3B.11 SINGLE-COLUMN MODEL STUDIES FOR IMPROVING THE REPRESENTATION OF ANTARCTIC CLOUD COVER

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1. INTRODUCTION

The Antarctic Plateau, being the coldest and driest location on earth, presents unique challenges to climate modeling simulation. Current GCMs continue to make significant errors with respect to cloud climatology and atmospheric radiation balance over Antarctica, and there is a need to improve the physical representation of clouds in this extreme environment.

To test new parameterizations for cloud physics and radiation, as they are developed or refined from field data, we have adapted the Scripps Single Column Model (SCM). Because there are often large temperature variations in the lower Antarctic troposphere over a few hundred meters (i.e., strong temperature inversions), we resolved the SCM atmosphere into 53 pressure levels. To determine the realism of the SCM's simulation of cloud amount, we forced the SCM with ECMWF analyses from 1992-93, ran the model for a grid cell centered about the South Pole, and validated the cloud simulations with cloud observations from the South Pole Weather Office. We find that, generally speaking, prognostic cloud prediction schemes result in a more realistic cloud simulation than diagnostic schemes, although diagnostic schemes can be tuned to yield acceptable results. We also find that the model, forced with ECMWF reanalyses, provides realistic simulations of cloud amount as a function of wind direction in the lower troposphere: air masses reaching the South Pole from the directions of the Weddell or Ross Seas are warmer, more moist, and bring about more cloud cover, while the opposite is true for air masses reaching the South Pole from Ellsworth Land or Wilkes Land.

Our ongoing work with the SCM involves (1) testing the latest available GCM cloud parameterizations, including one that can simulate clear-sky precipitation, and (2) evaluating the response of the SCM, with appropriate forcing, to increased greenhouse gas concentrations.

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2. MODEL DESCRIPTION

The single-column model (SCM) is a diagnostic model resembling a single vertical column of a 3-dimensional general circulation model (GCM).The SCM contains a full set of parameterizations of subgrid physical processes that are normally found in a modern GCM and is applied at a specific site having a horizontal extent typical of a GCM grid cell. Since the model is one-dimensional, the advective terms in the budget equations must be specified from observations or operational numerical weather prediction analyses.

The configuration of the single column model used in this study has 53 vertical layers (Lane et al., 2000) and a timestep of 7.5 minutes. A diurnally varying solar signal dependent on the latitude and time of year is applied at the top of the model atmosphere. The SCM is modular in design allowing for easy switching between alternative parameterizations (Iacobellis and Somerville, 2000). The control version of the SCM contains the longwave radiation parameterization of Mlawer et al. (1997) and the solar radiation parameterization of Fouquart and Bonnel (1980). Cloud water and cloud amount are calculated using the formulation of Tiedtke (1993). This cloud scheme introduces two new prognostic equations for cloud liquid water/ice and cloud amount. Terms representing the formation of clouds and cloud water/ice due to convection, boundary layer turbulence and stratiform condensation processes are included in these equations. Cloud water/ice is removed through evaporation and conversion of cloud droplets and ice to precipitation. The visible cloud optical depth is calculated using the parameterizations of Slingo (1989) for water clouds and Ebert and Curry (1992) for ice clouds. The effective cloud droplet radius (R_e) is computed using the parameterizations of Bower et al (1994) for liquid water clouds and Wyser (1998) for ice clouds. We have assumed maximum overlap of clouds. In this study, the land surface temperature is specified from observations and surface latent and sensible heat fluxes are set to monthly mean values (King and Connolley, 1997).

3. DATA

ECMWF analysis products available from NCAR (UCAR data set d111.0) are used to produce the horizontal advection of heat, moisture and momentum that are used to force the SCM. The SCM is initialized using temperature profiles obtained from UAD (Upper Air Dropsondes) and the relative humidity profiles from the ECMWF analysis products. The UAD temperature profiles provide a finer vertical resolution than the ECMWF and are thus better suited to resolve the boundary layer structure. We use the ECMWF relative humidities due to problems with the UAD humidity sensors in the Antarctic environment.

4. EXPERIMENTS

At the meeting we will present results from various SCM experiments performed at the South Pole. The model results we plan to show include surface radiative fluxes and the vertical profile of cloud amount and cloud optical properties. These model results will be compared against observations when available.

The results from these SCM experiments will illustrate the role that model vertical resolution, ice particle settling, and the inclusion of a prognostic cloud scheme have on modeling the Antarctic atmospheric environment.

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