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Clouds over Arabian Sea during winter

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ABSTRACT. Satellite pictures over Arabian Sea off Arabia coast show more or less semi-permanent cloudiness during winter season between 10°-20°N. An attempt has been made to explain the cloudiness in terms of surface and upper air data available in the region.

1. Introduction

Southwest Asia and the Arabian Sea provide a challenge to the meteorologists because of the general lack of meteorological observations in those regions.

Weather satellites are useful in the studies of data-sparse regions, and understanding the weather in the tropics.

Satellite pictures show persistence of clouds of similar nature over the west Arabian Sea off the Arabian coast during the winter. The formation of these clouds as seen from the satellite pictures (Fig. 1) appears to be from about 20°N between 60°-65°E and spreading towards southsouthwest and south off Arabian coast. These clouds appear in small packed cells often in bands in the north increasing in size and placed quite apart towards south.

2. Data

These clouds are seen persisting for many days during winter more or less over the same area of the Arabian Sea leaving cloud-free area towards north and west off the Mekran and Arabian coasts respectively. Such types of clouds very rarely occur over the Bay of Bengal during winter. It has already been mentioned that the area under consideration is generally lacking in data especially in the upper air. As such, there is no other alternative except to examine the available climatological data and the few radiosonde ascents available for the I.I.O.E. period.

3. Discussion

During I.I.O.E. period in November and December 1963, *Anton Brun*, a research vessel of U.S.A. had conducted radiosonde ascents over the north Arabian Sea. Of these, a few ascents are available over the area in which we are interested. Though these ascents are spread over two months, they are very important in this data-sparse region. As these ascents happen to be at 1200 GMT, diurnal variations in temperature and morning inversions are avoided. Though these ascents reached above 100-mb level, moisture values are available upto 700 mb only. Generally the northeasterly monsoon commences in the Arabian Sea and on the west coast of India in October and continues to blow from more or less a northerly direction upto April. The period when dry winds blow from the continent of Asia can be divided into two : January to February with comparatively low temperatures and March to April with high and increasing temperatures. It is presumed that the same atmospheric conditions as seen in the tephigrams of November and December months would prevail throughout the winter season over the north Arabian Sea.

Two tephigrams of interest are shown in Figs. 3(a) and 3(b). These refer to 4 and 5 November 1963 south of 20°N between 60—65°E. They show that there is a marked inversion in the lower levels between 1000-900 mb ; considerable decrease of mositure in the inversion layer and slightly superadiabatic lapse rate below the inversion. It is also seen that the air is dry above the inversion layer. Tephigrams off the west coast of India do not show any marked inversion at lower levels like the coastal stations. For instance the tephigram of 6 December 1963 at 23°N (Fig. 3c) does not show any inversion in the lower layers of the atmosphere. Though these ascents have been taken in days spread over more than a month, they are valuable in the absence of any other data in understanding the atmosphere over north Arabian Sea. During winter months the predominennt flow of air is from north to south over the Arabian Sea. During this period, on an average 6 to 7 western disturbances (Rao and Srinivasan 1966) per month of all intensities move eastwards across Iran and induce a surge of cold air over Arabian Sea in their

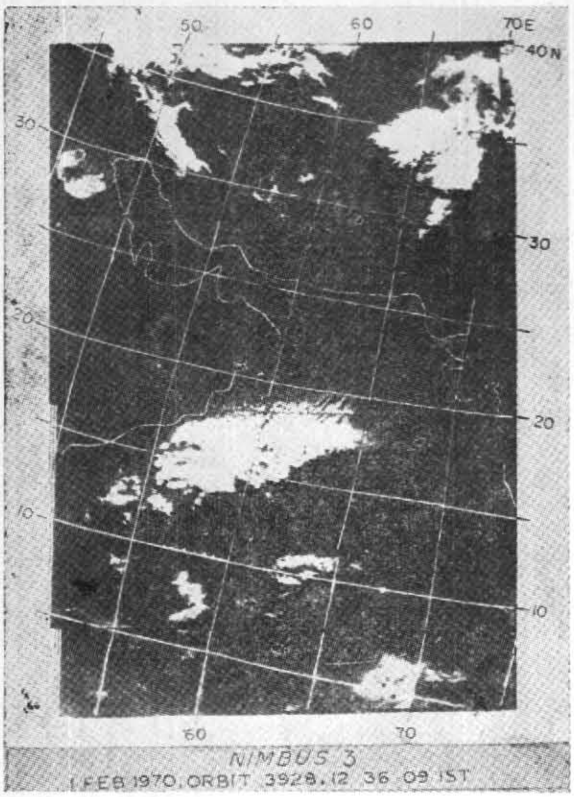

Fig. 1

rear. The invasion of cold air is more frequent over the Arabian Sea than over the Bay of Bengal. Most of the western disturbances dissipate over the U.P. hills and a small number of them with lesser intensity may reach the eastern parts of the country. The Himalayas are also, no doubt, as it is known, playing a prominent role in preventing the cold air from invading the Bay of Bengal.

Abrupt modifications take place in continental polar air when it crosses an extensive warm water surface. Cold dry air passing over the warm sea area has capacity to absorb more mositure. The air moving into lower latitudes becomes warmer and and hence its moisture-retaining capacity increases, reducing the possibility of precipitation.

It is seen from the mean isotherms of air and sea surface prepared by Netherlands Meteorological Institute (*see* Ref.) for January and February over Arabian Sea and Bay of Bengal (Figs. 2a and 2b) that the north Arabian Sea is warmer than air over it by about 1-1½°C. An isothermal high also exists along the west coast of India and a low along the Arabian coast. It can also be noticed that sea is warmer than air over north Bay of Bengal also but the Arabian Sea is colder than the Bay of Bengal. The difference between air and sea surface temperatures is more over the Arabian Sea and less over the Bay. But during February over north Arabian Sea the difference between air and sea surface temperatures is less than in January. Stations along the Mekran coast show lower temperature than over north Arabian Sea but Gujarat coast is as warm as the sea.

Analysing the IIOE data for January 1963 Suryanarayana and Sikka (1965) showed that maximum evaporation from the sea surface occurs along 17°N between 60-65°E over west central Arabian Sea and is higher than that over Bay of Bengal in the same month. Venkateswaran (1956) showed that there is maximum evaporation over Arabian Sea during the period December to February off Somalia coast with higher evaporation area running from Somalia to Konkan coast through central Arabian Sea. He also showed that the evaporation over Bay is less than over Arabian Sea during the same period.

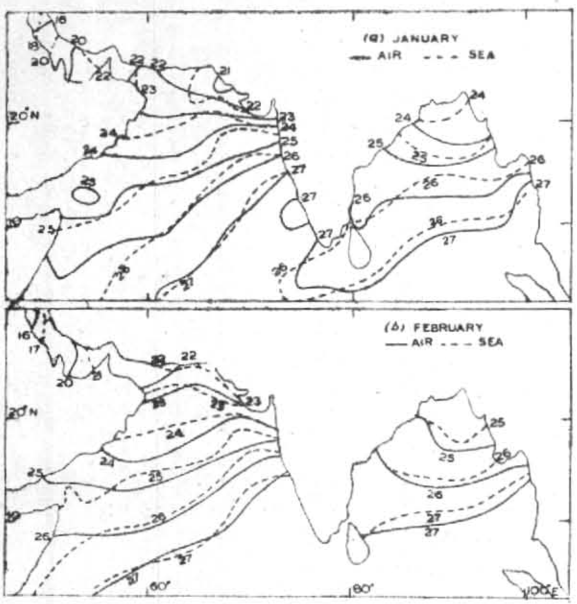

Fig. 2

Mean air and sea surface temperatures

Cold dry air, which is picking up moisture in its passage over Arabian Sea towards south, gets increased supply of moisture around 20°N as greater evaporation occurs between 20-15°N and the air becomes more moist and conditions become favourable for the formation of clouds. It has already been mentioned that the lower layer of the atmosphere is slightly super-adiabatic in this area and due to instability caused by evaporation, clouds form and reach upto inversion layer. Ludlam (1963) reviewing severe local storms said

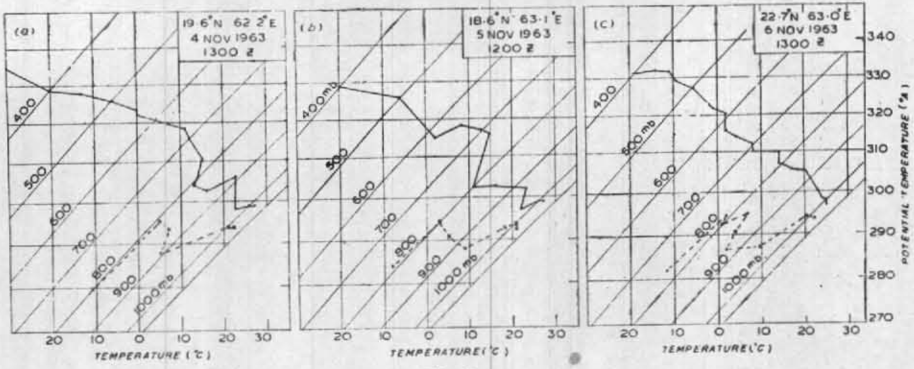

Fig. 3
Tephigrams of 4, 5 and 6 November 1963

that small scale nearly upright convection provides the lower atmosphere with energy partly as sensible heat and partly as latent heat of evaporated water and often manifests itself in the form of cumulus clouds in the tropical trade winds. Equatorward moving polar air is also traceable in satellite pictures (Vinicent *et al.* 1967). In these pictures cloud patterns identify the leading edge of a subsiding cold air outbreak as it moves into the subtropics. A thin broken line of cloud can persist for several days after frontal airmass discontinuities at the surface disappear. The appearance of these cloud lines portrays the strength of and penetration of polar outbreaks into the sub-tropics.

When polar continental air across North America passes over warm Gulf Stream, very closely packed lines of clouds form in the direction of the wind (NESC 1969). Down stream of the wind, the density of these cloud lines becomes less and less and eventually the cloud lines break into individual cells.

The clouds under study over Arabian Sea though similar to those of North Atlantic, are not so packed and the occurrence of cloud formation is quite away from the coast. The polar continental air invading over Arabian Sea is not so cold as the air passing over the Gulf Stream, and secondly the difference between air and sea surface temperatures over North Atlantic is more than over north Arabian Sea. This may be one of the reasons for the absence of clouds over north Arabian Sea off Mekran coast in addition to the low evaporation in that area.

Ficker, according to Riehl (1954), showed the occurrence of inversion at a height of 500 m at about 15 ° on either side of the equator over Atlantic Ocean off Africa coast and increasing to 2000 m towards equator and west. Riehl and his collaborators classified the trade wind structure over Pacific into 4 layers : (1) the sub-cloud layer extending from the surface to the base of cumuli, (2) the cloud layer which ends at inversion base, (3) the inversion layer, and (4) the air above the inversion top. The sub-cloud and cloud layers together form the moist layer.

Paul (1968) observed lower inversion between 980-850 mb over the tropical Eastern Pacific near Mexican coast during the cruise of the *Golden Bear* (winter of 1964) in the trade wind belt. He also observed that the lower inversion in that region had pronounced effect on weather. Fair weather cumulus and stratocumulus low clouds predominated and no precipitation occurred in that region.

Ships' reports in the region under study over Arabian Sea also indicate stratocumulus or cumulus with cloud base heights between 200-1000 m.

Cornford (1966) concluded from a study of stratocumulus clouds, that they once formed, persist as a result of the dynamic equilibrium between absorption of sunshine, loss of long wave radiation, heating or cooling from below and mixing with warm air from above the inversion. The cloud to persist unchanged, there must be a dynamic balance between the transport of moisture into the cloud from below and its export through the inversion.

It may be said that the extension of the cloud belt towards south lies in the direction of the wind and the increase in size of the clouds may be due to the increase in moisture content and inrease in inversion height.

However, Walker (1967) analysing IGY data concluded that the subsided air over trade wind cumulus clouds over Arabian Sea ascend into upper troposphere to arrive in or to the right of the axis of the jet stream at about 25°N.

During SW monsoon period also more or less semi-permanent clouds similar in [appearance to those clouds under study, often in lines, are seen in satellite pictures over central Arabian Sea between 13-22°N, east of 60°E. But the orientation of these cloud lines is west to east in the direction of the wind. During the winter period of the southern hemisphere persistence of clouds is noticed over south Indian Ocean but the nature of the clouds is different being mostly made up of cumulus and towering cumulus cloud lines, may be due to long travel of polar air over large areas of the sea surface.

4. Conclusion

Cold dry air while travelling towards south over north Arabian Sea picks up moisture. This moisture above the sea surface augumented by greater evaporation over west central Arabian Sea at about 20°N, tends to condense into cumulus and stratocumulus. The cloud free area off Mekran and Arabian coasts may be due to (1) general warmness of the cold polar continental air, (2) cold water along the coasts, and (3) less evaporation in that area. Inversion height seen in the tephigrams of November and the clouds are consistent with the conclusions of Ficker over Atlantic and the observations of Paul over East Pacific. Cloud heights reported by the ships over that area are more or less agreeing with the inversion heights seen in tephigrams. The clouds under study, seen in satellite pictures may be cumulus or stratocumulus and they are spread out in the direction of the prevailing low level winds. These clouds cannot rise through the inversion lid. The strength of the cold air invading Arabian Sea is indicated by the density of the small packed cells of clouds often in bands.

Almost non-occurrence of such clouds over Bay of Bengal may be due to — (1) less frequent invasion of cold air over Bay, (2) generally less temperature difference between air and sea surfaces, and (3) low evaporation over Bay of Bengal.

Further study is required to find out the persistence of clouds of similar nature over Arabian Sea between 13-22°N east of 60°E during summer season.

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DISCUSSION

DR. P. KOTESWARAM observed that similar type of clouding occurs along Florida coast where the Gulf Stream plays an important part.

SHRI V. BALASUBRAMANIAM : It is seen that the areas of clouds shift northwestwards towards the Arabian coast. Is there any explanation ?

SHRI G. GURUNADHAM : As fresh cold air invades the northern portions there may be generation of clouds there.

SHRI B. K. SRIDHAR : This type of clouding off Arabian coast has been noticed during strong and weak monsoon conditions also.

SHRI GURUNADHAM : The structure and nature of the clouds are entirely different. These are purely *Sc* type, whereas in monsoon we see *Cu* and large *Cu* clouds.