Two-Phase Modeling of Suspended Particle Flow

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Miami

Dredging Engineering Group Delft

“We believe that **knowledge** of dredging processes is the basis of a **competitive** and **sustainable** dredging industry which serves **mankind**”

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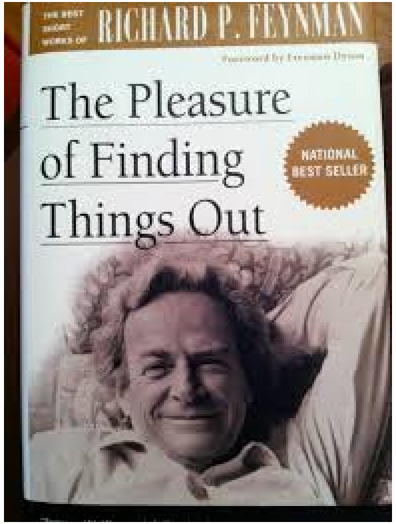
Why understanding?



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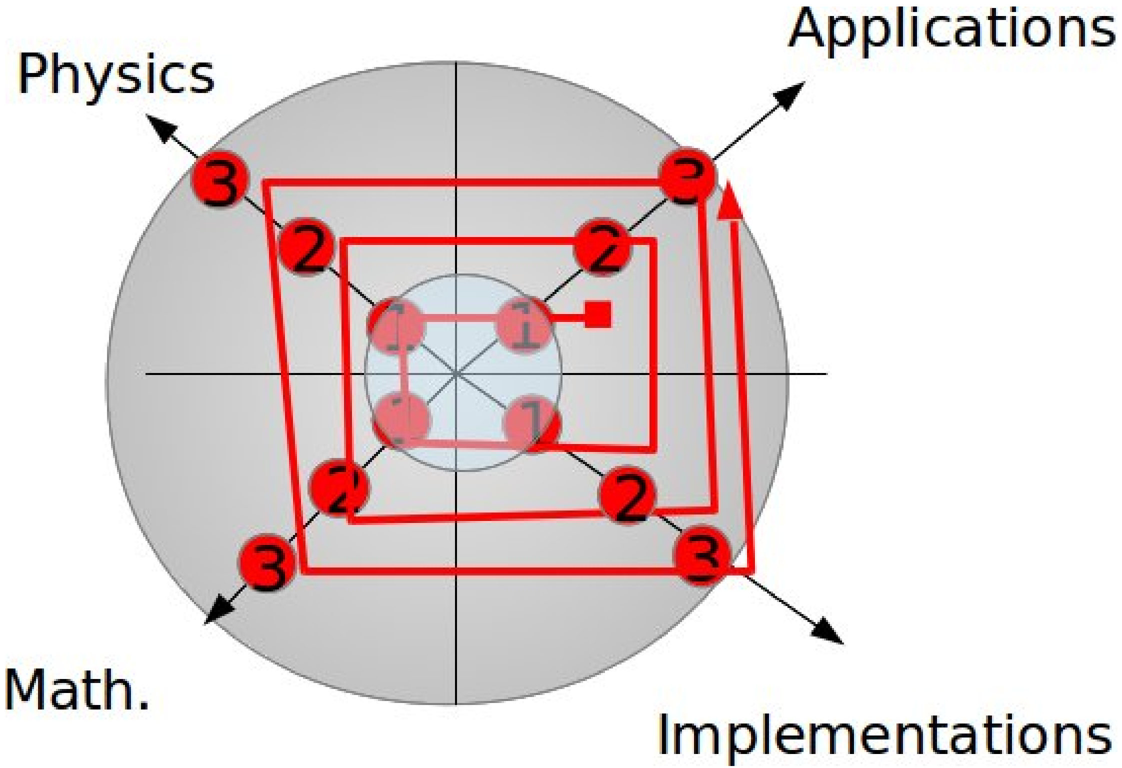
Research philosophy

“”**C**omputational **F**luid **D**ynamics is useful to acquire this knowledge”

CFD cycle



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or in short

1) Solve the right equations
2) Solve them right

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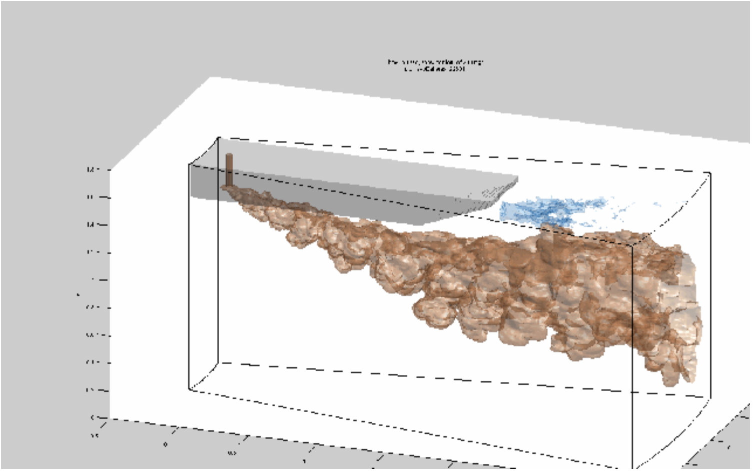
Example PhD project Lynyrd de Wit*



Overflow Plume of a TSHD

*Present affiliation: Svasek Hydraulics

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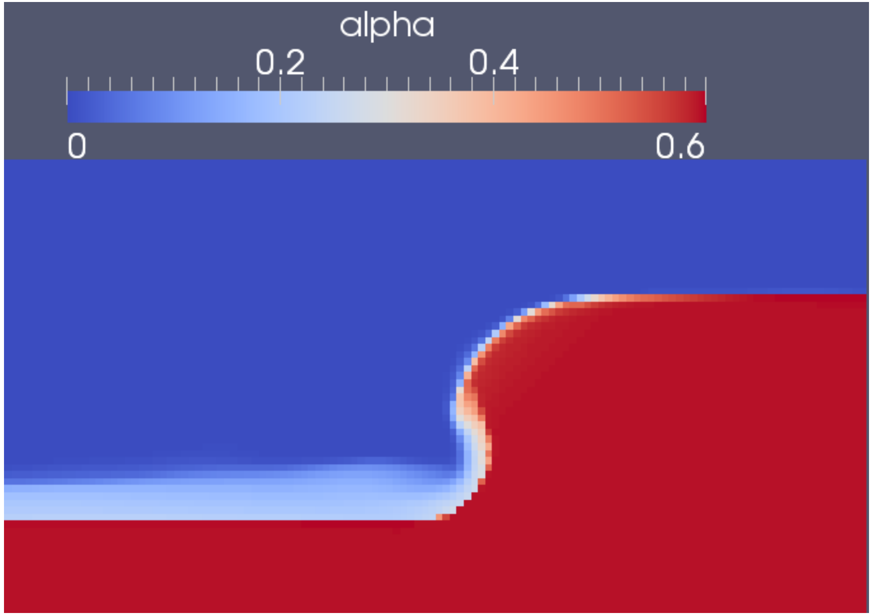
Example 2 Dave Weij



See his presentation on Thursday!

Unstable breaching / dilative slope failure ongoing work see his presentation!

Other PhD projects

- Frans van Grunsven, deep-sea mining plumes (presentation 6:30 PM)
- Rudy Helmons rock cutting deep-sea mining (presentation Thursday)
- Bas Nieuwboer, mixture formation in a cutter
- Joep Goeree, generic mixture formulation.
- ….

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General approach

Mixture approach involves super position

$$U_{particle} = U_{mix} + U_{settling} + U_{diffusion}$$

See e.g. Goeree et al, 2016, The Canadian Journal of Chemical engineering

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Superposition of three velocities

- U_{mix} Navier-Stokes equations for the mixture
- $U_{settling}$ settling test still water
- $U_{diffusion}$ passive scalar with many **corrections.**

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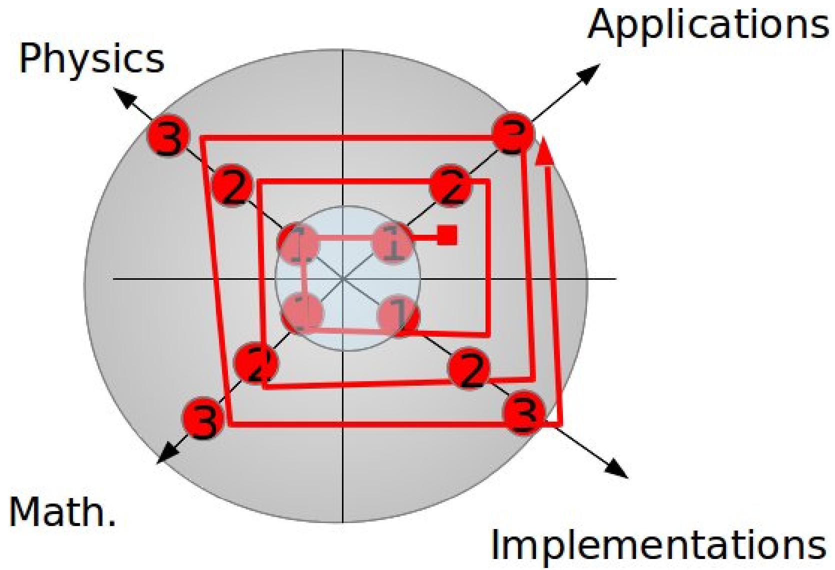
CFD Step 1

- Do we solve the right equations?



Do we solve the right equations?

Near sand-water interfaces/rough walls?

- Velocity scales (V): friction velocity
- Length scales (L): distance to bed

Characteristic time-scales (L/V) versus particle response times?

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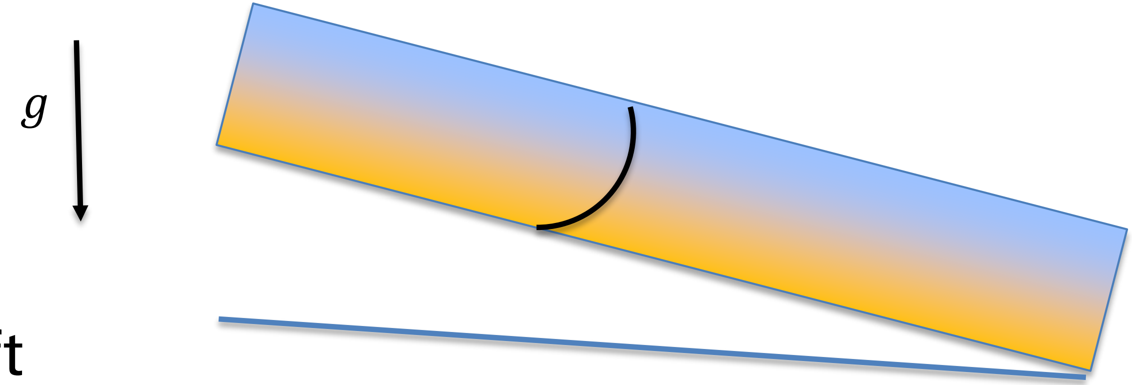
Original two-phase equations

- Momentum equation for water
- Momentum equation for solid
- Indicator function to detect presence of each phase
- Coupling forces between the solid and water velocity fields

Analysis of relevant scales in equilibrium channel flow problem

- Basic equations Drew (1975)
- Re-analysis and closures of Greimann et al, (1999) and (2001)
- Re-analysis Keetels et al (2016)



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Re-analysis by Keetels et al, 2016*

Relevant local scaling group based on

- Particle response time
- RMS solid velocity field fluctuations
- Turbulent diffusion coefficient

*Under review at Journal of Hydraulic Research

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Result

- Inertia terms in the solid momentum equations can not be neglected near the wall!
- For coarse particles with large response times these terms are even more important!
- Fine particles sufficiently far from wall safe to use mixture approach

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Fine particles

- Neglecting inertia terms in two-phase framework results in traditional profiles (Rouse 1937, Hunt 1954, Hallbron 1949)
- Generalization of Greimann et al, (2001) with respect to non-linear drag and hindered-settling (particle crowding effect)

Coarse particles

- Essential to model the inertia terms in the momentum equation of the solid phase
- Greimann, 2001 uncertainty in two-key parameters
- Coupling fluid and solid velocity fluctuations?
- Coefficient of restitution of particles in viscous flow?

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Coupling fluctuations solid and fluid

- Ct model of Issa and correction of Behzadi et al, (2004).

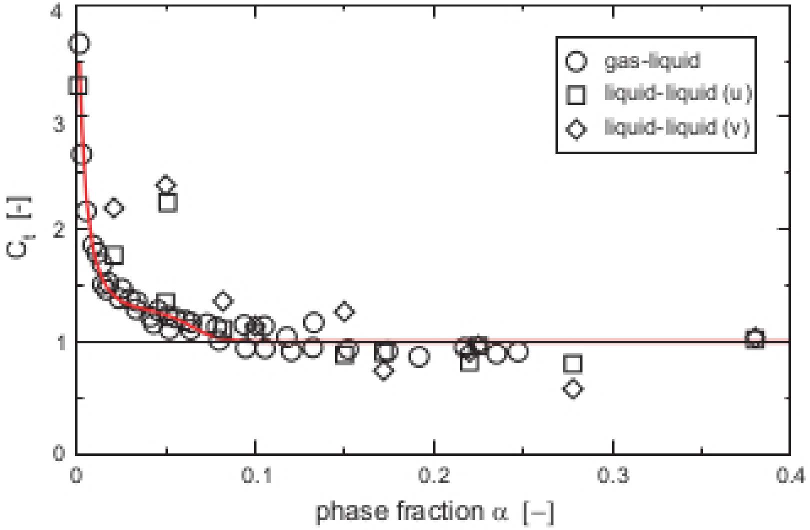

Fig. 3. Turbulence response function as a function of the phase fraction.

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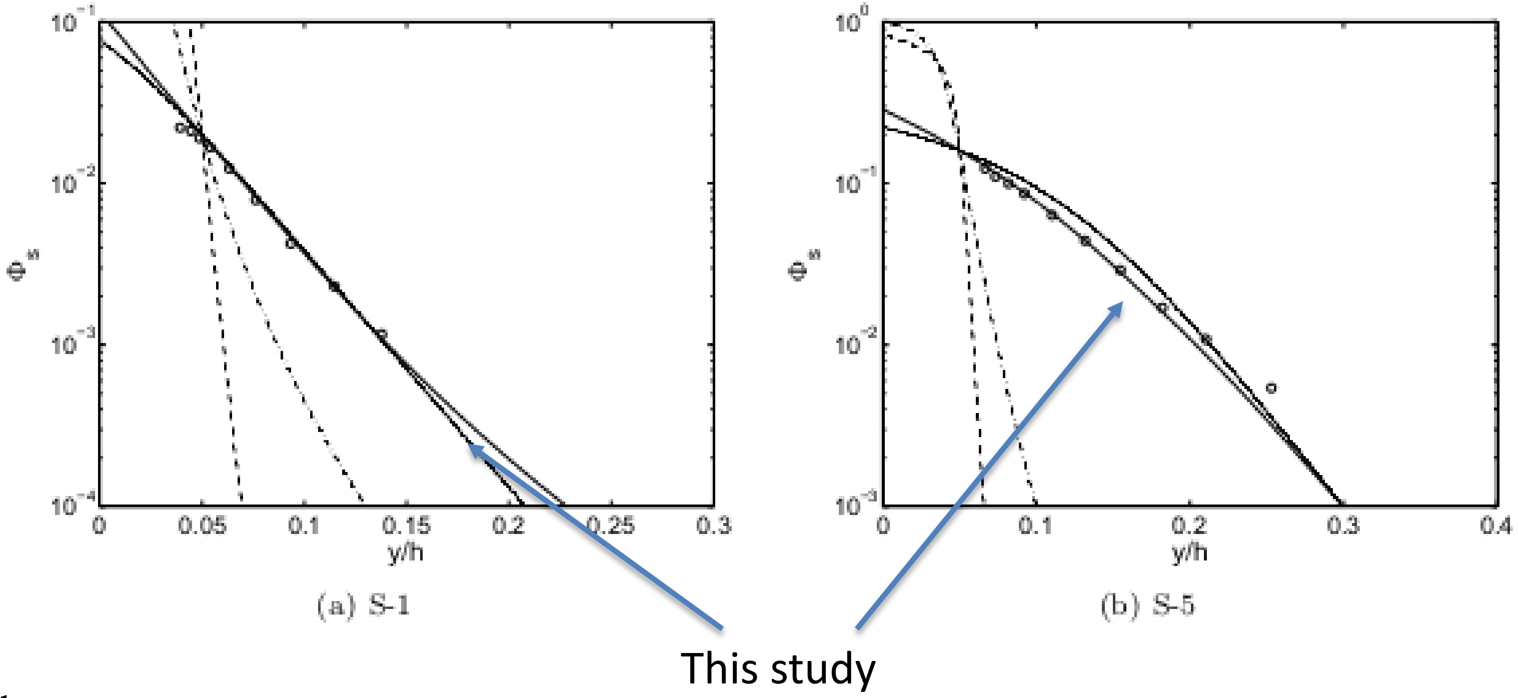
Restitution coefficient

- Experiments of Anguilar-Corona et al (2011)
- Correction of dry restitution coefficient as a function of a Stokes number alike parameter.
- Greimann 2001, used dry value because information in viscous flow was not available.

Concentration profiles



Conclusion

- Fine particle sufficiently far from wall safe to use mixture approach (super position of hindered-settling and diffusion)
- Coarse particle require two-phase approach
- With realistic closures reasonable accurate prediction of concentration profiles.

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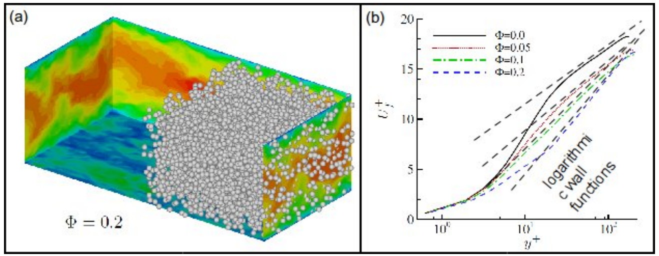
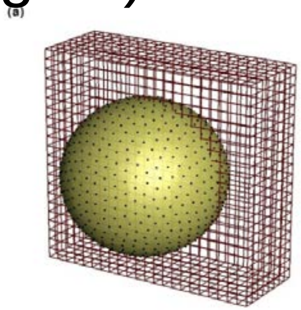
Next step

- More advanced modelling to predict both velocity and concentration profile, see also Goeree et al, 2016.
- Lack of information, Direct Numerical Simulation on particle level (Wim-Paul Breugem).





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Near-wall flow