NUMERICAL PREDICTION OF THE MONSOON DEPRESSION OF 5-7 JULY, 1979[1]

J. Shukla, R. Atlas, and W. E. Baker

1. INTRODUCTION

One of the primary objectives of the FGGE/MONEX effort is to determine the three dimensional structure of the atmosphere more accurately, thereby improving the quality of deterministic short range prediction. The detailed instantaneous structure of the monsoon circulation, which is perhaps the largest asymmetric perturbation of the general circulation of the atmosphere, had never been defined earlier because of the paucity of data over the Indian Ocean and the adjoining countries. Numerical predictions of the monsoon fluctuations, therefore, provide a good test to determine the impact of the FGGE/MONEX observing system on short range prediction. Although the large scale monsoon circulation is forced by planetary scale heat sources due to asymmetric continentality and differential heat capacity of land and ocean, the short term fluctuations are mainly caused by the synoptic scale disturbances referred to as the monsoon depressions. One such depression appeared over the Bay of Bengal during the first week of July 1979. This, fortunately, happened at a time when a large group of MONEX research scientists had gathered at Calcutta, India to observe and study the summer monsoon circulation. There were two MONEX research aircrafts (Electra from NCAR and P3 from NOAA) which could probe the formative and the growth stages of the monsoon depression. A well-defined monsoon depression was observed on July 7, 1979 which then moved over India and dissipated.

We have chosen this particular synoptic situation for two assimilation and forecast experiments. Starting from the initial conditions (provided by the NMC global analysis) of 0000 GMT 1 July 1979, one experiment utilized only the conventional surface and upper air data, and the other utilized the same conventional data plus all the available FGGE/MONEX data. We refer to these two assimilations as the control assimilation and the FGGE/MONEX assimilation. From the two initial conditions valid for 1200 GMT 7 July 1979, arrived at by assimilating the two different data sets, we have made numerical predictions with the GLAS general circulation model. In the following sections, we describe the model, the analysis and assimilation procedure, the differences in the analyses due to different data inputs, and the differences in the numerical predictions.

2. ANALYSIS AND ASSIMILATION OF FGGE/MONEX DATA

In this section we describe the objective analysis and assimilation procedure used with the FGGE/MONEX data.

[1] Published in Condensed Papers and Meeting Report: International Conference on Early Results of FGGE and Large-Scale Aspects of Its Monsoon Experiments, Jan. 12-17, 1981, Tallahassee, Florida. Published by the World Meteorological Organization, Geneva, Switzerland.

2a. The Model

The model is a global, primitive-equation model, discretized in finite-difference form. There are nine vertical layers equal in sigma with a horizontal resolution of 2.5° in latitude and 3° in longitude. The horizontal differences are second-order accurate on a staggered grid (Arakawa, 1966; 1972). The model differs from that described in Somerville et al. (1974) in its horizontal resolution and by the introduction of a split-grid, which at high latitudes modifies the longitudinal mesh size.

Time differencing is performed following the space-centered Euler-backward (Matsuno) scheme (Arakawa and Lamb, 1977). Due to a number of features of the difference scheme, such as the averaging required by the staggering of variables and the additional smoothing at high latitudes, the scheme is strongly dissipative. As a result, spurious high-frequency oscillations generated at the beginning of a forecast decay rapidly.

2b. The Data

For this study we utilized FGGE data collected from 1-7 July 1979 and the special MONEX data (dropwindsondes, aircraft, and enhanced TIROS-N retrievals). The data nominally available to the objective analysis program over the entire globe is listed by type in Table 1. Table 2 summarizes the MONEX data utilized over the Bay of Bengal.

Table 1. Typical number of "Soundings" for each 24 h period during the assimilation cycle (July 1-7, 1979).

Rawinsondes:	3000
Satellite winds:	5500
Satellite temp.:	8500
Aircraft:	3500
Constant level balloons:	250
Enhanced satellite temp. (Bay of Bengal):	175

The rms wind vector fit (final analysis vs. observations) for dropwindsondes and Wisconsin Indian Ocean clouds tracked winds was compared with that for rawinsondes. The rms fit for the dropwindsondes was quite similar to that for the rawinsondes. The Wisconsin winds exhibited a poorer fit due to less weight given in the analysis of that data and the higher data density.

An enhancement of the TIROS-N sounding data for the Bay of Bengal was performed in order to supplement the operational sounding data set with higher resolution soundings in meteorologically active areas, and with new soundings where data voids or soundings of questionable quality existed. Man-computer Interactive Data Access System (McIDAS) terminals, developed by the Space Science Engineering Center of the University of Wisconsin, were utilized for the display and enhancement of the TIROS-N soundings.

The algorithms for retrieving temperature profiles from the TIROS-N radiances were essentially the same as those used by NESS for the objective generation of operational temperature profiles. Three types of temperature retrievals are possible: (1) clear column, (2) partly cloudy retrievals utilizing infrared observations from the High Resolution Infrared Sounder (HIRS) instrument aboard TIROS-N, and (3) cloudy retrievals utilizing only microwave observations from the Microwave Scanning Unit (MSU) on TIROS-N. The operational temperature profiles have a horizontal resolution of 250 km, whereas enhanced temperature profiles can be retrieved at the resolution of the measurements. (30 km for HIRS and 150 km for MSU).

Subjective comparisons of enhanced and operational soundings and rawinsonde reports for the FGGE "Special Effort" (Atlas, 1980) have shown that the enhanced and operational retrievals tend to be similar in cloud free areas. However, large improvements in thickness and mandatory level temperature, and intensification of atmospheric thermal gradients occasionally result from the enhancement of cloudy and partially cloudy areas.

2c. Objective Analysis Procedure

In the GLAS objective analysis scheme (Baker et al., 1981) eastward and northward wind components, geopotential height and relative humidity are analyzed on mandatory pressure surfaces. The 6 h model forecast provides a first guess for these fields at 300 mb and sea level, where sea level pressure and sea level temperature are also analyzed. The first guess for the other levels is obtained from the model first guess modified by a vertical interpolation between the two closest completed analyses. Vertical consistency is maintained through static stability constraints. The analysis at each level is performed with a successive correction method (Cressman, 1959) modified to account for differences in the data density and the statistical estimates of the error structure of the observations. The average distance d between data points is found in a circle with a radius of 800 km centered at each grid point. Three scans are performed with a radius of influence $R_i = c_i d$, where the coefficients c_i (1.6, 1.4, 1.2) were chosen to minimize the analysis error (Stephens and Stitt, 1970). However, the radius of influence is not allowed to become smaller than 300 km. During this process, all data are checked for horizontal consistency. The completed analyses are smoothed and then interpolated to the model sigma levels.

The assimilation procedure provides for the intermittent analysis of batches of data grouped in a ± 3 h window about each synoptic time. In these experiments, the wind and height fields were analyzed independently with no explicit coupling or balancing.

2d. Differences between the control and the FGGE/MONEX assimilations

Fig. 1 shows the zonally averaged root mean square (rms) vector wind error between the control assimilation and the FGGE/MONEX assimilation for 1200 GMT 7 July 1979. It can be seen that the maximum differences occur in the southern hemisphere, especially near the poles. Since there is virtually no data in the control assimilation over that part of the globe, the control analysis on July 7 could not be very different from the model prediction except for the influences that might have propagated from the data-rich regions. These differences are therefore, an indication of the systematic model forecast errors. The difference is the smallest over the northern hemispheric mid-latitudes which contains the highest density of the conventional upper air network. Large differences in the northern hemispheric tropics are mainly due to the large number of fairly accurate cloud-tracked winds. Given such large differences in the initial conditions, it is natural to expect differences in the forecasts.

3. RESULTS

Due to the limited space available here, we present the results of verification over India only. Table 3 gives the S1 skill scores and rms error for sea level pressure and 500 mb geopotential height for forecasts starting from control and FGGE/MONEX assimilations on 1200 GMT 7 July 1979. Both forecasts were verified against the NMC global analysis. In general, there is a positive impact of FGGE/MONEX data; however, the differences after 24 h do not appear to be significant. The rms error for 500 mb geopotential height shows a negative impact for the first 36 h. It should also be pointed out that the location of the center of the monsoon depression in the FGGE/MONEX assimilation at 1200 GMT 7 July 1979 does not agree with a careful hand analysis.

In performing the numerical experiments, a number of problems were encountered with the tropical analyses. The horizontal resolution (2.5° x 3°) of the prediction model was too coarse to accurately define the monsoon depression. The assimilation of geopotential height data derived from satellite soundings generated gravity waves whose amplitudes were comparable to the meteorologically significant features we were attempting to predict. Gravity waves were particularly troublesome in the 6 h first guess during the assimilation cycle. The difficulty in utilizing satellite temperature soundings in the tropics was also compounded by the precipitable water contamination of the TIROS-N microwave retrievals (Phillips, 1980). The results of this study should be considered preliminary for these reasons. We plan to carry out further experiments using the official FGGE/MONEX database with improved assimilation and initialization techniques. It is only then that a more definitive statement can be made about the impact of FGGE/MONEX data on the predictability of the monsoon disturbances.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Messrs. G. Cole for his supervision of the sounding enhancement, D. Edelmann, M. Iredell and H. Carus for the preparation of the special MONEX data for analysis and E. Sabatino, R. Rosenberg and B. Doty for technical assistance and graphics support. We also wish to thank Miss D. Boyer for typing the manuscript and Ms. L. Rumburg for drafting the figure.

REFERENCES

Atlas, R., 1980: Evaluation of NESS soundings used in the FGGE special effort. NASA Conf. Publ. 2157, 31-40.

Arakawa, A., 1966: Computational design for long-term numerical integration of the equations of fluid motion: Two-dimensional incompressible flow. Part I. J. Comput. Phys., 1, 119-143.

Arakawa, A., 1972: Design of the UCLA atmospheric general circulation model. Tech. Rep. 7, Dept. of Meteorology, University of California at Los Angeles.

Arakawa, A., and V. R. Lamb, 1977: Computational design of the basic dynamical processes of the UCLA general circulation model. Methods in Computational Physics, 17, J. Chang, Ed., Academic Press, 173-265.

Baker, W. E., D. Edelmann, M. Iredell, D. Han, and S. Jakkempudi, 1981: Objective analysis of observational data from the FGGE observing systems. NASA Tech. Memo. 82062.

Cressman, G. P., 1959: An operational objective analysis system. Mon. Wea. Rev., 87, 367-374.

Phillips, N. A., 1980: Two examples of satellite temperature retrievals in the north Pacific. Bull. Amer. Meteor. Soc., 61, 712-717.

Somerville, R. C. J., P. H. Stone, M. Halem, J. E. Hansen, J. S. Hogan, L. M. Druyan, G. Russell, A. S. Lacis, W. J. Quirk, and J. Tenenbaum, 1974: The GISS model of the global atmosphere. J. Atmos. Sci., 31, 84-117.

Stephens, J. J., and J. M. Stitt, 1970: Optimum influence radii for interpolation with the method of successive corrections. Mon. Wea. Rev., 98, 680-687.

Table 2. MONEX data over Bay of Bengal (10N-25N, 80E-100E).

		Dropwindsonde	Aircraft	Wisconsin Winds	Enhanced Soundings
July 1	00Z	-		-	
	06Z	-		18	-
	12Z	-		34	
	18Z	-	1		
July 2	00Z	-	1		
	06Z	-	0		-
	12Z	-	1	23	
	18Z	-	2		
July 3	00Z	-			
	06Z	9	6	11	110
	12Z	3	0	25	
	18Z		1		
July 4	00Z		1		
	06Z		1	9	290
	12Z			38	
	18Z		1		
July 5	00Z				
	06Z	15	2	7	188
	12Z	7	2	20	
	18Z		2		
July 6	00Z				
	06Z	6	2	15	172
	12Z	3	3	9	
	18Z				
July 7	00Z		2		
	06Z	8	7	18	135
	12Z	8	3	19	
	18Z				
July 8	00Z		1		
	06Z	17	4	27	-
	12Z	1	1	38	
	18Z		1		
July 9	00Z				
	06Z	11	3	24	-
	12Z	3	1	49	
	18Z				
July 10	00Z		1		-

Table 3. Skill score (S1) and root mean square error (RMS) over India (6N-26N, 70E-100E) for control and FGGE/MONEX initial conditions of 1200 GMT 7 July 1979 for sea level pressure (SLP) and 500 mb geopotential height (Z500).

Impact for India (6-26N 70-100E), I.C. 7/7/79, 12Z

Hours	Control	FGGE	Impact
SLP S1			
12	66.8	62.6	+4.2
24	60.6	48.8	+11.8
36	65.7	63.1	+2.6
48	52.8	52.5	+.3
SLP RMS			
12	4.1	2.2	+1.9
24	4.0	2.4	+1.6
36	2.5	3.3	-.8
48	2.7	1.9	+.8
Z500 S1			
12	92.1	85.1	+7.0
24	99.4	94.0	+5.4
36	100.9	94.1	+6.8
48	104.1	106.2	-2.1
Z500 RMS			
12	32.4	43.9	-9.5
24	53.6	62.4	-8.8
36	49.3	51.2	-1.9
48	48.4	46.9	+1.5

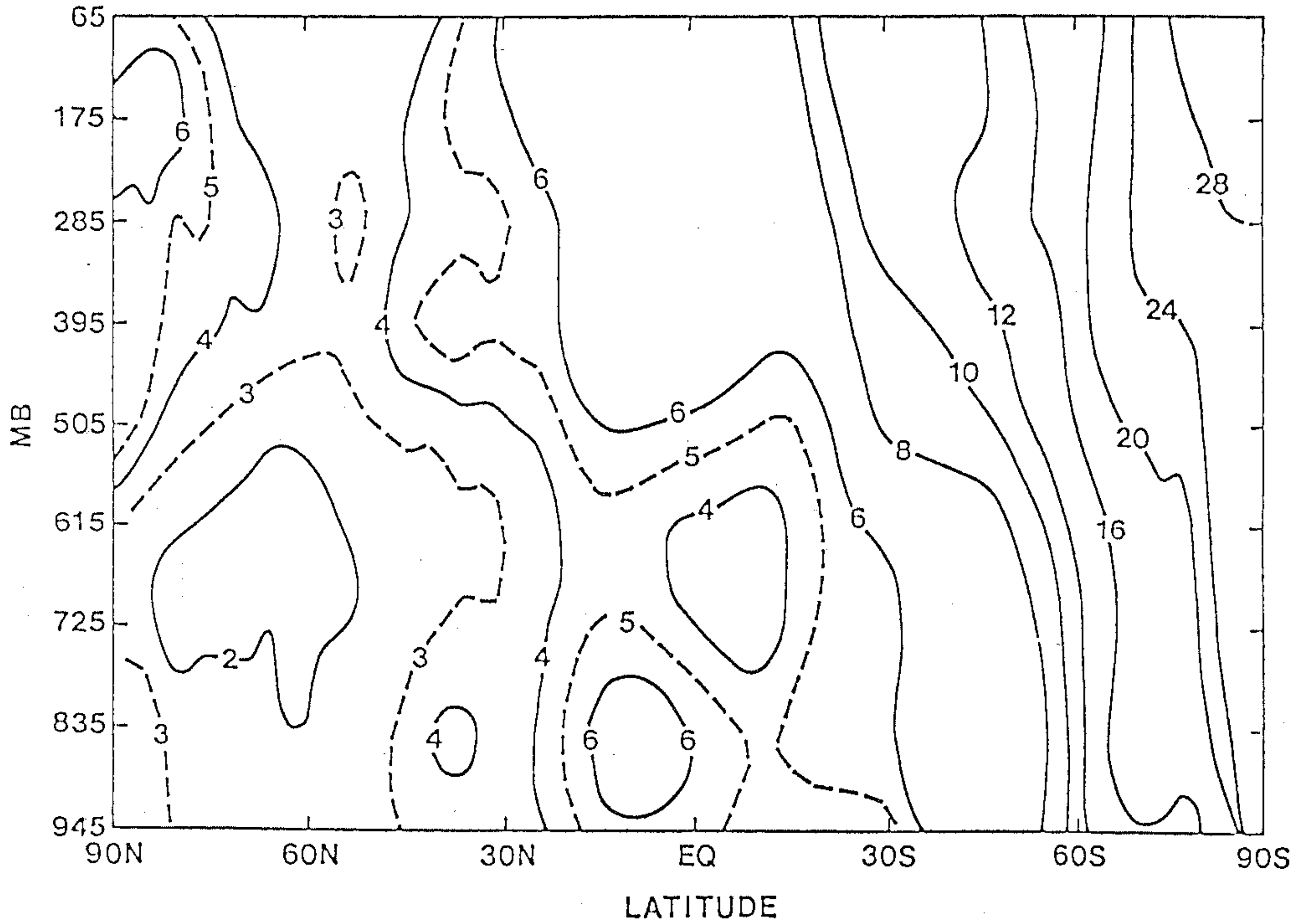

Figure 1. Rms vector wind error (m/s) between control and FGGE/MONEX assimilation.