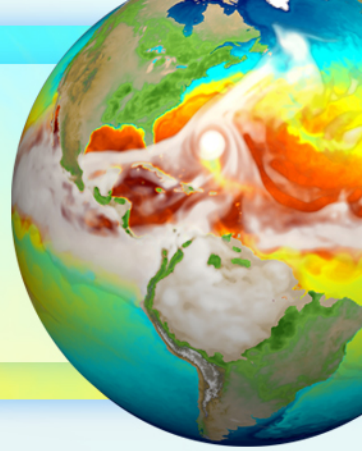
Impacts of new atmospheric forcing downscaling methods and topography-based subgrid structure on E3SM simulations



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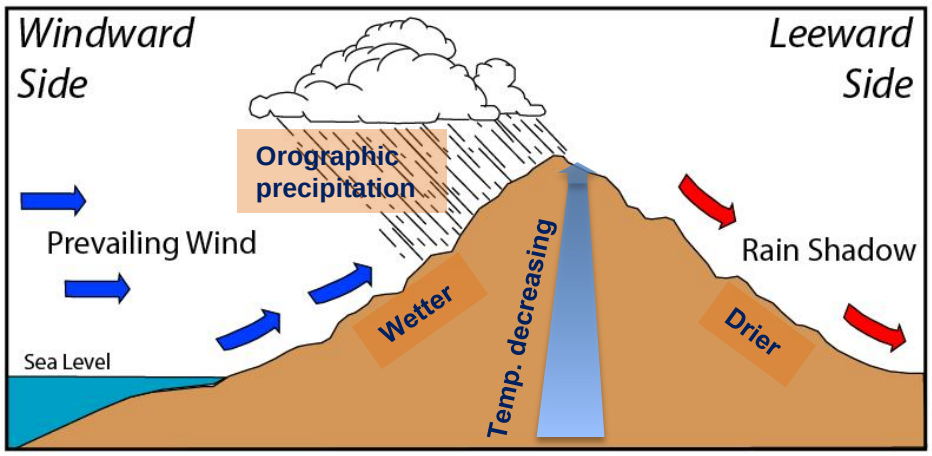
E3SM Energy Exascale Earth System Model

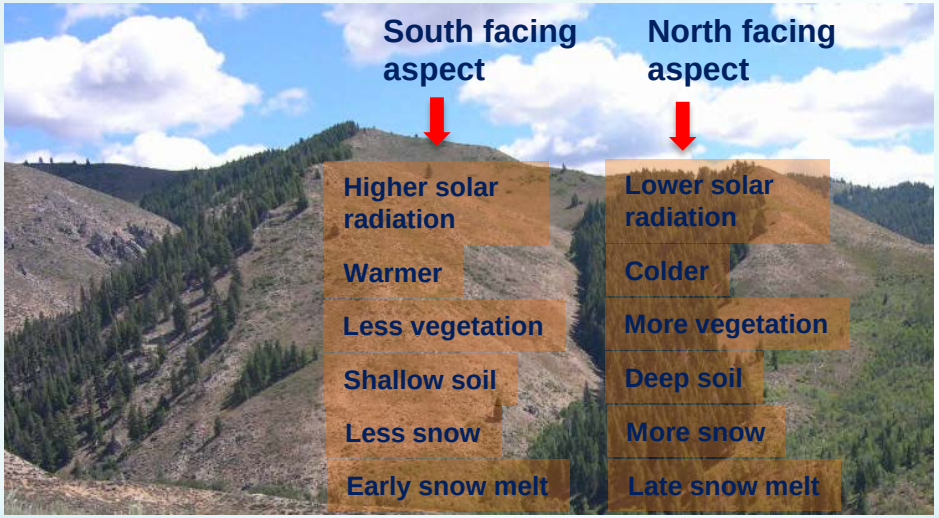
U.S. DEPARTMENT OF ENERGY

Motivations

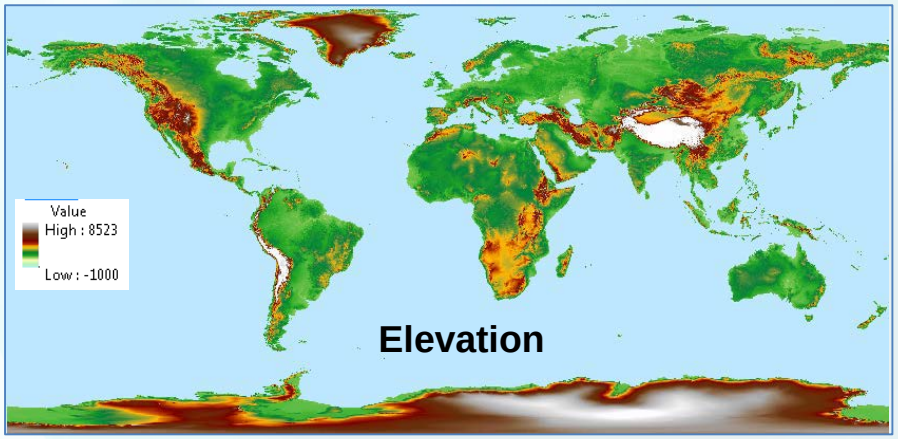
Topography Matters!

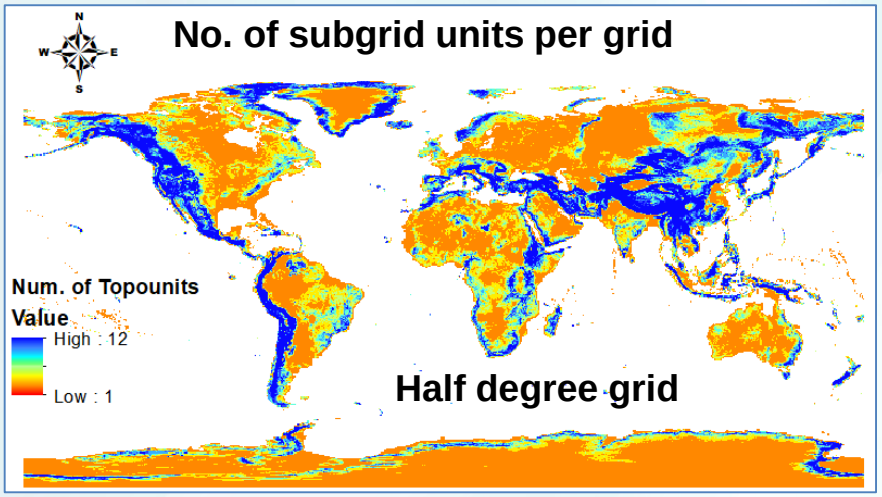
- It exerts major control on land surface processes; for example:
- Precipitation: Windward vs Leeward
- Temperature: high vs low elevation
- Energy balance: e.g. aspect
- Vegetation distribution: aspect, elev..
- Soil properties: aspect, slope etc.
- Limitation of current Earth System Models in representing effect of topographic spatial heterogeneity

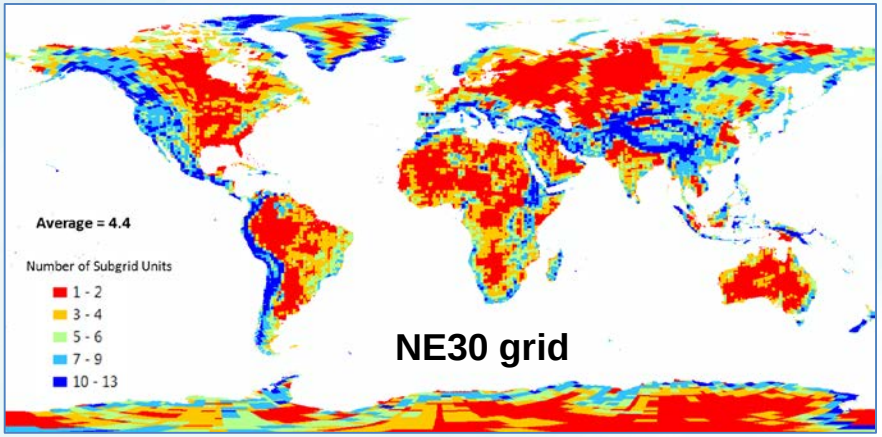




Efforts to develop topography-based subgrid structure for E3SM



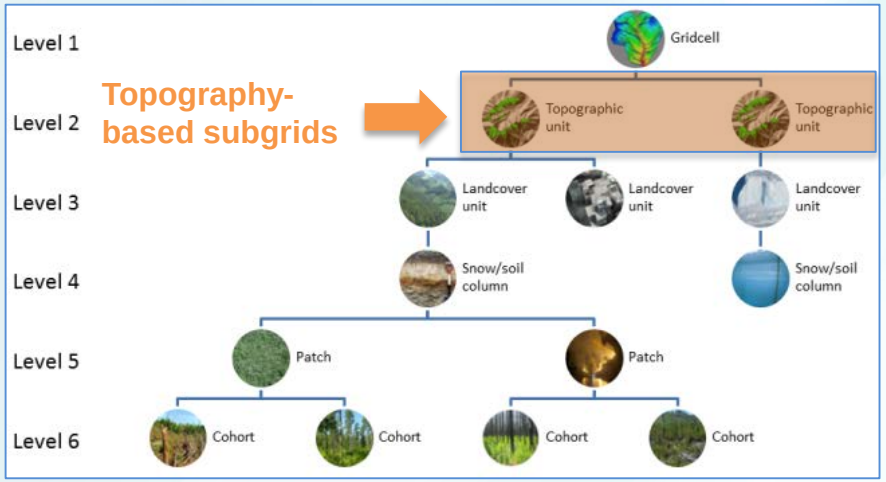




- Multiple types of subgrid structures have been developed using high resolution elevation data and evaluated for their capability to capture impacts of topographic heterogeneity (Tesfa and Leung, 2017).
- Capturing effects of topography on land surface processes, vegetation and land cover, and land-atmosphere interactions
- Representing topographic heterogeneity in the E3SM land model (ELM) using optimal number of subgrid units per grid
- Reduced computational demand compared to discretizing grid into fine resolution grids

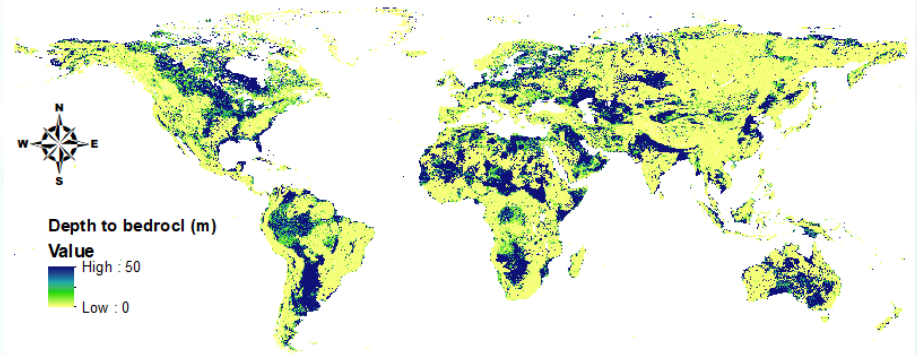
Efforts to implement the subgrid structure in E3SM

- **Two options**:
  - Single topounit per grid
  - Variable number of topounits per grid
- Default is single topounit per grid
- Variable number of topounits per grid reduced the total number of topounits by about 65% compared to when using same number of topounits per grid in all grids.
- Involves development of surface data based on the new subgrid structure

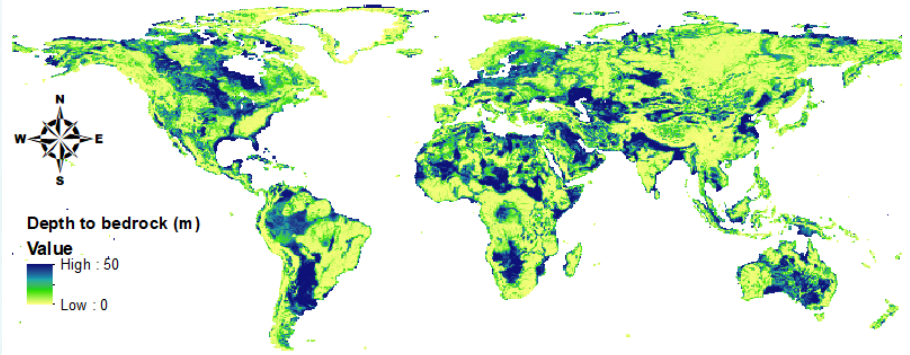


Hierarchical subgrid structure in ELM

High resolution input data of depth to bedrock

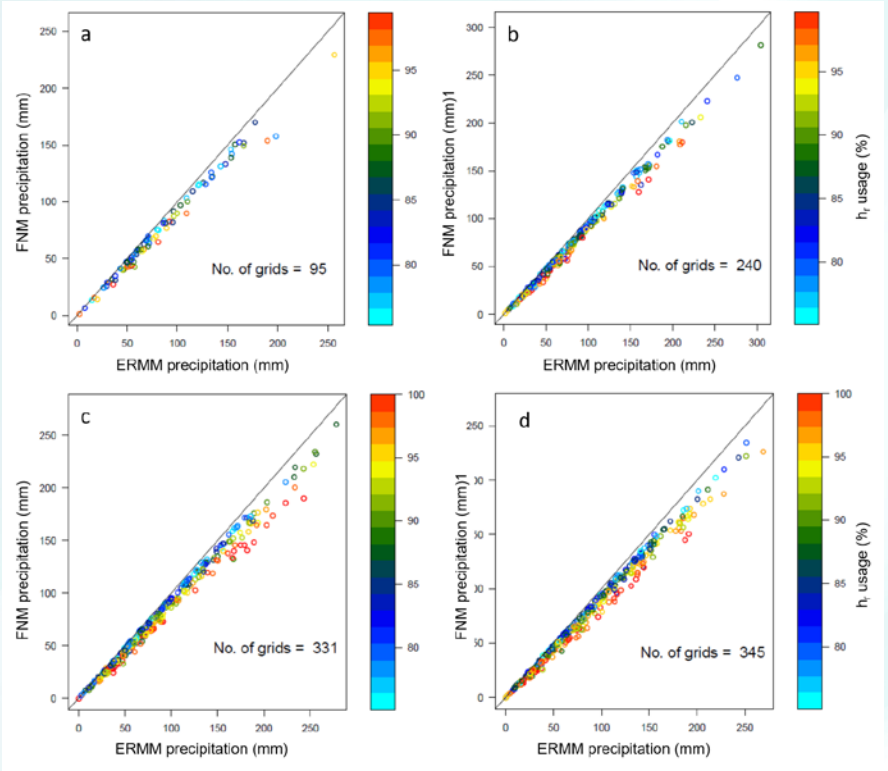


Topounit-based depth to bedrock data



Efforts to develop methods of downscaling atmospheric fluxes in E3SM

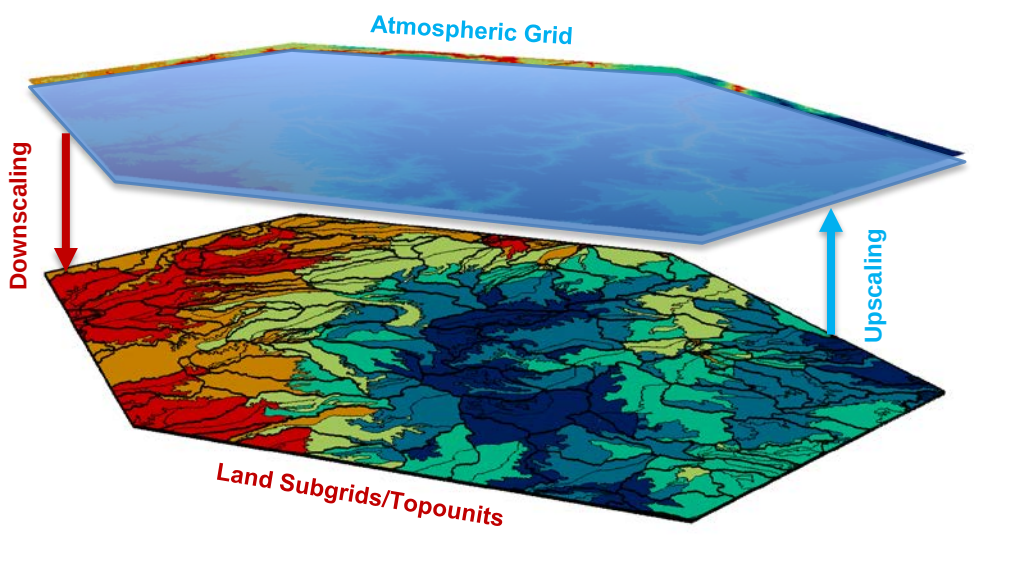
- To benefit from the new subgrid structure methods are needed to downscale atmospheric fluxes into the topounits.
- Four simple physically based downscaling methods of precipitation have been explored.
- The methods are simple because:
  - Inputs easy to obtain at global scale
  - Implementation of the methods in E3SM does not introduce additional computational burden
- The methods have been evaluated for their capability to capture effects of topographic heterogeneity and results have been published in JGR (Tesfa et al. 2020).
- Downscaling methods of other atmospheric forcing have been developed at the University of Arizona.



Performance of two selected downscaling methods (ERMM and FNM) using total MAM downscaled precipitation values of year 2015 at grids with gauging stations and hr usage greater than 75% at multiple spatial scales: 32 km (a), 64 km (b), 96 km (c), and 128 km (d).

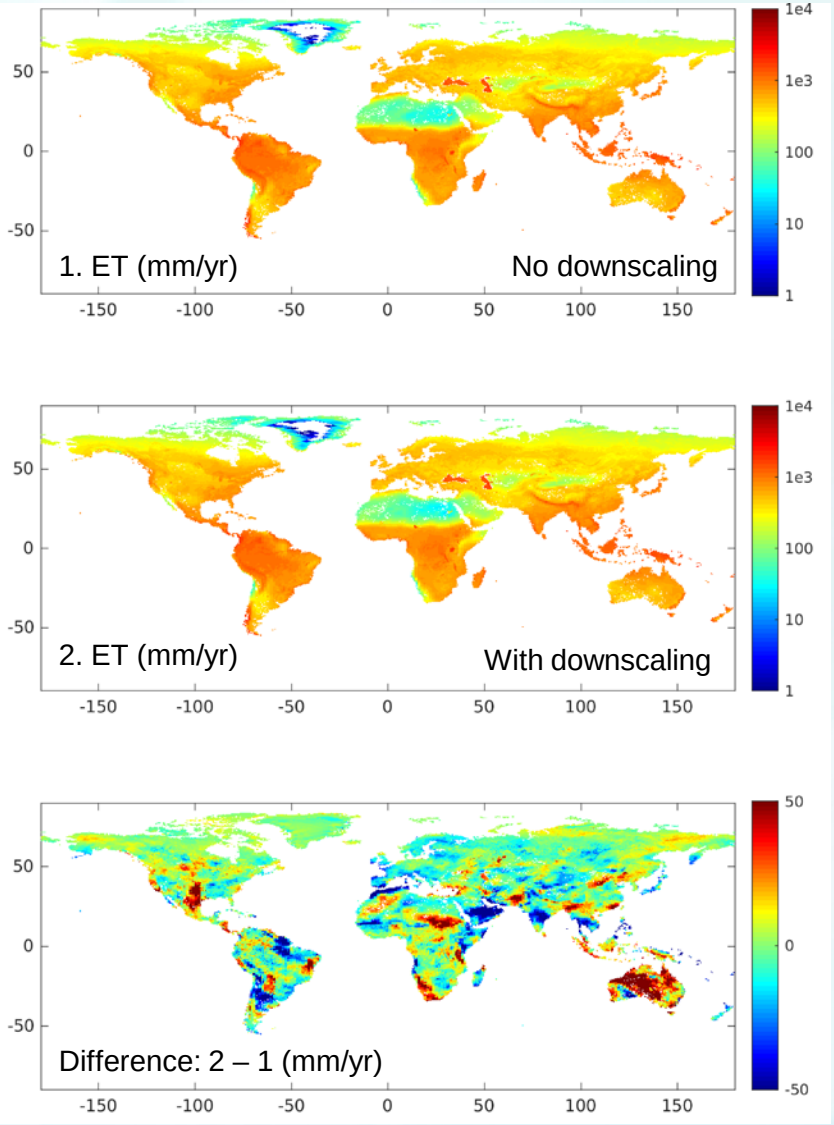
Efforts to implement downscaling methods of atmospheric forcing in E3SM

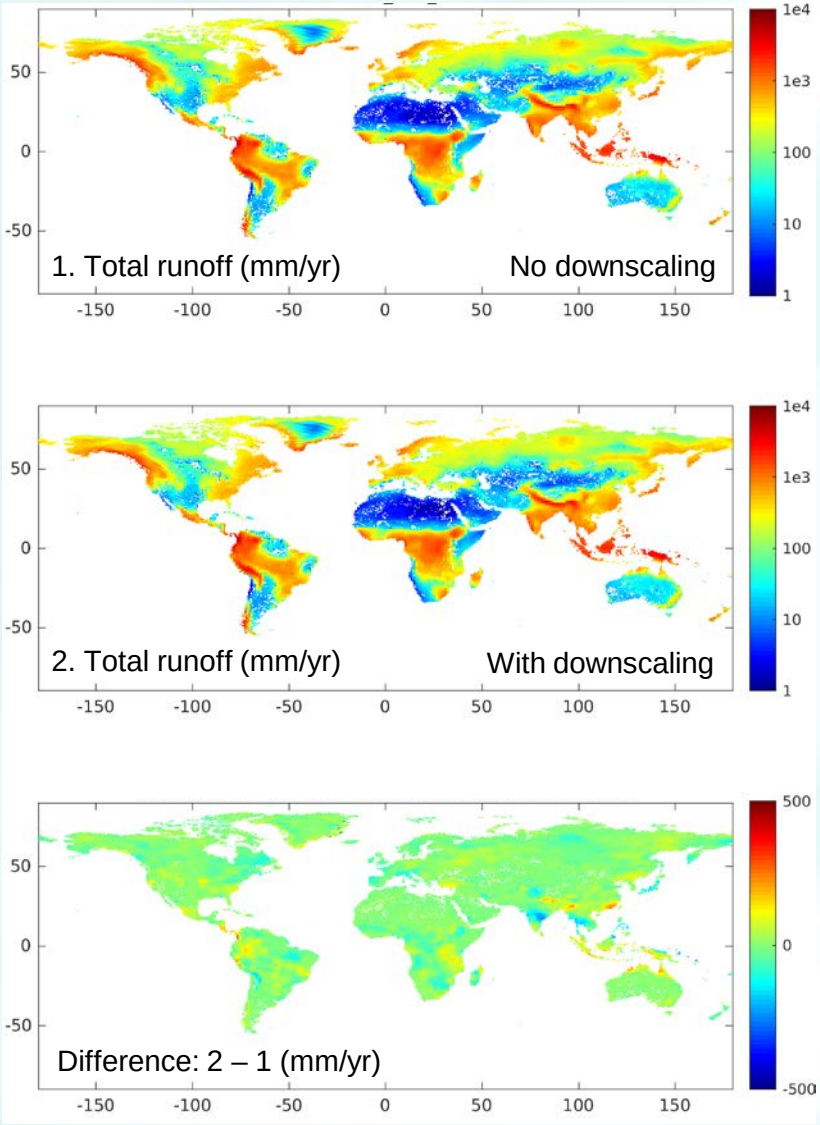
- With the new subgrid structure both the atmosphere and land models run on grid levels, while the land model grid is subdivided into topounits
- Capabilities to downscale atmospheric fluxes from grid level into the topounits of the land model have been implemented.
- Two downscaling methods of precipitation (ERMM and FNM) have been implemented.



- The ERMM precipitation downscaling method utilizes only topographic information to calculate topounit level precipitation. It can be turned on in both coupled and offline E3SM configurations.
- The FNM precipitation downscaling method combines topographic information with Froude Number calculated by the atmospheric model calculate topounit level precipitation. It is used only for coupled E3SM configuration.
- Furthermore, other downscaling methods developed at the University of Arizona have been implemented in E3SM to downscale grid level atmospheric forcing (Temperature, humidity, shortwave and longwave radiation) into the topounits.

Preliminary Results





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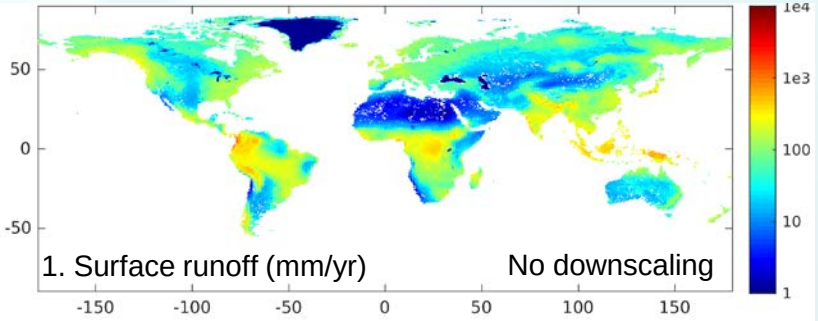

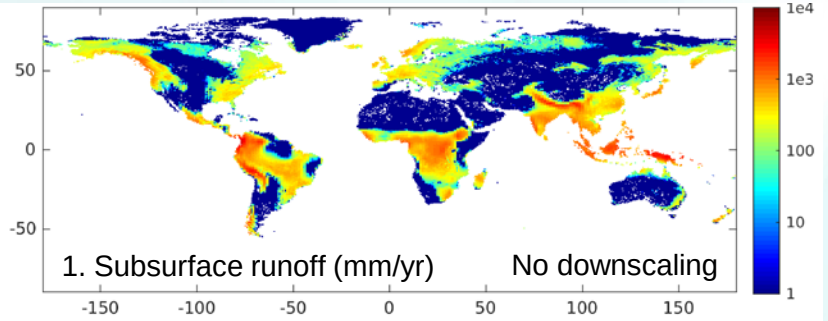

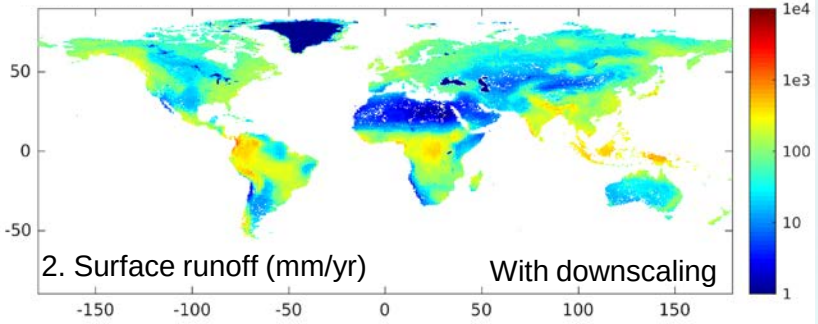

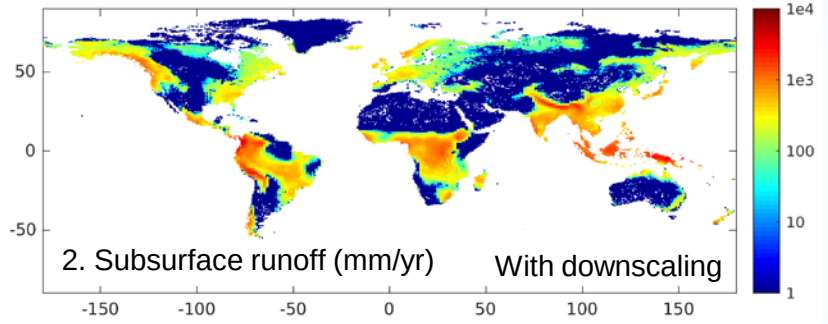

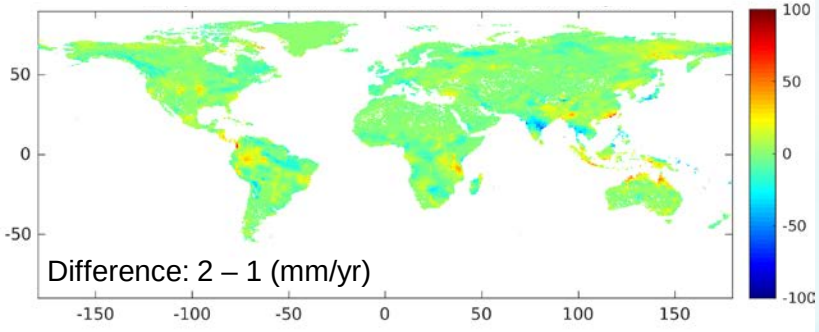

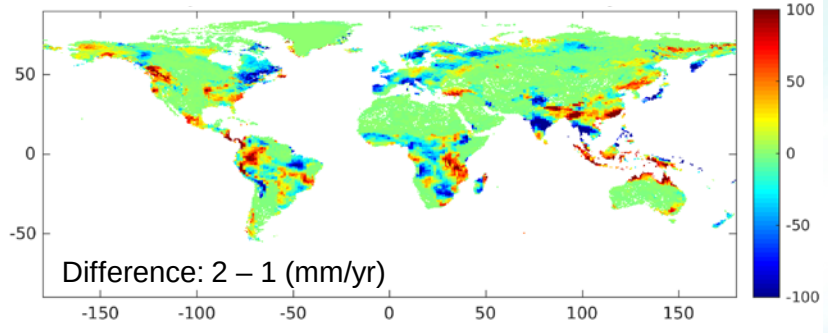

Summary

- Both the subgrid structure and downscaling methods have been implemented in E3SM and the PR for these features is under review.
- Various datasets required for the topography-based subgrid structure (Topounits) have been developed.
- Various simulations have been performed using offline and coupled configurations for both NE30 and half degree resolutions.
- The results shown so far are preliminary; however, since both simulations (with and without downscaling) are treated the same way except the downscaling feature, the results show that the downscaling feature has impacts on ET, total runoff, surface runoff and subsurface runoff.
- The effects on runoff seems to be more pronounced on the mountainous regions.
- Simulations with land initial file are in progress.
- Next step is to test the topounit and downscaling features with other recently merged features turned on, including irrigation and plant hydraulics.