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Signal processing and statistical descriptive reanalysis of steady state chute-flow experiments

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An accurate knowledge of snow rheology is needed for the mitigation against avalanche hazard. Indeed snow avalanches have a significant impact on the livelihoods and economies of alpine communities. To do so, 60 small-scale in-situ flow experiments were performed with various slopes, temperatures and flow depths. The investigation of these data previously seemed to show the dense flow of dry snow may be composed of two layers; a sheared basal layer made of single snow grains and a less sheared upper layer made of large aggregates. These outcomes were mainly based on the mean velocity profile of the flow and on interpretation in terms of rheological behavior of granular materials and snow microstructure [Pierre G. Rognon et al., 2007].

Here, the main objective remains the same, but the rheological and physical viewpoints are put aside to extract as much information contained in the data as possible various using signal processing methods and descriptive statistics methods as the maximum overlap discrete wavelet transform (MODWT), transfer entropy (TE) and maximum cross-correlation (MCC). Specifically, we aim at the improving the velocity estimations as function of the depth particularly the velocity fluctuations around the mean profile to better document the behavior of dense dry snow flows during a steady and uniform chute regime.

The data are composed of pairs of voltage signals (right and left), which makes that the velocity is known indirectly only. The MCC method is classically used to determine the time lag between both signals. Previously, the MCC method that showed the mean velocity profile may be fitted by a simple bilinear function [Pierre G. Rognon et al., 2007], but no interesting temporal dynamics could be highlighted.
Hence, a new process method was developed to provide velocity series with much better temporal resolution. The process is mainly made of a MODWT-based denoising method and the choice of window size for correlation. The results prove to be good enough in term of reasonable variability and measurement numbers.

A statistical descriptive analysis of the velocity results shows a disagreement with the previous outcomes. Indeed, the clustering method and the empirical probability distribution functions show that the vertical velocity profile may reflect three different behaviors, possibly corresponding to three layers and/or to transient flow layers. These flow layers are located at different heights depending on initial conditions of flow experiments (temperature, slope and depth).

Keywords: Maximum cross correlation, MODWT, probability distribution function