REMOTE AND IN SITU OBSERVATION OF PLUMES FROM SPACECRAFT ON AIRLESS BODIES SUCH AS EUROPA, ENCELADUS, OR IO. WHAT CAN WE LEARN ABOUT THE GROUND CONDITIONS BY USING DSMC SIMULATIONS? A. Mahieux[1,2], D. B. Goldstein[1], P. V. Varghese[1] and L. M. Trafton[3], [1] The University of Texas at Austin, Department of Aerospace Engineering and Engineering Mechanics, Austin, Texas (arnaud.mahieux@utexas.edu), [2] Belgian Institute for Space Aeronomy, Brussels, Belgium, [3] The University of Texas at Austin, Department of Astronomy, Austin, Texas.

Introduction: We address this topic by focusing on the Enceladus plume observations made by Cassini INMS and UVIS instruments.

The two-phase water vapor/ice grain plumes venting from the Enceladus South Pole up to hundreds of km above the surface are a key signature of what lies below the surface. Multiple Cassini instruments measured the gas-particle plumes during several close flybys, and a lot of work has been put into constraining the vent and flow characteristics, such as 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].

Near-field solution: We used a DSMC code [3] to simulate the plume as it exits the vent, under axisymmetric conditions, in a vertical axisymmetric domain extending up to 10 km [9], where the flows become collisionless. We performed a DSMC parametric study of the flow properties at 10 km, focusing on the number density, velocity and temperature, and considering eight vent 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 properties – number density, temperature, velocity components – as a function of the distance from the symmetry axis, using simple analytic expressions at the 10 km upper boundary.

Far-field solution: We then use these parametrizations to propagate the plumes to higher altitudes – up to thousands of km – assuming free-molecular expansion. The density field at higher altitudes is determined from the parametrizations described above, and explicit analytical expressions for the various force fields that the plumes are experiencing. This enables rapid numerical computation (0.2 s) and tabulation of the spatial density field for each plume.

Grouping plumes: For a given observation geometry, some plumes have a very similar contribution (highly correlated) to the measured profile along the spacecraft trajectory. Such plumes are grouped together to reduce the size of the free parameter space and avoid redundant contributions that cannot be deciphered.

Sensitivity analysis: We then performed a formal Monte Carlo sensitivity analysis of twelve vent parameters – those listed above plus vent latitude and longitude, and azimuth and zenith angles of the venting direction – constrained by the number density field measured by the INMS instrument and the vent geometry reported in [2]. The sensitivity analysis is used to determine which vent parameters of the groups defined in the previous paragraph should be considered for a subsequent fit to the INMS observation.

Markov Chain Monte Carlo (MCMC): We present an advanced way to constrain the vent parameters by performing an MCMC parametric inversion [10] that returns probability values for the set of preselected vent parameters, and apply this method to several INMS observations. This approach allows us to constrain many vent parameters, and return probability distribution for each of them. An example of a probability distribution is given in Figure 1 for the mass flux fit for a single vent, during the INMS E7 observation. The MCMC approach produces corresponding distributions for all the sensitive vent parameters revealed by the Monte Carlo sensitivity analysis. That is, we not only obtain a "best fit" value for a particular parameter, but we also obtain a probability distribution for that parameter. We believe a more complete understanding is crucial to planning for future observations.

Results: We will present and discuss the results we obtained for INMS observation E3, E5, E7, E14, E17, and E18, for the UVIS solar occultation.

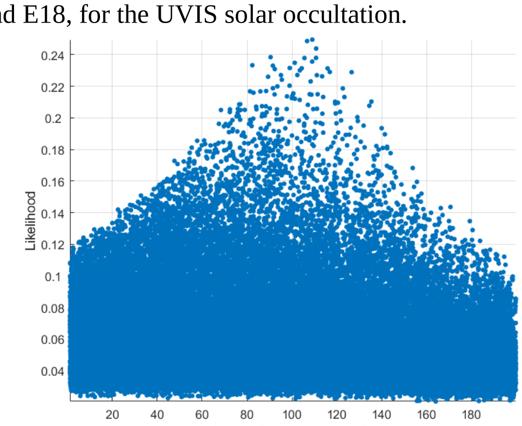

Figure 1: Example of probability distribution for the fit of the water vapor mass flux of vent #4 during the INMS E7 fly-by.

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