Title of Submission: Freezing behaviour of water droplets at the liquid-vacuum interface relevant to plume-forming regions on Enceladus

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Plain Language Summary: Pure water and saline droplets were injected into low pressure conditions to develop an understanding of the effects of pressure and salinity on the freezing time of droplets under Enceladus plume conditions. With high-speed videography and laser doppler velocimetry, we simulate the formation and behaviour of the precursor salty liquid droplets that undergo freezing within the vents supplying the plume.

Abstract

Salt-rich ice grains entrained within the plume at Saturn's moon Enceladus emanate from cracks in the ice shell, via conduits/vents that transport subsurface ocean material to the surface, where accessible to spacecraft. Likely to originate as dispersed ocean spray droplets representative of source liquid reservoir composition, expelled grains can be used as a tool to elucidate the chemistry and habitability of the otherwise inaccessible subsurface. However, the effects of rapid temperature and pressure changes on the freezing times of ice grains during eruption, which are vital in determining how ocean salts are transferred into observed plume particles, remain unknown. We aim to characterise freezing times of the precursor salty liquid droplets within the vents supplying the plume under predicted vent conditions, between the liquid ocean and vacuum interface (≤ 6 mBar). In addition, we aim to observe droplet behaviour during the freezing process to explore fragmentation that could link to variation in salt-rich grain compositions.

Through novel experiments conducted at Aarhus University, we employed their planetary simulation chamber to inject pure water and NaCl droplets into low-pressure (0.2 – 6 mBar) conditions. Specifically, we studied the effect of pressure and salt concentration on freezing time, using high-speed videography and laser doppler velocimetry, with future work aiming to explore parameters affecting composition within simulated plume ice grains. Experimental techniques refined here are crucial for interpreting solid plume fallout and understanding plume material formation processes at Enceladus and other cryovolcanically active bodies.