An aerial photograph of a vast forest landscape. The foreground and middle ground are filled with dense trees, many of which have turned shades of yellow, orange, and red, indicating autumn. In the distance, a large body of water, likely a lake or reservoir, is visible, surrounded by low mountains and hills under a clear, bright blue sky.

Introduction to the PhenoCam Network

Andrew D. Richardson
Northern Arizona University

Phenology

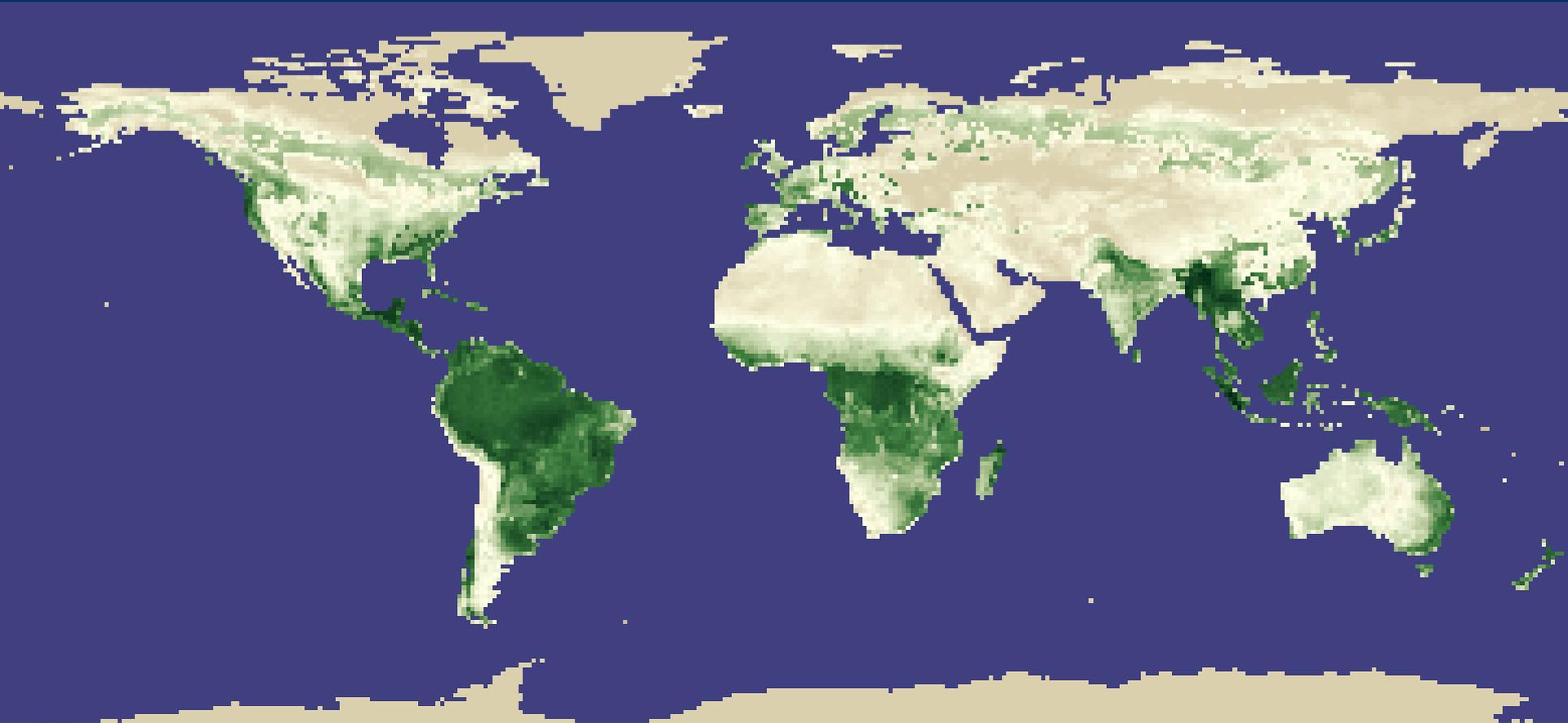


“The scientific study of periodic biological phenomena, such as flowering, breeding, and migration, in relation to climatic conditions.”

—*The American Heritage Dictionary*



Phenology: All around us, all the time



“The pulse of our planet”

(USA National Phenology Network)

“The rhythm of the seasons”

(Morissette et al. *Front. Ecol. Environ.* 2009)



The “Father of Phenology in America”



“It is astonishing how soon and unexpectedly flowers appear, when the fields are scarcely tinged with green. Yesterday, for instance, you observed only the radical leaves of some plants; to-day you pluck a flower.”

Henry David
Thoreau *Journals*

Plant phenology is
highly responsive to climate change

Climate change is causing shifts in the growing season

Spring leaf out
and development



Autumn coloration
and senescence



Phenology *“is perhaps the simplest process in which to track changes in the ecology of species in response to climate change”*

– IPCC (2007)
Fourth Assessment

PhenoCam:
Bringing a Victorian science into the
21st Century

The PhenoCam Network:

Automated monitoring of plant phenology

- PhenoCam uses imagery from digital cameras for continuous phenological monitoring
- Images recorded every 30 minutes, sunrise to sunset, 365 days a year
- A direct link between what is happening on the ground – at the level of individual trees – and what is seen by satellites









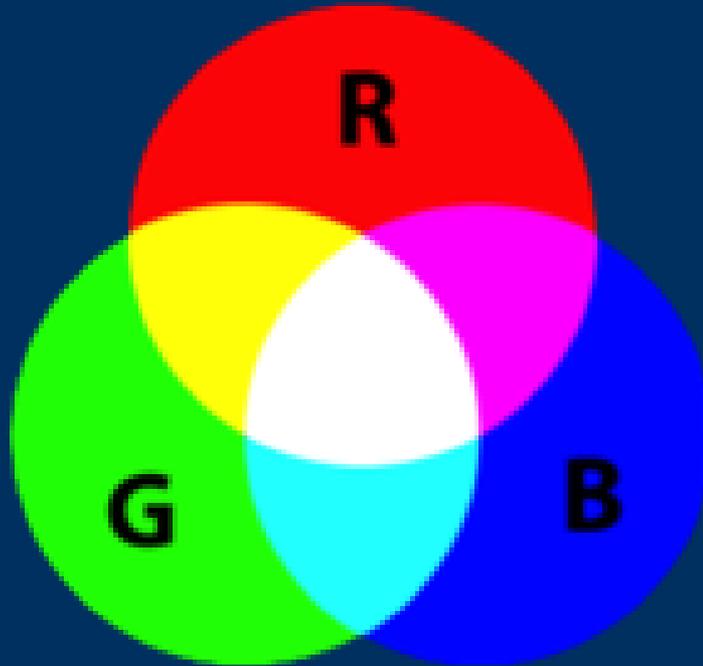




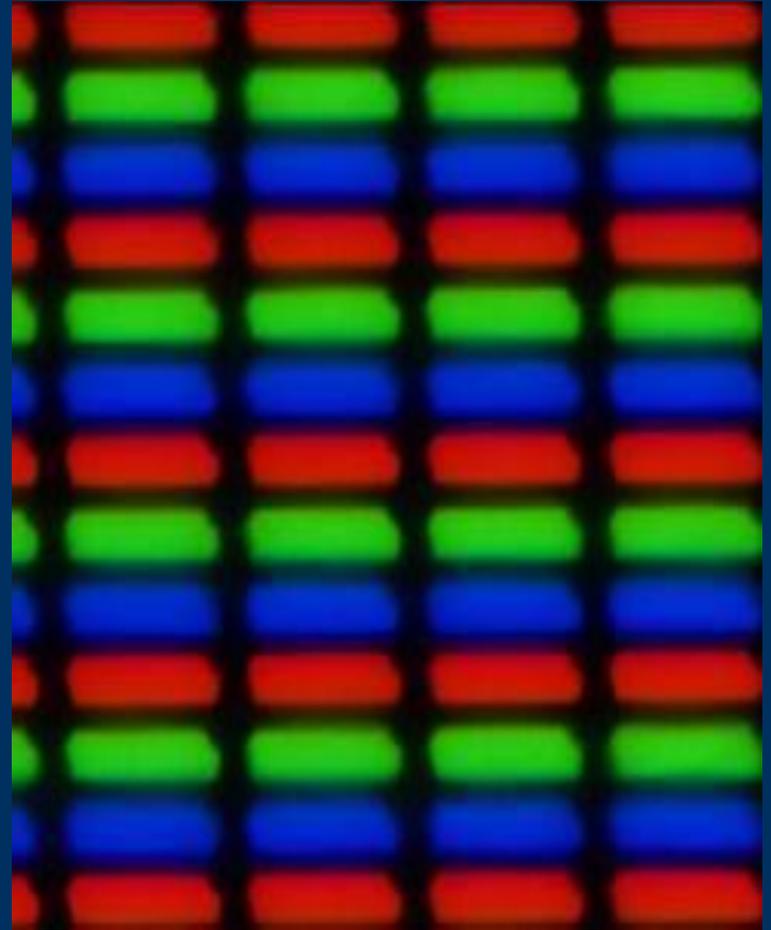


What do we do with the imagery?

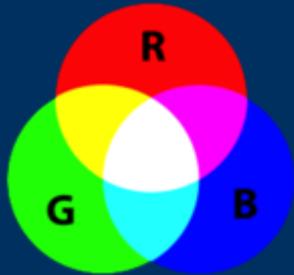
The Red-Green-Blue Additive Color Model



This is just like an old TV set



Quantitative analysis of PhenoCam pictures



RGB Color Model



RGB Triplet
(R_{DN}, G_{DN}, B_{DN})



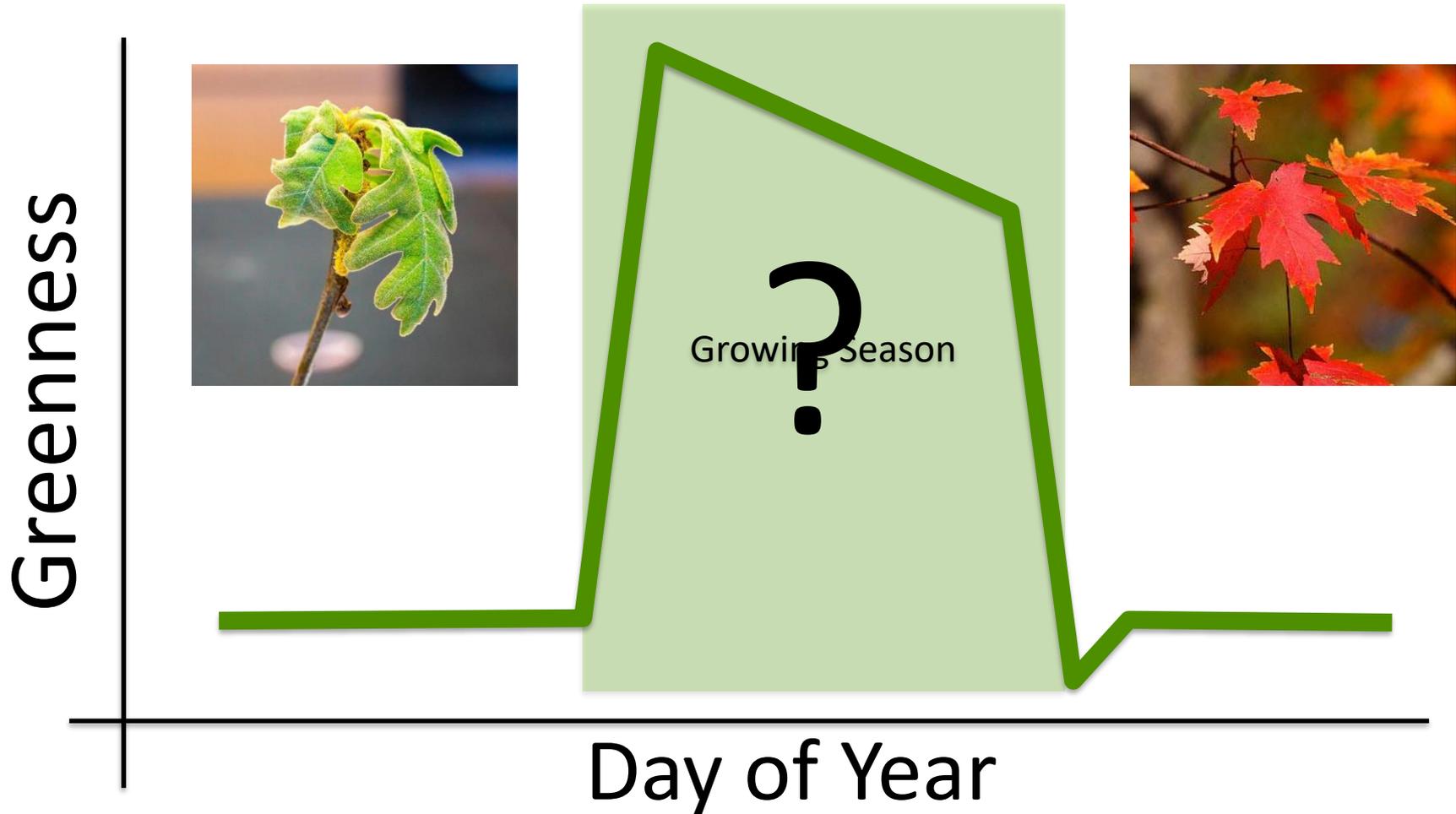
Canopy "Greenness"

$$= \frac{G_{DN}}{R_{DN} + G_{DN} + B_{DN}}$$



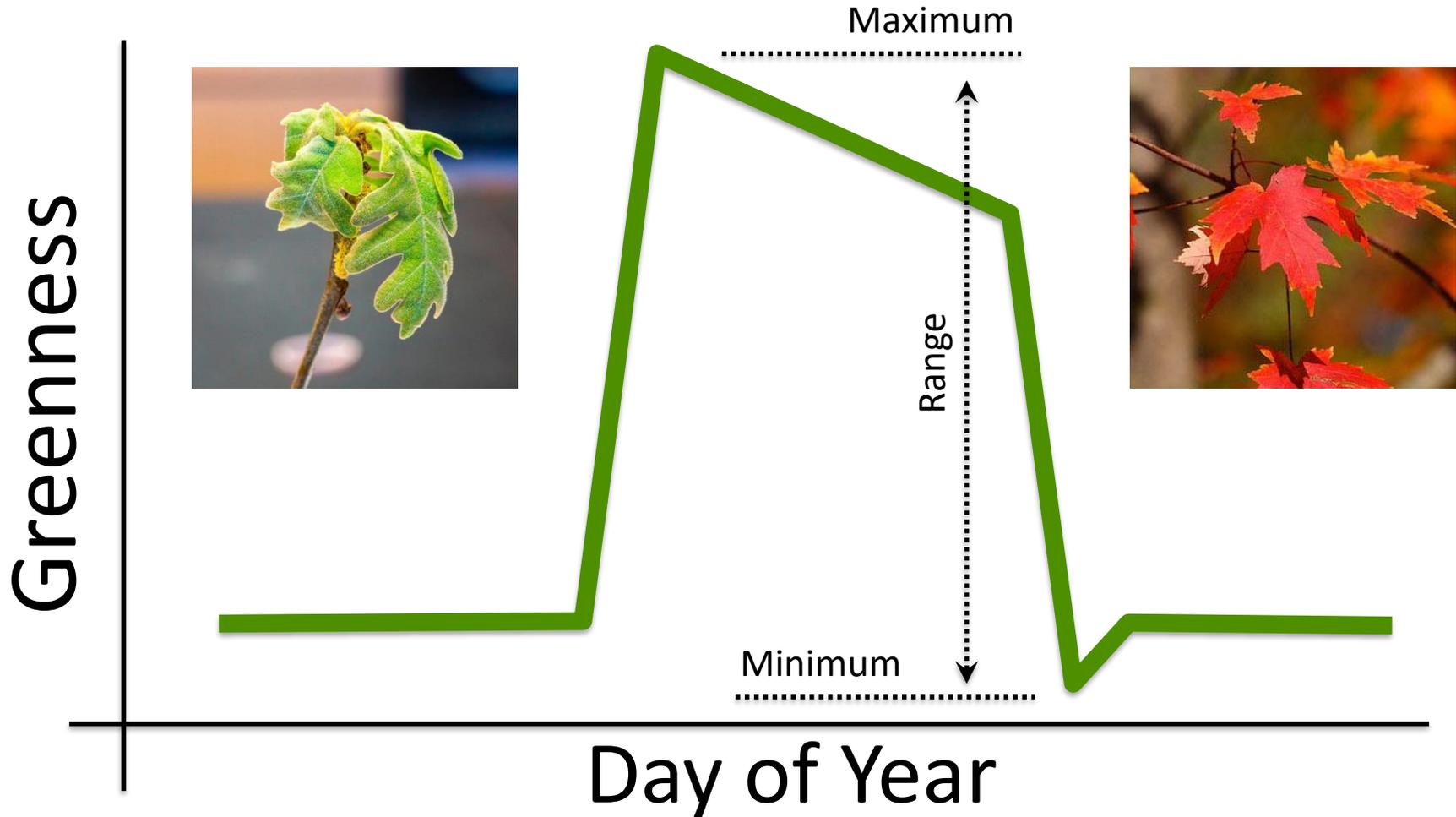
Transition dates:

Relating “greenness” to budburst and peak color



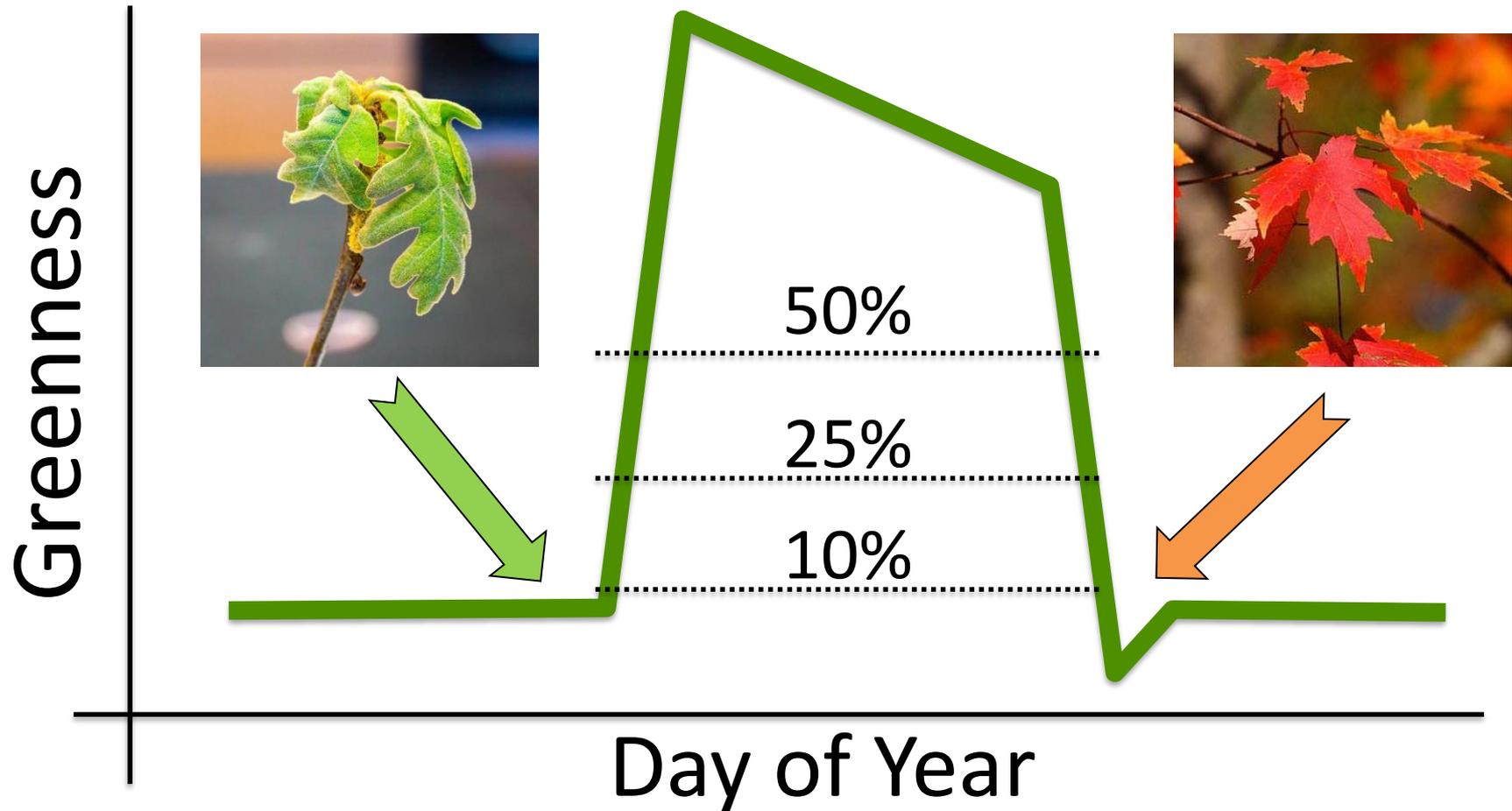
Transition dates:

Relating “greenness” to budburst and peak color



Transition dates:

Relating “greenness” to budburst and peak color





bartlettir - NetCam SC IR - Wed May 09 2018 11:55:06 EST - UTC-5
Camera Temperature: 47.0
Exposure: 300



Start of season – leaves emerging

bartlettir - NetCam SC IR - Thu Oct 04 2018 12:15:06 EST - UTC-5
Camera Temperature: 47.0
Exposure: 500



End of season – leaves at peak color

KamuelaCam Thu Dec 09 12:01:46 2010 HST Exposure: 151

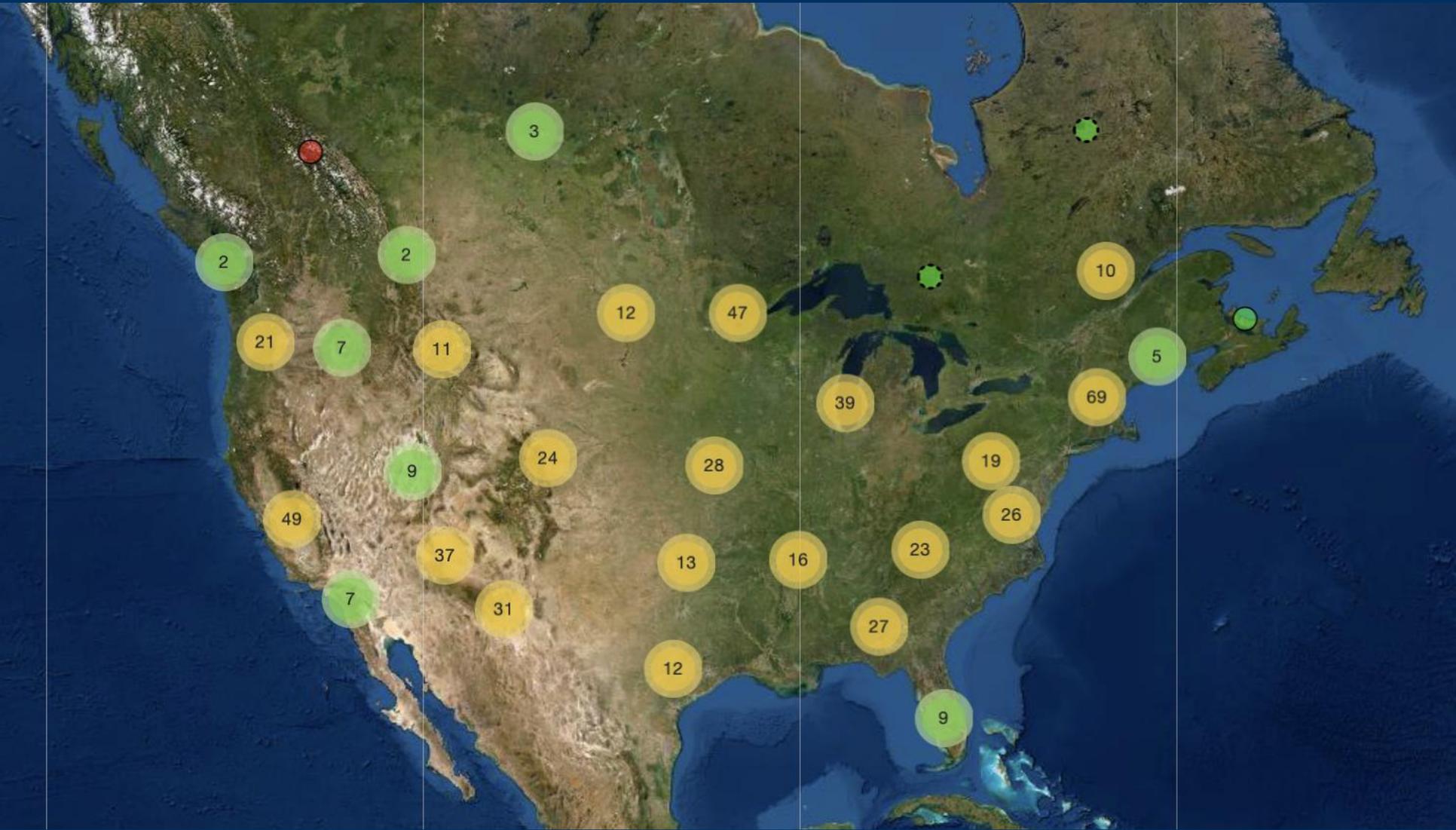
Camera temp 63.0 °C Air temp 28.0 °C / 82.4 °F

RH 40% Pressure 926.0 mb



A continental-scale phenological observatory

A network of over 650 cameras



Imagery and data available at: <http://phenocam.sr.unh.edu/>



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 55.5 °C
Exposure: 1/250



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 46.5 °C internal, 29.5 °C outside
RH: 50, Pressure: 927.0 millibars
Exposure: 1/50



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 50.0 °C internal
Exposure: 1/200



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 20.5 °C internal
Exposure: 1/250



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 26.5 °C
Exposure: 1/250



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 46.5 °C
Exposure: 1/250



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 50.0 °C internal
Exposure: 1/200



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 26.5 °C
Exposure: 1/250



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 26.5 °C
Exposure: 1/250



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 46.5 °C internal, 29.5 °C outside
RH: 50, Pressure: 927.0 millibars
Exposure: 1/50



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 50.0 °C internal
Exposure: 1/200



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 26.5 °C
Exposure: 1/250



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 26.5 °C
Exposure: 1/250



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 46.5 °C internal, 29.5 °C outside
RH: 50, Pressure: 927.0 millibars
Exposure: 1/50



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 50.0 °C internal
Exposure: 1/200



Redwood - NetCam SC IR - Sun Oct 21 2012 12:01:02 PM
Temperature: 26.5 °C
Exposure: 1/250

Summary & Take-home message

- The **PhenoCam** network uses **digital camera imagery** to track vegetation phenology across North America
- Data and imagery are publicly available, in near-real-time, through the **PhenoCam** web page:
<http://phenocam.sr.unh.edu/>
- We are using the data to understand how ecosystems are being affected by climate change.

