Long-Term Changes and Variability in Global Ecosystem Phenology From MODIS

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Minkyu Moon (BU), Tristan Green (BU), Grace Choi (NCSU), Xiaojie Gao (NCSU)

Project Description

- ***How has the timing and length of growing seasons changed over the MODIS era?***
- ***How do LSP anomalies and trends impact sub-seasonal and seasonal scale carbon fluxes?***
- *How can joint information from MODIS land surface temperature and land surface phenology be used to characterize the impact of droughts on ecosystems?*

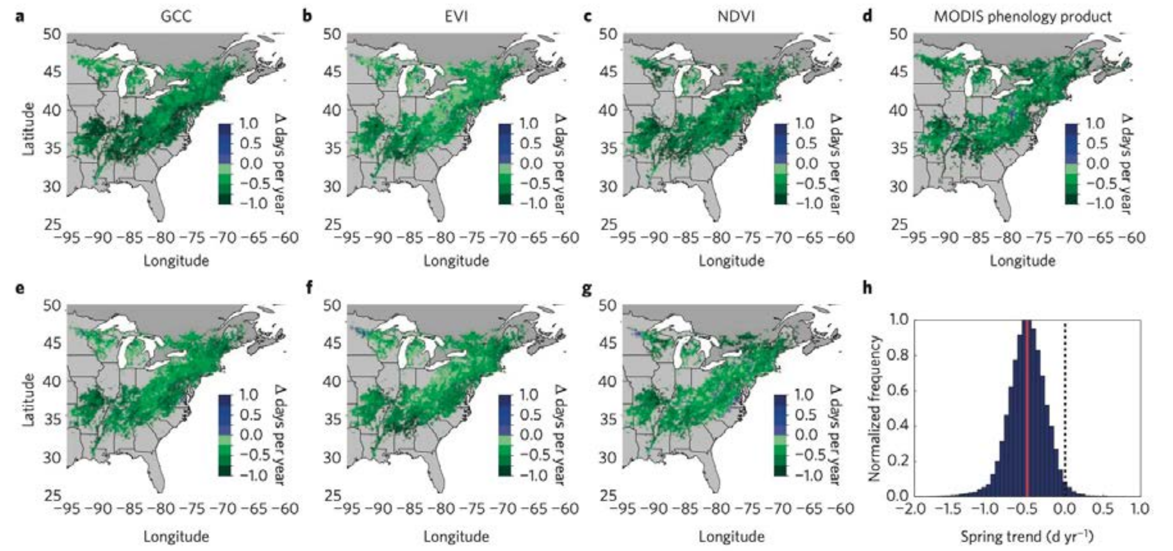
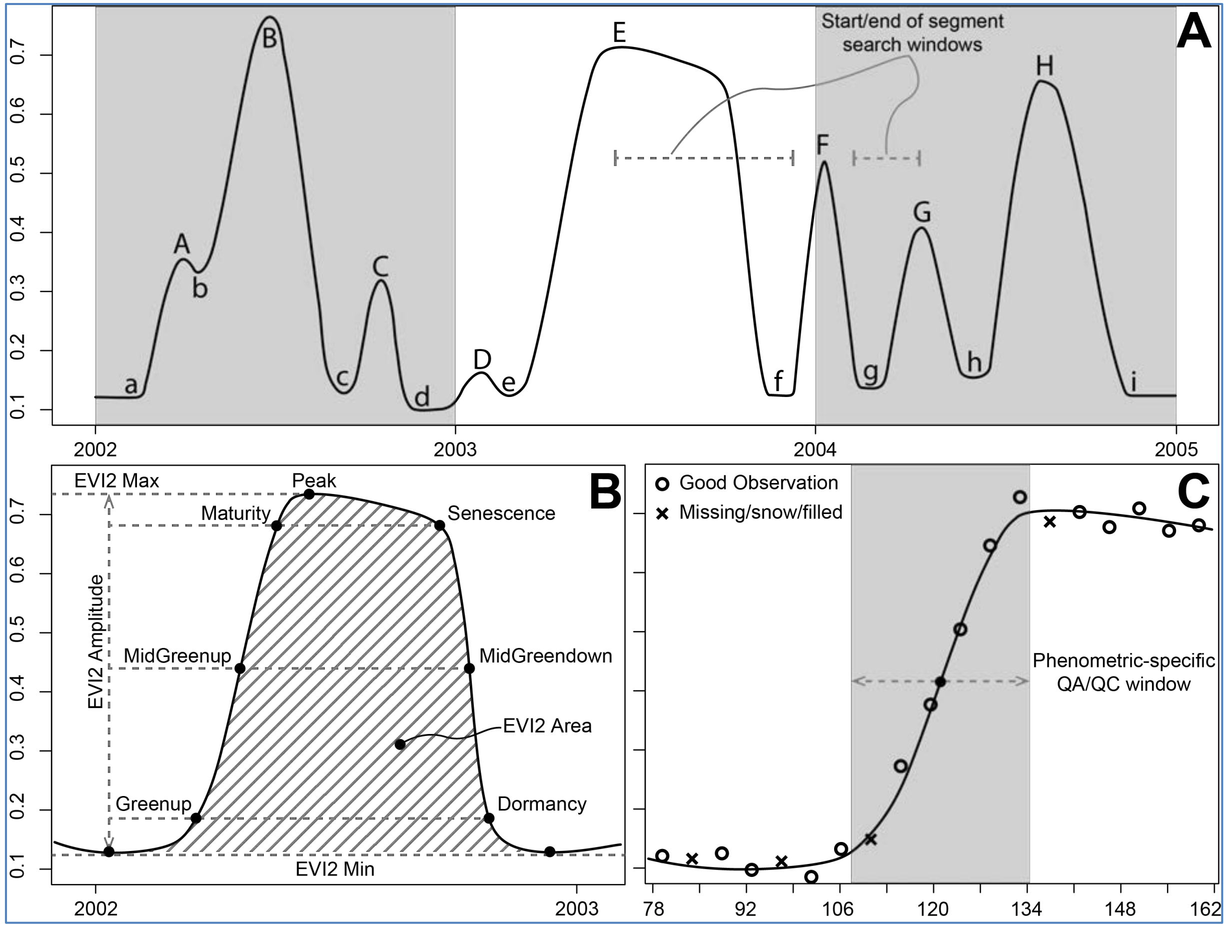


Figure 1 | Long-term changes in satellite-derived spring phenology. a–h, Regional changes in spring phenology for deciduous broadleaf forests in the Eastern US since the start of the century (2000–2012) based on remotely sensed daily greenness indicies: green chromatic coordinate (GCC (**a**,**e**)), enhanced vegetation index (EVI (**b**,**f**)), normalized difference vegetation index (NDVI (**c**,**g**)) and the 8-day MODIS phenology product (**d**). Daily indices were extracted using two date extraction techniques: a robust smoothing-spline approach (**a**–**c**) and a dual logistic greendown curve fitting method (**e**–**g**). All trends shown (estimated using panel analysis) are significant at $P < 0.05$ (96.7% of all deciduous broadleaf forest pixels). **h**, Histogram of all trends from all methods. The vertical red lines illustrate the mean trend across all indices and date extraction methods. See Methods section for a description of the indices used.

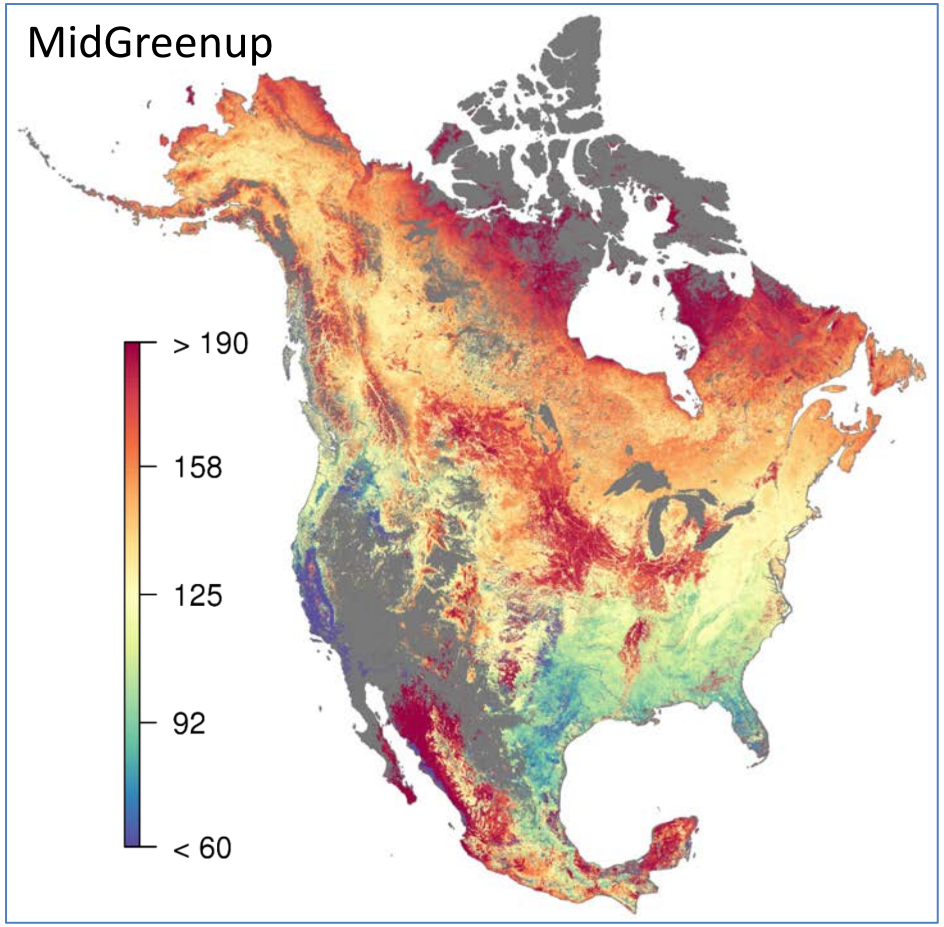
Keenan et al, Nature Climate Change, 2014

MCD12Q2: 22 Years (and counting) of Global Land Surface Phenology

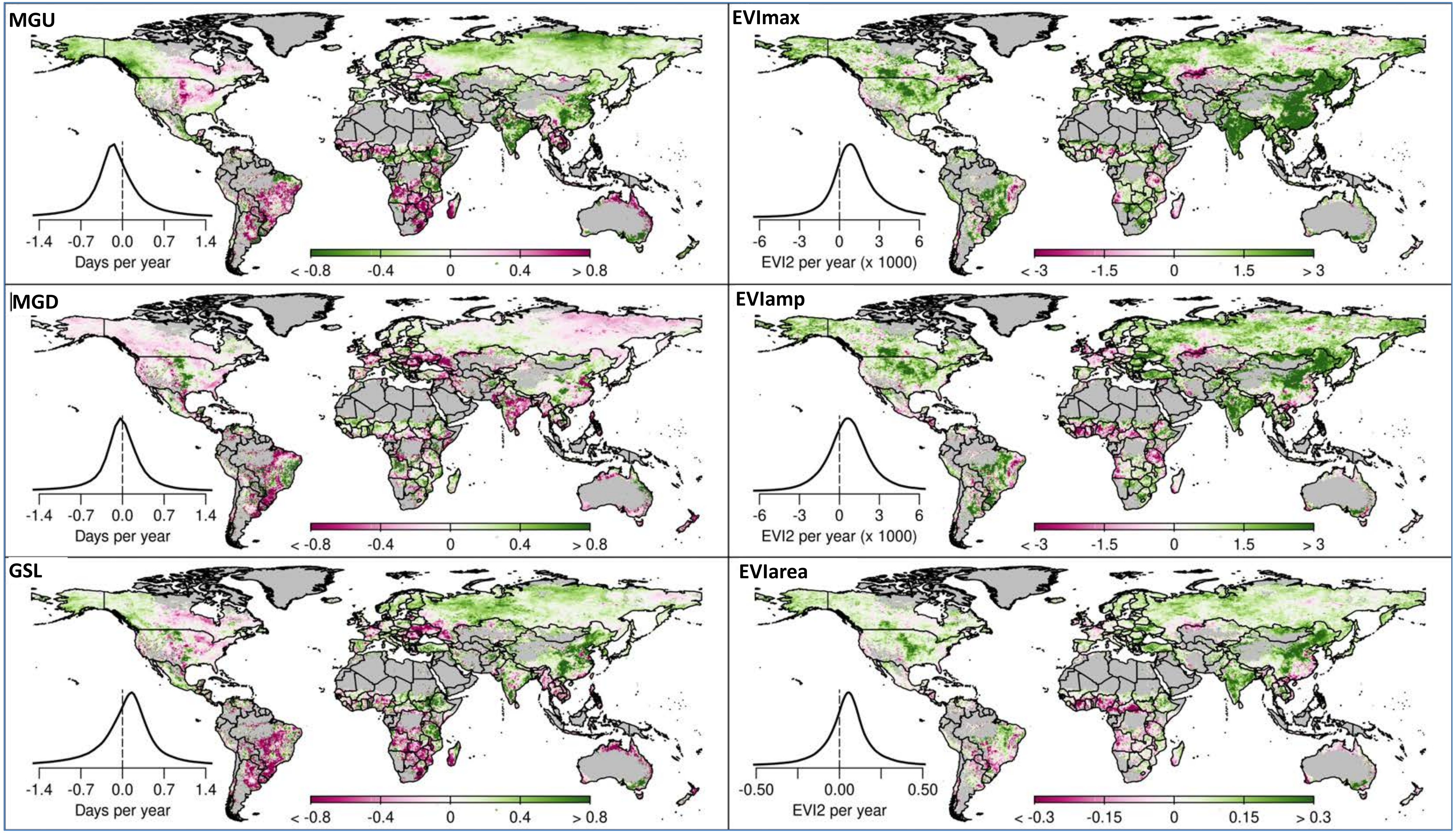
Algorithm



Product



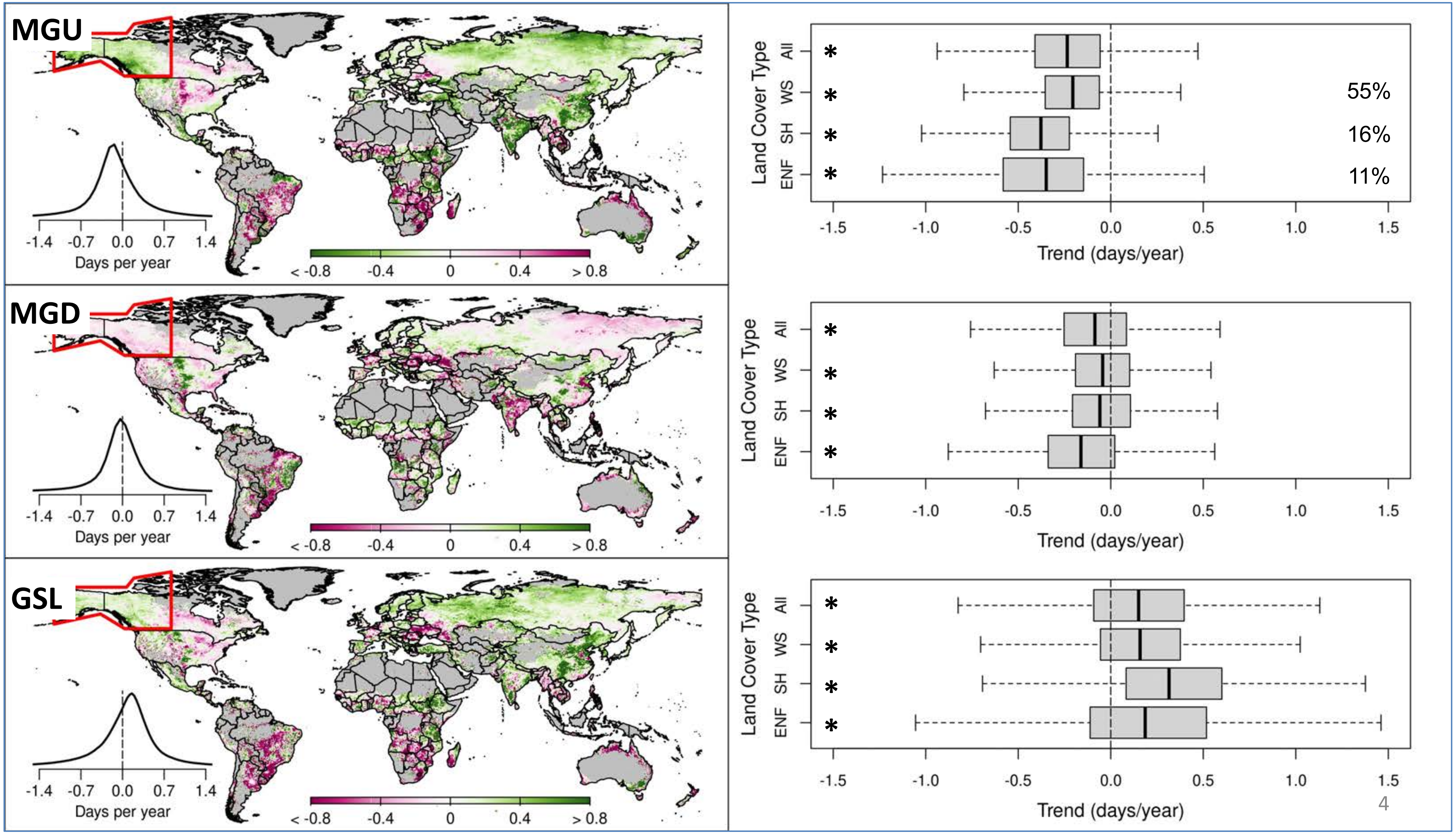
Progress and Results: Trends in GSL Timing & Length



Progress and Results: Trends in GSL Timing & Length

IPCC Climate Reference Regions

Northwestern North America

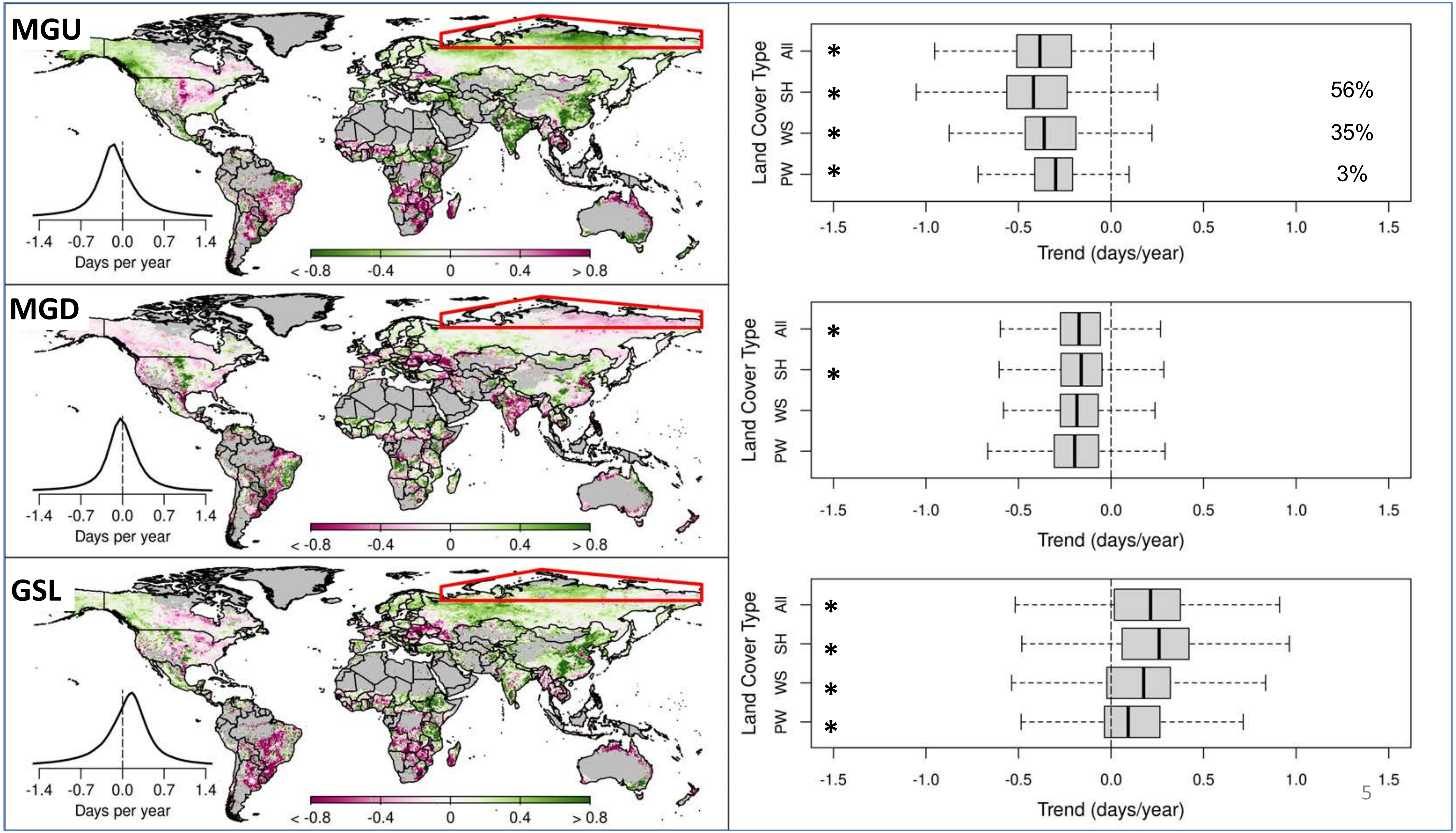


* Indicates $p < 0.05$ based on Ives et al, RSE, 2021

Progress and Results: Trends in GSL Timing & Length

IPCC Climate Reference Regions

Russian Arctic



* Indicates $p < 0.05$ based on Ives et al, RSE, 2021

Progress and Results: Sub-Seasonal & Seasonal Scale Carbon

$$GPP = \alpha \cdot CUP \cdot GPP_{max}$$

MODIS GSL and Max EVI do not reproduce results based on tower-based GSL and carbon uptake period

Challenge: MODIS does not capture site-specific variance, esp WRT GPP_{max} vs EVI_{max}

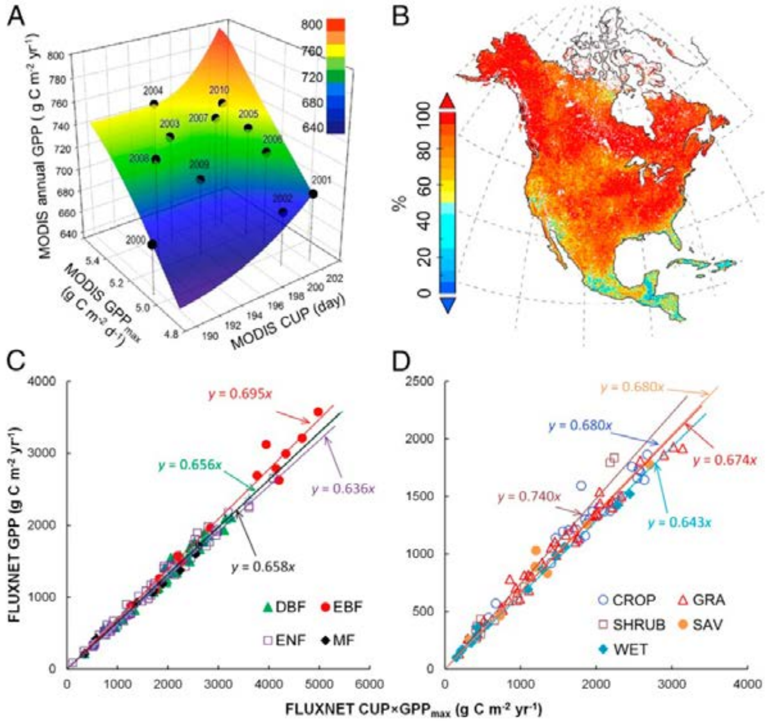


Fig. 1. Joint control of the temporal variability of satellite-derived annual GPP and the spatial variability of FLUXNET annual GPP by CUP and GPP_{max}. (*A*) The temporal variability of GPP in North America from 2000 to 2010 can be better understood by splitting annual GPP into GPP_{max} and CUP. The flat color interpolated surface reflects a good relationship between annual GPP and $GPP_{max} \times$ CUP ($R^2 = 0.95$, $P < 0.001$). Vertical lines were added to improve readability. (*B*) Contribution of $GPP_{max} \times$ CUP to GPP temporal variability over 2000–2010. The contribution in each grid cell was derived from the R^2 in the linear regression analysis between GPP and $GPP_{max} \times$ CUP. *C* and *D* show relationships between GPP and $GPP_{max} \times$ CUP across FLUXNET sites in forest and nonforest biomes, respectively. Each data point in *C* and *D* represents one flux site with average data over different years. CROP, cropland; DBF, deciduous broadleaf forest; EBF, evergreen broadleaf forest; ENF, evergreen needleleaf forest; GRA, grassland; MF, mixed forest; SAV, savanna; SHRUB, shrubland; WET, wetland.

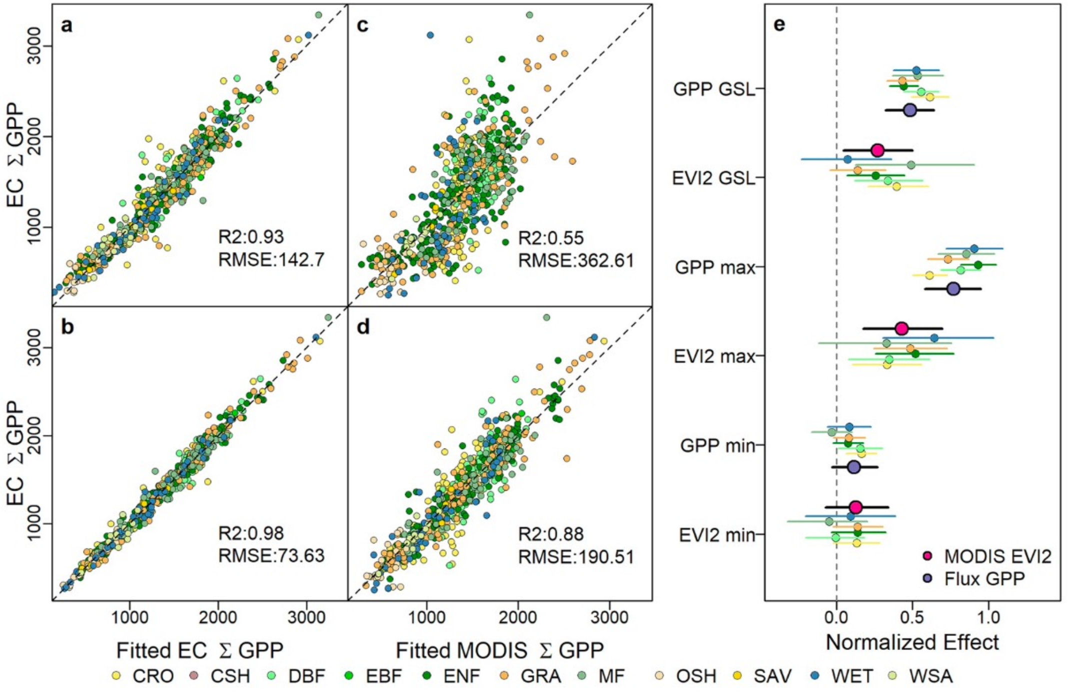


Figure 3. Bayesian hierarchical model results. (a) Gross primary productivity (GPP) metrics-based model with biome-level intercepts and slopes (Model 3); (b) GPP metrics-based model with site-level intercepts and slopes (Model 5); (c) Moderate Spatial Resolution Imaging Spectroradiometer (MODIS) LSP-based model with biome-level intercepts and slopes (Model 3); (d) MODIS LSP-based model with site-level intercepts and slopes (Model 5); (e) Comparison showing the normalized effect of GPP metrics- and LSP-based models on model results with site-level intercepts and slopes. Bars show 95% Bayesian credible intervals. The larger red and blue points in panel (e) show the overall effect across all biomes from the LSP- and GPP-derived metrics, respectively. ΣGPP (Unit: $gCm^{-2}\ yr^{-1}$) is the annual GPP at each EC tower.

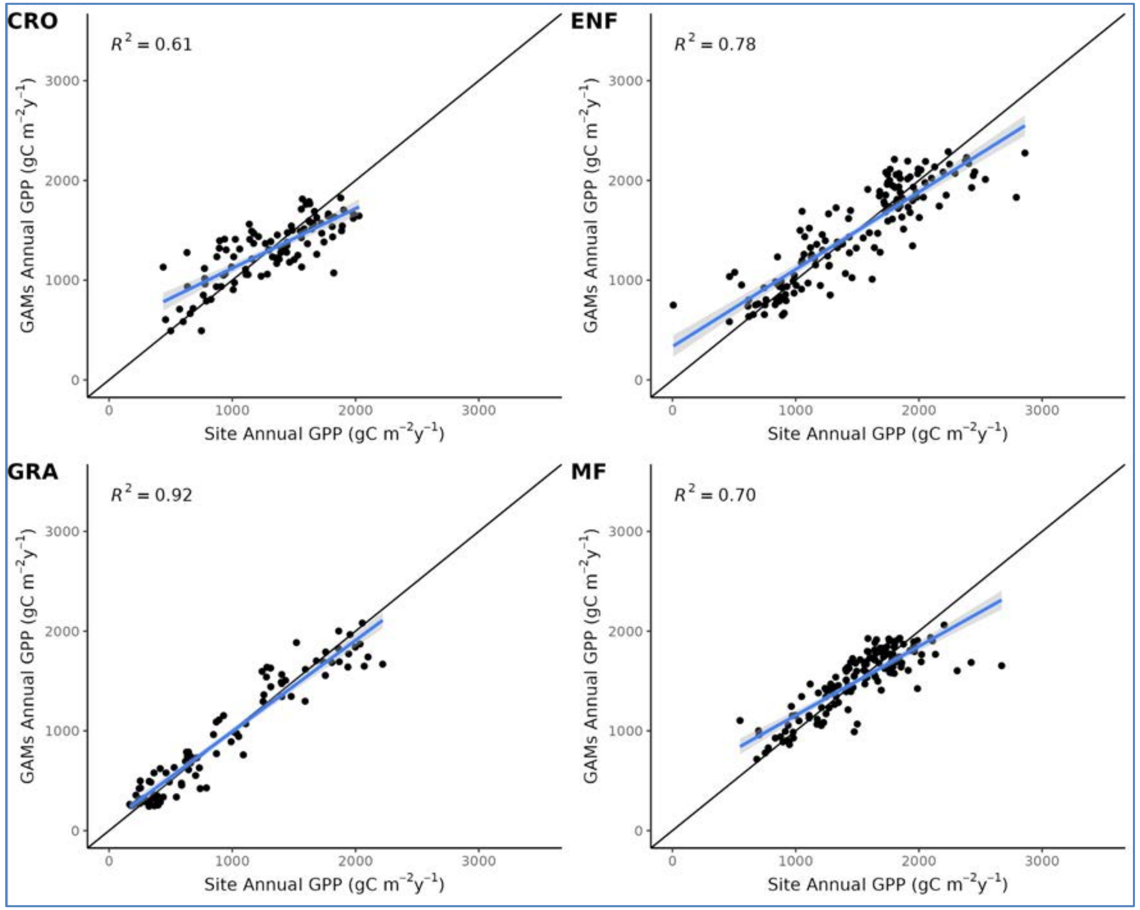
Xia et al, PNAS, 2015

Gao et al., Global Biogeochemical Cycles, 2023

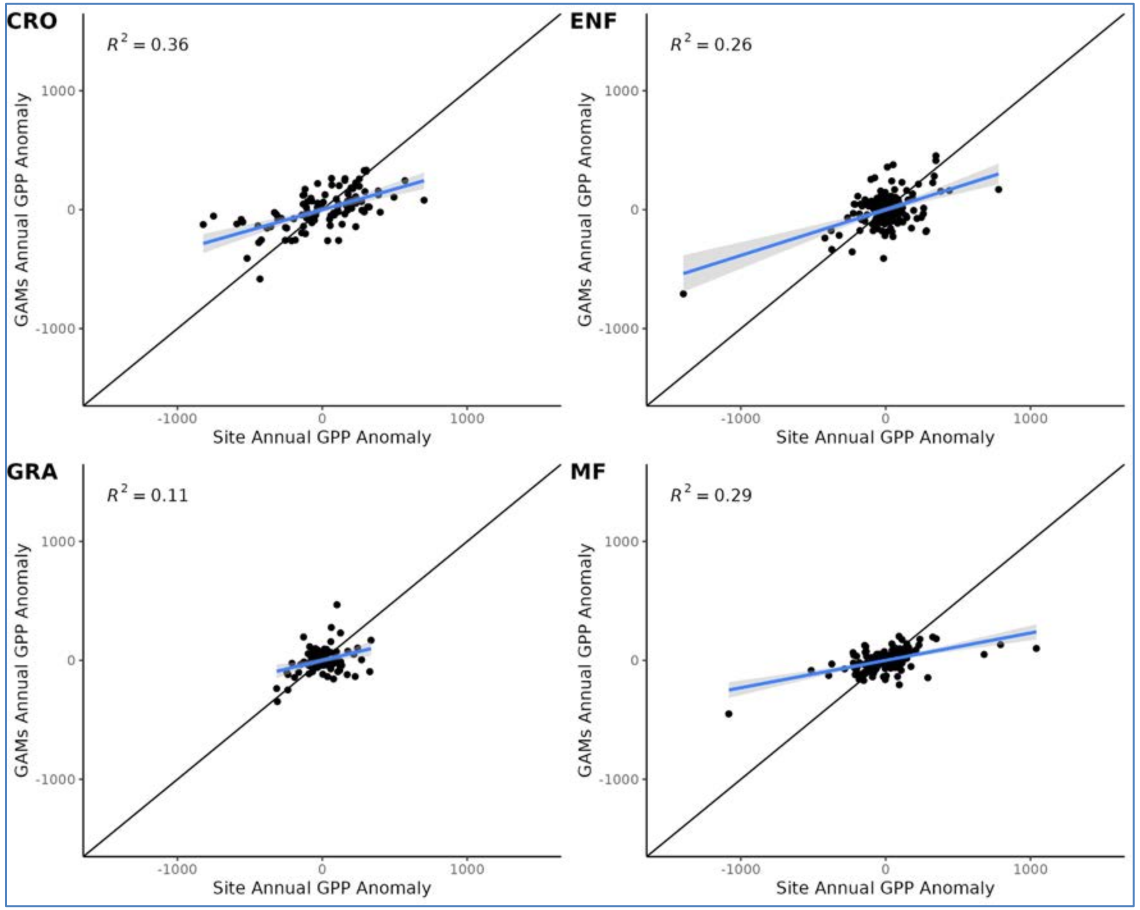
Progress and Results: Sub-Seasonal & Seasonal Scale Carbon

Generalized additive models (GAMs) estimated using gridded met data to capture site-specific variance at 73 AmeriFlux sites with 453 site-years of data spanning 4 cover types

Observed vs Modeled GPP



Observed vs Modeled GPP Anomalies

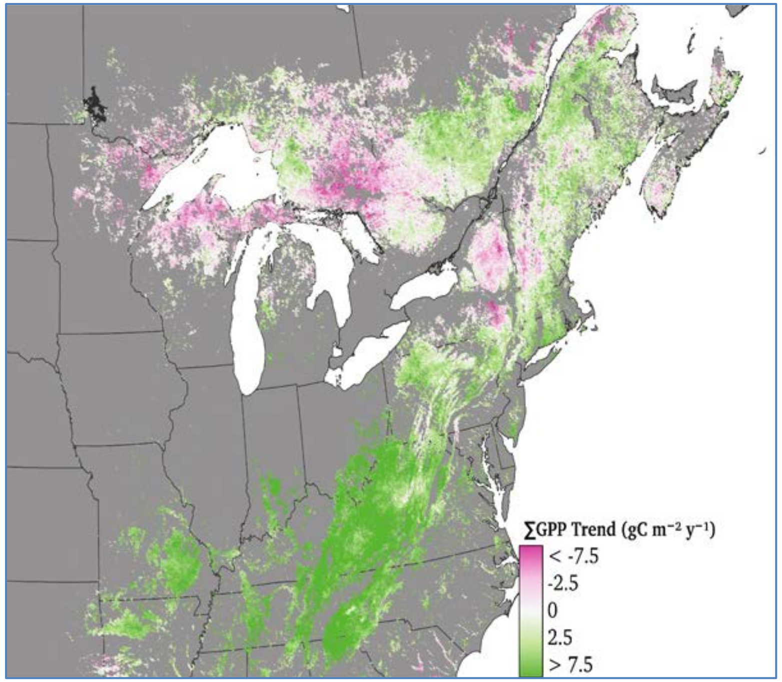


Progress and Results: Sub-Seasonal & Seasonal Scale Carbon

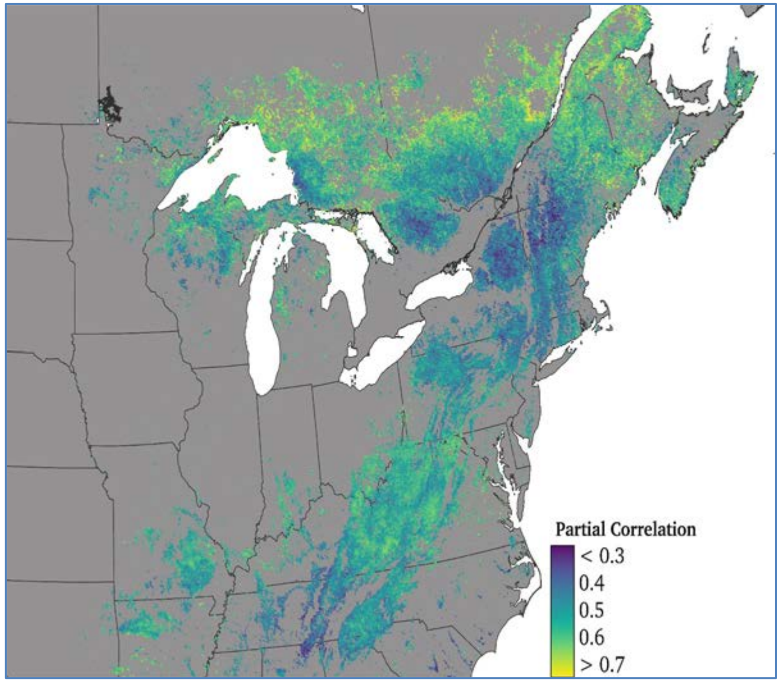
Upscaling tower-based results to biome scale in Eastern Temperate Forests

Biogeographic variation in drivers GPP trends

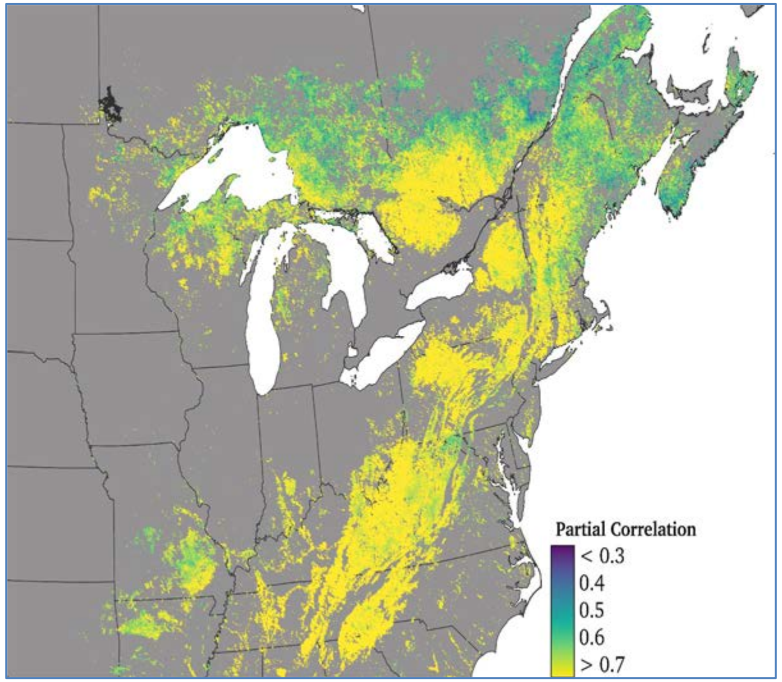
GPP Trend



GPP GSL



GPP Max



Next Steps

- *Synthesize LSP trend results (Moon et al., in prep)*
- *Continue and extend GPP analysis (Green et al., in prep)*
- *Analysis of trends and drivers of in arid/semi-arid systems (Choi et al)*
- *Start looking at LSP-Carbon-Drought signatures*

- *Publications:*

scientific **data**

Check for updates

OPEN

DATA DESCRIPTOR

A high spatial resolution land surface phenology dataset for AmeriFlux and NEON sites

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AGU ADVANCING EARTH AND SPACE SCIENCE

Global Biogeochemical Cycles

RESEARCH ARTICLE

10.1029/2022GB007462

Observations of Satellite Land Surface Phenology Indicate That Maximum Leaf Greenness Is More Associated With Global Vegetation Productivity Than Growing Season Length

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Key Points:

- Changes in green leaf growing season length (GSL) had less impact on vegetation productivity by ~30% than changes in photosynthetic duration
- Maximum leaf greenness affects vegetation productivity more than green leaf GSL