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The evolution of water ice reservoir in lunar polar regions

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In the permanently shadowed regions of lunar polar craters, there may exist significant reserves of water ice in the porous lunar regolith (1,2), offering the potential for scalable extraction to address the water supply bottleneck for lunar bases. However, there currently are only some indirect measurements of ice content on shallow surface layer. The scale and spatial distribution of water ice underneath the lunar surface are still largely unknown.

Here we study evolution of water ice in the permanently shadowed regions at geological time scale (~billion years). We establish a three-dimensional simplified model based on the assumption of quasi-steady-state heat and mass transfer in presence of rarefied vapor crystallization and ice vaporization. After modifying earlier approaches on dispersed fluid/cluster evolution in porous media (3), we propose diffusion and phase change equations suitable for extreme environment for ice and water vapor in lunar polar shadowed regions.

Accordingly, we are able to elucidate the dynamics of water ice accumulation & escape in polar lunar craters at geological time scale, and then estimate the scale of ice reservoirs within these specific areas. We also investigate the impact of possible sources of water ice within permanently shadowed regions: a) ice crystals brought by incoming meteorite impacts, and b) water vapor migration from low-latitude regions to high-latitude regions on the lunar surface (4, 5). We further provide projections for the distribution of water ice over a billion-year timescale, which may help the selection of water recovery sites in future lunar missions.

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