Comparison Between General Circulation Model Simulation and Central Equatorial Pacific Experiment Measurements

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Introduction

A general circulation model (GCM) is a very powerful tool for understanding many climate issues. However, it must be validated using observational data in order for the model results to be credible in climate prediction. Data from the Atmospheric Radiation Measurement (ARM) Program will provide a valuable avenue for model validation.

Effective use of GCMs can help to understand many important issues, such as the interaction between convection, boundary properties and surface radiative, and sensible and latent heat fluxes. To demonstrate the use of observed data for GCM validation, we compare the GCM simulation of the atmospheric fields with those from the field measurements during the Central Equatorial Pacific EXperiment (CEPEX).

The CEPEX field mission was conducted from March 7 to April 6, 1993. Details of the experiment can be found in CEPEX Experiment Design (1993) and the CEPEX Operations Summary (1993). The measurements used in this study were mainly from the R/V *Vickers*, which cruised during the CEPEX period from about 160E to about 16OW along 2S. Fifty-four soundings (including both Vaisala sondes and frostpoint hygrometer sondes) were launched during the course of the cruise. Surface data from the Tropical Ocean Global Atmosphere (TOGA) Tropical Atmosphere-Ocean (TAO) moored buoys are also used for comparison.

The GCM used for this study is from the Max-Planck Institute and the University of Hamburg, Germany (ECHAM3); it is described in detail by Roeckner et al. (1992). The simulation for the CEPEX period starts December 1, 1992. The lower boundary condition is from the interpolation of the monthly mean observed sea surface temperature (SST). The results averaged over the month from March 7 to April 6, 1993, are used for comparison with the field measurements.

Results

The water vapor profiles averaged along the *Vickers* track from both the observations and the GCM simulation are shown in Figure 1. Note that only the frostpoint hygrometer sondes are used for the upper tropospheric relative humidity owing to their high accuracy there. The error bars show the range of the daily averages of the simulated field along the track. The GCM simulates the vertical distribution of water vapor quite well, except it is slightly too dry in the middle and lower troposphere and slightly too moist in the upper troposphere below the 150-mb level. Figure 2 shows the first three empirical othorgonal functions (EOFs) for both the model simulation and the observation. The model qualitatively reproduces the vertical structure of the water vapor variance.

Surface latent heat flux is an important part of the atmosphere-ocean energy exchange. To examine the model performance in this field, we analyzed the data collected from the TAO moorings during the CEPEX period. The surface latent heat flux at each buoy site is computed from the observed SST, air temperature, relative humidity, and surface wind speed using a bulk formula as outlined in Zhang and McPhaden (in press). These fluxes are then averaged over the month and mapped using triangulation interpolation. For the GCM simulation, the monthly mean surface latent heat flux is sampled at the grid points closest to the buoy sites, then interpolated the same way as for the buoy data.

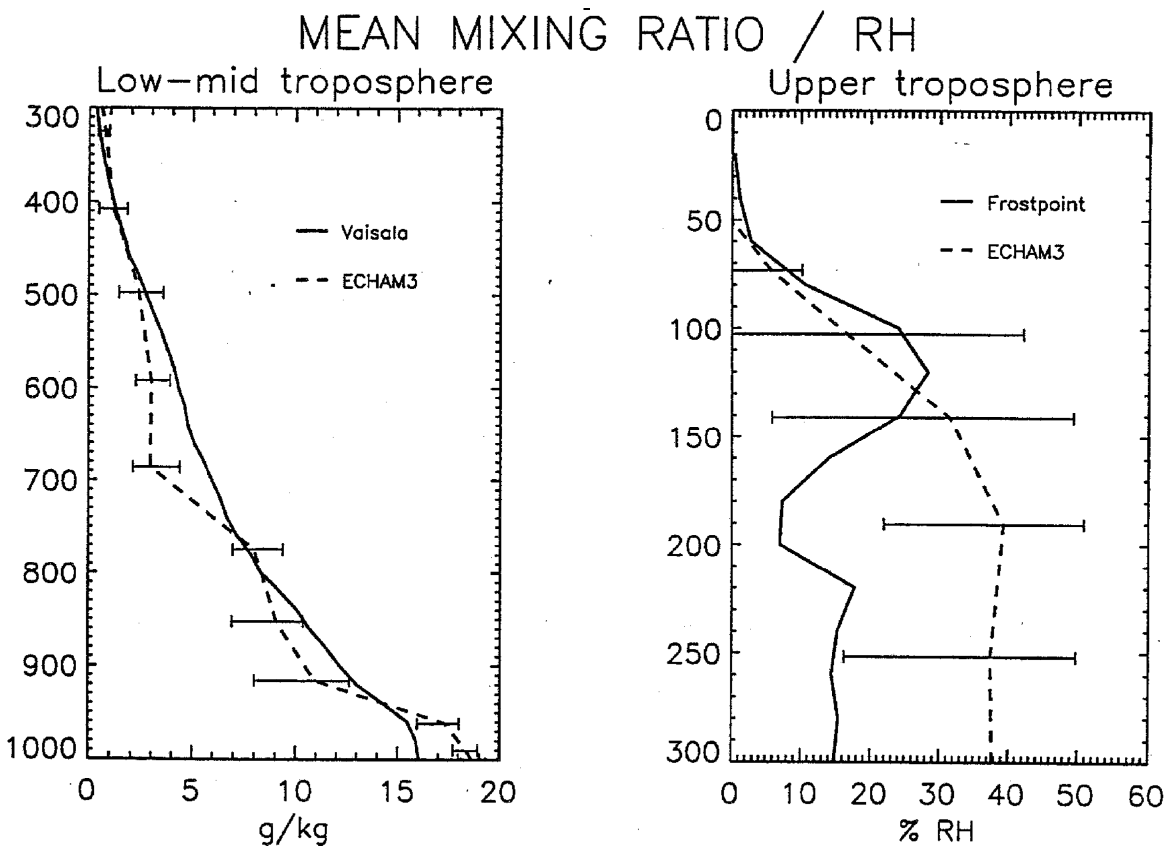

Figure 1. Mean humidity. The model does well except for a moist bias in the upper troposphere and dry biases below the freezing level and in the upper planetary boundary layer (800-900 mb). The discrepancy near the surface is due in part to an instrument bias which is currently under investigation. Means are from 54 observed soundings (launched from the R/V *Vickers*) and 2108 model soundings from the same locations during all of March, with error bars indicating estimates of minimum and maximum possible sample means along the ship track.

Figure 3 shows the latent heat flux distribution from both the observation and the model. The similarity between the two is evident. For example, both show the minimum latent heat flux near the equator across the equatorial Pacific. The longitudinal variation in the equatorial region is also well simulated; that is, low latent heat flux in the eastern Pacific, increasing to a maximum in the central equatorial Pacific, then decreasing toward the western Pacific. However, the model simulated flux is larger by 20 to 40 W/m^2 almost everywhere.

The surface wind speed (Figure 4) is also simulated reasonably well in its horizontal distribution, but the magnitude in the model is somewhat larger than observed, suggesting that the larger surface latent heat flux in the model is mostly a result of higher wind speed.

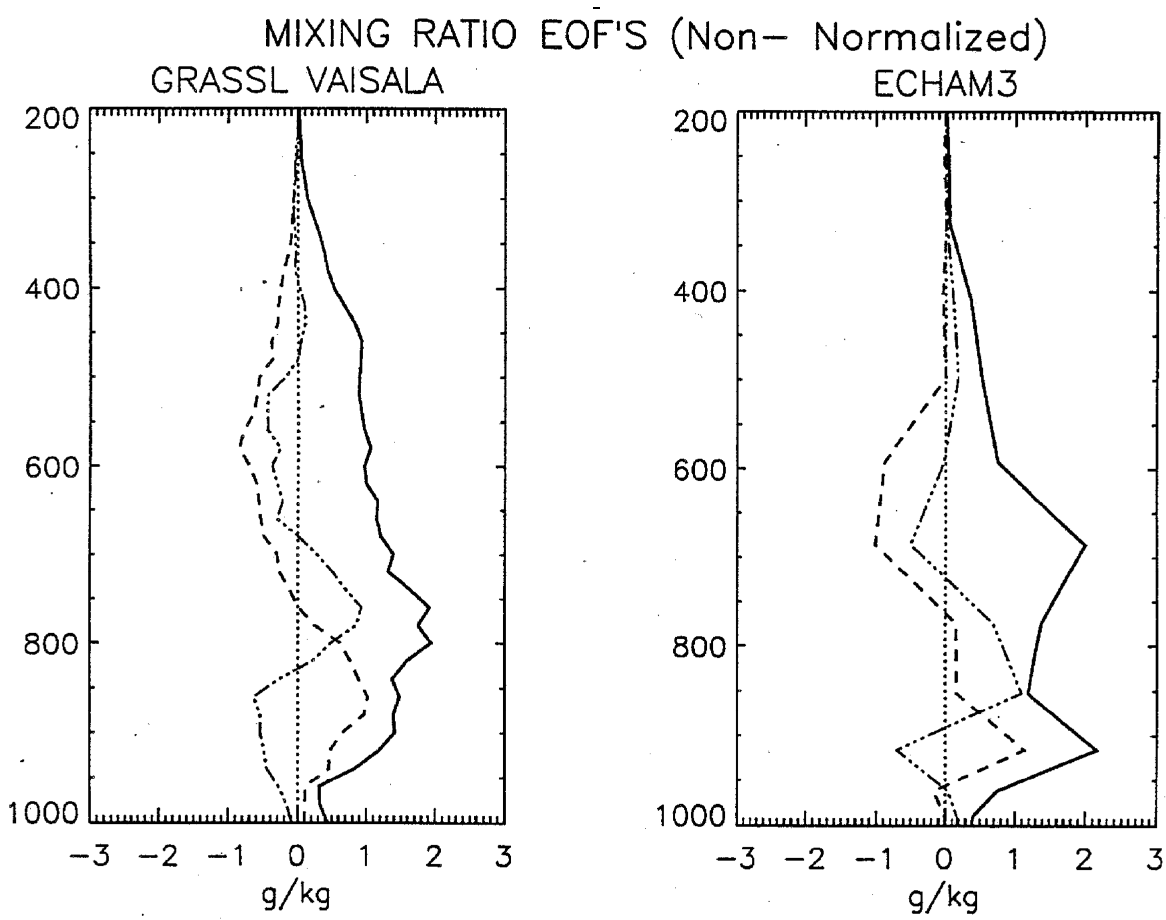

Figure 2. Humidity variability. Empirical othorganal functions (EOFs) computed from model and observed soundings along *Vickers* track. Magnitude here indicates root of variance accounted for by that mode (first mode, 61% of variance in observations; first three modes, 81%). The EOFs have similar magnitude and structure for model and observations; for instance, first mode in both cases is the most strongly correlated with surface moisture. The model is producing more variability than observed at those levels that are drier than observed, and vice versa, with too little model variability in the upper troposphere. This suggests that errors in fluctuating moisture sinks in the model (i.e., condensation) are responsible for the biases in Figure 1.

Discussion

The ECHAM3 GCM simulates reasonably well the water vapor distribution and surface latent heat flux observed during the CEPEX period. The high-quality water vapor measurement in the upper troposphere is especially important for model validation, since conventional measurement has poor accuracy there. Once the model is validated, it can be used to study important climate research issues such as the convection-water vapor feedback, which is not well understood. The tropical western Pacific would be an ideal region for such studies because of the abundance of convection there.

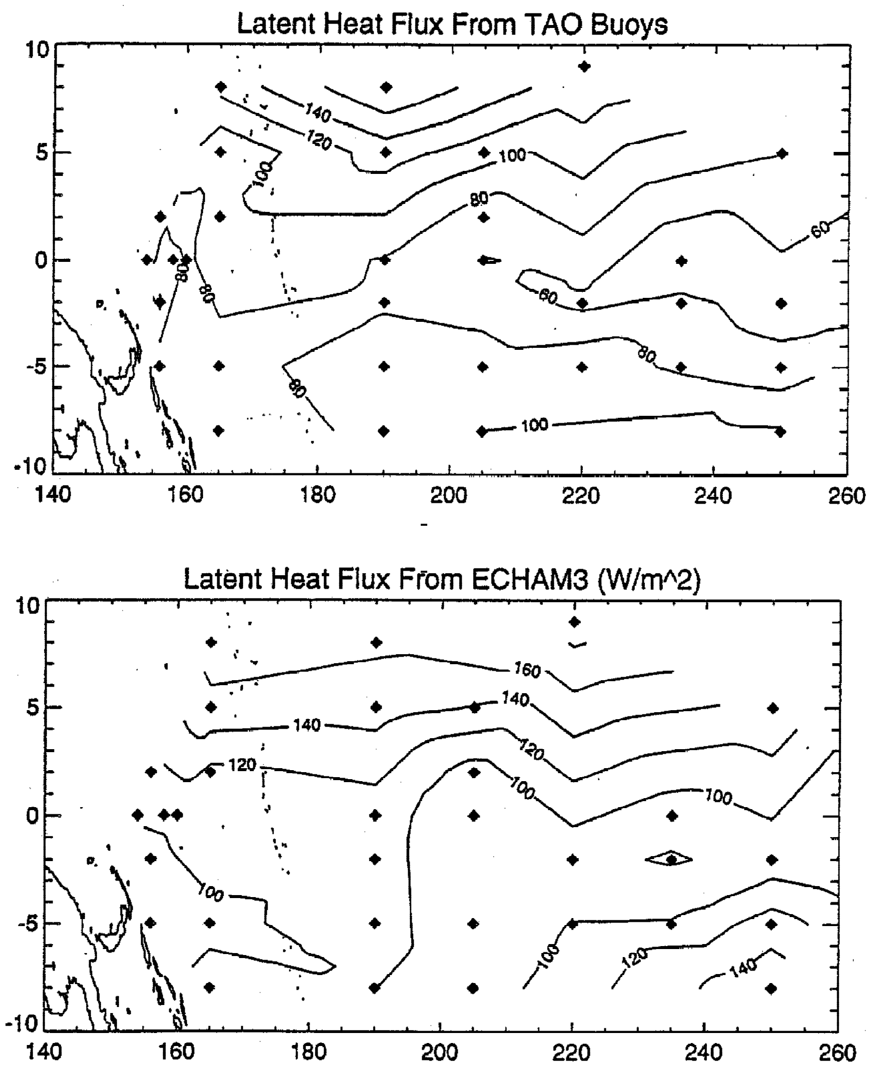

Figure 3. Surface latent heat flux during CEPEX (March 7 to April 6, 1993) obtained from TAO moored buoys (top) and ECHAM3 GCM (bottom), covering (10N, 10S) and (140E, 100W).

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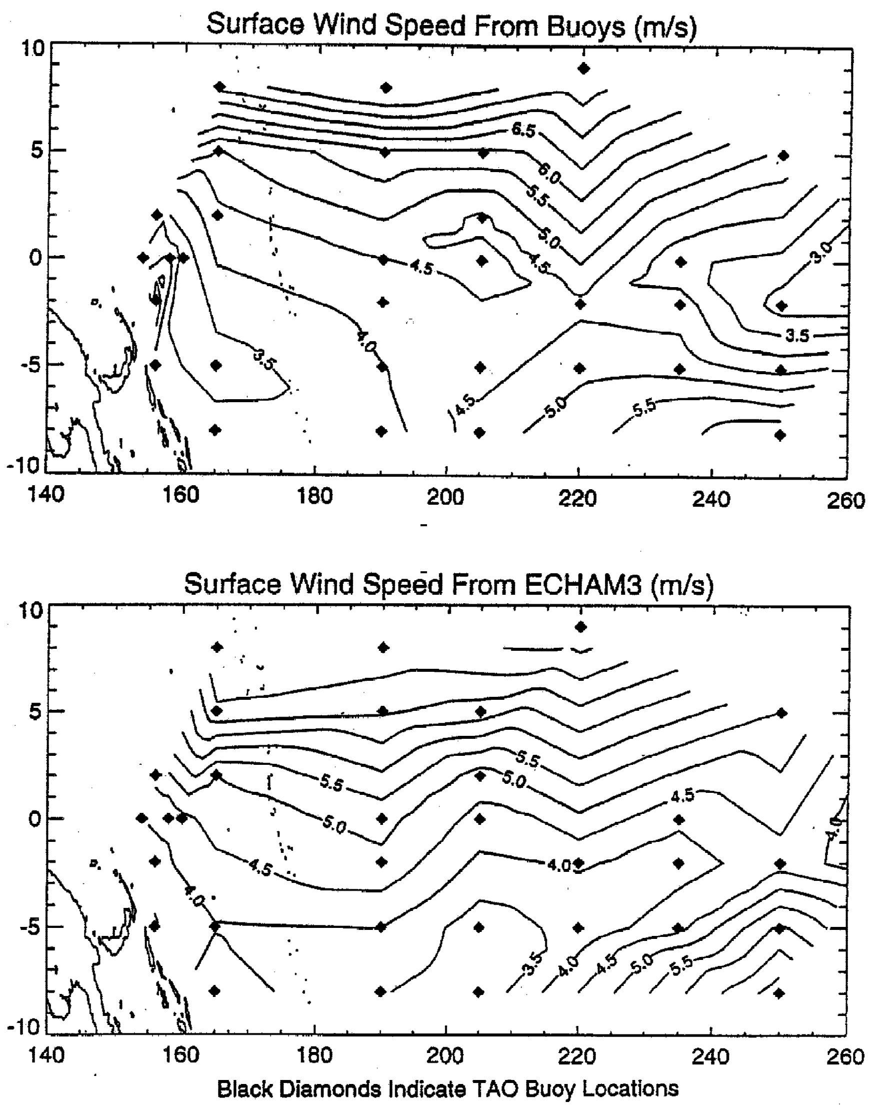

Figure 4. Surface wind speed during CEPEX (March 7 to April 6, 1993) obtained from TAO moored buoys (top) and ECHAM3 GCM (bottom), covering (10N, 10S) and (140E, 100W).

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