Validation of Water Vapour and Wind Speed products derived from MSMR payload onboard IRS_P4 Satellite and meteorological applications of data products.

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ABSTRACT

Geophysical parameters are being derived and received regularly since last more than one year, using the data received from the Multifrequency Scanning Microwave Radiometer (MSMR) payload launched onboard India's Remote Sensing Satellite IRS-P4 in May,1999.Two main products of interest from meteorological applications point of view are, water vapour and wind speed over the ocean surfaces, which are being received operationally at IMD. These data products have been validated by comparison with similar products derived from SSM/I sensors onboard DMSP Satellites of the USA. Quality of MSMR derived water vapour is found to be excellent. When compared with SSM/I, the root mean square error (rmse) is 0.36 gm/cm*2 and bias is -0.29 gm/cm*2. MSMR derived wind speed however, needs some improvements since it is found to be a little higher as compared to SSM/I derived wind speeds MSMR derived wind speed data is ,however, found to be good qualitatively as it generally brings out expected changes associated with synoptic scale flow patterns over the oceanic areas.. These data products have been used operationally during the two Monsoon Seasons (2000 & 2001) to monitor the onset of South West Monsoon over South Kerala Coast of India. They are found to provide useful clues for better monitoring of the onset of Monsoon on an operational basis. Use of water vapour product in conjunction with wind speed provide useful clues for identifying areas of moisture convergence leading to initiation of conditions responsible for heavy rainfall occurrence along the west coast of India. This is a useful information for operational forecasting of heavy rainfall. MSMR derived wind speed data is also potentially useful to monitor wind speed changes over Arabian sea, associated with westward propagating waves in the Southern Hemisphere which has linkages with the phase of Monsoon activity.

1. INTRODUCTION

Successful operation of a Multispectral Microwave Radiometer (MSMR) onboard India's IRS-P4 Remote Sensing Satellite launched in May 1999, has been a very important milestone in India's Space Programme. This payload provides useful data for some of the meteorological applications. Technical specifications of this radiometer, the channel details and the quantitative products derived from the MSMR data are described in some of the papers/reports published recently (Raju et al, 1999, Gohil et al, 1999 and 2000) Water vapour distribution and the wind speed over oceanic areas are two important products derived from MSMR data, which are potentially useful for meteorological applications. Preliminary results on the validation of these two products based on insitu ground truth data collected during ship cruises and limited comparisons with similar products derived from other

contemporary satellites have shown that (Ali, 1999 and Gohil et al, 2000) these products are of reasonably good quality and could be used by various perspective user for a number of potential applications. These results were also presented in the first scientific workshop on "MSMR: First Results" held at SAC ,Ahmedabad on 7-8 March, 2000. Bhatia et al, (2000) in their study with SSM/I derived products brought out the potential usefulness of water vapour and wind speed data for diagnostic studies of heavy rainfall event along the west coast of India. This study and the outcome of results of "First MSMR workshop" provided further impetus for undertaking more focused studies on the validation of MSMR products and use them for a few specific applications .Results of one such study have been well documented in two reports/papers (Bhatia et al, 2001 and Simon et al and Bhatia et al 2001). In these papers the usefulness of MSMR derived water-vapour and wind speed products for monitoring the onset of South West Monsoon over South Kerala coast of India during the year 2000 has been well brought out. These products are also found useful for predicting heavy rainfall events along West coast of India. The present paper brings out additional results based on the most recent studies carried out with MSMR derived products during the Monsoon onset phase of the year 2001

2. DATA USED FOR THE STUDIES

MSMR onboard IRS_P4 is a conical scanning radiometer operating in 8 microwave channels with both vertical and horizontal polarization in 4 frequencies. Two channels at 18 GHz and 21GHz are useful for derivation of ocean surface wind speed and water vapour over oceans. Based on certain validation studies conducted recently by SAC it had been concluded that these two products are generally of good quality and within reasonable limits of accuracy. These were therefore, used to monitor Monsoon (2001) onset in a manner similar to last year (2000). Scope of work plan was, however, improved based on experience of last year. A detailed work plan was prepared jointly by IMD and ISRO defining the geographical domain, frequency and mode of data reception .Two day composite maps were prepared for ocean surface wind speed and water vapour over ocean covering the areas 30 deg. S to 30 deg. N and 30 deg E to 120 deg E. The data were sent by NRSA, Hyderabad to IMD, New Delhi starting from 24 April 2001. Daily maps of these products were also prepared for routine operational use.SSM/I derived water vapour and wind speed products were also collected from INTERNET with a time delay of about 2 days and maps were prepared covering the same geographical area. In addition , daily water-vapour channel imagery from METEOSAT-5 and low level CMVs were also collected.

3. RESULTS AND DISCUSSIONS

During the year 2001, further detailed evaluation of the geophysical parameters i.e. water vapour and ocean surface wind speed derived from MSMR was carried out. Using the global data sets of SSM/I and MSMR derived products, match up data file for water vapour and wind speed were prepared on the basis of time and space coincident observations derived from the independent sources of data. Inter comparison of water vapour derived from SSM/I and MSMR shows that (Fig1) the agreement between the two is very good. Root mean square error is 0.36 g/cm2 and bias is – 0.29 g/cm2 indicating that the quality of MSMR derived water vapour is excellent., since it is based on a large number (>6000) of co located points. A qualitative comparison of the data sets on 12 May 2001 also shows that (Fig 2) the horizontal patterns of water vapour distribution are

almost identical in SSM/I and MSMR , thereby proving the good quality of MSMR water –vapour product. In many cases it was found that small scale patterns in water vapour distribution are better brought out in MSMR data as compared to SSM/I indicating the possible superiority of MSMR data.

Similar comparison of wind speed derived from MSMR and SSM/I was also done. It is however, noticed that MSMR wind speed is not of very good quality and some improvements are required in this product. Inter comparison of MSMR wind speed with SSM/I does not give very encouraging results. However, from qualitative point of view it is seen that MSMR wind speed does generally bring out the expected changes in the wind flow patterns over oceanic areas.

The time series of MSMR derived wind speed at specific geographical locations in the Arabian Sea i.e. at 9 deg N, 67 deg E (Fig 3) and 7 deg N , 69 deg E (Fig 4) brings out interesting results. At these locations, based on earlier studies (Krishnamurti et al , 1979), it has been found that wind speed at these locations increases soon after the onset of Monsoon over Kerala . The time series prepared with MSMR data also brings out similar results during the onset phase of Monsoon for the year 2001. It clearly brings out a surge observed in the westerly flow soon after 23rd May, 2001 which was followed by increased rainfall activity . This surge was responsible for onset of Monsoon over Kerala Coast on 23rd June 2001 and it was of a prolonged duration. The three days composite picture of MSMR derived wind speed is also shown in Figs-3 and 4 which clearly shows the increase in wind speed , soon after the onset of Monsoon. Similar observations were also recorded in the Monsoon season of 2000 for which results are already published (Bhatia et al 2001 and Simon et al and Bhatia et al 2001).

Monitoring of day to day changes in the water vapour over Arabian Sea and Bay of Bengal also brought out interesting results. It was found that in general the amount of water vapour was higher during late April and early May of current year (2001) as compared to the last year (2000). Fig 5 shows time sequence of water vapour distribution over Arabian Sea for the period 1st May to 23rd May 2001 depicting many interesting features before onset of Monsoon over Kerala Coast. It is seen that in the year 2001 the water vapour further increased progressively with the advancement of season. The areas of highest moisture content moved forward gradually from South Indian Ocean to the Arabian Sea. Particularly before the onset of Monsoon over Kerala, the area of highest water vapour moved in a systematic manner from 20th to 23rd May 2001 . This was in association with a tropical disturbance which later on (23rd May 2001) developed into a tropical cyclone. Thus during the year 2001 monitoring of the Arabian Sea part of the Monsoon current was fairly simple and MSMR derived water vapour did bring out the daily changes in the water vapour distribution as expected. The cyclone laid at the leading edge of the monsoon current. From the past studies also (Krishnamurti et al, 1981) it is seen that the onset of monsoon sometimes take place in connection with onset vortex. During the year 2001 the onset vortex had strengthened to the stage of even tropical cyclone. The Bay of Bengal portion of the Monsoon current could also be monitored to some extent with MSMR data. Monsoon advanced over Bay Islands on 17th May, 2001 and MSMR derived water vapour was useful to the forecaster for declaring this onset.

. MSMR derived water vapour and wind speed products were found to be useful for operational forecasting of possible areas of heavy rainfall occurrence along the west coast of India during premonsoon period and after the

onset of Monsoon . When these data products are used in conjunction with other conventional meteorological data, the areas of low level moisture convergence leading to conditions responsible for initiation of heavy precipitation, can be delineated 1-2 days in advance. MSMR products are therefore found useful for practical applications in day –to- day forecasting work. Earlier results of such studies have been published (Bhatia et al, 2000 and Bhatia et al, 2001) bringing out certain specific cases when MSMR products were found useful. During the year 2001, the water vapour and wind speed distribution over Arabian Sea on 9 – 10 June, 2001 (Fig 6) showed area of high moisture and wind speed a little away (15 deg N , 70 deg E) from the west coast of India off Konkan and adjoining Karnataka areas indicating that low level moisture convergence is taking place toward Goa and adjoining areas. Heavy rainfall was expected in the areas on 11-12 May, 2001. The rainfall map (Fig 7) of 12th May, 2001 really shows that the occurrence of heavy rainfall in the area with rainfall amounts as high as 13 cm at some stations and a number of stations reporting rainfall of about 7 cm. Operational availability of MSMR products to the forecasters was , therefore , useful in this case. Two more similar cases were observed in June, 2001 for which details are not reported in order to restrict size of paper.

During the year 2001 another interesting application of MSMR wind speed product has been found. It is well known that the westward propagating waves in the middle latitudes over the Southern Hemisphere parts of the South Indian Ocean affect the low level winds off Somali Coast and the Arabian Sea. These waves can be tracked even from the areas as far as Southern Hemisphere portions of the Atlantic Ocean and when they cross approximately 50 deg E longitude, there is a surge in the low level south westerlies over south western part of Arabian Sea, which influence the Monsoon over India. This observation has been made consistently using cloud imagery received from METEOSAT- 5 satellite located at 63 deg E along with the Cloud Motion Vectors (CMVs) superimposed on the imagery data. From the MSMR wind speed data of current year (2001) also it is noticed that in such events ocean surface wind speed increases and preliminary analysis of the data shows that there is correlation between the passage of middle latitude wave and the increase in ocean surface wind speed. This observation can have interesting applications for better understanding of distribution of monsoon rainfall in time since a surge in ocean surface wind speed over Arabian Sea is known to influence monsoon activity.

4.CONCLUSIONS

Operational availability of ocean surface wind speed and water vapour derived from MSMR onboard IRS-P4 has provided new data sources for better monitoring of the onset of Monsoon over Kerala Coast. During the year 2001 significant changes occurred in the amount of water vapour over Arabian Sea as the Monsoon current progressed forward from Southern Hemisphere, leading to onset of Monsoon over Kerala Coast. MSMR derived water vapour is of excellent quality as it compares very well with the SSM/I derived water vapour. The monsoon onset in 2001 took place in association with the formation of a cyclonic storm which lay at the leading edge of the Monsoon current. MSMR derived water vapour provided useful signal to depict changes occurring in the amount of water vapour over Arabian Sea associated with the onset of Monsoon. Ocean surface wind speed derived from MSMR was also found to bring out expected changes in the wind speed at specific locations in the Arabian Sea associated with onset of Monsoon over Kerala Coast.

Increase in the wind speed during 3 – 4 days soon after the onset of Monsoon has been well captured in MSMR data during the year 2001

Operational availability of ocean surface water Vapour and wind speed is found useful for forecasting possible areas of heavy precipitation along the West coast of India when these data are used in conjunction with other conventional meteorological observations, including cloud imagery data received from satellites . These new data products available from IRS – P4 satellite are also useful for better understanding of Monsoon activity and its linkage with eastward propagating waves in the middle latitudes over South Indian Ocean region

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REFERENCES

Bhatia ,R. C , L.R. Meena and R.K. Jain , 2000, Use of SSM/I derived products for diagnostic studies of Heavy Rainfall events over coastal areas of India , Proceedings of Tropmet –2000 , Ocean and Atmosphere, eds P.V. Joseph et al , Pub Pai & Co., Cochin, India PP 281-285.

Gohil,B.S, A.K. Mathur and A.K.Verma , 2000, Geophysical Parameters retrieval over Global Ocean from IRS-P4 /MSMR Data, PORSEC Proceedings Vol.1, Goa, India , PP 207-211.

Krishnamurti , T.N., A.Philip , Y. Ramanathan, P. Richard 1981: On the Onset vortex of the summer monsoon. Mon.Wea. Rev. 109,344-363.

Krishnamurti, T.N , H. Pan, C.B.Chang , J.Polseny and W. Oodally , 1979: Numerical weather prediction for GATE , Q.J.R Meteo. Soc,105, 979-1010

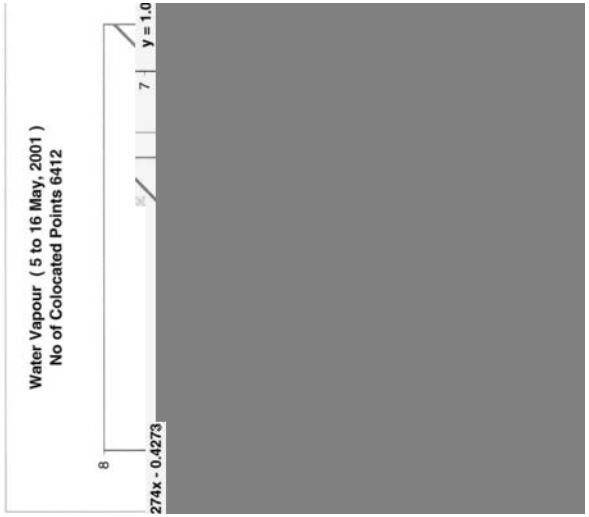
Bhatia ,R.C., Devender Singh, S.K. Mukherjee, B.Simon, P.K.Pal and P.C.Joshi, June, 2001, Potential of Monitoring Monsoon Onset with MSMR from IRS-P4, pp 73-80, Bulletin of the National Natural Resources Management System published by Dept. of Space, ISRO HQs , Bangalore.

Simon, B, et al , and Bhatia, R.C. et al, March 2001 , SAC- IMD Joint Report on "Utilization of MSMR Data for Monitoring Onset of Monsoon 2000". No.SAC/ RESA/MOG, IRS-P4, MSMR-UP-SR/01/2001.

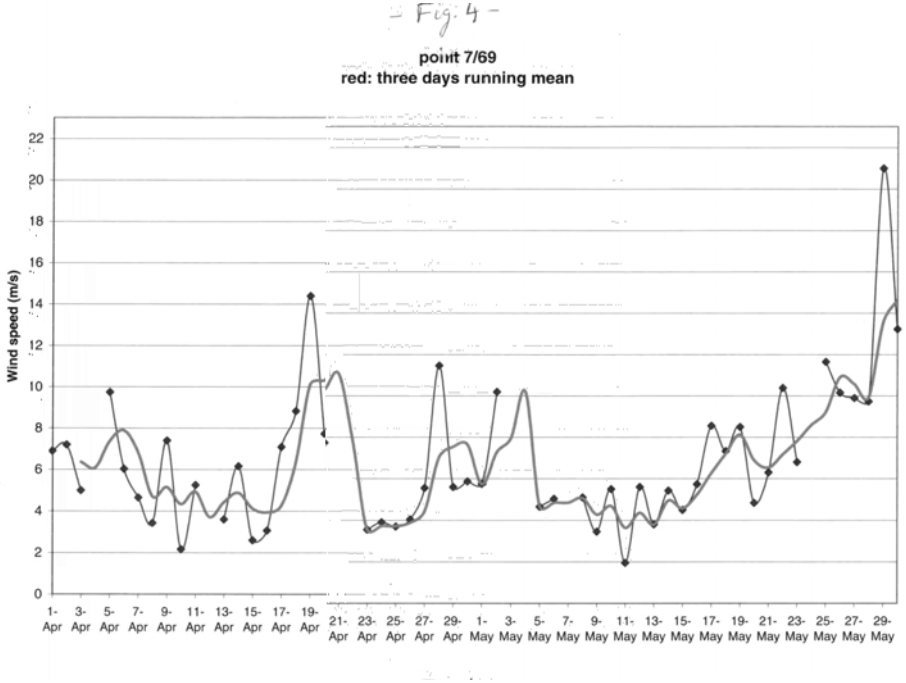
G.Raju and S.S. Rana , OCEAN SAT-1(IRS-P4) Satellite and Payloads , Proceedings of the First Megha – Tropiques Science Workshop, ISRO HQs, Bangalore 19 – 22 May, 1999, pp 3.1 – 3.4 , published by ISRO & CNES.

Gohil , B.S, Retrieval of Geophysical Parameters from IRS-P4 MSMR , Proceedings of First Megha – Tropiques Science Workshop,, ISRO HQs Bangalore 19 – 22 May,1999, pp 20.1-20.17 , published by ISRO and CNES.

Ali,M.M, Work plan for validating MSMR data , proceedings of the First Megha-Tropiques Science Workshop, ISRO HQs , Bangalore, 19-22 May 1999 pp 21.1-21.12, published by ISRO & CNES.


Water Vapour (5 to 16 May, 2001)
No of Colocated Points 6412
y = 1.0
7
8
274x - 0.4273

– Fig. 4 –


point 7/69
red: three days running mean
Wind speed (m/s)
0
2
4
6
8
10
12
14
16
18
20
22
1-Apr
3-Apr
5-Apr
7-Apr
9-Apr
11-Apr
13-Apr
15-Apr
17-Apr
19-Apr
21-Apr
23-Apr
25-Apr
27-Apr
29-Apr
1-May
3-May
5-May
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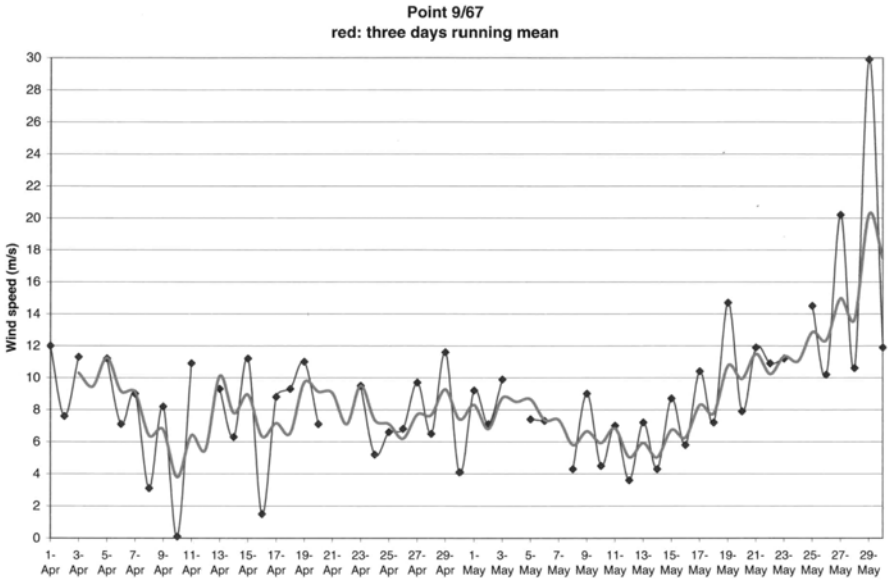
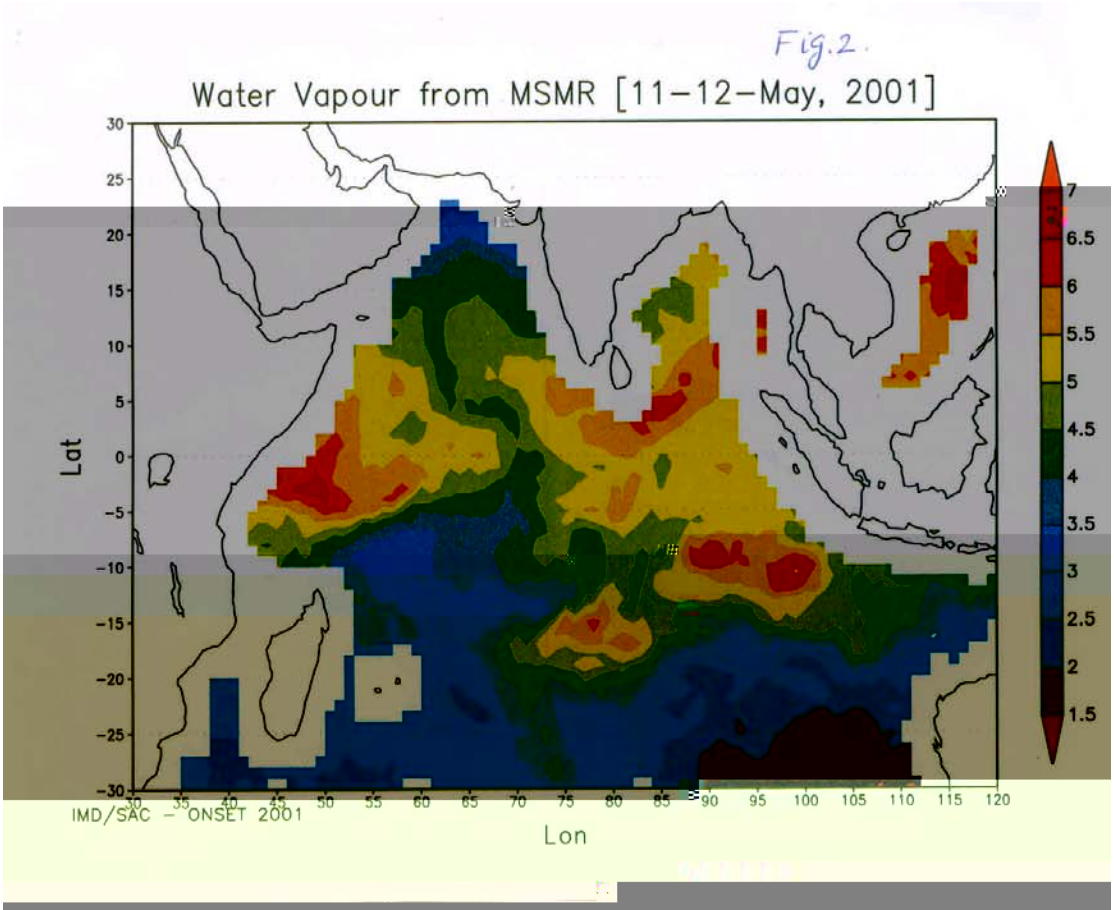
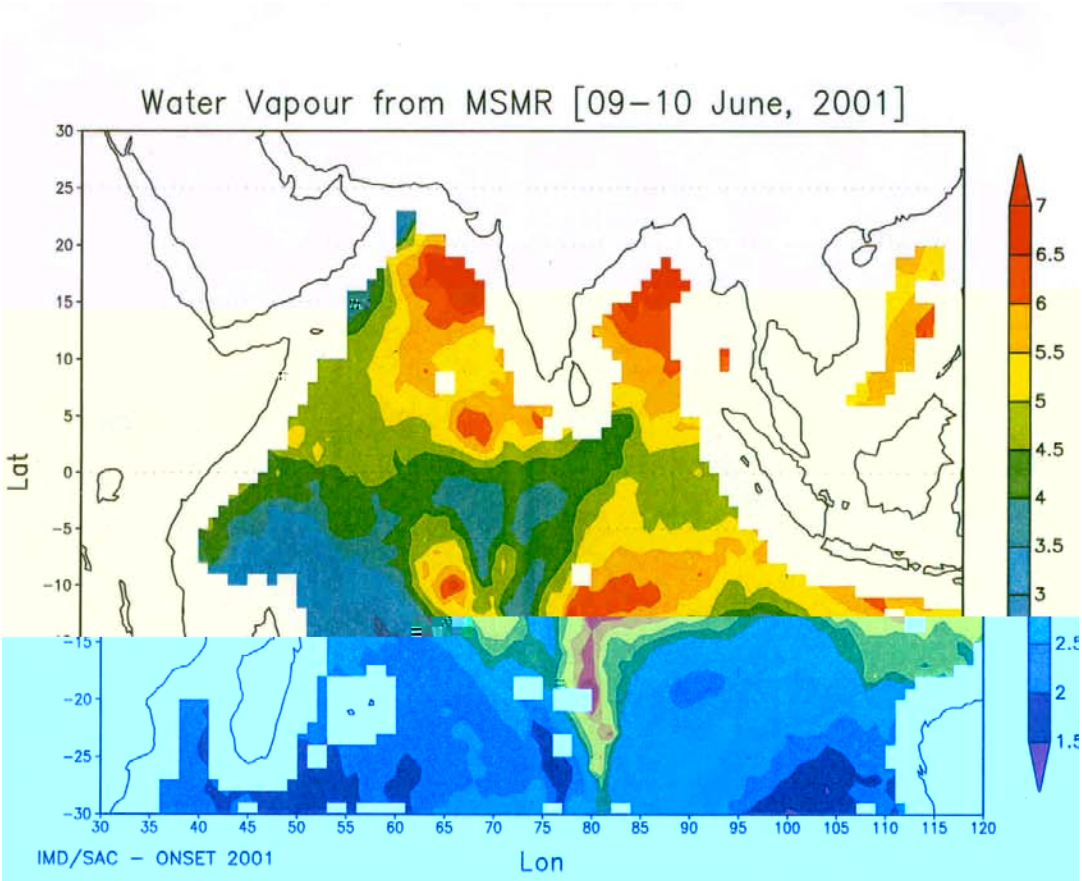
15-May
17-May
19-May
21-May
23-May
25-May
27-May
29-May

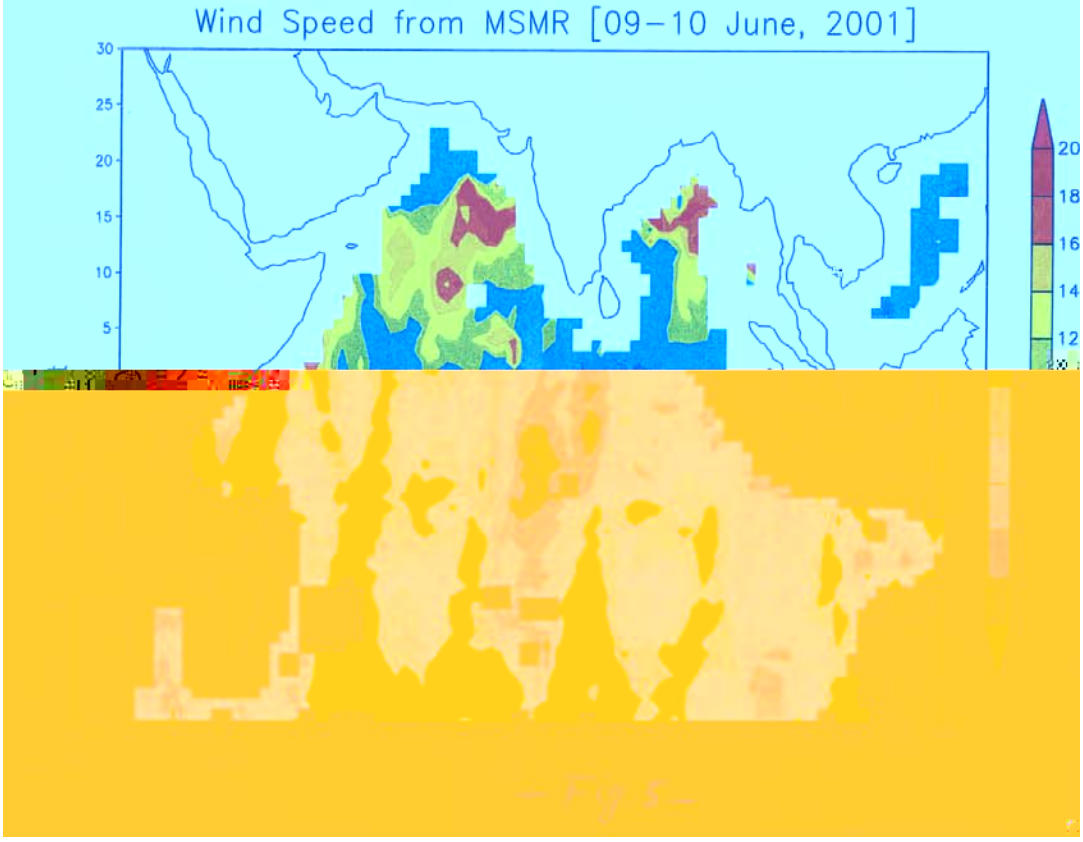

Point 9/67
red: three days running mean
Wind speed (m/s)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
1-Apr
3-Apr
5-Apr
7-Apr
9-Apr
11-Apr
13-Apr
15-Apr
17-Apr
19-Apr
21-Apr
23-Apr
25-Apr
27-Apr
29-Apr
1-May
3-May
5-May
7-May
9-May
11-May
13-May
15-May
17-May
19-May
21-May
23-May
25-May
27-May
29-May

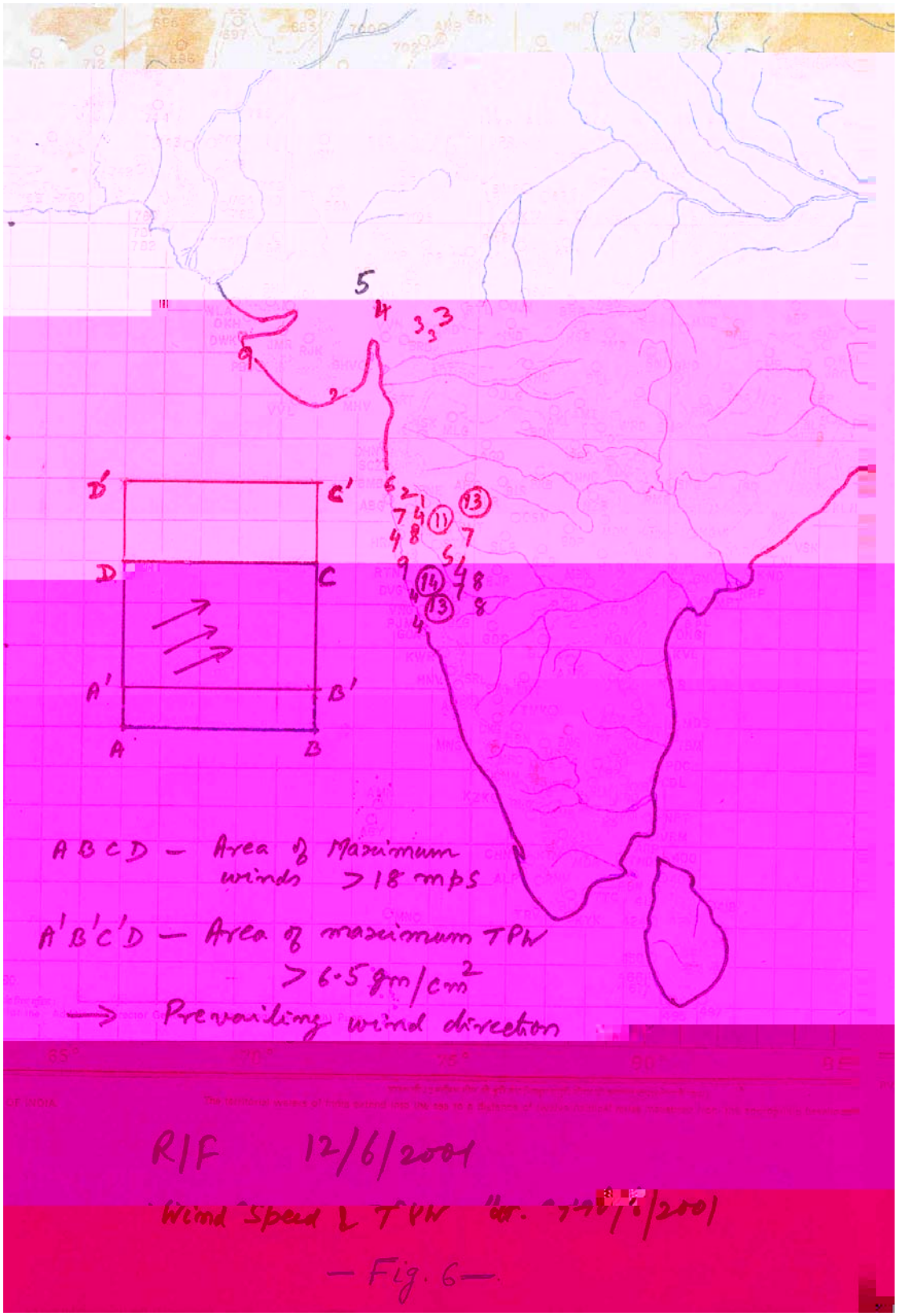
– Fig. 3 –

Fig.2.


Water Vapour from MSMR [11-12-May, 2001]
Lat
Lon
IMD/SAC - ONSET 2001
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5


Water Vapour from MSMR [09–10 June, 2001]
Lat
Lon
IMD/SAC – ONSET 2001


Wind Speed from MSMR [09–10 June, 2001]



RIF 12/6/2001

Wind Speed & TPW dt. 7/8/2001

— Fig. 6 —