Global distribution of double cloud bands over tropical oceans

By K. R. SAHA

Indian Institute of Tropical Meteorology, Poona-5, India

(Manuscript received 31 August 1972; in revised form 14 February 1973)

SUMMARY

Available observational evidence regarding occurrence of double cloud bands, one in each hemisphere, over tropical oceans is reviewed. An examination of their locations appears to suggest that these may be related to maxima in ocean surface temperature. Significant asymmetry and discontinuity are noticed over areas which are affected by cold ocean currents and monsoons.

1. OBSERVATIONAL EVIDENCE

During the last quarter century or so, there have been occasional references in literature to the occurrence of double cloud bands in the tropical zone, although definitive information regarding their origin, nature and locations relative to the Equator in different regions has been rather scanty. The earliest reference appears to be that of Fletcher (1945) who cites aircraft reports of frequent occurrence of double cloud lines, one on each side of the Equator, in equatorial eastern Indian Ocean during autumn through spring. Recently, after the introduction of meteorological satellites, double cloud bands have been observed in other parts of the Tropics as well. Fletcher’s original reports relating to the equatorial eastern Indian Ocean have been confirmed (Saha 1971). Similar double cloud bands have been observed in equatorial western Pacific. Kornfield and Hasler (1969) find evidence of occasional appearance of a feeble cloud band a few degrees south of the Equator in equatorial eastern Pacific during northern late winter and spring. Hubert, Krueger and Winston (1969) present maps of seasonally – averaged cloudiness, based on ess-3 and ess-5 brightness data relating to the Tropics during 1967 – 68, which show, inter alia, the presence of two bright cloud bands in the southern oceans, one in the Pacific and the other in the Atlantic. A global atlas of relative cloud cover, 1967 – 70, based on photographic signals from meteorological satellites, by Miller and Feddes (1971) gives, inter alia, monthly, seasonal, semi-annual and annual charts of tropical cloudiness. Fig. 1, adapted from the last-mentioned publication, shows the approximate mean locations of double cloud bands over tropical oceans, as observed from space platforms, during February and August. In both parts of the map the thick continuous lines indicate cloud bands which are prominent in intensity and have high frequency of occurrence whereas thin continuous lines show those that are feeble and rather unstable in character and have comparatively low frequency of occurrence.

Fig. 1 would appear to reveal the following salient features of the locations of the cloud bands:

(i) Double cloud bands are characteristic features of all tropical oceans;
(ii) The cloud bands do not cross the Equator in any region;
(iii) The intensity of the cloud bands generally varies with the seasons, the summer hemispheric band being the more intense.
(iv) In some regions such as the equatorial western Pacific, the cloud bands in both the hemispheres lie close to and are more or less parallel with the Equator. In equatorial eastern Indian ocean, the cloud bands during February also lie close to and more or less parallel with the Equator. In the Atlantic and the eastern Pacific, while the northern hemispheric cloud band lies close to and more or less parallel with the Equator, the southern hemispheric cloud band is displaced from the near-equatorial position and lies oblique to the Equator.
Figure 1. Maps showing approximate mean locations of double cloud bands over tropical oceans during February and August. Thick continuous lines represent bands which are well-developed, stable and have high frequency of occurrence and thin continuous lines those that are feeble, unstable and have low frequency of occurrence. Stippled areas have surface temperatures lower that 26°C. Dashed lines show axes of maximum ocean surface temperature. Ocean currents are indicated by arrows. Hatched regions are those covered by monsoon clouds.
(v) The continuity of the cloud bands in both the hemispheres is broken over some oceanic regions. Prominent among these regions are south-eastern Pacific, south-eastern Atlantic and western Indian ocean especially the western Arabian sea.

(vi) In the monsoon regions, while the cloud band in the summer hemisphere is attracted to the continental landmass, that in the winter hemisphere shifts little from its near-equatorial position. The cloud bands are thus widely separated from each other. These effects are most prominently seen in the regions of the summer monsoon of Asia and Australia.

2. Relationship with mean ocean surface temperature

The locations of the double cloud bands shown in Fig. 1 were examined in relation to distribution of mean surface temperatures over tropical oceans (Defant 1961). In Fig. 1, areas with surface temperatures lower than 26°C are stippled. In the present study, these areas are treated as cold oceans. In the tropical Atlantic and the Pacific oceans, the cold oceans are intimately linked with major ocean currents. The cold ocean currents shown in Fig. 1 are the Peruvian and the Californian currents in the eastern Pacific, the Canaries and the Benguela currents in the eastern Atlantic and the interhemispheric Somali current in the Indian ocean. Fig. 1 also shows the lines passing through maxima in ocean surface temperature (dashed lines), also taken from Defant (1961).

Data presented in Fig. 1 would seem to bring out the following interesting relationships:

(i) Double cloud bands occur, as a rule, over the warm oceans only. Their locations appear to correlate very strongly with maxima in ocean surface temperature.

(ii) In general, cloud bands in both the hemispheres appear to lie on the poleward side of the line of maximum ocean surface temperature.

(iii) Over the equatorial western Pacific where the maxima in surface temperature lie on or close to the Equator, two distinct cloud bands one on each side of and almost paralleling the Equator appear during both February and August. Similarly-located double cloud bands appear over equatorial eastern Indian Ocean during February.

(iv) There appears to be only a slight seasonal variation in the locations and intensities of the northern hemispheric cloud bands in the Pacific and the Atlantic. The cloud bands appear to be anchored to the lines of maximum ocean surface temperature. However, the locations and intensities of the southern hemispheric cloud bands vary considerably with the seasons. They are prominent during February but feeble during August. In fact, the cloud band in the south Atlantic practically disappears during August with the disappearance of a well-defined maximum in surface temperature.

3. Asymmetry and discontinuity over cold oceans

Fig. 1 shows that the cloud bands in both the hemispheres exhibit marked latitudinal and longitudinal asymmetry. They also disappear over some parts of the oceans. A study of the locations of the cloud bands in relation to equatorial distribution of ocean surface temperature shows that large asymmetry occurs over oceans which are dominated by cold ocean currents and that the nature and extent of asymmetry depends largely upon the disposition of the ocean currents. Large asymmetry is introduced by the Peruvian current in the eastern Pacific and the Benguela current in the eastern Atlantic, both of which are of southern hemispheric origin. Over these parts of the oceans, the cloud bands are highly displaced from their near-equatorial positions with the result that they lie oblique to the Equator. In fact, where the cold ocean currents maintain extremely low temperatures such as in south-eastern Pacific and south-eastern Atlantic, no cloud bands appear with the result that there are major discontinuities in the southern hemispheric cloud band over these parts of the oceans.

During February, the main discontinuities in the northern hemispheric cloud band arise over the western Indian ocean and the extreme western Pacific where the equatorial
oceans are generally cold during this period. As mentioned above, the major discontinuities in the southern hemispheric cloud band during this month occur in south-eastern Pacific and south-eastern Atlantic. The cloud band appears to have a complex structure in the Australian monsoon region.

During August, a major break in the continuity of the northern hemispheric cloud band occurs over the western Indian ocean where the Somali current maintains low surface temperature. The structure of the cloud band over south Asian region becomes complex due to monsoon. Major break in the southern hemispheric cloud band over south-eastern Pacific continues during August. No cloud band appears over southern Atlantic during August.

4. Conditions over monsoon regions

In the monsoon regions, cloud distribution is rather complex exhibiting poor organization in the distribution of clouds or cloud groups in the form of any cloud band. In fact, large areas are covered by convective clouds or cloud groups. In the Asian monsoon region, these areas over the oceans are roughly shown by hatching in Fig. 1. During February, the line of maximum ocean surface temperature lies south of the Equator and in the Australian monsoon region it moves to a position near the coast of Australia. During this period, practically the whole of the oceanic area between the Equator and the north Australian coast is covered by monsoon clouds and cloud groups. This is in marked contrast with condition in equatorial eastern Indian ocean where two symmetrically-placed cloud bands appear close to and on either side of the Equator during this month.

During August, the northern hemispheric cloud band over the Indian ocean appears to be attracted towards the landmass of Asia, while a feeble cloud band remains south of the Equator where the equatorial ocean is warm. But here also, the situation is complicated by the monsoon conditions and there is lack of organization in the form of any distinct cloud band over the northern oceans including the Arabian sea, the Bay of Bengal and the extreme western Pacific. Large cloud groups or cloud clusters some of which may cover millions of square kilometres of ocean space appear over the whole region. The situation is further complicated by the Somali current which maintains a cold ocean surface in the western Indian ocean especially in western Arabian Sea west of about 65°E. It is noteworthy in this context that the northern hemispheric cloud band over the Indian region has a sharp cut-off at longitude about 65°E.

In the African monsoon region, a single cloud band appears over the eastern Atlantic north of the equator during both February and August. Although the equatorial eastern Atlantic becomes warm during February, no near-equatorial cloud band south of the Equator has been reported over this part of the ocean so far.

5. Conclusion

The present study appears to suggest that the occurrence of double cloud bands over tropical oceans may be much more general than thought previously. However, considerable degree of zonal and meridional asymmetry in the location of the cloud bands is introduced by cold ocean currents and monsoons. As a rule, cloud bands do not appear over cold oceans and their structure appears to be complicated by monsoon influences.

References
