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THE RELATIONSHIP BETWEEN TOTAL PRECIPITABLE WATER AND PRECIPITATION RATES

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1. INTRODUCTION

Atmospheric water vapor is a necessary condition for precipitation. By exploring how water vapor affects precipitation rates on a global scale, it is hoped that the relationship between the two can be quantified in a meaningful way. This will be done through analysis of seasonal variations and conditional probabilities of rainfall rate and total precipitable water. The relationship between these two quantities is potentially useful for several purposes, including predicting the probability of rain, analyzing the performance of models, and comparing satellite retrieval algorithms.

2. DATASETS

The Blended Total Precipitable Water (bTPW) product comes from the Cooperative Institute for Research in the Atmosphere (CIRA) and is used for the total precipitable water (TPW) data. The Climate Prediction Center morphing method (CMORPH) is used for the rainfall rate (RR).

The bTPW product is formed by blending data from two passive microwave instruments, the Advanced Microwave Sounding Unit (AMSU) and the Special Sensor Microwave Imager (SSM/I), on six different satellites. This blending is done through matching probability distribution functions from the different instruments in order to combine them into one dataset, Kidder and Jones (2007). These TPW data are available only over the ocean, with the exception of the U.S., which has GPS TPW data.

The CMORPH product is created by combining data from three passive microwave instruments, the TRMM Microwave Imager (TMI), the Advanced Microwave Sounding Unit-B (AMSU-B), and the Special Sensor Microwave Imager (SSM/I), which are on seven different satellites. If all three estimates are available for a location, only one will be used to form the final product: TMI first, then data from SSM/I, then data from AMSU-B are used if the former data types are unavailable. When no data are available, the CMORPH product uses infrared data from various geostationary satellites to propagate the rainfall data so that datasets can be produced at the required spatial and temporal resolutions, Joyce et al. (2004). These data are available over both land and ocean.

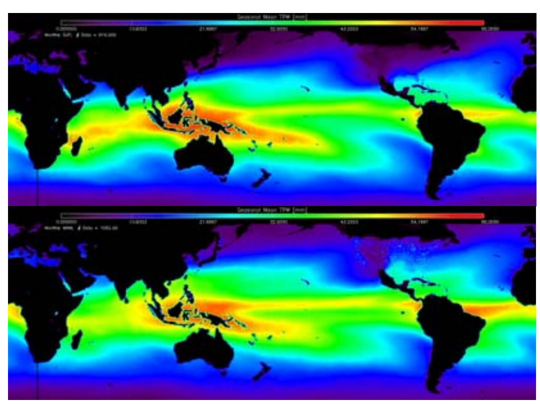
The study area for this project is from 60^o N to 60^o S. The data used is from February 2006 through December 2008, at a six hour time resolution. Since datasets are not available for every time period for both TPW and RR, the only time periods used are those when both types of data are available, or 3924 cases over the 35 month period. The data are spatially resolved to 0.25^o grid boxes. Since the TPW dataset was initially at a higher resolution, it was converted to the lower 0.25^o resolution by averaging all available TPW values within each 0.25^o square to give one TPW value for that location and time.

3. RESULTS

Some initial results demonstrate the importance of investigating temporal and spatial variations in the data.

3.1 *Seasonal Variations*

The mean TPW varies with season, as seen in fig. 1 below:



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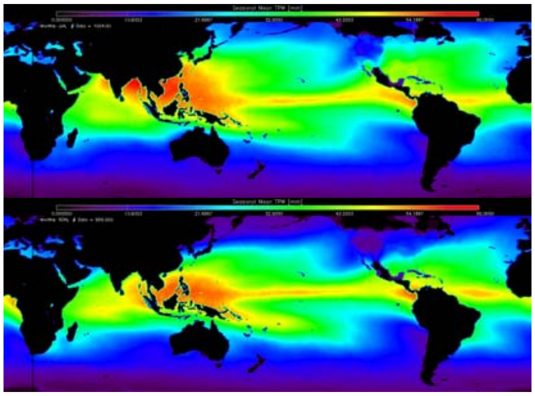

Fig. 1. Mean TPW according to season (top to bottom: DJF, MAM, JJA, SON). The scale is from 0 to 65 mm.

This effect can be seen in the latitudinal shift of maximum TPW toward each hemisphere's summer, as well as in the shift of maximum TPW values toward Southeast Asia during the South Asian Monsoon in June, July, and August. Changes in rain rate distributions with season are not as obvious:

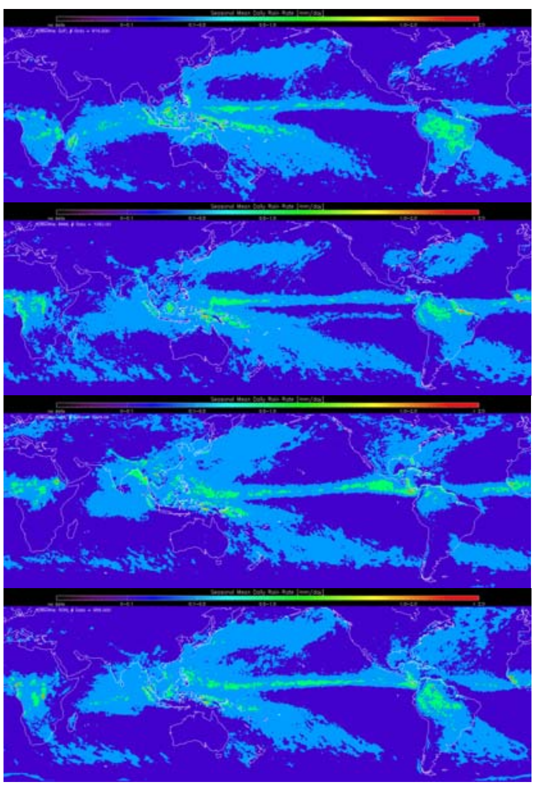

Fig. 2. Mean daily rain rate (mm/day) according to season (top to bottom: DJF, MAM, JJA, SON). Rain rate distributions vary with season. The scale is from 0-0.1 to >2.0 mm/day.

The average daily rain rate is higher in northern Australia and the southeastern United States during their respective summers and autumns. Rain distributions throughout Africa and the eastern tropical Pacific also vary greatly with season.

3.2 *Mean TPW Given Rain Rate*

Mean TPW values tend to be higher when rain rates are higher. Seasonal variations are also significant in this type of analysis.

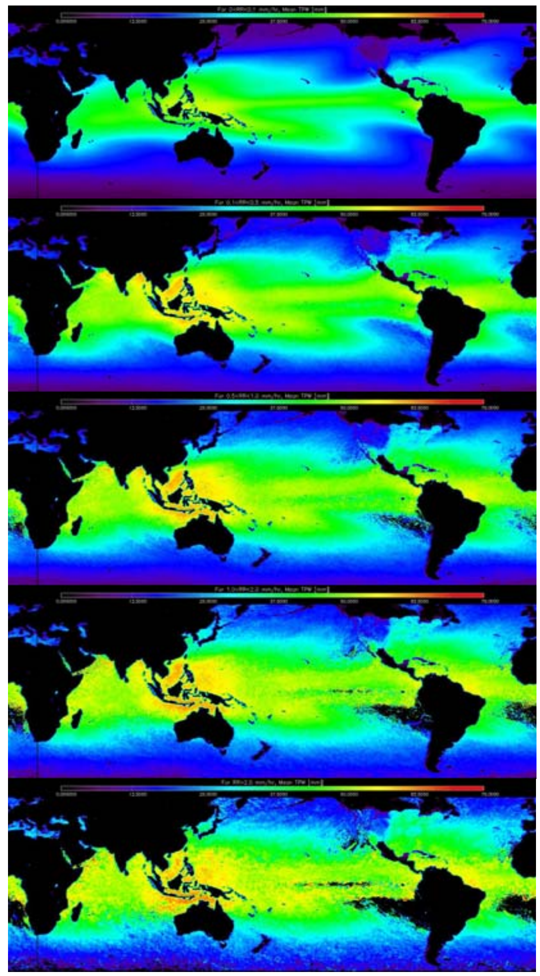

Fig. 3. Mean TPW in different rain rate regimes (top to bottom: 0<RR<0.1, 0.1<RR<0.5, 0.5<RR<1.0, 1.0<RR<2.0, RR>2.0 mm/hr). Year-round data. The scale is from 0 to 75 mm.

The increase in TPW with rain rate regime is most obvious in the western tropical Pacific and in the higher latitudes of the study area. TPW values closer to 75 mm are much more prevalent in the western tropical Pacific for RR>2.0 mm/hr than in the case of 0.1<RR<0.5 mm/hr. In the higher latitudes, there are few cases of TPW less than 12.5 mm for RR>2.0 mm/hr, while TPW is mostly less than 12.5 mm for RR<0.5 mm/hr, especially in the southern hemisphere.

In figs. 1 and 2, seasonal variations in TPW and rain rate are clearly present. In fig. 3 above, which includes data from all seasons, mean TPW also varies with rain rate regime. In fig. 4 below, which includes only June, July, and August data, the mean TPW distribution varies with rain rate regime in a different way than when data were analyzed year-round.

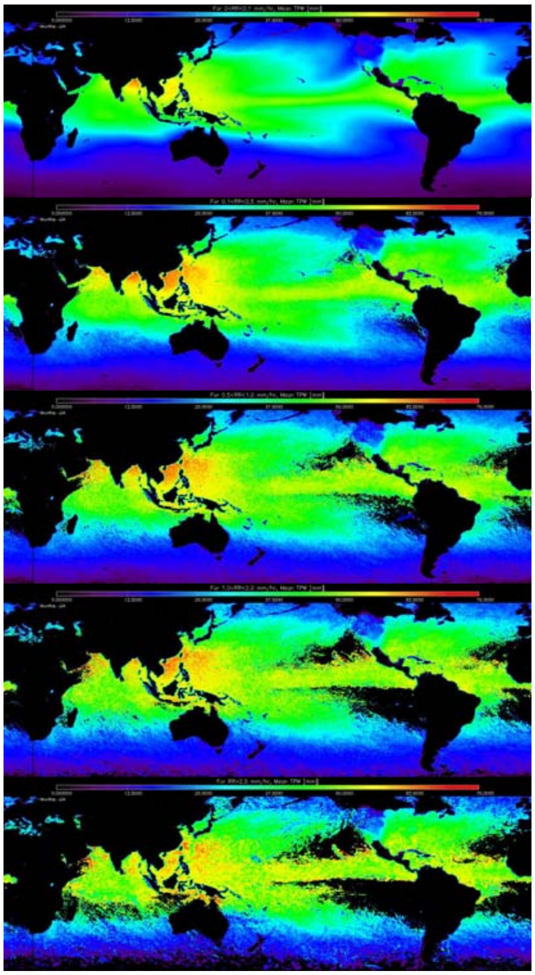

Fig. 4. Mean TPW in different rain rate regimes (top to bottom: 0<RR<0.1, 0.1<RR<0.5, 0.5<RR<1.0, 1.0<RR<2.0, RR>2.0 mm/hr). JJA data. The scale is from 0 to 75 mm.

Mean TPW still tends to be higher when rain rates are higher, and the distribution of higher TPW is skewed toward the northern hemisphere.

4. FUTURE WORK

This master's thesis project is scheduled to conclude in the summer of 2010, and there are many issues that still need to be investigated. For instance, since the CMORPH data comes at such a high spatial and temporal resolution, it would be interesting to use it to estimate global rainfall amounts. There are also different climates across the globe, which indicates that the relationship between TPW and RR may vary with region. Identifying these regions and the different statistics present will lead to better predictions of probability of precipitation.

In fig. 3, the mean TPW in different rain rate categories is displayed. In order to begin assessing the conditional probability of rain rate given TPW, similar analyses must be made of rain rates in different TPW regimes. However, this process is complicated, since the distribution of TPW is more Gaussian-shaped, while the distribution of rain rates is closer to an exponential decay. It may be the case that the shapes of these distributions vary with climate region or latitude, so the distributions of these variables must also be analyzed.

Another possible direction for this project is to incorporate another atmospheric variable, such as vertical motion. Given probable conditions for rain, such as relatively high TPW, a variable like vertical motion may act as a type of catalyst, making the occurrence of rain even more probable. Although TPW data is available only over the ocean (with the exception of the U.S.), finding a method to estimate precipitation rate would be highly beneficial in the event that TPW data is gathered over remote land areas in the future. This research could then be more easily extended over land and provide the opportunity to predict precipitation over areas without readily available meteorological data.

5. SUMMARY

Precipitation and precipitable water are closely related, and the availability of global datasets provides the opportunity to investigate this relationship more closely. Preliminary results demonstrate a quantitative relationship, but the data need to be analyzed more thoroughly in order that such quantities as annual global precipitation and conditional probability of rain rate may be identified.

Acknowledgements. This research is supported by the DoD Center for Geosciences/Atmospheric Research at Colorado State University under Cooperative Agreement W911NF-06-2-0015 with the Army Research Laboratory.

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