USE OF METEOSAT-5 DERIVED WINDS FOR ANALYSIS OF TWO TROPICAL CYCLONES AFFECTING GUJARAT COAST ON 20 MAY, 1999 AND ORISSA COAST ON 29 OCTOBER, 1999

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ABSTRACT

Since last 2 years the coverage and quality of satellite derived winds over the Indian Ocean region has improved considerably with the operation of METEOSAT – 5 from 63 deg E longitude starting July 98. Due to availability of water vapour channel on this satellite, good quality water vapour winds at middle to upper tropospheric levels are now available in large numbers. METEOSAT - 5 derived winds have been used to diagnose the motion of the two tropical cyclones that formed over the oceanic areas during the year 1999, including the one which struck Orissa coast on 29 October, 1999 causing a very widespread devastation. The data has also been found to be useful for understanding factors responsible for intensification of cyclone and to provide better insight into the possible causes of movement of tropical cyclones in particular directions. Impact studies on the track prediction by assimilating METEOSAT – 5 winds in the Limited Area Model forecast run operationally at IMD and in the Global Spectral Model run at NCMRWF show positive results. Use of METEOSAT – 5 winds in the model improves the track predictions.

1. Introduction

Persistent efforts of last several years by a few centres have culminated into production of high quality satellite derived winds operationally by many satellite operators. These winds have proved to be of immense use for a number of applications, particularly by the Numerical Weather Prediction Centres world over. A number of studies have been reported earlier showing the impact of satellite derived winds, particularly Water Vapour Winds (WVWs), on objective analysis and numerical forecasts. Velden et al. (1992) have shown that by including high- density satellite derived winds into the tropical cyclone analysis, the error of objective track forecasts can be reduced. Subsequently, while studying the sensitivity of GOES derived WVWs on spectral barotropic numerical hurricane track forecast model, Velden (1996) found that inclusion of WVWs gives rise to improvement in numerical track forecast. More recently, Velden et al. (1997) have reported results of assimilating the data into the State-of-the art primitive-equation analysis and prediction systems such as those developed at GFDL and NRL. Study of four storms during the year 1995 has shown improvements in hurricane track forecasting. It has been shown that assimilation of wind information results in a reduction of mean forecast error by 6 - 13% over the 24 – 72 hrs forecast period. The 6.7 μm channel derived WVWs contribute significantly to the improvements of medium and longer - range forecasts.

During 1999 two cyclonic storms affected Indian coasts. One had struck North Gujarat coast and adjoining areas of Pakistan coast on 20 May, 1999. The second one had crossed Orissa Coast on 29 Oct., 1999 and caused widespread damage to the Orissa state as it had attained the stage of a super cyclone. Meteosat-5 derived winds were obtained from EUMETSAT for these two events covering the entire period right from their inception to maturity stage. These data were used to better understand the movements of the storms in the particular directions in a qualitative manner. Impact studies were also done by ingesting these winds into the Limited Area Model (LAM) being run operationally at IMD in order to assess the sensitivity of this new data to the objective analysis and numerical prognoses . In particular, their impact on objective track forecast errors was studied and results obtained have been compared with similar studies conducted in the past by other authors. WVWs derived operationally by

CIMSS, University of Wisconsin using METEOSAT-5 data and disseminated through INTERNET , were also used in this study to examine particularly the factors responsible for strengthening of Orissa cyclone.

2. Current studies

In the present work a preliminary study of the impact of METEOSAT-5 derived winds on the cyclone track predictions by Limited Area Model has been carried out. These data have also been used to understand the motion of the two tropical storms mentioned above, focusing particularly on the question whether the observed track of the storms could be explained by the steering flow as inferred from the METEOSAT-5 winds. The problems of the data sparseness in oceanic regions and the consequent limitations of the track predictions by NWP model are well known. The present study is motivated by the need to fill the data gaps in the areas surrounding Indian Sub-continent with satellite derived information. With this end in view an attempt has been made to examine the utility of METEOSAT-5 derived CMVs and Water Vapour Winds for improving NWP model forecasts.

3. Super Cyclonic Storm Over the Bay of Bengal (25-31 October,1999)

It was the most intense cyclone in last 114 years for the state of Orissa. It was bettered for more than 2 days by its fierce winds and intense rains. It also produced huge storm surge and catastrophic floods causing severe damage in 12 districts of Orissa affecting a population of about 120 lakhs. It started as an initial disturbance on 24 October near Gulf of Thailand and emerged in North Andaman sea as a well marked low pressure area on the morning of 25 October. It concentrated into a depression in the evening of the same day and moved further in a west northwesterly direction. Meteosat-5 derived winds at 200 hPa level on 25 October (1200 UTC) clearly bring out the steering flow responsible for this movement. Subsequently , the system intensified further and developed in to a cyclonic storm on 26 October at 03 hrs UTC. The system had been moving northwestwards under the influence of a steering flow caused by a subtropical ridge to its northeast at 200 hPa level. The conventional meteorological observations are inadequate to define this flow clearly. However, METEOSAT-5 derived winds bring out this flow very clearly (Fig. 1) and were found to be useful in track prediction. By 03 hrs UTC of 27 October , the system intensified to the stage of a severe cyclonic storm and came under the influence of 200 hPa ridge axis providing upper level outflow favourable for its further developments. Once again METEOSAT-5 winds brought out very clearly this flow which is known to be conducive for further intensification. After 0900 hrs UTC of 27 October , 200 hPa anticyclone got positioned over the system as a result of which its movement was slowed down. These features are very well noticed in METEOSAT-5 winds. It was further upgraded to the stage of VSCS at 1500 hrs UTC on 27 October and moved in a west northwesterly direction.

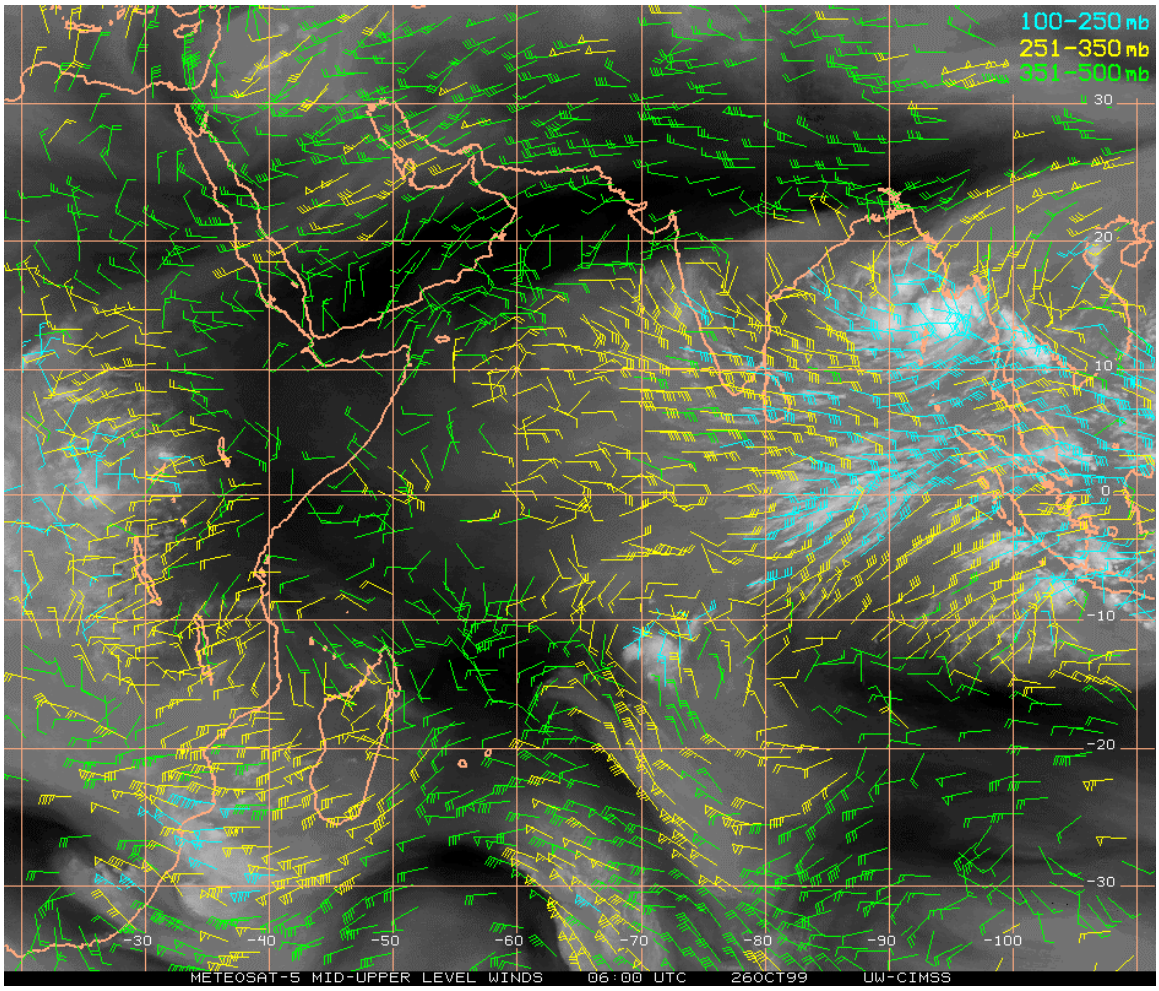

Figure 1. Meteosat-5 mid and upper level winds 26 October 1999 0600 GMT.

At this stage upper level flow as seen in METEOSAT-5 winds continued to be favourable for further development. A slight northward jog in the track was noticed which is well correlated with METEOSAT-5 winds. Forward motion was again slowed down and by 1800 hrs UTC of 28 October it become a super cyclone between 00 and 03 hrs UTC. It attained peak intensity at 03 hrs UTC just before landfall. It crossed Orissa coast close to and south of Paradip between 0430 and 0630 hrs UTC of 29 October. Next day morning (30 October) it was located in the col region (Fig 2) at 200 hPa with an anticyclone to its west over the western and adjoining areas of central India and another to the east covering parts of north Bay of Bengal and up to China sea. The Col region is brought out better in the METEOSAT – 5 derived winds. This situation continued up to 30th evening. The middle and upper tropheric WVWs by CIMSS with METEOSAT-5 also provided useful information on absence of shear in the upstream environment of the storm. Hence there was no disruptive influence on the storm as a result of which it continued its development process.

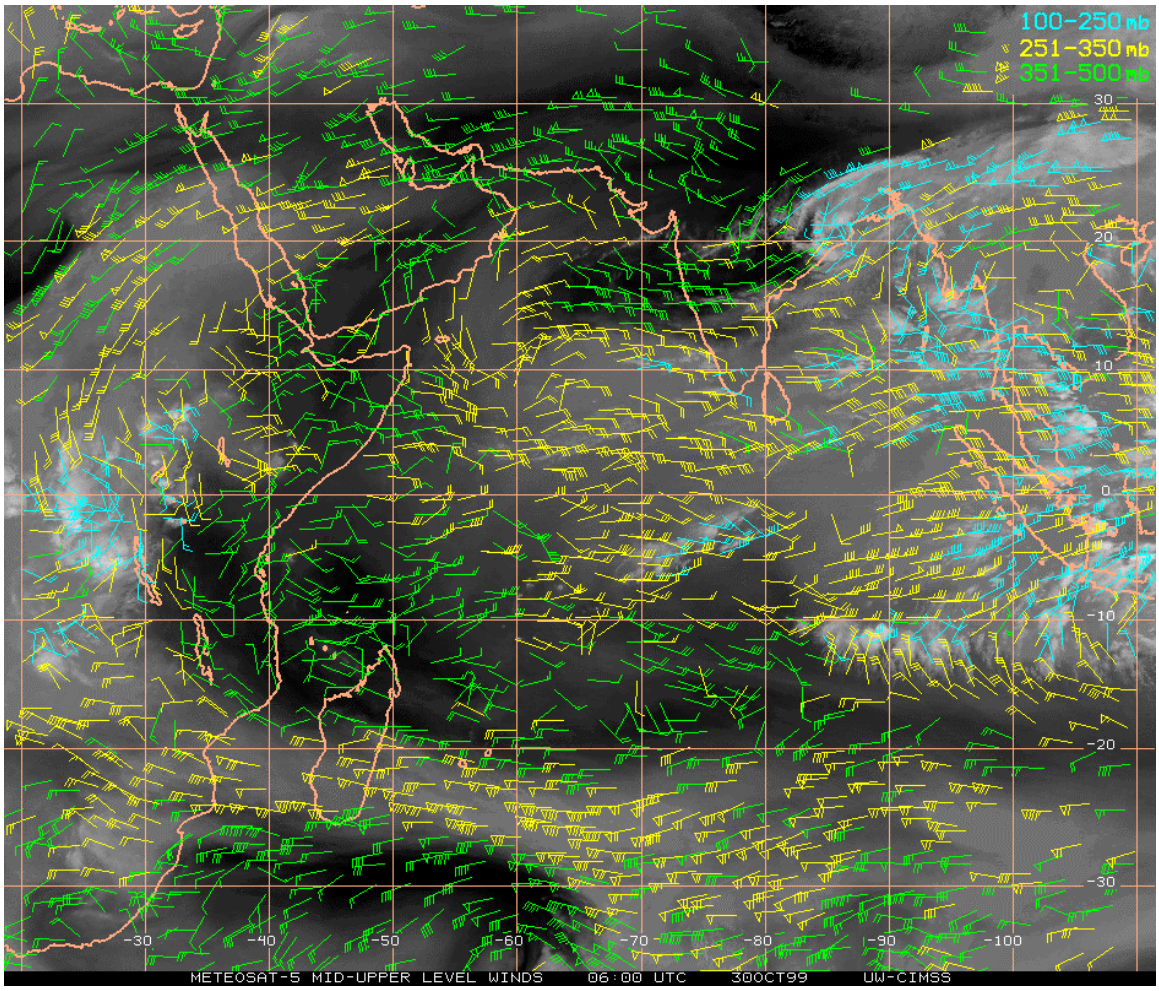

Figure 2. Meteosat-5 mid and upper level winds 30 October 1999 0600 GMT.

4. Very Severe Cyclonic Storm (VSCS) over Arabian Sea (16 - 22 May, 1999)

It was the case of one of the rare and intense storms that crossed into Pakistan coast of Sind which has not been visited by any tropical cyclone since 1948. It started as a low pressure system over southeast Arabian sea on 15 May ,1999 which intensified into a deep depression by 1800 hrs of 16 May and rapidly further intensified to the stage of VSCS by 1200 UTC of 17 May. Initially it was moving in a northwesterly direction , but after 0300 UTC of 18 May , 1999 it moved in a dead northerly direction. It skirted the Indian coast of Gujarat before crossing Pakistan coast close to the international border on 20 May , 1999. Subsequently it moved in a north eastward direction and lay over Jaisalmer in West Rajasthan as a deep depression at 1800 hrs UTC of 22 May. Its unique feature was northerly movement along 68 deg E longitude for a considerable period of time. The reason for this movement can be very well understood from the direction of middle level steering flow as seen from METEOSAT - 5 derived winds (Fig 3) for the period 18 – 19 May, 99. Storm was embedded in a persistent nearly Southerly steering flow for a considerable period. The ridge line at 200 hPa lay to the north of the system over Arabian Sea along 23 deg N latitude. Conventional charts could not bring out this feature adequately due to lack of data. Another feature noticed was that its movement was slow (8 - 10 knots) between 17 to 19 May, 1999. METEOSAT – 5 derived winds have provided better insight into the movement of this cyclone. There were generally weak winds at middle to upper tropospheric levels during this period.

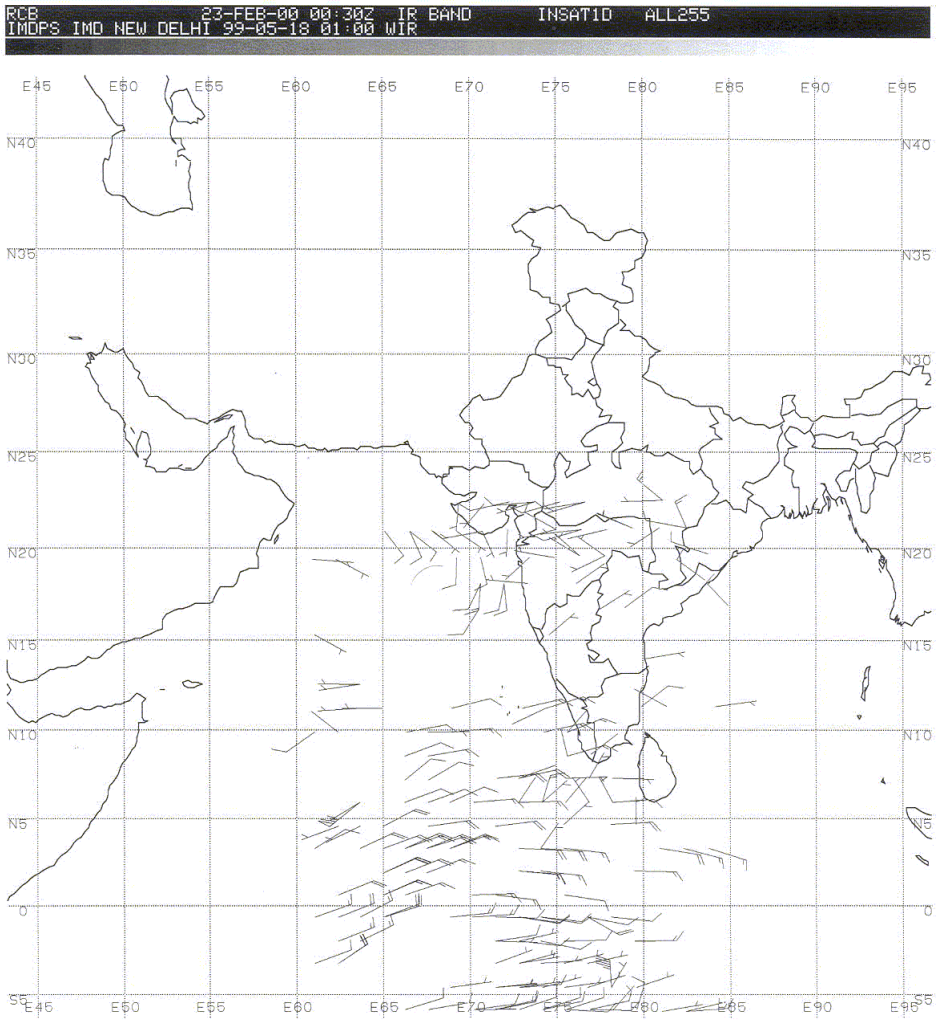

Figure 3. METEOSAT - 5 derived winds disseminated as SATOBs for the period 18 – 19 May, 99.

5. Impact studies on model forecast of a Limited Area Model

A Limited Area Model (LAM) adopted from Florida State University (Krishnamurti et al., 1990) is being run operationally at IMD since 1995. To start with, the model was run on NCMRWF's CRAY XMP – 14 Computer in experimental mode. It was made operational in August, 1995 on IMD's Cyber – 2000 computer. The model has at present a horizontal resolution of 1 deg x 1 deg lat./long. and 12 sigma levels in the vertical covering a geographical domain of 30 deg - 125 deg E and 25 deg S to 45 deg N. It is run operationally twice a day based on 00 and 12 UTC maps using real time GTS data. The data inputs include INSAT derived CMVs, but not the METEOSAT - 5 derived CMVs disseminated normally on GTS. Apart from generating the forecast of normal meteorological parameters with LAM for operational use, the track prediction model is also specially run at the time of formations of cyclonic storms and track forecasts are generated for use.

Experience of track predictions with the performance of LAM shows that the initial wind analysis over the oceanic areas is often inadequate as a result of which vortex is generally not brought out in the analysis. At times bogussing of data is resorted to and a synthetic vortex is implanted over the region of

cyclonic storm. This obviously results in poor performance of the model in capturing significant synoptic disturbances developing over the sea areas. METEOSAT - 5 derived winds which provide good coverage over the cyclone field could alleviate this problem to a some extent due to improved general analysis of the environment flow. In order to examine the impact of these data on track forecasts, above two cases of cyclones one over Bay of Bengal and one over Arabian Sea, were examined.

5.1 May, 1999 Cyclone

A control run (without METEOSAT–5 winds) and an experimental run (Including METEOSAT–5 winds) was executed on the initial conditions of 17 May, 1999. The Control run failed to take the track to the actually observed position and deviation was about 150 kms. However, the experimental run showed better results and the observed deviation from the actual track was found to reduce to 120 kms. The track predictions were also extended up to 48 hrs and it is noticed that even in the 48 hrs forecast, results of experimental run are slightly close to the actually observed track. The track is better predicted in the experimental run using METEOSAT– 5 derived winds.

5.2 29 October, 1999 Cyclone

Similar tests were also run on the initial conditions of 25 October, 1999 to find out impact on the 24 hrs and 48 hrs track forecasts for the devastating cyclone which struck Orissa on 29 October, 1999 using Global Spectral Model run at NCMRWF. Fig. 4 and Fig. 5 depict the results. It is noticed that use of METEOSAT-5 winds improves the track forecasts and also reduce the error. Mean error in analysis of four positions reduced from 5.5^0 to 3.7^0 and the mean error in forecast of two positions was reduced from 6.8^0 to 3.5^0 by using METEOSAT–5 winds. However, the problem of large error in the initial position still persists (though there was slight improvement) and further studies are needed to resolve it.

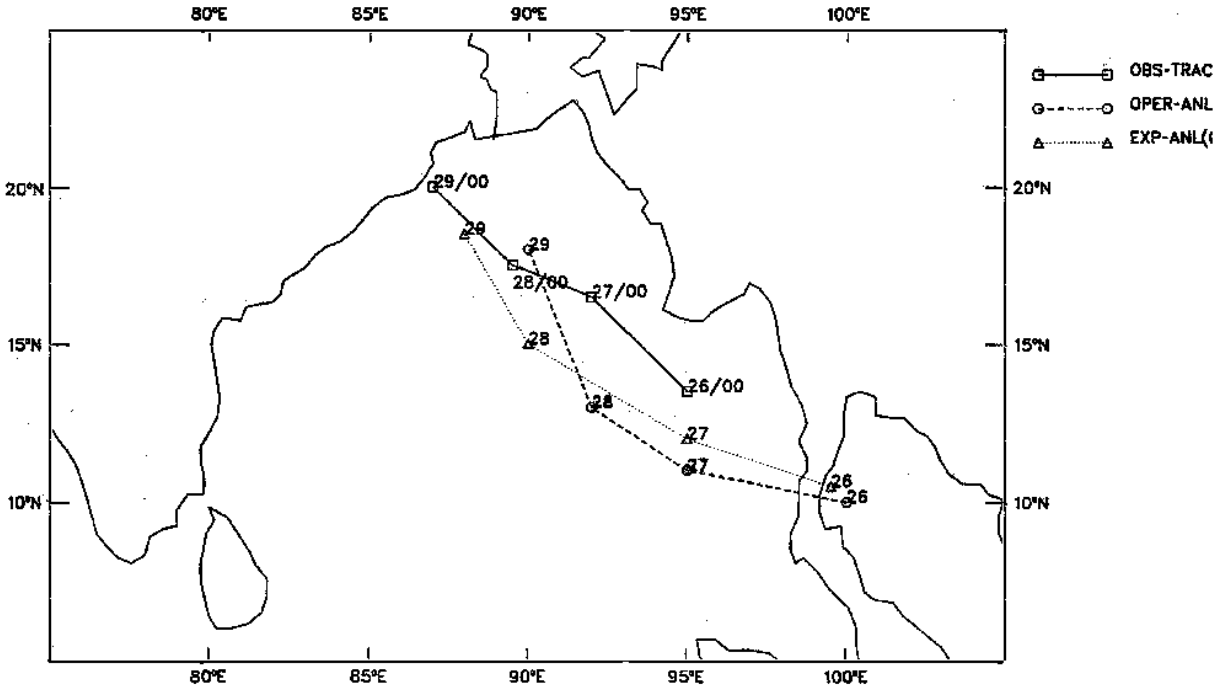

Figure 4. Analysis of the location of the storm Orissa.

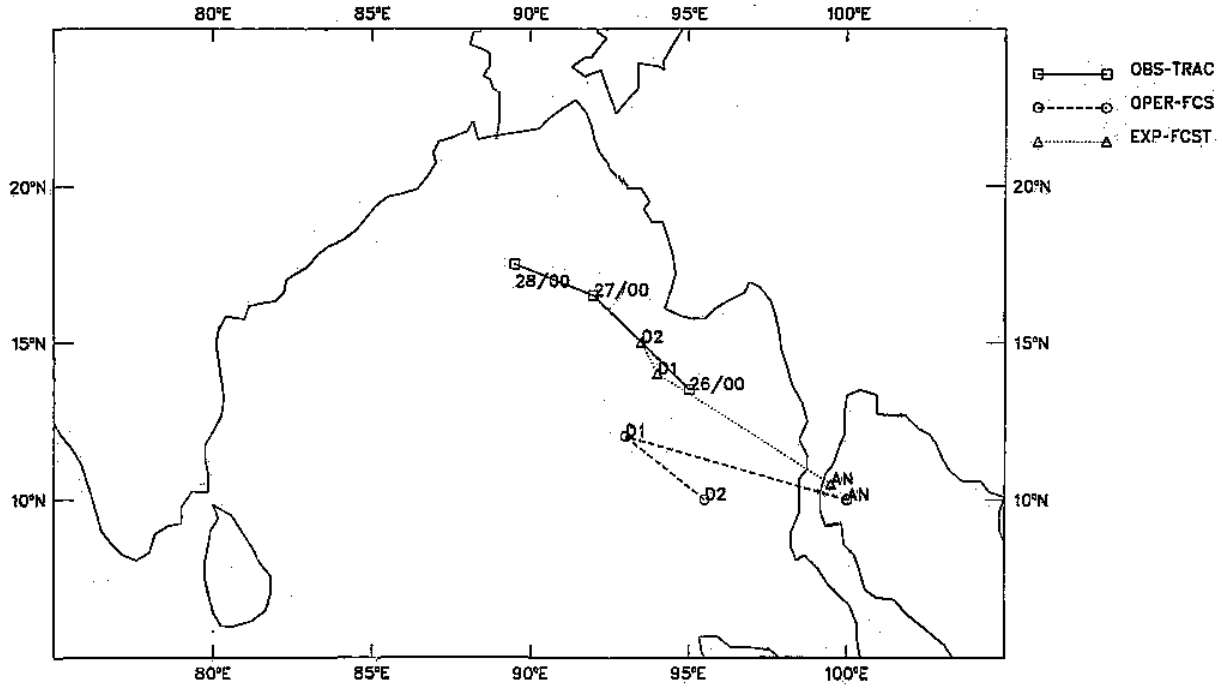

Figure 5. Forecast of the location of the storm Orissa.

The above two studies thus clearly bring out the slight positive impact of using METEOSAT-5 derived winds on the cyclone track forecasts based on Limited area and Global Models. These results are also consistent with findings of Velden et al. (1997).

6. Conclusions

METEOSAT-5 derived winds provide very good supplement to other conventional data sources over India and neighbouring oceanic regions and are useful for operational work of cyclone warning by providing better insight into the processes responsible for intensification of Tropical Cyclones and their movement. The middle level water vapour winds derived from METEOSAT – 5 are particularly useful to provide information on the effects of wind shear which are sometimes not observed in conventional satellite imagery. This information is very useful for forecasting intensity of Tropical cyclone which is vital for cyclone warning services. High level winds are found to be useful for depicting certain features above the center of the storm which are conducive to its further intensification.

Even for forecasting the movement of tropical cyclones METEOSAT-5 derived winds provide very useful guidance as they help to better define the direction of steering flow of the environment in which the storm is embedded. Use of this data in the track prediction done with the help of Limited Area and Global Models shows a slight positive impact on the track forecast. Impact is noticed in the form of better match between the actual and predicted track of the cyclone. Hence there appears to be a good potential in the use of METEOSAT-5 derived winds in improving the qualitative intensity forecasts of tropical cyclones and the track predictions by numerical models. They are also useful for track forecasts in a qualitative manner.

ACKNOWLEDGEMENT

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