Improvement and impact study of satellite derived CMVs over Indian region

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सार — अप्रैल 2003 से कल्पना −1 तथा इनसैट −3ए से हाल ही में अवरक्त आँकड़ों का उपयोग करके मेघ गति संदेश (सी. एम. वी.) प्राप्त किए जाने लगे हैं। वर्तमान तकनीक में मेघ गति संदेश के आँकड़ों की गुणवता की जाँच एल. ए. एम. मॉडल पूर्वानुमान आँकड़ों के साथ की गई है जिसका विस्तार क्षेत्र 40° पू. − 129° पू. तथा 29° द. − 45° उ. तक है। इसमें एल. ए. एम. मॉडल आँकड़ों की अनुपलब्धता के कारण 29 डिग्री दक्षिण के नीचे से प्राप्त मेघ गति संदेशों को छोड़ दिया गया है। अभी हाल ही में एल. ए. एम. मॉडल पूर्वानुमान के स्थान पर गलोबल पूर्वानुमान का उपयोग होने लगा है इसलिए अब मेघ गति संदेशों को अधिक विस्तृत क्षेत्र (40° पू. − 129° पू.) और (45° द.− 45° उ.) से प्राप्त किया जाता है जिसके फलस्वरूप अधिक संख्या में सही− सही मेघ गति संदेश प्राप्त होते रहे हैं। इन मेघ गति संदेशों को विश्व दूरसंचार प्रणाली (जी. टी. एस.) पर अंतिम प्रयोगकर्त्ताओं के लिए रखा जा रहा है। अभी हाल ही में कल्पना−1 और इनसैट−3ए से प्राप्त किए गए मेघगति संदेशों का संचयन इंटीग्रेटेड सेटलाइट विंड मॉनीटरन एन. डब्ल्यू. पी. एस. ए. एफ. साइट पर किया जा रहा है। मेघ गति संदेशों से प्राप्त आँकड़ों तथा भिन्न−भिन्न संख्यात्मक मौसम पूर्वानुमान मॉडल से प्राप्त आँकड़ों के संख्यात्मक त्रुटियों का विश्लेषण करने से पता चला है कि ये त्रुटियाँ उपग्रह से प्राप्त पवन गति एवं संख्यात्मक मौसम पूर्वानुमान मॉडल्स से प्राप्त आँकड़ों की त्रुटियों के कारण है। इस शोध−पत्र में हमने चक्रवात की स्थिति का अध्ययन करने हेतु एम. एम.−5 एन. डब्ल्यू. पी. मॉडल में इन आँकड़ों के प्रभाव का पता लगाया गया है। इस अध्ययन से यह पता चला है कि इस मॉडल के द्वारा पवन परिसंचरण, सतह दाब और वर्षा का पता लगाने में इन आँकड़ों का प्रभाव महत्वपूर्ण है। इस मॉडल में अतिरिक्त मेघ गति संदेश आँकड़ों के प्रभाव सकारात्मक और उपयोगी पाए गए हैं।

ABSTRACT. The derivation of Cloud Motion Vectors (CMVs) using infrared data has been started from Kalpana-1 in April 2003 and from INSAT-3A recently. In the present technique, the quality check of CMVs was carried out with LAM Model forecast data, which covers the area 40° E - 129° E and 29° S - 45° N). The CMVs derived below the 29° south were rejected due to non availability of LAM Model forecast data. Recently, the LAM Model forecast is replaced by global forecast and therefore CMVs are now derived over larger area (40° E - 129° E and 45° S - 45° N) resulting a significant increase in the number of good quality CMVs. These CMVs are put on GTS for end users. The Integrated Satellite Wind Monitoring NWP SAF site has recently started storing and monitoring of Kalpana-1 and INSAT-3A derived CMVs. The statistical error analysis has been carried out for the CMVs with different NWP models in order to identify and distinguish error contributions from satellite winds and NWP models. Further, in this paper, we have examined the impact of these data in the MM5 NWP model for a cyclone case study. This study demonstrates the impact of these data in the model to capture wind circulation, surface pressure and rainfall. The impact of additional CMVs data in the model is found positive and beneficial.

Key words − Cloud motion vector, Limited area model, Numerical weather prediction, National centre for environmental prediction and Satellite application facility.

1. Introduction

One of the key meteorological parameters for weather forecasting, meteorological studies and climate applications is wind. It has therefore been a major task for the science and operational community to exploit the imagery data from geostationary satellites in order to derive Atmospheric Motion Vectors (AMVs) by tracking observed cloud and moisture features. The globally derived AMV fields are an established and essential product, especially for Numerical Weather Prediction and are complemented by other satellite-based observations of the atmospheric flow. The biennial International Winds Workshops provide a forum used for cooperation in the operational and research community and have strongly contributed to the improvement in the quality of the derived wind fields.

Ever since the non-availability of data from INSAT-1D, India was looking forward for a suitable substitute to

give continuity to its space observations related to weather. India took a leap when it could place 950 kg weighing exclusive meteorological satellite in space by using its own launch vehicle namely Polar Satellite Launch Vehicle (PSLV) in the month of September 2002. This Satellite namely Kalpana-1 named after the Indian born US Astronaut Kalpana Chawala who lost her life during the return flight of Space Shuttle as a tribute to her. This satellite has a payload called Very High Resolution Radiometer (VHRR) with three channels, *viz*., Visible (0.55μ-0.75μ), Infrared (10.5μ-12.5μ) and Water Vapour (5.7μ- 7.1μ) with a ground resolution of 2 km, 8 km and 8 km respectively. After Kalpana-1 satellite became operational in the month of October 2002, IMD began deriving Cloud Motion Vectors (CMV) from the Infrared data, twice a day from the triplets at 2330, 0000 and 0030 UTC and 0700, 0730 and 0800 UTC. The history of CMV derivation in IMD from INSAT data started with Kelkar and Khanna (1986) using pattern matching by searching equality in pixel to pixel between tracer and target images.

Before the computation of Cloud Motion Vector, the classification of the tracked sub-set is performed. This is basically a validation step so as to ensure that the same cloud pattern was tracked. For each of the tracked cloud target, the four-bin histogram is generated as was done for the cloud tracer and the same classification criteria are applied. The cloud target is rejected if it is not of the type of cloud tracer. The centre of the reference / search window is the initial point of the vector and the location for which absolute maximum peak is obtained as the final position of the vector. From these positions, CMV is calculated. If correlation returns multiple locations with the same maximum value, the first one is accepted. Height assignment of the CMV's is being done using Infrared Window (IRW) technique at present. Mean temperature of the 25% coldest IR pixels (LeMarshal and Pascod, 1993; Merrill, 1989 and Nieman *et al*., 1997) is considered for assigning the height of the CMV. With the inception of IMDPS, cross correlation technique is being used for pattern matching. Several improvements have been carried out by various scientists (Bhatia *et al*., 1996; Khanna and Prasad, 1998; Khanna *et al*., 2000; Bhatia *et al*., 2002 and Singh *et al*., 2006) with better results and reduced rms errors and biases. The software of the system is being upgraded and the H$_2$O-IRW Intercept Method will also be tried shortly.

2.   Improvements of CMVs over southern hemisphere

In the present technique, the quality check of CMVs was carried out with LAM Model forecast data, which covers the area 40° E - 129° E and 29° S - 45° N). The
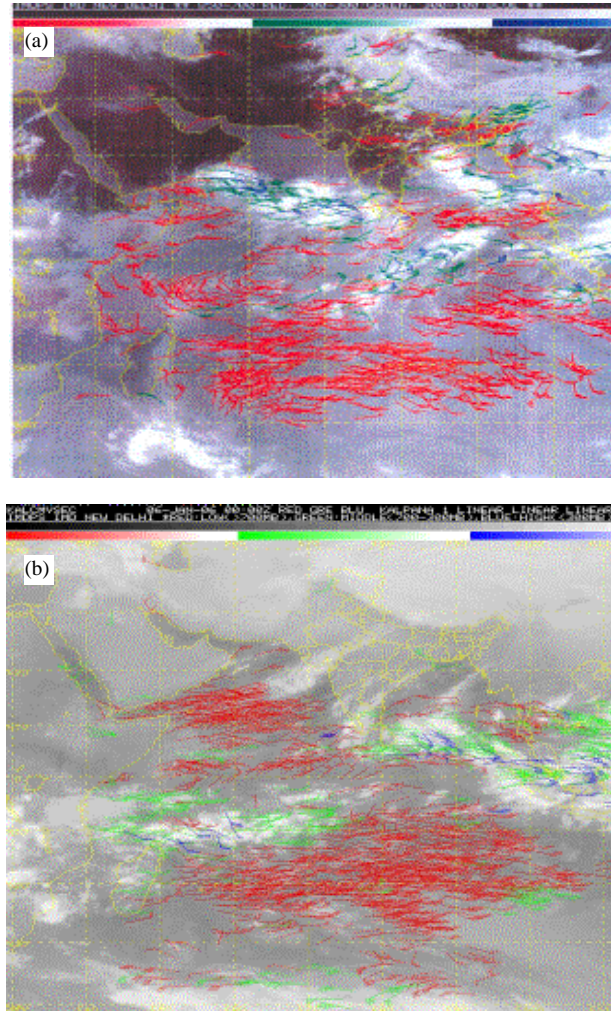

Figs. 1 (a&b).   (a) Cloud Motion Vectors (low, medium and high) by Kalpana -1 at 0000 UTC of 23 July 2003 and (b) Cloud motion vector's (low, medium and high) by Kalpana -1 at 1200 UTC of 24 July 2003

CMVs derived below the 29° south were rejected due to non availability of LAM Model forecast data. Recently, the LAM Model forecast is replaced by global forecast and therefore CMVs are now derived over larger area (40° E - 129° E and 45° S - 45° N) resulting a significant increase in the number of good quality CMVs. The Figs. 1(a&b) depicts the comparisons after extending the area up to 45° south. The derivation of winds over this extended area do not show zonal flow reported earlier. Actually it was not a zonal flow in the CMVs but because of the chopped area, it appeared like zonal flow. Due to increase in area, the increase in number of CMVs are confined only for lower and middle levels and not found at the higher levels as shown in Figs. 2(a-c) respectively and Fig. 2(d) represents for all the levels.
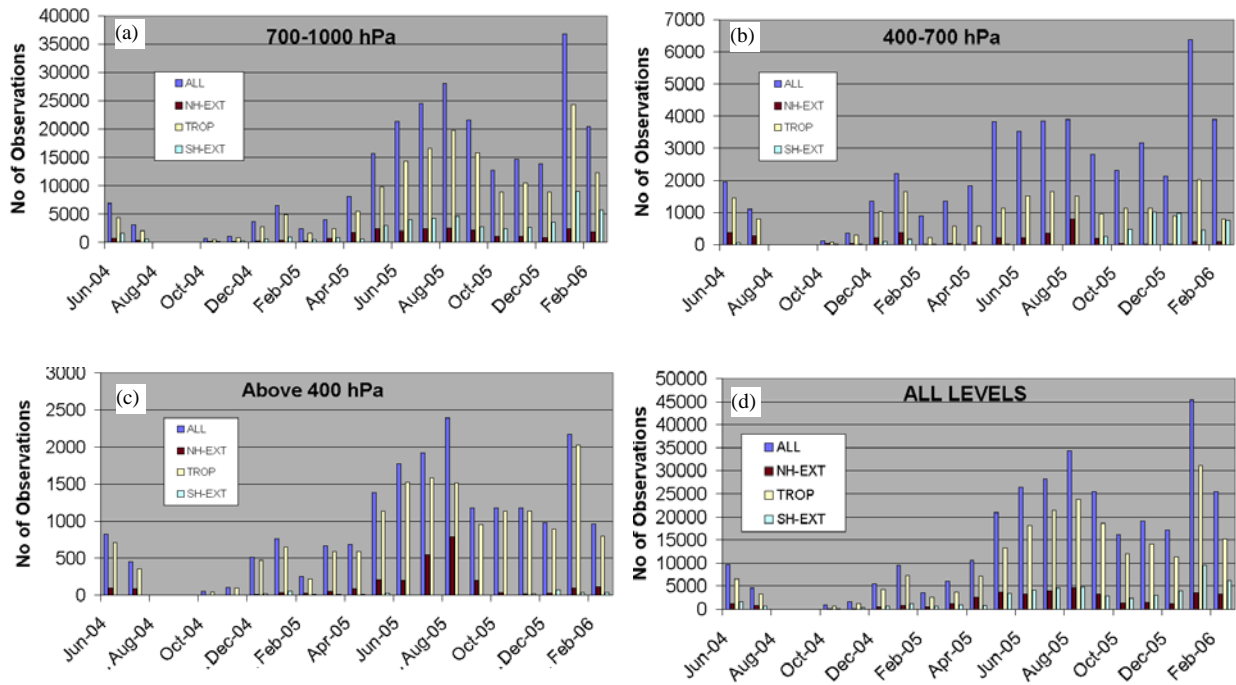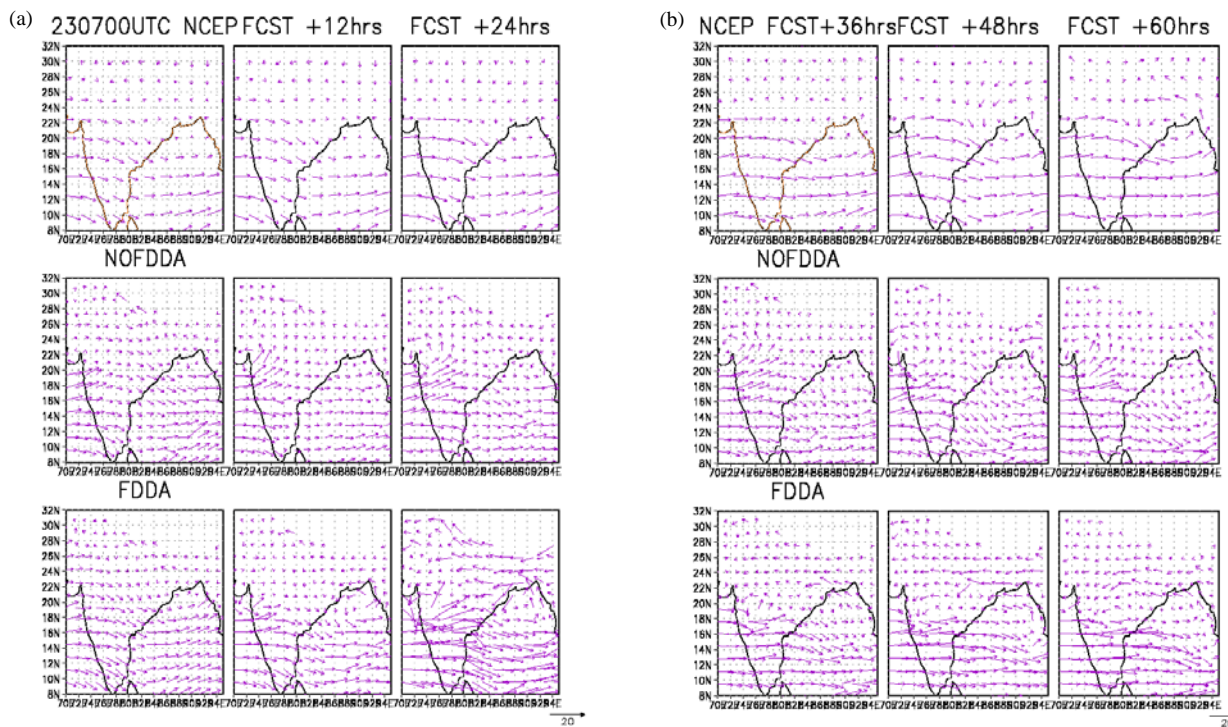
Figs. 2 (a-d). No. of observations of CMV at (a) 700-1000 hPa, (b) 400-700 hPa, (c) above 400 hPa and (d) at all the levels
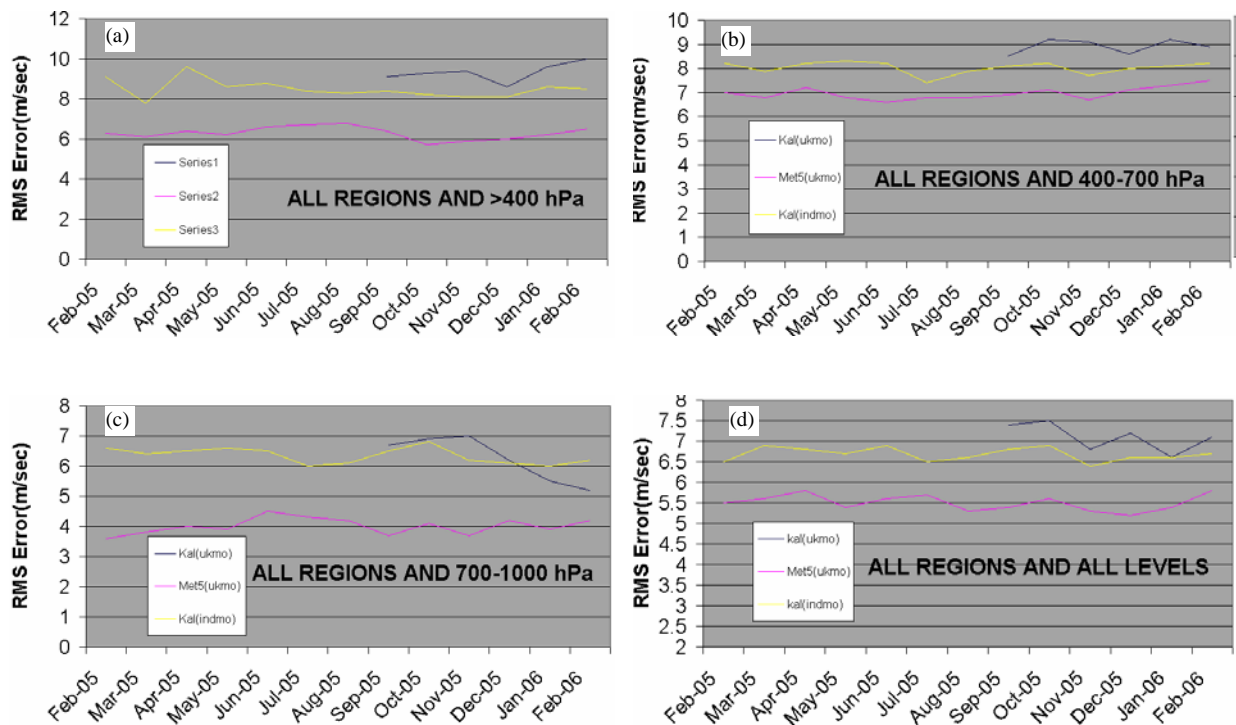

Figs. 3(a-d). RMS error (m/sec) at all regions and (a) > 400 hPa, (b) 400 -700 hPa, (c) 700-1000 hPa and (d) all levels
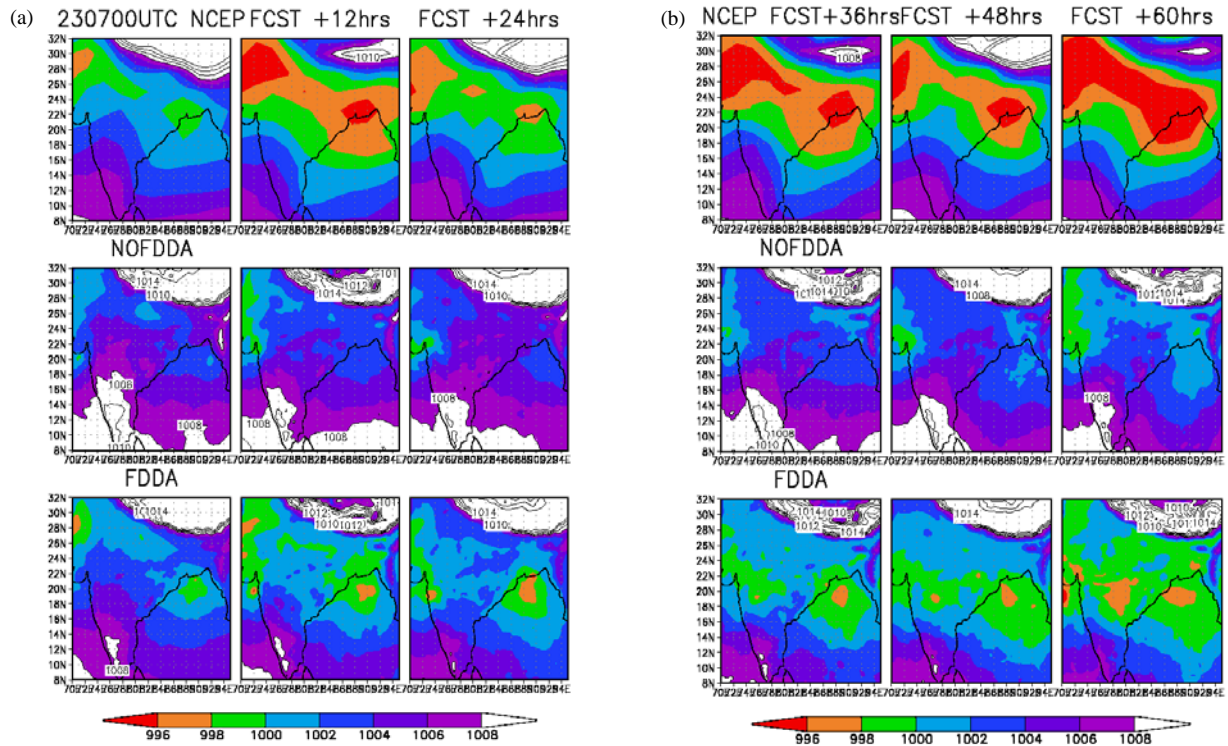
Figs. 4 (a&b).   Lower tropospheric winds with 24 hour accumulated rainfall on (a) 23 July 2003 and (b) 24 July 2003. (Top panel with NCEP reanalysis and middle and bottom from MM-5 data)

Figs. 5(a&b).   Sea level pressure (SLP) field of (a) 23 July 2003 at 0000 UTC and (b) 24 July 2003 at 1200 UTC. (Top panel with NCEP reanalysis and middle and bottom from MM-5 data)
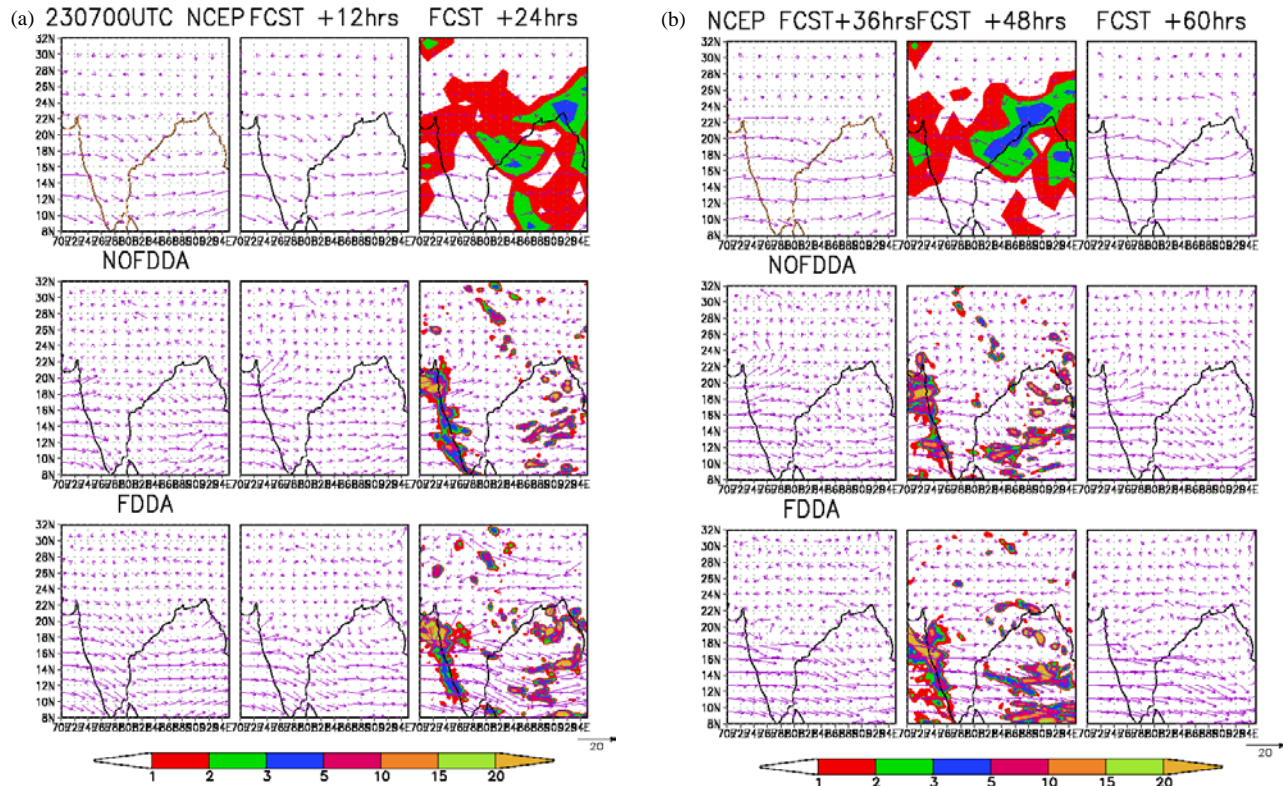
Figs. 6(a&b). Lower tropospheric winds with 24 hour accumulated rainfall. (Top panel with NCEP reanalysis and middle and bottom from MM-5 data)

3.   Intercomparison of CMVs with Meteosat-5

Monthly Statistics on rms errors and biases generated by Numerical weather prediction Satellite application facility (NWP SAF) was used for this purpose and a comparison of Kalpana-1 derived CMVs was made with METEOSAT-5 derived CMVs. The rmse of CMVs derived from Kalpana-1 against UK Model and IMD Model were generated for the comparisons. Figs. 3(a-d) depict monthly statistics for the period March, 2005 to February, 2006 for different pressure levels. It is seen that from these figures that rmse for all the three levels (low, medium and high) and at different regions are slightly larger by about 1.5 m/sec compared to Meteosat-5. Largest   differences have been observed over southern hemisphere extra tropics about the order of 2 m/sec. This could be due to very small number of CMVs over this area. Further, these differences are larger compared to UK Model analysis. This is because the IMD model assimilates Kalpana-1 satellite derived CMVs and these are not assimilated in UK Model.

4.   Impact of CMV's on MM5 Model

The present study utilized the MM5 version 3.6. The model was configured with twenty three vertical layers (centered at sigma = 0.995, 0.985, 0.97, 0.945, 0.91, 0.87, 0.825, 0.775, 0.725, 0.675, 0.625, 0.575, 0.525, 0.475, 0.425, 0.375, 0.325, 0.275, 0.225, 0.175, 0.125, 0.075, 0.025) and two nested domains (Outer Domain: 90 km grid spacing with 85×75 grid cells in east-west and north-south directions; Inner Domain: 30 km grid spacing with 130×118 grid cells in the east-west and north-south directions). Other model settings included:

MRF PBL scheme, the Grell cumulus scheme, a mixed phase Reisner scheme for explicit moisture, a cloud radiation scheme and a multi-level soil model. The NCEP reanalysis data available at a horizontal resolution of 2.5° Lat. × 2.5° Long. and a time resolution of 6 hours were used to develop the initial and lateral boundary conditions. A one-way nesting option was employed. Two numerical experiments were designed to study the effect of the ingestion and assimilation of the INSAT CMV winds, QuikSCAT surface wind vector over the oceans and IMD surface and upper air wind data on the prediction of a monsoon depression, which formed in the Bay of Bengal during July 2003. The first experiment (called no FDDA run) utilized the NCEP reanalysis for the initial and lateral boundary conditions and the MM5 model integrations were performed from 22 July 2003, 0000 UTC to 25 July 2003, 1200 UTC.

The second numerical experiment (called FDDA run) ingested and assimilated INSAT CMV winds, QuikSCAT surface wind vector over the oceans and IMD surface and upper air wind data for the time period between 22 July 2003, 0000 UTC to 23 July 2003, 0000 UTC to improve the NCEP reanalysis. The MM5 model was subsequently run in a free forecast mode from 23 July 2003, 0000 UTC to 25 July 2003, 1200 UTC. The results of the MM5 simulation corresponding to the two numerical experiments were then compared with NCEP reanalysis as well as with observations for the time period between 23 July 2003, 0000 UTC to 25 July 2003, 1200 UTC. All the MM5 results depicted are from the 30 km domain only.

Figs. 5(a&b) depict the sea level pressure (SLP) field at 0000 and 1200 UTC for 23-24 July 2003. The top panels show the SLP from the NCEP reanalysis while the middle and bottom panels show the SLP from the MM5 simulations without and with FDDA. It is clear from both the figures that middle panels (no FDDA run) is unable to simulate the large-scale structure of the SLP pattern with the SLP corresponding to the depression higher by as much as 4 hPa as compared to the lower panels (FDDA run). On the other hand, the lower panels (FDDA run) reproduce the large-scale structure of the SLP pattern and are closer to the NCEP reanalysis. Figs. (3&4) are similar to Figs. 5(a&b) and Figs. 6(a&b) except that the former depict lower tropospheric winds (sigma level = 0.995) as well as 24 hour accumulated rainfall. The no FDDA run shows well-defined cyclonic circulation over the Arabian Sea close to Gujarat coast while the cyclonic circulation over Bay of Bengal is not very clearly defined. The FDDA run, on the other hand simulates a relatively better cyclonic circulation over the Bay of Bengal. Both the MM5 runs simulate the maximum rainfall along the Western Ghats. This is due to the relatively higher horizontal resolution of the model. However, the effect of assimilation of winds (INSAT CMV, QuikSCAT, IMD surface and upper air winds) has not improved greatly the model simulation of the location as well as the amounts of the 24 hour accumulated precipitation.

5.   Conclusions

The derivation of winds over this extended area from 29° south to 45° south has result the increase in number of good quality winds. Further, these winds do not show zonal flow any more reported earlier. The CMVs derived from Kalpana-1 are comparable to that of Meteosat-5.

This study demonstrates the impact of these data in the model to capture wind circulation, surface pressure and rainfall. The impact of additional CMVs data in the model is found positive and beneficial.

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