IMPACT OF HIGH DENSITY ATMOSPHERIC MOTION VECTORS IN NCMRWF GLOBAL DATA ASSIMILATION-FORECAST SYSTEM

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ABSTRACT

The data scarcity over the Indian Ocean and adjoining African region is one of the major problems in defining the large-scale monsoon features. The coverage and quality of satellite derived winds over the Indian Ocean region has considerably improved with the operation of METEOSAT–5 from 63°E. Cloud motion winds (CMW) products of METEOSAT-5 for June 1999, has been assimilated in NCMRWF's Global Data Assimilation System at T80/L18 as well as T170/L28 resolution, along with other conventional data. The impact of CMW on the large scale circulation features associated with monsoon, such as cross equatorial flow, lower level jet etc. have been studied at T80/L18 resolution. The synoptic scale monsoon systems have been examined in T170/L28 resolutions. The global satellite winds from CIMSS have been assimilated and its impact has also been studied for June 2001. In general the medium range prediction of monsoon rainfall along the west coast of India during June 1999 and June 2001 has improved after inclusion of the satellite winds.

1. Introduction

One of the most fascinating large-scale atmospheric phenomenons, which occurs every year over the Indian subcontinent and accounts for about 80% of annual rainfall over India, is the southwest Monsoon of India. Southwest monsoon airflow is the extension of the cross-equatorial airflow over the Indian Ocean region. Fluctuations in the strength of the cross-equatorial flow are related to the intraseasonal fluctuations of the position and strength of the Mascarene High and have significant influence on monsoon activity over the Indian region. The data scarcity over the Indian Ocean and adjoining African region poses a major problem in defining these large-scale features. To overcome this problem, continuous efforts have been made at NCMRWF to utilize various satellite derived atmospheric motion vectors. However, these non-conventional data have their own limitations and their quality and impact needs to be studied carefully before these can be used on operational basis.

Atmospheric data assimilation is the process of determining a consistent four-dimensional atmospheric state using meteorological observations, background fields, physical constrains like mass-motion relationship and various types of statistical information about the observations. It is well known that the quality of any objective analysis of the atmospheric fields depends upon the density and the quality of the observations assimilated to produce the analysis.

The simulation of large scale monsoon flow and associated rainfall prediction by NCMRWF analysis-forecast system were compared to that of other major operational numerical weather prediction (NWP) centers (Basu et. al ,1999). The study revealed that although most of the large-scale monsoon features are captured well, yet the predicted rainfall is under estimated compared to observations and predictions by other NWP centers. Good quality initial analysis over data sparse Indian Ocean region may have an important role in rainfall prediction. The present study is motivated by the need to fill the data gaps in the areas surrounding Indian Sub-continent with satellite-derived winds for better analysis and prediction. European Space Agency (ESA) had specially shifted METEOSAT-5 at 63°E to monitor the weather phenomenon over Indian Ocean and adjoining region during INDOEX (Indian Ocean Experiment) period. Due to availability of water vapour channel on this satellite, water vapour winds at middle to upper tropospheric levels are available in large numbers. Since July 1998, large amount of valuable satellite derived atmospheric motion vectors have been generated over this region. The impact of the high density METEOSAT-5 CMW is assessed comparing the NCMRWF analyses and medium-range forecasts with and without the data over a period of one month during June 1999 at T80/L18. The same experiments have been repeated in T170/L28 resolution. The global atmospheric motion vectors from various satellites viz. GOES, METEOSAT, GMS are also being derived by Cooperative Institute for Meteorological Satellite Studies (CIMSS) and distributed to various other NWP centers for utilization. The impact of these data sets has also been studied for June 2001.

2. Global Data Analysis-Forecast System(GDAFS) Operational at NCMRWF

The Global Data Assimilation system (GDAS) operational at NCMRWF is a six-hourly intermittent three-dimensional scheme. It mainly consists of three components, namely (i) Data reception and quality Control (ii) Data Analysis and (iii) the NWP model. The meteorological data from various observing platforms from all over the globe is received at Region Telecommunication Hub (RTH), New Delhi through Global Telecommunication System (GTS) and the same is made available to NCMRWF. At NCMRWF, meteorological observations from all over the globe is assimilated four times a day viz. 0000, 0600, 1200 and 1800 UTC of everyday. Data used in the operational assimilation system of NCMRWF are SYNOP/SHIP, BUOY, TEMP, PILOT, AMDAR/AIREP, SATEM and SATOB from INSAT, METEOSAT at 0°, GMS and GOES (Das Gupta and Rizvi, 2001). The observations falling within ±3 hours of the respective hour of assimilation are being used in the corresponding hour assimilation. A six-hour prediction from NWP model (T80L18), with a previous initial condition, valid for the current analysis time is used as the background field, or the first guess for the subsequent analysis. The analysis scheme used in GDAS is based on the concept of Spectral Statistical Interpolation (SSI) technique developed at NCEP, USA (Parrish and Derber, 1992). The forecast model at NCMRWF is a T80/L18 spectral global model, the initial version of which is developed at NCEP (Kanamitsu, 1989). Recently the forecast model and analysis scheme of NCMRWF have been upgraded to increase its horizontal resolution to T170 with 28 vertical layers (Kar, 2002).

3. High Density Atmospheric Motion Vectors

The satellite wind products at comparatively lower resolution from INSAT, GMS, GOES and METEOSAT, available in SATOB code are being regularly used in operational GDAS at NCMRWF. The recent development resulted in developing automated techniques to produce satellite derived wind vectors at very high density. High density atmospheric motion vectors from METEOSAT-5 are being routinely generated at 90 minutes interval and distributed worldwide by EUMETSAT. These products have improved spatial resolution compared to the usual SATOB wind. All available channels (viz. IR, WV, VIS) are used in computation, but a global selection is finally performed based on Automatic Quality control (AQC) to constitute a single improved dataset (Holmund et al. 2001). AQC procedure attaches a Quality Indicator (QI) to each wind vector and the present study uses all the winds accepted by AQC. The composite wind flows at three different levels from METEOSAT-5 CMW product for 00UTC of June 1999 are depicted in Fig 1. As seen from the plot the equatorial region is well covered by wind observations at lower and upper level respectively, where as there are fewer observations in the middle level over equatorial region. The Arabian sea branch of the cross equatorial flow has been brought out well by the available wind observations in the lower level (Fig.1(a)), but the Bay of Bengal branch is not so well depicted. The eastern end of the Monsoon trough is also brought out well in the composite lower level wind flow. Similarly the composite wind flow of upper level (Fig.1(c)) also could capture all the main circulation features, such as subtropical anticyclone, Tibetan high and tropical easterly jet.

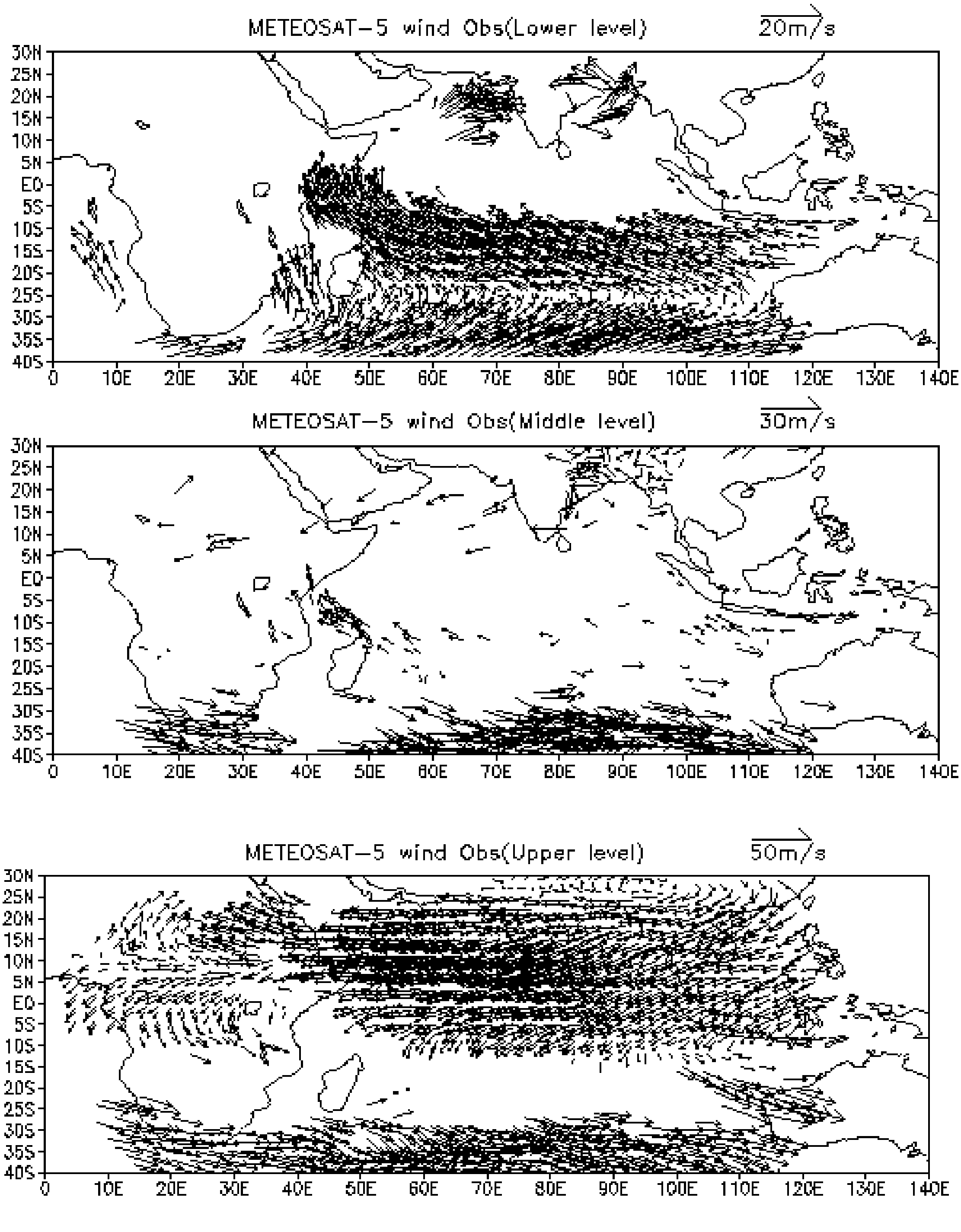

Fig. 1: Composite Wind Observations METEOSAT – 5 00UTC JUNE 1999
(a) Lower Level (1000 – 700 hPa), (b) Middle Level (600 – 400 hPa), (c) Upper Level (300 – 100 hPa)

CIMSS is also deriving the high density satellite winds (Velden, 1996) from GOES-E & W, METEOSAT-7 & 5 and GMS in a quasi operational mode and these are made available to user community in near real time basis through their ftp server. These winds are also being subjected to automatic quality control at the source and the resultant quality indicators are attached with the wind vectors. The complete AMW data sets from CIMSS are being regularly downloaded in a quasi-operational mode at NCMRWF.

4. Design of Experiments

The objective of the study is to assess the impact of the high density winds on the GDAFS system of NCMRWF with special emphasis on the prediction of summer monsoon systems and associated rainfall. Few experiments have been carried out by repeating the assimilation cycles after including the high density satellite derived winds. In the first experiment (CMW1), CMW products of METEOSAT-5 of EUMETSAT have been assimilated for a period of one month June 1999 at T80/L18 resolution. The experiment (CMW2) has been also carried out in T170/L28 version of the analysis-forecast system with CMW products from METEOSAT-5 for the same period. In another experiment (AMW), the CIMSS derived winds have been assimilated for the period of 5-30 June 2001. The respective forecast runs are also carried out upto 120 hours based on 00UTC initial condition of each day. The analyses and forecasts thus generated have been compared with the corresponding operational archives (CTL) for T80/L18 resolution and control run (CTL2) for T170/L28 .

5. Result and Discussion

The monthly mean for June 1999 of 00UTC analysed and forecast fields have been computed for the above mentioned experiments. It is well known that the lower level flow pattern defines the strength of monsoon and associated rainfall distribution. It is observed that the inclusion of CMW has strengthened the Arabian sea branch of the cross equatorial flow (CEF) in the analysis. The strengthening is noticed through out the depth upto 500 hPa level. This has helped in better representation of the southwesterly flow in the Arabian sea reaching the west coast of India. It also helped in restricting the unrealistic equator-ward penetration of the mid-latitude westerly regime noticed at middle troposphere over the Arabian sea region. How ever not much change in the monthly mean analysis is noticed in the Bay of Bengal branch of CEF.

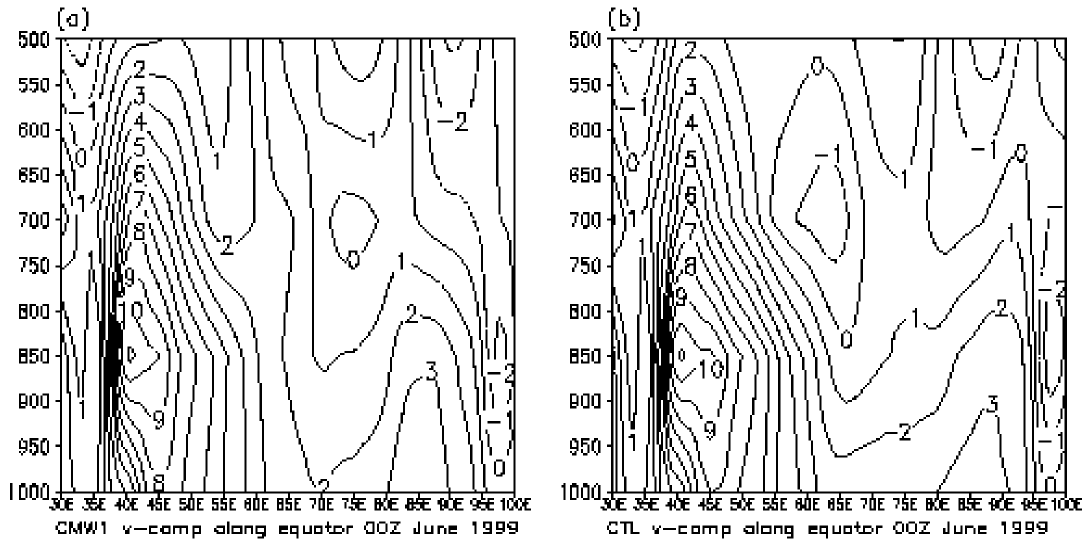

Fig.2: Monthly Mean Analysed Meridional(v) Component of Wind at Equator 00 UTC JUNE 1999 (a) CMW1 (b) CTL

Fig 2. depicts the height-longitude cross section of monthly mean analysed meridional wind at equator. It is clearly seen from the figure that the depth of the cross equatorial flow is enhanced particularly between 55ºE –75ºE(Arabian Sea). Around 700 hPa level the northerly winds in CTL is replaced by realistic southerly flow in CMW1. The north-south cross section of monthly mean analysed zonal component of wind along 60ºE, a longitude that falls within the regime of lower level jet (LLJ) is depicted in Fig. 3.

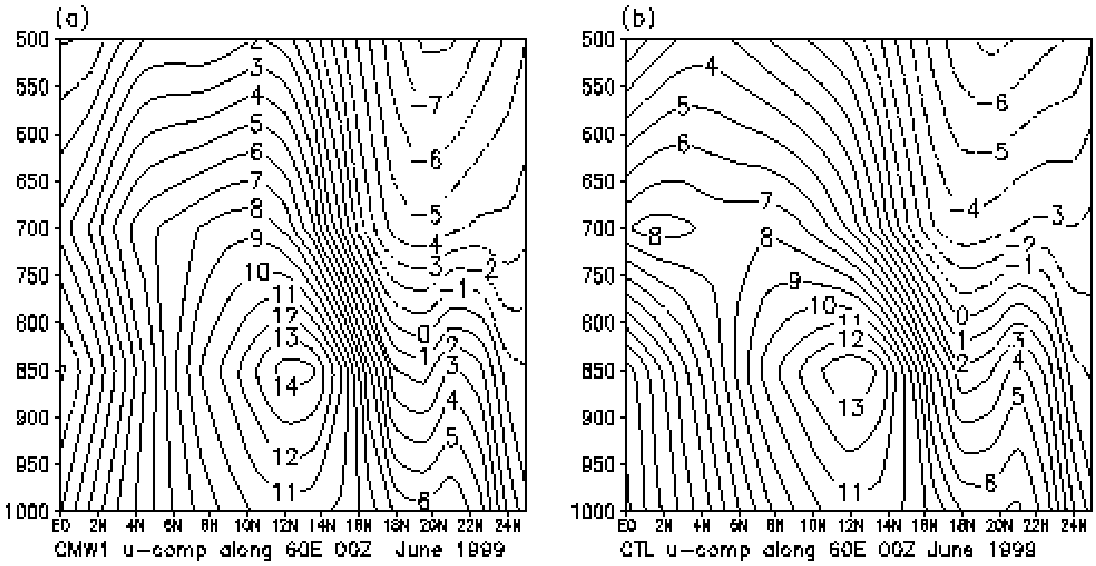

Fig.3: Monthly Mean Analysed Zonal(u) Component of Wind at 60^{0}E
00 UTC JUNE 1999 (a) CMW1 (b) CTL

The strengthening of the LLJ has been noticed in CMW1, though there is no change in the latitudinal position of the jet core (12ºN). It is noticed in Fig3., that near equatorial region around 700hPa level, the westerlies are stronger in CTL compared to CMW1, which is due to the equator-ward penetration of mid-latitude westerlies in the middle atmosphere, as discussed earlier. The strength of LLJ is also examined at75ºE, where the low-level westerlies interact with the west coast orography of Indian landmass leading to heavy rainfall over that region. The enhancement in the strength of the lower level jet in CMW1 is also maintained at 75ºE. This is consistent with the enhancement seen in cross equatorial flow. The inclusion of CMW has not brought out much change in the monthly mean intensity and position of Mascarene High but however the variation exits in day-to-day analysis of both the experiments. In the forecasted wind fields the cross equatorial flow and LLJ is found to be stronger in CMW1 compared to CTL. The systematic error of the model to intensify the CEF and weaken LLJ during the length of the forecast, remains unchanged. In general the strength of the cross equatorial flow has been increased with forecast time. Finally the medium range rainfall prediction of CMW1 and CTL have been compared with the monthly total observed rainfall (IMD, 1999).

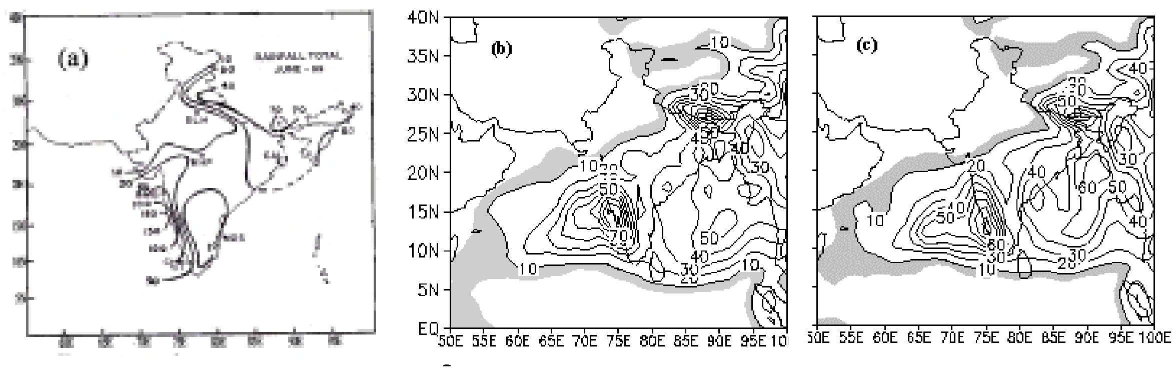

Fig. 4 : Total Rainfall Observation and 96hr. rainfall prediction for June 1999
(a) Observed rainfall (b) CMW1 (c) CTL

Fig. 4 shows the accumulated 96hr. prediction along with observed rainfall. It is seen that the observed rainfall maxima is centered along the west coast of India at 15ºN. As expected both for CMW1 and CTL, the rainfall amounts are less, compared to observations. However in CMW1 the position of the rainfall maxima along the west coast is centered around in 14.5ºN, which is much closer to he observed maxima compared to that of CTL(12ºN). Another area where an improvement in rainfall prediction is noticed, lies near the north-west Bay of Bengal and the adjoining land mass.

Over this region, the observed total rainfall is about 10-20 cm and CMW1 shows less rainfall (~30cm) compared to CTL(~40cm).

The large-scale monsoon features as obtained in T80/L18 based analysis-forecast system are essentially reproduced in T170/L28 system also, so these are not discussed here again. However the synoptic scale monsoon systems have been examined by the high resolution experiment (CMW2). A deep depression formed over north-west Bay of Bengal on 15th June 1999 and move northwestward direction upto central Indian region during 16-21 June.

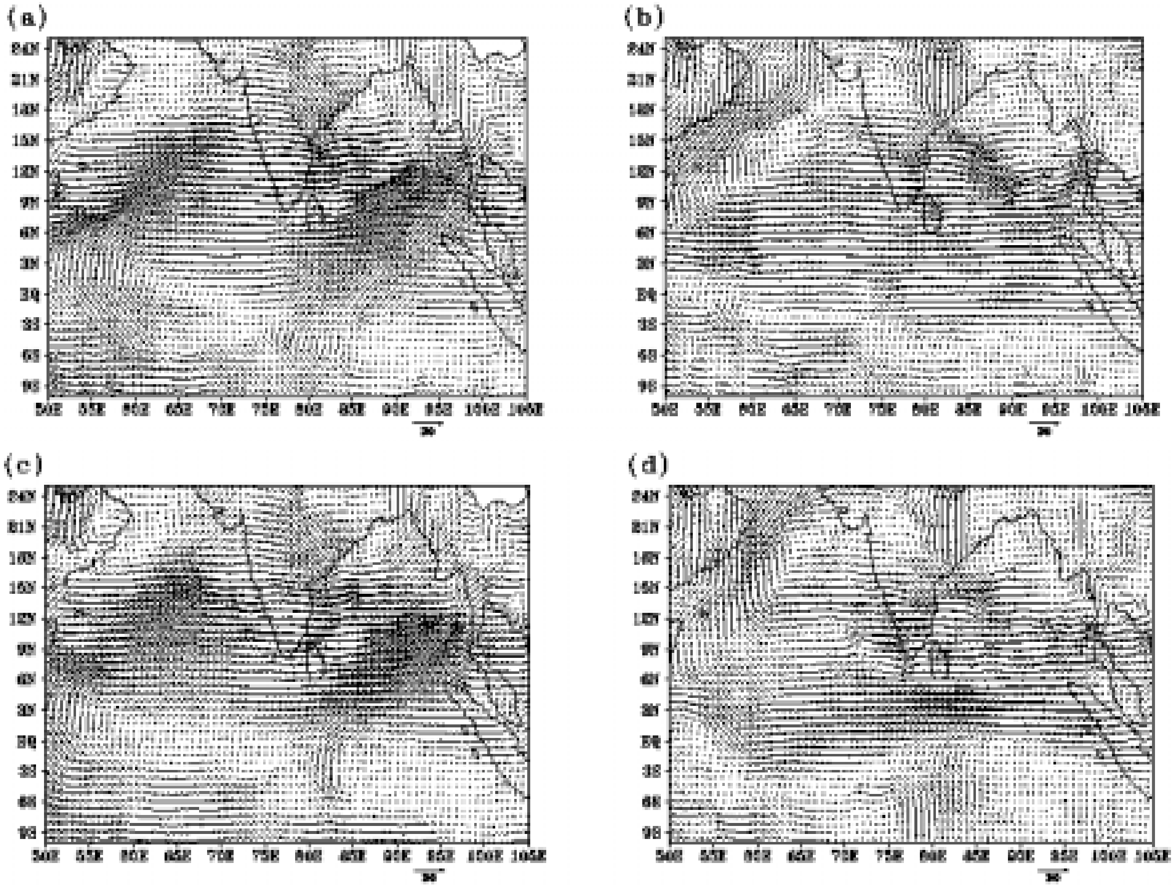

Fig 5.: Analysed Winds for CMW2 and CTL2 at 850 & 700 hPa on 00UTC 15 JUNE 1999 by NCMRWF T170/L28 Global Data Assimilation System
(a) 850 hPa CMW2, (b) 700 hPa CMW2, (c) 850 hPa CTL2 and (d)700 hPa CTL2

Fig. 5 shows both the analyses at 850 and 700 hPa levels on 00UTC of 15th June 1999. On 15th , CMW2 analysis could capture the cyclonic circulation over northwest Bay of Bengal extending upto 500 hPa level, whereas only a trough over that region is seen in the corresponding control (CTL2) at 850 hPa. At the same time, there was a circulation over West central Arabian sea in CMW2 analysis at 850 hPa , which is also supported by the lower level METOSAT-5 CMW winds. In CTL2 analysis the same circulation was analysed to the north of CMW2 position. Similar differences have also been noticed in the other levels upto 500 hPa. As a result, strong Arabian Sea branch of CEF is seen up to 12ºN at 700hPa level in CMW2. On 16th , the depression further intensified to a deep depression and both CMW2 and CTL2 analyses show intensification. The system is better organised and stronger upto 500hPa level in CMW2. In the analysis of 00UTC 17th June, the system is still lying on the sea, near Orissa coast in CMW2 as observed, where as in CTL2 it is on the coast. After this, the system actually moved over the land and so the analyses of the system are almost similar in CMW2 and CTL2. However the track prediction of the system has been generally improved in CMW2 compared to CTL2.

The mean monthly flow analysed with CIMSS winds(AMV) for June 2001 also shows the similar features e.g. strengthening of cross-equatorial flow, lower level jet etc. as discussed above for June 1999. The improvement in the medium range rainfall prediction is also achieved by inclusion of AMVs. Height and wind bias of both in the first guesses and analyses, for AMV and CTL compared to observations over Indian region has been shown in Fig 6.

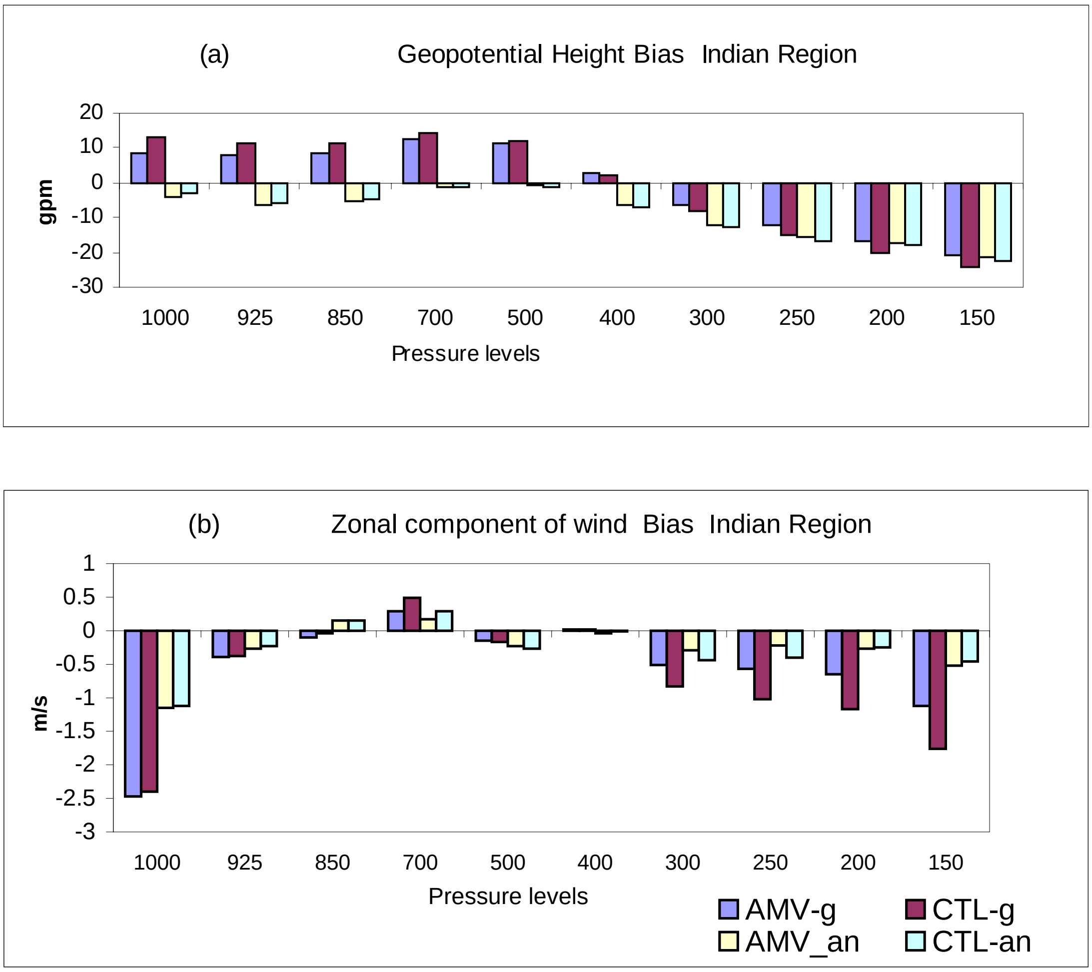

Fig.6 : Mean Monthly Bias of First Guess and Analysed Height and Wind Field 00UTC JUNE 1999

Reductions of bias in height as well as wind is noticed, specially in the higher levels. RMSE and anomaly correlation of forecasts (24hr -120hr.) with respect to respective analyses are also shown marginal improvement when computed over the global region. However improvement is more over southern hemisphere and over tropics.

6. Summary

Inclusion of high-resolution satellite winds from various geostationary satellites in the NCMRWF operational assimilation-forecast system produces a more realistic monsoon flow pattern. The cross equatorial flow and low-level westerly jet are better represented. The depth of monsoon circulation is also seen to be enhanced. The unrealistic equatorial-ward penetration of mid-latitude westerly in the middle troposphere is corrected by inclusion of satellite winds. This improved monsoon flow pattern results in better medium range rainfall prediction over Indian sub continent. In this study quality flag assigned by the respective data generators are used to define the data selection criteria. At present the data selection procedure based on the same global model short range forecast and the optimal thinning of high-density data is being tested at NCMRWF. In this study temperature and moisture information from NOAA satellites have been used in at very coarse resolution (~500Km) available for that period through GTS. It is also planned to conduct experiments using ATOVS product of NOAA 15&16 along with these high density AMWs may improve the analysis and forecast further.

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