METEOROLOGICAL CONTROL ON THE FORMATION OF MARTIAN PALEOLAKES. R.M. Haberle[1], C.P. McKay[1], J. Schaeffer[2], M. Joshi[3], N.A. Cabrol[1], and E.A. Grin[1]. [1] NASA Ames Research Center, Space Science Division, MS 245-3, Moffett Field, CA 94035-1000. [2] Raytheon Corp. Palo Alto, CA., [3] University of Reading, UK. e-mail: bhaberle@mail.arc.nasa.gov

Introduction: This is a companion paper to that of Cabrol et al. [1] who find evidence for lacustrine activity in impact craters as recent as the Middle Amazonian (perhaps 200-600 Myr ago). This is recent enough in Mars' past that these young paleolakes may have formed under climatic conditions not too different from those of the present epoch.

Approach: We investigate the possibility that these lakes are controlled by meteorological rather than geological factors. The model we adopt is an analog to the Antarctic dry valley lakes. These lakes are perennially covered with ice, but never freeze completely. Liquid water is maintained beneath the ice by glacial melting from nearby snow accumulations [2]. For this model to work, at least three conditions must be satisfied: (1) there must be a source of snow, (2) temperatures must exceed the freezing point at least several days out of the year, and (3) meteorological conditions must allow liquid water to be stable long enough to flow into the lake. All three of these conditions can be addressed with a general circulation model (GCM).

The GCM we use is described in [3] with two important changes: First, the model now uses the MOLA topography for its lower boundary condition [4]. This is important since it allows us to simulate surface pressures - an important control on the stability of liquid water - much more accurately than in the past. The model also simulates the daily ground temperature variations based on a soil conduction scheme that utilizes the Consortium albedo and thermal inertia data. Comparison of model surface pressures with Viking Lander data and model ground temperatures with recent MGS data show reasonable agreement, though there are some discrepancies. Second, for water vapor transport the model's dynamical core has been replaced by the NASA/GSFC Arakawa "C" grid which has a built in tracer transport scheme. We have used this scheme to simulate the present water cycle and the results compare favorably with Viking MAWD data.

Results: In Fig. 1 we show the model predictions for where, and for what length of time, liquid water could be stable on present day Mars over the course of a year. According to the model, there are five distinct regions where pressures and temperatures are above the triple point, but below the boiling point: near the equator in Amazonis, Chryse, and Elysium, and in the impact basins of Argyre and Hellas. A plot of the number of degree days above zero (not shown) gives a similar distribution with the maximum in each location well above 10 days - a typical value for the Antarctic dry valley lakes. Thus, requirements (2) and (3) can be plausibly met though there is still the issue of melting the ice before it evaporates [5].

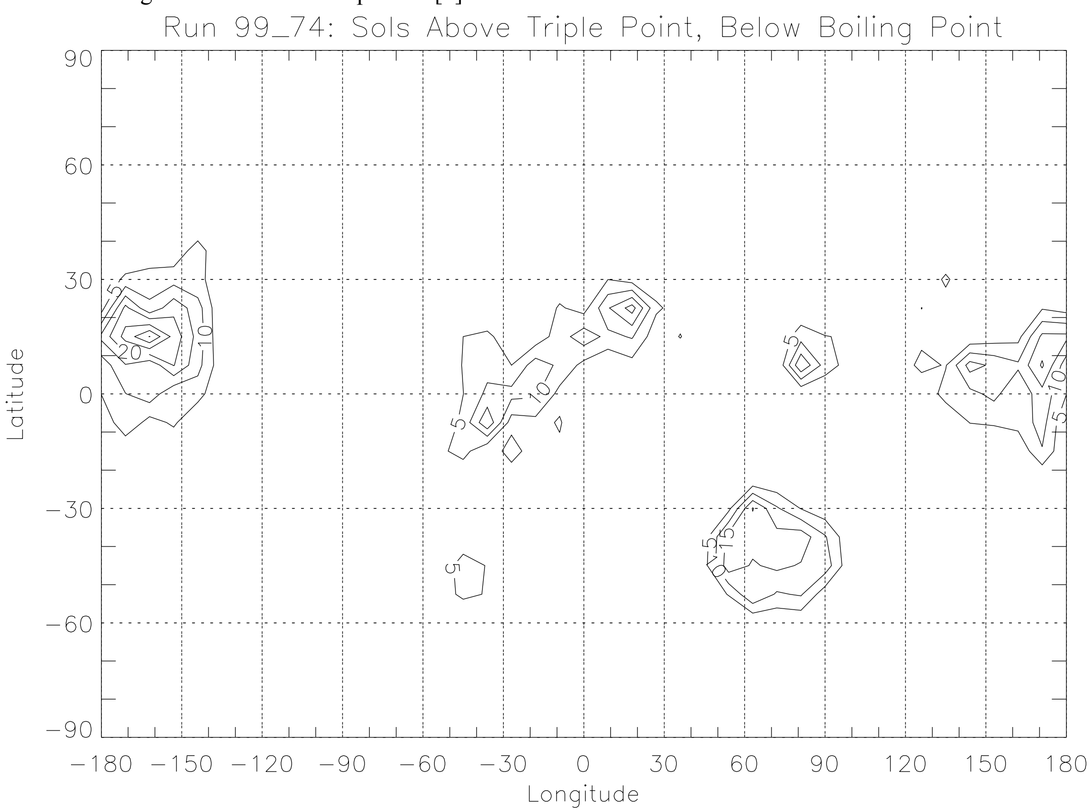

Fig. 1. Duration (Sols) and location where liquid water could be stable on present day Mars.

Interestingly, the places where the model predicts that the stability conditions are satisfied correlates well those places where Cabrol et al. find evidence for recent paleolakes. While the correlation is intriguing, it does not in itself show cause and effect as the first requirement - a source of snow - has yet to be met. Certainly, at the present time the tropics are desiccated [e.g., 6].

So how is it possible to get snow to accumulate in the tropics in relatively recent times? We explore two possibilities. First is the redistribution of oceanic water. The case for a past ocean on Mars has been strengthened by recent MGS observations [7], and may be an inevitable consequence of progressive crustal assimilation of an early surface reservoir [8]. However, the possibility is still controversial and the timing is very uncertain.

To investigate the potential fate of oceanic water, we have conducted simulations assuming an ice covered ocean exists in the northern plains at and below the -4km level. Preliminary analysis of these simulations indicate that a substantial hydrological cycle develops characterized in part by sublimation over the ocean, southward atmospheric transport, followed by considerable snowfall throughout much of the southern hemisphere. Whether the snow accumulates each year depends on the orbit parameters. For the present parameters, snow accumulation in the southern hemisphere occurs only in the polar region. For other parameters snow can accumulate elsewhere including Hellas, Argyre, and Tharsis. In the simulations conducted thus far, it appears possible that an ocean-driven hydrological cycle can provide enough snow to the lower latitudes to be a significant source of water for at least some of the paleolakes.

The second possibility is based on an idea originally proposed by Jakosky and Carr [9] where at high obliquity, water subliming from the north polar cap will precipitate and stabilize at low latitudes. Since that work, it is now known that Mars' obliquity is chaotic on time scales of 10^7 years and may have been as high as 60° [10,11]. For obliquities this high, the tropics receive less annual insolation than the poles and ice might therefore be more stable in the lower latitudes at these times.

We have simulated the water cycle at high obliquities and find that water ice at the north pole is rapidly sublimed into the atmosphere, transported southward, and some of it snows out and accumulates in the low latitudes confirming the original suggestion by Jakosky and Carr. However, the accumulations are limited regionally and do not cover all longitudes. As was the case with the ocean, enough snow accumulates to provide a significant source of water for palelolakes. Thus far, the simulated snow accumulation distribution that best matches the paleolake distribution is for the case when perihelion occurs close to northern summer solstice.

Conclusion: There appears to be at least two mechanisms by which large amounts of ice can accumulate at non-polar latitudes. One involves the redistribution of oceanic water and the other involves obliquity variations. It is important to note that the latter has a solid theoretical foundation and is much less speculative than the ocean hypothesis. Thus, our simulations suggest that at the very least, the surface water ice inventory on Mars has been - and will be - cycled between the poles and the tropics in rhythm with its orbital variations.

References: [1] Cabroll N.A. et al. (2000) *LPS XXXI*, this issue. [2] McKay C.P. et al. (1985) *Science*, 313, 561-562. [3] Haberle R.M. et al. (1999) *JGR*, 8957-8974. [4] Smith D.E. et al. (1999) *Science*, 284, 1495-1503. [5] Ingersoll A.P. (1970) *Science*, 168, 972-973. [6] Mellon, M.T. and Jakosky, B.M. (1995) *JGR*, 100, 11,781-11,799. [7] Head III J.W. et al. (1999) *Science*, 286, 2134-2137. [8] Clifford S.M. and Parker T.J. (2000), *Icarus*, submitted. [9] Jakosky B.M. and Carr M.H. (1985) *Nature*, 315, 559-561. [10] Touma J. and Wisdom J. (1993) *Science*, 259, 1294-1296. [11] Laskar J. and Robutel P. (1993), *Nature*, 361, 608-612.