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A STUDY OF RAINFALL ASYMMETRY IN TROPICAL CYCLONES USING TRMM MICROWAVE IMAGER.

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1. Introduction

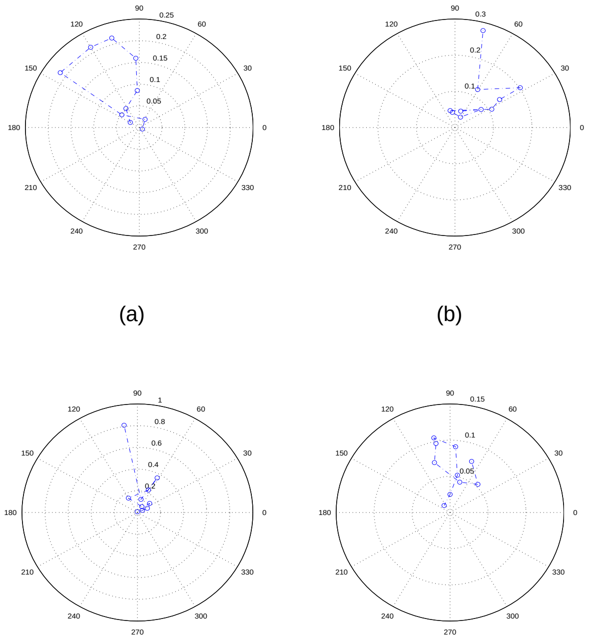
While predictions of tropical cyclones (TC) track and intensity are improving, there is still very little skill in quantitative precipitation forecast (QPF). One of the uncertainties in QPF is the lack of understanding of physical processes affecting rainfall structure in TC. Several mechanisms have been proposed previously to explain the spatial distribution of rain. For example, the presence of a relative flow, frictional convergence in the boundary layer (Shapiro, 1983), advection of planetary vorticity, or vertical wind shear (DeMaria, 1996) can induce asymmetry in TC rainfall. The importance of each factor is not known. Possible feedbacks of asymmetry on the storm are also unclear.

Observational studies have confirmed the presence of rainfall asymmetries. Marks (Marks, 1980), using an airborne radar, documents asymmetry in Hurricane Allen precipitation distribution. Eyewall rainfall peaks in the right-front quadrant. Out of the core, the maximum is in the same quadrant, but shifted clockwise. Burpee and Black (Burpee and Black, 1989) observe asymmetry in Hurricanes Alicia and Elena. Rodgers and Pierce (E. B. Rodgers and Pierce, 1994), using satellite observations of North Atlantic TCs, find an asymmetry in front of the storm for slow moving systems. The asymmetry shifts to the right for faster moving storms. These results are based on a limited amount of observations. A global analysis of rainfall structure is needed in order to improve QPFs, however. Estimates of precipitation from the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and Precipitation Radar (PR) offer the possibility to increase the size of the datasets and explore TC rainfall asymmetry in various environmental conditions globally.

The goals of our study are (1) to improve our understanding of TC precipitation by creating a global climatology of rain distribution, (2) to address physical mechanisms determining TC rainfall structure. This abstract focuses on the climatology results.

2. Methodology

Surface rain estimates from the NASA TRMM/TMI are used to quantify surface rainfall. TMI is a passive microwave radiometer measuring upwelling radiation at 10.7, 19.4, 21.3, 37 and 85.5 GHz over a 758.5 km swath.



(a) (b)

(c) (d)

FIG. 1: Asymmetries calculated in 50 km rings around storm center, as a function storm intensity: a) Tropical depressions and storms, b) category 1-2 storms, c) category 3-5 events, d) total distribution.

Between 1998 and 2000, near 250 storms developed worldwide, providing more than 2000 instantaneous observations with high data coverage. At the time of observation, 64% of these events were tropical depressions (TD) and storms (TS), 26% were category 1-2 hurricanes and the remaining 10% were category 3 or higher storms. Distributions of TRMM observations as a function of intensity and oceanic basins are representative of the actual climatology of TC occurrence.

To demonstrate asymmetry in TC surface rainfall, we study rain distributions in storm motion relative coordinates for 1999 observations. For each quadrant defined in the storm motion relative system, we compute mean rain rates in 50 km rings out to 500 km. In each ring, we determine the asymmetry by calculating the first order Fourier transform coefficients, using the mean rain rates in each of the quadrants. Observations are strati-

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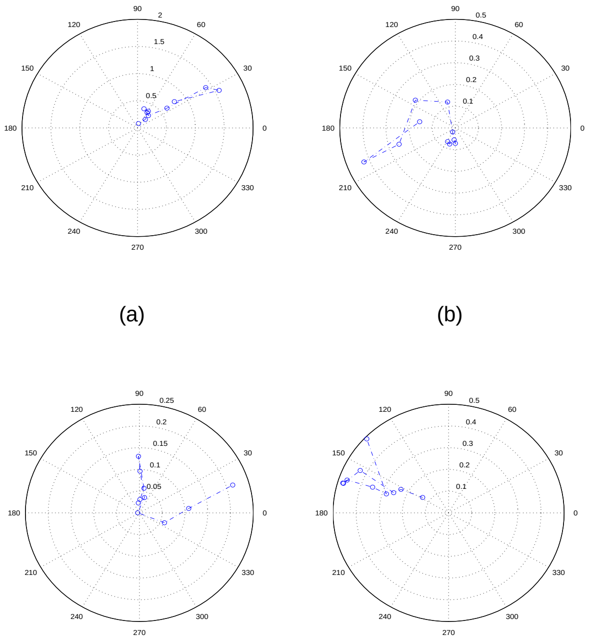

(a) (b)

(c) (d)

FIG. 2: Asymmetries calculated in 50 km rings around storm center, for a) Atlantic, b) East-Central Pacific, c) West Pacific, and d) South Pacific storms.

fied in intensity range and oceanic basins. Figs. 1 and 2 illustrate the results. The 90^o axis represents the storm motion vector. Each point on the figures corresponds to the asymmetry computation within one of the 50 km rings around the storm center.

3. Results

Fig. 1 shows asymmetries for all TC observations together and as a function of storm intensity. A magnitude of one on the graph means that the asymmetry is as large as the mean rain rate within the ring where the calculation is conducted. The largest asymmetries are observed within the 250 km inner core. Both magnitude and orientation of asymmetries vary with intensity. From a front-left quadrant location for TD and TS, asymmetries shift to the front-right quadrant for hurricane intensity systems. The asymmetry for all observations together lies ahead of the center in the direction of motion. Magnitudes remain small for most of the intensity range.

We have also stratified the observations in six basins. Large differences among basin asymmetries are observed. For example, Fig. 2 shows asymmetries for the Atlantic and Pacific basins. Asymmetries are in the front quadrants for most basins, which is in agreement with our results relating asymmetries to storm intensity. Magnitudes of asymmetries are however very different among basins. Magnitudes are small (lower than one) in the entire Pacific, while they are larger than unity in the Atlantic and Indian Oceans.

4. Conclusions

TRMM/TMI surface rainfall estimates are used on a sample of approximately 2100 TC instantaneous observations to characterize rain distributions in tropical storms. Our sample consists of 1998-2000 storm observations, globally distributed. We determine azimuthal averages and first order asymmetry in surface rainfall. For the azimuthal averages, observations are stratified by storm intensity and basin of occurrence. Increase in surface rainfall with storm intensity is observed. Azimuthal averages findings will be described more in details at the conference. Asymmetry were calculated using the observations for 1999. They vary both in location and magnitude with storm intensity and oceanic basin. A shift with intensity is observed, from front-left to front-right quadrants. For all storms averaged together, asymmetry aligns with storm motion, ahead of the center. Large asymmetry variability among different basins is observed. Atlantic and Indian Ocean storm have similar large asymmetry magnitudes, while Pacific storms are more symmetric. This study provides a global description of rainfall structures in tropical cyclones, which is central information towards improvement of QPFs.

5. Acknowledgements

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REFERENCES

Burpee, R. W. and M. L. Black, 1989: Temporal and spatial variations of rainfall near the centers of two tropical cyclones. *Monthly Weather Review*, **117**, 2204–2218.

DeMaria, M., 1996: The effect of vertical shear on tropical cyclone intensity change. *Journal of the Atmospheric Sciences*, **53**, 2076–2087.

E. B. Rodgers, S. C. and H. F. Pierce, 1994: A satellite observational and numerical study of precipitation characteristics in western north atlantic tropical cyclones. *Journal of Applied Meteorology*, **33**, 129–139.

Marks, F. D., 1980: Evolution of the structure of precipitation in hurricane allen (1980). *Monthly Weather Review*, **113**, 909–930.

Shapiro, L. J., 1983: The asymmetric boundary layer flow under a translating hurricane. *Journal of the Atmospheric Sciences*, **40**, 1984–1998.