Statistical relationship between ISCCP cloud type and relative humidity observed by radiosonde

Toshiro Inoue and Hirotaka Kamahori
Meteorological Research Institute
1-1 Nagamine, Tsukuba Ibaraki 305-0051, Japan

Abstract

The statistical relationship between ISCCP (International Satellite Cloud Climatology Project) cloud type and relative humidity profile observed by radiosonde was studied during the period from July, 1992 to June, 1994. The ISCCP-DX data of GMS were used to compute the cloud amount for each cloud type over the 1.5 degree grid area centered at the radiosonde station. To obtain the reliable cloud type classification, the data at 00 UTC when the visible data were available were used. The radiosonde observations when the 1.5 degree grid area is covered by single cloud type were used to compare the relative humidity profile. Four cloud types of low-level, middle-level, cirrus- and cumulonimbus-type cloud were selected for the comparison.

As was expected, the relative humidity was highest at all levels when the cumulonimbus-type cloud existed and was lowest at all levels when no cloud existed. The relative humidity was higher than that of a cloud-free case at middle-level (low-level) when middle-cloud (low-cloud) existed. Cirrus clouds are difficult to identify objectively from single infrared measurement. In ISCCP, however, cirrus cloud can be identified with the use of visible and infrared measurements. When cirrus cloud existed, the high level relative humidity showed local maximum and was higher than that when low- and middle-cloud existed.

1. Introduction

The presence of clouds influences the energetics of the atmosphere in two ways, the atmospheric water cycle and the radiation budget. In numerical weather prediction models, cloud amount is one of the important quantities to determine radiative fluxes (Saito and Baba, 1988). The ascent of damp air can lead to condensation and cloud is formed. During the ascent, although the mixing ratio of water vapor remains constant, the relative humidity increases and may reach 100% and condensation occurs. While, cloud will disappear when the cloud goes into drier air. Therefore, cloud is closely related with relative humidity at the level of cloud exists.

The study of the relationship between cloud and relative humidity is important in two ways, to estimate the relative humidity from the cloud amount, and to estimate the cloud amount from the relative humidity. The vertical moisture profiles have been estimated from GMS cloud data and used in the moisture analysis at the numerical weather prediction model in the Japan Meteorological Agency. The algorithm was statistically derived from the comparison between cloud data and moisture field observed by radiosonde.

Baba (1987,1995) improved the algorithm using the cloud data by considering mean cloud top temperature, minimum cloud temperature and standard deviation of brightness temperature within the 1 degree latitude/longitude area.

The former studies were based on single infrared measurement, which tends to misclassify the thin cirrus cloud as middle- or low-level cloud. The ISCCP (International Satellite Climatology Project) provides nine cloud types according to cloud height and optical thickness. In the cloud analysis, radiances are converted into cloud parameters with the help of a radiative transfer model and auxiliary data like temperature profiles derived from TOVS (Tiros Operational Vertical Soundings) and ozone information etc

In this study, cloud types classified in the ISCCP and cloud amount are taken into consideration to study the statistical relationship between cloud information and the vertical relative humidity profile, using data obtained during the period from July, 1992 to June, 1994.

2. Data

a) ISCCP-DX data

The ISCCP was established in 1982 and provided cloud information analyzed by combining satellite-measured radiances with TOVS atmospheric temperature-humidity data. The first version of

ISCCP products is called the C-series and the revised version of products is called the D-series. The pixel by pixel analysis is performed for satellite radiance data set and the results are reported in the DX data product, which has a nominal resolution of 30km and 3 hours. Here we use the ISCCP-DX data of GMS.
In ISCCP, visible (day only) and infrared data are used to retrieve cloud parameters. During day-time, the optical thickness of cloud is determined from visible reflectance. In the ISCCP-DX data, ice crystals with 30 μm effective radius are used to compute the optical thickness of clouds which are colder than 260K. The cloud top temperature is corrected for transmitted radiation as a function of optical thickness for transparent cirrus clouds. The ISCCP-DX data of daytime provides reliable cloud parameters by combining visible and IR data.

Based on these cloud optical thicknesses and heights, each cloudy pixel is classified into one of nine cloud types according to three cloud top pressure categories (divided at 440 and 680 hPa) and three visible optical thickness categories (divided at 3.6 and 23). In this study, we select four cloud types for simplicity in the comparison between cloud and radiosonde, instead of nine cloud types which are classified in the ISCCP. High-level cloud is classified as cirrus-type cloud with an optical thickness smaller than 3.6, and cumulonimbus-type cloud with an optical thickness greater than 3.6. Middle- and low-level cloud is combined as one cloud type, instead of the three cloud types at each level in ISCCP. We also consider the cloud-free case as another category

Since the ISCCP-DX data have a spatial resolution of 5km with sampled every 30km, we construct the 0.5 degree latitude/longitude grid map of cloud parameters over the GMS coverage of 50N-50S, and 110E-180E. The 00UTC data are used for comparison between cloud and radiosonde observations because the visible data of GMS is available at 00UTC.Cloud amount is computed over 3 by 3 grids (1.5 degree latitude/longitude area) data centered at the grid of the radiosonde station. The radiosonde data where only single cloud type exists over the 3 by 3 grids are used to study the relative humidity profile.

b) Radiosonde

To compare with cloud information from GMS, we use the 00UTC TEMP data, which coincide with the cloud observation. We use the standard level data of moisture information at 1000, 925, 850, 700, 500, 400 and 300hPa for computation of the relative humidity. Therefore, some fine vertical structures of moisture profiles are neglected.

Fig.1. shows an example of the position of radiosonde stations used in this study during August, 1993. The radiosonde stations are selected considering the height of the station and the effectiveness of the visible image at 00UTC during winter time. The radiosonde stations are selected near coasts or islands because the main purpose of this study is to find better relationship between cloud and relative humidity over the ocean where conventional radiosonde observations are sparse.

3. Results

ISCCP-DX data of GMS which is sampled every 30km is mapped onto a 0.5 degree latitude/longitude grid map. Every grid has cloud information of its nearest neighbor's original data. Cloud type is determined from the visible optical thickness and corrected cloud height is determined from visible and infrared data. Cloud amount is computed over 3 by 3 grids (1.5 degree latitude/longitude area) data centered at the grid of the radiosonde station.

Figure 2. shows the vertical profiles of mean relative humidity for four cloud types (low-level, middle-level, cirrus-type and cumulonimbus-type cloud) derived from ISCCP analysis and cloud free. As is expected, the relative humidity is higher at the level where cloud exists. The relative humidity is lowest for all levels in the cloud-free case. There is a local maximum of relative humidity at 850hPa. The water vapor is concentrated at lower levels when it is clear.

When cumulonimbus-type cloud exists, the relative humidity indicates the largest value for all levels. When the low-level cloud exists, the relative humidity at lower than 850 hPa is higher than when other cloud types exist except for when cumulonimbus-type cloud exists. When the middle-level cloud exists, the relative humidity at the level higher than 700hPa shows a larger value than low-level cloud. When cirrus cloud exists, the relative humidity at higher than 400hPa indicates a larger value than that of when middle-level cloud exists. However the relative humidity at lower levels is not significantly smaller, although it is smaller at the 850 and 700 hPa levels.

Generally, the humidity over the tropics is higher than that over the subtropics. We compare the cloud information with the northern subtropics (25N-50N), tropics (25N-25S) and southern subtropics (25S-50S). Regional characteristics of relative humidity profile was studied for each cloud type. Figures are shown only cloud-free (Fig.3.) and cirrus-type cloud (Fig.4) cases.

Cloud-free case

Figure 3. shows the vertical profile of relative humidity with standard deviation for the cloud-free case. The top shows the data computed from the area of the northern subtropics at a higher latitude than 25N, the middle shows the data over the tropics and the bottom shows the data over the southern subtropics higher than 25S. The salient features of high relative humidity at lower than 850hPa can be seen over the tropics. The northern subtropics tend to be drier at the level higher than 500hPa in comparison with other areas. Over the southern subtropics, the relative humidity is rather drier at all levels.

Low-level cloud

The vertical profile of relative humidity over the northern subtropics is similar to that over the tropics. Again, the relative humidity over the southern subtropics tends to be drier at the level lower than 500hPa. A significant difference in relative humidity at lower levels can be seen in comparison with low-level cloud and the cloud-free case over the mid-latitudes of both hemispheres. However, over the tropics the vertical profile of relative humidity is similar to the cloud-free case, although the relative humidity is much larger at low levels.

Midle-level cloud

The vertical profile of relative humidity over the northern subtropics is similar to that over the southern subtropics except for higher levels. The relative humidity at lower levels is moist over the tropics. A large difference of the vertical profile of relative humidity can be seen for the mid-level cloud case at all levels and for all regions in comparison with the cloud-free case.

Cirrus-type cloud

It is interesting to find a similar vertical profile of relative humidity and local maximum at 400 hPa for both subtropical regions when cirrus cloud exists (Fig.4.). Again, the relative humidity tends to be drier at all levels for the southern subtropics. We cannot see the local maximum of relative humidity at higher levels over the tropics, although the relative humidity is larger especially at higher levels in comparison with the cloud-free case.

Cumulonimbus-type case

The vertical profile of relative humidity over the northern subtropics is similar to that over the tropics, although with a slight difference at lower levels. The relative humidity is drier at all levels over the southern subtropics.

4. Concluding Remarks

Using the reliable cloud information derived from ISCCP-DX, we studied the statistical relationship between cloud type and relative humidity profile observed by radiosonde observation. The studied region is the GMS coverage area and the studied period is the two year period from July 1,1992 to August 31, 1994. The 00UTC radiosonde observations are compared with the cloud information from GMS visible and infrared data taken at 00UTC. The spatial resolution of ISCCP-DX data is 5km and sampled every 30km. The satellite data are mapped onto 0.5 latitude/longitude grids. The cloud information is retrieved over the 1.5 by 1.5 latitude/longitude (3 by 3 grid) area centered at the radiosonde station. The five cloud types (including the cloud-free case) are derived from optical thickness and cloud height by ISCCP-DX data. They are low-level cloud , middle-level cloud, cirrus-type cloud and cumulonimbus-type cloud. The low-level and middle-level clouds are defined as cloud lower than 600hPa, and cloud higher than 600hPa and lower than 440hPa, respectively. The cirrus-type cloud is defined as cloud higher than 440hPa with visible optical thickness smaller than 3.6. The cumulonimbus-type cloud is defined as cloud higher than 440hPa with visible optical thickness larger than 3.6. The reader should note that the cloud type classification is slightly different from the original cloud type name in ISCCP.

The radiosonde observation of relative humidity is used for comparison when the 1.5 by 1.5 latitude/longitude area is covered by a single cloud type. The characteristics of the vertical profile of relative humidity are statistically studied in terms of cloud type and regional difference.

As is expected, the vertical profile of relative humidity is highest at all levels when cumulonimbus type cloud exists and is lowest at all levels when no cloud exists. The relative humidity is higher than that of the cloud-free case at middle-level (low-level) when middle-cloud (low-cloud) exists. In the cloud-free case, the tropics shows a very high relative humidity maximum at 850hPa, which is not seen in mid-latitudes.

When cirrus cloud exists, the high level relative humidity is higher than that when low- and middle-cloud exists. We expect the local maximum of relative humidity at higher levels for the cirrus cloud case, however, the feature is seen only mid-latitude and not in the tropics. The middle-level (low-level) relative humidity is also higher than that when low-level (middle-level) cloud exists. Cirrus cloud is often associated with lower level clouds. In this multi-layer cloud case the satellite cloud retrieval algorithm tends to retrieve only higher cloud. This is one reason for the relatively higher relative humidity at middle- and low-level than in the cloud-free case.

Generally, the relative humidity over the southern subtropics is smaller in comparison with the northern subtropics and tropics. The 'Vaisala' radiosonde is used in Australia. It is known that the 'Vaisala' radiosonde shows a dry bias. The relative humidity at high levels tends to be larger over the northern subtropics than other places.

Acknowledgment

ISCCP-DX data of GMS were obtained from the NASA Langley Research Center EOSDIS Distributed Active Archive Center.

References

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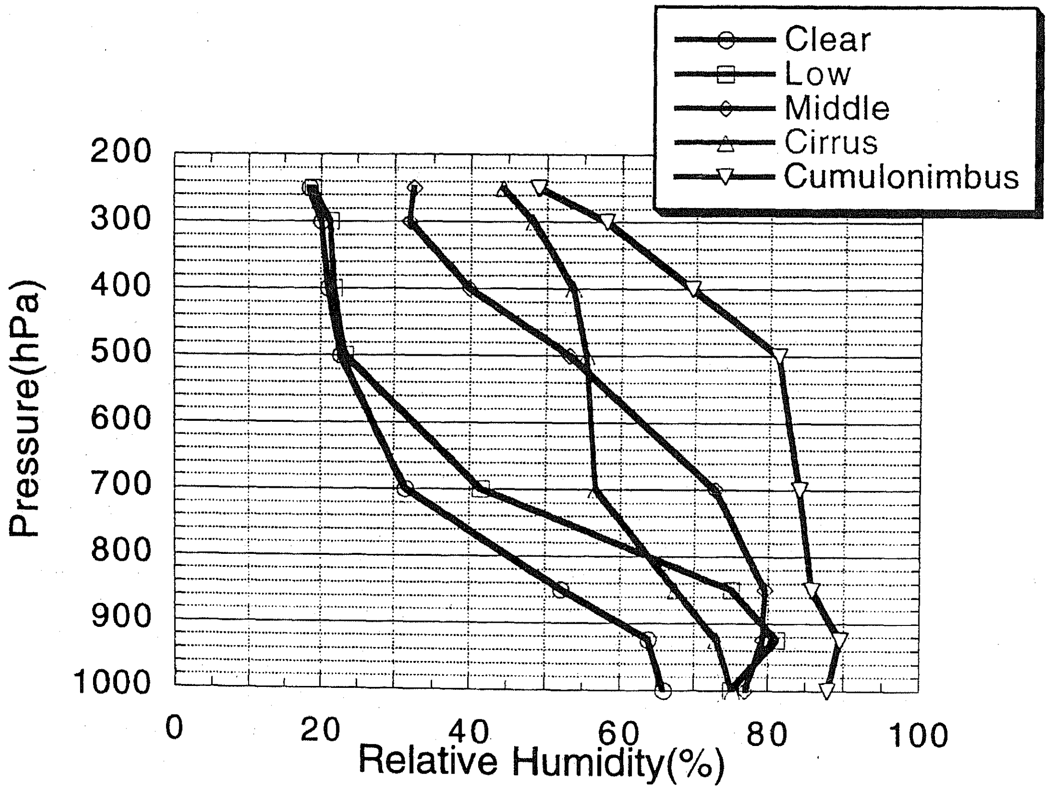

Fig.2. Mean vertical profile of relative humidity for each cloud-type.

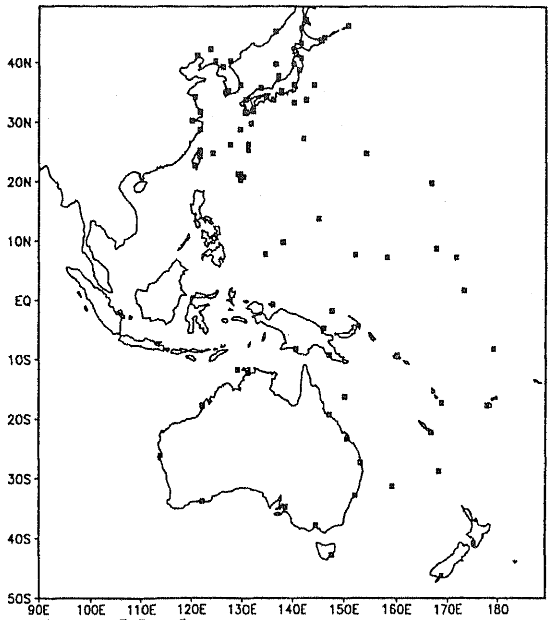

Fig.1. Radiosonde stations (black dot) used in this study.

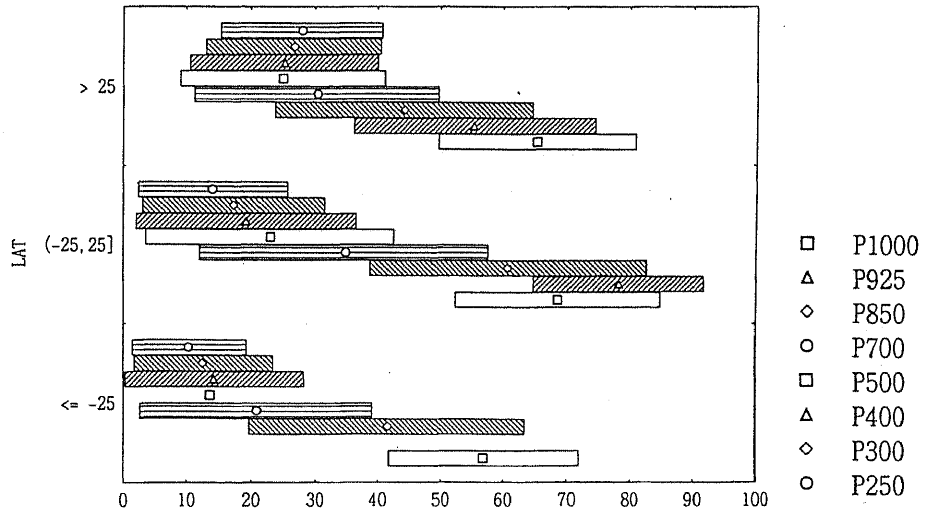

Fig.3. Regional difference of vertical profile of relative humidity for cloud-free case.

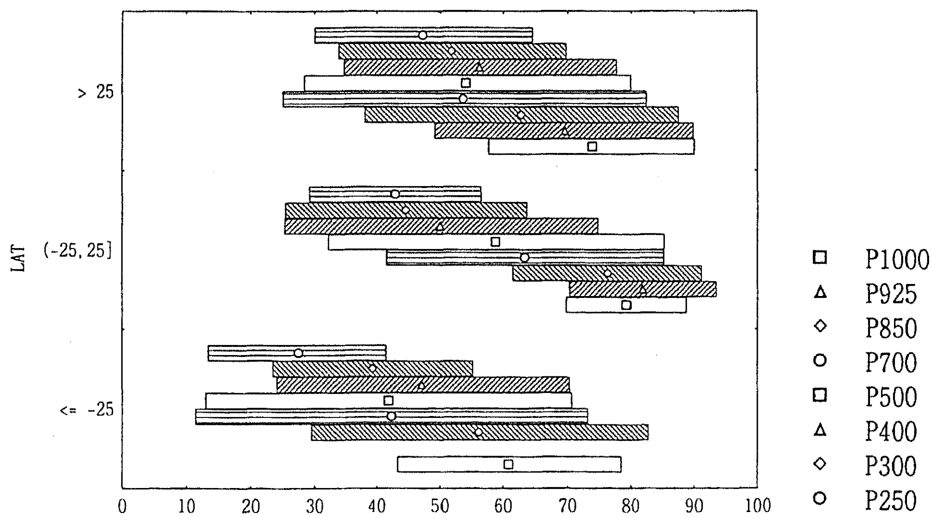

Fig. 4. Regional difference of vertical profile of relative humidity for cirrus-type cloud.