Assessing Hurricane Katrina Vegetation Damage at Stennis Space Center using IKONOS Image Classification Techniques

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ASPRS 2007 National Convention
Tampa, Florida, USA
May 6–11, 2007

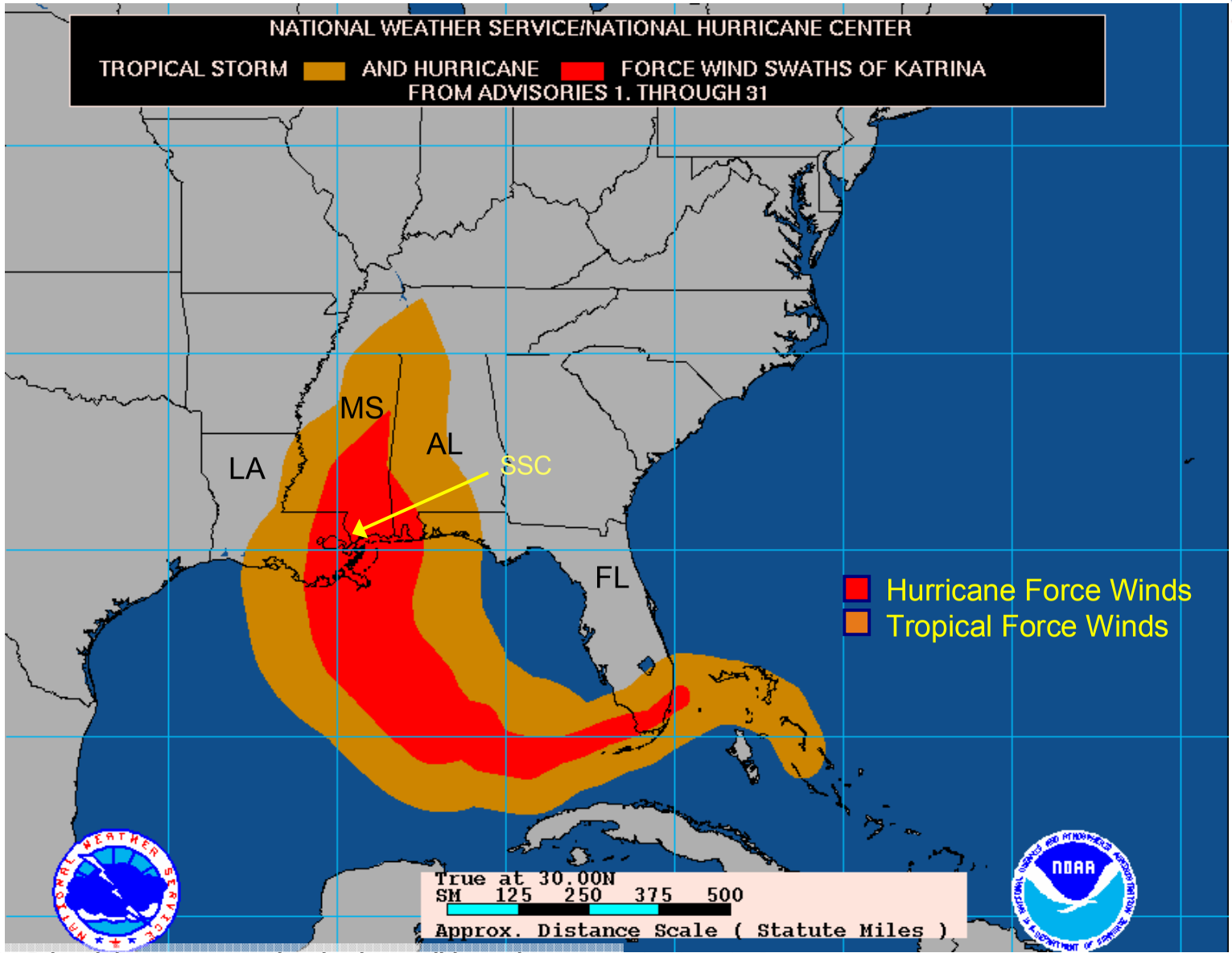
Discussion Items

- Project Background
- Research Objectives
- Remote Sensing Data Acquisition and Processing Methods
- Results
- Concluding Remarks

Project Background

- Hurricane Katrina hit southwestern Mississippi on August 29, 2005, at 9:45 a.m. CDT as a category 3 storm with surges up to ~9 m and sustained winds of ~120 mph
- The hurricane's wind, rain, and flooding devastated several coastal towns, from New Orleans through Mobile
- The storm also caused significant damage to infrastructure and vegetation of NASA's SSC (Stennis Space Center)
- Storm recovery at SSC involved not only repairs of critical infrastructure but also forest damage mitigation (via timber harvests and control burns to reduce fire risk)
- This presentation discusses an effort to use commercially available high spatial resolution multispectral IKONOS data for vegetation damage assessment, based on data collected over SSC on September 2, 2005

Hurricane Katrina's Swath



Katrina's Approach to Mississippi Shown on GOES-12 Satellite Imagery

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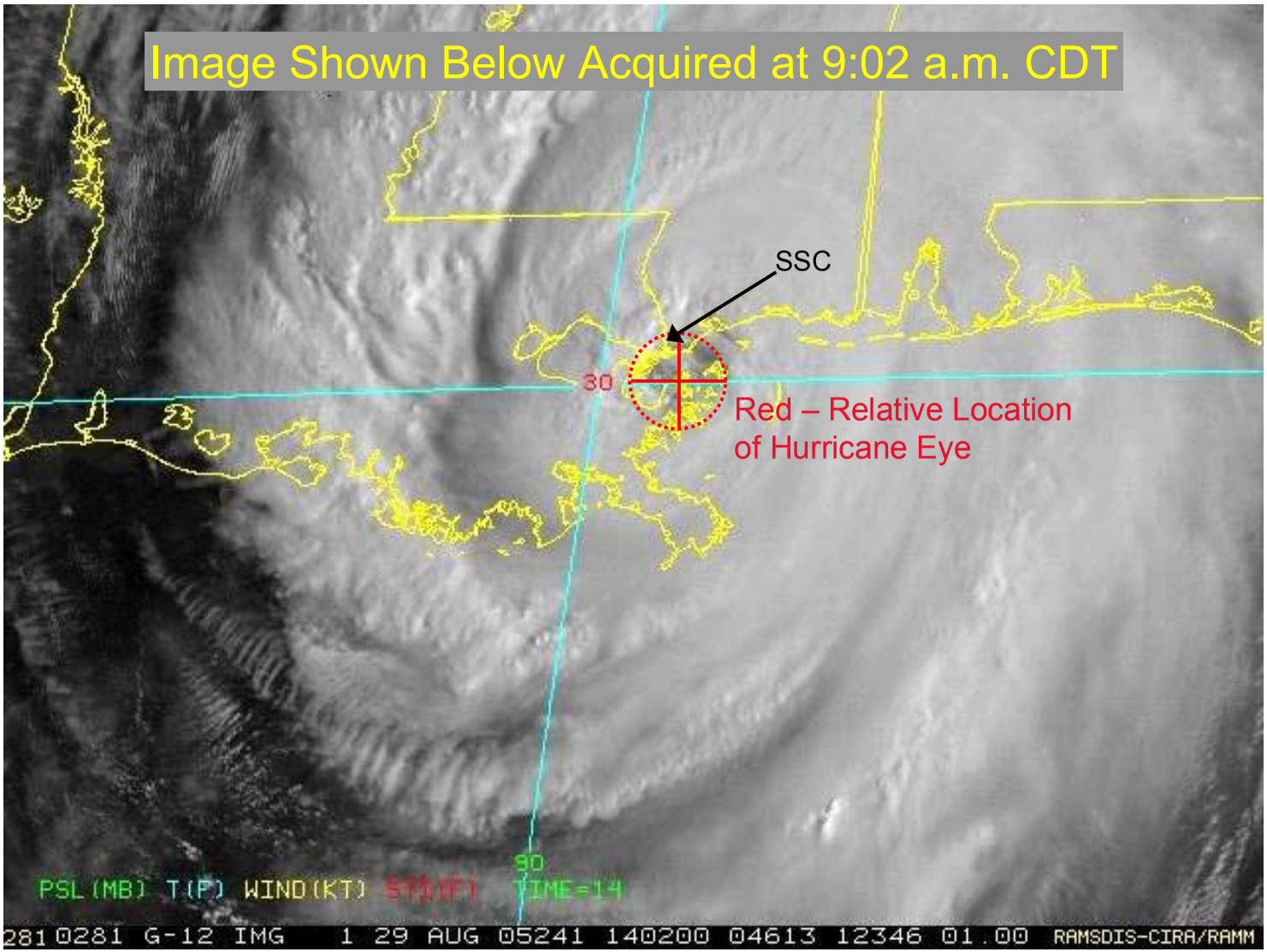

Importance of Vegetation Management to Stennis Space Center Operations

- NASA SSC's primary business is the testing of rocket engines used by Space Shuttles
- SSC is surrounded by a buffer zone for noise abatement of rocket engine testing
  - 125,000 acres, primarily forest
  - No settlements occur within this buffer
- SSC forest land is also managed for timber production, wildfire management, and wildlife conservation
- Hurricane-damaged forests decrease the noise abatement capacity of the SSC buffer zone area
- Damaged forests also increase wildfire and forest health risks, further threatening infrastructure and noise mitigation
- In response, NASA SSC management required hurricane impact assessment to vegetation in the buffer zone

Preliminary Map of Katrina Forest Damage by USDA Forest Service

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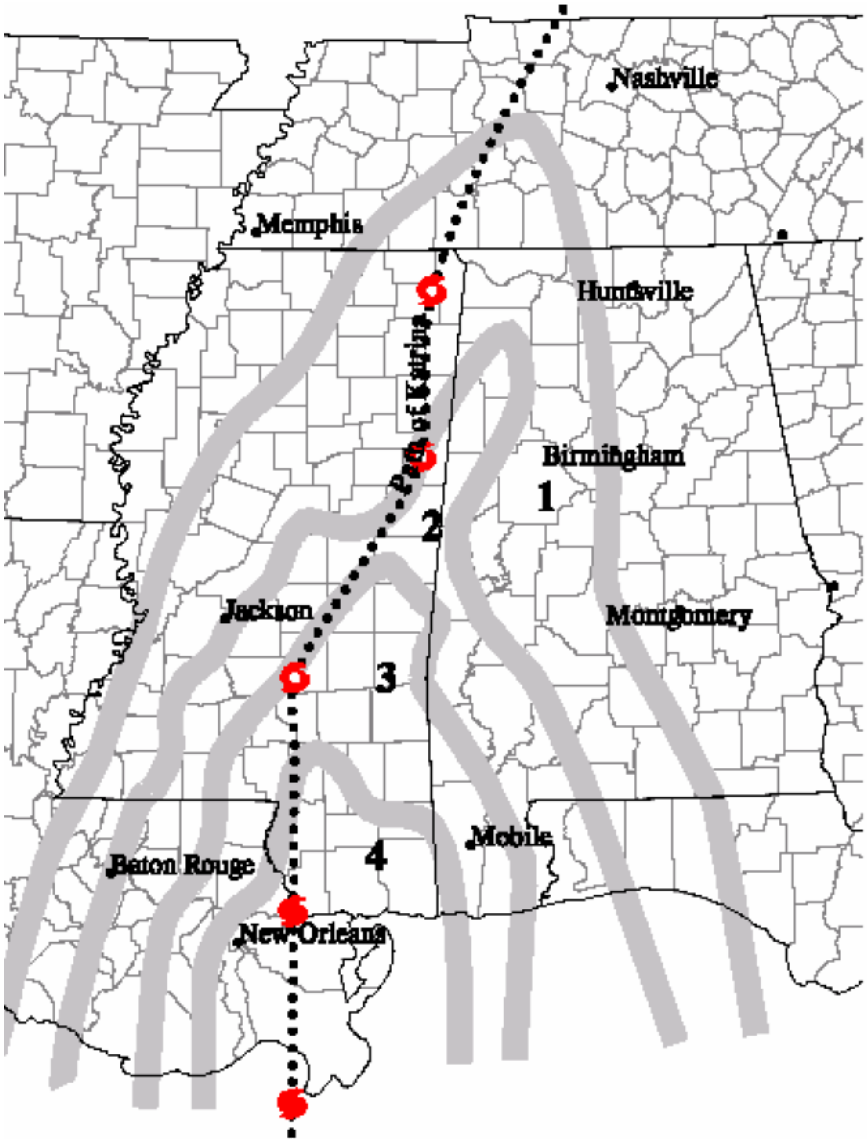

Map Legend

1 = Scattered, Light
2 = Light
3 = Moderate
4 = Severe (includes SSC)

Hurricane Force Winds
Tropical Storm Winds

Map Source: USDA Forest Service Inventory and Analysis
http://www.srs.fs.usda.gov/katrina/

Objectives of Study

- Assess early post-storm 4-meter multispectral IKONOS data for showing hurricane-induced vegetation damage at SSC
  - Does data depict targeted cover types?
  - Does data show hurricane damage to vegetation in terms of defoliation, flooding, mud deposition, wind-thrown trees?
- Assess traditional image classification techniques for classifying types of storm damage from IKONOS multispectral data
  - Can data be processed with traditional techniques (ISODATA unsupervised clustering and Maximum Likelihood classification) to geospatially depict cover type and damage state?
  - Can IKONOS classifications identify hurricane-flooded vegetation not mapped as flooded on FEMA storm surge maps?

Location of Study Area in Regard to Northern Gulf Coast

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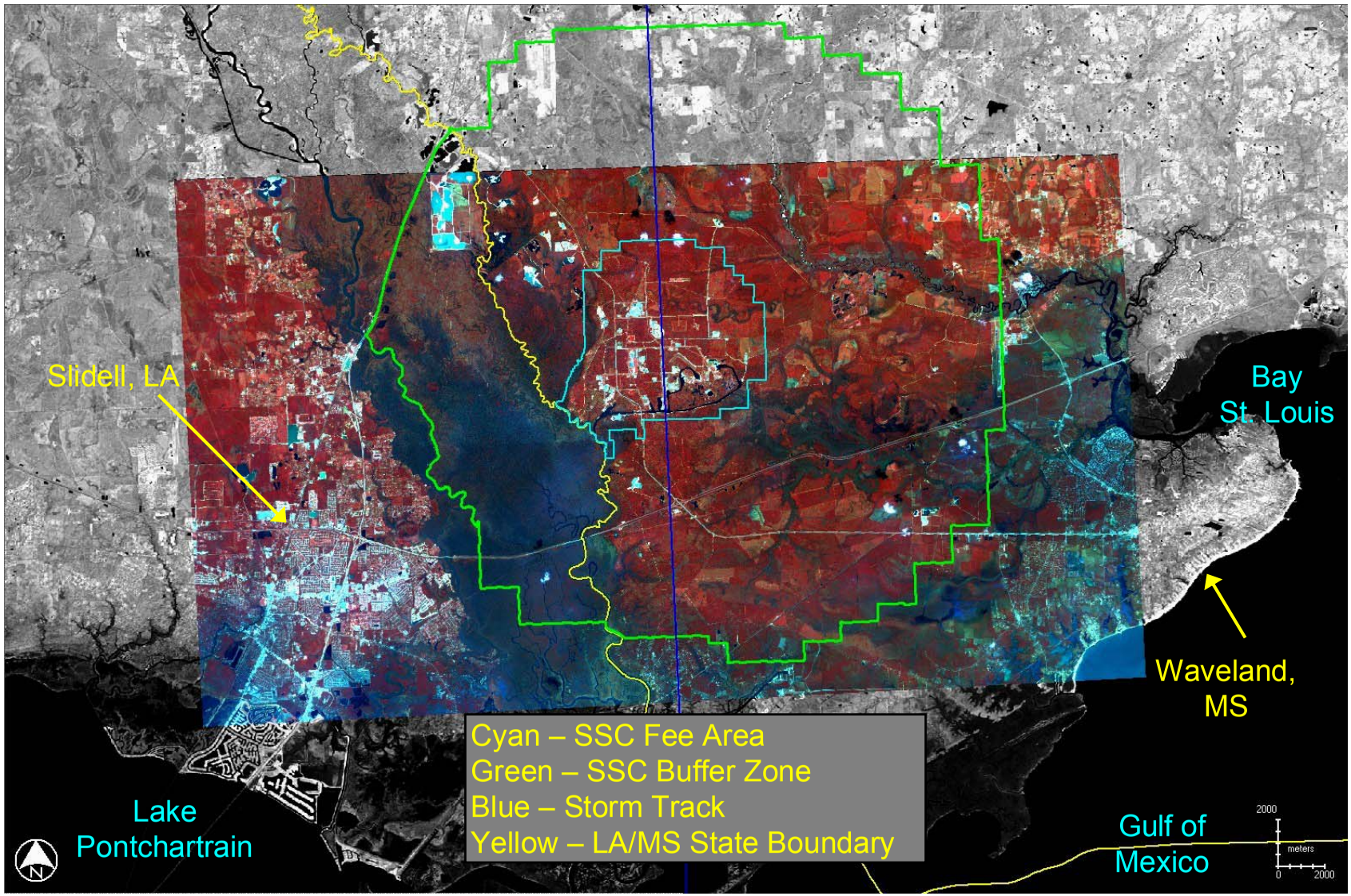
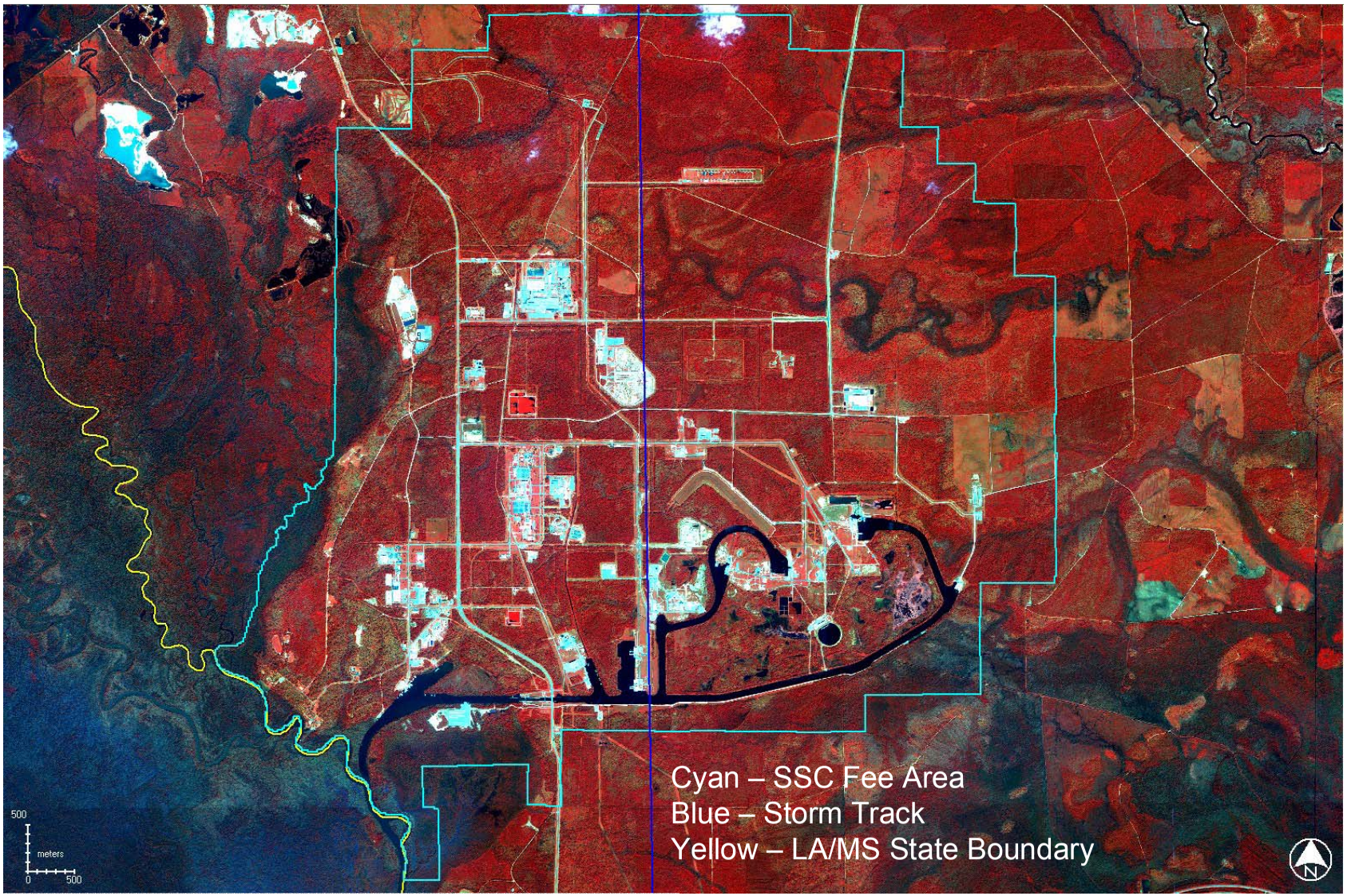
IKONOS Data Acquired 9/2/2005 Overlain on Landsat 5 Data Acquired in Fall 2005



IKONOS View of SSC Fee Area

IKONOS Color Composite – Bands 4,3,1 Loaded into RGB



Examples of Hurricane Damage To SSC Forest Vegetation (1)

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Semi-Open Pole-Sized Pine Overstory
Wind-Snapped and Wind-Thrown Trees
Sparsely Foliated Residual Crowns
Thick Ground Cover

Mature Dense Pine Overstory
Wind-Snapped and Wind-Thrown Trees
Reduced Crown Foliage
Moderately Thick Ground Cover

Examples of Hurricane Damage To SSC Forest Vegetation (2)

Mixed Wood Riparian Forest
Wind-Thrown Trees Overlain on Creek
Thick Ground Cover

Pole-Sized Pine
High-Density Wind-Snapped Trees
Moderately Thick Ground Cover

Preparing IKONOS Data for Classification

- Acquired IKONOS data from a USGS Katrina Disaster Response Web site for Federal Agency support
  - Source - http://gisdata.usgs.net/hazards/katrina/
  - Data originally acquired 9/2/2005 and later obtained for use through a Department of Defense ClearView contract
- Stacked visible and NIR multispectral band tiff files into multiband image
- Subset portion relevant to SSC buffer zone
- Applied "bootstrap" haze correction to individual using minimum value subtract technique (Jensen, 1996)
- Georegistered data to control point network at SSC
- Applied look-up table stretches to enhance visualization of vegetation patterns on IKONOS color composites

Sources:
Jensen, J.R., 1996. Introductory Digital Image Processing: A Remote Sensing Perspective. 2nd ed. Upper Saddle River, New Jersey: Prentice Hall.

IKONOS Image Classification Methodology

- Used ERDAS IMAGINE® to run series of ISODATA unsupervised classifications from subset IKONOS imagery to collect signatures needed to classify entire study area
- Assigned cluster classes to cover type conditions based on comparison to reference data
  - Post Katrina pan-sharpened 1-meter IKONOS RGBs, NOAA aerial data, USACE aerial data, field photography, GPS data, and FEMA flood map data
- Appended all cluster class signatures obtained from 12 individual unsupervised classifications into master signature file of 227 cluster classes as a precursor to supervised classification
- Applied master signature file, IKONOS data, and maximum likelihood (ML) algorithm to produce wall-to-wall supervised classification of 227 classes
- Refined final classification through recoding, GIS editing, and filtering into final classification of 17 cover types

Training Areas Used in Generating ISODATA Clustering Signatures

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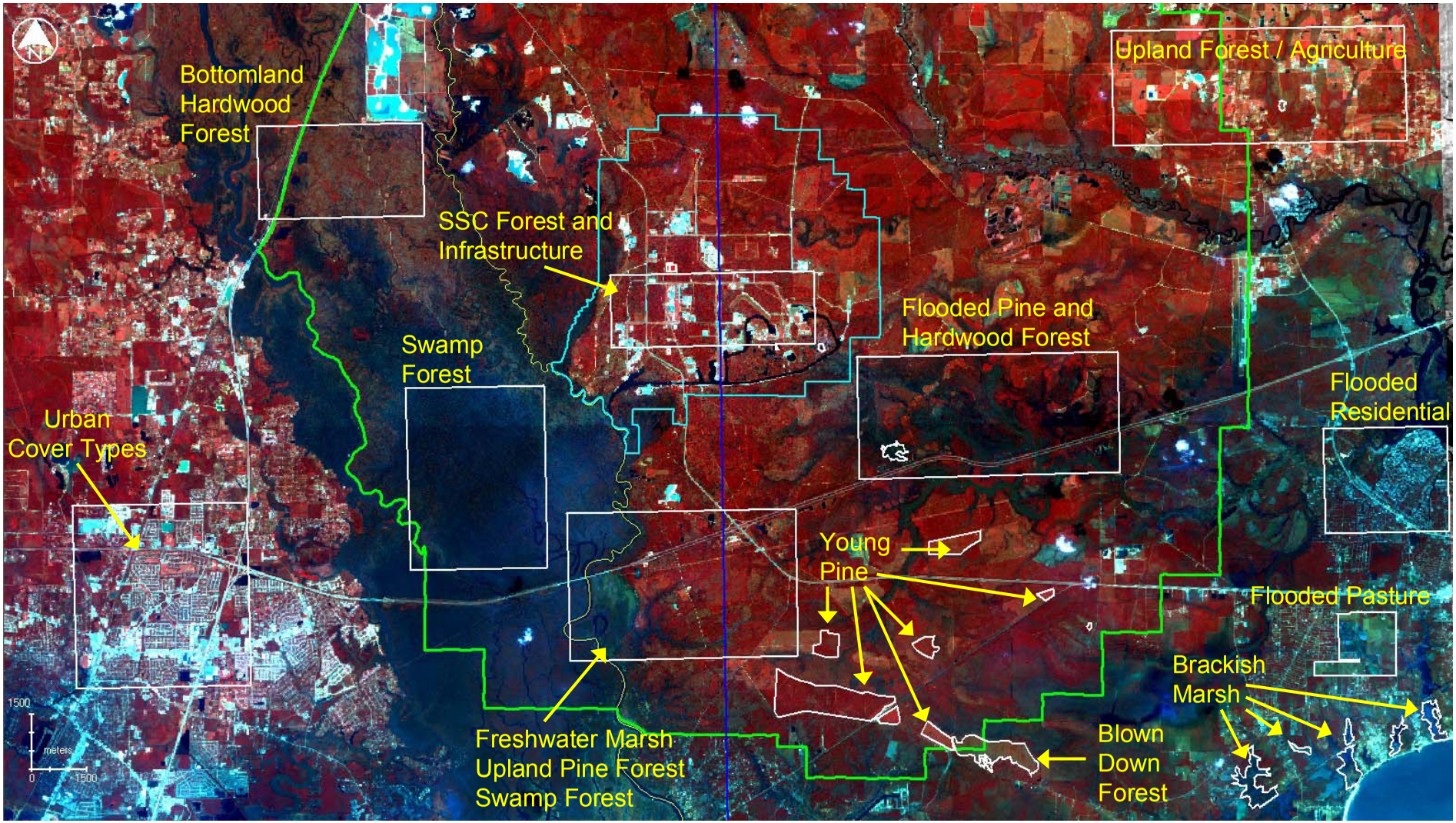
Training Areas – White Polygons Overlain onto IKONOS RGB



Final Classification Filtered (Without GIS Editing of Marsh)

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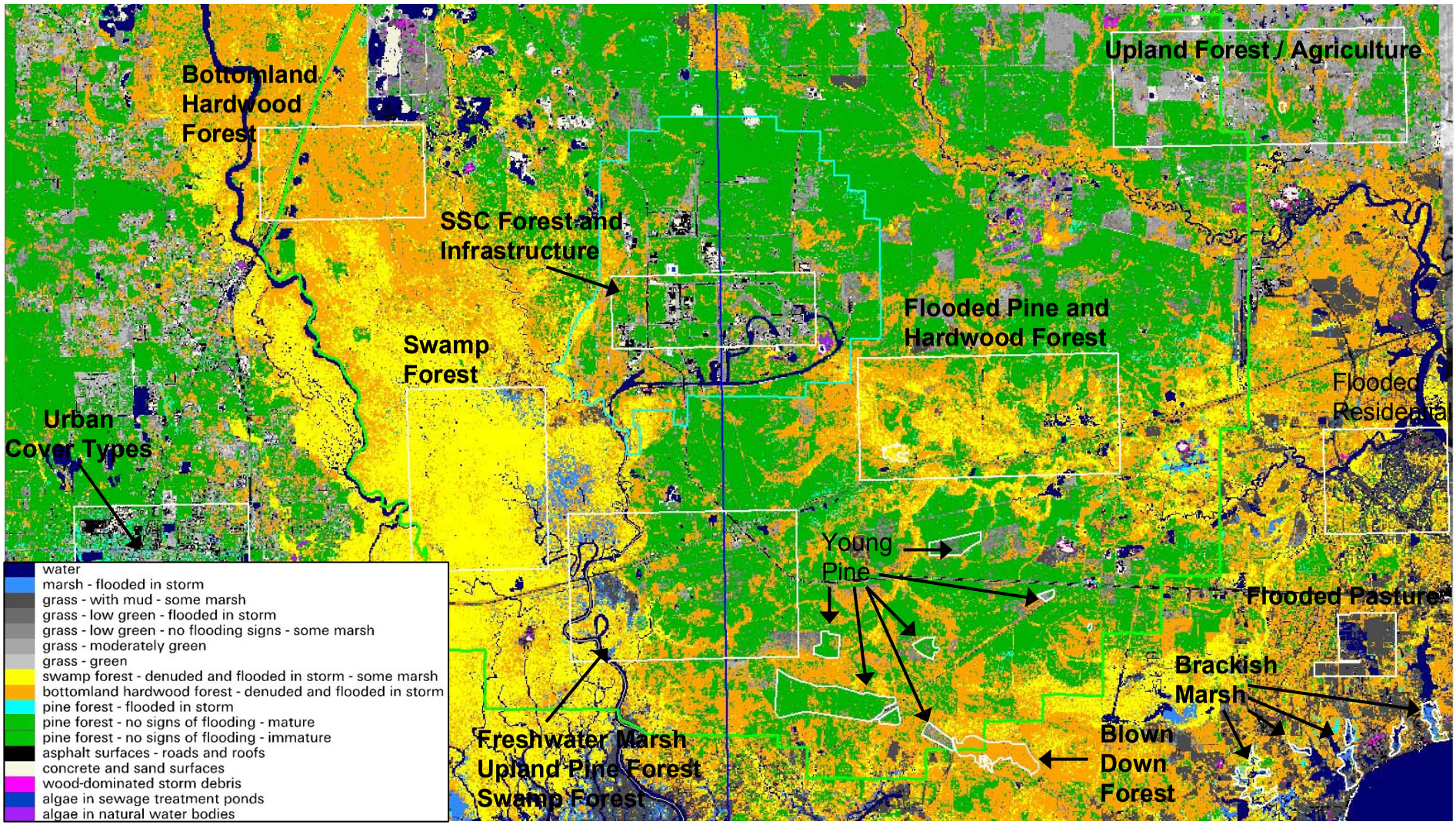
Training Areas – White Polygons Overlain onto IKONOS RGB



Final Classification Filtered - Recoded (Flood Related Classes in Sky Blue)

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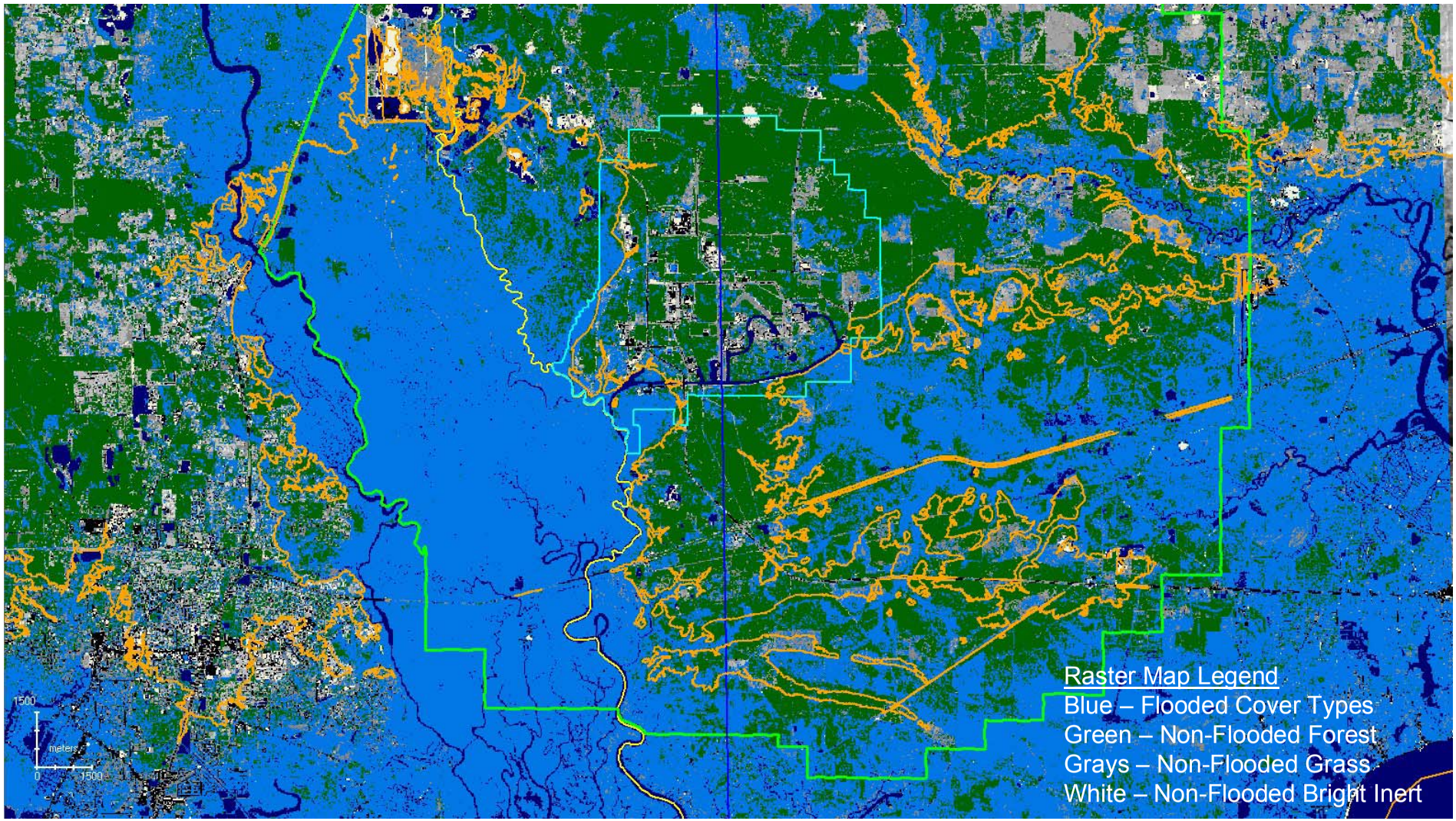
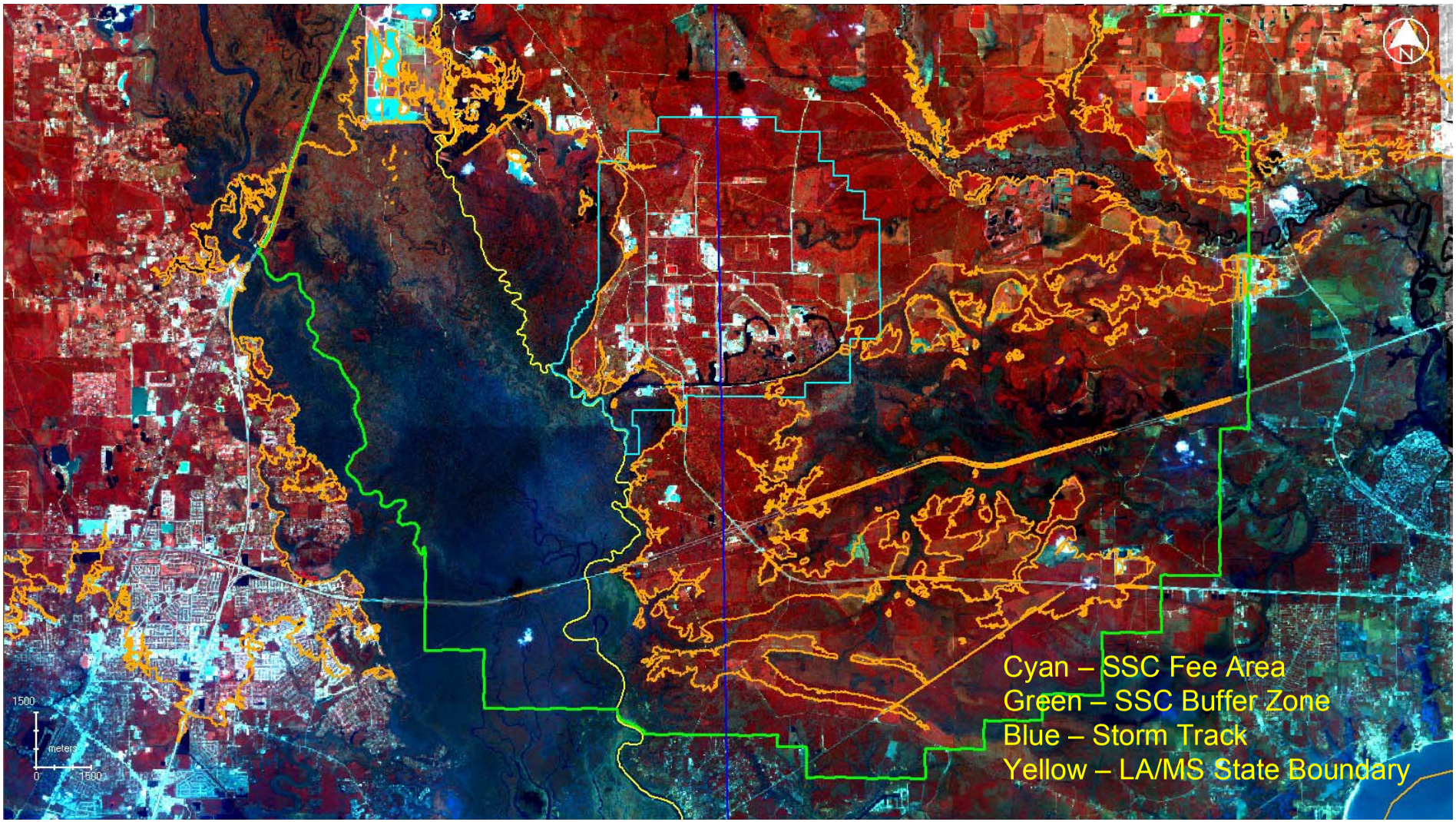
FEMA Storm Surge Vectors in Orange



FEMA Storm Surge Vectors Overlain on IKONOS RGB

FEMA Storm Surge Vectors in Orange



Visualization of Hurricane Vegetation Damage on the IKONOS RGBs

- False-color IKONOS RGBs showed several patterns of vegetation damage
  - Flooded, defoliated forest, and non-flooded defoliated forest
  - Defoliated deciduous forests
  - Partially defoliated, yet green pine forests – some flooded
  - Variations in greenness and flooding amongst marshes
  - Mud-covered non-forested surfaces (vegetated and bare urban)
  - Wood-dominated storm debris from destroyed coastal houses
- Pan-sharpened 1-meter IKONOS RGBs showed some single-tree and multi-tree blow downs, though not consistently
- The IKONOS data discussed here was collected shortly after the storm's landfall and does not show vegetation stress effects that occurred afterward due to drought

Observations on Classification Results

- Mapping of vegetation cover types
  - The classification identified pine, bottomland hardwoods, and swamp forest as well as two size classes of pine forest
  - Marsh was mapped as one type, being sometimes confused with mud-covered grass and denuded swamp forest with sawgrass. GIS editing reduced this error.
  - Some confusion occurred between pavement, roofing, and mud-covered herbaceous vegetation.

- Mapping of vegetation damage
  - Classification identified forest vegetation in terms of defoliation and flooding effects and agreed visually with IKONOS RGBs and aerial remote sensing data.
  - Mud-covered grass was identified and was indicative of flooding.
  - Wood-dominated storm debris was classified for open areas, which is potentially useful for storm mitigation and fire hazards.

- Overall, the “traditional” processing of the IKONOS data led to a wall-to-wall (i.e., area-wide) land cover damage classification for much of the SSC buffer zone
  - Flooded vegetation types taken as a whole compared well to the FEMA storm surge map.
  - This product provided site managers with alternative geospatial information on SSC flood risk potential and forest damage status.

Concluding Remarks

- The IKONOS classification gave SSC managers alternative geospatial information on location of flooded vegetation compared to FEMA storm surge maps, as SSC was also influenced by riverine flooding
- Defoliation and flooding effects often occurred together so wind and water impacts could not be always separated using this technique
- More work is required to quantify accuracy of vegetation damage classification derived from the IKONOS multispectral data
- Future work will involve use of multitemporal IKONOS and Landsat data for understanding MODIS change detection results in monitoring vegetation damage and recovery from Hurricane Katrina

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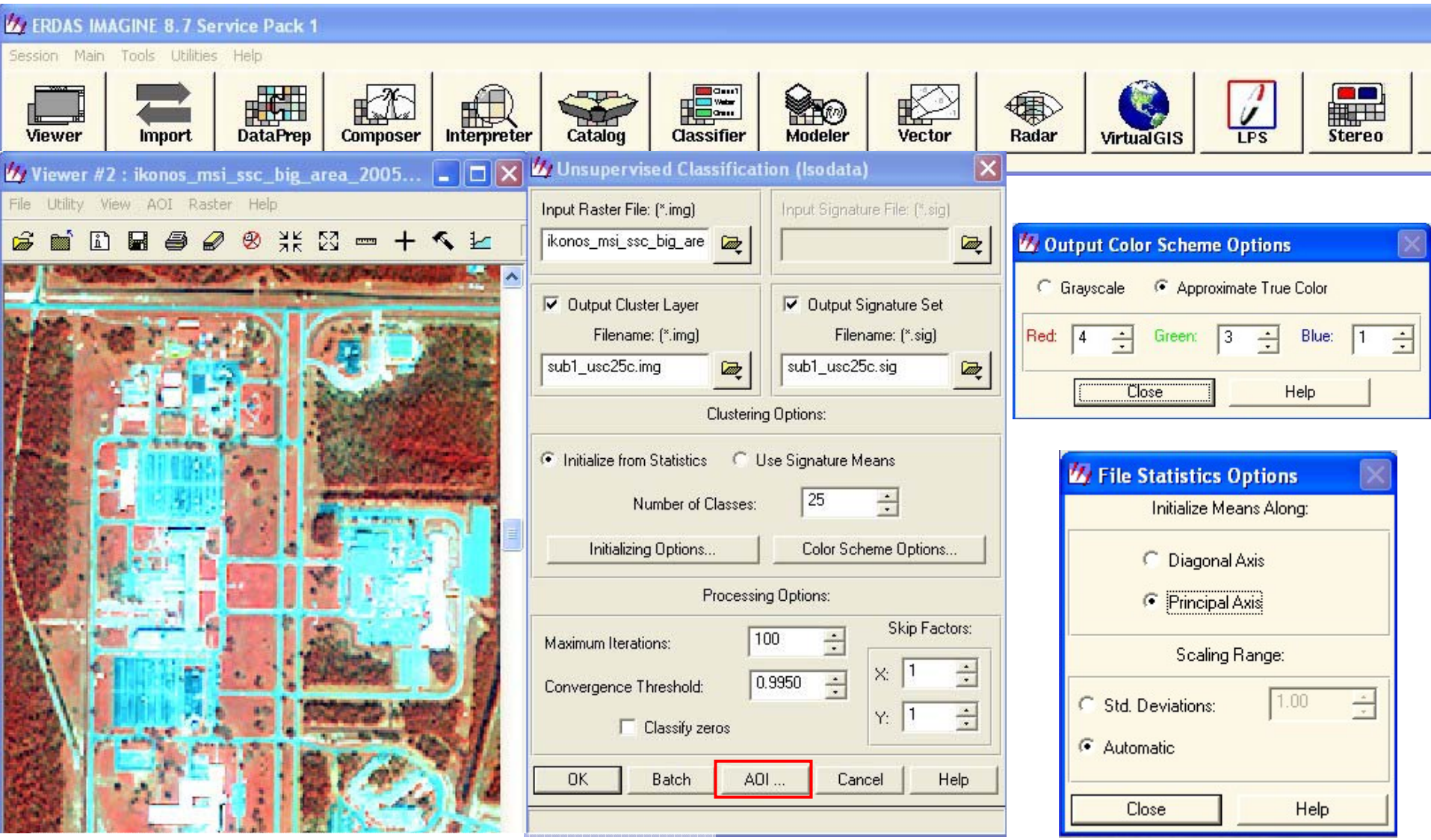
Participation in this work by Science Systems and Applications, Inc., was supported by NASA at the John C. Stennis Space Center, Mississippi, under Task Order NNS04AB54T.

Extra Slides

Setup for Typical ISODATA Classification Run



Additional Information on Isodata Classifications

Summary Statistics for Preliminary Training Classifications Used in Final Land Cover Map

Classification #	Classification Description	# Clusters	Total Hectares
1	SSC Fee Area	25	1119
2	Flooded forested area near 1-10 just west of Stennis International Airport	15	2376
3	Upland forest and agriculture landscape with flooding along riparian zones	25	2539
4	Swamp, marsh, and forest near visitor center by I-10	25	2536
5	Slidell residential housing	25	2400
6	Shoreline Park Bay St. Louis subdivision	20	980
7	Swamp and marsh north of I10	10	1888
8	Algae covered water - SSC sewage treatment ponds	10	9
9	Bottom-land hardwood forest - mostly just SE of I59	12	1152
10	Flooded and non-flooded agricultural pasture - Waveland	25	300
11	Immature pine forests - seedling and sapling sized	15	438
12	Marsh - flooded and non-flooded - within and near Buccaneer State Park	20	183
Total	All 12 Classifications	227	15919