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Katabatic jumps over Martian polar terrains

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Recent observational and modeling studies have shed light on the key role of mesoscale phenomena in driving the Martian climate and giving rise to remarkable signatures in the temperature, wind, pressure, and aerosol fields of the Martian atmosphere. At the mesoscale, Mars appears as an intense and exotic counterpart to the Earth, mainly as a result of pronounced diurnal and regional contrasts of surface temperature, and the much thinner atmosphere.

While observations of clear-cut katabatic events are difficult on Earth, except over vast ice sheets, those intense downslope circulations are widespread on Mars owing to near-surface radiative cooling and uneven topography. Their intensity and regularity can be witnessed through numerous aeolian signatures on the surface, and distinctive thermal signatures in the steepest craters and volcanoes.

Several observations (radar observations, frost streaks, spectral analysis of ices, ...) concur to show that aeolian processes play a key role in glacial processes in Martian polar regions over geological timescales. A spectacular manifestation of this resides in elongated clouds that forms at the bottom of polar spiral troughs, which dominates the polar landscape both in the North and South. An analogy with the terrestrial "wall-of-snow" over e.g. Antarctica slopes or coastlines posits that those clouds are caused by local katabatic jumps, also named Loewe phenomena, which can be deemed similar to first order to hydraulic jumps in open channel flow.

With mesoscale modeling in polar regions using 5 nested domains operating a model downscaling from horizontal resolutions of about twenty kilometers to 200 meters, we were able 1. to predict the near-surface wind structure over the whole Martian polar caps, with interactions between katabatic acceleration, Coriolis deflection, transient phenomena, and thermally-forced circulations by the ice / bare soil contrast and 2. to show that katabatic jumps form at the bottom of polar troughs with an horizontal morphology similar to trough clouds, strong ascending motions at the jump reaching 1.5 m/s (a significantly large value in the stable polar atmosphere), and temperature perturbations propitious to cloud formation.

Mesoscale modeling suggests here that trough clouds are present manifestation of the ice migration that yielded the internal cap structure discovered by radar observations, as part of a "cyclic step" process. This has important implications for the stability and possible migration over geological timescales of water ice surface reservoirs.