ICES ON MARS: DYNAMICS, DISTRIBUTION, AND QUESTIONS. M. T. Mellon, Southwest Research Institute, 1050 Walnut St., Boulder, CO 80305.

Introduction: Water and carbon-dioxide ices are known to occur seasonally and permanently on Mars and in a variety of reservoirs. Additionally, species of clathrate hydrates are suspected to occur naturally, but have yet to be detected. The body of Mars research on these ice species is vast and every increasing. The current state of knowledge of ices will be briefly reviewed with emphasis on distribution and dynamic exchange between reservoirs. Open questions will be discussed.

Carbon Dioxide Ice: Carbon dioxide is the primary constituent of the Mars atmosphere, making up about 95% of the typically 6 mb surface pressure. At this pressure CO_2 will condense onto surfaces at about 150K. This surface temperature is readily achieved seasonally in the polar region and high latitudes, and occasionally at night in lower latitudes. Additionally, saturated conditions can also be met resulting in CO_2 ice clouds. In winter, CO_2 frost blankets the surface at high and polar latitudes to depths of many decimeters to more than a meter, cycling about 30% of the atmosphere onto the surface [1]. Perennial CO_2 ice occurs at the south polar cap, but is absent in the north [2].

Recently, Phillips et al. [3] reported detection of a large buried deposit of nearly pure CO_2 ice within the south polar cap. The volume of this deposit large enough that if it were released, the atmosphere pressure would be doubled and would likely have a substantial impact on the modern martian climate.

Water Ice: Water on Mars has received a great deal of attention, primarily due to its relevance to the martian climate, geologic processes, and its importance to biology. Despite the fact that water in the martian atmosphere is found only in trace quantities, water on Mars is quite dynamic, exchanging readily between ice reservoirs through this atmospheric conduit.

Water ice has now been observed and inferred to occur on Mars in a variety of forms. At present H_2O ice has been observed at the polar surface [4] and is inferred to occur within the bulk of the polar deposits based on a number of observations. H_2O ice is also found to occur in the shallow permafrost at middle- and high-latitude regions from remote sensing [5,6] and direct sampling (Fig 1). While detected ice is only centimeters below the surface, deeper ice is inferred to be present to depths of kilometers [7]. However, local glacial deposits have been recently confirmed through sounding radar [8]. Clouds, hazes and ice fogs result from water ice in the atmosphere under saturated conditions. Water ice has also been observed as diurnal surface frosts and cold trapped by seasonal CO_2 frosts.

These reservoirs of water ice are dynamic, actively exchanging readily between polar, regolith surface, subsurface, and atmospheric reservoirs. Small amounts of water can be transported on seasonal and interannual time scales. However, on longer time scales the orbit of Mars undergoes dramatic cycles which can result in cyclic glaciations and the removal and redeposition of vast portions of the polar water-ice deposits.

Clathrate Hydrate: Clathrate hydrate is a form of water ice that owes the stability of its cage-like structure to the presence of a "guest" molecule. On Earth, common forms of clathrate include methane (found in sea floor deposits), nitrogen, and oxygen (found in Antarctic ice). While on Mars clathrate has yet to be observed, CO_2 clathrate has been inferred to be stable in the polar ice deposits below a few ten's of meters [9]. Remote detection of clathrates is difficult due the need of overburden pressure to maintain stability. Clathrates are important as a reservoir of trapped CO_2.

Figure 1. Subsurface H_2O ice at the Phoenix landing site (68° N latitude). This ice, shown here in a localized 99% pure deposit was found a few centimeters below the surface. Most subsurface ice, however, was observed to be in the form of ice-cemented soil [6].

References: [1] James et al., in *Mars* pg 934, 1992; [2] Thomas et al., in *Mars* pg 767, 1992; [3] Phillips et al, *Science, 332*, 838, 2011; [4] Kieffer et al., *Science 194*, 1341, 1976; [5] Feldman et al., in *The Martian Surface*, pg 125- 2008; [6] Mellon et al *JGR, 114*, E0E07, 2009; [7] Clifford, *JGR, 98*, 10,973,

1993; [8] Plaut et al., *GRL, 36*, L02203, 2009; [9] Miller and Smythe, *Science, 170*, 531, 1970.