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Observations of Cloud Distributions over the Indo-China Peninsula by Aerial Photographs

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Abstract

A flight observation for cloud distributions was made over the Indo-China Peninsula, utilizing a routine passenger airplane on Oct. 7, 1965. Photographs of the clouds were taken by a 16 mm time-lapse movie camera, and were analysed by the trigonometric method, using successive pictures.

The results of the analysis showed that the dense cloud regions exactly coincided both with mountain regions and with an intertropical convergence zone connecting two depressions. Therefore, it was difficult to distinguish the effect of the convergence zone on the cloud formation from that of the mountains.

The direction of anvils of Cb clouds agreed with that of vertical wind shear between 300 and 450 mb levels.

1. Introduction

As part of the "Study on clouds over the Pacific Ocean", observation flights to obtain cloud distributions over the West Pacific Ocean and Southwest Asia were made on the 1st and 7th day of October 1965 by the authors[1),2),3)], utilizing a routine passenger airplane. This paper describes the results of observations of cloud distributions over the Peninsula of Indo-China. This observation flight was made on 7th October 1965 along the return route from Singapore via Bangkok to Hong Kong. Clouds were photographed by a 16 mm time-lapse movie camera, and the horizontal distribution of the clouds was analysed by the trigonometric method from the photographs which were taken at 6 second intervals as made in the previous observation[2)]. The flight altitude was between 9,000 and 10,000 meters between Bangkok and Hong Kong. The mean ground speed was 248 meters per second.

2. Results of cloud observation

The airplane took off at the Bangkok International Airport at 09:37 Z (16:37 LST), and cloud photographing was begun at the same time. The

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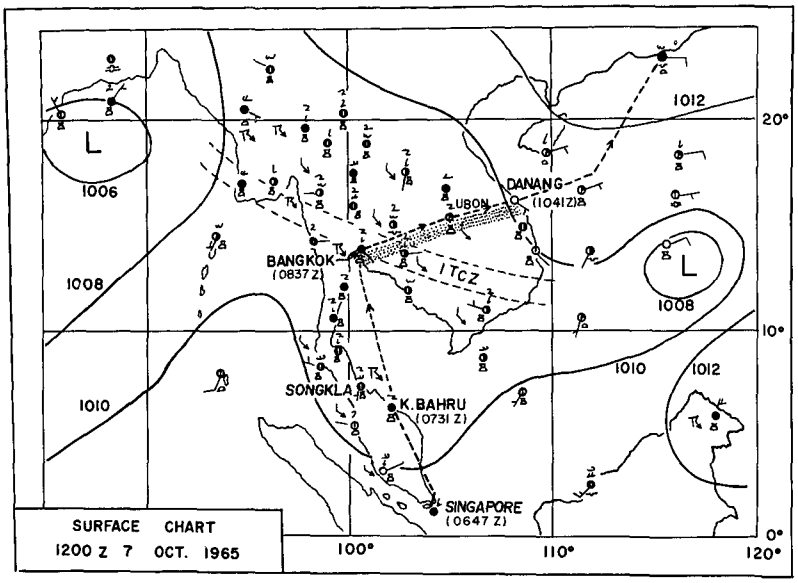

Fig. 1 Surface chart and Intertropical Convergence Zone connecting two depressions.

flight path is shown by a dashed line, and the area of the cloud analysis is shown by dotted areas in the weather chart in Fig. 1, respectively.

2.1 *Synoptic situation*

The surface weather chart for 12:00 Z (19:00 LST) October 7th which was the nearest to the cloud observation time 16:00～18:00 LST is shown in Fig. 1. It shows two depressions, one in the Bay of Bengal and another in the South China Sea respectively. According to the Thai Meteorological Department, an intertropical convergence zone existed between these two depressions. In the neighbourhood of this zone, cumulonimbus clouds and lightning were reported at many sites. However, the wind reported was weak throughout the peninsula.

2.2 *Horizontal distributions of clouds*

The horizontal distributions of clouds observed are analysed and mapped in Fig. 2. The photographic number and its angle of view are given by the triangle on the flight path in the figure. The configuration is also added by contours in the figure in order to render an easy comparison with the cloud distributions.

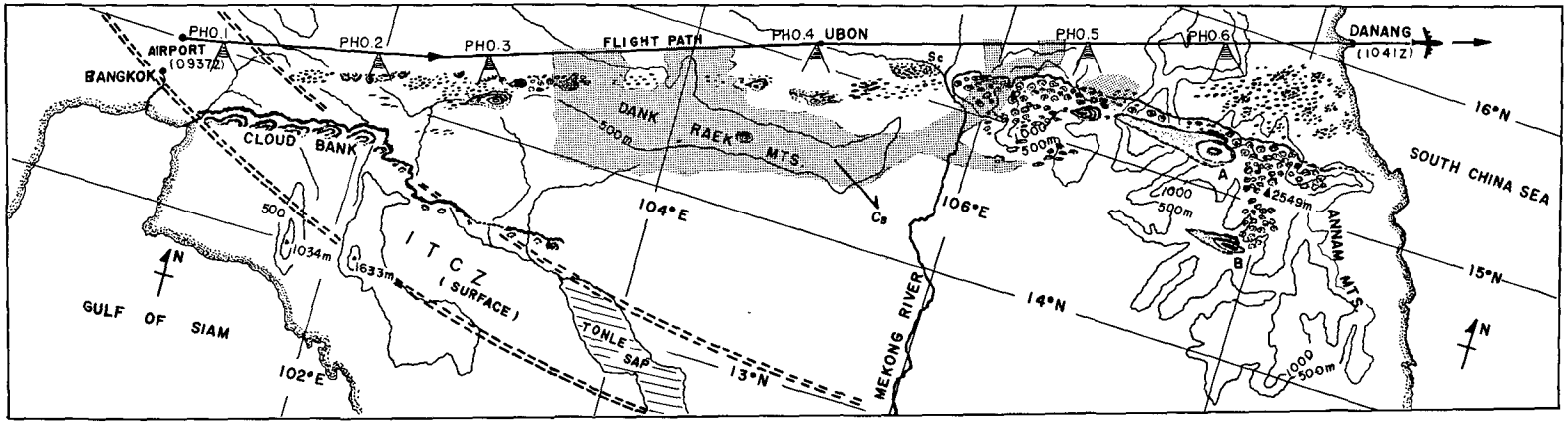

Fig. 2. Horizontal distribution of clouds over the Indo-China Peninsula. Anvil clouds were predominant over the Annam Mountains, SW of DaNang. ITCZ is mapped by a zone bounded by two doubled broken lines.

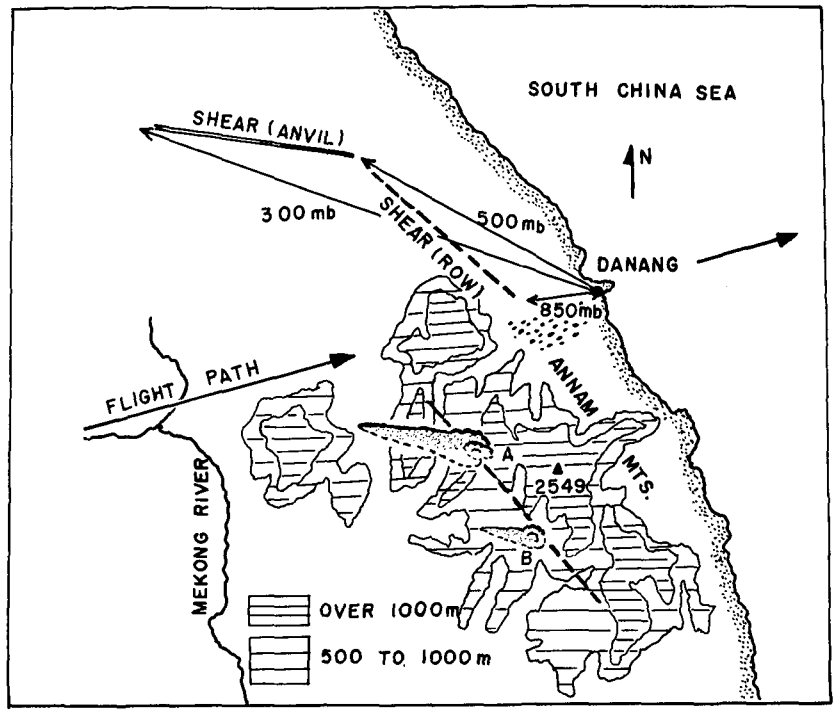

Fig. 3. The hodograph at DaNang and the direction of the anvil clouds. The topography of Annam Mountains are also shown.

Cloud distributions to the east of Bangkok: At the beginning of the observation flight from Bangkok International Airport, a bank of dense towering clouds was observed, as illustrated in Photos. 1 and 2 in Pl. I. The cloud bank continued to the area of high Cs clouds in the center part of Fig. 2. It was cloudless over the lower planes, as shown in the lower half of Photo. 1. The cumulus clouds in the lower half of Photo. 2 were located over the root of the Dank Raek Mountains, and it was also cloudless over the valley between the cumulus clouds over the mountains and the cloud bank. An isolated cumulonimbus cloud was observed over the root of the Dang Raek Mountains, as shown in Photo. 3.

As stated above, a line of cloud banks existed over the mountain area to the southeast, from Bangkok to the high Cs clouds. It may be seen in Fig. 2 that the location of the cloud bank roughly coincided with that of the surface intertropical convergence zone which was mapped by the Thai Meteorological

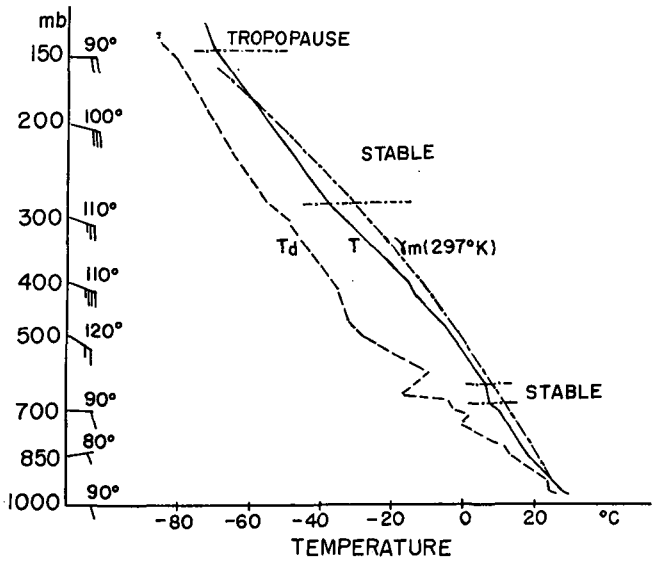

Fig. 4. Vertical profile of air temperature, dew point temperature, wet adiabat and wind at DaNang.

Department. It may also be seen that the area of the high Cs clouds coincided with the eastern part of the Dang Raek Mountains.

Clouds over the valley near the Mekong River: After passing through the Cs clouds, a characteristic isolated cloud was observed to the south of Ubon at the center of the flight path, as shown in Photo. 4. It appeared that the cloud had several roots (several convergence bands) which were composed of low level Cu clouds. The cloud form as shown in Photo. 4 suggests that a fairly high cumulus cloud was formed by collecting low level cumulus clouds.

A group of stratocumulus clouds were distributed over the Mekong River as indicated by dots near Ubon in Fig. 2. It was considered that the clouds were immediately below a stable layer at 700 mb level which is seen in Fig. 4.

Cloud distributions over the Annam Mountains: Cumulonimbus and many towering cumulus clouds were observed again on a high plateau on the east side of the Mekong River. Photo. 5 gives an example of the cumulonimbus cloud.

Two anvil clouds were observed over the Annam Mountains, as designated by A, B in Photo. 6 of Pl. I. According to the results of photographic analysis, these anvil clouds were located on the west slope of the Annam Mountains, and these anvils were all directed towards the west as mapped at

the right end of Fig. 2, and their height reached the 300 mb level. It may also be seen that there were many streets of fair weather cumulus clouds in the lower level between one of the anvil clouds and Da Nang. The direction of streets was from east to west.

3. Consideration

3.1 *Cloud distributions over the mountains near the east of Bangkok and the lower plain area*

It is well known that topography is an important factor in the formation of convective clouds. The observation flight was made at the end of the rainy season. As seen in Fig. 2, the horizontal cloud distributions coincided with the mountain area, and only a few isolated local clouds were distributed over the low plain areas.

According to the surface weather map of 12:00 Z prepared by the Thai Meteorological Department, as shown in Fig. 1, a convergence zone was mapped across the southern part of the peninsula. The beginning of the present cloud observation was made near this convergence zone. As seen in the results of cloud analysis, it was found that the towering cumulus cloud bank was quite in accordance with the convergence zone on the surface. However, this cloud bank also coincided with the southern mountain area. Therefore, it is uncertain as to whether the cloud bank was formed by the effect of the convergence zone or not. It is probable that the line of the cloud banks were formed by the combined effects of the convergence zone and the mountains.

Towering cumulus and cumulonimbus clouds were located on the fringe of the Dang Raek Mountains along the observation flight. The distribution of such clouds in the area is in substantial agreement with the distribution of the mountains. Therefore, it seems to be quite reasonable to consider that the convective clouds in this area were formed mainly by the effect of mountain ranges.

As shown previously in Photo. 4, an isolated towering cumulus with several convergence bands around its root was observed over the area near the Mekong River. Such a cloud distribution was also seen at the eastern entrance of the Bight of Bangkok[3] It is noted that an isolated towering cumulus frequently takes such a form. The authors considered that the range of converging area in the lower portion gives the size of the sucking area for the active towering cloud.

3.2 *Cloud distributions over the Annam Mountains*

Anvil clouds over the Annam Mountains near the east side of the Peninsula attracts special interest in this portion of the observation flight. A detailed discussion of the anvil cloud will be made below.

The horizontal distribution of these anvil clouds is shown in detail in Fig. 3. It may be seen that two anvil clouds were lined up over to the west side of a high ridge of the Annam Mountains. Such a lined-up cloud distribution was also observed over the west side of a mountain range over the Malayan Peninsula[1]. On the formation mechanism of the anvil clouds, the following consideration was made. The surface of the west slope of the mountains was locally heated by sunshine in the afternoon, and then local thermals occurred along the west slope of the mountain. When the moist air which came from the sea borne by the easterly winds passed over the peak of the mountain, the ascending motion of the air was accelerated by the local thermals, which then developed into a towering cumulus with an anvil under a stable layer. The direction of the anvil will be discussed later.

Radiosonde data obtained at DaNang at the time is shown in Fig. 4. It is noted in the ascent curve of the air temperature that two stable layers existed at about 700 mb and at layers higher than 300 mb, as indicated by chain lines in the figure. It was considered that these stable layers suppressed the top of the clouds, namely, the stratocumulus clouds near Ubon and the anvil clouds shown in upper part of Photo. 6, respectively.

As seen in Fig. 3, the anvil of the two clouds was in parallel with each other. This is reasonably understood from the wind conditions measured at DaNang. Because the height of the anvils ranged from 500 mb to 300 mb levels, the direction of the anvils might be determined by the vertical wind shear between these two levels, which is shown by a thick line in the hodograph in Fig. 3. It may be seen that the direction of the anvil was in parallel with the wind shear.

As seen in the figure, the direction of a line connecting the two anvil clouds was roughly in parallel with the wind shear between 850 mb and 500 mb levels, as shown by a dashed line in the hodograph. The low cumulus streets were in parallel with the wind at the 850 mb level.

According to the result of observations made by Malkus[4] in the tropical Pacific Ocean, the direction of anvils was in parallel with the vertical wind shear between 30,000～40,000 ft and the lower trade, and the towering cumuli were lined up in a parallel fashion with the wind shear between 20,000～

25,000 ft and the lower trade. The low cumuli were in parallel with the lower trade. In the present case, even if we take the wind shear between 300 and 850 mb levels, instead of 300 and 500 mbs, the direction of the anvil is roughly in parallel with the wind shear. Therefore it may be said that the result of our observation agrees with that of Malkus when viewed as a whole. However, it is noted that in the present case, the location of the anvil clouds might be effected by the topography. In the case of observations over the Malayan Peninsula[1], the row of tall clouds was in parallel with both the surface wind and the direction of a valley. The display of such a row is similar to the present one which is in parallel with a high mountain ridge. Taking these results into account, the authors consider that the distribution of the mountain ranges has an important effect on the row of tall clouds which are observed on the land area.

It is a matter of course that the direction of lower cumulus streets was in parallel with that of 850 mb level wind.

4. Conclusion

Because the observation flight was made in the rainy season when the air was very unstable, cloud distributions were effected by the topography. Therefore, it was difficult to distinguish the effect of the general wind system on the cloud distribution from that of the topography. However, the upper layer cloud distribution where the effect of the topography was weak, could be satisfactorily explained by the upper wind conditions.

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Plate I Aerial photographs of clouds over the Indo-China Peninsula

Photo. 1 Cloud deck to the south-east of Bangkok.

Photo. 2 Clouds near the root of the Dang Raek Mountains. (lower portion)

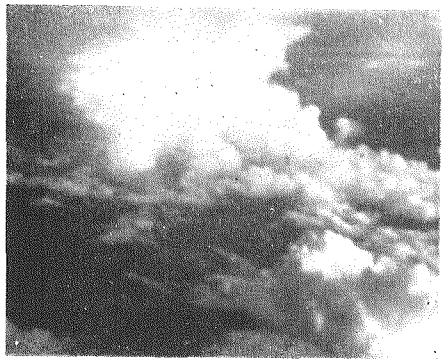

Photo. 3 Cb clouds over the Dang Raek Mountains.

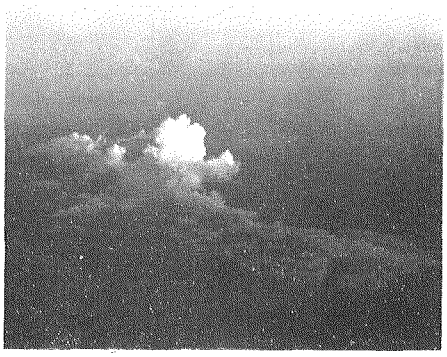

Photo. 4 An isolated cloud with several roots over the Ubon region.

Photo. 5 A Cb cloud over a high plateau near 15°N 106°E.

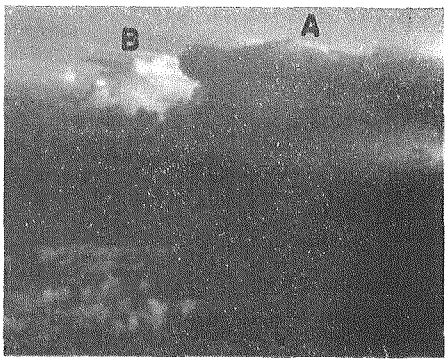

Photo. 6 A line of anvil clouds over the Annam Mountains.