



**HAL**  
open science

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

Mohamed El Ouafa, Stéphane Vincent, Vincent Le Chenadec, Benoît Trouette

► **To cite this version:**

Mohamed El Ouafa, Stéphane Vincent, Vincent Le Chenadec, Benoît Trouette. Algebraic momentum preserving method with a fully-coupled 3D solver. 4th International Conference on Numerical Methods in Multiphase Flows (ICNMMF), Sep 2022, Venice, Italy. hal-04079984

**HAL Id: hal-04079984**

**<https://hal.science/hal-04079984v1>**

Submitted on 24 Apr 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Public Domain

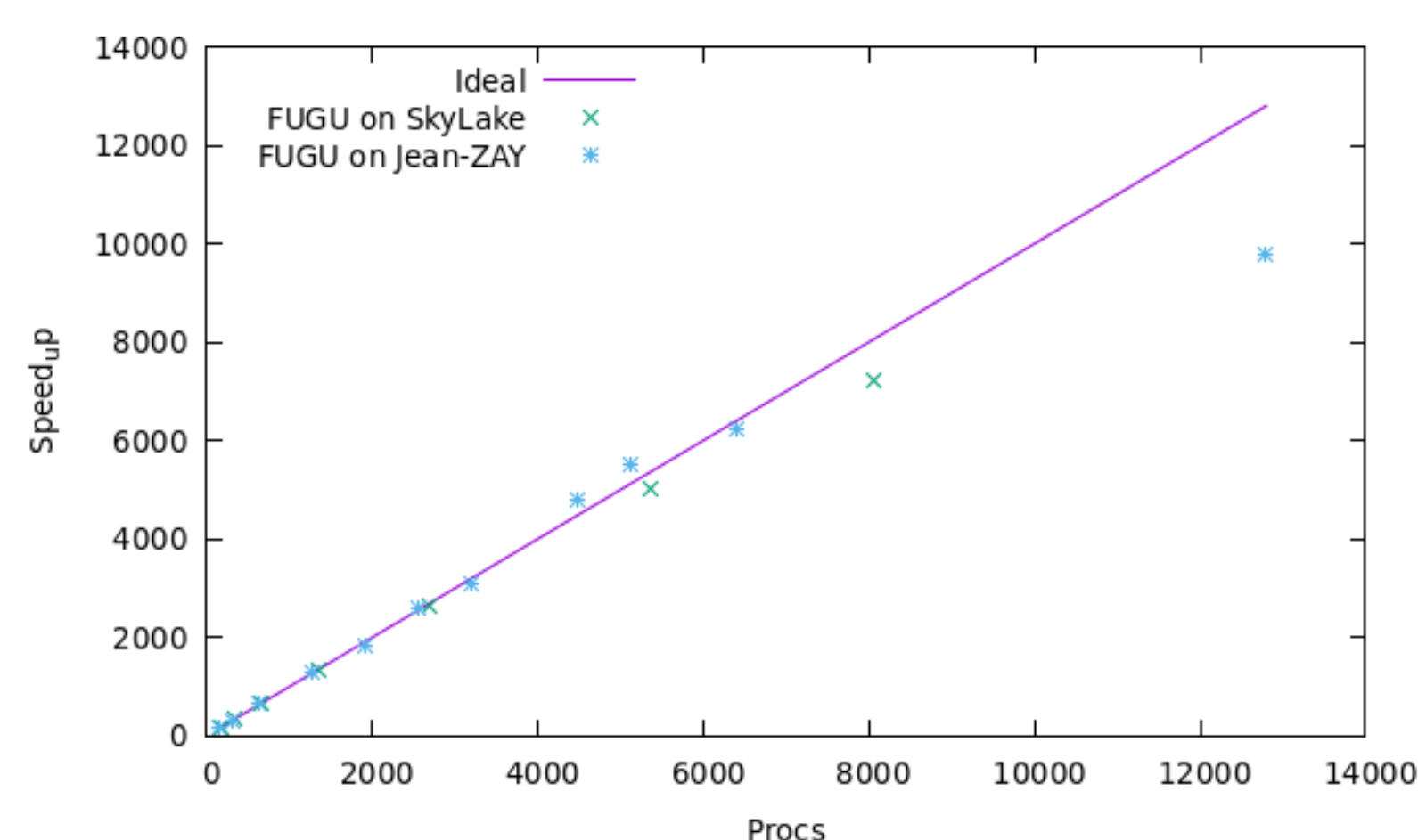


## PROBLEM

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

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

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

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

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

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

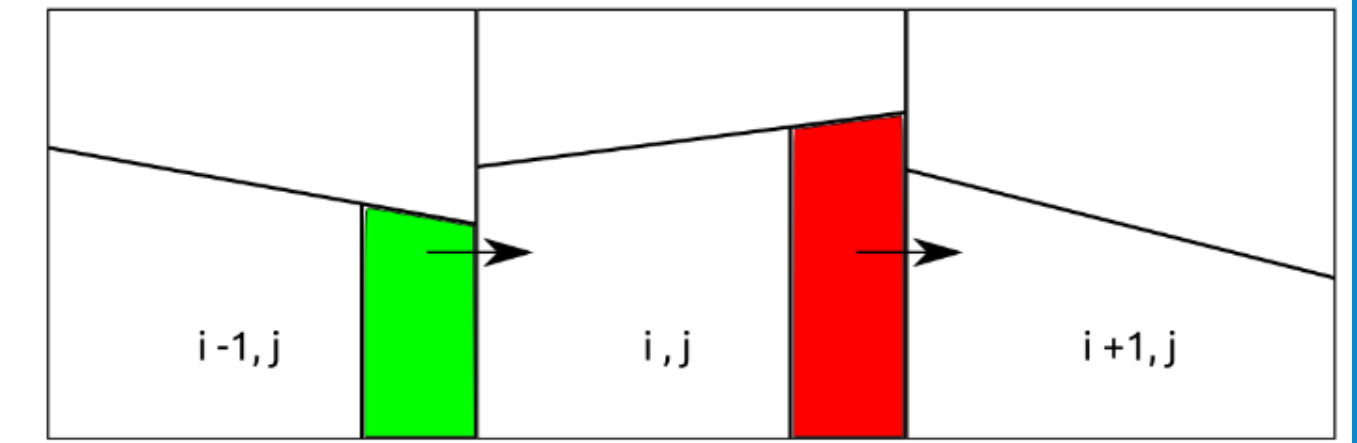
Fully coupled solver [2]

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

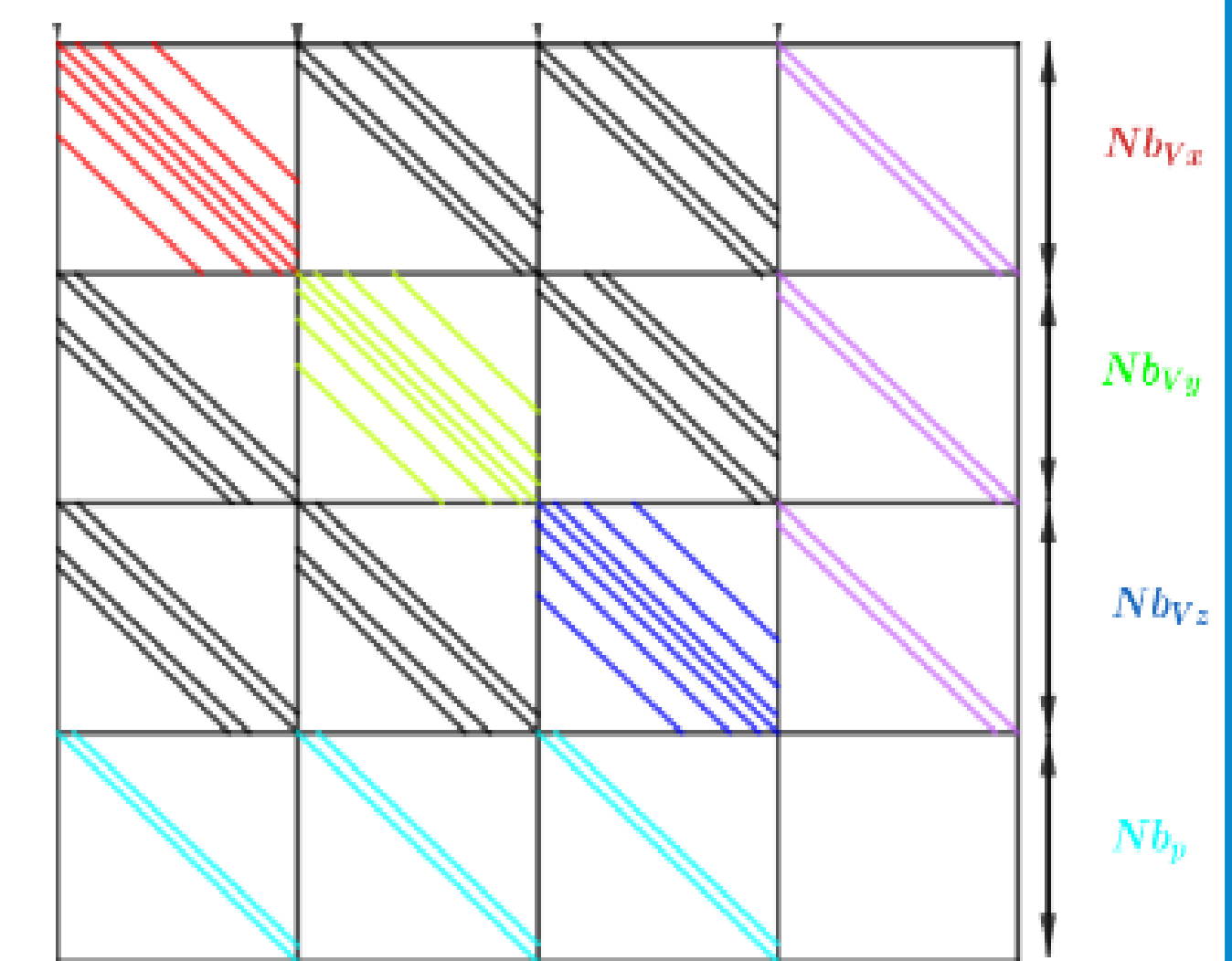
Transforming the original system  $\mathbf{Ax} = \mathbf{b}$  into an equivalent one  $\mathbf{P}^{-1} \mathbf{Ax} = \mathbf{P}^{-1} \mathbf{b}$ .

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

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



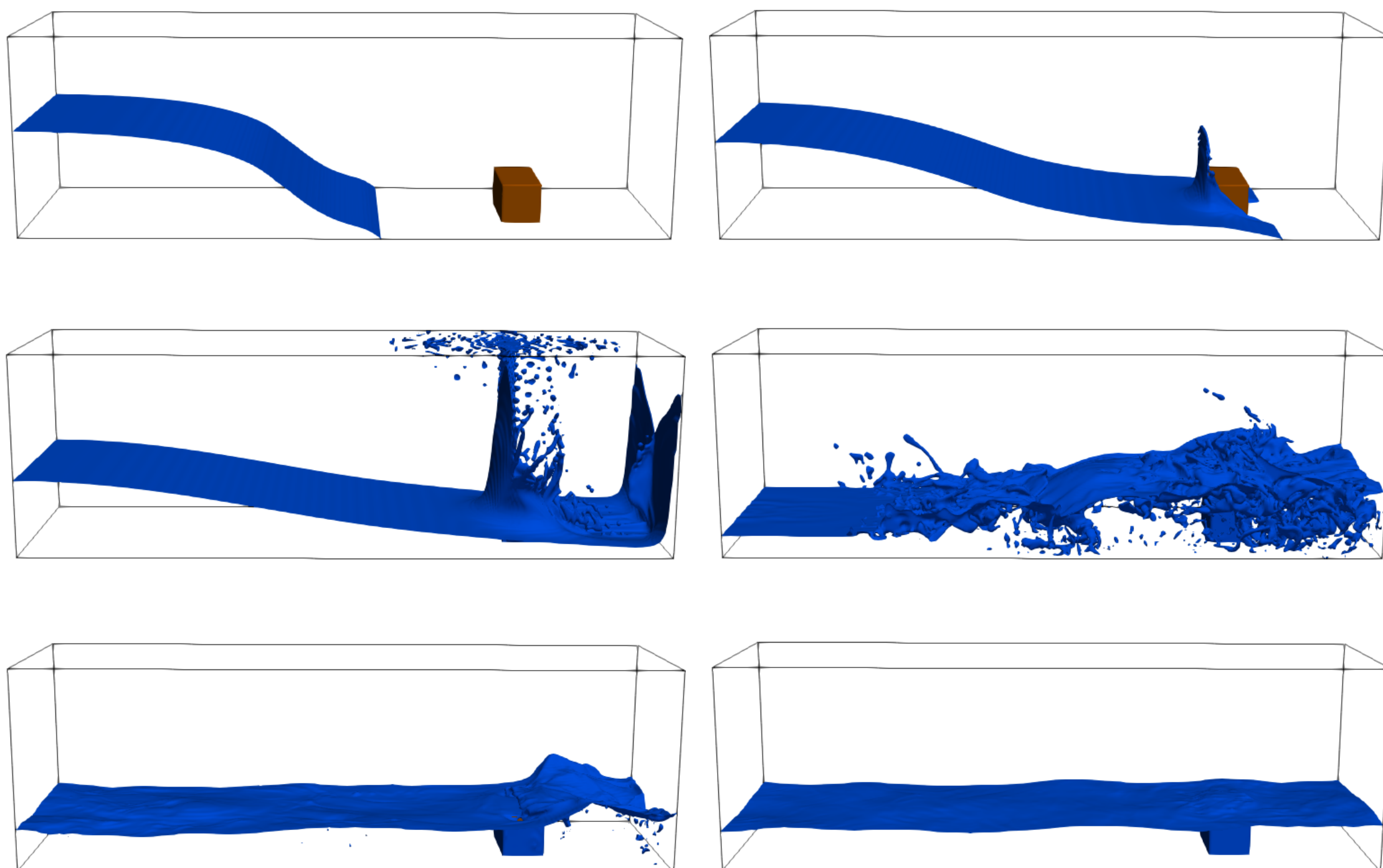
Eulerian Implicit (WY) in 2D



Matrix Structure

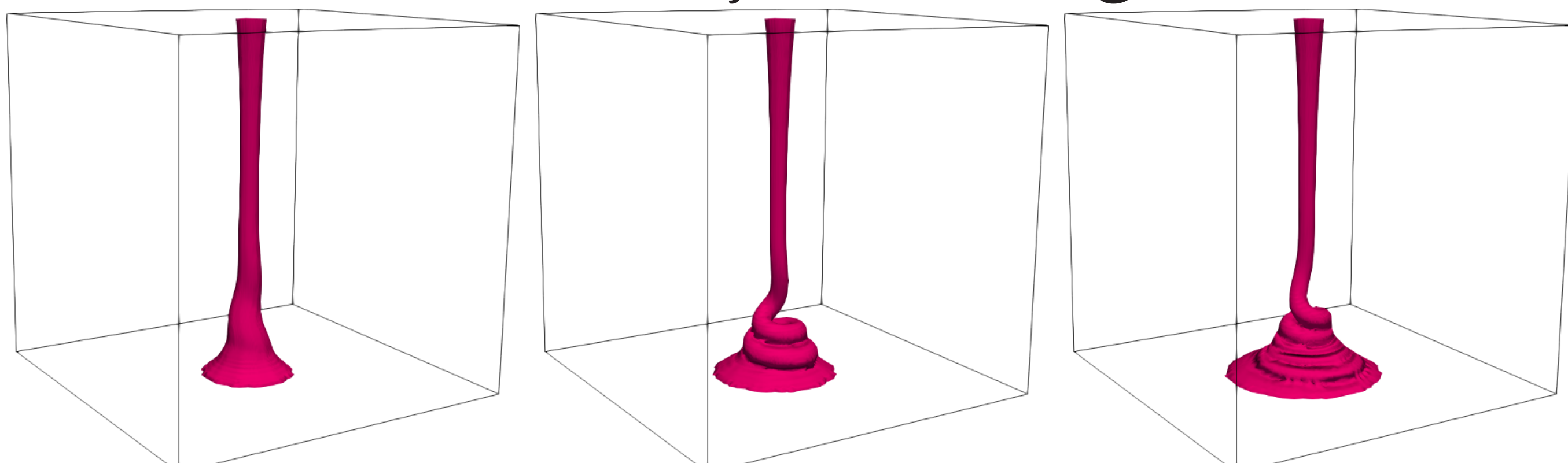
## RESULTS

### Dam-Break Flow with obstacle



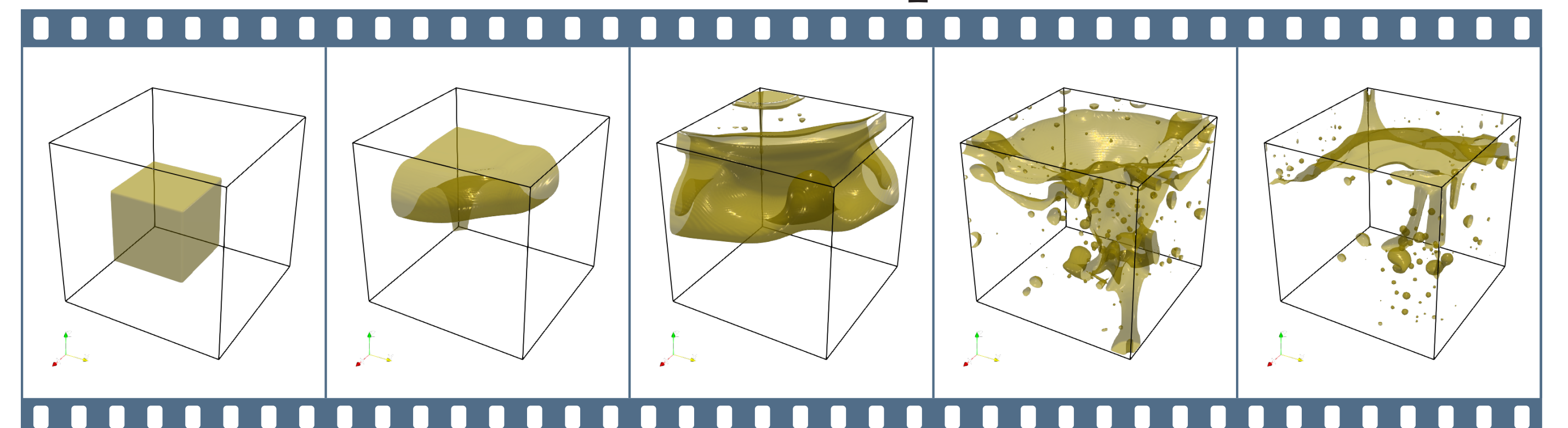
Changing the air/water interface for different times. (Mesh:  $322 \times 100 \times 100$ , CFL=0.4.)

### Viscous jet buckling



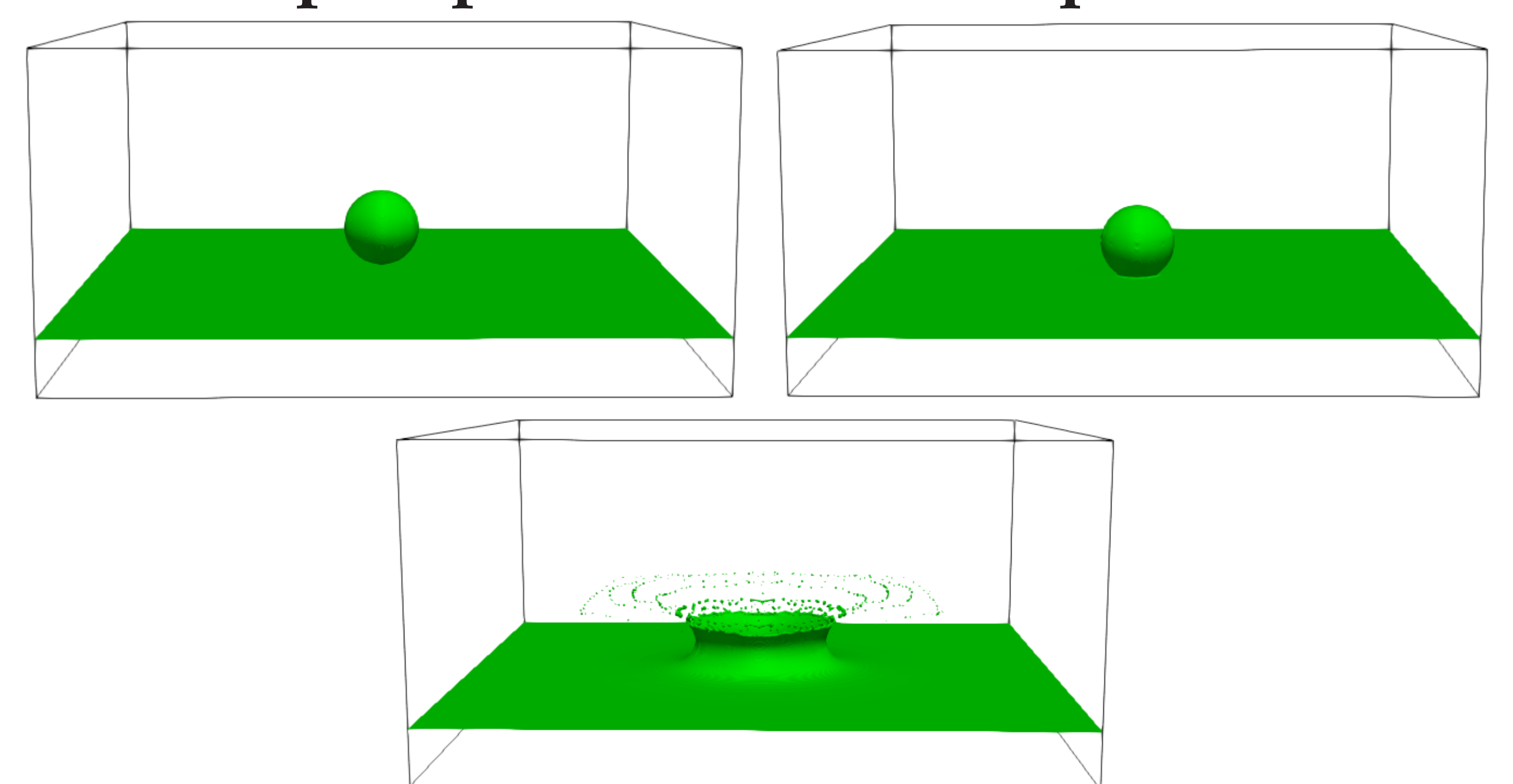
Propergol/air interface for different times. Mesh  $120^3$  refined at the injector. The aspect ratios of  $H/D > 3\pi$  and  $Re < 0.52$ .

### Phase inversion problem



Oil/water interface over time. Mesh  $256^3$ . HPC DNS calculations  $\approx 12800$  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  $\approx 8000$  processors of the HPC Jean Zay cluster of IDRIS.

## ACKNOWLEDGMENT

We are grateful for access to the computational facilities of the French CINES and TGCC granted by GENCI under project numbers A0092B06115. We thank the technical and administrative teams of these super-computer centers and to S. Fereka (MSME).

## 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.