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

2010 US-IALE Presentation by:
Joseph Spruce, SSAI
William Hargrove, USDA Forest Service
Gerald Gasser, Lockheed Martin
James Smoot, SSAI
Kenton Ross, SSAI
Project Background

- 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.
Which Phenology Products?

- 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

Focus of this presentation
• 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
- Green – 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 – Decreases 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

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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)
Participation in this work by Science Systems and Applications, Inc., was supported by NASA at the John C. Stennis Space Center, Mississippi, under contracts NNS04AB54T and NNS10AA14T.