CHARACTERIZING THE MARS DIURNAL CO_2 CYCLE. T. N. Titus[1], [1]United States Geological Survey Astrogeology Science Center, 2255 North Gemini Dr., Flagstaff, AZ 86001 USA (ttitus@usgs.gov).

Introduction: While a significant amount of study has been conducted to characterize and model the annual CO_2 cycle on Mars, little has been done to investigate and characterize the extent of the diurnal CO_2 cycle. There are two general locations where the diurnal exchange of surface CO_2 ice with the atmospheric can occur: (1) at higher elevations of the Tharsis region [1,2] and (2) in the regions of the seasonal polar caps which experience both solar illumination and darkness (e.g. the edges of the seasonal polar caps). This paper will focus on what happens at the cap edge.

Motivation: While the effects of the cap edge diurnal CO_2 cycle on the atmospheric pressure are negligible, the nightly formation of CO_2 ice and subsequent complete sublimation the next day could possibly be an analysis tool for probing the near-surface properties, e.g. the thermal inertia of the surface material or depth to the H_2O ice table.

The theoretical (via modeling) understanding of the seasonal cap edge diurnal CO_2 cycle was needed in order to plan a coordinated observing campaign by the two Mars spacecraft that are in early morning and mid-afternoon orbits: Odyssey and Mars Reconnaissance Orbiter (MRO). The major question in designing an observing campaign is the duration of the diurnal CO_2 ice. If the diurnal ice only reforms the night after the seasonal CO_2 ice sublimes, and not any subsequent nights, then the region must be specifically targeted (complete with Roll Only Targeted Observations (ROTOs)) that afternoon and the immediately following morning. However, if the diurnal ice reforms on several nights, then fewer constraints are on the observing coordination.

First-order Considerations: Even without computer simulations, a few basic properties of the diurnal CO_2 cycle can be deduced. For nighttime condensation and complete daytime sublimation to occur, the process requires both a period of sunlight and of darkness. Therefore, a diurnal cycle cannot occur during mid-to-late spring as the sun never sets on retreating cap edge due to the occurrence of polar day. (See Fig. 1).

Thermal Model: A simple thermal model that solves the thermal diffusion equation using the Runge-Kutta method [3] was used. The model, while not as sophisticated as other thermal models (e.g. KRC [4, 5]), was specifically written to model and track the effects of diurnal CO_2 condensation and sublimation. For the retreating seasonal cap, the subsurface was set to 145 K since the regolith has had all "winter" to dissipate the thermal pulse from summer time heating. The bottom boundary layer is adiabatic. The current version of the model does not have an atmosphere, but that will be corrected in the next version. Therefore results presented provide a validation of the model and a qualitative (but not quantitative) understanding of the effects of the diurnal CO_2 cycle at the edge of the seasonal cap. The model initial conditions used are shown in Table 1.

Parameter	Value	Units
Soil Bond Albedo	0.2	
CO_2 Ice Bond Albedo	0.65	
Soil Thermal Inertia	203	$J\ m^{-2}\ K^{-1}\ s^{-½}$
Ice thermal inertia	2000	tiu
Model Layer Thickness	0.01	meters
Number of Layers	100	
Time Interval	0.035	seconds

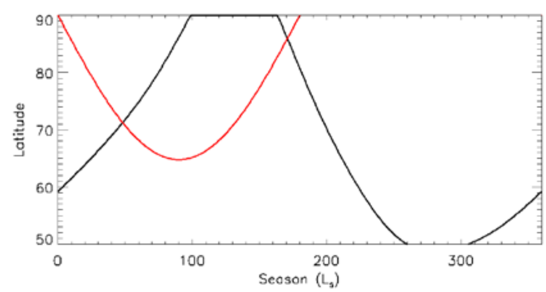

Figure 1: Cap Edge vs. Season. The black line is the latitude of the observed seasonal cap edge as a function of season. The red line shows the extent of the polar day, a range of latitudes during which the sun never sets.

Basic Questions: There are several basic questions concerning the diurnal CO_2 cycle and what effects may be observable.

- What is the effect of a near-surface H_2O ice table on the diurnal CO_2 cycle?
- What is the effect of atmospheric opacity?
- At what season and latitudes (and possibly longitudes) are the effects of the diurnal CO_2 cycle most apparent?
- What is the effect of elevation on the diurnal CO_2 cycle? For example, is diurnal ice more or less likely to be observed on the floor of Hellas Basin than on the surrounding plains?

Modeling Results: The results are preliminary but will be useful in planning an observation campaign where afternoon observations from MRO CRISM can be compared to early morning observations from Mars 2001 Odyssey THEMIS.

Local time. The local time when the seasonal CO_2 ice completely sublimes is an input parameter. Preliminary model results suggest that the deposition of diurnal CO_2 ice is sensitive to the local time when the seasonal ice disappeared. If the seasonal CO_2 ice disappeared in the morning, the ground would become too warm for subsequent nighttime deposition. Because the complete sublimation of seasonal CO_2 ice is expected to be spatially patchy due to small-scale variations in slope and regolith properties, any nighttime deposition can also be expected to be patchy.

Retreating cap. As previously noted, the diurnal CO_2 ice is not expected during the mid-to-late spring. However, diurnal CO_2 ice is possible during the initial phase of cap retreat. Model predictions suggest that the diurnal CO_2 ice will need a highly coordinated campaign as the cycle only occurs for a single night during the early spring. However, late winter observations of the cap edge may show the deposition and complete sublimation over a period of two days as shown in Fig 2.

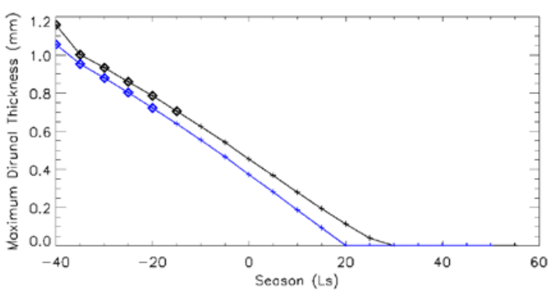

Figure 2: Maximum diurnal CO_2 ice thickness as a function of season. The black line assumes a thermal inertia of 200 J m^{-2} K^{-1} $s^{-½}$, extending to the full model depth. The blue line assumes that a water-ice table exists under the same material at a depth of six millimeters. The diamonds indicate that the diurnal CO_2 ice recondensed on at least two consecutive nights, whereas the plus signs are when the diurnal CO_2 ice only forms that night immediately following the complete sublimation of the seasonal CO2 ice. The effects of near-surface H_2O ice results in less diurnal accumulation and an earlier secession of the diurnal cycle.

The time of day that the seasonal ice completely sublimates also affects the occurrence of diurnal ice. If the seasonal ice completely sublimes during the morning, the ground will sufficiently warm to prevent an onset of diurnal ice. Therefore the observation of diurnal ice during the spring will generally be difficult.

Inflection Point. The inflection point is the season at which the seasonal cap is at its maximum extent. This is period of time when the diurnal CO_2 ice should deposit nightly (with subsequent daytime sublimation) for the longest duration, thus providing an opportunity for either extended observations or less coordinated observations.

Advancing cap. Results for the advancing cap, while not shown here, will be presented later. The previous initial conditions of setting the depth profile to the condensation temperature of CO_2 ice is not realistic as the regolith has had all summer to warm. Longer model runs will be needed to allow for model spin-up.

Summary: Model results suggest that the diurnal deposition of CO_2 ice along the seasonal cap edge should occur under proper conditions. The thickness of the diurnal ice and the number of sols for which diurnal ice occurs is dependent on thermal inertia, including the presence of near-surface ice. Therefore, the observational characterization of this process will provide a probe to the physical properties of the near-surface.

Future Model Modifications:

- Add in a Mars-like atmosphere with both solar and thermal opacity.
- Increase the length of the model runs (to allow for spin-up) to analyze the diurnal CO_2 cycle while the seasonal cap is advancing.
- While all preliminary results presented here have been for the northern hemisphere, a similar study will be conducted and presented for the south.

Acknowledgements: This project was partially funded through the THEMIS/Odyssey Project and CRISM/MRO Project offices.

References: [1] Cushing, G.E. & T. N. Titus (2008) JGR, 113, CiteID E06006. [2] Titus T. N. & Cushing G. E. (2015) *LPS XLVI*, Abstract #1181. [3] Press W. H. et al. (1992) Numerical Recipes in C, Cambridge Univ. Press. [4] Kieffer, H. H., et al. (1977) *J. Geophys. Res.*, 82, 4249–4291. [5] Kieffer, Hugh H., (2013) *J. Geophys. Res.*: Planets, 118(3), 451-470.