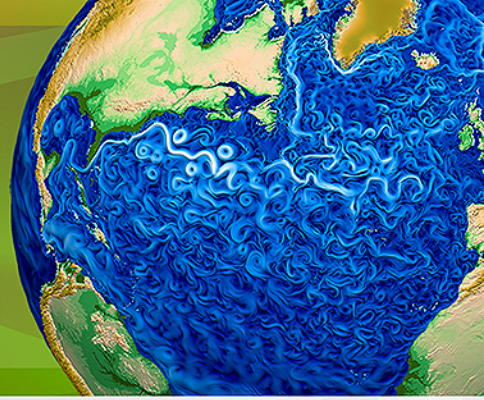
ACME
Accelerated Climate Modeling for Energy



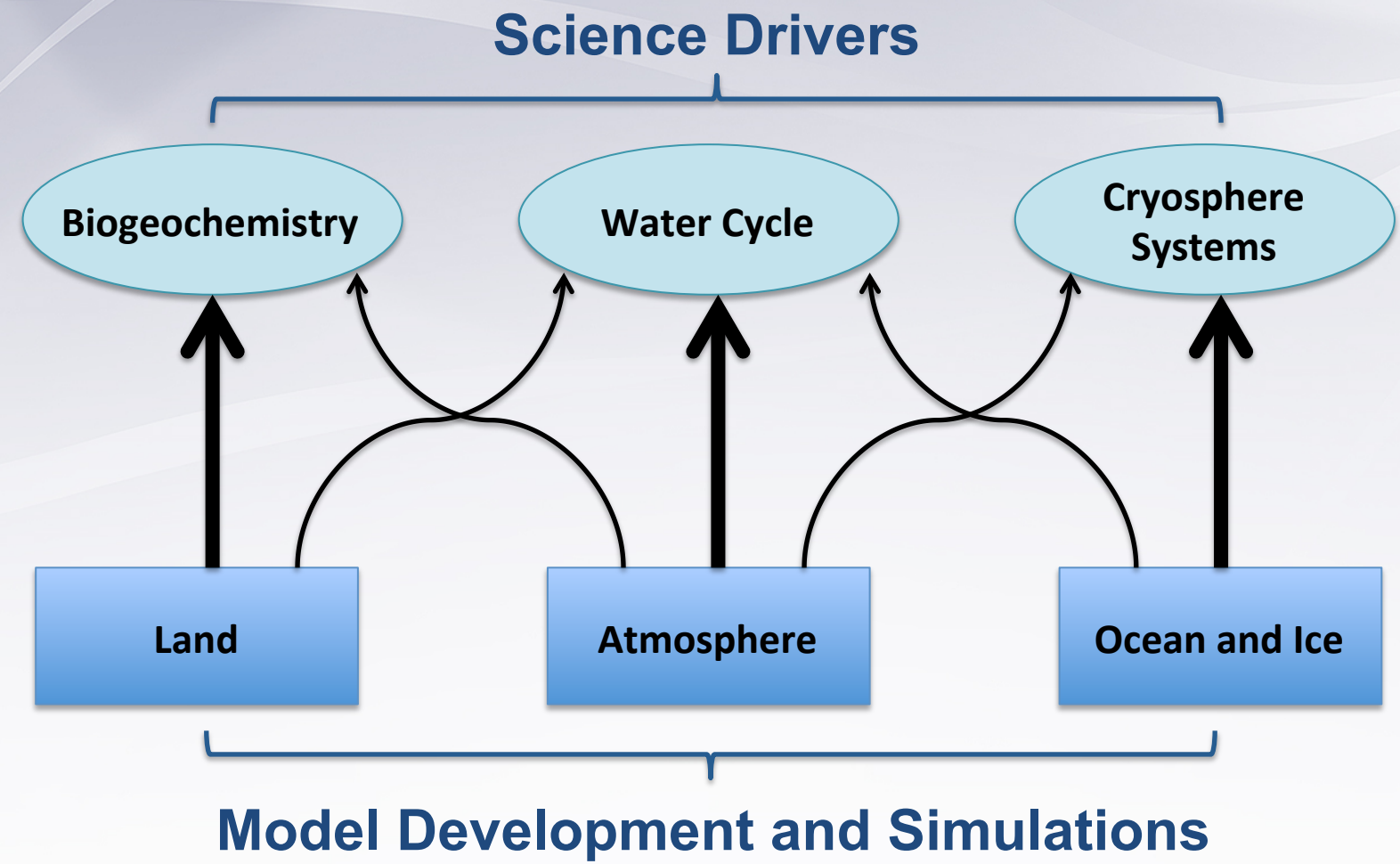
Science Status and 1, 5, and 10-year Vision

L. Ruby Leung

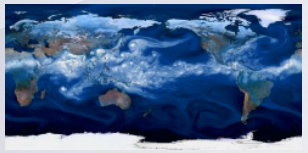
ACME June 2016 All Hands Meeting
June 7 - 10, 2016
Rockville, MD

U.S. DEPARTMENT OF ENERGY

ACME V1 campaign



Water cycle experiments



- **Question:** How will more realistic portrayals of earth system features affect the simulation of Earth's water cycle, including river flow and freshwater supplies at the watershed scale?
- **Hypothesis:**

Land use, water use, and aerosol impacts dominate river flow changes

GHG emissions dominate river flow changes

1970 **2010** **2050**

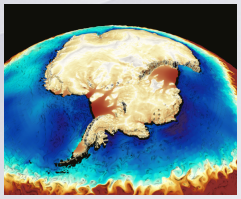
- **Model configurations:**

Low resolution (L)	High resolution (H)	Regional refinement (RR) (North America and Asia)
A: 1° L: 1° O: 30-60 km CICE: same as O LI: 0.5 – 1 km in regions	A: 0.25° L: 0.25° O: 15-5 km CICE: same as O LI: 0.5 – 1 km in regions	A: 1° - 0.25° L: 1° - 0.25° O: 60-5 km CICE: same as O LI: 0.5 – 1 km in regions

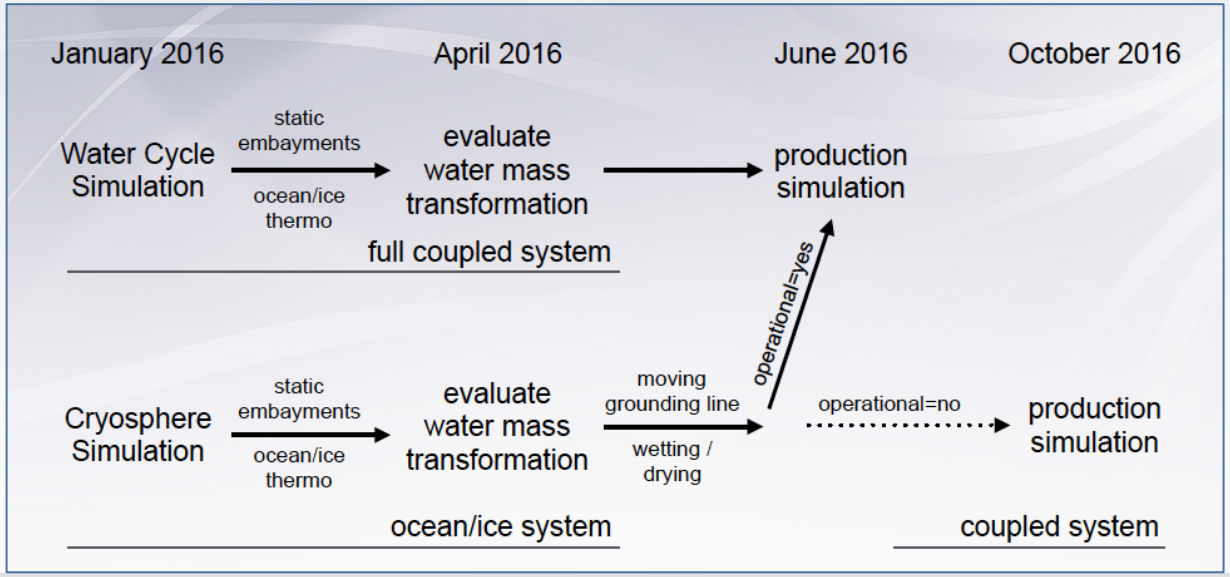
Water cycle experiments: prioritization

- **Impacts of model features on water cycle simulations**
  - **TR simulations (1970-2050) with aerosols, GHG, LULC forcing**
  - Resolution effect:
    - **V1 simulations at L and H resolutions**
    - V1 simulations with RR over North American and Asia
  - Feature effect: Comparison with V0 L and H resolution simulations
- **Impacts of human perturbations on water cycle**
  - **PI simulations with pre-industrial forcing at L and H resolutions**
  - PD simulations with present-day forcing at L and H resolutions
  - Limited single forcing experiments

Cryosphere experiments

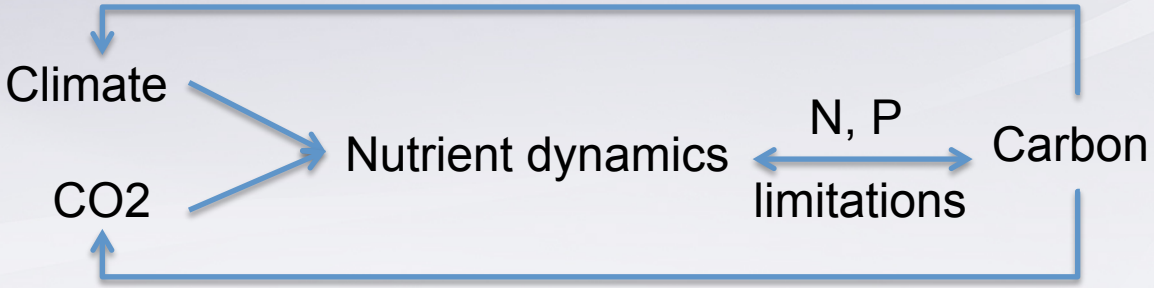


- **Question:** How do rapid changes in cryospheric systems interact with the climate system?
- **Goal:** Explore likelihood of abrupt Antarctic change and rapid sea-level rise due to ocean-land ice interactions, targeting simulations that include dynamically-coupled ocean-land ice systems
- **A coordinated water cycle and cryosphere simulations plan:**



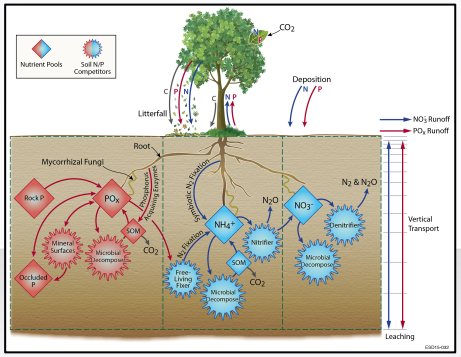
Biogeochemistry experiments

- **Question:** What are the nitrogen (N) and phosphorus (P) effects on C-Climate and C-concentration feedbacks (*gamma* and *beta*) in the presence of Land Use and N and P deposition trajectories?
- **Hypothesis:**

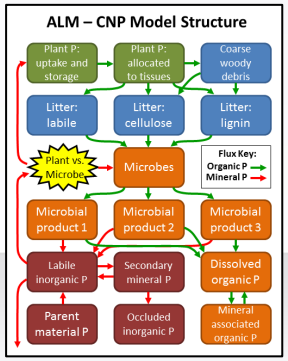


- **Experiments:**
  - Follow C4MIP protocol with C-only, CN, and CNP, for each competition parameterization (RD and ECA) at 1-degree resolution

Equilibrium Chemistry Approximation



Relative Demand



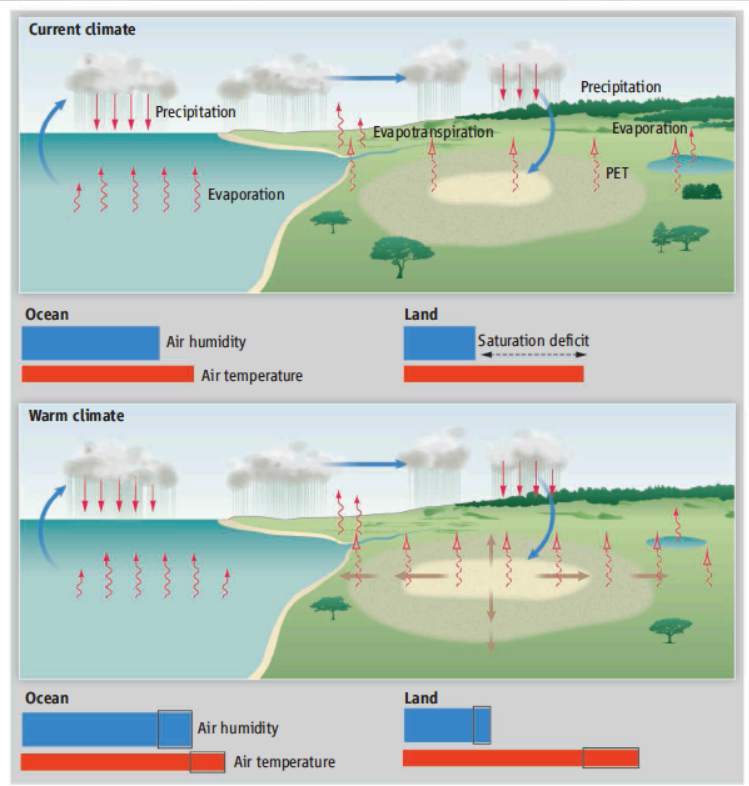
V2 - Water Cycle
Moisture supply for precipitation over land

- What are the moisture sources for precipitation over land?
- Do models converge with increasing resolution, and what controls this behavior?
- How will the moisture sources and precipitation over land change in a warmer climate?

Moisture supply may change with aridity changes

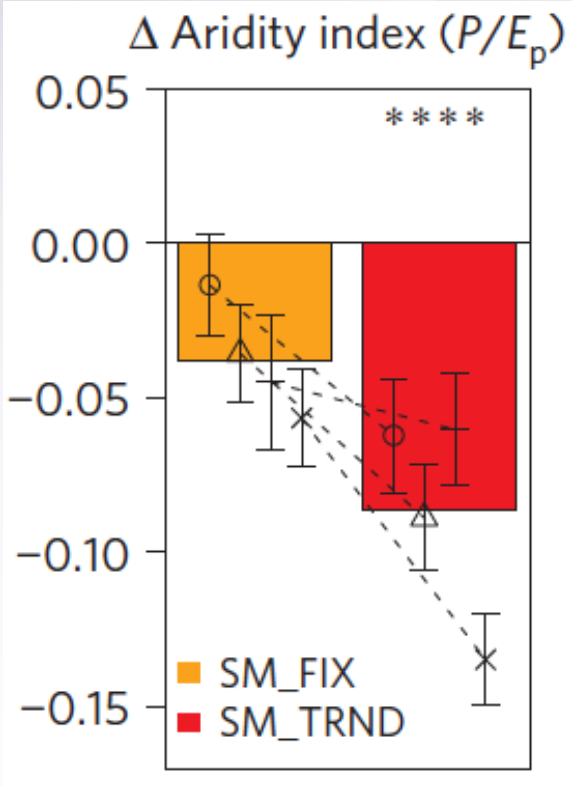
- The relative moisture supply from ocean vs. land for land precipitation is expected to change in a warmer climate, with important implications for regional precipitation changes in the future

Ocean / atmosphere processes dominate aridity changes



(Sherwood and Fu 2014, Science)

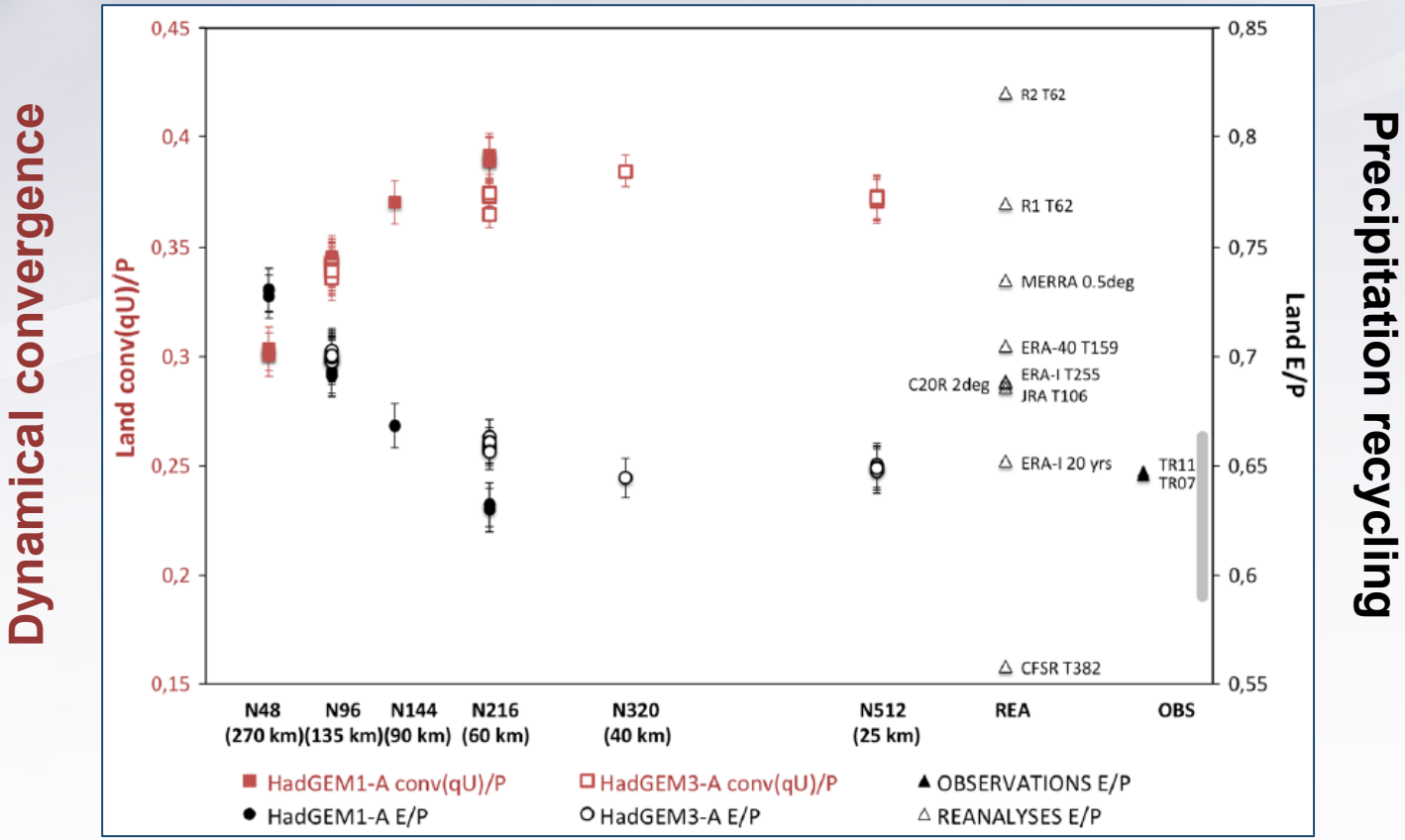
Land-atmosphere feedbacks amplify aridity



(Berg et al. 2016, Nature Climate Change)

Ocean vs. land supply changes with resolution

- Relative contribution of moisture from ocean and land to land precipitation changes with resolution and converge at ~50 km resolution
- Is this behavior model dependent and what are the implications for projecting responses of precipitation over land to human perturbations?



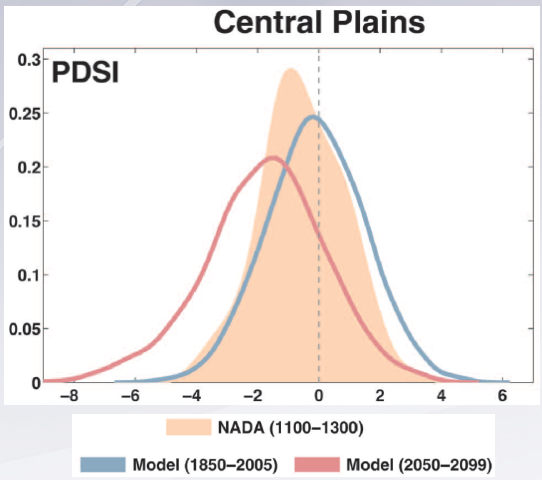
(Demory et al. 2014 Clim. Dyn.)

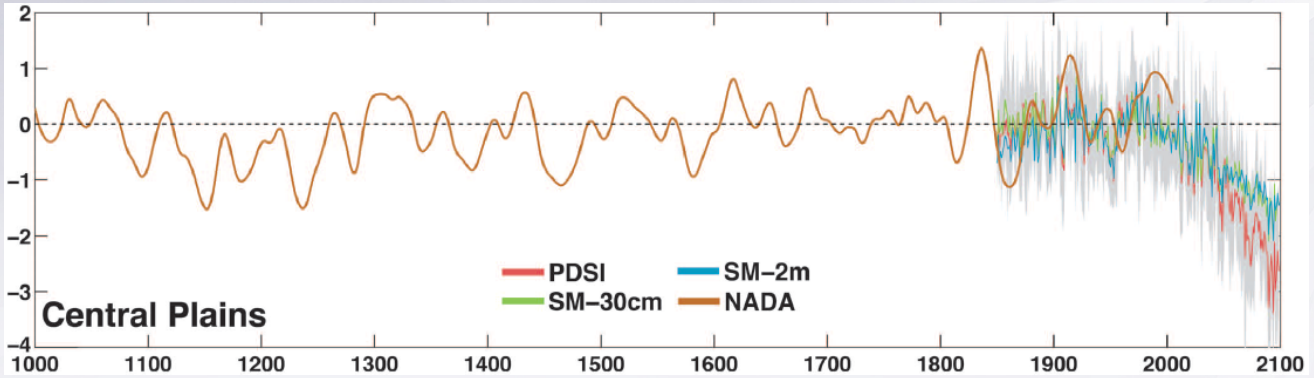
V2 - Biogeochemistry
Impacts of carbon reduction pathways on carbon sink and water availability

- What are the impacts of different carbon reduction pathways on the carbon sink and water availability?
- How might terrestrial-aquatic processes currently not represented in Earth system models influence the net carbon sink and the effectiveness of mitigation scenarios?

Unprecedented droughts and increased water deficits challenge bioenergy production in the future

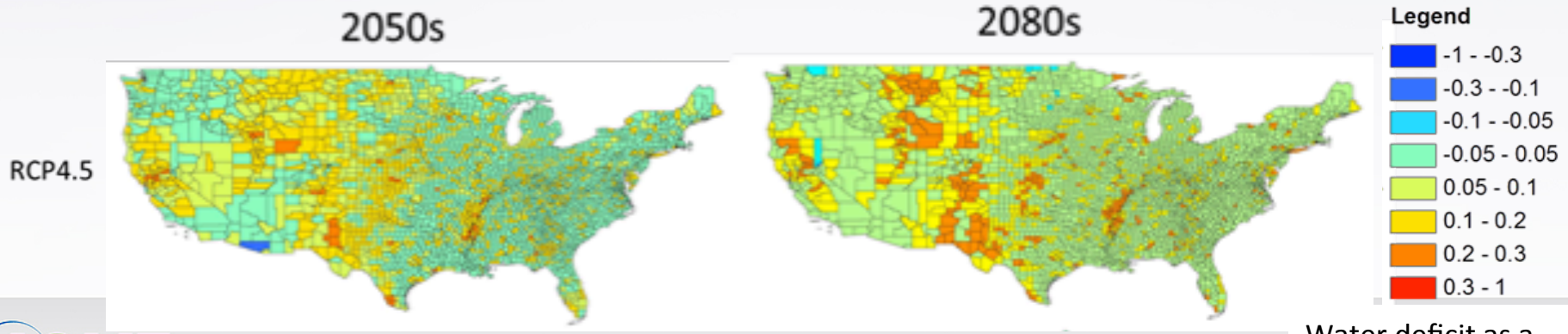
CMIP5 models projected future drought risks exceeding the driest centuries of the Medieval Climate Anomaly (1100–1300CE)





(Cook et al. 2015 Sci. Rep.)

Increased irrigation water demand from bioenergy crops increases water deficits



(Hejazi et al. 2015 PNAS)

Water deficit as a fraction of demand

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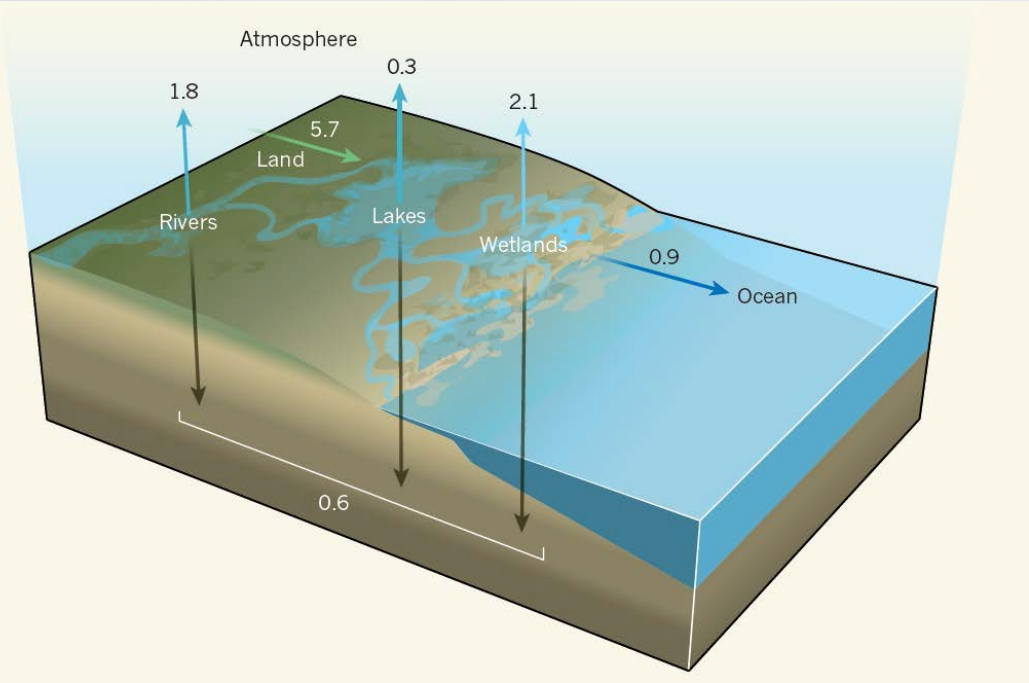
Role of terrestrial – aquatic BGC in carbon sink

- Large C, N, and P fluxes from terrestrial systems to coastal margins affect ocean biogeochemistry and net GHG exchanges
- These processes are largely missing in ESMs



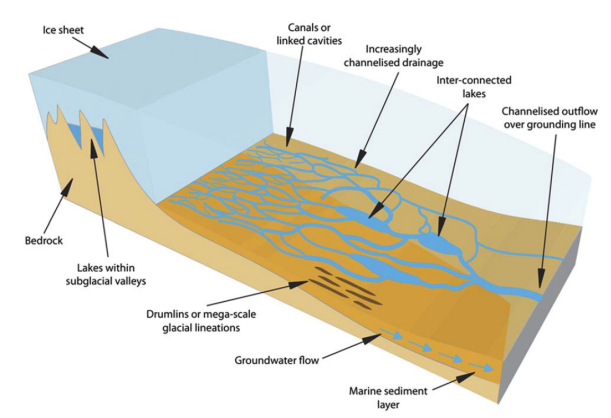
Carbon fluxes related to inland aquatic ecosystems (Streams, Rivers, Lakes, and Wetlands) hold the potential to explain a large portion of the unknown residual land sink.

Bernhard Wehrli, 2013, Nature
Raymond et al., 2013, Nature

V2 - Cryosphere Systems
Regional sea level rise and implications to coastal inundation

- What processes and their model representations contribute to key uncertainty in projecting regional sea level rise?
- What are the implications to coastal inundation that result from interactions between sea level rise and extreme storms?

Sources of uncertainty in projecting regional sea level rise

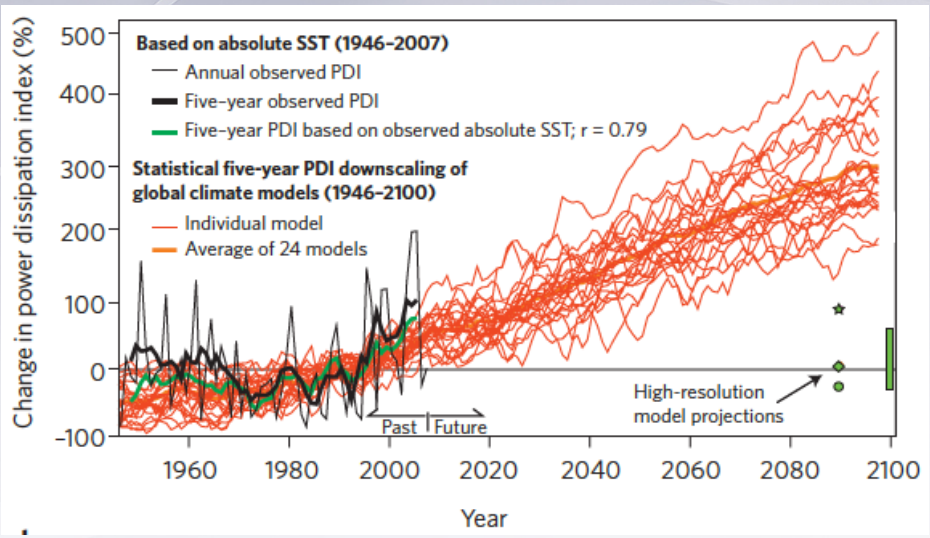


(Ashmore and Bingham 2014)

- Water mass transformation and deep water creation around Antarctica
  - Upper Circumpolar Deep Water
  - Weddell Sea Deep Water
- Solid and liquid discharge from ice sheets
  - Subglacial hydrology
  - Topographic mapping
- Snow processes on sea ice
  - Blowing, compaction and metamorphosis of snow

SLR combined with more intense hurricanes in the future increases the risk of storm surge

Projected increase in Atlantic hurricane intensity



(Knutson et al., 2010, Nature Geosci.)

- High resolution atmosphere and ocean modeling is critical for simulating tropical cyclones and their intensifications
- Coastal ocean and wave modeling for storm surge, and river modeling of inundation provide an opportunity to explore the coastal impacts of regional SLR

10-year Vision

- **Water Cycle:** How will the integrated water cycle, extending from bedrock to the tropopause, evolve in a warmer climate with changes to land and water use, and changing concentration of atmospheric radiative forcing agents (aerosols, greenhouse gases)?

- **Biogeochemistry:** How will coupled terrestrial and coastal ecosystems drive natural sources and sinks of carbon dioxide and methane in a warmer environment?

- **Cryosphere Systems:** How will regional variations in sea level rise interact with more extreme storms to enhance the coastal impacts of SLR?