Geophysical Research Abstracts
Vol. 20, EGU2018-10128, 2018
EGU General Assembly 2018

Transfer of heat and water through the high-pressure ice layers of Ganymede and Titan

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We study dynamics of the high-pressure (HP) ice layers of Ganymede and Titan by solving the conservation equations of mass, momentum, and energy of a two-phase mixture in 2D geometry. We investigate the possibility to generate liquid water at the interface with the silicate core and we also study the subsequent fate of meltwater. Our results indicate that melt can be produced at the silicate/HP ice interface if the layer is not too thick ($H \lesssim 200$ km) and ice viscosity not too small ($\mu \gtrsim 10^{15}$ Pa s). If generated, meltwater is then transported through the convecting layer by the upwelling plumes. Depending on the vigor of convection, it may stay liquid or freeze before melting again as the plume reaches the partially molten layer at the interface with the ocean. The thickness of this layer as well as the amount of melt that is extracted is controlled by the ice permeability. This process may enable the transfer of volatiles and salts that might have been leached from silicates by percolating meltwater. Our results suggest that this exchange process is operating in thinner HP ice layers and therefore, in the case of Ganymede, was more likely earlier in Ganymede's history before its HP ice layer thickened and became impermeable for liquid water transport. On the other hand, in the case of Titan, for which the current estimates of its HP ice layer thickness are a few hundreds of kilometers less than those of Ganymede, the exchange processes between the silicate core and the deep ocean may be ongoing. To first order, such a thin permeable HP ice layer may explain the atmospheric abundance of ^{40}Ar, which comes from the decay of ^{40}K most likely present in the silicate core. Moreover, if silicates are being hydrated at the interface between the HP ice layer and the silicate core, then H_2 produced by this reaction could be easily transported to the ocean. The reaction of H_2 with C-bearing molecules would eventually form methane, making the process described in this study a key component of the methane cycle on Titan.