Role of MODIS Vegetation Phenology Products in the U.S. ForWarn Early Warning System for Forest Threats

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Introduction

• U.S. forests occupy ~751 million acres (~1/3 of total land)
• Several abiotic and biotic damage agents disturb, damage, kill, and/or threaten these forests
• Regionally extensive forest disturbances can also threaten human life and property, bio-diversity and water supplies
• Timely regional forest disturbance monitoring products are needed to aid forest health management work at finer scales
• Daily MODIS data provide a means to monitor regional forest disturbances on a weekly basis, leveraging vegetation phenology
• In response, the USFS and NASA began collaborating 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)
What is ForWarn?

- ForWarn is an on-line geospatial data analysis tool for detecting and tracking regionally evident forest disturbances in the U.S.
- Developed by the US Forest Service in collaboration with NASA, ORNL, and the USGS per mandate of the Healthy Forest Restoration Act.
- Uses 250m MODIS satellite NDVI data products to detect changes in vegetation canopy greenness that are anomalous in terms of normal phenology.
- Includes a suite of annual MODIS NDVI phenology products and near real time forest change products derived from these products.
U.S Forest Change Assessment Viewer
(FCAV) - New Products Every 8 Days

The FCAV is ForWarn’s Geospatial Data Viewer

http://forwarn.forestthreats.org/fcav/
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**Process for Computing ForWarn MODIS NDVI Phenology Products**

**Input MOD13 Maximum Value NDVI Products**
Preprocessed with Time Series Product Tool (TSPT)

**Processing with Phenological Parameters Estimation Tool (PPET)**

- **Identify the Growing Season**
- **Locate Seasonal Transition Points**
- **Identify Seasonal Values and Dates**
- **Calculate Seasonal and Cumulative Integrals**

**Output Phenology Products**

**Phenology Parameters** (NDVI and DOY for 7 Key Points)
- Left Minima
- Left 20% of Seasonal Maximum
- Left 80% of Seasonal Maximum
- Seasonal Maximum
- Right 80% of Seasonal Maximum
- Right 20% of Seasonal Maximum
- Right Minima

**NDVI Integral Products**
- Small Integral of Growing Season NDVI
- Large Integral of Growing Season NDVI
- 46 Cumulative Integral NDVIs per Year

**% NDVI Change Products**
- Change vs. Previous Year
- Change vs. 3 Previous Years
- Change vs. All Previous Years

**Compute 24 Day eMODIS NDVIs**

**Compute 24 Day Historical NDVI Baselines**
Example MODIS Phenology Products

CONUS Historical NDVI Phenology Products for 2000 – 2011

Positive NDVI's Scaled from 0.0 to 1.00
Series 1 – Examples of ForWarn MODIS Change Products With Regionally Evident Abiotic Forest Disturbances

2011 Tornadoes in Alabama and Mississippi  
Source: NOAA

2012 High Park Fire in Colorado Front Range  
Source: NASA

2012 Hail Damage Asheville Watershed, NC  
Source: USFS

2011 Drought in Texas, and Adjacent States  
Source: NOAA
MODIS View of 2012 High Park Fire in Colorado Front Range

Forest % NDVI Change for August 4 – 27, 2012 versus 2011

Burned area from fire includes NDVI drops of minus 50% or more
MODIS View of 2012 Hail Damage to Asheville, North Carolina Watershed

Landsat 7 False Color RGB from 6/2/2012

Defoliation from Hail Storm

Asheville, NC Water Supply

MODIS % NDVI Change for 5/16 to 6/8/2012 vs. 2011

Defoliation from Hail Storm

Area Field Checked 6/14/2012
MODIS View of 2011 Drought in Southeastern U.S.

Land %NDVI Change for June 18 through July 11 of 2011 versus 2003-2010

Large areas in 5 States with high NDVI drops exceeding minus 50%
U.S. Drought Monitor View of 2011
Drought in Texas and Adjacent States

US 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 ForWarn MODIS Change Products Showing Regionally Evident Biotic Forest Disturbances

2012 Spring Defoliation in Louisiana Swamps from Caterpillars

2012 Summer Spruce Beetle Mortality in Rio Grande NF of Colorado

2011 Summer Budworm Defoliation in Washington State

2011 Fall Defoliation in Pennsylvania From Fall Webworm

Source: LSU

Source: CSU

Source: USFS

Source: Texas FS
MODIS View of 2012 Wetland Forest Defoliation in Coastal Louisiana

Stennis Space Center

MODIS Forest % NDVI Change Product (Date Ending 4/21 for 2012 versus 2011)  Aerial Oblique Below Acquired by DAF (Days After Initial ForWarn Notification)

MODIS products showing locations of insect defoliated swamp forests – were used to aid aerial detection surveys by LDAF and the USFS

Above: Pearl River, LA photos of forest tent caterpillar and related tree defoliation acquired by NASA

2012 MODIS Product with LDAF 2012 Aerial Survey Polygon from 4/19/2012

Landsat False Color RGB Image from 4/12/2012 (Healthy Forest Orange/Brown)
MODIS View of Potential New 2012 Spruce Beetle Mortality in Colorado

Forest % NDVI Change for Date Ending July 2 of 2012 versus 2011

Spruce/Fir Forest - Close to Areas Recently Attacked by Spruce Beetle

Aspen Forest According to Landfire/GAP map

Area within Rio Grande NF
2011 MODIS View of Spruce Budworm Defoliation Area in Washington

Stennis Space Center


Western Spruce Budworm Related Disturbance Shown in Green to Yellow Orange Tones

Attribution Based on News Accounts, USFS Communications, and 2010 Aerial Survey Data

MOD09 NDVI Products
% Change in NDVI
-100%
-60%
-15%
-12%
-10%
-8%
-5%
-3%
-1.5%
0%
+33%
+100%

0 15 km
MODIS View of 2011 Fall Webworm Defoliation in Pennsylvania

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

Attribution Confirmed By Allegheny National Forest Staff and Landsat Data
**ForWarn NDVI Profile of Hemlock Woolly Adelgid Forest Mortality Area**

**Oblique View of Hemlock Mortality**

**Great Smoky Mountains National Park**

**Hurricane Creek (Cataloochee Creek)**

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*Decreasing NDVI minima in hemlock mortality area for 2000 - 2010*

*Above – NAIP Aerial True Color Image*

Source: USFS
Comments on Example Results for 2011-2012

- NRT MODIS CONUS forest change products showed multiple regional forest disturbances
  - Including abiotic, biotic, and anthropogenic disturbances in softwood, hardwood, and mixed wood forests
  - New disturbances were best detected using the previous year NDVI as the baseline
  - Multiyear disturbance events were best assessed using all three historical NDVI baselines (previous 1, 3 and all years)
- Detected disturbances were assessed with news accounts, aerial disturbance survey, fire, and Landsat data
- ForWarn disturbance detection results were conveyed to Federal and State forest health monitoring community
Conclusions

• Since 2010, NRT MODIS % NDVI change products have been produced for the U.S. every 8 days, usually posted on ForWarn 1-2 days after the last collection date

• ForWarn disturbance detection success requires use of daily MODIS satellite-based phenology data

• Future work
  – Improving change product freshness and data quality
  – More retrospective forest change products
  – More product validation studies

• For more information, email joseph.p.spruce@nasa.gov

• Visit the ForWarn web site at: http://forwarn.forestthreats.org
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.