Improved Characteristics of Tropical Cyclone Precipitation from Satellite Passive Microwave Measurement

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Introduction

Tropical Cyclone (TC) activities can be only globally tracked and monitored by satellite remote sensing. The Geostationary satellite Infrared/Visible (GEO IR/VIS) sensors provide frequent observations of TCs, but only for top of TC clouds. Low Earth Orbit (LEO) satellite passive microwave (PMW) sensors can provide high spatial resolution but less frequent observations of TCs. The available conical scan PMW sensors for TC tracking and monitoring are the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave and Imager (SSM/I) series, the Special Sensor Microwave Imager/Sounder (SSMIS) series, Advanced Microwave Scanning Radiometer for EOS (AMSR-E), AMSR2, Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI), Global Precipitation Measurement (GPM) Microwave Imager (GMI).

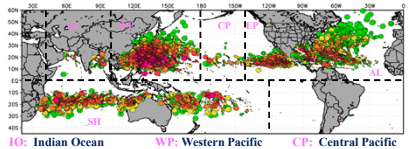
The extremely amount of precipitation is one of the leading factors on impacts from TC activities. The newly released NASA GPROF precipitation data for all PMW sensors provides a golden opportunity to improve our understanding of TC precipitation. This study based on the long-term and consistent GPROF rain retrievals presents distinguished patterns of precipitation regarding direction of TC movement and direction of the 200-850 mb vertical wind shear.

The features of GPROF TC precipitation are utilized to assess uncertainties of JAXA Global Satellite Mapping of Precipitation (GSMaP) hourly rain products for TC applications.

Datasets

1: NASA GPM GPROF precipitation in 1998-2012
2: JAXA GSMaP precipitation in 2000-2012
3: NRL TC database in 1987-2012

Tropical Cyclone Climatology Based on Satellite Passive Microwave Observations (1987-2012)



IO: Indian Ocean WP: Western Pacific CP: Central Pacific
SH: Southern Hemisphere EP: Eastern Pacific AL: Atlantic Ocean

Saffir-Simpson Classification of Tropical Cyclones

	TD	TS	Cat1	Cat2	Cat3	Cat4	Cat5
Wind Speed	<17 m/s <33 knots	18-32 m/s 34-63 knots	33-42 m/s 64-82 knots	43-49 m/s 83-95 knots	50-58 m/s 96-112 knots	59-70 m/s 113-136 knots	≥70 m/s ≥137 knots

Fig. 1: TC classifications and distribution climatology from satellite PMW sensor measurements in 1987-2012.

Characteristics of Global Composite TC Precipitation

NRL TC Database

Brightness temperatures of TCs observed by all available conical scan PMW sensors collected and calibrated to 89 GHz at high frequency channels, center-fixed with ARCHER and interpolated to 1km x1km with Backus-Gilbert scheme are processed and archived at NRL-Monterey, along with their Vmax, minimum surface pressure, and motion direction. This database can be used for studies of TC climatology, characteristics of intensity and evolution, and other applications. Table 1 presents distributions of the GPROF precipitation for TCs in 1998-2012.

Table 1: Distribution of Observed TC Precipitation from PMW sensors (1998-2012)

Basin	TD	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
AL	3797	6351	1733	570	512	388	68
CP	533	215	98	33	49	57	21
EP	4617	3379	822	375	346	224	24
IO	1351	995	124	33	62	43	14
SH	7353	6494	1593	757	769	572	76
WP	7139	6022	2163	1195	1093	1102	234
Total	24790	23456	6533	2963	2831	2386	437

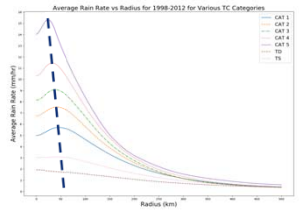


Fig. 1: Global composite TC precipitation azimuthal-averaged radius patterns at each category. The heavy dashed line is for the maximum rainfall location.

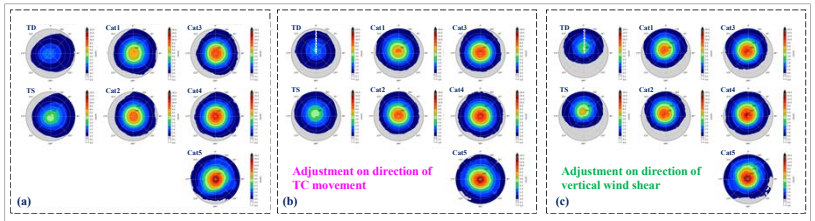


Fig. 2: Precipitation distributions of global TCs at each category for composition technique of (a) north direction, (b) direction of TC movement, and (c) direction of 200-850 mb wind shear. The white arrow is for direction of TC movement or vertical wind shear. A consistent TC precipitation pattern is shown with adjustment on direction of the vertical wind shear.

Composite Precipitation Patterns for Global Major Hurricanes in 1998-2012

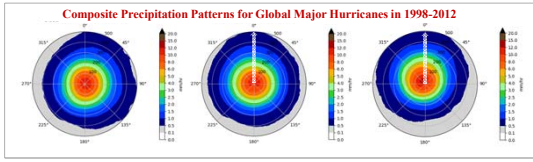
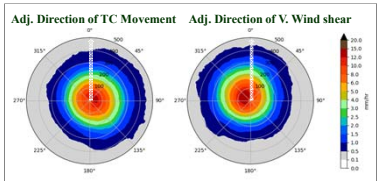


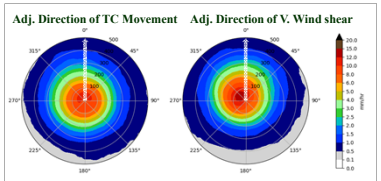
Fig. 3: Comparison of TC precipitation patterns from different composition method for global major hurricanes. The left, middle and right panel is for composition with north direction, direction of TC movement, and direction of 200-850 mb vertical wind shear, respectively. White arrow is for direction of TC movement or direction of the 200-850 mb wind shear. The important impact by direction of TC movement and direction of vertical wind shear is demonstrated.

Regional Difference of TC Precipitation



Atlantic Cat 3-5 TCs

Fig. 4: Precipitation patterns of major hurricanes over Atlantic basin in 1998-2012. The white arrow is for direction of TC movement or vertical wind shear. Left panel is for adjustment of direction of TC movement, while right panel is for adjustment of direction of vertical wind shear. Their different impacts are obvious in this figure.



West Pacific Cat 3-5 TCs

Fig. 5: Same as Figure 4, except for West Pacific. The regional differences of TC precipitation are evident. However, The maximum rainfall located in the downshear left (DSL) quadrant is consistent for each TC category and every basin.

GSMaP Precipitation for TC Applications

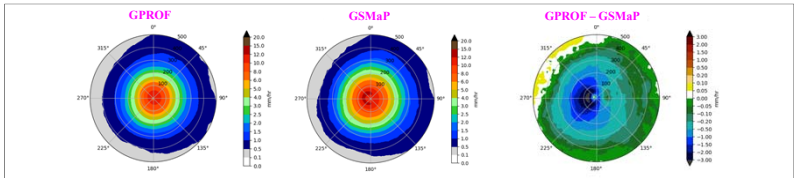


Fig. 6: Comparison of the composite precipitation distribution for global major hurricanes between GPROF and GSMaP in 2000-2012.

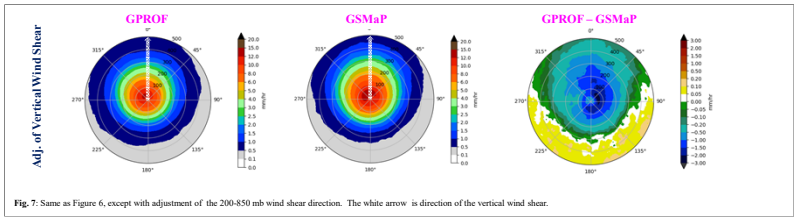


Fig. 7: Same as Figure 6, except with adjustment of the 200-850 mb wind shear direction. The white arrow is direction of the vertical wind shear.

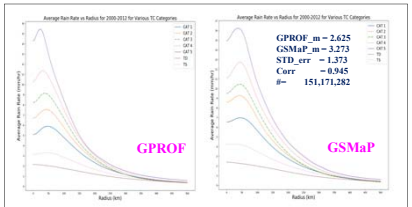


Fig. 8: Comparison of global TC precipitation azimuthal-averaged radius patterns between GPROF and GSMaP in 2000-2012 . Both similarity and difference are clearly shown here. Key stats are inserted.

Conclusions

1. The consistent and long-term GPROF rain products from all PMW sensors lead to improved characteristics of TC precipitation distributions.
2. The azimuthal-averaged radius distribution of precipitation at each TC category displays a radius decrease of the maximum rain locations with increase of the TC intensity.
3. The maximum rainfall is mostly located in the forward quadrants of TC movement with evident regional differences.
4. The dominant factor in determining TC precipitation distribution is direction of the 200-850 mb vertical wind shear. The maximum rainfall is consistently located in the dowshear left quadrant for every TC category. For both TD and TS categories, the maximum rainfall is located along the shear direction.
5. GSMaP can present realistic characteristics of TC precipitation, however, there are uncertainties associated with rain intensity and distributions for TC applications.