Seeing the Forest for the Trees: Observing and Modeling Phenology Across Multiple Scales

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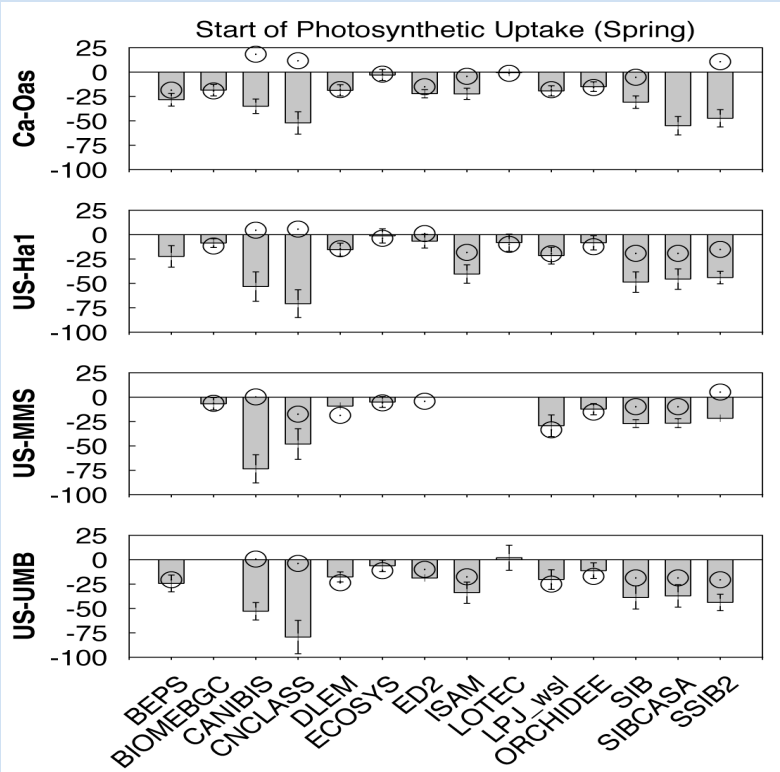
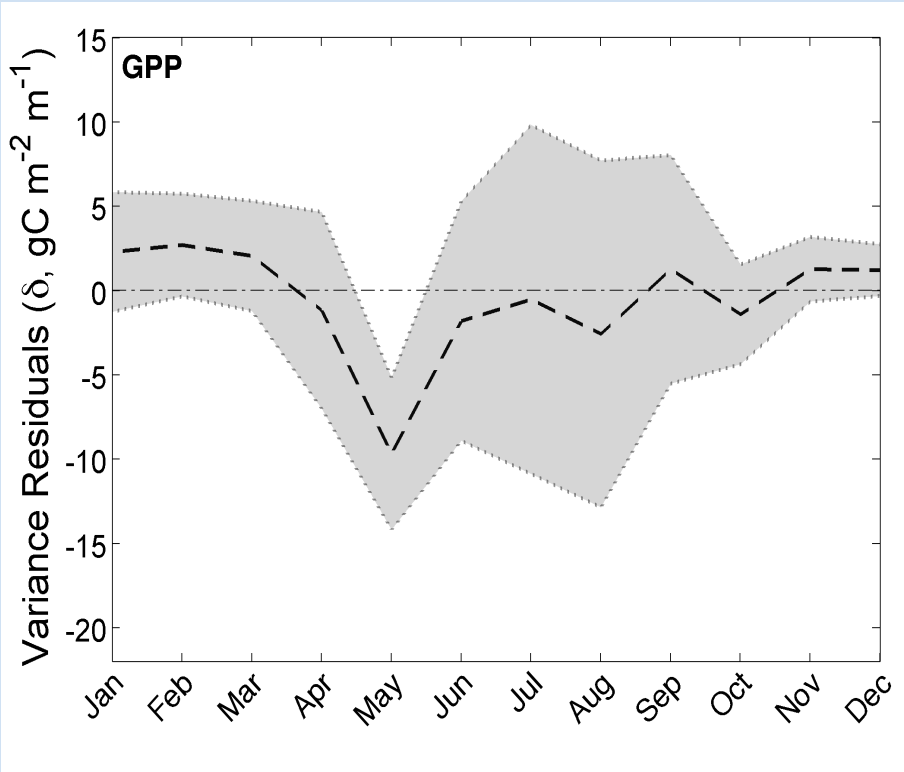
Representation in Biosphere Models

Phenology sub-models in land surface models predict biased phenology



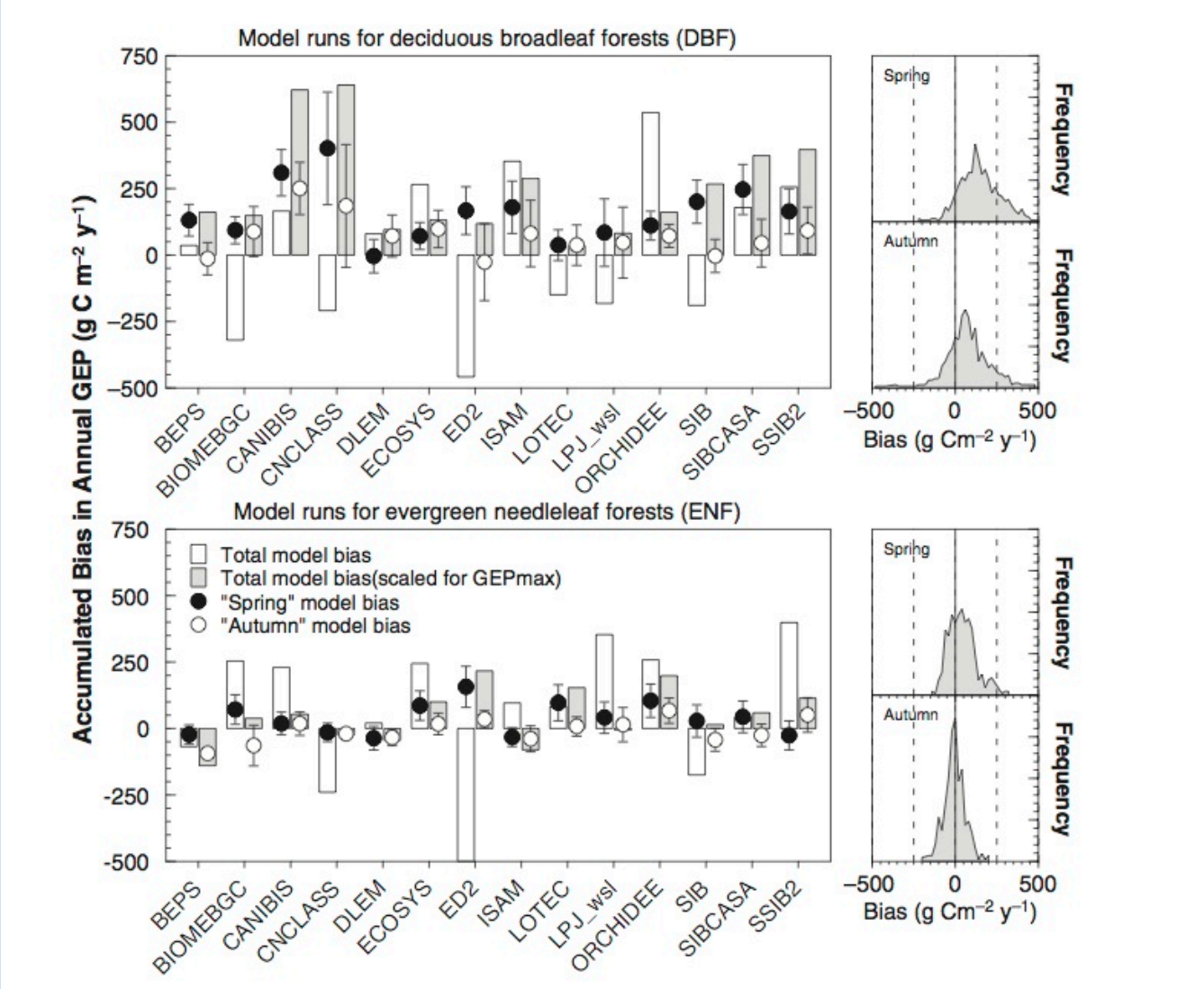
Richardson et al. (2012) Global Change Biology

Models also systematically underestimate variability in spring phenology.



Keenan et al. (2012) Global Change Biology

Impacts on Regional & Global Carbon Cycle



Richardson et al. (2012) Global Change Biology

Outline

- *Data sources: from leaves to landscapes*
  - *In-situ observers, webcams, Landsat, MODIS*
- *Seeing the forest for the trees: extracting information from short, noisy time series*
  - *Anomalous spring climate in 2010*
    - *Sensitivity and response to unusually warm spring*
    - *Damage from late spring frost*
  - *Analogue of things to come in temperate hardwood forests of North America?*

Data Sources: In-Situ Observers

Human observers recording continuous metrics or day of year for specific "phenophase" transitions

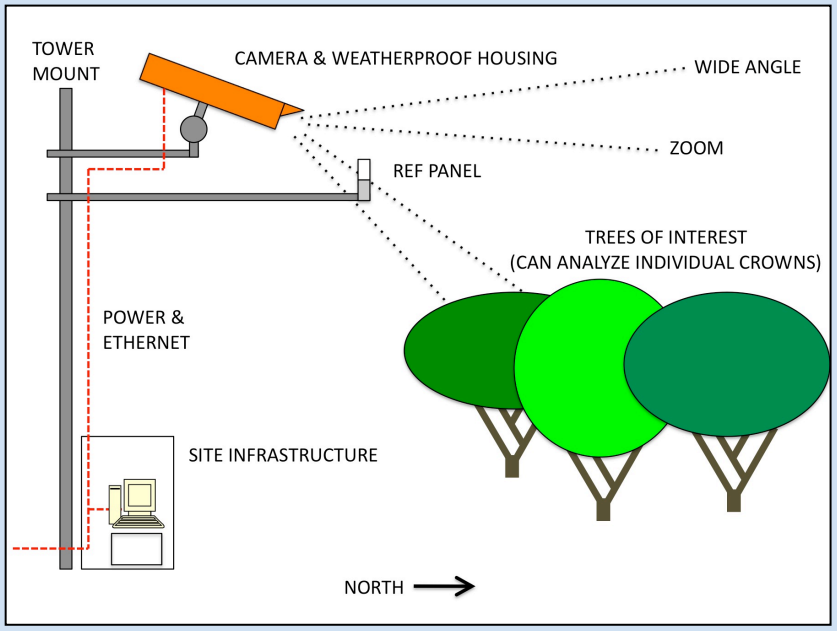
- Different data sets, different protocols

Three main sources:

- Hubbard Brook Experimental Forest
- Harvard Forest LTER
- National Phenology Network

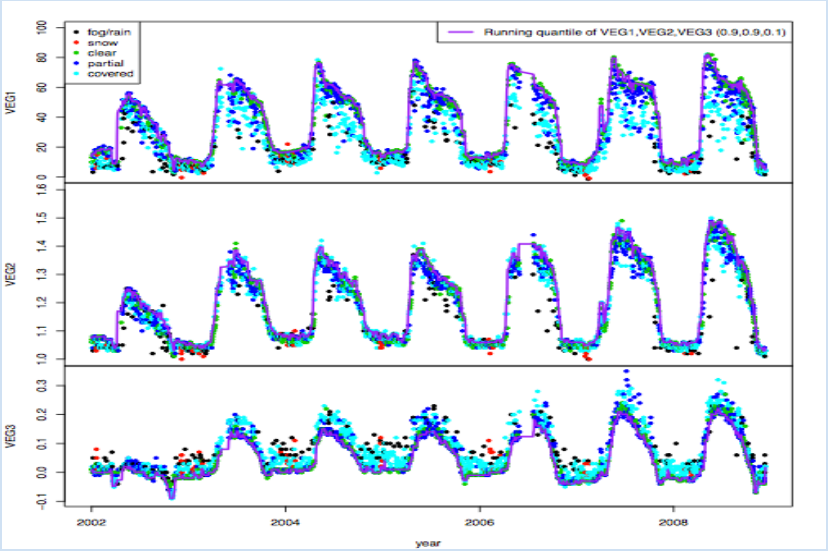
Individual plants; 5-7 day frequency

Data Sources: Webcams



Commercial webcam technology

- Low cost, widely available
- Allow continuous monitoring of canopy
- By extracting digital data from red, green, blue color planes, can extract time series of vegetation indices
- Landscape scale; ~mulitple times/day



Continental-scale PhenoCam coverage

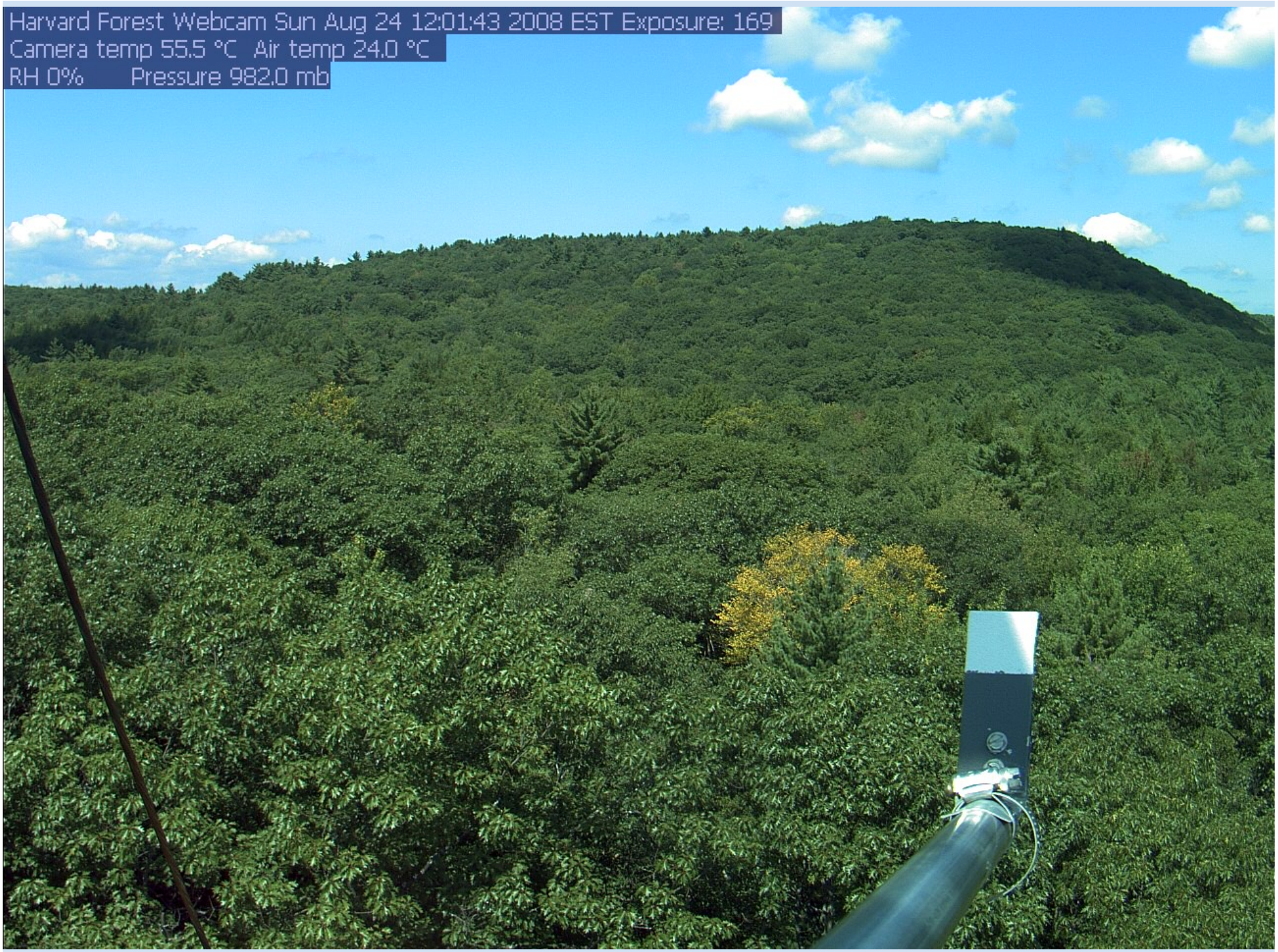
Some data records 10+ years in length

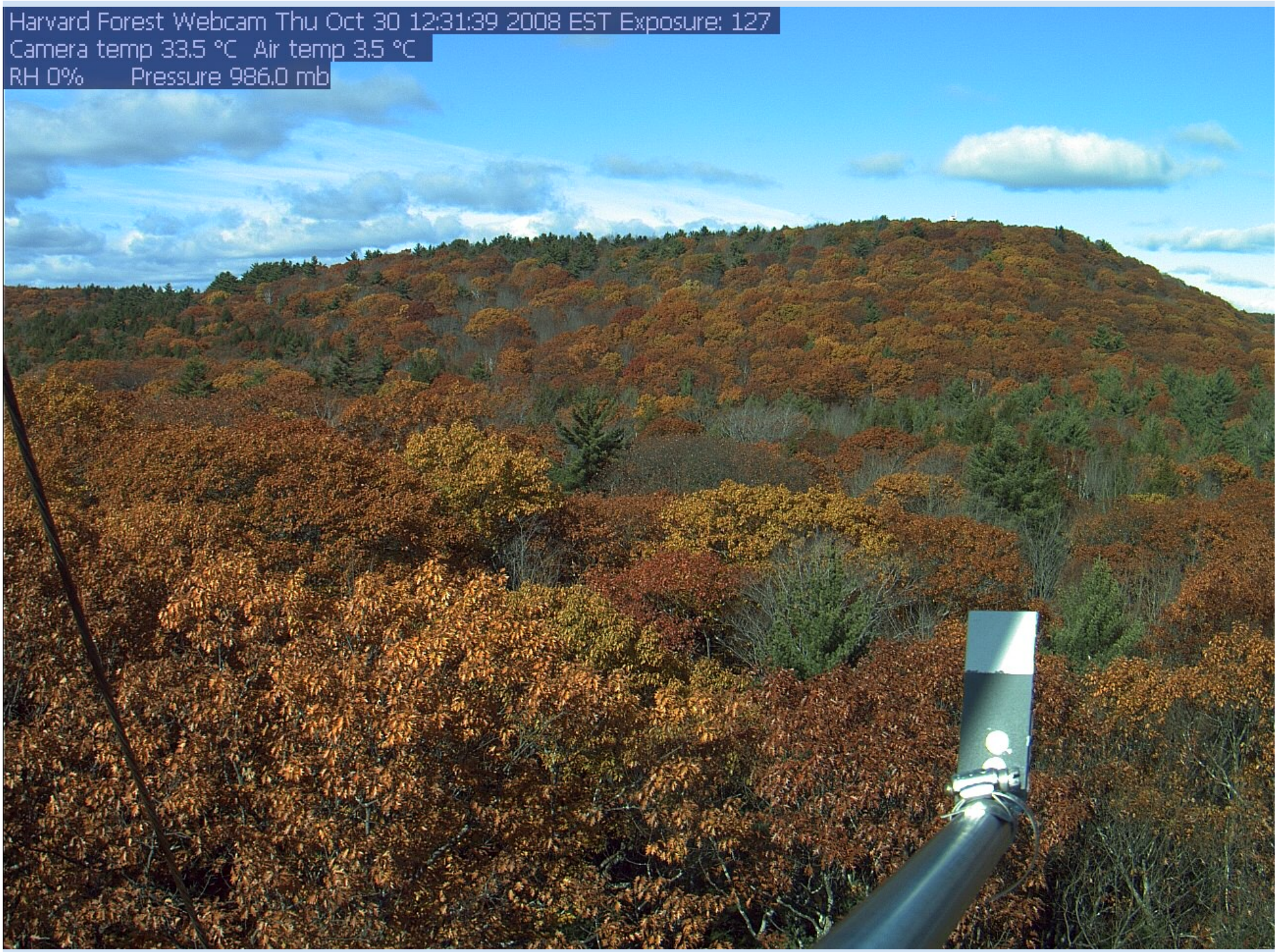
~50 core sites; 60-70 affiliated sites covering a wide range of ecosystem types


Harvard Forest Webcam Mon Apr 07 12:31:41 2008 EST Exposure: 137
Camera temp 37.0 °C Air temp 6.5 °C
RH 0% Pressure 992.0 mb


Harvard Forest Webcam Sun May 11 12:01:40 2008 EST Exposure: 127
Camera temp 46.5 °C Air temp 16.0 °C
RH 0% Pressure 971.0 mb


Harvard Forest Webcam Thu Jun 12 13:31:42 2008 EST Exposure: 171
Camera temp 51.5 °C Air temp 22.0 °C
RH 0% Pressure 984.0 mb

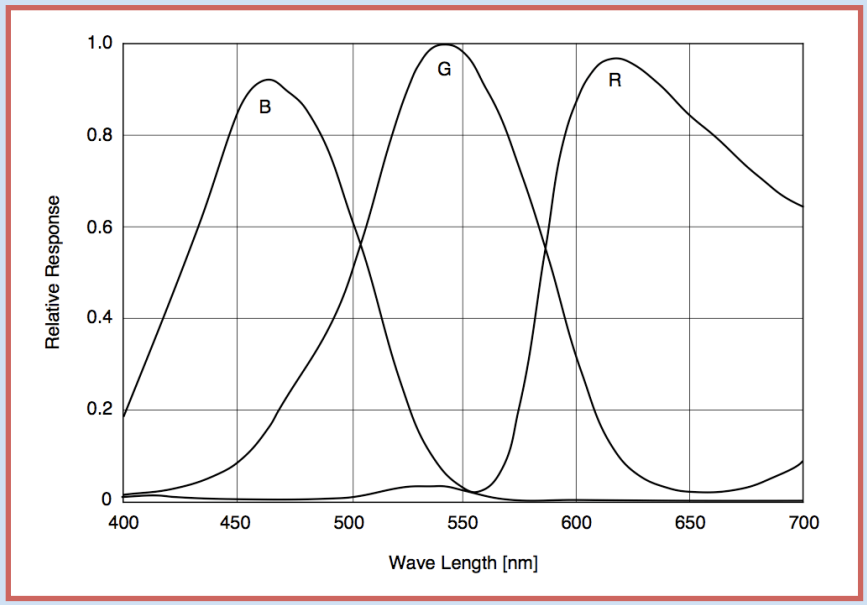

Harvard Forest Webcam Sun Aug 24 12:01:43 2008 EST Exposure: 169
Camera temp 55.5 °C Air temp 24.0 °C
RH 0% Pressure 982.0 mb

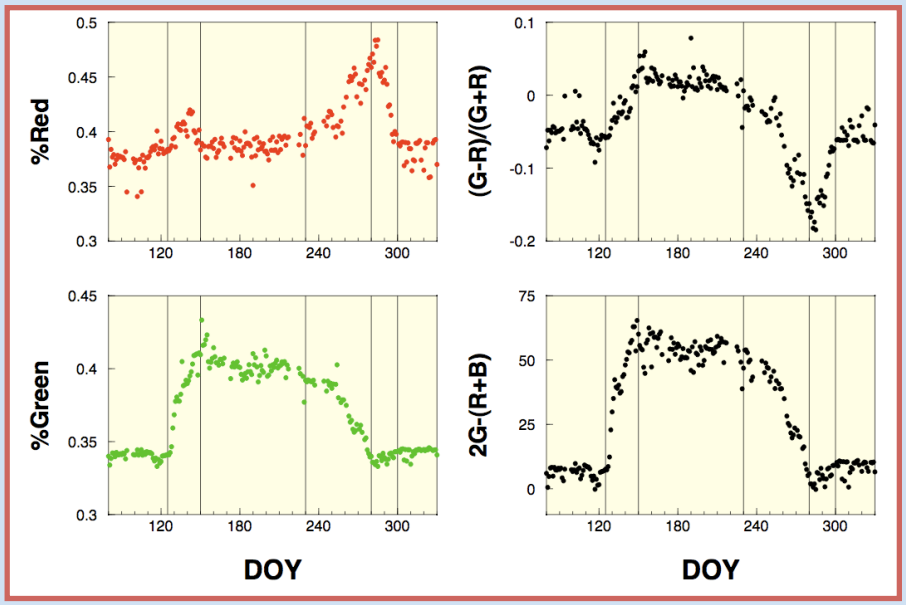

Harvard Forest Webcam Thu Oct 30 12:31:39 2008 EST Exposure: 127
Camera temp 33.5 °C Air temp 3.5 °C
RH 0% Pressure 986.0 mb

PhenoCam Indices

Image analysis (RGB channel extraction) to quantify phenological dynamics

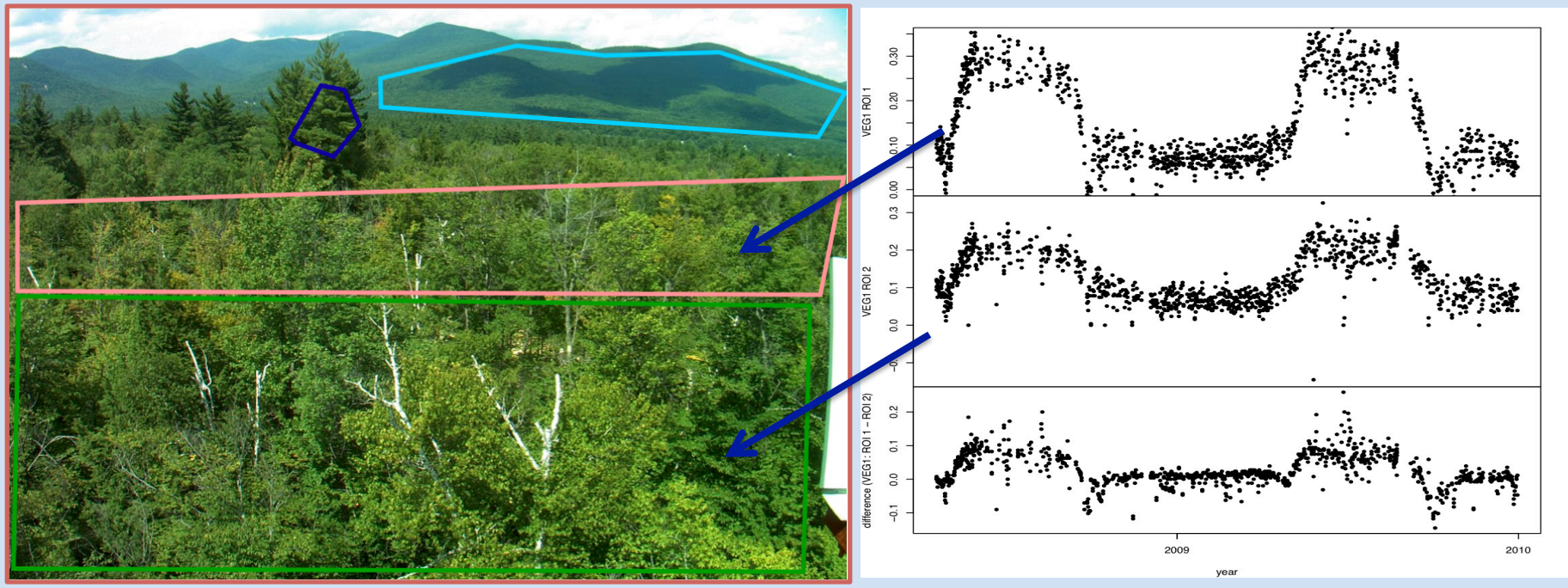
– *Richardson et al., 2007, Oecologia; Richardson et al, 2009, Ecological Applications*





Challenge: Extracting high quality vegetation index time series

Phenocam Data Processing
1. Selection of ROI



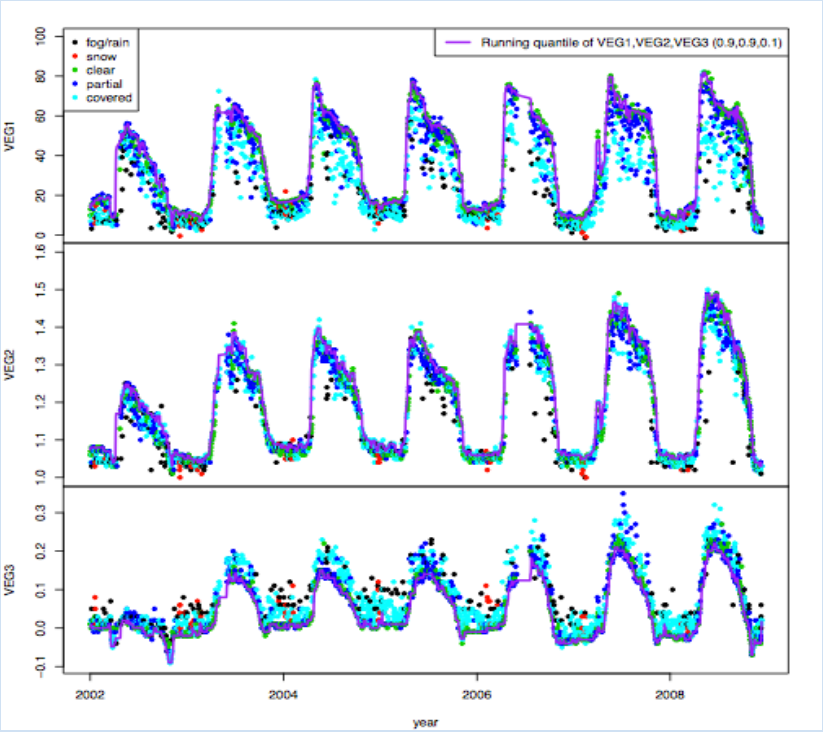
Sky, shadow, foreground, background, conifer, broadleaf…

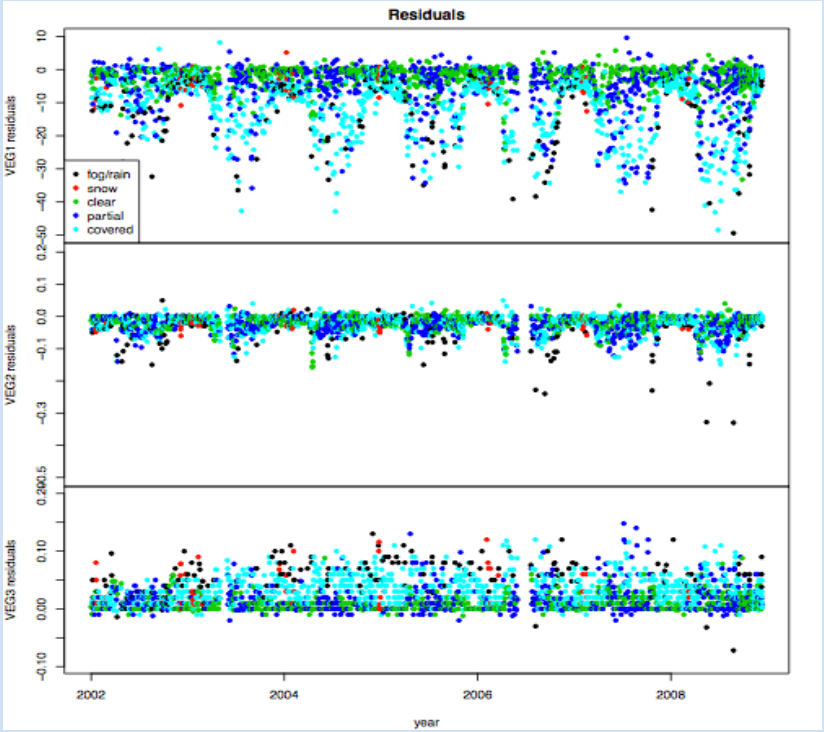
Different ROI's have different VI's values and levels of noise

<u>*Selecting representative ROI in foreground improves S/N*</u>

Hufkens et al., RSE 2012; Sonnetag et al., AFM, 2012

Phenocam Data Processing
2. Noise Reduction



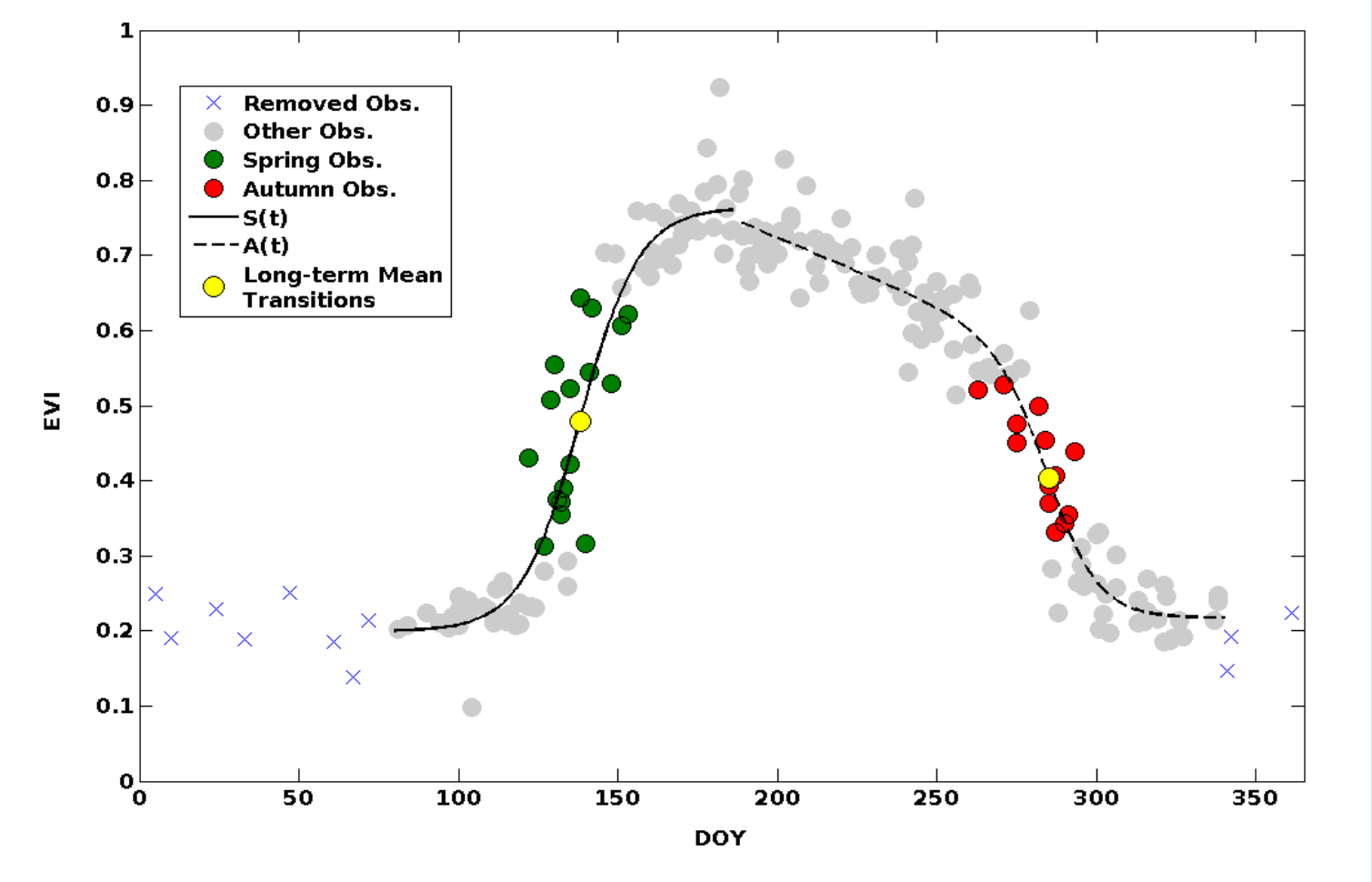


Illumination, sky conditions significantly VI's

<u>Filtering based on upper envelope seems to work quite well</u>

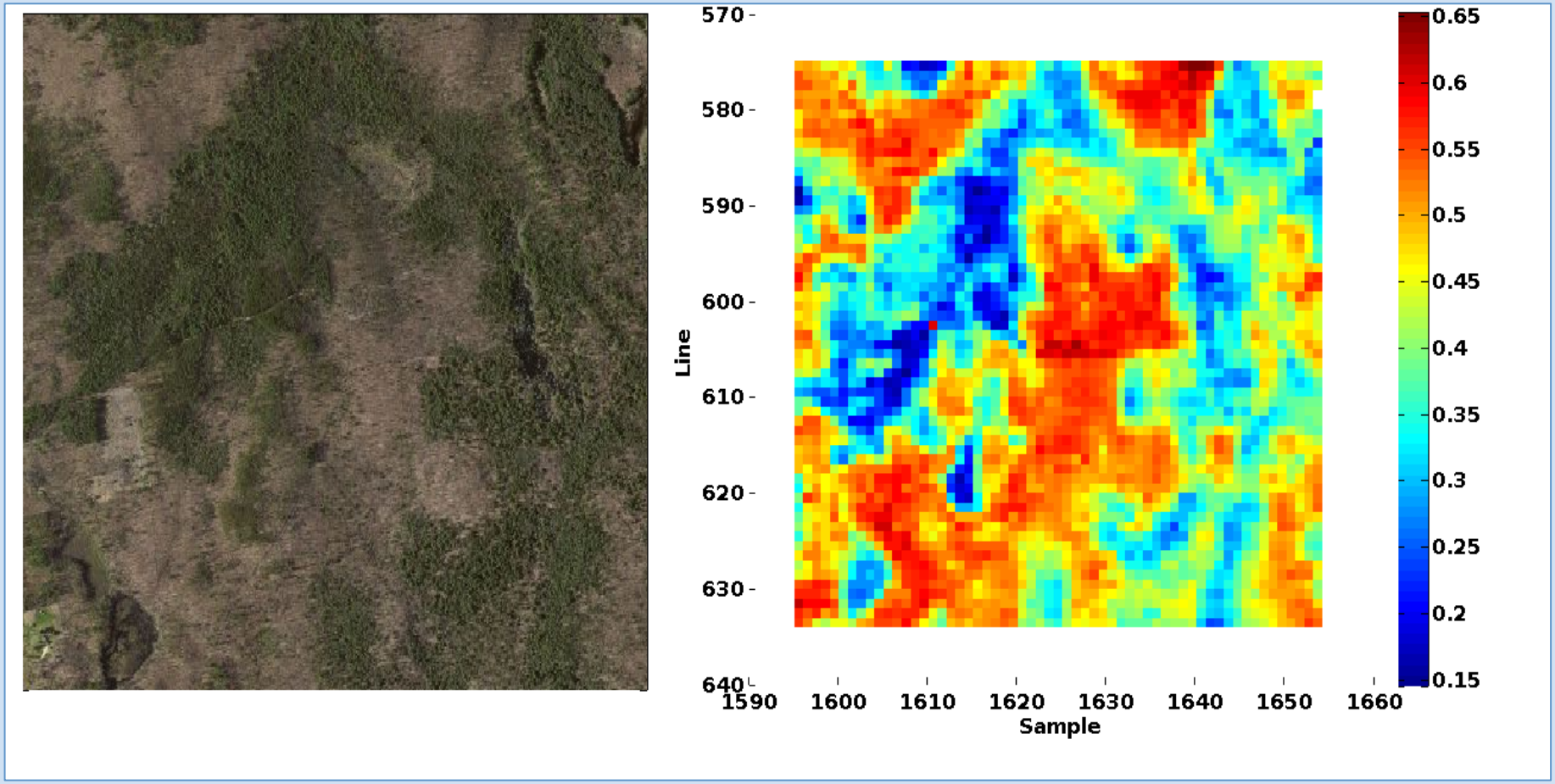
Hufkens et al., RSE 2012, Sonnetag et al., AFM, 2012

Data Sources: Landsat

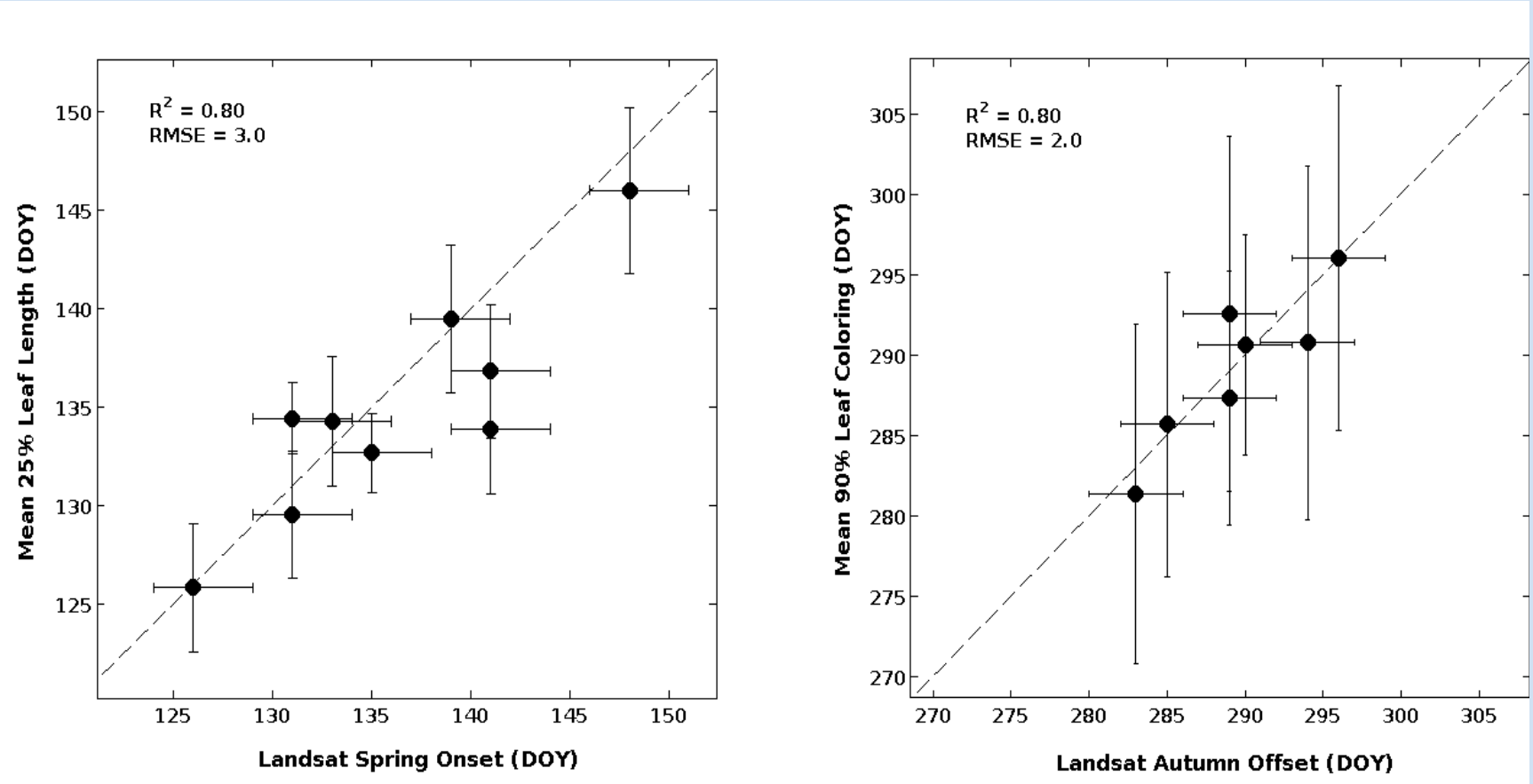


30 meter pixels, 16 day repeat under clear skies

Landsat Amplitude = "Deciduousness"

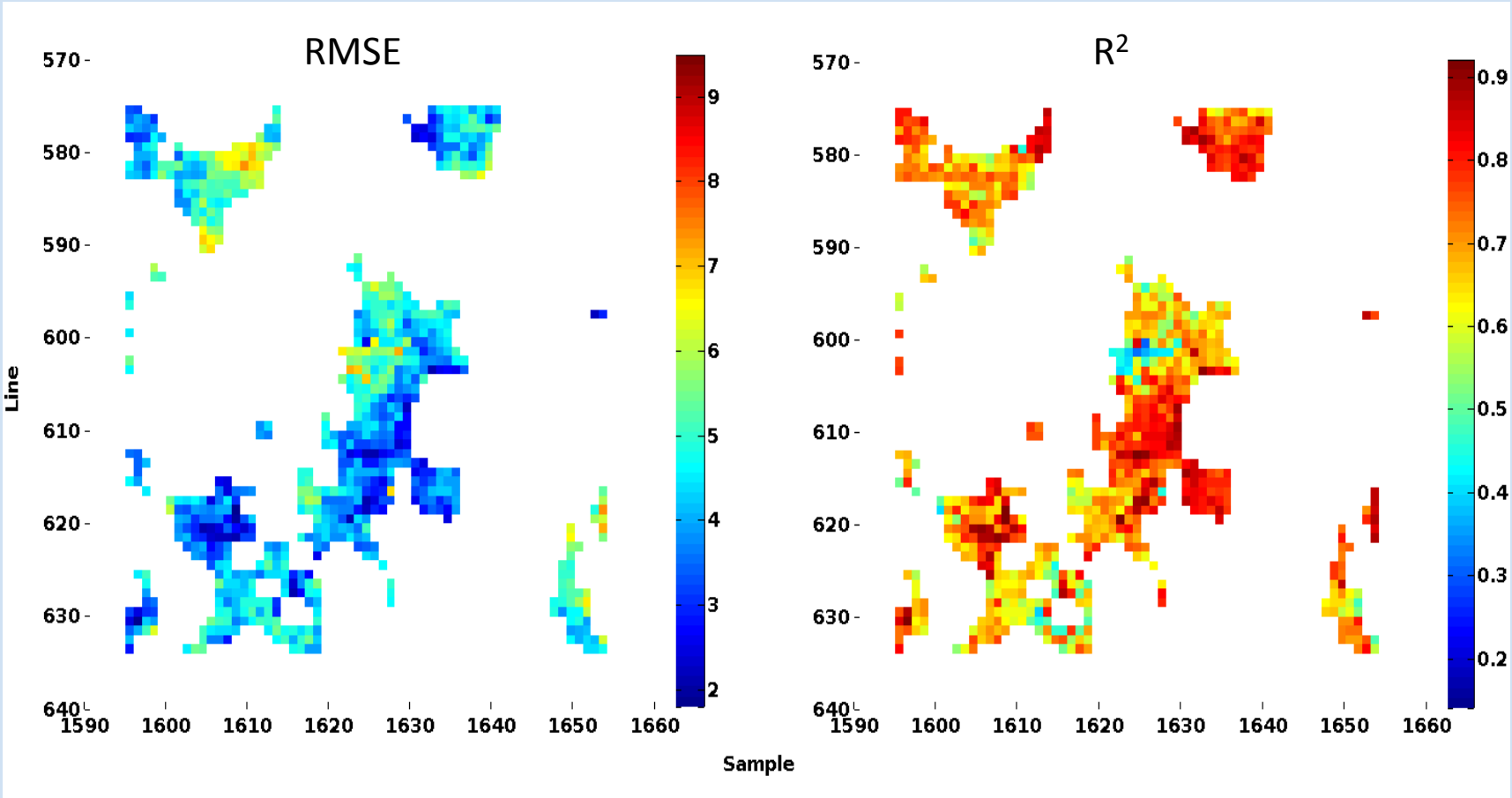


Data Sources: Landsat



Spring onset from Landsat versus 100% budburst 50% coloring for Red Oak at Harvard Forest
Single pixel centered over EMS tower

Spring Onset from Landsat vs 100% Budburst (Red Oak): 1982-2000



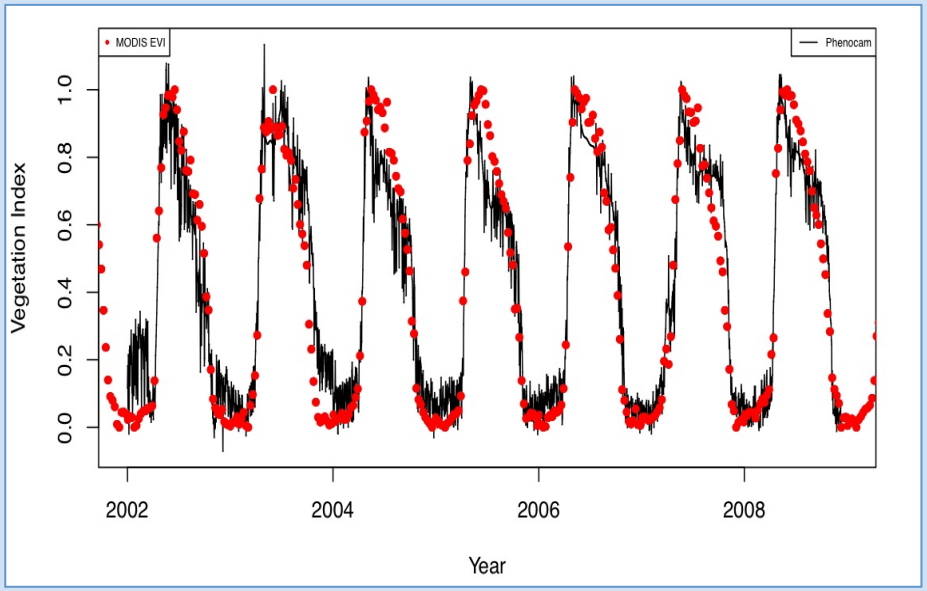
MODIS vs PhenoCam & Fluxes

Mammoth Cave, KY Webcam:

Clear phenology, modest noise level

Agrees well w/MODIS

Hufkens et al., RSE 2012



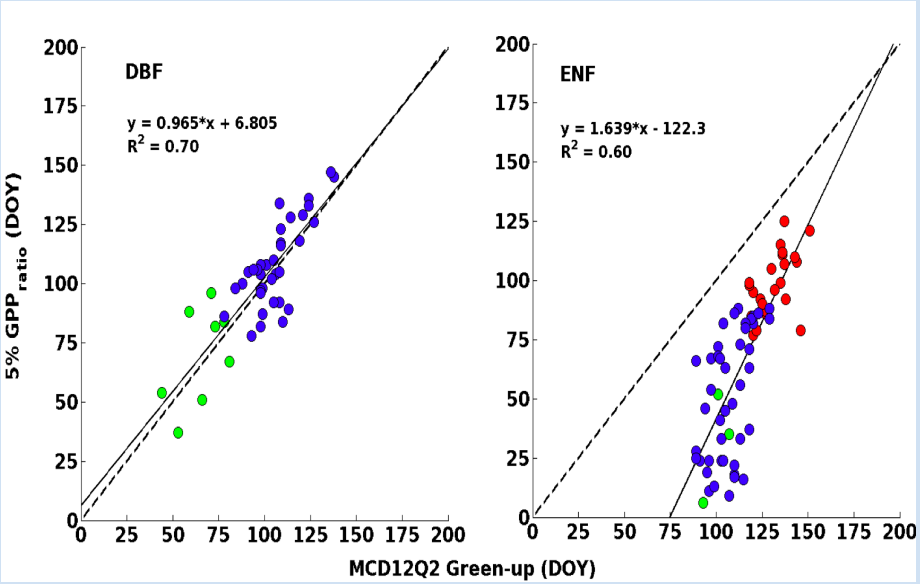
La Thuille Fluxnet Dataset:

Onset of season based on GEP

Strong correlation, no bias in DBF

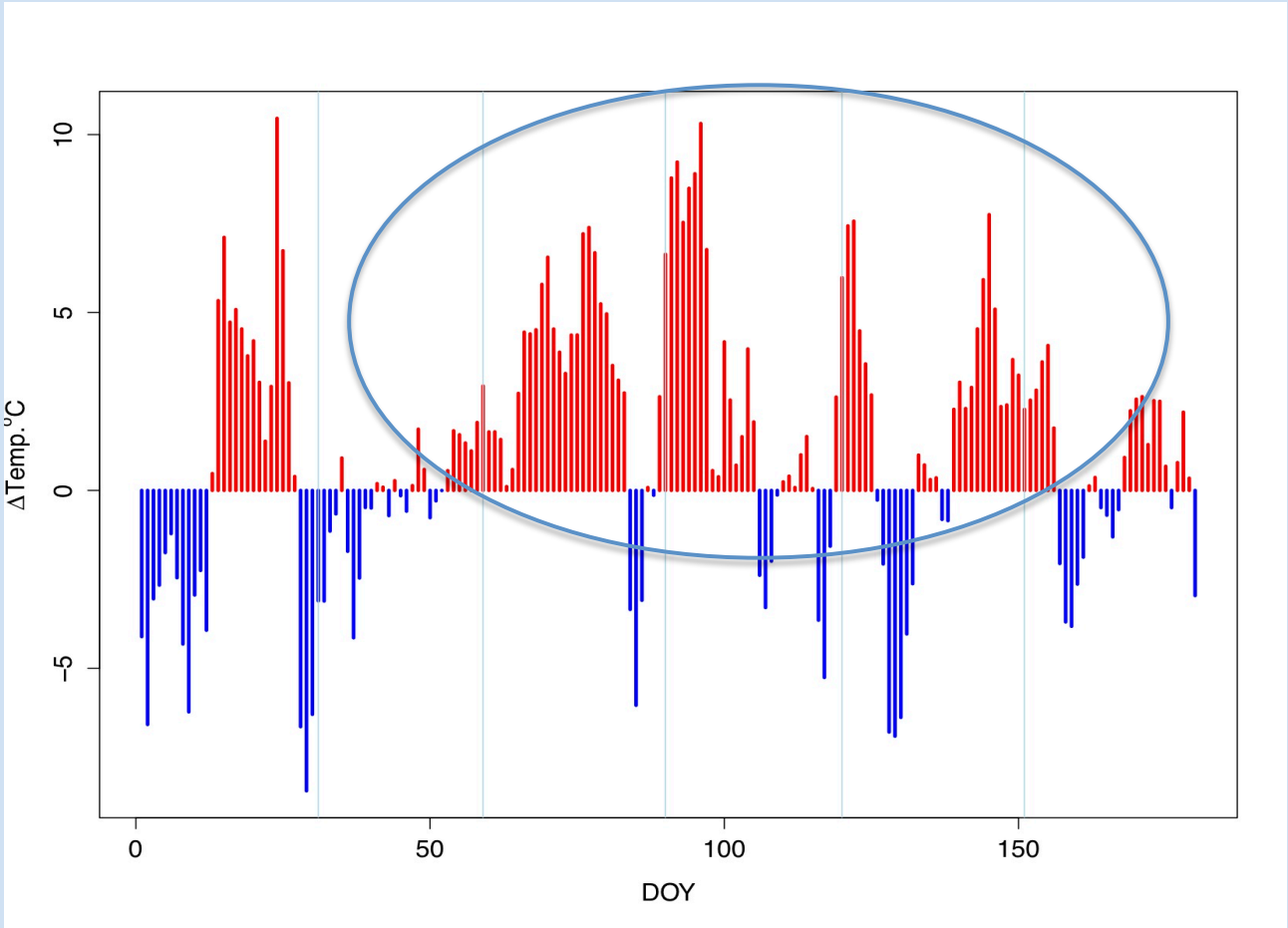
Good correlation, large bias in ENF

Melaas et al., in revision AFM



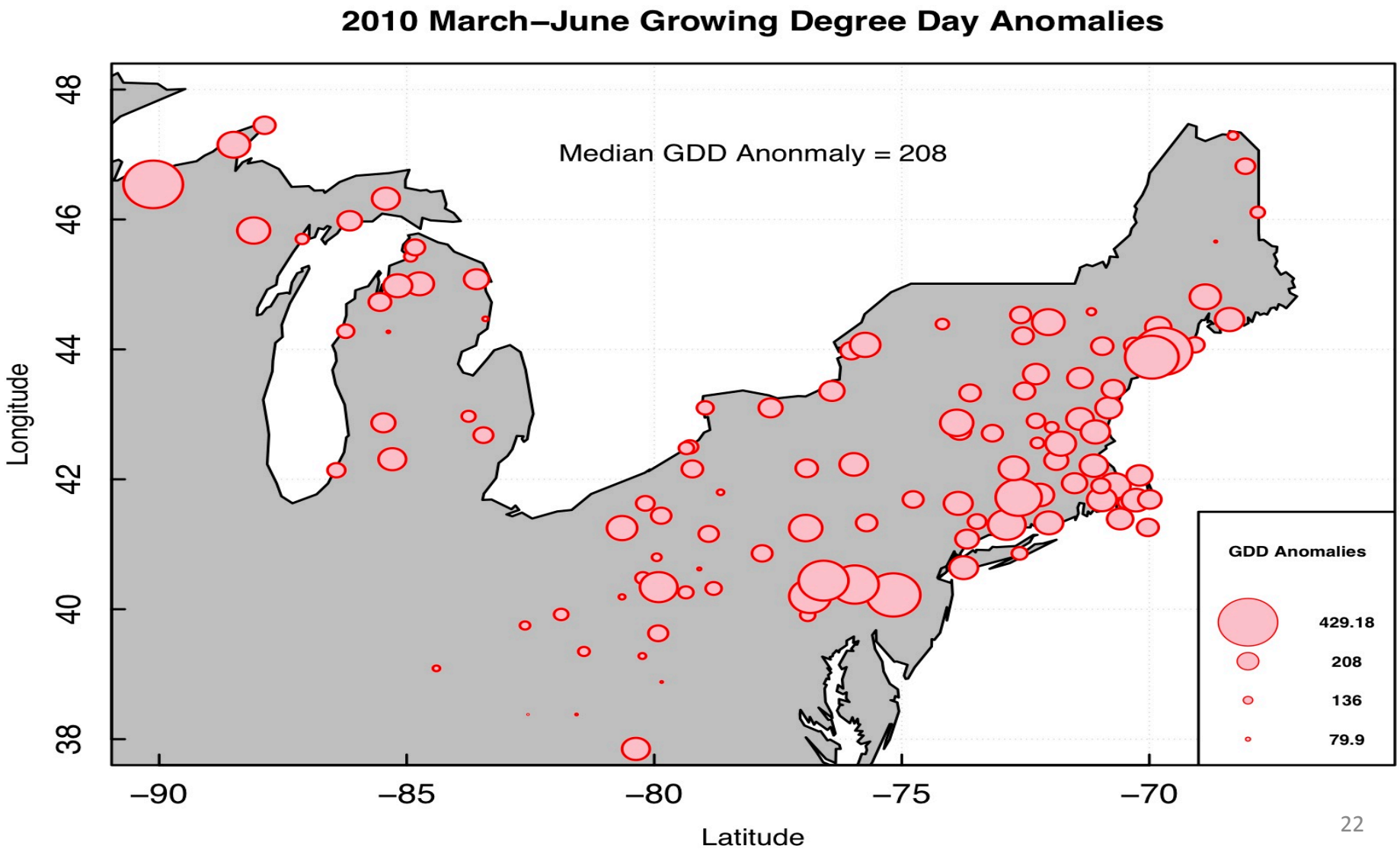
Temperature Anomalies in Spring 2010 Northeastern United States

(120 Stations; Relative to 1979-2009 mean)

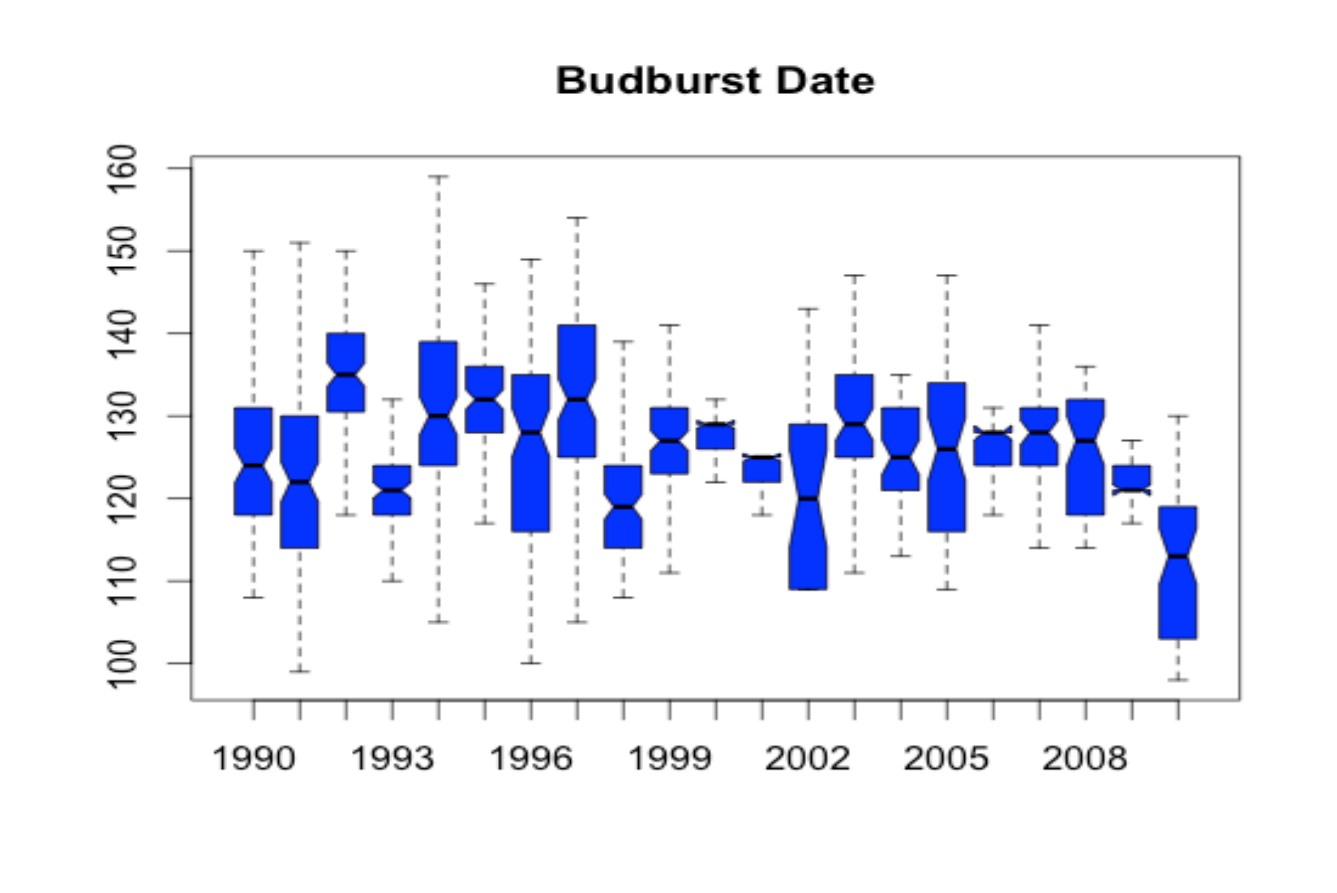


GDD Anomalies at NOAA COOP Stations

(120 Forested Sites; DOY 60-180)

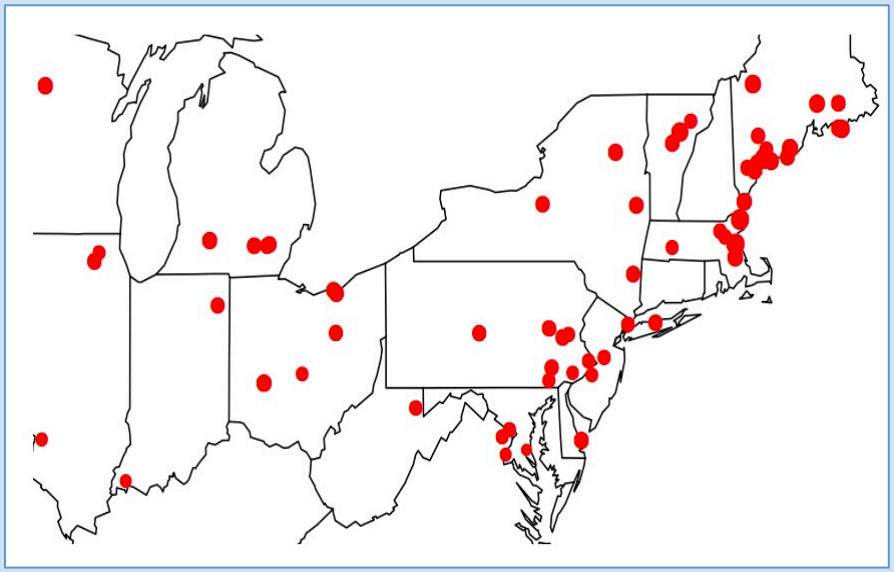


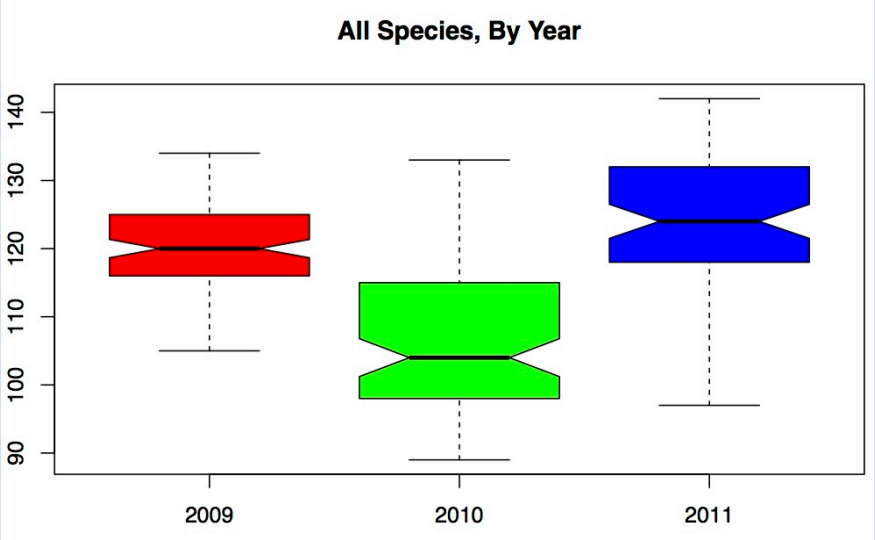
Annual Time Series of Budburst at Harvard Forest



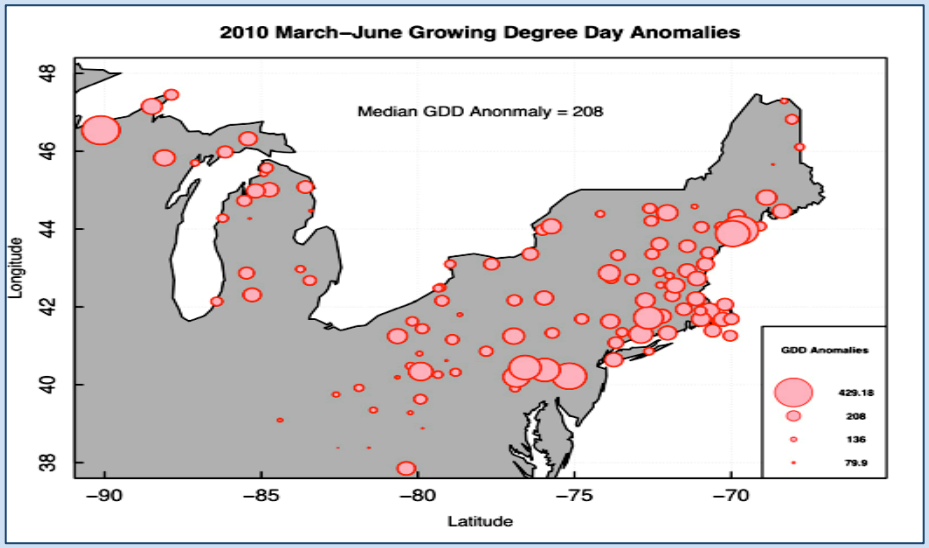
NPN Data from Northeastern US

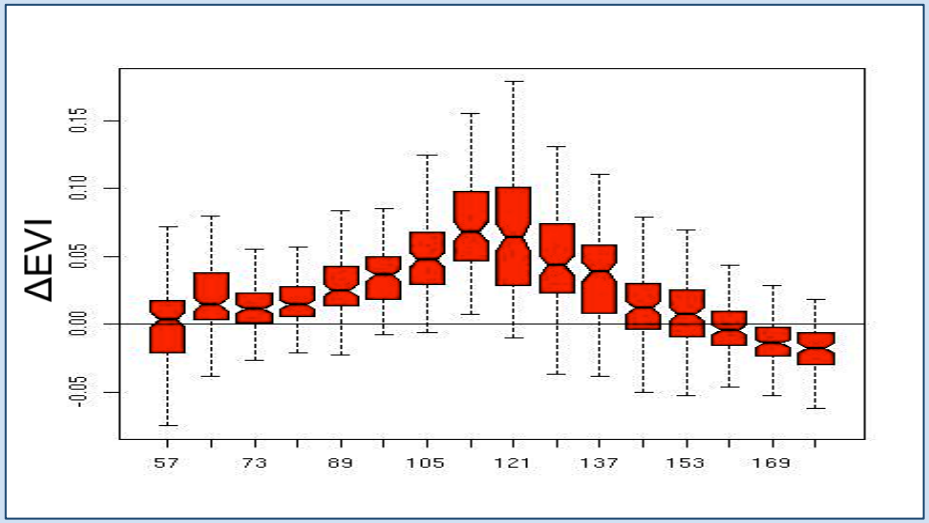
(283 total data points; 69 points common to 2010 and either 2009 or 2011)

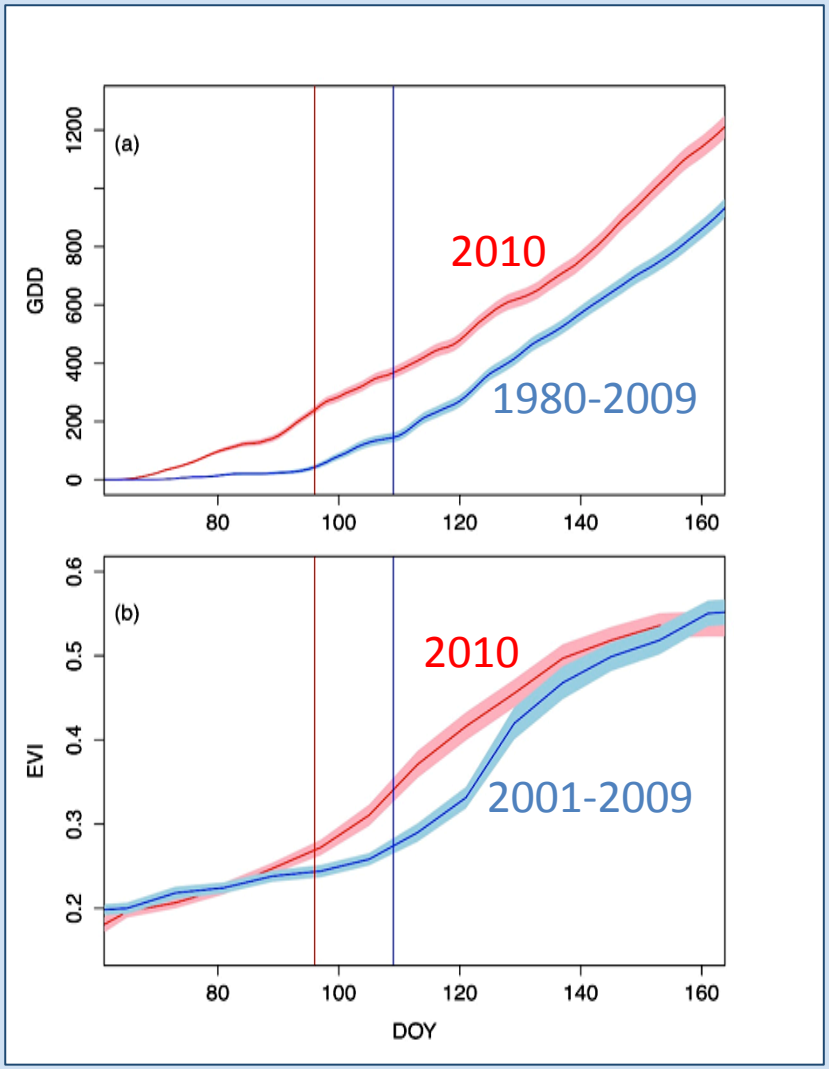




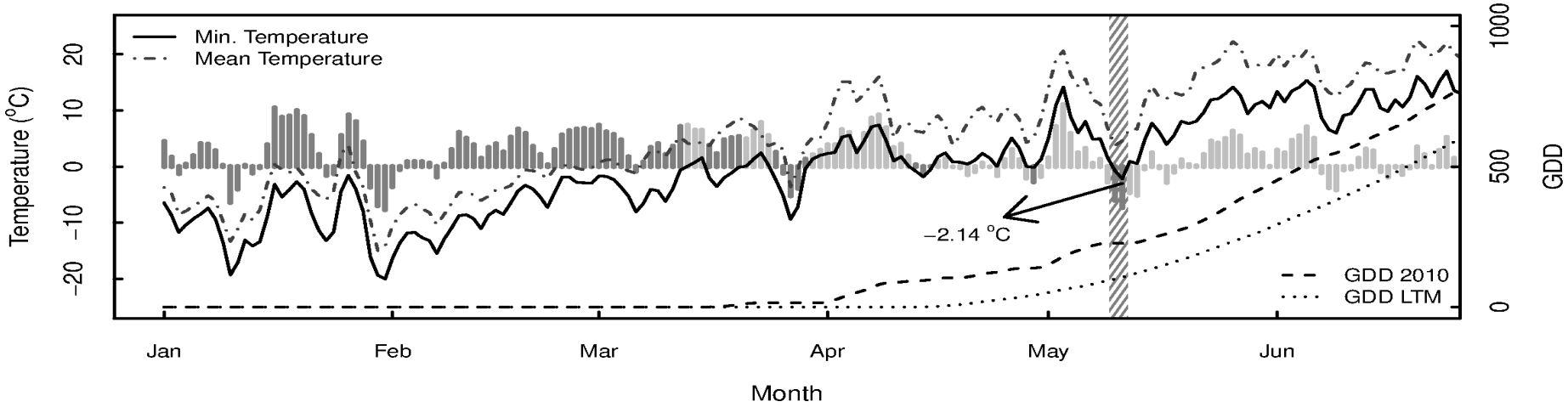
Signature of Spring Temps in MODIS





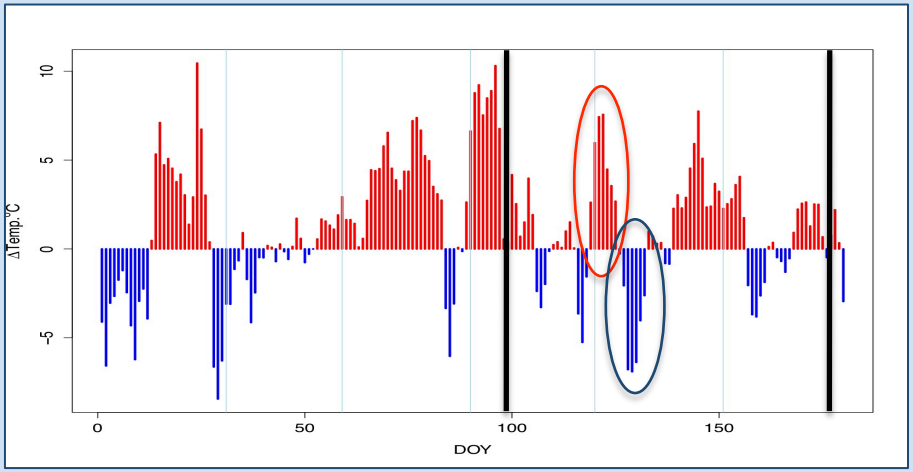


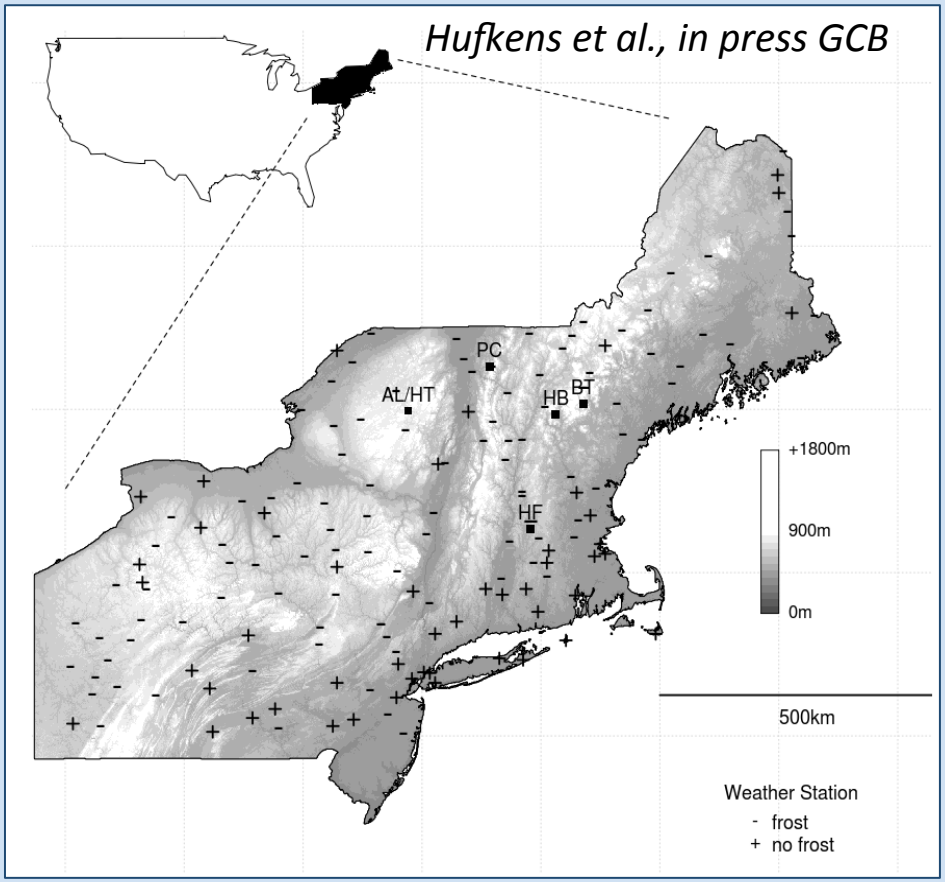
Leaf Damage from Frost

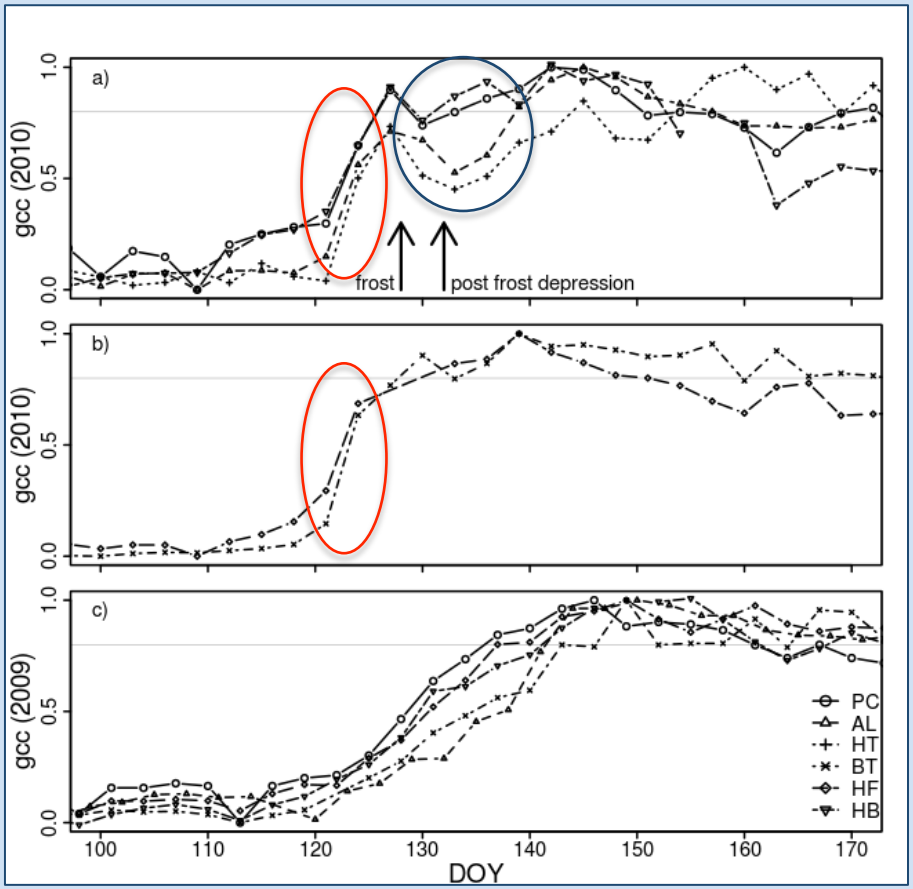


Phenocam Phenology at Six Sites

- Harvard Forest, Hubbard Brook, Proctor MRC, Huntington Forest, Bartlett Forest, Arbutus Lake
- Compare 2010 vs 2009
- Early, steep warming, response to frost





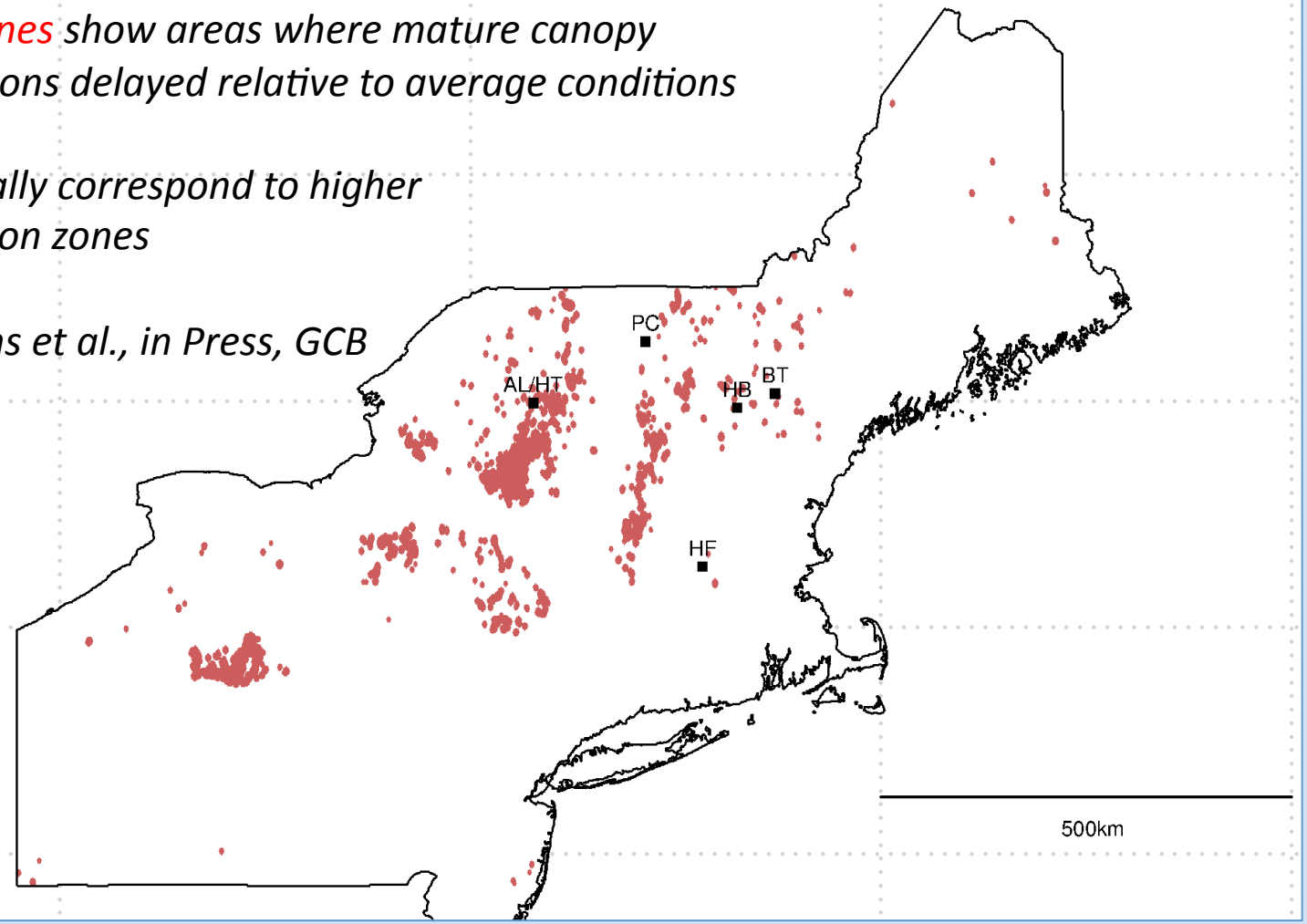


Widespread Delayed Leaf Maturity from MODIS

Red zones show areas where mature canopy conditions delayed relative to average conditions

Generally correspond to higher Elevation zones

Hufkens et al., in Press, GCB



Summary & Conclusions

Patterns in phenology provide a key diagnostic of climate change

- *Significant implications for ecosystem function and climate-biosphere interactions*

Multiple sources of data at multiple scales available provide complementary information related to phenology

Anomalous climate events (e.g., spring 2010) provide opportunities to understand how ecosystems will respond to future climate change