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Numerics of the 1D Richards Equation and implications for land surface modelling on the kilometer-scale

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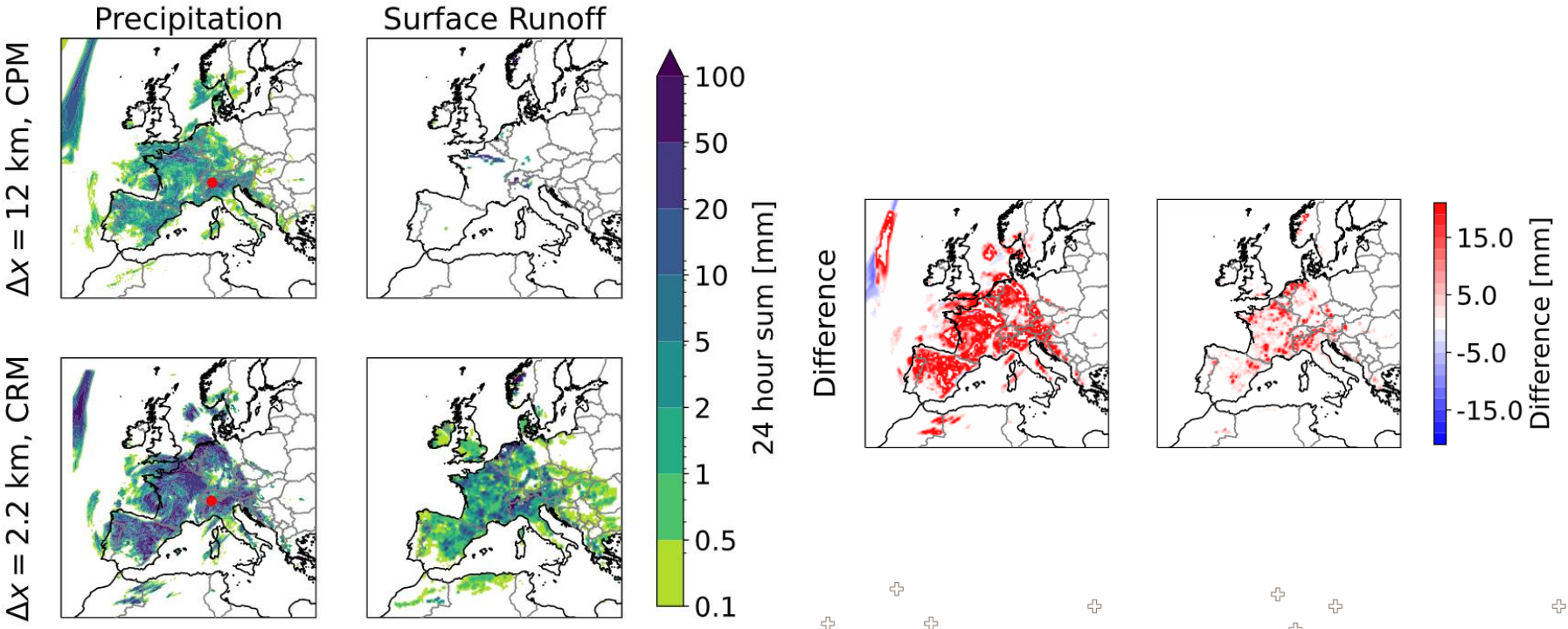
Surface Runoff Formation in COSMO

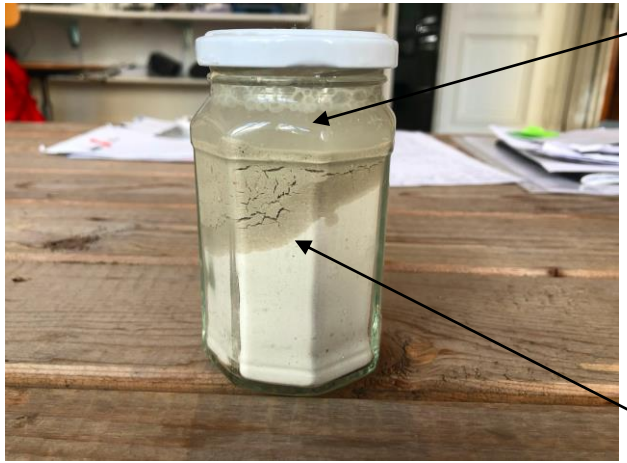


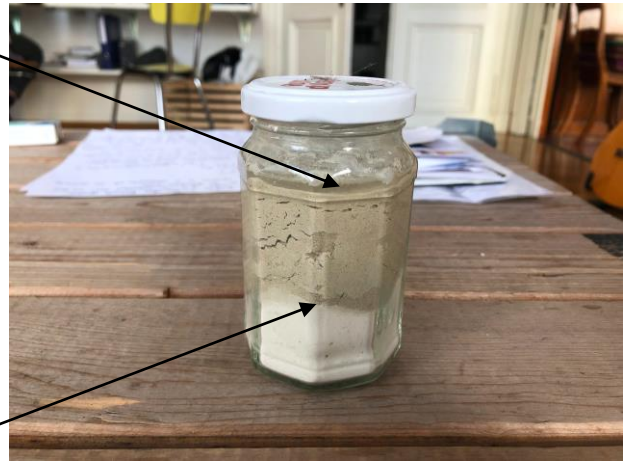
Propagation of soil water

5 min

Ponding Water

1 hour





Wetting Front

Mathematical Formulation

$$\frac{\partial \theta}{\partial t} = -\frac{\partial F}{\partial z} + I - Q - ET$$

Mass Conservation

Mathematical Formulation

$$\frac{\partial \theta}{\partial t} = -\frac{\partial F}{\partial z} + I - Q - ET$$

Mass Conservation

$$F = -D(\theta)\frac{\partial \theta}{\partial z} + K(\theta)$$

Darcy's Law

Mathematical Formulation

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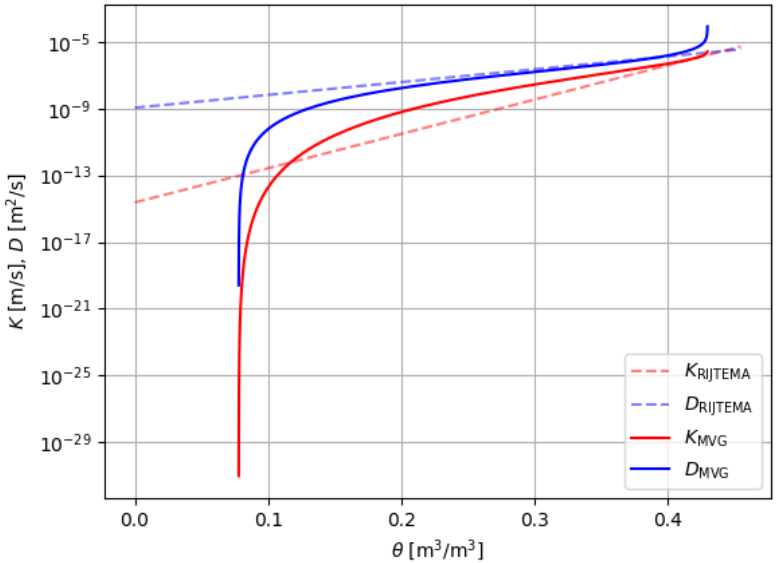
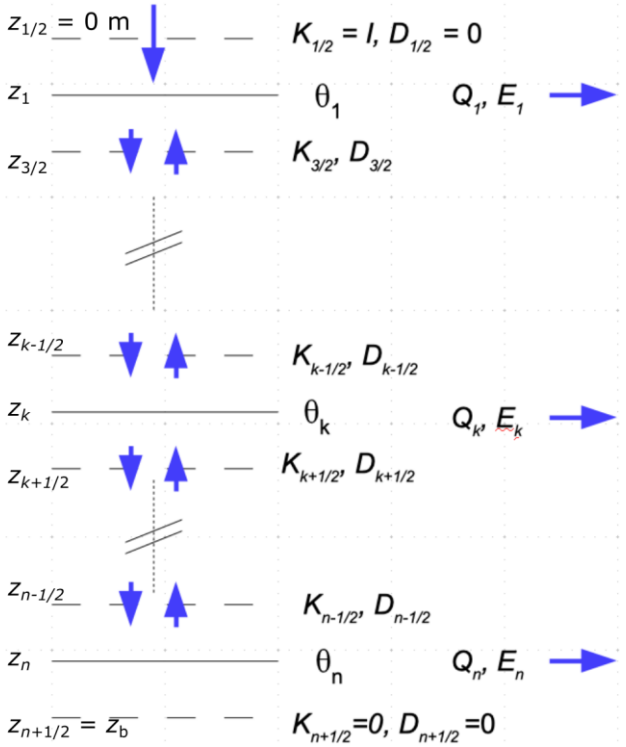


Assumptions on K, D from soil physics.
E.g. Rijteema (1969) or Mualem – van Genuchten (1976, 1980)

Numerical Implementation



Follows TERRA ML implementation.

Staggered Grid with fluxes on layer interfaces.

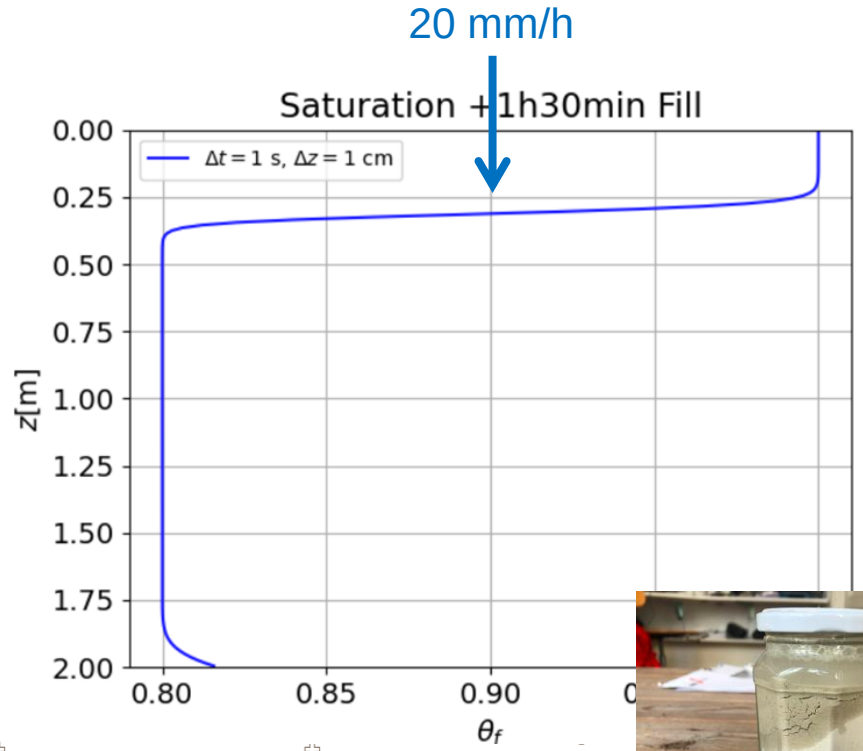
Zero flux bottom BC + Diagnosed Runoff Q (Schlemmer et al., 2018).

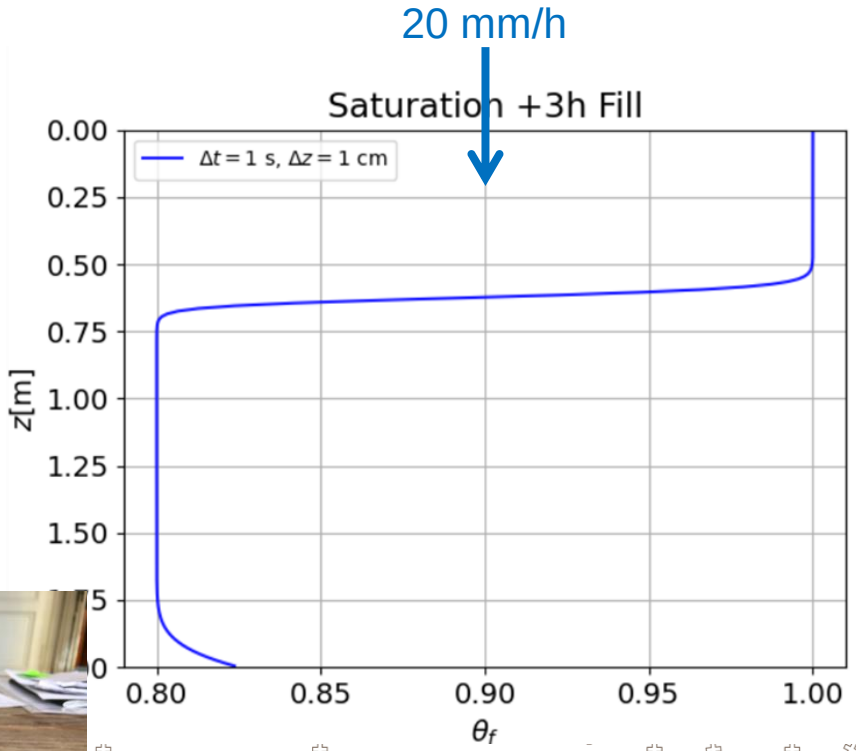
Hydraulic Diffusion treated implicitly.

Flux corrected transport for explicit part (Boris and Book, 1973; Zalesak, 1979; Schlemmer et al., 2018).

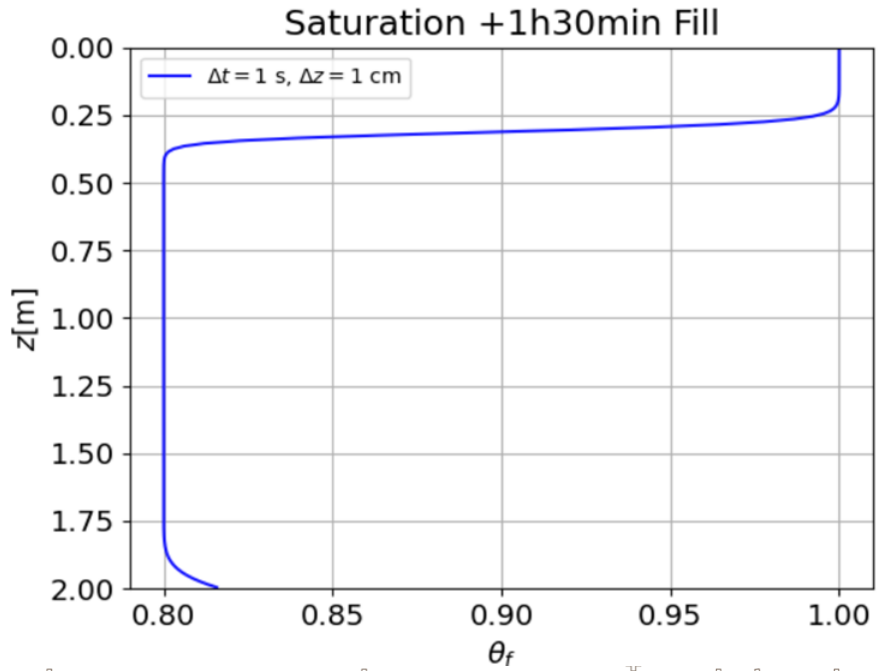
Available as Python Standalone.

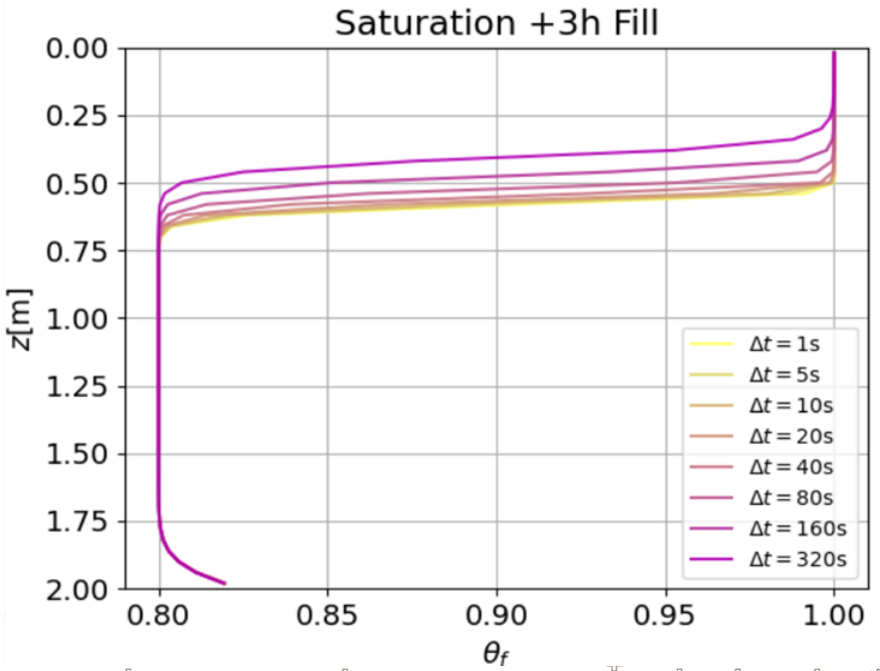
Fill Experiment



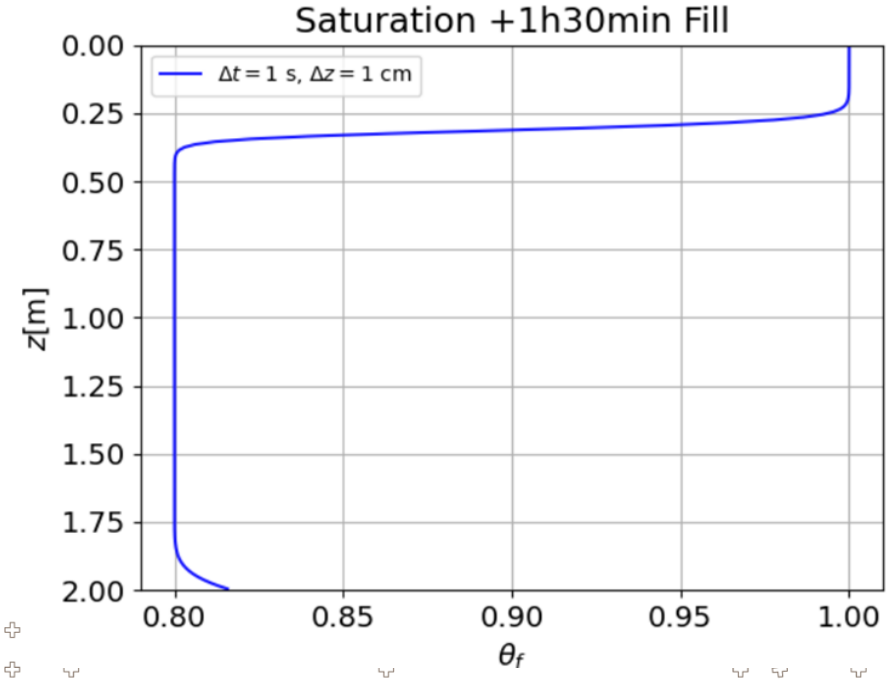


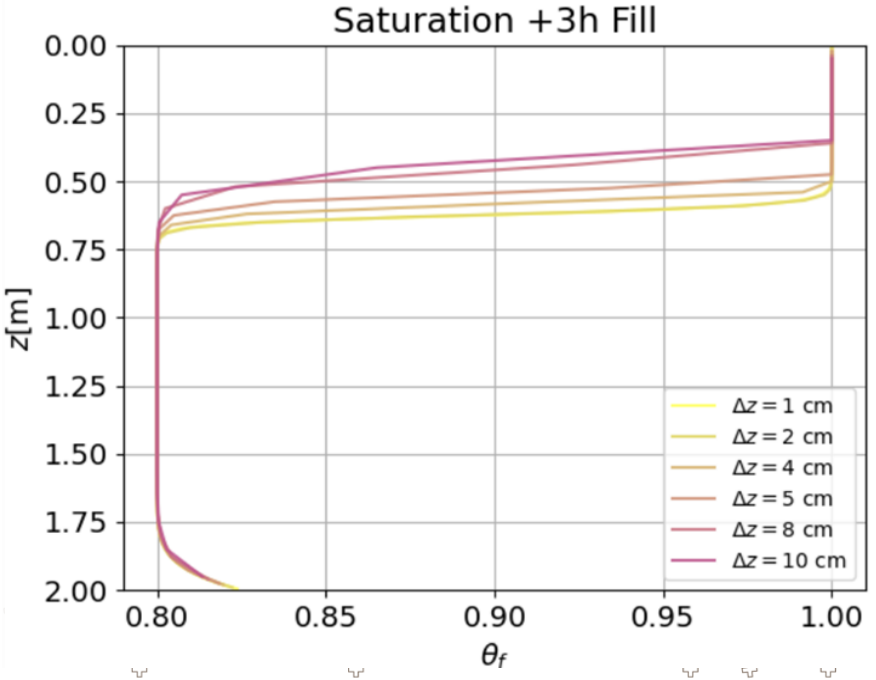
Time Step Dependency



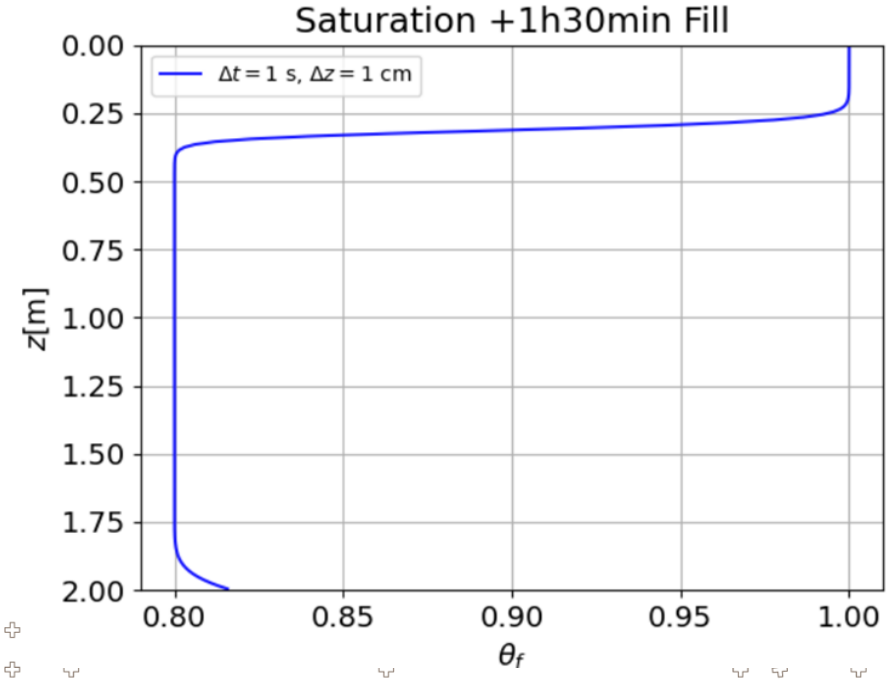


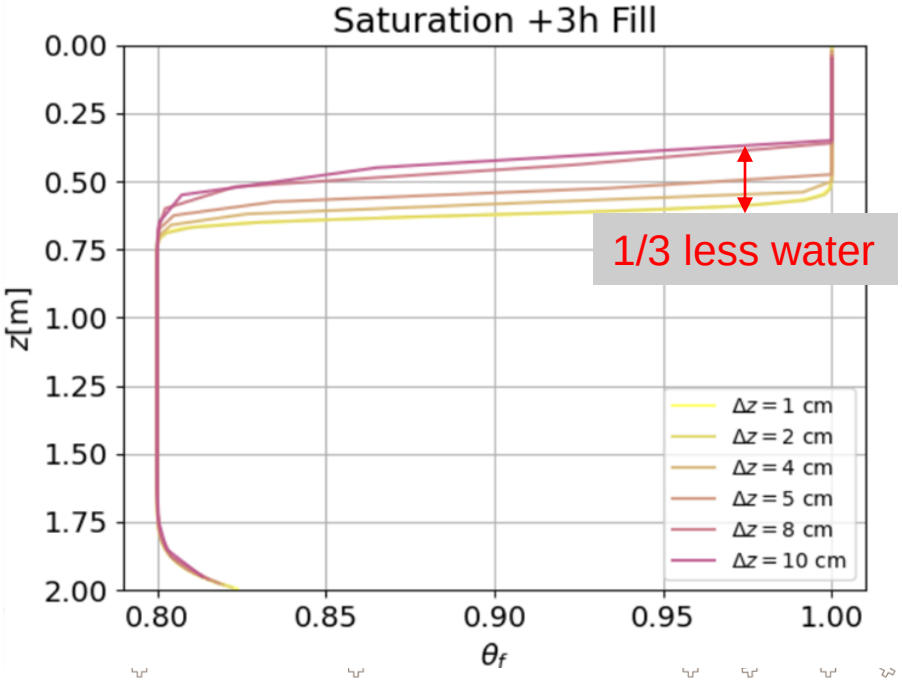
Resolution Dependency



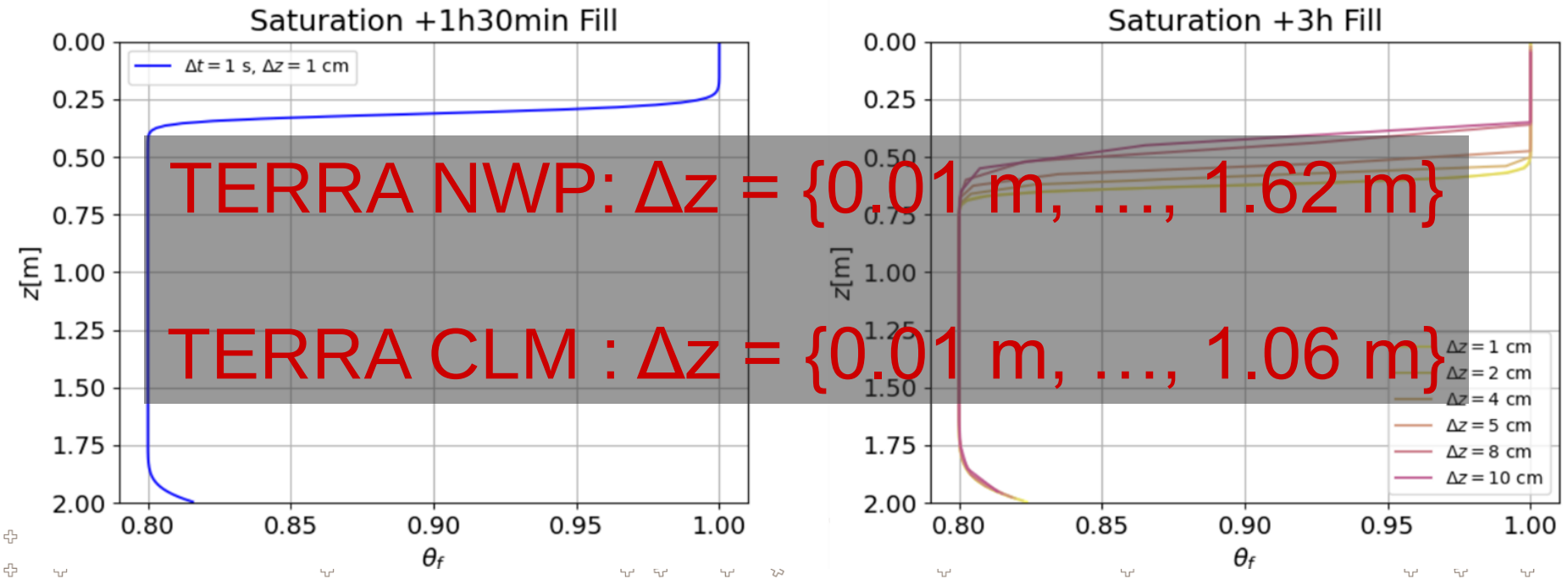


Resolution Dependency





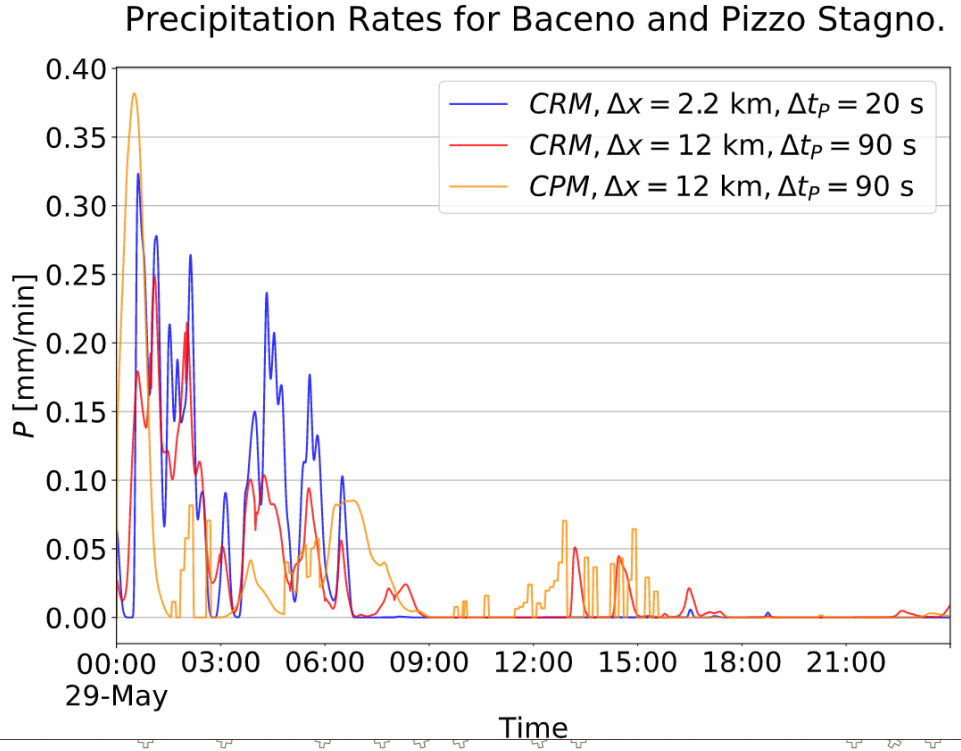
Resolution Dependency



TERRA NWP: Δz = {0.01 m, …, 1.62 m}

TERRA CLM : Δz = {0.01 m, …, 1.06 m}

‘Realistic’ Precipitation Experiment

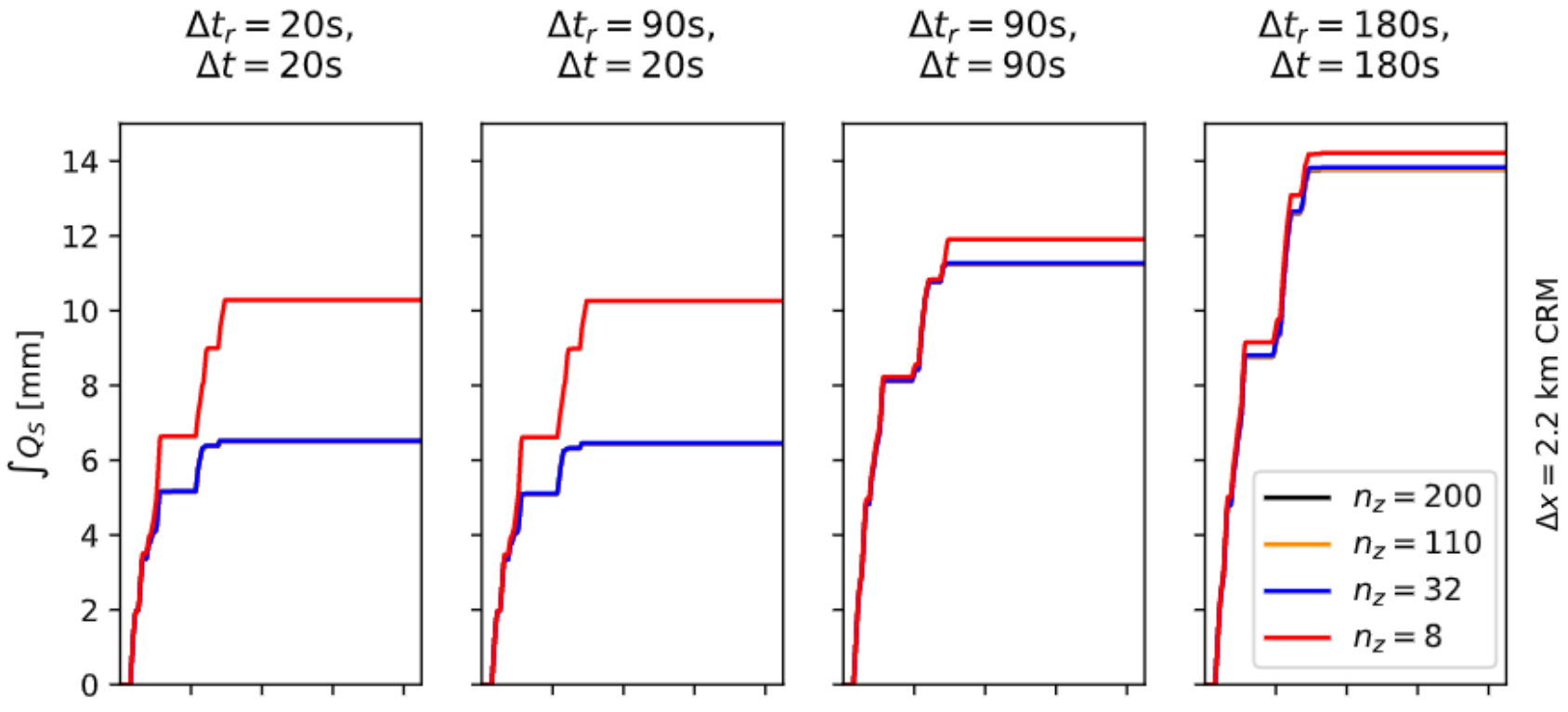


Extracted from 24h forecast experiment

Precipitation output on time step level

Python standalone forced with precipitation time series.

Surface Runoff Formation



Summary

- 1D Richards Equation is sensitive to vertical discretization and time stepping.
- Vertical resolution in many LSMs to coarse to achieve an adequate representation of the solution during the infiltration process
- Direct impact on water partitioning at the surface.

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