SOUTH POLAR COLD TRAP TEMPERATURES DURING THE KPLO PRIMARY MISSION.

J.-P. Williams[1], D. A. Paige, P. Mahanti, M. S. Robinson, M. S. Siegler, and J. Martinez-Camacho[2], [1]Affiliation (include full mailing address and e-mail address if desired) for first author, [2]Affiliation for second author (full mailing address and e-mail address).

Introduction: The relatively low obliquity of the Moon's spin axis relative to the ecliptic (1.54°) results in many regions around the lunar poles with low elevations, particularly crater interiors, to remain permanently shadowed [1,2]. These permanently shadowed regions (PSRs) are of particular interest due to their potential to be cold enough to cold trap volatile species, including water and carbon dioxide [3].

The ShadowCam instrument aboard the Korean Pathfinder Lunar Orbiter (KPLO/Danuri) spacecraft has been designed specifically to image PSRs at high resolution (~1.7 m pix^{-1}) and high signal-to-noise [4]. The ShadowCam investigation will provide critical observations for better understanding polar volatiles including mapping of albedo features and patterns and identifying landforms that may be indicative of ice either on the surface or within the sub-surface, and identify any temporal changes that might occur through the year of the primary mission.

The Diviner instrument on the Lunar Reconnaissance Orbiter (LRO) has been making temperature observations of the polar regions since 2009 [5] and has shown how polar temperatures have varied with seasons and time of day [6,7]. Temperatures within PSRs have been found to vary considerably with season and the seasonal temperature amplitude can be comparable or larger than the diurnal temperature amplitude in many of the larger south polar PSRs [7,8]. Extensive regions beyond the boundaries of the PSRs can also become shadowed for extended periods of time (i.e. substantial fraction of the draconic year) [7,9,10].

Temperature is a fundamental quantity in determining where and when volatile species are capable of being cold trapped or remobilized on the lunar surface. Several recent studies have used Diviner data to map the cold trapping area of various volatile species using the time-integrated potential sublimation rate [8,11] or the sublimation rate at peak temperature [12] of volatile compounds.

In this investigation, we use a thermal model that accounts for large-scale topography and direct and indirect infrared and solar radiation on the thermal balance of the regolith surface [6]. Coupled with the Diviner observations acquired during similar subsolar longitude and seasons, we estimate and predict the temperatures of the ShadowCam targets throughout the KPLO primary mission.

Methods: For our initial model simulations, we have focused on a the south pole down to 80° S latitude using a digital elevation model (DEM) comprised of a ~500 m triangular mesh (Fig 1) with each triangle coupled to a 1D regolith thermal model as described in [6]. The model results provide a time-series of the KPLO primary mission for this region.

Diviner Reduced Data Records (RDR) provide brightness temperatures for individual LRO orbit tracks which can be binned and converted to bolometric temperatures as described in [6]. Polar Cumulative Products (PCP) are derived from binning the Diviner RDR data into 240 m pix^{-1} polar stereo grids and 15° subsolar longitude bins, and 6 seasonal bins (defined by the ecliptic longitude, L_s) [8].

These Diviner datasets can provide bolometric temperatures at corresponding seasons and time of day of ShadowCam observations. We continue to tune the model using the Diviner data; however initial modeling provides general agreement with Diviner temperatures [13]. As the diviner data has not been able to sample all potential combinations of local times and seasons that may be observed by ShadowCam, the model will be a useful tool for providing temperature estimates at precise observation times.

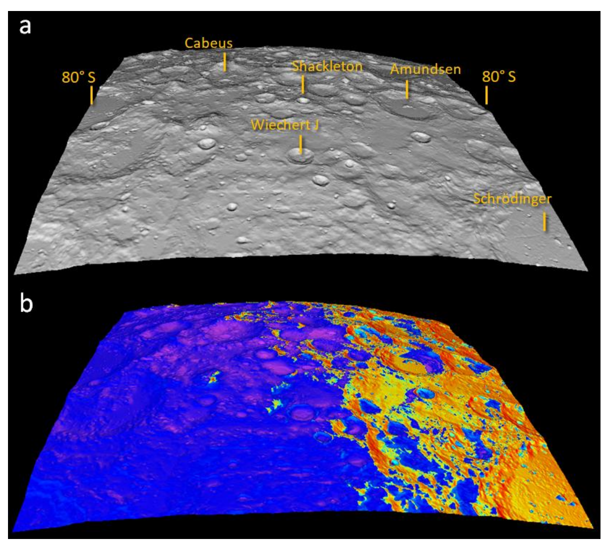

Fig. 1: (a) Shaded relief of the model DEM used in the thermal model. (b) Model temperatures for 1-Jan-2023, the approximate start of the KPLO primary mission.

Discussion: The KPLO primary mission is planned for ~1 year allowing for observations through an entire draconic year and providing ShadowCam the opportunity to image polar shadowed areas during all seasons. During this period, the cold trapping surface area of many volatile species will grow and contract. Using Diviner data, coupled with our model, we have the ability to map the predicted growth and contraction of these areas which will contribute to our understanding and interpretation of features observed in ShadowCam images, especially if changes in albedo are observed.

Fig. 2 shows the area where modeled surface temperatures are below the volatility temperatures of water, 110 K, and CO_2, 54 K, defined as the temperatures at which ≤1mm Gyr^{-1} of sublimation will occur [14].

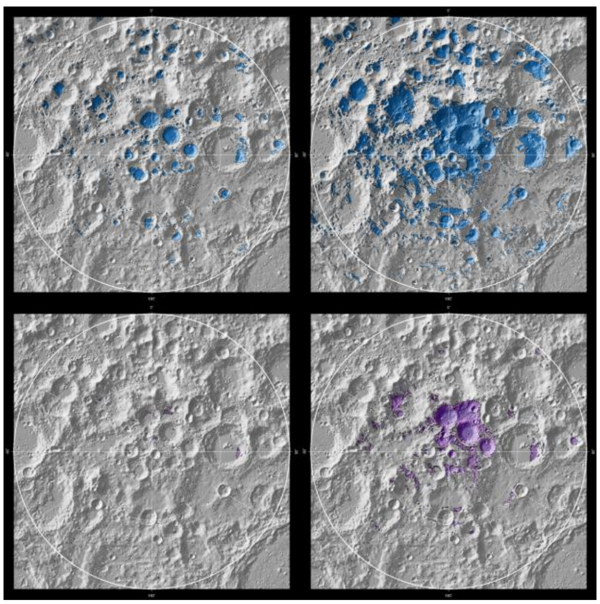

Fig 2: Modeled cold trapping area of (*top*) water and (*bottom*) carbon dioxide at the (*left*) start and (*right*) middle of the KPLO primary mission corresponding to southern summer and winter respectively. Color shaded areas are where surface temperatures are perpetually below the volatility temperature of water (blue), and CO_2 (purple) throughout an entire lunation.

Summary: The ShadowCam instrument aboard KPLO will collect images of the PSRs at a high resolution and signal-to-noise. This will enable the identification and characterization of albedo patterns and other landforms that may be indicative of the presence of ice along with any temporal changes that may suggest accumulation and/or mobilization of volatile deposits. Diviner data and thermal modeling will provide estimates of the temperatures of the surfaces imaged by ShadowCam and can provide a thermal history (time series) of locations within the images. This will be an important component in interpreting the images and constraining potential volatile compounds that may be present.

Acknowledgments: The Reduced Data Records and Polar Cumulative Products used in this study are publicly available via the Geosciences Node of the Planetary Data System [14,15].

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