# An introduction to the hydrological modelling suite PARFLOW: pros, cons, bottlenecks and future directions


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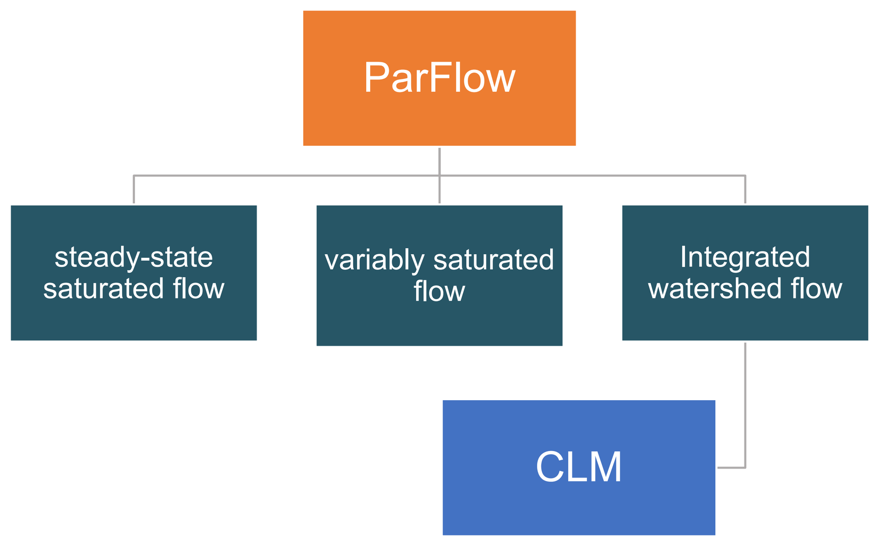
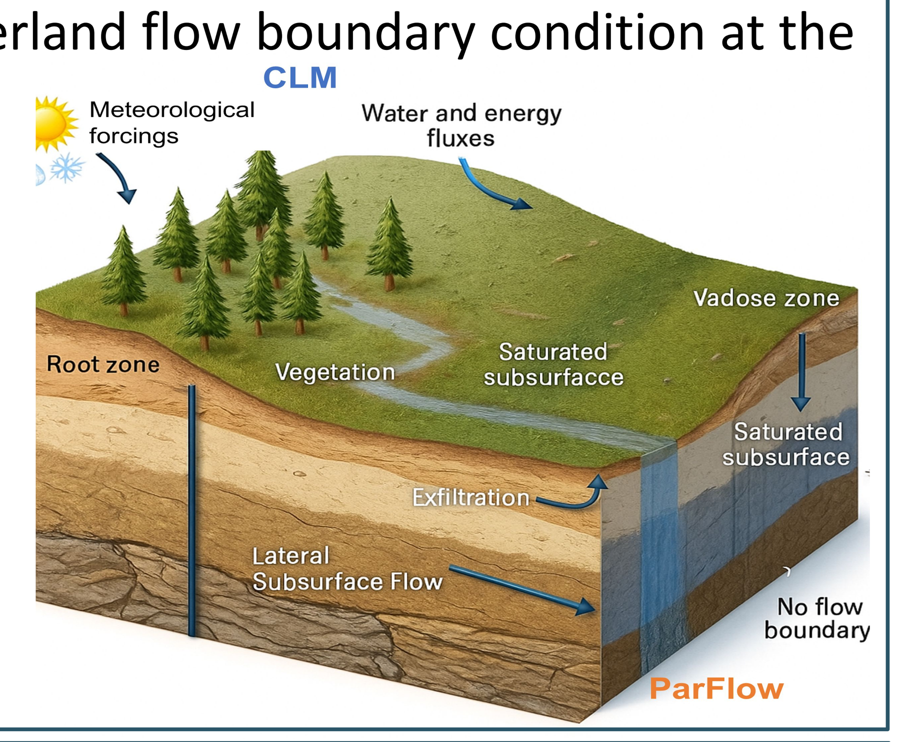
## Introduction

- **Par**allel **Flow** is a state-of-the-art, parallel and fully distributed modeling platform with a burgeoning community, pledging coupled surface and subsurface flow simulations via use of uses partial differential equations (Kollet and Maxwell, 2006).
- Integrated with **CLM** (Common Land Model) (Dai et al., 2003), **ParFlow** stands as alternative hybrid modelling option to its commercial counterparts.
- Coupled form of Parflow-CLM provides a physically based representation of the full terrestrial water and energy balance, integrating hydro(geo)logical and land-surface processes within a consistent modeling environment.
- Its fully parallelized system is configured for execution on High-Performance Computing (HPC) infrastructures.

## Methodology

- IMPES and RICHARDS solvers are responsible for fully saturated steady state and variably saturated flow simulations, respectively
- Parflow grid can be conformed to the topography via terrain following grid formulation
- Surface flow can be simulated via overland flow boundary condition at the top domain grid by SWE.




## Advantages

- Water cycle representation from bedrock to atmosphere
- Physically-based integration
- 3D representation of subsurface heterogeneity
- Simulates variably saturated and overland flows
- Represents vegetation dynamics, ETP, and energy balance

## Disadvantages

- Computationally expensive
- Extensive input data
- Requires expertise in numerical modeling, hydrology and LSM
- Complexity can make it difficult to diagnose problems
- Steep learning curve

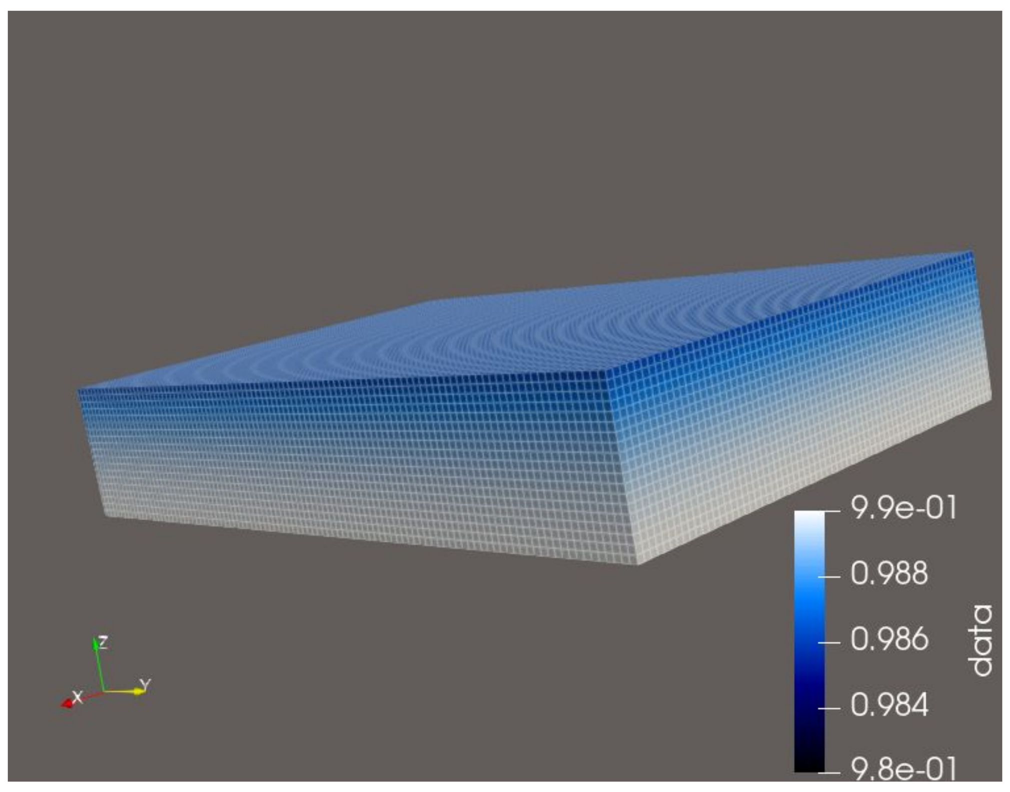
## Workflow

- Elevation, Soil, Geology
- Land cover
- Climate data

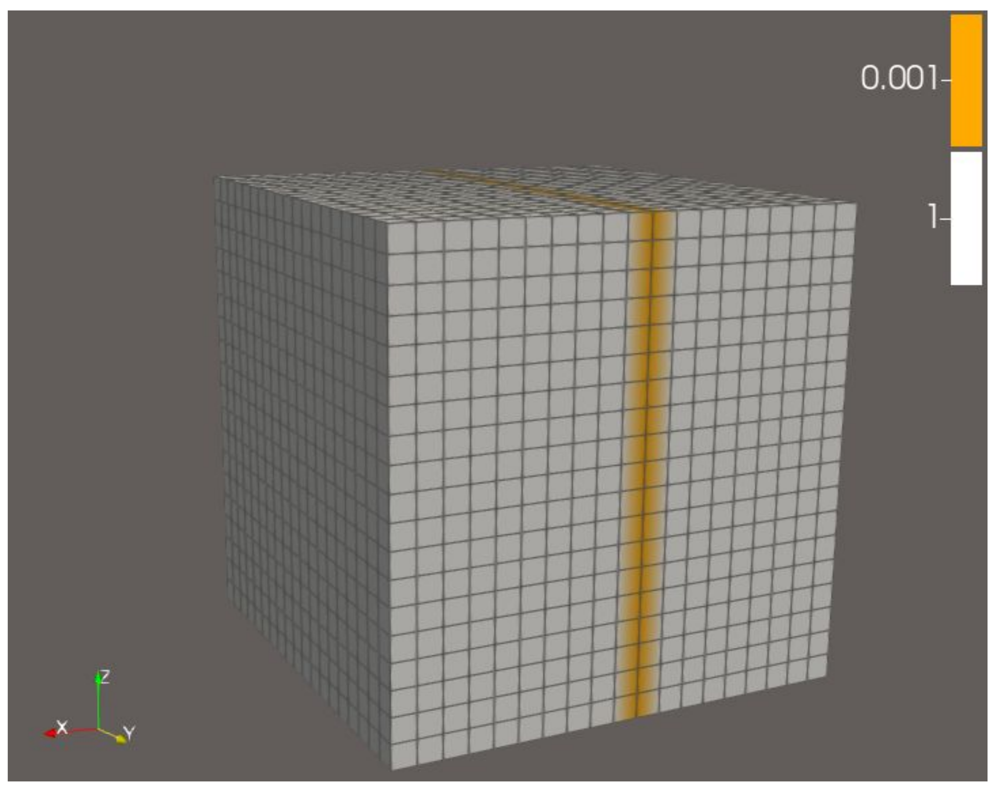
- Input script (.tcl or .py)
- Kinematic, diffusive wave
- Richards & Impes solvers

- No visualization module
- .nc, .silo or .pfb
- CLM & ParFlow outputs

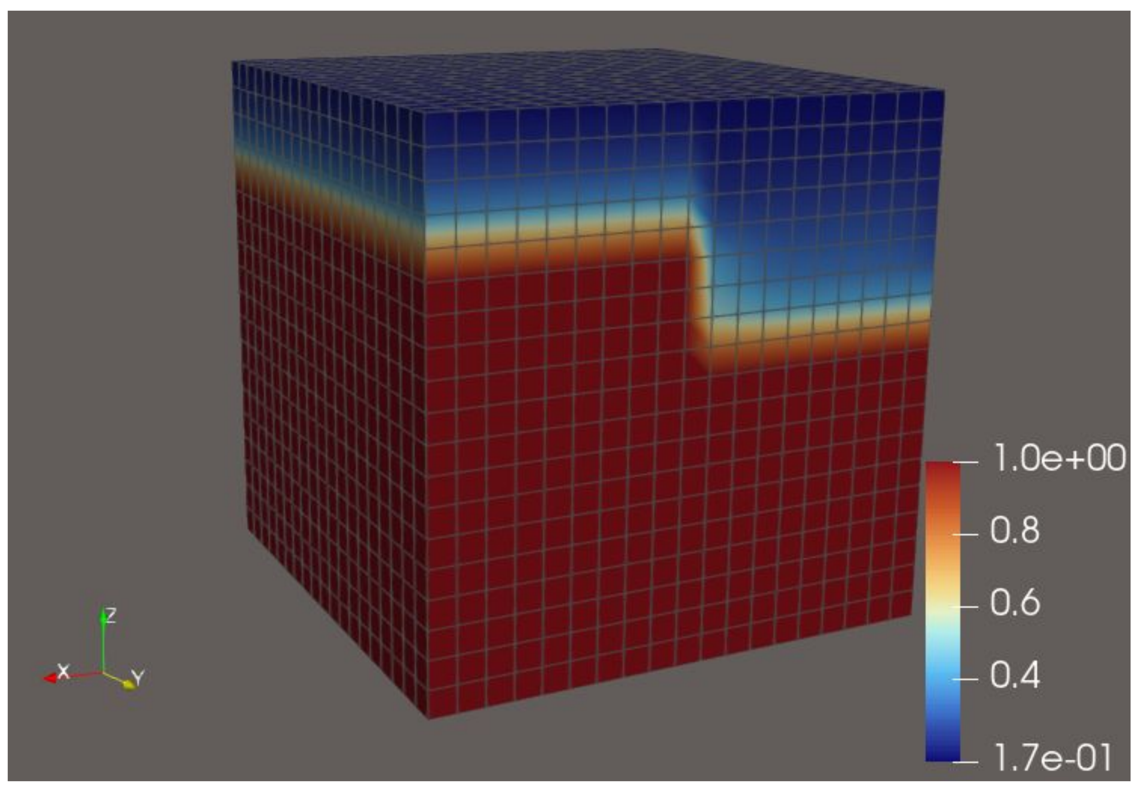
## Preliminary model structure - test runs



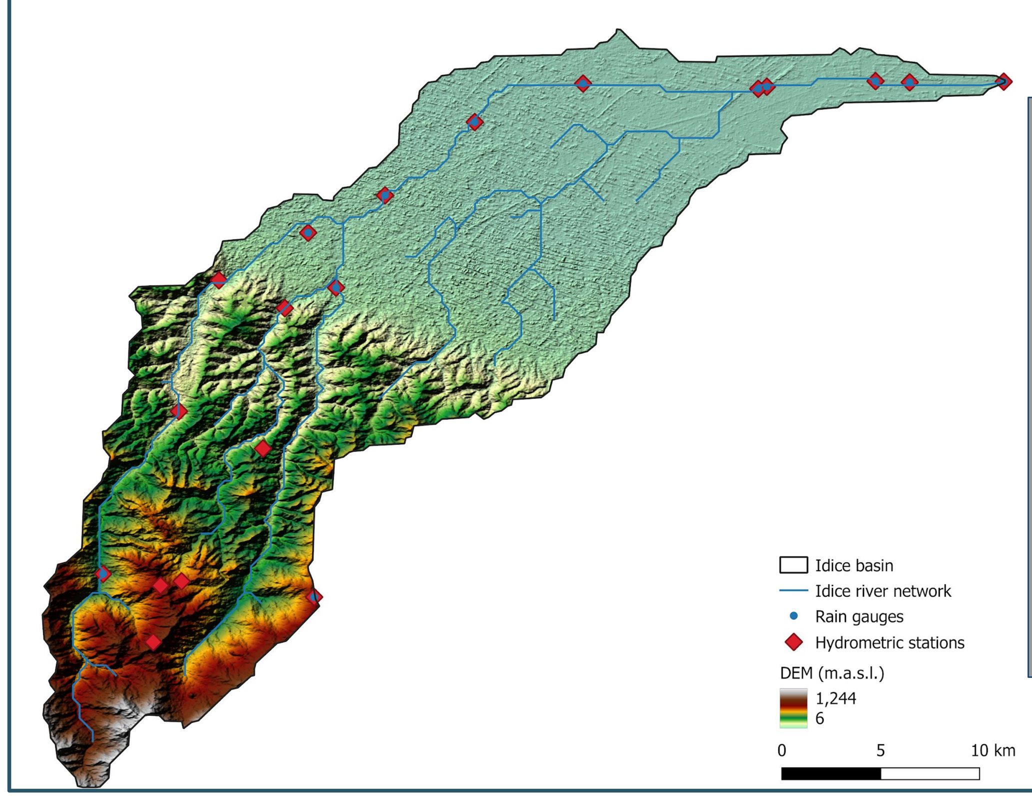

Basin test run - Saturation output

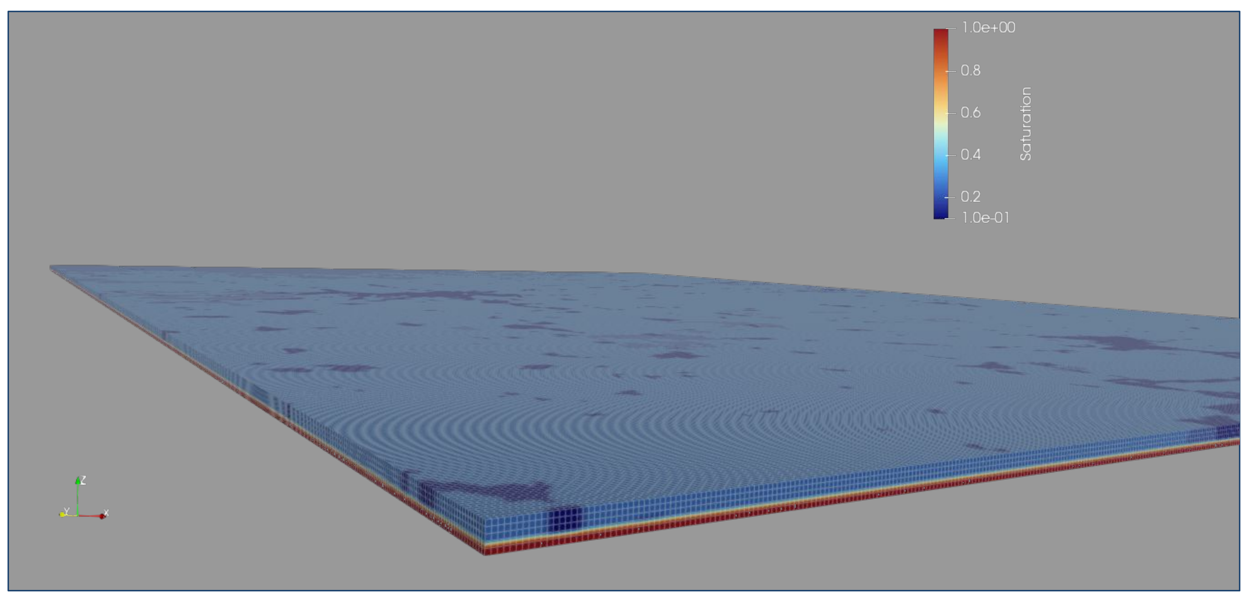



Flow barrier run




Saturation output



Case study development - Idice basin region :

- 100m and 1km resolution models are considered
- 700 x 1040 x 6 grids with 100 m resolution
- Ground and climate data will be integrated
- CLM coupling is under development
- 2m and 20 m subsurface geometry
- Active and inactive cells will be conformed via solid files (.pfsol)
- Terrain following grid formulation for topography integration

## References


Dai, Y., Zeng, X., Dickinson, R. E., Baker, I., Bonan, G. B., Bosilovich, M. G., ... & Yang, Z. L. (2003). The common land model. Bulletin of the American Meteorological Society, 84(8), 1013-1024.

Kollet, S. J., & Maxwell, R. M. (2006). Integrated surface–groundwater flow modeling: A free-surface overland flow boundary condition in a parallel groundwater flow model. *Advances in Water Resources*, *29*(7), 945-958.



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