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GCM simulation of the Mars water cycle with detailed cloud microphysics

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Abstract

A detailed size-resolving microphysical model of water ice clouds is coupled with Mars atmosphere general circulation model in order to simulate global water cycle. The model reproduces observed zonal variations in the water vapor and cloud distribution associated with stationary planetary waves.

1. Introduction

Water ice clouds are known to be important component of the Martian water cycle [1,2]. GCM simulations of the water cycle with simplified microphysical schemes reveal inconsistence between ice particle sizes and sedimentation rates necessary to maintain global balance of water [2]. On the other hand, observations suggest a wide spectrum of water ice particle sizes ranging from 0.3 mm to 4 mm [3]. This invokes more detailed microphysical models with resolved size distribution of cloud particles [4]. Radiative properties of water ice clouds are also highly sensitive to size distribution. These circumstances motivated the development of a comprehensive microphysical model and its coupling with GCM based on GFDL dynamical core. Simulation results were compared with several experiments on the monitoring of Mars water cycle.

2. The model

The model is based on GFDL's FMS dynamical core, with aerosol and radiation blocks being adapted to a comprehensive microphysics of water ice clouds. Cloud model involves 16 logarithmically spaced size bins in the range 0.01 – 10 micron both for dust and ice particles. It is assumed that dust particles provide nucleation cores for ice condensation. Contact parameter retrieved from laboratory studies of condensation processes under Martian conditions [5] has been adopted. The microphysical model was tested offline with a 1D model, with vertical mixing being simulated by the fractional eddy diffusion model.

2. Results

The model reproduces several types of water ice clouds consistent with observations: mid-altitude clouds at saturation level at 12-30 km depending on season, the aphelion cloud belt, near-surface fogs and polar hoods. Excessively dense clouds are predicted above the North polar cap during the aphelion season, which contradicts numerous observations. This contradiction may be resolved by taking into account sedimentation which facilitates the removal of cloud particles from the atmosphere, but the inconsistence of the model dynamical core - insufficient polar warming in the descending branch of the Hadley cell - cannot be excluded.

Zonal modulation of both water vapor and clouds reveal regular, seasonally changing wave-2 and wave-3 features, which implies the contribution of planetary and mesoscale atmospheric waves to the water cycle. Simulations show that providing sufficiently small ice particles allow for high supersaturation within cloud layers, and significant water mass may penetrate above condensation level in the vaporized form. Being condensed at high altitude and transported to high latitudes, this water forms diffuse aerosol layers composed of submicron particles, consistent with solar occultation measurements [3].

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