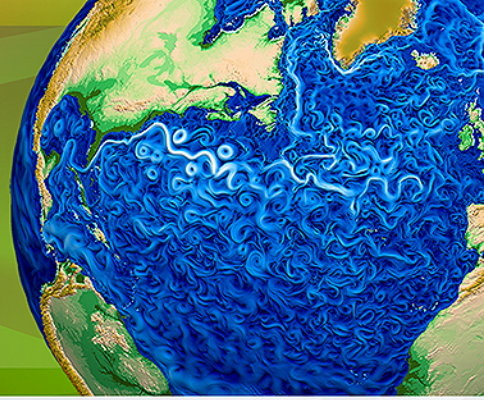
ACME
Accelerated Climate Modeling for Energy



ACME Land Model (ALM): v1 Progress and v2 Plans

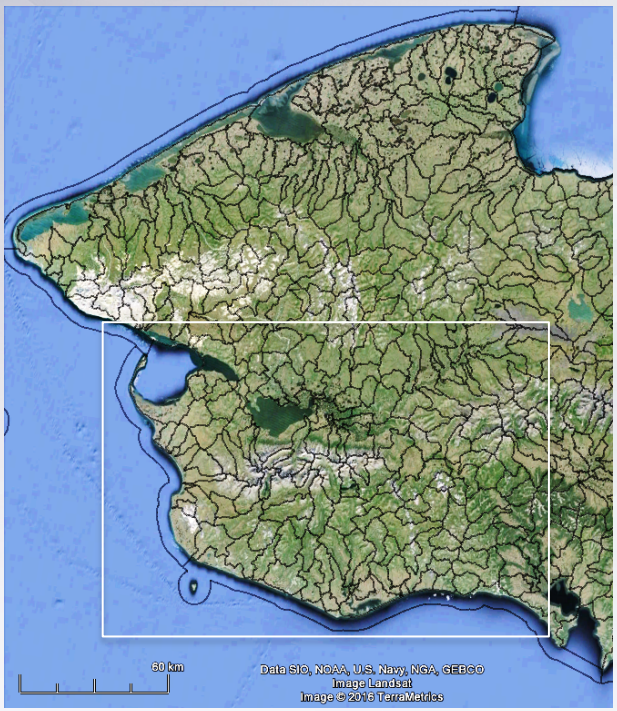
Bill Riley and Peter Thornton, Land Group Co-Leads

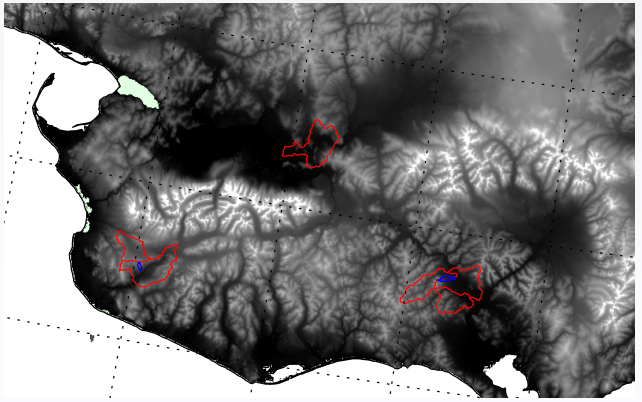
U.S. DEPARTMENT OF ENERGY

ALM Progress: Delivered for v1

- Hydrology
  - New river routing (MOSART)
  - New soil hydrology (VSFM)
  - Datasets for watershed grid
- Subsurface reactive transport
  - Multi-phase, multi-tracer (BeTR)
- Biogeochemistry
  - Coupled CNP dynamics:
    1. Relative Demand
    2. Equilibrium Chemistry Approximation (ECA)
- Vegetation
  - New crop model
  - Dynamic rooting
  - Trait-based root and leaf CNP stoichiometry (ECA)
  - Allocation (from PiTS)
- Infrastructure/Architecture
  - UQ framework
  - Benchmarking (iLAMB)
  - Spinup acceleration
  - Functional unit testing
  - Modular interfaces
  - Sub-grid architecture

ALM datasets for watershed grid



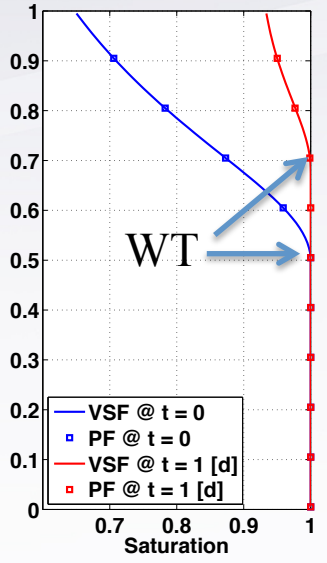


(collaboration with NGEE Arctic)

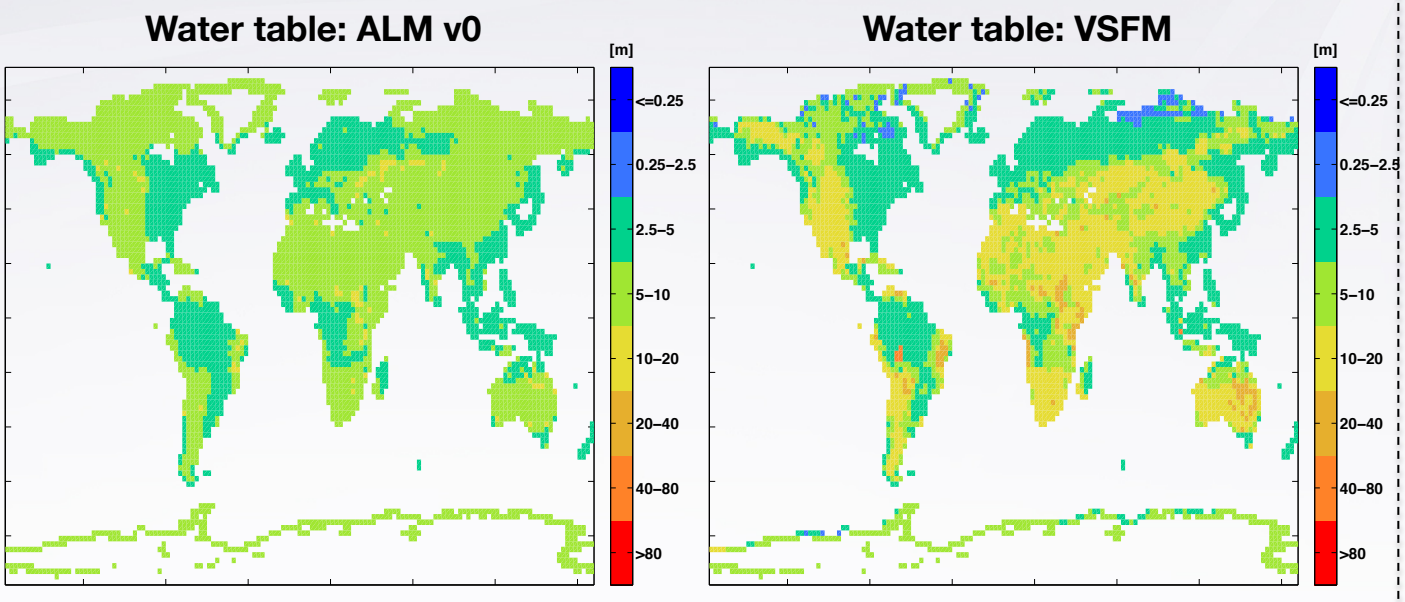
Variably Saturated Subsurface Model (VSFM)

- Unified physics in unsaturated and saturated zone.
- Uses PETSc for numerical solution.
- Benchmarked against multiple solutions for different conditions.
- Improves global water table depth predictions compared to Fan et al (2013).

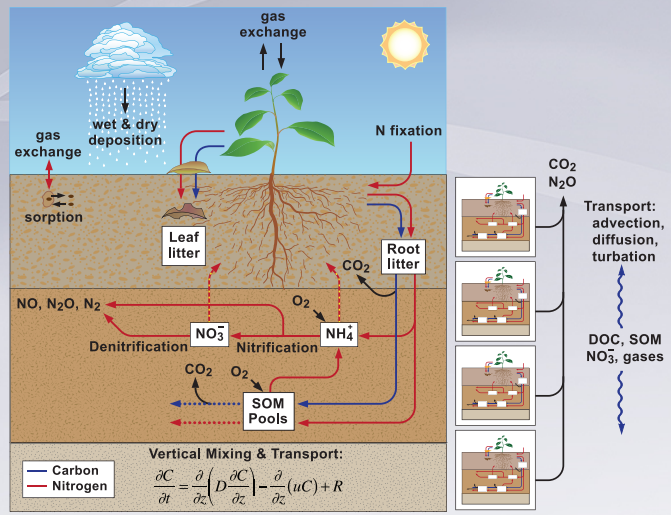
Water table dynamics benchmark



1.9^0 x 2.5^0 : 1991-2010

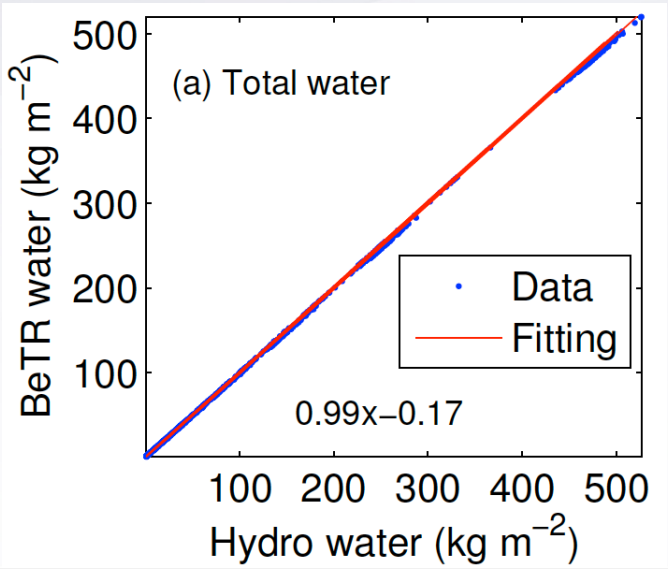


Biogeochemical Transport and Reactions (BeTR) Module

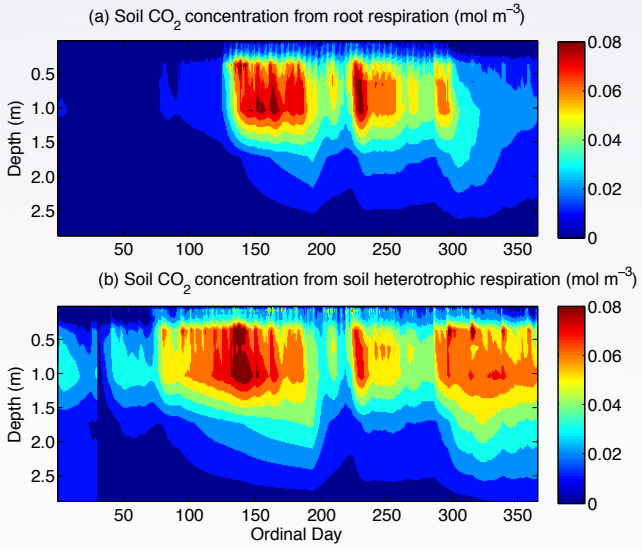


- Simulates multiphase transport for arbitrary number of tracers
- Supports flexible reaction networks for different soil BGC formulations

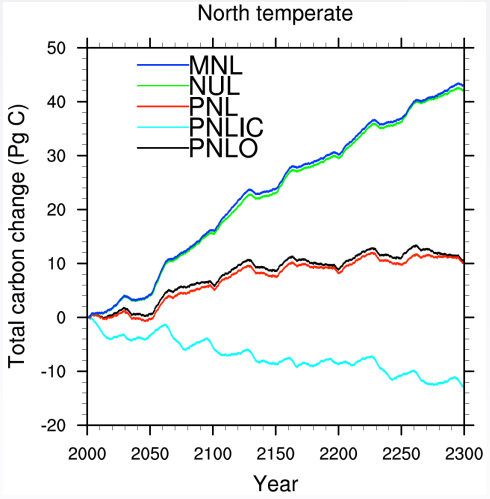
Accurate H_2O tracer transport



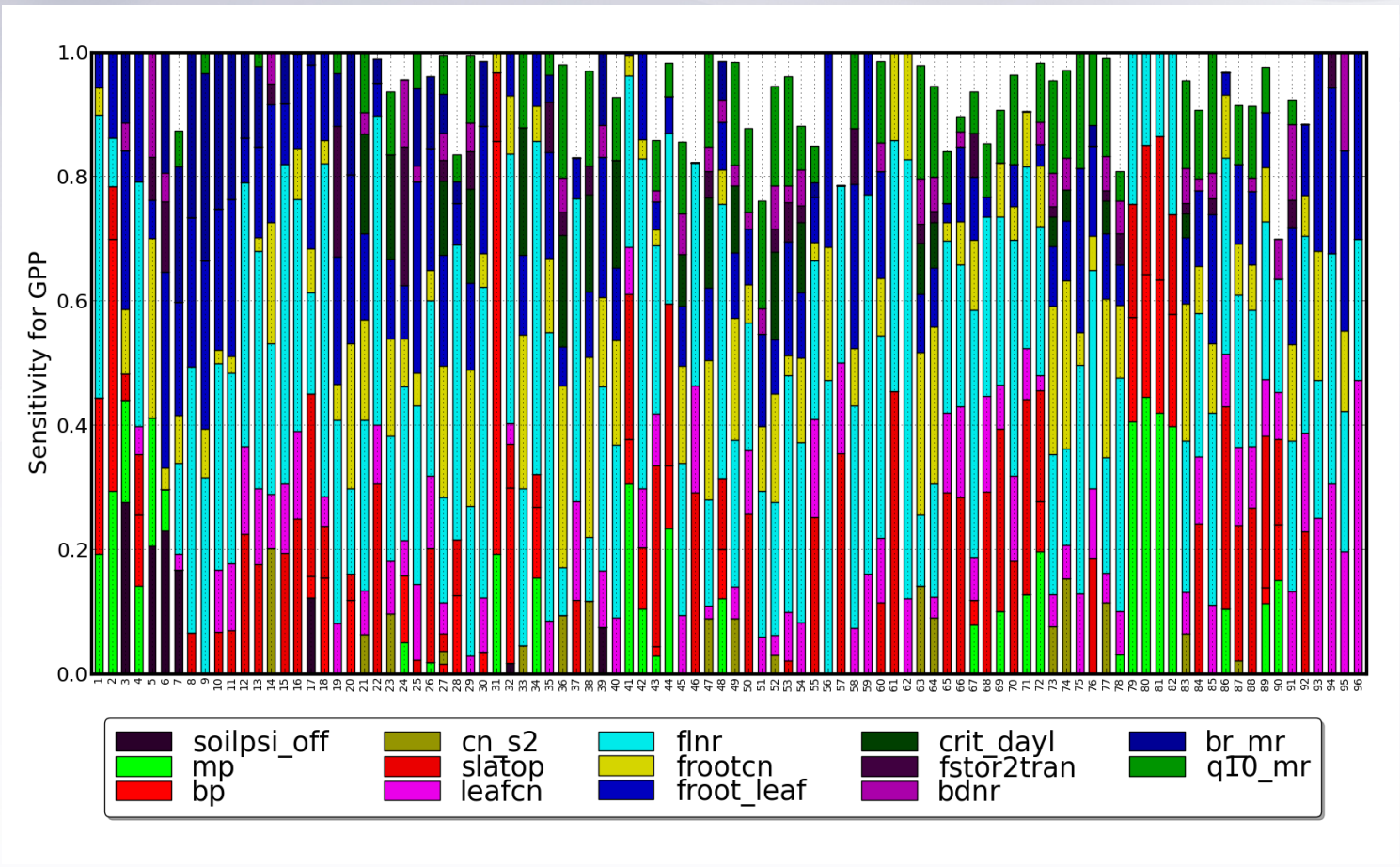
Tagged CO_2 transport



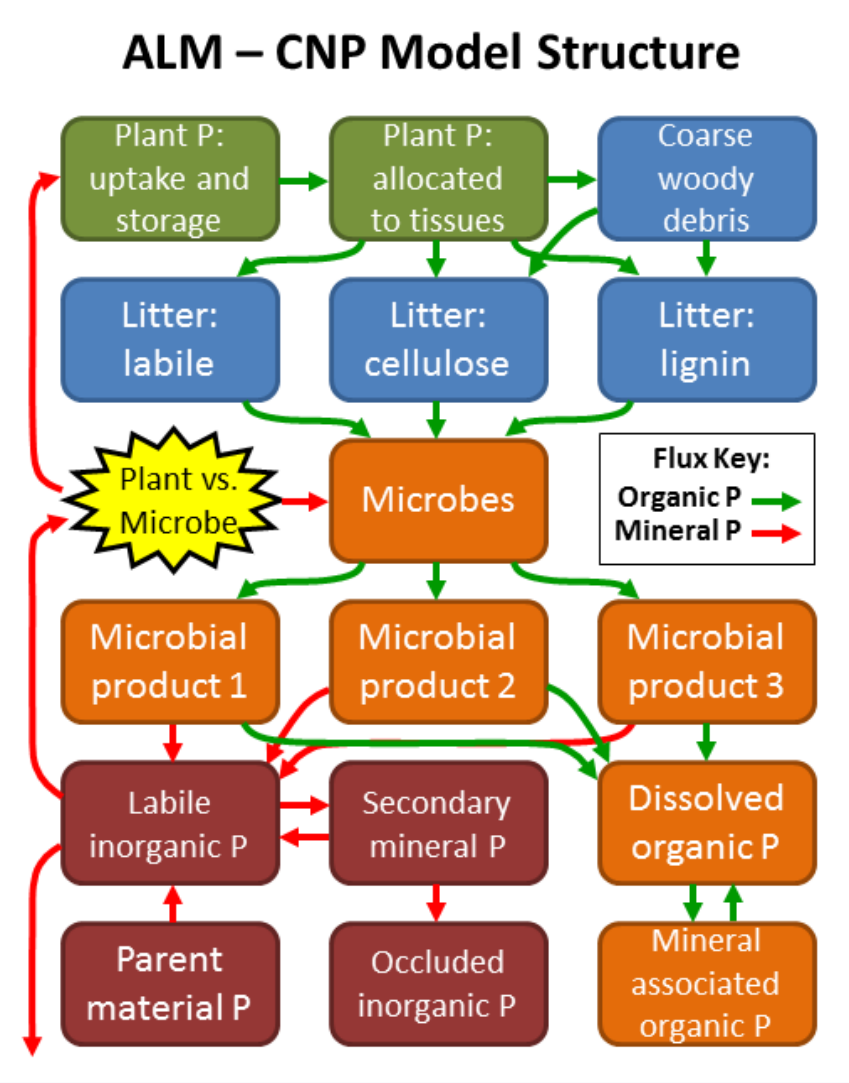
Structural uncertainty assessment



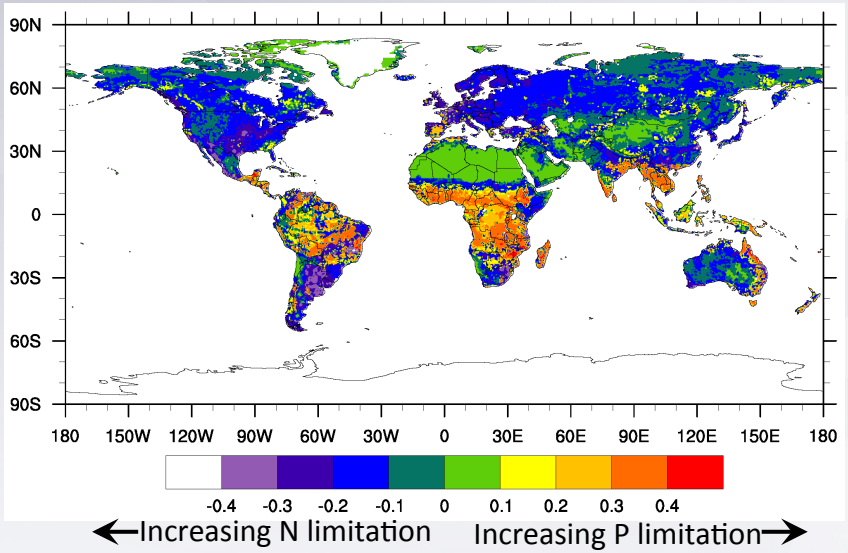
ALM Uncertainty Quantification:
Parameter sensitivity from 3000 ensemble members at 96 FluxNet sites



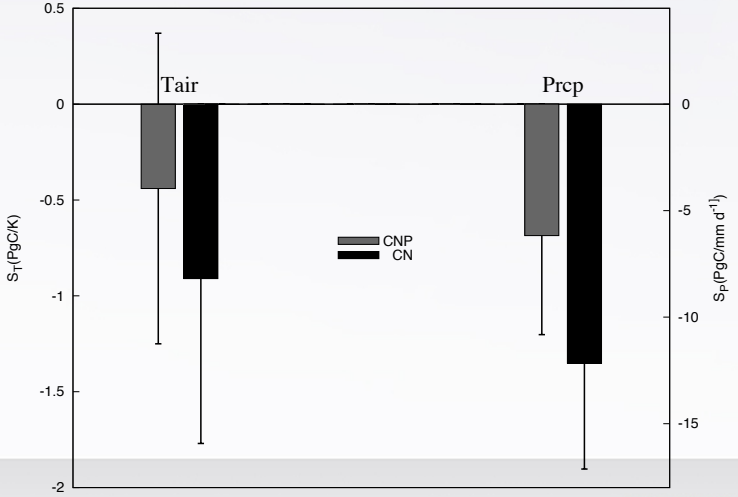
CNP model with Relative Demand



N vs. P limitation



Sensitivity of Global NEE to temperature and precipitation



CNP model with Equilibrium Chemistry Approx.

- **N & P competition resolved with ECA**
- **Successfully evaluated at tropical forest, alpine grassland, and arctic tundra sites and globally for N flux partitioning.**

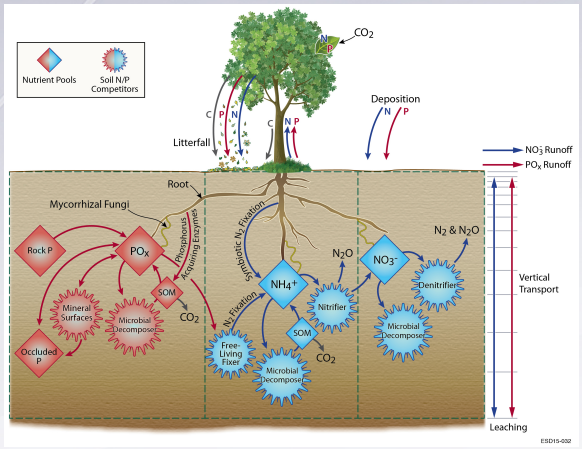


Fig 1. model schematic diagram

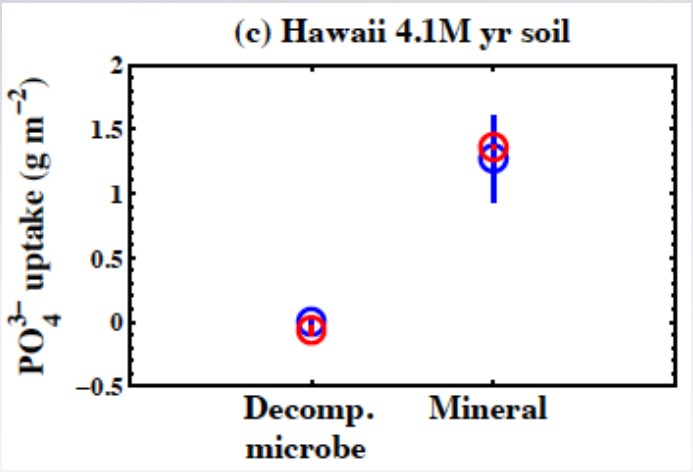


Fig 2. Tropical site (Zhu et al. 2016 *Biogeosciences*)

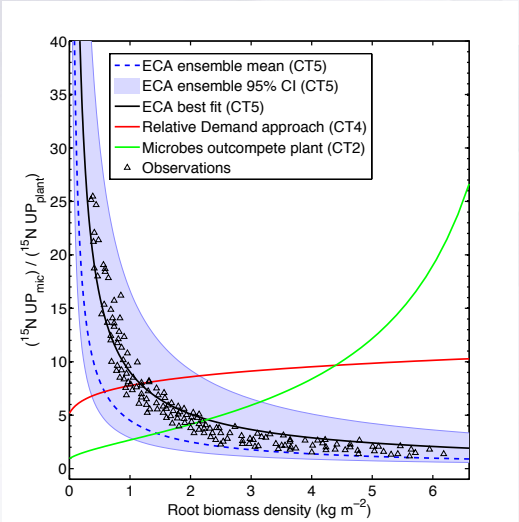


Fig. 3. grassland site (Zhu et al., under revision)

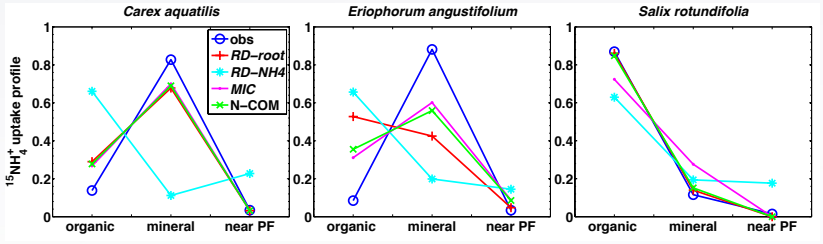


Fig. 4. arctic tundra (Zhu et al., under review)

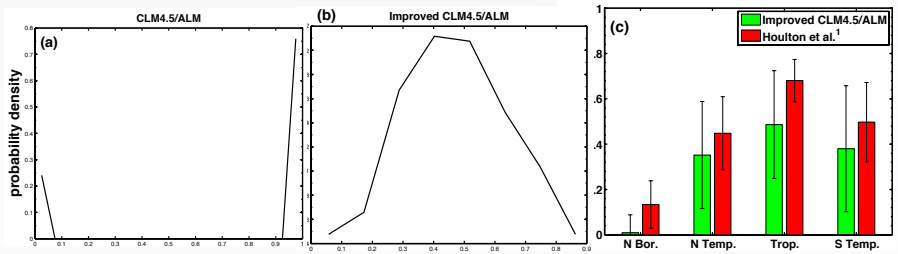


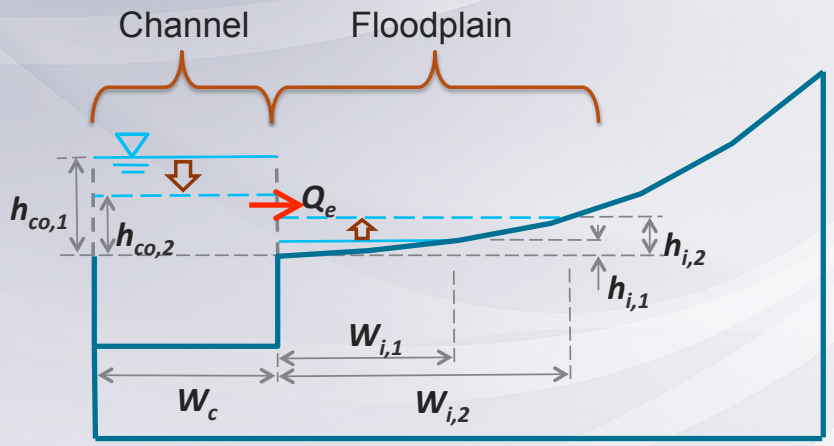
Fig. 5. leaching vs denitrification (Zhu and Riley 2015 *Nature Climate change*)

ALM Development Plans for v2

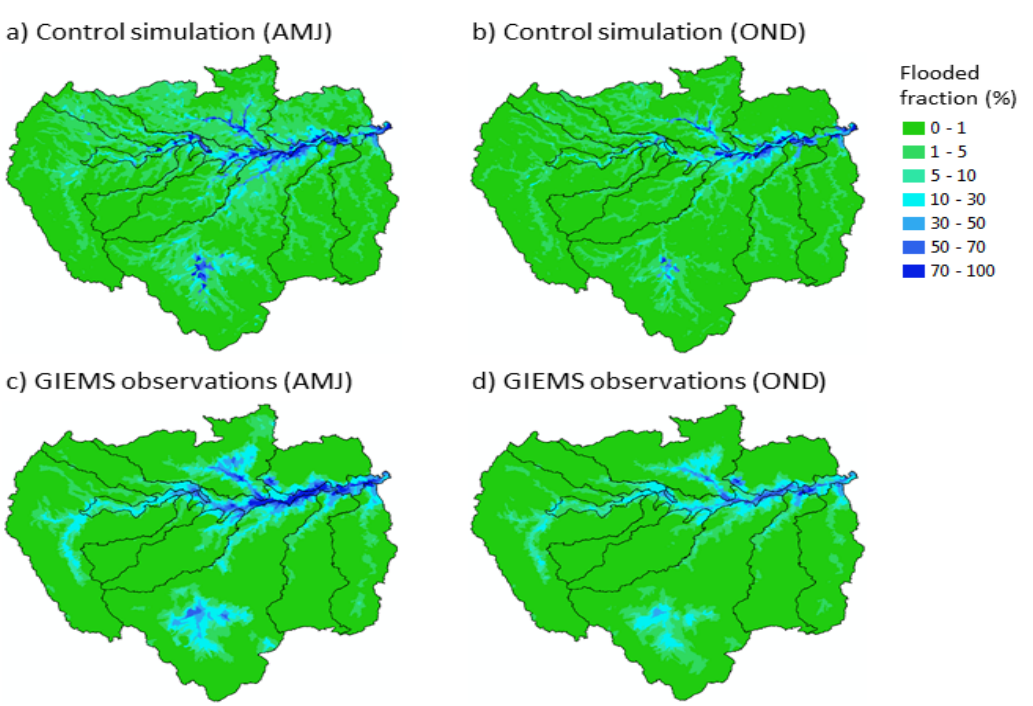
- Hydrology / Physics
  - Topography
  - Lateral subsurface flow
  - Variable soil depth
  - VIC runoff
  - Inundation dynamics
  - Prognostic canopy air space
  - Stream temperature and sediment transport
  - PFLOTRAN subsurface physics
- Biogeochemistry
  - Explicit microbial models, CH_4
  - Microbe-mineral interactions
  - Redox state
  - Stream BGC and nutrient transport
  - Wetland biogeochemistry
- Vegetation
  - Ecosystem demography
  - Dynamic plant traits
  - Carbon and nutrient storage, transport, and allocation
  - Plant hydraulics and mortality
- Human Dimensions
  - Water Management
  - Crop management
  - New historical datasets and LULCC mechanisms
  - iESM experiments
- Infrastructure/Architecture
  - UQ framework
  - Benchmarking
  - Functional unit testing
  - ACME-NGEE integration
  - Sub-grid architecture

Inundation dynamics

- Inundation influences:
  - Land-atmosphere interactions
  - Surface water – groundwater interactions
  - River – floodplain exchange
- The MOSART river transport model has been extended with a computationally efficient inundation scheme for Earth system modeling
- Simulations in the Amazon basin
  - 15% of the world's total river discharge (Paiva et al. 2013)
  - Floodplains and wetlands account for ~14% of the entire basin (Hess et al. 2015)
  - The framework can produce flood extent comparable to the GIEMS satellite data

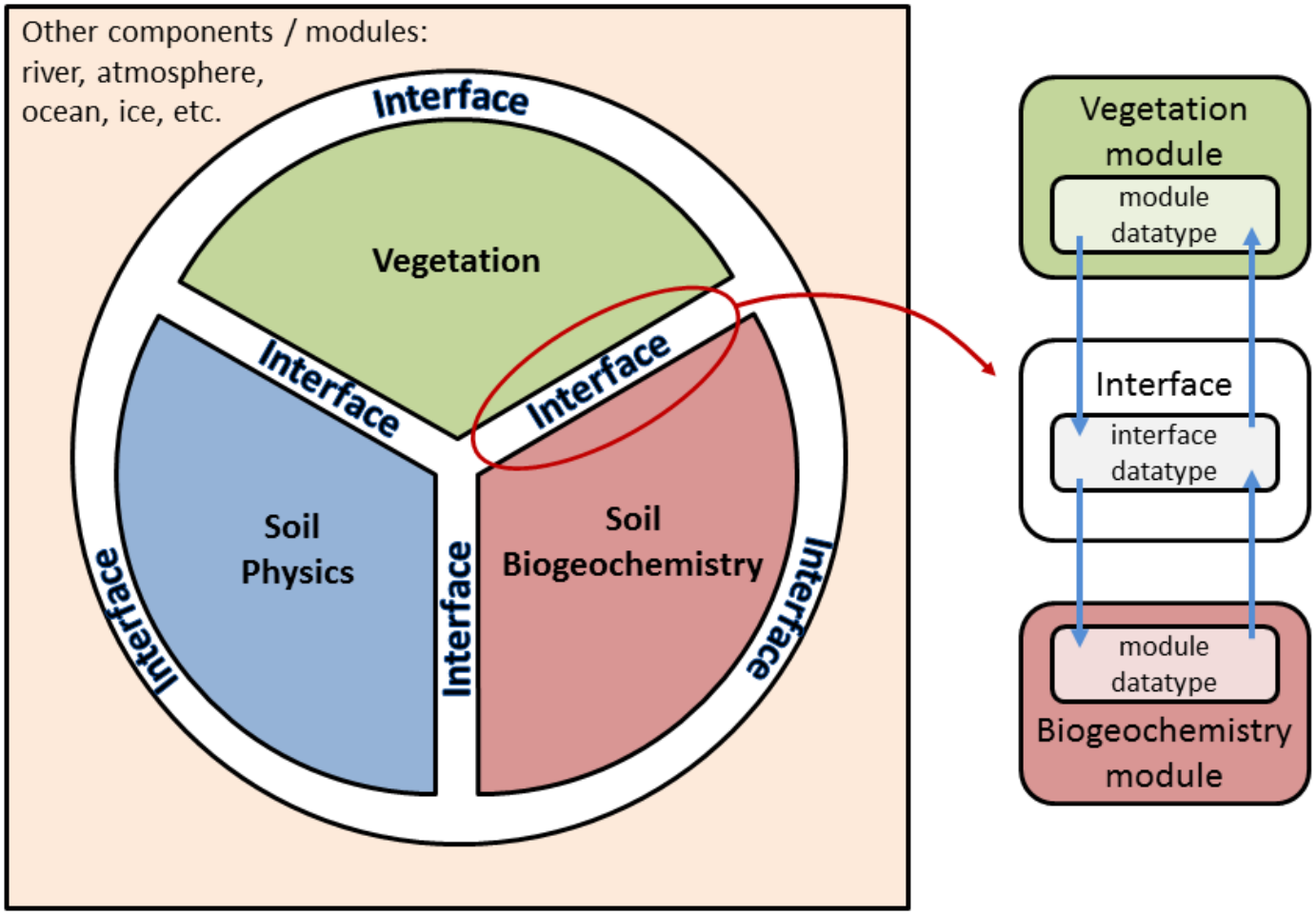


Averaged spatial pattern of flood extent for 1995-2007



Questions?

ALM modular interfaces



(developed in collaboration with NGEEs)