Assessing Potential of VIIRS Data for Contribution to a Forest Threat Early Warning System

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Outline

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- Background on Healthy Forest RPC Experiment

- Project Rational and Study Area Selection

- Experiment Methodology

- Results (Representative Sample)

- Concluding Remarks

Forest Threat Early Warning System

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- The Healthy Forest Restoration Act of 2003 mandates development of national Early Warning System (EWS) for forest threat monitoring and mitigation

- NASA Stennis is working with the US Forest Service to develop needed components of this EWS

- One component regards use of MODIS data for monitoring forest disturbance at broad regional scales

- This RPC experiment was initiated to assess potential of the MODIS follow-on, VIIRS, for monitoring forest disturbance at broad scales and thereby contributing to the EWS

  - MODIS 250-meter NDVI products differ from 400-meter VIIRS products; such differences can be application dependent

# Selection of Case Study

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- The monitoring of gypsy moth defoliation was selected for the RPC study using an area prone to such defoliation
  - One of the largest threats to eastern U.S. hardwood forests
  - One of eight threats mentioned in Healthy Forest Restoration Act of 2003

- The study area includes portions of West Virginia, Virginia, Pennsylvania, and Maryland

- Gypsy moth defoliation occurred in this area in multiple years during MODIS era (2000–Present)

- Cloud statistics challenging – area frequently cloudy

- Area contains significant topographic relief, complicating spectral response of remotely sensed data

Gypsy Moth Study Area Location

~15.5 Million Acre Study Area Highlighted in Yellow Below

This Area Received Heavy GM Damage in 2001
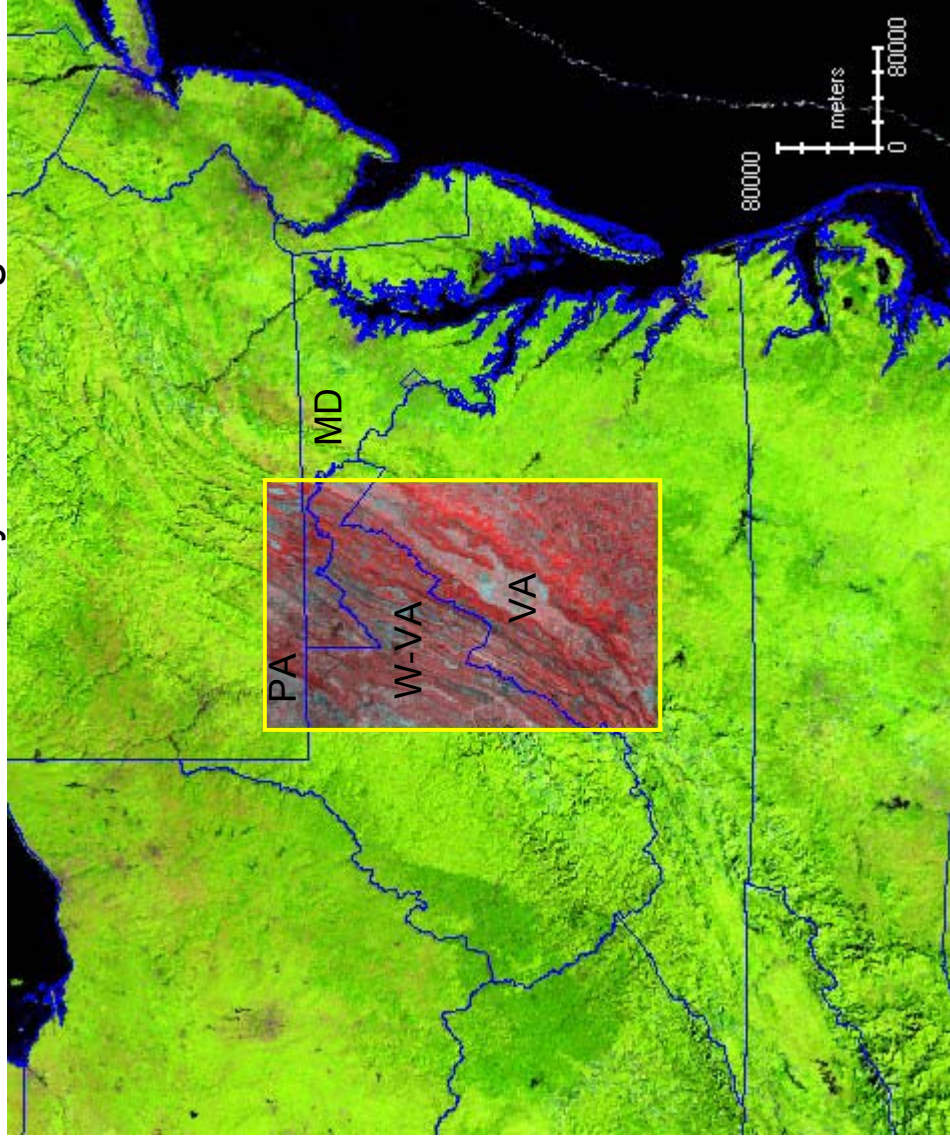
Landsat Circa 2000 Mosaic is in Foreground

MODIS Terra 2001 Mosaic is in Background

Objectives of RPC Experiment

1. Compute and validate simulated VIIRS products from MODIS data
   - Use Hyperion data to assess ability of MODIS data to simulate VIIRS radiance and planetary reflectances
   - Use of Application Research Toolbox and Time Series Product Tool to simulate VIIRS Time Series

2. Assess results of simulated VIIRS gypsy moth defoliation detection products
   - Examine utility of standard anomaly detection approaches utilizing pest vegetation phenology
     - Multitemporal image classification
     - Percent change in maximum NDVI during the peak defoliation period of a given year compared to maximum peak defoliation NDVI across the entire 2000-2006 time frame (considers defoliated and non-defoliated years)
   - Compare results to reference data
     - High-resolution NASA satellite data (Landsat, ASTER, ALI, Hyperion)
     - USFS data (defoliation sketch maps and trap count GIS data)

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Visible and NIR Reflectances versus
Vegetation Foliage Conditions

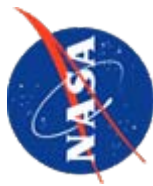## Spectra – Healthy vs. Sick Leaves
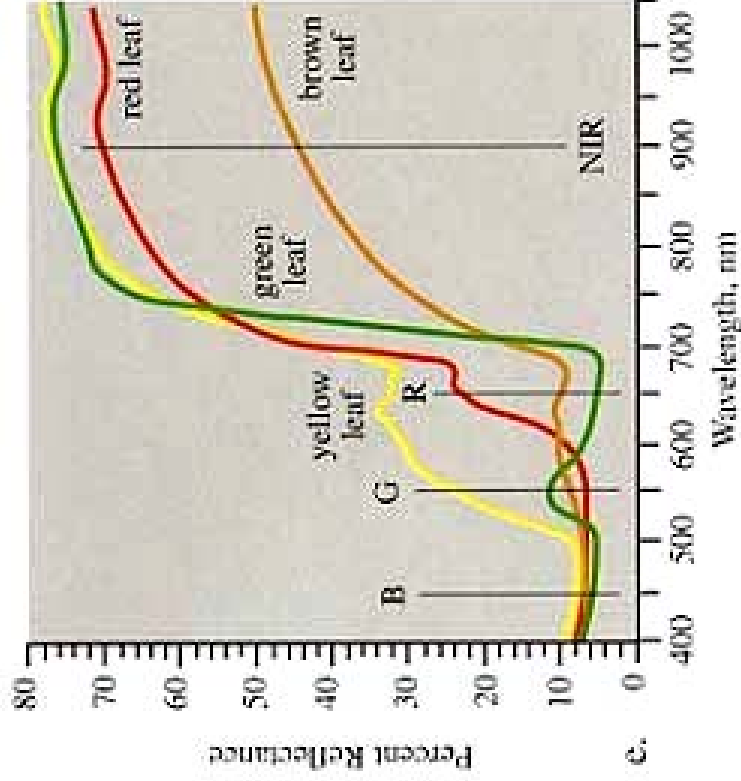
Source: CERES

NDVI – Green versus Brown Crowns
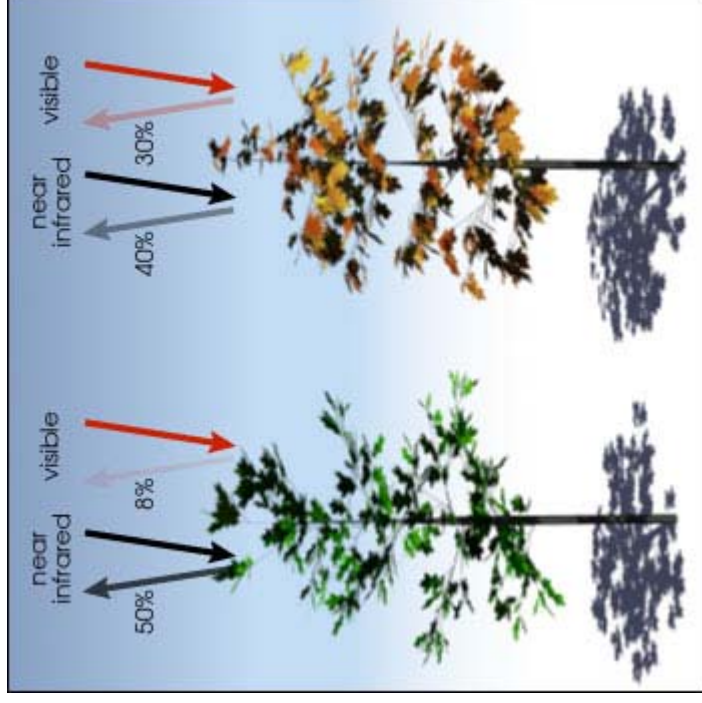
Source: NASA

$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72$$
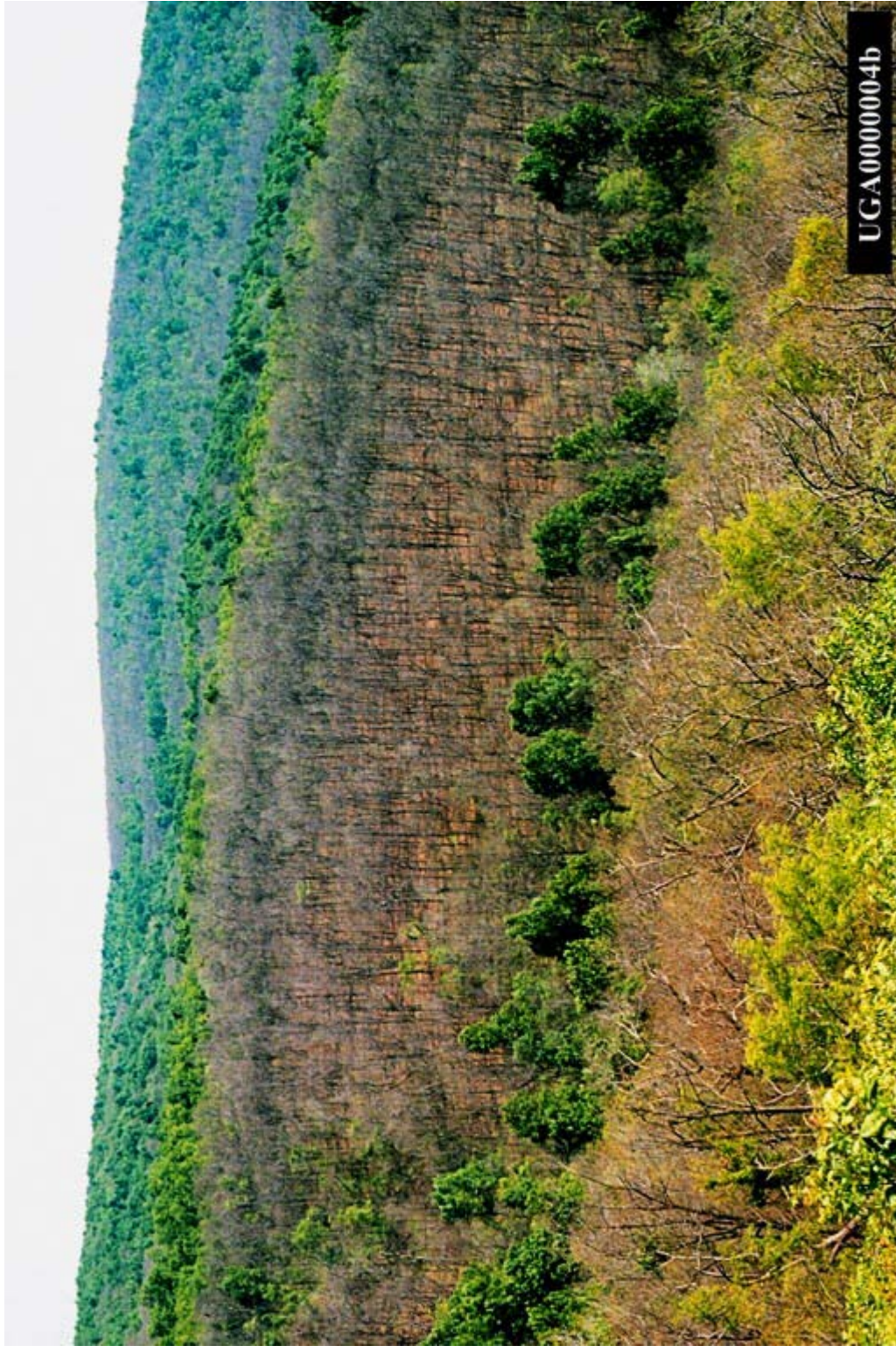
$$\frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

Visible Patterns in Gypsy Moth Defoliation

Denuded, Partially Denuded, Chlorotic, and Green Forest Vegetation

UGA0000004b

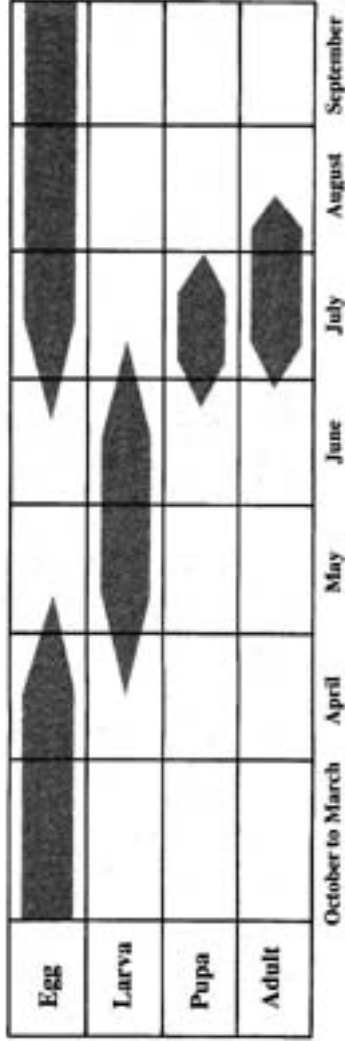# Gypsy Moth Defoliation Phenology

Defoliation in the Study Area – Apparent Mid to Late June

Maryland GM Life Cycle

Tennessee GM Life Cycle
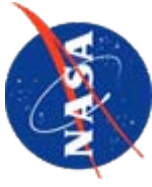
Gypsy Moth Activity Calendar

	September to March	April	May	June	July	Aug.
Caterpillars Present						
Feeding Damage Occurs						
Pupae Present						
Adults Present						
Egg Masses Present						
Destroy Egg Masses						
Apply Pesticides						
Burlap Strips on Trees						
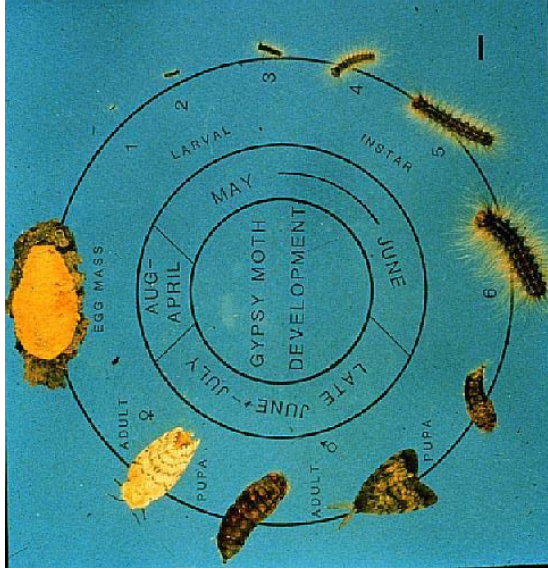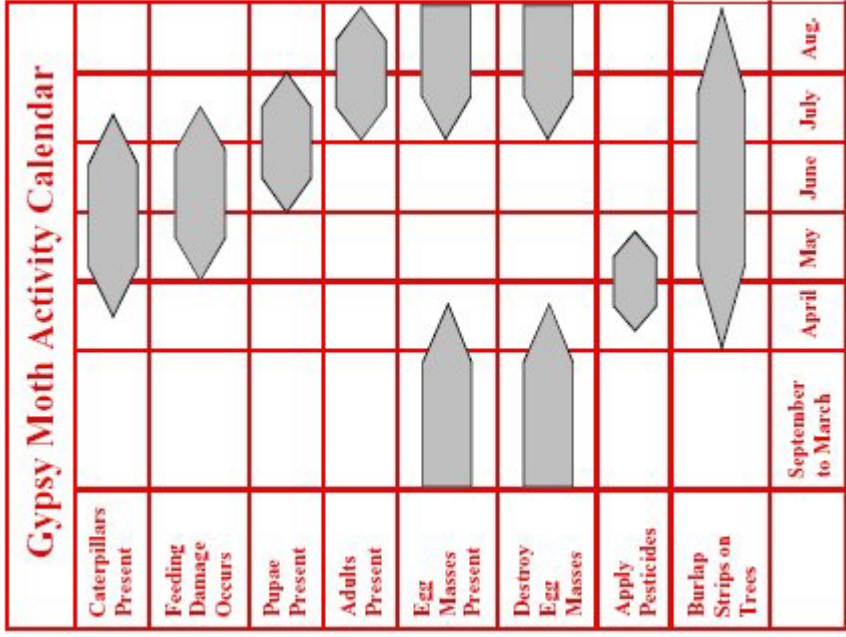
North Carolina GM Life Cycle

Assessing Requirements for Sketch Mapping GM Defoliation

USFS Metadata for GM Forest Defoliation Sketch Mapping Product

"Each state in the Northeast monitors gypsy moth defoliation annually using aerial sketch maps. Maps are sketched during a series of low-level reconnaissance flights in late July when defoliation is at its peak. Defoliation of 30 percent is considered the lower threshold for detection from the air. Where the cause of the defoliation is in doubt, ground checks are made for the presence of gypsy moth life stages. Initially, aerial sketch mapping is done using standard USGS (1:24000) topographical maps as the base. Composite mosaics then are generated for each state on maps of varying scales and projections. Mapping processes vary among state agencies and years, resulting in a strong likelihood of significant data errors from both systematic and nonsystematic sources. The likely presence of these errors dictated the coarse spatial resolution of maps (2 x 2 km)."

On-line source: http://www.fs.fed.us/ne/morgantown/4557/AFPE/metadata/gm_annual_defoliation.htm#6

National Aeronautics and Space Administration

Sketch Mapping GM Defoliation in WV and VA

Defoliation surveys were conducted from the air during June 2001 by the Virginia Department of Forestry and the West Virginia Department of Agriculture.

On-line source: http://www.fs.fed.us/r8/gwi/projects_plans/monitoring/011101_Gypsy_Moth_Report.pdf

State of Virginia collected defoliation sketch map data in late June – early July for 2001.
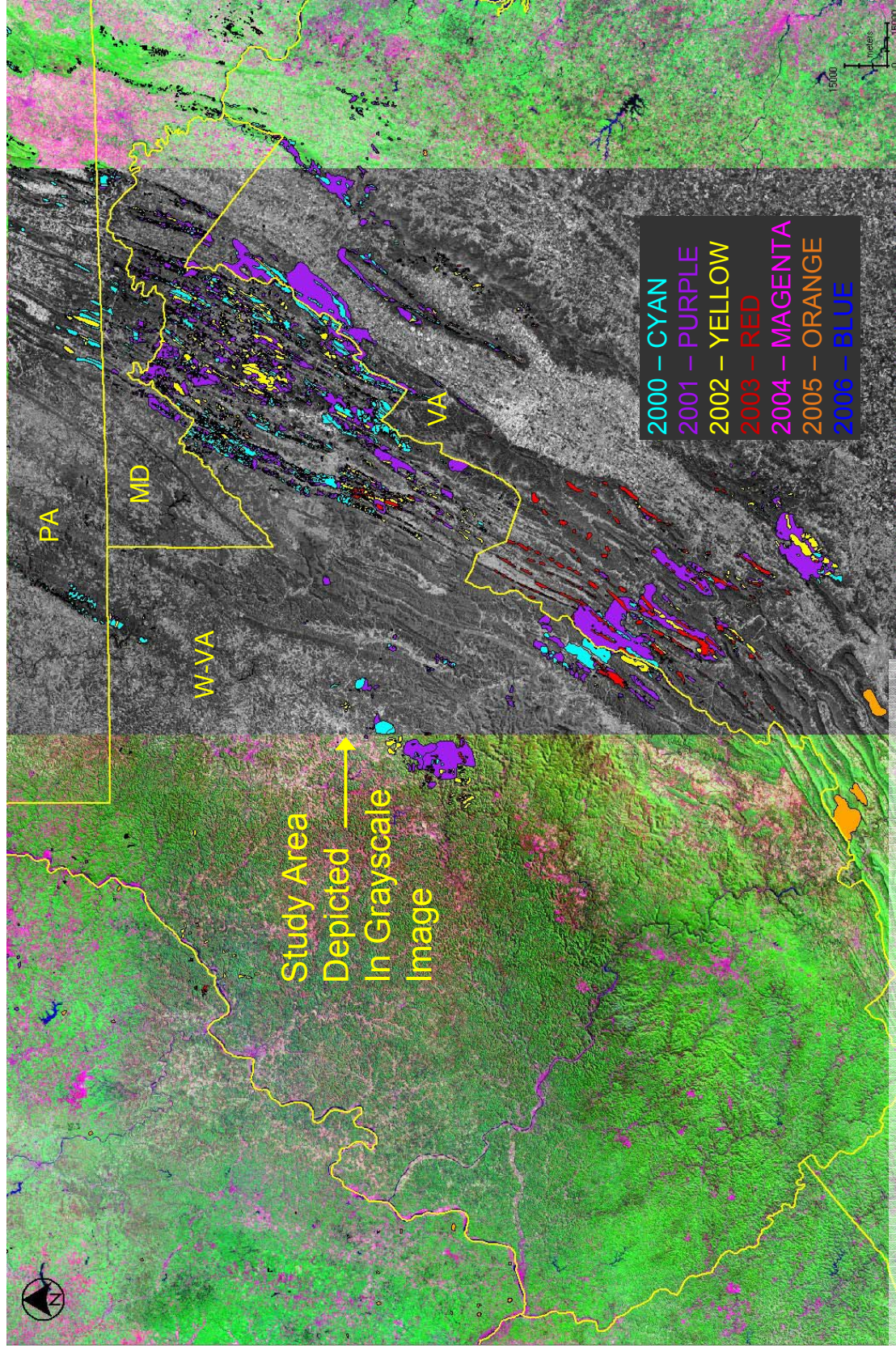
On-line source: http://www.dof.virginia.gov/resinfo/gypsy-moth-2001-index.shtml

Preliminary Requirements for GM Forest Defoliation Sketch Mapping

• Temporal Requirement – Data collection in late June – early July during peak defoliation
• Spatial Resolution Requirement – 2 km or better (MODIS 250-1000 meter pixels) - TBD
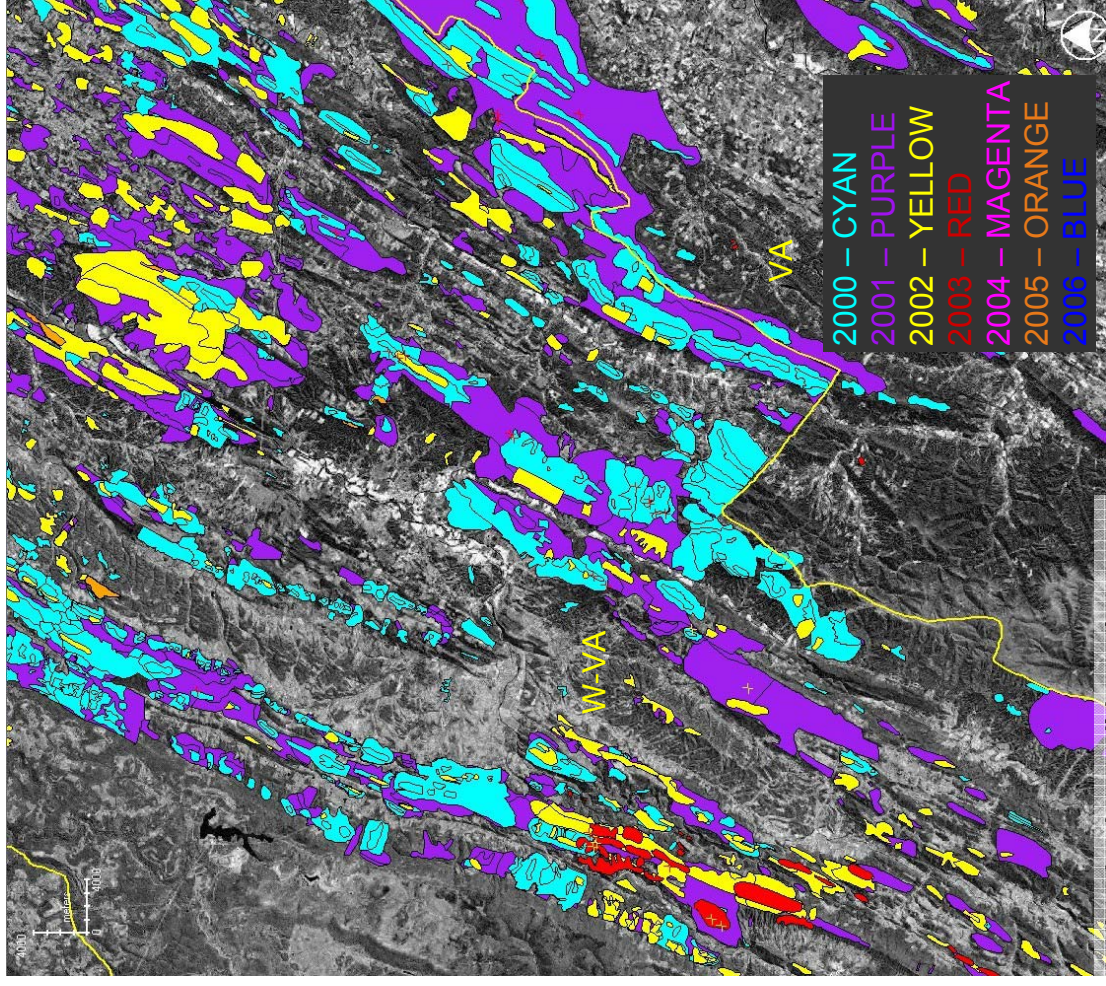• Target Mapping Requirement – Areas with 30% defoliation or greater

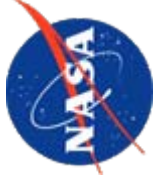# USFS Sketch Maps of GM Defoliation (2000–2006 Time Frame)

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Study Area
Depicted
In Grayscale
Image

PA
MD
W-VA
VA

2000 – CYAN
2001 – PURPLE
2002 – YELLOW
2003 – RED
2004 – MAGENTA
2005 – ORANGE
2006 – BLUE

USFS Sketch Maps of GM Defoliation
(Enlargement of Previous Slide)

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Legend:
- 2000 – CYAN
- 2001 – PURPLE
- 2002 – YELLOW
- 2003 – RED
- 2004 – MAGENTA
- 2005 – ORANGE
- 2006 – BLUE

Development of GM Defoliation Detection Products

- Computing GM Defoliation Maps from MODIS Data
  – Multitemporal Image Classification
  – Percent Change in Maximum NDVI During the Peak Defoliation Period of a Given Year Compared to Maximum Peak Defoliation NDVI Across the Entire 2000-2006 Time Frame

- Comparing MODIS GM Defoliation Maps to Reference Data
  – Landsat Data
  – USFS Sketch Maps
 – Available In-situ Data (e.g., GM Trap Data)

# Landsat Views of Healthy and GM Defoliated Oak Forest

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Landsat ETM+ Acquired July 15, 2001
Includes Heavy GM Defoliated Forest Stands

Yellow Vectors – 2001 Sketch Map

Defoliated Oak Forests

Landsat ETM+ Acquired June 10, 2000
Scene With Low Gypsy Moth Defoliation

Green Vectors – 2000 Sketch Map

Healthy Oak Forests
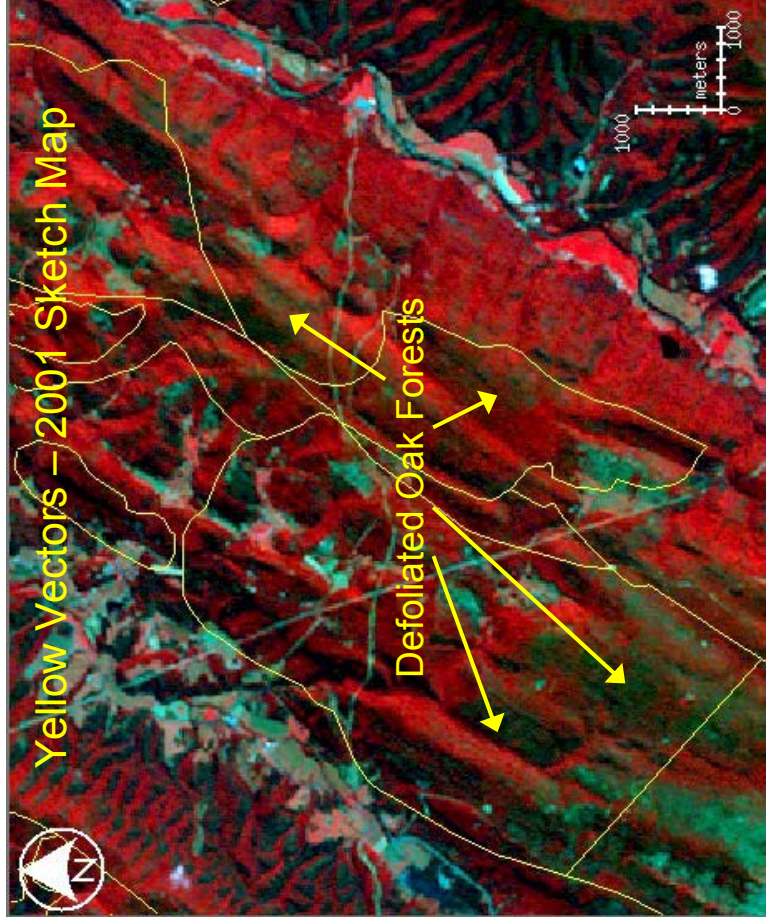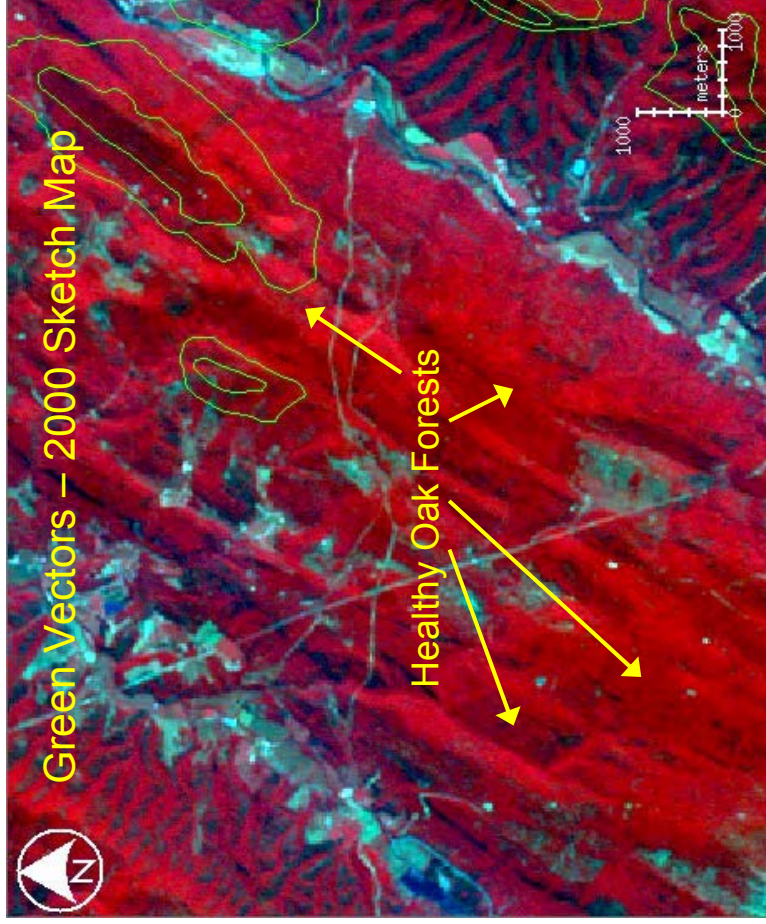
Landsat Data and USFS sketch maps of GM defoliation do not show 1-to-1 correspondence. GM defoliation is minimally evident on the June 10, 2000, Landsat scene yet is common on the July 15, 2001, scene.
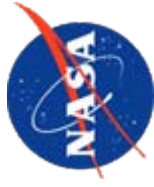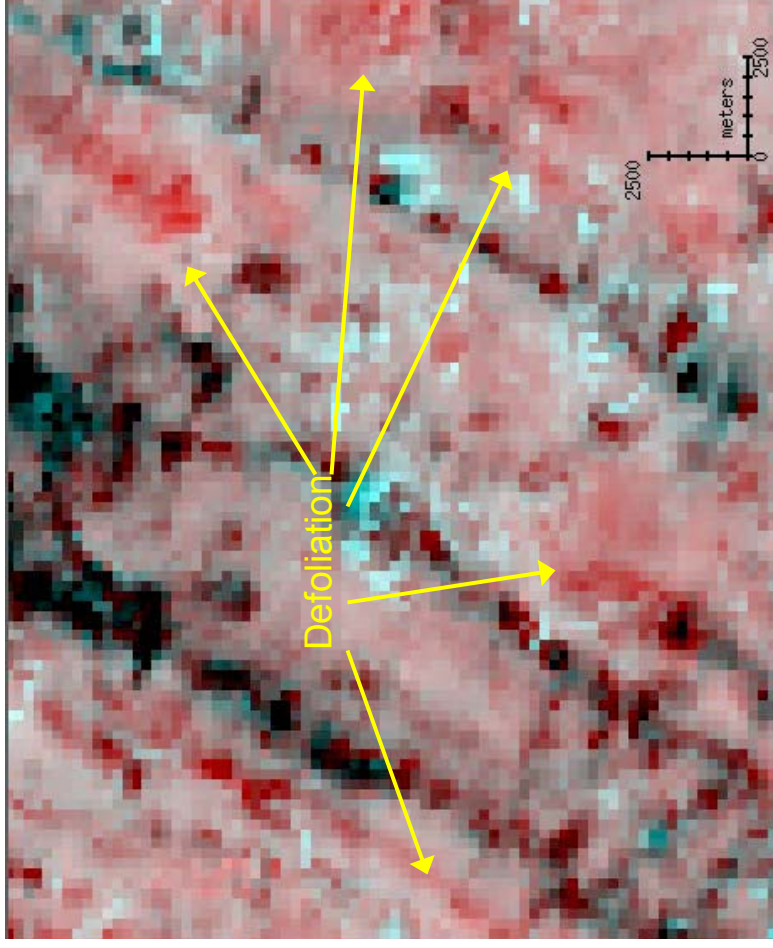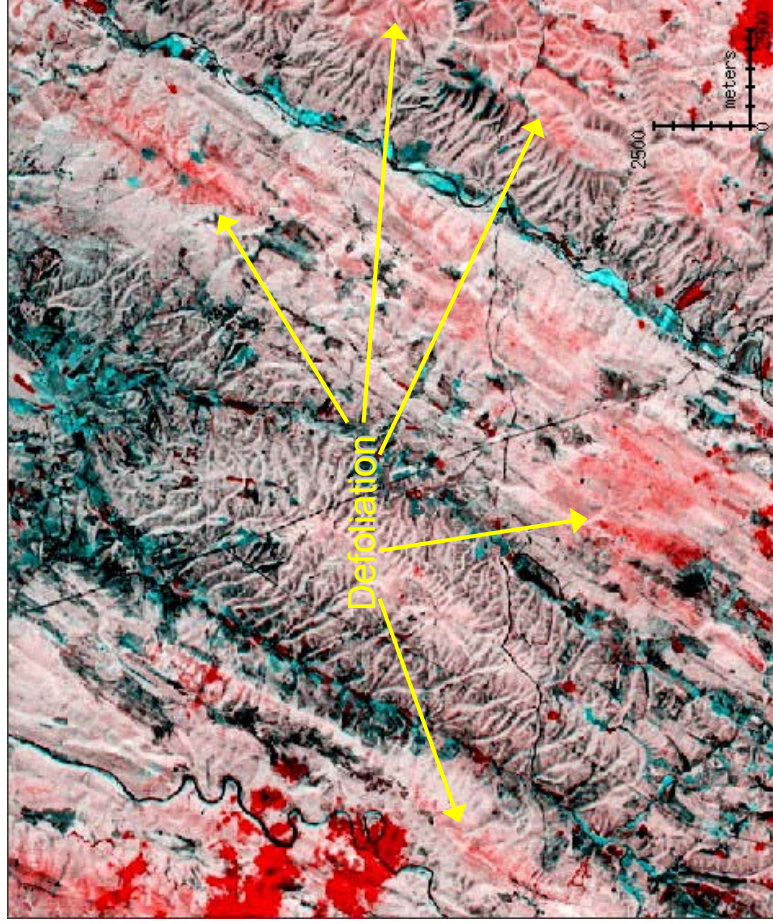
2 Date NDVI RGBs:

LS7 versus MODIS MOD13

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2-Date NDVI RGB Assignment

6/10/2000 NDVI Loaded in Red; 7/15/2001 NDVI Loaded into Blue and Green

LS7 2-Date NDVI RGB

MODIS 2-Date NDVI RGB (MOD13)

Deep Red – Clouds in 2001
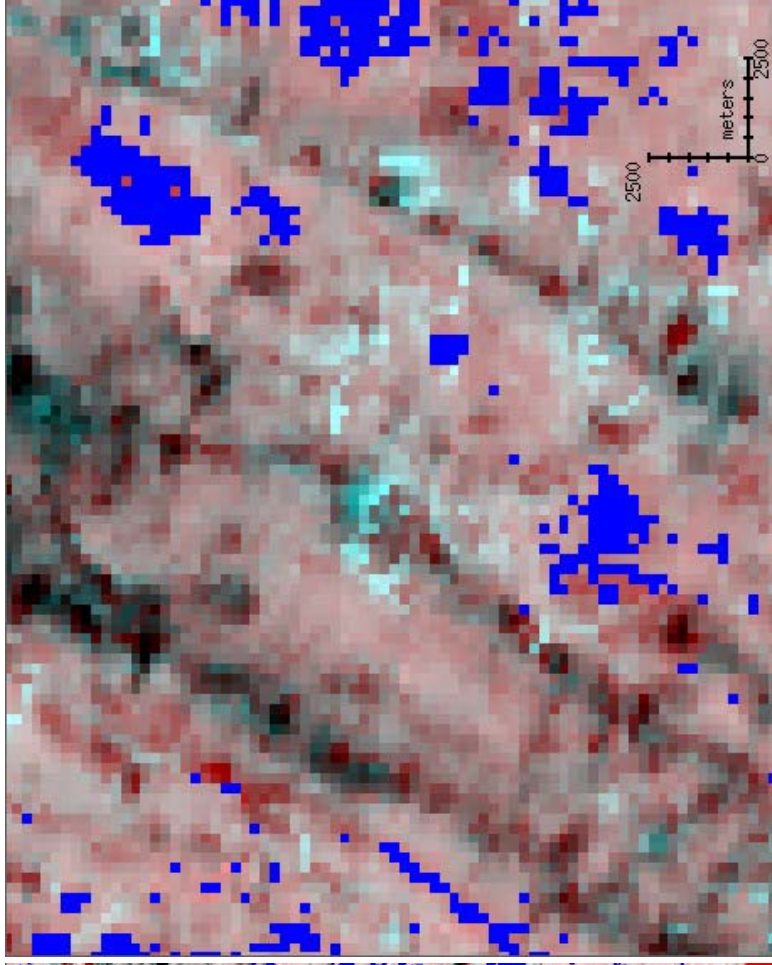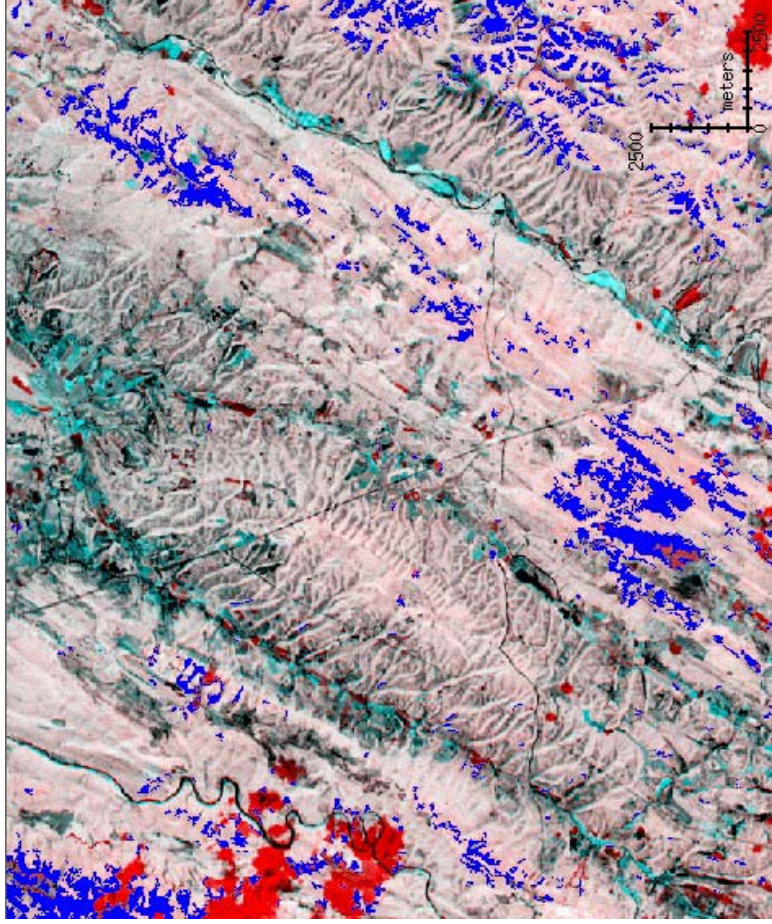Light Rose – Defoliation in 2001

GM Defoliation Maps from 2-Date NDVI

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RGBs: LS7 versus MODIS MOD13

GM Defoliation Classification - LS7 NDVIs
Landsat Data – 30-meter Resolution

GM Defoliation Classification – MOD13 NDVIs
MODIS Data – 250-meter Resolution

Each image shown shows defoliation areas in blue draped over a 2 date NDVI RGB
Background RGBs: 6/10/2000 NDVI Loaded in Red; 7/15/2001 NDVI Loaded into Blue and Green

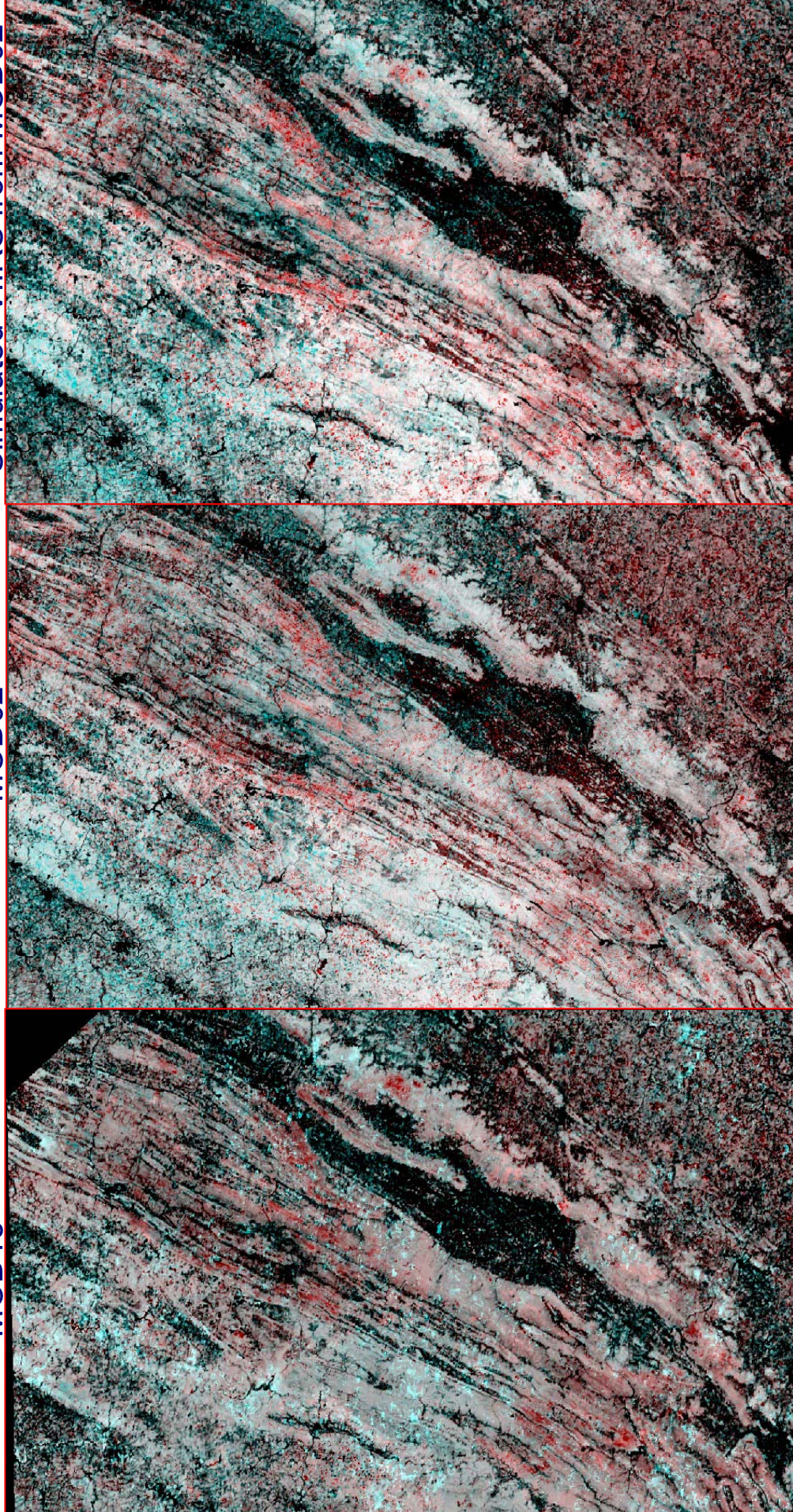# Comparison of Similar Date NDVI RGBs from
MOD13, MOD2, and MOD02-based VIRS

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Simulated VIIRS from MOD02

MOD02

MOD13

All RGBs - June 10, 2000, loaded in Red; July 15, 2001, loaded in Blue and Green. Defoliation is shown in deepest red tones

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2001 GM Defoliation Classifications from
MOD13, MOD2, and MOD02-based VIIRS

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Simulated VIIRS from MOD02

MOD02

MOD13

NON-FOREST – TAN
HEALTHY FOREST – GREEN
DEFOLIATED FOREST - RED
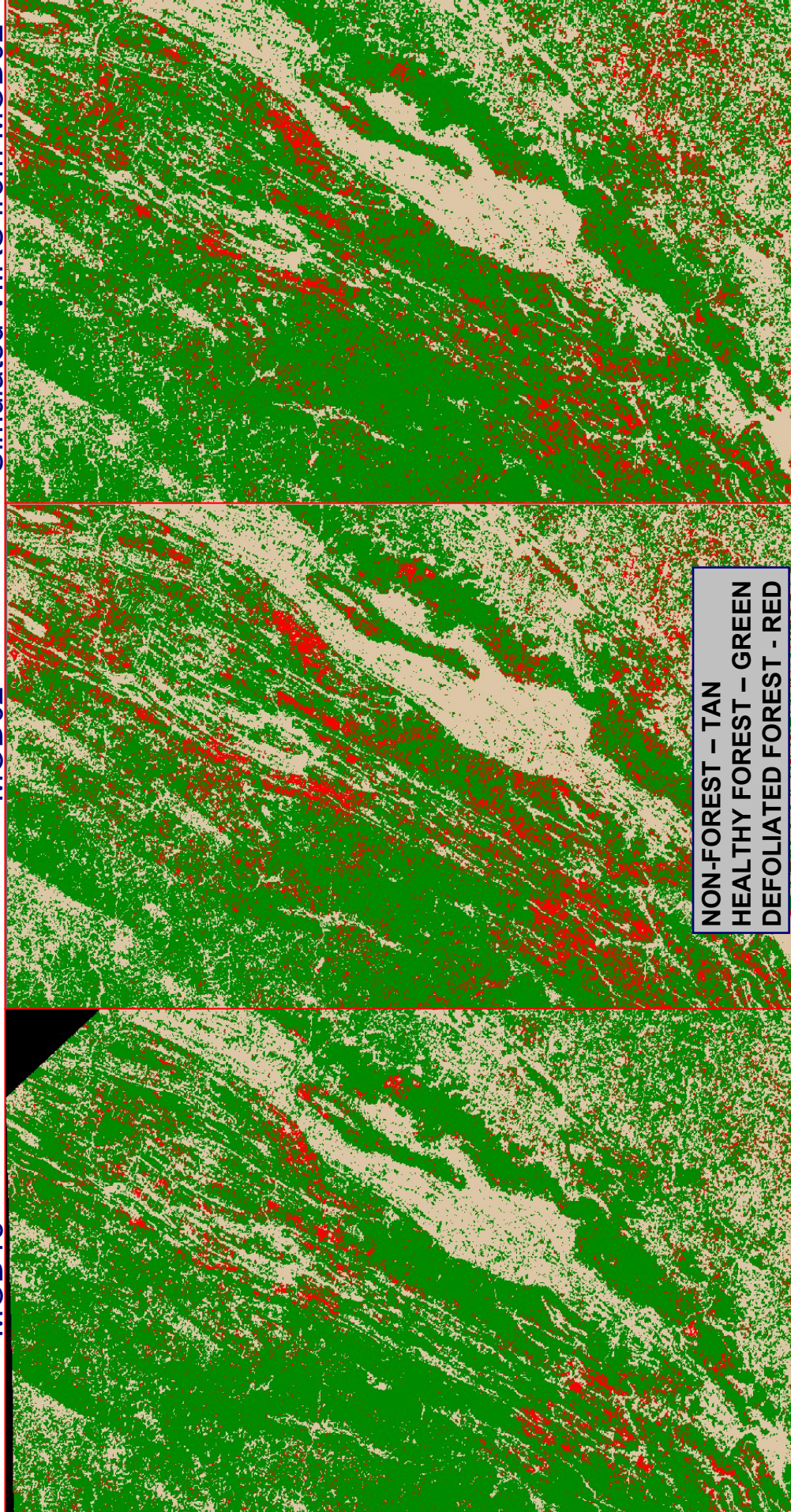
The MOD13 shows less GMD commission error than the MOD02 and simulated VIIRS products.

However, MOD013 products appear to omit real defoliation areas detected on MOD02 and VIIRS.

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Comments on MODIS and Simulated
VIIRS GMD Classification Results

- Multitemporal MODIS data can be classified into general GM defoliation maps, although omission error occurs for small patches and patches with moderate defoliation intensity

- Useful classification results were obtained from MOD02, MOD13, and VIIRS data simulated from MOD02

- Temporal processing of MODIS and simulated VIIRS time series data increased utility of the data for this application

- Future work will consider if NDVI anomaly detection with MODIS time series data can enable an automated method for predicting GM defoliation at broad regional scales

- Quantitative accuracy assessment is also being done on MODIS and simulated VIIRS classifications of gypsy moth defoliation