IMPACT OF INSAT-OBSERVED KELVIN WAVE-TYPE DISTRUBANCES DURING SUMMER MONSOON

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Abstract

In this study, role of equatorial wave disturbances over the tropical Indian Ocean and their linkage in the genesis and intensification of monsoon systems over north Indian Ocean have been investigated. For this purpose, unique features of major cloud clusters of the size extending around 1000-2000 km longitudinally and about 500-700 km latitudinally were examined from satellite observed cloud imagery and CMVs obtained from INSAT satellites during different monsoon seasons for the period 1988 to 2007. NCMRWF, ECMWF and NOAA data have been utilized for monitoring the dynamical changes during the eastward propagation of super cloud clusters over the equatorial Indian Ocean. Influence of these wave disturbances in the form of rhythmic eastward propagation of cloud clusters without loosing their identity have been further investigated for the genesis/intensification of monsoon systems over the north Indian Ocean, particularly over the Bay of Bengal.

It is inferred from the results of our study that in rare cases super cloud clusters are formed over the equatorial Indian Ocean and propagate eastward. They look like Kelvin wave-type disturbances and in INSAT imagery they resemble fairly well with those imageries for super cloud clusters observed by GMS and GOES satellites over the equatorial Pacific Ocean. But over the Indian Ocean they are little bit less in convection and confined to 10° N and 10° S with less pr opagation speed of the order of 5°~7° day. It is further revealed that super cloud cluster developed off Somali coast propagates along the equator and when it passes below Indian peninsula on third and fourth day then there is sudden excitation of strong southwesterly winds at 850 hPa in the domain equator to 10° N and 80° E - 90° E. This 850 hPa wind analysis of ECMWF is modified with inputs of INSAT CMVs resulting in better vorticity and moisture advection over the Bay of Bengal thus supporting for the genesis/ intensification of monsoon systems over the north Indian Ocean.

INTRODUCTION:

Vigorously investigated meteorological subject in the recent years is the role of cumulus convection in large-scale atmospheric circulation. Particularly, in the tropics, cumulus convection is very active and hence it is important to clarify its development, propagation and effects. Presence of a series of equatorial modes was predicted by Matsuno (1966) as the response to the sinusoidal mass input along the equator. Gill (1980) extended his study to the steady response to an equatorial heat source with finite area and obtained a famous “Gill’s pattern”, i.e. the Kelvin wave-type response to the east and the Rossby wave-type response to the west of the heat source. Important research on the role of tropical cumulus convection was the discovery of the atmospheric 30~60 day oscillation by Madden and Julian (1971, 1972). They analyzed the tropical station data and found a prominent wavenumber 1 component propagating eastward along the equator mainly in the upper and the lower level zonal wind component. They also demonstrated insight by suggesting that the 30~60 day oscillation was associated with the zonal march of the Walker circulation accompanied by cumulus convective activities. It was Yasunari (1979, 1980) who showed that the 30~60 day oscillation was associated with cumulus convection. He

measured the brightness of the daily visible mosaic pictures taken by NOAA-2 satellite to obtain the cloudiness and explained how the large-scale cloud systems propagated eastward from the Arabian Sea in the equatorial region in association with the 30~60 oscillation. Y.Y. Hayashi and Nakazawa (1989) showed the existence of the super cloud cluster along the equator in the real atmosphere. They pointed out that the eastward-propagating convective activity associated with the 30~60 day oscillation presented with 5-day mean OLR by Lau and Chan (1986) was a filtered feature of the activity modulation of the eastward-propagating super cloud clusters.

Global observations of atmospheric winds are very essential for atmospheric studies and operational weather forecasting. This is especially true at low latitudes, where the wind field cannot be inferred from the mass field and upper air soundings from conventional network are meager. Observations of wind flow over the oceanic areas are important prerequisite for accurate weather forecasts by numerical weather prediction (NWP) models. India is surrounded by three oceans such as the Arabian Sea, the Bay of Bengal and the south Indian Ocean. Lack of conventional wind data in these areas causes inaccuracy in weather forecasts. Therefore, it is valuable evaluating the impact of satellite-derived winds on objective analysis of the wind field for getting proper depiction of different atmospheric systems over the Indian region.

Here, first of all, utility of satellite-derived AMVs for improving forecast over the Indian region is highlighted in brief. Archiving of satellite derived wind data from INSAT imagery commenced during 1984 at MDUC (Meteorological Data Utilization Centre), New Delhi using automated technique (Kelkar and Khanna, 1986). With subsequent increase in areal coverage of CMVs, interactive quality control procedures were introduced. Some of the earlier investigators carried out impact studies of different observing systems during FGGE period; these observations included satellite-derived observations of winds. Bengtsson et al. (1982) concluded that satellite-derived wind data have significant impact on forecasts in the tropics and are more significant for southern hemispheric circulations than for those in the northern hemisphere. However, Rajamani et al. (1982) illustrated that aircraft/ship data have a bigger positive impact in the analysis than satellite-derived wind data. Utilizing conventional and non-conventional MONEX-79 data over the Indian region, these results were brought out. They also suggested that this could be due to the satellite-derived wind data not being exactly at 850-hPa level, where the analysis was made. Joshi et al. (1987) suggested that the use of satellite-derived wind data at few intermediate levels would lead for the better forecast over the Indian region. Mahajan et al. (1992a) established an empirical relationship between satellite-derived winds obtained from GOES satellite and conventional winds reported by the research ships at different pressure levels. They showed that satellite-derived wind data could be used for the construction of vertical wind profile over the Indian Ocean. In their further study (Mahajan et al. 1992b) they used these winds in objective analysis of the wind field and showed that constructed winds are of potential use for depicting major circulation features over the seas surrounding India. Later, for utilization of INSAT winds they developed (Mahajan et al. 1995) another regression relationship between INSAT winds and the radiosonde winds of island stations over the Indian seas. They used modified INSAT CMVs as an input in objective analysis of the wind field and showed that they are of potential use in depicting better monsoon circulation features over the Indian region.

In this paper, we showed the impact of eastward propagating super cloud clusters on excitation of southwesterly winds over the equatorial Indian region. This has been achieved through inputs of INSAT CMVs in the objective analysis of the wind field at 850 hPa. We also highlighted the role of more moisture and vorticity advection for the genesis/intensification of monsoon systems over the north Indian Ocean, particularly the Bay of Bengal.

DATA:

Visible and Infrared imageries of INSAT satellites for the period 1988-2007 are utilized over the domain 10°N to 10°S and 40°-100°E for observing cases of super cloud clusters propagating eastward over the

equatorial Indian region during different monsoon seasons, for which only super cloud clusters were available. OLR data obtained from NOAA were exploited for seeing eastward propagation of major convection of super cloud clusters on day to day basis. INSAT-derived CMVs were used for giving its inputs in objective analysis of the wind field at 850 hPa. India Meteorological Department's daily data were used for monitoring genesis/enhancement of monsoon systems over the Bay of Bengal region.

METHODOLOGY:

In the period of study, only three super cloud clusters across the equatorial Indian Ocean were observed. The phenomena are clearly displayed using INSAT imageries in Fig.1 showing a case of super cloud cluster during July 1991. Super cloud cluster had the size of about 1000-2000 km in zonal direction and extended from 10° N to 10° S latitudinally. Moreover, int ensity of convection is displayed in Fig.2 through OLR data. In order to examine the cloud activity, the INSAT infrared data prepared by India Meteorological Department were utilized. The domain for this study is considered as 10° N to 10° S and 40° E to 100° E for finding eastward propagation of su per cloud clusters from off Somali coast to the Sumatra coast. Super cloud clusters confining to this domain and typically moving along the equator were studied. Hovmoller diagrams were prepared for all the cases of super cloud clusters observed during monsoon seasons. This was set to observe eastward movement of major convective cells over the equatorial Indian Ocean. During the period of 1988-2007 only three cases of super cloud clusters were observed. Impact of these eastward propagating cloud clusters was examined on the fluctuations of the wind fields at 850 hPa particularly close to equatorial region. For this purpose, objective analysis of the wind field was made considering first guess as the 850 hPa winds of ECMWF reanalyzed winds. Additional inputs of modified winds obtained from INSAT CMVs were exploited in objective analysis of the wind field for the generation of better wind field during propagation of super cloud clusters (Fig.3). This better wind field analysis was used for the computation of vorticity advection over the Indian region. Simultaneously, moisture advection was also computed using NCEP data for the same period. Characteristic features such as sudden strengthening of southwesterly winds from equator to around 10° N was noted under the influence of eastward propagating super cloud clusters. Its impact on genesis/intensification of monsoon system over the Head Bay was also seen through vorticity and moisture advection.

RESULTS AND DISCUSSIONS:

The following are the main results of the study:

- Kelvin wave-type disturbances in the form of super cloud clusters formed over the equatorial Indian Ocean and propagated eastward with the speed of 5°~7° day without loosing much of its identity.

- Only three cases of super cloud clusters were observed over the equatorial Indian Ocean during monsoon seasons for the years 1988-2007.

- During development and propagation of super cloud cluster it was found that when it came south of Indian peninsula on 3rd and 4th day there was sudden excitation of strong southwesterly winds in the domain equator to 10° N and 80° E – 90° E.

- For each case of propagation of super cloud cluster a strong southwesterly wind forcing was generated resulting in maximum vorticity and moisture advection over the Bay of Bengal region.

- On 5th day there was development of low over Head Bay as reported by India Meteorological Department during 1988 and 1991. But during 1995 already low was available from the beginning over Head Bay and on 5th day it was intensified into depression.

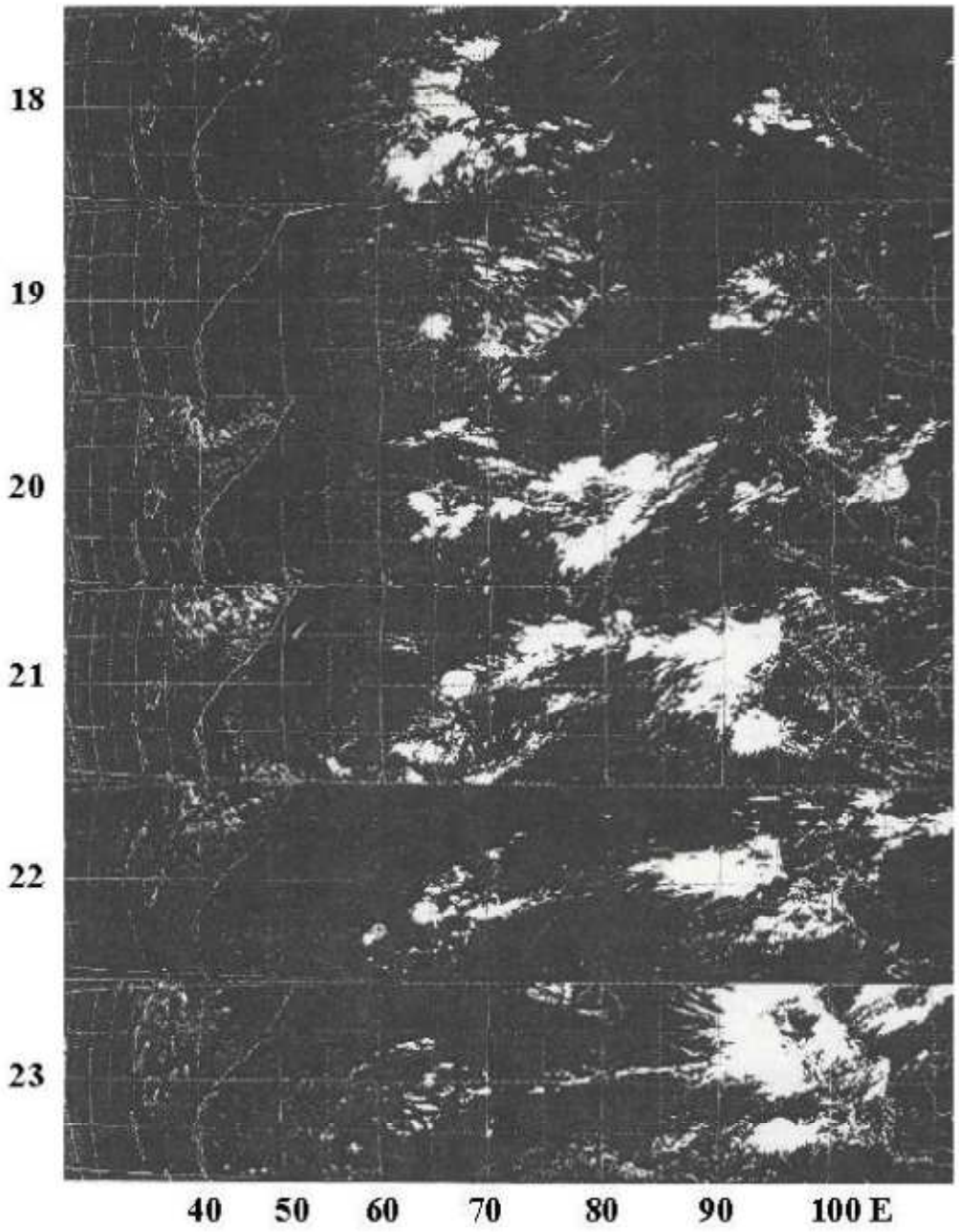

Figure 1: **Daily INSAT pictures associated with super cloud clusters for 18-23 July 1991 from 10º N to 10º S.**

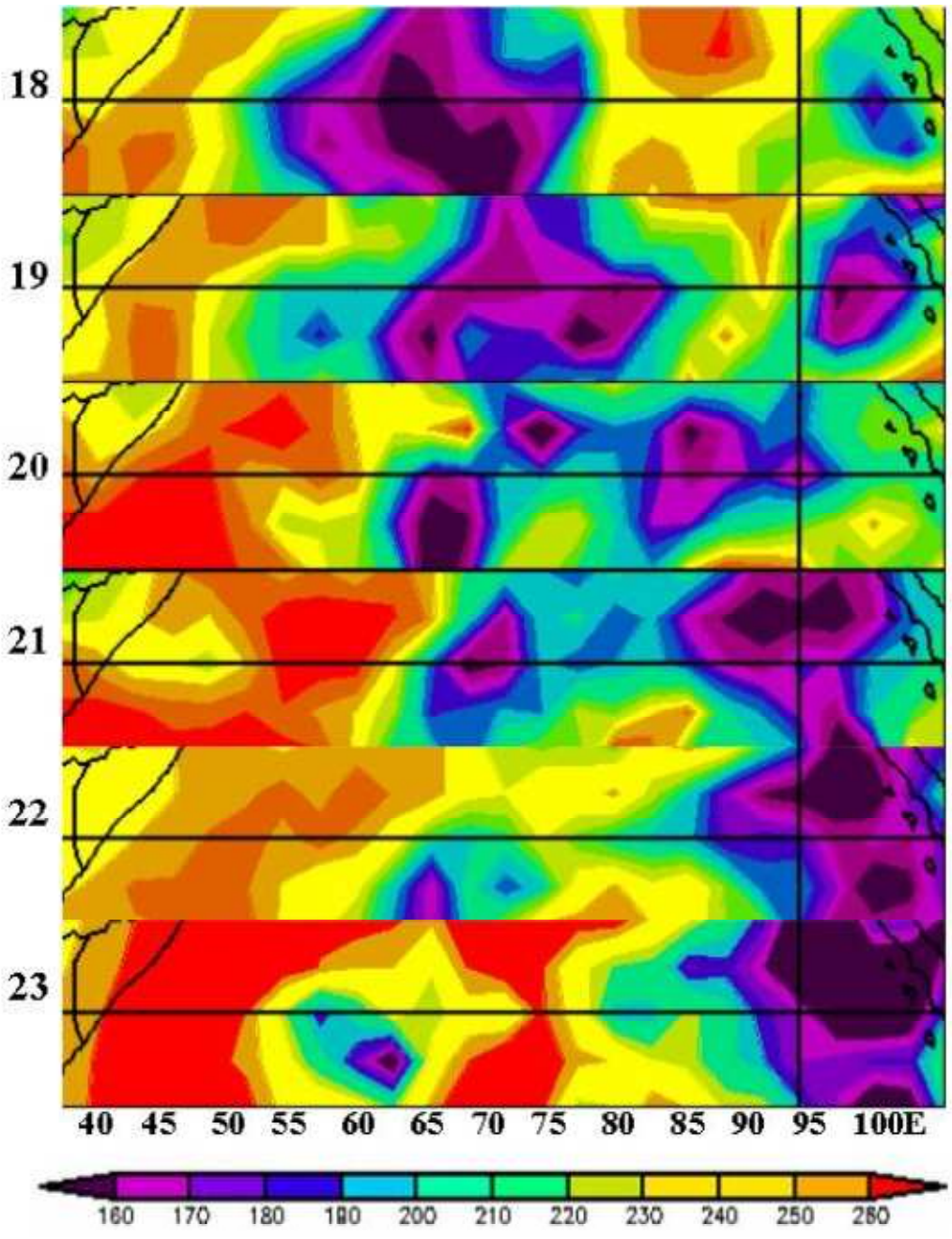

Figure 2: **Daily NOAA OLR analysis of super cloud clusters for 18-23 July 1991 from 10º N to 10º S.**

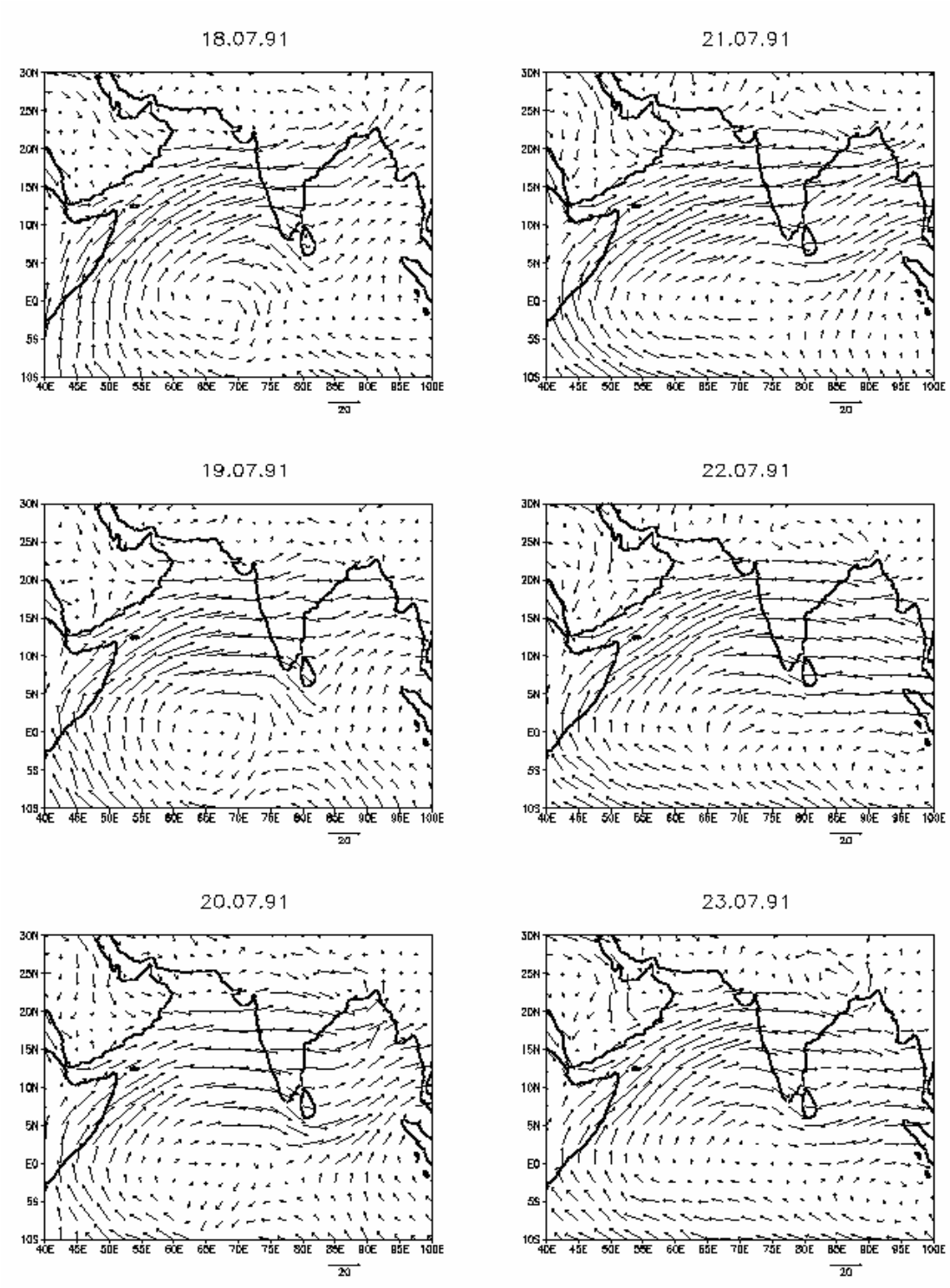

Figure 3: **Objective analysis (OI) of the wind field at 850 hPa with inputs of INSAT CMVs during 18-23 July 1991.**

It is seen that the formation of super cloud clusters over the equatorial Indian Ocean are mainly associated with low pressure system propagating eastward. It may not be like the super cloud clusters that are developed over the equatorial Pacific Ocean which show eastward and westward propagation response of cloud cells like Kelvin wave type and Rossby wave type. With the passage of super cloud clusters over the equatorial Pacific Ocean there is increase in westerly winds at 850 hPa observed in almost all the cases of these super cloud cluster movements. Propagation speed of these clusters is of the order of 10°~12°/day. Super cloud clusters over t he equatorial Indian Ocean have less propagating speed i.e. 5°~7°/day and they don't even keep the sa me entity and major convection throughout propagation. Here, Kelvin wave-type disturbances cause sudden trigging of southwesterly winds on 3rd and 4th day when they pass below Indian peninsula region. We get strong westerly wind at 850 hPa over the equatorial Pacific region during eastward propagation of super cloud clusters and don't get southwesterly wind forcing over that region. This is because over the Pacific region of 10° N and 10° S no land region or any high pressure cell is dipping down in that region during summer monsoon season. But over the equatorial Indian region southern tip of Indian peninsula is dipping down with near conical high pressure isobar within 10° N and 10° S.

Generally during monsoon period we do get maximum pressure conical isobar (1010 mb) just below Indian peninsula and it remains of the same intensity throughout monsoon season. Whenever super cloud cluster passes below this high pressure conical shaped isobar then suddenly pressure gradient develops between peninsular region and super cloud cluster region. This causes sudden establishment of strong southwesterly winds starting from equator to 10° N and 80° E to 90° E. This affects more vorticity and moisture advection over the Bay of Bengal making suitable condition for the genesis of low over Head Bay. If low is already available over the Head Bay then it intensifies into depression because of this strong southwesterly wind forcing. In our study we could get proper enhanced forcing with additional inputs of INSAT-derived CMVs in objective analysis of wind field at 850 hPa.

CONCLUSION:

In this study Kelvin wave-type disturbances in the form of super cloud clusters propagating eastward over the equatorial Indian Ocean are studied during monsoon seasons for the period 1988 to 2007. Sudden establishment of strong southwesterly wind forcing is generated under the influence of the super cloud clusters supporting the genesis/enhancement of monsoon system over the Bay of Bengal region.

ACKNOWLEDGEMENT:

The authors wish to thank Prof. B.N.Goswami, Director, Indian Institute of Tropical Meteorology for providing facilities and keen interest in the study.

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