Airborne and Satellite Oil Spill Remote Sensing in Support of Disaster Response

Ira Leifer[1,2], Bill Lehr[3], Greg Swayze[4], Roger Clark[4], Deborah Simecek-Beatty[3], Catherine Jones[5], Ben Holt[5], Philip Dennison[6], Eliza Bradley[2], Dar Roberts[2], Scott Matheson[6], Molly Reif[7], Jennifer Wozencraft[7], Yongxiang Hu[8], Jan Svejkovsky[9]

[1]Bubbleology Research International. [2]University of California, Santa Barbara
[3]NOAA ORR, [4]USGS, [5]JPL, [6]Univ Utah, [7]US Army Corps of Engineers, [8]NASA Langley, [9]Ocean Imaging

California Oil Spill Prevention and Response Chevron Technology Workshop
San Ramon CA, Feb 26-28 2013

Thanks to the critical enabling support from….

NASA

Jet Propulsion Laboratory
California Institute of Technology

NOAA

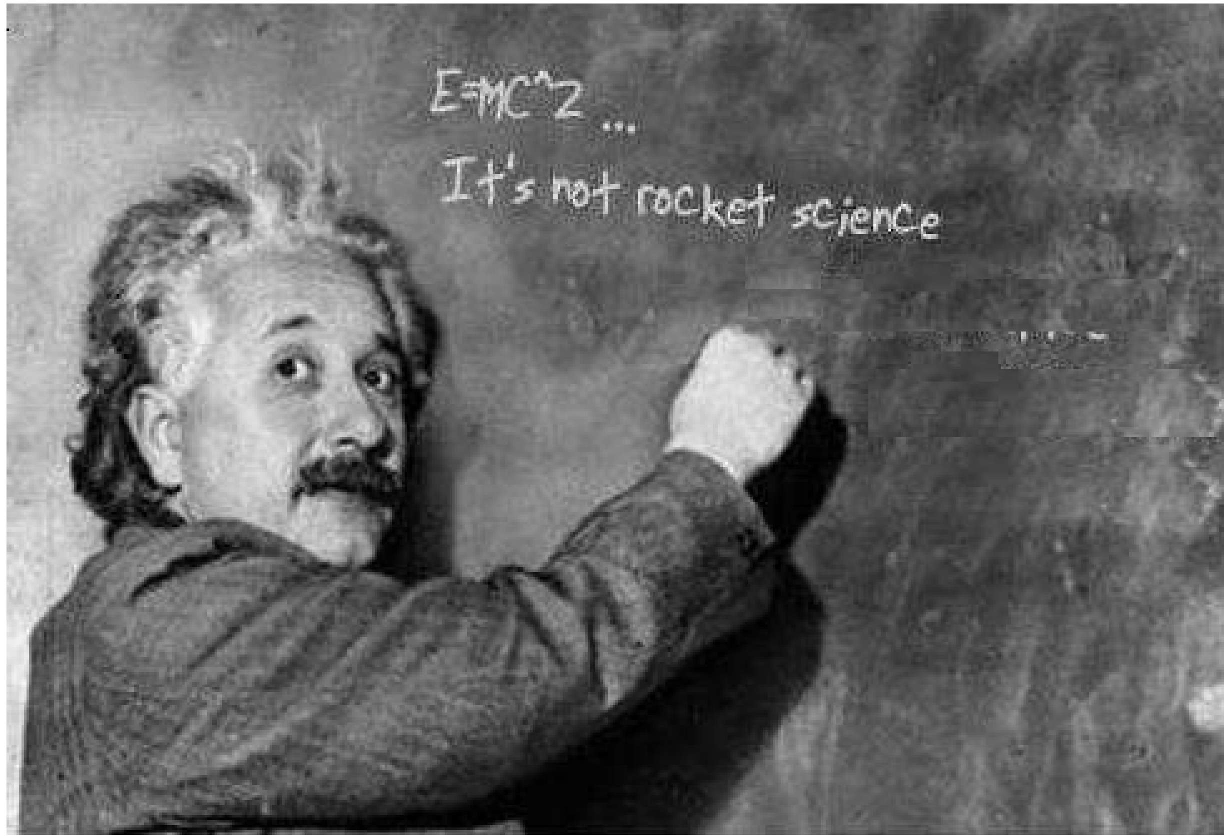
USGS
science for a changing world

US Army Corps of Engineers

Oil spill response is need-based science

Needs:

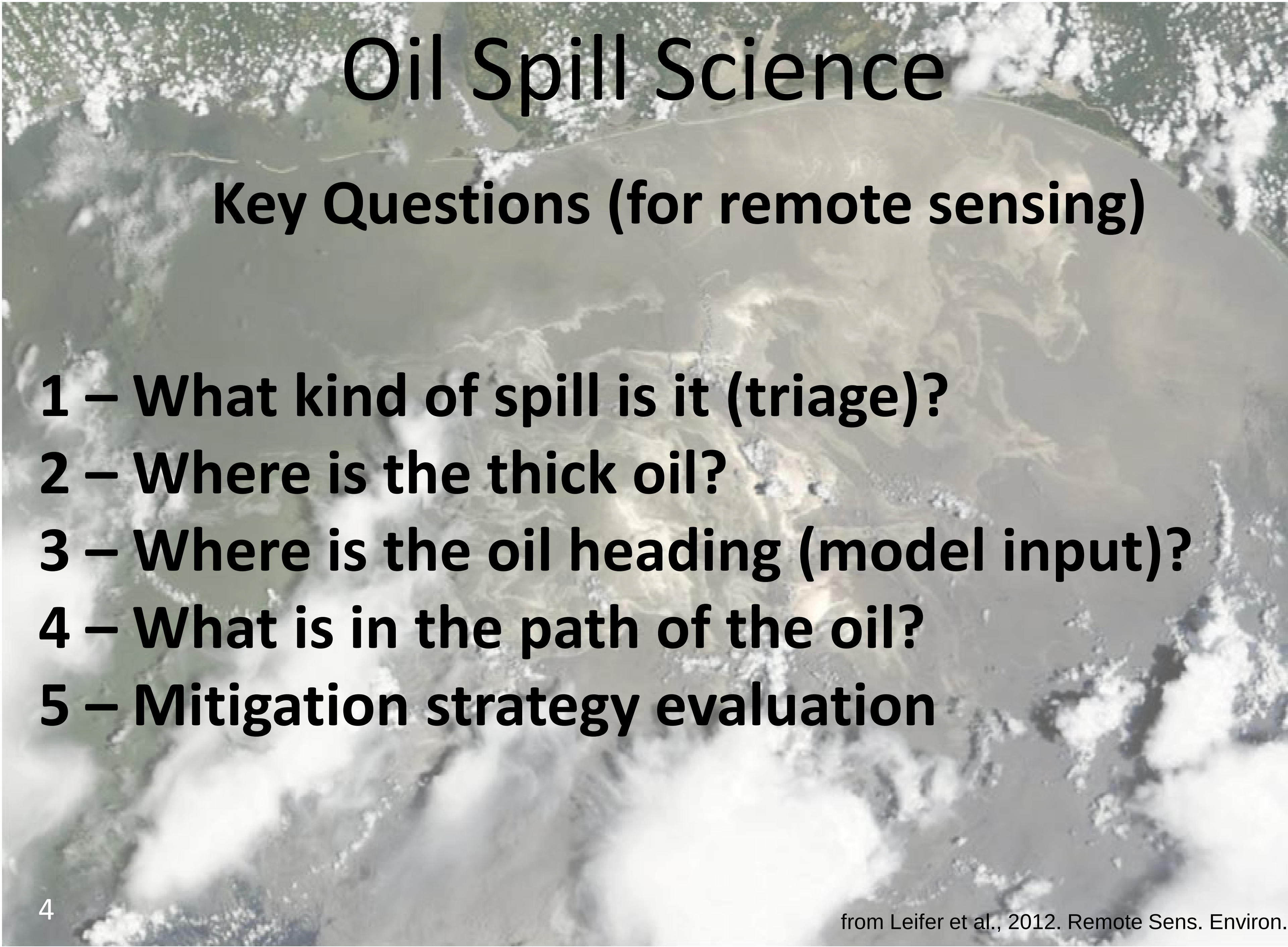
Fast
Proven
Reliable
Well Understood
USEFUL!!!



Useful => Answers useful questions in a useful manner.

Oil Spill Science

Key Questions (for remote sensing)



1 – What kind of spill is it (triage)?

2 – Where is the thick oil?

3 – Where is the oil heading (model input)?

4 – What is in the path of the oil?

5 – Mitigation strategy evaluation

from Leifer et al., 2012. Remote Sens. Environ.

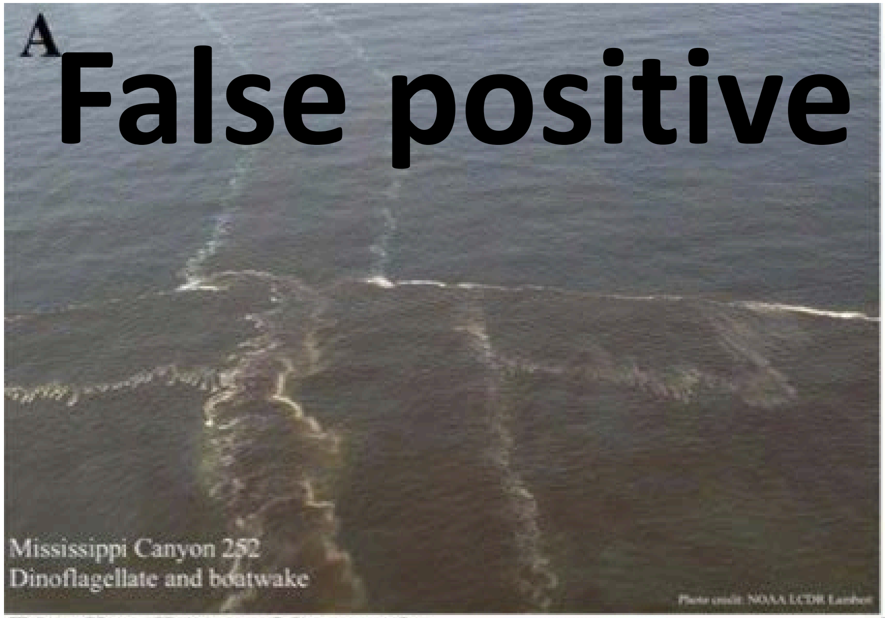
Useful Oil Spill Remote Sensing

1 - Triage – first-est is best-est.

2 – Where is the thick oil? Is there thick oil?
False positives.

3– What is in the path of the oil?
Ecosystem mapping

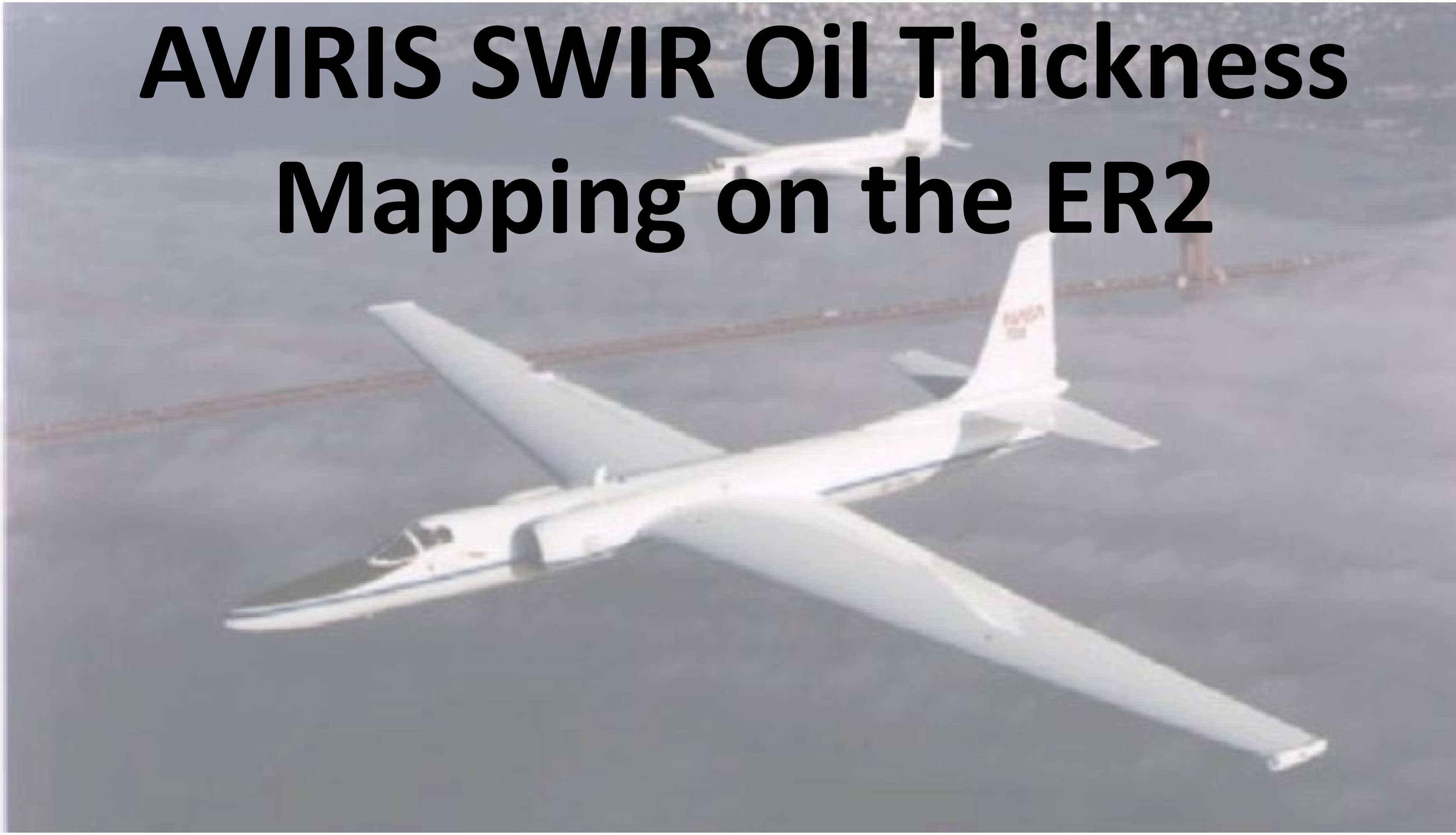
4 – Mitigation strategy evaluation



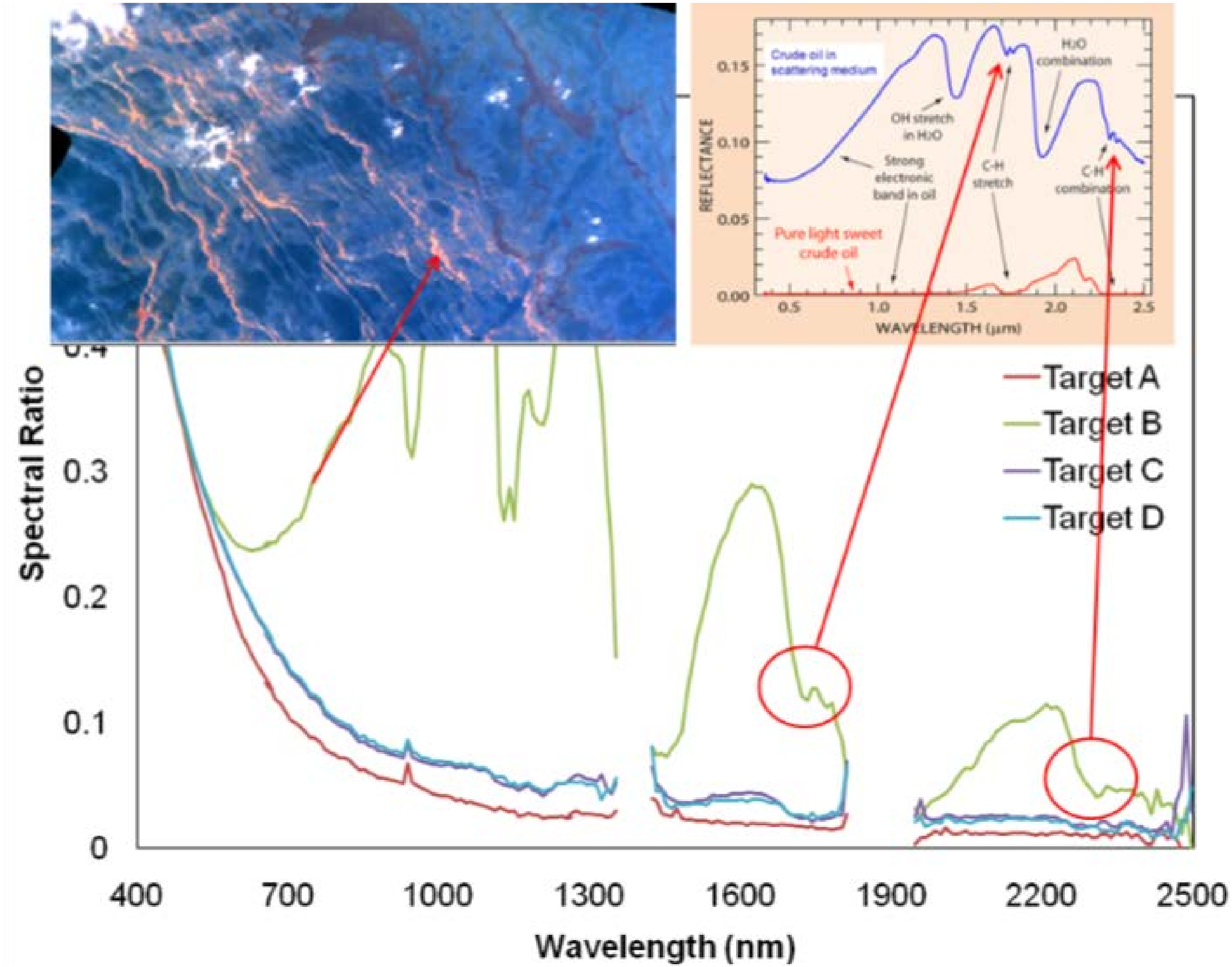
Dinoflagellate and boatwake

Red emulsified oil with dull and silver sheens in convergence

AVIRIS SWIR Oil Thickness Mapping on the ER2

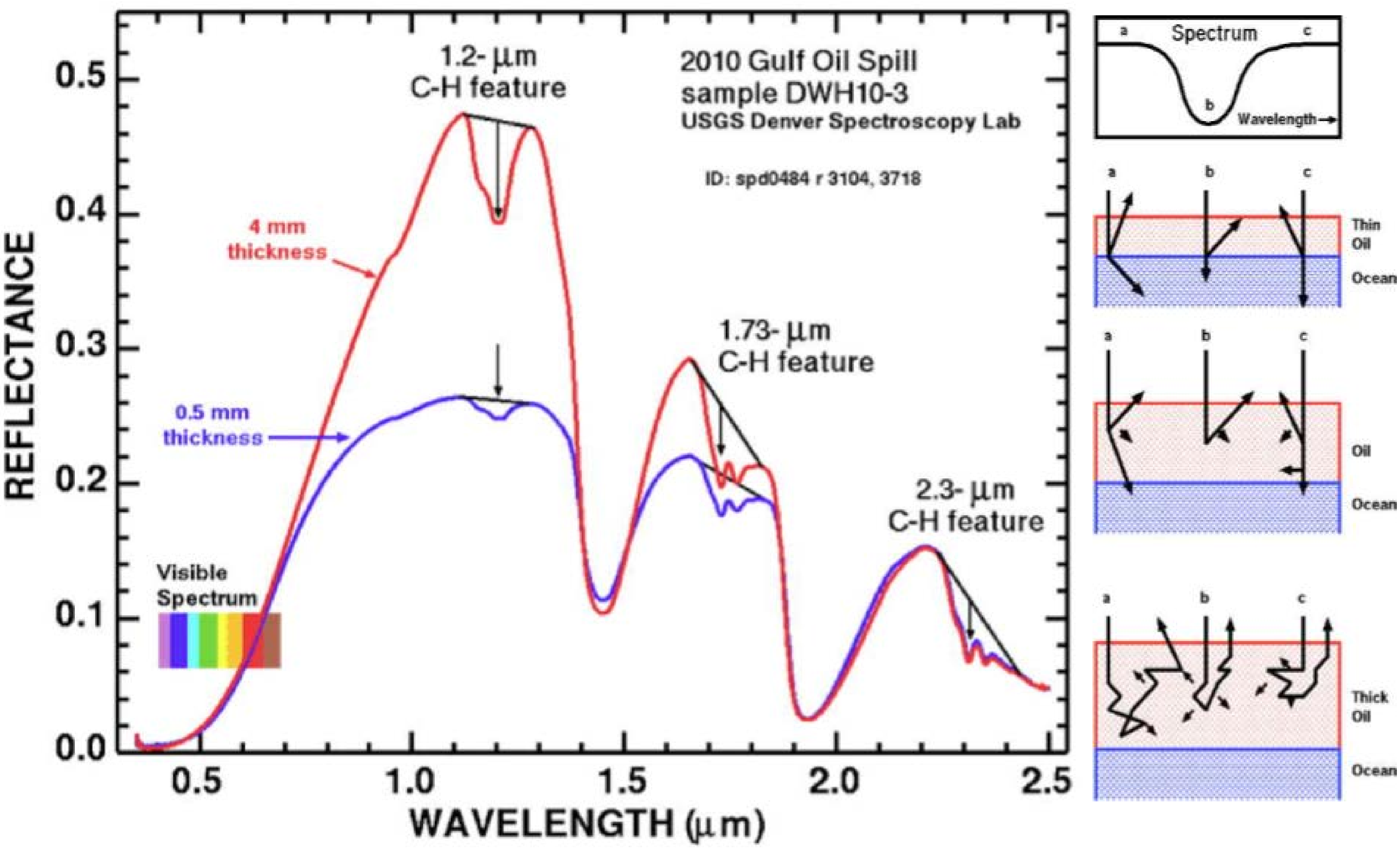


AIRIS Measurements of Carbon-Hydrogen Bond Spectral Signature in Gulf Oil Spill



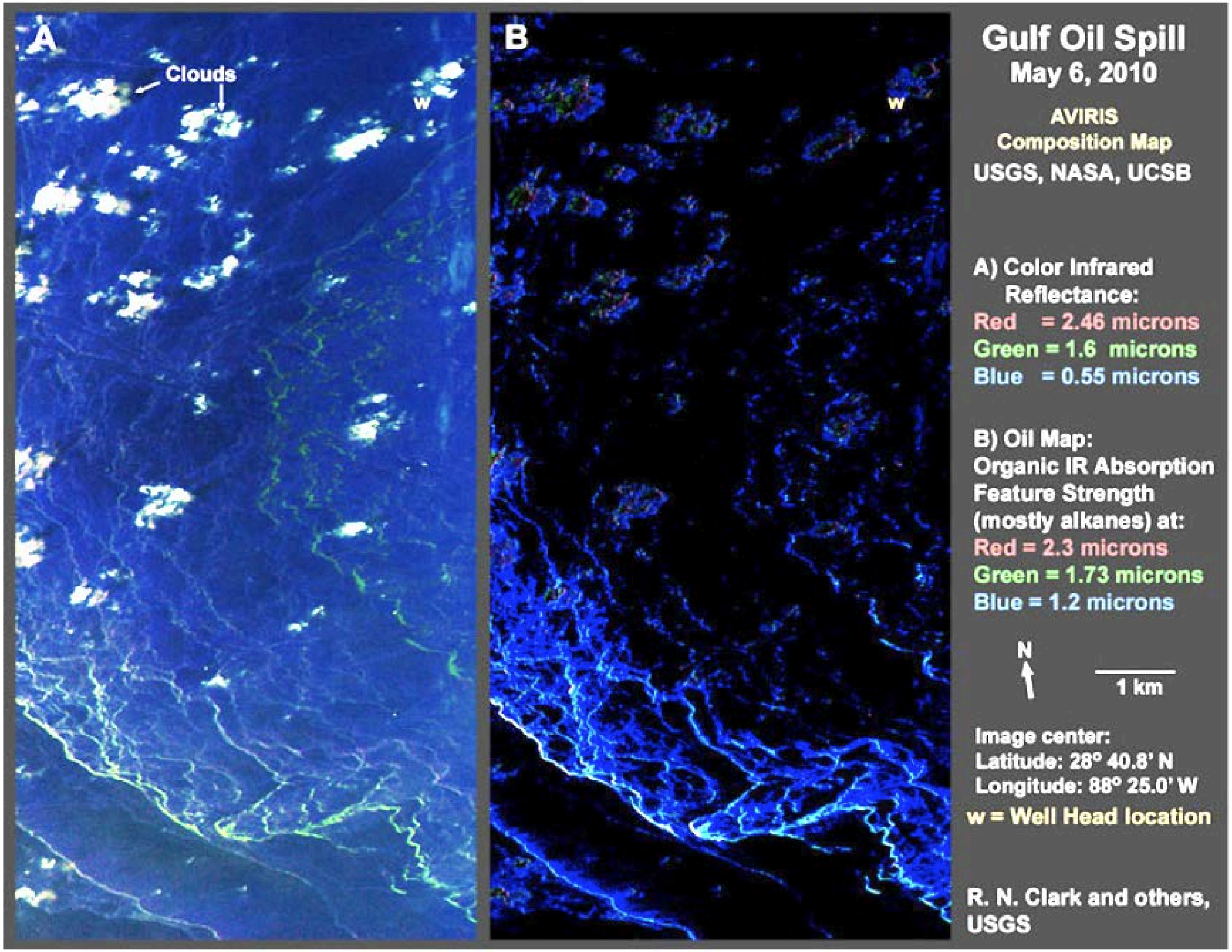
First AVIRIS results over the Gulf Oil Spill showed the spectroscopic signature of the crude oil carbon-hydrogen bond SWIR absorption features.

Oil Imaging Spectroscopy



from Clark et al., 2010b. Open source report

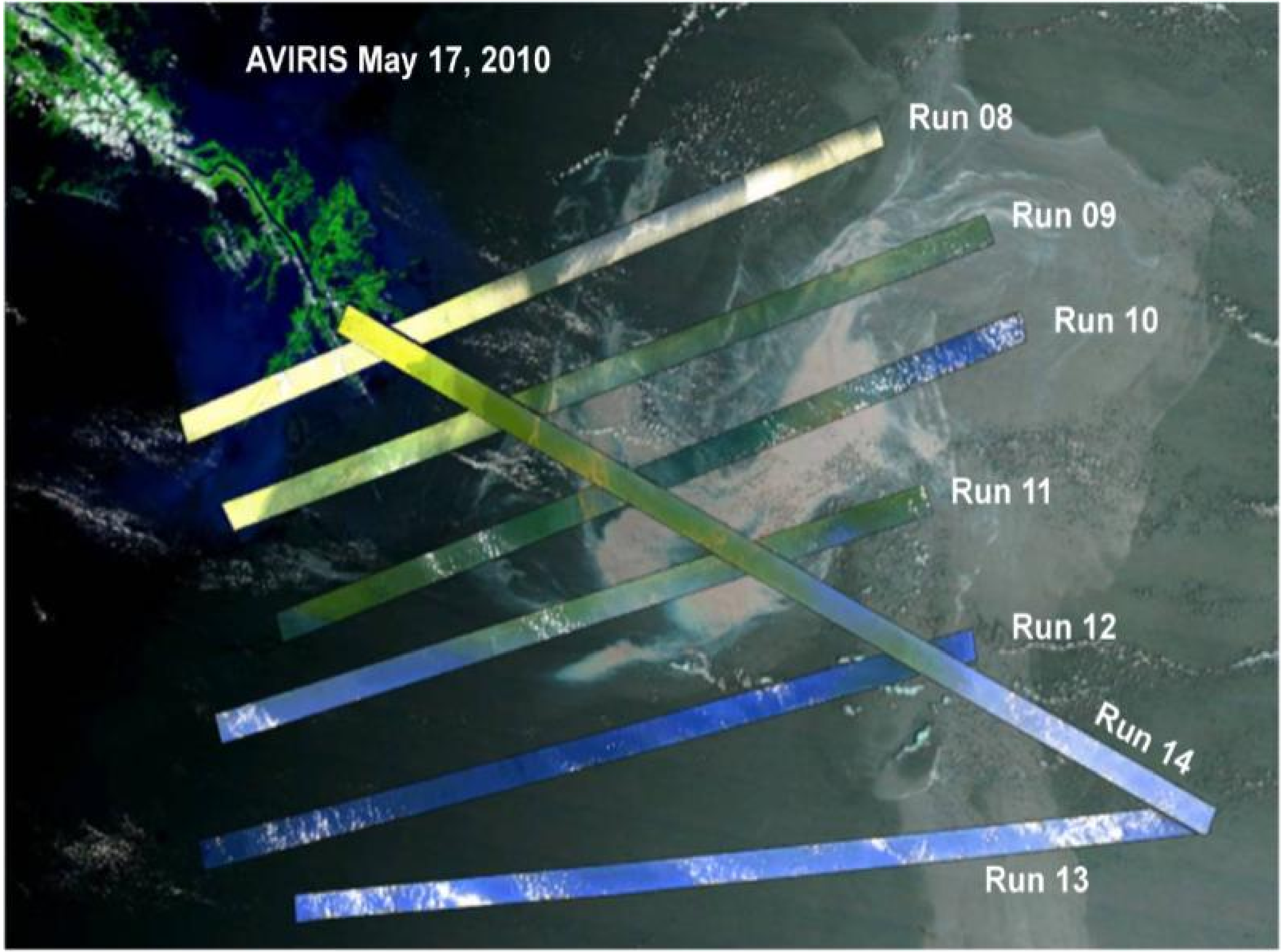
USGS first Mapping of 1200, 1730, and 2300 nm Carbon-Hydrogen Bond Absorption with AVIRIS



Key Hurdle: Captured Phenomena

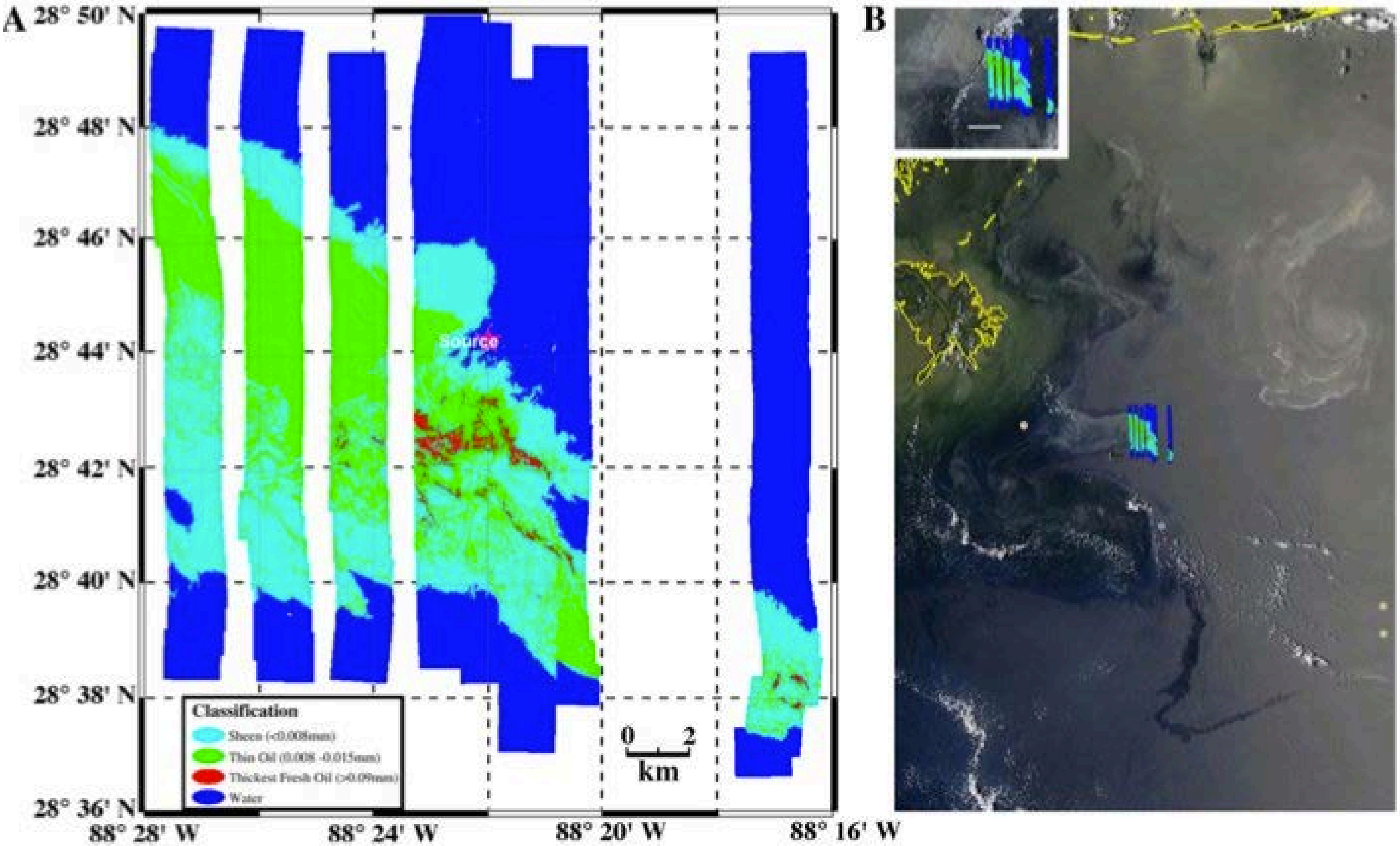
from Clark et al., 2010b. Open source report

AVIRIS oil slick coverage on the ER2



From Clark et al., 2010b open file report

Ocean Imaging – Timely Oil Thickness Classification



please pay attention during Jan's talk

Total oil AVIRIS mapped 17 may 2010

Table 2. Oil volume calculation from May 17 over flight.

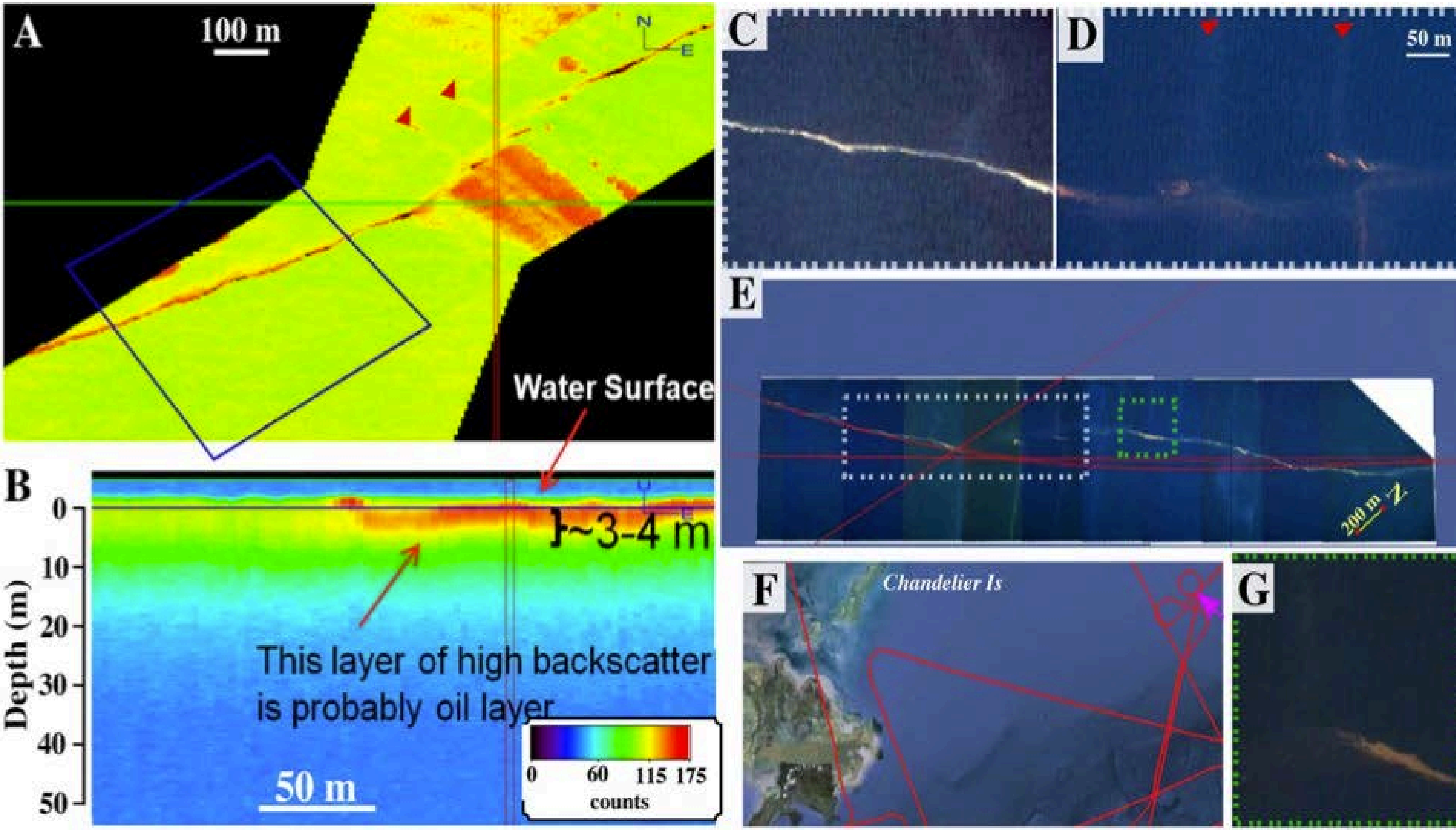
AVIRIS May 17, 2010

Total oil found Runs 08-11 & 14

Run	Conservative	Aggressive	Possible
08	14,384 liters	72,133 liters	79,796 liters
09	523,743 liters	911,280 liters	4,592,215 liters
10	845,240 liters	1,656,678 liters	3,834,731 liters
11	1,143,797 liters	1,866,838 liters	12,646,467 liters
14	494,846 liters	945,667 liters	3,239,775 liters
08	90 barrels	454 barrels	502 barrels
09	3,294 barrels	5,732 barrels	28,884 barrels
10	5,316 barrels	10,420 barrels	24,119 barrels
11	7,194 barrels	11,742 barrels	79,543 barrels
14	3,112 barrels	5,948 barrels	20,377 barrels
Total:	3,022,010 liters	5,452,596 liters	24,392,984 liters
	19,006 barrels	34,296 barrels	153,425 barrels

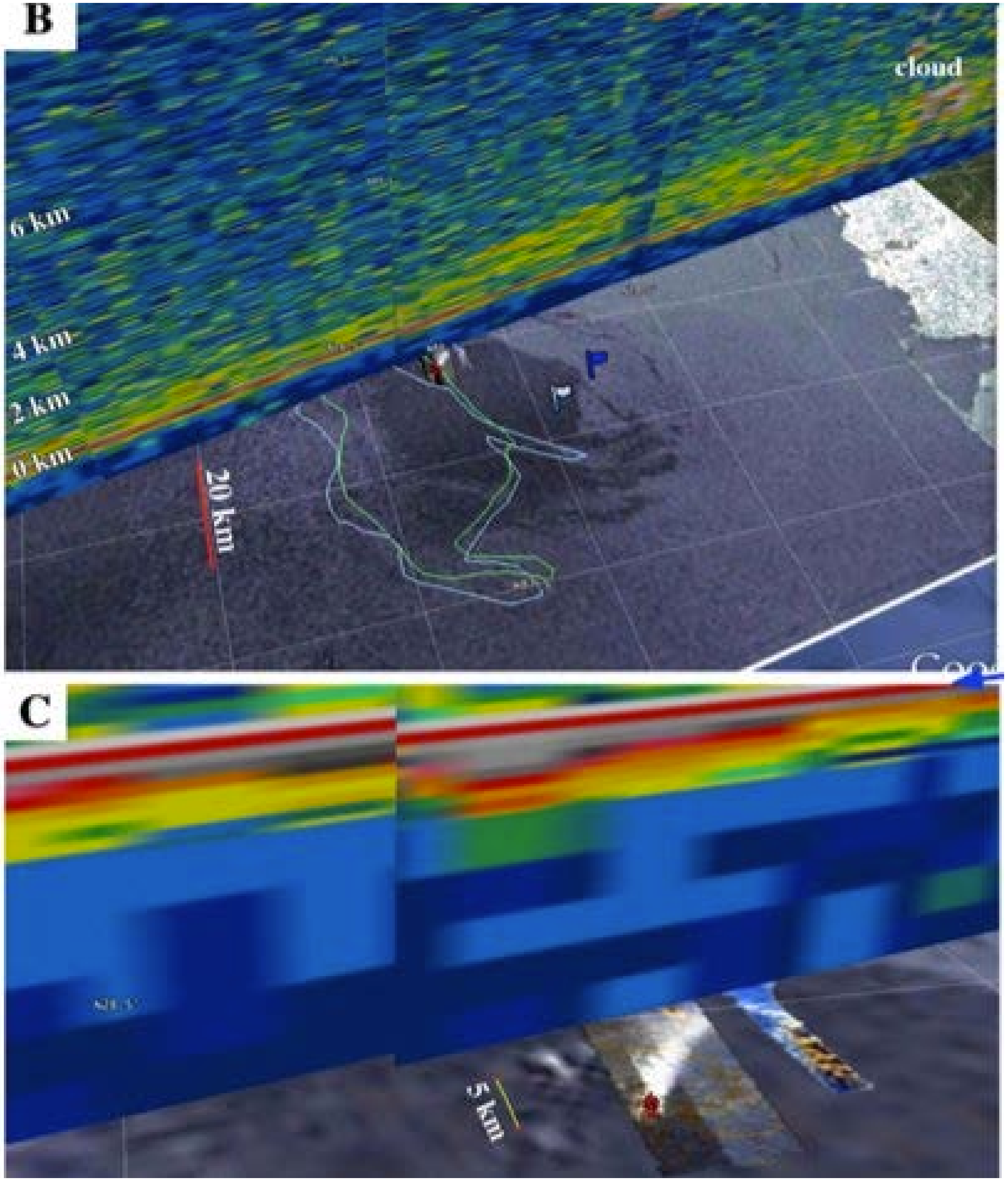
From Clark et al., 2010b open file report

Airborne LIDAR for submerged oil detection



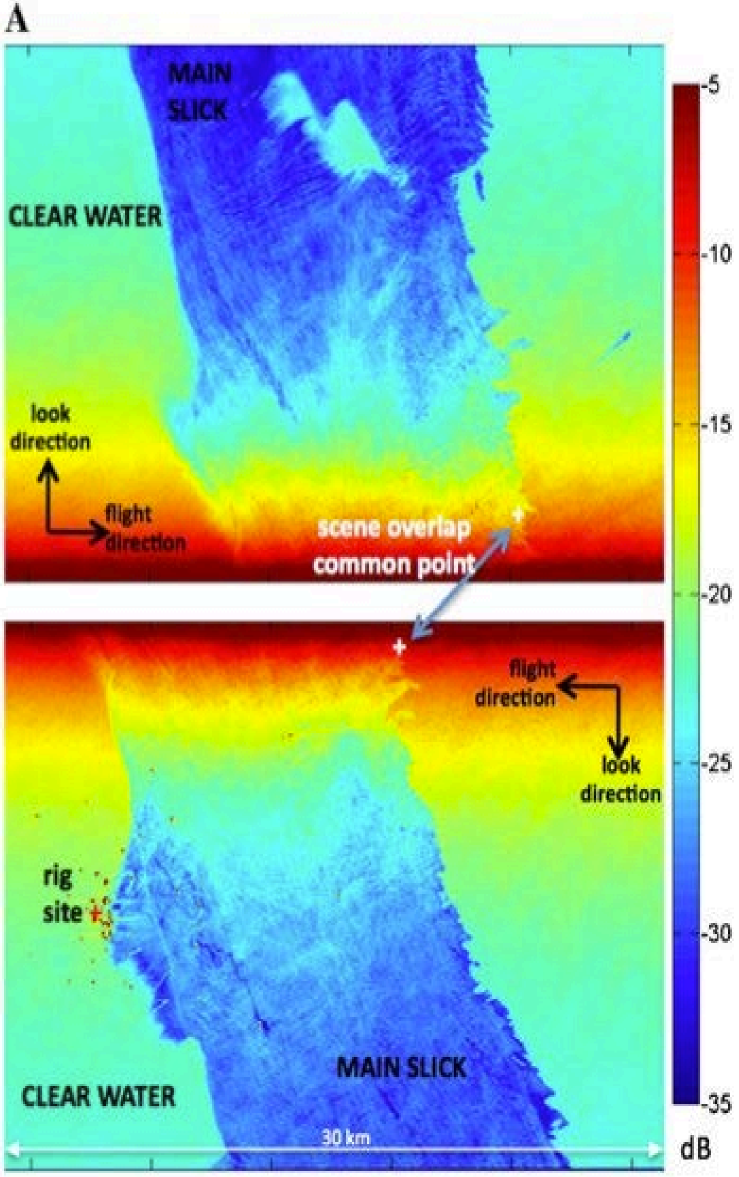
From Leifer et al., 2012 *Remote Sensing of Environment*

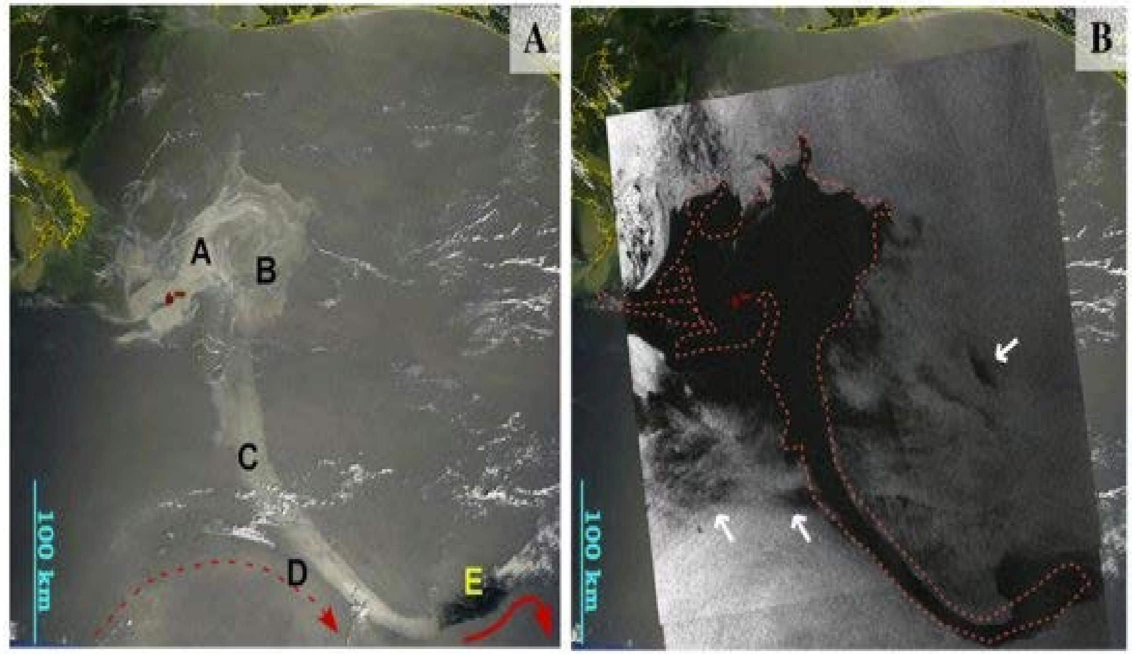
Satellite LIDAR for submerged oil detection



From Leifer et al., 2012
Remote Sensing of Environment

Airborne UAV SAR high resolution Oil slick thickness mapping

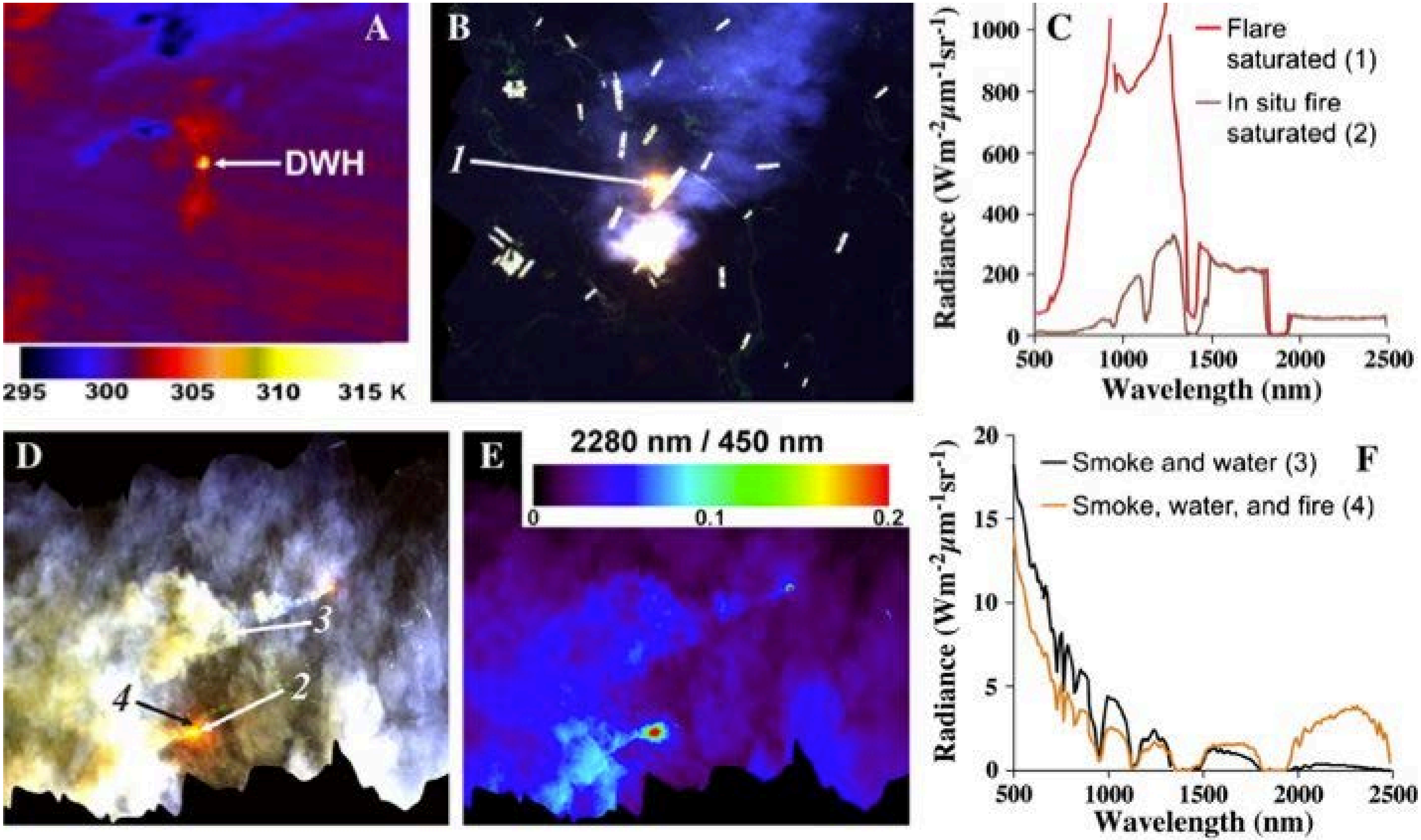




UAVSAR High sensitivity allows sensing of dielectric coefficient of oil slick

From Leifer et al., 2012 *Remote Sensing of Environment*

Infrared Hyperspectral Monitoring of In Situ Burn (AVIRIS)



From Leifer et al., 2012 *Remote Sensing of Environment*

Federal Oil Spill Team for Emergency Response using Remote Sensing *FOSTERRS*

Participation : NOAA, NASA, NRL, USGS, USCG . . . .

Mission: **To coordinate the dissemination of information on current State-of-the-Art remote sensing technology in support of spill response and policy decision**

- Collect and disseminate comprehensive information on state-of-the-art, oil spill response technologies and platforms.
- Solicit Readiness Assessments of technologies.
- Establish Agency Point(s) of Contact.
- Provide current information on asset availability for rapid tasking and efficient data delivery in support of oil spill responders.
- Organize focused workshops and meetings.

Airborne Oil Spill Remote Sensing Instruments

Table 2
Summary of oil spill remote sensing relevant airborne sensors.

Instrument	Region (bands)	Range (nm)	Platform	Resolution (m)	Cross track (pixels)	Primary link	Full name	Agency	Comment
AVIRIS	UV–NIR (224)	380–2500	Twin Otter, ER-2	4.4–20	677	http://aviris.jpl.nasa.gov/	Airborne Visible Infrared Imaging Spectrometer	NASA/Jet Propulsion Laboratory	Whisk broom
HyMap	UV–NIR (128)	450–2480	Multiple	3–10	512	www.hyvista.com	HYperspectral MAPping	HyVista Corp.	Whisk broom
SEBASS	MIR, TIR (128)	2500–5200, 7500–13,500	Twin Otter	2–7	128	www.aero.org/capabilities/documents/AER027_SEBASS_Final.pdf	Spatially Enhanced Broadband Array Spectrograph	The Aerospace Corp.	128 × 128 imaging element
ASPECT Multi-spectral	MIR, TIR (16)	3410–5330, 8730–11,360	Aero Commander 680 (twin engine)	1.1	1	http://www.epa.gov/NaturalEmergencies/flyinglab.htm	Airborne Spectral Photometric Environmental Collection Technology	EPA	Line scanner, flown at 1000 m
ASPECT FTIR	TIR (2048)	1266–	Aero Commander 680 (twin engine)	9	1	www.epa.gov/NaturalEmergencies/flyinglab.htm	Airborne Spectral Photometric Environmental Collection Technology	EPA	Fourier transform spectrometer
UAVSAR	L-band	1.2175–1.2975 GHz	Gulfstream 3	1.7–0.6 single look	9900	http://uavsar.jpl.nasa.gov/	Uninhabited Aerial Vehicle Synthetic Aperture Radar	NASA/Jet Propulsion Laboratory	22–65° incidence angles
HSRL	Vis, NIR (2)	532, 1064	B200 or Learjet	–	1	http://science.larc.nasa.gov/hsrl/	High Spectral Resolution Lidar	NASA/Langley	
CHARTS	Vis, NIR (2)	532, 1064	Twin engine	2/5 (topographic/hydrographic)	500	www.jalbtcx.org	Compact Hydrographic Airborne Rapid Total Survey, Optech Inc.	US Army Corps of Engineers/JALBTCX	3 or 20 kHz sample, to 60 m, SHOALS-3000 T20
CASI-1500	Vis–NIR (36)	375–1050	Twin engine	0.25–10	1500	www.jalbtcx.org	Compact Airborne Spectrographic Imager, ITRES	US Army Corps of Engineers/JALBTCX	Push broom, operates with CHARTS

UV—Ultraviolet, Vis—Visible, NIR—Near Infrared, MIR—Mid Infrared, TIR—Thermal Infrared. JALBTCX—Joint Airborne Lidar Bathymetry Technical Center of Expertise.

Satellite Oil Spill Remote Sensing Instruments & Platforms

Table 3
Summary of oil spill remote sensing relevant spaceborne sensors.

Instrument (satellite)	Bands (# bands)	Band range (nm)	Resolution (km)	Swath (km)	Revisit[A] (days)	Rapid response	Link	Acronym	Comment
LandSat 5, LandSat 7	Vis, NIR, TIR (8 bands)	450–12,500 nm	0.030–0.120	185	16	No	http://landsat.gsfc.nasa.gov/about/ http://landsat.usgs.gov/	Land Satellite	LandSat 7 had Scan Line Corrector failure
LandSat TM	Vis, NIR, TIR (7 bands)	450–12,500	0.03, 0.120	185	1–3/16	No	http://landsat.gsfc.nasa.gov/about/tm.html http://landsat.usgs.gov/	Land Satellite Thematic Mapper	Rapid revisit is for of-nadir
MODIS (Terra, Aqua)	Vis, MIR, TIR (36 bands)	405–14,385	0.25, 0.5, 1.0	2330	1–2	Yes	http://modis.gsfc.nasa.gov/	Moderate Resolution Imaging Spectroradiometer	120 m in TIR band
ASTER (Terra)	VNIR, NIR, TIR (14 bands)	520–11,650	0.015/0.03/0.09	60	4–16	No	http://asterweb.jpl.nasa.gov/	Advanced Spaceborne Thermal Emission and Reflection Radiometer	
MISR (Terra)	Vis, NIR (4 bands)	446.4–866.4	0.275–1.1	360	2–9	No	http://www-misr.jpl.nasa.gov/	Multiangle Imaging SpectroRadiometer	9 different, simultaneous along track viewing angles
MERIS (ENVISAT)	Vis–NIR (15 bands)	412.5–900	2.36×0.30–1.04×1.2	1150	3		http://miravi.eo.esa.int/en/ http://www.esa.int/esaEO/SEMWYN2VQUD_index_0_m.html	Medium Resolution Imaging Spectrometer	Bands can be reprogrammed
HICO	Vis–NIR (90 bands)	390–1040	0.95	43	–	No	http://www.nasa.gov/mission_pages/station/research/experiments/HREP-HICO.html	Hyperspectral Imager for the Coastal Ocean	International Space Station
Quickbird	Vis–NIR (4 bands)	450–900	.00061/0.0024	16.4	1–3.5	Yes	http://www.digitalglobe.com http://www.satimagingcorp.com/satellite-sensors/quickbird.html	–	Panchromatic has higher resolution
AVHRR/3 (POES)	Vis, MIR, TIR (6 bands)	580–12,500	1.09	2440	0.5	No	http://noaasis.noaa.gov/NOAASIS/ml/avhrr.html http://www.class.ngdc.noaa.gov/data_available/avhrr/index.htm	Advanced Very High Resolution Radiometer (Polar-orbiting Operational Environmental Satellites)	
RadarSat1	C-band	5.3 GHz	0.008–0.1	50–500	24	Yes	http://www.asc-csa.gc.ca/eng/satellites/radarsat1/	Radar Satellite-1	
RadarSat2	C-band	5.405 GHz	0.001–0.100	20–1000	12	Yes	http://www.asc-csa.gc.ca/eng/satellites/Radarsat2/ http://gs.mdacorporation.com/SatelliteData/Radarsat2/Features.aspx	Radar Satellite-2	Left and right look halves revisit time
ASAR (ENVISAT)	C-band	5.331 GHz	0.010–1.0	10–1000	35	Yes	http://envisat.esa.int/instruments/asar/	Advanced Synthetic Aperture Radar (ENVIronmental SATellite)	Provides continuity with ERS-2
ERS-SAR (ERS-2)	C-band	5.330 GHz	0.006–0.030	5–100	3/35/168	Yes	http://earth.esa.int/ers/	European Resource-Sensing—Synthetic Aperture Radar	Orbital adjustment with different repeat cycles Mission ended 5 Sept.,2011
Cosmo SkyMed2	X-band	9.6 GHz	0.001–0.1	10–200	0.5–1.25	Yes	http://www.telespazio.it/cosmo.html	Constellation of Small Satellites for Mediterranean basin Observation	A constellation of 4 satellites, steerable
PALSAR (ALOS)	L-band	1.270 GHz	0.007–0.1	20/40/70–350	46/2	No	http://www.eorc.jaxa.jp/ALOS/en/about/palsar.htm	Phased Array-type L-band Synthetic Aperture Radar (Advanced Land Observing Satellite)	Multiple resolution modes, fast revisit by targeting. 20 km is experimental mode.
TerraSAR-X	X-band	9.6 GHz	0.001–0.018	5–150	2.5	Yes	http://www.infoterra.de/terrasar-x-satellite	Terra Synthetic Aperture Radar Xband	Has twin, TanDEM-X satellite
CALIOP (CALIPSO)	Vis, NIR (2 bands)	532, 1064	0.1	–	16	No	http://www-calipso.larc.nasa.gov/	Cloud Aerosol Lidar with Orthogonal Polarization (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation)	Vertical resolution is (0.03–0.60 km)
SCIAMACHY (ENVISAT)	UV, Vis, NIR (15 bands)	240–2380	30x60–32x215	1000, 32×215, 1000	3	No	http://envisat.esa.int/instruments/sciamachy/	Scanning Imaging Absorption Spectrometer for Atmospheric CHartographY (ENVIronmental SATellite)	1000 km for limb mode
ASMR-E (Aqua)	Microwave (12 bands)	6.925–89 GHz	6×4–74×43	1445	1	No	http://wwwghcc.msfc.nasa.gov/AMSR/	Advanced Microwave Scanning Radiometer—Earth Observing Satellite	Ceased operation 4 Oct. 2011

Vis—Visible spectrum, NIR—Near infrared, UV—Ultraviolet, TIR—Thermal infrared. [A] repeat day is maximum.

Conclusions

- **Hyperspectral SWIR imaging spectroscopy is diagnostic of thickness, oil:water ratio.**
- **Lidar can remotely sense subsurface oil.**
- **Combined Lidar, and hyperspectral spectroscopy can monitor dispersant effectiveness.**
- **UAVSAR maps oil thickness.**
- **SWIR can be used to monitor *in situ* burning.**
- **Satellite SAR is more sensitive than visible satellite, but trigger level is uncertain.**

- **Optimum time for developing oil spill remote sensing technologies is NOT during a spill.**

(but often the only time significant surface oil and resources are available is during an oil spill)

References

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