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1. Introduction

The problem of numerical forecasting is more difficult in the tropics than in mid and high latitudes for the following reasons: 1) There has always been a lack of reliable large scale observations in the tropics. This is partly due to the low land coverage in the tropics, and more importantly, to the need to measure the wind field rather than the mass field, which results in a challenging problem of instrumental accuracy. 2) The fact that the dominant instability in the tropics is convective rather than baroclinic as in the extratropics. This implies very fast growth rates, and requires an accurate representation of subgrid scale forcing, especially convective heating, which is one of the most difficult problems of atmospheric modeling. 3) The "no skill competition", persistence, against which numerical forecasts are compared, is more accurate in the tropics than in the extratropics, and therefore more difficult to be improved upon (Shukla, 1981).

During the Global Weather Experiment (GWE or FGGE) year of 1979, a special effort was made to gather data in the tropics including unconventional observing systems such as satellite temperatures and cloud-track winds, dropwindsondes, research aircraft, etc.

In this study we examine the mean error characteristics of two series of forecasts of the tropical flow. By using as initial conditions analyses made with and without the FGGE special observing system, we estimate the impact that initial data has on the accuracy of the forecasts.

2. Description of the Experiments

The results reported here are obtained from the global assimilation and forecast experiments performed by Halem et al. (1981) for the purpose of assessing the impact of satellite data upon extratropical analysis and forecasting.

The GLAS analysis/forecast system for producing a global gridded analysis consists of an objective analysis scheme which makes use of the continuity provided by a first guess which is a 6 hour forecast from the previous analysis. The first guess is then corrected by all the data collected within a ± 3 hour window about each analysis time. The analysis scheme (Baker et al. 1981) is a modified successive correction method (Cressman, 1959) which takes into account the density and the quality of the observations. The model used in both the analysis cycle and the forecast is the GLAS fourth-order global atmospheric model described in Kalnay-Rivas et al. (1977) and Kalnay-Rivas and Hoitsma (1979). It is based on an energy conserving scheme with all horizontal differences computed with fourth order accuracy. A 16th order Shapiro filter is applied periodically to remove unresolved scales. The parameterization of subgrid physical processes is identical to that of the GLAS climate model (Shukla et al. 1981). It includes long and short wave radiation with a diurnal cycle which allows a convective cloud parameterization, conditional instability supersaturation clouds, a bulk formula parameterization of surface fluxes and a realistic orography. The resolution used in these experiments, 4° latitude x 5° longitude and 9 vertical levels, is somewhat coarse, but this is partly compensated by the improved accuracy of the finite differences used in the model.

Two analysis cycles were performed for the first FGGE Special Observing Period (SOP-1), from January 5 to March 5, 1979. In one of them, denoted FGGE, all available FGGE II-b data were assimilated. In the second experiment, denoted NOSAT, only conventional data (rawinsonde, pilot balloon, aircraft and surface land and ship reports) were utilized (Table 1, from Halem et al., 1981).

Fourteen 5 day numerical forecasts were then generated every four days from the initial conditions of both the FGGE and the NOSAT assimilation experiments.

3. Results

We present here preliminary comparisons of the mean and standard deviations of the forecast error. The mean errors represent the systematic forecast errors which may be due either to the parameterization of forcing, or to systematic observational errors or lack of data. The standard deviation of the forecast error is a measure of the skill in predicting the evolution in time of the atmospheric systems.

The error has been computed by subtracting the GLAS FGGE analysis from the forecast. Even though the choice of analysis clearly influences the "error", over most of the globe, the forecast error after one day is larger than the uncertainty in the analysis. A comparison made with the NMC operational analysis, based on a very different analysis/forecast scheme, and which used only NESS operational winds and no satellite temperatures in the Northern Hemisphere, agrees well with the results presented here in most regions.

3.1 FGGE forecasts

Figs. 1 to 3 correspond to the forecast error in the meridional velocity v as computed from FGGE initial conditions. Fig. 1 presents the average error in v at 850 mb after 1, 3 and 5 days. It may be seen that at low levels the systematic errors are dominated by large scales, both in the tropics and in the extratropics. This, combined by the fact that their phase is rather constant, indicates that they are associated with forcing, both thermal and orographic. For example, the fact that the forecasts overpredict the equatorward flow over the Andes even after one day, indicates that the mountains are generating more drag in the model than in the real atmosphere. At 300 mb, the average error in the tropics is still of planetary scale, but in the extratropics the error is of cyclonic scale. This, and the change in phase in the error after 1, 3 and

5 days indicates that the error in the extratropics is dominated by the systematic component in the forecast of moving cyclones.

The systematic error grows in amplitude from daya 1 to day 3. There is further growth from day 3 to day 5 in the extratropics, indicating further forecast skill. In the tropics the systematic errors seem to have attained its maximum amplitude by day 3.

Fig. 3 presents the ratio between the average or systematic errors and the standard deviation of the error at 850 mb and 300 mb. Values smaller than one indicate that the error is dominated by transient features, and values larger than one indicate that the systematic error is more important. It may be observed that the extratropical error is dominated by the transients, whereas in the tropics the systematic error is very important, especially at low levels. Fig. 4 presents the heating rate at 500 mb as computed by the model during the January 1979 assimilation cycle. a comparison of Figs. 3 and 4 confirms that the large systematic errors are associated with regions of strong heating, as well as with orographic forcing.

3.2 Comparisons of FGGE, NOSAT and PERSIS forecasts

Here we compare the systematic and transient errors of the forecasts obtained from the FGGE and NOSAT analysis cycles. Persistence forecasts, in which the forecasts coincide with FGGE initial conditions are also presented, and denoted PERSIS. Figs. 5 and 6 present the 3 day mean and standard deviation of the error in the zonal velocity u at 300 mb.

It may be seen that the systematic errors in from NOSAT initial conditions (Fig. 5b) are only slightly larger than those of FGGE initial conditions. This indicates that systematic errors are due more to model parameterization deficiencies than to initial data. It is interesting that both forecasts show characteristics similar to those of a "warm episode" of the Walker circulation, with enhanced easterlies and stronger subtropical jets in the Pacific (Horel and Wallace, 1981; Julian and Chervin, 1978). At low levels, not presented here, the error is reversed, completing an east-west circulation. The systematic error in the PERSIS forecast (Fig. 5c) is much smaller than either NOSAT or FGGE in the tropics. This is not surprising because, for a large enough sample, there should be no systematic errors in persistence forecasts. In the extratropics the average PERSIS errors are dominated, once again, by the cyclonic scales that have the largest changes after 3 days. It should be remembered that the 14 forecasts are spaced by intervals of 4 days.

Fig. 6 presents the standard deviation of the 3 day forecast errors of u. The regions with errors smaller than 6 m sec^{-1} have been hatched, and those with errors larger than 12 m sec^{-1} are indicated by bold contours. A comparison of Figs. 6a and b indicates that the use of the FGGE special observing system has improved both the tropical and extratropical forecast of the transient features. We see in Fig. 6c that the PERSIS forecast of transient features is, not surprisingly, much worse than either FGGE or NOSAT in the extratropics.

The FGGE forecast errors are better than those of PERSIS in the subtropics and slightly better in the tropics, indicating some skill in predicting transient features.

The improvement in the forecast of the transient features using the FGGE analysis compared to either the NOSAT or PERSIS forecast is also clear after 5 days, both in the tropics and in the extratropics.

4. Conclusions

From this preliminary study, several conclusions may be drawn. we have found that the systematic error dominates the tropical forecast error. This error seems to be more dependent on model deficiencies than on the initial data and becomes large amplitude in a few days. The model forecast error then becomes comparable to the persistence forecast error in 3 to 5 days. On the other hand, the model retains some skill in the prediction of transient features in the tropics after 3 days.

This study suggests that a major obstacle in accurate low latitude forecasting is the prediction of the large scale quasi-stationary tropical circulation.

Acknowledgments

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Figure 1: Mean forecast errors in the meridional velocity v at 850 mb. Interval: 3 m sec^{-1}.

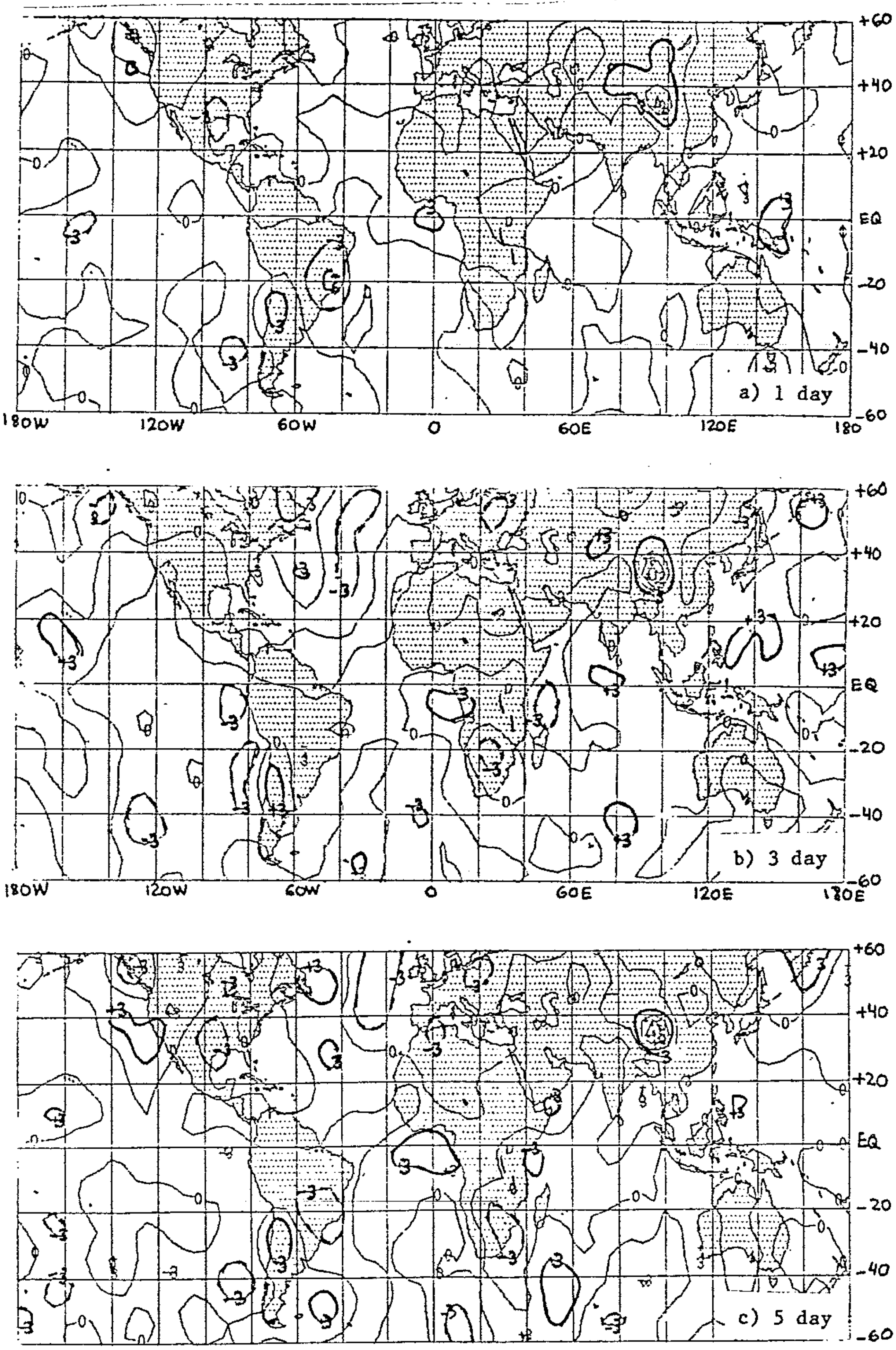


Figure 2: Mean forecast errors in the meridional velocity v at 500 mb. Interval: 3 m sec^{-1}.

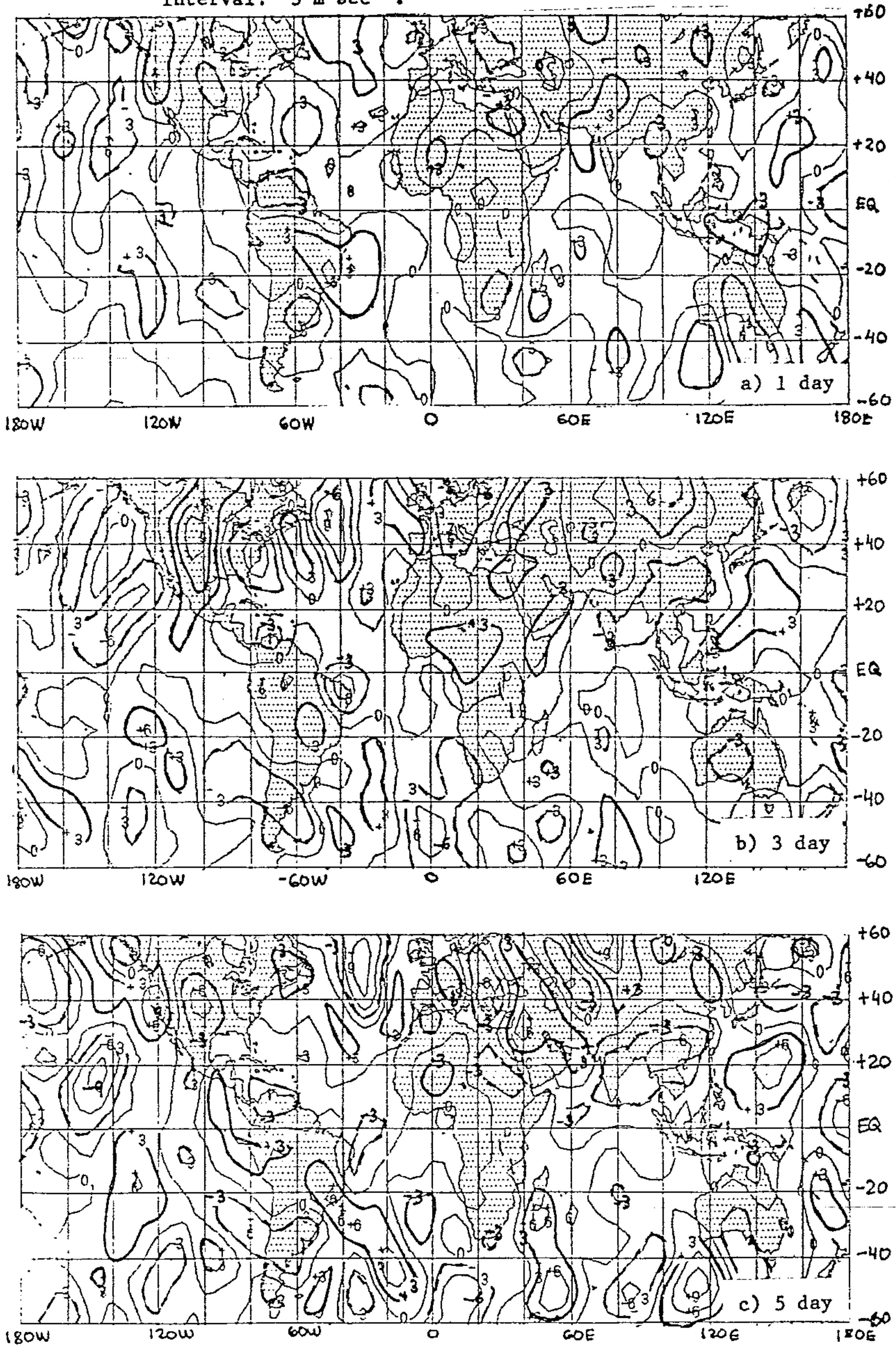


Figure 3: Ratio between the mean and the standard deviation of the 5-day forecast errors in the meridional velocity v. Interval: 0.50.

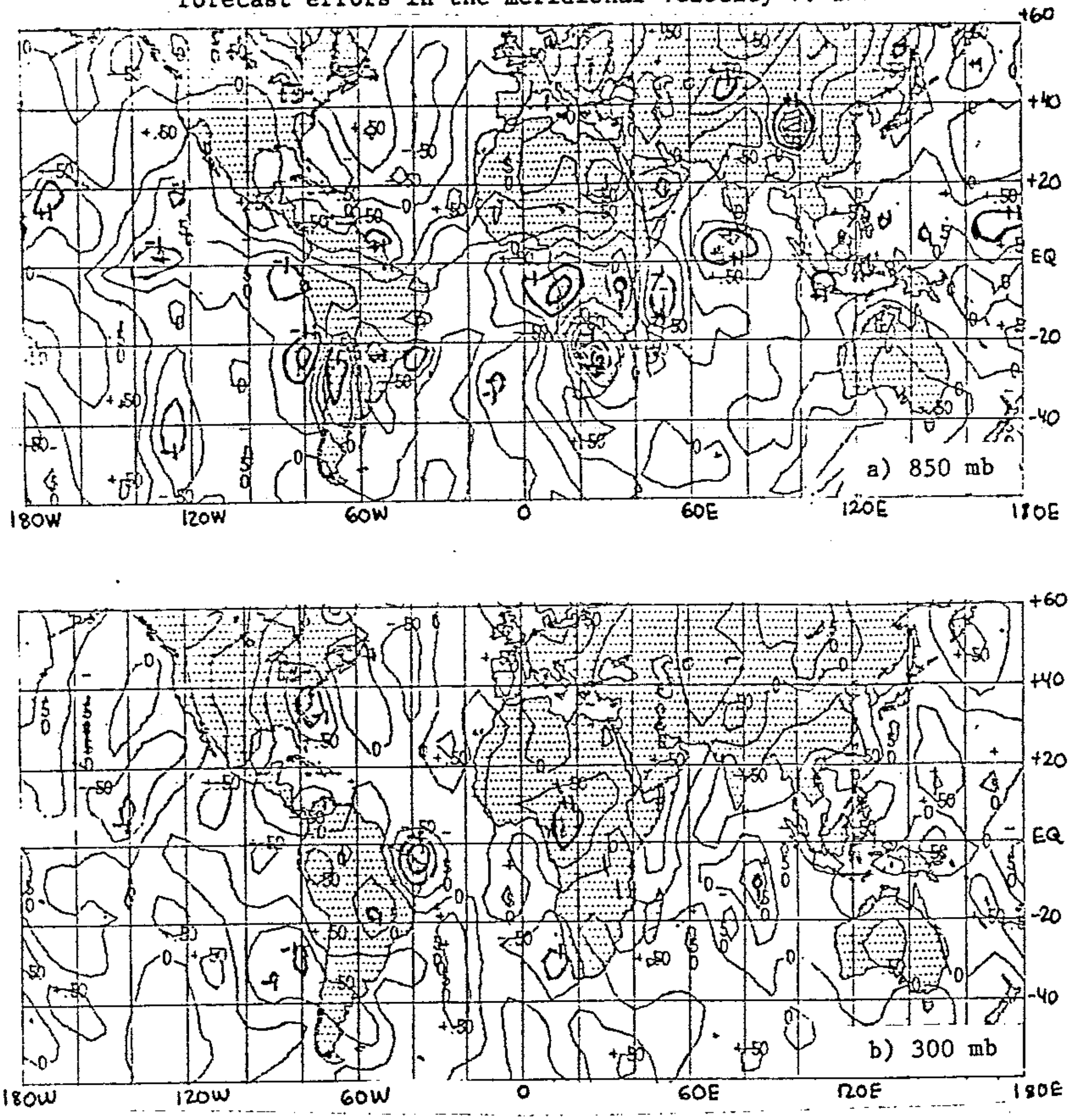
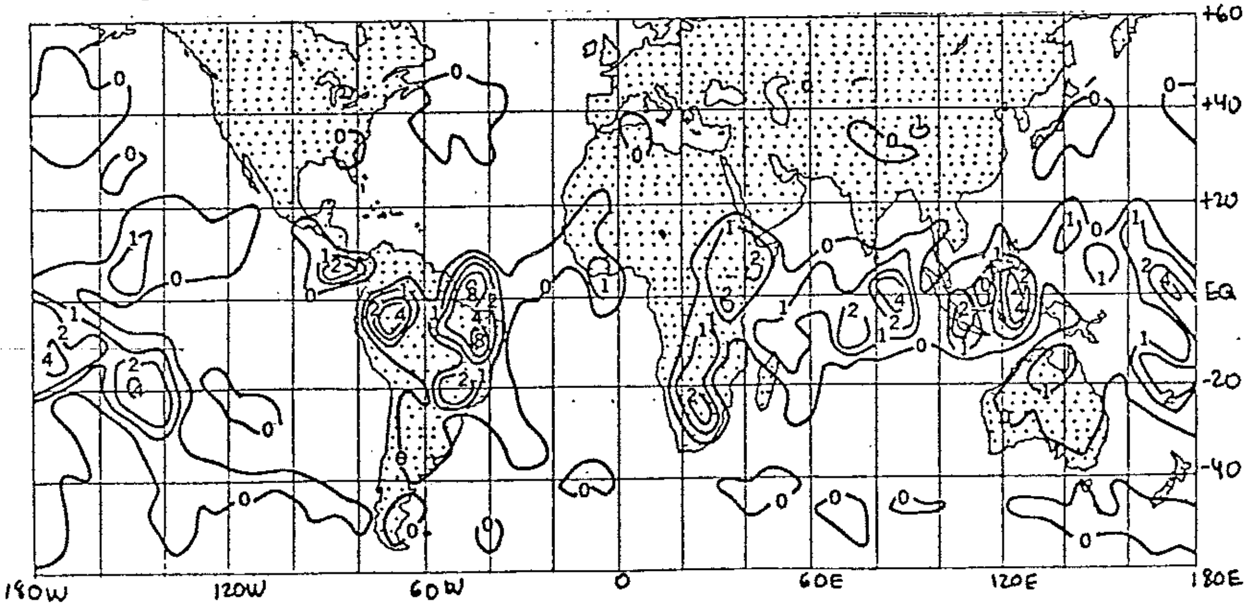


Figure 4: January assimilation heating rates at 500 mb (deg/day).



Interval: 3 m sec^{-1}

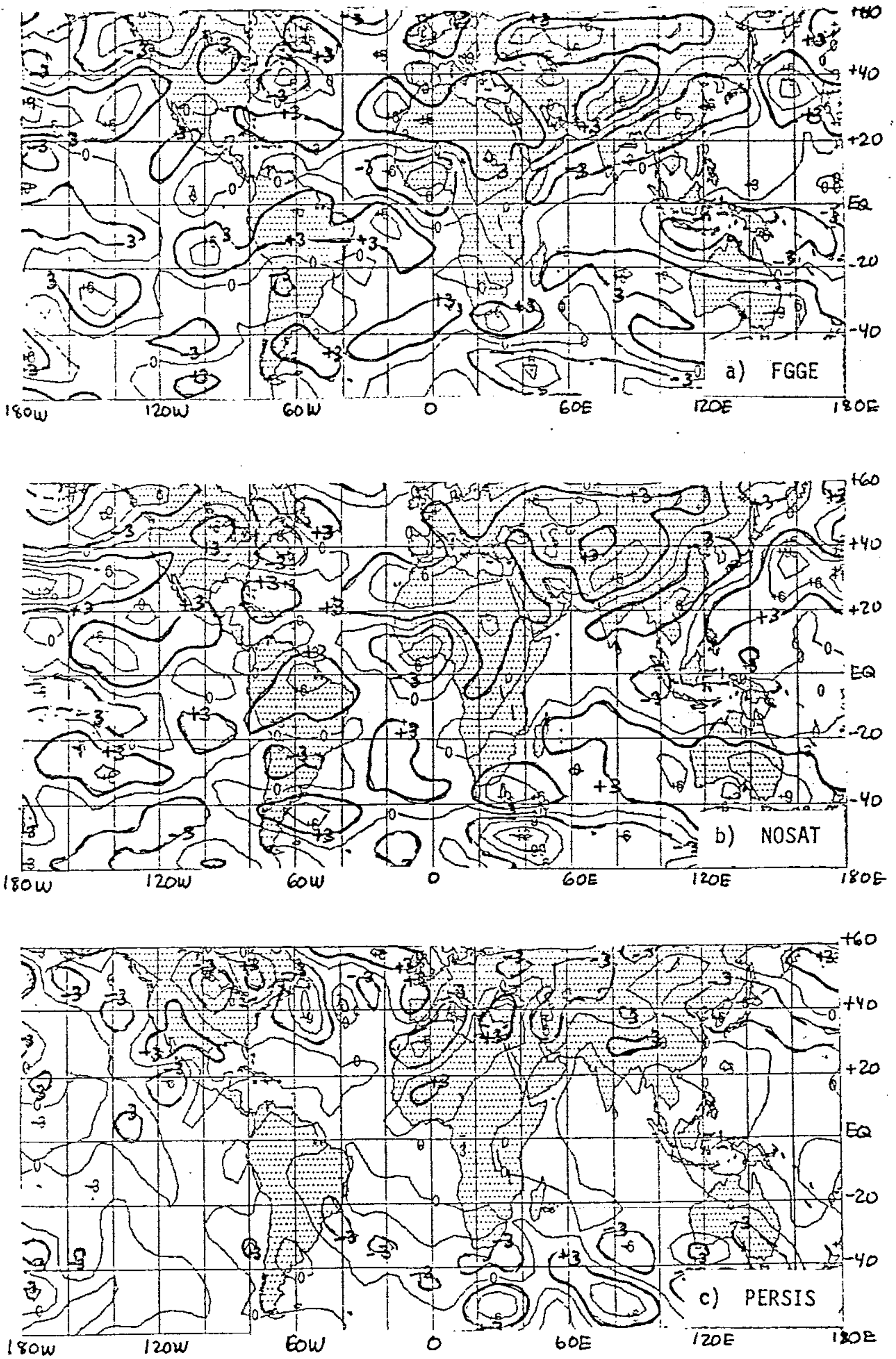


Fig. 6: Standard deviation of the 3-day forecast errors of the zonal velocity at 300 mb. Interval: 3 m sec^{-1}