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

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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.
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

**Modified TIMESAT Parameters**

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

**Key phenology dates**

TIMESAT - a program for analyzing time-series of satellite sensor data
How to Determine the Key Phenology Dates

![Diagram showing EVI and its third derivative over days. The key phenology dates are marked at 20% of the seasonal amplitude.]
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}
• 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)

![Web camera images with日期和VI值图](image-url)

- **04/28**: Day 0
- **5/16**: Day 0.2
- **8/28**: Day 0.4
- **10/15**: Day 0.6
- **11/01**: Day 0.8

**VI**

- **NDVI**
- **EVI**

**Dates**
- 01/09
- 05/09
- 06/09
- 10/07
- 10/24
Comparison with Field Record

\[ R^2 = 0.66 \]

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

http://accweb.nascom.nasa.gov/
Application: Mapping nectar flow phenology with satellites and Honey Bee hives to assess climate impacts

• \( \sim 10^5 \) Flowering plant species.
• \( \sim 10^4 \) 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.
Honey Bee Nectar Flow (HBNF) Metrics

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

Begin Peak End
Median = 50%
Duration

Highland 2006

Avg Peak 147
50% 147
50% nc 146
Linking Scale Hive Observations MODIS Phenology product (1)
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

**TIMESAT SMOOTHING**

- **MODIS Land Product**
  - Data Quality
  - Time-series Data
  - **Initial TIMESAT Fit**
    - Calculate distance between fit and original data
    - **Succeed?**
      - Yes (case 1) **Save Original High Quality Data for Gap-Filling Process**
      - No **New Weights**

- **MODIS Land Cover (MOD12Q1)**
  - **Typical Smoothed Curve for Each Land Cover in a Tile**
    - **Regress high quality data against corresponding dates from typical curve for the given land cover and tile.**
    - **Yes**
      - **Regress high quality data against high quality data from adjacent pixel.**
    - **No**
      - **Use regression to fill gaps**

**GAP FILLING**

- **For case 2 pixels**
  - **Curve available from adjacent pixel?**
    - **Yes**
      - **Regress high quality data against high quality data from adjacent pixel.**
    - **No**