Evolution of Extreme Precipitation: A Satellite Based Investigation

Ryan Gonzalez[1]; Christian Kummerow[2]; Janice Bytheway[2]
Texas A&M University, College Station, Texas[1]
Colorado State University, Fort Collins, Colorado[2]

INTRODUCTION

Accurately measuring global precipitation is key to understanding the water and energy budgets of the Earth. This project focuses on the expected increase of extreme precipitation over tropical oceans in response to an increase in water vapor. As surface temperatures increase due to a warming climate, the water holding capacity of the atmosphere will increase at roughly 7%K^{-1} according to the Clausius-Clapeyron equation (Trenberth et al. 2003). Arguments have been made stating that an increase in water vapor will correspond to a corresponding increase in precipitation rates which would lead to a significant increase in extreme rain rates with fewer light and moderate events (Trenberth et al. 2003, Allen and Ingram 2002, Meehl 2000).

The Global Precipitation Measurement (GPM) Core Observatory satellite was launched on the 28th of February 2014 as a shared project between NASA and JAXA. The satellite offers an ideal platform to observe precipitation rates that can be related to the water vapor content of the atmosphere. Probability density functions (PDFs) of rain rates were created using a merged dataset comprised of GMI and ERA-Interim reanalysis data. PDFs were generated for a small percent change in water vapor in similar climatological regimes: tropical oceans. This same experiment was performed for separate categories of CAPE and vertical profiles of specific humidity.

Do we observe an increase in extreme rain rates in response to an increase in water vapor? Are differences in extremes related to dynamics or microphysics?

Experiment

Using a merged GPM and ERA-Interim dataset, a comparison between probability density functions of rain rates in a summation of five tropical ocean boxes was made. Three comparisons of differing values of water vapor were looked at: 40mm vs. 42mm, 50mm vs. 52mm, and 60mm vs. 62mm. All boxes consist of a 30°×30° square from 15°N to 15°S with varying longitudes as shown in figure 4. To understand a role of dynamics, CAPE values were separated into a high and low category for each ocean box. In order to look at a role microphysics and cloud structure play on extreme rain rates, specific humidity values were taken at 950mb and 500mb. The mean value at each pressure level was computed. PDFs were generated for values above the mean at both levels and for values below the mean at both levels.

Role of Water Vapor

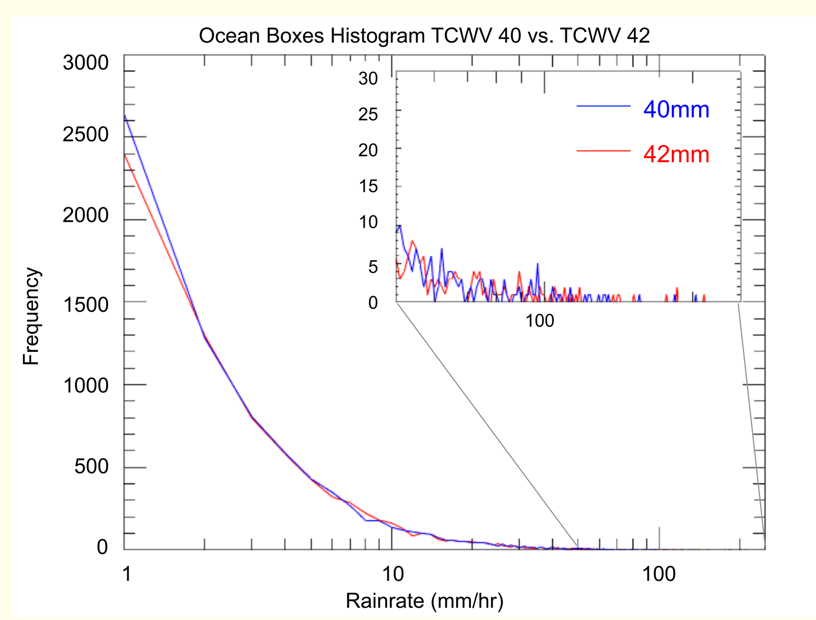


Figure 1. PDF of rain rates at water vapor values of 40mm(red) and 42mm(blue).

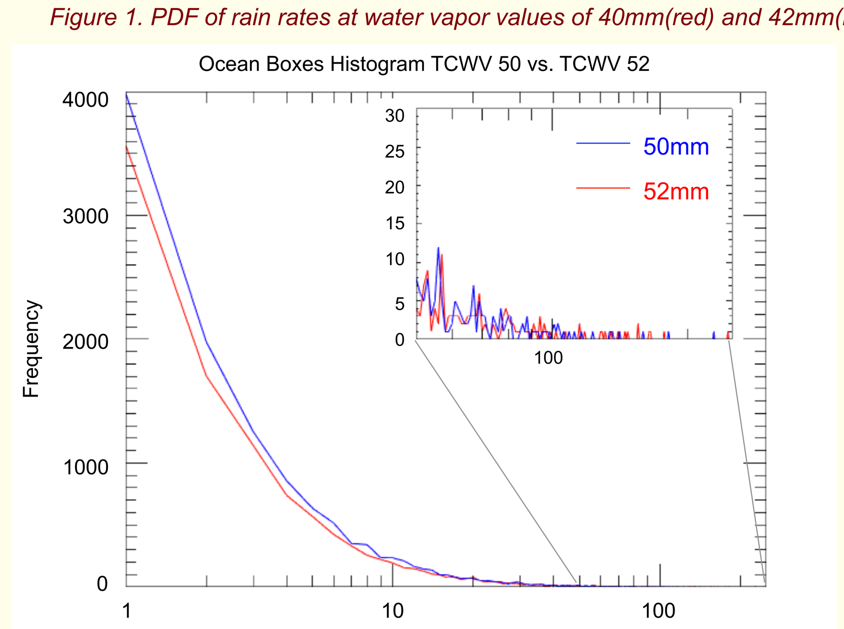


Figure 2. PDF of rain rates at water vapor values of 50mm(red) and 52mm(blue).

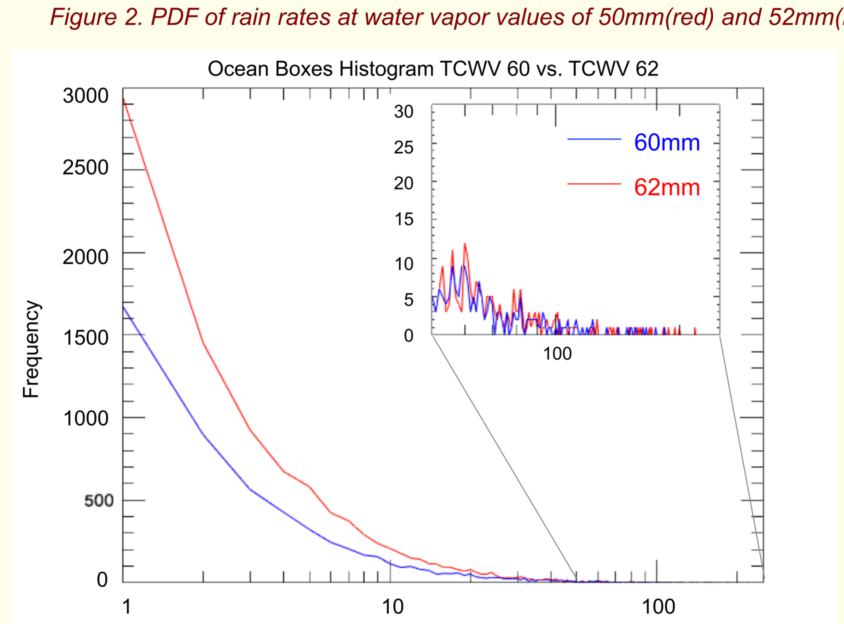


Figure 3. PDF of rain rates at water vapor values of 60mm(red) and 62mm(blue).

- Increase in water vapor not associated with increase in extreme rain rates
- Increase in light rain events from 40mm to 50mm with the opposite occurring between 50mm and 60mm

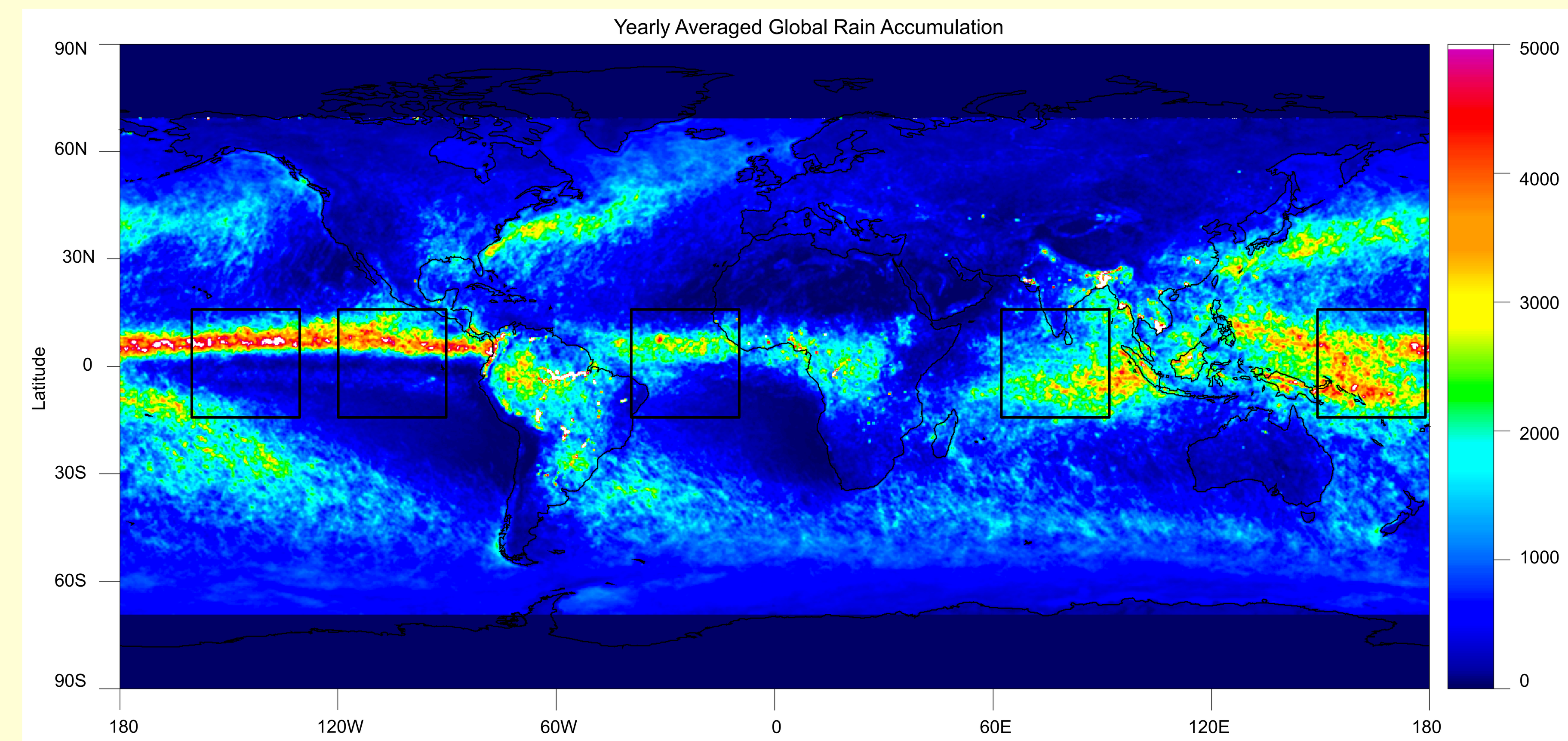


Figure 4. Yearly averaged rain accumulation for a year of GPM data with five dynamically different ocean boxes.

Role of Dynamics

Low Cape

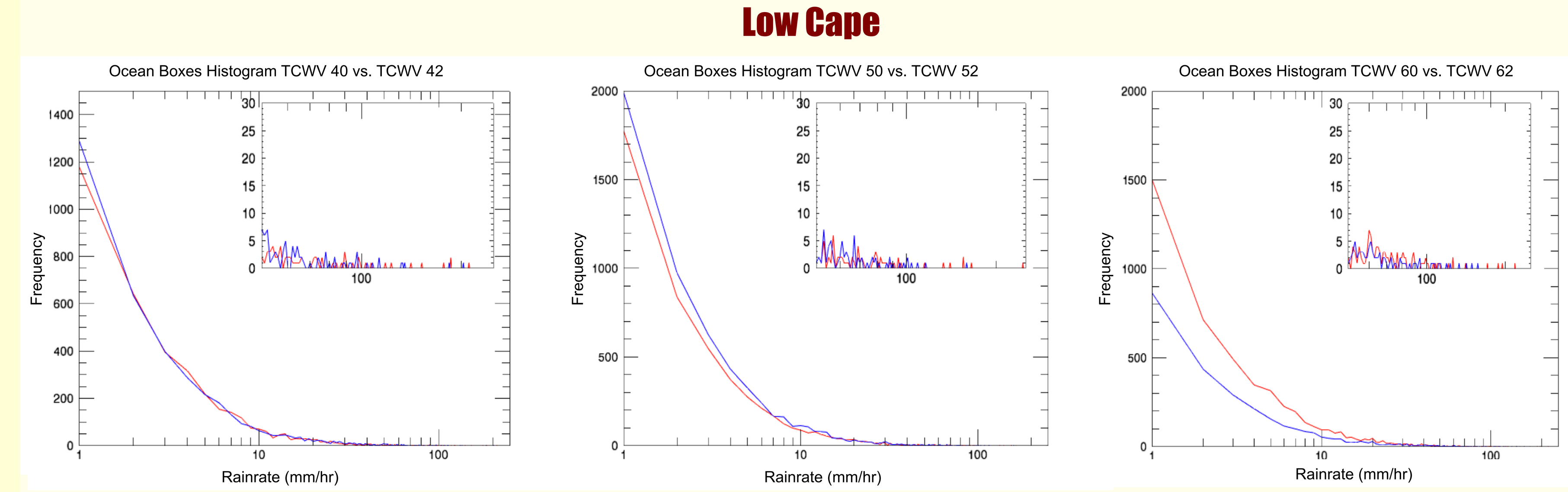


Figure 5. PDF of rain rates for low values of CAPE over all ocean boxes.

High Cape

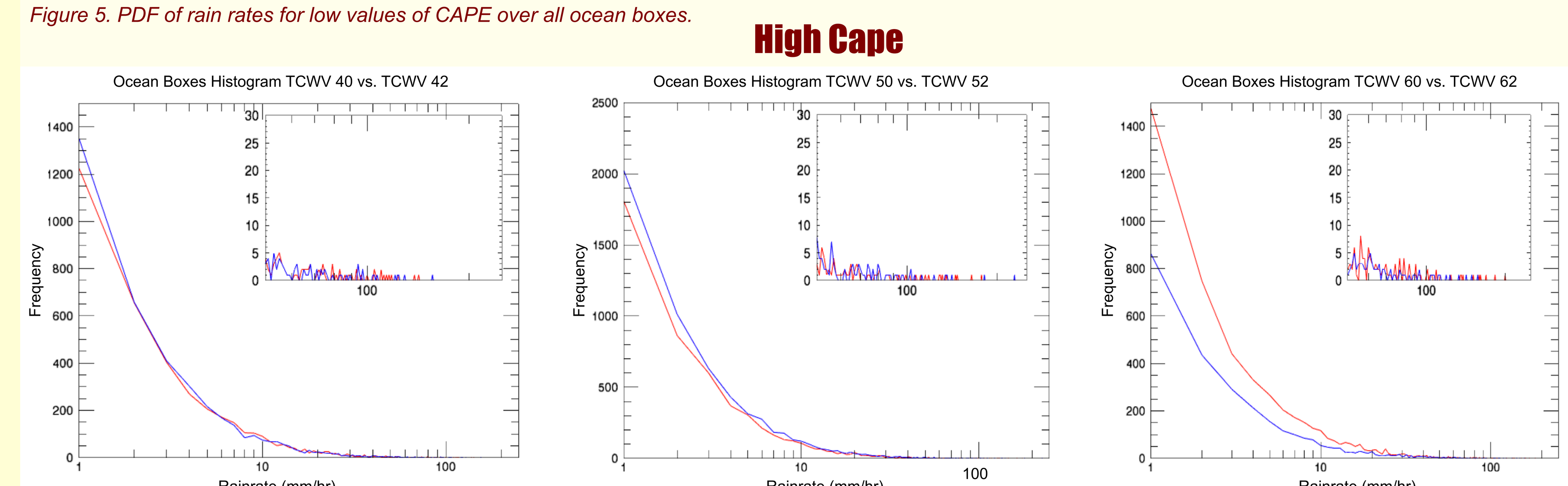


Figure 6. PDF of rain rates for high values of CAPE over all ocean boxes.

- CAPE is not a good precursor for heavy rain events in the tropics
- Agrees with Barkidija & Fuchs (2013), Sobel et al. (2004), and Yano et al. (2005)

Role of Microphysics

Low Specific Humidity

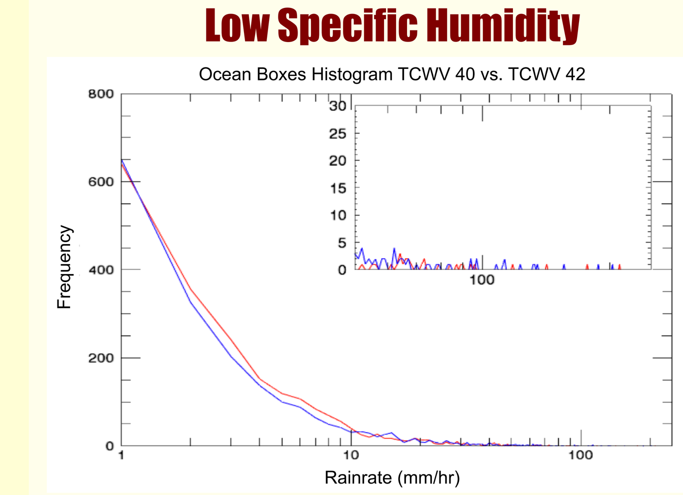


Figure 8. PDF of rain rates for low values of specific humidity over all ocean boxes.

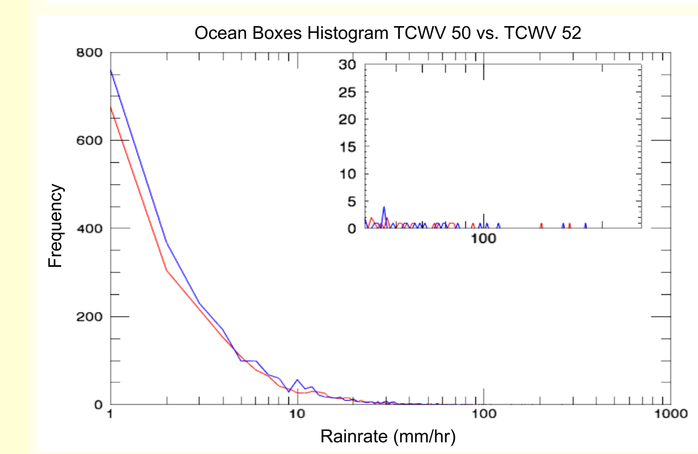


Figure 9. PDF of rain rates for low values of specific humidity over all ocean boxes.

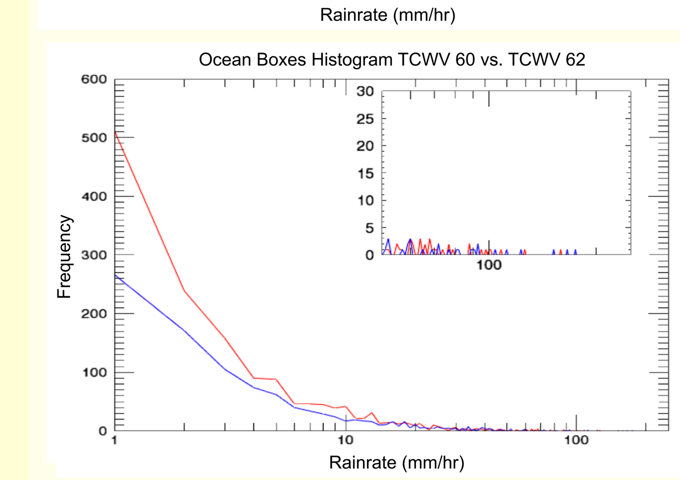


Figure 10. PDF of rain rates for low values of specific humidity over all ocean boxes.

High Specific Humidity

Figure 11. PDF of rain rates for high values of specific humidity over all ocean boxes.

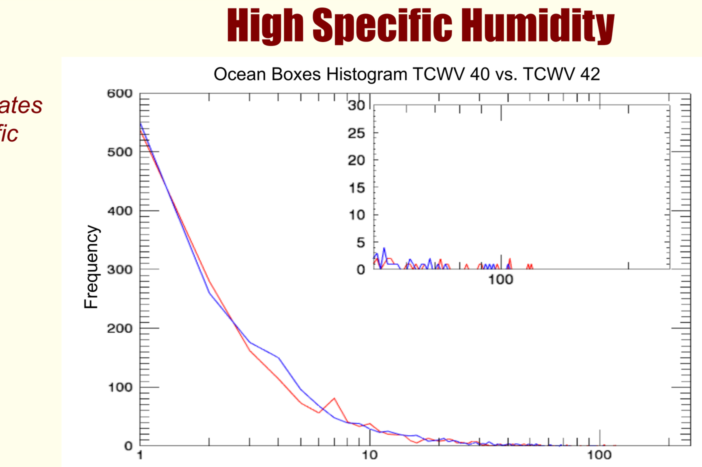


Figure 12. PDF of rain rates for high values of specific humidity over all ocean boxes.

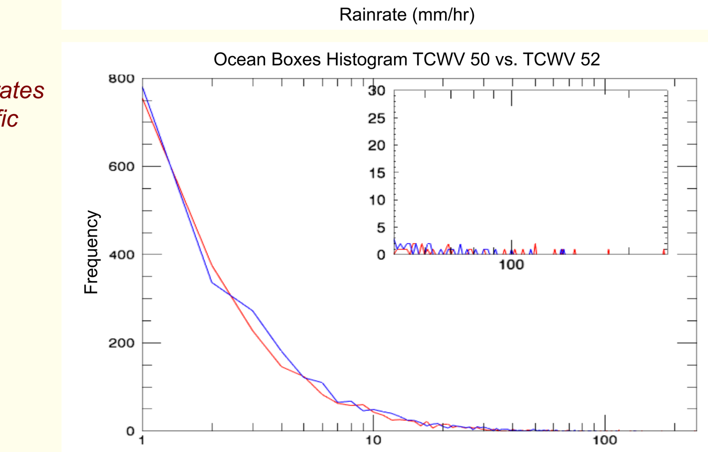
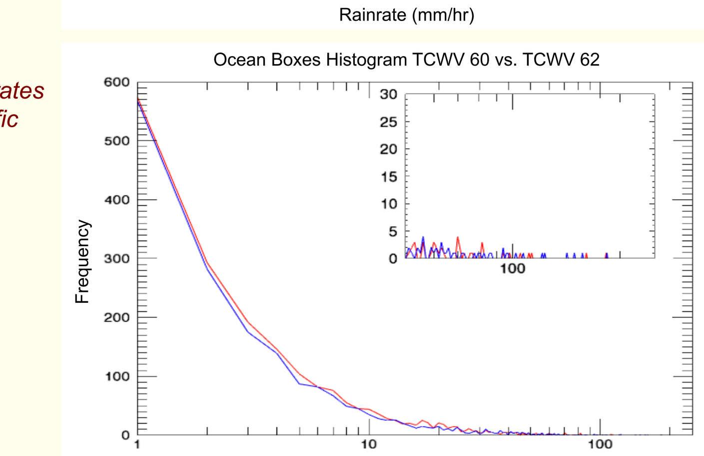


Figure 13. PDF of rain rates for high values of specific humidity over all ocean boxes.



- Little correlation between specific humidity and rain rates

Conclusions

- An increase in water vapor alone does not increase precipitation rates
- CAPE is poorly correlated with rain rates in the tropical oceans
- Specific humidity values show little correlation between high and low values and rain rates

Future Work

- Using GPM satellite for three dimensional structure of rain and microphysical properties
- Generating normalized PDFs
- Tracking global oscillations such as the Madden-Julian Oscillation

Acknowledgements

A special thanks to Chris Kummerow and Janice Bytheway for their patience and guidance throughout this project. This work has been supported by the National Science Foundation Research Experiences for Undergraduates Site in Climate Science at Colorado State University under the cooperative agreement No. AGS-1461270.

References

Barkidija et al. "Precipitation correlation between convective available potential energy, convective inhibition and saturation fraction in middle latitudes." *Atmospheric Research* 124. (2003): 170-180
Ingram, William J., and Myles R. Allen. "Constraints on future changes in climate and the hydrological cycle." *Nature* 419. (2002): 224-232
Meehl et al. "Trends in Extreme Weather and Climate Events: Issues Related to Modeling Extremes in Projections of Future Climate Change." *AMS* 81.3. (2000): 427-436
Sobel et al. "Large-Scale Meteorology and Deep Convection during TRMM KWAJEX." *AMS* 132. (2004): 422-444
Trenberth et al. "The Changing Character of Precipitation." *AMS*. (2003): 1205-1217
Yano et al. "A generalization of CAPE into potential-energy convertability." *RMS* 131. (2005): 861-875