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Comparison of Grid- and Subbasin-Based Approach to Representing Land Surface Processes

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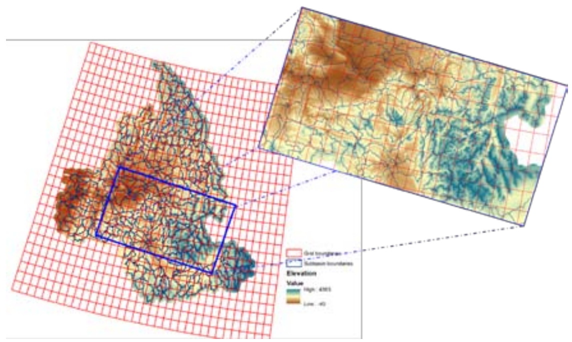
Improving the Scalability of CLM

- Comparison of grid based vs subbasin based representations
  - Topography has a dominant influence on hydrological processes such as runoff
  - One-to-one correspondence between subbasins and the river network structure makes it easy to parameterize runoff routing

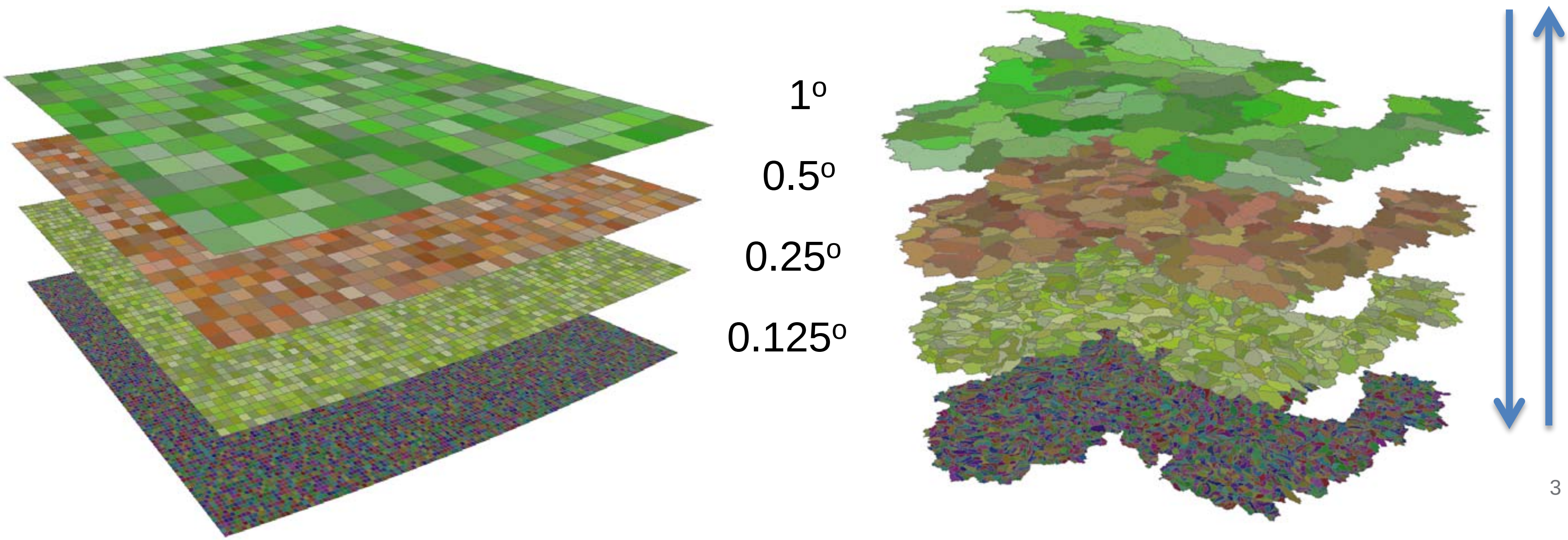


- The MOSART scale-adaptive river transport model works well across a range of resolutions with grids or subbasins (Li et al. 2013)
- Subgrid representations of surface heterogeneities (joint topography and PFT) and surface processes

Numerical experiments

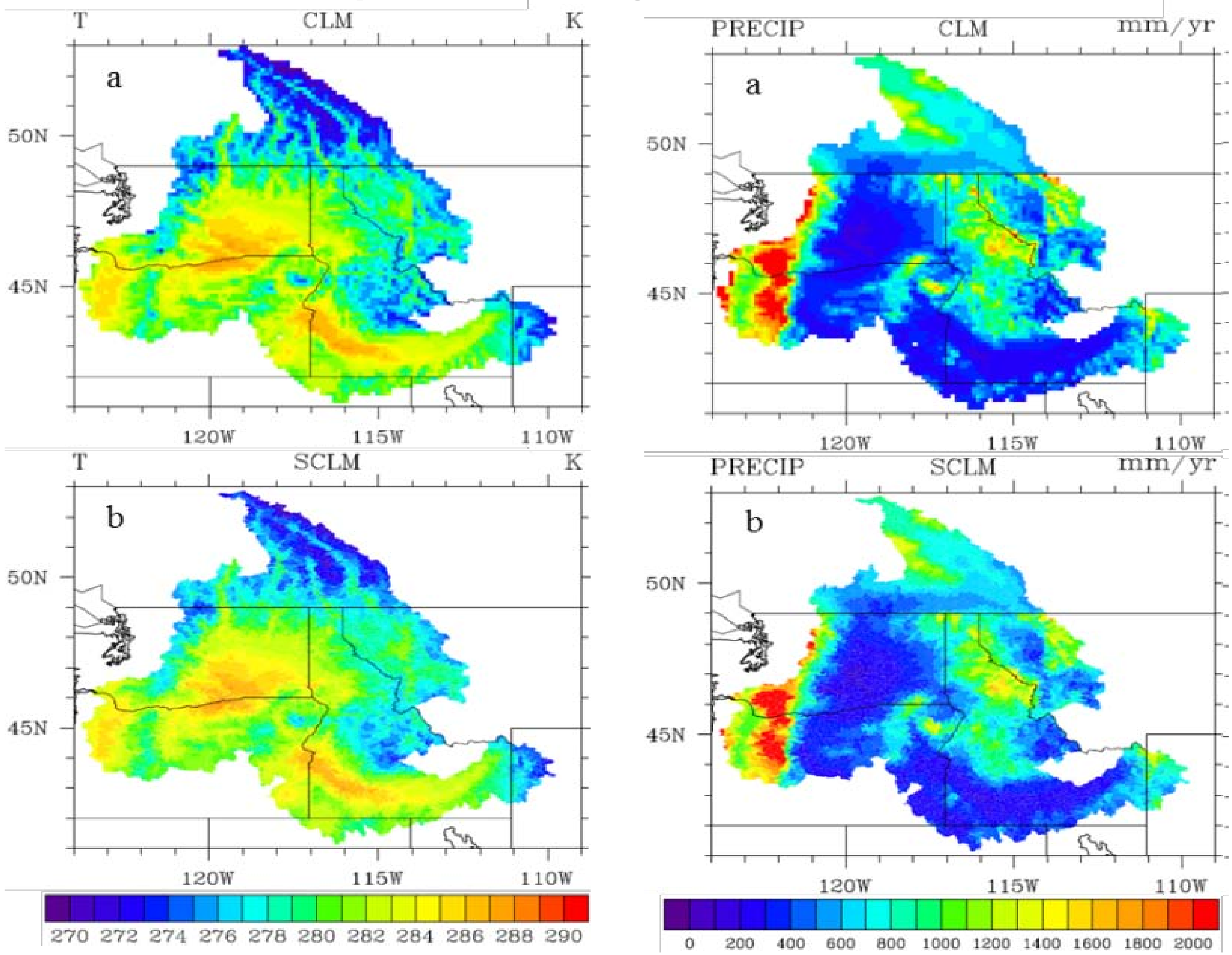
- Simulations are performed at multiple spatial resolutions, with the 0.125^{o} simulations used as “reference solutions”
- Aggregate results from 0.125^{o} to coarser resolutions for comparison with simulations at the coarser resolutions
- Interpolate results from coarser resolutions to 0.125^{o} for comparison with the simulation at 0.125^{o}

Grid-based representation (CLM) **Subbasin-based representation (DCLM)**



Basin characteristics

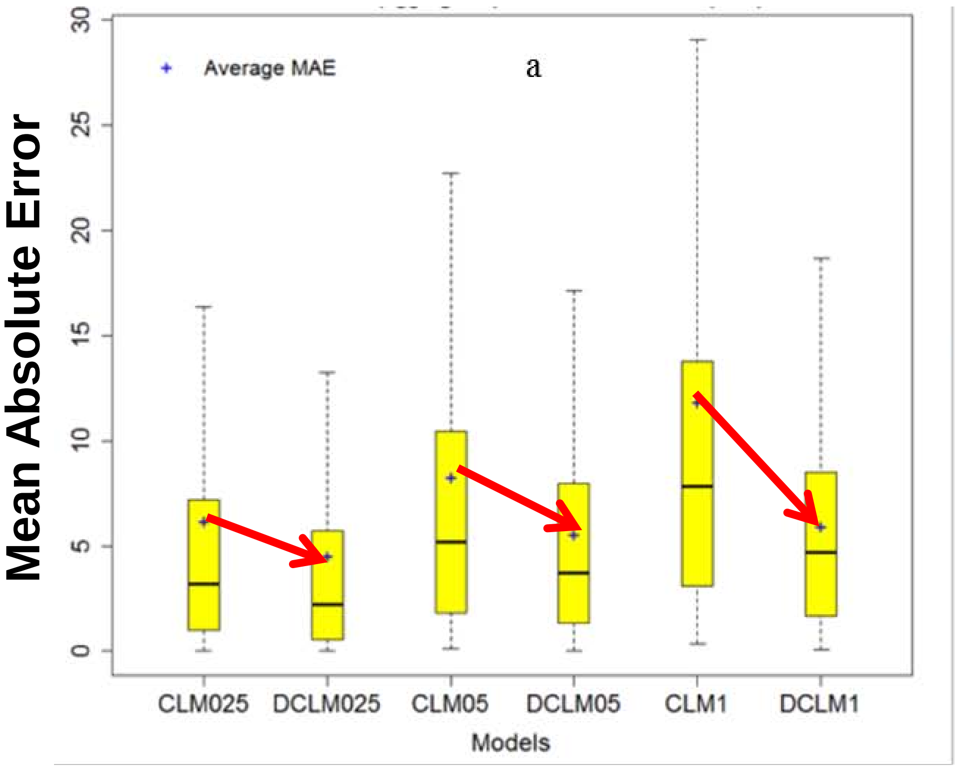
Atmospheric forcing at 0.125° resolution



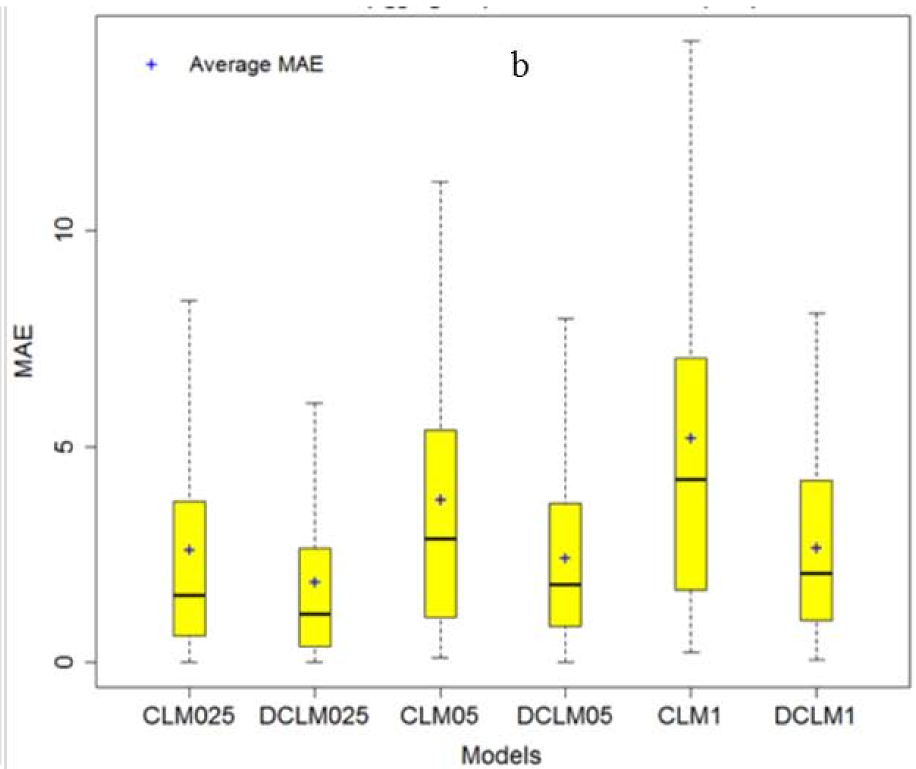
DCLM has improved scalability compared to CLM

- Differences between coarse resolution simulations and results aggregated from 0.125º to the coarse resolutions are smaller in DCLM than CLM

Total Runoff

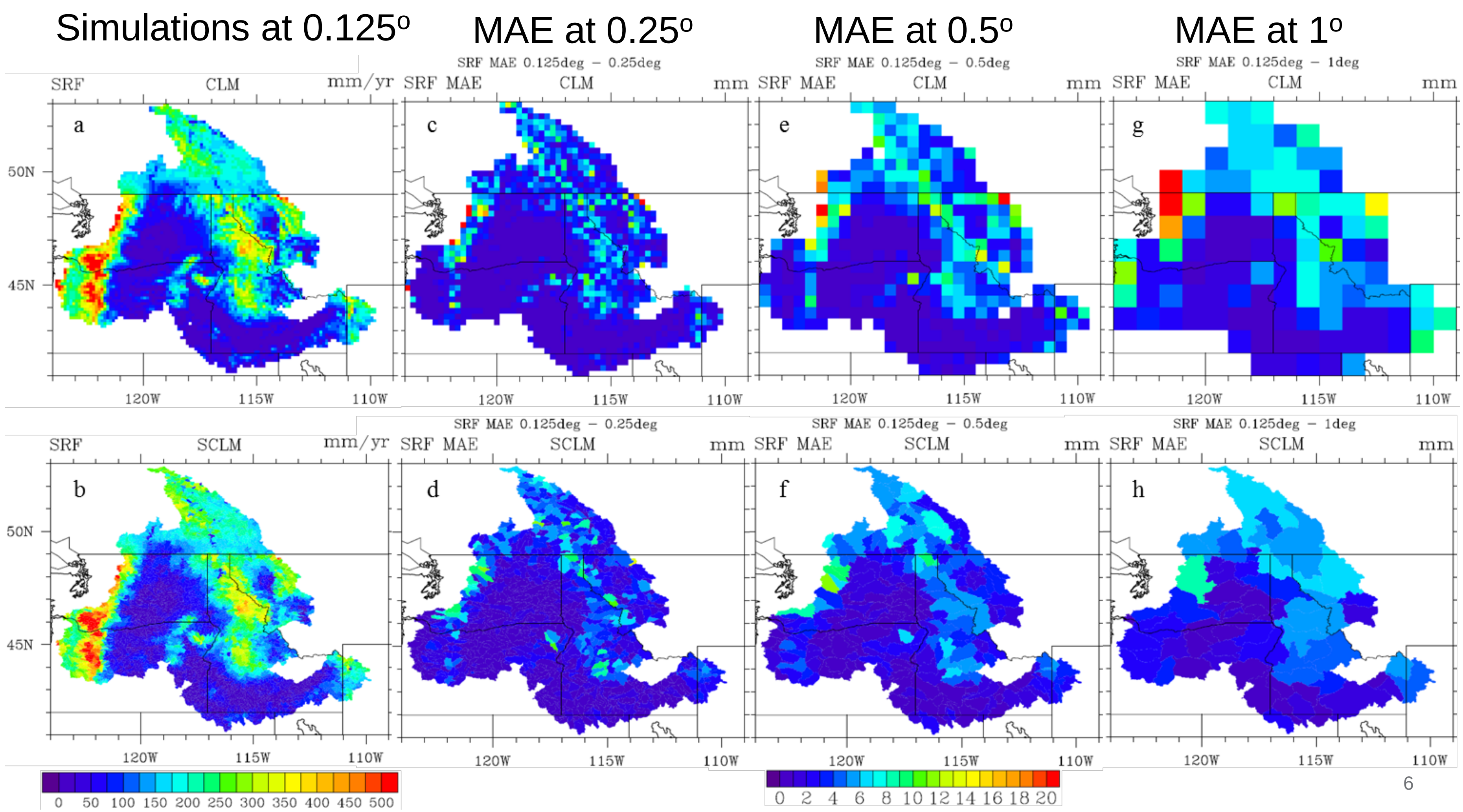


Surface Runoff



Surface runoff simulated by CLM and DCLM

- 'Errors' at coarse resolutions are associated with mountains



Where does the improvement come from?

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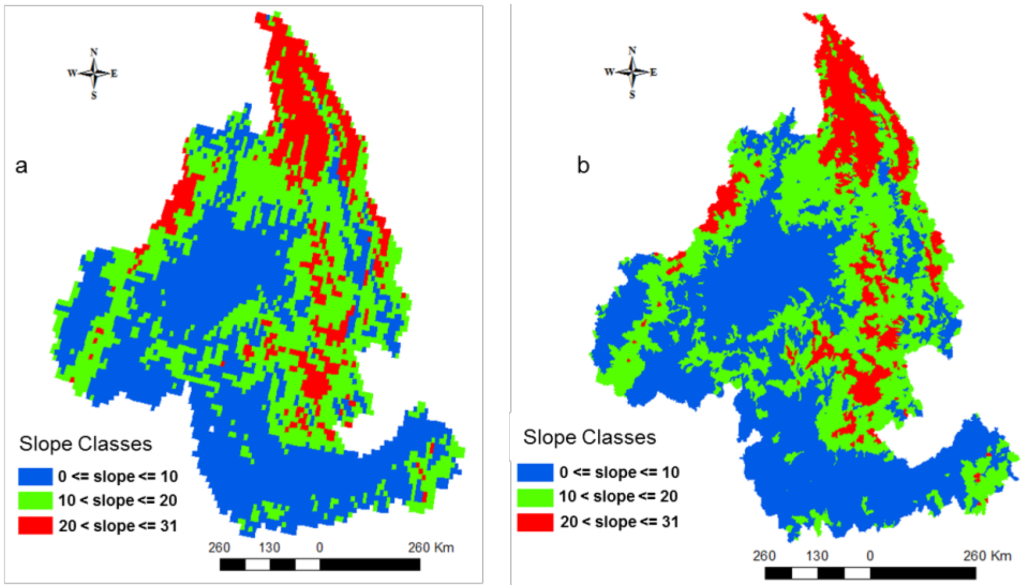
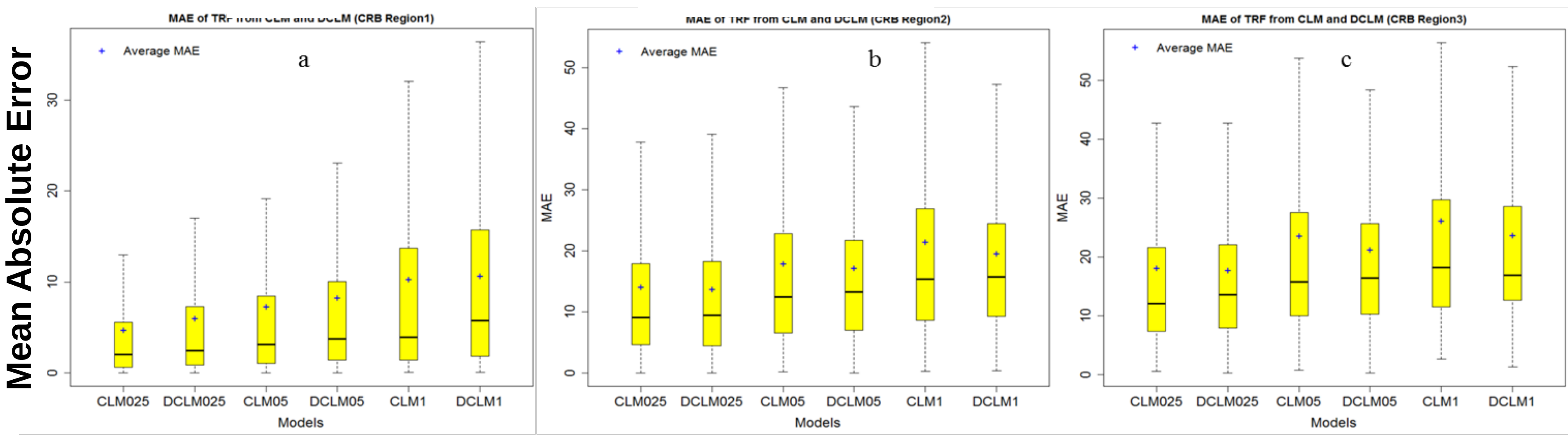


- The basin is partitioned into 3 regions defined by the average slope
- The improved scalability mainly comes from the mountainous regions due to improved scalability of elevation in the subbasin representation

Flat **Intermediate** **Steep**



Scalability of snowfall

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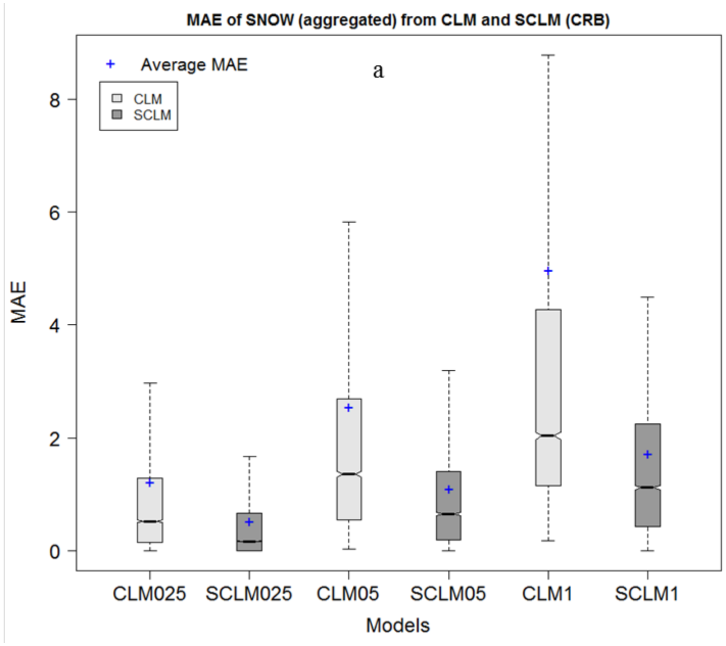
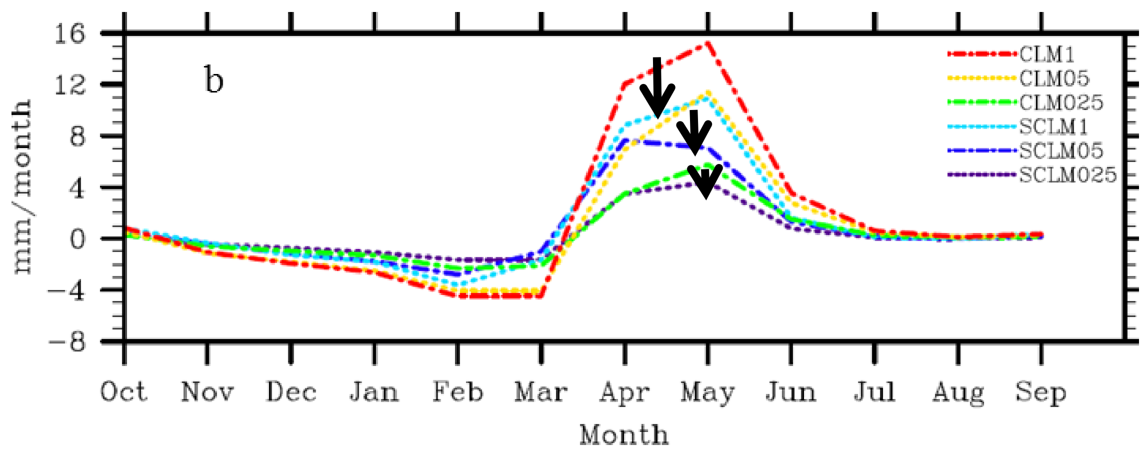
- Significant improved scalability in snowfall in the subbasin-based approach derived from scalability of surface elevation

MAE of snowfall



MAE of snowmelt

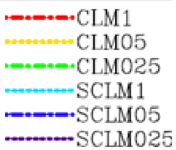


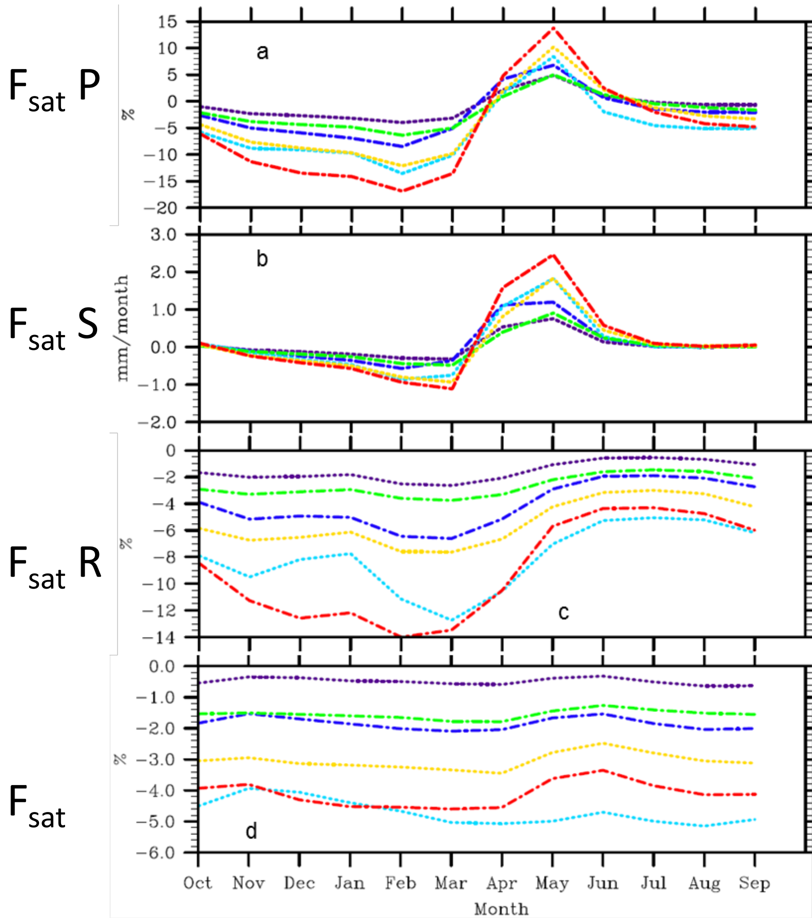
Contribution from surface runoff parameterization?

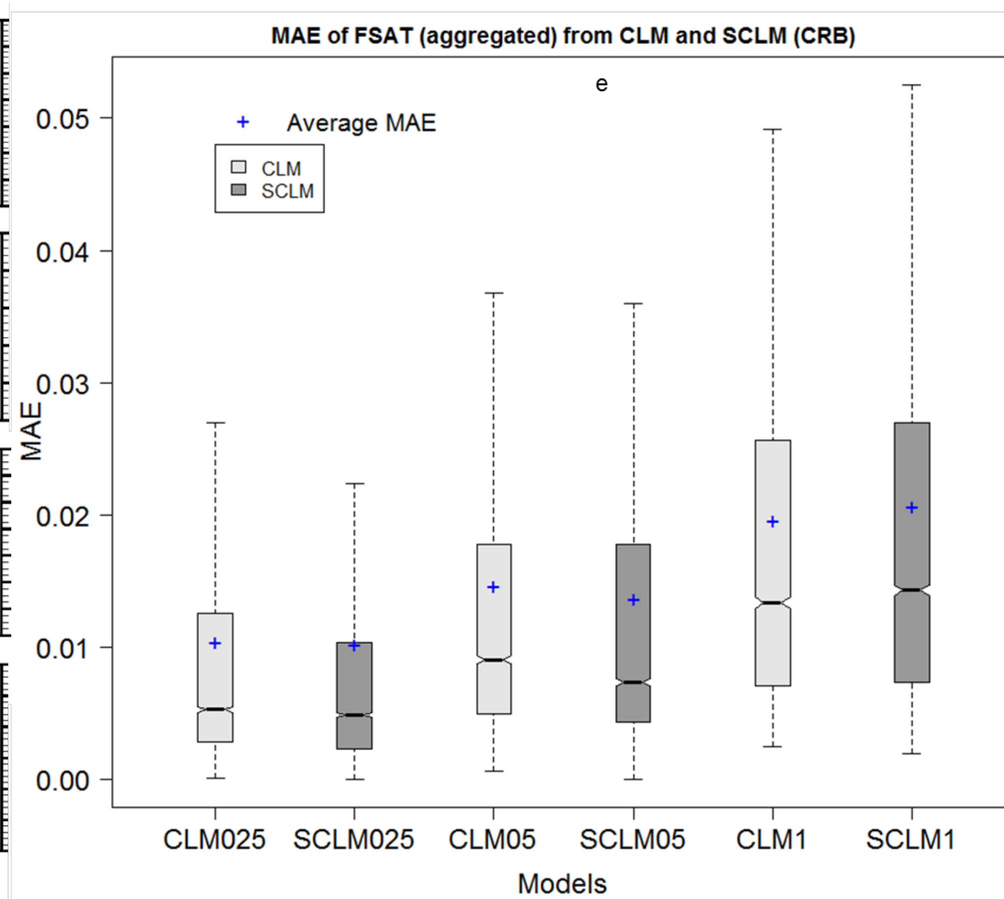
Saturation excess   Infiltration excess

$$SRF = \underbrace{F_{sat}P}_{\text{Saturated}} + \underbrace{(1 - F_{sat})max[0,(P - I}_{\text{Unsaturated}}$$

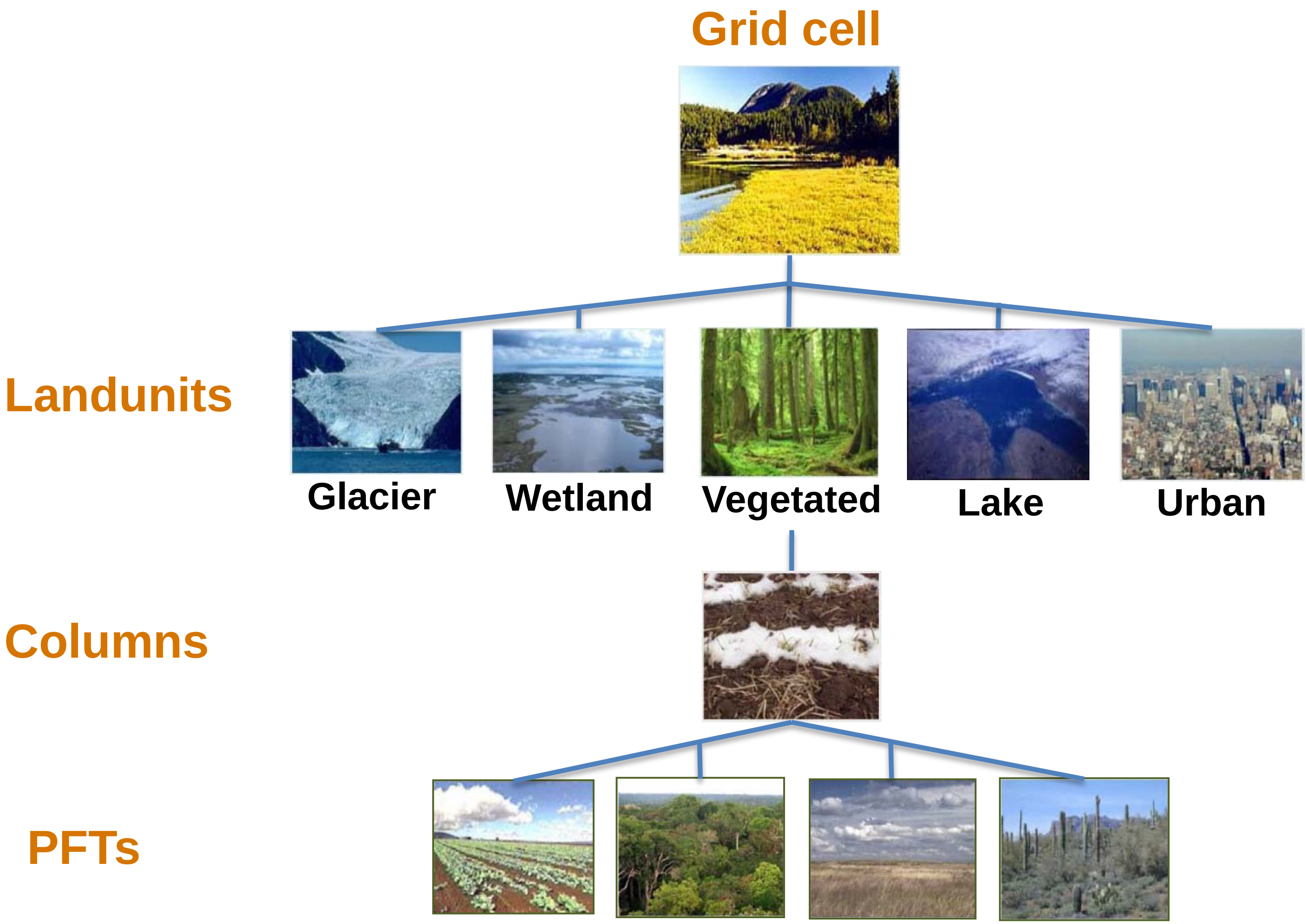
$$F_{sat} = F_{max}exp(-C_s f_{over} z)$$





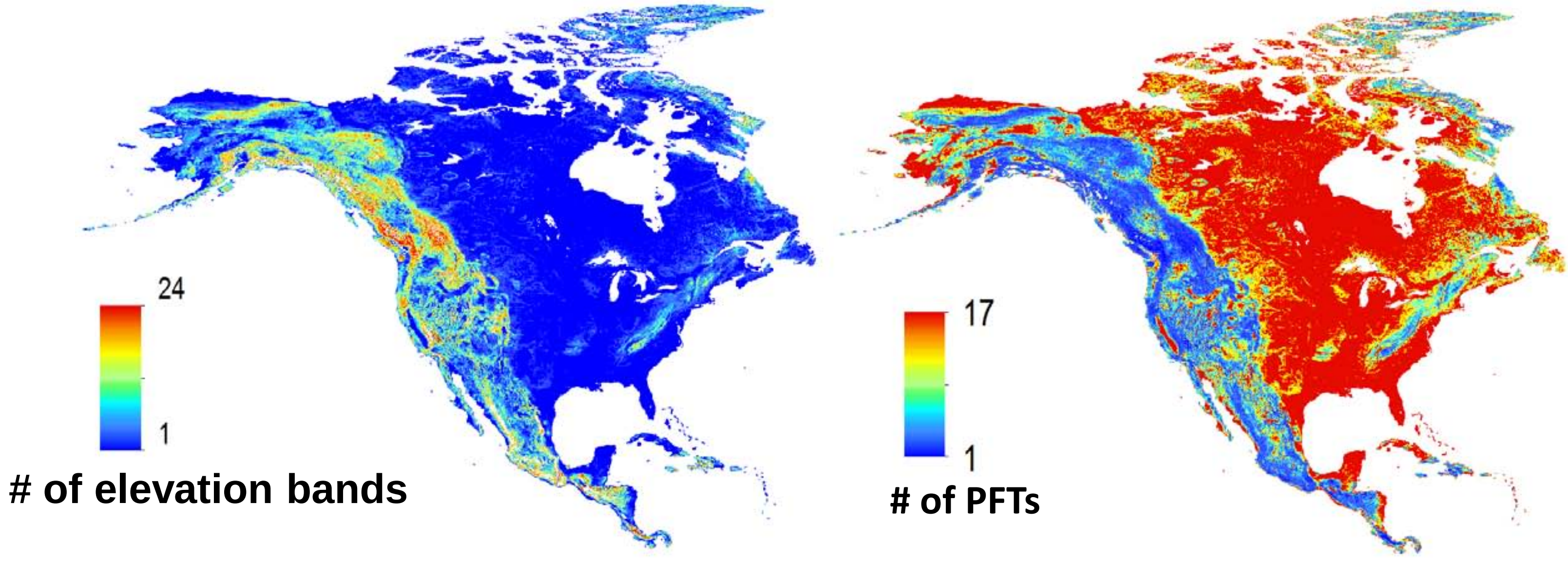


The CLM subgrid structure



Representing subgrid topography

An optimal approach to represent both subgrid vegetation and elevation



- Developed an optimal subgrid classification of elevation and vegetation in CLM (Ke et al. 2013)
- Disaggregate atmospheric forcings for subgrid elevation classes using simple lapse rates or a subgrid orographic precipitation scheme (Leung and Ghan 1995; 1998)

Summary

- Without any changes in parameterizations, improved scalability can be achieved by using subbasins rather than regular grids as computational units
- The improved scalability is related to scalability of surface elevation following subbasin boundaries, leading to:
  - More accurate atmospheric forcing such as temperature and snowfall, and consequently snowmelt driven runoff
  - More accurate estimation of topographic index used in the saturation excess runoff parameterization
  - Small improved scalability in surface fluxes in this energy limited regime
- The subbasin based framework also provides a more logical way to model river routing and water management
- Spatial structures that take advantage of spatial characteristics of atmospheric and hydrologic processes can improve model scalability: subbasin vs subgrid topography