CURRENT STATUS OF OPERATIONALLY DERIVED INSAT-CMVS QUALITY, DETAILS OF RECENT IMPROVEMENTS AND UTILISATION OF DERIVED PRODUCTS

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ABSTRACT

Certain vital changes have been incorporated in the operational scheme of INSAT CMVs derivation at INSAT Meteorological Data Processing System (IMDPS) for providing satellite derived winds of improved quality to the users. The changes include improved height assignment technique, better navigation of images, use of Limited Area Model forecast field in quality control and minor bias adjustments of derived wind vectors. As a result of these changes the quality of INSAT CMVs being disseminated operationally on GTS, has improved considerably. Checks on quality are being made on a daily routine basis. Root Mean Square error (rmse) of high and medium level CMVs has now reduced from 10m/sec to about 5 m/sec. BIAS has also reduced from 10 m/sec to less than 1m/sec. Low level CMVs have also improved considerably and they bring out the general circulation patterns of synoptic scale systems. A long time series of error characteristics of CMVs prepared upto March, 2002 shows that the improved quality of CMVs is being sustained since more than last two years. INSAT CMVs are now found to be comparable in quality to the METEOSAT-5 derived CMVs. Various users have also confirmed improvements in quality of operational CMVs and have found them useful for their routine operations.

1 Introduction

Upper level winds derived quantitatively by tracking the movement of clouds in successive half hourly pictures taken from geostationary meteorological satellites, are an important data source to supplement the conventional meteorological observations.
India Meteorological Department has been deriving CMVs from INSAT cloud imagery data and disseminating them to the users on an operational basis since 1987 on the Global Telecommunications System (GTS) network of the world weather watch. Initially, CMVs were derived based on the automated technique developed by Kelkar et al., (1986), using pattern matching procedure which attempts to search for a pixel-to-pixel equality between two grey shade distributions. Subsquently, with the installation of a new INSAT Meteorological Data Processing System (IMDPS) at IMD in 1992 for processing of cloud imagery data from 2nd generation of INSAT satellites of INSAT-2 series, improvements were incorporated in the CMV algorithm which resulted in better quality of CMVs (Kelkar et al. 1993). A number of workers in next few years introduced certain changes in the derivation scheme giving rise to marginal improvements (Bhatia, et al. 1996, Khanna et al. 1998). More recently (Khanna et.al 2000) some additional improvements in the quality of INSAT derived CMVs have been reported as a result of certain changes in the algorithm. INSAT derived CMVs were also found useful for improving the synoptic scale analysis of upper-air charts produced operationally (Bhatia et.al 1996). Inspite of these improvements by a few workers, the consistency of improved products disseminated operationally on GTS was lacking. Many of the numerical weather prediction centers found it difficult to operationally assimilate INSAT CMVs in their models due to higher rms errors and biases . Intensive studies were, therefore, started from November,1999 and a few major changes introduced to affect significant improvements in the quality of operational CMVs and to sustain them on routine operational

basis. Results of these studies, operational changes made and consequent impact on the quality are reported in this paper.

2 Algorithm of CMV Derivation and Chronology of Changes Introduced

CMVs are being derived operationally thrice a day since 1992 using triplet of INSAT images taken around 00, 06 and 1200 hrs UTC. All images are navigated separately with precision using well distributed ground control points and orbital parameters. As a slight modification to the original alorgithm, a few years back navigation of the central image was copied on the other two images taken at half hourly intervals. This was done to increase the number of CMVs. Potential tracers are selected at equi-spaced grid points in terms of line/pixels and their separation is configurable. The central image of the triplet, called tracer image, is analysed in segments (Reference window) with their sizes configurable. Pixel analysis in reference window is done on the basis of brightness temperature(TBB) and individual pixels are classified, using a four bin histogram, as clear, low, medium or high. Ultimately the reference window under analysis is classified as low,medium or high on the basis of relative frequency of various pixels. If the window is found to have evenly distributed cloud type with no dominance of a single layer, it is classified as multilayered cloud window and is not used for CMV computations.Tracking is done by matching the reference window at different lag positions of larger search window in the preceeding and succeeding half hourly images. Cross-correlation method is used for pattern matching. Displacement vector is computed using precisely navigated images. Height is assigned using modal temperature of IR image for identified cloud type. Two sets of computed vectors from triplet of images are then passed through a two step quality control procedure involving automated and manual controls. Automatic control involves tests based on absolute threshold of speed, time and space consistency and comparison with numerical model generated forecast fields. Manual editing is done by experienced meteorologist. Finally two sets of CMVs are combined to give only one set which is transmitted on GTS. Following problems were noticed in INSAT-derived CMVS.

(i) RMSE and Biases were quite high for all levels
(ii) No winds derived over the areas influenced by synoptic scale tropical disturbances.
(iii) Low level CMVs of comparatively poor quality
(iv) Tendency for CMVs to show more zonal flow.
(v) Large negative bias of high level CMVs.

All problems were analysed critically by detailed analysis of a large data set. Main reasons for quality of INSAT-CMVs being not up to the mark are : (i) Image to image registration, in terms of lines and pixels, was not satisfactory, particularly due to the fact that INSAT-ID satellite currently in use for CMV derivations, is being operated in an inclined orbit mode which has resulted in large yaw build-up. Hence just copying of navigation from tracer image to target images did not improve the registration of images. (II) Low emissivity, sub-pixel size clouds and thin cirrus caused warmer TBB thereby resulting in lower height assigned. Such CMVs were rejected when compared with forecast field during quality control. In addition, due to use of a single IR channel in height assignment, there are inherent limitations. (iii) As INSAT CMVs were not found to be of good quality, they were not taken as input to the the numerical models run operationally by various centres, the world over. Hence the model based forecasts generated operationally by the numerical model centres do not adequately represent the synoptic situations over the coverage area of INSAT-CMVs perticularly over the large oceanic areas where other conventional observations are scanty. Therefore, quality control based on the model forecast will reject many good quality INSAT derived CMVs. A major effort was, therefore, initiated to improve the quality of operational INSAT CMVs with a view to provide better quality product to the end users on a regular basis. The improvements were carried out in 3 phases.

2.1 Phase l (From 1 Nov., 1999)

In the first phase, Limited Area Model (LAM) forecast being run operationally at IMD was used during automatic quality control. LAM generates 1° x 1° (1000 hPa to 50 hPa) forecast for the geographical domain 300S to 450N and 400E to 1200E. Since operational LAM assimilates INSAT CMVs, it was anticipated that the quality of INSAT CMVs will improve. TBB for the tracer type was used to assign nearest pressure level and height using LAM forecast. The u and v components for the appropriate assigned level were converted into vector (speed and direction). If the differences in the colocated forecast wind and satellite computed wind was found within the specified threshold limit, the vector was accepted, otherwise it was flagged as invalid. The use of LAM forecast made a positive impact on the CMVs quality as anticipated. A continuous 2 to 3 weeks generation of CMVs using LAM forecast improved the coverage in terms of both, quality and quantity. U.K. Met. Office in its communication had also indicated a noticeable improvement in bias and rms errors.

2.2 Phase-2 (From 2 Dec., 1999)

In the second phase, the earlier procedure of copying navigation of central image to the other two images of the triplet, was discontinued and the original scheme of navigation of each triplet was used. This resulted in improvement of registration of tracer/target images thereby minimizing the spurious wind component and resulting in more number of acceptable satellite derived winds with lower bias and rmse.

2.3 Phase-3 (From 1 Feb., 2000)

In order to account for the problem associated with the emissivity and keeping in view the limitation of single IR channel for height assignment, the following steps were taken to further improve the quality of CMVs. The statistics of low, medium and high clouds in each tracer chip are available as part of CMV generation scheme. The mean, median and mode were found to be very close in the distribution of grey shade counts and the frequency in the tracer chip showed a near normal distribution. Using these attributes of the distribution of various cloud types, the mean temperature of the 25% coldest pixels (John LeMarshal et al.1993, Merrill R 1989, Nieman S. J et al. 1997) was taken as the TBB rather than the modal temperature used earlier. To compute the mean of 25% of coldest pixels, there were two possible approaches.

(a) While performing 4-bin histogram analysis, arrange the pixels in decreasing order of temperature for each bin and compute the mean temperature of 25% coldest pixels for the cloud type that was predominant. This meant completely rewriting the code for 4 bin histogram analysis. This was not done.
(b) The four bin histrogram analysis of original scheme does provide for each bin (i) frequency (ii) mean (iii) median (iv) mode (v) standard deviation and (vi) upper and lower thresholds of count values.
Using the above mentioned information the predominant cloud type and its range of counts for coldest and warmest pixels can be found out by mean,median and mode and lower thereshold and upper threshold values of counts respectively. Therefore it is possible to find the count value for 50% and 25% of coldest pixels in the predominant cloud type using the following logic:

count value for 50% of coldest pixels (C50%) = Lower threshold value of count + (Upper threshold value of count - Lower threshold value of count) / 2

Further, the count value for 25% of coldest pixels in the predominant cloud type may also be calculated using the following logic:

count value for 25% of coldest pixels (C25%) = Upper threshold value of count – [C50% + (Upper threshold value of count - C50%) / 2]

Thus, the count value calculated for 25% of coldest pixels of predominant cloud type is converted into brightness temperature(TBB) using calibration data.The new TBB was used to reassign the pressure level and height using the nearest ±0.50 celsius temperature in the forecast field. The u, v components of derived satellite winds were then compared with the space/time colocated u, v components of the forecast field. Satellite derived winds outside the tolerance of the grid forecast were declared invalid. The net effect of introducing this modified scheme was the following improvements.

(i) More number of CMVs of acceptable quality.
(ii) Use of this approach provides some valid winds around tropical disturbances.
(iii) INSAT derived CMVs agreed even more closely with the colocated METEOSAT-5 CMVs.
(iv) Mid latitude targets (500 hPa level) which were not clearly brought out earlier, became more noticeable after this modification, thereby giving rise to improved quality of middle and high level CMVs.
(v) Satellite winds in the stronger wind shear zones became available after the change.

3 Results and Discussions

3.1 Improvements in Quality of INSAT-CMVs

After incorporating above mentioned changes in the algorithm, quality of the derived product was checked. Two methods were used for quality checks. Firstly, the INSAT derived CMVs were compared qualitatively with METEOSAT-5 derived CMVs since both satellites have fairly large common areas of coverage. Qualitative checks on the quality of INSAT derived CMVs were also done by visual examination of their matching with the large scale and synoptic scale flow patterns obtained from conventional upper-air charts and the supporting satellite pictures which normally indicate the positions of troughs and ridges. Quantitative checks of the quality were made by comparing them with the first guess forecast field of U.K. Met. Office (UKFCST) and Limited Area Model Forecast (LAM) field generated operationally by IMD. Monthly Statistics on rms errors and biases generated by UKMO was used for this purpose and a comparison of INSAT derived CMVs was also made with METEOSAT-5 derived CMVs using UKMO's statistics. A long-time series of rmse and biases of INSAT CMVs was generated to study the effectiveness of changes and the sustainance of improved quality. Fig. 1(a-h) and Fig 2 (a-h) depict monthly statistics for the period Jan. 1999 to March, 2002. Fig 1 is for all regions put together and Fig 2 is for tropics only. Different sub-sections of these figures show for various levels of the monthly bias and rmse for INSAT CMVs and the METEOSAT-5 derived CMVs. Monthly Statistics were also generated from Jan., 2000 by comparing INSAT CMVs with the Limited Area Model Forecast being run operationally at IMD, New Delhi. It is seen that from Nov., 1999 onwards there is a drastic reduction in the rmse and biases, for all the three levels (low, medium and high). Large fluctuations in the monthly statistics are also arrested from November, 1999. Prior to this date, errors and biases were quite high and were also beyond acceptable limits. In particular, referring to the Figs. 1 (e-f) and Fig 2(e-f), it may be noted that for medium level CMVs, the bias of INSAT CMVs is now reduced to 1.0 m/sec or better as compared to 4 m/sec or more prior to introduction of changes. Rmse of INSAT CMVs is also reduced from about 12 m/sec to a steady value of 6 m/sec for medium level CMVs which is fairly close to rmse of METEOSAT-5 CMVs. Same is the case with high level CMVs where rmse and biases have reduced to about 7 m/sec and 0.5 m/sec respectively after introduction of changes in the algorithm and these values are also now fairly close to the corresponding figures for METEOSAT-5 derived CMVs. For low level CMVs [Fig.l and 2 (g-h)] also there is a drastic improvement in the rmse and bias from November 1999 after incorporating changes in the operational CMV algorithm. However, the rmse of INSAT derived low-level CMVs (5.5 m/sec) is a little higher as compared to that of M-5 derived CMVs (3.5 m/sec). But the large fluctuations in rms errors of low level INSAT-CMVs prior to November, 1999 (with values of the order of 10 m/sec) have now been arrested and lower errors are now observed on a sustained basis. Biases of INSAT low level CMVs are also now reduced from about 4 m/sec to less than 1 m/sec. on a sustained basis.

3.2 Quality analysis based on ECMWF Satob Data Monitoring Reports

European Centre for Medium-Range Weather Forecasts (ECMWF), U.K. produces quarterly reports on the quality of satellite derived winds transmitted by all satellite operators on the GTS. The quality statistics given in these reports are based on the comparison of satellite winds against the first guess forecast field and the aircraft reports. A comparison of statistics of METEOSAT-5 derived CMVs and INSAT-ID derived CMVs for the periods Nov., 1999 and Feb., 2002 is shown in Table-1. It is seen that biases of INSAT CMVs are now comparable to those of METEOSAT-5 for most of the cases indicated in the table below.

REGION		METEOSAT-5		INSAT 1D	
		Sep-Nov 1999	Dec-Feb 2002	Sep-Nov 1999	Dec-Feb 2002
NH EXT TROP.	1000 – 701 hPa	5.3	7.3	7.5	5.8
TROPICS	1000 – 701 hPa	3.6	4.1	7.5	4.9
SH EXT TROP.	1000 – 701 hPa	2.6	2.8	9.0	5.3
NH EXT TROP.	700 – 401 hPa	6.0	8.0	9.1	8.0
TROPICS	700 – 401 hPa	5.8	7.6	7.5	5.5
SH EXT TROP.	700 – 401 hPa	7.1	7.0	15.5	6.8
NH EXT TROP.	400 – 100 hPa	6.7	7.9	11.8	6.6
TROPICS	400 – 100 hPa	4.9	5.5	8.4	7.6
SH EXT TROP.	400 – 100 hPa	8.1	7.2	11.7	9.2

Table – 1: Comparison of CMV (IR) R.M.S Error (m/s) of Meteosat 5 and INSAT 1D

3.3 Qualitative checks on the INSAT-CMVs

After the relocation of one of the METEOSAT Satellites (M-5) over Indian ocean at 630E longitude from July, 1998, a large independent data set of satellite derived winds is available for qualitative checks of INSAT-CMVs. Daily qualitative checks made by comparing the CMVs derived from INSAT and METEOSAT-5 derived CMVs showed fairly good agreement. Eventhough the number of INSAT-CMVs are small as compared to M-5, the synoptic scale flow patterns are generally very well brought out in both types of data. Figure 3 shows a sample of inter-comparison of CMVs derived from INSAT and M-5 for lower, middle and upper level on 28-01-2000 at 06:00 hrs UTC. It is seen that the circulation over east coast of Medagaskar is well brought out in both data sets. Such consistencies were seen for many days in succession after making changes in the INSAT-CMVs algorithm. Improvements in the quality of INSAT-CMVs are, therefore, noticeable after changes in the algorithm. This shows that winds derived from INSAT are quite improved and are now comparable to METEOSAT-5 derived winds. Using the monitoring statistics information a quantitative comparision of winds derived from INSAT and other geostationary satellite (M-5) is also carried out. The bias and rmse of INSAT derived winds are very close to that of Meteosat-5 derived winds (fig.1and 2). Various users also reported the improvements of

INSAT-CMVs and their better fit into the operational analysis and positive impact on the numerical model forecasts.

4 Conclusion

Use of high spatial resolution LAM forecast produced operationaly in IMD, in the operational INSAT CMV derivation scheme for automatic quality control has resulted in improvements in the derived CMVs. This is because the model assimilates INSAT derived CMVs and has higher spatial resolution. The high spatial resolution of model also partially removed the zonal flow reported earlier. Since INSAT has only one channal in IR band, use of mean temperature of certain percentage (25 %) of coldest cloudy pixels for height assignment helped reducing the emissivity problem to a certain extent. The qualitative comparision of winds derived from INSAT and METEOSAT-5 showed that, in general almost similar wind flow patterns are depicted every time in satellite winds derived from INSAT and METEOSAT-5. RMSE of high and medium level CMVs has now reduced from 10m/sec to about 5.5 m/sec. Bias has also reduced from 10m/sec to less than 1m/sec. Low level CMVs have also improved considerably.

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REFERENCES

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 Winds Workshop,10-12 June,Ascona,Switzerland.

Kelkar R.R, and P.N.Khanna (1986) Automatic extraction of cloud motion vector from INSAT 1B imagery, Mausam 37,4,495-500 pp.

Kelkar R.R, A.V.R.K.Rao and R.C.Bhatia (1993) Recent improvements in Cloud Motion Vector Derivation from INSAT. Proceedings of second International Winds workshop, 13-15 December, Tokyo, Japan, EUMETSAT Publication No.EUMP-14, 65-70 pp.

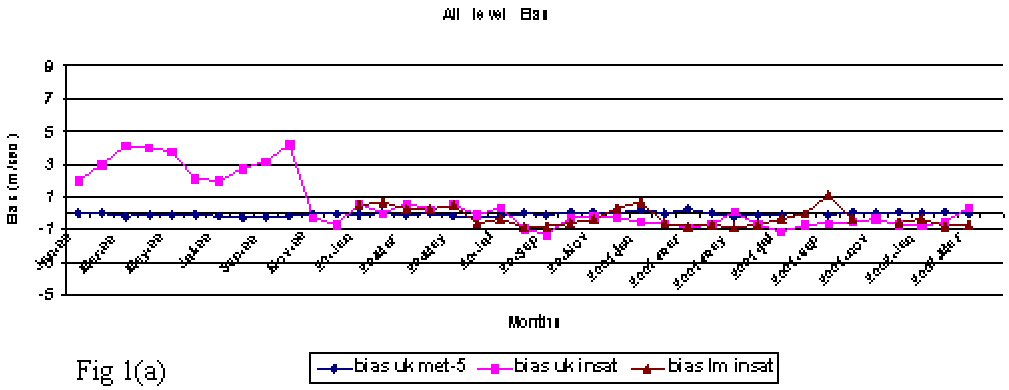
Khanna P. N and Sant Prasad (1998) New Approach for Height Assignment and Stringent Quality Control Tests for INSAT derived Cloud Motion Vector. Proc. of 4th International Winds Workshop, Oct. 20-23, Saanenmöser, Switzerland, 255-262 pp.

Khanna, P.N. R.C.Bhatia,Devendra Singh (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.

LeMarshall 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-stationery satellite imagery , Proc. fourth conf. Satellite meteorology, San Diego, CA, Amer. Meteor. Soc., 246-249 pp.

Neimen S. J.(1997) Fully automated cloud drift winds in NESDIS operation, BAMS vol. 78, no. 6, 1121-1133 pp.



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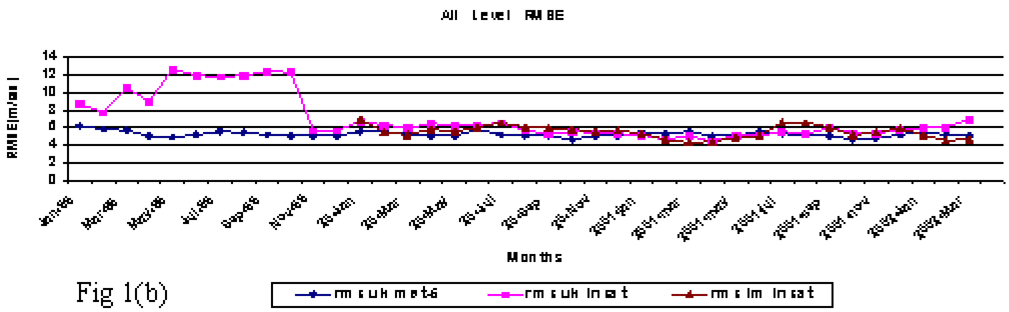

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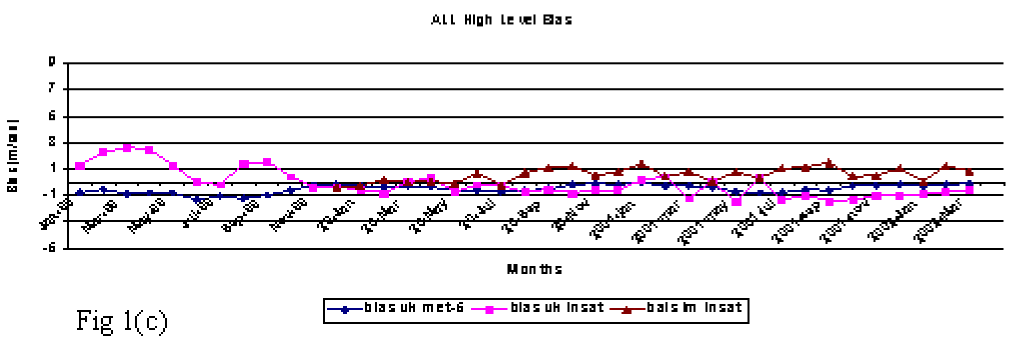

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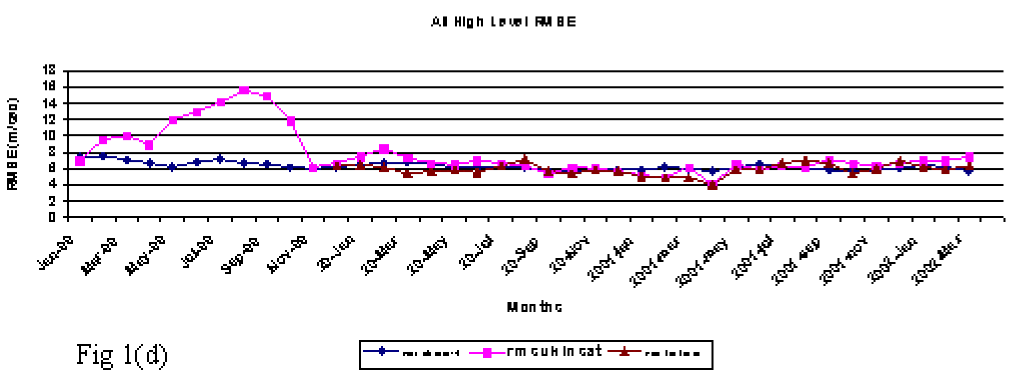

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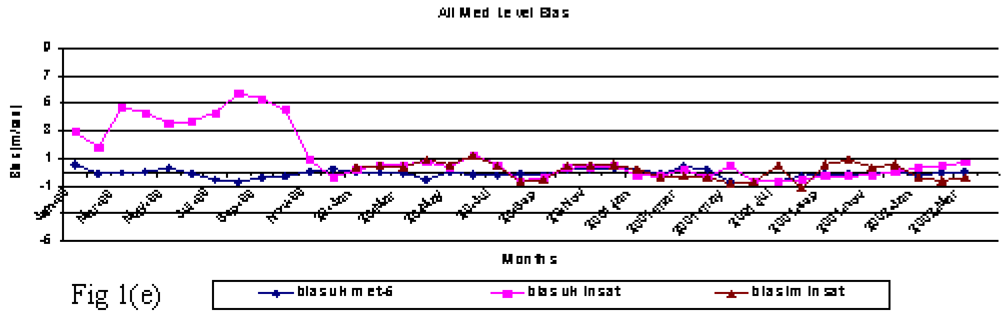

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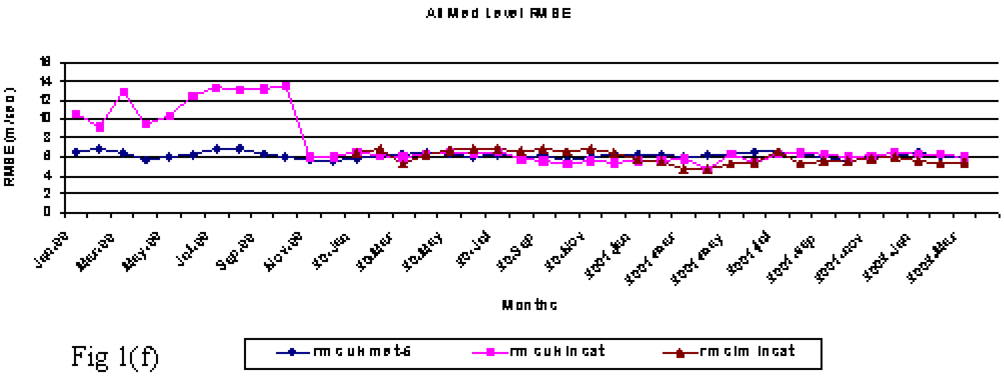

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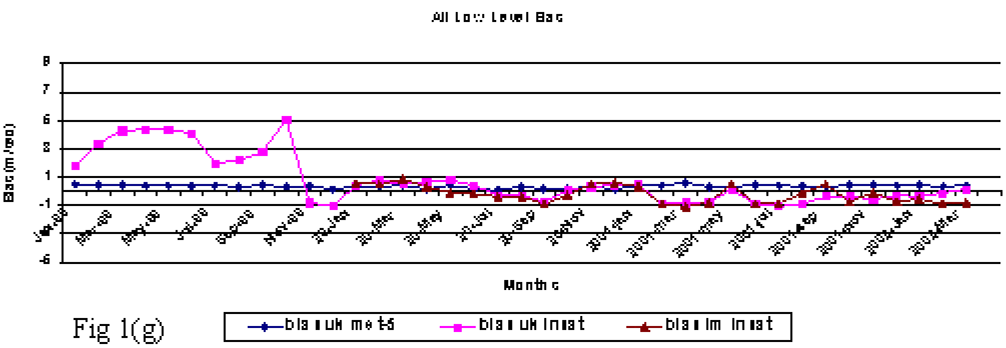

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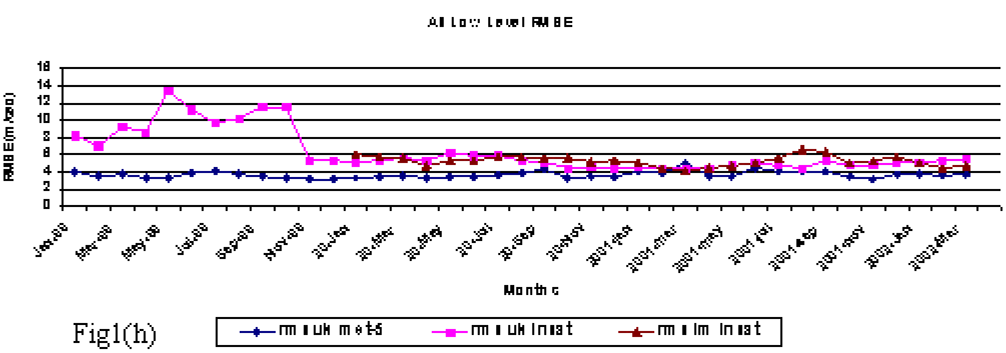

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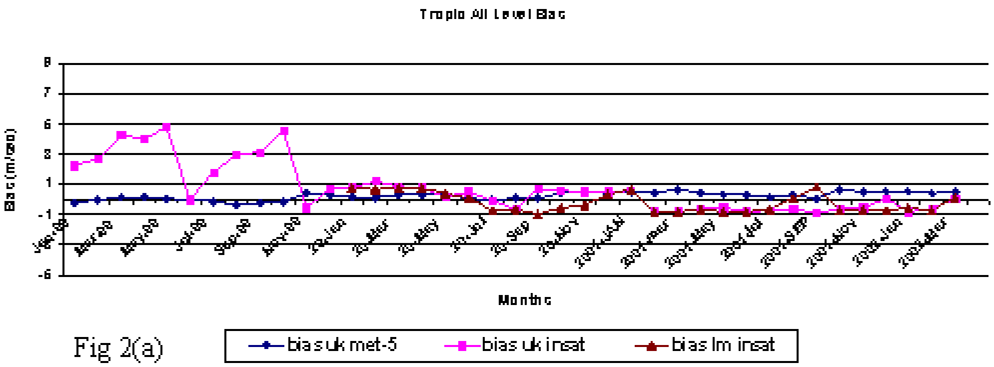

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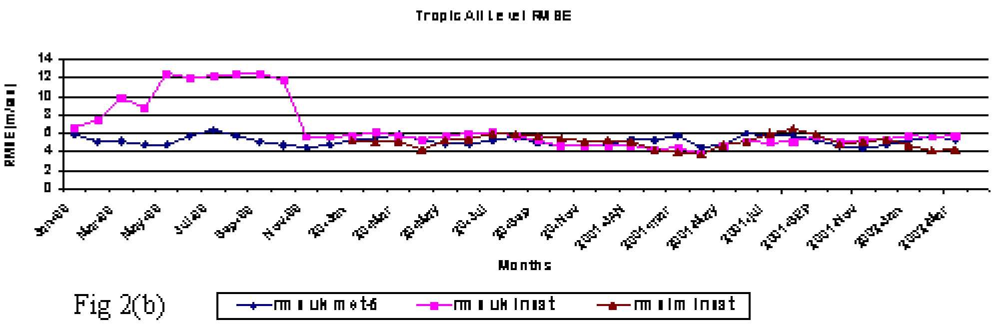

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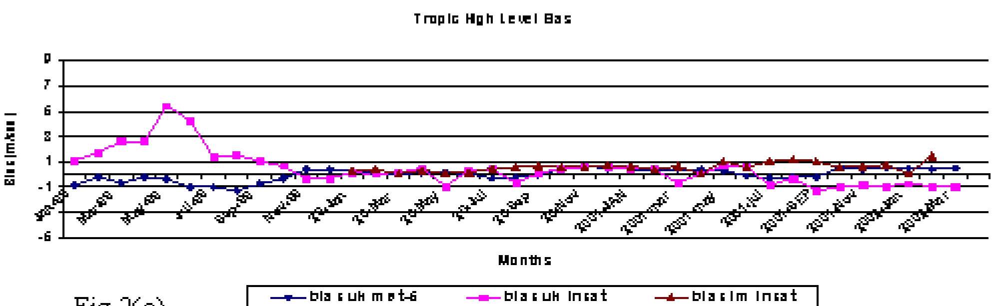

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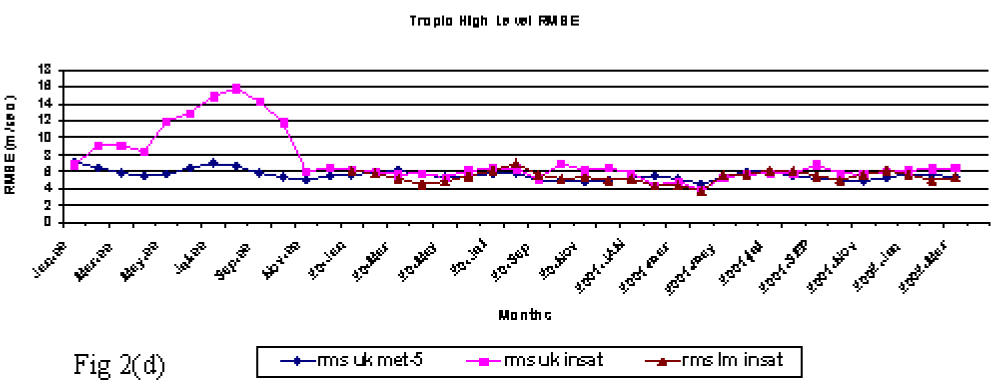

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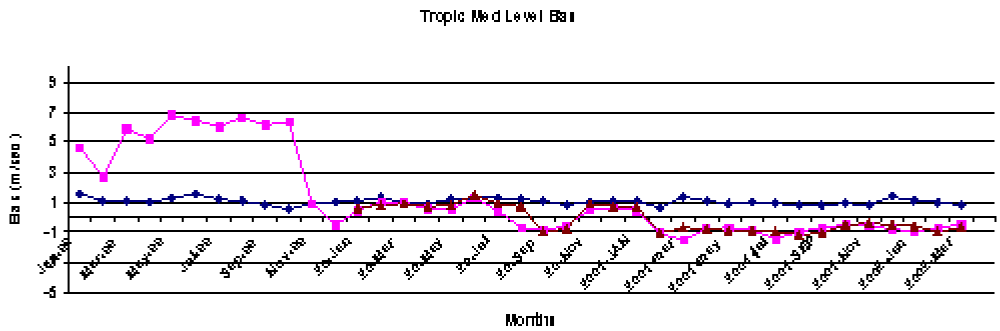

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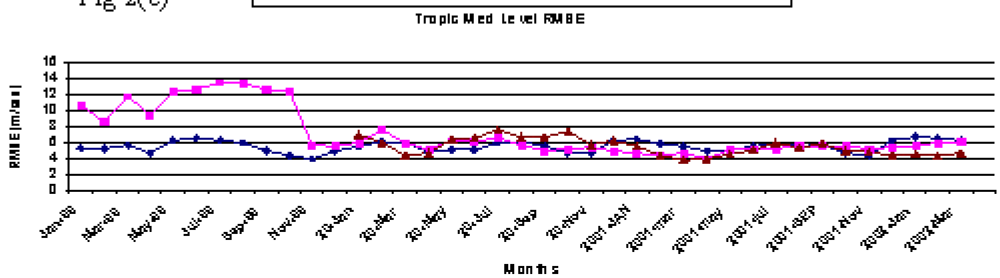

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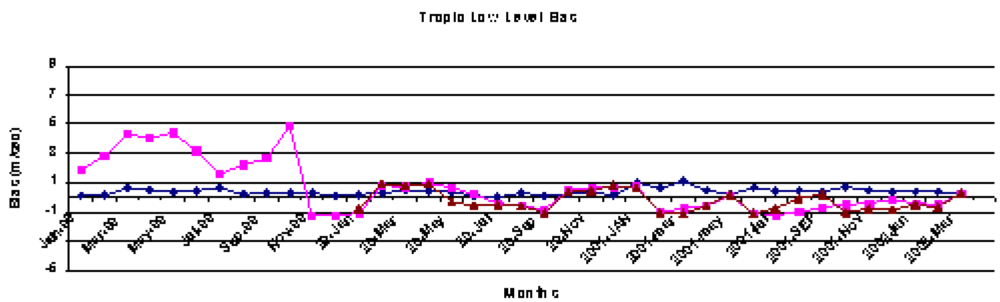

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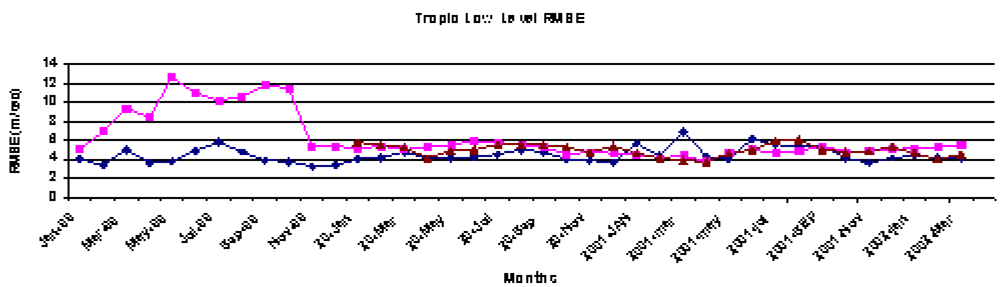
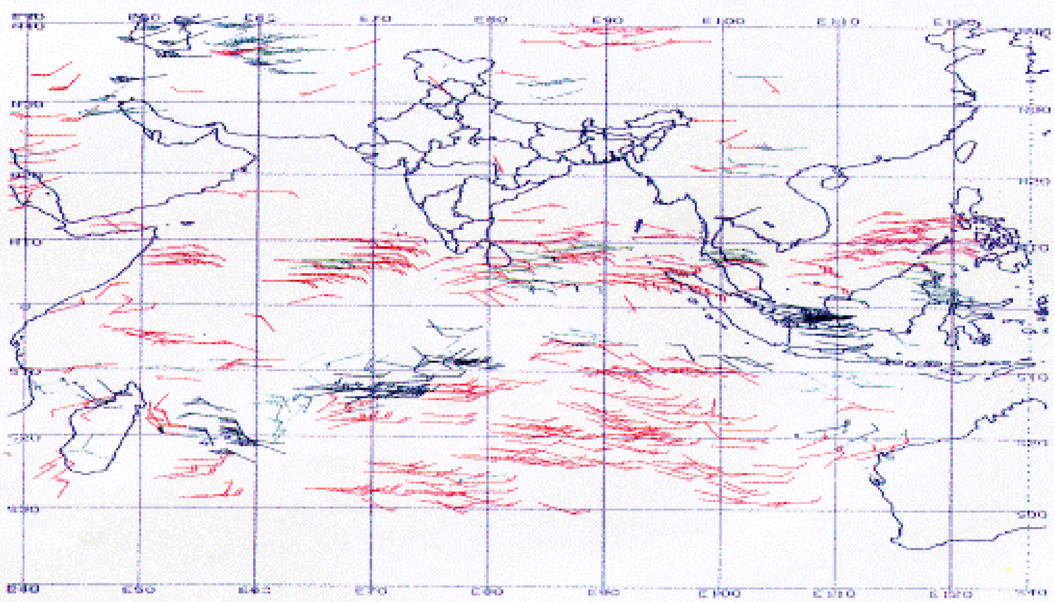


Fig 2(h)

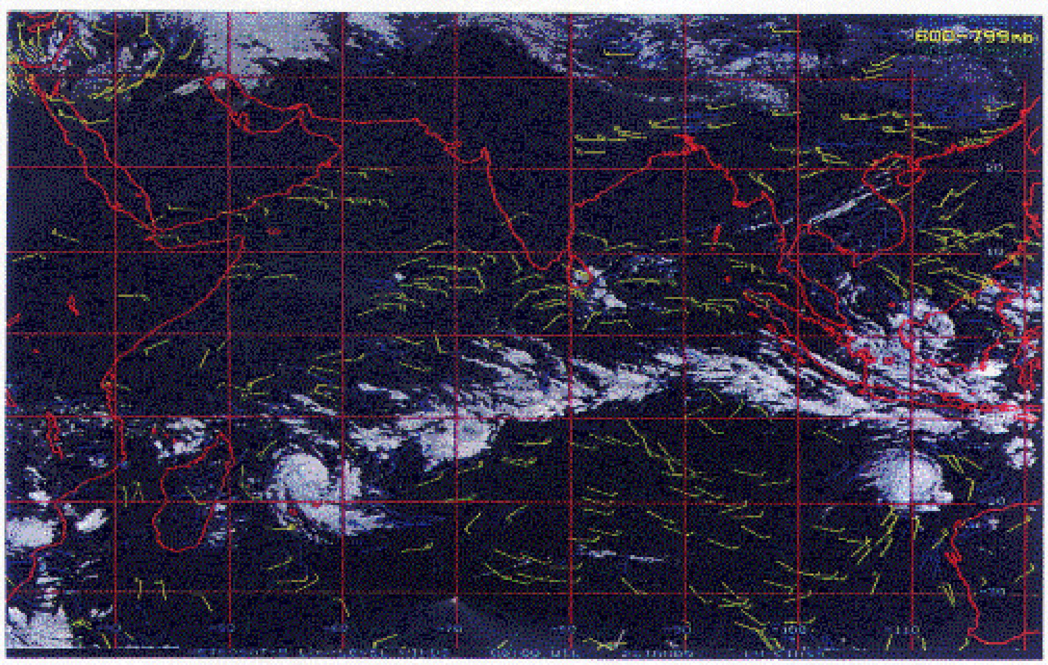
CLOUD MOTION VECTORS OF INSAT IR AND METEOSAT-5 IR

(28-01-2000 06:00 UTC)



INSAT (601-950 hpa , 600-301 hpa , 300-200 hpa)

Fig 3(a)



METEOSAT-5 (800-950 hpa , 600-799 hpa , 400-599 hpa)

Fig 3(b)