Secondary Volcanically-Induced Lunar Atmosphere and Lunar Volatiles: 3-D Modeling and Analysis

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The fact that the Moon could have a transient secondary atmosphere due to volcanic outgassing has been known for some time, though typically such an atmosphere was believed to be extremely thin (~10⁻⁸ bar) [1]. But recent research by Needham and Kring (NK) [2] suggests that during the peak of volcanic activity ~3.5 Ga such a volcanically-outgassed atmosphere could reach ~10⁻² bar of surface pressure. In similar research Wilson et al. [3] proposed a more conservative estimate, arguing that the thickness of such an atmosphere would depend on the intervals between major eruptions and may not exceed microbar densities. In either case a collisional atmosphere could be present, which would control transport of outgassed volatiles (such as H₂O) and their deposition in polar regions, where they could be preserved until modern day frozen in permanently shadowed regions (PSR) or buried beneath the regolith.

Here we study such a hypothetical atmosphere to investigate its stability, meteorological properties and the effect on transport of volatiles. We use the ROCKE-3D planetary 3-D General Circulation Model (GCM)[4]. The insolation and orbital parameters were set to conditions 3.5 Ga. The atmospheric composition, based on the list of outgassed species presented by NK in combination with our estimates for atmospheric escape, condensation and the results from our 1-D chemistry model, was chosen to be either CO-dominated or CO₂-dominated (depending on atmospheric temperature). In this study we restricted ourselves to relatively "thick" lunar atmospheres of 1-10 mb, though we believe that our results will scale to thinner atmospheres as well.

We present the results for ground and atmospheric temperature for modeled atmospheres over a wide parameter space. In particular we consider different atmospheric compositions (CO or CO₂ dominated), a set of atmospheric pressures from 1 mb to 10 mb and a set of obliquities from 0° to 40°. We also present an experiment of a single major eruption [5] and show that in just 3 years
~80% of the outgassed water is deposited in polar regions. This demonstrates the efficiency of such an atmosphere in delivering volatiles. We argue that a secondary lunar atmosphere could play a significant role in forming volatile deposits currently observed in the polar regions of the Moon.

References: