Contribution of Near Real Time MODIS-Based Forest Disturbance Detection Products to a National Forest Threat Early Warning System

Presented to the 2011 AGU Fall Meeting by:
Joseph Spruce, Computer Sciences Corporation (CSC)
William Hargrove, USDA Forest Service
Gerald Gasser, Lockheed Martin
James Smoot, CSC
Philip Kuper, CSC
Introduction

- U.S. forests occupy ~751 million acres (~1/3 of total land)
- These forests are exposed to multiple biotic and abiotic threats that collectively damage extensive acreages each year
- Hazardous forest disturbances can threaten human life and property, bio-diversity and water supplies
- Timely regional forest monitoring products are needed to aid forest management and decision making by the US Forest Service and its state and private partners
- Daily MODIS data products provide a means to monitor regional forest disturbances on a weekly basis
- In response, we began work in 2006 to develop a Near Real Time (NRT) forest monitoring capability, based on MODIS NDVI data, as part of a national forest threat early warning system (EWS)
• The EWS was mandated by the Healthy Forest Restoration Act (HFRA) of 2003, Section VI
  – “In carrying out the program, the Secretary (of Agriculture) shall develop a comprehensive early warning system for potential catastrophic environmental threats to forests”
• Threats include those from insects, diseases, invasive species, fire, weather-related risks and other episodic events, as well as forest loss and degradation
• The HFRA discusses the EWS as part of a forest inventory and monitoring program to improve detection and response to environmental threats
• The EWS is to provide timely regional forest monitoring and threat assessment data for government and public use
Objectives for 2011 NRT MODIS Forest Disturbance Detection Products

• **Objective 1** – Contribute nationwide weekly NRT MODIS %NDVI forest disturbance detecting products to USFS EWSs
  – U.S. Forest Change Assessment Viewer (FCAV)
  – U.S. Forest Disturbance Mapper (FDM)

• **Objective 2** – Conduct in-season rapid preliminary assessments of MODIS %NDVI for detecting regional forest disturbances in NRT according to:
  – Biotic damage agents
  – Abiotic damage agents
  – Forest cover types (general and specific)
  – U.S. regions
  – Seasons within calendar year
U.S Forest Change Assessment Viewer
(New Products Every 8 Days)

2011 Forest % NDVI Change versus Previous Year for November 1 - 24

National Aeronautics and Space Administration

Contribution of Near Real Time MODIS-Based Forest Disturbance Detection Products to a National Forest Threat EWS
MODIS NDVI Processing Method

Process historical MOD13 NDVI data with TSPT (Time Series Product Tool)
- Remove clouds, shadows, snow
- Reduce residual noise
- Constrain viewing geometry
- Fuse Terra/Aqua products
- Interpolate data voids
- Savitzky Golay filtering
- Re-aggregate as 24 day composites refreshed every 8 days – 44 products per year

Forest Mask from USGS and USFS Data Sources

Compute Forest Change Products For Given 24 Day Interval
- % Change in NDVI for current vs. previous year
- % Change in NDVI for given vs. previous 3 years
- % Change in NDVI for current versus previous 8 years

Compute NRT products using expedited eMODIS NDVI data
- Remove clouds, shadows, snow
- Fuse Terra/Aqua data
- Re-aggregate into 24 day temporal composites

MOD13 NDVI
MOD35 Clouds, Snow
MOD03 Geo-location
eMODIS NDVI
Series 1 – Examples of MODIS Change Products
Detecting Regionally Evident Abiotic Forest Disturbances

• April 27, 2011 tornadoes in Mississippi and Alabama
• 2011 Los Conchas fire of New Mexico
• 2011 Mississippi River flooding impacts on wetland forests of Louisiana and Mississippi
• 2011 drought in Texas and adjacent states
• All shown products were posted in NRT on the FCAV during 2011
MODIS View of 20111 Los Chonchas Fire in New Mexico

Burned area from fire is shown in deep red tones with NDVI drops often exceeding minus 50%
MODIS View of Mississippi River Flooding of Wetland Forests

Forest %NDVI Change for May 9 through June 1 of 2011 versus 2010 – Counties in White

Wind Damage

Mississippi

Louisiana

Flood Impacts

MOD09 NDVI Products
% Change in NDVI
-100%
-60%
-40%
-20%
-10%
-5%
-3%
-1.5%
0%
+33%
+100%
MODIS View of 2011 Drought in Texas and Adjacent States

Land %NDVI Change for June 18 through July 11 of 2011 versus 2003-2010
U.S. Drought Monitor View of 2011
Drought in Texas and Adjacent States

U.S. Drought Monitor Product for July 12, 2011

**Intensity:**
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

**Drought Impact Types:**
- ~ Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)
Series 2 – Examples of MODIS Change Products Showing Regionally Evident Biotic Forest Disturbances

• Spring 2011 - wetland forest defoliation in Louisiana
• Summer 2011 – potential bark beetle induced forest mortality in Utah
• Summer 2011 - spruce budworm forest defoliation in Washington
• Fall 2011 - fall webworm defoliation in Pennsylvania
• All shown products were posted in NRT on the FCAV during 2011
**View of Wetland Forest Defoliation in Coastal Louisiana**

*Forest %NDVI Change for April 15 through May 8 of 2011 versus 2003-2010 – Counties in Black*

[Map showing forest defoliation with MOD09 NDVI Products legend]
MODIS View of Potential Expansion of Bark Beetle Mortality in Utah

Forest %NDVI Change for 8/21 through 9/13 of 2011 versus 2010 – National Forests in Black

Area of Concern Within Area Subject To Known Multiyear Bark Beetle Outbreak
MODIS View of Apparent Spruce Budworm Defoliation in Washington


Attribution Based on 2011 Wenatchee National Forest News Accounts and 2010 Aerial Disturbance Survey Data
MODIS View of Fall Webworm Defoliation in Pennsylvania

Attribution Confirmed By National Forest Staff

MOD09 NDVI Products
% Change in NDVI
- 100 %
- 60 %
- 15 %
- 12 %
- 10 %
- 8 %
- 5 %
- 3 %
- 1.5 %
0 %
+ 3 %
+ 100 %
Comments on 2011 Results

- NRT MODIS CONUS forest change products were used to detect multiple regional biotic and abiotic forest disturbances.
- Recent disturbances were most readily identified on change products using the previous year NDVI as a baseline.
- Longer multiyear NDVI baselines were useful for assessing insect defoliation, as well as chronology, persistence, and duration of multiyear disturbance events.
- News accounts, aerial disturbance surveys, fire maps, and Landsat data were used to evaluate apparent forest disturbances.
- Forest disturbance detection can depend on the damage agent, season, and location.
- Improved snow masks aided change product interpretability.
Final Remarks

- The 2011 NRT MODIS % NDVI change products in the FCAV enabled regional forest monitoring across the U.S.
- Regional disturbance events observed on these products tended to show visual agreement with reference data.
- Weekly change products were contributed to the FCAV and FDM with typical latencies of 1-2 days after the last collection date.
- Future work will include additional product automation, validation, testing alternative historical baseline methods, and improving MODIS true color composite products.
- The FCAV can be viewed on-line at ews.forestthreats.org/gis/ews_gis.htm.
- For additional information, email joseph.p.spruce@nasa.gov.


Participation in this work by Computer Sciences Corporation, Inc., was supported by NASA at the John C. Stennis Space Center, Mississippi, under contract NNS10AA35C. Project funding was provided to NASA by the USDA Forest Service Eastern and Western Threat Assessment Centers.
Extra Slides
Product Development History

• 2006-2008
  – Conducted R&D to compute regional forest monitoring products
  – Began computing CONUS MODIS vegetation phenology products
  – Performed retrospective regional forest disturbance detection studies, based on MODIS NDVI phenology products

• 2009
  – Began NRT regional forest disturbance detection studies
  – Published PE&RS highlight article on initial NRT results

• 2010-2011
  – Weekly NRT CONUS forest disturbance detection products posted on multiple USFS prototypical EWS web mapping services, including the U.S. Forest Change Assessment Viewer (FCAV)
  – RSE publication - initial retrospective case study on use of MODIS NDVI for detecting regional forest defoliation from gypsy moths