

**BAYESIAN CONSTRAINTS ON THE OUTGASSING PARAMETERS OF ENCELADUS PLUMES USING DSMC SIMULATIONS.** A. Mahieux<sup>1,2,3</sup>, D. B. Goldstein<sup>1</sup>, P. V. Varghese<sup>1</sup> and L. M. Trafton<sup>4</sup>, <sup>1</sup> The University of Texas at Austin, Department of Aerospace Engineering and Engineering Mechanics, Austin, Texas (arnaud.mahieux@utexas.edu), <sup>2</sup> Belgian Institute for Space Aeronomy, Brussels, Belgium, <sup>3</sup> Fonds National de la Recherche Scientifique, Brussels, Belgium, <sup>4</sup> The University of Texas at Austin, Department of Astronomy, Austin, Texas.

**Introduction:** The two-phase water plumes arising from the Enceladus South pole and extending up to hundreds of km from the moon are a key signature of what lies below the surface. Multiple Cassini instruments measured the gas-particle plume over the warm Tiger Stripe region during several close flybys, and a lot of work has been put into constraining the vent and flow characteristics, such the vent positions and orientations, the mass flows, speeds and temperatures [1-7]. Numerous observations also exist of the near-vent regions in the VIS and IR.

The most likely source for these extensive geysers is a subsurface liquid reservoir of somewhat saline water and other volatiles boiling off through crevasse-like conduits into the vacuum of space [2, 8]. The plumes thus provide a window for understanding Enceladus' subsurface composition and geysering.

**Close-field solution:** We used a DSMC code [3] to simulate the plume, as it exits a vent, under axisymmetric conditions, in a vertical domain extending up to 10 km [9], where the flows become collisionless, as depicted in Figure 1. We performed a DSMC parametric study of the flow parameters (number density, velocity and temperature) considering the following eight parameters: vent diameter, outgassed flow density, water vapor/ice mass ratio, gas and ice speed, ice grain diameter, temperature and vent exit angle.

We constructed parametric expressions for the plume characteristics – number density, temperature, velocity components – using simple analytic expressions to depict the constrained surfaces of these parameter values, at the 10 km upper boundary.

**Far-field solution:** We use these parametrizations to propagate the plumes to higher altitudes – up to thousands of km, assuming free-molecular conditions. The density field at higher altitude is determined from the parametrizations described above, and explicit analytical expressions for the various force fields that the plumes are experiencing: Enceladus and Saturn gravity fields, Coriolis and centripetal accelerations due to Enceladus rotation.

This enables very rapid numerical computations – ~10 minutes – and tabulations of the density and velocity fields in space. An example of density fields for the E7 CASSINI observation, based on the fit of the

INMS in-situ measurements, considering the 8 vent configuration described in Porco et al. (2007), is in Figure 2.

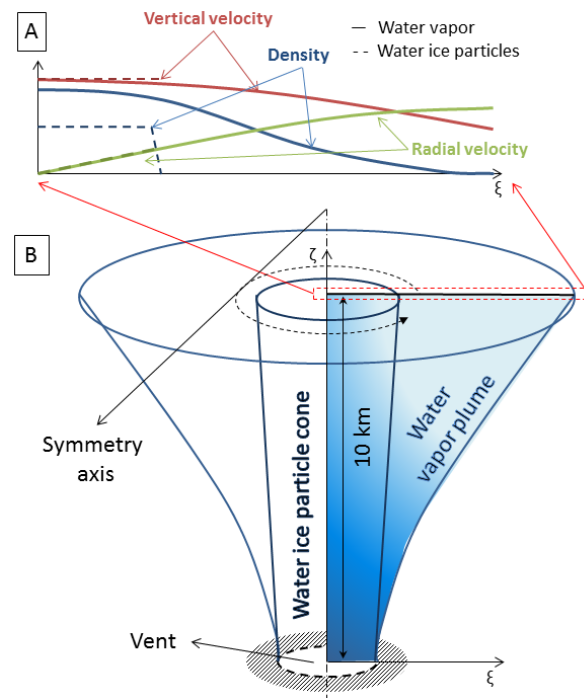


Figure 1: Panel A: Sketch of the number density, vertical and radial velocity radial profiles as a function of radial distance for water vapor (solid) and water ice particles (dashed) at 10 km of altitude. Panel B: Representation of the flow based on the DSMC calculation assuming cylindrical symmetry with respect to the central axis. The water ice particles form a cone that remains close to the symmetry axis whereas water vapor extends to much larger distances at 10 km.

**Sensitivity analysis:** We then present a formal Monte Carlo sensitivity analysis [10] of twelve vent parameters – vent diameter, outgassed flow density, water gas/ice mass flow ratio, gas and ice speed, ice grain diameter, vent exit angle, latitude, longitude, azimuth and zenith angles of the venting direction – conditioned on the number density field measured by the INMS instrument, considering the 98-vent geometry reported in [2]. The sensitivity analysis is used to

determine which vent parameters should be considered for a subsequent fit of the INMS observation.

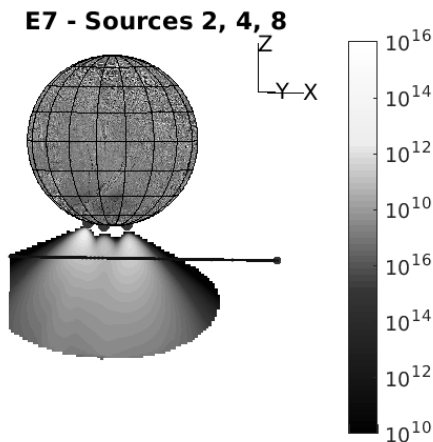


Figure 2: Example of density fields calculated using our parametrization. The spacecraft trajectory is depicted by the black line, flying right to left in the figure. Three out of the eight vents are supposed to be active during this flyby. The gray-scale bar gives the local density, and the surface depicts the density along a plane encompassing CASSINI's trajectory and the Enceladus South Pole.

**Bayesian inversion:** We present an advanced way to constrain the vent parameters by performing a Monte Carlo Bayesian inversion [11] that returns probability values for the preselected vent parameters, considering a few INMS observations.

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