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Abstract

Quantification of Precipitation Asymmetries in Tropical Cyclones and Their Relationship to Storm Intensity Changes Based on TRMM Data

by

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The climatology of precipitation and convection asymmetries in Tropical Cyclones (TCs) and their relationship to TC intensity changes using 16 years of data from the Tropical Rainfall Measuring Mission (TRMM) satellite. TRMM Microwave Imager (TMI) 2A12 rain rate (R) is categorized into four precipitation types: total precipitation ($R \geq 0.5$ mm hr^{-1}), heavy precipitation ($R \geq 10$ mm hr^{-1}), moderate precipitation (10 mm $hr^{-1} > R \geq 5$ mm hr^{-1}), and light precipitation (5 mm $hr^{-1} > R \geq 0.5$ mm hr^{-1}). TC Inner core precipitation asymmetries under the effects of vertical wind shear and storm motion was quantified using the Fourier wavenumber decomposition method upon the pixel level data of 3,542 TRMM TMI overpasses. Composites of wavenumber–1 and wavenumber 1–6 total precipitation asymmetries were constructed to show the distribution pattern under different storm motion speed, vertical wind shear and the combined effects of varying vertical wind shear and storm motion. Results indicate that motion–relative total precipitation asymmetry is generally located down–motion. The phase of motion–relative maximum asymmetry shifts cyclonically by adding the wavenumber–2–6 asymmetry to wavenumber–1. Shear is more dominant than motion on the distribution of precipitation asymmetry. Due to the averagely stronger shear magnitude in Southern Hemisphere (SH), the asymmetric magnitude of shear–relative composite of SH is higher than that in Northern Hemisphere (NH). For the CAT 1–2 and CAT 3–5 storms, the light surface rainfall tends to distribute upshear. The moderate and heavy surface rainfall are downshear left. The analysis of combined effects of motion and shear shows when shear is weak, and shear is to the left of motion, the precipitation asymmetry is explained more by storm motion. The main contributor to the general asymmetry pattern is from the moderate and heavy precipitation. The wavenumber 2–6 energy localizes the maximum heavy precipitation asymmetry, and the location changes slightly from the original location of wavenumber–1 maximum asymmetry.

The quantified wavenumber 1–6 asymmetry is also applied to differentiate between different intensity change categories and the asymmetry evolution of a rapidly intensifying storm. Firstly, the precipitation asymmetry properties of rapid intensification (RI) and non–RI storms are examined. The dataset of 2,186 global tropical storms through category 2 hurricanes is divided by future 24–h intensity change and exclusively includes storms with at least moderately favorable environmental conditions. The normalized wavenumber 1–6 asymmetry, indicates quantitatively that in favorable environmental conditions, the lower asymmetry of light precipitation is most strongly correlated with future intensity change. For all four types of precipitation, non–RI storms are generally more asymmetric than RI storms. The asymmetry of heavy precipitation is higher than the other three types of precipitation in RI storms, which is considered as a necessary condition for storm to intensify. Secondly, the 595 sampled overpasses are classified into 14 categories in the timeline of an RI event from 48 hours before RI until RI ends. The decrease of normalized wavenumber 1–6 asymmetries in the inner core region of all four types of precipitation several hours before RI onset was quantitatively demonstrated to be critical for TC RI.

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