Three dimensional modelling of the dynamics of Io's atmosphere.

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Introduction: Io is the innermost galilean satellite of Jupiter and subject to extreme tidal forces. As a result of these forces Io is the most volcanically active body in our solar system. Different volcanic features can be found all over Io's surface. For example volcanic plumes can rise up to several hundred kilometers above the surface and are a known partial source of Io's SO_2 atmosphere. Additionally, the surface of the moon is covered with frost which sublimates in sunlight and condenses during the night or when Io enters eclipse behind Jupiter. Therefore, Io's atmosphere is a result of the combination of volcanism and sublimation, but it is unknown exactly how these processes work together to maintain the observed atmosphere [1]. This has motivated us to investigate an approach to modelling Io's atmosphere and hence provide a better understanding of the ongoing dynamic processes. We want to study the influence and contribution of different processes or even single parameters on each other and the whole atmosphere by developing a simple model which is easy to modify and returns fast results.

Methods: Both, the gas flow of volcanic plumes and the sublimation atmosphere, are modelled using the Direct Simulation Monte Carlo (DSMC) method first utilized by G. A. Bird [2]. Therefore, we are using the ultraSPARTS DSMC code by Plasma T.I. The DSMC method is the most suitable for our case since the gas dynamics can be modelled over a broad range of gas densities which is especially important for rarefied gas flows at high altitudes and on the night side of Io. It is a particle-based numerical method which returns a 3D gas flow field as a result. For this result a three dimensional spatial domain is decomposed into cells. Within each cell particles are simulated and their properties are sampled while they move and collide. Moreover, different conditions are set for the boundaries of the domain, such as reflecting walls, vacuum outlet, inlet boundary, etc. Currently we are mainly working on studies with sulfur dioxide as the main species in single species simulations while in some cases we are adding oxygen as a non-condensable second species. Our DSMC code is designed to support multiple species enabling us to study the gas emission of other volcanic features such as, for example, lava lakes. Additionally, we can account for the heating of the atmosphere by plasma bombardment. For this case we are adding incoming particles from the outer boundary of our simulation domain which adds energy to the system. The idea of our work is based on former plume simulations [3], atmospheric simulations [4] and studies of plasma heating [5].

In a second step we are able to insert dust particles into our model. For the computation of the dust flow field we are using the DRAG3D code originally developed for cometary research [6],[7] which is based on a fourth order Runge Kutta method. The movement of the dust particles is calculated from the 3D gas flow field result. In this process we can set a certain range of dust sizes, a dust to gas ratio, a scattering model and a dust size distribution law.

Results: We will present simulation results of different scenarios and combinations of a sublimation atmosphere, volcanic features and plasma heating. Also, we will be able to take a closer look at the interaction of those processes and their influence on the global column density distribution. For instance, figure 2 shows an example of the temperature profile of a slice through a half spherical domain containing a uniform sublimation atmosphere, a volcanic plume structure in the middle and the influence of plasma heating coming from the top (figure 1 shows a schematic of the approach). By varying different factors, we can perform parameter studies of the single processes or their interactions with each other. Our final goal is to gain a better understanding of the plume structure, the interaction with the ambient atmosphere, and the overall contribution of different processes to Io's atmosphere in preparation for future missions such as JUICE, Europa Clipper and a possible future Io Volcano Observer.

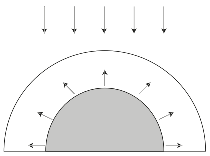

Fig. 1

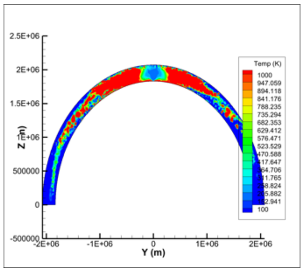

Fig. 2

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