NUMERICAL EXOSPHERIC SIMULATION OF WATER DELIVERY TO THE LUNAR POLAR REGIONS

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Introduction

Cabeus crater, and other low lying areas near the southern pole of the Moon are known to be permanently shadowed regions (PSRs) [1,2] where water ice can be trapped. These PSRs receive no direct solar radiation and thus fall over 60 K below water's volatility threshold [3]. Signals of water ice near the lunar poles have been observed through neutron spectroscopy [4,5,6]. Reflectivity of Lyman-alpha [7] and ultraviolet albedo spectra [8] have also been observed by the Lunar Reconnaissance Orbiter (LRO) and the Crater Observation and Sensing Satellite (LCROSS) found evidence of sub-surface ice in Cabeus crater in its analysis of the ejected plume of material [9]. Recently, it has been proposed that the offset between the observed neutron enhancements from the north and south poles of the Moon are due to True Polar Wander (TPW) [10]. This would imply that the subsurface ices of Cabeus crater are several Ga old and that new delivery of ice to polar PSRs is relatively insignificant. However, Moores [11] showed that the cold temperatures of the poles create potential energy barriers for incoming particles which in turn allow lower latitude craters to have higher concentrations than their poleward neighbours: a process comparable to rain shadows [11] observed for terrestrial precipitation. The purpose of this project is to come to a better understanding of why the lunar poles look the way they do, in terms of icy deposits.

Method & Results

This effect was further explored using a combination of numerical models of ballistic transport of water vapour on the present-day lunar surface including both a validated Monte Carlo model [11] and a full lunar exospheric model [12] which had not previously been explored pole-ward of 85ºS or 80ºN. Compared to its southern counterpart, the northern lunar pole has less trapping area due to its higher average topographical height. To compensate for this, I chose to include PSRs up to 10º from the pole. As shown in Figure 1, for the full exospheric model, all southern PSRs accumulated fractional concentrations of water ice compared to Cabeus similar to those reported previously [11]. Though, Figure 2 shows crater concentration values are dominated by their distance from the poles rather than trapping efficiency of their neighbours.

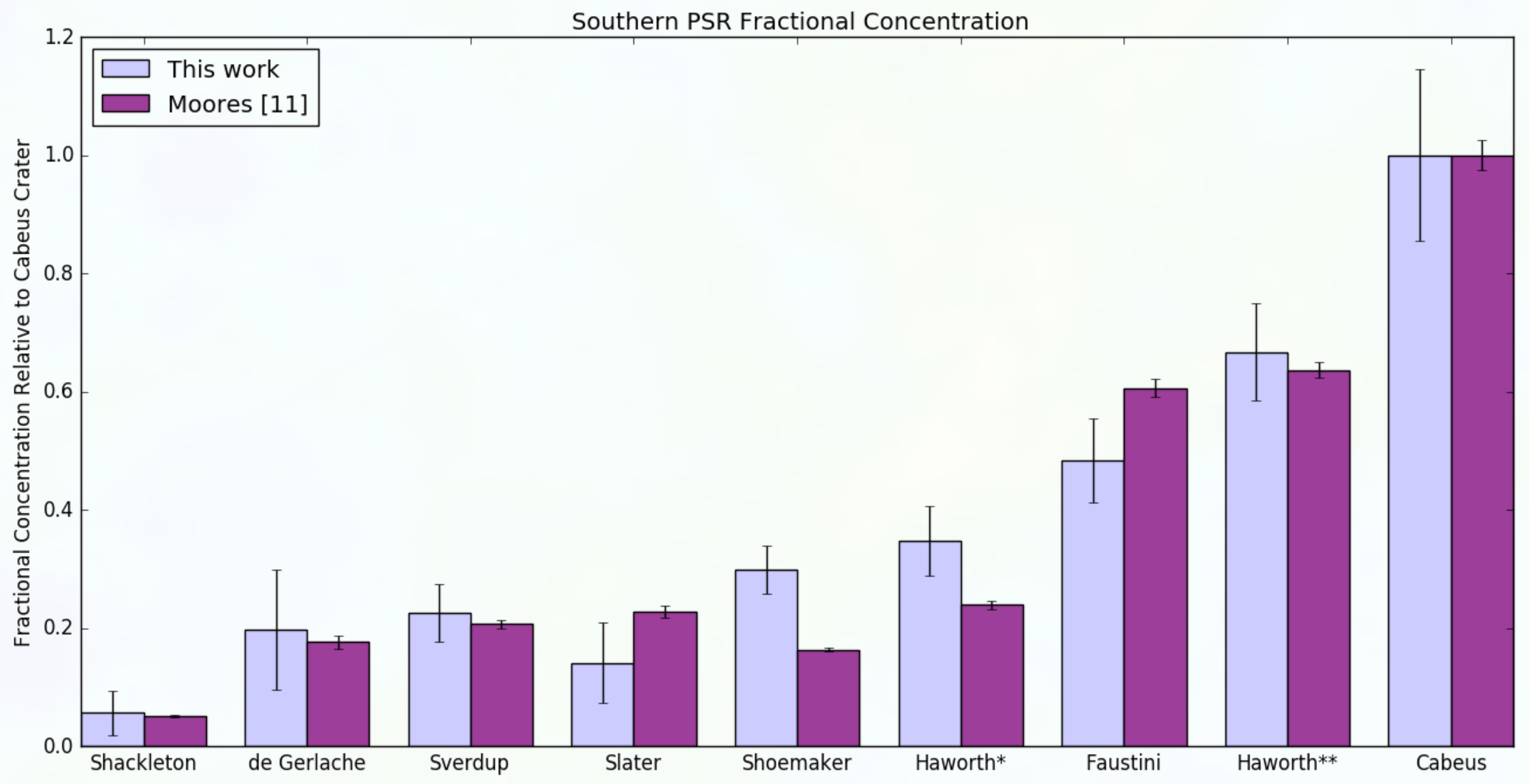

*Figure 1. Model-predicted thickness of water ice deposits relative to Cabeus crater. Traps are organized by distance from the South pole: Shackleton residing at 0.4° from pole and Cabeus being 5.5° away. Each PSR's fractional concentration is found by taking the number of particles trapped and dividing by the area of the respective trap. The concentrations are then scaled about Cabeus by being divided by its concentration. Cabeus shows the highest fractional concentration at 1, as craters farther poleward have smaller fractional concentrations. This work is compared to the results from [11]. * Crater, ** Lowlands*

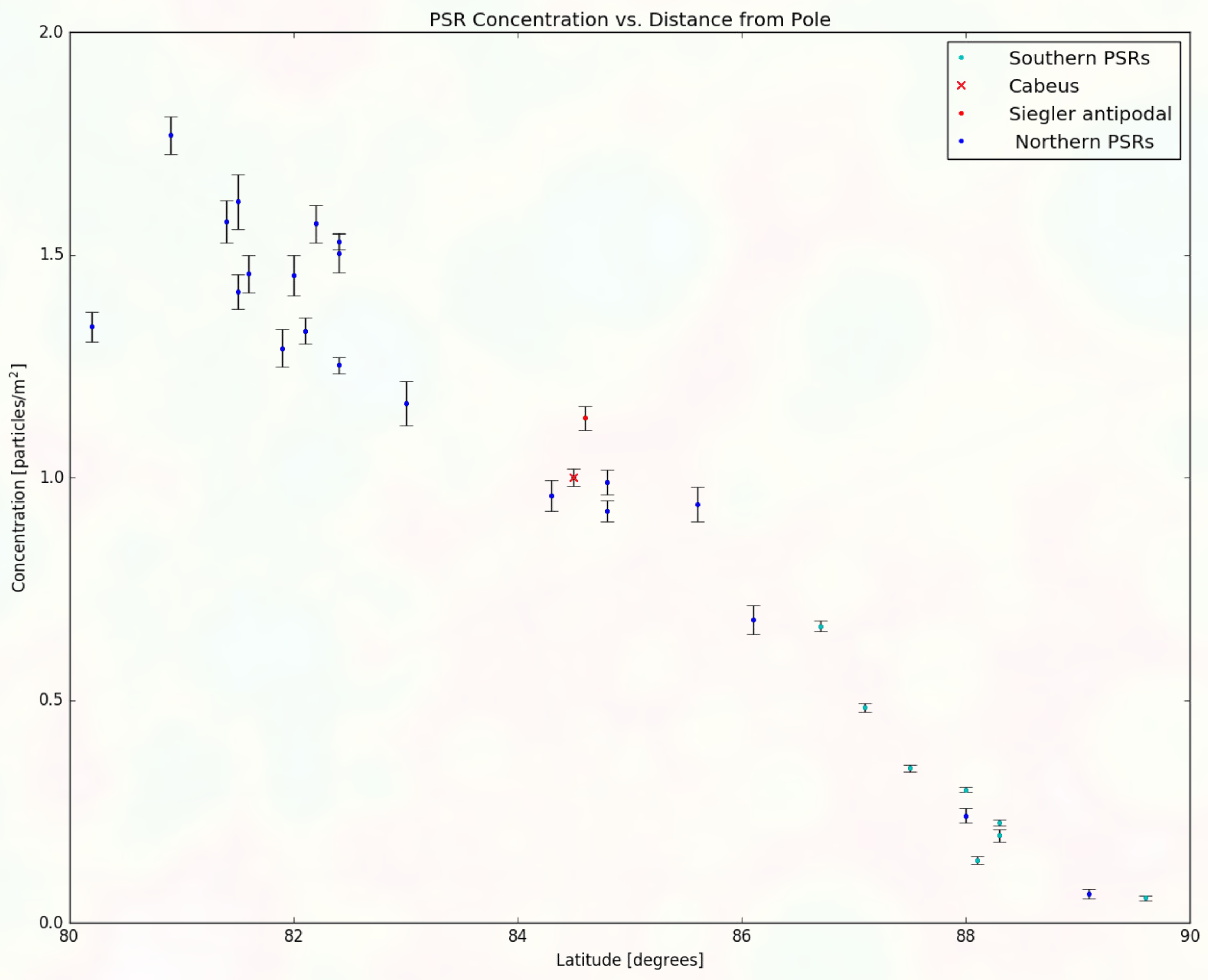

Figure 2. Ice water thickness of all PSRs relative to Cabeus crater. Concentrations are plotted against absolute latitude in order to discern the dependence on distance from the poles. The linear correlation between the concentration of trapped particles and the position of the involved crater seems to be present. Error bars represent 95% confidence intervals. As stated by [10], Cabeus and its northern counter part have similar concentrations of 1.00 ± 0.02 and 1.13 ± 0.03. The relatively high concentrations of craters beyond Cabeus is expected — as particles in this area have smaller residence times and an easier time arriving to these locations — even though we do not see hydrogen signals of this magnitude from these areas of the Moon today.

Discussion & Conclusion

The confidence intervals reported for this work are larger compared to the work by Moores [11] due to the differences in simulation method. As opposed to this previous method [11], the full exospheric model simulates all particles simultaneously stepping the entire exosphere forward in time evenly. With additional simulation time, these intervals are expected to shrink and be comparable to Moores' results [11].

This work simultaneously supports the hypothesis that diffusive water migration in an exosphere is a viable process for water collection in the Moon's PSRs and can generate an offset water distribution in the modern era and the fact that the two antipodal regions discussed in TPW theory [10] exhibit similar concentrations. Currently, there is no apparent potential boundary phenomenon causing pole-side craters to have lower concentrations, as hypothesized by Moores [11]. The antipodal regions not linked as previously suggested, rather both regions contain a large PSR whose antipodal parallelisms are coincidence. This work has revealed that the exospheric model yields a linear relationship between trapping efficiency and distance from the poles. The high concentrations in PSRs south of 85ºN are relics of the simulation method. The code does not take into consideration any seasonal fluctuations in rotation, reflections of light into PSRs or ice stability depth.

References

[1] Watson, K., B. C. Murray, and H. Brown, 1961a, J. Geophys. Res., 66(5), 1598–1600. [2] Watson, K., B. C. Murray, and H. Brown, 1961b, J. Geophys. Res., 66(9), 3033–3045. [3] Paige, D. A., et al., 2010, Science, 330, 479–482. [4] Feldman, W. C., et al., 1998, Science, 281(5382), 1496–1500. [5] Mitrofanov, I., et al., 2010, Science, 330(6003), 483–486. [6] Mitrofanov, I., et al., 2012, J. Lunar and Planetary Science XLVIII (2017) 2144.pdf Geophys. Res., 117, E00H27. [7] Gladstone, G. R., et al., 2012, J. Geophys. Res., 117 E00H04. [8] Hayne, P. O., et al., 2015, Icarus, 255, 58 - 69. [9] Colaprete, A., et al., 2010, Science, 330, 463–468. [10] Siegler, M. A., et al., 2016, Nature, 531, 480 -484. [11] Moores, J. E., 2016, J. Geophys. Res. Planets, 121, 46–60. [12] Schorghofer, N., et al., 2016, Geophys. Res. Lett., 43, 6783–6789.