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Frontal Dynamics of Powder Snow Avalanches

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We model the dynamics of the head of dilute powder snow avalanches sustained by a massive frontal blow-out, arising as a weakly cohesive snow cover is fluidized by the very pore pressure gradients that the avalanche induces within the snow pack. Such material eruption just behind the front acts as a source of denser fluid thrust into a uniform ambient air flow at high Reynolds number. In such "eruption current", fluidization depth is inversely proportional to a bulk Richardson number representing avalanche height. By excluding situations in which the snow cover is not fluidized up to its free surface, we derive a criterion combining snow pack friction and density indicating which avalanches can produce a sustainable powder cloud. A mass balance involving snow cover and powder cloud sets avalanche height and mean density. By determining which solution of the mass balance is stable, we find that avalanches reach constant growth and acceleration rates for fixed slope and avalanche width. Under these conditions, we calculate the fraction of the fluidized cover that is actually scoured and blown-out into the cloud, and deduce from a momentum balance on the head that the avalanche accelerates at a rate only 14% of the gravitational component along the flow. We also calculate how far a powder cloud travels until its mean density becomes constant. Finally, we show that the dynamics of powder snow avalanches are crucially affected by the rate of change of their width, for example by reaching an apparent steady speed as their channel widens. If such widening is rapid, or if slope inclination vanishes, we calculate where and how powder clouds collapse. Predictions agree well with observations of powder snow avalanches carried out at the Vallee de la Sionne (Switzerland).