Loosely-coupled integration and distributed execution of HYDRUS-1D and MODFLOW

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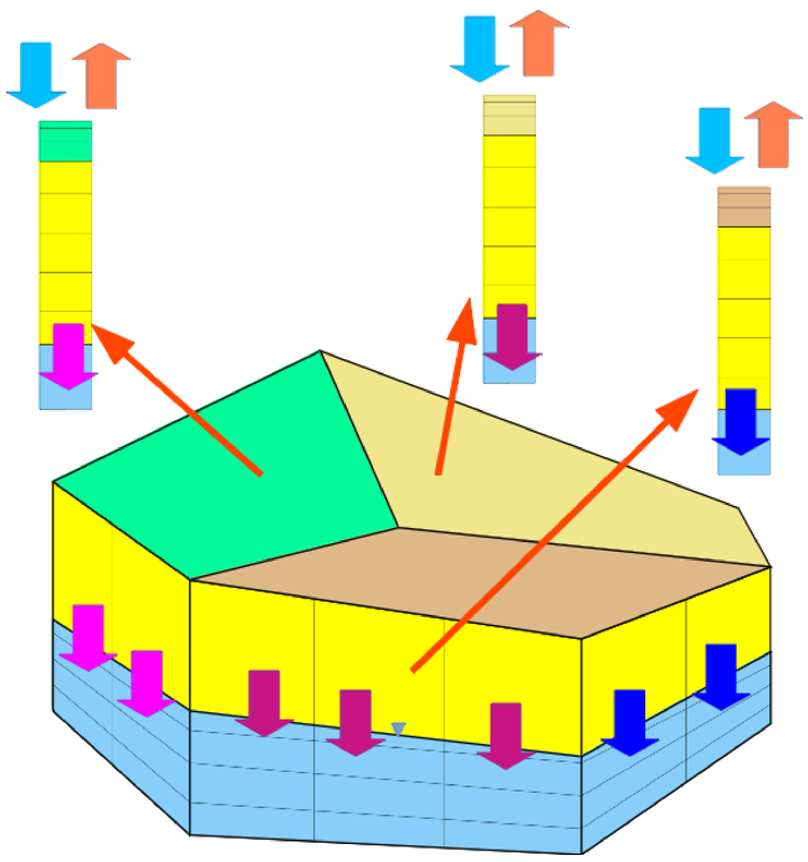
Motivation

- need for intermediate complexity models integrating vadose zone and groundwater processes
- taking advantage of state-of-the-art computer codes MODFLOW and HYDRUS-1D
- updating the existing HYDRUS Package for MODFLOW[1,2]

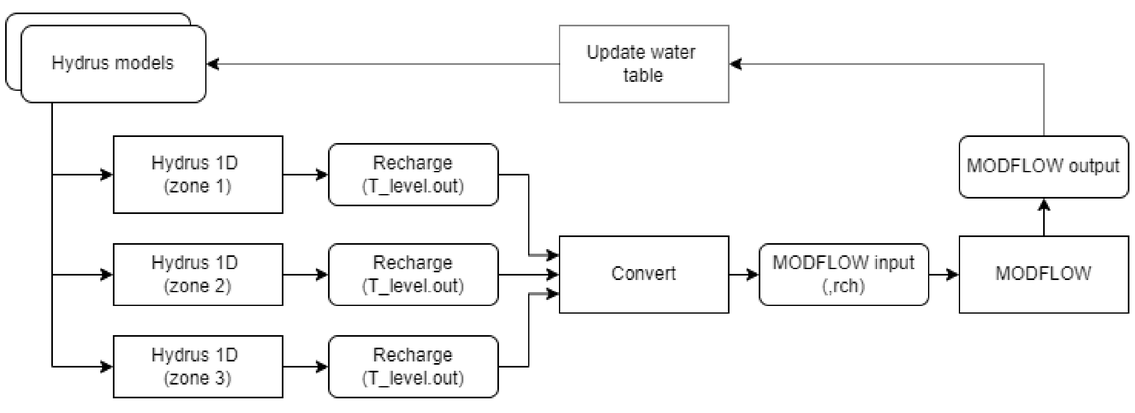
General concept



1D vertical flow in vadose zone (HYDRUS-1D)

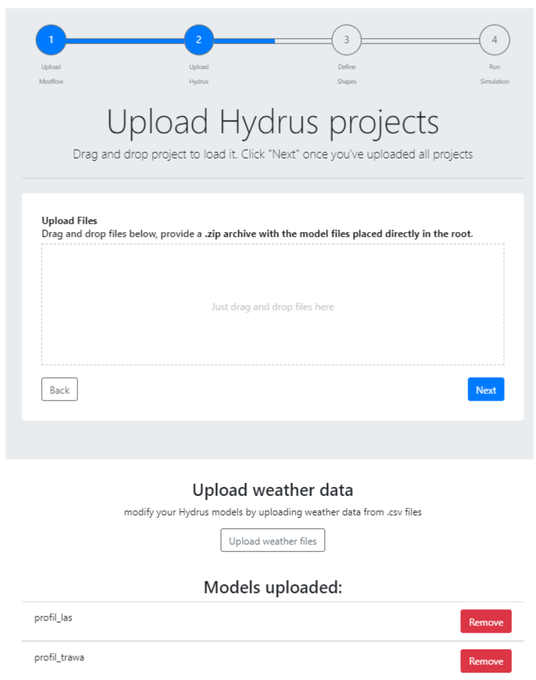
3D flow in groundwater zone (MODFLOW)

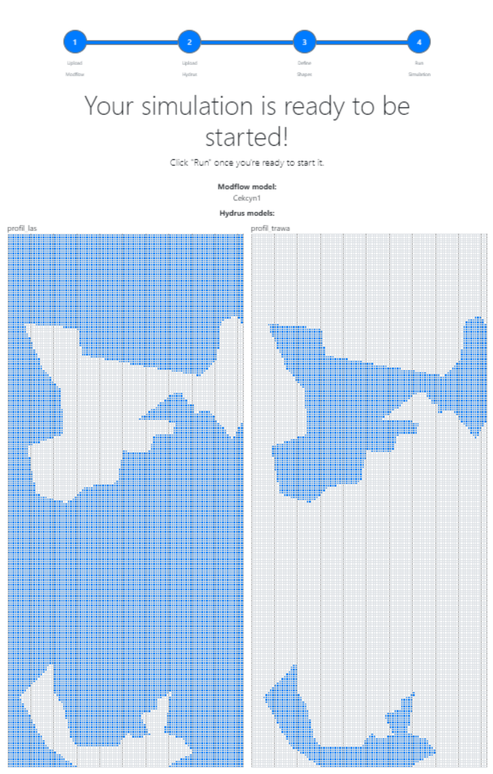
- loose coupling via external scripts, without modifying MODFLOW and HYDRUS-1D source code
- MODFLOW model area divided into zones characterized by representative HYDRUS-1D soil profiles
- automatic zonation based on existing RCH file in MODFLOW model
- parallel execution of HYDRUS-1D instances
- currently HYDRUS-1D simulations run with constant position of the water table, dynamic water table condition will be implemented



Implementation

- mostly Python, use of FloPy[3] and PHydrus[4] libraries
- 3 deployment modes
  - local: the application is run as a standalone program and requires separate installation of Hydrus and MODFLOW
  - Docker: the application in run in Docker containers, no additional software needs to be installed
  - Kubernetes: the application is deployed in a Kubernetes cluster (which can be hosted locally or in the cloud)
- In all three cases, a web-based interface is provided to configure and run the simulation





Perspectives

- updating water table position in HYDRUS-1D[2]
- extension to MODFLOW 6
- importing recharge zones as shapefiles
- integration with GIS
- extension to solute transport

References

[1] Seo, H., J. Šimůnek, and E. Poeter. 2007. Documentation of the HYDRUS package for MODFLOW-2000, the US Geological Survey modular ground-water model. IGWMI 2007-01. Integr. GroundWater Model. Ctr., Colorado School of Mines, Golden, CO.

[2] Beegum, S., Šimůnek, J., Szymkiewicz, A., Sudheer, K. P., & Nambi, I. M. (2018). Updating the Coupling Algorithm between HYDRUS and MODFLOW in the HYDRUS Package for MODFLOW. Vadose Zone Journal, 17(1), 1-8.

[3] Bakker, M., Post, V. +., Langevin, C. D., Hughes, J. D., White, J. T., Starn, J. J., & Fienen, M. N. (2016). Scripting MODFLOW model development using Python and FloPy. Groundwater, 54(5), 733-739.

[4] Collenteur, R.A., Brunetti, G., and M. Vremec (2019) Phydrus: Python implementation of the HYDRUS-1D unsaturated zone model.

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