A Statistical Comparison of the Eastern Pacific Low-level Clouds from Cloud Object Analysis and Upgraded Multi-scale Modeling Framework Simulation

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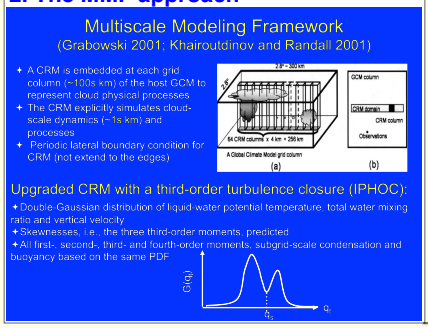
1. Introduction

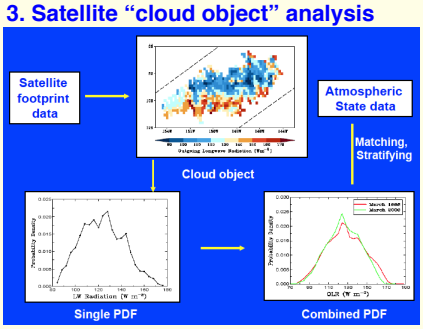
Motivations for the present study include

- There is a need for an alternative method for performing model evaluation, in particular, simulated cloud physical properties, beyond the grid-means with long-term time averages;
- Satellite orbital data are under utilized, esp., stratified to individual cloud-system types;
- Representation of clouds in climate models, especially low-level clouds, should be improved;
- The multi-scale modeling framework (MMF; "super parameterization") is unable to resolve turbulent circulations of small spatial scales that are embedded in low-level clouds despite its success in simulating deep convective clouds.

2. The MMF approach



3. Satellite "cloud object" analysis



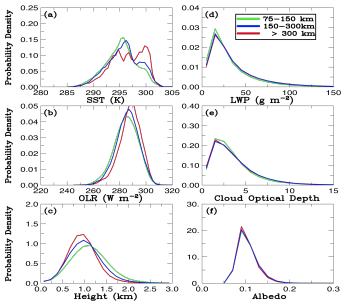
Each cloud object is identified from satellite orbital data (level-2 footprint data) and selection criteria:
a) All footprints within boundary-layer cloud objects must have effective cloud top heights less than 3 km;
b) "Cumulus" with footprint cloud amount of 0.1-0.4;
c) "Stratocumulus" with footprint cloud amount > 0.4.

Observed cloud object results shown in this study:

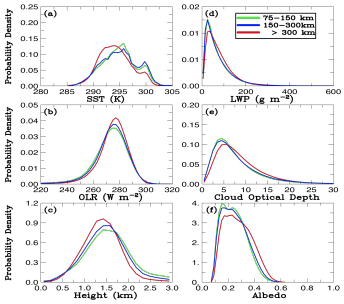
- Aqua satellite from July 2002 to June 2004
- The southeast Pacific region (35S-5N; 80W-110W)
- Daytime observations only
- Total numbers of footprint in each size category:

	75 – 150 km	150 – 300 km	> 300 km
Cumulus	311,548	251,775	168,675
Stratocumulus	344,484	517,265	2618,793

Observed "cumulus" cloud object properties



Observed "stratocumulus" cloud object properties

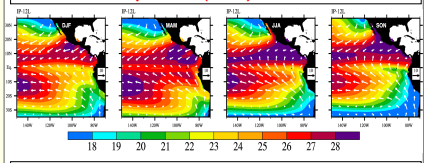


4. The MMF simulation

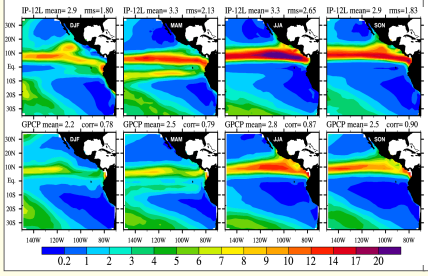
- The model, SPCAM-IPHOC, is Community Atmosphere Model version 3.5 with finite-volume dynamic core as the host GCM.
- The CRM is the 2-D version of System for Atmospheric Modeling (SAM) with IPHOC higher-order turbulence closure, the grid spacing is 4 km, with 32 columns within a GCM grid box.
- Simulation IP-12L: SPCAM-IPHOC with grid spacing of 1.9°x2.5°; doubling the number of levels below 700 hPa (6 to 12); the total number of vertical layers is 32.
- The simulation is forced with climatological SST and sea ice distributions (not an AMIP simulation).
- Simulation duration is 10 years; with last nine years analyzed (Xu and Cheng 2012a,b; *J. Climate*, submitted).

5. Seasonal variations of eastern Pacific: Comparing with observations

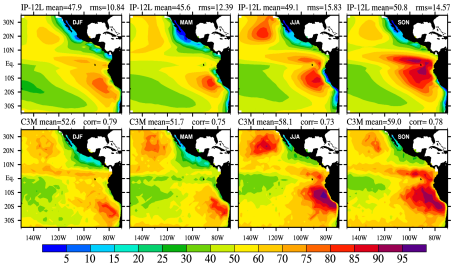
Sea surface temperature (color) and MMF wind vector



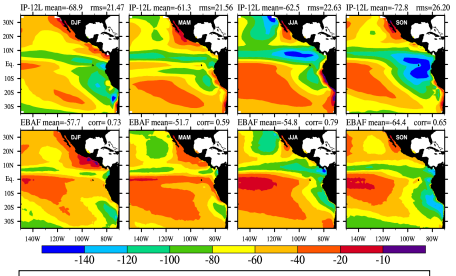
Surface precipitation: MMF vs. Obs. (GPCP)



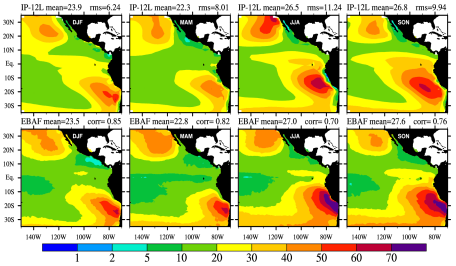
Low-level cloud amount: MMF vs. Obs. (C3M)



Sfc. SW cloud radiative effect: MMF vs. Obs. (CERES)



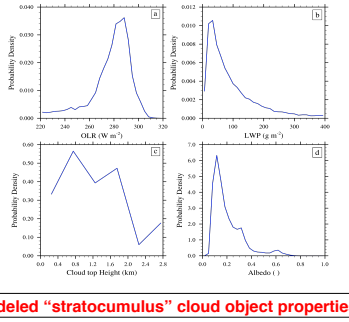
Sfc. LW cloud radiative effect: MMF vs. Obs. (CERES)



6. Hourly MMF statistics compared with cloud-object observations

- Cumulus: grid points with low cloud amounts 10-40% and cloud top heights less than 3 km;
- Stratocumulus: grid points with low cloud amounts > 40% and cloud top heights less than 3 km.
- The model can capture the qualitative differences in several properties between the two cloud object types;
- Overestimates in liquid water path (LWP) and albedo are rather pronounced for both cloud-object types;
- Overestimates in cumulus top heights are due to the diagnostics (not "radiatively") used in the MMF output.

MMF-modeled "cumulus" cloud object properties



Modeled "stratocumulus" cloud object properties