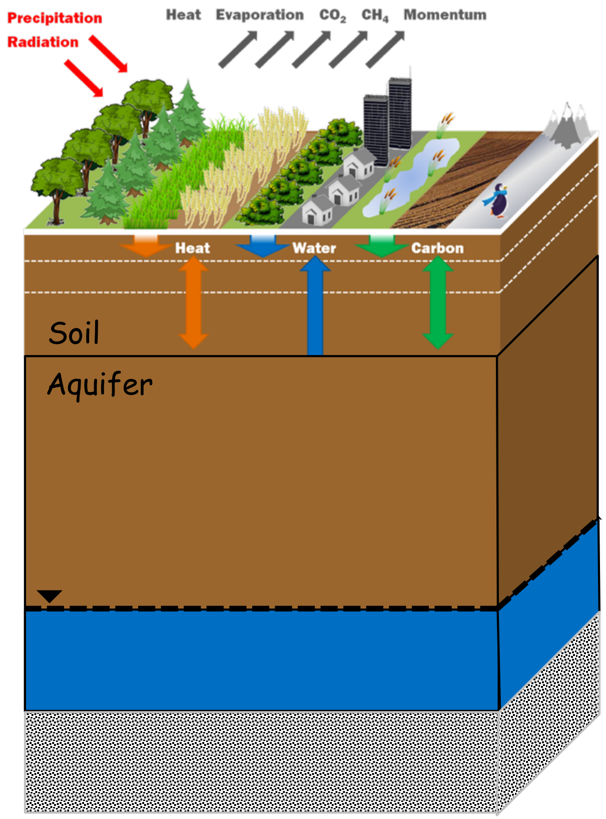
Are we over-complicating our models?

Towards a more efficient and robust representation of sub-surface hydrological processes in Earth System Models



Rafael Rosolem

rafael.rosolem@bristol.ac.uk

Mostaquimur Rahman* (University of Bristol)

Stefan Kollet (University Bonn and Jülich Research Center)

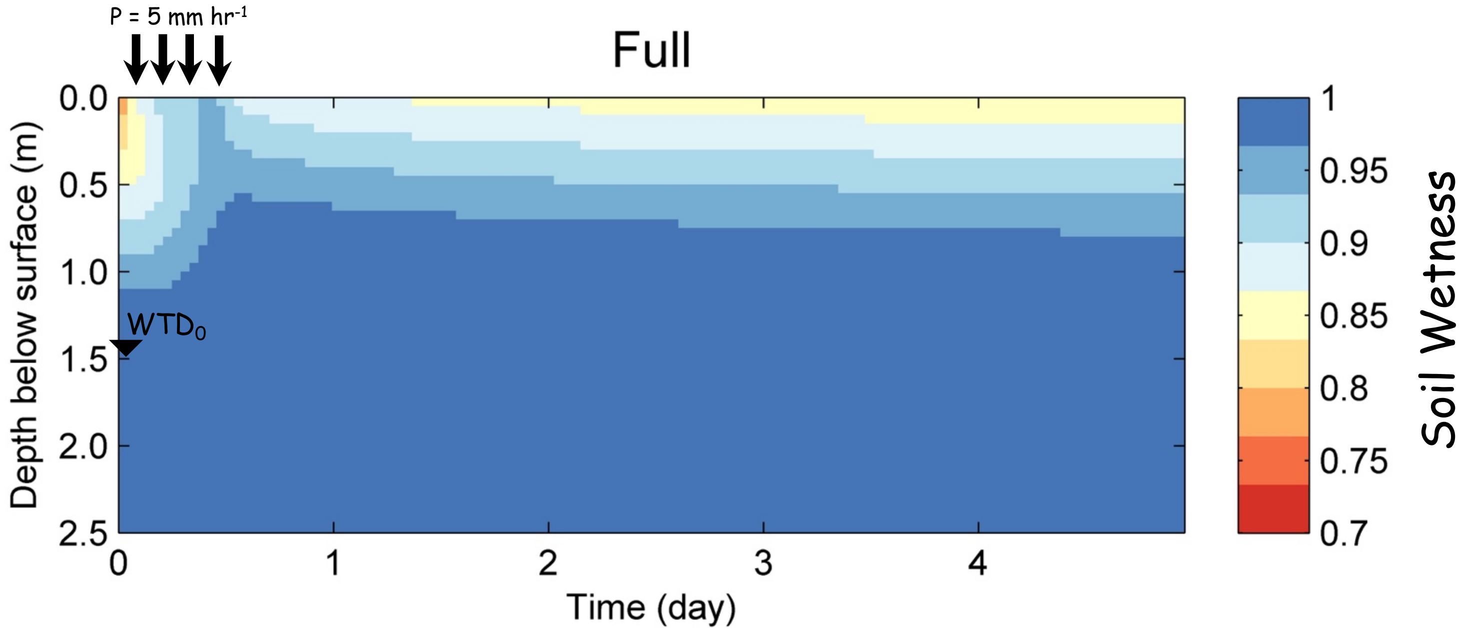
Thorsten Wagener (University of Bristol)

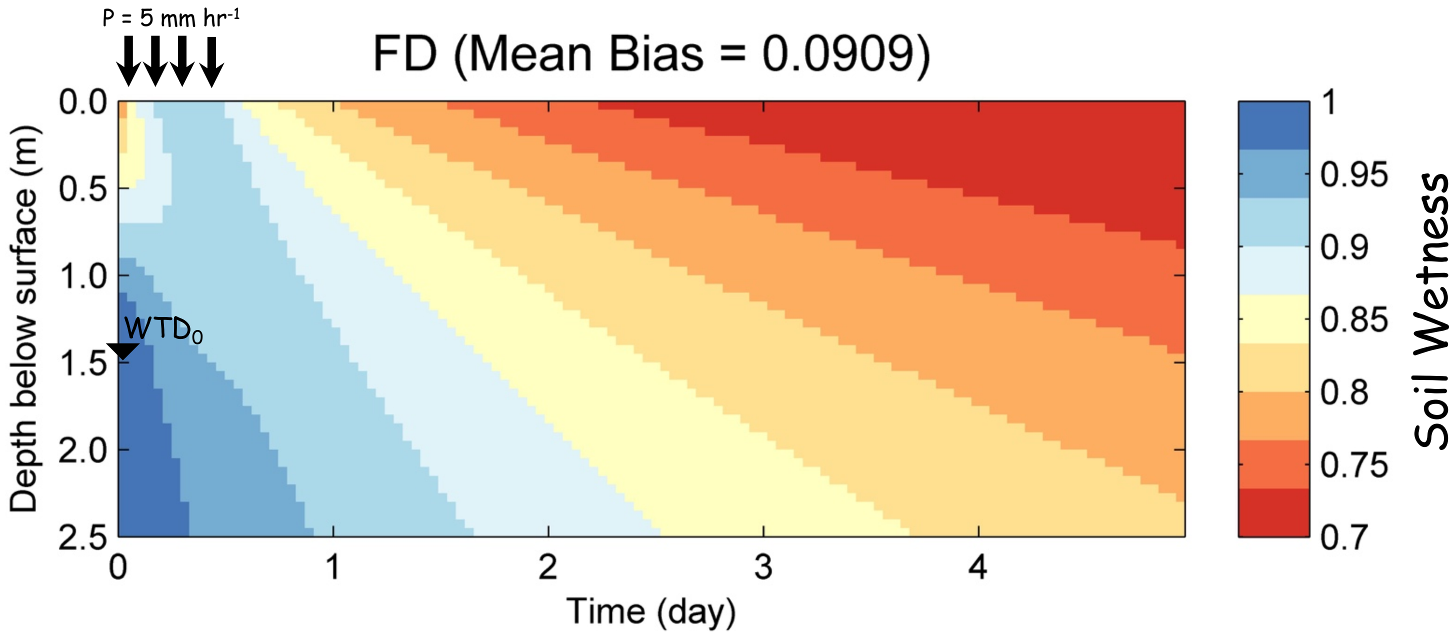
University of BRISTOL

JULES Annual Meeting
27 June 2017

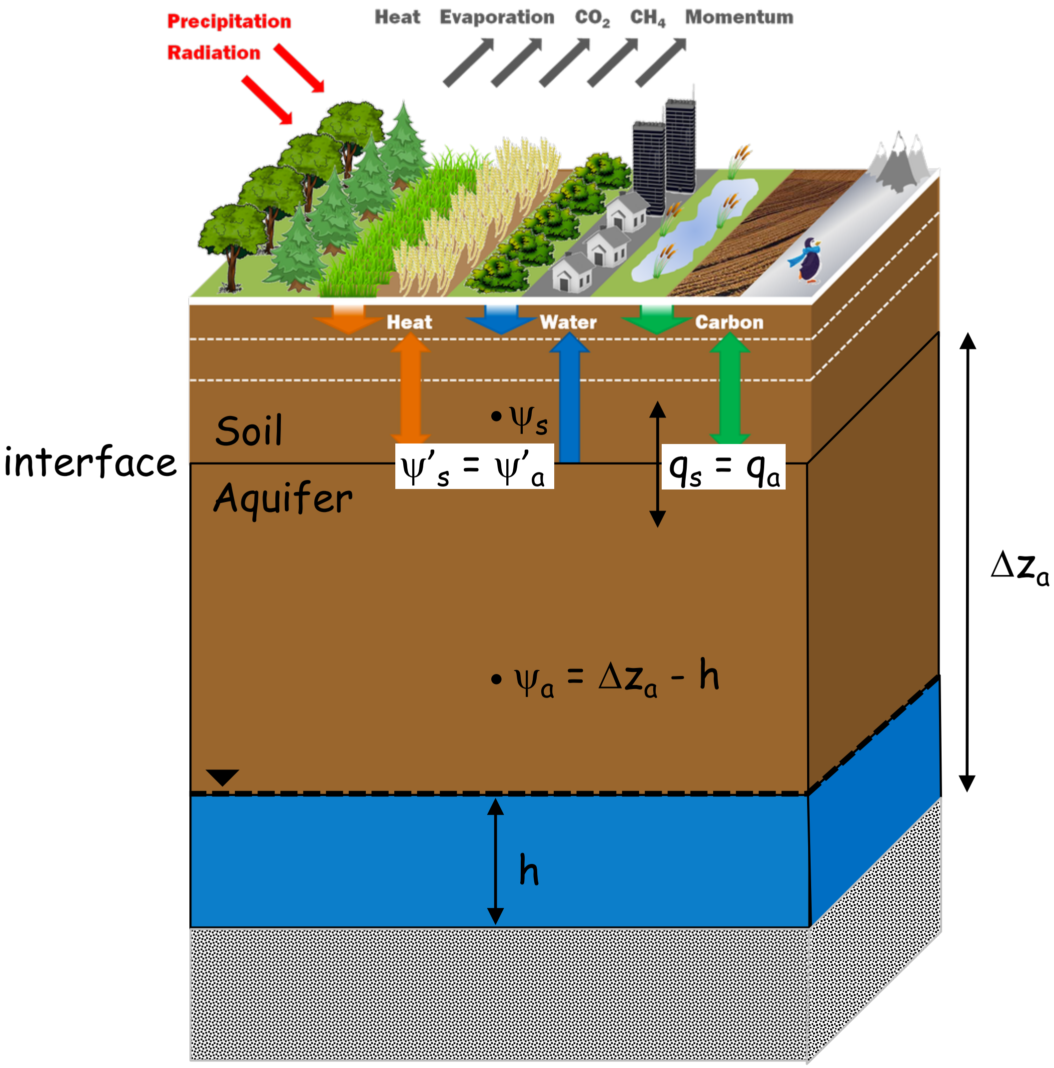
NERC SCIENCE OF THE ENVIRONMENT

Free Drainage (FD) boundary condition exacerbates soil drying considerably when compared to coupled soil-aquifer simulation





Our proposed approach couples a soil model to an aquifer model



At the soil-aquifer interface, we assume:

Pressure continuity → groundwater table depth (h) defined based on pressure head (ψ_s) at the last layer of soil model

Flux continuity ($q_s = q_a$) → Lower boundary condition from soil model defined by the aquifer model

We refer to our approach as GroundWater Boundary "GWB"

Our model development attempts to simultaneously maximize its robustness and efficiency

Robustness *~ a model that performs well even if its assumptions are somewhat violated by the true model from which the data were generated*

Efficiency *~ a model that tends to reduce to a "minimum" the time necessary for completing a number of predefined tasks*

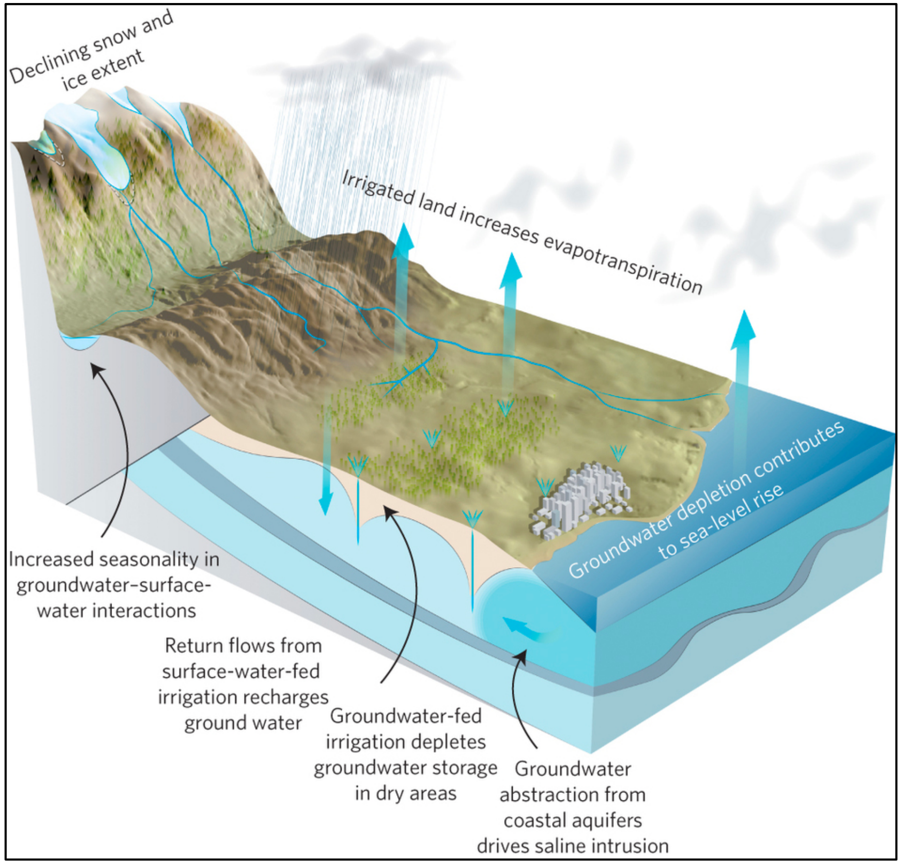
Our model development attempts to simultaneously maximize its robustness and efficiency

Robustness → *How much our proposed groundwater model deviates from a much more complex model (taken here to be the "truth")?*

Efficiency → *How much faster does our proposed model complete its simulations compared to the complex model?*

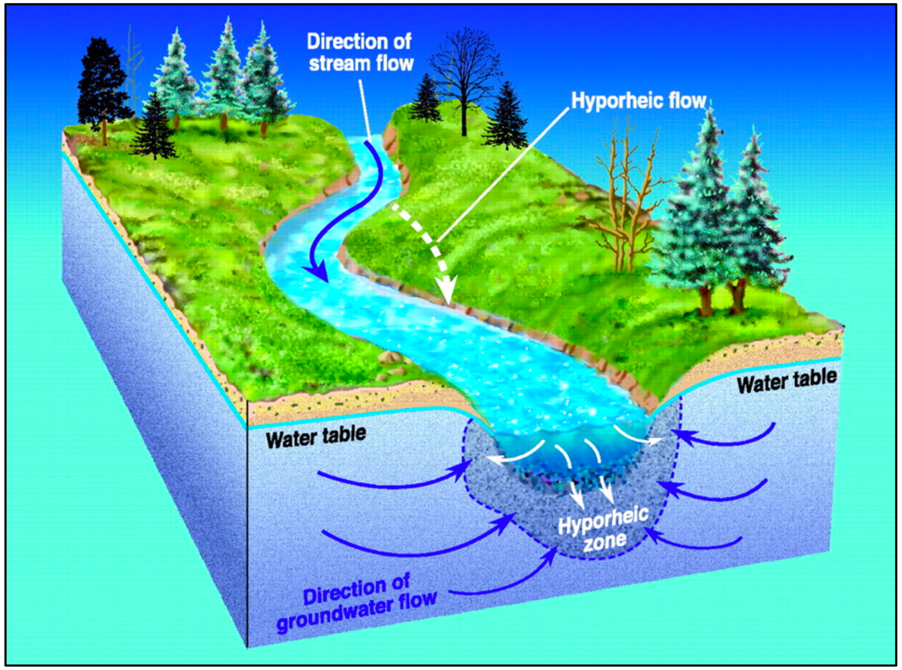
Robustness and efficiency are computed based on two key processes for Earth System Models

Groundwater Recharge



Taylor et al. (2013; Nat. Clim. Change)

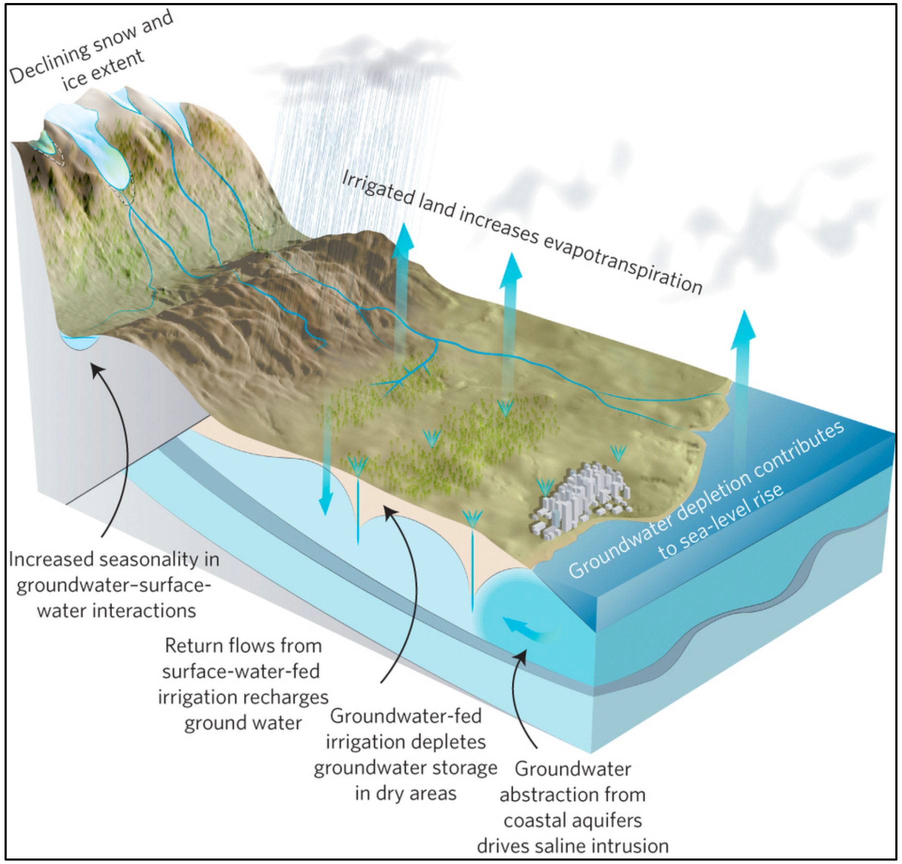
Groundwater Discharge



Alley et al. (2002; Science)

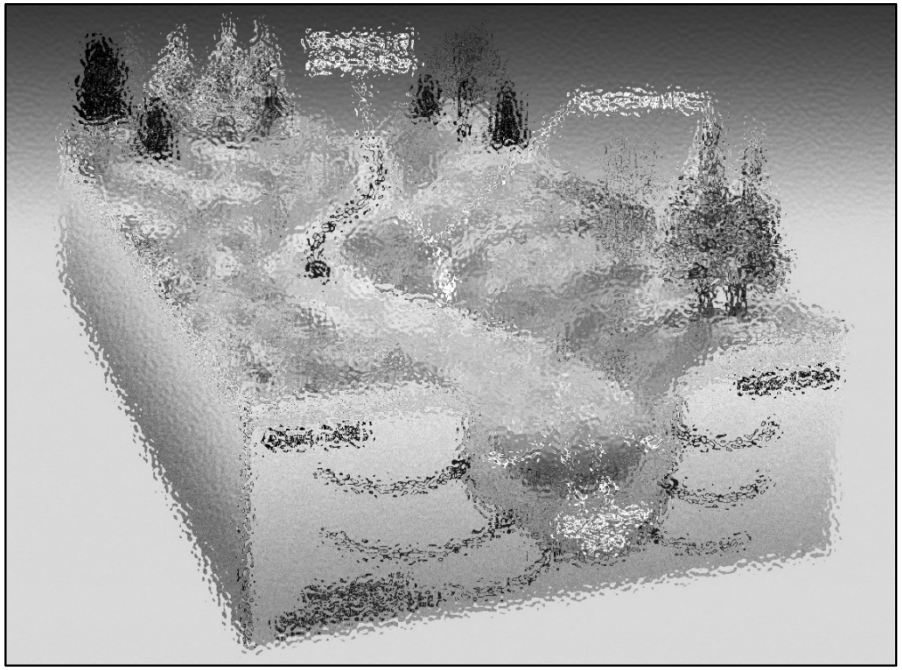
But we will focus on groundwater recharge today

Groundwater Recharge



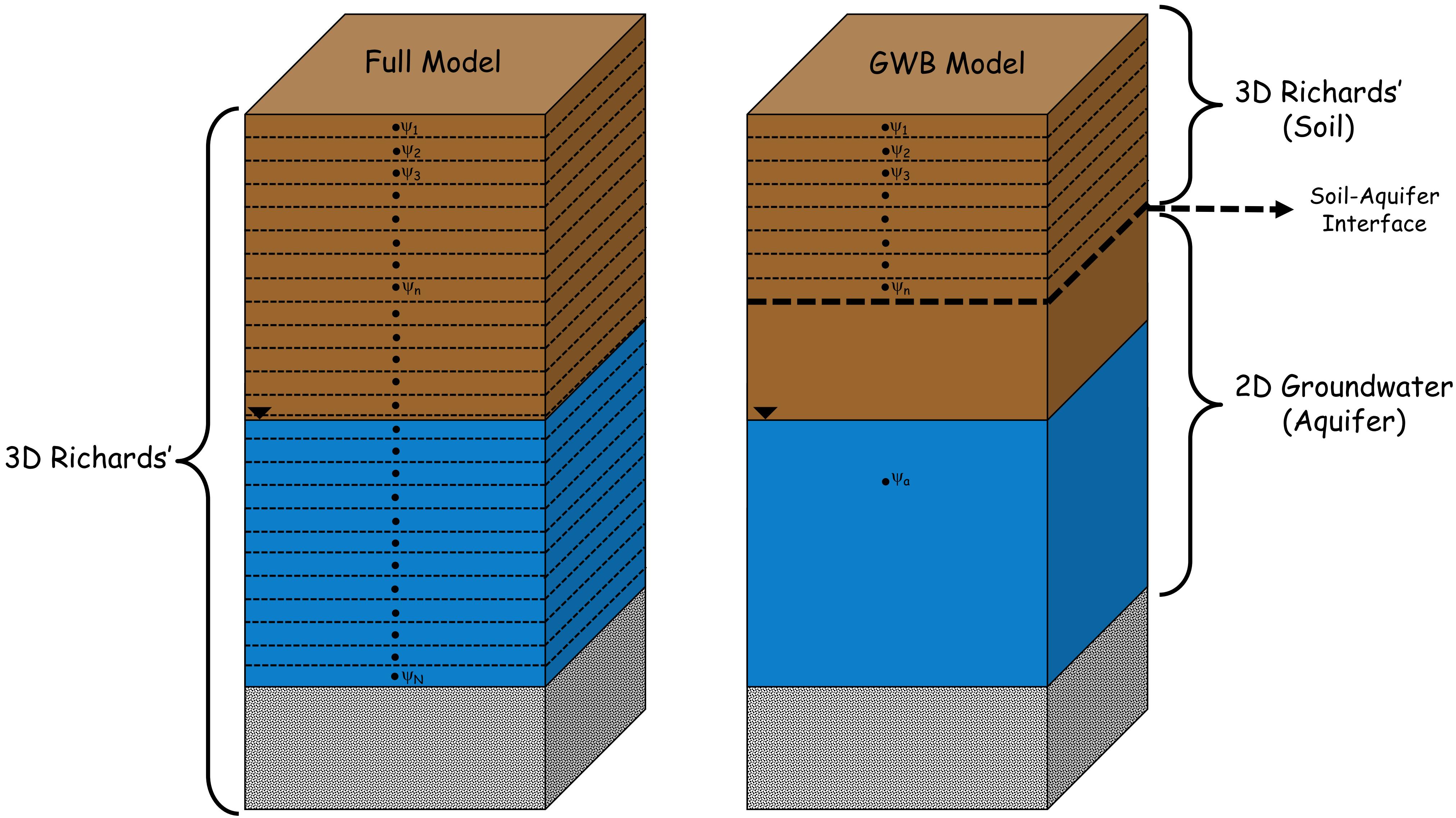
Taylor et al. (2013; Nat. Clim. Change)

Groundwater Discharge

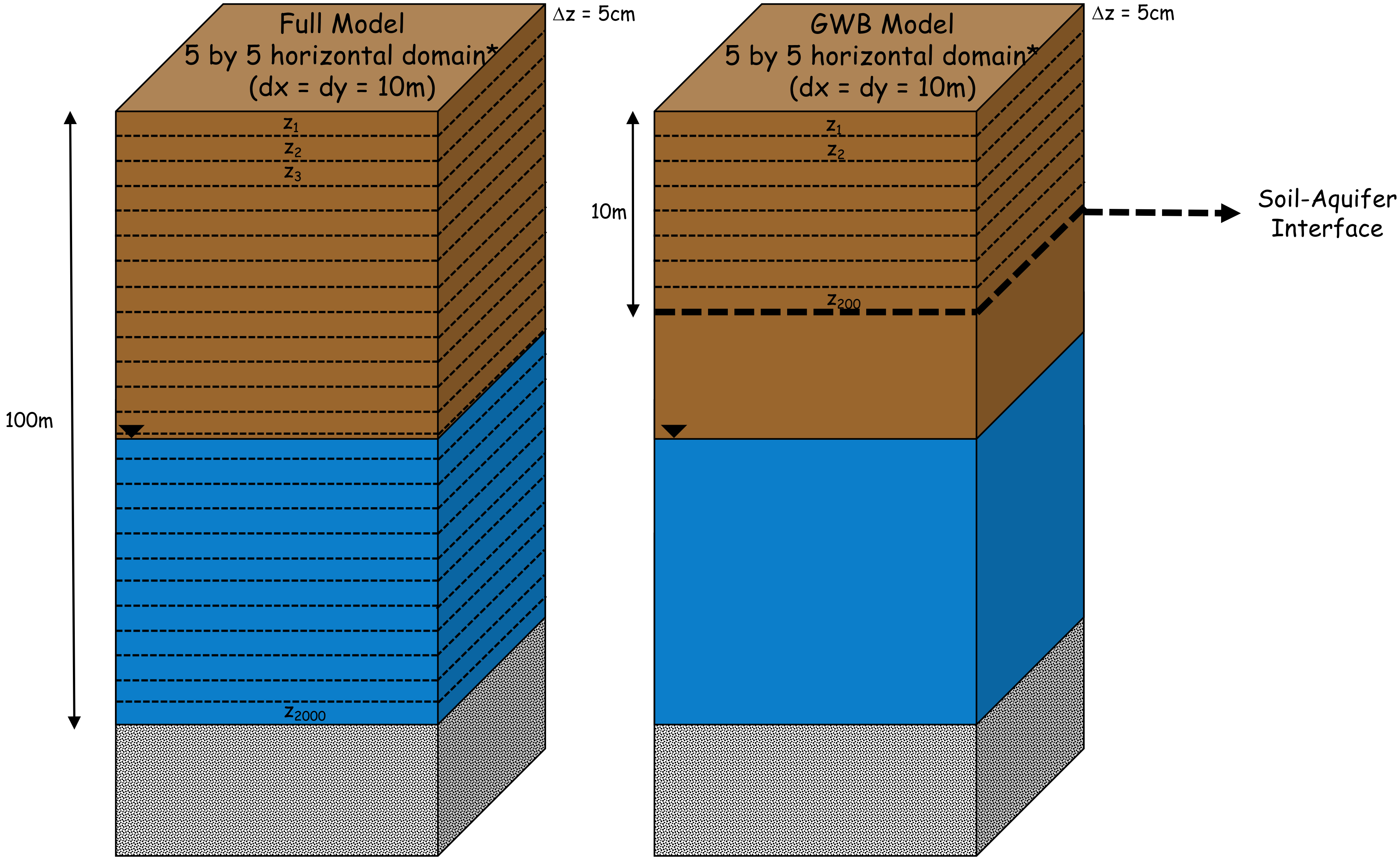


Alley et al. (2002; Science)

We compare the impact of our approach with a more complex model simulating 3D water dynamics within the entire domain

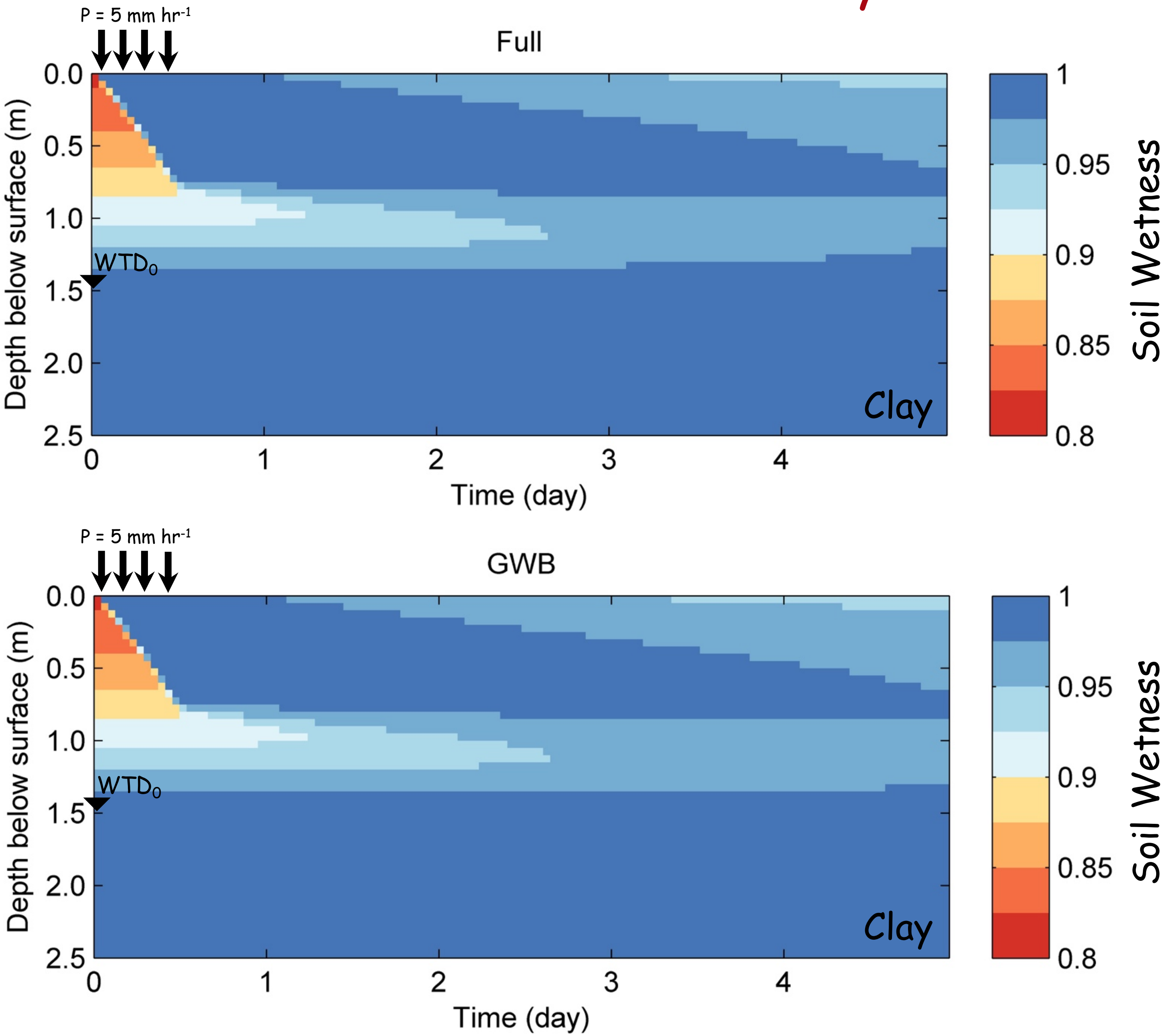


Groundwater Recharge: Experimental Setup

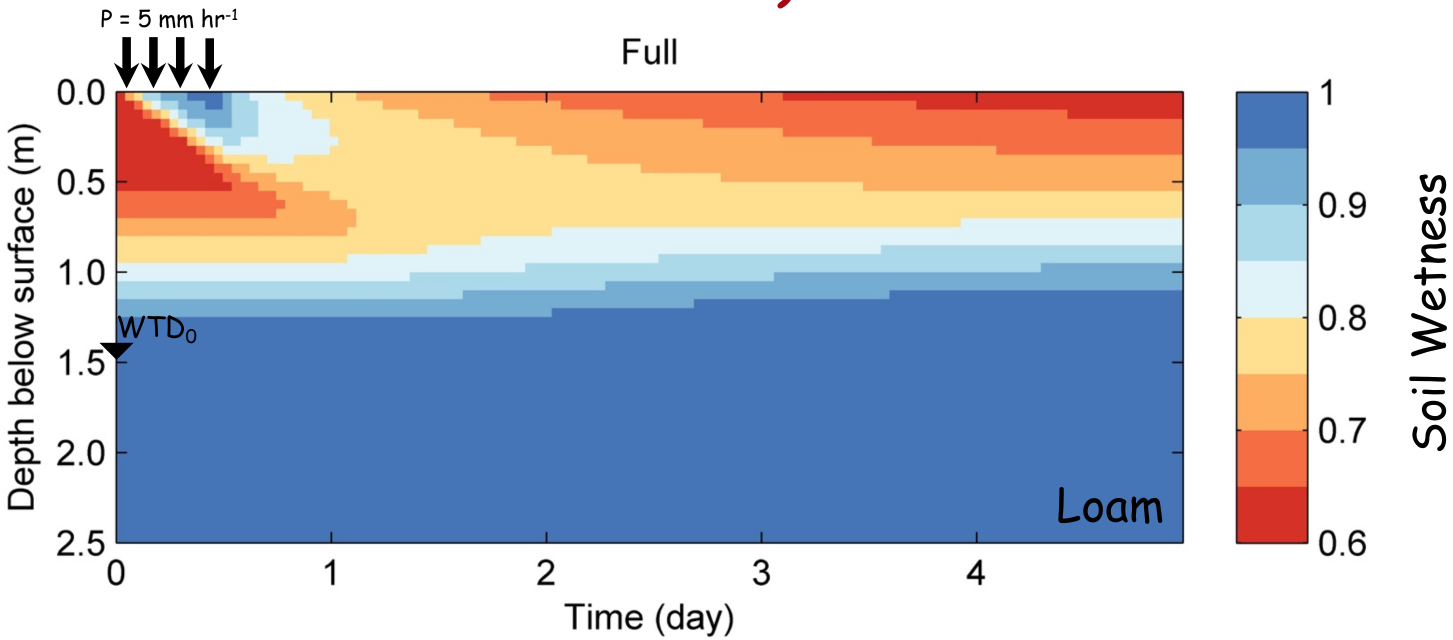


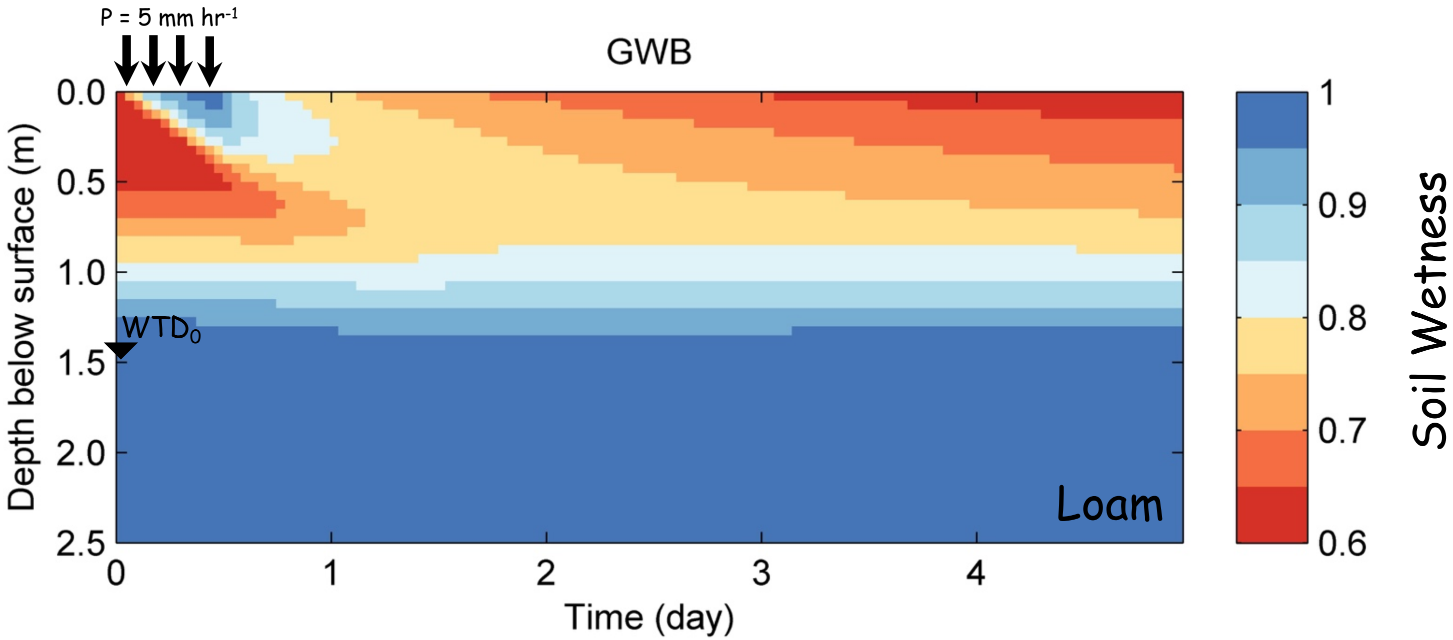
* Results shown for center grid point only

Very little difference between GWB and Full model for fine soil texture such as clay

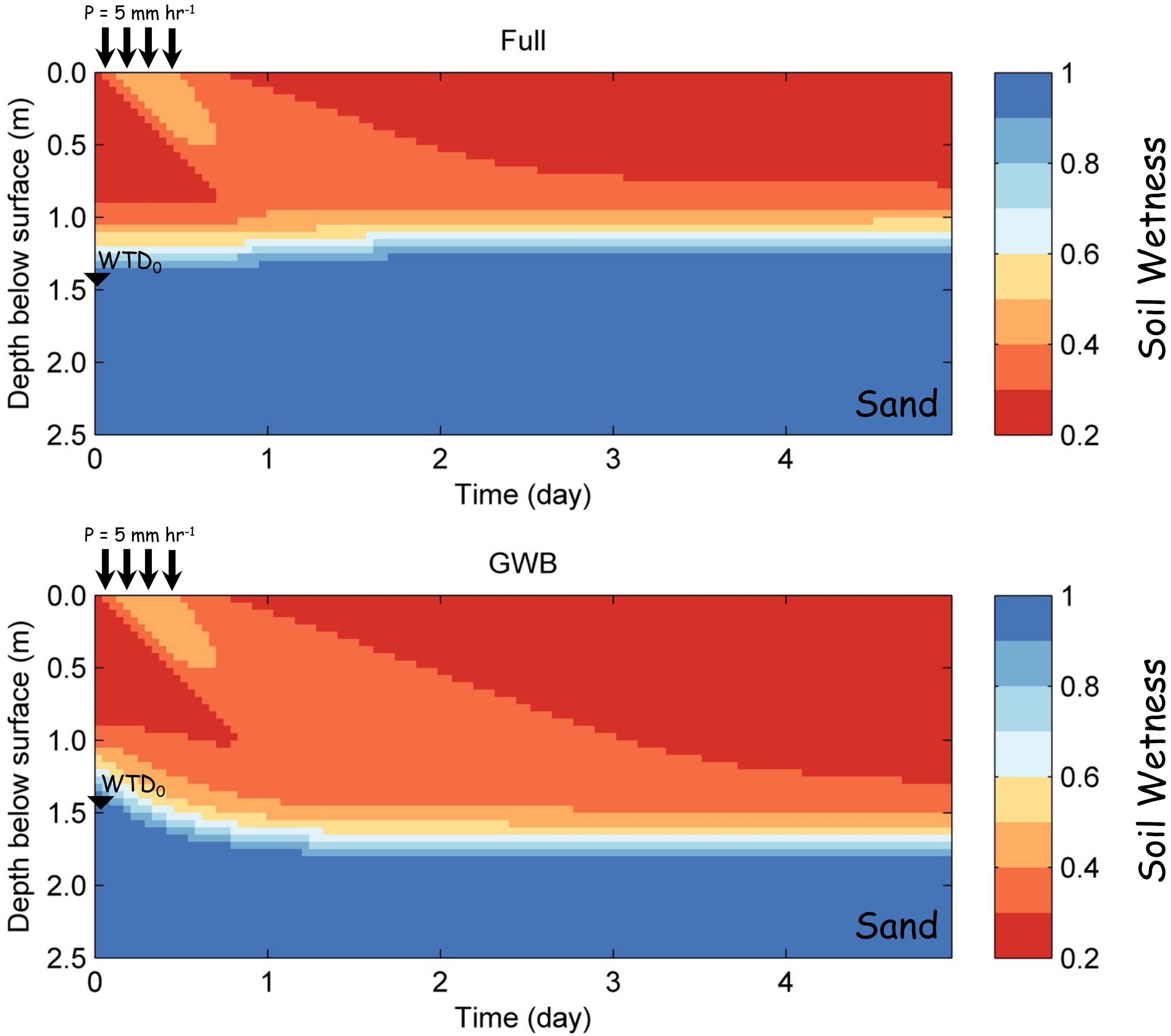


GWB deviates from Full as soil texture becomes coarser (e.g., loam)

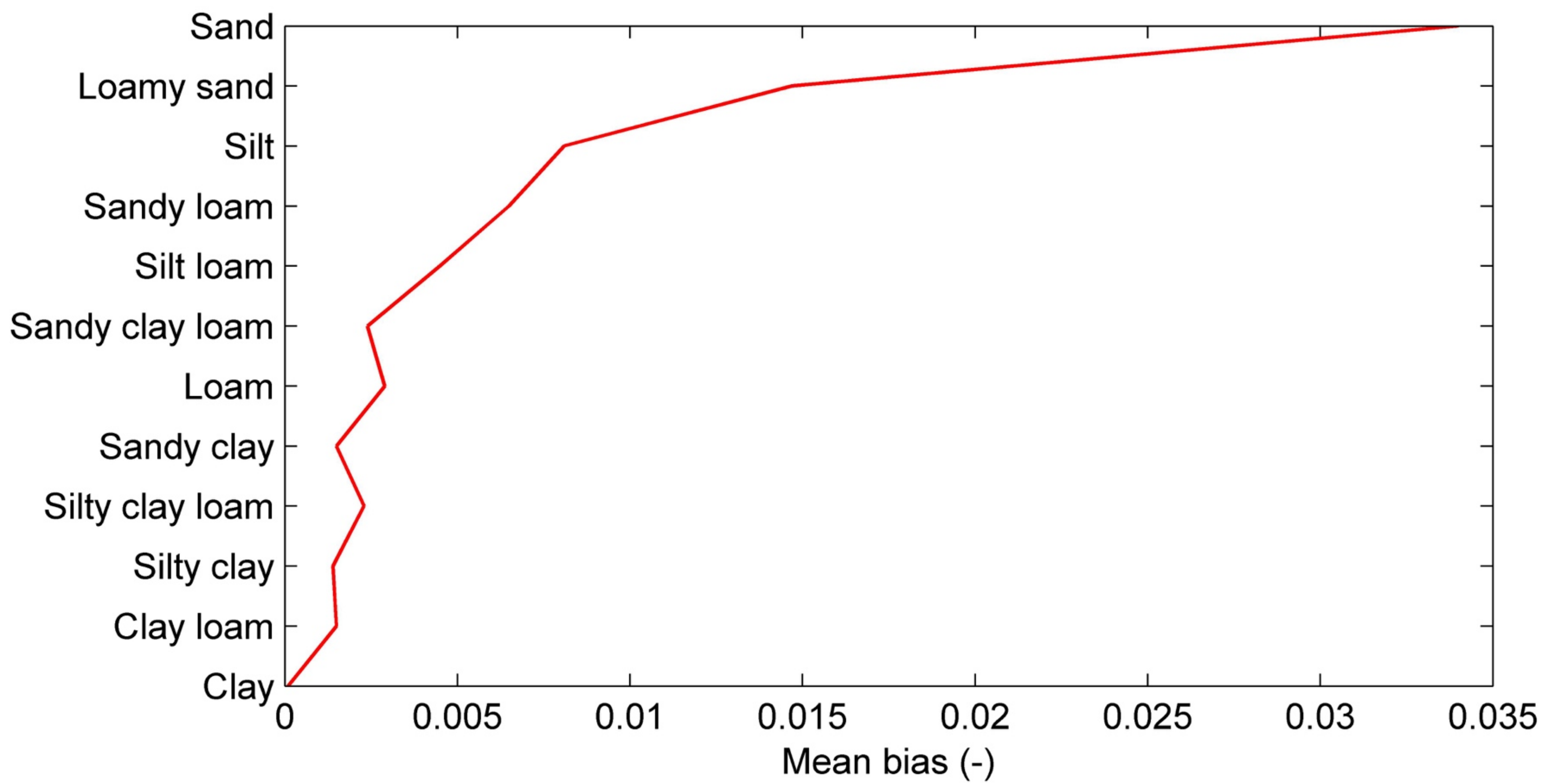




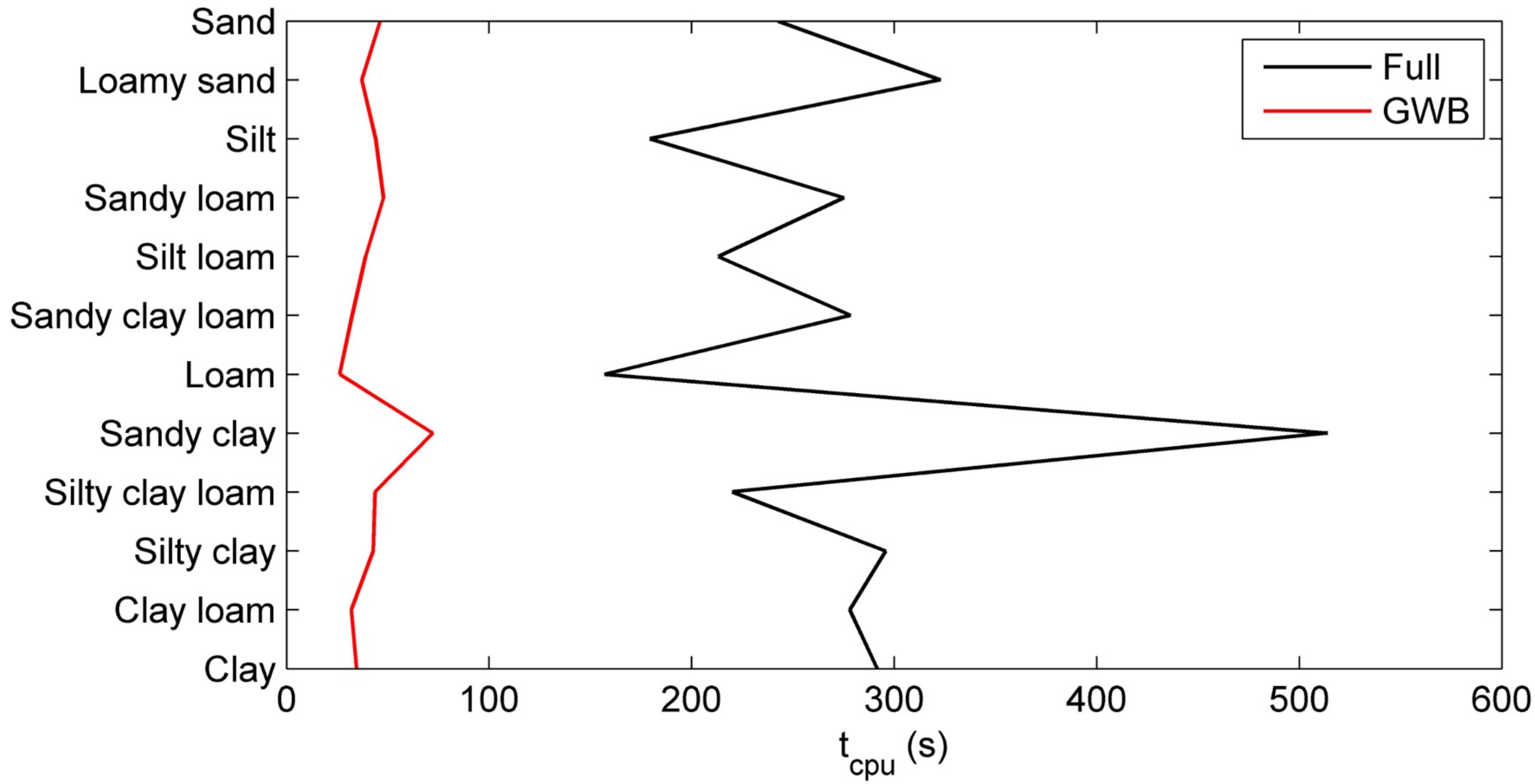
Highest deviations are observed for very coarse soils such as sand



Mean (Soil Wetness) Bias (entire period and within 0-10m soil domain) suggests GWB results to be highly robust, especially for relatively fine soil texture

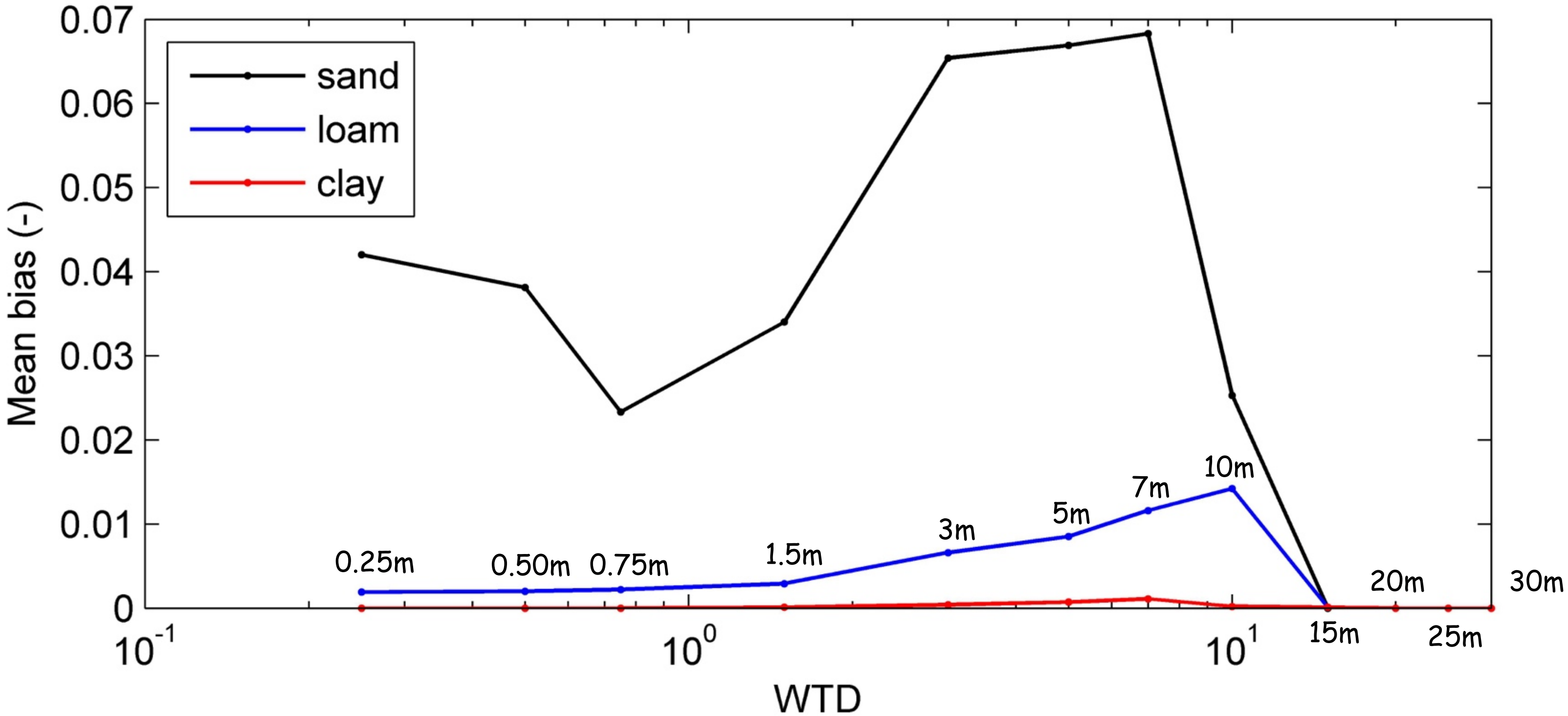


Our results also suggest that GWB is approximately one order of magnitude more efficient than the Full model regardless of soil type



CPU time

GWB's performance for different initial WTD suggest very good performance within the first meter (root active layer) and below 10m.



Initial Water Table Depth (m)

Summary

New GWB model incorporates groundwater dynamics assuming pressure and flux continuity at the soil-aquifer interface

We simplify a complex model to better understand the benefits/limitations of GWB model when applied to controlled experiments

Our overall "recharge" results indicate GWB model to be approximately one order of magnitude more efficient than complex model in simulating soil-aquifer interactions while showing high degree of robustness

Our "discharge" experiments suggest similar preliminary results (not shown today)

GWB is already implemented in our JULES version (more to come in the next few months)