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3 D numerical model of snow deformation without failure; cold room experiments and snow-cover applications

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The developments of a constitutive equation for snow and of three-dimensional numerical simulations describing the slow deformation of snow covers are required for many applications. As regards avalanche forecasting, they are specially necessary to allow computing the stress and strain fields in snow covers on irregular slopes so as to detect potential failure zones. They are also needed to assess the creep-stress on avalanche defence structures. During the last years, a three-dimension numerical model has been developed at the C.E.N. (Centre d'Etudes de la Neige de Météo-France) to simulate the slow deformation, without macroscopic failure, of a stratified snow-cover. This model uses the Flac-3D code with a non-linear viscous-elastic constitutive law developed by the C.E.N. The different mechanical parameters depend on the density and the temperature, the viscous parameters are also functions of the strain-rate, and the bulk and deviatoric parts of the strain and stress tensors are separated. Snow densification is calculated from the bulk strain tensor. In a first stage, this three-dimensional model has been used to simulate mechanical experiments performed in a cold laboratory at L.G.G.E. (Laboratoire de Glaciologie et Géophysique de l'Environnement). The snow was placed in a convergent channel (closed on the four sides), then compressed by a piston at different controlled velocities (between 1 to 10 μms-1). The results of the numerical simulations were compared with the measurements of the normal stress acting on the piston and with the displacement of markers measured by image processing. Then, this model has been used to simulate the movements of a snow cover (stress and creep strain) and the compressive effects on snow-protection nets. Developments have been made to take into account a gradual settling of snow, the snow-cover basal

friction and the elasticity and porosity of the net. The results have been compared with the net anchorage-forces measured by the CEMAGREF-ETNA (France) at an experimental site in the massif of Chablais (France). This study has been developed as part of the PRANE program (program on structures of protection subjected to the action of snow). Currently the model is developed to take into account the anisotropy of the snow-cover and to simulate and study other applications, as triaxial mechanical tests.