OBLIQUITY DRIVEN CLIMATE CHANGE IN MARS' RECENT PAST. R.M. Haberle[1], F. Montmessin[1], F. Forget[2], A. Spiga[3], and A. Colaprete[4]. [1]Space Science Division, MS 245-3, NASA/Ames Research Center, Moffett Field CA, 94035, Robert.M.Haberle@nasa.gov. [2]Laboratoire de Météorolgie Dynamique, Universite Paris, 4 pl. Jussieu, 75252 Paris Cedex 05-FRANCE, forget@lmd.jussieu.fr. [3]Ecole Polytechnique, 91128 Palaiseau, Cedex FRANCE, Aymeric.Spiga@polytechnique.org. [4]SETI Institute, Space Science Division, MS 245-3, NASA/Ames Research Center, Moffett Field CA, 94035, tonyc@freeze.arc.nasa.gov.

Introduction: To explain the equatorial valley networks on Mars, Jakosky and Carr [1] suggested that water ice now stored in the north polar region would be mobilized at high obliquity and precipitate out at low latitudes. Extrapolating the present day latitudinal distribution of water vapor to high obliquity conditions, and noting that the low latitude atmosphere would be saturated, they predicted substantial surface ice deposits would accumulate in the tropics at such times.

The first general circulation model simulations to verify this prediction were reported by Haberle et al. [2] who found that while ice can accumulate at low latitudes at high obliquity, it is distributed regionally depending on orbital conditions. Forget [3], Richardson and Wilson [4], and Mischna et al. [5], subsequently obtained similar results with independent models. Thus, obliquity driven climate change may help explain the many tropical landforms thought to be sculpted by water in one form or another (see, for example, refs [6], [7], and [8]).

While low latitude ice accumulations at high obliquity appears to be a robust result, the major challenge now facing models is predicting ice accumulations in the same places where the geological evidence suggests it occurred. This will depend not only on orbital conditions, but also on what physical processes the models include in the hydrological cycle. For example, none of the models mentioned above include the radiative effects of water vapor or clouds, yet both are expected to be in abundance at high obliquity. And none of the models has a very realistic cloud microphysics scheme, which can have a significant effect on how clouds affect the planet's radiation balance.

Here we extend these early modeling results by including a more sophisticated cloud microphysics package, as well as the radiative effects of water vapor and clouds.

Model description: We use the NASA/Ames C-grid Mars general circulation model with an updated radiation code and cloud microphysics scheme. To speed up the simulations, we run the model at fairly coarse resolution (7.5° latitude x 22.5° longitude). Future efforts will examine the effect of resolution on the results.

Radiation Code Fluxes and heating rates are calculated from a radiation code based on the two-stream solution to radiative transfer that fully accounts for multiple scattering in the presence of gaseous absorption. The model has 12 spectral intervals. Dust and water ice scattering properties are included. For dust, we use the Ockert-Bell [9] values in the visible, and Forget [10] values in the infrared. For ice, we can either compute them online as the cloud evolves, or we can specify them. Gaseous opacities for water vapor and CO_2 are calculated from correlated k-distributions taken from full line-by-line models.

Cloud Microphysics Our cloud scheme is based on a moment/order scheme in which the mass mixing ratio and number density of the cloud ensemble are the advected species. From these we obtain a mean particle size and an estimate or the particle size distribution (assuming a variance) which we then divide into 8 bins. Cloud microphysics is performed in each of these bins and includes nucleation, condensation, and gravitational settling. Dust is treated as a tracer and serves as condensation nuclei. The altered size distribution is then converted back into a mean size, a mixing ratio, and a particle number density.

Results: We have conducted simulations for a variety of different obliquities, all at present solar luminosity. In each case the model is spun up from dry initial conditions with a residual ice cap at the north pole. After several years, depending on obliquity, the atmosphere equilibrates and repeats from year-to-year. A sample result for the 60° obliquity simulation, without the radiative effects of clouds or water vapor, is shown in Fig. 1. The top panel in Fig. 1 is the zonally averaged column water vapor as a function of time for 7 Mars years. The middle and bottom panels are similar, but for cloud mass and surface ice, respectively.

Water ice subliming from the north residual cap during summer is rapidly transported southward. Clouds form in low northern latitudes and ice precipitates to the surface. The remainder is transported into the southern hemisphere and condenses onto the south seasonal CO_2 ice cap which extends almost to the equator at the solstice. When the south cap retreats, water is released into the atmosphere where some precipitates back to the surface and the remainder is transported north. Again clouds form in the low latitudes and ice precipitates to the surface. At equilibrium, thousands of precipitable microns of water vapor appear in the summer polar regions. There is more water in the south than the north because the south cap is a better trap for water, and because the Southern Hemisphere is warmer during summer than in the north. Cloud abundances also reach the thousand precipitable micron mark with model predicted particle sizes in the 20-30 micron range. These particles are much bigger, and subsequently fall out faster, than those for present obliquity.

Eventually, permanent deposits form (i.e., ice remains on the ground all year long) in the low latitudes of each hemisphere. These deposits are concentrated along the northern flanks of the Tharsis region and to the northeast of the Hellas basin. Topography plays a key role on where the deposits form through its influence on the circulation. The deposits do not necessarily form in locations where the mean annual surface temperatures are a minimum. They form where the saturation state of the atmosphere is highest. This, in turn, is influenced not only by the thermal structure of the atmosphere, but also by the transport characteristics of the atmosphere.

Simulations which include the radiative effects of water vapor show similar results, but with (a) an increase in the amount of surface ice, (b) a slight shift in the location of the deposits, (c) a cooler and cloudier atmosphere, and (d) slightly warmer surface temperatures. We are presently undertaking simulations with the radiative effects of clouds included and will report the results at the meeting. However, off line 1-D simulations using the predicted cloud abundances indicate they will have a much greater influence on the results than water vapor alone. Their abundances (~ 1000 pr-μm), particle sizes (20-30 μm), widespread occurrence, and impact on the solar and infrared radiation fluxes give clouds a much greater role in determining the climate at high obliquity than for present day conditions.

Conclusions: Mars has a natural mechanism for experiencing significant climate change and redistributing surface ice. Obliquity changes alone are quite capable of moving ice into low latitudes and may provide an explanation for the many geological landforms that strongly indicate recent climate change.

References: [1] Jakosky, B.M. and Carr, H.H. (1985) *Nature, 315,* 559-561. [2] Haberle, R.M., et al. (2000) *LPS XXX1,* Abstract #1509. [3] F. Forget (2001), personal communication. [4] Richardson, M.I., and Wilson R.J., *JGR, 107,* 5031-5049. [5] Mischna, et al. (2003) *JGR,* In press. [6] Cabrol, N.A. and Grin, E.A. (2001). Icarus, 149, 291-328. [7] Kargel, J. (2001) DPS Abstract # 48.12. [8] Head, J.W. and Marchant, D.R. (2003) 6th International Mars Conference, Abstract #3807. [9] Ockert-Bell, M.E. et al. (1997). *JGR*, *102*, 9039-9050. [10] Forget, F. (1998). *GRL*, *25*, 1105-1108.

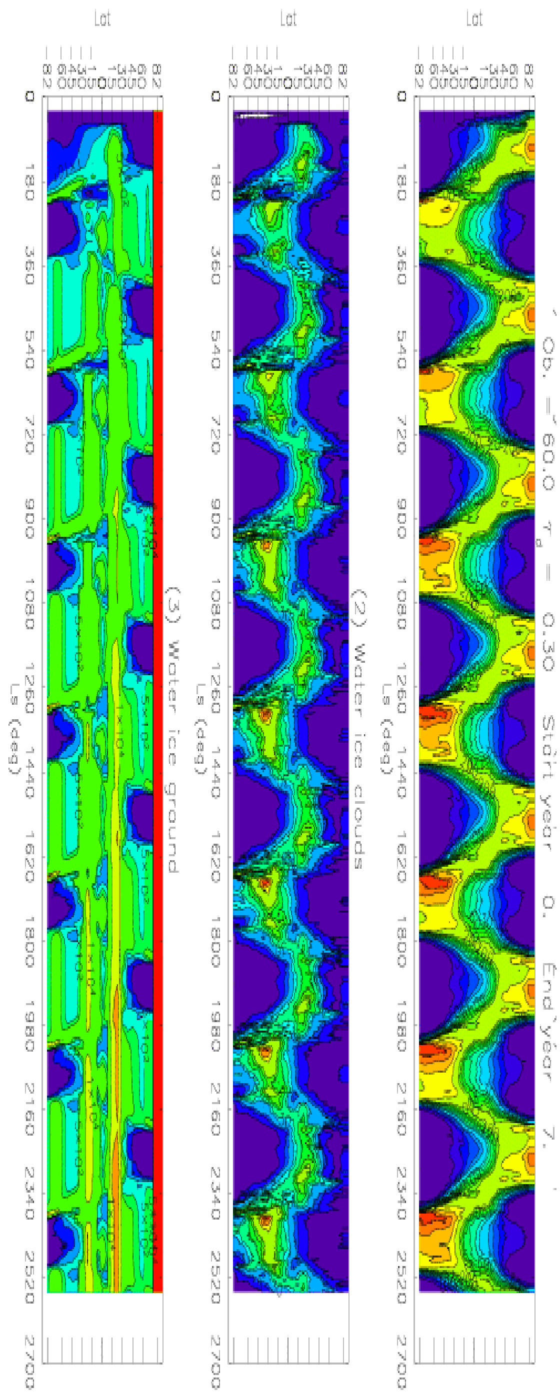

Figure 1