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Discrepancies in satellite-derived LAI products and effects on simulated carbon and water fluxes

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Outline

1 Introduction

- Understanding the terrestrial carbon and water cycles is crucial for mitigation and adaptation for climate change. Gross primary productivity (**GPP**) and evapotranspiration (**ET**) are two key components of the terrestrial carbon and water cycles.
- Leaf area index (**LAI**) is a key biophysical parameter in process-based ecosystem models for simulating GPP and ET. Several previous studies have evaluated multiple LAI.
- The **uncertainty** in the satellite-derived LAI products can lead to uncertainty in GPP and ET simulated by diagnostic ecosystem models.
- **However**, **the uncertainty in satellite-derived LAI products and their effects on the simulation of carbon and water fluxes at regional scales remain unclear**.

1 Introduction

- In this study, we compared and evaluated **three** existing satellite-derived **LAI products** and examined the influences of these products on annual GPP and ET of terrestrial ecosystems in **China** at both site and regional scales.

- We used a process-based diagnostic model- Boreal Ecosystem Productivity Simulator (**BEPS**) to simulate GPP and ET.
  - **1st objective**: to compare the magnitude, spatial patterns, and trends of the LAI products.
  - **2nd objective**: to evaluate the accuracy of the three products using Landsat-derived LAI estimates and field LAI measurements at site and regional scales.
  - **3rd objective**: to assess the effects of LAI on simulated carbon and water fluxes at both site and regional scales.

2 Data and methods

2.1 LAI data products

- We used three LAI datasets derived from satellite observations from the MODIS: the **MODIS** LAI product, the Global LAnd Surface Satellite (**GLASS**) LAI product, and the four-scale geometric optical model (**FSGOM**) based LAI product.

Products	Version	Spatial resolution	Temporal resolution	Spatial extent	Temporal extent
GLASS	V3.0	1 km	8-day	Globe	2000-2012
MCD15	C5	1 km	8-day	Globe	2003-2012
FSGOM	V1.0	500 m	8-day	China	2000-2014

2 Data and methods

2.2 GPP and ET simulations

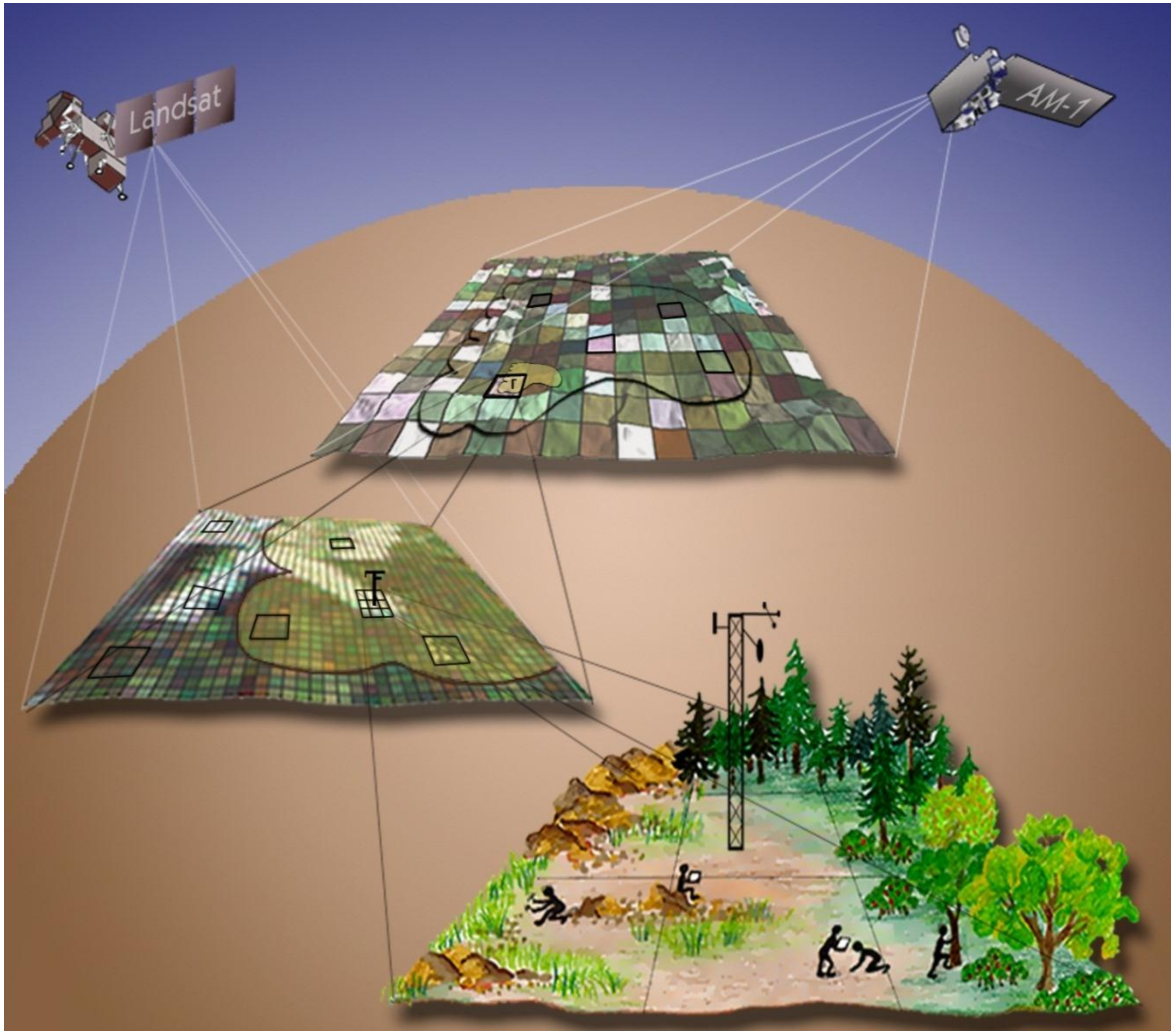
- **BEPS simulates GPP and ET at the daily time step.**
  - **GPP** of an ecosystem is the sum of photosynthetic CO_2 assimilation of canopy separately simulated by sunlit and shaded leaves.
  - **ET** of an ecosystem is calculated as the sum of canopy transpiration from sunlit and shaded leaves and evaporation from soil surface and intercepted water by leaf surface.
- LAI is prescribed in BEPS. Besides LAI, BEPS is driven by

Inputs	Spatial Res.	Temporal Res.	Temporal extent	Notes
CO2	Txt	yearly	2003-2012	
Landcover	500 m	yearly	2003-2012	MCD12Q1 V051
Soil	1 km			volumetric fractions of clay, sand, and silt
Meteorological	500 m	daily	2003-2012	maximum and minimum air temperatures, precipitation, incoming solar radiation, and relative humidity

2 Data and methods

2.3 Evaluation of the LAI products

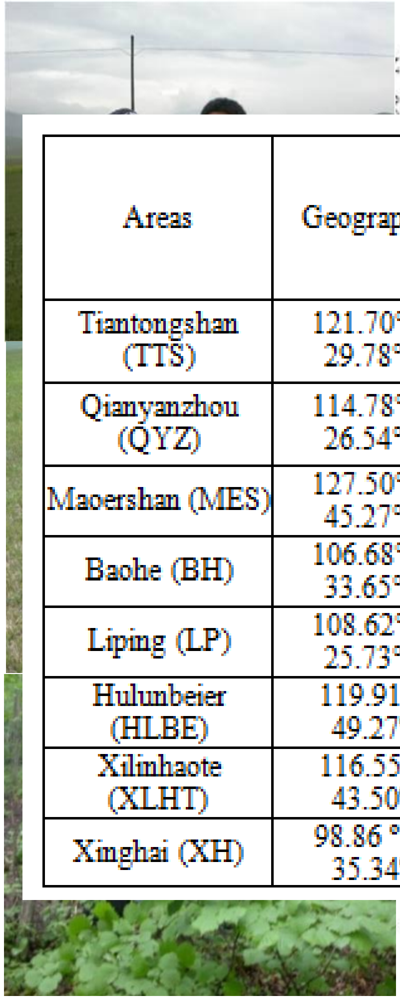
- The quality of the three LAI products was evaluated according to the framework "Validation of global moderate-resolution LAI products" proposed by **CEOS WGCV**.
- We used **upscaled LAI maps derived from the Landsat** TM/ETM+ **imagery** to evaluate the quality of the three LAI products.

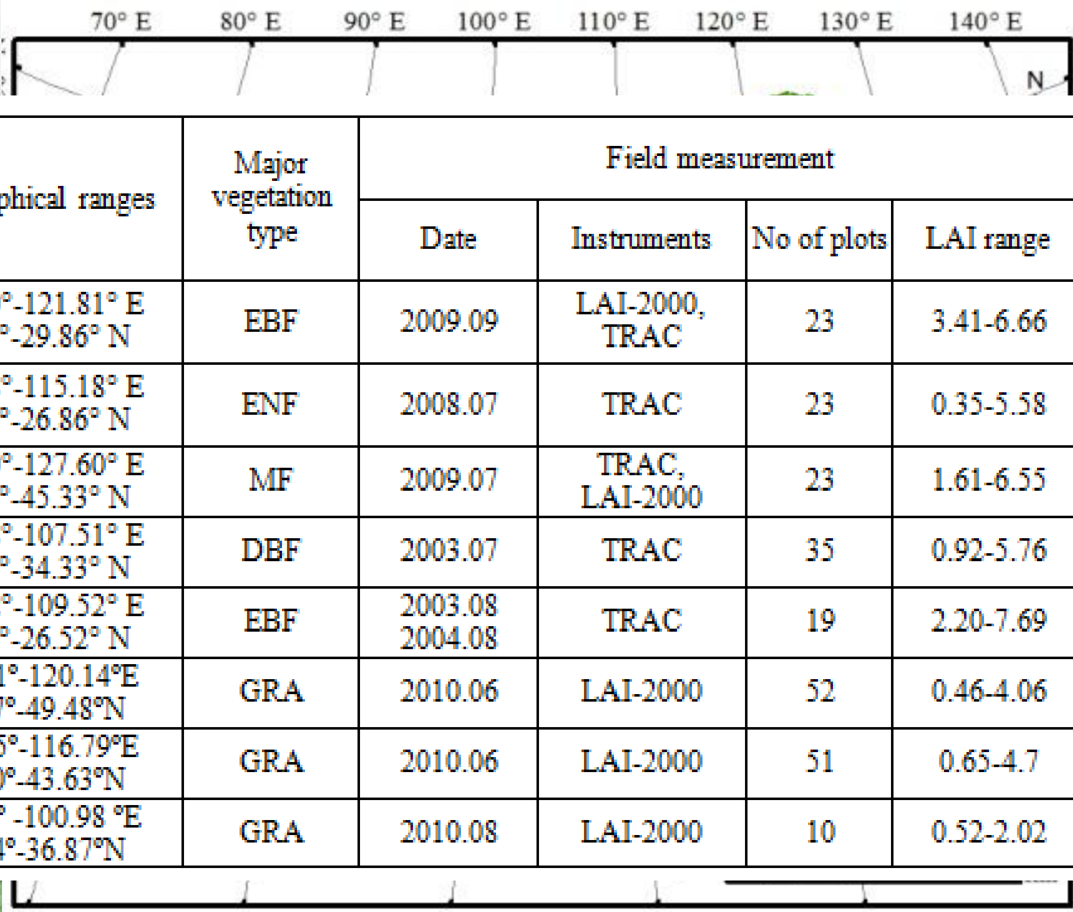


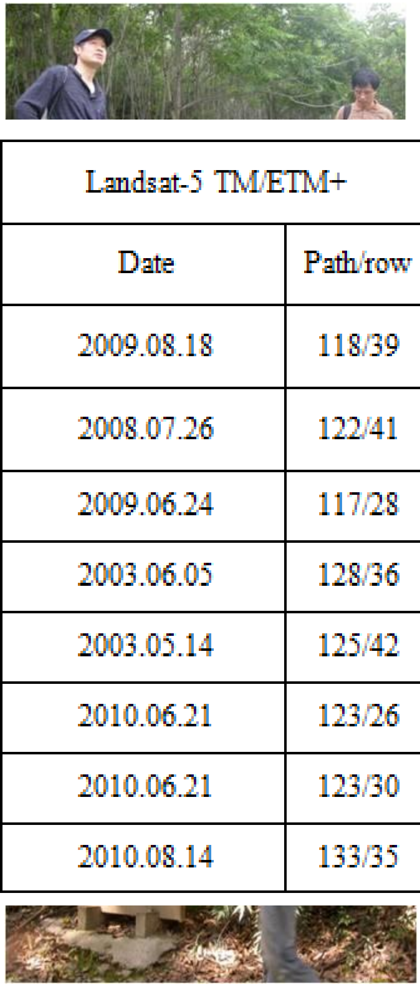
Cohen et al., 2006@TGRS

2 Data and methods

2.3 Evaluation of the LAI products





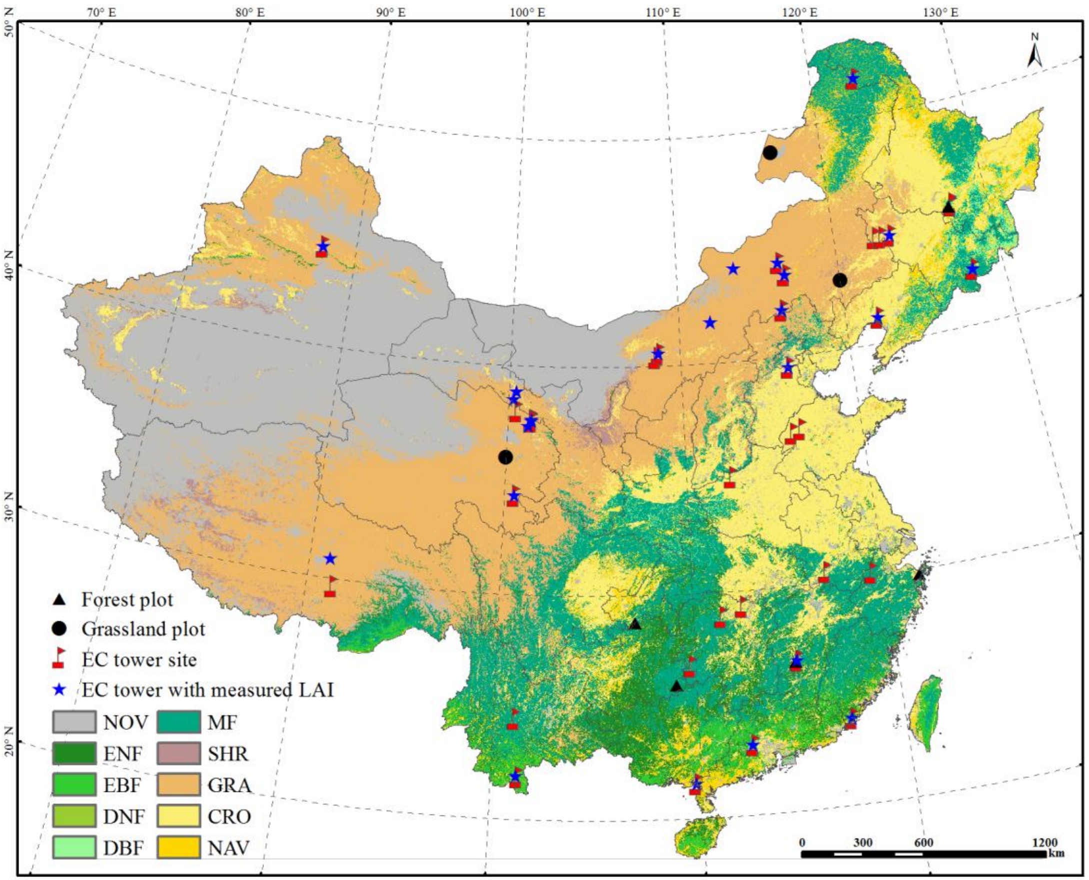


Areas	Geographical ranges	Major vegetation type	Field measurement				Landsat-5 TM/ETM+	
			Date	Instruments	No of plots	LAI range	Date	Path/row
Tiantongshan (TTS)	121.70°-121.81° E 29.78°-29.86° N	EBF	2009.09	LAI-2000, TRAC	23	3.41-6.66	2009.08.18	118/39
Qianyanzhou (QYZ)	114.78°-115.18° E 26.54°-26.86° N	ENF	2008.07	TRAC	23	0.35-5.58	2008.07.26	122/41
Maoershan (MES)	127.50°-127.60° E 45.27°-45.33° N	MF	2009.07	TRAC, LAI-2000	23	1.61-6.55	2009.06.24	117/28
Baohe (BH)	106.68°-107.51° E 33.65°-34.33° N	DBF	2003.07	TRAC	35	0.92-5.76	2003.06.05	128/36
Liping (LP)	108.62°-109.52° E 25.73°-26.52° N	EBF	2003.08 2004.08	TRAC	19	2.20-7.69	2003.05.14	125/42
Hulunbeier (HLBE)	119.91°-120.14°E 49.27°-49.48°N	GRA	2010.06	LAI-2000	52	0.46-4.06	2010.06.21	123/26
Xilinhaote (XLHT)	116.55°-116.79°E 43.50°-43.63°N	GRA	2010.06	LAI-2000	51	0.65-4.7	2010.06.21	123/30
Xinghai (XH)	98.86 ° -100.98 °E 35.34°-36.87°N	GRA	2010.08	LAI-2000	10	0.52-2.02	2010.08.14	133/35

2 Data and methods

2.3 Evaluation of the LAI products

- We obtained the annual **maximum LAI values for 26 EC flux sites** across China from the literature.
- Annual GPP data from 38 EC flux sites across China (15 forest sites, 6 cropland sites, 14 grassland sites, and 3 wetland sites from the literature
- Annual ET from 26 EC flux sties (9 forest sites, 12 grassland sites, 3 cropland sites, and 2 wetland sites from the literature)



Location and distribution of LAI field measurement plots and EC flux sites across China.

2 Data and methods

2.4 Comparison and evaluation of simulated GPP and ET

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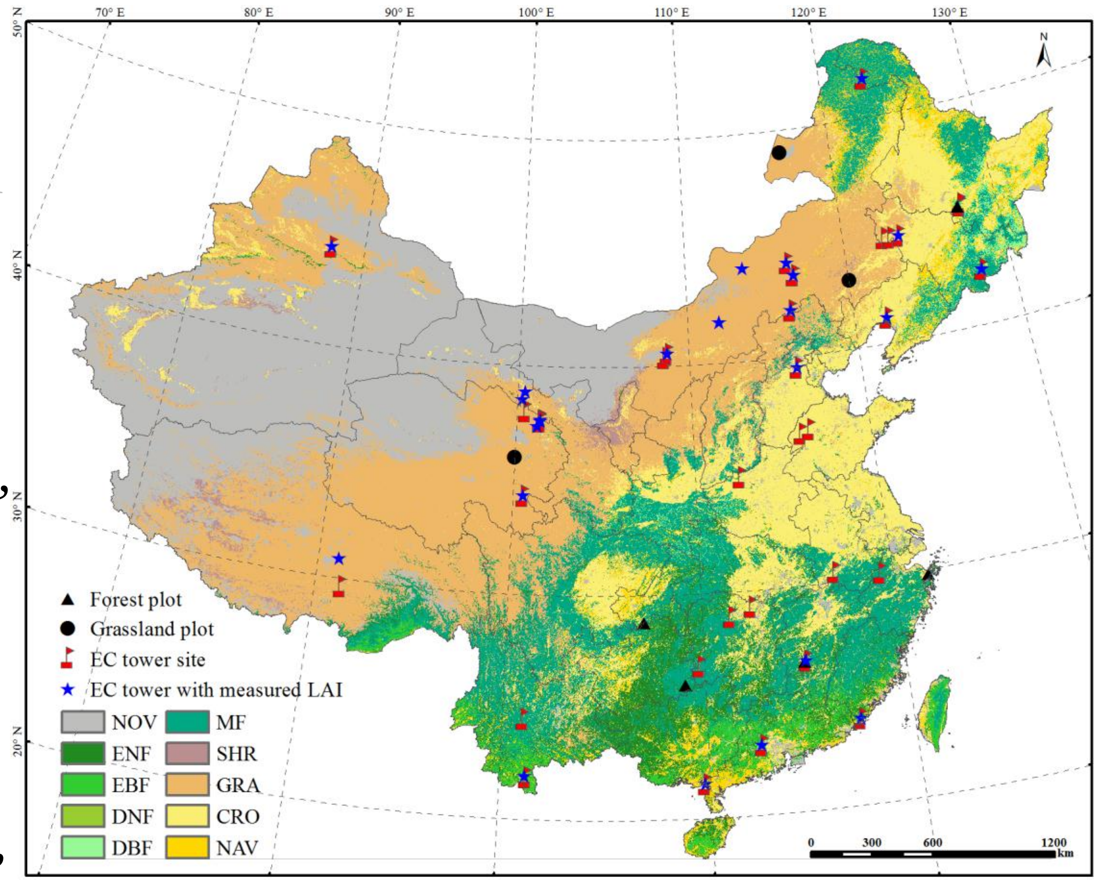
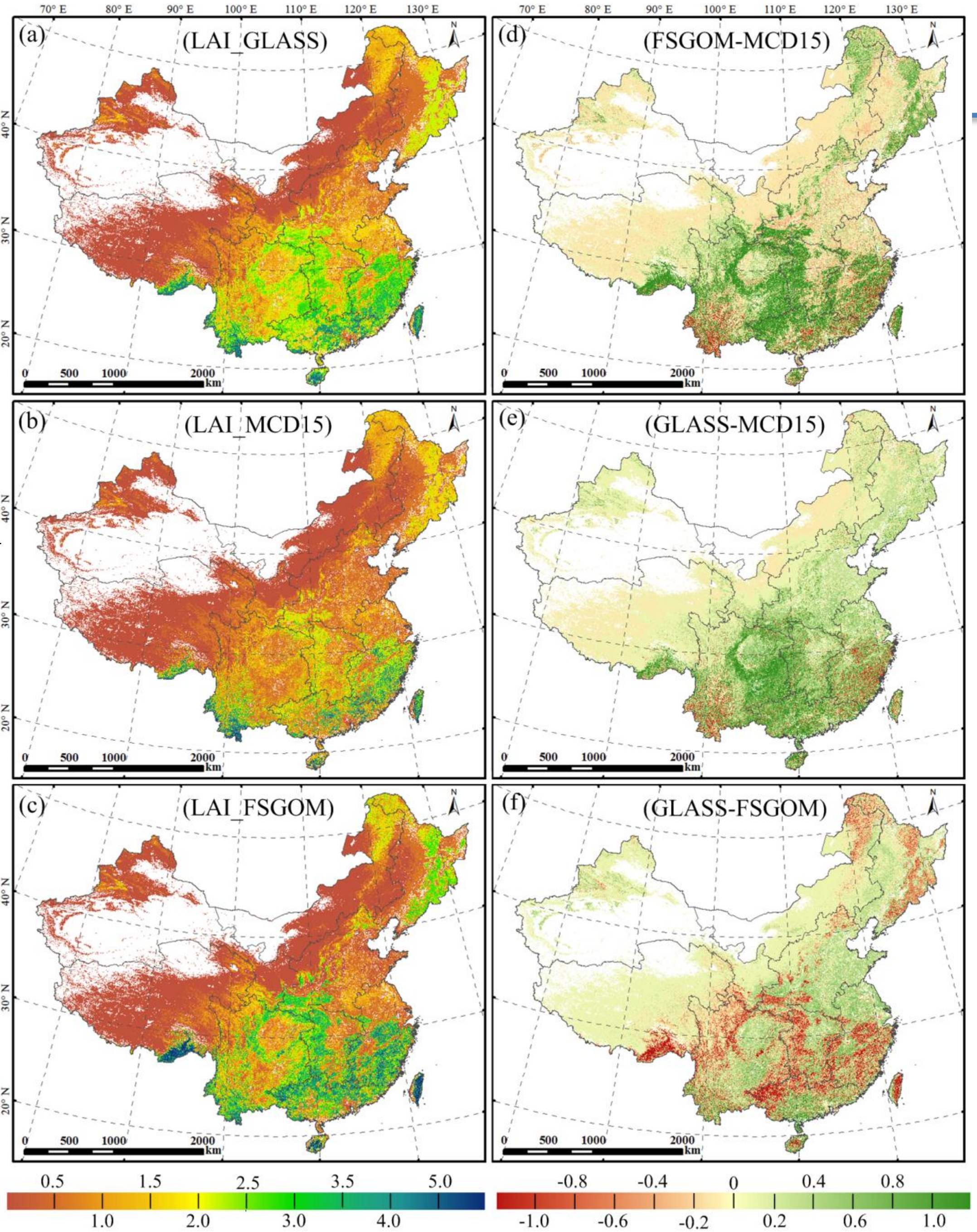


Location and distribution of LAI field measurement plots and EC flux sites across China.

3 Results

3.1 Comparisons of LAI products

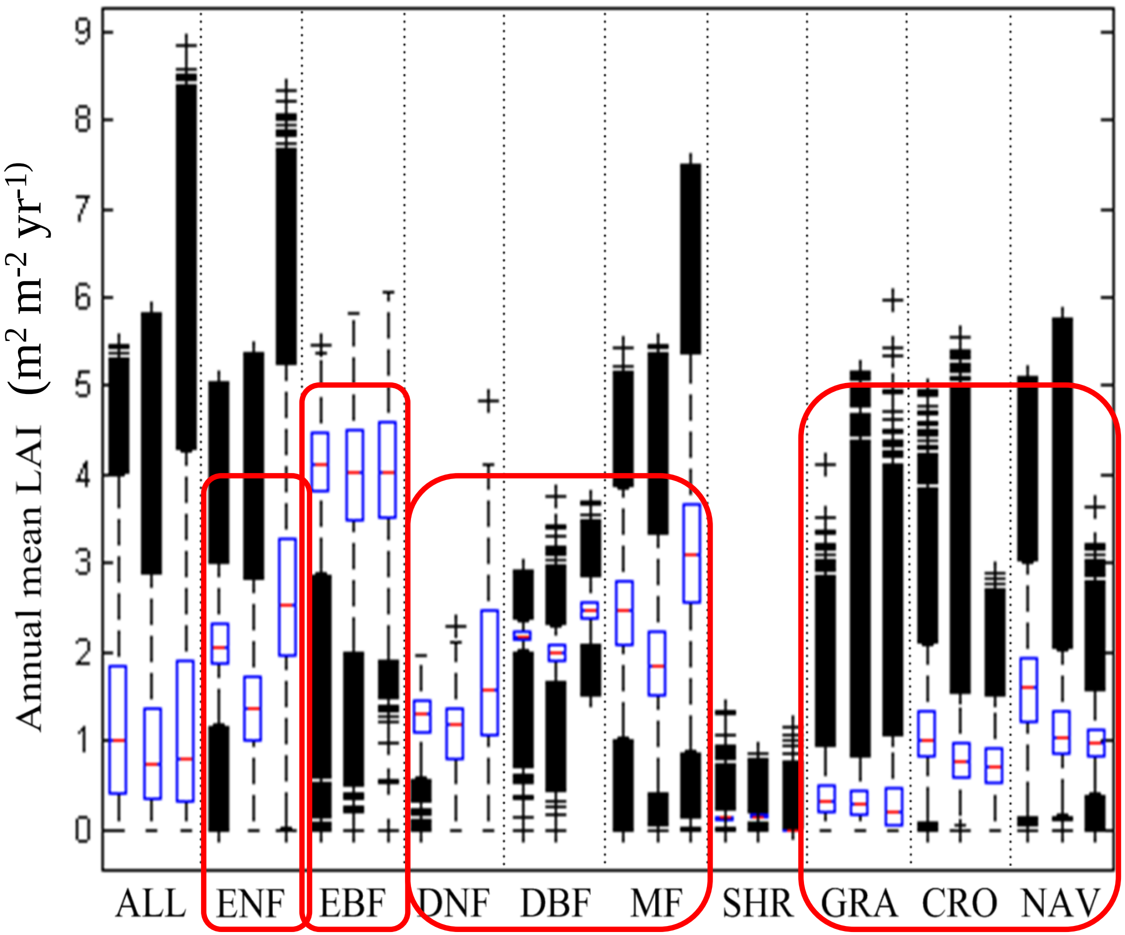
- **The three LAI products differed in magnitude, spatial patterns, and trends in LAI**.
- **Forested** areas: FSGOM generally had the highest LAI, GLASS had intermediate values, and MCD15 had the lowest values.
- For **croplands**: GLASS generally had the highest LAI values, followed by MCD15; FSGOM had the lowest values.
- For **grasslands**: the LAI values of GLASS and MCD15 were slightly higher than those of FSGOM.



3 Results

3.1 Comparisons of LAI products

- **GLASS** had slightly higher nationally-averaged LAI (**0.93**) than **FSGOM** (**0.92**) , while **MCD15** exhibited much lower LAI (**0.74**) than the other two products.
- The LAI of ENF, DBF, and MF derived from FSGOM was much higher than that of GLASS and MCD15.
- GLASS exhibited higher LAI than MCD15 and FSGOM in EBF, GRA, CRO and NAV.

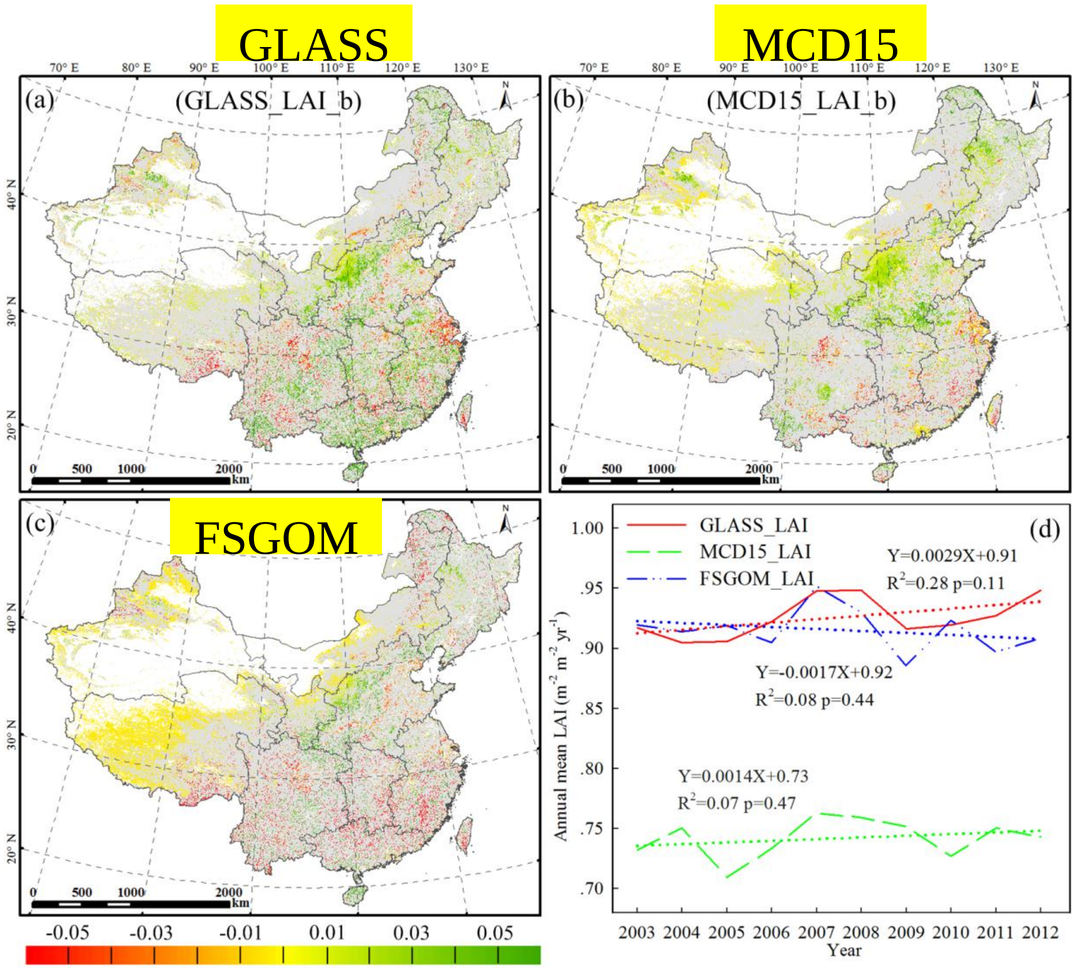


Box plots of per-pixel annual mean LAI of China's terrestrial ecosystems. Each group consists of the three LAI products: GLASS, MCD15, and FSGOM (from left to right) for the period of 2003–2012.

3 Results

3.1 Comparisons of LAI products

- LAI significantly **increased** over 14.9%, 11.7%, and 6.1% of China's vegetated area for GLASS, MCD15, and FSGOM, respectively, and significantly **decreased** over 7.9%, 4.3%, and 6.5% of the vegetated area for GLASS, MCD15, and FSGOM, respectively.
- The nationally-averaged LAI showed slight **upward** trends for **GLASS and MCD15** and a slight **downward** trend for **FSGOM** during the study period, and these trends were statistically insignificant.

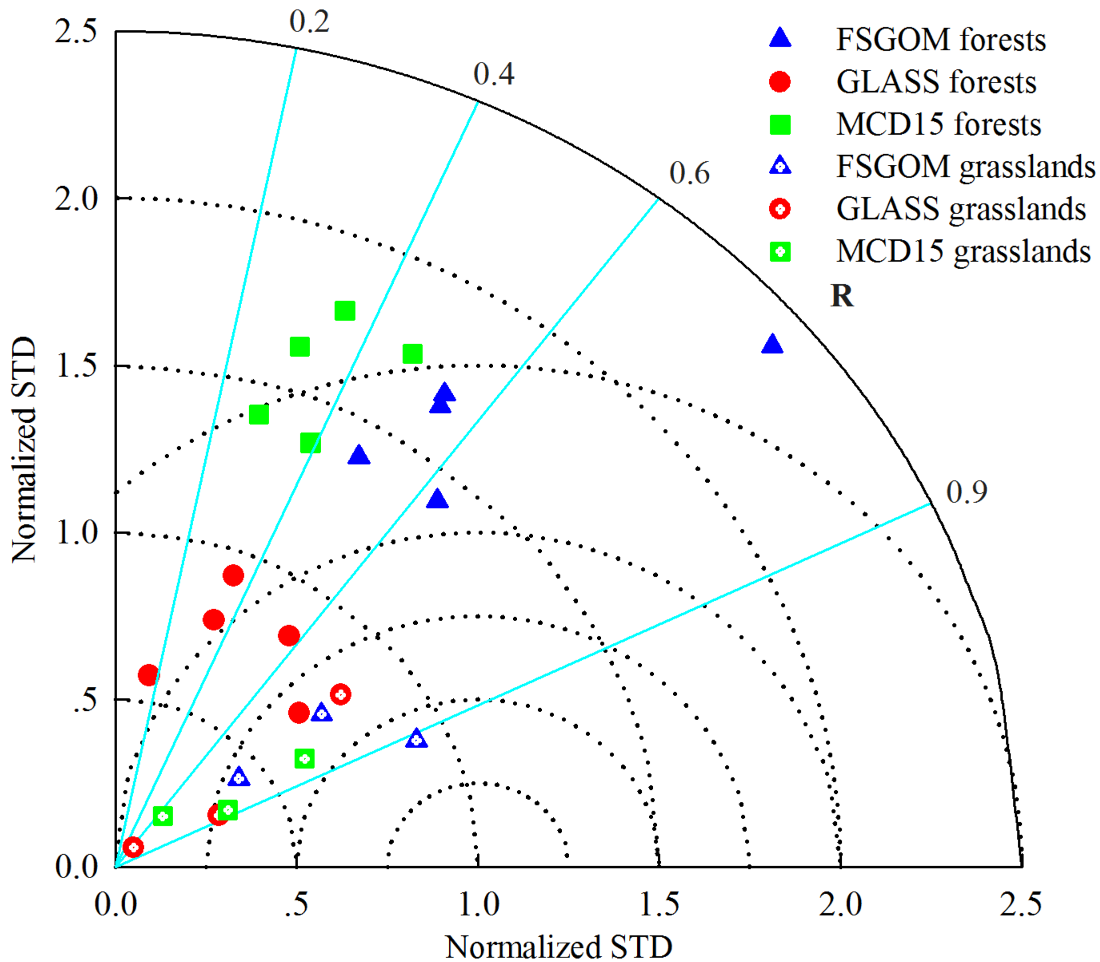


Trends of per-pixel and nationally-averaged annual mean LAI of China's terrestrial ecosystems during the period 2003-2012

3 Results

3.2 Evaluation of LAI products

- Overall, the three LAI products **performed slightly better in grasslands than in forests**.
- **GLASS** had higher accuracy than FSGOM and MCD15 for **forests**.
- while **FSGOM** had higher accuracy than MCD15 and GLASS for **grasslands**.



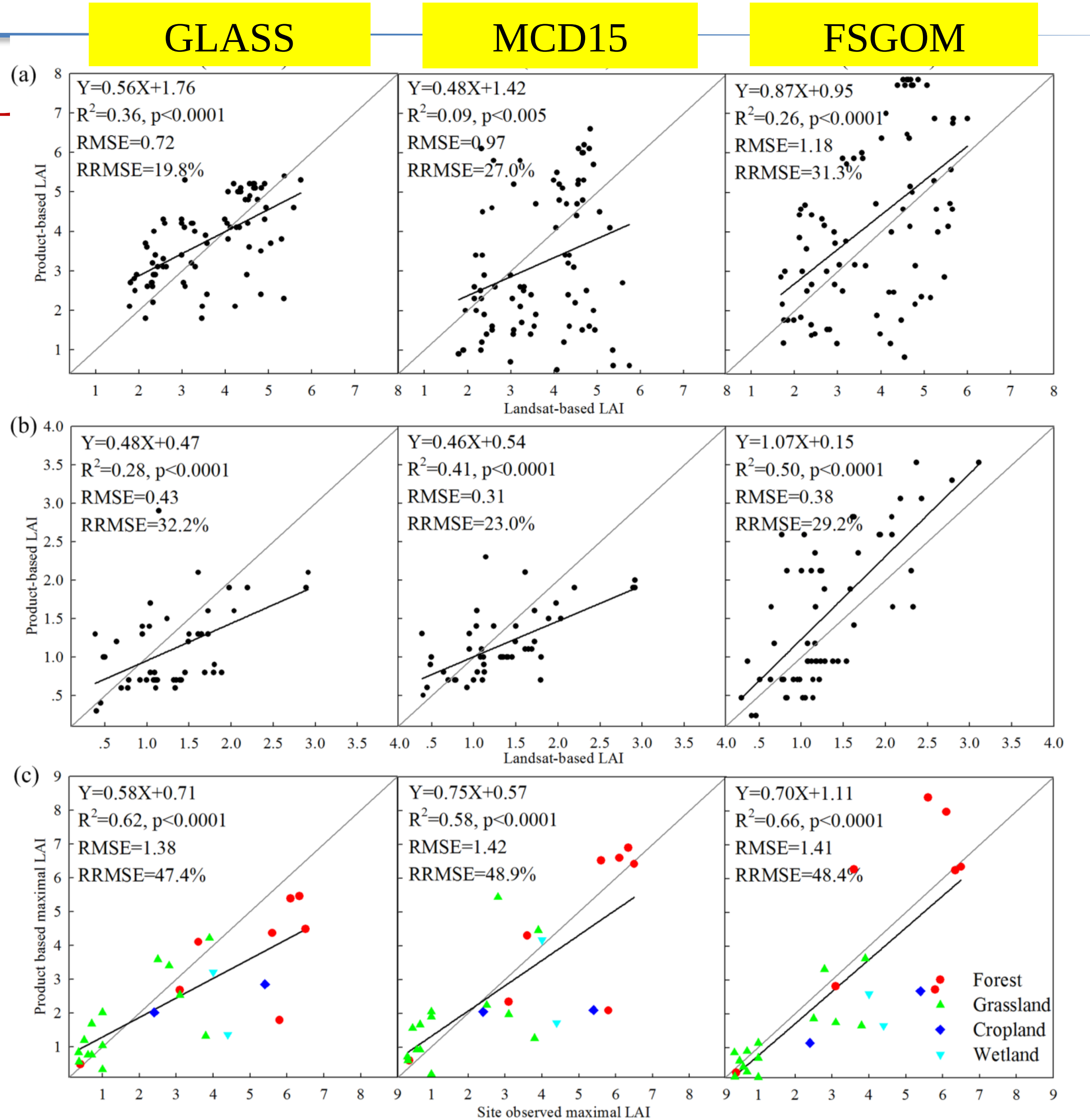
Taylor diagram of the three different LAI products against LAI field measurement plots at eight representative regions

3 Results

3.2 Evaluation of L

- The performances of the three LAI products in grasslands were different from their performances in forest

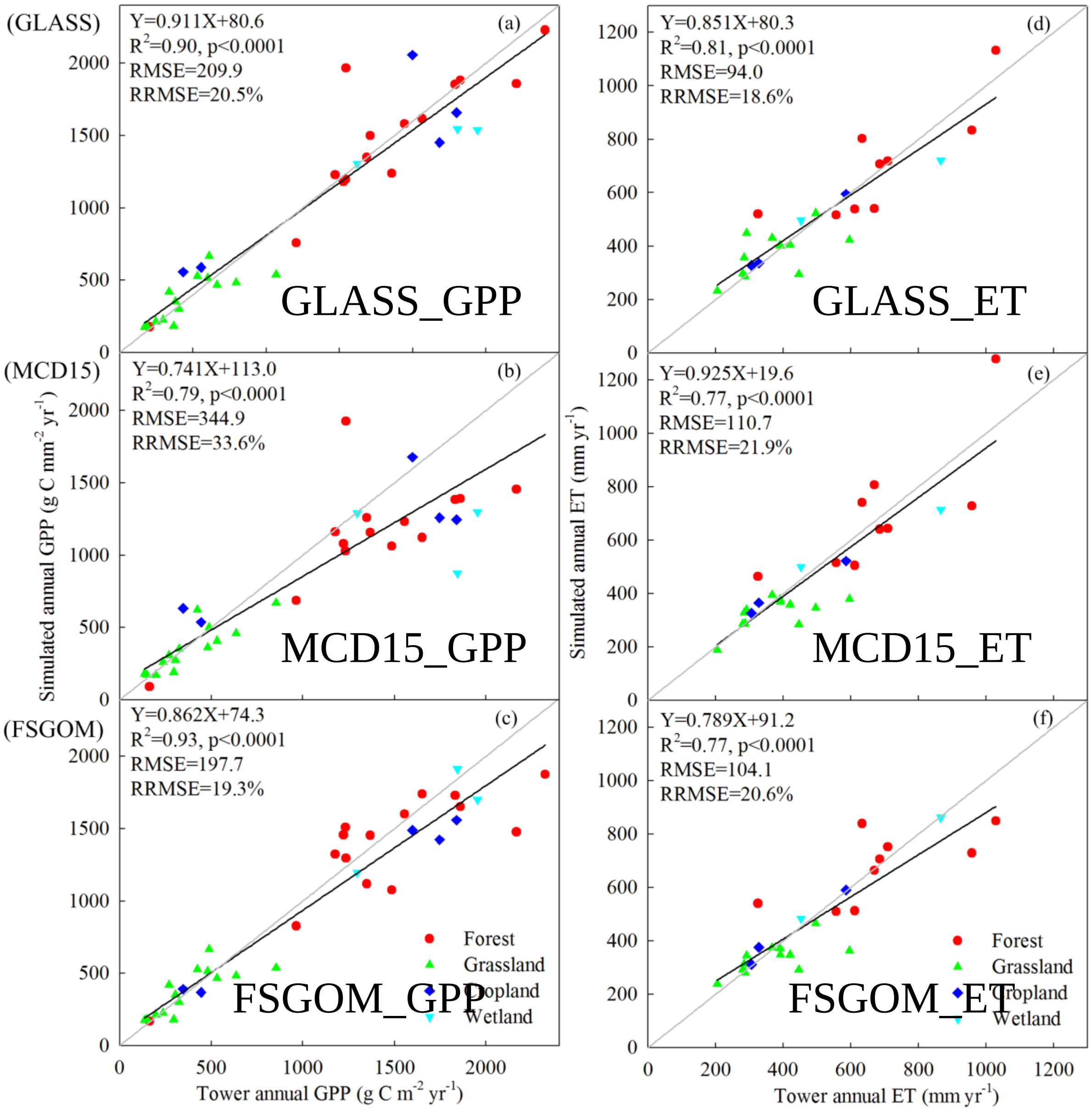
- The **annual maximum LAI** values derived from GLASS, MCD15, and FSGOM showed fairly good agreement with the measured LAI from EC flux sites



3.3 Evaluation of simulated GPP and ET based on EC flux data

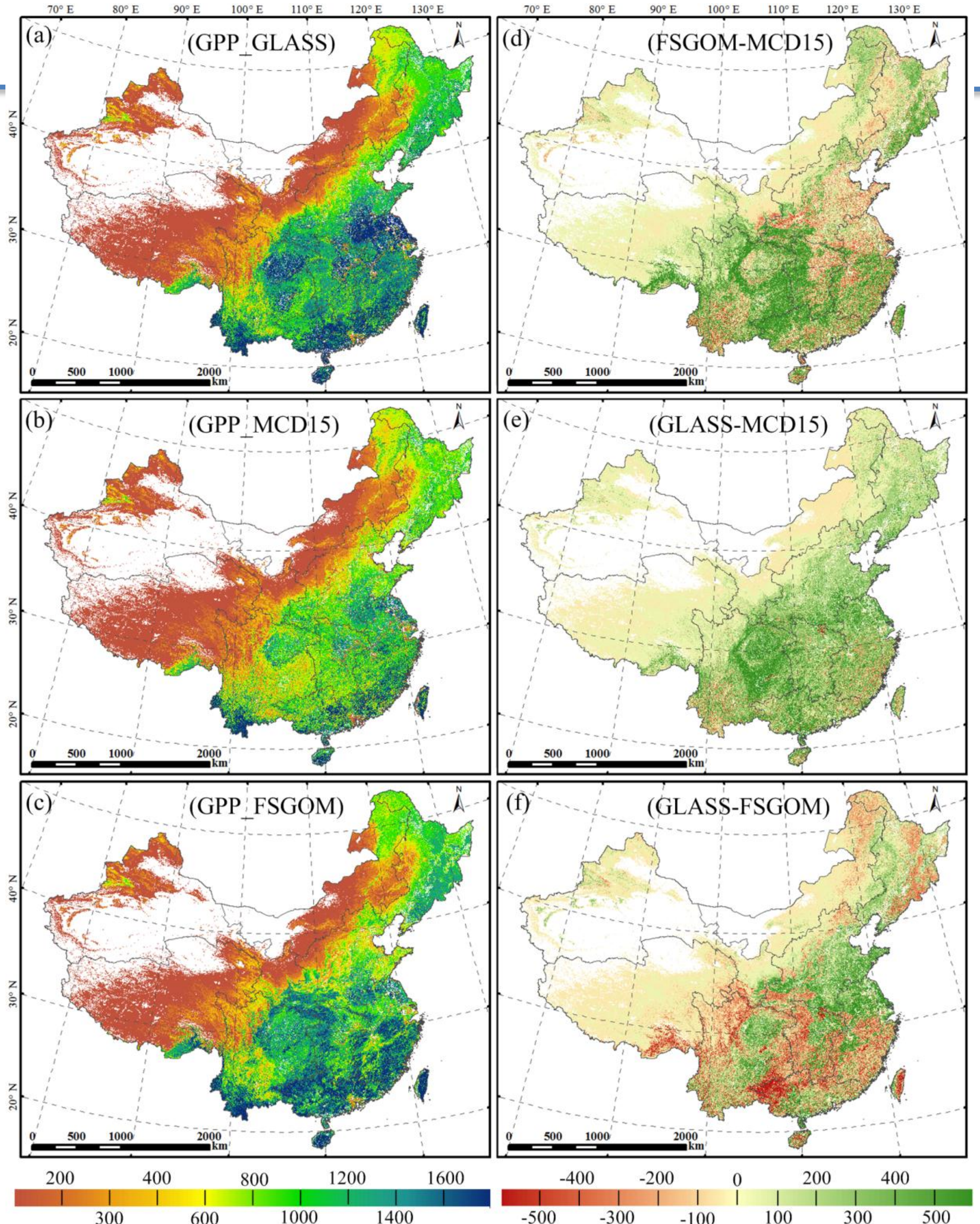
- The comparisons between the simulated GPP/ET and flux tower GPP/ET showed that the three LAI products **generally led to reasonable** annual GPP/ET **estimates at the site level.**

- Both R^2 and RRMSE values for **GPP were more variable than those for ET** among the three LAI products, indicating that photosynthesis is likely more sensitive to vegetation LAI than is ET.



3.4 Comparisons of simulated GPP and ET based on the three LAI products

- The three LAI products led to **large differences in** simulated annual GPP and ET at the **regional scale**.
- Mean annual total GPP for China's terrestrial ecosystems based on **GLASS** (**6.32** Pg C yr^{-1}) and **FSGOM** (**6.15** Pg C yr^{-1}) was 22.5% and 19.2% higher than that based on **MCD15** (**5.16** Pg C yr^{-1}), respectively.
- National annual ET based on GLASS (379.9 mm yr^{-1}) and FSGOM (374.4 mm yr^{-1}) was 7.9% and 6.3% higher than that based on MCD15 (352.1 mm yr^{-1}), respectively.



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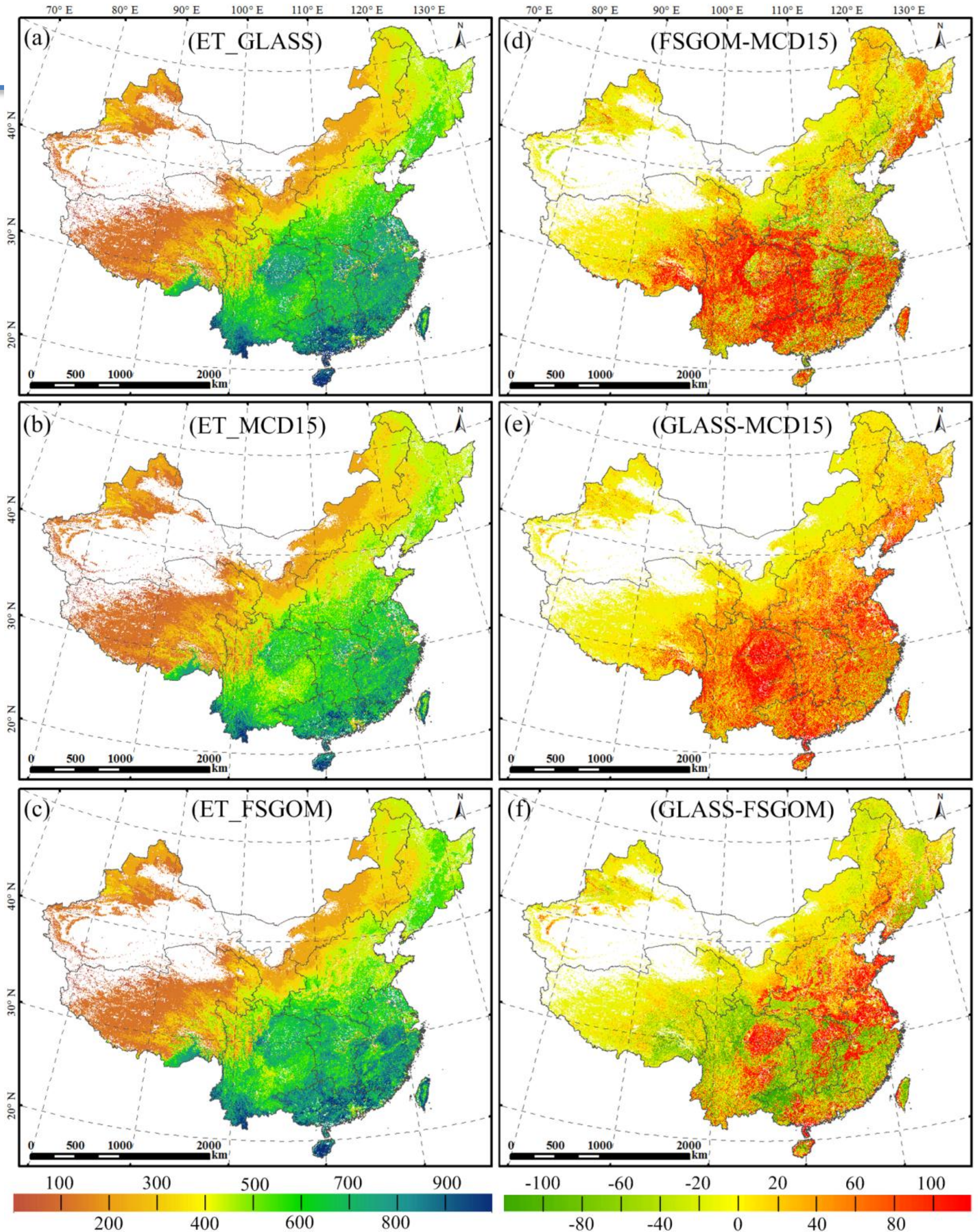
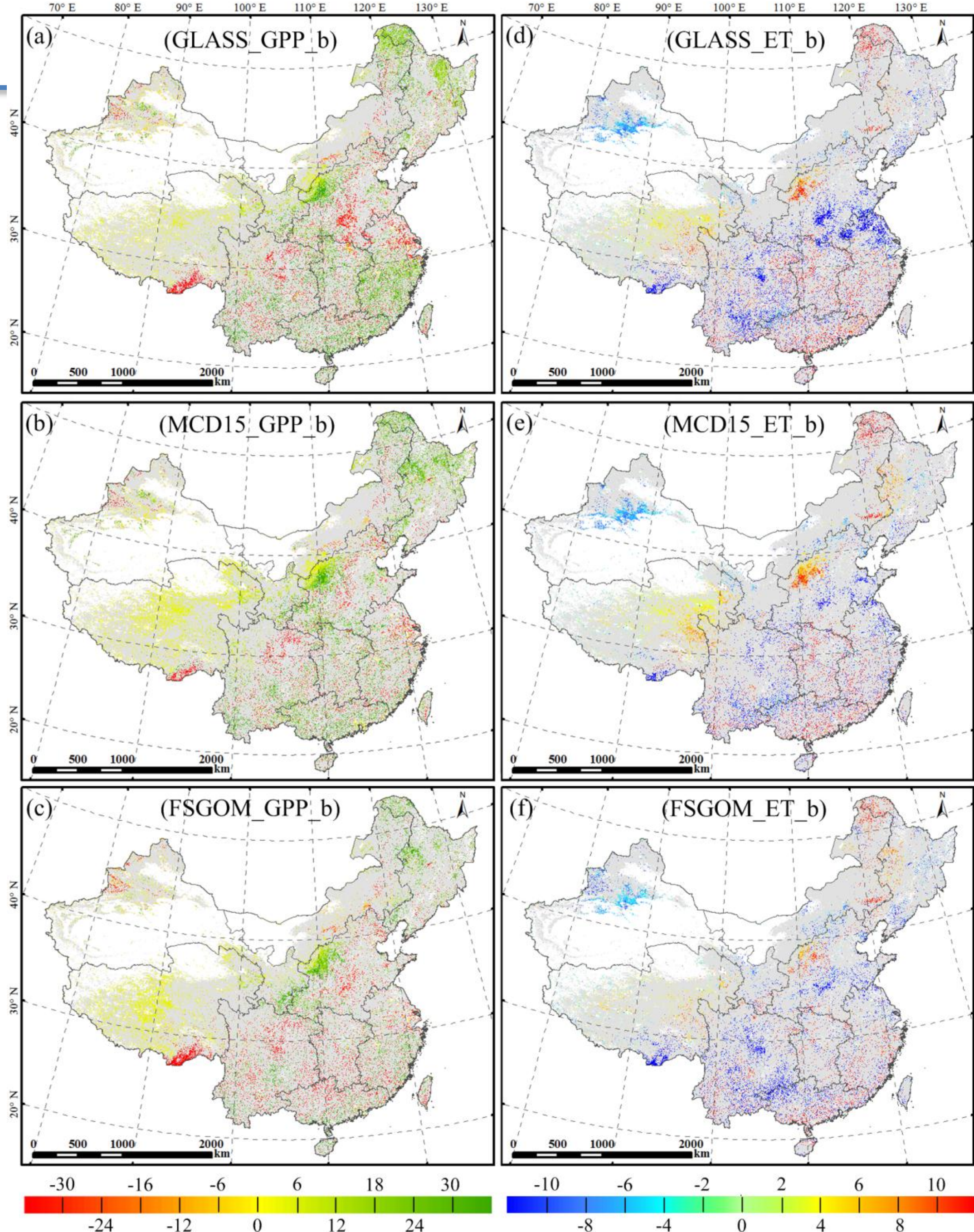


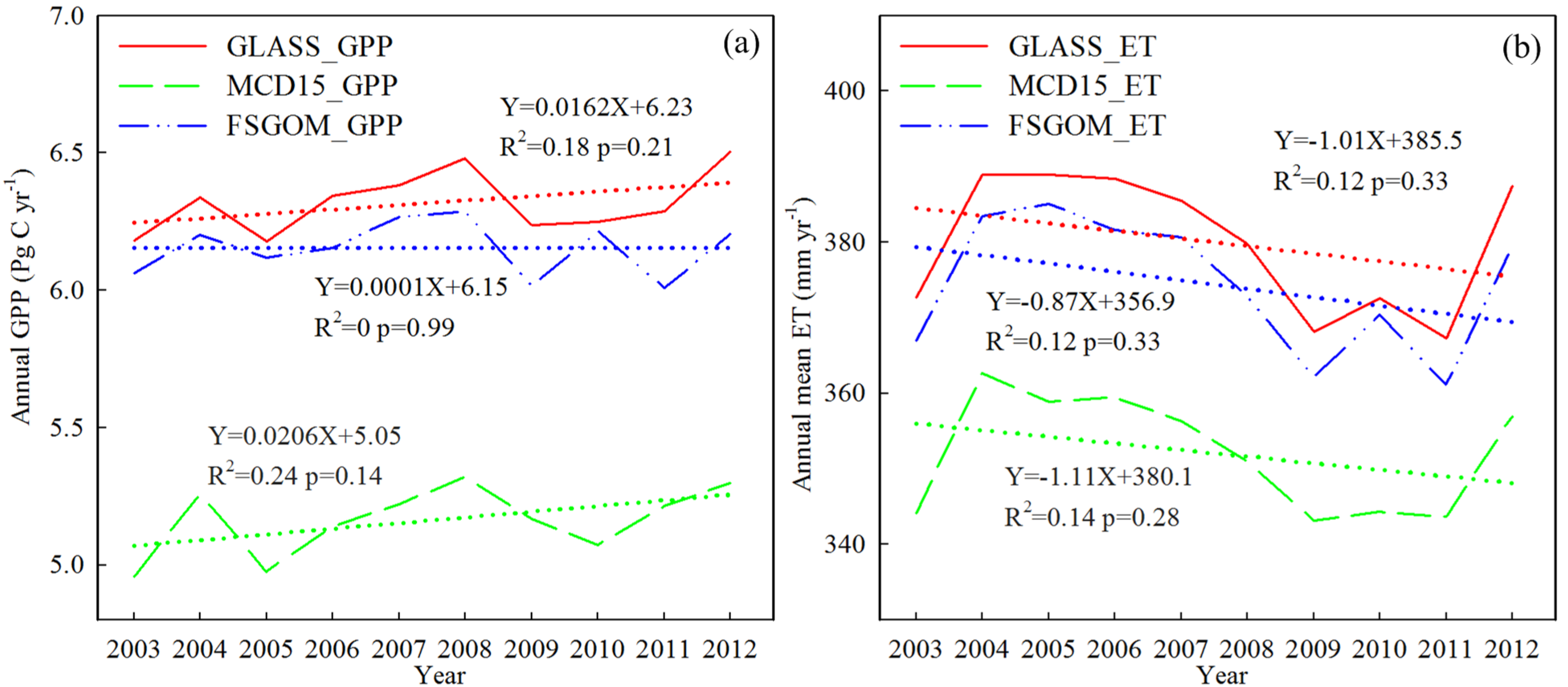
3.5 Trends of simulated annual GPP and annual ET

- **Annual GPP** simulated from GLASS and MCD15 **increased** over 15.9% and 17.3% of China's vegetated area while **decreased** over 9.4% and 9.3% of the vegetated area.
- FSGOM led to slightly lower percentage area with **increasing** GPP (12.6%) than GLASS and MCD15 and similar percentage area with **decreasing** GPP (8.7%).
- **Annual ET** exhibited larger percentage areas with **increasing** ET trends for GLASS (5.7%) and MCD15 (5.8%) than for FSGOM (3.9%).



3.5 Trends of simulated annual GPP and annual ET

- The nationally-integrated GPP exhibited **insignificant** **upward** trends for all the LAI products.
- All the three LAI products led to **decreasing** trends in nationally-averaged annual ET in China's landmass, and these trends were statistically **insignificant**.



4 Discussion

- The discrepancies observed between the three LAI products and Landsat-based LAI maps could be attributed to the uncertainty in both LAI products and Landsat-based maps.
- Field LAI measurements were typically only made during a very limited number of specific dates. The collection of ground-based LAI time series will help evaluate the seasonality of the satellite-derived LAI products.
- The availability of high quality and consistent surface reflectance and land cover data and sound retrieval algorithms will improve the accuracy of moderate resolution LAI products.
- Further research is needed to disentangle the relative effects of LAI and other model input (e.g., meteorological data, land cover) on carbon and water cycle modeling.
- The development of more accurate LAI products and their assimilation into model simulations will improve the simulation of carbon and water fluxes for prognostic terrestrial biosphere models.

5 Highlights

- Satellite-derived LAI products (MCD15, GLASS, FSGOM) exhibited large discrepancies.
- These LAI products had substantial differences in magnitude, patterns, and trends.
- These LAI products led to large uncertainty and discrepancies in modeled GPP and ET.
- GLASS and FSGOM led to in much higher annual GPP and ET estimates compared to MCD15.
- More accurate LAI products will improve regional carbon and water flux simulations.

THANK YOU

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