RECENT IMPROVEMENTS IN THE QUALITY OF INSAT DERIVED CMVS AND THEIR USE IN NUMERICAL MODEL FORECAST

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ABSTRACT

INSAT derived Cloud Motion Vector (CMVs) have been improved recently by introducing the new scheme proposed during 4th International Wind workshop (Khanna et al. 1998). India Meteorological Department (IMD) is generating Limited Area Model (LAM) forecast operationally for last five years. Earlier Quality Assurance (QA) tests of INSAT derived CMVs were done using low resolution 12 hour forecast from NCEP Washington or ECMWF. These forecasts earlier did not use satellite derived CMVs from INSAT or other satellites from data sparse Indian Ocean. Other centers did not find INSAT CMVs of reliable quality. Before July 98, no other satellite except INSAT covered the data sparse Indian Ocean. In July 98, METEOSAT-5 was shifted over Indian ocean at 63 deg. E. Recently improved algorithm uses LAM forecast in QA tests. Pressures and heights are assigned on the basis of mean temperature of certain percentage of cloud population at the cold end of the spectrum. Detailed comparison of CMVs from INSAT and METEOSAT-5 has been done. The improved CMVs from INSAT and METEOSAT-5 show quite good agreement qualitatively. The bias and RMS also show improvements. Zonal winds reported earlier have shown improvement. The lesser number of INSAT CMVs is due to lower spatial resolution of INSAT radiometer compared to METEOSAT–5. The two sets of CMVs generated from triplet of images are being combined, taking care of excluding the collocated CMVs in the two sets. The improved INSAT derived CMVs have shown positive impact on the Model forecast. This is mainly due to proxy data (CMVs) assimilation in the model.

1. Introduction

The Cloud Motion Vector derivation is a challenging job. The challenges involve, 1) Tracer, Target image registration and navigation, 2) Passive tracer selection, 3) Pattern matching of the reference window of tracer image at different lag positions in search window of target image, 4) Vector computation, 5) Height assignment to derived vector, 6) QA tests on derived vectors 7) Manual editing any spurious vectors. Height assignment is the most challenging. LAM (Krishnamurti T. N. et. al, 1990) is being used operationally in IMD since 1995. The model has horizontal grid of 1^0x 1^0, in latitude/longitude and uses 12 sigma levels. The model uses all conventional and satellite derived information in its assimilation scheme covering, vast data sparse Oceanic areas around India. It was, therefore felt that presently generated IMD LAM forecast is more reliable for QA tests. Recently METEOSAT-5, an additional data source over Indian Ocean has become available. However, it will take some time before this data can be assimilated into the model. The only limitation of LAM model forecast is the limited area (40 deg. E to 129 deg. E, -29 deg S to 45 deg N). There is scope for improvements in quality of INSAT derived CMVs. The approach needed improvement in image to image registration, and image navigation. Any error in registration translates into additional vector thereby resulting in poor quality of CMVs (Daniels J. M et. al. 1990). The quality of the numerical weather forecast has also direct impact on the quality of CMVs since the forecast is used in QA tests for CMVs. It is, therefore desirable that the numerical forecast uses conventional as well as satellite derived information from Indian ocean area in its data assimilation scheme. The model forecasts from NCEP and ECMWF did not assimilate INSAT CMVs into the model. This resulted in rejection of CMVs in QA tests. The zonal flow, high speed bias and RMS compelled other centers not to use INSAT CMVs. Forecast over Indian Ocean indicated improvement, when model for the region assimilated INSAT or METEOSAT-5 CMVs for oceanic area. Any other approach only marginally improved CMVs. In view of the above problems the improvements in CMVs were attempted in phased manner. After every change, the quality of CMVs were monitored by analyzing the statistics. These

statistics were computed using the formulae used in ECMRWF SATOB Monitoring reported in the proceedings of third International Wind workshop.

2. CMV generation prior to the improvements

Before the improvement, the selection of cloud tracers was done on four-bin histogram basis. The four-bin histogram classified cloud tracers to low, medium, high or of mixed type. In the case of mixed clouds, the computation was not attempted. The same approach was applied for various lag positions of search window and CMVs were computed using Sequential Similarity Detection Algorithm (SDDA) for pattern matching at different lag positions (Kelkar R.R and Khanna P.N 1986). Later pattern matching has been done, using cross-correlation technique. The navigated images provided wind vectors. The two sets after going through spatial, temporal consistency and QA test were submitted for the manual editing. CMVs were flagged at each stage when they failed. Finally the second set was transmitted on GTS. This provided CMVs with zonal flow and fewer in number. The coarser resolution of model forecast used in QA tests and coarser resolution of imagery resulted in zonal flow.

3. Improvements made in the derivation of CMVs

The improvements in INSAT CMVs were attempted in phased manner. After each attempt the CMVs were monitored to ensure steady and gradual improvements. The attempts were made in three phases.

3.1 Phase 1 (Introduced operationally from 1st Nov, 1999)

The existing registration / navigation approach was not changed and the tracer selection was done on the basis of four bin histogram. The histogram with maximum frequency was the basis of cloud tracer selection. Low medium and high clouds were assigned pressure 925 to 601 hPa., 600 to 301 hPa., and 300 to 200 hPa. The tracer image chip in tracer image and target image chip for different lag positions were pattern matched using cross-correlation. This has been the approach by most of the centers generating CMVs. The tracers in southern hemisphere south of 20 deg. S bring out cloud motion clearly and the coverage of CMVs is very good. These tracers are generally passive and provide CMVs with good coverage and high confidence. The derived CMVs were assigned height and pressure level using LAM forecast to the level at which temperature of cloud cluster matched best with LAM forecast. The CMVs were then quality controlled using collocated forecast, because It uses INSAT derived CMVs in its assimilation scheme and is of high spatial resolution. The quality of INSAT CMVs as reported by UKMO showed smaller speed bias (Fig. 1a, 1b, 1c and 1d) and slight improvement in RMS error for all levels (Fig. 2a, 2b, 2c and 2d). The gap in the data plots for June, 99 is due to missing data. Other centers were still not using INSAT CMVs in their assimilation scheme. After these changes INSAT derived CMVs showed better agreement with METEOSAT-5 derived winds in qualitative terms.

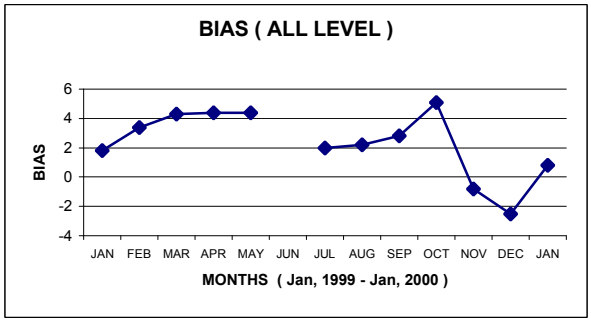

Fig - 1a

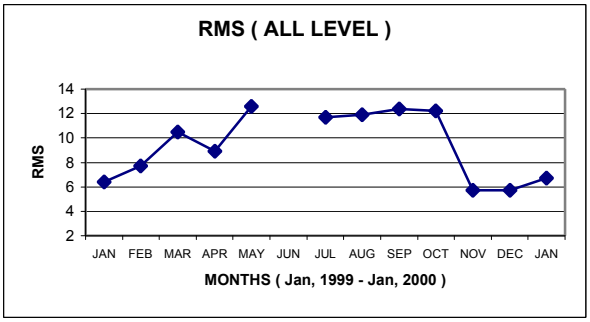

Fig – 1b

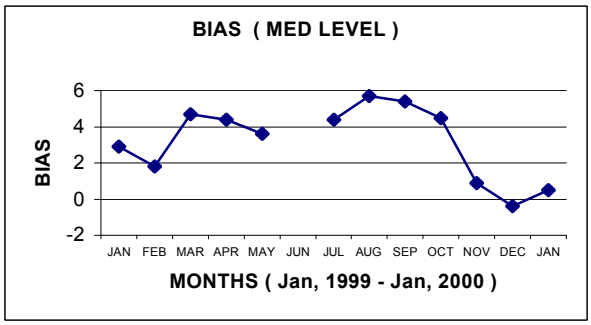

Fig – 1c

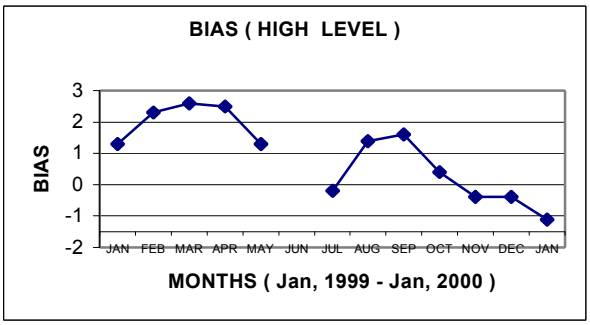

Fig – 1d

Fig 1. Statistics of INSAT CMVs with UKMO Forecast at different levels Note: Data for June, 1999 is not available.

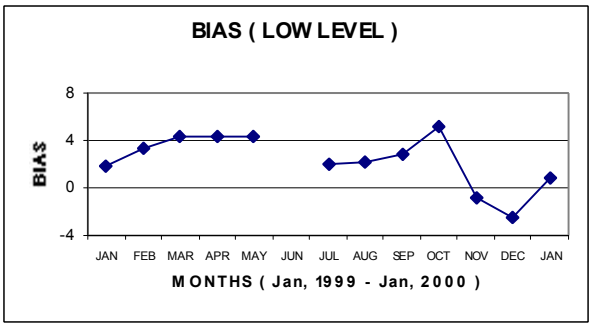

Fig – 2a

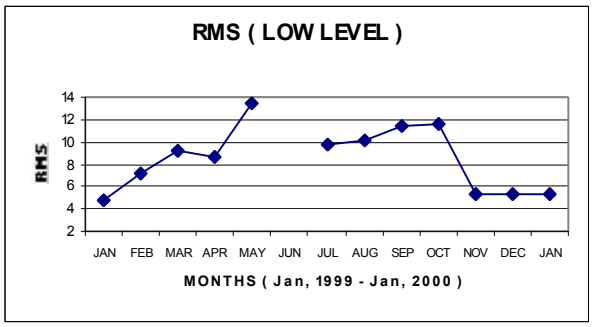

Fig – 2b

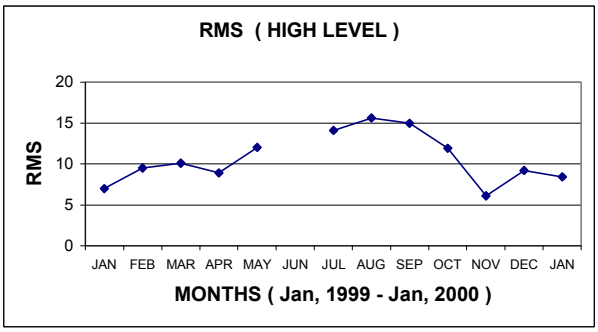

Fig – 2c

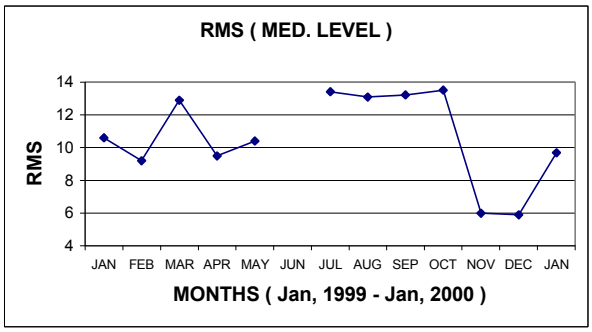

Fig – 2d

Fig 2. Statistics of INSAT CMVs with LAM Forecast/Analysis, Note: Data for June, 1999 is not available.

3.2 Phase 2 (Introduced operationally from 2nd Dec., 1999)

At present INSAT-1D is the only operational Indian satellite, providing meteorological services much beyond the normal expected life. It is now operating in an inclined orbit with its inclination close to 1.8 deg. The successive half–hourly images show poor registration when the images are seen in line/pixel coordinate system. Since all the images are navigated individually, the images in geocentric coordinates system are reasonably registered. The land features showed appreciable movement in the line/pixel coordinate system but in lat/long coordinate system these features show very little movement. The tracer selection for passive tracers was retained to use four-bin histogram. These tracers were tracked using cross-correlation for pattern matching. The height assignment and QA tests were done in the same way. Since LAM has been assimilating INSAT CMVs, it showed gradual improvement as a result of continued use. RMS error (Fig 3) and Speed bias (Fig. 4) for INSAT CMVs show improvement.

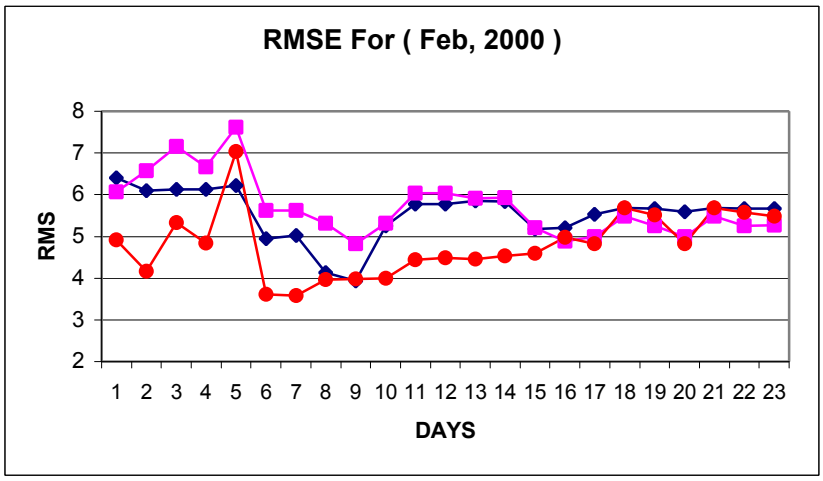

Fig – 3 25 – 601 hpa (Blue) , 600 – 301 hpa (Pink) , 300 – 200 hpa (Red)

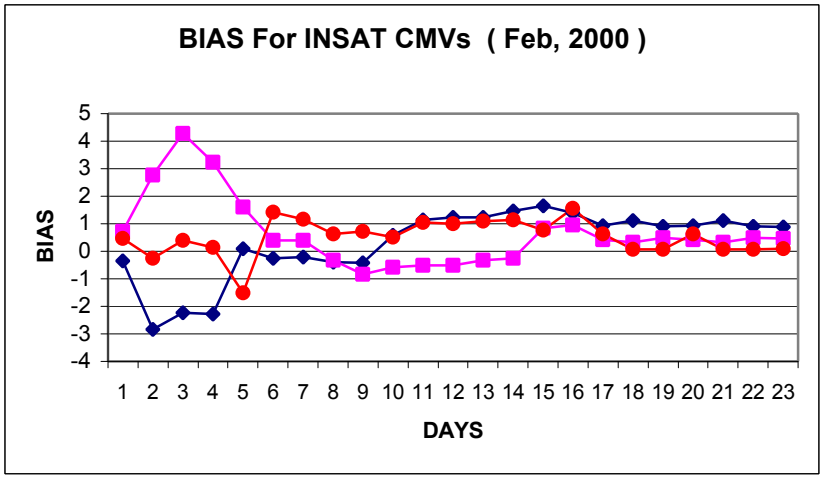

Fig – 4 925 – 601 hpa (Blue) , 600 – 301 hpa (Pink) , 300 – 200 hpa (Red)

3.3 Phase 3 (Introduced operationally from 2nd Feb., 2000)

Registration of images was further improved and height was assigned on the basis of the cloud top temperature using mean temperature of 25% of the coldest pixels (Nieman S. J et al. 1997). The cloud types and cloud heights were reassigned on this basis. These changes brought out very well even strong winds with speeds 80 to 100 kts, generally experienced during winter at 10 to 12 km height. These features were not being brought out earlier. These improved CMVs are in close agreement with METEOSAT-5 derived CMVs. Some meteorological features which were not brought out earlier by INSAT CMVs are being brought out very clearly. INSAT CMVs agreed very closely with METEOSAT–5 CMVs. QA tests with LAM forecast have improved INSAT CMVs. Inter-comparison of RMSE for GOES, GMS, MEOSAT-5 and INSAT from NCMWF shows close agreement (Fig. 5).

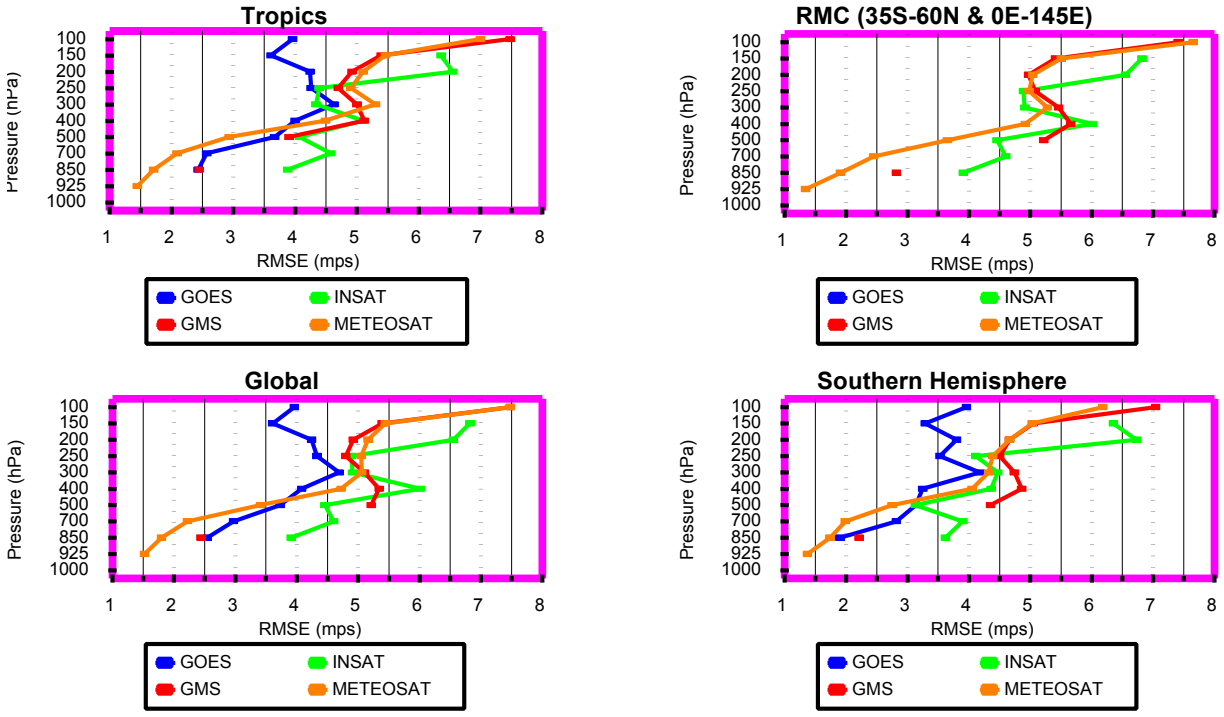

Fig - 5 Vector Wind RMSE of different Satellite with NCMWF Forecast (Jan & Feb, 2000)

4. Development plan for future

Further improvements have been planned based on the cluster classification using objective analysis (Cockley, Bretherton 1982; Schmetz et. al. 1993). This is expected to improve the quality of CMVs, bringing their overall quality closer to those generated by other centers. INSAT-3A VHRR with Infrared, visible and water vapor channels of higher spatial resolution, than that of INSAT 1D, will be available in the year 2001. It will also have a CCD payload with 1km resolution in Visible, Near IR and Short-wave IR bands. The ground processing system is being upgraded for additional processing load. It will provide CMVs more frequent and of better quality. In addition Water Vapor Winds (WVWs) will also be derived operationally providing extensive coverage more frequently. CCD will provide capability of more rapid scanning which will be useful to provide high resolution CCD CMVs more frequently using thermal IR and WV bands from VHRR for correct height assignment using IR - WV intercept approach (Nieman et. al. 1997). This is expected to provide more frequent, extensive coverage of satellite derived winds from CCD, IR and WV bands of VHRR (Velden C. S et al 1997).

5. Conclusions

Use of high spatial resolution LAM forecast produced in IMD has shown the improvements in the derived CMVs. This is because the model assimilates INSAT derived CMVs and has higher spatial resolution. The spatial resolution also partially removed the zonal flow reported earlier. INSAT does not have CO_2 ratioing or IR – WV intercept option, this caused poor height assignment resulting in CMV rejection in case of sub-pixel sized clouds or thin Cirrus with lower emissivity. Taking recourse to mean temperature of certain percentage (25 %) of coldest cloudy pixels helped reducing the emissivity problem.

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