Environment Canada Environnement Canada

Oil Spill Remote Sensing

Dr. Carl E. Brown

Environment Canada

NOAA-Environment Canada UAS Arctic Scoping Workshop
Boulder, Colorado, September 25-26, 2012

Overview

- Introduction
- The Need for Remote Sensing
- Visibility of Oil
- Sensor Types
- Integrated Airborne Sensor Systems
- Satellite-borne Sensors
- UAV-mounted Sensors
- Towed Sensors
- Future Developments
- Conclusions

Introduction

- Oil spills are inherently dynamic and are affected by;
  – Physical environment
  – Changing chemical composition
- Spill Response
  – Location and extent of the spill needed for effective spill countermeasures
- Remote sensing
  – Tactical or short-term - airborne sensors
  – Strategic overview or long-term – satellite-borne sensors
- Latest generation satellite-borne sensors
  – Tactical oil spill response role?

The Need for Remote Sensing

- Oil cannot be distinguished from background
  - Among weeds, ice, or oil is in small pancakes or on the shoreline
  - Interference from municipal or industrial discharges
- In fog or darkness
- Extent of spill too great to map manually
  - Not generally a problem in smaller freshwater environments

Visibility of Oil

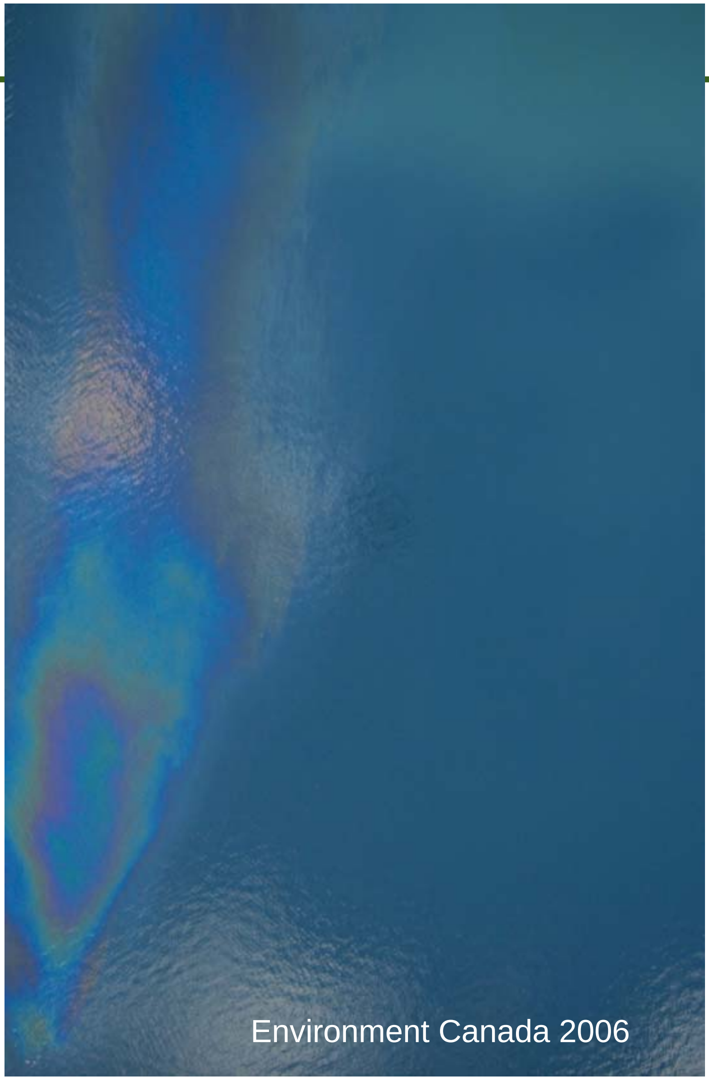
- Under many circumstances oil on the water's surface is not visible to the naked eye
- Depends entirely on thickness, oil type and on weather conditions
- Thin oil is not always visible
- Thick oil – especially heavy fuel oil and crude, is often visible

Interferences to Visual

- Weeds
- Wind slicks
- Sun glitter
- Organic / Biogenic slicks
- Trash
- Fog/mist patches
- Ice
- Shallows/bottom colours
- Industrial or Municipal outflows

Optical Sensors

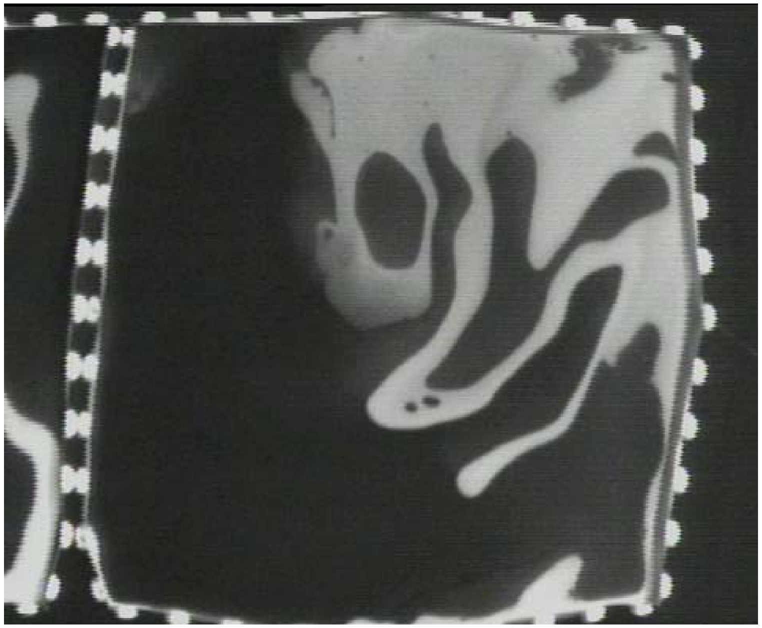
- Include cameras and scanners in the visible, infrared and ultraviolet
- Generally suffer from same limitations as visible sensors
- Are relatively economical and readily available



Infrared

- Thermal infrared (8-12 μm) and mid-infrared (3-5 μm)
  - Thermal infrared preferred
- Give indication of relative thickness (thick or not)
  - Useful for countermeasures such as skimmers or use of sorbents
- Sometimes combined with UV for overall slick profile

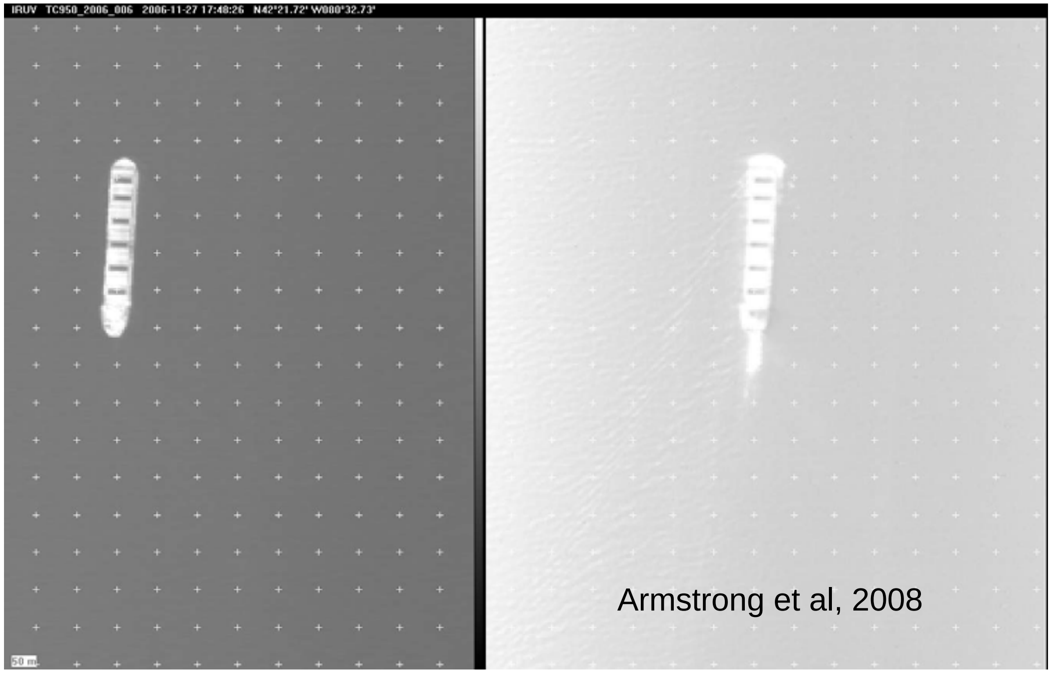
Oil – Visible (left) and Infrared (right)



Photos – Ron Goodman

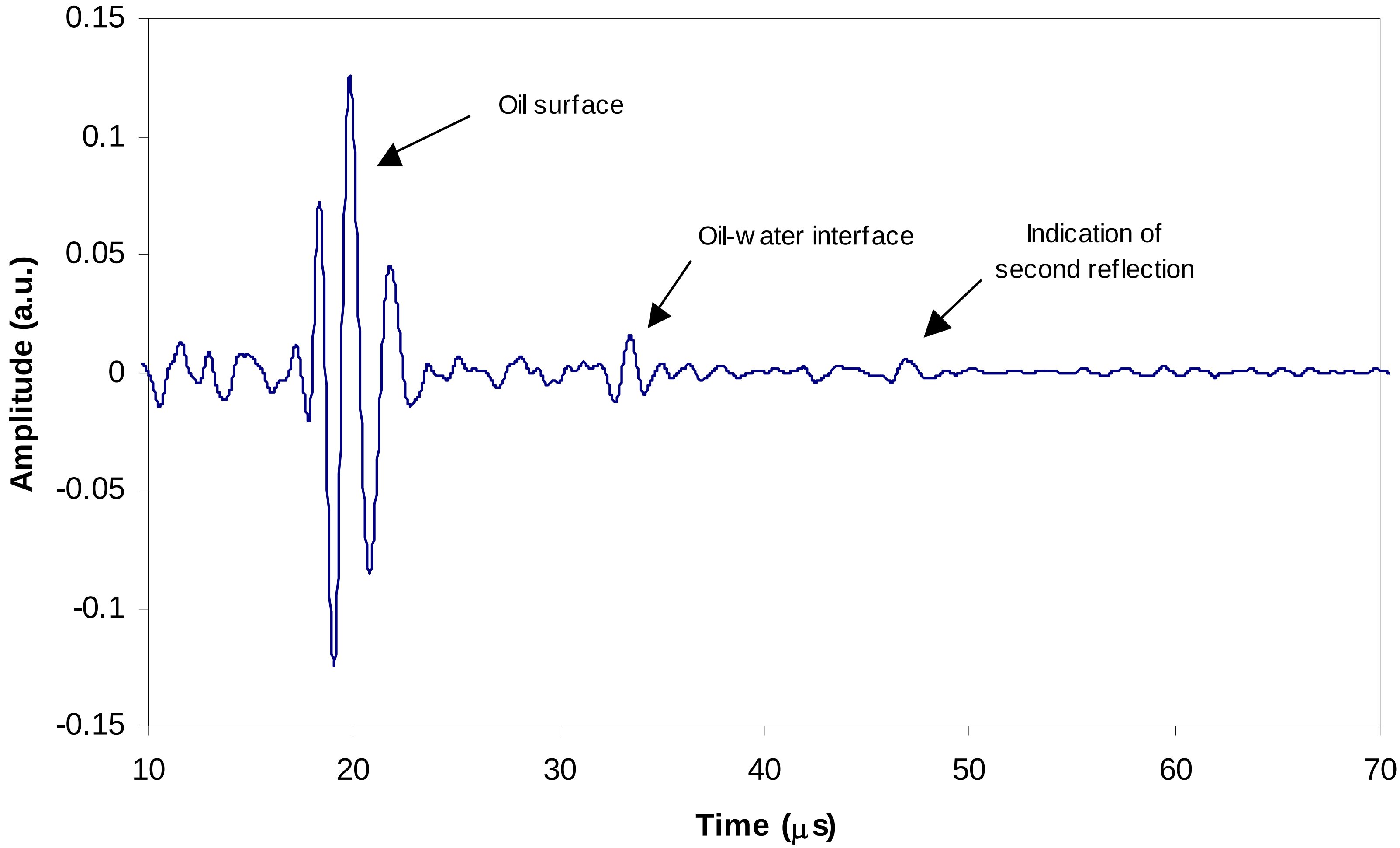
Ultraviolet

- Reflectivity of oil in the ultraviolet is much higher than surrounding water
- Excellent for mapping overall extent of the slick including sheen
- Subject to many false positives including sun glint, wind slicks and biogenic materials
- Daytime only



Infrared Ultraviolet

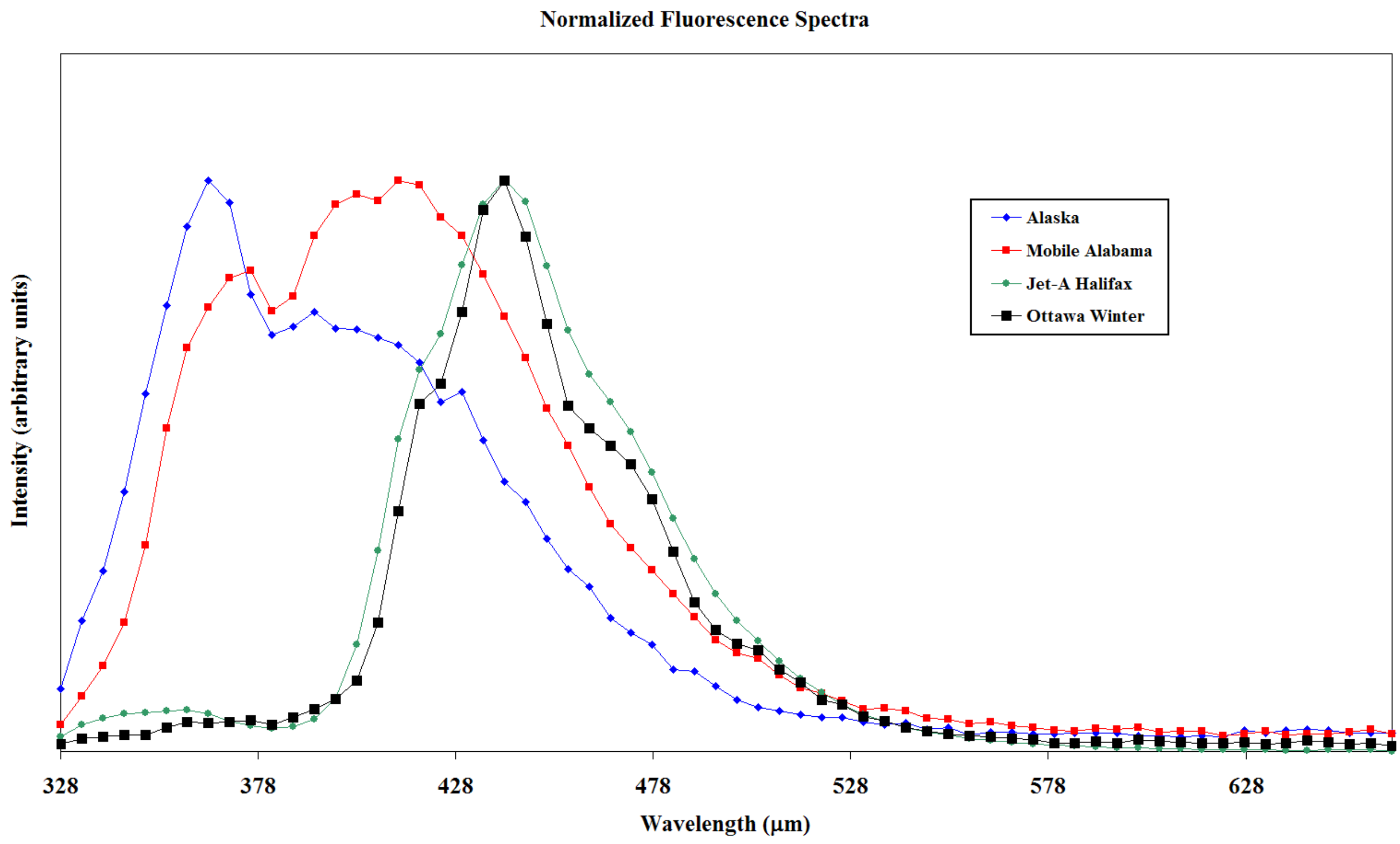
Thickness Sensor - LURSOT (04-26-2005)



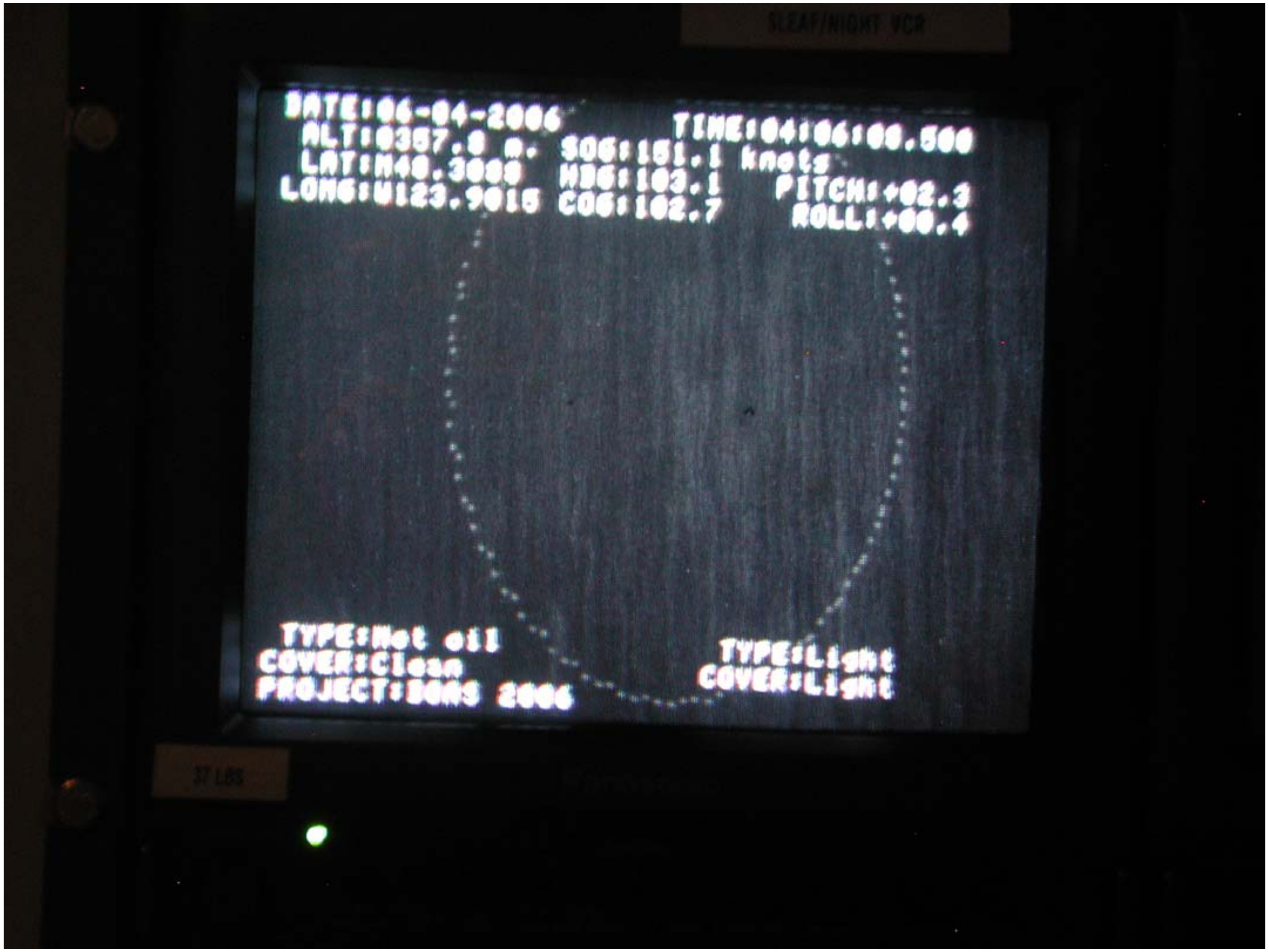
Laser Fluorosensors

- "Active" sensor – day/night capabilities
- Ultraviolet excitation (typically at 308 nm)
- Aromatic compounds in oil absorb UV laser energy and fluoresce in the visible
- Real-time detection and characterization of oil and related petroleum products (light, medium, heavy) (via Principle Component Analysis)
- Range-gated detection
- Geo-coded / date-stamped data
- Graphical map display of oil contamination

Typical Fluorosensor Spectra - SLEAF



Night Vision Cameras



Radar

- Active sensors operating in the microwave region
- Backscattering of radar energy by capillary waves is reduced (calmed) by oil on the surface
  - Dark area on bright background image
- Operates in limited surface wind speed window between 2 to 7 m/s
- Subject to a large number of false positives by other phenomena that suppress capillary wave action
- V,V polarization provides a superior clutter to noise ratio (CNR) over H,H polarization for oil spill detection

Airborne Radar

- SLAR (side-looking airborne radar) and SAR (synthetic aperture radar)
- Major advantages
  - Day/night and foul weather capability
  - Operate at high altitude
  - Useful for large slicks, very rapid mapping
- Disadvantages
  - High cost and dedicated aircraft and crew
  - Many false positives, particularly in smaller freshwater environments, detection of secondary characteristic of oil
  - Difficulties related to airborne operation in narrow confined environments (e.g. narrow channels, cliff areas)

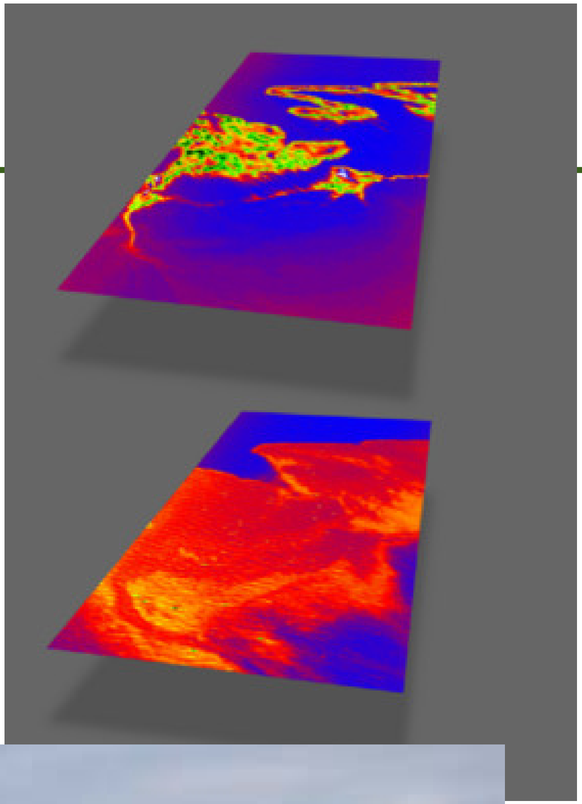
Integrated Airborne Sensor Systems

- Commercially available
- Integration of several optical and microwave sensors
- Increased confidence, reduced false positives
- Real-time graphical display of oil slick location, aerial extent, relative thickness information
- Direct data/image downlink to vessels or ground stations plus satellite communications
- Transport Canada now operates 3 airborne multi-sensor systems in coastal environments
- Lack of private sector airborne service providers

MEDUSA - Optimare

MEDUSA

- Side-looking Airborne Radar
- IR/UV Line Scanner
- VIS Line Scanner
- Microwave Radiometer
- Laser Fluorosensor



MSS-6000 Swedish Space Corporation

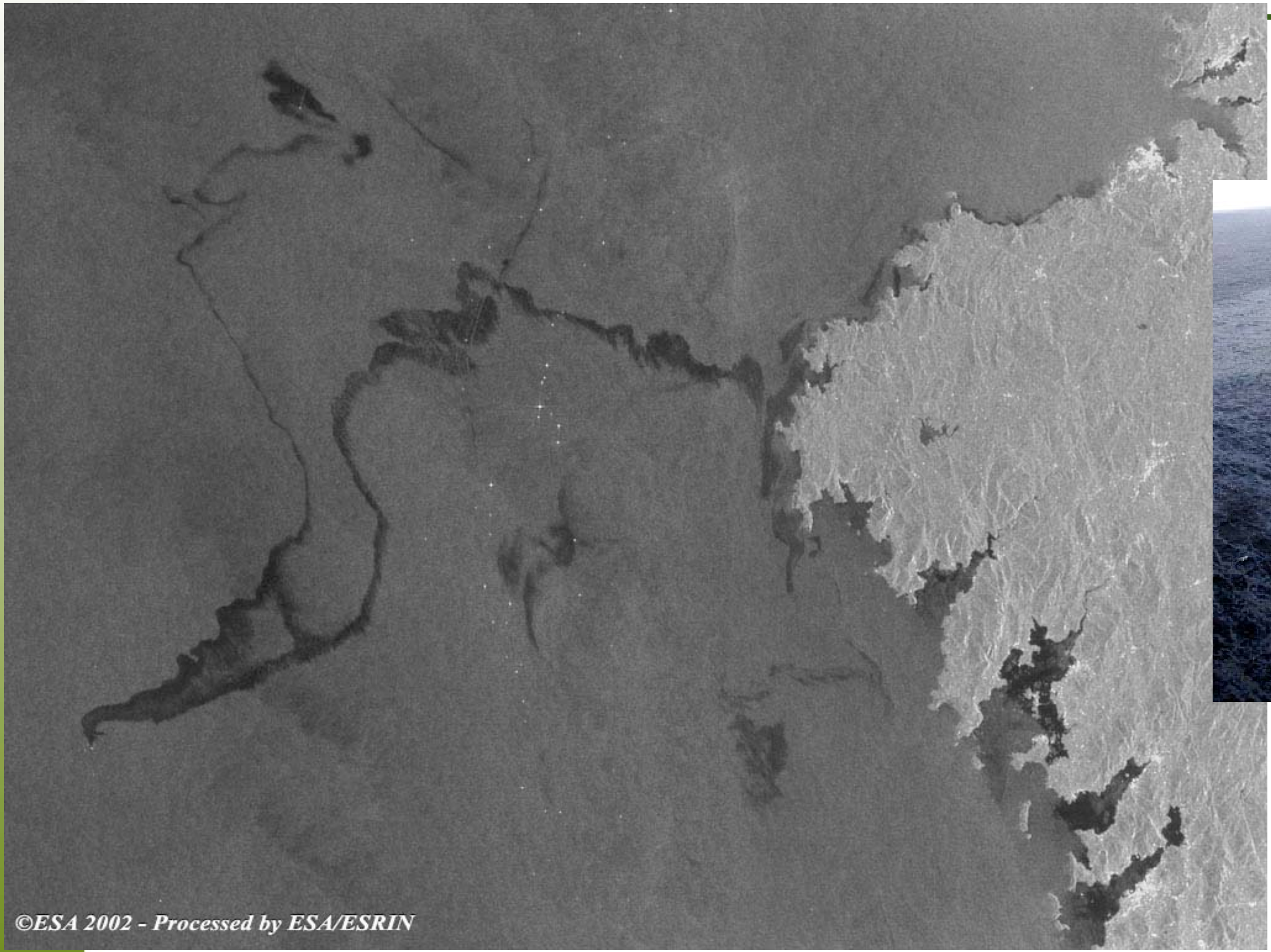
- Mission Management & Integration
- SLAR
- IR/UV
- Cameras
- AIS - Automatic Identification System
- Options
  - FLIR - Forward Looking Infrared
  - Search Radar
  - MWR
  - LFS
  - SATCOM
  - VMS

Dash 8 (C-GSUR) Transport Canada

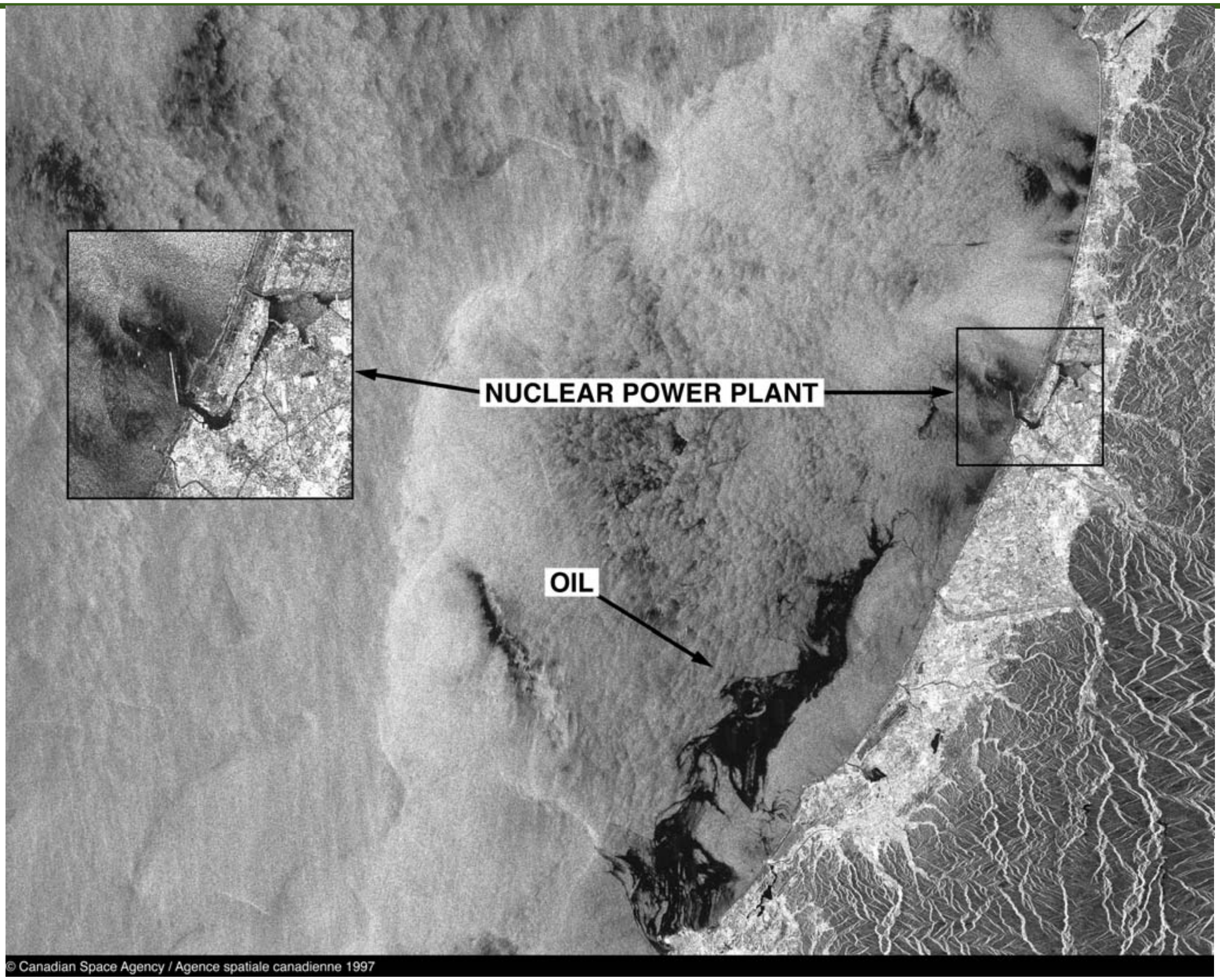
Satellite-borne Sensors

- Radar satellites very useful for large-scale slick mapping
  - Use history is poor because wind speed limitations apply (3 to 17 knots) and many false targets
  - Overpass frequency was very limited in the past
  - Spatial resolution was very coarse until recently
- Visible satellites - documentation only
  - Infrequent passes, oil on ice somewhat visible but confused with sediment
  - No distinguishing spectral feature of oil in the visible spectrum
  - In most cases extensive work required to track down a known slick – e.g., Exxon Valdez
  - Newer satellites have enhanced resolution e.g., QuickBird 60 cm which are more applicable to inland freshwater environments

Prestige Oil Spill - Spain



Nadkhodka Oil Spill – Japan RADARSAT-1



Current Satellite-borne SAR Sensors

(adapted from Topouzelis, 2008)

Satellite (Sensor)	Launch Date	Owner/Operator	Band
ERS-2	1995	ESA	C
RADARSAT-1	1995	CSA	C
RADARSAT-2	2007	CSA/MDA	C
ALOS (PALSAR)	2006	JAXA	L
TerraSAR-X	2007	DLR	X
Cosmos Skymed-1/2	2007	ASI	X

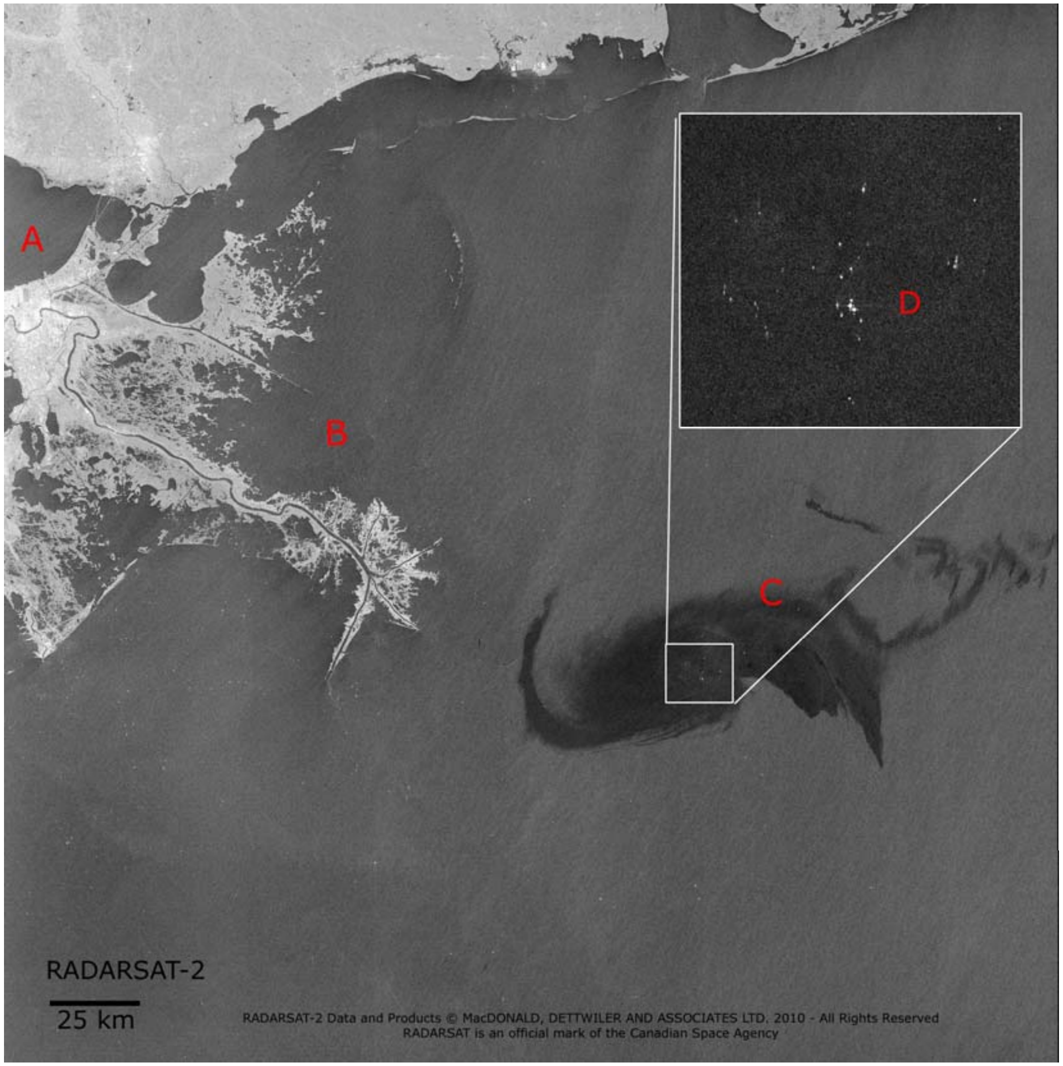
New Satellite-borne SAR Sensors

- Improved capabilities of newer generation SAR satellites may have application for oil spill remote sensing
  - Polarimetric imaging modes (some experimental, some operational)
  - Much higher spatial resolution (down to 3 m)
- Increased number of SAR satellites
- Plans to operate constellations of small satellites like Cosmos (Constellation of Small Satellites for Mediterranean basin Observation)
- Increased temporal coverage with revisit times down to a few hours in some circumstances
- The opportunity for increased frequency of image collection should prove useful to the oil spill response community

RADARSAT-2

- Operational commercial satellite
  - Can be tasked to respond to emergency situations like major oil spills
  - Time required to task is now 4 hours, which is a large improvement from the 12 hours required to task its predecessor
  - Fully polarimetric
  - Investigation of utility of dual channel ScanSAR mode V,V/V,H polarizations for oil and ship detection respectively as part of the Integrated Satellite Tracking of Pollution (ISTOP) program (DeAbreau et al., 2006)

RADARSAT-2 Gulf of Mexico 2010



TerraSAR-X Gulf of Mexico July 2010

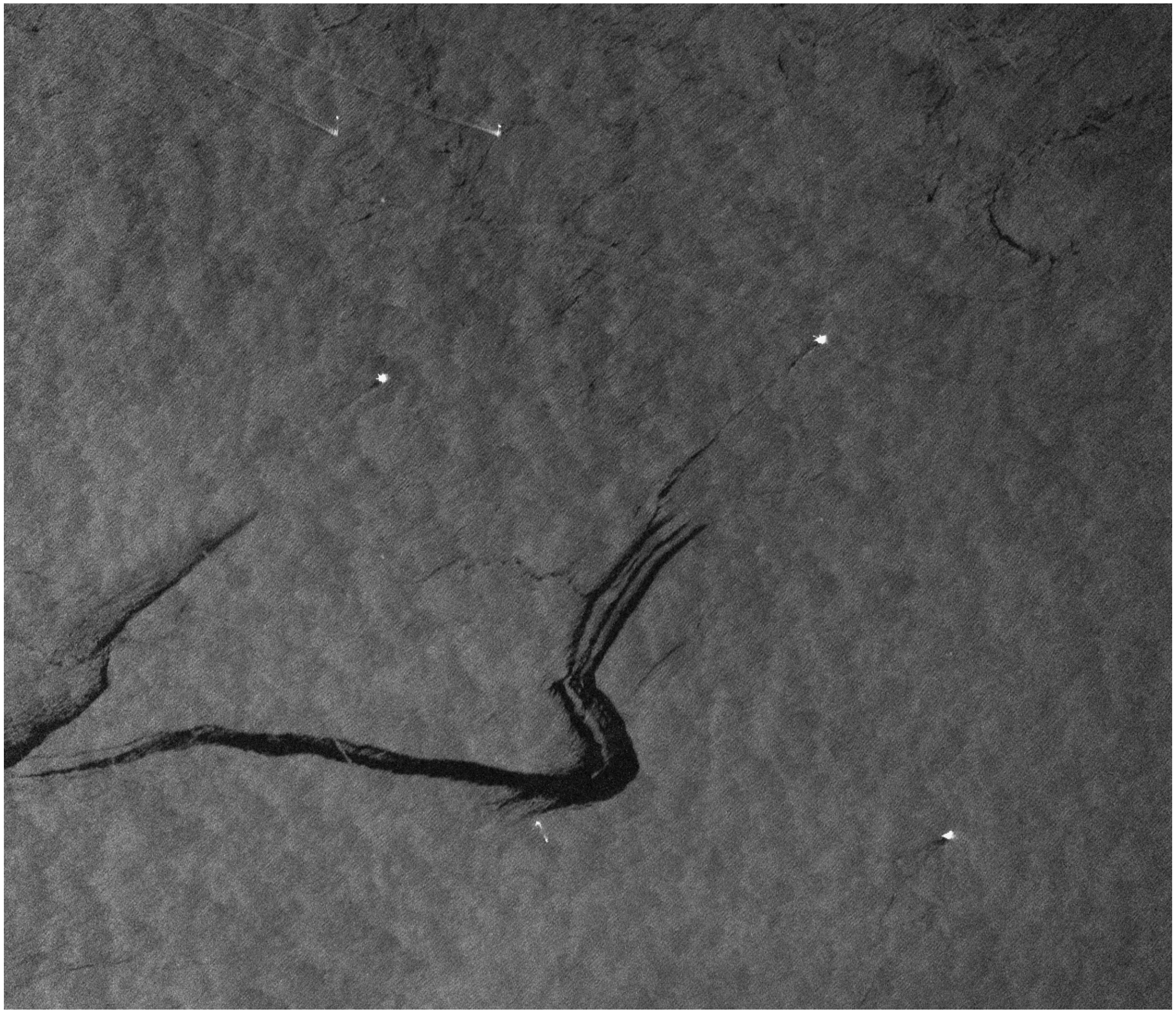


Image courtesy DLR

EXPERIMENTAL MARINE POLLUTION SURVEILLANCE REPORT

Analysis Provided by: The National Oceanic and Atmospheric Administration/National Environmental Satellite, Data and Information Service (NOAA/NESDIS)

REPORT DATE: MAY 11, 2010
REPORT TIME: 0400Z (05/10/2010 2300 CDT)
ANALYST: SHEFFLER/SALEMI

DATA SOURCE: Cosmo/Skymed
MODE: ScanSAR, VV
RESOLUTION: 30 Meter
IMAGE DATE/TIME: 05/10/2010 2339Z (1839 CDT)

Legend

Anomaly

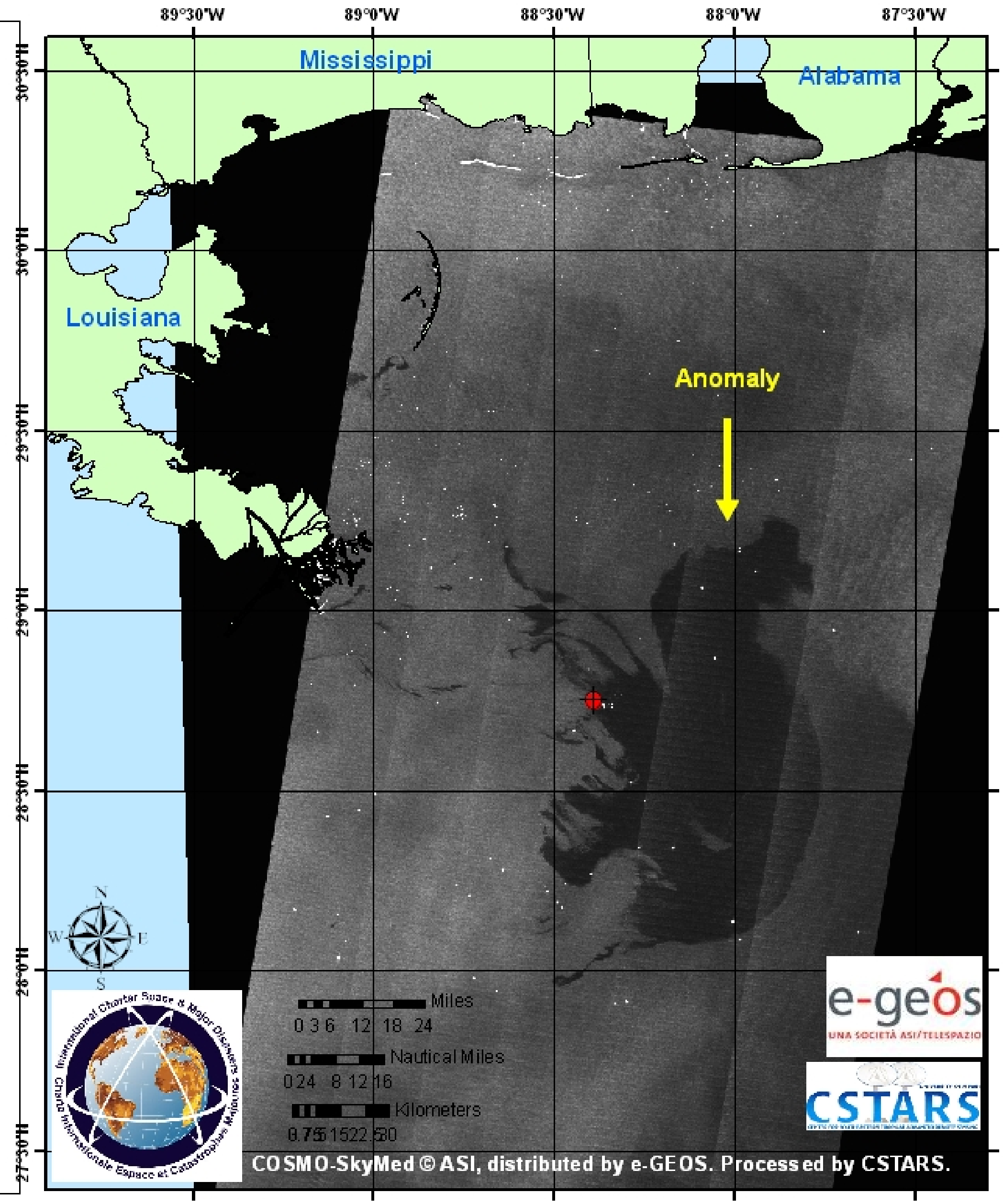
Location of Deepwater Horizon Platform: [28°44'12" N / 88°23'14" W]

N/A	Estimated Area of Anomaly

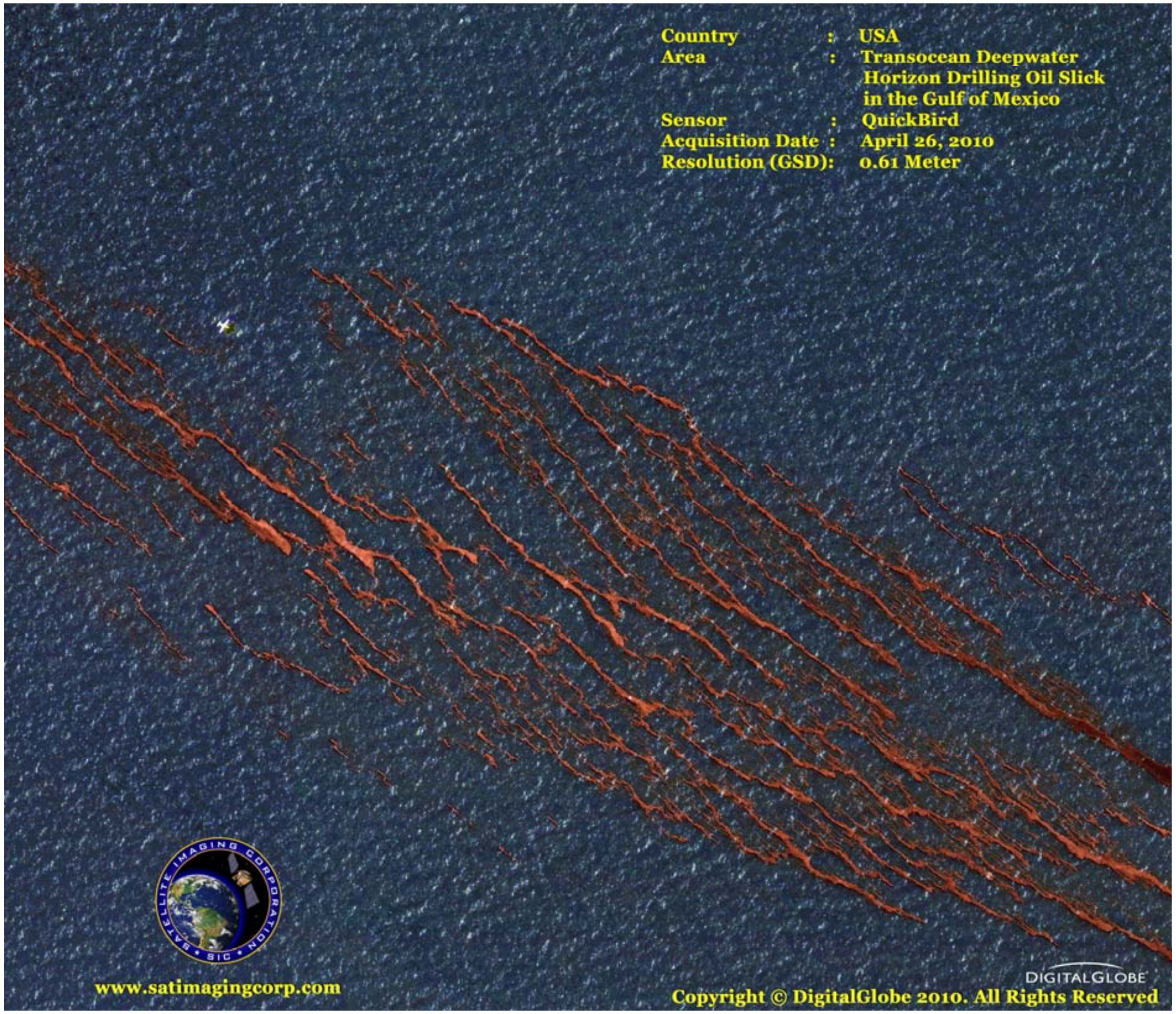
REMARKS:

The main swath of oil remains east of the spill site. Several smaller areas can be seen to the west near the Brenton and Chandeleur Sounds and south of the southern most portion of Plaquemines Parish.

This is an experimental product of the Satellite Analysis Branch and not operationally maintained. We will do our best to make it available in a timely manner.



QuickBird – Gulf of Mexico April 26 2010



Selendang Ayu Spill – QuickBird

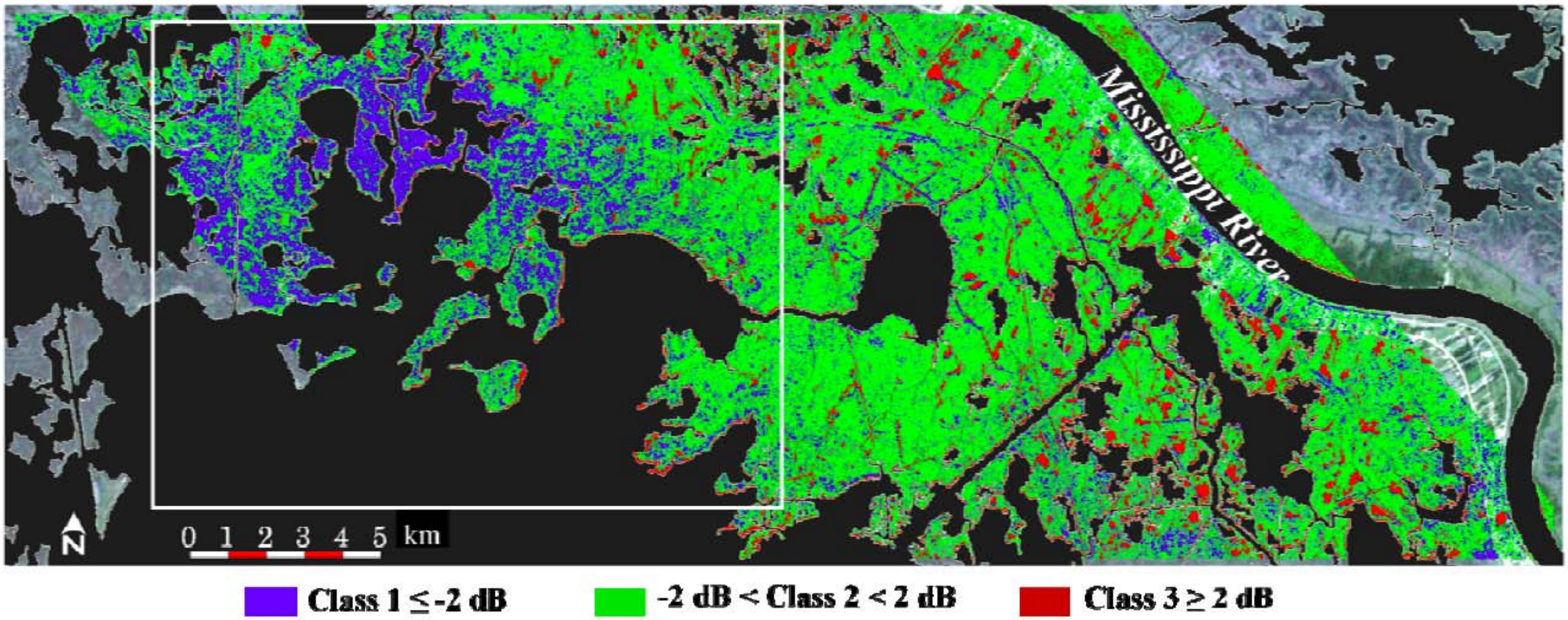
QuickBird Image
(60 cm resolution)

Selendang Ayu Spill
Unalaska Island,
Alaska

Unmanned Airborne Systems (UAS)
UAVSAR - NASA

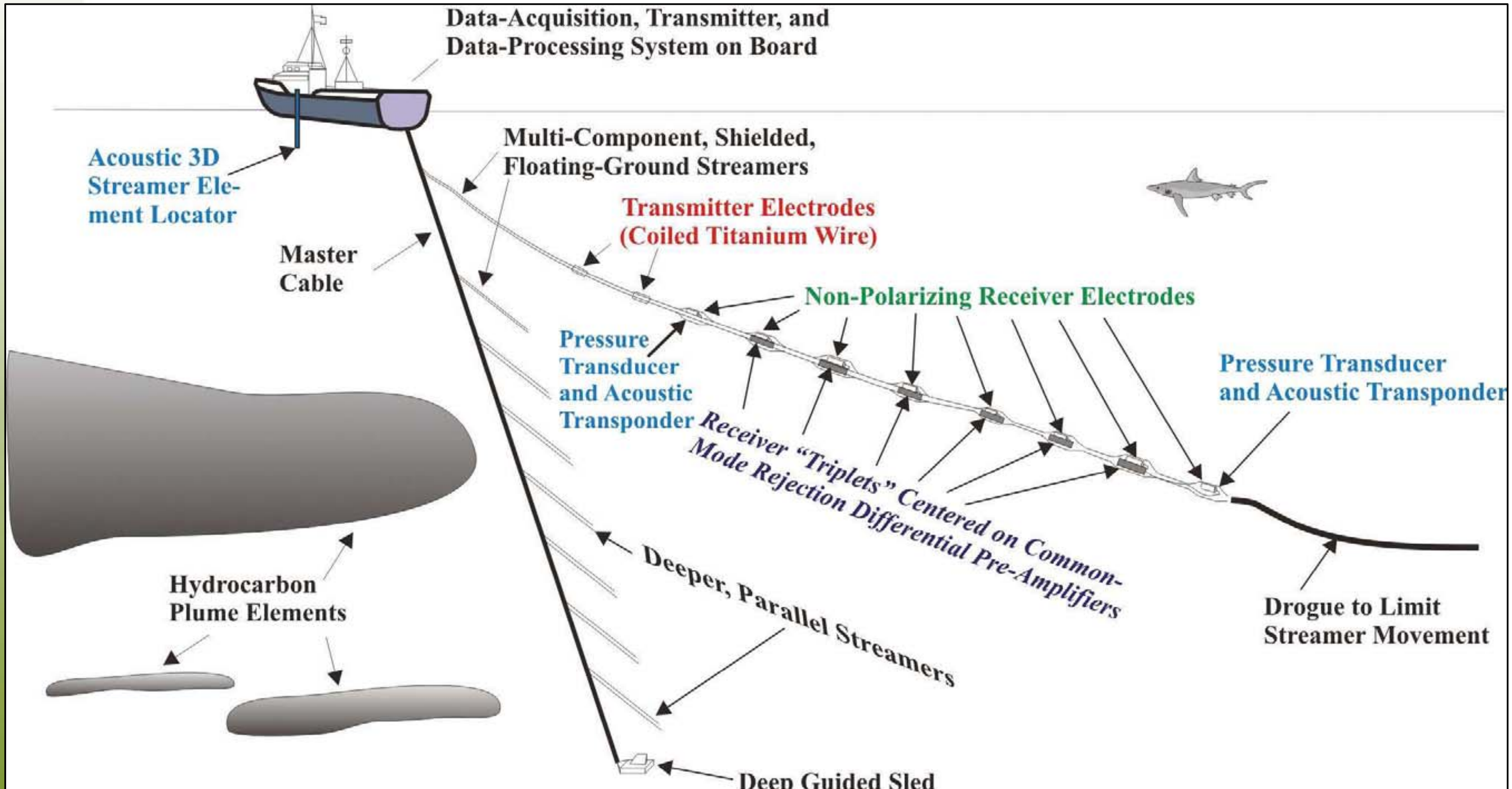
- Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR)
- E. Ramsey III, A. Rangoonwala, Y. Suzuoki, and C.E. Jones, “Oil Detection in a Coastal Marsh with Polarimetric Synthetic Aperture Radar (SAR)”, Remote Sensing, Vol. 3, pp. 2630-2662, 2011
- UAV-mounted Polarimetric L-band SAR
- Low-noise, high-spatial resolution, PolSAR used to identify marsh areas affected by oil slicks, ground-truthed, SCAT observations
- Further studies needed to validate the potential capability of L-band radar to detect sub-canopy oil impacts within interior marshes (change in dominant scattering mechanism)
- High resolution instrument such as UAVSAR can be used to develop algorithms for lower resolution satellite-based instruments

UAVSAR – NASA, Ramsey et al. 2011



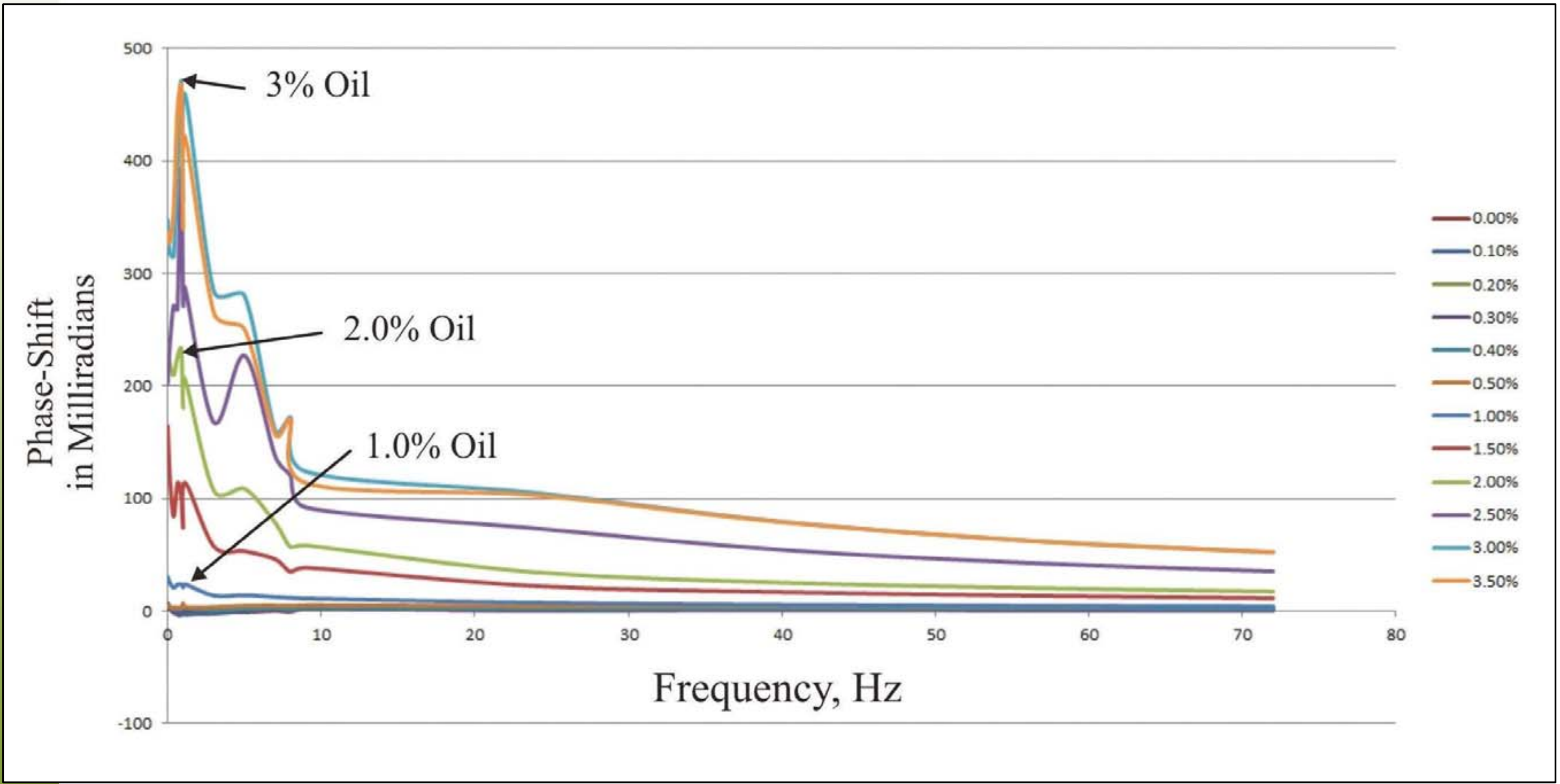
Difference in horizontal send and receive (HH) backscatter intensity between 2009 and 2010 UAVSAR data of the Mississippi River Delta flight line overlain on a Landsat Thematic Mapper image. The white box contains the study area.

Towed Sensors
Induced Polarization – Oil in Seawater



J. Wynn, M. Williamson, J. Fleming, Induced Polarization for Subseafloor, Deep-Ocean Mapping, Sea Technology, September 2012, pp. 47-50.

Towed Sensors
Induced Polarization – Oil in Seawater



Laboratory IP results for a range of oil-in-saltwater mixture

J. Wynn, M. Williamson, J. Fleming, Induced Polarization for Subseafloor, Deep-Ocean Mapping, Sea Technology, September 2012, pp. 47-50.

Future Developments

Recent advances in sensor technology will continue to drive use

- Reduced sensor size, complexity and cost
- Commercially integrated sensors packages
- True real-time processing with improved computer capabilities
- Unmanned Aerial Vehicles (UAVs) with oil spill remote sensors
  - Growing area of interest

Needs

- Smaller more economical and energy efficient laser-based sensors
  - Requires advances in solid-state laser technology
- Smaller and more energy efficient sensors will allow for their installation in smaller, more economical aircraft including UAVs

Conclusions

Effective response to major oil spills requires;

- Combination of airborne and satellite-borne sensor systems
- Near real-time information on oil slick location and relative thickness

Latest generation satellite sensors – tactical role?

- Higher resolution sensors
- Multiple imaging modes, steerable
- Increased coverage, shorter revisit times satellite constellations

Airborne oil spill remote sensing platforms

- Integrated airborne sensor systems
- Strategic role, real-time oil slick location information
- Unmanned Aerial Vehicles (UAVs) with oil spill remote sensors

Benefits of Oil Spill Remote Sensing

- Real-time oil spill remote sensing information can help mitigate the potentially disastrous effects of major oil spills on marine and freshwater environments

Environment Canada 2006