Geologic Process Modeler (GPM)

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Introduction

Geologic process modeling is the modeling of sedimentary and structural process through geologic time (emphasis is on sedimentation). It is a way to produce a quantitative model of a basin or reservoir constrained by geologic knowledge, and can be used as a tool to understand physical processes that have operated in the geologic past.

GPM is a software environment that lets a user model these processes through geologic time. It is written by Dan Tetzlaff who did his PhD on this topic and later published a book together with Harbaugh with the title "Simulating clastic sedimentation".

The GPM software consists of a pre and postprocessor written in Petrel/Ocean, and a simulator doing the actual simulations. It has a number of processes that can act on the model, like steady and unsteady flow, wave action, tectonics and carbonates.

One of the differences between a "normal" environmental simulator, like beach management, and GPM is the timespan involved in the simulation. Simulating thousands/millions of years puts restrictions on the time that can be spent on each time cycle.

The sediments used in GPM are grain types with given characteristics, like density, diameter and so on. A layer in the GPM model consists of a mix of fractions of the different grains in the model.

The GPM software is currently single threaded, and that has influenced the choices made for the algorithms in the implementation.

The language of choice for implementation for the proposals is less important, provided that the concepts and libraries used are sufficiently high level.

For all the proposals, the outcome we would like to see is:

- An implementation with improved sediment transport and fluid flow
- Testing of the implementation towards published results and/or lab reports on flow and sediment transport
- Parallel implementation suggestion with runtime estimates.

Steady state sediment transport

Proposal

Steady state sediment transport – implementation and verification with analogue of a steady state sediment transport simulator using the Lattice-Boltzmann formulation. The project will be co-advised by SLB and the master project may include a stay at SLB in Stavanger.

Current implementation in GPM:

Steady flow has to be able to cope with parts of the model being dry and lake at rest.

Steady flow is implemented today by doing a force balance of the vertical water columns in the grid points of our model with a bottom friction coefficient (Manning's friction coefficient). The transport of sediments is done by transforming water velocities to diffusion coefficients.

The flow can have Froude numbers larger than 1.

References:

Well-Balanced Positivity Preserving Central Upwind Scheme for the shallow water system with friction terms: **http://www4.ncsu.edu/~acherto/papers/CCKW.pdf**

Explicit Shallow Water Simulations on GPUs: Guidelines and Best Practices:
http://cmwr2012.cee.illinois.edu/AdvancesHeterogeneousComputing%28Proceedings%29.html

Stability of system:

Today all sub systems in GPM are solved by explicit time steps given by the user. Given different subsystems having different time step requirements, what would be valid approaches on how to run these in concert and keep the time steps as large as possible, but in subsystems in sync at the right points in time.

Proposal:

Look into methods to orchestrate different processes at different time steps. These can be either by syncing processes at time steps or by looking into stability by looking at other regimes, like implicit methods

Unsteady state sediment transport.

Proposal

Unsteady state sediment transport - Implementation and verification with analogues of a unsteady state (turbidities) sediment transport simulator using the Lattice-Boltzmann formulation. The project will be co-advised by SLB and the master project may include a stay at SLB in Stavanger.

Current implementation in GPM:

Current implementation in GPM is a particle method (Point in Cell) for both flow and sediment transport

References:

Numerical simulation of turbidity currents: a new perspective for small- and largescale sedimentological experiments, Snorre Heimsund

https://bora.uib.no/bitstream/handle/1956/2270/Masterthesis_Heimsund.pdf?sequence=3

Simulation of slope instability

Proposal

Simulation of slope instability – The accumulation of sediments changes the stress state in the sediment package. In the current GPM implementation non-linear events are explicitly put in. For example a given number of turbiditic events in a given time period. This project will investigate methods for identifying different slope instabilities, turbiditic flow, slumping and faulting. The project will combine geomechanical stability analysis and statistical analysis of instability event size and frequency. The project will be co-advised by SLB and the master project may include a stay at SLB in Stavanger.

Current implementation in GPM:

None.

Aeolian sand transport

Proposal

Aeolian sediment transport processes - GPM has currently no simulation of aeolian processes. The project will be an implementation and verification of an aeolian processes simulator. The project will be co-advised by SLB and the master project may include a stay at SLB in Stavanger.

Many examples and reference to aeolian sand transport can be found at:
http://www.comphys.ethz.ch/hans/dunes.html

Current implementation in GPM:

None.