Numerical Modeling of Turbidity Flow with the Lattice Boltzmann Method

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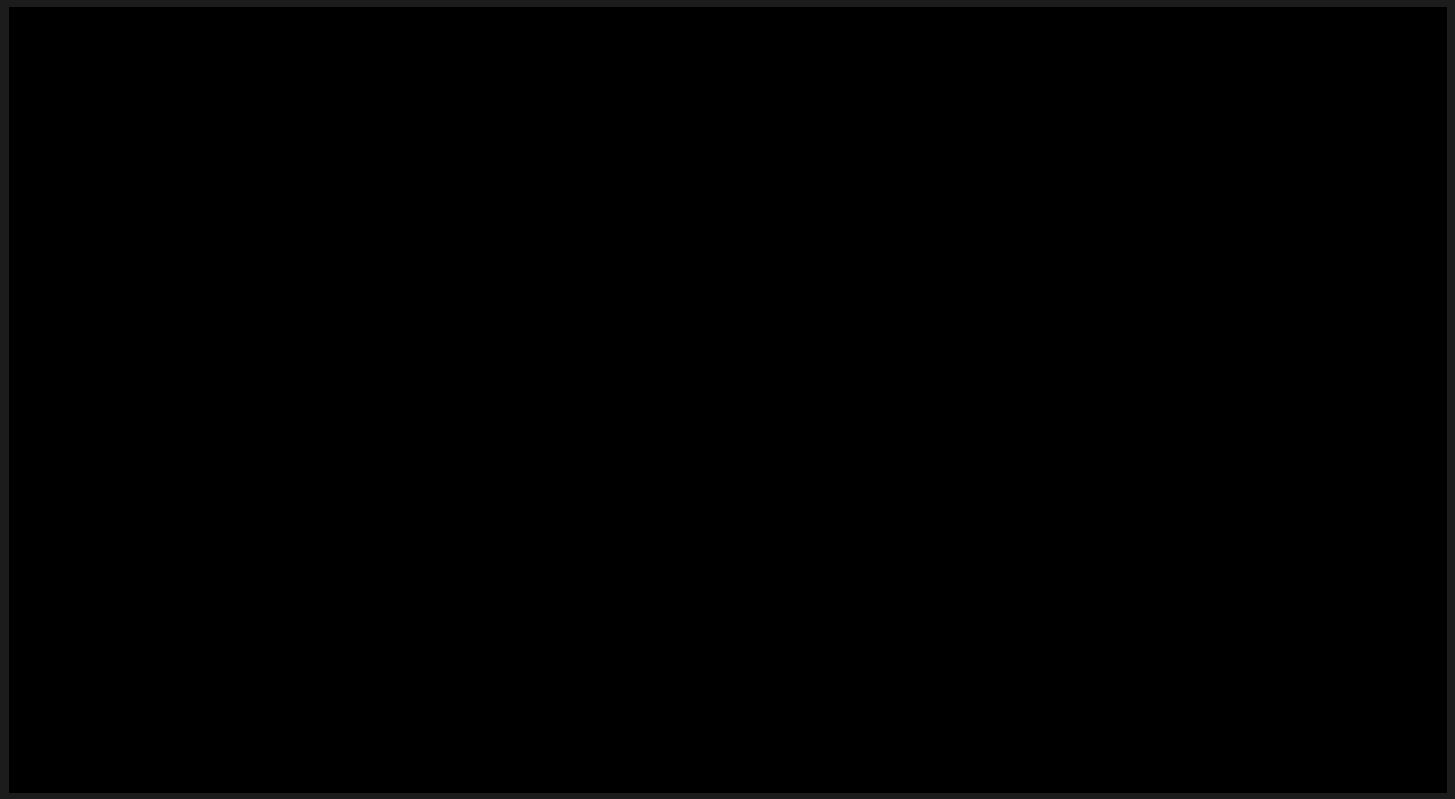
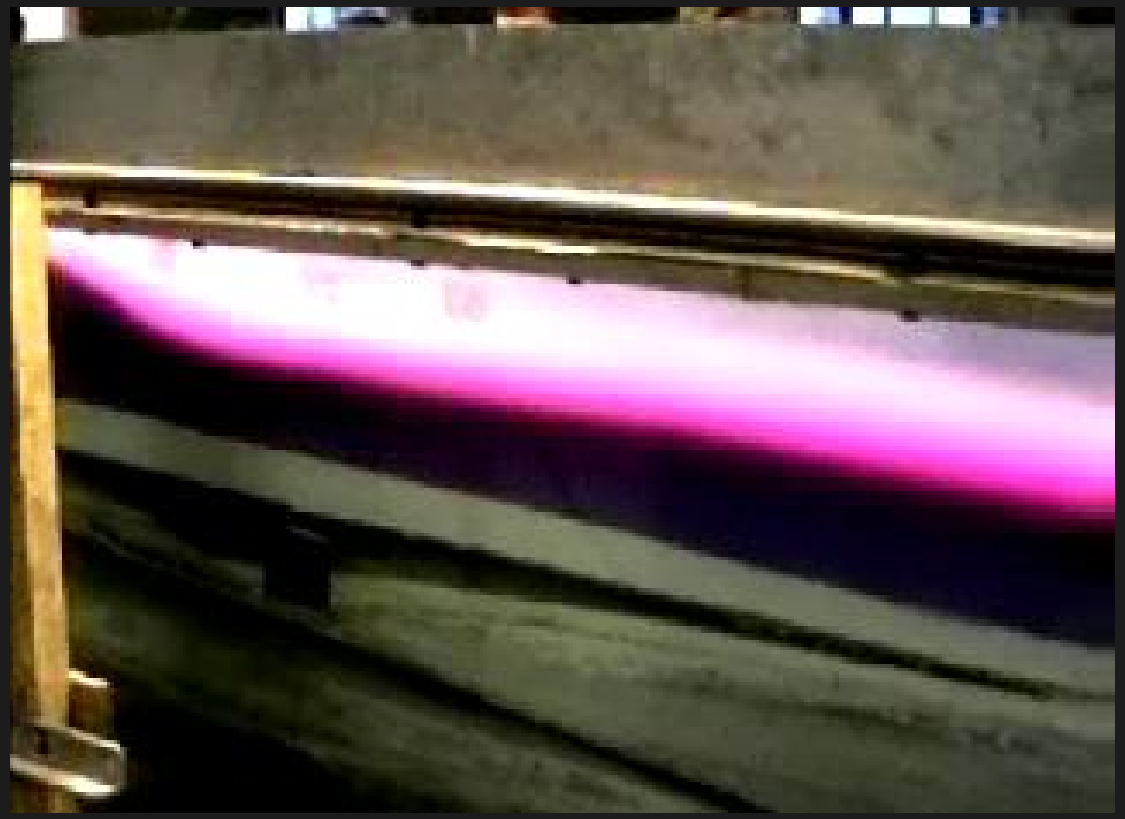
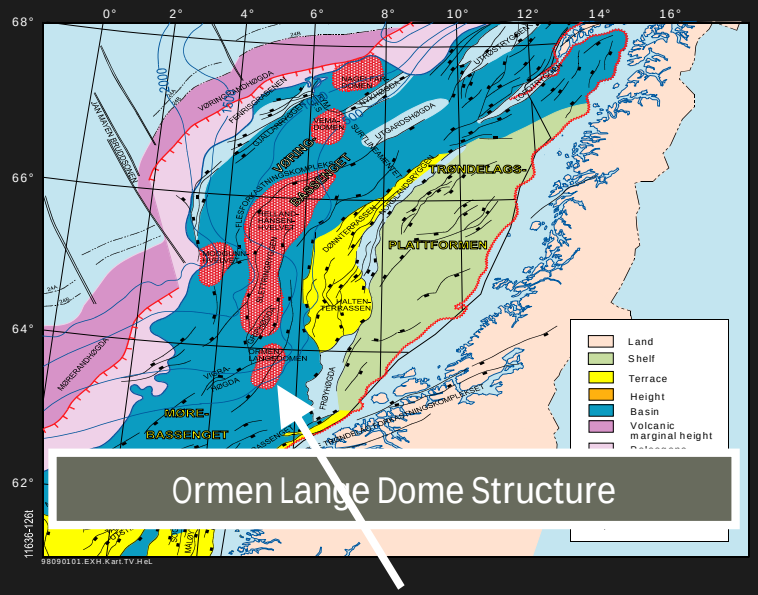
Turbidity currents are sand-laden, highly turbulent fluid flow



Turbidity currents often arise in deep submarine areas triggered by earthquaqes or tsunamis



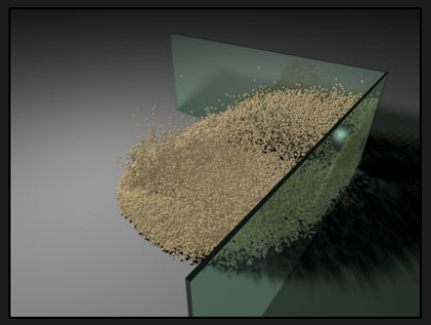
Deposits from turbidity currents constitute important hydrocarbon reservoirs



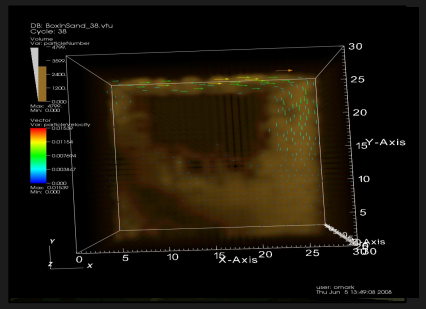
The Ormen Lange gas field in the Norwegian Sea comprises deep marine turbidite deposits

This presentation will outline our approach in the modeling of turbidity current

Lattice Boltzman method for modeling water

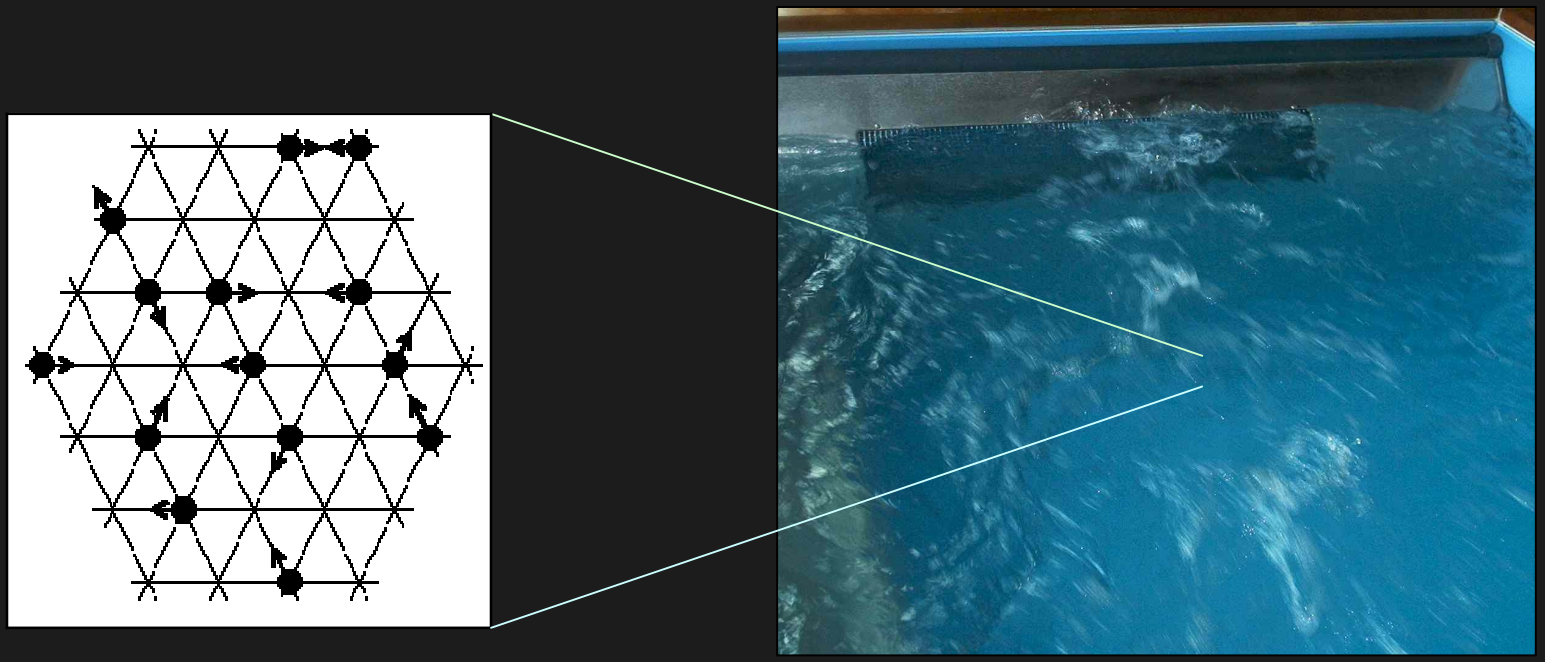


Modeling sand transport in fluid flow



A coupled sand-fluid model

The Lattice Boltzmann paradigm is a particle based approach for simulating fluid flow



Macroscopic fluid variables like the pressure and velocity are calculated from averaged microscopic quantities

The Lattice Boltzmann equation is simple and easily extendable

Hydrodynamic variables

$$\rho(x,t) = \sum_i f_i(x,t)$$

$$u(x,t) = \frac{1}{\rho(x,t)} \sum_i f_i(x,t) c_i + \frac{\tau F}{\rho(x,t)}$$

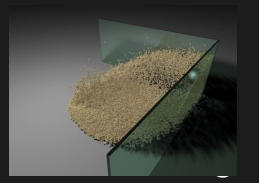
$$f_i(\mathbf{x} + c_i, t+1) = f_i(\mathbf{x}, t) - \frac{f_i(\mathbf{x}, t) - f_i^{eq}(\mathbf{x}, t)}{\tau}$$

The distribution function

Viscosity term

The sand phase is modeled as consisting of individual particles

Conventional methods model the sand as a continium



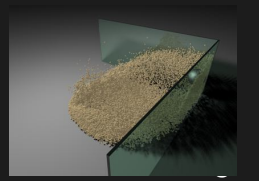
Individual particles obey the Bassinet-Boussinesq-Oseen (BBO) equation

$$\frac{dv_p}{dt} = \frac{1}{\tau_p}\left(v_p - u\right) + g - \frac{\rho_p}{\rho} g + \ldots$$

Drag force

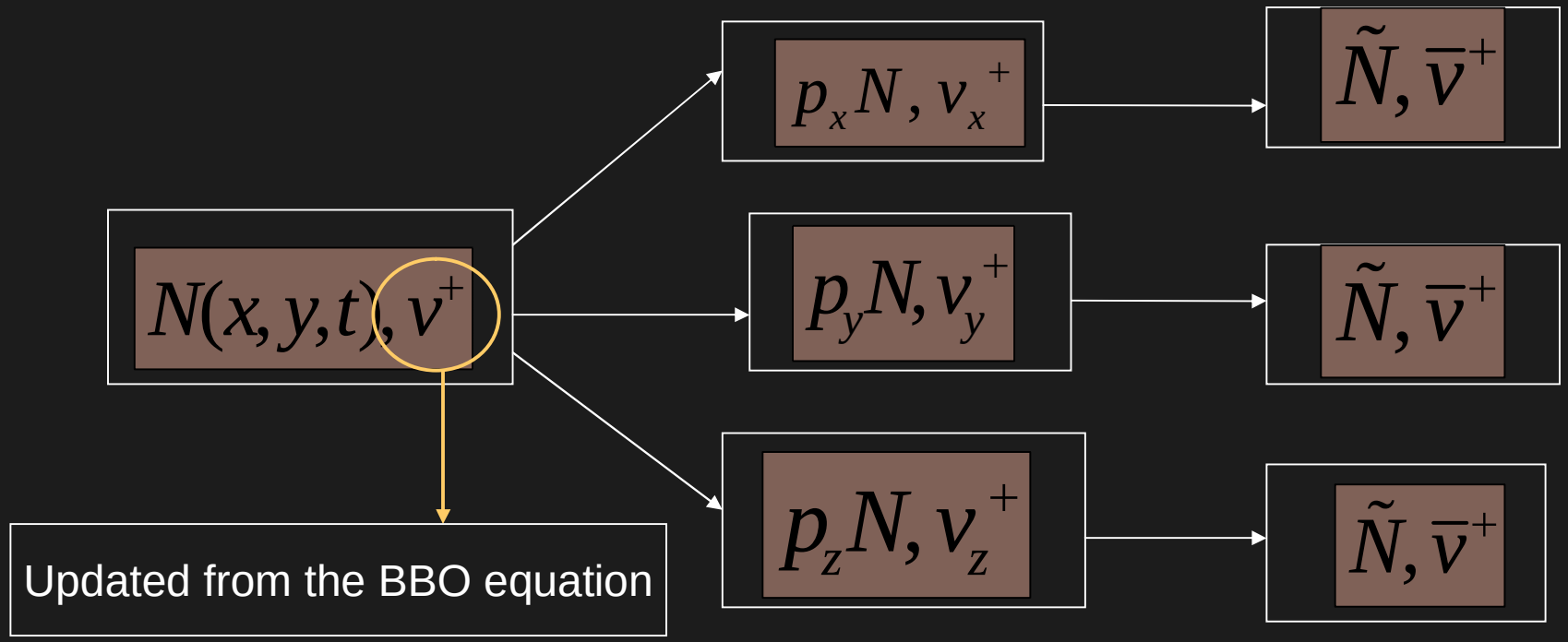
Effective gravity

The BBO equation is solved numerically for a representative number of sand constituents

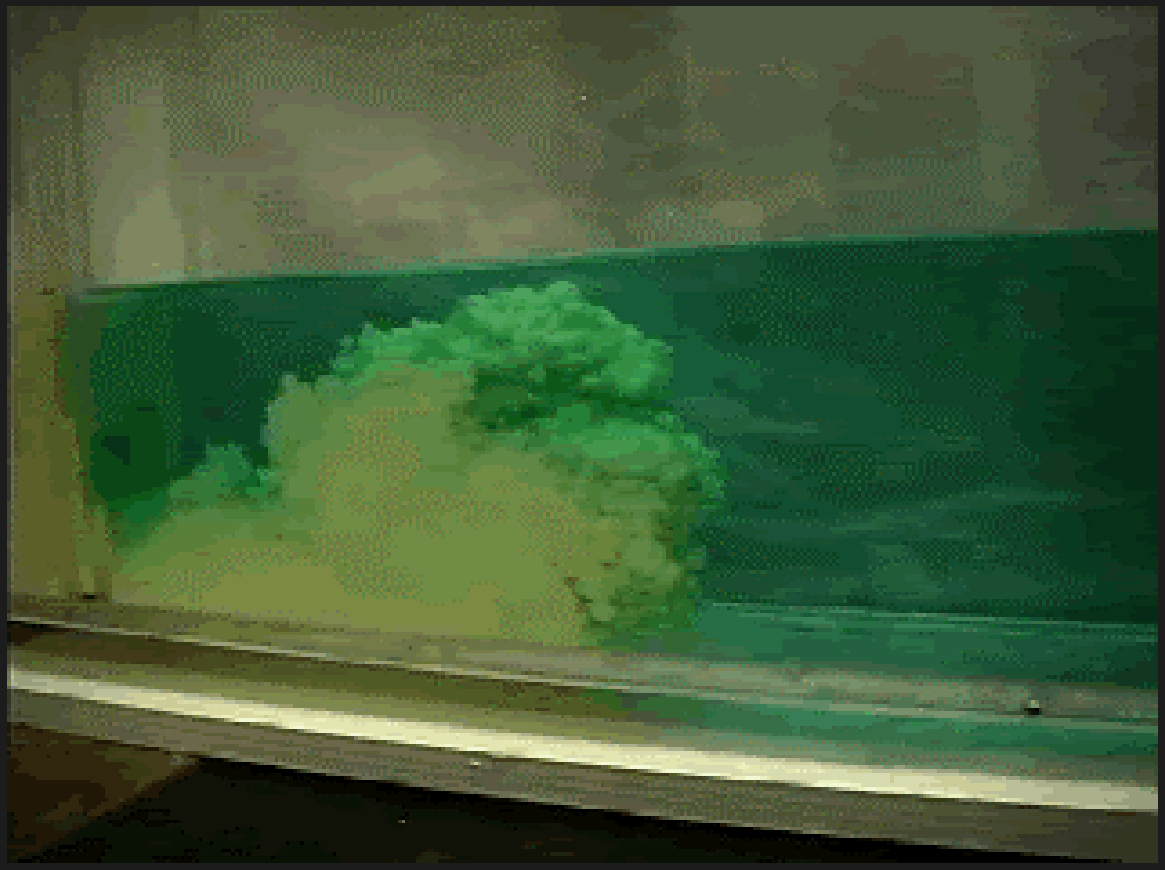


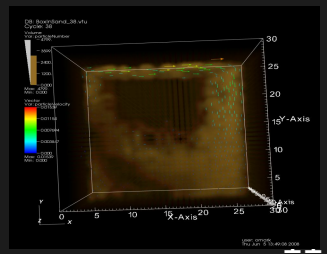
Instead of tracking each particle, we study the effects of the BBO equation on one quasi particle

Each quasi-particle consitst of N(x,y,z) sand particles with an average velocity v

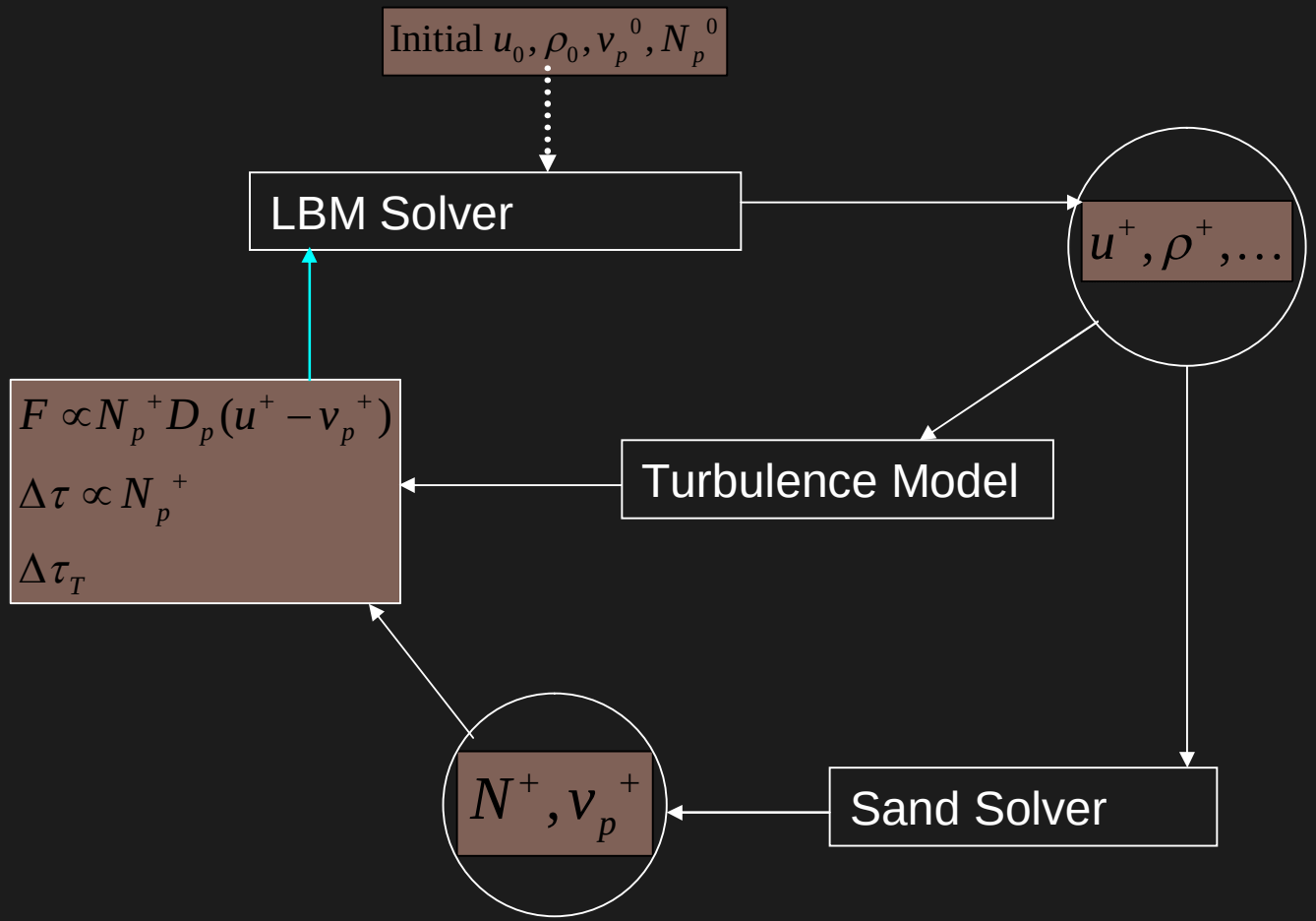


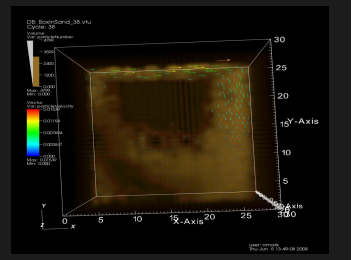
The simulation of the sand-fluid system requires a two-way coupling





The temporal evolution of the sand-laden fluid is done iteratively





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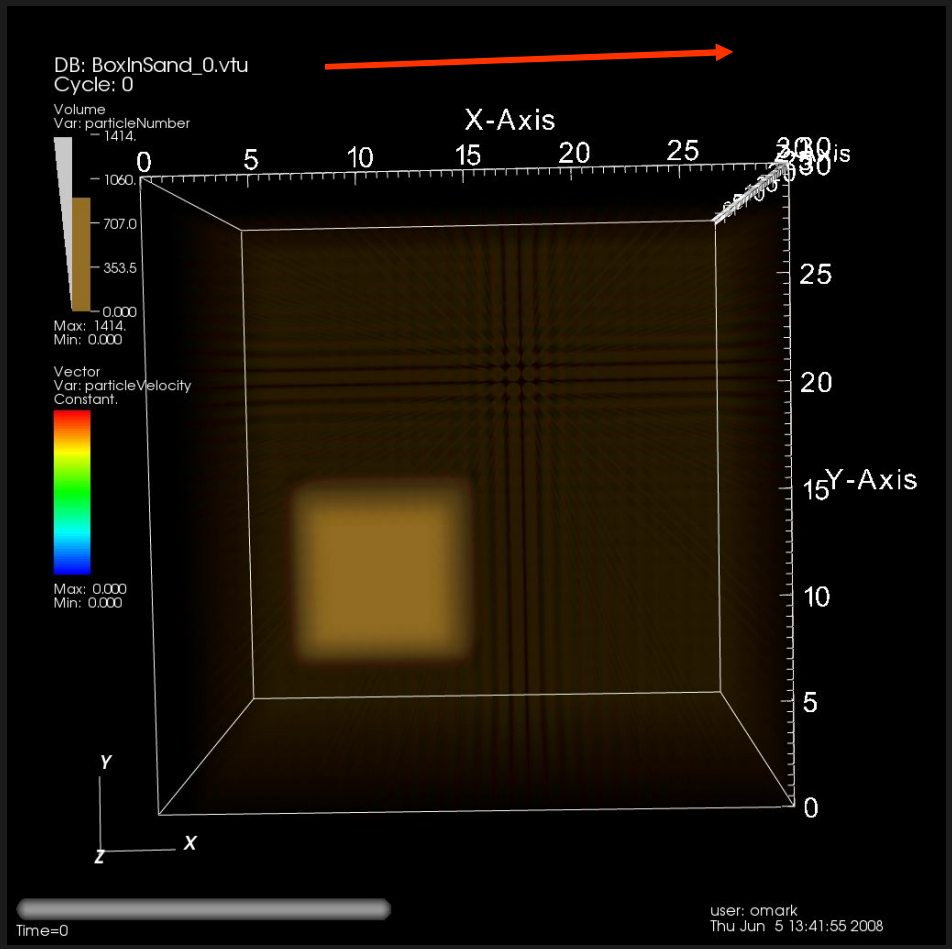
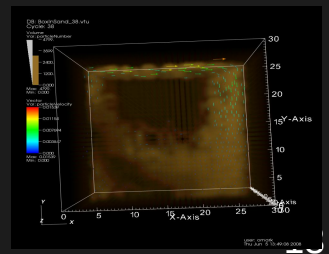
A cube of evenly distributed sand particles is simulated in a lid driven cavity



The cube consists of about 500.000 particles



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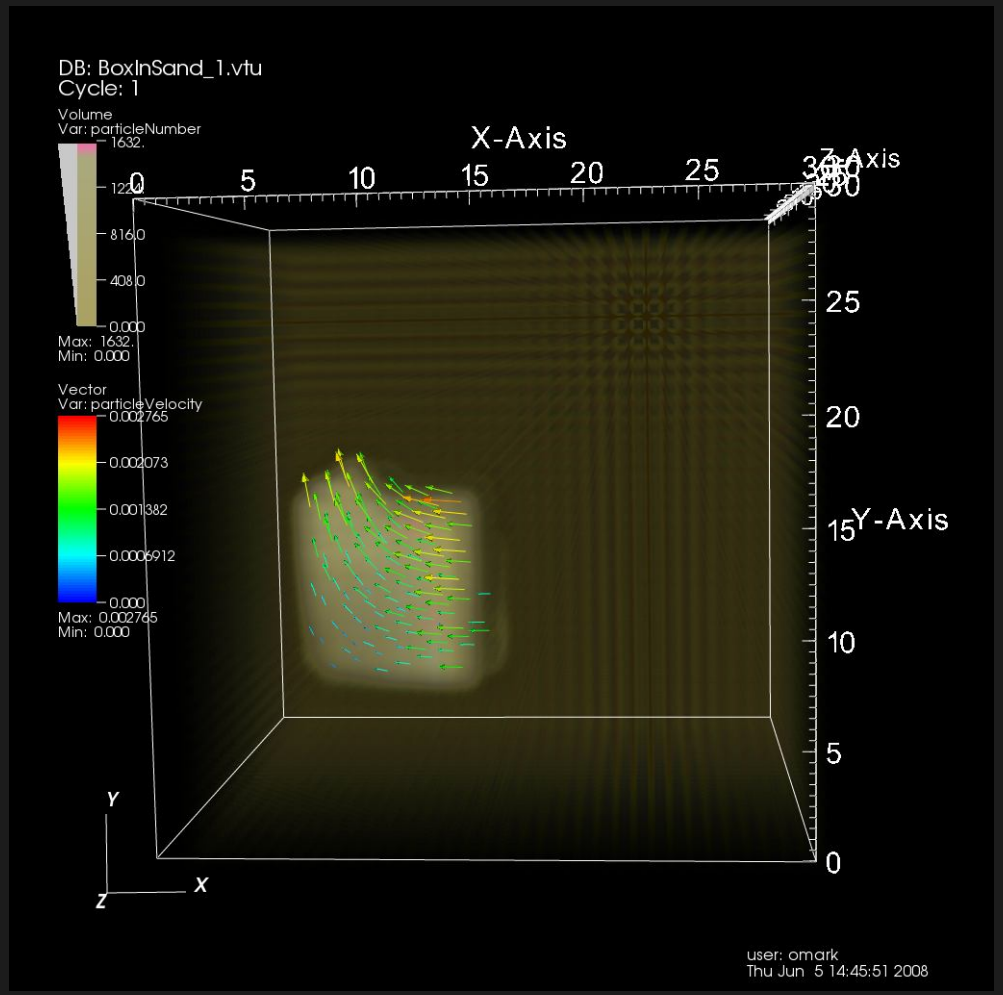
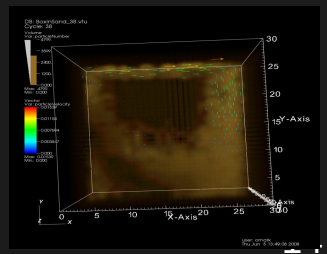
This movie shows the sand velocity field





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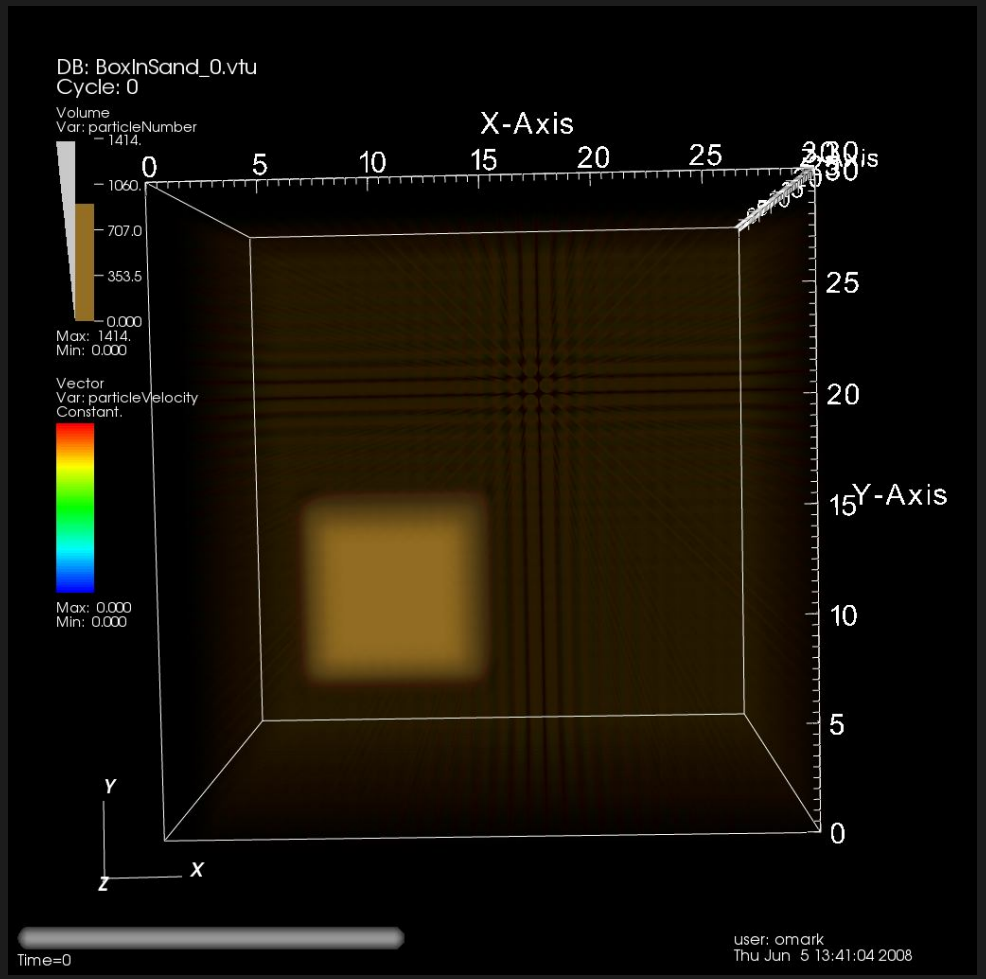
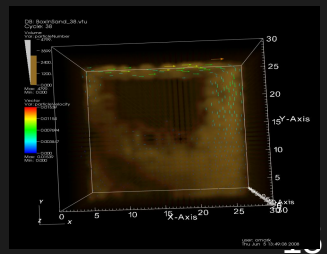
Adding gravity to the sand adds an additional dispersion effect



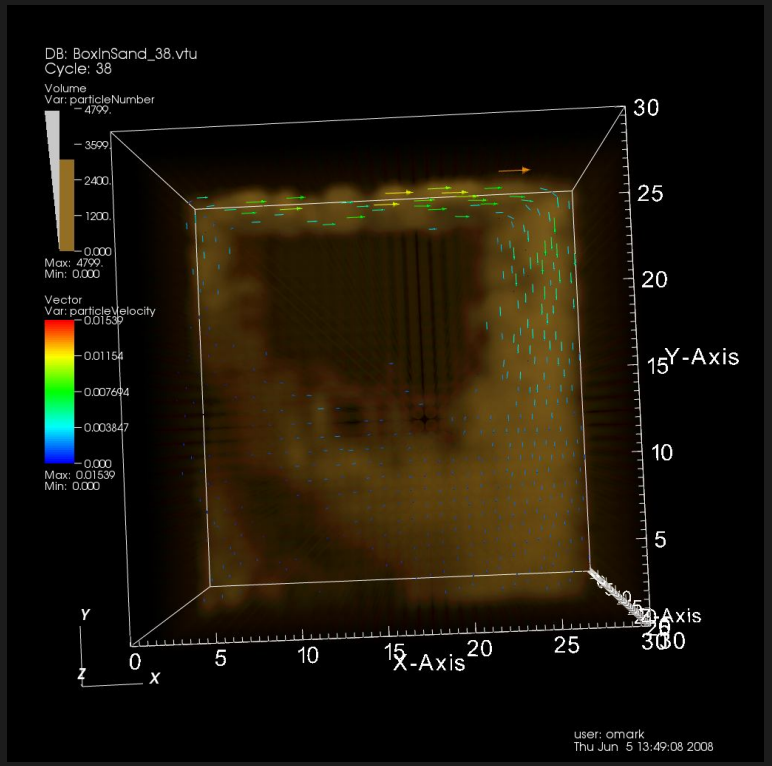


Further improvements of the model is planned

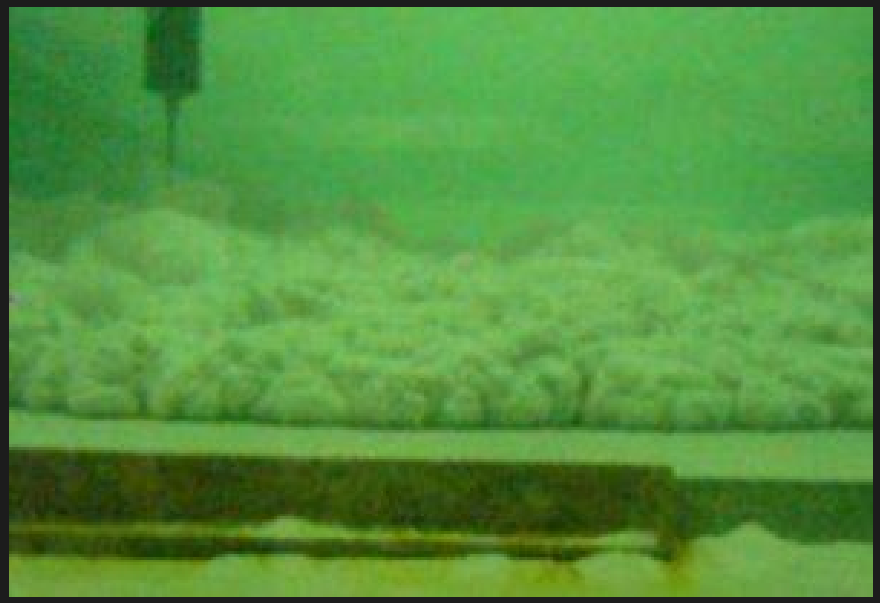
The implementation of an algorithm for deposition and erosion

Implementation of a Smaroginsky turbulence model.

An increase in the fluid viscosity depending on sand density



In conclusion, we report significant progress in our model of turbidity currents



Thank you for your attention

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