Comets as a source of lunar volatiles: tracking water from impact to permanent shadows

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Abstract. Over the years, several missions have detected signs of water and other volatiles in cold, permanently shadowed craters near the lunar poles. Observations suggest that some of these volatiles could have been delivered by comet impacts, and therefore, understanding the impact delivery mechanism becomes key to explaining the origin and distribution of lunar water. During impact, the ices that constitute a cometary nucleus vaporize. A significant part of this vapor remains gravitationally bound to the Moon, transforming the tenuous lunar exosphere into a transient atmosphere. We use numerical simulations to investigate the physical processes governing volatile transport in the transient atmosphere generated after a comet impact, with a focus on how these processes influence the accumulation of water in polar cold traps.

It is observed that the transient atmosphere maintains a certain characteristic structure for several days after impact, during which time volatile transport occurs primarily through low-altitude winds that sweep over the lunar day-side. Meanwhile, reconvergence of vapor antipodal to the point of impact results in preferential redistribution of water in the vicinity of the antipode. The sheer quantity of vapor that remains gravitationally bound can result in an atmosphere that is sufficiently dense that lower layers are shielded from photodestruction, prolonging the lifetime of water molecules and allowing greater amounts of water to reach cold traps. Short-term ice deposition patterns are markedly non-uniform and the variations that arise in simulated volatile abundance between different cold traps could potentially explain the variations observed through remote sensing.