Vegetation Phenology Metrics Derived from Temporally Smoothed and Gap-filled MODIS Data

Bin Tan[1,2], Jeff Morisette[3], Robert Wolfe[1], Wayne Esaias[1], Feng Gao[4], Greg Ederer[1,5], Joanne Nightingale[1,5], Jamie. E. Nickeson[1,5], Pete. Ma[1,5] and Jeff Pedely[1].

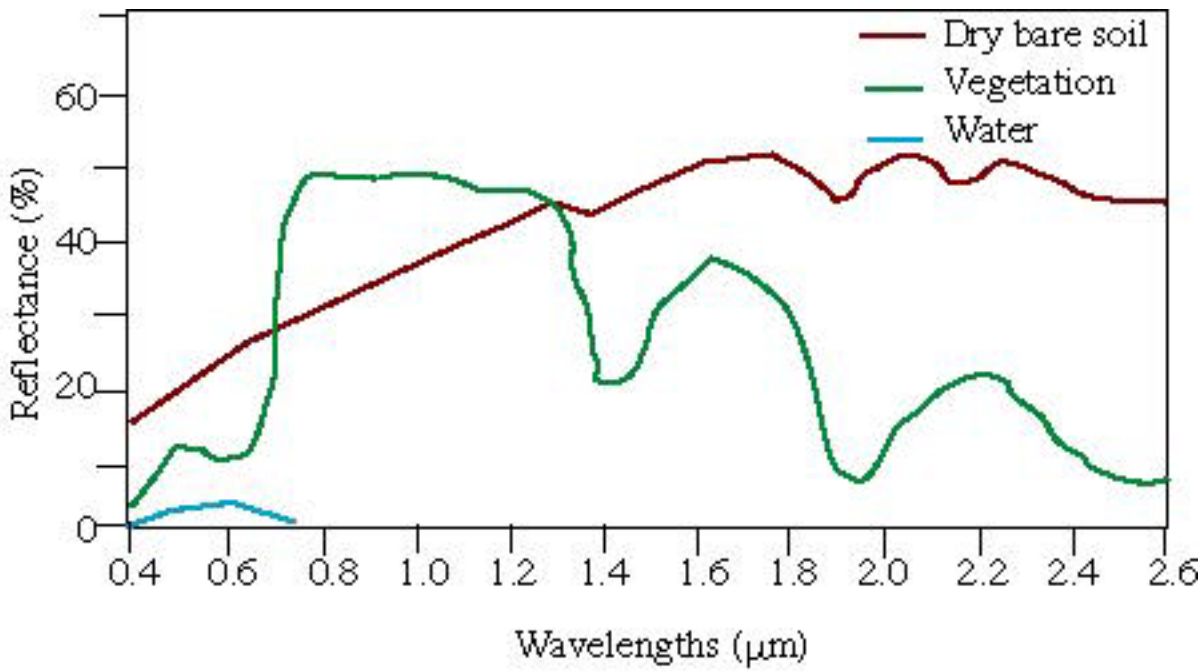
[1] Terrestrial Information Systems Branch (614.5)
NASA Goddard Space Flight Center, Greenbelt, MD, USA
[2] ERT Inc., [3] USGS, [4] USDA, [5] Sigma Space Inc.

Background

Why the vegetation phenology is important:

- Reflect the dynamics of the Earth's climate and hydrologic regimes.
- Connect biosphere and atmosphere
- Large-scale vegetation phenology is useful for studies of seasonal and interannual variability in carbon exchange, vegetation-climate interactions and other ecology processes.

Background



Typical spectral reflectance curves for vegetation, soil, and water.

Vegetation Index

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

$$EVI = G \times \frac{(NIR - RED)}{(NIR + C_1 \times RED - C_2 \times BLUE + L)}$$

For MODIS, G=2.5, C_1=6, C_2=7.5 and L=1

Challenges in deriving phenology metrics from remote sensing data

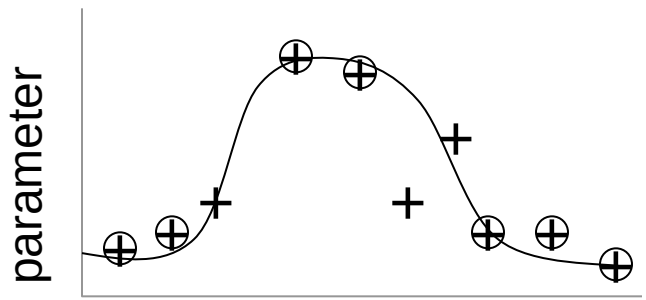
- The inherent noise due to variations in viewing geometry, and less than ideal atmospheric conditions, etc., reasons.

- Occasional missing data due to cloud cover and dead sensor, etc., unpredictable situations.

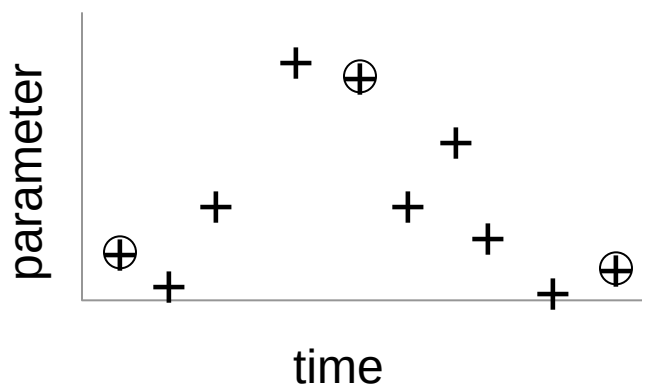
Solution:

Estimate phenology metrics from smoothed and gap-filled data sets.

Two Temporal Curve Fitting Cases



Case 1 – typical situation: enough high quality data to adequately fit curve to the retrievals



Case 2 – degenerate situation: not enough high quality pixels to adequately fit curve to the retrievals

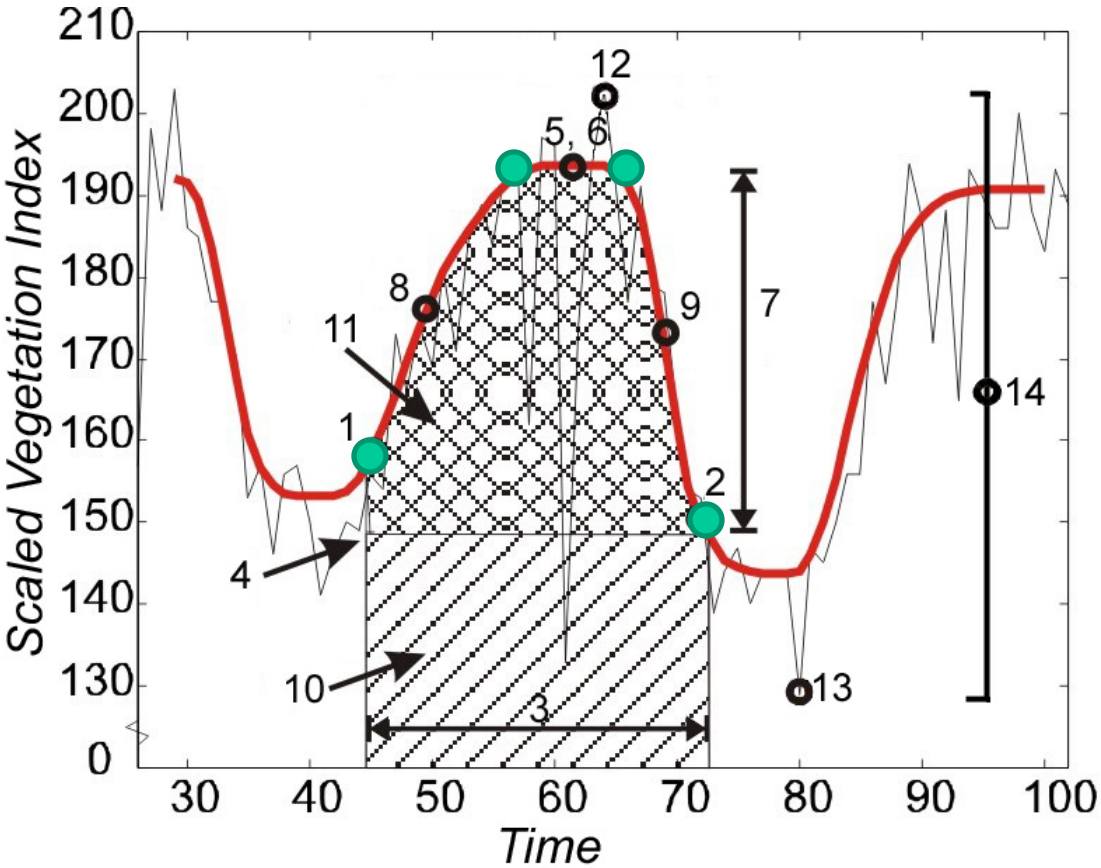
+ Original time series

⊕ High quality values

—— Temporal curve fitting

F. Gao, J. T. Morisette, R. E. Wolfe, G. Ederer, J. Pedelty, E. Masuoka, R. Myneni, B. Tan and J. Nightingale, "An algorithm to produce temporally and spatially continuous MODIS-LAI time series," *IEEE Tran Geosci Remote Sens Letters*, 5, 60-64, 2008.

Modified TIMESAT Parameters

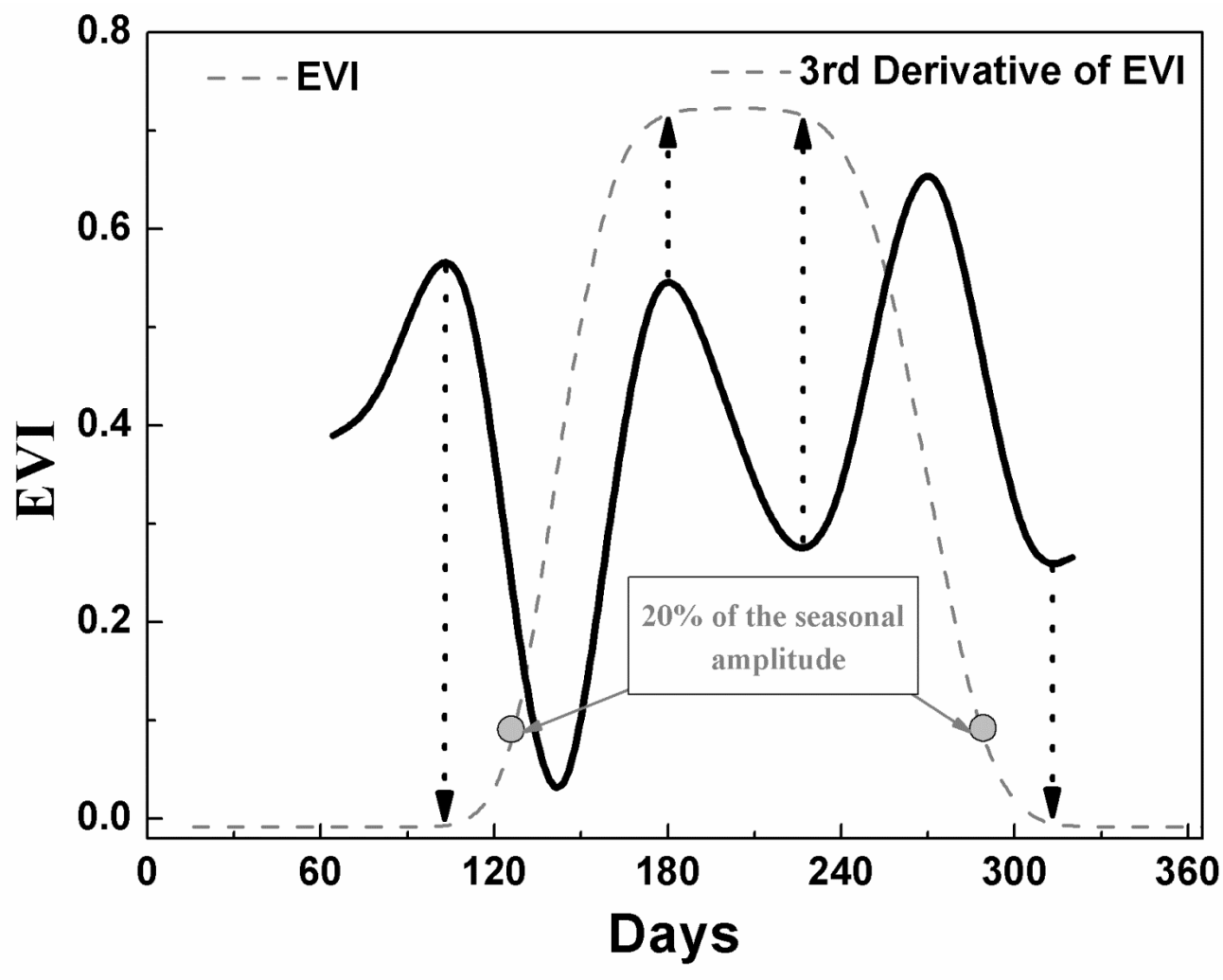


- Key phenology dates

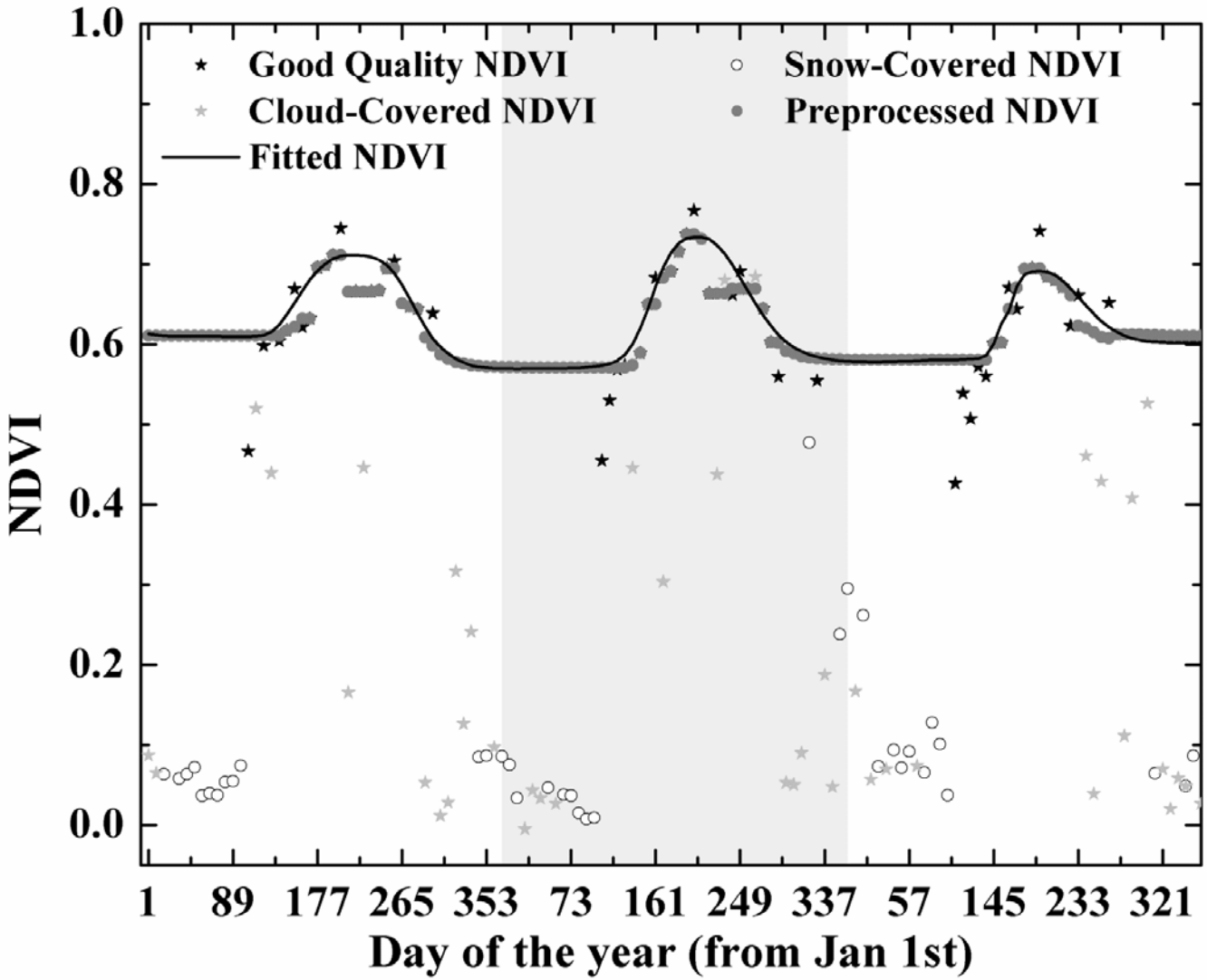
1. Beginning of season
2. End of season
3. Length of season
4. Base VI value
5. Peak time
6. Peak value
7. Amplitude
8. Left derivative
9. Right derivative
10. Integral over season - absolute
11. Integral over season - scaled
12. Maximum value
13. Minimum value
14. Mean value
15. RMSE

TIMESAT - a program for analyzing time-series of satellite sensor data
Per Jonsson & Lars Eklund, Computers & Geosciences 30:833-845, 2004.

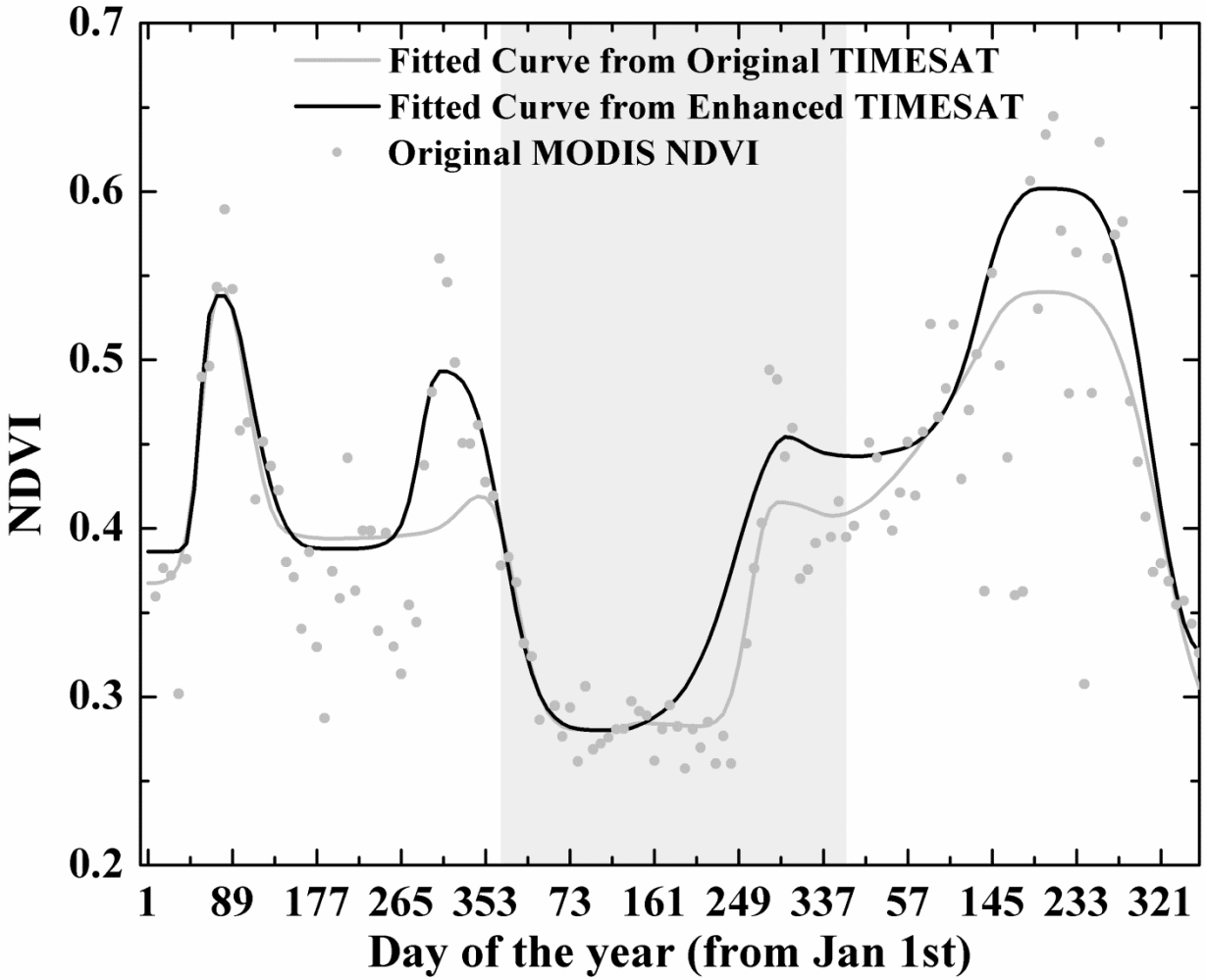
How to Determine the Key Phenology Dates



Eliminate noise and fill data gap during the winter

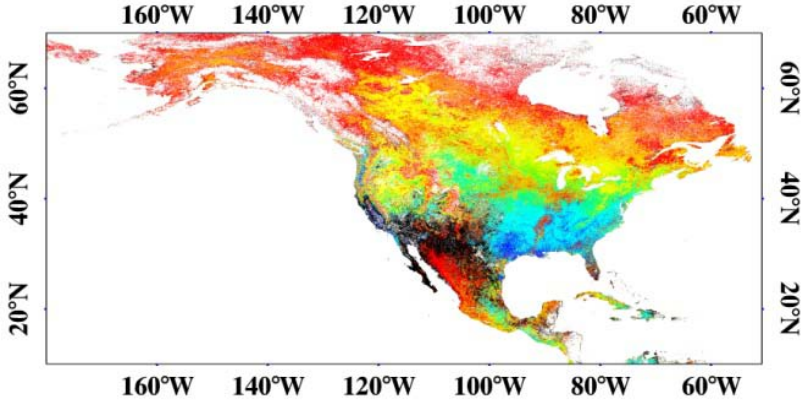


Retrieve unevenly distributed growing seasons

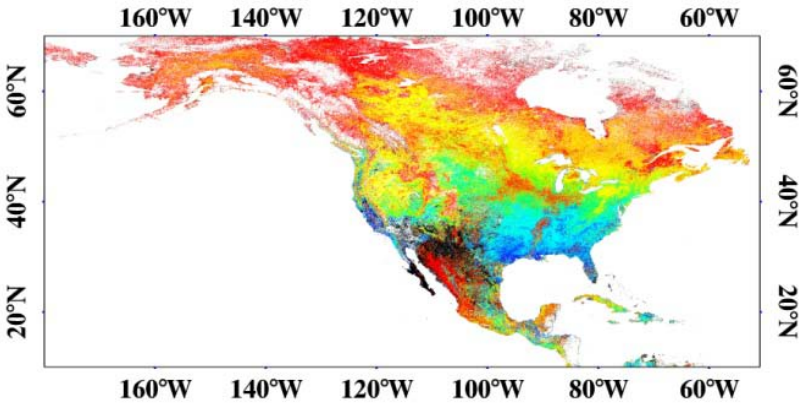


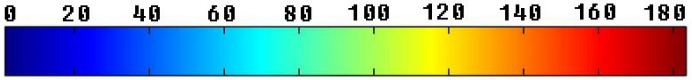
Phenology Dates NDVI vs. EVI (1)

Greenup$_{NDVI}$

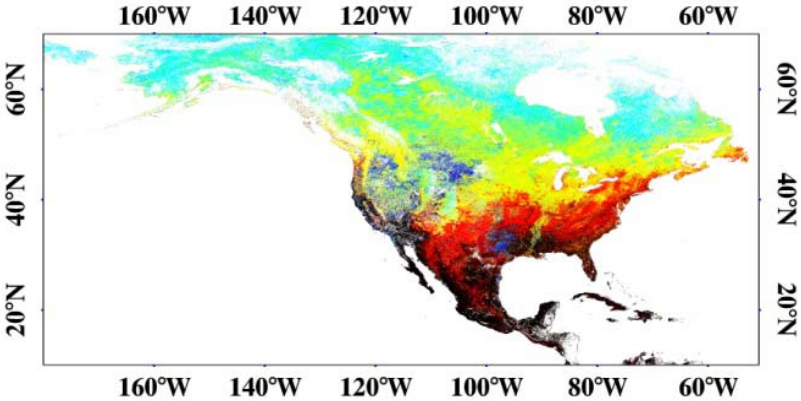


Greenup$_{EVI}$

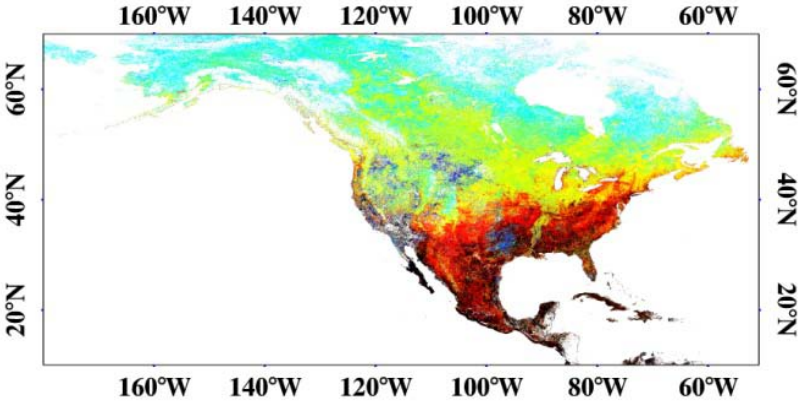


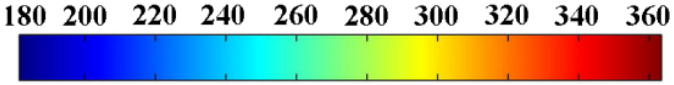


Browndown$_{NDVI}$

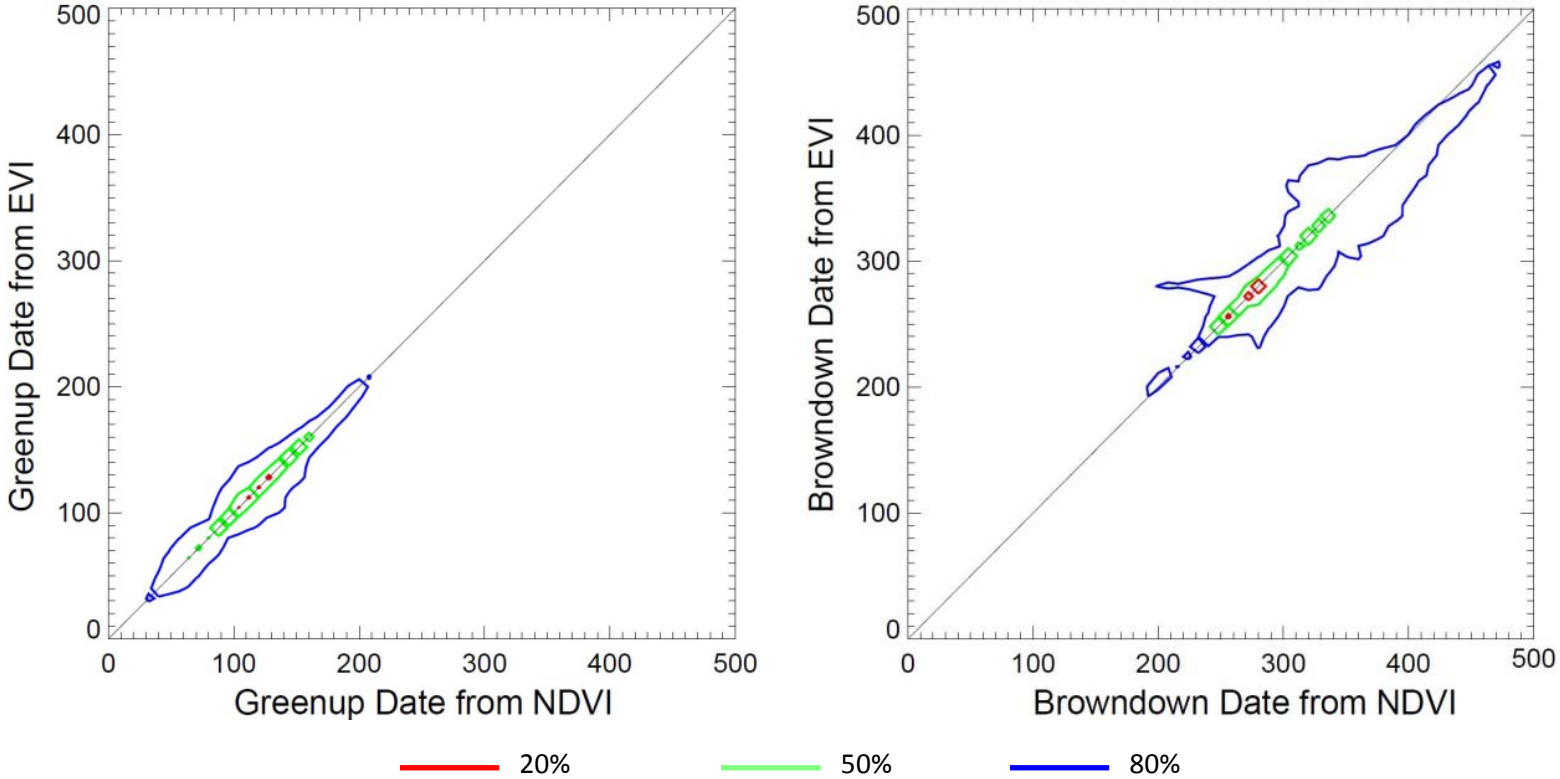


Browndown$_{EVI}$





Phenology Dates NDVI vs. EVI (2)

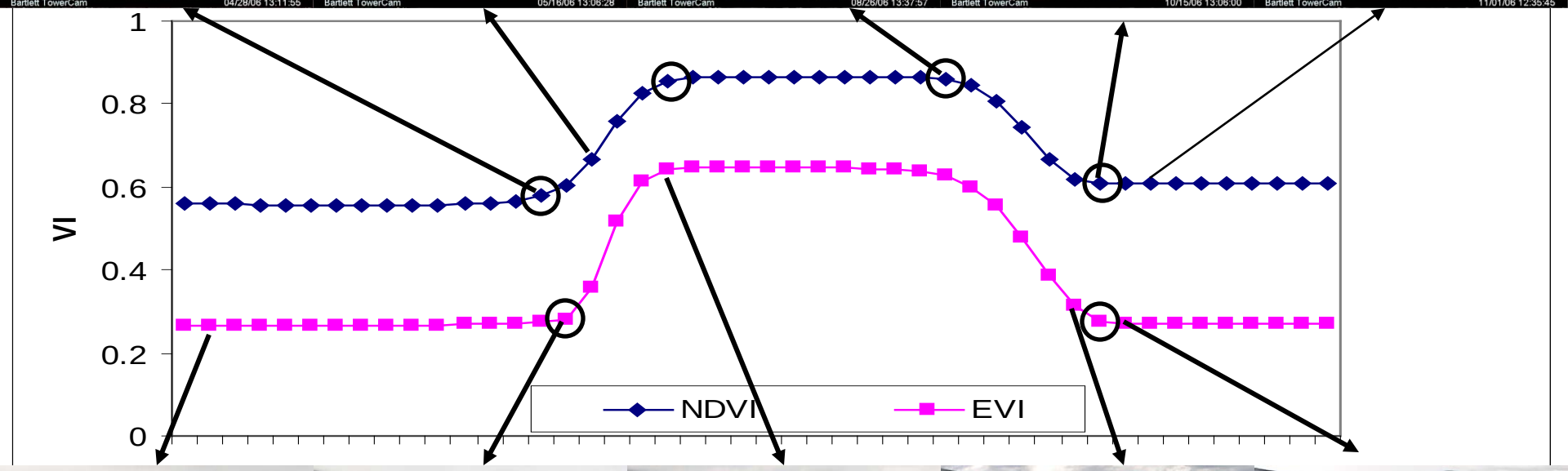


• More than 50% of the pixels have similarly retrieved greenup/browndown dates.

• More difference between browndown dates because the browndown is a more gradual progress than greenup, which makes greenup easier to determine.

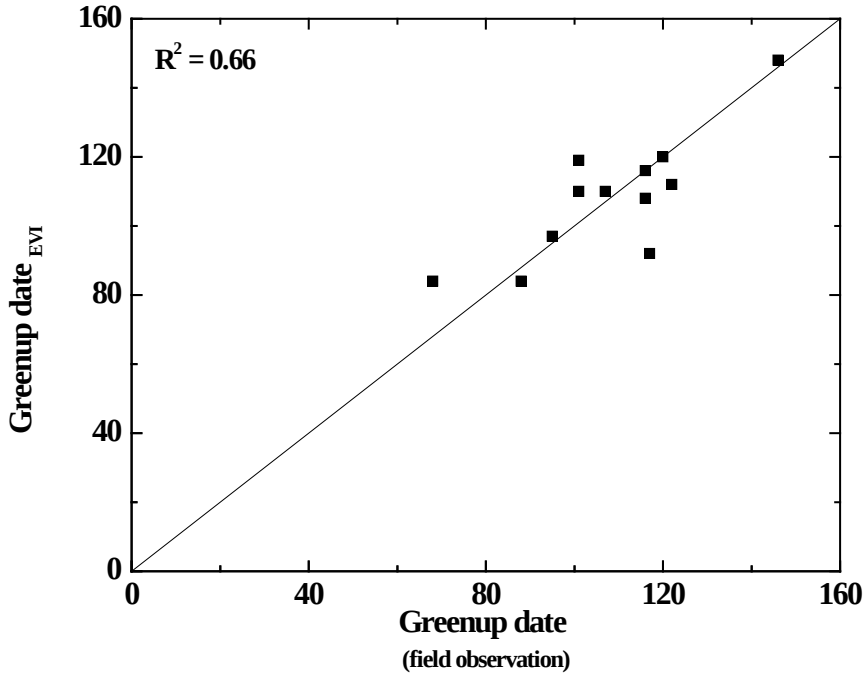
Web camera images (Bartlett FLUX site)

04/28 5/16 8/28 10/15 11/01



01/09 05/09 06/09 10/07 10/24

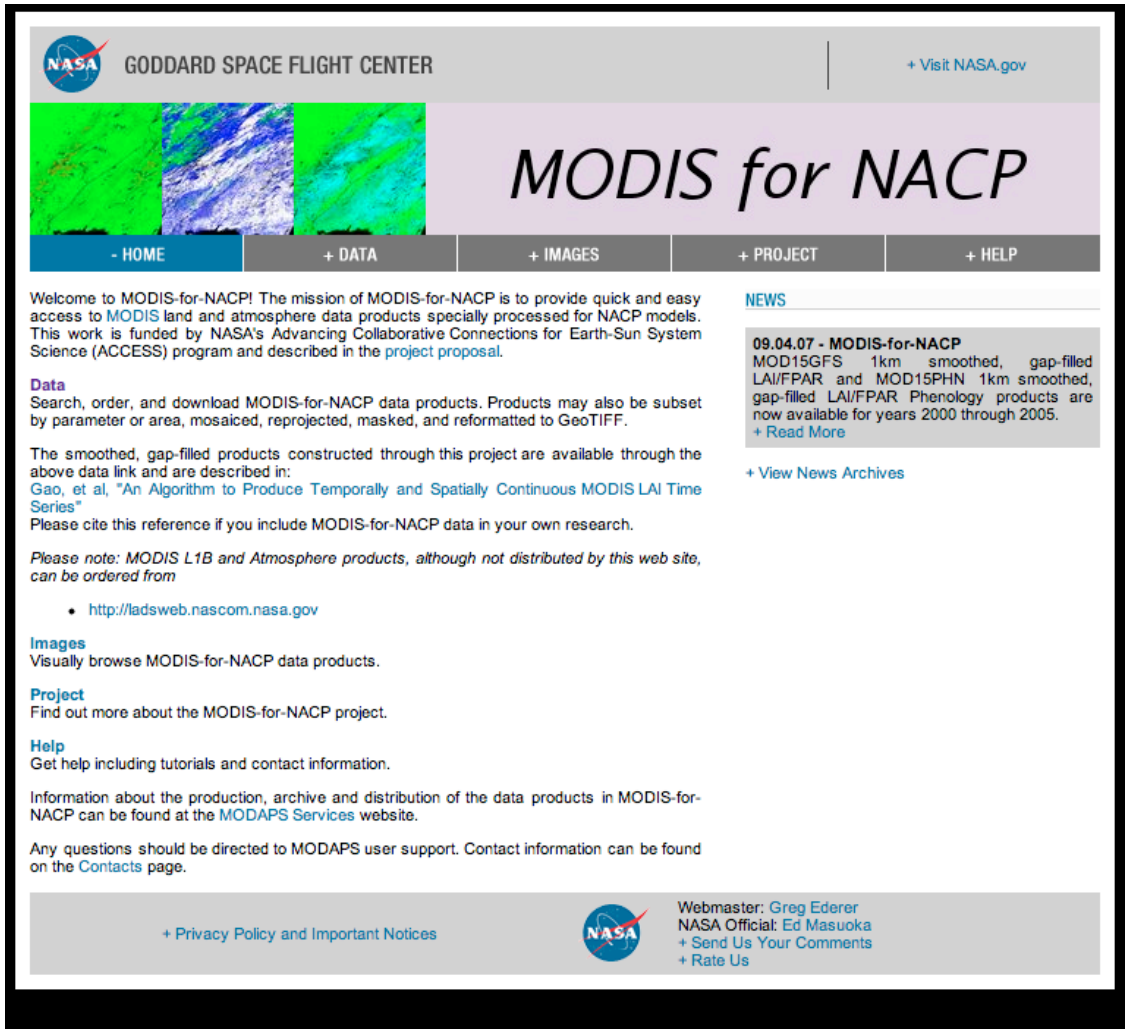
Comparison with Field Record



Site/Network Name	Site Numbers	Observed Events
Chequemegon Ecosystem Atmosphere Study	2	First Appearance of leaves
GLOBE	5	First Appearance of leaves
Harvard Forest LTER	1	First Appearance of leaves
Howland Research Forest	1	First Appearance of leaves
Long Lake Conservation Center	1	First report of land surface temperature > 60° F
Prairie Westlands Learning Center	1	First report of Chorus Frogs and Trumpeter Swans
Rocky Mountain Biological Laboratory	1	First Appearance of leaves

Web-based data distribution system

http://accweb.nascom.nasa.gov/

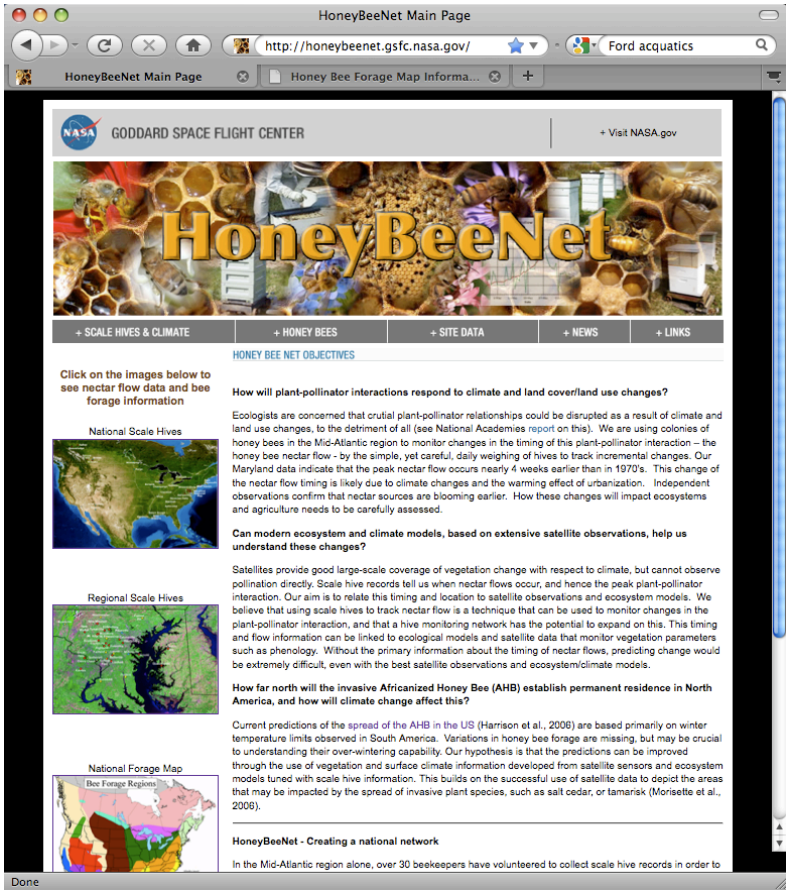


Offering ***original, smooth/gap-filled*** **LAI, FPAR, EVI & NDVI**, ***and phenology metrics derived from LAI/EVI/NDVI*** products with the following data services:

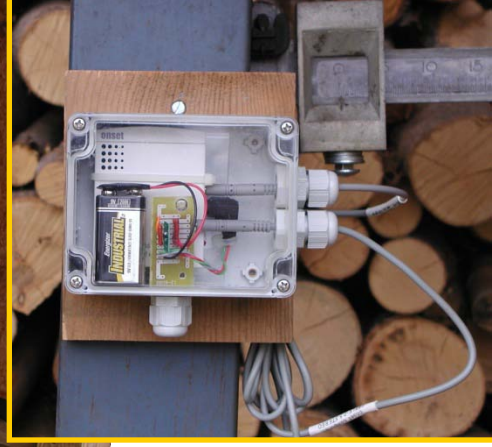
- Subset by geographic area
- Subset by data layer
- Reproject
- Mosaic
- Aggregation
- Re-format (to GeoTIFF).

Application: Mapping nectar flow phenology with satellites and Honey Bee hives to assess climate impacts

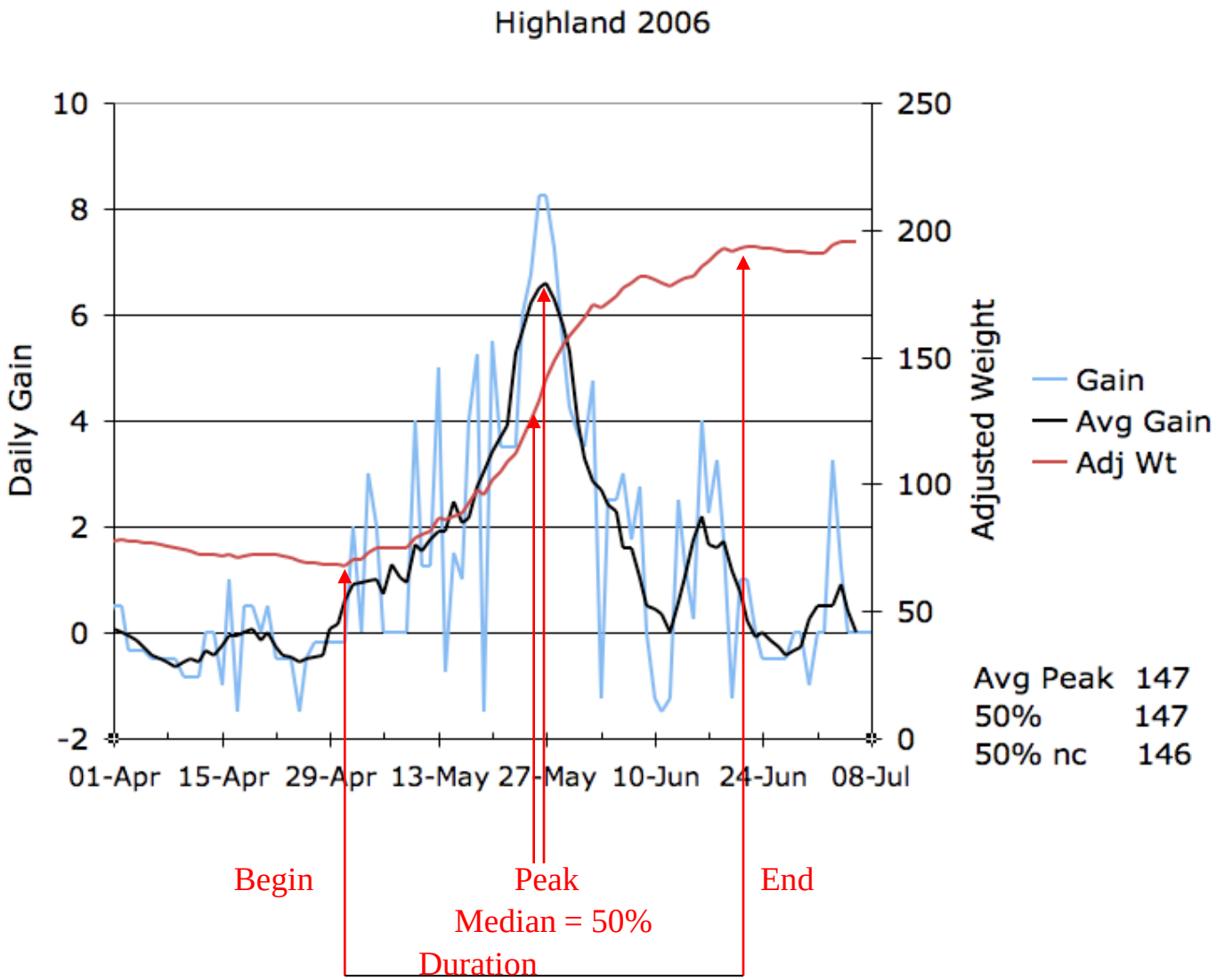
- ~10^5 Flowering plant species.
- ~10^4 Pollinating insect sp., many in decline.
- Dependencies, Areal Abundances, Trends, and Climate Response Functions of individuals or their partners are very poorly known.
- Our bees, ecosystems, and food depend on these interactions being successful.
- Little time for a species-by-species approach, we need to generalize in a smart way.



FAIRBANKS
74

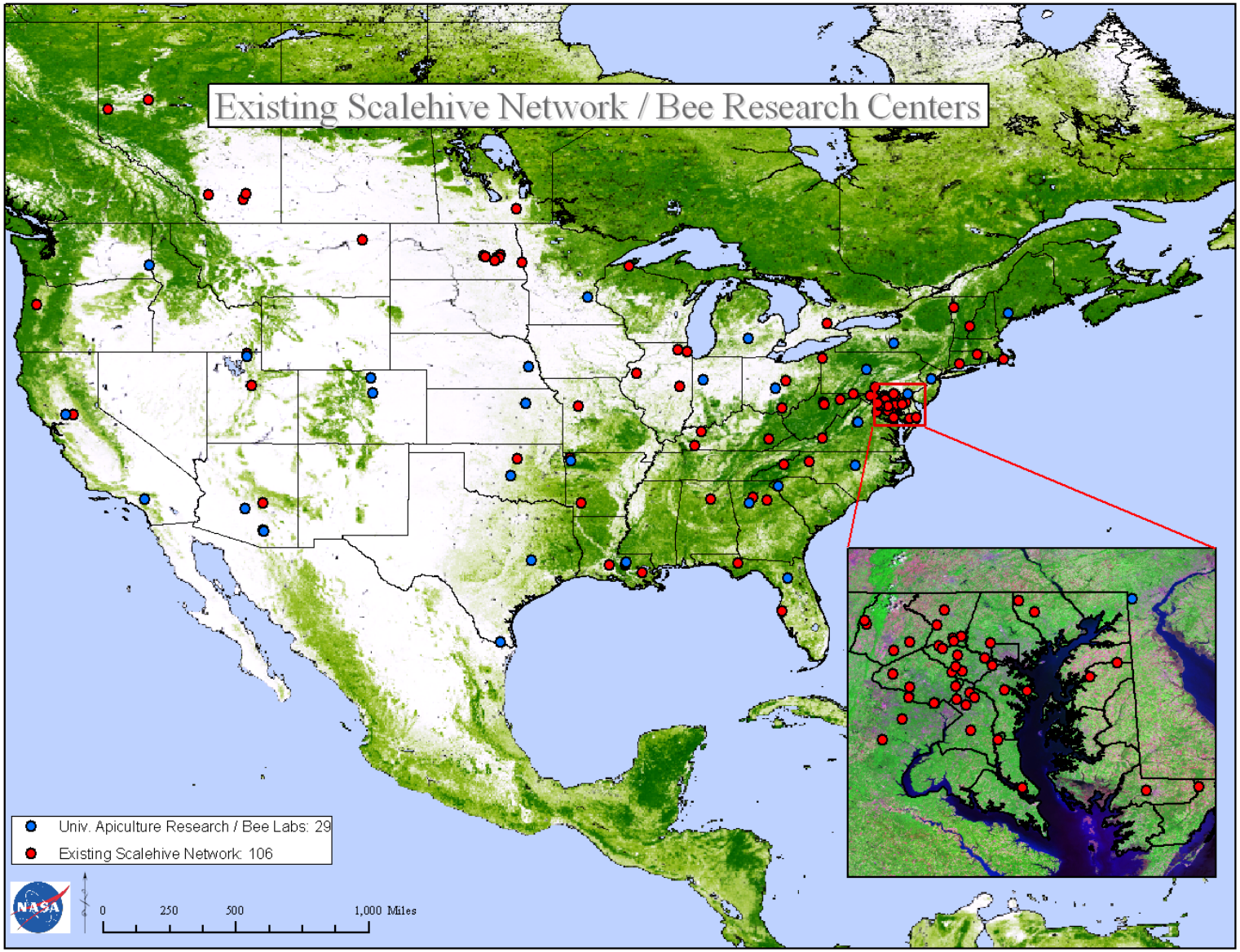

onset
INDUSTRIAL

Honey Bee Nectar Flow (HBNF) Metrics

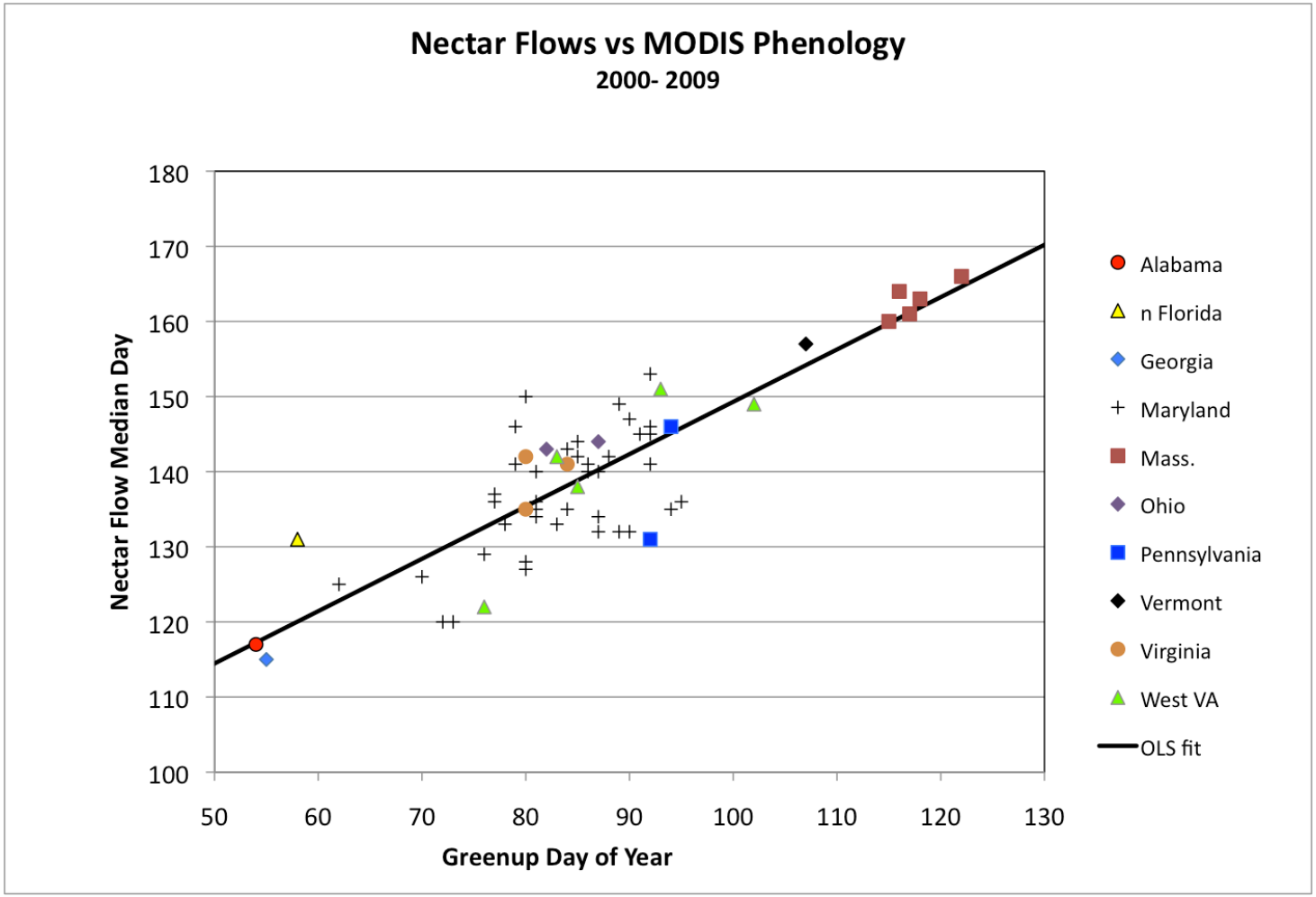


Composite integral covering ~ 1000 hectares, of plants, pollinators, and environmental variables of successful interactions.

Linking Scale Hive Observations MODIS Phenology product (1)

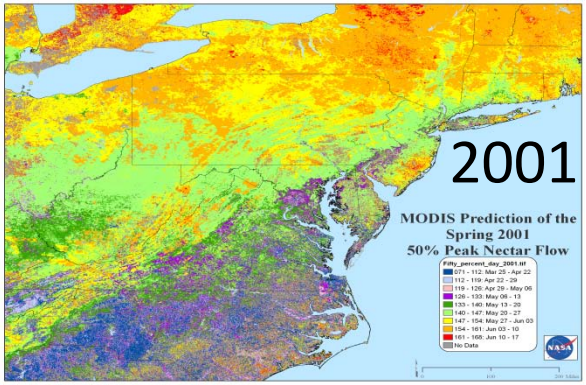


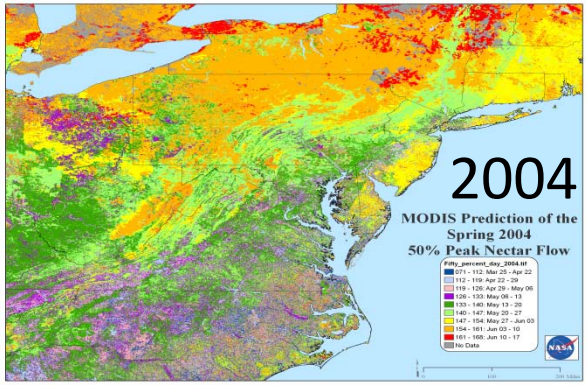
Linking Scale Hive Observations MODIS Phenology product (2)

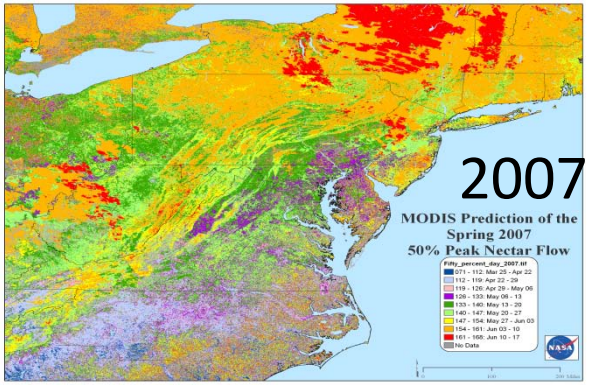


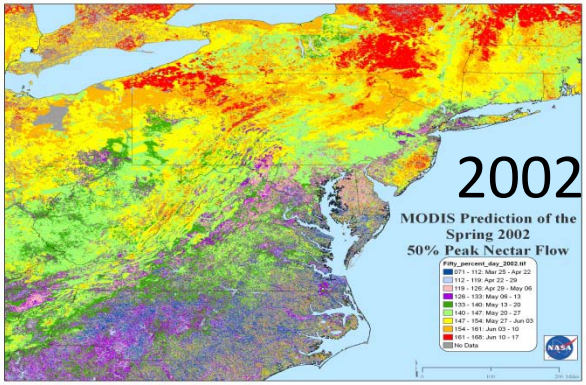
Spring , Median (50% gain), Eastern US, edited with QC criteria. Louisiana, S. Florida excluded. For trees, shrubs, mixed cropland mosaic, urban land cover types.

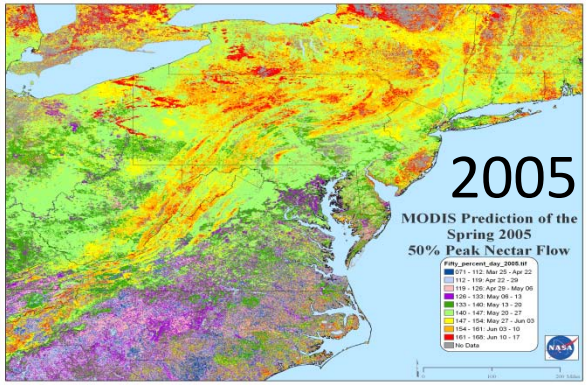
Retrieved 50% nectar flow date

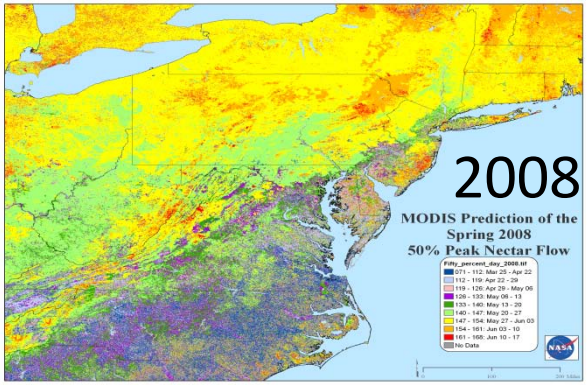


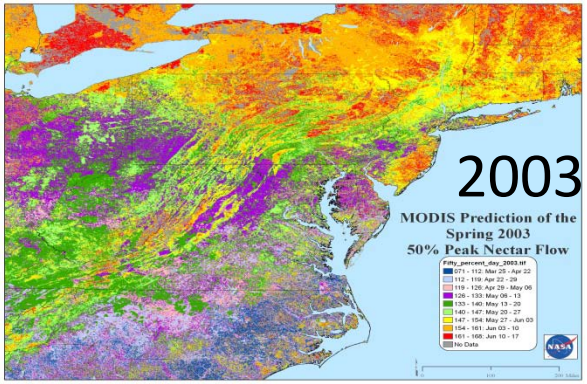


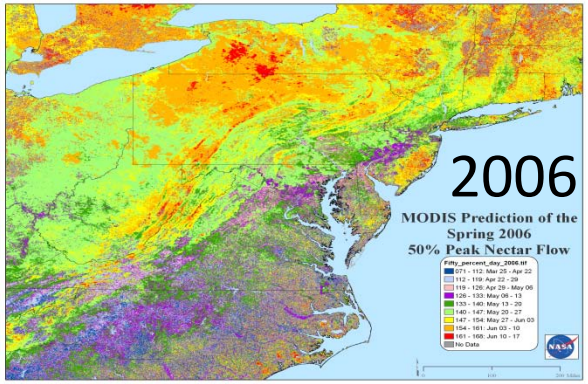


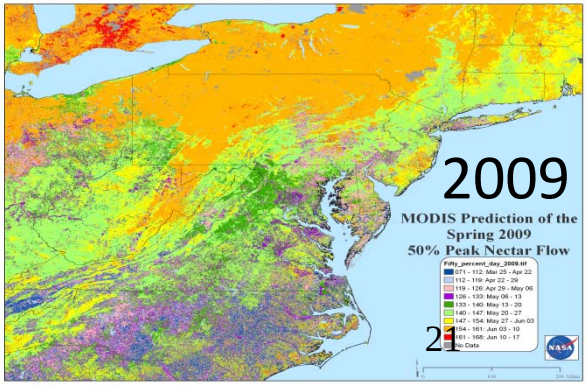










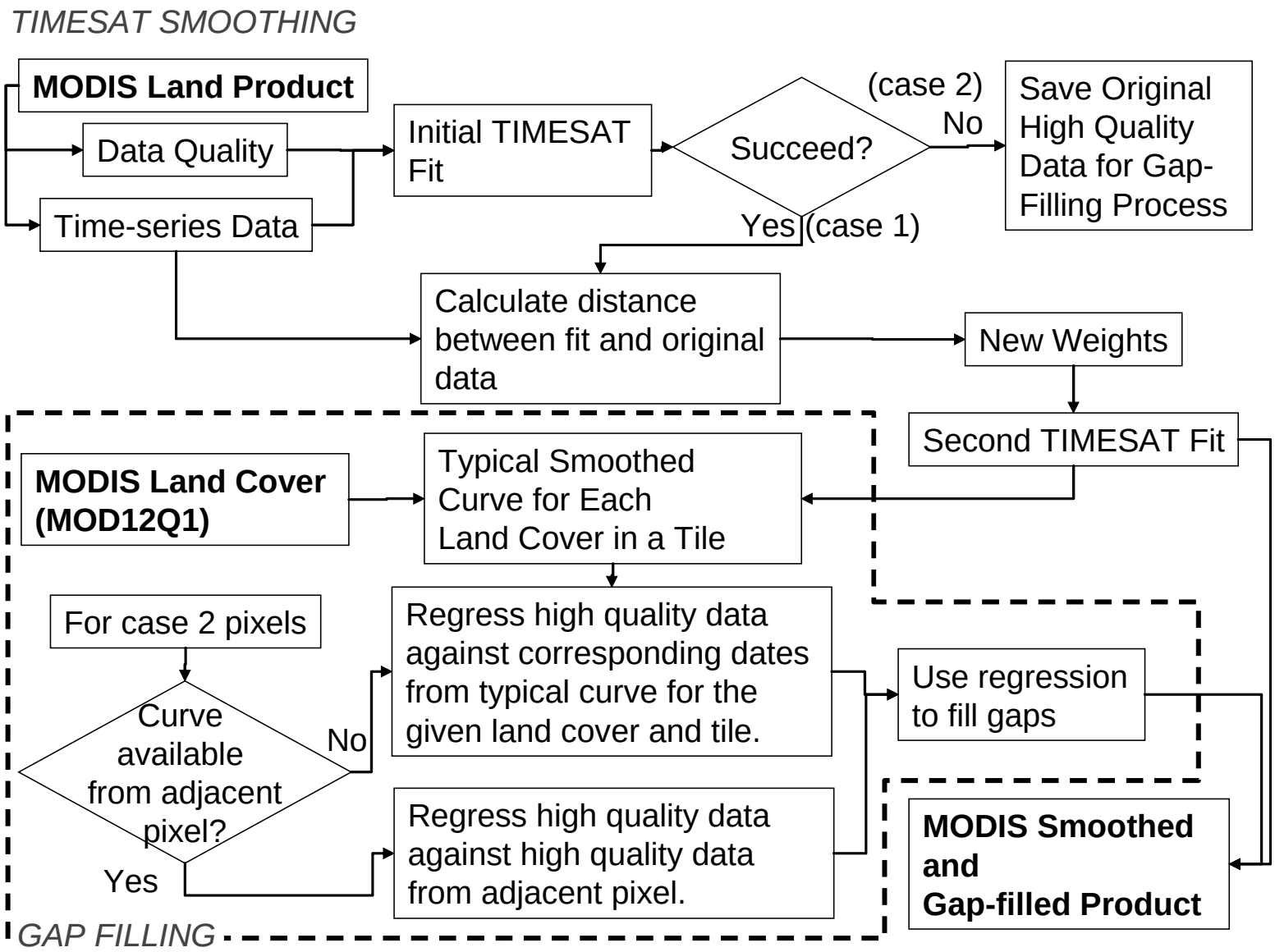
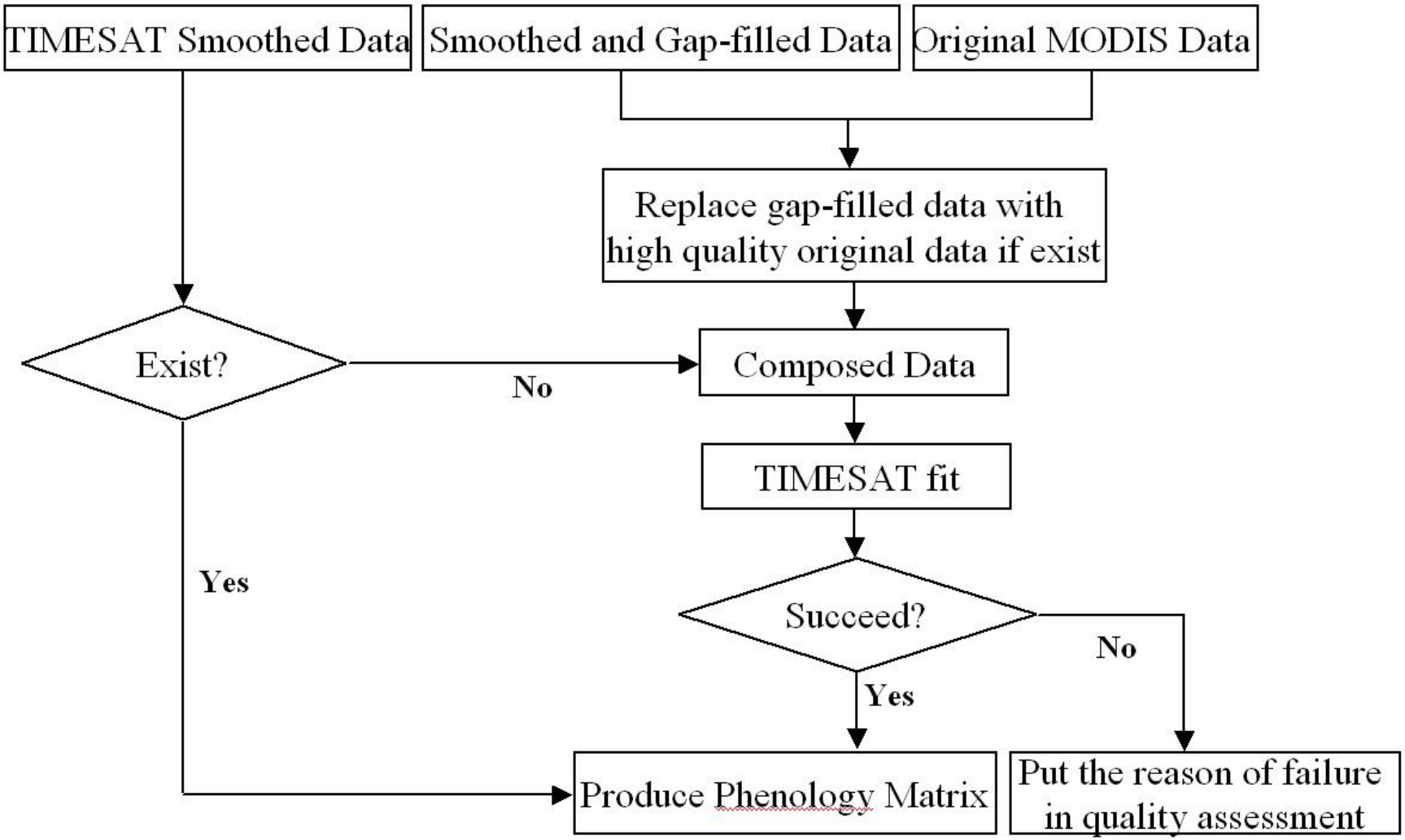


Summary

- **Smoothed and gap-filled VI provides a good base for estimating vegetation phenology metrics.**
- **The TIMESAT software was improved by incorporating the ancillary information from MODIS products.**
- **A simple assessment of the association between retrieved greenup dates and ground observations indicates satisfactory result from improved TIMESAT software.**
- **One application example shows that mapping Nectar Flow Phenology is tractable on a continental scale using hive weight and satellite vegetation data.**
- **The phenology data product is supporting more researches in ecology, climate change fields.**

Questions?

Smooth and Gap-fill algorithm



Gap-fill Phenology Algorithm