Space-Based Oil Spill Remote Sensing

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Thanks ….

To the critical enabling support of:

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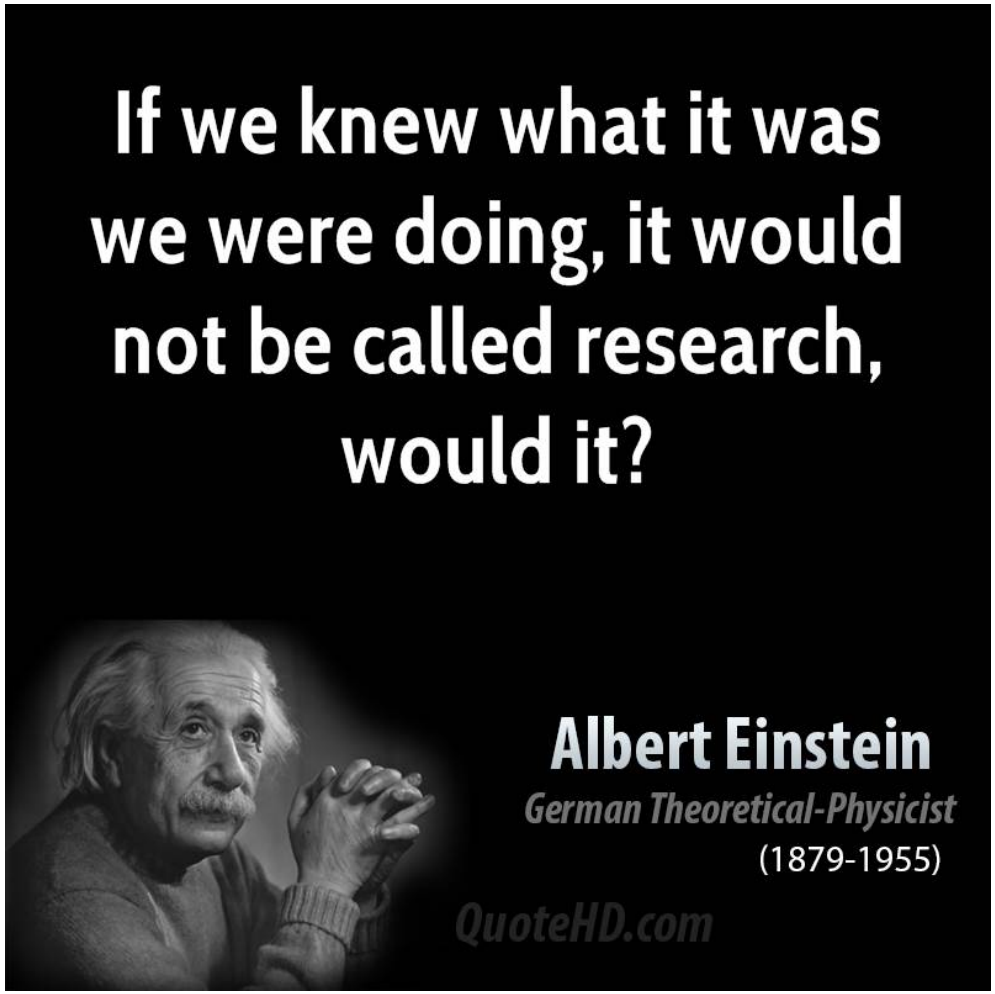
http://www.imdb.com/media/rm2092021760/tt0099785?ref_=ttmd_md_pv#

General Disclaimer



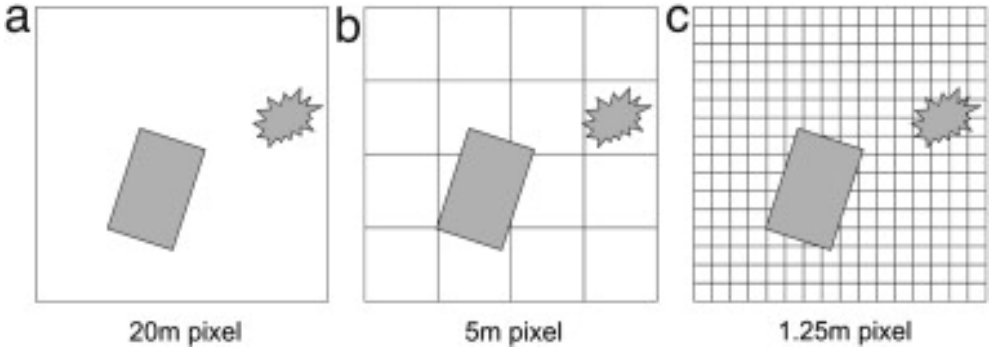
http://www.quotehd.com/quotes/albert-einstein-physicist-if-we-knew-what-it-was-we-were-doing-it-would-not-be

What is Remote Sensing?

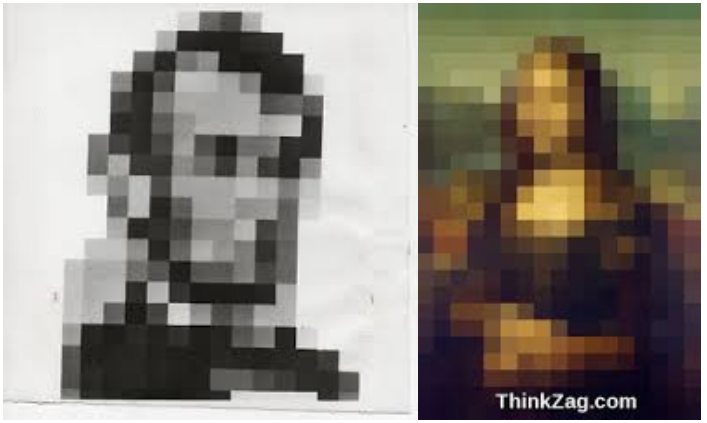
- The analysis of reflected/scattered electromagnetic radiation to determine the characteristics of the surface
- Passive reflected radiation from the sun or thermal emissions
- Active reflected radiation – typically radar or lidar for oil remote sensing
- Analysis generally involves turning into a map

Remote Sensing Analysis

- Generally to produce a map
- Pixel-based spectroscopy – use of colors (or shades of grey to make maps
- Pattern or texture-based (image segmentation)
- Pixel resolution is key (though poor works if pattern is well-defined)



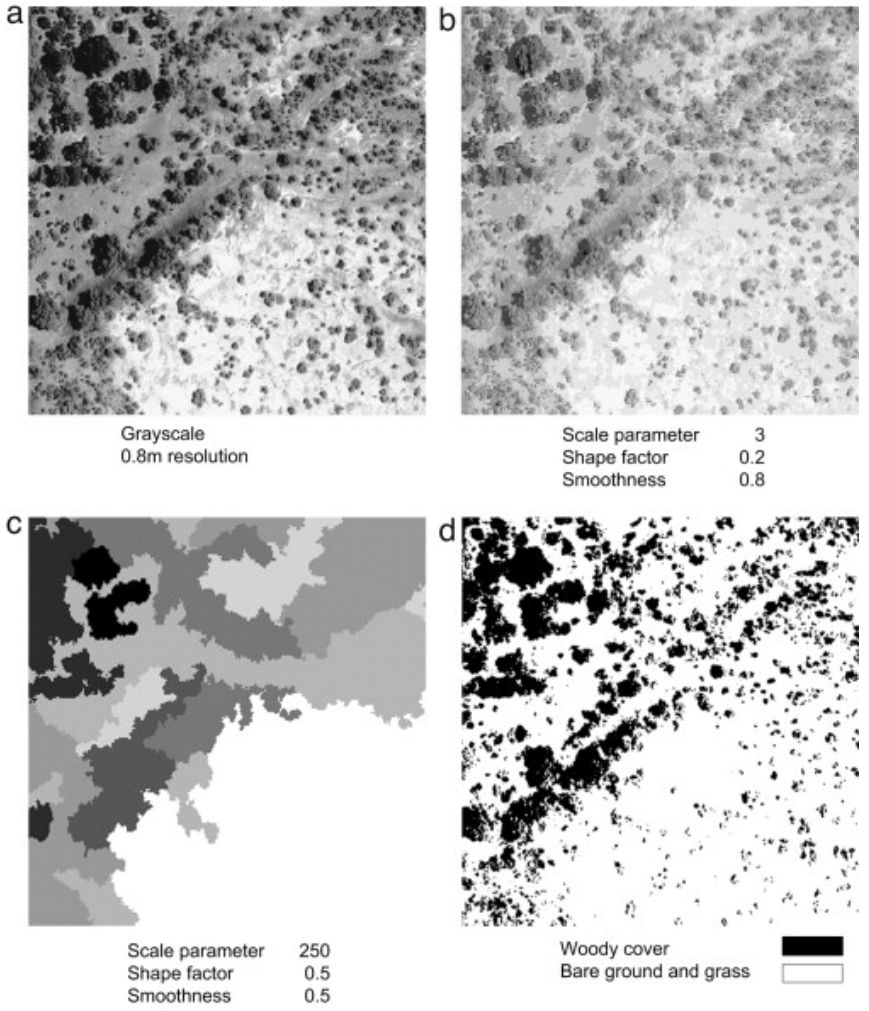
- Pattern recognition can follow pixel analysis



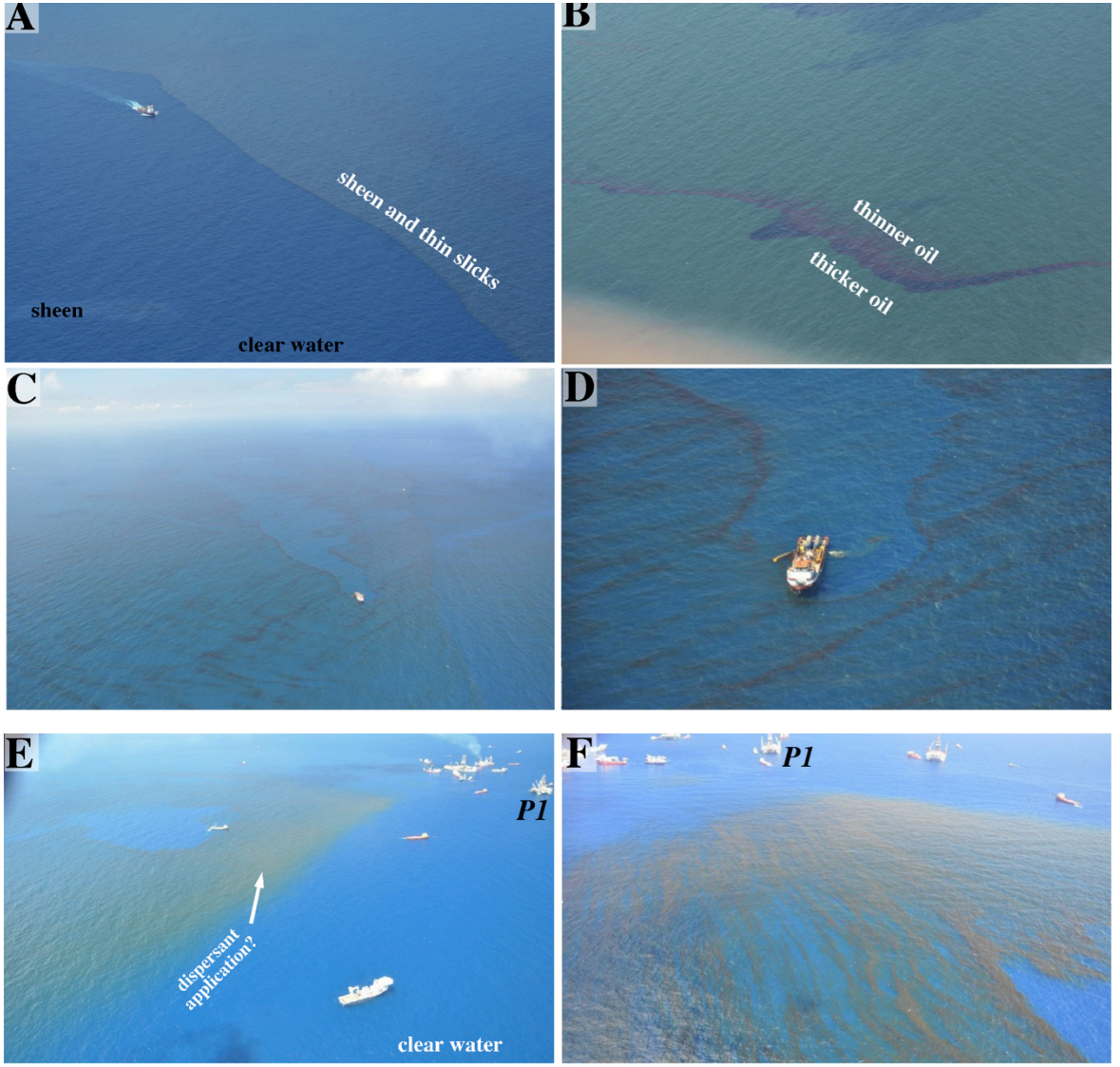
http://www.britannica.com/topic/perception/images-videos

Remote Sensing Analysis

Pixel classification (assignment) poor if based on grayscale intensity



Experienced Observers use patterns and colors
Human eye – Very broad band spectroscopy



Colors can deceive
Human eye – very broad spectroscopy

Dinoflagellate and boatwake

Red emulsified oil with dull and silver sheens in convergence

Sargassum

Red-orange emulsified oil in bands with windrows of silver and dull sheen

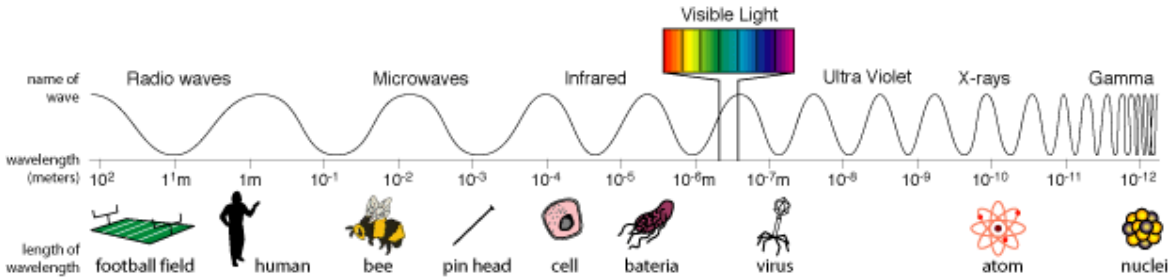
Brown Algae

Dark brown oil ~0.4 - 0.8 km from source

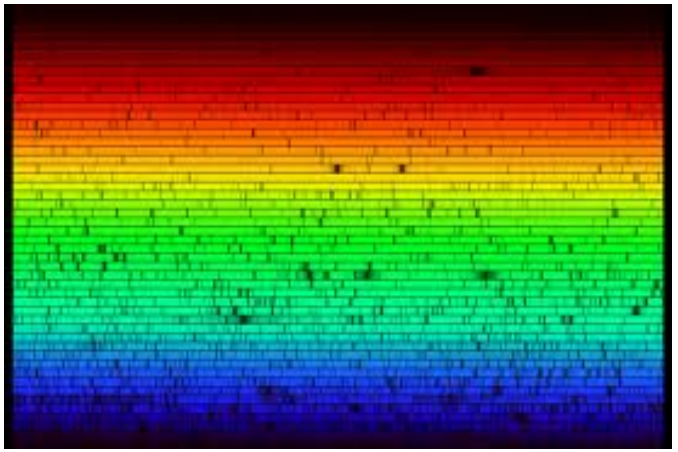
Remote Sensing Spectroscopy

- Everything has color, lots of them, more than you can see
- However, the pure rainbow of the sun is ruined by molecular absorptions

http://en.wikipedia.org/wiki/File:GeordiLaForge.jpg

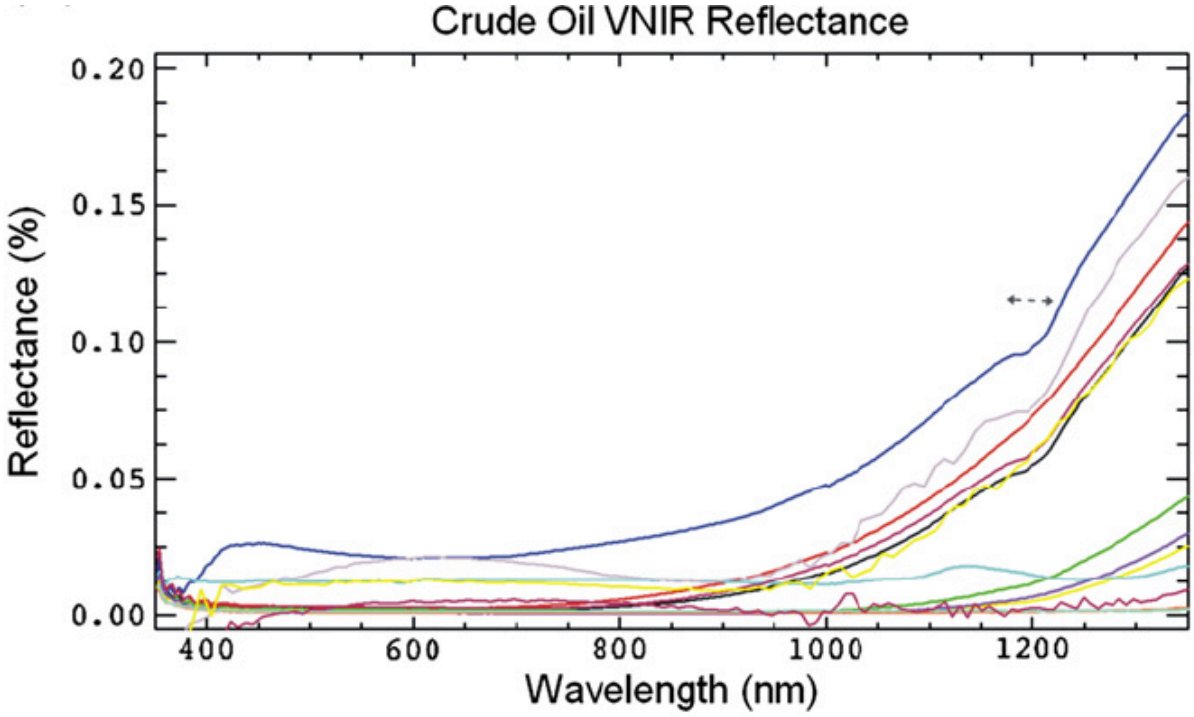


http://science.hq.nasa.gov/kids/imagers/ems/

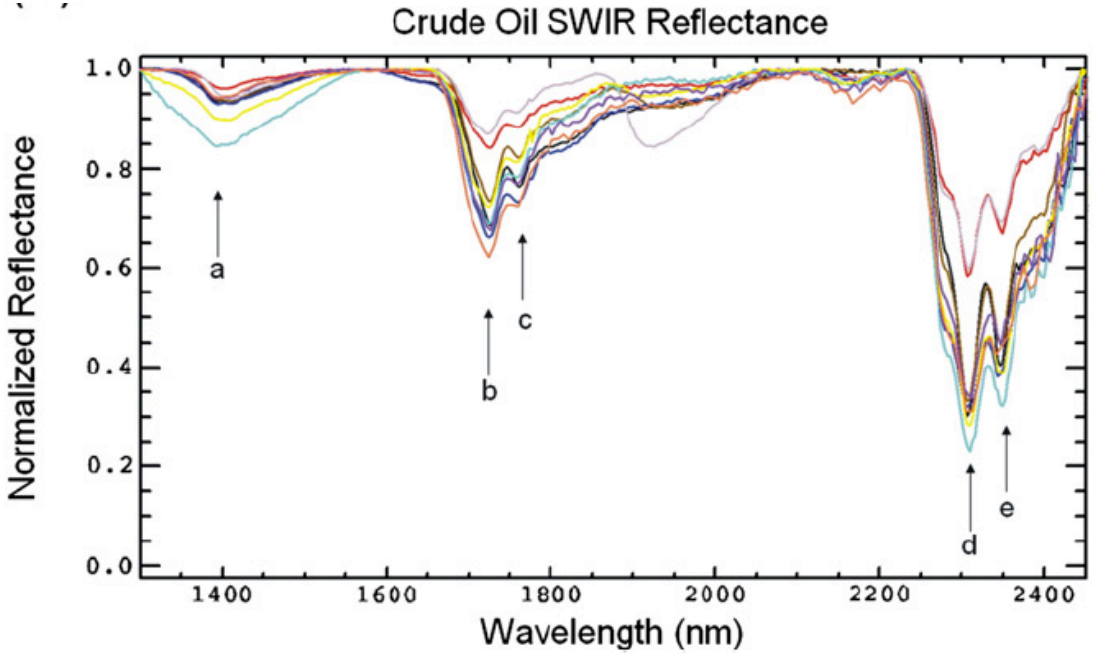


http://apod.nasa.gov/apod/ap100627.html

Oil VIS-SWIR spectroscopy



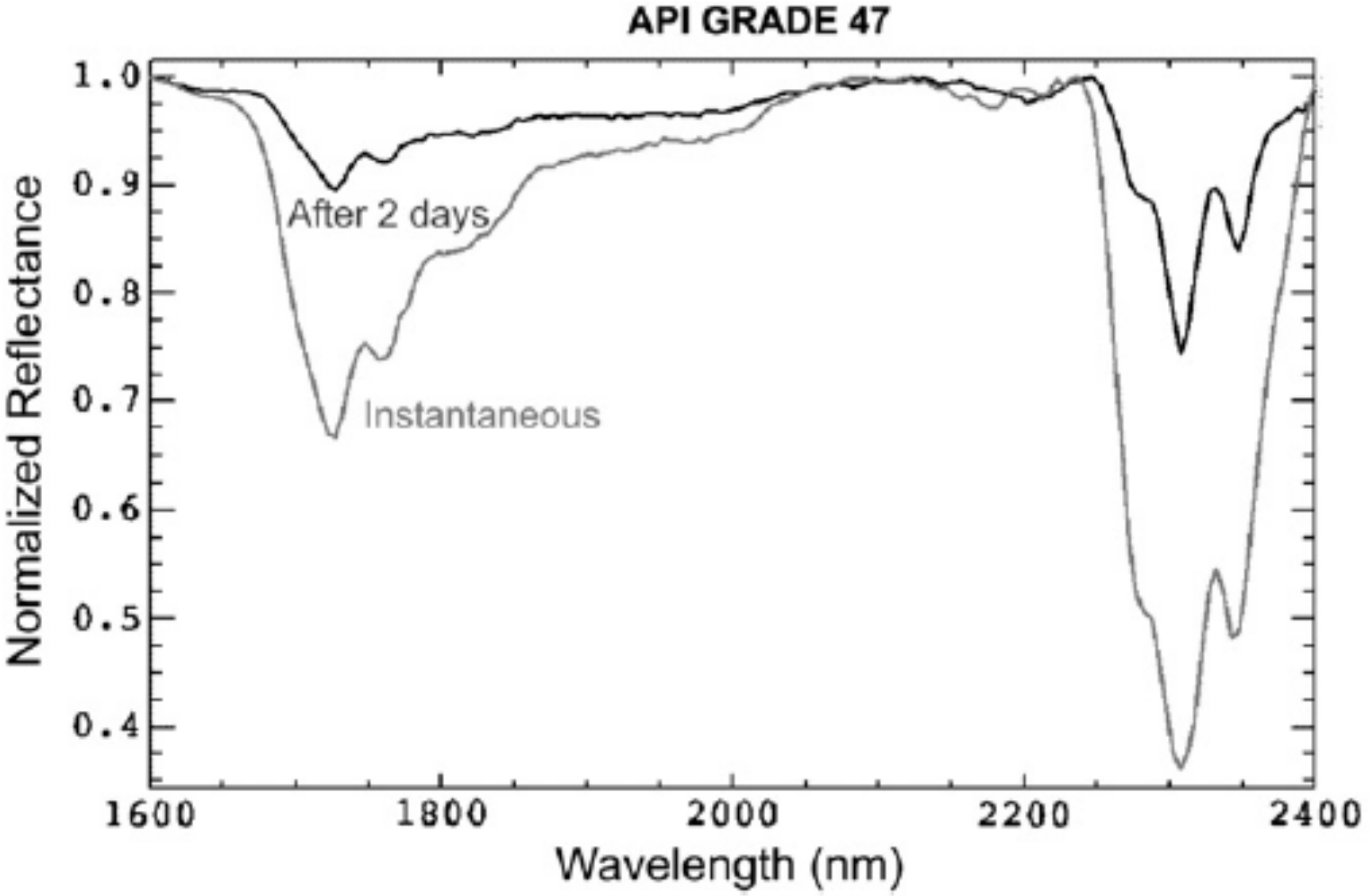
VNIR crude oil reflectance spectra showing range of C-H 2nd overtone



SWIR crude oil reflectance spectra continuum removed

From Lammoglia et al 2011

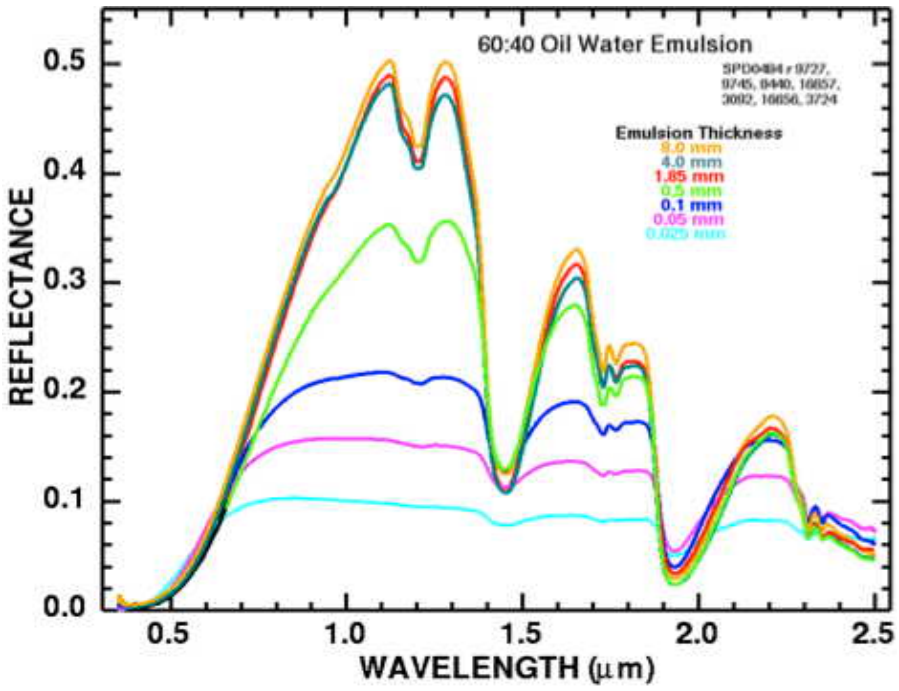
Oil near and short wave infrared spectroscopy

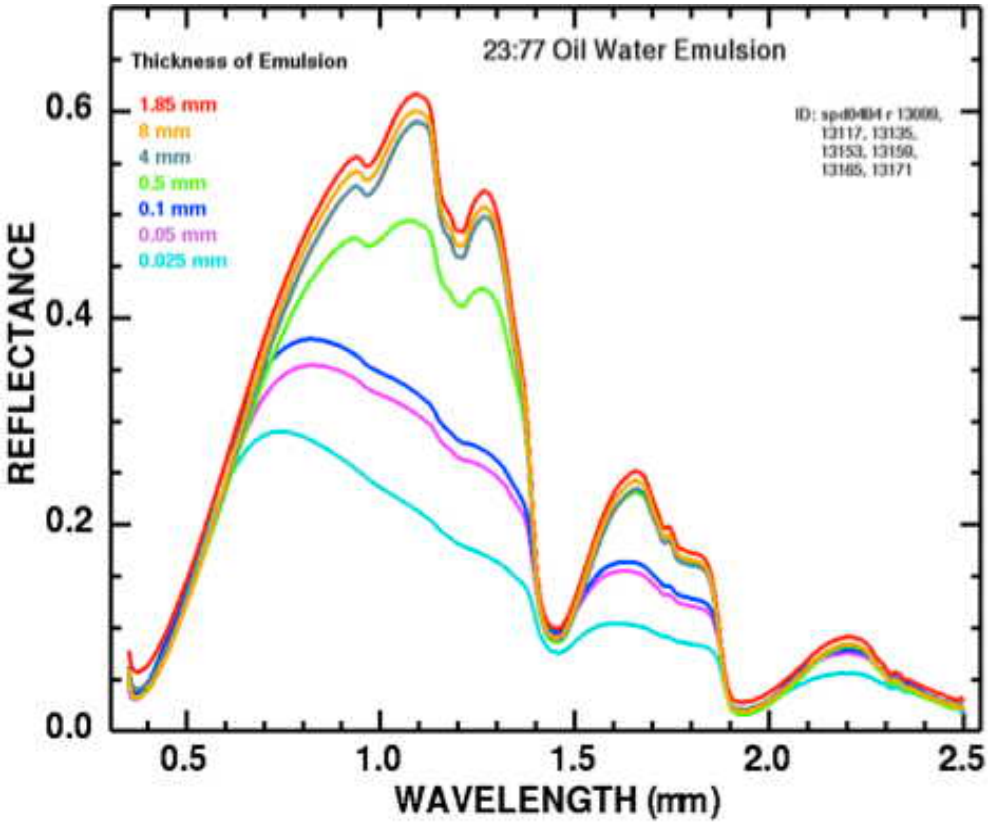


Reflectance spectra for API47 oil initial and after 2 days of weathering.

From Lammoglia et al 2011

Example Laboratory Spectra for Deepwater Horizon Spill Oil Emulsions





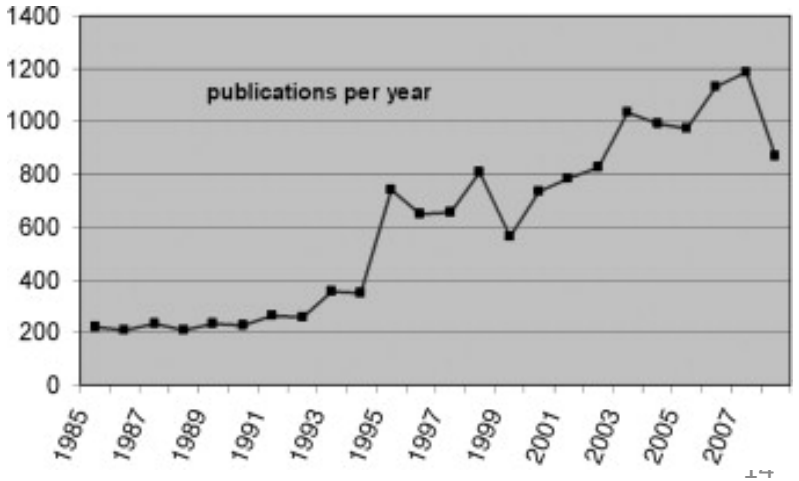
Laboratory spectra show spectral variability with thickness and oil to water emulsion ratio

from Clark et al., 2010b.; Leifer et al. 2012

Why Space Remote Sensing (oil)

- Space remote sensing can provide a *synoptic* view
- Can inspect remote areas as quickly as targetable
- Can collect data when weather prevents airborne observers take off
- Some products can be communicated readily to public
- Can evaluate ecological damage

https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=30028



Space Remote Sensing Issues (oil)

- Visual spectral approaches require no clouds and daylight – can be a big limitation
- Radar allows 24/7 observations if winds are in a narrow range, but many false positives (other data may reduce)
- Satellites feature: coarse resolution, poor coverage, infrequent revisit
- Slow revisit enhances cloud risk
- All space-based current approaches are non-diagnostic - most useful if a spill is known and well behaved
- Visual spectral approaches work poorly at high latitudes (too much air)

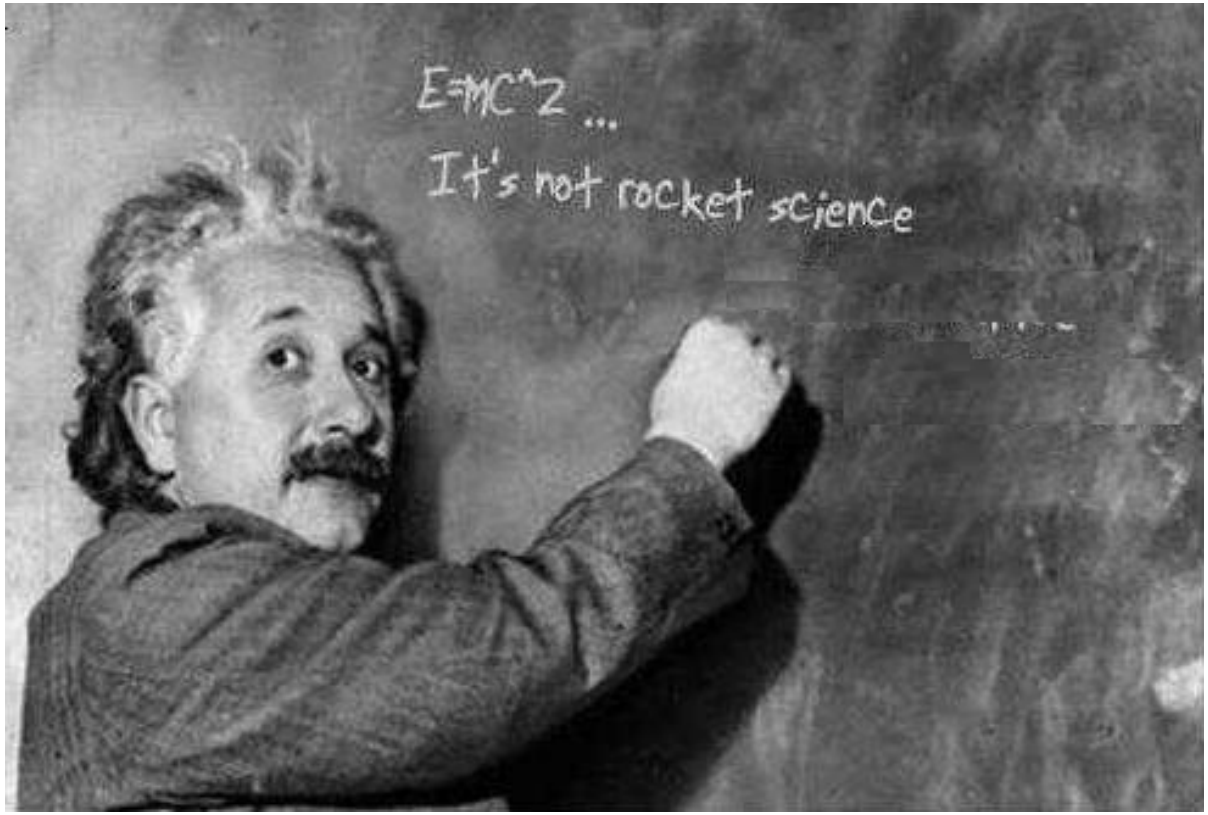
Why Air Remote Sensing (oil)

- Often can provide a synoptic view (for typical oil spills smaller than Deepwater Horizon)
- Easily taskable – can fly between clouds, loiter, launch late or early, land at different airport
- Higher spatial resolution improves accuracy
- Higher signal to noise (less air) possible
- Airborne Hyperspectral Imagers are available
  - diagnostic capability

(Spaceborne Hyperspectral Imager - HyspIRI - launches in 5-10 yrs)

What is Oil Spill Science?

- Fast
- Proven
- Reliable
- Well Understood
- Fast
- *USEFUL!!!*



Oil spill science is need-based science

Oil Spill Response Science

Remote Sensing – what can it do?

1 - Triage – first-est is best-est.

2 – Where is the thick oil? Is there thick oil? False positives. How much (qualitative)?

3 – Where is the oil spill going (trajectory)?

4 – What damage is being done to the Ecosystem?

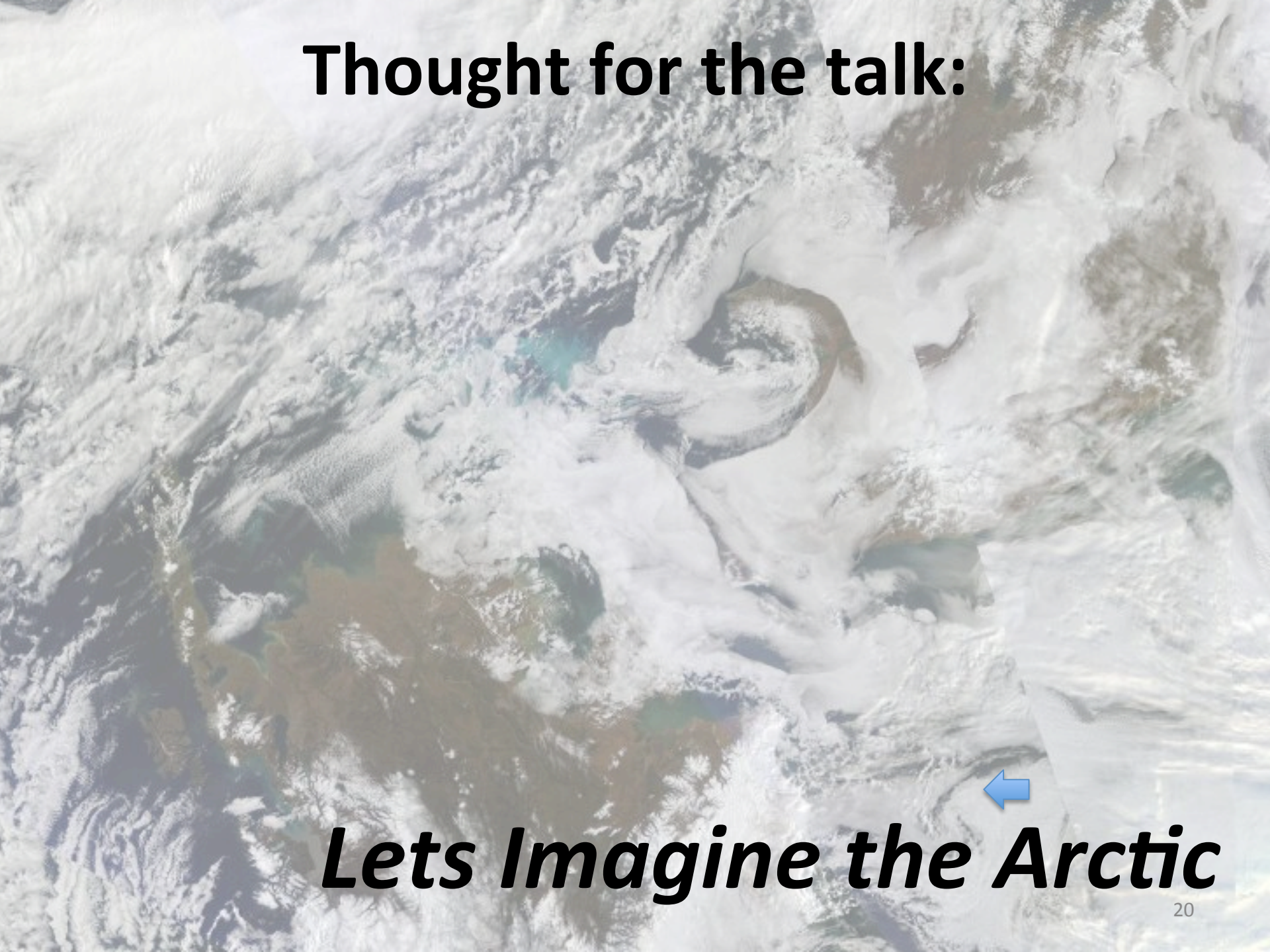
5 – Mitigation strategy evaluation

Thought for the talk:

Persistence works for the weather, not for fighting the next oil spill based on the war.

Every oil spill is unique and special!

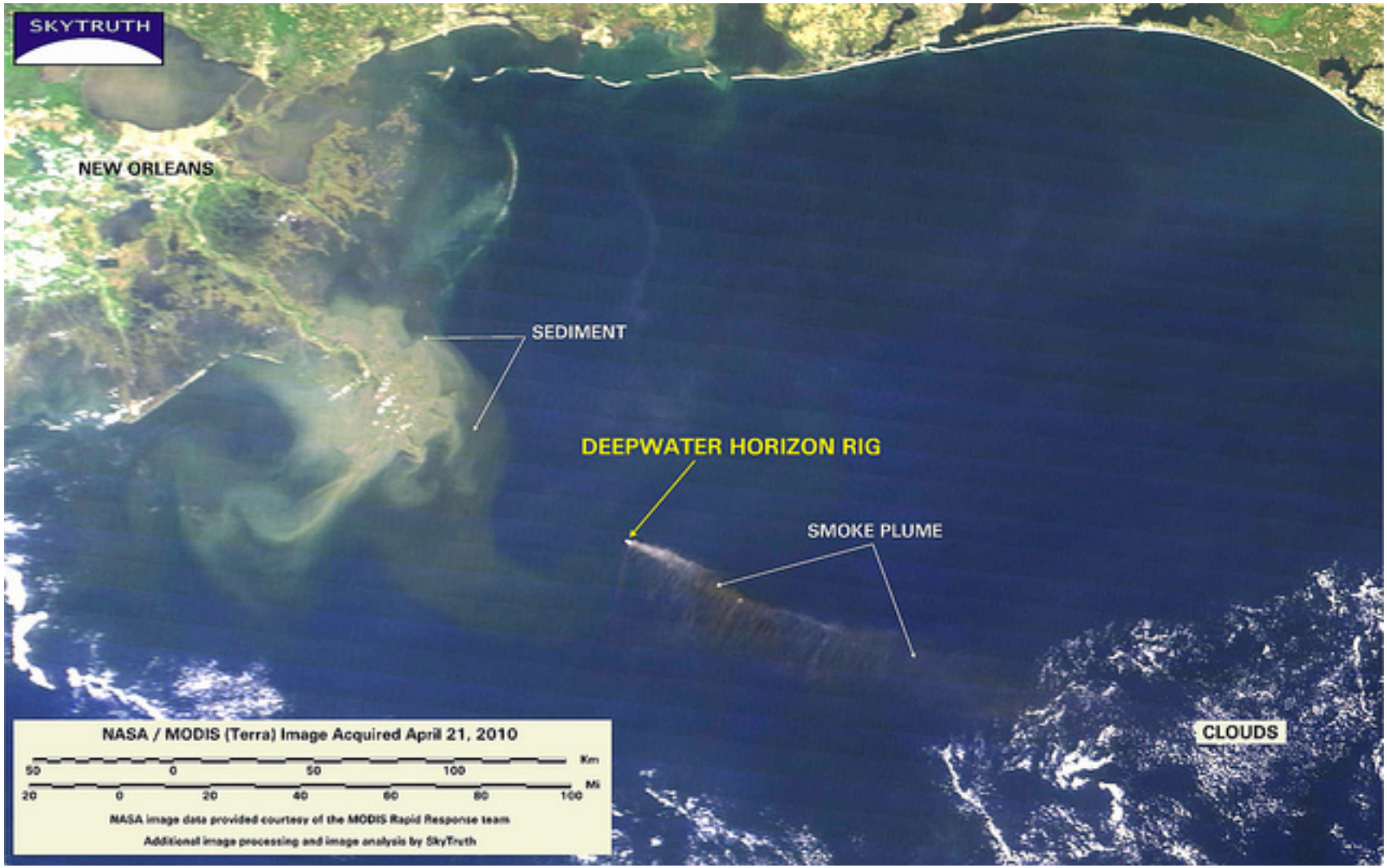
Thought for the talk:



Lets Imagine the Arctic

For this talk:

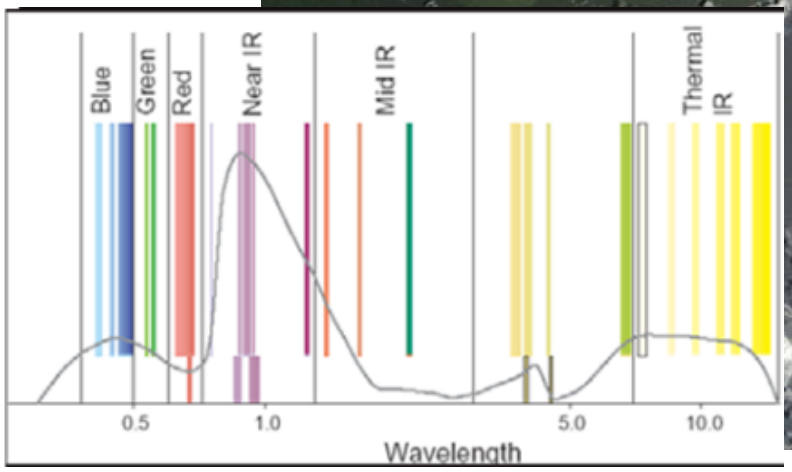
way back when



https://www.flickr.com/photos/skytruth/4544329078

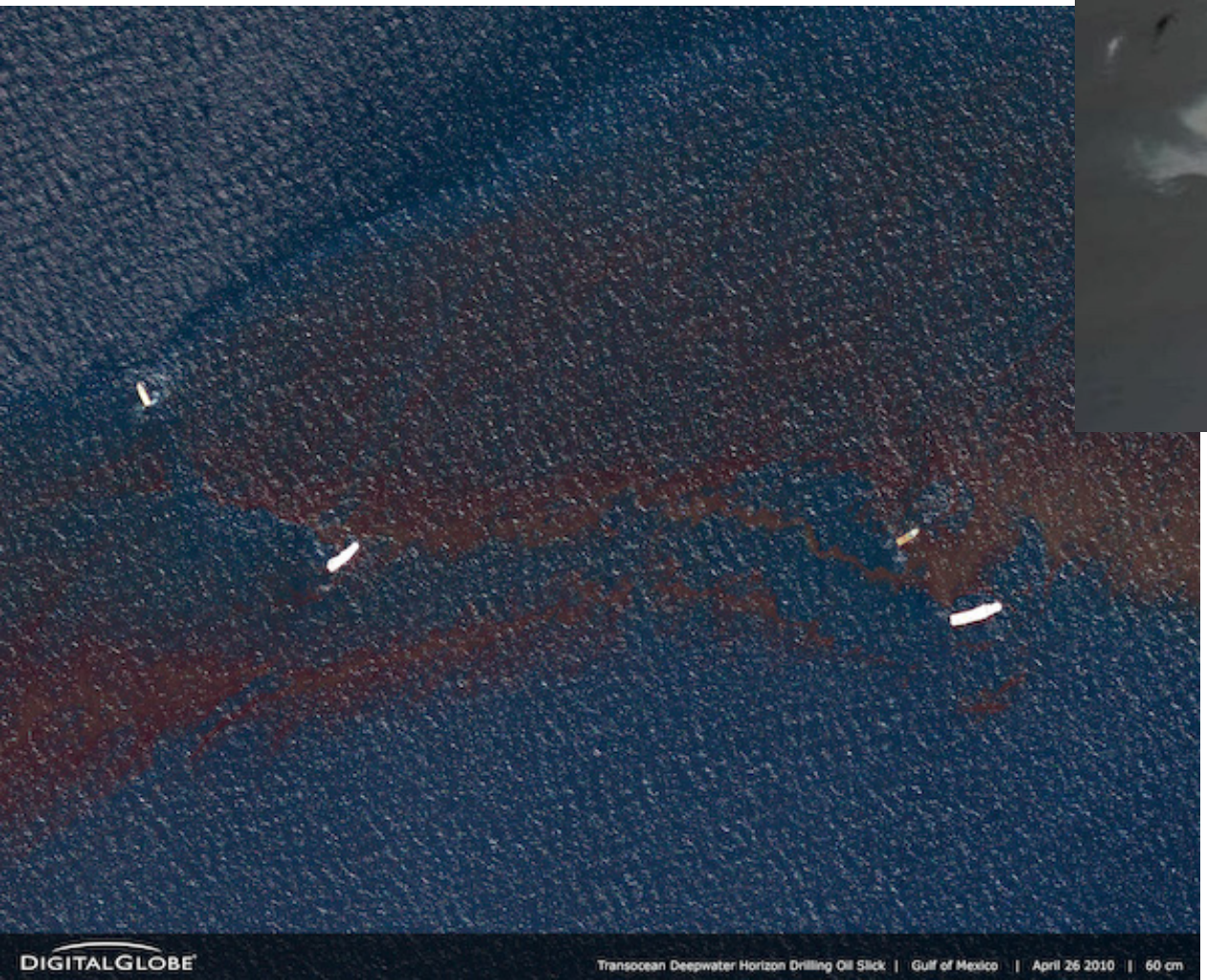
April 21, 2010

Visual Spectrum Oil Remote Sensing – OMG look at all the oil in the central Gulf!

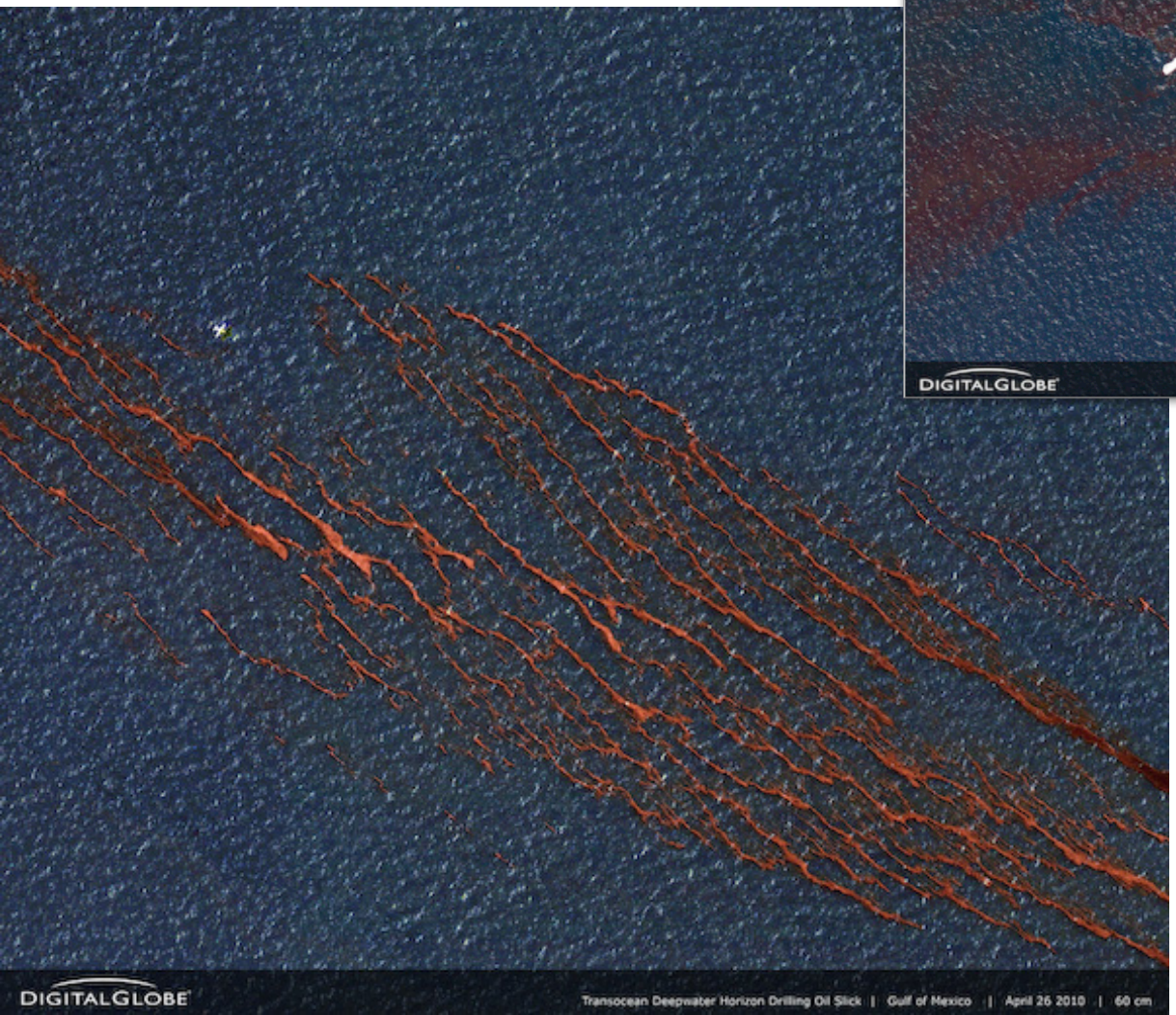


http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=44527

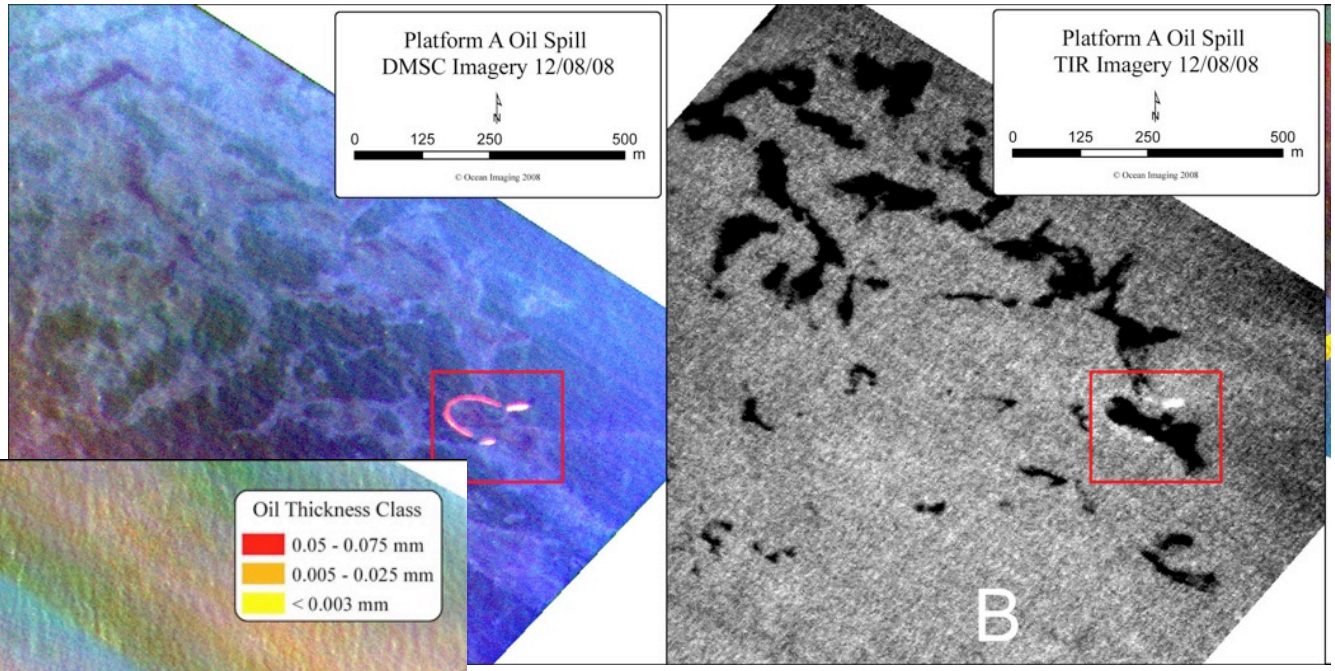
Let's talk spatial resolution: MODIS-synoptic misses almost all slick structural detail

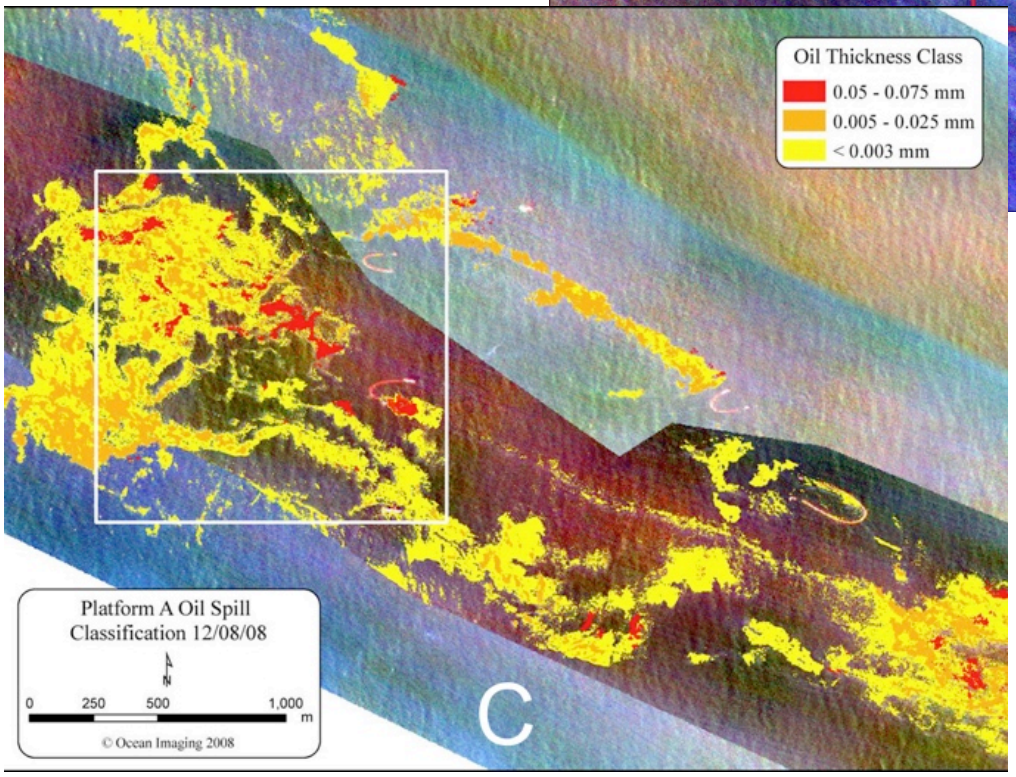


High Resolution Captures Structure Misses Synoptic



Very broad-band airborne oil imaging





Thick oil is hot

from Leifer et al. 2012

The hottest spill on the satellite data record*!!*

Figure 1.
Enhanced AVHRR Channel 4 at 10:38 UT
(Local Time 13:38) on February 1, 1991.

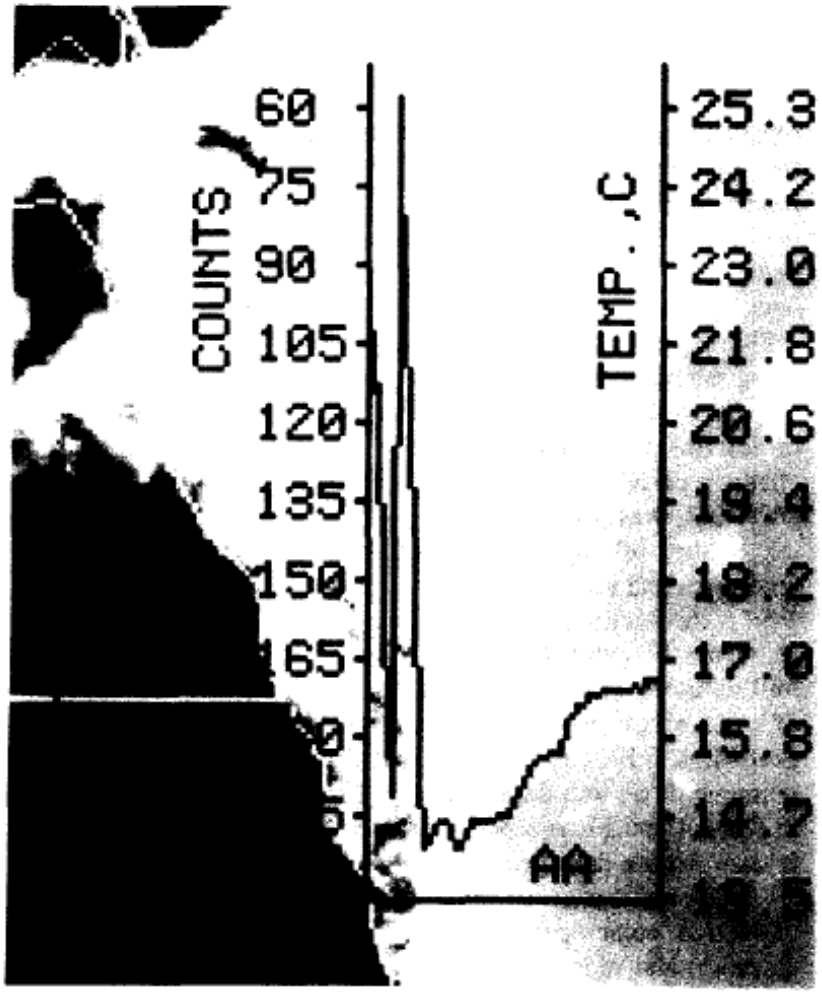
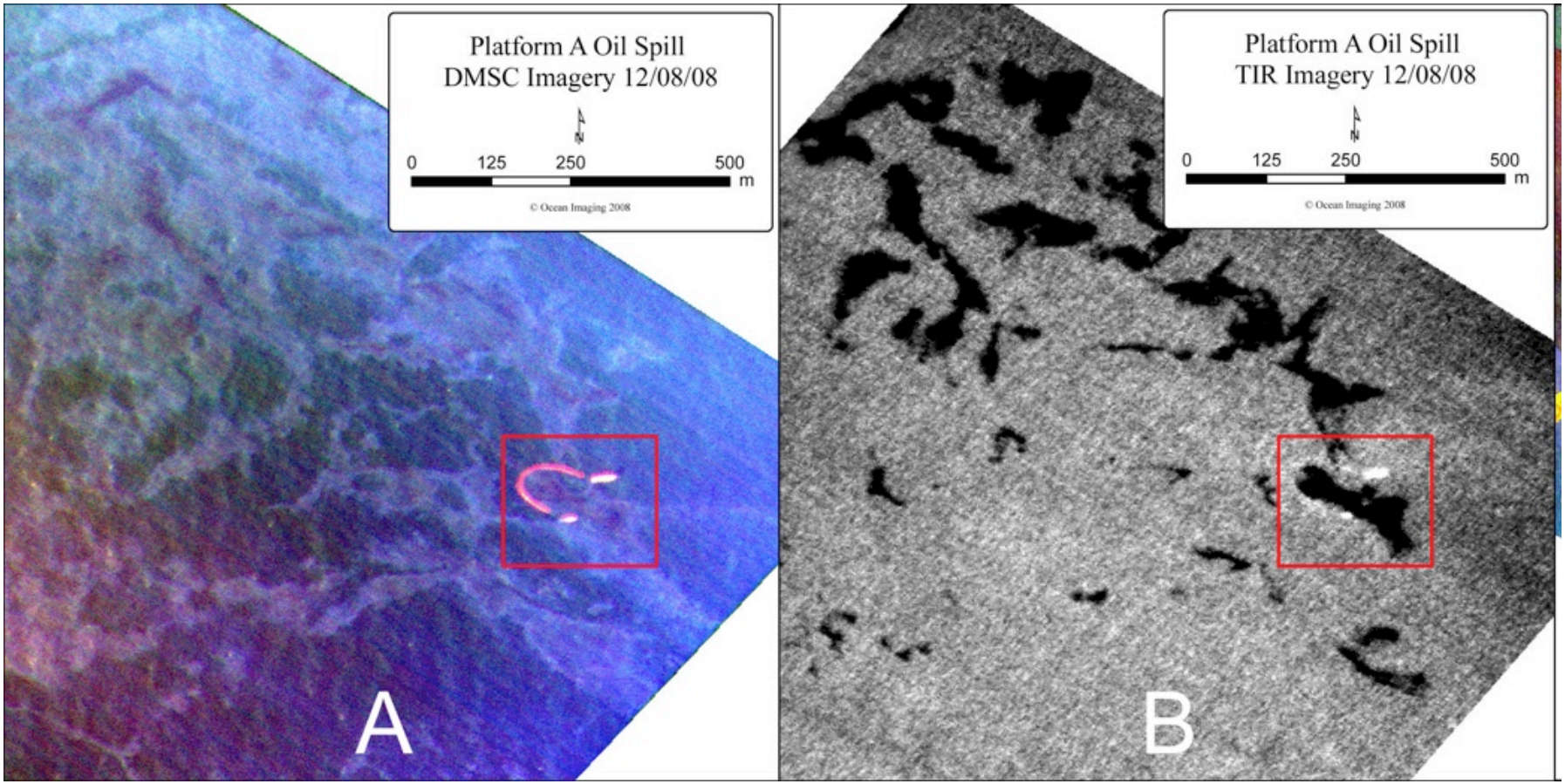


Figure 2.
Enlarged SST Distribution across
an East-West Transection, AA, in Figure 1.

from Tseng et al., 1994

So thermal doesn't see thin oil…



from Leifer et al. 2012

Or does it…

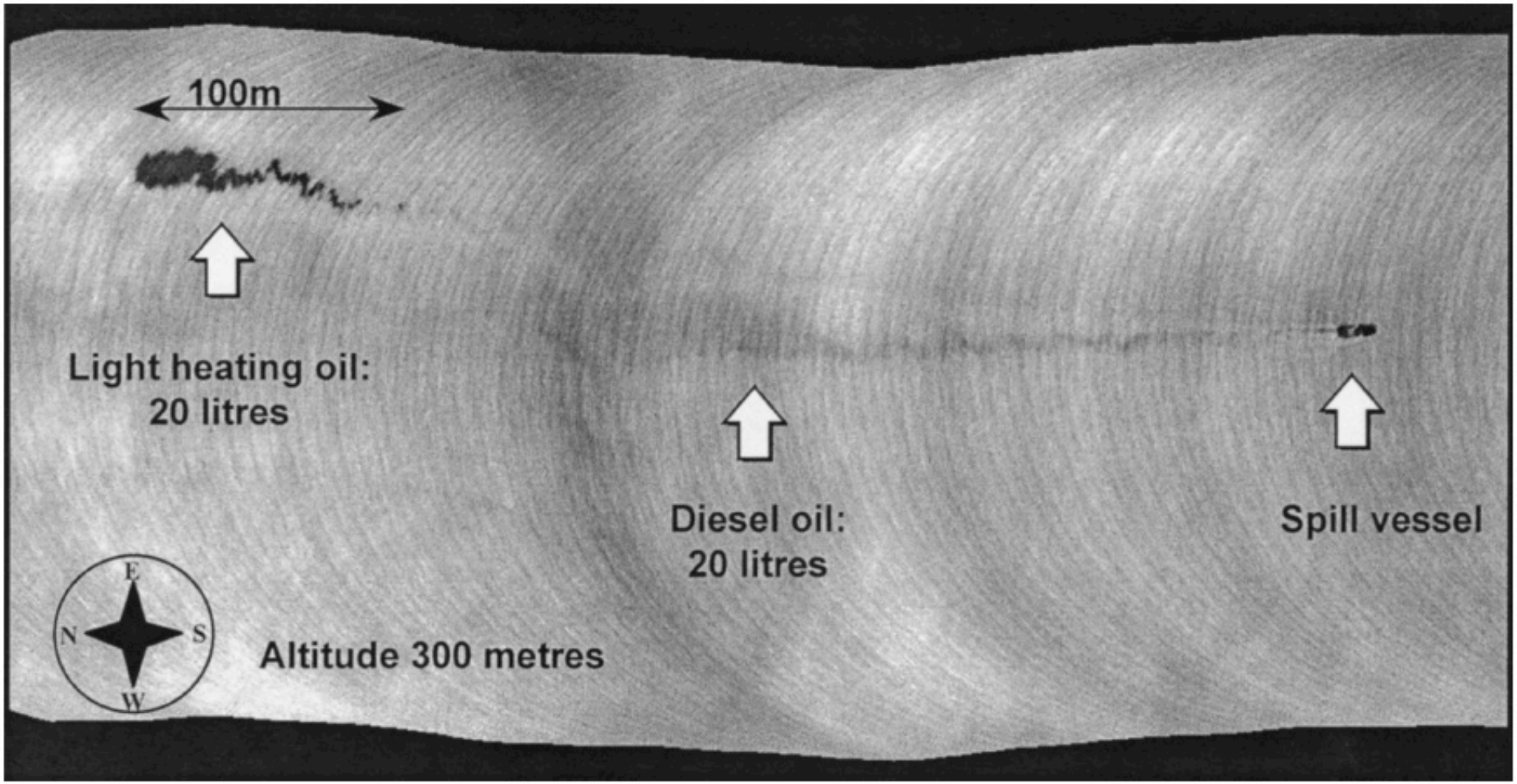


Figure 3. Thermal imagery of the oil residue spills taken in darkness.

Depends on the instrument

from Grierson 1998

The famous tiger tail

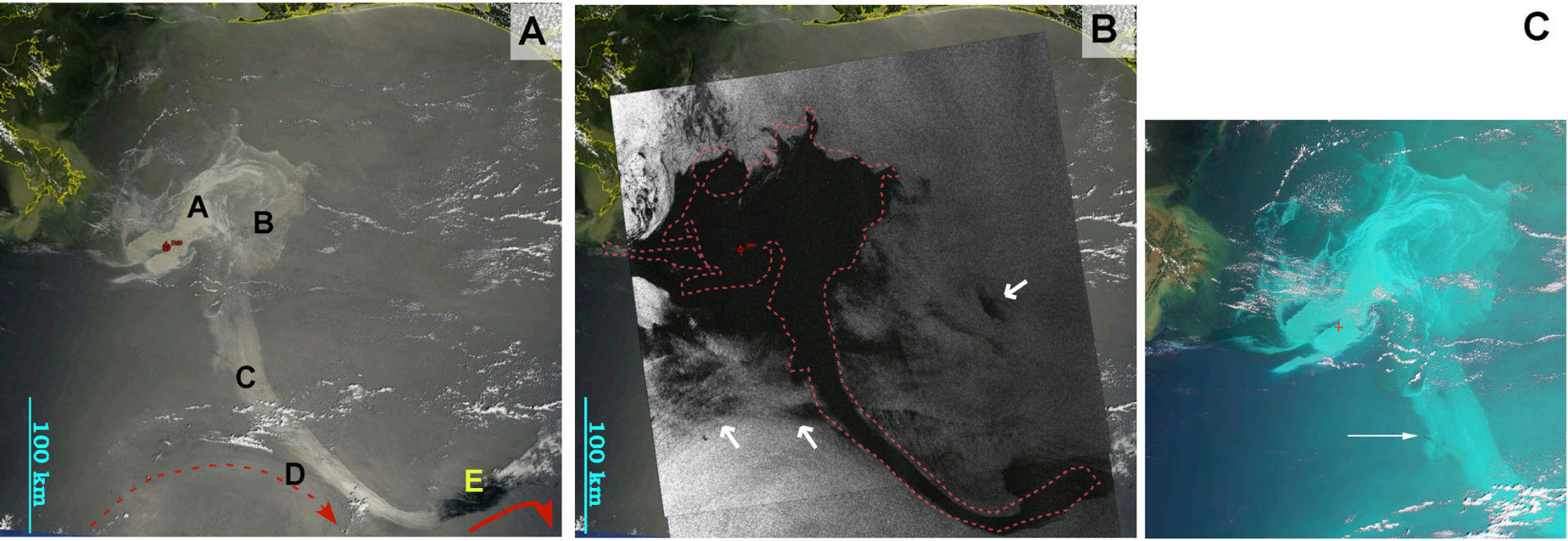
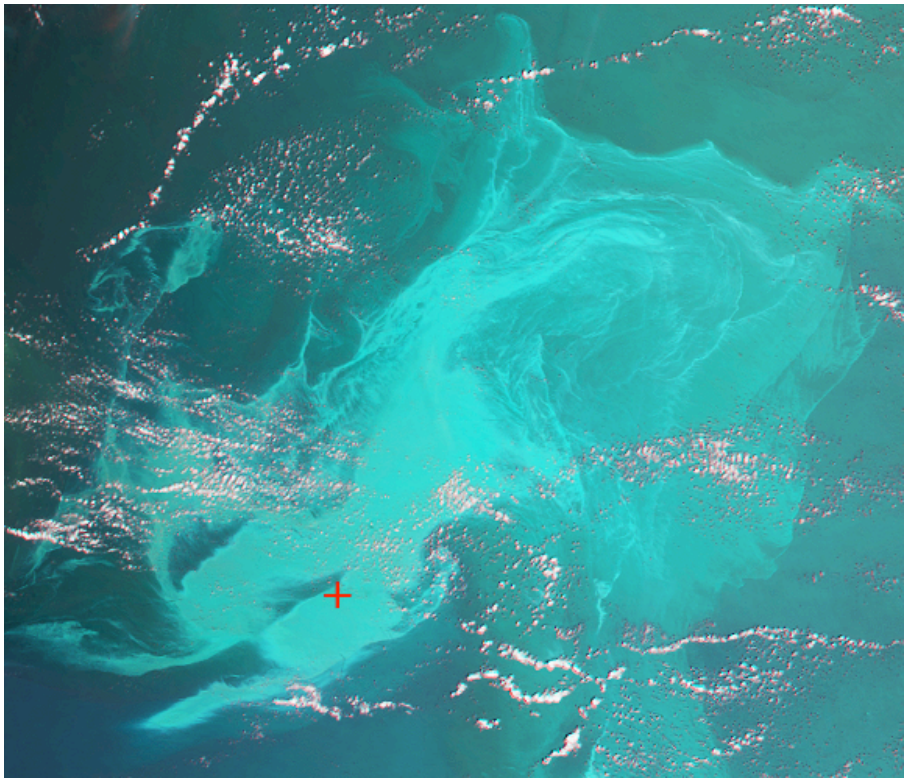


Fig. 11. A. MODIS Terra image and B, RADARSAT-2 SAR image of the *Deepwater Horizon* spill, acquired 17 May 2010 at different times. Note greater spatial extent of the SAR-identifiable spill in B (dashed red line shows oil slick outline from A, white arrows indicated false positives). C MISR false color image based on combination of nadir viewing blue and green with 26° forward red band, arrow indicates smoke from in situ burn (MISR 2010). See text for discussion. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

from Leifer et al. 2012

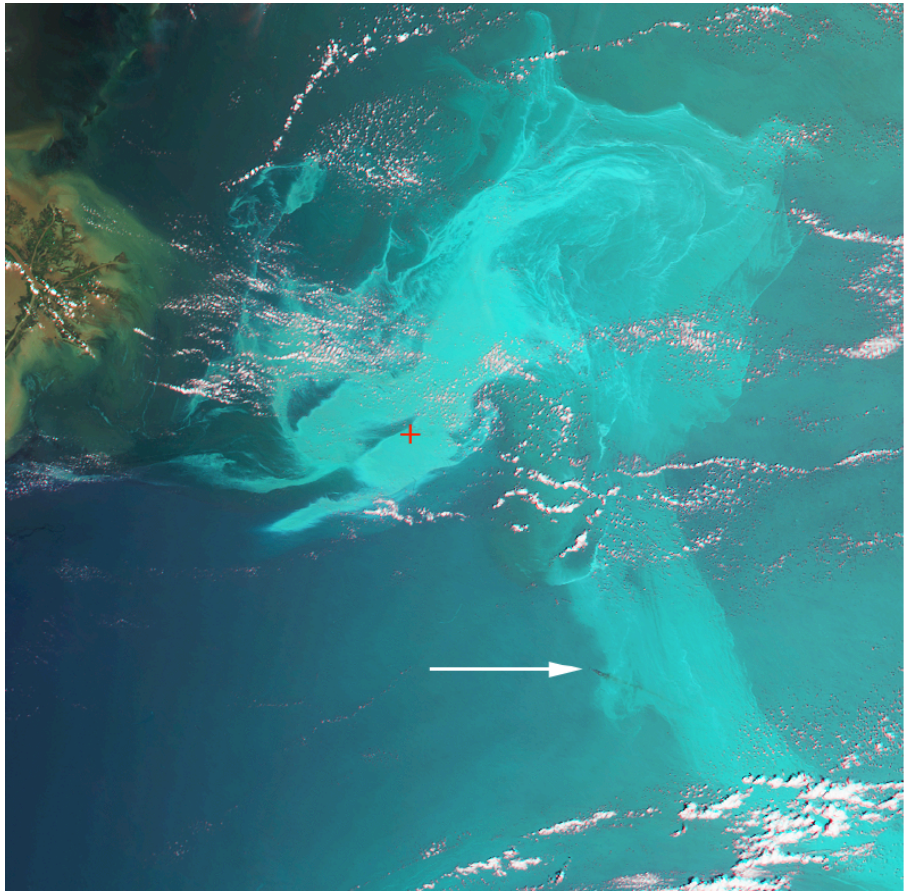
The famous tiger head in thermal

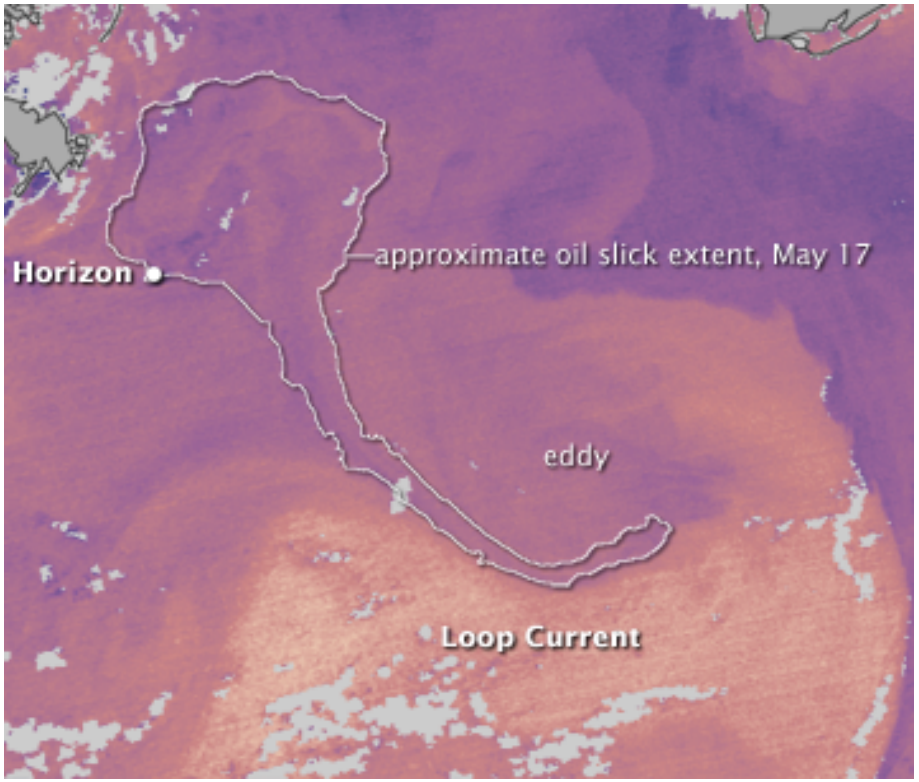


from Leifer et al. 2012

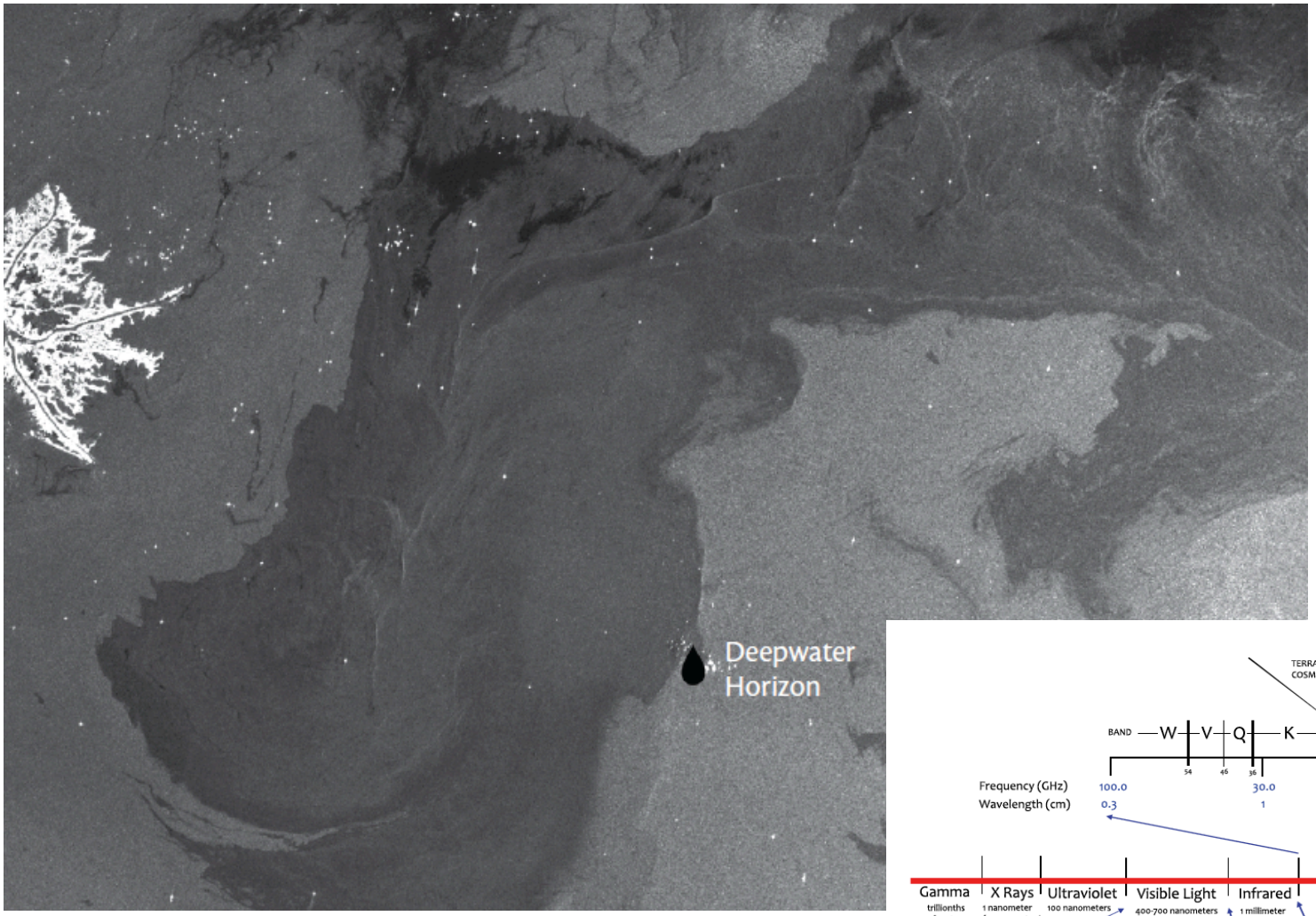
MODIS Thermal from LSU website

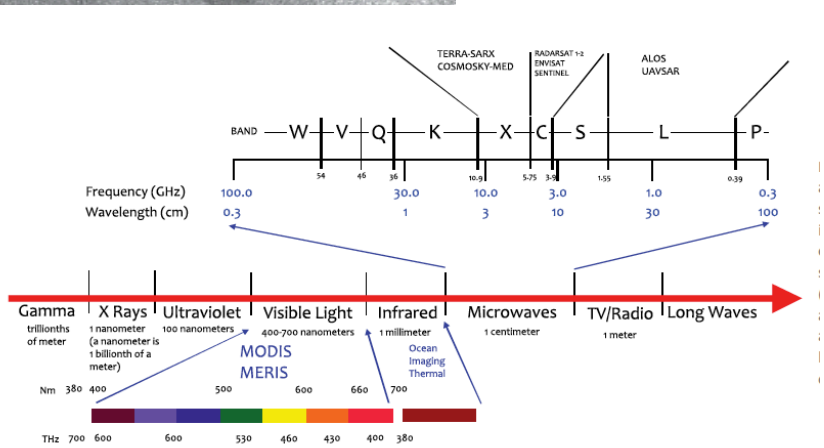
The famous tiger tail in thermal





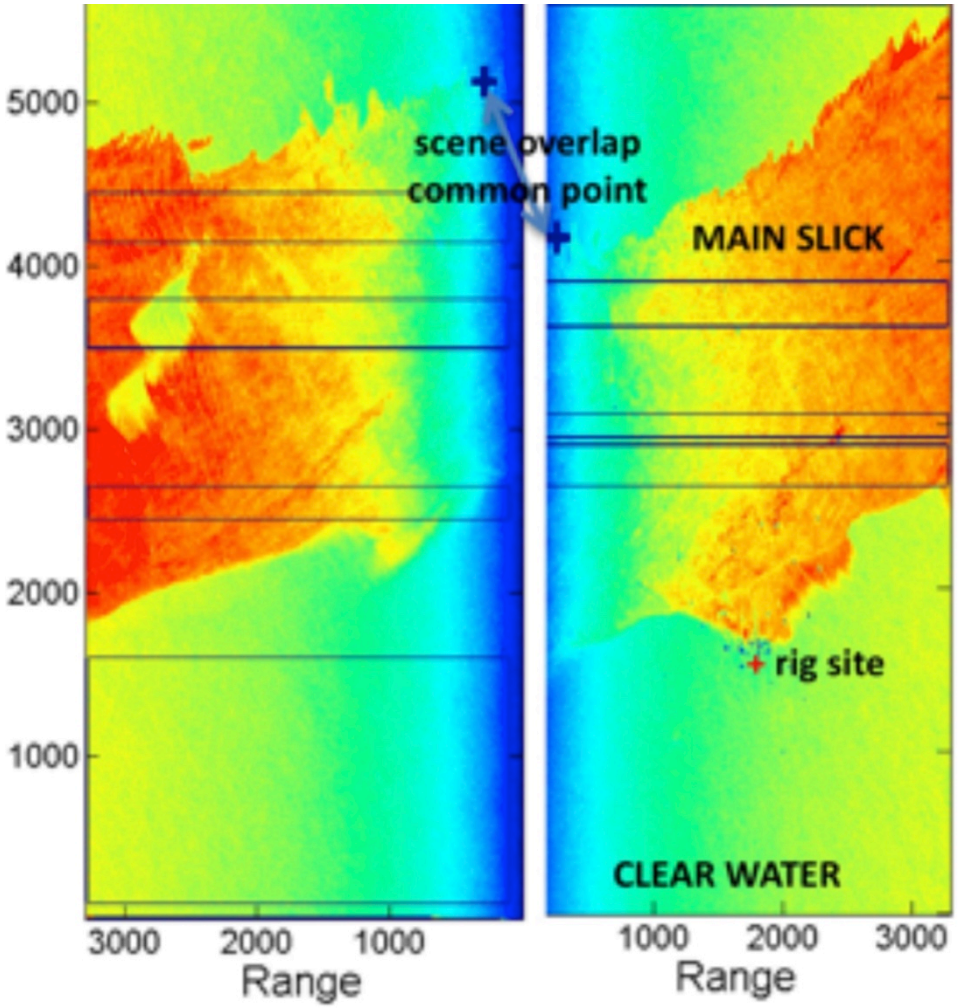
So what does SAR see?

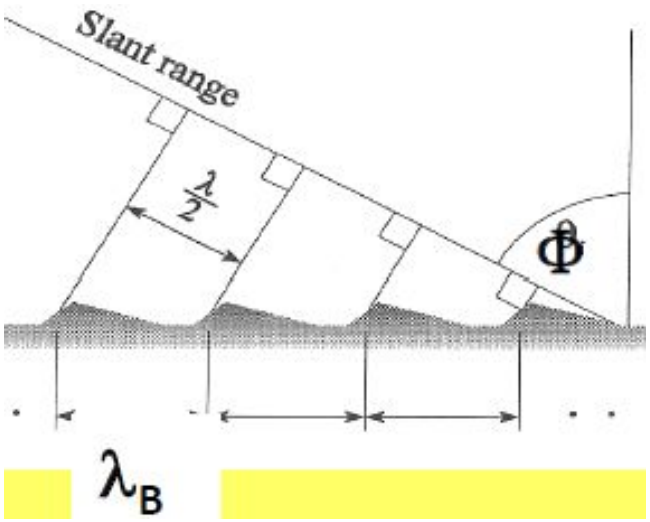




from Garcia-Pineda et al. 2013

So what does SAR see?

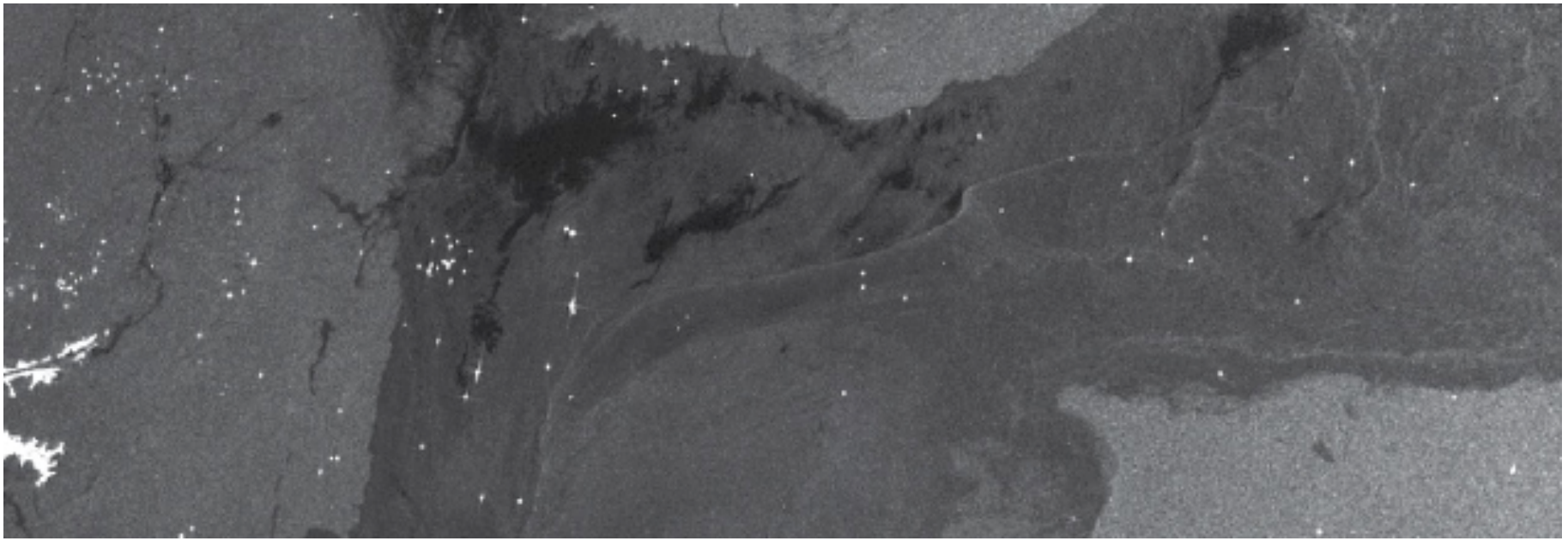


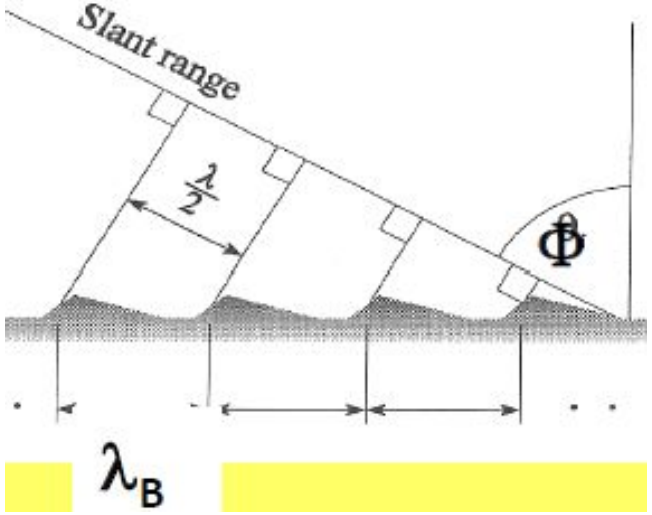


Airborne SAR – Dielectric

from Leifer et al. 2012

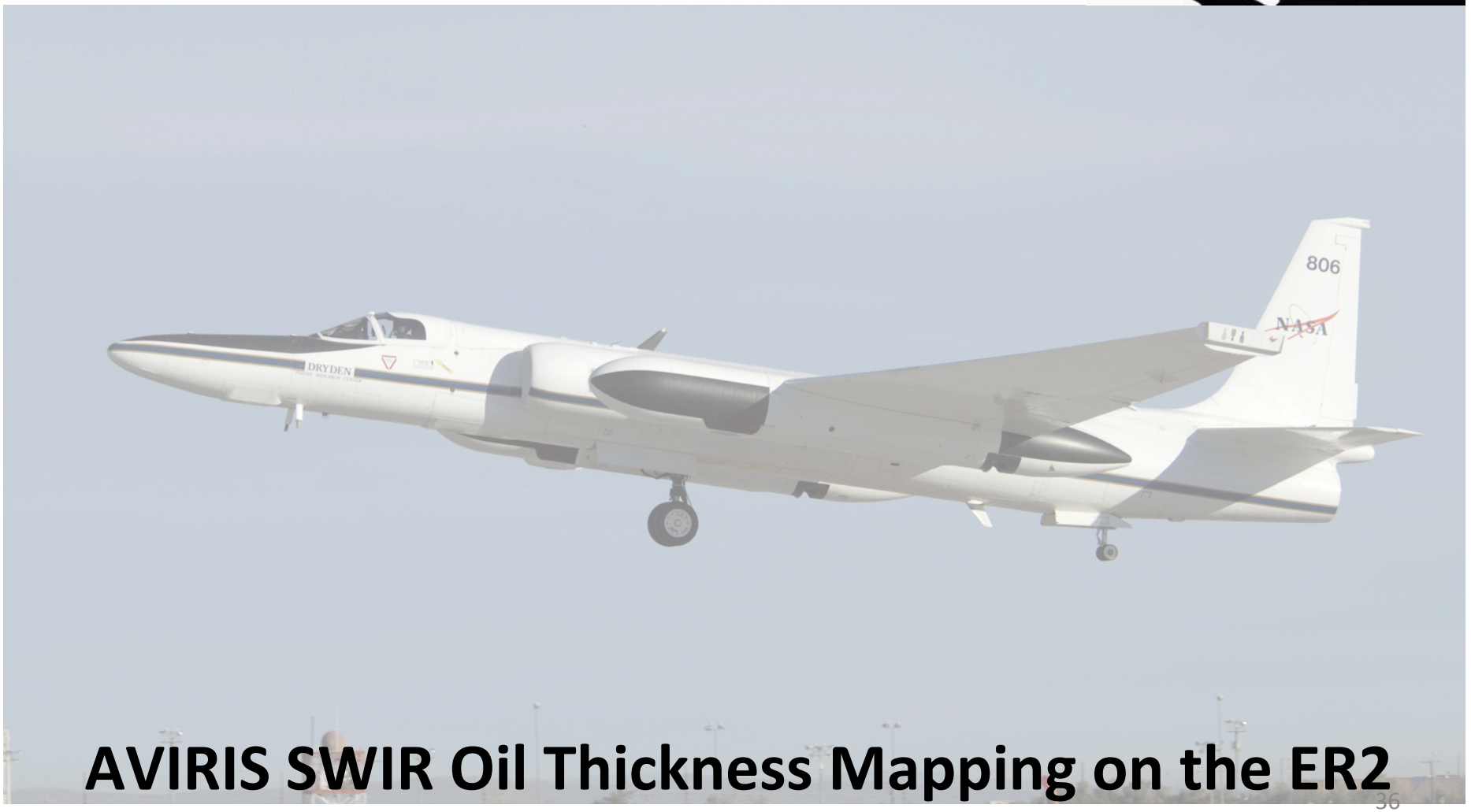
So what does sat SAR see?





Bragg reflection, and….

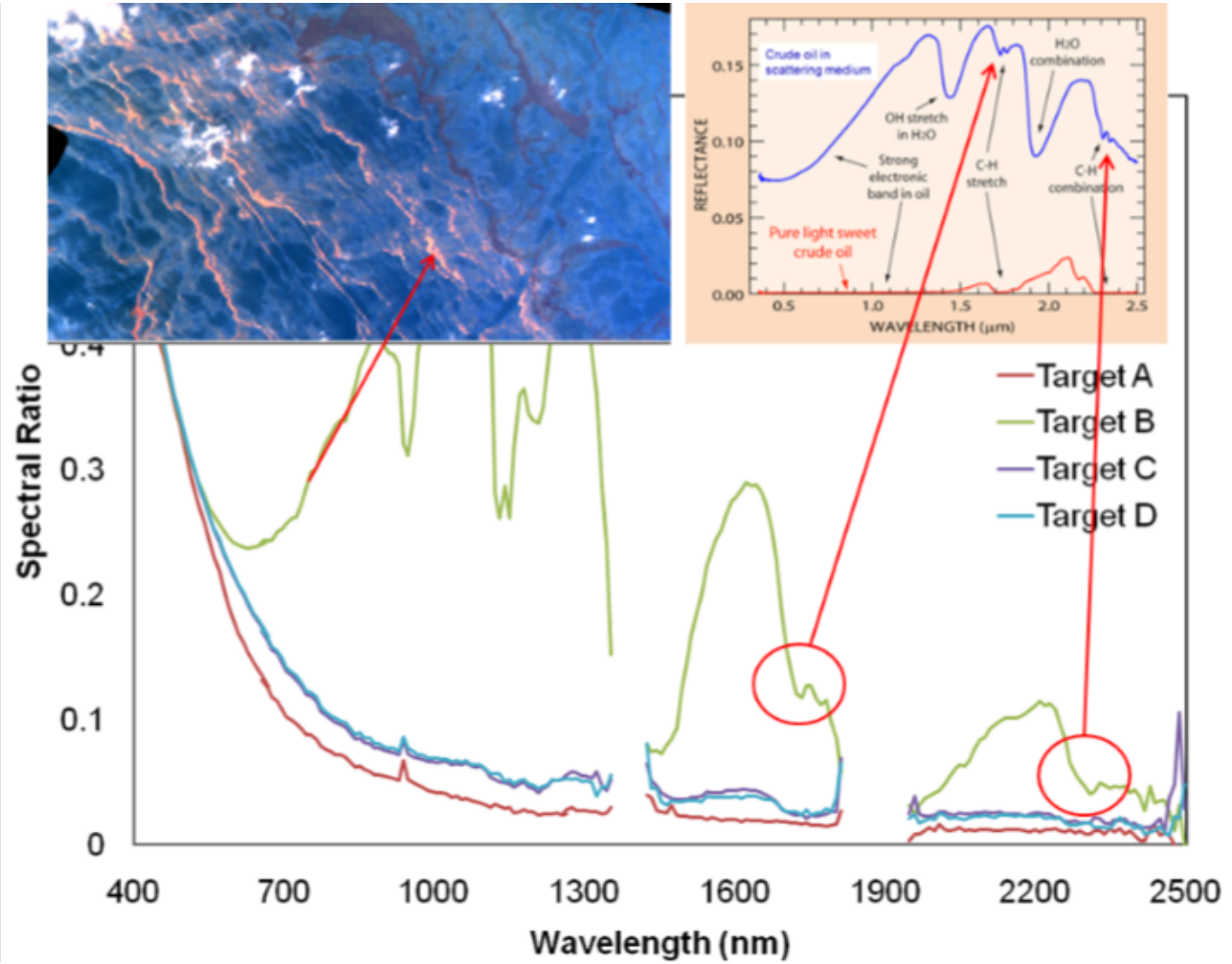
The future is spectroscopic
Elementary – it's diagnostic



AVIRIS SWIR Oil Thickness Mapping on the ER2

http://www.coinbooks.org/esylum_v17n15a15.html; http://aviris.jpl.nasa.gov/

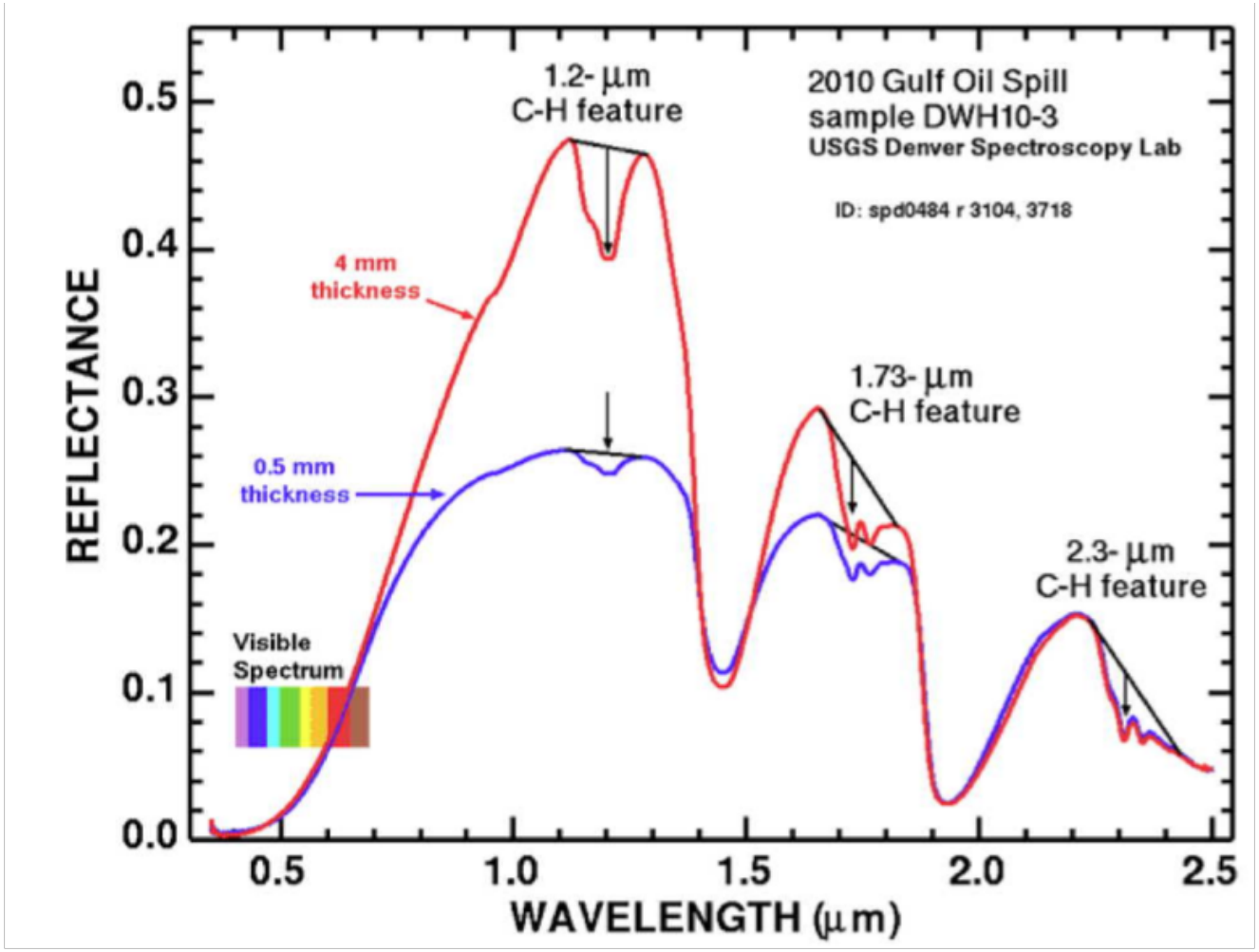
AVIRIS Measurements of Carbon-Hydrogen Bond Spectral Signature in Gulf Oil Spill

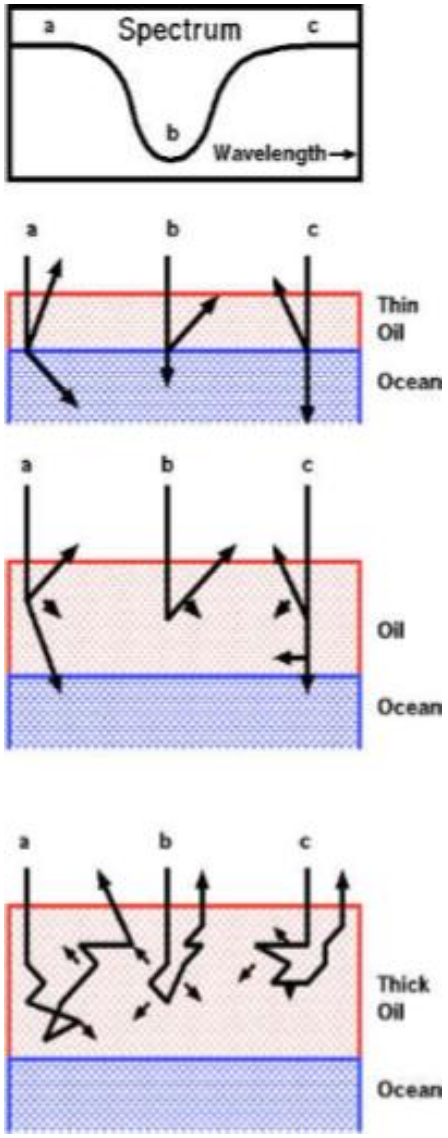


First AVIRIS results over the Gulf Oil Spill showed the spectroscopic signature of the crude oil carbon-hydrogen bond SWIR absorption features

Roger Clark, USGS, unpublished, 2010

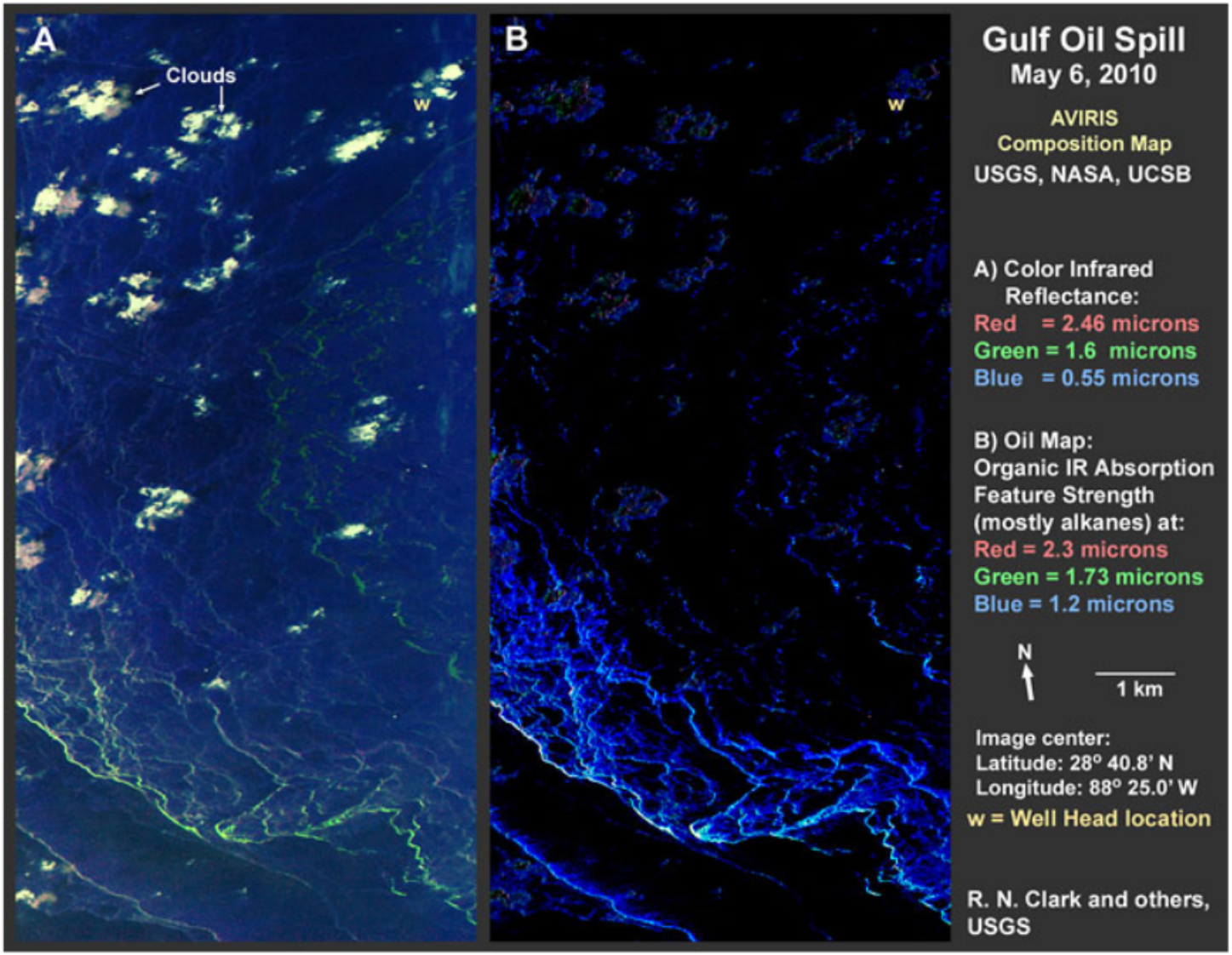
Oil Imaging Spectroscopy





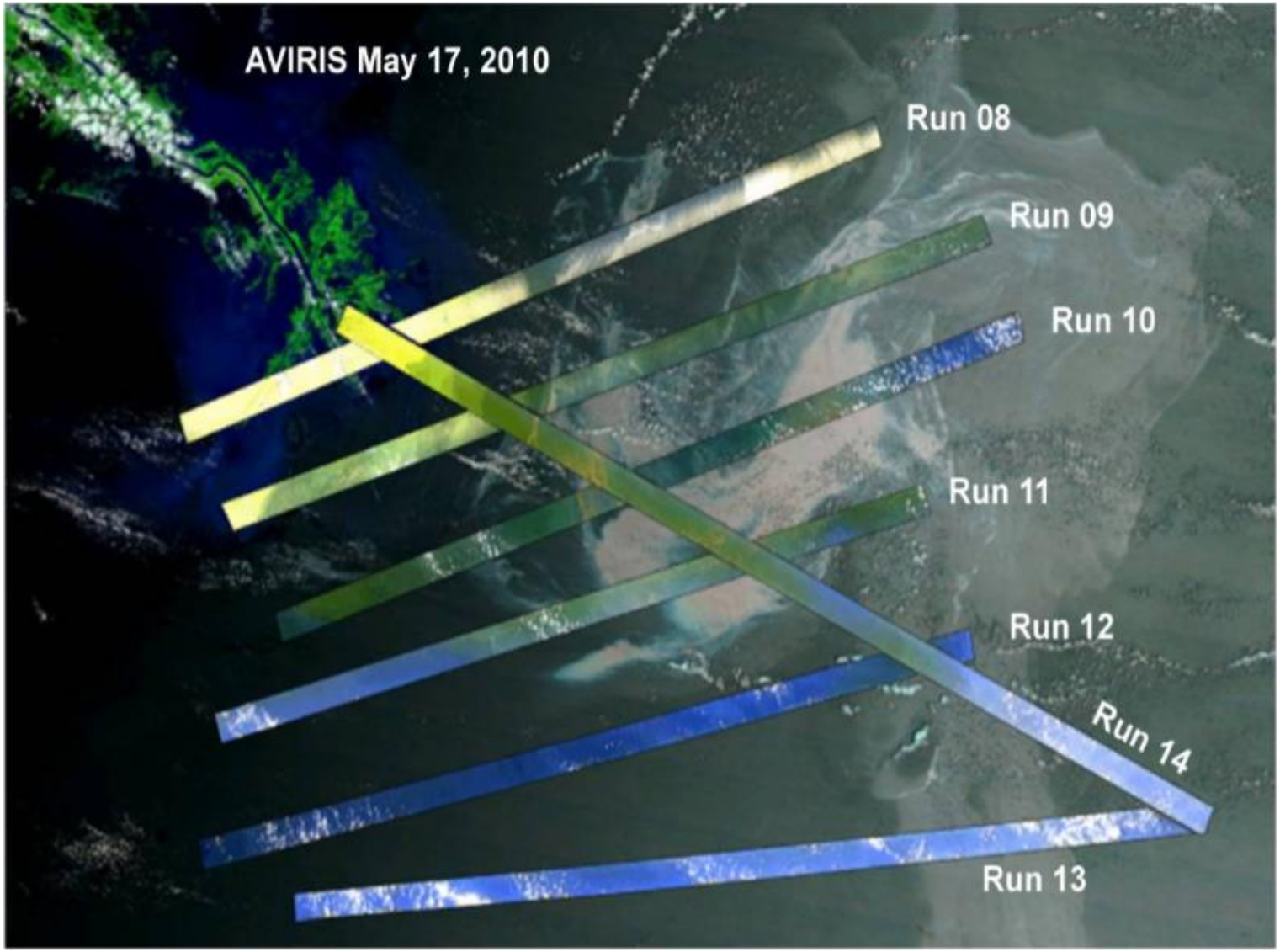
from Clark et al., 2010b. Leifer et al., 2012

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



from Clark et al., 2010b. Leifer et al., 2012

AVIRIS oil slick coverage on the ER2



From Clark et al., 2010b; Leifer et al., 2012

Back to Thermal – Unused Spectral Potential

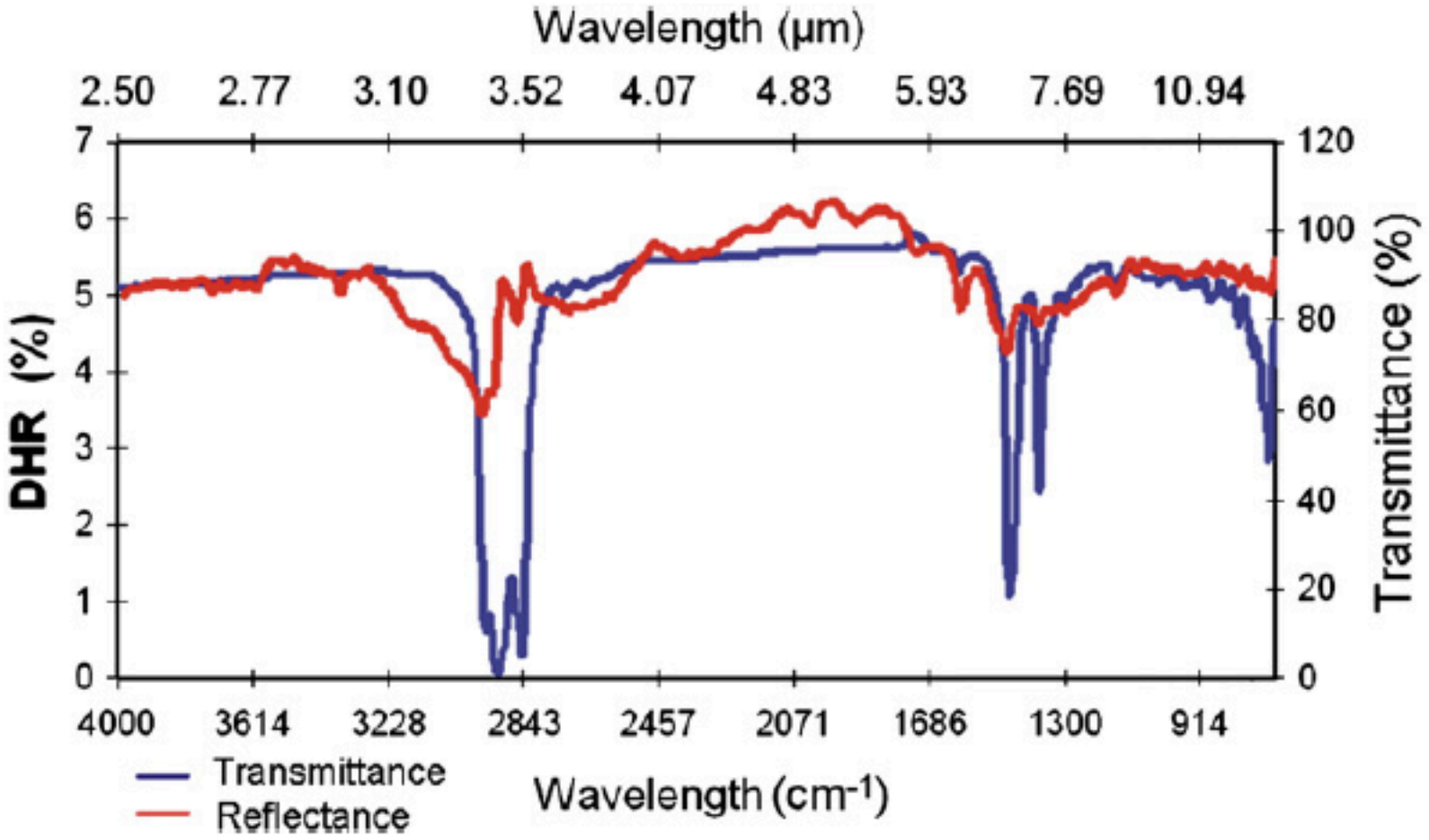
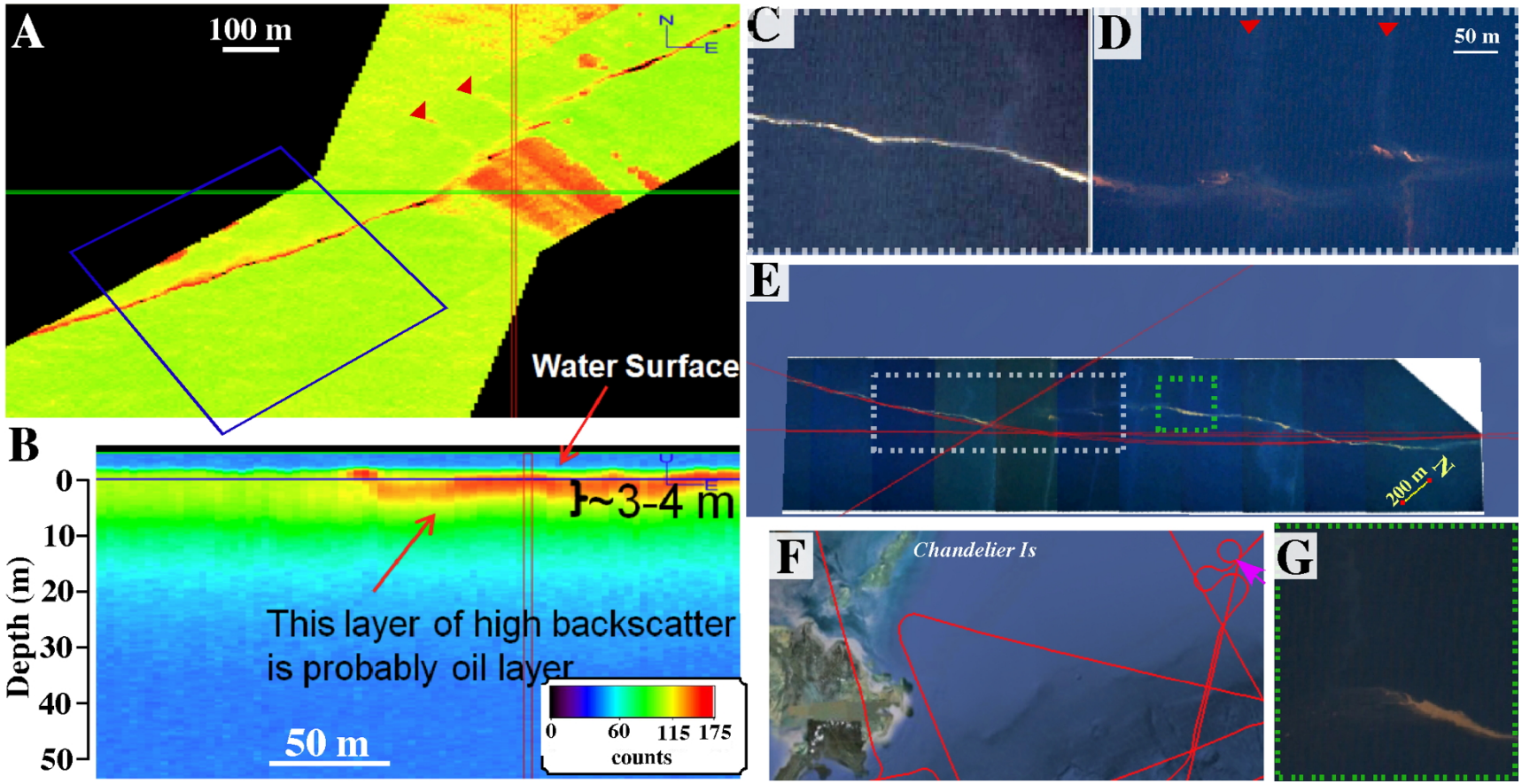


Fig. 10. Comparison of transmittance and reflectance spectra of crude oil sample (ºAPI 47) indicating portions dominated by surface scattering (3.4/3.5 μm) and volume scattering (6.8/7.2 μm).

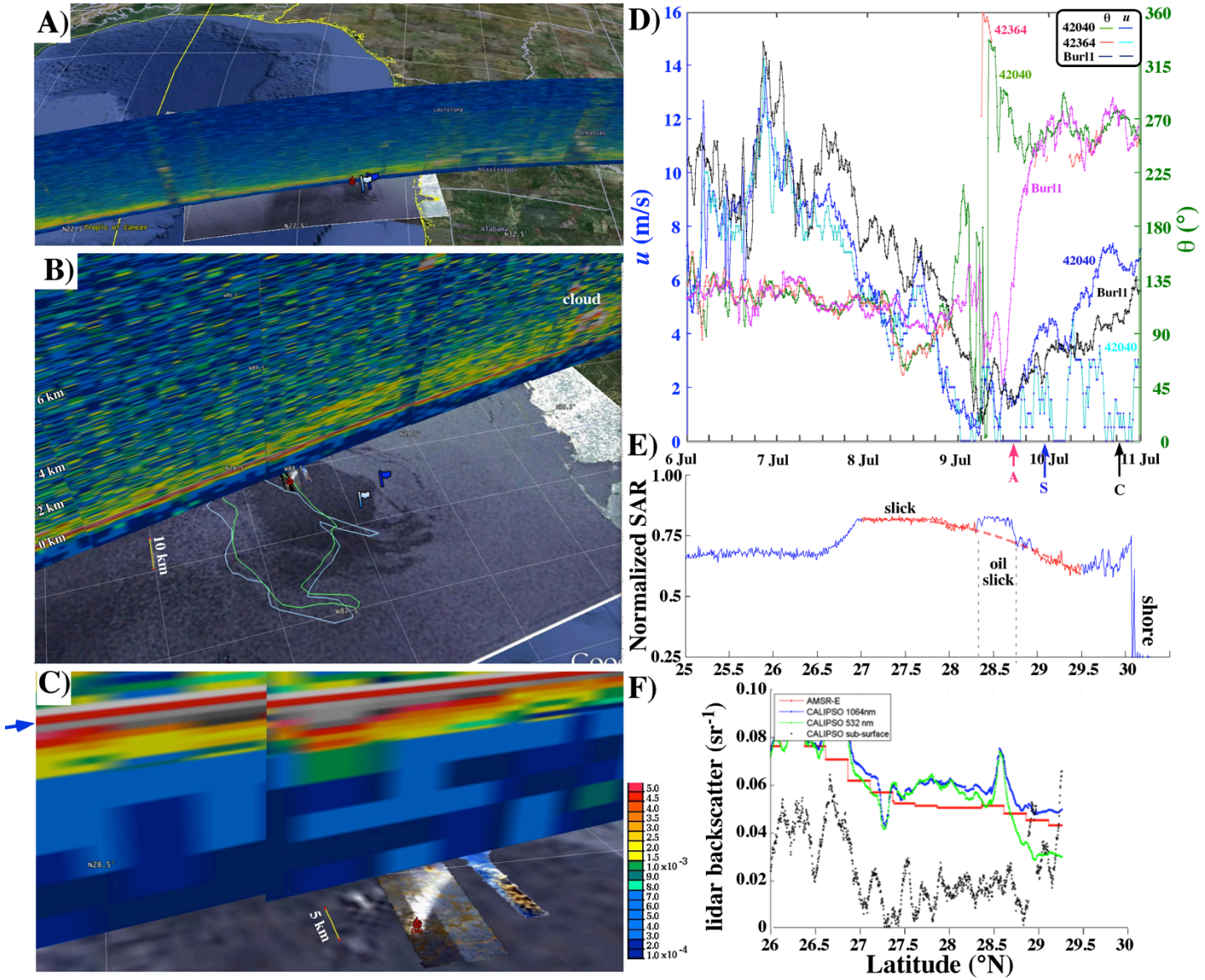
from Lammoglia & Filho, 2011

Random Oil Remote Sensing (Airborne)



from Leifer et al. 2012

Random Oil Remote Sensing – Lidar (Space)

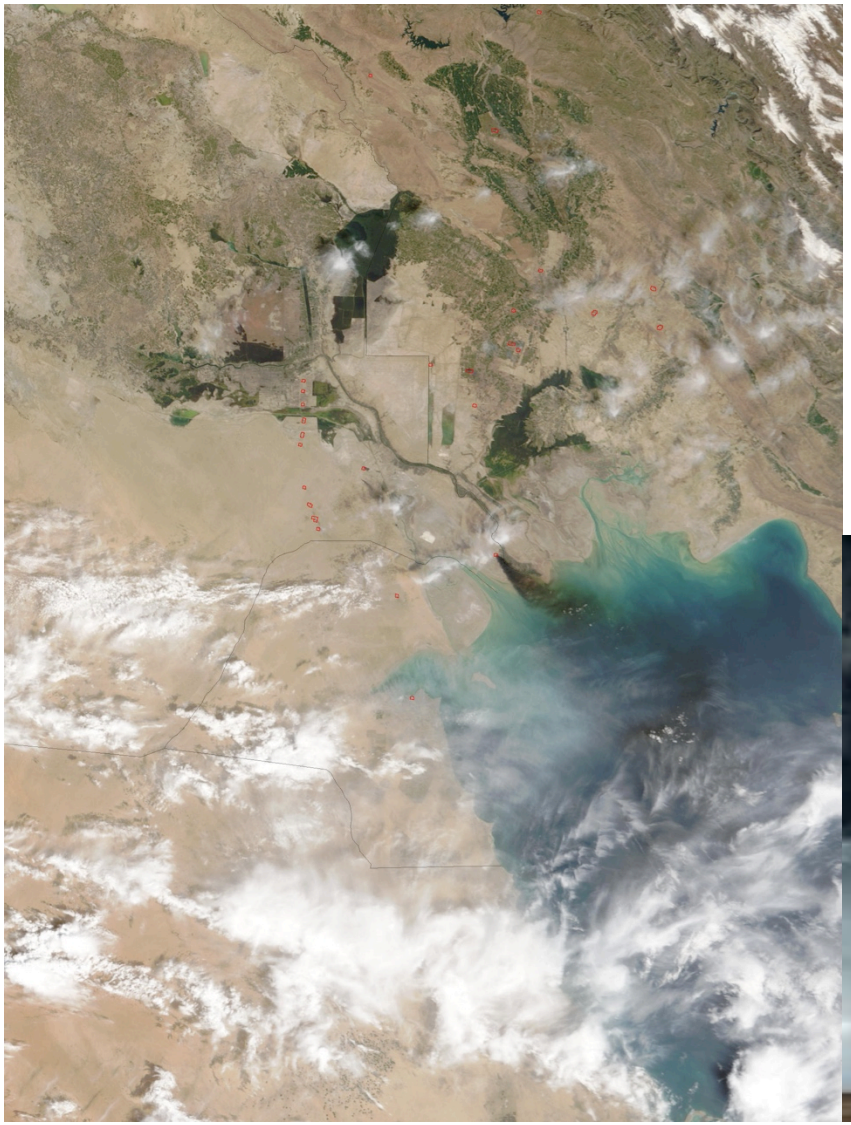


from Leifer et al. 2012

Random Oil Remote Sensing – Fire! (Space Thermal)

https://en.wikipedia.org/wiki/Gulf_War#/media/File:Operation_Desert_Storm_22.jpg

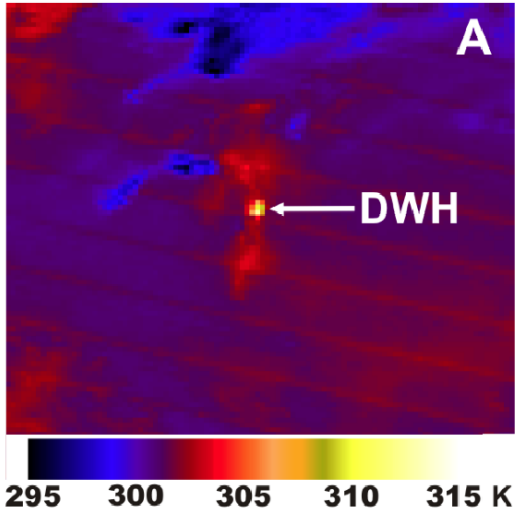
Random Oil Remote Sensing – Smoke! (Space)

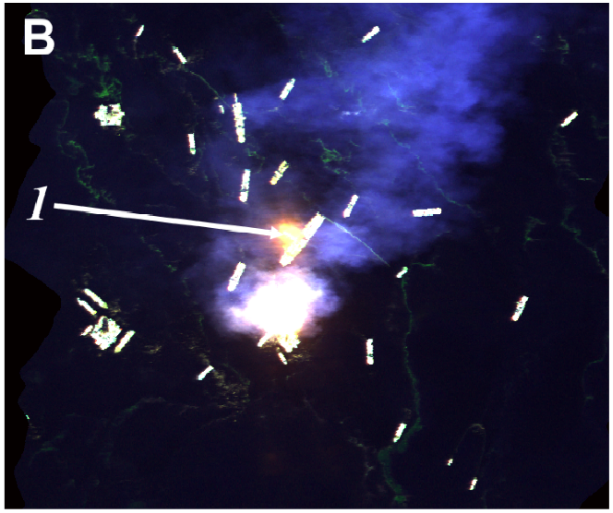


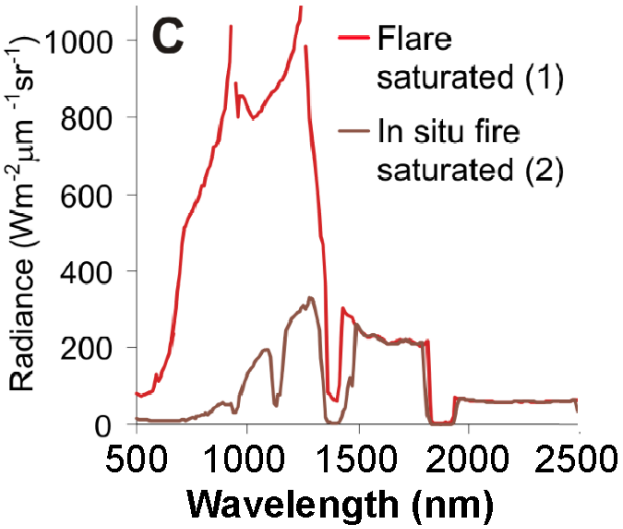
NASA/MODIS

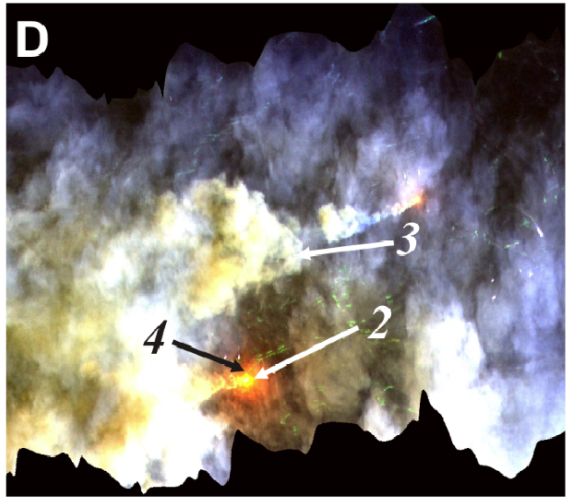
https://www.flickr.com/photos/52587508@N00/211540617/

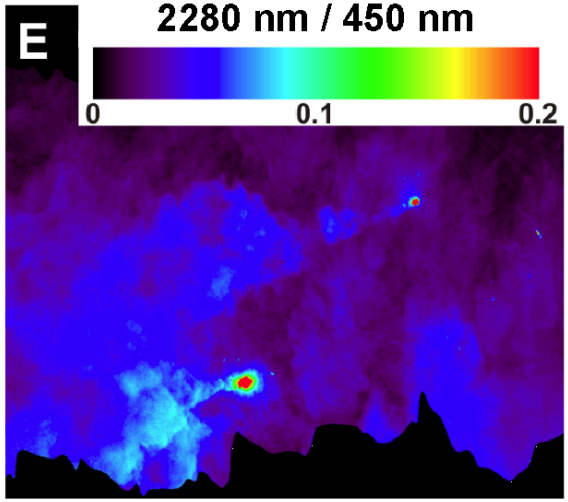
Airborne Fire Remote Sensing Could Monitor In Situ Burns

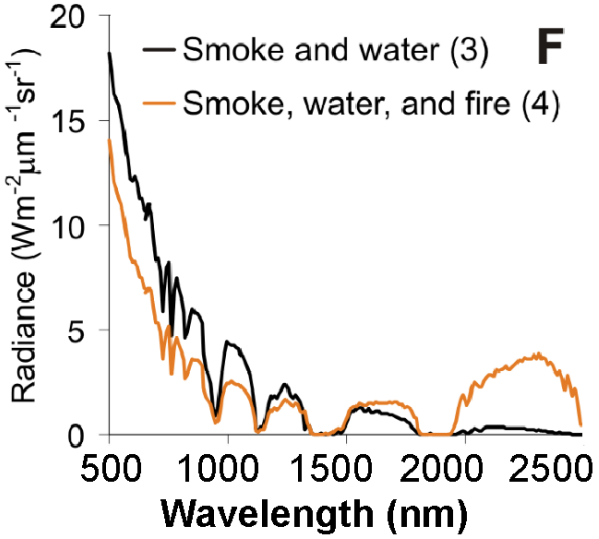




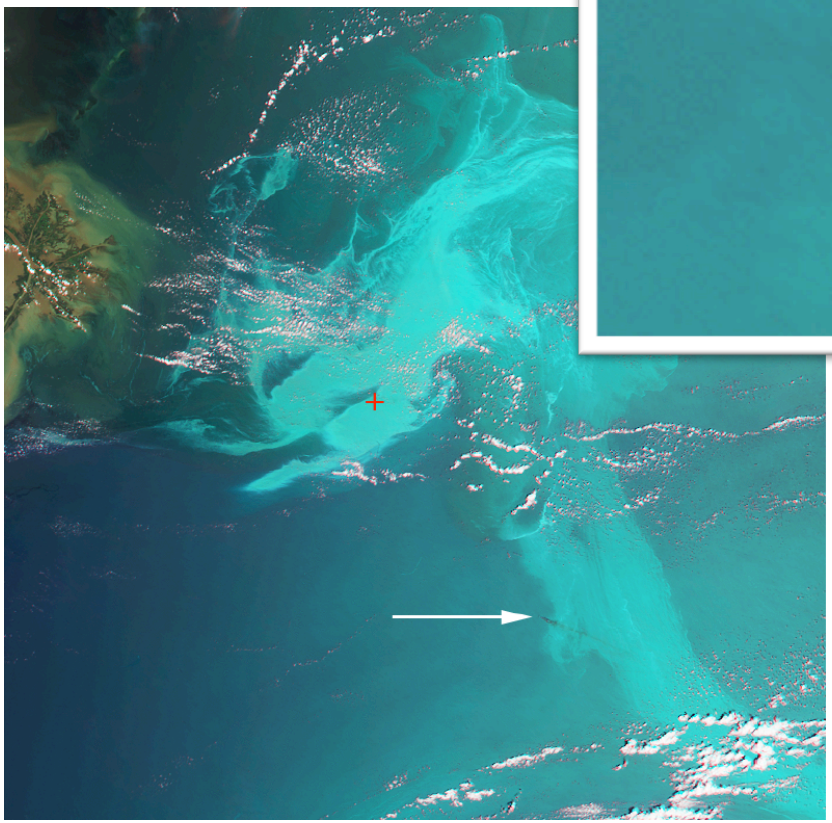








Satellite Remote Sensing Monitors In Situ Burn (MISR)



from Leifer et al. 2012

The Beauty of Santa Barbara

Some key points

Remote sensing has many advantages

Pattern recognition has significant false positives

-requires ancillary data (other sensors, other info, model)

Spectroscopy is diagnostic – not yet in space

http://hyspiri.jpl.nasa.gov/

Many novel applications, at lab research stage

Thermal spectroscopy is feasible, not implemented

The next spill will be different

Remote sensing can help

https://stemn.com/projects/somp---students-oxygen-measurement-project

https://en.wikipedia.org/wiki/CubeSat#/media/File:CubeSat_in_hand.jpg

Discussion – Think Arctic

- Six months dark – no passive visible/NIR
- Lots of clouds – SAR works, but ice confusion
- Thermal works
- Airborne – what altitude – current approaches all require flying low
- Weather in the Arctic is miserable – takeoff can be a problem
- Basing