Use of Multi-Year MODIS Phenological Data Products to Detect and Monitor Forest Disturbances at Regional and National Scales

2010 US-IALE Presentation by:
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• This presentation discusses an effort to use select MODIS phenological products for forest disturbance monitoring at the regional and CONUS scales
• Forests occur on ~1/3 of the U.S. land base and include regionally prevalent forest disturbances that can threaten forest sustainability
• Regional and CONUS forest disturbance monitoring is needed for a national forest threat early warning system being developed by the USDA Forest Service with help from NASA, ORNL, and USGS
• MODIS NDVI phenology products are being used to develop forest disturbance monitoring capabilities of this EWS
The project employs several MODIS phenology products:
- Phenological state products that record NDVI magnitude and Day of Year (DOY) for multiple phenological states
- Cumulative integral NDVI products (22 per year)
- Other NDVI integral products for the growing season

With phenological state products, baselines can be normalized for a given phenological parameter, instead of fixed sampling time frame (e.g., June 10 – July 27)

MODIS phenology products can be used to compute multiple disturbance monitoring products:
- Current NDVI or DOY versus baseline RGB visualization products
- % Change in NDVI or DOY for given phenological state
- Classification products based on unsupervised clustering
Goal and Objectives

• Goal - Assess use of multi-year MODIS MOD13 NDVI-based phenology products for detecting forest disturbances evident at regional and CONUS scales

• Objective 1 – Assess phenological state products (e.g., NDVI magnitude and Day of Year) for developing useful forest disturbance detection products

• Objective 2 – Assess cumulative NDVI integral products for developing useful forest disturbance detection products
Phenological Product Development Background

- Project employs MODIS phenological parameter products from C5 MOD13 NDVI 16-day 250 m time series data
  - 2003–2008 NDVI time series products were computed using Time Series Product Tool software in conjunction with MODIS Aqua and Terra products
  - Phenological state and cumulative integral NDVI products were computed using the Phenological Parameter Estimation Tool software
Method for Computing Baseline Products

• NDVI magnitude products
  – A maximum NDVI baseline was computed for each phenological state for the 2003–2008 period

• DOY products
  – A median DOY baseline was computed for each phenological state for the 2003–2008 period

• Cumulative integral NDVI products
  – A maximum cumulative integral NDVI baseline was computed for each cumulative integral across the calendar year
Evaluation Methods

- Assess phenological state products with respect to reference data on known disturbances
- Assess quality of products in terms of completeness and noise artifacts
- Assess products compared to higher resolution satellite and aerial data
- Assess products for potential in near real time applications
Example Multi-Year NDVI Magnitude Products for Select Phenological States

2005 Forest Defoliation from MODIS
Peak Growing Season NDVI

RGB = Baseline Peak NDVI in Red; 2005 Peak NDVI in Blue and Green

Red tones – Decreases in NDVI (e.g., Forest Defoliation)
2006 Forest Defoliation from MODIS Peak Growing Season NDVI

RGB = Baseline Peak NDVI in Red; 2006 Peak NDVI in Blue and Green

Red tones – Decreases in NDVI (e.g., Forest Defoliation)
2007 Forest Defoliation from MODIS Peak Growing Season NDVI

RGB = Baseline Peak NDVI in Red; 2007 Peak NDVI in Blue and Green

Red tones – Decreases in NDVI (e.g., Forest Defoliation)
2008 Forest Defoliation from MODIS Peak Growing Season NDVI

RGB = Baseline Peak NDVI in Red; 2008 Peak NDVI in Blue and Green

Red tones – Decreases in NDVI (e.g., Forest Defoliation)
2008 USDA Forest Service Defoliation Sketch Maps versus MODIS Product

RGB = Baseline Peak NDVI in Red; 2008 Peak NDVI in Blue and Green

Red tones – Decreases in NDVI (e.g., Forest Defoliation)

Sketch Map Legend
Dark Green – Gypsy Moth
Purple – Forest Tent Caterpillar
Cyan – Hemlock Woolly Adelgid
Magenta – Beech Bark Disease
Blue – Misc. Hardwood Defoliators

Sketch maps missed some defoliation
Example Intra-Seasonal NDVI Magnitude Products for Select Phenological States

Application: 2008 Ephemeral Forest Defoliation
2008 Forest Defoliation from MODIS 80% Left NDVI

RGB = Baseline 80% Left NDVI in Red; 2008 80% Left NDVI in Blue and Green

Red tones – Decreases in NDVI (e.g., Forest Defoliation)
2008 Forest Defoliation from MODIS Peak Growing Season NDVI

RGB = Baseline Peak NDVI in Red; 2008 Peak NDVI in Blue and Green

Red tones – Decreases in NDVI (e.g., Forest Defoliation)
2008 Forest Defoliation from MODIS 80% Right NDVI

RGB = Baseline 80% Right NDVI in Red; 2008 80% Right NDVI in Blue and Green

Red tones – Decreases in NDVI (e.g., Forest Defoliation)
Example Day of Year Products for Select Phenological States

Application: Views of Forest Phenology Change Associated with 2008 Hurricane Landfalls
2008 Forest Phenology Change
Based on 80% Right DOY Data

RGB = Baseline 80% Right DOY in Red; 2008 80% Right DOY in Blue and Green

Red tones – Increases in DOY (e.g., 80% Reached Earlier Due to Storm)

Hurricane Ike
Landfall – 9/13/2008

Hurricane Gustav
Landfall – 9/1/2008
2007 Forest Phenology Change Based on 80% Right DOY Data

RGB = Baseline 80% Right DOY in Red; 2007 80% Right DOY in Blue and Green

Red tones – Decreases in DOY for the 80% Right DOY

Hurricane Ike
Landfall – 9/13/2008

Hurricane Gustav
Landfall – 9/1/2008
Initial Findings

• Phenology NDVI magnitude products
  – 80% Left, Peak, and 80% Right NDVI products all depict regional patterns of insect defoliation
  – All products capture large fire and clearcut disturbances

• Phenology DOY products
  – DOY products noisier than NDVI magnitude products
  – DOY products appear to show drought-impacted forest

• General
  – Forest mask useful for focusing assessments of forest
  – Products could be improved to eliminate data voids
  – Product line could benefit from expanded baseline from 2000 to present
  – Products can show intra-annual defoliation persistence trends
Final Remarks

• The assessed phenological state products showed promise for detecting and tracking regional forest disturbances
• It’s possible that NDVI magnitude and DOY products could be used together for NRT disturbance detection
• For a given phenological state, an NRT system could be established as follows:
  – A median DOY baseline product could be applied to determine when to collect relevant NDVI imagery for the current season
  – The current NDVI magnitude product could then be compared to the historical max NDVI baseline product to compute percent change in NDVI for that phenological state
• Cumulative integral NDVI also has good potential for aiding NRT disturbance detection (discussed in next presentation)
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