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Subject: Technical Procedures Bulletin No. 67: THE LIMITED AREA FINE MESH (LFM) MODEL

To: Recipients of Technical Procedures Bulletin Series

This bulletin was prepared by Frederick P. Ostby of the Technical Procedures Branch from information provided by Messrs. J. Howcroft and A. Desmaris of the National Meteorological Center. It highlights the major differences between the LFM and PE models and also describes the facsimile depiction of the LFM package.

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THE LIMITED AREA FINE MESH (LFM) MODEL

1. INTRODUCTION

Output from the Limited Area Fine Mesh (LFM) Model has been made available to the field on National Facsimile (NAFAX) on a routine basis since September 29, 1971. While some of the model's details have been made known to forecasters (e.g., the August 10 memorandum from the Director), there are additional aspects that have not been covered before that are worth mentioning. Of particular interest are the significant differences between the operational 6-layer NWP model (hereafter referred to simply as the PE model) and the LFM (also a PE model). There are more similarities than differences because, basically, the LFM is the PE model on a finer grid [2].

This bulletin was prepared with the idea in mind of pointing out these differences in a simplified manner without going into a great deal of detail. (Details of the PE model can be found in Weather Service Forecasters Handbook No. 1 [9] with updated material contained from time to time in the Technical Procedures Bulletin Series.) Also contained herein is a description of the LFM depiction on NAFAX. Improvements in both the model and its depiction are being worked on and will be described in future bulletins.

2. COMPARISON WITH THE OPERATIONAL PE MODEL

This section highlights the significant differences between the LFM and the PE. For convenience, a summary is provided in outline form in Table 1.

2.1 STRUCTURE

The LFM uses a grid length that is one-half that of the PE with a corresponding halving of the time period between solutions of the prediction equations (time step) from ten to five minutes. To bring the increased number of computations to within prescribed computer schedules, the geographical area for which the model produces a 24-hr forecast is reduced (see Figure 1).

Use of a shorter grid length means that more data points are used to depict any given circulation feature and, consequently, these features can be more faithfully represented in the initial data. Use of a finer mesh also decreases the truncation errors that arise in calculating gradients by finite differencing schemes and should improve the forecast motion of short-wave troughs and ridges.

The vertical structure of the LFM and the PE is the same (Figure 2), however, the underlying terrain is somewhat different because of the greater detail that the LFM is able to portray (Figure 3).

Another differing feature is the grid orientation. One axis of the PE grid system is parallel to 80° West, while the LFM has one axis parallel to 105° West.

2.2 ANALYSIS PROCEDURES

Both the LFM and the PE require objective analyses of heights and temperatures at ten constant pressure surfaces for model initialization. The procedure for both models is essentially the same, i.e., the so-called successive approximation technique is used in which corrections are applied to a first-guess field based on a comparison of the data with the interpolated value of the guess field at an observation point [1]. The LFM incorporates the latest procedure in first-guess production recently introduced into the PE whereby 300 mb has become the key upper level rather than 500 mb [5].

a. Balance Equation

Initial winds for the PE model are derived from objectively analyzed wind fields interpolated from constant pressure surfaces to PE sigma surfaces [7]. The LFM still uses the older procedure of employing the nonlinear balance equation to obtain initial wind fields given the objectively analyzed geopotential height fields [3]. Investigations are being carried out to determine if direct wind analysis can be incorporated in the LFM.

b. Boundaries

One difference in analysis procedure is a consequence of the fact that the LFM boundaries are located in meteorologically active regions as opposed to the near-equator boundaries of the PE. Instead of using data to analyze for grid points along the LFM boundaries, first-guess values are used (the previous 12-hr PE prog).

c. Moisture

There is a major difference in moisture analysis procedure between the LFM and the PE. A more detailed description of this procedure will be the subject of a future Technical Procedures Bulletin. The moisture analysis supplied to the PE model is based on the mean surface-to-500 mb relative humidity analysis. This comes primarily from radiosonde data (as seen on NAFAX charts N24 and N90) with some modification based on evidence of visual moisture from surface snyoptic reports and satellite data [4]. Each of the three moisture-bearing layers in the PE model (boundary layer, lowest and middle tropospheric layers--Figure 2) is initially assigned the same value of relative humidity for a given grid point as the mean of the entire three layers.

For the LFM, relative humidity is analyzed separately, sigma layer by sigma layer. Briefly, the analysis procedure consists of first computing mean relative humidities for individual sigma layers from radiosonde observations. A computed relative humidity report only affects the four grid points surrounding that station location. After assigning the value of the first such report to the surrounding grid points, these grid points are subsequently modified if there are additional nearby observations. These modifications are made as an inverse function of the distance between the grid point and the observation (closer observations receive more weight). This procedure is carried out for all radiosonde data, and all grid points which remain unaffected by radiosonde data are "flagged."

To provide estimates of relative humidity for these flagged grid points, inferences are made using the more numerous surface snyoptic reports.

(1) Boundary layer - The mean relative humidity for this layer is derived from a combination of surface humidity, present weather, and low-cloud amount information. Present weather is converted to a relative humidity value using a table similar to Table 1 in Technical Procedures Bulletin No. 55 (or Appendix 12 of Forecasters Handbook No. 1). Low-cloud amount (base below 2000 ft) is also empirically converted to a relative humidity value (RH range: 60% for no low clouds to 98% for overcast). These three values are then averaged to provide the boundary layer mean relative humidity.

(2) Lowest tropospheric layer - Estimated mean relative humidity for this layer is an average inferred from low cloud amount (RH range: 60% to 90%) and present weather components.

(3) Middle tropospheric layer - The value used for this layer is based solely on middle cloud amount (RH range: 45% to 75%).

All inferred humidity values are used in the same manner as for radiosonde reports, but applied only to previously flagged grid points. In no case is a grid-point value from radiosonde data replaced by inferred data. At this juncture any grid point still flagged as unassigned is given the 12-hr forecast RH value from the previous operational PE run for the appropriate sigma layer.

2.3 FORECAST PROCEDURES

The only significant difference between the LFM and PE as far as forecast procedures are concerned lies in the handling of the boundaries. The LFM boundary values (acquired initially from the previous PE forecast) are held constant with time rather than being allowed to vary as is the case in the PE model. This procedure gives rise to nonmeaningful noise which creeps into the grid during the course of the forecast. The boundaries, however, are sufficiently removed from the area of interest to prevent this contamination from seriously affecting the quality of a short range forecast.

One undesirable manifestation of this boundary treatment has been the so-called "pillow" which refers to a substantial over- or under-forecast in sea-level pressure (but also observed to a lesser extent at other levels) over a large portion of the forecast area. This particular effect is caused by fixing the boundaries initially with conditions that reflect either a net gain or loss of mass in the limited volume considered by the model. Since these boundaries are not permitted to change their values with time, some mass is pumped into (or out of) the volume at each time step and steadily increases (or decreases) the total mass contained in the volume. By adjusting the net flow initially, it has been possible to keep the pillow within an acceptable figure of a few millibars. Since the pillow effect tends to be distributed more or less uniformly over fairly large regions, the resulting <u>configuration</u> of the pressure field (gradients and locations of significant features) is generally not substantially affected by the pillow. More research is being devoted to the correction of this problem.

The present version of the LFM forecasts precipitation in the same fashion as does the PE [4] including the convective rain routine [6].*

2.4 OUTPUT

The only difference in output between the LFM and the PE that warrants mention involves vertical velocity. The vertical velocity (interpolated to 700 mb) is time averaged using every other time step during the one-hour period ending with the valid time (6 values). The PE vertical velocity is similarly averaged using every other time step, but since the PE time step is double the LFM's, this amounts to a two-hour period. There is no difference in the calculation of vorticity from the forecast wind fields of the two models. The larger values of the vorticity centers and steeper gradients from the LFM can be attributed to its finer grid mesh.

*Effective 12/1/71, the saturation criterion for the LFM will be changed from 90% to 100%, i.e., precipitation will not begin until 100% relative humidity is reached in any layer. Also the depicted LFM RH on fax will no longer be inflated. The PE RH will remain unchanged, i.e., 90% saturation criterion and 11% inflation in depiction.

3. LFM DEPICTION

The depiction of the LFM on facsimile is undergoing improvement. Such things as stippling of QPF areas, addition of more state boundaries, and varying the intensity of different types of contours are expected to be implemented in the near future. Notification of these improvements will be made by GENOT.

3.1 ANALYSES (Charts N21, N87)

Left Panel - 500 MB HEIGHT AND VORTICITY. Height contours (dashed) are at 60 meter intervals and vorticity isopleths (solid) at intervals of 2×10^{-5} sec^{-1}. Absolute vorticity "channels" will be stippled between 14 and 18, 22 and 26, etc. Vorticity maxima and minima are printed (but not labeled) as + or -, respectively.

Right Panel - RELATIVE HUMIDITY. Contours are solid lines for 10, 30, 50, 70, and 90% but labeled with a single digit (1, 3, 5, 7, 9). Areas of humidity above 70% are stippled.

3.2 PROGNOSES (Charts N22, 25, 88, 91)

Upper-left Panel - 500MB HEIGHT AND VORTICITY. Depiction same as analysis.

Upper-right Panel - RELATIVE HUMIDITY. Depiction same as analysis.

Lower-left Panel - SEA-LEVEL PRESSURE AND 1000-500MB THICKNESS. Isobars (solid) are drawn at intervals of 4 millibars and thickness contours (dashed) at 60 meter intervals. High and low centers (sea level) are depicted and labeled in tens and units of millibars.

Lower-right Panel - QPF AND 700MB VERTICAL VELOCITY. Quantitative precipitation forecasts cover 12-hr periods ending at the valid time of the chart (0-12 hr QPF for the 12-hr prog and 12-24 hr QPF for the 24-hr prog). Isohyets are solid lines drawn for values of 0.01", 0.50", 1.00", 1.50", etc. Precipitation amount maxima are located by a + and are followed by their values in centi-inches.* Vertical velocity isopleths are drawn as dashed lines at intervals of 2 microbars per second. Centers of maximum upward and downward motion are printed out as + and -, respectively.

4. USING THE LFM GUIDANCE

We have not had enough experience yet to say much about the performance characteristics of the LFM and how the field forecaster can make adjustments to improve the forecasts. It is recommended that some time be spent by forecasters in comparing the relative humidity, 500-mb flow, sea-level pressure, and 1000-500 mb thickness forecast with the corresponding forecast variables from the PE model.

*QPF stippling was added 11/16/71. Alternate half-inch "channels" are stippled. Possible ambiguity between dry areas and areas where there is more than 0.50" but less than 1.00" can be resolved by noting whether there is a maximum value printed out. If there is no maximum value then the area is a dry one.

Preliminary verification figures for the 24-hr sea-level pressure forecasts indicate that the LFM has been performing substantially better than the PE as measured by the S_1-score [8]. This verification system emphasizes skill in prediction of gradients and locations of significant features (agreed to be more important than the absolute values of sea-level pressure) so that the pillow does not usually hurt the forecast. To detect the presence of a pillow one should focus attention on high pressure centers which seem to be obviously too high when the pillow is present. Also, a comparison with the previous set of PE surface progs (FOFAX only) can offer a possible clue. When there does appear to be a substantial pillow, it should be noted that the 1000-500 mb thickness values may not give good guidance for rain-snow discrimination. The thickness pattern, incidentally, in combination with the forecast sea-level pressure pattern can be an excellent indicator of frontal positions [10].

One should also note that, in the QPF panel, precipitation amounts cover a 12-hr period ending at the valid time. It is possible, however, to roughly infer the "spot" precipitation by noting the areas on the mean relative humidity panel that have values of 90% or more.

Additional information on the use of LFM guidance and verification results will be sent to the field when it becomes available. Watch for this in future Technical Procedures Bulletins and NMC Newsletters.

5. REFERENCES

1. Cressman, G.P., "An Operational Objective Analysis System," Monthly Weather Review, Vol. 87, No. 10, October 1959, pp. 367-374.

2. Howcroft, J.G., "Local Forecast Model: Present Status and Preliminary Verification," National Meteorological Center Office Note 50, January 1971.

3. Technical Procedures Bulletin No. 13: "Divergent Initialization of the 6-Layer (PE) Numerical Prediction Model," Technical Procedures Branch, May 1968.

4. Technical Procedures Bulletin No. 55: "Latest Change and Summary of Current Procedures in Precipitation Forecasting in the 6-Layer (PE) Numerical Prediction Model," Technical Procedures Branch, NWS, October 1970.

5. Technical Procedures Bulletin No. 63: "New NMC 'First Guess' and Monitoring Procedures," Technical Procedures Branch, NWS, June 1971.

6. Technical Procedures Bulletin No. 64: "Convective Rain in the PE Model," Technical Procedures Branch, NWS, July 1971.

7. Technical Procedures Bulletin No. 65: "New Initialization Procedure for the 6-Layer (PE) Numerical Prediction Model," Technical Procedures Branch, NWS, August 1971.

8. Teweles, S. and H. B. Wobus: "Verification of Prognostic Charts," Bulletin of the American Meteorological Society, Vol. 35, No. 10, December 1954, pp. 455-463.

9. Weather Service Forecasters Handbook No. 1 - Facsimile Products; Chapter 6 "Upper Air Prognosis," Section UP-O, Rev. 19, August 1971, pp. 6-1 to 6-16.

10. Western Region Technical Attachment No. 71-45: "Use of LFM Forecasts," Western Region Staff Notes, NWS, October 19, 1971.

Table 1. SUMMARY OF MAJOR DIFFERENCES BETWEEN LFM AND PE MODELS

		LFM	PE
STRUCTURE	Grid orientation	One axis parallel to 105W	One axis parallel to 80W
	Grid spacing	190.5 km at 60N (1/2 PE)	381 km at 60N
	Basic time step	5 min	10 min
	Grid area	North America plus adjacent oceans	Most of Northern Hemisphere
ANALYSIS	Initialization	Balance equation	Direct analysis of winds (TPB#65)
	Boundaries	12-hr PE forecast	As per 10-level analysis program
	Moisture	Direct analysis of raobs by sigma layers. Inferences from surface synoptic reports when raobs unavailable.	Surface to 500-mb RH analysis. All sigma layers given same value (TPB#55)
FORECAST	Boundaries	Constant with time	Allowed to vary with time
OUTPUT	Vertical velocity	Time-averaged using every other time-step during one hr ending with valid time.	Time-averaged using every other time step during 2 hr ending with valid time.

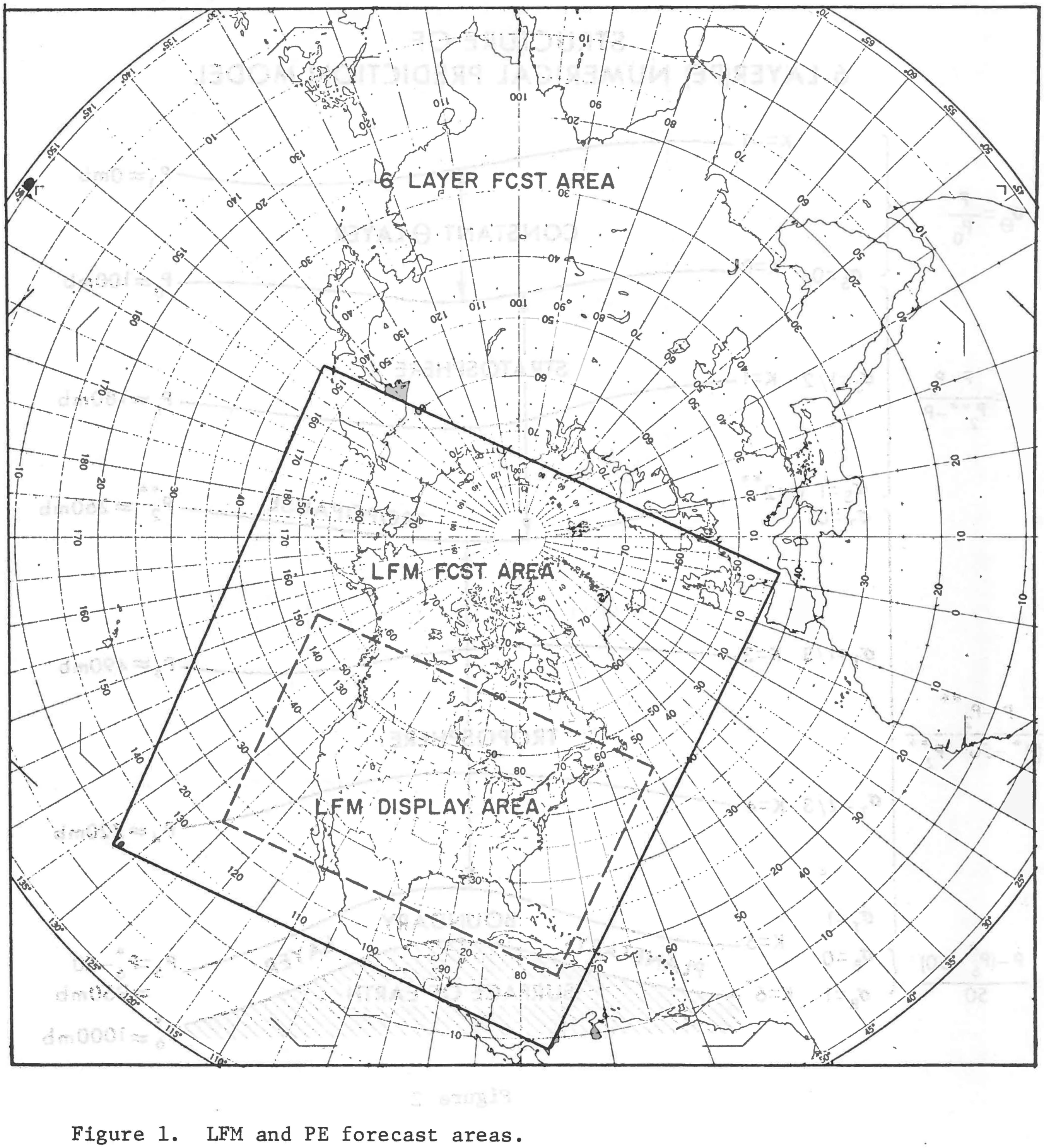

Figure 1. LFM and PE forecast areas.

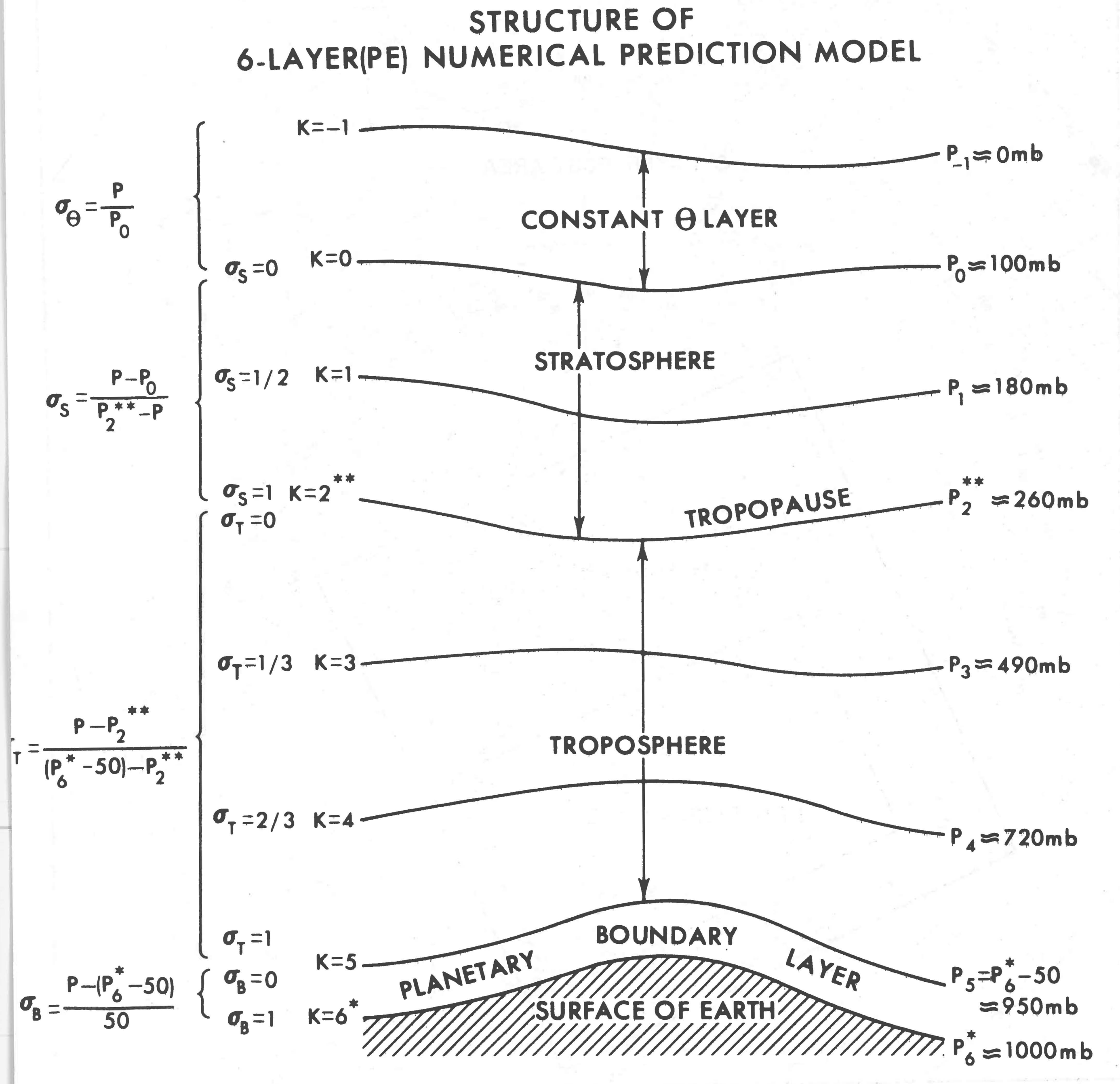
STRUCTURE OF
6-LAYER(PE) NUMERICAL PREDICTION MODEL
K=-1
P_{-1}≈0mb
σ_Θ = P/P_0
CONSTANT Θ LAYER
σ_S=0 K=0
P_0≈100mb
σ_S = (P−P_0)/(P_2**−P)
STRATOSPHERE
σ_S=1/2 K=1
P_1≈180mb
σ_S=1 K=2**
σ_T=0
TROPOPAUSE
P_2**≈260mb
σ_T=1/3 K=3
P_3≈490mb
σ_T = (P−P_2**)/((P_6* −50)−P_2**)
TROPOSPHERE
σ_T=2/3 K=4
P_4≈720mb
σ_T=1
BOUNDARY
K=5
PLANETARY
LAYER
σ_B=0
P_5=P_6*−50
≈950mb
σ_B = (P−(P_6*−50))/50
σ_B=1 K=6*
SURFACE OF EARTH
P_6*≈1000mb

Figure 2

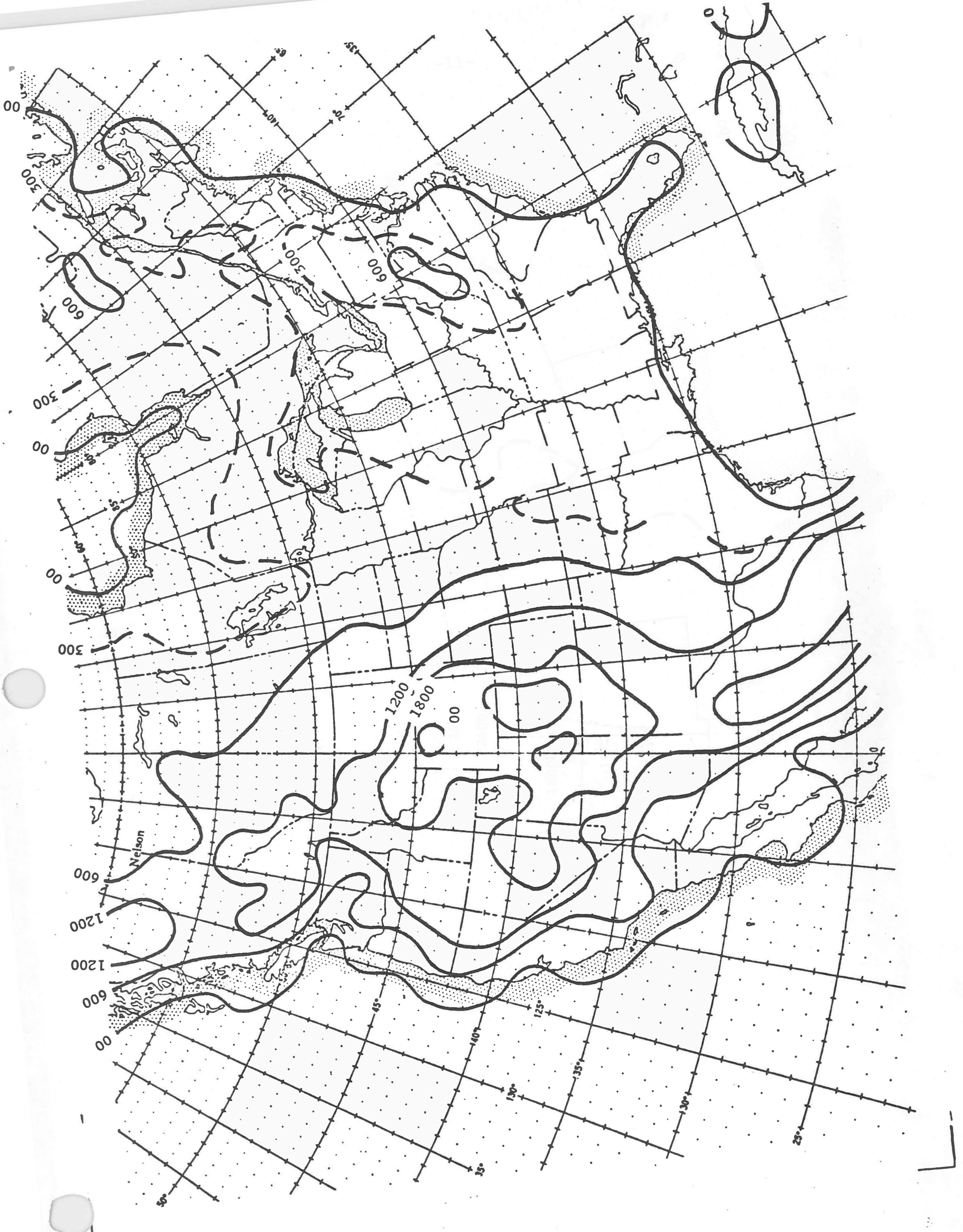

Figure 3 LFM Terrain (Meters)