Operational Multi-Source Imaging of Land Surface Phenology

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Land Surface Phenology

- Indicator of how climate change is impacting terrestrial ecosystems
- Driver of carbon uptake by vegetation
- Provides information on land use
  - Natural vs managed systems
  - Crop type discrimination

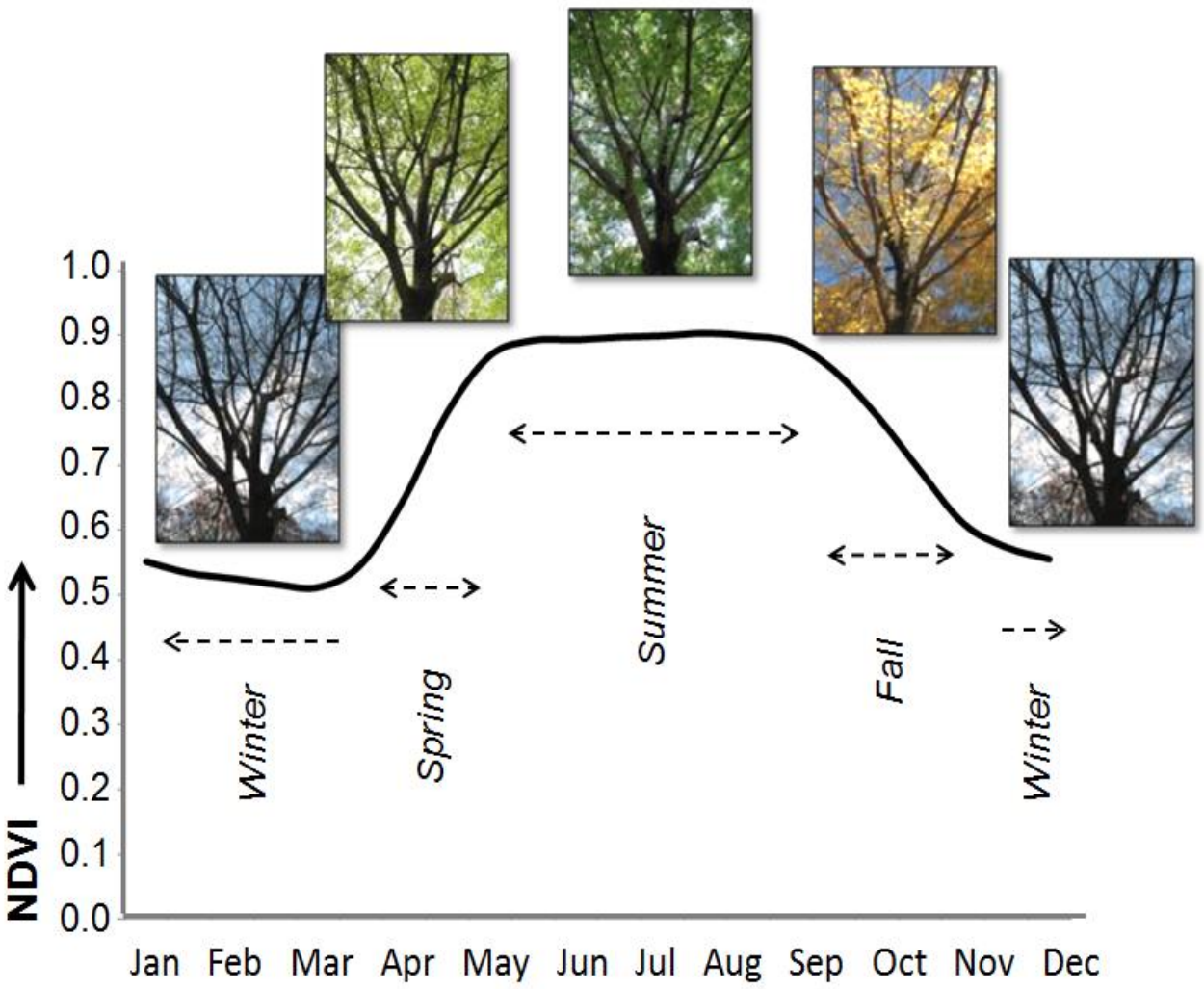
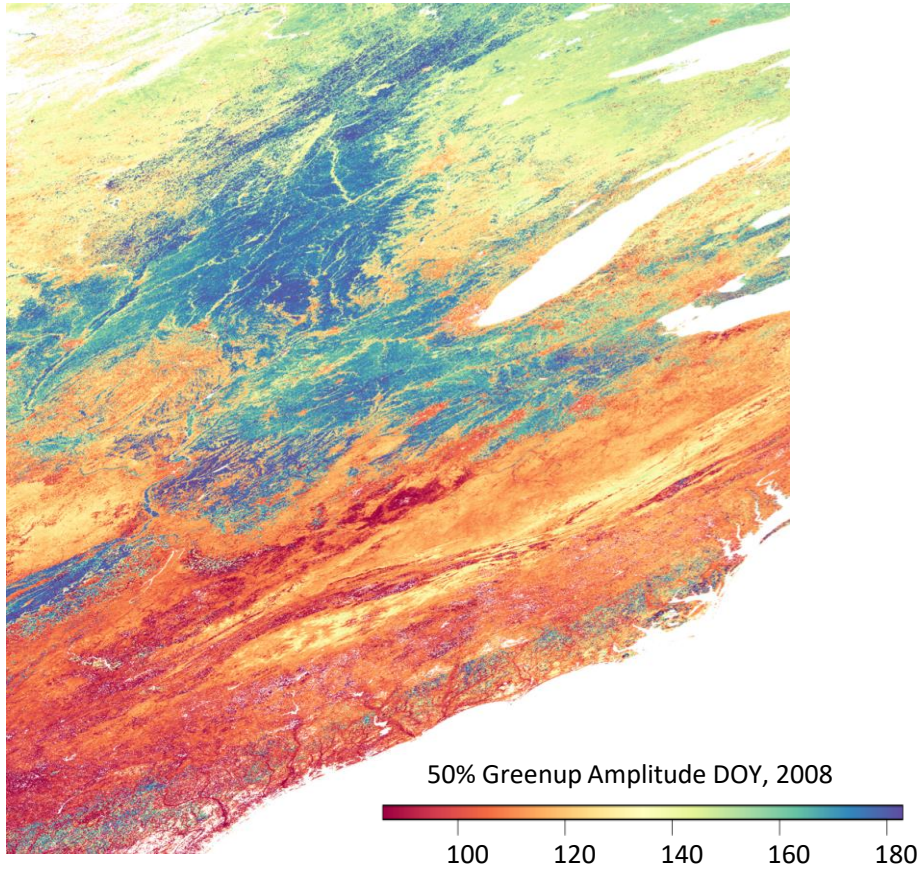


image credit: Bill Hargrove (ForWarn)

Remote Sensing of Phenology

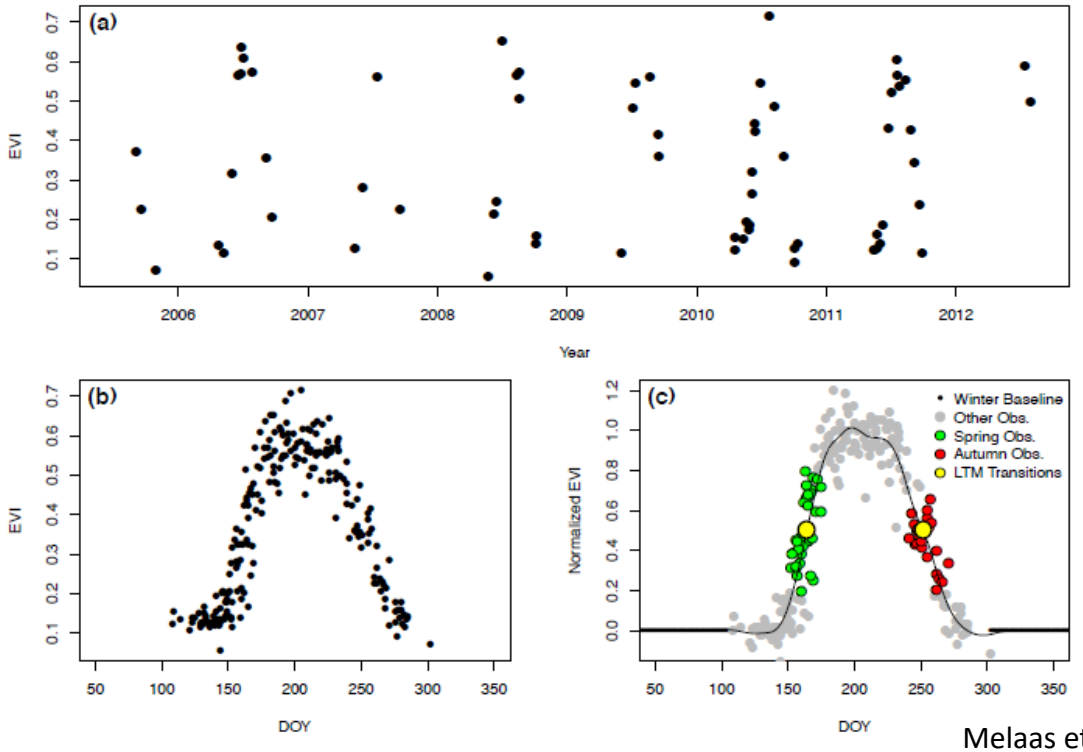
MODIS

Phenology at coarse resolution (500m)



Landsat

Data density too low to assess individual years



Melaas et al 2016

*This example is in a Landsat sidelap (double data density)

Harmonized Landsat Sentinel (HLS)

Three satellites

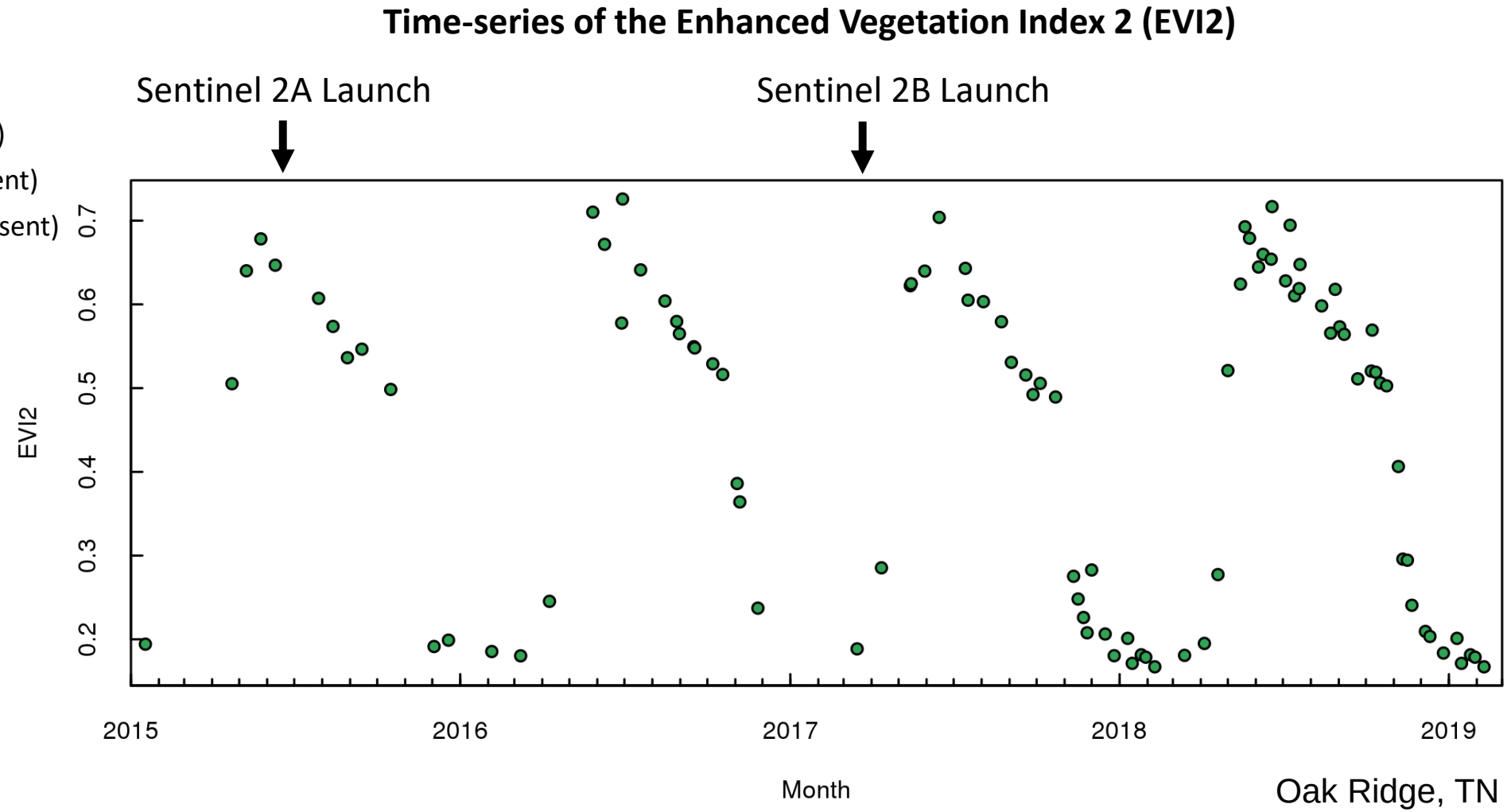
- Landsat 8 (Feb 2013-Present)
- Sentinel 2A (June 2015-Present)
- Sentinel 2B (March 2017-Present)

High temporal resolution

- 2-3 day revisit time at 30m spatial resolution

Analysis ready

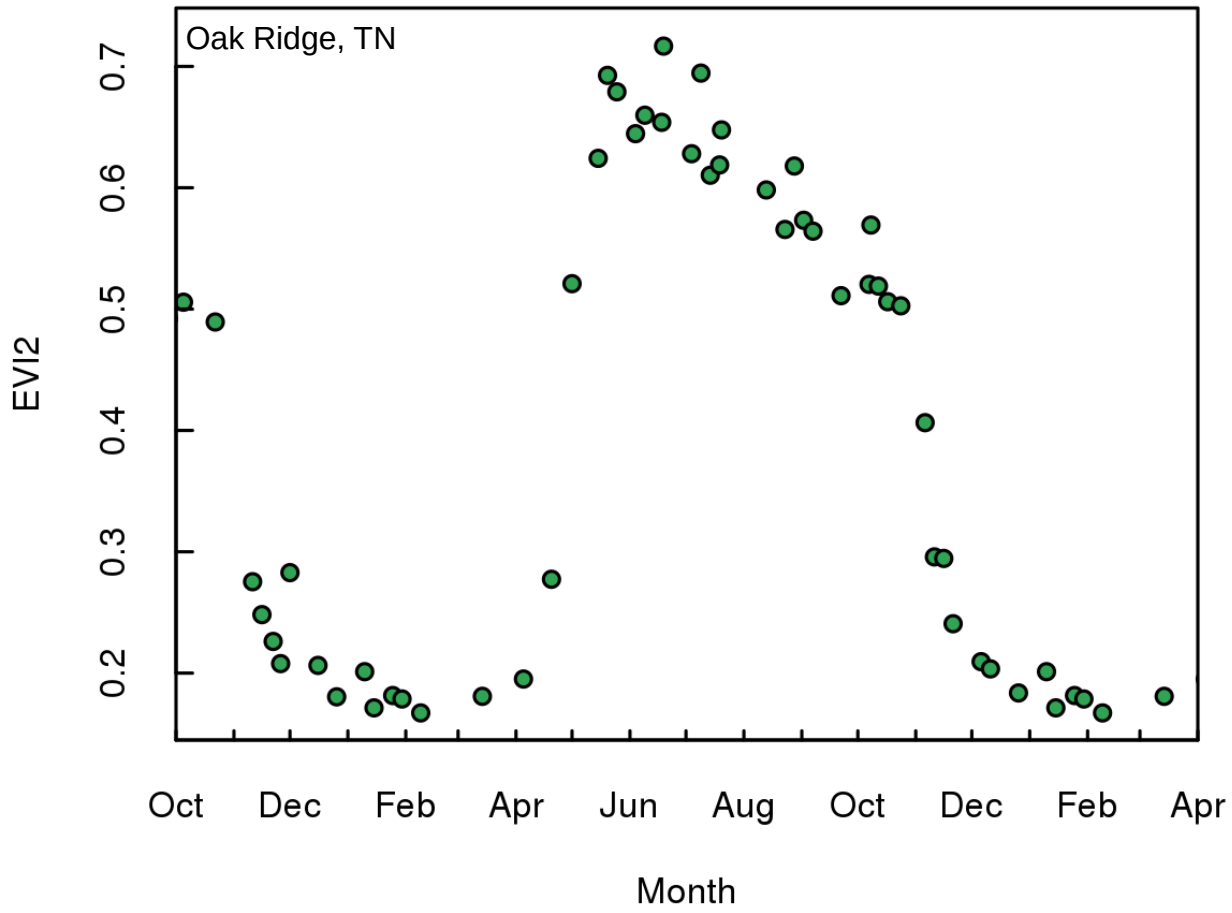
- Cloud/shadow mask
- Atmospheric correction
- BRDF normalized
- Band pass adjustment



Multisource Land Surface Phenology (MS-LSP)

- Fit smoothing splines on an annual basis
- Detect time-series peaks
- Determine greenup and greendown periods by identifying time-series troughs
- Identify phenology dates during greenup and greendown

Time-series of the Enhanced Vegetation Index 2 (EVI2)



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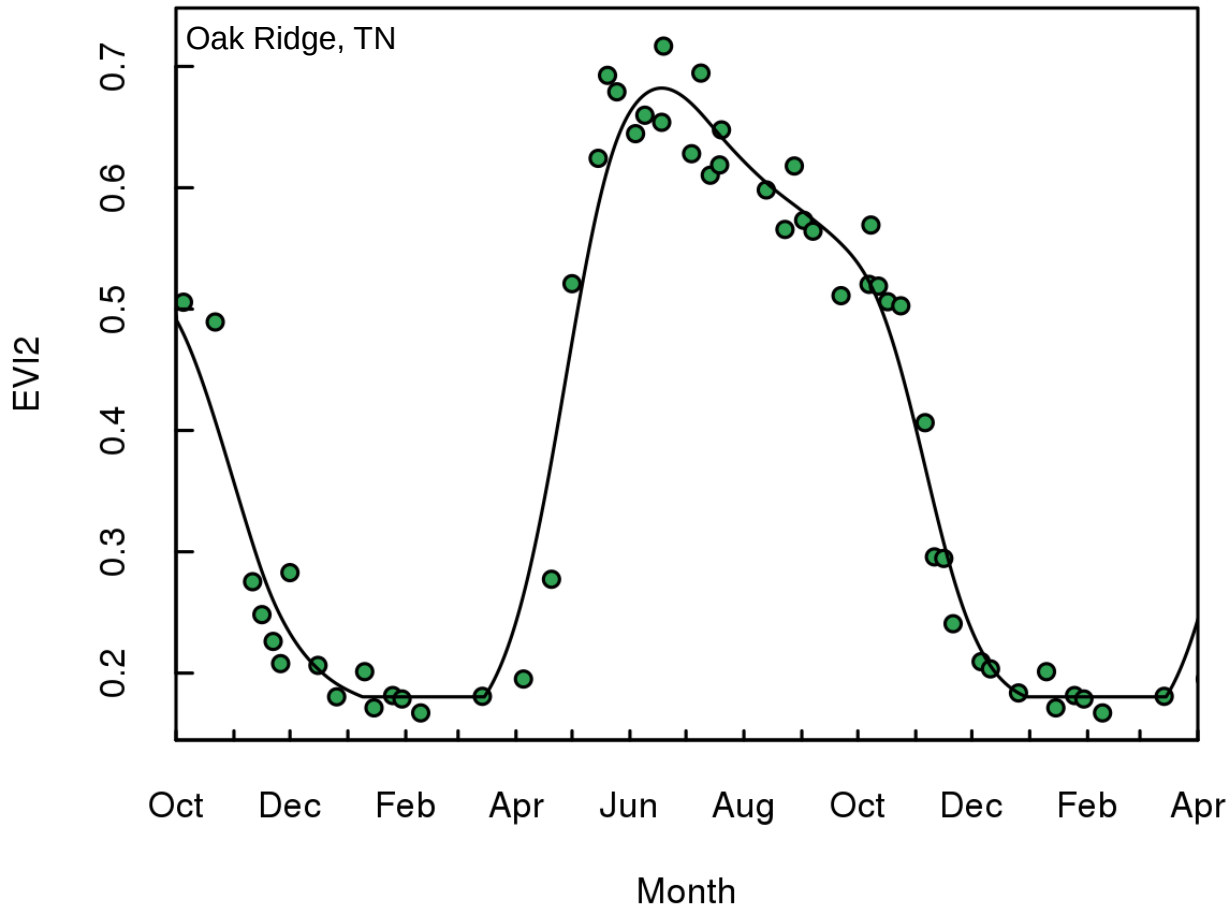

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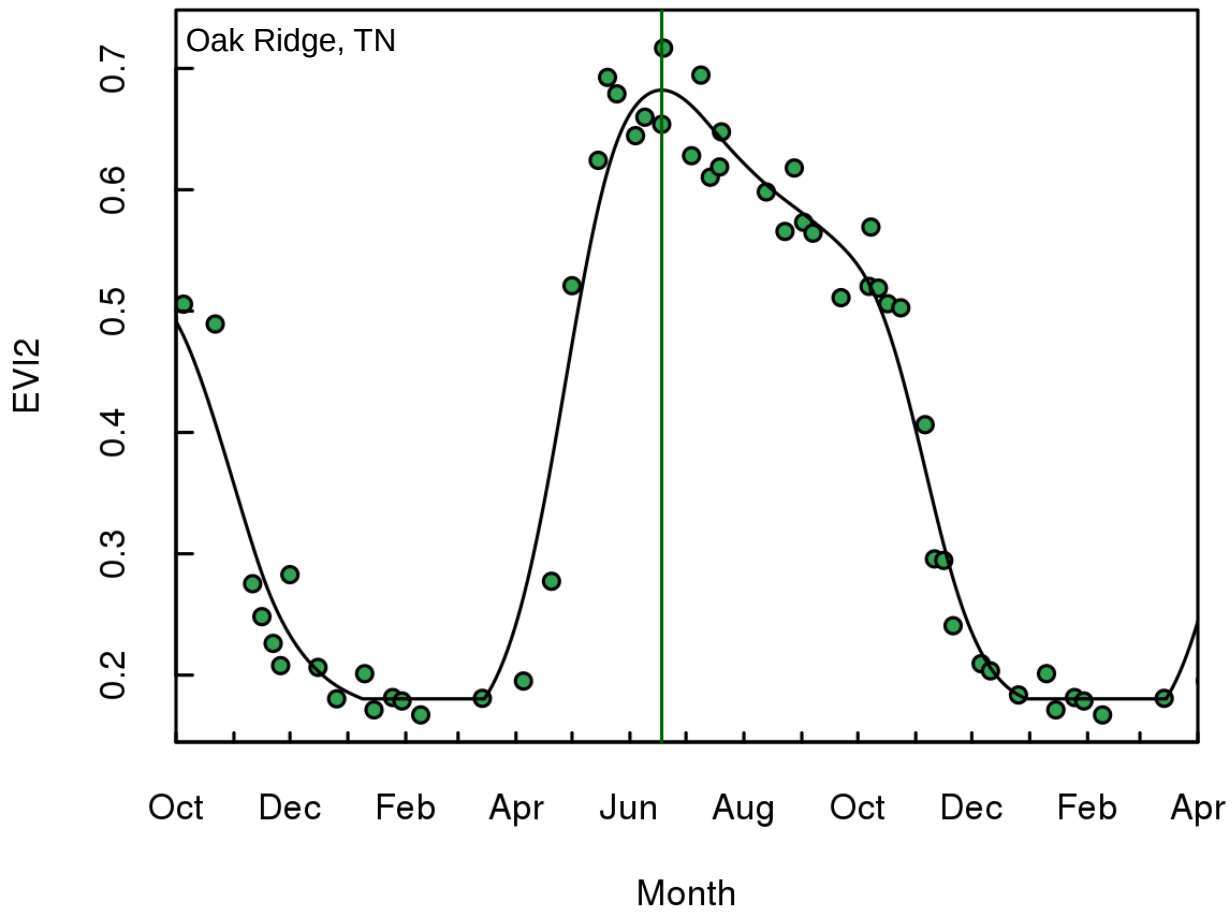

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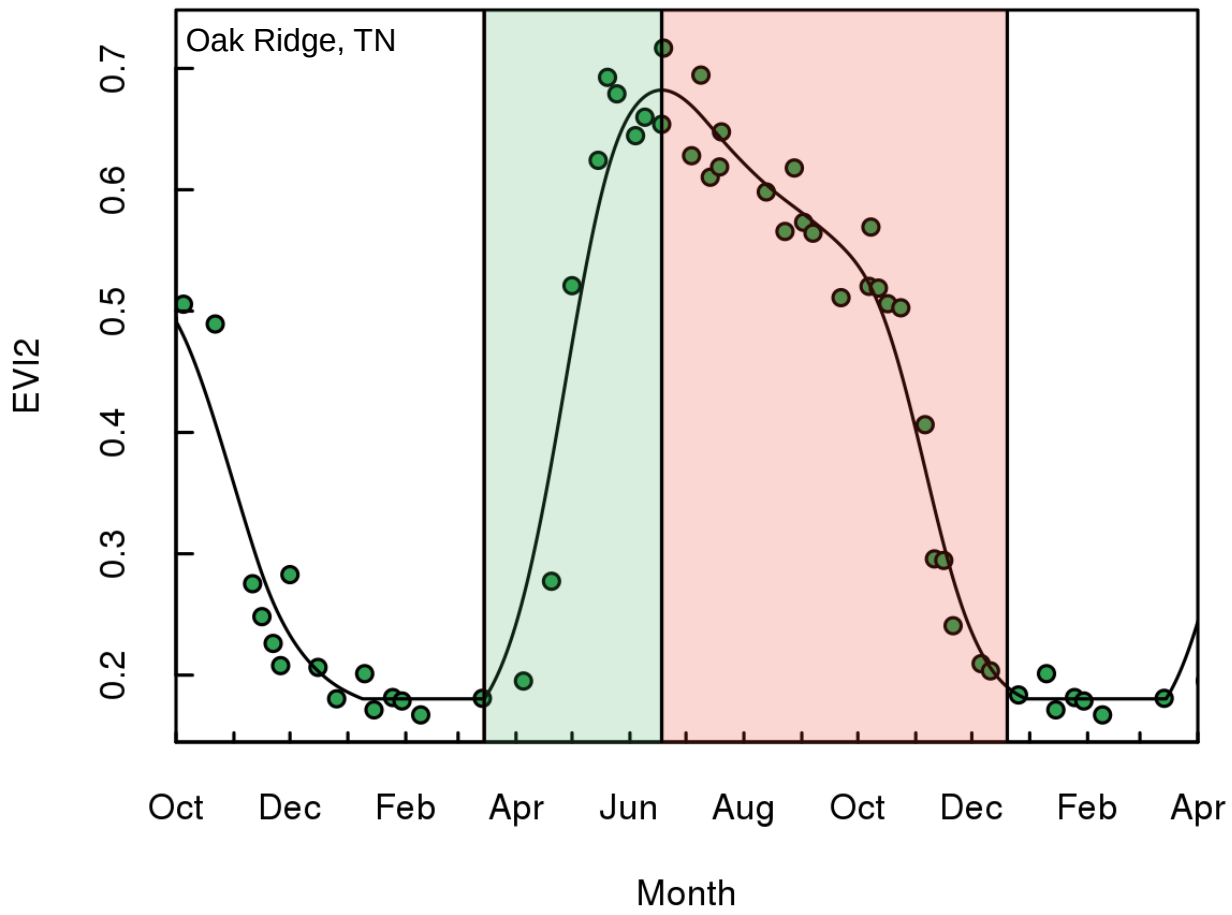

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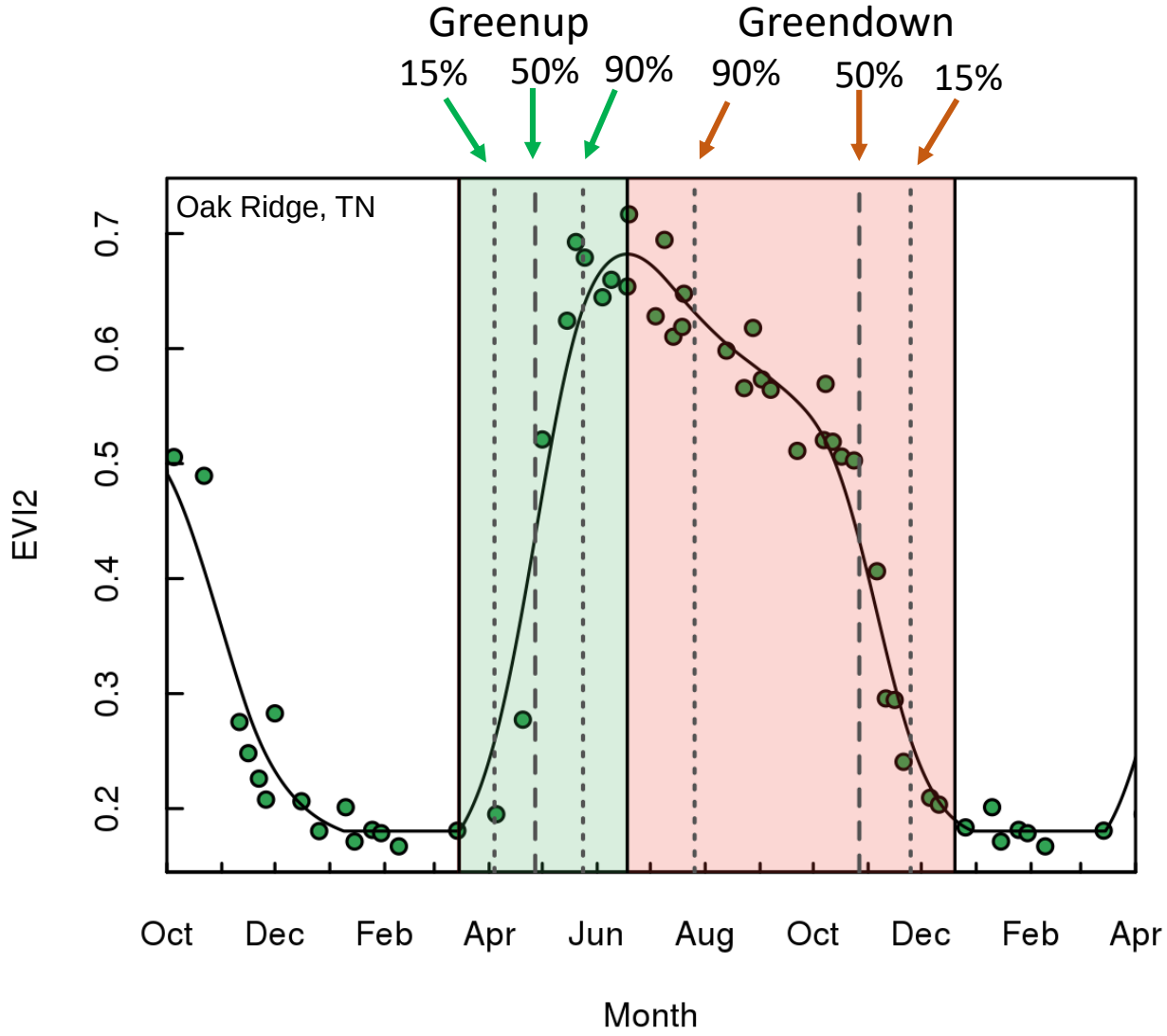
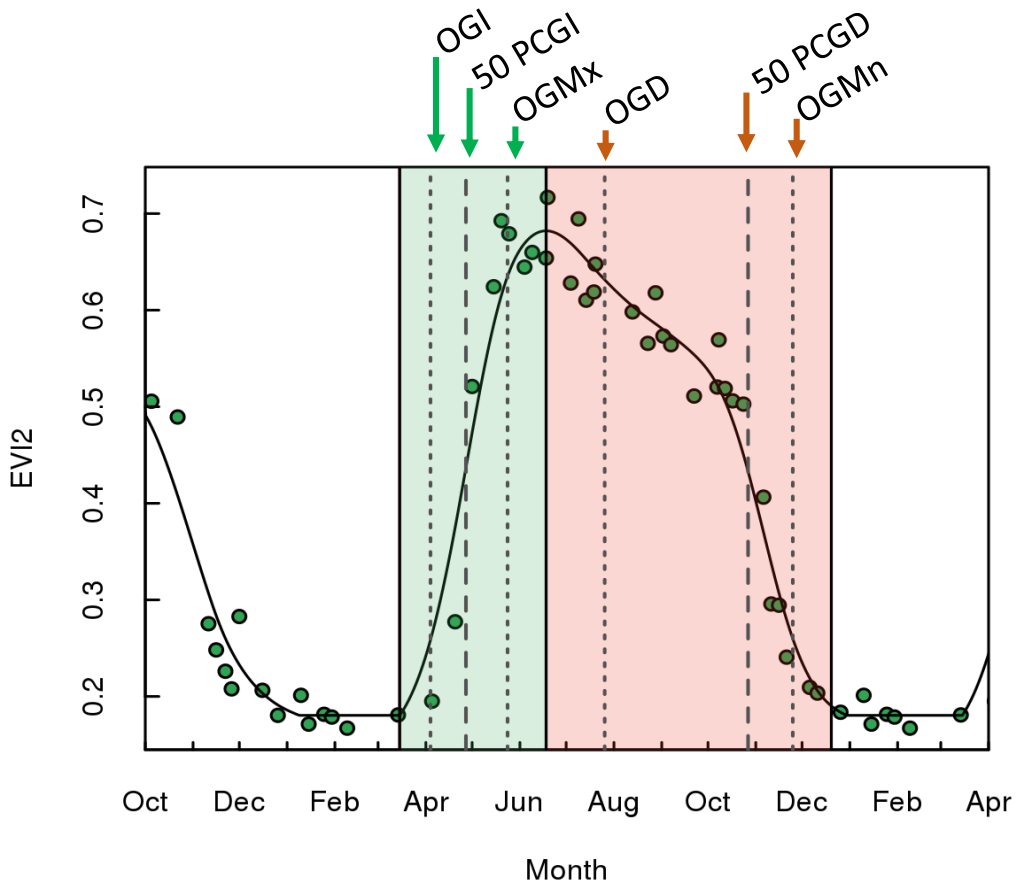
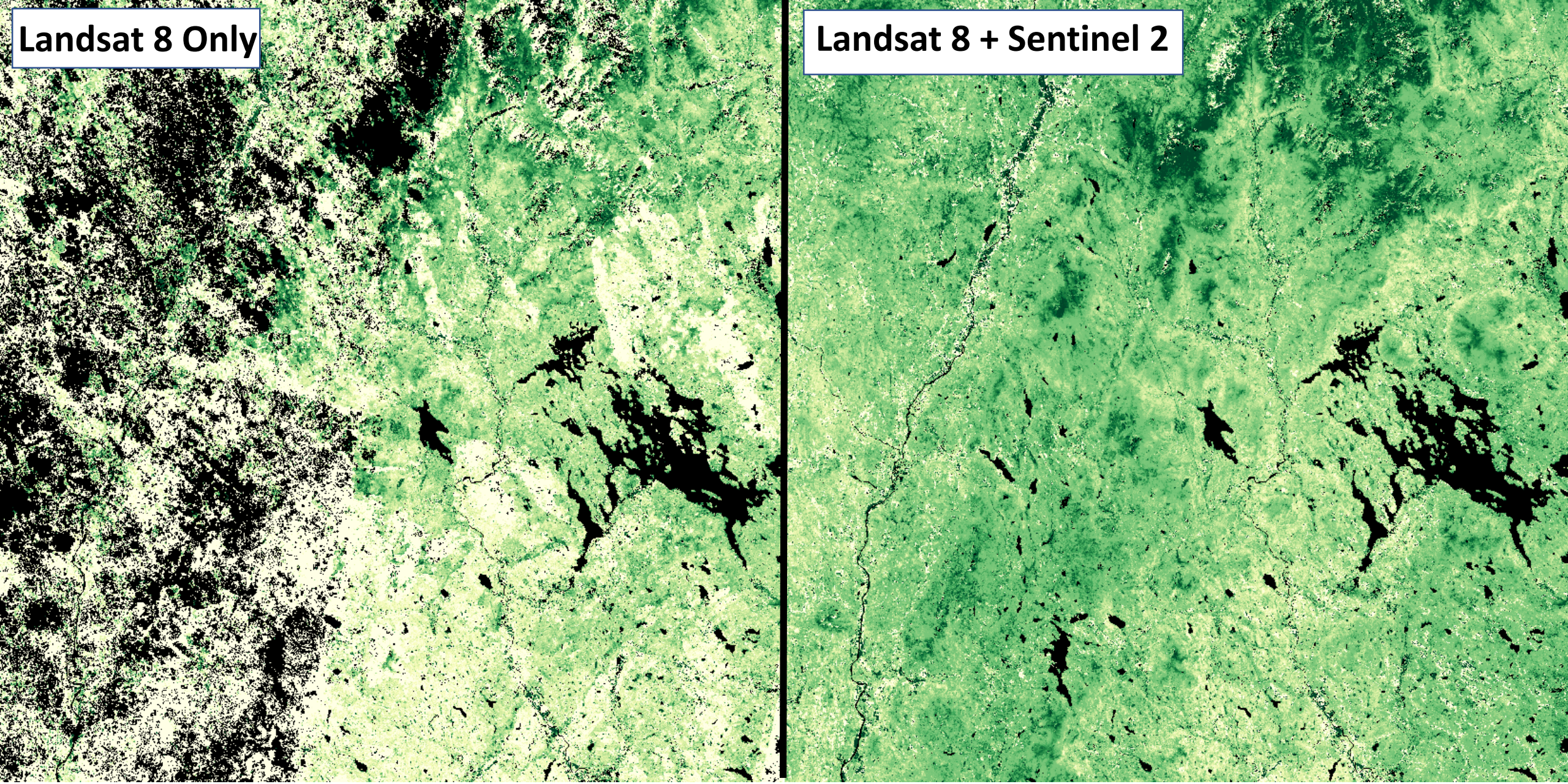


Multisource Land Surface Phenology (MS-LSP)

Distributed via LP-DAAC



Phenological Timing Metrics	
Onset Greenness Increase (OGI)	Date, number of days from Reference Date
50 Percent Greenness Increase (50PCGI)	Date, number of days from Reference Date
Onset Greenness Maximum (OGMx)	Date, number of days from Reference Date
Onset Greenness Decrease (OGD)	Date, number of days from Reference Date
50 Percent Greenness Decrease (50PCGD)	Date, number of days from Reference Date
Onset Greenness Minimum (OGMn)	Date, number of days from Reference Date
Integrated Greenness	Sum of daily EVI during growing season
HLS Reflectance Metrics	
HLS Reflectance on OGI Date	Bands 1-6 HLS surface reflectance on OGI date
HLS Reflectance on 50PCGI Date	Bands 1-6 HLS surface reflectance on 50PCGI date
HLS Reflectance on OGMx Date	Bands 1-6 HLS surface reflectance on OGMx date
HLS Reflectance on OGD Date	Bands 1-6 HLS surface reflectance on OGD date
HLS Reflectance on 50PCGD Date	Bands 1-6 HLS surface reflectance on 50PCGD date
HLS Reflectance on OGMn Date	Bands 1-6 HLS surface reflectance on OGMn date
LSP Mean and Anomaly Metrics	
Long Term Weekly Mean EVI	Average EVI across available years, at 7-day time steps; Available in 2019.
Weekly EVI Anomaly	In-season anomaly in EVI, relative to long-term mean, at 7-day time steps; Available in 2019.
Cumulative EVI Growing Season Anomaly	Sum of anomalies in daily interpolated EVI versus long-term mean at each pixel; Available in 2019.


Landsat 8 Only
Landsat 8 + Sentinel 2
Hubbard Brook, NH
50% Greenup (Day Of Year)
130
140
150
160
No prediction

Preprocessing steps

- **Running Fmask 4.0 on Sentinel images**

- Performing topographic correction (Tan et al. 2013 – Rotational Correction)

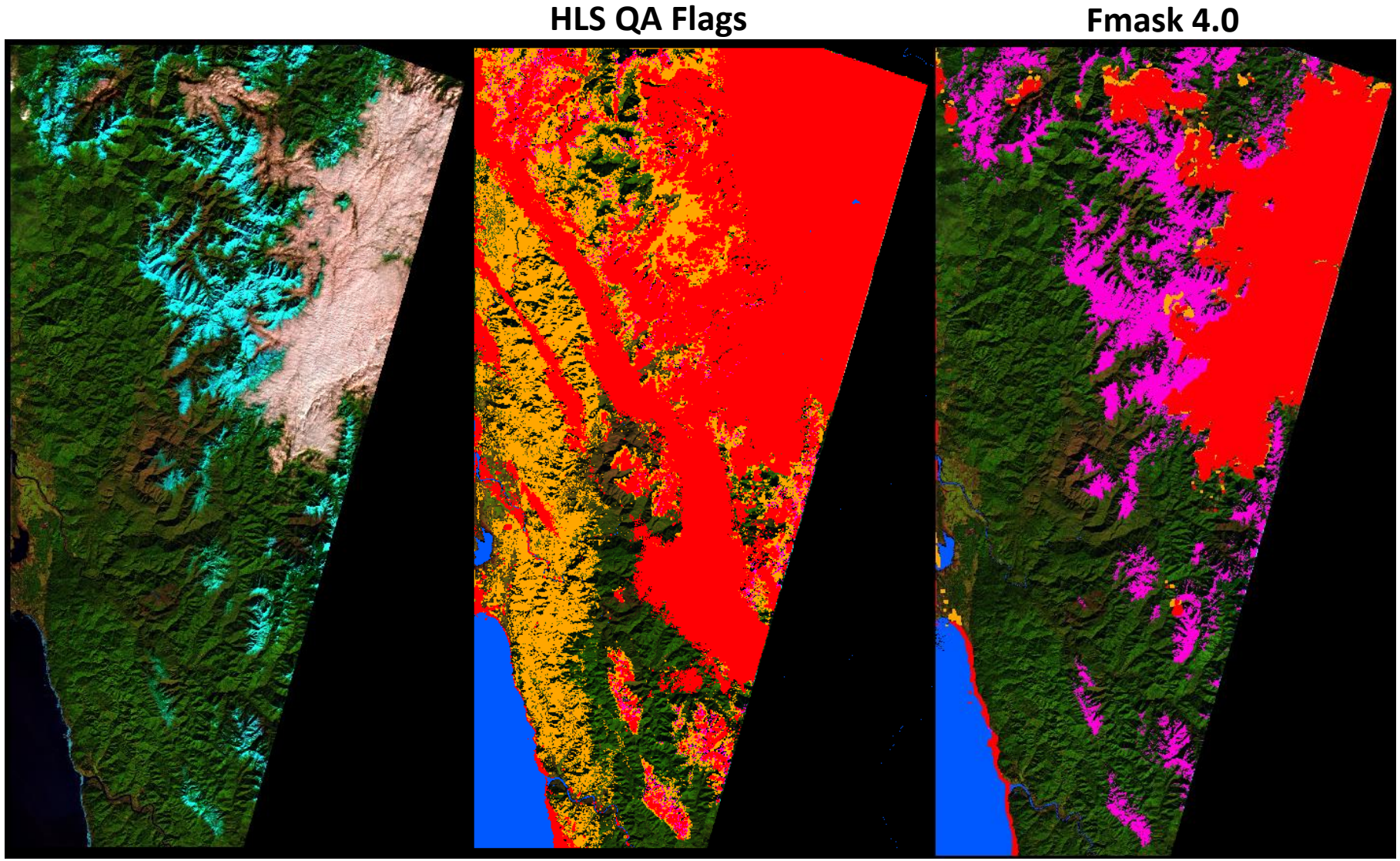
- Additional snow screening using the normalized difference moisture index (NDMI) (Based on Wang et al. 2015)

- Time-series gap filling
  - Fill snow observations with dormant value
    - 5th percentile of EVI2 from 2016-2018
    - Spline weight of 0.5

  - Gap fill with observations from “similar” years
    - Spline weight determined by similarity between years
    - Max spline weight of 0.1

Preprocessing steps – Running Fmask 4.0

- High observation density is **critical** for phenology
- For some Sentinel images, HLS over predicts clouds and shadows

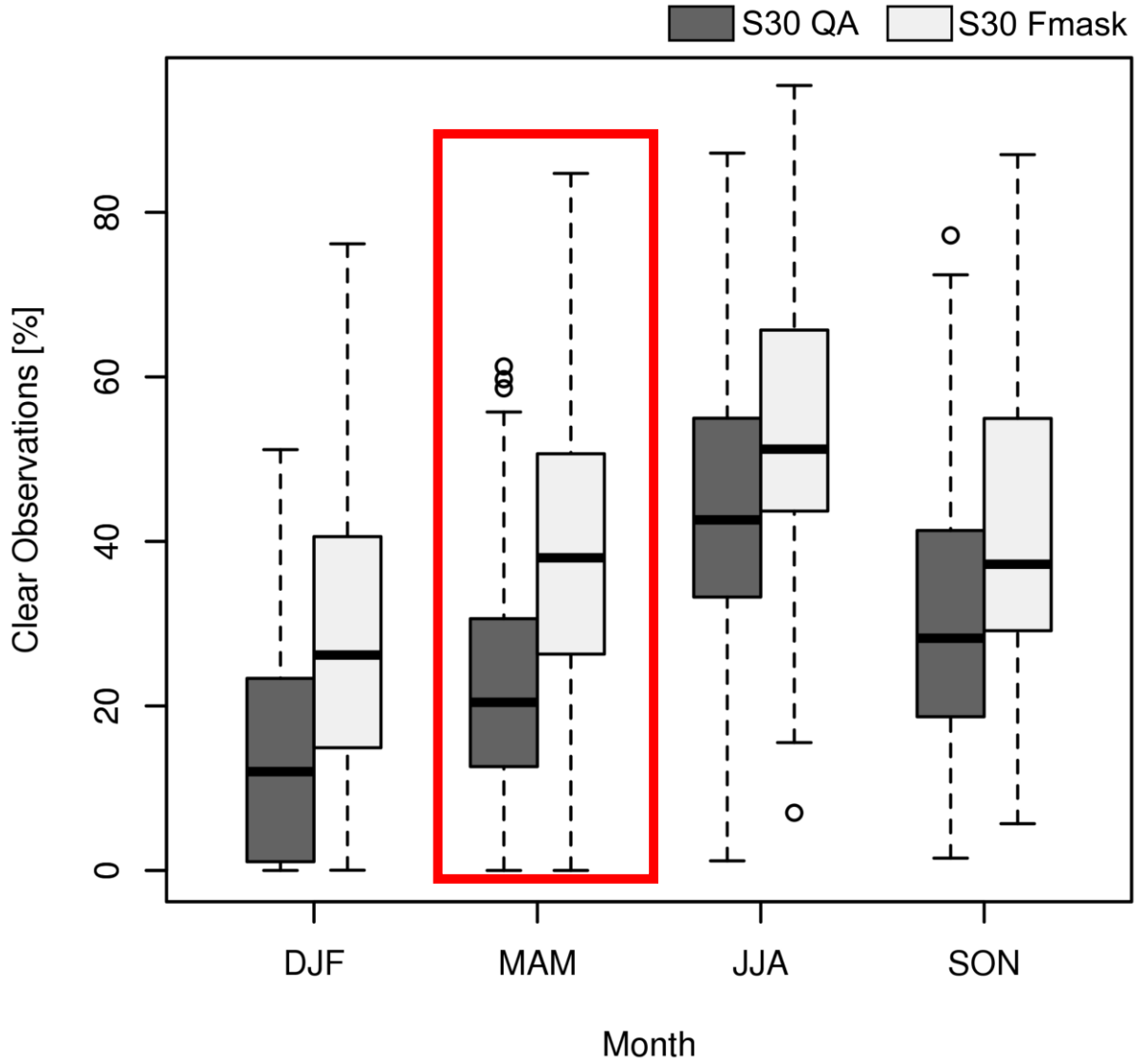


Preprocessing steps – Running Fmask 4.0

Compared HLS QA against Fmask 4.0 for 176 test tiles

% of clear observations lower for HLS QA than Fmask 4.0

Running Fmask 4.0 for Sentinel images only



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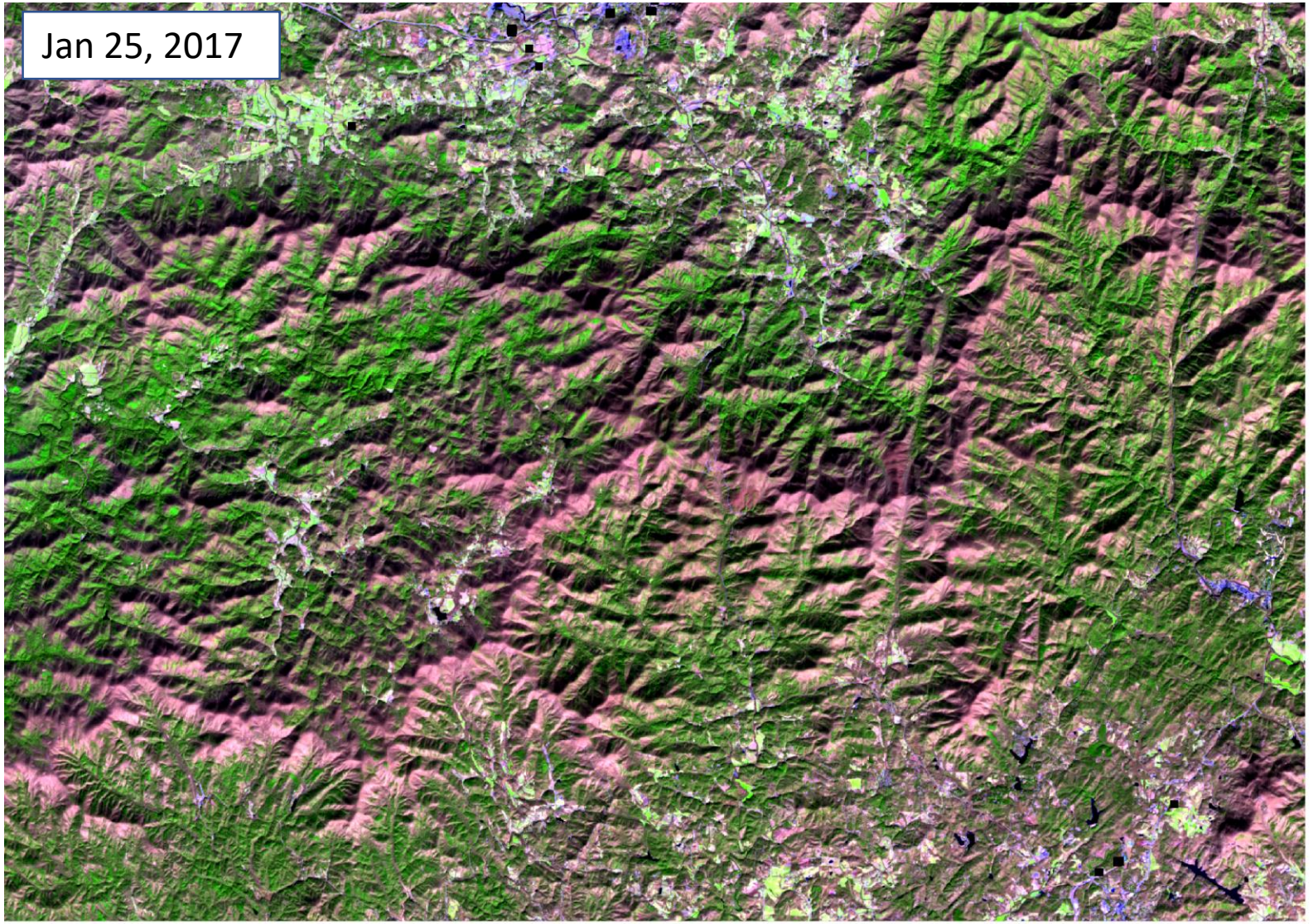

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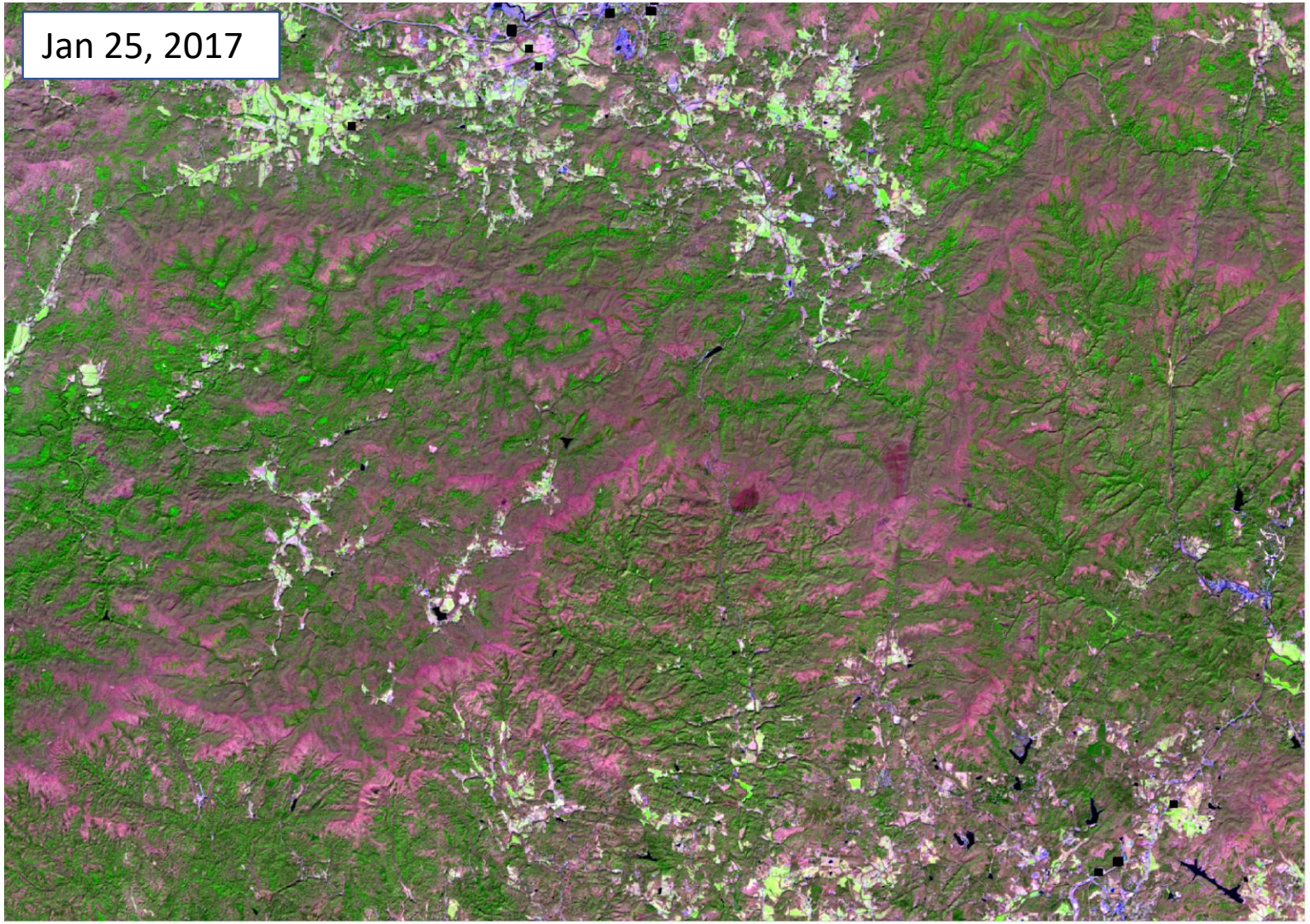
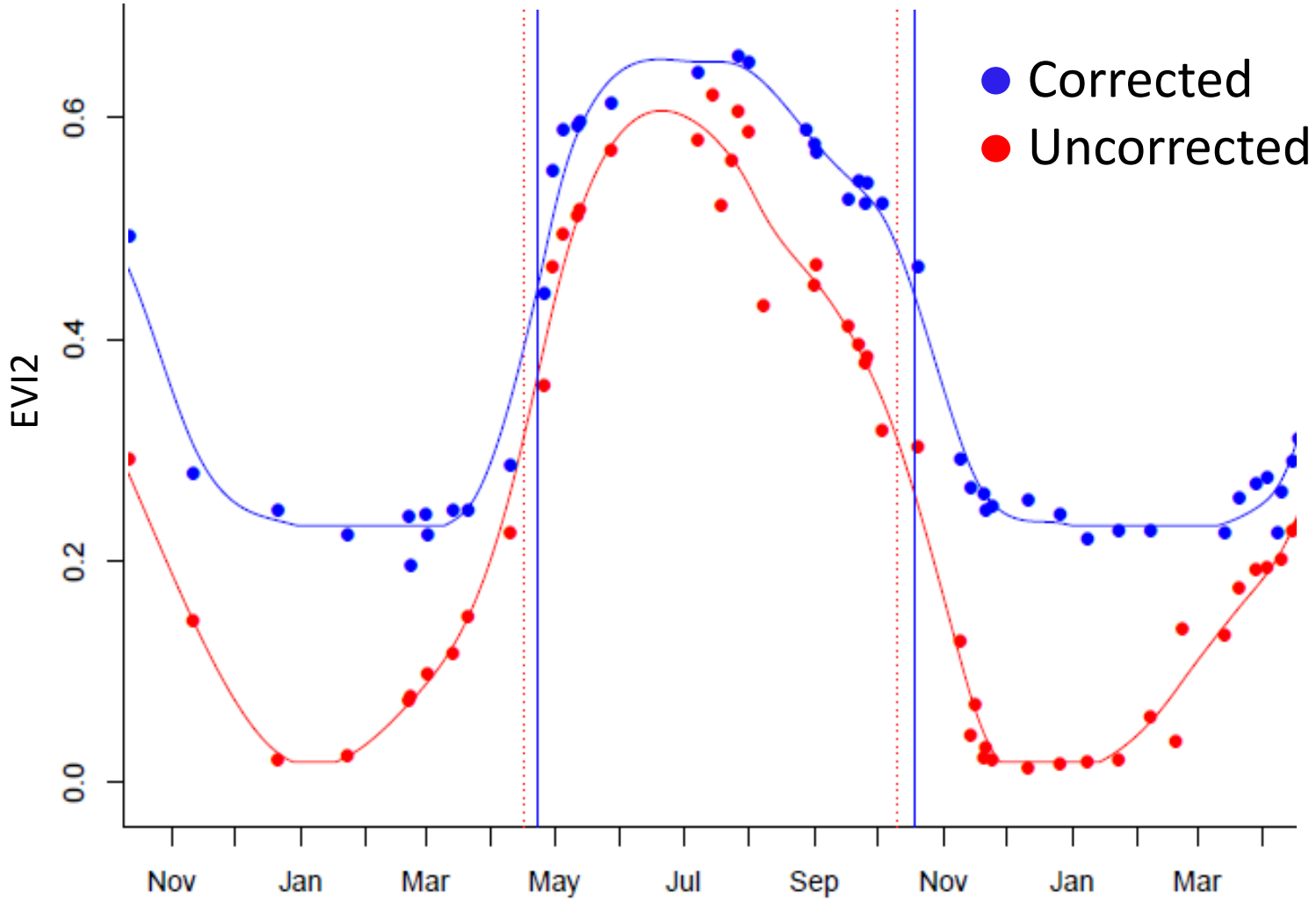


Preprocessing steps – Topographic Correction

North facing deciduous forest pixel

More realistic EVI2 amplitude after correction

One week shift in 50% amplitude dates



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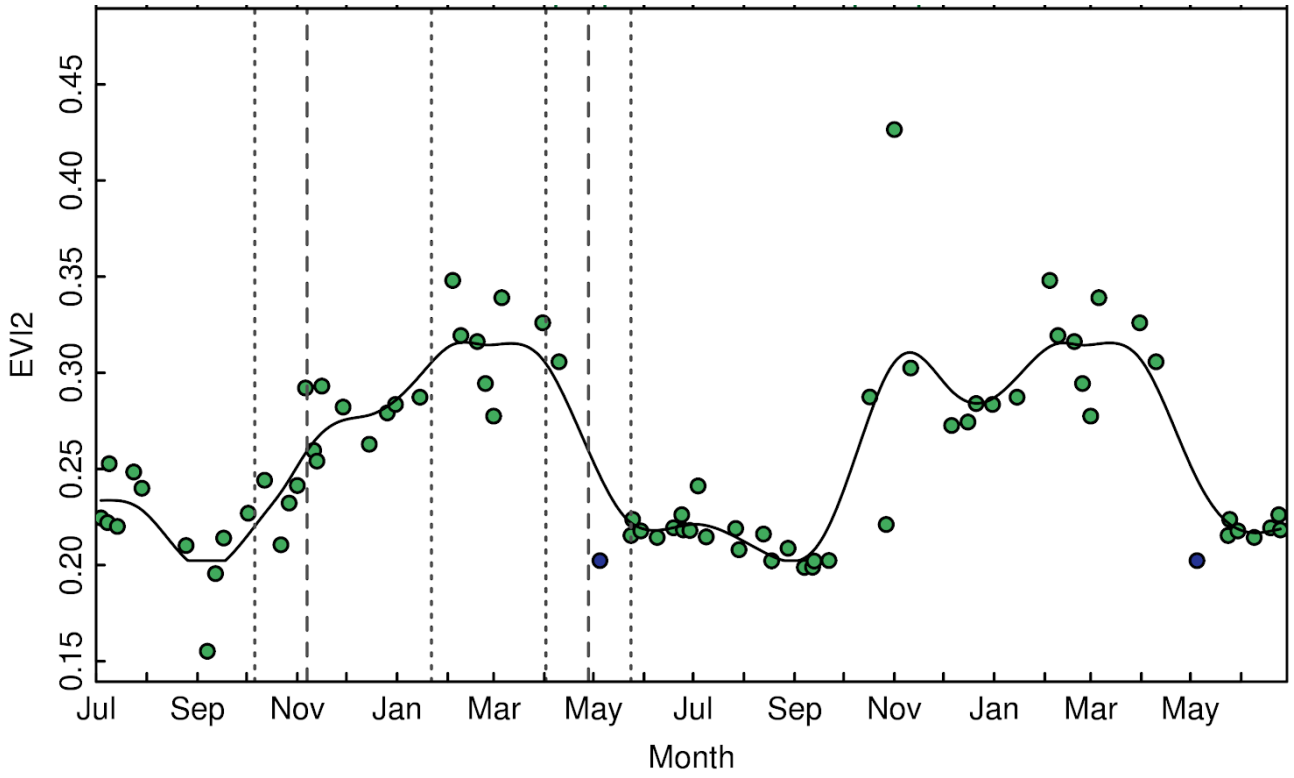
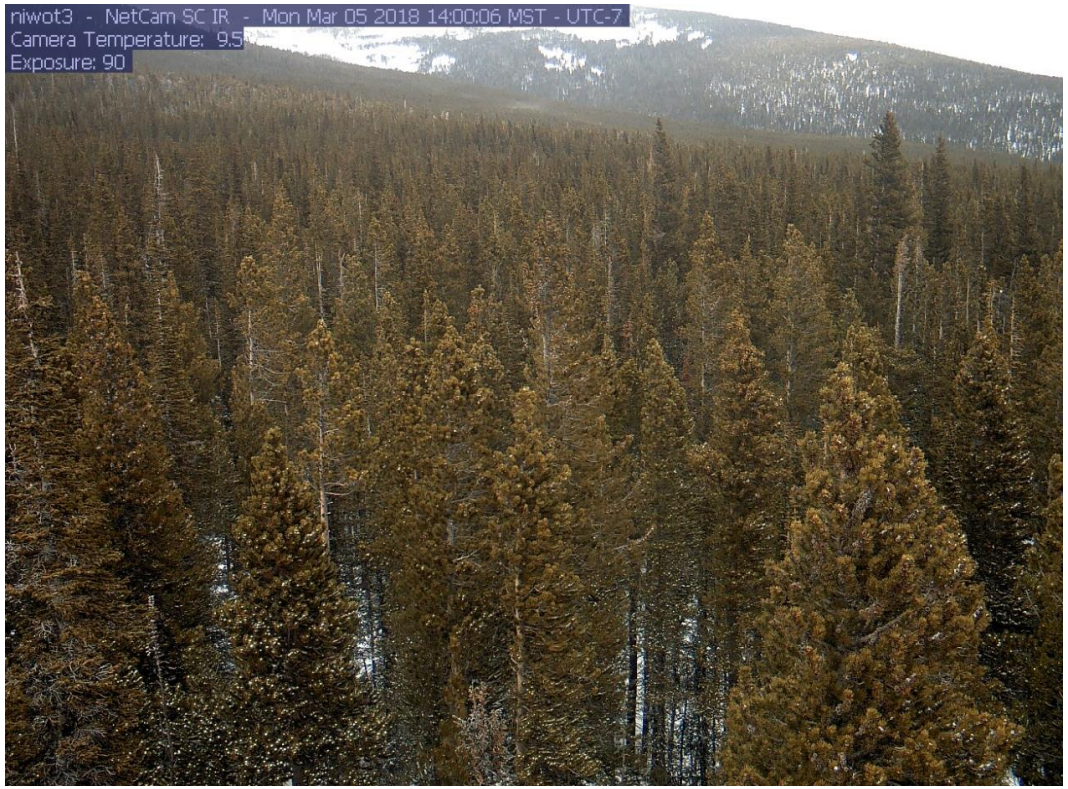
Preprocessing steps – Snow under canopies

- False EVI2 peaks in winter due to snow under evergreen canopies
- Mask observations when NDMI > 0.5 (Wang et al. 2015)





Only applied when snow detected within 5km of pixel!

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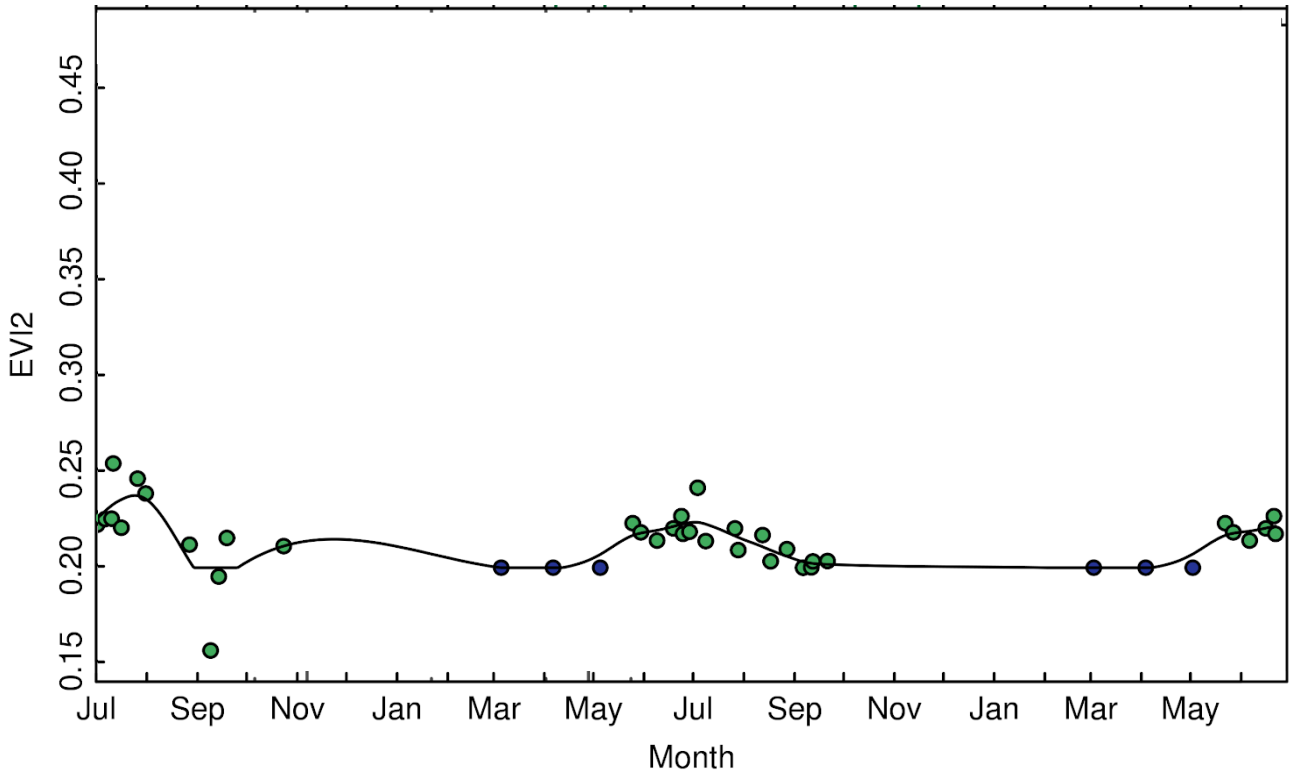

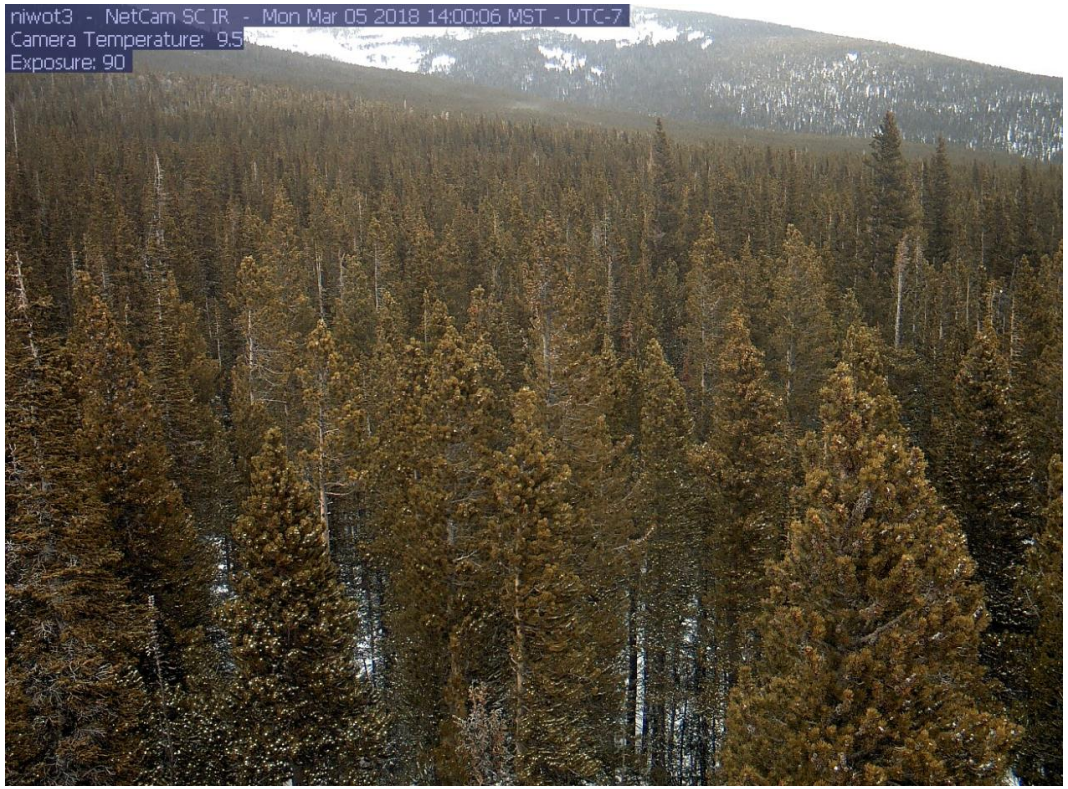

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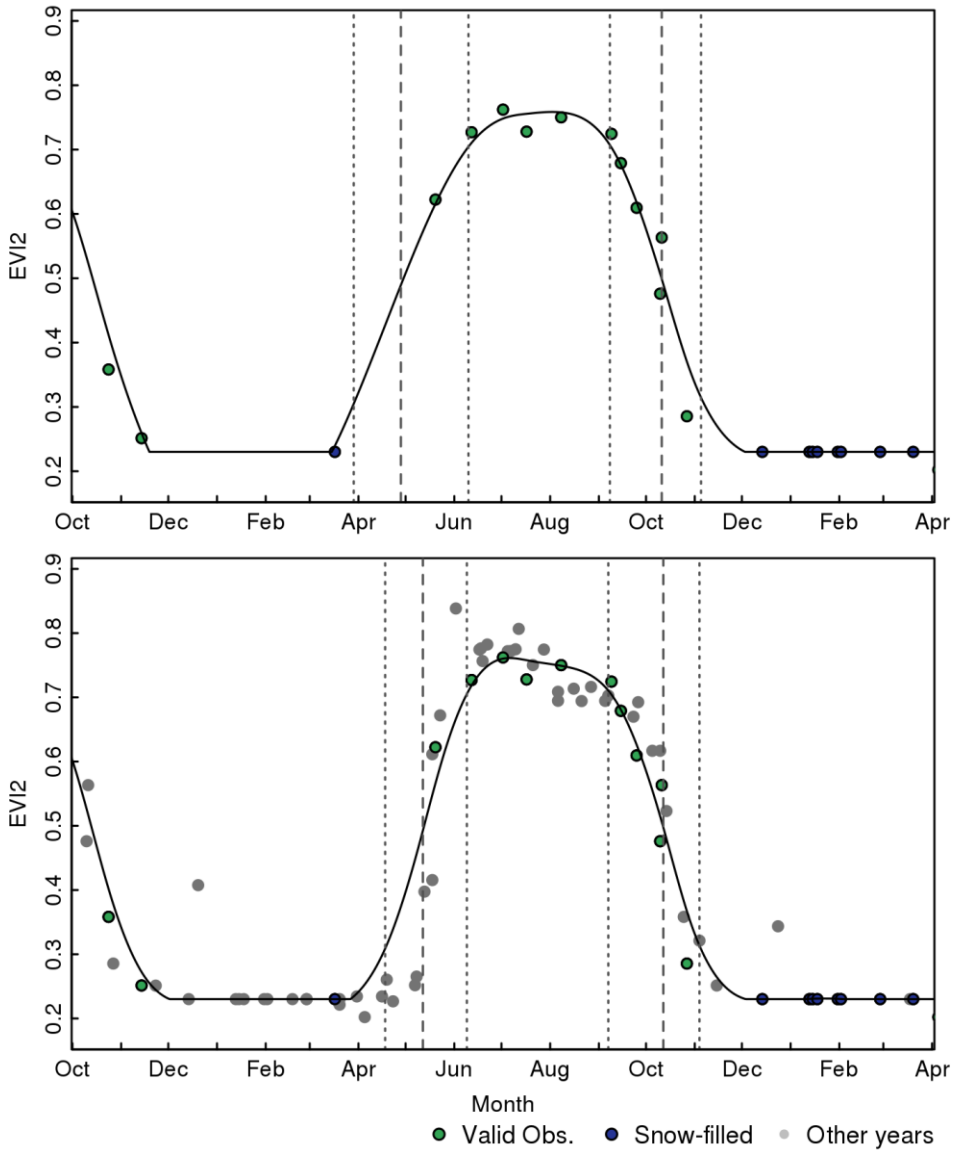

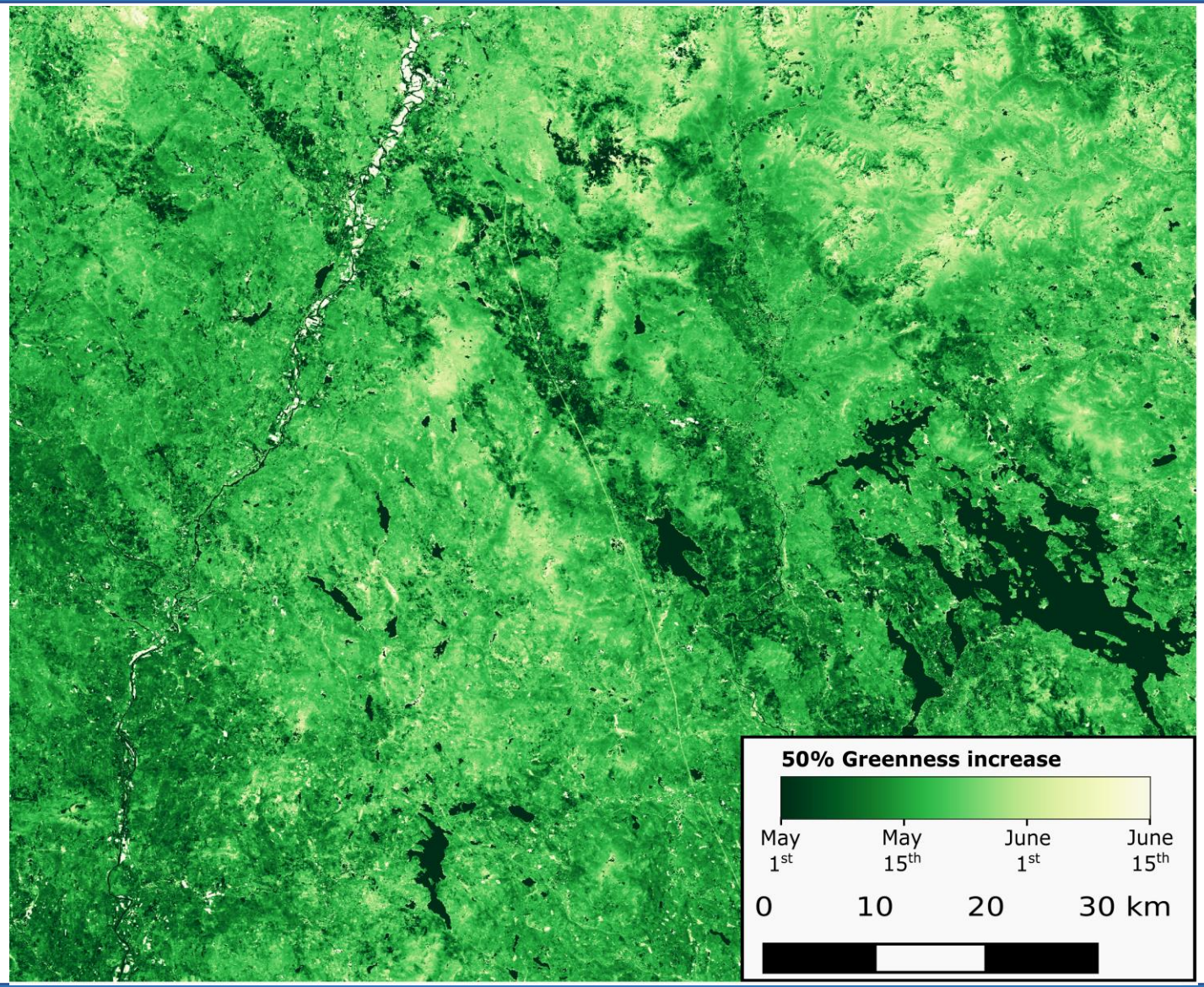

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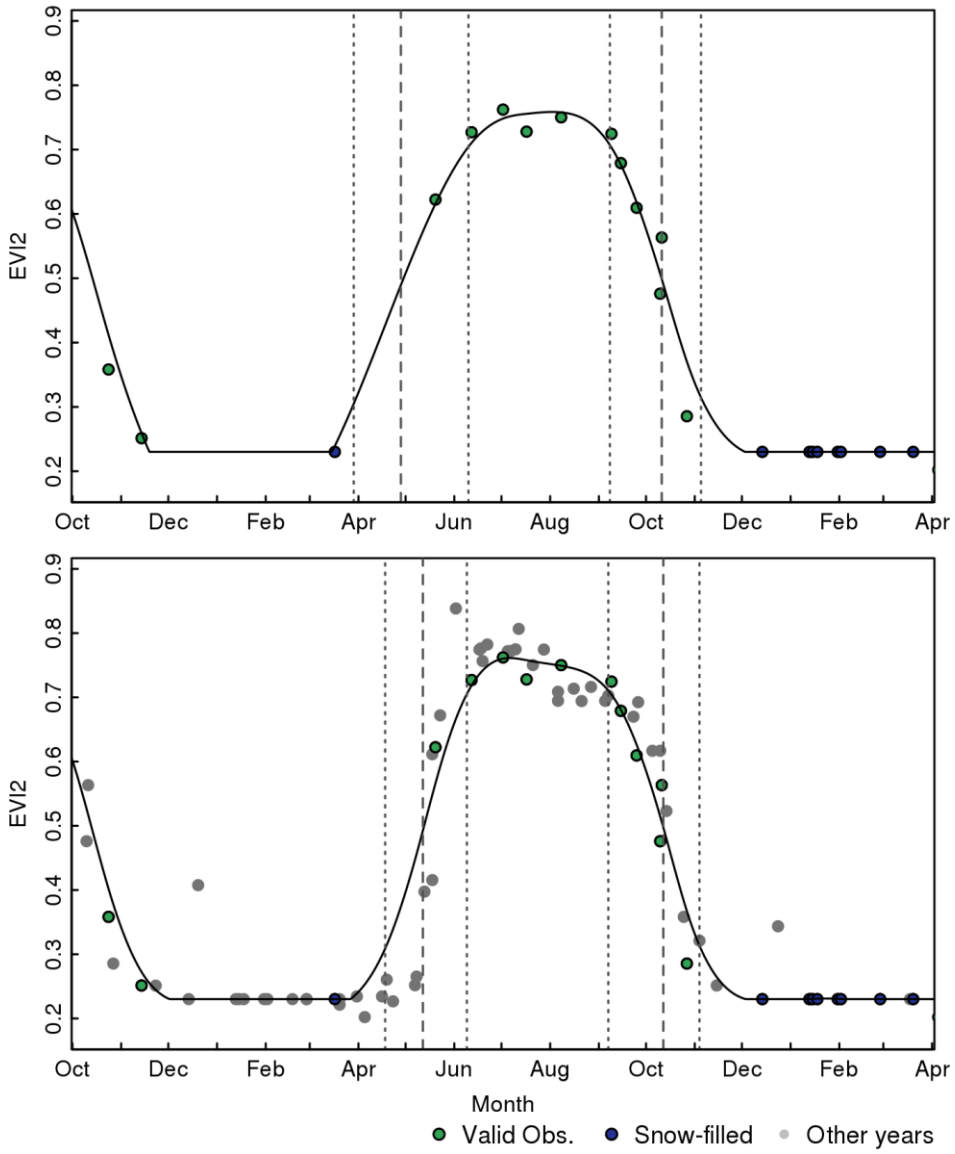
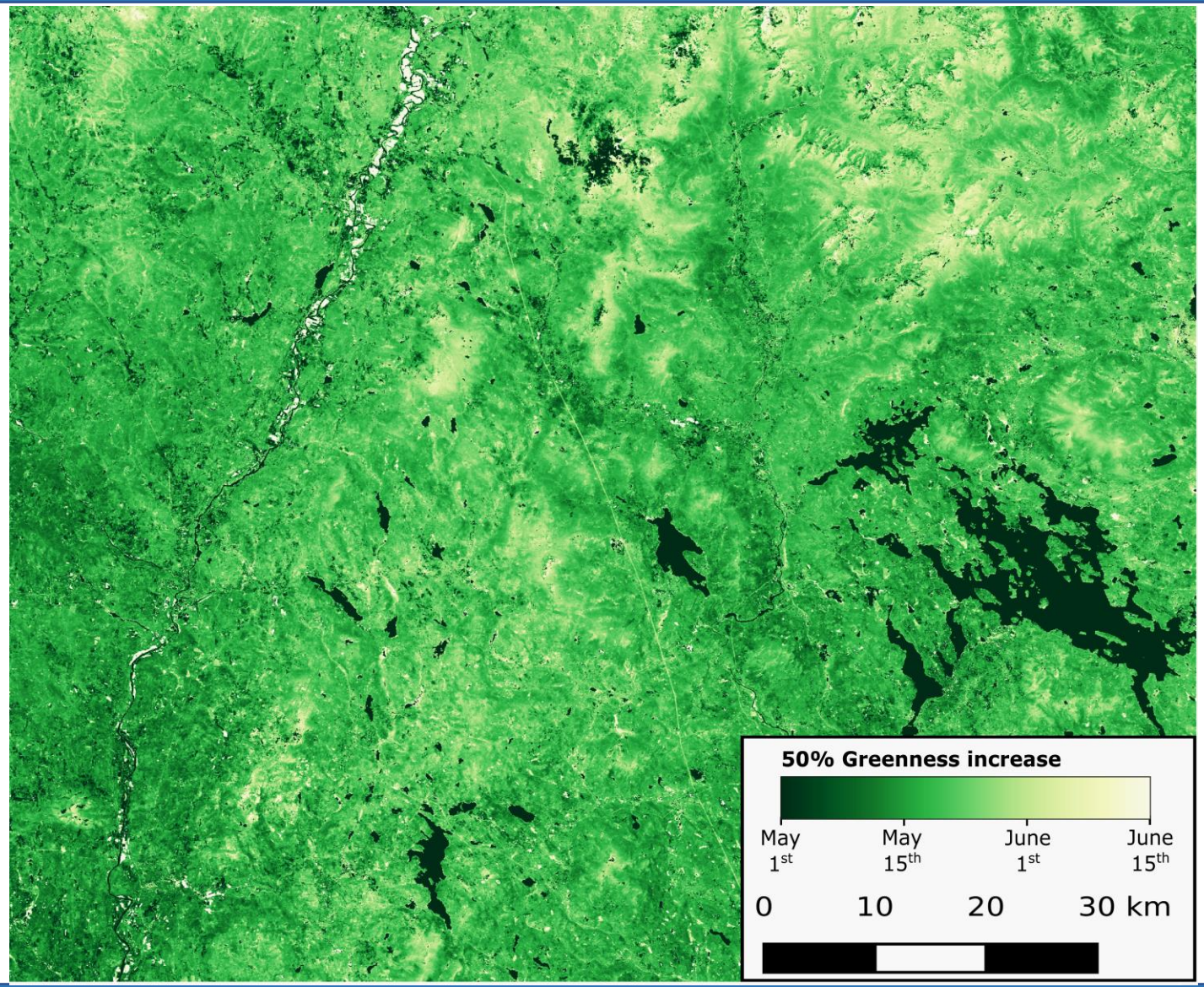
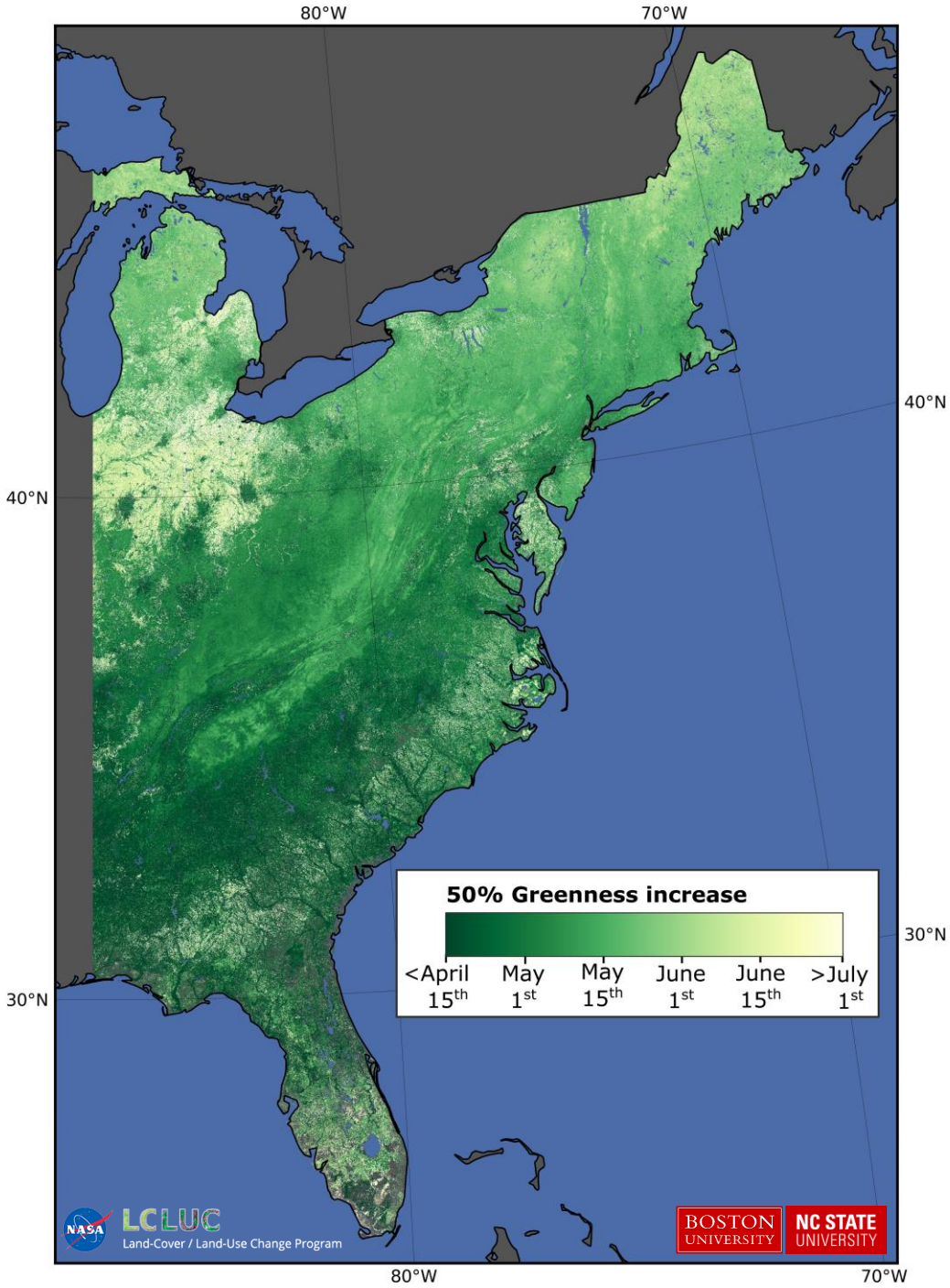
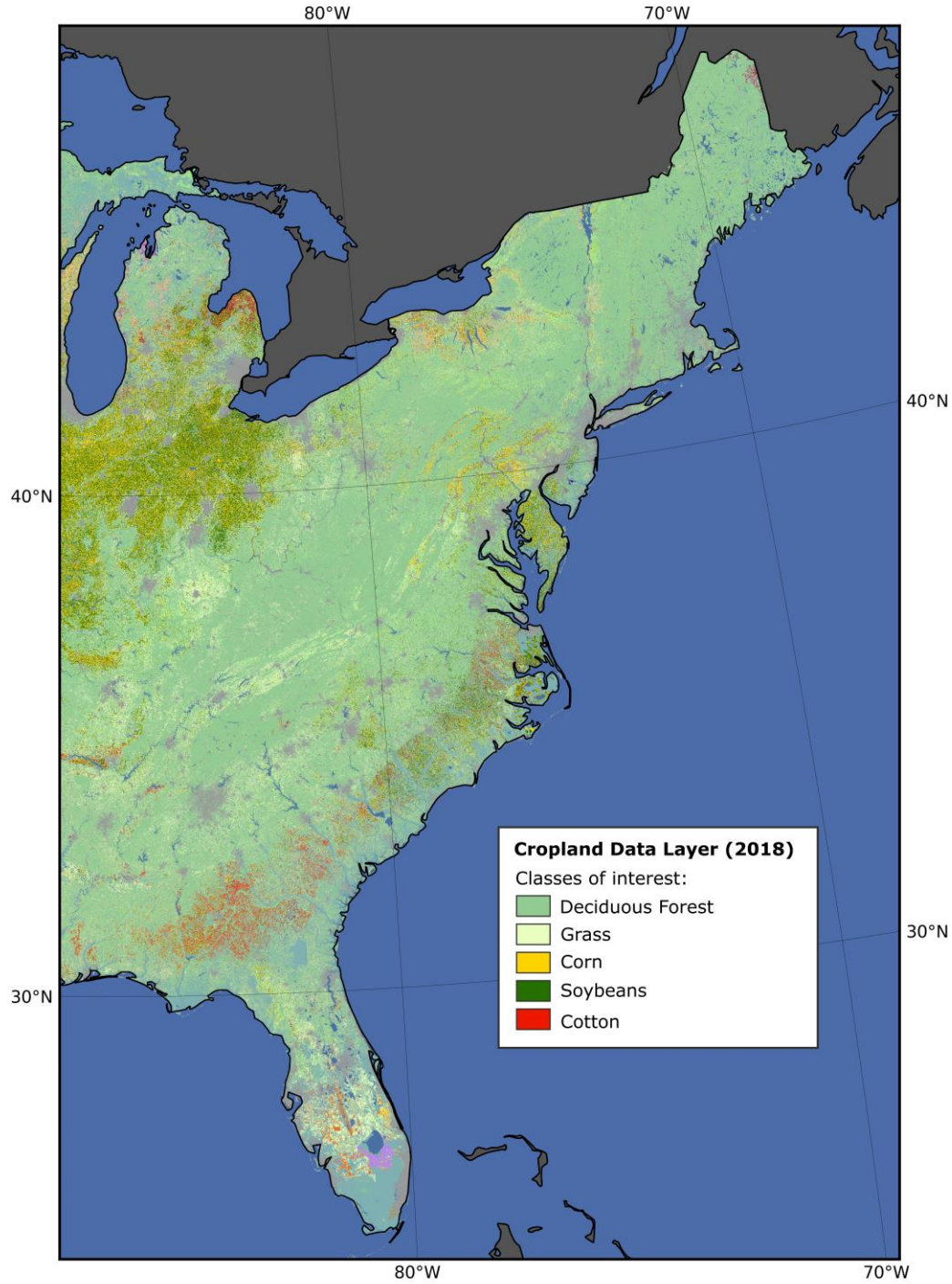


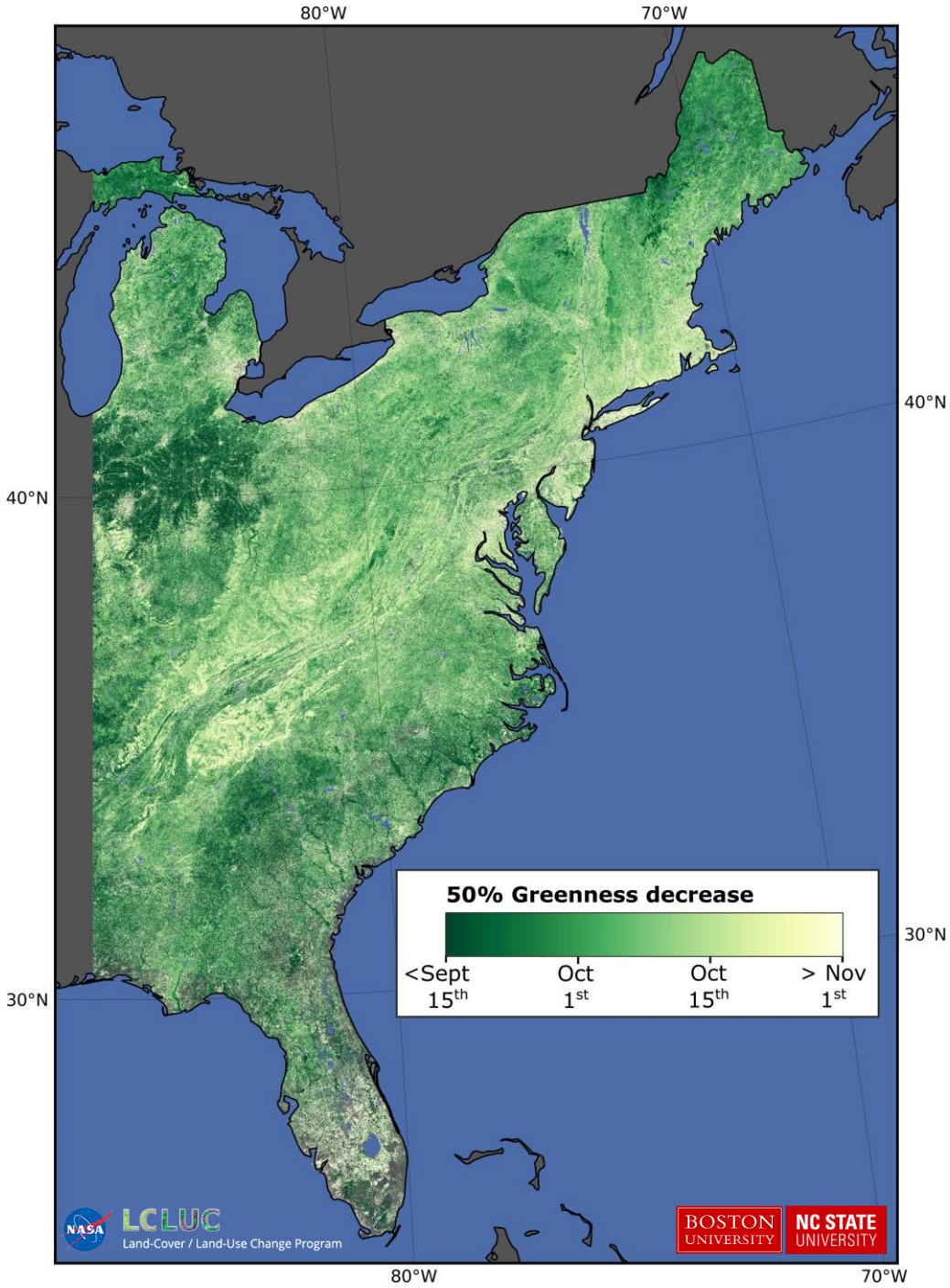


MS-LSP Product Status

- Produced full scale results for eastern United States
- Conducted validation against >400 site years of phenoCam data
- Built computing environment and completed test runs on Amazon Web Services (AWS)
  - Will begin full scale processing of North America in the coming weeks
- Reached out the LP-DAAC to discuss data distribution and documentation


80°W
70°W
40°N
30°N
50% Greenness increase
<April 15th
May 1st
May 15th
June 1st
June 15th
>July 1st
LCLUC
Land-Cover / Land-Use Change Program
BOSTON UNIVERSITY
NC STATE UNIVERSITY


80°W
70°W
40°N
30°N
Cropland Data Layer (2018)
Classes of interest:
Deciduous Forest
Grass
Corn
Soybeans
Cotton


80°W
70°W
40°N
30°N
50% Greenness decrease
<Sept 15th
Oct 1st
Oct 15th
> Nov 1st
LCLUC
Land-Cover / Land-Use Change Program
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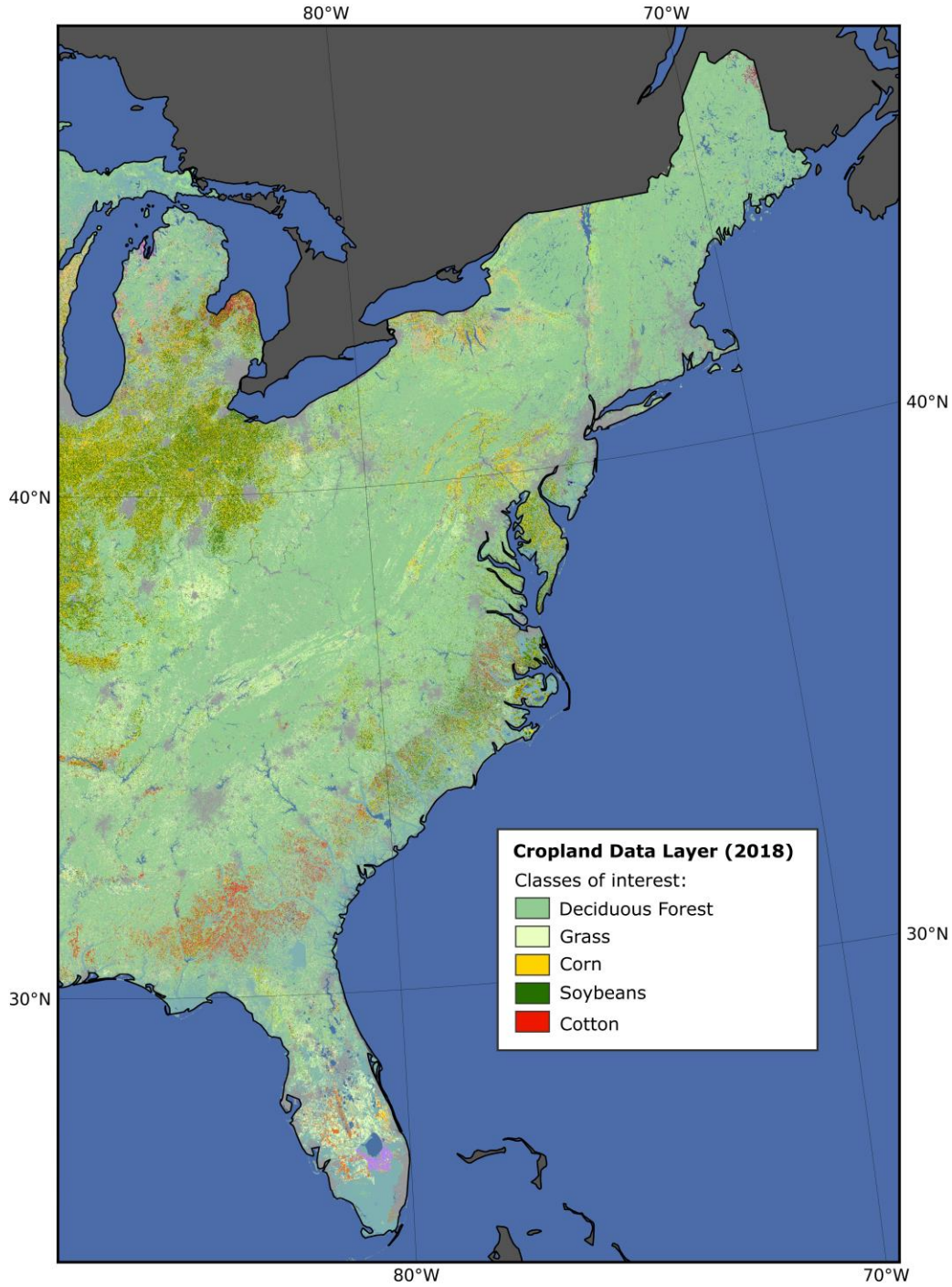
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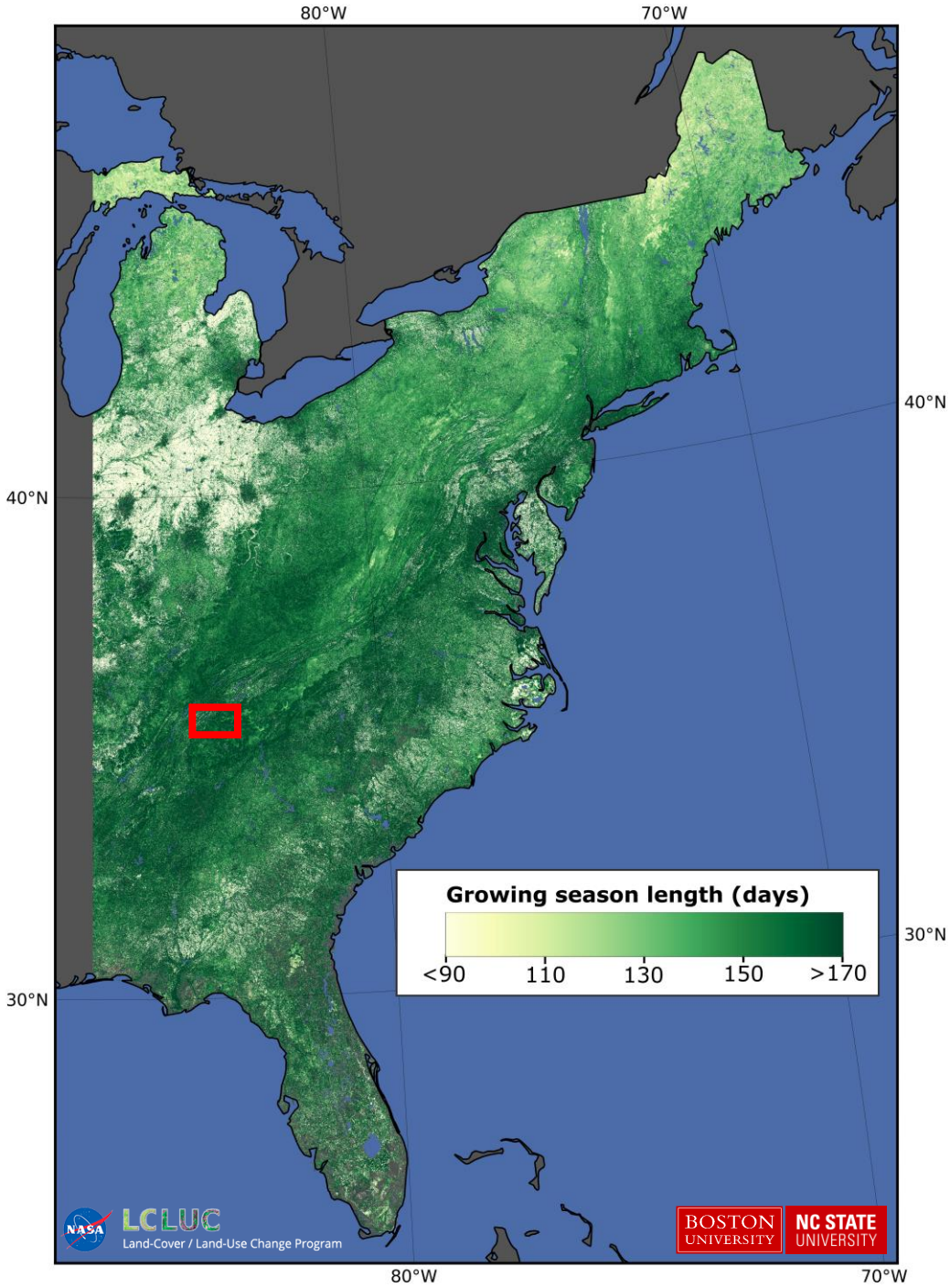
80°W
70°W
40°N
30°N
Growing season length (days)
<90
110
130
150
>170
LCLUC
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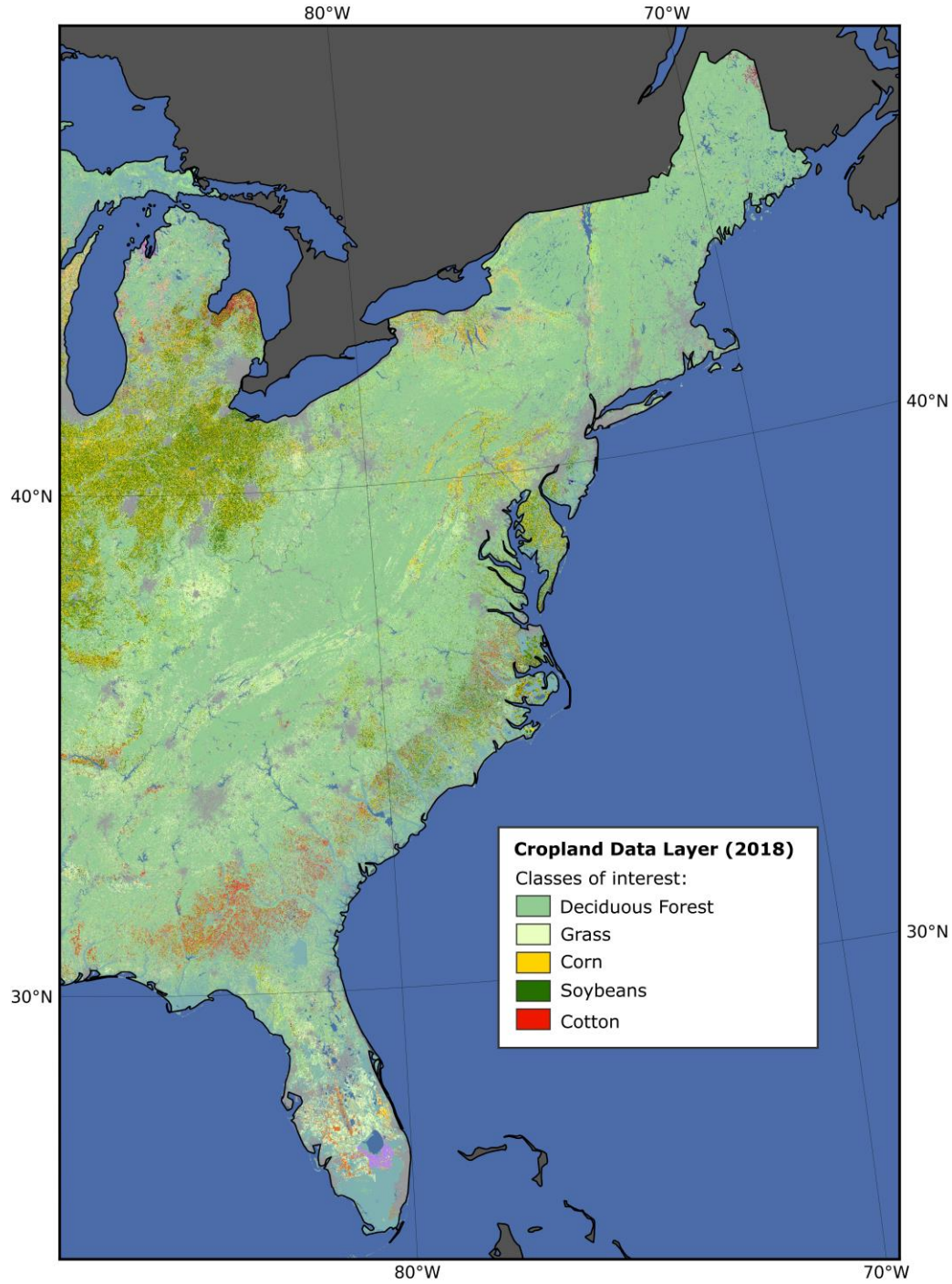
80°W
70°W
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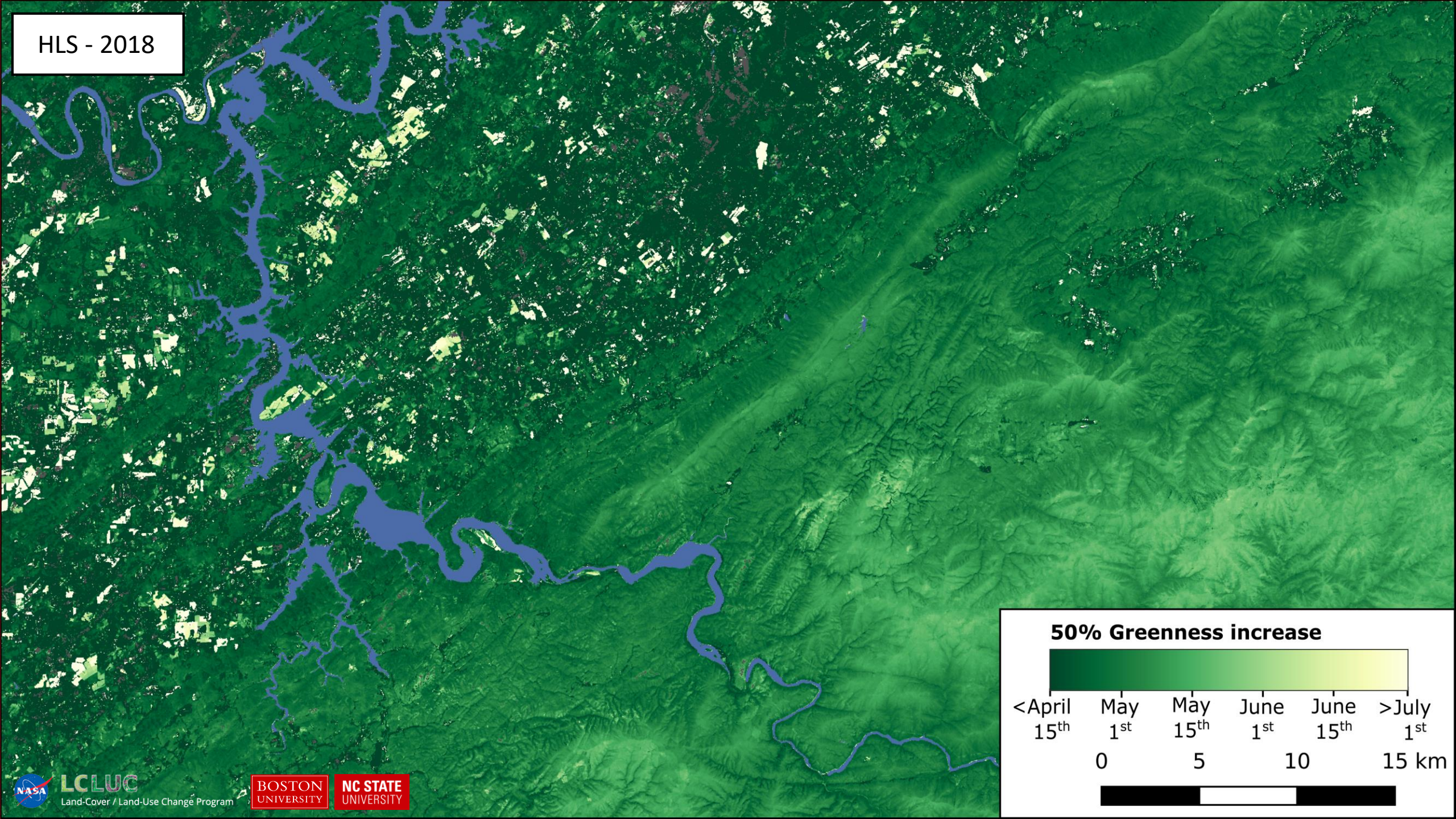
HLS - 2018
50% Greenness increase
<April 15th
May 1st
May 15th
June 1st
June 15th
>July 1st
0
5
10
15 km
LCLUC
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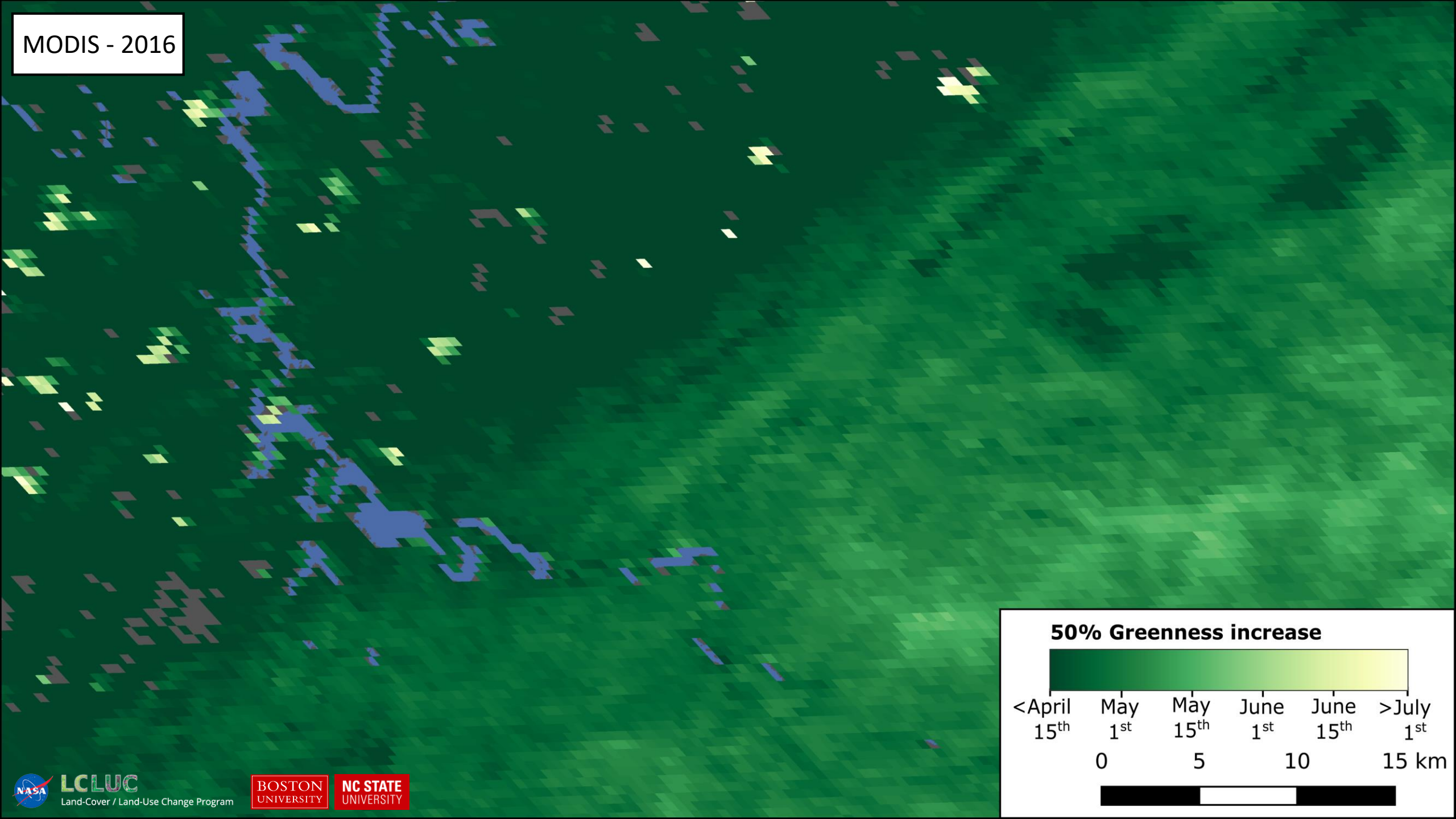
MODIS - 2016
50% Greenness increase
<April 15th
May 1st
May 15th
June 1st
June 15th
>July 1st
0
5
10
15 km
LCLUC
Land-Cover / Land-Use Change Program
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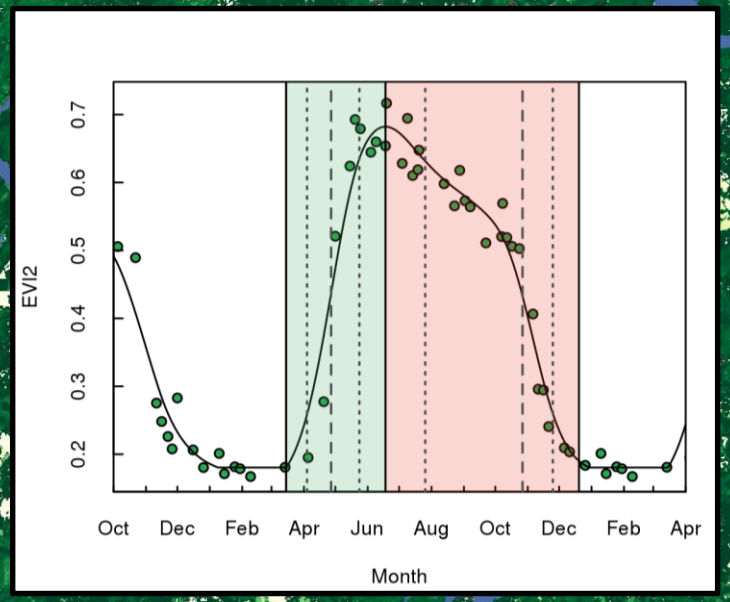

50% Greenness increase

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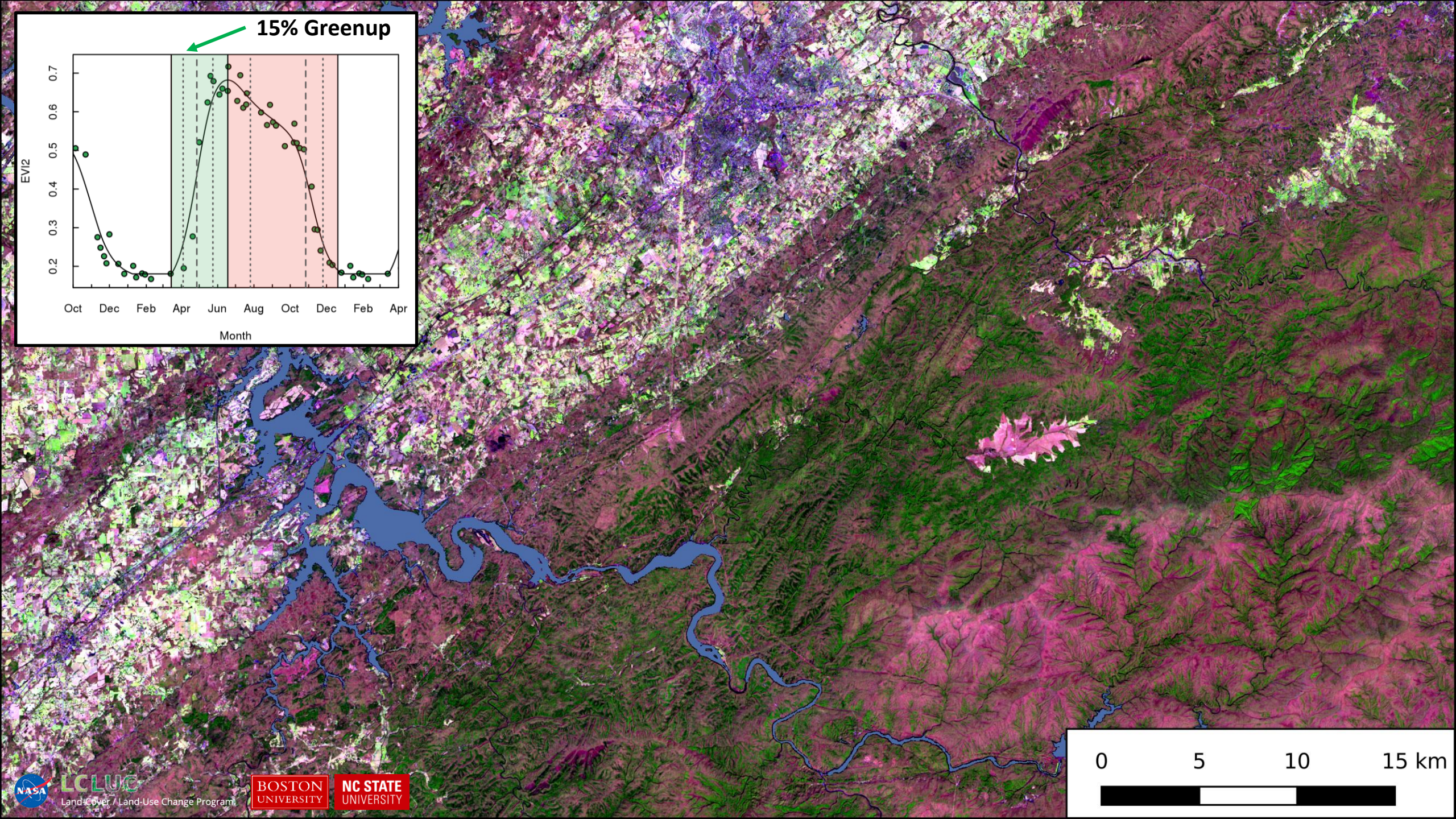
15% Greenup
EVI2
0.2
0.3
0.4
0.5
0.6
0.7
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Month
0
5
10
15 km
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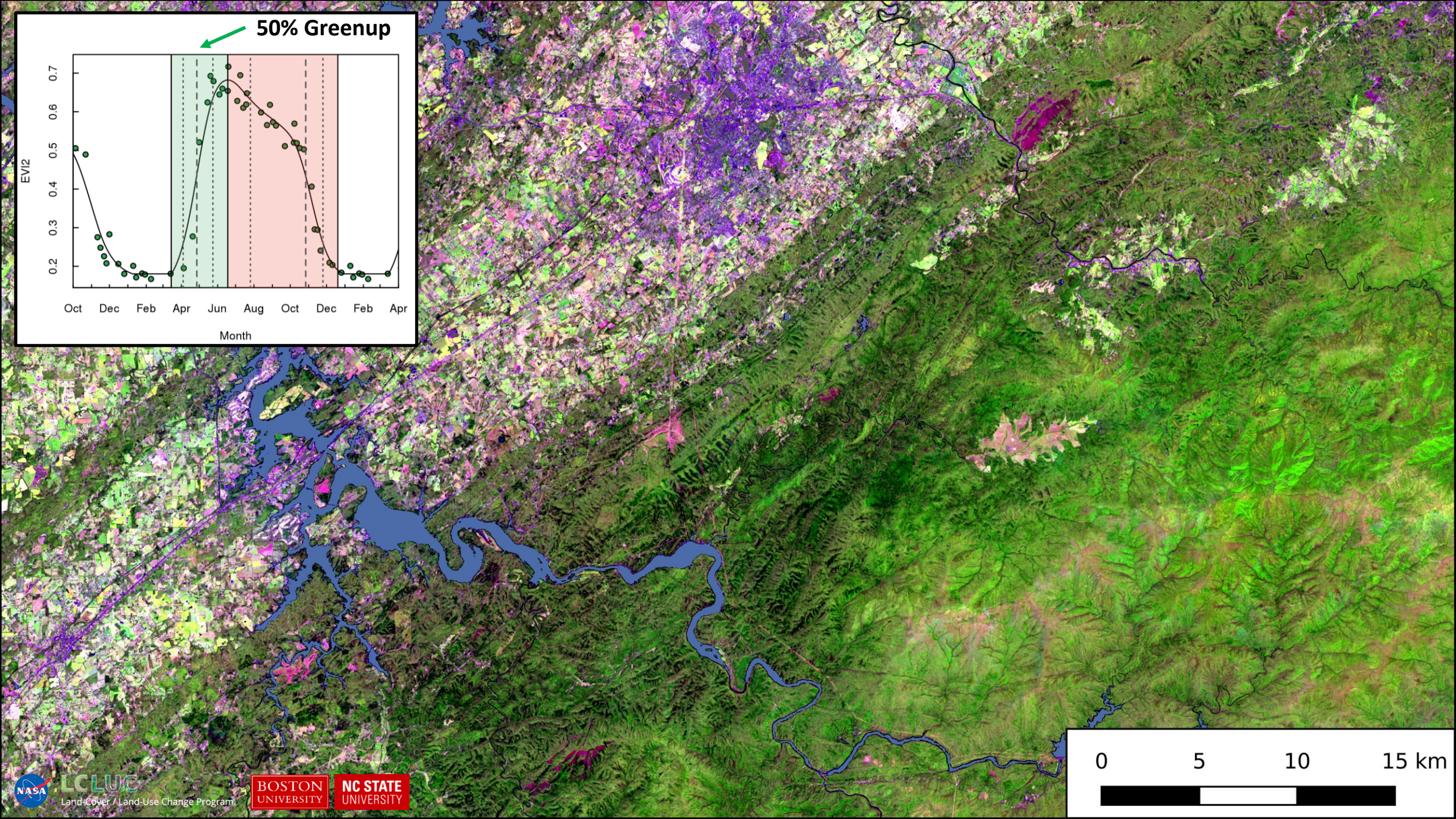
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EVI2
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0.5
0.6
0.7
Oct
Dec
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Apr
Jun
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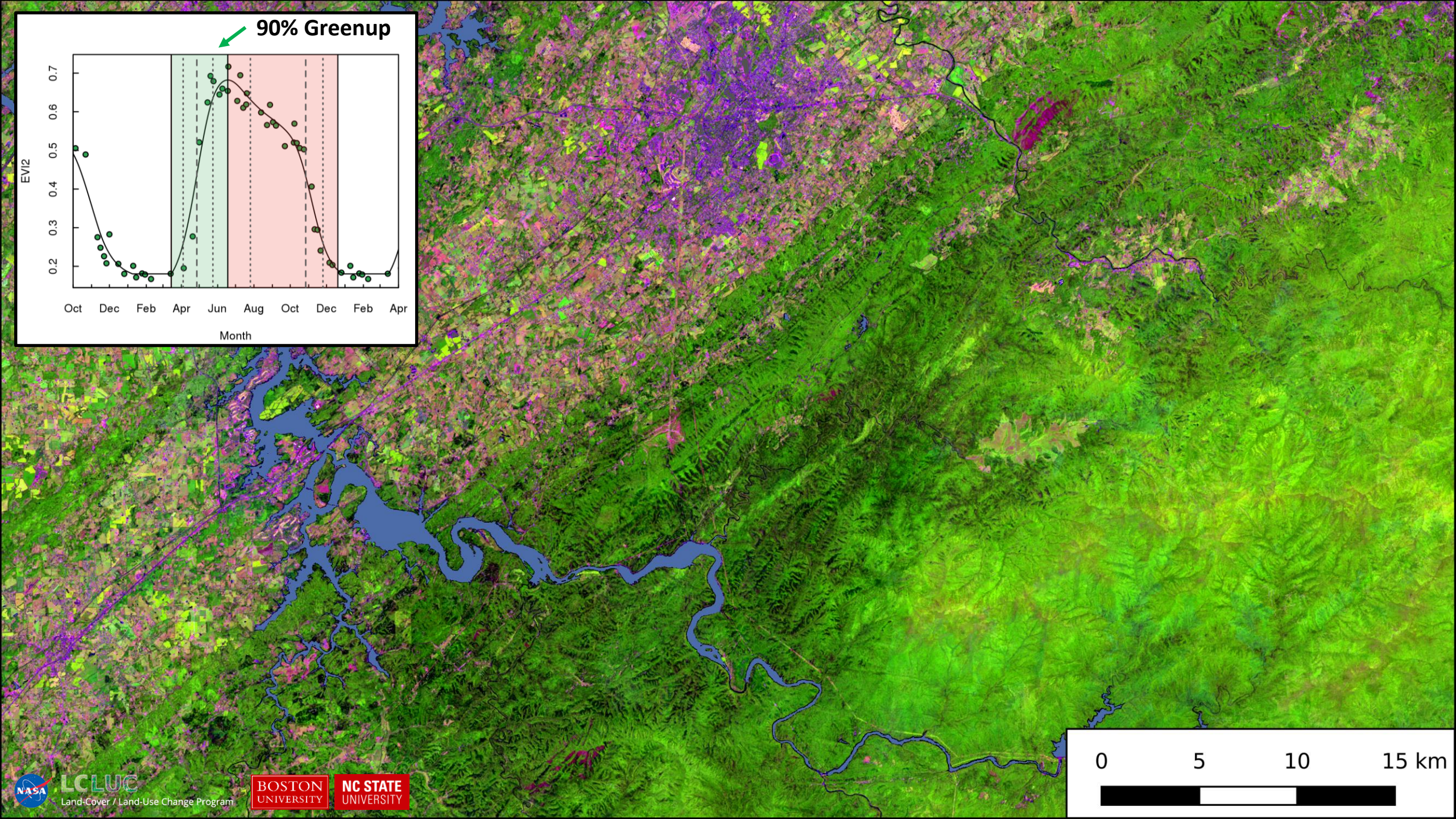
90% Greenup
EVI2
0.2
0.3
0.4
0.5
0.6
0.7
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Month
0
5
10
15 km
NASA
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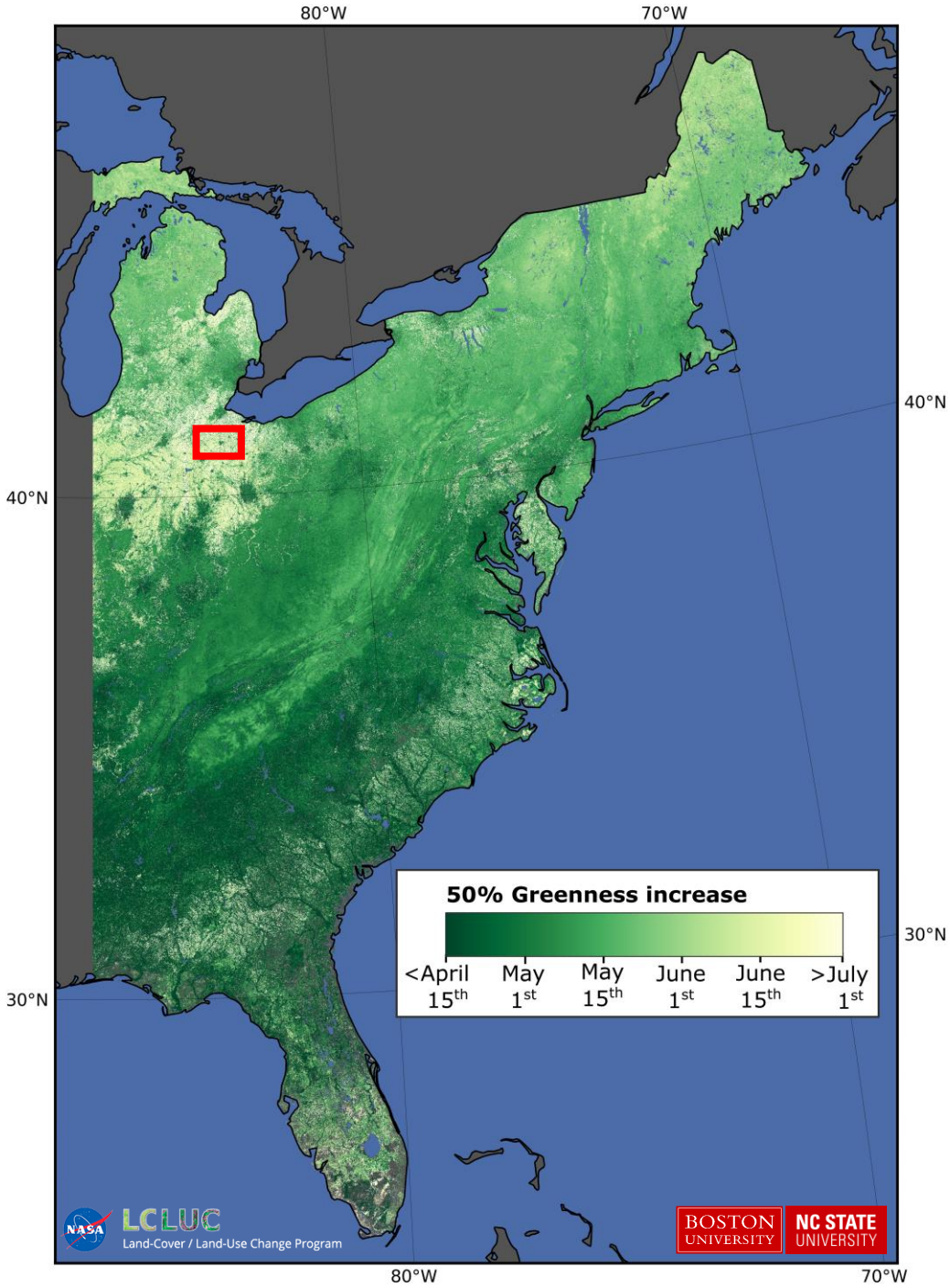
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BOSTON UNIVERSITY
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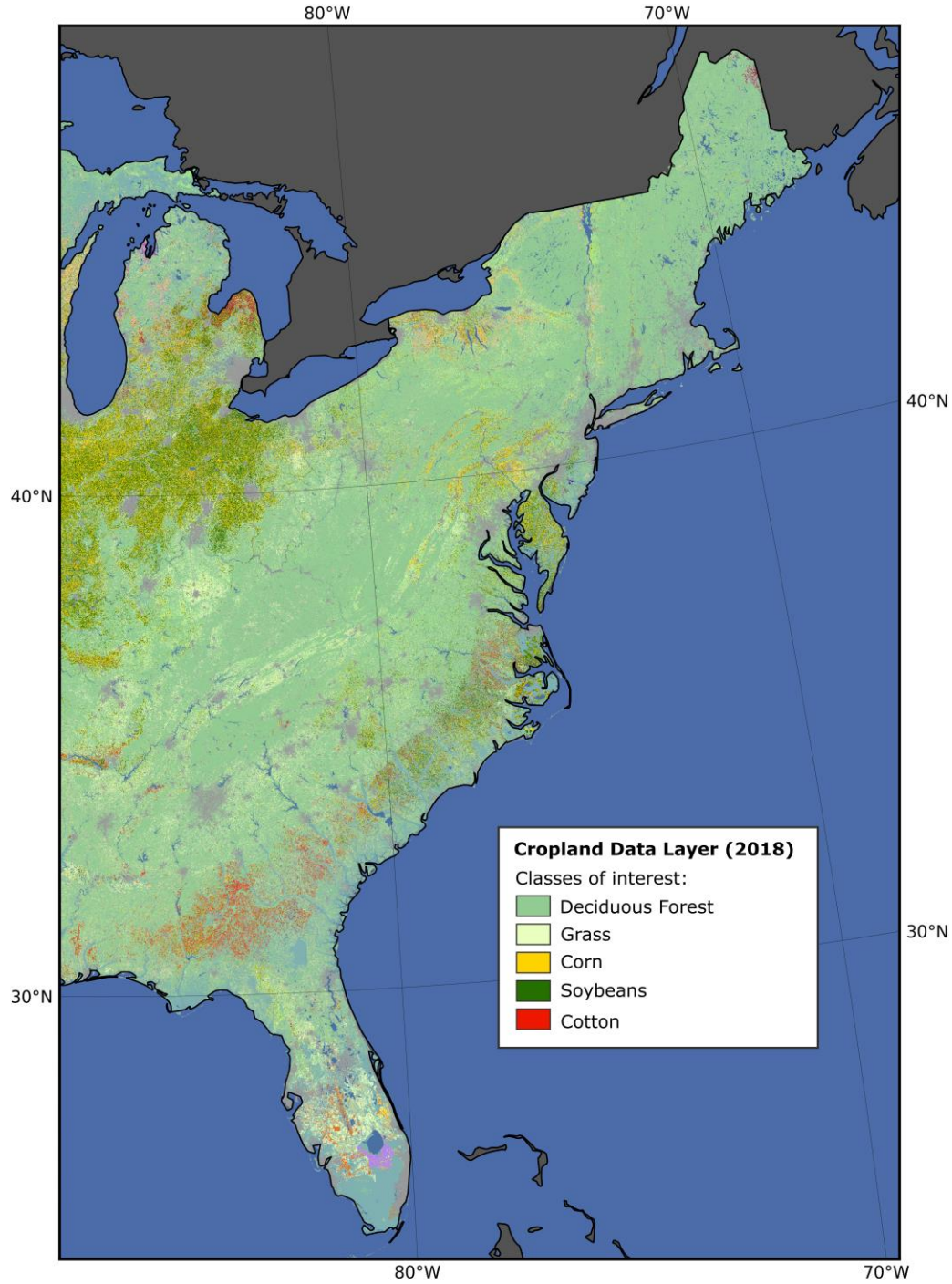
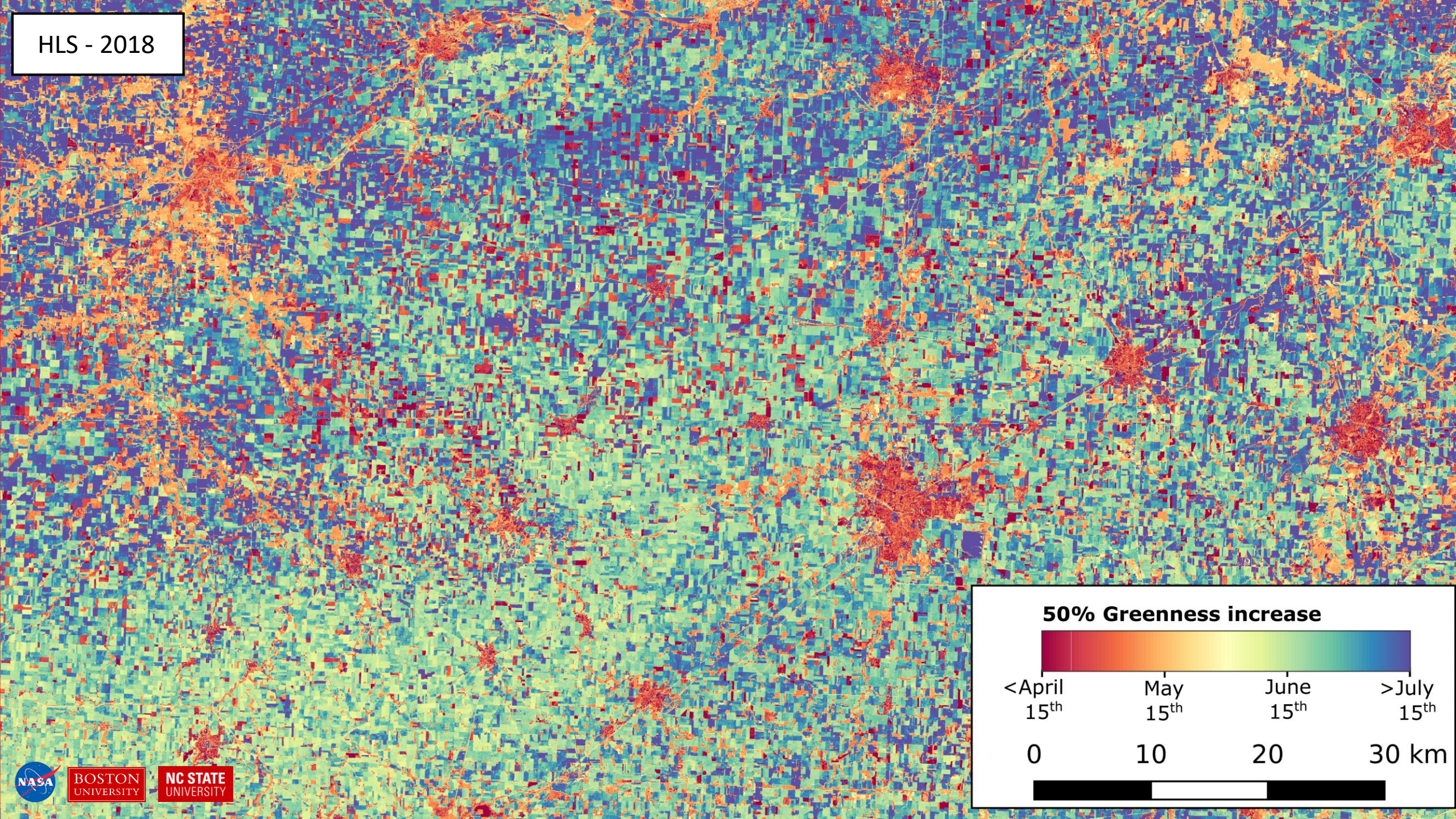

80°W
70°W
40°N
30°N
Cropland Data Layer (2018)
Classes of interest:
Deciduous Forest
Grass
Corn
Soybeans
Cotton


HLS - 2018
50% Greenness increase
<April 15th
May 15th
June 15th
>July 15th
0
10
20
30 km
NASA
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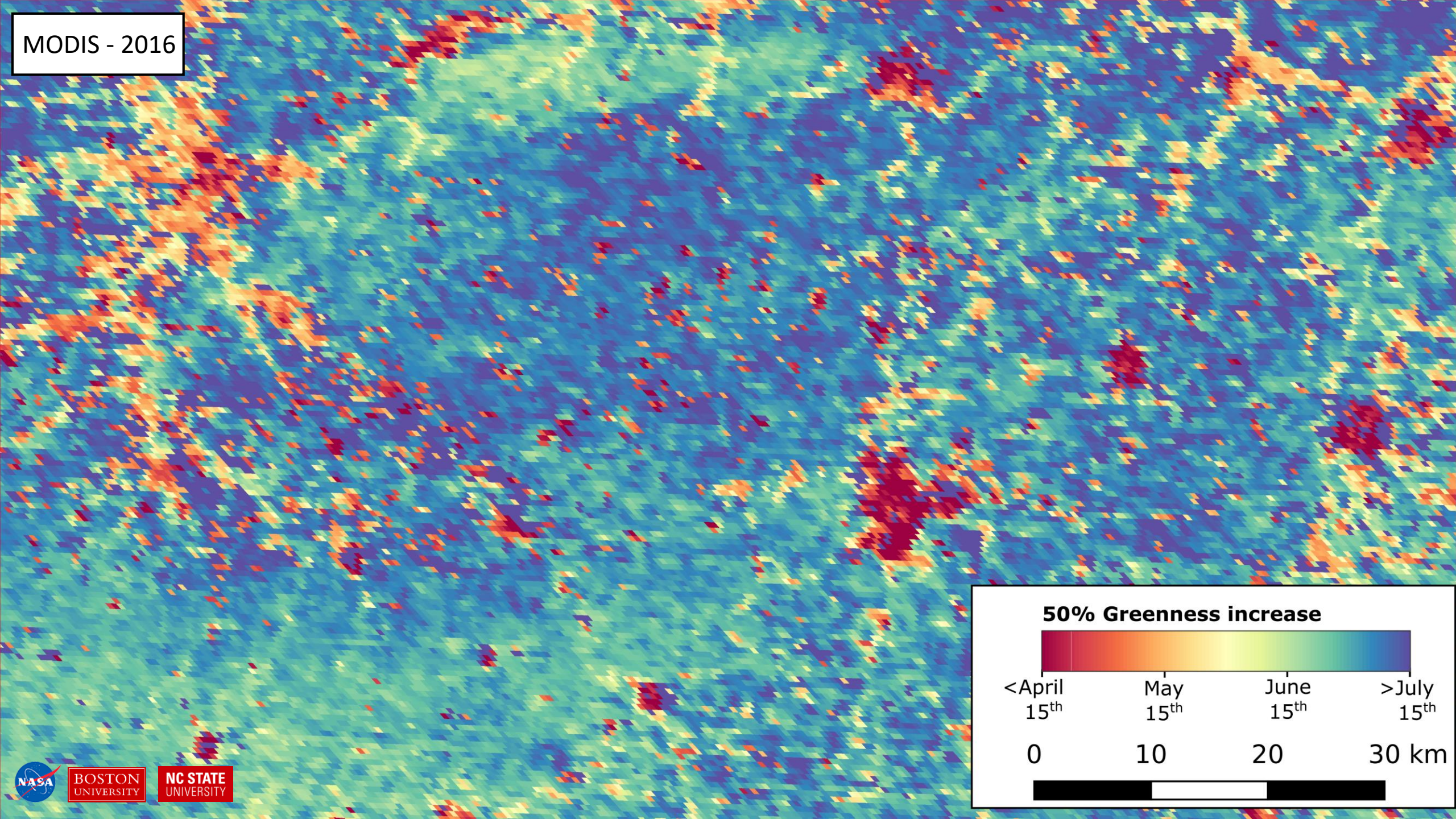
MODIS - 2016
50% Greenness increase
<April 15th
May 15th
June 15th
>July 15th
0
10
20
30 km
NASA
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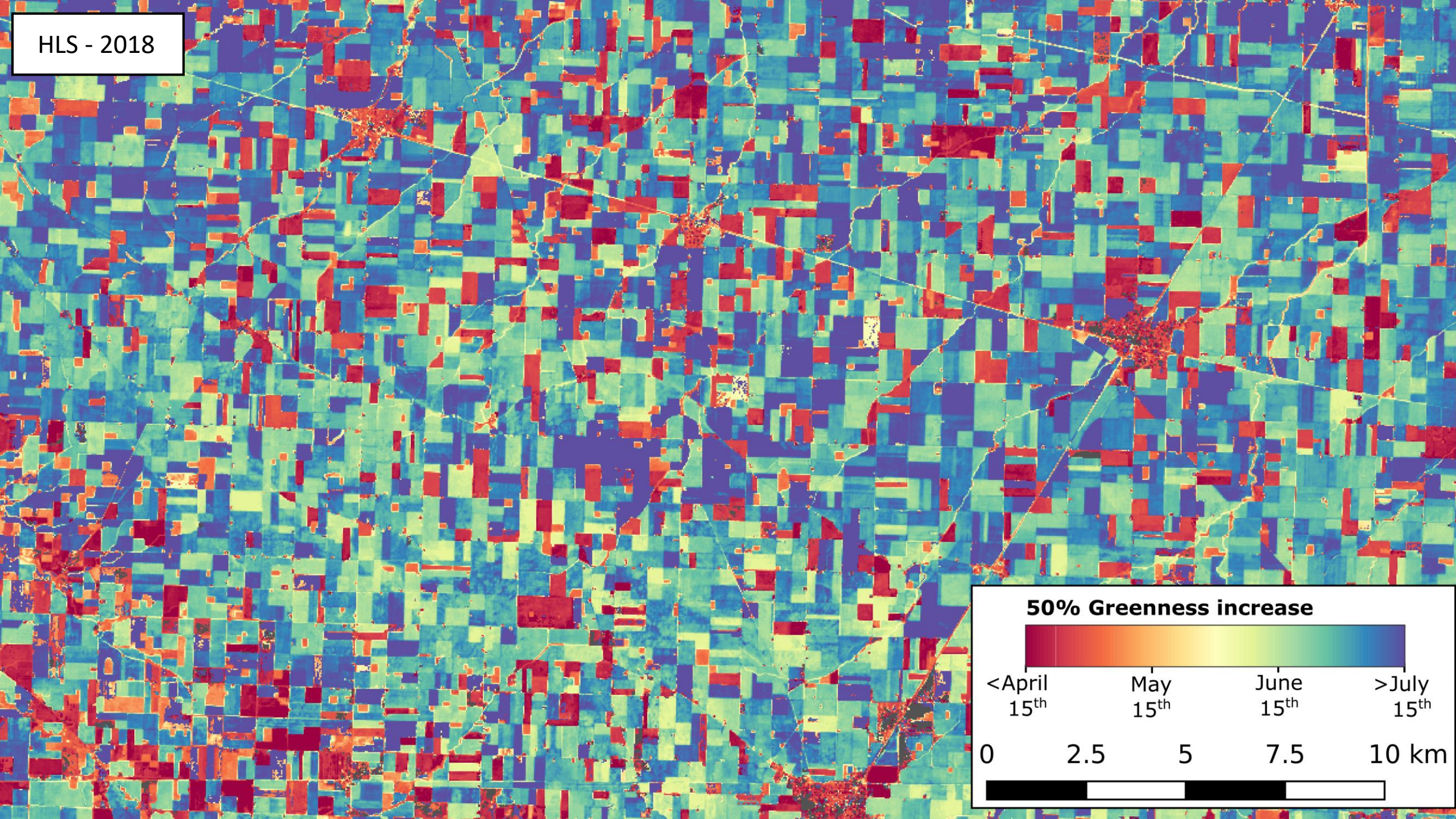
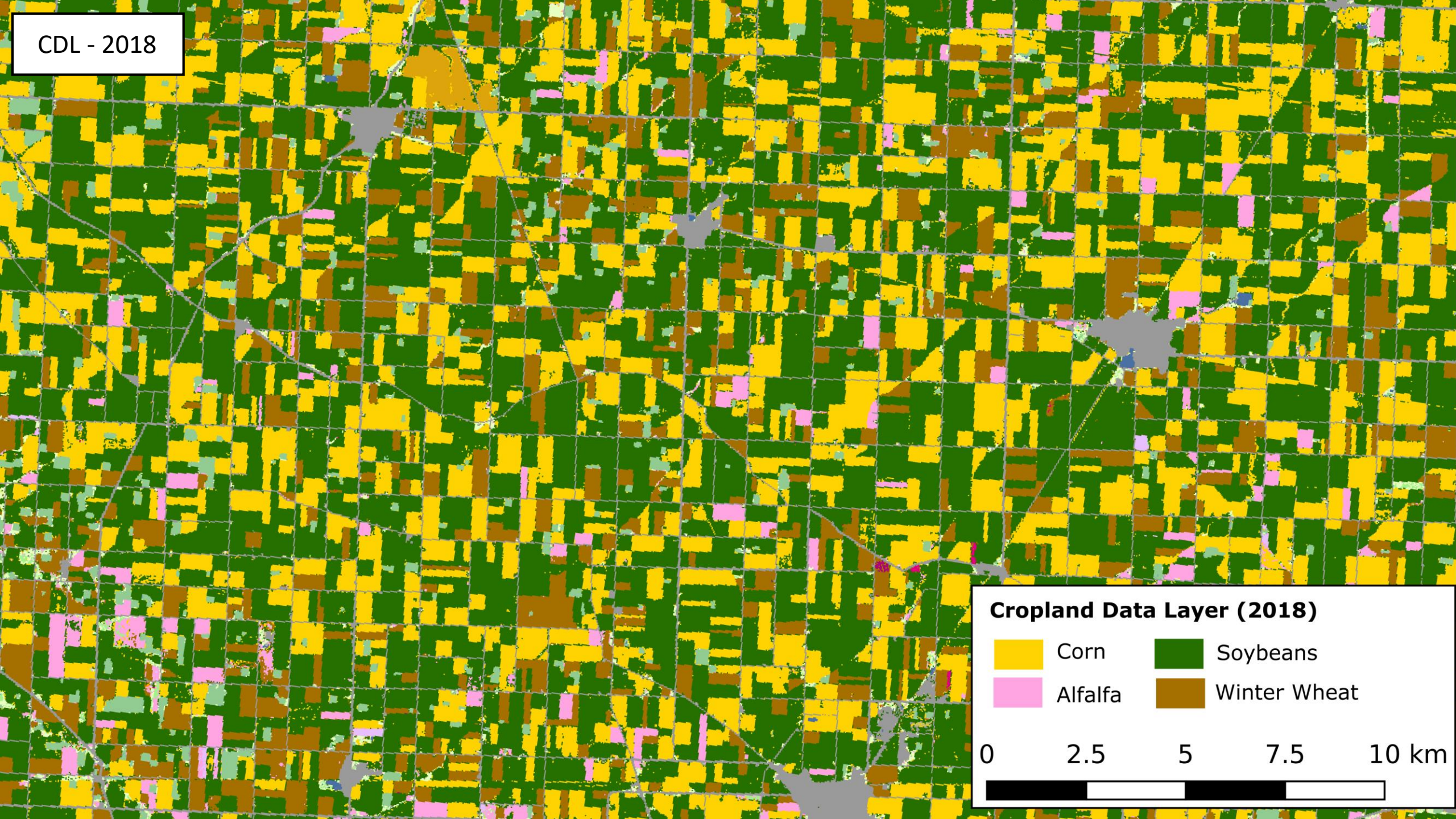
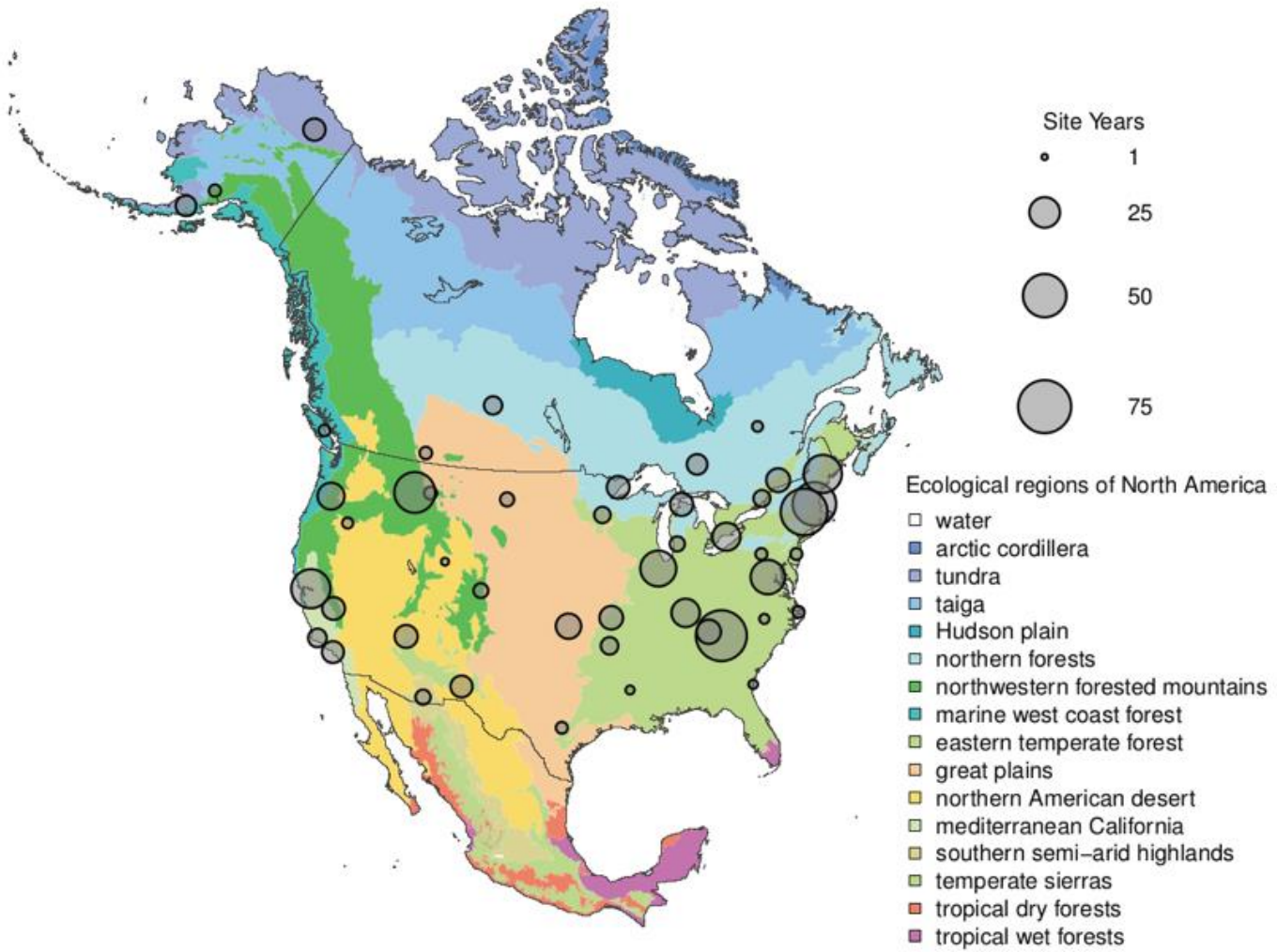

HLS - 2018
50% Greenness increase
<April 15th
May 15th
June 15th
>July 15th
0
2.5
5
7.5
10 km


CDL - 2018
Cropland Data Layer (2018)
Corn
Soybeans
Alfalfa
Winter Wheat
0
2.5
5
7.5
10 km

Comparison against phenoCam

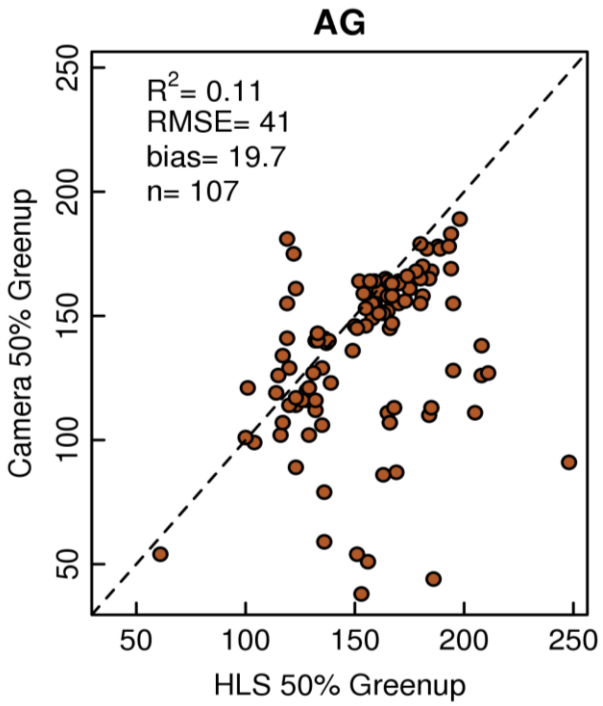
Compare against phenoCam network

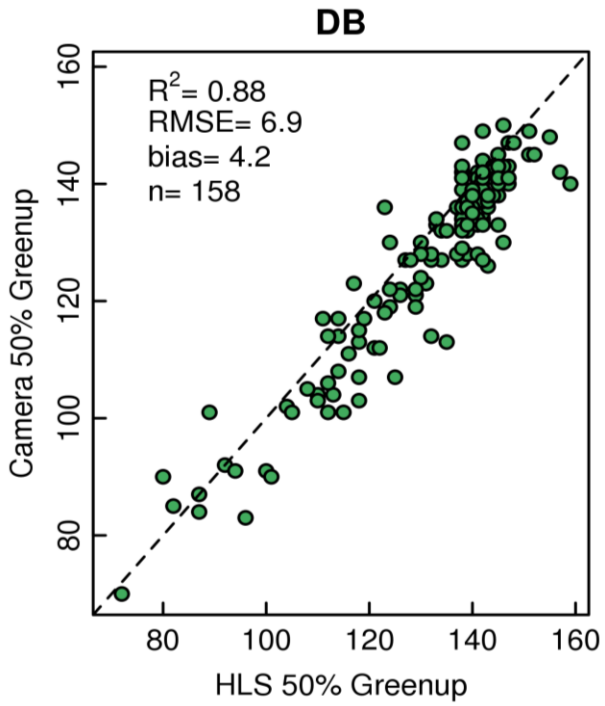
> 400 total site-years

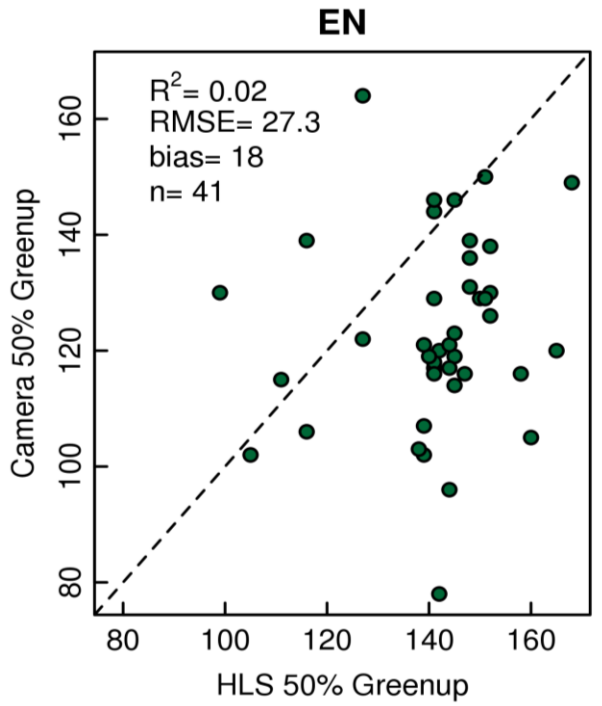


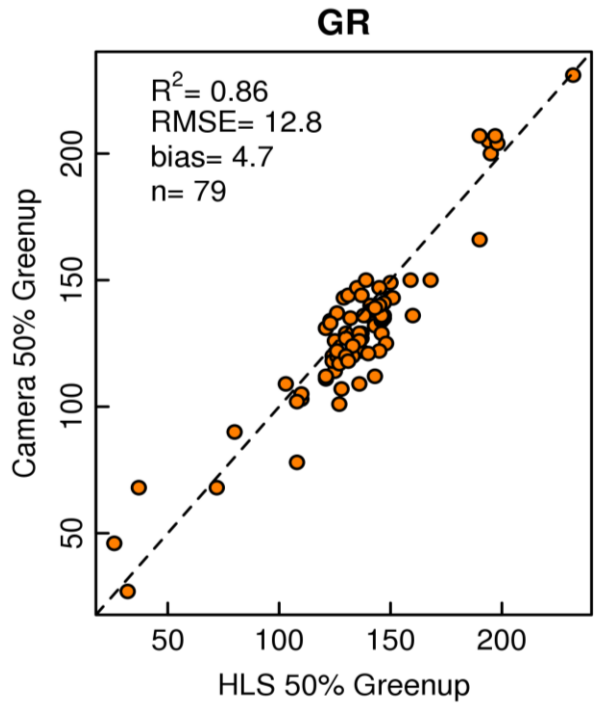
Source: Richardson et al. 2018

Comparison against phenoCam

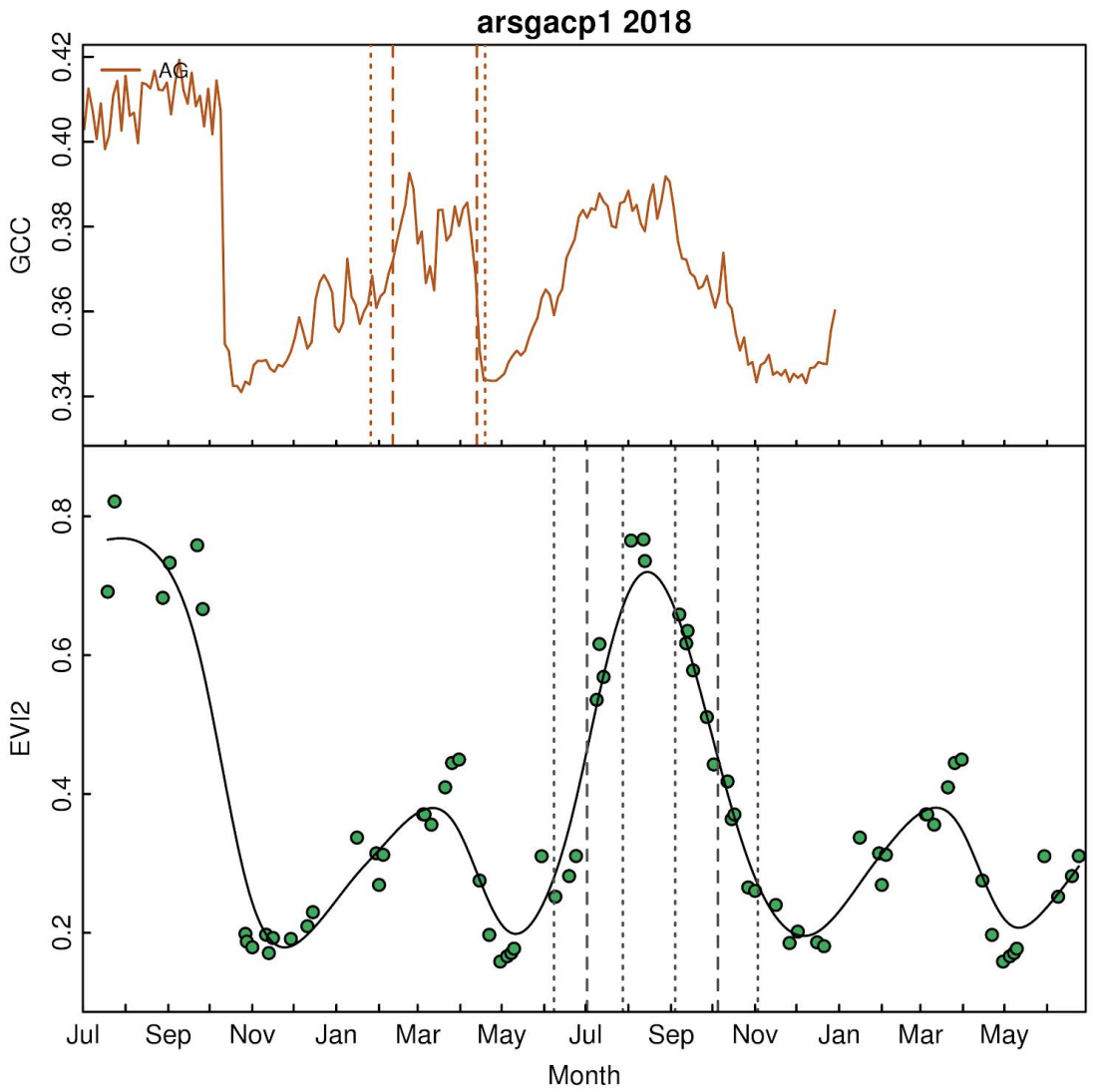








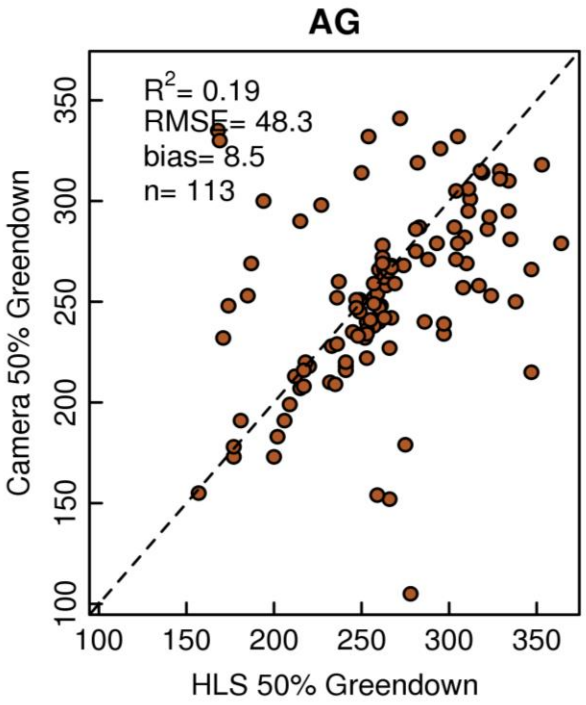
Comparison against phenoCam

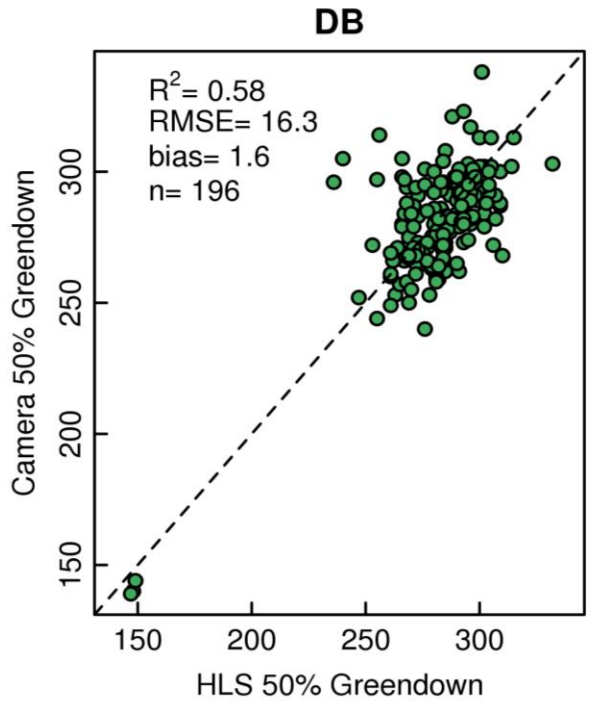


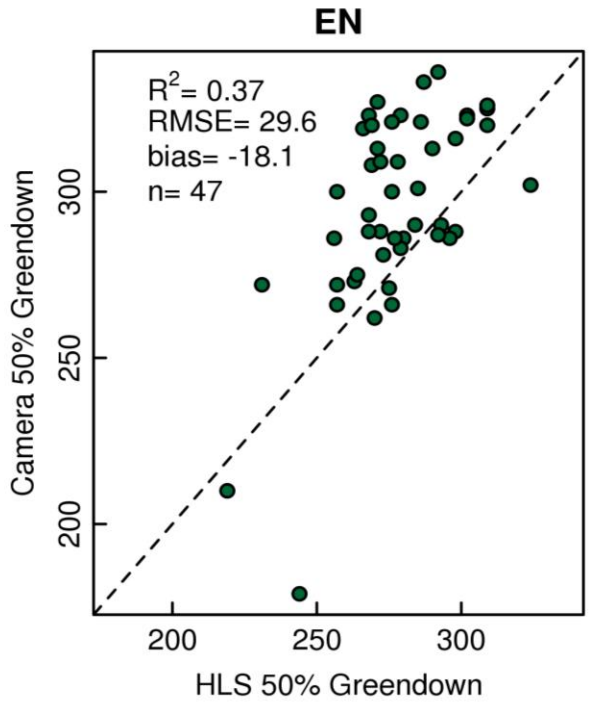
Feb 15, 2018

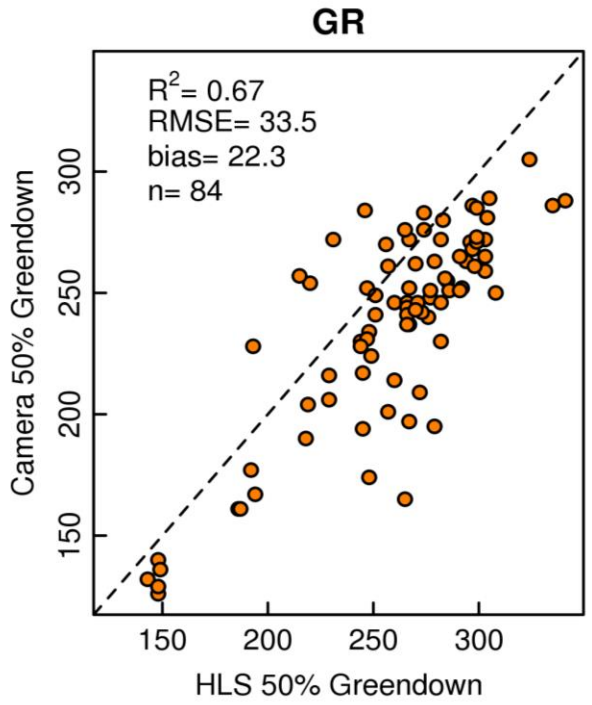
Tifton, Georgia

Comparison against phenoCam

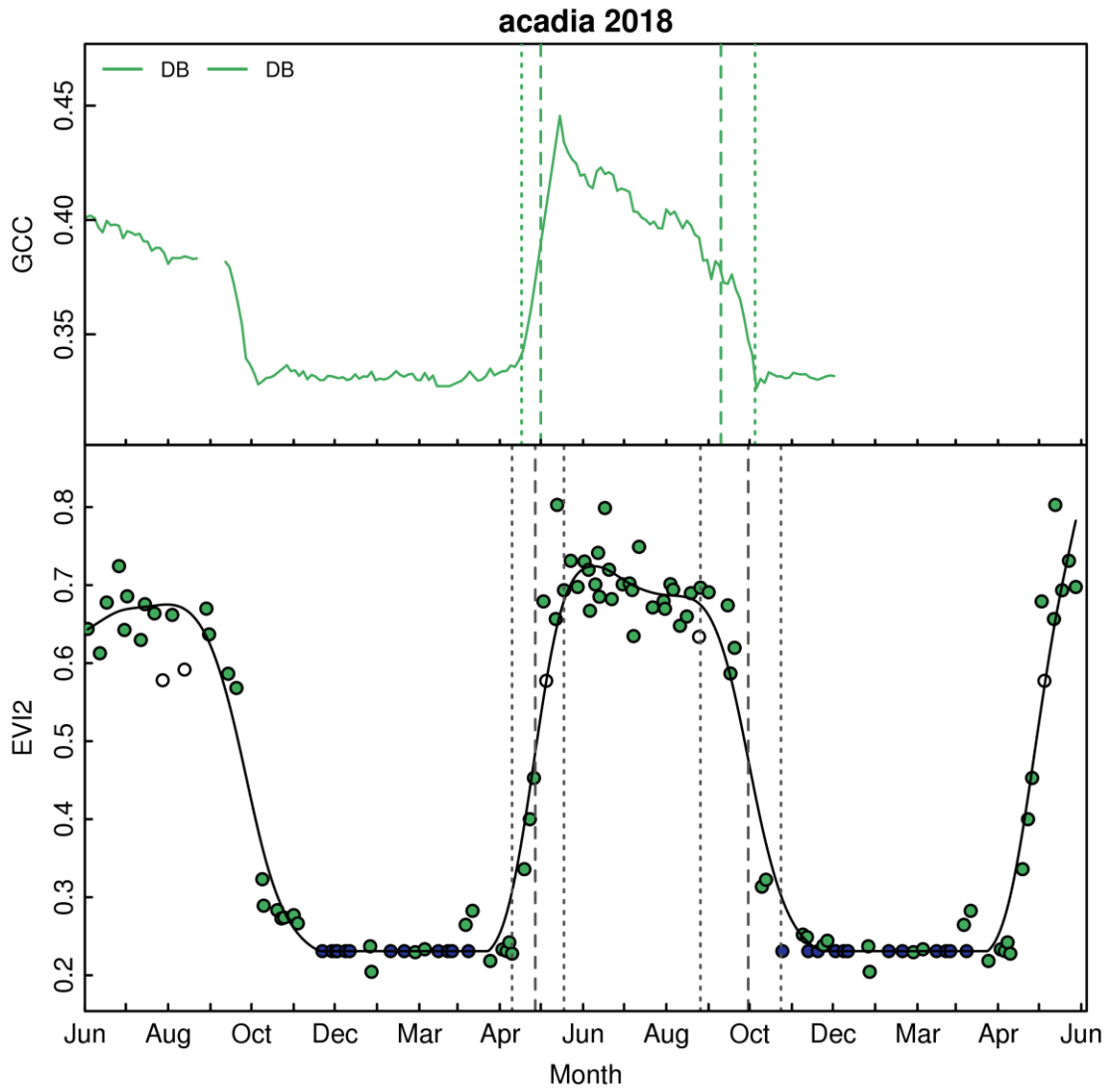








Comparison to PhenoCams

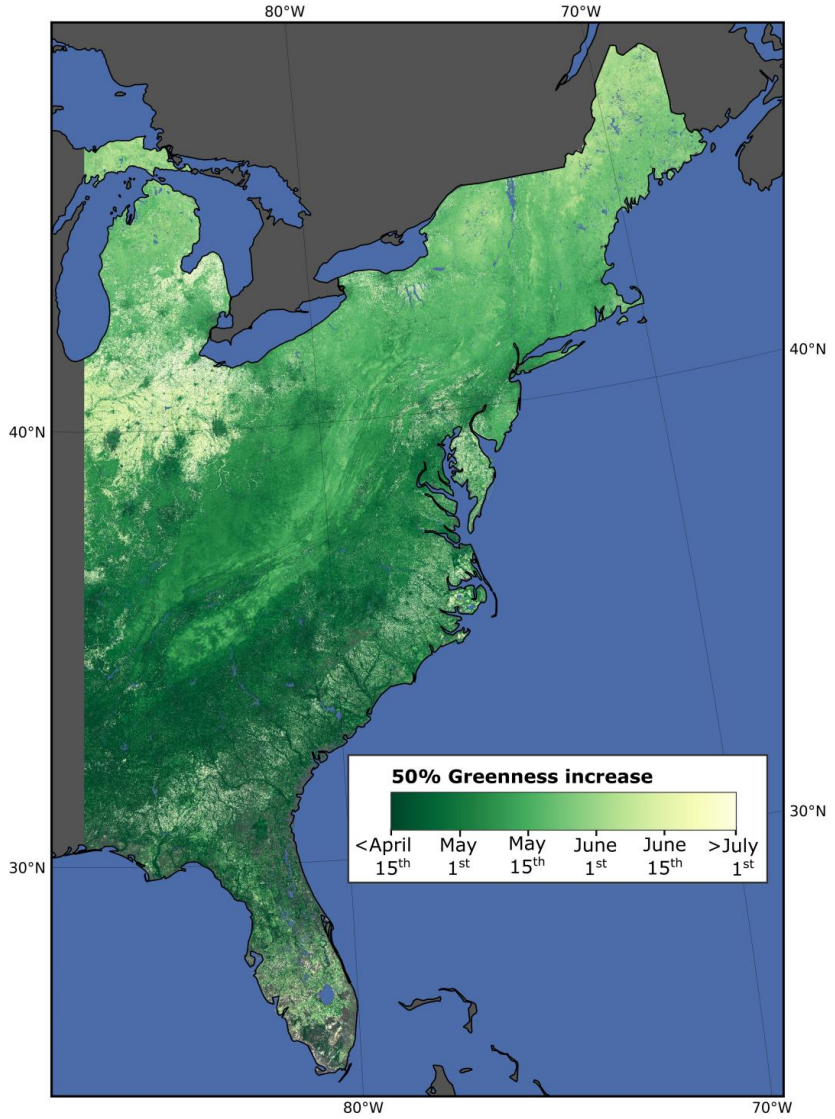


Oct 2, 2018

Acadia National Park, Maine

Conclusions

- Close to production of a 30m phenology product for North America
- Promising comparisons against phenoCam data
- **Final steps:**
  - Full scale runs on AWS
  - Delivery of data and documentation to LP-DAAC in the summer of 2019



Thank you!

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www.bu.edu/lcsc

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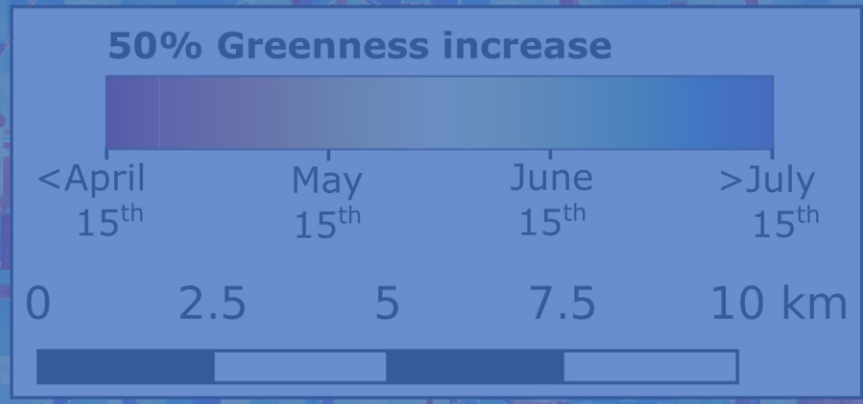
NASA LCLUC
Land-Cover / Land-Use Change Program



References

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