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COMPARISON OF INSTANTANEOUS TMI AND PR RAINFALL DATA FROM THE TRMM SATELLITE

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Abstract **– Results are presented from analysis of the Tropical Rainfall Measuring Mission (TRMM) data from the perspective of comparisons of precipitation retrievals between instruments. The instruments specific to this study are the Precipitation Radar (PR) and the TRMM Microwave Imager (TMI).**

1. Introduction

The joint U.S./Japanese Tropical Rainfall Measuring Mission (TRMM) satellite was launched from Tanegashima Island, Japan on November 27, 1997 for the purpose of gaining insight into tropical precipitation processes. The satellite includes two microwave precipitation sensors: the TRMM Microwave Imager (TMI) and the Precipitation Radar (PR). The TMI is an enhanced version of the SSM/I passive microwave radiometer. In contrast, the PR is an active microwave sensor which provides profiling information. An in-depth discussion on the specifics of the complete TRMM sensor package can be found in Kummerow et al. (1998). The work presented here focuses exclusively on the microwave instruments.

Data from the TRMM satellite is processed at the TRMM Science Data and Information System (TSDIS) using retrieval algorithms provided by the Joint TRMM Science Team consisting of U.S. and Japanese scientists and the National Space Development Agency of Japan (NASDA). TRMM data is processed through a series of levels creating data products that are passed on to the National Aeronautics and Space Administration (NASA) Goddard Distributed Active Archive Center (GDAAC) for public distribution. Periodically, the entire set of mission data is reprocessed with improved algorithms. Version 5 data are currently being produced.

Data products are created from the level 0 (raw binary packets) through level 3 (temporal and spatial rainfall averages). Level 1 data consist of geolocated, instantaneous field of view (IFOV) sensor measurements such as brightness temperatures (TMI) or reflectivity (PR). Level 2 data consist of retrievals of physical parameters, such as rainfall rate, at IFOVs similar to level 1. Level 2 rainfall products are very large; a single orbit of level 2 PR rainfall data is 257MB in size. The storage needed to access a large amount of this instantaneous data is typically not available to individual researchers. The TSDIS algorithm testing system allows for the online storage of several months of level 2 TRMM data. This allows the analysis of the instantaneous data over long periods of time and the ability to generate statistics not found in the standard TRMM level 3 products.

One of the roles performed by TSDIS is the analysis of the TRMM algorithms in cooperation with the TRMM science team. In an attempt to verify the standard TRMM algorithms and instruments, TSDIS has conducted several simple statistical studies. For example, comparisons of PR and TMI rainfall retrievals provide some insight into the strengths and weaknesses of the respective algorithms and instruments. Note the distinction here between these consistency studies and traditional validation, which assumes an independent, more trusted, data set. This paper presents results from some of these consistency studies.

2. Method

Investigators (Kummerow et al., 2000) have compared zonal monthly averages of the PR rainfall rate algorithm (PR rain) and the TMI rainfall rate algorithm (TMI rain) to assess their bulk accuracy. (The TRMM IDs of PR rain and TMI rain are 2A25 and 2A12.) In contrast, this work compares 2-dimensional distributions (TMI vs. PR) of instantaneous rainfall rate in order to explore the behaviour of PR rain and TMI rain during August 1998. The influence of surface type is investigated since TMI rain uses a different algorithm for ocean, land, and coast. TMI rain uses a 0.25×0.25 degree grid to determine surface type and records this for each pixel in the TMI rain product. The influence of rain type is also investigated since PR rain uses different reflectivity vs. rain (Z-R) relations depending on whether the rain type is stratiform or convective. The rain type used by PR rain is recorded in the PR qualitative product (TRMM ID 2A23).

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To make pixel to pixel comparisons, a common set of pixel locations was constructed using two resolutions: fine and coarse. To construct the fine resolution data set, first the 760 km wide TMI swath was reduced to match the 215 km wide PR swath. Second, the ~4 km PR IFOVs were mapped into the TMI rain coordinate system (4.6 km × 13.9 km pixels). PR rain IFOVs were averaged. PR rain type IFOVs were combined using majority rule to decide between stratiform and convective, with ties thrown out. The resulting common set of pixels is at the TMI rain pixel resolution.

To assess the effect of resolution size, a second data set was constructed. This coarse resolution data set was constructed using a larger box size: 5 along track by 13 cross track TMI rain pixels, creating a box 69 km along track and 60 km cross track.

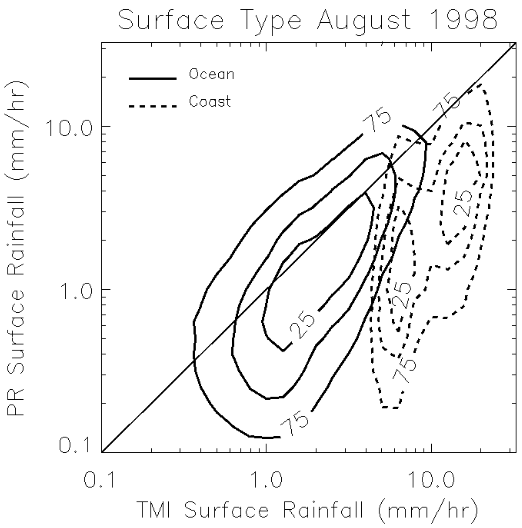

Fig. 1. Joint probability distribution of TMI Surface Rainfall Rate vs. PR Surface Rainfall Rate plotted on a logarithmic scale. Bin size is one decibel of rainfall rate (mm/hr). Contour interval is conditional cumulative probability of 25%. For example, the bins inside the contour labeled 75% contribute 75% of the total rain volume of pixels that are raining in both TMI and PR. Solid contours are ocean pixels at fine resolution (4.6 km × 13.9 km). Dashed contours are coast pixels at fine resolution. Version 5 data were used.

3. Results

The influence of surface type on surface rainfall rate is explored in Fig. 1, which shows two TMI vs. PR distributions. One is the distribution of ocean pixels, which is somewhat oriented along the 1-1 line with a slight majority of pixels having higher TMI than PR rain, in agreement with comparisons of zonal monthly averages (Kummerow, et al., 2000). The other

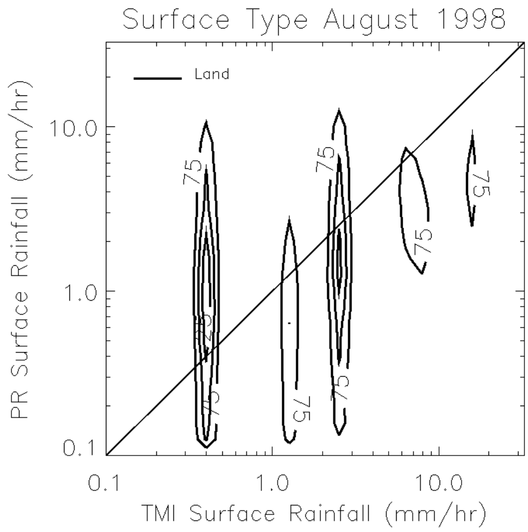

Fig. 2. Same as Fig. 1 except solid contours are land pixels at fine resolution.

distribution, of coast pixels, shows a weak relationship between PR and TMI rain. A large majority of coast pixels have higher TMI than PR rain. In fact, the mean TMI rain was twice as high as the mean PR rain for coast pixels. The TMI coast distribution includes very few rain rates lower than 4 mm/hr and a double peak. The double peak may be due to one peak for stratiform and another for convective conditions (Kummerow, personal communication). There is a large overlap between the ocean and coast PR distributions, but only a small overlap between the ocean and coast TMI distributions. The land distribution (Fig. 2) shows a very weak relationship between TMI and PR rain. In addition, the TMI distribution is strongly quantized, i.e., the TMI land algorithm has a strong preference for specific rainfall rates.

The influence of rain type determined by PR is investigated in Fig. 3, which shows two distributions of surface rainfall rate: stratiform rain pixels and convective rain pixels. To remove the influence of surface type, only ocean pixels were included. The stratiform distribution is somewhat oriented along the 1-1 line, but the convective distribution is well off the 1-1 line. The convective distribution extends into higher rain rates than the stratiform distribution, as expected. Interestingly, stratiform pixels usually have higher TMI rain than PR rain, but convective pixels usually have lower TMI rain than PR rain. In fact, the ratio of the TMI mean rainfall rate over the PR mean rainfall rate is 1.3 for stratiform pixels and 0.62 for convective pixels.

The above results used the fine resolution data set, but a TMI to PR comparison for assessing accuracy would average over a larger box since the observations used to create a TMI rain pixel have footprints as large as 37 km × 63 km (Kummerow et al., 1998). Fig. 4 shows the

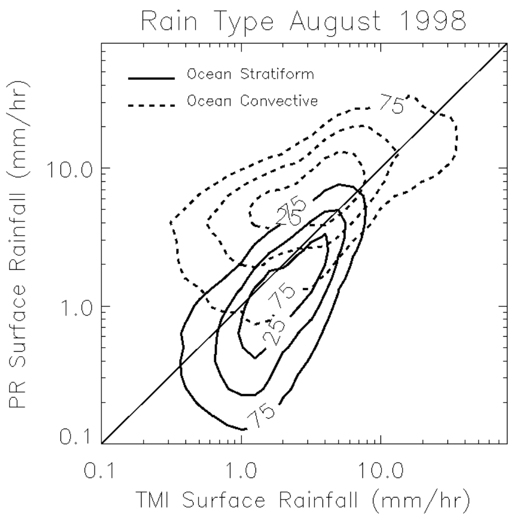

Fig. 3. Same as Fig. 1 except solid contours are ocean stratiform pixels. Dashed contours are ocean convective pixels.

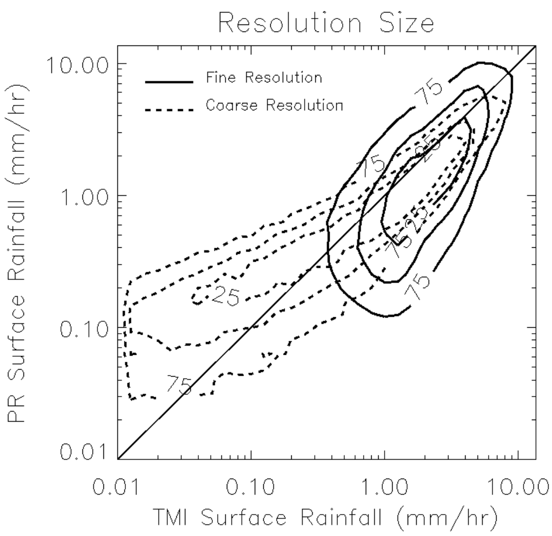

Fig. 4. Same as Fig. 1 except solid contours are ocean pixels at fine resolution (4.6 km × 13.9 km). Dashed contours are ocean pixels at coarse resolution (60 km × 69 km).

influence of resolution size on the TMI to PR comparison. To remove the influence of surface type, only ocean pixels were included. The TMI PR relationship at surface rainfall rates above 1 mm/hr is stronger for the coarse resolution than for the fine resolution. The relationship at lower rain rates is poor for the coarse resolution, but those rain rates contribute little to total rainfall volume. To assess the contribution to total rainfall volume, the product of rainfall rate and frequency for each bin is shown in Fig. 5. The rainfall rate used was the average of the TMI and PR rainfall rates for the joint bin. The correlation between TMI and PR rainfall rates is higher for the coarse resolution than the fine resolution data set.

4. Conclusions

Some of the results of the analysis presented here are being studied for possible improvement of the TRMM production algorithms. These types of statistics are provided by TSDIS as an ongoing effort to improve the TRMM algorithms. As precipitation retrieval algorithms and the instruments themselves become more complex, e.g. a possible Global Precipitation Mission (GPM), the need for simple algorithm consistency studies is expected to continue.

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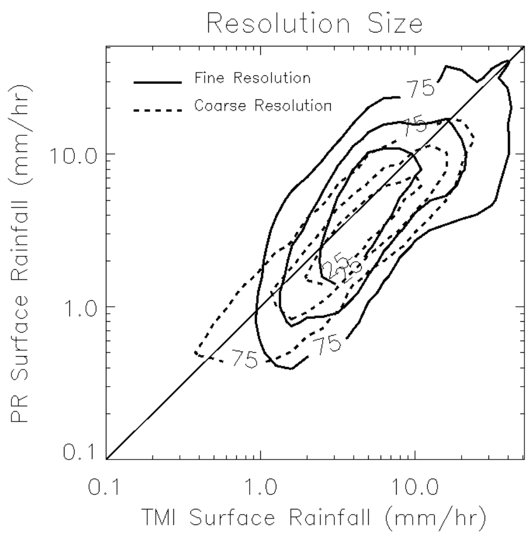

Fig. 5. Same as Fig. 4 except joint distribution of contribution to total rain volume is plotted.

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