Improvements in Automated Cloud Motion Vectors (CMVs) derivation scheme using INSAT VHRR data.

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ABSTRACT

Cloud Motion Vectors (CMVs) are being derived operationally over large areas of Indian Ocean since January, 93 with INSAT data, using the upgraded data processing facilities established in September, 92 as part of the INSAT-II meteorological applications programme. Results of initial studies presented during International Wind Workshop of 1993 did indicate lot of improvements in the quality of INSAT derived CMVs.

Two more improvements have been done recently in the Automated CMV generation scheme i.e., in the cloud classification and in the scheme for quality controls on CMVs using two picture pairs. Earlier, the cloud classification was being done using a four bin histogram for clear, low, medium and high clouds on the basis of temperature threshold and using various tests on the frequency of different bins. In the new approach a cloud class having maximum frequency is identified as predominent class using four bin histogram approach and the clouds are tracked. This has improved identification of a prominent single layer for tracking in a multi-layered cloud complex. The quality controls are now being applied on winds derived from both pairs of half-hourly images by comparing with NMC forecast . Finally valid winds from either or both of these pairs are accepted as good winds. Such tests were earlier being done in a rather subjective manner.

After incorporating these changes in the wind derivation scheme the number of good quality CMVs has increased. Analysis of the results has shown that the rms error and bias of the CMVs compared to the radiosonde derived winds has improved after these changes.

1. Introduction:

Operational derivation of Cloud Motion Vectors (CMVs) was started by IMD during 1984 using visible channel data transmitted by the first generation of Indian National Satellite (INSAT-1) System. With the major upgradation in 1992 of the INSAT meteorological ground segment for data processing, a sea change has occurred in the capability for CMV derivation. Preliminary details of the new software package's capability for CMV derivations were presented (Gopala Rao, 1991) during the first International Wind Workshop held during 1991 in Washington. Further details of the software capability alongwith the few improvements made during 1993 were presented (Kelkar et al 1993) during the 2nd International Wind Workshop (1993)held in Tokyo. During this workshop results of a few validation studies done during 1993 were also presented and it was concluded that the general quality of INSAT derived CMVs is good.

2. Further evaluation work of CMVs:

Quality evaluation work of CMVs was continued. Two distinct approaches were used for this purpose. One is by conventional means of comparison with Radiosonde and Airep winds and finding out the standard statistical parameters. Second approach was evaluating them more from qualitative point of view rather than quantative. This is particularly necessary in the Vast oceanic areas south of India where conventional observations are generally not available. In this approach CMVs are monitored daily to find out whether they are consistent with the movement of large migratory extra tropical systems seen in the Southern Hemisphere as revealed by the daily Satellite pictures. Over certain other areas where some conventional land-based upper air observations are available and analysis is done on the basis of these observations, an attempt is made to find out whether the CMVs also fit the general flow patterns brought out by the analysed charts.

Based on extensive validation tests and studies on the use of data, the general quality of CMVs was found to be good and accepatable for operational utilisation in daily analysis of synoptic charts (Bhatia et. al). Use of INSAT CMVs for this purpose was therefore started in middle of 1994 keeping a critical watch on their quality and the problems associated with the product on some of the days. More efforts were also directed in solving the problem areas.

3. Improvements in CMV algorithms:

Daily statistics was collected on the number of CMVs rejected during the automatic quality control checks and the total number of CMVs computed. After a careful study on the reasons for rejection of CMVs it was concluded that some of the quality control checks were too stringent and during the process of automatic quality checks some of the good winds could also have been rejected. Suitable changes were introduced in the threshold limit of the parameters associated with the quality checks. Details of changes made are as follows (TABLE-2)

Triplets of half hourly images centered at 00 and 12 UTC are used for derivation of CMV. This results in two sets of CMVs. The automatic quality control tests for quality assurance include time consistency, gradient and forecast/climatology test.

Time consistency checks the stability and consistency of pair of colocated winds computed from the triplets. The directional stability checks have been made more stringent, the threshold for tolerance of direction for low, medium and high clouds have been changed from 60 degree, 45 degree and 30 degree to 40 degree, 30 degree and 30 degree.

In the new scheme gradient test has been dropped. However forecast field/climatology tests are performed on both the CMV sets. Earlier the forecast field test was applied after a sample CMV for a location was computed from the two sets. The thresholds for speed and direction in forecast field test have been modified from 30,30 to 20 and 45 respectively. In the event of two colocated CMVs from two sets, if absolute difference in speed exceeded 20 knots, the two winds are rejected, if the two pass the test the resultant CMV is computed from the average of U and V components from the two winds.

NMC forecast is being used in forecast field test. It was felt that use of NMC forecast was resulting in large rejection, specially around Arabian Sea and Bay of Bengal. On few occasions some of the flagged winds had to be reclaimed to support the synoptic situation and associated cloud imagery. It was therefore desirable that the tolerance in the direction may be increased to accomodate the winds that were rejected due to stringent limits.

In order to increase the coverage of CMVs grid point seperation for making search for potential tracers was reduced from 16 IR pixels/ line to 14 IR pixels/line. This increased the No. of potential tracers and the No. of computed winds. Further the CMVs were being computed over an area of 35 degree radius about the sub-satellite point (SSP). It was increased to 40 degree thereby increasing the CMV coverage. Modification in grid separation and radius resulted in about 50% increase in the number of raw CMVs computed.

The modifications mentioned have resulted in about 100% increase in the valid CMVs that are being disseminated on the GTS.

With the above changes in the configuration file, CMVs were computed regularly for a period of 15 days and slight improvement in quality was found. Regular transmission of these improved quality CMVs was started on GTS from Nov. 1994 and ECMWF was asked to give a special report on their quality based on 15 days monitoring. Slight improvement in quality was also confirmed by the ECMWF.

4. Derivation of 6Z CMVs based on visible images:-

INSAT ID has 11 km resolution in the Infrared band (10.5 to 12.5 Um) and 2.75 KM in the visible band (0.5 to 0.7 UM). In order to take advantage of higher resolution, CMVs are now being computed using visible band data of INSAT 1D in non-operational mode. The tracers and targets are from triplet of images at 06:00, 06:30 and 07:00 UTC. CMVs are computed using Cross Correlation of reference window of 14x14 size with different lag positions in search window of 96x96 size.The grid separation is kept at 42 pixels/line. In order to save the computer time fine correlation option is kept on. It computes best match using coarse cross-correlation using a sampled data and finally finds the best match using fine cross correlation from full resolution data around the lag position that gave best coarse cross correlation. The CMVs computed are assigned height on the basis of modal temperature in the central IR band imagery using sounding/forecast temperature profile. The CMVs are finally subjected to the time consistency / stability test, gradient test and Forecast grid/climatology tests with the tolerance thresholds similar to the ones used for quality control tests on CMVs derived from IR band data. Visible CMVs have been found to bring out the cross equitorial flow just before and after the onset of south west Monsoon over Indian sub continent.

5. Results and Discussions:

Recent changes in the automatic quality control scheme of CMV computations have resulted in improved quality of the CMVs. Number of computed CMVs and the number of valid CMVs has also increased substantially. Rejection of winds in quality control has also reduced after the changes. Qualitative checks of the derived CMVs during last 10 months show that they generally fit into the synoptic upper air charts and bring out the flow pattern. Rigorous comparison of INSAT derived CMVs with the co-located Radiosonde observations over a selected 10 days period has shown that the mean absolute speed error of low level CMVs has reduced from 16.45 knots to 10.75 knots after the changes. There is also slight reduction in the mean absolute error in speed of medium level CMVs from 9.63 knots to 8.26 knots as a result of these changes. There is practically no impact on the quality of high level CMVs. Detailed results are given below in Table-1.

The mean absolute error in the direction of CMVs compared to the radiosonde does not show encouraging results. This appears to be due to the fact that INSAT-CMVs are heavily biased in favour of NMC forecast which may not represent the true picture over the Indian ocean areas since INSAT-CMVs are probably not being assimilated in the medium range numerical forecast models. As there are signs of slight improvements in the quality of INSAT CMVs, perhaps their use on operational basis in the medium range models will improve the forecast which, in turn, will give rise to improved CMVs.

6. Problem areas:

Thin cirrus, sub-pixel size clouds and area filled with multilayered clouds pose real challenge in derivation of CMVs and assignment of suitable height to them. Small cumulie/ strato-cumuli with life cycle of about one hour are the ideal tracers and they are known to represent wind at their base level. Such tracers are found in abundance in the southern hemisphere, without much land mass. The CMV cover from south of 10 degree south is generally very good with little rejection in forecast field test. However, in tropics north of equator, cloud coverage is generally multilayered specially associated with disturbances, the outer periphery of the which is cirrus. Thin cirrus due to poor emissivity results in lower height assigned to it. IR band alone cannot ascertain correct height of Thin Cirrus. Large number of such CMVs are rejected by forecast field tests. Further in association with disturbance in tropics multilayered clouds may have large cumulus or cumulonimbus which are not suitable tracers. The winds computed automatically from such tracers do not represent wind at one level and stronger wind shear in vertical makes it further difficult to assign proper height. These are thus rejected by forecast field test. This results in poor coverage of CMVs over Bay of Bengal and Arabian Sea. A scheme that may separate low, medium and high clouds and then track each layer separately may help in sorting out CMV computation and height assignment. Low resolution of IR band in INSAT 1D adds to the problem. INSAT 2E water vapour channel will help in estimation of emissivity of cirrus and thus assesment of correct height. INSAT 2E is scheduled to the launched in early 1998.

7. Conclusions:

Persistent efforts over the last few months to improve the quality of INSAT derived CMVs has shown good results, particularly in the speed of low level CMVs. Mean absolute speed error of low level CMVs compared with the colocated Radiosonde observations, has been now reduced to about 10 knots. This is also consistent with the results brought out in the ECMWF monitoring reports where comparisons are done on the basis of First Guest Forecast Field. Overall number of valid CMVs has also increased after the changes. Mean absolute Error in direction of CMVs compared to the Radiosonde observation however does not show encouraging results. Further efforts are therefore needed to look into this problem. The earlier reported problem of zonalisation of CMVs has now been improved considerably as a result of recent changes in the computation scheme. Overall quality of INSAT-CMVs is good and they fit into the synoptic analysis upper air charts. Hence from qualitative point of view also INSAT-CMVs stand validated.

References:

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TABLE-1

CMV Computation (OLD Scheme)

Mean Absolute Error (RS-CMV)

level	Counts of Co-located CMV's	Direction	Speed kts
Low	179	37.63	16.45
Medium	159	47.32	9.63
High	63	36.01	7.97
Total no of CMVs Co-located with Radio sonde			401
Total no of CMVs Computed			16905
Total no of CMVs Valid			4413
Percent Rejection in Quality Control test			73.6

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CMV Computation (New Scheme)

Mean Absolute Error (RS-CMV)

level	Counts of Co-located CMV's	Direction	Speed kts
Low	306	36.22	10.75
Medium	418	41.27	8.26
High	153	31.58	7.87
Total no of CMVs Co-located with Radio sonde			877
Total no of CMVs Computed			25172
Total no of CMVs Valid			8453
Percent Rejection in Quality Control test			66.4

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TABLE-2

Modification in Computation and Quality Control Parameters

Parameter	Previous Value	Changed Value	Remarks
Grid width	16 IR Pixel/line	14 IR Pixel/line	Search for more tracers
Area	35 degree about SSP	40 degree about SSP	Increase in CMV coverage
Test for Time Consistency			
Low	60 degree	40 degree	tolerance limits made stringent for directional stability
Medium	45 degree	30 degree	
High	30 degree	30 degree	
Forecast test			
Speed	30 knot	20 knot	NHC grid forecast used stringent speed test and relaxation in tolerance for direction with increase of radius for forecast field
Direction	30 Degree	45 degree	
distance	300 km	500 km	
Climatology test			
speed	30 knot	20 knot	Climatology test applied only when forecast grid not available. Limits consistent with the forecast test limits.
direction	30 Degree	45 degree	
distance	300 km	500 km	