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Further Experimentations with Quasi-Lagrangian Prediction Model: Effect of High Vertical Resolution

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INTRODUCTION

This note describes results from numerical integrations of Quasi-Lagrangian Nested Grid Model (QNGM) using high vertical resolutions and LFM II horizontal grid structure. Details of the model are given by Mathur (1981). The primitive equations with σ as the vertical coordinate are integrated using a second order quasi-Lagrangian advective scheme. The model can be integrated using any desired horizontal and vertical resolutions and over any geogrpahical area. Results with the 10 layer version of the model on LFM II horizontal grid in the six model intercomparison test cases are described by Collins et al. (1981). One of the above test cases (tropical storm David 1979) has been integrated using 15 and 20 vertical layers respectively. Considerable improvement in the prediction of areas of heavy precipitation is achieved when the vertical resolution of the model is increased. The intensity and location of the storm are best predicted with 15 layer QNGM.

CASE STUDY: TROPICAL STORM DAVID

A. Surface Pressure

Tropical storm David was located over South Carolina (central pressure at 995 mb) at 12 GMT, 5 September 1979. It moved north northeastward with little change in its intensity. The center of the storm was positioned over eastern Pennsylvania at 12 GMT 6 September 1979 (Fig. 1a).

Forecasts valid at 12 GMT 6 September 1979 from several model integrations are shown in Fig. 2. The 10 L LFM II model predicts an open low (lowest pressure at 1002 mb) near the observed center of the storm (Fig. 2a). The 10 L QNGM performs better than 10 L LFM II. It predicts a closed low pressure area with central pressure at 997 mb (Fig. 2b). The intensity of the storm is best predicted by 15 L QNGM. The central 996 mb contour (Fig. 2c) is located nearly in the same area as the observed 996 mb contour (Fig. 1a).

B. Height and Vorticity at 500 Mb

A maximum in absolute vorticity of 18 units (= 18 * 10^{-5} sec^{-1}) is located above the surface center at 12 GMT 6 September 1979 (Fig. 1b). This analysis of vorticity is obtained from operational LFM FM00 file. Since the post processed fields in FM00 are obtained using LFM I (coarse) grid, it is likely that the actual maximum value of absolute vorticity at 500 mb near the center is somewhat larger than 18 units. (The maximum value near the center at 12 GMT 5 September 1979 was 20 units.)

The maximum in absolute vorticity and the contour height at 500 mb in storm David are better predicted in 10 L QNGM (Fig. 3b) compared to those obtained using 10 L LFM II (Fig. 3a). The locations of maximum (20 units) in absolute vorticity and low pressure (height) area are better predicted by 20 L QNGM (Fig. 3d) compared to those obtained from 15 L QNGM (Fig. 3c).

C. Precipitation

The 12-hour precipitation ending at 12 GMT 6 September 1979 is shown in Fig. 4. A large area with amounts exceeding 1" extends from Virginia to southern New York State.

The corrected precipitation amounts predicted by 10 L LFM II for the above 12-hour period are shown in Fig. 5a. The area with maximum precipitation (0.5") is predicted somewhat to the west of area of observed maximum precipitation (see Fig. 4). The area of heaviest amounts of precipitation (amounts exceeding 1.5") predicted by 15 L QNGM also lies to the west of area of observed heavy precipitation. The precipitation forecast is somewhat better in 10 L QNGM than 10 L LFM II.

Note that the initial relative humidity (RH) fields for QNGM are derived from LFM analyses of precipitable water in the three lowest σ layers of 7 L LFM I. The values of RH are calculated in σ layers. The values of RH at standard

pressure levels between 1000 and 300 mb are derived from the above analyses and are saved 'daily' on operational FM00 archive file. For the initialization of QNGM, the above analyses of relative humidity between 1000 and 300 mb are used. The values of RH at higher elevations are obtained by assuming that RH above 300 mb decreases at the rate of 2% per 100 mb. Further, the relative humidity is assumed to remain constant (value at 100 mb) at pressures below 100 mb. We can not expect to capture the realistic vertical structure of relative humidity by the above procedure. In spite of this crude representation of RH; the QNGM model's performance in predicting more accurately the areas of heavy precipitation when higher vertical resolution is used, appears to be very satisfactory. One can expect the model to perform better when a more detailed analysis of RH (in vertical) becomes available to initialize QNGM.

CONCLUDING REMARKS

The initial data in both LFM and QNGM are derived from Cressman analysis. The lateral boundary conditions are derived in both models from a previous (prediction) cycle of NMC's operational large scale model. Numerical results from 24-hour integration of models show that in the case of tropical storm David, the 10 L QNGM predictions are superior to those obtained from 10 L LFM II. The intensity of the storm at the surface and the middle troposphere and precipitation are better predicted in 10 L QNGM than 10 L LFM II.

The results from 24-hour integrations of the models are only presented above. The 10 L QNGM and 10 L LFM II were integrated to 48 hours. The observed lowest surface pressure and maximum value of absolute vorticity at 500 mb at 12 GMT 7 September 1979 in storm David were 986 mb and 16 units respectively. The predicted surface pressure near the observed storm center was 984 mb in 10 L QNGM and 995 in 10 L LFM II. A maximum in absolute vorticity at 500 mb of 16 units was predicted in 10 L QNGM near the storm center. No maximum in absolute

vorticity at 500 mb near the storm center was predicted in 10 L LFM II. The performance of 10 L QNGM model at 48 hours was therefore also better than 10 L LFM II.

The QNGM model was also integrated using 15 and 20 layers respectively. The intensity of the storm at the surface and the middle troposphere and heavy precipitation amounts were significantly better predicted by 15 L QNGM when compared to those obtained using 10 L QNGM.

The performance of 20 L QNGM was somewhat less impressive than that of 15 L QNGM. The intensity of the storm at surface and heavy precipitation amounts were better predicted in 15 L QNGM than 20 L QNGM. However, the location of intense vorticity maximum (20 units in both cases) was better predicted in 20 L QNGM. It was located just above the surface center of the storm in 20 L QNGM but was displaced to the west of center in 15L QNGM.

The somewhat poorer performance of 20 L QNGM compared to that of 15 L QNGM is likely to be related to the inclusion of parameterization of physical processes (presently) in very simplified forms. For instance, the effect of surface frictional stress is assumed to vanish at the top of lowest layer. The thickness of this layer in 10 L and 15 L QNGM was $\Delta\sigma = 0.05$, while it was set to be $\Delta\sigma = .025$ in the 20 L QNGM. The effect of surface friction is therefore more pronounced in the (shallower) lowest layer of 20 L QNGM compared to that in 10 L or 15 L QNGM. Also, the cumulus clouds are allowed to originate from one of three lowest layers in the model. The third layer in 10 L, 15 L, and 20 L QNGM were located at σ equal to .85, .875, and .925 respectively. The convective clouds could therefore originate from somewhat higher elevations in 10 L and 15 L than in 20 L QNGM. It is also pointed out above that only a crude analysis of relative humidity distribution in vertical is currently available for the fine mesh models. Although some of the above differences

can be easily rectified (e.g. the depth of the lowest layer can be made same in all versions of QNGM), a complete impact of inclusion of increased vertical resolution on predictions can be only assessed after a more complete parameterization of surface and Ekman layers and radiational effects are incorporated in the model and a better analysis of moisture field becomes available. Work to incorporate more sophisticated parameterization procedures in QNGM is in progress.

REFERENCES

Collins, W., et al., 1981: Region Model Intercomparison, NMC Report.

Mathur, M. B., 1981: Design and present status of Quasi-Lagrangian Nested Grid Prediction Model. AMB Paper No. 16.

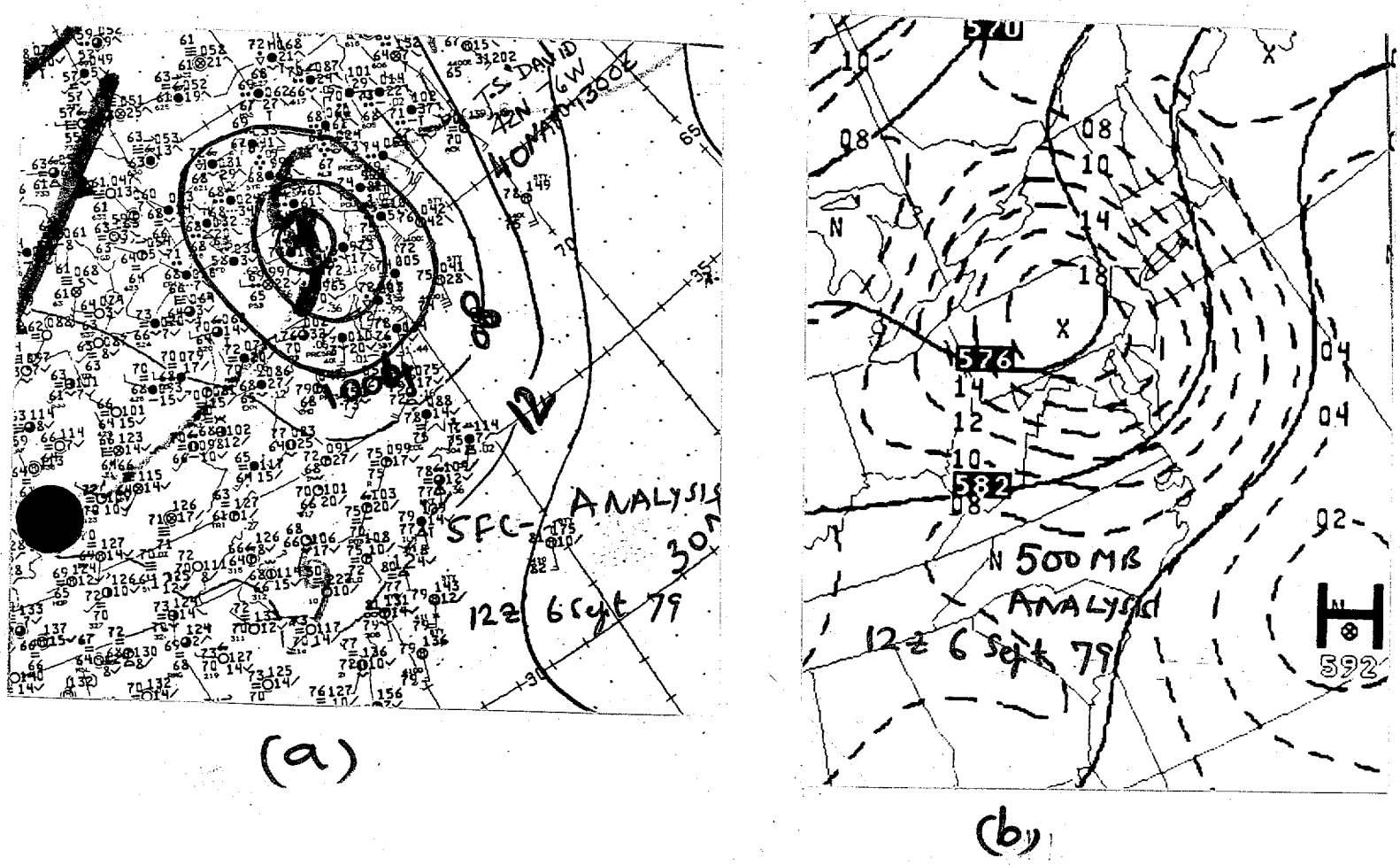

Fig. 1. (a) Surface pressure analysis at 12 GMT 6 September 1979; (b) height and vorticity analyses at 500 mb, 12 GMT 6 September 1979.

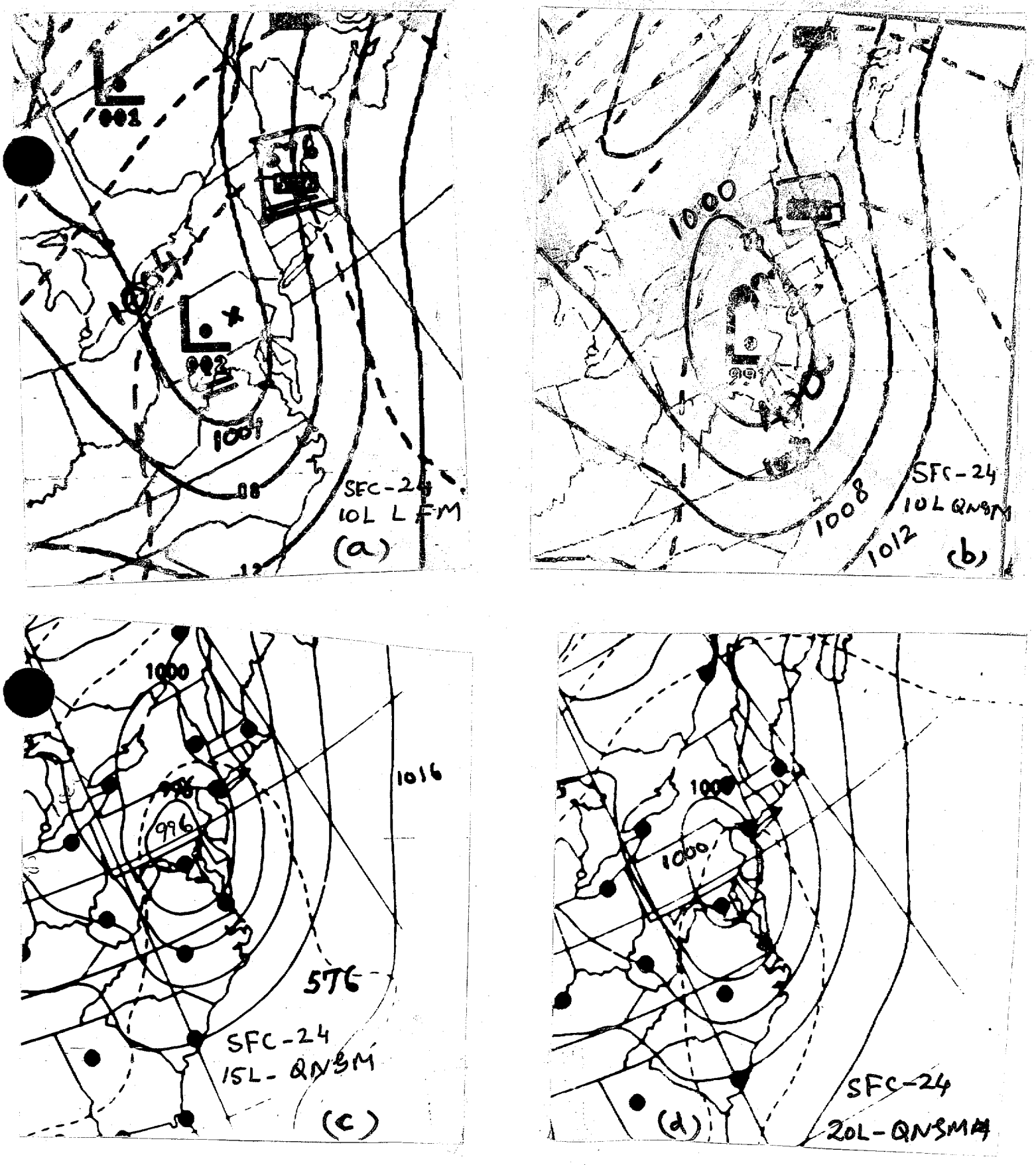

Fig. 2. Surface pressure and 1000-500 mb thickness forecasts valid 12 GMT 6 September 1979: (a) 10 L LFM II, (b) 10 L QNGM, (c) 15 L QNGM, and (d) 20 L QNGM. 24 HR FORECASTS.

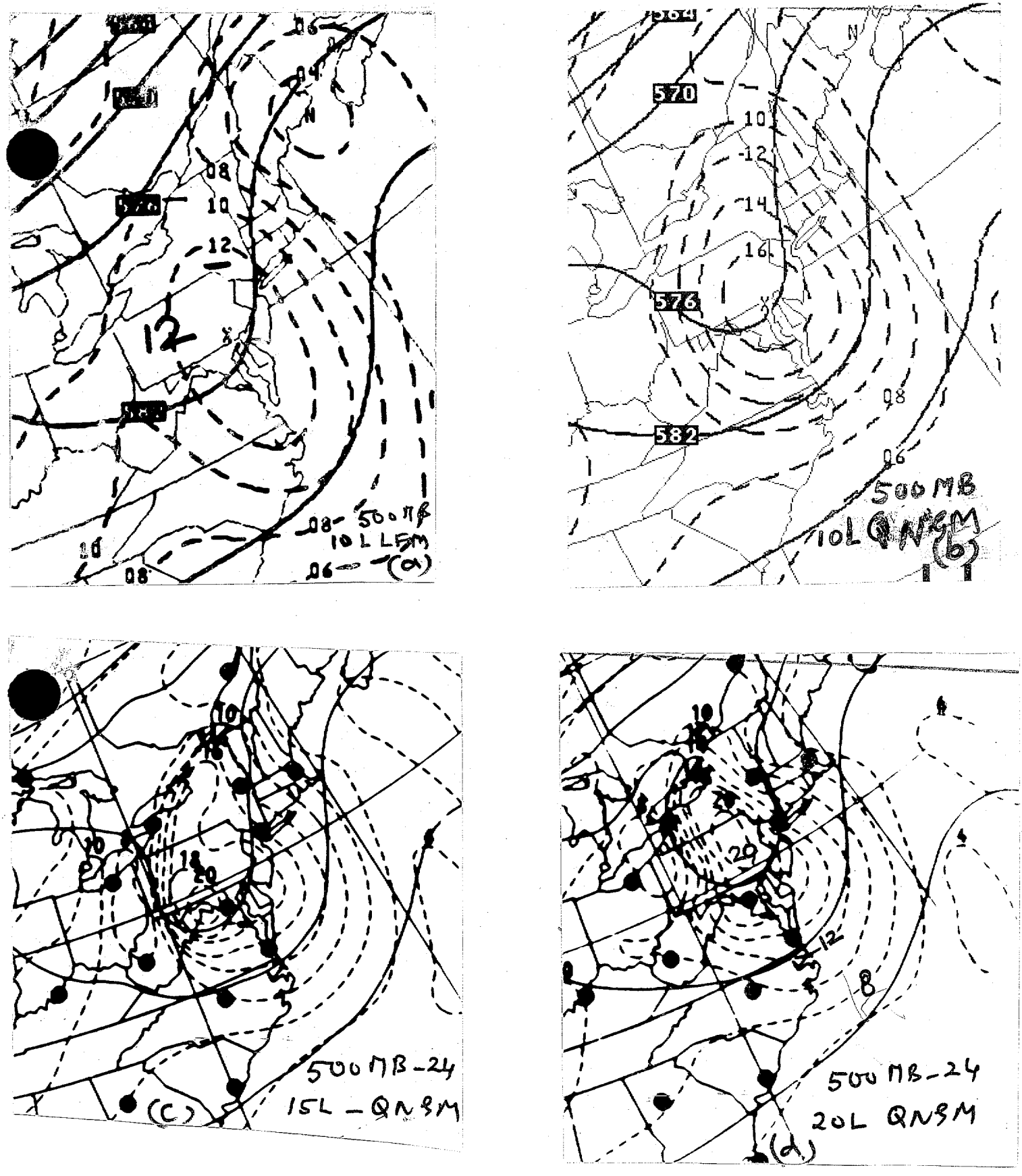

Fig. 3. 24-hour 500 mb height and vorticity forecasts valid 12 GMT 6 September 1979: (a) 10 L LFM II, (b) 10 L QNGM, (c) 15 L QNGM, and (d) 20 L QNGM.

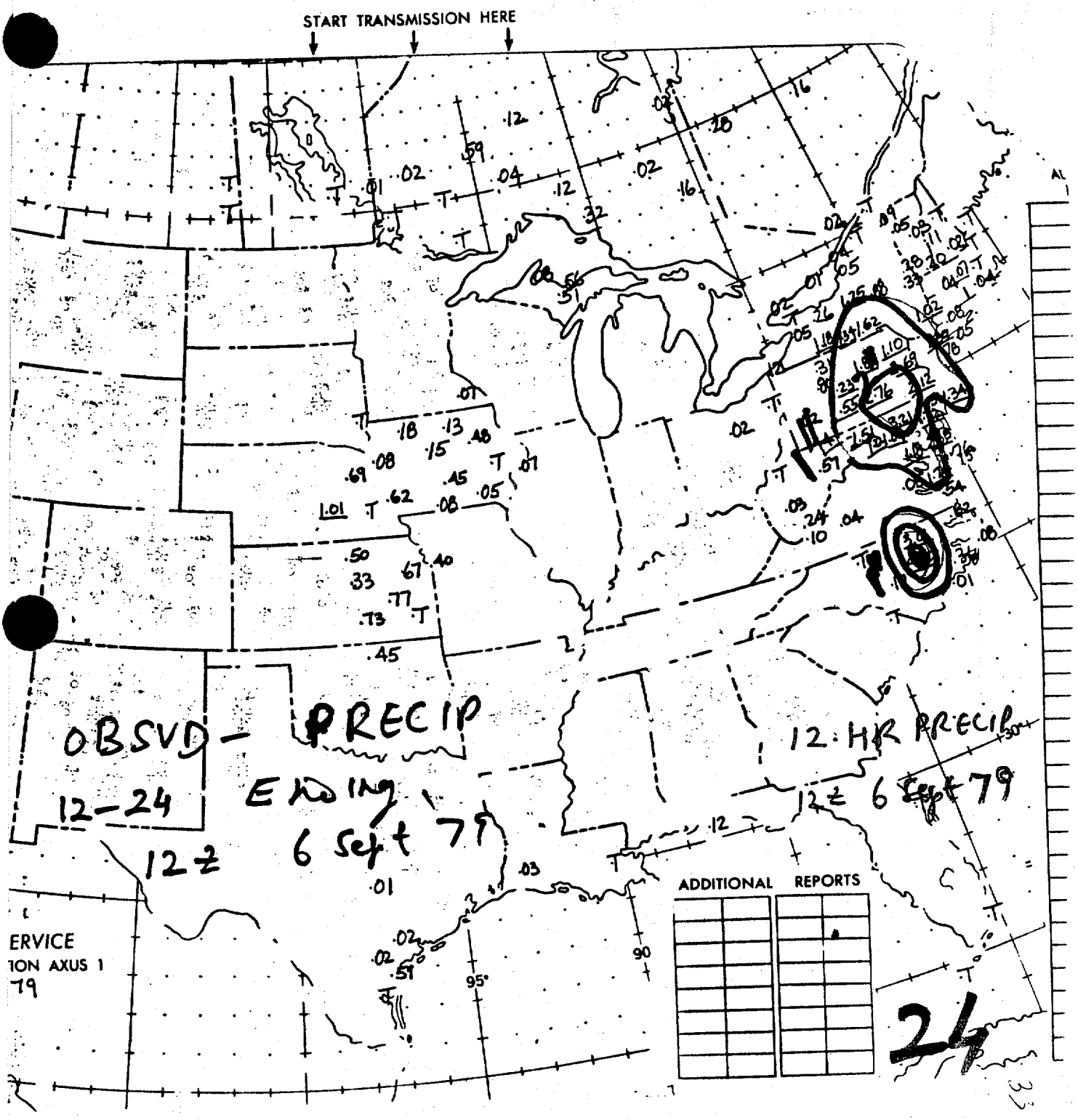

Fig. 4. Observed 12-hour precipitation ending at 12 GMT 6 September 1979.

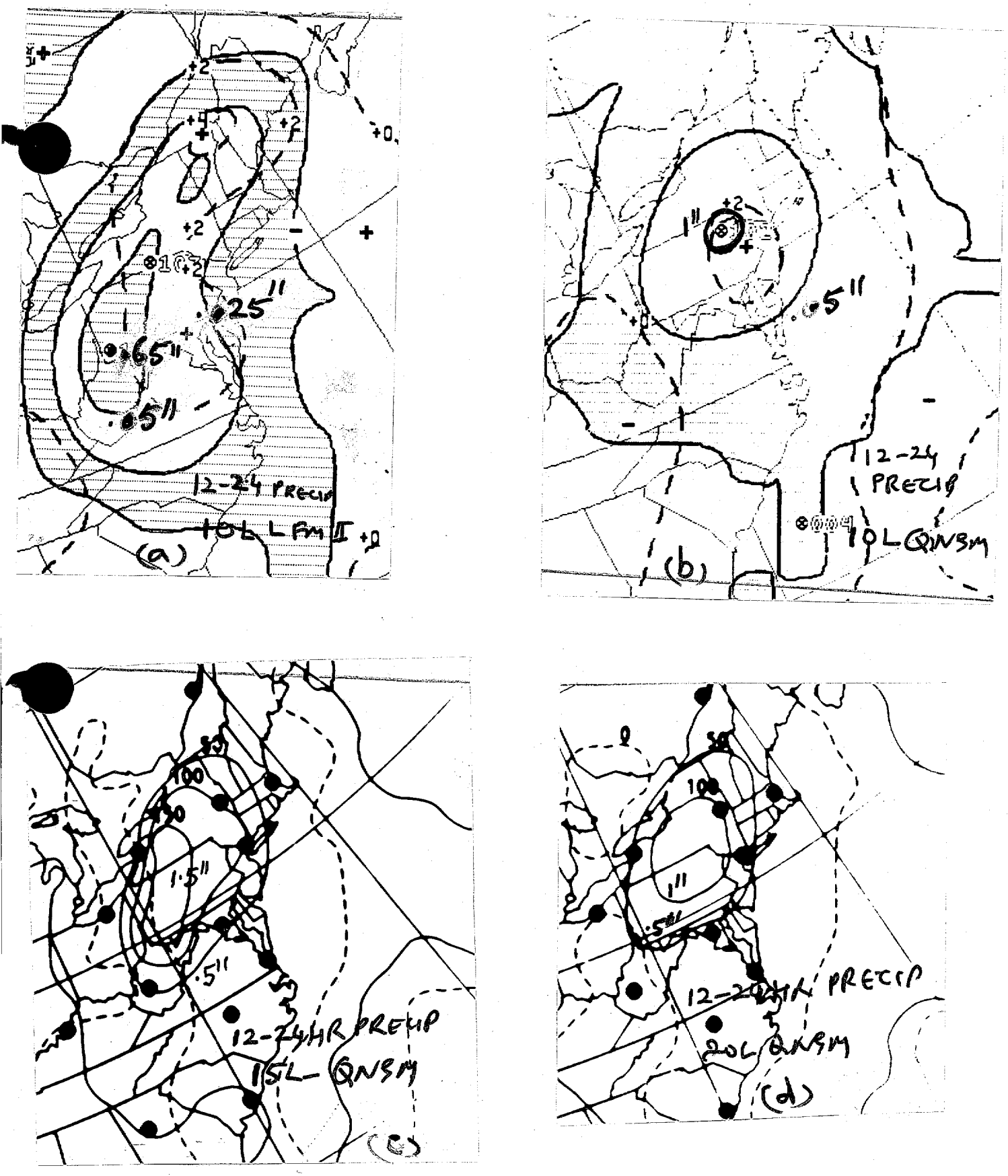

Fig. 5. 12-24-hour precipitation forecasts valid 12 GMT 6 September 1979: (a) 10 L LFM II, (b) 10 L QNGM, (c) 15 L QNGM, and (d) 20 L QNGM.