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Modeling and observations of the atmospheric water cycle and isotopic fractionation on Mars

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Abstract

Detection of the water isotopic ratios (mainly HDO/H_2O and H_2O^{18}/H_2O^{16}) on Mars will provide important information for the investigations of the history and visualization of water cycle. We are planning the observations of the water isotopic ratios by the sub-millimetre wavelength, as well as starting the 3-dimensional simulations of water cycle including the isotopic fractionations. Here we show our plan of the observation and current status of our Mars general circulation model (MGCM) including the preliminary results.

1. Introduction

Though the current Mars is a dry planet, there are many topographic evidences of past liquid water flow. Some of the liquid water is thought to have escaped into space, while some seems to have moved to the polar regions and underground. For the investigations of the history of water cycle and escape processes which connects to the long-term climate change of Mars, detections of the isotopic ratios in water molecules (e.g. D/H and O^{18}/O^{16}) in the atmosphere and on/under the surface of Mars should provide important hints. Moreover, the mapping of the isotopic ratios has been done for terrestrial atmosphere to visualize the physical processes on the water cycle, and making the mapping on Mars as well is also expected to reveal the water cycle in current Mars environment, especially the moving in and out between surface and atmosphere. At present the observations of water isotopic ratios on Mars have only been done from the ground-based telescopes and Herschel Space Observatory, with low spatial resolutions.

2. Mars SMM Sounder FIRE

Detections of the isotopic ratios for the investigation of the climate changes are considered in future Japanese Mars missions, such as using a sub-millimeter sounder FIRE. The advantage to use the sub-millimetre wavelength is that the retrieval is not affected by atmospheric dust, and we can observe the field of temperature and atmospheric compositions regardless of the dust conditions. Our current plan is to observe H_2O and HDO simultaneously using the wavelength band of 550-620 GHz (see Figure 1). We are also considering to observe H_2O^{18} using its absorption line nearby.

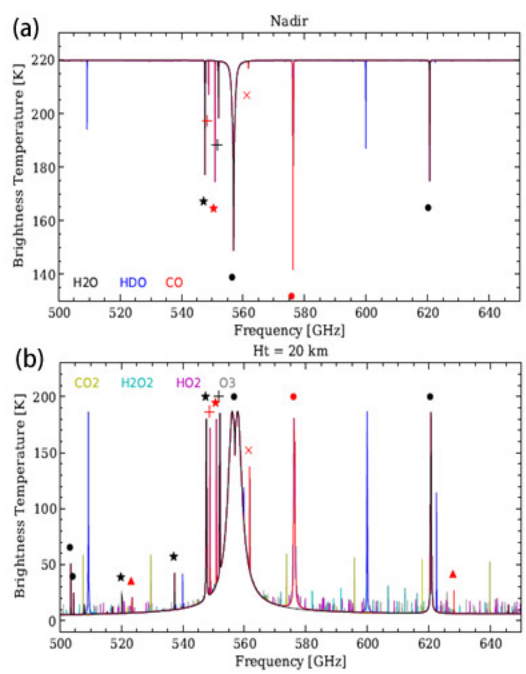

Figure 1: Simulated sub-millimeter spectra of Mars atmosphere assuming the geometries of (a) nadir and (b) limb/tangential height of 20 km [1].

3. MGCM Simulation

The DRAMATIC (Dynamics, RAdiation, MAterial Transport and their mutual InteraCtions) MGCM is based on a spectral solver for the three-dimensional primitive equations [2,3]. In this simulation the horizontal resolution is set at about 5.6°×5.6° (~333 km at equator), the vertical grid consists of 49 σ-levels with the top of the model at about 100 km. Realistic topography, albedo, thermal inertia and roughness data for the Mars surface are included. Radiative effects of CO_2 gas (considering only LTE) and dust, in solar and infrared wavelengths, are taken into account.

The water cycle and isotopic fractionation of HDO/H_2O are implemented in the MGCM. Figures 2 and 3 show the preliminary results of simulated latitudinal and time variances of water vapor column density and HDO/H_2O ratio in the water vapor column, respectively. The simulations are performed for two cases, with and without the consideration of supersaturation (up to 10 times) as indicated in the recent observation [4]. The detailed description of the schemes and the condition of the calculations are written in [3].

In the future we plan to implement the surface-atmosphere interactions of water transport, photochemical processes in the atmosphere and escape processes of particles in connection with the thermosphere/ionosphere simulations into this MGCM, toward the investigation of the water transport processes from ground to space and long-term evolution on the water environment of Mars.

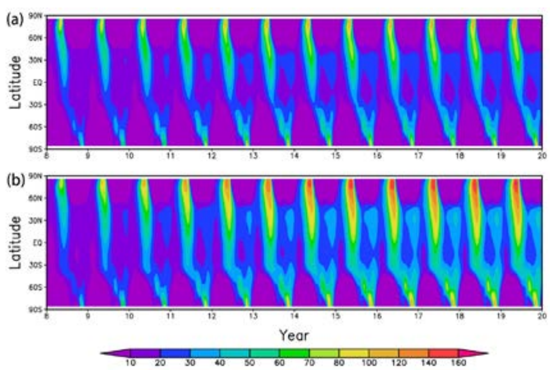

Figure 2: Zonal-mean water vapor column density [pr.μm] simulated by DRAMATIC MGCM for 8-20 Martian years from the dry isothermal state, (a) without supersaturation and (b) including suparsaturation up to 10 times.

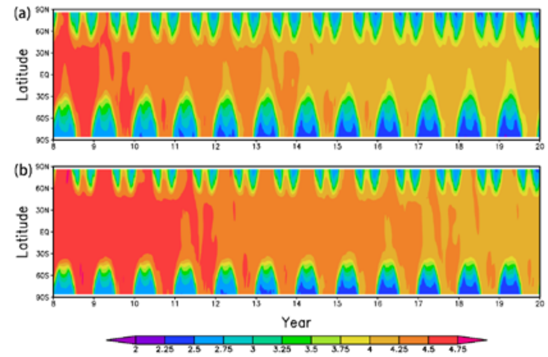

Figure 3: Same as Fig.2, except the HDO/H_2O ratio [wrt. SMOW] in the water vapor column.

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