

Precipitation Characteristics in the CAM3 Using Traditional Cumulus Parameterization and Cloud Resolving Models

Charlotte A. DeMott and David A. Randall

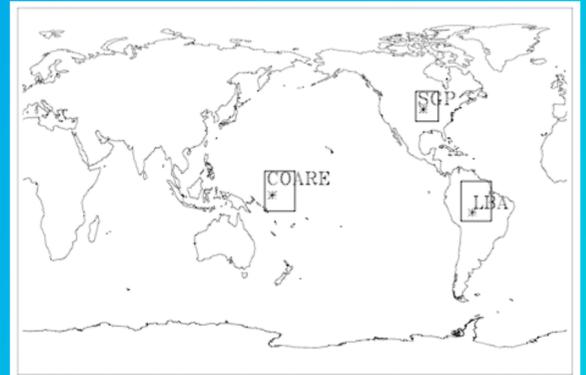
Department of Atmospheric Science, Colorado State University, Fort Collins CO, USA

Introduction

Proper simulation of precipitation variability is a rigid test for GCM performance. Previous work has illustrated that two configurations of the CAM3 produce different mean rainfall and rainrate PDFs across the globe. The two versions of the CAM3 studied are:

- CAM3 with Zhang-McFarlane cumulus parameterization (**CAM3**).
- CAM3 with a cloud resolving model embedded in each grid cell in place of the traditional cumulus parameterization (**MMF**).

Understanding the differences in rainrate PDFs requires an examination of the interactions between convection and the environment on diurnal timescales.



Amazon Basin, DJF

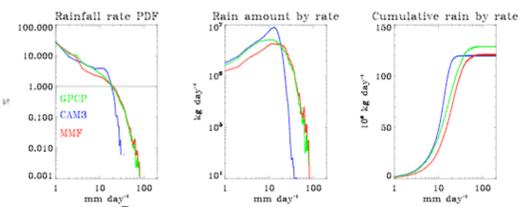


Fig. 1. Probability distribution functions (PDFs) of daily mean rainrate from models and GPCP combined satellite-gage product. Data taken from boxed area on map.

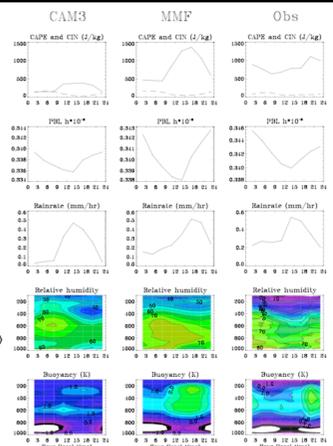


Fig. 2. Mean diurnal cycles from models and observations. Observed rainrates from TRMM 3G68 data. Other variables from LBA sounding network (asterisk on map).

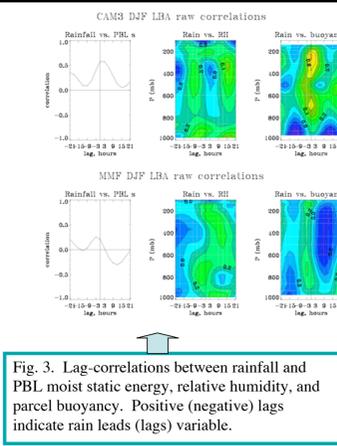
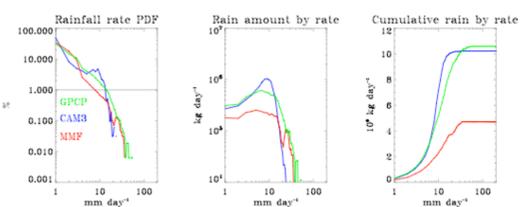


Fig. 3. Lag-correlations between rainfall and PBL moist static energy, relative humidity, and parcel buoyancy. Positive (negative) lags indicate rain leads (lags) variable.

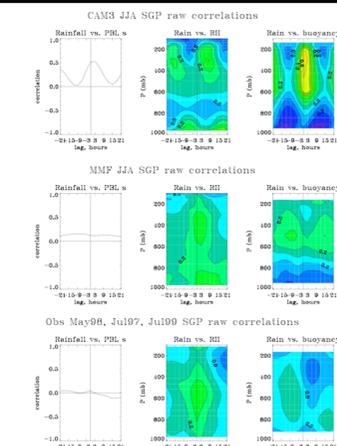
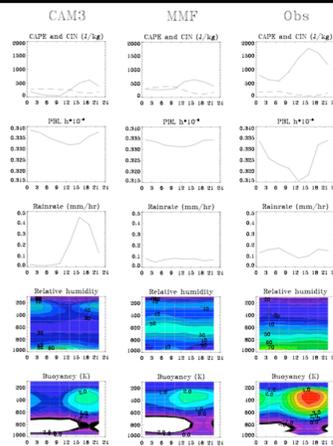
Notes on Amazon precipitation

- Both the CAM3 and the MMF produce reasonable seasonal mean rainfall.
- CAM3 produces too little rainfall at high rainrates; MMF produces too little rainfall at low rainrates.
- MMF produces a more realistic diurnal cycle of precipitation and buoyancy profile.
- Lag correlations between rainfall and other variables indicate that CAM3 rainfall is coincident with maximum surface moist static energy and buoyancy.
- MMF rainfall occurs after low-level moistening of the atmosphere has been achieved. Upper levels are moistened several hours after maximum surface rainfall.
- CAM3 precipitation is dominated by diurnal frequencies (not shown)
- NOTE: lag-correlations not available from TRMM 3G68 data.

North American Great Plains, JJA



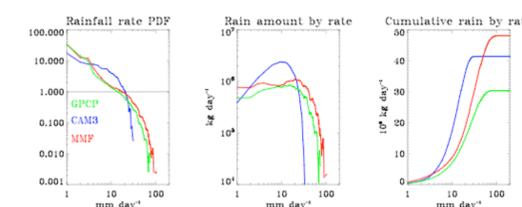
Same as above, but observed rainfall is from NEXRAD radar data.



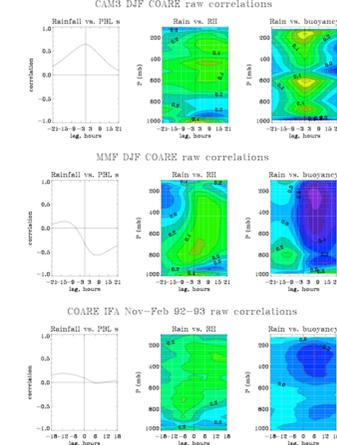
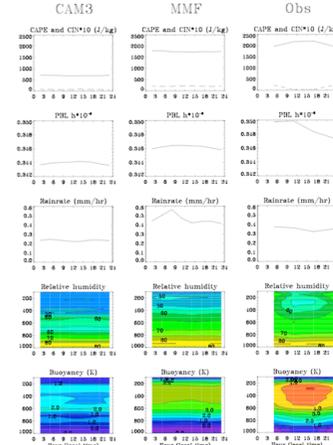
Notes on Great Plains precipitation

- CAM3 simulation produces the more reasonable seasonal mean rainfall.
- CAM3 precipitation is again dominated by rainrates 10–20 mm/day.
- MMF precipitation PDF is more broad, but again lacks sufficient rainfall at low rainrates. Seasonal mean is much too low.
- Neither CAM3 nor MMF produce realistic diurnal cycles of rainfall and relative humidity.
- Rainfall diurnal cycle is difficult to evaluate, as there is much scatter about the observed precipitation diurnal cycle.
- CAM3 again exhibits strong dependence of precipitation on the overly strong diurnal variability of relative humidity, moist static energy, and buoyancy.

West Pacific (TOGA COARE), DJF



Same as above, but observed rainfall is from merged IFA sounding and radar data.



Notes on TOGA COARE precipitation

- CAM3 and MMF both produce too much precipitation when compared to GPCP data.
- Dominance of low to moderate rainrates again seen in CAM3. MMF produces slightly too much rainfall at all rainrates.
- Diurnal cycles of all simulated variables are too weak compared to COARE observations.
- CAM3 precipitation is again locked to the phase of moist static energy and buoyancy, whereas MMF precipitation shows a more realistic lag relationship.
- The relationship between rainfall and relative humidity profiles seen in the Amazon basin is repeated here: low-level moistening precedes rainfall, which precedes upper-level moistening.

Discussion

High-frequency observations from various field campaigns allow us to study the relationships of simulated precipitation variability to environmental conditions. Rainfall PDFs of daily mean rainfall rates suggest that the CAM3 produces too much rainfall at low rainrates, and not enough at high rainrates. The phase of CAM3 precipitation is “locked” to the diurnal phase of large-scale variables such as boundary layer moist static energy and environmental stability. In contrast, MMF precipitation appears to correctly simulate the observed lag between precipitation and these variables, which do not exhibit the strong diurnal signal that is seen in the CAM3 (not shown). Moistening of the lower troposphere prior to precipitation, and subsequent upper-tropospheric moistening, is somewhat better simulated in the MMF than the CAM3. The strong diurnal cycle in the CAM3, the narrow rainrate PDF of the CAM3, and the better lag-correlations of the MMF suggest that MMF precipitation has a more realistic relationship to the large-scale environment. Perhaps the MMF, with the fine horizontal resolution and small time step of the embedded CRM, is better able to simulate the effects of shallow, detraining cumulus and their interaction with the underlying surface.

Current Efforts

The CAM3 and MMF are currently being re-run for one JJA and DJF period. High frequency output of surface energy and moisture budget variables are being saved to allow a more thorough analysis of the interaction of convection and environmental conditions. Although the MMF offers some clear improvements over the CAM3 in terms of precipitation variability, concerns about its seasonal mean precipitation exist, particularly in the West Pacific (too high in summer) and over North America (too low during summer months). The cyclic boundary condition employed in the CRM is a possible culprit, and we continue to examine the effects of this condition.