GENERATION OF TOPOGRAPHIC WAVES AT AN ICE-AIR INTERFACE BY SUBLIMATION IN A TURBULENT STEADY FLOW

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The surface shape of glaciers is controlled by various processes, which include ice accumulation, ice ablation and ice deformation. In specific environments, where the partial pressure of water in the atmosphere is low, sublimation significantly contributes to ablation and, as such, takes a part in the development of surface landforms on glaciers. For example, complex interactions between sublimation-related mass transfers and turbulent flow in the lower-atmosphere lead to the development of stunning spiral-shaped topographic waves at the surface of the North Polar cap of Mars. Interpretations of topographic data, optical images, spectroscopic data and stratigraphic radar soundings reveal that periodic spatial variations in sublimation-related ablation rates are responsible for the development of these topographic waves [1, 2]. To explore the role of sublimation in the development of such wavy patterns, we have conducted experiments in an atmospheric wind-tunnel using dry ice as a sublimating material. The growth of a small-amplitude wave into a ripple pattern has been observed experimentally under terrestrial conditions. In the present work, in order to identify the relevant dynamical mechanisms controlling the mass and energy balance, we apply a linear stability analysis on the coupled ice-airflow interface under turbulent flow conditions. We first solve the flow dynamics in response to rippled ice surface using numerical techniques analogous to those used in sand-wave models [3]: because the topographic evolution is slow compared to the relevant time-scales of the atmospheric turbulent flow, we can use the Reynolds-averaged Navier-Stokes equations (RANS) with a Prandtl-like closure in addition to the continuity equation of flow. We employ an exponential damping of the Prandtl mixing length described by the Van Driest formula in the vicinity of a smooth surface. We then use the transport/diffusion equation of vapor and the surface energy balance. An analogy between momentum and mass transfer is explored as a means for evaluating the turbulent diffusion terms. Wave induced variations of the normal convective flow combined with the properties of turbulence induces a periodic variation of the transfer. We evaluate the phase of the spatial variation of the sublimation rate to determine the evolution of the ice surface and the amplification or damping of the initial ice-ripple perturbation.

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References

[1] Herny, C., Massé, M, Bourgeois, O, Carpy, S., Le Mouélic, S., Appéré, T., Smith, I.B., Spiga, A., and Rodriguez, S.: *Sedimentation waves on the Martian North Polar Cap: Analogy with megadunes in Antarctica*, Earth and Planetary Sciences Letters, **Vol 403**, pp. 56-66, (2014).

[2] Smith, I.B., Holt, J.W., Spiga, A., Howard, A.D., and Parker, G.: *The spiral troughs of Mars as cyclic steps,* Journal of Geophysical Research (Planets), **118 (9),** pp. 1835-1857 (2013).

[3] Charru F., Andreotti B. and Claudin P.: *Sand Ripples and Dunes,* Annu. Rew. Fluid Mech., **45,** pp. 469-493 (2013).