Mausam, (1992), **43**, 3, 307-310

551.501.75 : 551.542

A note on the polynomial surface fitting method for estimation of winds at different isobaric levels using the observed wind at 850 hPa level

S. N. BAVADEKAR and R. M. KHALADKAR
Indian Institute of Tropical Meteorology, Pune

(*Received 13 May 1991*)

सार — 35° पू०-140° पू० रेखांश तथा 30° द०-40° उ०अक्षांश सीमित प्रक्षेत्र में विविध समदाब स्तरों के पवन अभिकलन के लिए तीसरी घातांकी बहुपद पृष्ठ समंजन तकनीक को अपनाया गया है। विविध स्तरों के पवन के 850 एच. पी. ए. पवन के साथ अनुपात के लिए पूर्वी तथा उत्तरी पवन घटकों के लिए अलग-अलग पृष्ठों का समंजन किया है। अंत में 850 एच. पी. ए. का प्रेषित पवन और अपरिनिर्दिष्ट तकनीक से पाये गये अभिकलित गुणकों के साथ विविध स्तरों के पवनों का पुनर्निर्माण करके उनके अंतरिम परिणामों को प्रस्तुत करके तत्संबंधी चर्चा इस शोध पत्र में की गई है।

ABSTRACT. A third degree polynomial surface fitting technique is adopted to compute the winds at different isobaric levels for the limited area domain from 35°E to 140°E and 30° S to 40°N for the month of June. The polynomial surfaces are fitted to the ratios of the monthly mean winds at different isobaric levels with the 850 hPa winds. The surfaces are fitted to the *u* and *v* components of the winds separately. The winds for the levels are then reconstructed using the computed coefficients and observed wind at 850 hPa. The results of the technique are presented and discussed in the paper.

Key words — Polynomial surface fitting, Cloud motion vector, Numerical weather prediction, Objective analysis, Iterative method, IIOE—International Indian Ocean Expedition, Data generation

1. Introduction

Due to introduction of geostationary satellites of INSAT-1 series, cloud imageries on synoptic scale are now available at the interval of every 30 minutes over the oceanic regions surrounding India. The winds derived over oceanic regions through cloud motion vectors (CMVs) technique are now available on routine basis from INSAT-1D (previously from INSAT-1B) satellite. These winds are obtained either at cloud base level (850 hPa) or at cloud top level (200 hPa) over data sparse (oceanic) regions and thus provide the useful information for the analysis of wind in these regions.

The one level wind data either at 850 hPa or 200 hPa are, however, not sufficient for numerical weather prediction (NWP). The attempts were made, therefore, to derive the vertical wind profiles from the CMVs using MONEX-1979 data by Begum (1986) and Begum and Datta (1986) for Arabian Sea and Bay of Bengal respectively using empirical formulations. The winds are computed on daily basis for 1 to 5 May 1979 for two stations, namely, Minicoy (Arabian Sea) and Port Blair (Bay of Bengal) for standard pressure levels and were compared with the actual observations. The results presented for these stations are quite satisfactory. They have stated that the winds at the other locations can be obtained by little adjustment of the constants. Mahajan *et al.* (1990) constructed vertical wind profile using satellite derived winds of MONEX-1979. The winds were constructed by using linear regression equations between CMVs and ship winds for the domain 0°-26° N and 48°-60° E. The RMS errors as estimated, were less than 5 mps below 500 hPa and less than 8 mps above 500 hPa.

In the present paper we have adopted the polynomial surface fitting method to derive the winds at different isobaric levels in the limited domain from 35°E-140°E and 30°S-40°N for June. The polynomial surfaces are fitted to the ratios of V_L/V_{850}, where, V_L represents the grid point wind at level L and V_{850} is the corresponding grid point wind at 850 hPa. Both V_L and V_{850} are the grid point winds obtained from the analysed charts, in the present study. The polynomial surfaces are thus fitted to the observed ratios of V_L/V_{850} at all the grid points in the domain and the coefficients of the polynomial equation are obtained. For assessing the application of this technique, the polynomial equation is evaluated again using the computed coefficients and thus the ratios V_L/V_{850} are computed at different grid points. If these ratios are now multiplied by the corresponding V_{850} winds we can get the computed winds V_L which are compared with the observed (analysed) winds V_L. The wind V_{850} is thus assumed to be the observed or known wind. The results of the technique are statistically evaluated in the paper.

2. Data

The source for the observed monthly mean data is the analysed upper air wind charts published by

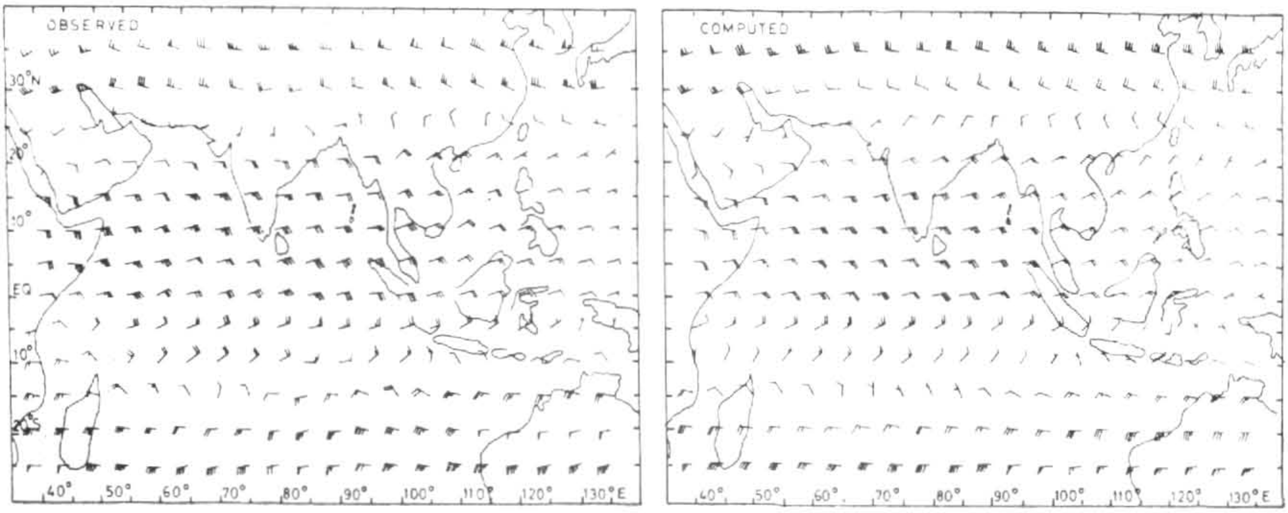

Fig. 1. Observed (left) and computed (right) 200 hPa winds

TABLE 1

Comparison of observed and computed winds
(Unit of wind : kt)

Level (hPa)	Obs. mean	Comp. mean	Corr. coeff.	Obs S.D.	Comp. S.D.	RMS deviation
For u component of wind						
200	4.08	2.04	0.98	31.53	24.14	9.4
250	4.55	2.58	0.98	25.77	19.73	7.7
300	5.01	3.21	0.97	20.37	15.25	6.8
400	5.00	3.72	0.96	14.63	11.19	5.1
500	4.99	4.23	0.88	9.82	7.42	4.8
600	4.53	4.10	0.81	7.00	5.16	4.2
700	4.06	3.98	0.67	5.92	3.71	4.3
800	2.18	2.29	0.75	6.88	4.94	4.6
For v component of wind						
200	—5.16	—5.09	0.68	7.60	5.91	5.5
250	—3.47	—3.66	0.70	5.96	4.48	4.2
300	—1.79	—2.24	0.55	5.52	3.49	4.6
400	—1.15	—1.44	0.43	3.49	1.97	3.2
500	—0.51	—0.65	0.25	3.07	1.17	3.0
600	—0.01	—0.09	0.30	2.69	0.90	2.6
700	0.48	0.47	0.42	3.30	1.15	2.0
800	1.73	1.67	0.67	4.09	1.84	3.2

TABLE 2

Error in absolute values for DD and FF

	Levels (hPa)							
	200	250	300	400	500	600	700	800
Error in DD	30.7°	29.2°	33.8°	27.6°	75.2°	71.3°	49.2°	35.7°
Error in FF (kt)	7.3	6.0	5.3	4.0	3.0	3.1	3.0	3.4

Ramage and Raman (1972). The winds at 5°×5° grid are picked from these charts for the month of June, for the limited area domain from 35°E to 140°E and from 30°S to 40°N. The winds are available at 200, 300, 500, 700 and 850 hPa levels. The winds at intermediate levels 250, 400, 600 and 800 hPa are obtained by linear interpolation method. The wind components u and v are smoothed before applying the polynomial surface fitting method.

The present method attempts at estimating the monthly winds for June on a regular grid at different isobaric levels assuming that the winds are available at 850 hPa level in the limited area domain.

3. Computational procedure

Polynomial surface fitting technique is adopted by Hamilton *et al.* (1987) for analysing the monthly climatological fields of temperature, sunshine, rainfall etc. The method is used operationally at the Irish Met. Service. They have used second degree polynomial for their purpose. In the present work we have adopted third degree polynomial equation, as the region of analysis is quite large and contains 330 data points. The polynomial equation used in the present work is :

$$f(x,y) = A_0 + A_1x + A_2x^2 + A_3x^3 + A_4y + A_5y^2 + A_6y^3 + A_7xy + A_8x^2y + A_9xy^2 \quad (1)$$

where, $f(x, y)$ represent the wind values in ratio form as mentioned earlier in the text with x and y as their location coordinates and A_0 to A_9 are the ten co-efficients of the third degree polynomial. The method seeks to choose the coefficients A_0 to A_9 so that the polynomial will be as accurate a fit as possible in the usual least square sense to the data in the given domain.

In the present work Jacobi's iterative method has been used to solve the resultant matrix equation.

The constants for u and v components are obtained separately for all the levels. The wind components are now computed using these constant, at all the grid points of the domain using Eqn. (1). The total wind is then constructed using the comupted wind components.

4. Discussion of the results

The polynomial surface fitting method is applied to basic analysed wind data for June obtained from the *Meteorological Atlas of the IIOE* period (Ramage and Raman 1972). The polynomial surface fitting method provides the coefficients of the third degree polynomial equation using the basic observed winds at 850 hPa level only as mentioned in the text. The coefficients are obtained for u and v components of the wind separately, for all the levels above 850 hPa. The computed wind components can be obtained by using the coefficients and the 850 hPa wind at all the grid points in the given domain. The total wind is then constructed from the computed wind components and compared with the observed winds.

In Table 1 the statistical parameters such as mean (average for the domain), standard deviation, correlation coefficient between observed and computed wind and RMS deviation are shown for different levels. The mean and the standard deviation for the computed u component are somewhat lower than the observed values. The computed mean values of u component are comparable to the observed values for all the levels especially below 250 hPa level. The RMS deviations are small and the correlation coefficients are quite high. The correlation coefficients are also highly significant. The technique thus gives very good representation for the u component of the wind at all levels.

Similar calculations are also made for v component of the wind. The mean v component is comparable for all the levels in Table 1. The standard deviations are somewhat smaller compared to observed values in the lower levels. RMS deviations are small and correlation coefficients are smaller in magnitude compared to those for u component of the winds. These results are expected since the meridional flow is generally very weak and not as steady as the zonal flow and, therefore, cannot be resolved with sufficient accuracy. The correlation coefficients for 500 and 600 hPa levels are especially very small. The meridional circulations at these levels are quite weak.

The errors in absolute values for DD and FF are shown in Table 2. The direction of the wind (*i.e.*, DD) is largely affected at 500 and 600 hPa levels.

The observed and computed winds are compared for the levels 200, 300, 500 and 700 hPa. For the want of space, however, Fig. 1 for 200 hPa only is shown. At 500 hPa level the winds are not properly resolved by this technique. The observed winds in the region 10°S-20°N are very weak and the errors in computed wind directions are quite large for the weak winds and hence the circulation cannot be reproduced properly by this technique. The computed winds at 500 and 600 hPa levels, therefore, should be taken into consideration with proper care.

The validation of this technique is also tested with independent monthly mean winds for June 1985 and

TABLE 3

Observed and computed winds for the stations in the domain for June 1985 and 1986

(Computed winds are shown below the observed winds)
(Unit of wind : kt)

Station	200 hPa	300 hPa	500 hPa	700 hPa
Seychelles-85	07424	09717	14405	25317
	06423	06711	03103	19601
Diego-Garcia-85	07534	10717	13407	25807
	06324	07512	02503	23903
Bombay-85	08321	07511	25213	24505
	06723	07710	01302	27807
Bombay-86	08421	09109	07613	19609
	06622	07610	01402	27807
Visakhapatnam-85	09521	05211	34105	35507
	06524	07111	34201	27706
Visakhapatnam-86	08524	08511	30407	30313
	06525	07111	34101	27606
Goa-85	09432	08213	27105	27213
	07231	08115	02202	27506
Madras-85	08336	08009	28713	28217
	07133	07917	05502	27306
Madras-86	08130	08009	26709	28013
	07033	07917	05302	27405
Port Blair-85	06536	06613	23915	24923
	06632	07416	07103	27105
Port Blair-86	07524	06713	23709	25311
	06528	07315	07003	27104
Minicoy-85	08642	08917	22715	28115
	07539	08221	06104	26804
Minicoy-86	08642	06017	25407	26703
	07540	08211	06104	26805
Trivandrum-85	07748	07013	28009	27719
	03439	08221	06404	26905
Trivandrum-86	08638	08813	33601	28719
	07537	08220	06504	26904
Bangkok-85	08024	06011	27007	27019
	06324	06912	08202	27104
Penang-85	07140	07221	23705	26715
	06525	07414	08004	25302
Penang-86	06730	06817	25201	28309
	06424	07413	08004	25302
Kota Bharu-85	07040	06819	25407	27113
	06225	07514	08305	25402
Kota Bharu-86	07130	07019	05501	28407
	06524	07413	08304	25302
Singapore-85	09544	08823	17303	24607
	06422	07412	08205	23302
Singapore-86	07130	08017	10203	28007
	06220	07211	08104	23102
Shanghai-85	28225	27540	26019	23905
	28424	28920	26811	26007
Shanghai-86	28246	27036	26023	23713
	28325	28820	26812	26007
Hongkong-86	03011	07723	22603	22709
	00608	03805	25803	26705
Jeddah-86	14909	14703	09712	26507
	19213	21008	06404	27907
Abu-Dhabi-86	20007	26003	04512	13303
	13304	19203	07405	27708
Calcutta-86	11009	15003	20612	29105
	03914	02306	08103	27907

TABLE 4

Average errors in absolute values in DD and FF for June 1985 and June 1986 (FF values are in kt)

	Levels (hPa)							
	200		300		500		700	
	DD	FF	DD	FF	DD	FF	DD	FF
Average error	17.6°	6.9	27.6°	4.9	136.9°	4.6	32.4°	8.1

June 1986. The winds for various reporting stations in the domain for these months are obtained from the *Monthly climatic data for the world* (1985, 1986). The observed winds at 850 hPa for these stations and their location coordinates (latitude and longitude) are fed for computation of vertical wind profile. The coefficients used for the computations, although not very appropriate, are the same as obtained in this study for the IIOE (June) winds. The observed and computed winds for the stations are shown in the Table 3. The computed winds are quite close to the observed winds at 200, 300 and 700 hPa levels. The winds at 500 hPa are not reproduced properly as expected. The average errors in absolute values are also shown in Table 4. The large error in direction of the wind at 500 hPa level is seen.

5. Concluding remarks

The method seems to be useful in deriving the vertical wind profile based on the observed winds at 850 hPa level at any location in the given domain. The method of computation is tested only for June winds and gives a good accuracy for all the levels except for 500 and 600 hPa.

The method of computation can also be used to derive the vertical wind profile over oceanic region of the domain using the satellite winds which are generally available at the cloud base (850 hPa) level, provided the appropriate coefficients of the polynomial equations are obtained for the observed winds. The method of computation can also be suitably modified to work with the observed wind at 200 hPa instead of 850 hPa. The method of computation, therefore, will be useful in objective analysis of the wind at different isobaric levels over oceanic region using the satellite wind data either at 850 hPa level or 200 hPa level.

References

Begum, Z.N., 1986, "Modelling of wind profile over Arabian Sea," *Mausam*, **37**, 4, pp. 537-538.

Begum, Z.N. and Datta, R.K., 1986, "A model for deriving vertical wind profile over Indian seas using cloud vector winds", *Vayu Mandal*, **16**, 1 & 2, pp. 53-55.

Hamilton, J., Lennon, P. and O'Donnel, B., 1987, "Objective analysis of climatological fields of temperature, sunshine and rainfall", Tech. Note No. 49, Glassnvin Hill, Dublin, 9, Ireland, pp. 1-17.

Mahajan, P.N., Talwalkar, D.R., Nair, S. and Rajamani, S. 1990, "Construction of vertical wind profile using satellite derived CMVs and its impact on objective analysis over the Indian region", "International Symp. on Optical and Radio Remote Sensing of Atmospheric Environment", National Physical Laboratory, New Delhi (24-26 Oct. 1990), pp. 62-65.

Monthly Climatic Data for the World, June 1985, **38**, No. 6.

Monthly Climatic Data for the World, June 1986, **39**, No. 6.

Ramage, C.S. and Raman, C.R.V., 1972, "*Meteorological Atlas of the International Indian Ocean Expedition*", vol., **2.**, U.S. National Science Foundation.