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Overview of optical remote sensing of marine oil spills

— detection, spectral discrimination, and optical processes

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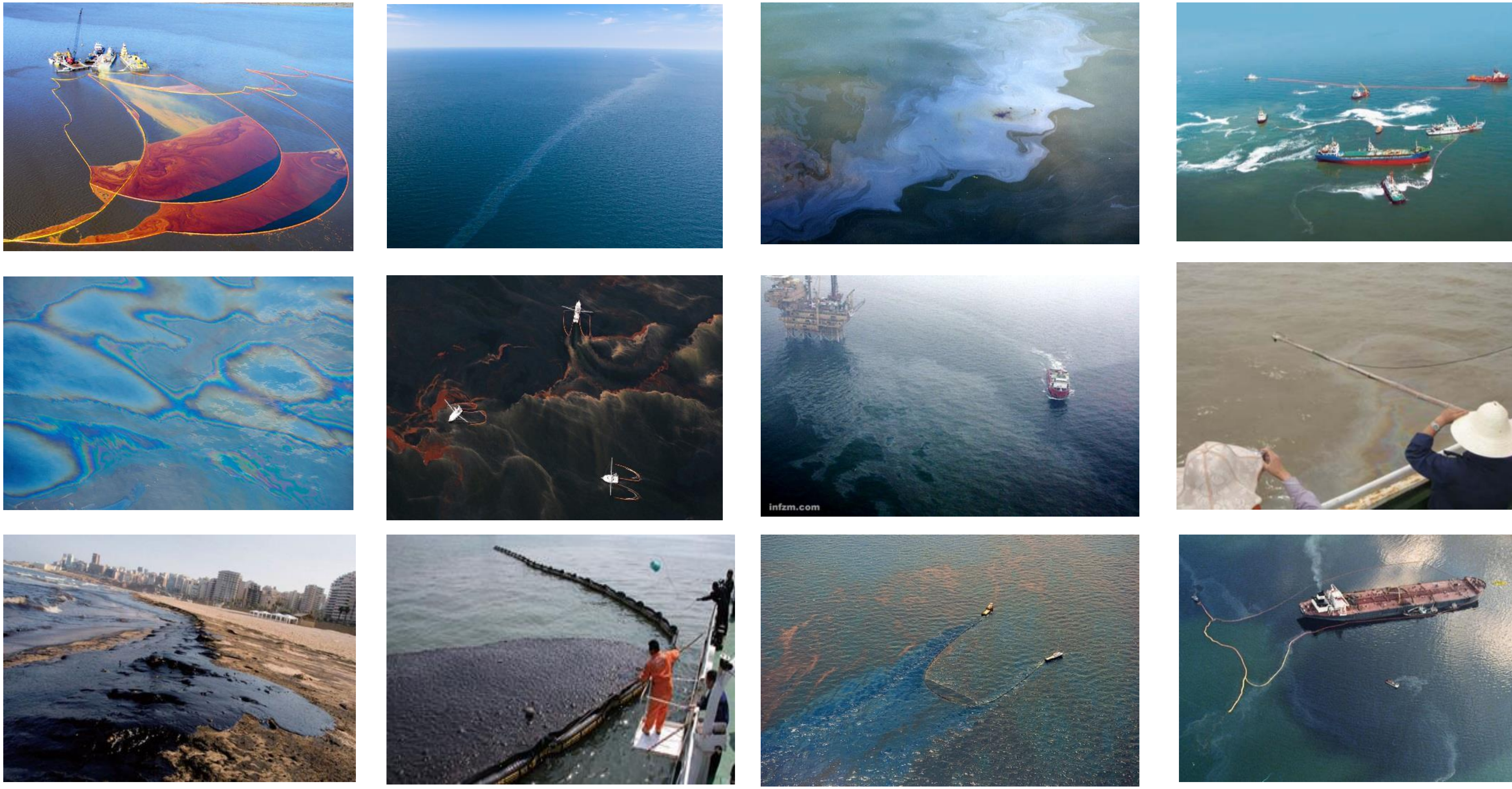
Outline

1. Visual appearance and spectral discrimination

2. Optical processes

3. Applications and challenges

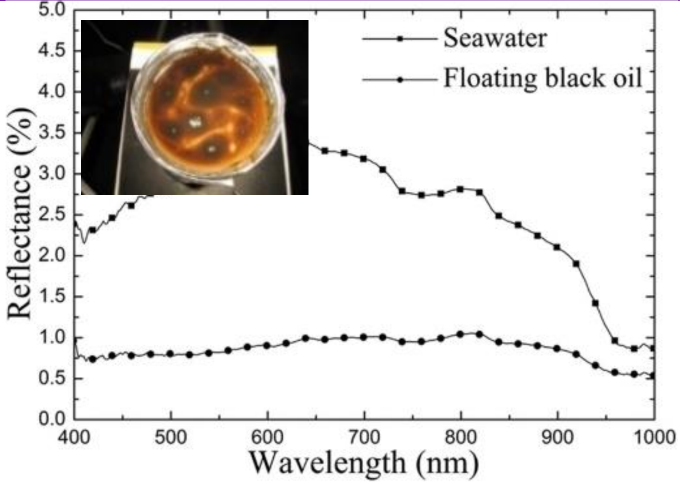
1. Visual appearance and spectral discrimination



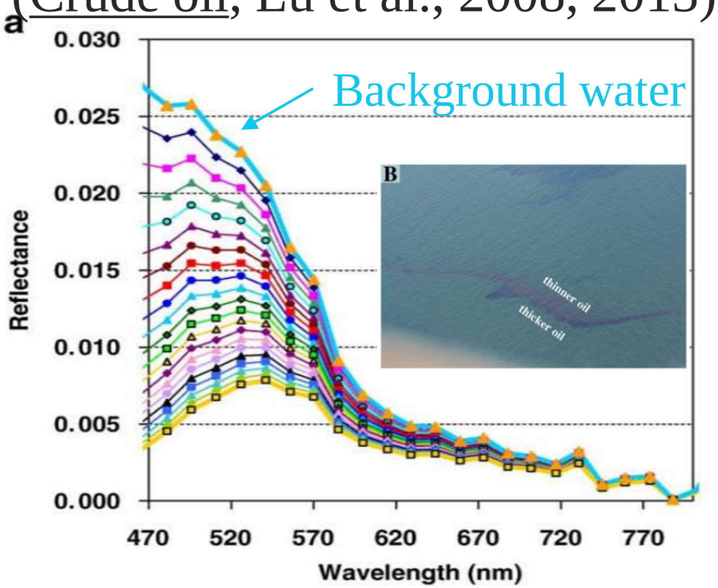
Various visual features of spilled oils !

- *Can these visual features be used in optical remote sensing of oil spills?*
- *How to identify and quantify various spilled oils with optical remote sensing imageries?*

1. Visual appearance and spectral discrimination

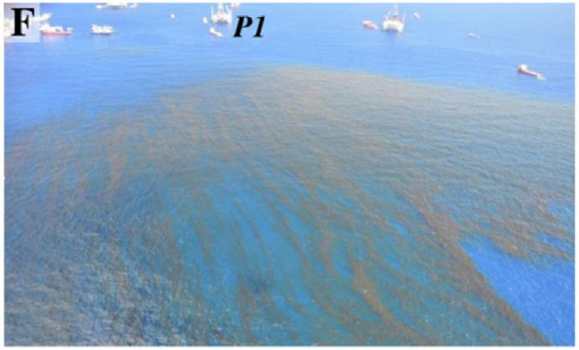


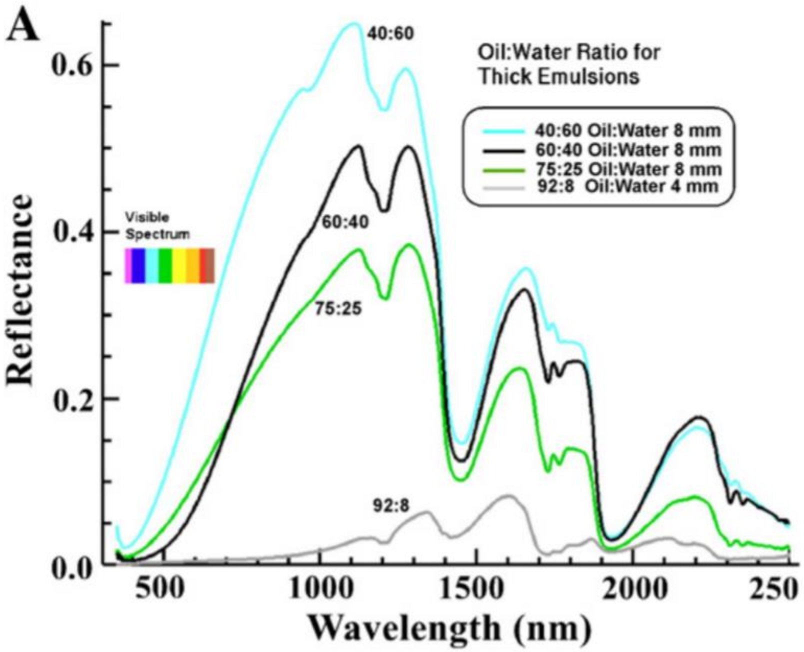
(Crude oil, Lu et al., 2008, 2013)



Oil slicks with different thickness

(Wettle et al., 2012)





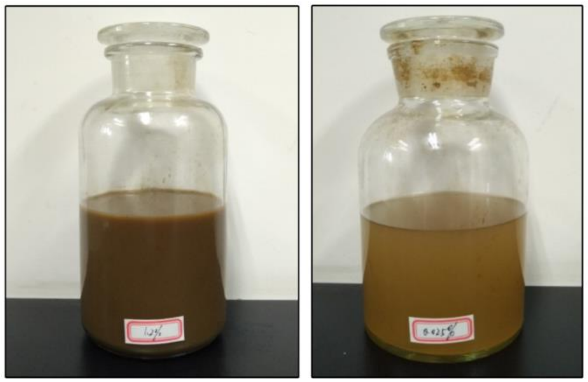
Oil emulsions in BP oil spill

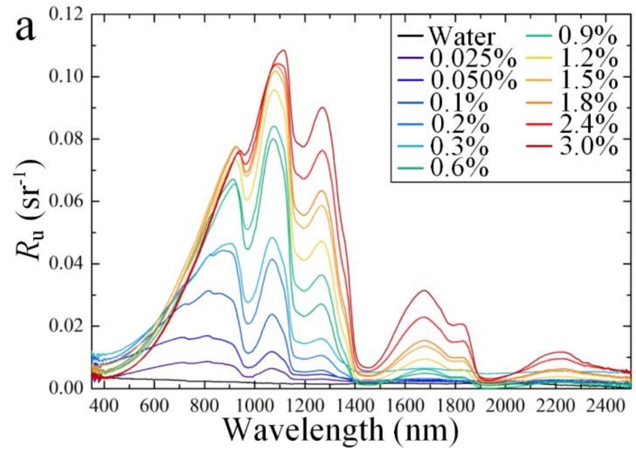
(Leifer et al., 2012)

(Clark et al., USGS report, 2010)

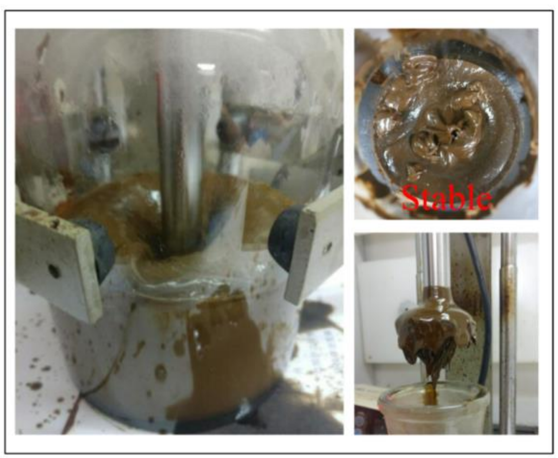
1. Visual appearance and spectral discrimination

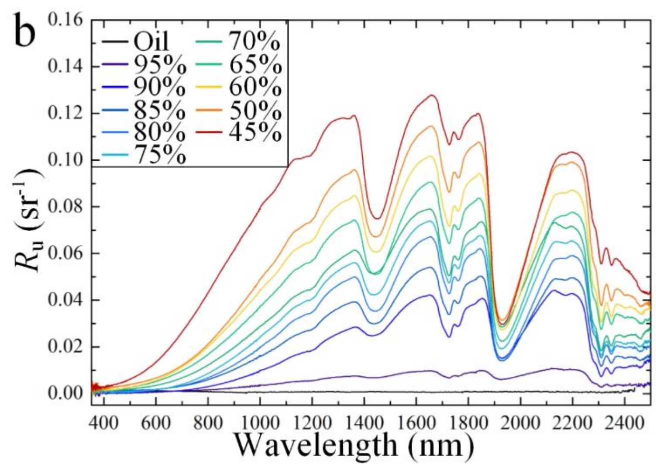
Oil emulsions generally have two different forms: water-in-oil (WO) emulsions and oil-in-water (OW) emulsions (Lu, Hu, et al., 2018, Submitted to RSE).





- OW emulsion: Small water are entrained in oil





- WO emulsion: Consists of small oil droplets incorporated in water

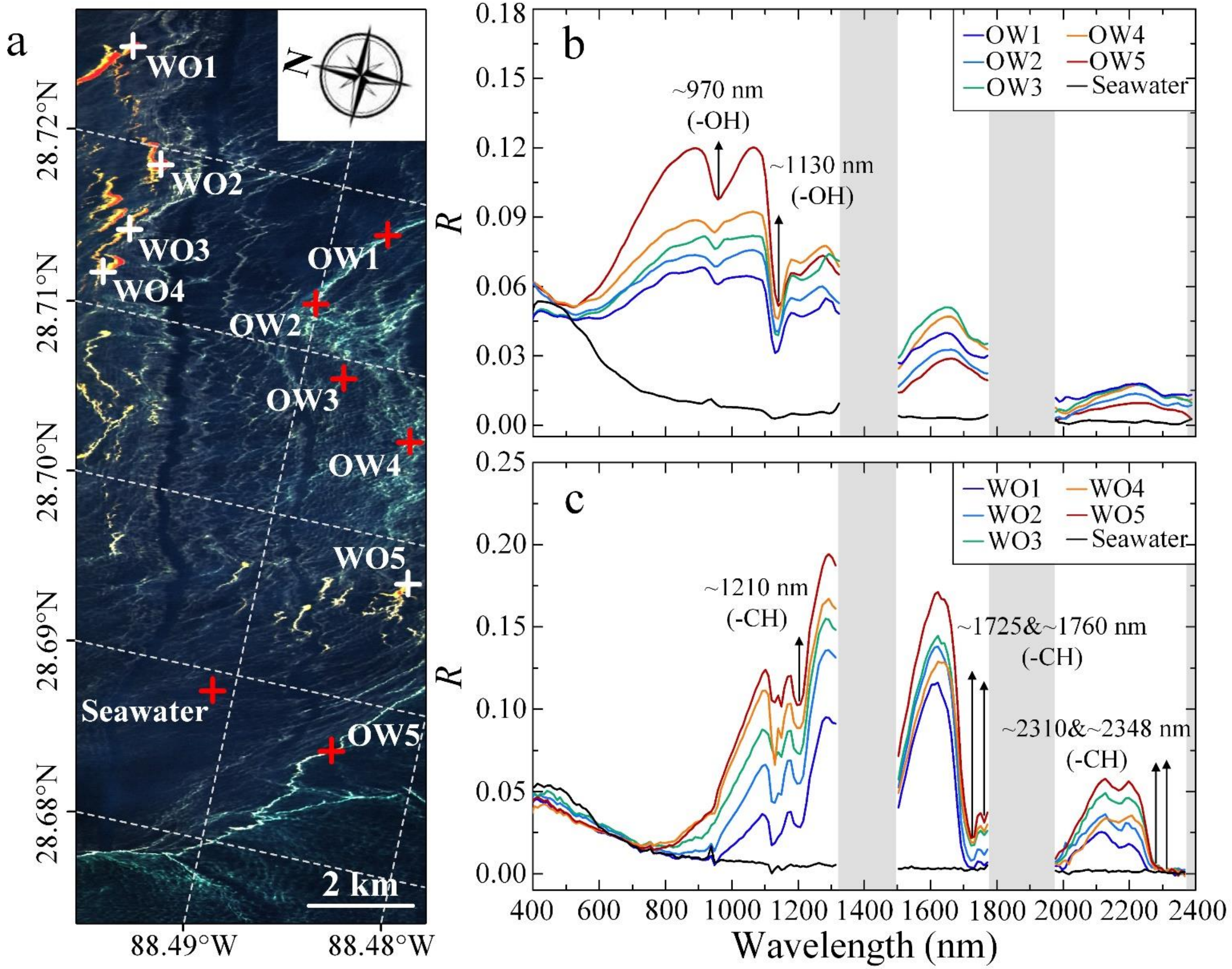
Please notes:

Wavelength

350-2500 nm;

$R_u = L_{oil}/E_d$

1. Visual appearance and spectral discrimination

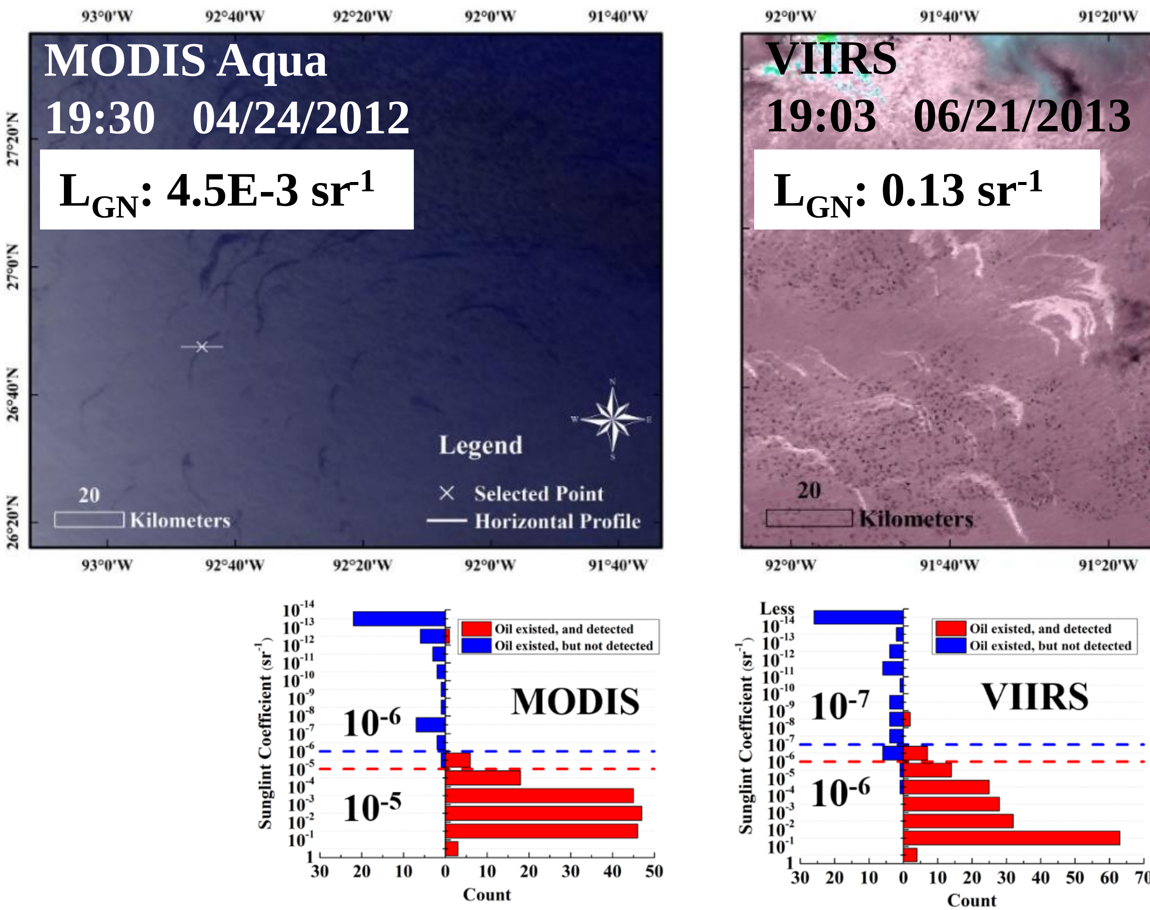


Proof-of-concept with AVIRIS observation

(R: 1672 nm, G:831.5 nm, B:647.8 nm)

2. Optical processes

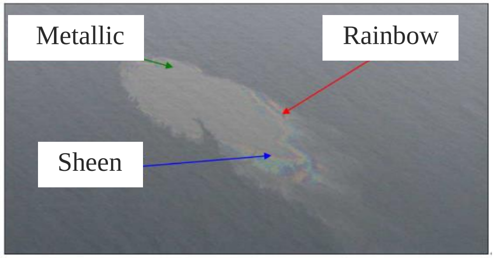
Sunglint helps detection but presents challenges on classification and quantification of spilled oils.

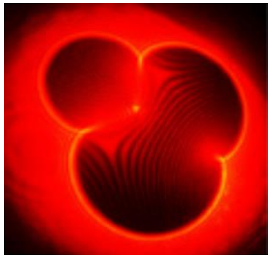


Minimum sunglint required to observe thin films.

Sun & Hu, 2016

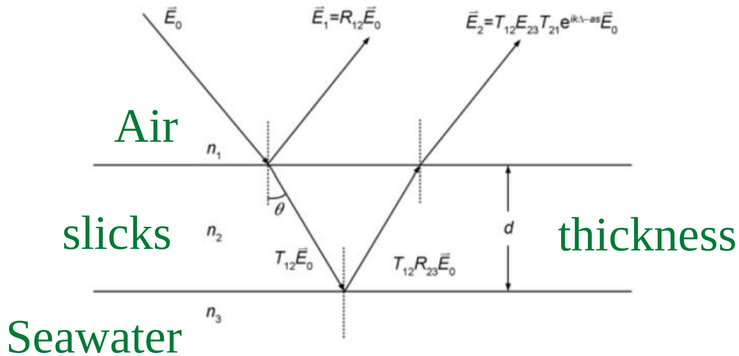
2. Optical processes





Bonn Agreement, Kukhtarev et al., 2011

Light interference theory
describes optical process of oil slicks

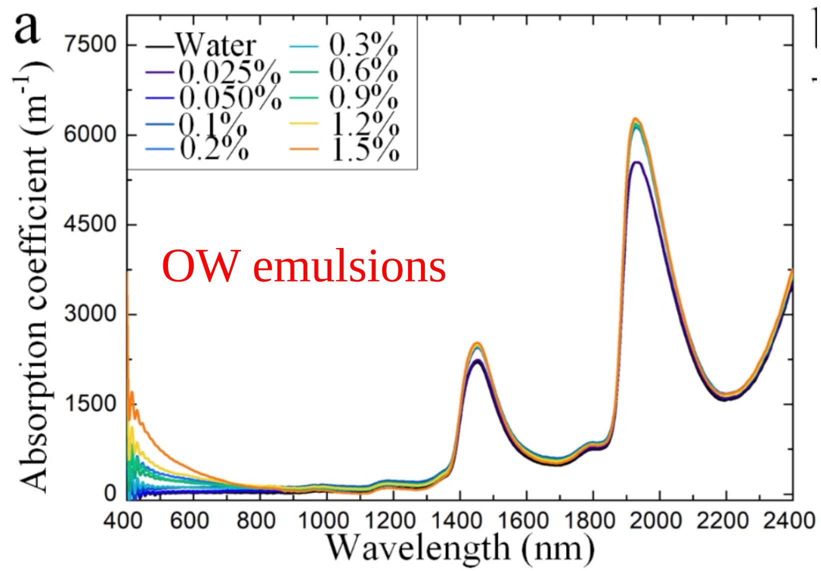


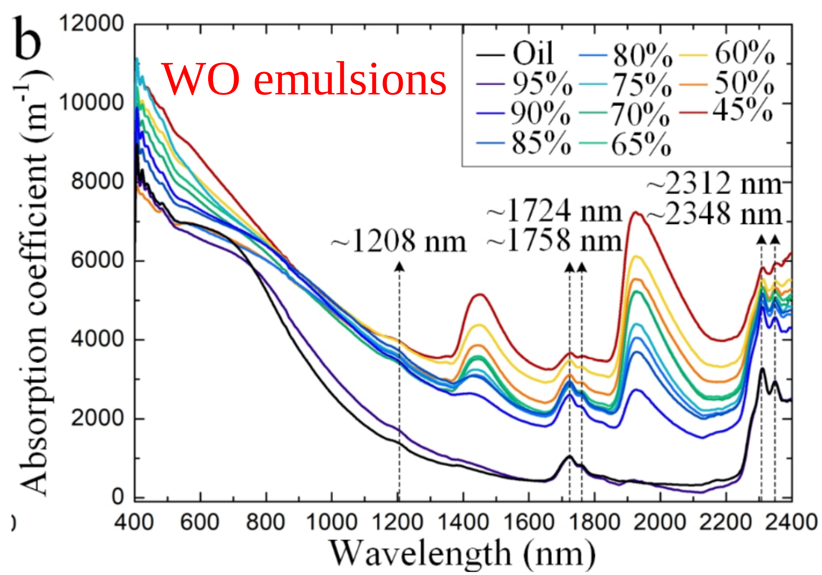
Two-beam interference model of oil slick

$$R=R_{oil\text{-}max}+(R_{water}-R_{oil\text{-}max})e^{-2ad}$$

a is extinction coefficient of oil; d is thickness; $R_{oil\text{-}max}$ is reflectance of the thicker oil slick.

(Lu et al., 2011, 2012)



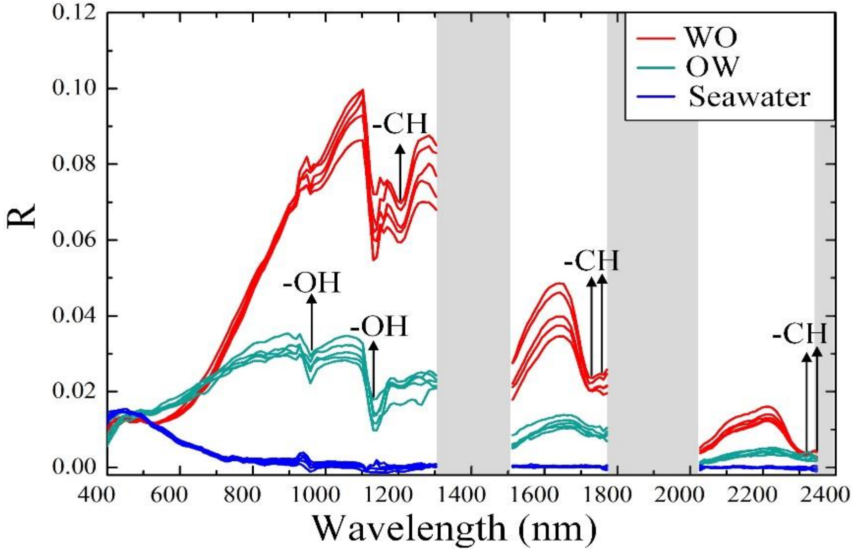


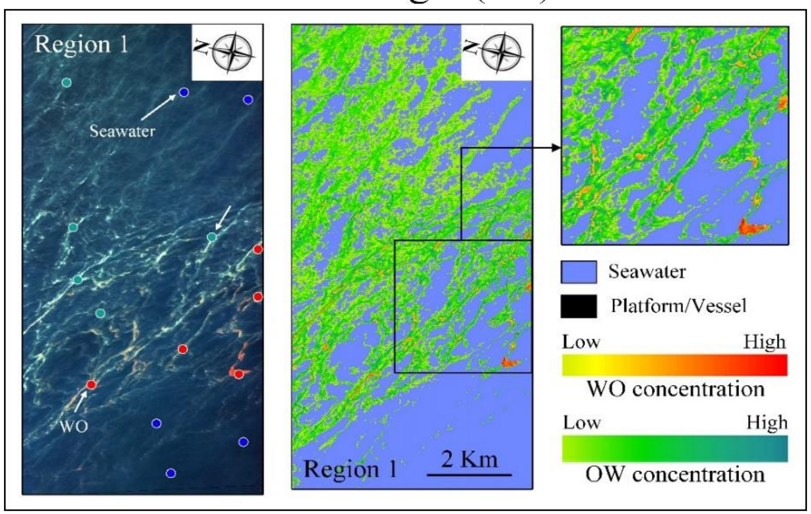
Lu, Hu et al., Submitted to RSE

Please note the wavelength is 400-2500 nm.

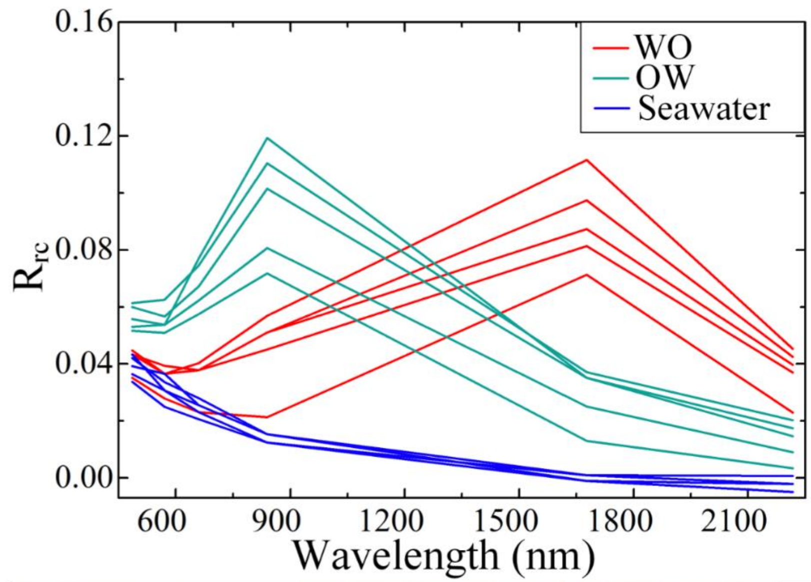
3. Applications and challenges

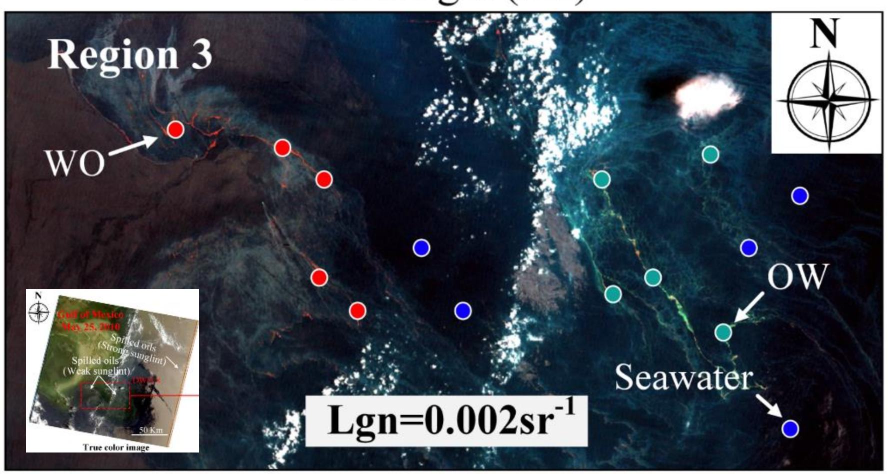
Spectra-based classification





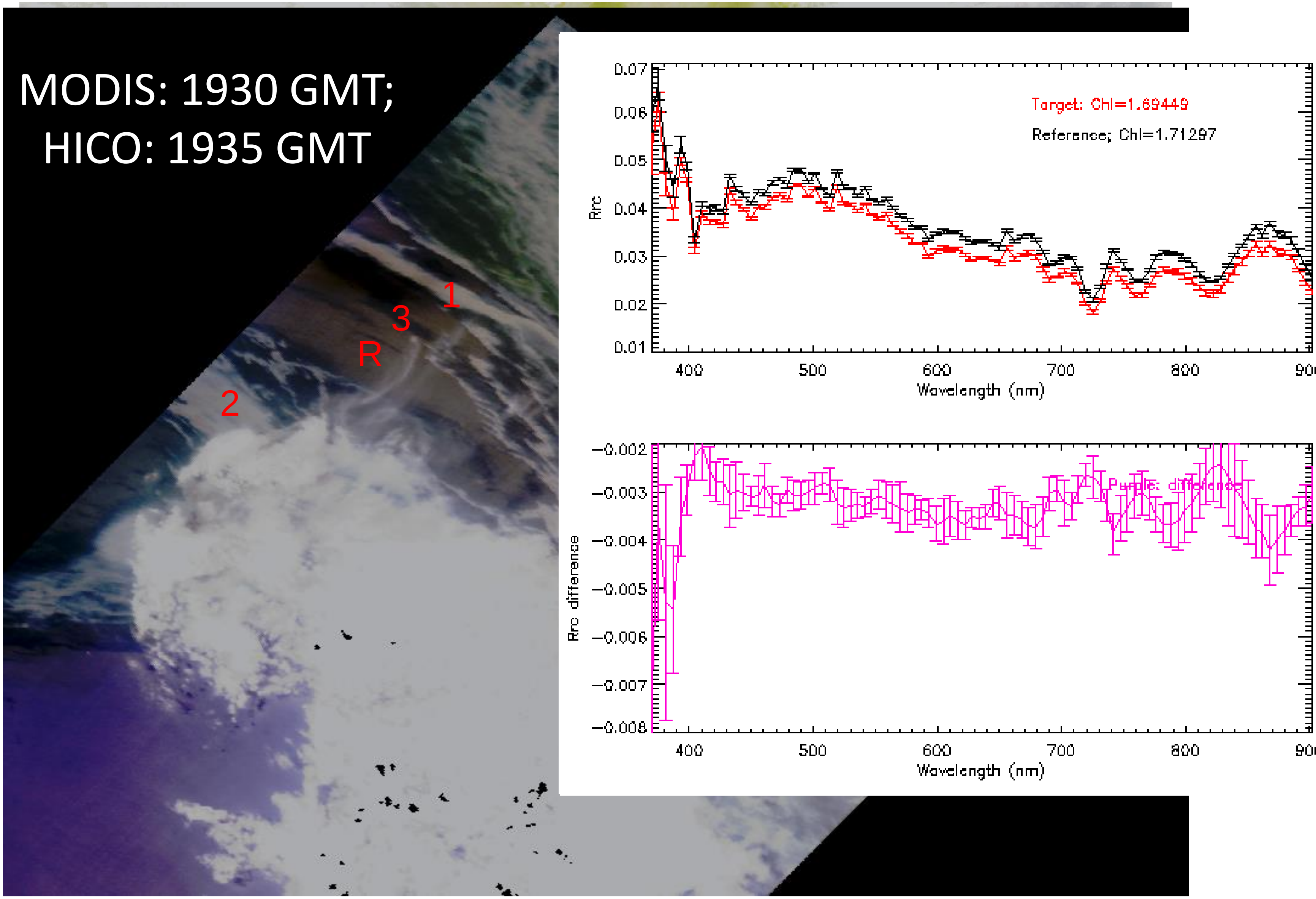
AVIRIS false color image (1672, 831, 658 nm)





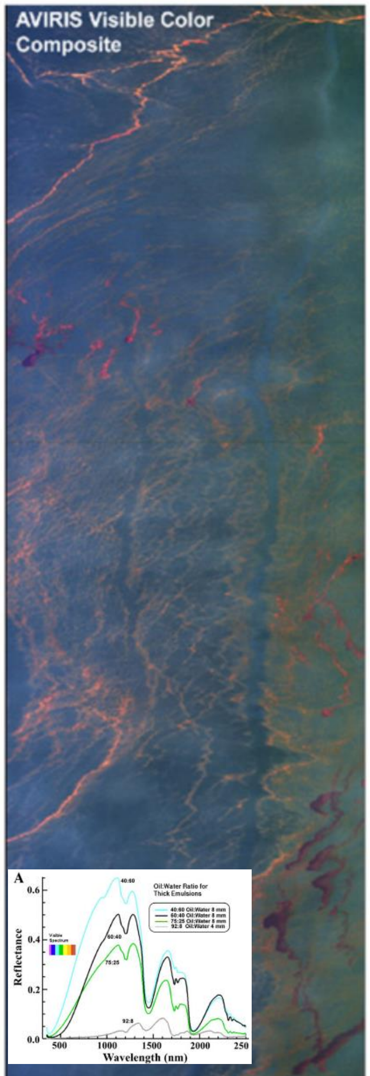
Landsat false color image (1677, 839, 660 nm)

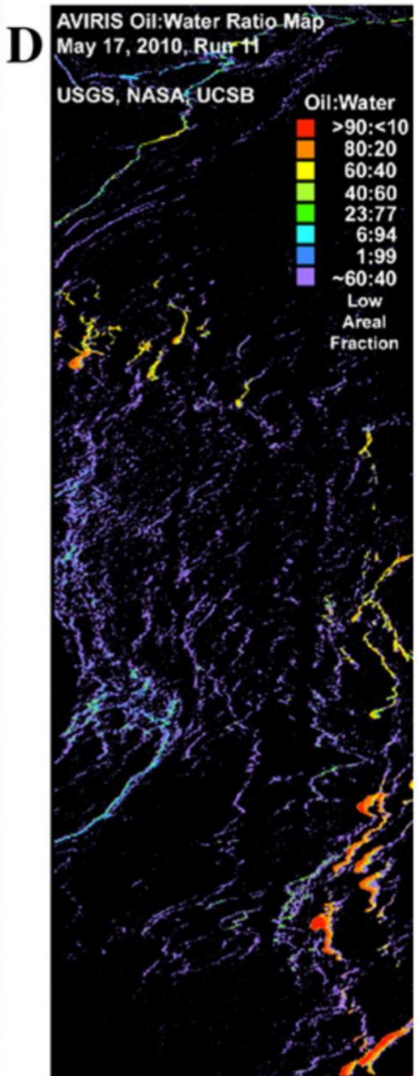
3. Applications and challenges



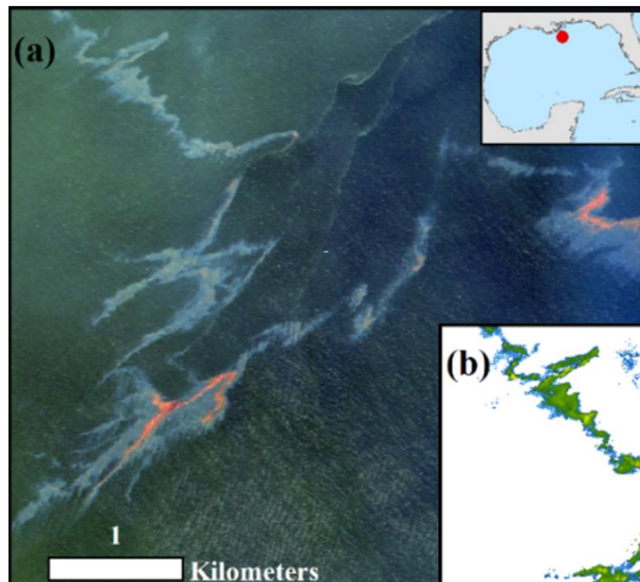
3. Applications and challenges

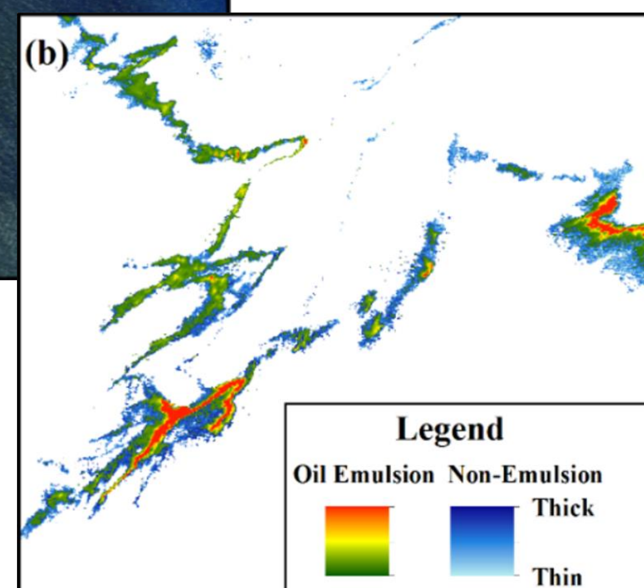
Remote estimation of oil volume from oil emulsions





Oil appearance and thickness was used to estimate oil volumetric from AVIRIS images without sunglint (Leifer et al., 2012; Clark et al., 2010).





Sun & Hu, 2018

3. Applications and challenges

Significant progresses

(1) Various spilled oils (i.e., non-emulsion oil slicks, WO and OW emulsions) have the different spectral features which have been clarified from Lab-measurements and verified by airborne observations of AVIRIS.

(2) These different oils have different optical processes when interacting with light as they can reflect, absorb, and scatter the incident light, resulting in different optical contrast from surrounding oil-free water and thus providing a theoretical basis for their detection, classification, and quantification through optical remote sensing

Challenges

(1) How to calculate sunglint reflectance of various oils?

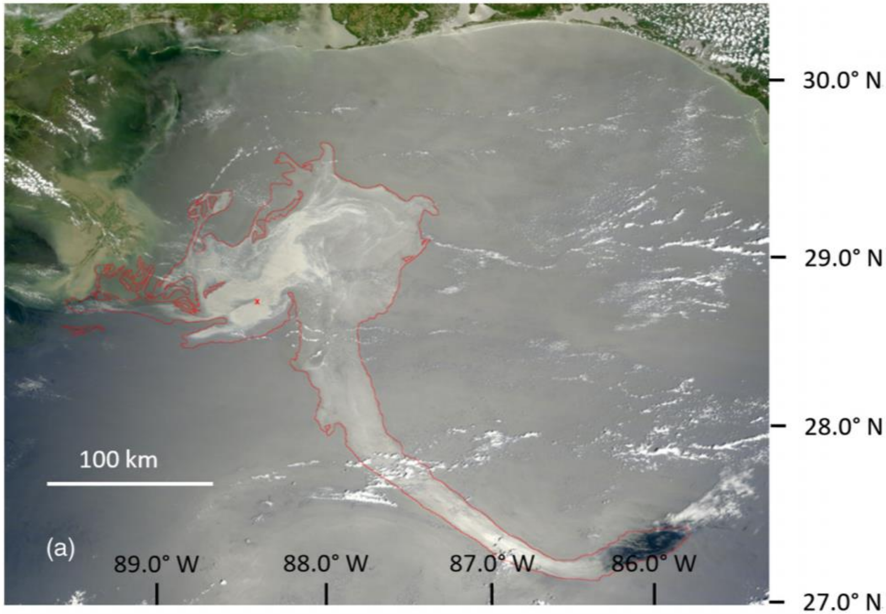
Refractive index and surface roughness of various oils cannot be given until now.

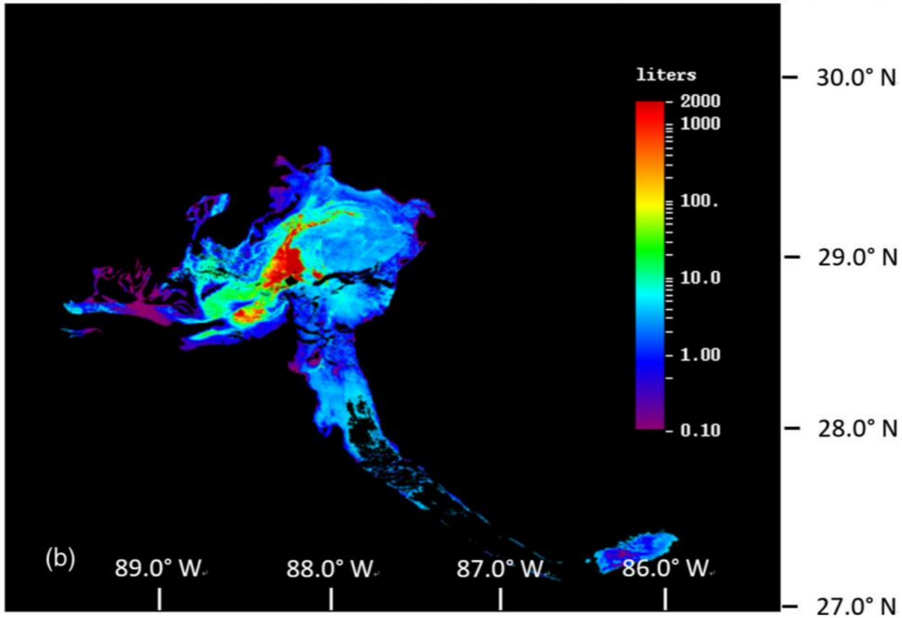
(2) Optical remote estimation model is hard to develop due to high heterogeneity of spatial distribution of various weathered oils (Mixing spectra).

(3) How to verify calculated results from remotely sensed imageries is still a challenge.

Poster: Optical interpretation of oil emulsions in the ocean – From laboratory measurements to remote sensing applications

3. Applications and challenges





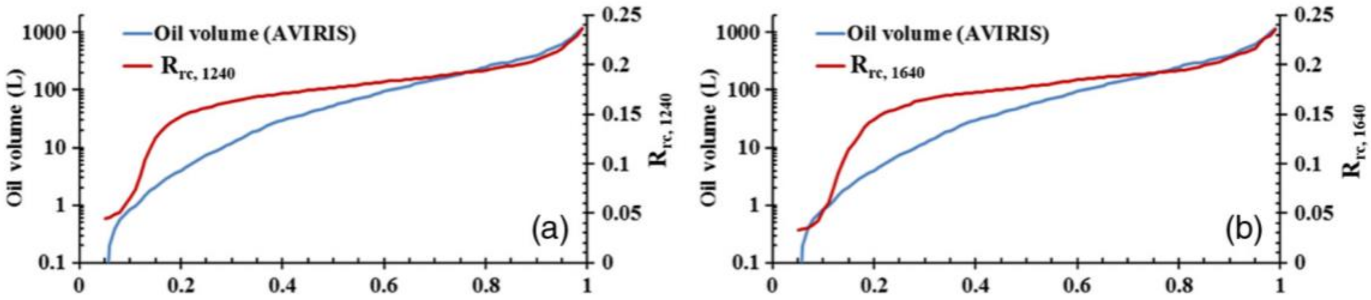


Fig. 4 Cumulative histograms of MODIS Rayleigh-corrected reflectance (a) $R_{rc,1240}$ (aqua) and (b) $R_{rc,1640}$ (terra; both after subtraction of the nearest water background), and AVIRIS-derived surface oil volume for the AVIRIS flight line Run10 in Fig. 1(b). The x-axis shows the cumulated frequency. Note that oil volume is plotted in log scale. They show different shapes in the cumulative histograms but are forced to agree with each other at each x-axis point using regressions, as shown in Fig. 5.

Hu et al., 2018