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Modelling Subaqueous Debris Flows - A comparison of two state-of-the-art integrated models

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With the gradual depletion of nearshore resources and technological advances in oil and gas production, developments are now often located beyond the continental shelf in environments susceptible to mass movement events. The risk to subsea infrastructure from these events is often quantified through: i) an assessment of potential unstable slope areas and ii) numerical modelling of the potential slide runout behaviour.

This submission compares two different state-of-the-art depth-averaged numerical models for debris flow runout. These models both incorporate advanced rheology modelling and are capable of modelling slide behaviour over complex 3D bathymetry, but solve the governing equations in two drastically differing fashions – the first of which solves these equations within an Eulerian, Finite Volume framework, whilst the second solves the equations within a Lagrangian framework through a technique known as Smoothed Particle Hydrodynamics (SPH).

The relationship between shear stress and shear strain rate is modelled using either the linear viscoplastic Bingham or non-linear viscoplastic Herschel-Bulkley model. These numerical models also have a facility for the modelling of soil strength degradation during runout as a consequence of remoulding, as well as through the entrainment of ambient fluid. The soil mass itself is modelled as a rigid plug layer with an internal shear strain rate of zero, overlying a sheared layer where the shear stress at the interface between these layers is equal to the yield stress of the soil. The velocity in the plug layer is constant throughout its depth, whilst in the sheared layer it gradually diminishes to zero.

The Eurlerian model relies on an unstructured triangular mesh for the representation of the bathymetry. This is constructed using a generator which provides for local refinement in the area of anticipated runout and along steeper slopes or channelised areas. The equations are solved using a finite volume approach, using a Riemann solver based on the Harten-Lax-VanLeer (HLL) scheme, with lateralised treatment of the non-conservative products in order to achieve robustness and accuracy in areas of steep gradients.

SPH was initially developed for solving astrophysics problems, but has since been extended to many fields of research, including sediment mobility. It is a mesh-free Lagrangian method which solves the governing equations by dividing the fluid mass into a series of discrete elements, known as particles. The method is based on the concept that the value of any function can be interpolated from known values at other locations.

The results from this comparison are presented through integration with Geographic Information System (GIS) software in the context of a deep-sea case study, where properties such as flow thickness and velocity against time are examined for each of the models along with runout distance and lateral extent. The submission elaborates on respective strengths, limitations and the complementarity of both approaches, and concludes with some perspectives for future model development.