LUNAR POLAR ICE AND THE OBLIQUITY HISTORY OF THE MOON. M.A.. Siegler[1] B.G. Bills[2] D.A. Paige[1], [1]UCLA Dept. of Earth and Planetary Sciences, Los Angeles, CA, 90095 (siegler@ucla.edu), [2]NASA Jet Propulsion Laboratory, Pasadena, CA, 91109

Abstract: Water ice is currently stable in shadowed environments near the lunar poles. This however has not always been true. Roughly halfway through its outward migration (due to tidal interaction with the Earth) the Moon was tilted (currently 1.5^{o}) up to 83^{o} with respect to the ecliptic. During this time, illuminated polar craters would have been far to warm (up to 380K) to preserve water ice [1].

This extreme change in insolation is a result of a spin-orbit configuration, within which the Moon currently resides, known as a Cassini state. A Cassini state results from dissipation within the satellite and drives the spin axis of the satellite to precess at the same angular rate as its orbit. As spin precession is controlled by the satellite moments of inertia and orbit precession by its semimajor axis, the satellite is driven into an obliquity that will cause their angular rates to sychonize [2].

According to theory, when the lunar semimajor axis measured roughly 30 Earth radii (currently 60.2) it transitioned between two stable Cassini states, reaching very high obliquities ($\sim 77^{o}$) [1,3]. Since that time (roughly 2.5-3.5 Bya) the obliquity has slowly decrease (to the current 6.7^{o}), causing each currently shadowed crater to go through a period of partial illumination.

During these periods, water molecules reaching such regions of the lunar surface may have been in the right temperature range to be considered stable, but mobile. This is important as lack of current surface ice deposits in polar craters imply that some mechanism of burial is required to preserve ice before it is lost to surface processes. When in the right temperature range, ice may be stable in the near subsurface, but mobile enough to be driven downward by diffusion along thermal gradients at a faster rate than it is lost.

When a given environment was in this "icetrap" temperature regime, generally between 95 and 150K (depending on supply rates and temperature amplitudes), ice had a better chance to be preserved by burial via thermal diffusion processes than any time before or since. Once a shaded environment cools below roughly 90K, thermal diffusion processes can be considered negligible and only burial by impact gardening [4, 5] has been proposed as a viable mode of ice preservation.

We examine the thermal environments resulting from the slow orbital evolution since the Cassini State transition. With new topographic thermal models produced in association with the Diviner Lunar Radiometer [6], we can examine how changing insolation impacted temperatures at specific locations near the lunar poles. These models have been shown to accurately reproduce current surface temperatures and can be extracted to depth based on past subsurface temperature measurements [7].

Given an assumed supply and loss rate, one can then model how specific locations would have gained or lost subsurface ice by vapor diffusion [8,9]. Such modeling has proven to accurately reproduce ground ice distribution on Mars [10] and differs here only in that past supply rate of water molecules to the surface is unknown. However, given the reasonable assumption that the supply rate of volitiles was higher in the past [11] and the fact that more of icetrap regions existed at higher obliquties this appears to be a viable mode to deliver ice in the quantities observed on the Moon today [12, 13].

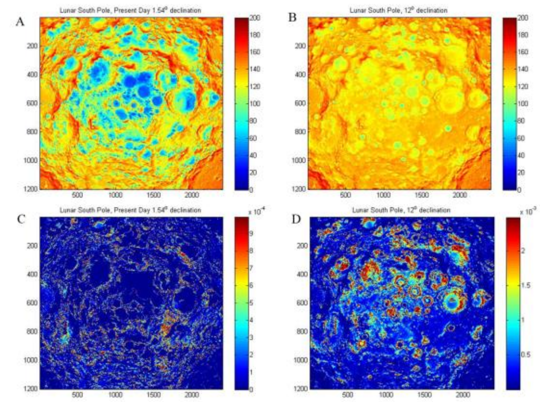

Figure 1: (A) Mean annual temperature in the current (1.54^{o} tilt) lunar south polar region (stretched 0-200K), (B) Mean annual temperatures at 12^{o} tilt, (C) Modeled ice mass (kg m^{-2} yr^{-1}) gained at 1.54^{o} assuming simple model [8], (D) Modeled ice mass (kg m^{-2} yr^{-1}) gained at 12^{o}.

References:

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