Analysis and dynamic monitoring of marine environment and coasts with modern remote sensing methods

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Publication Date:
2003

Permanent Link:
https://doi.org/10.3929/ethz-a-004660743

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Analysis and dynamic monitoring of marine environment and coasts with modern Remote Sensing methods

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Introduction, Remote Sensing

Definition of Remote Sensing

- Feeling without touching
- Remote Sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analysing and applying that information.

Advantages of Remote Sensing

- Coverage of large areas
- Repetitive coverage
- Variety of platforms and sensors, covering a large range of the electromagnetic spectrum
- Dense and accurate measurements possible
- Speed of information delivery
- Costs
Existing platforms and sensors

Platforms

- Satellites, 250 - 850 km flying height, > 100 platforms
- Airplanes, deployment flexibility, control of imaging conditions
- Helicopters, easy landing, maneuverability
- Other

Sensors (various regions of electromagnetic spectrum)

- Visible range, 0.40 - 0.70 micrometers
- Infrared (near, middle, thermal), 0.7 to 13 micrometers
- Microwaves, 1cm to 1 m

Sensors (types)

- Cameras / detectors - panchromatic, multispectral, hyperspectral
- Radar (SAR) - multi-frequency, multi-polarimetric
- Laser (Lidar)
Existing platforms and sensors

**Sensors (type of illumination)**
- Passive (sun illumination needed)
- Active (radar, laser): function day and night, radar weather independent

**Important trends**
- Multiple sensors on same platform -> sensor fusion
- Use of GPS and INS for navigation, sensor positioning (-> geocoding)

**Most sensors digital. Exceptions:**
- Aerial film imagery
- Very few satellite cameras (Russian)
Existing platforms and sensors

Resolution

- Spatial (geometric): many definitions, often ground pixel size difference to geometric accuracy and image quality
- Spectral: number of bands and band characteristics (band center and width)
- Temporal (satellites): how often the same region can be imaged
- Radiometric: (number of bits per pixel)
Basic methods and products

- Preprocessing (image improvement)
- Determination of sensor internal geometry, position and attitude
- Generation of Digital Terrain / Surface Models
- Transformation of images to a local map coordinate system
  - geocoding, orthophoto generation
    - with or without Ground Control Points
    - with or without Digital Terrain Models
- Interpretation and measurement of objects and their properties
- Production of maps:
  - topographic or orthophotomaps and thematic (land use / land cover)
- Visualisation, animation

Often analysis of data within a GIS in combination with other data
- decision support, realisation of different scenaria
New airborne digital sensors - example ADS40 (Leica)

- Use of linear CCDs (other systems (DMC, UltraCam) use area CCDs)

**Panchromatic and spectral band filters**
High resolution satellite imagery - Ikonos

Nisyros volcanic island, Greece - EU project Geowarn
Distribution of Ground Control Points (GPS)
High resolution satellite imagery - Ikonos

Nisyros volcanic island, Greece - variable definition quality of GCPs
High resolution satellite imagery - Ikonos

Nisyros volcanic island, Greece - Pansharpened image
High resolution satellite imagery - Ikonos

Nisyros volcanic island, Greece - Orthophoto map
High resolution satellite imagery - Ikonos

Differential SAR interferometry - change of surface (University of Athens)
High resolution satellite imagery - Ikonos

- Movie - Orthophoto and DTM
Optical Imagery - Multitemporal Changes

ï Aral Sea in 1973, 1987 and 2000 (from right to left)
Radar - vertical subsidence

- Example from Venice (firm Gamma RS, CH) - Radar interferometry
- Subsidence in mm/year
Radar - vertical subsidence

Example from Venice (firm Gamma RS, CH) - Validation
Hyperspectral imaging - Imaging Spectroscopy

Imaging Spectroscopy: The Data Cube Principle
Hyperspectral imaging - Imaging Spectroscopy
Hyperspectral imaging - Imaging Spectroscopy

Unambiguous Identification of Spectral Diversity

- Kaolinite
- Dolomite
- Hematite

Reflectance [scaled from 0-1]

Wavelength [nm]

- Kaolinite Absorption Feature
- Hematite Absorption Feature
- Dolomite Absorption Feature
Laser Principles

- Scanning pattern (Toposys)
Laser Principles

- Multiple reflections and registered echoes for one single laser pulse
- Important especially for measuring terrain and deriving vegetation-related parameters
Laser Principles

- Registration of intensity possible, but quality worse than that of cameras
Laser combination with Cameras

Example of firm Geolas, Germany
Laser Measurement

- Digital Surface Model versus Digital Terrain Model
- Using filtering techniques objects on terrain (trees, buildings etc.) can be removed automatically
Laser Applications - Tidal Flats

- 10 x 9 km, 3 h night flight, 2m elevation range, 5m grid spacing (Geolas)
Laser Applications - Coastal Erosion

Sylt, North Sea, yearly laser surveys (firm Toposys, Germany) and sonar
Bathymetry

- High resolution digital multibeam sonar system
- USGS Pacific Seafloor Mapping Project (data from 1996, 98, 99)
Bathymetric Lidar

Principle (double wavelength: near InfraRed and green)
Bathymetric Lidar

**Principle (double wavelength: near InfraRed and green)**

- Detection of depths up to ca. 40-50 m
- Depends on water turbidity (detection of depths up to 2-3 times Secchi depth)
Bathymetric Lidar

*Optech, bathymetric laser, effect of boats (see two peaks on the left; on the right data after postprocessing)*
Laser Applications - Sea Bottom Objects

Bathymetric values; on the right a zoom; object shown on next slide.
Laser Applications - Sea Bottom Objects

- Left: sunken ship (see also previous slide), firm Optech (Canada)
- Right: laser system Hawkeye (Sweden), ship 3m below sea level
Laser Applications - Coastal and Sea Mapping

ï Optech, Perdido (CA)
ï Simultaneous surveying of water, coast and land
Bathymetric Lidar

*Shoals system (USA), Yucatan, 90 million points, coral reefs, navigation charts*
Bathymetric Lidar

Shoals, Yucatan, 3D visualisation
Bathymetric Lidar

Shoals, Solander, NZ, sanctuary, safe navigation
Water clarity and Secchi depth
Application example

Water clarity from Landsat TM sensor
Application example

Top:
Model relating Secchi depth (water clarity) to values of Thematic Mapper (TM) channels 1 and 3

\[ \ln(\text{Secchi}) = b_0 + b_1 \frac{TM_1}{TM_3} \]

Bottom:
Relation (correlation) between observed and predicted (using the above model) values
Application example

Water clarity before (left) and after (right) postprocessing
Wetlands/Biotopes - Salt marshes in Mesopotamia

*Landsat*; *Multitemporal changes 1973-76 (MSS) to 2000 (ETM+)*, reduction to 15% of originally 20,000 sqkm
Multitemporal changes

- Shuttle hand-held photography
- North Sinai Agricultural Development
Multitemporal changes  *(Aster on Terra (USA), data gratis, Cyprus)*
Multitemporal changes  *(Aster on Terra (USA), data gratis, Cyprus)*

Data set: ASTER L1B REGISTERED RADIANCE AT THE SENSOR V003
Granule: SC:AST_L1B_003:2003209333
Local granule ID: AST_L1B#003_05312001084313_06082001032130.hdf
Center lat/lon: 34.87° Lat, 33.42° Lon
Waves (surface)

- Bay of Bengal, ASTER sensor
- Right half: colliding opposing waves
Waves (internal)

- Space Shuttle
- Diurnal tidal flow, highlighted by sun glint
Oil slicks and waves

- Space Shuttle, SIR-C/X-SAR, Arabean Sea

- Drilling platforms (bright), oil slicks (mostly in wind direction)

- Internal waves (upper center; interface of warm and cold water)

- Wind waves
Oil slicks

- ERS-SAR (ESA)
- Prestige (bottom left)
- Galicia, Spain
- 15,000 tons / day
Oil slicks

- Radarsat (Canada)
- Galicia, Spain
- 21 Nov. 2002
Oil slicks

ï Ikonos (USA)

ï Galicia, Spain

ï 21 Nov. 2002

ï Optical imagery is compared to SAR less suitable for oil slick detection and obstructed by clouds
Oil slicks

SIR-C/X-SAR, North Sea, Germany
Experiment, distinguish petroleum (2) and natural oil (6) slicks (60 - 400 liters)
Eddies

ï Topex / Poseidon, Gulf of Alaska, 2000
ï Warm eddies, higher than water around
Sea surface temperature (global)

- TRMM satellite, TRMM Microwave Imager (Nasa/Nasda)
- Relation of surface temperature and hurricane intensity (water cooling after the hurricane pass)
Sea surface topography (global)

- Topex / Poseidon (USA / France), 1336 km

- Accuracy of 4-5 cm, global mean sea level accuracy of several mm
Sea surface temperature and vegetation (global)

- 1983 El Nino, 1989 La Nina (compare vegetation in Australia, Brazil etc. for these two events)
Wind measurement (global)

- Quickscat, Hawaii (USA)
- Reduction of wind speed west of the islands, start of current thousands of km long, reaching to Asia
Algae / Phytoplankton - Chlorophyll A

- Orbview-2 satellite, SeaWIFS sensor (USA)
- EU project, monitoring of spring phytoplankton bloom
- Part of the algae harmful, killing fishes -> need of field measurements
Lake Water Quality and Clarity Analysis

- Eagan, Minnesota (USA), Ikonos
- Water clarity decreases from blue to red
- Water quality estimation: Blue/Red high when water has high quality
Water turbidity and mixing

SeaWifs, Azov Sea, 10/2/2002
MAMA EU Project

- Mediterranean network to Assess and upgrade the Monitoring and forecasting Activity in the region
- New high-resolution sensor for SeaSurfaceTemperature, AMSR (NASDA) on Aqua (May 2002) -> clouds are transparent
- Assessment of 37 variables of user interest. More accurate info on:
  - water temperature, phytoplankton biomass
  - sea level, surface waves, changes of coastline position
- Available NearRealTime data for Mediterranean (temperature, wind, chlorophyll, height)
The role of carbon on life on Earth

- SeaWifs on Orbview - 2
- Chlorophyll in oceans, vegetation on land
Multi-Angular Sensors (example MISR, NASA)

- 9 cameras: 1 nadir, 4 backward, 4 forward
- Each camera has 4 spectral channels (B, G, R, NIR)
Multi-Angular Sensors (example MISR)

- Nadir (right, true color and NIR), 60 deg red (left)
- Left: better discrimination of wetlands -> role of view angle
Multi-Angular Sensors (example MISR)

- Everglades, Florida
- Left: true color, nadir. Right: red channel, 46° Backward (Red), Nadir (Green) and 46° Forward (Blue) -> Blue = surface water
Existing problems

- Suitability, availability, delivery speed (some needed in NRT) and cost of data

- Different maturity of processing methods from
  - standard/fully operational to research / locally valid
  - sometimes intensive and complicated processing

- Long-term establishment of appropriate state/private etc. organisations and respective infrastructure for collection, processing and dissemination of information on marine environment and coastal regions
Conclusions

- Remote Sensing is a powerful observation tool for both marine and coastal regions

- Selection of data and processing methods need to be considered carefully

- Combination with other data / information, including terrestrial methods, necessary

- Observation of these regions should be integrated within a national framework of spatial data acquisition, management and analysis