Characterizing leaf phenology of different vegetation types from local to hemispheric scale in the CLM

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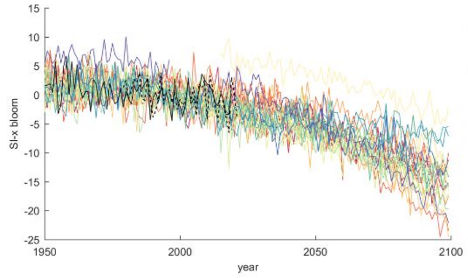
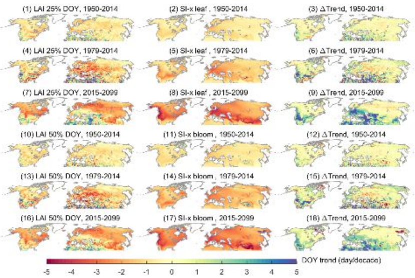
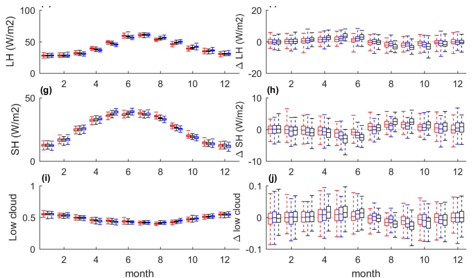
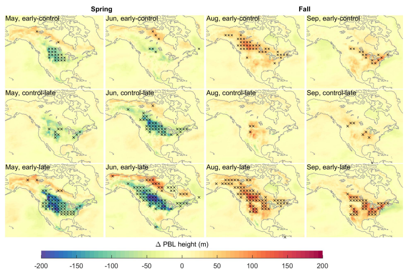
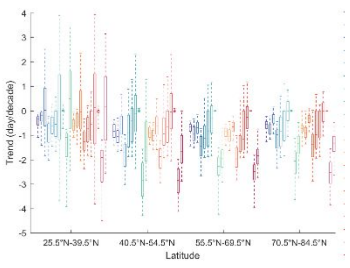
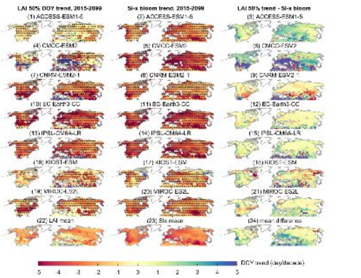












Phenology: why should we care?

1. Phenology: timing of biological events and forces that cause their variations

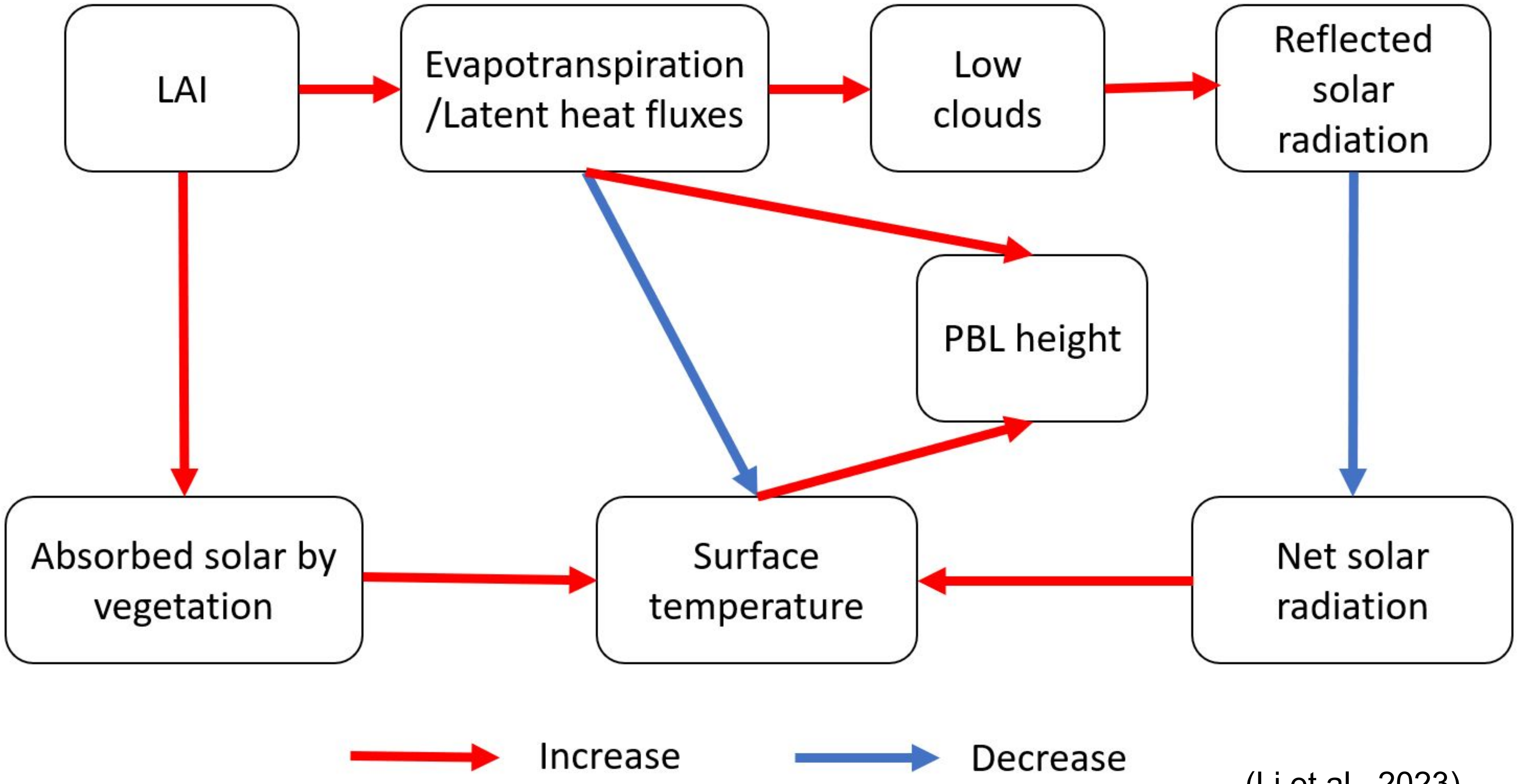
- One of the most visible and well-documented indicators of seasonal transitions;
- Indicator of climate change impacts on ecosystems;
- Timing matters: pollinators, migratory birds, human health and recreation.

Phenology: why should we care?

1. Phenology: indicator of climate change impacts on ecosystems.

2. Phenology regulates land-atmosphere interactions:

- Directly influences energy and water exchanges;
- Indirectly changes cloud cover and albedo.



(Li et al., 2023)

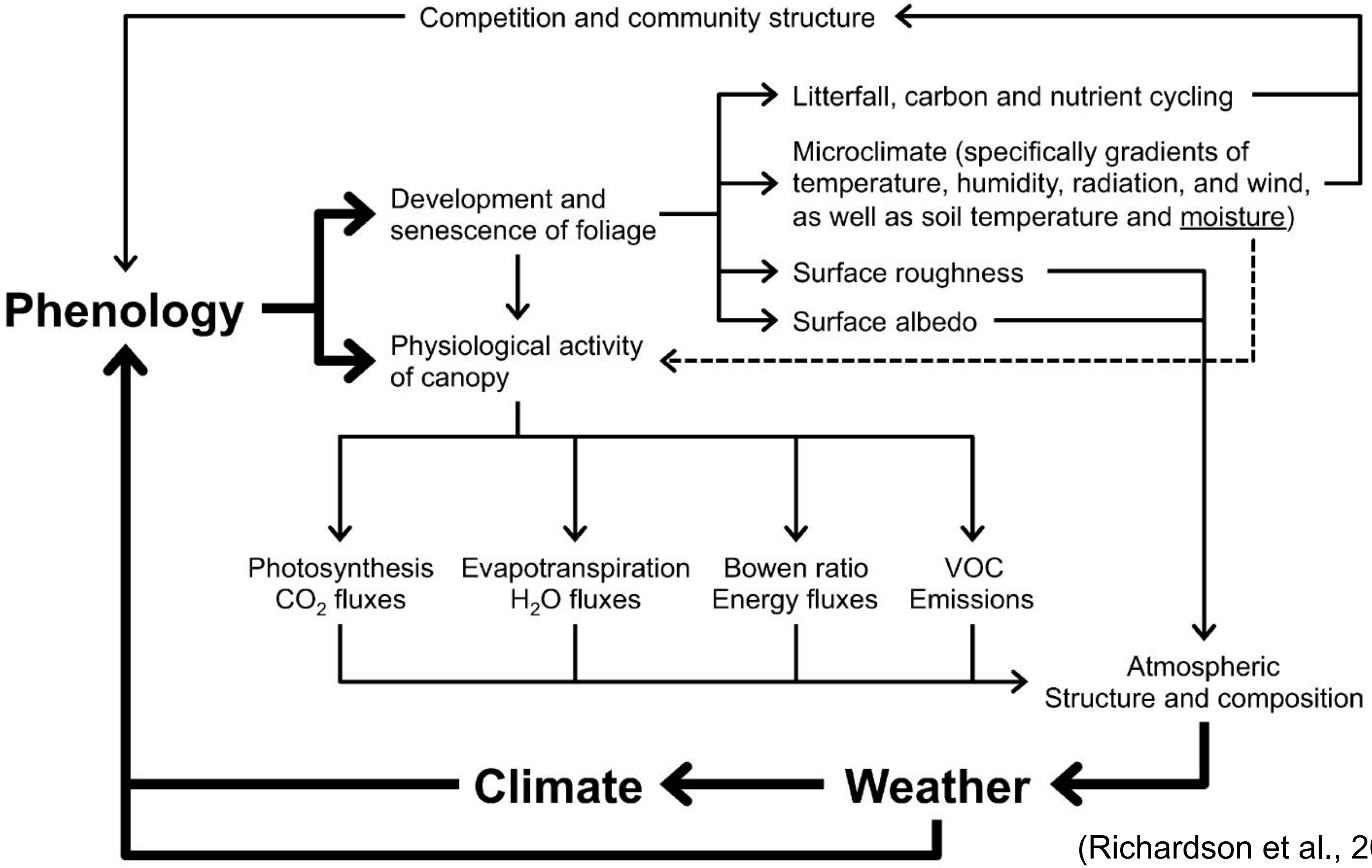
Phenology: why should we care?

1. Phenology: indicator of climate change impacts on ecosystems.

2. Phenology regulates land-atmosphere interactions.

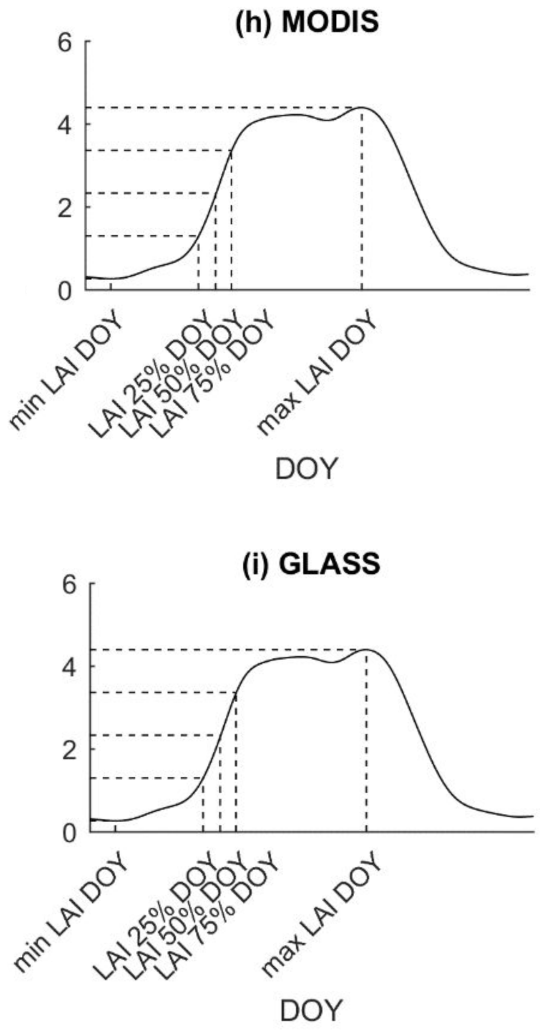
3. Phenology influences primary production and the carbon cycle:

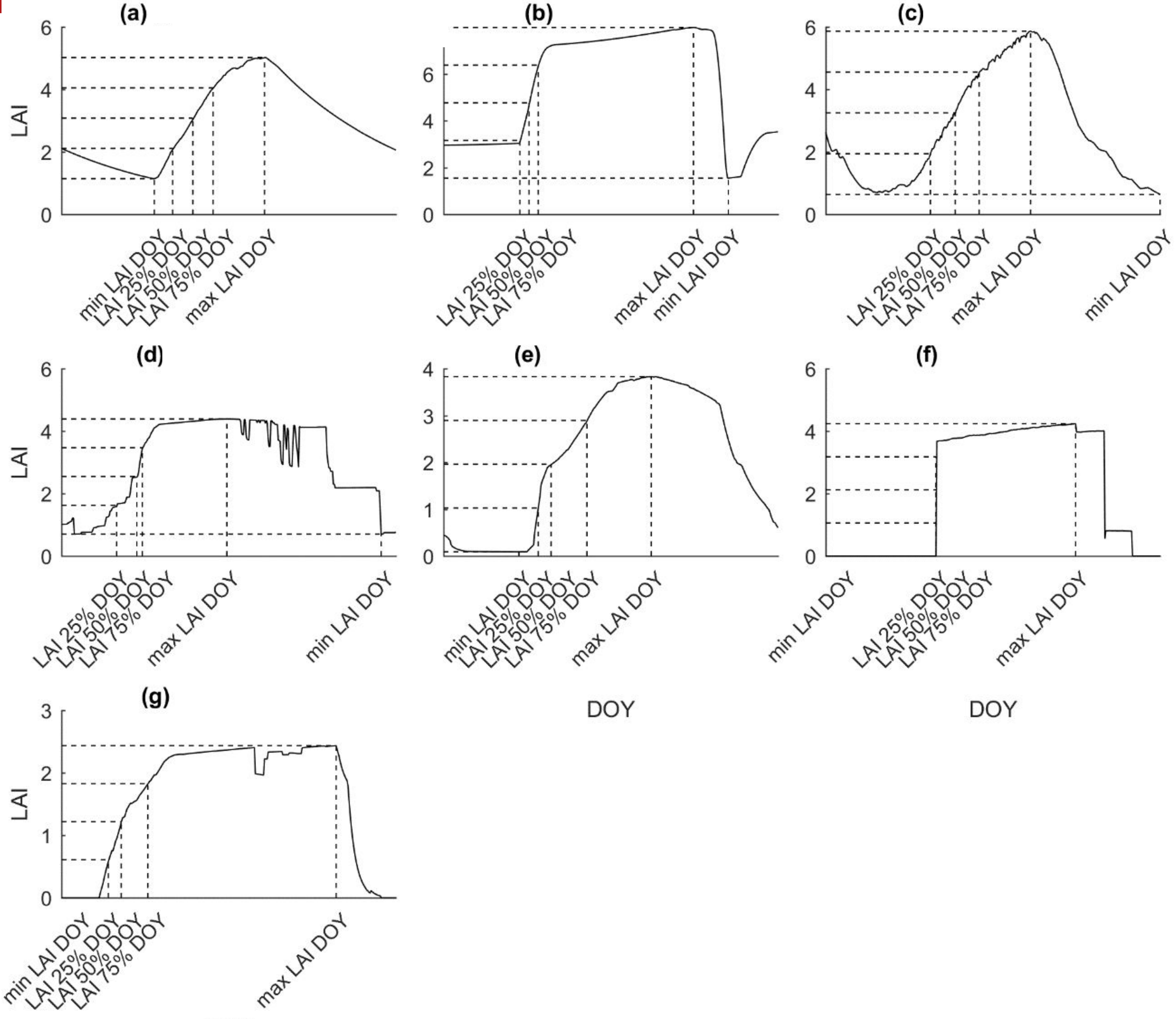
- Modulates growing season, leaf development, and primary production;
- Influences ecosystem structure and function.



(Richardson et al., 2013)

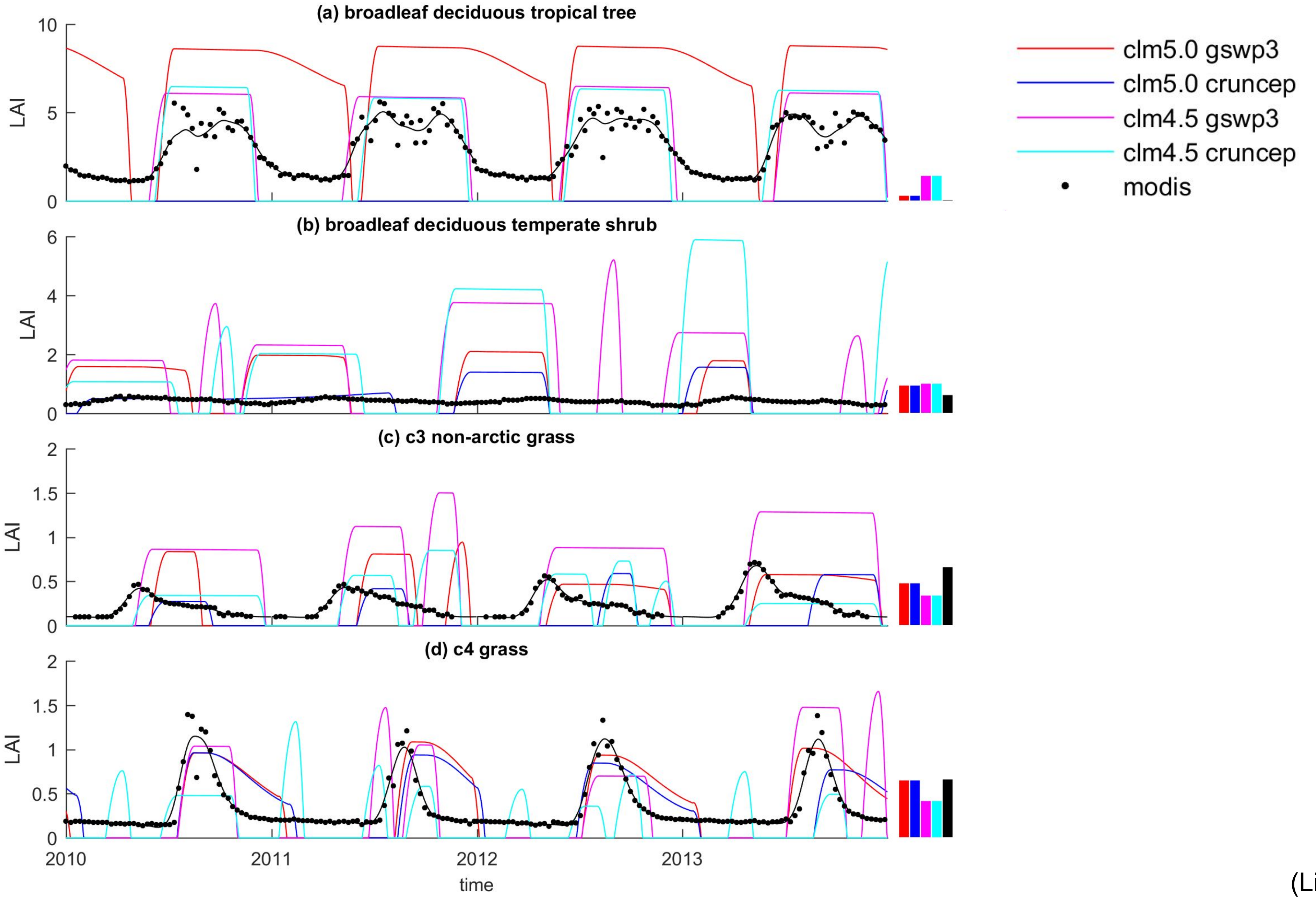
Leaf phenology differ in different land surface models





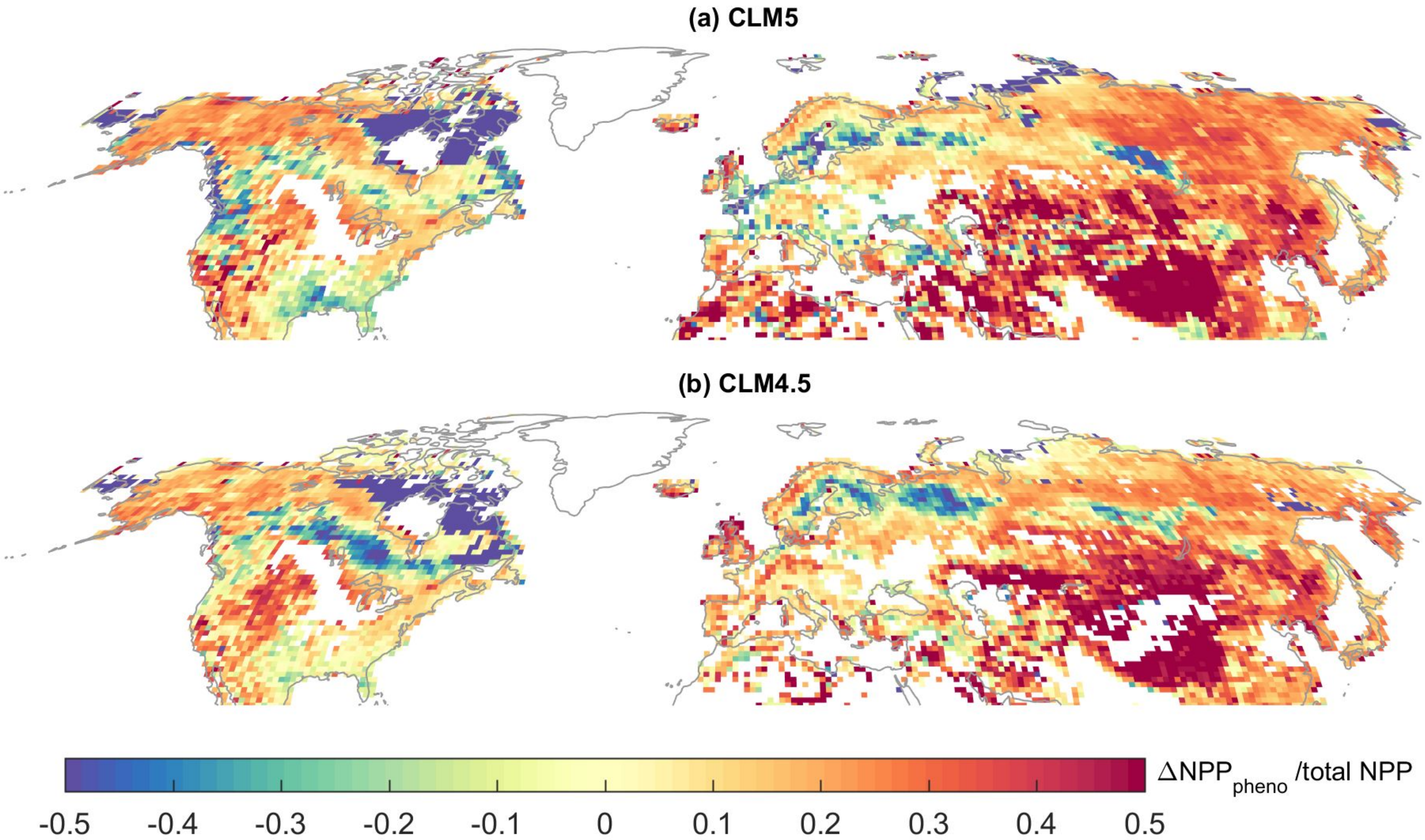
(Li et al., under review)

Delayed spring onset and longer peak growing season



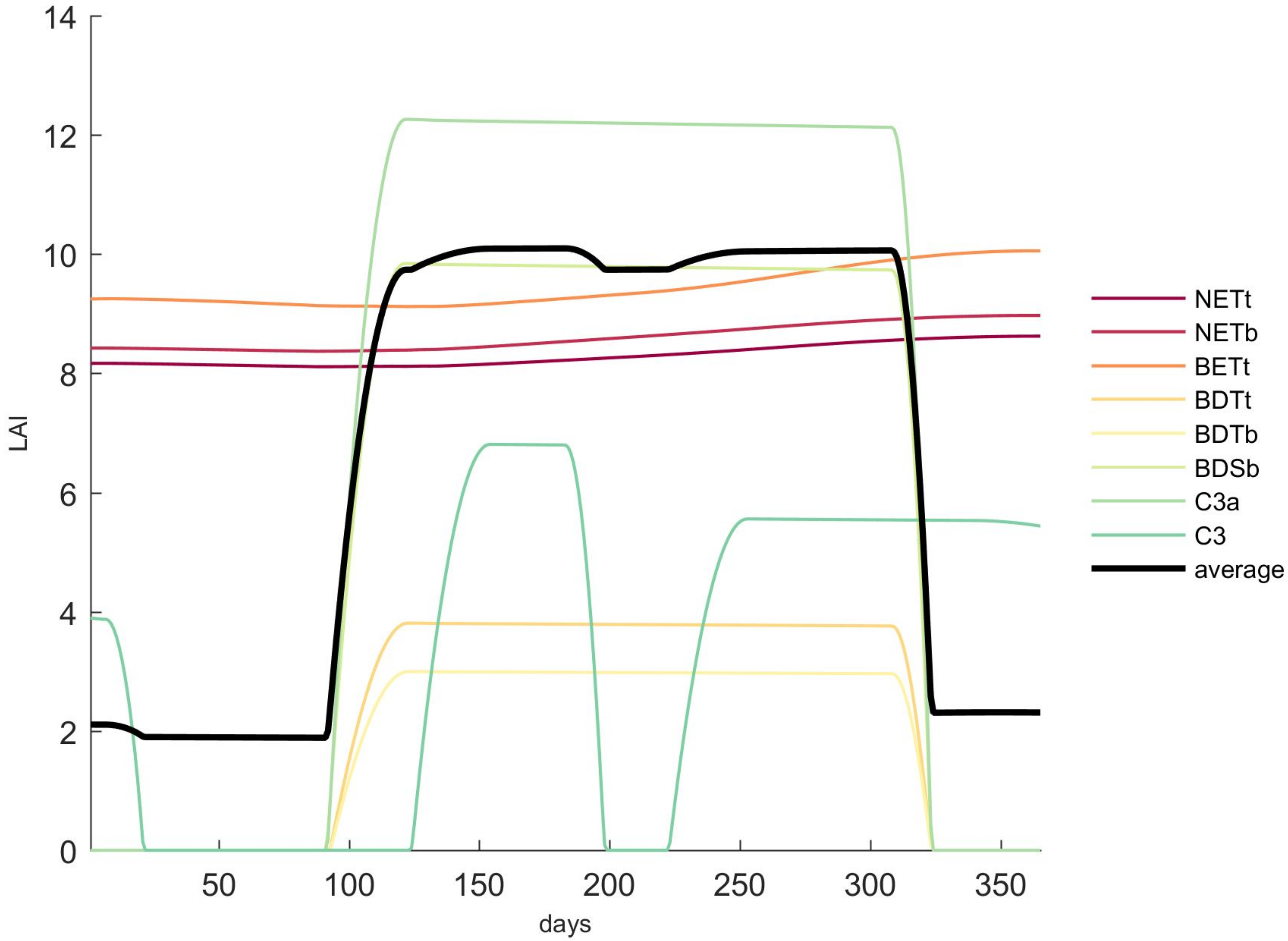
(Li et al., 2022)

Phenology discrepancies can result in large NPP biases



Fraction of total annual net primary production that is produced during the difference between MODIS peak growing season as indicated by LAI75% threshold and that of (a) CLM5.0, and (b) CLM4.5, averaged between 2003-2014. (Li et al., 2022)

Leaf phenology differ for different PFTs



Research questions

- Across PFTs, how well can CLM simulate LAI variability estimated from MODIS and how does the CLM-MODIS agreement change with PFT and location?

- How sensitive is simulated plant phenology to environmental factors such as soil temperature and soil moisture?

- How may these disagreements influence how CLM simulates the carbon cycle?

Data and method

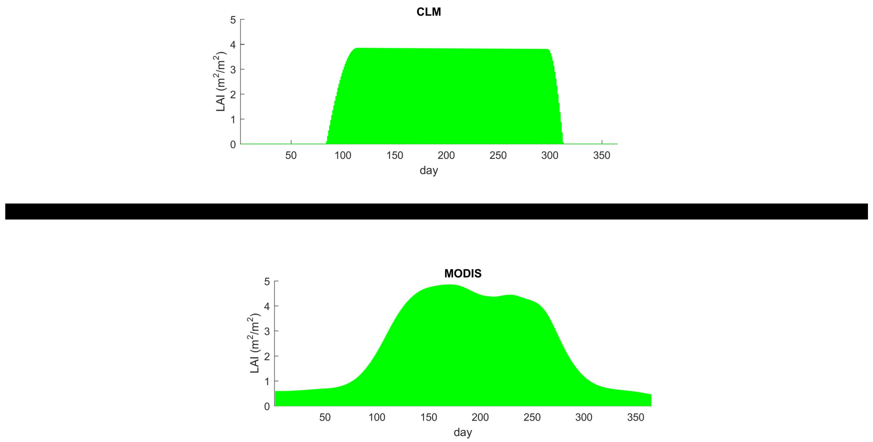
- CLM4.5 and CLM5.0 with GSWP3 historical forcing dataset

- LAI from MODIS TERRA MOD15A2H.v006 and land cover type from MCD12Q1

Data and method

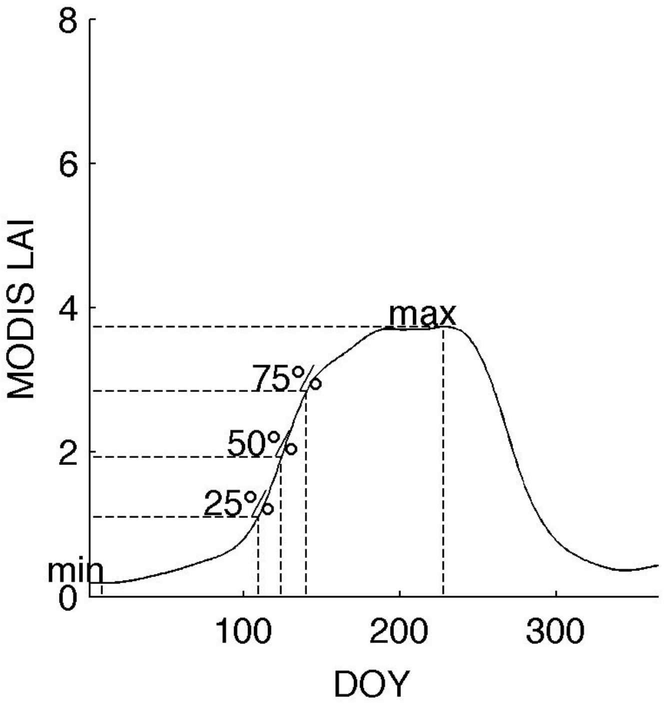
- LAI ratio

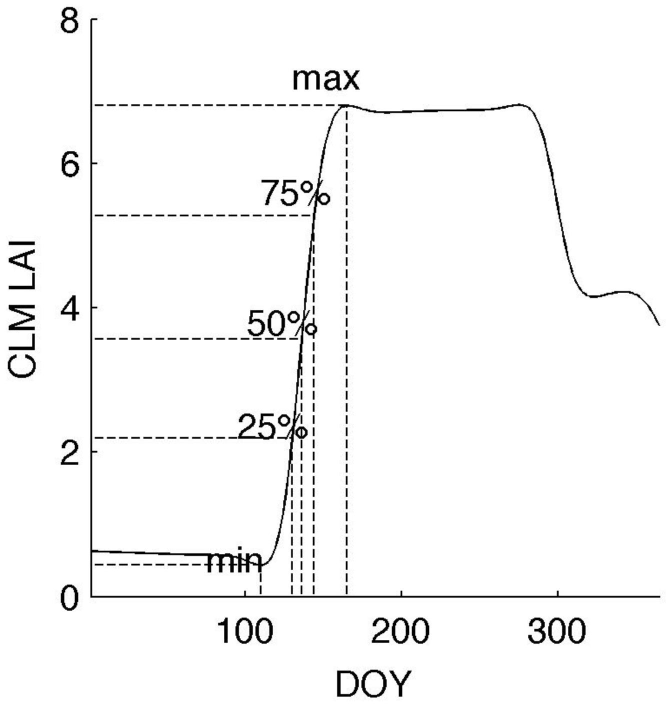
$$log(LAI\ ratio) = \log\left(\frac{\overline{LAI_{CLM}}}{\overline{LAI_{MODIS}}}\right)$$



- LAI threshold-based DOYs

  - Annual dynamical range = max LAI – min LAI
  - 50% thresholds





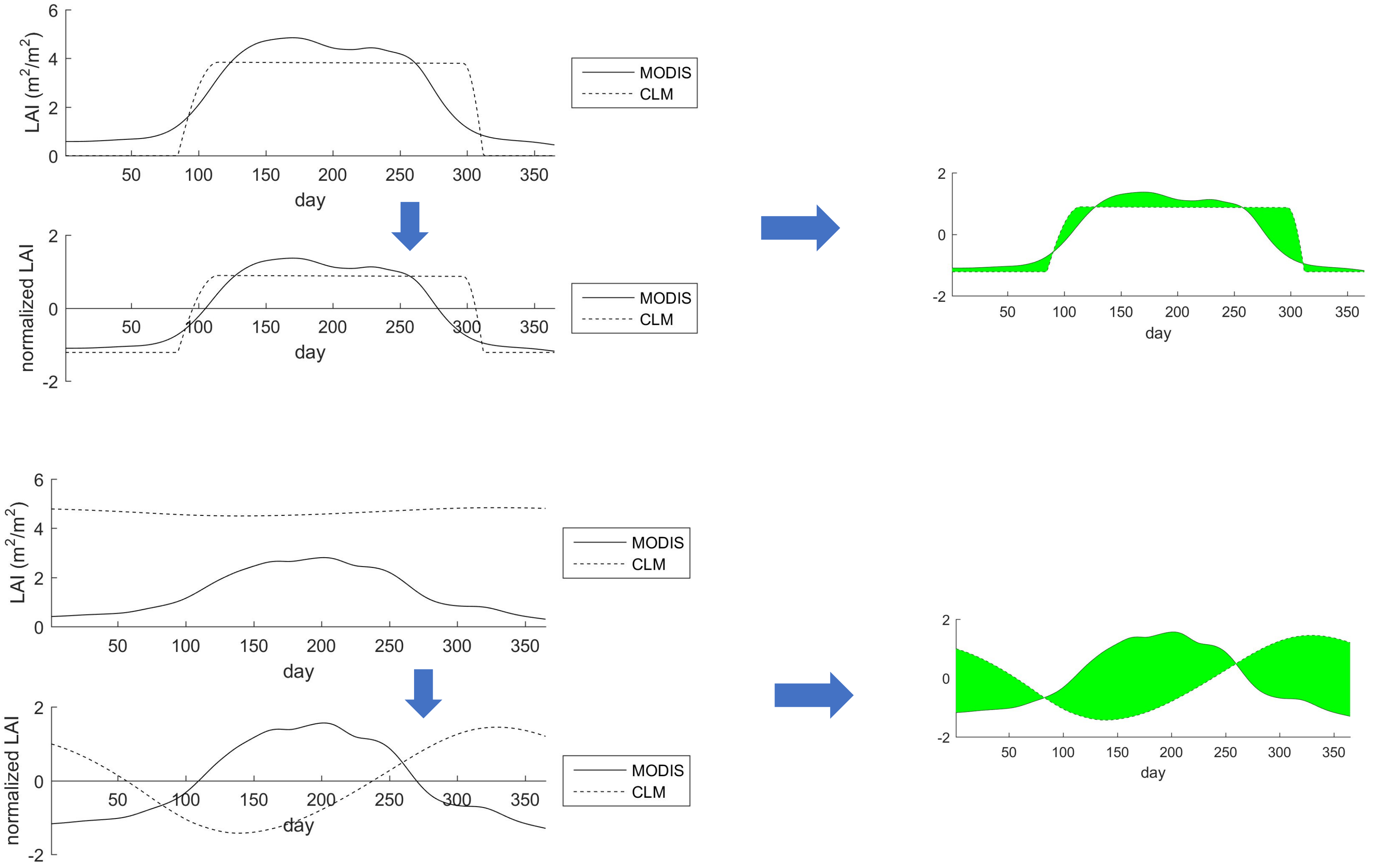
Data and method

- Seasonal ratio

  $RMSE_{normLAI}$:

  root mean square error (RMSE) between normalized CLM LAIs and MODIS LAIs

$$RMSE_{normLAI} = \sqrt[2]{mean[(\frac{LAI_{CLM}-\overline{LAI_{CLM}}}{\sigma(LAI_{CLM})} - \frac{LAI_{MODIS}-\overline{LAI_{MODIS}}}{\sigma(LAI_{MODIS})})^2]}$$

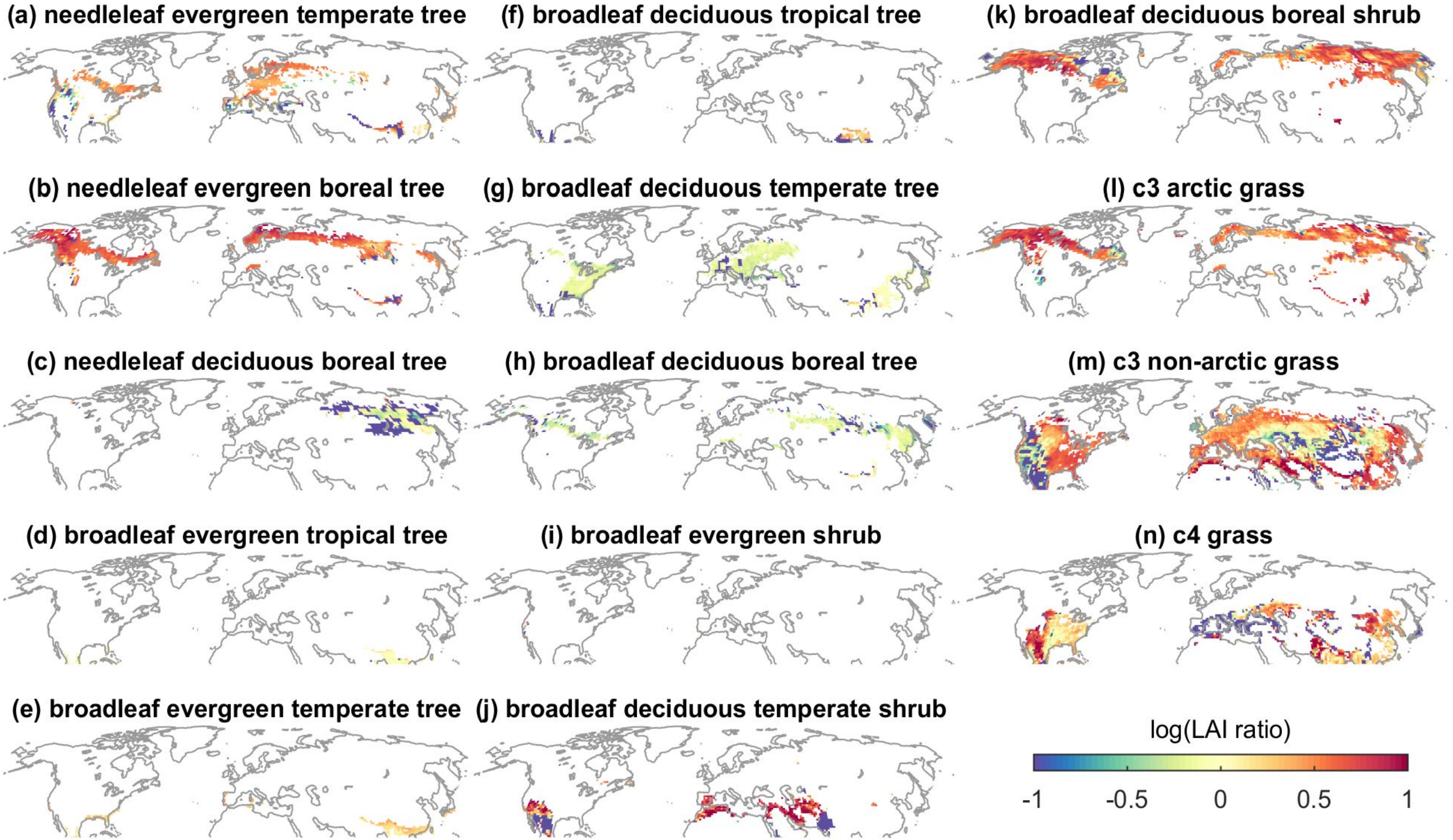


Data and method

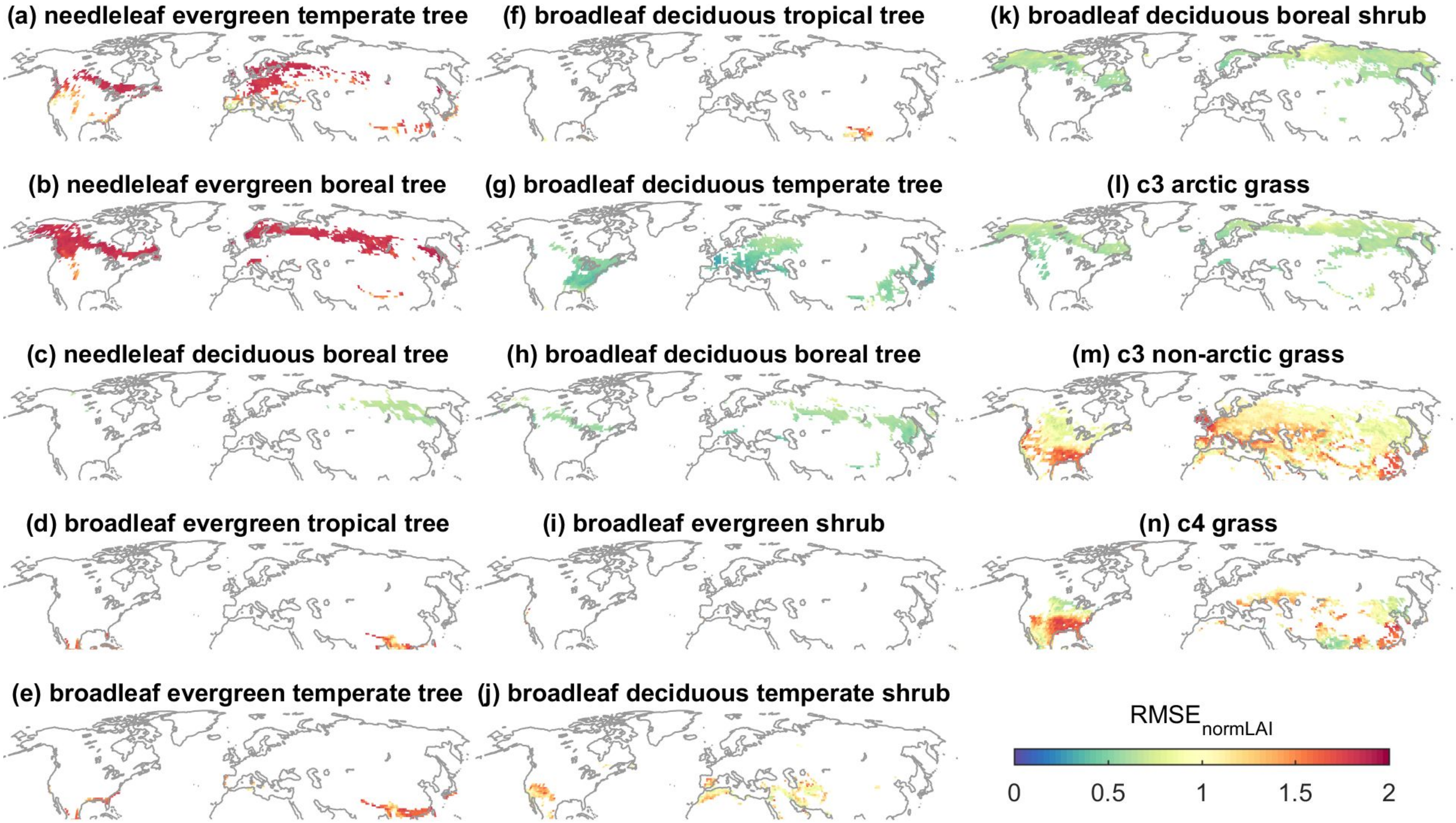
- Peak growing season: days when LAI > 75% LAI annual dynamical range for each PFT.

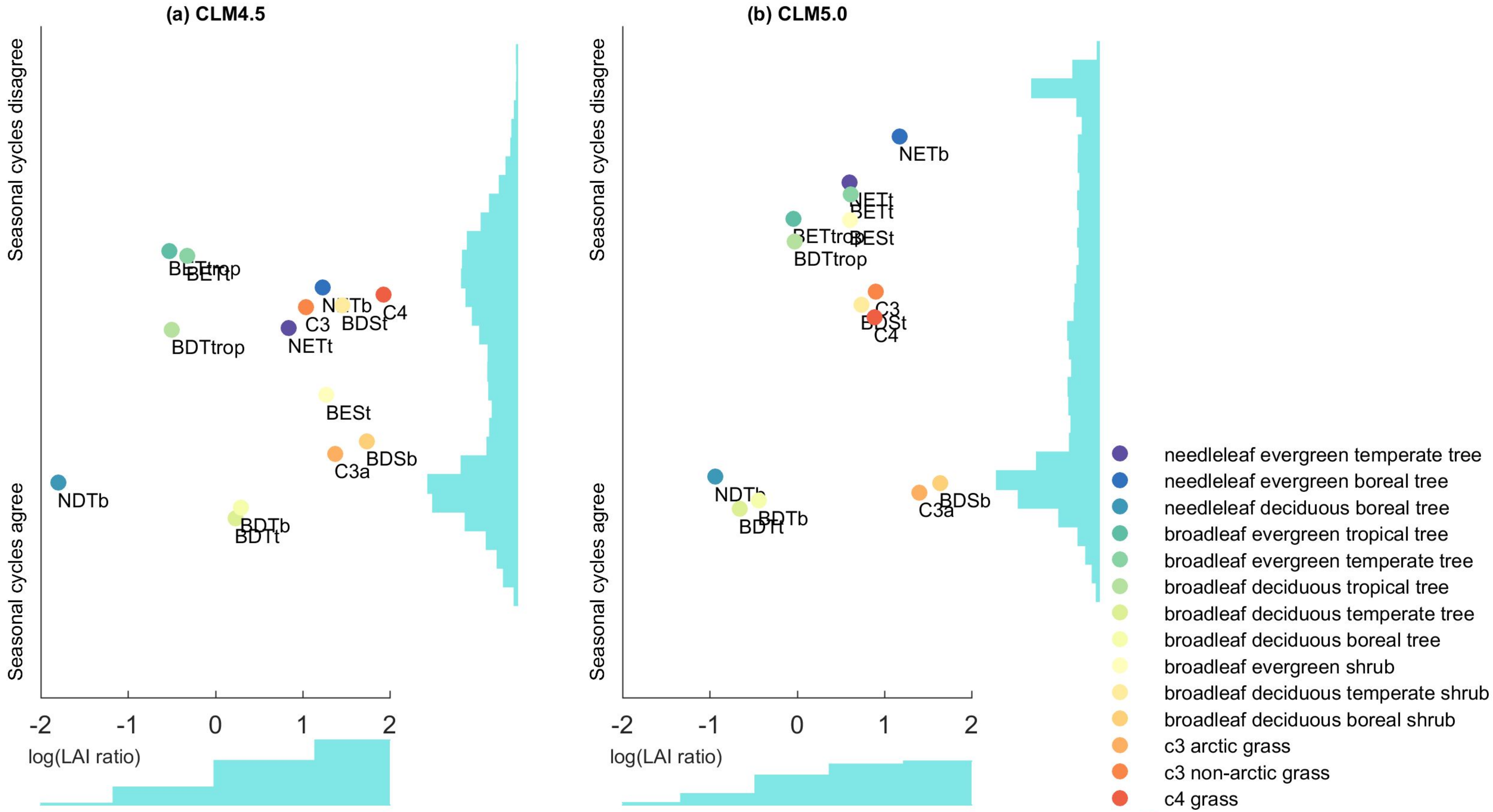
- Phenology induced GPP differences ΔGPP_{pheno}: GPP simulated by each PFT in CLM during the difference window between CLM and MODIS peak growing season differences due to phenology disagreements.

Amplitude and seasonal cycle of annual LAI

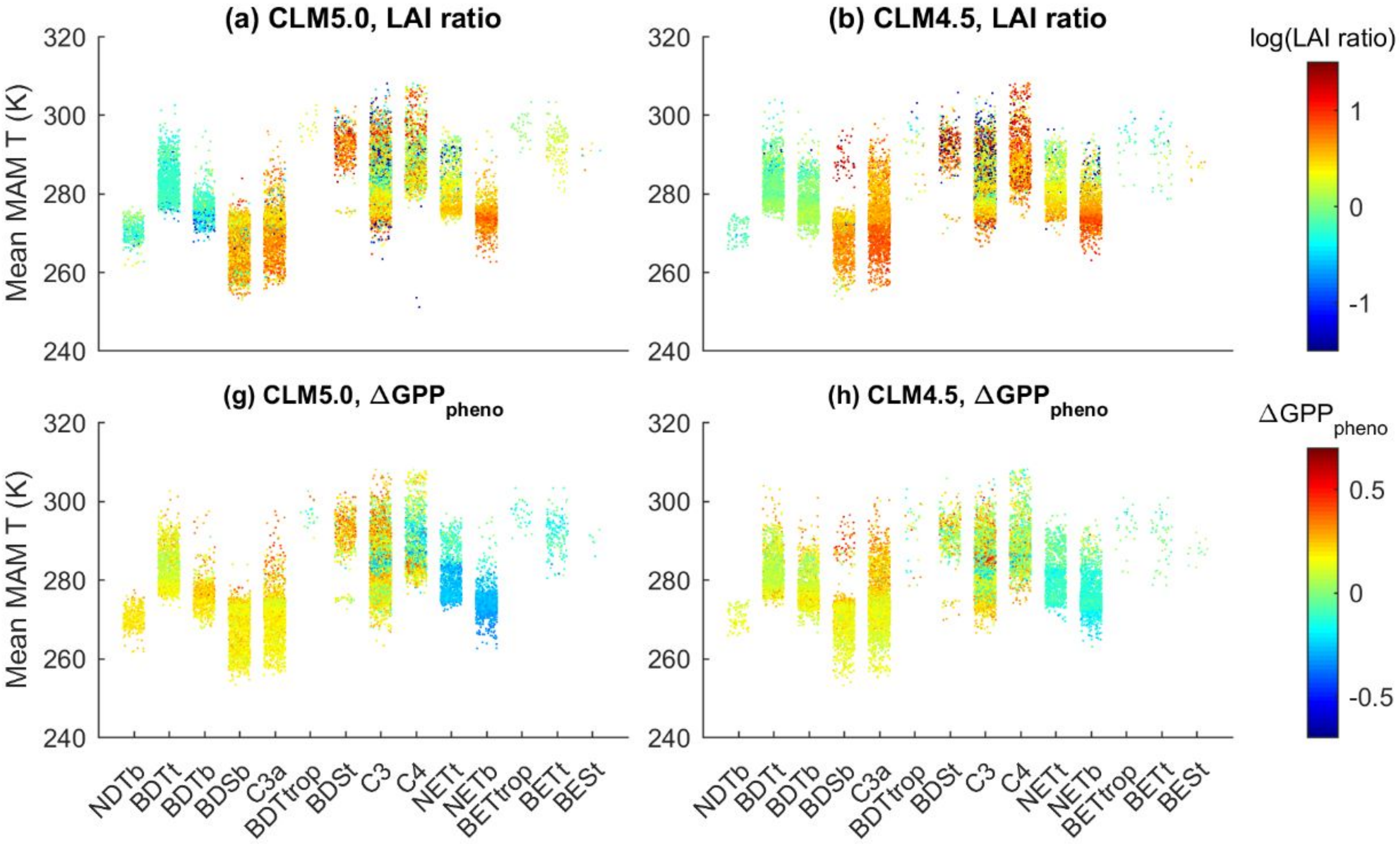


Amplitude and seasonal cycle of annual LAI

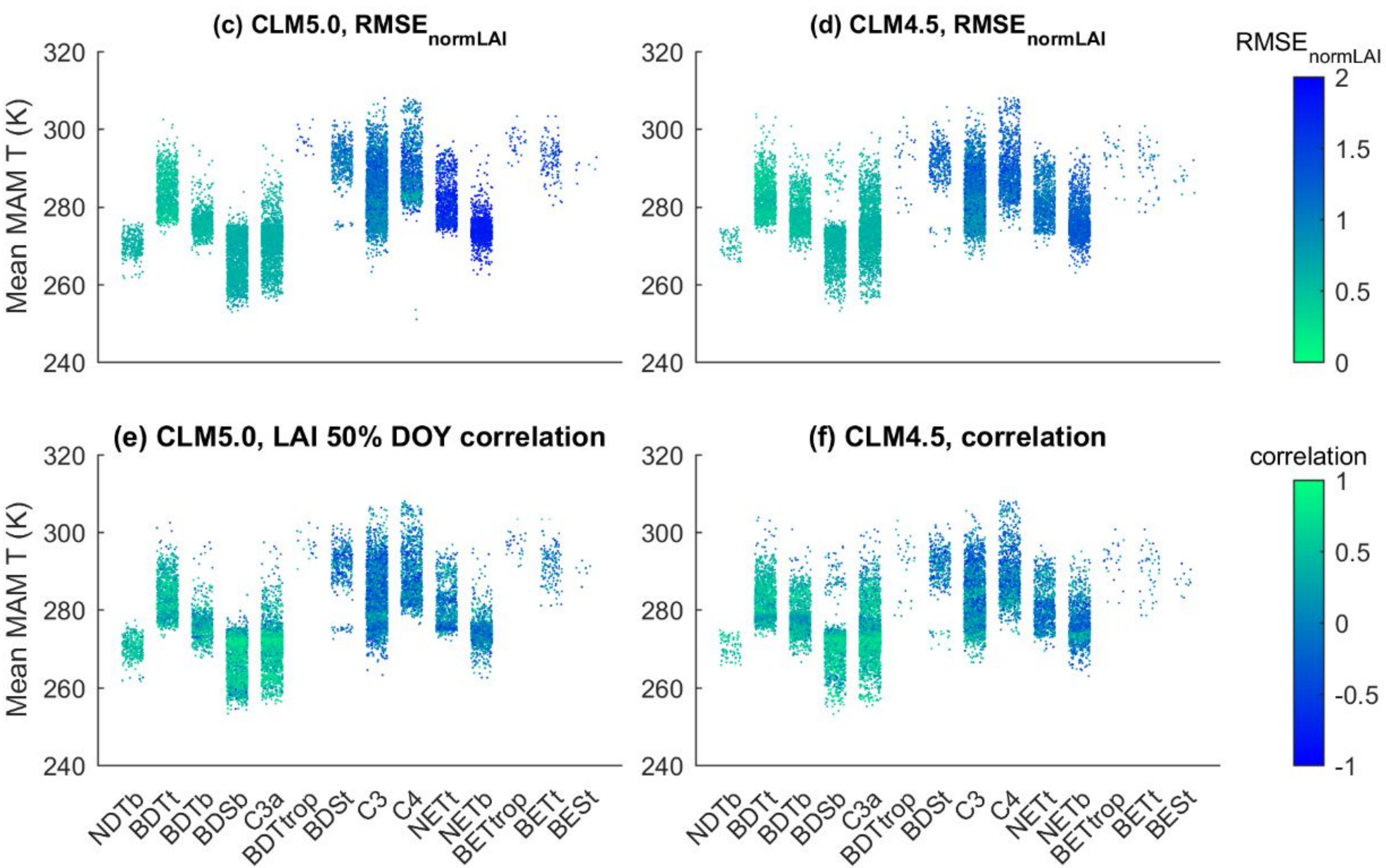



(a) CLM4.5
(b) CLM5.0
Seasonal cycles disagree
Seasonal cycles agree
log(LAI ratio)
-2
-1
0
1
2
BETtrop
BETt
BDTtrop
NETb
C3
BDSt
C4
NETt
BESt
BDSb
C3a
NDTb
BDTb
BDTt
needleleaf evergreen temperate tree
needleleaf evergreen boreal tree
needleleaf deciduous boreal tree
broadleaf evergreen tropical tree
broadleaf evergreen temperate tree
broadleaf deciduous tropical tree
broadleaf deciduous temperate tree
broadleaf deciduous boreal tree
broadleaf evergreen shrub
broadleaf deciduous temperate shrub
broadleaf deciduous boreal shrub
c3 arctic grass
c3 non-arctic grass
c4 grass

Influences of PFT and spring temperature



Influences of PFT and spring temperature



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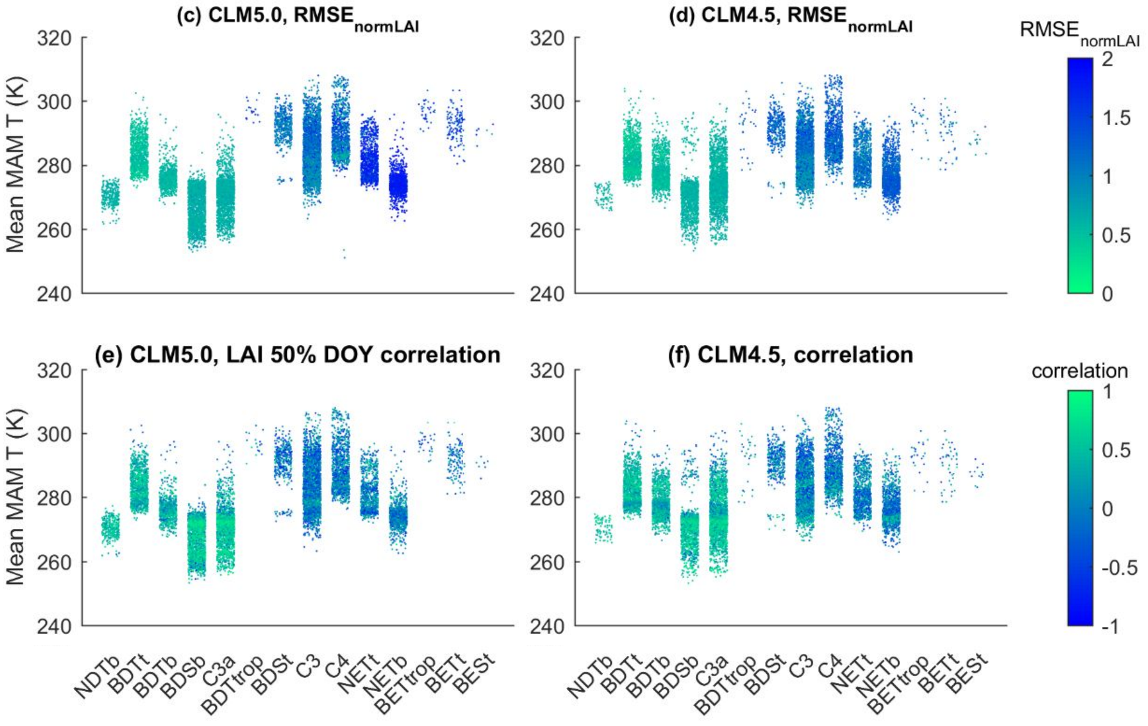
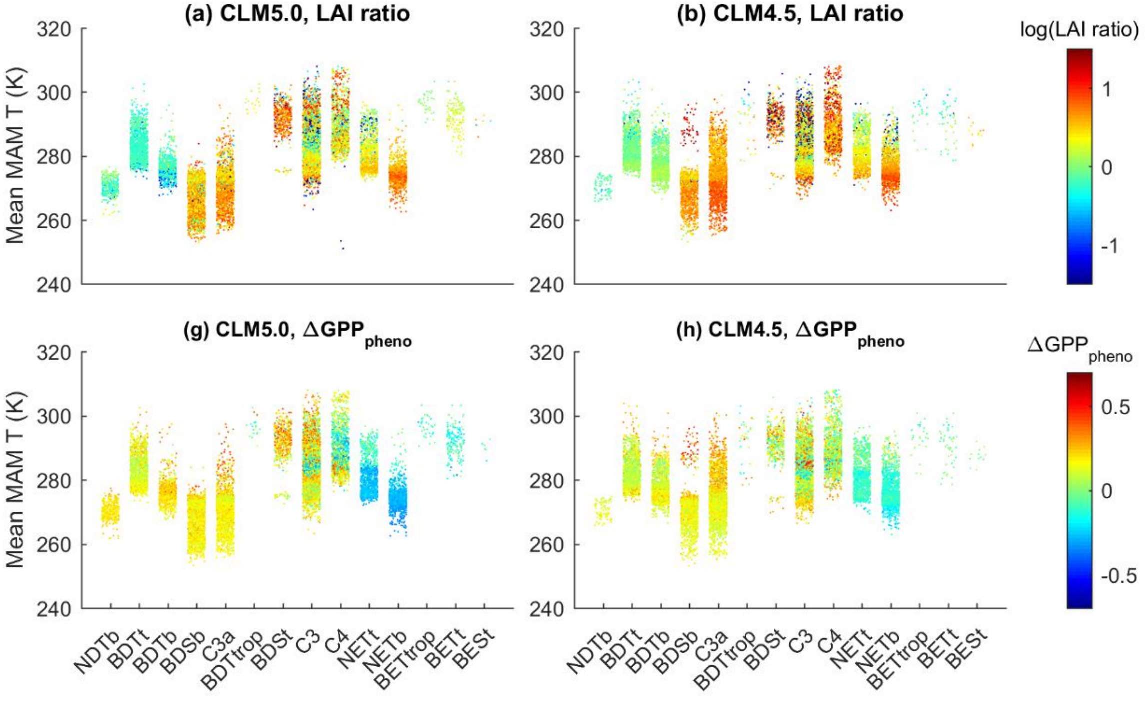
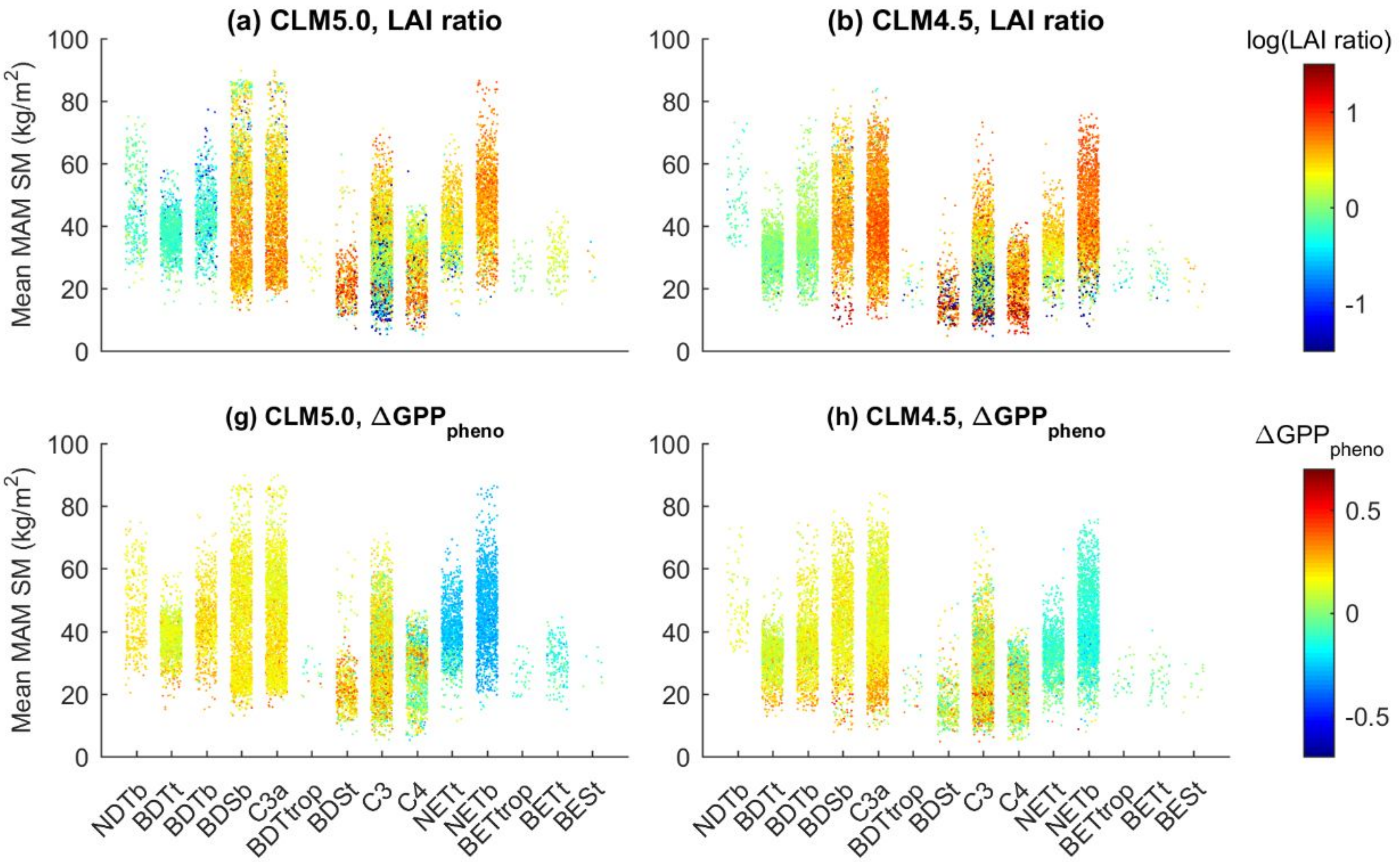
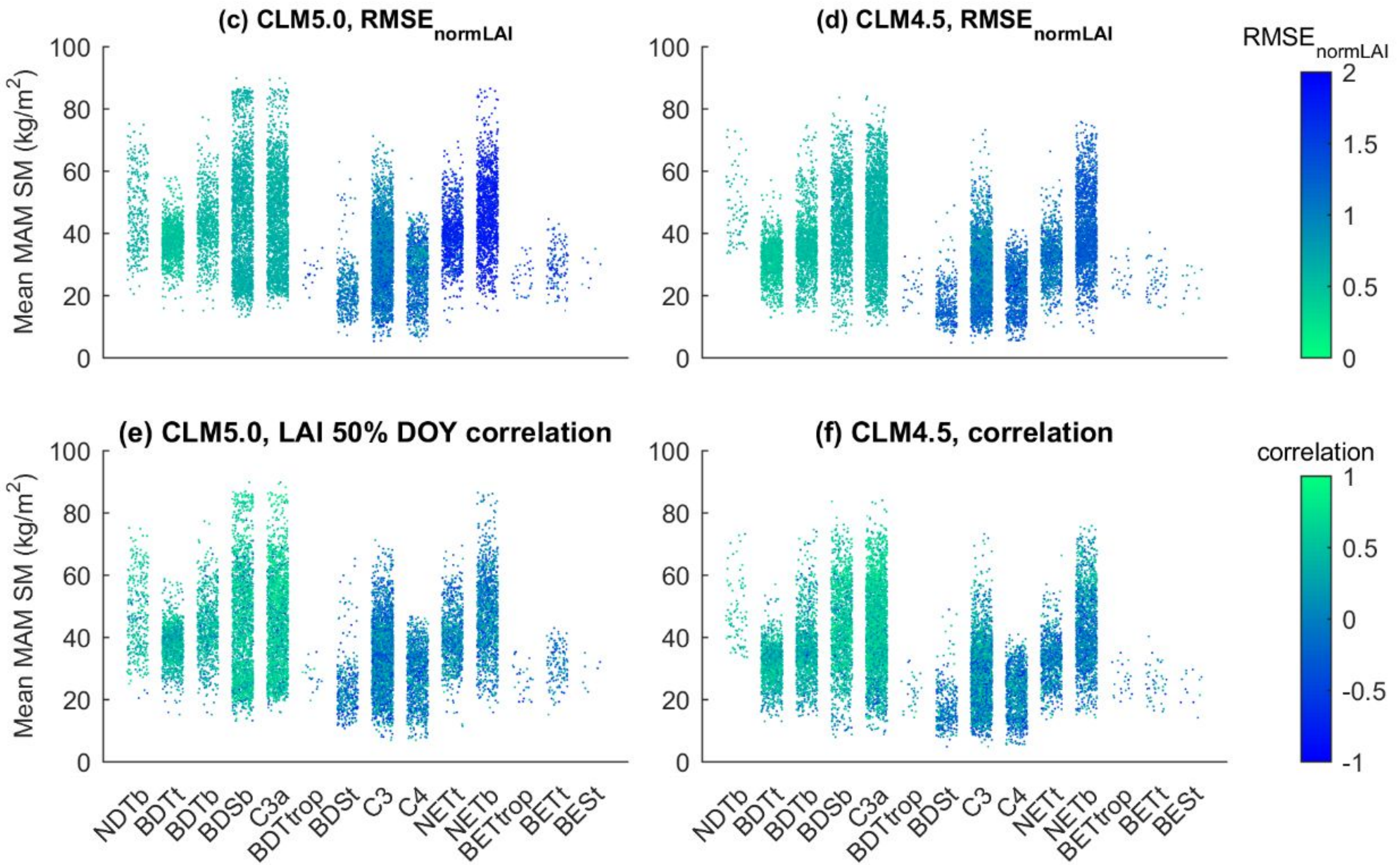




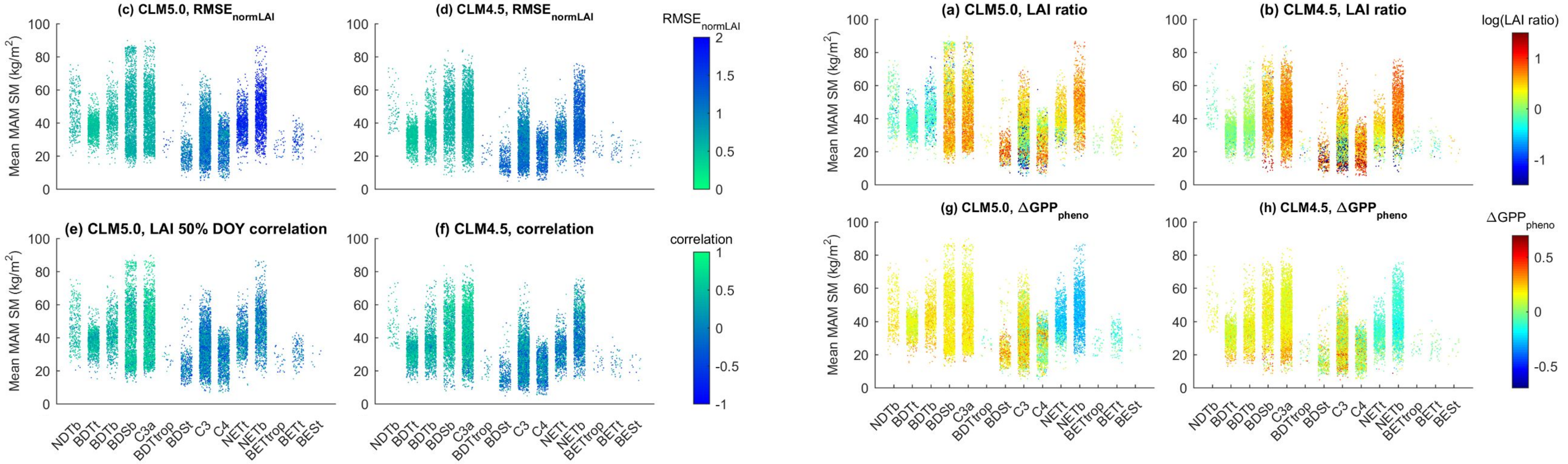
Influences of PFT and soil moisture



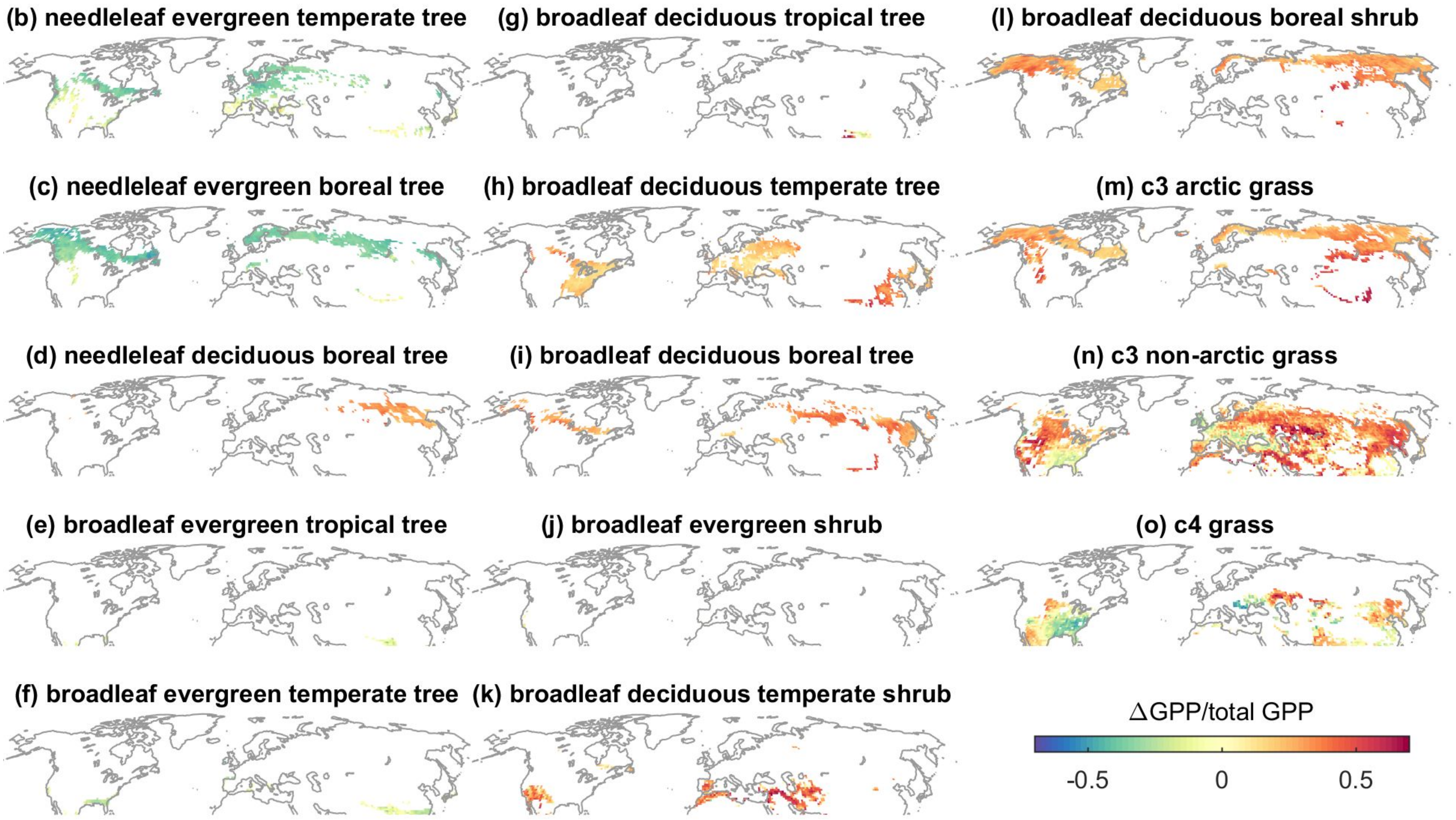
Influences of PFT and soil moisture



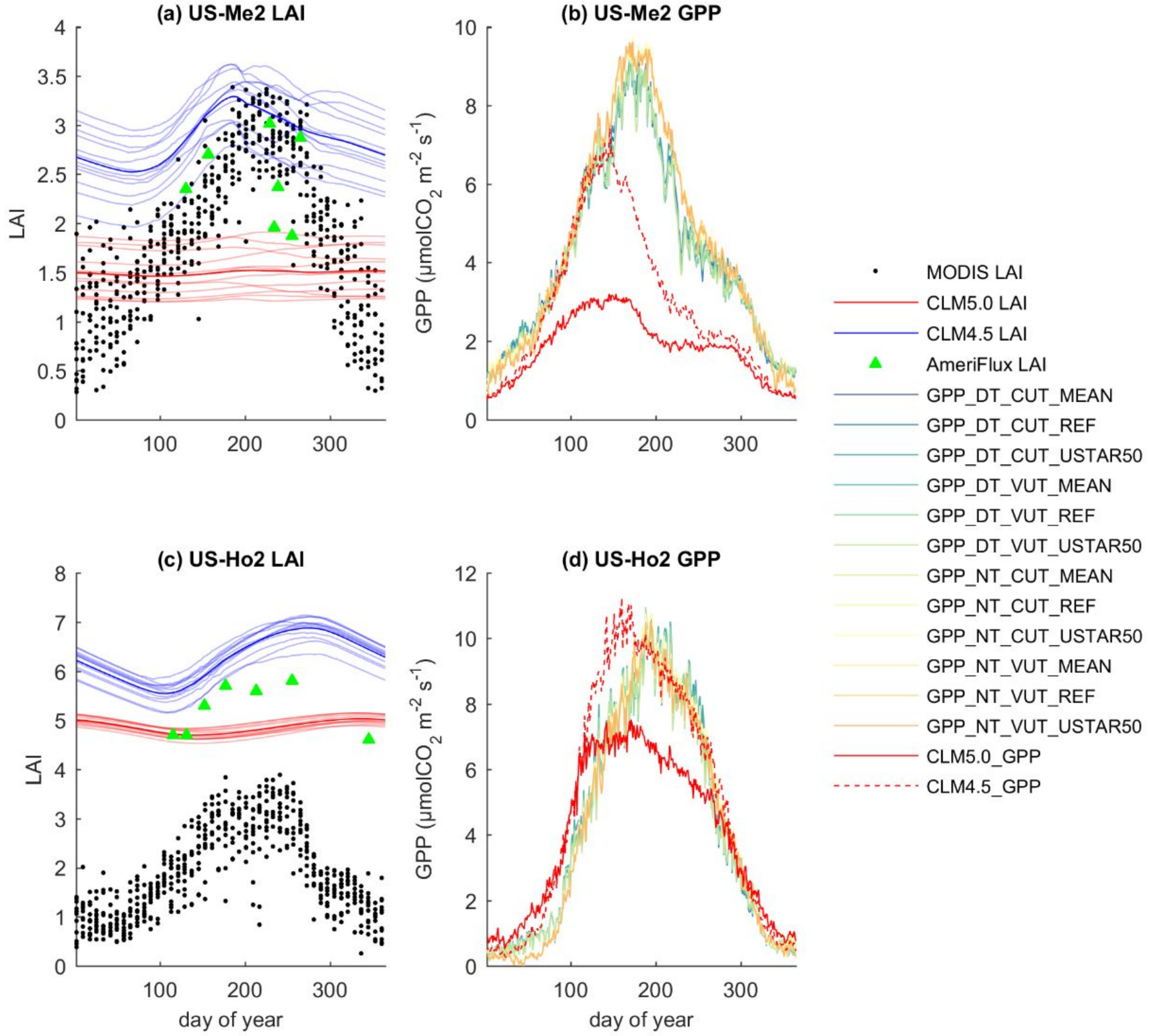
Influences of PFT and soil moisture



GPP differences due to phenology disagreements (CLM5)



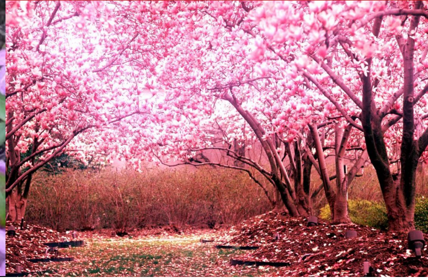
Comparison at flux tower sites



Evaluating CLM phenology from local to hemispheric scale

Conclusions

- Best agreement: seasonal deciduous PFTs & deciduous broadleaf trees;
- LAI amplitudes are sensitive to environmental factors while LAI seasonal cycle is mostly determined by the phenology scheme.
- CLM displays large cross-PFT variation in LAI values, seasonal amplitude, and seasonal cycle.
- Environmental factors influence simulated phenology by determining the PFT and by influencing LAI amplitudes.
- Smaller biases in GPP than LAI, but LAI discrepancies result in GPP biases.



Thank you!

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References:

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