

# Eastern Forest Environmental Threat Assessment Center

USDA Forest Service, Southern Research Station, Asheville, NC

1. **Introduction**
2. ***ForWarn II***
3. **Disturbance Assessments (S2)**
  - **SPB/IPS Host Mapping (GA)**
  - **Puerto Rico, Hurricane Maria**
  - **Florida, Hurricane Irma**
4. **Expectations Going Forward**

*Photo by Paul Merten, Entomologist, Forest Service*



**2018 SGSF GIS Committee Annual Meeting**  
February 12-16, 2018    Mobile, AL







EFETAC

EASTERN FOREST  
ENVIRONMENTAL THREAT  
ASSESSMENT CENTER

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## Climate Influences the Male-Female Balance in Longleaf Pines

Researchers studying longleaf pines have discovered that temperature changes may be related to a shift in the density of pollen, with implications for cone crops, seed production, and future long-term sustainability.

[Learn more...](#)

*Photo by University of Georgia, Bugwood.org.*



### RECENT PUBLICATIONS [view all recent publications](#)

Landscape correlates of forest plant invasions: A high-resolution analysis across the eastern United States

Dominant forest tree mycorrhizal type mediates understory plant invasions

Translating national level forest service goals to local level land management: carbon sequestration

The effects of stream crossings on total suspended sediment in North Carolina Piedmont forests

Quantifying seasonal patterns in disparate environmental variables using the PolarMetrics R package

### LATEST NEWS [view all the latest news](#)

#### [Adaptations Help Illustrate Importance of Biodiversity](#)

Protection and restoration of open pine ecosystems in the Coastal Plain of southern Arkansas has been a high priority of the Arkansas Natural Heritage Commission and partners for over two decades.

#### [Bottomland Hardwood Restoration – What Happens Belowground?](#)

If something looks like a forest, does it act like a forest?

#### [U.S. Drought Monitor tracks drought across the nation](#)

View current drought conditions and forecasts from the U.S. Drought Monitor.

# ForWarn

Satellite-Based Change Recognition and Tracking

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SEARCH

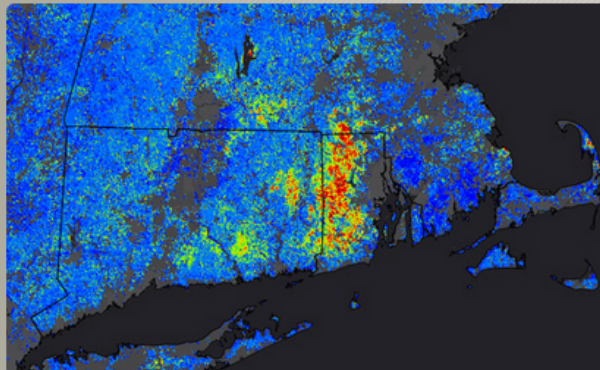
Home

Overview

Highlights

Products

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## Monitoring the state of Rhode Island's forests

Remote sensing technologies provide an increasingly efficient way to monitor large tracts of forest canopy conditions in near-real-time and seasonally. Observational systems, such as ForWarn's MODIS-based product line, provide a continuous weekly stream of observational...

[read more »](#)

3 OF 7

PREVIOUS PAUSE NEXT

### Get Started

ForWarn provides near-real-time tracking of vegetation changes across landscapes in the United States. Useful for both monitoring disturbance events as well as year-to-year variability, derived products can also be used to develop insights into seasonal and inter-annual dynamics.

» [Introduction to ForWarn](#)

» [Data Access](#)

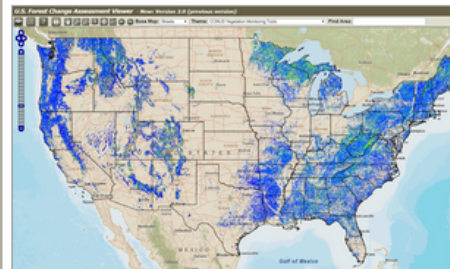
» [Sign up for updates](#)

» [Contact Us](#)

### Forest Change Assessment Viewer

The Forest Change Assessment Viewer provides a vegetation change recognition and tracking system for ForWarn that uses high-frequency, moderate resolution satellite data.

#### FORWARN Viewer



### Recent News

#### [ForWarn featured in NASA Earth Observatory](#)

11/16/2016 - 11:03 Sap-sucking insects called hemlock woolly adelgids are draining the life from a common evergreen tree in the eastern United States. Once the non-native bugs become well-established, the consequences...

#### [Featured in Compass Magazine: Here Today or Here to Stay?](#)

09/22/2016 - 09:47 Some disturbances come and go, leaving forests no worse for the wear. Hailstorms, insect defoliations, and light prescribed fires, for example, commonly occur early in the growing season, but...

#### [ForWarn data on Okefenokee National Wildlife Refuge presented at Texas fire conference](#)

11/23/2015 - 13:49 ForWarn team members attended the 2015 Association for Fire Ecology Meeting in San Antonio, TX in November 2015 to present research on long-term monitoring based on ForWarn's NDVI products. You can...

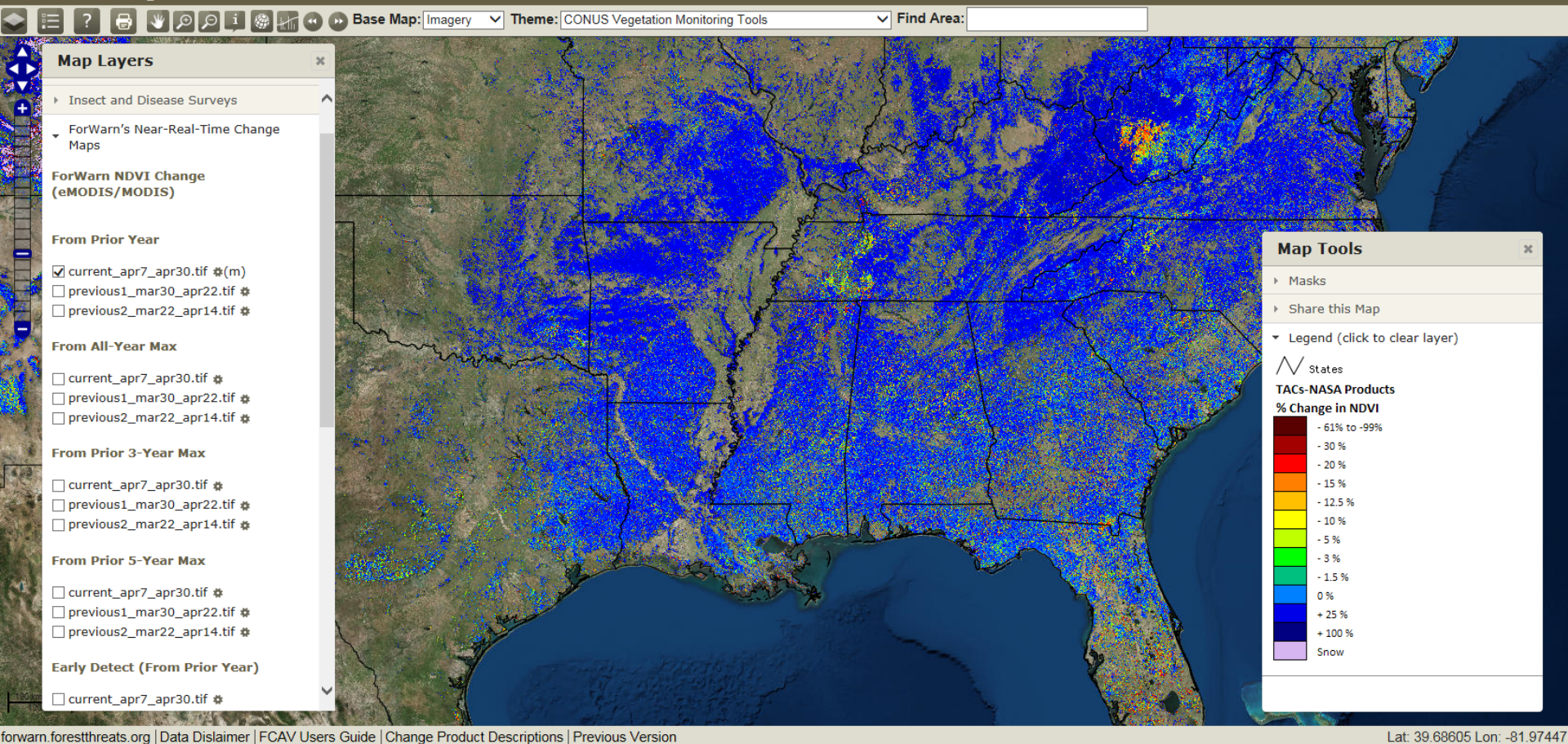
[more news »](#)





<https://forwarn.forestthreats.org/fcav2>

# U.S. Forest Change Assessment Viewer



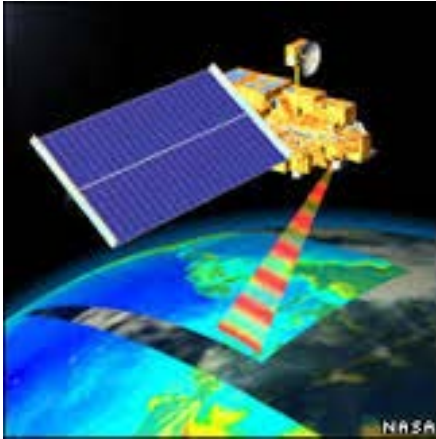
forwarn.forestthreats.org | Data Disclaimer | FCAV Users Guide | Change Product Descriptions | Previous Version

Lat: 39.68605 Lon: -81.97447

## ForWarn point of contact

Bill Christie, Eastern Forest Environmental Threat Assessment Center  
[wchristie@fs.fed.us](mailto:wchristie@fs.fed.us) 828.257.4370





*strategic*



*tactical*

## *ForWarn's Context*

- The *ForWarn* System covers essentially 100% of the forests within the lower 48 United States every 8 days
- **Tier 1: Strategic** – The *ForWarn* system routinely monitors wide areas at coarse resolution, repeated frequently – it produces alerts or warnings that forest vegetation at particular locations may be affected by forest threats
- **Tier 2: Tactical** – Airborne overflights and ground inspections of areas of potential interest – Insect and Disease Surveys (IDS) monitoring – to determine if such warnings are confirmed and become alarms
- The two tiers are complementary:
  - *Tier 1 can be used to optimally direct the labor-intensive efforts of Tier 2, which are limited in coverage and frequency*
- The two different systems can support each other well



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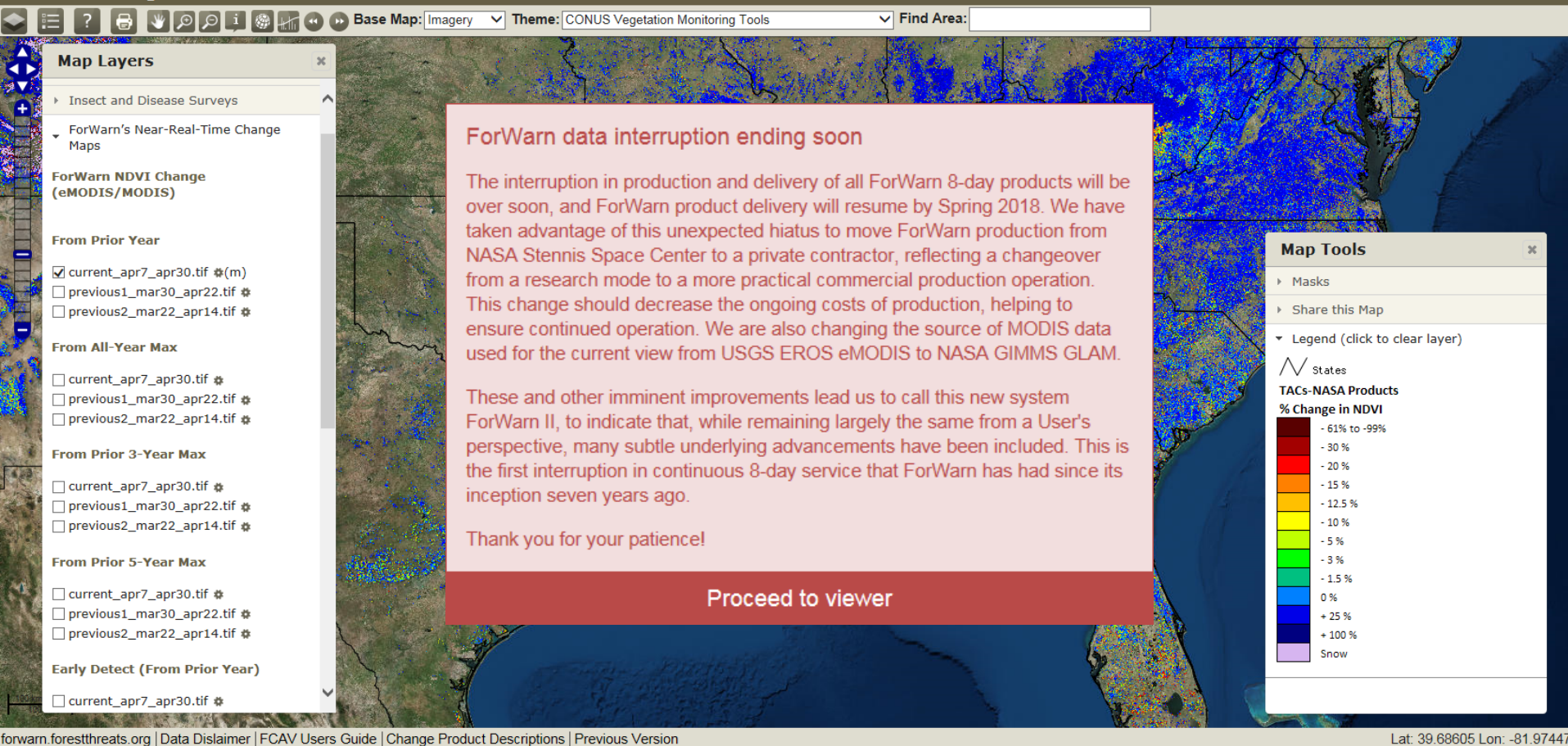






<https://forwarn.forestthreats.org/fcav2>

## U.S. Forest Change Assessment Viewer





*ForWarn II Server*  
at ERC Asheville

## ***Background***



- Our long-term partner, **NASA Stennis Space Center** was no longer allowed to perform "**Applied Science**" work
- This forced a *ForWarn* interruption and an "opportunity" for changes
- Our three *ForWarn* NASA colleagues transferred to **Leidos**, a nationally-known consulting and subcontracting company, assuring continuity
- EFETAC established a new sole-source contract with Leidos for *ForWarn* production and development
- Moved *ForWarn* server computers to Asheville, NC
- Moving from a more Research-oriented environment to a more Production-oriented environment, with an associated reduction in production costs
- Ultimately plan to move Production to virtual "Cloud Computing" - More Sustainable for the Future



# A New Name: *ForWarn II*

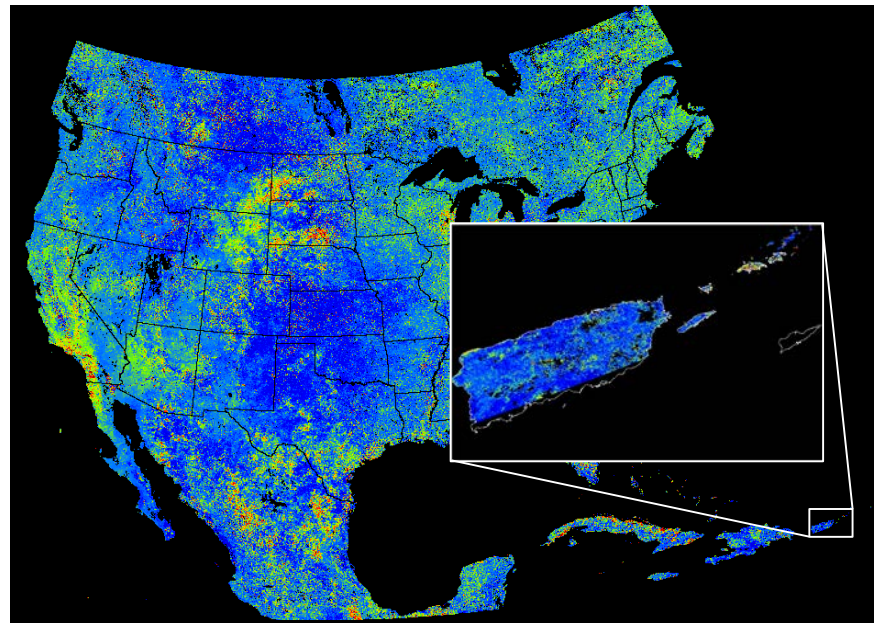
## What Changed?

*'kinda the same, but kinda different'*

- No longer using expedited-MODIS from USGS EROS Data Center – current view imagery has switched over to using **NASA Goddard GIMMS/GLAM** (*Global Inventory Modeling and Mapping Studies/GLocal Agricultural Monitoring*)
- EFETAC, Leidos, UNCA-NEMAC, and Oak Ridge National Lab remain active partners
- *Forwarn II* production tests and evaluations are underway now
- Hope to be up and running by the beginning of the 2018 growing season

Few changes from the *ForWarn* User's perspective:

- Same *ForWarn* Viewer
- Same *ForWarn* Algorithm
- Cross-border view, incl. PR-VI
- **Evaluating a new product...**

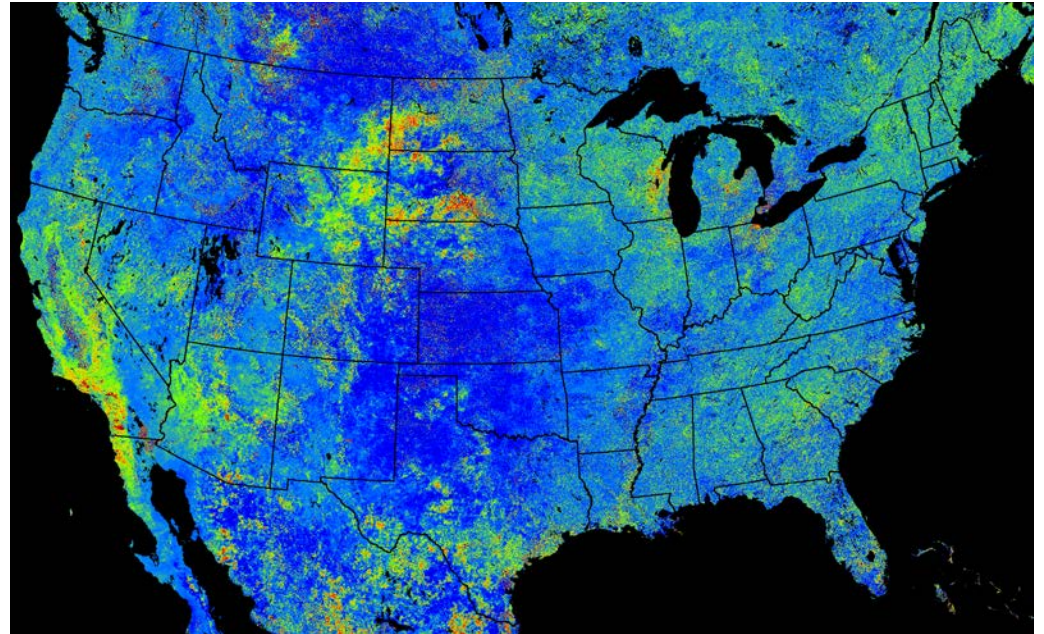




# The 'Square Root' Product

Standard, NDVI 'Percent Change' Algorithm:  $(\text{Current} - \text{Baseline}) / \text{Baseline}$

- This Ratio implicitly assumes that greener vegetation can withstand a greater decrease in NDVI
- The Denominator drags down the impact of decreasing NDVI
- The same absolute decrease in NDVI will show less change in the *ForWarn* map within really green vegetation, and will show more change within less green vegetation
- Grasses, herbs and shrubs are hyper-sensitive to disturbance, while tree responses are muted (especially evergreens)
- Take the 'square root' of the denominator instead
- **RESULT** - trees retain their relative sensitivity to even minor NDVI drops, while grasses, herbs and shrubs have more muted responses





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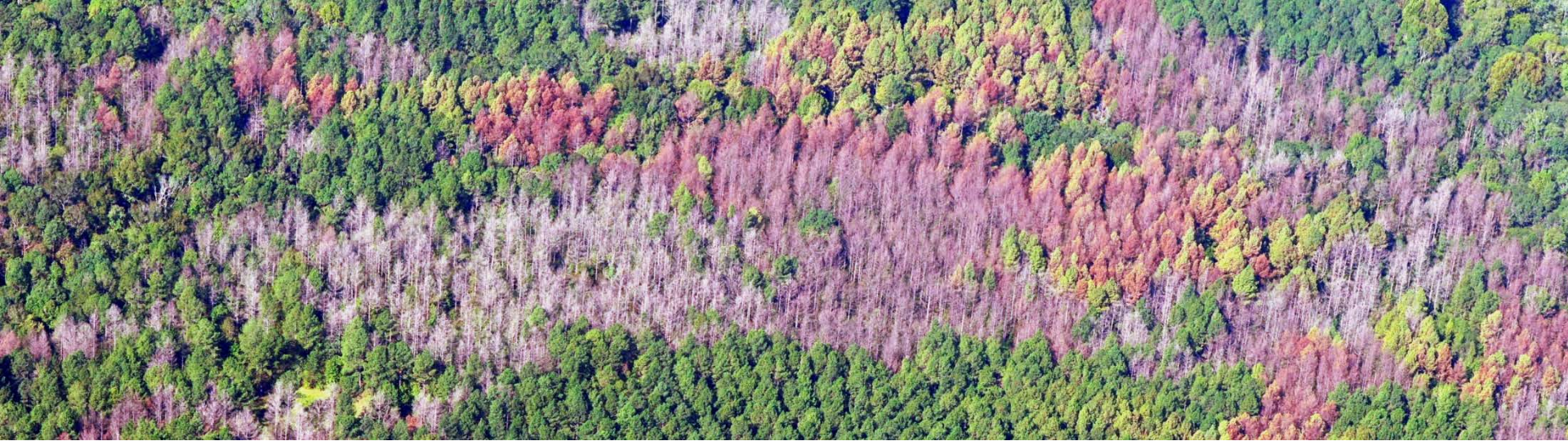
*Photo by Paul Merten, Entomologist, Forest Service*



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## Use of Sentinel-2 10m imagery in SPB/lps Mapping

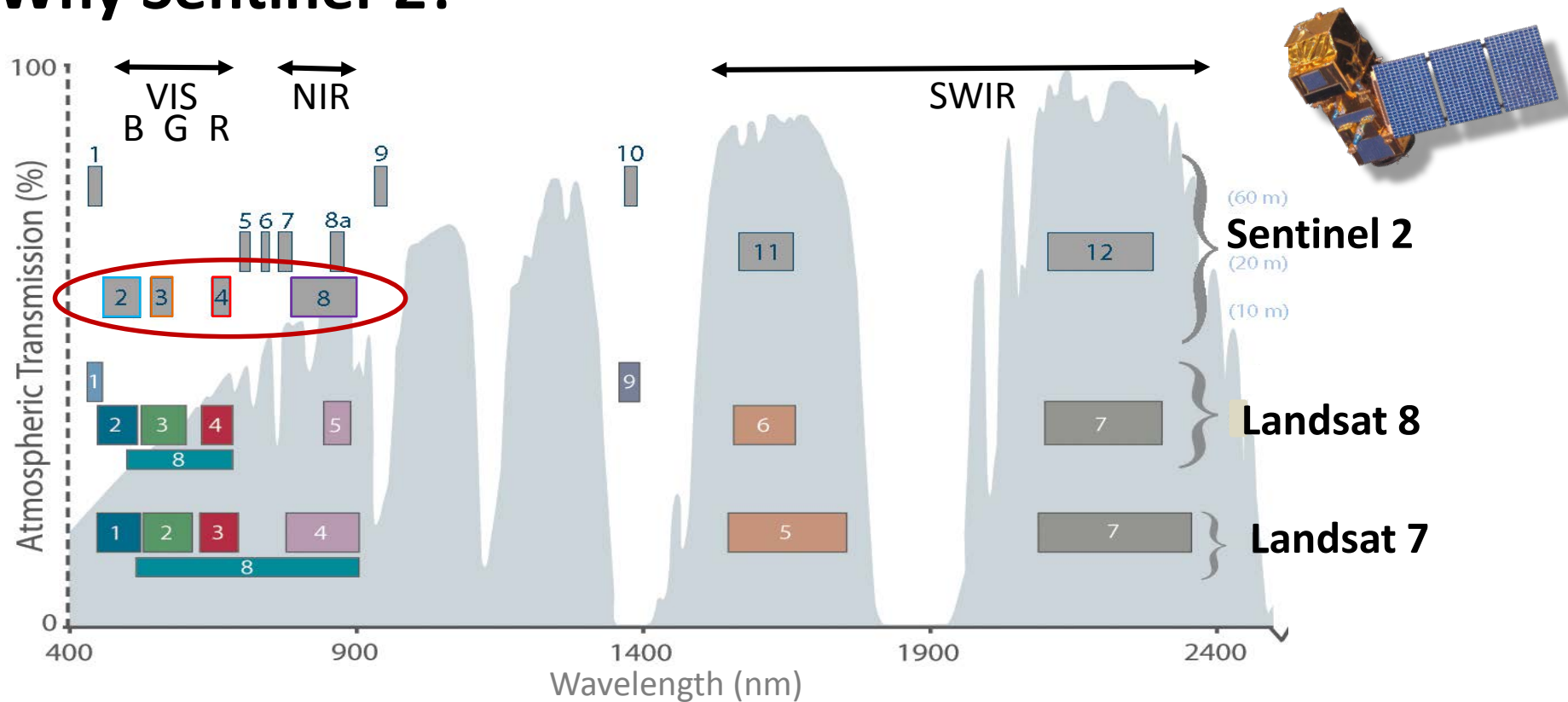


1. *Manual Image Interpretation*
2. *Percent Change in NDVI*
3. *Host Map Differencing*





# Why Sentinel-2?



Satellite, Instrument	Spatial resolution	Temporal resolution	Historical Availability	Source
Sentinel-2a/b, MSI	<b>10m</b> (20m)	<b>5 day</b> (both)	Jun 2015 -	Euro. Space Agency
Landsat 8, OLI	30m (15m)	8 to 16 day	2013 -	US NASA
Landsat 7, ETM+	30m (15m)	(with both)	1999 - ...	
Landsat 5, TM, MSS	30m (15m)		1984-2012	
Terra/Aqua, MODIS	500m (250m)	2 passes/day	2000 -	US NASA



# What does a 10m spatial resolution tell us?

Plantation pine and hardwoods – Oconee National Forest, GA





# Typically-used spatial resolutions of Sentinel-2 (10m) compared to Landsat (30m)





# Key monitoring question:

- Can we capture and map progressive mortality as it unfolds?

*Southern pine beetles, Oconee NF, GA*

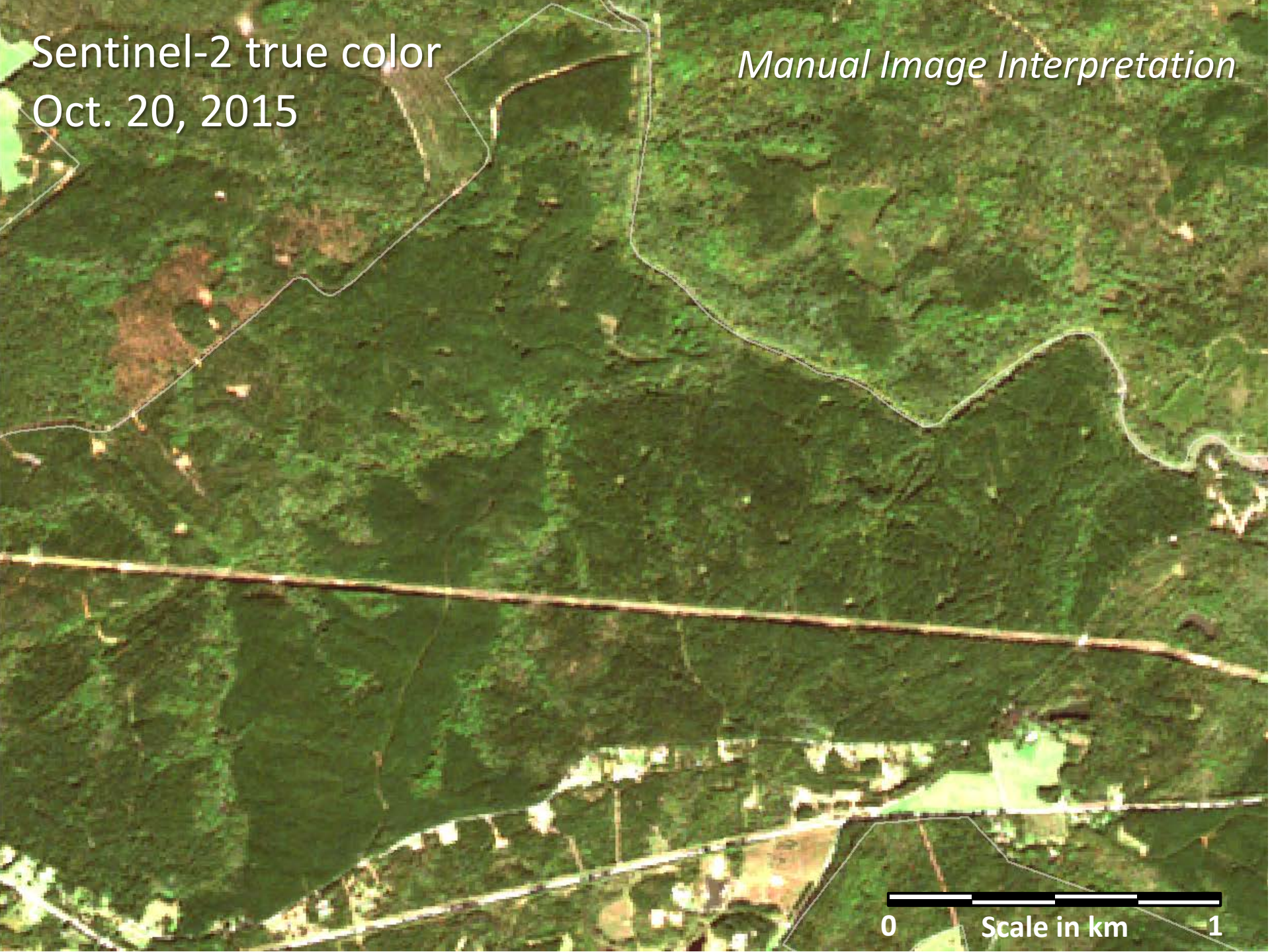


Sentinel-2



Sentinel-2 true color  
Oct. 20, 2015

*Manual Image Interpretation*

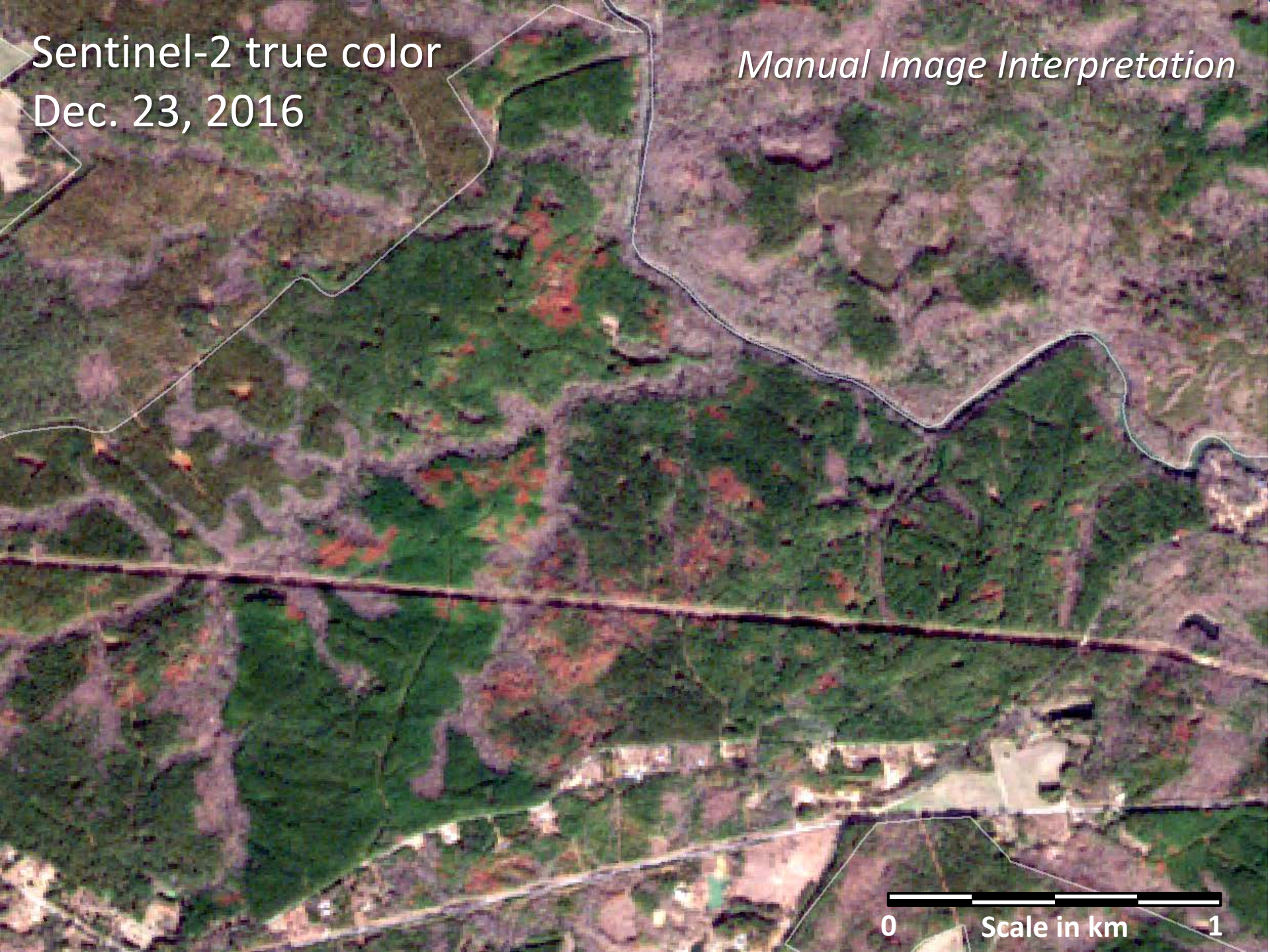


0 Scale in km 1



Sentinel-2 true color  
Dec. 23, 2016

*Manual Image Interpretation*



0 Scale in km 1



Sentinel-2 true color  
May 2, 2017

*Manual Image Interpretation*



0

Scale in km

1



Sentinel-2 true color  
Sep. 19, 2017

*Manual Image Interpretation*

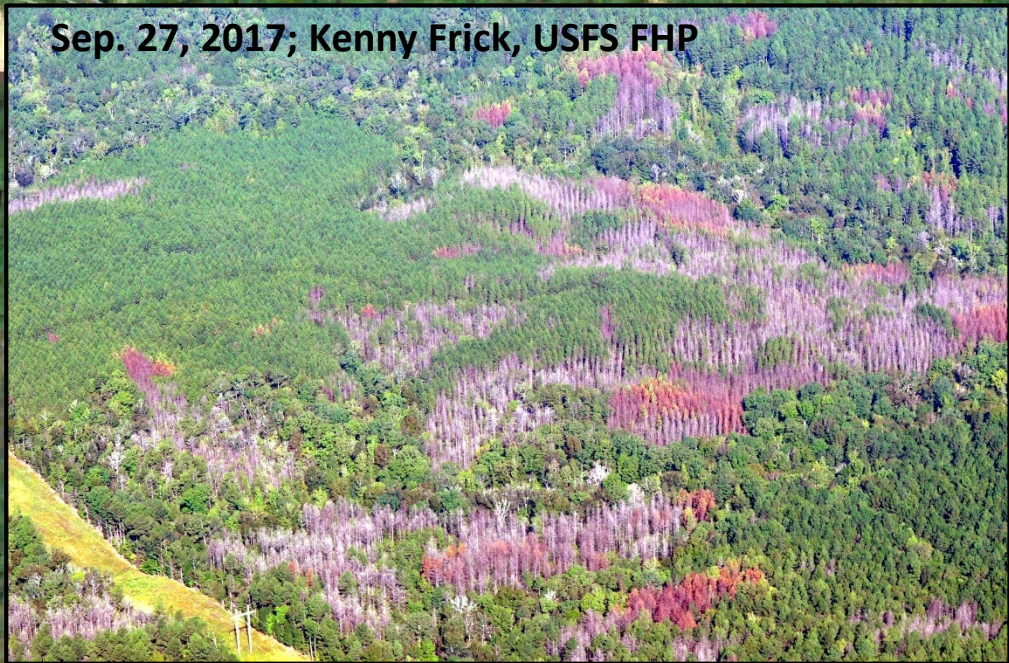


0 Scale in km 1



Sentinel-2 true color  
Sep. 19, 2017

Sep. 27, 2017; Kenny Frick, USFS FHP



VIEW

0 Scale in km 1



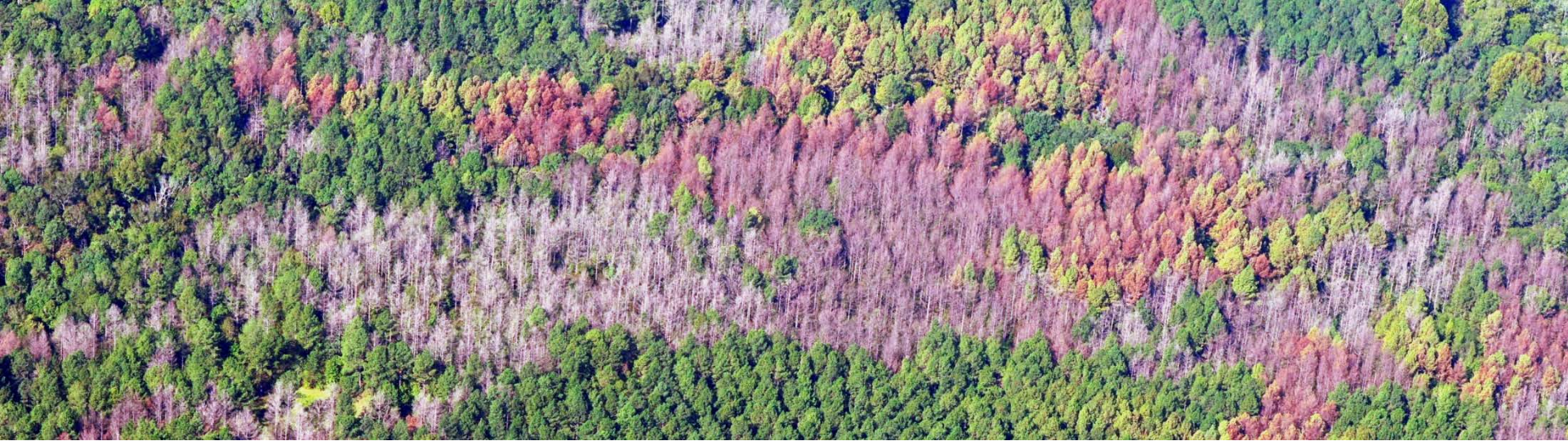
Sentinel-2 true color  
Jan. 2, 2018

*Manual Image Interpretation*



0 Scale in km 1





# Use of Sentinel-2 10m imagery in SPB/lps Mapping



1. *Manual Image Interpretation*
2. ***Percent Change in NDVI***
3. *Host Map Differencing*

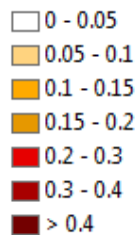




1-year change in winter NDVI  
Dec. 23, 2016  
vs. Jan. 2, 2018

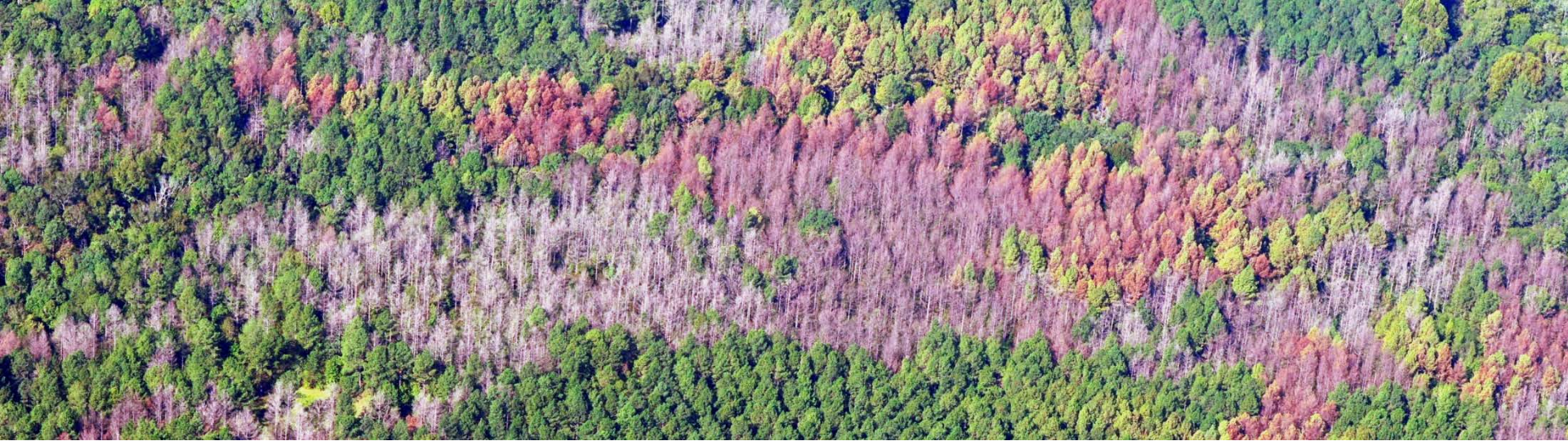
NDVI 'Percent Change' Algorithm:  
 $(\text{Current} - \text{Baseline}) / \text{Baseline}$

Δ NDVI



0 Scale in km 1





## Use of Sentinel-2 10m imagery in SPB/lps Mapping



1. *Manual Image Interpretation*
2. *Percent Change in NDVI*
3. ***Host Map Differencing***





Sentinel-2 CIR 843rgb

**Winter NDVI-max composite: 11/15/2016 – 02/28/2017**

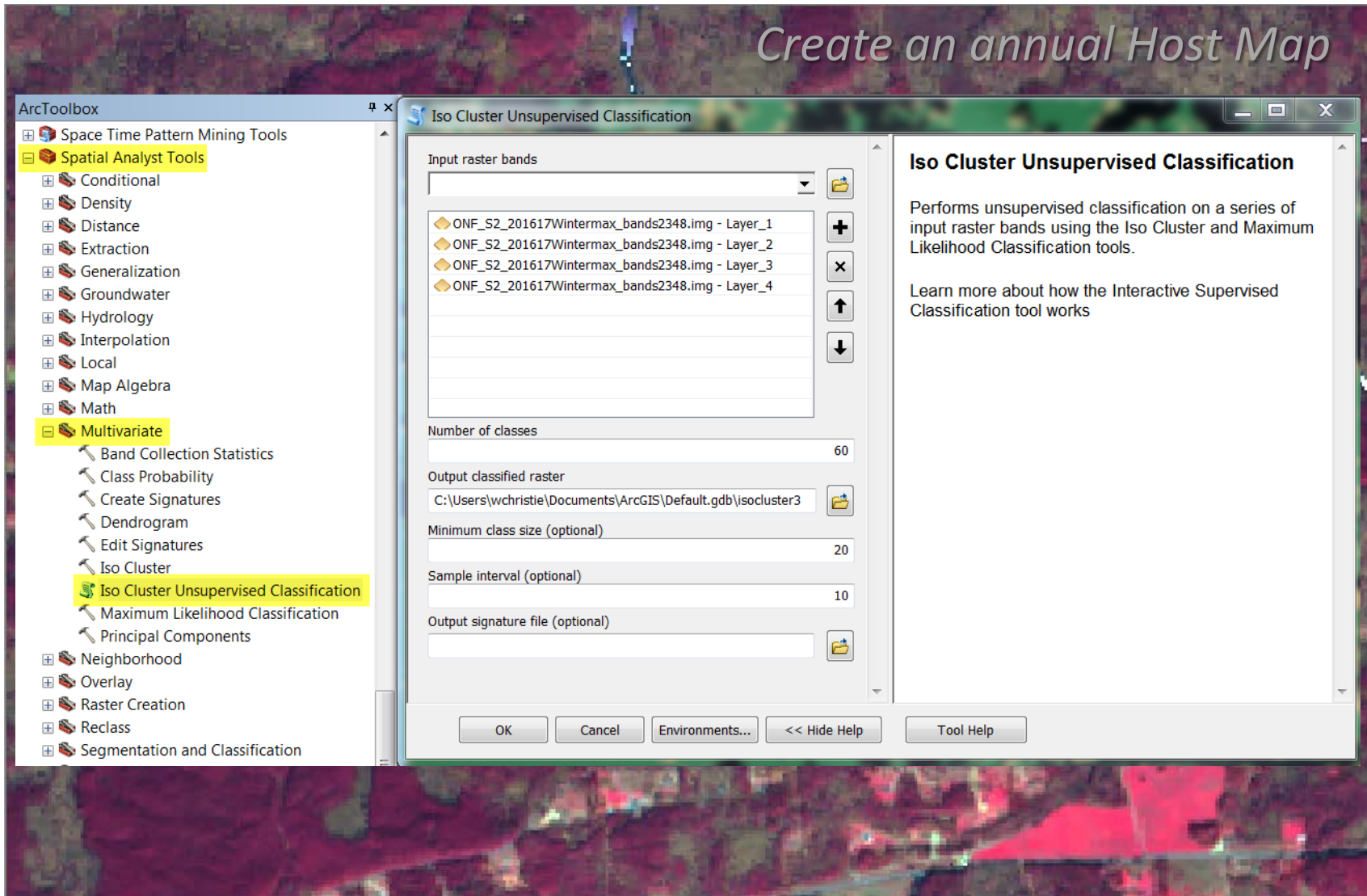




# Unsupervised Classification

## Clustering to create evergreen binary mask for winter, 2017

*Create an annual Host Map*

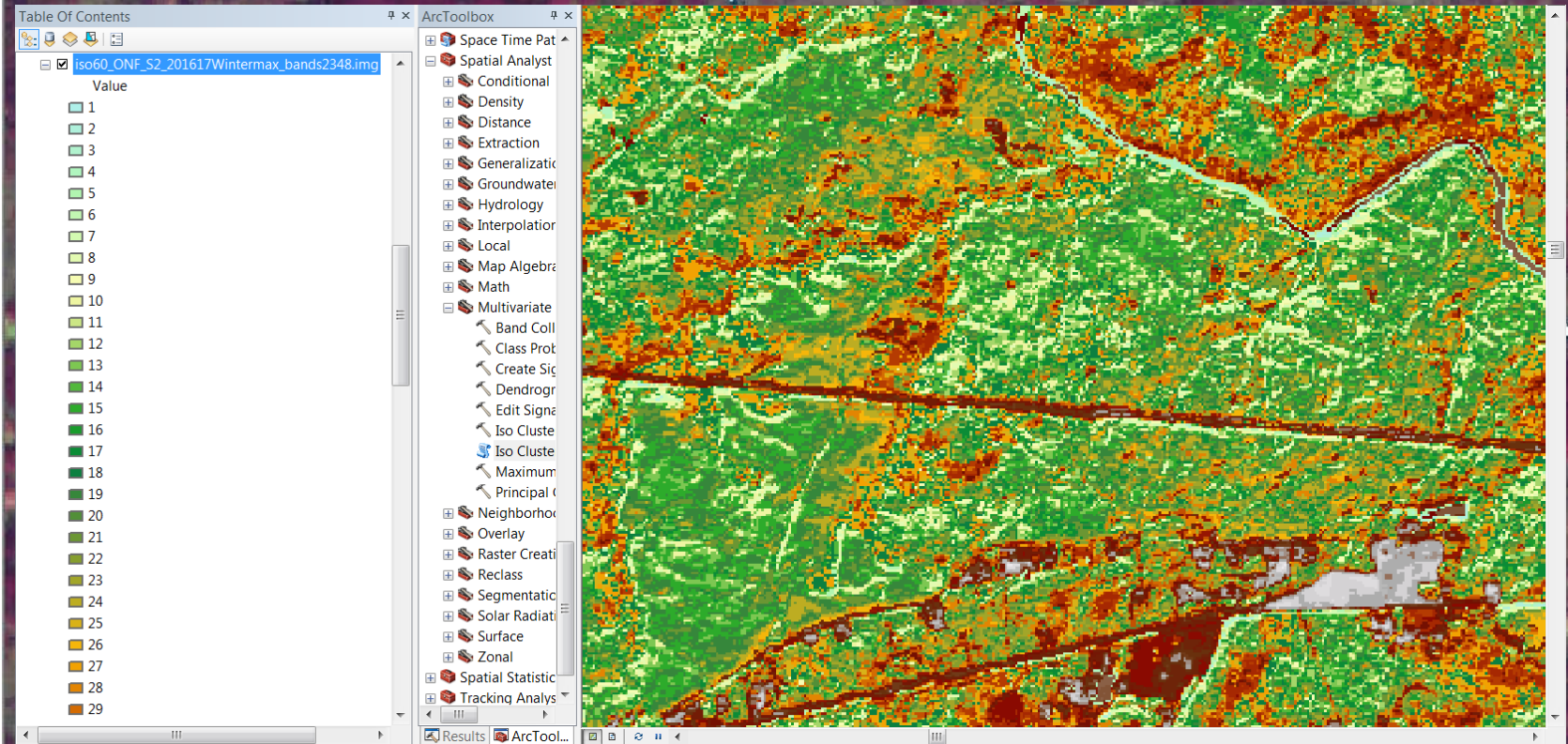




# Unsupervised Classification

## Clustering to create evergreen binary mask for winter, 2017

*Create an annual Host Map*

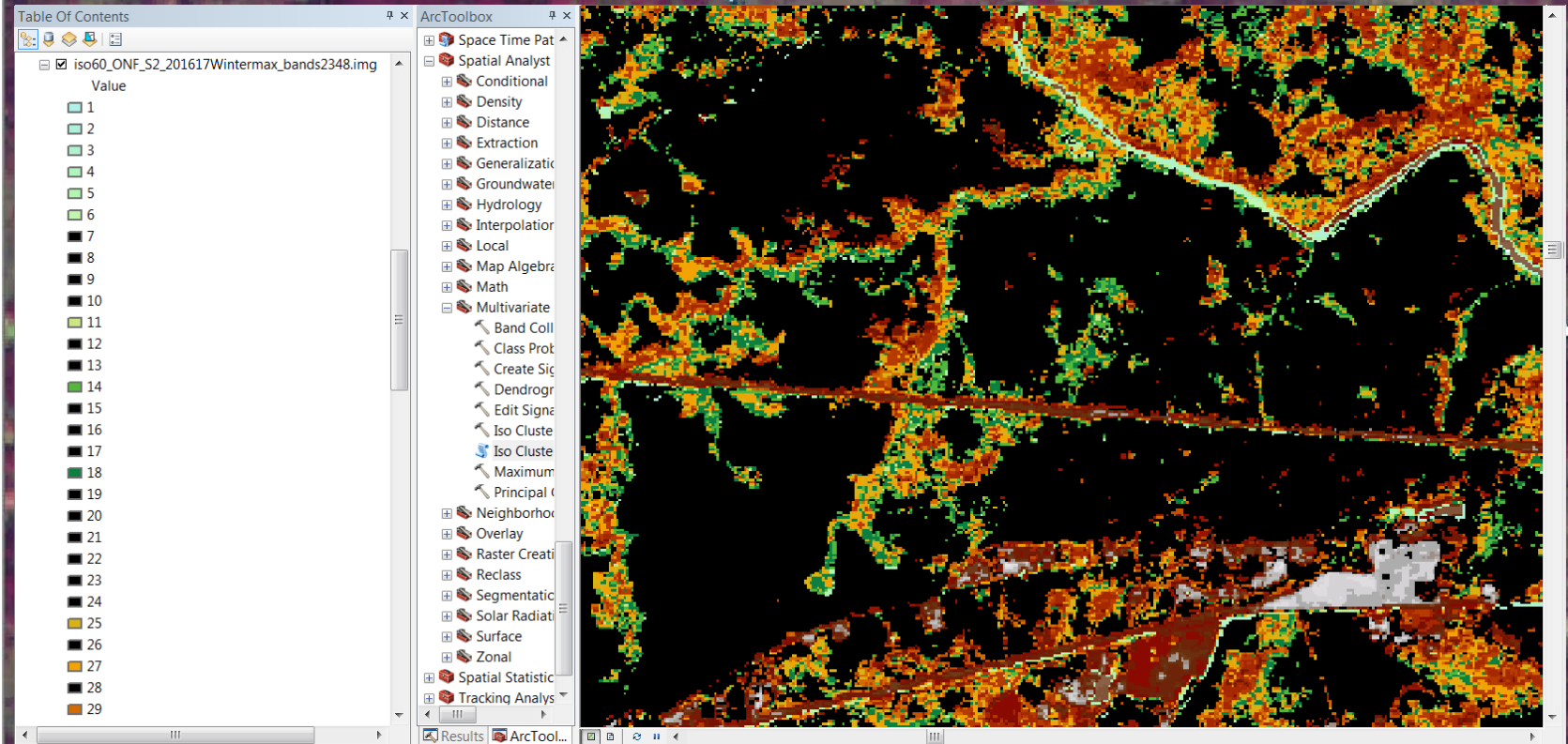




# Unsupervised Classification

## Clustering to create evergreen binary mask for winter, 2017

*Create an annual Host Map*





# Unsupervised Classification

## Clustering to create evergreen binary mask for winter, 2017





Sentinel-2 CIR 843rgb

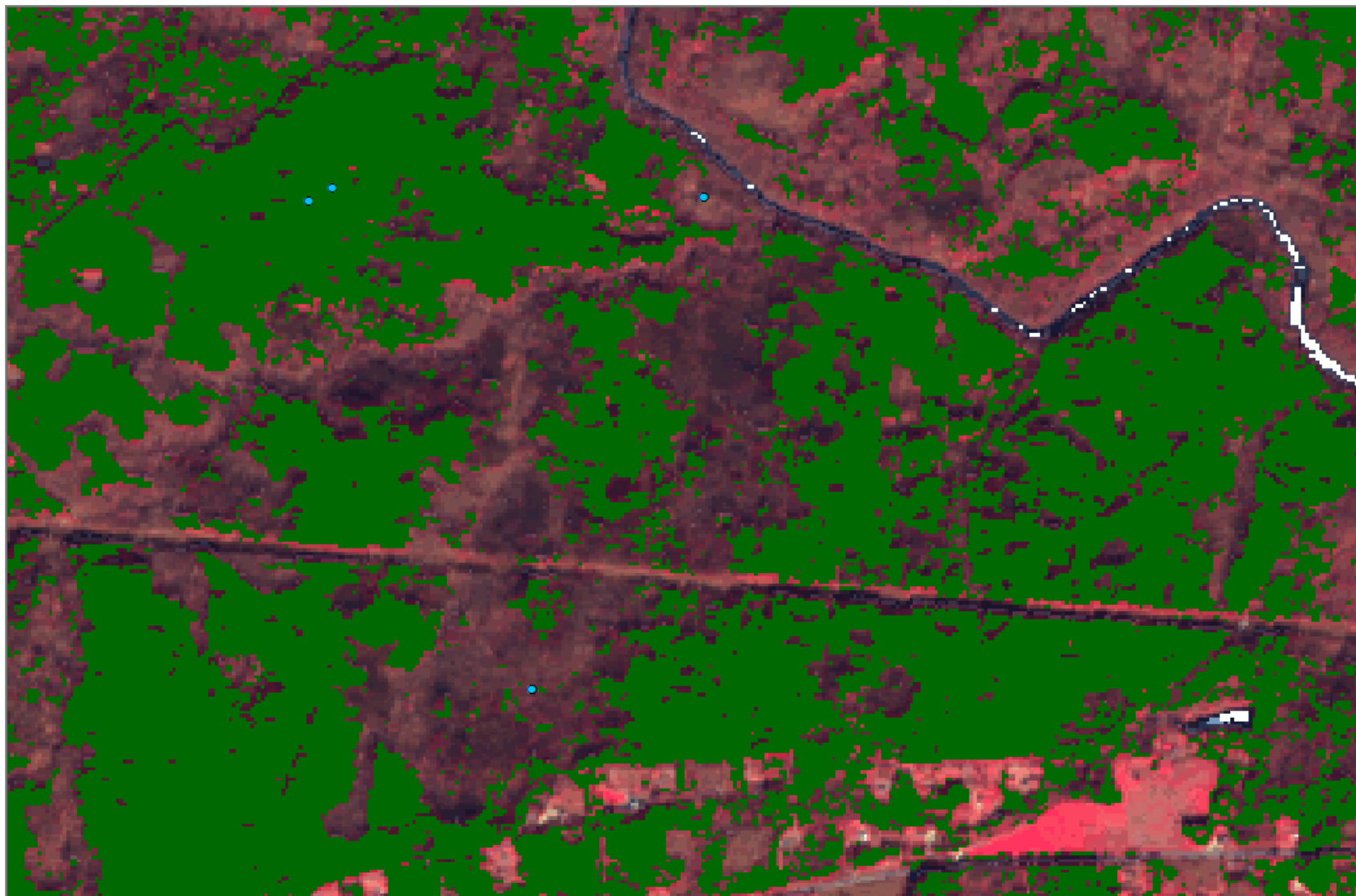
**Winter NDVI-max composite: 11/15/2017 – 02/28/2018**





# Unsupervised Classification

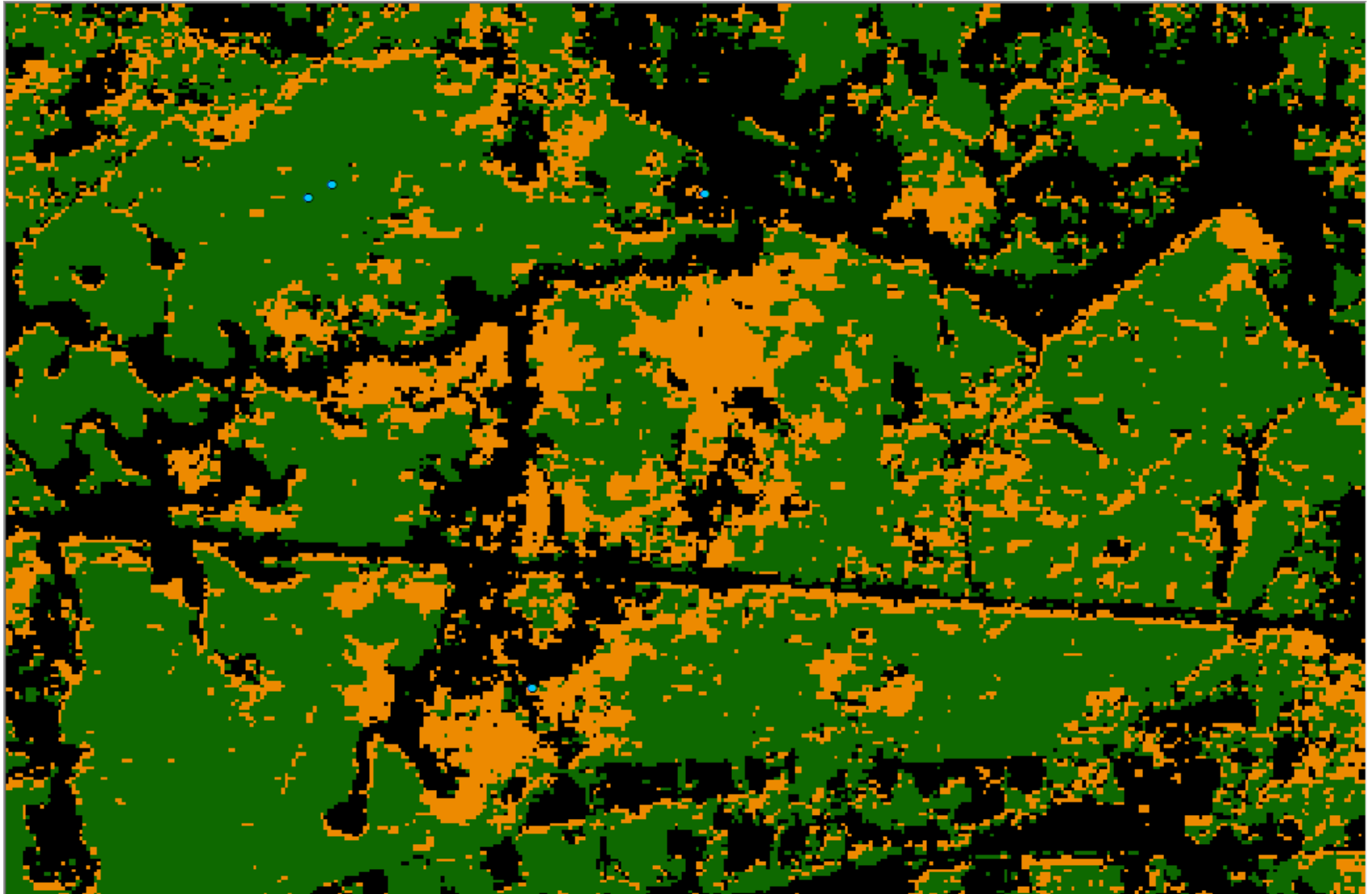
## Clustering to create evergreen binary mask for winter, 2018





# Differencing annual Host Maps

## **Pine beetle mortality and logging during 2017** (orange)





# Benchmark Example

## Statewide dNDVI Calculation from Annual Composites

The screenshot displays the Google Earth Engine web interface. The top navigation bar includes the Google Earth Engine logo, a search bar, and user information (srs4854gee). The left sidebar shows a list of scripts, with 'Christie/R8 S2 SBPHOST 201618 Wintermax ST...' selected. The main editor area contains a JavaScript script that loads a S2 2016-2017 wintermax image collection, filters it by date and bounds, and adds a new band named 'dNDVI'. The right sidebar features an 'Inspector' panel showing the console output, which lists the loaded image collection (335 elements) and the resulting image (17 bands). Below the map, a 'Layers' panel shows the active layer 'S2CIR201617Wintermax' and its visualization parameters, including a range of 94 to 2200 and a gamma of 1.00.

Google Earth Engine

Search places and datasets...

Help srs4854gee

Scripts Docs Assets

Christie/R8 S2 SBPHOST 201618 Wintermax ST... Get Link Save Run Reset

```
// Load a S2 2016-2017 wintermax
var S2201617Wintermax = ee.ImageCollection('COPERNICUS/S2')
  .filterDate('2016-11-16', '2017-03-17')
  .filterBounds(table);

// Add NDVI as a band named NDVI to image layer stacks
var addNDVI = function(S2201617Wintermax) {
```

Inspector Console Tasks

Use print(...) to write to this console.

- ImageCollection COPERNICUS/S2 (335 elements) JSON
- Image (17 bands) JSON
- ImageCollection COPERNICUS/S2 (478 elements) JSON
- Image (17 bands) JSON

Layers

- Layer 7
- MS\_Bienville\_NF
- dNDVI post div pre
- ☒ S2CIR201617Wintermax
- MS S2 2018 Wintermax NDVI
- S2CIR2017Wintermax
- MS S2 2017 Wintermax NDVI

S2CIR201617Wintermax visualization parameters

☐ 1 band (Grayscale) ☒ 3 bands (RGB)

B8 B4 B3

Range: 94 - 2200 Custom

Opacity: 1.00 Gamma 1.00 Palette

Import Apply Close

### Run Times:

- create 2017 and 2018 statewide winter max-NDVI composite, calculate dNDVI and draw it – 2 sec.
- download the dNDVI result to your Google Drive – 27 min; file size to download from Drive – 5.8GB



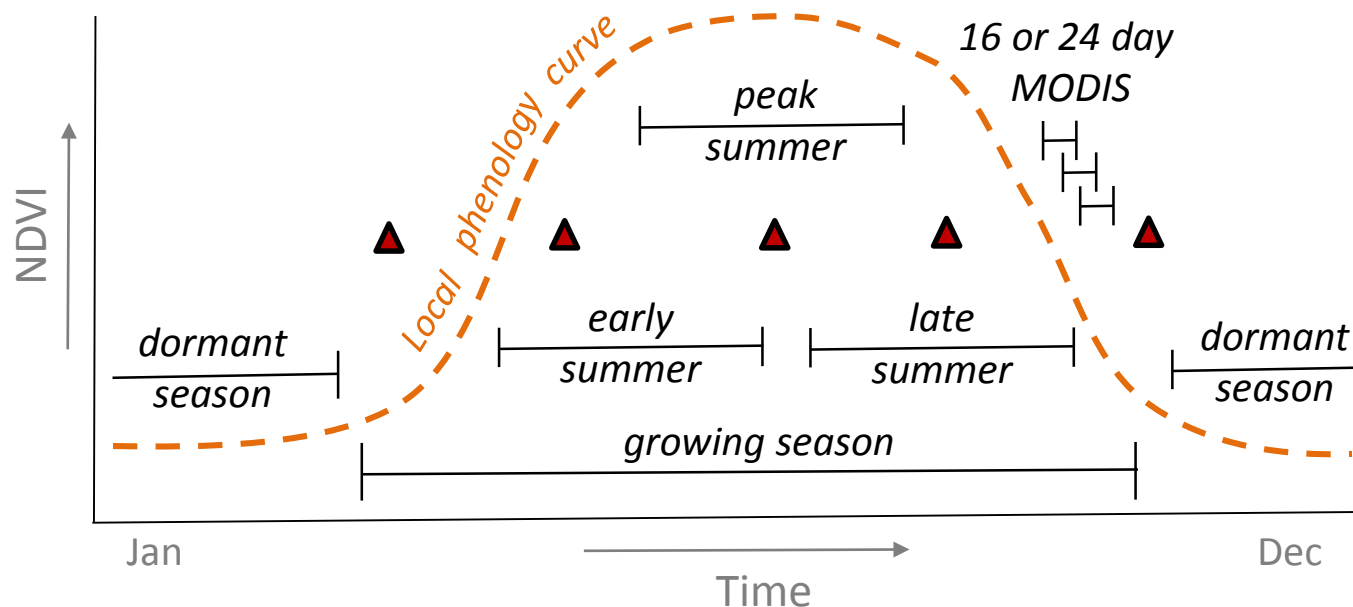
Can we get more accurate and efficient answers with multi-date compositing? *That depends.*

Image stack ↑

**Approaches for period compositing**  
*Best quality?*  
*Highest NDVI?*  
*Most recent?*

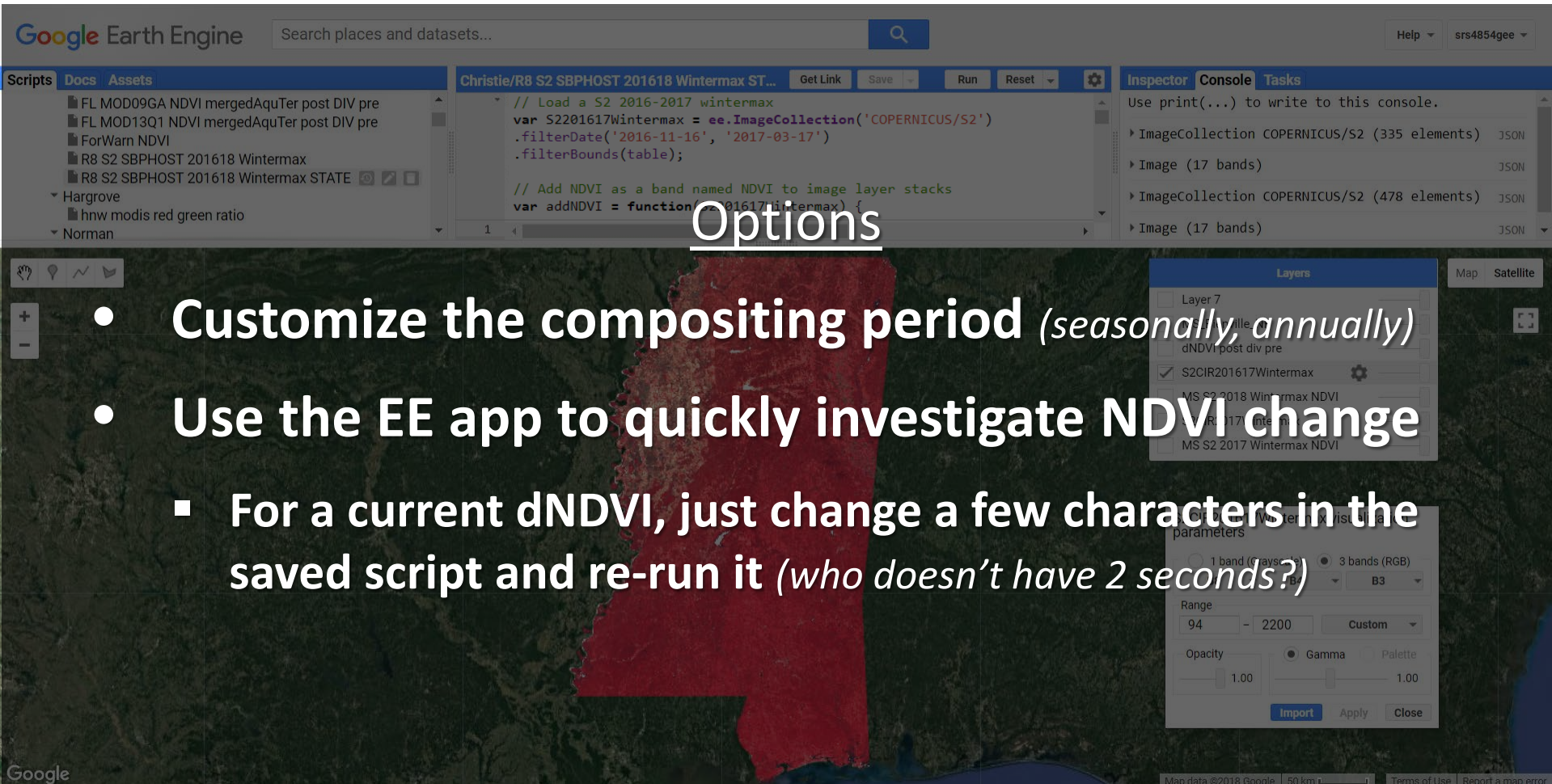
**Composites provide “window-resolution” answers:**

▲ This can be problematic when a disturbance or rapid recovery occurs at different times during a long composited window.





# Earth Engine Example Using 10m Sentinel2 Statewide dNDVI Calculation from Annual Composites



**Options**

- **Customize the compositing period** (*seasonally, annually*)
- **Use the EE app to quickly investigate NDVI change**
  - For a current dNDVI, just change a few characters in the saved script and re-run it (*who doesn't have 2 seconds?*)

## Run Times:

- create 2017 and 2018 statewide winter max-NDVI composite, calculate change and draw dNDVI – 2 sec.
- download the dNDVI result from EE to Google Drive – 27 min.; then from Drive to local – 5.8GB



# Sources for Sentinel 2 imagery

Google Earth Engine

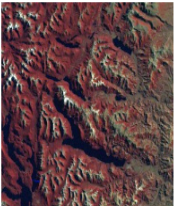
FAQTIMELAPSEDATASETS CASE STUDIESPLATFORM BLOGSIGN UP

DATASETS

TERMS OF SERVICEPRIVACYABOUT GOOGLE

Earth Engine's [public data catalog](#) includes a variety of standard Earth science raster datasets. You can [import](#) these datasets into your script environment with a single click. You can also upload your own [raster data](#) or [vector data](#) for private use or sharing in your scripts.

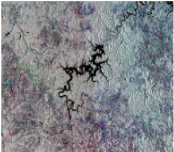
IMAGERYGEOPHYSICALCLIMATE & WEATHERDEMOGRAPHIC



### Landsat

Landsat, a joint program of the USGS and NASA, has been observing the Earth continuously from 1972 through the present day. Today the Landsat satellites image the entire Earth's surface at a 30-meter resolution about once every two weeks, including multispectral and thermal data. Earth Engine makes this data available in its raw form, as TOA-corrected reflectance, and in various ready-to-use computed products such as NDVI and EVI vegetation indices.

[Search Landsat data in Earth Engine.](#)



### Sentinel

ESA's Sentinel-1 mission uses radar to image the Earth in all weather conditions, even at night. The satellites capture C-band synthetic aperture radar (SAR) image data at 30- to 120-meter resolution in several polarization modes. Earth Engine includes a growing collection of Sentinel-1 data preprocessed using the Sentinel 1 Toolbox.

[View Sentinel data in Earth Engine.](#)

The free, full and open data policy adopted for the Copernicus programme foresees access available to all users for the Sentinel data products, via a simple [self-registration](#). News and further information about the service is available [here](#).

<https://sentinel.esa.int/web/sentinel/sentinel-data-access>

22 January 2018

A routine decontamination activity of the Sentinel-2A MSI is planned over a continuous period of roughly 24-hours between 07:10 03 February 2018 and 06:20 04 February 2018 UTC (corresponding approximately to between absolute orbits 13674 to 13687). During this time window no MSI acquisition will take place.

Lat: 33.360, Lon: -83.440, Scale: 1:36K

0 0.3 0.6mi

Show Metadata

Map Credits | Accessibility | FOIA | Privacy | Policies and Notices



# Sources for Sentinel 2 imagery

Google Earth Engine

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Sentinel Online



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You are here [Home](#) > [Data Access](#)

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### Access to Sentinel Data



**sentinel open access hub >**

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### Data Access

[Data Access Home](#)  
[Use Typologies and available Services](#)  
[User Support and Registration](#)  
[Access to Sentinel Data](#)

### Latest News

**[Sentinel-2A MSI decontamination between 03 and 04 February 2018](#)**  
22 January 2018

A routine decontamination activity of the Sentinel-2A MSI is planned over a continuous period of roughly 24-hours between 07:10 03 February 2018 and 06:20 04 February 2018 UTC (corresponding approximately to between absolute orbits 13674 to 13687). During this time window no MSI acquisition will take place.

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0 0.3 0.6mi

Show Metadata

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# Sources for Sentinel 2 imagery

The image displays the Sentinel2Look web application interface, which is used for viewing and processing Sentinel-2 satellite imagery. The interface includes a top navigation bar with links to Google Earth Engine, DATASETS, TERMS OF SERVICE, PRIVACY, and ABOUT GOOGLE. The main header features the ESA Sentinel Online logo and a row of satellite icons. The central area shows a satellite image of a coastal region with various overlays, including a red boundary line and black arrows. A sidebar on the left contains a 'Need Help?' link, 'Missions' information, and a 'You are here' section. A 'Modify Images' panel on the right allows users to adjust the image display, including setting the active date (17 Jan 2018), video format (Video for Windows (AVI)), and image display options (Active Date Only, Mosaic, Dynamic Image Refresh). The bottom of the interface shows the map coordinates (Lat: 33.360, Lon: -83.440, Scale: 1:36K) and a scale bar (0 to 0.6mi). The bottom right corner contains links for Map Credits, Accessibility, FOIA, Privacy, and Policies and Notices.

Google Earth Engine

FAQ TIMELAPSE DATASETS CASE STUDIES PLATFORM BLOG SIGN UP

**DATASETS**

TERMS OF SERVICE PRIVACY ABOUT GOOGLE

**esa** Sentinel Online

**USGS Sentinel2Look**

Need Help?

Missions

You are here

Acc

Lat: 33.360, Lon: -83.440, Scale: 1:36K

0 0.3 0.6mi

Show Metadata

**Modify Images**

**Active Date**

17 Jan 2018 17 Jan 2018

Video Format [Video for Windows (AVI)]

**Displaying 2 of 2 Images**

17 Jan 2018 S2

**Image Display**

☐ Active Date Only

☒ Mosaic

☒ Dynamic Image Refresh

**Image Enhancements**

☐ None

☒ Percent Clip

☐ 3 Std. Dev. Stretch

**Image Transparency**

off on

Map Credits | Accessibility | FOIA | Privacy | Policies and Notices



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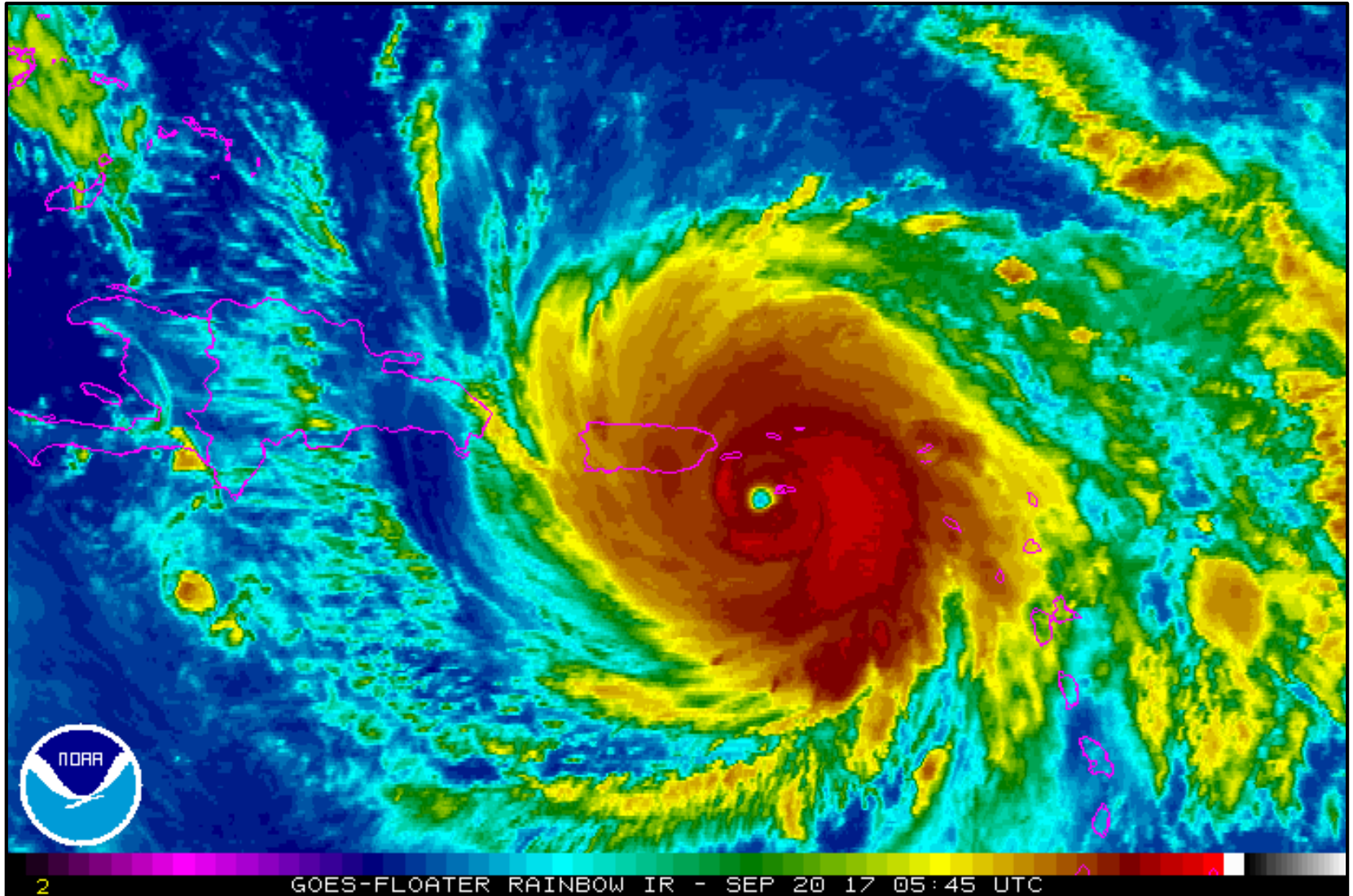


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# Hurricane Maria traversed Puerto Rico on Sep. 20, 2017 with 110-155 mph eye-winds





# El Yunque National Forest

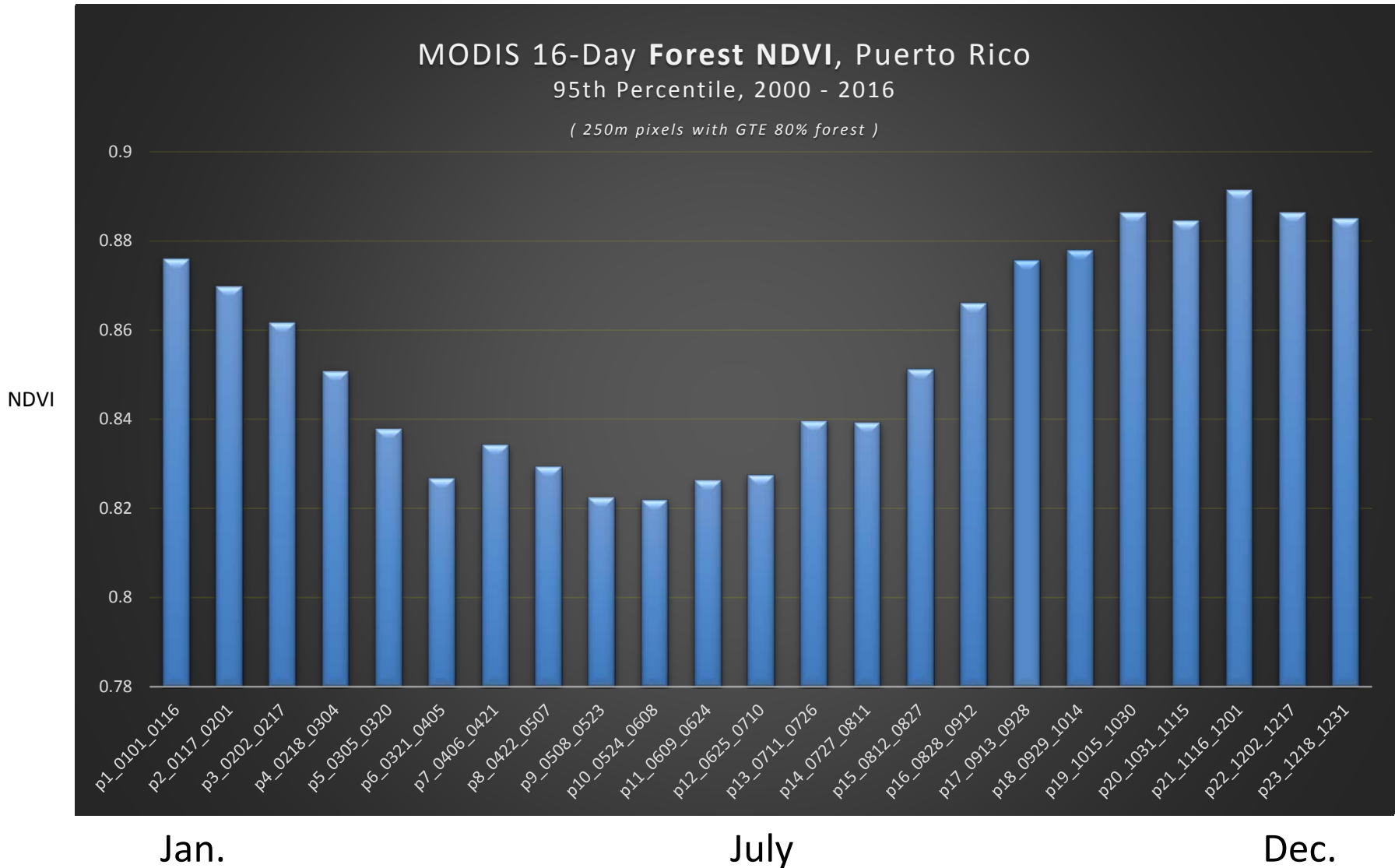






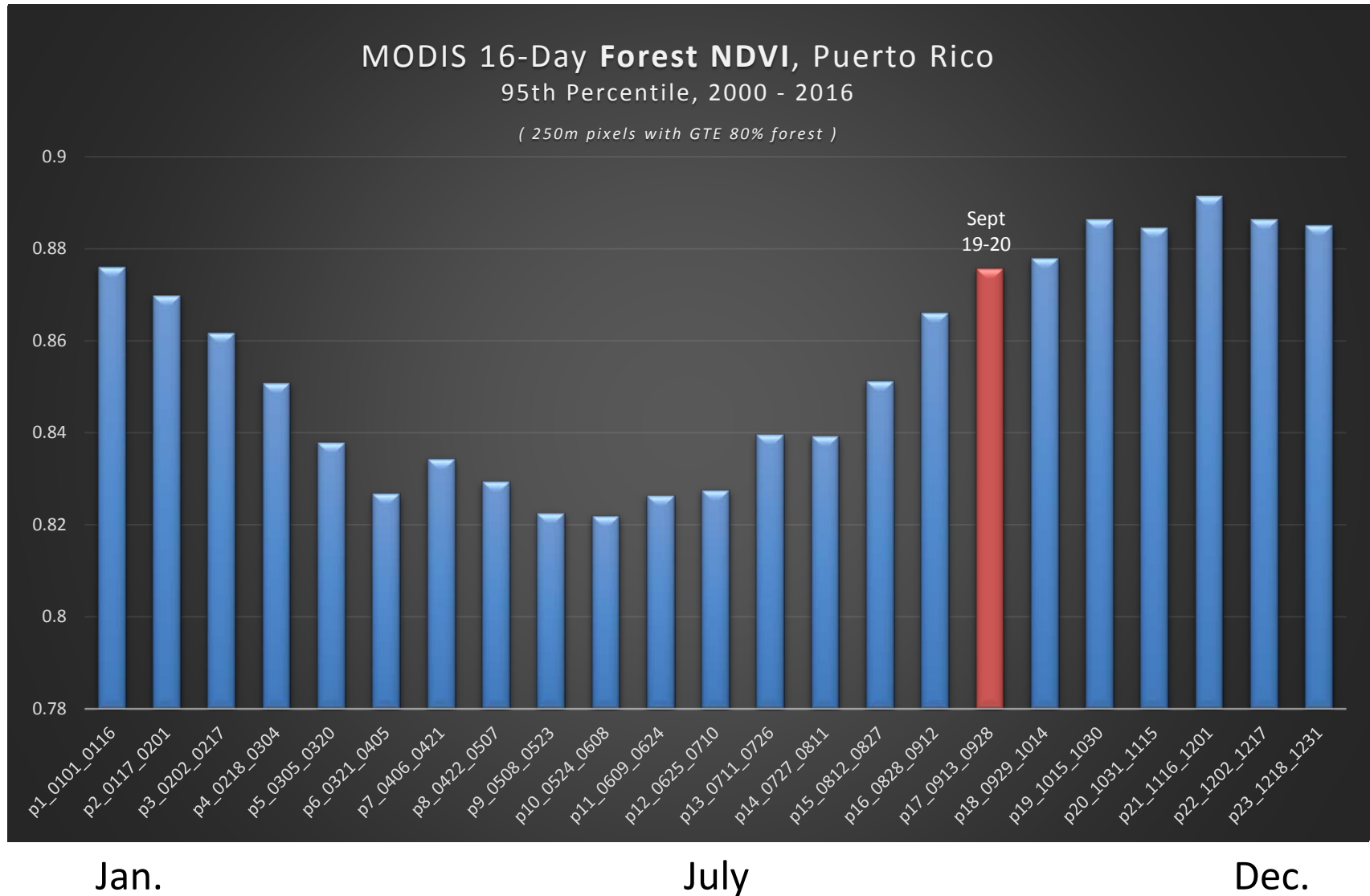


# What is the Phenology of Tropical Forests in Puerto Rico?





# Determining the pre- and post-disturbance compositing date-range (contextualized within the annual phenological curve)

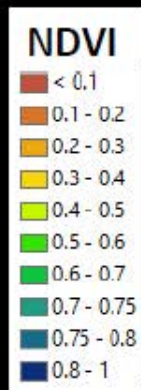
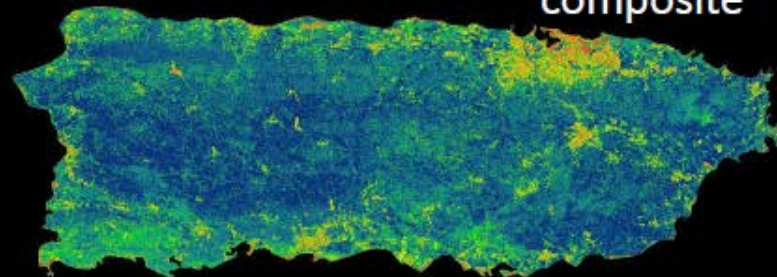




Sentinel-2 true color 10-20-2017



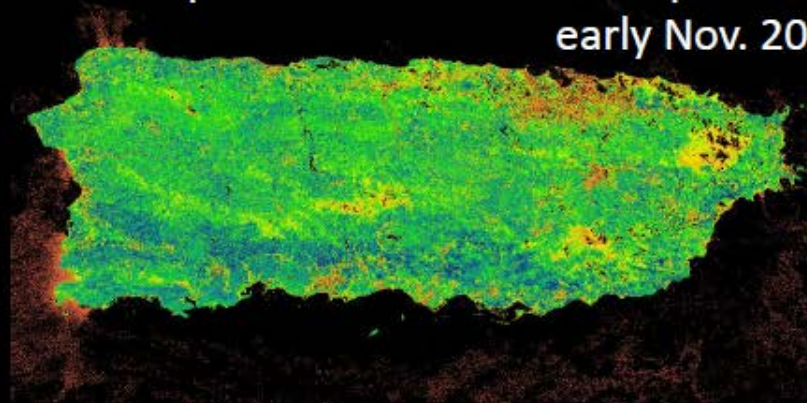
Sentinel-2 pre- H. Maria 3-yr. max. NDVI composite



Sentinel-2 true color 10-25-2017



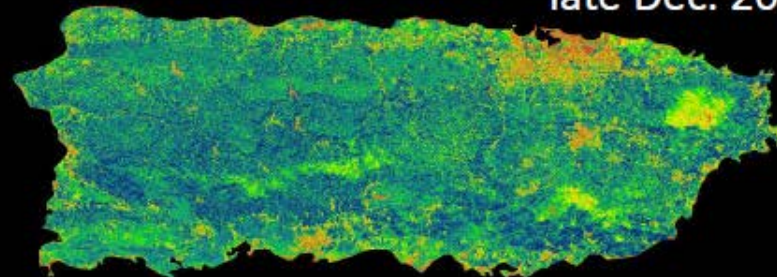
Sentinel-2 post-H. Maria NDVI composite through early Nov. 2017



Sentinel-2 true color 11-04-2017



Sentinel-2 post H. Maria NDVI composite through late Dec. 2017

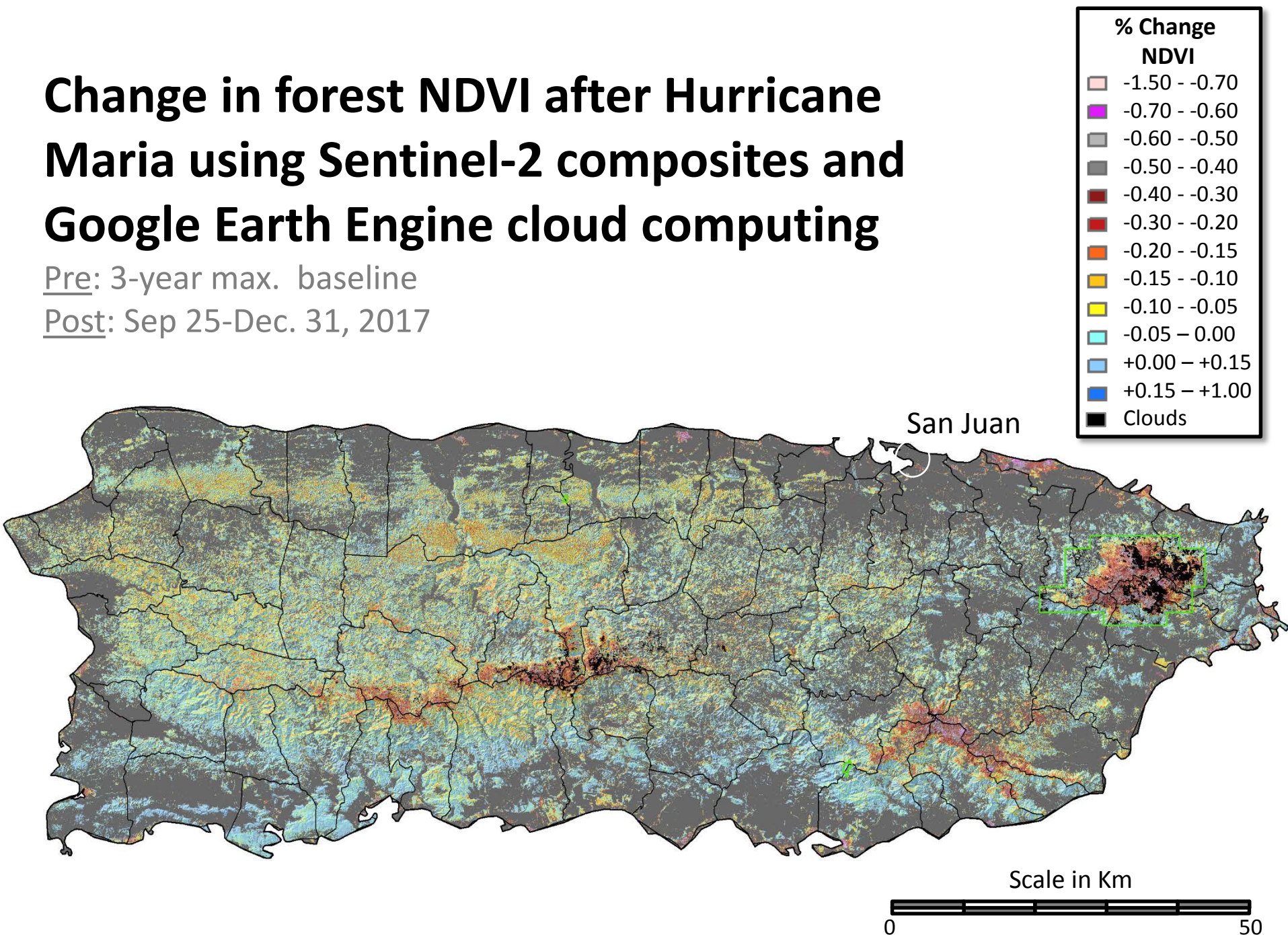




# Change in forest NDVI after Hurricane Maria using Sentinel-2 composites and Google Earth Engine cloud computing

Pre: 3-year max. baseline

Post: Sep 25-Dec. 31, 2017





# Eastern Forest Environmental Threat Assessment Center

USDA Forest Service, Southern Research Station, Asheville, NC

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## 2. *ForWarn* II

## 3. Disturbance Assessments (S2)

- SPB/IPS Host Mapping (GA)
- Puerto Rico, Hurricane Maria
- Florida, Hurricane Irma

## 4. Expectations Going Forward

*Photo by Paul Merten, Entomologist, Forest Service*



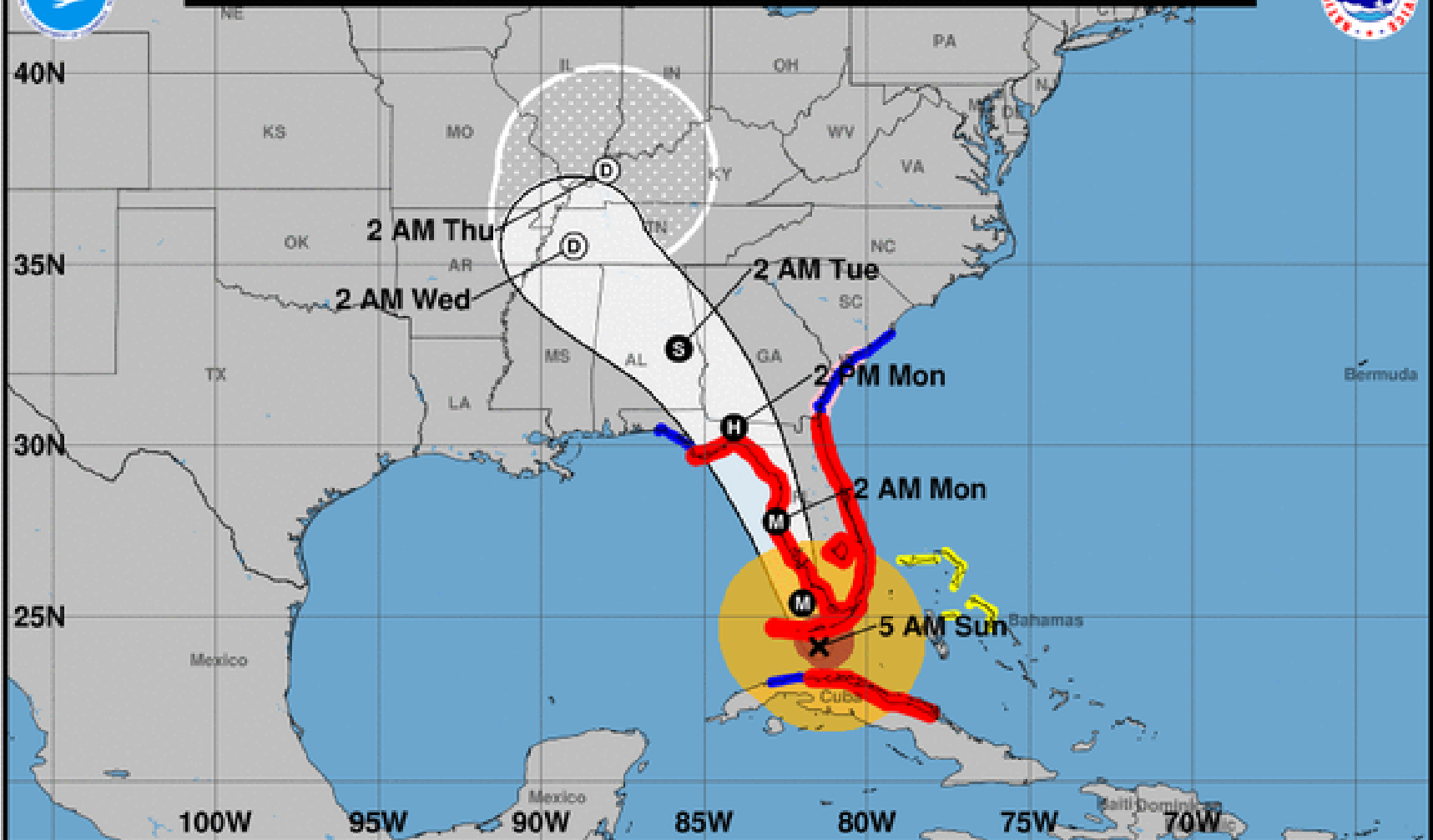
**2018 SGSF GIS Committee Annual Meeting**  
February 12-16, 2018    Mobile, AL







Note: The cone contains the probable path of the storm center but does not show the size of the storm. Hazardous conditions can occur outside of the cone.



### Hurricane Irma

Sunday September 10, 2017

5 AM EDT Advisory 45

NWS National Hurricane Center

### Current information: x

Center location 24.1 N 81.5 W

Maximum sustained wind 130 mph

Movement NW at 8 mph

### Forecast positions:

● Tropical Cyclone ○ Post/Potential TC

Sustained winds: D < 39 mph

S 39-73 mph H 74-110 mph M > 110 mph

### Potential track area:

Day 1-3 Day 4-5

### Watches:

Hurricane Trop Stm

### Warnings:

Hurricane Trop Stm

### Current wind extent:

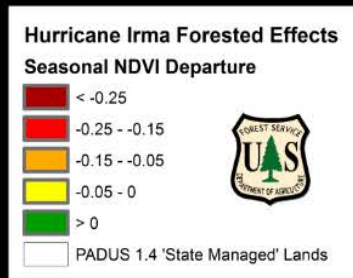
Hurricane Trop Stm



# Delta-NDVI using Forest Service GTAC MODIS Imagery

*when time is of the essence, availability on, or the day after a disturbance*

## Forest NDVI Change from Hurricane Irma in South Florida



### Provisional Research Dataset

wchristie@fs.fed.us

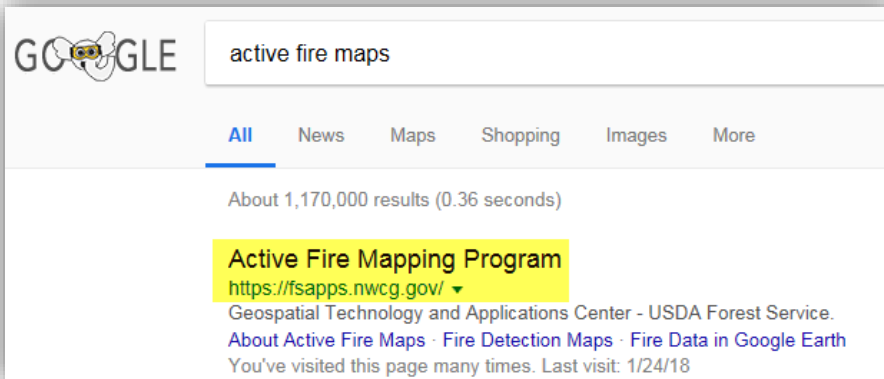
09/21/2017

### Sources

USDA-FS-RSAC MODIS Terra and Aqua NDVI satellite imagery (250m);  
pre-disturbance dates March 16 and 22, and May 27 and 28, 2017;  
post-disturbance dates September 12, 15, 17 and 20, 2017.

NLCD 2011 used to mask land cover to forested-only classes  
(deciduous, evergreen, mixed forest and woody wetlands)





## 2x Daily MODIS Availability *for time-critical mapping*

USDA FOREST SERVICE

REMOTE SENSING APPLICATIONS CENTER

# Fire Imagery - Geospatial Technology and Applications Center

Current Large Incidents (Home)

New Large Incidents

Fire Detection Maps

MODIS Satellite Imagery

VIIRS Satellite Imagery

Fire Detection GIS Data

Fire Data in Google Earth

Fire Data Web Services

Latest Detected Fire Activity

Other Near Real Time Products

Frequently Asked Questions

About Active Fire Maps

This image subset is provided as a 3-band JPEG or GeoTIFF, or as a 7-band BSQ (band sequential) image. [Click here](#) for a description of the 7 MODIS spectral bands used for land remote sensing and subset projection information.

**JPEG**  
Bands 1, 4, 3  
True Color  
(JPEG)  
6.68 MB

**JPEG**  
Bands 7, 2, 1  
False Color  
(JPEG)  
7.63 MB

**BSQ**  
Bands 1 - 7  
(BSQ)  
46.74 MB

**True and False Color (GeoTIFF)**  
24.93 MB

Use this calendar to access previously acquired imagery

February 2018						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
28	29	30	31	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	1	2	3

Texas (East)

02/08/2018

19:05:07 GMT

Satellite: Aqua

GTAC

Geospatial Technology and Applications Center

2222 West 2300 South  
Salt Lake City, UT  
84119 - 2020

voice: (801) 975-3737  
fax: (801) 975-3478



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## ForWarn II

- Back-fill all change products where we left off in 2017
- Resolve the addition of the new 'SQRT' product(s) into *The Forest Change Assessment Viewer*
- Be operational for the beginning of the 2018 growing season

## SPB/lps

- Explore production of annual host maps for the SGSF region
- Explore production of annual host map change products
- Refine Sentinel 2 image processing methods in an effort to (1) identify outbreaks and (2) map the progression, mortality stages of active SPB/lps occurrences

*Photo by Paul Merten, Entomologist, Forest Service*



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# Questions?

Bill Christie

[wchristie@fs.fed.us](mailto:wchristie@fs.fed.us)

(828) 257-4370

*Photo by Paul Merten, Entomologist, Forest Service*



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