Are we over-complicating our models?
Towards a more efficient and robust representation of sub-surface hydrological processes in Earth System Models

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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 $\Rightarrow$ groundwater table depth ($h$) defined based on pressure head ($\psi_s$) at the last layer of soil model

Flux continuity ($q_s = q_a$) $\Rightarrow$ 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**

- Declining snow and ice extent
- Irrigated land increases evapotranspiration
- Increased seasonality in groundwater-surface-water interactions
- Return flows from surface-water-fed irrigation recharges groundwater
- Groundwater-fed irrigation depletes groundwater storage in dry areas
- Groundwater depletion contributes to sea level rise

**Groundwater Discharge**

- Alley et al. (2002; Science)

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Taylor et al. (2013; Nat. Clim. Change)
But we will focus on groundwater recharge today.
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.
GWB’s performance for different initial WTD suggest very good performance within the first meter (root active layer) and below 10m.
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).