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Comparison of Aerial Cloud Pictures with Satellite Cloud Pictures over the AMTEX Area

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Abstract

During AMTEX '74 and AMTEX '75, aerial picture observations were carried out from a commercial passenger airplane and the pictures were analyzed by the stereophotogrammetric method. Then, the results were compared with satellite cloud pictures. It was found about the brightness of satellite cloud pictures that the brightness was related to the cloud amount in the case where the cloud thickness was roughly the same and the brightness was related to the cloud volume in the case where the cloud thickness was not the same with each other.

It was noted that sea-surface temperature affected the formation of a cellular and/or band structure cloud which was often observed in the AMTEX area in winter season.

1. Introduction

It is well known that a large amount of heat and moisture is supplied from the sea surface and the cold air mass is extremely modified during the winter season over the ocean to the east of the continent. In such an area where the air mass transformation is active, to clarify the transfer processes of heat, moisture and momentum from the ocean to the air is the objective of the Air Mass Transformation Experiment (AMTEX). Since a large amount of heat and moisture supplied from the sea surface are redistributed to the free atmosphere mainly by convective transfer, the cumulus convection will play an important role in the transfer processes.

In order to study the relation between features of convective clouds and related atmospheric conditions, satellite cloud pictures were often used in the analysis of cloud distributions over wide areas (e.g. Ninomiya and Akiyama, 1973). When we use satellite cloud pictures for meteorological analysis, it is

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important to understand what the pictures represent. In order to understand satellite cloud pictures, Honodel (1964) and Vederman and Nagatani (1967) took cloud pictures from jet aircrafts and compared aerial cloud pictures with satellite cloud pictures. But, their analyses were qualitative. Later, Magono et al. (1969) made similar observations and compared satellite cloud pictures with the horizontal distributions of clouds analyzed quantitatively from aerial cloud pictures. Because the resolution power of the satellite cloud pictures was poor compared with that of the aerial cloud pictures, it was difficult to identify individual clouds, however a good correlation was obtained between the brightness in the satellite cloud pictures and the cloud amount calculated from the aerial cloud pictures. In their analysis, the cumulus humilis clouds had roughly the same cloud thickness.

In order to understand satellite cloud pictures, aerial cloud pictures were taken from a commercial passenger airplane over the AMTEX area and satellite cloud pictures were compared with the horizontal distribution of clouds analyzed quantitatively from aerial cloud pictures. Then, a study was conducted to determine what the brightness of satellite cloud pictures represent in the case where there are several kinds of clouds with different dimension of cloud thickness.

2. Methods of observation and analysis

A receiving apparatus was set up temporarily at Okinawa Meteorological Observatory by Meteorological Laboratory, Hokkaido University and satellite cloud pictures by ESSA-8 APT system were intercepted in order to observe cloud distributions over the AMTEX area during AMTEX '74. Then, grids of latitude and longitude were overlayed on the satellite cloud pictures. During AMTEX '75, satellite cloud pictures by NOAA-4 offered by Japan Meteorological Agency were used for this analysis.

During AMTEX'74, aerial pictures of clouds were taken every 30 seconds by a 35 mm motor driven camera and 16 mm time-lapse movie camera set up in a commercial passenger airplane between Tokyo and Taipei in order to obtain detailed cloud distributions over the AMTEX area. The flight course is shown in Fig. 1 by a solid line. Pictures by a 35 mm motor driven camera were used in this analysis. From two adjoining pictures, the three dimensional positions of clouds were obtained by stereophotogrammetric analysis. Exact data for the flight conditions of an observation airplane are required on this analysis. Flight height, ground speed and heading of the

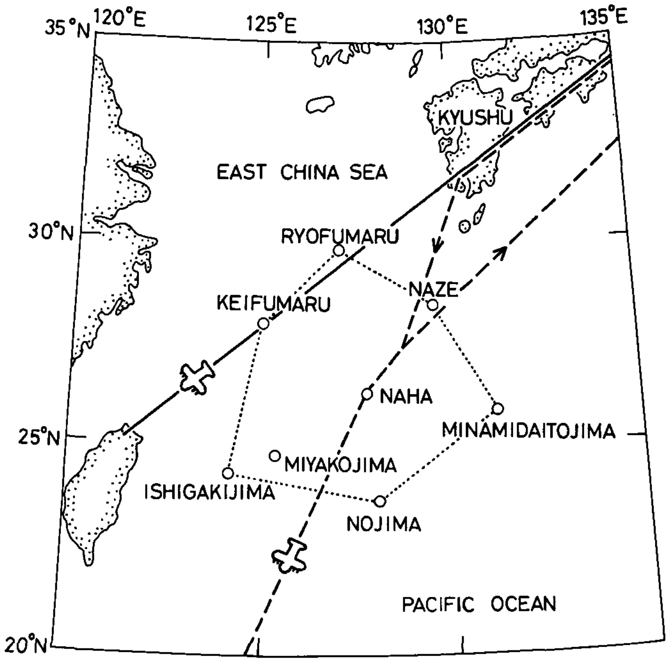

Fig. 1 Observation flight courses and upper air observation stations during AMTEX '74 and AMTEX '75. A solid line and two broken lines show the flight courses during AMTEX '74 and AMTEX '75, respectively.

airplane were obtained from the flight recorder. The dip angle of camera was obtained as follows. First, the determination of a true horizon on the aerial picture was made in such a way as described by Magono and Kasai (1966). Then, the dip angle of camera was calculated from the position of the true horizon on the aerial picture. During AMTEX '75, aerial pictures were taken from a commercial passenger airplane between Tokyo and Manila. The flight courses are shown in Fig. 1 by two broken lines.

3. Results

3.1 Comparison of aerial cloud pictures with satellite cloud pictures

Cloud distributions and satellite cloud pictures on 15 February, 16 February, 20 February during AMTEX '74 are shown in Figs. 2, 3 and 4. Cloud distributions determined from aerial cloud pictures are shown in the lower part of Figs. 2, 3 and 4. The height of the cloud top is indicated

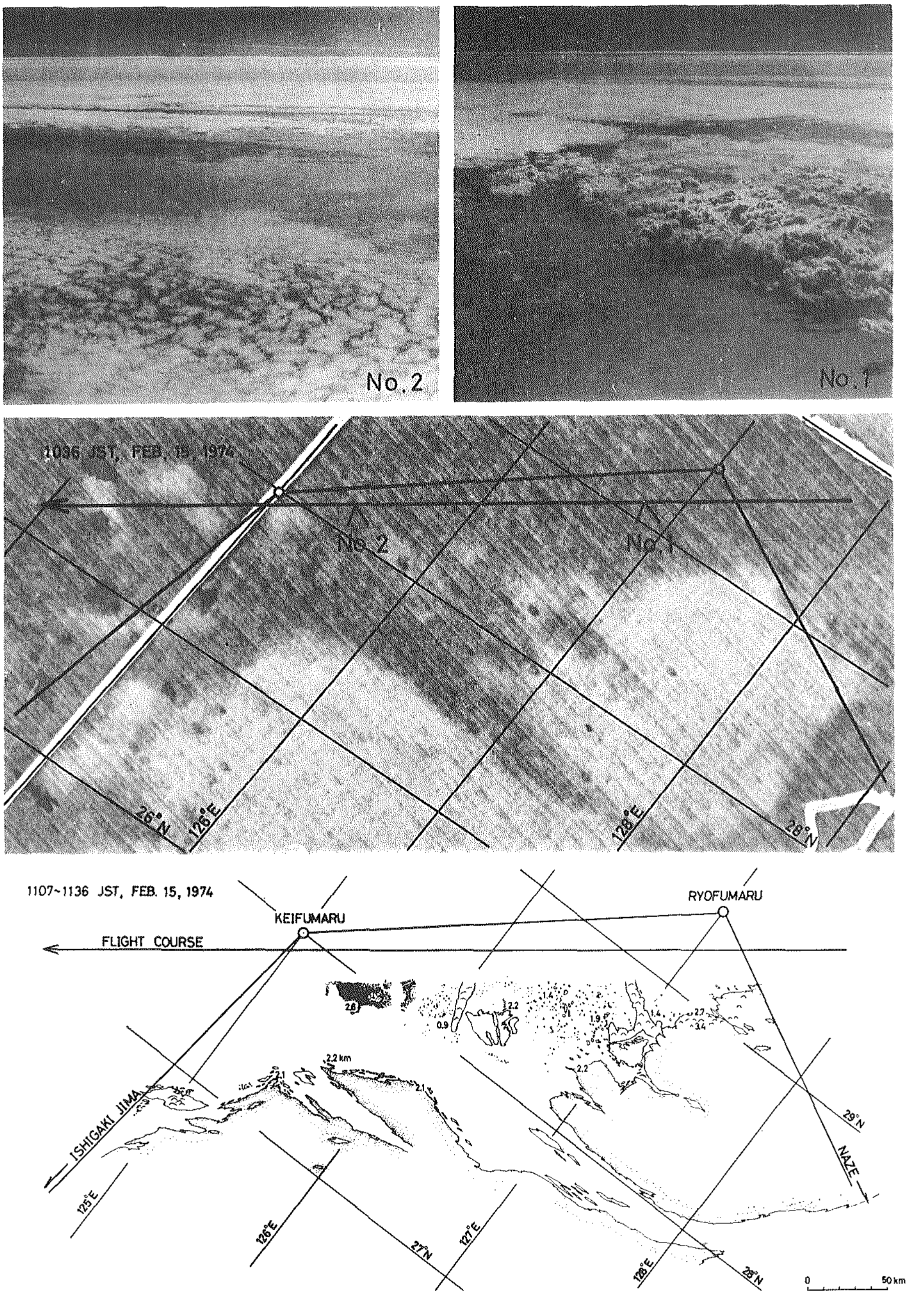

Fig. 2 Comparison of satellite cloud picture with cloud distributions determined from aerial pictures on 15 February 1974. Typical cloud pictures are shown at the top of this figure.

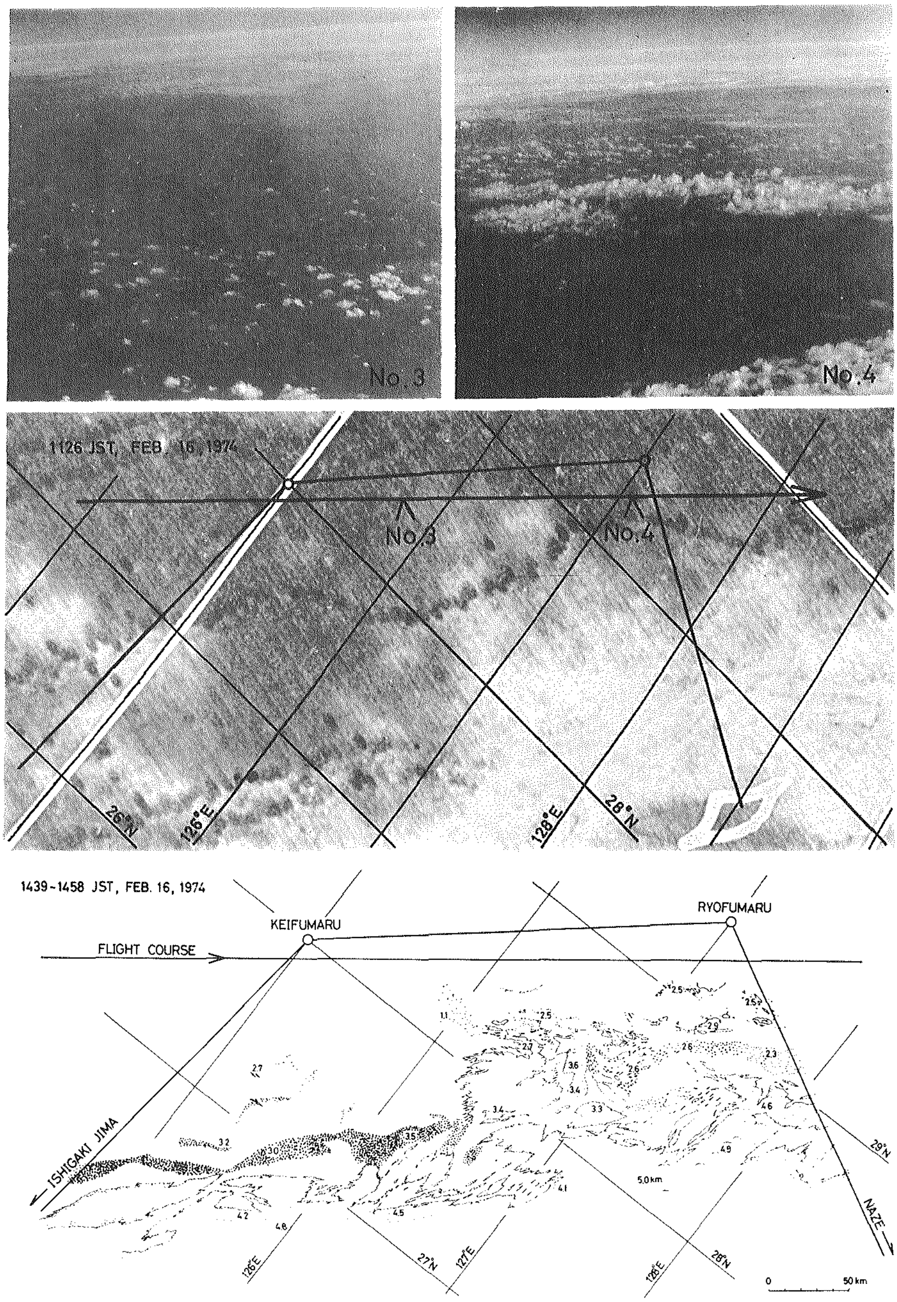

Fig. 3 Same as Fig. 2 except on 16 February 1974.

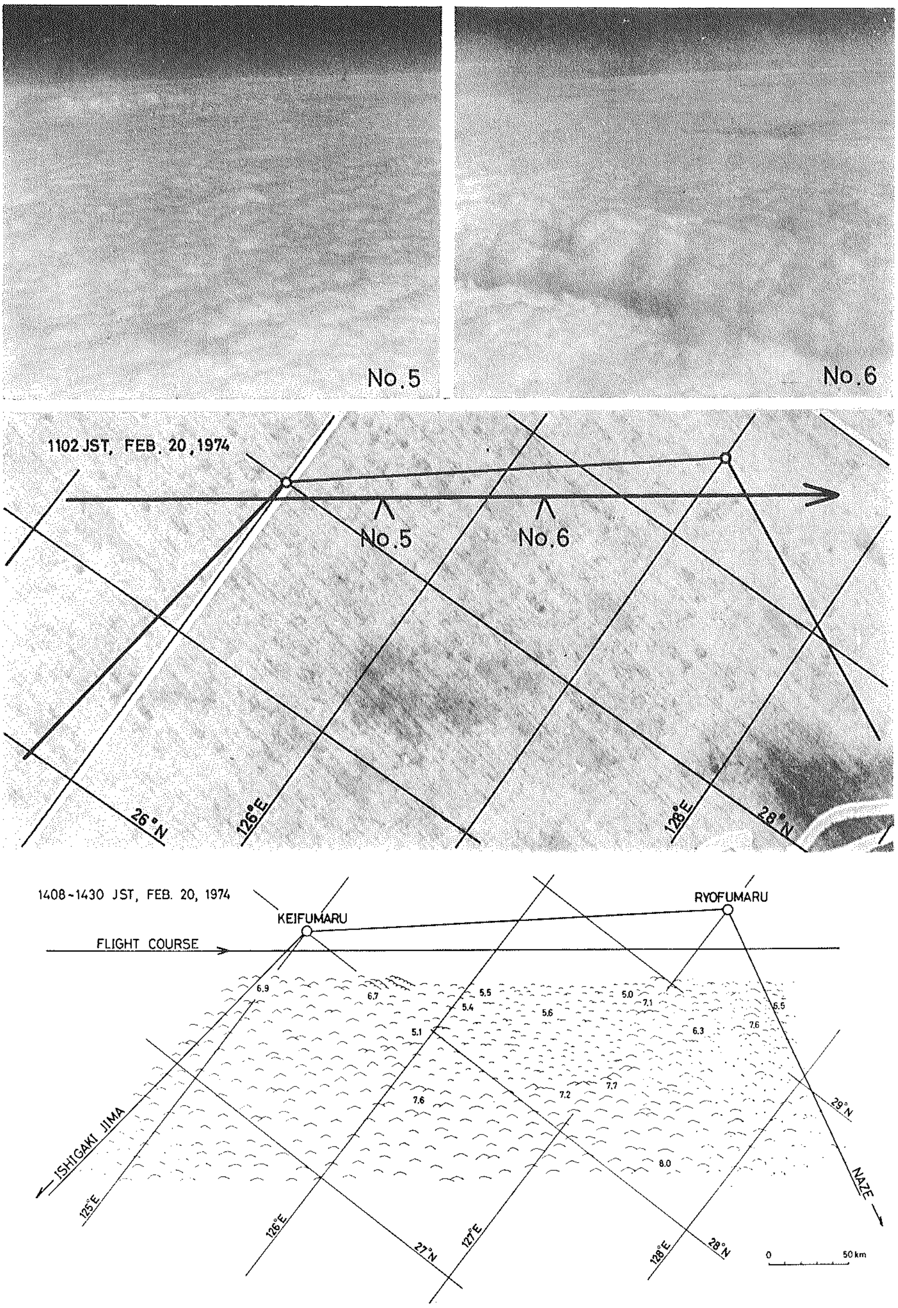

Fig. 4 Same as Fig. 2 except on 20 February 1974.

by numerals in km in the figures. The satellite cloud pictures are enlarged to the same size as that of cloud distributions and shown in the middle part of the figures. On each picture the flight course is drawn by an arrow. The aerial pictures at the top of the figures were taken at the positions which are indicated by Nos. on the satellite cloud pictures.

Fig. 2 shows the cloud distribution on 15 February. The coincidence of both observation times was good on 15 February. It is seen in the cloud distribution and aerial cloud pictures that there were cumulus clouds near the flight course and stratocumulus clouds in the distance. It may be seen in the figure that areas on the satellite cloud picture corresponding to the dense stratocumulus clouds were bright and areas corresponding to sparse cumulus clouds were weak in brightness.

Fig. 5 shows sounding curves of air temperature and relative humidity measured on board of Keifumaru and Ryofumaru. It is seen from the sounding curves at 0900 JST obtained from Keifumaru that there was an inversion layer at 2.4 km which separated a moist lower layer from a dry upper layer. The height of inversion layer at 1500 JST was the same as that at 0900 JST. Based on the value of cloud top height, it is considered that the clouds near Keifumaru were formed under the inversion layer. On the other hand, the

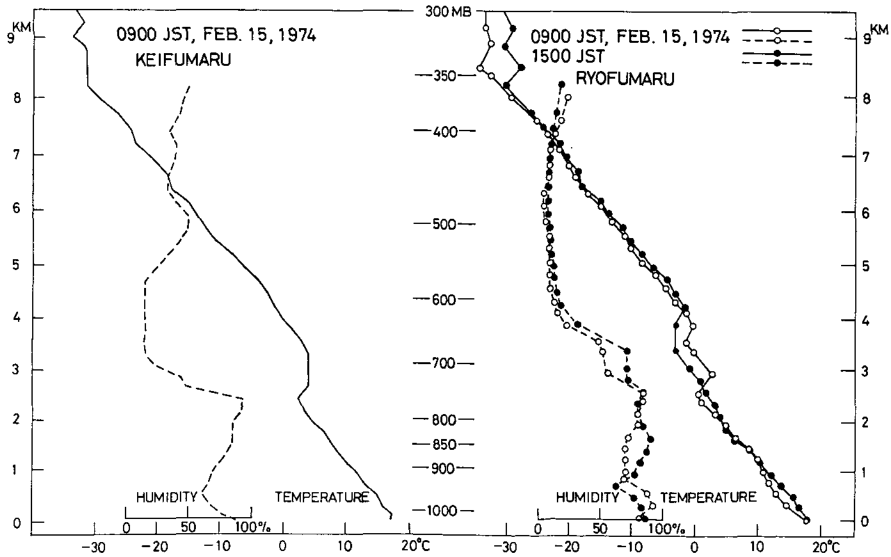

Fig. 5 Sounding curves of air temperature and relative humidity obtained on board of Keifumaru and Ryofumaru.

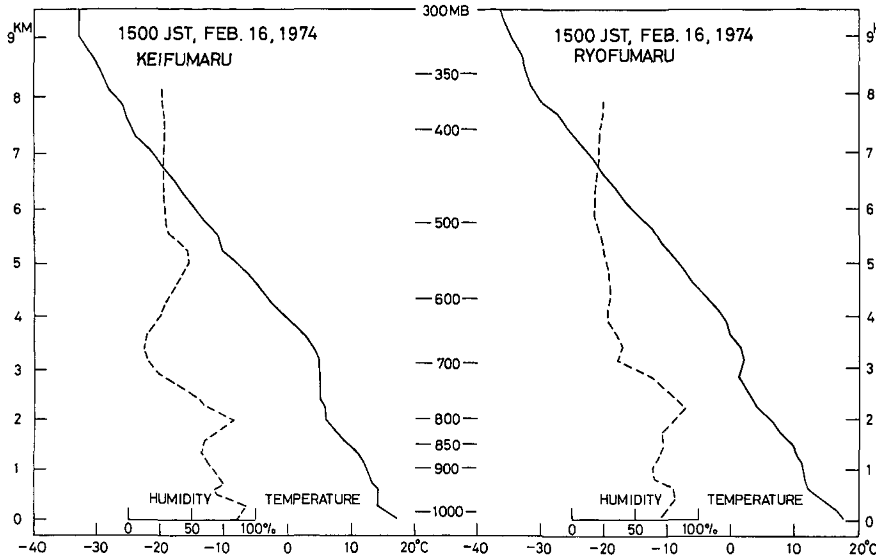

Fig. 6 Same as Fig. 5 except on 16 February 1974.

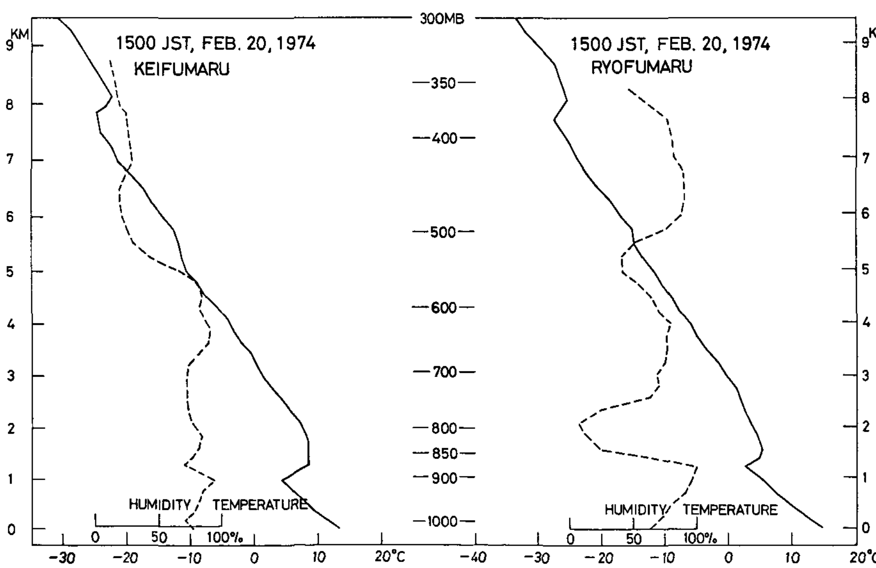

Fig. 7 Same as Fig. 5 except on 20 February 1974.

inversion layer over Ryofumaru became higher from 2.5 km at 0900 JST to 3.5 km at 1500 JST. The clouds near Ryofumaru were formed under the inversion layer, likewise. It is considered that the difference of cloud top height observed from Keifumaru and Ryofumaru were caused by the difference of inversion layer height.

Fig. 3 shows the cloud distribution on 16 February. The aerial cloud observation was carried out after 3 hours of satellite observation. It is seen in the figure that there were cumulus clouds near the flight course and stratocumulus clouds in the distance. It is seen that the bright areas on the satellite cloud picture corresponded to areas of dense and tall stratocumulus clouds.

Fig. 6 shows the sounding curves at 1500 JST obtained on Keifumaru and Ryofumaru. It is seen from sounding curves obtained on Keifumaru that there was shallow moist layer only near the sea surface. The observational results correspond to the fact that there were hardly any clouds near Keifumaru. On the other hand, it is seen from sounding curves on Ryofumaru that there was an inversion layer at 2.8 km which separated a moist layer from a dry upper layer. Based on the value of cloud top height, it is considered that the clouds near Ryofumaru were formed under the inversion layer.

Fig. 4 shows cloud distributions formed near a cold front on 20 February. It is seen from the horizontal distributions of clouds and aerial cloud pictures that the observational area was overcasted by dense clouds with cloud tops of 5.0～8.0 km. This observational result corresponds to the fact that the brightness on the satellite cloud picture was roughly uniform.

Fig. 7 shows sounding curves obtained on Keifumaru and Ryofumaru. There was an inversion layer at 8 km over both observation points. Under the inversion layer there were several moist layers. It is considered that clouds could grow up to 8 km over this observation area.

Study group on AMTEX (1973) reported that two different types of cloud distribution are often observed in the AMTEX area in the winter season; one is a cellular and/or band structure, and the other is the organization of clouds into a cluster. The former is associated with a rather shallow cloud layer topped with an inversion layer around the 800 mb level which distinctly separates a moist unstable low layer from an extremely dry upper layer, while the latter is found in the presence of a deep moist layer up to the 500 mb level without a noticeable inversion layer. It is considered from aerial cloud pictures, cloud distributions and sounding curves that the clouds on 15 and 16

February correspond to the former and the clouds on 20 February correspond to the latter.

In the case where the cloud thickness is the same as each other in such cloud distributions on 15 February, the brightness of satellite cloud pictures in the corresponding area is stronger, as the cloud amount increases. Magono et al. (1969) have already pointed out the relationship. Park et al. (1974) reproted that the brightness of satellite cloud pictures contains information about cloud thickness, also, thus it is considered that the brightness is not determined from only the cloud amount in the case where the cloud thickness is not the same with each other. In the next section a quantitative analysis will be carried out regarding the factors which determine the brightness of satellite cloud pictures.

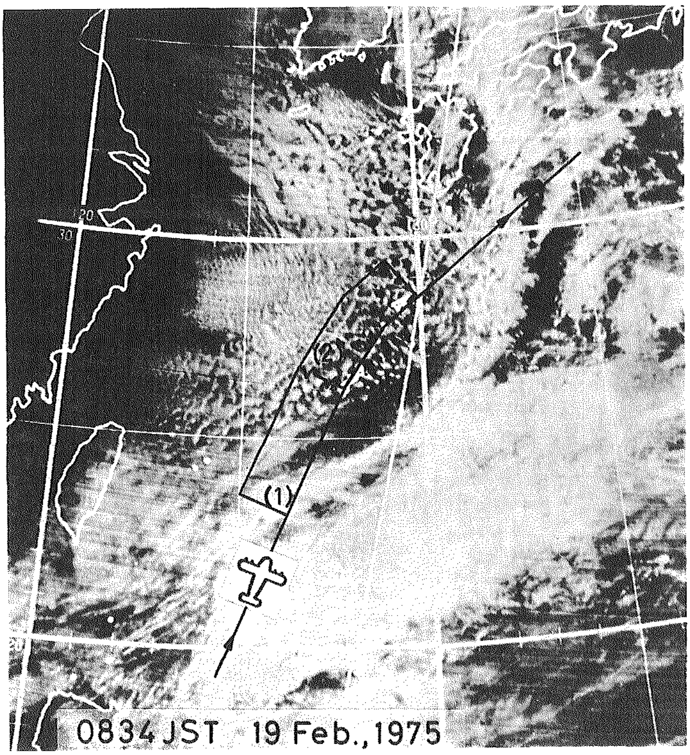

Fig. 8 Satellite cloud picture over the AMTEX area. Observation flight course is shown by an arrow.

3.2 Relation between the brightness of satellite cloud pictures and the volume of clouds

Based on the results of Magono et al. (1969) and Park et al. (1974), it is considered that the brightness of satellite cloud pictures is related to the cloud amount and cloud thickness. Hence, the relation between the brightness of satellite cloud pictures and the volume of clouds will be examined in this section. Satellite cloud pictures by NOAA-4 during AMTEX '75 were used for the measurement of the brightness, because the resolution power of pictures by NOAA-4 was good compared with that of pictures by ESSA-8 APT system. The picture are shown in Fig. 8. The horizontal distributions of clouds were analyzed over the belt area along a flight course. The analyzed horizontal distributions of clouds are shown in Figs. 9 and 10. It is seen that area (1) was covered with altostratus clouds with a cloud top of 5 km and area (2) was covered with cumulus clouds with a cloud top of 2 km. The cloud amount and cloud volume in 0.25×0.25 deg^2 area of latitude and longitude were estimated from the horizontal distributions of clouds in Figs. 9 and 10 for the comparison of the brightness of pictures. On the other hand,

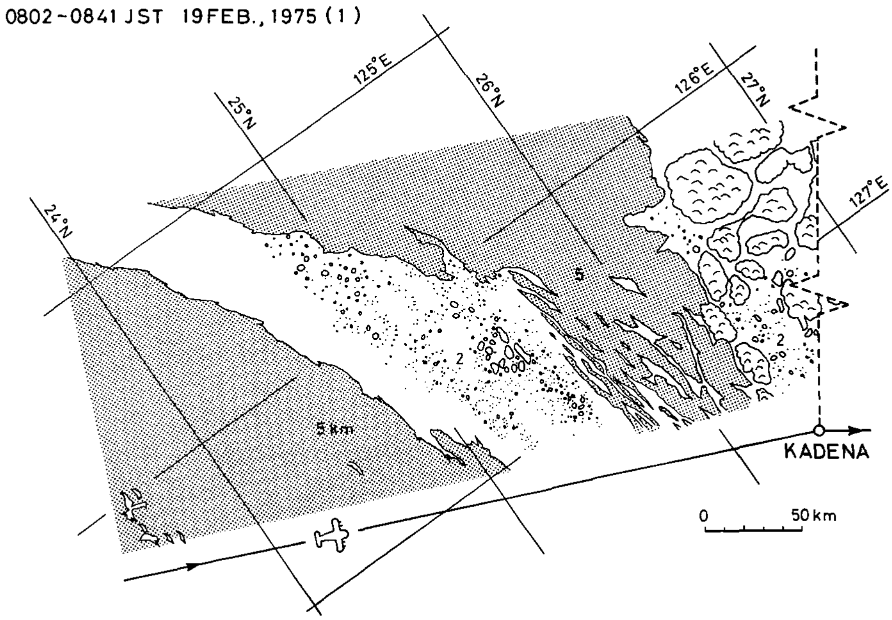

Fig. 9 Cloud distributions determined from aerial pictures over area (1).

the brightness of the satellite cloud picture was divided into 12 grades. The brightness was plotted against the cloud amount and cloud volume of the corresponding area, respectively. They are shown in the left part and right part in Fig. 11. Open circles and solid circles show altostratus clouds and cumulus clouds, respectively. It is seen that the brightness is nearly the

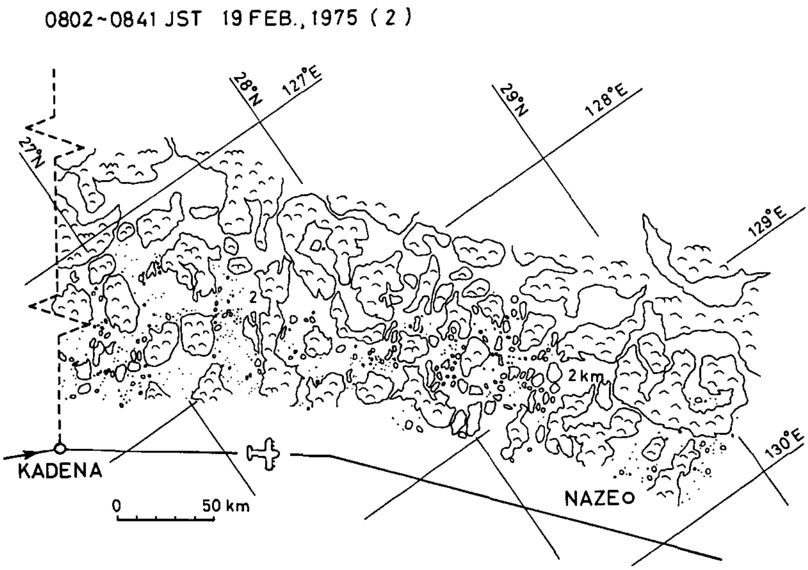

Fig. 10 Same as Fig. 9 except over area (2).

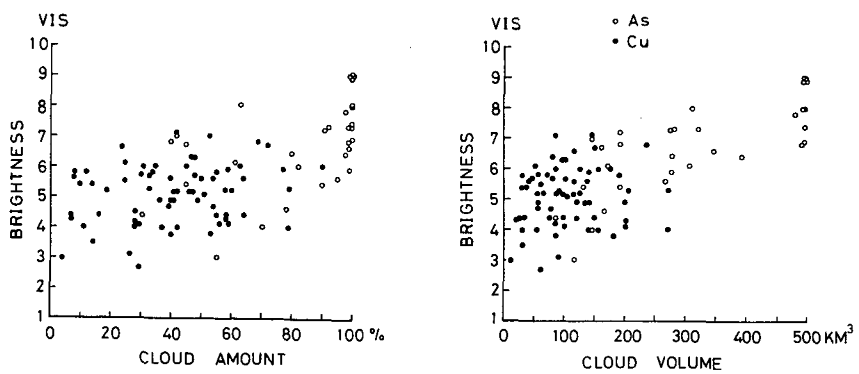

Fig. 11 Relation between brightness of satellite cloud pictures and cloud amount, and relation between brightness of satellite cloud pictures and cloud volume.

same regardless of the cloud amount except for 100% cloud amount. On the other hand, it may be seen that the brightness increases as the cloud volume increases, although the values are scattered. Therefore, it is considered that the brightness of satellite cloud pictures is well related to the cloud volume more than the cloud amount in the case where the cloud thickness is not the same with each other.

3.3 Mean cloud distribution over the AMTEX area

In the winter season two different types of cloud distribution are often observed in the AMTEX area, one is a cellular and/or band structure (Study group on AMTEX, 1973). The cloud distributions of this type will be examined in this section. Satellite cloud pictures during AMTEX '74 were used in this analysis. The cloud amount was estimated by naked eye from satellite

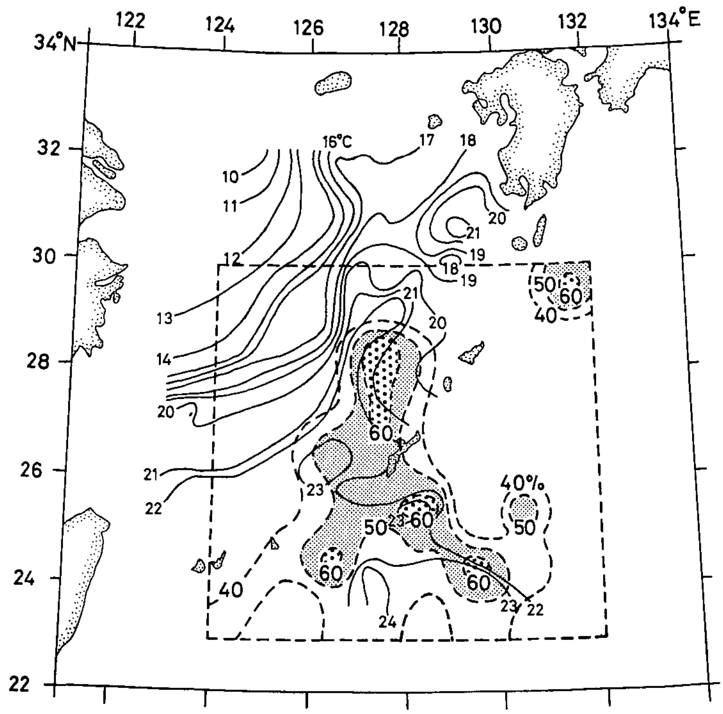

Fig. 12 Relation between the distribution of mean cloud amount and that of sea-surface temperature. Broken lines and solid lines show mean cloud amount and sea-surface temperature, respectively.

cloud pictures. The cloud amount in each $1/3 \times 1/3$ deg^2 area of latitude and longitude was taken to be as 1 (or 0) if the cloud coverage is larger (or smaller) than the half. Then, the area mean cloud amount in 1×1 deg^2 area of latitude and longitude was calculated from the values. In order to pick up only cellular and/or band structure cloud, a map of mean cloud amount was made from the daily maps of cloud amount of days when disturbances did not exist in this area. The result is shown in Fig. 12. The square surrounded by broken lines shows the area used for the analysis of cloud amount. The shaded areas have a cloud amount more than 50%. It is seen that the area of larger cloud amount extends from north to south in the area off Okinawa Island. The solid lines in this figure show the sea-surface temperature which was measured by observation ships during AMTEX '74. It may be seen that the area of larger cloud amount corresponds to the warm area surrounded by the line of 21°C. Therefore, it is considered that the cloud distribution of this type is closely related to the sea-surface temperature in that area.

4. Concluding remarks

In order to study what kinds of cloud characteristics satellite cloud pictures show, satellite cloud pictures were compared with the results of aerial cloud observations. It was obtained regarding the brightness of satellite cloud pictures that the brightness was related to the cloud amount in the case where the cloud thickness was roughly the same and the brightness was related to the cloud volume in the case where the cloud thickness was not the same with each other.

Two different types of cloud distribution were observed in the AMTEX area, one was a cellular and/or band structure. It was noted that the cloud of this type was often formed in the area where sea-surface temperature was warm.

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