Global simulations, evaluations and applications of CLM4 at ORNL

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Acknowledgment *to modeling group members at ORNL*

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Modeling uncertainties

- *Initial conditions*
- *Internal processes*
- *Parameters*
- *External environmental drivers (This talk mainly)*

CLM4 global offline simulations

- *30 minutes time step, global half-degree, single- and multi-forcing historical simulations (1850-2010)*
- *Climatic change only (CRUNCEP), changing CO_2, anthropogenic airborne nitrogen deposition and dynamic LULCC*

Global evaluations and applications

- *Test the model beyond the single-site calibration*
- *Performance of the model against large-scale "observations" and multi-model simulations*
- *Inform the model improvement and new measurements for next steps*
- *Improve understanding of ecosystem structure, function and climate-carbon cycle feedback at relevant spatial-temporal scale*

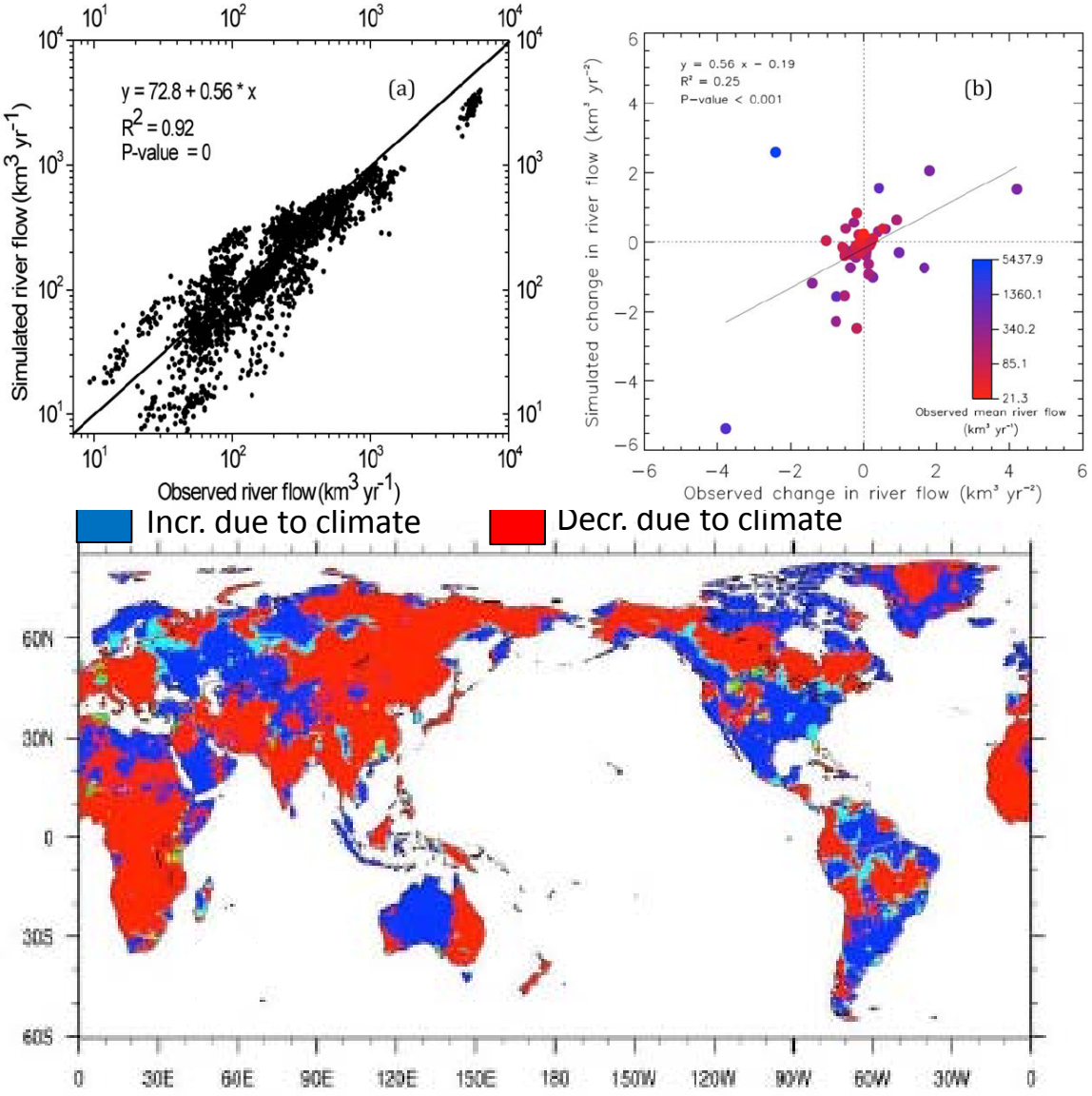
Riverflow

Objective

- Explore the relative influence of climate and multiple anthropogenic forcings on trends in **river flow** as simulated by CLM4

Significance

- CLM4 vs. observations in reasonable agreement (top figure)
- Simulated river flow dominated by climate; direction and magnitude of trend varies by region (bottom figure).



Shi *et al*. (2011) *Geophysical Research Letters*

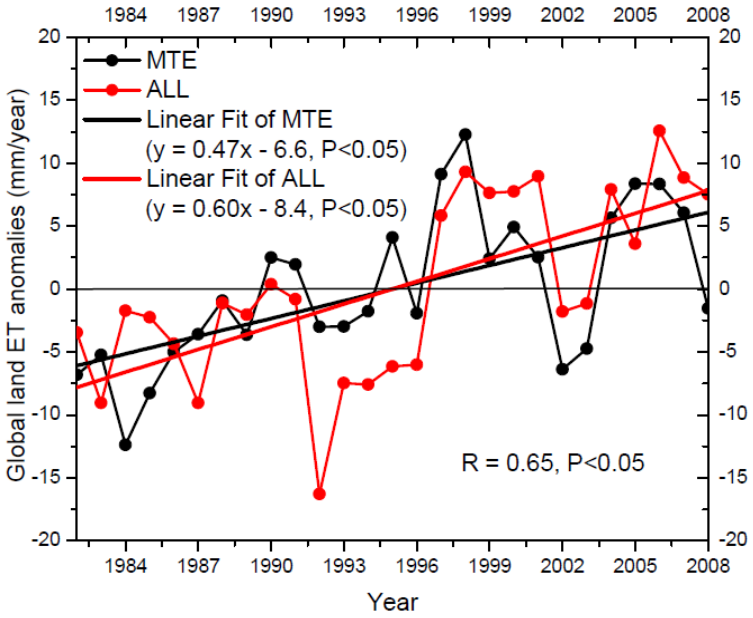
Evapotranspiration

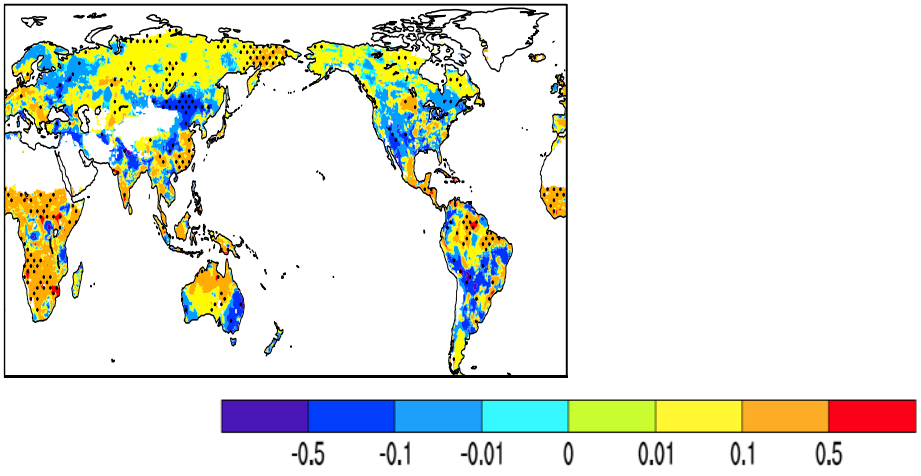
Objective

- CLM4 & global ET (FLUXNET-MTE) to identify the causative factors for annual ET trend

Significance

- CLM4 captures the spatial distribution and interannual variability of ET well when compared to observation-based estimates
- climate trends and variability dominate predicted variability in ET
- Other environmental factors are less pronounced and regionally dependent





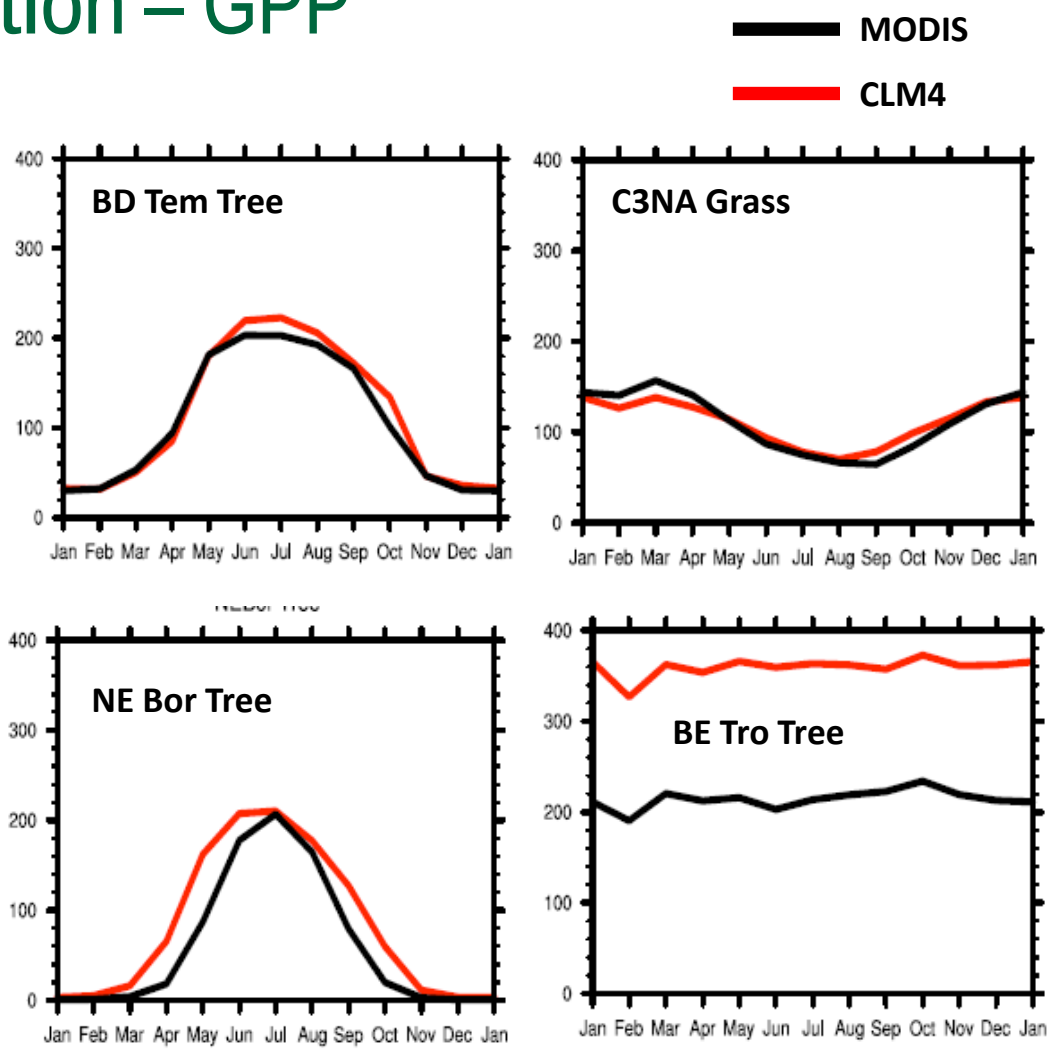
Remote sensing evaluation – GPP

Objective

- Evaluate CLM4 GPP with satellite-based estimates (MODIS)

Significance

- First example of systemic comparison and evaluation of modeled GPP using latest satellite estimations.
- Understanding the performance of CLM4 GPP at various spatial-temporal scales.
- CLM4 GPP compares well with independent remote sensing estimates and correlations with climate.
- New quantitative and objective metrics for model GPP evaluation



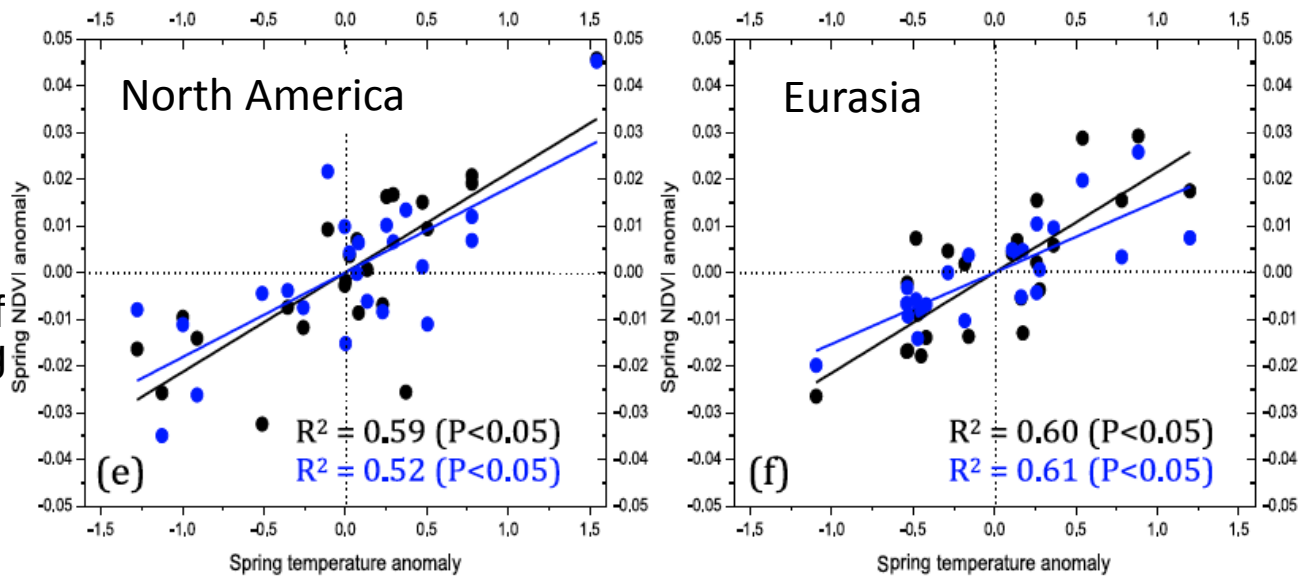
Phenology

Objective

- CLM4 & remotely-sensed NDVI (GIMMS) to quantify the impact of forcing factors on spring vegetation growth

Significance

- Direct comparison of observed NDVI against an ecosystem model.
- Understanding the nonlinear dynamics of vegetation growth
- CLM4 dynamics compare well with independent estimates
- New quantitative, objective metrics for model evaluation



Simulated dominant driving factors for NDVI trends

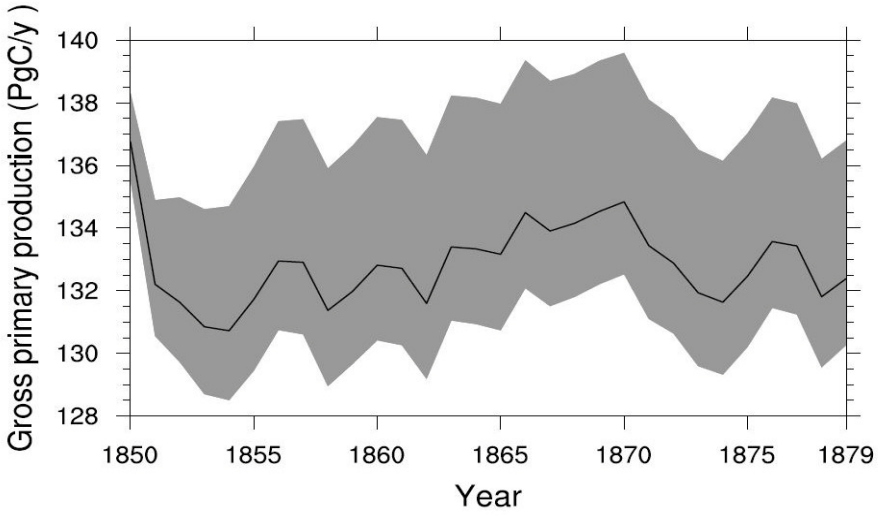
Global sensitivity analysis

Objective

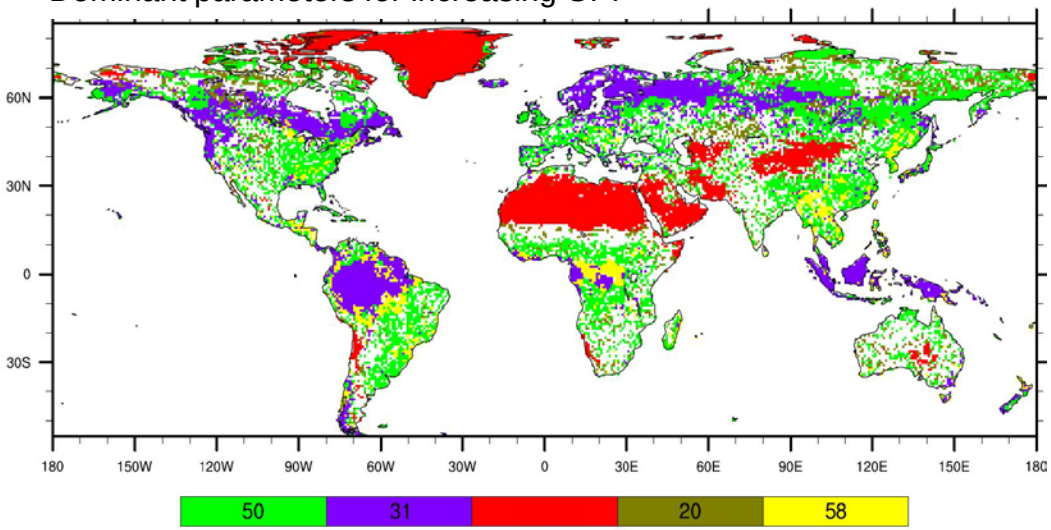
- Single factor sensitivity analysis of global CLM offline simulation

Significance

- Full-spectrum single factor analysis (77 biogeochemical / biogeophysical parameters)
- Scalable simulation framework on ORNL Leadership Computing Facility (~60000 cores)
- Global temporal range analysis and spatially-explicit impact rank analysis



Dominant parameters for increasing GPP



Wang *et al*. (2012) *under review*

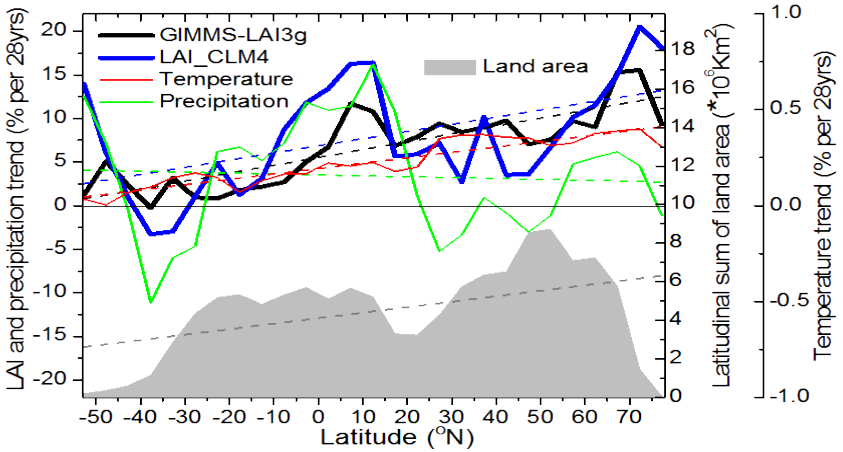
Forcing factors – LAI

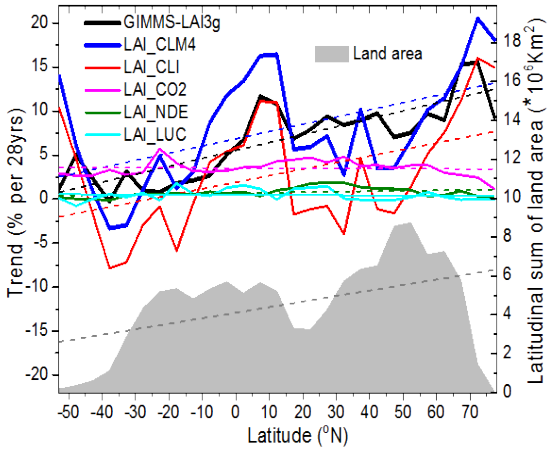
Objective

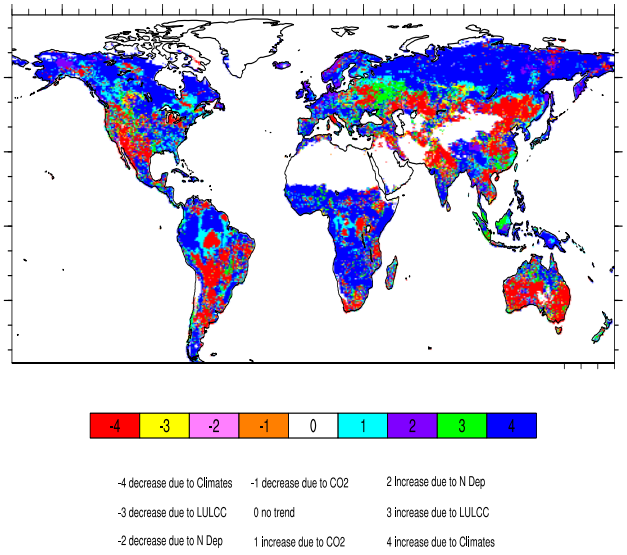
- CLM4 & latest satellite LAI (GIMMS-LAI3g) to understand the response of vegetation growth to inhomogeneous land warming and different forcing factors (1982-2009)

Significance

- Significant increasing trend in annual vegetation growth and substantial LAI change asymmetry were consistently revealed in both products
- The asymmetric land surface warming was diagnosed to drive this latitudinal trend of LAI
- Heterogeneous precipitation considerably regulated the local LAI change
- Globally, CO_2 fertilization was simulated to dominate the increasing vegetation growth







On-going global research with CLM

- ✧ Warming and drought
- ✧ Litterfall, Biomass and Soil Respiration
- ✧ FPAR, CMIP5 LAI, MsTMIP efforts
- ✧ CLM-CNP global simulations
- ✧ iESM coupling and applications
- ✧ CLM point-level simulation using global modeling structure
- ✧ CLM4 2-layer soil BGC model development using EBIS
- ✧ PiTS, SPRUCE and NGEE (Arctic and Tropics)

- CLM4 generally demonstrated good performance in annual changes of carbon and hydrology fluxes, and vegetation structures
- Global climate variability and CO_2 concentration function as two dominant drivers for annual trends
- Nitrogen deposition and LULCC induced changes are regionally dependent and follow the different trend changes of forcing agents
- Global evaluations and factorial simulations add further insight into ecosystem dynamics and environmental correlations
- New quantitative and objective metrics for evaluation of land surface models

Thank you for attention!
Questions and comments?