MODELING MARTIAN WATER CYCLE WITH MODIFIED GM3

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Introduction:

Initial results from our ongoing work on the modelling of the global water cycle on Mars within the framework of the Global Mars Multiscale Model (GM3) [Moudden and McConnell, 2005] are presented.

In the model the atmospheric water consists of two phases, ice and vapour. The ice is treated as a bulk particle with a specified radius and thus sedimentation velocity. Water vapour is allowed to condense into the bulk ice particles and is resupplied as they evaporate. Both the vapour and ice are transported by the resolved circulation, eddy diffusion in the PBL and molecular diffusion in the thermosphere. We also assume that water is continuously present in both Polar Regions as permanent ice caps above 80° latitude. In addition, water is also assumed to be present in the regolith as absorbate, vapour and solid ice. This is quite similar to the water model of Momtemoussin et al (2004) and Richardson (2002). There is also a separate project to reproduce the Mars water cycle for chemistry by Moudden and McConnell [2006] which does not address the contribution of the regolith.

The model is able to reproduce reasonably well the global water cycle observed by the TES instrument. However, we underestimate the column amount of water at northern mid-latitude in the early northern summer.

Model Description:

The dynamical core of the model is provided by GM3 with the addition of a new boundary layer, a multilayer soil model and CO_2 phase change schemes [Akingunola and McConnell]

As noted above, water vapour and water ice are treated as passive tracers. Vertical diffusion of water vapour is achieved by solving the classic tracer diffusion equation with both molecular and thermal diffusion coefficients. The amount of vapour pressure is checked against the saturated vapour pressure of water over ice in each model grid at every time step. Whenever the saturated vapour pressure is greater than the vapour pressure, water ice equal to the difference in pressure are formed. Water ice sedimentation is modeled after the Stoke-Cunningham flow (Jacobsen, 1998). Both the atmospheric water vapour and water ice are transported are achieved through the model built-in tracer transport mechanism which is semi-lagrangian.

The model assumes the presence of an inexhaustible water ice cap 80^0N and above in the northern hemisphere, and from 85^0S southward of the southern hemisphere. Evaporation of water vapour from the surface is achieved through the turbulent lifting of the water vapour in the surface layer from the boundary layer model. The amount of water vapour at the base of the atmosphere is communicated to the sub-surface by balancing the flux at the surface to the water vapour flux from/into the subsurface from the regolith model.

The regolith model is modeled after the subsurface transport model of water vapour of Zent et al. (1993), using the adsorption isotherm on Palagonite materials of Zent and Quinn (1997). The subsurface transport model assumes water to exist in 3 states in the Martian regolith, the adsorbed, gaseous and solid states. The diffusion equation is solved for the water vapour, and the total amount water concentration obtained from the thermodynamic equilibrium of the adsorption and water vapour in each layer of the regolith model is calculated. Subsurface water ice presence are assumed the same way it is done in the atmosphere – by checking the water vapour pressure against the saturated vapour pressure.

Model Results:

The coupled regolith-atmospheric scheme for the water vapor cycle on Mars, with sufficient small model time-step allows us to capture the diurnal properties of the atmospheric water vapour. Figure 1 shows the diurnal variation of atmospheric water vapour at the Viking 1 lander site on Ls=110^0. As discussed by Zent et al. (1993), during the night the lower atmosphere is depleted of water vapour, before the desorption begins to occur as the regolith warms up in the late morning hours, and subsequently filling the lower atmosphere with water vapour. The model is also able to predict the amount of subsurface solid water ice formed.

The global water vapour cycle on Mars in the form of the integrated water vapour predicted by the model in precipitable microns of water is shown in Figure 2. Its agreement with the observation from the MGS TES instrument is quite encouraging. The model is able basic asymmetry in the peak water vapour at the polar regions of the summer hemispheres of Mars.

Further work to elaborate on the impact of the Regolith in global water transport will be discussed at the workshop.

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Figures:

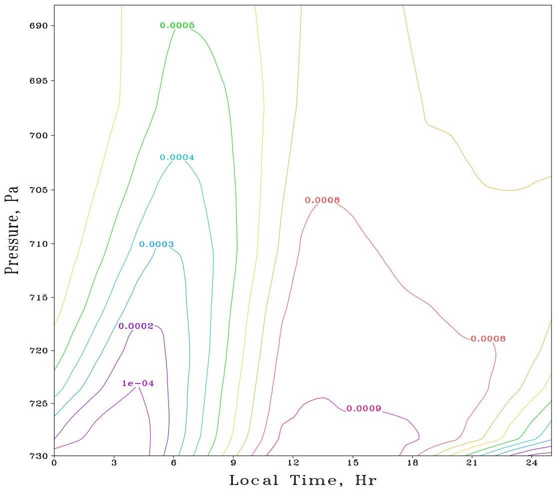


Figure 1: Diurnal variation of the atmospheric water vapour volume mixing ratio at the Viking 1 site on Ls=110^0

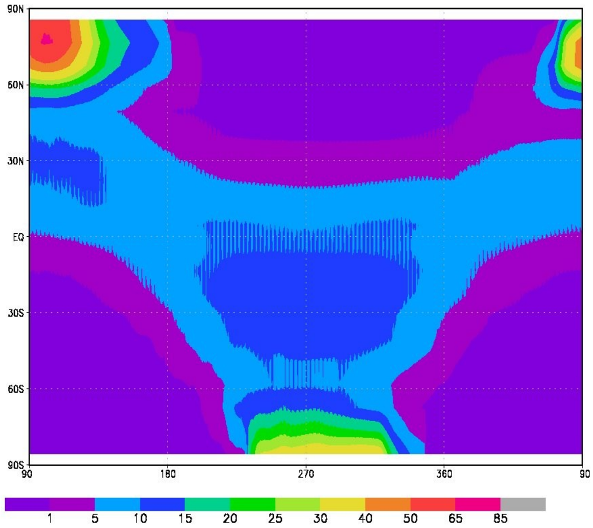
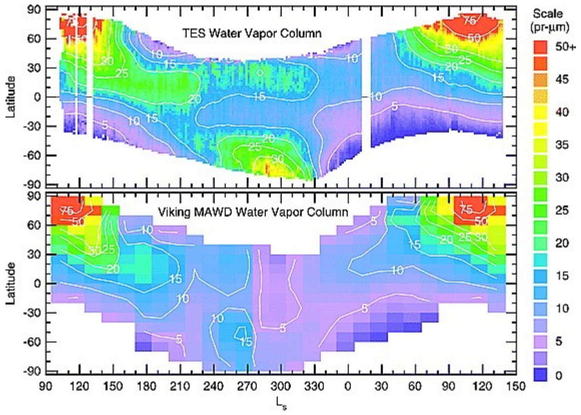


Figure 2: The integrated atmospheric water vapour content in precipitable microns predicted by the model.



The column abundance of water vapor as a function of L$_s$ and latitude: (top) as observed by TES. Contours show a smoothed representation of the results, and (bottom) as observed by Viking MAWD (Jakosky and Farmer, 1982).

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