Mausam, (1986), 37, 3, 289-292

551.557 : 551.501.75

Optimum grid length for analysis of wind field with respect to the existing network of upper air observing stations over India and its neighbourhood

S. RAJAMANI, D. R. TALWALKAR, SATHY NAIR and D. R. SIKKA

Indian Institute of Tropical Meteorology, Pune

(*Received 10 September 1984*)

सार — भारत और उसके पड़ोसी देशों के ऊपरी वायु प्रेक्षण स्टेशनों में विद्यमान संजाल के संबंध में पवन क्षेत्र के विश्लेषण के लिए ईष्टतम ग्रिड लम्बाई निर्धारित की गई। इसको निम्नलिखित तरीके से किया गया है : मानक वस्तुनिष्ठ विधि द्वारा छत्रः विभिन्न ग्रिड लम्बाइयों के लिए 31 दिनों (जुलाई 1979) तक 700 मि० बार स्तर पर पवन क्षेत्र का विश्लेषण किया गया और विश्लेषण के मूल माध्यम वर्ग त्रुटियों का अभिकलन किया गया। ग्रिड लम्बाई, जहां पर कि औसत मूल माध्यम वर्ग त्रुटि न्यूनतम है वहां पर इसका निर्धारण किया गया। निवेश के रूप में उपयोग किए गए प्रेक्षणों की संख्या पर मूल माध्य वर्ग त्रुटियों की आश्रिता की भी जांच की गई है।

ABSTRACT. The optimum grid length for the analysis of wind field with respect to the existing network of upper air observing stations over India and the neighbourhood is determined. This is done in the following way. Analyses of wind field at 700 mb level for 31 days (July 1979) for six different grid lengths were made by a standard objective method and the root mean square errors of analysis were computed. The grid length for which the average root mean square error has been minimum, was determined. The dependence of root mean square errors on the number of observations used as input has also been examined.

1. Introduction

Diagnostic and prognostic studies by numerical methods require that the upper air data are available at equally spaced grid points. This is achieved by interpolating the data from irregularly spaced observing stations through suitable objective analysis schemes. Depending upon the scale of the meteorological system one is interested, appropriate grid length required for the study is to be selected, *e.g.*, a grid length of 10° or 5° intervals, would be sufficient for the studies on the planetary scale whereas the grid length of 2° interval would be suitable for regional studies. However, the selection of the grid length may also depend upon the density of observational networks. In this study, it is proposed to determine the grid length which is optimum with respect to the existing upper air observing stations over India.

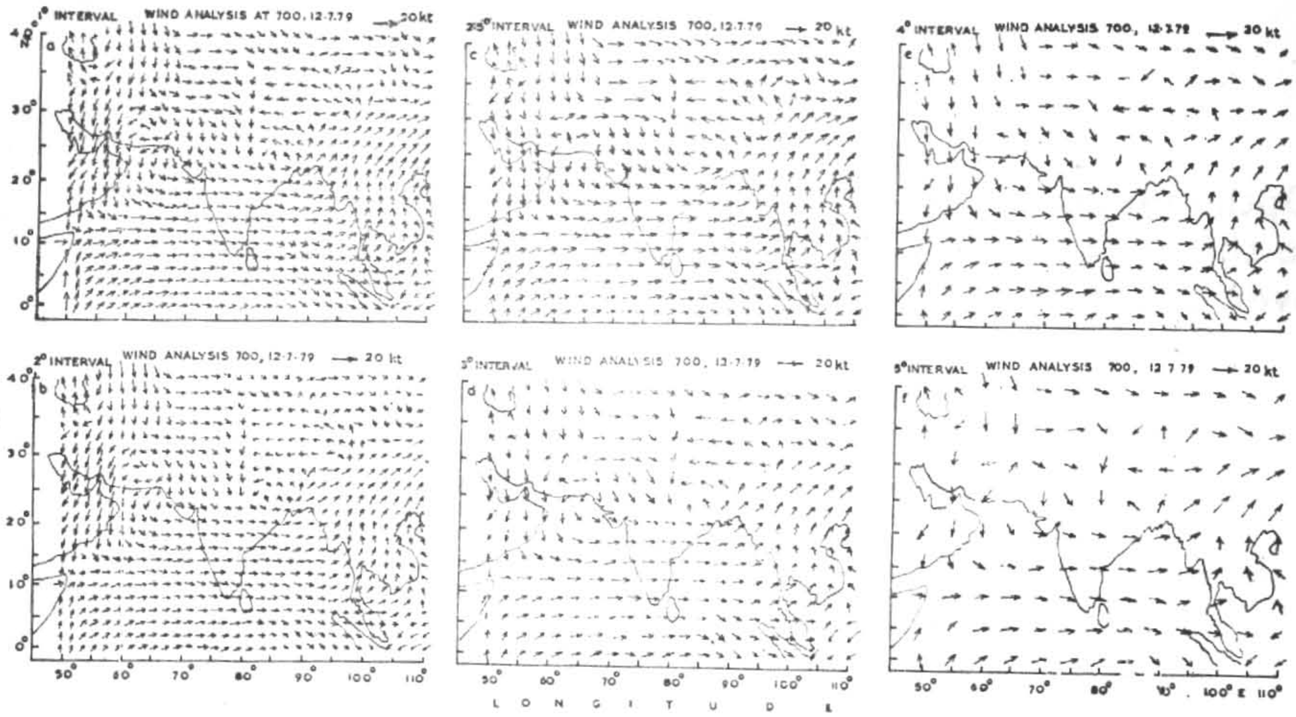
2. Methodology

Objective analyses of wind field over the Indian region from the equator to 40° N and from 50° to 110° E were made using a standard objective analysis scheme developed in an earlier study (Rajamani *et al.* 1982) and the grid data obtained at different grid intervals, *e.g.*, 5°, 4°, 3°, 2.5°, 2°, 1° latitude/longitude. Based on these analyses, the winds were interpolated to the observing stations and the root mean square (R.M.S.) errors between the observed and the interpolated winds were computed. The analysed wind fields for different cases were obtained as plotted maps through the computer.

In order to examine how the root mean square errors vary with the number of observations used as input for the analysis, the correlation coefficient between them were computed and their significance tested. The averages for R.M.S. errors for 6 sets each of 31 analyses were obtained for different grid intervals to determine the optimum grid length which had the minimum R.M.S. error.

2.1. *Data and the region of analysis*

During Monex-79, data over oceanic regions were obtained through research vessels, research aircrafts and other special observing platforms and also, over the land, already existing upper air observing stations were augmented by establishing new stations. So the period 1 to 31 July 1979 was chosen for this study. Daily analyses of wind field for this period (31 days) were made at 700 mb for 00 GMT observations. During this period, there were different types of synoptic weather situations like 'active' monsoon period (with monsoon depressions), break monsoon period, etc. The number of observations also varied from day to day ranging between 148 stations for the maximum observations (data density 6.2 stations per 10° square Lat./Long.) and 69 stations for the minimum observations (data density 2.9 stations per 10° square Lat./Long.).



Figs. 1(a-f). Wind analysis at 700 mb at 00 GMT on 12 July 1979 with : (a) 1° grid interval, **(b)** 2° grid interval, (c) 2.5° grid interval, (d) 3° grid interval, (e) 4° grid interval and **(f)** 5° grid interval

Fig. 2. Root Mean Square (R.M.S.) errors for different grid lengths and number of observations from 1 to 31 July

TABLE 1

Root mean square errors in m.p.s. for 1-31 July 1979 for six different grid lengths

Date (Jul 1979)	No. of stns.	5°	4°	3°	2.5°	2°	1°
1	100	6.0	5.9	5.2	5.8	5.7	5.7
2	116	5.4	5.3	5.1	5.1	5.1	5.0
3	135	4.5	4.3	4.0	4.0	4.2	4.0
4	119	3.9	3.7	3.6	3.6	3.8	3.7
5	148	4.0	3.9	3.8	4.0	3.9	3.8
6	146	4.4	4.1	4.0	4.0	4.0	3.9
7	128	4.9	4.7	4.8	4.8	4.7	4.7
8	114	5.1	4.9	4.8	4.9	4.9	4.8
9	69	5.1	5.0	5.0	5.0	5.1	5.1
10	72	4.2	3.9	3.9	4.1	4.0	3.9
11	138	4.1	4.0	3.7	3.8	3.8	3.7
12	131	4.5	4.4	4.2	4.2	4.2	4.1
13	77	4.5	4.4	4.2	4.4	4.5	4.5
14	103	5.4	5.5	5.1	5.3	5.4	5.2
15	113	3.9	4.0	3.9	4.0	4.0	3.9
16	131	3.7	3.6	3.4	3.4	3.4	3.4
17	132	3.6	3.6	3.2	3.4	3.6	3.6
18	100	4.8	4.9	4.7	4.6	4.9	4.7
19	101	3.8	3.8	3.5	3.7	3.6	3.5
20	131	3.8	4.0	3.8	3.7	4.4	4.0
21	145	3.7	3.6	3.4	3.5	3.6	3.5
22	142	3.7	3.6	3.5	3.4	3.7	3.6
23	147	3.7	3.5	3.3	3.4	3.4	3.3
24	136	4.7	4.5	4.4	4.5	4.3	4.2
25	123	3.5	3.4	3.3	3.4	3.2	3.2
26	113	4.5	4.6	4.3	4.5	4.4	4.4
27	138	4.4	4.3	4.1	4.2	4.1	4.2
28	125	3.5	3.5	3.4	3.3	3.3	3.2
29	101	4.2	4.2	3.9	4.1	4.2	4.2
30	97	4.8	4.8	4.6	4.7	4.6	4.7
31	126	4.3	4.3	4.3	4.3	4.3	4.3
Mean		4.33	4.26	4.08	4.16	4.20	4.13

TABLE 2

Correlation coefficient (r) between the number of observations and the R.M.S. errors and the student's t-test for different grid lengths

Grid length	Average R.M.S. error	Corr. coeff.	t
5°	4.333	—0.427**	—2.543**
4°	4.263	—0.451*	—2.721**
3°	4.079	—0.470*	—2.867*
2.5°	4.161	—0.491*	—3.035*
2°	4.207	—0.494*	—3.060*
1°	4.137	—0.517*	—3.253*

where, $t = \frac{r}{\sqrt{1-r^2}} \sqrt{n-2}$ ***

*Significant at 1% level.

** Significant at 2% level.

*** n=total number of analyses=31

The region from the equator to 40° N and from 50° E to 110° E was considered for the analysis. Apart from considering the wind observations from the stations within this region, those outside the region but within 5° from the boundaries of this region were also taken into account. Successive correction method of objective analysis of wind field adopted to the Indian region (Rajamani *et al.* 1982) was used. The scan length used for the analyses was determined everyday on the basis of mean distance of the observing stations. If 'd' was the mean distance between the stations on a day, the scan length $5d$, $4d$, $3d$, $2.5d$ were used during successive scans for the analysis on that day. However, on a day the number of observations and consequently the scan length was constant for different cases of analyses at varying grid lengths. For the set of analyses discussed here, even though the scan length changed from the situation to situation depending upon the data density, the results are not likely to be vitiated as the statistics for each day were derived from a fixed scan length for all six cases.

3. Discussion of results

3.1. *Analysis*

These objective analyses by and large agreed with the corresponding subjective analyses. The analyses became more and more smoothed as the grid length increased from 1° to 5° [In the analyses of 1° grid length, Fig. 1(a), winds were plotted at alternate grid points, *i.e.*, only at even latitudes and longitudes]. A typical case of the objectively analysed winds for 12 Jul '79 for the six different grid lengths, plotted by the computer CYBER-170, are shown in Figs. 1 (a-f). The length of the arrows is proportional to the wind speed.

3.2. *Input data density and the R.M.S. errors*

The root mean square (R.M.S.) errors for 31 days (n) for different grid lengths are shown in Fig. 2. From the figure it is seen that the day to day variations in the R.M.S. errors for different grid lengths show similar behaviour, *i.e.*, they decreased or increased together. This means that the variations in the number of observations used in the analysis, which mainly affect the analyses and consequently the R.M.S. errors, or any other factors, affected the analyses for all the six cases in the same way. The R.M.S. errors are tabulated (Table 1) for quantitative examination. In order to study the effect of the number of observations used as input on the R.M.S. errors, the curve representing the number of observations is also plotted in Fig. 2. This curve is seen to be oppositely correlated to the curves representing the R.M.S. errors. The correlation coefficients between the number of observations with each set of the R.M.S. errors have been calculated (Table 2) and compared with standard values for significance (Fisher 1941). The correlation coefficient is negative for all the cases, (significant at 1% level for the grid lengths 1° to 4° and at 2% level for the grid length 5°). Students t-tests (Table 2) also showed that negative correlations of observations used as input and the R.M.S. errors were significant at 1% level for the cases, 1° to 3° grid lengths and at 2% level for the cases 4° and 5° grid lengths. The dependence of the analysis on the data density is an expected result. However, in the series of analyses presented the data density varied from 2.9 to 6.2 observations per 10° square. Even for the largest grid length (5°), there was a tendency for the R.M.S. errors to decrease with the increase of observations, suggesting that even with the available best data density, the observing system was not over representative, nor reached a saturation stage. This is in contrast to the earlier study (Rajamani *et al.* 1983) in which case, there was a decrease of R.M.S. errors with the addition of satellite data to some extent and further addition of data increased R.M.S. errors. The reason, possibly, is the introduction of noise because of the satellite data, the noise level becoming critical beyond some stage. This did not happen in the present case, in which, satellite data were not included. So, the inference made here is that even with the best data density because of special observations (Monex-79 data), the data input for the analysis have not reached a saturation stage.

3.3. *Optimum grid length*

The average R.M.S. errors for the six different grid lengths based on 31 analyses is also shown in Table 1. It is seen that the differences in the average R.M.S. error for different grid length are not appreciable. However, the lowest error (4.08 m.p.s.) is for the grid length of 3° and the largest error (4.33 m.p.s.) is for the grid length of 5°. For the existing network of observing stations, 3° interval seems to be optimum. This can be explained in the following way. When the analyses were made for greater grid length the resultant analyses would be smoothed with the waves less than twice the given grid length being filtered out. Hence, winds interpolated from this analysed field to observing stations would also be smoothed having greater deviations from the observed winds and thus, results in the increase of R.M.S. errors. As the grid length is decreased, the degree of smoothing is reduced and so, that part of the root mean square error contributed by the smoothing processes would be reduced. However, for a given distribution of observing stations the informations about the weather systems smaller than certain limits will not be available and consequently decreasing the grid length will not give new informations, but will increase the interpolation error and so the R.M.S errors increase for further decrease of grid length. Thus, it can be inferred from these results that 3° grid length is the optimum grid length with regard to the existing network of observing stations for the lower troposphere during monsoon season. For the tropical regions, NWP models require grid length of 2° or even less. Thus, in order to depict the weather systems in an optimum way through objective analysis, there is still a scope and requirement for enhancement of existing upper air network if grid length of 2° or less is used for the prediction models. Further study is needed to determine the extent of observational enhancement needed by similar analysis for other seasons and more levels.

4. Concluding remarks

From the above discussions on the results, the following inferences could be made :

(*i*) For the existing network of upper air observing stations, 3° grid length seems to be optimum for the analysis of wind field in the lower troposphere.

(*ii*) The variations in the number of observations used as input for the analysis affect the root mean square errors or the quality of the analysis for different grid length in the same way.

(*iii*) The expected result that the increase in the number of observations improve the analysis is confirmed on the basis of statistical tests, the result being significant at 1% level.

(*iv*) The presently available network of observing stations require enhancement if a grid length of 2° or less is to be used for prediction model.

Acknowledgements

The authors thank Dr. Bh. V. Ramana Murty, Director, Indian Institute of Tropical Meteorology, Pune for his interest in this study and for his constant encouragement. They also wish to thank Shri S.S. Aralikatti, for the useful discussions on plotting of winds by the computer and Shri P.P. Kamte for the discussions on standard statistical tests. Lastly, they wish to thank Shri P.U. Upasani and Km. N. Vijayalakshmi for their help in data processing and computations, and Shri K.D. Barne for typing the manuscript.

References

Fisher, R.A., 1941, *Statistical Methods for Research Workers*, Oliver and Boyd, Eighth Edition, London, pp. 167 & 202.

Rajamani, S., Talwalkar, D.R., Upasani, P.U. and Sikka, D.R., 1982, "Impact of Monex-79 data on the objective analysis of wind field over Indian region," *Pure & applied Geophys.*, **20**, pp. 422-436.

Rajamani, S., Talwalkar, D.R., Ray, S.P. and Upasani, P.U., 1983, "Objective analysis of wind field over Indian region by optimum interpolation method", *Mausam*, **34**, pp. 43-50.