
**Background:** The obliquity of Mars – that is, the angle between its spin axis and orbit normal – undergoes large variations due to a coupling between the motion of its orbit plane and the precession of its spin axis [1]. Currently 25.19°, orbital dynamics calculations show that for the past 3 Myr the obliquity has oscillated between 15° and 35° with a dominant periodicity of ~120,000 years and a modulation period of ~1.3 Myr [2]. At low obliquity the polar regions receive less annual insolation and can reach a point where the total CO2 sublimation at the pole becomes less than the total condensation – 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”. As the atmospheric pressure decreases (more precisely, the partial pressure of CO2, pCO2), so does the CO2 frost-point temperature (Tf); but any decrease in the temperature of CO2 ice on the surface decreases the condensation rate because the dominant sink for latent heat is thermal radiation to space. This negative feedback acts to keep the annual average temperature of the perennial CO2 ice cap and annual average atmospheric pressure in solid-vapor equilibrium, while the obliquity determines which pair of equilibrium values (Tf; pCO2) are selected through its control of the polar heat balance [3,4].

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 and emissivity. An important consequence of this pressure drop is that it causes a decrease in the thermal conductivity of porous regolith materials. This effect, which has not been considered previously in studies of Mars’ climate, can lead to increased subsurface temperatures as the planetary heat flow becomes trapped below a more insulating upper layer [5]. The degree of subsurface warming depends strongly on the minimum atmospheric pressure reached (pmin). The value of pmin is also important for controlling the flux of micrometeors that reach the surface – evidence for which could provide constraints on atmospheric collapse and/or surface erosion rates [6,7].

Modeling of this process is sensitive to the assumed solar albedo A and thermal emissivity εf of CO2 ice at the poles. Values obtained from best-fit modeling 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 [8], 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 Af values as high as 0.83 and εf close to unity [9].

The first long-term climate model that included a seasonally-resolved model of polar energy balance [10] used values of A = 0.67 and ε = 0.55 that precluded the formation of perennial CO2 ice caps unless the obliquity was less than 13°, and therefore predicted no atmospheric collapse during the past 10 Myr. The first long-term climate model to include the latest calculations of Mars’ orbital and axial variations [1] predicted a minimum pressure of 30 Pa in the past 1 Myr [11], using A = 0.70 and ε = 1.0, but did not include the effects of subsurface heat conduction.

**Current Work:** We have performed seasonally-resolved calculations of the evolution of Mars’ atmospheric 4 pressure over the past 1 Myr using a model that includes subsurface heat conduction and the latest calculations of Mars’ orbital and axial variations [1]. 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. We found that for values of A = 0.60, 0.65, and 0.70 (with ε = 1.0 in all cases), the minimum pressures reached were 113 Pa, 69 Pa, and 45 Pa, respectively (Fig. 1). Higher A values would give lower minimum pressures but would also produce stable perennial CO2 ice caps at both poles at the present obliquity, which is not observed. In our model, the lowest possible pressure is 29 Pa, due to the presence of 7.9 kg/m2 of non-condensible gases.

We will present more recent calculations using insolation-dependent albedo as suggested by Viking IRTM observations [9].


Figure 1