BRIGHT-BAND HEIGHT STATISTICS OBSERVED BY THE TRMM PRECIPITATION RADAR

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1. INTRODUCTION

A bright-band is a melting layer of snow and ice that usually lies above the stratiform type of rain. On the meteorological radar, a bright-band can be seen as a nearly horizontal thin bright echo layer with a large radar reflectivity factor Z. The bright-band height gives an important indication in estimating the height of the stratiform type of rain and the 0℃ isotherm height, i.e. the freezing height. The rain height is one of the important parameters to retrieve the rainfall rate from the brightness temperature data obtained by the microwave radiometer.

In the design of the satellite communication link of the microwave and millimeter radio waves, the rain height is also considered to be an indispensable parameter to evaluate the effect of rain attenuation, which is a main factor of deterioration of the communication link. Therefore, the International Telecommunication Union (ITU) uses the database of the 0℃ isotherm height with the grid spacing of 1.5 degrees (latitude) by 1.5 degrees (longitude), which is based on the long term meteorological data provided by the European Centre for Medium-Range Weather Forecast (ECMWF).

The ECMWF database of the 0℃ isotherm height, however, is composed mainly of the data observed on the ground at the mid-latitudes and the climatic numerical models, and scarcely includes the data observed on the ground of the tropical and subtropical regions, most of which, as a matter of course, are covered with ocean.

We focus our attention on utilizing the precipitation radar (PR) 3A25 data of the Tropical Rainfall Measuring Mission (TRMM), which aims at observing the tropical and sub-tropical precipitation, and compare the bright-band height statistics calculated from the TRMM PR data with the database of the ECMWF 0℃ isotherm height.

2. COMPARISONS OF BRIGHT-BAND HEIGHT YEARLY VARIATION

We have analyzed the six-year (1998-2003) annual mean variations of bright-band heights over the entire globe (at the fixed latitude and the longitude from 0 to 360 degrees). From the results of the analysis, we could learn the zonal averages of the bright-band height of 1998 are higher than those of the other five years around the regions from the equator to the latitude of approximately 20 degrees south. This can be considered the effects of the 1998 El Nino event, which was the largest in the 20th century.

We have also found that the yearly variations of the bright-band heights are smaller at the higher latitude in both hemispheres. Apart from the year of El Nino 1998, the bright-band heights shows almost the same figures and change in a similar way as a function of latitude in the other five years (1999-2003). However, if we look at the figures carefully, the height of bright-band is a little higher in 2002 than in the other years. This may be caused by the small El Nino, which was seen during March 2002 to March 2003. The bright-band heights are virtually constant at the low latitude (+/-10 degrees) and the figures decrease gradually as the latitudes goes higher in both hemispheres. These downward trends of the bright-band height in each hemisphere are, however, asymmetric, and the bright-band heights are slightly higher in the north hemisphere than in the south hemisphere. Each of the yearly variations of the ocean and the land shows the similar trend to that of the whole globe.

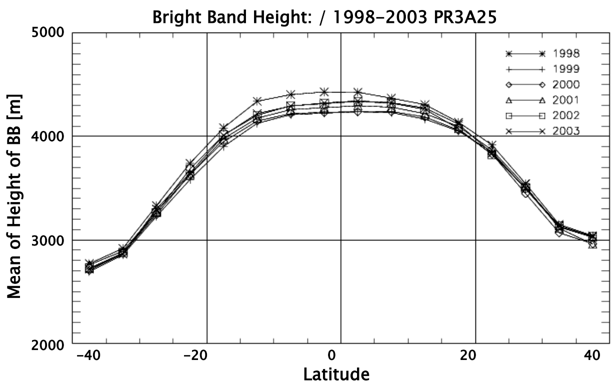

Figure 1: Zonal average of bright-band height (1998-2003)

3. MONTHLY COMPARISONS OF BRIGHT-BAND HEIGHT VARIAION YEAR TO YEAR

We have analyzed six-year (1998-2003) variations of the mean bright-band heights on a monthly basis over the whole globe. The zonal averages of the bright-band heights from January to May are higher in 1998 than in the other five years, especially in the tropical area. This anomalous phenomenon might be associated with El Nino event, which had continued since 1997 and suddenly came to an end in May 1998. Figure 2 shows the variation of the bright band height of every January of six years

(1998-2003). It is clearly shown that the bright-band height in 2003 is the second highest, which may be the effect of the small El Nino of 2002-2003.

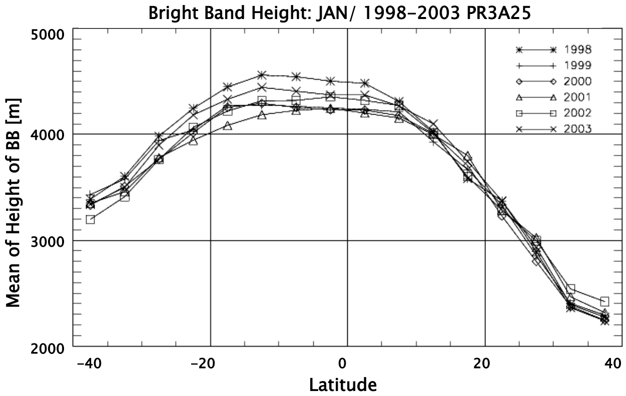

Figure 2: Variations of bright-band height of every January of 1998-2003

4. THE SEASONAL VARIATION OF THE BRIGHT-BAND HEIGHTS AND THE 0℃ ISOTHERM HEIGHTS

We have focused on a seasonal aspect of the variations of the mean bright-band heights respectively over the whole globe. Figure 3 shows seasonal variations of bright-band height (1998-2003). The zonal averages of the bright-band heights are the lowest in the winter season (December through February in the north hemisphere, and June through August in the south hemisphere) and are the highest in the summer season (June through August in the north hemisphere, and December through February in the south hemisphere). While almost no seasonal variations can be seen in the tropical area, the bright-band heights show larger seasonal variations at the higher latitudes; about 1.5 km of the bright-band height variations are recorded at the latitude of around 35 degrees north and about 1km of the bright-band height variations at the latitude of around 35 degrees south. Particularly in the north hemisphere, the seasonal variation is larger over the land than over the ocean.

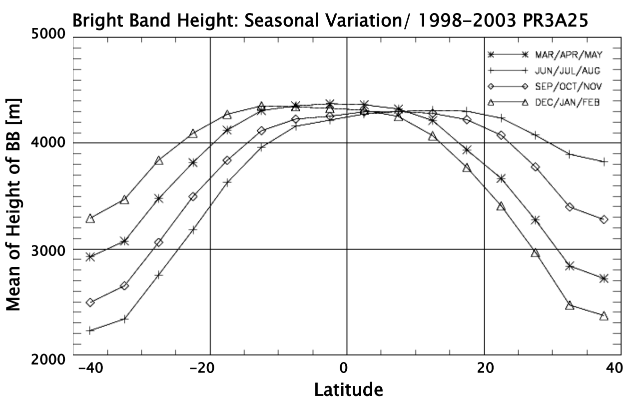

Figure 3: Seasonal variations of bright-band height (1998-2003)

Figure 4 show the seasonal variation of the 0℃ isotherm by the ITU database. We have looked into the seasonal variations of the 0℃ isotherm heights and have found out that zonal averages of the 0℃ isotherm heights are the lowest in the winter season (December through February in the north hemisphere, and June through August in the south hemisphere) and are the highest in the summer season (June through August in the north hemisphere, and December through February in the south hemisphere) just like the bright-band height variations. There is almost no seasonal variations of the 0℃ isotherm heights around the tropical area, and on the other hand, the 0℃ isotherm height variations are larger at the higher latitudes.

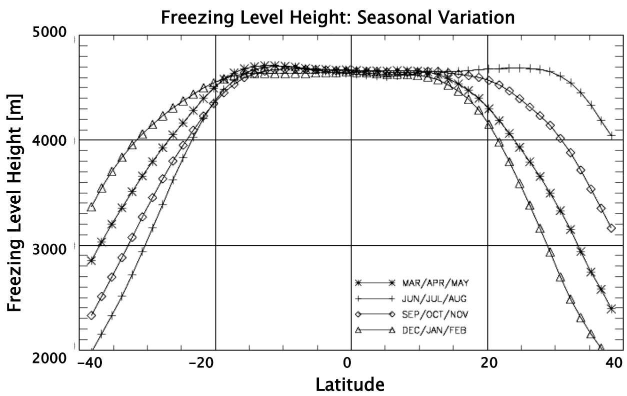

Figure 4: Seasonal variations of 0℃ isotherm by ITU database

5. COMPARISON OF THE BRIGHT-BAND HEIGHT WITH THE 0℃ ISOTHERM HEIGHTS

We have made a scatter diagram composed of a horizontal axis containing the mean bright-band heights for every 1.5 degrees of latitude and longitude and a vertical axis representing ECMWF 0℃ isotherm heights (Figure 5). The data do not include the bright-band heights less than 2 kilometers. The correlation coefficient is 0.90, which means there is a fairly good relationship between these heights. Figure 6 is a histogram of the differences between the 0℃ isotherm heights and the bright-band heights. Approximately 95% of the calculated differences between the 0℃ isotherm heights and the bright-band heights range between 0 and 600 meters, and its mean value is about 304 meters.

The values of differences between 0℃ isotherm heights and bright-band heights are plotted as a function of latitude in Figure 7. In the tropics and in the areas at the latitude of up to ± 10 degrees, the differences are low in magnitude and their spread of variation are also low. However, the spread of the differences are noticeably larger at the higher latitudes.

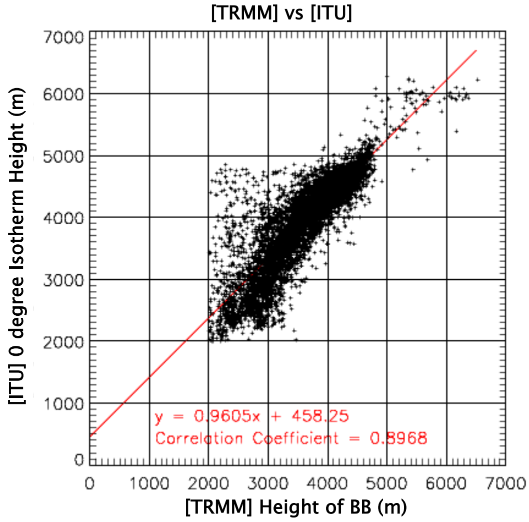

Figure 5: [TRMM] versus [ITU]

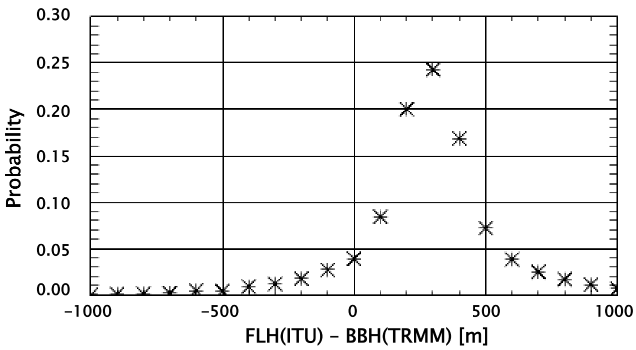

Figure 6: Histogram of differences between 0℃ isotherm height and bright band height

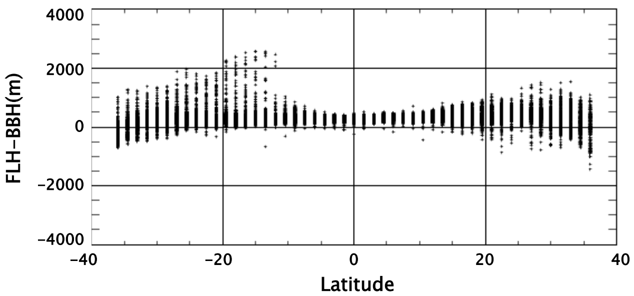

Figure 7: Latitude dependence of the differences between 0℃ isotherm height and bright-band height

6. COMPARISON OF BRIGHT-BAND HEIGHT WITH SST

Figure 8 is a scatter diagram for every 5 degrees of latitude and longitude, of the monthly mean SST (Sea Surface Temperature) on the horizontal axis and monthly mean bright-band height on the vertical axis. The SST are retrieved from TMI and 5° x 5° grid data are obtained by averaging the original 0.25° x 0.25° grid data. The period is from January 1998 to July 2001.

The correlation coefficient is 0.82 and good correlation can be seen from the scatter diagram. The bright-band height increases by about 1km every 6℃ increase of the SST.

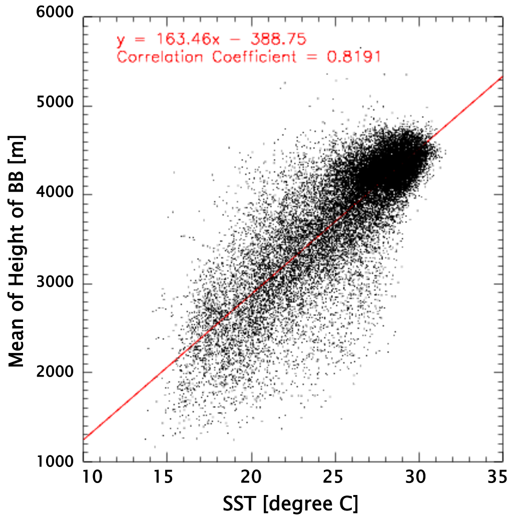

Figure 8: TRMM/TMI derived SST versus TRMM/PR derived bright-band height

7. CONCLUSIONS

TRMM PR data provide much information on the bright band height statistics, which is useful for estimating the 0℃ isotherm heights. We have analyzed TRMM PR 3A25 six-year data (1998-2003) to obtain the monthly, yearly and seasonal variations of the bright-band heights over the ocean and the land within the latitude of +/- 40 degrees and have compared the mean values of the bright band heights of those six years with the ECMWF 0℃ isotherm heights. The bright-band heights were slightly higher in the tropics during the periods of the El Nino 1998 and 2002. The mean value of the differences between the 0℃ isotherm heights and the bright-band heights is 304m, which is consistent with the previously reported value.

The TRMM satellite is continuing its mission in very good condition as of July 2004, at the time of writing. It is a great pity that NASA and JAXA has decided to terminate the operation of TRMM in the very near future.

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REFERENCES

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