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Are avalanche models correct? An uncertain view on convergence

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At the core of many avalanche simulation tools, numerical kernels are utilized to solve flow model equations. Aside from trying to fit the models as best as possible to the current understanding of actual flow mechanisms, these kernels have to fulfill general mathematical requirements, such as convergence, stability and consistency. The precision of numerical solutions is limited and needs to be determined by appropriate uncertainty quantification approaches. It is also necessary to assess the impact of input variability propagating through the numerical kernel.

To allow kernel testing and uncertainty quantification, the AvaFrame framework provides a suite of test cases as well as analysis tools. This includes tests with known solutions usable to determine the kernel errors (ana1Tests) and idealized/real world topographies to estimate effects of varying simulation setups. By changing numerical settings, flow model setup or input data it is possible to show their effects on simulation results in a quantitative manner. It therefore allows us to relate input variations to the uncertainty in simulation results. Error and uncertainty quantification is done using modules for computing statistical measures (ana4Stats), indicators along an avalanche path (ana3AIMEC) and various visualization routines.

We showcase this for our com1DFA dynamical dense flow avalanche (DFA) module. The kernel of com1DFA is based on depth integrated governing equations (shallow water) and solved numerically using the smoothed particle hydrodynamics (SPH) method. Applying our analysis tools, we evaluate the convergence of the DFA kernel with regard to the numerical parameters time step, SPH kernel size and particles size. We investigate the accuracy and precision of the numerical solution using the similarity solution test, a test with a semi-analytic solution for depth integrated equations. It allows us to establish a suitable relation between time step, SPH kernel size and particles size for the com1DFA kernel.

Using the same approach for an avalanche setup, we can also vary selected input parameters like friction coefficients and/or release thickness and quantify the resulting uncertainties on simulation results, e.g. runout and peak flow variables.