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Testing basin-scale evolution concepts on a supercomputer at realistic tectonic and sedimentary rates

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Growing interest in understanding the interaction between tectonic and surface processes has encouraged the development of new numerical packages and the combination of pre-existing tools to provide the geoscience community with robust quantitative methods for studying and modelling the Earth surface dynamics.

While complex methods for simulating hydrodynamics and sediment transport exist they are not adapted to the geological time scales. Diffusive models have been successfully used to study geomorphic changes through geologic periods, but these usually fail to include detailed sedimentary information making difficult the establishment of a clear relationship between imposed tectonic and sedimentation.

We present through a series of conceptual rifting experiments the results obtained from the coupling between two open-source codes: Tellus and Underworld. (1) Tellus is a new 3D-parallel code based on particle-in-cell technique capable of simulating geomorphic and stratigraphic evolution. Tellus solves the shallow water equation to simulate various types of flow materialised by fluid particles on an unstructured grid. A sediment transport criterion allows siliciclastic materials to be eroded, transported and deposited. The code is also capable of modelling compaction based on sediment loading. External forces such as sea-level fluctuation, rainfall, river inflows and vertical displacement can be imposed. (2) Underworld is a 3D-parallel geodynamic numerical framework based on a Lagrangian particle-in-cell finite element scheme and capable of simulating rheologically and thermally consistent tectonic models, at all scales and over geologic time.

We coupled Underworld and Tellus in order to:
- compute self-consitent uplift and subsidence movements at realistic geologic rates,
- compute any resulting hydrostatic forces at the base of the lithosphere to account for mass transfer at the large-scale,
- calculate flow directions and track siliciclastic sedimentary facies and deposits geometries in basins and channels under imposed climatic forces.

This coupled method allows us to investigate at multiple spatial and time scales and under controlled tectonic setting, the impact of surface processes on rates of deformation, and examine the inherent stratigraphic record.