Use of MODIS Forest Monitoring Products in Developing a Forest Threat Early Warning System

2011 USGS NWRC Presentation by:
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Outline

- Introduction
  - Project rationale and history
- Developing forest monitoring products and capabilities for the EWS
  - Phase 1 - Retrospective case studies at regional scales
  - Phase 2 - Near Real Time (NRT) studies at CONUS scales
  - Phase 3 – CONUS NRT products integrated into prototypical EWS
- Example Prototypical Early Warning System (EWS) results
  - Posting of NRT results on-line for use by USFS and it partners
- Final Remarks
  - Role of NDVI-based detection products for aiding EWS
  - Value of daily versus temporally composited products
  - Next steps

Introduction

- The Healthy Forest Restoration Act of 2003 mandates that the USDA build and maintain a National Forest Threat Early Warning System for monitoring forest threats
  - Goal – more quickly identify threats for aiding forest management
- In response, the USDA Forest Service began developing such a system with the help of NASA, ORNL, USGS, and other agencies and NGOs
- In 2006, NASA Stennis began developing and testing MODIS forest monitoring products as inputs to the EWS
  - MODIS satellites collect reflectance data twice per day globally
  - MODIS data includes 250 meter reflectance band data needed for computing NDVI (Normalized Difference Vegetation Index) products
  - MODIS sensors are well calibrated and also collect other spectral and temperature data needed for atmospheric corrections

Why MODIS NDVI and How?

- MODIS NDVI was selected as the primary input for regional forest monitoring products because:
  - Availability at CONUS and broad regional scales
  - 250 meter resolution is better than 1 km AVHRR
  - NDVI can also be computed with AVHRR and other multispectral sensors and is therefore a continuity index
  - MODIS NDVI can be used not only to monitor vegetation canopy greenness but also can be used to monitor vegetation phenology (i.e. timing of annual vegetation growth)
  - Twice daily collection provides improved means for computing effective wall to wall regional and CONUS products
- Ok but how should it be applied?
  - Can we effectively do this retrospectively and in near real time?

Phase 1 – MODIS-Based Regional Gypsy Moth Defoliation Detection

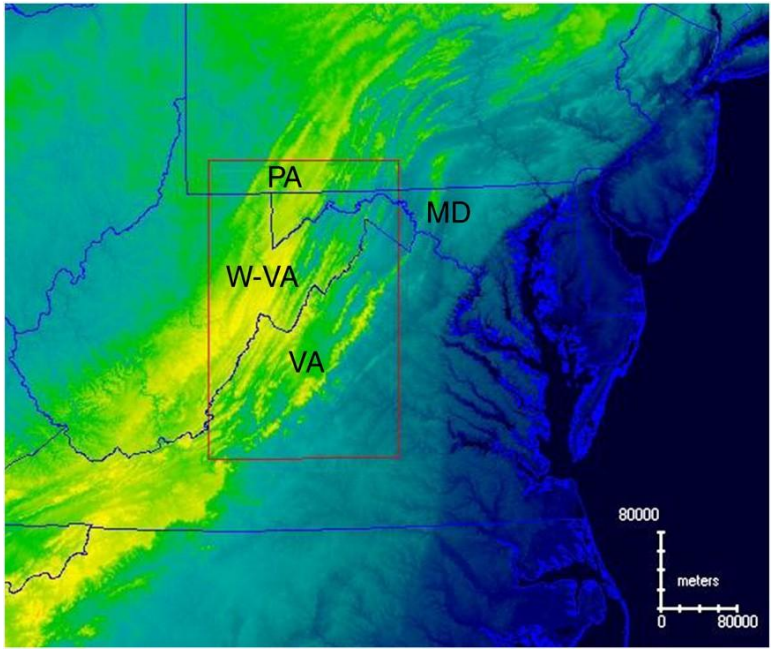
- 2001 Gypsy Moth Defoliation in the Central Appalachian Highlands
- Retrospective study conducted in 2006-2007, based on use of various daily and composited MODIS NDVI products
- Results were recently published in Remote Sensing of Environment by Spruce et al., (2011)

Research Objectives

- Assess agreement of historical, regional MODIS gypsy moth defoliation products with available reference data
  - 30 meter Landsat and 15 meter ASTER satellite imagery
  - USFS Aerial Detection Survey data (general reference)
- Assess results of multiple MODIS NDVI time series defoliation detection products in regard to requirements for a national scale forest threat EWS

Location of Study Area

Central Appalachian Highlands



Study area encompasses portions of 4 states and is 15.5 million acres in extent

Typical Gypsy Moth Defoliation Within Study Area

Defoliation during outbreak years tend to be extensive and highly visible

MODIS Data Acquired for Study (All MODIS Terra Collection 4)

- MOD02 Radiance – Daily data not yet corrected for atmospheric effects
- MOD09 Reflectance – Daily atmospherically corrected data
- MOD13 NDVI – based on MOD09 data
- MOD43 Reflectance – corrected for atmospheric and BRDF effects
- MOD03 – Geo-referencing data
- MOD35 – QA data including masks for clouds and shadows
- NOTE 1 – Only MODIS Terra data was used since outbreak event occurred in 2001 and MODIS Aqua did not start collecting data until early 2002

Time Series Data Processing Method

- Employed TSPT software for processing multiple MODIS time series data sets
- TSPT (Time Series Product Tool) provides means to:
  - Geo-reference data to a map projection
  - Reduce noise and bad data due to poor viewing geometry
  - Interpolate data voids, making use of good data from adjacent dates
  - Process daily or previously temporally composited data
  - Process data from multiple standard MODIS products and resolutions
  - Compute over a dozen different vegetation indices
  - Output products that are in GIS readable formats
- We used TSPT to compute daily and 16 day compositied NDVI products, though later re-aggregated into 48 day maximum value NDVI composites for the main defoliation period (~June 10 – July 27)

Computing Maximum NDVI Composites For the Defoliation Time Frame

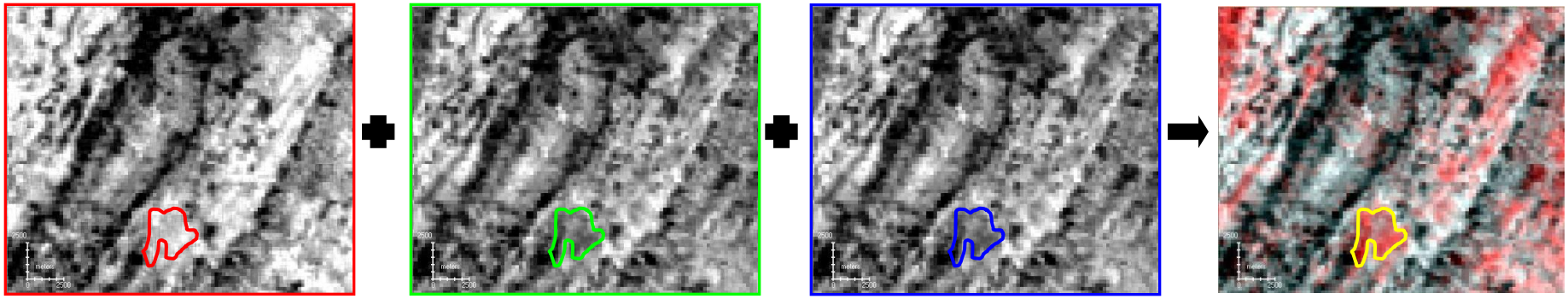
- Computed maximum NDVI composite for the gypsy moth defoliation time frame (DTF) of each year (June 10–July 27)
  - 2001 date records NDVI during 2001 gypsy moth defoliation event
  - Computed max NDVI baseline from 2000-2006 (includes years with minor to no regionally evident gypsy moth defoliation)
- Copied 2001 and baseline NDVI to 2 channel data stack
- Used data stack to compute defoliation detection products

MOD02 Maximum NDVI during DTF for 2000-2006 (Set to Red Color Gun)

Maximum NDVI for 2001 DTF (Assigned to Green)

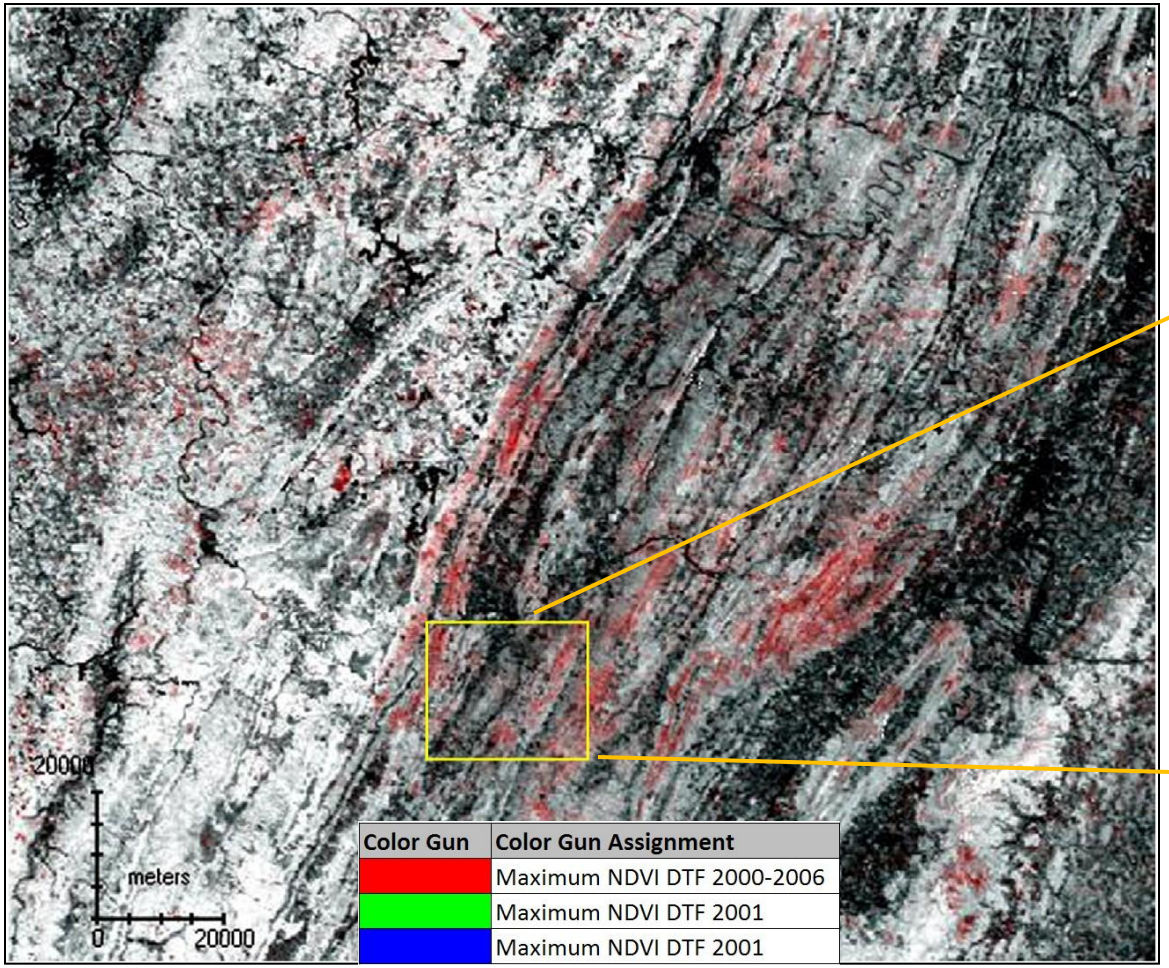
Maximum NDVI for 2001 DTF (Assigned to Blue)

Defoliation RGB - Based on Maximum NDVI DTF for All Years vs. 2001

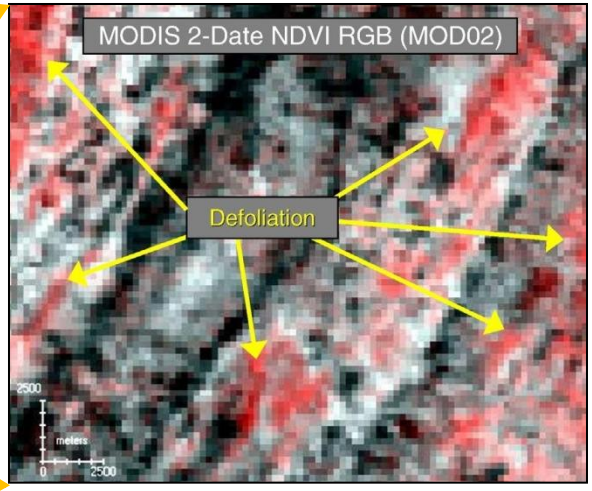


Example MODIS MOD02 Images of 2001 Defoliation within Study Area

2-Date MODIS Maximum NDVI RGB for June 10 – July 27

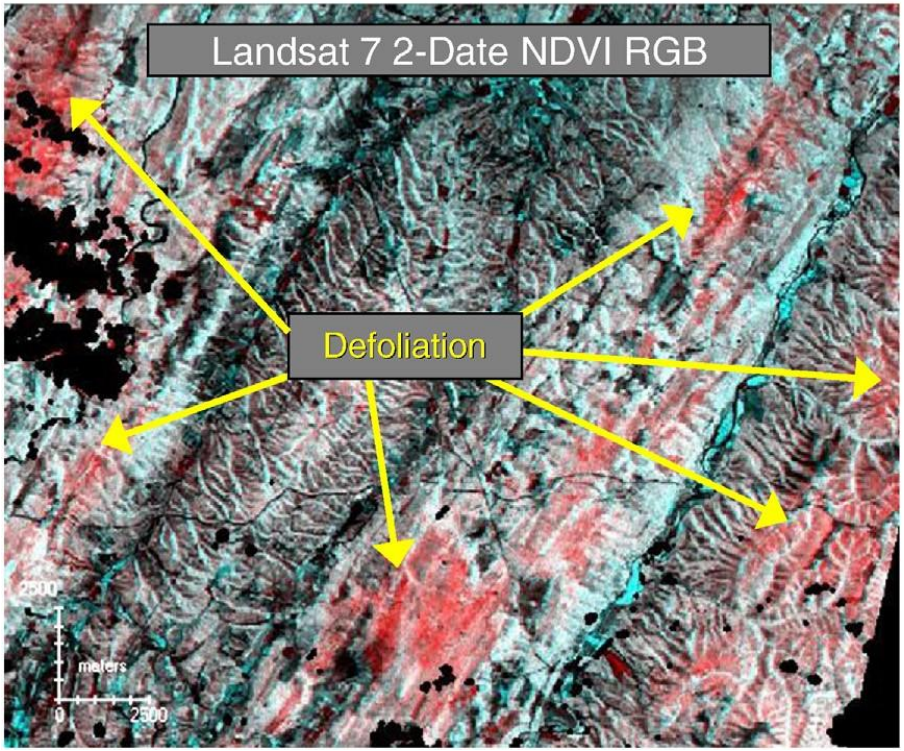


Zoom of Image on Left

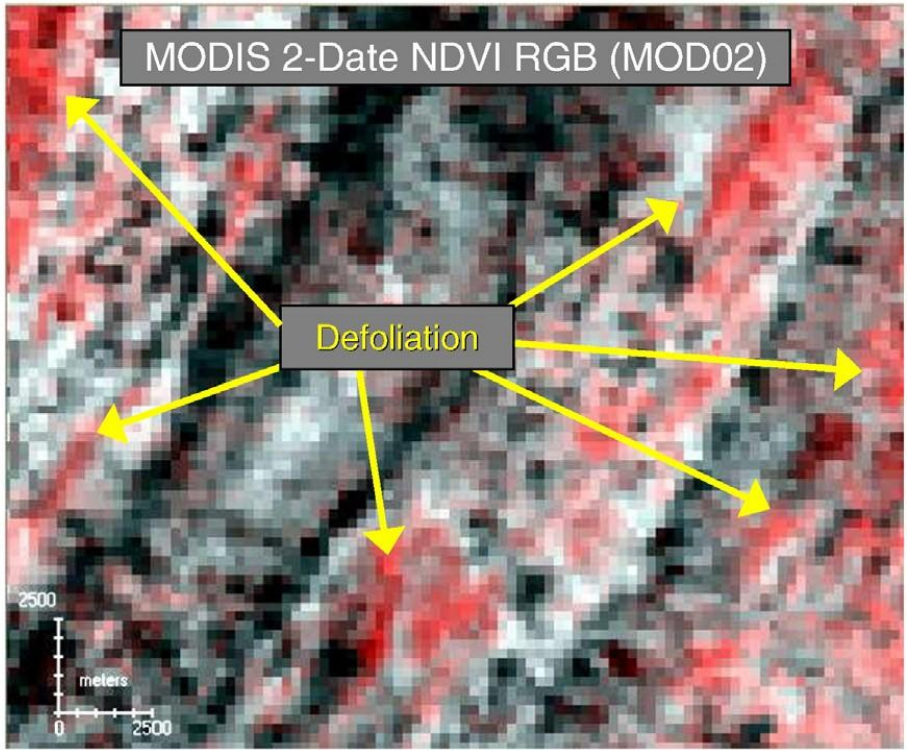


Red Tones = NDVI Drops
Cyan Tones = NDVI Gains
Gray Tones = No NDVI Change

Gypsy Moth Defoliation
Landsat versus MODIS NDVI

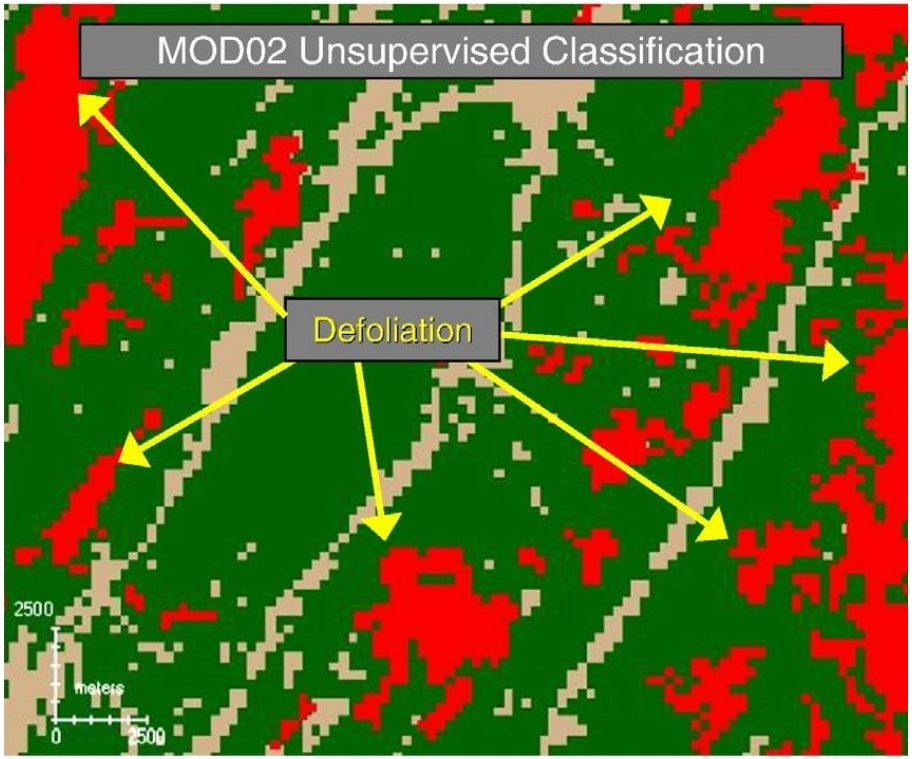


Color Gun	Color Gun Assignment
	Maximum NDVI - June 10, 2000
	Maximum NDVI - July 15, 2001
	Maximum NDVI - July 15, 2001

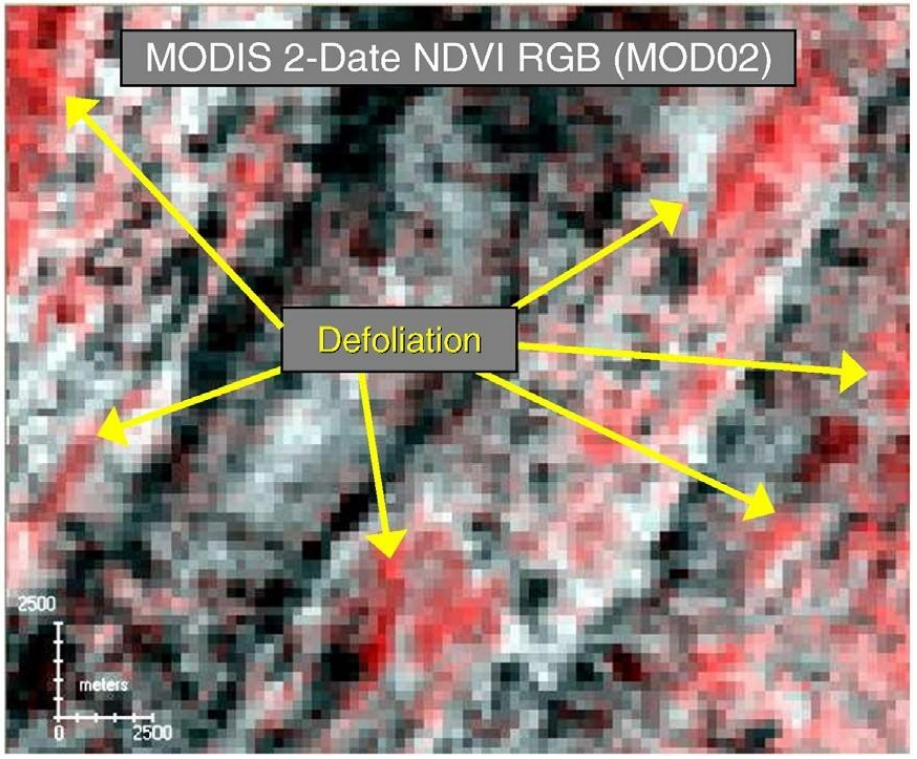


Color Gun	Color Gun Assignment
	Maximum NDVI DTF 2000-2006
	Maximum NDVI DTF 2001
	Maximum NDVI DTF 2001

MOD02 Unsupervised Classification versus MOD02 NDVI RGB

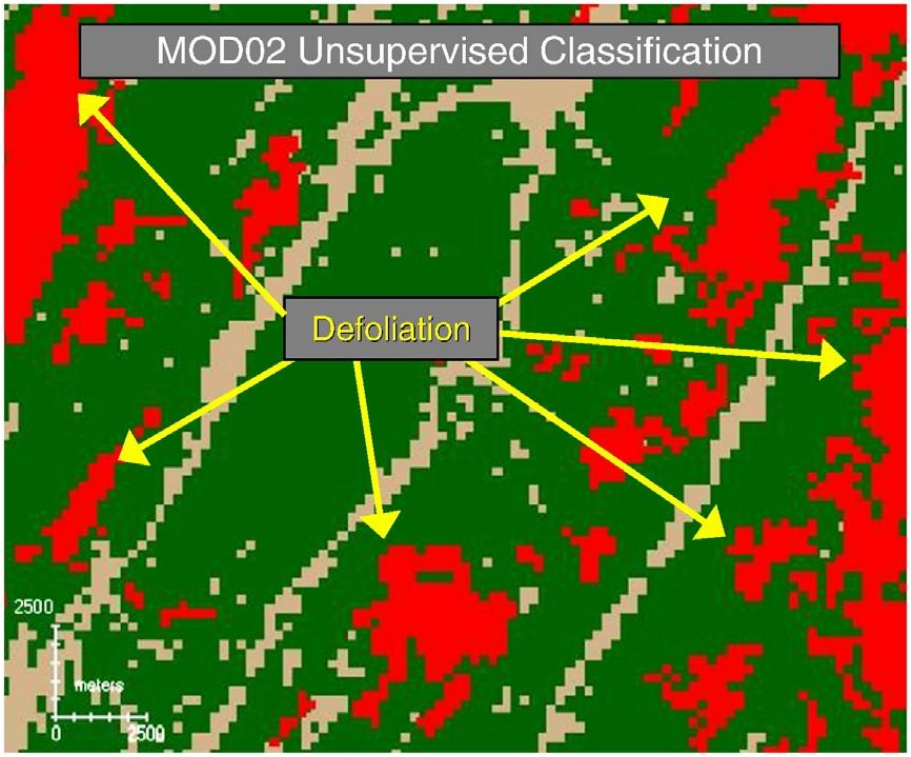


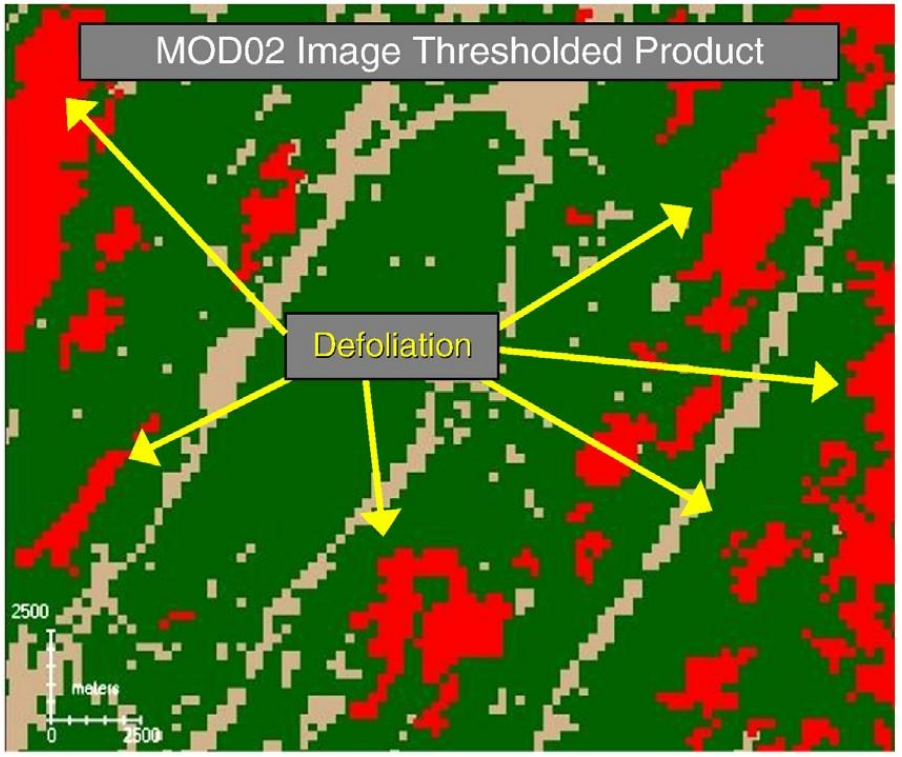
Map Color	Class Description
	Forest - Defoliated
	Forest - Non-Defoliated
	Non-Forest



Color Gun	Color Gun Assignment
	Maximum NDVI DTF 2000-2006
	Maximum NDVI DTF 2001
	Maximum NDVI DTF 2001

Example MODIS-Based Gypsy Moth Defoliation Detection Products





Map Color	Class Description
	Forest - Defoliated
	Forest - Non-Defoliated
	Non-Forest

Assessing Product Agreement with Available Reference Data

- Drew stratified random sample locations from best apparent classification (MOD02 250-meter result)
  - Drew samples for defoliation versus other classes
- An image analyst interpreted each sample location Landsat or ASTER as to being defoliated or other
- Interpretation results were then compared to each test classification
  - E.g., 250 meter MOD02 and MOD13 products
- Final results were summarized for defoliated forest versus “other” classes and overall

Relative Accuracy of Example 2001 MODIS Defoliation Detection Products

2001 Gypsy Moth Defoliation Detection Product	Defoliated Forest			Other Land Cover			Overall	
	PA	UA	Kappa	PA	UA	Kappa	OA	OK
MOD02 NDVI 250 m Unsupervised Product	91% (52/57)	78% (52/67)	0.67	87% (101/116)	95% (101/106)	0.86	88% (153/173)	0.75
MOD02 NDVI 250 m Thresholded Product	84% (48/57)	79% (48/61)	0.68	89% (103/116)	92% (103/112)	0.76	87% (151/173)	0.72
MOD13 NDVI 250 m Unsupervised Product	44% (25/57)	86% (25/29)	0.79	97% (112/116)	78% (112/144)	0.33	79% (137/173)	0.46

PA = % Producer's Agreement (# correct/total)
UA = % User's Agreement (# correct/total)
Kappa = Kappa Statistic (0 to 1 scaling)
OA = % Overall Agreement (# correct/total)
OK = Overall Kappa

Some Key Points

- MODIS NDVI products showed sufficient agreement with reference data to enable subsequent follow-on work
- MODIS daily MOD02 products outperformed the MOD13 16 day composites, though both products showed potential
- Although MOD13 product was a conservative estimator of defoliation, it was in agreement with the reference data when it did detect defoliation
- Better results also occur using “C5” products, which have better atmospheric correction than Collection 4 products
- Better results should occur using both Aqua and Terra data – this study only used MODIS Terra
- The project also yielded multiple advances in developing NRT MODIS disturbance products for the EWS

Phase 2 - Developing CONUS NRT Disturbance Detection Products

- Current expedited USGS eMODIS NDVI data was used with MOD13 historical NDVI products to compute NRT disturbance detection products at CONUS and regional scales
- Product display advances also were made
- Initial NRT products were discussed in Hargrove et al., (2009) highlight article in Photogrammetric Engineering in Remote Sensing

MODIS MOD13 NDVI Data Processing Method for Computing EWS Products

MOD13 NDVI

MOD35 Clouds, Snow

MOD03 Geo-location

Process historical MOD13 NDVI data with TSPT (Time Series Processing 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 – 42 products per year

eMODIS NDVI from USGS EDC

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

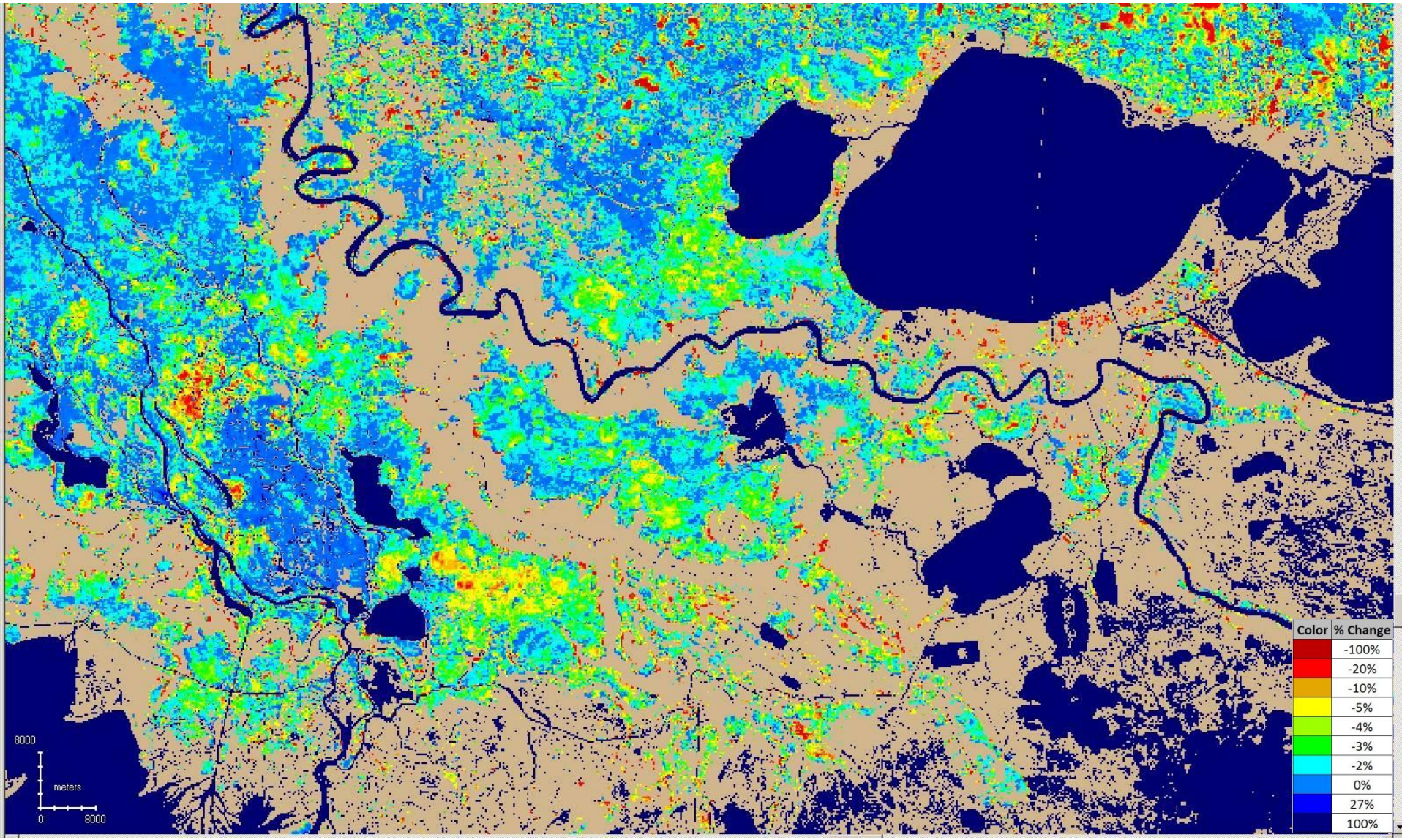
Compute Change Products for Given 24 Day Period, Based on Maximum NDVI from Current versus a Given Historical Baseline

1) % Change in NDVI for current vs. previous 7 years
2) % Change in NDVI for current vs. previous 3 years
3) % Change in NDVI for current vs. previous year

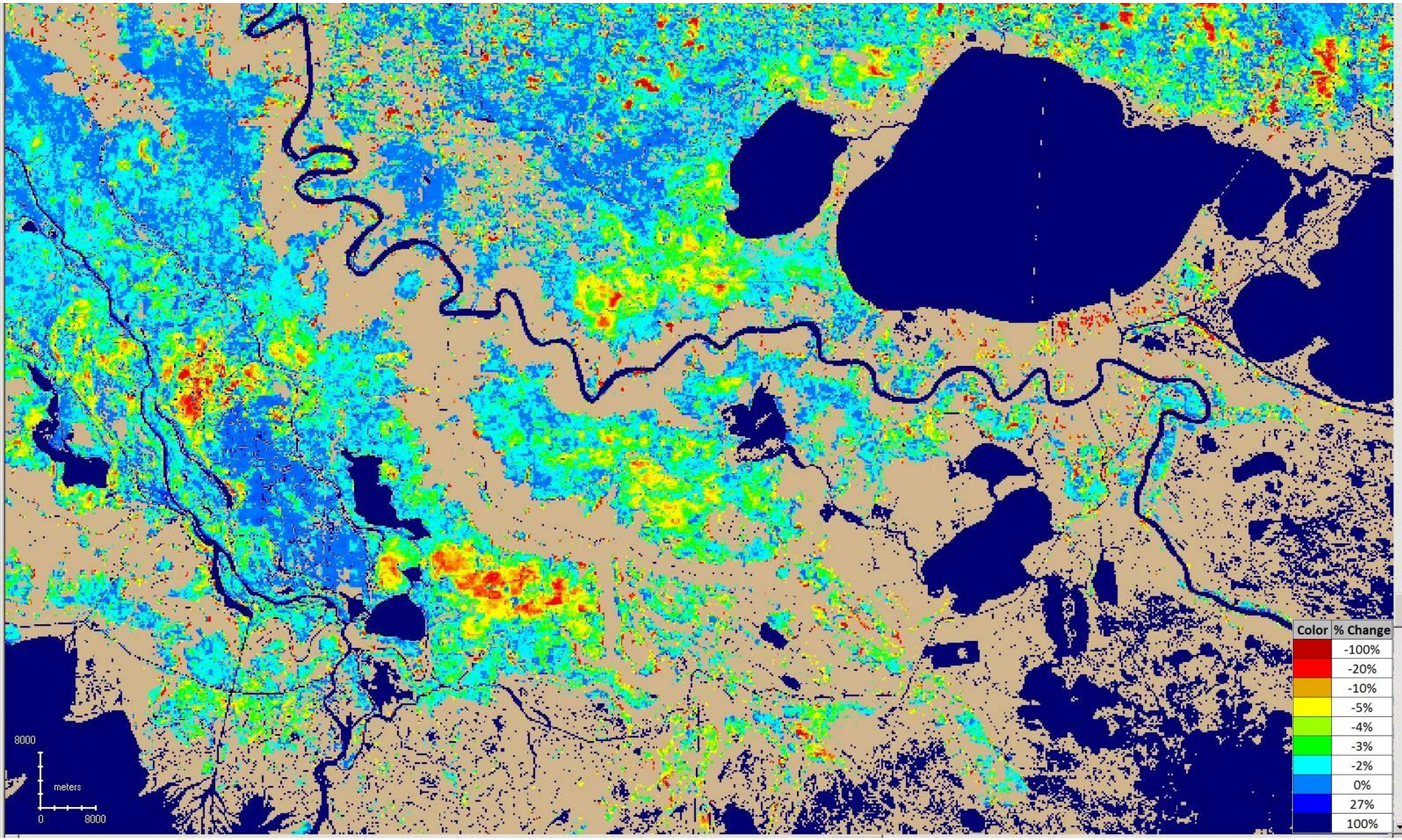
MODIS-Based Views of 2010 Coastal Louisiana Swamp Forest Defoliation

- Series of NRT MODIS % Change in Maximum NDVI Products for a given 2010 time frame versus a 2003-2009 Baseline
- Includes comparison of MODIS- and Landsat-based Defoliation Detection Products
- Note – NRT MODIS change product latencies are generally 1-2 days after last data collection date

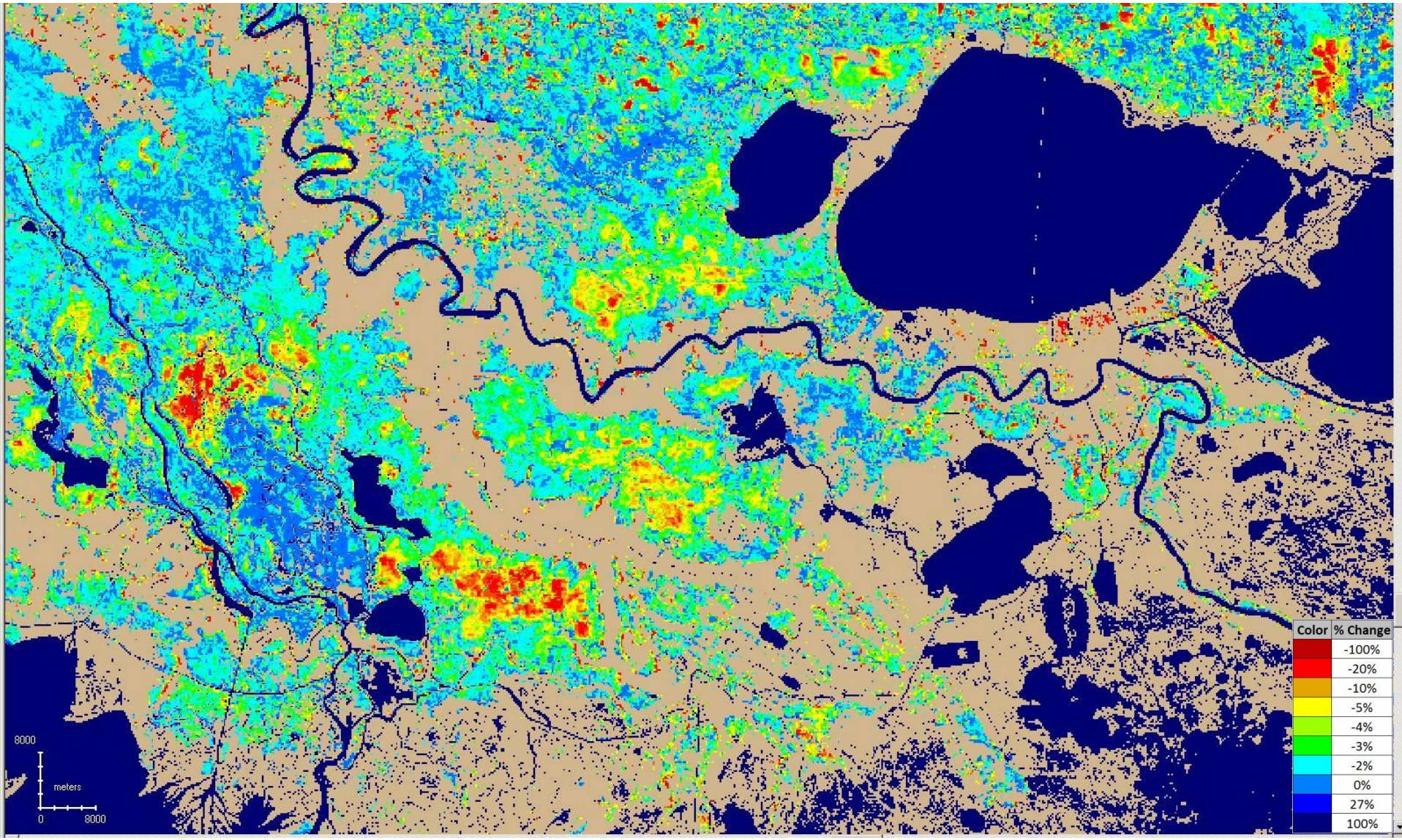
March 30 – April 22, 2010



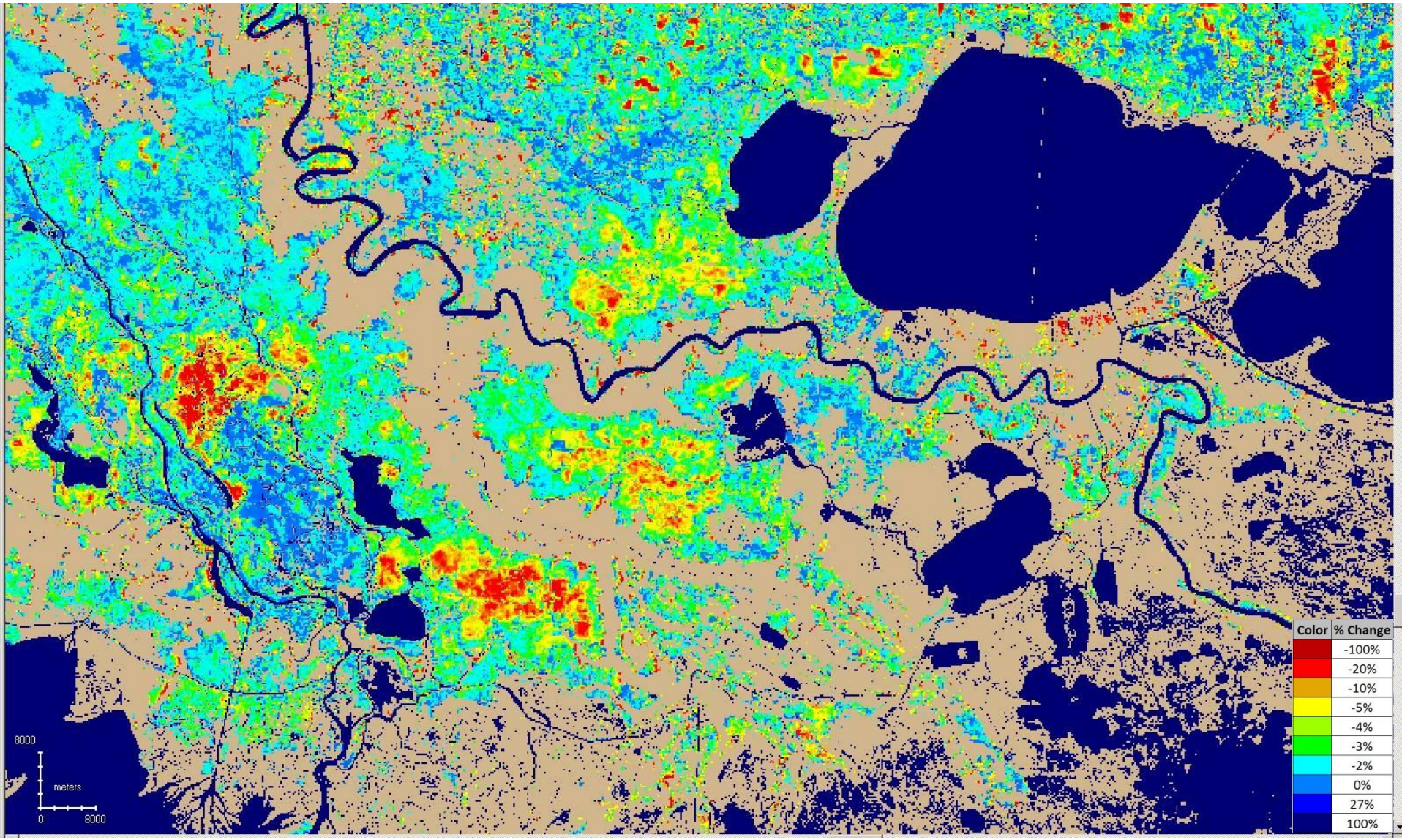
April 7 – April 30, 2010



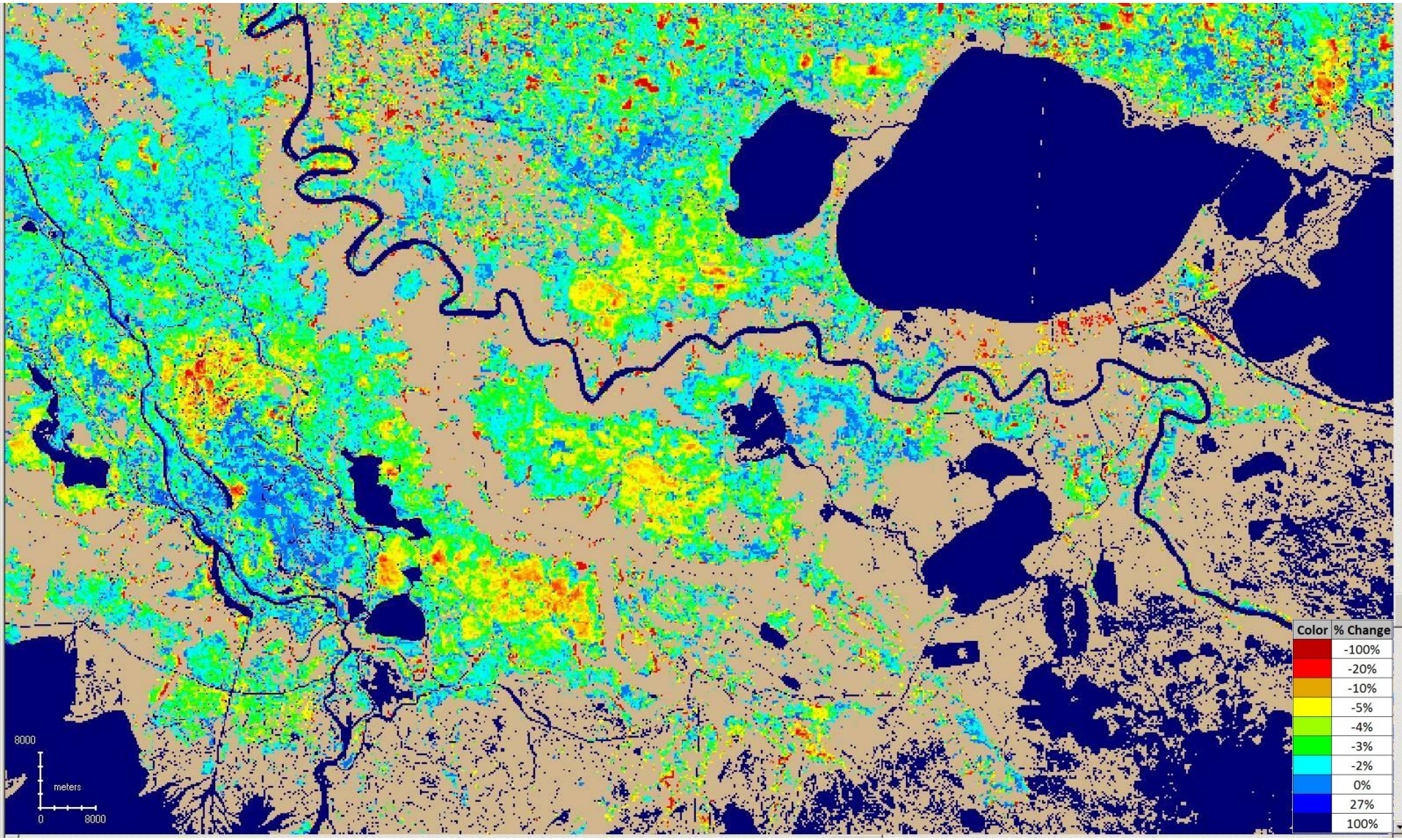
April 15 – May 8, 2010



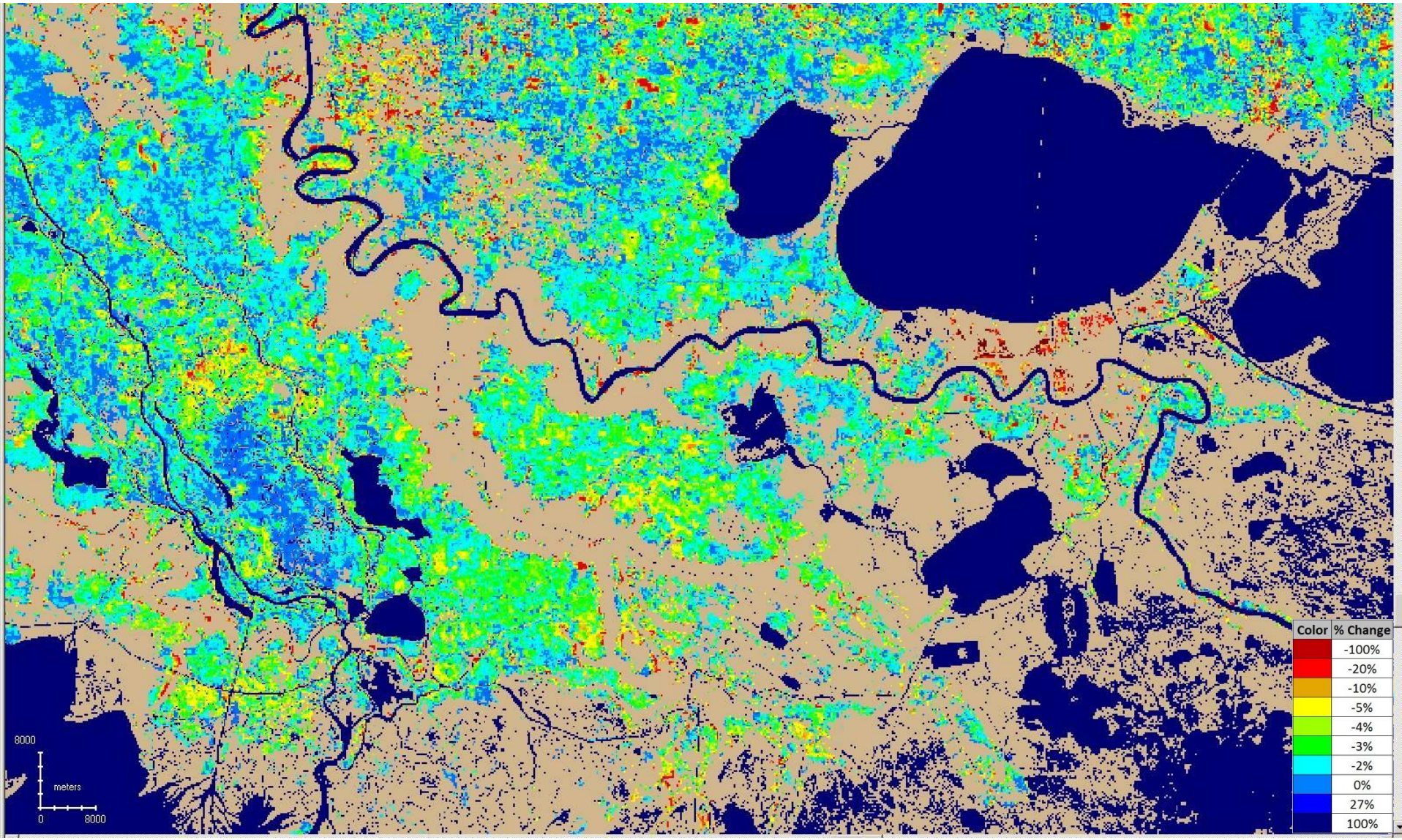
April 23 – May 16, 2010



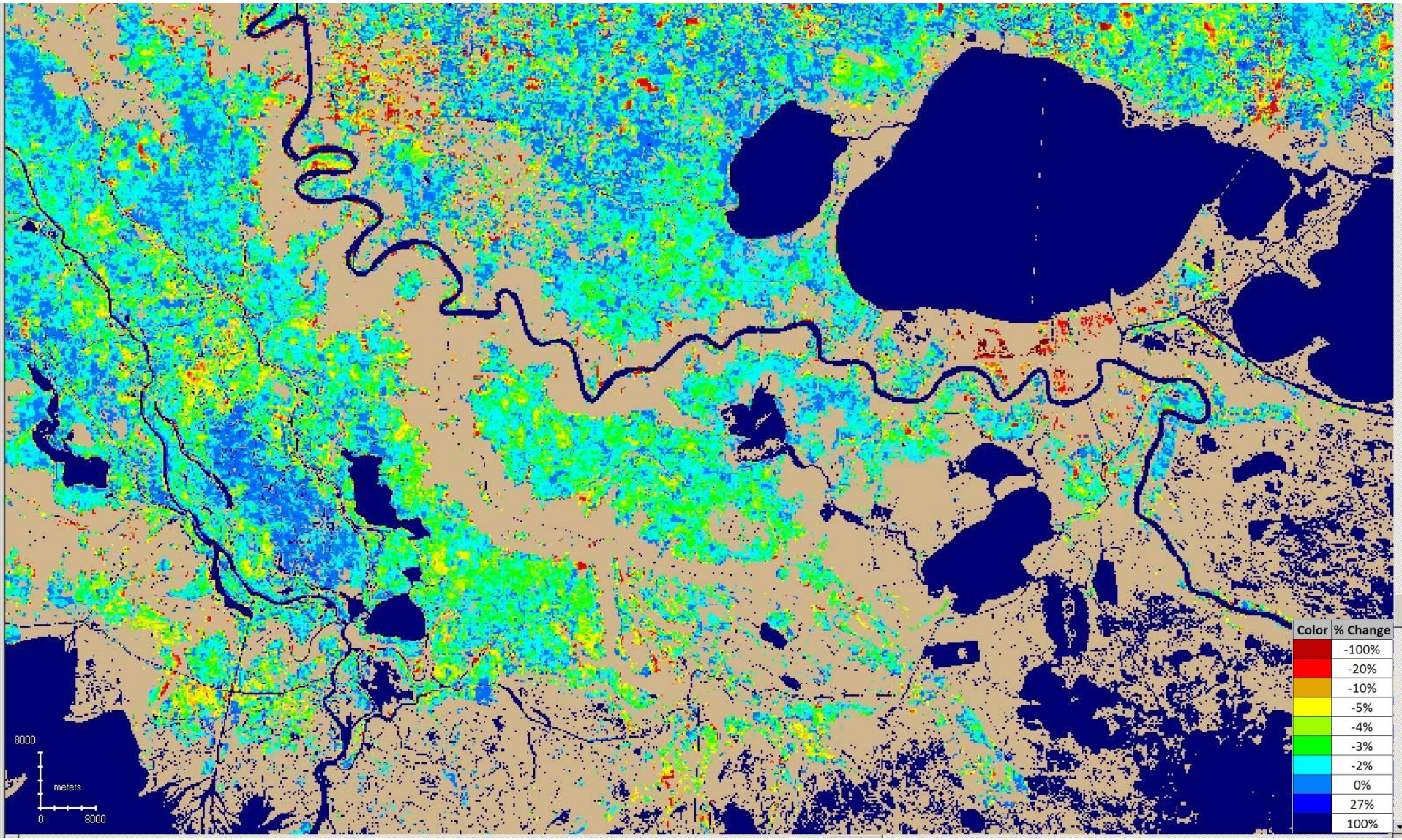
May 1 – May 24, 2010



May 9 – June 1, 2010



May 17 – June 9, 2010

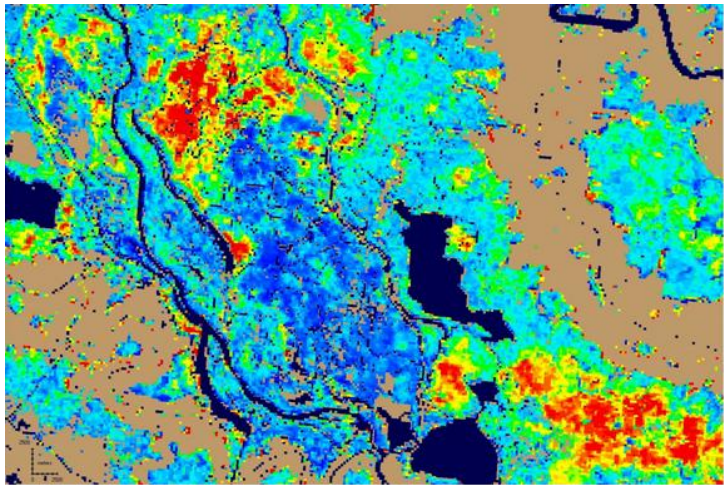


MODIS versus Landsat Views of Swamp Forest Defoliation Areas

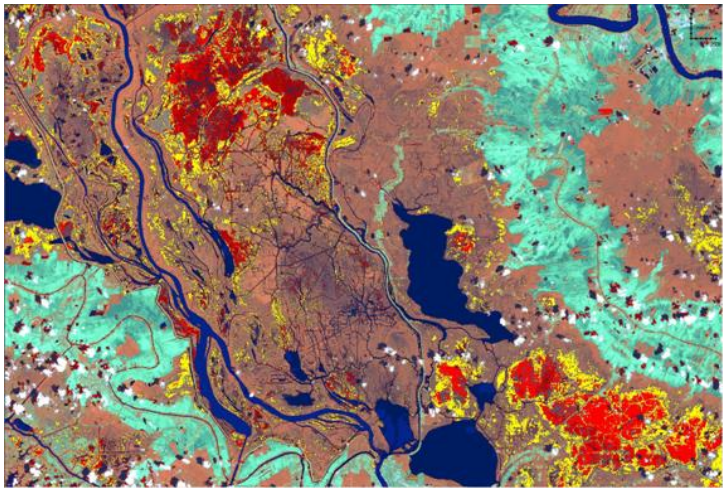
Stennis Space Center

MODIS % NDVI Change – 4/15 to 5/8/2010

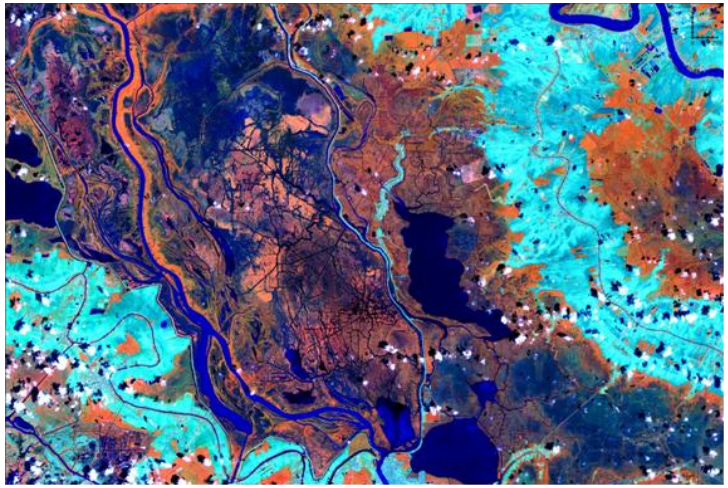
Color	% Change
	-100%
	-20%
	-10%
	-5%
	-4%
	-3%
	-2%
	0%
	27%
	100%



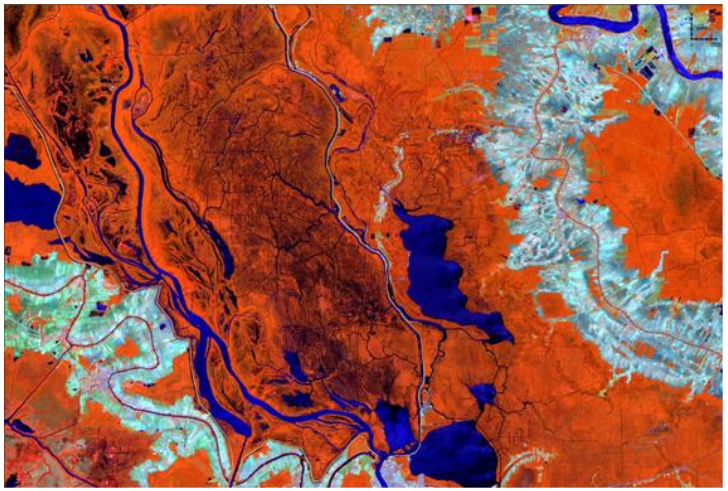
Landsat Defoliation from 4/21/2010 Data



Landsat False Color RGB from 4/21/2010

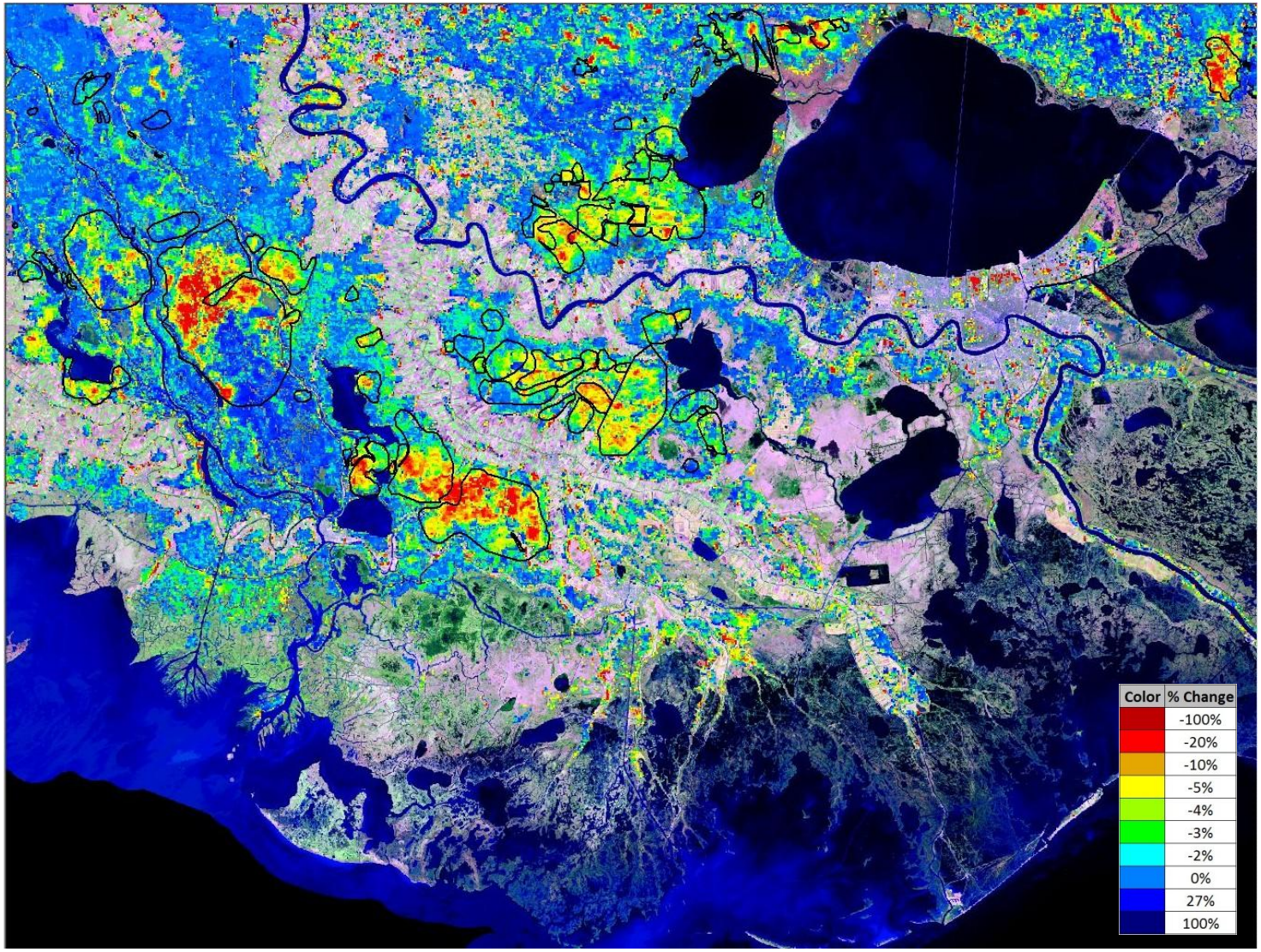


4/14/2001 Landsat RGB – Low Defoliation



Example Louisiana Swamp Forest Detection Product with ADS Vectors

2010 MODIS % NDVI Change for April 23 to May 16



Phase 3 – Integrating NRT Disturbance Detection Products into the EWS

- CONUS NRT products were computed and posted for use in a prototypical National Forest Threat EWS
- Products were produced every 8 days throughout the year, since 2010
- Feed back by USFS internal end-users enabled improvements to MODIS products

2010 Example Screen of U.S. Forest Change Assessment Viewer

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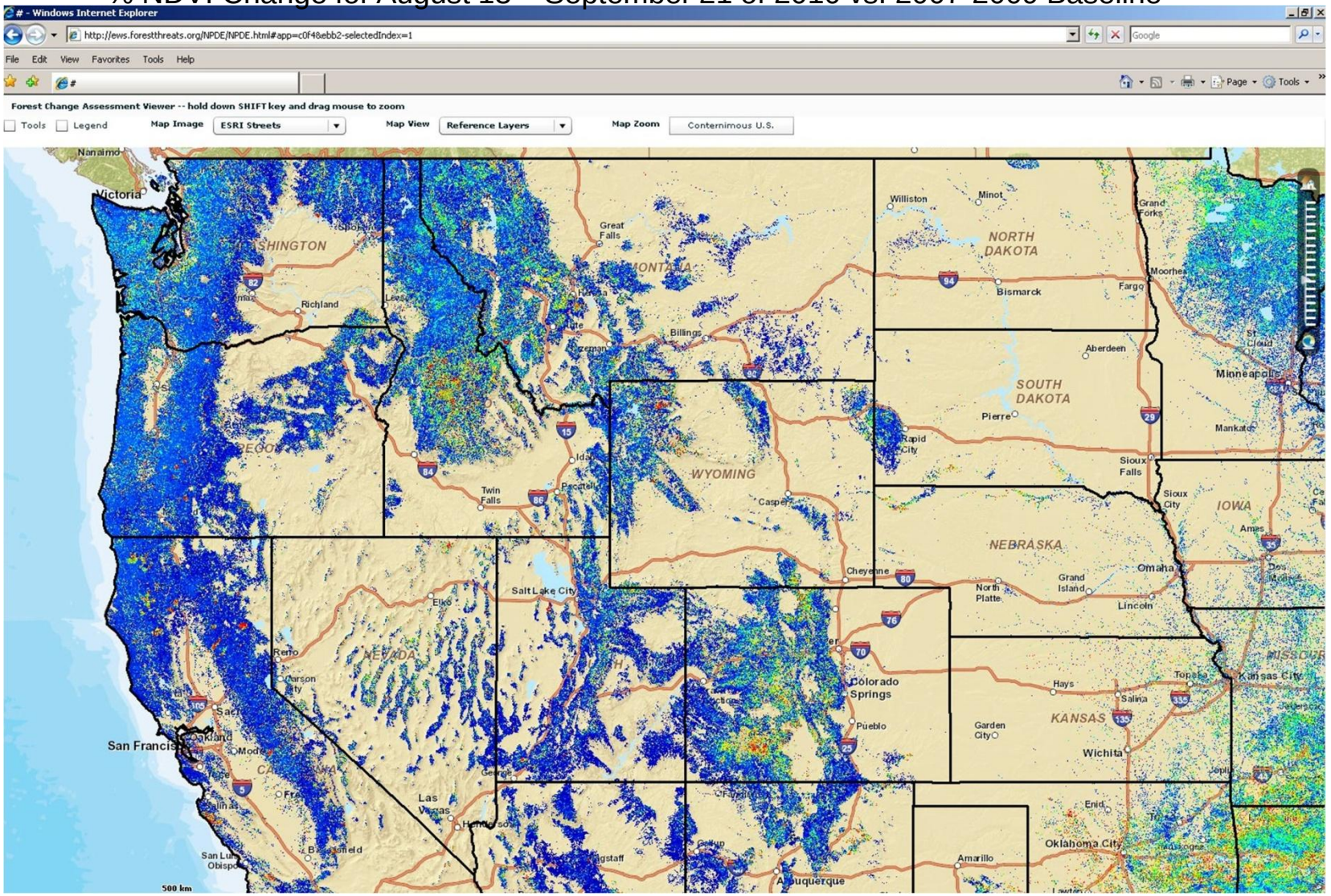
% NDVI Change for August 13 – September 21 of 2010 vs. 2007-2009 Baseline



MODIS versus Landsat Detection of Spruce Beetle and Budworm Damage

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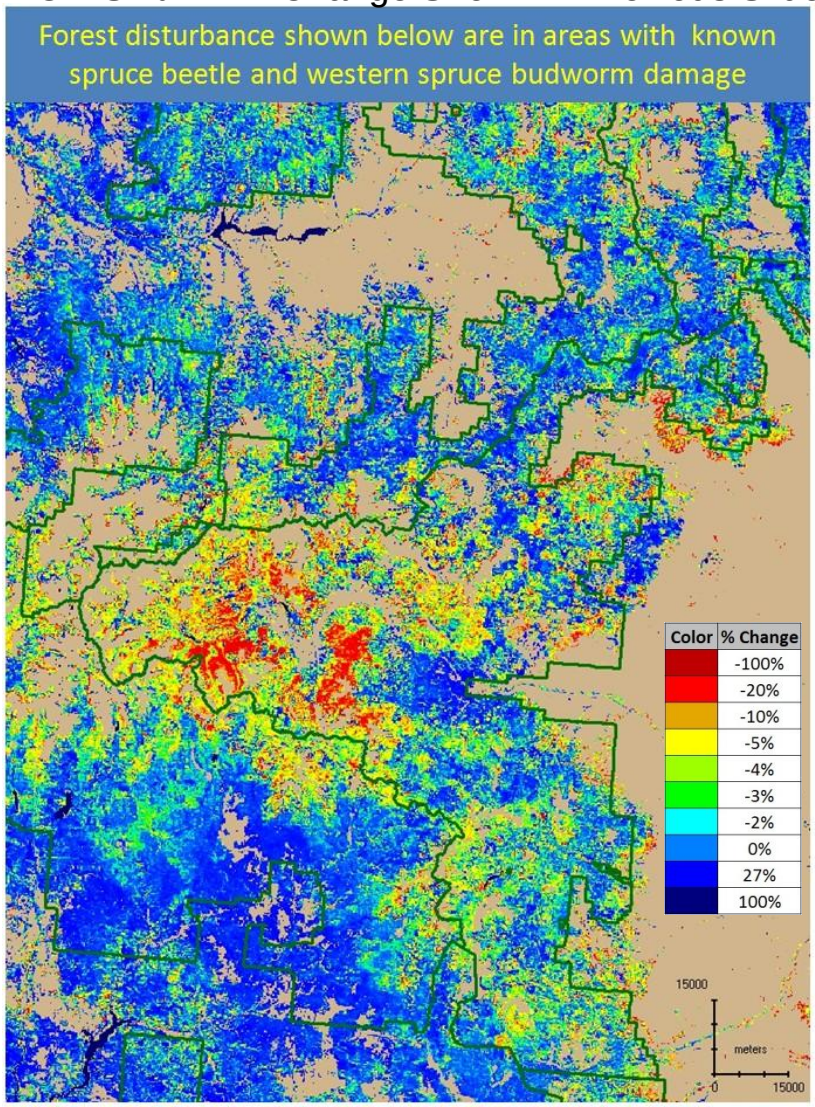
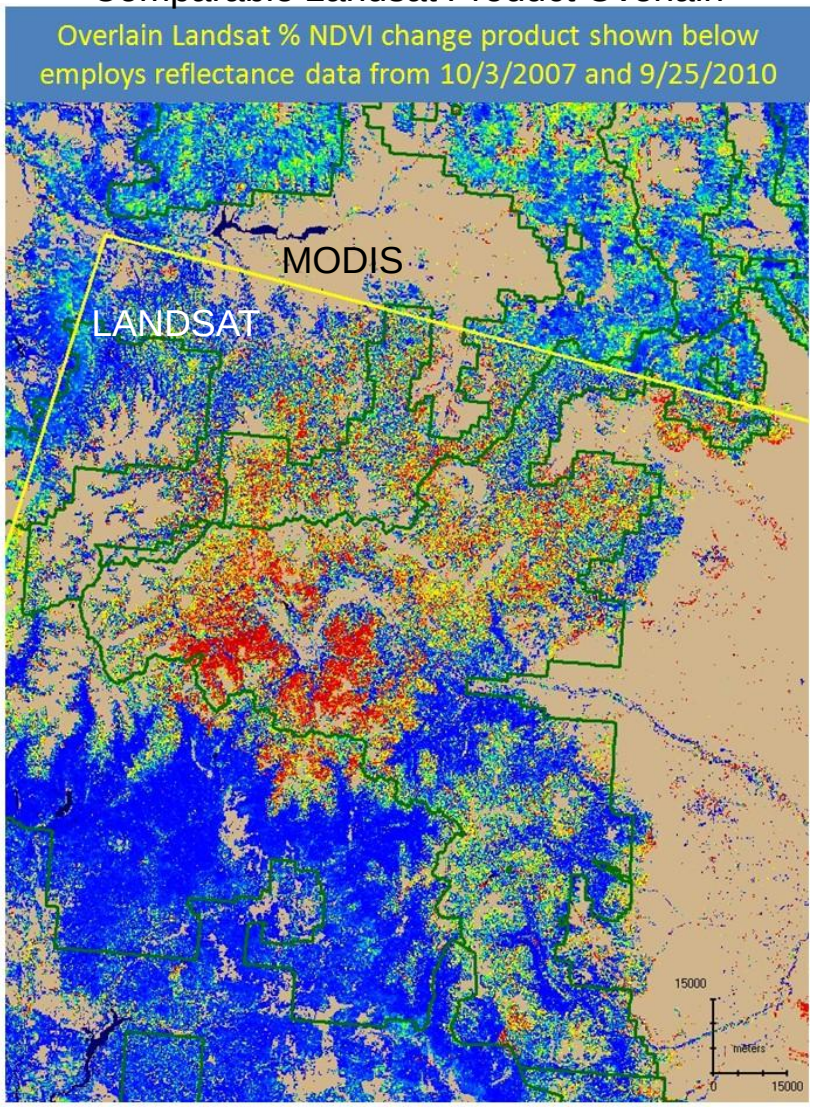
MODIS % NDVI Change Shown in Previous Slide

Comparable Landsat Product Overlain





2010 FCAV View of Main Coastal Louisiana Swamp Forest Zone

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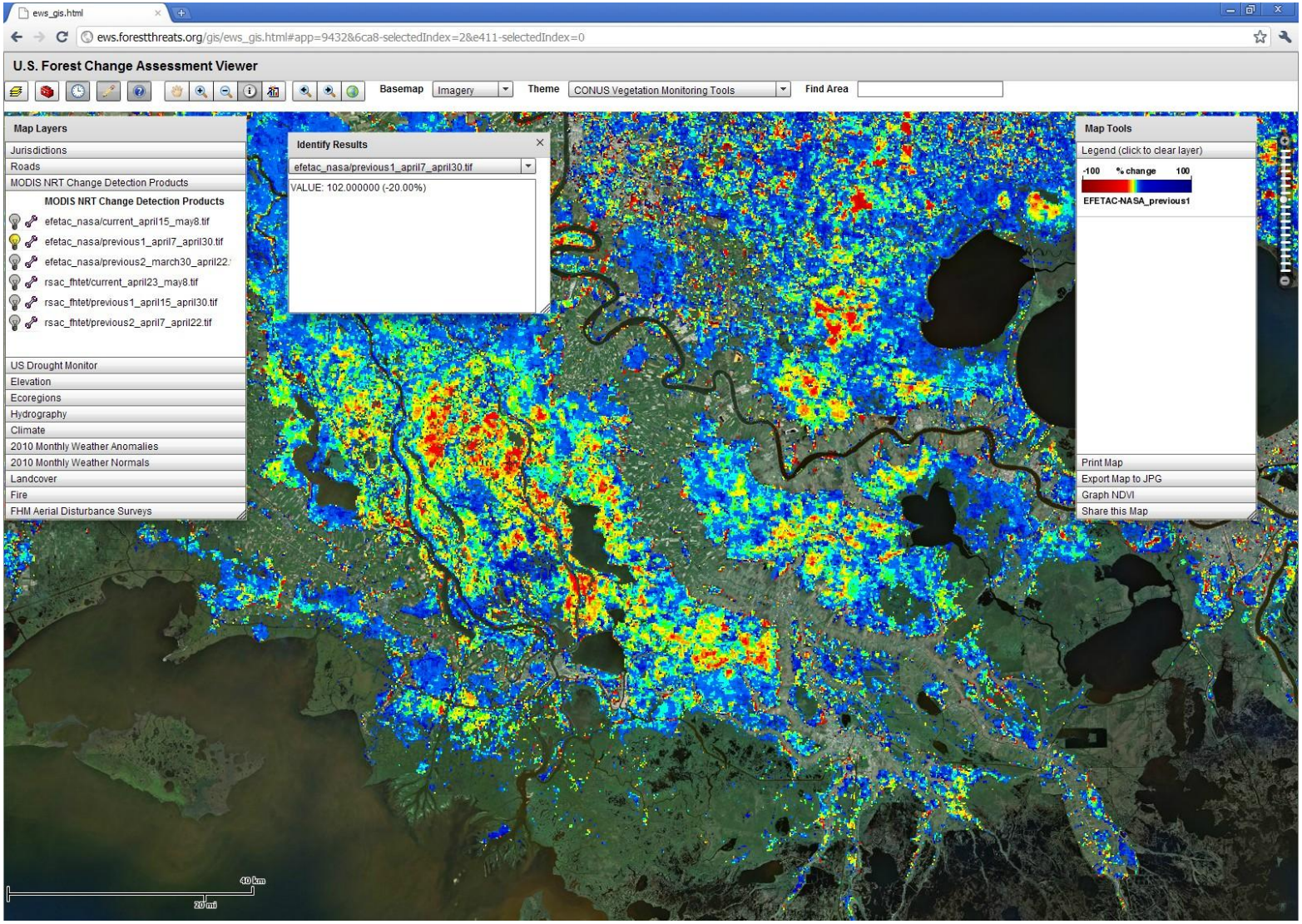
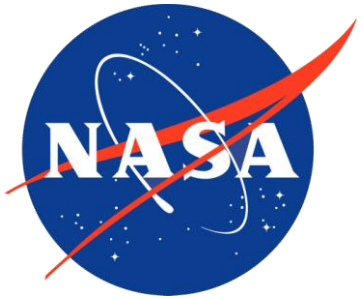
For more information, see: http://ews.forestthreats.org/gis/ews_gis.html



Final Remarks

- MODIS NDVI-based forest disturbance detection products have been developed, tested, and integrated into a prototypical EWS, the U.S. Forest Change Assessment Viewer
- To date, several biotic and abiotic-induced forest disturbances can be viewed on MODIS change products, providing such disturbances are regionally extensive – this aids USFS Threat Center customers
- Daily MODIS NDVI enabled better change products for the EWS
- Daily NDVI products also have great potential for more in depth assessments, such as storm damage and recovery studies
- Additional MODIS NDVI-based phenology products are being used as well for aiding the EWS. In particular, MODIS phenology image classification products are also being developed for the EWS
- Future work includes additional development of the FCAV tool as well as additional quantitative accuracy assessment of MODIS forest disturbance detection products



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