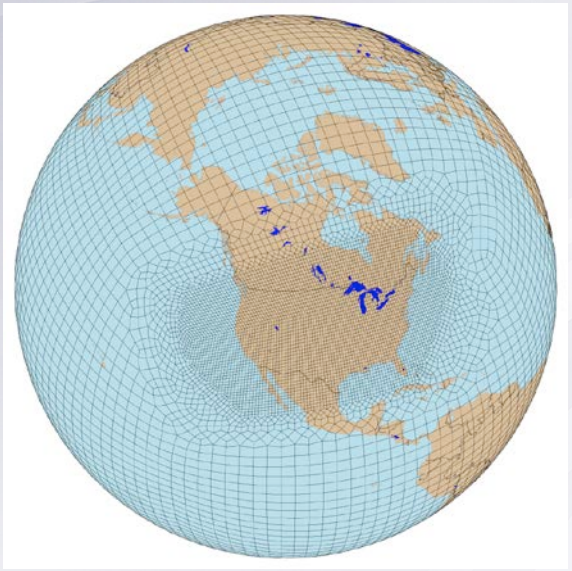
Top priority high resolution science questions and experiments: water cycle experiments

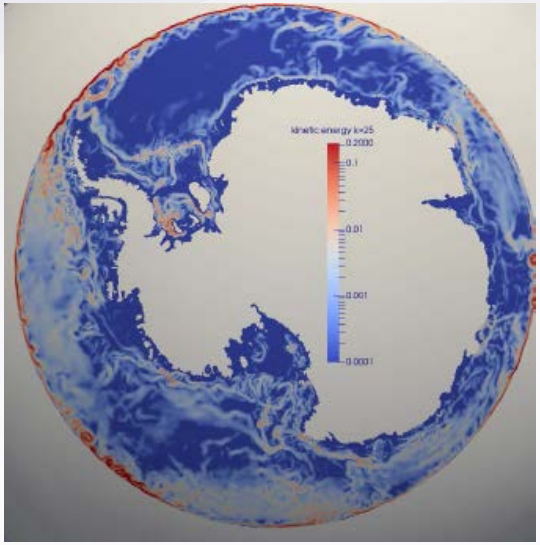
- **Question:** How will improved portrayals of earth system features affect the simulation of Earth's water cycle, including river flow and freshwater supplies at the watershed scale?
- **Hypothesis:** Changes in river flow over the last 40 years have been dominated primarily by land and water use and climate change associated with aerosol forcing. During the next 40 years GHG emissions following an RCP 4.5 or 8.5 scenarios will produce changes to river flow with signatures that dominate those of other forcing agents in at least one of the study regions
- **Model configurations:**
  - Focus study regions: North America and Asia
  - Model domains: Global low (L) and high (H) resolutions; global with regional refinement (RR) over focus regions
  - Atmosphere: L = 100 km; H = 25 km (72 levels)
  - Land: L = 100 km; H = 25 km; River: L = 0.5^{o}; H = 0.125^{o}
  - Ocean: L = 30 km E, 60 km P; H = 15 km E, 5 km P (100 levels)
  - Sea ice: same as ocean
  - Land ice: 0.5 km to 1 km in regions

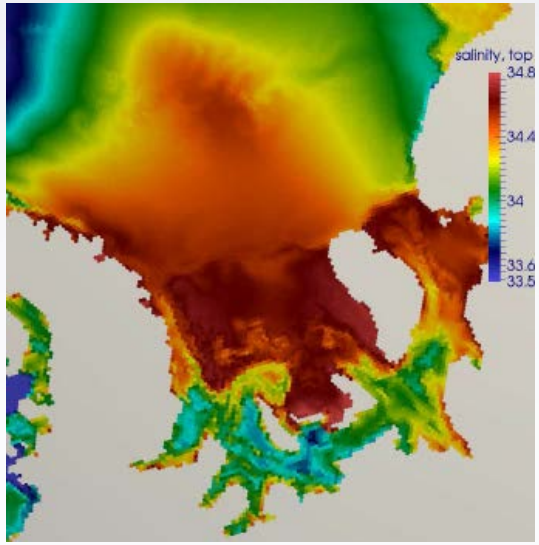
Water cycle experiments

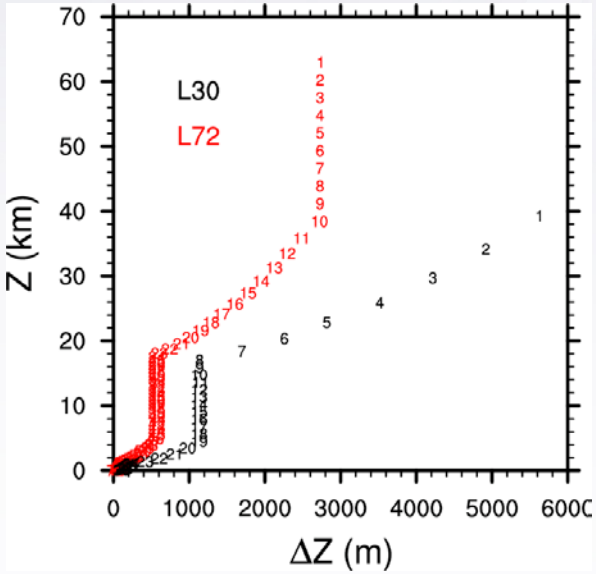
- **Forcing experiments for L, H, and RR:**
  - Simulation period: 1950 – 2050
  - Pre-industrial (PI) forcing
  - Present day (PD) forcing
  - Transient (TR) forcing (RCP4.5/RCP8.5)
  - TR with PI aerosols / GHG / LULC / water use
  - Multiple ensemble members



MPAS-O: Circulation Beneath and Coupling to Antarctic Ice Shelves







Process model advancements

- **Atmosphere v1:**
  - CAM-SE dycore, 72L, model top ~60 km
  - Ice microphysics improvements
  - Convective aerosol transport
  - Marine organics in sea spray
  - Shallow convection – CLUBB; cloud microphysics – MG2
- **Atmosphere v2:**
  - CAM-SE non-hydrostatic dycore; MMF
  - Subgrid orographic precipitation coupled with land subgrid topography
  - Mountain stresses, gravity wave drag
  - Updated convection (organization, microphysics, interactions with surface heterogeneities, triggers, stochastic elements)
  - Improved aerosols (treatment of SOA, reactive photochemistry for aerosols and methane, stratospheric aerosols, physical/chemical properties)
  - Numerical methods: pressure gradient term, hybrid isentropic coordinate

Process model advancements

- **Land v1:**
  - Hydrology: Variably Saturated Subsurface Model, MOSART
  - BGC: Coupled Carbon-Nitrogen-Phosphorus models; Alternative plant-microbe competition approaches; Generic 3-way interface for vegetation, soil physics, and soil BGC
  - Human Dimensions: New crop models
  - Infrastructure for Model Evaluation: Parametric and structural UQ approaches; Land model benchmarking package (ILAMB)
- **Land v2:**
  - Spatial structure: watershed with hierarchical subgrid units
  - Hydrology: Floodplain inundation; Stream temperature; Variable soil depth; Lateral transport; Improved thermal-hydrology; Perched water table wetlands
  - Vegetation and BGC: Dynamic vegetation; Plant carbon and nutrient allocation, transport, and storage; Improved root and plant hydraulics, and connection to mortality; Explicit microbes, CH_4, and improved mineral interactions; Riverine sediment and BGC
  - Human dimensions: water management; crop physiology and management

Process model advancements

- **Ocean and cryosphere v1:**
  - Ocean: 15-5km, 100 L; eddy resolving down to 1-5 km in regions
  - BGC: one-degree equivalent mesh
  - Sea ice: Elastic-viscous-plastic; CICE5 physics; BGC
  - Land ice: Antarctic grid; SMB in land model; shelf-ocean coupling; moving grounding line and ice shelf boundaries
- **Ocean and cryosphere v2:**
  - Ocean: Quasi-isopycnal vertical; new scale-dependent eddy treatment; MPAS-coastal
  - Sea ice: Snow model; anisotropic dynamics; variable ice shelf calving front
  - Land ice: Improved calving; dynamic calving front; Basal hydrology
- **Interest in CPT approach:**
  - DOE climate programs adopt approaches similar to CPT (e.g., MODEX approach used in NGEE Arctic and NGEE tropics; joint research in ARM-ASR-RGCM-ESM)
  - Areas of interest: Diurnal precipitation; marine biogenic aerosols and cloud effects; water mass transformation around Antarctica;

Example V2 science questions:

- Moisture source for precipitation over land
  - Sensitivity to model resolution (moisture flux convergence from ocean vs. evapotranspiration)
  - Implications to regional precipitation and water supply
- Energy-water-land nexus
  - Feasibility of different mitigation scenarios of land use (bioenergy crop productivity, water availability) with projected droughts
  - Terrestrial carbon sink and implications to carbon reduction pathways and costs
- Terrestrial-aquatic interface
  - Effects of C, N, and P fluxes from terrestrial systems to coastal margins on ocean BGC and net GHG exchanges
  - Contributions from extreme precipitation and inundation to C, N, P, and sediment fluxes to the ocean and impacts on biogeochemistry cycle and potential changes in the future