THE CASE FOR STABLE ENTOMBED CO2 IN MARS' SOUTH POLAR LAYERED DEPOSITS.

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Introduction: We use a one-dimensional thermal model of the Martian polar caps to show that it is possible for solid carbon dioxide to be stably buried under a layer of water ice. This study is motivated by the discovery of a massive buried reservoir (9,500–12,500 cubic kilometers) of CO_2 ice in the South Polar Layered Deposits (SPLD) of Mars [1], where such a configuration exists. Burial of solid CO_2 under solid H_2O was thought to be difficult on Mars because the water ice warms up in the summer and conducts heat down into the CO_2, resulting in a net mass loss of CO_2 [2]. Preliminary model results indicate that if the CO_2 ice is not in vapor contact with the atmosphere and is pressurized by the ice above it, there are realistic situations for which the buried CO_2 can experience no mass loss, thereby explaining the existence of the large buried CO_2 reservoir.

Model: Our model calculates the temperature evolution of N H_2O layers overlying M CO_2 layers. Each layer has a thickness d so that the total thicknesses of H_2O and CO_2 are $N{\cdot}d$ and $M{\cdot}d$, respectively. Temperatures are evaluated at the center of each layer. Heat fluxes are evaluated at the boundaries between layers. Seasonal CO_2 frost is allowed to condense and sublimate on top of the H_2O layer. We specify input parameters that will be used in the calculations, including fundamental constants, ice thermal properties, and Mars' planetary characteristics.

Results: To determine if the buried CO_2 ice is stable, we calculate the temperature evolution of the CO_2 layers and evaluate whether they exceed their sublimation temperature under hydrostatic pressure at depth.

In our preliminary study, we let the thickness and albedo of the overlying H_2O ice vary between 1–10 m and 0.2–0.6, respectively, and solve for a region of phase space where buried CO_2 ice experiences no mass loss throughout a martian year. Lower H_2O albedos require thicker H_2O layers to make buried CO_2 stable. This follows from the reasoning that lower albedos increase the heat flux into the ice layers, and so require greater hydrostatic pressure to maintain CO_2 in the solid phase in pressure-temperature space.

Discussion: Besides identifying where CO_2 can be successfully buried in the SPLD, this model might also be used for the purpose of linking the sequestered CO_2 deposits with the Residual South Polar Cap (RSPC, [3]), which overlap in planform [1]. It may be possible that these two CO2 reservoirs are exchanging, or that the presence of one reservoir may stabilize the other reservoir. Perhaps differences between the albedo of the RSPC and the surrounding water ice act to protect the buried deposit. We may also incorporate the effects of the RSPC into a 3-layer model, including the RSPC, water ice, and buried CO_2 deposit.

Mars is known to have wild obliquity swings on Myr timescales [4]. The buried CO_2 ice was probably in the atmosphere at some point and condensed onto the pole during a low-obliquity period, when insolation at the poles was at a minimum. Whether this buried reservoir can survive high obliquities, when summer insolation is at a maximum, is an open question that we will address in future modeling.

A major unknown in this scenario is whether water ice can form a pressure seal at the temperatures and pressures on Mars, either now or in the past. Scintering [5] is one such process, but the rate of scintering is roughly proportional to the vapor pressure, which decreases rapidly with temperature. Other ways to form a pressure seal are also being investigated.

References: [1] Phillips R. J. et al. (2011) *Science*, *332*, 838–841. [2] Ingersoll A. P. (1974) *J. Geohys. Res.*, *79*, 3403–3410. [3] Thomas P. C. et al. (2013) *Icarus*, *225*, 923–932. [4] Laskar J. et al. (2002) *Nature*, *419*, 375–377. [5] Eluszkiewicz J. (1993) *Icarus*, *103*, 43–48.