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Experimental and Numerical Study of **Depositional Mechanism of Mudflow**

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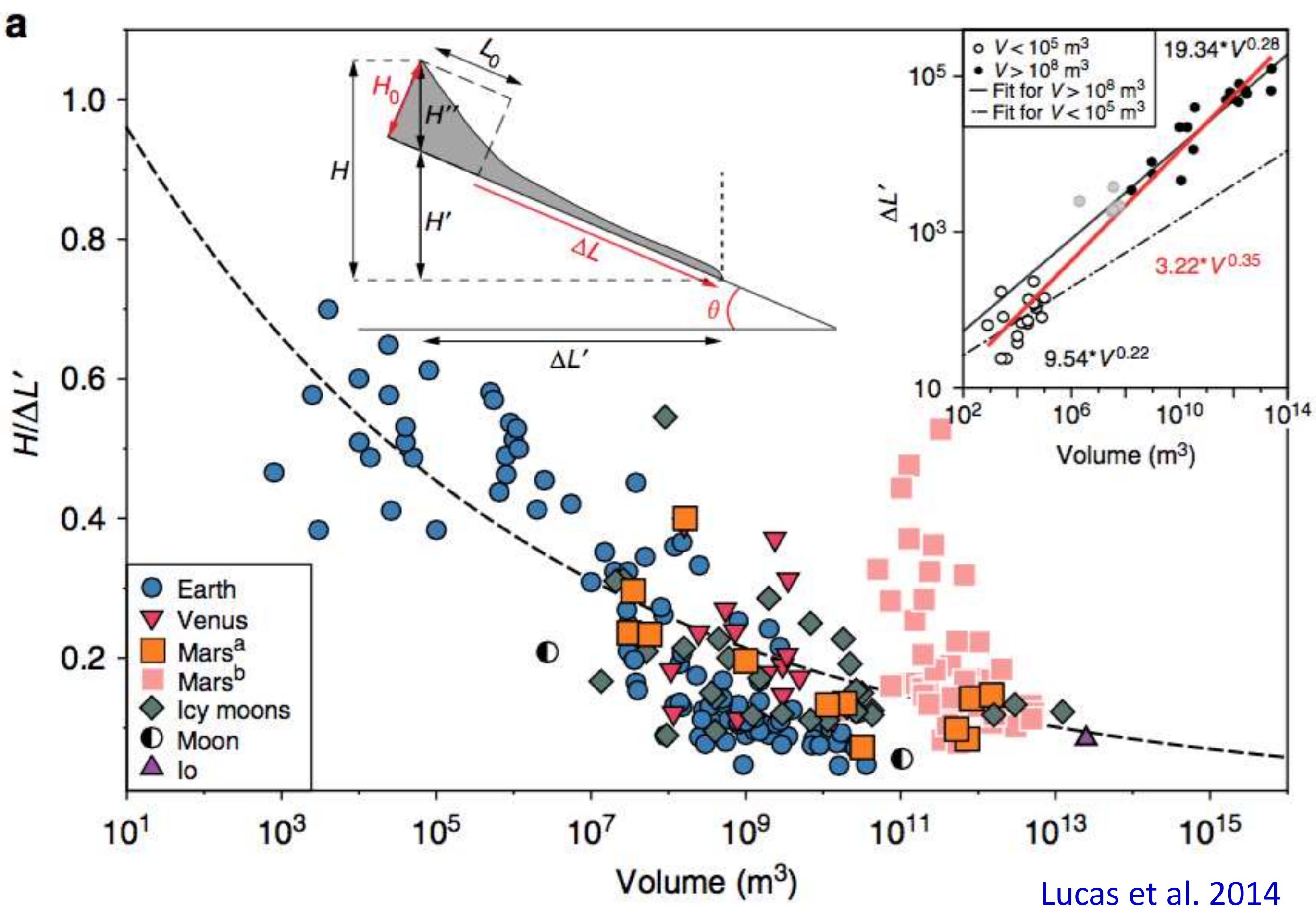
Mudflow in Nature

Viscoplastic Fluid

Experiments

de Haas et al. 2015

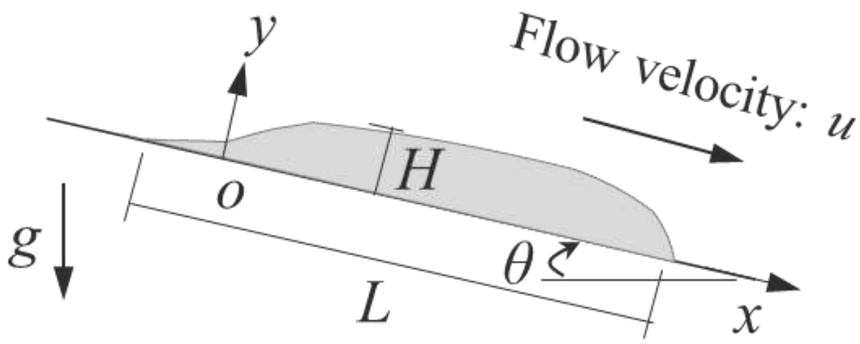
Scaling Runout



Lucas et al. 2014

Viscoplastic behavior
Only geometric parameter (simple dimensional argument)

Dynamic Similarity



$$u = f(g, L, H, t, \theta, \rho, \sigma, \mu, \tau_y)$$

stress

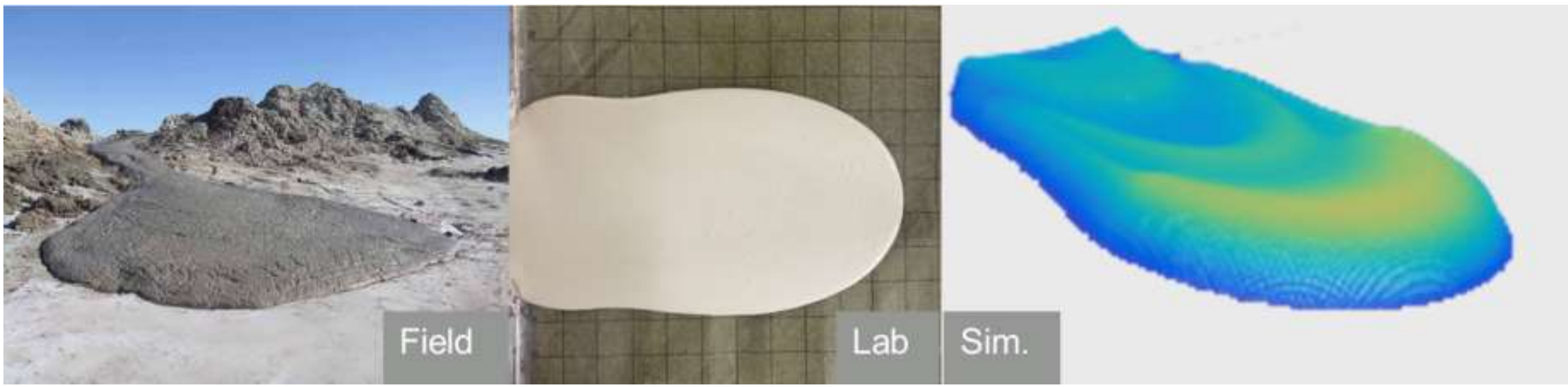
Dimensional analysis

$$\frac{u}{\sqrt{gL}} = \mathbf{F}\left(\frac{H}{L}, \frac{t}{\sqrt{L/g}}, \frac{\sigma}{\rho g H}, \frac{\mu}{\rho\sqrt{gH^3}}, \frac{\tau_y}{\rho g H}, \theta\right)$$

$$\mu \sim H^{3/2}, \quad \tau_y \sim H.$$

Viscosity Yield stress

Strategy



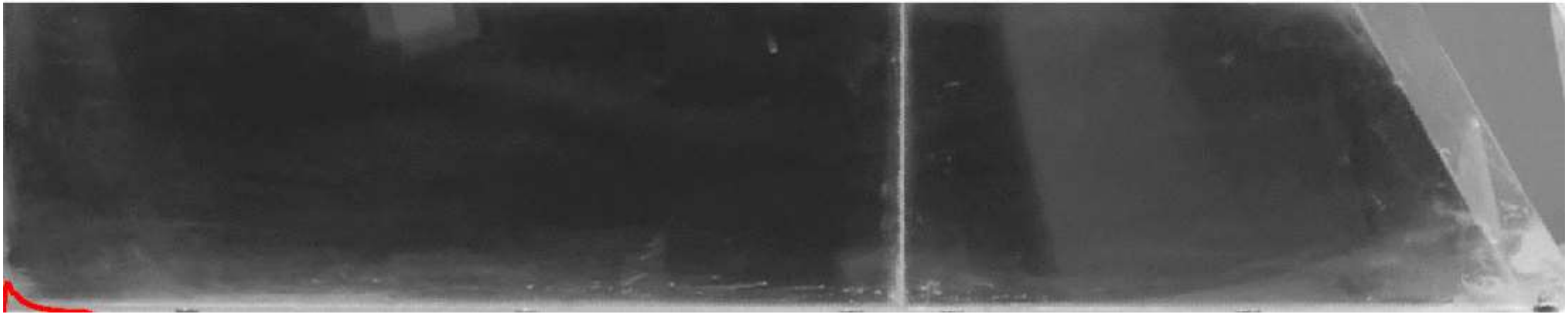
Flume System

Front view

Side view

Cameras

Image Processing



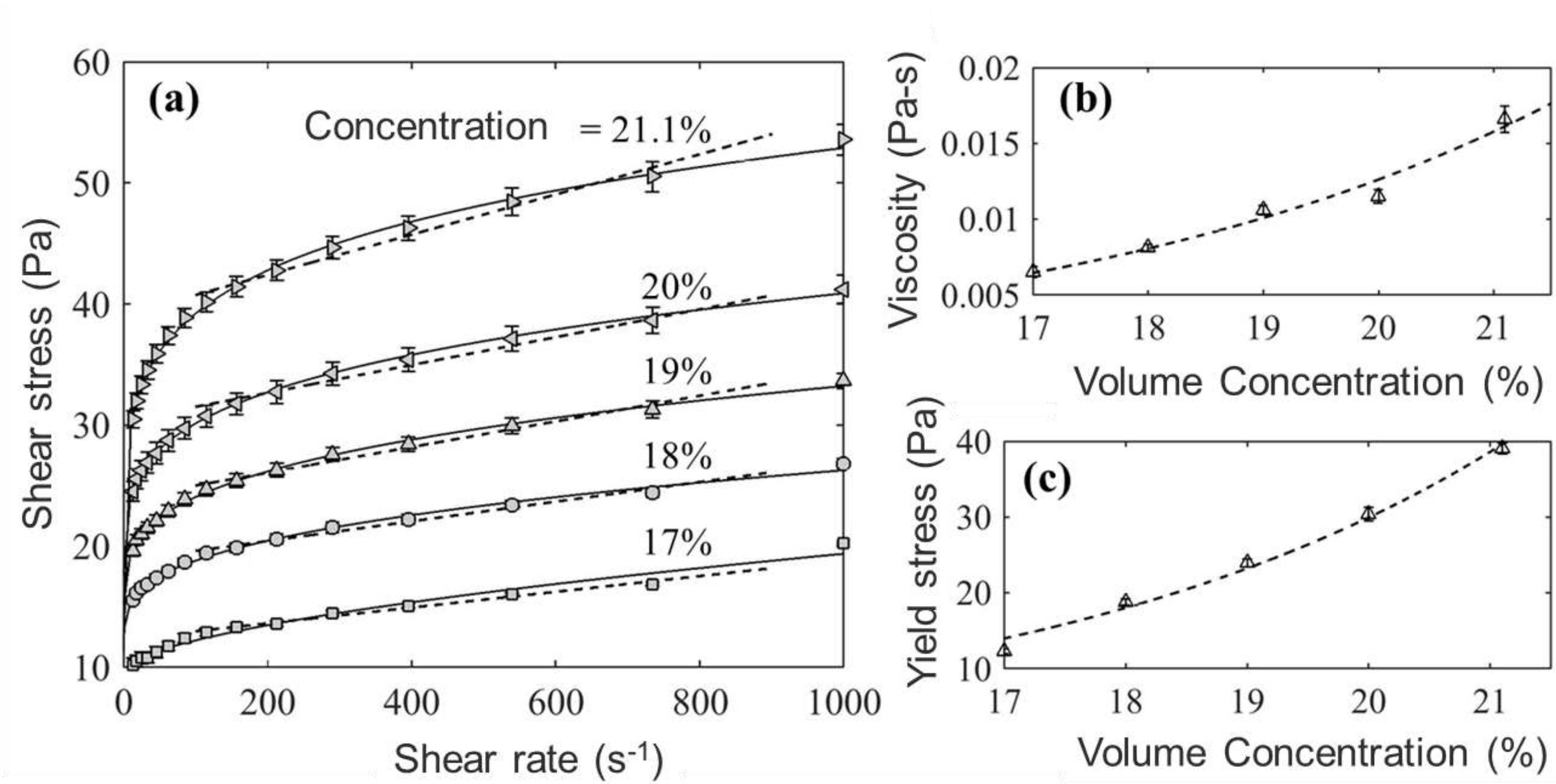
Improved from Matlab Opticalflow toolbox

Slurry Preparation

Kaolinate clay

Rheometer
(R/S SST200 soft solid tester)

Rheometry



Viscoplastic models

$\tau = \tau_y + \mu\dot{\gamma}$

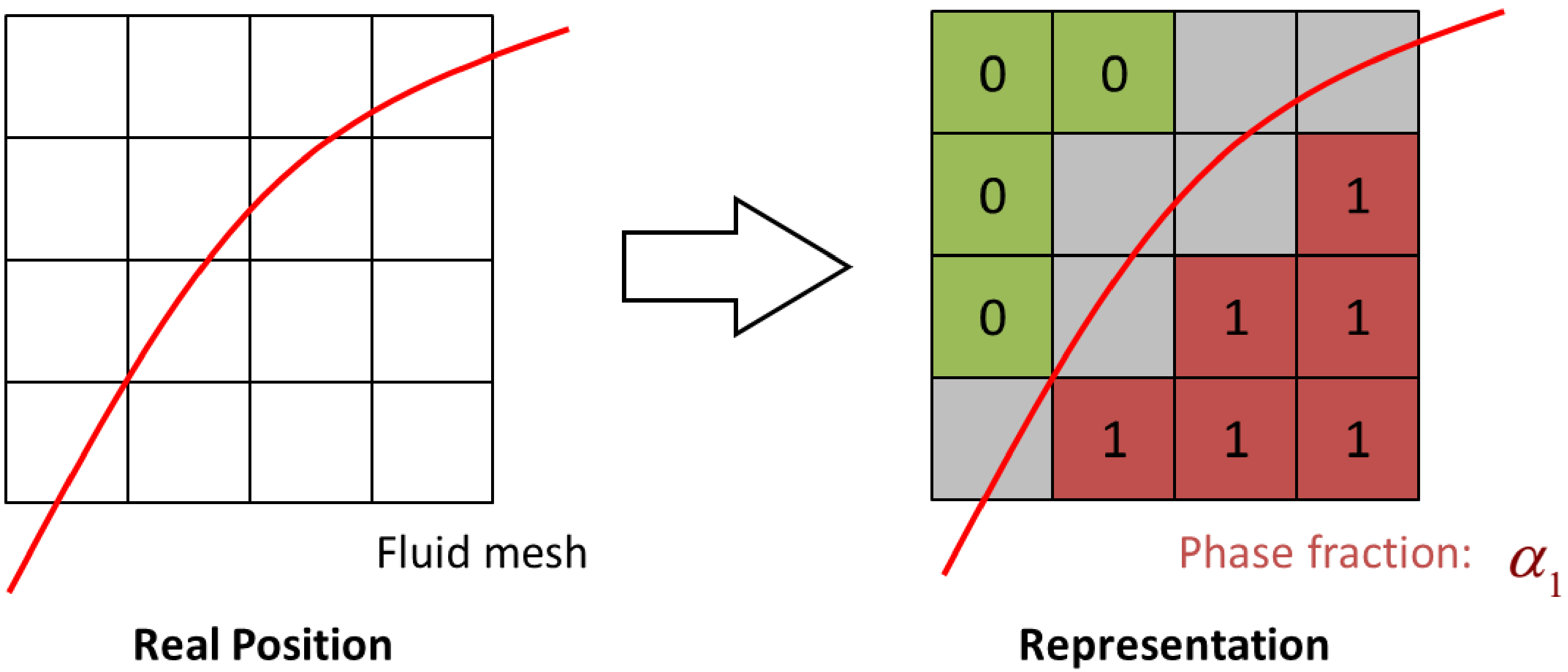
Bingham model

$\tau = \tau_y + K\dot{\gamma}^n$

Herschel-Bulkley model

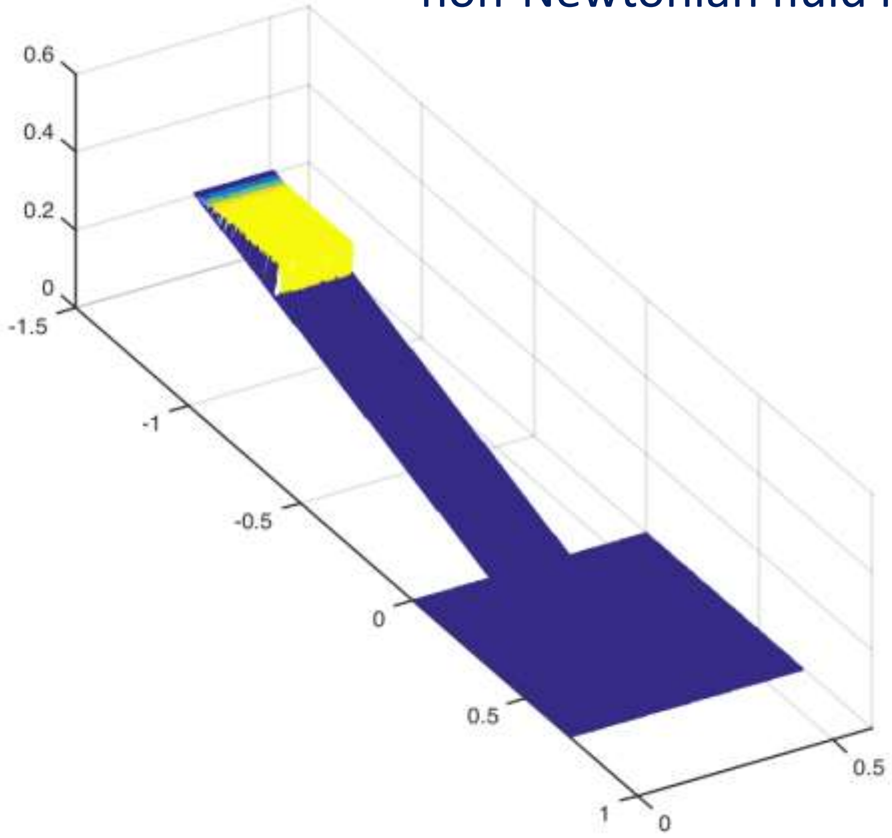
Computational Fluid Dynamics (CFD)

Free-surface Tracking: Volume of Fluid (VOF)



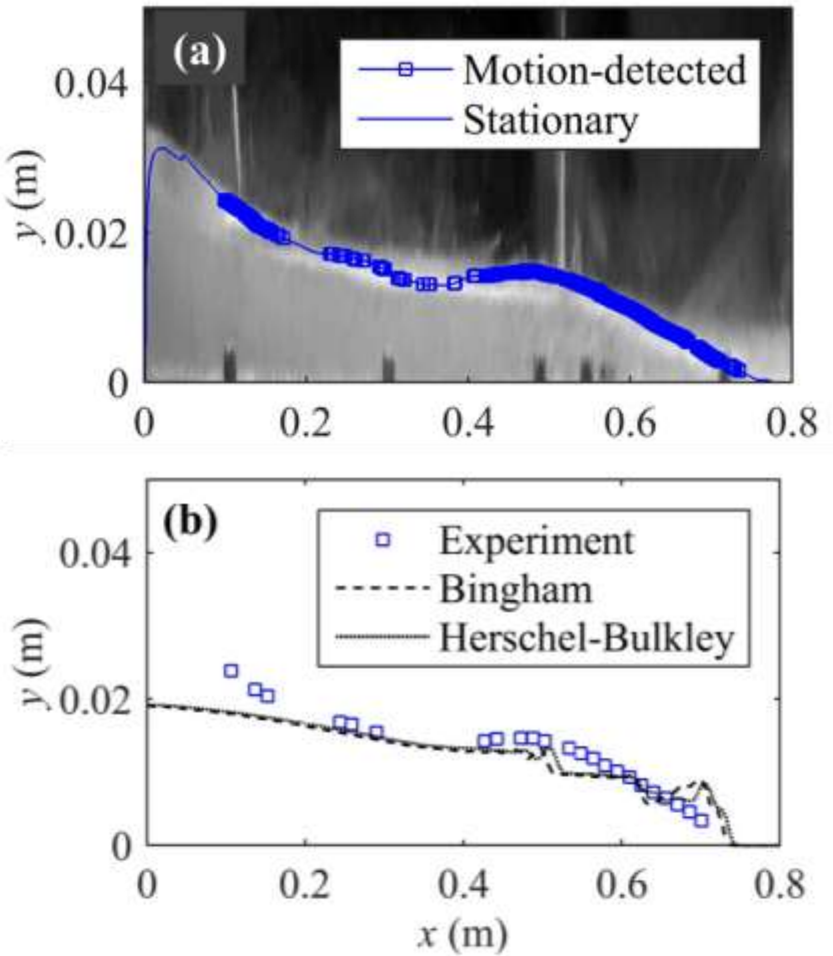
Validation (1)

CFD simulations
- Finite volume scheme
- Free surface tracked by VOF method
- non-Newtonian fluid model (Bingham, HB)

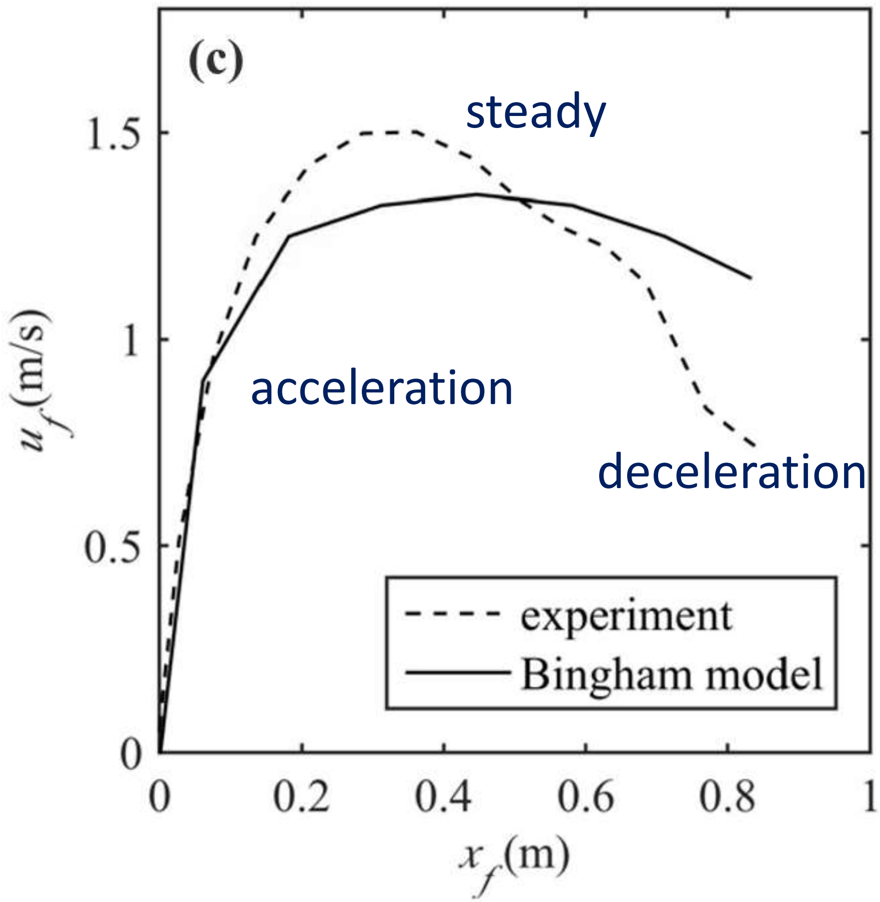


20% slurry

Validation (2)

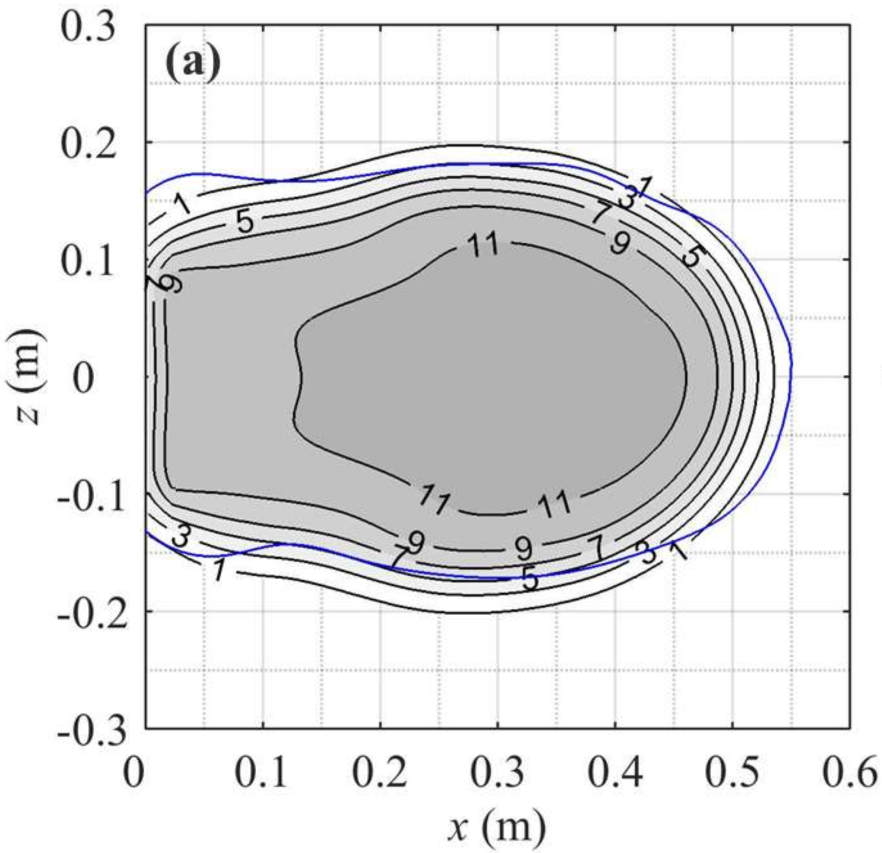


Flow profile (depth)

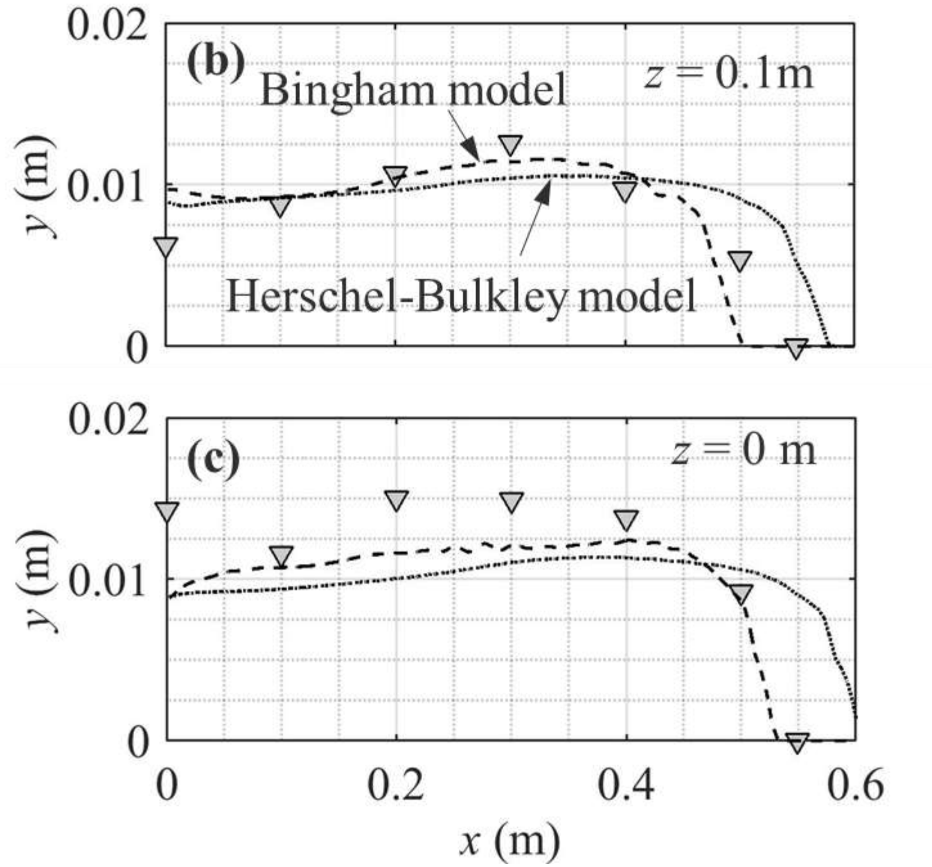


Flow velocity at the front

Validation (3)

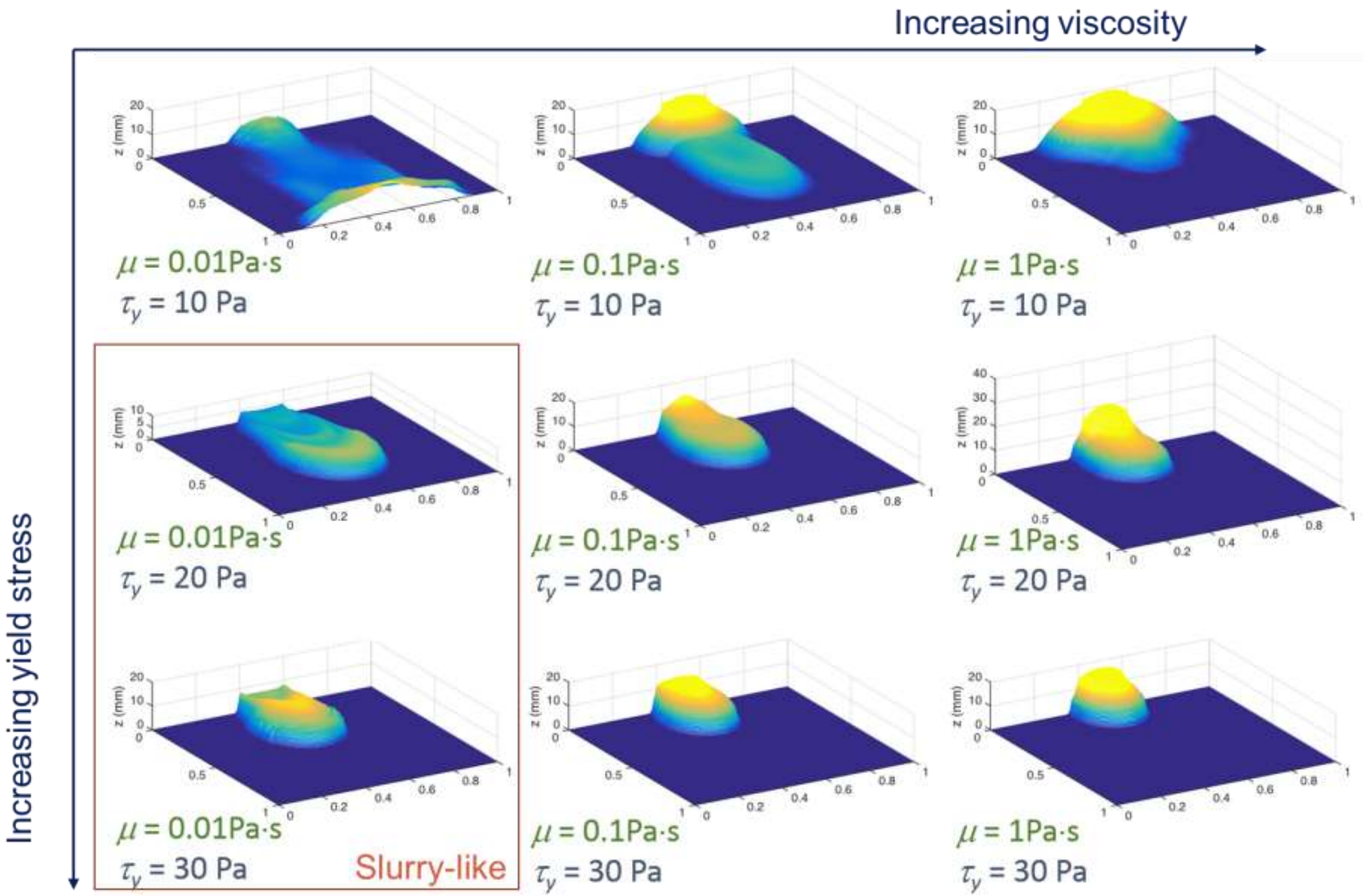


Final deposition: shape

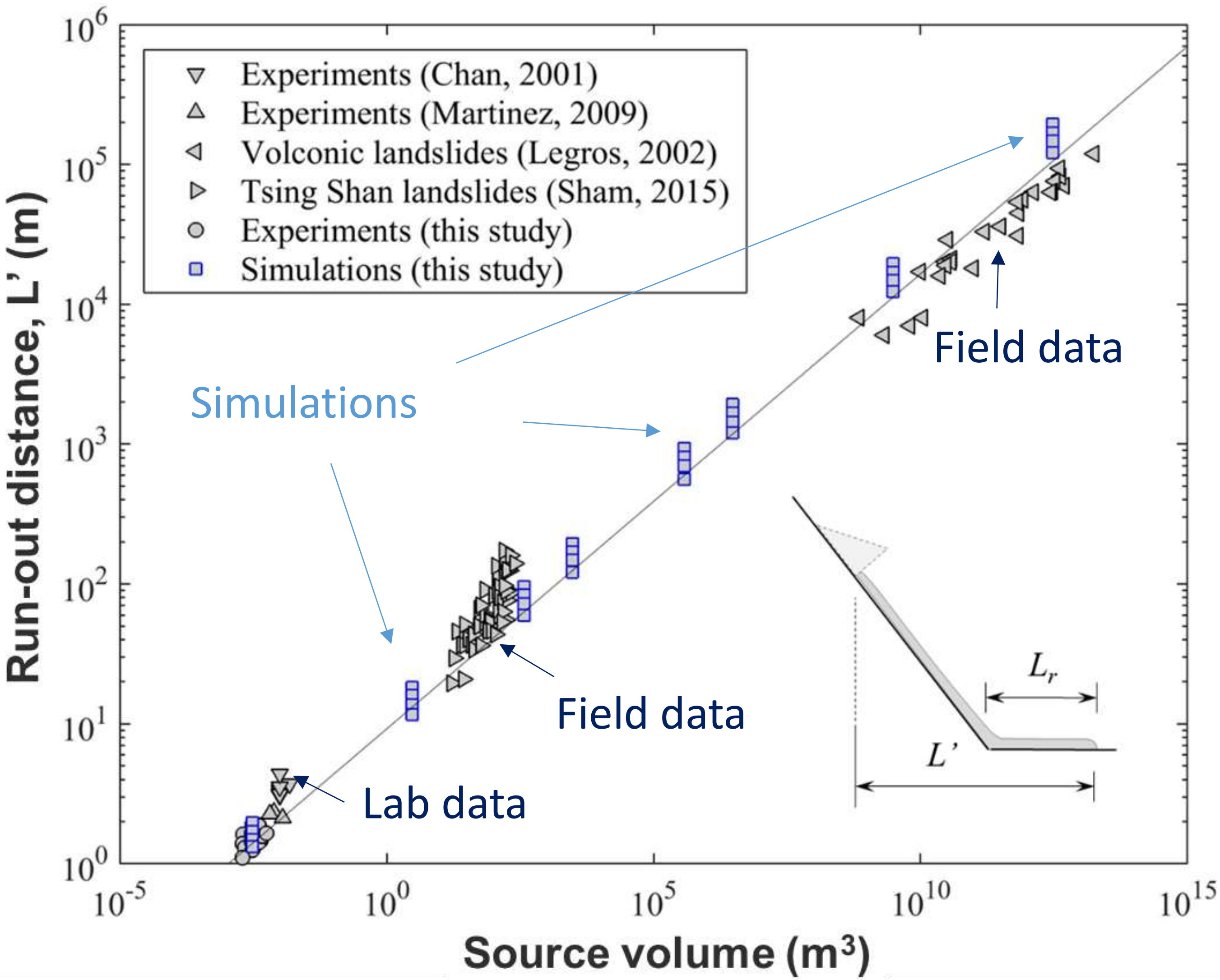


Final deposition: depth

Deposit Morphology



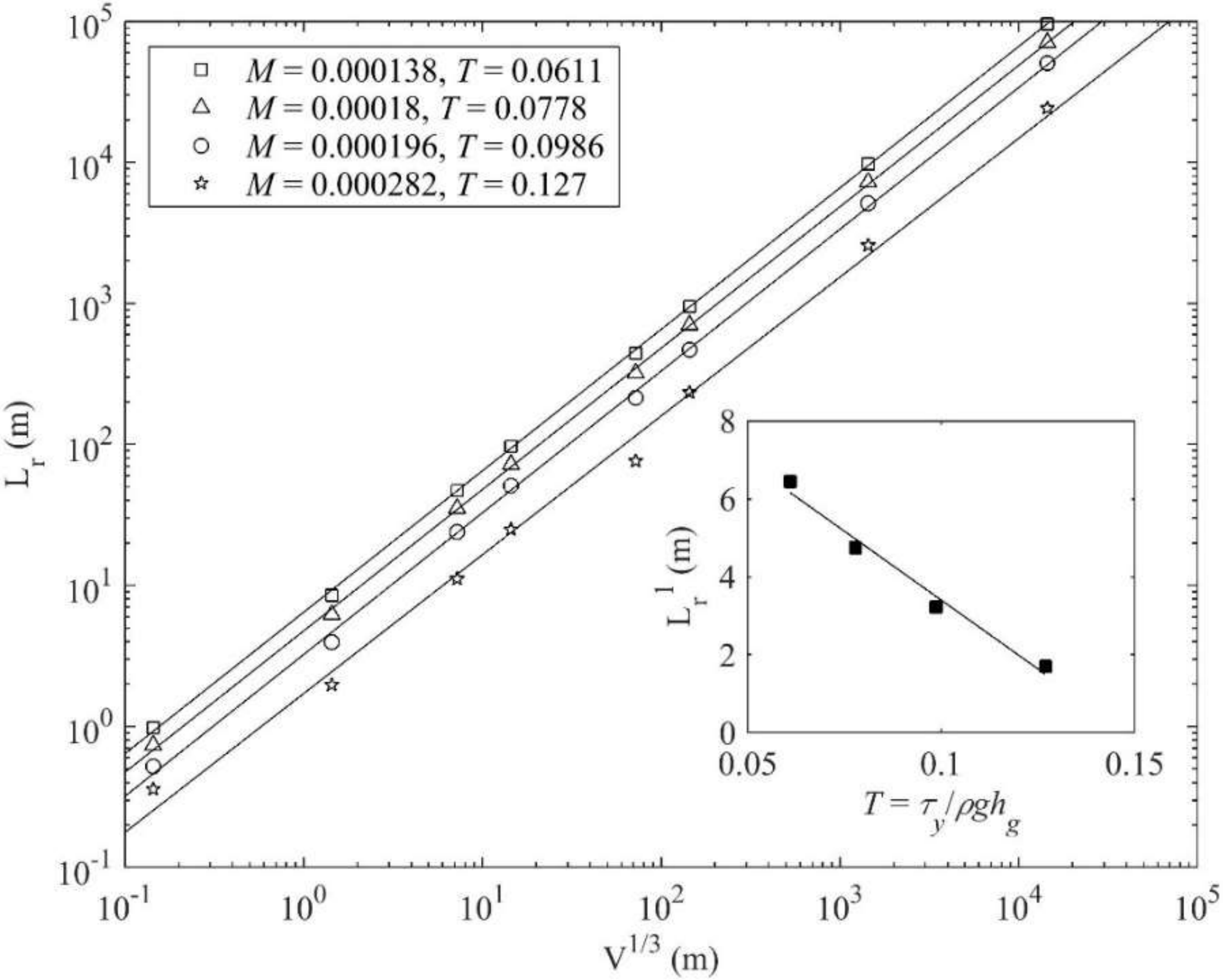
Dynamic Similarity



$\mu \sim H^{3/2}$

$\tau_y \sim H$

A Scaling Law



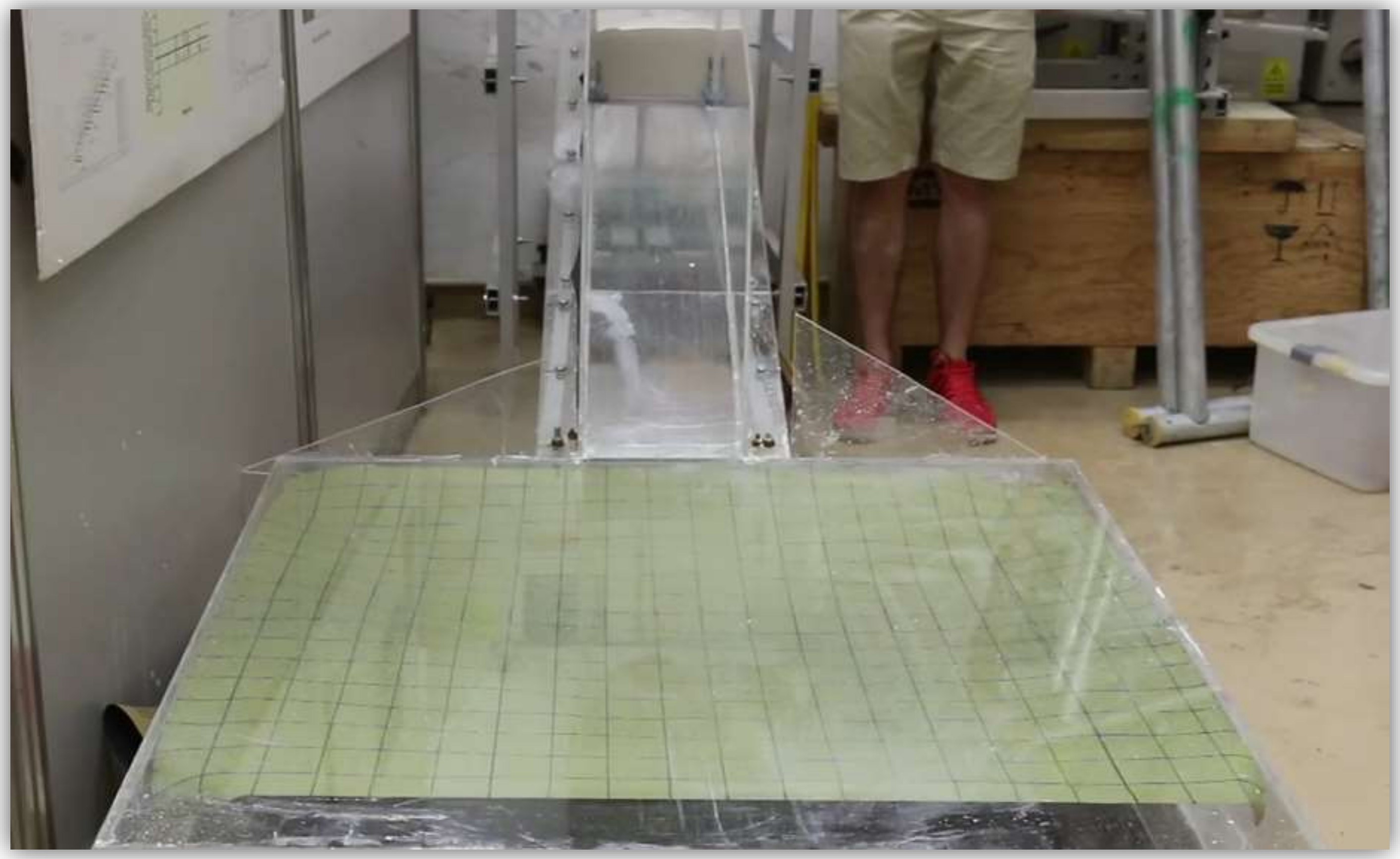
$$M = \mu / \rho \sqrt{g h_g^3}$$

$$T = \tau_y / \rho g h_g$$

$$L_r = \bar{L}(T) V^{1/3}$$

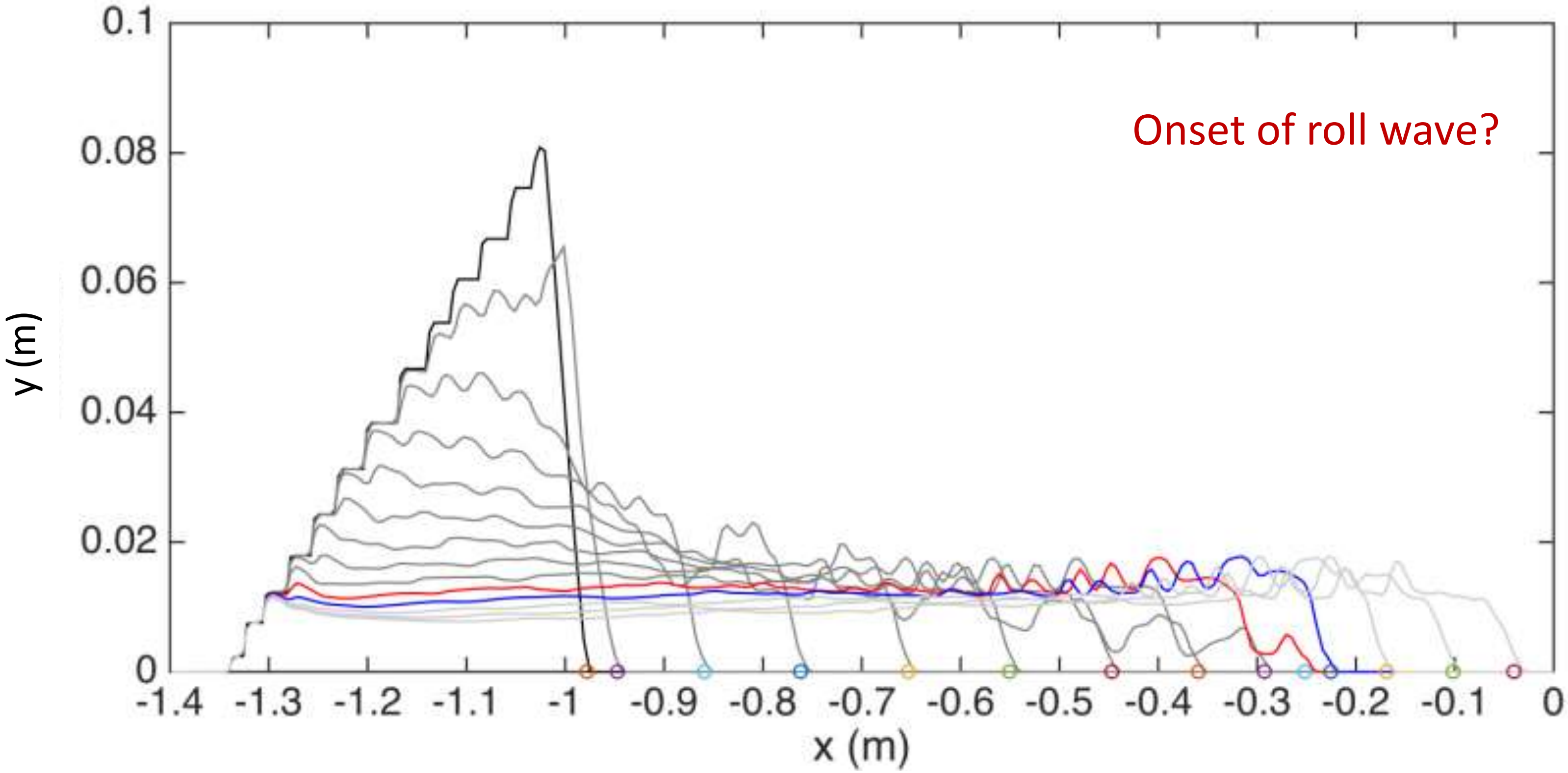
$$L_r = f_1(P) \left(V^{\frac{1}{3}} \right)^{f_2(P)}$$

Future Work



Concentration: 21.1%; Viscosity: ~0.09Pa-s; Yield stress: 36.4Pa; Slope: 18 deg

Future Work



τ_y = 40 Pa, μ = 0.05 Pa-s; 2s

Summary

Deposition of slurry relevant to natural mudflows:

- Fast runout and stoppage due to relatively low viscosity
- Elongated shape due to fast runout
- Remains stuck on the channel and steep edges due to high yield stress

A scaling law

- Has been tested from small-scale lab to large-scale simulation
- Incorporated with rheological parameters

Authors of this work: Jing L, Kwok CY, Leung, YF, Zhang Z, Dai L.