ON THE SEARCH FOR WATER AT THE LUNAR POLES: RESULTS OF FORWARD MODELING OF PERMANENTLY SHADED AREAS AND LUNAR PROSPECTOR MEASUREMENTS.

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Introduction: Cold-trapped volatiles at the lunar poles would provide extremely valuable scientific information stretching back to the early solar system, and are also a potential resource for use in long-term human exploration. While Clementine radio science data was interpreted in favor of the presence of lunar polar ice [1], this has been disputed [2]. Nevertheless, it is clear that there are polar enhancements of hydrogen, and it has been argued that these are in the form of shallowly buried ice [3,4,5]. The Lunar Prospector neutron spectrometer data currently provides the most severe constraints on how much water may be present in the Moon's polar regions, and where it may be found [5]. But how do the neutron spectrometer data compare to what we know of permanently shadowed areas at the lunar poles?

Lunar Prospector NS Measurements: Decreased epithermal neutron count rates measured by the Lunar Prospector NS have been interpreted as indicating the presence of hydrogen in the form of water ice shallowly buried at and near the poles of the Moon [3,4,5]. There may also be a hydrogen contribution from solar wind and hot magnetospheric particles. The inferred water abundances based on NS measurements is about 1.5 ± 0.8 %. The actual abundance on/under the surface, however, depends on the areal distribution of the permanently shadowed regions, including the very numerous small craters near the poles. Based on conservative estimates of only a few hundred square kilometers of permanent shade, the water abundance upper limit of 10% was found [5]. Increases in shadowed areas lead to decreases in cold-trapped water abundance at any one location.

Polar Shadow Modeling: The combination of Clementine imagery and radar observations now leave little doubt that sizeable areas of the Moon's poles are permanently shadowed. Recent estimates of approximately 7500 and 6500 km^2 for the north and south poles, respectively, come from analysis of simple craters less than 20 km in diameter [6]. Key to the question of cold-trapped water retention is an accurate digital elevation model for the polar regions. Initial attempts at this using Clementine stereo imaging have been carried out [6], and continue.

Forward Modeling: Here we describe a forward-modeling approach to the neutron spectrometer-shadowed region problem. We take a single illumination model for the polar regions, assume a water ice abundance in the permanently shadowed locales, and then artificially "fly" the LP NS detector over the pole for many "orbits", acquiring data with realistic Poisson statistics for that water ice distribution.

Figure 1 illustrates the results of an initial simulation. The upper left panel portrays a simple illumination model based on Clementine imaging of the north lunar polar regions. The deepest shadows, indicated by white in the upper right panel, are assumed to contain water ice. In this case the water abundance is assumed to be 1.5%. The lower left panel shows "raw data" binned in 2-km bins as the result of 8 lunations-worth of continuous orbital data acquisition. This acquisition includes statistics. Finally, a smoothed version of the map is seen in the lower right panel, which displays the average count rates in counts/sec. The dynamic range of count rates in this case is very similar to what has been actually measured from the low-altitude phase of the Lunar Prospector mission, with an average orbital altitude of 30 km.

The fifth panel at the bottom shows LP NS data gathered from this orbit phase, in counts per 8 seconds. There appears to be good correspondence between several of the features. The next step in our process will be to reduce or enhance water abundances on the basis of the disagreement, and re-run the forward problem. The hope is to iterate on a solution that provides a good agreement between the simulated LP NS "data" and the actual observations. As the illumination models improve, so does the fidelity of the only locations where truly cold-trapped water can be found.

This process should, in the end, provide a map of potential sites for high water abundance, sites that would prove fruitful in both exploration and science endeavors at the Moon.

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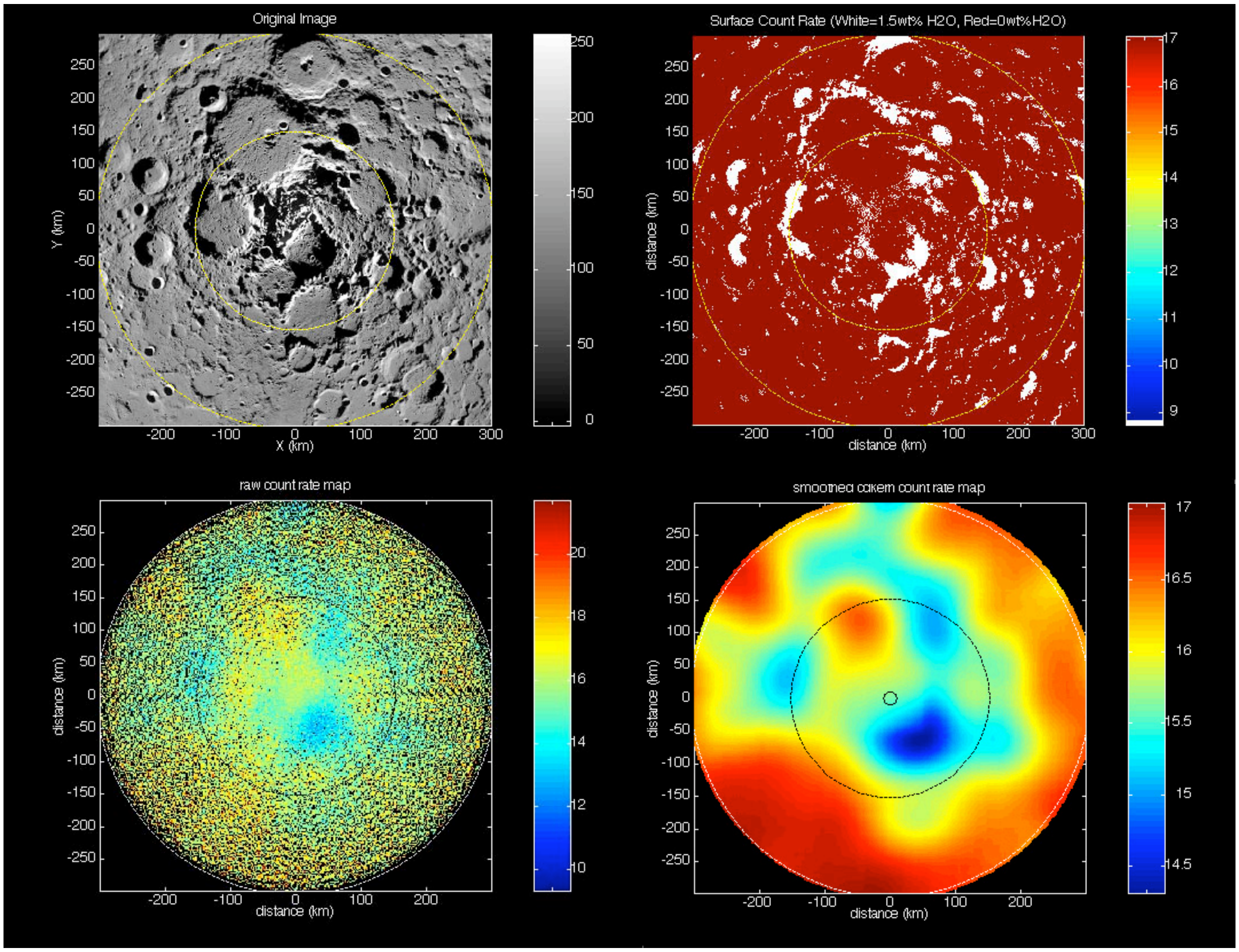
Original Image
Y (km)
X (km)
Surface Count Rate (White=1.5wt% H2O, Red=0wt%H2O)
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raw count rate map
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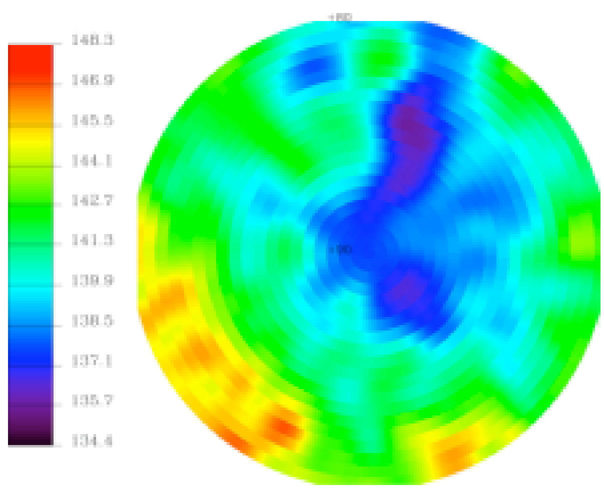
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