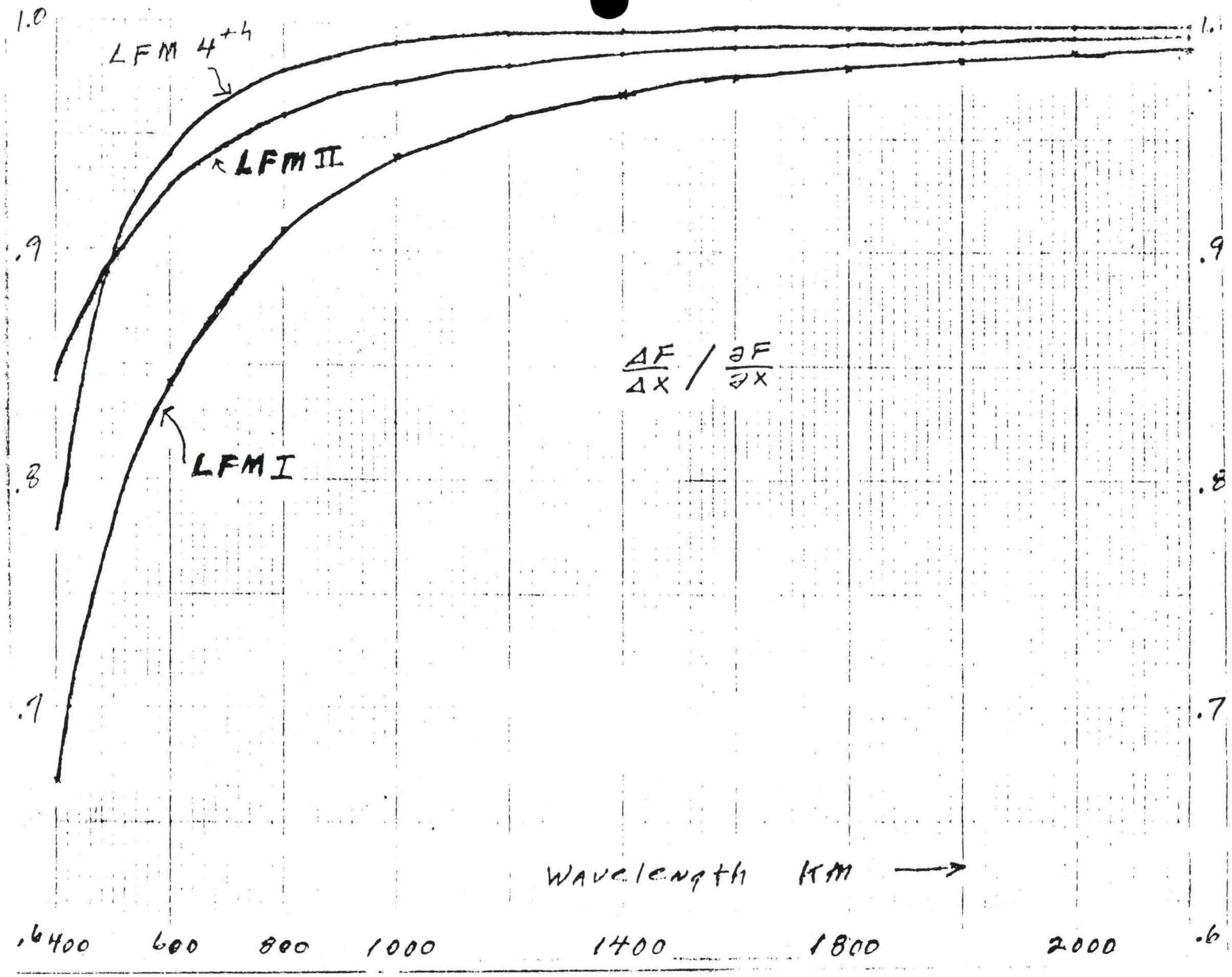

Figure 1. Ratio of the amplitude of the finite differencing estimate to the analytic derivative for the LFM I, LFM II, and the new fourth-order version. The function $\sin(\frac{2\Pi}{L} x)$ (L = wavelength) was used to calculate the truncation error.

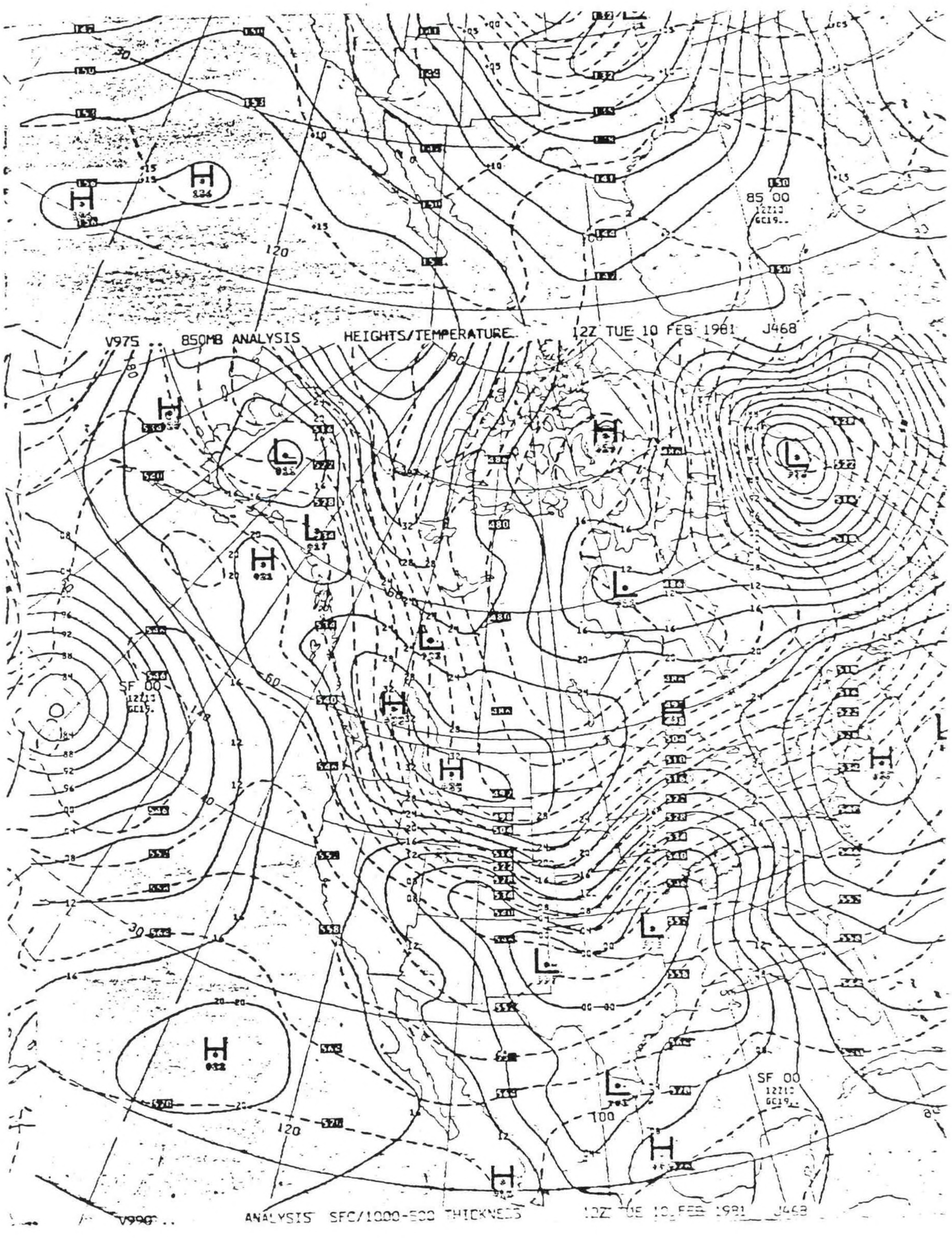

Figure 2. LFM II analysis of sea level pressure and 1000-500 mb thickness for 12Z Tuesday, 10 February 1981.

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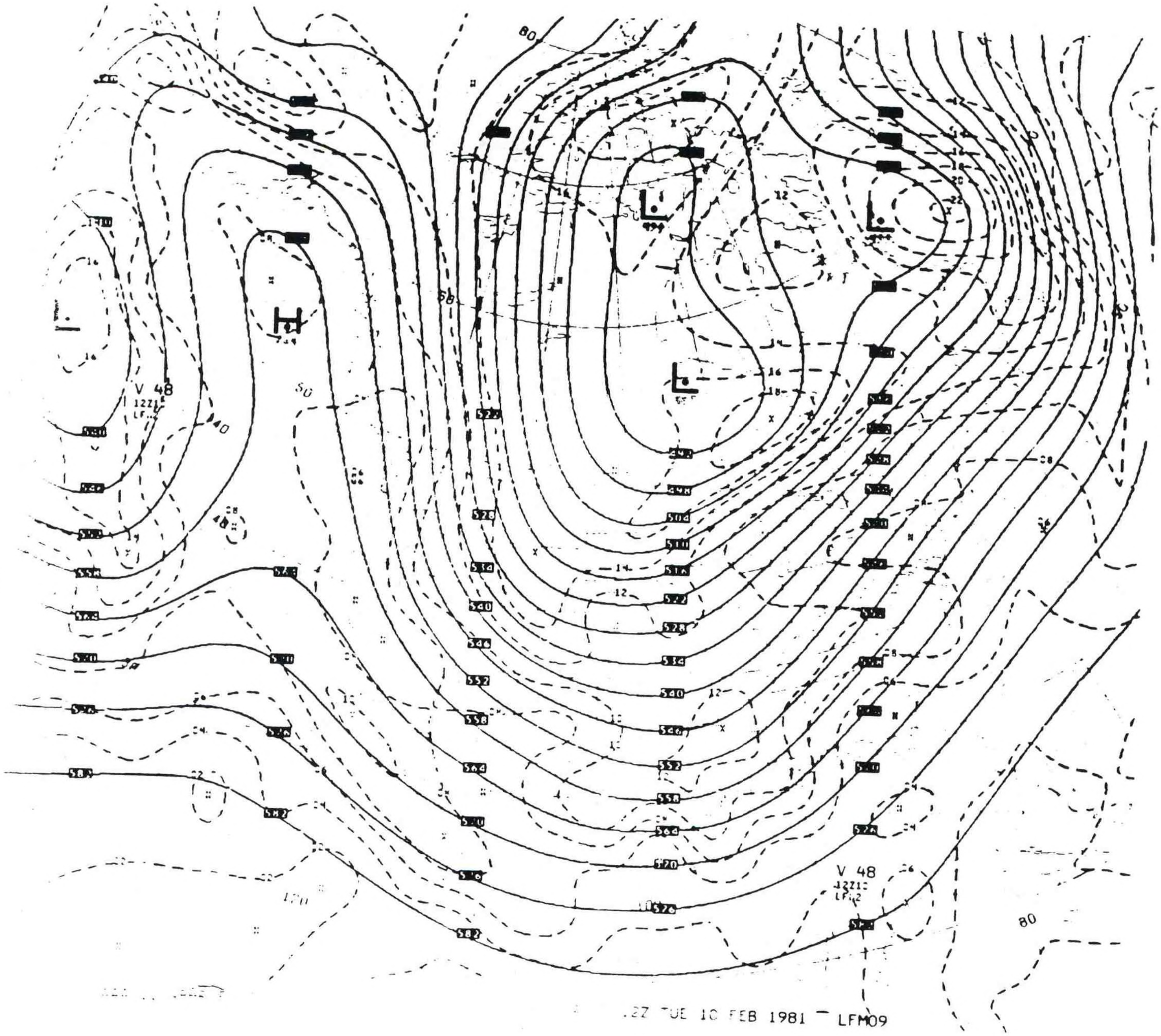

Figure 5. LFM II 48-hour forecast of 500 mb height and vorticity verifying at 12Z Tuesday, 10 February 1981.

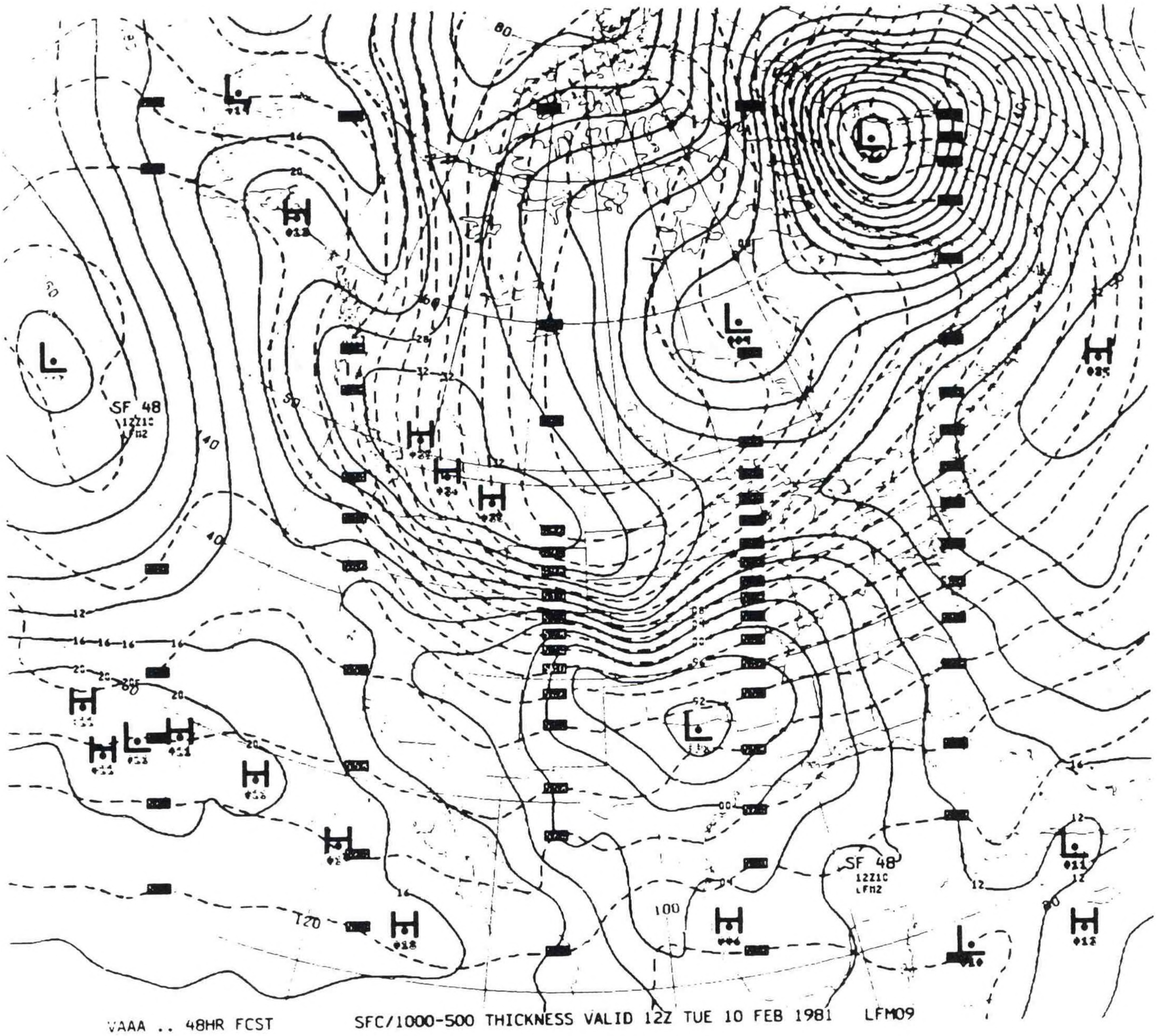

Figure 6. In-core fourth-order LFM 48-hour forecast of sea level pressure and 1000-500 mb thickness verifying at 12Z Tuesday, 10 February 1981.

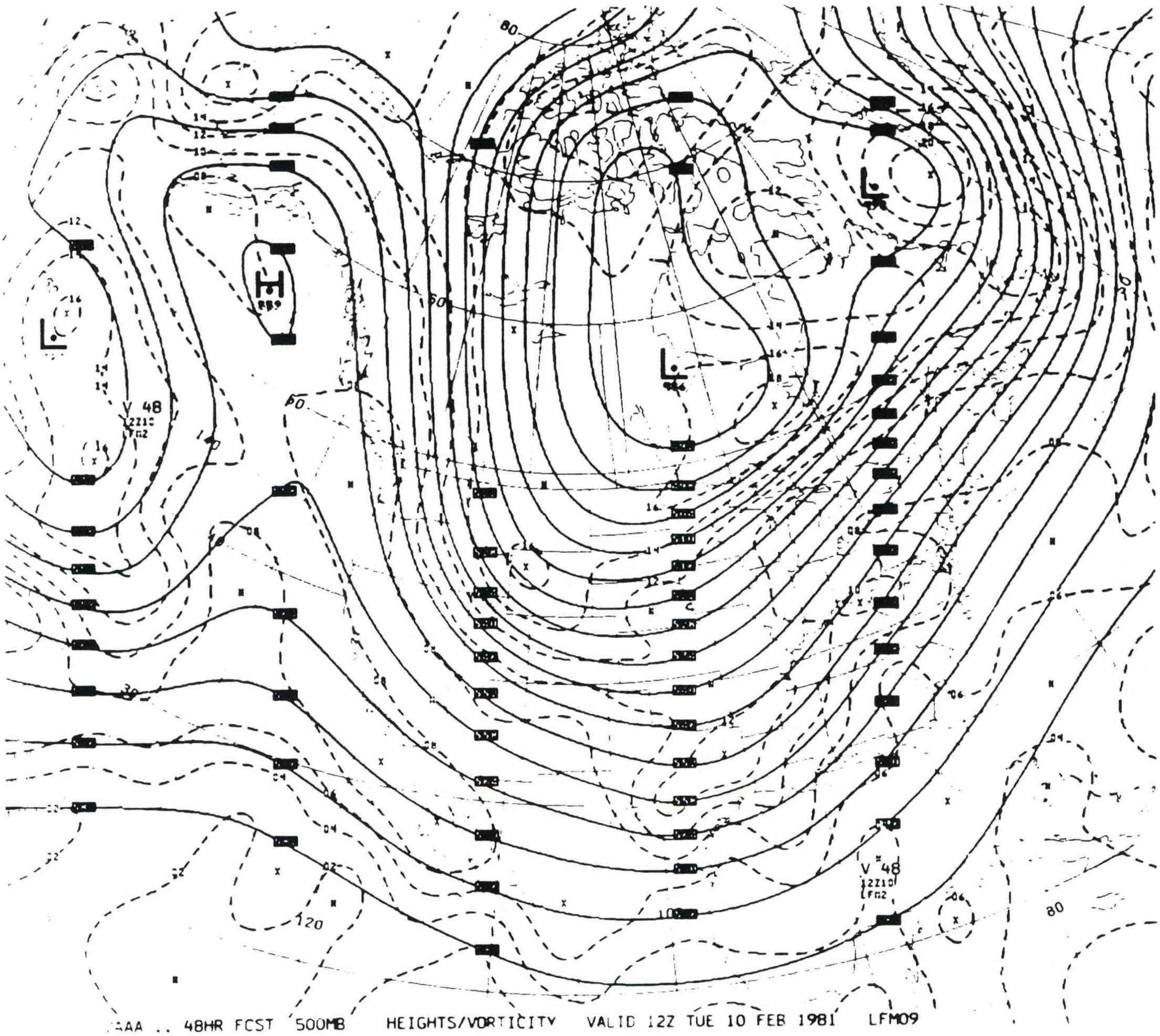

Figure 7. In-core fourth-order LFM 48-hour forecast of 500 mb height and vorticity verifying at 12Z Tuesday, 10 February 1981.