DOWNSLOPE WINDSTORMS IN THE MARTIAN POLAR REGIONS: A SENSITIVITY STUDY.
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Introduction: When large-scale flow takes place over and across an obstacle (*e.g.*, a mountain range) or the flow over a plateau reaches a topographical (often steep) downward slope, strong downslope surface winds – attributed to the *shooting effect* or to *downslope windstorms* – are observed along the lee sides of the obstacles or of the topographical drops (see *e.g.* [1]). On Earth these downslope storm events are known with a number of regional names such as föhns, boras and chinooks depending on the region and whether the flow is typically colder or warmer than its surroundings.

The occurrence of a downslope windstorm is linked with a combination of subcriticality or criticality of a flow arriving at the obstacle or the slope edge, and subsequent supercriticality of the flow at the edge or further down the slope, and ensuing conversion of potential energy to kinetic energy[1]. In supercritical flow the local Froude number Fr > 1. The Froude number is defined as

$$\mathrm{Fr} = \frac{\bar{u}^2}{c^2} = \bar{u}^2 \frac{1}{gH} \frac{\rho_1}{\delta\rho},$$

where $\bar{u}$ is the mean flow speed, c the shallow-water wave speed, g the acceleration of gravity, H the mean height of the strongly stable near-surface layer and $\delta\rho_l/\rho$ the fractional change in density across the interface between the lower stable layer and the weakly stable layer above it.

Plausibility and indications of Martian downslope windstorms: Due to the spring- and summertime sublimation flows off of the polar caps and due to the steeply sloped topographical features in, *e.g.*, the Hellas and Argyre impact basins, the downslope windstorms are plausible in especially the southern polar regions of Mars. Recently this author and coworkers have used the Dep. of Meteorology / Univ. of Helsinki (DMUH) 2-D Mars Mesoscale Circulation Model (MMCM; for model features *see* [2] and [3] and references therein) to simulate combined ice cap edge and slope winds in idealized conditions corresponding to the Martian late winter season and the southern slopes of the Hellas and Argyre impact basins [4]. CO_2 ice coverage and subsequent low surface temperature on the plateau above the sloped region renders the near-surface flow arriving at the slope edge highly stable. The results of the simulations reported in [4] with southerly, downslope, large-scale flow (7 m/s, estimate derived from the NASA Ames Mars Global Circulation Model), indicate downslope wind component enhancement clearly exceeding the large-scale flow contribution and supercriticality of the flow above the sloped region (Fig. 1).

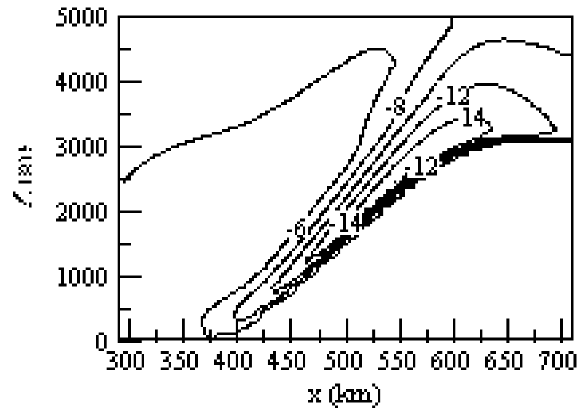

Fig. 1 The difference in the up-/downslope wind component u at approximately 1600 local time between simulations with no large-scale wind and with southerly (from the right) 7 m/s large-scale wind. The slope angle is 0.6° and the plateau on the right hand side is fully covered with CO_2 ice with the coverage fraction gradually decreasing to zero by $x = 350$ km.

Maximum wind speeds in the simulations exceed 30 m/s and surface stresses are of the order of 20 mN/m^2, *i.e.*, close to dust lifting threshold estimates. The windstorms may hence play a significant role in lifting dust – at least in the impact basin regions – since these regions are also known areas of dust lifting and dust storm activity [5].

Sensitivity study: In [4] the single, vertically constant large-scale wind of 7 m/s and fixed slope angle of 0.6° were used. In this work the sensitivity to large-scale flow and to slope angle have been investigated. The dust optical thickness has been set to $\tau = 0.3$, approximately corresponding to the Martian dust background. The season(s) and latitude(s) are chosen to be in line with the locations of the seasonal ice cap edge(s) and plausible sloped terrains in the polar regions.

Sublimation flow. Since the Froude number increases as the square of the mean flow speed, even relatively small increases in the flow speed may induce significant changes in the windstorm spatial and temporal patterns and characteristics. In this work simulations have been made using a set of vertically constant wind fields with varying magnitudes.

CO_2 sublimation flow off of the polar caps is particularly relevant special case of large-scale flow in the Martian polar regions. Since the source of the mass flow is the surface ice, the flow tends to be concentrated close to the surface. To simulate the specific influence of the sublimation flow on the windstorms, the DMUH MMCM provision for use of vertically varying large-scale flow structure – previously used in study of the sensitivity of the southern polar cap edge winds to the sublimation flow [3] – has been used. The sublimation flow vertical structure my trigger downslope windstorms even in conditions of generally quiescent large-scale winds at higher altitudes.

Slope angle. The slope angle value 0.6° used in [4] is a representative value derived from the DTM topography data set. According to the DTM even steeper slopes may occur in the Hellas basin; also, the topographies and slopes of the polar regions are – until the surface mapping by the Mars Global Surveyor's altimeter observations – so far known less than satisfactorily. To shed light in the correlation between the steepness of the slope and the characteristics of the windstorms, a number of simulations have been carried out using a set of reasonable slope angle values.

References:

[1] B. W. Atkinson (1981) Meso-scale Atmospheric Circulations. Academic Press, London. [2] H. Savijärvi and T. Siili, (1993) *J. Atm. Sci., 50*, 77-88. [3] T. Siili *et al.*, (1997) *Adv. Sp. Res., 19*, 1241-1244. [4] T. Siili *et al.* (1998) submitted to *Planet. Space Sci.* [5] R. A. Kahn *et al.*, (1992) pp. 1017-1053 in H. H. Kieffer *et al.* (Eds.), *Mars*. Univ. of Arizona Press, Tucson.