Simulation of March 1998 Tropical Deep Convection Using the UCLA/LaRC CRM

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1. Introduction

The "cloud object" approach groups satellite footprints (*field of views*, fovs) by cloud system type without reference to any arbitrary earth's grid. A cloud object is a contiguous patch of the Earth with a single dominant cloud-system type. This classification of satellite data shifts the traditional Eulerian view of cloud systems to the Lagrangian view. The identified cloud objects from satellite data are then matched with nearly simultaneous atmospheric state data. The atmospheric state and the associated advective tendency data are used as inputs for cloud model simulations of the cloud objects.

This study presents modeling results using the UCLA/LaRC (Krueger 1988; Xu and Randall 1995) cloud-resolving model (CRM) and ECMWF prediction against satellite observations.

2. Methodology

A "region-growing" strategy based upon imager-derived cloud properties is used to identify cloud objects using a set of selection criteria. The detailed procedure of this strategy can be found in Xu et al. (2005). For example, the criteria for tropical deep convective cloud objects are:

1) the footprints must have 100% cloud fraction,
2) the cloud optical depth must have a minimum value of 10,
3) the cloud top height must be greater than 10 km, and
4) the cloud footprints must be located between 25 °S and 25 °N of the Pacific.

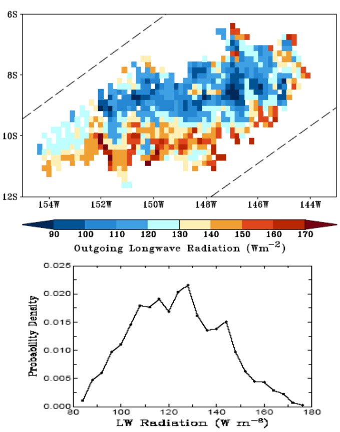

Fig. 1: (a) Horizontal distributions of longwave radiation flux and (b) associated histogram representation for a 17 March 1998 tropical deep convective cloud object.

Once a cloud object is identified, its spatial variability can be concisely represented by a histogram or probability density function (PDF; **Fig. 1**) of the measurements of a particular parameter. The individual cloud-object histograms of a particular parameter are used to produce the overall statistics (called "summary PDFs") of this parameter for a large ensemble of cloud objects in a given geographic region. The summary diagrams will be compared with the simulated ones. Their differences can be quantified statistically with the bootstrap method (Xu 2005).

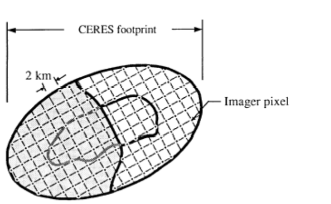

Fig. 2: A typical satellite footprint or field of view for the CERES instrument.

How do we compare satellite observations with CRM or single-column model (SCM) simulation/prediction?

For CRMs, several adjacent columns, with each of them satisfying the same cloud-object selection criteria, *are averaged* to obtain the statistical properties of simulated cloud objects. The averaging column is equivalent to the average footprint size in the satellite observations (5 columns for a 2 km CRM grid).

For SCMs or GCMs, each grid *is divided* into many subgrid cells (30 for ECMWF with a grid cell of 0.5° x 0.5°). The SCM cloud fields are then distributed horizontally and vertically, following the maximum-randomly overlap procedure outlined in Klein and Jacob (1999). Condensate mixing ratios are assumed to be horizontally homogeneous. Then, a radiation parameterization is used to obtain the cloud optical/radiative properties for each subgrid cell. The subgrid columns that satisfy the cloud-object selection criteria are used to produce the summary histograms of statistical properties of the SCM cloud fields

3. Simulation of the March 1998 Cloud Objects with CRM and ECMWF

The simulations are designed to address how well models capture the differences among the three size categories of tropical deep convective cloud objects (equivalent diameters of 100-150 km, 150-300 km and > 300 km). CRM simulations will be compared with forecasted clouds from the ECMWF model. There were 126 small-size, 136 intermediate-size and 68 large-size cloud objects observed during March 1998. The CRM is driven by the ECMWF advective tendencies. Every cloud object is simulated for 24 hours, starting from nearly simultaneously matched ECMWF sounding. The last 12 h is analyzed by selecting the "cloud object" columns using the selection criteria described previously.

CLOUD-OBJECT OBSERVATIONS

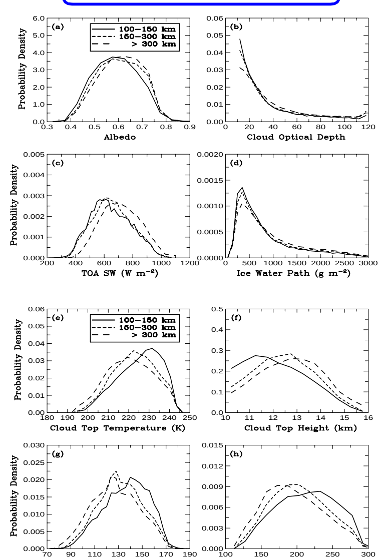

Fig. 3: Summary histograms of the observed properties of tropical deep convective cloud objects for three size categories: (a) TOA albedo, (b) TOA reflected shortwave flux, (c) cloud optical depth, (d) ice water path; (e) cloud top temperature, (f) outgoing longwave radiation, (g) cloud top height and (h) cloud top pressure.

How well do the CRM and ECMWF reproduce the observations, in particular, the differences among the three size categories?

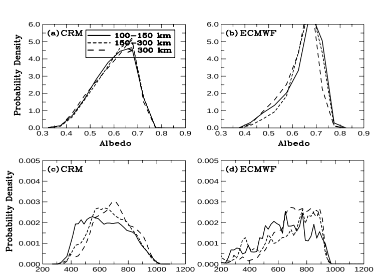

Fig. 4: Same as Figs. 3a, c, except for CRM simulations (a, c) and ECMWF prediction.

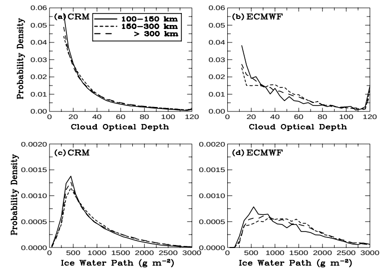

Fig. 5: Same as Figs. 3b, d except for CRM simulations (a, c) and ECMWF prediction (b, d).

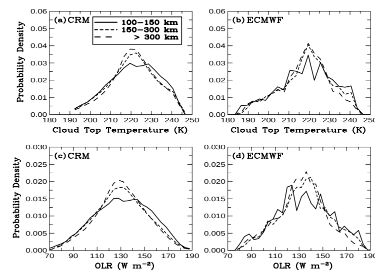

Fig. 6: Same as Figs. 3e, g except for CRM simulations (a, c) and ECMWF prediction (b, d).

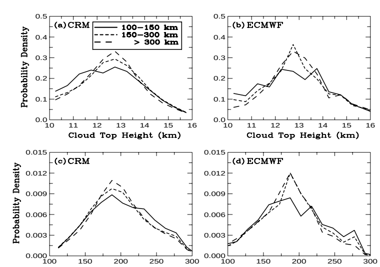

Fig. 7: Same as Figs. 3f, h except for CRM simulations (a, c) and ECMWF prediction (b, d).

4. Summary

This study has presented a new method for evaluation of CRM and SCM performance. The integrated observational and modeling approach will be very useful to point out problems in these models and suggest for further improvement. An iterative process can be adopted to improve the model performance using the cloud-object data sets. Major conclusions of this study are summarized as follows:

- the CRM simulations capture the differences between the small- and intermediate-size categories rather well, but the simulated summary PDFs for the large-size category are somewhat different from the observations despite of using very large horizontal domain (1024 km);
- the ECMWF predicted cloud fields are also very close to the observed, but their differences from the observations are slightly larger than those between the CRM simulations and the observations.
- the assumption of horizontal homogeneity of condensate in the ECMWF may play important roles in determining the microphysical and optical properties (Figs. 4 and 5).
- the macrophysical cloud properties of the CRM simulations share many deficiencies with the ECMWF prediction, due probably to poor advective tendencies (Figs. 6 and 7).

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