A one Dimensional Coupled Air-Sea Model for Diagnostic Studies during TOGA-COARE

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ABSTRACT

A process-oriented diagnostic model has been developed, which couples an atmospheric column model to an upper ocean model. In vertical structure and representation of physical processes, the atmospheric model resembles a single horizontal grid point of a general circulation model. It includes vertical transports by convection and turbulent mixing, radiative transfer with interactive clouds, and a complete hydrologic cycle. The ocean model is a simple mixed layer, synchronously coupled to the atmosphere through a surface energy budget computation.

Time-dependent observational analyses of horizontal atmospheric transports of momentum, heat and moisture are used to force the coupled model. The model then produces such fields as temperature, humidity, cloudiness and diabetic heating rate components, all as functions of height and time. Sample integrations of the model for test cases in the 1979 Indian summer monsoon onset are presented and verified against observations. These diagnostic analyses suggest that this type of model may be useful in TOGA COARE for applications such as interpretation of results from multidimensional models, validation of surface flux data, and estimation of sensitivity to alternative physical processes. It may also be used to aid in designing the intensive field phase of TOGA COARE by means of numerical observing system simulation experiments.

1. Introduction

A one-dimensional diagnostic model of an atmospheric column coupled to and upper ocean has been developed. The essential time-dependent input to the model is the large-scale wind field, together with observed horizontal gradients of temperature and moisture. From these data, the model then computes the time evolution of variables such as precipitation, surface fluxes and the vertical profiles of temperature, humidity, cloudiness and diabatic heating rate components. These results may be verified against detailed local measurements.

The atmospheric component of the model is a generalization of a typical radiative-convective model, which has been supplemented by additional parameterizations of diabatic processes and subgrid transports. This portion of the model thus closely resembles a single column of a modern atmospheric general circulation model. The physical parameterizations in our model include shallow convection (Tiedtke et al., 1988), deep moist convection (Kuo, 1974; Anthes, 1977), solar radiative transfer (Lacis and Hansen, 1974), terrestrial radiative transfer (Morcrette, 1984), distribution of surface fluxes (Krishnamurti et al., 1987), prognostic clouds (Slingo, 1987), and vertical diffusive mixing. At present, the atmospheric model is coupled to a very simplistic ocean mixed-layer model (Niiler and Kraus, 1977).

The principal role of such a process-oriented model is not as a predictive tool, but as a test environment for parameterization development and as a mean of gaining physical insight. This diagnostic model can also be a valuable aid in explaining the behavior of multidimensional forecasting models. The restriction to one space dimension makes the model computationally efficient and relatively easy to interpret. At each atmospheric level, the model produces budgets of heat, moisture and momentum which are consistent with the observationally derived estimates of horizontal advection. In TOGA COARE, potential applications of this model include assessments of the role of cloud-radiation interactions, validation of model surface flux data, estimating sensitivity of multidimensional models to alternative physical parameterizations, and performing observing system simulation experiments to aid in the design of the intensive field phase. As an example of the capabilities of the model, we now present results from applying it to a particular case study: the onset of the Indian summer monsoon in 1979.

The model examines an area four degrees in latitude by four degrees longitude which extends from the surface to the top of the atmosphere (0.50 mb). The time period of the model run is four weeks, extending from May 27 to June 23, 1979 (in this year the monsoon onset occurred on approximately June 17). The model atmosphere is divided into 15 layers in addition to the underlying ocean mixed layer. The model uses a timestep of one hour, a surface albedo of 0.05 (typical of ocean surfaces) and a solar constant of 1360.0 $W.m^{-2}$. The model has been applied at two locations in the Arabian sea. Area 1 extends from 66°E to 70°E and from 12°N to 16°N while area 2 covers 68°E to 72°E and 6°N to 10°N.

2. Model results

The vertical profiles of both temperature and specific humidity from both areas correspond well when compared to observational data supplied from the FGGE III-b data set and TOVS satellite data. Some minor discrepancies in the model temperatures include a slight underestimation of the temperature at higher altitudes (above 500 mb) and a sharp drop in the 500 mb temperature at the time of the monsoon onset which has been determined to depend sensitively on the timing of the occurrence of deep convection in the model.

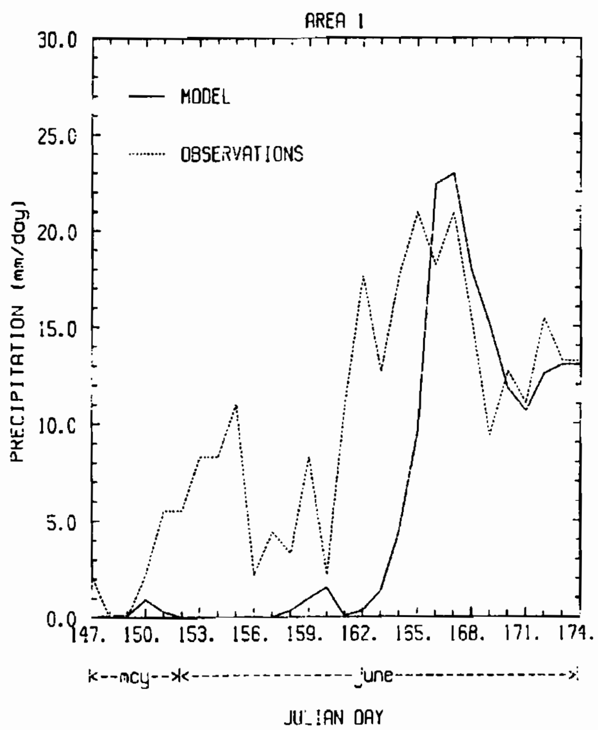

FIG.1a. Area 1 precipitation vs. time. Solid line denotesdata from model and dashed line is observational data

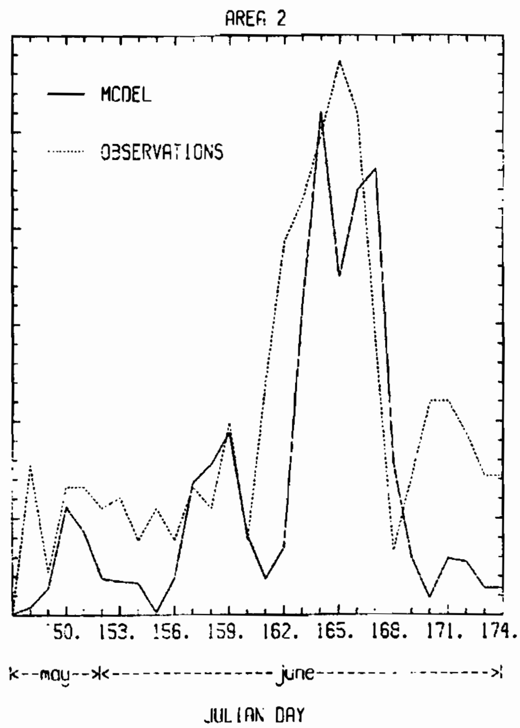

FIG.1b. Same as figure 1a, except for area 2.

Figure 1a shows a comparison between the model precipitation in area 1 and observational rainfall data taken from Cadet and Greco (1987). Figure 1b shows the same comparison for area 2. In both areas the model data compares well with the observational data, especially at the time of the monsoon onset where the precipitation reaches a maximum. During the pre-onset phase the observational data may be overestimating the precipitation as the method employed by Cadet and Greco does not account for any moistening of the atmosphere. Figures 2a and 2b show a comparison between the model values and satellite derived values (Gautier, 1986) of the average daily net short-wave at the surface (NSW). Throughout the integration period there is very good agreement between the model data and the satellite data including the large drop of NSW at the time of the monsoon onset. There are three instances where the model is underestimating the NSW when compared to the satellite data, at approximately day 150 and day 160 in area 1 and at day 151 in area 2. These three brief underestimations of the NSW can be seen to directly correspond with three episodes of minor rainfall. It appears that the cloud parameterization is producing too much cloudiness, hence lowering NSW at the surface, during episodes of low convective rainfall. During periods of large rainfall amounts such as those associated with the monsoon onset, the NSW corresponds very well with the satellite data thus implying that the amount of cloudiness produced by the model during these conditions is representative of the actual cloudiness. This simple analysis indicates that the cloud parameterization used in this model may need some refining for low convective rainfall amounts. This analysis also illustrates how this type of simple yet physically realistic model may be used to evaluate parameterization schemes.

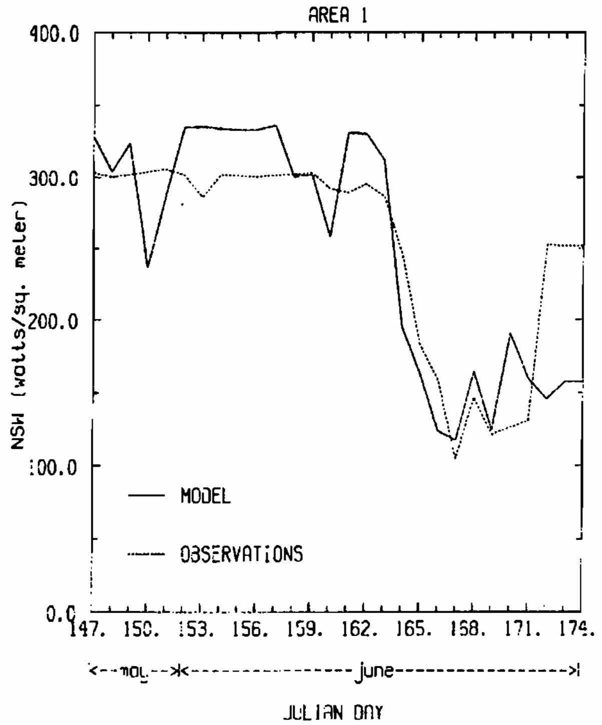

FIG.2a. Area 1 netshort-wave radiation (NSW) at surface vs. time. Solid line denotes data from model and dashed line is satellite observations.

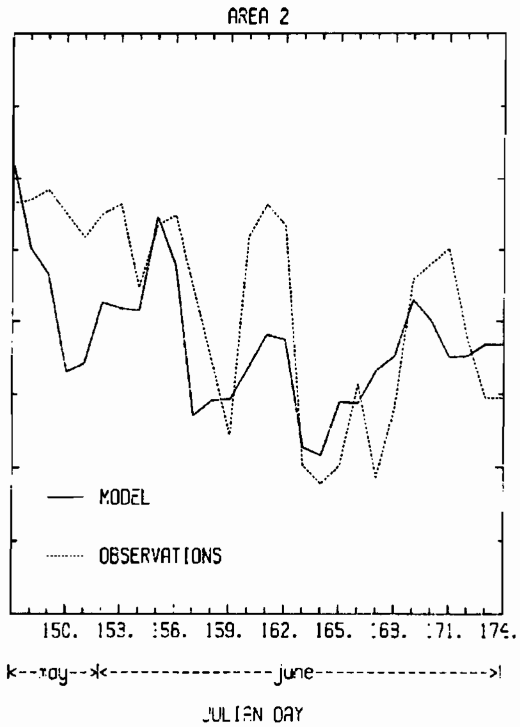

FIG.2b. Same as figure 2a, except for area 2.

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