Airborne Hyperspectral Imaging of Oil Spills and Oil Impacted Areas

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Outline

- Introduction
- Purpose of this study
- Hyperspectral Imaging
- Sites & Data Collection
- Classification Methods
- Detection Results
- Summary

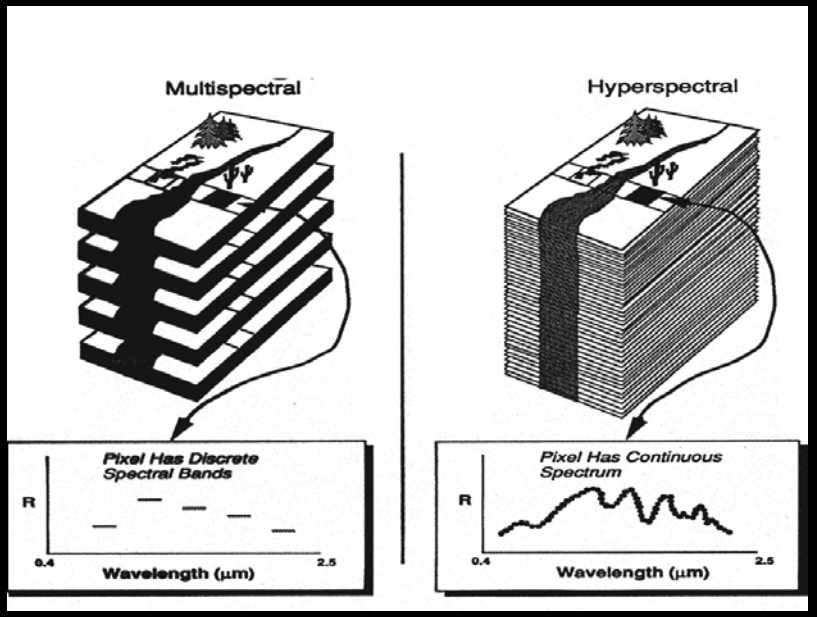
Introduction

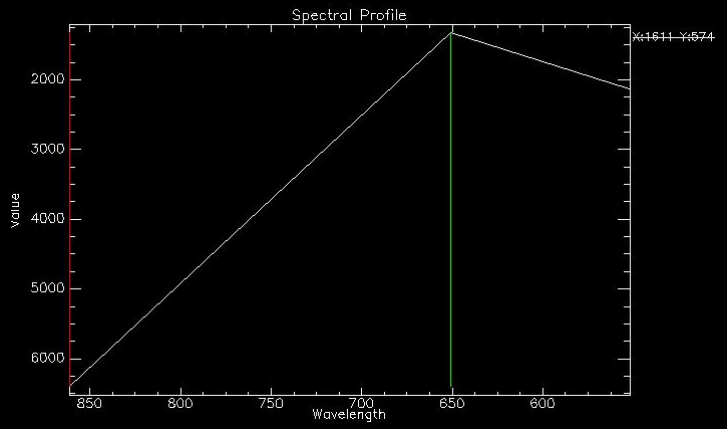
- Deepwater Horizon Oil Spill - April 20, 2010 – July 15, 2010
- Largest oil spill in the history
- Approx. 5 million barrel or 206 million gallons of crude oil were released in the Gulf of Mexico (up to 100,000 barrels per day)
- spill caused extensive damage to marine and wildlife habitats as well as the Gulf's fishing and tourism industries
- Only a small portion of the oil had been removed from the Gulf
- The rest of the oil still remains (underwater plumes, submerged oil mats (SOMs), …)

Purpose of this study

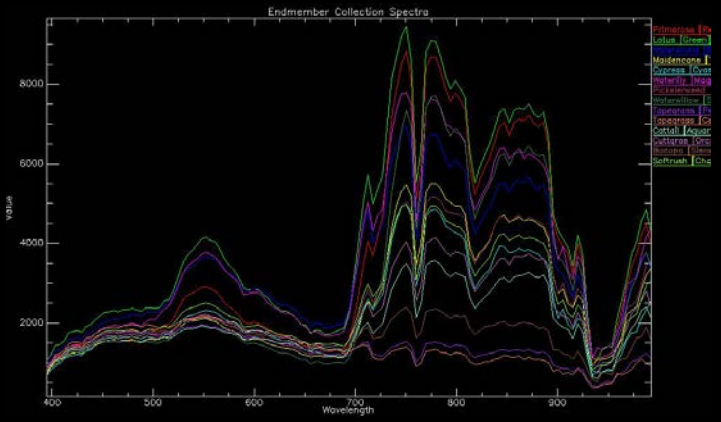
- Self funded proof-of-concept in the Gulf of Mexico in Summer 2010 (Galileo Group, Inc. & ACA)
- Show progression and extent of oil impact, to include gradient concentrations
- Quantitative spectral mapping of oil abundance from hyperspectral data and high-resolution orthophoto
- Developed unique hyperspectral target signature libraries by cross referencing with high resolution camera system
- Focus on detection methodologies applied to practical scale level production operations
- Use of multiple remote sensors

Hyperspectral Imaging





Aerial Imagery (3 bands)



Hyperspectral Imagery (128 bands)

Hyperspectral Imaging
Sensors

- VIS/NIR – AISA Eagle – 12 bit
  - -- 400-1000 nm
  - -- 244 channels at 2.2 nm intervals
  - -- Spectral resolution of 2.9 nm

- SWIR - AISA Hawk – 14 bit
  - -- 1,000 – 2,400 nm
  - -- 254 channels at 5.5 nm intervals
  - -- Spectral resolution of 8.5 nm

- Inertial Measurement Unit (IMU)
  - -- Continuously measures all inertial aircraft motion
  - -- GPS acquires positional data
  - -- Post processing software utilizes this information to provide corrected image
  - -- Spectral radiometric corrections also performed in software

VIS/NIR Unit Installed

SWIR Unit on Bench

Hyperspectral Imaging

Applications

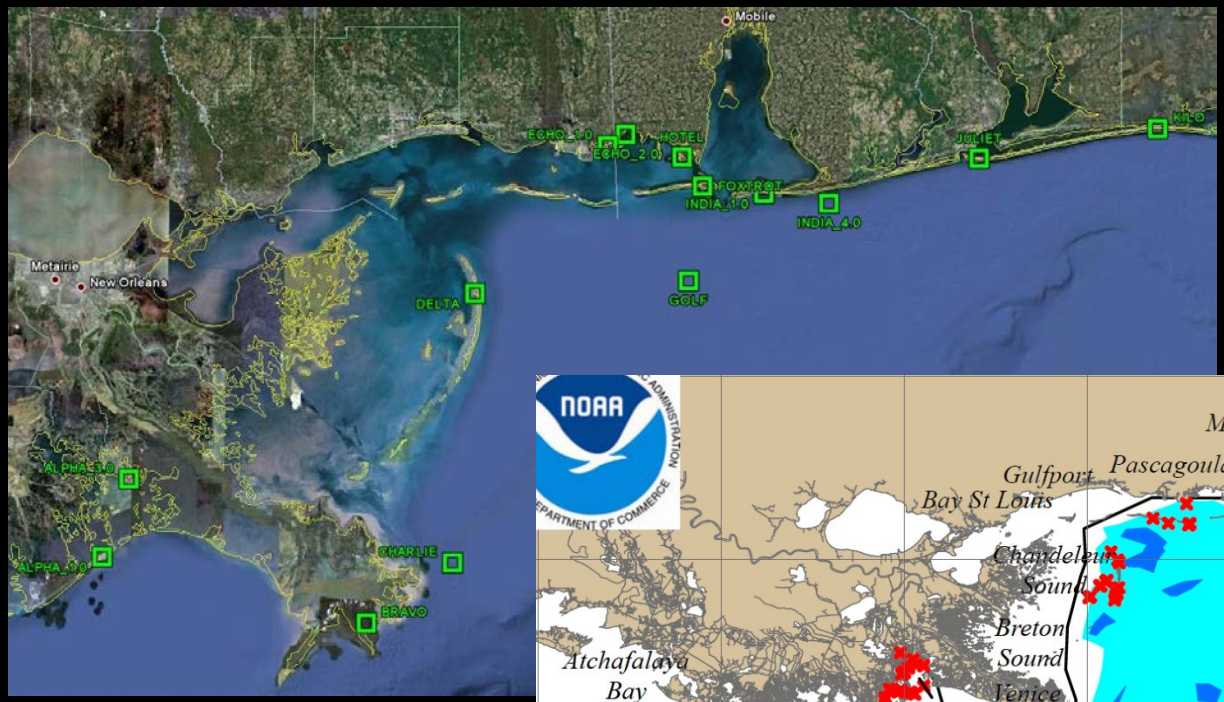
- Ecology
  - Coastal and wetlands monitoring
  - Change detection and trend analysis
  - Habitat Mapping
  - Invasive species Mapping
  - Submerged Aquatic Vegetation (SAV) mapping
- Oceanography
  - Pollution monitoring
  - Coral Reef monitoring
  - Water quality
- Geology
  - Oil & Gas exploration
  - Mineral exploration
- Snow hydrology
- Cloud and atmospheric studies
- Precision Agriculture
  - Disease Management
  - Forest Inventory

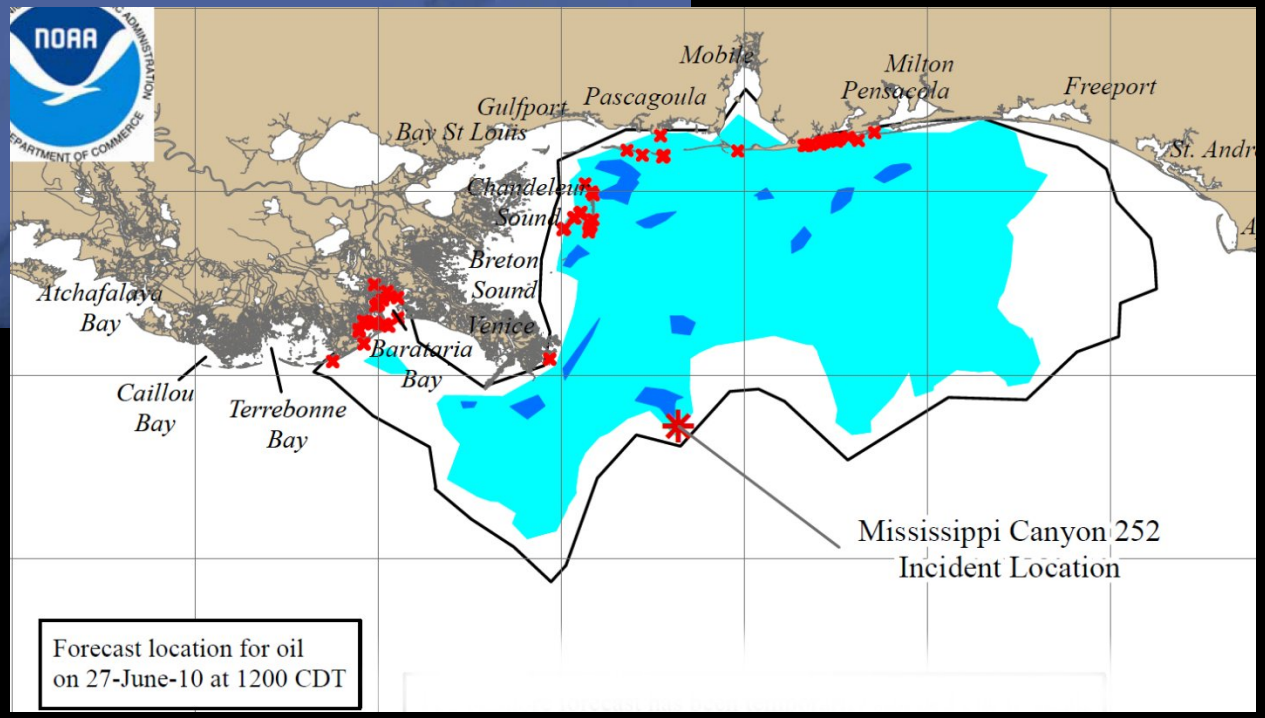
Collection Sites

- Simultaneous multi-sensor data collection of 11 sites in Gulf of Mexico
- Target classes: Wetland, beach, open water, with various levels of oil impact ranging from high, to medium to low.
- Detection examples from three key grids representing target classes ranging from high to moderately oil impacted areas:
  - ALPHA 3 grid (West of Port Sulphur, LA)
  - INDIA grid (Open Ocean N. of Oil Rig Site)
  - KILO grid (Ft. Walton Beach, FL)
- Timeline
  - Imaging operations executed June 21-25 2010

Collection Sites

Target Test Grid Sectors Shown in Green





Data Collection

Multi-Sensor-Suite

- Cessna 208
- AISA EAGLE
  - 128 bands
  - 1 m GSD
- RIEGL LMS-Q680i
  - Up to 400 Khz pulse rate
  - Full waveform
  - 75 cm point spacing
- UCX Ultracam X
  - 10 cm GSD

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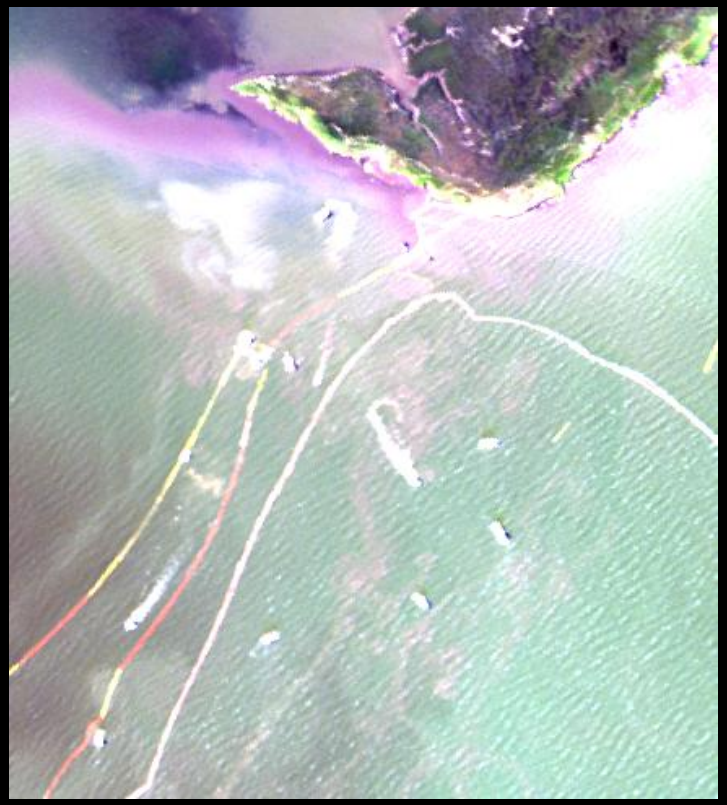
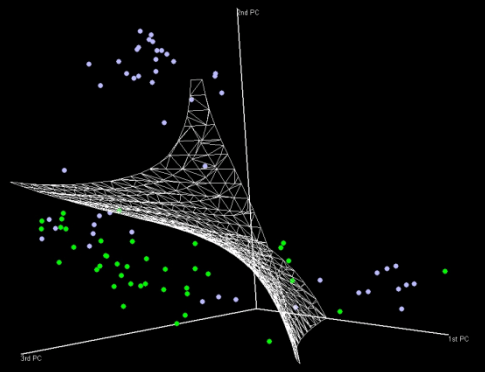
Pre-processing: Deglinting



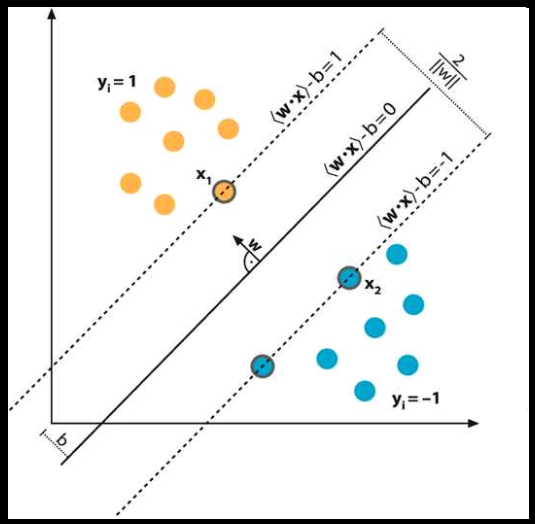
Binary Approach

- Support Vector Machines (SVM)

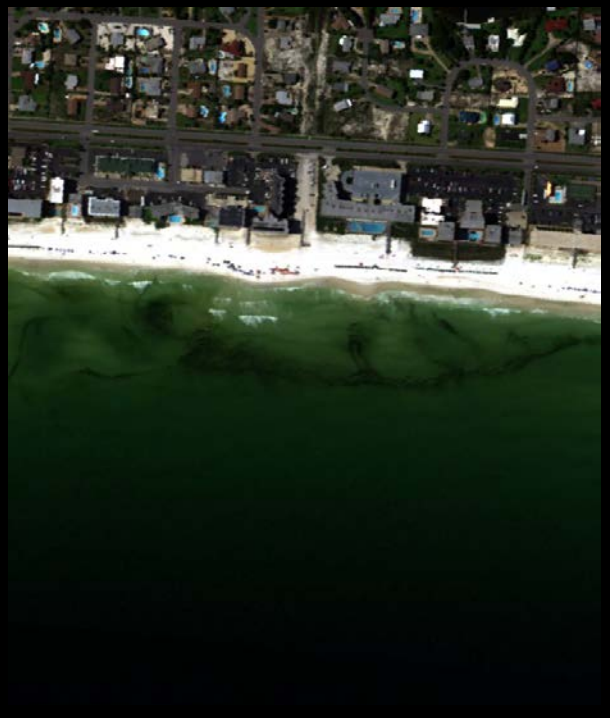


  - Derived from statistical learning theory
  - Binary classifier
  - separates the classes with a decision surface ‘hyperplane’ that maximizes the margin between the classes
  - Pairwise classification method for multiclass classification
  - Radial basis function (RBF) as non-linear kernel function

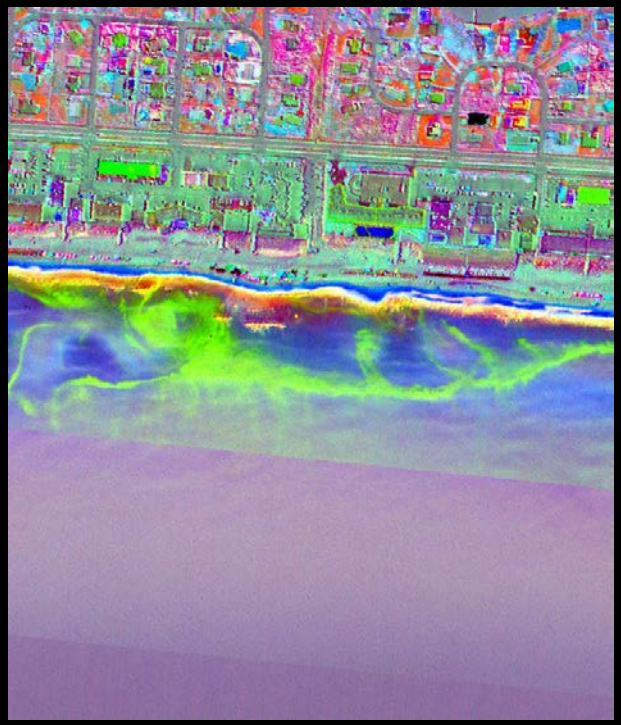
$$k(\mathbf{x_i}, \mathbf{x_j}) = \exp(-\gamma \|\mathbf{x_i} - \mathbf{x_j}\|^2)$$



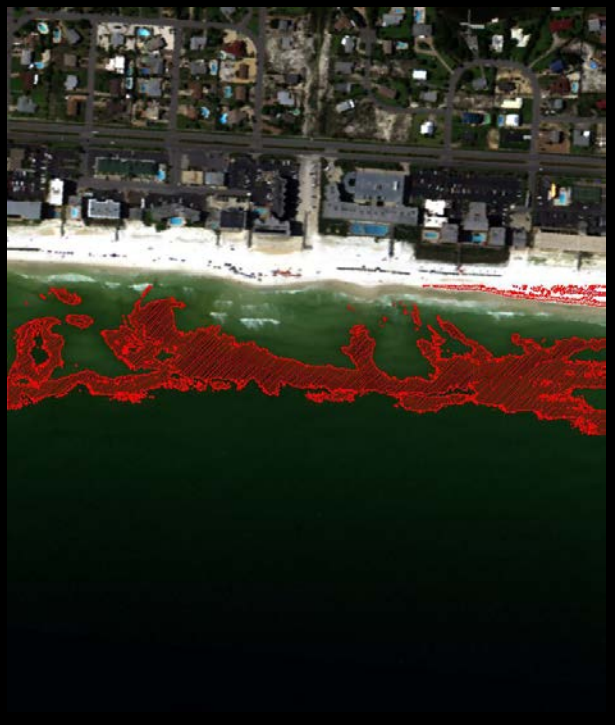
SVM Oil Classification



RGB Imagery (hyperspectral)



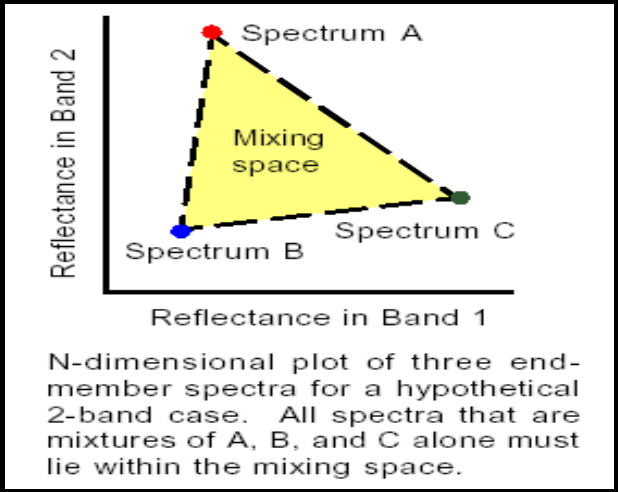
MNF Transformation



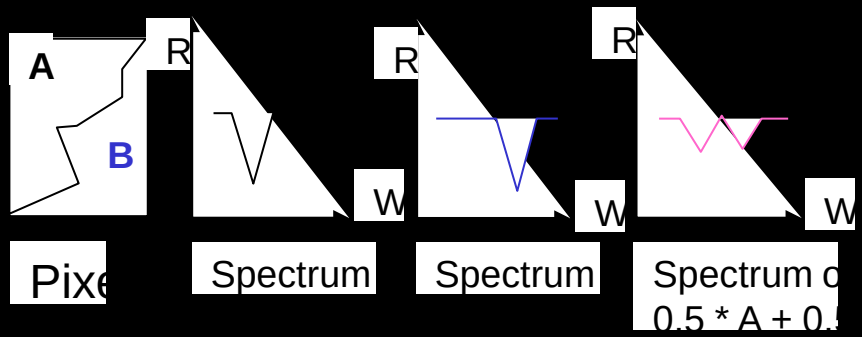
Classification result (SVM)

Quantitative Oil Mapping Approach

- Pure spectral end-members (targets) identified from hyperspectral data with enhanced visualization from high resolution UCX Ultracam imagery
- Linear Spectral Unmixing (LSU) used to estimate abundance of each end-member in each pixel
- Quantitative estimate of oil abundance (0-100%) for each pixel



N-dimensional plot of three end-member spectra for a hypothetical 2-band case. All spectra that are mixtures of A, B, and C alone must lie within the mixing space.



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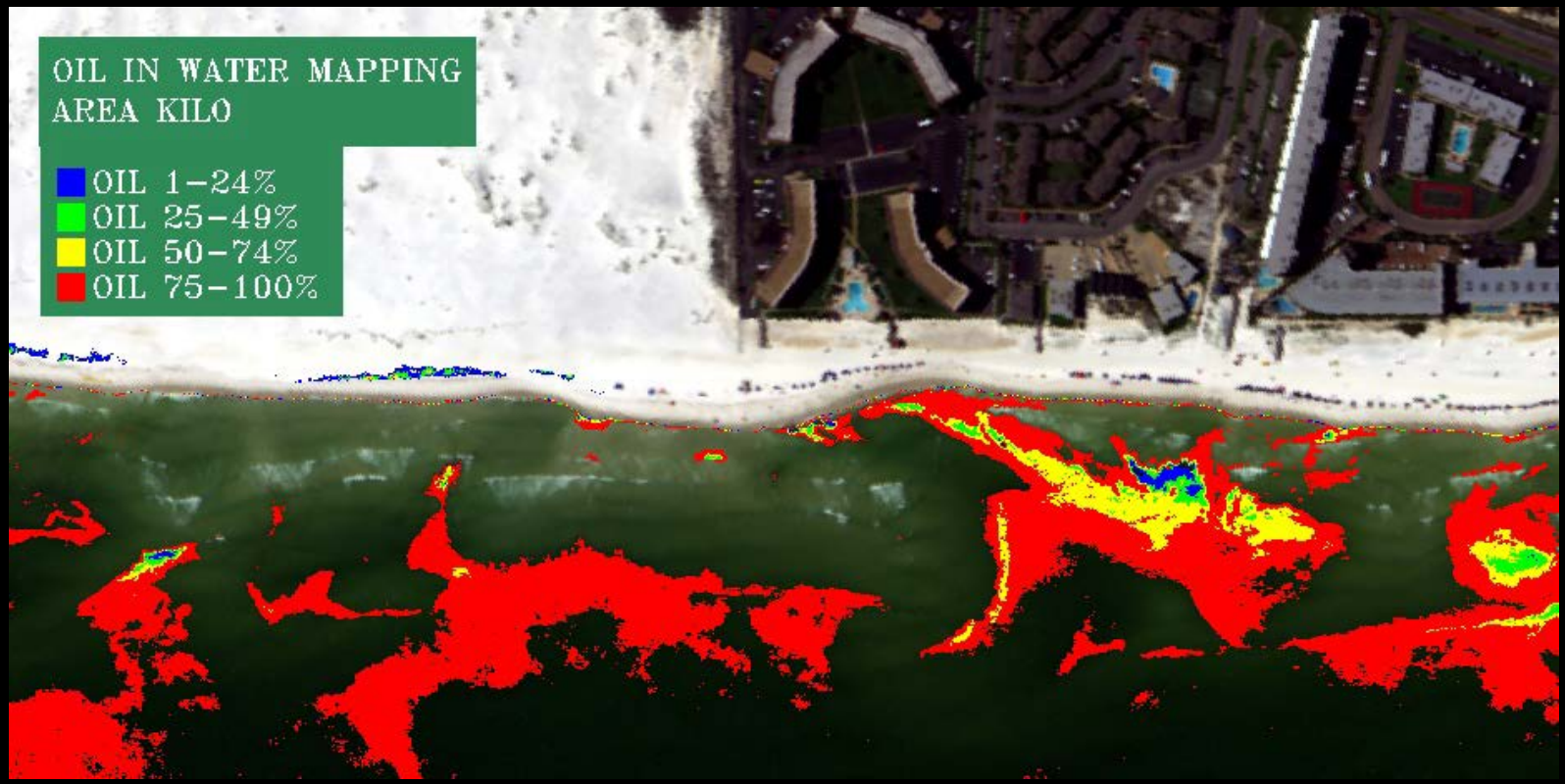
LSU Classification

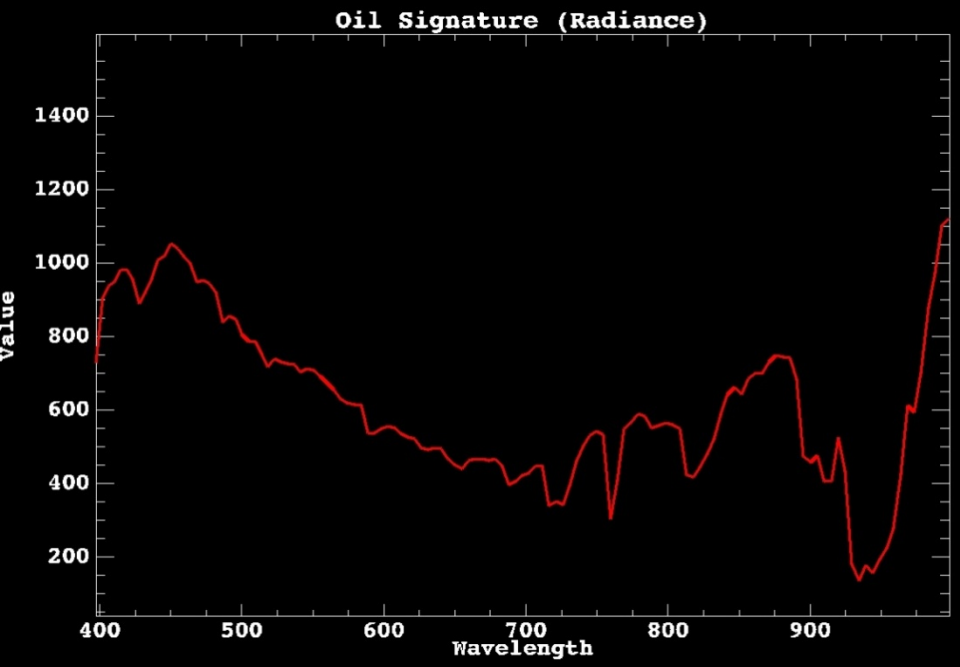


ALPHA 3: Spatial
Resolutions Comparison

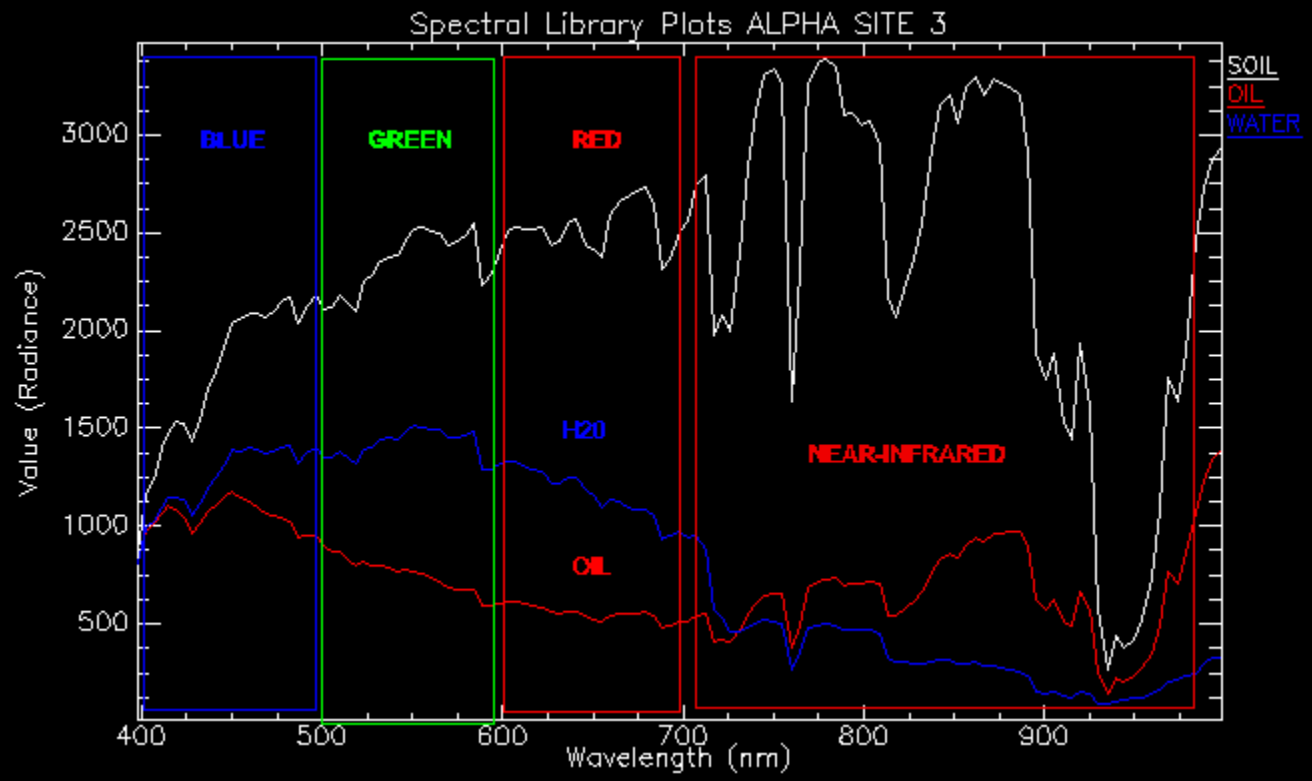
AISA Eagle True Color 1 m resolution

UCX UltraCam 0.1 m resolution

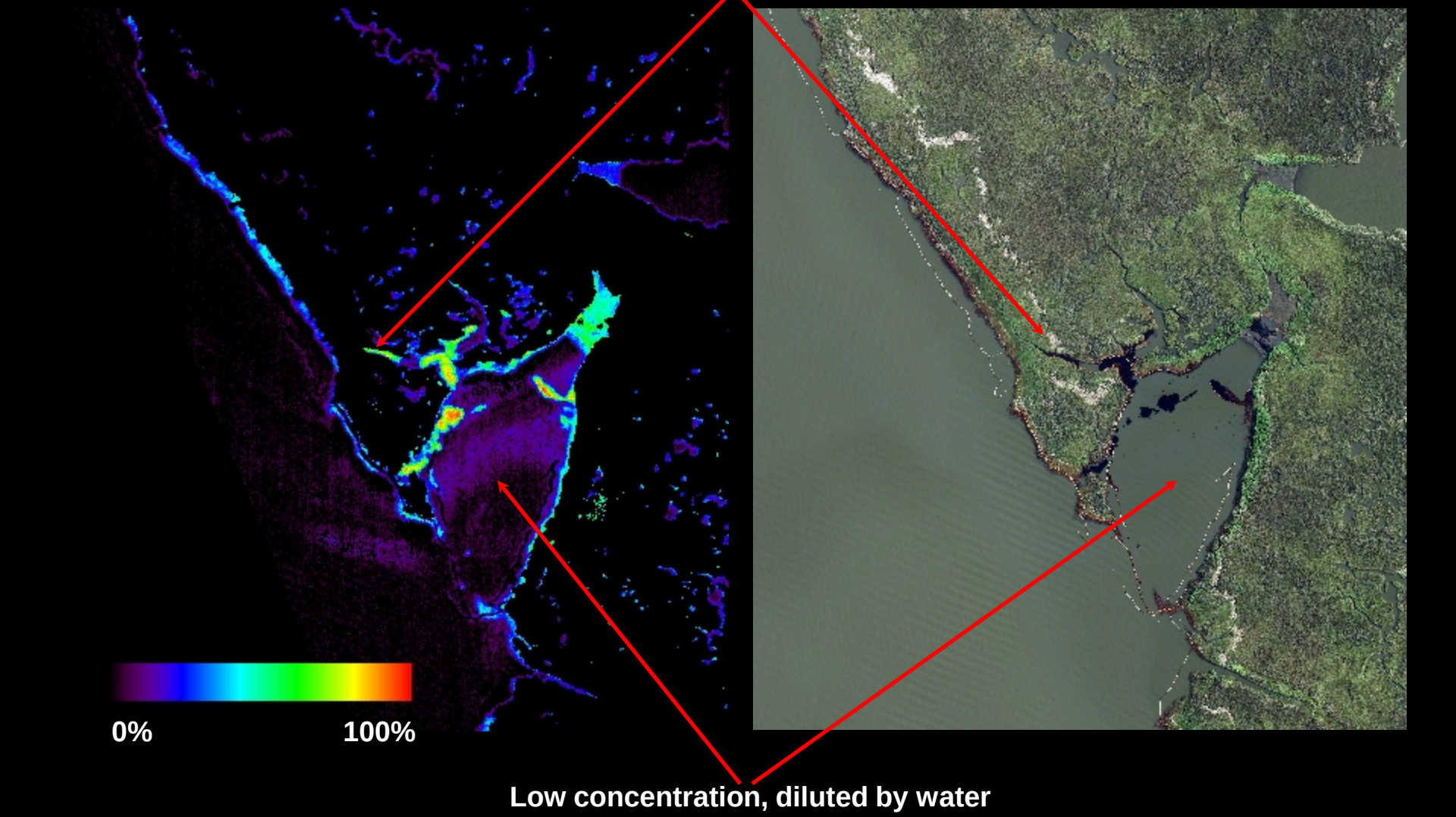
ALPHA 3: Oil Spectral Signature



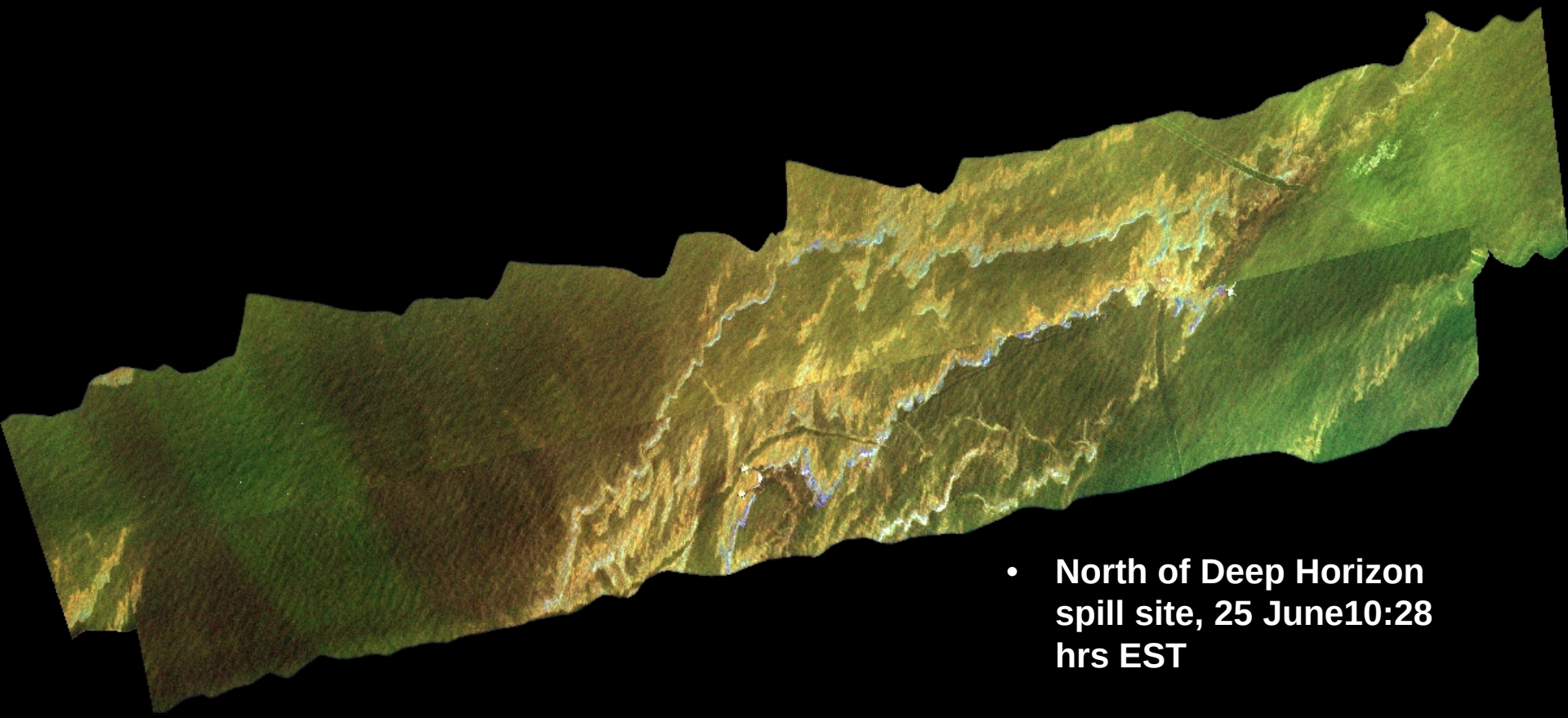
Spectral Endmembers



ALPHA 3: Analysis

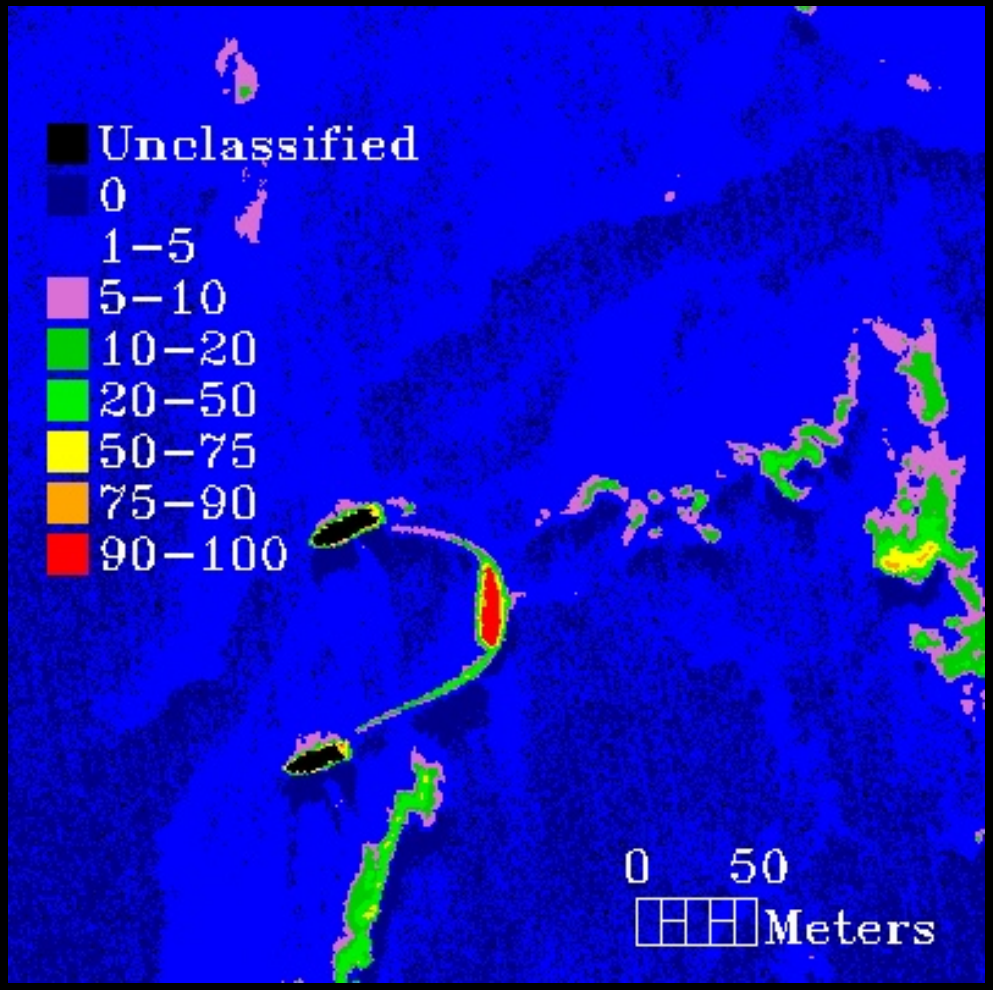


Site 2: INDIA Grid
Open Ocean N. of Oil Rig Site



- North of Deep Horizon spill site, 25 June10:28 hrs EST

INDIA Grid Oil Fractions From Hyperspectral Image Analysis



- Oil < 5% widespread
- Highest % inside skimmer
- Oil detected on ship hulls

Site 3: KILO Grid: Ft. Walton Beach, FL

Beach Impact

KILO Grid - Impacted Beach Site:

Oil on beach is present as a mixture of weathered oil-sand/sediment (tar balls, SOMs); Note - Oil fractions are not directly comparable to oil in water at ALPHA 3

KILO Grid - Impacted Beach Site:

High Resolution UCX Camera View “Aerial Ground Truth”

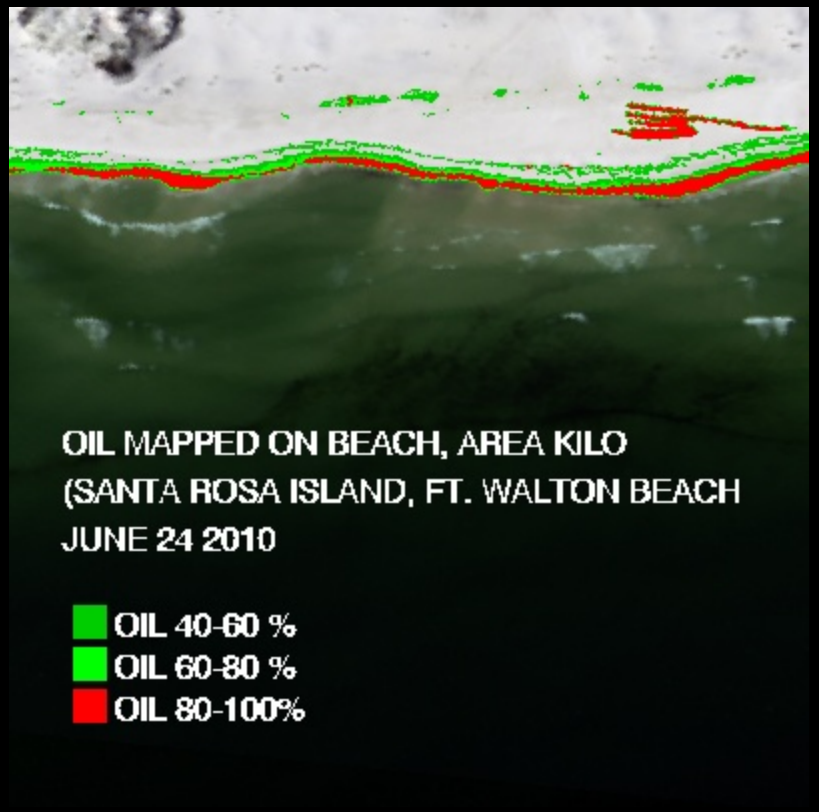
Mapping Oil On Beach

High oil cover along wrack line

Oil soaked boom debris (upper right)

Oil on beach is present as a mixture of weathered oil-sand/sediment (tar balls)

Oil fractions are not directly comparable to oil in water detected at ALPHA 3



Summary

Key Benefits of Approach

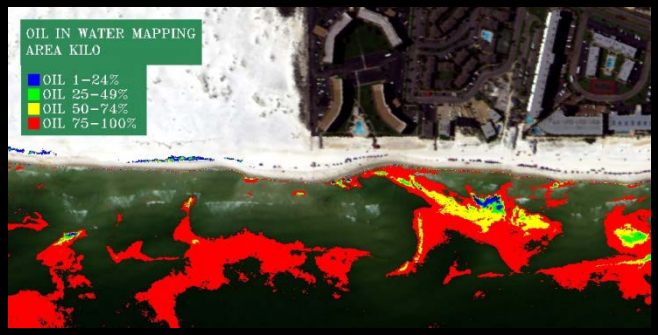
- Ideal for large, remote areas
- Collected data should be extremely valuable for containment and abatement activities
- Digital processing = rapid mapping, greater accuracy; repeatable objective results
- Utility for emergency response, NRDA & long term recovery assessment
- Ability to quantitatively measure temporal changes
- Provides improved environmental protection and management capabilities

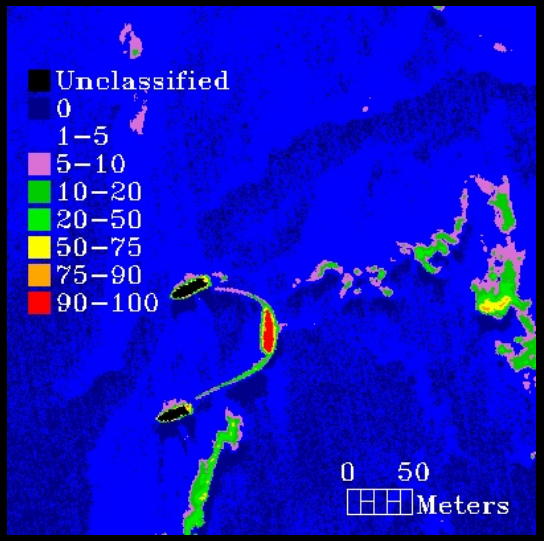
Oil slick

Helicopter patrol detected in ALPHA 3 grid
Oil land, slick, and boom visible

Summary

- Approach capable of quantitative oil spill mapping across a range of gradient observables
- Able to map fresh floating oil, as well as weathered surface (tar balls, subsurface oil mats (SOMs)) and submerged oil plumes
- Able to un-mix oil fraction from sand/soil as well as water and vegetation end-members
- Algorithm applicable to large area mapping for transition to near-term production level detection operations
- High thematic and spatial accuracy fusion possible with conventional orthophoto images
- Provide this capability in a manner that supports focused business planning and remediation efforts to save time and money, and document “before and after” measurements to show demonstrable progress





Future Operations

- Quantitative values: continue validation with ground-truth sampling to calibrate (i.e weathered oil)
- Continue to refine and more fully automate workflow elements and target detection
- Re-fly select test areas and perform Pilot Studies with Client Cooperation and Input
- Assist with NRDA and monitoring
- Act as key member of abatement activities including ability to provide quantitative mapping input in clean up efforts.

Thanks to

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