THEMIS OBSERVES EARLY MORNING ATMOSPHERIC H_2O AND CO_2 ICE ON MARS: PRELIMINARY OBSERVATIONS. G. E. Cushing[1] and T. N. Titus[1], [1]U. S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Dr. Flagstaff AZ, 86001. gcushing@usgs.gov.

Introduction: Recent adjustments to the Mars Odyssey spacecraft's orbit have enabled the THEMIS instrument [1] to acquire observations in the first hour after sunrise at both visible (VIS) and thermal-infrared (TIR) wavelengths. The first hour of daylight is an interesting (and not well-observed) time on Mars—when solar energy initiates katabatic winds and interacts with volatiles freshly deposited overnight. The thin martian atmosphere does little to stabilize surface temperatures—which, during polar springtime, often plunge to CO_2 condensation temperatures overnight before rapidly increasing from nearly the first instant of sunshine. Accordingly, CO_2 and H_2O frost or snow can accumulate overnight [2,3] and sublime rapidly at sunrise – possibly influencing fog and/or cloud formation through atmospheric density variations.

Observations: Searching for examples of early morning ground fog, we surveyed all concurrently acquired THEMIS VIS/TIR early-morning imagery (incidence angle between 75°-90°) covering the north polar region (>60° latitude) in mid-to-late spring (L_s=30°-90°) of Mars Year (MY) 33. While the great majority of early-morning observations (with the sun < 15° above the horizon) show no visible increase in atmospheric opacity due to clouds or fog, we have identified about a dozen observations with at least some form of cloud or fog coverage. Here we discuss four of these observations where different circumstances have induced the formation of ground fogs or low-level clouds with topographically induced lee waves.

The temperatures discussed henceforth are THEMIS Band-9 brightness temperatures. For each observation, these temperatures were re-calibrated to CO_2 temperatures using clearly identifiable CO_2 ice deposits, if present.

V60793009 / I60793008: The VIS image (Figure 1) shows a small scene in the first hour of daylight with the sun only 11.1° above the horizon (L_s=33.7°, Latitude = 68.2°). An optically thick 'fluffy-looking' layer of either ground fog or blowing CO_2 snow closely blankets the local terrain. The concurrent TIR image is nearly featureless (which is expected of regions covered with CO_2 ice) except for a darker region corresponding to the region in Figure 1—consistent either with reduced IR emissivities from opaque CO_2 fog or with small grain sizes of freshly deposited CO_2 snow. According to [3, 4], regions of enhanced precipitation will likely show decreased surface emissivity because the accumulating deposits would have relatively small grain sizes compared with the surrounding frosts. [3] modeled CO_2 snowfall rates as high as 0.75 g/cm^2/hr. However, if Figure 1 is showing ground fog, this would imply that atmospheric conditions were already near the CO_2 condensation point and either a decrease in atmospheric pressure (possibly from Bernoulli's principal and early-morning katabatic winds passing over Heimdal crater to the north) or a decrease in near-surface temperatures caused ice-crystal formation resulting in ground fog.

V61625003 / I61625002: Figure 2 shows an interesting scene with a 40-km fog-filled crater with snow-covered rim walls and a frosted dune field on its floor (L_s=64.1°, Latitude = 69.9°). Brightness temperatures for the scene were calibrated assuming CO_2 snow on the rim walls (~145 K). The dune-field temperatures are more consistent with frozen H_2O (~165 K), and the fog regions warmer still (~180 K), indicating a composition of H_2O ice vapor.

Figure 1. Optically thick CO_2 ground fog or windblown snow <1 hour after sunrise. Crater in center of image is ~4 km across.

V62138007 / I62138006: Topographically induced lee waves in H_2O ice clouds formed by passing over Escorial crater (305° E, 77° N; Figure 3, left). Waves are spaced ~3 km apart. Cloud waves like these are common occurrences at all martian latitudes [5] and are too highly organized to have formed in the time since sunrise, so it is unlikely that the clouds in this observation result from the polar location or early time of day.

V61102010 / I61182009: Topographically induced lee waves in CO_2 ice clouds formed near Koralev crater (Figure 3, right), with waves spaced 3-5 km from crest to crest. Similar to the H_2O lee waves described above, these are common occurrences and are not strongly dependent on latitude or sun position. A subsequent VIS / TIR observation of this location two mornings later at the same time shows no indication of cloud activity.

Figure 2. Unnamed 40-km fog-filled polar crater with H_2O frost-covered dune field on floor (upward arrow), and CO_2 snow deposits on the rim walls (down arrow).

Discussion: THEMIS observations have verified that early morning ice fogs occur on Mars, when conditions permit, throughout springtime in the North Polar Region. Favorable conditions appear to occur most frequently near the retreating seasonal cap edge, where fog formation is likely influenced (perhaps indirectly) by northward H_2O migration and by solar energy interacting with surface volatiles that precipitated or condensed overnight.

We have not determined times and positions of the MY 33 northern cap-edge retreat. However, assuming that data from the prior retreats of MY 29-31 [6] is reasonably comparable, it appears that all four of the observations presented here lie within a few degrees of the retreating cap edge at their respective positions in solar longitude. The two examples containing H_2O ice were observed just south of the purported cap edge, while the two CO_2 observations were just to the north. A discussion of surface and temperature variations will be presented.

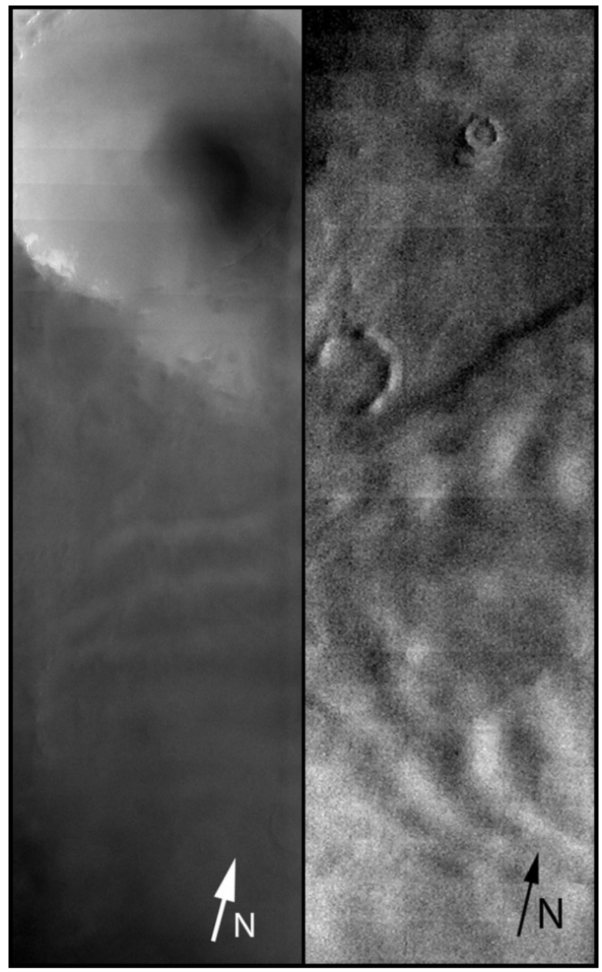

Figure 3. Topographically induced atmospheric lee waves. Left panel shows waves in H_2O clouds south of Escorial crater. Right panel shows waves in CO_2 ice clouds northeast of Koralev crater.

References: [1] Christensen P. R. et al. (2004) Sp. Sci. Rev., 110, 85-130. [2] Titus T. N. et al. (2001) JGR, 106, 23181-23196. [3] Colaprete A. and Toon O. B. (2002) JGR, 107, 5.1-5.16 [4] Forget F. et al. (1995) JGR, 100, 21219-21234. Colaprete A. et al. (1999) JGR, 104, 9043-9054. [6] Calvin W. M. et al. (2015) Icarus, 251, 181-190.