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報 告 番 号	※　　　　　　　　第　　号

主　論　文　の　要　旨

論 文 題 目　Heavy Precipitation Biases in the TRMM PR and TMI Products and Their Origins Assessed with CloudSat and Reanalysis Data
(TRMM PR および TMI プロダクトの強雨バイアス検証ならびに CloudSat および再解析データを用いたその要因評価)

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論 文 内 容 の 要 旨

This study aims to 1) identify the properties of the differences in extreme rain estimations among the Tropical Rainfall Measuring Mission (TRMM) data products, that is, the precipitation radar (PR) 2A25 TRMM Microwave Imager (TMI) 2A12, and TRMM Multisatellite Precipitation Analysis (TMPA) products, and 2) characterize the background physical processes in the development of those heavily precipitating clouds that contribute to the inter-product differences. In the first step, a case study over the Maritime Continent is conducted to identify the statistical properties of the climatological and extreme precipitation. The analysis is then extended to different regions over the globe in light of the atmospheric environment responsible for the algorithmic errors. The global observations of the TRMM, CloudSat, and ECMWF Reanalysis (ERA) Interim datasets from 2006 to 2014 are utilized to explain the precipitation biases. An extreme rain database is constructed by extracting the highest portion of the rain-rate distribution from the rain-rate climatology at each 0.25° × 0.25° grid resolution.

The Maritime Continent climatology, which is first studied as a pilot case study, shows that the PR-TMI rain rate differences are larger over land and coast than over ocean. When extreme rain is isolated, a higher frequency of occurrence is identified by the PR over ocean, followed by the TMI and the TMPA. Over the Maritime Continent land, the TMI yields higher rain frequencies than the PR with an intermediate range of rain rates (between 15 mm h^{-1} and 25 mm h^{-1}, but it gives way to the PR for the highest extremes. The turnover at the highest rain rates over the Maritime Continent arises because the heaviest rain depicted by the PR does not necessarily accompany the strongest ice-scattering signals, which the TMI relies on for estimating precipitation over land and coast. The PR identifies heavy rain events with lower storm top heights, and the PR rain-rate increases downward to the surface while such a vertical gradient is absent for the TMI.

In order to understand the sources of precipitation biases in more depth, the analysis is expanded to other geographical regions across the global tropics. In general, the PR identifies a larger number of rain events in the upper end of the rain-rate distribution, similarly to the Maritime Continent. Over land, the TMI detects a large number of extreme events associated with abundant ice particles during afternoon peak precipitation, while the PR does not observe as many extreme events. Over ocean, the TMI identifies extreme events with stronger emission signals than the PR. The TMI ice-scattering channels also capture a regional gradient between Eastern and Western Pacific Ocean. TMI extreme events are associated with higher ice-scattering signals than the PR over Western Pacific Ocean, but lower signals over Eastern Pacific Ocean. Nevertheless, the PR overall exceeds the TMI in extreme rain estimates over the entire ocean domains.

The TRMM PR and TMI precipitation estimates are studied in light of the CloudSat radar reflectivity and ERA-Interim data to assess the atmospheric environment such as the cloud structure and thermodynamic field associated with the precipitation system. The CloudSat and ERA-Interim data are composited with respect to the occurrence of extreme rains to identify the detailed cloud structures and the background environmental conditions which are not captured by the TRMM. The CloudSat composite analysis shows that the PR and TMI capture different degrees of convective organizations. Over the tropical ocean, the TMI identifies heavy rainfall events with notable convective organizations and clear regional gradients between the western and eastern Pacific Ocean, while the PR fails to capture the eastward shallowing of convective systems. Over tropical land, the TMI tends to preferentially detect deep isolated precipitation clouds in relatively drier and unstable environments, while the PR identifies more organized systems. The PR-TMI differences for the moist and stable environments are reversed over tropical land. The cloud vertical-horizontal extents at different level of organizations affect the distribution of liquid and ice particles, which are responsible to the PR-TMI estimation biases in extreme rainfall.