SEASONAL SURFACE FROST AT LOW LATITUDES ON MARS. Norbert Schorghofer[1] and Kenneth S. Edgett[2], [1]*Institute for Astronomy, 2680 Woodlawn Drive, Honolulu, HI 96822, USA (norb1@ifa.hawaii.edu)*, [2]*Malin Space Science Systems, P.O. Box 910148, San Diego, CA 92191, USA.*

The continuous or nearly-continuous south polar seasonal cap has long been known to extend from the pole to about 60°S[1]. In Hellas, the cap extends further north, covering all of Hellas Planitia[2]. Viking IRTM observations showed that temperatures across Hellas at this time of year are consistent with CO_2 freezing at slightly higher temperatures than it does at the pole, owing to the greater atmospheric pressure in the basin[3].

Less well known or recognized is the presence of southern winter frost at lower latitudes. During the past 4 Mars years, MGS MOC blue WA and NA imaging capabilities have been used to document occurrence of seasonal patches of frost at latitudes as low as 35°S, and even 24°S.

Figure 1 reveals seasonal frost in the form of bright patches on polefacing crater walls in the region 40–36°S 134–140°E. For instance, R02-00411 shows frost in at least nine craters on south or south-southwest facing slopes. The frost was observed in the southern winter of 1999 (Mars year 1), was monitored by MOC in 2002/2003 (Mars year 3), and is also present in the current southern winter (Mars year 4). No blue filter MOC images (except 7.5 km/pixel daily global images) were taken at this site in the southern winter of 2001 (Mars year 2). These observations demonstrate that frost forms in this region annually.

During the MOC-WA monitoring in 2002/2003 frost was first observed at L_s=114° and not yet discernible at L_s=106°. Frost persisted until L_s=145° in several craters, but disappeared earlier in others. No visible frost was left by L_s=148°.

Thermal Emission Spectrometer (TES) surface temperatures for the geographic area 40°S–36°S, 221°W–225°W (Figure 2) indicate that nighttime winter temperatures are close to the frost point of CO_2 and reach a minimum around $L_s \approx 90^\circ$. It can be expected that polefacing slopes reach even lower temperatures and accumulate CO_2 frost.

Crater wall slopes obtained from MOLA gridded topography are about 16°, which, at this latitude, implies that even the polefacing walls are illuminated by the sun every sol. Model calculations show that the minimum daily mean solar insolation occurs at L_s=88° and minimum temperatures on flat ground are reached at L_s=90°. In Mars year 3, frost becomes visible only one to two months after the winter solstice.

A thermal model[4] is used to obtain temperatures on crater walls. In this model, the heat balance on the surface consists of direct solar insolation, conduction into the ground, thermal emission from the atmosphere and from other slopes, thermal reemission from the surface, and the latent heat of CO_2 on the surface. The model simultaneously calculates surface and subsurface temperatures at the crater floor and on the crater wall, taking into account the thermal radiation of the crater floor onto the walls. As expected, the model predicts the formation of CO_2 frost (Figure 3).

Model temperatures have little azimuthal asymmetry. Carbon dioxide frost extends to azimuths of 40° east and west of the polefacing direction, consistent with observations. The frost patches on the crater walls in Figure 1 have an apparent north-northeast orientational preference. This might be an illumination bias. The northwest slopes of the craters are shadowed at the time the images are acquired.

At low temperatures, even small amounts of energy change the thermal balance and the time period and amount of frost depend sensitively on several model parameters, especially atmospheric dust content. However, frost as late as L_s=145° is readily possible and the amount of frost is on the order of 50 kg/m^2 ($\gtrsim$3 cm thick). The model leaves unexplained why frost becomes visible late. If the frost does not become visible on MOC-WA until a certain incidence angle, layer thickness, or surface roughness is reached, the time it is first observed can be past the winter solstice.

The frost point temperature of H_2O in the southern hemisphere is ∼196 K[5]. Carbon dioxide frost exists at ∼147 K and should hence be preceded by H_2O deposition. The cold slopes also attract water by cold trapping. Figure 3 shows the theoretically estimated duration of water ice deposits. The observed albedo patches could contain H_2O frost, but the amount of H_2O may not be large enough to cause discernible albedo variations in wide-angle imagery. Additional data analysis is ongoing.

Unlike the south, the northern hemisphere has not exhibited seasonal frost at latitudes lower than about 48° (i.e., Viking 2 lander site). Since in southern winter the planet is closer to aphelion than in northern winter, minimum temperatures are substantially lower in the south. Hence, sites on the northern hemisphere are less likely to reach the CO_2 frost point.

North of Hellas in winter, frost and low, ground-hugging fogs are observed to latitudes as low as 24°S (Figure 4). In other areas, blue WA images document frost as far north as 37°S, and a single crater at 35°S has consistently shown frost in NA images acquired during several of the previous 4 Mars years (e.g., E02-00757, E03-01581, R03-00172).

The presence of low-latitude wintertime frost offers opportunities for future exploration. For example, a 2009 Mars Science Lander (MSL) mission to a southern mid-latitude crater, even as far north as 35°S, may offer an added bonus of wintertime frost observation. The same is the case for a MSL (or other, future lander) mission to Terby Crater, located north of Hellas Planitia and filled with a several kilometers-thick section of sedimentary rocks[6].

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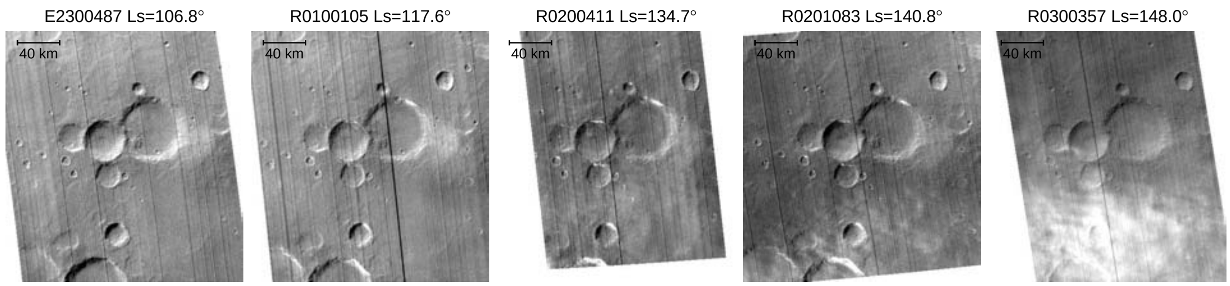

Figure 1: Seasonal frost monitoring at 38°S 223°W with blue MOC wide-angle images. Patches of bright frost appear and disappear annually at pole facing crater walls. Image headers indicate image id and areocentric solar longitude. North is up in all images and illumination is from the upper left. Local time is about 3pm.

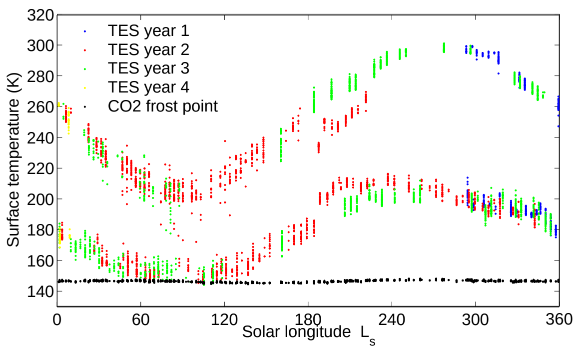

Figure 2: TES surface temperatures in the area 40–36°S, 221–225°W at 1–3pm and 1–3am local time. Black dots indicate the CO_2 frost point calculated from TES surface pressures.

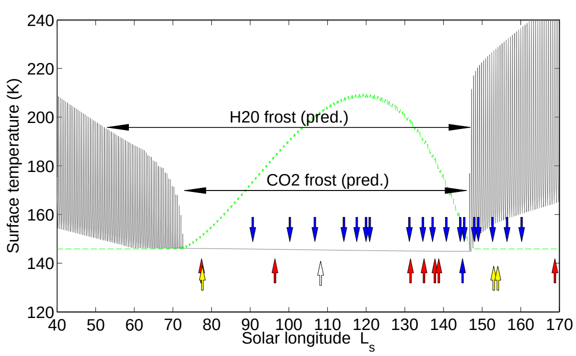

Figure 3: Model temperatures on a sloped surface, using a crater wall slope of 16°, an azimuth of 200°, and TES thermal inertia and albedo typical for this region. Blue and red arrows mark the solar longitude of blue and red MOC-WA images, respectively; yellow arrows indicate THEMIS infrared images, and the white arrow a Viking Orbiter image. The dash green line shows the amount of predicted CO_2 frost in arbitrary units.

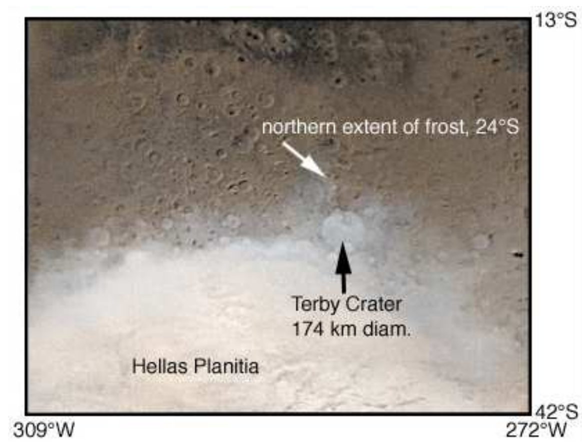

Figure 4: Color composite of MOC daily global images E23-01291 and E23-01292 showing the northernmost extent of frost in the area north of Hellas at $L_s = 145°$. (Acknowledgment: The picture was extracted from daily global maps prepared by Bruce Cantor.)