MODELING THE RECENT EVOLUTION OF MARS PERENNIAL CO₂ CAPS AND ATMOSPHERIC MASS. S.E. Wood¹, R. J. Phillips², I. B. Smith³, N. E. Putzig⁴, C. J. Bierson⁵, ¹University of Washington, Seattle, WA, 98195-1310, sew2@uw.edu, ²Southwest Research Institute, Boulder, CO. ³University of California, Santa Cruz, CA.

Introduction: At low obliquity the polar regions of Mars receive less annual insolation and can reach a point where the total CO₂ sublimation at the pole becomes less than the total condensation at the pole forming a perennial CO₂ ice polar cap. Below this critical obliquity the mass of the CO₂ polar cap(s) increases at the expense of the atmosphere, potentially leading to atmospheric “collapse”. Recent radar evidence for a massive buried deposit of CO₂ ice within the south polar layered deposits presented by Phillips et al. (2011) [1] has bolstered the case for this scenario. An important consequence of this pressure drop is that it can cause a significant decrease in the thermal conductivity of uncedmented porous regolith materials [2]. This effect can lead to increased subsurface temperatures as the planetary heat flow becomes trapped below a more insulating upper layer [3]. The degree of subsurface warming depends strongly on the minimum atmospheric pressure reached, as well as the assumed heat flow, but has the potential to produce episodic liquid water by melting deep ground ice or dewatering of hydrated minerals. Even in the absence of melting, this warming could have significant geomorphic effects by increasing flow rates of buried ice such as lobate debris aprons. At the very least, it would cause the loss or vertical redistribution of as much as 5000 kg/m² of ground ice (or ~25 m of 20%-porosity-filling ice) during each low obliquity period.

While the precise magnitude of atmospheric collapse at low obliquity is uncertain, the fact that a significant decrease in atmospheric pressure can occur is a robust conclusion for a wide range of realistic values of CO₂ frost albedo (Aₙ) and emissivity (εₙ). Values of Aₙ and εₙ obtained as best-fits in models of the seasonal pressure cycle may not be representative of the entire seasonal CO₂ polar cap because the atmospheric mass is most strongly affected by the lower latitude portions (50°–70°) where they have the greatest surface area [4], and where they are more likely to be affected by dust storms. Observational studies have shown that the central portions of the seasonal polar caps can be much brighter than the outlying portions, with springtime Aₙ values as high as 0.83 and εₙ close to unity [5].

Model: We have performed seasonally-resolved calculations of the evolution of Mars’ atmospheric pressure over the past 1 Myr using a model [3] that includes subsurface heat conduction and the latest calculations of Mars’ orbital and axial variations [8]. The zonally-symmetric model calculates the amount of surface CO₂ condensation or sublimation 12 times per year at 23 latitudes (clustered near the poles) based on a surface energy balance using daily average insolation rates. Subsurface heat conduction is computed using a semi-implicit numerical scheme (~2nd order accuracy) using 40 vertical gridpoints divided into 2 layers with differing thermal properties (Chebyshev spacing in each layer with flux matching at interface). Zonally-averaged Viking IRTM soil albedo and thermal inertia values were used for the upper layer at each latitude, with zonally-averaged MOLA topography to calculate local atmospheric surface pressure and CO₂ frost temperature [3]. We found that for values of Aₙ = 0.60, 0.65, and 0.70 (with εₙ = 1.0 in all cases), the minimum pressures reached were 113 Pa, 69 Pa, and 45 Pa, respectively. Results for this model with Aₙ = 0.65 and εₙ = 1.0 for CO₂ surface ice are shown in Fig. 1.

Figure 1 (A) Colors indicated the annual maximum mass (per unit area) of CO₂ ice as a function of latitude and time for the past 1 Myr. The black curvy line indicates obliquity for reference. Areas colored red generally correspond with locations of perennial CO₂ ice.
Insolation-dependent CO$_2$ frost albedo: Guo et al. (2010) [12] performed simulations of the seasonal CO$_2$ cycle with a Mars GCM using an insolation-dependent CO$_2$ frost albedo based on Viking IRTM observations. They found that including this effect produced a stable perennial CO$_2$ south polar ice cap near the south pole for the present orbital configuration, similar to what is actually observed on Mars, because the albedo effect outweighs the elevation effect described above. We used a similar, but hemisphere-dependent function in our model simulations (Fig. 2).

Atmospheric Inflation?: The total mass of buried CO$_2$ ice recently discovered near the south pole is estimated to be ~80% of the present global atmospheric mass [1]. If this reservoir was released into the atmosphere, perhaps during a favorable high obliquity period in the past 1 Myr, then it would nearly double the global mean surface pressure which could have significant climatic effects related to aeolian transport and liquid water stability among others [1]. In order to explore its potential effects on past atmospheric collapse and subsurface warming, we performed some model simulations with a doubled CO$_2$ inventory (400 kg/m$^2$ global). An example of our results is shown in Fig. 3, for a case in which we also used an insolation-and hemisphere-dependent CO$_2$ frost albedo (Fig. 2), produces perennial CO$_2$ ice deposits at the south pole comparable in thickness to the buried deposit recently detected [1].

**Acknowledgements:** This work was supported by NASA Mars Fundamental Research Program grant NNX13AG73G.


**Figure 2**

**Figure 3**  (A) Annual min. thickness of CO$_2$ ice predicted at several polar latitudes, calculated assuming a solid ice density of 1600 kg/m$^3$, and assuming burial occurs for CO$_2$ ice deposited after 400 kya. (B) Global average atmospheric pressure corresponding to the simulation shown in (A).