Remote Sensing for Spatial Analysts

Delivered by

NOAA Coastal Services Center

for the

George Washington Regional Commission

18 March, 2010

Fredericksburg, VA

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Virginia Coastal Zone
MANAGEMENT PROGRAM

Training Opportunity for GIS Users:
Remote Sensing for Spatial Analysts

This one-day introductory technical training course offers spatial analysts in the field of coastal resource management an opportunity to understand remote sensing techniques by providing hands-on computer training. By the end of the course, attendees will:

- Understand how remotely sensed data can be used to address coastal resource management issues,
- Be aware of the benefits and limitations of remote sensing,
- Use remote sensing data in a geographic information system (GIS) environment.

Students will use remote sensing techniques, in combination with spatial data, to investigate issues such as land cover and change detection. Familiarity with ArcGIS is required.

Remote Sensing for Spatial Analysts

March 18, 2010

University of Mary Washington, Center for Professional & Graduate Studies

This course is from the training curriculum developed by the National Oceanic and Atmospheric Administration Coastal Services Center.

Instructor: *Shan Burkhalter*

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Course Outline

GWRC Workshop:

- Land Cover Change and Analysis
  - Remote sensing techniques for land cover and change analysis
  - Remote sensing techniques for land cover and change analysis
  - Image acquisition and processing
  - Image difference change detection
  - Supervised image classification
  - Unsupervised image classification and change analysis
  - Post classification change analysis

Additional Training Reference Material:

- Benthic Habitat Mapping
  - Management issues and benthic habitat
  - Remote sensing of benthic habitat
  - Image rectification, transformations and re-sampling
  - Aerial photograph rectification
  - Principles of photo interpretation and mapping
  - Sea grass habitat delineation

- Coastal Ocean Monitoring
  - Management issues and coastal ocean remote sensing
  - Data availability and formats
  - Sea surface temperature
  - Extracting SST values and defining temperature habitats
  - Ocean color
  - Using ocean color imagery to determine monitoring strategies

- Coastal Topographic Applications
  - Topographic management issues
  - Topography and accuracies
  - Methods for measuring topography
  - Determining the setback line in a barrier island community
  - Comparing topography data for land-use decisions

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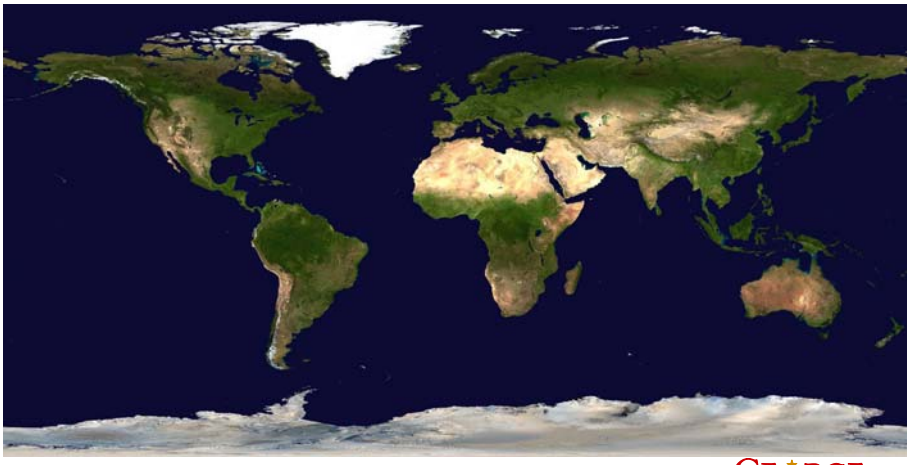

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Remote Sensing for Spatial Analysts

Instructor introduction

Name and educational background

Remote sensing experience

Student introductions

Name

Organization

Remote sensing experience

Two expectations from this class

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Remote Sensing for Spatial Analysts

Overview

- Introduction
  - Exercise: Working with Rasters
- Land Cover and Change Analysis
  - Exercise: Image Acquisition and Processing
  - Exercise: Image Difference Change Detection
  - Exercise: Supervised Image Classification
  - Exercise: Unsupervised Image Classification and Change Analysis
  - Exercise: Post Classification Change Analysis
- Summary

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Goals

- Understand the utility of remote sensing in coastal applications.
- Recognize the benefits and limitations of remote sensing.
- Examine remote sensing data in a geographic information system (GIS).

Visible oblique aerial photo, Assateague Island, Maryland.

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A Definition

IKONOS multispectral image, April 16, 2001
Nikomaroro Atoll, Republic of Kiribati.

Remote sensing is the science of gathering information from a distance.

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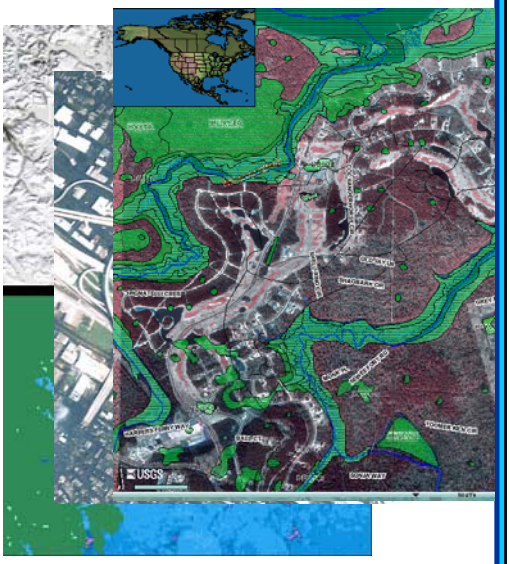
Why Use Remote Sensing?

Remote sensing can provide

- data in areas not suited to in situ sampling
- a synoptic, “big-picture” view
- consistency of data coverage
  - in time
  - in space
- a backdrop for other data



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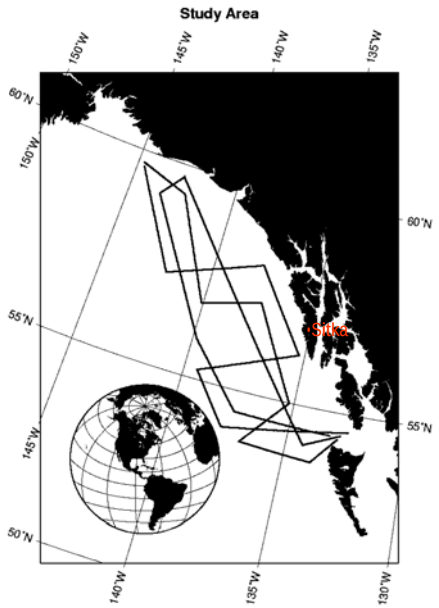
Sitka Gyre

- Shipboard sampling
  - 3 cruises
  - 21 days
  - $210,000
- 3-hour interval
- 1/2-hour interval



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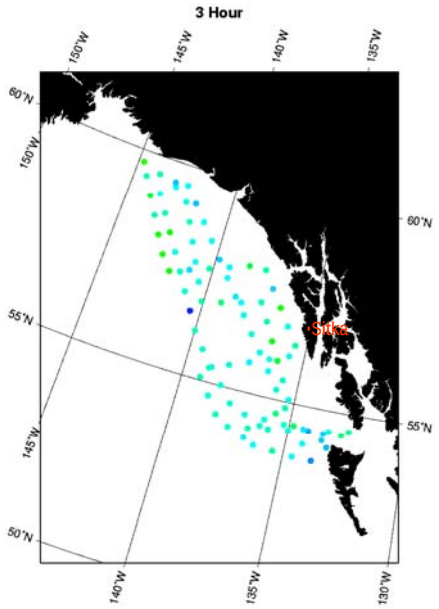

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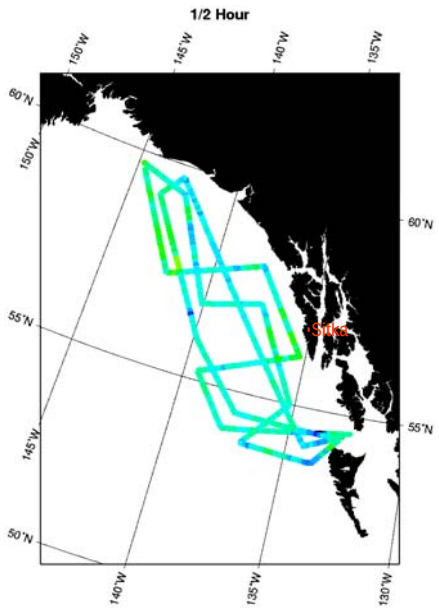

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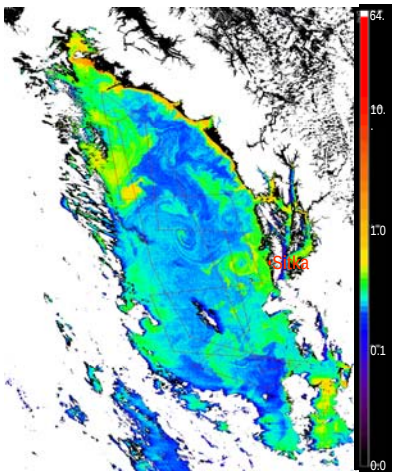
Coastal Zone Color Scanner,
May 15, 1979



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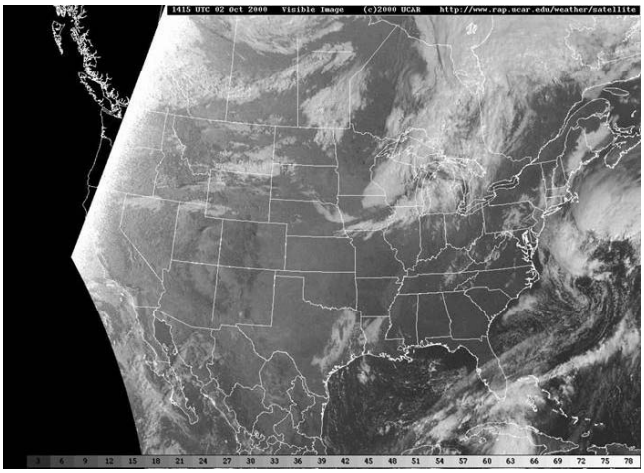
Short-range weather forecasting and description of current conditions

- Daytime clouds and sea ice
- Water vapor
- Sea surface temperature



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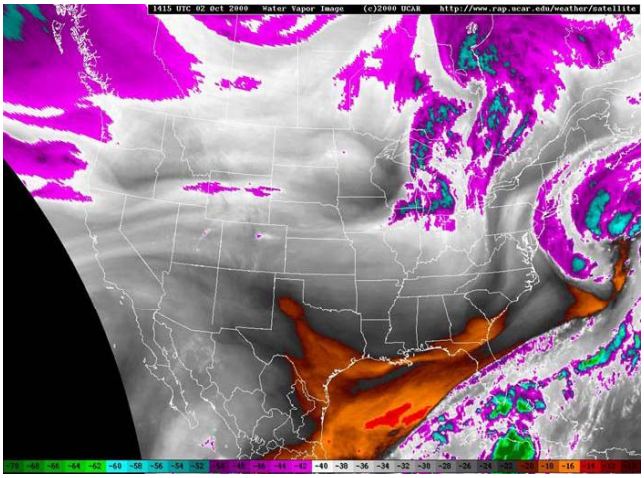

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Short-range weather forecasting and description of current conditions

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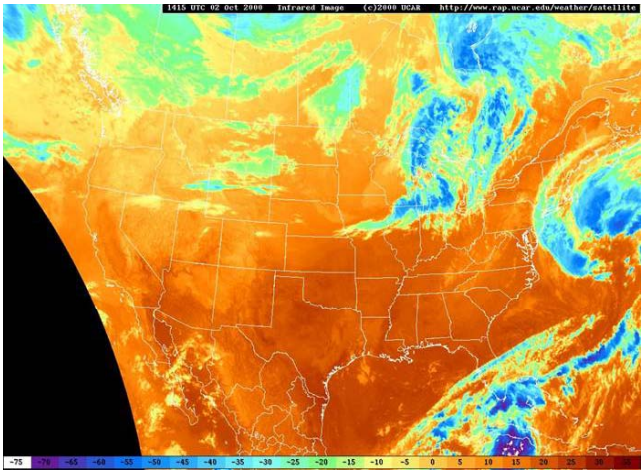

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Fundamental Remote Sensing Concepts

- Process
- Sensors
- Platforms
- Orbits
- Spectrums
- Data Structures
- Resolution/Scale
- Rectification
- Trade-offs

SeaWiFS true color image.

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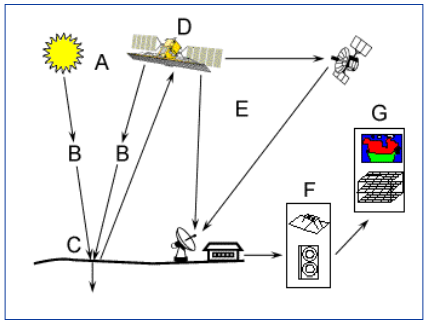
The Remote Sensing Process

A. Energy source
B. Transmission through a medium
C. Interaction with the target
D. Recording of energy by sensor
E. Transmission, reception, and processing
F. Interpretation and analysis
G. Application



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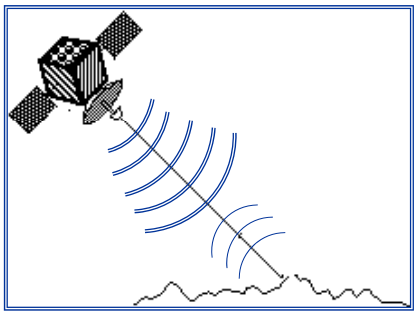
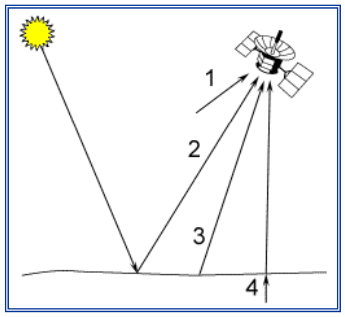
Sensor Types

Active sensors
propagate energy toward the target and record the reflected response.

Passive sensors
record energy produced by the sun or earth that is reflected or emitted back to the sensor.





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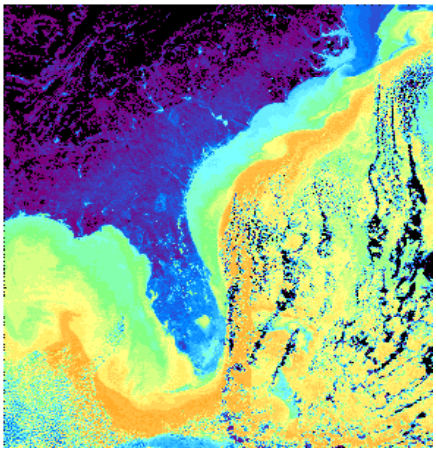
Spaceborne Platforms

Advantages

- Consistent revisit
- Potential large-area coverage

Common Sensors

- SPOT
- IKONOS
- RADARSAT
- Indian Remote Sensing
- Landsat
- SeaWiFS
- GOES
- AVHRR



Sea surface temperature image provided by the Advanced Very High Resolution Radiometer (AVHRR) aboard the POES system.

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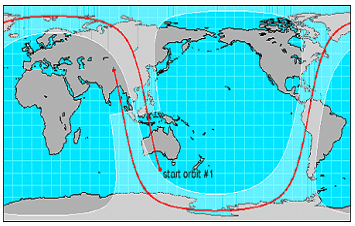
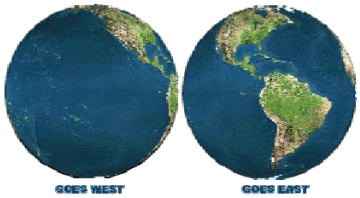
Satellite Orbits



Polar orbital path and global coverage.

- Geostationary Orbits
- Polar Orbits
  - Sun-synchronous orbits



GOES global coverage.

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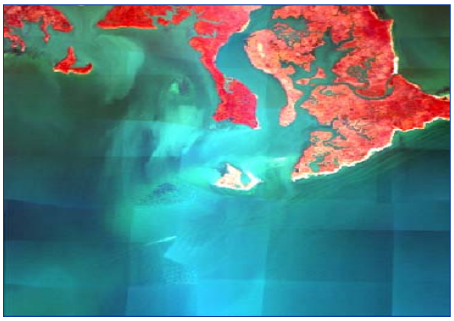
Airborne Platforms

Advantages of Airborne Platforms

- Flexible geographies
- Flexible timing or conditions
- Multiple-sensor packages



DMC mosaic of Grand Bay NERR, Mississippi

Common Data Sources

- Aerial photography
- Digital camera imagery
- LIDAR
- RADAR
- Hyperspectral Sensors (*e.g.*, CASI, AISA)
- Videography

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Shipboard Platforms

Advantages of Shipboard Platforms

- Flexible geographies
- Opportunity for real-time field reference collection
- Multiple-sensor packages

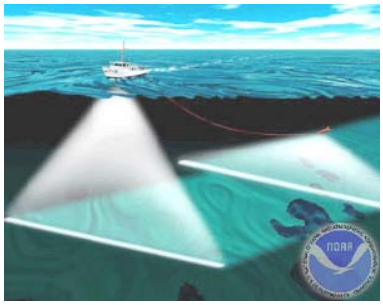
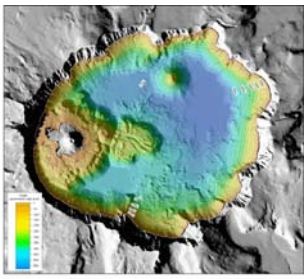


Diagram of a ship with a multibeam sonar and
A side-scan sonar towfish.

Common Sensor Types

- Acoustics
- Laser line scanners
- Underwater video



Bathymetry derived from multibeam sonar data.

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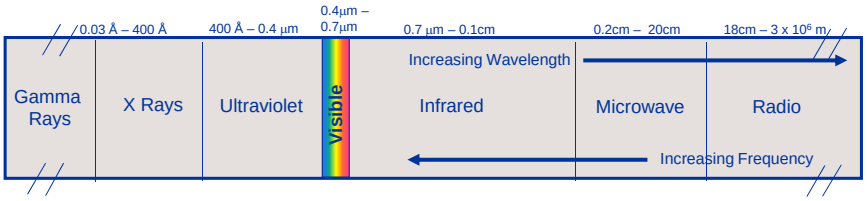
Electromagnetic Spectrum



Different sensors detect different wavelengths of the electromagnetic spectrum.

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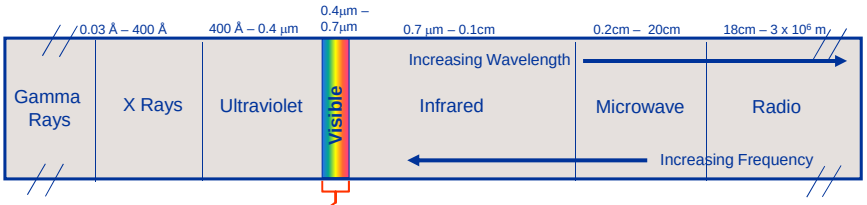
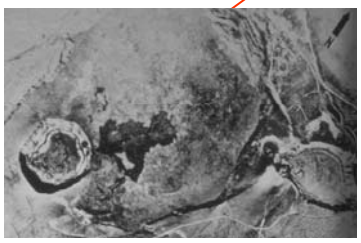
Sensors, Wavelengths, and Applications





Panchromatic visible imagery

One broad band shown in black and white

Black and white aerial photograph of volcanic calderas

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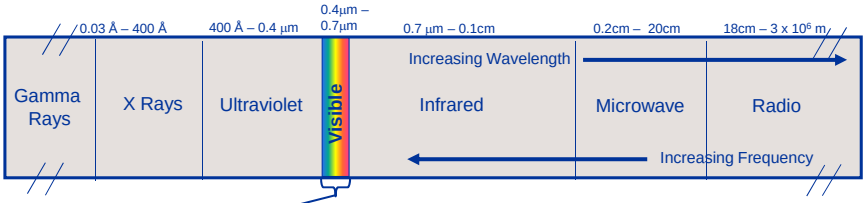
Sensors, Wavelengths, and Applications



Multi-spectral visible imagery

3-band pseudo true-color composite

IKONOS 4-m imagery of Hong Kong

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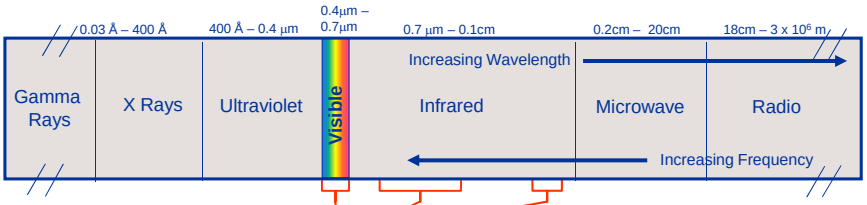
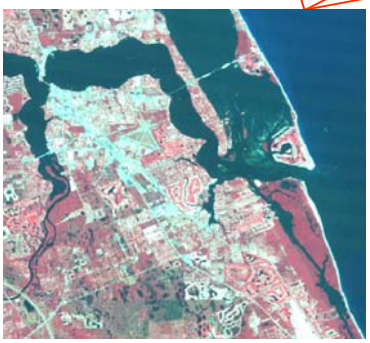
Sensors, Wavelengths, and Applications





Multi-spectral visible/infrared imagery

3-band false-color composite

Landsat Thematic Mapper data senses the visible, near-infrared, short wave infrared (2 bands), and thermal infrared

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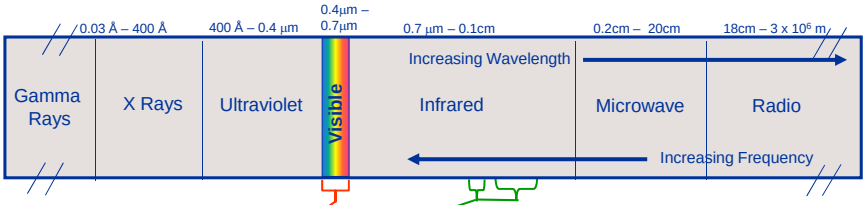
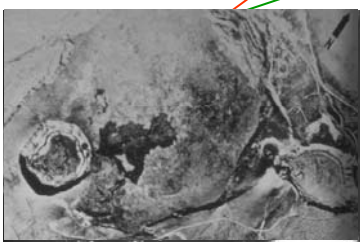
Sensors, Wavelengths, and Applications





Panchromatic visible imagery

One band shown in black and white

Volcanic calderas

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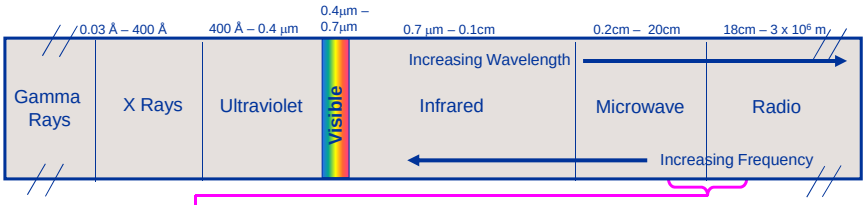
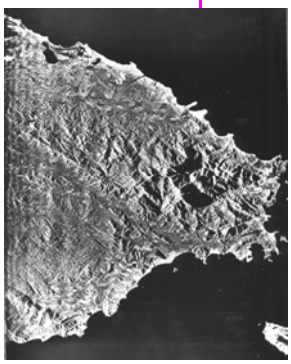
Sensors, Wavelengths, and Applications





Radar imagery

Strength of return shown: high return, white; low return, black

Shuttle Imaging Radar

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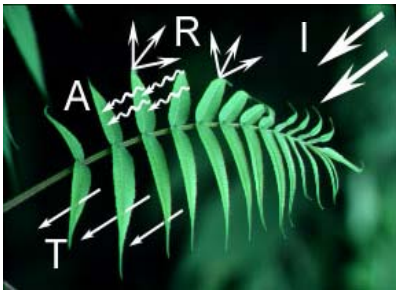
Surface Interactions



Graphic courtesy of Daniel L. Civco, University of Connecticut

Remote sensing is based on the interaction of electromagnetic energy with a surface.

(I) Incoming radiation is either

- **(R)** reflected from or re-emitted by,
- **(T)** transmitted through**,** or
- **(A)** absorbed by a feature at a given wavelength.

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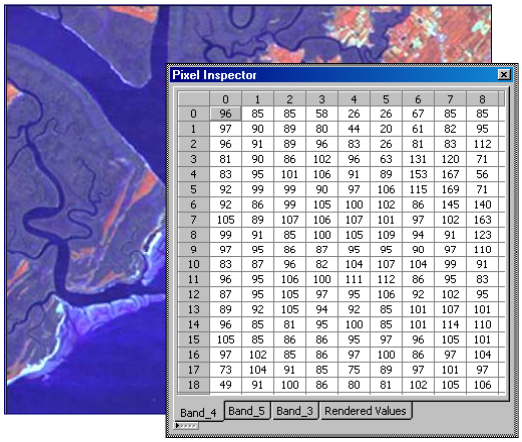
Image Structure: Raster/Grid



	0	1	2	3	4	5	6	7	8
0	96	85	85	58	26	26	67	85	85
1	97	90	89	80	44	20	61	82	95
2	96	91	89	96	83	26	81	83	112
3	81	90	86	102	96	63	131	120	71
4	83	95	101	106	91	89	153	167	56
5	92	99	99	90	97	106	115	169	71
6	92	86	99	105	100	102	86	145	140
7	105	89	107	106	107	101	97	102	163
8	99	91	85	100	105	109	94	91	123
9	97	95	86	87	95	95	90	97	110
10	83	87	96	82	104	107	104	99	91
11	96	95	106	100	111	112	86	95	83
12	87	95	105	97	95	106	92	102	95
13	89	92	105	94	92	85	101	107	101
14	96	85	81	95	100	85	101	114	110
15	105	85	86	86	95	97	96	105	101
16	97	102	85	86	97	100	86	97	104
17	73	104	91	85	75	89	97	101	97
18	49	91	100	86	80	81	102	105	106

Data are stored as a picture element, or pixel. Each pixel has a digital number (DN) that represents a reflectance value in a given band or channel.

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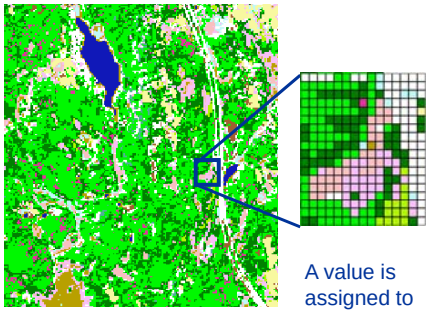
Data Product: Raster or Vector

Raster



Graphics courtesy of Daniel L. Civco, University of Connecticut

A value is assigned to each place in the grid.

Vector

Point - a single *X,Y* pair displayed using a symbol.

Line - a string of connected *X,Y* pairs.

Polygon - a set of *X,Y* coordinates that enclose an area.

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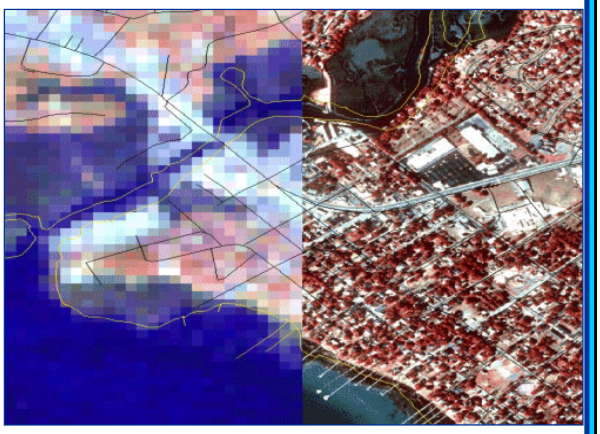
Spatial Resolution

Spatial resolution is the size of the smallest object or feature detectable by a given sensor system.

- Defined by pixel size in digital imagery
- Combination of film resolution, contrast, lens, and scale for analog imagery



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Standard spatial resolution examples at 1 to 1

¼-meter

0.25 m
1/100th mi²

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Standard spatial resolution examples at 1 to 1

1-meter

1 m
14th mi²

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Standard spatial resolution examples at 1 to 1

5-meter

5 m
3.5 mi^2

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Standard spatial resolution examples at 1 to 1

10-meter

10 m
14 mi^2

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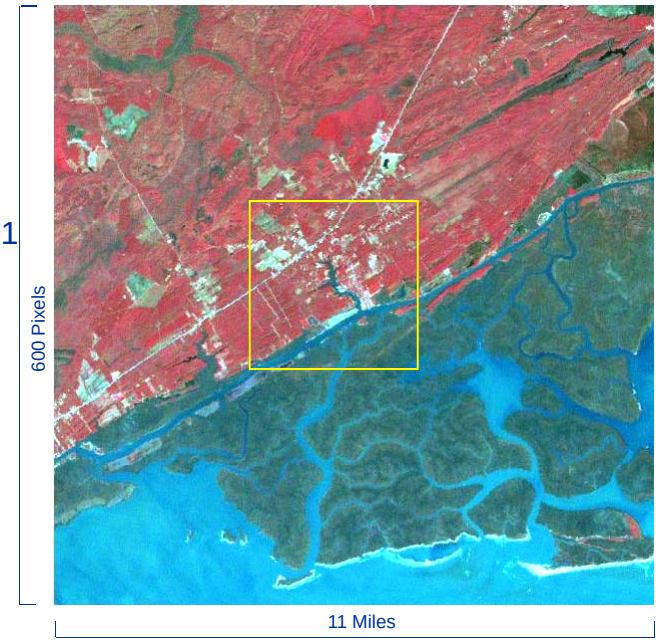
Standard spatial resolution examples at 1 to 1

30-meter

30 m
120 mi^2



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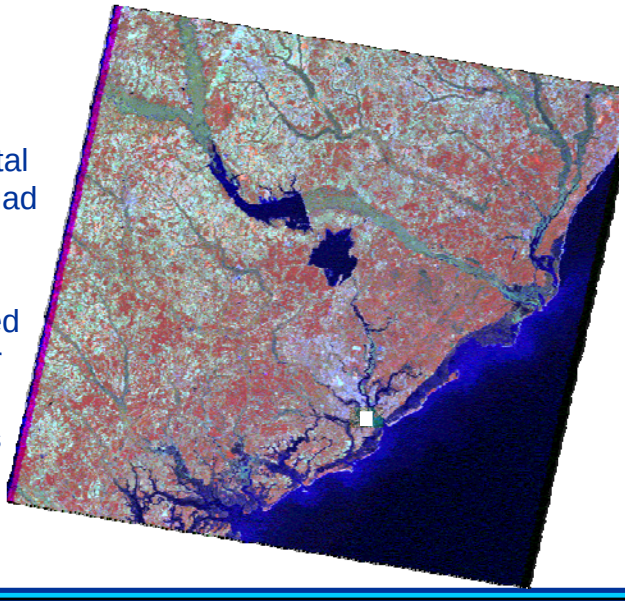
Resolution versus Coverage

- White box represents a Digital Ortho Quarter Quad
  - 3.5 miles across
- Image is one full Landsat Enhanced Thematic Mapper (ETM) scene
  - 100 miles across



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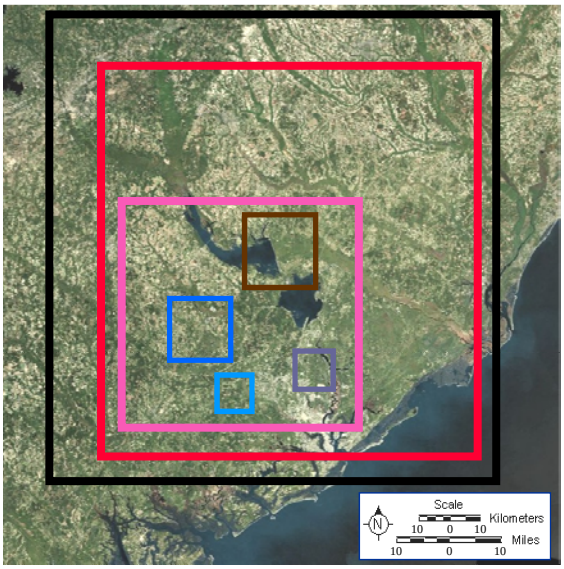
Selected Satellite Footprints

Landsat 7	185 by 170 km 30m multispectral 15m panchromatic
Indian Remote Sensing	145 by 145 km 25m multispectral 5m panchromatic
SPOT	60 by 60 km 20m short wave IR 10m multispectral 2.5m panchromatic
WorldView1	17.6 km Swath .5m panchromatic
QuickBird 2	16 km Swath 2.5m multispectral .75m panchromatic
IKONOS	11 by 11 km 4m multispectral 1m panchromatic
OrbView 3	8 by 8 km 4m multispectral 1m panchromatic



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Map Scale

1:100,000
Small map scale,
objects appear smaller.

1:12,000
Large map scale,
objects appear larger.

The **scale** of an image or map is the relationship between distances measured on the image and the corresponding distance on the ground.

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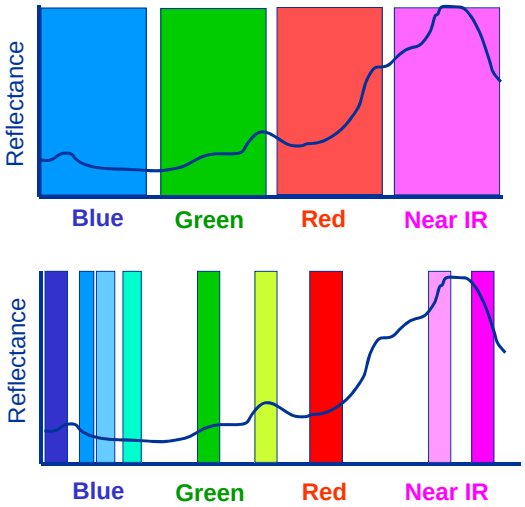
Spectral Resolution

Spectral resolution is the number and width of bands of electromagnetic energy detectable by a sensor system.



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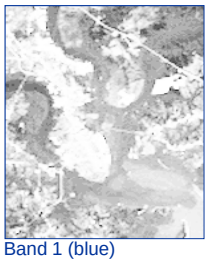
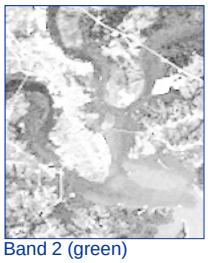
Landsat 5 Thematic Mapper Spectral Band/Channel Examples

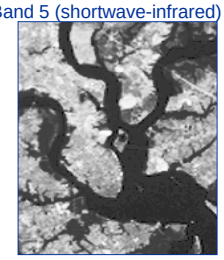

Band 1 (blue)


Band 2 (green)

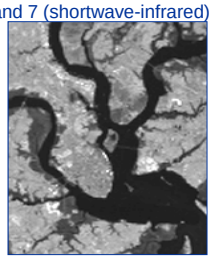
Band 3 (red)

Band 4 (near-infrared)

Band 5 (shortwave-infrared)



Band 7 (shortwave-infrared)



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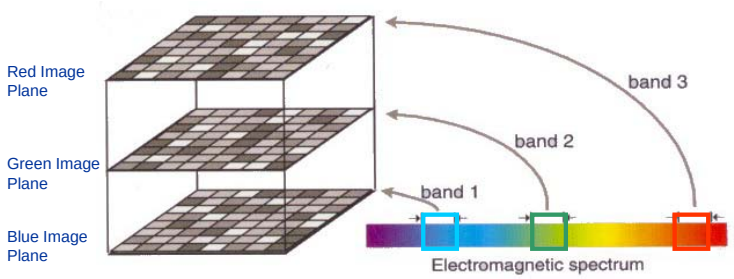
Spectral Composites

Different spectral bands can be combined to produce images that portray varying degrees of spectral sensitivity. These composite images are categorized by two types: **1) true color** or **2) false color composite**.



Graphic courtesy of Daniel L. Civco , University of Connecticut

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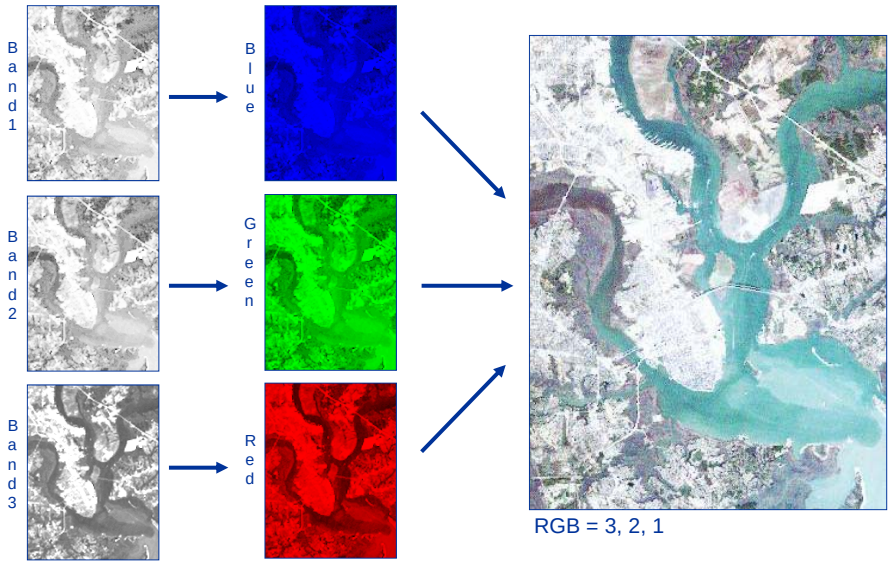
True Color Spectral Composites



CRT color guns

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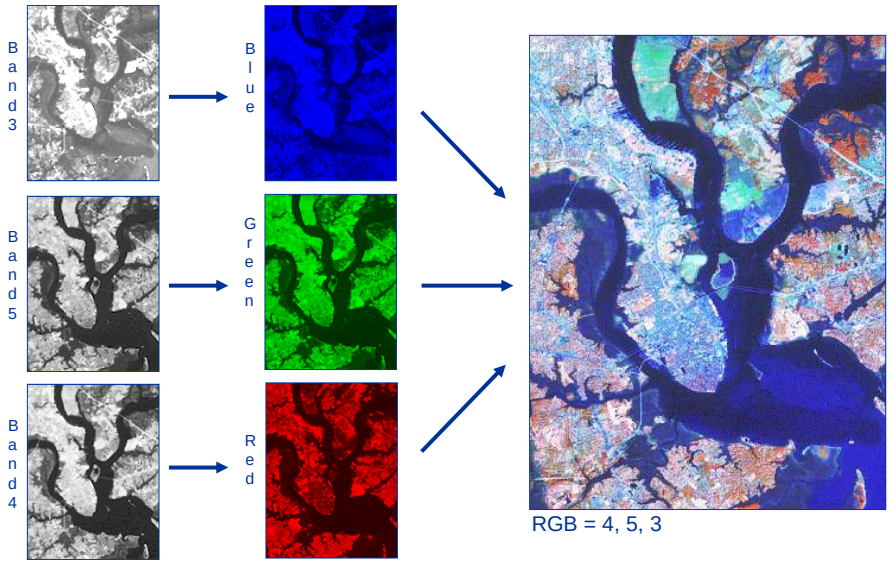
False Color Spectral Composites



CRT color guns

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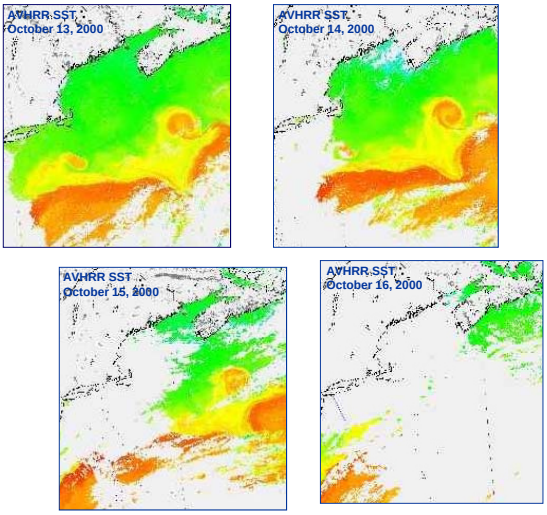
Temporal Resolution

Temporal resolution is the number of images obtainable for a given area over a given time-frame.



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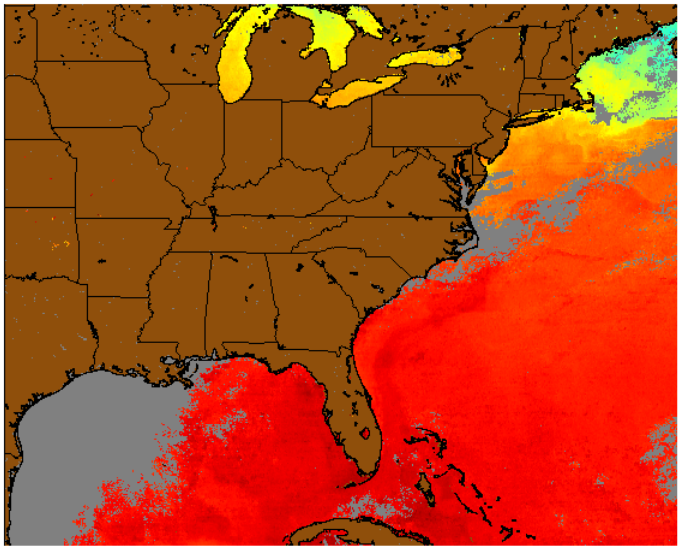
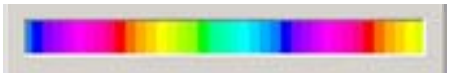


Radiometric Resolution

8-bit color ramp

24-bit color ramp



Radiometric Resolution is the number of bins into which a spectral measurement in a given band or channel can be assigned.

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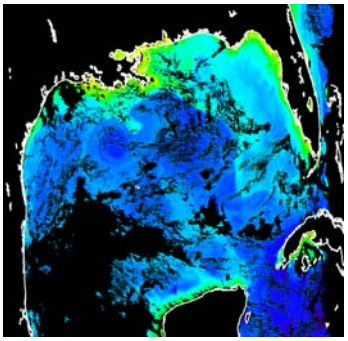
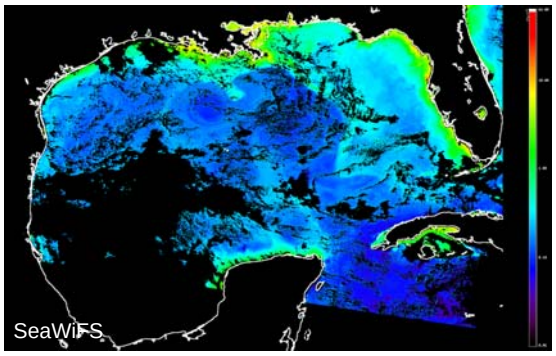
Image Rectification

Image rectification is the process of assigning real-world coordinates to image pixels.





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Rectification Types

Registration - The process of relating two spatial data sets to each other. No coordinate system needed.

Georeferencing - The process of assigning map coordinates to already projected spatial data.

Rectification - Involves warping an image to fit a given projection.

Ortho-rectification - Rectification process that includes elevational data and corrects for terrain displacement.

Source: ERDAS Field Guide

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Remote Sensing Decision Criteria

- Application
  - Can remote sensing help solve the problem?
  - Can it detect the features I'm concerned with?
- Logistics and Finances
  - Where can I get the imagery?
  - How long does it take to obtain? To process?
  - Is it compatible with my other hardware, software, data, etc.?
  - Where can I go for expertise in processing and interpretation?
  - How much does it cost?

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Costs and Benefits Continuum

Spatial Resolution	High Detail	Limited Coverage
Spectral Resolution	Increased Information	Complex Processing
Processing Software	Advanced Analysis Capability	High Skill Requirement
Data Availability	Few Sources of Imagery	Near Real-Time Downloads
Data Restrictions	Single-User Licenses	Unlimited Distribution
Infrastructure Considerations	In-House Capacity	Contracted Service

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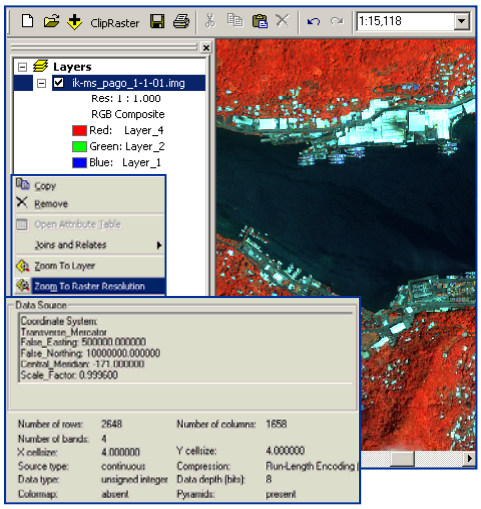
Exercise 1: Working with Raster Data

Objectives

- Understand the display techniques for multiband continuous data.
- Inspect the display characteristics to improve interpretation or features.

Steps

- Display a remote sensing image in ArcGIS.
- Manipulate the display of spatial and spectral characteristics.



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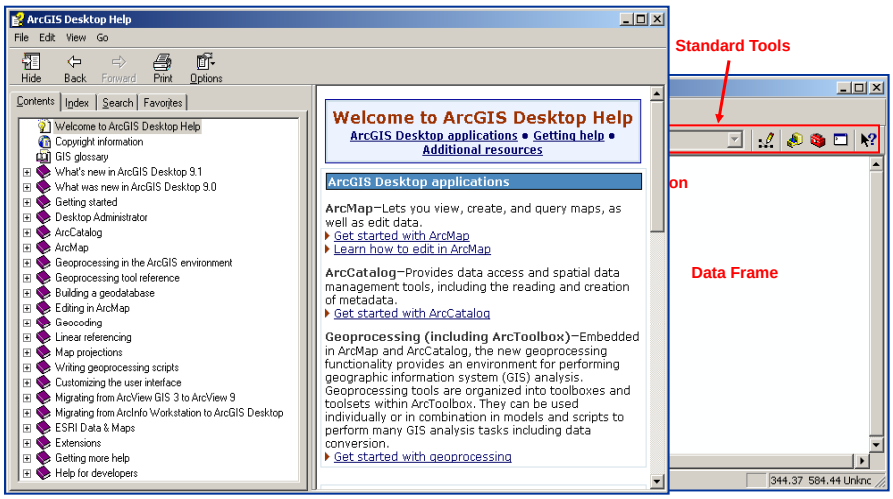
ArcGIS Interface



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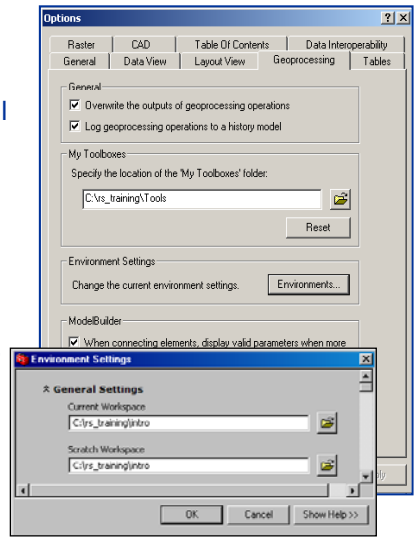
Working with Raster Data in ArcGIS

Consider environmental settings such as the directory path to your data, standard protocol for displaying types of data, and what tools or extension will be needed.

- Data c:\rs_training\intro
- Toolbox c:\rs_training\tools
- Scratch c:\rs_training\intro

When working in ArcMap, intermediate data sets are often created. Setting the scratch workspace gives the user control over where these files are stored.



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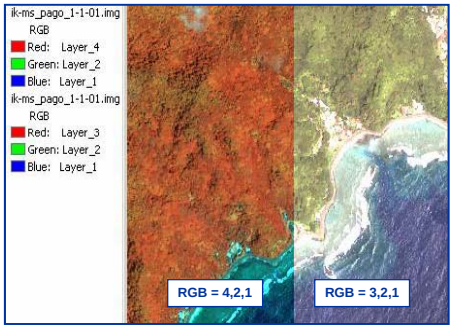
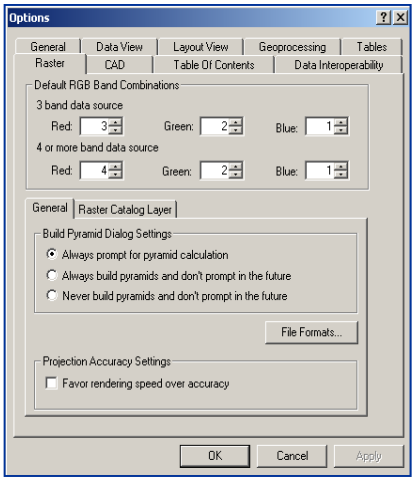
Working with Raster Data in ArcGIS

Set default RGB band combinations to establish standard viewing parameters for multi-band raster data.

3 band data source, RGB = 3,2,1

4 or more band data source, RGB = 4,2,1





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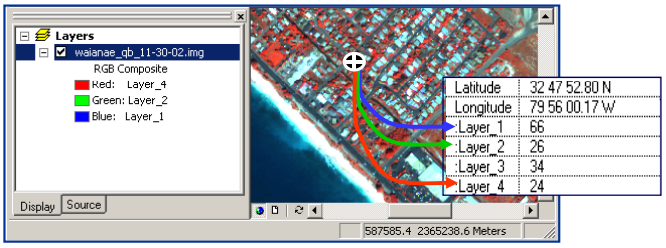
Data Type

Continuous Data are represented by a general gradation of values. In the case of 8-bit (2^8) data there would be 256 values (0-255). For most raw remotely sensed imagery, these values represent brightness, *i.e.*, the amount of energy reaching a sensor that is reflected or emitted from the earth's surface.



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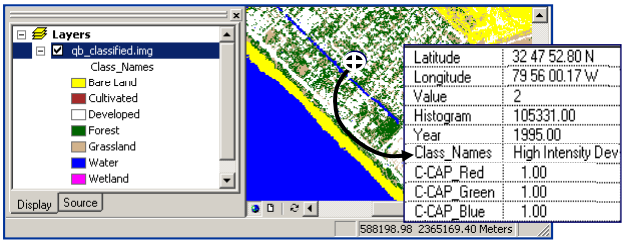
Data Type

Thematic Data represent a discrete range of values, *i.e.*, categories in a thematic map. Only one value per pixel is displayed. ArcView stores all of the categories in a single band. This data type is generally used to represent some value-added procedure applied to raw remotely sensed imagery.



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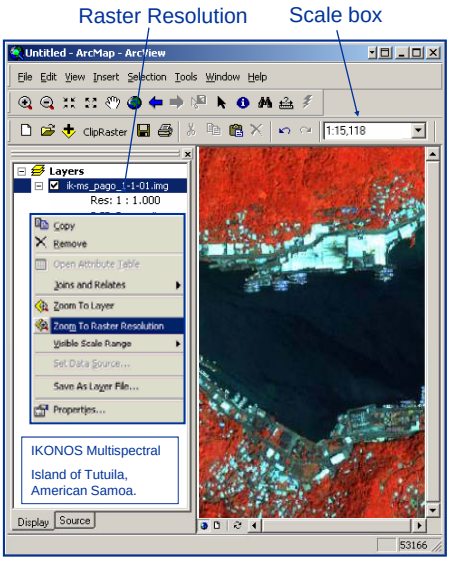
Spatial Characteristics

- **Spatial Resolution** indicates the size of each picture element (pixel).
- **Raster Resolution** is the ratio of screen pixels to image pixels.
- **Map Scale** is the ratio of units on a map, or in this case an image display, to units on the ground.



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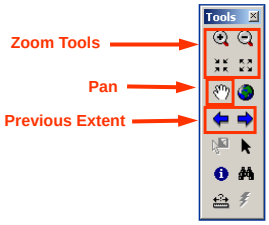
Navigation and Raster Effect Tools



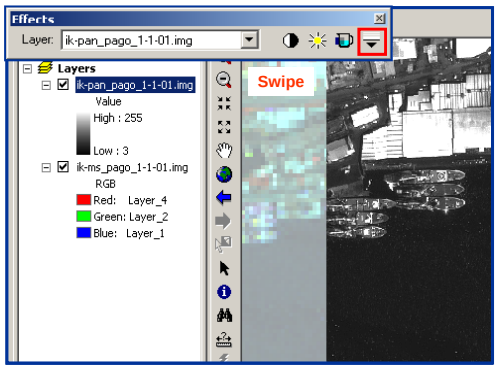


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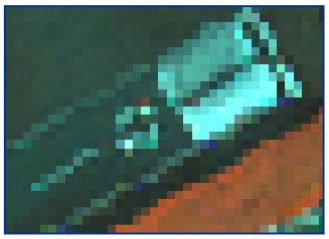
Image Display Resampling

- **Nearest Neighbor** takes the value of the closest pixel.
- **Bilinear Interpolation** pixel values are determined from the output average of a 2 by 2 pixel filter.
- **Cubic Convolution** pixel values are derived from the output function of a 4 by 4 pixel filter.



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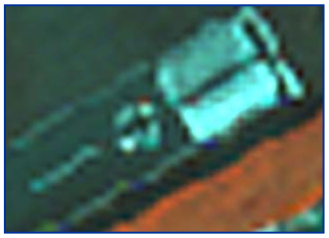

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Spectral Characteristics

Layer Properties

- Band combinations
  - RGB image planes
- Brightness
- Contrast
- Histogram stretch

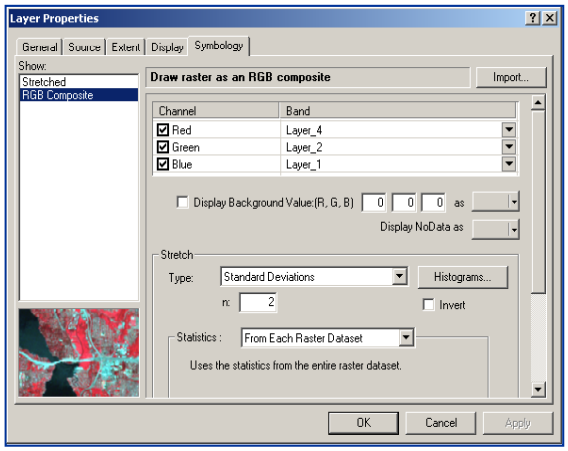

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Image Histogram

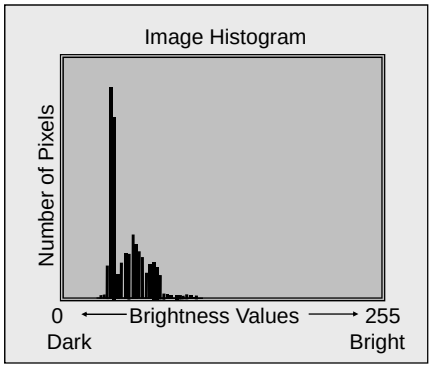

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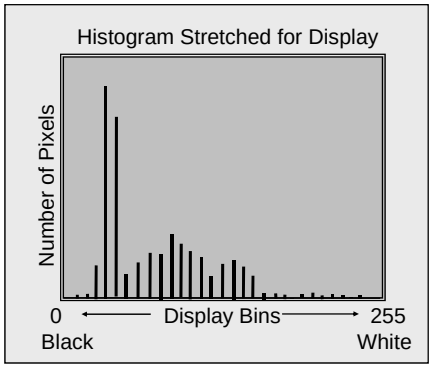
Image Histogram



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Exercise 1: Working with Raster Data

Objectives

- Understand the display techniques for multiband continuous data.
- Inspect the display characteristics to improve interpretation of features.

Steps

- Display a remotely sensed image and manipulate the display of spatial and spectral characteristics.
- Apply image enhancement techniques to improve the ability to interpret features in the image.

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Exercise 1. Summary:

Skills practiced

- Band combination display using combinations of the red, green, and blue image planes.
- Spatial resampling techniques.
- Histogram stretches to enhance features.

Important things to remember

- ArcGIS tools support basic raster image processing functions such as importing, viewing, and spectral/spatial image enhancements.
- Additional raster analysis functions used to derive thematic and quantitative information from continuous imagery are available with the ESRI Spatial Analyst Extension.

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Exercise 1. Summary:

- **Continuous data** are represented by a general gradation of values and usually represent brightness values.
- **Thematic data** are discrete in that they display only one value per pixel.
- **A false-color composite,** with the NIR band displayed in the red image plane is the most commonly used method for displaying terrestrial remote sensing data. Vegetation appears red in this band combination.
- Three image resampling techniques can be applied to an image display: **nearest neighbor, bilinear interpolation,** and **cubic convolution**.
- For each spectral band, every pixel is assigned a brightness value. The range of pixel values may not take up the full range of available display bins but can be adjusted by performing **histogram stretches**.

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Coastal Applications

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Land Cover and Change Analysis

Overview

- **Coastal Issues of Concern**
  - Urban Growth
  - Resource management
- **Management Needs**
  - Resource Inventory
  - Analysis of Landscape Change
- **Remote Sensing Solutions**
  - Image Analysis
  - Image processing techniques
  - Applications
- **Exercises**
  1. Image Acquisition and Processing
  2. Image Difference Change Detection
  3. Supervised Image Classification
  4. Unsupervised Image Classification and Change Analysis
  5. Post Classification Change Analysis

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Coastal Issues of Concern

Urban Growth in the Coastal Zone

- Greater than 50 percent of the U. S. population lives within 100 miles of the coast
- 3,500 new residents move into the coastal zone each day
- Competition for land and water resources continues to increase

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Coastal Issues of Concern

Resource Management

- Protect natural resources
- Manage coastal development to reduce the impact of natural hazards
- Protect and restore coastal water quality
- Support comprehensive planning and management of coastal resources
- Coordinate and simplify governmental decision making

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Management Needs

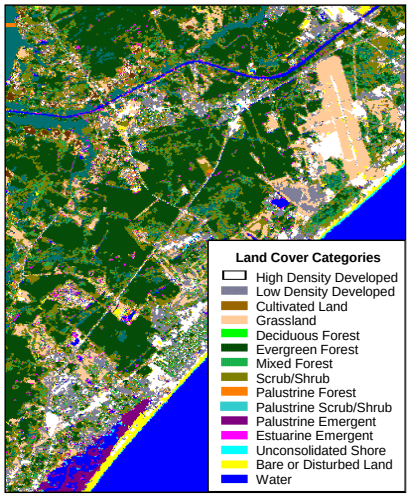
Resource Inventory

Habitat Types

- Wetlands
- Estuaries
- Forests
- Dunes
- Barrier islands

Benefits

- Air and water quality
- Habitat
- Hazard mitigation
- Recreation
- Cultural and economic resources



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Management Needs

Landscape Change

- Habitat fragmentation
- Loss of wetlands
- Loss of forest buffers
- Expansion of impervious surfaces

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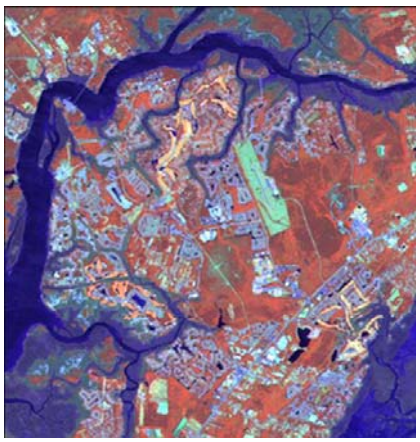
Management Needs

Landscape Change

- Habitat fragmentation
- Loss of wetlands
- Loss of forest buffers
- Expansion of impervious surfaces



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Management Needs

Landscape Change

- Habitat fragmentation
- Loss of wetlands
- Loss of forest buffers
- Expansion of impervious surfaces

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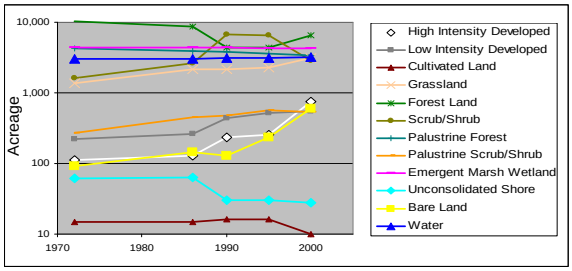
Trend Analysis



	Land Cover Category	1972	1986	1990	1995	2000
	High Intensity Developed	112	130	235	255	745
	Low Intensity Developed	219	266	435	524	547
	Cultivated Land	15	15	16	16	10
	Grassland	1,364	2,150	2,127	2,303	3,087
	Forest Land	10,417	8,718	4,339	4,396	6,548
	Scrub/Shrub	1,615	2,593	6,752	6,549	2,902
	Palustrine Forest	4,212	3,908	3,847	3,607	3,406
	Palustrine Scrub/Shrub	270	445	477	561	533
	Emergent Marsh Wetland	4,394	4,339	4,340	4,252	4,225
	Unconsolidated Shore	61	63	30	30	28
	Bare Land	91	144	130	233	601
	Water	3,062	3,062	3,104	3,104	3,201

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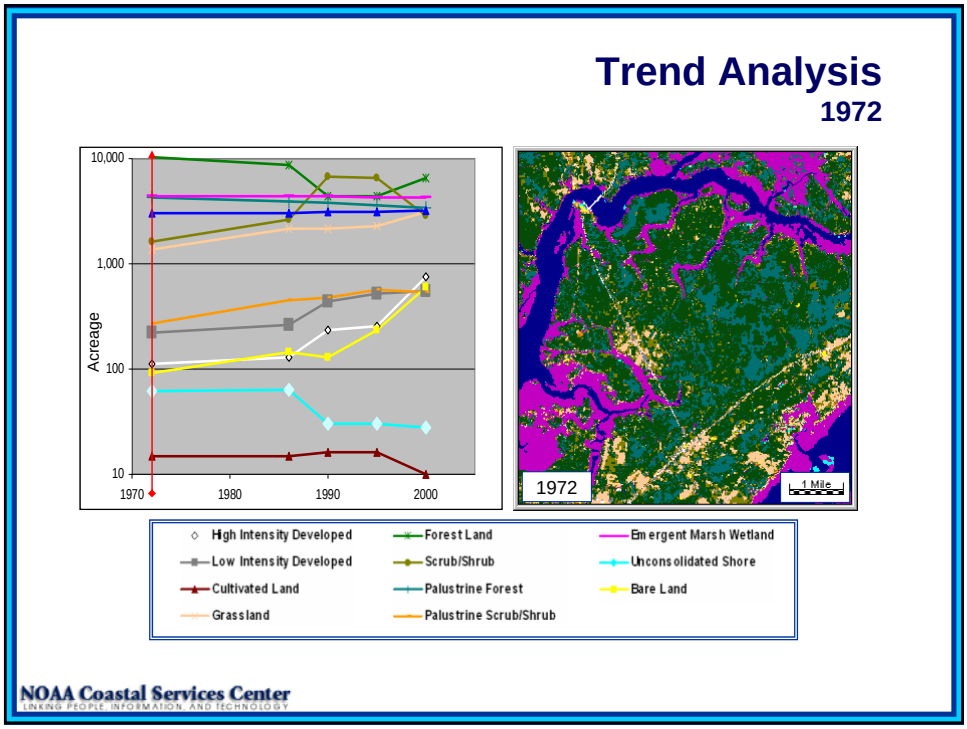
Trend Analysis
1972
10,000
1,000
100
10
Acreage
1970
1980
1990
2000
1972
1 Mile
High Intensity Developed
Forest Land
Emergent Marsh Wetland
Low Intensity Developed
Scrub/Shrub
Unconsolidated Shore
Cultivated Land
Palustrine Forest
Bare Land
Grassland
Palustrine Scrub/Shrub
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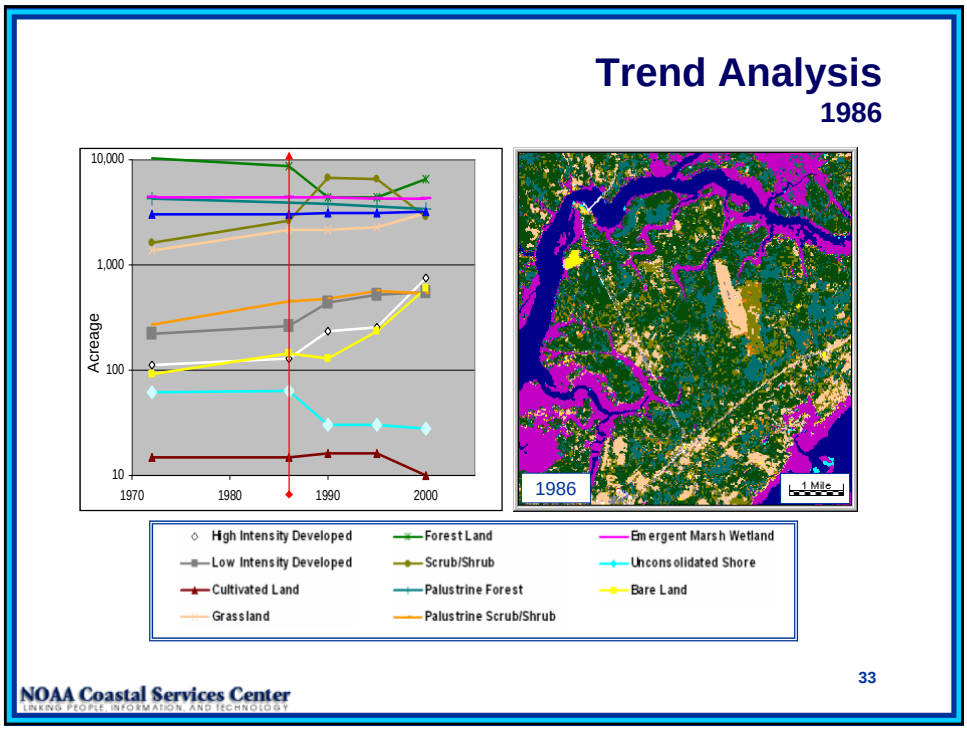
Trend Analysis
1986
10,000
1,000
100
10
Acreage
1970
1980
1990
2000
1986
1 Mile
High Intensity Developed
Forest Land
Emergent Marsh Wetland
Low Intensity Developed
Scrub/Shrub
Unconsolidated Shore
Cultivated Land
Palustrine Forest
Bare Land
Grassland
Palustrine Scrub/Shrub
33
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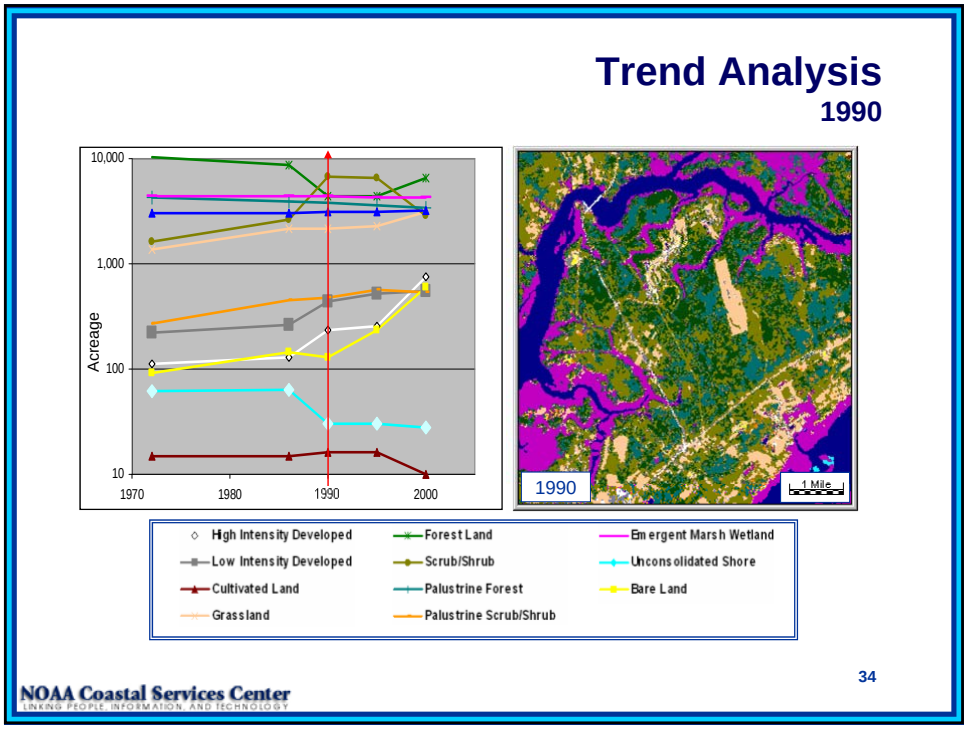
Trend Analysis
1990
10,000
1,000
100
10
Acreage
1970
1980
1990
2000
1990
1 Mile
High Intensity Developed
Forest Land
Emergent Marsh Wetland
Low Intensity Developed
Scrub/Shrub
Unconsolidated Shore
Cultivated Land
Palustrine Forest
Bare Land
Grassland
Palustrine Scrub/Shrub
34
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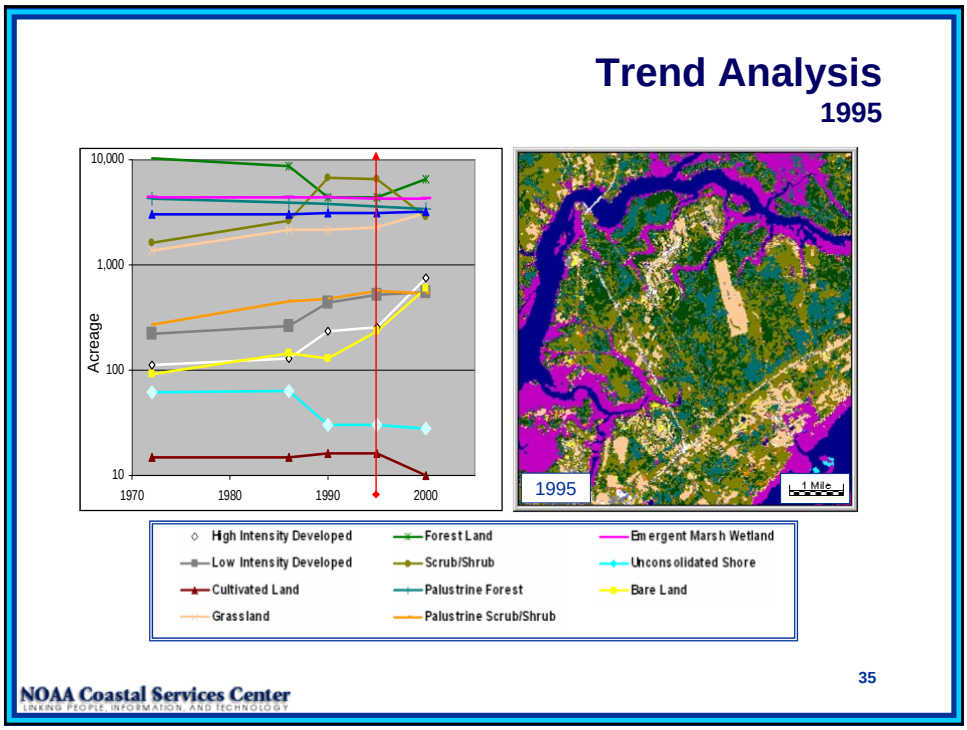
Trend Analysis
1995
10,000
1,000
100
10
Acreage
1970
1980
1990
2000
1995
1 Mile
High Intensity Developed
Forest Land
Emergent Marsh Wetland
Low Intensity Developed
Scrub/Shrub
Unconsolidated Shore
Cultivated Land
Palustrine Forest
Bare Land
Grassland
Palustrine Scrub/Shrub
35
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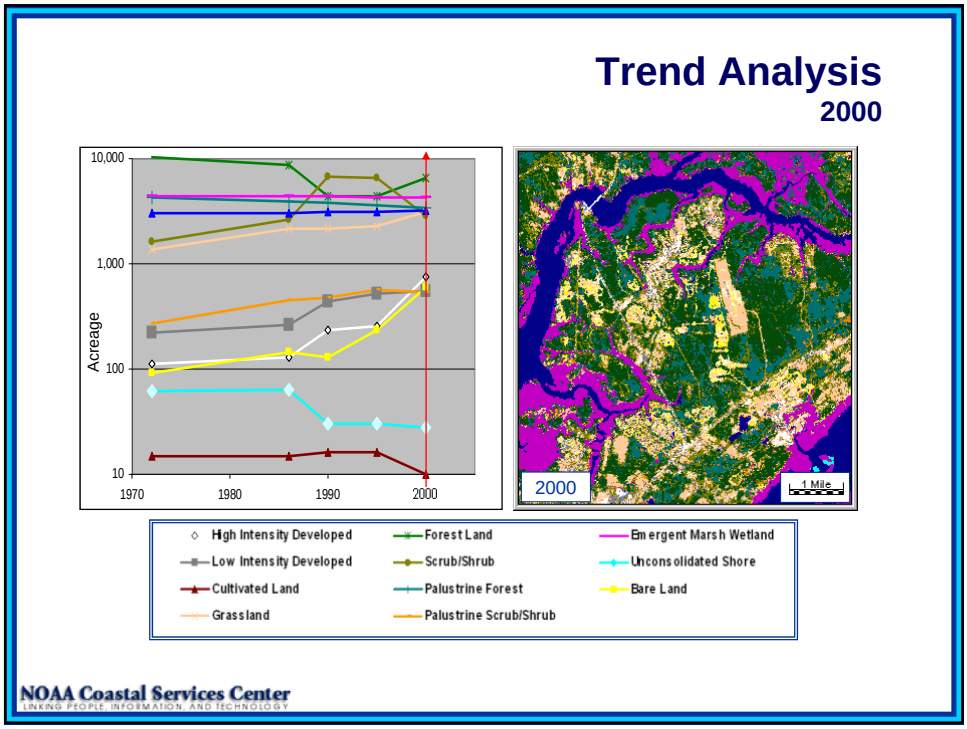
Trend Analysis
2000
10,000
1,000
100
10
Acreage
1970
1980
1990
2000
2000
1 Mile
High Intensity Developed
Low Intensity Developed
Cultivated Land
Grassland
Forest Land
Scrub/Shrub
Palustrine Forest
Palustrine Scrub/Shrub
Emergent Marsh Wetland
Unconsolidated Shore
Bare Land
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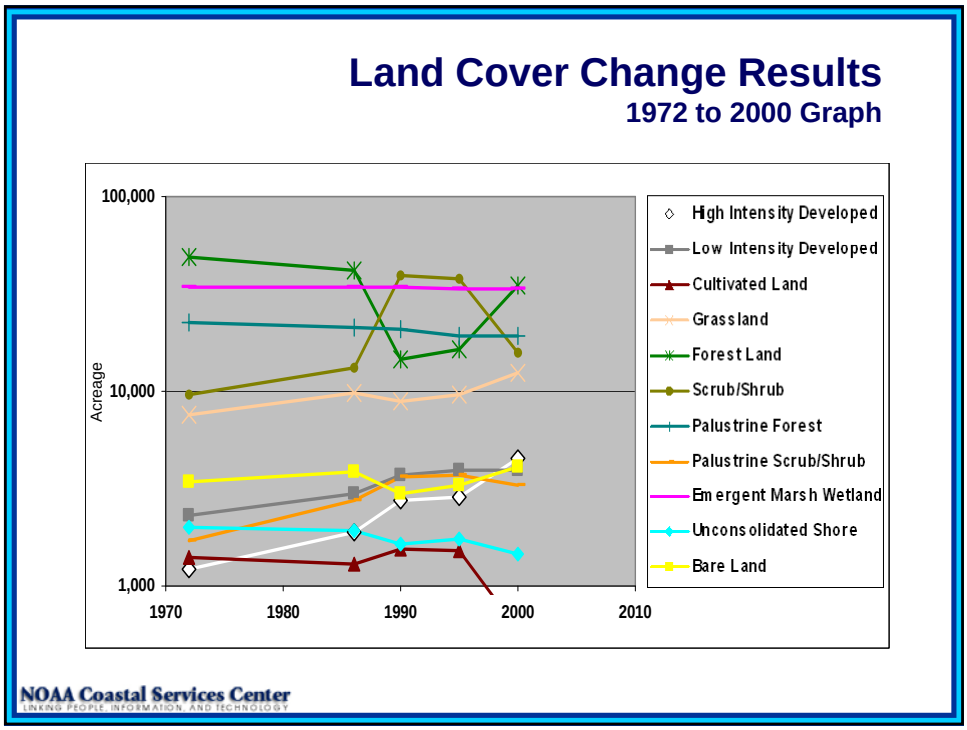
Land Cover Change Results
1972 to 2000 Graph
100,000
10,000
1,000
Acreage
1970
1980
1990
2000
2010
High Intensity Developed
Low Intensity Developed
Cultivated Land
Grassland
Forest Land
Scrub/Shrub
Palustrine Forest
Palustrine Scrub/Shrub
Emergent Marsh Wetland
Unconsolidated Shore
Bare Land
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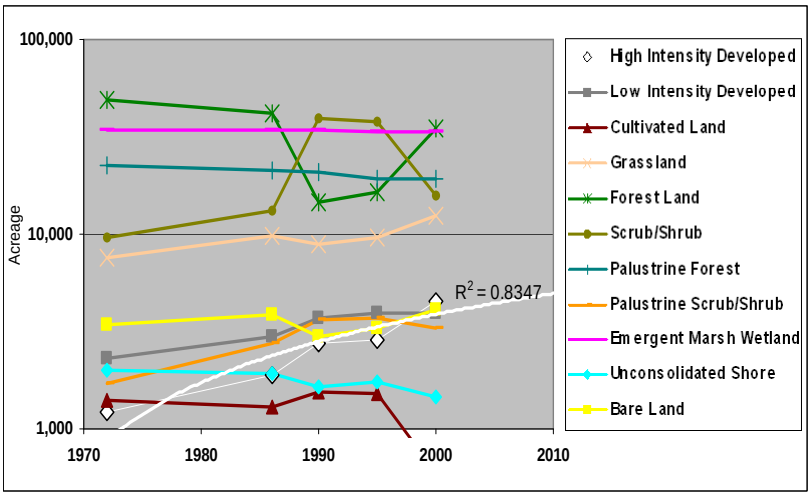
1972 to 2000 Graph

Linear Trend Line - Forecast Forward 10 years



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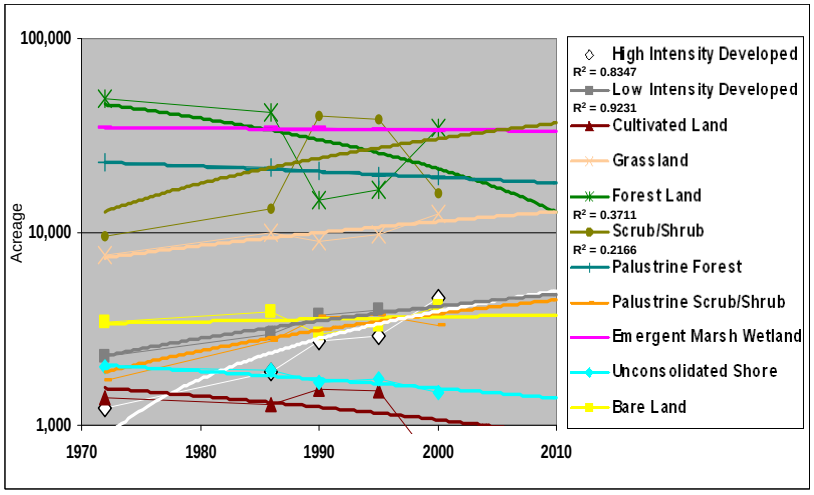
1972 to 2000 Graph

Linear Trend Line - Forecast Forward 10 years



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Remote Sensing Solutions

A remotely sensed image is essentially a map. It is a picture that captures the location and state of Earth surface features at an instance in time.

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Cultural Resources

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Historical Resources

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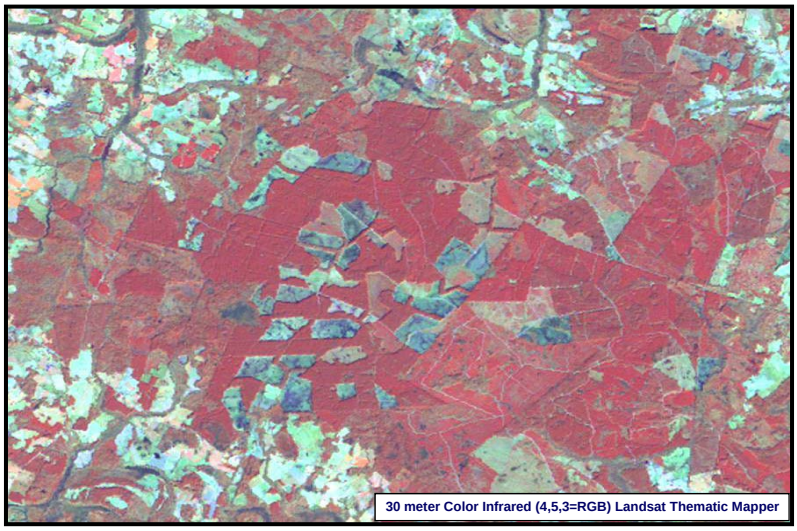
Natural Resources



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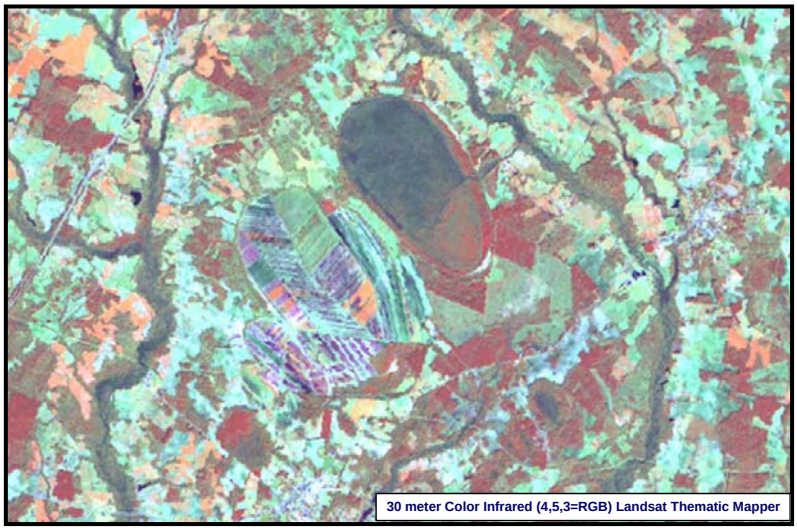
Unique Resources



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Land Use Patterns

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Landscape Change

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Landscape Change

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Landscape Change

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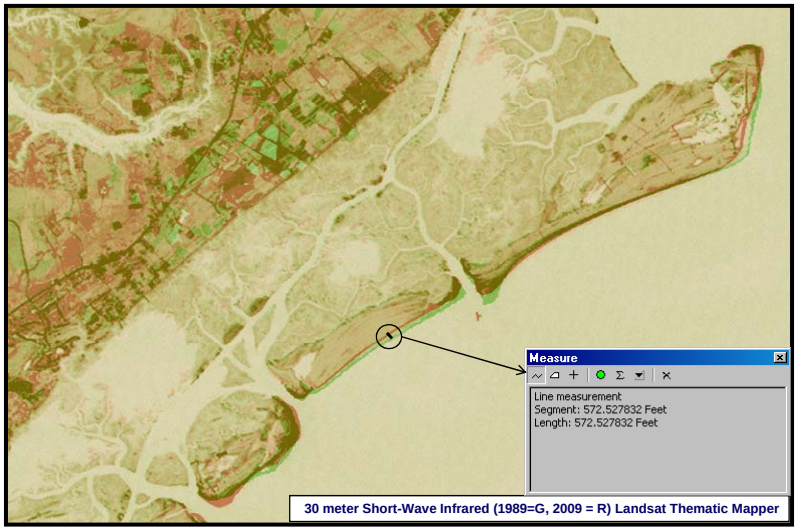
Landscape Change



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Remote Sensing of Vegetation

- About 70 percent of the Earth's land surface is covered with vegetation
- Multispectral sensing devices are well suited to analyze the characteristics of vegetation
- Scientific and commercial applications of remote sensing analysis include agricultural land management and wetland delineation

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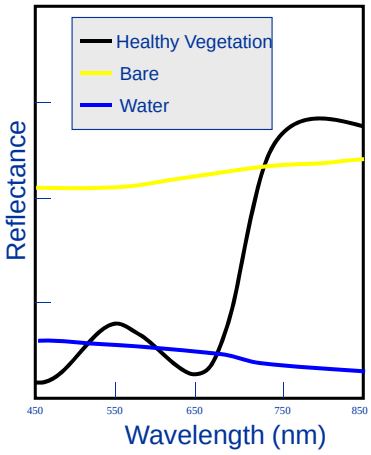
Multispectral Characteristics of Vegetation

- Chlorophyll absorption in the blue and red portions of the spectrum
- High reflectance of near-infrared radiation
- Inverse relationship between red and near-infrared



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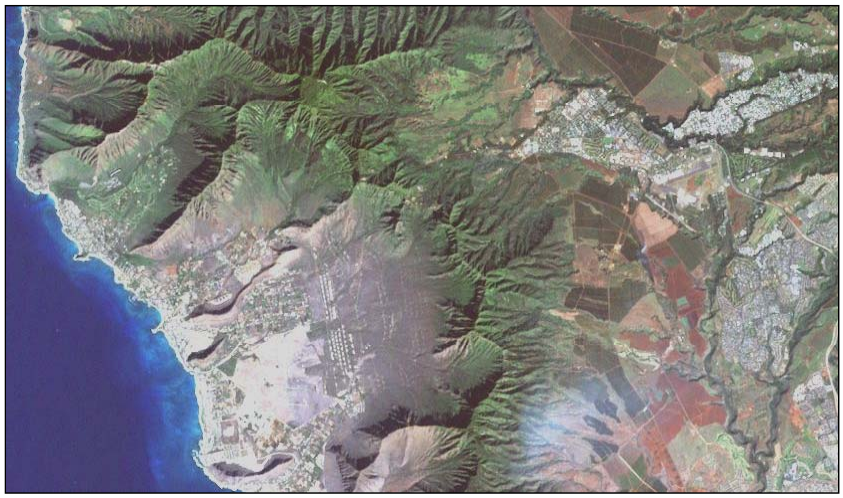
True Color Composite



Enhanced Thematic Mapper, RGB = 3, 2, 1

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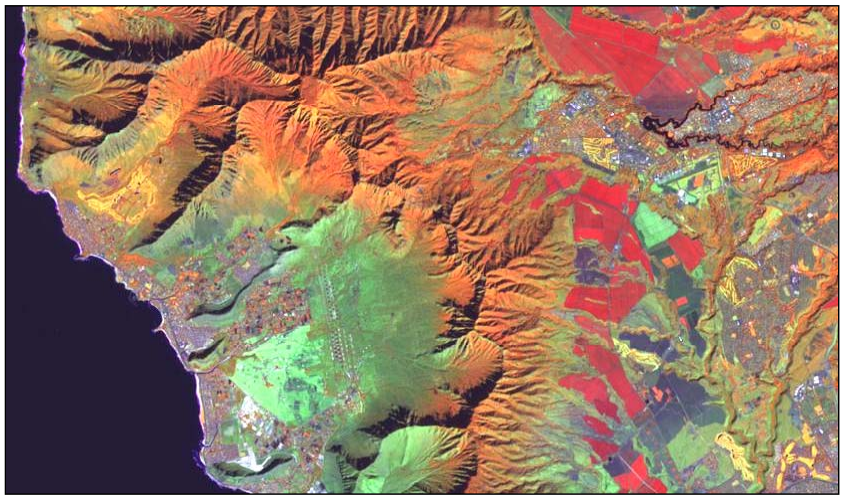
Color Infrared Composite



Enhanced Thematic Mapper, RGB = 4, 5, 3

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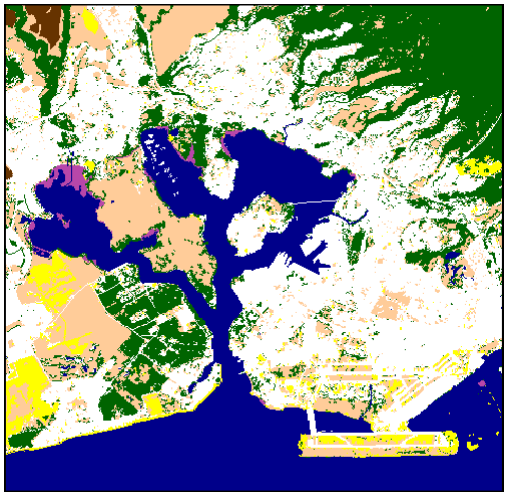
Land Cover Classification



- Developed
- Grassland
- Forest
- Wetland
- Bare Land
- Water

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Land Cover Classification

Coastal Change Analysis Program
Land Cover Categories

- High Density Developed
- Low Density Developed
- Cultivated Land
- Grassland
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Scrub/Shrub
- Palustrine Forest
- Palustrine Scrub/Shrub
- Palustrine Emergent
- Estuarine Emergent
- Unconsolidated Shore
- Bare or Disturbed Land
- Water

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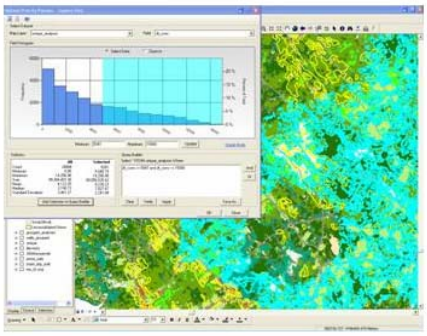
Land Cover Analysis Tools

HPP

Habitat Priority Planner

Helps to identify priority locations for conservation and restoration planning (extension to ArcGIS with Spatial Analyst)



Features

- **Inventories specific habitat or land-use types** relevant to the site in question
- **Assesses target habitat or land-use type conditions** with a process that automates the pre-packaged spatial analysis metrics
- **Analyzes "what if" scenarios** such as the impact of new development or how restoration might change overall habitat function; participants can quickly and easily set the parameters—and change them as needed
- **Gets people involved** thanks to the fast, interactive environment this easy-to-use system provides
- **Creates maps, reports, and data tables** to enhance communication and the decision-making process

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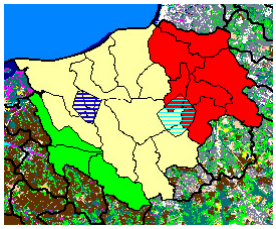
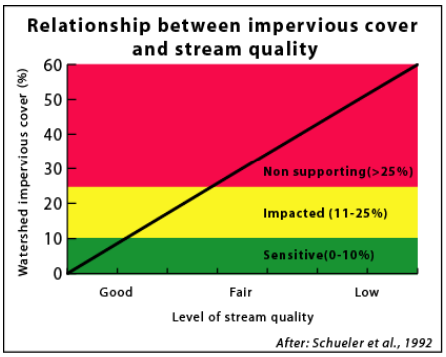
Land Cover Analysis Tools

ISAT

Impervious Surface Analysis Tool

Calculates the percentage of impervious surfaces for a selected geographic area (extension to ArcGIS with Spatial Analyst)





Features

- **Calculates the percent impervious area** and total impervious surface area of each selected polygon
- **Categorizes polygons to represent conditions** of good, fair, and poor water quality based on calculated imperviousness
- **Incorporates land cover change scenarios** to examine how changes influence impervious surfaces

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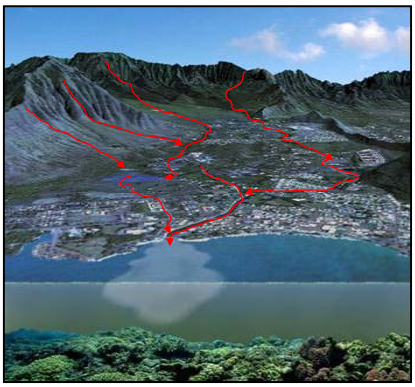
Land Cover Analysis Tools

N-SPECT

Nonpoint-Source Pollution and Erosion Comparison Tool

Impervious surfaces prevent infiltration, increase runoff quantity and intensity, and increase sediment and pollutant loads to water bodies.



Features

- **Provides projections and maps** of surface water runoff volumes, pollutant loads, pollutant concentrations, and total sediment loads
- **Helps users see areas** that might benefit from changes to proposed development strategies
- **Processes digital elevation data** quickly and easily
- **Provides a means to analyze** "what if" land use change scenarios

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Land Cover and Change Analysis

-

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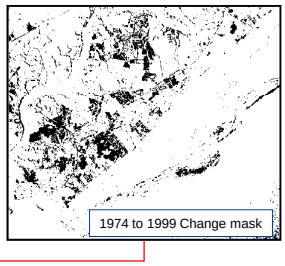

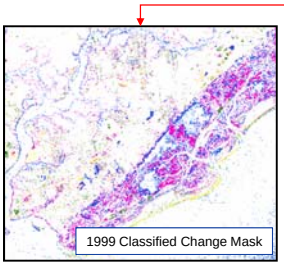

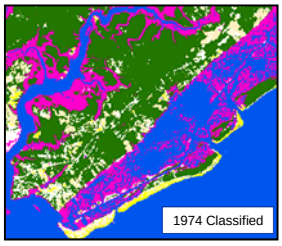

1974 to 1999 Thematic Change Matrix

From/To	1999					
1974	Developed	Grassland	Forest	Wetland	Bare Land	Water
Developed	2346	5899	1426	3242	1106	66
Grassland	68	16251	385	532	106	1146
Forest	19346	55	2387	60	1918	597
Wetland	337	340	391	488	143	3572
Bare Land	411	430	2387	1659	302	2014
Water	6364	9426	1256	850	89	23695

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Land Cover and Change Analysis

This section will introduce image acquisition and processing for land resource mapping and change detection.

- Exercise 1
  - Identify and acquire remotely sensed data
  - Import these into ArcMap® and clip to a defined study area
- Exercise 2
  - Visualize landscape change using two dates of remotely sensed imagery
  - Use digital image processing techniques to define change areas
  - Create a change versus no-change mask

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Land Cover and Change Analysis

- Exercise 3
  - Identify the spectral characteristics of major landscape features
  - Create and map land cover categories in an image using supervised classification techniques
- Exercise 4
  - Mask areas from a remotely sensed image
  - Perform unsupervised image classification of the masked image
- Exercise 5
  - Compare two dates of classified imagery for the same study area
  - Document *from-to* land cover changes
  - Summarize the type and amount of landscape change

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Exercise 1: Image Acquisition and Processing

Objectives

- Become aware of remote sensing data sources
- Understand image acquisition and initial processing steps

Steps

- Query and select data from an archive of remotely sensed products
- Combine individual bands into a multispectral image
- Create a subset of the image for a specific study area

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NOAA Coastal Services Center

- The DigitalCoast Website provides data required by coastal resource management professionals, as well as the tools, training, and information needed to turn these data into useful information. www.csc.noaa.gov/digitalcoast/
- NOAA Coastal Services Center provides a list of Coastal Geospatial Information: www.csc.noaa.gov/products/datasites
- Geospatial Resources - Handout

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Landsat series of satellites

Landsat Multispectral Scanner (MSS) 1972-1992
Landsat Thematic Mapper (TM) 1982-present
Landsat Enhanced Thematic Mapper (ETM) 1999-2003

Landsat Characteristics	MSS Sensor		TM Sensor		ETM Sensor	
Band	Spectral Resolution	Spatial Resolution	Spectral Resolution	Spatial Resolution	Spectral Resolution	Spatial Resolution
Blue			0.45-0.52 µm	28.5 x 28.5 m	0.45-0.52 µm	28.5 x 28.5 m
Green	0.50-0.60 µm	79 x 79 m	0.52-0.60 µm	28.5 x 28.5 m	0.52-0.60 µm	28.5 x 28.5 m
Red	0.60-0.70 µm	79 x 79 m	0.63-0.69 µm	28.5 x 28.5 m	0.63-0.69 µm	28.5 x 28.5 m
Near-Infrared (NIR)	0.70-0.80 µm	79 x 79 m	0.76-0.90 µm	28.5 x 28.5 m	0.76-0.90 µm	28.5 x 28.5 m
NIR	0.80-1.10 µm	79 x 79 m				
Short Wave Infra-Red (SWIR)			1.55-1.75 µm	28.5 x 28.5 m	1.55-1.75 µm	28.5 x 28.5 m
SWIR			2.08-2.35 µm	28.5 x 28.5 m	2.08-2.35 µm	28.5 x 28.5 m
Thermal			10.40-12.50 µm	114 x 114 m	10.40-12.50 µm	57 x 57 m
Panchromatic					0.50-0.90 µm	14.25 x 14.25 m
Quantization Level	6 bits/pixel, 64 gray levels		8 bits/pixel, 256 gray levels		8 bits/pixel, 256 gray levels	
Orbit	18/16 days		16 days		16 days	
Altitude	919 km		705 km		705 km	
Swath	185 km		185 km		185 km	

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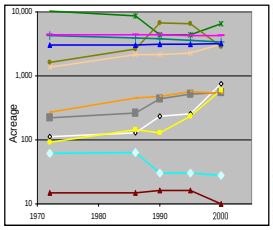
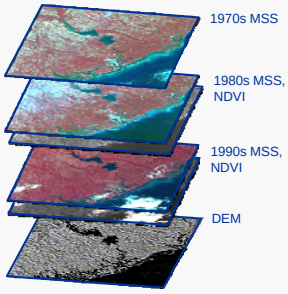
North American Landscape Characterization Program

The North American Landscape Characterization Program (NALC) was devised to mine the extensive Landsat archive and provide co-registered sets of MSS data from the 1970s, 1980s, and 1990s for the purpose of studying environmental change.



Standard NALC Product

- Georeferenced
- Terrain corrected
- Resampled to 60-meter pixel



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The National Map

The National Map is an online archive of standard spatial data products maintained by the U.S. Geological Survey.

Primary raster data products
- Digital Elevation Models
- Digital Raster Graphics
- Digital Ortho Quarter-Quads
- National Land Cover Data

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Global Land Cover Facility

The Global Land Cover Facility (GLCF) is a global archive of remote sensing data and products. A major component is access to free Landsat MSS, TM, and ETM data.

glcf.umiacs.umd.edu

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Earth Science Data Interface

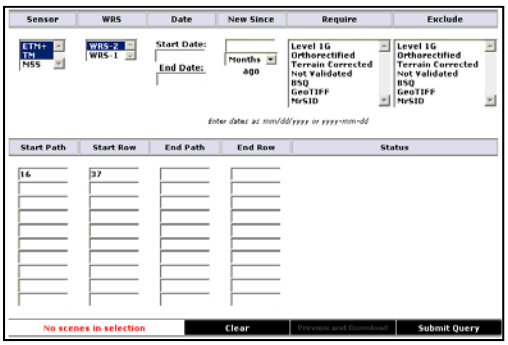
Landsat path/row designated in the Worldwide Reference System (WRS).

Landsat 1-3 = WRS-1

Landsat 4-7 = WRS-2

Charleston is located in path 17 in WRS-1 and path 16 in WRS-2.

Path/Row Search



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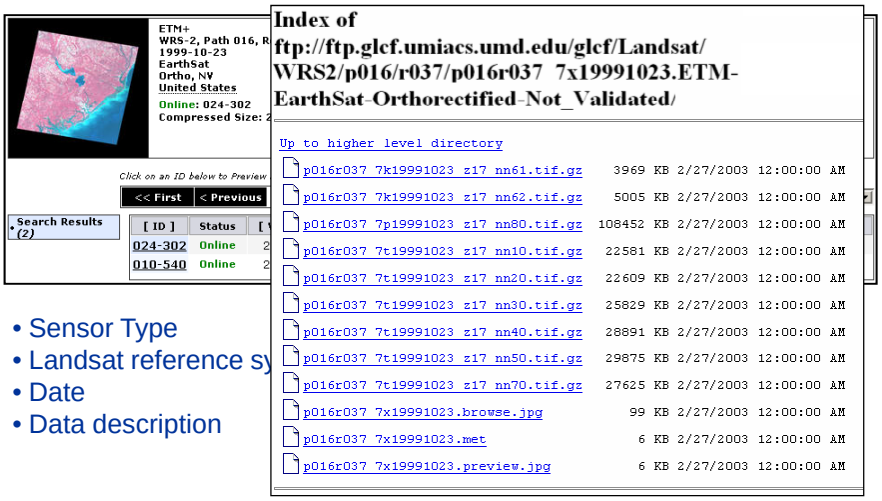
Earth Science Data Interface



- Sensor Type
- Landsat reference sy
- Date
- Data description

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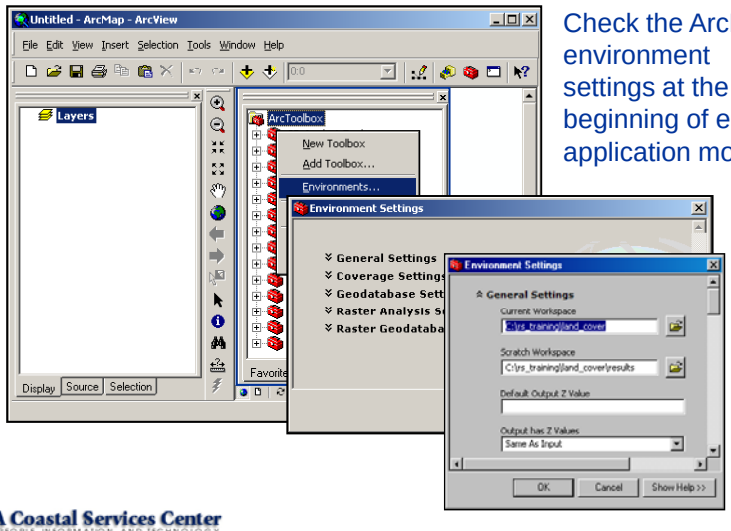
ArcMap Environments



Check the ArcMap environment settings at the beginning of each application module.

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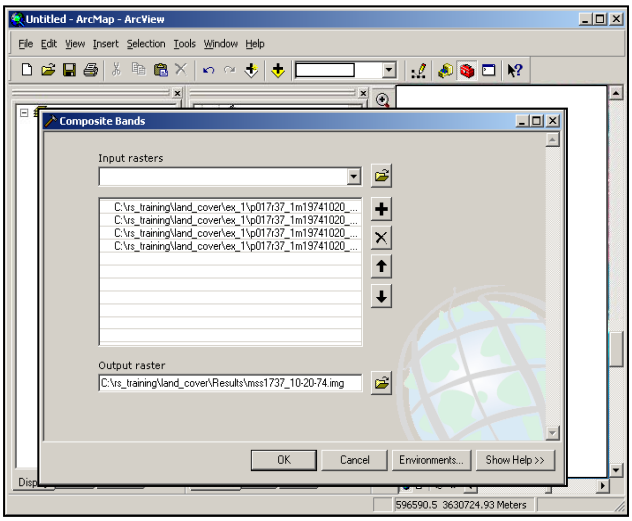
Initial Processing: Data Import

Import the individual Landsat bands to an ERDAS Image (.img) file by using Raster Composite Bands Tool.

ArcToolbox > Data Management Tools > Raster > Composite Bands



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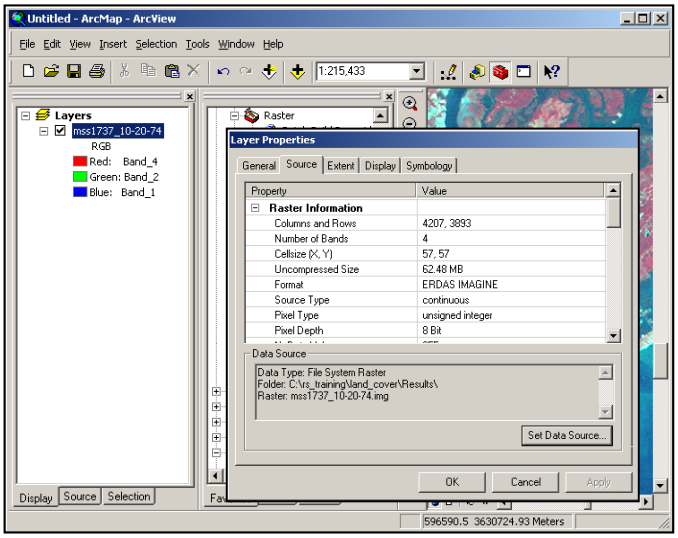
Initial Processing: Data Import



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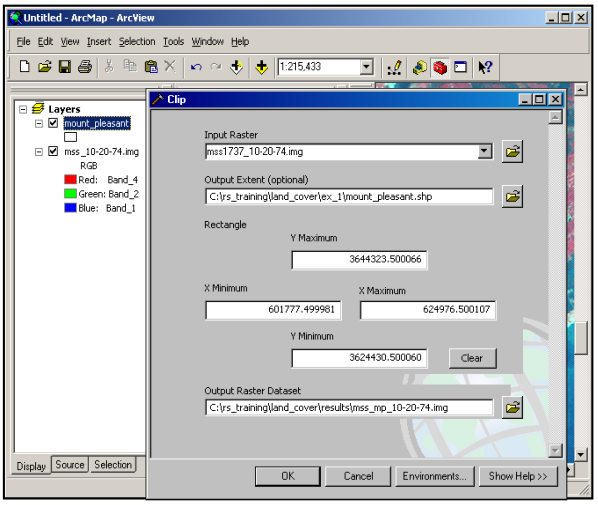
Initial Processing: Clip to a Study Area

Add study area layer mount_pleasant.shp

Raster Clip



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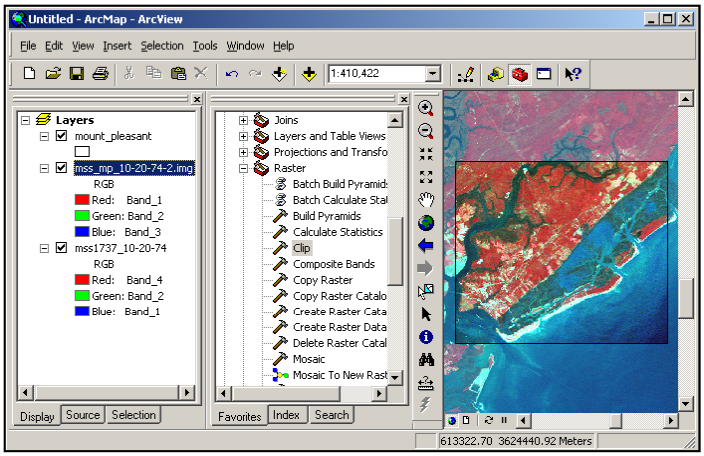
Initial Processing: Clip to a Study Area



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Exercise 1: Image Acquisition and Processing

Steps

- Query and select data from an archive of remotely sensed products
- Combine individual bands into a multispectral image
- Create a subset of the image for a specific study area

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Exercise 1: Summary:

Skills practiced

- Identification and acquisition of remotely sensed data
  - NOAA Coastal Services Center: www.csc.noaa.gov/products/datasites
  - USGS Earth Explorer: edcsns17.cr.usgs.gov/EarthExplorer
  - National Map: nationalmap.gov/
  - North American Landscape Characterization program: edcwww.cr.usgs.gov/products/satellite/nalc.html
  - Global Land Cover Facility: glcf.umiacs.umd.edu
- Combining the layers of image data
  - Raster Composite Bands Tool
- Creating a subset of the image data
  - Set mask environment, and use Raster Clip tool

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Exercise 2: Image Difference Change Detection

Objectives

- Visualize landscape change using two dates of remotely sensed imagery
- Use digital image processing techniques to define change areas
- Create a change versus no-change mask

Steps

1. Load two dates of remotely sensed imagery to ArcMap and compare the differences
2. Normalize the two dates of imagery
3. Perform image difference change analysis
   - Subtract one date of normalized imagery from the other
   - Analyze the image difference file to identify change versus no change

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Visualizing Change Detection

Effects Toolbar

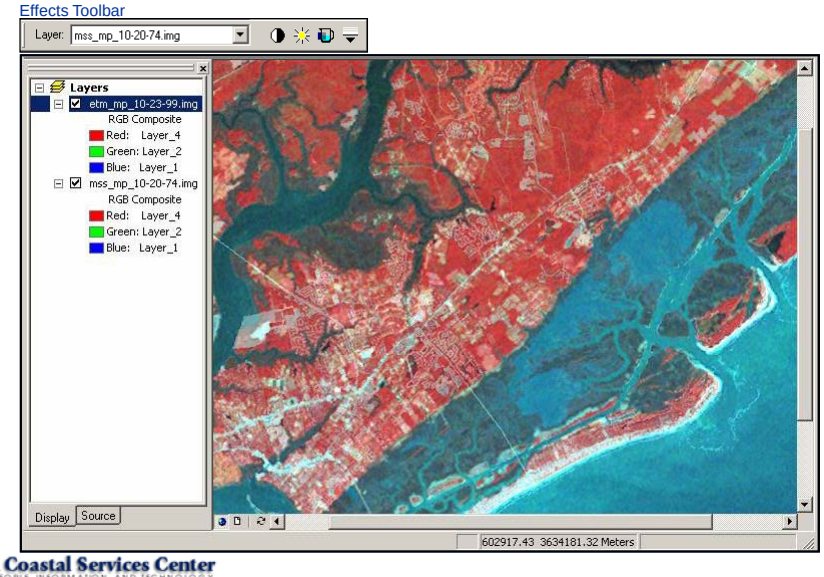

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Image Difference: Subtraction

Pixel brightness values (BV) that change little between the two dates will have values near 0 in the difference image. In locations where change has likely occurred, the pixel values will be further from 0 in the difference image. These include higher positive and lower negative values. Interpretation and processing of the difference image will yield a change mask, a binary digital file that displays change versus no change.

56	54	48	50
57	52	52	55
61	55	53	58
68	72	58	63

BVs for Date 1

-

53	50	52	55
59	55	82	79
60	55	85	88
51	49	92	90

BVs for Date 2

=

3	4	-4	-5
5	-3	-30	-24
1	0	-32	-30
17	-29	-34	-27

Difference Image BVs

3	4	-4	-5
5	-3	-30	-24
1	0	-32	-30
17	23	-34	-27

Likely unchanged

Likely changed

Change Interpretation

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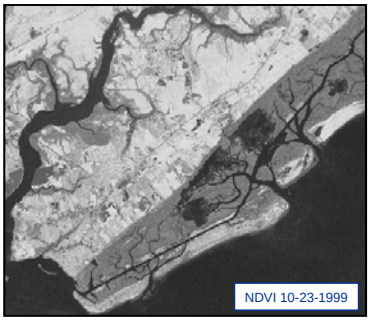
Image Difference

- **Single-Band Spectral Differencing**
- **Spectral Differencing of Normalized Imagery**
  - **Normalized Difference Vegetation Index (NDVI)**



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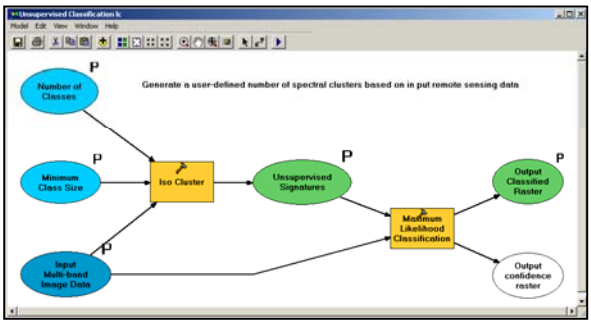
NOAA Remote Sensing Models

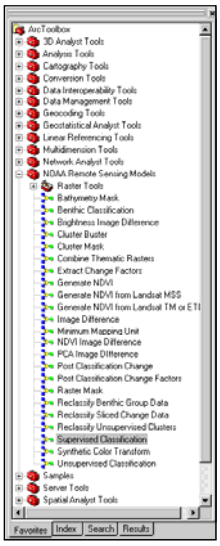
Raster processing models have been developed in **ArcGIS Model Builder** for this course.

Right-click **ArcToolbox;** select **Add Toolbox;** navigate to c:\rs_training\tools > **NOAA Remote Sensing Models**.

To use a model, double-click.

For more information, right-click > help or edit.





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Normalized Difference Vegetation Index

NOAA Model: Generate NDVI

$$NDVI = \frac{NIR-Red}{NIR+Red}$$

MSS **Red band is Layer 2** and the **NIR band is Layer 4**

Name the Output Image **ndvi_mp_74.img**

ETM **Red Band is Layer_3** and the **NIR Band is Layer_4**

Name the Output Image **ndvi_mp_99.img**

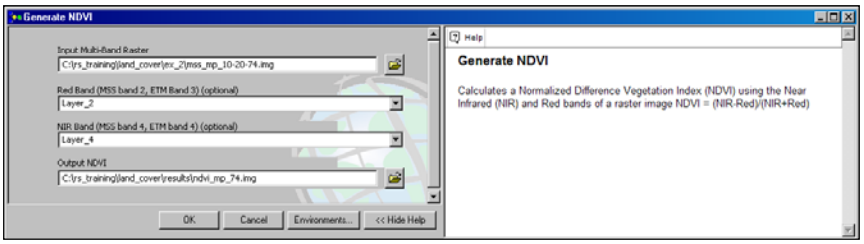

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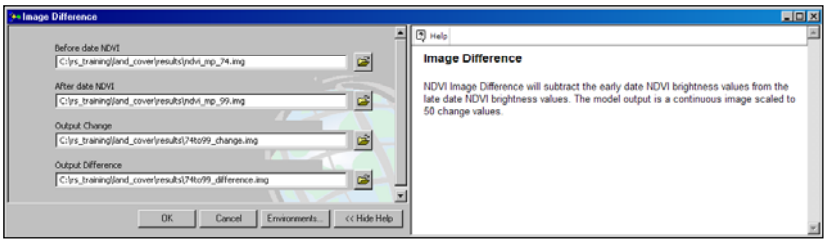
Image Difference Change Detection

NOAA Model: Image Difference

The early-date raster will be subtracted from the late-date raster. There will be two output files:

1. The NDVI *Difference Image* is a continuous image containing the result of the image subtraction. Darker and brighter pixels in this file are a likely indication of change.
2. The NDVI *Change Image* is thematic, scaled to 50 values.



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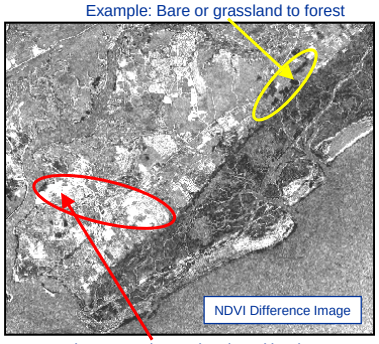
Interpret the Image Difference Change

NDVI Difference Image is grayscale representation of the image subtraction results

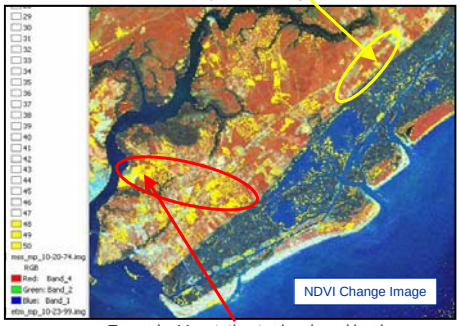
The **NDVI Change Image** is thematic, scaled to 50 values

Example: Bare or grassland to forest



Example: Vegetation to developed land

Example: Bare or grassland to forest



Example: Vegetation to developed land

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Create a Binary Change File

notes from step 10:

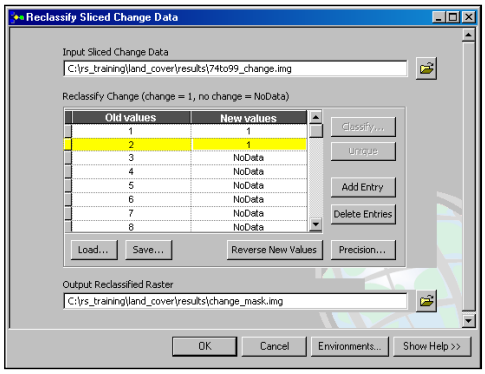
1-2 and 47-50 = Change

3-46 = No Change

NOAA Model Reclassify Sliced Change Data. Go to **ArcToolbox > NOAA Remote Sensing Models > Reclassify Sliced Change Data**.

No-change = NoData

Change = 1



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Exercise 2: Image Difference Change Detection

Steps

1. Load two dates of remotely sensed imagery to ArcMap and compare the differences
2. Add the toolbox, NOAA Remote Sensing Models
3. Normalize the two dates of imagery with the Generate NDVI model
4. Perform image difference change analysis with the Image Difference model
   - Subtract one date of normalized imagery from the other
   - Analyze the image difference output files to identify change versus no change

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Exercise 2: Summary:

- Thirty years of Landsat data offer a unique opportunity to document landscape change
- ArcGIS Model Builder tools can apply mathematical functions to digital imagery
- Add, subtract, multiply, or divide bands of an image
- Subtracting one date of imagery from another will yield a difference image that can be used to determine areas of change versus no change

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Exercise 3: Supervised Image Classification

Objectives

- Identify the spectral characteristics of major landscape features
- Create and map land cover categories in an image using supervised classification techniques

Steps

- Create a shapefile that identifies samples of the major land cover types
- Create a class signature file and perform a supervised classification on a continuous image

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Image Classification

Digital image classification groups pixels within an image according to spectral similarities

- Pixels are sorted into a finite number of individual categories or classes based on their brightness value
- Image classification turns the continuous data of a raw image into thematic data with a discrete number of classes
- Two standard processes are used for classification: *supervised* and *unsupervised*

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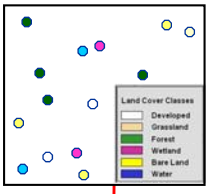
Supervised Image Classification

NOAA Model: Supervised Classification

Input sample data (shapefile)



Input multi-band image

- Input class sample data
- Input image data
  - Output spectral signatures
- Maximum Likelihood Supervised Classifier
  - Output classified map

Spectral signature file (.gsg)

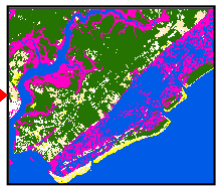
```
#   Training File:
    c:\rs_training\land_cover\results\signatures.shp
#   Stack :
    c:\rs_training\land_cover\mss_mp_10-20-74.img
# Number of Grids :  4

#  Type   Number of Classes   Number of Layers
    1            4                  4
# ========================================

# Layers      1          2          3          4
# Means   43.8604    25.8334    20.6759    20.2325
# Covariance
   1       31.59345    23.8630   -47.2241   -63.961
   2       23.86300    29.8573    7.08714   -41.708
   3       -47.2241    7.08718   323.7106   365.125
   4       -63.9617   -4.70804   365.1258   421.139
```

Maximum Likelihood Classifier

Output classified file



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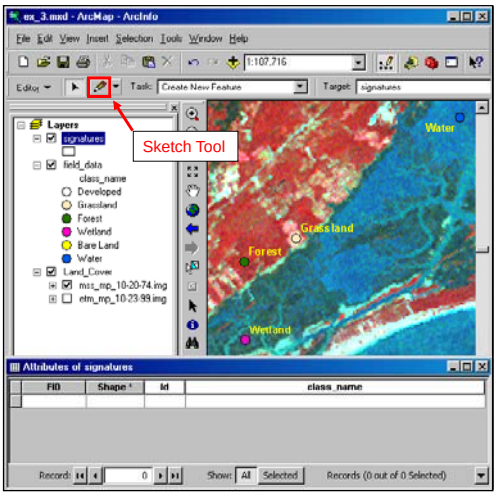
Create Class Samples

Go to **Editor > Start Editing**

Use the sketch tool to draw polygons representative of the spectral characteristics for each of the land cover categories

- Developed
- Grassland
- Forest
- Wetland
- Bare Land
- Water



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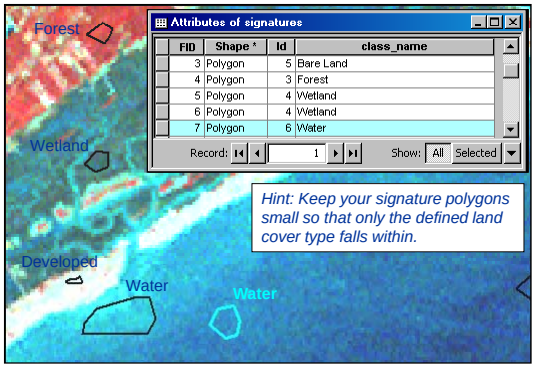
Create Class Samples

Be sure that the spelling and case match for each class label. These attributes serve as the database links to each of the thematic land cover files.

ID	Class_name
1	Developed
2	Grassland
3	Forest
4	Wetland
5	Bare Land
6	Water

When finished, go to **Editor > Stop Editing > Save Edits**



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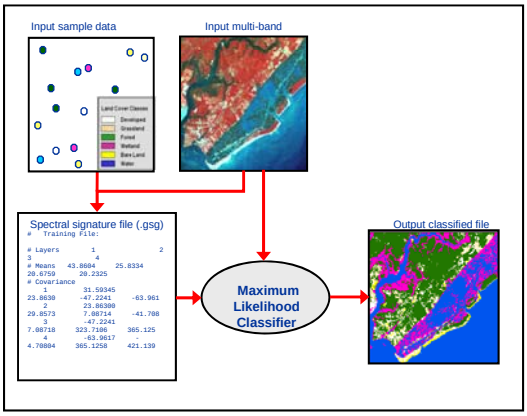
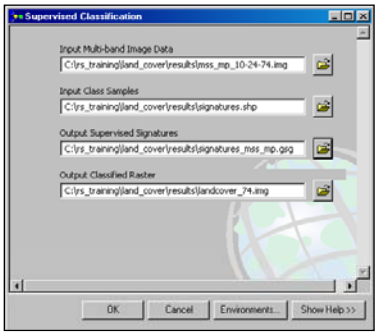
Supervised Image Classification

NOAA Model: Supervised Classification





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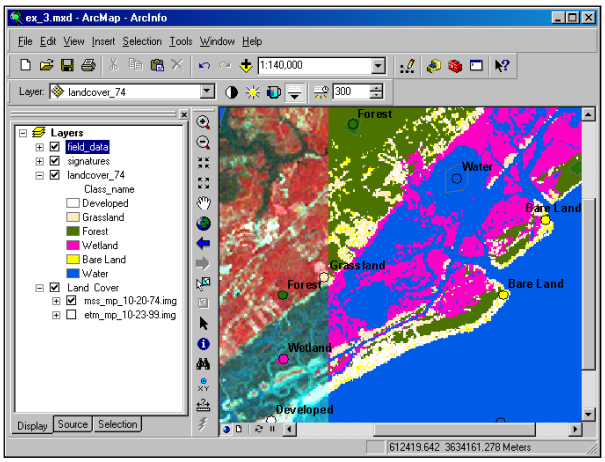
Supervised Image Classification

Review the output classified map using

- mss_mp_10-20-74.img
- field_data.lyr

To adjust how categories are mapped, make changes to the sample shapefile and run Supervised Classification again.



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Exercise 3: Supervised Image Classification

Steps

- Create a shapefile that identifies spectral signatures for the major land cover types
- Use the signature file to perform a supervised classification on a continuous image

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Exercise 3: Summary

- **Supervised classification** of imagery is controlled by the analyst, who selects sample sets of pixels that are representative of recognized patterns in the data.
- The **NOAA Supervised Classification Model** will produce a text signature file based on input multi-band image data and input land cover examples in a shapefile.
- The model runs a Maximum Likelihood Classification using the gsg signature file and the multi-band image file. The output will be a classified land cover map.

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Exercise 4: Unsupervised Image Classification and Change Analysis

Objectives

- Mask areas from a remotely sensed image
- Perform unsupervised image classification of the masked image

Steps

1. Turn the raster change image created in Exercise 2 into a polygon change mask
2. Eliminate unchanged areas from the 1999 image using the change mask and Image Analysis Subset tool

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Exercise 4: Unsupervised Image Classification and Change Analysis

Steps

3. Use the NOAA Unsupervised Classification Model to group the 1999 change image into 10 clusters
4. Interpret and label the clusters then use the Spatial Analyst Reclassify command to save
5. Use the Spatial Analyst Reclassify tool and Raster Calculator to combine the 1974 supervised image and 1999 unsupervised land cover images

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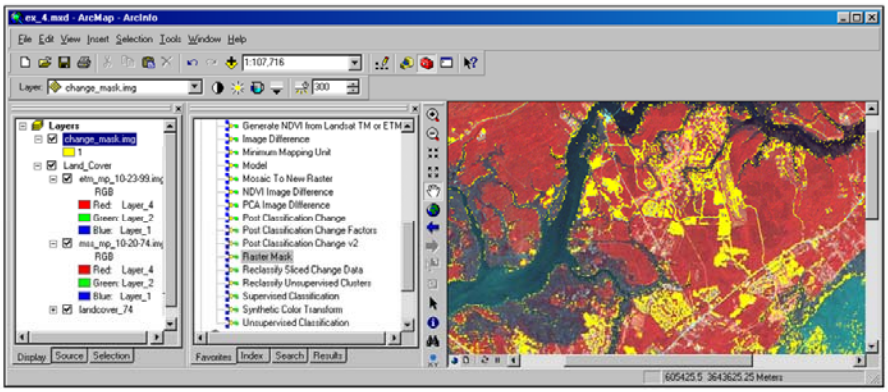
Create an Image Mask

- Use the NOAA model, **Raster Mask**, to extract those areas identified as change from the late date Landsat data.



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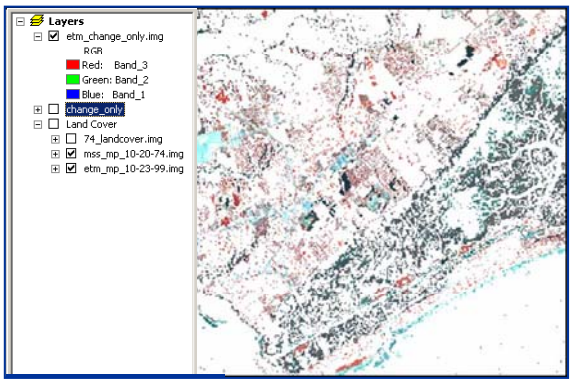
Create an Image Mask

NOAA Model: Raster Mask

The product will be a multispectral image that has NoData values for all areas that did not change from 1974 to 1999. Use Unsupervised Classification to map the land cover in the change image.



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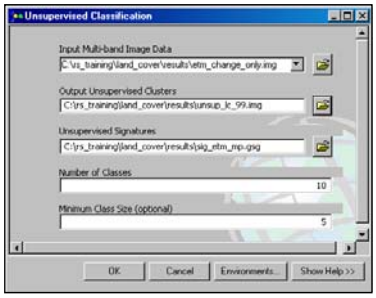
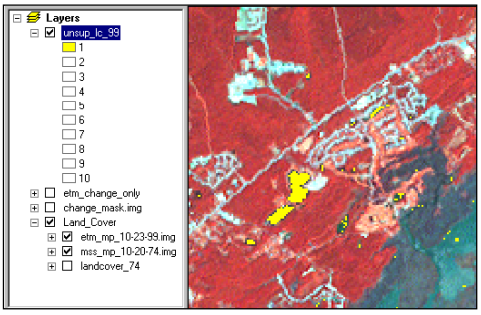
Unsupervised Classification

NOAA Model: Unsupervised Classification

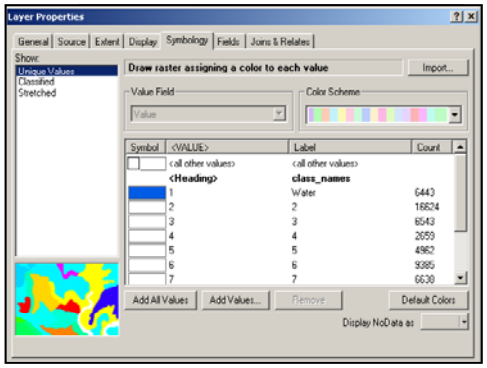
The model will produce a text signature file (.gsg) using the Spatial Analyst **Iso Cluster** tool to sort spectral information from input multi-band image data into natural groupings. The model then runs the **Maximum Likelihood Classification** tool using the input gsg signature file and the multi-band image file. The output will be a thematic layer segmented into a user-specified number of clusters.





Unsupervised Classification

- Open layer properties
- Review each cluster and label with appropriate class name



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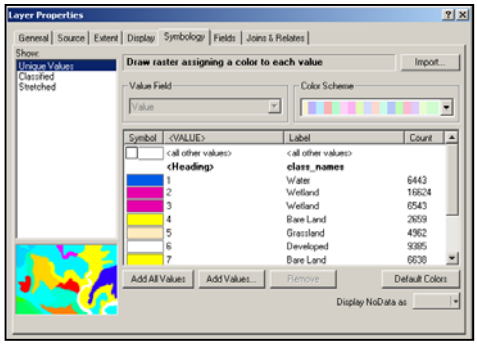
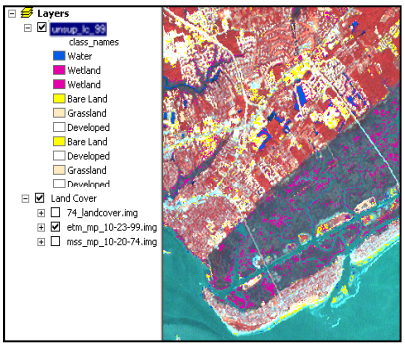
Unsupervised Classification

- Review each cluster and label with appropriate class name
- Reclassify the unsupervised image





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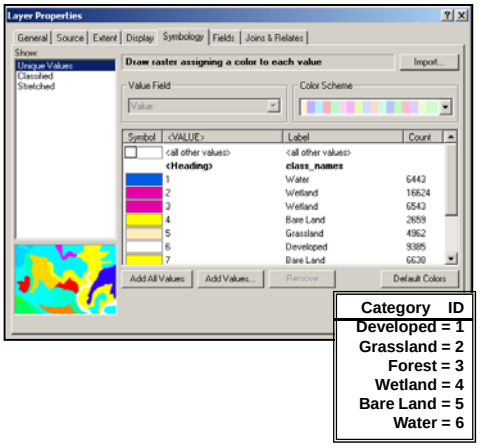
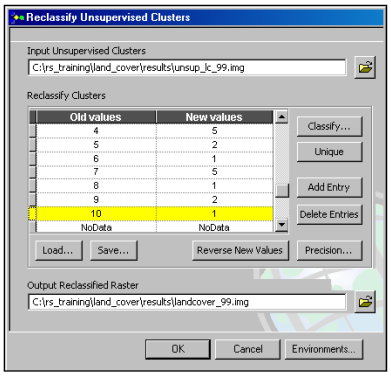
Reclassify Unsupervised Results

NOAA Model: Reclassify Unsupervised Classification



Category	ID
Developed	1
Grassland	2
Forest	3
Wetland	4
Bare Land	5
Water	6



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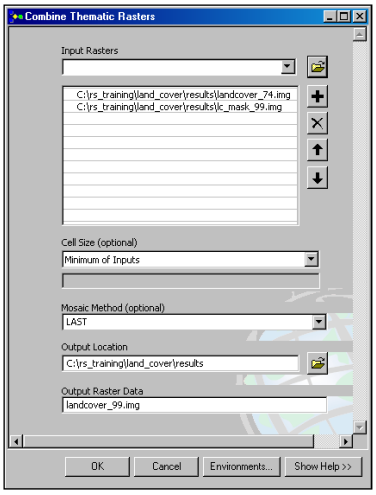
Combine the 1974 and 1999 Land Cover

NOAA Model: Combine Thematic Rasters

By inserting the land cover values mapped for the change areas in the 1999 image into the 1974 land cover map, a new 1999 land cover map for the entire Mount Pleasant study area is created.



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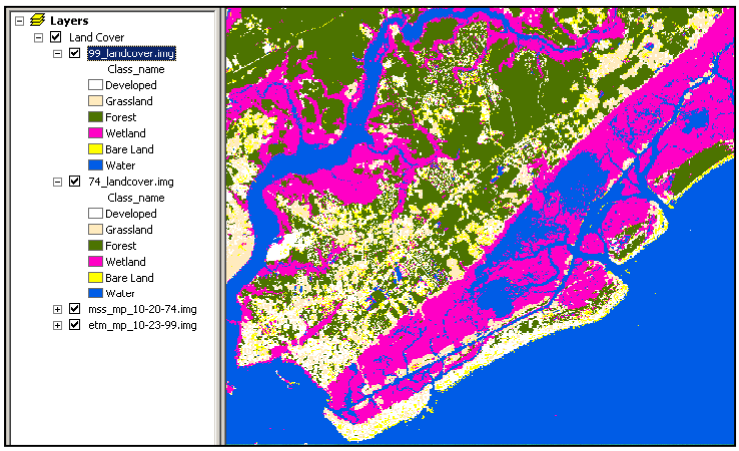
1999 Land Cover



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Exercise 4: Unsupervised Image Classification and Change Analysis

Steps

1. Eliminate unchanged areas from the 1999 image using the NOAA Raster mask model
2. Use the NOAA Unsupervised Classification model to group the 1999 change image into 10 clusters
3. Interpret and label the clusters then use the Spatial Analyst Reclassify command to save
5. Use the Mosaic to new Raster model to combine the 1974 supervised image and 1999 unsupervised land cover images

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Exercise 4: Summary

Skills practiced

- Raster to feature conversion
- Using a polygon feature file to mask areas from a raster image
- Unsupervised image classification
- Combining two thematic raster images to create a third thematic raster image

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Exercise 5: Post Classification Change Analysis

Objectives

- Compare two dates of classified imagery for the same study area
- Document “from-to” land cover changes
- Compare the type and amount of landscape change in a change table

Steps

- Input two classified images to generate a thematic change image
- Analyze the area and type of landscape change

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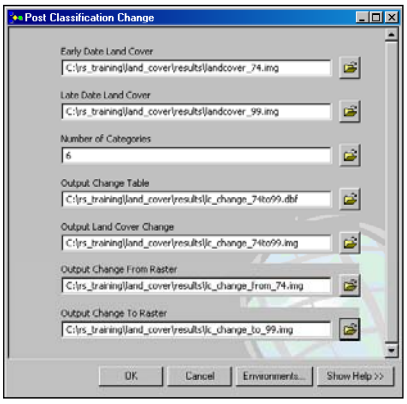
Post Classification Change Analysis

NOAA Model: Post Classification Change

Post Classification Change, will take the before and after land cover data to produce an *n-by-n* change image. Additional output from the model is a '*from-to*' change table in dbase 4 format, and layers that display what land cover changed from and to. These are useful when interpreting land cover change results.



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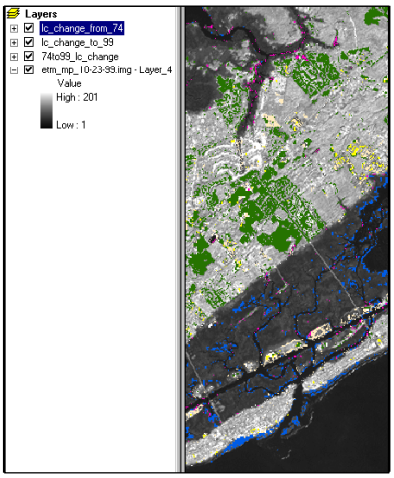
Post Classification Change Analysis

The change image will be added to the data frame when the model is complete. Notice that the default symbology three symbology layers are available. Each lists all the possible change categories and has a color legend that shows *change-from*, *change-to*, or *all possible changes*.



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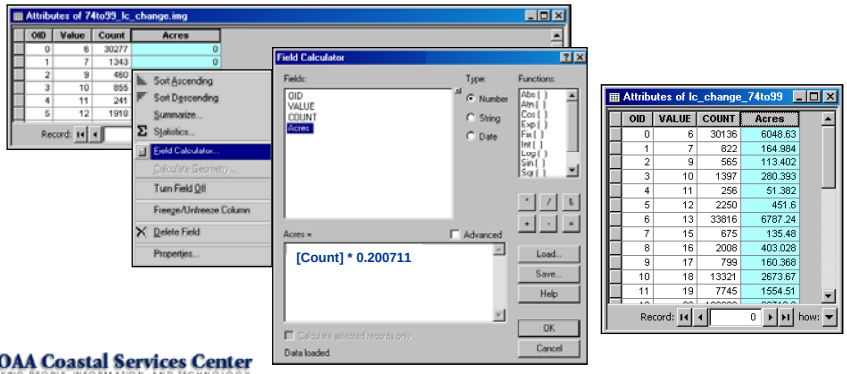
Post Classification Change Analysis

Ad an acreage field with an expression that converts square pixels to acres to review the quantity of change



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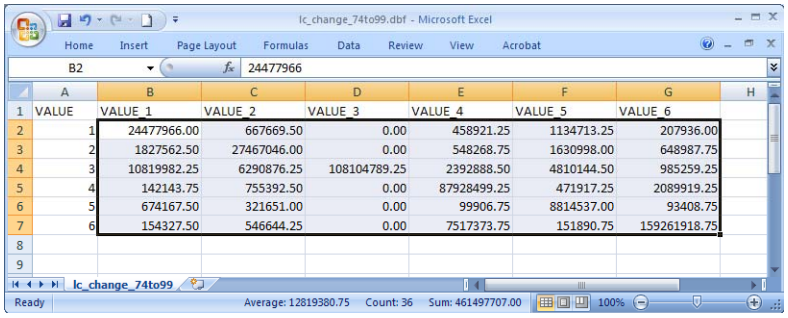
Generate Post-Classification Change Tables

- Import the *n-by-n* change database (dBase4) into Microsoft Excel
- Copy the values and paste them into a preformatted change table



VALUE	VALUE_1	VALUE_2	VALUE_3	VALUE_4	VALUE_5	VALUE_6
1	24477966.00	667669.50	0.00	458921.25	1134713.25	207936.00
2	1827562.50	27467046.00	0.00	548268.75	1630998.00	648987.75
3	10819982.25	6290876.25	108104789.25	2392888.50	4810144.50	985259.25
4	142143.75	755392.50	0.00	87928499.25	471917.25	2089919.25
5	674167.50	321651.00	0.00	99906.75	8814537.00	93408.75
6	154327.50	546644.25	0.00	7517373.75	151890.75	159261918.75

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Quantitative Change Table

Land_Cover_Change_Table.xls [Compatibility Mode] - Microsoft Excel

Land Cover Change Table by Meters Square

from\to	Developed	Grassland	Forest	Wetland	Bare Land	Water	Total
Developed	24,477,966	667,670		458,921	1,134,713	207,936	26,947,206
Grassland	1,827,563	27,467,046		548,269	1,630,998	648,988	32,122,863
Forest	10,819,982	6,290,876	108,104,789	2,392,689	4,810,145	985,259	133,403,940
Wetland	142,144	755,393		87,928,499	471,917	2,089,919	91,387,872
Bare Land	674,168	321,651		99,907	8,814,537	93,409	10,003,671
Water	154,328	546,644		7,517,374	151,891	159,261,919	167,632,155
Total	38,096,150	36,049,280	108,104,789	98,945,858	17,014,201	163,287,430	461,497,707

Land Cover Change Table by Acres Square

from\to	Developed	Grassland	Forest	Wetland	Bare Land	Water	Total
Developed	6,048.6	165.0		113.4	280.4	51.4	6,658.8
Grassland	451.6	6,787.2		135.5	403.0	160.4	7,937.7
Forest	2,673.7	1,554.5	26,713.2	591.3	1,188.6	243.5	32,964.7
Wetland	35.1	186.7		21,727.5	116.6	516.4	22,582.3
Bare Land	166.6	79.5		24.7	2,178.1	23.1	2,472.0
Water	38.1	135.1		1,857.6	37.5	39,354.3	41,422.6
Total	9,413.7	8,907.9	26,713.2	24,450.0	4,204.3	40,348.0	114,038.1

Land Cover Change Table by Total Pixels

from\to	Developed	Grassland	Forest	Wetland	Bare Land	Water	Total
Developed	30,136	822		565	1,397	256	33,176
Grassland	2,250	33,816		675	2,008	799	39,548
Forest	13,321	7,745	133,093	2,946	5,922	1,213	164,240
Wetland	175	930		108,253	581	2,573	112,512
Bare Land	830	396		123	10,852	115	12,316
Water	190	673		9,255	187	196,075	206,380
Total	46,902	44,382	133,093	121,817	20,947	201,031	568,172

Land Cover Change Table (acres) | Paste Table | Land Cover Change Table

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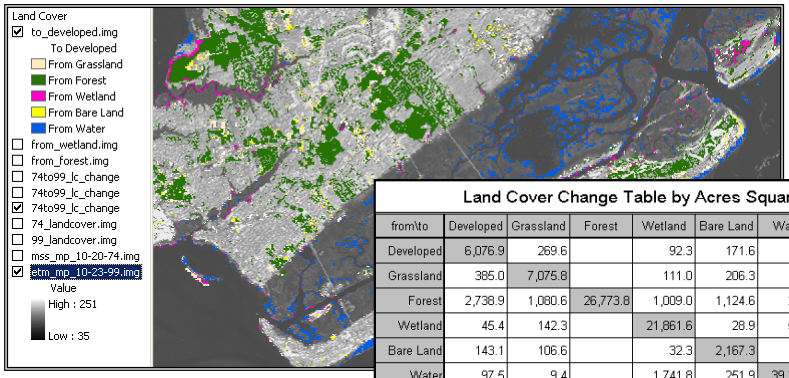
Evaluate Land Cover Change 1974 to 1999

- Review the table and change maps
- Look at the categories and total area for each
- Consider questionable change categories
- Examine questionable change classes to determine if the change is real



Land Cover Change Table by Acres Square

from\to	Developed	Grassland	Forest	Wetland	Bare Land	Water	Total
Developed	6,076.9	269.6		92.3	171.6	48.4	6,658.8
Grassland	385.0	7,075.8		111.0	206.3	159.6	7,937.7
Forest	2,738.9	1,080.6	26,773.8	1,009.0	1,124.6	238.4	32,965.3
Wetland	45.4	142.3		21,861.6	28.9	504.2	22,582.3
Bare Land	143.1	106.6		32.3	2,167.3	22.7	2,472.0
Water	97.5	9.4		1,741.8	251.9	39,321.7	41,422.4
Total	9,486.8	8,684.3	26,773.8	24,848.0	3,950.6	40,295.0	114,038.4

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Exercise 5: Post Classification Change Analysis

Steps

- Input two classified images to generate a thematic change image
- Generate change tables
- Analyze the area and type of landscape change

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Exercise 5: Summary

Skills practiced

- Highlighting land cover changes using post-classification techniques
- Documenting the types and amounts of land cover changes

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Exercise 5: Summary

Numerous spatial data assets have been generated to evaluate land cover changes. Review and compare these to draw conclusions about how and where the landscape is changing. Discuss the following:

- Which change category registered the greatest amount of change?
- Which land cover category registered the greatest amount of change?
- What is the most significant change in your map?
- Does land cover misclassification effect your change map?
- How much?

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Land Cover and Change Analysis Summary

- Remote sensing and image processing can support coastal resource managers as they address such issues as urban growth and the subsequent need for wise resource management.
- The analysis of remotely sensed imagery can provide a map of the coastal landscape, an inventory of natural resources, and documentation of landscape change.

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Land Cover and Change Analysis Summary

- Managers can search for free, preprocessed remotely sensed data when starting a project that requires spatial information.
  - The NOAA Coastal Services Center provides a list of coastal geospatial information: *www.csc.noaa.gov/products/datasites* *www.csc.noaa.gov/digitalcoast*
  - The Landsat archive can be queried through the USGS Earth Explorer: *edcsns17.cr.usgs.gov/EarthExplorer/*
  - Free, preprocessed Landsat MSS, TM, and ETM data are available on-line through the Global Land Cover Facility: *glcf.umiacs.umd.edu*

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Land Cover and Change Analysis Summary

- ArcGIS, ArcToolbox, and Spatial Analyst extension functions are used to derive thematic information from continuous imagery.
  - Supervised classification sorts image pixels into predefined categories. These are based on spectral signatures defined by the analyst.
  - Unsupervised classification techniques allow the computer to sort image pixels into a discrete number of clusters based on spectral similarity. These clusters are then labeled by the analyst.
  - Change detection compares two thematic files representing different image dates.

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Remote Sensing for Spatial Analysts: Course Evaluations

Delivered by

NOAA Coastal Services Center

for the

George Washington Regional Commission

18 March, 2010

Fredericksburg, VA

GWRC NOAA Remote Sensing for Land Cover & Land Use Change Analysis March 18, 2010

1. Please select the instructors of your course.

	Response Percent	Response Count
Shan Burkhalter	**92.9%**	**13**
Mark Finkbeiner	7.1%	1
	answered question	**14**
	skipped question	**0**

Page: Demographic Information

2. Please tell us which of the following best describes your organization:

	Response Percent	Response Count
Federal Government - NOAA (including contractors)	0.0%	0
Federal Government - Non-NOAA (including contractors)	0.0%	0
State Government	7.1%	1
Local Government	35.7%	5
University/Academic	7.1%	1
NGO/Non-Profit	0.0%	0
General Public	0.0%	0
Private Industry/Business/Consultant	0.0%	0
	answered question	**14**
	skipped question	**0**

2. Please tell us which of the following best describes your organization:

	Military	0.0%	0
	International	0.0%	0
	Tribal	0.0%	0
Show replies	**Other (please specify)**	**50.0%**	**7**
		answered question	**14**
		skipped question	**0**

3. Please tell us which of the following best describes your primary role:

	Response Percent	Response Count
Program Management	14.3%	2
Community Planning	35.7%	5
GIS	**50.0%**	**7**
Data Management	0.0%	0
Extension/Education	0.0%	0
Communication/Outreach	0.0%	0
Research/Science/Engineering	0.0%	0
Recreational Use	0.0%	0
Commercial Use	0.0%	0
Student	0.0%	0
Volunteer	0.0%	0
Other (please specify)	0.0%	0
	answered question	**14**
	skipped question	**0**

4. Please tell us how you heard about this course:

	Response Percent	Response Count
CSC Web site	7.1%	1
CSC Publication	0.0%	0
Local Host	**71.4%**	**10**
Supervisor	14.3%	2
Conference	0.0%	0
Show replies Other (please specify)	7.1%	1
	answered question	**14**
	skipped question	**0**

Page: Course Format

5. Presentation materials (slide shows, flip charts, overheads, etc.):

	Response Percent	Response Count
Detracted from understanding 1	0.0%	0
2	0.0%	0
3	0.0%	0
4	14.3%	2
Enhanced understanding 5	**85.7%**	**12**
	answered question	**14**
	skipped question	**0**

6. Course manual:

	Response Percent	Response Count
Detracted from understanding 1	0.0%	0
2	0.0%	0
3	0.0%	0
4	0.0%	0
Enhanced understanding 5	**100.0%**	**14**
	answered question	**14**
	skipped question	**0**

7. The presenter(s) were:

	Response Percent	Response Count
Poorly prepared 1	0.0%	0
2	0.0%	0
3	0.0%	0
4	14.3%	2
Well prepared 5	**85.7%**	**12**
	answered question	**14**
	skipped question	**0**

8. The presenter(s) communicated concepts and ideas:

	Response Percent	Response Count
Poorly 1	0.0%	0
2	0.0%	0
3	0.0%	0
4	**50.0%**	**7**
Very well 5	**50.0%**	**7**
	answered question	**14**
	skipped question	**0**

9. There was a good balance between lectures and activities:

	Response Percent	Response Count
Strongly disagree 1	0.0%	0
2	0.0%	0
3	0.0%	0
4	28.6%	4
Strongly Agree 5	**71.4%**	**10**
	answered question	**14**
	skipped question	**0**

10. I would recommend this course for others in my field:

	Response Percent	Response Count
Strongly Disagree 1	0.0%	0
2	0.0%	0
3	0.0%	0
4	7.1%	1
Strongly Agree 5	**92.9%**	**13**
	answered question	**14**
	skipped question	**0**

Page: Course Pace

11. The pace of the class was:

	Response Percent	Response Count
Too Slow 1	7.1%	1
2	0.0%	0
Just Right 3	42.9%	6
4	**50.0%**	**7**
Too Fast 5	0.0%	0
	answered question	**14**
	skipped question	**0**

12. The time allotted for discussion was:

	Response Percent	Response Count
Too Short 1	7.1%	1
2	0.0%	0
Just Right 3	**85.7%**	**12**
4	7.1%	1
Too Long 5	0.0%	0
	answered question	**14**
	skipped question	**0**

Page: Course Content

13. Can you...

	I am not able to do this.	I was able to do this prior to the course. The course did NOT improve this ability.	I was able to do this prior to the course, but the course DID improve this ability.	I am able to do this because of this course.	Not Applicable	Response Count
Describe the utility of remote sensing in coastal applications	0.0% (0)	0.0% (0)	28.6% (4)	**71.4% (10)**	0.0% (0)	14
					answered question	**14**
					skipped question	**0**

13. Can you...

Evaluate the benefits and limitations of remote sensing	0.0% (0)	7.1% (1)	35.7% (5)	**57.1% (8)**	0.0% (0)	14
Demonstrate the use of remote sensing data in a GIS	0.0% (0)	0.0% (0)	21.4% (3)	**78.6% (11)**	0.0% (0)	14
					answered question	**14**
					skipped question	**0**

Page: Course Applicability

14. I gained knowledge and skills that I will apply in my job

		Response Percent	Response Count
Strongly Disagree 1		0.0%	0
2		0.0%	0
3		0.0%	0
4		**57.1%**	**8**
Strongly Agree 5		42.9%	6
Not Applicable		0.0%	0
		answered question	**14**
		skipped question	**0**

15. The course maintained a good balance between technique and application

	Response Percent	Response Count
Strongly Disagree 1	0.0%	0
2	0.0%	0
3	0.0%	0
4	**57.1%**	**8**
Strongly Agree 5	42.9%	6
	answered question	**14**
	skipped question	**0**

16. Prior to this course what was your level understanding of the subject matter covered?

	Response Percent	Response Count
0%	0.0%	0
20%	**64.3%**	**9**
40%	28.6%	4
60%	7.1%	1
80%	0.0%	0
100%	0.0%	0
	answered question	**14**
	skipped question	**0**

17. After this course what is your level of understanding of subject matter?

	Response Percent	Response Count
0%	0.0%	0
20%	0.0%	0
40%	14.3%	2
60%	21.4%	3
80%	**57.1%**	**8**
100%	7.1%	1
	answered question	**14**
	skipped question	**0**

18. Please list any new skills that you learned that you are likely to apply to your current projects:

	Response Count
Show replies	7
answered question	**7**
skipped question	**7**

Page: General Comments

19. List 3 important ideas that you will take away from this course

		Response Percent	Response Count
Show replies	**1)**	**100.0%**	**8**
		answered question	**8**
		skipped question	**6**

19. List 3 important ideas that you will take away from this course

Show replies	**2)**		**100.0%**	**8**
Show replies	**3)**		**100.0%**	**8**
			answered question	**8**
			skipped question	**6**

20. What part was most helpful/informative or what did you like best? Why?

	Response Count
Show replies	9
answered question	**9**
skipped question	**5**

21. What part was least helpful/informative or what did you like least? Why?

	Response Count
Show replies	6
answered question	**6**
skipped question	**8**

22. What topics/skills would you have liked more information on?

	Response Count
Show replies	8
answered question	**8**
skipped question	**6**

23. What are your suggestions for improving this course?

	Response Count
Show replies	5
answered question	**5**
skipped question	**9**

24. Other comments?

	Response Count
Show replies	2
answered question	**2**
skipped question	**12**

NOAA Remote Sensing Class – Detailed Class Member Responses to Questions 18 - 24

18. Please list any new skills that you learned that you are likely to apply to your current projects:

1. Tools
2. Land cover classification
3. How to improve impervious surface data gathering for project & how to calculate land cover and land cover change
4. Ability to calculate change between raster datasets.
5. Land use change analysis and processing of remote sensing data; acquisition of available data.
6. Better able to scope out a project involving the application of RS to land use & cover change, regional planning, etc
7. Manipulating raster images. Change analysis between raster years

---

19. List 3 important ideas that you will take away from this course (8 responses out of 14 participants)

1. Land cover classification uses
2. Supervised Classification
3. How to do imagery analysis with GIS
4. Importance of imagery resolution
5. Land cover change
6. Location of data sources
7. What remote sensing is
8. Remote Sensing Data is easily accessible and free in many cases

---

9. Do best to minimize variables
10. Image Classification
11. importance of government offered education programs
12. Consistency of data for change analysis
13. NDVI
14. Concepts of raster data
15. Where to acquire data
16. Remote sensing can be used to create land cover layers

---

17. Only process what actually changes
18. Basic GIS knowledge
19. Development new land cover project for region
20. Availability of free analytical tools
21. Supervised vs. unsupervised classification
22. Procedures and properties of raster data and the ability to see the differences between datasets
23. How to utilize it for land cover analyses
24. Less detailed photography can be more beneficial than high res depending on the use

---

20. What part was most helpful/informative or what did you like best? Why?

1. Liked hearing about all the interesting uses for remote sensing; i.e. using signs of vegetation stress to detect subterranean structures
2. Exercises are always the best!
3. Simple step by step course of complex data for fast results
4. Reference to the free tools to supplement the change analysis
5. Simply recognizing the tool and the analytical resources it offers. This is something that can be very valuable to us if incorporated into the day to day.
6. New locations of data sources, with the ability to use the tools to process the data
7. The exercises and the stories of practical applications from past participants were very helpful in understanding how this information can be applied in different ways.
8. Hands-on exercises reinforced the process for accomplishing the tasks.
9. Actually going through the process, following the manual

---

21. What part was least helpful/informative or what did you like least? Why?

1. Sometimes having the examples already set up, means I have a tough time remembering how to find the data and what to use for what when I try again later.
2. There were no bad parts
3. Got a little lost in the overlaying of exercises, building one on top of another
4. Short amount of time.
5. N/A - it was all very good
6. Lecturing through the exercise instructions was redundant

---

22. What topics/skills would you have liked more information on?

1. Deciding correct resolution to work in
2. Creating Excel sheet from file, the unsupervised classification was confusing
3. It was fine for my skills and abilities
4. ETIS, N-SPECT, Habit Priority Planner
5. Better understand of why and what exactly we navigate to in order to properly run the analysis. Right now I feel like I can follow most of the directions on how to accomplish the task but not totally know how I got there.
6. Processes to combine raster datasets
7. Applicability at a local level -- better understanding of the level of resolution required for particular projects. Is it by geographic area or by the type of data to be analyzed?
8. Using the tools on more developed areas.

---

23. What are your suggestions for improving this course?

1. Perhaps some kind of visual that outlines entire process to refer back to between each step to remind students how that particular step fits into the whole process
2. Maybe it should be 2 days! or different depending on your level of GIS knowledge
3. Make it two day class
4. Longer. A lot of information for a one-day training.
5. More exercises and less lecture. Too much time allotted for exercises.

---

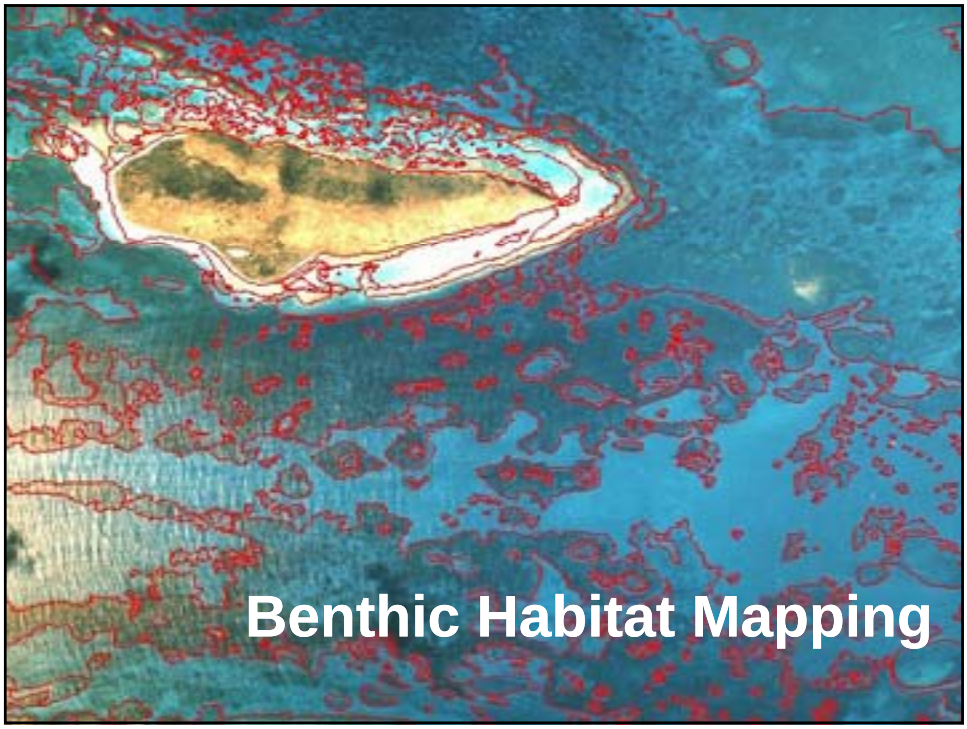
24. Other comments?

1. Overall a good experience
2. This was a very informative course. I enjoyed the real world examples and general clarity in the direction

Supplemental Lecture Presentations from

NOAA's Regular 2-Day Remote Sensing Workshop

Virginia Coastal Zone
MANAGEMENT PROGRAM



Overview

- Coastal Management Issues and Benthic Habitat
- Remote Sensing of Benthic Habitat
- Image Rectification, Transformations, and Resampling

  Exercise 1 - Rectifying an Aerial Photograph
- Developing Data from Airborne Multi-spectral Imagery

  Exercise 2 - Seagrass Habitat Mapping
- Sources of Aerial and Satellite Imagery

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Benthic Habitat

Benthic - Relating to, or occurring at the bottom of a body of water.

Habitat - The place or environment where a plant or animal naturally or normally lives and grows.

Defined by the Magnuson-Stevens Fisheries Conservation and Management Act as:
"those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

Typical Habitats
- Algal communities
- Hardbottoms
- Shellfish beds
- Seagrass meadows
- Coral reefs

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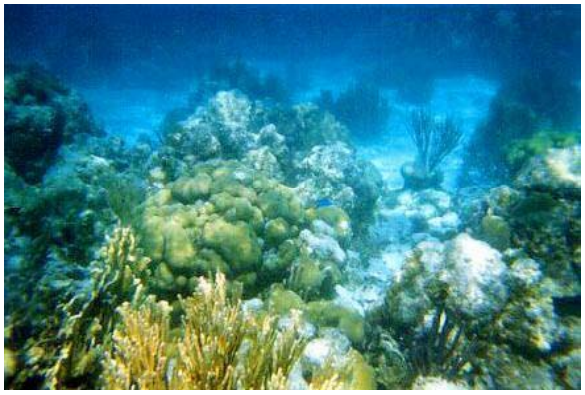

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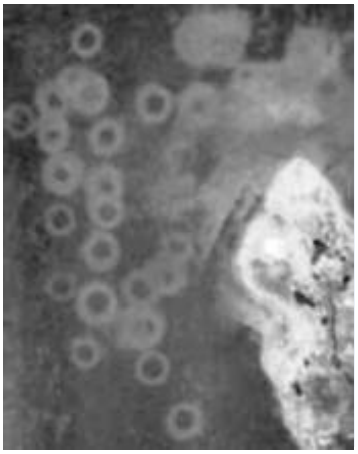
Coastal Issues and Benthic Habitat

Shellfish Lease Management

Certain benthic habitats have direct commercial value

- Kelp and other algae
- Clams, mussels, oysters etc.

Harvesting activities can impact other habitats i.e. seagrass meadows. These have indirect value because they are the preferred habitat for bay scallops.



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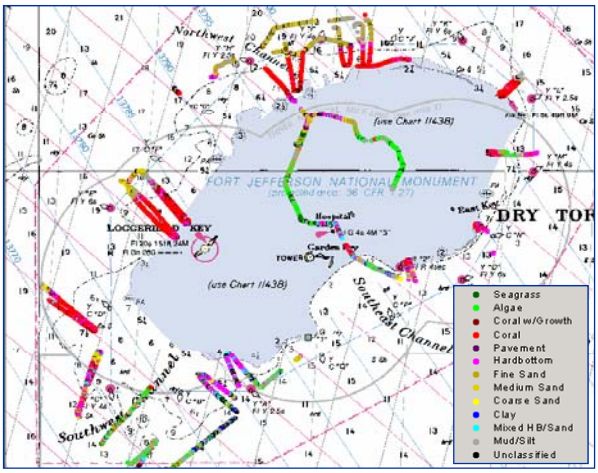
Issues Related to Benthic Habitat

Marine Protected Area Siting

Knowledge of benthic habitat is fundamental to proper siting and must be monitored to evaluate the site's effectiveness.



Tortugas Ecological Reserve North Unit, Florida Keys National Marine Sanctuary.

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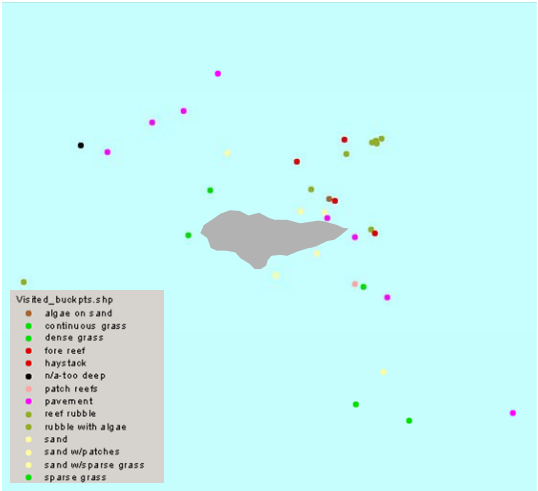
Remote Sensing Contribution

- Synoptic perspective
- Able to image the bottom in clear water up to 30 meters deep
- Provides a framework for more detailed studies



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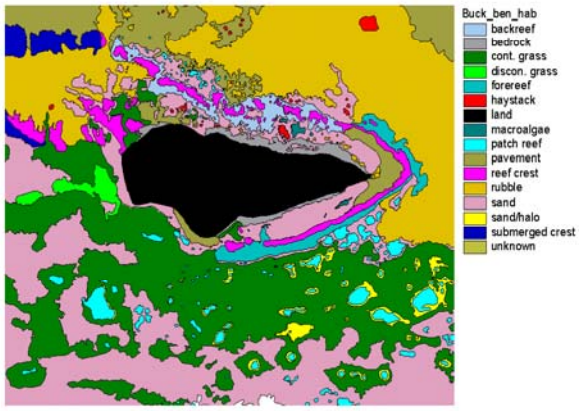

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Challenges to Optical Remote Sensing of Benthic Habitats

Environmental Conditions

- Sun glint
- Turbidity
- Sea state
- Tidal stage
- Clouds and shadows

Physical Constraints

- Depth limits
- Lack of control

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Challenges to Optical Remote Sensing of Benthic Habitats

Environmental Conditions

- Sun glint
- Turbidity
- Sea state
- Tidal stage
- Clouds and shadows

Physical Constraints

- Depth limits
- Lack of control

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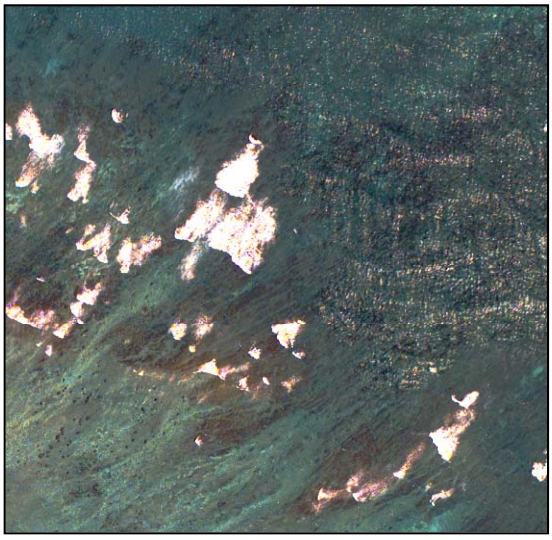
Challenges to Optical Remote Sensing of Benthic Habitats

Environmental Conditions

- Sun glint
- Turbidity
- Sea state
- Tidal stage
- Clouds and shadows

Physical Constraints

- Depth limits
- Lack of control



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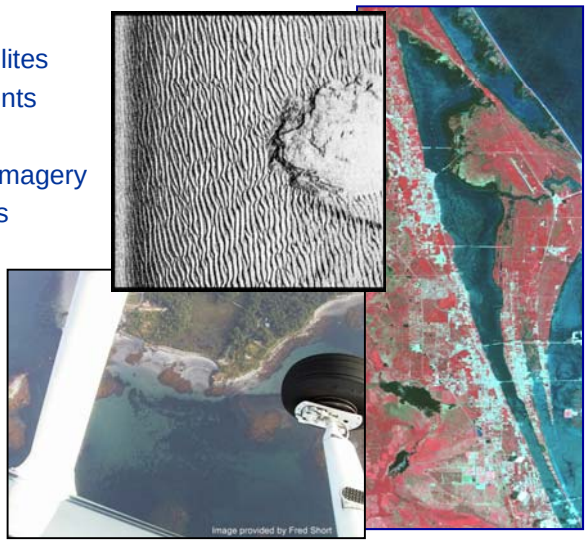
Sensors Useful for Benthic Habitat Monitoring

Sensors

- Medium-resolution satellites
- Hyper-spectral instruments
- Aerial photography
- Airborne multi-spectral imagery
- High-resolution satellites
- Single-beam sensors
- Side-scan sonar
- Multibeam sonar
- Bathymetric LIDAR



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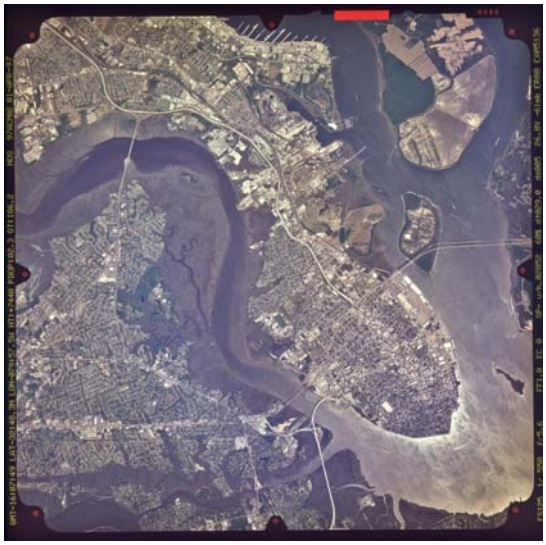
Aerial Photography

General Characteristics

- Emulsion based imaging
- Extremely high spatial resolution
- Affected by film processing
- Coarse spectral data
- Requires rectification
- RGB *or* CIR
- Stereo coverage available
- Large archive



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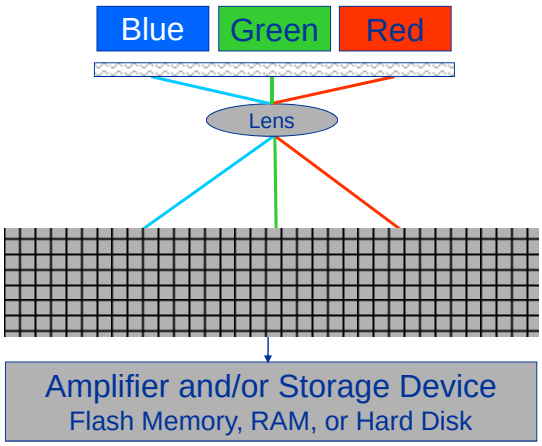
Digital Camera Imagery

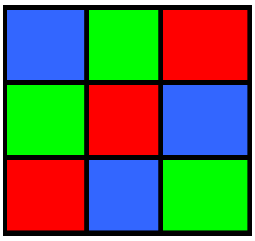


Single-chip camera system, for example, Emerge.

Subject

- One chip for all colors
- Interpolated spectral information

Pixel array.



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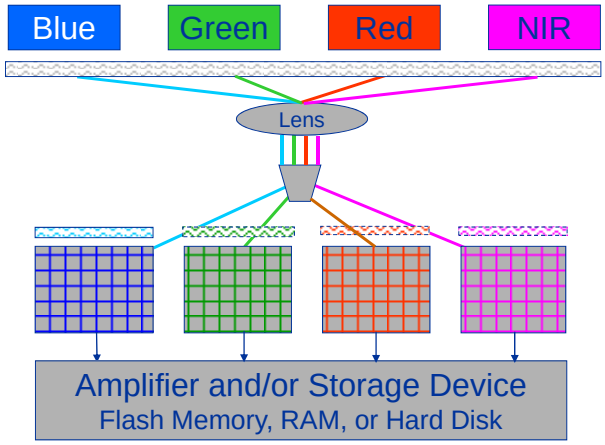
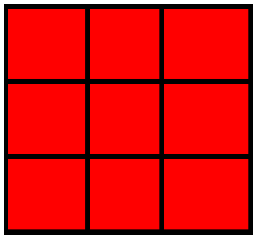
Digital Camera Imagery



Multi-chip camera system, for example, DMC.

- One chip per band
- Beam splitter or filters
- Pure spectral data

Pixel array.



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Analog vs. Digital Imagery

Film Characteristics

- Extremely high spatial resolution
- Stereo coverage easily available
- Large archive exists
- Emulsion based imaging affected by processing
- Coarse spectral data
- Requires rectification
- Decreasing use

Digital Characteristics

- Availability of multiple bands
- Provided as rectified product
- Pure spectral data
- Increased radiometric resolution
- Growing number of service providers
- Currently more expensive
- Large file sizes

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Multi-Spectral vs. Acoustic Data

Multi-Spectral Characteristics

- Comprehensive coverage in shallow areas
- Multiple bands possible
- No reliable depth information
- Superior at biotic cover characterization
- Affected by depth and turbidity
- More vulnerable to environmental conditions
- Captures land-sea interface

Acoustic Characteristics

- Comprehensive coverage in deeper water
- Usually provides depth information
- Superior at substrate characterization
- Single wavelength (frequency)
- Logistically difficult in shallow water
- Less suitable for automated analysis

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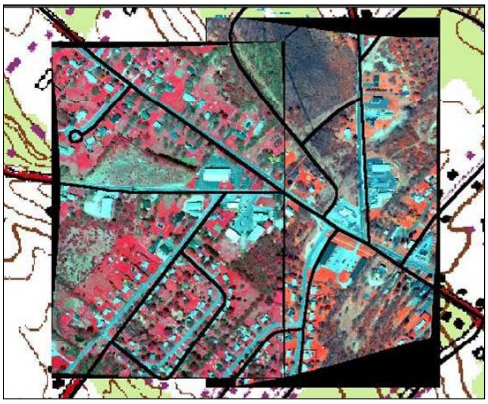
Image Rectification

Image Rectification processes assign real-world coordinates to image pixels

Rectification is essential to:

- Create the backdrop for other data.
- Mosaic multiple images.
- Examine relationships with other data.
- Segment the image and assist with image analysis.



Graphics and text courtesy of Daniel L. Civco, University of Connecticut

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Rectification Types

Registration - The process of relating two spatial data sets to each other. No coordinate system needed.

Georeferencing - The process of assigning map coordinates to already projected spatial data.

Rectification - Involves warping an image to fit a given projection.

Ortho-rectification - Rectification process that includes elevational data and corrects for terrain displacement.

Source: ERDAS Field Guide

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Two Steps in Rectification

1. **Spatial Interpolation**
   - establishes geometric relationship between input pixels' *x-y* locations and corresponding real world coordinates
     - uses ground control points (GCPs)
     - performs least squares analysis
2. **Spectral Interpolation**
   - determines the intensity (brightness) values of a spatially-interpolated output pixel from the intensity value(s) of related pixels in the original image
     - nearest neighbor
     - bilinear interpolation
     - cubic convolution

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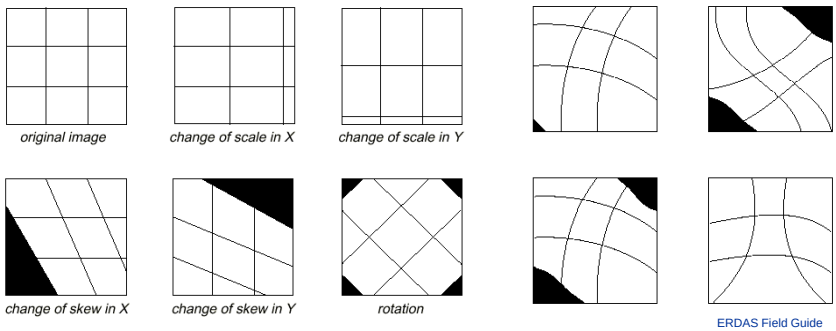
Transformation Orders

1st Order Transformation

- Requires the fewest control points.
- Appropriate for use in low-relief areas where the image is nearly vertical.

2nd and Higher Order Transformations

- Appropriate in high-relief areas or when the imagery has less of a vertical perspective (oblique).



ERDAS Field Guide

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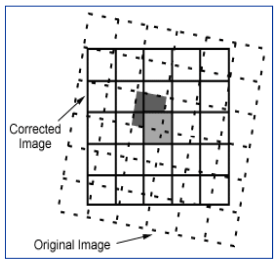
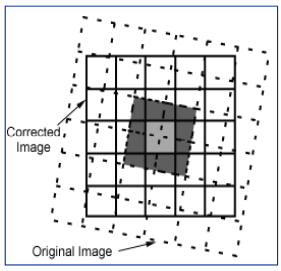
The Three Resampling Methods

The relationship between surrounding input pixels (dark grey) used in assigning spectral values to the output image pixel (light grey).

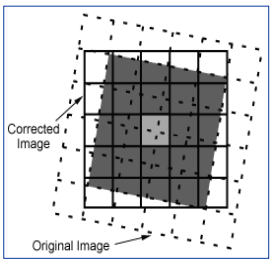
Nearest Neighbor



Bilinear Interpolation



Cubic Convolution



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Advantages and Disadvantages of Each Resampling Method

Resampling Method	Advantages	Disadvantages
Nearest Neighbor	Best preserves spectral integrity Simplest to perform	May break up linear features such as roads May drop data values
Bilinear Interpolation	Most spatially accurate	Some smoothing of edges Loss of extreme data values
Cubic Convolution	Produces a smooth image for mosaicking Tends to reduce noise in the data	Computationally intensive Significant alteration of spectral values

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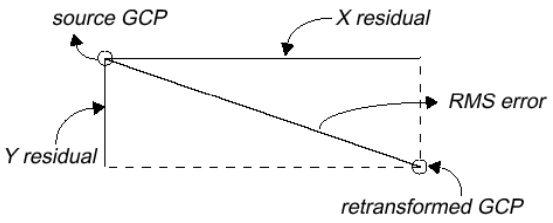
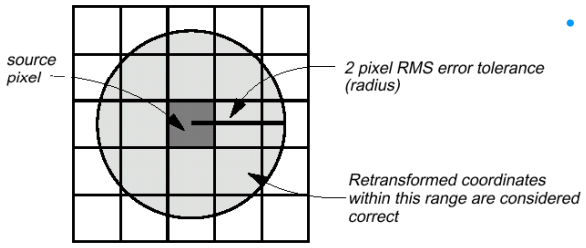
Root Mean Square Error (RMSE)

- Expresses the internal quality "fit" of the transformation.





- Doesn't necessarily mean that the model is in the correct ground position; requires spatial accuracy test.

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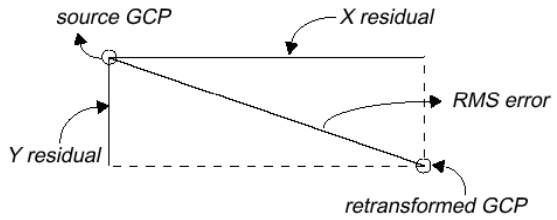
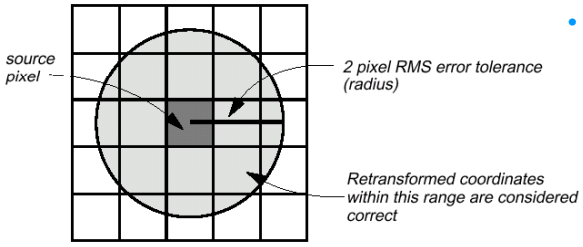
Spatial Accuracy

- Actual statistical evaluation of positional accuracy on the ground.





- Doesn't necessarily mean that the model is in the correct ground position; requires spatial accuracy test.

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Exercise 1: Aerial Photograph Rectification

Objectives

- Recognize the sources of spatial error in an aerial photograph
- Demonstrate the ability to use supporting data to rectify an aerial photograph
- Understand the need to assess the accuracy of rectification

Steps

- Rectify an aerial photo using digital orthophotos as a reference
- Assess the resulting spatial accuracy using RMS

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Exercise 1: Display the Unrectified Image

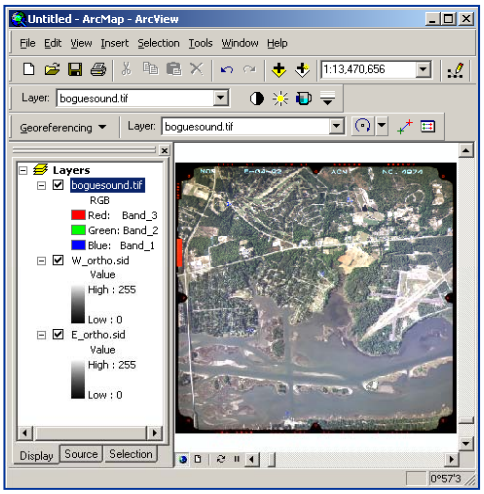
Navigate to c:\rs_training\benthic_habitat\ex_1.

Add:

- boguesound.tif
- E_ortho.sid
- W_ortho.sid

Activate:

- **Georeferencing** toolbar
- **Effects** toolbar



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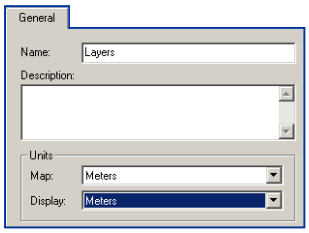
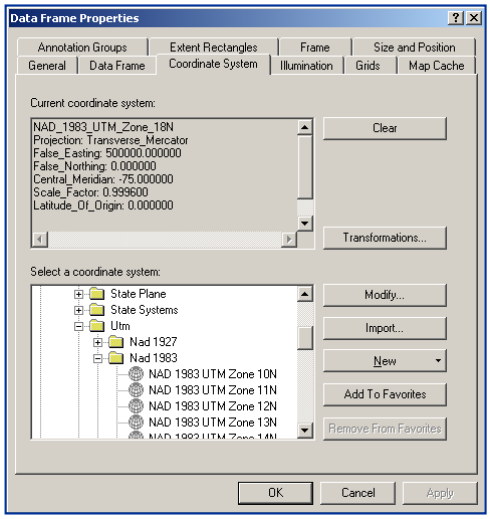
Exercise 1: Select the Coordinate System

The Bogue Sound image will be georeferenced to Universal Transverse Mercator (UTM) zone 18 North, North American Datum (NAD) 1983, meters.





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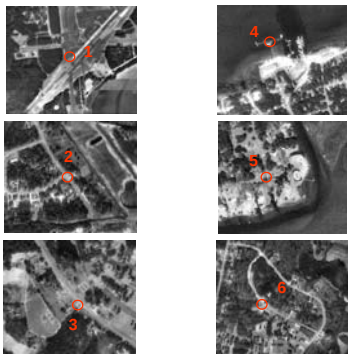
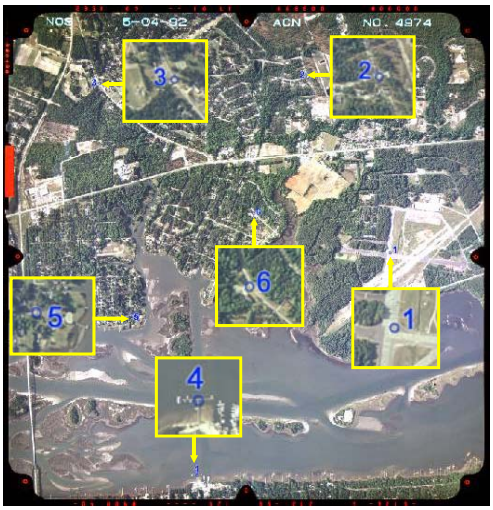
Exercise 1: Examine Features for Control

Review the individual points used to perform the rectification.





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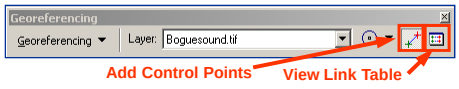
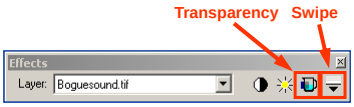
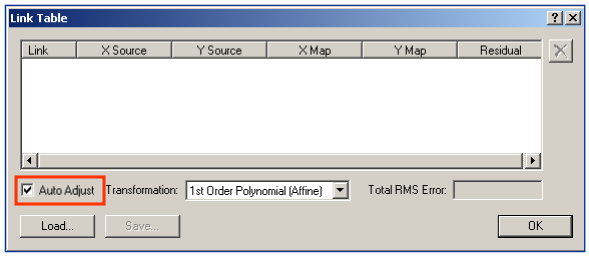
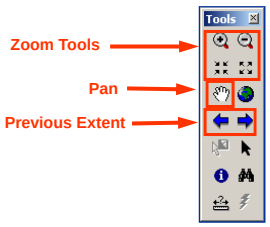
Exercise 1: Georeferencing Tools

The Georeferencing toolbar offers a control point collection tool and link table that displays the source image and projected image coordinates, plus RMS error. Control points are collected by selecting common geographic features in the source and projected imagery.









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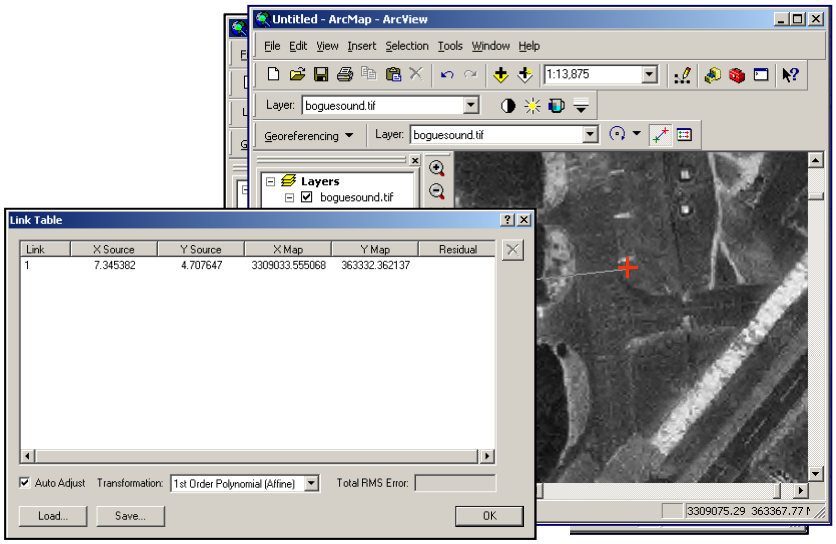
Exercise 1: Establish the Geographic Links



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Exercise 1: Establish the Geographic Links

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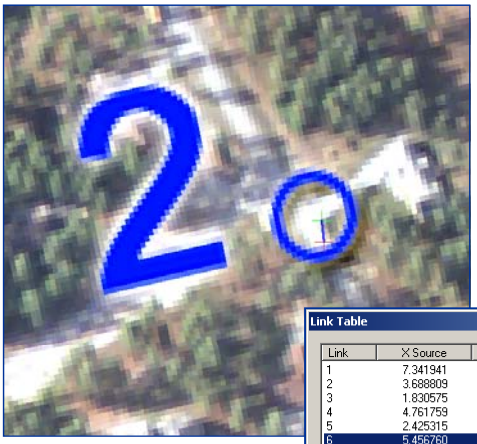
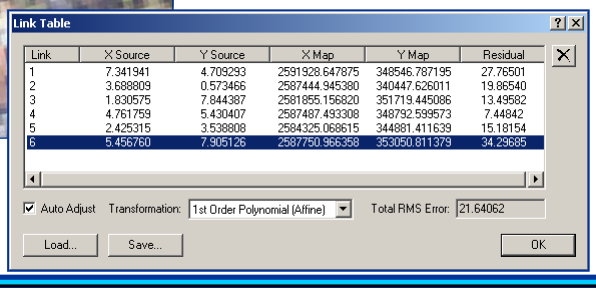
Exercise 1: Review the Geographic Links



The target RMS error for this rectification is ± 3 meters. The rectification solution can be improved by deleting the control point links with the worst RMS errors. Recreate or establish alternate control points as necessary.



Link	X Source	Y Source	X Map	Y Map	Residual
1	7.341941	4.709293	2591928.647875	348546.787195	27.76501
2	3.688809	0.573466	2587444.945380	340447.626011	19.86540
3	1.830575	7.844387	2581855.156820	351719.445086	13.49582
4	4.761759	5.430407	2587487.493308	348792.599573	7.44842
5	2.425315	3.538808	2584325.068615	344881.411639	15.18154
6	5.456760	7.905126	2587750.966358	353050.811379	34.29685

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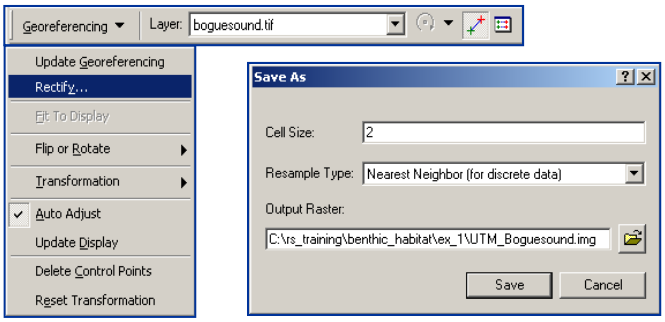
Exercise 1: Rectify the Image



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Exercise 1: Summary

Skills Practiced

- Geographic feature recognition.
- First order transformation procedures.
- "Fine-tuning" a rectification to improve the spatial accuracy (RMS) of the output data.

Important Things to Remember

- Field reference is needed for spatial accuracy assessment.
- Spatial error comes from several sources:
  - the sensor,
  - the platform,
  - the terrain,
  - the measurement process,
  - the source of control.

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Documenting the Results

Information that needs to be documented

- The final RMS of the rectification
- The source of control
- Descriptions of the GCPs
- The transformation order and resampling technique

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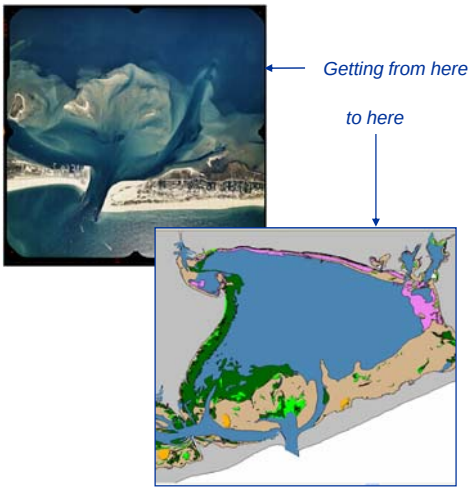
Developing Benthic Data from Aerial Imagery

Analysis Methods

- Manual delineation
- Unsupervised clustering
- Supervised clustering
- Feature analysis*
- Image segmentation*

Field data collection at several points in the process

* Separate software modules



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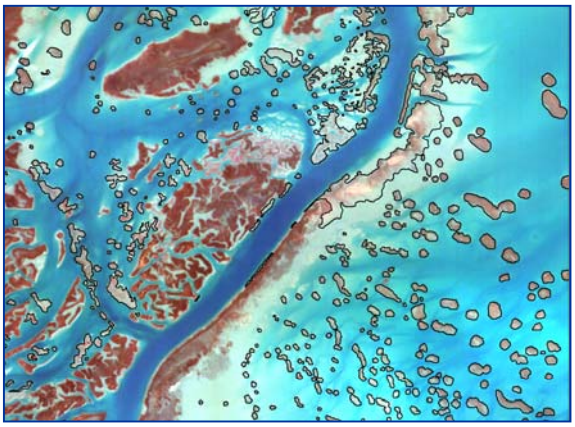
Manual Delineation

Advantages
- Simplest to perform
- Least infrastructure required

Disadvantages
- Vulnerable to subjectivity
- Depends strongly on skilled analysts
- Less repeatability



Consider when:
- Other methods no longer yield useful results
- Limited digital analysis options exist
- When using analog photography

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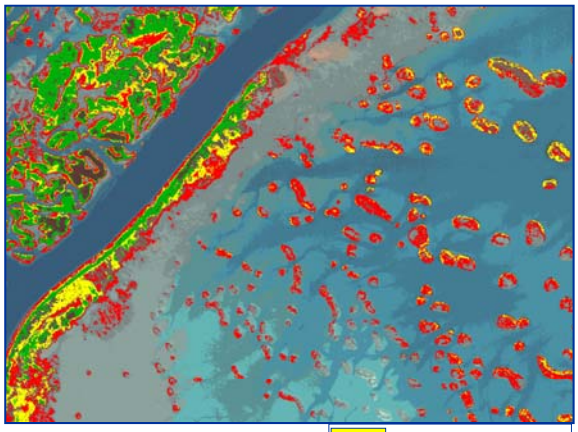
Unsupervised Clustering

Advantages
- Works from native image information
- No requirement for initial field data

Disadvantages
- May require more iterations than other methods



Consider when:
- Good spectral information is present
- Limited field data exists

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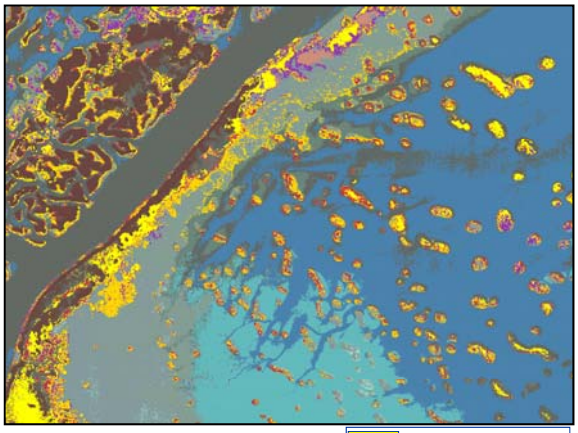
Supervised Clustering

Advantages
- Works from field information

Disadvantages
- Requires field data
- Field data may not be optimal for whole image area



Consider when:
- Field data is available
- Target features are well understood

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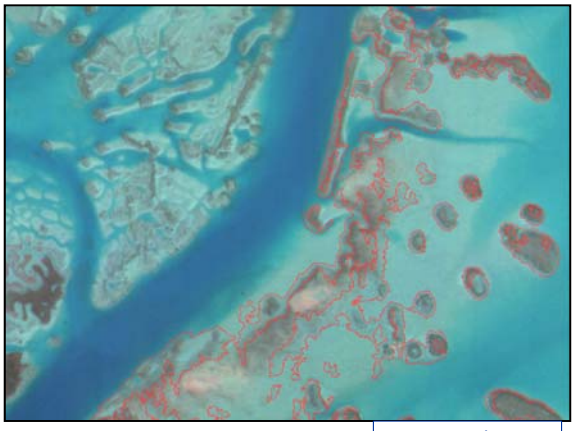
Feature Analysis

Advantages
- Incorporates more than spectral information
- Preserves "learning process"
- Improves by repeated iterations

Disadvantages
- Target focused
- Limited research to date
- Only in one software



Feature Analyst 1st Pass

Consider when:
- Shape, configuration, and texture strongly characterize target
- Single feature detection required
- Spectral information alone insufficient

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Principles of Mapping

Photointerpretation

Shape

Shadow

Texture

Hue/Color

Context

Size

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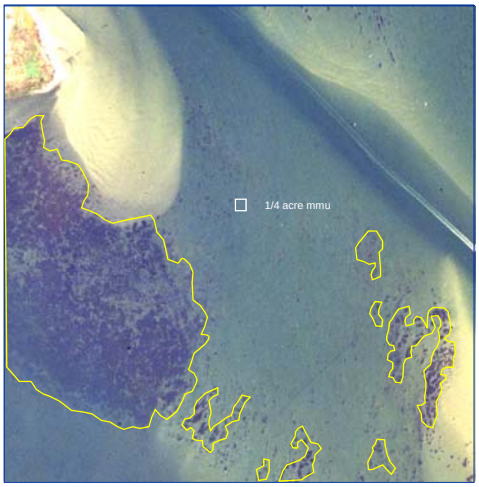
Principles of Mapping

Minimum Mapping Unit

- Smallest contiguous unit that will be mapped
  - Any smaller habitats or features will be aggregated into larger units
- Smaller unit = more detail, but increased effort
- Based on scale/resolution of imagery
  - *Can't be smaller than smallest pixel*



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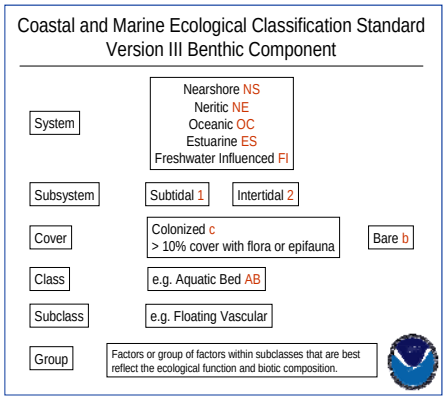
Principles of Mapping

Classification System

- Hierarchical systems are most appropriate for remotely sensed data. They allow for both general and detailed information as imagery/data permit.
- The categories should be exclusive and well defined.
- Confusion in classification systems can be a source of thematic inaccuracy.
- Coastal and Marine Ecological Classification Standard (CMECS)



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Principles of Mapping

Decision Rules

- Important for classes that are inherently a mixture of different components
- Often involve a percentage of the mixture class
- Rules for assigning image features to thematic classes should be well described and followed

A. Outer boundaries of beds are more important than internal structure (patchiness, shapes of sand patches within beds).
B. Outer boundaries of beds are more important than density categorizations within beds.
C. It is more important to capture small isolated patches of seagrass than similar sized patches that are part of a larger bed.
D. Err on the side of including patches rather than excluding them.
E. Where drift algae have accumulated in a seagrass bed, attribute the polygon as seagrass.

SJRWMD seagrass mapping decision rules.

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Exercise 2: Seagrass Habitat Mapping

Objectives

- Integrate ancillary data for image segmentation
- Use field data to guide supervised spectral clustering
- Edit confused clusters

Steps

- Use an ancillary data set to constrain the clustering.
- Use supervised image processing techniques to identify shallow water seagrass meadows.
- Apply a minimum mapping unit filter.

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Exercise 2: Reference Information

Primarily eelgrass (*Zostera marina*)

- Occurs primarily on unconsolidated substrates in low and medium energy environments
- Normally not deeper that 2.5 meters but can go deeper
- Grows up to 2 meters in height

Image Appearance

- Dark hue
- Shallow areas
- Clumps and patches
- Small open-bottom areas within beds

Sources of Confusion

- Deep water
- Dark bottom sediments
- Algae

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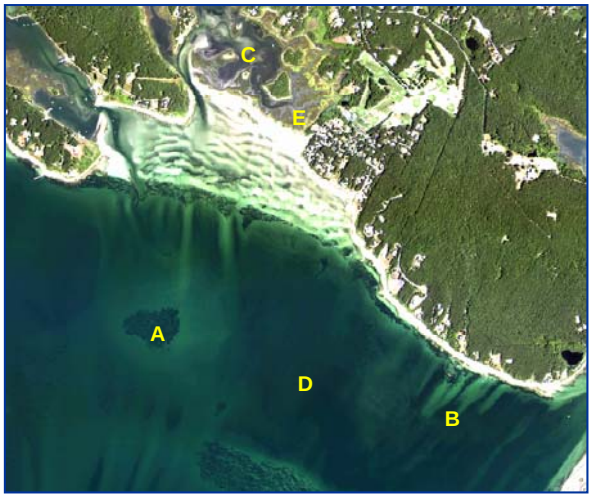
Exercise 2: Signature Development

Image Features

A. Seagrass, note clump pattern and sharp edges
B. Drift algae, note deeper water and soft edges, also linear drift patterns
C. Dark anoxic sediment, note smooth texture and location
D. Deep water, note color and location
E. Emergent marsh



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Exercise 2: Reviewing the Imagery

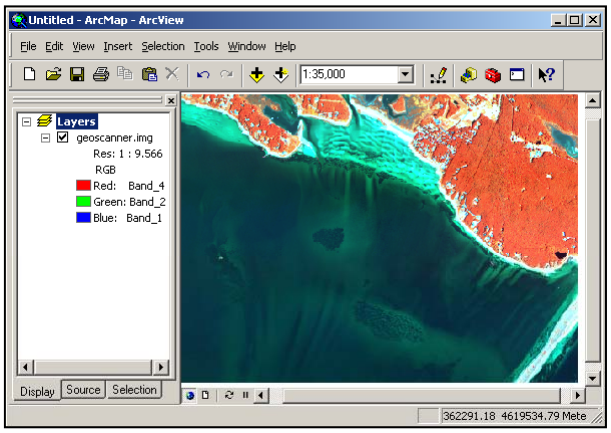
Geoscanner
1-meter resolution
4 spectral bands

1 = Blue

2 = Green

3 = Red

4 = NIR



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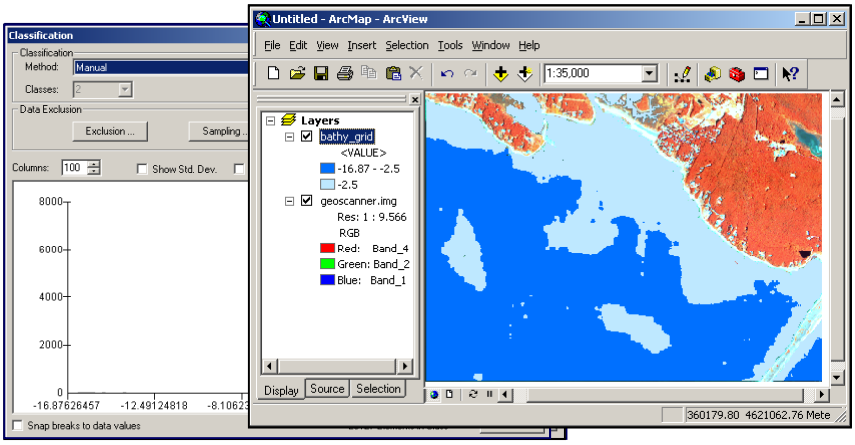
Exercise 2: Classifying the bathymetry



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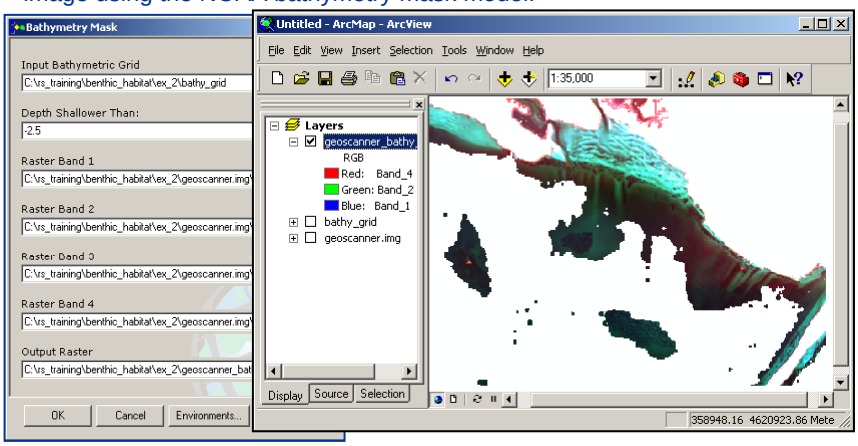
Exercise 2: Subsetting the Shallow Multispectral Image

NOAA Model: Bathymetry Mask

Subset submerged areas less than 2.5 meters in depth from the GeoScanner image using the NOAA bathymetry mask model.



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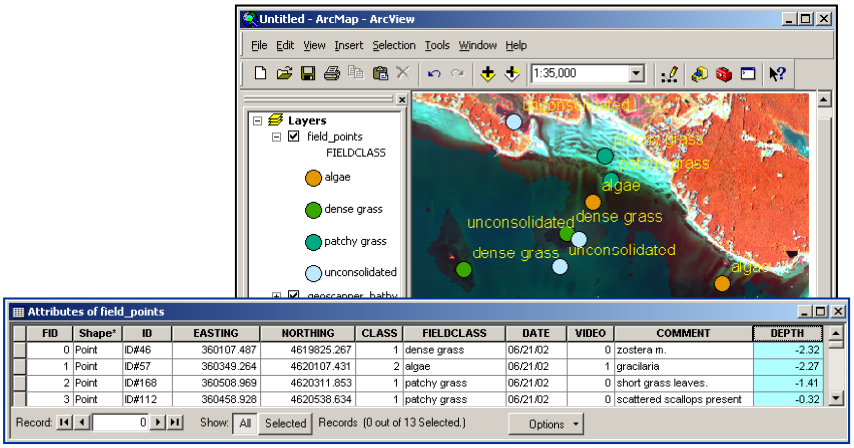
Exercise 2: Integrating Field Points for Training Samples



FID	Shape*	ID	EASTING	NORTHING	CLASS	FIELDCLASS	DATE	VIDEO	COMMENT	DEPTH
0	Point	ID#46	360107.487	4619825.267	1	dense grass	06/21/02	0	zostera m.	-2.32
1	Point	ID#57	360349.264	4620107.431	2	algae	06/21/02	1	gracilaria	-2.27
2	Point	ID#168	360508.969	4620311.853	1	patchy grass	06/21/02	0	short grass leaves.	-1.41
3	Point	ID#112	360458.928	4620538.634	1	patchy grass	06/21/02	0	scattered scallops present	-0.32

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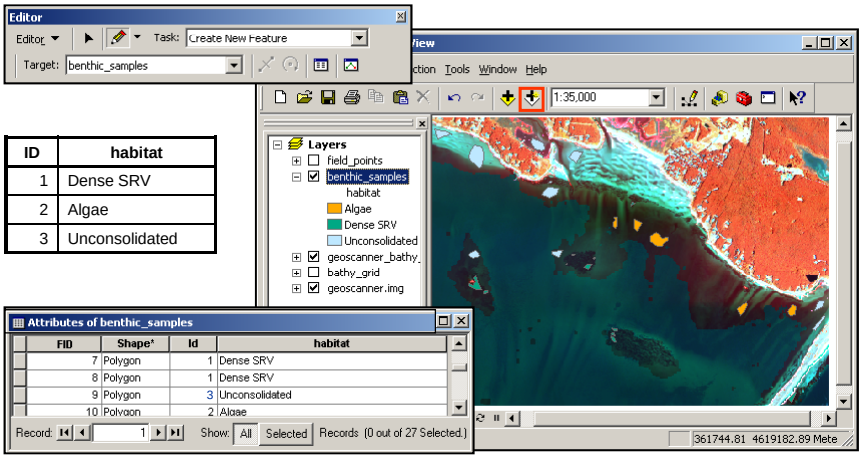
Exercise 2: Creating a Polygon Signature File



ID	habitat
1	Dense SRV
2	Algae
3	Unconsolidated

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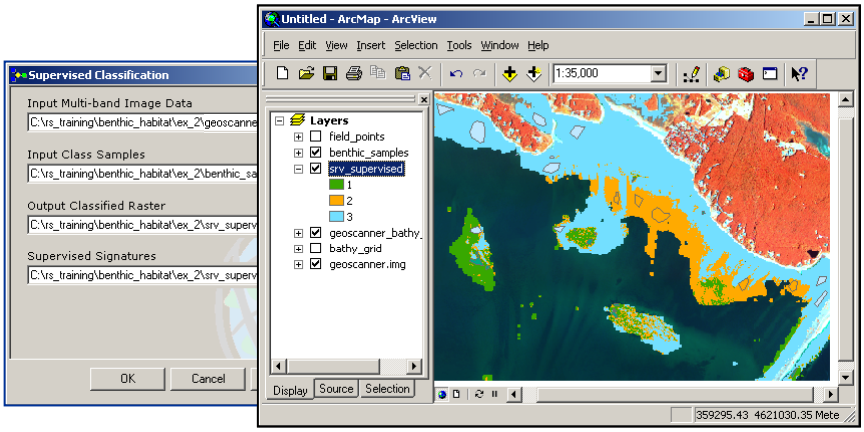
Exercise 2: Supervised Classification

NOAA Model: Supervised Classification



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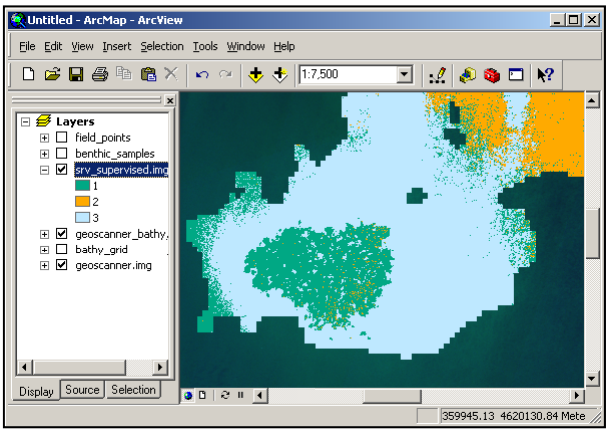
Exercise 2: Reviewing the Cluster Results

Spatial Analyst Generalization and Extraction tools.

- Majority Filter to consolidate clusters
- Boundary Clean smooth edges
- Region Group to uniquely identify contiguous clusters
- Extract by Attribute tool to select groups that satisfy the MMU



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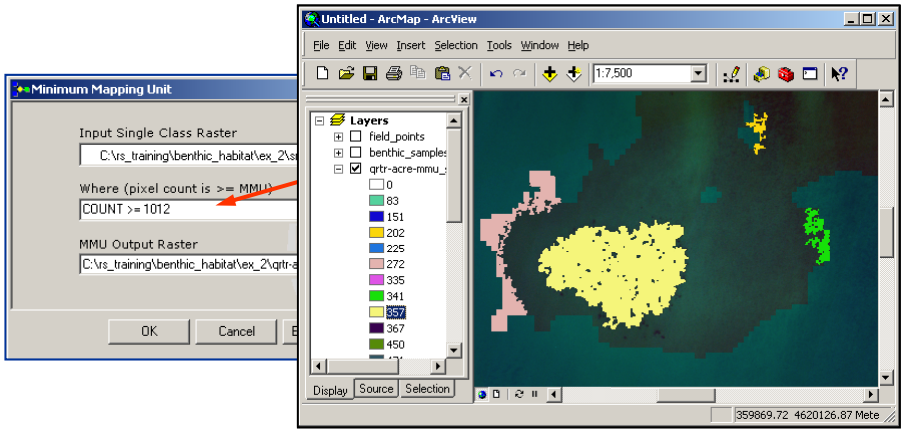
Exercise 2: Applying the Minimum Mapping Unit

NOAA Model: Minimum Mapping Unit



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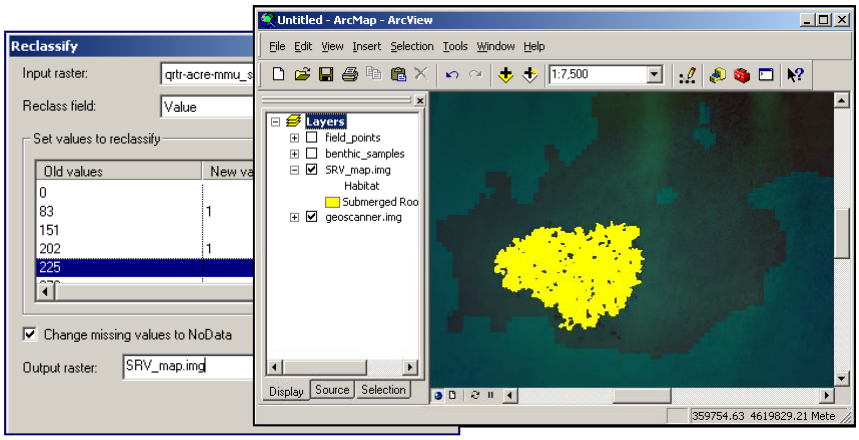
Exercise 2: Review and Eliminate MMU Clusters



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Exercise 2: Summary

Skills Practiced

- Integrate ancillary data with a remotely sensed image
- Use field data to guide supervised spectral clustering
- Review and edit mapping results

Important Things to Remember

- Supervised classification is controlled by the analyst who creates sample sets of pixels.
- The NOAA MMU model can be used to consolidate clusters, filter extraneous clusters, and provide an opportunity to review and eliminate misclassified clusters.

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Documenting the Results

Information that needs to be documented

- Classification system
- Minimum mapping unit
- Thematic accuracy
- Spatial accuracy
- Data development methods
- Assessment methods
- Ancillary data employed

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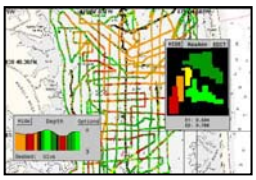
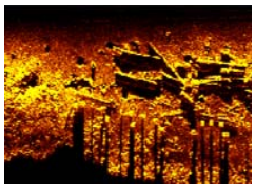
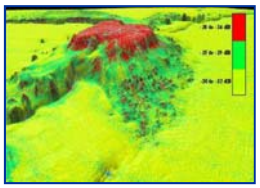
Other Benthic Mapping Technologies



- Single-Beam Seabed Classification
  - Transects, depth, and acoustic response



- Side-Scan Sonar
  - Backscatter image with bathymetry*



- Multi-Beam Sonar
  - Bathymetry with backscatter

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Summary

Important Considerations for Benthic Mapping

Environmental Conditions – Strongly affect project success

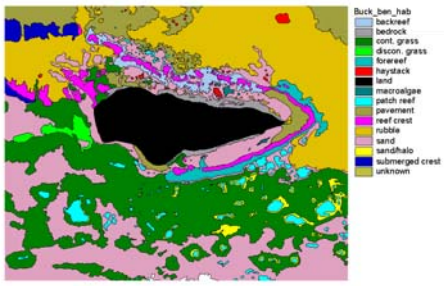
Rectification – Challenging over open water

Classification Accuracy – Field verification especially critical

Historical Data – Available, but often not suitable

Share Resources – Lots of utility for high-resolution imagery

Integrate Technologies – There is no "one technology" solution



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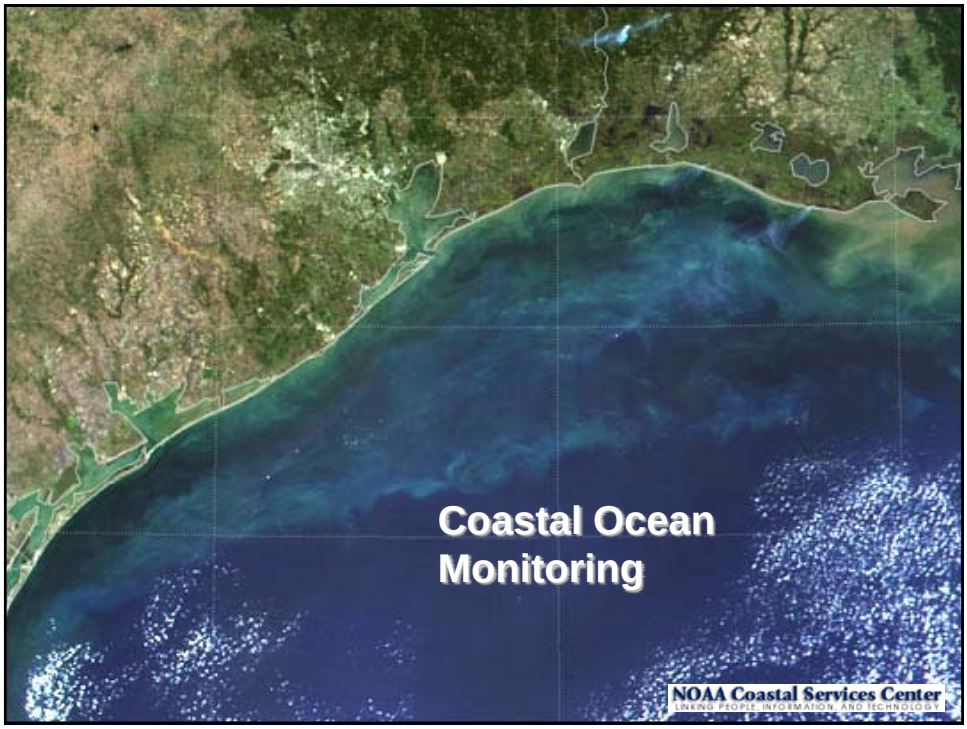
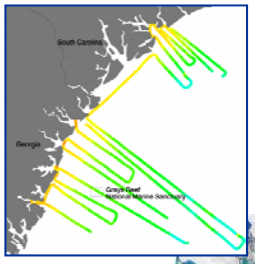
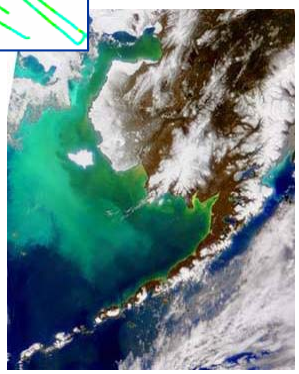


Overview



Airborne:

CASI



Satellite:

SeaWIFS

- Introduction to Ocean Sensors
- Data Availability
- Sea Surface Temperature Imagery
- Exercise
- Ocean Color Imagery
- Exercises

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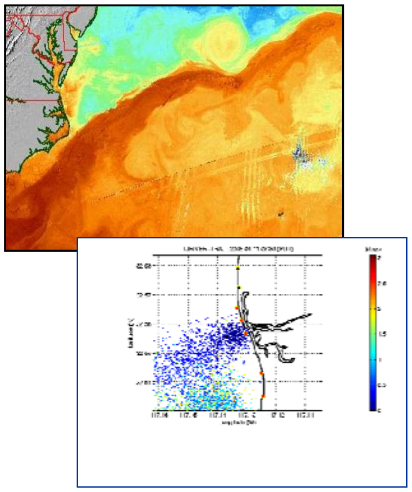
Remote Sensing of the Coastal Ocean



http://www.sccoos.org/data/tracking/IB/

Coastal Issues

- Routine monitoring of temperature and chlorophyll
- Fisheries applications
- Harmful algal blooms
- Monitoring sewage outfall
- Flooding effects
- Habitat characterization
- Climate change monitoring
- Oil spill response
- Coral bleaching events

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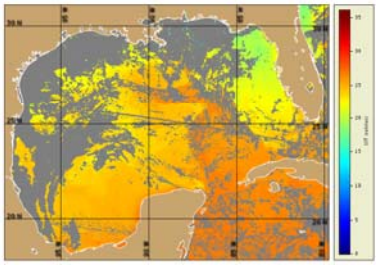
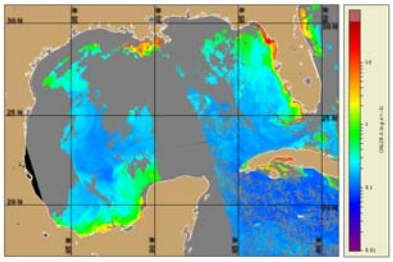
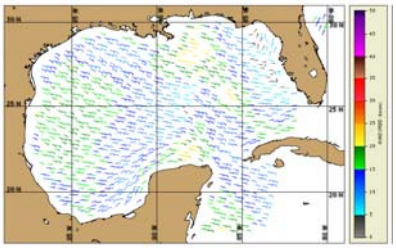
Remote Sensing of the Coastal Ocean





Parameters

- Temperature
- Chlorophyll
- Turbidity
- Currents
- Winds



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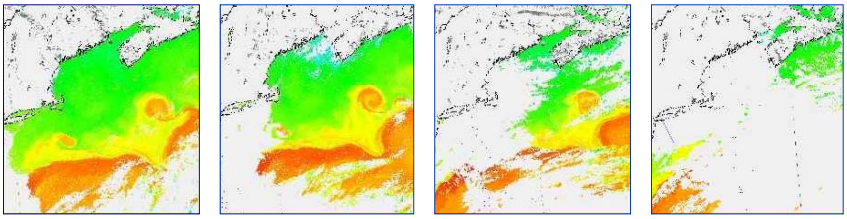
Remote Sensing and Water

- Observe remote areas of water
- Near-surface view
- Waters are dynamic environments – need for frequent access to near real-time imagery



Daily Advanced Very High Resolution Radiometer (AVHRR) sea surface temperature.

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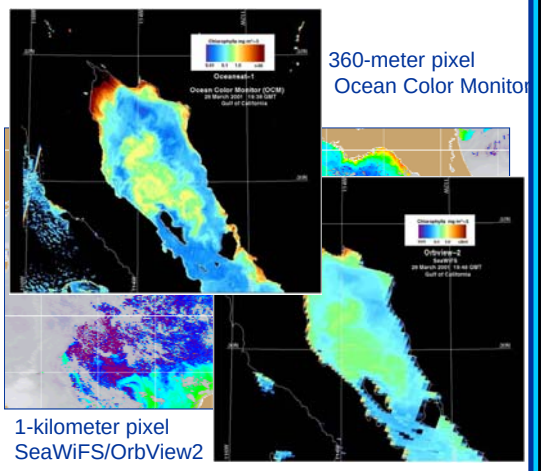
Spatial Resolution

- Original use of satellites was for large features (1-kilometer resolution)
- Coastal waters need new satellite sensors (360 to 250-meter resolution) or aircraft sensors



360-meter pixel
Ocean Color Monitor

1-kilometer pixel
SeaWiFS/OrbView2

Images courtesy of SeaSpace Corporation.

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Ocean Observing Systems

Integrated Ocean Observing System (IOOS) - network of observations designed to measure and predict the effects of global climate change, coastal ecosystems, and human activities.

- Validate image data using in-situ sensors
- In-situ sensors provide information throughout the water column
- In-situ sensors provide information at higher temporal resolution

http://obsregistry.org/index.php

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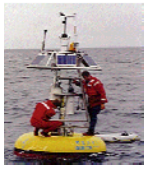

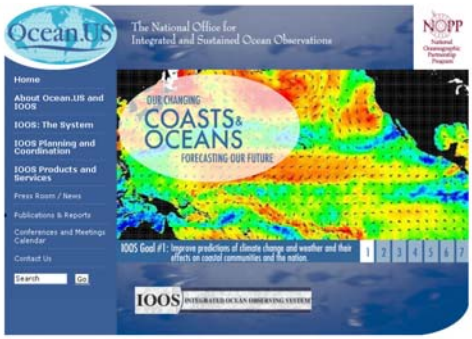

http://www.ocean.us/

http://obsregistry.org/index.php

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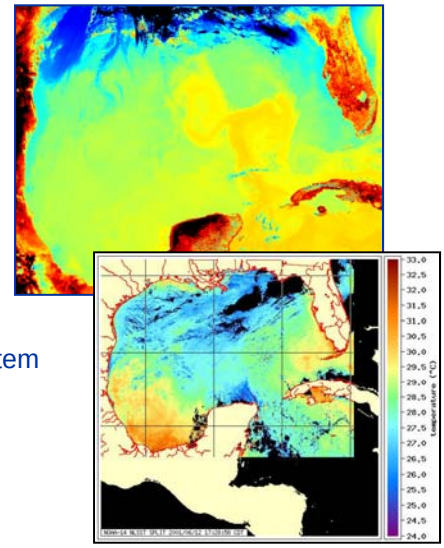
Data Availability and Formats

Considerations

- Application
  - Base Map
  - Data
- Software Compatibility
  - Graphics package
  - Geographic information system
  - Image analysis



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Data Formats

Format	Product	Use	Pros	Cons
GeoTIFF	Ocean Color	GIS	Retains easy georeferencing	Data values are scaled
	GOES-SST	Graphics	Easy to import	
Binary Raster	Ocean Color	GIS	Retains values for analysis	Requires header file and data file
	POES-SST			
HDF/CEOS	Ocean Color	Scientific Analysis	Retains georeferencing,	Large image size
			Contains all spectral bands in one file	Requires special software
GIF	Ocean Color	Graphics	Easy to import	No georeferencing
	GOES-SST		Small file size	Data values are scaled
NetCDF	HF Radar	Scientific Analysis	Becoming a standard for array and gridded data	New to the user community
				Data translation methods still in development

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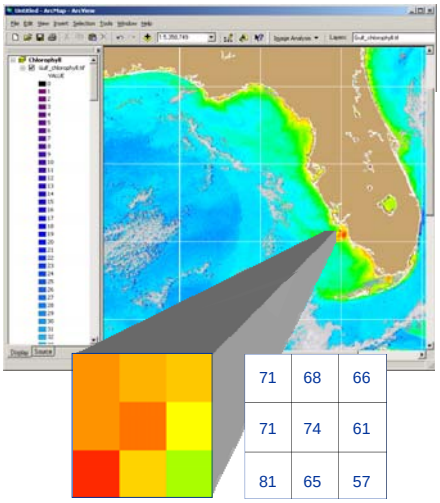
GIS-Compatible Data Formats



GeoTIFF

- Grid of pixels
- Usually 8-bit (values limited to integer numbers from 0 to 255)
- Widely compatible with common software
- Image and georeferencing information in a single file

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More GIS-Compatible Formats

Binary Raster

- Two files – data and header
- 32-bit floating point binary provides greater precision
- Cannot be viewed directly

Example of binary raster header (.hdr) file

```
ncols 512
nrows 512
xllcorner -10894558.08
yllcorner 2785236.934
cellsize 1469.953191
nodata_value
-999.0000000
byteorder LSBFIRST
```

Example of gridded 32-bit data (.flt) file

23.0000	24.350000	20.38000
10.00000	-999.0000	15.320000
2.300000	-1.423000	0.000000

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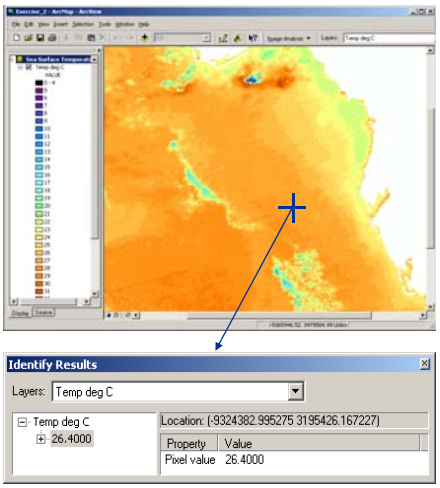
ESRI GRID Format



- GRID supports 32-bit integer and 32-bit floating-point raster grids.
- ArcGIS can convert binary raster data into GRID.
- Array of equally sized square cells with individual values.
- GRIDs can represent complex gridded data values.

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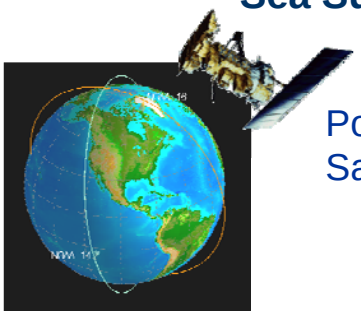
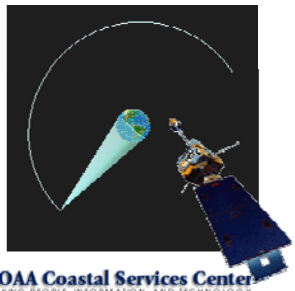
Sea Surface Temperature Sensors



Polar Operational Environmental Satellites (POES)

- Advanced Very High Resolution Radiometer (AVHRR)
- Moderate resolution Imaging Satellite (MODIS)



Geostationary Operational Environmental Satellites (GOES)

- Imager

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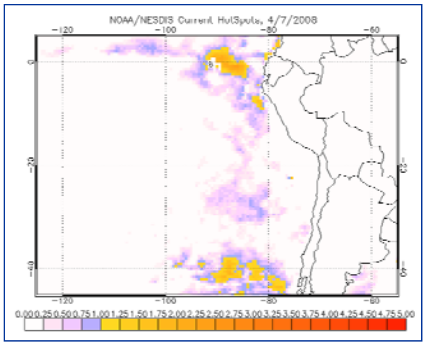
Sea Surface Temperature Uses



http://coralreefwatch-satops.noaa.gov/SBA.html

- Sea turtle and marine mammal habitat
- Monitoring and modeling larval recruitment
- Monitoring industrial sewage treatment outfalls
- Sport fishing locations and sailing routes
- Climate change monitoring
- Coral bleaching warnings

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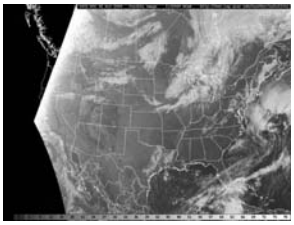
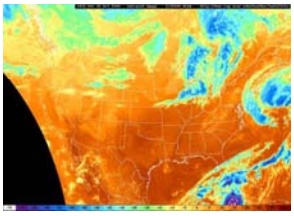
Visible and Infrared Sensors

Band	Wavelength Range (um)	Application
1	0.58 – 0.68 (visible)	Cloud, pollution, and haze detection; severe storm
2	0.73 – 1.10 (shortwave IR)	Surface water, snow, ice
3	3.55 – 3.93 (thermal IR)	Fog, water, clouds, and snow; fires and volcanoes; sst
4	10.30 – 11.30 (thermal IR)	Day/night clouds and surface temperature
5	11.5 – 12.5 (thermal IR)	Moisture/water vapor; sst; dust and volcanic ash





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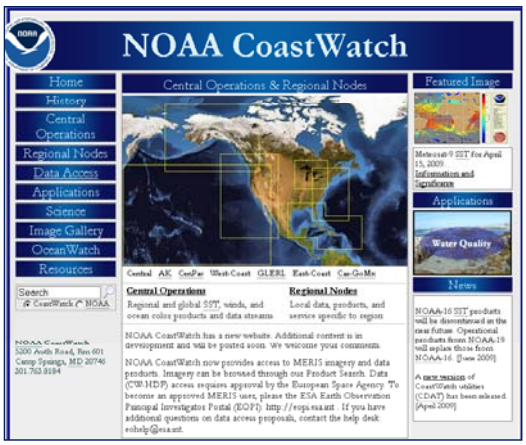
Access to SST

NOAA

- Near Real-Time – Coastwatch
- Historical – Satellite Active Archive

Other sources

- Integrated Ocean Observing System
- Academic – regional coverage
- Commercial – value added



http://coastwatch.noaa.gov/cwn/search/interface.html

http://obsregistry.org/index.php

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Exercise 1: Extracting SST Values and Defining Temperature Habitats

Objectives

- Recognize tools to improve image interpretation for ocean features.
- Evaluate the use of SST imagery with vector data to identify ocean habitat.

Steps

- Convert SST binary raster files to GRID format
- Extract values of SST from image
- Analyze imagery with additional data layers
- Query data for specific fish habitats

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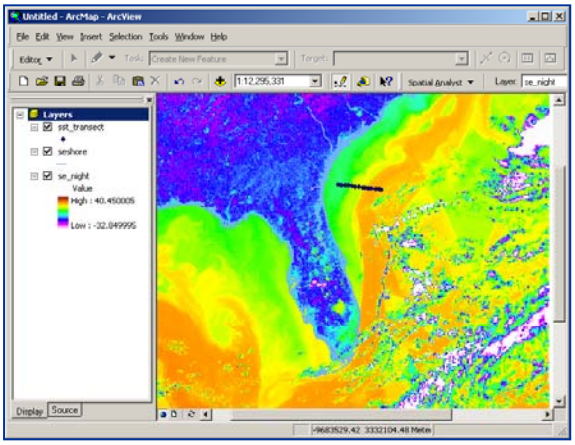
Extracting SST along a Transect

- Validate and verify point and image-derived temperature
- Provide data between stations
- Visual context for measurements



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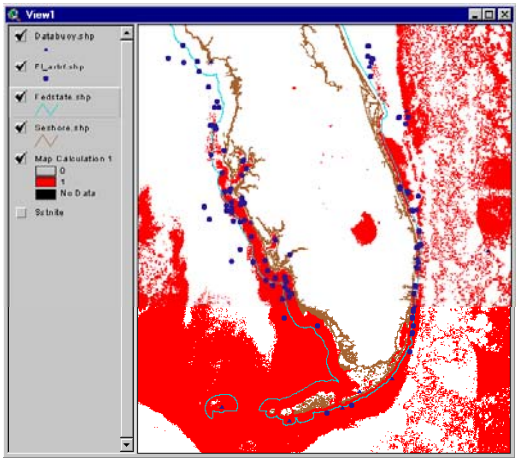
Habitat Characterization for Fisheries Management



- **Imagery**
  - Temperature preferences
- **Vector data**
  - Bathymetry
  - Jurisdictional boundaries

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Exercise 1: Extracting SST Values and Defining Temperature Habitats

Objectives

- Recognize tools to improve image interpretation for ocean features
- Evaluate the use of SST imagery with vector data to identify ocean habitat

Steps

- Convert SST binary raster files to GRID format
- Extract values of SST from image
- Analyze imagery with additional data layers
- Query data for specific fish habitats

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Summary for Exercise 1

- SST imagery provides a regional perspective for the surface water temperature.
- Rescaling imagery may improve the visualization of the data and make interpretation easier.
- Metadata that specifies the projection of the imagery is important for use with other geographic data.
- Oceanographic information, such as SST, changes rapidly. Quick and easy access to imagery is important for many applications.

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Ocean Color

Ocean color is determined by the absorption and scattering of light by the contents of the water.

- Phytoplankton
- Sediments
- Colored dissolved organic matter
- Water

Image Source: SeaWiFS

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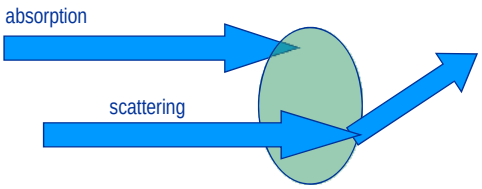
Absorption and Scattering of Light

Absorption – light absorbed by water or something in the water

Scattering – light scattered off of water molecules or particles

Fluorescence – light absorbed and re-emitted at a longer wavelength



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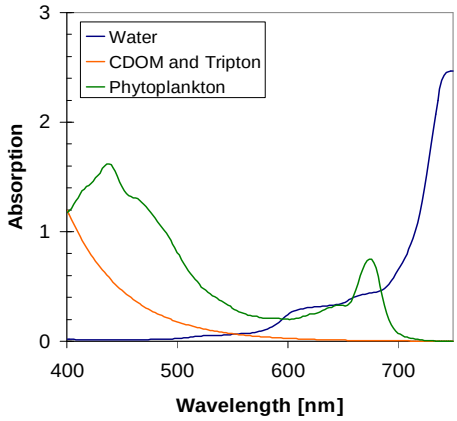
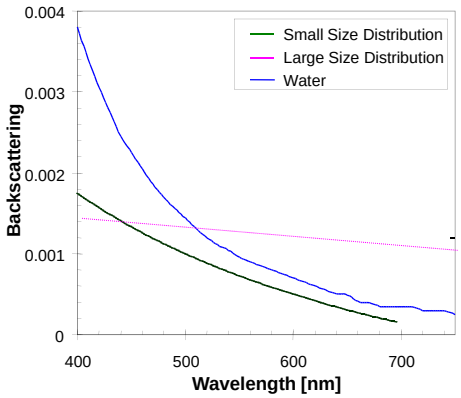
Absorption and Scattering Spectra





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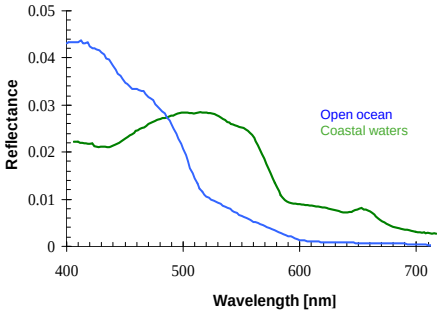
Ocean Color Reflectance

Reflectance $\propto$ $\frac{\text{Backscattering}}{\text{Absorption}}$



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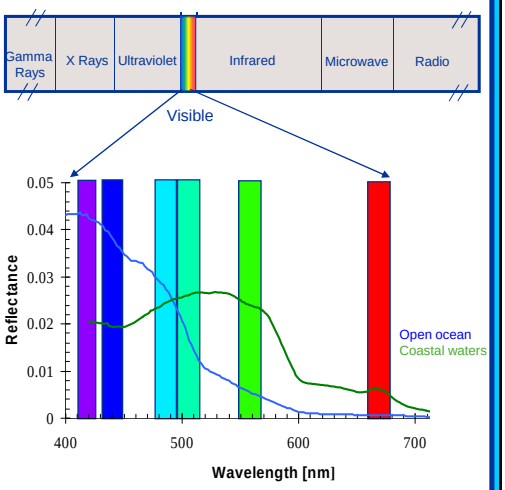
Sensor Specifications

- Narrow bands in the visible
- Placed to estimate sediments, organic materials, or phytoplankton at the surface



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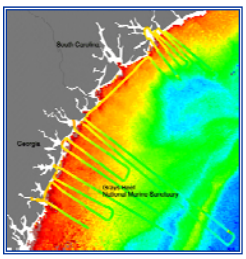
Ocean Color Platforms

Satellite Sensors

- SeaWiFS/OrbView2 – U.S. government and private industry
- MODIS on Aqua – U.S.
- Ocean Color Monitor (OCM) – India
- MERIS – European Space Agency
- VIIRS – U.S.

Aircraft Sensors

- SeaWiFS Airborne Simulator (MicroSAS)
- Compact Airborne Spectrographic Imager (CASI)
- (AISA)



Aircraft

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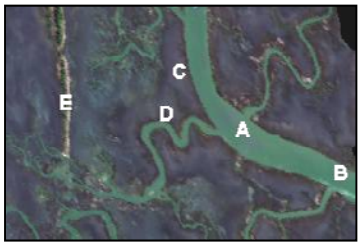
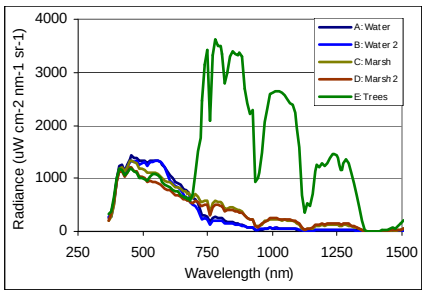
Hyperspectral Aircraft Sensors

- Detect energy over many wavelengths, usually at least 50 or more
- Used for land and ocean feature discrimination
- Discriminate subtle differences between similar targets
- Increased data makes computation intensive
- More commonly available in research community



Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) image



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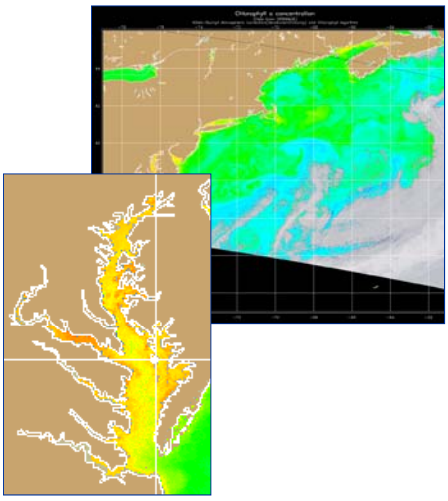
Ocean Color Interpretation



Passive sensors are less accurate in coastal areas than open ocean.

- Difficult to distinguish between chlorophyll, dissolved organics, and turbidity
- The bottom affects measurements in shallow waters
- Small areas of interest not captured by the satellite spatial resolution of 1 kilometer
- Atmospheric effects

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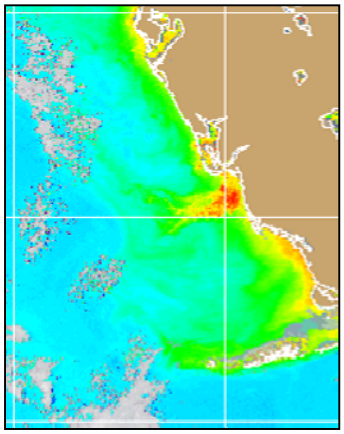
Exercise 2. Using SeaWiFS Ocean Color Imagery to Determine Monitoring Strategies

Objectives

- Become familiar with the use of imagery in GeoTIFF format
- Recognize differences between actual values and scaled data
- Assess the use of imagery for water quality monitoring

Steps

- Convert scaled data to chlorophyll concentration
- Evaluate the use of imagery in monitoring for harmful algae



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Summary for Exercise 2

- GeoTIFFs provide valuable information in a scaled format.
- Multiple types of data and imagery used together will reveal more information than any of the data types used alone.
- Ephemeral nature of phytoplankton bloom illustrates need for high temporal resolution data.

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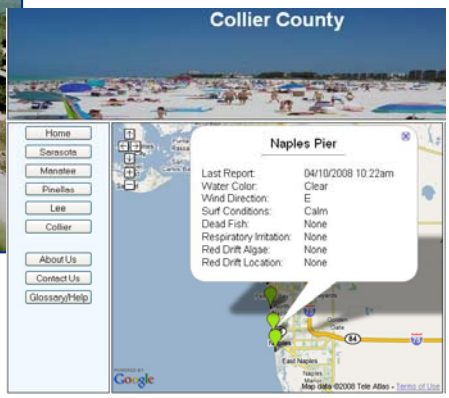
Algal Bloom Monitoring

Karenia brevis

Port Charlotte, Florida
October 2000



http://www.coolgate.mote.org/beachconditions

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Broader, Fenstermacher

Gulf of Mexico Harmful Algal Bloom Bulletin

5 December 2005
NOAA Ocean Service
NOAA Satellites and Information Service
Last bulletin: December 2, 2005

Conditions Report

Harmful algal blooms have been identified in patches from Dixie to Levy, Pinellas to Charlotte Counties, and Monroe County. Very low impacts are possible today in Pinellas County. Low impacts are possible today in Dixie, Levy, Manatee, Charlotte, and Monroe Counties, with possible very low impacts tomorrow through Wednesday. Patchy moderate impacts are possible today in Sarasota County, with possible very low impacts tomorrow through Wednesday. Discolored water may be present.

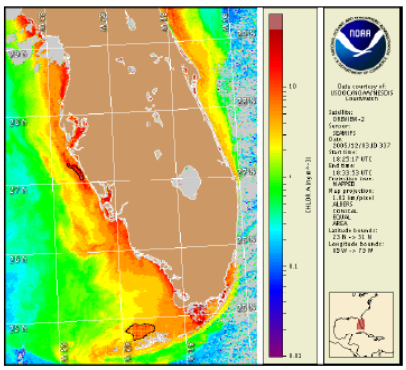
Analysis

The bloom persists along shore from Dixie to Levy, Pinellas to Charlotte Counties, and offshore of Lee and Collier Counties. FWRI sample data from last week indicate medium concentrations of *Karenia brevis* in Sarasota County and a high concentration off shore of Collier County. Imagery from 12/3 continues to show an high chlorophyll feature extending along the coast from just south of Tampa Bay to just north of Charlotte Harbor. Near the north end of this feature, at 27°24'N 82°48'W, imagery indicates a chorophyll concentration >17 μg/L. Near the south end of said feature, at 26°50'N 82°28'W, the concentration is 10 μg/L. Several points within this feature had concentrations >20 μg/L, including 27°05'N 82°32'W. A wind transport model indicates northward bloom transport of 20 km since 12/1. Offshore expansion and intensification of the bloom is possible through Wednesday.

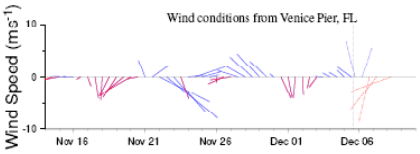
A bloom has formed near the Florida Keys. Mote Marine Lab sample data from last week shows low *Karenia brevis* concentrations north and south of the Keys. Fish kills and discolored water were reported as well. Imagery indicates a chlorophyll concentration >5 μg/L north of the lower Keys at 24°50'N 81°42'W. Variable winds through Wednesday will result in little net movement of the bloom.

Please note the following restrictions on all SeaWiFS imagery derived from CoastWatch.

1. Data are restricted to civil marine applications only; i.e. federal, state, and local government use/distribution is permitted.
2. Image products may be published in newspapers. Any other publishing arrangements must receive OrbImage approval via the CoastWatch Program.



Satellite chlorophyll image with possible HAB areas shown by red polygon(s).



Wind speed and direction are averaged over 12 hours from buoy measurements. Length of line indicates speed; angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts.

SW Florida: Winds will be southwest (15 kts, 8 m/s) today, northeast (20 kts, 10 m/s) tomorrow through Wednesday.

Lower Keys: Winds will be southeast (9 kts, 5 m/s) today, west becoming north (13 kts, 7 m/s) tomorrow, east (13 kts, 7 m/s) Wednesday.

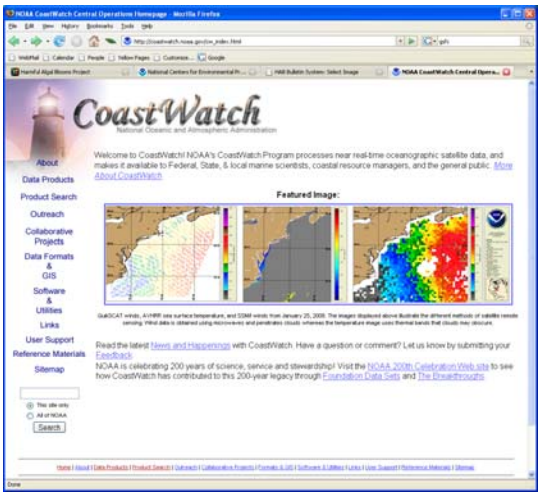
Sources for Satellite Ocean Color Data

SeaWiFS

- NASA Goddard Distributed Active Archive Center
- CoastWatch
- OrbImage, Inc.

MODIS

- NASA MODIS Web
- CoastWatch
- Academic Institutions
- IOOS Observation Registry



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Conclusion

- Multiple types of data and imagery used together will reveal more information than any of the data types used alone.
- SST data are available at no cost from NOAA CoastWatch and other institutions in several formats.
- Ocean color data are available from government, commercial, and academic providers. The choice of provider will depend on the use for the data, available resources for processing data, and the need for real-time access.
- Real-time uses for oceanic (and atmospheric) imagery require high temporal resolution with rapid processing and easy availability.

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Overview

- **Defining Elevation Data**
- **Management Issues and Topographic Applications**
- **Definitions and Accuracy**
- **Methods for Measuring Topography**
- **Exercises**
  1. Determining the Setback Line in a Barrier Island Community
  2. Comparing Topography Data for Land-Use Decisions

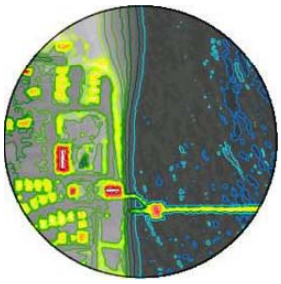
Wrightsville Beach, North Carolina.

- Defining Elevation Data

Topography
The general shape or form of the land surface, determined by analyzing the elevation of the land

Bathymetry
The general configuration of the seafloor represented by depth data

Data can be displayed in various formats:
- Points
- Contour lines
- Raster



Ground elevation contours were derived from LIDAR point data and draped on top of the LIDAR "intensity image." Source: CSC Website

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Erosion Issues

- Natural migration of barrier islands
- Shoreline protection
- Setback lines
- Storm-driven
- Long-term erosion

United States Geological Survey

National Park Service

Habitat Issues

- Sea Beach Amaranth
  - Grows only in the Carolinas and Long Island
  - Narrow range of elevation above sea level.
  - Endangered colonizing species
- Brown Pelican
  - Only nests on islands that have sufficient high ground to avoid tidal flooding

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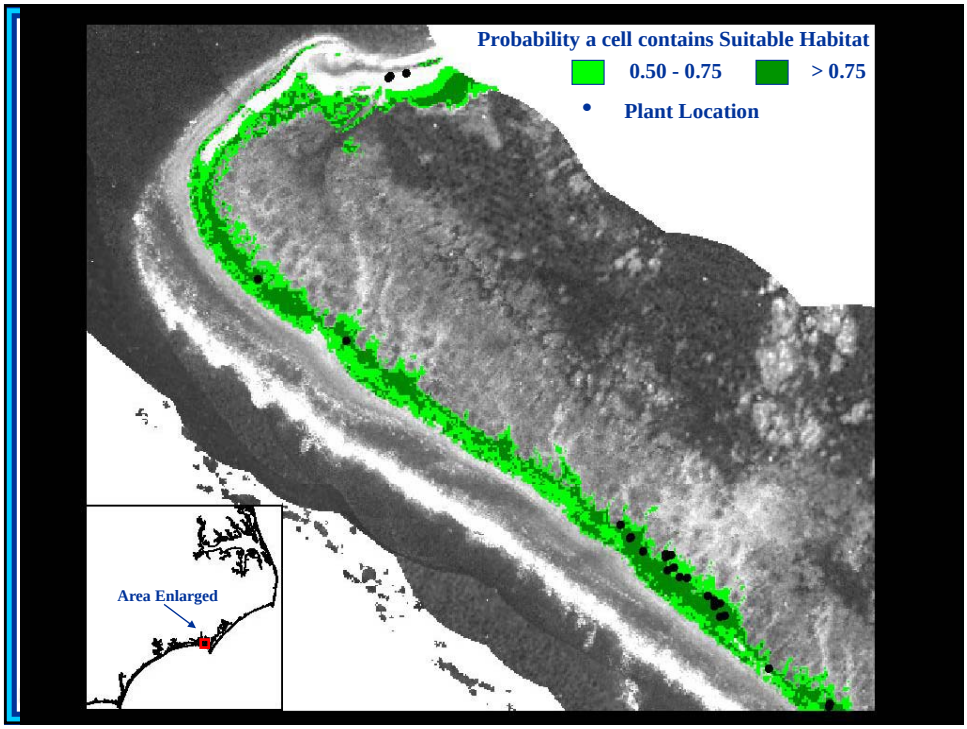
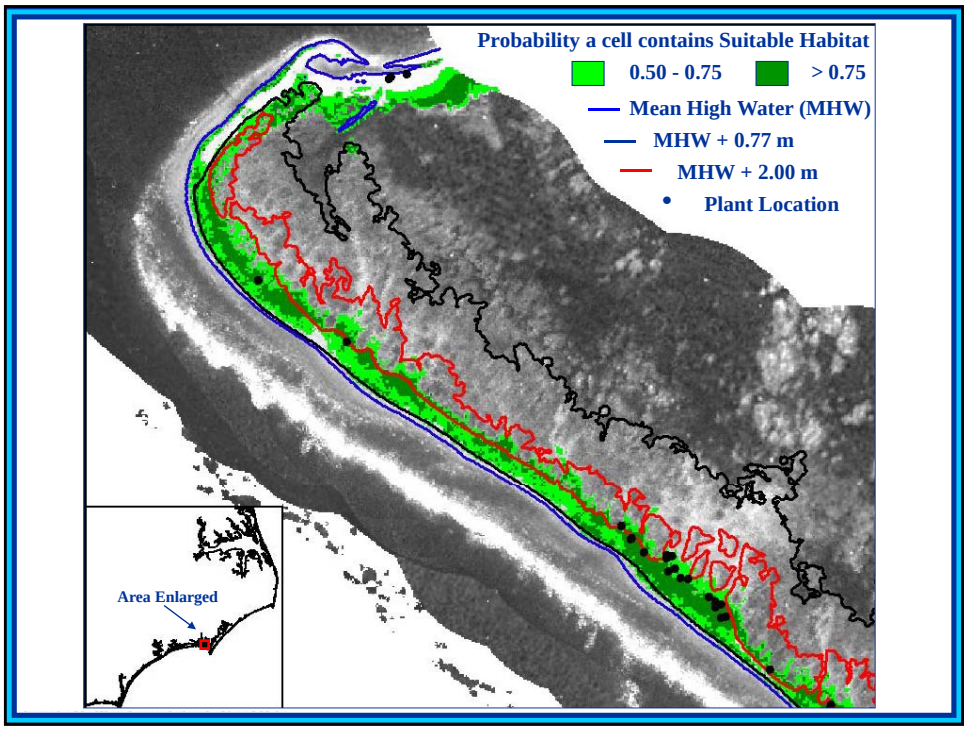
Amaranthus pumilus

- **fugitive**
- **intolerant of competition**
- **requires disturbance**
- **narrow elevation range on non-eroding beaches (Bücher and Weakley 1990)**
- **habitat is relatively homogenous**


Probability a cell contains Suitable Habitat
0.50 - 0.75
> 0.75
Plant Location
Area Enlarged


Probability a cell contains Suitable Habitat
0.50 - 0.75
> 0.75
Mean High Water (MHW)
MHW + 0.77 m
MHW + 2.00 m
Plant Location
Area Enlarged

Habitat Issues

Brown Pelican

- Only nests on islands that have sufficient high ground to avoid tidal flooding
- On the endangered species list in most of the U.S.

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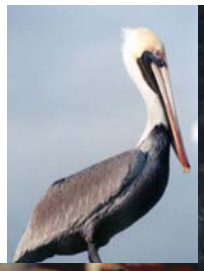
Habitat Issues



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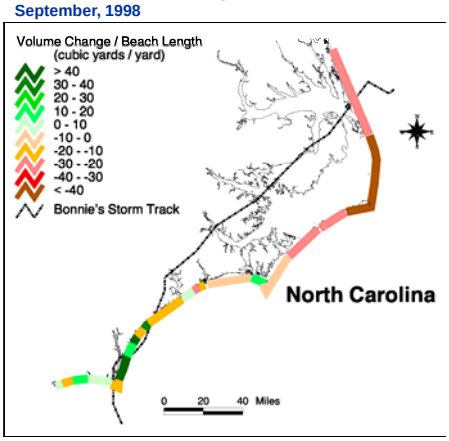
Topography Applications

North Carolina beach change due to Hurricane Bonnie, September, 1998



- Statewide erosion analyses
- Floodplain mapping
- Local erosion analyses
- Local management decisions

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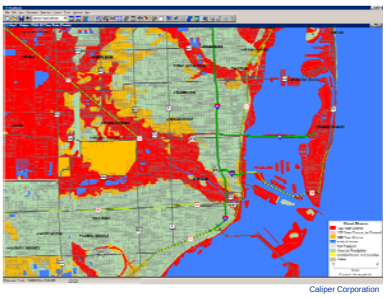
Topography Applications

- Statewide erosion analyses
- Floodplain mapping
- Local erosion analyses
- Local management decisions



Caliper Corporation

FEMA Floodplain map for the Miami, Florida, region, created with Maptitude® GIS for Windows

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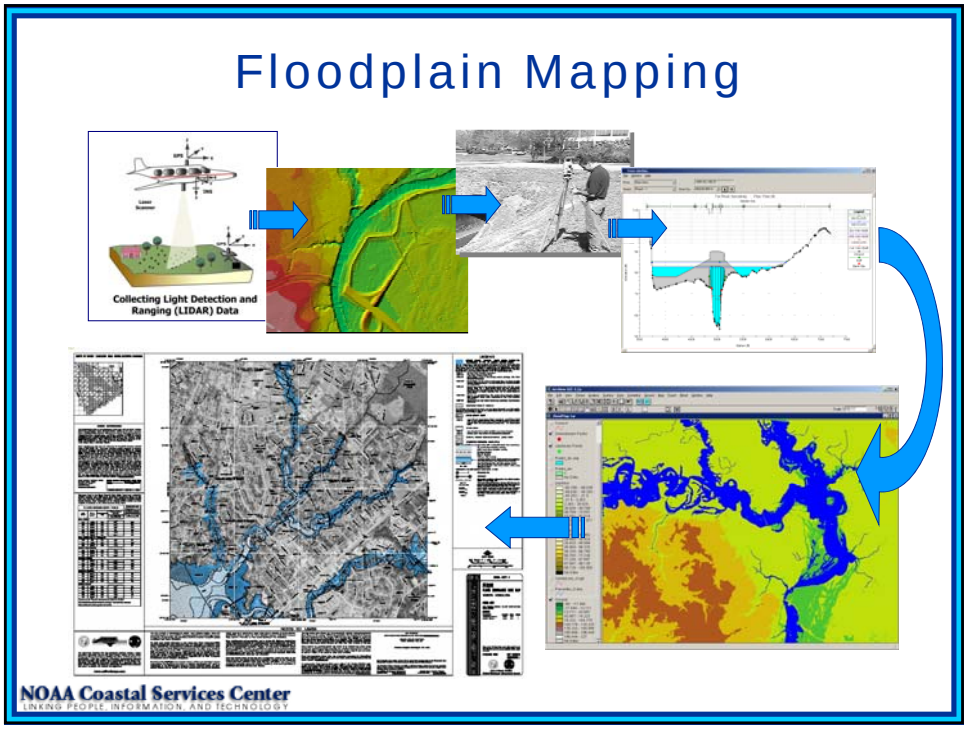
Floodplain Mapping
Collecting Light Detection and Ranging (LIDAR) Data
NOAA Coastal Services Center
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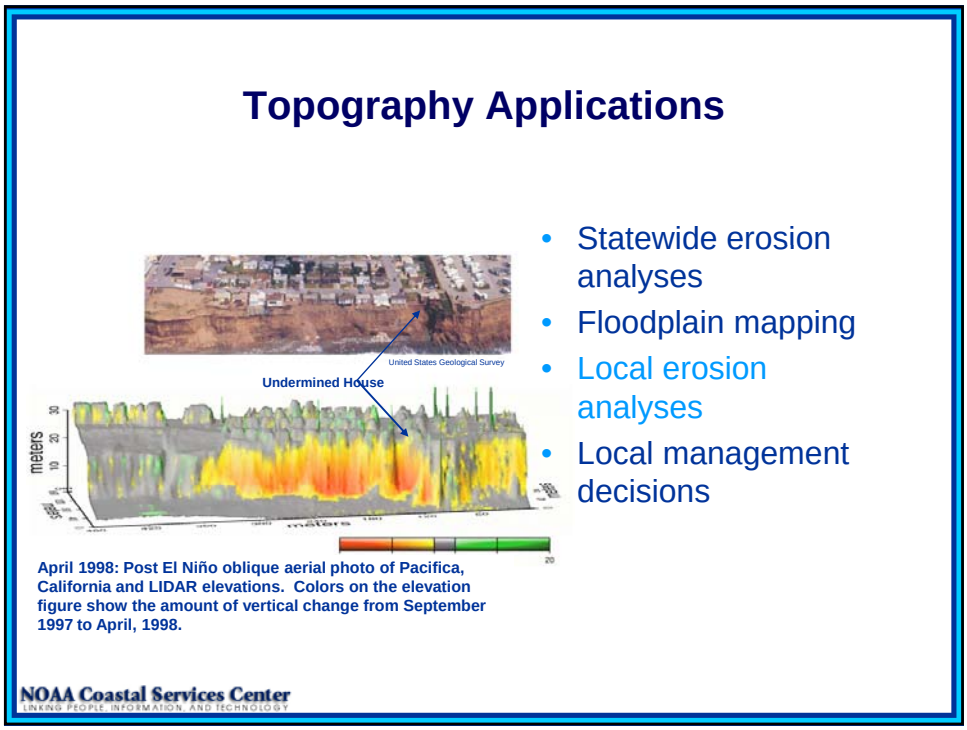
Topography Applications
Statewide erosion analyses
Floodplain mapping
Local erosion analyses
Local management decisions
United States Geological Survey
Undermined House
meters
April 1998: Post El Niño oblique aerial photo of Pacifica, California and LIDAR elevations. Colors on the elevation figure show the amount of vertical change from September 1997 to April, 1998.
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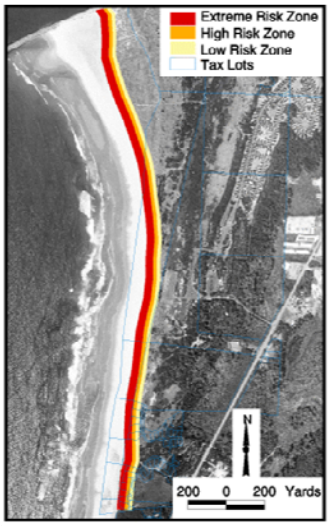
Topography Applications



Risk zones due to long-term erosion, Newport, Oregon.

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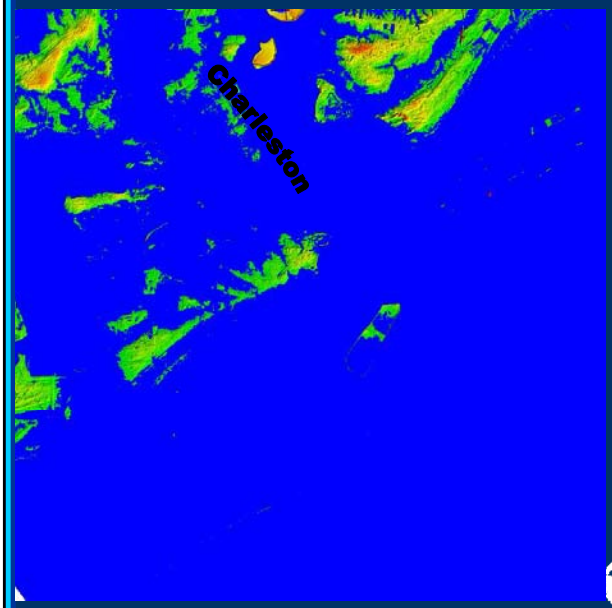
- Statewide erosion analyses
- Floodplain mapping
- Local erosion analyses
- Local management decisions

Coastal Planning



- MSL
- MHW
- MHW + 0.6 m
- MHW + 0.8 m
- Hurricane Hugo
- Hugo + 0.8

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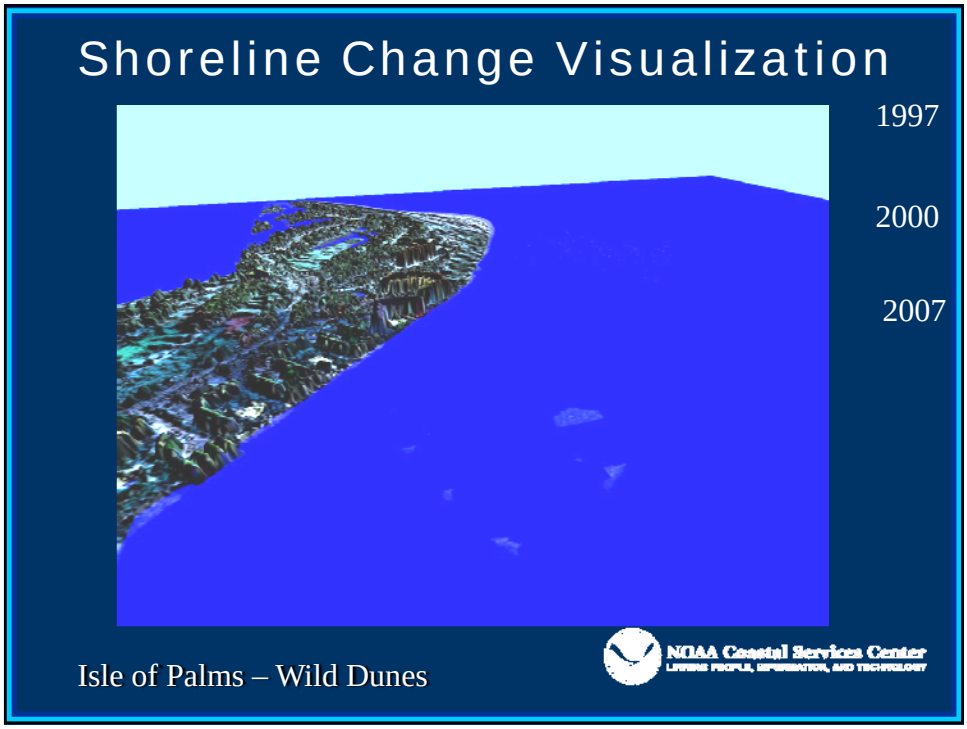
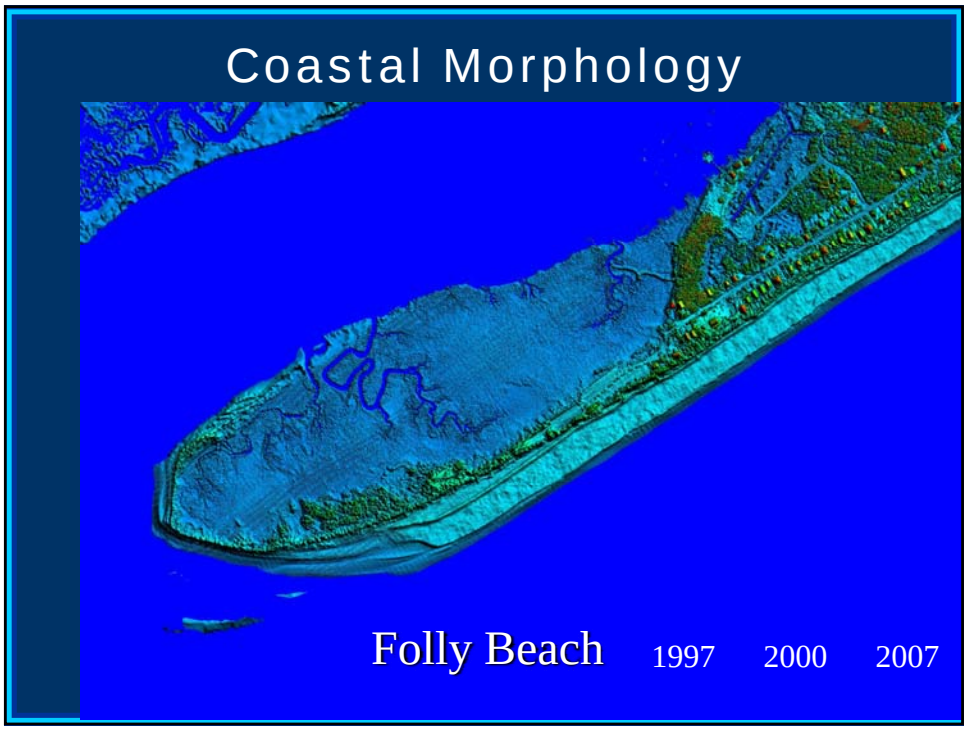
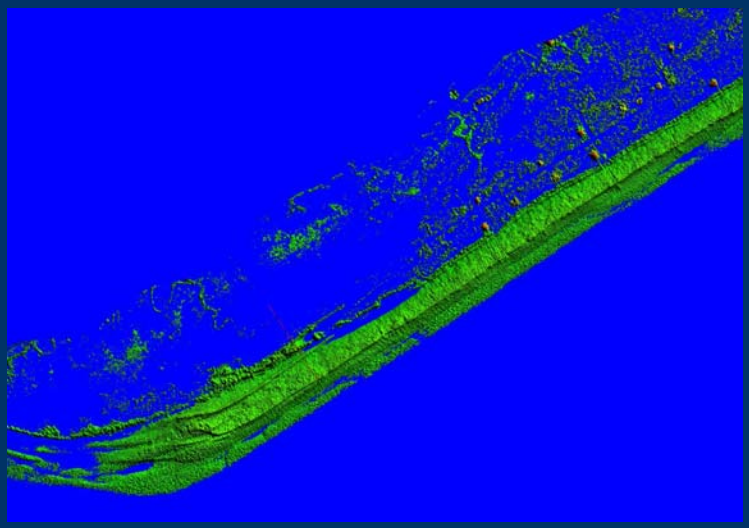

Shoreline Change Visualization
1997
2000
2007
Isle of Palms – Wild Dunes
NOAA Coastal Services Center


Coastal Morphology
Folly Beach
1997
2000
2007

Volumetric Analysis



2000

2007

Change

Folly – Quantifying Change

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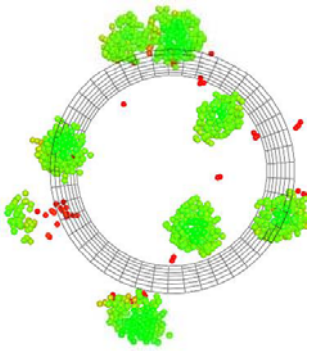
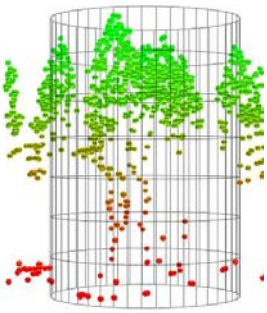
Forestry Applications with Lidar



Top View

With high resolution, can model:

- Tree size
- Tree density
- Canopy Volume
- Crown Bulk



Side View

From McGaughey et al., "Direct Measurement of Individual Tree Characteristics from Lidar Data", USDA Forest Service

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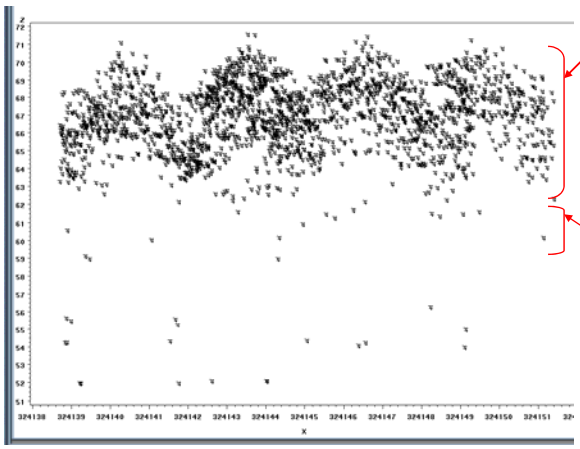
Base of Live Canopy from LIDAR



Remove majority of canopy points from 1st return data.

Retain highest remaining points to surface base of canopy.

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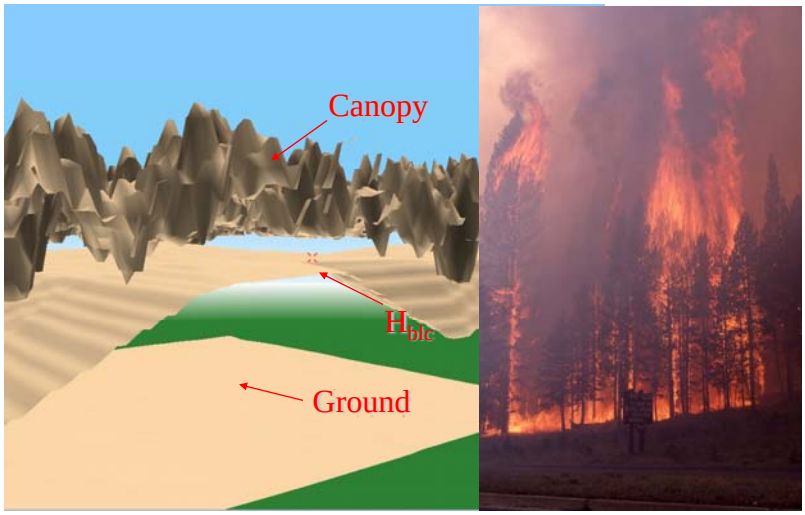
Height to Base of Live Canopy (H_{blc}) Determination



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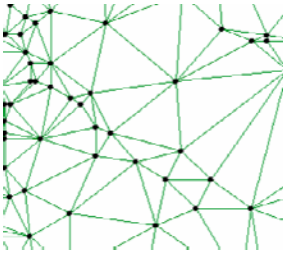
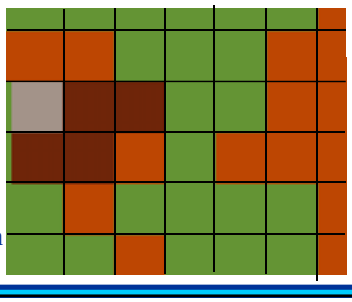
Common Terminology

- DEM – Digital Elevation Model
- TIN – Triangulated Irregular Network
- DSM – Digital Surface Model
- DTM – Digitial Terrain Model
- DTED – Digital Terrain Elevation Data



TIN representation



Raster DEM representation

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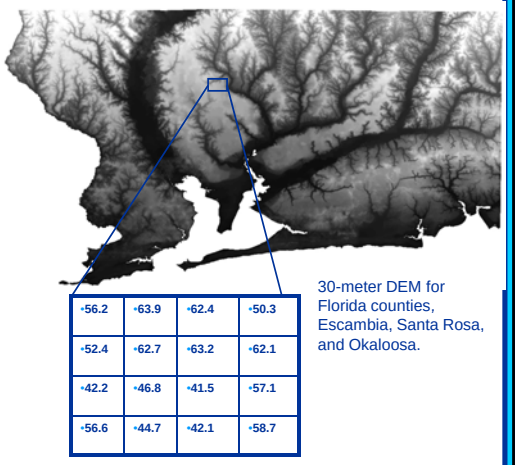
- Digital Elevation Models

- A digital elevation model (DEM) is a model containing elevations at points arranged in a raster data structure where each cell value represents a height or depth value
- DEMs are used in a number of applications, including
  - 3D visualization
  - Watershed delineations
  - Flood modeling and mapping
  - Coastal hazards mapping
  - Shoreline change



30-meter DEM for Florida counties, Escambia, Santa Rosa, and Okaloosa.

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Accuracy: Perfection Is Not An Option

- Accuracy is defined as "the closeness of an estimated value to a standard or accepted (true) value of a particular quantity" (National Digital Elevation Program).
- Horizontal and vertical accuracy is the positional accuracy in relation to a specified horizontal and vertical datum.
- Vertical accuracy is the primary factor for specifying the quality of elevation data.
- Accuracy requirements depend on the intended application; high vertical accuracy is normally required for floodplain management applications.

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Vertical Accuracy

- Multiple ways to express an accuracy standard
- National Standard for Spatial Data Accuracy (NSSDA) is the current standard
- Root Mean Square Error vertical ($RMSE_z$) measurement assumes a normal distribution of errors

NMAS Equivalent Contour Interval	**NMAS** VMAS 90 percent confidence level Max Error Tolerance	**NSSDA** $RMSE_z$	**NSSDA** $Accuracy_z$, 95 percent conformance level
1 ft	0.5 ft	0.30 ft or 9.25 cm	0.60 ft or 18.2 cm
2 ft	1 ft	0.61 ft or 18.5 cm	1.19 ft or 36.3 cm
4 ft	2 ft	1.22 ft or 37.0 cm	2.38 ft or 72.6 cm
5 ft	2.5 ft	1.52 ft or 46.3 cm	2.98 ft or 90.8 cm
10 ft	5 ft	3.04 ft or 92.7 cm	5.96 ft or 1.816 m
20 ft	10 ft	6.08 ft or 1.853 m	11.92 ft or 3.632 m
40 ft	20 ft	12.16 ft or 3.706 m	23.83 ft or 7.264 m
80 ft	40 ft	24.32 ft or 7.412 m	47.66 ft or 14.528 m

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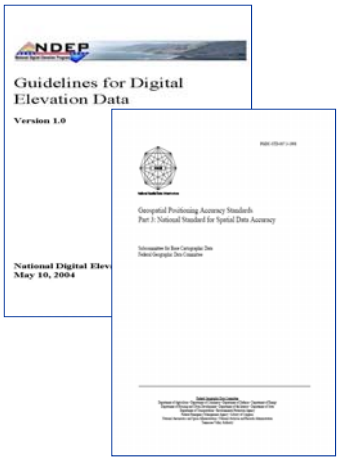
Accuracy Standards and Guidelines

- National Map Accuracy Standards (NMAS)
- National Standard for Spatial Data Accuracy (NSSDA): http://www.fgdc.gov/standards/standards_publications/
- International Hydrographic Association Standards for Hydrographic Surveys: http://www.iho.shom.fr/
- National Digital Elevation Program Guidelines for Digital Elevation Data: http://www.ndep.gov/



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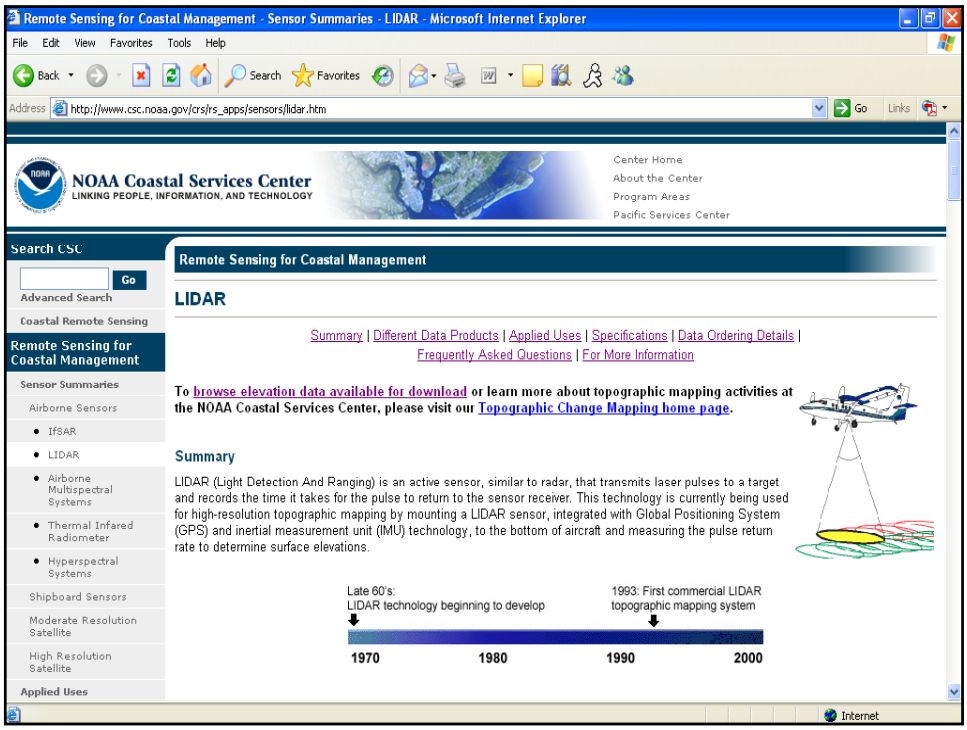
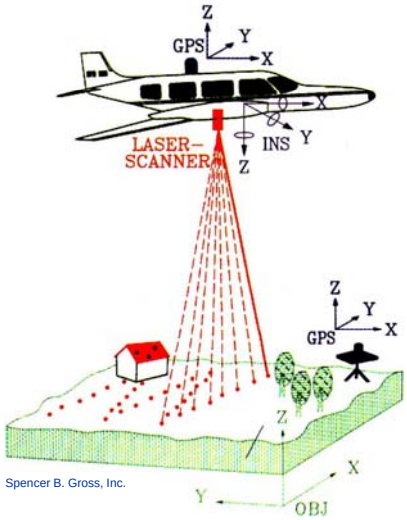


Remote Sensing Topography: LIDAR



Spencer B. Gross, Inc.

- Light Detection and Ranging (LIDAR)
- Usually aircraft platforms
- High vertical accuracy
  $\pm$10 centimeters $RMSE_z$
- Laser measures aircraft-ground distance
- GPS, INS give precise location and orientation of aircraft
- Post-flight, calculate ground elevation

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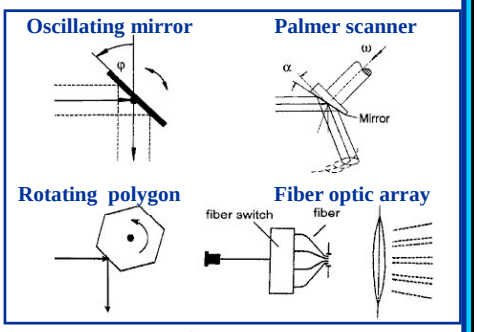
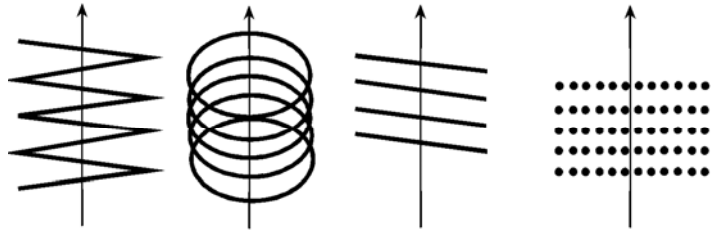
Laser Scanner Patterns

After Wehr, A. and U Lohr, 1999, Airborne laser scanning - an introduction and overview, ISPRS Journal of Photogrammetry and Remote Sensing, 54, 68-82, adapted by the University of Texas at Austin Coastal Studies Group.





Oscillating mirror | Palmer scanner | Rotating polygon | Fiber optic array

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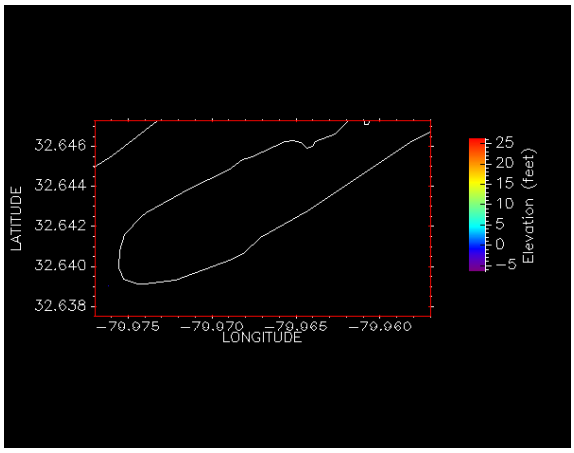
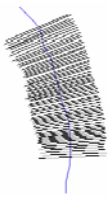
LIDAR Collection Example



- Rotating mirror gives helical scans
- Multiple passes for coverage and data density

Oscillating mirror scanner

Rotating polygon scanner



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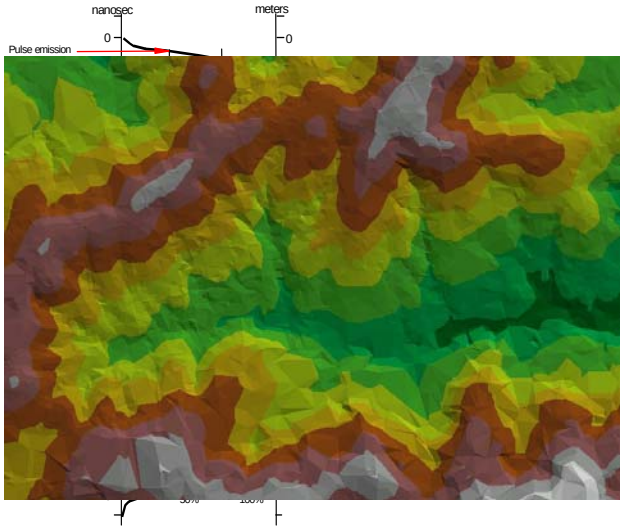
Multiple-Return LIDAR

- Multiple returns from one laser pulse
- Tree, shrub, and ground elevations



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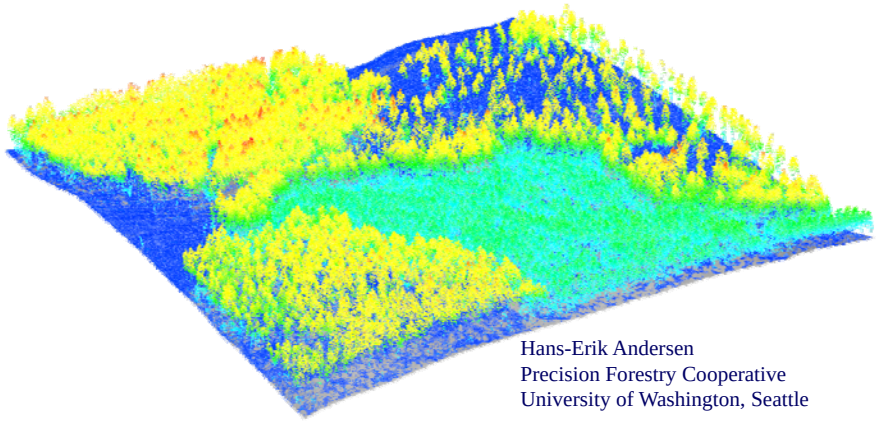
LIDAR-derived
Bare-Earth Surface Model



Hans-Erik Andersen
Precision Forestry Cooperative
University of Washington, Seattle

Steve Reutebuch & Bob McGaughey
USDA Forest Service
PNW Research Station
Seattle, Washington

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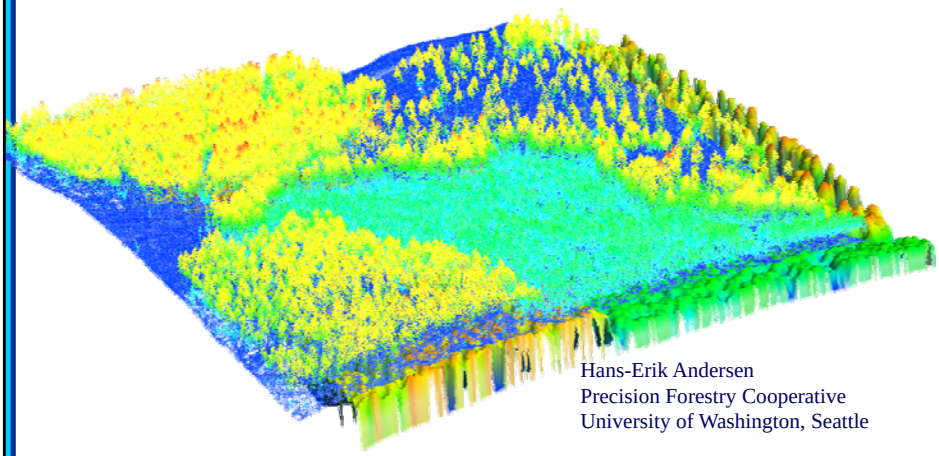
LIDAR-derived
Canopy Surface Model



Hans-Erik Andersen
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University of Washington, Seattle

Steve Reutebuch & Bob McGaughey
USDA Forest Service
PNW Research Station
Seattle, Washington

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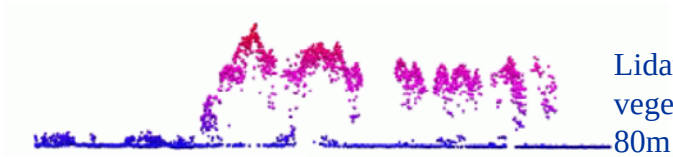
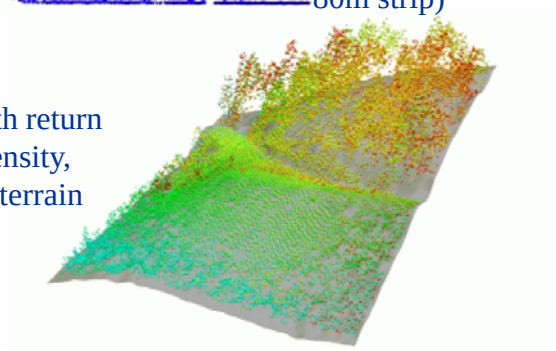
Vegetation in Lidar



Lidar profile through vegetation (4m by 80m strip)



One-hectar area with return data colored by intensity, overlain on shaded terrain model.

From McGaughey and Carson, "Fusing LIDAR Data, Photographs, and Other Data Using 2D and 3D Visualization Techniques", USDA Forest Service

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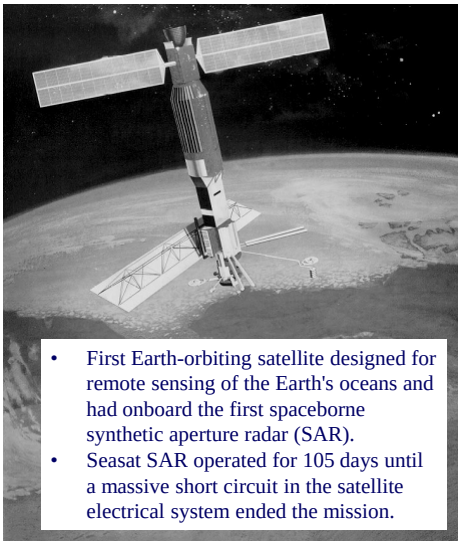
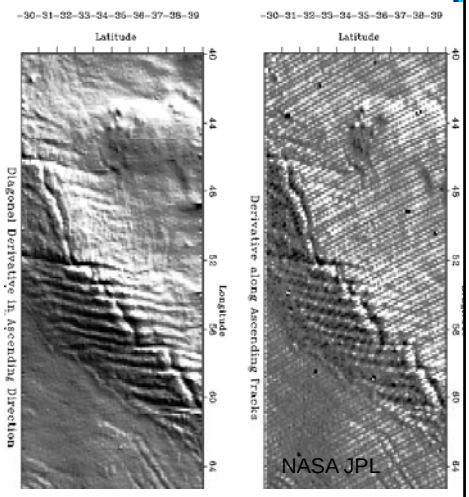
SeaSat



- First Earth-orbiting satellite designed for remote sensing of the Earth's oceans and had onboard the first spaceborne synthetic aperture radar (SAR).
- Seasat SAR operated for 105 days until a massive short circuit in the satellite electrical system ended the mission.



Initial maps of global seafloor topography using SeaSat altimetry, SAR, and ship depth soundings.

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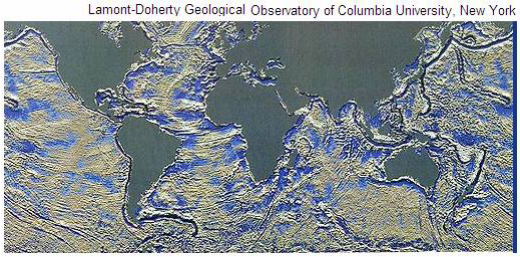
SeaSat

- Maps sea floor spreading
- Supports emerging theory of plate tectonics
- Maps plate boundaries

Lamont-Doherty Geological Observatory of Columbia University, New York



The map shows the morphological features of the ocean floor at a gross scale. These features are largely the mid-ocean ridges, the trenches, and the many transverse faults that emanate from either side of the ridges as the sea floor spreads in both directions away from these ridges.

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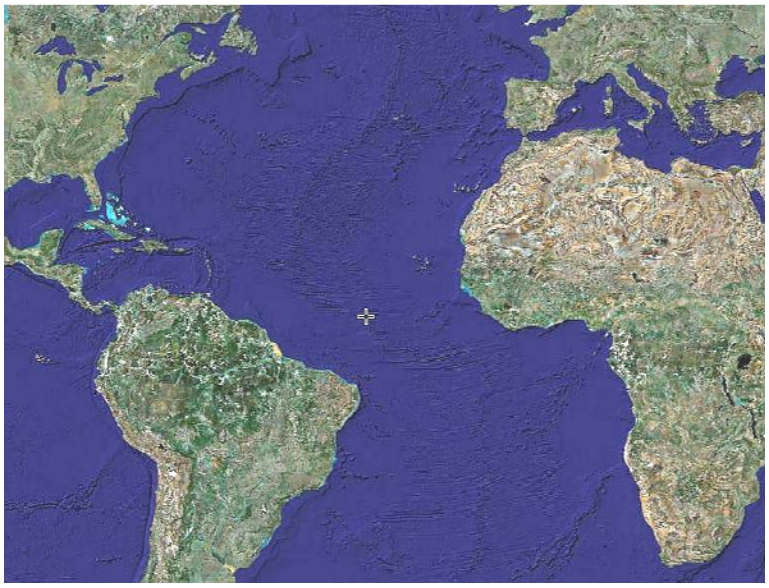
SeaSat



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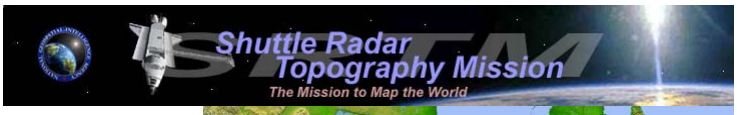
Shuttle Imaging Radar Missions



Shuttle Radar Topography Mission
C-band

The SRTM radar contained two types of antenna panels, C-band and X-band. The near-global 30 meter resolution topographic maps of Earth are made from the C-band radar data

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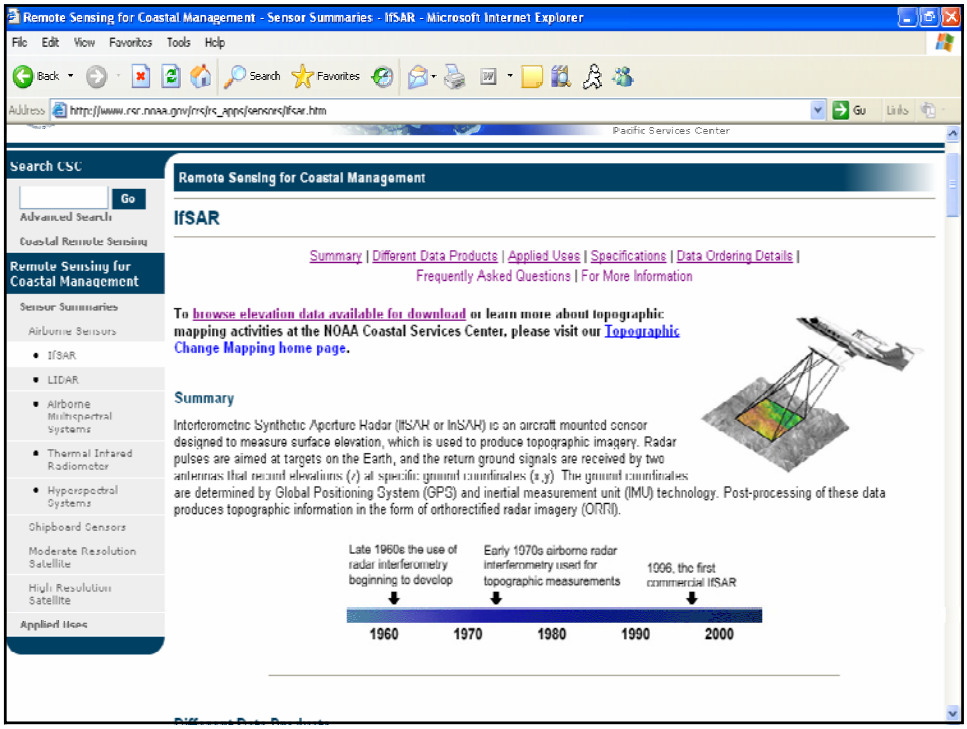
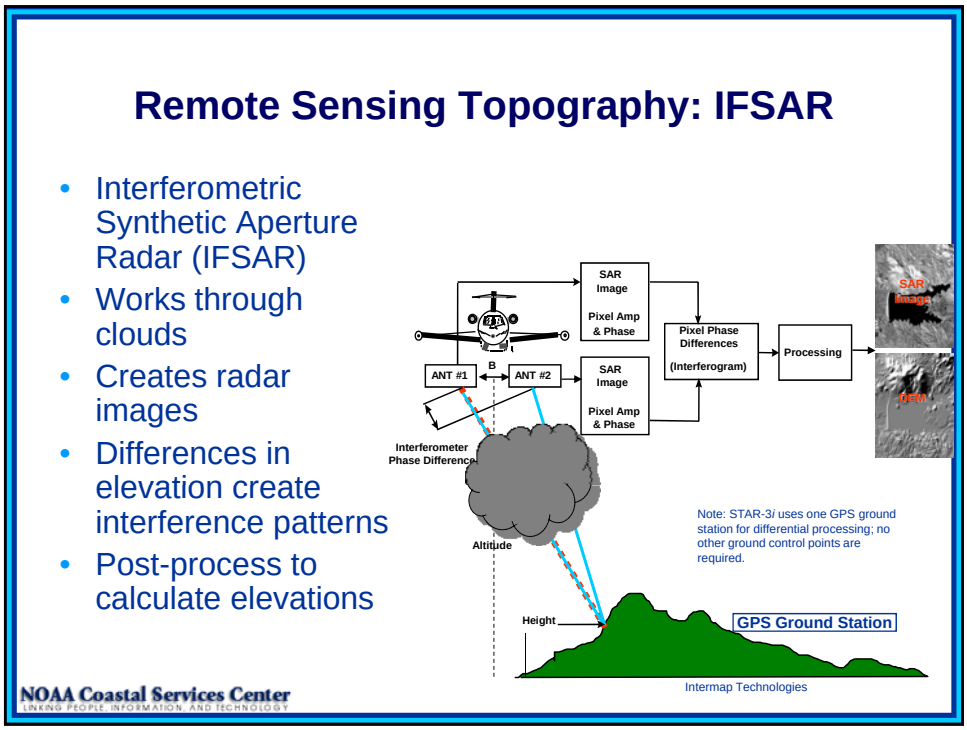

Remote Sensing for Coastal Management - Sensor Summaries - IfSAR - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://www.csc.noaa.gov/crs/rs_apps/sensors/ifsar.htm
Go Links
Pacific Services Center
Search CSC
Go
Advanced Search
Coastal Remote Sensing
Remote Sensing for Coastal Management
Sensor Summaries
Airborne Sensors
IfSAR
LIDAR
Airborne Multispectral Systems
Thermal Infrared Radiometer
Hyperspectral Systems
Shipboard Sensors
Moderate Resolution Satellite
High Resolution Satellite
Applied Uses
Remote Sensing for Coastal Management
IfSAR
Summary | Different Data Products | Applied Uses | Specifications | Data Ordering Details |
Frequently Asked Questions | For More Information
To browse elevation data available for download or learn more about topographic mapping activities at the NOAA Coastal Services Center, please visit our Topographic Change Mapping home page.
Summary
Interferometric Synthetic Aperture Radar (IfSAR or InSAR) is an aircraft mounted sensor designed to measure surface elevation, which is used to produce topographic imagery. Radar pulses are aimed at targets on the Earth, and the return ground signals are received by two antennas that record elevations (z) at specific ground coordinates (x,y). The ground coordinates are determined by Global Positioning System (GPS) and inertial measurement unit (IMU) technology. Post-processing of these data produces topographic information in the form of orthorectified radar imagery (ORRI).
Late 1960s the use of radar interferometry beginning to develop
Early 1970s airborne radar interferometry used for topographic measurements
1996, the first commercial IfSAR
1960
1970
1980
1990
2000


Remote Sensing Topography: IFSAR
Interferometric Synthetic Aperture Radar (IFSAR)
Works through clouds
Creates radar images
Differences in elevation create interference patterns
Post-process to calculate elevations
SAR Image
Pixel Amp & Phase
Pixel Phase Differences
(Interferogram)
Processing
SAR Image
DEM
ANT #1
B
ANT #2
SAR Image
Pixel Amp & Phase
Interferometer Phase Difference
Altitude
Height
Note: STAR-3i uses one GPS ground station for differential processing; no other ground control points are required.
GPS Ground Station
Intermap Technologies
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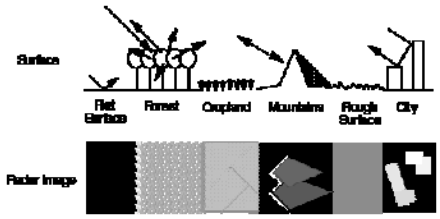

Imaging different types of surface with radar

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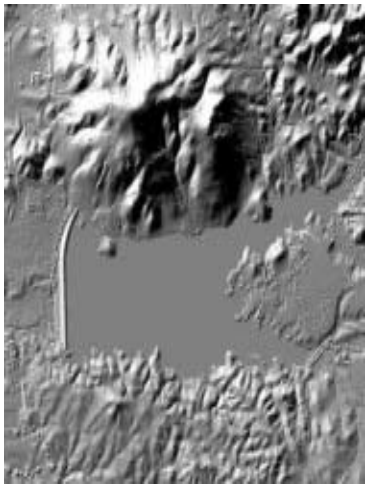
IFSAR Examples

Synthetic Aperture Radar Image

Digital Elevation Model



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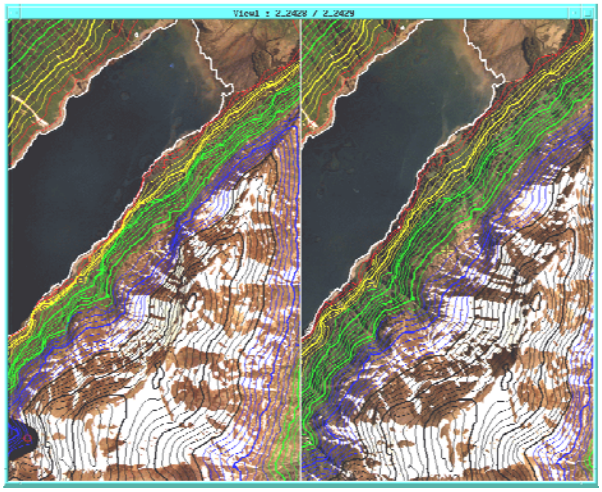
Remote Sensing Topography: Photogrammetry

- Stereo-pair photographs
- Usually from aircraft
- Manually and/or automatically compare to derive elevations



Sadie Cove, Alaska.

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Topography Method Comparison

	Accuracy RMSE	See through clouds?	Night-time acquire?	Vegetation Problems
Air Photo	< 10 cm	No	No	Must see ground from two angles
LIDAR	10 cm	No	Yes	Must see ground from one angle
IfSAR	50 cm	Yes	Yes	P-band can penetrate

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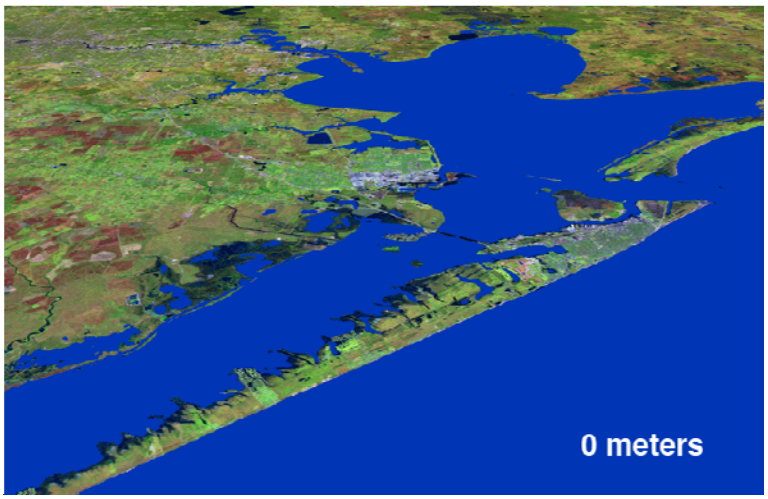
Inundation Modeling

photojournal.jpl.nasa.gov/archive/PIA06674.gif



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Horizontal Resolution

- Needs are application dependent.
- IfSAR is currently about 2.5 meter at best.
- Lidar varies a lot
  - Often 1 or 2 meter spacing between points for flood mapping.
  - Often greater than 4 points per square meter for forestry applications.
  - Laser spot size may be a limiting factor.
  - Multiple flights can be used to increase resolution.

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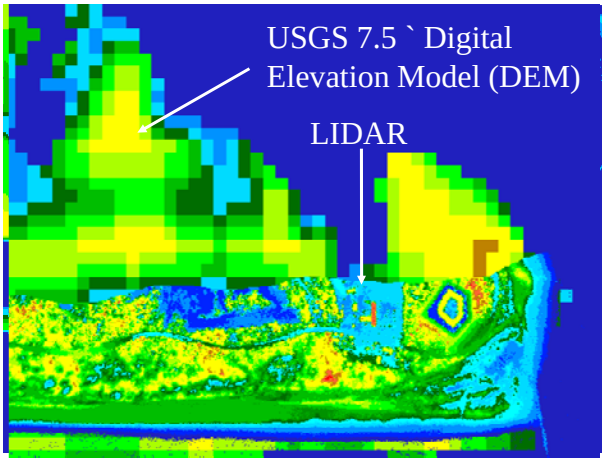
Horizontal Resolution



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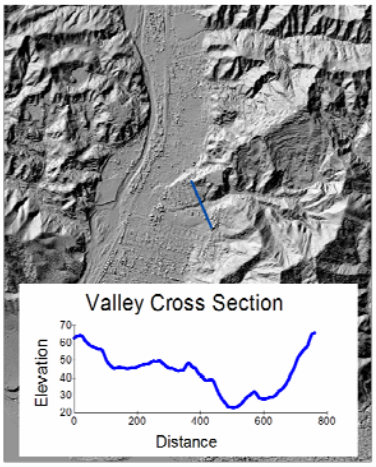
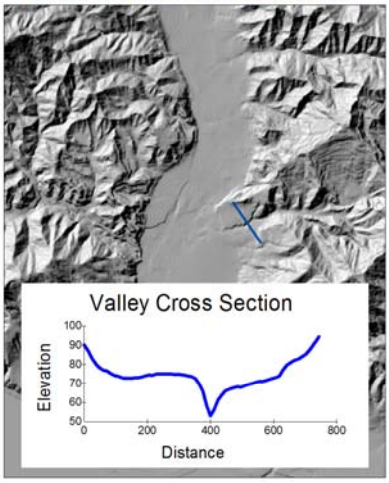
Horizontal Resolution Effects

Entrenchment Calculation with IFSAR



Entrenchment Calculation with USGS 10m DEM



- The entrenchment calculation being applied in Southern California evaluates the width to depth ratio of active channels

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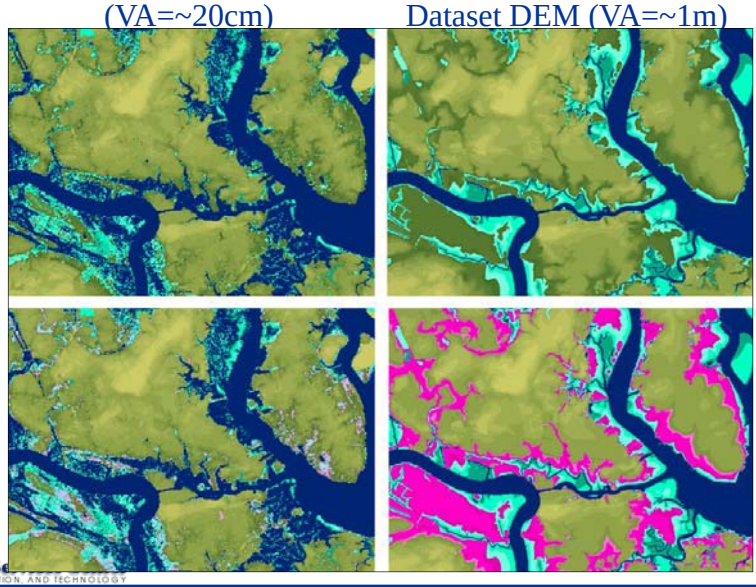
DEM Accuracy and Sea Level Rise Results

3m lidar DEM (VA=~20cm)

10m National Elevation Dataset DEM (VA=~1m)

0.5m Sea Level Rise

0.5m Sea Level Rise + 1 Root Mean Square Error (RMSE)



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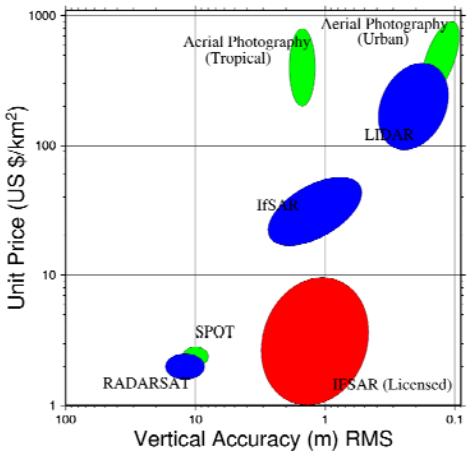
Costs

- Accuracy and resolution determine cost
- As technologies mature, costs decrease
- Data licensing can be an issue



Adapted and updated from Mercer, B.J., Thornton, S., Tennant K. *Operational DEM Production from Airborne Interferometry and from RADARSAT Stereo Technologies*, 1998 ASPRS - RTI Annual Conference.

Note: Graphic for general guidance only.

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Factors Affecting Cost

- Flightline complexity
- Point density or horizontal ground sample distance
- Processing/product requirements (e.g. bare earth)
- Acquisition constraints
  - Specific tide conditions
  - Airspace restrictions
- Weather
  - Areas that are typically cloudy
- Mobilization
- Accuracy requirements

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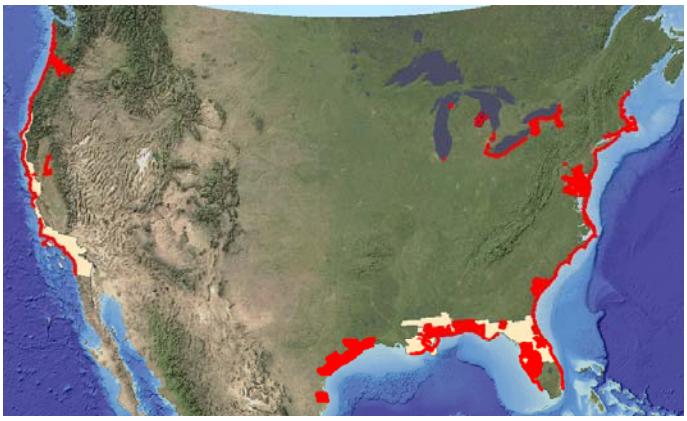
Topographic Data:
Where Is Elevation Data Available for Download?



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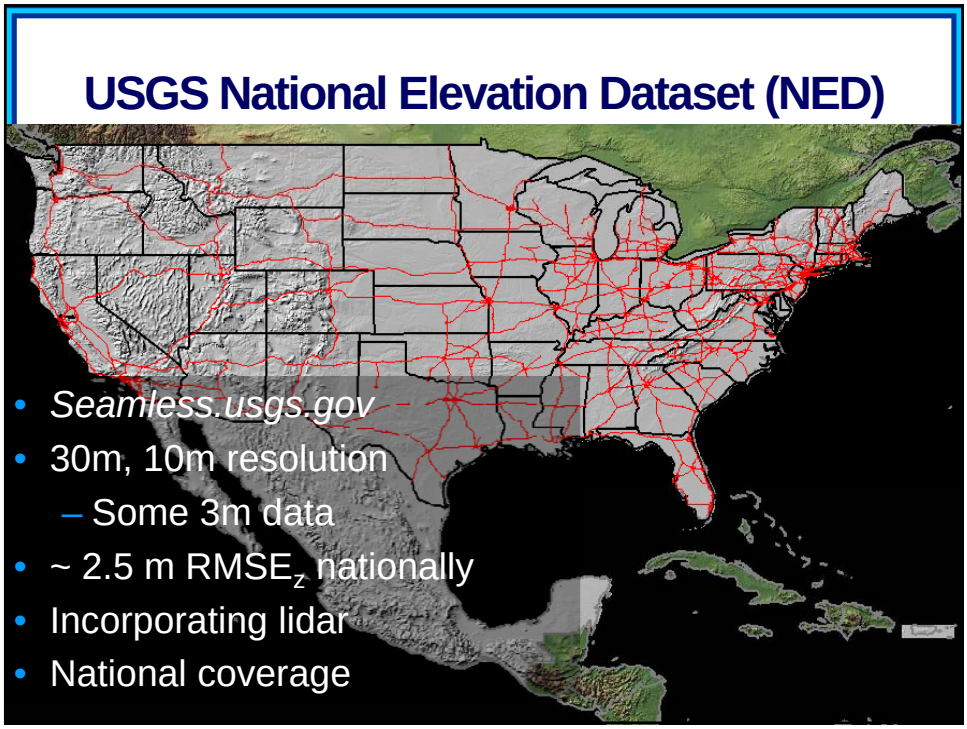
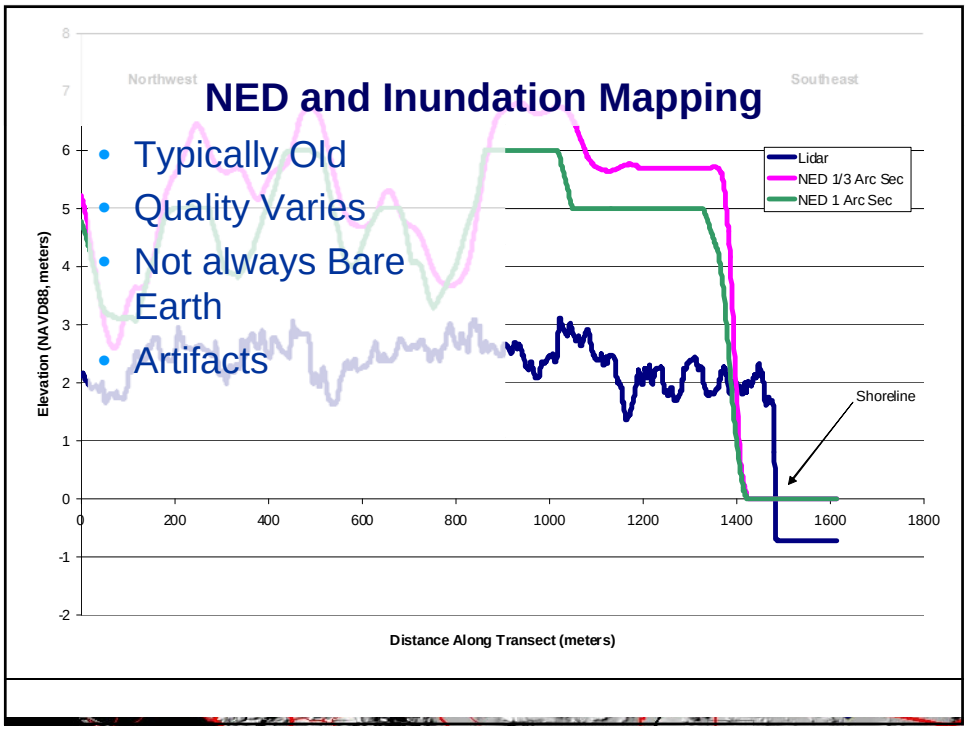
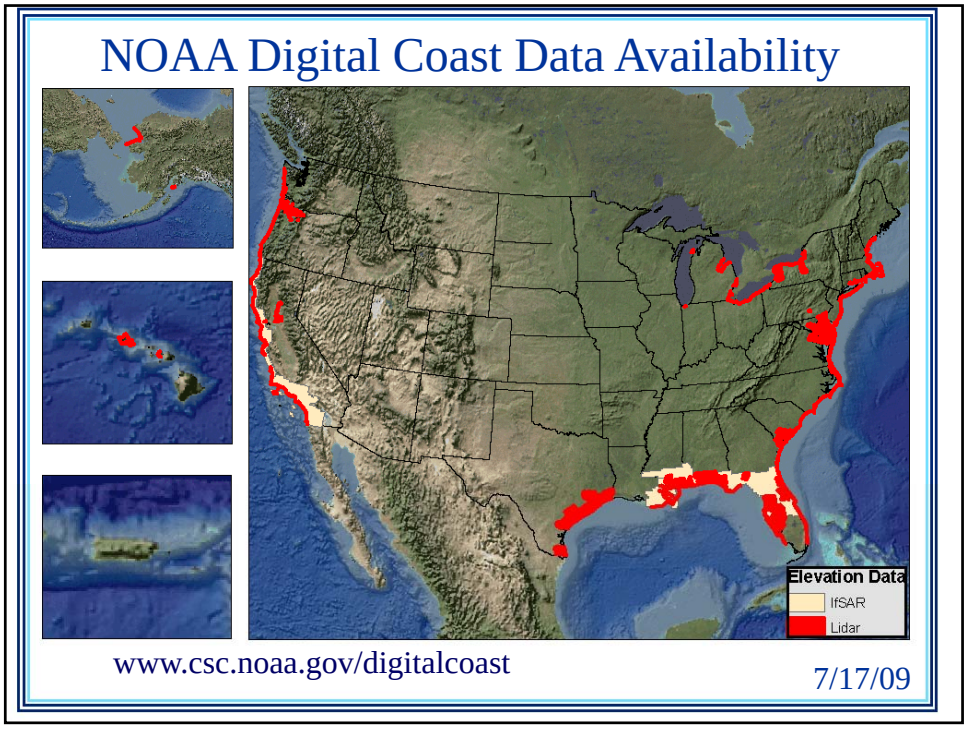
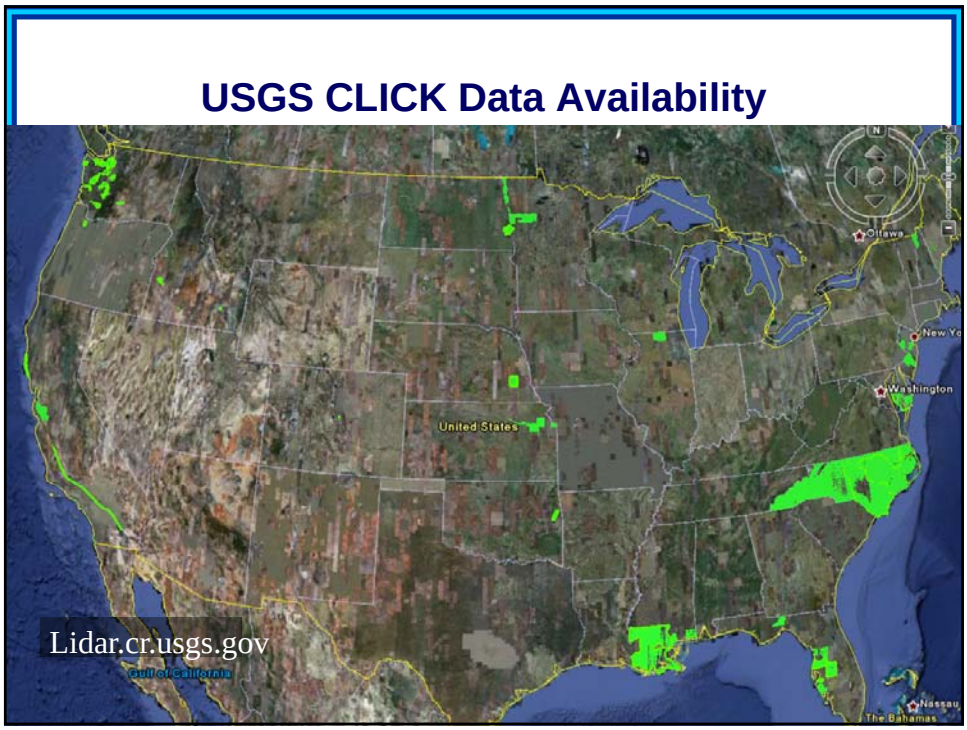
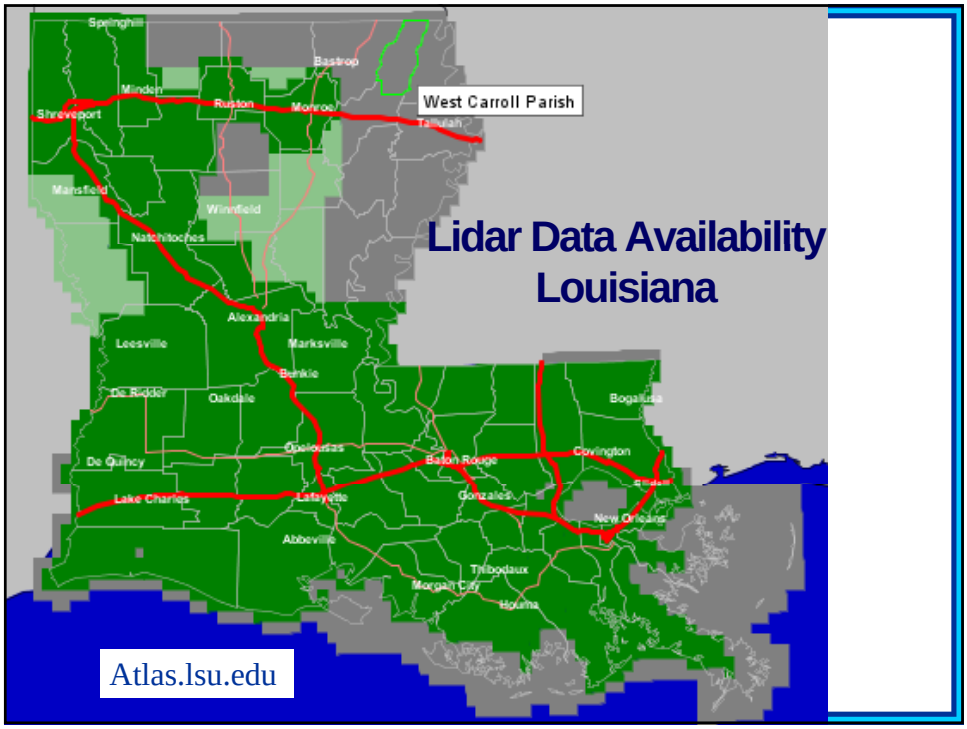

USGS National Elevation Dataset (NED)
Seamless.usgs.gov
30m, 10m resolution
– Some 3m data
~ 2.5 m RMSE$_z$ nationally
Incorporating lidar
National coverage

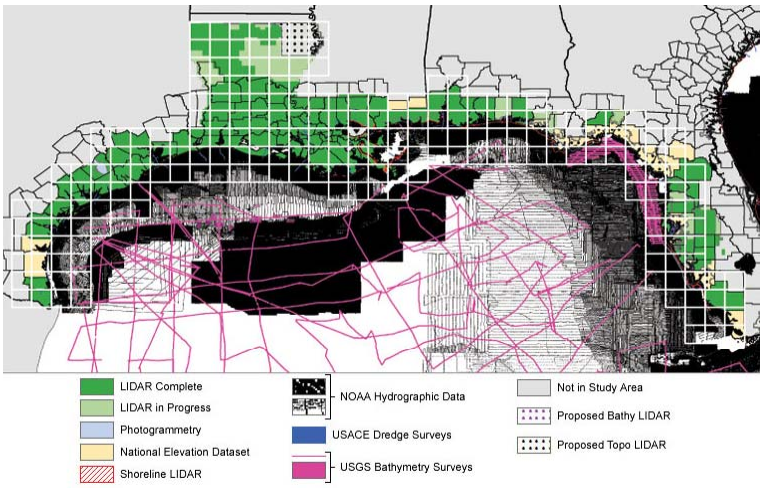

NED and Inundation Mapping
Typically Old
Quality Varies
Not always Bare Earth
Artifacts
Northwest
Southeast
Lidar
NED 1/3 Arc Sec
NED 1 Arc Sec
Shoreline
Elevation (NAVD88, meters)
Distance Along Transect (meters)
8
7
6
5
4
3
2
1
0
-1
-2
0
200
400
600
800
1000
1200
1400
1600
1800


NOAA Digital Coast Data Availability
Elevation Data
IfSAR
Lidar
www.csc.noaa.gov/digitalcoast
7/17/09


USGS CLICK Data Availability
Lidar.cr.usgs.gov
United States
Washington
Ottawa
Nassau
The Bahamas



Topo/Bathy Data Availability



www.csc.noaa.gov/topobathy

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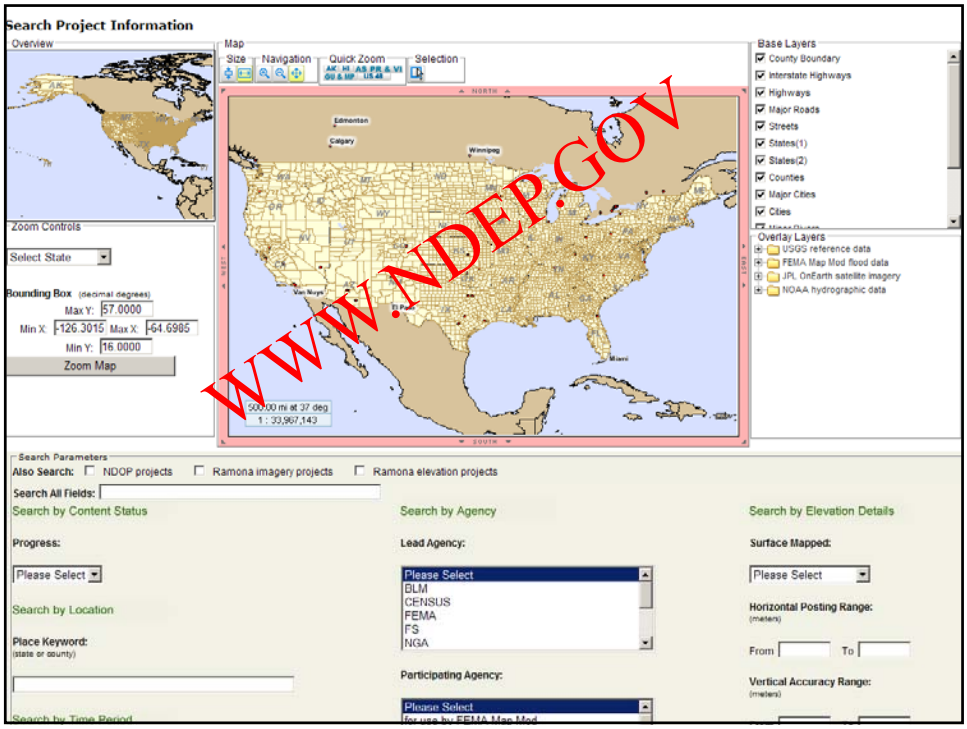
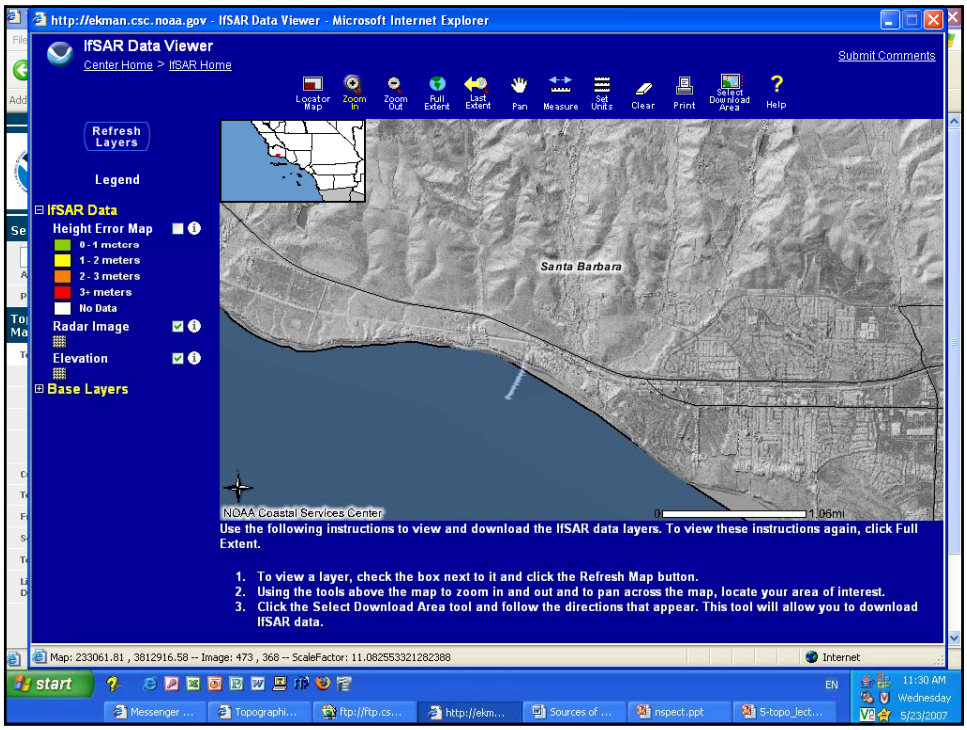

Search Project Information
Overview
Map
Size
Navigation
Quick Zoom
Selection
Base Layers
County Boundary
Interstate Highways
Highways
Major Roads
Streets
States(1)
States(2)
Counties
Major Cities
Cities
Overlay Layers
USGS reference data
FEMA Map Mod flood data
JPL OnEarth satellite imagery
NOAA hydrographic data
Zoom Controls
Select State
Bounding Box (decimal degrees)
Max Y: 57.0000
Min X: -126.3015 Max X: -64.6985
Min Y: 16.0000
Zoom Map
Search Parameters
Also Search: NDOP projects Ramona imagery projects Ramona elevation projects
Search All Fields:
Search by Content Status
Progress:
Please Select
Search by Location
Place Keyword:
Search by Agency
Lead Agency:
Please Select
BLM
CENSUS
FEMA
FS
NGA
Participating Agency:
Please Select
Search by Elevation Details
Surface Mapped:
Please Select
Horizontal Posting Range:
From
To
Vertical Accuracy Range:
WWW.NDEP.GOV


http://ekman.csc.noaa.gov - IfSAR Data Viewer - Microsoft Internet Explorer
IfSAR Data Viewer
Center Home > IfSAR Home
Submit Comments
Locator Map
Zoom In
Zoom Out
Full Extent
Last Extent
Pan
Measure
Set Units
Clear
Print
Select Download Area
Help
Refresh Layers
Legend
IfSAR Data
Height Error Map
0 - 1 meters
1 - 2 meters
2 - 3 meters
3+ meters
No Data
Radar Image
Elevation
Base Layers
Santa Barbara
NOAA Coastal Services Center
1.06mi
Use the following instructions to view and download the IfSAR data layers. To view these instructions again, click Full Extent.
1. To view a layer, check the box next to it and click the Refresh Map button.
2. Using the tools above the map to zoom in and out and to pan across the map, locate your area of interest.
3. Click the Select Download Area tool and follow the directions that appear. This tool will allow you to download IfSAR data.
Map: 233061.81 , 3812916.58 -- Image: 473 , 368 -- ScaleFactor: 11.082553321282388
Internet
start
11:30 AM
Wednesday
5/23/2007

Land cover:

- **NOAA Coastal Change Analysis Product**
- **Multi-Resolution Land Characteristics (MRLC) National Land Cover Database 2001**
- **USGS Land Cover Institute**

Topography:

- **NOAA CSC Topographic Change Mapping**
- **USGS National Elevation Dataset**

Soil:

- **USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database**

R-Factor (rainfall-runoff erosivity factor):

- **USDA NRCS Electronic Field Office Technical Guide (eFOTG)**
- **USDA NRCS National RUSLE2 Database**

Precipitation:

- **Oregon Climate Service PRISM Group**
- **NOAA National Climatic Data Center**

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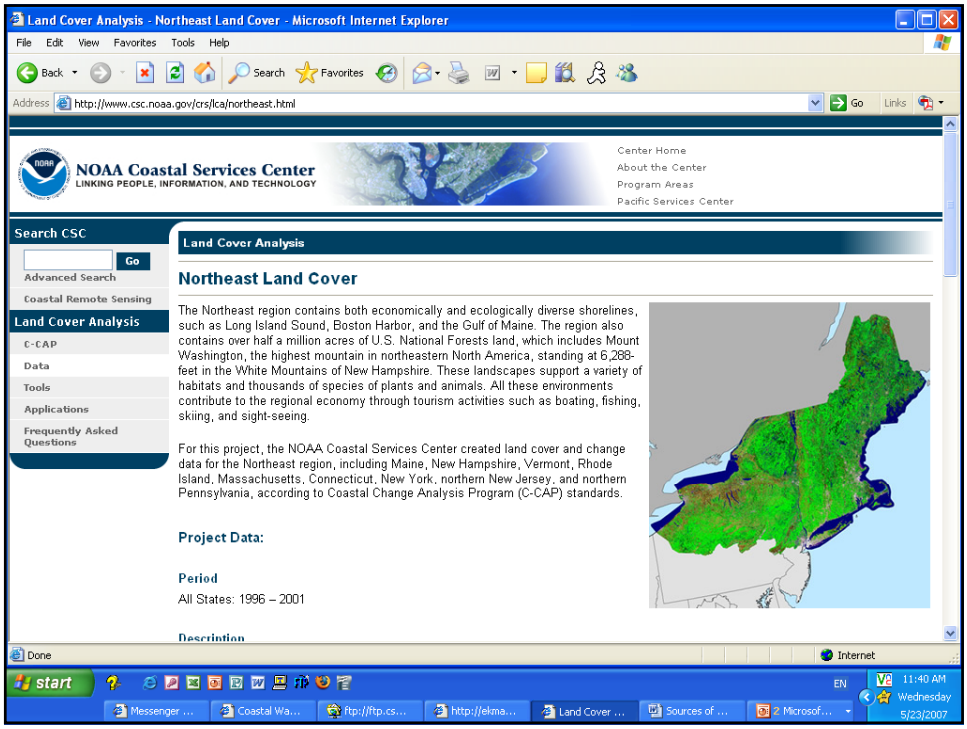
Land Cover Analysis - Northeast Land Cover - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://www.csc.noaa.gov/crs/lca/northeast.html
Go Links
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Coastal Remote Sensing
Land Cover Analysis
C-CAP
Data
Tools
Applications
Frequently Asked Questions
Land Cover Analysis
Northeast Land Cover
The Northeast region contains both economically and ecologically diverse shorelines, such as Long Island Sound, Boston Harbor, and the Gulf of Maine. The region also contains over half a million acres of U.S. National Forests land, which includes Mount Washington, the highest mountain in northeastern North America, standing at 6,288-feet in the White Mountains of New Hampshire. These landscapes support a variety of habitats and thousands of species of plants and animals. All these environments contribute to the regional economy through tourism activities such as boating, fishing, skiing, and sight-seeing.
For this project, the NOAA Coastal Services Center created land cover and change data for the Northeast region, including Maine, New Hampshire, Vermont, Rhode Island, Massachusetts, Connecticut, New York, northern New Jersey, and northern Pennsylvania, according to Coastal Change Analysis Program (C-CAP) standards.
Project Data:
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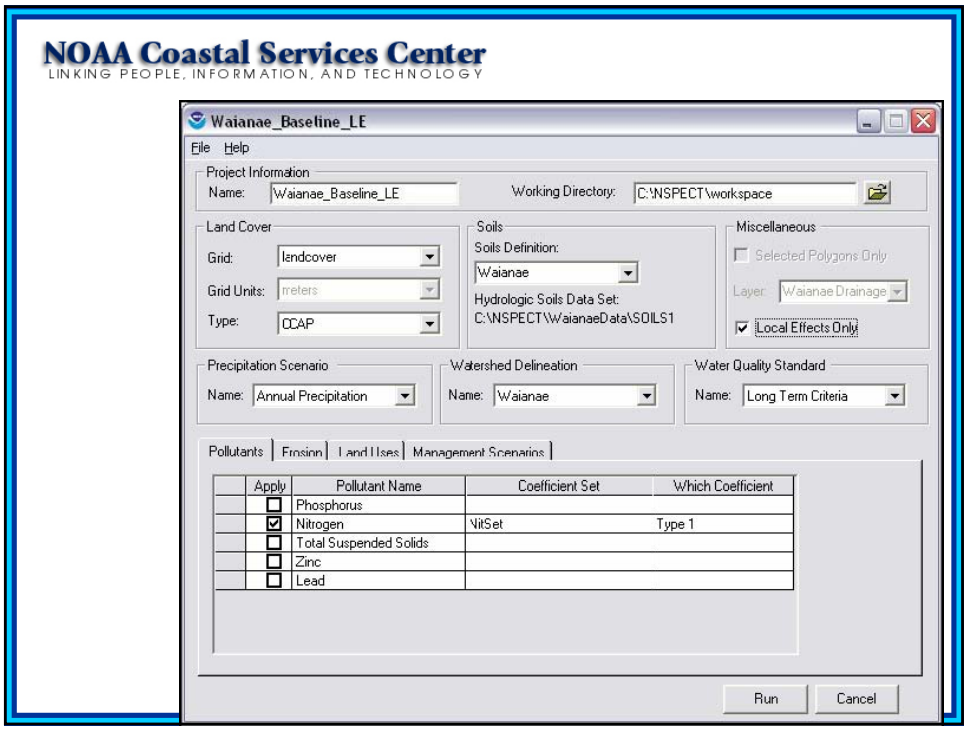
All States: 1996 – 2001
Description
Done
Internet
start
EN
11:40 AM
Wednesday
5/23/2007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Waianae_Baseline_LE
File Help
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Grid Units: meters
Type: CCAP
Soils
Soils Definition:
Waianae
Hydrologic Soils Data Set:
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Miscellaneous
Selected Polygons Only
Layer: Waianae Drainage
Local Effects Only
Precipitation Scenario
Name: Annual Precipitation
Watershed Delineation
Name: Waianae
Water Quality Standard
Name: Long Term Criteria
Pollutants
Erosion
Land Uses
Management Scenarios
Apply
Pollutant Name
Coefficient Set
Which Coefficient
Phosphorus
Nitrogen
NitSet
Type 1
Total Suspended Solids
Zinc
Lead
Run
Cancel

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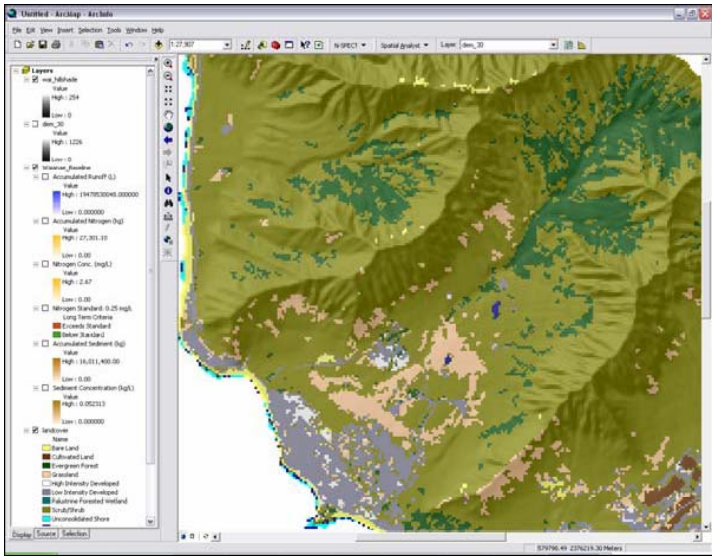

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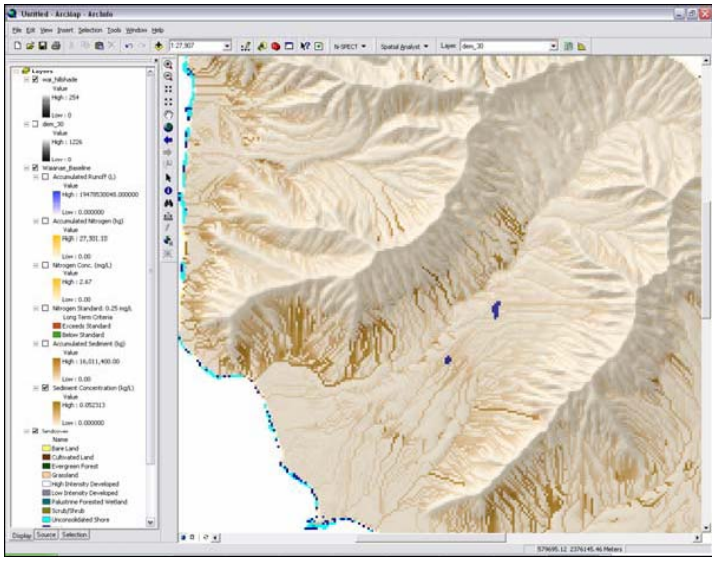

Topography Summary

- There are now more remote sensing options available for topography data with the addition of lidar and IfSAR.
- Consideration must be given to the application requirements before selecting the technology.
- There are many trade-offs between technologies that need to be considered.
  - Accuracy
  - Cost
  - Operating constraints (night/clouds)
  - Horizontal resolution

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Exercise 1: Determining Setback Lines in a Barrier Island Community

Pawley's Island, South Carolina

- County and private citizens built a new dune
- Can it be used as a new baseline?

Dunes which survived Hurricane Bertha were completely lost during Hurricane Fran, resulting in extensive damage on Topsail Beach, North Carolina.

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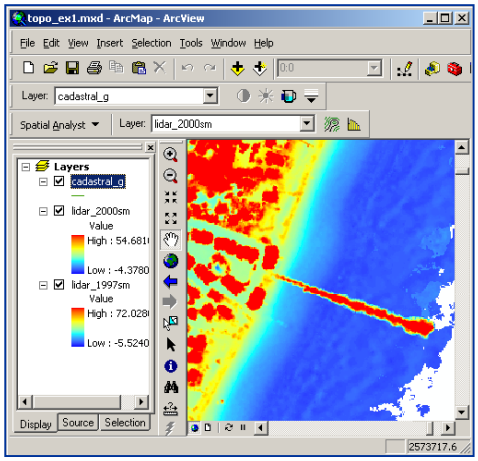
Exercise 1: Determining Setback Lines in a Barrier Island Community

Objectives

- Evaluate data in both raster and vector formats
- Examine the artificially built dune to identify and create the new baseline

Steps

- Examine 1997 and 2000 LIDAR elevation grids
- Identify the primary dune and create a line coverage along its crest



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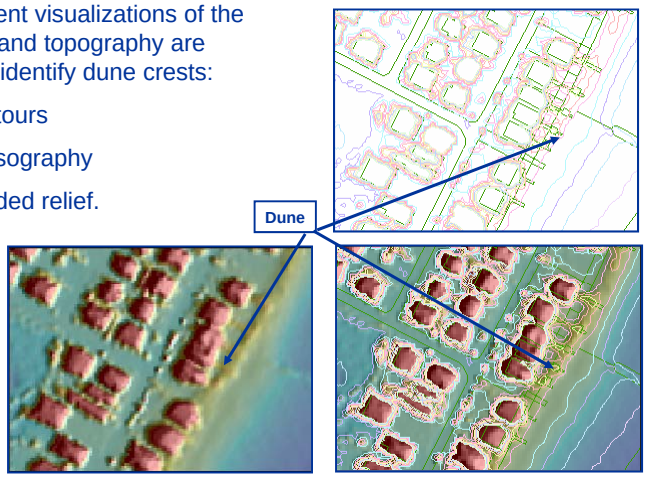
Exercise 1: Determining the Setback Line in a Barrier Island Community

Identify the Dune Crest

Three different visualizations of the Pawley's Island topography are available to identify dune crests:

- contours
- hypsography
- shaded relief.



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Exercise 1: Determining Setback Lines in a Barrier Island Community

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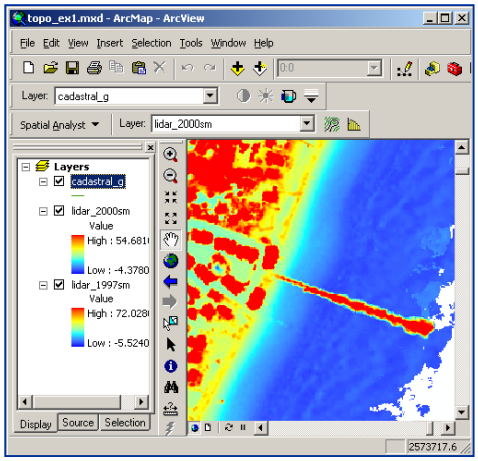

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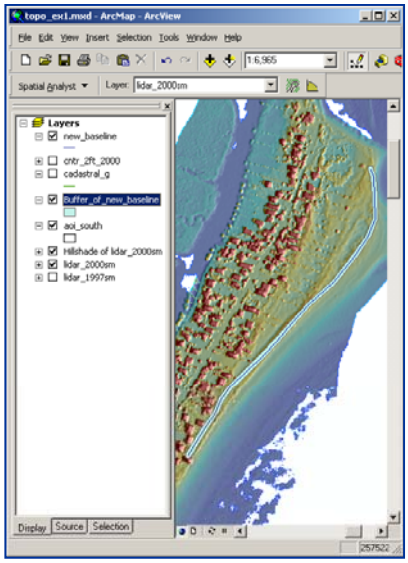
Exercise 1: Summary

- Metadata is required to use projected remote sensing data with other spatial data.
- Grid data can be displayed in several formats that may be useful for identifying features. Several displays can be used simultaneously.
- Should the baseline be moved?



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Exercise 2: Comparing Topography Data for Land Use Decisions

North Carolina

- Multiple datasets are available
- Counties often have permitting rules that require topography
- Apply different datasets and compare the decisions

Undermined house along the Raging River, WA
Photo courtesy of Department of Natural Resources, Kings County, WA

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Exercise 2: Comparing Topography Data for Land Use Decisions

Objective

- Incorporate topography data in a land use management decision

Steps

- Convert units
- Generate raster slope
- Generate raster distance from river
- Determine building suitability

Franklin, County, North Carolina
Photo courtesy of Franklin Area Chamber of Commerce

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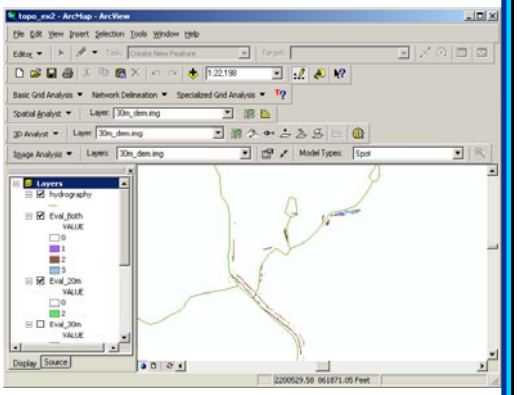
Exercise 2: Summary

- Data resolution and accuracy needs to be appropriate to the question.
- Multiple rasters can often be combined into a single raster with the information intact.



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Exercise 2: Comparing Topography Data for Land-Use Decisions

- Which DEM resulted in the greatest area unavailable for building?
- How much difference existed between the DEMs?
- The resolution of the DEM clearly had an effect on your permitting results. What resolution do you think would be optimal for making this permitting decision?
- Suppose you had three data sets to compare instead of two. What value would you give the “true” for each data set to allow you to separate the results when you added the sets together?

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Course Summary

- Remote sensing provides a unique perspective on environmental features and conditions.
- Choose the sensor and resolution that best fits your needs and budget.
- Remember to consider the decision criteria before committing to a remote sensing project.
- Determine if the benefits from using the data are consistent with the costs.
- Be sure to ask, “Can it help? Can I get it? Can I afford it?”
- Share expertise, expenses, and other resources whenever possible.

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Remote Sensing for Spatial Analysts Evaluation at Survey Monkey

http://www.surveymonkey.com

http://www.surveymonkey.com/s.aspx?sm=1LFHU0L2bcyJtdPP4b35ow_3d_3d

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Is That All There Is?

- We haven't told you everything! The world of remote sensing is very large.
  - Atmospheric studies
  - Hyperspectral
  - Radar (airborne, spaceborne, CODAR, …)
  - Acoustics
  - Magnetic
  - Astronomy
  - Medical (x-ray, MRI, …)
  - Lots of other software (GUI and non-GUI)
  - Other things we've never heard or thought of

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NOAA Coastal Services Center

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Kirk Waters
Kirk.Waters@noaa.gov

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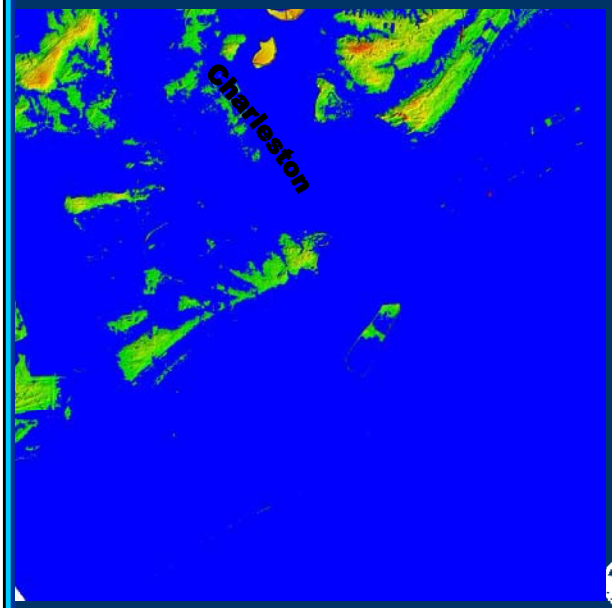
Coastal Planning



- MSL
- MHW
- MHW + 0.6 m
- MHW + 0.8 m
- Hurricane Hugo
- Hugo + 0.8

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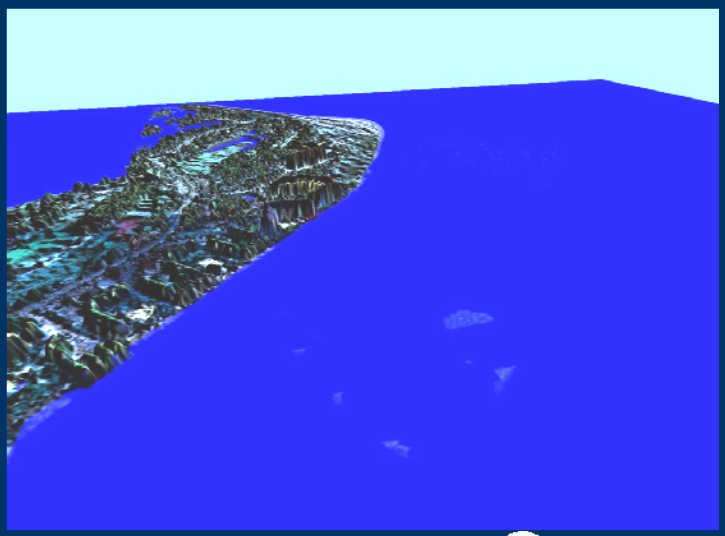
Shoreline Change Visualization



1997

2000

2007

Isle of Palms – Wild Dunes

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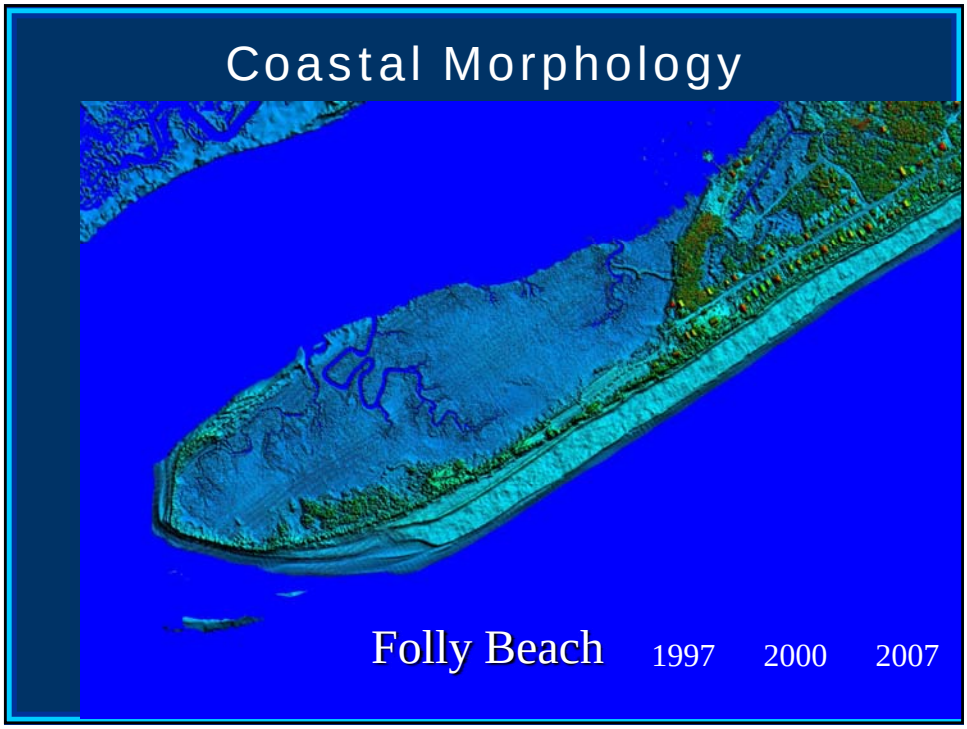
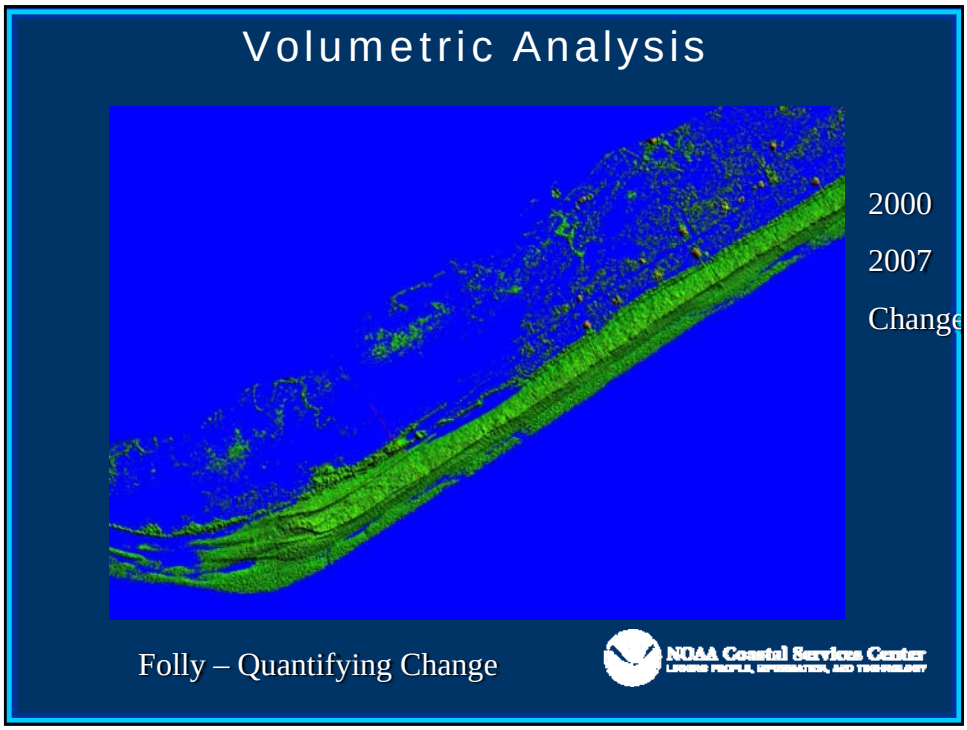

Coastal Morphology
Folly Beach
1997
2000
2007


Volumetric Analysis
2000
2007
Change
Folly – Quantifying Change
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Inundation Modeling

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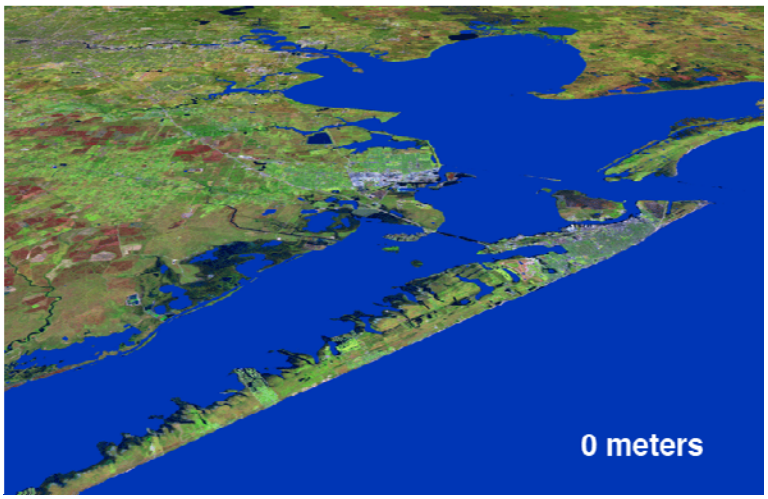

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