New Views of Old Volatiles (Overview Talk)

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Water ice, with its exceptionally low vapor pressure, can be found in the Inner solar system in comets, on a few asteroids, in various reservoirs on Mars and Earth, and in the polar regions of the Moon and Mercury. Its presence is determined by the history by which it forms and the processes that enable it to survive, the latter being better constrained than the former.

When exposed to vacuum, the sublimation loss rate of H_2O ice becomes negligible at temperatures below 120 K, which gives rise to the concept of "cold traps", e.g. in permanently shadowed areas of Mercury. When buried, temperatures around 145 K still allow ice to survive over the age of the solar system, a concept known as "buried snowline". Such continuously low temperatures occur in the Inner solar system due to one or the other of the following two reasons. The first applies to bodies whose rotational spin axis is almost perpendicular to the orbital plane (Mercury, the Moon, and possibly Ceres). Craters near the poles are permanently shadowed and, even without craters, the Sun rises barely above the horizon. The second reason is that on atmosphereless bodies, particulate matter can have astonishingly low thermal conductivity. Such layers not only prevent warm daytime temperatures from penetrating too deeply but also lead to rapid cooling of the surface at night, which averages to temperatures lower than naively expected.

On planetary bodies with atmospheres, i.e. Earth and Mars, H_2O is exchanged between the atmosphere and several reservoirs, but still strongly controlled by temperature. On present-day Mars, water ice is almost always found at locations below 200 K, when the atmosphere saturates, irrespective of where on Mars. CO_2 ice forms below 150 K at present-day atmospheric pressure, a temperature reached not only during polar winters but also seasonally at pole-facing slopes in the tropics.

While it has long been known that Mars has polar caps that mainly consist of water ice, several additional ice reservoirs (some huge) have been discovered over the last decade. We now know that at least one fifth of the planet's surface has ground ice. Moreover, various types of localized ice deposits (e.g., lobate debris aprons, mountain glaciers, pedestal craters) are found in all latitude zones. Evidence has also amassed for repeated and recent glaciation on Mars, similar to the ice age cycles on Earth. There is significant redistribution of ice over the time scale of orbital variations (due to redistribution of sunlight on the planet's surface), if not shorter (due to major dust storms or an internal climate cycle controlled by the south polar cap, estimated to be a few centuries long).

Volatiles are substances that easily transition from the condensed phase into vapor. The classification is context specific (e.g., H_2O is not a volatile on Titan; in a broader sense, dust on Mars behaves as a volatile). The two most abundant volatiles in the Inner solar system are H_2O and CO_2 (e.g., Mars has seasonal H_2O ice, seasonal CO_2 ice, perennial H_2O ice, and perennial CO_2 ice; comet Hartley 2 outgasses both H_2O and CO_2). The number of minor volatile species is large and includes organics.