

of the specific humidity is very small. The y- components of the wind are smaller than the x- components, and the variance of x- components of the wind (not shown) are very similar the variance of the total wind speeds. At the west side of each cloud cluster, the strong surface westerly prevail up to the eastern edge of the super cluster. This is also pointed out by Nakazawa. The areas of large evaporation correspond to the areas of strong surface westerlies. Thus, it is concluded that evaporation is determined almost by the intensity of surface winds. Summarising the above features, the fluctuations of 2000 km and a few days are well represented in the evaporation field of ECMWF data.

8.4.6 Remarks

An evaluation of ECMWF latent heat flux from the data on the TOGA CD-ROM has been conducted for the monthly time scale and the synoptic scale. The ECMWF evaporation data was compared with Japanese Meteorological Agency model generated estimates and climatological estimates, and it is shown that the spatial distributions are similar in these estimates. But there are quantitatively large differences, especially over the Pacific ocean in the summer hemisphere.

For the synoptic time scale, we found that 1000-2000 km scale fluctuations relating the tropical disturbances is well represented there. This variation of evaporation is determined by the variation of the wind fields. The wind variation generated by models was reliable, which was indicated by the comparison with independent wind observation. In other words, such tropical disturbances can be well represented in the model. The model's estimates of latent heat fluxes are qualitatively useful for studying these disturbances.

Finally, the ECMWF latent heat fluxes have obviously weak biases in the tropics, comparing with other estimates. However, these biases are improved recently. The reliable data for a longer period is necessary for climate studies. Reanalysis by the recent model is indispensable for climate studies.

8.5 Air sea interaction during summer monsoon period of 1979

M R Ramesh Kumar

8.5.1 Introduction

The southwest monsoon or the summer monsoon plays a major role in the economy of an agricultural country like India as about 60% to 90% of the annual rainfall for the various meteorological sub-divisions is received during this period (June to September). Recognising its importance, it was made a sub-program of the First GARP Global Experiment (FGGE) conducted during 1979.

The Indian Ocean differs significantly from the other major oceans because of the exceptionally strong air sea interaction processes taking place during the monsoon months in the form of exchange of heat and momentum fluxes. These large scale processes affect the evaporation rates which in turn influence the net

water vapour transport into the Indian subcontinent. There are conflicting theories regarding the source of moisture for the summer monsoon rainfall, with one school supporting the Arabian Sea and the other the southern Indian Ocean. The inadequate surface and upper air observations over the oceans was one of the major reasons for the above controversy. In the present study we have used the satellite data from a variety of sensors like AVHRR for Sea surface temperature; SMMR for Precipitable Water, (PW) and Visible and IR imageries for the *cloud motion vector* (CMV) winds from GOES satellite data, along with the available surface meteorological observations over the Indian Ocean, for obtaining more information about the various air sea interaction processes involved in the monsoon dynamics.

8.5.2 Data and methodology

The summer monsoon season of 1979 was one of the poor monsoon rainfall years with most of the meteorological sub-divisions in the country receiving deficient rainfall. Furthermore, the onset of the summer monsoon was delayed by about two weeks (the onset took place on 12th June 1979) as compared to the normal onset date of the first of June. The 1979 summer monsoon also had the largest break in monsoon conditions, of about three weeks.

The sea surface temperature data needed for the present study has been extracted from the Global Operational Sea Surface Temperature Computational (GOSSTCOMP) charts prepared by NOAA for the period May to September 1979. The zonal anomaly of SST then has been computed following Ramesh Kumar et al. (1986).

During 1979 the Goes satellite was specially repositioned at 58° E to provide meteorologists an opportunity to view the monsoon circulation over the Indian Ocean for the first time. The CMV winds used in the present study have been extracted from the atlas prepared by Young et al. (1980). It provides vast amount of information about the wind field over the Indian Ocean on a synoptic scale for individual days for both the lower and upper tropospheric levels. The precipitable water needed for the present study has been derived from the SMMR data of the Nimbus-7 satellite. The Scanning Multichannel Microwave Radiometer (SMMR) has two channels closely spaced at 18 and 21 GHz. The difference between the brightness temperature in these two channels yields a measure of water vapour in the atmosphere. The Nimbus-7 SMMR data has some systematic calibration bias. Prabhakara et al. (1982) have found that this bias is less for vertical polarisation compared to the horizontal polarisation. Hence, in this study, we have used the vertical polarisation for deriving the precipitable water values for the study period.

The Indian National Satellite (INSAT) series provides data on CMV winds over selected regions, Outgoing Longwave Radiation and Quantitative Precipitation Estimates over the tropical Indian Ocean on an operational basis from 1987 onwards. The annual water vapour flux divergence over the Indian Ocean has been computed as the difference between evaporation and precipitation following the equation of conservation of water. We have used the mean annual evaporation rates over the tropical Indian Ocean from Ramesh Kumar and Rao (1990). The annual

precipitation values over the tropical Indian Ocean have been obtained from the INSAT data. The INSAT has a Very High Resolution Radiometer (VHRR) working in the 10.5 - 12.5 μm . It is this channel which is used for deriving the quantitative precipitation estimates. Vinayachandran and Ramesh Kumar (1990) have validated the satellite derived precipitation values with the observed island rainfall data of two stations (Amini and Minicoy in the Laccadive group of Islands in the Arabian Sea) and have found that the percentage differences between them varied from 1 to 44% with a mean value of about 25%. The annual water vapour flux divergence over the tropical Indian ocean showed that in the eastern Indian ocean and Bay of Bengal in particular, there is a large scale convergence of moisture.

The surface meteorological parameters like sea surface temperature, dew point temperature, wind speed, cloudiness etc. needed for the present study has been extracted from the Indian Daily Weather Reports. The evaporation rates (E) over the study area (the Arabian Sea) has been computed following Sadhuram and Ramesh Kumar (1988) using the above data. The rate of precipitation over the study area has been computed from the above E values and the net moisture flux divergence from Murakami et al. (1984).

8.5.3 Results and discussion

An analysis of the GOSSTCOMP charts along with the zonal anomaly charts for the period May to September 1979 shows the following features:

- (a) An analysis of SST charts in the month of May shows weak temperature gradients in the Arabian Sea and Bay of Bengal. The SSTs started falling with the onset of the summer monsoon whereas the weak temperature gradient prevailed over the tropical Indian Ocean indicating weak surface winds throughout the season.
- (b) An analysis of the zonal anomaly of SST during the onset phase does not show any significant features, see Fig. 8.9(a). The active monsoon conditions as in Fig. 8.9(b), clearly reveal the upwelling features off Somali and the Arabian coasts are of a lesser extent compared to a good monsoon year. Also, the east to west temperature gradient is also less (more) in comparison to a poor (good) monsoon year (Ramesh Kumar et al. 1986).

The CMV wind data used in the present study has been extracted for three regions in the axis of the Somali Level Jet. They are (a) Arabian Sea (10° to 13° N; 58° to 60° E) (b) Equatorial Area (2° N to 2° S; 40° to 43° E) and (c) Indian Ocean (10° to 13° S; 50° to 53° E). A time series analysis of the wind speeds in the above three areas revealed that the maximum variations occur in the Arabian Sea and Indian Ocean region compared to the equatorial area. An interesting feature observed in the month of June is the establishment of the low level jet off the Somali coast on 9th June and the monsoon onset over the Kerala coast on 12th June, with a lag of 3 days. This result agrees well with the study of Cadet et al. (1981) who after studying the trajectories of constant level balloons suggested that the low level jet/air flow crossing the equator takes about 3 to 4 days to reach the Indian coast. Figures 8.9(c) and 8.9(d) depict the lower tropospheric wind flow during the

onset and active monsoon conditions. A combined analysis of the zonal anomalies of SST with the lower level tropospheric winds shows that there is not a one to one correspondence between the two parameters.

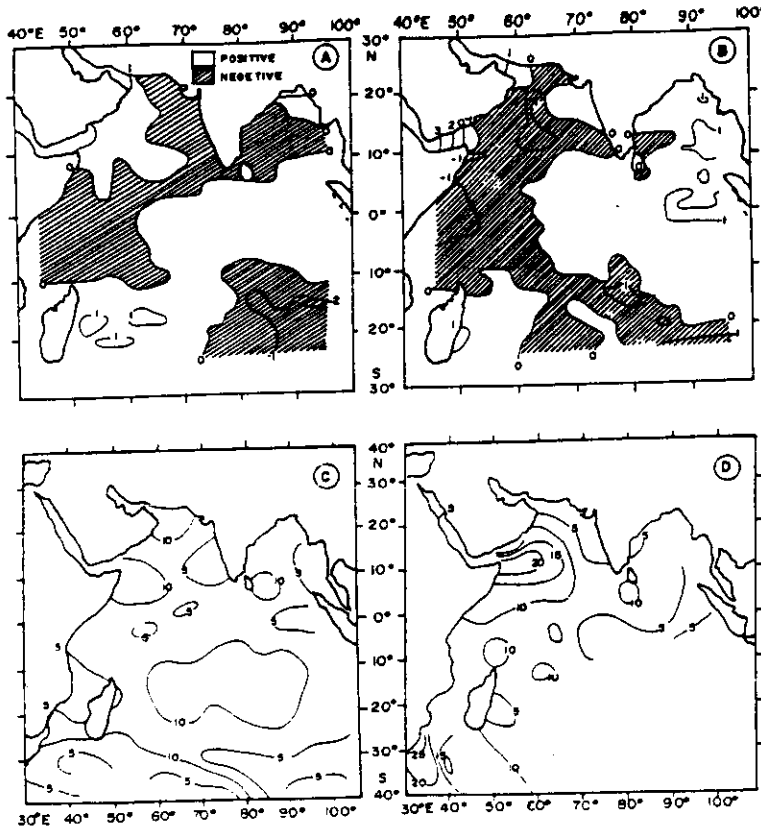


Fig. 8.9 Zonal anomaly of SST (a) on 12-6-1979; (b) on 24 -7-1979, Low level CMV winds (ms^{-1}); (c) on 12-6-1979; (d) on 24-7-1979.

An analysis of the evaporation rates over the Arabian sea shows that the rate of evaporation decrease gradually with the onset of the monsoon with a sharp fall in values from July to August. This fall could be due to an overall decrease in the surface wind fields. An interesting result is that the precipitation rates are closer to evaporation rates and they almost balance each other. The overall values of evaporation and precipitation are 2.78×10^{10} tons and 2.21×10^{10} tons respectively (Sadhuram and Ramesh Kumar, 1988). This shows that about 80% of the evaporation is used for precipitation. Hence, we feel that the contribution of moisture from the Arabian Sea for the summer monsoon rainfall is minimal. A recent study of Ramesh Kumar and Sastry (1990) has shown that the evaporation rates over the Arabian Sea on a seasonal scale is the same during a good or bad monsoon composite.

The distribution of precipitable water over the tropical Indian Ocean has been studied for the period May to September, 1979. We have derived the maps of

precipitable water on a fortnightly and monthly basis. These maps are presented in the study of Ramesh Kumar et al. (1992). Here we are depicting only four maps representing the premonsoon onset, active and withdrawal phases (Figures 8.10(a), (b), (c) and (d) respectively). In an earlier study Prabhakara et al. (1982) have shown that there is good agreement between SMMR derived precipitable water and that obtained from the ship's radiosonde measurements, with an rms error of only 0.25 g cm^{-2} .

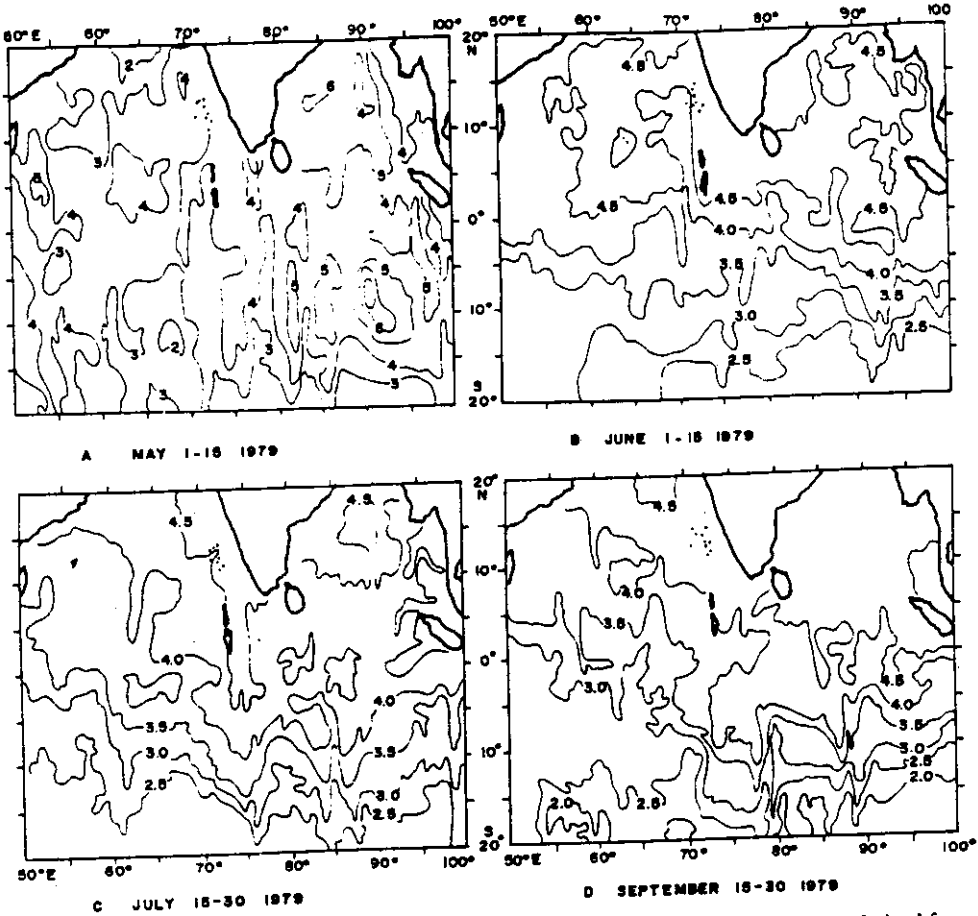


Fig. 8.10 Distribution of precipitable water (g cm^{-2}) in the atmosphere over the Indian Ocean derived from Nimbus 7 SMMR data for the period.

An interesting feature in Fig. 8.10(a) is the minima of PW in the northern Arabian Sea in the premonsoon month of May (1-15) of about 2 g cm^{-2} which almost doubles with the onset of southwest monsoon to about 4.5 g cm^{-2} , as shown in Fig. 8.10(b). These higher values of precipitable water persist throughout the monsoon season in the Arabian Sea. Another feature observed in the Bay of Bengal is the decrease of precipitable water values from premonsoon season (of the order of 5 to 6 g cm^{-2}) to lesser values with the progress of the southwest monsoon.

8.5.4 Summary

The present study highlights the utility of satellite derived parameters like SST, precipitation, CMV winds in the lower troposphere etc. in supplementing the in-situ observations. This information can lead to a better understanding of the monsoon circulation and features like onset, active and withdrawal phases of the summer monsoon. Some of the findings of the present study are the following:

1. The establishment of a Low Level Jet off the Somali coast can be used for accurately predicting the onset of the summer monsoon over the Kerala Coast.
2. The weak zonal anomalies of SSTs off the Somali and Arabian coasts and the weak temperature gradient prevalent throughout the monsoon season in the Arabian Sea, Bay of Bengal and Indian Ocean are associated with the weak monsoon activity/ rainfall over the Indian subcontinent.
3. The annual water vapour flux divergence estimated over the tropical Indian Ocean shows large scale low level convergence of moisture in the Bay of Bengal.

It is further proposed to study these aspects in greater detail using more data like outgoing long radiation data from INSAT, Water Vapour and surface winds from SSMI.

8.6 Study on air sea interactions in the OMLET

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8.6.1 Introduction

In the ocean, the uppermost layer is influenced strongly by air sea interactions. The layer changes in a period of hours to a few days. The dynamics of this layer is directly related to the air sea fluxes, e.g. radiation fluxes (short wave and long wave) and turbulent fluxes (latent and sensible heat fluxes and momentum flux). For example, a daily thermocline, which is driven mainly by the solar radiation, has a typical time scale of a day and a depth scale of a few tens of meters.

For conventional oceanographic observation methods, using ships and buoys, it is quite difficult to capture spatial variabilities of the physical parameters associated with the air sea fluxes, such as cloud, wind and sea surface temperature (SST).

Generally speaking, satellite remote sensing has characteristics of a wide coverage, frequent regular observation and a high spatial resolution, though the characteristics are different for each of the sensors. The satellite sensors used in the present study have an observation frequency of more than twice in a day, and coverage of a few thousands square kilometres. Although the physical parameters derived from the satellite remote sensing need to be validated carefully by comparing the in-situ measurement, the above mentioned advantages are useful for the air sea interaction research in a wide ocean.

In the present study, the air sea interaction in the OMLET area south of the