# Simulating Rayleigh-Taylor in a Hele-Shaw Cell

2.29 Final Presentation

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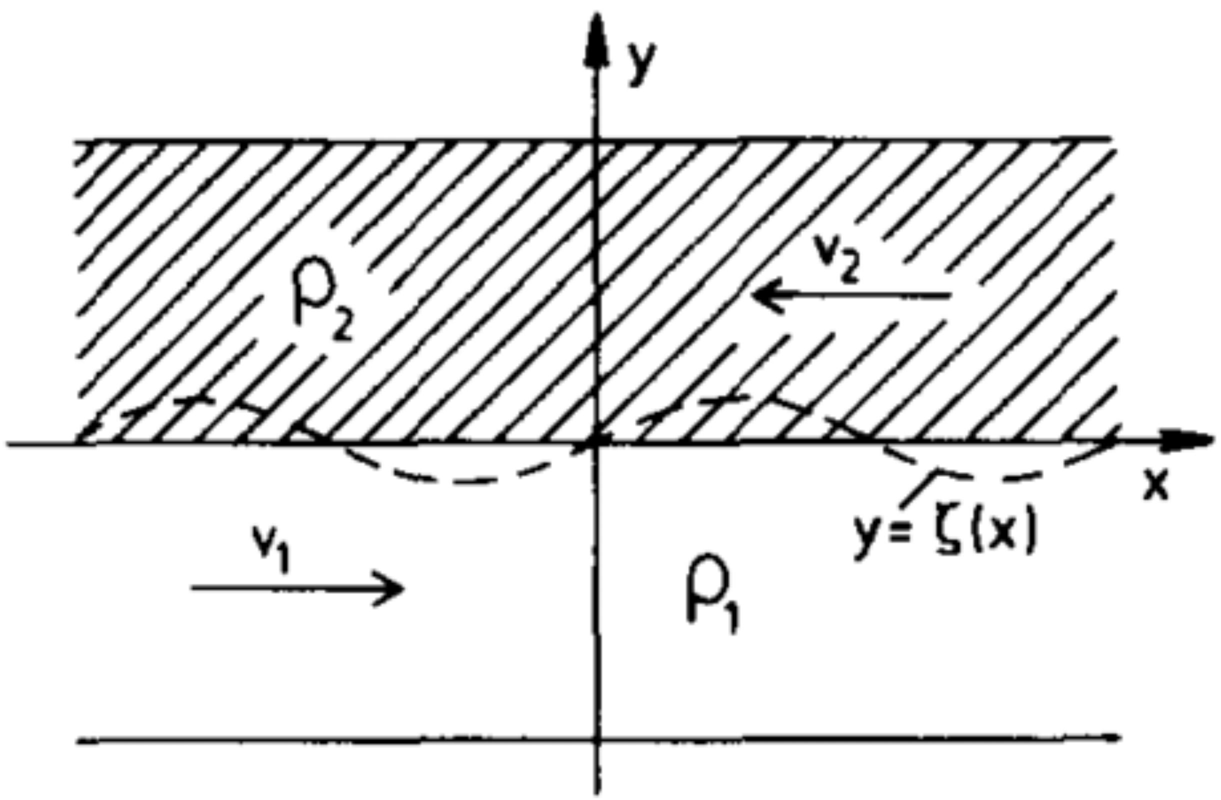
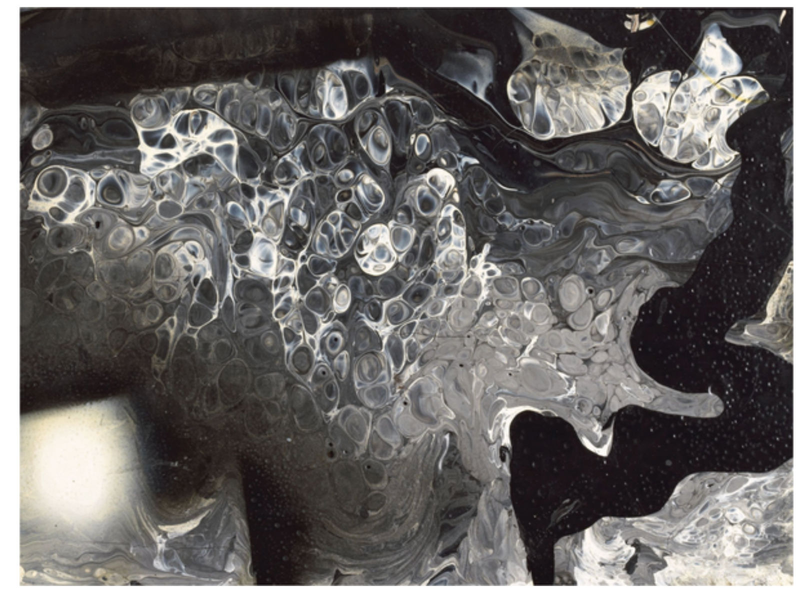
# Outline

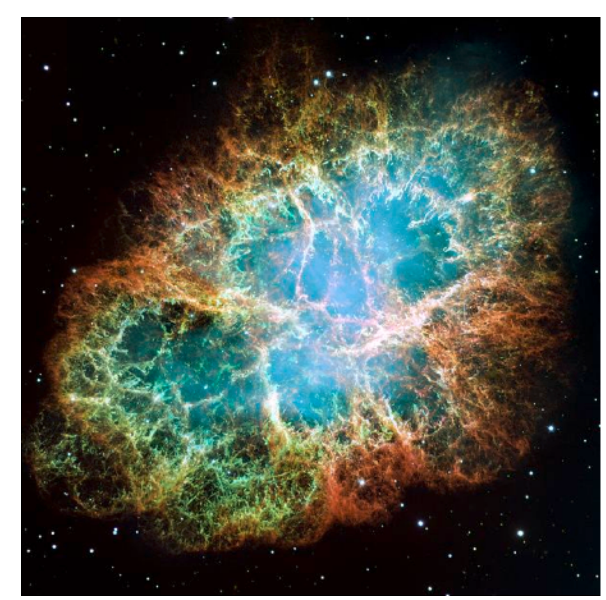
- Rayleigh-Taylor and experimental setup
- Simulation: governing equations, numerical schemes
- Results
  - Instability dynamics
  - Refining mesh
  - Comparing schemes
  - Modeling physics
- Conclusions

# Rayleigh-Taylor instability



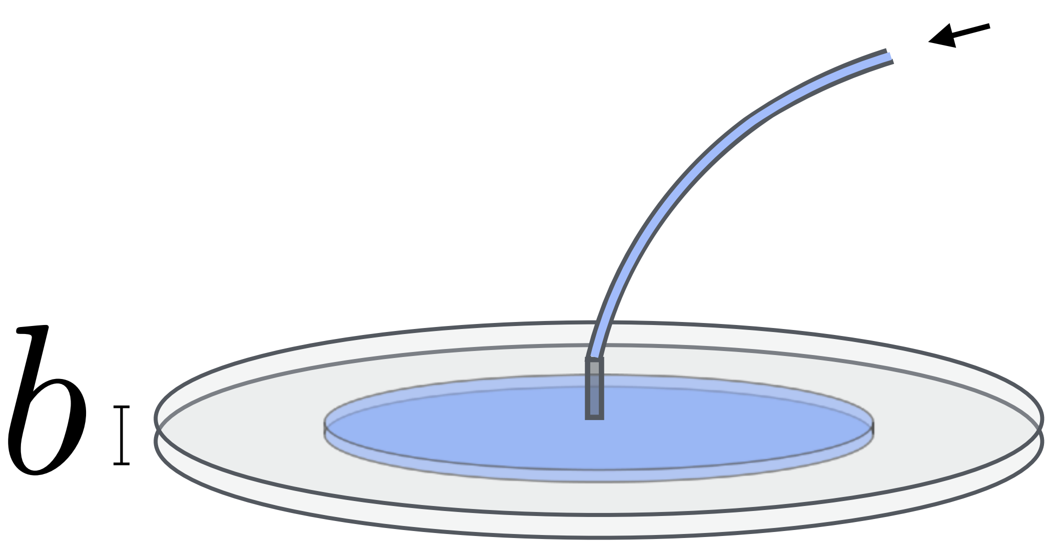
David A. Siqueiros
“accidental painting” technique



expansion of universe

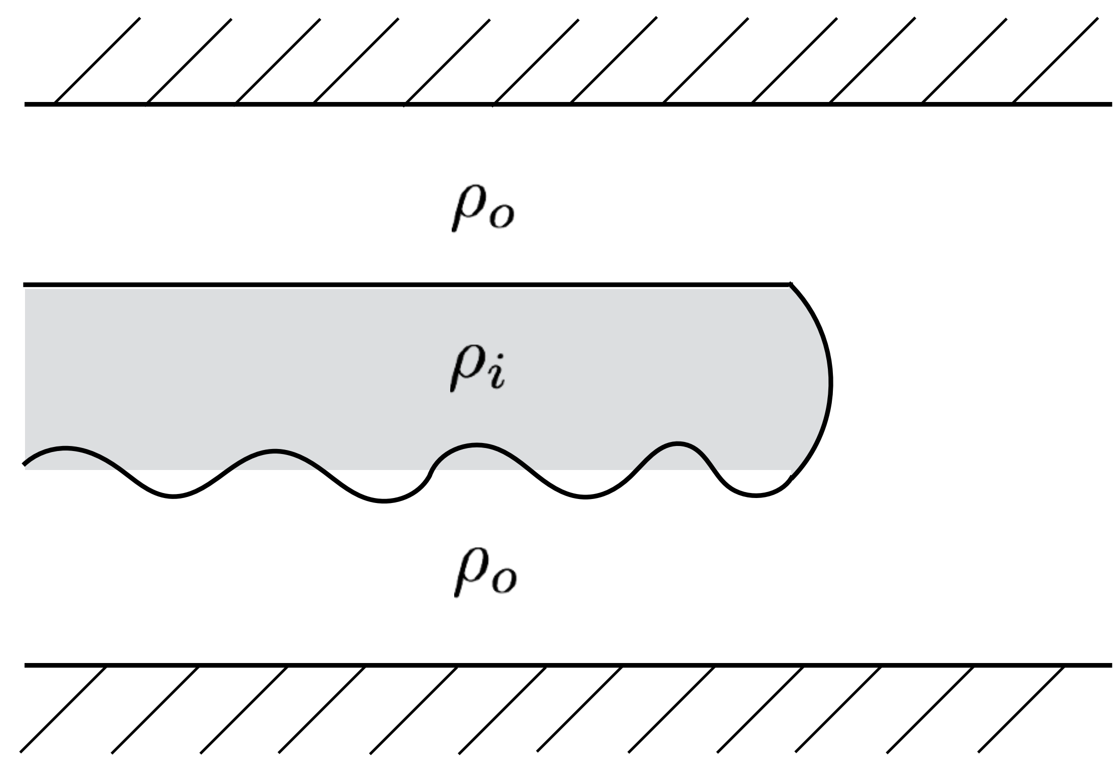
# RT in Hele-Shaw

Experimental setup:
Hele-Shaw cell

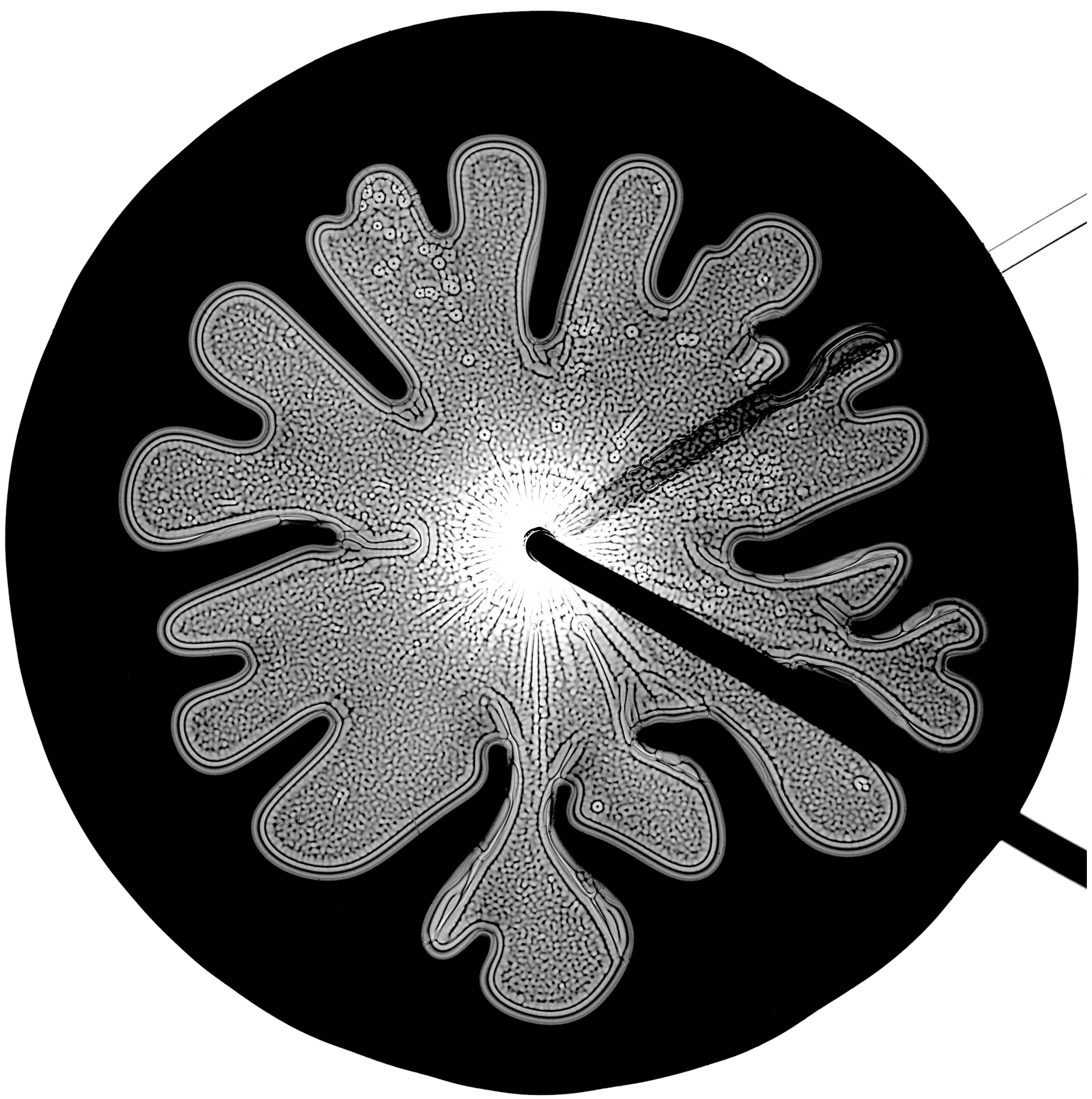


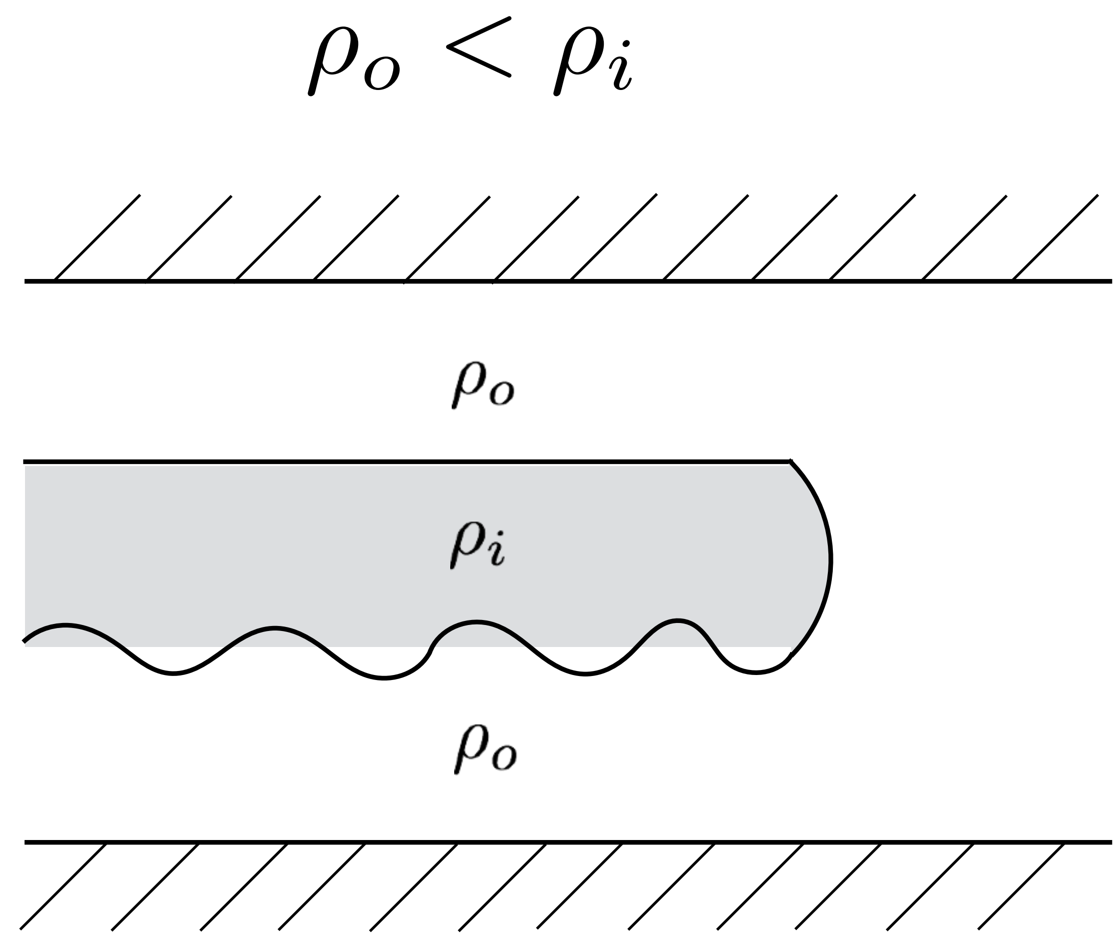

30μm < $b$ < 2500μm

$$\rho_o < \rho_i$$



# RT in Hele-Shaw






*Rayleigh-Taylor instability from top view*

# Governing equations

Navier-Stokes

$$\nabla \cdot (\rho \vec{u}) = 0$$

$$\partial_t u + \nabla \cdot (\vec{v} v) - \nabla \cdot (\nu \nabla \vec{v}) = -\nabla p$$

Transport

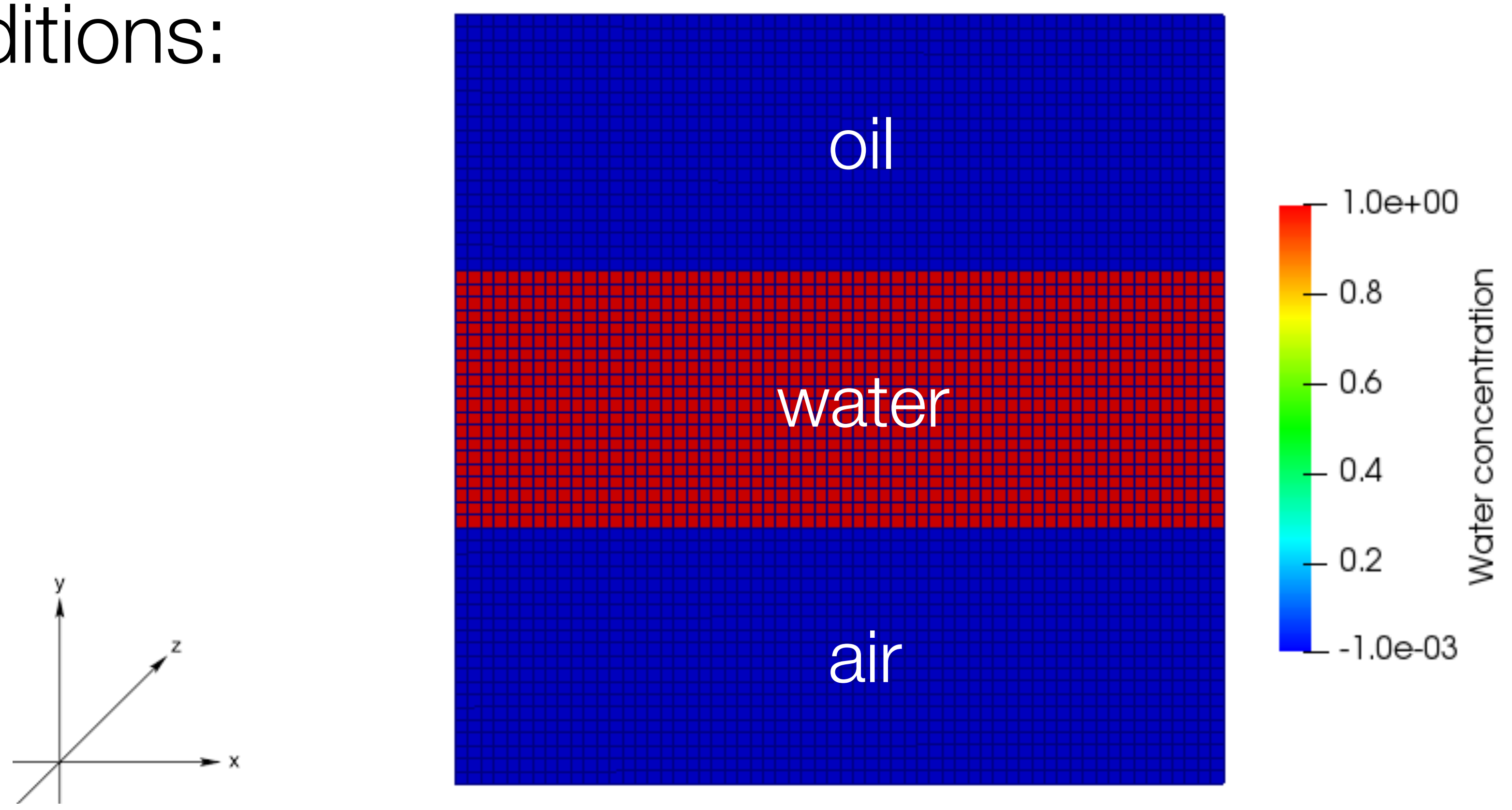
$$\partial_t c + \vec{u} \cdot \nabla c = D \nabla^2 c$$

# Schemes

- used interFoam solver
  - MULES method
- space descritization
  - convection term in momentum equation uses Gaussian quadrature integration with upwind interpolation.
  - the divergence in conservation of mass uses Van Leer
- time-marching
  - Euler, first-order implicit

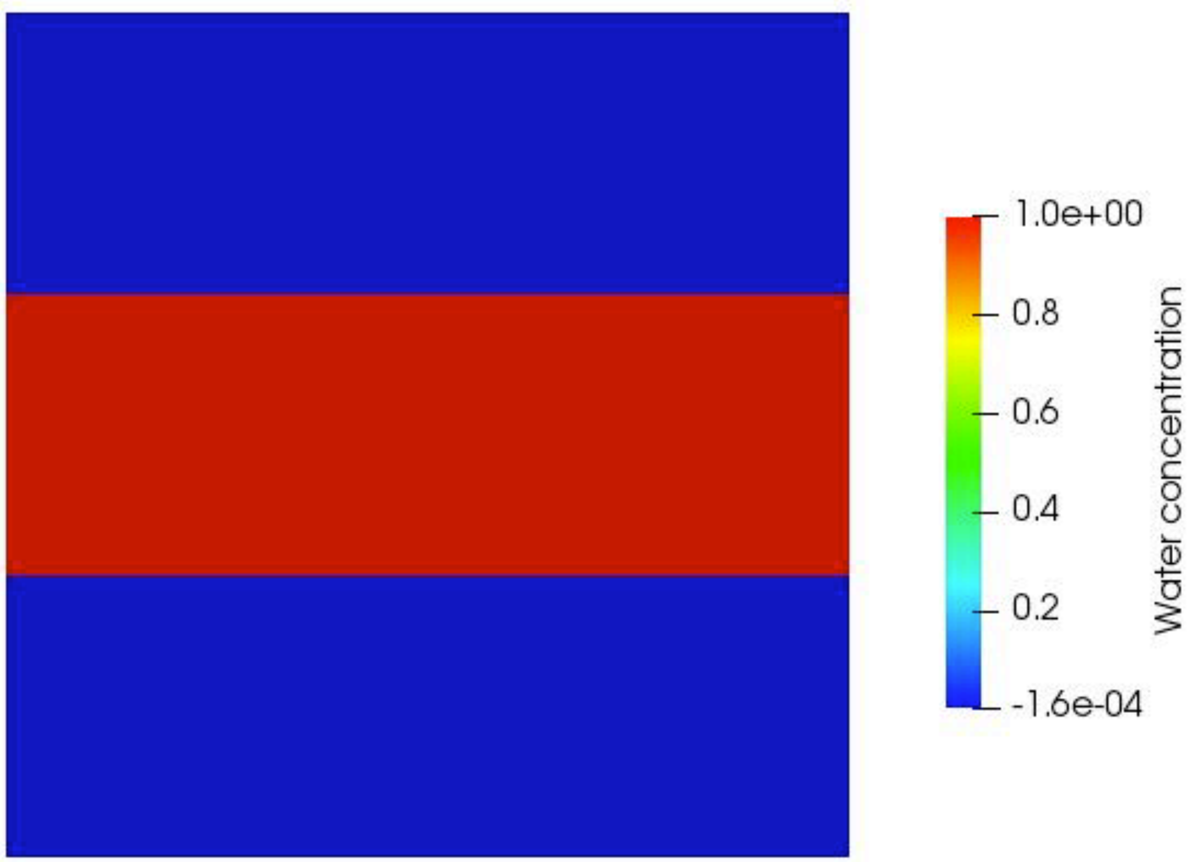
# Simulation

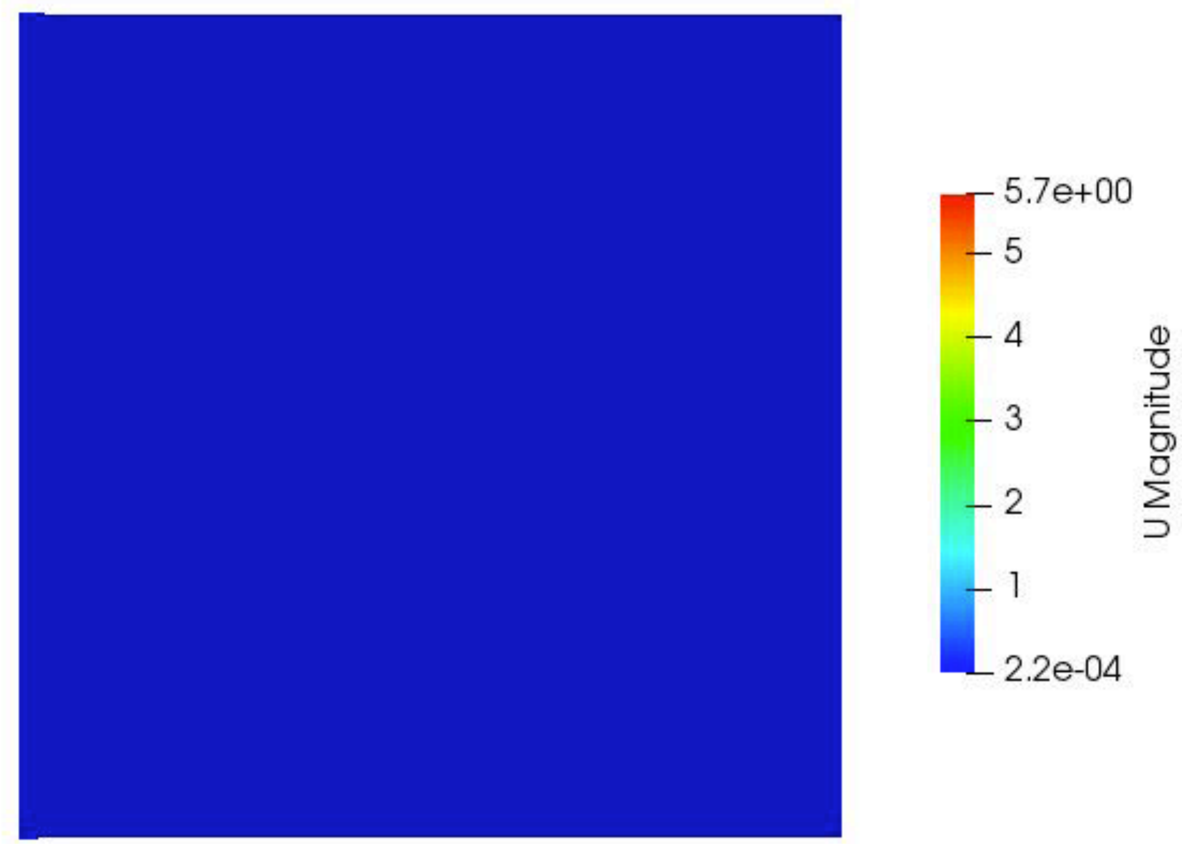
- OpenFOAM interFoam solver using volume of fluid method
- boundary conditions: three solid walls and “atmosphere” on one side
- initial conditions:



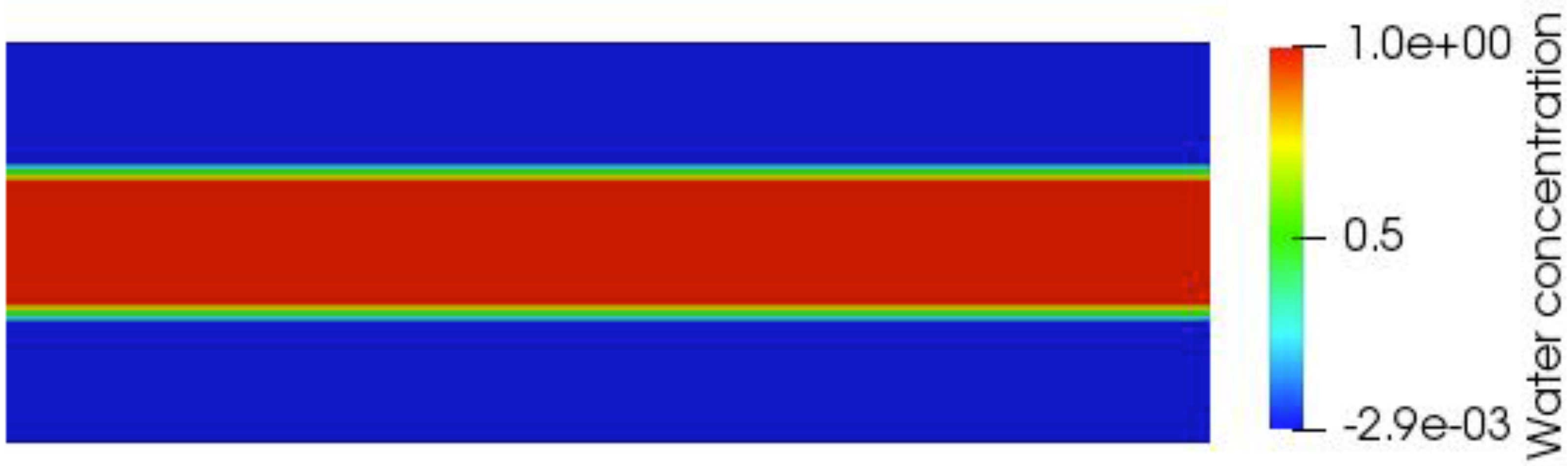
# Results

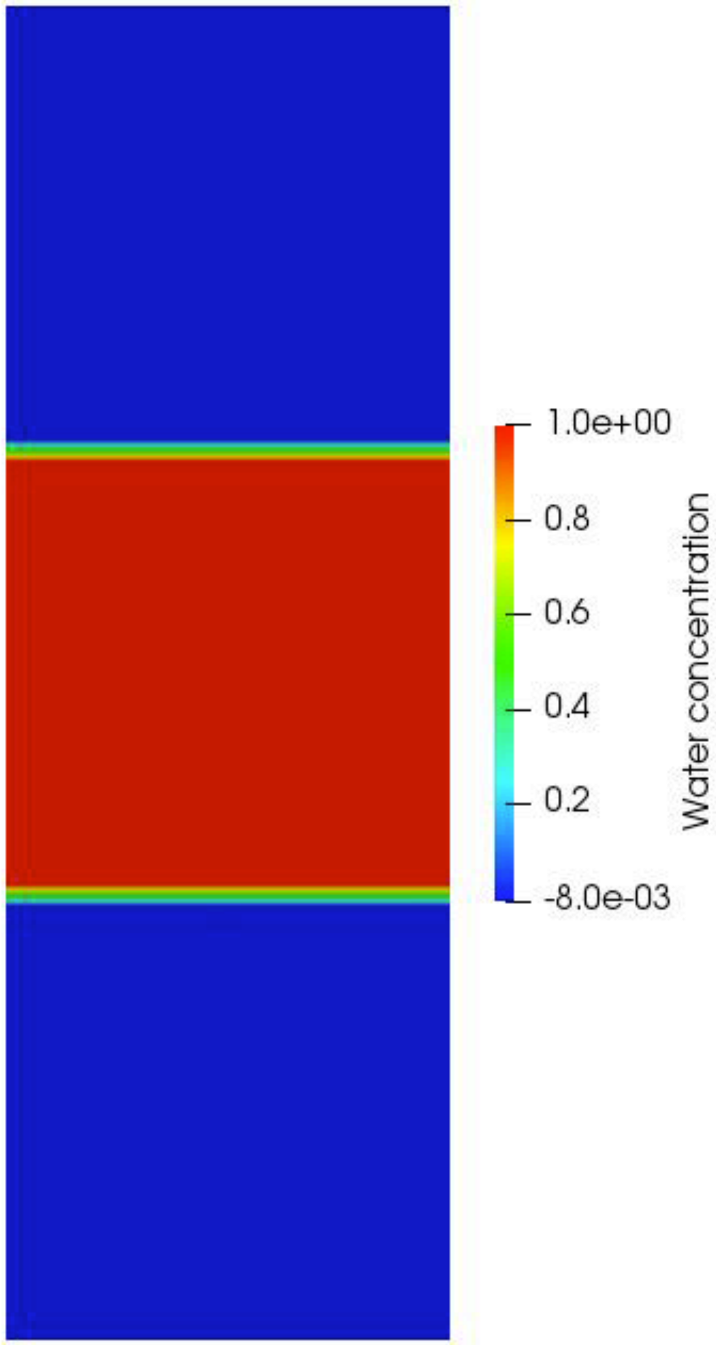
# RT instability dynamics



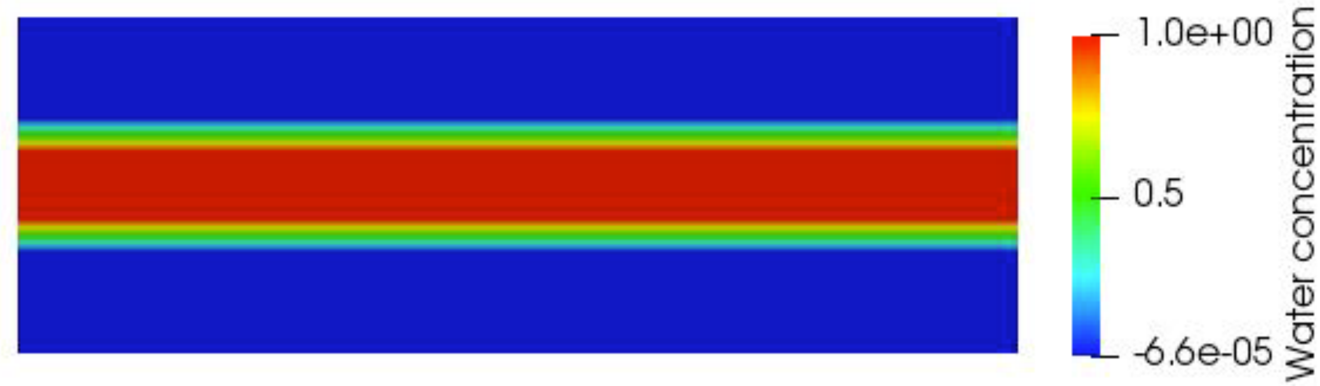



# Changing grid shape

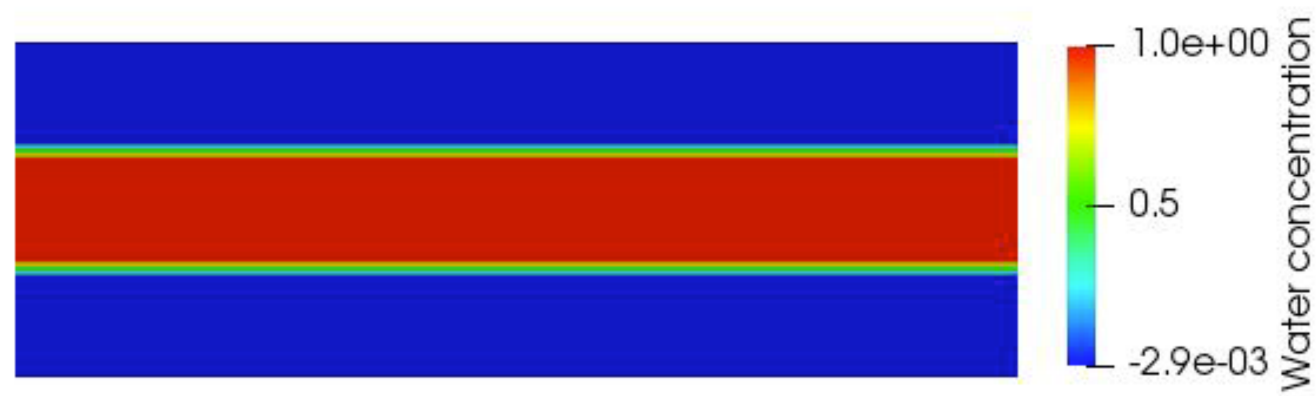


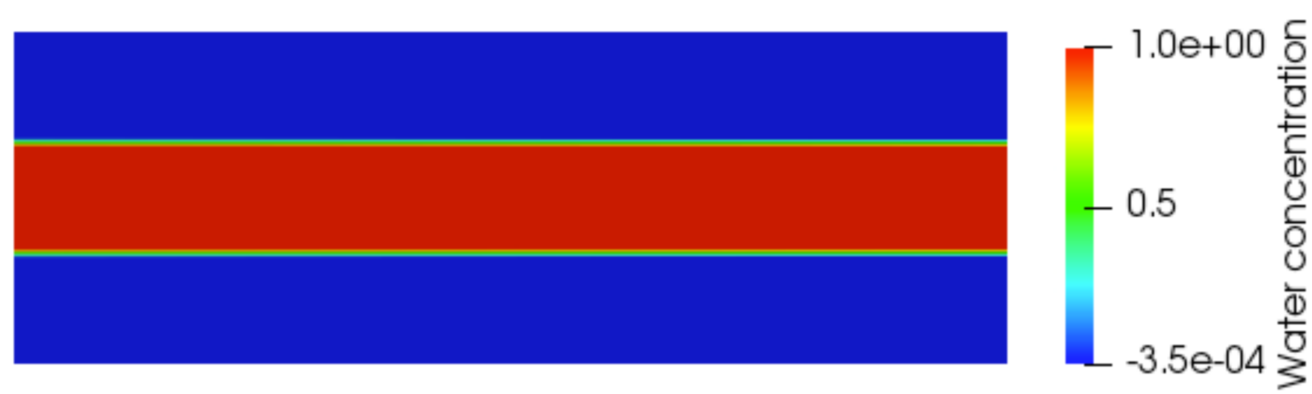
# Changing grid resolution




$$\Delta x = 3\Delta y = 0.005$$
$$t = 32\text{s}$$




$$\Delta x = 3\Delta y = 0.0025$$
$$t = 364\text{s}$$




$$\Delta x = 3\Delta y = 0.001$$
$$t = 2778\text{s}$$

$$\mathcal{O} \sim 2.7$$

# Comparing schemes

- For time-marching, tried:
  - transient, first-order implicit Euler
  - transient, second-order implicit Euler
  - transient, second-order implicit Crank-Nicolson
    - pure (1)
    - off-centered (0.9 CN; 0.1 Euler)

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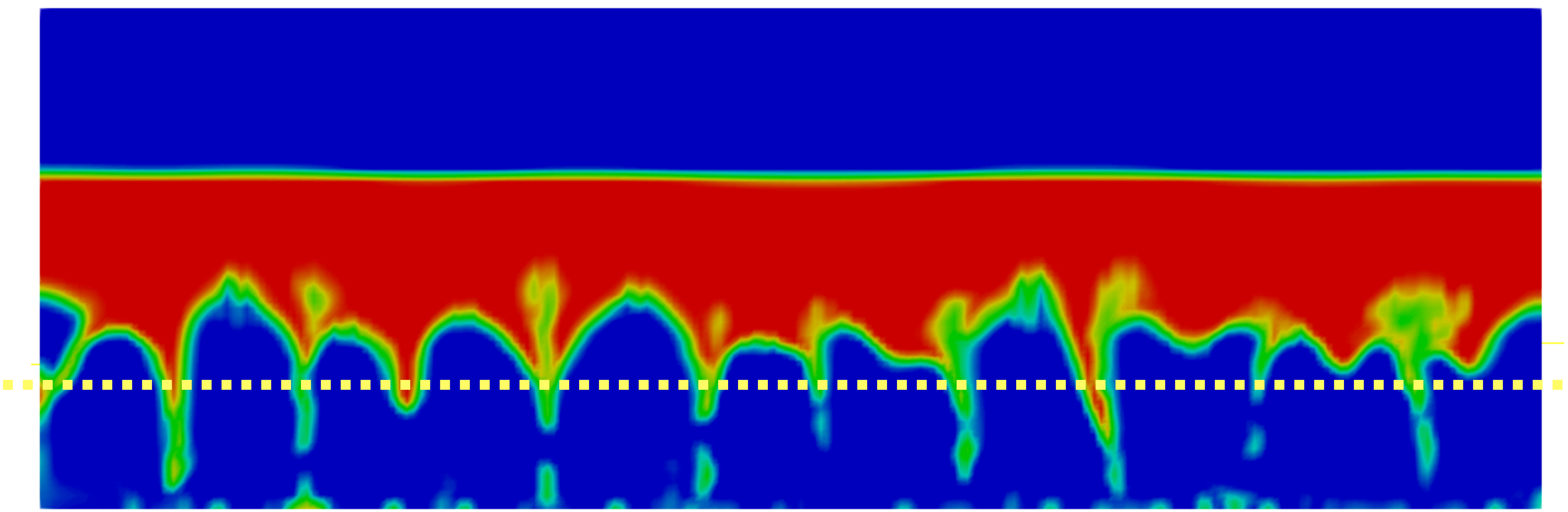
# Modeling the physics

# Wavelength info



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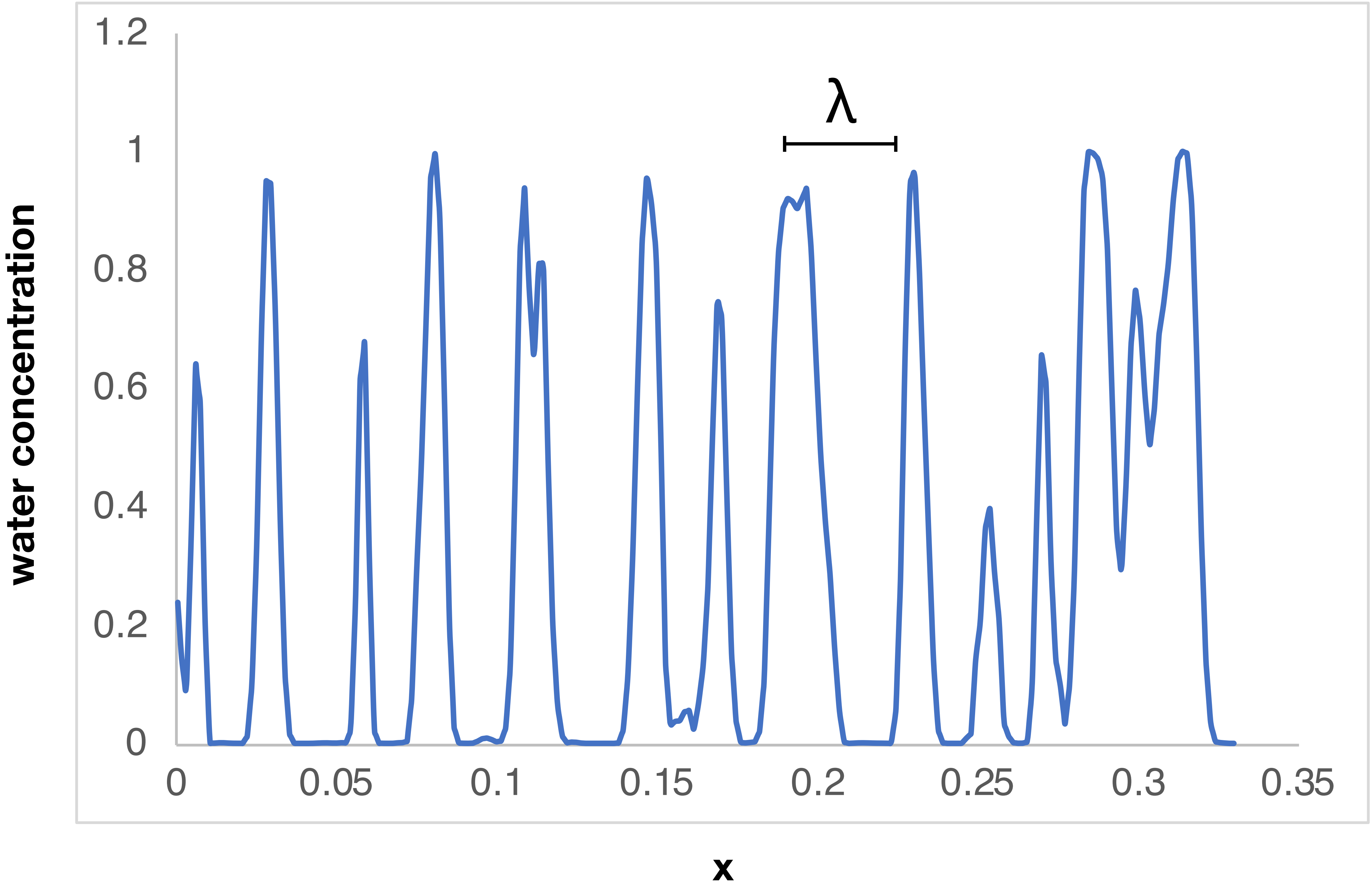

# Conclusions

- OpenFOAM is a powerful tool for fluids simulations and analysis, allowing a lot of user-modification and flexibility (albeit still requires some “coding”)
- simulation depicts Rayleigh-Taylor dynamics in a confined geometry and effects of scale
- first-order backward Euler is most stable scheme
- Future work:
    - change boundary conditions and compare simulation results to experimental data