Recent developments in the CMVs derived from KALPANA-1 AND INSAT-3A Satellites and their impacts on NWP Model.

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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 40E-129E and 29S-45N). The CMVs derived below the 29-degree 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 (40E-129E and 45S-45N) 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.

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 23:30 , 00:00 and 00:30 UTC and 07:00, 07:30 and 08:00 UTC. The history of CMV derivation in IMD from INSAT data started with Kelkar et.al(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 is 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 (John LeMarshal et al. 1993, Merrill R 1989, Nieman S. J 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 et.al 1998, Khanna et.al 2000,Bhatia et al., 2002,Singh et al., 2006) with better results and reduced rms errors and biases.The software of the system is being upgraded and the H_2O- 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 40E-129E and 29S-45N). The CMVs derived below the 29-degree 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 (40E-129E and 45S-45N) resulting a significant increase in the number of good quality CMVs. The figure-1 (a and b) depicts the comparisons after extending the area up to 45 degree 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 figure 2(a and b) and figure 2(c) respectively.

3. Intercomparision of CMVs with Meteosat-5

Monthly Statistics on rms errors and biases generated by 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. Fig. 3(a,b,c and d) depict monthly statistics for the period march 2005 to Feb, 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 2m/sec. This could be due to very small number of CMVs over this area. Further, theses 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.

3. 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 x 75 grid cells in east-west and north-south directions; Inner Domain: 30 km grid spacing with 130 x 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 o lat x 2.5 o lon 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 00 UTC to 25 July 2003 12 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 00 UTC to 23 July 2003 00 UTC to improve the NCEP reanalysis. The MM5 model was subsequently run in a free forecast mode from 23 July 2003 00 UTC to 25 July 2003 12 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 00 UTC to 25 July 2003 12 UTC. All the MM5 results depicted are from the 30km domain only.

Figure 5(a and b) depict the sea level pressure (SLP) field at 00 and 12 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. Figure 2 is similar to Figure 1 except for 12 and 00 UTC for 24-25 July 2003. 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 is closer to the NCEP reanalysis. Figure 3 and 4 are similar to Figures 5(a and b) and 6(a and 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.

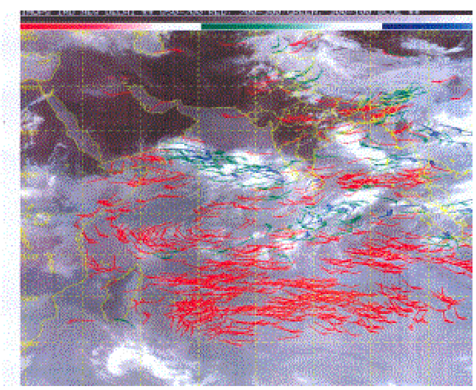
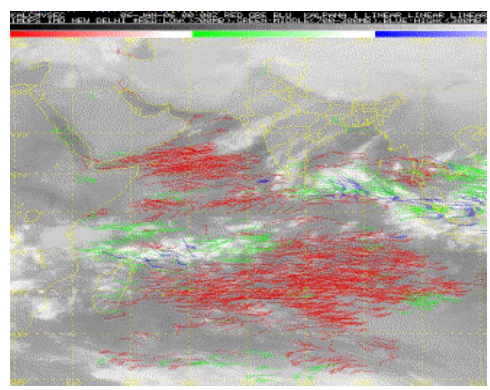


Figure-1(a)



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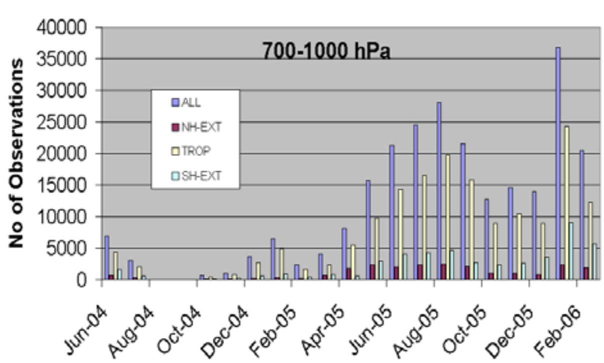

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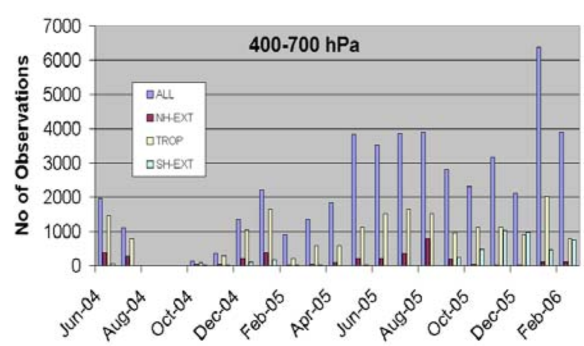

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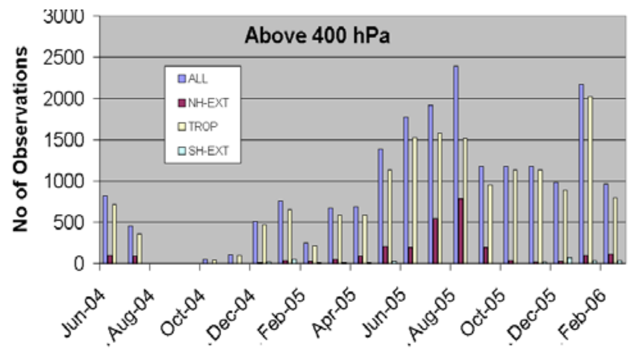

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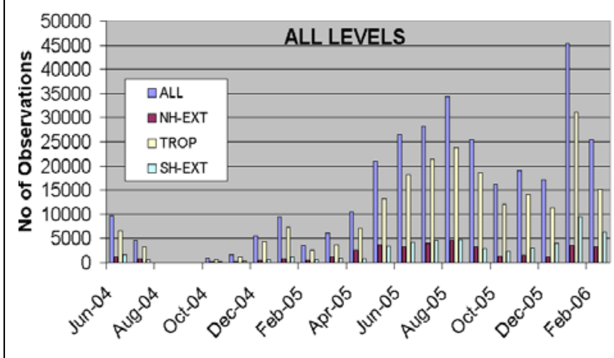

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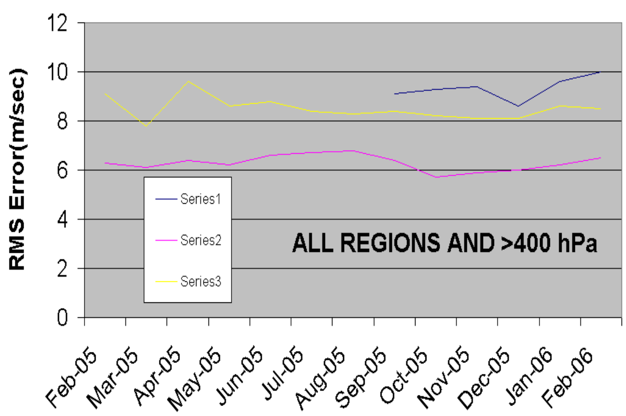

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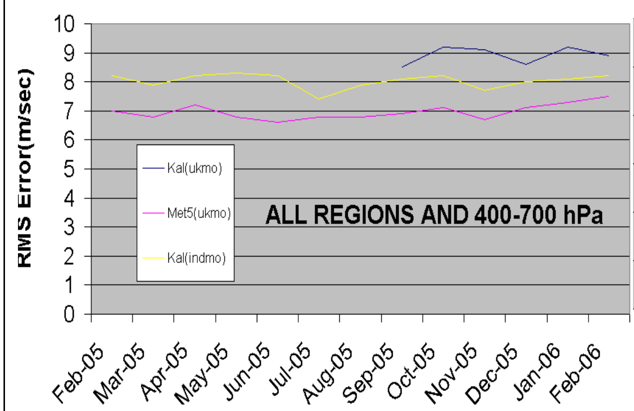

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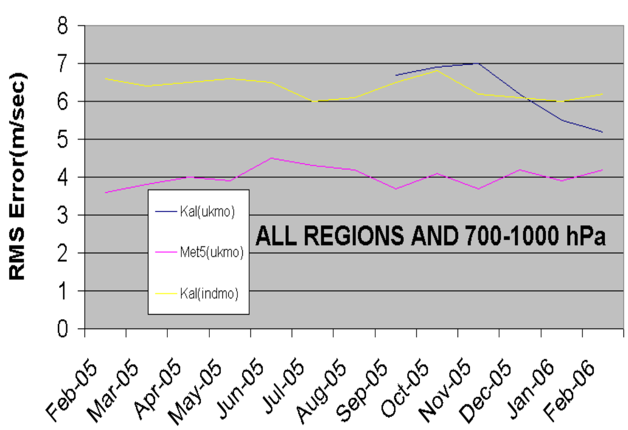

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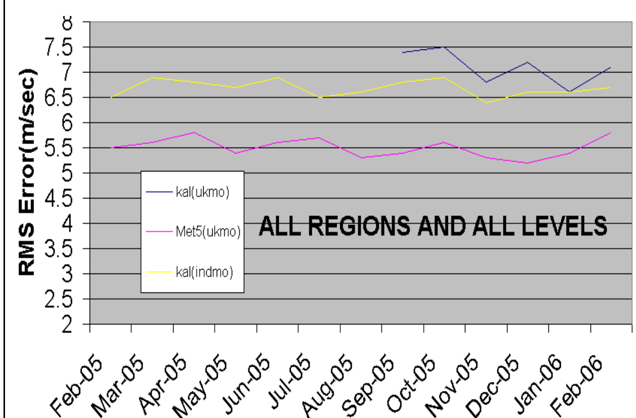

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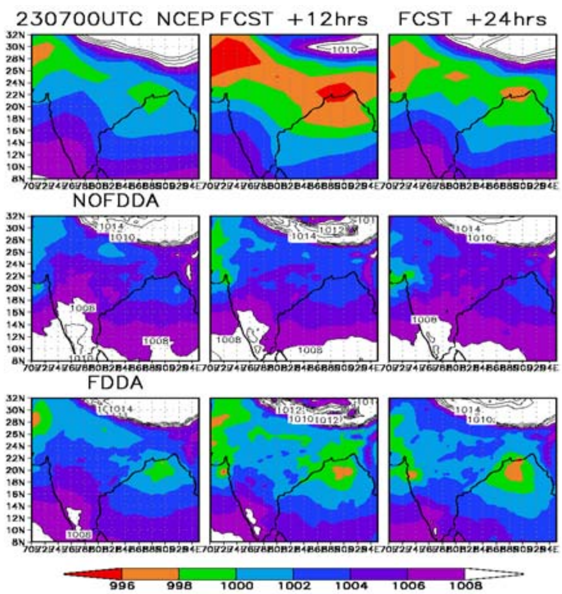

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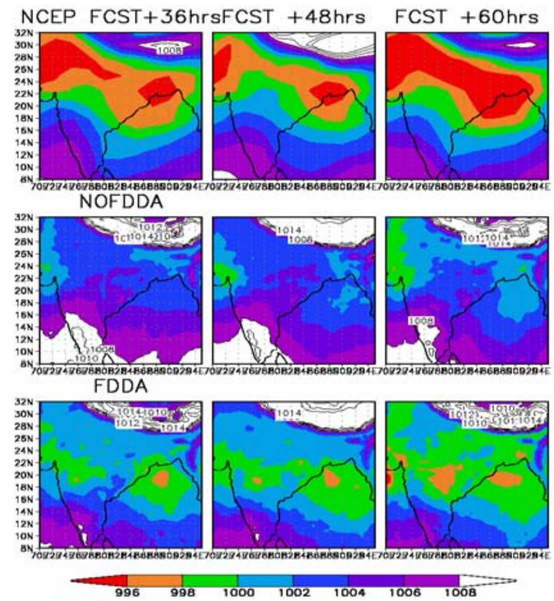

Figure-4(b)

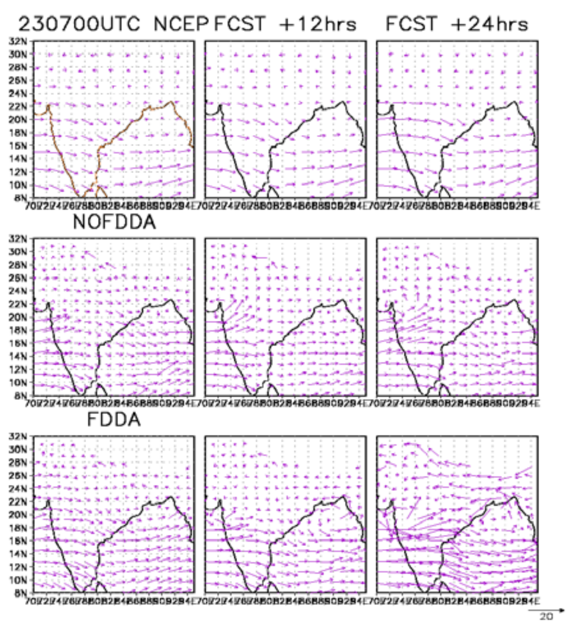

Figure-5(a)

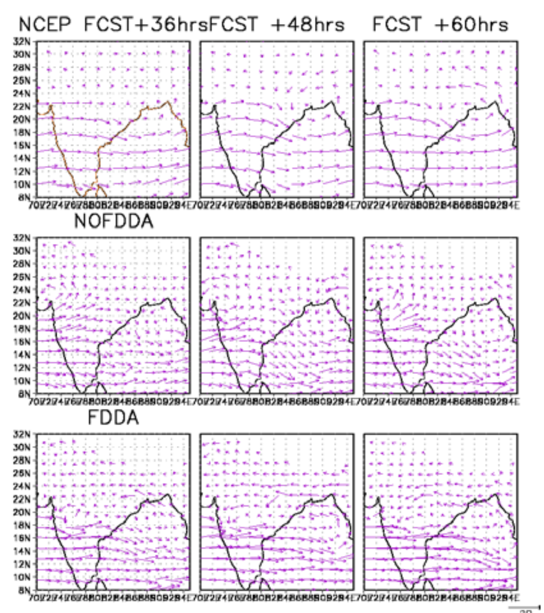

Figure-5(b)

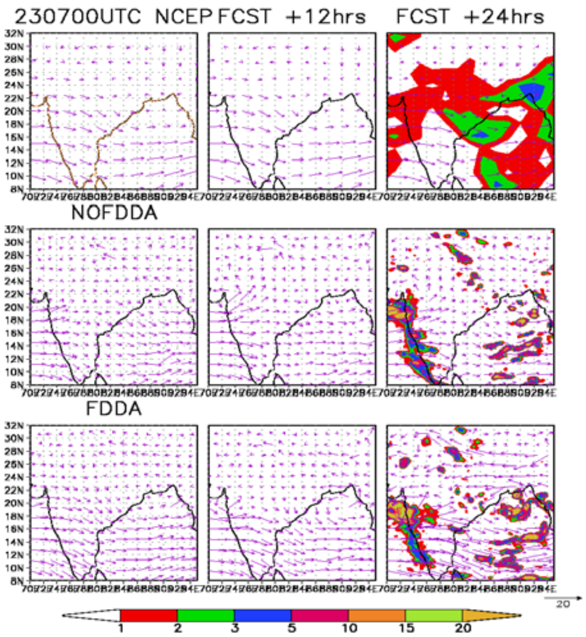

Figure-6(a)

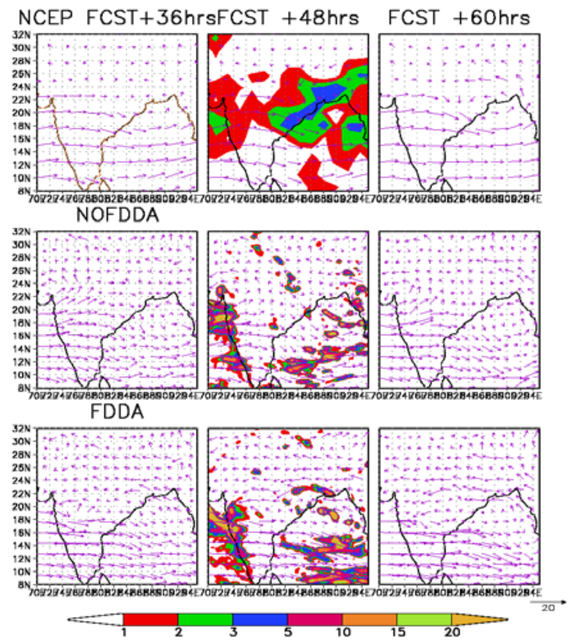

Figure-6(b)

Conclusions

The derivation of winds over this extended area from 29-degree south to 45-degree south has resulted 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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References

Bhatia,R.C , Singh Devendra ,Sant Prasad and Mukharjee, S.K“ Recent improvements in INSAT derived CMVs”, Sixth International wind workshop, Wisconsin,USA , 4 – 9 May ,2002.

Bhatia, R.C., Ram Sanehi and P.N.Khanna (1996) Validation of INSAT derived CMVs and their use for improving the analysis of synoptic scale weather systems, Proceedings of third international Wind Workshop, 10-12 June, Ascona, Switzerland.

Kelkar R. R, Khanna P. N, 1986: Automatic extraction of cloud motion vector from INSAT 2B imagery, Mausam, **37**, 495-500.

Khanna P.N., R.C. Bhatia, Devendra Jsingh (2000) Recent improvements in the quality of INSAT derived CMV and their use in numerical model forecast. Proceedings of Fifth International Winds Workshop, Australia, 103-108 pp.

Khanna P. N, Sant Prasad 1998 “ New Approach for Height Assignment and Stringent Quality Control Tests for INSAT derived Cloud Motion Vector, Proc. of 4th International Wind Workshop, Oct. 20-23, Saanenmoser, Switzerland, 255-262.

Le Marshall J.,N. Pascod (1993) Real time Cloud Drift Wind calculation and application in Australian Region, Report from Bureau of Meteorology Research Center, Bureau of Meteorology, Melbourne 1-6 pp.

Merrill R. (1989) Advances in automated production of wind estimates from Geo-stationary satellite imagery, Proc. Fourth conf. Satellite meteorology, San Diego, CA, Amer. Meteor. Soc., 246-249 pp.

Nieman S. J. et. al., 1997: Fully automated cloud drift winds in NESDIS operation, Bull. Amer. Meteor. Soc., 78, 1121-1133.

Singh, Devendra , Bhatia,R.C, Srivastav,S.K, Sant Prasad and Giri,R.K 2006,’ Operational use of improved CMVs derived from INSAT IR data in NWP Model over Indian region’, Mausam,vol.59,2(April 2006).