Contribution of National Near Real Time MODIS Forest % Maximum NDVI Change Products to the U.S. ForWarn System

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This presentation reviews the development, integration, and testing of Near Real Time (NRT) MODIS forest % maximum NDVI change products resident to the USDA Forest Service (USFS) ForWarn System. ForWarn is an Early Warning System (EWS) tool for detection and tracking of regionally evident forest change, which includes the U.S. Forest Change Assessment Viewer (FCAV) (a publically available on-line geospatial data viewer for visualizing and assessing the context of this apparent forest change). NASA Stennis Space Center (SSC) is working collaboratively with the USFS, ORNL, and USGS to contribute MODIS forest change products to ForWarn. These change products compare current NDVI derived from expedited eMODIS data, to historical NDVI products derived from MODIS MOD13 data. A new suite of forest change products are computed every 8 days and posted to the ForWarn system; this includes three different forest change products computed using three different historical baselines: 1) previous year; 2) previous three years; and 3) all previous years in the MODIS record going back to 2000. The change product inputs are maximum value NDVI that are composited across a 24 day interval and refreshed every 8 days so that resulting images for the conterminous U.S. are predominantly cloud-free yet still retain temporally relevant fresh information on changes in forest canopy greenness. These forest change products are computed at the native nominal resolution of the input reflectance bands at 231.66 meters, which equates to ~ 5.4 hectares or 13.3 acres per pixel. The Time Series Product Tool, a MATLAB-based software package developed at NASA SSC, is used to temporally process, fuse, reduce noise, interpolate data voids, and re-aggregate the historical NDVI into 24 day composites, and then custom MATLAB scripts are used to temporally process the eMODIS NDVIs so that they are in synch with the historical NDVI products. Prior to posting, an in-house snow mask classification product is computed for the current compositing period and integrated into the change images to account for snow related NDVI drops. The supplemental snow classification product was needed because other available QA cloud/snow mask typically underestimates snow cover. MODIS true and false color composites were also computed from eMODIS reflectance data and the true color RGBs are also posted on ForWarn's FCAV; this data is used for assessing apparent occasional quality issues on the change products due to residual unmasked cloud cover. New forest change products are posted with typical latencies of 1-2 days after the last input eMODIS data collection date for a given 24 day compositing period.

Once in the FCAV, these current forest change products can be visually compared to several geospatial data sets depicting forest disturbances, i.e., from aerial detection surveys (ADS), current and historical fires, tornado damage locations, land cover, climate parameters, and topographic variables. The FCAV includes current as well as retrospective forest change products available for 2010 to present. Forest change products have been validated retrospectively and in rapid response "now cast" mode by using available geospatial reference data, as well as news accounts and communications with federal and state agency forest health specialists. Completed retrospective studies include assessment of MODIS forest change product ability to detect regional disturbances from (1) gypsy moth defoliation and (2) hurricane induced damage. A case study currently underway is assessing MODIS forest change products for detecting disturbance and mountain pine beetle induced forest mortality in the Rocky

Mountains.   Validation studies like these compare MODIS forest change products to higher spatial resolution satellite and in-situ data. Apparent disturbances on current NRT change products are assessed qualitatively by comparing them to Landsat-based RGBs and change detection products, and to historical disturbance data, news accounts, and communications with Forest Health Monitoring (FHM) experts. Fortunately, current Landsat data products are posted shortly after each collection date. However, the current lack of fresh Landsat 5 data impedes the use of Landsat for assessing current MODIS forest change products. When the ForWarn/FCAV change products show unusual, potentially detrimental disturbances (i.e. anomalies), map displays can be saved as an URL and emailed to perspective end-users, i.e. those conducting ADS works, entomologists, pathologists, and others state and federal forest health specialists. In some cases, more expedited MODIS forest change products have also been computed to aid rapid response damage assessment surveys (e.g., for the April 2011 tornado outbreak in the southeastern US and for 2011 spring flooding in coastal Louisiana).

FHM specialists have used these change products to help assess regionally evident conterminous forest disturbances from multiple biotic and abiotic damage agents. These products have been utilized to help evaluate insect defoliation disturbance in the spring, summer, and fall; and have also been used to help assess areas where western U.S. bark beetle have induced extensive mortality . Use of multiple change products based on multiple baselines enhances assessment of disturbance vintage and persistence. Change based on previous year's baseline is useful for evaluating new change hotspots and the intensification of change, versus the previous year.   Use of change products based on a given multiyear base line can help improve detectability and characterization of forest change due to annual insect defoliation, like what can occur in coastal Louisiana swamp forests. While these change products do not depict forest disturbances at the Landsat spatial resolution, they do provide a general indication of the location and relative intensity of forest disturbances that can be conveyed to the FHM so that more intensive aerial and field surveys can be produced. These change products have been used to help focus more intensive forest health aerial and field surveys.   The high temporal resolution of the near daily MODIS Aqua and Terra data offers an unprecedented way to regionally monitor forest change throughout the growing season and calendar year.

Future work will include additional product validation studies as well as developing methods to improve the quality, use, and automated computation of these products.

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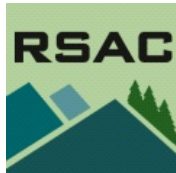
Introduction

- U.S. forests occupy ~751 million acres (~1/3 of total land)
- Several biotic and abiotic 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 monitoring products are needed to aid forest monitoring and management work at finer scales
- Daily MODIS data provide a means to monitor regional forest disturbances across the country on a weekly basis
- 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)

Rationale for EWS: Healthy Forest Restoration Act of 2003

- ## The EWS was mandated by the Healthy Forest Restoration Act 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"*

- ## The EWS is to contribute to a forest inventory and monitoring program for aiding environmental threat detection and response

    - *Threats include insects, diseases, invasive species, fire, weather, storm damage, and forest loss and degradation*
    - *ForWarn contributes current regional monitoring to this EWS*

U.S. ForWarn System for Regional Forest Disturbance Monitoring

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http://forwarn.forestthreats.org

U.S Forest Change Assessment Viewer (FCAV) - New Products Every 8 Days

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2011 Forest % NDVI Change versus Previous Year for November 1 - 24
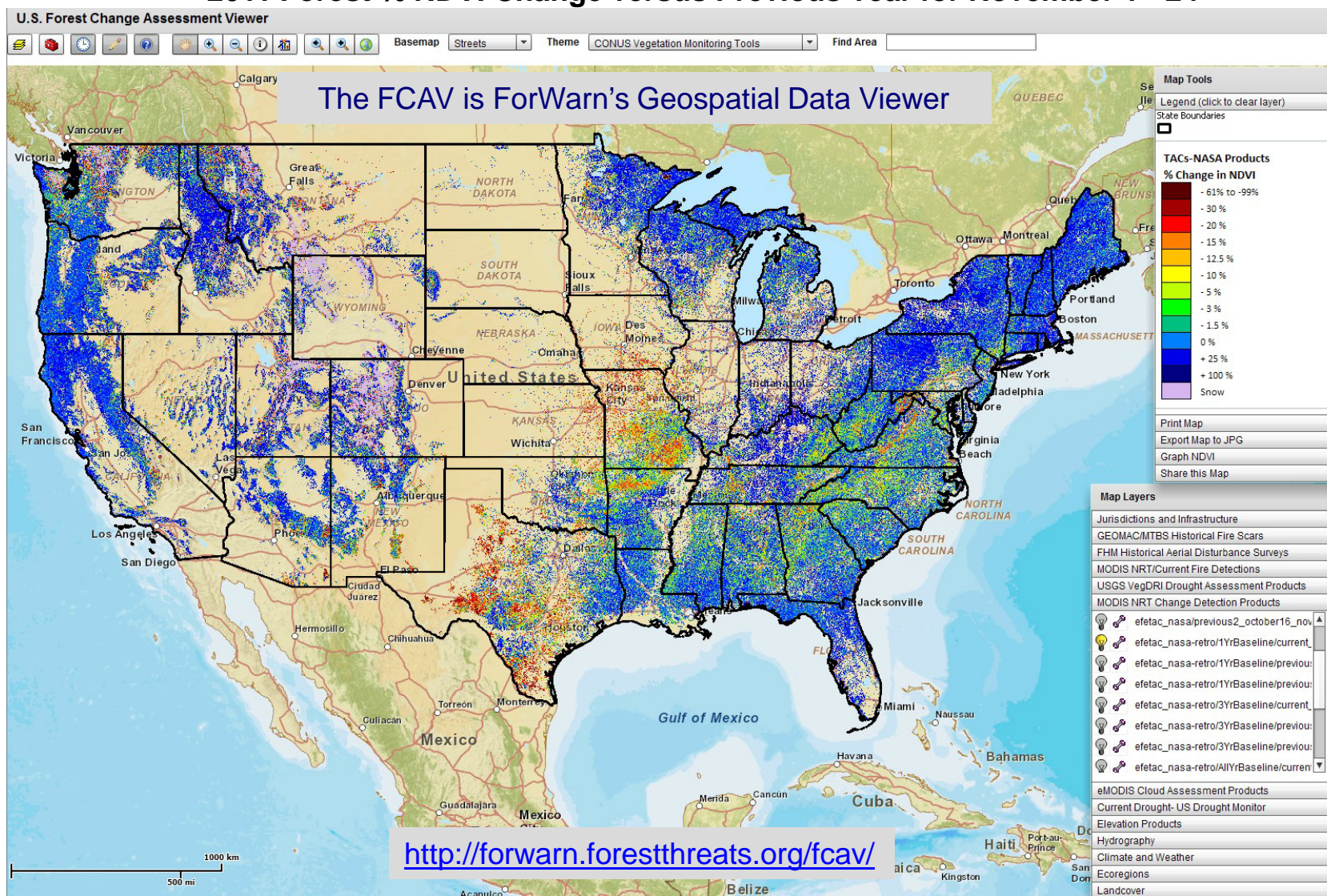
Objectives for ForWarn's NRT MODIS Forest Disturbance Detection Products

- **Objective 1** – Contribute nationwide weekly NRT MODIS %NDVI forest disturbance detecting products to USFS EWSs
  - *U.S. ForWarn System (USFS EFETAC and WWETAC)*
  - *U.S. Forest Disturbance Mapper (USFS FHTET)*
- **Objective 2** – Conduct in-season rapid preliminary assessments of NRT MODIS %NDVI change products for detecting regional forest disturbances
- **Objective 3** – Perform product validations for specific damage events and geographic regions

Processing Method for ForWarn's MODIS % NDVI Change Procucts

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MOD13 Tiles NDVI

MOD13 Tiles Clouds, Snow

MOD13 Tiles Geo-location

USGS EDC LP DAAC

Process historical MOD13 NDVI data with Time Series Product Tool software (MATLAB code)
- Input MODIS HDF tile data
- Remove clouds, shadows, snow
- Reduce residual noise
- Constrain viewing geometry
- Fuse cleaned Terra/Aqua data into 8 day maximum NDVI composites
- Interpolate data voids
- Apply Savitzky-Golay filtering
- Re-aggregate tiles into mosaic of CONUS 24 day NDVI composites
- Compile historical CONUS multi-year 24 day baseline products

USGS EDC NLCD

Forest Mask from USGS and USFS Data Sources

USFS FHTET

Compute NRT CONUS forest % NDVI change products for given 24 day interval, using ERDAS Imagine scripts
- Compute % NDVI change for current versus previous year
- Compute % NDVI change for current versus previous 3 years
- Compute % NDVI change for current versus all previous years
- Refresh forest change products every 8 days with 1 - 2 day latency after last input collection date
- Post change products to USFS EWS (US Forest Change Assessment Viewer)
- Spot check products with Landsat data

USGS EDC eMODIS

eMODIS CONUS NDVI

Process NRT NDVI data using expedited eMODIS NDVI and MATLAB code
- Remove clouds, shadows, snow
- Fuse Terra/Aqua NDVI data
- Re-aggregate into 24 day temporal composites of maximum NDVI

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
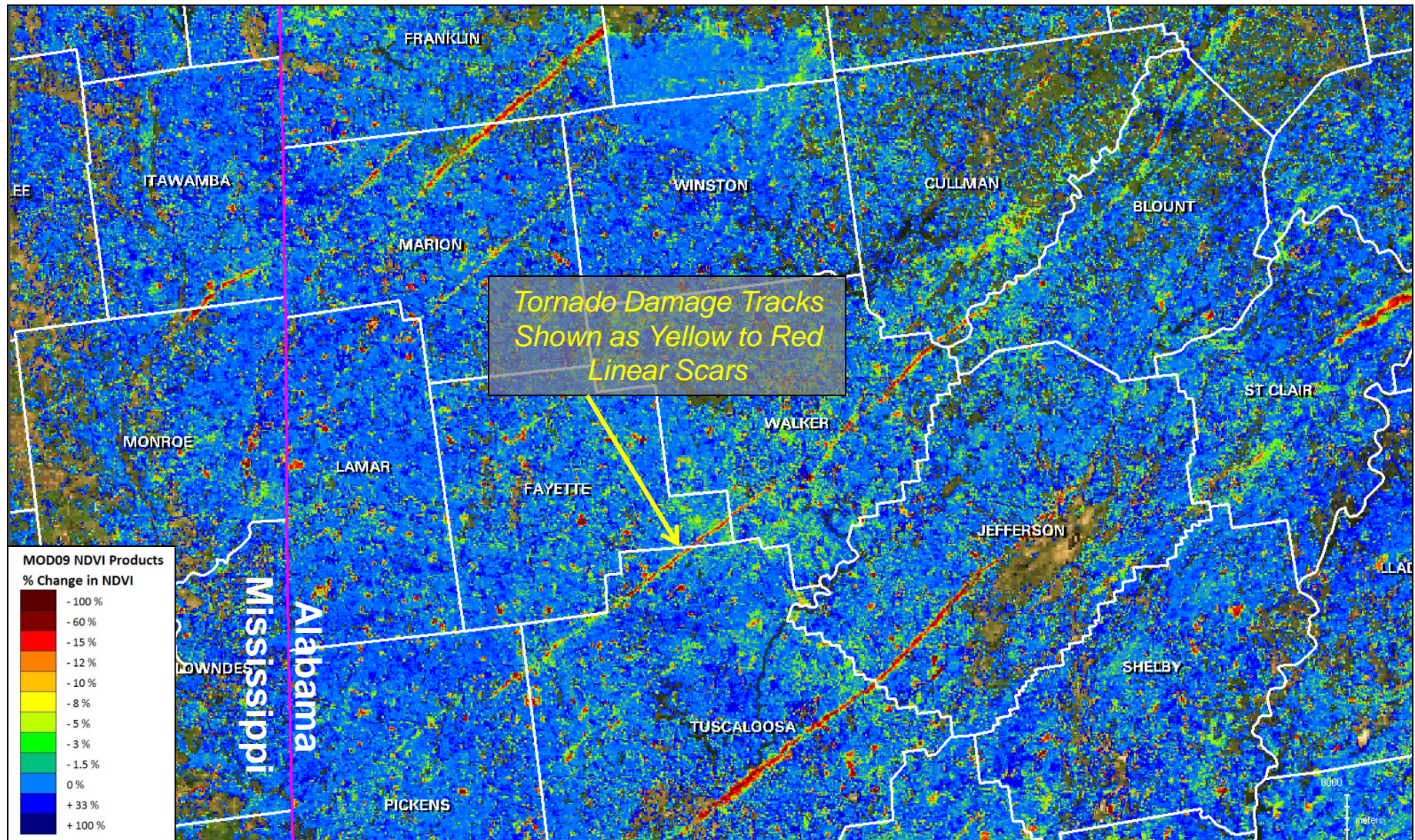

Source: USFS

Source: NOAA

MODIS View of April 27, 2011 Tornadoes in Mississippi and Alabama

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Forest %NDVI Change for May 1-24, 2011 versus 2010 – Counties in White
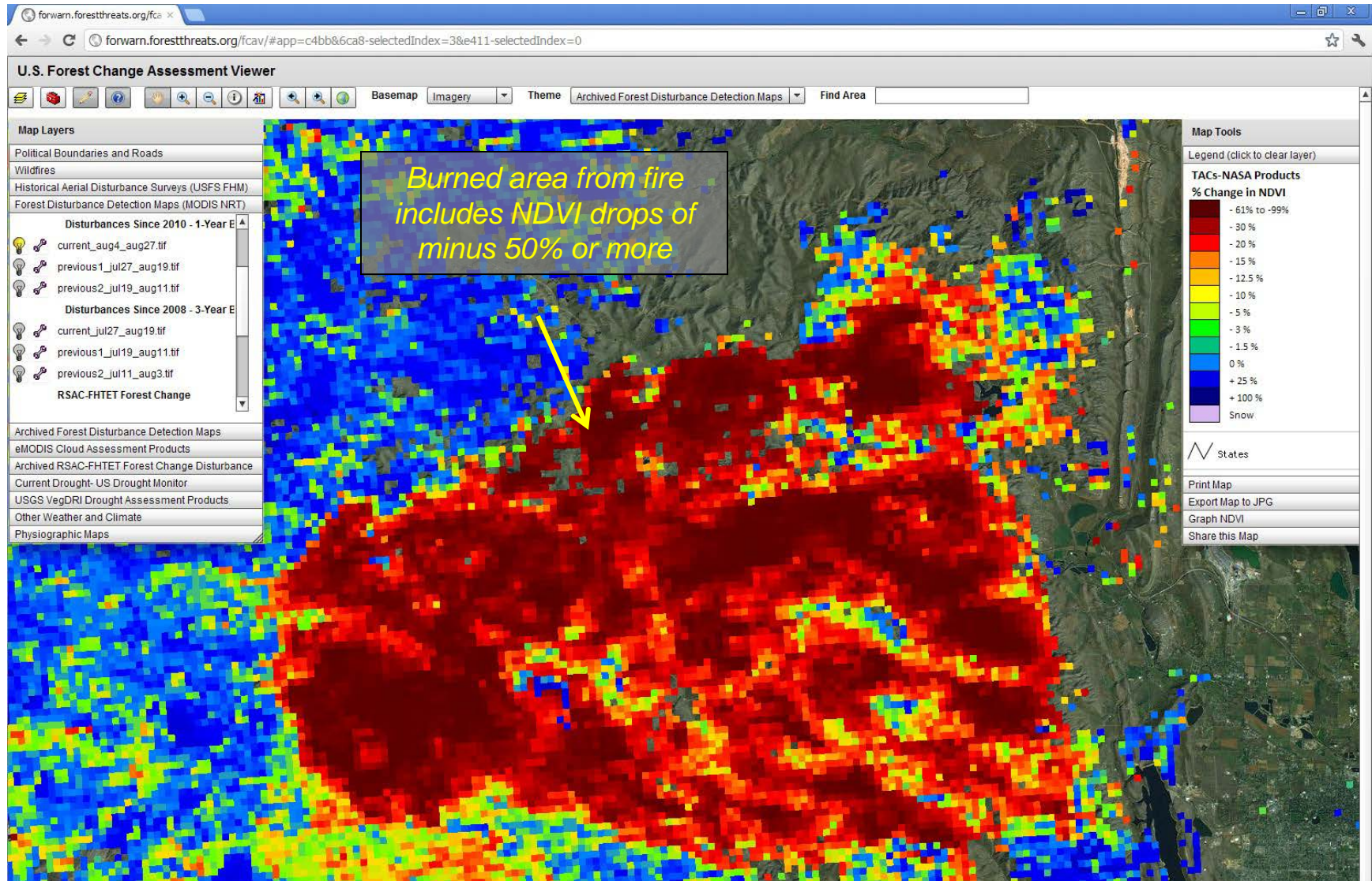

Tornado Damage Tracks Shown as Yellow to Red Linear Scars

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

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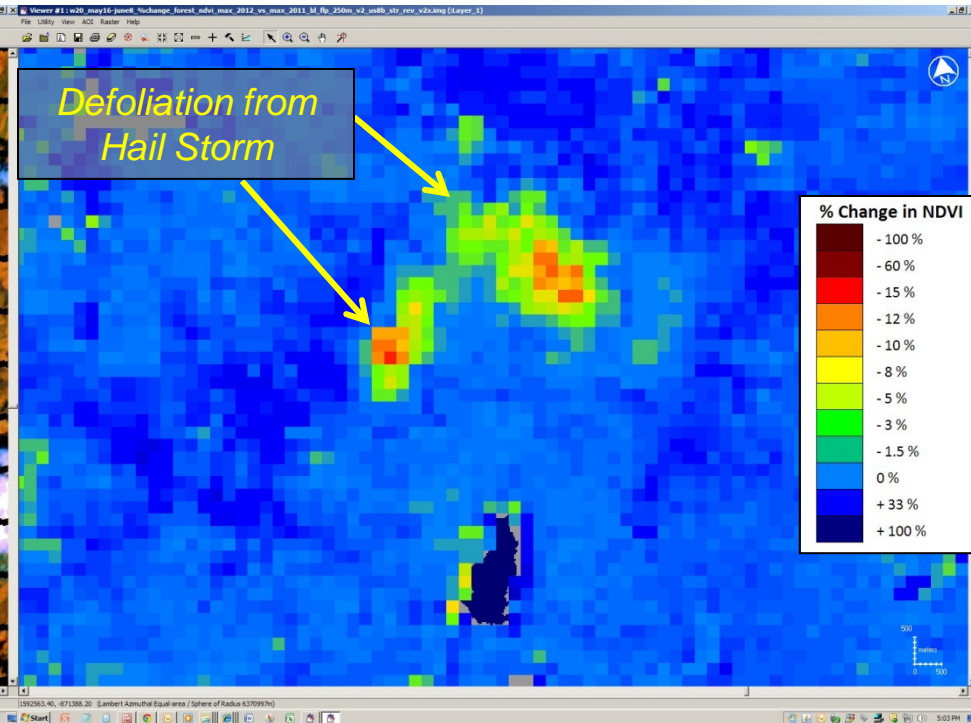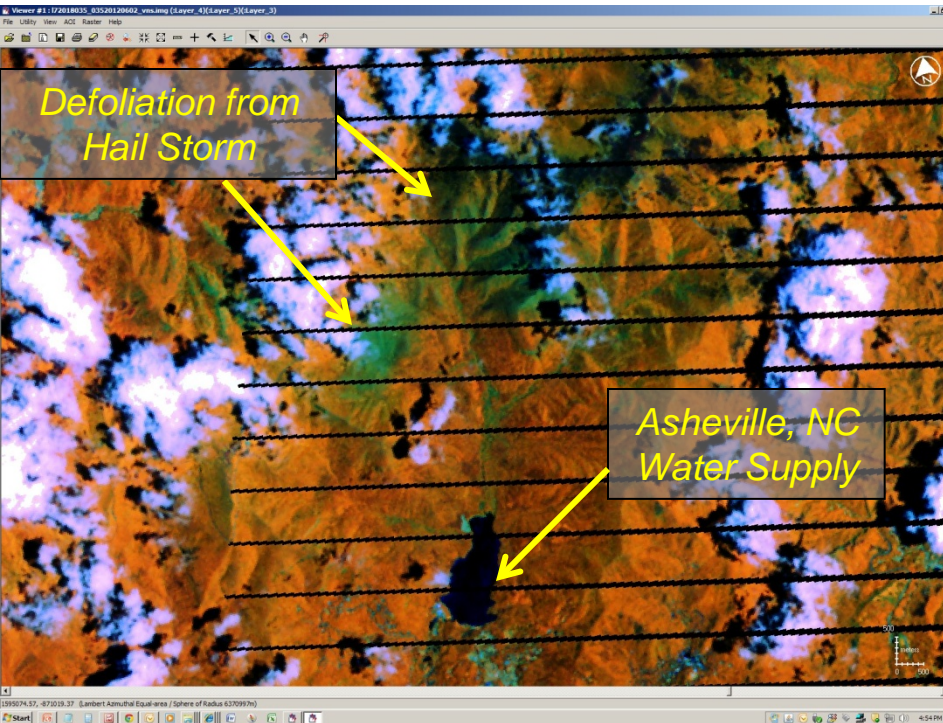*Forest % NDVI Change for August 4 – 27, 2012 versus 2011*

MODIS View of 2012 Hail Damage to Asheville, North Carolina Watershed

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Landsat 7 False Color RGB from 6/2/2012
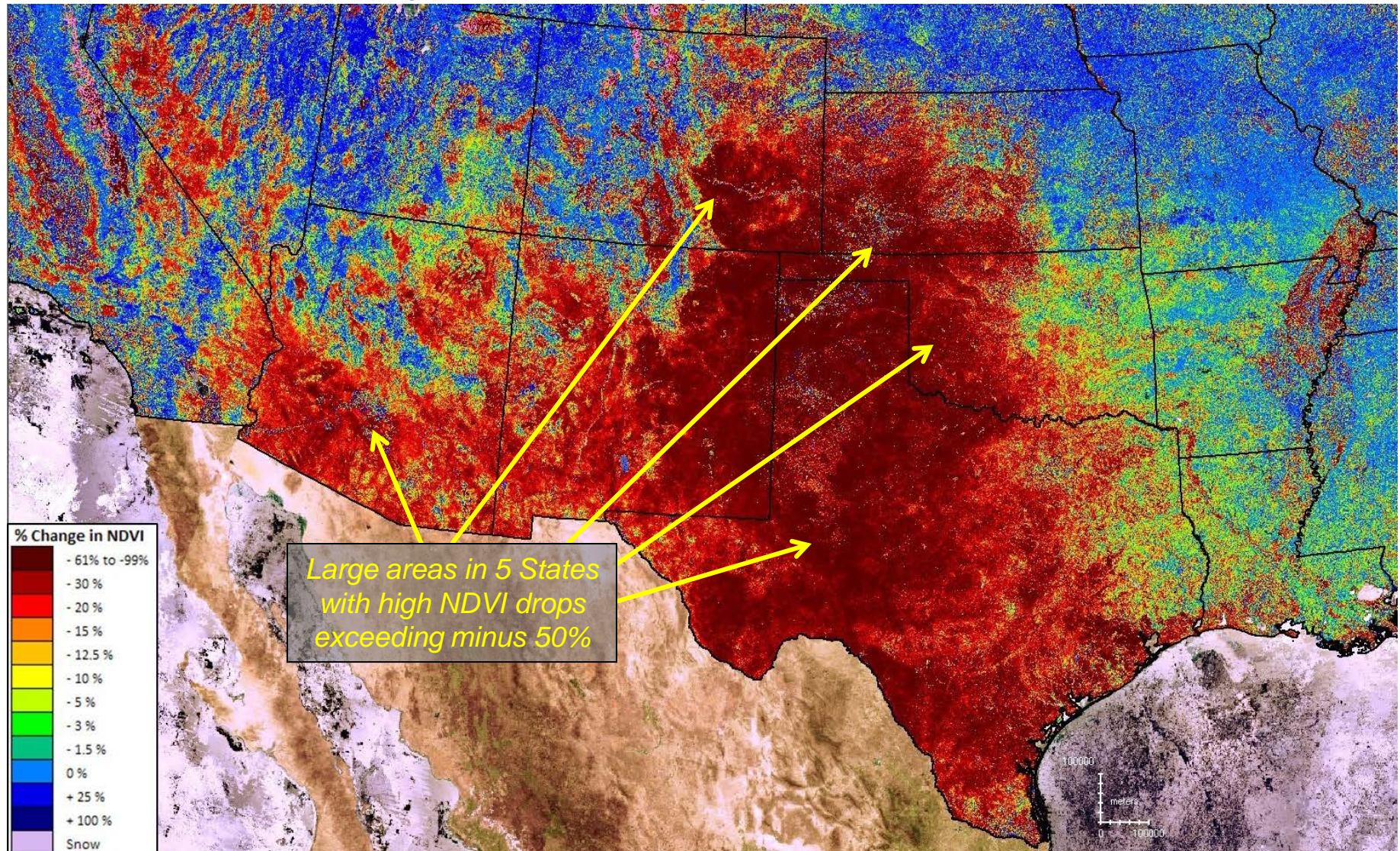
MODIS % NDVI Change for 5/16 to 6/8/2012 vs. 2011

Area Field Checked 6/14/2012

MODIS View of 2011 Drought in Texas and Adjacent States

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

% Change in NDVI

- 61% to -99%
- 30 %
- 20 %
- 15 %
- 12.5 %
- 10 %
- 5 %
- 3 %
- 1.5 %
0 %
+ 25 %
+ 100 %
Snow

Large areas in 5 States with high NDVI drops exceeding minus 50%

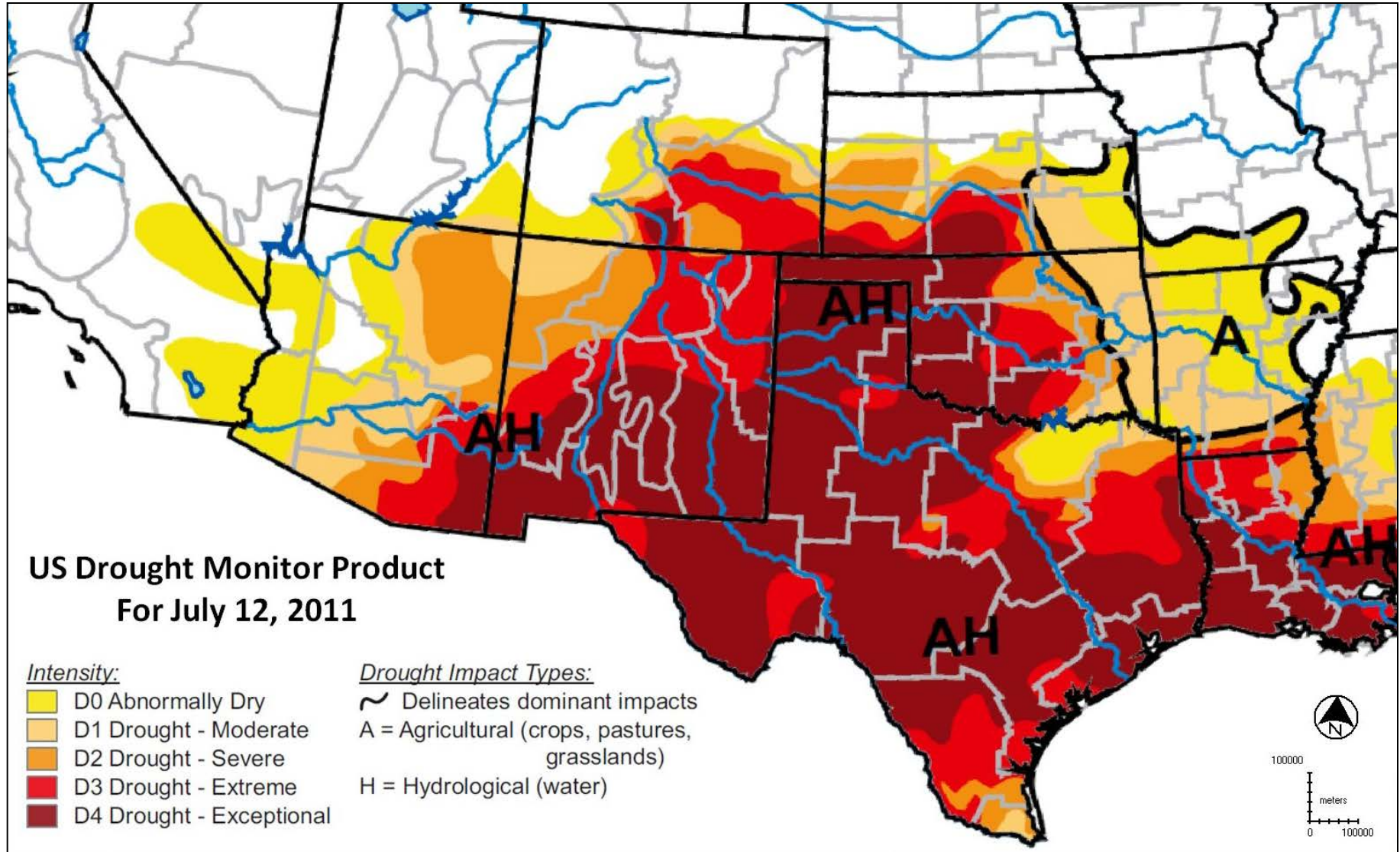# U.S. Drought Monitor View of 2011 Drought in Texas and Adjacent States

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

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
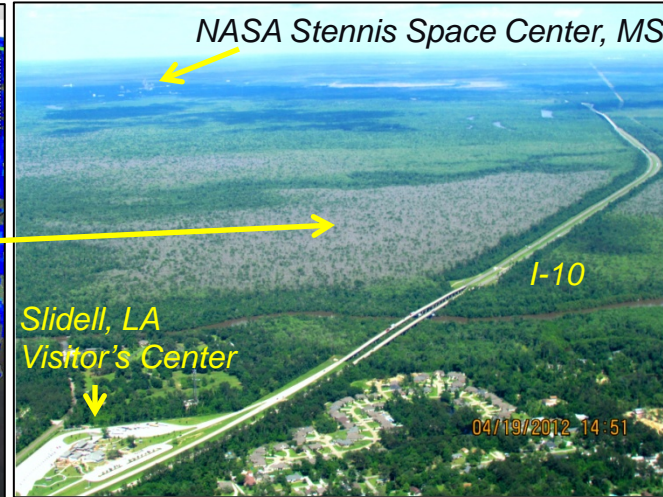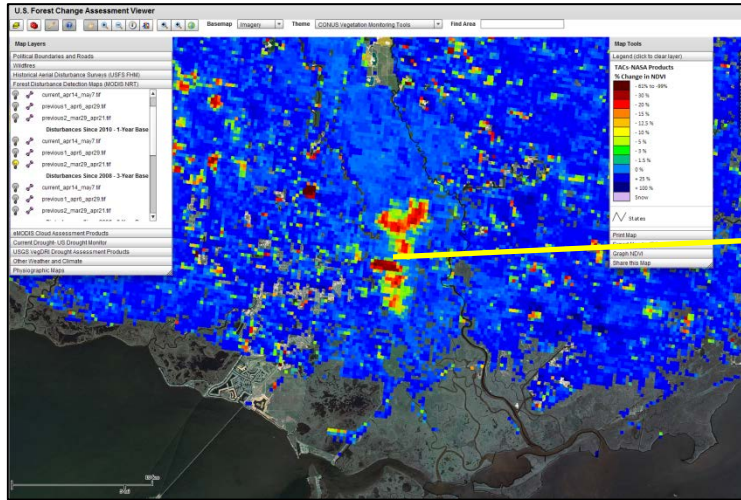

Source: LSU

Source: CSU

Source: USFS

Source: Texas FS

MODIS View of 2012 Wetland Forest Defoliation in Coastal Louisiana

MODIS Forest % NDVI Change Product (Date Ending 4/21 for 2012 versus 2011)

Aerial Oblique Below Acquired by DAF (Days After Initial ForWarn Notification)

NASA Stennis Space Center, MS

Slidell, LA Visitor's Center

I-10

04/19/2012 14:51

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)
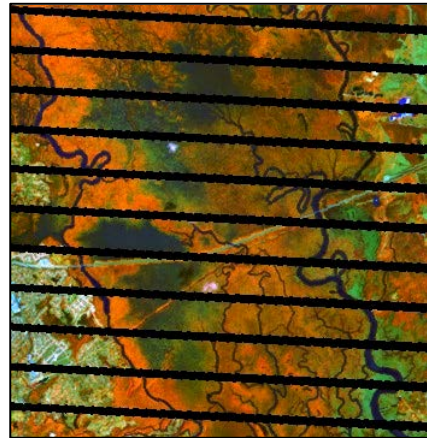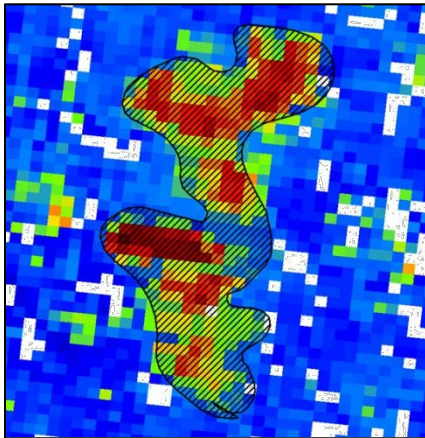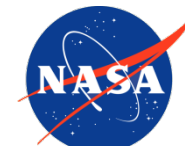

MODIS products showing locations of insect defoliated swamp forests – were used to aid aerial detection surveys by LDAF and the USFS

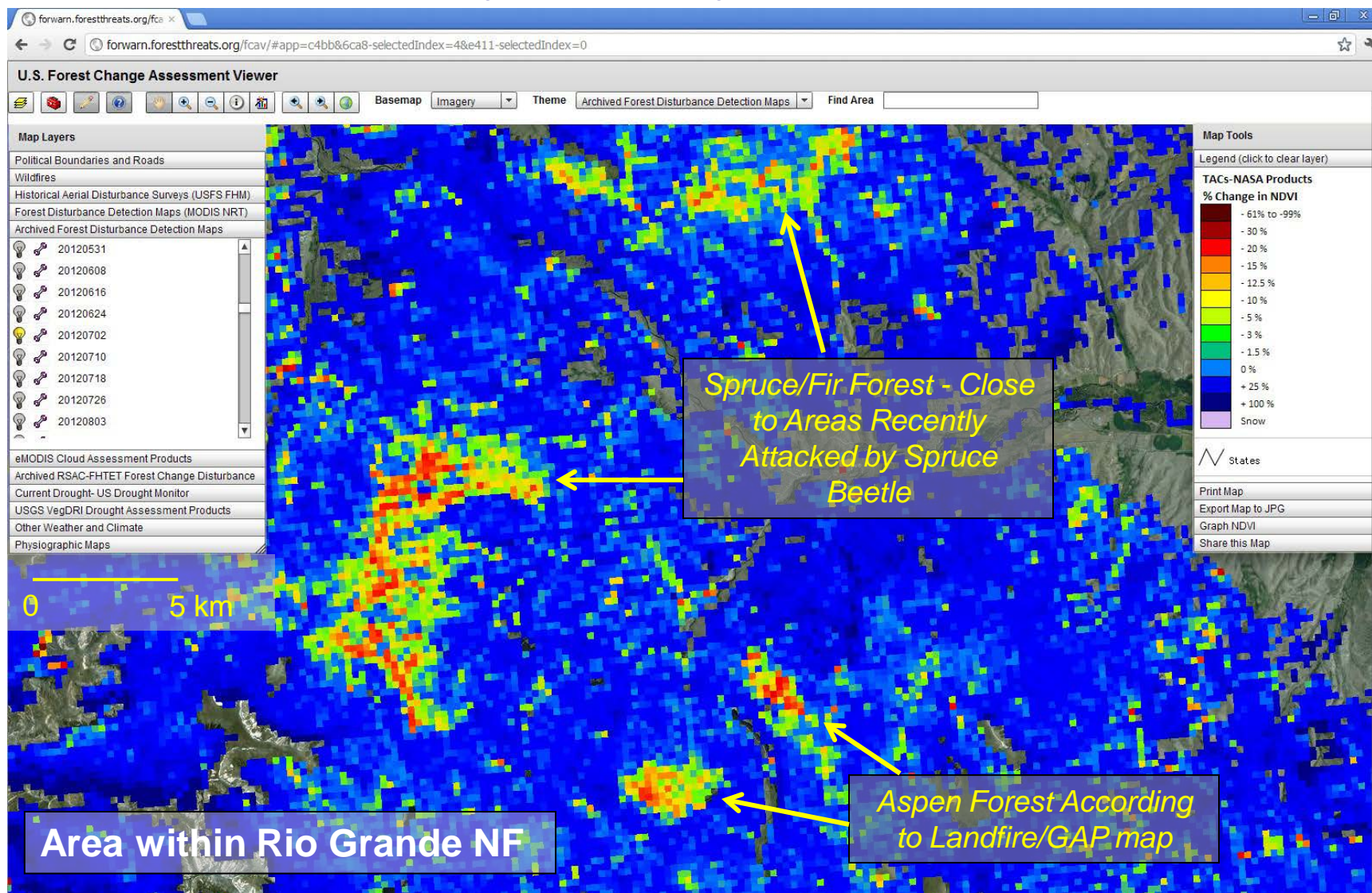*Pearl river, LA photos of forest tent caterpillar and defoliation*

MODIS View of Potential New 2012 Spruce Beetle Mortality in Colorado
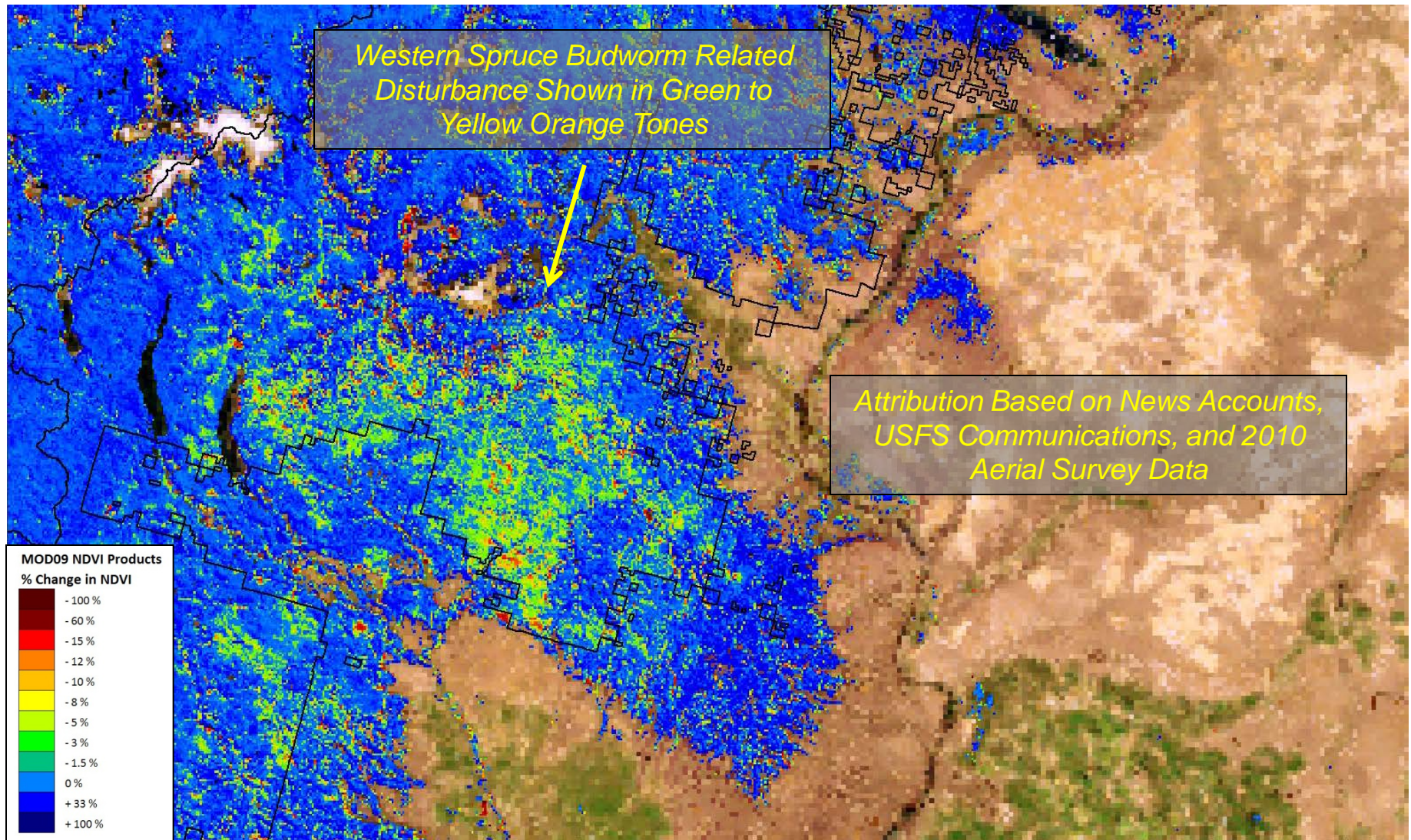
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Forest % NDVI Change for Date Ending July 2 of 2012 versus 2011

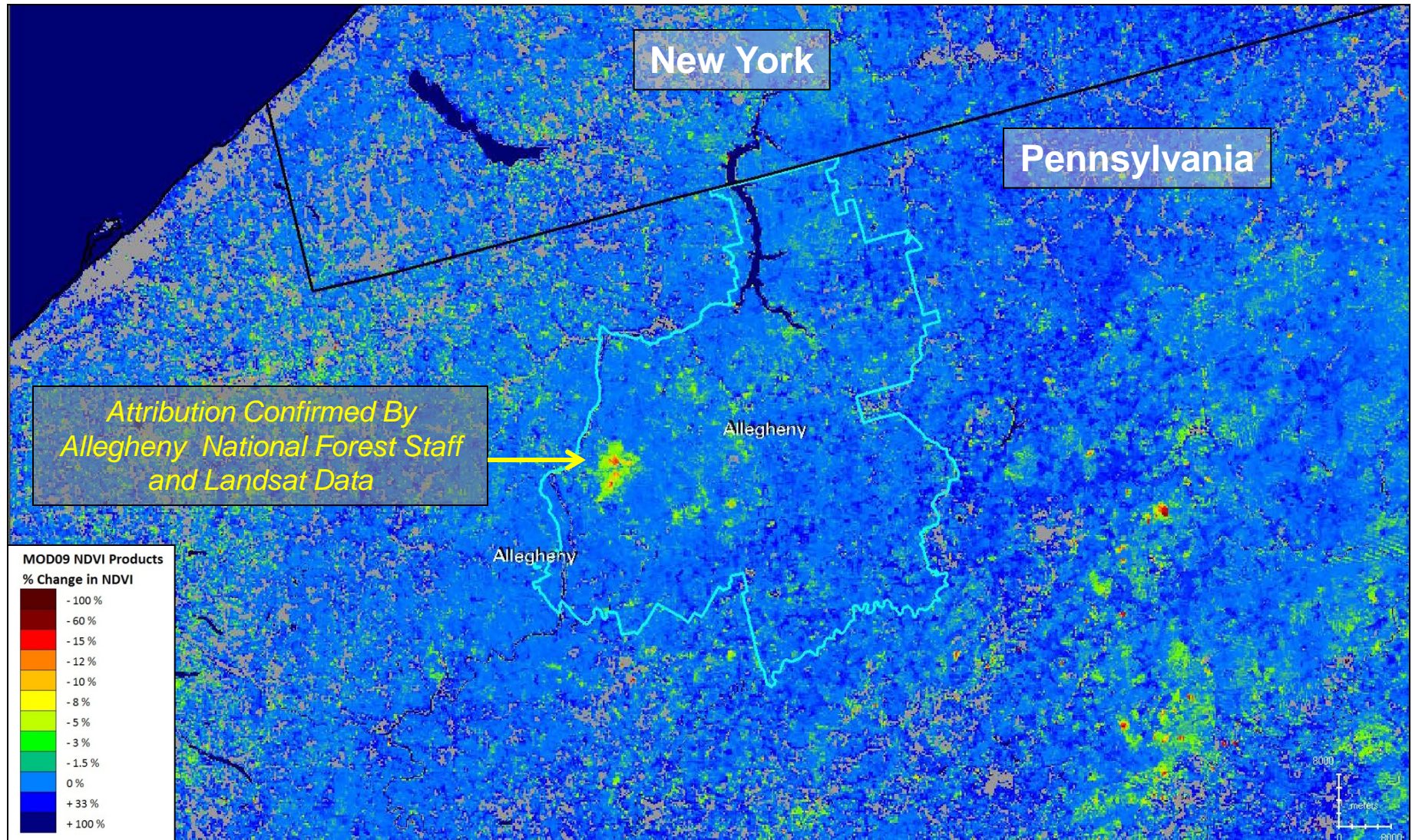# MODIS View of Apparent Spruce Budworm Defoliation in Washington

Stennis Space Center

Forest %NDVI Change for 8/21 through 9/13 of 2011 versus 2008-2010 – National Forests in Black

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 %

MODIS View of Fall Webworm Defoliation in Pennsylvannia

New York

Pennsylvania

Attribution Confirmed By Allegheny National Forest Staff and Landsat Data

Allegheny

Allegheny

MOD09 NDVI Products
% Change in NDVI

- -100 %
- -60 %
- -15 %
- -12 %
- -10 %
- -8 %
- -5 %
- -3 %
- -1.5 %
- 0 %
- +33 %
- +100 %

Comments on Example Results for 2011-2012

- NRT MODIS CONUS forest change products showed multiple regional forest disturbances
  - *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 surveys, fire maps, and Landsat data
- ForWarn disturbance detection results were conveyed to Federal and State forestry specialists for aiding forest health monitoring

Final Remarks

- Since 2010, NRT MODIS % NDVI change products have been produced for the U.S. every 8 days
- These were usually posted on the ForWarn FCAV within 1-2 days after the last collection date
- These products show regionally evident multi-seasonal biotic or abiotic disturbance to both conifer and hardwood forests across the U.S.
- Future work
  - ForWarn FCAV upgrade – new functions and products
  - MODIS change product development, revision, and validation
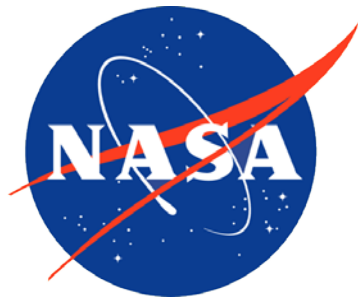- For more information, email joseph.p.spruce@nasa.gov

Project Publications

W.W. Hargrove, J.P. Spruce, G.E. Gasser, and F.M. Hoffman, 2009, Toward a national early warning system for forest disturbances using remotely sensed canopy phenology. Photogrammetric Engineering & Remote Sensing 75:1150-1156.

McKellip, R., D. Prados, R. Ryan, K. Ross, J. Spruce, G. Gasser, and R. Greer, 2008: Remote-sensing time series analysis, a vegetation monitoring tool, NASA Tech Briefs 32(4):63-64.

Ramsey E., J. Spruce, A. Rangoonwala, Y. Suzuoki, J. Smoot, and J. Gasser, and T. Bannister, 2011: Daily MODIS data trends of hurricane-induced forest impact and early recovery, Photogrammetric Engineering and Remote Sensing, 77 (11):133-143.

Spruce, J.P., S. Sader, R. E. Ryan, J. Smoot, P. Kuper, K. Ross, D. Prados, J. Russell, G. Gasser, R. McKellip, and W. Hargrove, 2011, Assessment of MODIS NDVI time series data products for detecting forest defoliation from gypsy moth outbreaks, Remote Sensing of Environment, 115:427–437.