Nov 19, 2026

Land modeling in CLM6: What's new and improved?

Will Wieder on behalf of the LMWG, TSS, & many more

CGD Exchange and CLM Tutorial



Research questions

Where do we put the **carbon**?

How do we grow enough **food**?

Will we have enough **water**?

How can we **adapt** to novel conditions?



New Features

Biophysics

- Dust emissions [Danny Leung & Erik Kluzek]
- Updated MEGAN BVOC emissions [Hui Wang]
- Surface roughness [Ronnie Meier, Keith Oleson]
- Biomass heat storage [Sean Swenson]
- Multi-layer canopy* [Gordon Bonan]

Hydrology, Lakes & Rivers

- Representative hillslope hydrology* [Sean S]
- mizuRoute* [Naoki Mizukami & Erik K]
- Dynamic lake capabilities* [Inne Vanderkelen]

Cryosphere

- SNICAR snow albedo updates [Cenlin He]
- Excess permafrost ice [Hannay Lee, Mat Debolskiy]
- Snow thermal conductivity [A. Damseaux]

Vegetation & Biogeochemistry

- Arctic and boreal phenology updates [Leah Birch]
- N fixation temperature function [Tom Bytnerowicz]
- FATES SP & no competition* [Rosie Fisher, Charlie Koven, Adrianna Foster & more]
- FATES LULCC & C-based wood harvest* [Charlie]
- MIMICS soil BGC model* [Will Wieder, Sam Levis]
- Flexible foliar C:N ratios* [Emma Hauser]
- Improved vertical soil NO_3- movement* [Jinmu Luo]

Urban Model (CLM-U)

- Explicit AC adoption [Cathy Li]
- Updated urban properties [Keith, Johannes Feddema]
- Transient urban capabilities [Bowen Feng]

Land Use, Land Management & Fire

- Crop phenology & planting dates [Sam Rabin]
- Tillage & Residue removal [Mike Graham, Sam R]
- Biogenergy Crops [Yanyan Cheng]
- Fire model updates [Fang Li]
- Gross unrepresented land use change* [P Lawrence]

Parameter Calibration

- Matrix-CN Spinup [Chris Lu & many more]
- Parameter Perturbation Experiment [Linnia Hawkins; Daniel Kennedy, Katie Dagon, Adrianna Foster]

Datasets & Capabilities

- CRUJRA data atmosphere [Adrianna, Keith, Sean]
- Updated surface dataset [Sam L, Erik, Peter & more]
- CMIP7 forcings [Sam L, Erik, Peter]
- Python based land diagnostics integrated into CUPiD [Will, Justin R, Teagan K, Mike L & others]
- Tower simulations [Danica Lombardozzi, Will, Negin Sobahni, Teagan King]
- Simple Land Model, SLIM [Marysa Lague, Erik K.]

New Features

Biophysics

Hydrology, Lakes & Rivers

Hillslope Hydrology

Cryosphere

Vegetation & Biogeochemistry

FATES (Jessie's Talk)

Urban Model (CLM-U)

Urban: Transient & High Res Datasets

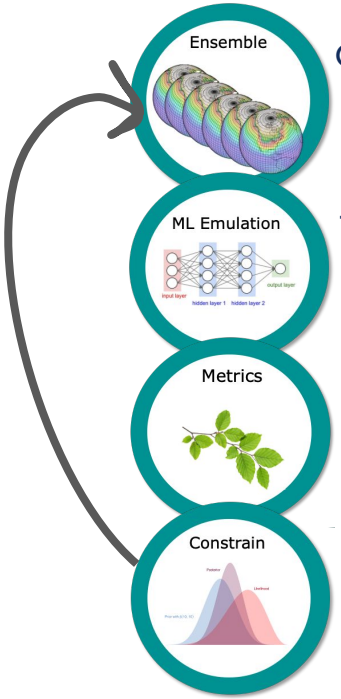
Land Use, Land Management & Fire

Parameter Calibration

ML Parameter Calibration

Datasets & Capabilities

Land Model Calibration



Generate a perturbed parameter ensemble

56 parameters
200 ensemble members

Train Emulator

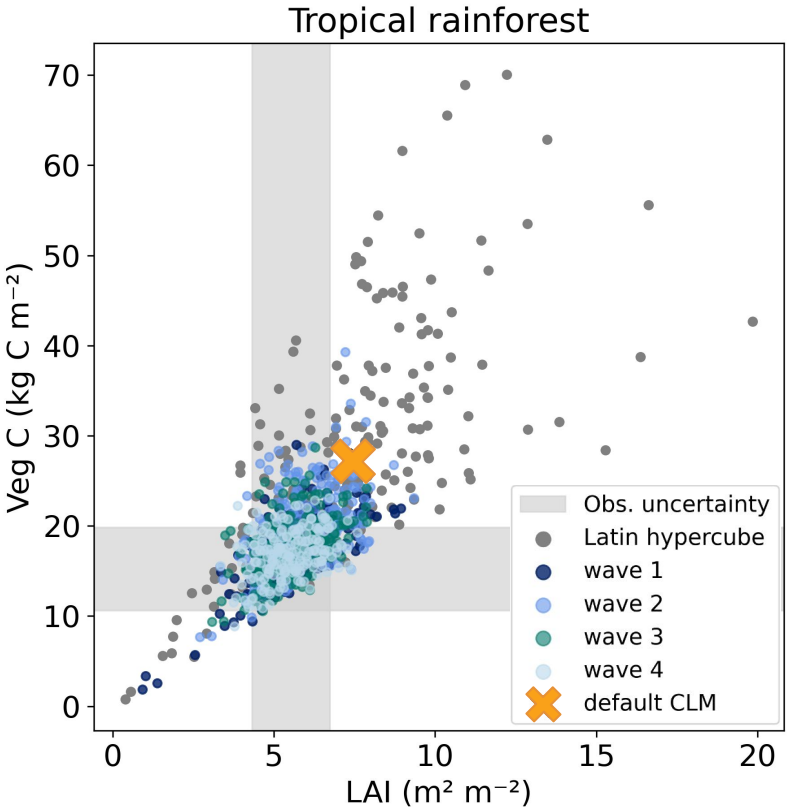
Emulate a large sample

Introduce observational constraints

Leaf Area, GPP, Biomass, Evapotranspiration
Biome mean, annual mean

Constrain parameter posteriors

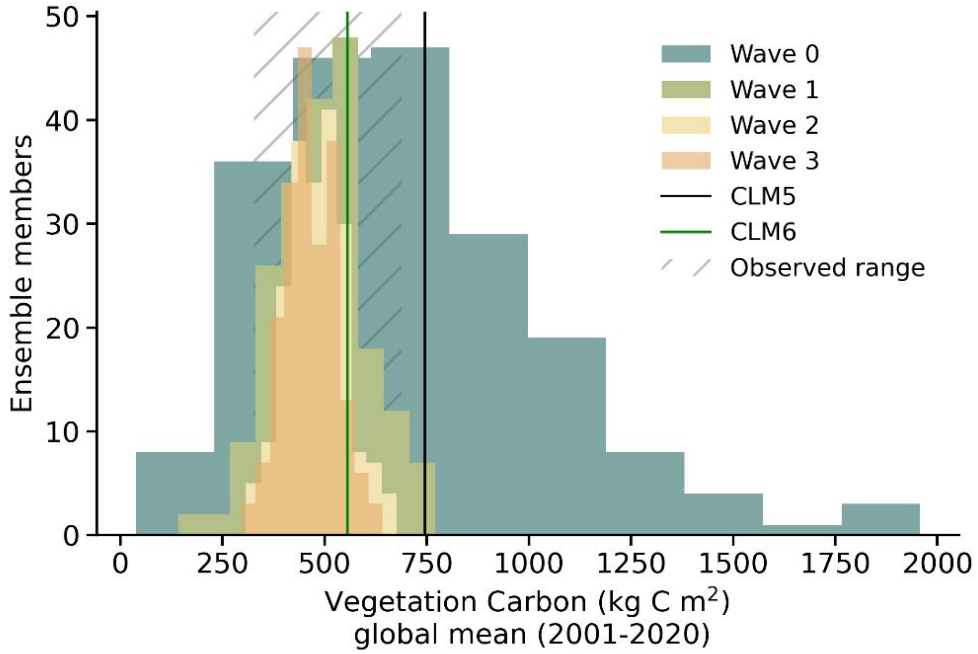
Rule out implausible parameter sets
Resample from constrained posteriors



1000 member PPE



Calibrated CLM6 for CESM3



	CLM6	CLM5
Ecosystem and Carbon Cycle		
Biomass		
Burned Area		
Carbon Dioxide		
Gross Primary Productivity		
Leaf Area Index		
Global Net Ecosystem Carbon Balance		
Net Ecosystem Exchange		
Ecosystem Respiration		
Soil Carbon		
Nitrogen Fixation		
Hydrology Cycle		
Evapotranspiration		
Evaporative Fraction		
Latent Heat		
Runoff		
Sensible Heat		
Terrestrial Water Storage Anomaly		
Snow Water Equivalent		
Permafrost		
Surface Soil Moisture		
Radiation and Energy Cycle		
Albedo		
Surface Upward SW Radiation		
Surface Net SW Radiation		
Surface Upward LW Radiation		
Surface Net LW Radiation		
Surface Net Radiation		
Ground Heat Flux		

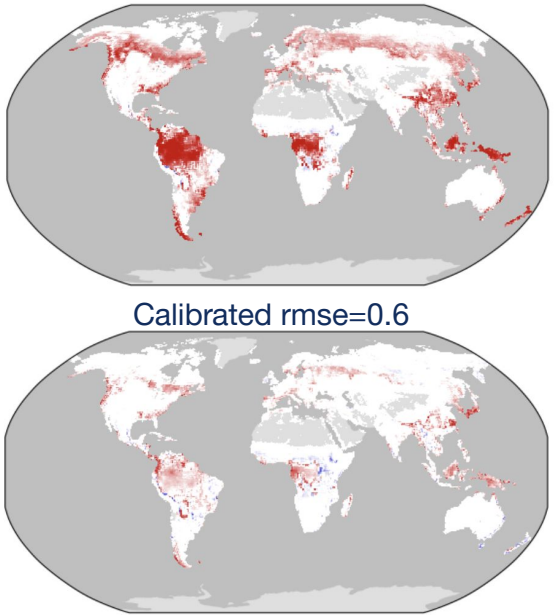


Calibrated CLM6 for CESM3

Leaf Area Bias

Default rmse=1.36

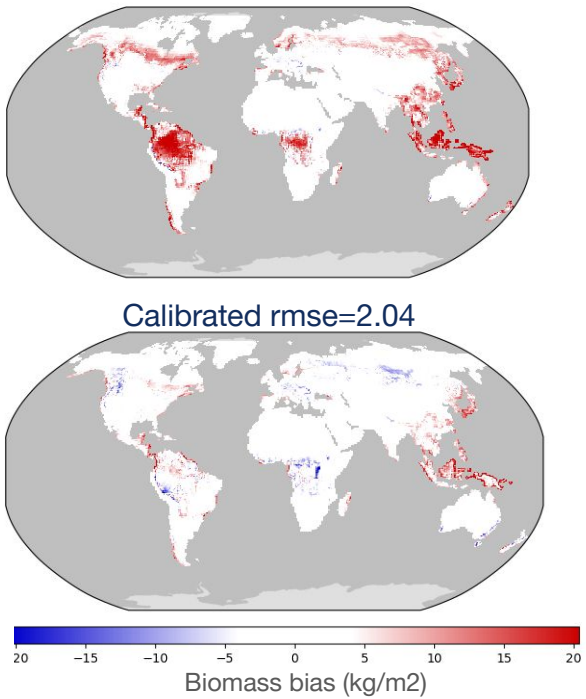
Calibrated rmse=0.6



Biomass bias

Default rmse=4.09

Calibrated rmse=2.04



	calibrated	default
Ecosystem and Carbon Cycle		
Biomass		
Burned Area		
Carbon Dioxide		
Gross Primary Productivity		
Leaf Area Index		
Global Net Ecosystem Carbon Balance		
Net Ecosystem Exchange		
Ecosystem Respiration		
Soil Carbon		
Nitrogen Fixation		
Methane		

Relative Scale

Worse Value — Better Value

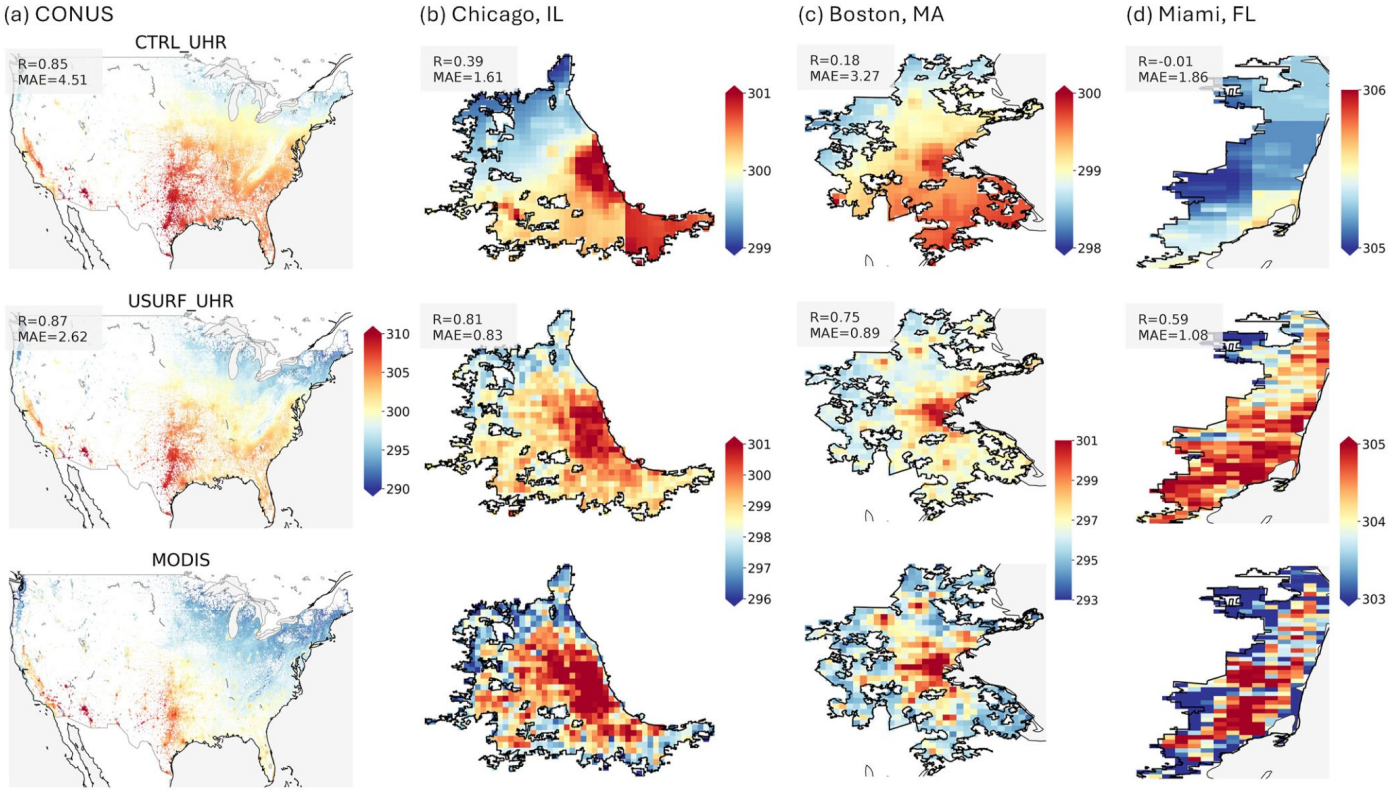


Transient (high res) Urban Dataset



Markley Boyer
(AR3, 2011)
From K. Oleson

High resolution, Transient Urban Properties



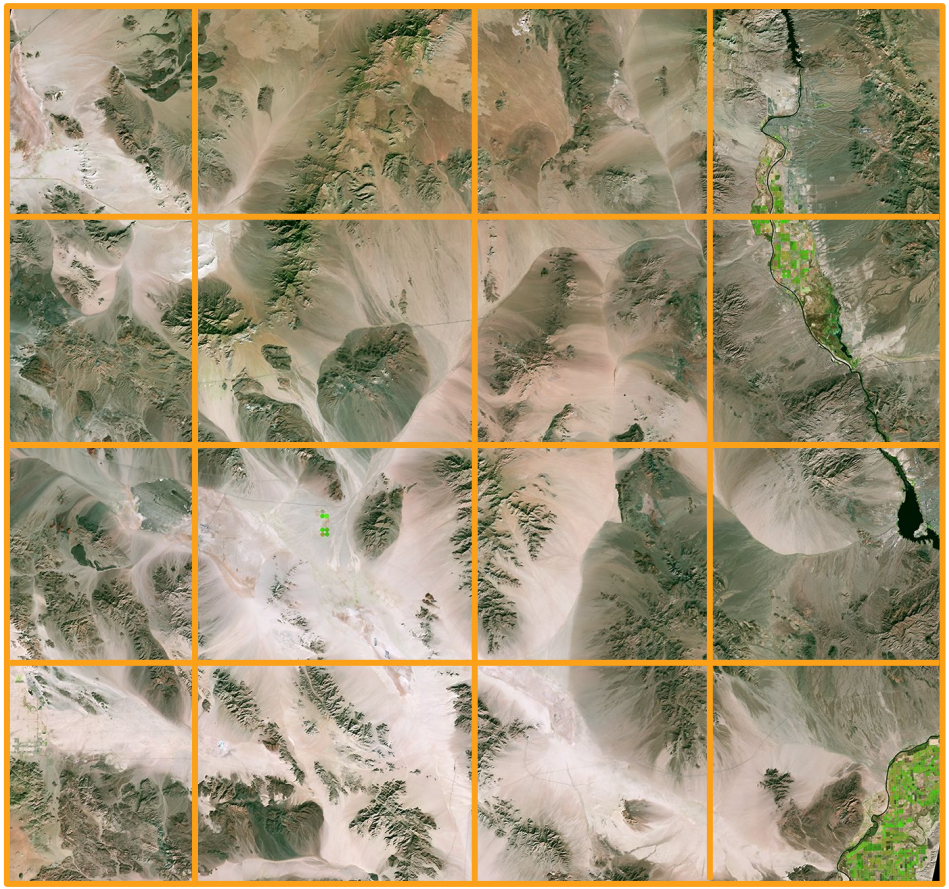


JAMES

Importance of Spatially Continuous Urban Surface Properties in Urban-Resolving Earth System Modeling

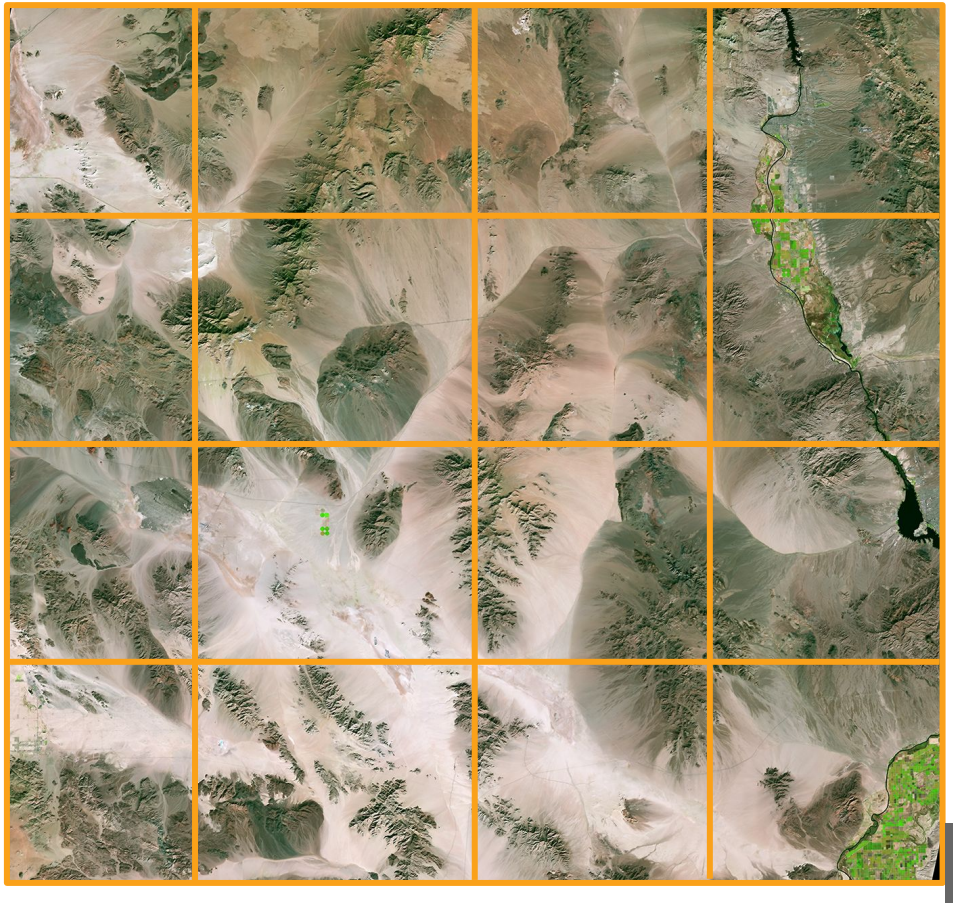
Yifan Cheng, Lei Zhao, Keith Oleson, TC Chakraborty, Keer Zhang, Cenlin He, Joyce Yang

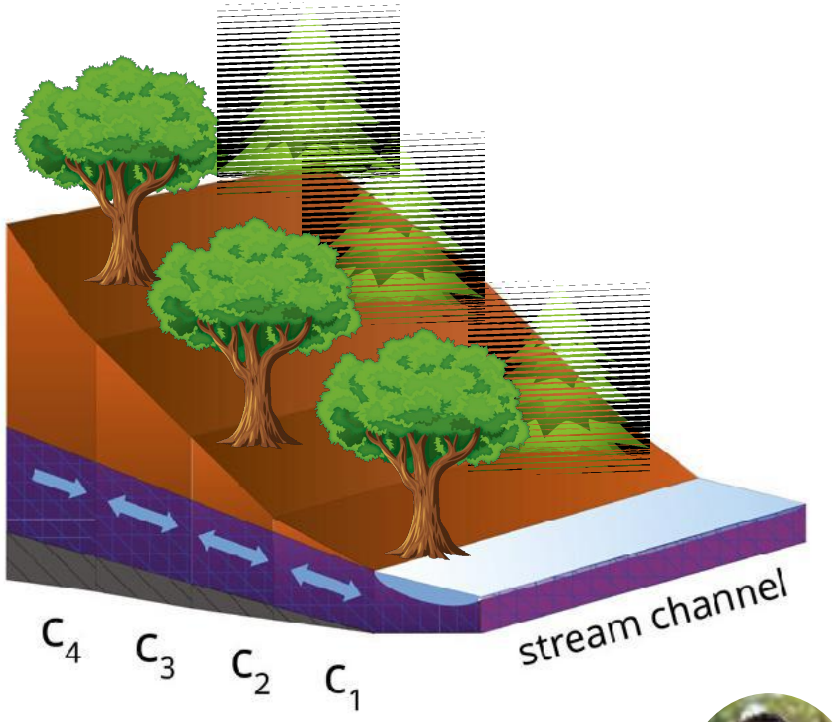
High Resolution?





High Resolution: Hillslope Hydrology!



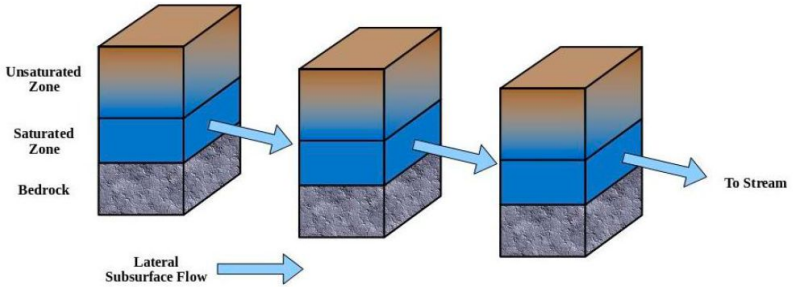




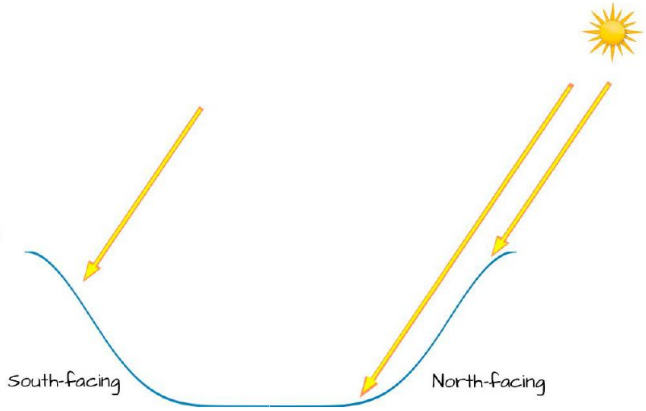
From Swenson & Lawrence 2025

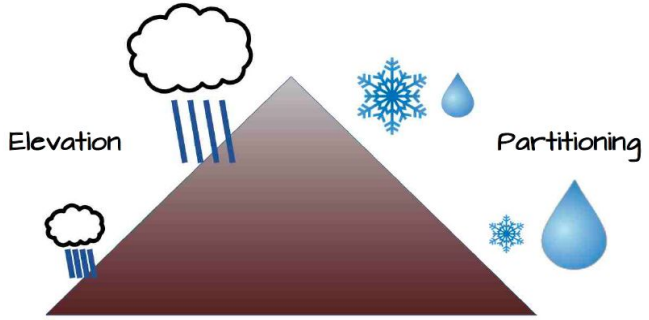
High Resolution: Hillslope Hydrology!

Explicit Lateral Flow Within Gridcell



Downscaled Meteorology

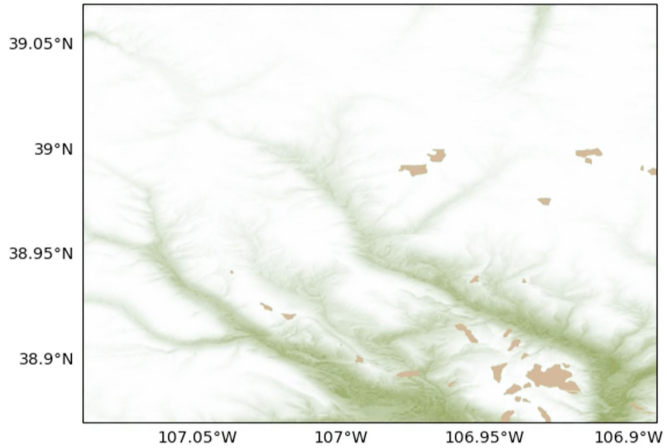






Hyper resolution: CLM Hillslope Hydrology + ML

April 15

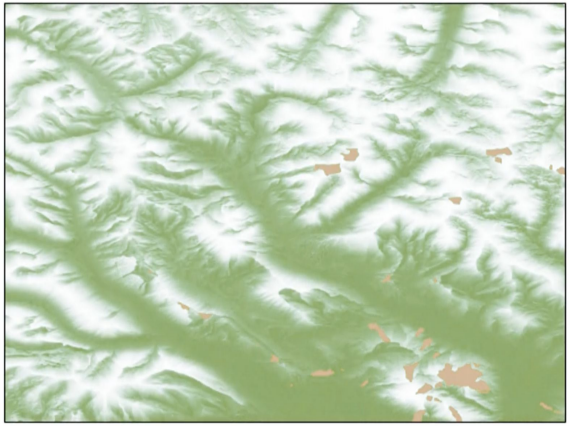


- Represents meaningful terrestrial heterogeneity
- Computationally efficient
- (30m) spatial extrapolation with machine learning tools

KEY FINDING

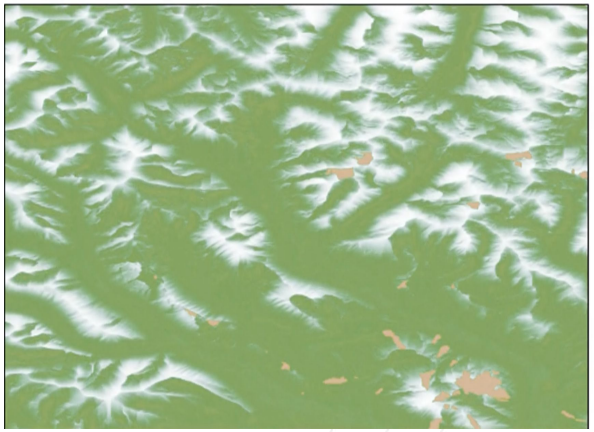
Evolution of snowpack around Crested Butte, CO

May 15





June 15

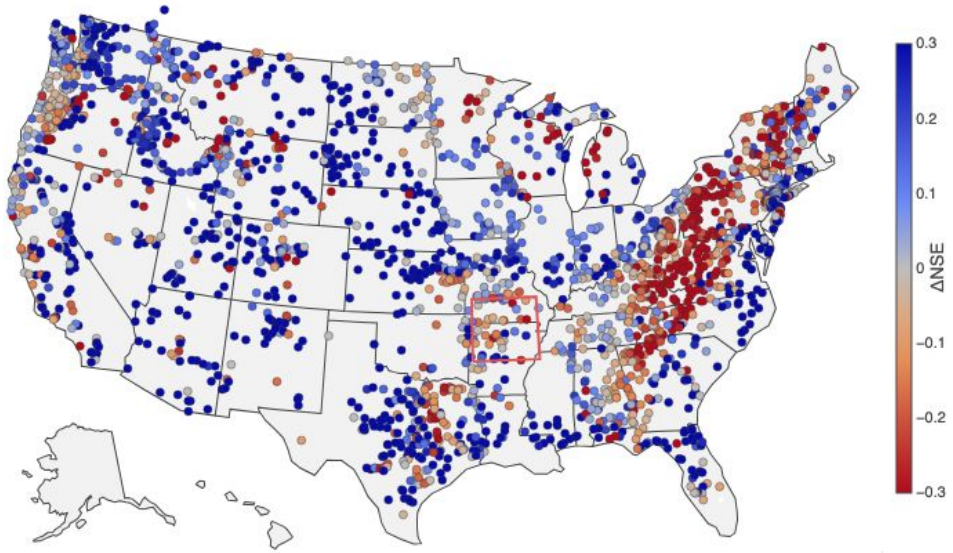


Hydrologic predictability with CLM6

KEY FINDING

Hillslope Hydrology configuration of CLM improves hydrologic predictions in most US regions

- 1/8th degree simulations
- 5 CLM configurations tested
- 38 Year simulations forced with NLDAS atmosphere
- Interactive website with diagnostics and evaluation
- Code repository, technical report
- 2-month CGD SIF-T project



2,286 streamflow gauges evaluated

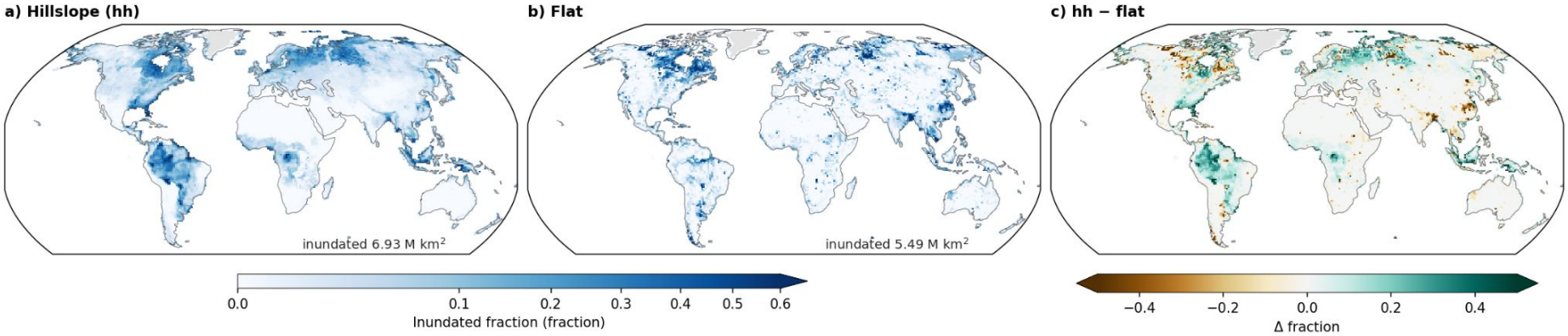
Project page



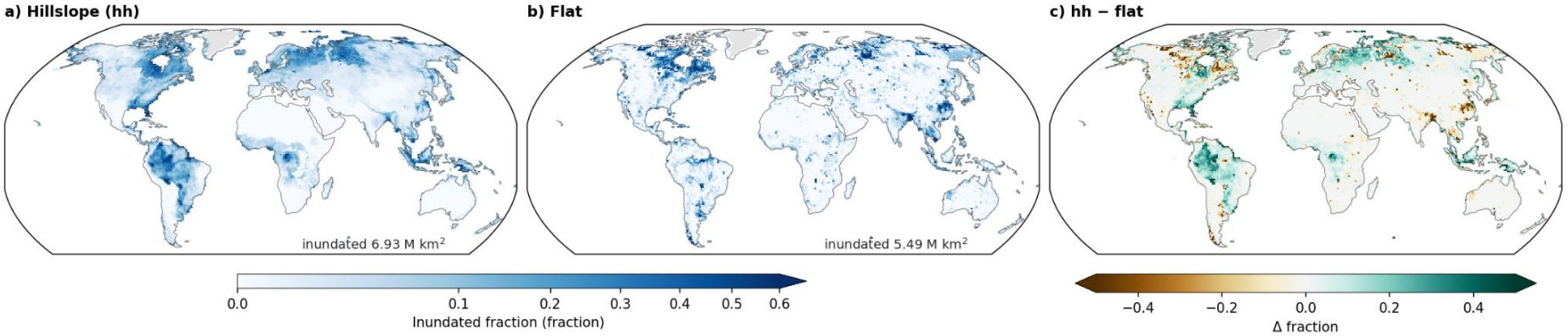
Mozhgan A. Farahani
With Andy Wood, Sean Swenson, Naoki Mizukami

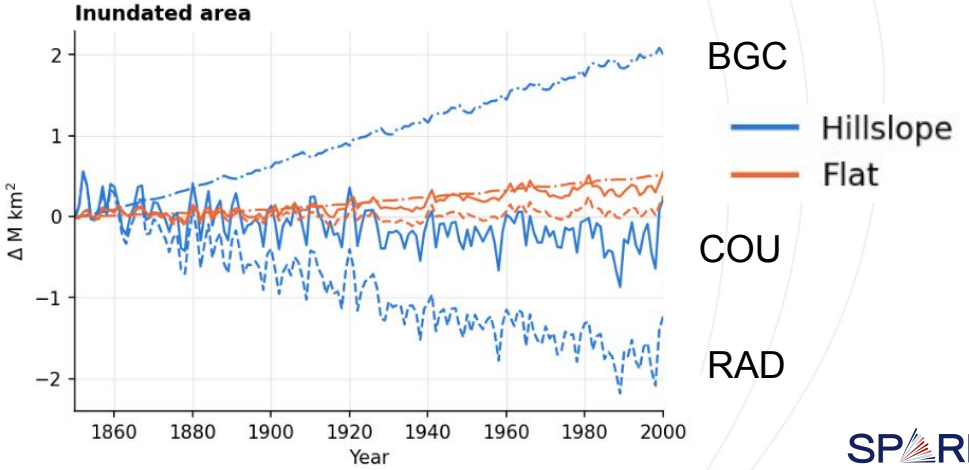
https://project.cgd.ucar.edu/projects/ctsm-conus/

Prognostic Wetland Extent

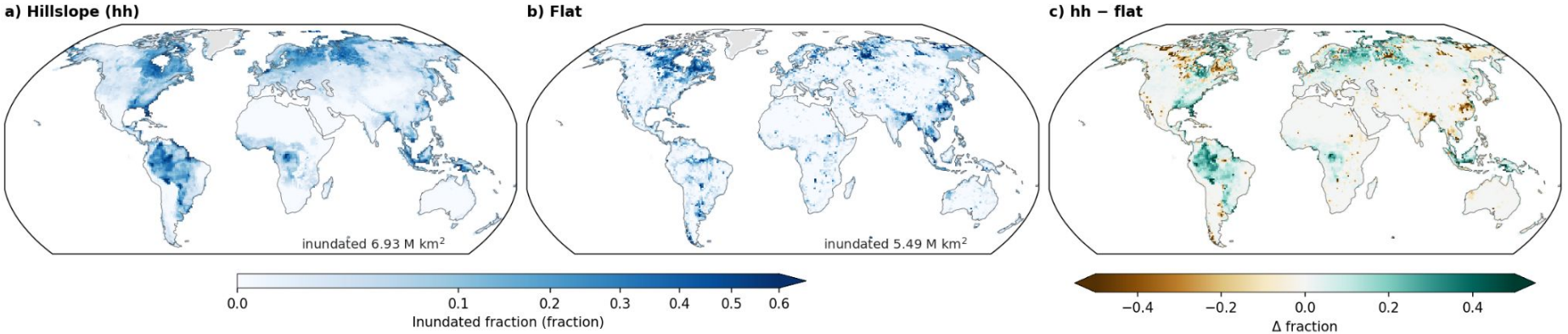


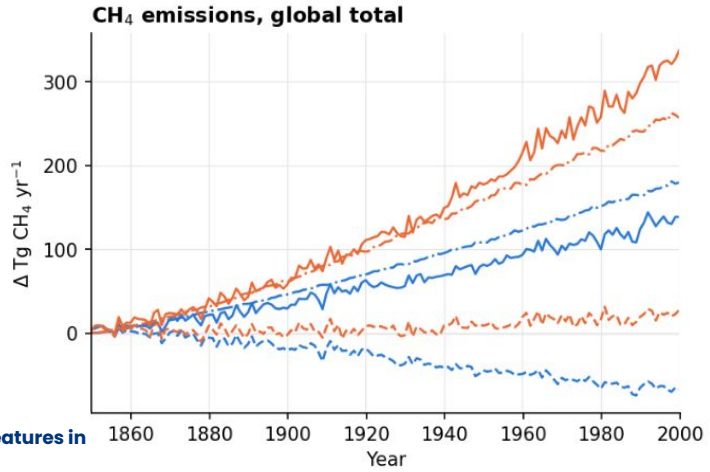
Prognostic Wetland Extent

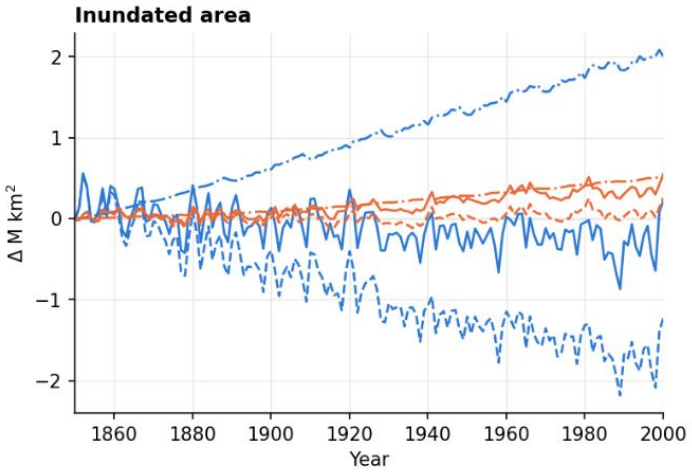




Prognostic Wetland Extent & Methane Fluxes







BGC

Hillslope

Flat

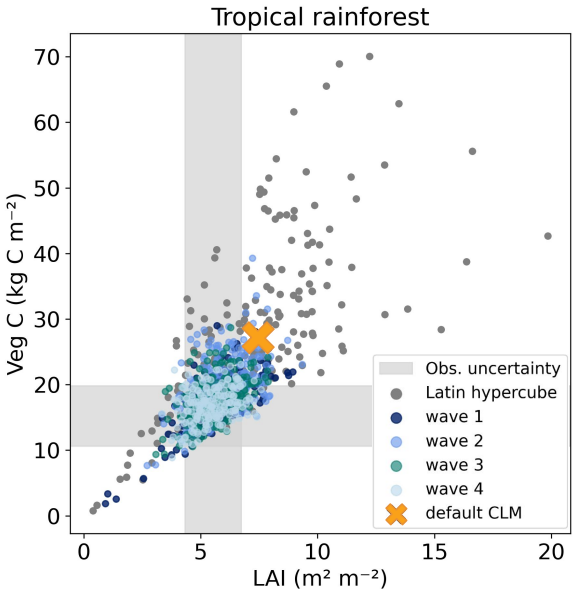
COU

RAD

(Abbreviated) CLM6 Feature Highlights

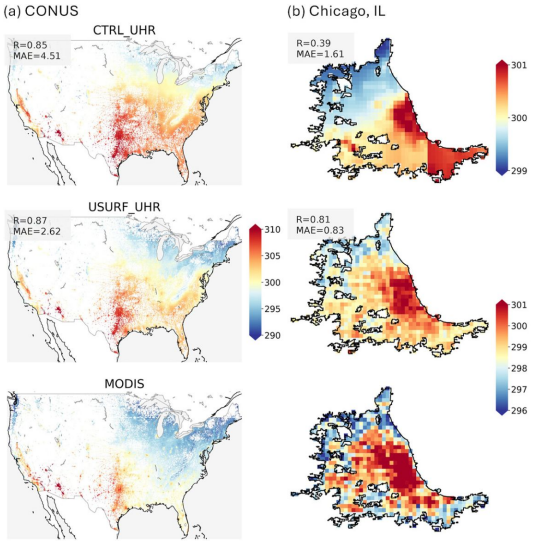
Parameter Calibration

Machine Learning Emulation



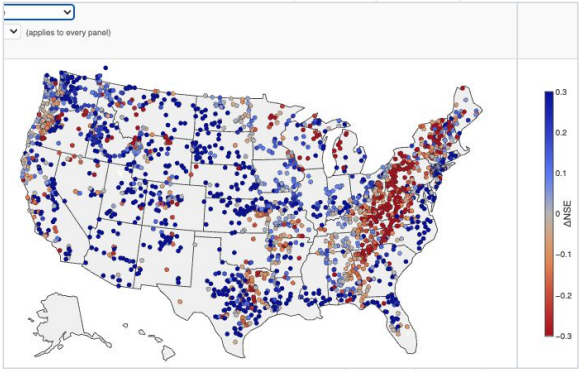
Urban

High Resolution Capabilities



Hillslope Hydrology

Initialized Predictions &
Improved Process Representation

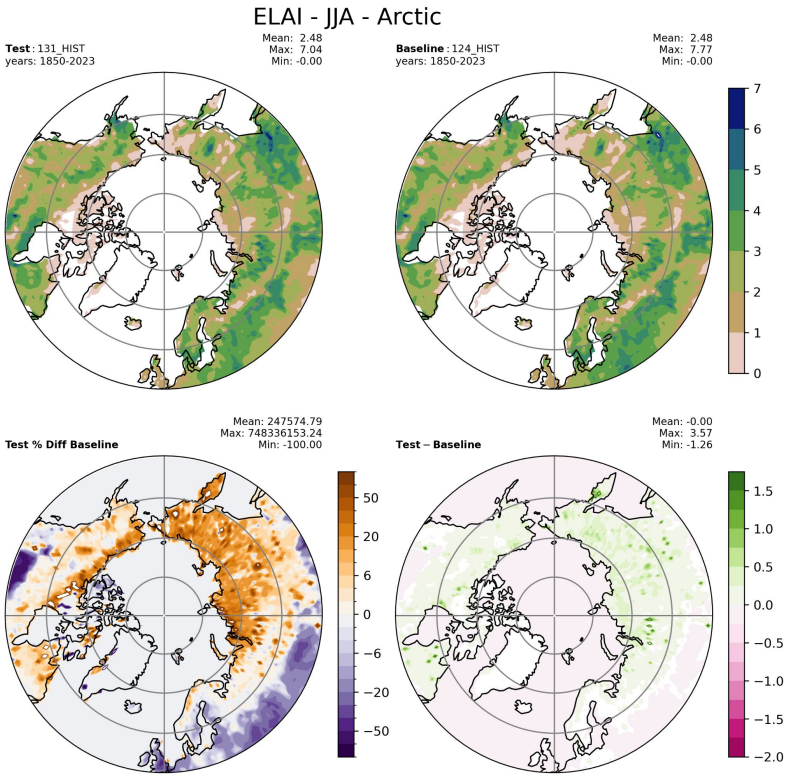


Diagnostic Capabilities

CUPID



LDF



ILAMB

Ecosystem and Carbon Cycle			
Biomass			
Burned Area			
Carbon Dioxide			
Gross Primary Productivity			
Leaf Area Index			
Global Net Ecosystem Carbon Balance			
Net Ecosystem Exchange			
Ecosystem Respiration			
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Ground Heat Flux			