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Topography based avalanche equations and a hierarchy of avalanche models

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When dealing with geophysical flows across three-dimensional topography, for the physical modelling and for computational reasons it is more convenient to use curvilinear coordinates adapted to the basal solid surface. Using such coordinates, e.g. introduced by Bouchut and Westdickenberg (Comm. Math. Sci. 2(3), 2004) we derive the non-dimensional depth integrated mass and momentum balance equations. Then, we develop a hierarchy of model equations which differ by degrees in shallowness, basal curvature, peculiarity of constitutive formulation and velocity profile parametrization. An interesting result is that differences due to constitutive behaviour are largely eliminated by scaling approximations. We distinguish four main classes:

(i) When the rheology is weakest, the rheological response is that of the Eulerian fluid, except that non-uniformities in the velocity profile can be accounted for by coefficients of Boussinesq type.

(ii) For slightly larger resistance to shear, only the basal shear stress is relevant, and may in this case be parameterized by a Coulomb or a viscous stress contribution or both.

(iii) For even more resistive rheology, in addition to the basal shear stress, the depth averaged shear stress on planes parallel to the basal surface becomes significant.

(iv) The most complex formulation emerges when the depth integrated values of the stresses acting on planes perpendicular to the basal surface are sufficiently large to

have to be considered. All earth pressure models are of this kind.