IMPACT OF MSMR SURFACE WIND SPEED ON THE ANALYSIS AND FORECAST OF A LIMITED AREA MODEL

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ABSTRACT

India launched its first oceanic remote sensing satellite IRS-P4 (Oceansat-1) on May 26, 1999. The satellite carries a Multi frequency Scanning Microwave Radiometer (MSMR) which provides marine atmospheric data over the Global Ocean. The surface wind speed is available at the resolutions of 75 km and 150 km. In this paper, impact of MSMR surface wind speed on the analysis and forecast of the operational NWP model of India Meteorological Department (IMD) has been examined.

The wind direction computed based on early run of model analysis is used to derive u and v components from the MSMR surface wind speed. The analysis scheme is rerun using these modified u-v data. Modified analysis field obtained thus is used for the 24 hours model run. The experiments are carried-out with the data of May 2001 during the period of progress of Indian summer monsoon over the Indian sub-continent and development of a cyclonic storm in the east Arabian Sea The model surface wind analysis has shown substantial improvement with this data, particularly during the development of tropical cyclone over the data sparse region of the tropics as revealed from this study.

1. Introduction

The skill of NWP deteriorates over the tropics due to significant data gap over the Ocean. In spite of the use of vast amount of synoptic and non conventional data sets from satellite, large data gaps are evident over the ocean areas in tropics. A major problem in the use of numerical model for the forecasting of synoptic features such as progress of Indian summer monsoon, formation and intensification of tropical cyclone is the near absence of conventional and inadequacy of non conventional data out in the sea areas where these activities originate. In view of the importance of accurate oceanic initial conditions in tropical numerical weather prediction, it is necessary to maximize these data from non-conventional sources (Prasad et. al, 1997; Rao et. al. 2001). Availability of ocean surface wind speed and water vapour data obtained from MSMR onboard IRS-P4 has opened up new possibility of using these data sources in NWP modelling. In this paper, the study is taken to examine the impact of surface wind from MSMR on the model analysis and forecast during the progress of Indian summer monsoon and development of a tropical cyclone over the India Sea.

2. Description of MSMR Data

The Multi frequency Scanning Microwave Radiometer (MSMR) on board IRS-P4 (Oceansat-1) with capability of Global coverage with two day repetivity has been providing data since its launch in May 26, 1999. MSMR is an eight band (four frequency in dual polarizations) passive microwave radiometer with a conical scan mechanism. The frequency combinations of MSMR, i.e., 6.6, 10.6, 18 and 21 GHz facilitated generation of geophysical parameters: sea surface wind speed, sea surface temperature, total cloud water and total water vapour in the marine atmosphere. The first version of data product software for both the Brightness Temperature data as well as the Geophysical Parameters were developed by the IRS-P4 Data

Product Project team at the Space Application Center (Indian Space Research Organization) including the Geophysical retrieval algorithm software (Gohil et. al, 2000). The validation study made by Ali (2000) reveals that the total atmospheric water vapor and surface wind speed as derived from MSMR are fairly accurate and acceptable for use in applications. The MSMR data are available in three grid sizes as shown in table-1. The present study uses the surface wind speed available at the resolution of 75 km.

Table 1: Operational Parameters from MSMR

Parameters	Channels	Grid Size (km)	Range	Expected Accuracy
Total Water Vapour	21 + 18, 10	50	0.2 - 7.5 gm/cm^2	0.3 g/cm^2
Sea Surface Wind Speed	10 +6, 18, 21	75	2 - 24 $m\ s^{-1}$	1.5 $m\ s^{-1}$
Sea Surface Temperature	6 +10, 18, 21	150	273-303 ^oK	1.5^{o}K
Cloud Liquid Water	21 +18, 10	50	0-80 mg/cm^2	

3. Data Analysis Procedure

3.1 Surface Wind

For the grid points where MSMR data are available, wind directions for corresponding grids are computed based on u and v fields from the early run of model analysis. The wind directions thus obtained are used to derive u and v components from the MSMR surface wind speed. The analysis scheme is rerun using these modified u v data. Modified analysis field generated thus is used for the 24 hours model forecast run.

3.2 IMD's Operational NWP System

IMD's operational NWP system is based on a Limited Area analysis and Forecast System (LAFS) which consists of real time processing of data received on Global Telecommunication System (GTS), Objective analysis by 3-dimensional multivariate Optimum Interpolation (OI) scheme and limited area forecast model.

3.2.1 Input Data

The grid point fields for running the model are prepared from the conventional and non-conventional data received through GTS. The data consists of surface, SYNOP/SHIP, upper air TEMP/PILOT, SATEM, SATOB, AIREP, DRIBUE and AMDAR which are extracted and decoded from the raw GTS data set. The synthetic observations such as cyclone bogusing data (Prasad et. al, 1997) is also included whenever needed (from depression stage). All the data are quality controlled and packed into spatial format for objective analysis.

3.2.2 Analysis Procedure

The objective analysis is carried out by 3-dimensional multivariate optimum interpolation procedures. The variables analyzed are the geopotential, u and v components of wind and specific humidity. Temperature fields are derived from the geopotential fields hydrostatically. Analysis is carried out on 12 sigma surfaces from 1.0 to 0.5 in the vertical and $1^o x 1^o$ horizontal lat/long grid for limited area analysis domain of 30^oS to 60^o N; 0 to 150^o E.

3.2.3 Forecast model

The forecast model is a Florida State University based semi-implicit, semi-Lagrangian, multi level primitive equation model cast in sigma co-ordinate and staggered Arakawa C-grid in the horizontal. The model consists of the usual equations of motion, thermodynamic energy equation, mass continuity equation, moisture continuity equation, hydrostatic equation and equation of state and includes all comprehensive physical processes.. The details of the model formulation can be found in Krishnamurti et. al.(1990).

The horizontal resolution of the coarser grid (operational) model is 0.75^o X0.75^o lat./long. and 16 sigma levels in the vertical. The orography prescribed in the model is smoothened by a nine point smoother to prevent instability due to steep gradients of terrain over the Himalayan region. The other features of the model include time dependent lateral boundary conditions and dynamic normal mode initialization. Lateral boundary conditions of the model are obtained online from the global spectral model (T-80) run of the National Center for Medium Range Weather and Forecasting (NCMRWF), New Delhi and are updated every 6 hours. The time step of the model is 600 seconds. The first guess field for objective analysis is also provided by NCMRWF forecast.

4. The Impact Study

The impact study is carried out for the period of May 2001 corresponding to the progress of summer monsoon over Indian sub-continent and development of a very severe cyclonic storm over the Arabian Sea.

The southwest monsoon advanced into south Andaman Sea and adjoining southeast Bay of Bengal on 15 May 2001. It further progressed and set in over Kerala, the extreme southern state of India on 23 May (Fig. 1)

A low pressure area formed over east central Arabian sea near lat 13.5^o N/ lon. 67.5^o E in the morning of 21 May. It intensified into a cyclonic storm (with center near lat 14^o N /lon. 71^o E) in the morning of 22 May (Fig. 2). Thereafter it further intensified into a very severe cyclonic storm in the morning of 23 May with center close to lat. 14.5^o N/ lon. 71.5^o E. It attained its peak intensity in the afternoon of 24 May when estimated maximum sustained surface wind speed reached 57 m s^{-1} and retained the intensity of severe cyclonic storm till 26 May morning hours. Thereafter the system started weakening before recurvature to the north. The system remained over the sea for more than a week as a low pressure area and disappeared thereafter.

The surface wind analysis (m s^{-1}) for 6 May and 14 May morning (respectively 9 days and 1 day prior to commencement of monsoon progress) in the control (without MSMR) and experimental (with MSMR) runs are shown in Fig.3. As the monsoon started progressing towards Indian sub-continent, the area of maximum wind moves north wards On 14 May 2001 both control and experimental runs show sharp increased south westerly wind over the south east Bay of Bengal and adjoining south Andaman Sea. A comparison reveals that for the experimental run strong southwesterly flow are confined over south east Bay of Bengal and adjoining south Andaman Sea where as in the control run stronger belt of wind extended over the south west Bay of Bengal also.

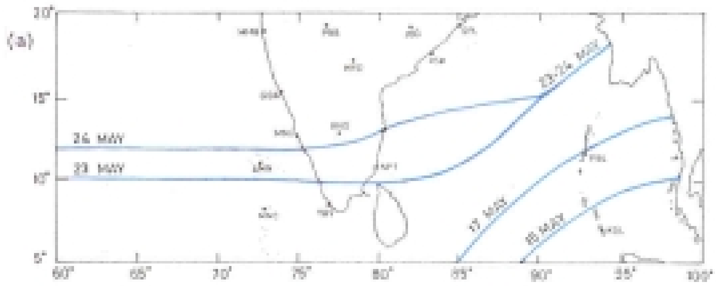

Figure.1 Advance of summer monsoon towards Indian sub-continent during May 2001

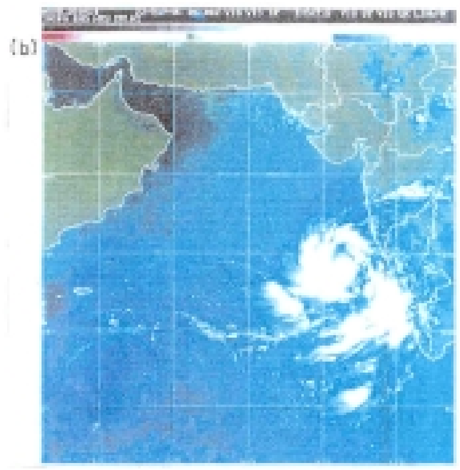

Figure.2 Satellite picture showing cloudiness in association with a cyclonic storm in the east Arabian Sea

Fig. 4 represents surface wind analysis for 20 May and 22 May during the formation and intensification of the cyclonic storm in the south east Arabian Sea. It is very interesting to note that experimental run could capture circulation and strengthening of winds over the area of disturbance on 20 May, one day prior to the formation of low pressure area. Further strengthening of winds are noticed on 22 May when cyclonic storm was actually formed Strengthening of south westerly wind over the south Arabian Sea on 22 May also consistent with the onset of monsoon over Kerala on 23 May. These features reflected more distinctly in the experimental run. Fig 5 illustrates the surface wind analysis of 26 and 27 May during the matured and decaying stage of this cyclonic storm. On 26 May the system maintained the intensity of severe cyclonic storm and subsequently on 27 May the system weakened and became a cyclonic storm. Again it is interesting to notice that for 26 May experimental run shows significantly under estimation of wind speed. This deficiency in the MSMR wind may be due to the high cloud top associated with the matured cyclone. For 27 May when the system became weak experimental surface wind analysis is found consistent with the control run. Thus it reveals that during the stage of formation and intensification of the system into a cyclonic storm the MSMR wind data has a positive impact in the analysis where as during the matured stage of the cyclone no improvement in the analysis is found.

24 hours forecast run is carried out with the improved analysis field of 20 May. But no significant improvement is noticed in the forecast (figure not shown).

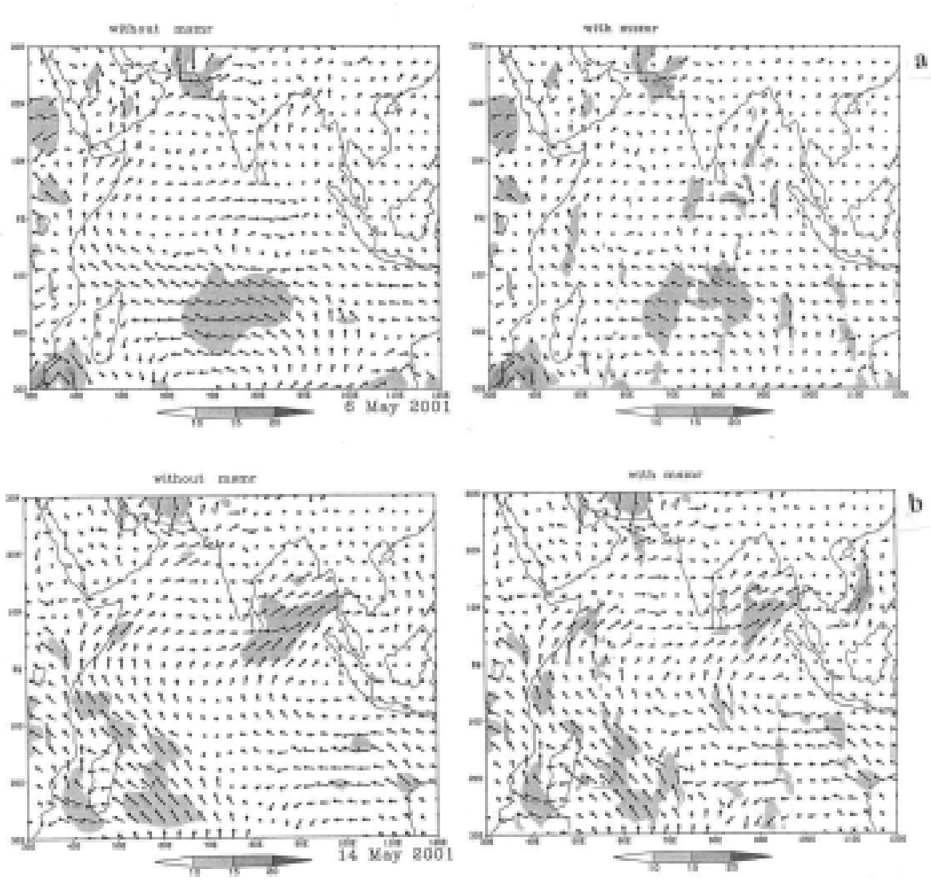

Figure.3 Model surface wind (ms^{-1}) analysis on (a) 6 May 2001 and (b) 14 May 2001. Shaded regions denote higher magnitude of winds

5. Summary and Concluding Remarks

In this paper impact of MSMR surface wind speed in the analysis and forecast of IMD's operational NWP model is examined with the data for the period of May 2001 corresponding to the progress of summer monsoon over Indian sub-continent and development of a very severe cyclonic storm over the Arabian Sea. The study has brought out a distinct positive contribution of MSMR surface wind in the limited area analysis scheme on the initial analysis which suffers in the oceanic region due to sparsity of data. The model analysis with MSMR surface wind appears to carry interesting signals as monsoon current progresses forward from southern hemisphere. Significant improvement in the analysis field is noticed during the development of a cyclonic storm (20-22 May) in the east Arabian Sea. However, no improvement in the analysis field during the matured stage of the cyclone is found. This deficiency in the MSMR wind may be due the high cloud top associated with the matured cyclone.

In the forecast no significant difference is noticed between control and experimental runs. In this context it needs to be mentioned that an inherent spin up problem arises in most NWP models. The spin up arises due to inconsistency of initial wind and moisture fields. During this spin up time divergent wind, diabatic heating and surface pressure field undergoes an adjustment (Krishnamurti et. al, 1991). The distribution of humidity is very important in this regard. In these experiments MSMR derived moisture field is not used. It is expected that surface wind along with moisture profile derived from MSMR may improve initial analysis in a more consistent manner and thereby improving the forecast. Our future work would be towards this direction.

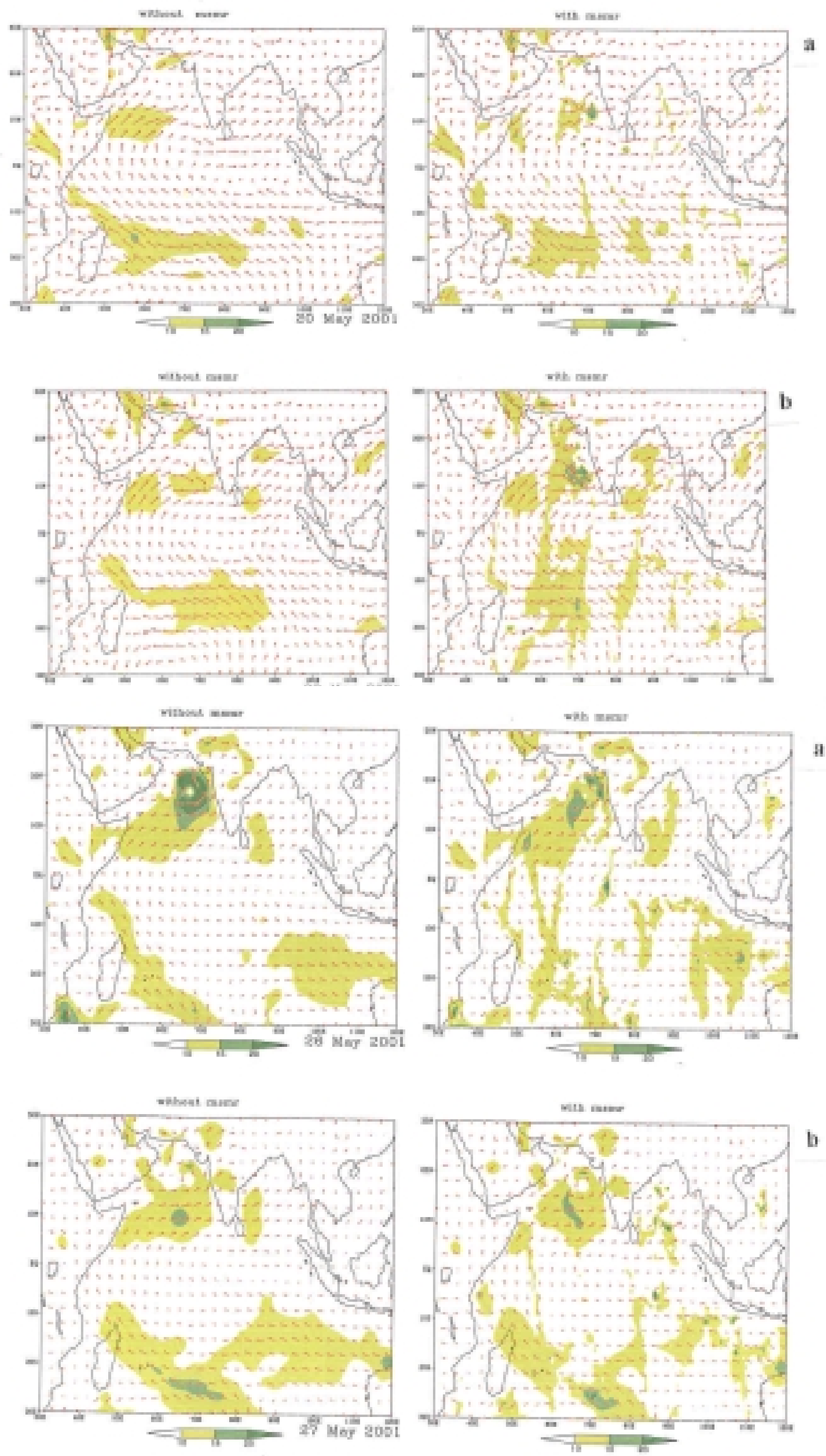

Figure. 5. Same as Fig. 4 except for (a) 20 May 2001 and (b) 22 May 2001.
Colored regions denote higher magnitude of winds

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