ForWarn: Detecting Forest Disturbance from Satellite in Near-Real-Time

William W. Hargrove, Joseph P. Spruce, Steven P. Norman, William M. Christie, Jitendra Kumar, and Forrest M. Hoffman

EFETAC, USDA Forest Service, CSC, NASA Stennis, EFETAC, USDA Forest Service, EFETAC, USDA Forest Service, Oak Ridge National Laboratory, and Oak Ridge National Laboratory

**A national-scale near real-time "eye-in-the-sky" satellite-based recognition
and tracking system for forest disturbances**

ForWarn covers the entire lower 48 United States

Generates new potential disturbance maps every 8 days,
even throughout the winter

Detects all types of forest disturbances

231 meter resolution map cells

ForWarn is the result of an ongoing, substantive cooperation among
four different government agencies
USDA, NASA, USGS, and DOE
(Forest Service, Stennis Space Center, EROS Data Center,
and Oak Ridge National Laboratory, respectively)

News Releases from the Southern Research Station

March 19, 2012
Perdita B. Spriggs
828-230-3292
pspriggs@fs.fed.us

USDA Forest Service and NASA release Web-based forest disturbance monitoring tool

Asheville, NC -- The USDA Forest Service's Eastern Forest and Western Wildland Environmental Threat Assessment Centers recently unveiled a product that helps natural resource managers rapidly detect, identify, and respond to unexpected changes in the nation's forests by using web-based tools. ForWarn, a satellite-based monitoring and assessment tool, recognizes and tracks potential forest disturbances caused by insects, diseases, wildfires, extreme weather, or other natural or human-caused events. The tool complements and focuses efforts of existing forest monitoring programs and potentially results in time and cost savings.

The prototype version of **ForWarn** has successfully operated since January 2010 and uses NASA MODIS (Moderate Resolution Imaging Spectroradiometer) satellite imagery to recognize and track changes in vegetation across the nation, providing a near-real-time view of potential forest disturbance and recovery. ForWarn uses a web-based map tool, the Forest Change Assessment Viewer, to provide an 8-day coast-to-coast snapshot of the US landscape, interpret images, and create geographically relevant maps. The viewer allows users to explore and share recent and archived forest disturbance maps.

"ForWarn epitomizes the type of product envisioned when the Threat Assessment Centers were created," says Danny C. Lee, Director of the Eastern Threat Center. "This tool literally puts space-age technology into the hands of forest resource professionals. It's a remarkable collaborative achievement." The Eastern and Western Threat Centers are jointly supported by the Forest Service's National Forest System, State and Private Forestry, and Research and Development.

ForWarn Official Forest Service/NASA Unveiling and Roll-Out, March 19, 2012, but *ForWarn* has been operating since January 2010

ForWarn
Satellite-Based Change Recognition and Tracking

U.S. Forest Service · NASA · USGS · Oak Ridge National Laboratory

Home | Overview | News | Highlights | Data | Support

ForWarn team wins award for excellence in Science Delivery
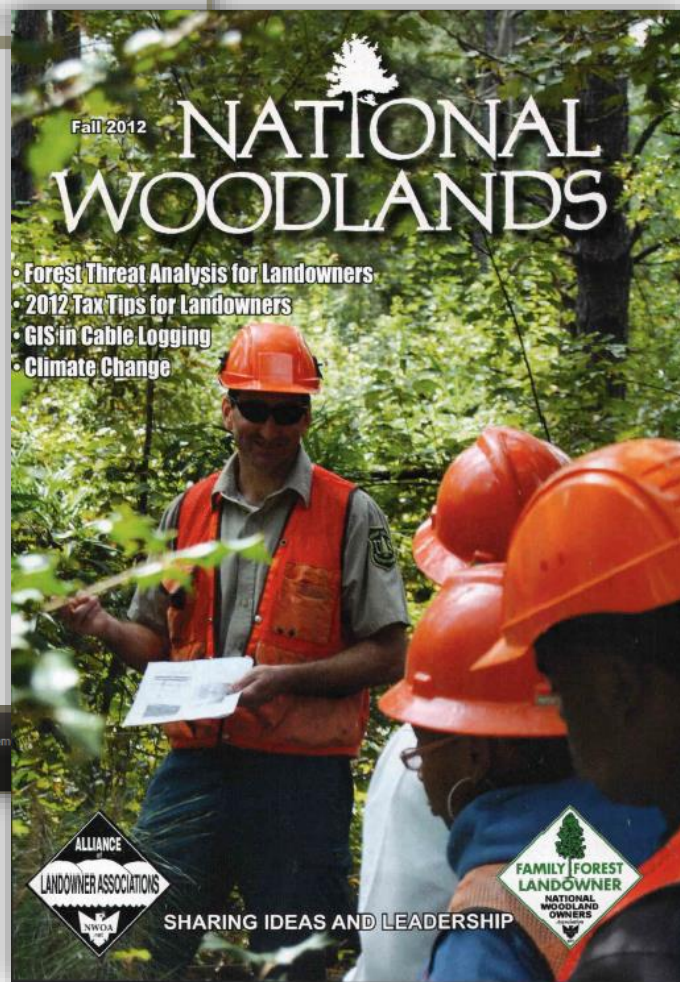
FRI, 12/07/2012 - 14:40 -- CADOUGHE

In October 2012, the 16-person ForWarn Team, which includes employees of four different U.S. Government Agencies (USDA Forest Service, NASA Stennis Space Center, US Geological Survey EROS, and DOE Oak Ridge National Laboratory), were selected by Dr. Rob Doudrick, Station Director at USDA Forest Service Southern Research Station, to receive the **2012 Southern Research Station Director's Award for Excellence in Science Delivery**. The honor was given "for exceptional creativity and performance in development and deployment of the ForWarn Forest Disturbance Monitoring Tool."

ForWarn team wins Interagency Partnership Award

FRI, 12/07/2012 - 14:41 -- CADOUGHE

The ForWarn team, on behalf of the USDA Forest Service, Stennis Space Center, Oak Ridge National Laboratory, and the US Geological Survey, has been chosen as the 2013 recipient of the **Federal Laboratory Consortium for Technology Transfer's (FLC) Interagency Partnership Award**. This award—one of the FLC's highest honors—recognizes the efforts of laboratory employees from at least two different agencies who have collaboratively accomplished outstanding work in the process of transferring a technology.

In recognition of their hard work and dedication in promoting technology transfer, the team will be honored at the 2013 FLC Awards program on Thursday, April 25, 2013 in Westminster, Colorado.

USDA Forest Service   EFETAC   WWETAC   Policies and Links   Privacy Policy   Accessibility Statement   FOIA   Non-discrimination Statement
White House   usa.gov

Fall 2012
NATIONAL WOODLANDS

- Forest Threat Analysis for Landowners
- 2012 Tax Tips for Landowners
- GIS in Cable Logging
- Climate Change

ALLIANCE LANDOWNER ASSOCIATIONS · NWOA

FAMILY FOREST LANDOWNER · NATIONAL WOODLAND OWNERS

SHARING IDEAS AND LEADERSHIP

The Forest Change Assessment Viewer is the main delivery vehicle for output from ForWarn

Developed by the University of North Carolina Asheville National Environmental Modeling and Analysis Center (NEMAC)

- **The Assessment Viewer is totally open to anyone, no userid, no password is required**
- **Runs on almost any computer using any browser; nothing is downloaded**
- **Intuitive and easy to use, similar to the Google Maps interface**
- **Shows the three most-recent national ForWarn disturbance maps, as well as all historical ForWarn products since Jan 2010**
- **Shows other relevant maps in the same spatial context**
- **Assess likely causes of potential disturbances based on past disturbance history using a "weight-of-evidence" approach**

Resource managers (and anyone else!) can see the newest national disturbance maps at the same time the Threat Centers do

How Does *ForWarn* Work?

Based on a Simple Comparison between historical and current greenness

We find potential disturbance by comparing current greenness with the "normal," historically observed greenness that would be expected for healthy, undisturbed vegetation growing at this location during this time

- We develop this expected greenness from the 11-year historical MODIS satellite record
- Locations that are currently less-green than we expect are marked as potentially disturbed
- Locations having more actual greenness than we expected may represent vigorous or recovering vegetation, and will become the new expected value for next year

Only forested areas are shown, but *ForWarn* detects disturbances in all vegetation, including agricultural crops and rangeland forage

Compare actual greenness as a percentage of expected greenness

- Less than 100% of expected greenness = Potential Disturbances -- shown as Greens, Yellows, and Reds
- Greater than 100% of expected greenness = Vegetation Recovery -- shown as Blues

TACs-NASA Products

% Change in NDVI

	- 61% to -99%
	- 30 %
	- 20 %
	- 15 %
	- 12.5 %
	- 10 %
	- 5 %
	- 3 %
	- 1.5 %
	0 %
	+ 25 %
	+ 100 %
	Snow
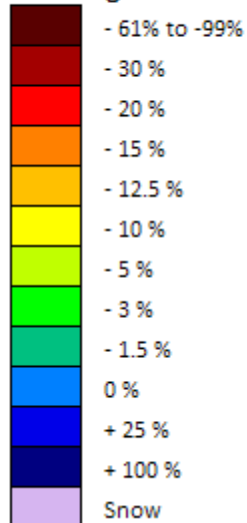
Age of Disturbances and Length of Reference Baselines

We are producing 3 slightly different national disturbance maps at every 8-day interval

Differences relate to the age of the disturbances that are mapped

Three reference baselines of different length historical periods are used to calculate the normal, expected NDVI values:

- A short-term history baseline (the prior year only) shows only recent disturbances
- A mid-term history baseline (the previous 3 years) shows intermediate-age disturbances
- A long-term history baseline (the entire available baseline period) shows all disturbances since MODIS

ForWarn: May 23, 2012
Change since 2011

Twin tornado tracks
from March 2, 2012

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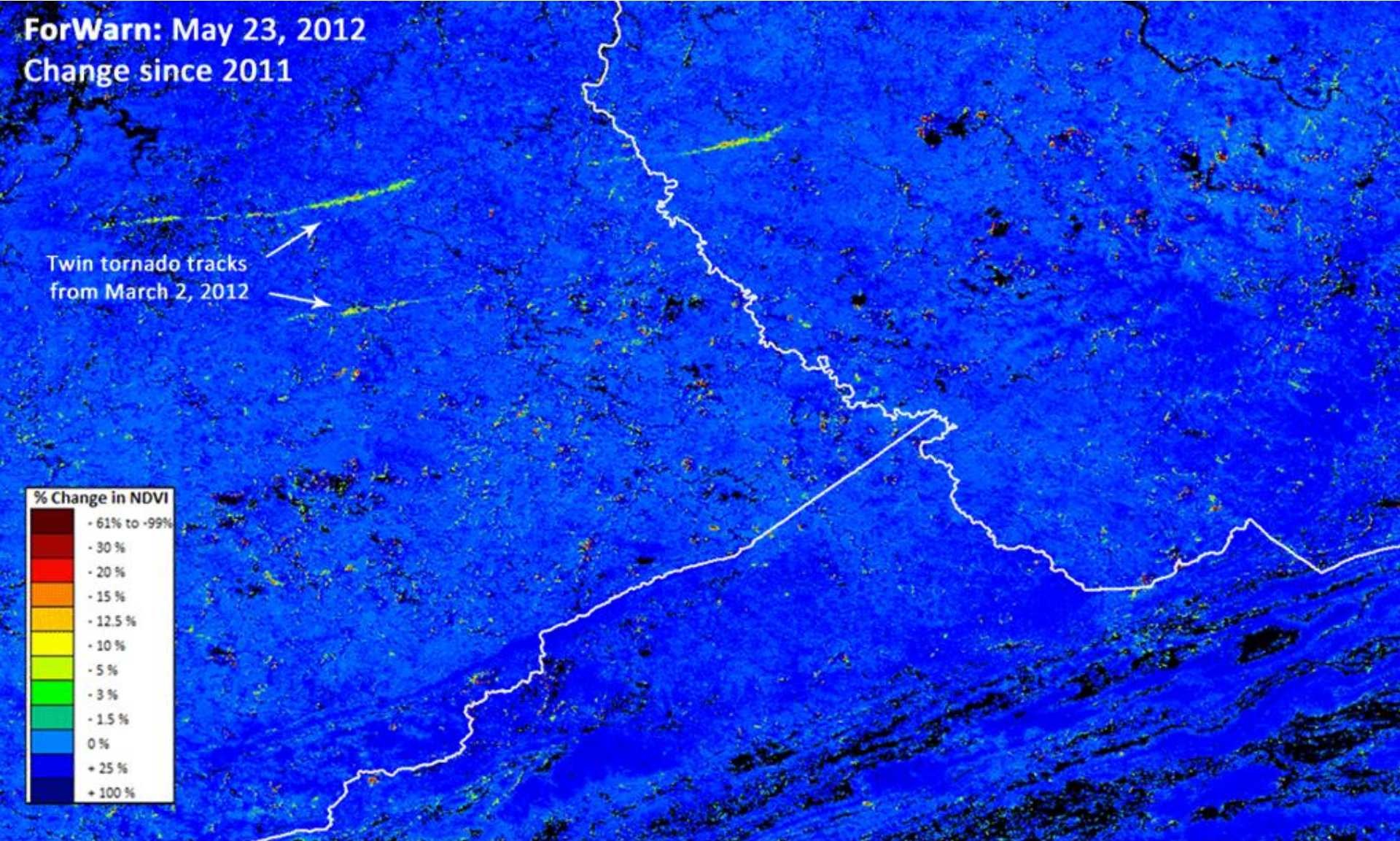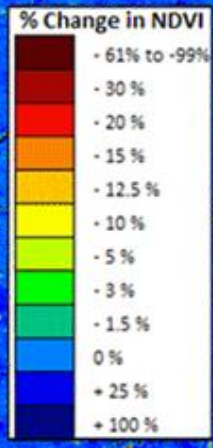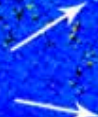
ForWarn: May 23, 2012
Change since 2000

Twin tornado tracks
from March 2, 2012

WV

KY

Strip
mining

VA

% Change in NDVI
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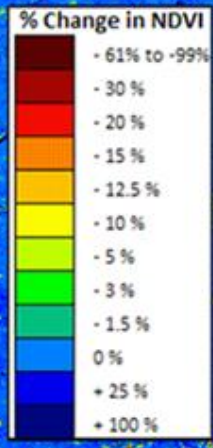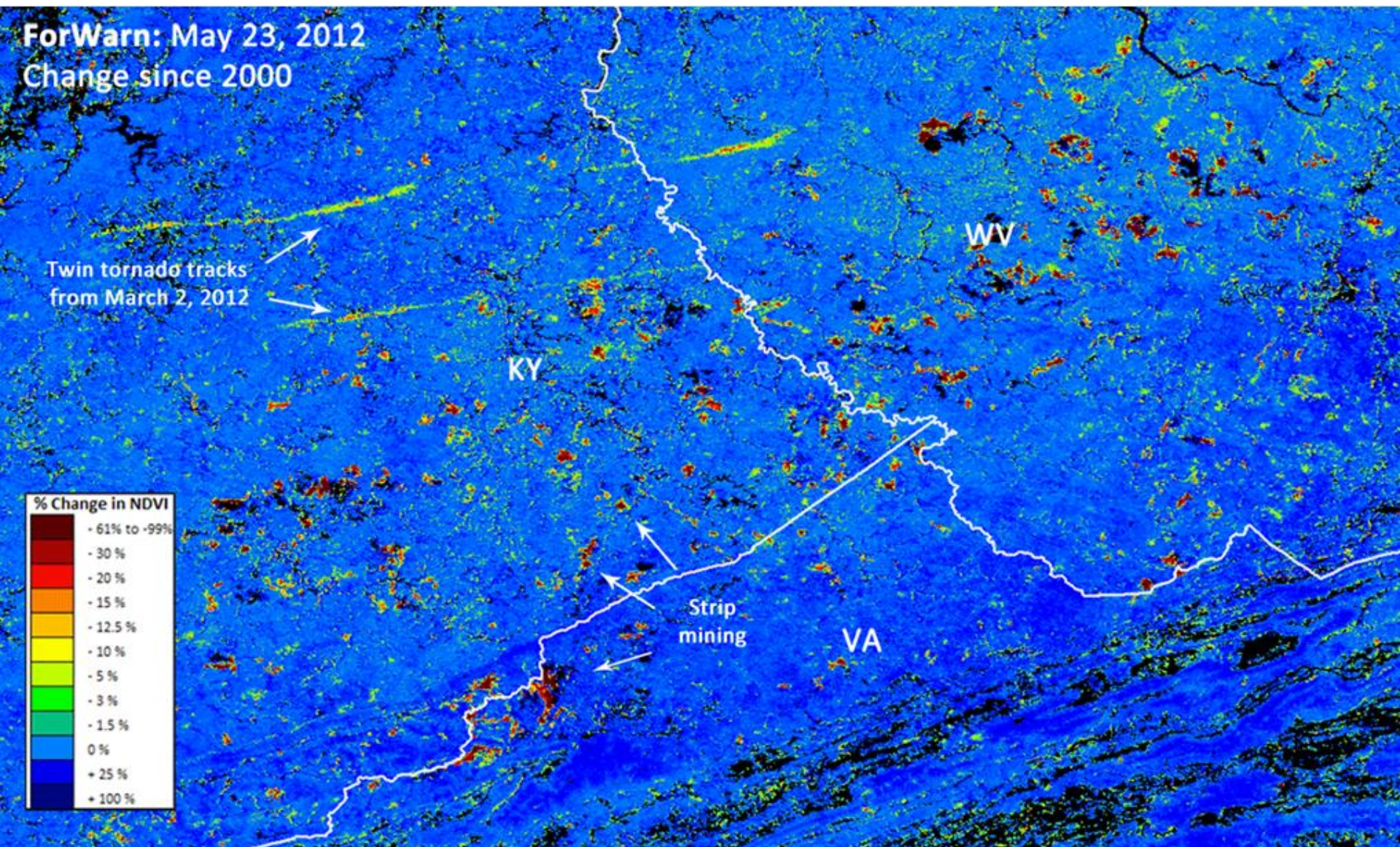
Examples of forest disturbance, or recovery,
seen in the *ForWarn* forest change images

Natural disturbances causing a decline in NDVI value

Tornados and hurricane events

Wind, hail and ice storm damage

Drought and flood conditions

Insect and disease outbreaks

Fall season brown-up

Snow pack extent

Wildfire events

Human-Induced disturbances causing a decline in NDVI value

Forest fragmentation, conversion and urban sprawl

Forest clear-cutting and stand thinning

Mining, oil and natural gas activities

Non-native plant species invasions

Climate variability and change

Prescribed fire

Arson wildfire

Events that can increase NDVI values

Vegetative recovery from disturbance

Non-native plant species invasions

Precipitation events in arid locales

Forest canopy closure

Forest plantings

Spring leaf-out

Forest disturbance events often display degrees of severity.
Variation in rates of recovery can relate to ecological, or vegetative resilience.
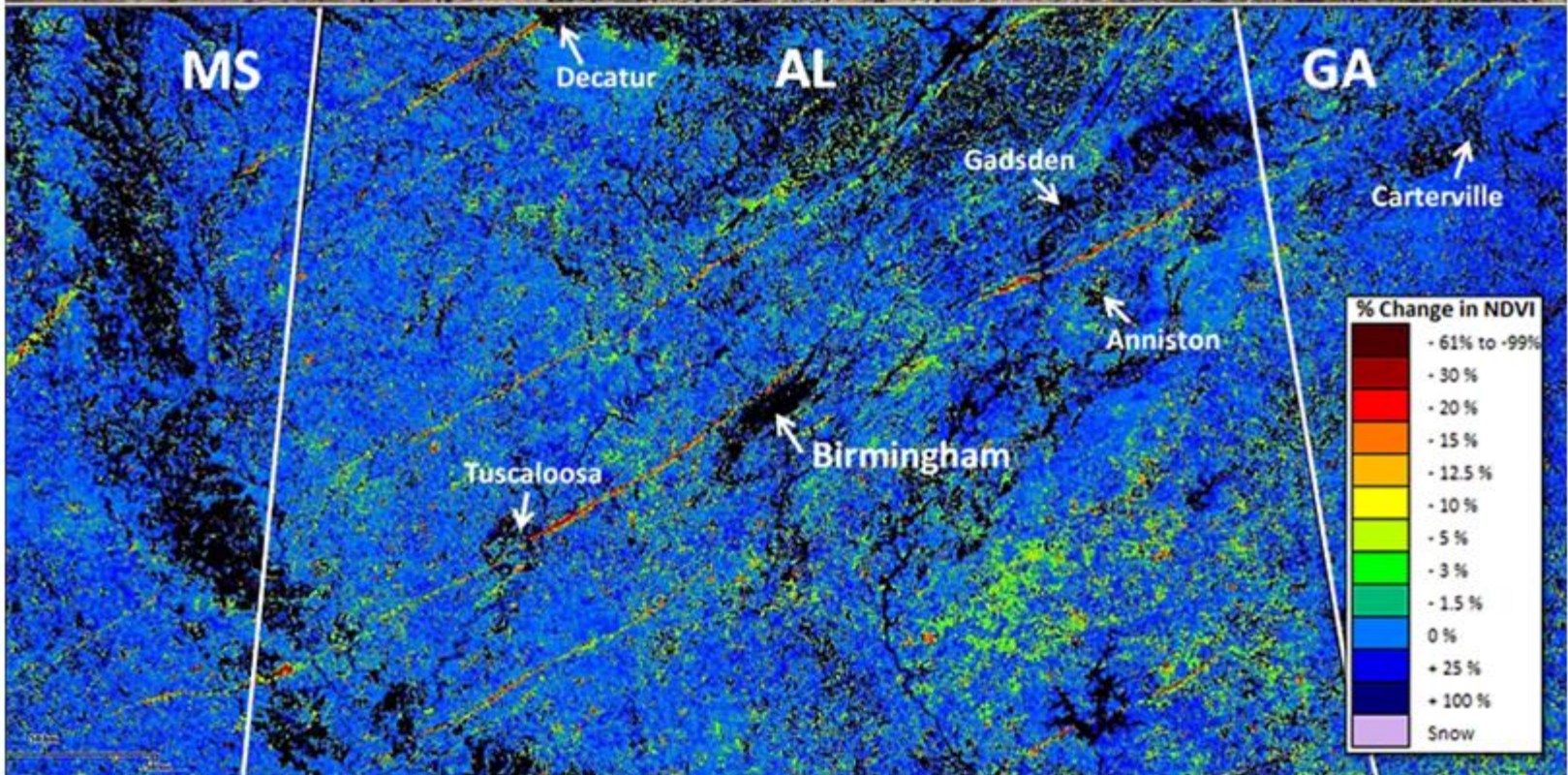
ForWarn image from June 1 (bottom), black areas are non-forest, such as agriculture or urban areas.
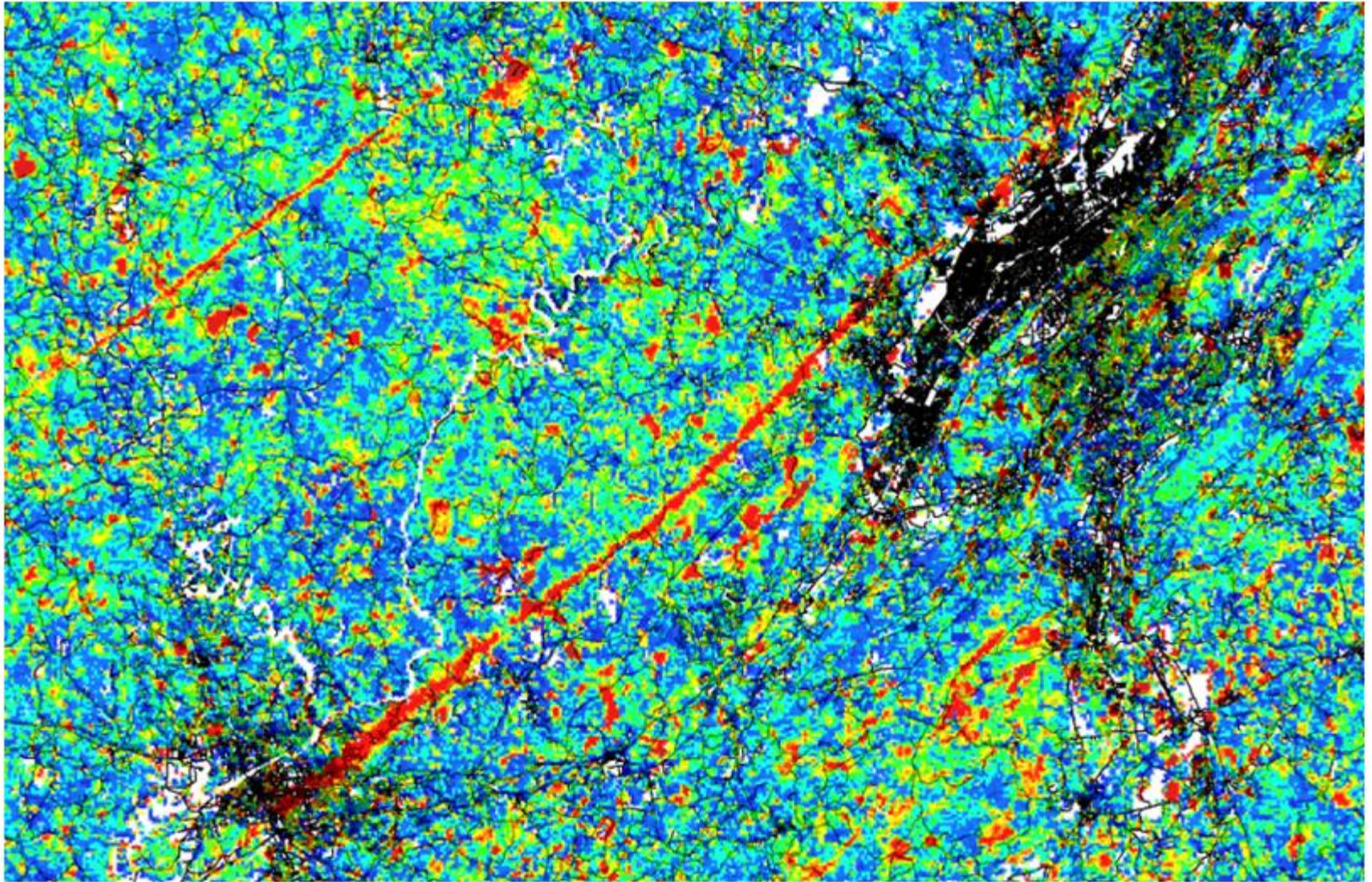
April 27, 2011 Tornadoes Through Northern MS and AL
Track through Tuscaloosa/Birmingham, AL on May 24, 2011

May 1 – May 24, 2011
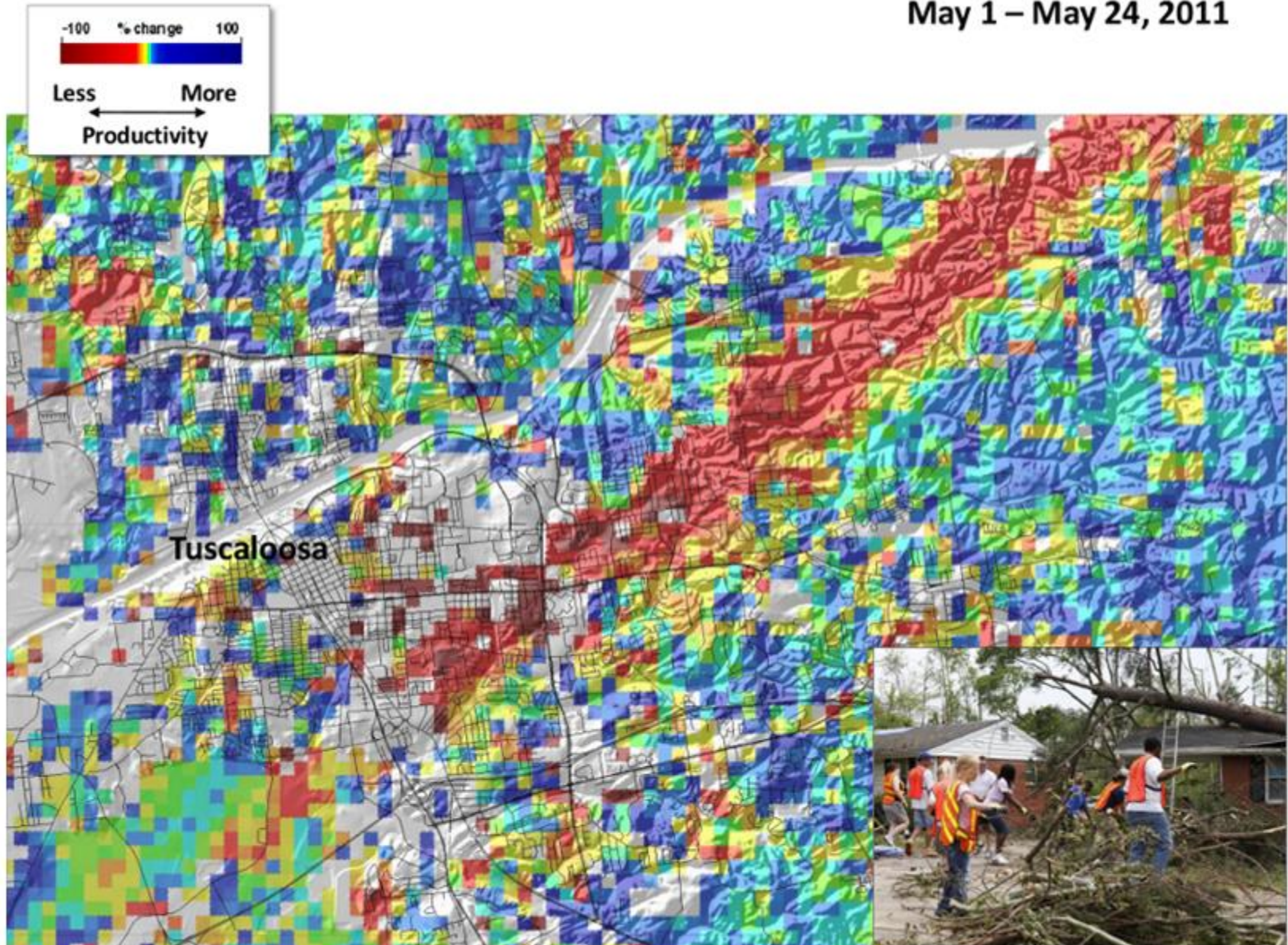
*ForWarn* damage from Tornado track through Tuscaloosa, AL, USA, May 24
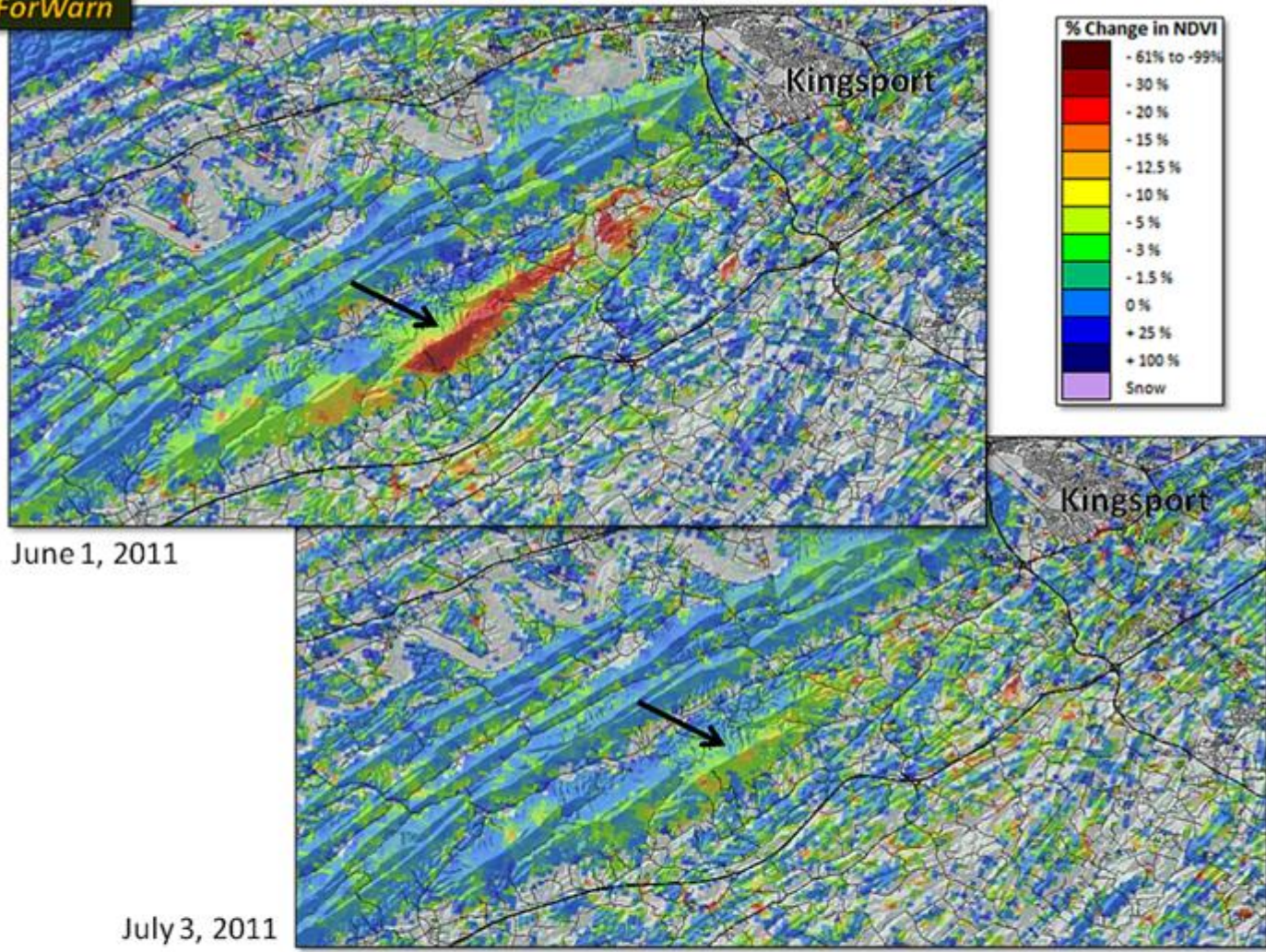
One month after the April 2011 tornado outbreak (top), *ForWarn* mapped a localized linear windstorm event on a ridgeline forest southwest of Kingsport, TN. Two months later (bottom), the vegetation had almost completely recovered. Regular observations are needed to spot such ephemeral forest damage.
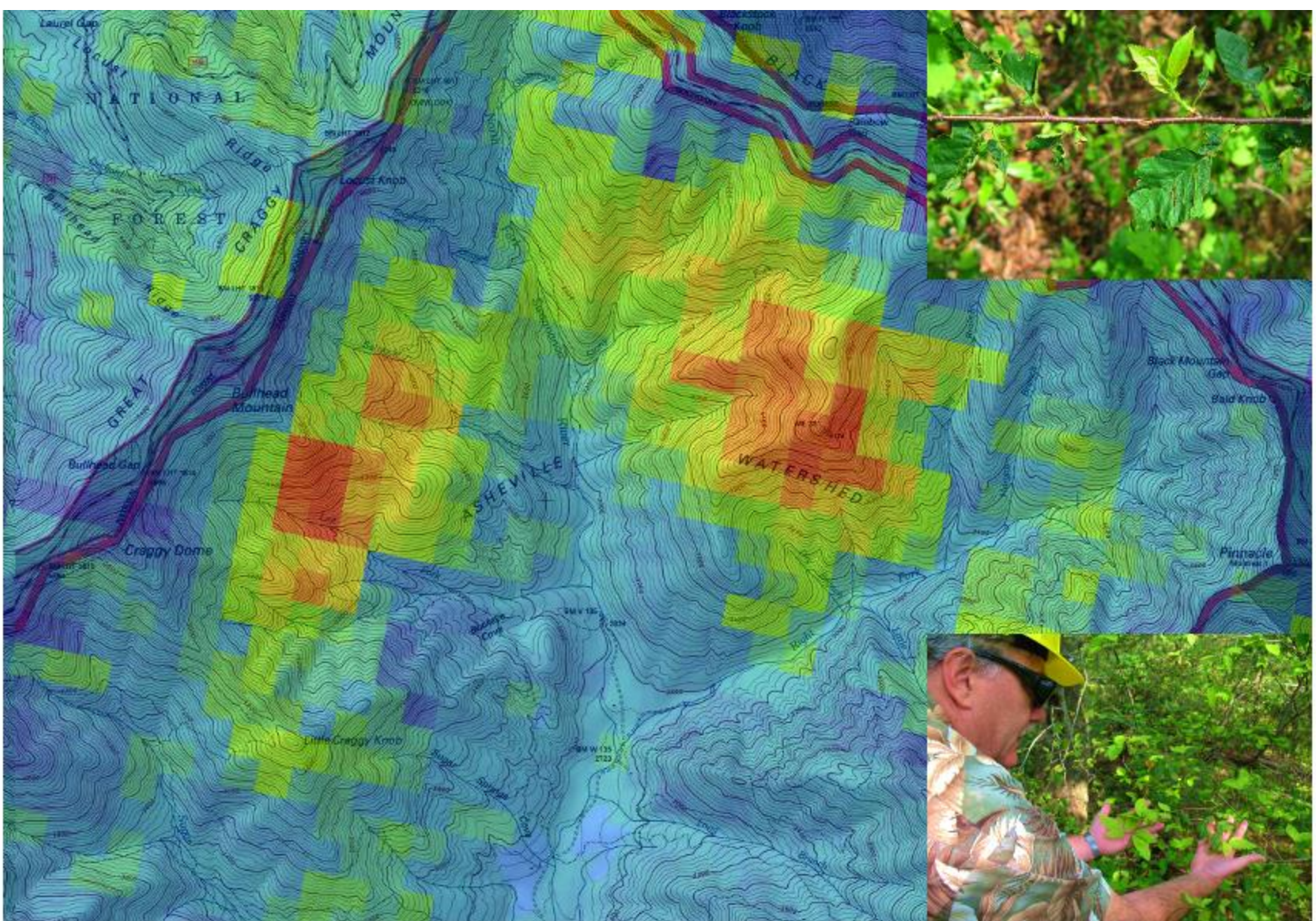
In June 2012, *ForWarn* detected a disturbance within the Asheville Watershed, from which the city of Asheville gets all of its drinking water. Visiting there with the AVL Municipal Water managers, we found evidence of a severe-but-localized hail storm, which had shredded leaves and left scars on the upper sides of branches.
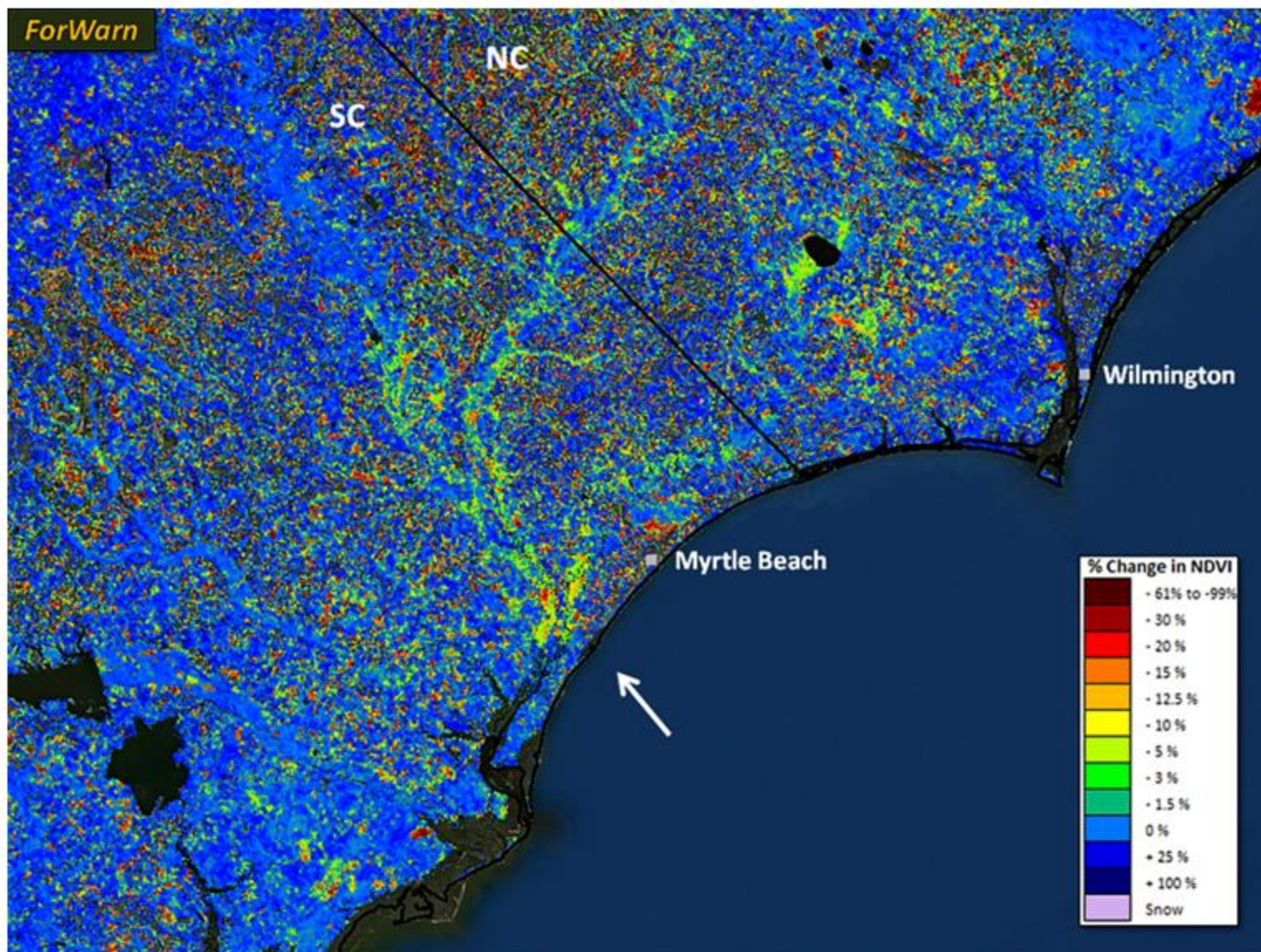
Not the result of flooding during a low-flow period, these riparian disturbances were caused by forest tent caterpillar defoliation, confirmed by ADS.
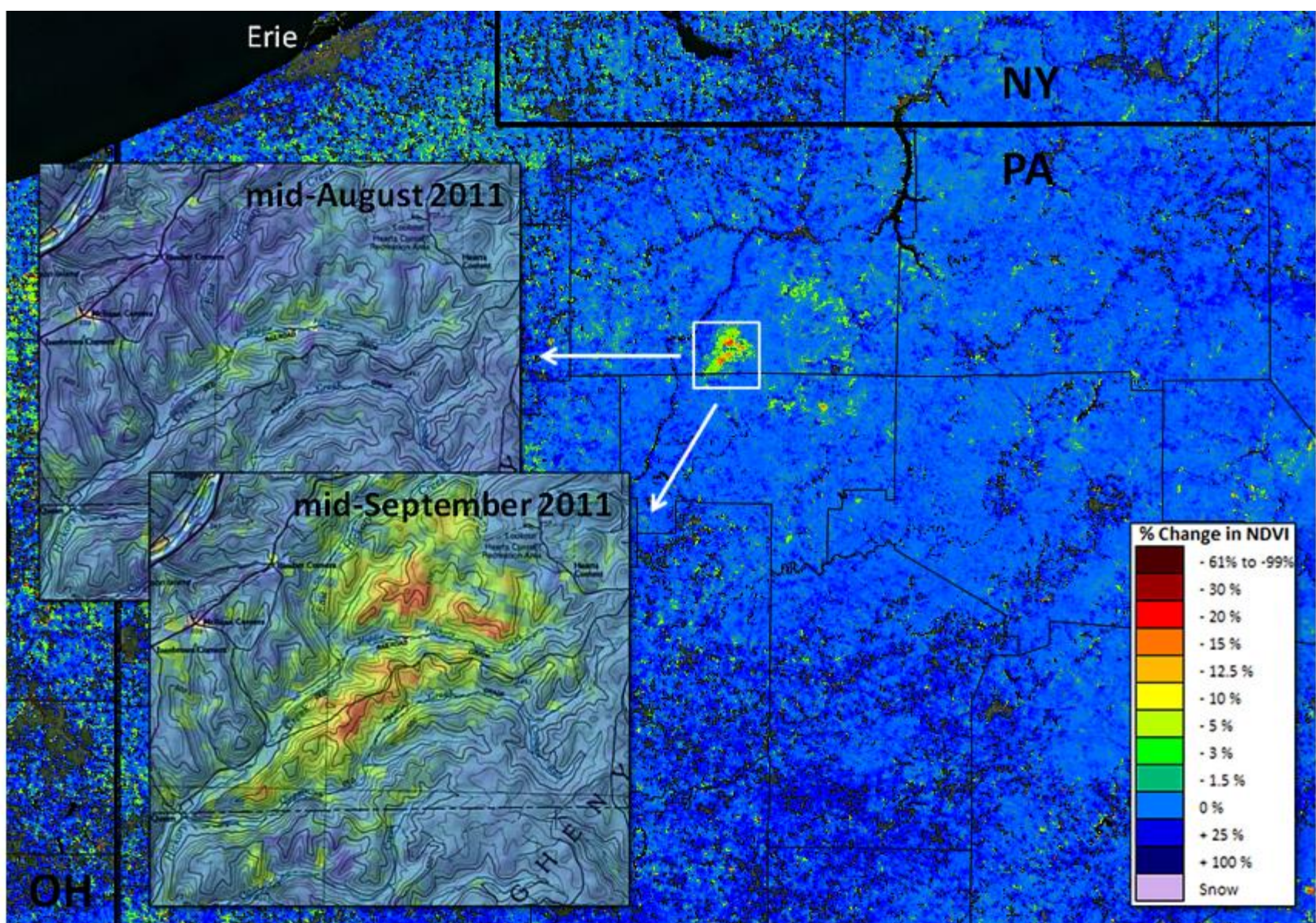
04/19/2012 14:51

Aerial photo verifying FTC defoliation near the Pearl River, Louisiana detected by *ForWarn* **in mid-April, 2012.**
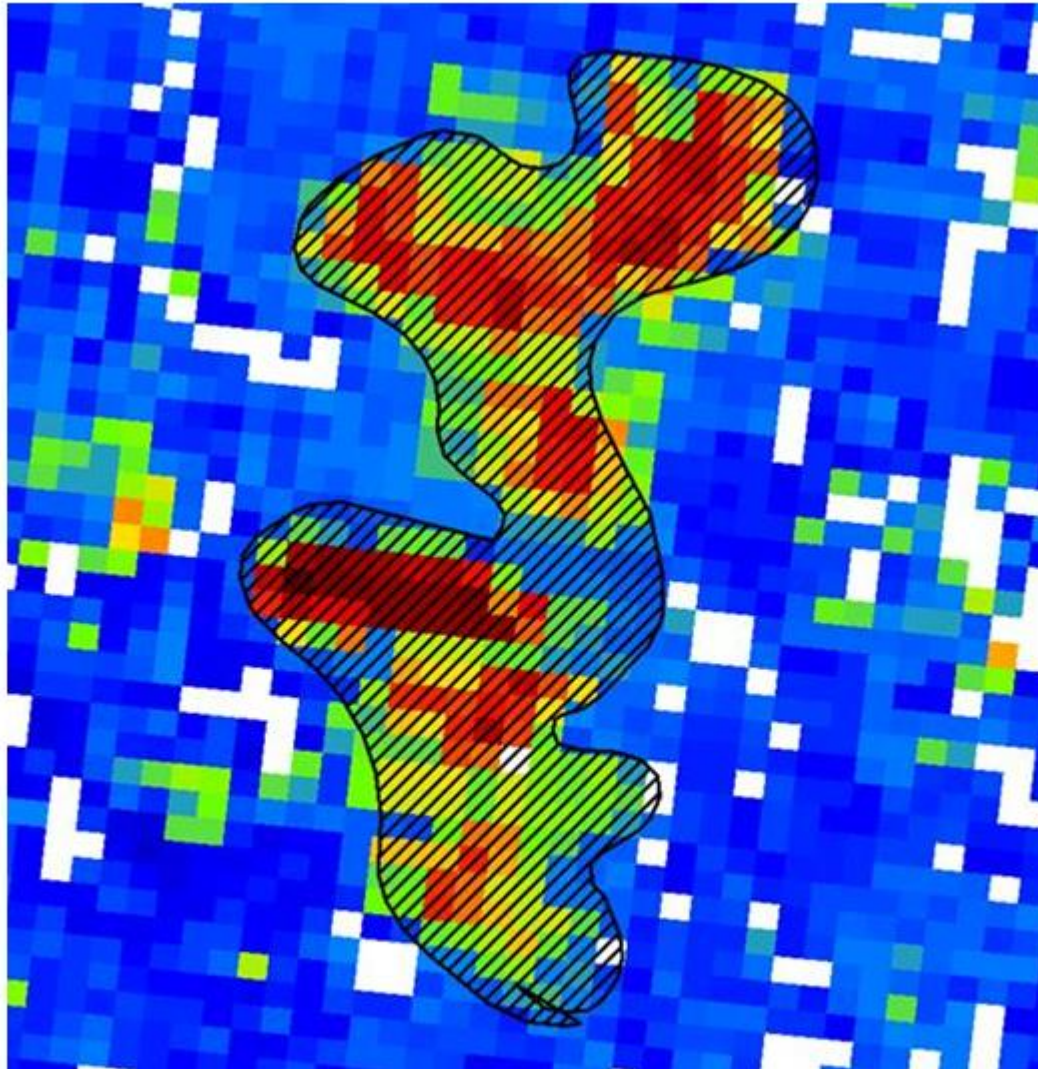
Louisiana Department of Agriculture and Forestry flown GPS polygon matching FTC defoliation detected by *ForWarn* in mid-April, 2012.
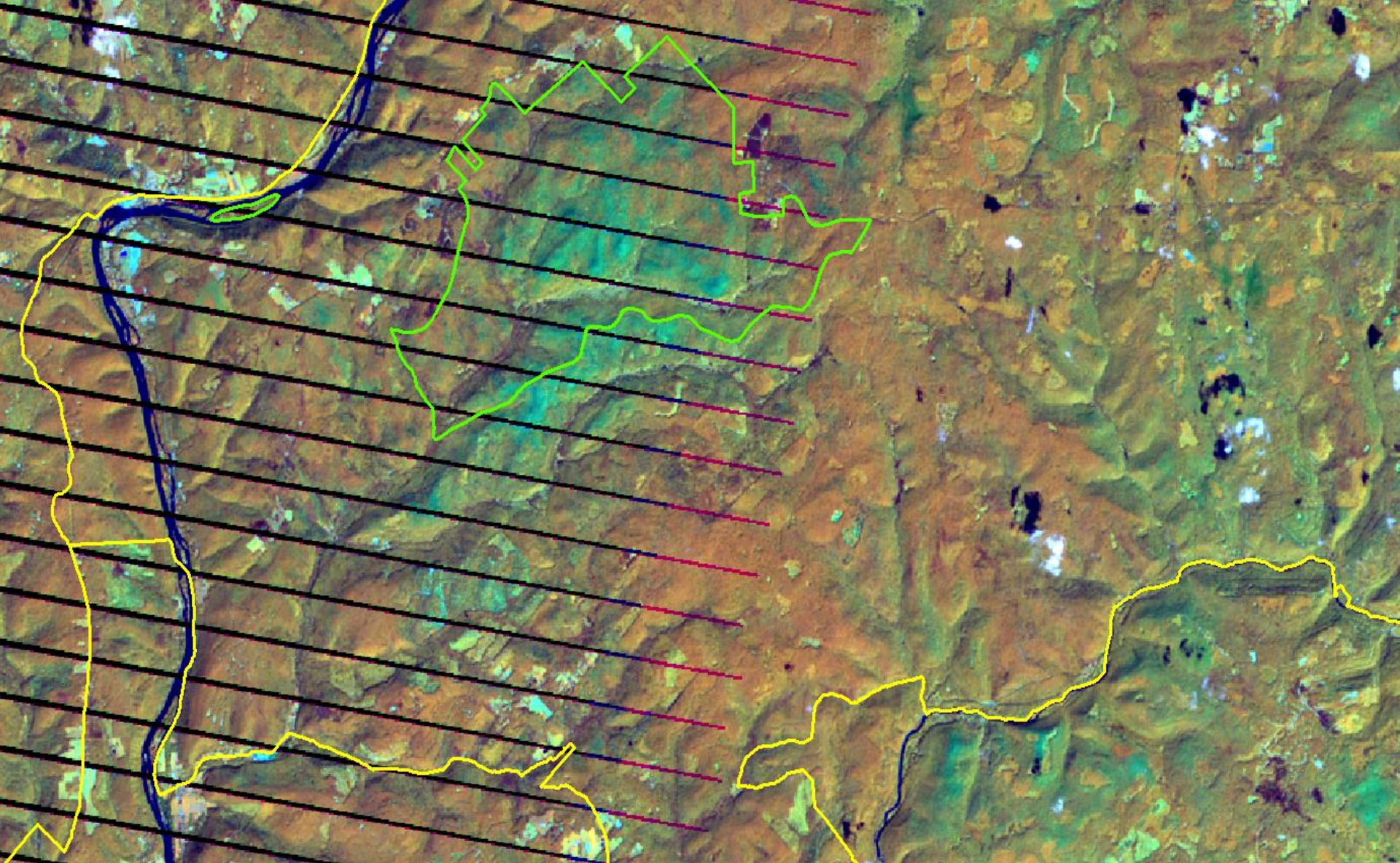
Fall webworms in the Hickory Creek Wilderness Area. Minimal indications of defoliation in mid-August, 2011, but clear patterns by mid-September, until leaf loss. In 2012, this area experienced an even more severe and widespread outbreak of fall webworms, detected by *ForWarn*.

TACs-NASA Products
% Change in NDVI

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- 12.5 %
- 10 %
- 5 %
- 3 %
- 1.5 %
0 %
+ 25 %
+ 100 %
Snow

Area of vegetative recovery from forest disturbance pre-2010
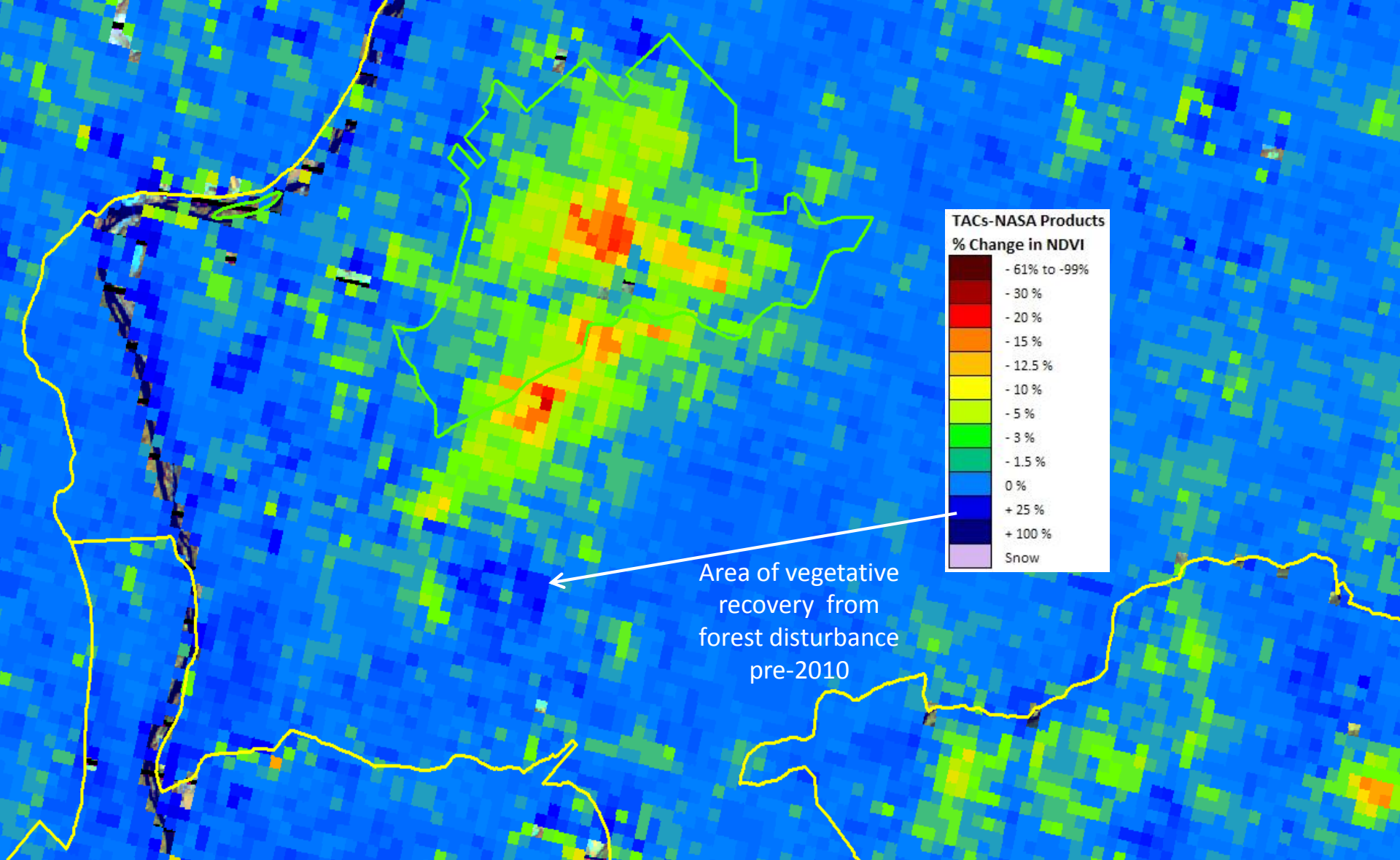
Allegheny National Forest
Hickory Creek Wilderness area
Forest Change Assessment Viewer (FCAV)
09/13/2011 1-yr baseline

Allegheny National Forest
Hickory Creek Wilderness area
Landsat 7TM on **09/13/2011** , 453 RGB

ForWarn

forwarn.forestthreats.org

May 24

Jun 25

Jul 27

Aug 28

Sep 29

Oct 31

% Change in NDVI

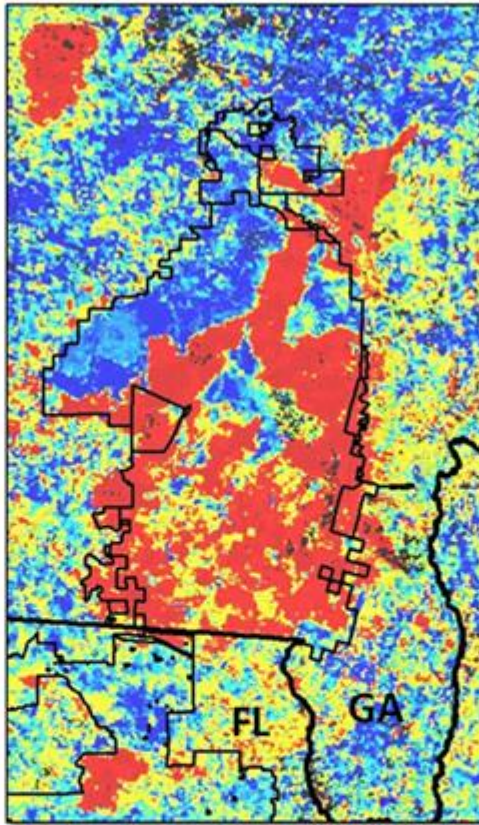Snow | +100 % | +25 % | 0 % | -1.5 % | -3 % | -5 % | -10 % | -12.5 % | -15 % | -20 % | -30 % | -61% to -99%
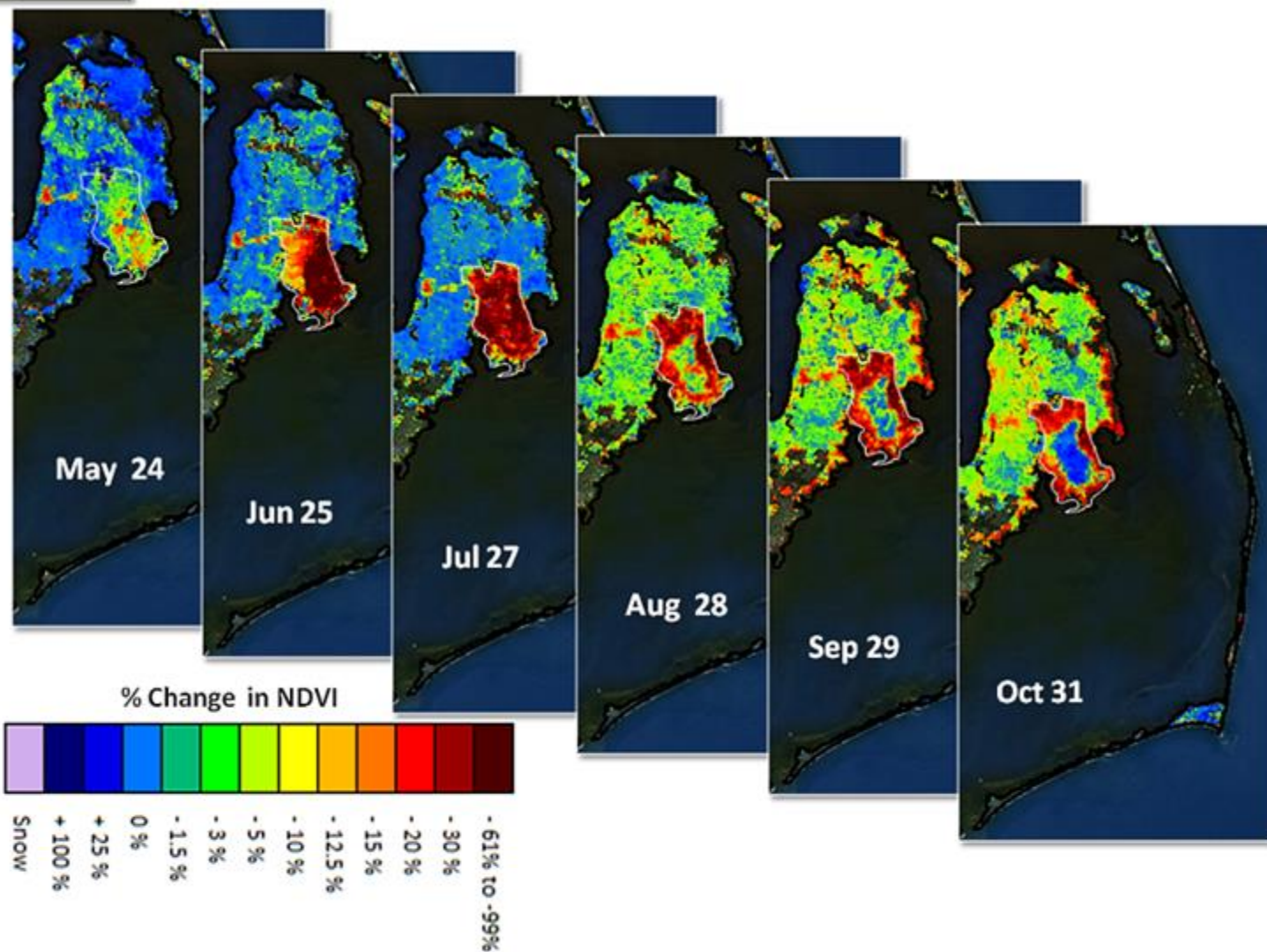
The center of the Pains Bay fire burned lightly, with low severity, allowing amazingly rapid recovery of herbs, ferns, and sprouting woody species by August. But an outer ring of the burn scar shows a longer lasting departure from prior years.
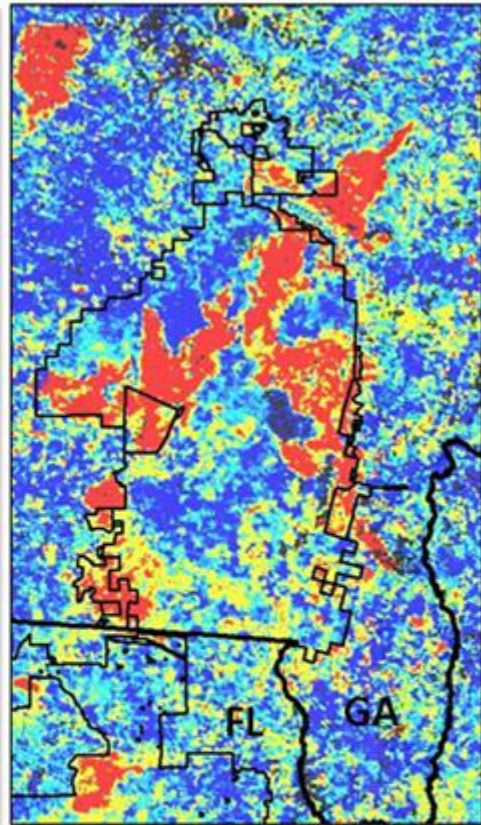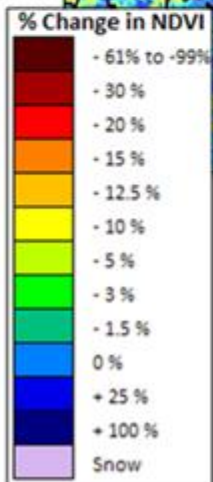
% Change in NDVI

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Snow
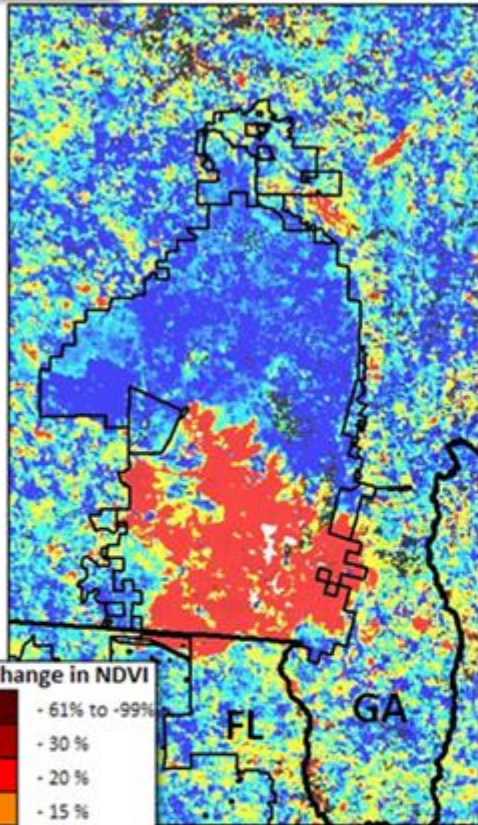
June 17, 2011   July 19, 2011   August 20, 2011

FL   GA

The *ForWarn* System is:

Not Measuring Disturbance in a Strict Sense,
but instead Departure from Normal Phenological Timing

Not just detecting insects, diseases, invasives, storms, wildfire

Also detecting weather departures caused by precipitation and temperature
deviations: extremes of hot and cold, or wet and dry periods

ForWarn has proven to be sensitive to drought, warm/cold periods, shifts in timing of
leaf greenup and senescence
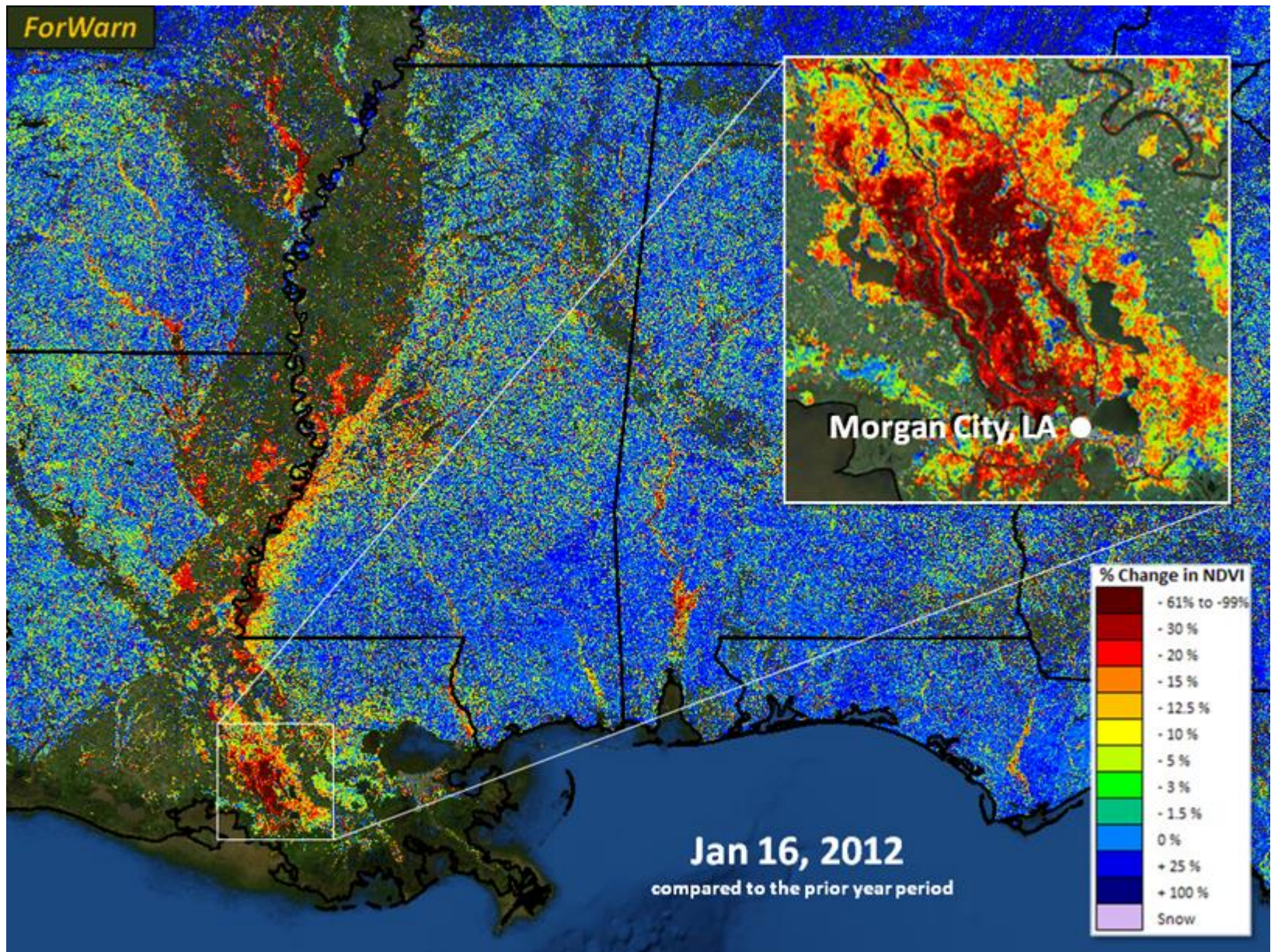
The Atchafalaya basin's forests thrive with seasonal flooding, yet high water is normally a spring phenomenon there. During the past month, unusually high water levels have inundated wetlands and forests along and near the Mississippi River basin. From space, floodwaters appear to decrease existing vegetation, as water masks low lying plant cover. According to the USGS, river discharge at Morgan City, Louisiana was 145,000 ft3/sec on January 16, 2012 compared to 84,000 ft3/sec the prior year. (See http://waterdata.usgs.gov.)
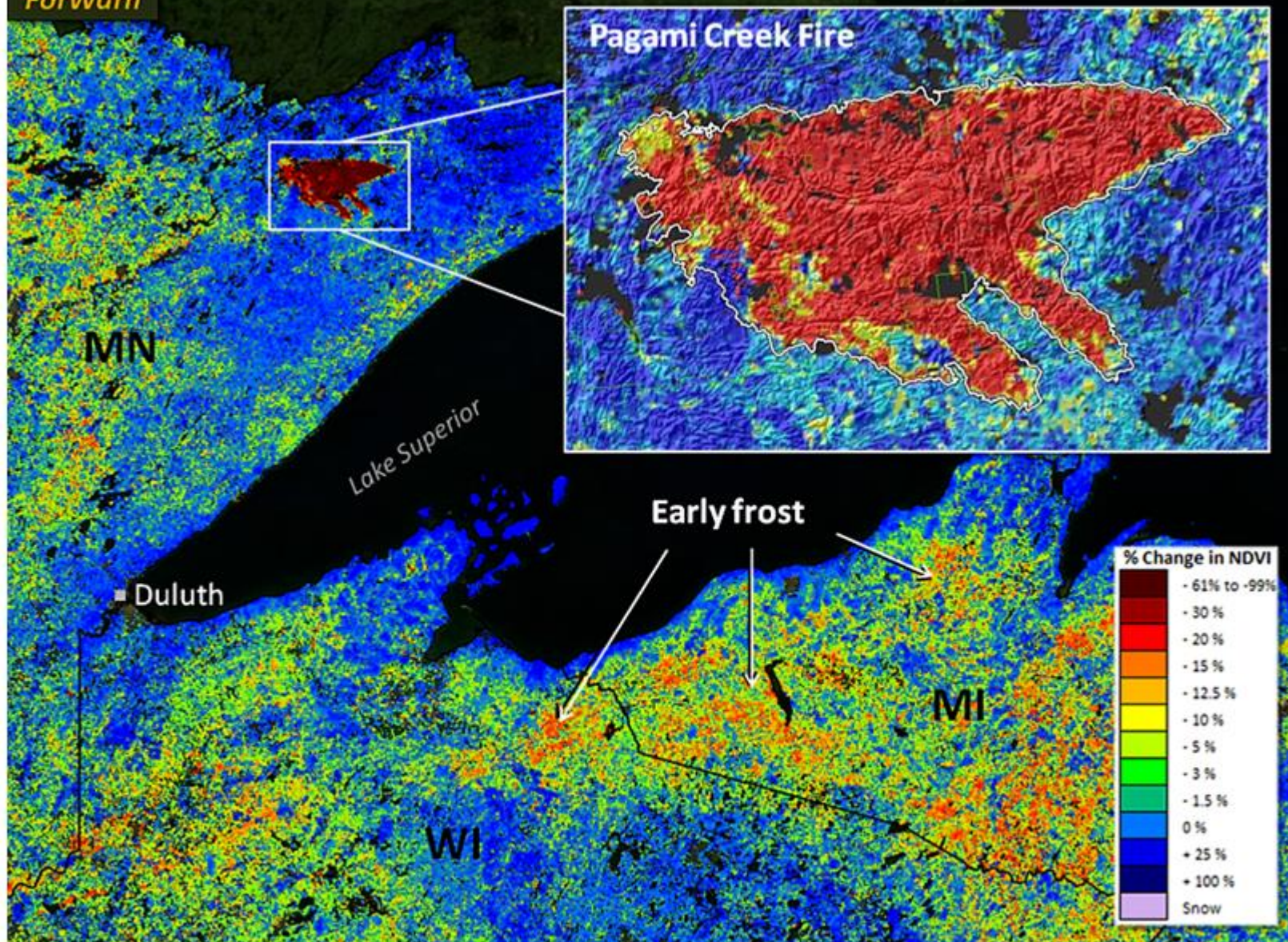
A single October, 2011 *ForWarn* image shows the final high-severity Pagami Creek Fire (92 thousand acres), as well as forest disturbance resulting from an early hard frost that hastened the end of the growing season in northern Wisconsin and Michigan.
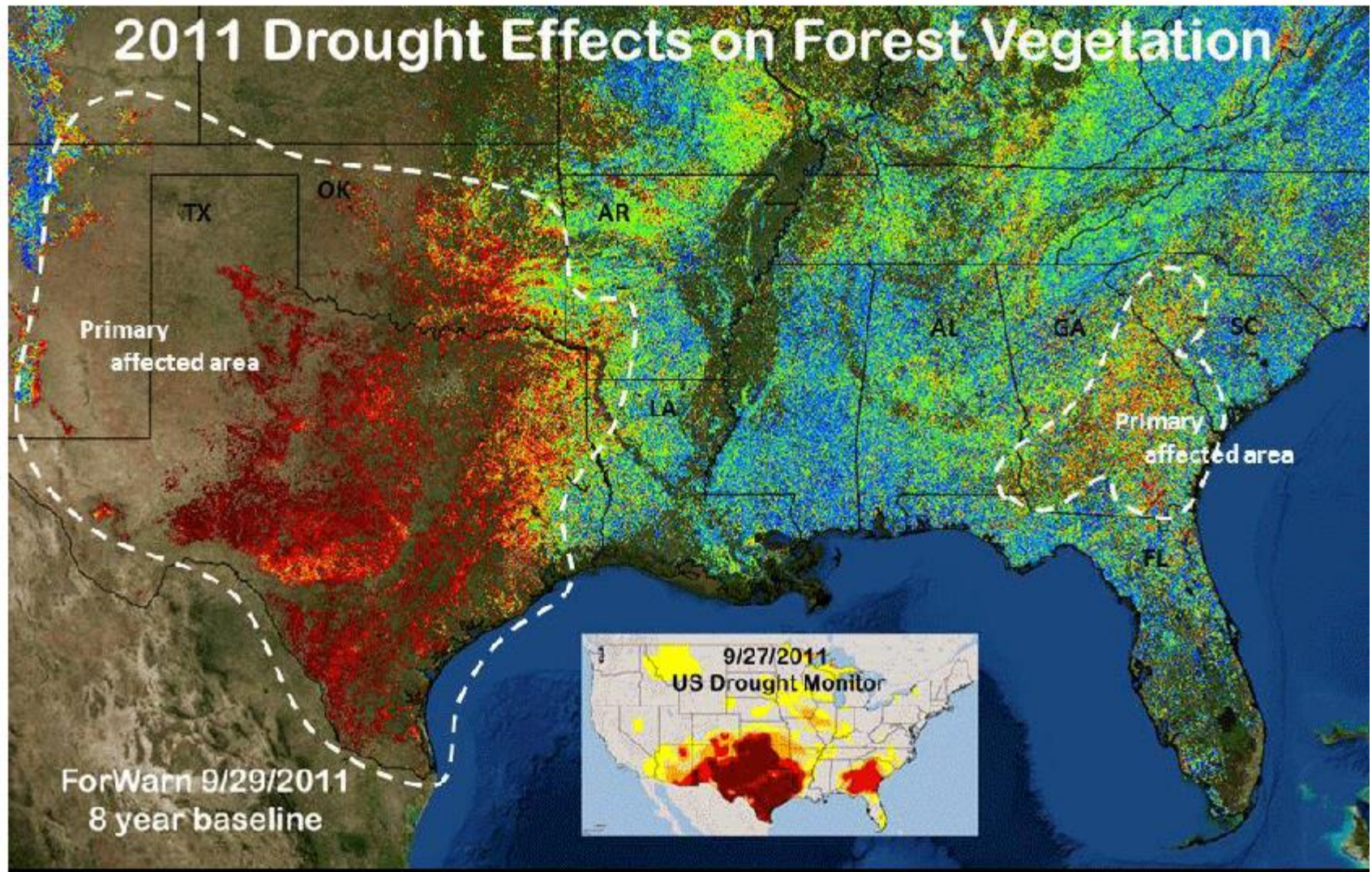
The *ForWarn* system is a sensitive indicator of drought,
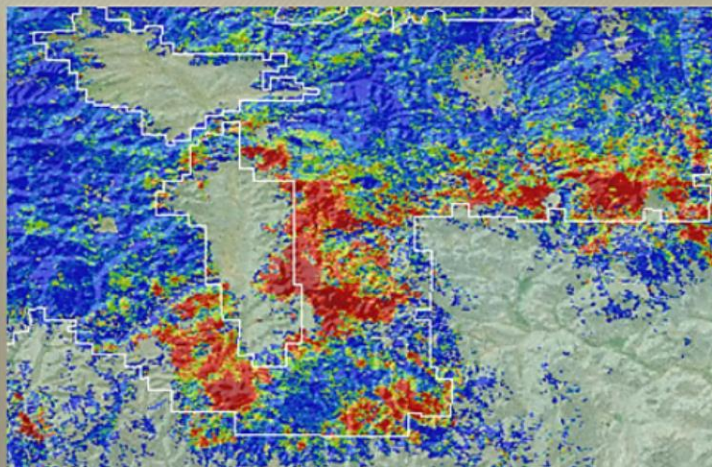which is a precursor to regional wildfire

ForWarn
Satellite-Based Change Recognition and Tracking

Overview

Introduction
Causes of Forest Change
The Science of Detection
The Science of Assessment

Introduction
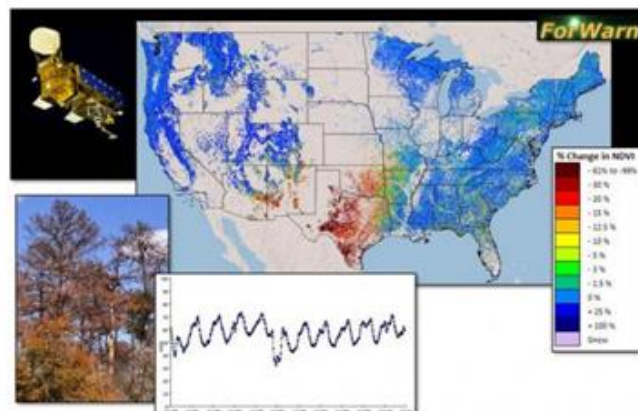
ForWarn is forest change recognition and tracking system that uses high-frequency, moderate resolution satellite data. It provides near real-time forest change maps for the continental United States that are updated every eight days. These maps show the effects of disturbances such as wildfires, wind storms, insects, diseases and human development, in addition to departures from normal seasonal greenness caused by anomalous weather. Using this state of the art tracking system, it is possible to monitor post-disturbance recovery months to years after disturbance occurs.

This technology supports a broader cooperative forest management initiative known as the National Early Warning System (EWS). The EWS network brings together various organizations involved in mapping disturbances, climate stress, aerial and ground monitoring, and predictive efforts to achieve more efficient forest planning and management across jurisdictions.

ForWarn consists of a set of inter-related products including near real time forest change maps, an archive of past change maps, an archive of seasonal vegetation phenology maps, and derived map products from these efforts. For a detailed discussion of these products, or to access these map products in the project's Assessment Viewer or to explore these data using other GIS services, look under the Data header.

Highlights

Multiple baselines reveal short and long-term change
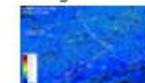
The browning of the Black Hills

The Exceptional Drought of 2011

Defoliation on the bayou

more highlights »

ForWarn
Satellite-Based Change Recognition and Tracking

U.S. FOREST SERVICE · NASA · USGS · OAK RIDGE National Laboratory

Data

Data Access

Forest Change Products

Basic Phenology Products

Derivative Phenology Products

Datasets for Assessment Support

Data Access

ForWarn data are readily accessed through the project's Forest Change Assessment Viewer using a standard internet browser.

To learn more about the functions and features of the Assessment Viewer, please read the Forest Change Assessment Viewer Users Guide
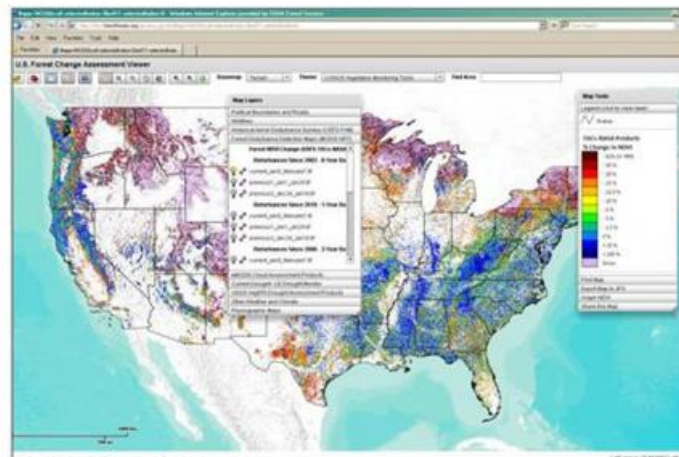
Web Map
Service (WMS) Access

WMS allows access to the ForWarn forest change images using your desktop GIS or mobile mapping application software. The advantages of viewing the forest change images locally are: (1) to overlay with your GIS layers, (2) to screen-digitize disturbance extent and severity, (3) the increased use and functionality of a desktop GIS, and (4) to view the forest change images via mobile devices (such as using OruxMaps with Droid-based handhelds). Use the following WMS connection strings to access the ForWarn data products:

WMS Dataset	Contents	Connection URL (ArcGIS users denote version 1.0.0)
All-Year baseline forest change images (Web Mercator)	Begins 01/08/2010 for all-year baseline-only; current, previous 1 and previous 2 available for all baseline periods, disregard 16-day composite products	http://wms.forwarn.forestthreats.org/ews [GetCapabilities]

Highlights

Multiple baselines reveal short and long-term change
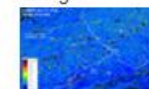
The browning of the Black Hills

The Exceptional Drought of 2011

Defoliation on the bayou

more highlights »

ForWarn
Satellite-Based Change Recognition and Tracking

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Training

- Download the Forest Change Assessment Viewer Users Guide!

- ForWarn Presentation Slides, March 1, 2012

ForWarn Overview Webinars

Webinar 1, *An Introduction and Overview of the ForWarn System*

Share   ▼ More info

% Change in NDVI

Mar 29

Apr 30

Jun 1

Jul 3

Aug 4

Spring greenup was delayed compared to the 8-year normal, and follows elevational gradients, esp. on the Olympic penninsula. Greenup proceeds from south to north from May through July.
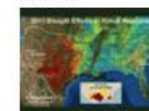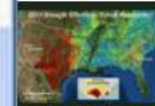
Highlights

Multiple baselines reveal short and long-term change

The browning of the Black Hills

The Exceptional Drought of 2011

Defoliation on the bayou

more highlights »

U.S. Forest Change Assessment Viewer

Basemap: Imagery | Theme: CONUS Vegetation Monitoring Tools | Find Area

Map Layers

Political Boundaries and Roads

Boundaries
- Cities
- State Boundaries
- County Boundaries
- Federal Land Boundaries
- Federal Lands (Agencies)

Roads
- Interstates
- Secondary Roads

Fires
Historical Aerial Disturbance Surveys (USFS FHM)
Forest Disturbance Detection Maps (MODIS NRT)
eMODIS Cloud Assessment Products
Drought- US Drought Monitor
USGS/NDMC VegDRI Drought Assessment Produc
Other Weather and Climate
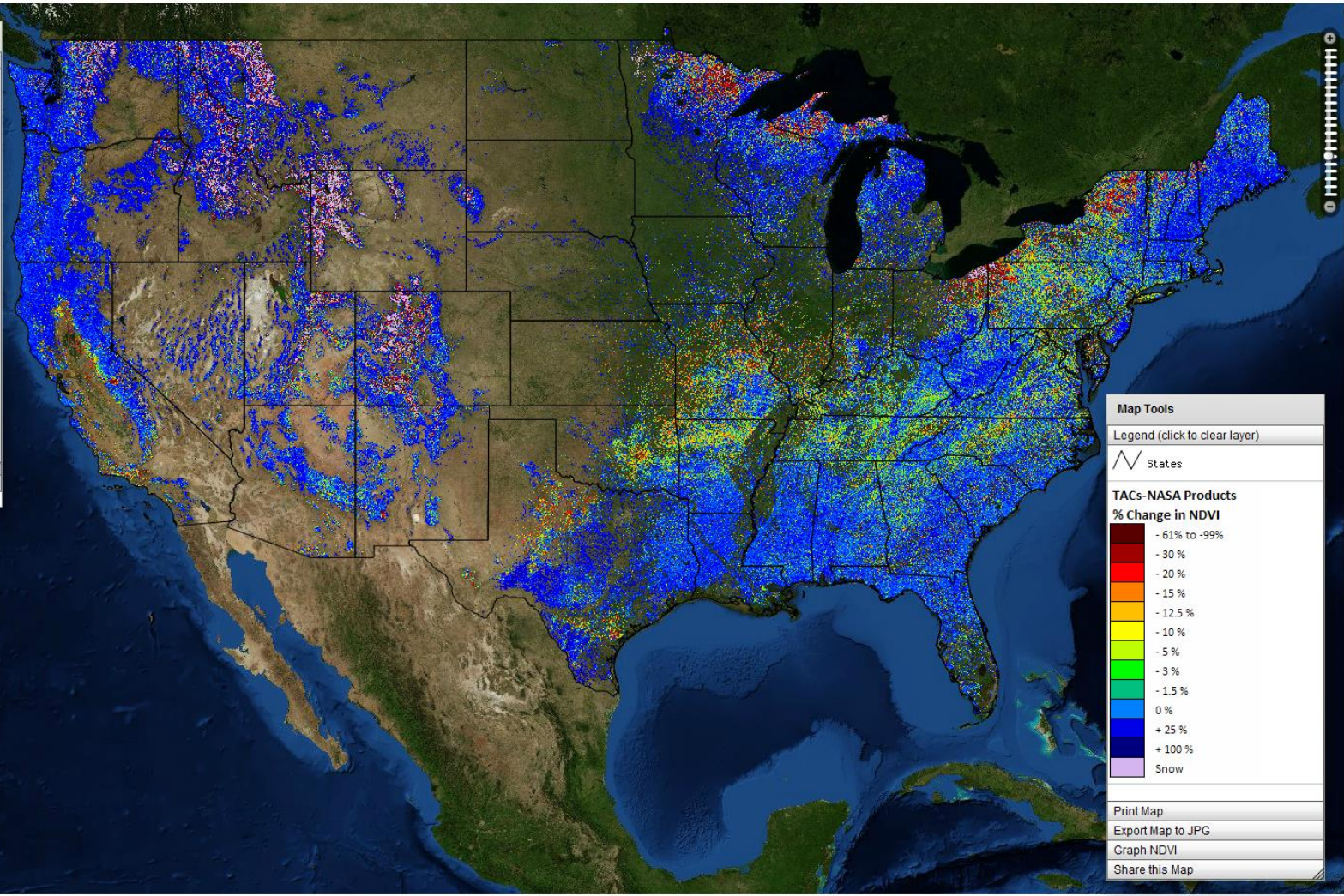
Map Tools

Legend (click to clear layer)

⋀ States

TACs-NASA Products
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+ 100 %
Snow

Print Map
Export Map to JPG
Graph NDVI
Share this Map

1000 km
500 mi

forwarn.forestthreats.org | Data Disclaimer | FCAV Users Guide | Change Product Descriptions | FCAV 2.0

Lat/Long is: 33.988850 / -64.857867

ForWarn Quick Start Guide

1. Open this URL in a web browser
    http://forwarn.forestthreats.org/fcav

2. In the Table of Contents window, click on the tab heading **"Forest Disturbance Detection Maps"** to expand and view the data layers (NRT – near real time)

3. By default, the most recent forest change image in the "All-Year" baseline will be displayed. This image is a result of comparing the most recent MODIS NDVI image to the maximum NDVI value over the entire MODIS NDVI history (12+ years), and shows all forest disturbances over the entire historical period.

4. Turn-off the most recent "All-Year" baseline image and turn-on the most recent in the "1-Year" baseline group. This allows one to view only forest disturbance, or recovery, that has occurred within just the past one year (for this specific time period).

5. Use the map controls to zoom and pan, or type the name of a county in the "Find Area" box in the top-right area of the FCAV viewer window

6. Use the 'wrench' icon to adjust the transparency of any layer to better view the basemap , or other layers
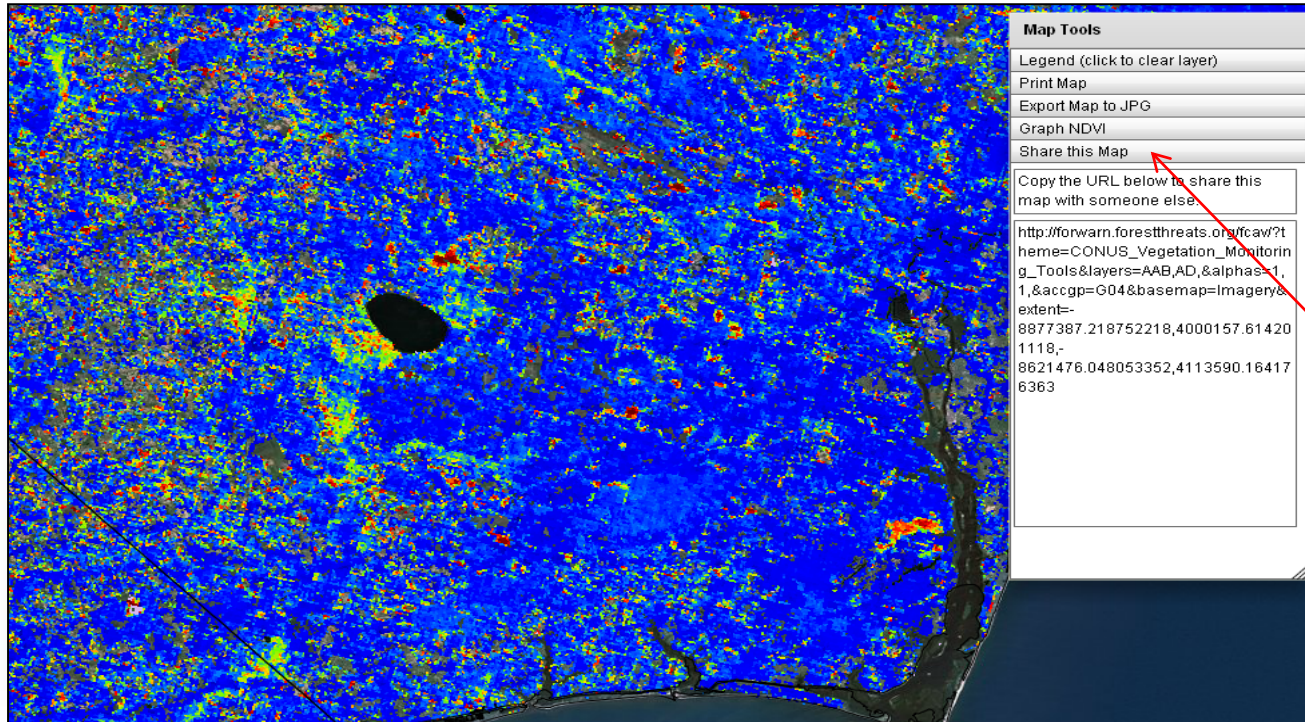
Table of Contents window expanded

Map Layers

Political Boundaries and Roads

Fires

Historical Aerial Disturbance Surveys (USFS FHM)

Forest Disturbance Detection Maps (MODIS NRT)

Forest NDVI Change (USFS TACs-NASA)

Change from All-Year Baseline

current_jan9_february1.tif
previous1_jan1_jan24.tif
previous2_dec24_jan16.tif

Change from 1-Year Baseline

current_jan9_february1.tif
previous1_jan1_jan24.tif
previous2_dec24_jan16.tif

Change from 3-Year Baseline

current_jan9_february1.tif
previous1_jan1_jan24.tif
previous2_dec24_jan16.tif

eMODIS Cloud Assessment Products

Drought- US Drought Monitor

USGS/NDMC VegDRI Drought Assessment Products

Other Weather and Climate

Physiographic Maps

TACs-NASA Products
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- 20 %
- 15 %
- 12.5 %
- 10 %
- 5 %
- 3 %
- 1.5 %
0 %
+ 25 %
+ 100 %
Snow

Share Disturbance Events with Colleagues

Map Tools

Legend (click to clear layer)
Print Map
Export Map to JPG
Graph NDVI
Share this Map

Copy the URL below to share this map with someone else

http://forwarn.forestthreats.org/fcav/?theme=CONUS_Vegetation_Monitoring_Tools&layers=AAB,AD,&alphas=1,1,&accgp=G04&basemap=Imagery&extent=-8877387.218752218,4000157.614201118,-8621476.048053352,4113590.164176363

• The "Map Tools" box in the upper right portion of the Viewer offers the capability to send a URL of a view via your email client to a colleague.

• Click the "Share this Map" tab, then highlight and copy the URL, and paste the link into your email program. Your colleague can open the Viewer to the same extent and data layers you were using to explore a disturbance event.

• Printing, graphing NDVI history and the ability to save a JPEG of the view is also available from the Map Tools tabs.

forwarn.forestthreats.org/fcav

Application Limitation
- Detection delay due to compositing method -

Detection Delays are caused by the fixed-length 24-day Maximum Compositing currently used to get rid of Clouds in the Current View

Unfortunately, clouds act to lower NDVI, just like true forest disturbances - Can cause false positives - Cloud contamination is continuous, not binary

We currently use the **MAXIMUM NDVI** seen over a 24-day compositing period to generate the Current view as cloud-free as possible

BUT

Taking the maximum NDVI seen over the period guarantees that the newly-lowered NDVI from a new forest disturbance **WILL NOT BE DETECTED** until after the 24-day compositing period has passed

This creates a delay in detection of new disturbances

Three additional change products now available:
(1) derived from an 'Adaptive Length Compositing' method, and
(2) called Seasonally Adjusted, which mitigates annual seasonal variations in the timing of spring and fall

Application Limitation
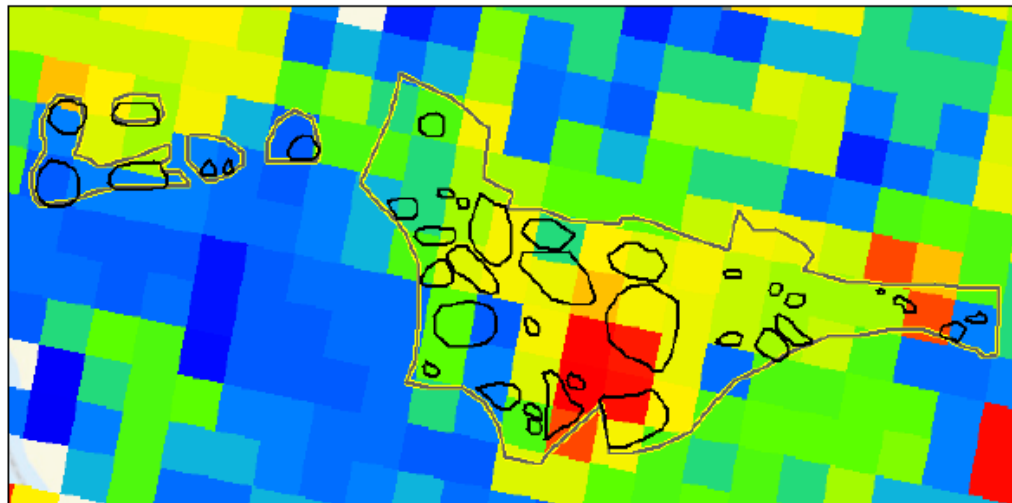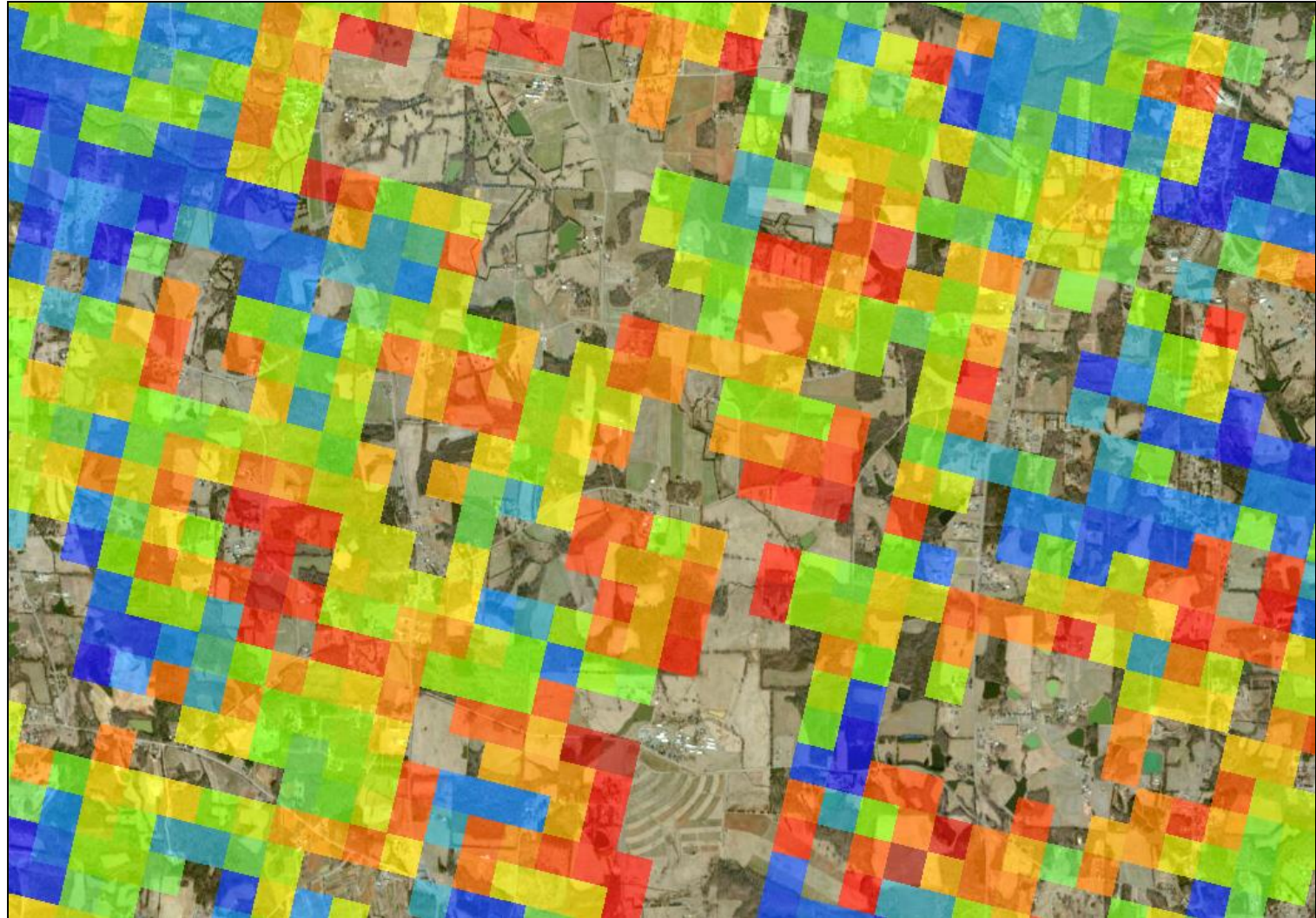## - *Spatial resolution* -

08/14/2012
Landsat 453

08/19/2012
ForWarn 11yr

GEORGIA FORESTRY
COMMISSION

Application ~~Limitation~~ Awareness
- "Edge-of-the-mask" mixed pixels -

Drought Sensitivity at the 'edge-of-the-mask'
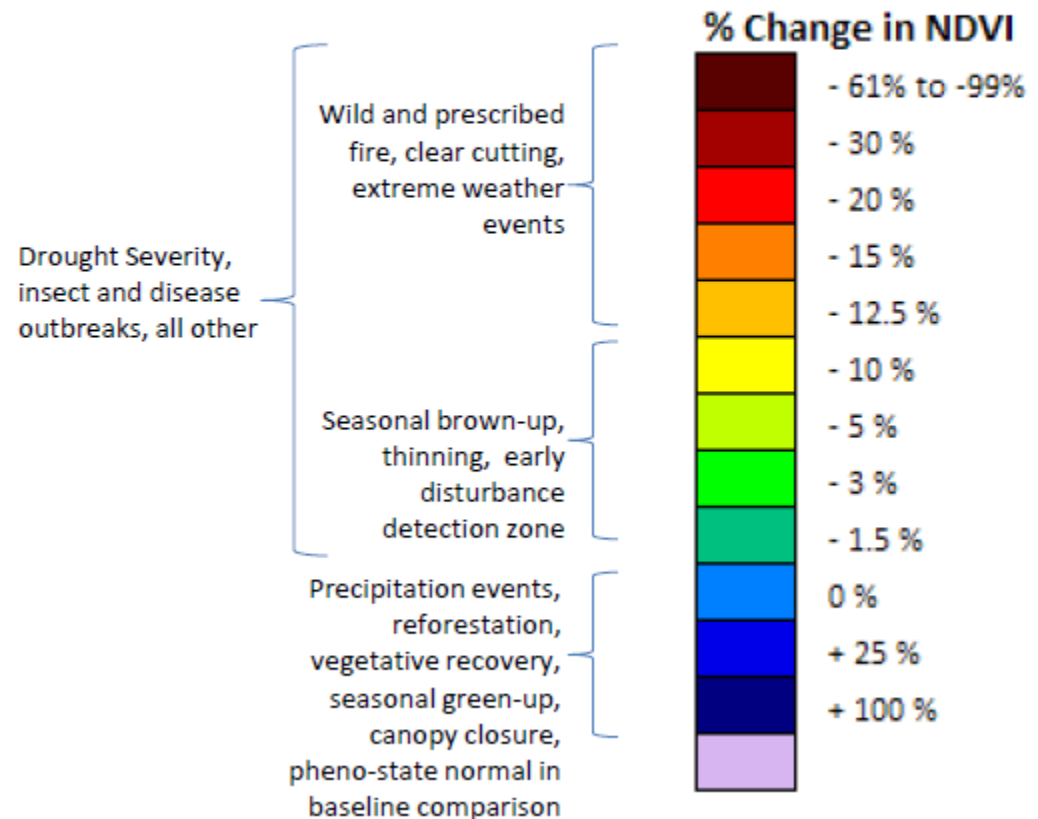
Forest Disturbance Assessment Layers

The FCAV contains ancillary data layers that can be used to identify variables that can help explain change in expected NDVI values.

Map Layers
Political Boundaries and Roads
Wildfires
Historical Aerial Disturbance Surveys (USFS FHM)
Forest Disturbance Detection Maps (MODIS NRT)
eMODIS Cloud Assessment Products
Current Drought- US Drought Monitor
USGS VegDRI Drought Assessment Products
Other Weather and Climate
Physiographic Maps

Wildfire

Insects "& Dis.

Clouds

Drought/
Flood

Desktop-based information, such as State specific current NAIP, current Landsat download via GLOVIS, local datasets

Web-based searches and sites, such as use of Google to search the area/county/state for local news and current information, federal wildfire websites

FCAV Multigraph NDVI, when viewing the 3-year and 8-year baseline forest change products

Wild and prescribed fire, clear cutting, extreme weather events

Drought Severity, insect and disease outbreaks, all other

Seasonal brown-up, thinning, early disturbance detection zone

Precipitation events, reforestation, vegetative recovery, seasonal green-up, canopy closure, pheno-state normal in baseline comparison

% Change in NDVI

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

Forest Disturbance Assessment Process

1. *Locate* *(understand geographic site and situation)*

    - **Land cover / land use** (recent aerials)
    - **Topographic position** (in mountainous terrain elevation and aspect may be important, use topographic maps, hill shade)

2. *Characterize* *(NDVI departure)*

    - **Progression speed and duration** (fast vs. slow, obs. successive images)
    - **Severity, or percent NDVI change** (positive or negative, light-to-heavy)
    - **Spatial extent** (large area or localized)
    - **Pattern and shape** (spotty/scattered, bulls-eye, target-like, linearity)
    - **Edges** (hard, well defined or trails-off, feathers out with less departure)
    - **Seasonality** (in spring and fall, the regional variation in annual phenology can cause NDVI departure, positive or negative)

3. *Assess* *(using data layers in the Forest Change Assessment Viewer)*

    - **Use ancillary data layers in the 'Viewer' to vet disturbance or recovery**
    - **Reference 'Disturbance Protocol' document**

Next Steps to Develop Additional Future *ForWarn* Capacities

- ~~NLCD-based "Masks"~~

- ~~New Open-Source "FCAV Viewer"~~

- Clip, Zip and Ship functionality

- Download data by point/line/polygon

- User-shapefile upload

- Disturbance auto-detect

- Disturbance auto-notify via any
  social media format

For More Information...

- *ForWarn Home Page:*
  http://forwarn.forestthreats.org

- *Forest Change Assessment Viewer for the ForWarn System:*
  http://forwarn.forestthreats.org/fcav

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Many persons at many agencies and institutions
have contributed to this work

Thank you for the invitation!