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Algebraic momentum preserving method with a fully-coupled 3D solver

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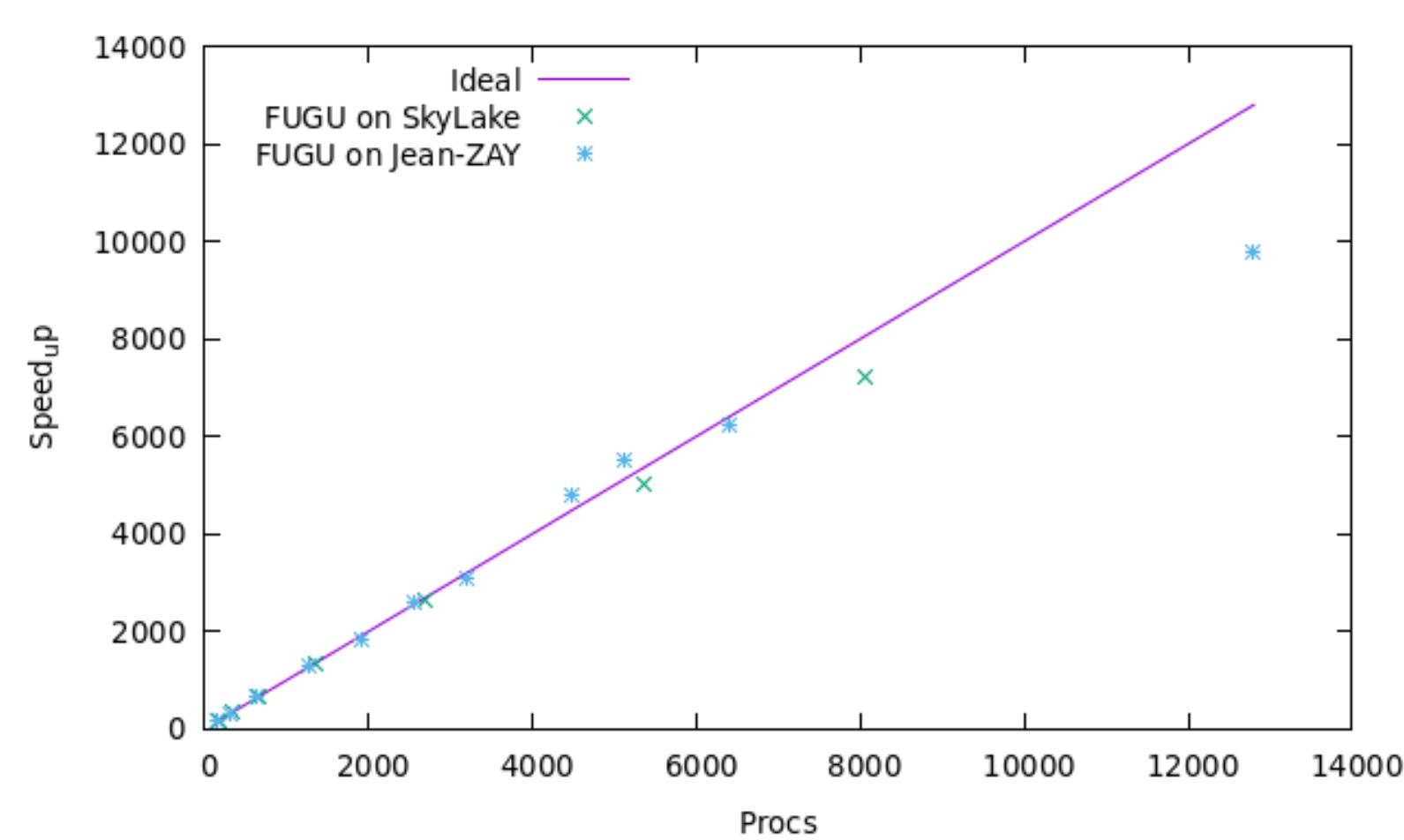
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PROBLEM

Investigate the accuracy and robustness of Fully-coupled 3D parallel solver for incompressible two phase flows at large density and viscosity ratios.

NUMERICAL METHODS

- Finite-Volumes on staggered grids.
- Fully-coupled solver for Pressure / Velocity coupling.
- Penalty methods.
- Conservative VOF method.
- MPI based parallelizations.



MATHEMATICAL MODEL

$$\frac{\partial \rho \mathbf{u}}{\partial t} + \nabla \cdot (\rho \mathbf{u} \otimes \mathbf{u}) = -\nabla p + \nabla \cdot [\mu (\nabla \mathbf{u} + \nabla \mathbf{u}^T)] + \mathbf{f} \Rightarrow \text{Conservation of momentum}$$

$$\nabla \cdot \mathbf{u} = 0 \Rightarrow \text{Mass conservation}$$

$$\frac{\partial C}{\partial t} + \nabla \cdot (\mathbf{u} C) = C \nabla \cdot \mathbf{u} \Rightarrow \text{Advection of volume fraction}$$

$$\mu = \mu_1 C + (1 - C) \mu_2 \Rightarrow \text{Mixture viscosity}$$

$$\frac{\partial \phi}{\partial t} + \nabla \cdot (\phi \mathbf{u}) = 0 \Rightarrow \text{Algebraic Momentum Preserving (AMP)} (\phi = \rho, \phi = \rho \mathbf{u}) [1]$$

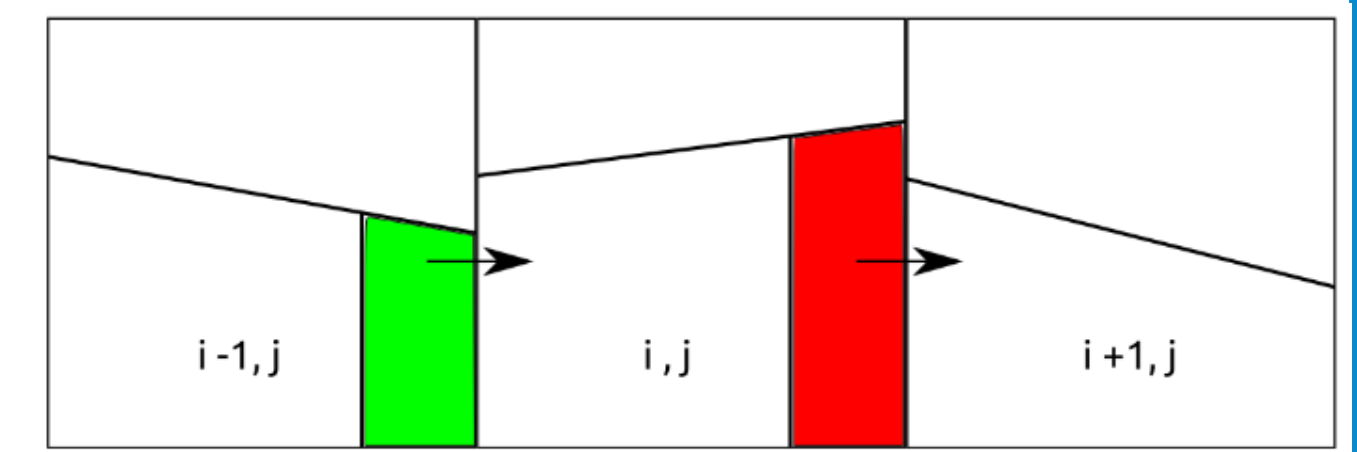
Fully coupled solver [2]

$$\begin{pmatrix} M_u^{(\rho)} + L_u^{(\mu)} & B_p^T \\ B_u & 0 \end{pmatrix} \begin{pmatrix} \mathbf{u}^{n+1} \\ p^{n+1} \end{pmatrix} = \begin{pmatrix} \mathbf{g} \\ 0 \end{pmatrix} \text{ or } \mathbf{Ax} = \mathbf{b}$$

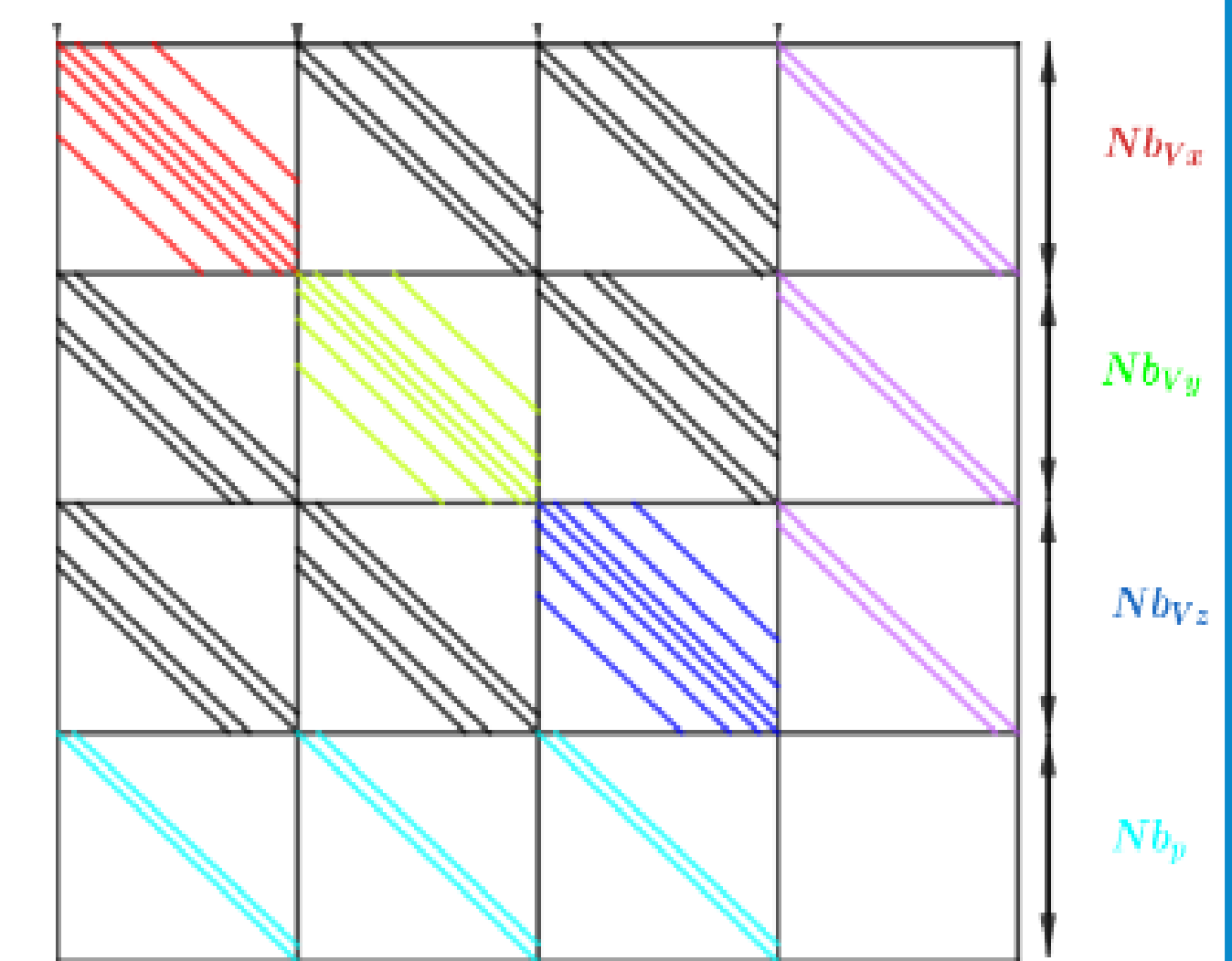
Transforming the original system $\mathbf{Ax} = \mathbf{b}$ into an equivalent one $\mathbf{P}^{-1} \mathbf{Ax} = \mathbf{P}^{-1} \mathbf{b}$.

$$\mathbf{P} \approx \begin{pmatrix} \hat{\mathbf{F}}_u & B_p^T \\ 0 & \hat{\mathbf{S}}_p \end{pmatrix}$$

$\hat{\mathbf{F}}_u$ by Neumann series expansion and $\hat{\mathbf{S}}_p$ by the PCD operator [3]



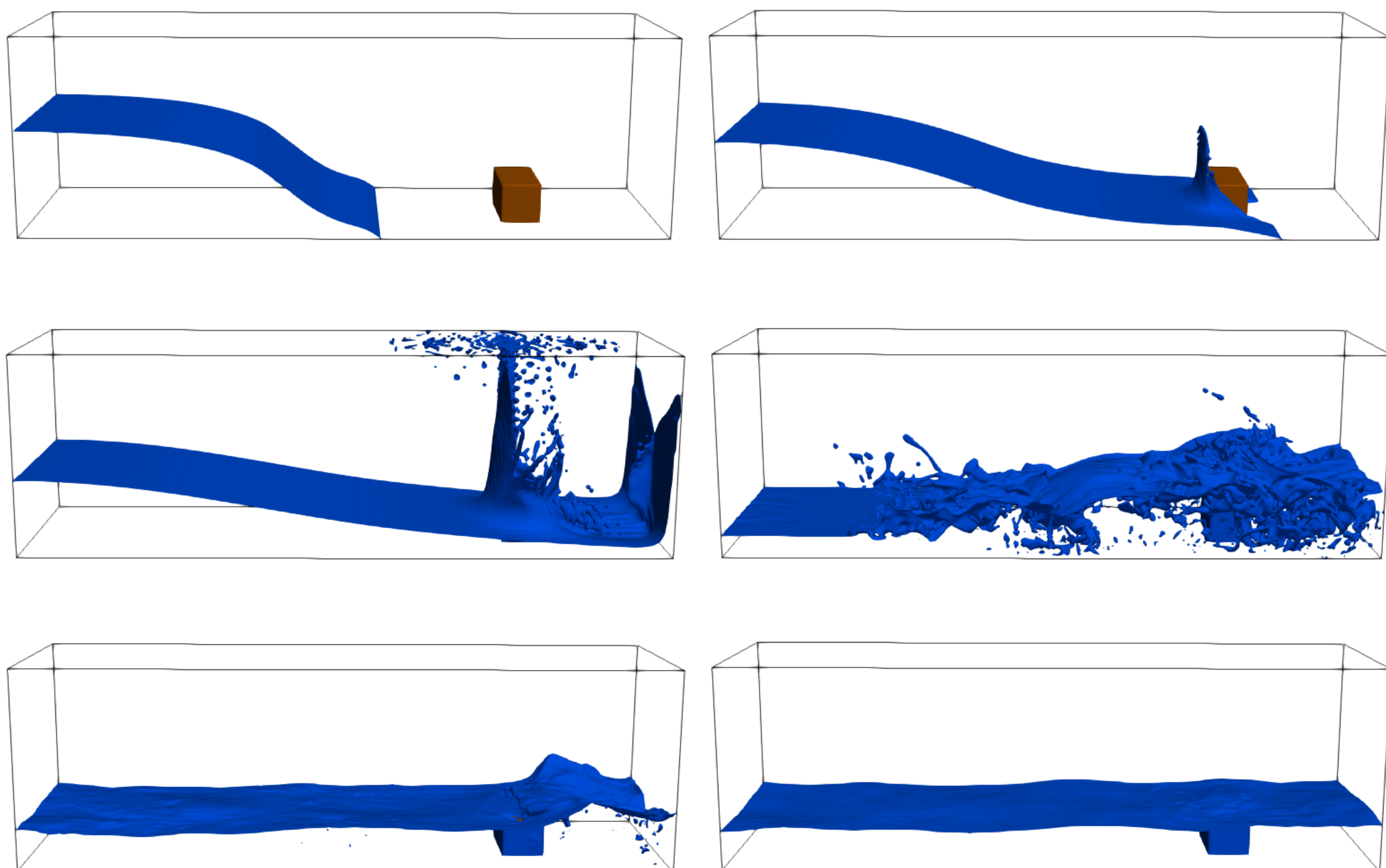
Eulerian Implicit (WY) in 2D



Matrix Structure

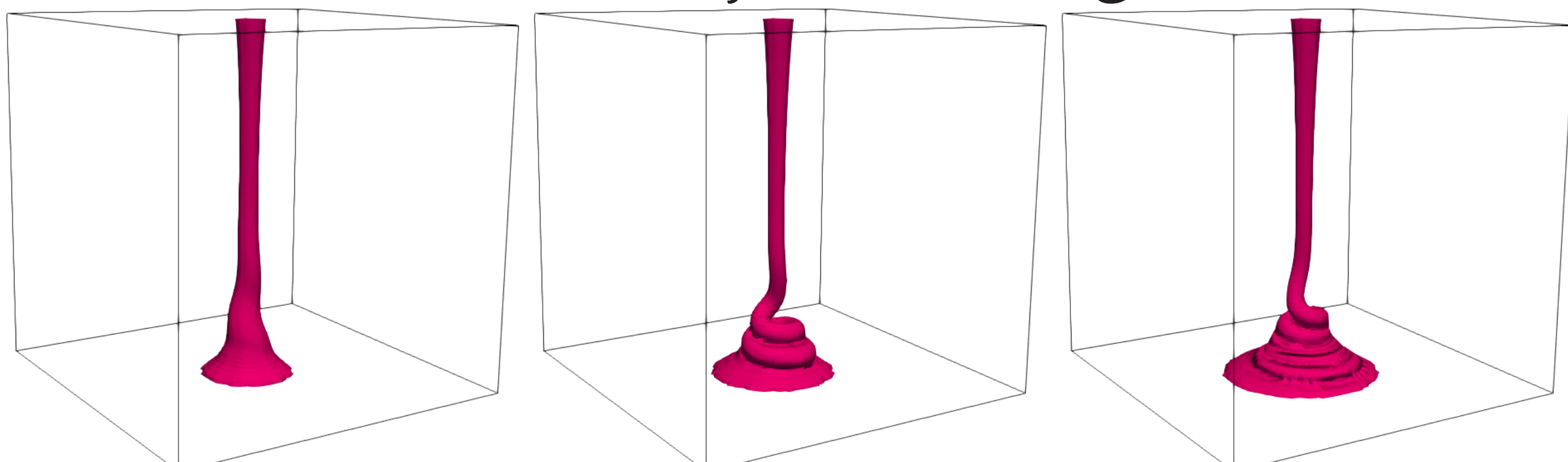
RESULTS

Dam-Break Flow with obstacle



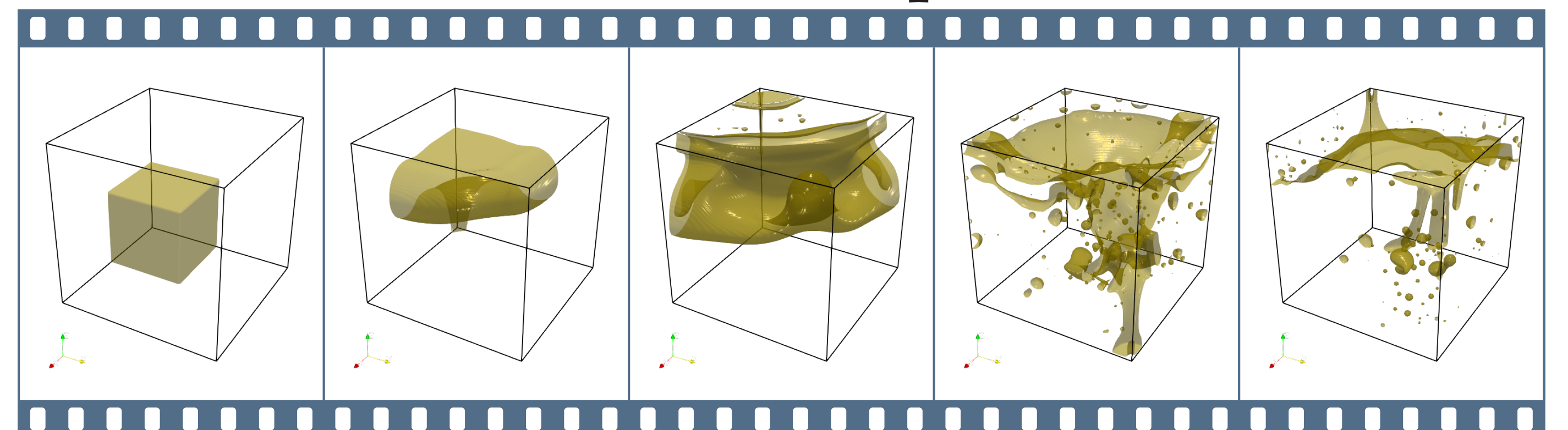
Changing the air/water interface for different times. (Mesh: $322 \times 100 \times 100$, CFL=0.4.)

Viscous jet buckling



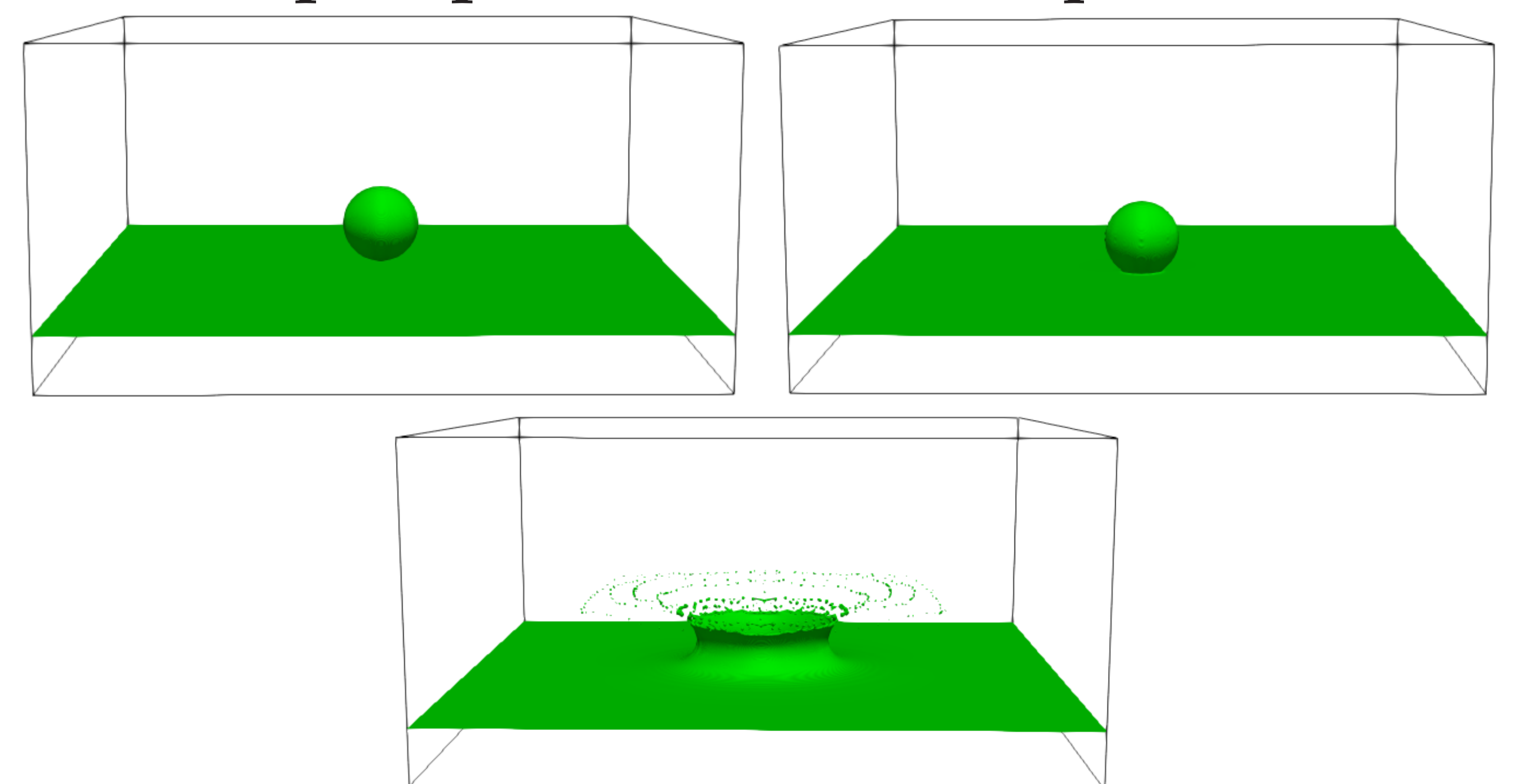
Propergol/air interface for different times. Mesh 120^3 refined at the injector. The aspect ratios of $H/D > 3\pi$ and $Re < 0.52$.

Phase inversion problem



Oil/water interface over time. Mesh 256^3 . HPC DNS calculations ≈ 12800 processors of the HPC Occigen cluster for CINES.

Drop impact on viscous liquid film



Impact of water droplet on a liquid film. Crown formation and delayed splashing. (Mesh: $1024 \times 1024 \times 512$, CFL=0.4). HPC DNS calculations ≈ 8000 processors of the HPC Jean Zay cluster of IDRIS.

ACKNOWLEDGMENT

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REFERENCES

- [1] N. Nangia et al. A robust incompressible navier-stokes solver for high density ratio multiphase flows. *Journal of Computational Physics* 2019.
- [2] M. El Ouafa et al. Navier-stokes solvers for incompressible single- and two-phase flows. *Communications in Computational Physics*, 2021.
- [3] N. Bootland et al. Preconditioners for Two-Phase Incompressible Navier-Stokes Flow. *SIAM Journal on Scientific Computing*, 2019.