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Numerical simulations of cryolava flows at the surface of Titan

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Titan, Saturn's largest moon, is one of the most interesting objects of our Solar System. Among other things, Titan possesses a dense atmosphere that harbours a complex organic chemistry; hydrocarbon seas are present in polar regions, and it's subsurface contains a liquid water ocean. Although Cassini-Huygens mission has led to major advances in our understanding of Titan, several major scientific questions still have no clear answers. For instance, the methane destruction rate by photodissociation [Galand et al., 2010] implies an atmosphere replenishment through a mechanism which is not known. Another important open question, linked to astrobiology, is the possible interaction between liquid water and organic material [Neish et al., 2018, Hedgepeth et al., 2022].

Several clues, such as the abundance of radiogenic argon (40Ar) in the atmosphere, suggest exchanges between the subsurface and the exterior [Niemann et al., 2010], and thus open the door to a possible filling of methane through these exchanges. Several scenarii have been proposed to support a methane release, including the destabilisation of methane clathrate hydrate, and its transport to the surface by cryovolcanism [Davies et al., 2016].

Even if there is currently no firm evidence of an active cryovolcanism on Titan, we have still a few candidates cryovolcanoes, identified using morphological criteria [Lopes et al., 2013]. Concerning impact craters, which could have produced important cryolava flows [Neish et al., 2014, Hedgepeth et al., 2020] leading to possible interaction between "hot water" and surface organic material [Neish et al., 2018], a set a ~90 of such craters have been detected [Hedgepeth et al., 2020].

Many numerical simulations have been carried out to understand the behaviour of lava flows on Earth. These simulations were used in the context of habitat risk assessment. Even if the first Computational Fluid Dynamics (CFD) simulations were performed using the finite elements method, another approach is getting more and more popular: the Smoothed-Particle Hydrodynamics (SPH) [Prakash et al., 2011]. This Lagrangian and meshless method [Gingold et al., 1977; Lucy, 1977] has several advantages and it is particularly suited to fluid flows including a free surface. The work to be presented consists of a series of numerical simulations, based on this method. With our computations, we address the spatial extension and the thermal behaviour of cryolava flows relevant to Titan's impact craters or cryovolcanoes. We explore several scenarii according to which we study the influence of parameters governing the properties of these lava flows.

Our project is particularly relevant for the Dragonfly mission [Lorenz et al., 2018], which is expected to explore the Selk crater region in the 2030s. Extensions of our work could also be applied to the volcanism of Europa and thus be relevant for the Europa Clipper and Juice missions.

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