Northern Hemisphere patterns of land surface phenology in the Community Land Model and remote sensing

Xiaolu Li, Eli K Melaas, Toby Ault, Carlos M Carrillo, Mark A Friedl, Andrew D Richardson

Characterizing spring onset in land surface models

- Model evaluations have been focusing on productivity, LAI, or specific PFT/sites (e.g. Richardson et al., 2012; Mahowald et al., 2016)

- But large scale seasonality and phenology is important!

- Absolute values may have different meanings in the model and in observations

- How about seasonal cycle or phenology?

Goals

- Develop spring onset indicators from CLM outputs that are comparable to land surface phenology from remote sensing

- Characterize large scale patterns of CLM spring onset

- Build a set of tools and analysis that can be used to evaluate land surface model outputs against large-scale observations

Defining spring onset in CLM
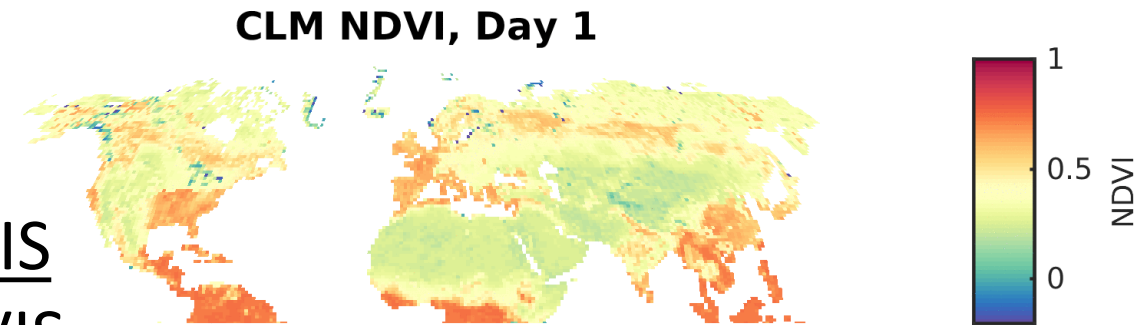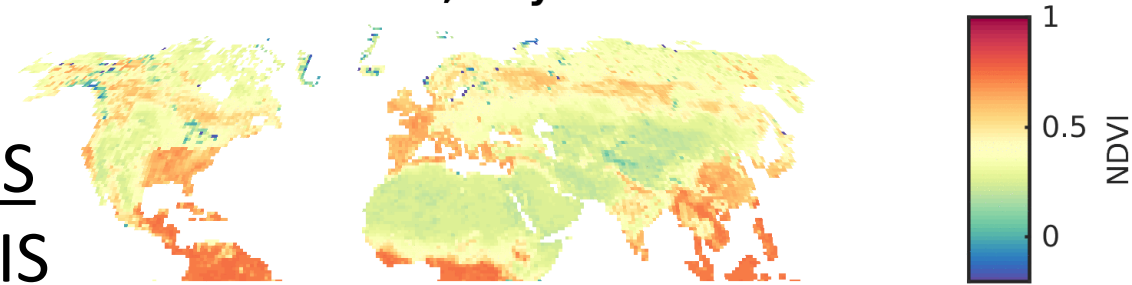
Defining spring onset in CLM
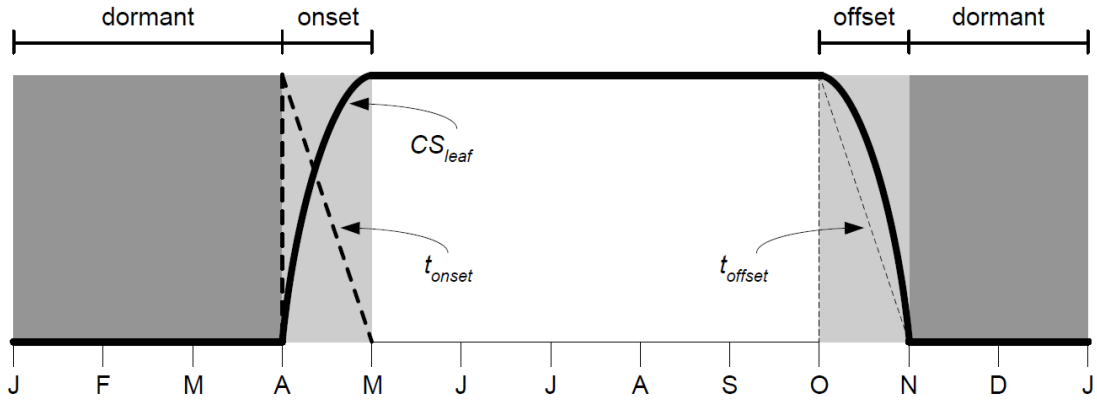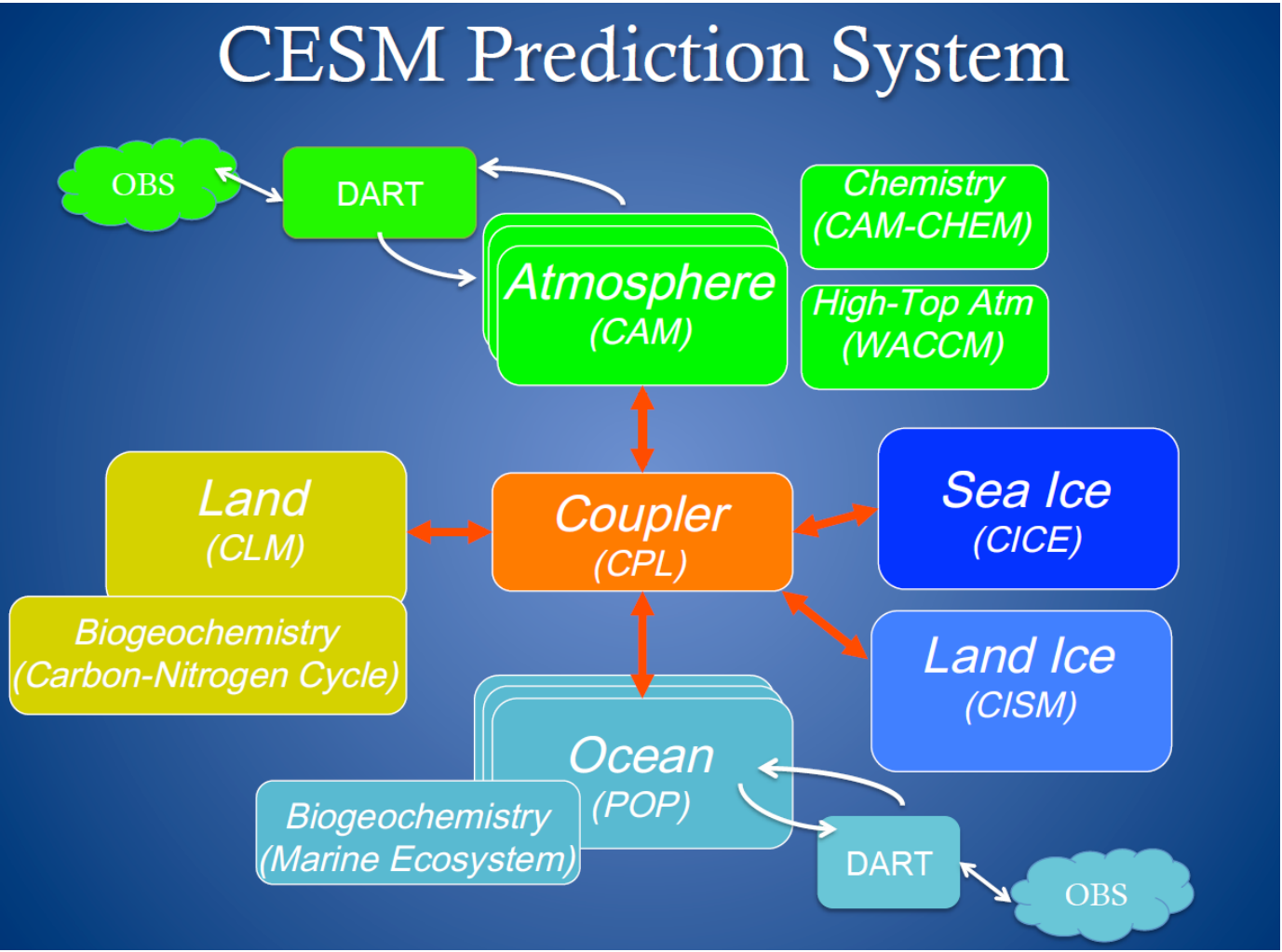
(Oleson et al., 2013)

Normalized Difference Vegetation Index (NDVI)

- CLM

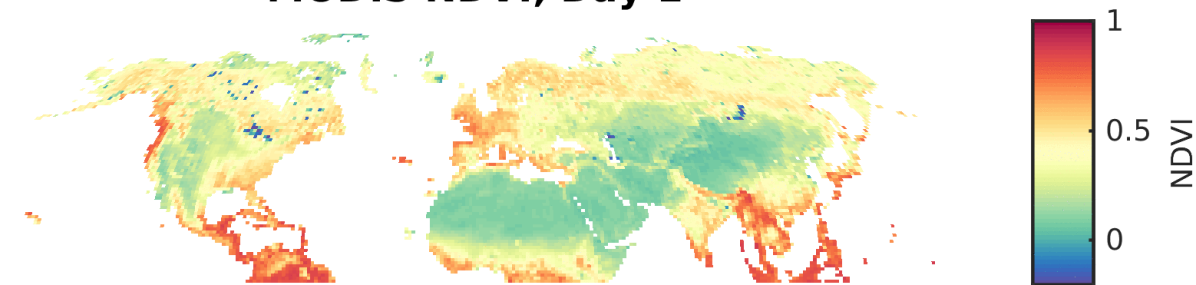$$\text{CLM NDVI} = \frac{\text{reflected NIR - reflected VIS}}{\text{reflected NIR + reflected VIS}}$$

$$= \frac{\text{(FSRND+FSRNI) - (FSRVD+FSRVI)}}{\text{(FSRND+FSRNI) + (FSRVD+FSRVI)}}$$

CLM NDVI, Day 1

Normalized Difference Vegetation Index (NDVI)

- CLM

  CLM NDVI= $\dfrac{\text{reflected NIR - reflected VIS}}{\text{reflected NIR + reflected VIS}}$

CLM NDVI, Day 1

- MODIS

  NDVI= $\dfrac{\text{NIR - Red}}{\text{NIR + Red}}$
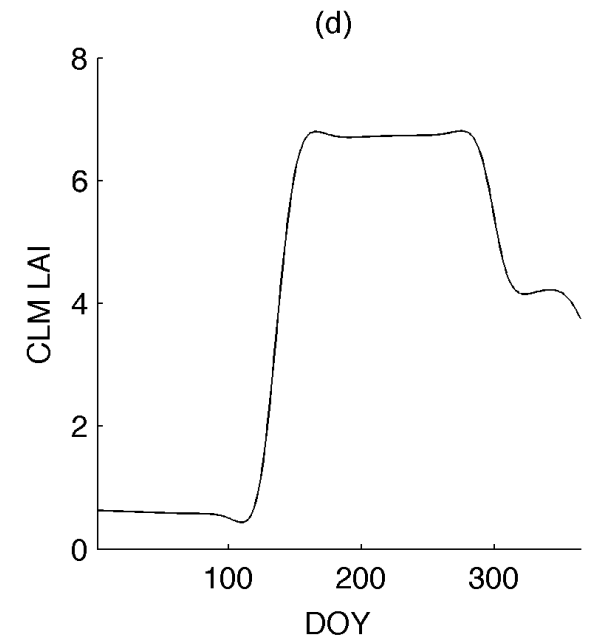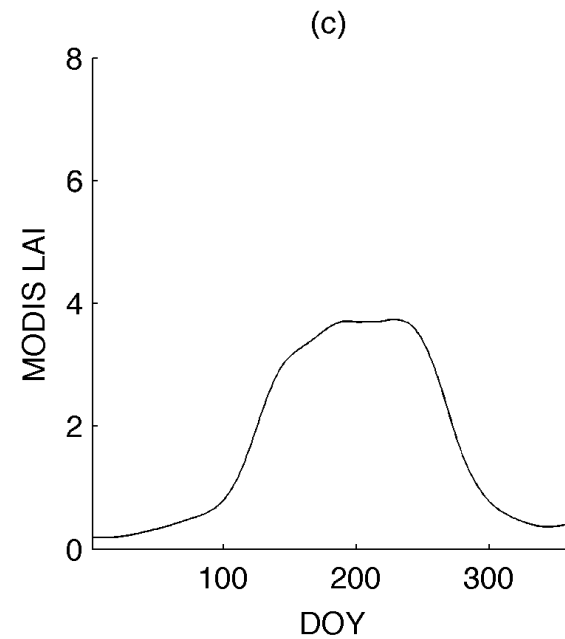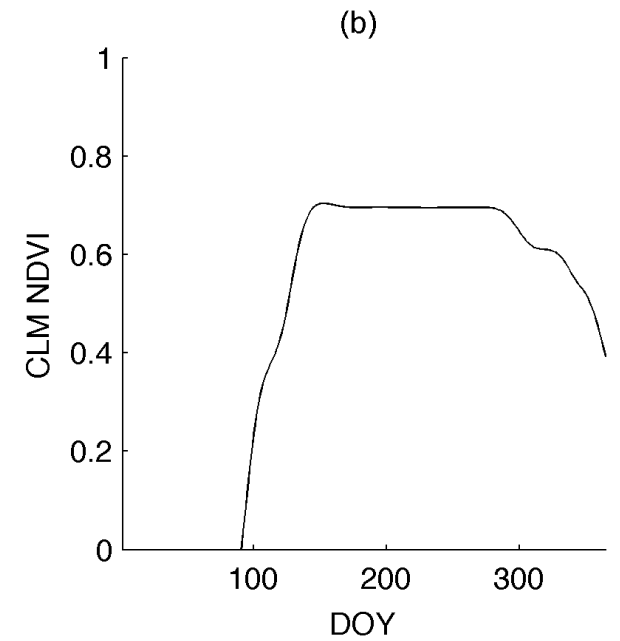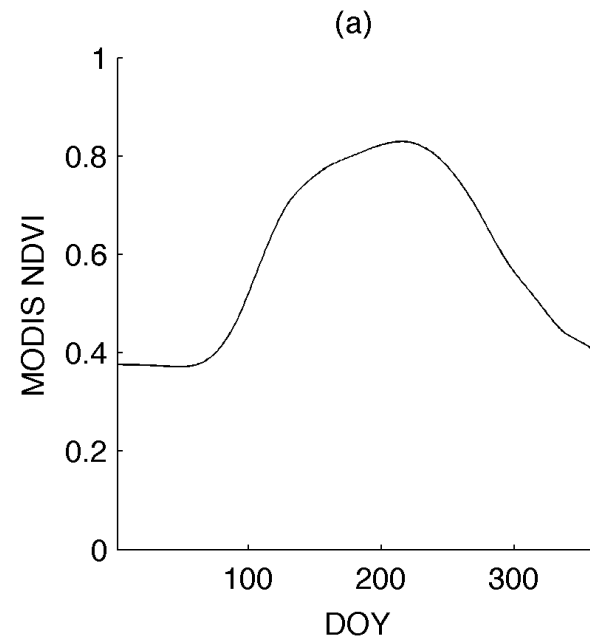
MODIS NDVI, Day 1

Leaf area index (LAI)

- CLM

CLM LAI

CLM LAI, Day 1
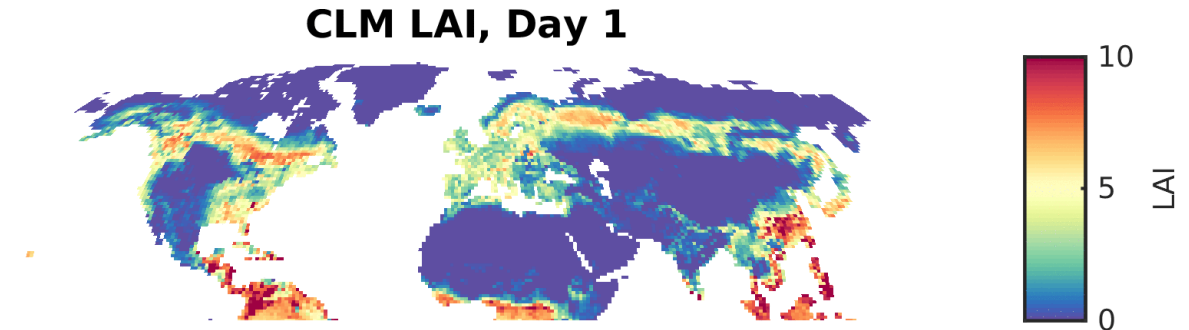
- MODIS

Based on surface reflectance
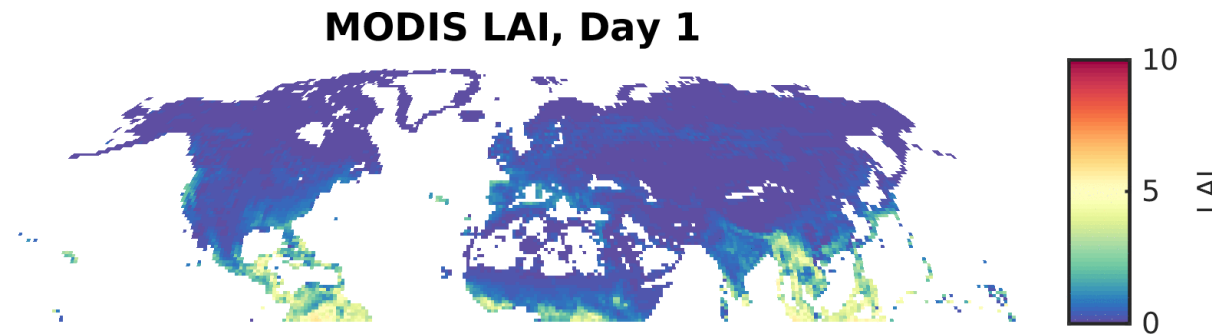
MODIS LAI, Day 1

Defining spring onset in CLM

(a) MODIS NDVI vs DOY

(b) CLM NDVI vs DOY

(c) MODIS LAI vs DOY

(d) CLM LAI vs DOY
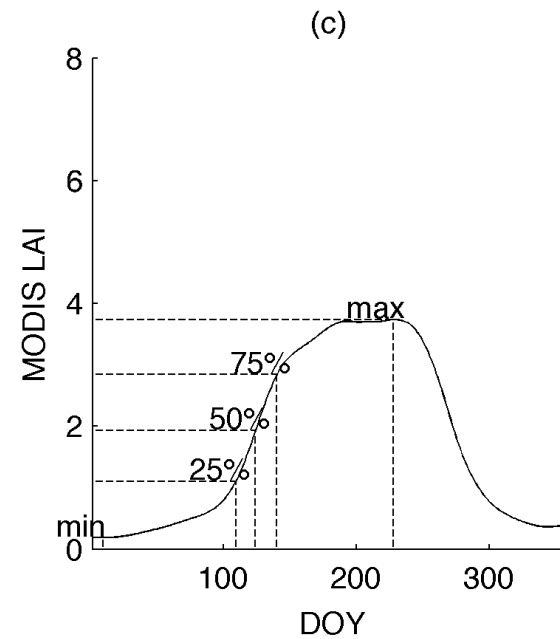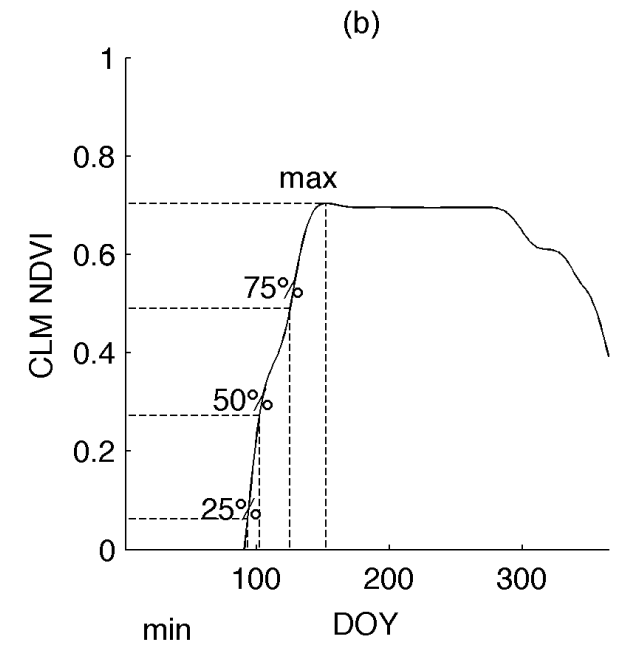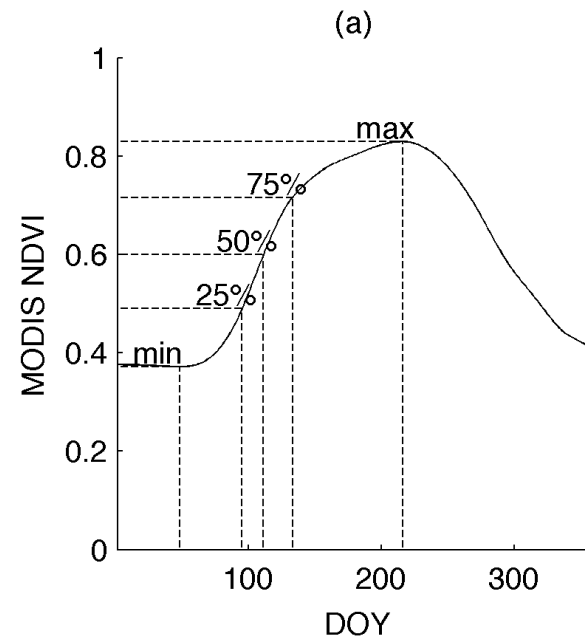
Annual cycle of NDVI and LAI from MODIS and CLM4.5 (CRUNCEP) from a grid point near Ithaca (42.44°N, 76.5°W)

Defining spring onset CLM
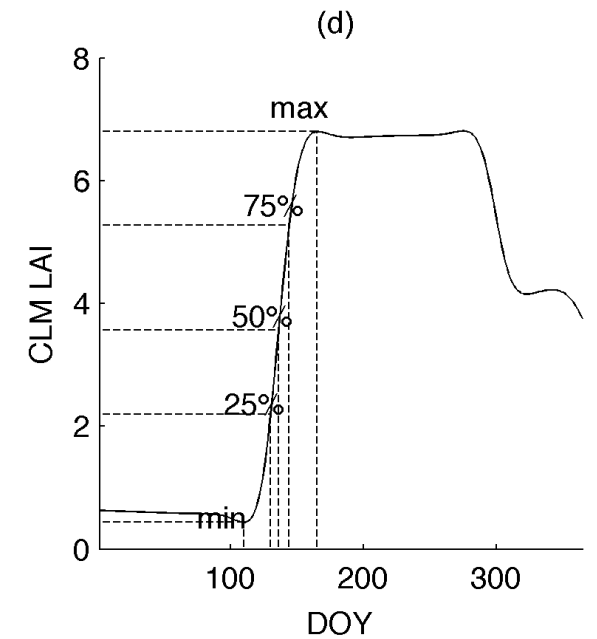
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Goals

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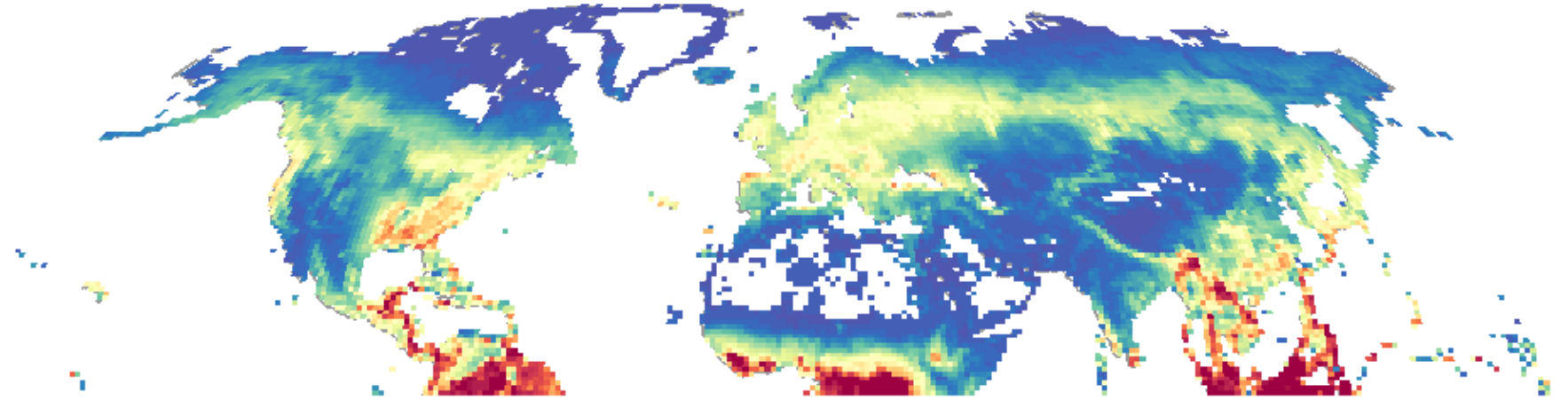
Data and method

- Community Land Model 4.5
  - Run CLM4.5BGC/CLM5BGC at 1° resolution from 1970 to 2016/2014
  - Year 2000 initial condition
  - Data atmosphere: CRUNCEP, GSWP3
  - Snow-free
  - Calculate day of the year (DOY) when predefined thresholds are reached in the spring
- MODIS
  - MOD13C1 v006 & MOD15A2H v006
  - Averaged to CLM grid
  - Interpolated to daily temporal resolution using a cubic spline
  - Calculate start of spring dates

Results

Mean seasonal LAI values from MODIS and CLM (April, May, and June), averaged between 2003-2016

MODIS LAI (April, May, June average)

CLM LAI (April, May, June average)

LAI (m^2/m^2)

0   0.5   1   1.5   2   2.5   3   3.5   4   4.5   5
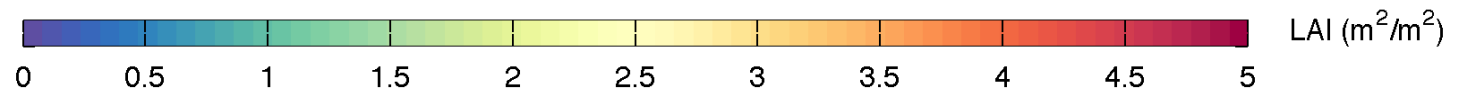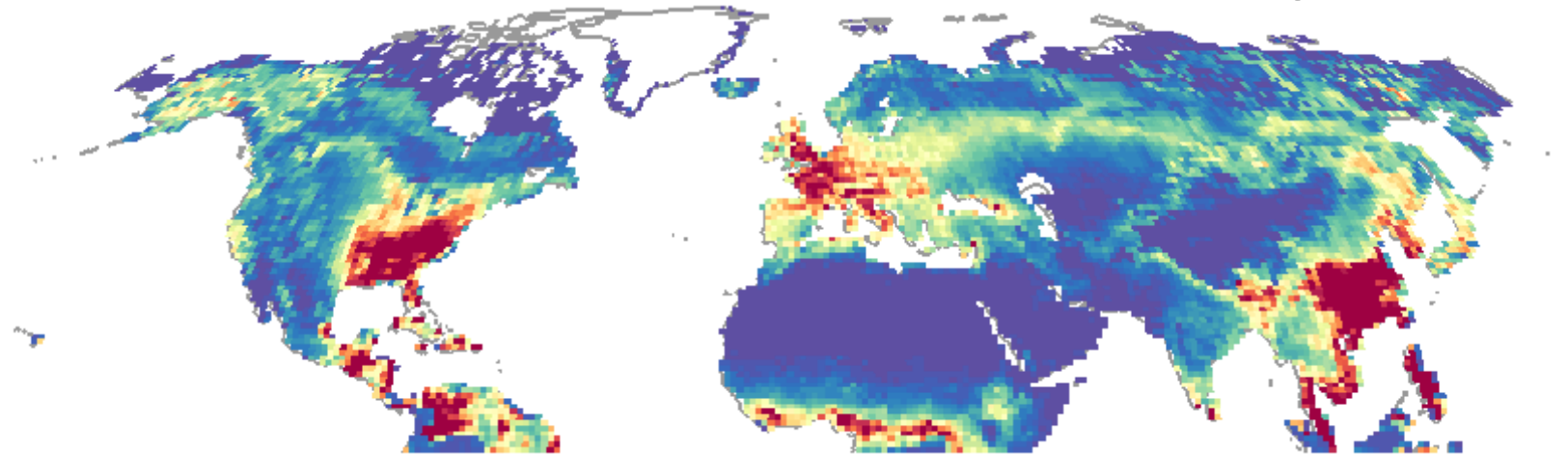
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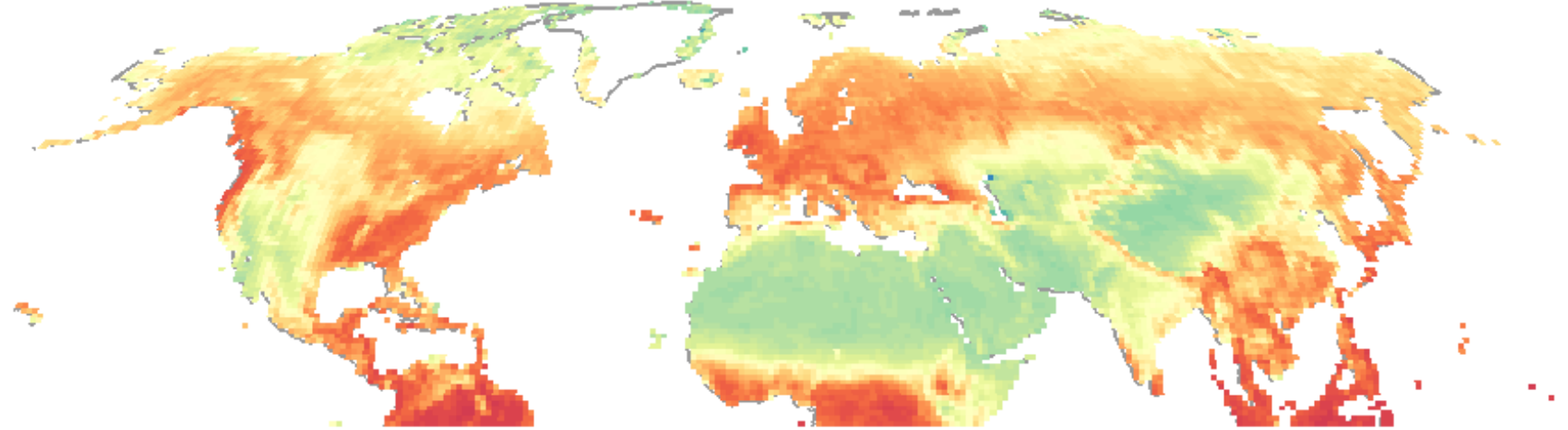
CLM NDVI (April, May, June average)
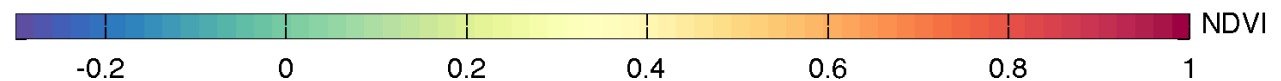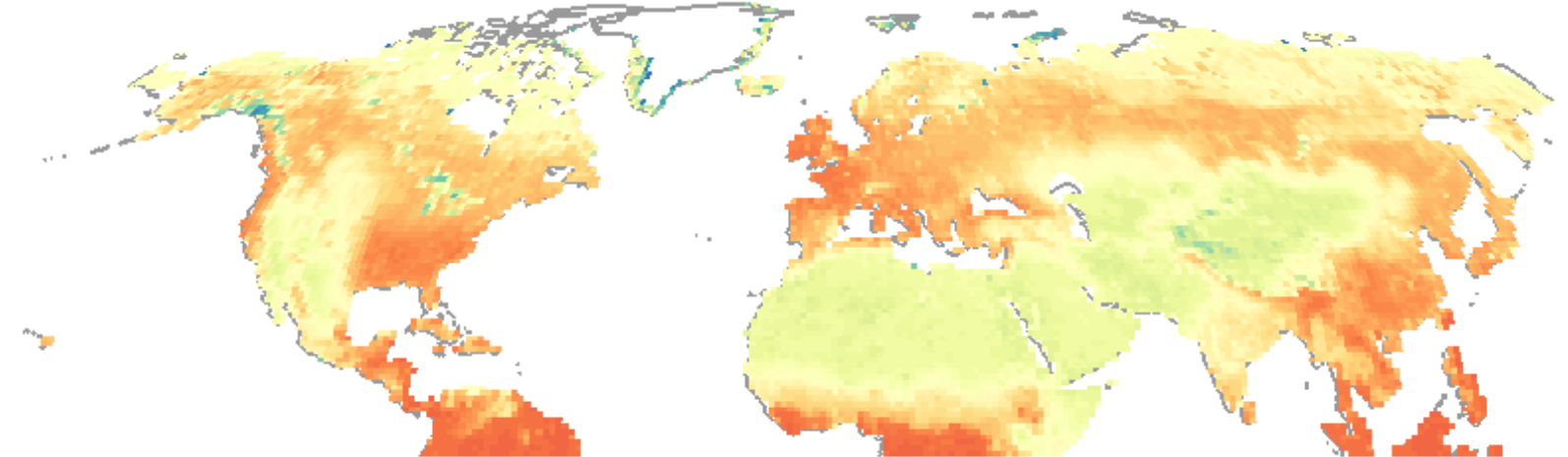
Results

Mean DOY when LAI crosses 50% threshold of annual dynamical range from MODIS and CLM, averaged between 2003-2016

MODIS LAI$_{50\%}$

CLM LAI$_{50\%}$

DOY
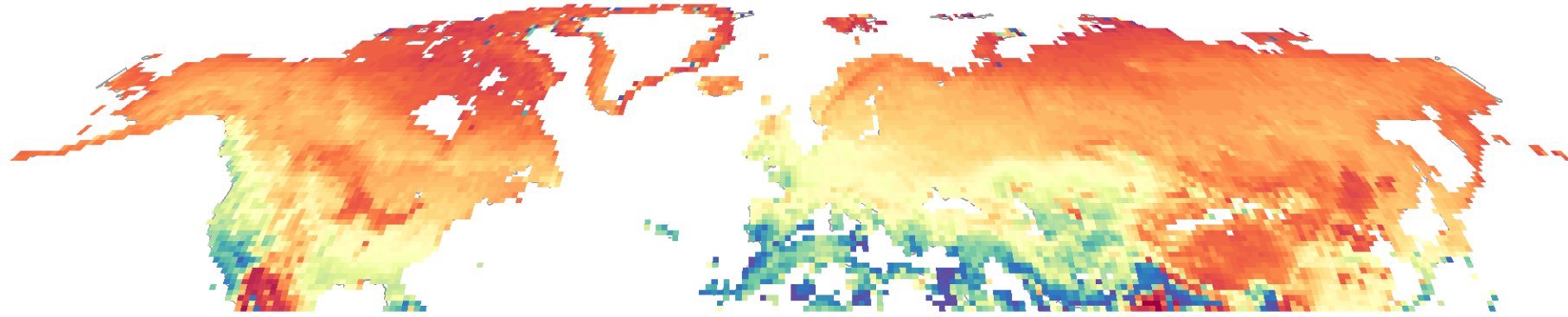
0 20 40 60 80 100 120 140 160 180 200
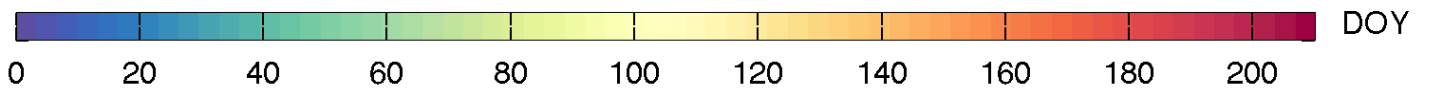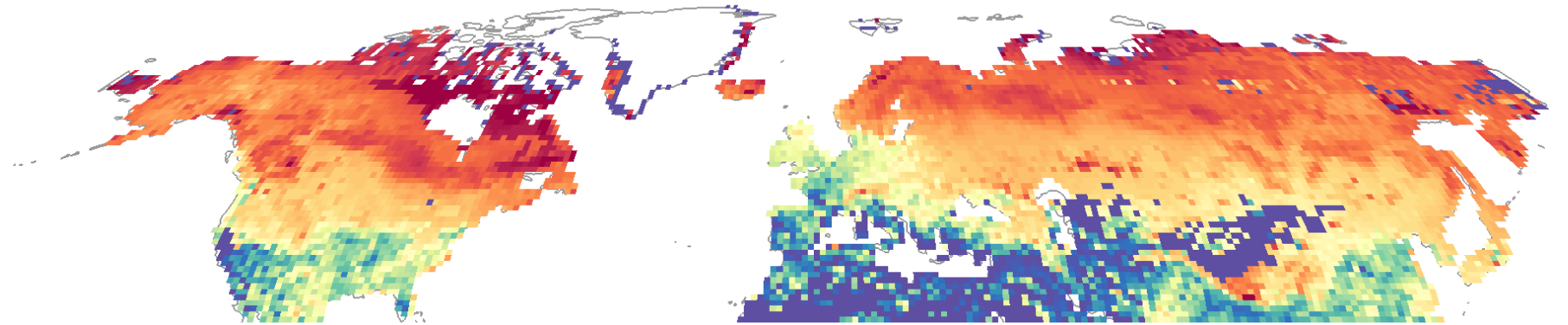
Results

Mean DOY when LAI reaches annual maximum value from MODIS and CLM, averaged between 2003-2016

MODIS LAI$_{max}$
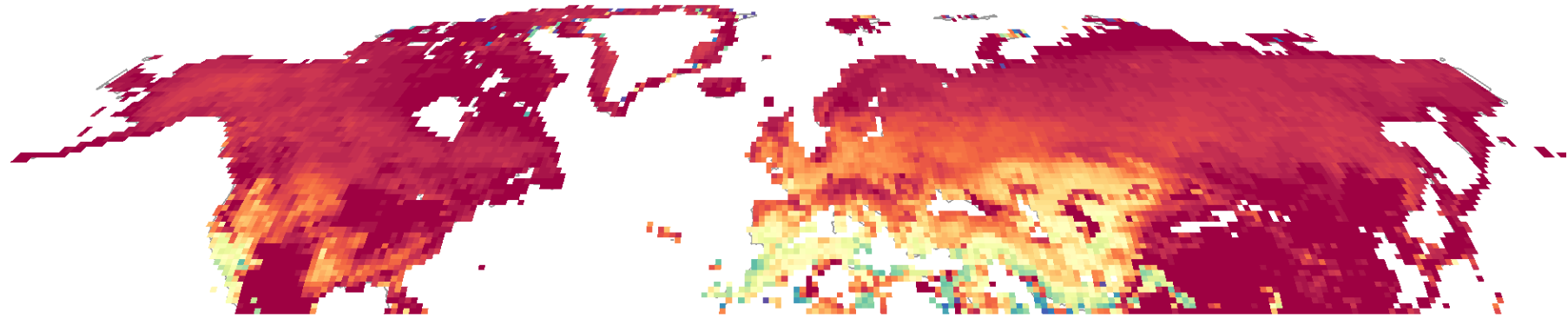
CLM LAI$_{max}$
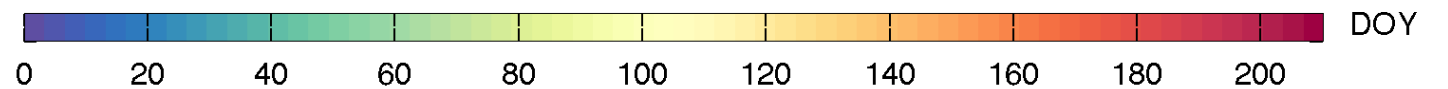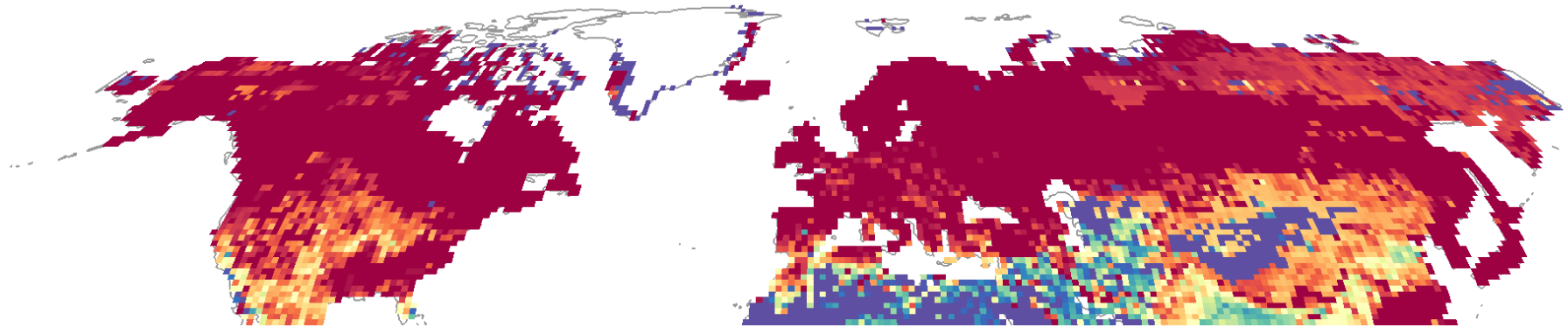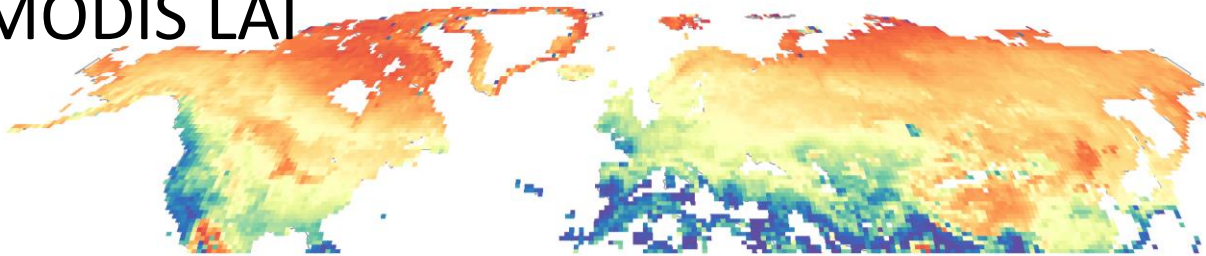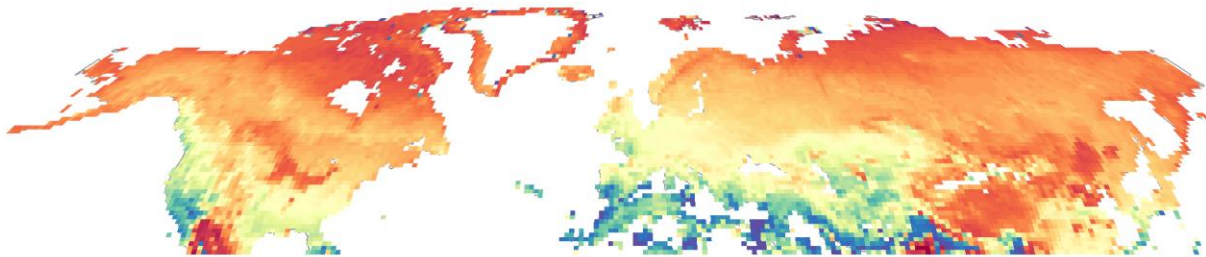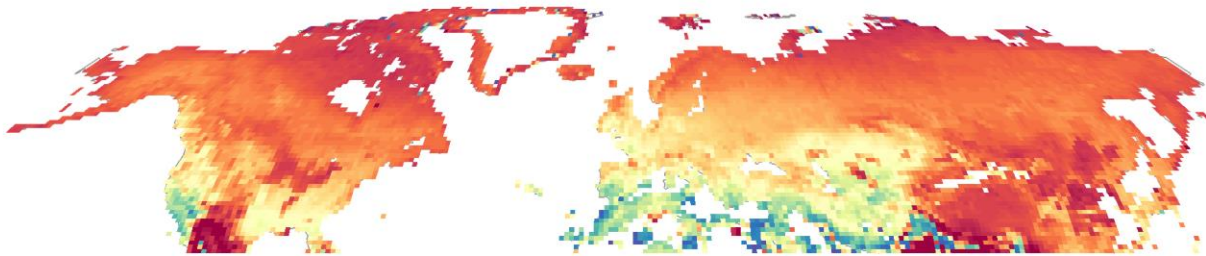
DOY

0   20   40   60   80   100   120   140   160   180   200

MODIS LAI

(a) 25% threshold

(b) 50% threshold

(c) 75% threshold

(d) 100% threshold

Days
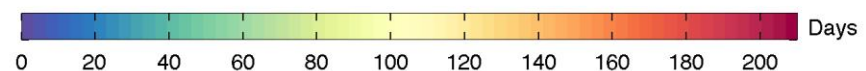
0 20 40 60 80 100 120 140 160 180 200

CLM LAI

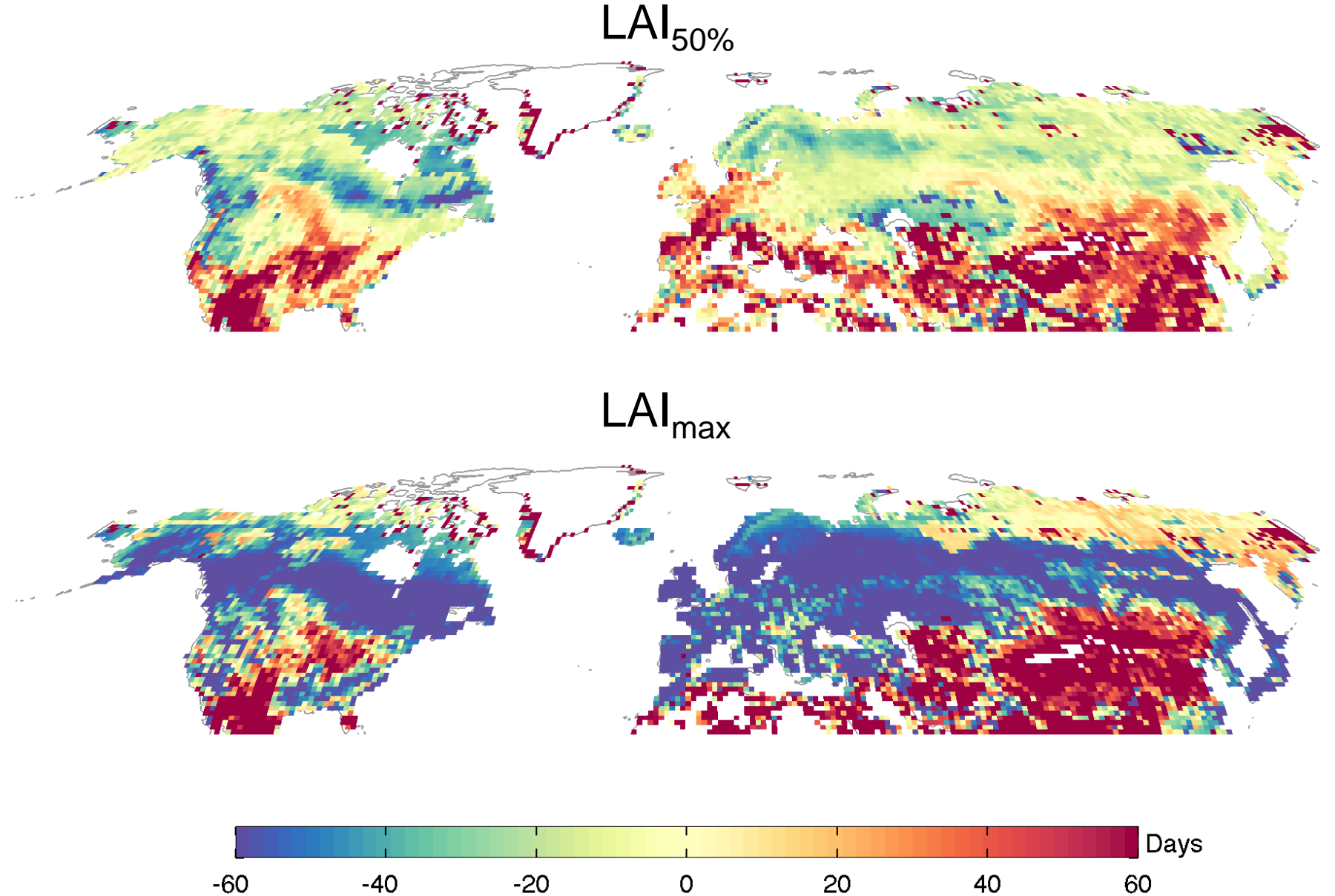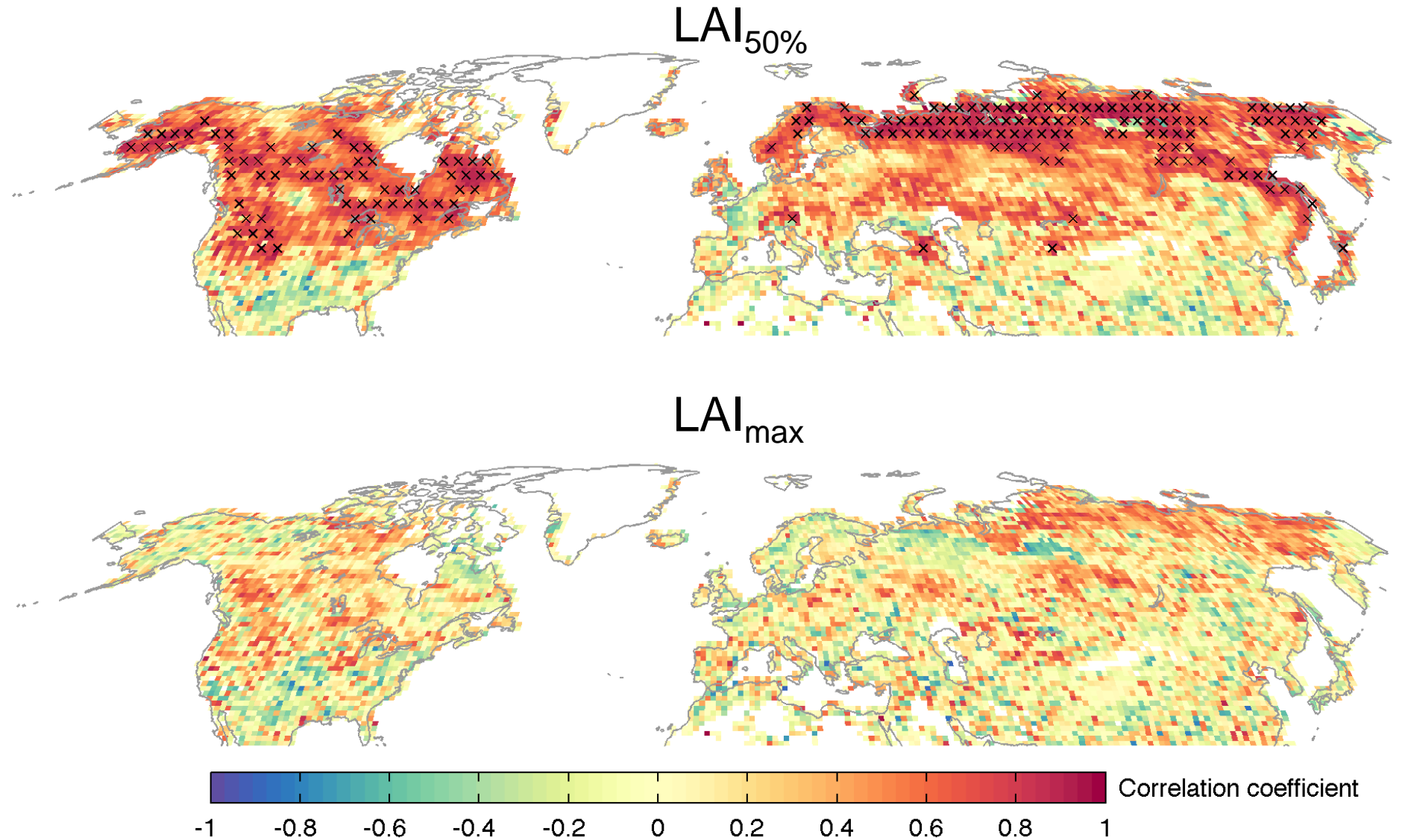(a) 25% threshold

(b) 50% threshold

(c) 75% threshold

(d) 100% threshold

Days

0 20 40 60 80 100 120 140 160 180 200
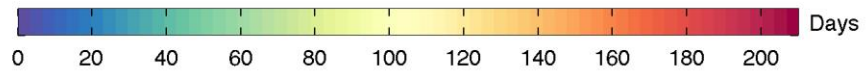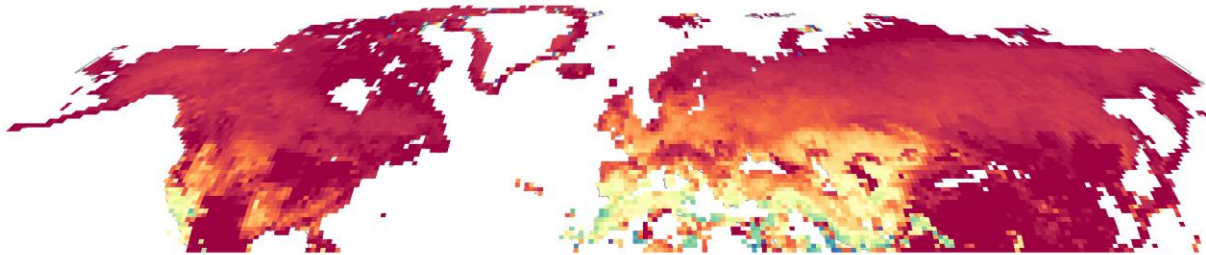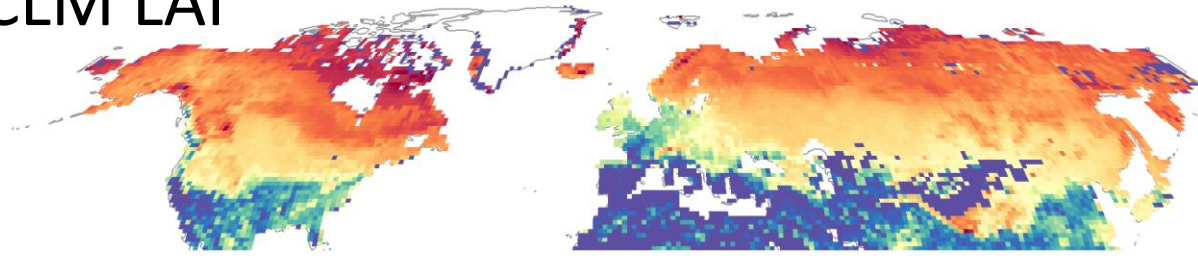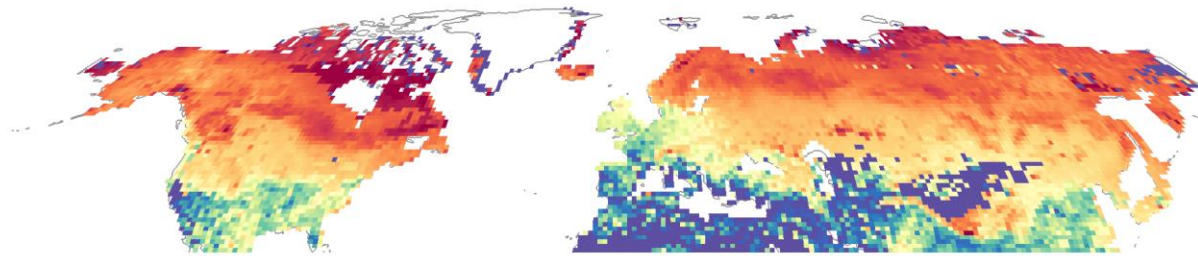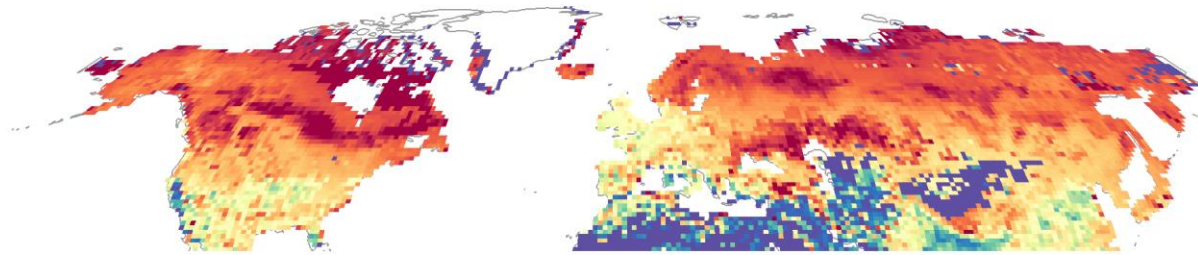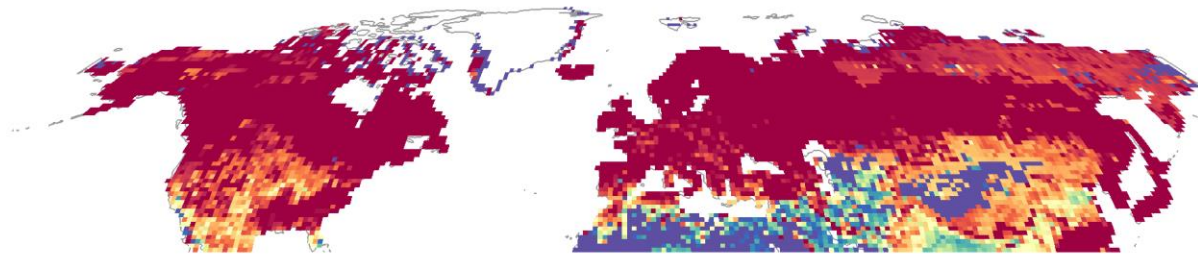
Results

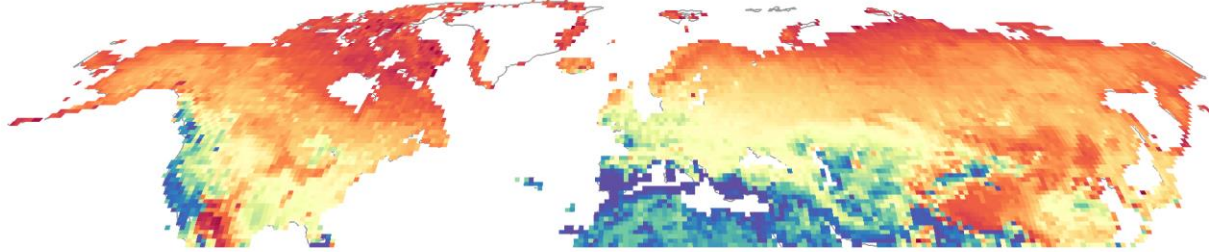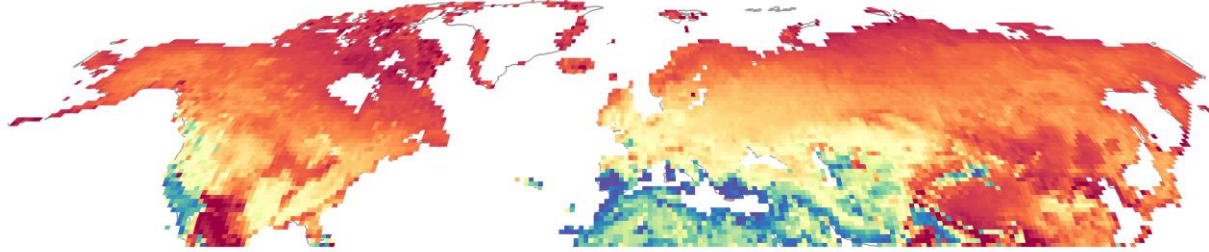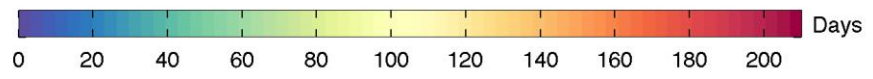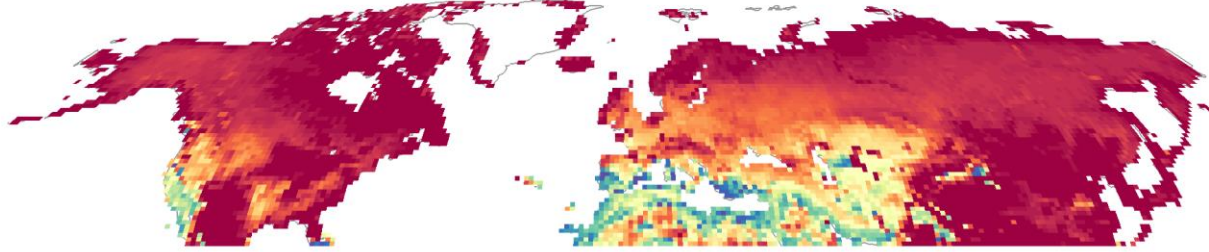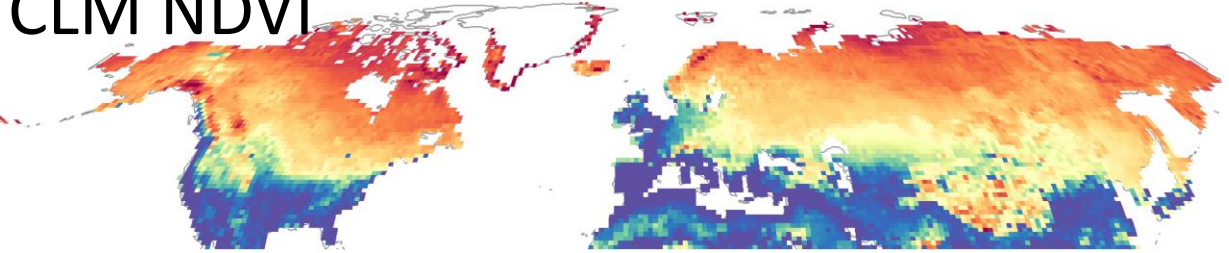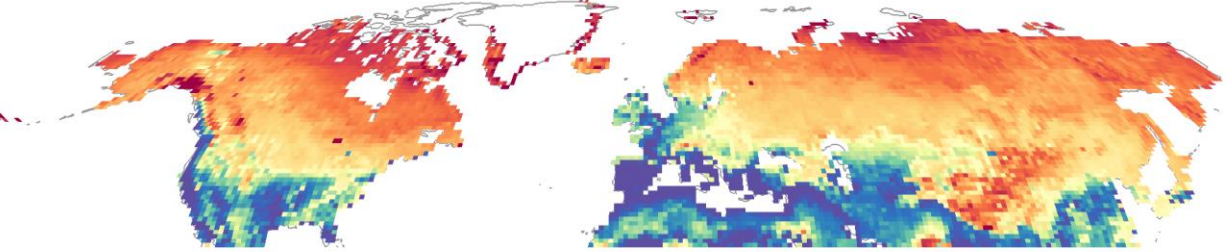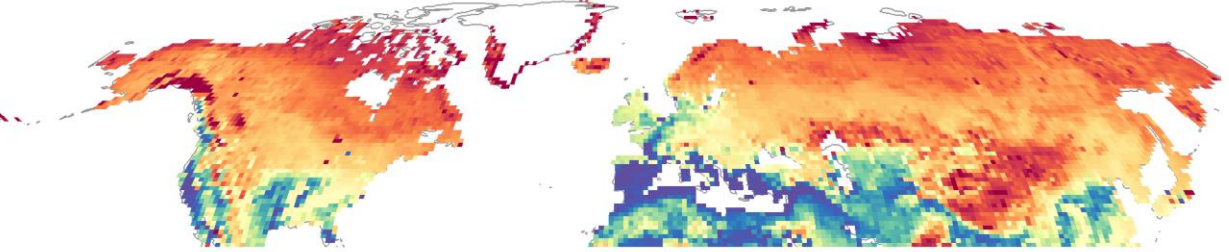Difference between mean DOY when LAI reaches each threshold (MODIS-CLM), averaged between 2003-2016

$LAI_{50\%}$

LAI_{max}

Days

Results

Correlations between CLM and MODIS LAI-based DOYs at each threshold during 2003-2016
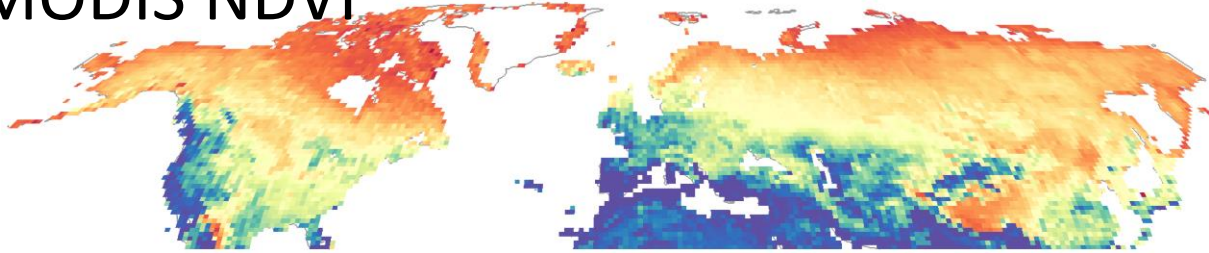
$LAI_{50\%}$

LAI_{max}

Correlation coefficient

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

MODIS NDVI

CLM NDVI

(a) 25% threshod
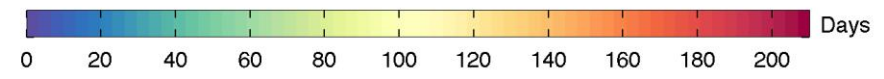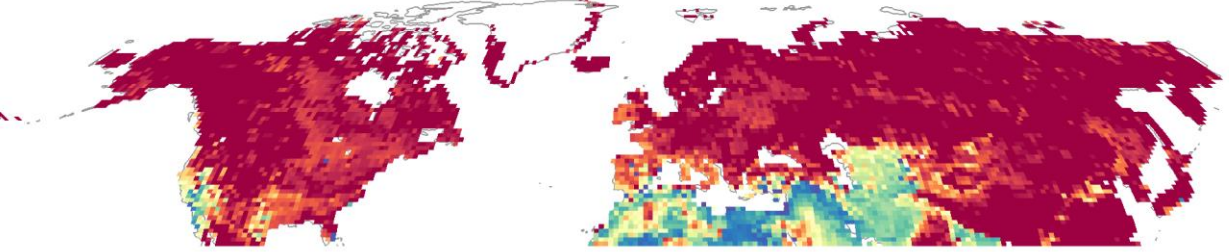
(a) 25% threshod

(b) 50% threshod

(b) 50% threshod

(c) 75% threshod

(c) 75% threshod

(d) 100% threshold

(d) 100% threshold

Days

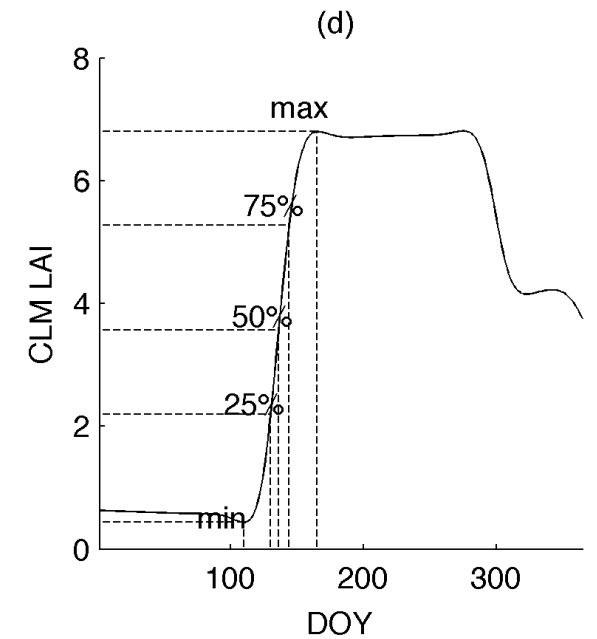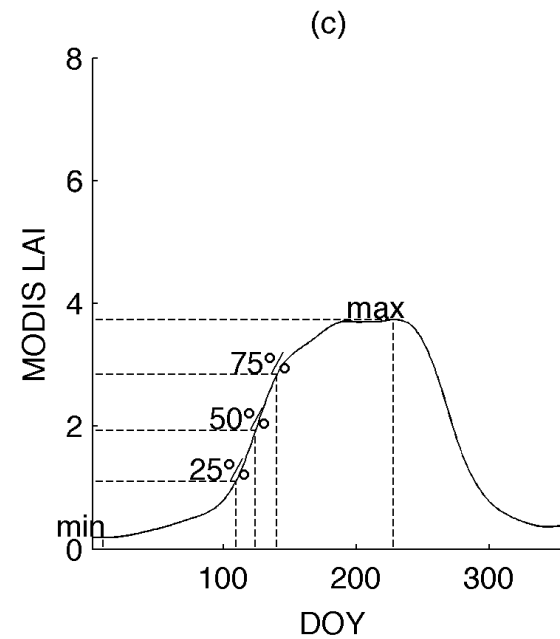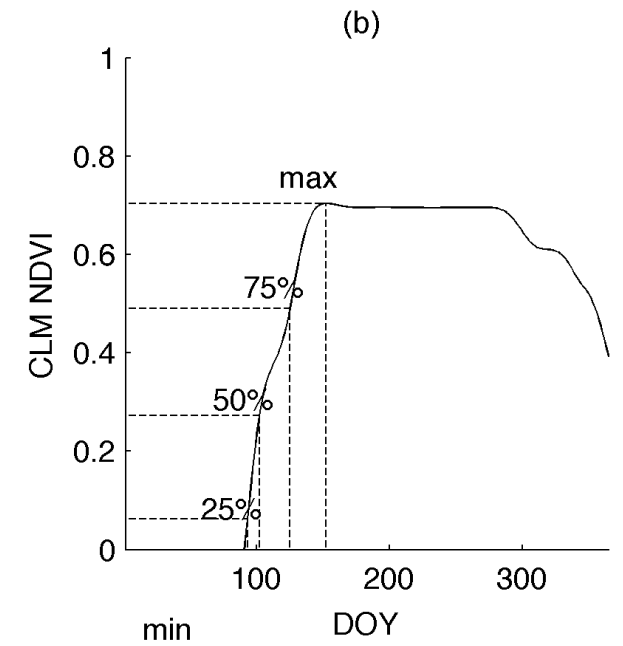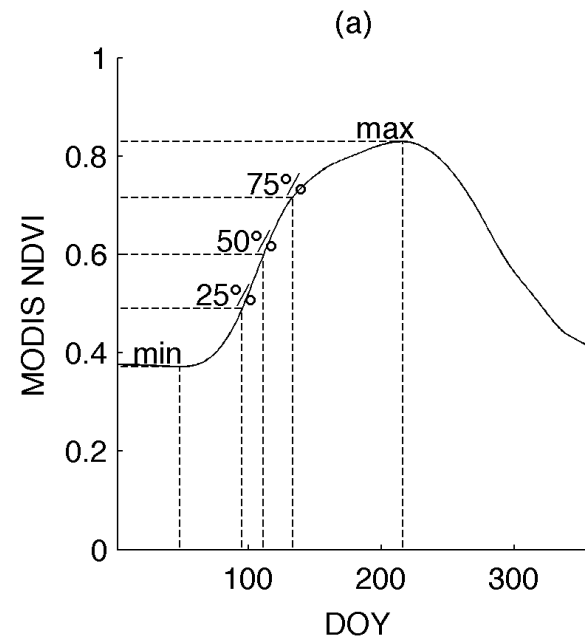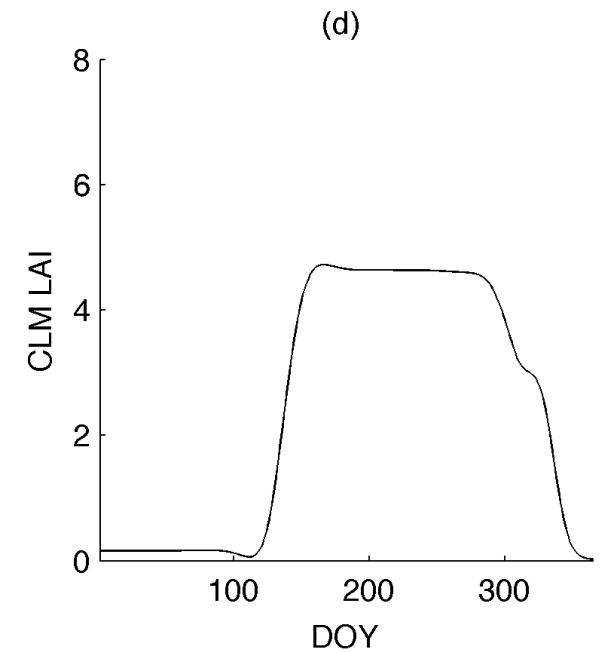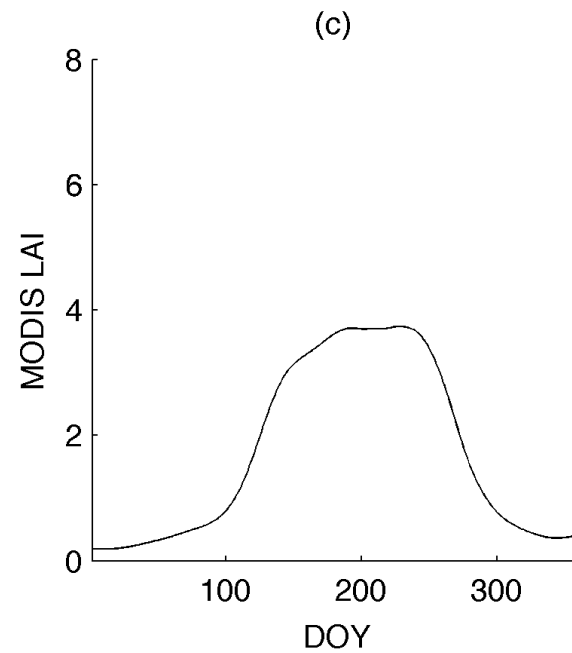Days
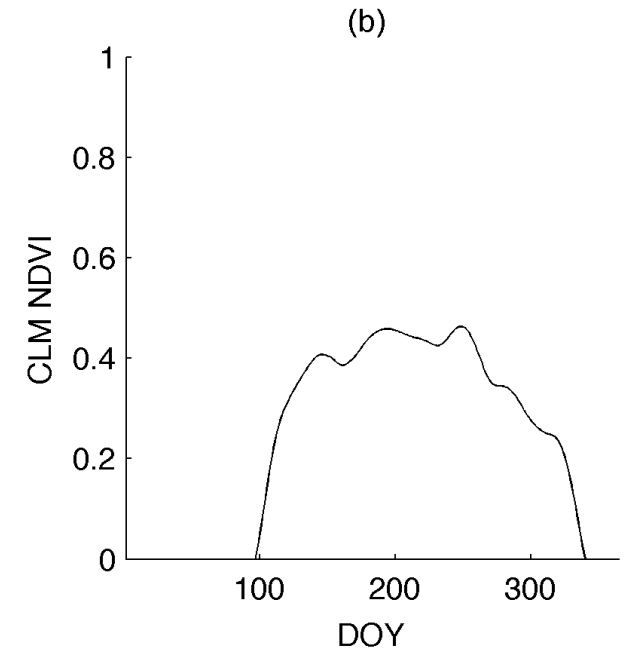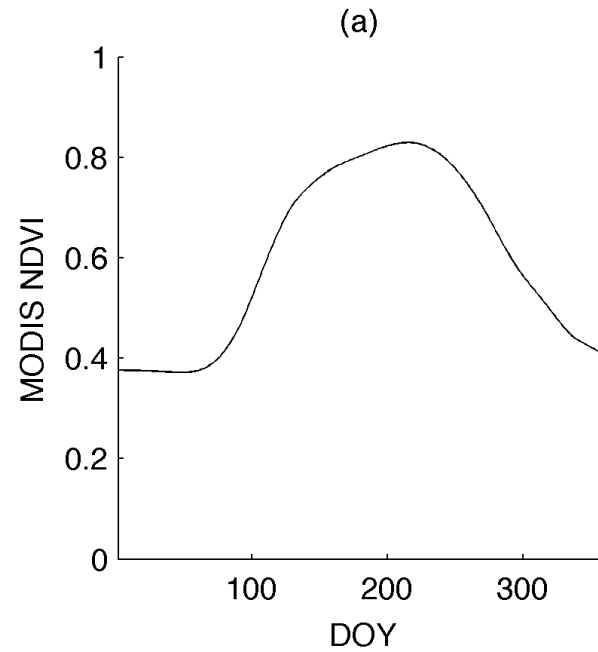
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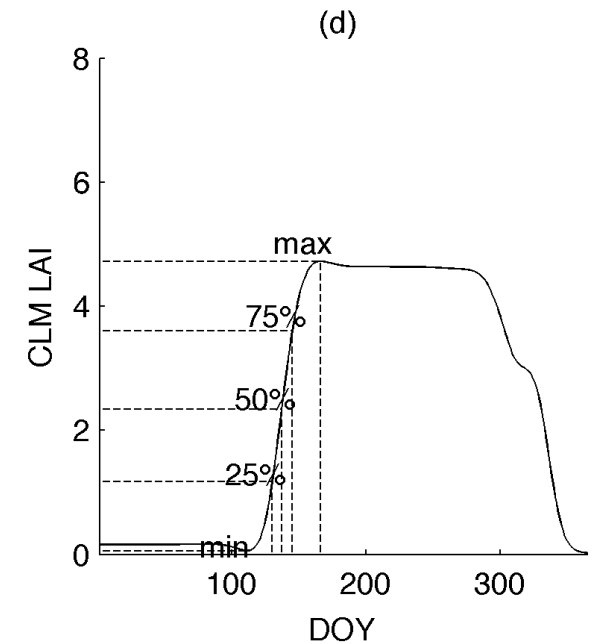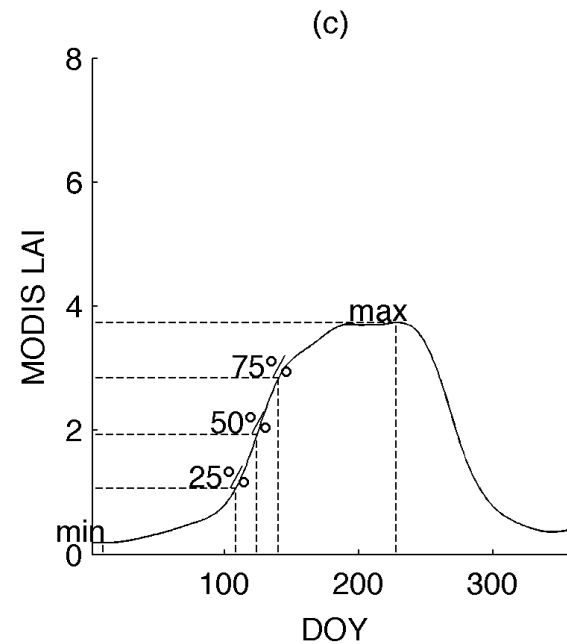
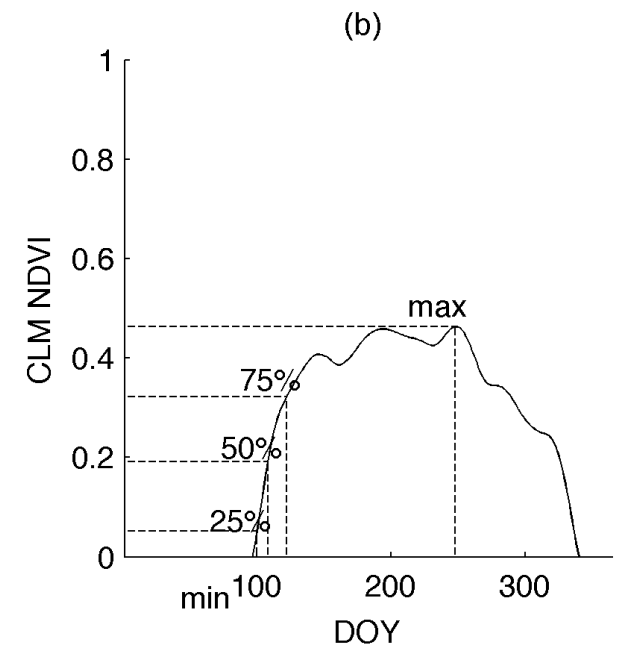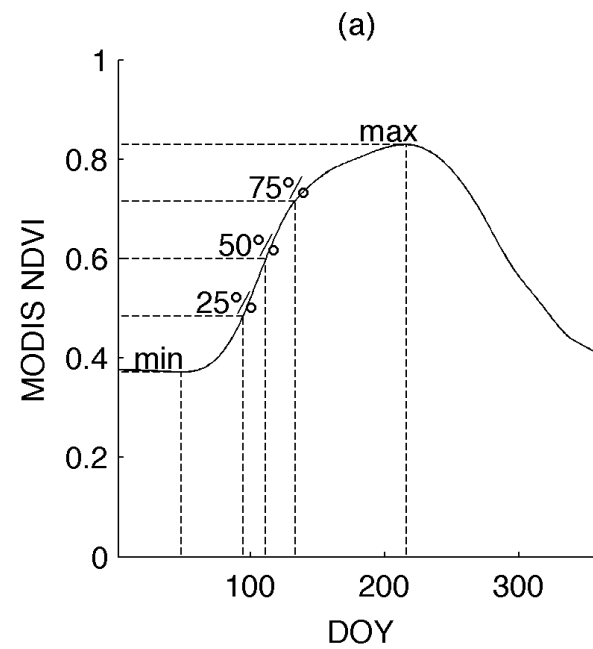# Defining spring onset CLM

Annual cycle of NDVI and LAI from MODIS and CLM4.5 (CRUNCEP) from a grid point near Ithaca (42.44°N, 76.5°W)

Defining spring onset in CLM

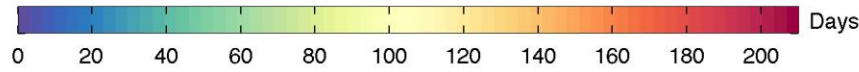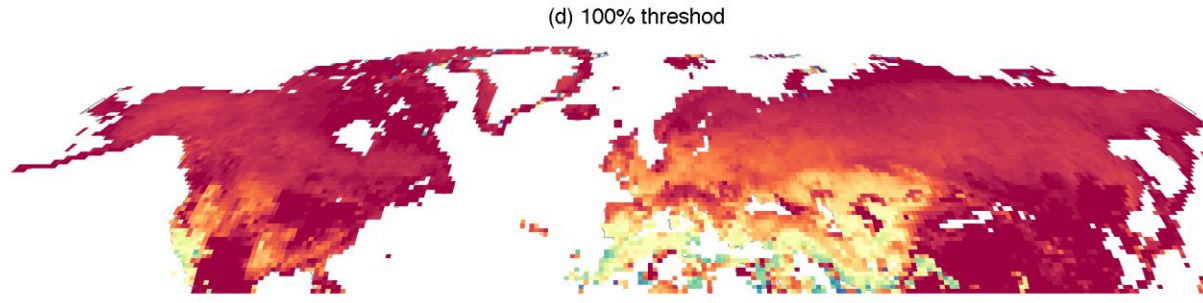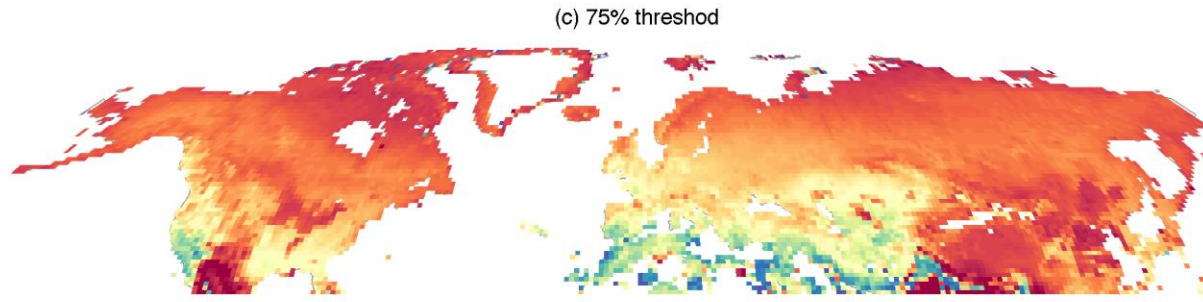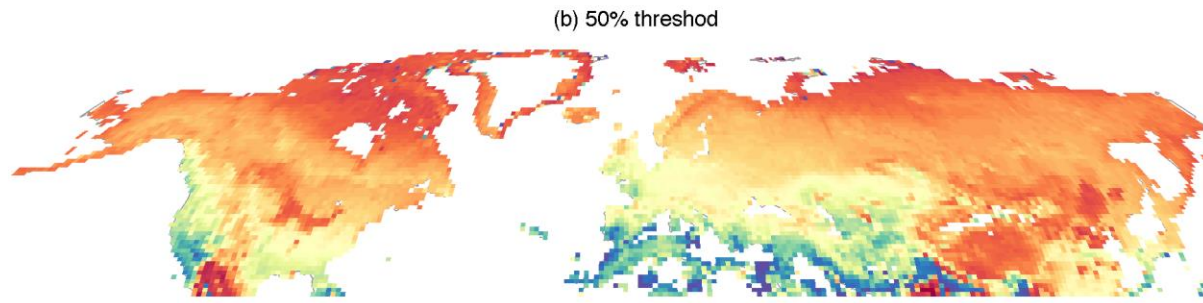Annual cycle of NDVI and LAI from MODIS and CLM5.0 (GSWP3) from a grid point near Ithaca (42.44°N, 76.5°W)

Defining spring onset in CLM
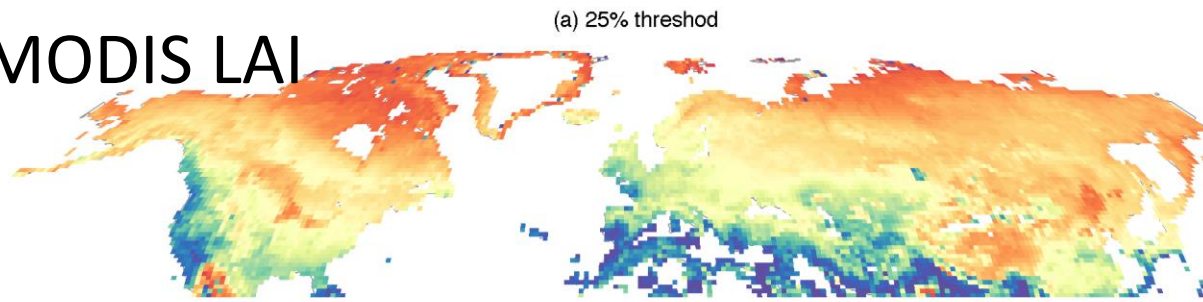

Annual cycle of NDVI and LAI from MODIS and CLM5.0 (GSWP3) from a grid point near Ithaca (42.44°N, 76.5°W)

MODIS LAI

CLM LAI

(a) 25% threshold
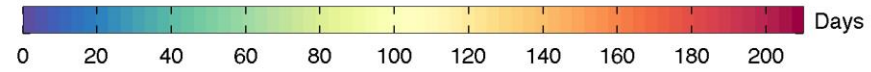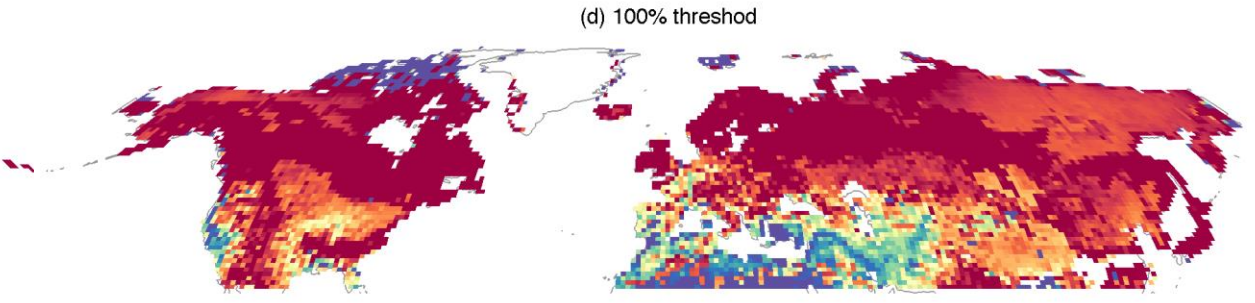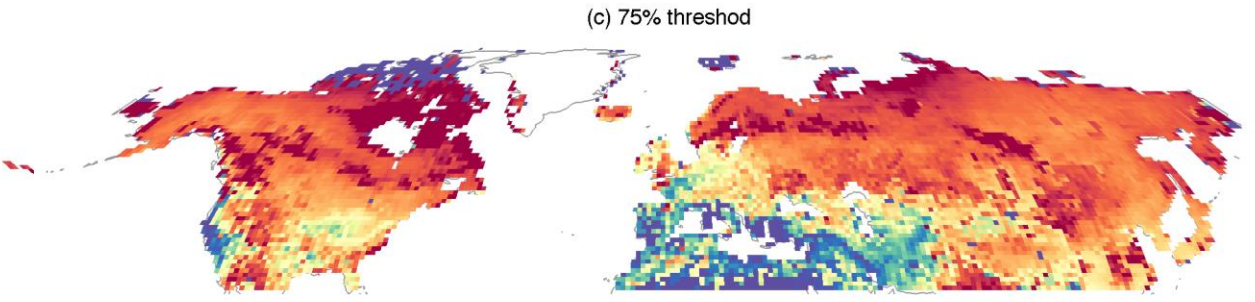
(b) 50% threshold

(c) 75% threshold

(d) 100% threshold

(a) 25% threshold

(b) 50% threshold

(c) 75% threshold

(d) 100% threshold

Days

0 20 40 60 80 100 120 140 160 180 200

Days

0 20 40 60 80 100 120 140 160 180 200
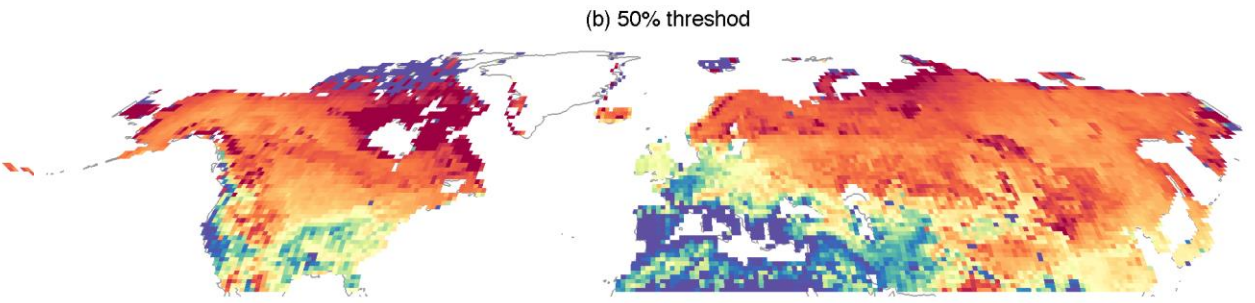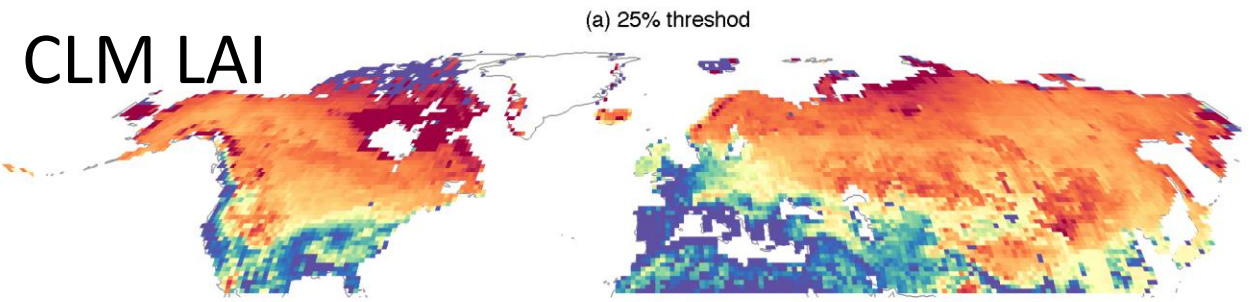
Difference between
mean DOY when LAI
reaches each threshold
(MODIS-CLM5.0),
averaged between
2003-2014

(a) 25% threshold

(b) 50% threshold

(c) 75% threshold

(d) 100% threshold

Days

-60   -40   -20   0   20   40   60
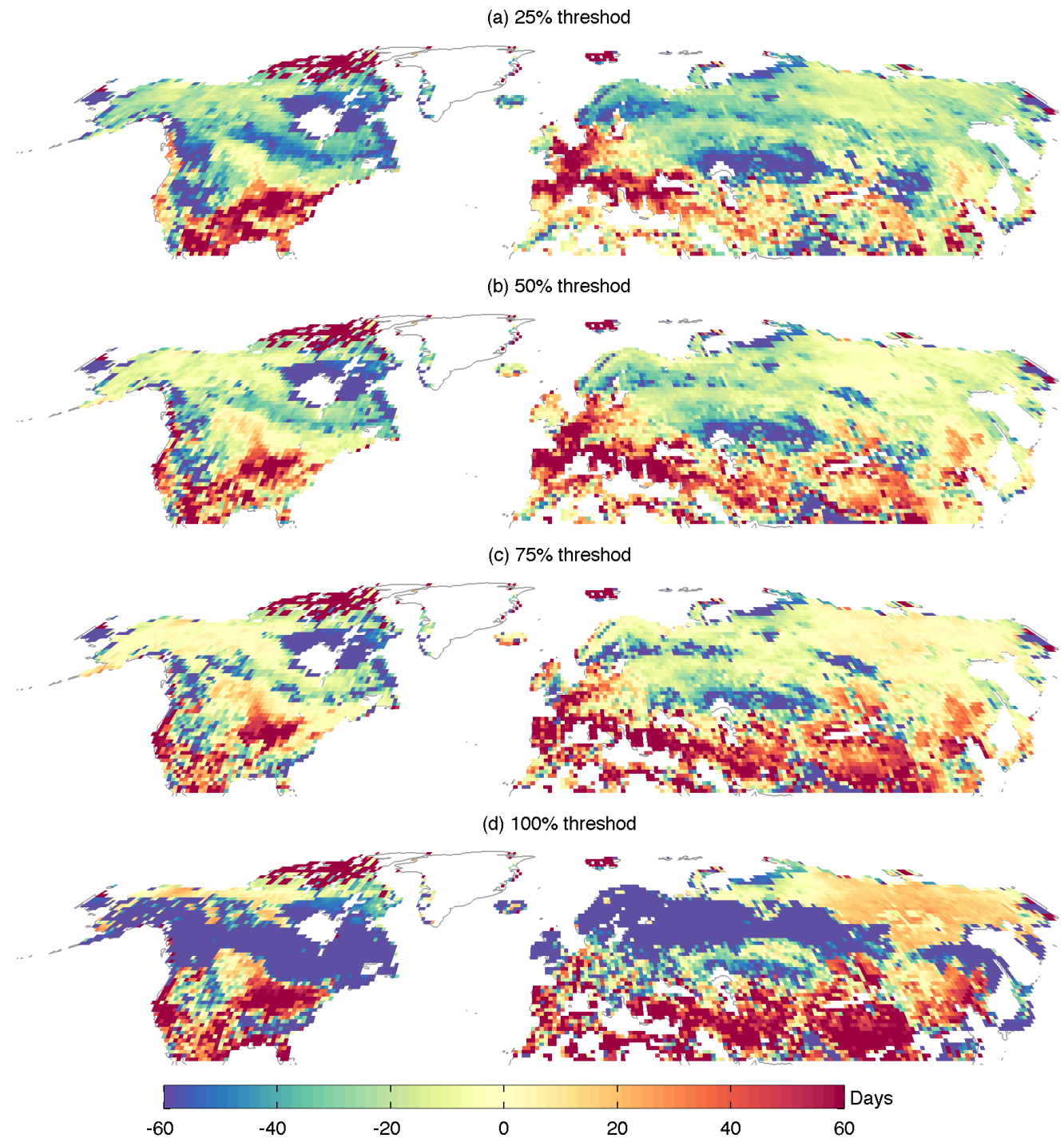
Correlations between CLM5.0 and MODIS LAI-based DOYs at each threshold during 2003-2014

(a) 25% threshod

(b) 50% threshod

(c) 75% threshod

(d) 100% threshold

Correlation coefficient

-1   -0.8   -0.6   -0.4   -0.2   0   0.2   0.4   0.6   0.8   1
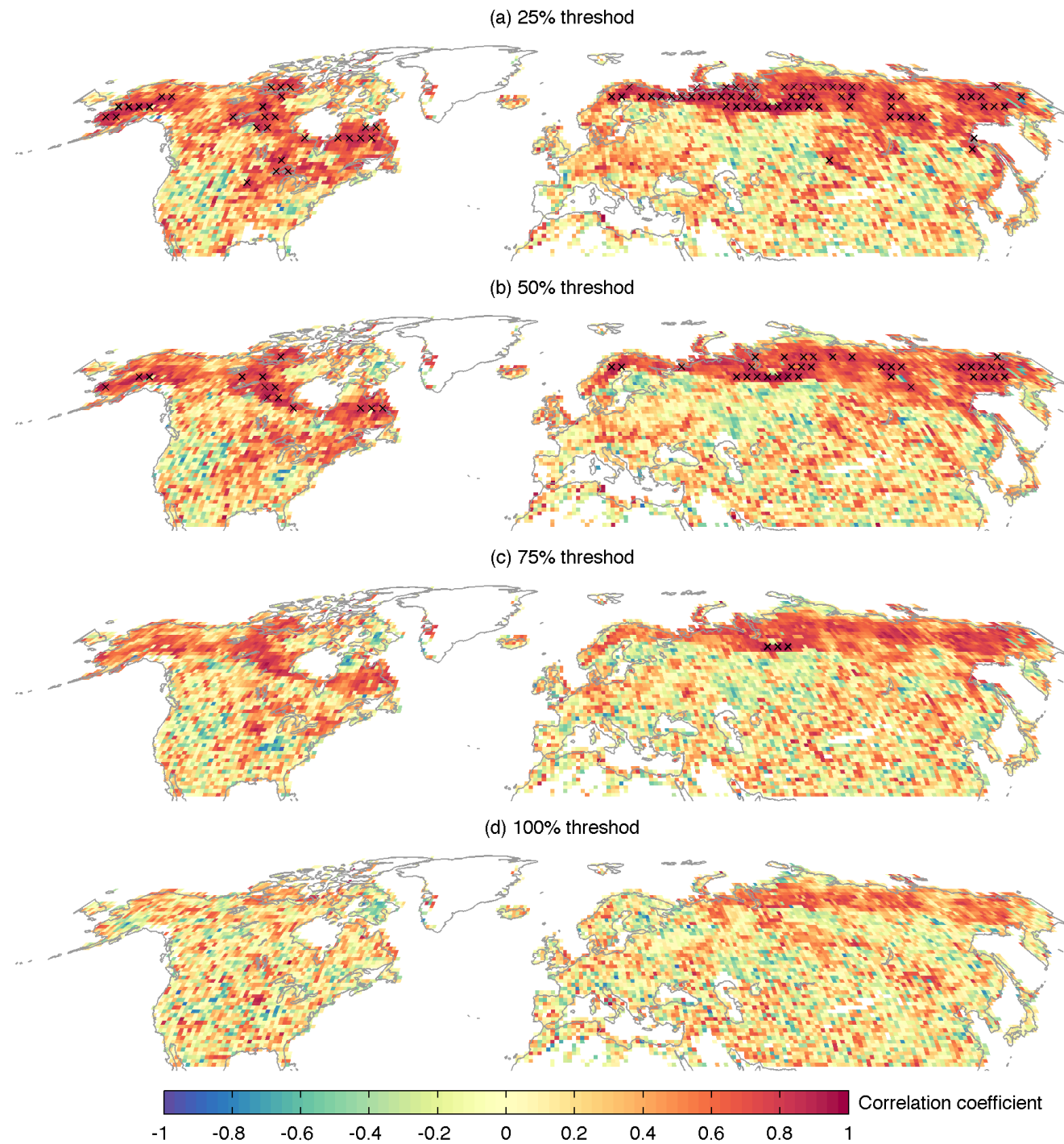
Conclusions and future work

- A new system for LSM diagnostics

- Results emphasize fundamental differences in phenology derived from these two state-of-the-art large scale products

- PFT, LSM phenology, etc.

Thank you!