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Time-dependent solutions for daily-periodic slope flows driven by surface energy budget

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Diurnal wind systems generated from daytime heating and nighttime cooling of valleys and slopes are a very common feature over mountainous terrains. Despite their frequent occurrence and relevance for a variety of applications, ranging from pollutant transport to convection initiation, slope winds are far from being fully understood and still provide an open research topic.

A well-known steady-state analytical model is the one developed by Prandtl (1942). Then, a first time-dependent analytical model was proposed by F. Defant (1949) and later extended by Zardi and Serafin (2015). These models provide slope-normal profiles of temperature and along-slope wind velocity as a response to a sinusoidal forcing representing the surface temperature. The resulting profiles exhibit sinusoidal oscillations at every distance from the surface, although with different phase lags under different regimes, determined by different combinations of slope angle and stability of the unperturbed ambient atmosphere. As a consequence, they can not explain the observed differences between daytime upslope and nighttime downslope winds in terms of magnitude and height of the peak of wind velocity, as well as the different timing characterising nighttime, daytime, and the two reversal phases.

In the present work, the solutions derived in Zardi and Serafin (2015) are extended to include a more realistic daily-periodic surface forcing taking into account the daily evolution of the surface temperature computed on the basis of a surface energy budget. Incoming solar radiation is represented by means of a Fourier series expansion derived from well-established relationships taking into account latitude, day of the year, slope angle, exposition and other astronomical and atmospheric factors. Based on these expansions, suitable harmonic solutions are derived for the heat flux into the ground and sensible heat flux in the atmosphere, and hence for the daily evolution of slope-normal profiles of along-slope wind velocity and potential temperature.

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