Analysis–Prediction Experiments over Indian Region Using Primitive Equation Barotropic Model

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ABSTRACT

The impact of initial guess and grid resolutions on the analysis and prediction has been investigated over the Indian region. For this purpose, an univariate objective analysis scheme and a primitive equation barotropic model have been used. The impact of initial guess and the resolutions on analysis and prediction is discussed.

I. INTRODUCTION

In an earlier study, Sikka et al. (1980) assessed the impact of special observational data of Monex–79 on the analysis and forecast fields. In the present study we propose to determine the suitable initial guess field and the grid length for analysis and prediction. An analysis–prediction experiment has been done with data of 700 hPa level of 12 GMT, 5, 6 and 7 July 1979 using two sets of analysis. The two sets of analysis are objectively analysed data set using optimum interpolation scheme with forecast field as initial guess and the objectively analysed data set using the same scheme but with persistency as initial guess. The primitive equation barotropic model has been used to produce 24 hr forecasts for these two sets of data with 220 km and 100 km horizontal grid resolutions. The root mean square (RMS) errors of wind field and the positional vector errors of the centre of the monsoon depression for 24 hr forecast have been computed. The relative performance of the two input data sets on model forecast in terms of circulation, RMS errors and the positional vector errors for coarse and fine horizontal grid resolutions have been presented and discussed.

II. METHODOLOGY

1. *Objective Analysis Scheme*

It is now largely accepted that in low latitudes the flow patterns depicted by the winds are more reliable than those deduced from contour analysis. It was therefore thought more appropriate to use wind information as the basic input in a prediction model.

The scheme utilised for making analysis of wind field is the univariate optimum interpolation (O.I.) method first suggested by Gandin (1963). This method has been used in modified form in various operational forecasting centres all over the world and has been discussed widely in the literature and hence the scheme is not discussed in detail here. However, some important assumptions and relations are given below following Rajamani et al. (1983). In this O.I. scheme, the weighting factor for any observation with respect to any grid point is determined from the rate of the decrease of the correlation coefficient with distance and is computed from set of equations obtained with the condition that the mean interpolation error over the region is minimum.

The equation obtained thus, is

$$\sum_{j=1}^{n} \mu_{ij} P_j + \lambda^2 P_i = \mu_{oi} \qquad (i = 1,2,3,\cdots,n)$$

Where

$$\mu_{ij} = \frac{\overline{\hat{f}'_i \hat{f}'_j}}{\sigma_o^2}; \qquad \mu_{oi} = \frac{\overline{f'_o \hat{f}'_i}}{\sigma_o^2}; \qquad \lambda^2 = \frac{\sigma_{\varepsilon_i}^2}{\sigma_o^2};$$

$$\sigma_o^2 = \overline{\sigma_i^2} - \sigma_{\varepsilon_i}^2$$

$\overline{\hat{f}'_i \hat{f}'_j}$, $\overline{f'_o \hat{f}'_i}$, are the covariance of the parameter "f" between stations "i" and "j" and grid point "O" and station i' respectively, $\sigma_{\varepsilon_i}^2$ is the mean random error and $\overline{\sigma_i^2}$ is mean variance of the parameter. Solving the n number of equations, the weighting factors P_i's are obtained. The important assumptions made here are, firstly, the correlation field is both isotropic and homogeneous, and secondly, the errors in the observation are independent of the actual magnitude of the values as well as the errors in the neighbouring observing stations. The two sets of analysis of wind field were made using two initial guess fields viz. 12 hr forecast and analysed field of 12 hr earlier time (persistency).

The observations within 10° from the grid point were considered. The analyses are done with two grid resolutions viz. with 220 km and with 100 km grid size. The domain of analysis for 220 km grid resolution extends from 18°S to 43°N and 43°E to 120°E whereas for 100 km grid resolution the domain extends from 13°S to 37°N and 53°E to 112°E respectively.

2. *Model*

The numerical model used for the analysis–prediction experiment is a primitive equation barotropic model similar to the one used by Singh and Saha (1976). The model equations are the shallow water equations in cartesian coordinates in flux form on Mercator projection. The finite difference scheme of Arakawa et al. (1974) has been adopted for space derivatives and the leap frog with Asselin (1972) time filter is used for time integration. The time invariant boundary conditions are adopted at the lateral boundaries. The objectively analysed data have been used as input.

III. DATA AND COMPUTATION

The synoptic case for the present analysis–prediction experiments is that of a monsoon depression from 3 to 8 July 1979. The input to the model is wind and geopotential height. The geopotential heights are taken from the FGGE analysis in all the experiments. The wind fields are taken from the OI analysis described in subsection 1 of II. For both objective analyses, the special observations for MONEX–79 such as radiosonde data from research ships, dropsonde data from research aircrafts and data from other special observational systems have been fully made use in this study. One set of data is the objectively analysed field from OI scheme in which 12 hr forecast has been used as a first guess and the second data set is objectively analysed field using the same OI scheme in which 12 hr persistency has been used as a first guess. The above two sets of data will be referred to as Set–1 and Set–2 respectively. The two data sets have also been prepared for 100 km grid resolution in the same way as done for 220 km.

IV. DISCUSSION OF THE RESULTS

1. *Objective Analysis*

The objective analysis of wind field was made using univariate optimum interpolation scheme for 220 km horizontal grid resolution. The experiment was carried out in two ways for a typical case of the monsoon depression from 5 to 7 July 1979. In the first experiment, 12 hour forecast from P. E. barotropic model was used as initial guess and in the second experiment, the wind field 12 hour prior to the time of analysis, i.e., persistence was used as initial guess. For a better depiction of the system the same experiments were also carried out for 100 km horizontal grid resolution.

The analyses by adopting either forecast or persistence as initial guess fields by reducing grid length were evaluated. For this purpose RMS errors were computed comparing the station observations and the positional vector difference were also computed.

Table 1. Positional Vector Difference of the Centre of Monsoon Depression and RMS Error of Vector Wind in Objective Analyses (220 km grid resolution)

Input date	Positional vector difference (km)		RMS errors of vector wind of objectively analysed field, compared with station observations ($m\ s^{-1}$)	
	Set 1	Set 2	Set 1	Set 2
5 July 1979	110	55	4.5	4.6
6 July 1979	120	110	4.0	4.1
7 July 1979	225	80	4.0	4.3

(100 km grid resolution)

Input date	Positional vector difference (km)		RMS errors of vector wind of objectively analysed field, compared with station observations ($m\ s^{-1}$)	
	Set 1	Set 2	Set 1	Set 2
5 July 1979	55	110	4.5	4.6
6 July 1979	120	55	4.2	4.3
7 July 1979	120	120	4.4	4.9

It could be seen from Table 1 that the positional vector difference in data set 1 is slightly more than those found in data set 2 for 220 km grid distance. However, this difference is not clearly visible in case of 100 km grid resolution. It could further be seen from this table that the RMS errors are more or less similar in both cases of analysis. The finer resolution of 100 km has not shown positive impact on the analysis.

2. *Forecast Results*

The model was integrated for three input days viz., 5, 6 and 7 July and for each day with two sets of input data separately with 220 km and 100 km grid resolutions. We carried out the model runs using the objectively analysed data directly as input to the model. The forecast in case of 220 km grid was found very satisfactory upto 24 hr and beyond that damped rapidly. The monsoon depression got filled up rapidly and appeared as east–west oriented trough in 48 hr forecast field. In case of 100 km grid resolution the forecast was also found

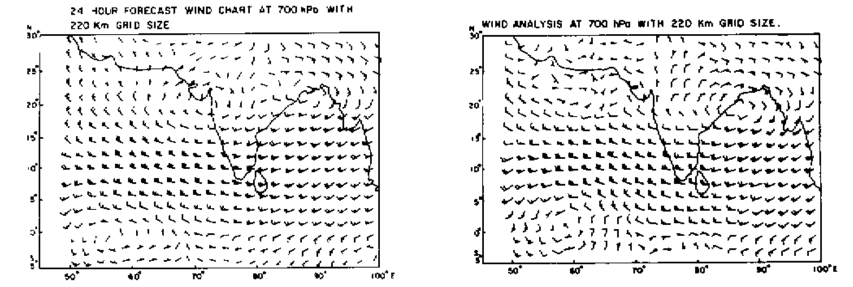

Fig.1. (a) 24 hour forecast wind field at 700 hPa Input: 12 GMT, 6 July 1979 with 220 km grid size, data set 1. (b) wind analysis at 700 hPa level of 12 GMT, 7 July 1979 for 220 km grid size.

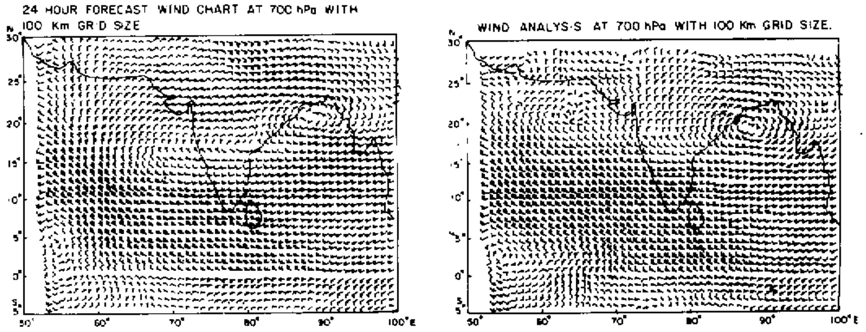

Fig.2. (a) Same as Fig.1 (a) except with 100 km grid size. (b) Same as Fig.1(b) except with 100 km grid size.

very satisfactory upto 24 hr and beyond that deteriorated rapidly. A spurious circulation was found in the Arabian sea in 48 hr forecast field.

In order to see whether the forecast could be improved beyond 24 hr, a dynamic initialization scheme following Singh, et al. (1980) was used to balance the initial data. However, no improvement was found in forecast field with application of initialization scheme and as such the model was run upto 24 hr in all cases using objectively analysed data as input to the model. The finite difference analogue appears to be quite effective to suppress the spurious growth at least upto 24 hr of integration.

Although, prediction was done with data set 1 and set 2 of three days, viz. 5, 6 and 7 July 1979, the figures were presented for data set 1 of 6 July 1979 only. Figs.1 (a,b) present the 24 hr forecast and the corresponding verification wind fields for 220 km grid resolution. In the forecast field, the centre of depression is located at 21.5°N, 88.5°E whereas in the observed field it is located at 19.5°N, 87°E. Figs. 2(a,b) show the 24 hr forecast and the corresponding verification wind fields for 100 km grid resolution. The centre of depression is located at 20°N, 88.5°E in the forecast field whereas in the observed field it is located at 19.5°N, 88.5°E. It should be noted that in case of 100 km grid size, the geometry of the cyclonic circulation is better depicted and the forecast centre of circulation is found closer to the observed centre of circulation.

The positional vector errors of centre of monsoon depression of data sets 1 and 2 are presented in Table 2. It may be noted that in case of 220 km grid resolution, the positional vector errors are smaller in data set 2 than those found in data set 1. However, in case of 100 km grid size the opposite picture emerged.

Table 2. Positional Vector Error in Centre of Monsoon Depression in 24 hr Forecast

Input date	(220 km grid resolution)		(100 km grid resolution)	
	Set 1	Set 2	Set 1	Set 2
5 July 1979	235	110	440	280
6 July 1979	280	55	55	125
7 July 1979	250	200	80	175

Table 3. RMS Errors of *u*–field and *v*–field in 24 hr Forecast

Input date	(220 km grid resolution)				(100 km grid resolution)			
	u–field		*v*–field		*u*–field		*v*–field	
	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2	Set 1	Set 2
5 July 1979	3.8	4.0	4.0	4.1	4.5	4.2	3.1	3.2
6 July 1979	2.6	3.0	3.0	3.3	4.6	4.5	3.0	3.5
7 July 1979	3.0	4.0	2.6	2.7	4.4	4.4	3.1	3.3

Table 3 shows the RMS errors of wind fields. It should be noted that the RMS errors in set 1 is either smaller or nearly equal to the errors found in set 2 for both grid resolutions. It may be inferred that the model produced forecast is marginally superior with 100 km grid resolution and with the data set 1 than those with 220 km and with data set 2.

V. CONCLUSIONS

1. The objective analyses based on both the initial guess fields are very satisfactory and similar. The RMS errors in wind field are also found comparable in both the analyses.

2. The forecast circulation is better depicted with the data input in which analysis is done with forecast as initial guess field.

3. Although there is no apparent improvement found in the analysis with 100 km grid resolution, the forecast cyclonic circulation is better depicted.

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