A Conceptual Model of H2O/CO2 Frost Sublimation and Condensation Caused Albedo Change in Crater Interiors, Martian Seasonal Polar Cap Regions

H. Xie[1], H. Guan[2], M. Zhu[3], M. Thueson[1], [1]Earth and Environmental Science, The University of Texas at San Antonio, San Antonio, TX 78249, U.S.A., Hongjie.Xie@utsa.edu; [2]School of Chemistry, Physics and Earth Sciences, Flinders University, Australia; [3]Research Center of GIS and RS, East China Institute of Technology, Fuzhou, Jiangxi 344000, China.

Introduction: With increasing spacecraft explorations, our knowledge and understanding of Martian geology and climate is expanding. Although progress continues to be made with each new Mars mission, there is still no consensus on how the Martian atmosphere evolved and how it helped shape the surface that we see today. Understanding the Martian polar caps and their seasonal and annual changes is a key to answering those questions. Recent advances based on remote sensing technology have significantly improved our understanding of some important issues. For example, there is a consensus that the water ice in the north polar cap is partially covered by CO2 ice during the cold seasons, and totally uncovered during the warm seasons, while in the south polar cap, the majority of water ice is normally covered by a thin bright CO2 veneer in all seasons [1,2,3,4]; One quarter of CO2 in the atmosphere above the north cap condenses in later summer each year theoretically [5,6,7], resulting in the atmosphere being nearly saturated with water vapor [8,9].

Unlike the perennial polar caps closely related to Martian climate history, the seasonal polar caps are a major element of the current Mars' climate and circulation. Understanding the sublimation and condensation of CO2 and H2O is a key to understanding recent, current, and future Martian climate, seasonal change, atmosphere circulation, and the hydrological cycle. The impact craters or craterforms at the seasonal polar cap regions, especially those associated with high-albedo deposits of frost and/or ice observed in later spring to summer seasons, provides a great opportunity to study H2O and CO2 condensation and sublimation, and their temporal and spatial distributions.

Many of the best-preserved impact craters in the north polar region, but away from the perennial polar cap, are associated with high-albedo deposits of ice and frost and detected first by Viking Orbiter/MGS [10]. [11] used Mars Orbiter Laser Altimetry (MOLA) on board Mars Odyssey to study the geometric characteristics of 15 of these craters (latitude 73°N-85°N) and suggested that the formation of these high albedo ice/frost deposits in craters forms by, either episodic advance of the polar cap margin, continuous deposits from the cavity interior, or ice/dust deposits. It is clear (1) that [10,11] treated these high-albedo deposits as a permanent phenomenon with associated craters; (2) that, based on limited data (Viking and MOLA) available during that time, they did not know these high-albedo deposits have actual seasonal changes; and (3) that they were not clear whether or not those high-albedo deposits are CO2 and/or H2O ice/frost. [12] studied the high-albedo deposits inside the Korolev crater (one of the 15 craters studied by [11]) for its seasonal changes of albedo and bolometric temperature derived from TES. They found that those high-albedo materials seems not appear year round, but only from later spring to middle summer. They suggest that the high-albedo deposits (in the summer period) is newly formed water frost, which was originally released from the extremely ice-rich layer in the subsurface of the crater interior and re-condensed on the surface of the crater floor. This explanation is similar to [13]. Using the OMEGA images [14], it was found that, in this crater region (*77N/90E)*, combination of water frost sublimation and decrease of atmospheric aerosols concentration caused the increase of albedo. But both (in Ls=96° and in Ls=118°) were actually water frost (ice). [15] studied a crater (70.5N/103.2E) and documented the evolution of water ice patches in the crater interior. Based on above studies, we propose a new conceptual model of H2O/CO2 frost sublimation and condensation caused albedo change in crater interiors. This model assumes a permanent existence of water ice patches in a crater interior. The water ice patches originated from either episodic advance of the polar cap margin or ice/dust deposits. With the existence of water ice patches in a crater, it is then possible that the high-albedo phenomenon in those crater interiors can be observed in the Martian later spring to middle summer period.

Model description: Figure 1 is the proposed conceptual model of sublimation/condensation (or decrease/ increase of mass or extent) of CO2 frost and H2O frost/ice within a crater. Bottom part of the figure is the TES-derived bolometric temperature versus time (Ls) for the polar ring [16], which approximately represents the temperature trend of any polar crater. Our model is based on an existing high-albedo water ice patch covering part of or the entire crater interior. The model explains very well the albedo change via time associated with CO2/H2O frost sublimation and condensation:

(1) From Ls=0° to ~60°, the major process is sublimation of CO2 frost (fine grain), along with small amount of condensation of H2O frost, resulting in the decrease of CO2 mass or extent on

top of water ice, while increasing the albedo due to exposure of water frost and/or water ice.

(2) From Ls=60° to ~160°, the major process is sublimation of H2O frost, resulting in the albedo decreasing first (mass decrease) and then increasing (mass increase). The decrease is due to the dust left after all CO2 frost sublimation and major H2O frost sublimation. The increase is due to the exposure of old and large grain size of water ice, after the sublimation of majority of H2O frost (new and fine grain). Dust left previously may be absorbed by water ice and/or fall into the cracks of larger grain of water ice.

(3) From Ls=160° to ~ 190°, the major process is condensation of H2O frost (fine grain) (mass increase), together with two other possible mechanisms: regolith or underlying terrain may be exposed after extensive H2O sublimation (Ls=60 to 160) and serious dust storms during the time. The resultant effect is albedo decrease.

(4) From Ls=190° to ~360°, the major process is condensation of both CO2 and H2O frost (mass increase). But H2O frost is minus in the time range, while CO2 condenses very rapidly in the first 30-40 sols, then slowly condensing later.

This is a genetic model for the north polar region and should satisfy all high-albedo associated craters observed in later spring to middle summer time period in the north polar region, though the exact time range might change a little bit depending on the location (latitude) of craters. Similar model for south polar region can be established based on previous studies found from literatures and our data.

References: [1] J.-P. Bibring et al., Nature 428, 627 (2004). [2] J.-P. Bibring et al. Science 307: 1576-1581 (2005). [3] S. Byrne et al. Geophys. Res. Lett. 30, 1696 (2003). [4] T.N. Titus et al. Science 299: 1048-1051 (2003). [5] Leighton and Murray, Science 152, 136-1(1966). [6] Forget et al., Icarus 131, 302-316 (1998). [7] Tillman et al., J. Geop. Res. 98: 10963-10971(1993). [8] Farmer et al., Science 194: 1339-1341(1976). [9] Jakosky and Haberle, in eds. of Kieffer H.H. et al., 969-1016(1992). [10] Garvin and Frawley, Geophys.Res.Lett.25: 4405-4408(1998). [11] Gavin et al., Icarus 144:329-352(2000). [12] Armstrong et al., Icarus 174:360-372(2005). [13] Bass et al., Icarus 144: 382-396. [14] Vincendon et al., 37th LPSC, abs. #1769(2006). [15] Xie et al. 37th LPSC, abs. #1764(2006), . [16] T.N. Titus, Science 299: 1048-1050(2003).

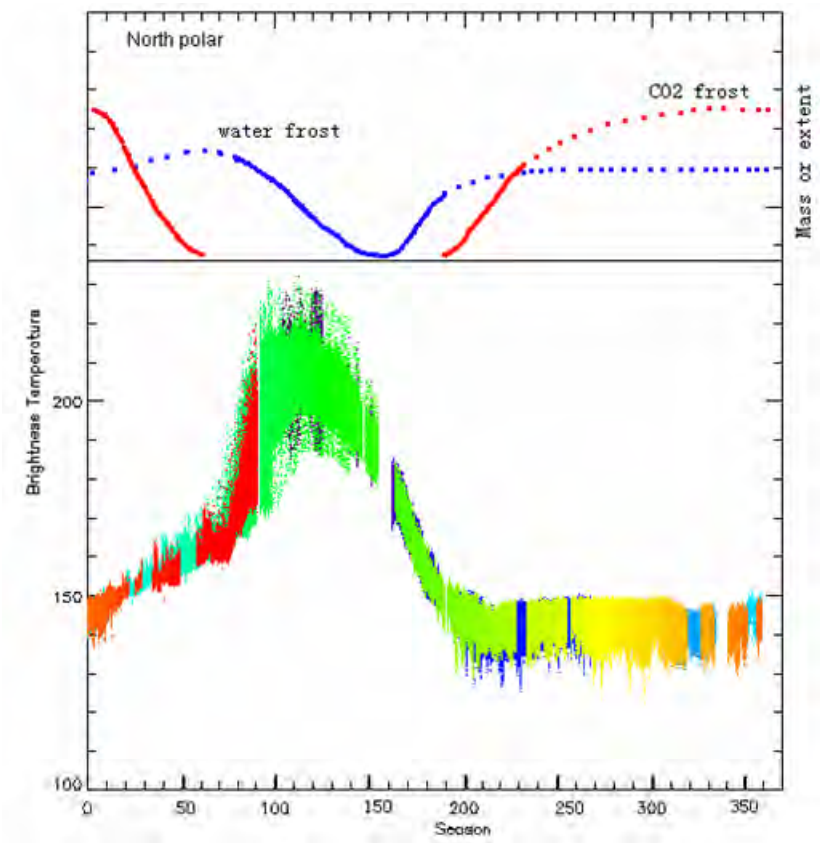

Figure 1: Conceptual model of sublimation/condensation (or decrease/increase of mass or extent) of CO2 frost and H2O frost on a crater floor via time. Solid lines represent the major sublimation/ condensation processes, while dotted lines the minor processes. Bottom part of the figure is a TES-derived bolometric temperature (K) versus time [16].