Improving the representation of lateral flow in E3SM land model

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E3SM
Energy Exascale Earth System Model

1. Background

- Motivation: Sub-grid heterogeneity of landscape and its associated lateral flow have important implications for water, energy, and carbon cycles. However, they are not explicitly considered in E3SM land model (ELM).

- Problem: How do we balance the physics, accuracy and computational cost when implementing the lateral flow in ELM?

- Our solution: Couple h3D hydrological model (Hazenberg et al. 2015) with ELM to simulate lateral flow along hillslopes.

2. h3D Hydrological Model

- h3D is a hybrid-3D hillslope hydrological model that couples a 1D vertical soil column model with a lateral pseudo-2D saturated flow model and overland flow model for use in ESMs

- lateral flow model is based on the Hillslope-storage Boussinesq (hsb) model proposed by Troch et al. (2003)

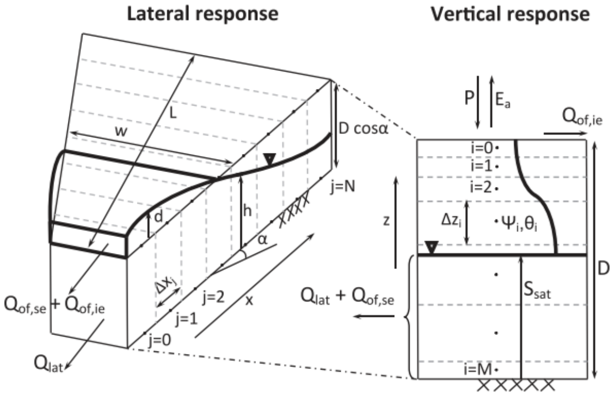


diagram of the h3D model

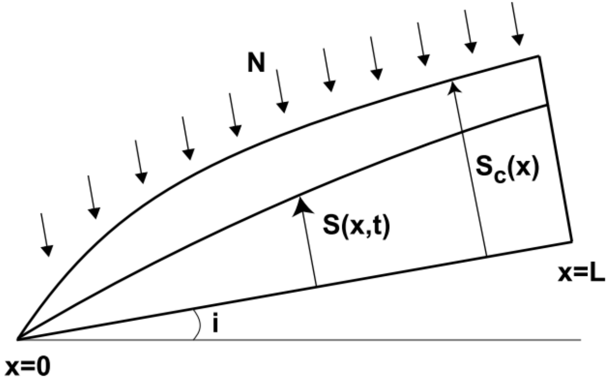
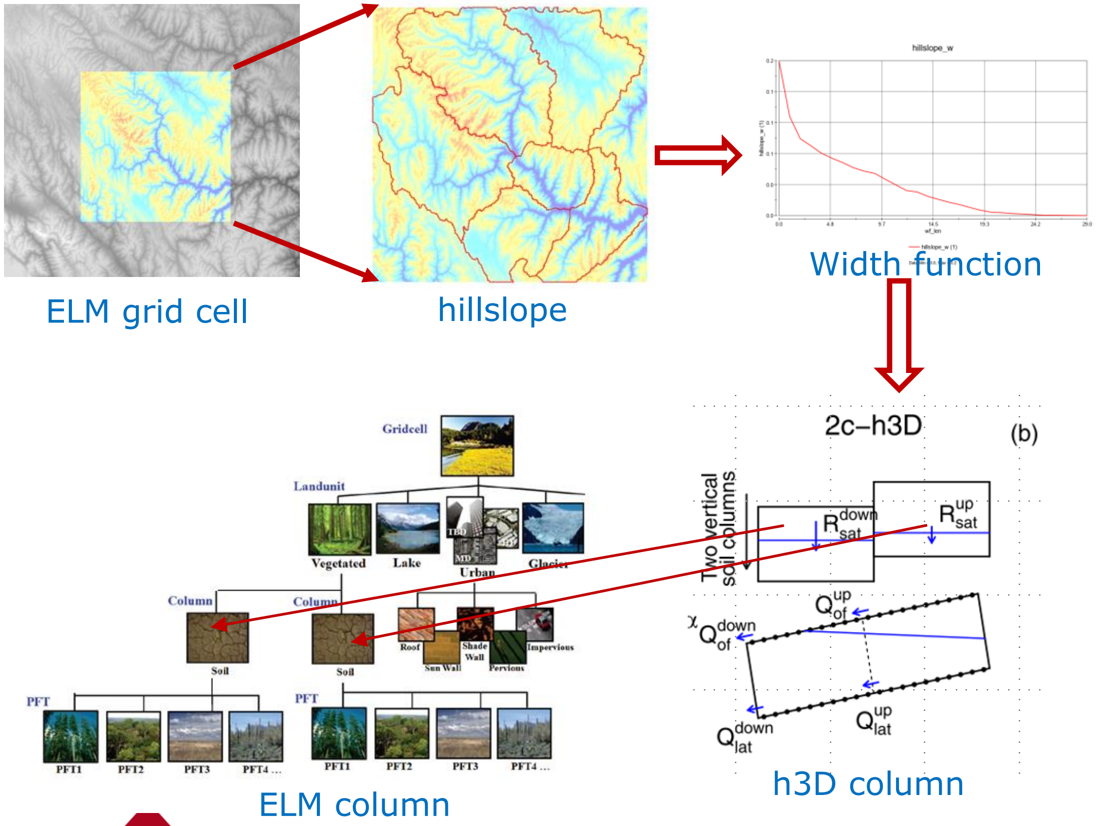


diagram of the hsb model

3. Coupling Scheme

- Generalize a single "representative hillslope" in each ELM grid
- Discretize hillslope into soil columns based on hillslope width function
- Implement h3D into vegetated/bare soil land units of ELM



4. Preliminary Results

Global simulation

Model Configuration

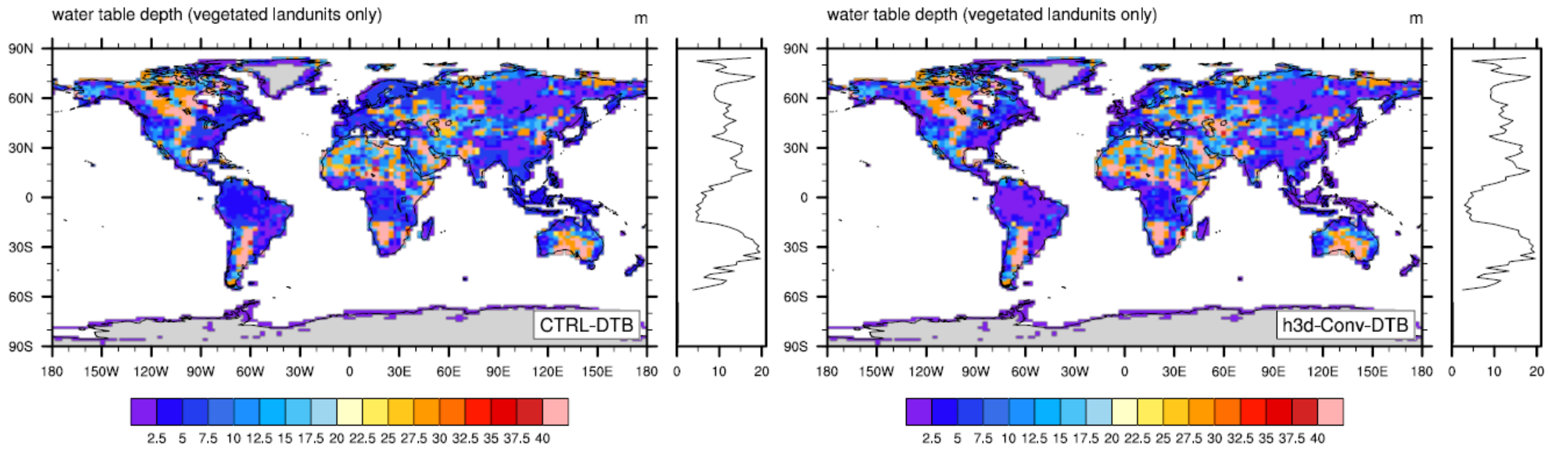
- compset: ICRUCLM45 (ELM+MOSART)
- resolution: f19_f19 (1.9 deg x 2.5 deg)
- 5 h3D columns per land unit
- with variable soil thickness

Some Simplifications

- use idealized width functions (uniform, convergent, divergent)
- assume soil columns in same land unit have:
  - same PFTs
  - same soil depth
  - same slope

4. Preliminary Results

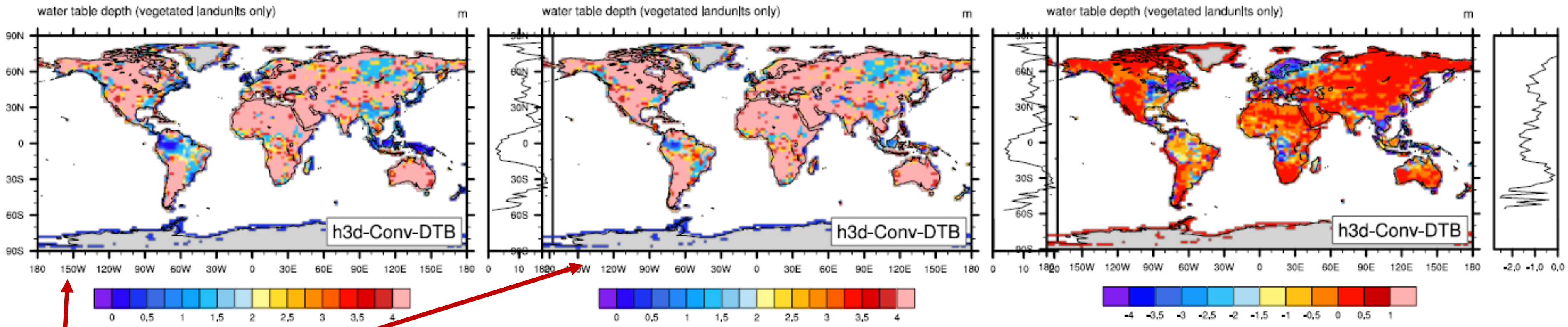
Water table depth simulated by ELM/h3d is comparable to that simulated by the standard ELM at grid cell level.

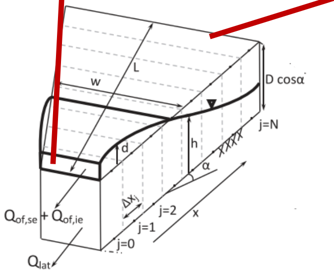


2000-2010 climatology water table depth at grid cell level (left: control run; right: h3D run)

4. Preliminary Results

ELM/h3d can produce water table depth variability along hillslope



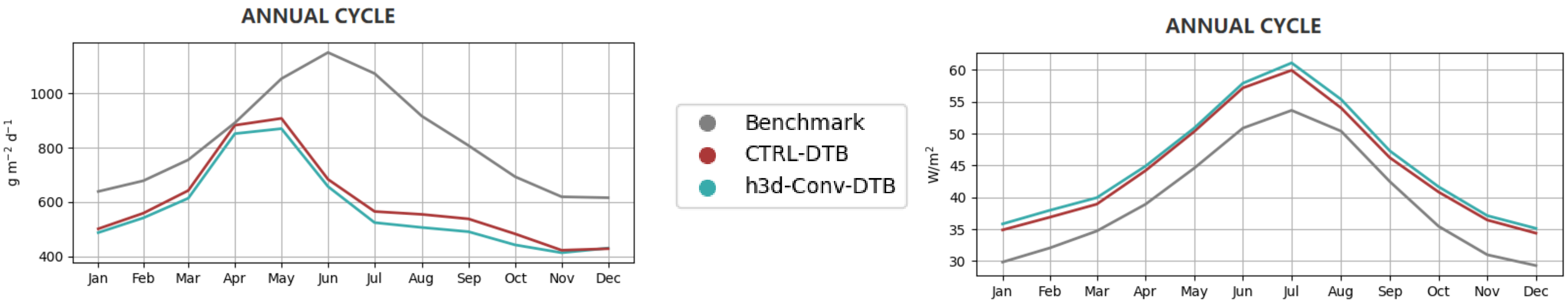


2000-2010 climatology water table depth at soil column level
(left: hillslope valley column; middle: hillslope top column; right: valley - top)

4. Preliminary Results

Evaluation using iLAMB shows runoff and latent heat flux from control and h3D runs are comparable at grid cell level.

Control and h3D runs are biased compared to iLAMB benchmark data, which might result from model forcing, resolution and/or calibration.



2000-2010 climatology of runoff and latent heat flux
left: runoff (benchmark - LORA); right: latent heat flux (benchmark - FluxNet MTE)

5. Conclusion

- ✓ H3d model is coupled to ELM. Preliminary evaluation proves ELM/h3d can produce comparable results to those simulated by standard ELM at grid cell level.

- ✓ ELM/h3d can produce sub-grid variability of water table depth (and many other variables) that affect land surface processes.

Next Steps:

- Calibrate the model to better match benchmark observational data

- Analyze the impact of sub-grid water table variability on global water, energy and carbon cycles.