ESTIMATION OF LARGE SCALE WIND FIELDS OVER OCEANIC AREAS AROUND INDIA USING INSAT DERIVED CLOUD MOTION VECTORS IN CONJUNCTION WITH SHIP/BUOY DATA AND SCATTEROMETER DATA

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ABSTRACT

The low-level Cloud Motion Vectors (CMVs) derived from INSAT data are useful for estimating sea surface wind and ultimately wind stress over the large oceanic areas within reasonable limits of accuracy. CMVs are compared to ship/buoy observations collected over the oceans and the results indicate that low-level CMVS could be used to estimate surface winds to an r.m.s. accuracy of about 3m/sec in speed and about 30 degree in direction or even better, depending upon wind speed. The auto-correlation coefficients were also calculated to evaluate the consistency in CMVs and the ship data. These results are based on the limited comparison done using the available scatterometer data over the common coverage areas. Study shows the feasibility of estimating large scale wind field over the data sparse oceanic regions using all three data sets i.e. CMVs, ship/buoy and scatterometer. Such type of data sets have potential application for better analysis of synoptic charts during the summer monsoon season which is very important for routine operations.

1. INTRODUCTION

A few improvements have been carried out over the last few years to the INSAT derived Cloud Motion Vectors (CMVs). These have been discussed at length in several papers (Bhatia et al, 1996, Kelkar et al 1993, Khanna et al, 1998 and

Prasad et al 1998). Periodic monitoring reports of ECMWF have also brought out slight improvements in the INSAT derived CMV. RMS errors and the biases in the CMVs have now been found slightly on the lower side. They have also been found to be useful in improving the synoptic scale analysis of weather charts (Bhatia et al, 1996). Considering the effect of seasonal south west monsoon over Indian Ocean on the ocean circulations, an attempt has been made to make use of low level INSAT derived CMVs to study the wind stress over the ocean surface. Particularly during the monsoon season over the Indian seas, availability of surface wind over the large oceanic areas is essential for better understanding of air-sea interactions related to the monsoon circulation patterns. Low level INSAT CMVs have been compared with the wind reports obtained from ship observations and limited number of ocean data buoys deployed over oceanic areas close to the Indian coast line. Surface wind speed data derived over oceans from the ERS-2 scatterometer were also compared with ship observations over Indian Ocean region. Good agreement was found between these two data sets. Hence whenever possible, scatterometer-derived wind speeds were also compared with CMVs. Statistical relationship have been derived which can be used to estimate, within certain bounds of error limits, the ocean surface wind over the areas not covered with ship reports. Large scale surface wind field over the oceans can thus be derived, which is useful for air sea interaction related studies. Similar work has also been reported earlier by Wylie et al (1981) using only ship data and the FGGE data sets collected by GOES-IO during summer MONEX-79 period. This study was, however, done for a very limited period.

2. PERIOD OF STUDY AND DATA USED

Initial studies were done using data for the period January-March, 1998. All the available ship reports and the reports from ocean data buoys being operated by National Institute of Ocean Technology (NIOT), Chennai, were used for this purpose. Observations from data buoys are generally available at 03 hrs UTC and the observations from ships are available every six hours (main synoptic hours of observations). Operational weather charts produced daily at the Northern Hemisphere Analysis Centre (NHAC), New Delhi, plot these data on daily basis. Good agreement is found between ship data and the buoy data, and experience over the last few months shows that both the types of data fit very well on the surface weather charts. INSAT-CMVs are derived thrice a day at 00, 06 and 12 hours UTC and are disseminated daily on GTS. For the present study only 06 hrs UTC CMVs derived with visible channel data were used.

Good results were obtained from the initial studies. The period of study was, therefore, later on extended further to include south west monsoon season of June-September, 1998 when extensive data sets were used for the study. Area of coverage was limited to 40ºS-25ºN and 40ºE-100ºE. In view of the limited swath available from scatterometer, at times the coverage area was extended further beyond the above mentioned bounds of longitude limit so as to find maximum possible number of colocated observations from different platforms. For the purpose of comparison of observations time difference was taken as only 3 hours between buoy observation and CMV observation time. For ship reports, however, precise time coincident observations with INSAT CMVs were used. Spatial co-location was limited to within half a degree between two different methods of observations , except in certain cases where coverage from scatterometer was not adequate. In such cases co-location was extended to a maximum limit of only one degree.

3. RESULTS OF COMPARISONS

In order to derive a reasonably good statistical relationship between low level INSAT - derived CMVs and the wind reported from ships/buoys, a large number of co-located points were chosen during the study period. A total of about 600 comparisons could be done by this method. Cross-correlations were calculated between CMVs and the ship reported winds. For the zonal component of wind, a cross-correlation of 0.75 was found, whereas for the meridional component a cross-correlation of 0.65 was found. All cloud-motions at 850 mb level were also combined into low-level gridded fields using suitable interpolation techniques at the Numerical Weather Prediction Centre (NWPC) functioning in the India Meteorological Department at New Delhi. For the purpose of comparison with ship data, sometimes even this interpolated data were also used. From the wind field data depicted over the charts produced at the NWPC it is noticed that the cloud motion data depict mainly the large-scale flow features over the ocean. It can, therefore, be inferred that the interpolation scheme should not have changed the spatial patterns of the cloud motion analysis.

3.1 Comparisons of wind speeds

The observed relationship between wind speeds measured by ships and cloud motion (Fig.1) shows that cloud motion derived wind speed is generally higher (by about 25%) than the ship/buoy reported wind speed. Separate analysis for the monsoon period also showed that during this period the difference (CMV-ship) is even higher (about 35%). Generally the wind speed at ocean surface is 20% of the wind at the top of frictional boundary layer. Further, during the southwest monsoon season over the Indian Ocean, the wind speeds generally increase with height beyond the top of the frictional boundary layer. One would, therefore, expect a difference of even 30% between CMV and ship reports and the observed results are in general agreement with this physical reasoning.

In order to quantify this relationship a linear regression between the two data sets was fitted using the method of least squares. With this method, however, the scatter of only one variable could be reduced along the regression line. As a matter of fact some finite scatter exists in both data sets and neither of the two is perfectly known because of the inherent limitations of the two methods. Therefore, two independent regressions of the form $Y = A_{XY} X + B$ were calculated. In one regression cloud measurement was taken as independent variable and in the other ship measurement was taken as independent. The best fit regression was taken as mean of the two. The calculated best fit regression relation comes out to be WS(SHIP)+0.65 WS(CLOUD) + 1.4 where "WS(SHIP)" represents wind speed measured with SHIP and "WS(CLOUD)" represents wind speed derived from CMV. Using this relationship, verification was done for a separate two months period when surface wind speed was derived with CMV. Results showed good comparison with actual ship data.

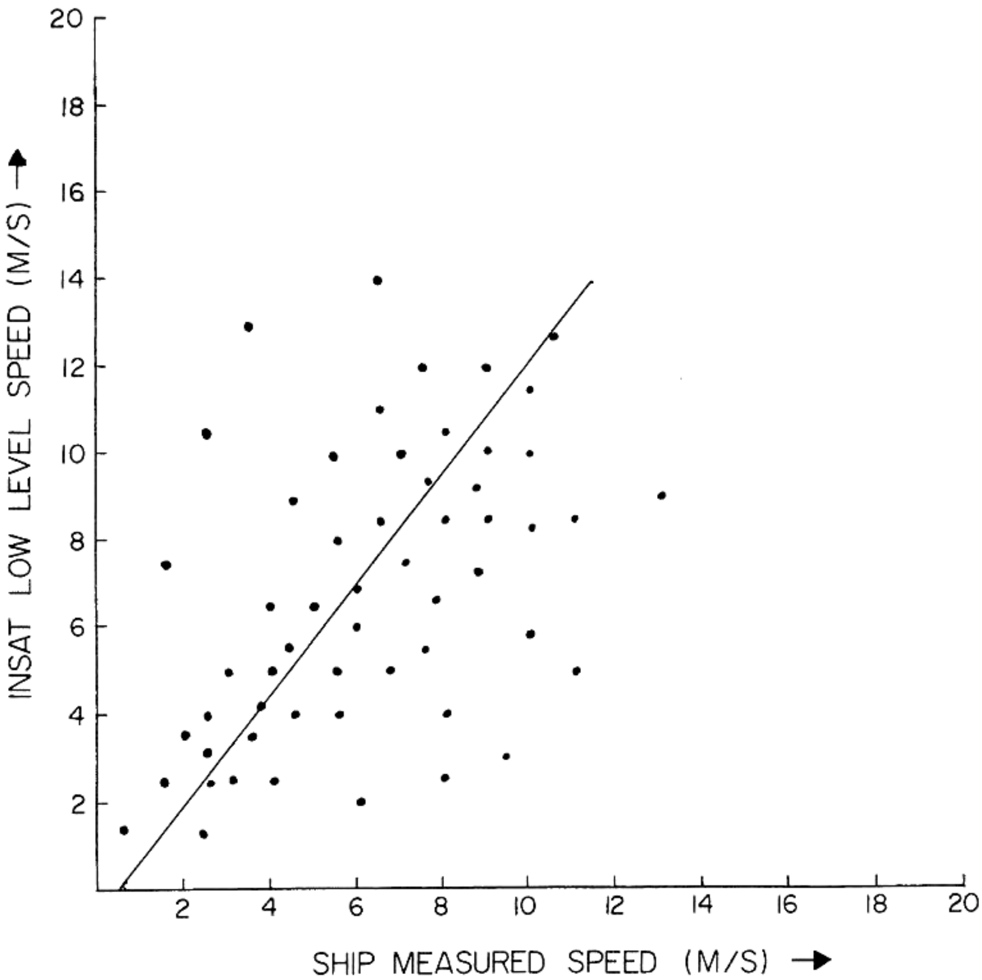

Fig. 1

3.2 Wind direction comparisons

For wind direction, unique relationship could not be found. In general the relationships were found to be more complicated than the speed relationships. For comparison, cloud minus ship observed wind directions were computed, positive differences indicating frictional veering in the northern hemisphere. It was also found that directional differences vary with geographical location. Actual wind speed and direction also influence the directional differences. Hence, for this part of the study, the Indian Ocean was divided into three main areas. The observed winds were also classified into two classes of wind speeds viz., less than 8m sec^{-1} and higher than 8m sec^{-1}. This classification was considered necessary since higher wind speeds are generally found in the strong monsoon areas. During the time before development of monsoon current, lower wind speeds are generally encountered. One of the most important observations to be noted from this data set is that differences are generally smaller for high wind speeds than the low wind speed. This observation is consistent with the physical reasoning since at higher speeds shear in the boundary layer increases as a result of which the turbulent mixing increases thereby diminishing the secondary circulations.

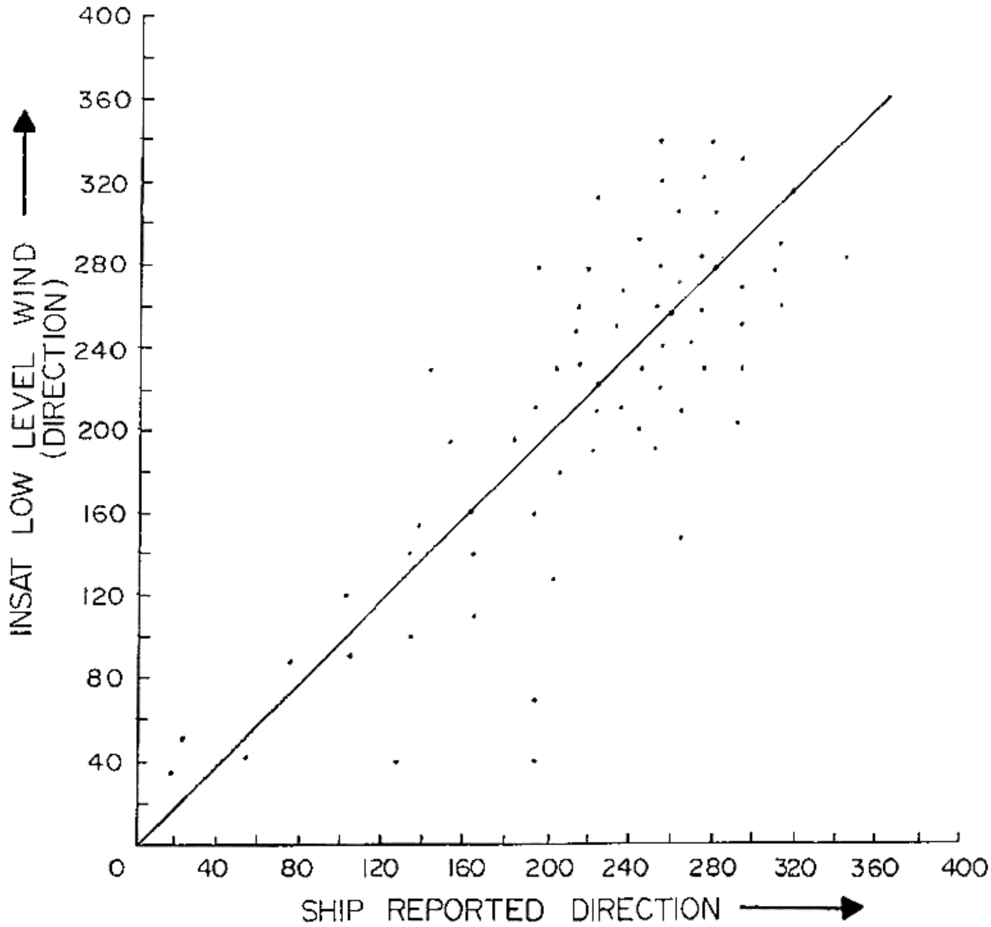

Fig. 2

Frictional veering is also generally indicated in the cloud-ship relationships. For majority of comparisons made, westerly winds were generally observed. It was also found that the scatter in the CMV-ship direction comparisons is generally 25^{o}(r.m.s) for high wind speed areas. For low wind speeds scatter was observed to be much higher (30^{o} to 50^{o}) r.m.s. Scatter plot for wind direction is shown in **Figure-2** corresponding to one particular region of observation over Bay of Bengal.

4. CONCLUSION

INSAT derived low level Cloud Motion Vectors (CMVs) can be used to estimate sea surface winds with reasonable degree of accuracy limits of 30º in direction and 3 m sec^{-1} in speed. This data when combined with other conventional data is found to be of reasonably good degree of accuracy to estimate large scale wind field over the Indian Ocean region. Even by using other conventional methods the present accuracy for measurement of wind speeds over oceans is 1.5-2 m sec^{-1}. It is also found that in general cloud-derived winds have higher spatial correlation than ship-derived winds which is easily explainable from physical reasoning.

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