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)
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http://forwarn.forestthreats.org
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
The FCAV is ForWarn’s Geospatial Data Viewer

http://forwarn.forestthreats.org/fcav/
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 Historical NDVI Baselines

Compute 24 Day eMODIS NDVIs
Seasonal States of Individual Tree Compared to Phenology Parameters

- Maximum Vegetation Index Value (NDVI)
- Left 80% of Max
- Right 80% of Max
- Left 20% of Max
- Right 20% of Max
- Spring
- Growing Season
- Fall
- Left Minimum
- Right Minimum
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
- 2012 High Park Fire in Colorado Front Range
- 2012 Hail Damage Asheville Watershed, NC
- 2011 Drought in Texas, and Adjacent States

Source: NOAA
Source: NASA
Source: USFS
Source: NOAA
MODIS View of April 27, 2011
Tornadoes in Mississippi and Alabama

Tornado Damage Tracks Shown as Yellow to Red Linear Scars

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

Defoliation from Hail Storm

Asheville, NC Water Supply

Defoliation from Hail Storm

Landsat 7 False Color RGB from 6/2/2012

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

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  
Source: LSU

2012 Summer Spruce Beetle Mortality in Rio Grande NF of Colorado  
Source: CSU

2011 Summer Budworm Defoliation in Washington State  
Source: USFS

2011 Fall Defoliation in Pennsylvania From Fall Webworm  
Source: Texas FS
MODIS View of 2012 Wetland Forest Defoliation in Coastal Louisiana

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


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

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

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

National Aeronautics and Space Administration
ForWarn NDVI Profile of Hemlock Woolly Adelgid Forest Mortality Area

Oblique View of Hemlock Mortality

Source: USFS

Great Smoky Mountains National Park
Hurricane Creek (Cataloochee Creek)

Decreasing NDVI minima in hemlock mortality area for 2000 - 2010

Above – NAIP Aerial True Color Image
• 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
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