DEPARTMENT OF COMMERCE * UNITED STATES OF AMERICA *

NOAA Technical Memorandum NWS WR-141

COMPARISON OF LFM AND MFM PRECIPITATION GUIDANCE FOR NEVADA DURING DOREEN

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Salt Lake City, Utah
April 1979

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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NATIONAL WEATHER SERVICE
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COMPARISON OF LFM AND MFM PRECIPITATION GUIDANCE FOR NEVADA DURING DOREEN

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I. INTRODUCTION

The National Weather Service Western Region, in a continual effort to improve weather forecasts, has a long history of forecast verification. In recent years the Probability of Precipitation (PoP) forecasts have received the greatest attention. The field forecaster, when confronted with the possibility of significant amounts of rainfall over terrain that is flash-flood prone, is likely to be much more concerned with accuracy of Quantitative Precipitation Forecast (QPF) guidance. However, to date, there is very little documentation of the performance of different operational models in the area of forecasting precipitation amounts over the western United States.

The best method(s) for judging the performance of numerical models remains an area of dispute. A number of investigators (Houghton and Irvine, 1976) have suggested using what has been termed "dynamically significant parameters". This approach is based on the concept that higher order derivatives of the mass and/or wind field are more sensitive and delineate more centers of action than simple use of the geopotential field. It has also been argued that areal extent and amounts of precipitation forecast may be the ultimate measure of numerical model performance. The major pitfall is, of course, that precipitation is parameterized. This makes it difficult to distinguish between possible shortcomings in model dynamics and possible poor parameterization of the precipitation process.

The intent of this case study is to present a brief qualitative comparison of Limited-Area Fine Mesh (LFM) and Movable Fine Mesh (MFM) precipitation forecasts which may hopefully become part of sufficient documentation to help field forecasters utilize MFM guidance. The case provided is for the period 17-18 August 1977, when the remnants of Hurricane Doreen moved northward into southwestern United States. Large amounts of moisture spread into Nevada, producing significant rainfall over all but the northwest corner of the state.

II. OBSERVED DATA

Validity of constructing isohyets from widely and unevenly dispersed precipitation measuring sites is open to considerable (and justifiable) question. This is especially true in mountainous areas such as Nevada. Figures 1a through 1d depict precipitation analyses of accumulated totals for 12-hour periods ending at the dates and times indicated. The isohyets were constructed utilizing precipitation reports, visible and infrared satellite imagery, and radar reports. Greatest weight was given to rain-gage measurements, all of which are located in valleys. No attempt was made to incorporate terrain effects and it is likely that mountainous areas received substantially greater amounts of rainfall than are presented in Figure 1. As will be shown, however, this will not significantly affect conclusions reached in the study.

The analyses indicate that with time the center of significant precipitation entered the southeast corner of Nevada, followed an arc-shaped course northwestward into central Nevada, and then exited via the northeast corner of the state. It should be pointed out that the northward moving remnants of Hurricane Doreen split. A second area of major precipitation moved northwestward across southern and central California on the west side of the Sierra Nevada*.

III. PHYSICS OF THE MODELS

The LFM model used operationally by the National Weather Service (NWS) during Doreen was a "regional" Primitive Equation (PE) numerical model with a grid spacing of 190.5 km at 60° latitude to 160 km at 35° latitude. Dynamics of the model are well documented in the NWS Forecaster's Handbook Number 1 (1976). Terrain used in the model is shown in Figure 2. Details of other physical effects included in the model have also been documented by Stackpole (1973) and Badner (1974). Of special significance to this study is the method the model uses to generate precipitation. This is handled by two parameterizations. The first incorporates large-scale processes forecast by the LFM through a laminated moisture model and seasonally adjusted thresholds of precipitable water (Technical Procedures Bulletin ((TPB)), 1972). Small-scale convective precipitation is also parameterized through a parcel ascent technique (TPB, 1971). However, latent heat released by this process is not accounted for in the model as is done in the large-scale parameterization. TPB 174 (1976) explains how space filtering techniques employed can cause facsimile chart displayed precipitation fields to suffer an information loss.

Only limited information regarding the structure, dynamics, and parameterizations used in the MFM has reached field forecasters. Shuman (1978) and TPB 160 (1976) provide some general information about the model. Additional details pertinent to this study were supplied by Livezey (1978).

The MFM uses a smoothed LFM terrain and can be run in two different modes. The hurricane tracking mode has movable mesh with grid spacing of 60 km. It is initialized through spectral analysis and permits artificial insertion of a vortex. The heavy precipitation mode uses a fixed grid array with 100-km spacing. It is initialized in the same manner as the LFM (Cressman analysis). This was the mode which provided guidance to the field during "Doreen".

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*[Editor's Note: Since the author had detailed precipitation observations for Nevada only, he limited his study to that area.]

In addition to increased horizontal resolution, the MFM also contains ten layers in the vertical as opposed to the six-layer LFM. Another major difference between the two models is the method of generating precipitation. The MFM parameterization is based on the concept that the statistical contributions to the rate of latent heat release and vertical transports of sensible heat, moisture, and horizontal momentum by subscale convective motions can be modeled in terms of the large-scale variables (Kuo 1965, 1974). The amount and vertical distribution of the latent heat released by large-scale convergence-controlled deep cumulus convection is modeled from the moisture convergence and the temperature difference between the cloud and environment. The vertical transport of heat and moisture produced by shallow convection unrelated to large-scale convergence is attributed to convection from the warm surface below and calculated in terms of the heat and moisture fluxes at the surface by the use of a plume-type model.

Output from the MFM in the heavy precipitation mode is relayed to field offices via facsimile and consists of contoured analyses of 6-hour accumulated precipitation totals. Forecasts displayed usually cover time periods from 18 to 36 hours after the initial time, mainly to allow noise problems to smooth out. Thus, comparison of the precipitation forecasts from information available to the field generally reduces to forecasts of 12-hour accumulated precipitation totals at 24 and 36 hours after initialization.

When comparing the performance of the two numerical models, it should be kept in mind that both are primitive equation models, both have essentially the same terrain, and both are initialized from the same data base. The most significant differences in the models appear to be the spacial resolution (horizontal and vertical) and the method of precipitation parameterization.

IV. PERFORMANCE OF THE MODELS

Figures 3a and 3b depict LFM 24-hour and 36-hour forecasts of 12-hour accumulated precipitation totals ending at 1200 GMT 17 August. Referring to Figure 1a, this was the period of the initial surge of precipitation into the southeast corner of Nevada. The 24-hour LFM forecast was fairly successful in delineating the northward extent of measurable precipitation. It also gave an indication of significant amounts reaching extreme southern Nevada but greatly underforecast totals. The 36-hour forecast from the previous LFM run did not catch this initial surge of significant rainfall.

MFM 24- and 36-hour forecasts valid at the same time are shown in Figures 3c and 3d. Both prognoses indicated significant precipitation entering southern Nevada but amounts were greatly underforecast. Also, the 24-hour forecast spread lighter precipitation (<.25") northward too rapidly while the 36-hour forecast from the previous run verified much better.

Figures 4a through 4d are similar to Figure 3, except the model forecasts are valid at 0000 GMT 18 August. Comparisons with Figure 1b shows that the LFM moved the center of maximum precipitation and area of measurable rainfall a bit too far northwestward in both runs. The QPF was reasonable although a little low in both cases. The corresponding MFM output also underforecast precipitation amounts and was too slow on the northward movement of the area of significant rainfall. In fact, little movement of the area was forecast.

MFM forecasts from the 0000 GMT 18 August operational run were available in time to output 6- and 12-hour forecasts to the field. In Figure 5, 12- and 36-hour LFM/MFM forecasts are shown for comparison with Figure 1c. As can be seen, both models completely missed the continued northward movement of the area of maximum precipitation on the 12-hour forecasts. Since the models performed in a similar manner, it could be that a poor initialization of the moisture field was a large contributor to these poor forecasts. Not having available the initial moisture fields, this was not investigated.

The corresponding 36-hour LFM forecast (Figure 5b) was more successful, although it again tended to track the maximum precipitation center too far northwestward. The 36-hour MFM overforecast amounts for the first time. The model again "locked in" the center of maximum rainfall over southeast Nevada.

In summary, the performance of the models for this case indicates that in general both tended to underforecast amounts. The LFM tended to move the center of significant precipitation too far northwestward. This may have been due to the model's inability to delineate the precipitation center over Nevada from the second observed center over California. This apparently resulted in a forecast of a single center, which fell somewhere between the two actually observed areas.

The MFM showed skill in differentiating the two centers of maximum precipitation but was unable to forecast movement of the Nevada center. From Figure 2 it appears that the smoothed LFM terrain used by the MFM may have resulted in the precipitation center being locked in the area of modeled upslope terrain (and hence convergence) over southeast Nevada. The increased skill in forecasting the two centers is likely attributable to better spacial resolution and the more physically realistic precipitation parameterization of the MFM.

V. CONCLUSIONS AND RECOMMENDATIONS

During the surge of precipitation into the southwestern United States from the remnants of Hurricane Doreen, the LFM appeared to provide better QPF guidance than the finer mesh, more physically realistic MFM. However, at least in this one case, the apparent superior skill was possibly superficial. The LFM, unable to resolve the split in the moisture surge, forecast a single center of activity. The MFM successfully delineated the split but the QPFs over Nevada suffered since the center of significant precipitation remained locked in an area of modeled upslope. This apparently created a spurious area of large-scale convergence, an error which the precipitation parameterization method used by the model would be very sensitive to.

It is suggested that forecasters utilizing MFM guidance in the future watch for this type of error. Since the MFM was originally designed for tropical application over relatively flat terrain, it may prove to be extremely sensitive to deficiencies in modeled mountainous terrain over the western United States. This is, of course, only a single limited study and the MFM may vindicate itself in the future. However, if additional verification of MFM performance indicates this type of error is common, the knowledge should lead to much better use of the model's guidance by field forecasters.

Finally, it is recommended that a comprehensive discussion of the dynamics and parameterizations used in the MFM be made available to the field as soon as possible. This information would greatly assist forecasters in interpreting and interacting with MFM guidance.

VI. ACKNOWLEDGMENTS

The author wishes to thank Dr. Thomas Grayson for his encouragement and critical reviews of this paper. Thanks are also expressed to Dr. R. Livzey of the Modeling Branch Development Division of NMC for providing information on the MFM model.

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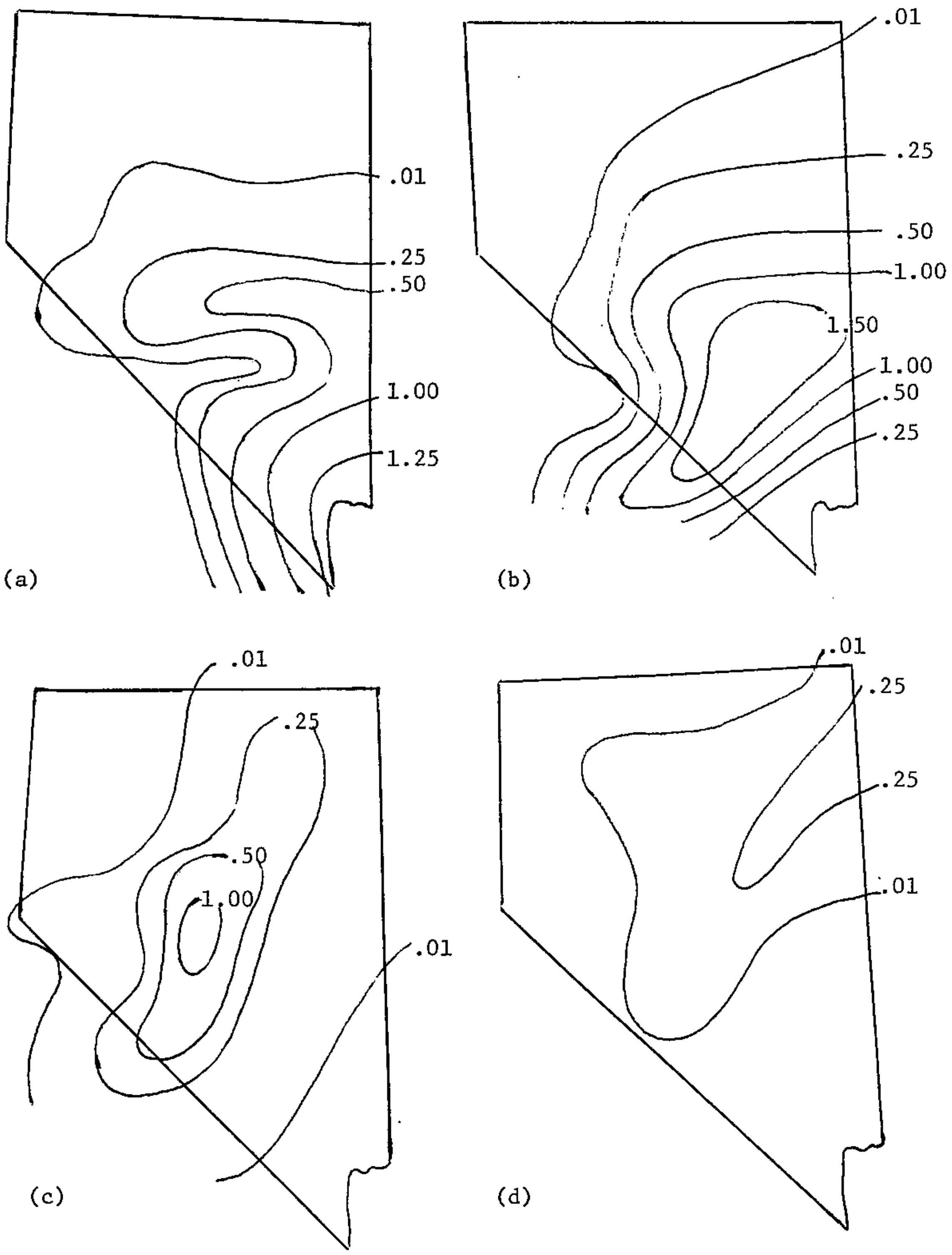

Figure 1. Accumulated Precipitation Totals for 12-hour Periods Ending
(a) 1200 GMT 17 August 1977, (b) 0000 GMT 18 August,
(c) 1200 GMT 18 August, and (d) 0000 GMT 19 August.

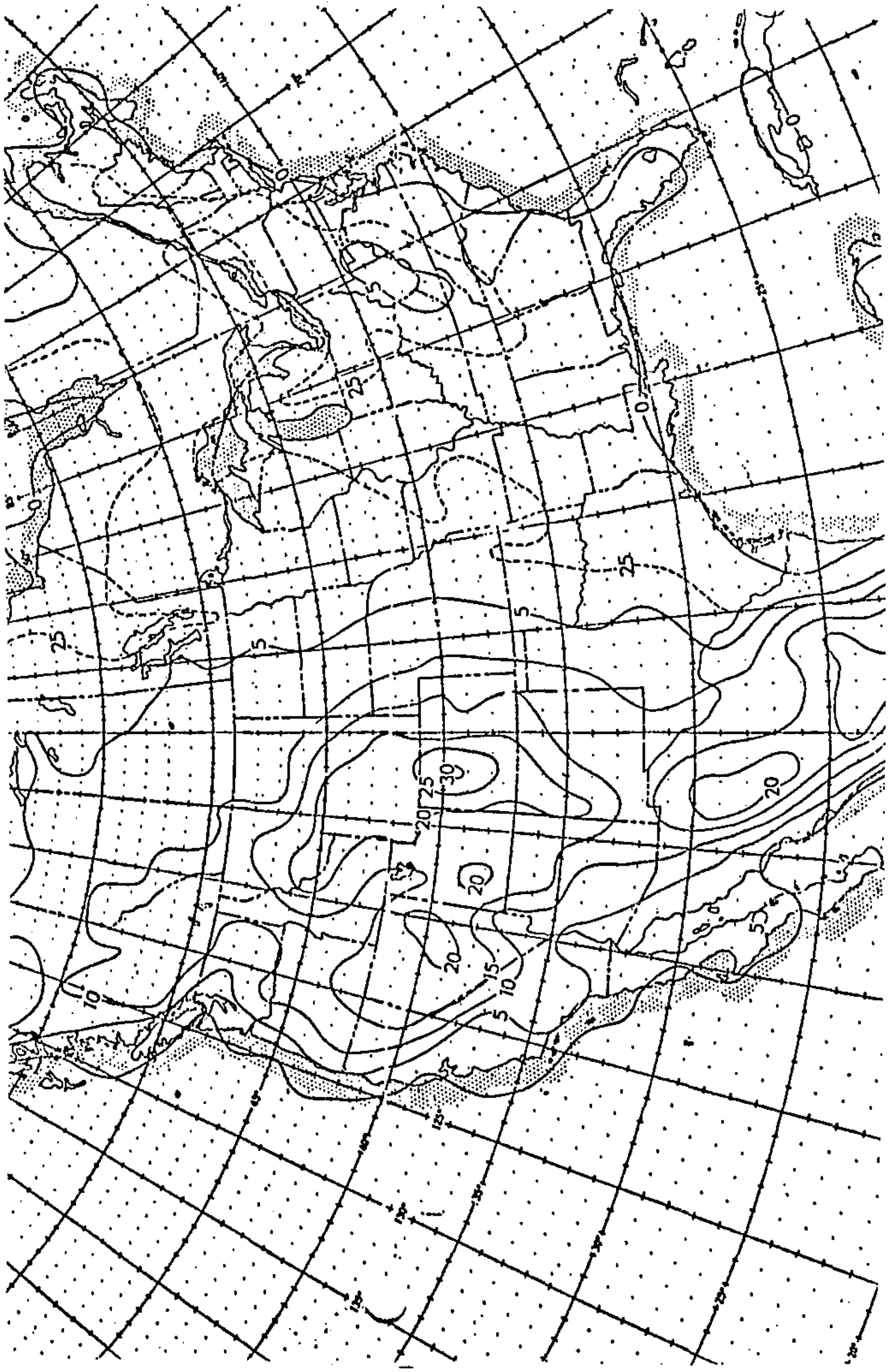

Figure 2. LFM Terrain (Meters).

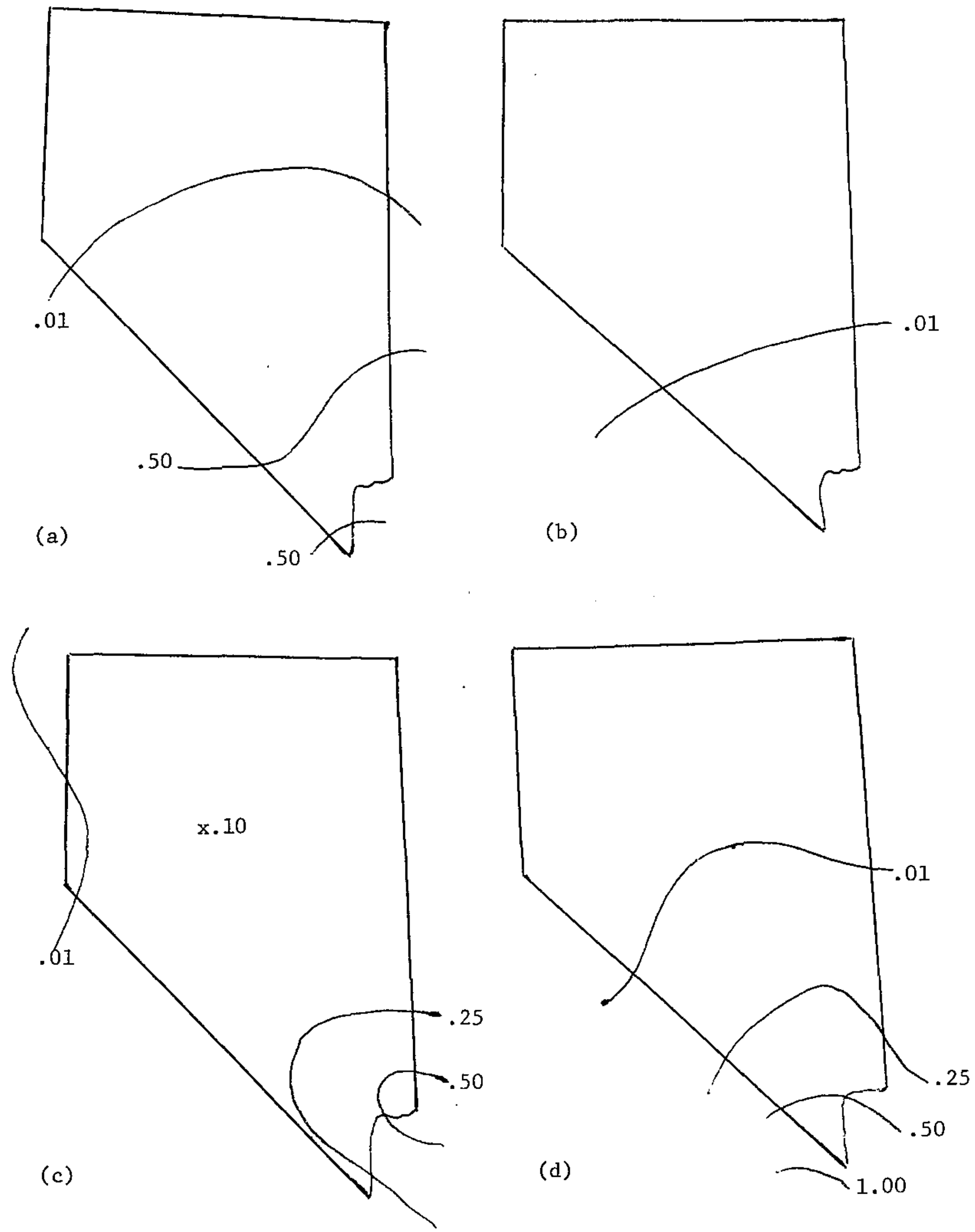

Figure 3. Model Forecasts of 12-Hour Accumulated Precipitation Totals in Inches, valid 1200 GMT 17 August 1977. (a) LFM 24-hour forecast, (b) LFM 36 hour, (c) MFM 24 hour, (d) MFM 36 hour.

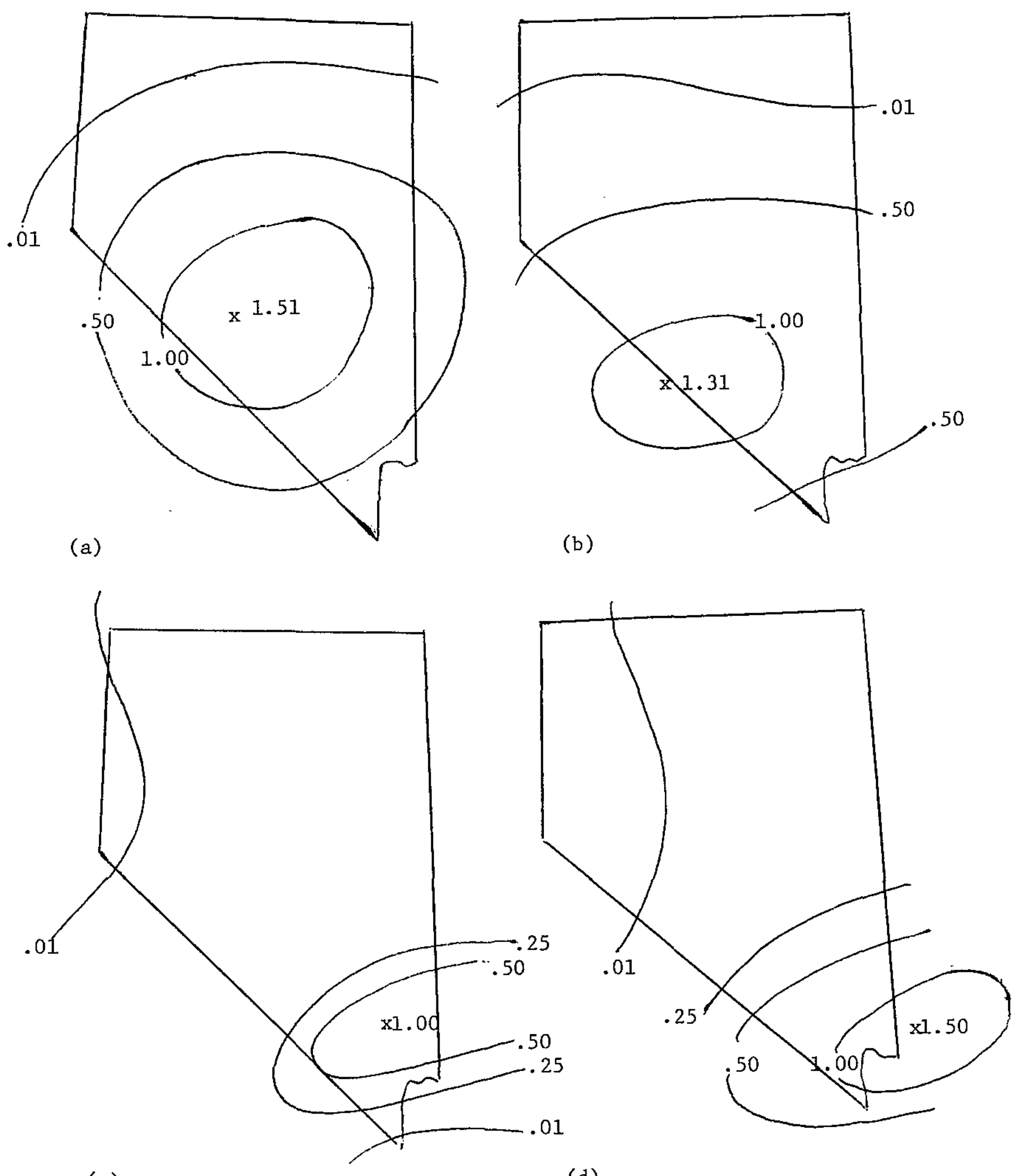

Figure 4. Model Forecasts of 12-Hour Accumulated Precipitation Totals in inches, valid 0000 GMT 18 August 1977. (a) LFM 24-hour forecast, (b) LFM 36 hour, (c) MFM 24 hour, (d) MFM 36 hour.

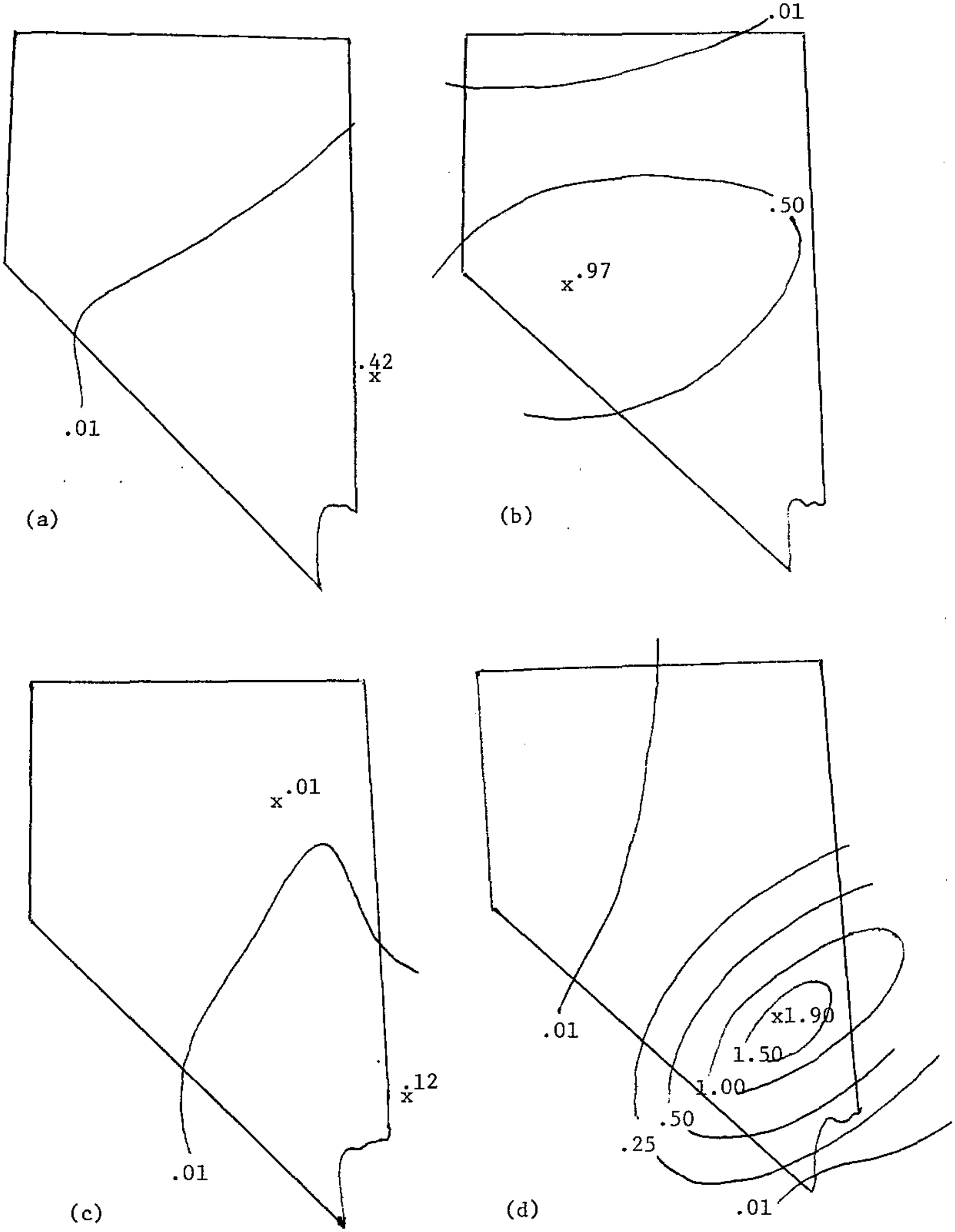

Figure 5. Model Forecasts of 12-Hour Accumulated Precipitation Totals in inches, valid 1200 GMT 18 August 1977. (a) LFM 12-hour forecast, (b) LFM 36 hour, (c) MFM 12 hour, (d) MFM 36 hour.

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