Abstract

Evaluating Precipitation Features and Rainfall Characteristics in a Multi-scale Modeling Framework

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Cloud and precipitation systems over the tropics and subtropics are simulated with a multi-scale modeling framework (MMF) and compared against the TRMM radar precipitation features (RPFs) product. A methodology, in close analogy to the TRMM RPFs, is developed to analyze simulated cloud precipitating structures from the embedded two-dimensional cloud-resolving models (CRMs) within an MMF. Despite the two-dimensionality of the CRMs, the simulated RPFs population distribution, and horizontal and vertical structure are in good agreement with TRMM observations. However, some deficits are also found in the model simulations. The model tends to overestimate mean convective precipitation rates for RPFs with a size less than 100 km, contributing to the excessive precipitation biases in the warm pool and western Pacific, western and northern India Ocean, and eastern Pacific commonly found in most MMFs. For large features with a size greater than 150 km, both convective and stratiform rain rates are underestimated. The distribution of maximum radar echo top heights as a function of RPF size is well simulated except the model tends to underestimate the occurrence frequency of maximum heights greater than 15 km. The maximum echo top heights for convective cells embedded within large RPFs with a size greater than 150 km are also underestimated. The cyclic lateral boundary with a limited model domain generates artificial occurrences for RPFs with a size close to the model domain size, producing a significant contribution to the total rainfall due to their sizes. This cyclic lateral boundary effect can be easily identified and quantified in both probability and cumulative distribution functions of RPFs. The geophysical distribution of the population of the largest RPFs in the control experiment shows they are mainly located in the Subtropics but also partially contribute to the common MMF biases of excessive precipitation in the Tropics. Sensitivity experiments using CRMs with different domain sizes and different grid spacings show larger domains (higher resolution) tend to shift the RPFs distribution to large (small) sizes. The cyclic lateral boundary biases increase as CRM domain size decreases. The impacts of model horizontal and vertical resolution on simulated convective systems are also investigated.

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1. Overviews

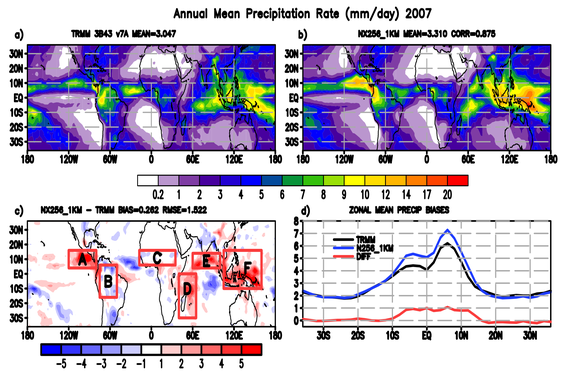
Objectives:

- to assess the Goddard MMF (GMMF) simulations of cloud and rainfall characteristics such as type, size, vertical and horizontal structure, occurrence, intensity, and global distribution against TRMM RPFs products.
- to identify and quantify possible causes of tropical rainfall biases in the GMMF

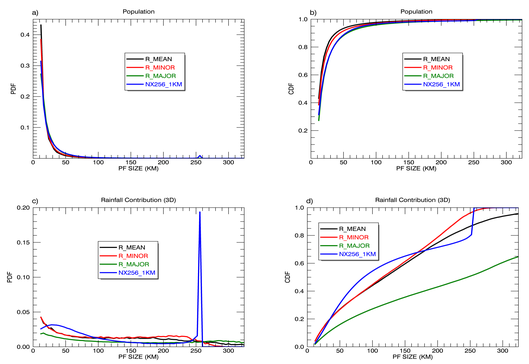
Approaches:

- 1-year (2007) TRMM level-2 Radar-defined Precipitation Features (RPFs) product Is used as a validation dataset
- Five 1-year (2007) GMMF simulations with different combinations of CRM domain size (128, 256, 512km) and grid spacing (1,2,4 km) are carried out
- A methodology, in close analogy to the TRMM RPFs, is developed to produce simulated precipitation features (PFs) from the output of the embedded two-dimensional (2D) cloud-resolving models (CRMs) within the GMMF (GMMF)
- The Goddard SDSU is used to convert 3-hourly instantaneous GMMF output into TRMM satellite measurable signals such as radiance/brightness temperature and radar reflectivity to enable the production of a Level-2 simulated RPF dataset.

2. Precipitation Biases in the GMMF



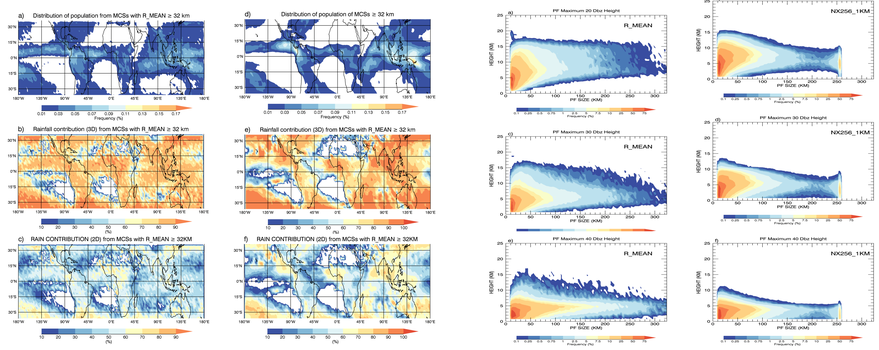
3. Population and Rainfall Contributions of Precipitation Features (PFs)



PDFs and CDFs of PFs over the Tropics and Subtropics (36S-36N)

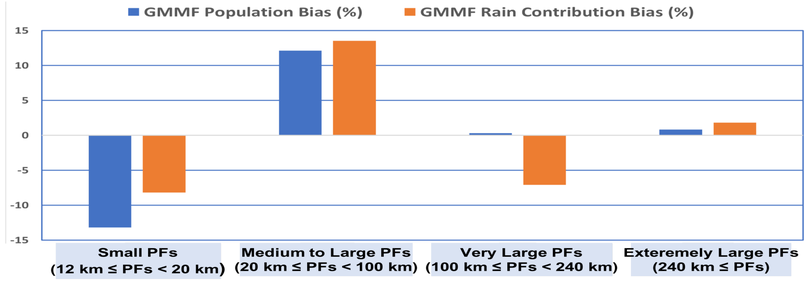
5. Key Findings

- **Many characteristics of simulated rain features are in reasonable agreement with the TRMM observations**

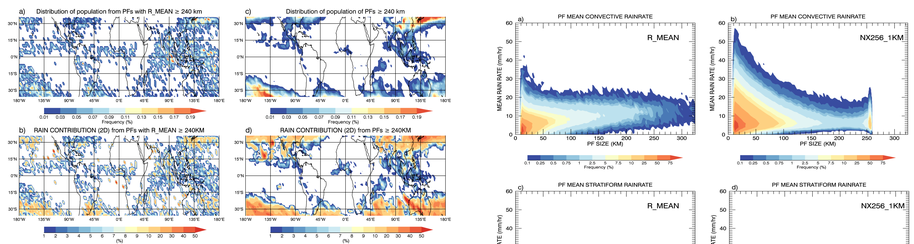


geographical distributions of MCSs vertical structure of PFs

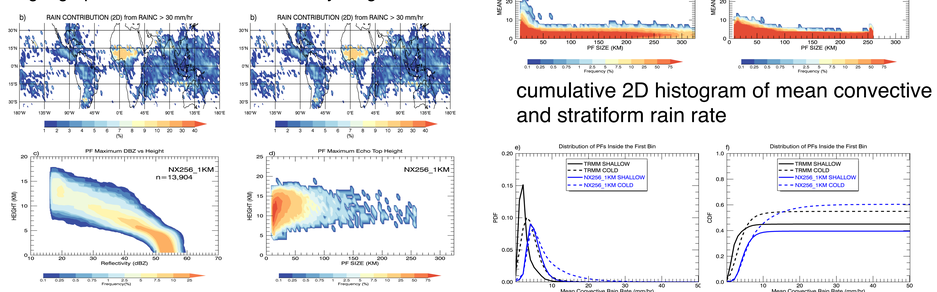
- **Model biases can be classified into four size categories**



- **Four different major mechanisms were found that could account for the GMMF biases in each different category**
  - **Small PFs: the two-dimensionality of the CRMs**
  - **Medium to Large PFs: a positive convection-wind-evaporation feedback loop**
  - **Very Large PFs: an artificial dynamic constraint in a bounded CRM domain with cyclic boundaries**
  - **Extremely Large PFs: the limited CRM domain size**

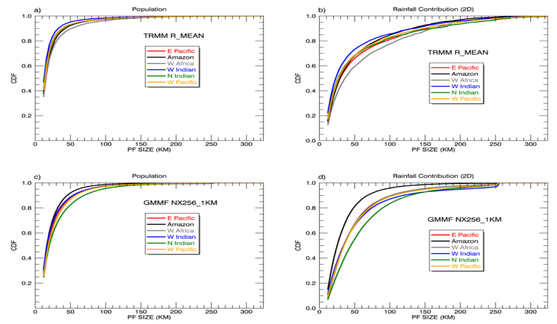


geographical distributions of Extremely Large PFs cumulative 2D histogram of mean convective and stratiform rain rate



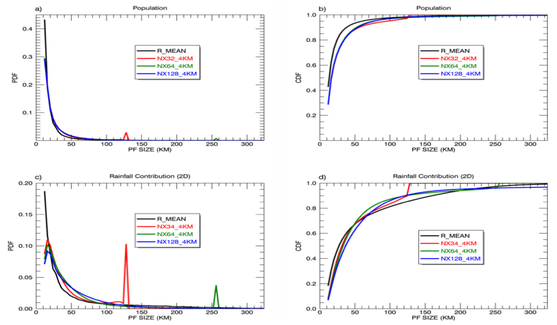
geographical distribution and vertical structure of PFs with extreme mean convective rainfall rate > 30 mm/hr

distribution of mean convective rain rate of the smallest PFs

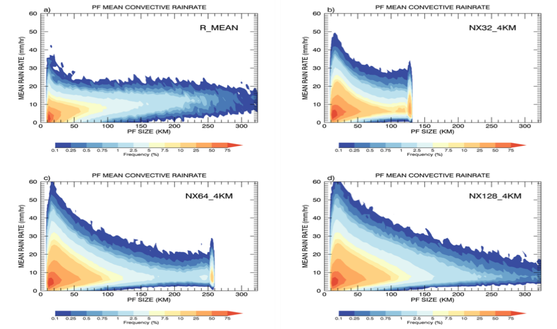


Regional population and rainfall contribution of PFs: the tropical eastern Pacific Ocean (box A), the western Indian Ocean (box D), the northern Indian Ocean (box E), and the tropical western Pacific Ocean (box F), the Amazon (box B) and western Africa (box C)

4. Effects of CRM Domain Size



PDFs and CDFs of PFs from 3 GMMF with various domain sizes (128, 256, and 512 km)



Cumulative 2D histogram of mean convective rain rate rom 3 GMMF runs with various domain sizes (128, 256, and 512 km)

- The smaller the domain, the greater the limited domain effect becomes
- Larger domains (higher resolutions) tend to shift PF populations toward larger (smaller) sizes.
- The rainfall contribution increases (decrease) as the domain size decreases for small (medium to large) PFs
- The GMMF with a 512 km CRM domain increases the rainfall distribution toward large PFs and mitigates the effect of cyclic boundaries
- Typical MMF configuration with 128 km or 256 km CRM domain size can not realistically simulate large precipitation features