Cluster Analysis of Tropical Cloud Regimes in Measurements and a Global Climate Model

Yonghua Chen[1] *Tony Del Genio[2]*

[1]Columbia University, New York, NY [2]Goddard Institute for Space Studies, NASA, New York, NY

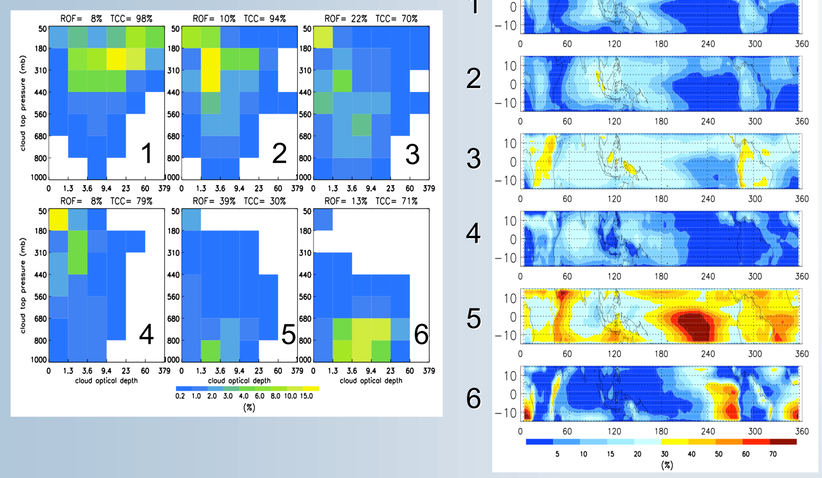
Motivation

Errors in cloud feedback estimates in GCMs are associated with both incorrect occurrences of different weather states and errors in the cloud properties within these states. In this study, we use a K-means clustering algorithm to objectively identify different cloud regimes in ISCCP data and the GISS GCM for 1999-2003 over the tropics (± 15º). We then focus on the TWP and compare the cloud vertical distribution diagnosed from the ARM ARSCL product at Manus Island to that retrieved by ISCCP to understand the weaknesses in the satellite cloud products in the presence of thin upper level or multilayer clouds.

Data and Model

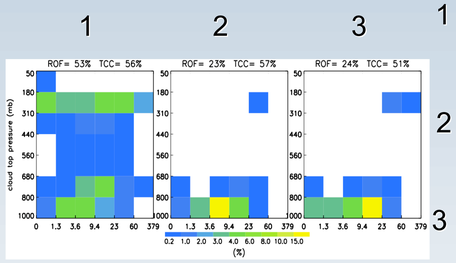
- ISCCP D-1 3-hourly cloud top pressure-cloud optical thickness histogram
- ARSCL cloud top and base measurements at the TWP Manus site
- NASA/GISS 2°x2.5°x32L Model E simulated versions of above fields

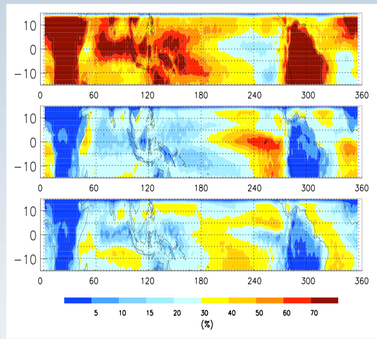
ISCCP cluster analysis of weather states



The figures above show 6 cloud regimes (left) and their geographic occurrence frequency (right) based on the cluster analysis, which are consistent with the results of Rossow et al. (2005). Clusters 1-4 correspond to regimes dominated by deep convective clouds, cirrostratus anvils, midlevel cumulus congestus, and isolated cirrus respectively, which all have a preference to occur in the ITCZ and SPCZ. The other 2 clusters represent suppressed cloud regimes: shallow trade cumulus over the central/east Pacific, and marine stratocumulus off the west coast of South America.

GCM cluster analysis of weather states





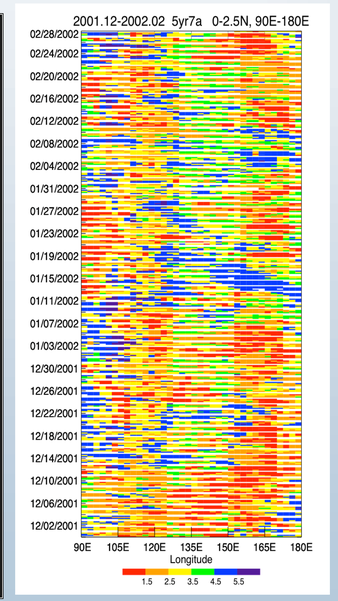
GISS Model E only separates the two suppressed regimes from a single convectively disturbed cloud regime. The two suppressed regimes have some similarity to those from ISCCP. The convectively disturbed regime instead combines all high cloud types from ISCCP regimes 1-4, plus spurious low clouds. In particular, the model's SPCZ region at times is dominated by low clouds at its eastern end, unlike that observed.

Preliminary Results — at Manus

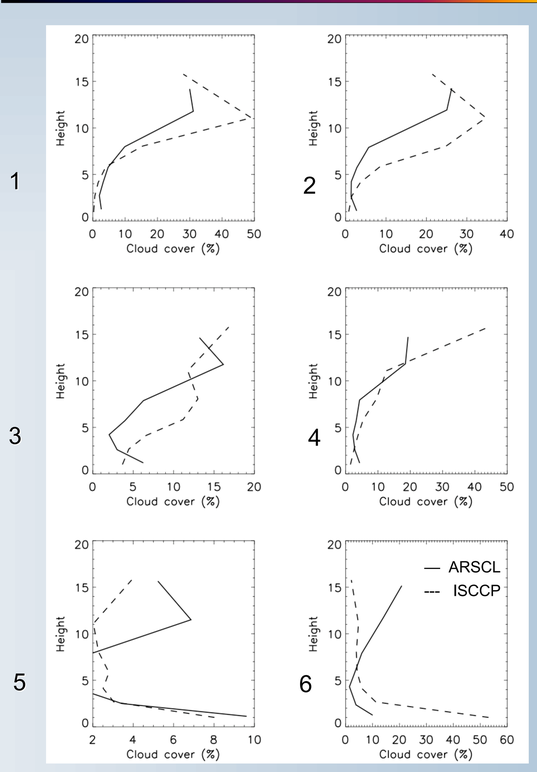
The figure on the left shows the six cloud regimes at Manus. The first five regimes occur with roughly equal frequency at this site, which is different from the behavior for the tropics as a whole. This reflects Manus' warm pool location and frequent deep convection.

TWP weather state Hovmöller diagram

We color code the 6 ISCCP regimes (red = deep convective, etc.) and construct a Hovmöller diagram of cluster occurrence for DJF 2001-2 in the region 0-2.5°N, 90°E-180°E. The results at right show eastward propagation of the deep convective state with a period of ~30 days, suggestive of the MJO, but also some westward propagation under suppressed (blue) conditions. The sequence at some locations and times suggests a transition from suppressed to midlevel to deep convective, as envisioned in theories of tropospheric moisture pre-conditioning of MJO onset, with anvils and thin cirrus appearing after deep convection decays.



ARSCL vs. ISCCP at Manus



The figure above shows the vertical distribution for each cloud regime at Manus from ARSCL and ISCCP data. ISCCP underestimates the high cloud peak by several kilometers in the disturbed states and overestimates midlevel and low cloud in more suppressed conditions. ISCCP also overestimates the cloud fraction for the disturbed states.

Discussion and Future Work

- Some of the model-data difference in identifying cloud regimes may be an artifact of ISCCP's difficulty in multilayer cloud situations, but overall this may be an indication of the lack of a distinct GCM convective lifecycle, with systematic transitions from Cb to Cs to Ci.
- ARSCL cloud profiles at Manus indicate that differences in the vertical distribution berween states are more subtle than the ISCCP impression
- T, q, ω, profiles and precipitation from ARM surface measurements, soundings and reanalyses will be identified for each regime to isolate the most important sources of GCM parameterization error.

Contact Information: Yonghua Chen; Email: ychen@giss.nasa.gov Voice: 212-678-5592

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

Goddard Institute for Space Studies