Integration of Multi-Source Spatial Information for Coastal Management and Decision Making

Ron Li

Mapping and GIS Laboratory
The Ohio State University
Email: li.282@osu.edu
URL: http://shoreline.eng.ohio-state.edu/research/diggov/DigiGov.html
Project Goal and Objectives

• Goal:
  – Investigate and develop technologies to enhance the operational capabilities of federal, state, and local agencies responsible for coastal management and decision making

• Objectives:
  – Enhance capabilities for handling spatio-temporal coastal databases,
  – Build a fundamental basis of coastal geospatial information for inter-governmental agency operations, and
  – Provide innovative tools for all levels of governmental agencies to increase efficiency and reduce operating costs.
Research Tasks

IKONOS, SAR/INSAR, LIDAR, etc.
- Shoreline and bathymetric mapping, change detection, and coastal DEM generation
- Modeling of coastal terrain and changes, modeling of erosion and environmental changes
- Coastal spatial-temporal modeling: uncertainty and shoreline generalization

GPS Buoy, Satellite Altimetry
- Sea model assimilation
- Modeling of water surface
- Digital shoreline generation from digital CTM and WSM, tide-coordinated shoreline calculation, shoreline prediction

Great Lakes Forecasting System
- Hydrodynamic modeling, hind- and forecasting

Geospatial database, digital models
- Support of government decision making
- Integration with government geospatial databases

ODNR Permitting System

On-Site Mobile Wireless System
- Digital shoreline production and future shoreline prediction

Pilot erosion awareness system

Visualization of spatial and temporal changes, Internet-based visualization of operational results from distributed databases
Multi-source Spatial Data

Multi-Source Data:

- Water gauge data
- Buoy data
- Bathymetric data
- Satellite altimetry data (TOPEX/POSEIDON)
- Hydrological water surfaces (GLFS)
- DEMs derived from high-resolution IKONOS satellite images and aerial photographs
- GPS survey data
Gauge, Altimetry and Bathymetry
Gauge Data


High and low water levels at the tide-gauge stations at Cleveland and Marblehead, Ohio
Water Surfaces

Grid size: 2km

GLFS Hindcast Mean Water Surface 1999-2001
Use Rational functions (RF):

\[ x = \frac{P_1(X, Y, Z)}{P_2(X, Y, Z)} \quad y = \frac{P_3(X, Y, Z)}{P_4(X, Y, Z)} \]

The following two methods are used to improve the RF accuracy:

- Refine the RF coefficients using ground control points
- Transfer the derived coordinates from the vendor-provided RF coefficients using ground control points
DEM Generated from IKONOS Stereo Images

3D Shoreline Extracted from IKONOS Stereo Images
Coastal Terrain Model

- **Generation Process**
  - Bathymetry Data (NOAA)
  - DEMs: USGS DEM, IKONOS DEM, and Aerial Photo DEM
  - Datum: NAVD 88
10 year water level variation comparison
(GLFS water surface and T/P Altimetry)

Water Level Comparison between GLFS Water Surface and Altimetry (Long Track)
Digital Shoreline

IKONOS Orthophoto Shoreline and the Digital Shoreline from IKONOS CTM/MW Surface

Legend
- Digital Shoreline from IKONOS CTM/MW Surface
- Shoreline from IKONOS Orthophoto

[Diagram showing comparison between digital and orthophoto shoreline]
Shoreline Erosion Awareness System

Painesville Shoreline Erosion Awareness System
Collaboration with Lake County Planning Commission, OH
ODNR Coastal Structure Permit System
Integrating Wireless Technology, Internet-based GIS, and Spatial Data

Lake Erie

GPS  Satellite

PDA  Cellular Phone

On-site Mobile Spatial Subsystem

Server

Shoreline Erosion Awareness Subsystem

Internet

Coastal Structure Permit Subsystem

Computer

Computer
Seagrasses (Greening, 2000; Johansson, 2000)
- Maintain water clarity by trapping fine sediments and particles with their leaves;
- Provide shelter for many fishes, crustaceans, and shellfish;
- Provide food for many marine animals and water birds;
- Reduce the impact from waves and currents; and
- Is an integral component of shallow water nutrient cycling process.

In Tampa Bay, turtle grass and shoal grass are dominant, and widgeon grass, manatee grass, and star grass are also found.

Turtle grass  Shoal grass  Manatee grass
Historical Background

Facts about seagrass coverage in Tampa Bay, FL (Johansson, 2000):
• In late 1800s, approximately 31,000 ha of seagrass were present in Tampa Bay
• In 1950, 16,500 ha seagrass coverage, about 50% losses.
• In 1982, 8,800 ha seagrass coverage, more than 70% losses of the historical seagrass coverage.
Causes of Seagrass Loss

Reasons of seagrass losses:
• Excessive loading of nutrients from the watershed, or eutrophication (Greening, 2004)
• Population growth of the bay area and increase in commercial activities (Johansson, 2000);
• Various dredging operations and shoreline developments (1950s – 1970s). Increase turbidity of water column and sediment deposition on the meadows (Johansson, 2000).

Factors influencing seagrass growth:
• Water quality (Janicki and Wade, 1996)
  – Nitrogen
  – Chlorophyll
  – Turbidity
• Light attenuation (Janicki Environmental, Inc., 1996)
• Water depth (Fonseca et al., 2002)
• Wave effect (Fonseca et al., 2002)
• Offshore sandbar (Fonseca et al., 2002)
Related Physical Factors

• **Water depth**
  – Bathymetry (SHOALS)
  – Water level (Gauge stations)
  – Coastal changes (shoreline positions)

• **Offshore sandbar**
  – Bathymetry
  – Hydrodynamic variables (wave, current)

• **Wave and current effects**
  – Water level
  – Hydrodynamic variables (wave, current, temperature,...)

• **Spatial distribution of seagrass**
  – Patchy or Continuous
  – Seagrass mapping (High-resolution satellite imagery)
• High-resolution seagrass mapping and 3D shoreline change detection
  – QuickBird Imagery
    • Sub-meter stereo panchromatic imagery
    • 2.5 m stereo multispectral imagery
  – IKONOS Imagery
    • One-meter stereo panchromatic imagery

• Observe seagrass changes and temporal patterns
Integration of physical modeling and bioinformatics

• Advantages of physical modeling
  – Detailed coverage information in seagrass mapping and monitoring based on high-resolution satellite imagery
  – Quantitative numerical hydrodynamic modeling of wave and current effects on seagrass degradation and restoration
  – Highly-accurate physical environment change monitoring based on three-dimensional satellite imagery and GPS
  – Highly-accurate bathymetry with SHOALS technology
  – Integration of physical monitoring and modeling capabilities and ecological factors

• Collaborators
  – Keith Bedford (hydrodynamic modeling, OSU)
  – Holy Greening (Tampa Bay Estuary Program)
  – Mark Luther (Ocean Modeling and Prediction, USF)
  – NOAA and USGS
Research Plan

Analysis of spatial distribution patterns of seagrass and environment
- Spatial locations of seagrass coverage: Patchy and Continuous
- Water quality
- Bathymetry
- Water surface and current modeling
- Shoreline changes

Prediction
- Very fine analysis and modeling of a small area
- Extension of the result to the entire bay