Water Mapping®

Fingerprinting oil thickness in Satellite Remote Sensing

Oscar Garcia-Pineda
Gordon Staples, George Graettinger

The work presented here thanks to:
WaterMapping, NOAA, MDA-Coorporation, NASA, USGS, Stratus Consulting.

Monitoring Oil Spills with SAR is a well stablished task, so, what is new?

This talk:

Beyond of: Is it ‘oil’ or ‘not-oil’?....

Is it ’thin oil’ or **‘thick oil’....**

Is it recoverable?



Background,

What has been done for oil thickness detection….

(Using Microwave Remote Sensing)

Quad-pol

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

When anisotropy is zero, the scattering mechanism is azimuthally symmetric. Therefore, anisotropy can also be considered the measure of the lack of azimuthal symmetry or as an indication of small-scale surface roughness [47], [49]. Whenever entropy is low ($\lambda_1 \gg \lambda_2$) anisotropy is highly affected by noise [45]. We expect UAVSAR to provide better evaluations of anisotropy in low entropy areas because UAVSAR has a higher signal-to-noise ratio (SNR) (discussed later) than any other operational SAR system.

The mean scattering parameter, $\bar{\alpha}$, which is calculated from the eigenvectors, $\mathbf{u}_i$, of (14) as

$$\bar{\alpha} = \sum_{i=1}^{3} p_i \alpha_i \quad 0^\circ \leq \alpha \leq 90^\circ \tag{18}$$

indicates the types of scattering mechanisms present in the distributed target. Over the ocean, we can expect a dominant surface scattering component, so $\bar{\alpha}$ for the free ocean surface in moderate winds is less than 42.5° and increases with increasing incidence angle. When volume scattering becomes a primary contributor to the total backscatter, $\bar{\alpha}$ is greater than 42.5°. When ships are present, $\bar{\alpha}$ should be greater than 60°[44].

For Bragg scattering from an untilted, horizontal surface, the coherency matrix has a single dominant eigenvalue ($\lambda_1 > 0, \lambda_2 \approx 0, \lambda_3 \approx 0$) whose corresponding eigenvector is

$$\begin{aligned} \mathbf{u}_1 &= \mathbf{k}_{Bragg} \\ &= \frac{1}{\sqrt{2}}[S_{HH} + S_{VV} \quad S_{HH} - S_{VV} \quad 0]^T \\ &\approx m_s[R_{HH} + R_{VV} \quad R_{HH} - R_{VV} \quad 0]^T \end{aligned} \tag{19}$$

where m_s is the roughness coefficient [49]. In this case, the entropy is very low. The scattering parameter, $\bar{\alpha} \approx \alpha_1$, is independent of surface roughness and increases as a function of only the dielectric constant and incidence angle [45], [50] as

$$\tan(\alpha) \approx \frac{|R_{HH} - R_{VV}|}{|R_{HH} + R_{VV}|}. \tag{20}$$

III. *In Situ* Oil Spill and Environmental Observations

The oil released from the DWH well is classified as Mississippi Canyon Block 252 (MS252) (South Louisiana sweet crude) oil, which is a comparatively light crude that contains significant quantities of natural gas when released. The characteristics of the surface oil in the main slick varied greatly, from thicker layers of crude to thinner sheens, and a range of aggregated and weathered forms of oil-water emulsion. On June 23, 2010, the second day of the UAVSAR campaign and the day that the main spill site was imaged, the containment cap, which had been successfully capturing significant quantities of oil for removal to ships, had to be removed because of a mishap when a robotic arm hit one of the vents in the cap. The removal of the cap thus restarted the release of the full flow rate of oil so at the time of the UAVSAR overflights the oil in the study area was

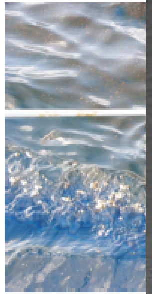


Fig. 2. Surface oil near
(Photograph provided by

mainly freshly releas
taken near the spill si

During the perio
ous daily overflight
vide information an
erties for first respo
helicopter imagery a
deepwater_horizon_
Protection Agency (
multiple aerial and
cal Survey archive (
disaster=201004_Oi

We identified a se
tion over the main b
mately 7 h of the tim
tracks, which occurr
shows representative
Based on these colle
properties of the oil
the bulk of the oil spi
primarily of brown
in color, mixed with thinner (silver and rainb
Dispersants are thought to have been applied
slicks [Fig. 3(c) and (d)] because of the clo
slick appearance. The dispersants break do
particles or droplets, which then settle into th
least to shallow depths, thus forming a cloudy
than the streaky slicks seen in Fig. 3(b). Bas
field guide for aerial observations [51], these
the following range of thicknesses: emulsi
3 mm with a mean of 1 mm; rainbow sh
0.005 mm and mean = 0.001 mm; silver
to 0.0003 mm with a mean of 0.0001 mm.

Both buoy data and Wavewatch III postd
to obtain the sea surface conditions at t
UAVSAR data were acquired. The wave mo
the surface conditions were nearly uniform
in our analyses. At the nearby ocean bu
(28.191° N, 88.496° W), from 1200–1700 UTC, wind speeds ranged between 4 and 6 m/s with directions from 130° to 160°, with waves of significant wave heights of 1.0–1.5 m and

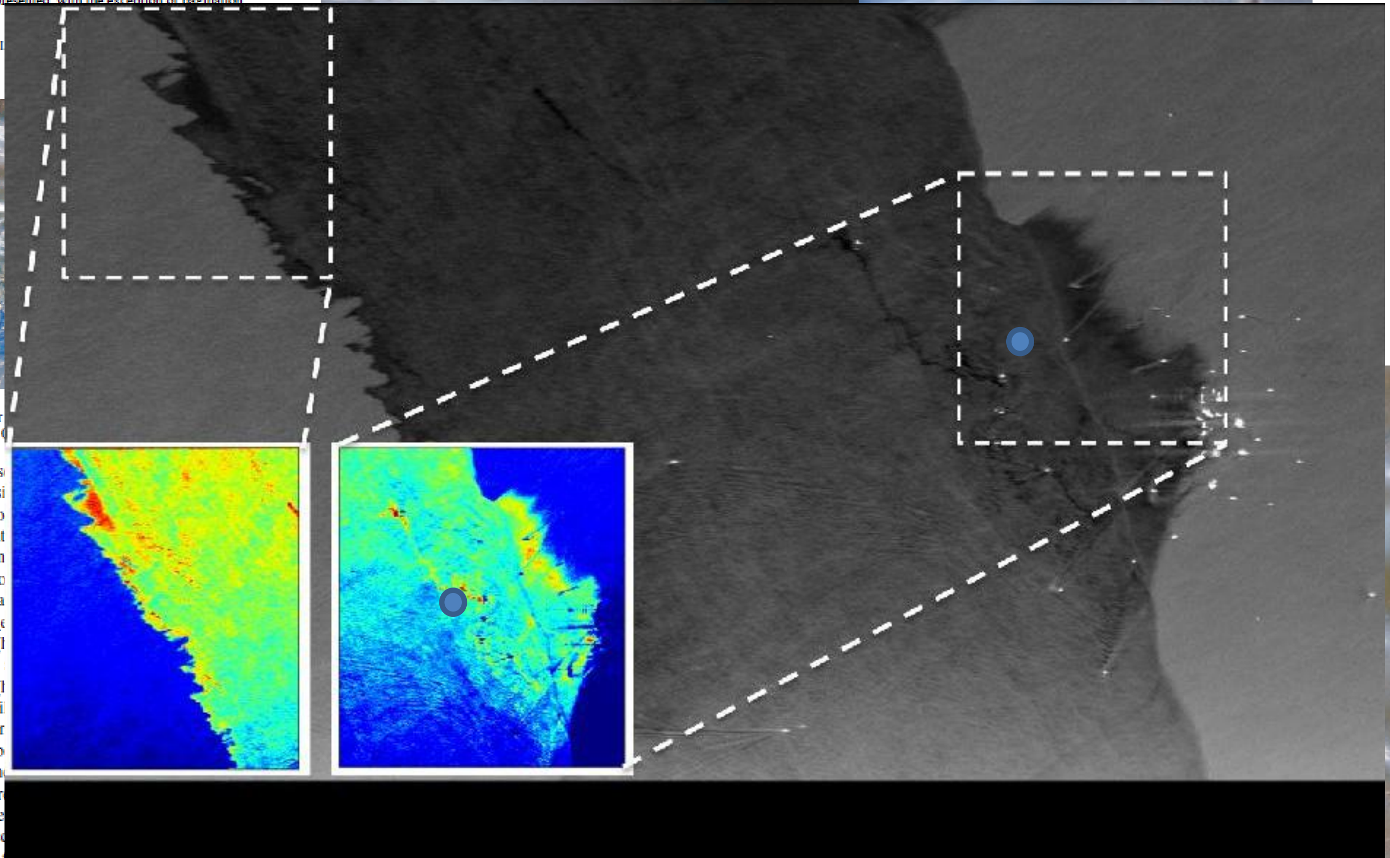
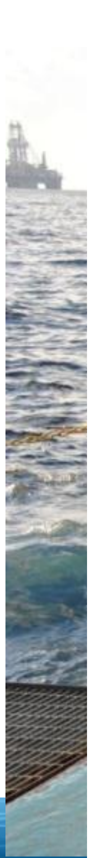
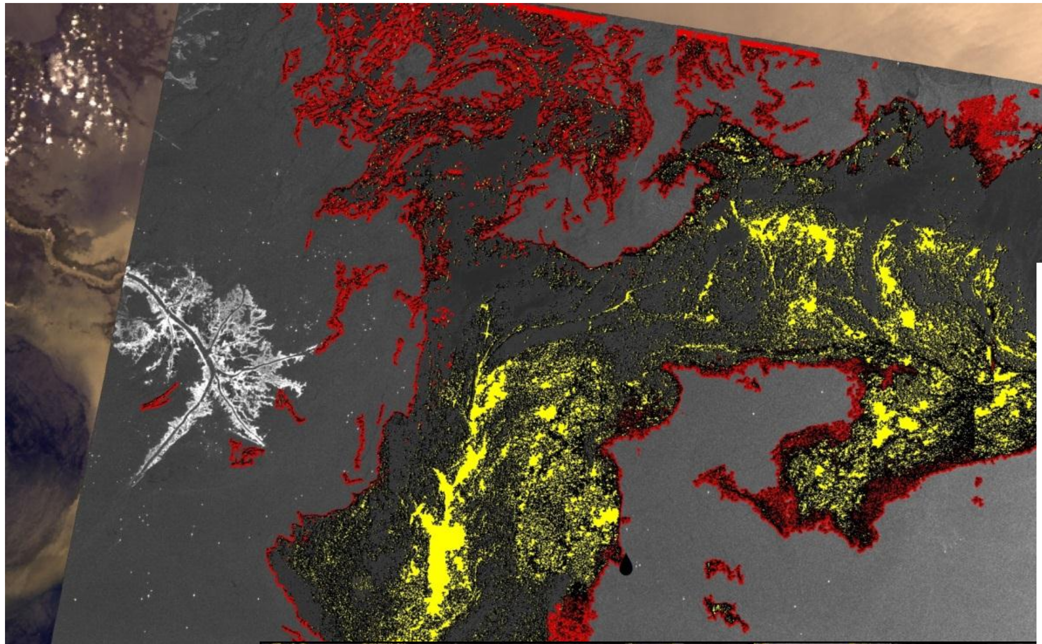


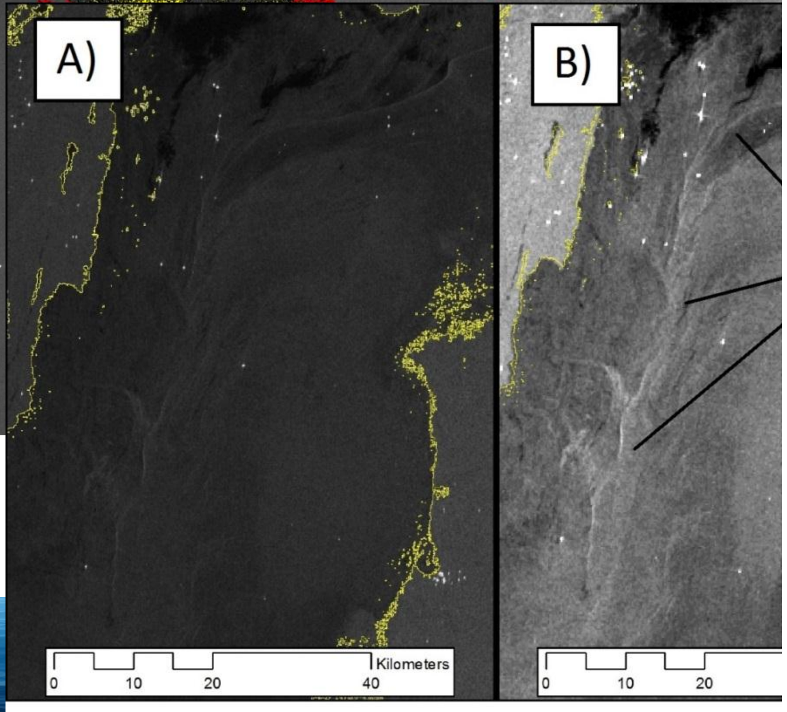
Image Courtesy of NASA, JPL

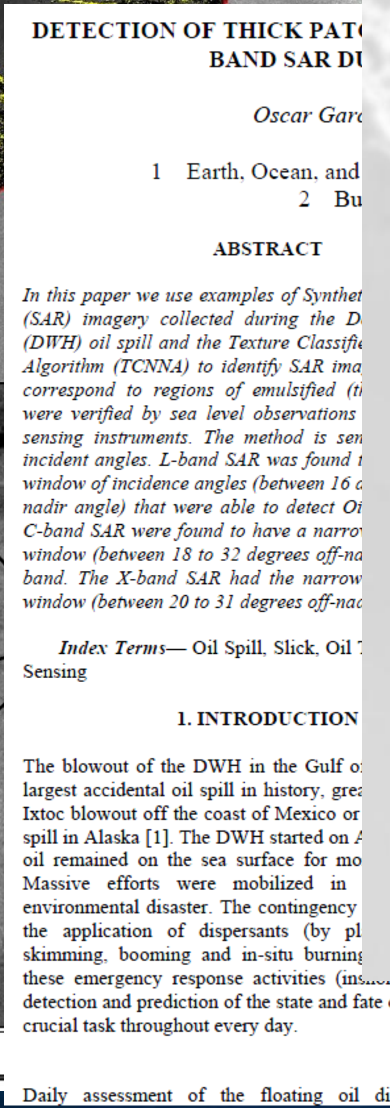


What has been done for oil thickness detection ….
(Using Microwave Remote Sensing)

Single-pol






DETECTION OF THICK PATC
BAND SAR DU

Oscar Garc

1 Earth, Ocean, and
2 Bu

ABSTRACT

In this paper we use examples of Synthet
(SAR) imagery collected during the D
(DWH) oil spill and the Texture Classifie
Algorithm (TCNNA) to identify SAR ima
correspond to regions of emulsified (th
were verified by sea level observations
sensing instruments. The method is sen
incident angles. L-band SAR was found t
window of incidence angles (between 16 d
nadir angle) that were able to detect Oi
C-band SAR were found to have a narrow
window (between 18 to 32 degrees off-na
band. The X-band SAR had the narrow
window (between 20 to 31 degrees off-nad

Index Terms— Oil Spill, Slick, Oil T
Sensing

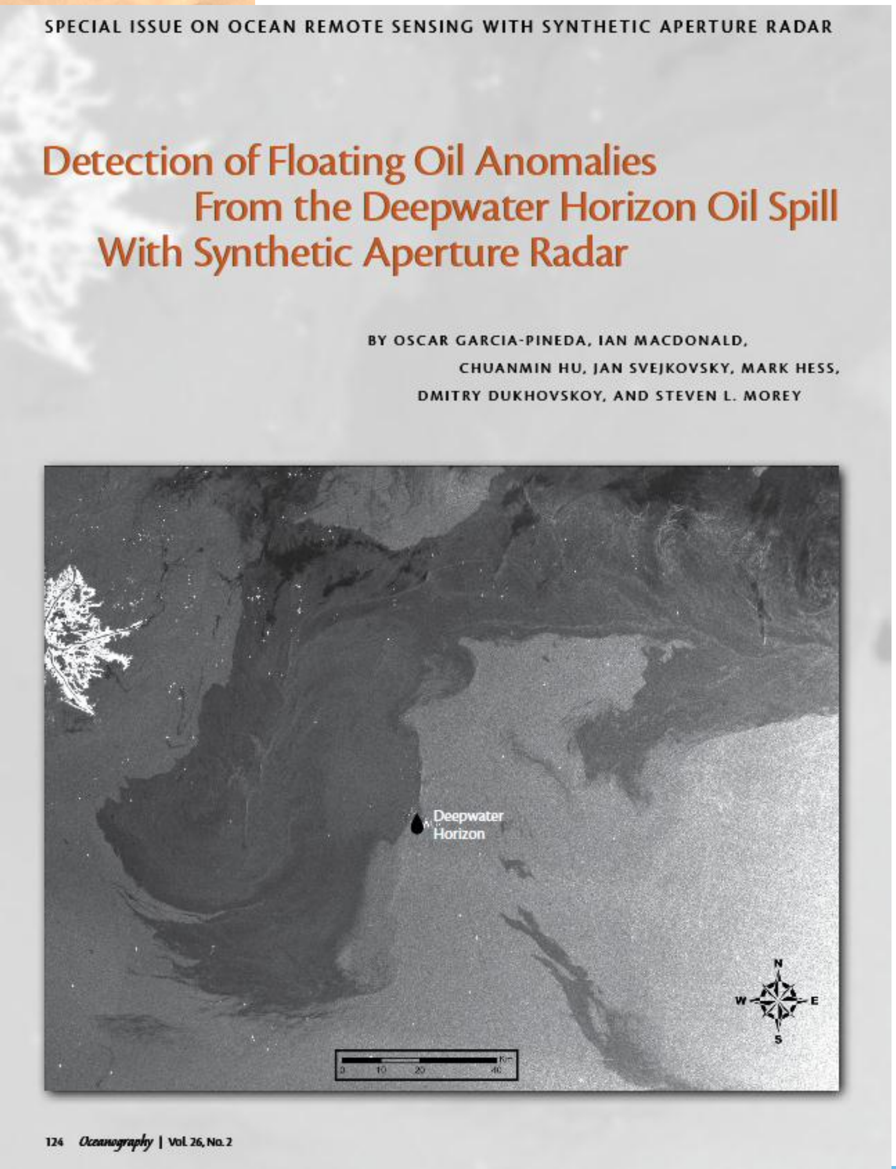
1. INTRODUCTION

The blowout of the DWH in the Gulf o
largest accidental oil spill in history, grea
Ixtoc blowout off the coast of Mexico or
spill in Alaska [1]. The DWH started on A
oil remained on the sea surface for mo
Massive efforts were mobilized in
environmental disaster. The contingency
the application of dispersants (by pl
skimming, booming and in-situ burning
these emergency response activities (in
detection and prediction of the state and fate of the oil was a crucial task throughout every day.

Daily assessment of the floating oil distribution and

Figure1. Oil slick produced by DWH oil spill. Image collected by Radarsat on May 10, 2010.

When crude oil reaches the surface of the ocean, it continues to react dynamically with biological, physical,


SPECIAL ISSUE ON OCEAN REMOTE SENSING WITH SYNTHETIC APERTURE RADAR

Detection of Floating Oil Anomalies From the Deepwater Horizon Oil Spill With Synthetic Aperture Radar

BY OSCAR GARCIA-PINEDA, IAN MACDONALD, CHUANMIN HU, JAN SVEJKOVSKY, MARK HESS, DMITRY DUKHOVSKOY, AND STEVEN L. MOREY

124 *Oceanography* | Vol. 26, No. 2

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Taylor Oil Spill Experiment

Spill Background:

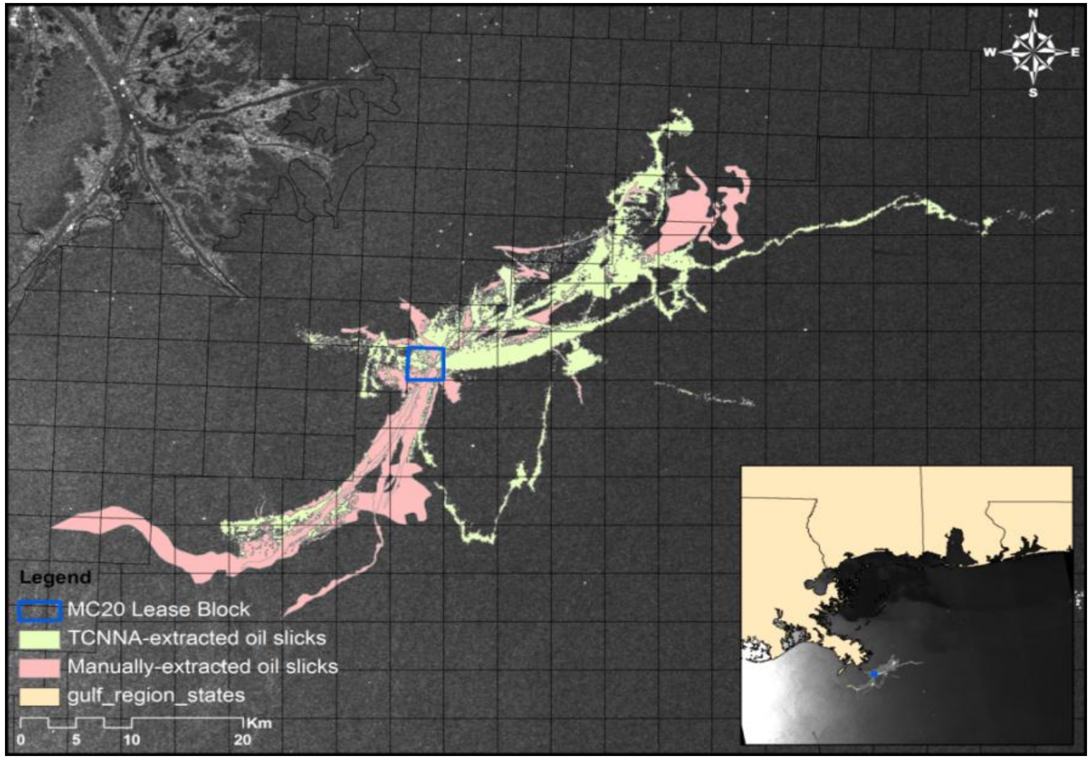


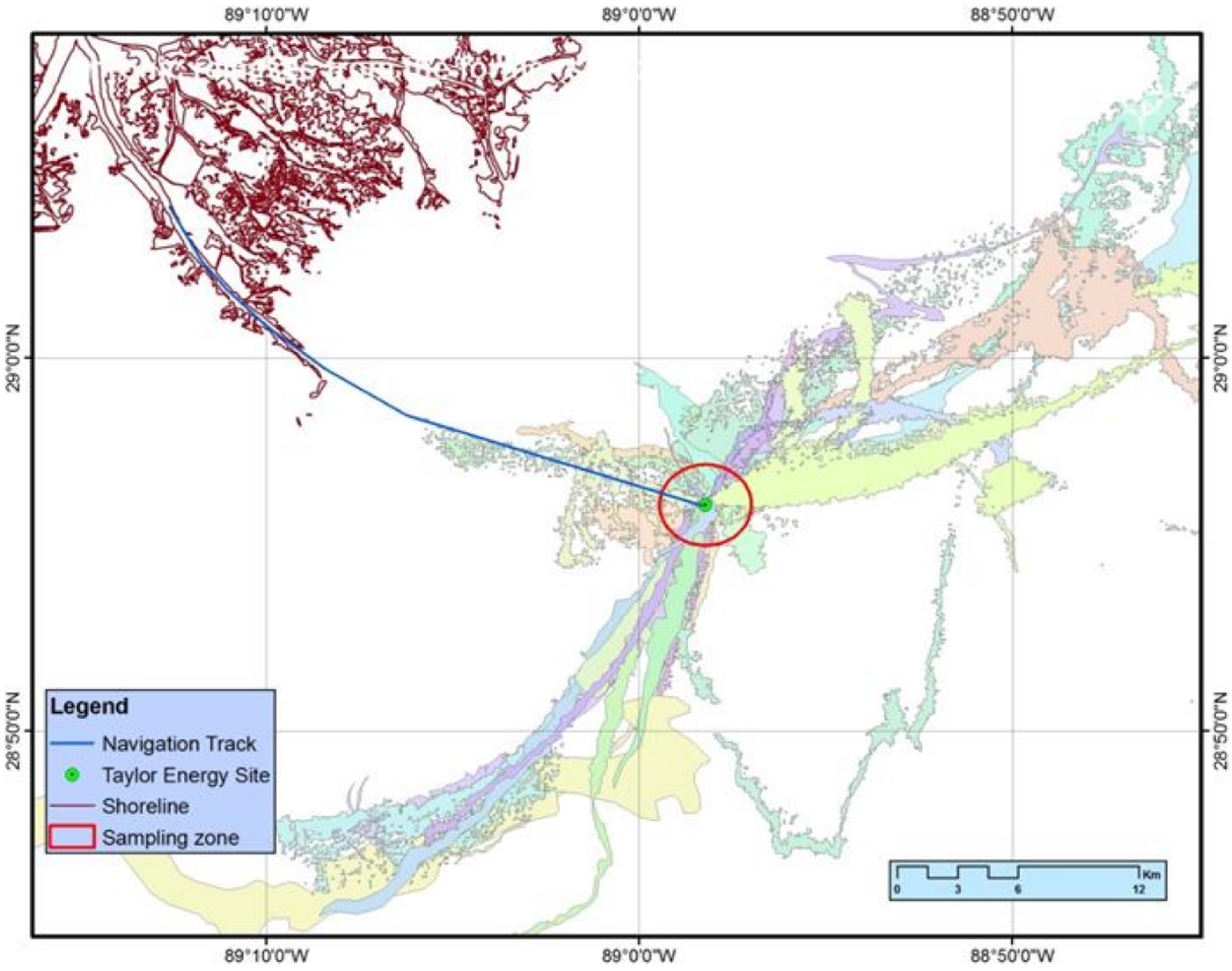
Figure 1: Composite of TCNNA and manually extracted oil slicks associated with the Taylor site in BOEM lease block MC020: August 2010 to January 2012. These outlines are from oil signatures sourced from the Taylor site and imaged by radar and optical satellites. Gridded outlines show BOEM lease blocks in region. Energy production platforms are visible as radar-bright targets. The background corresponds to a SAR image collected in 2012.

Taylor Energy oil platform, destroyed in 2004 during Hurricane Ivan, is still leaking in Gulf

4 comments

A 32-mile-long oil slick stretches east from the former site of Taylor Energy's Mississippi Canyon 20 A platform (X), which was knocked down and covered by a landslide during Hurricane Ivan in 2004. *(NASA Aqua satellite)*

TOSS Expedition



Expedition objectives:

- Identify oil features
- Collect oil samples
- Collect video & photography of oil features

Assets:

- Aerial support from WoC
- Boat with Structure Scan Sonar
- Spectro-radiometer

Satellite data acquired:

- Fine Quad-PolSAR (Radarsat-2)
  (3m resolution SAR C-band)
- TerraSar-X Single pol VV
  (10m resolution SAR X-band)
- Hyperion (EO-1)
  - Hyperspectral
- ALI (EO-1)
  - Multispectral
- MODIS (Aqua-Terra)

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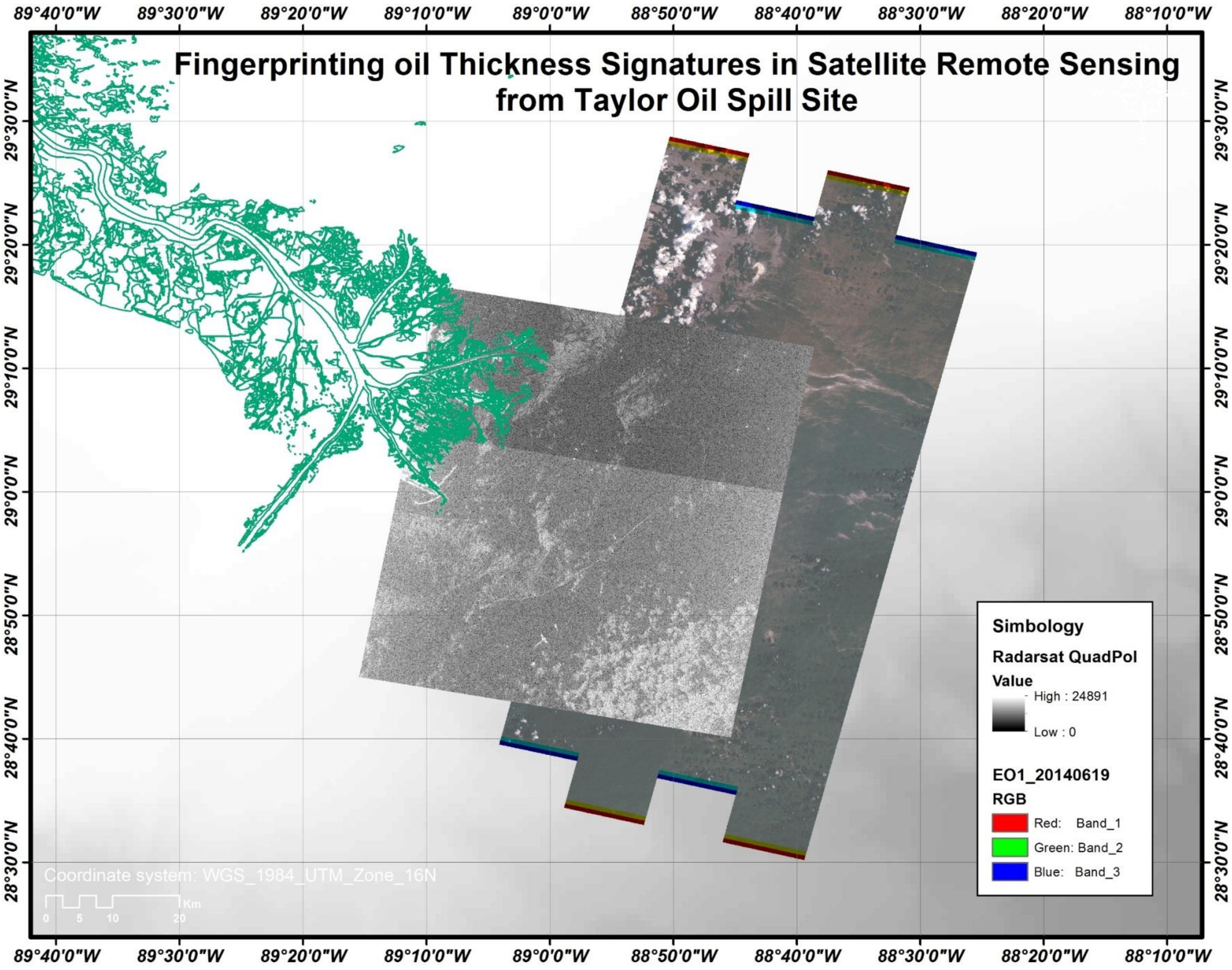
Time to watch a movie!



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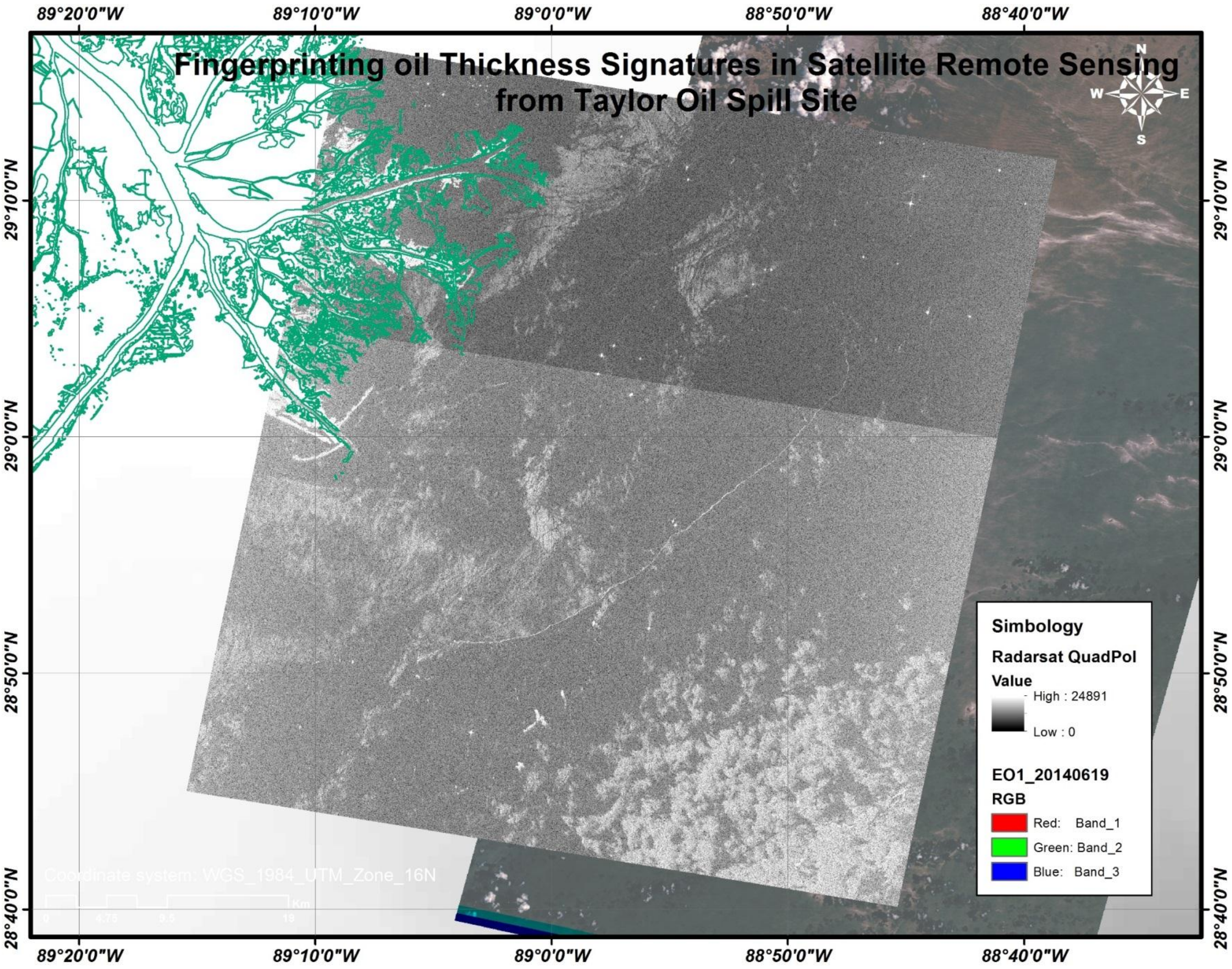
Fingerprinting oil Thickness Signatures in Satellite Remote Sensing from Taylor Oil Spill Site
89°20'0"W
89°10'0"W
89°0'0"W
88°50'0"W
88°40'0"W
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29°0'0"N
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Green: Band_2
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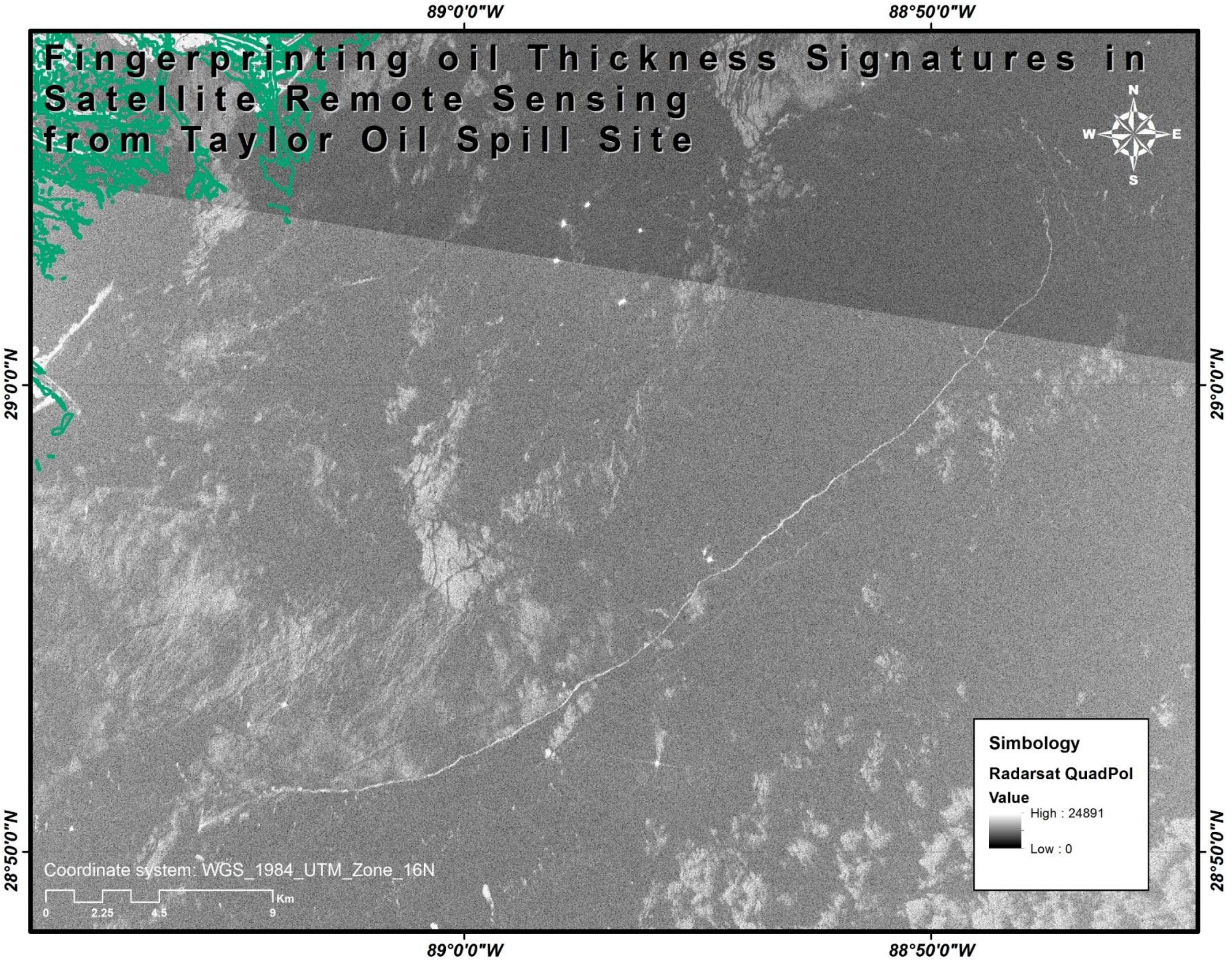
Coordinate system: WGS_1984_UTM_Zone_16N



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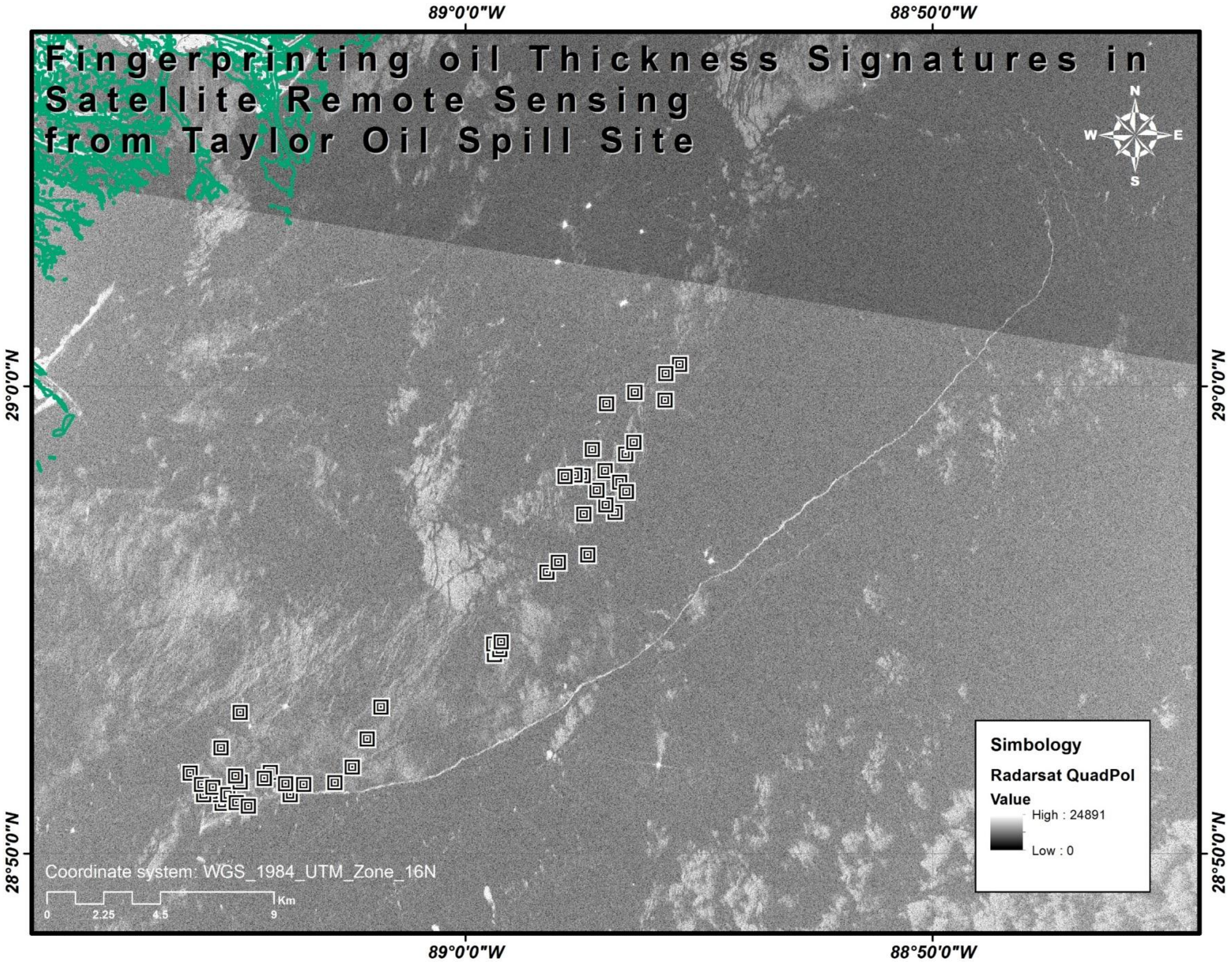

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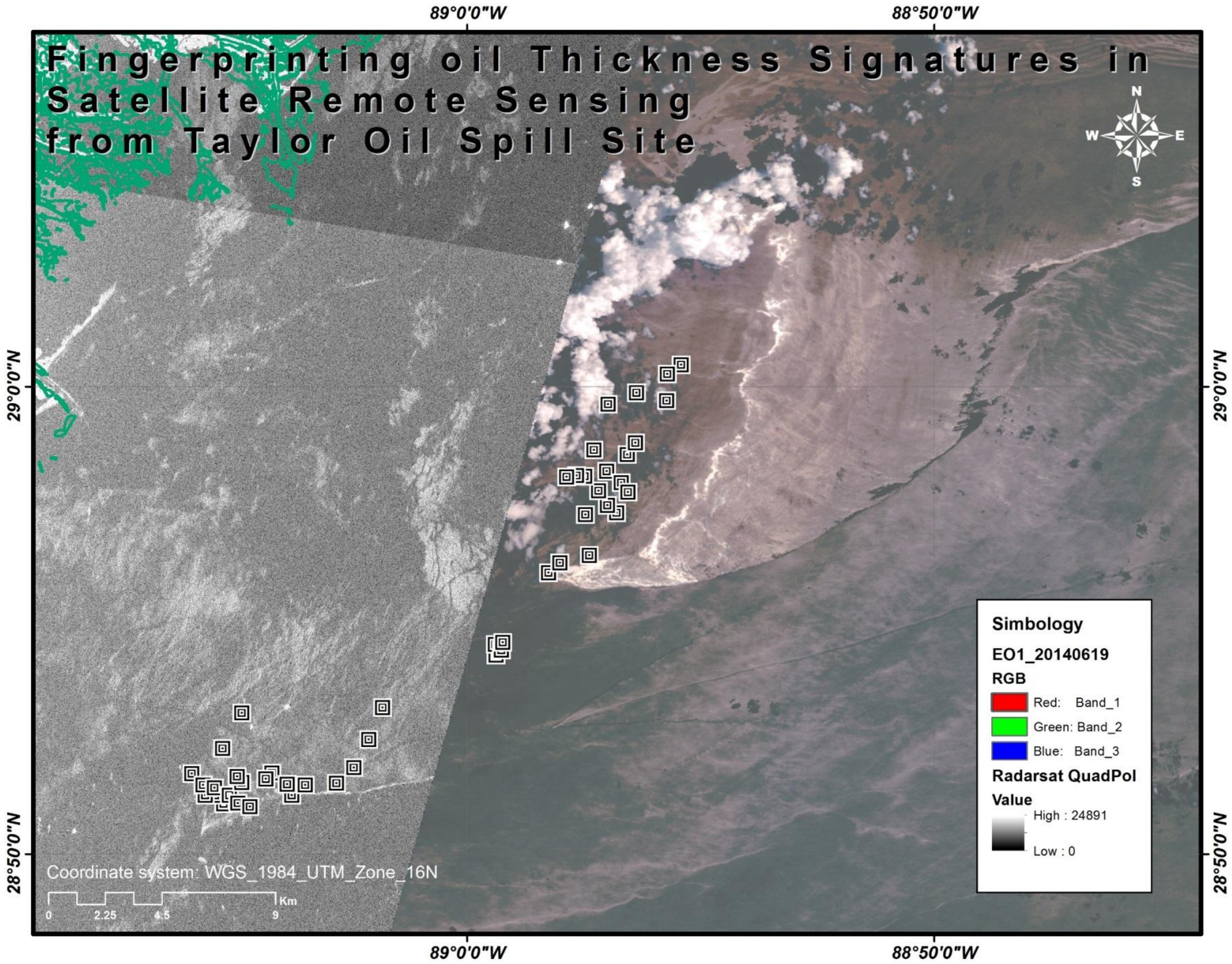
Fingerprinting oil Thickness Signatures in Satellite Remote Sensing from Taylor Oil Spill Site
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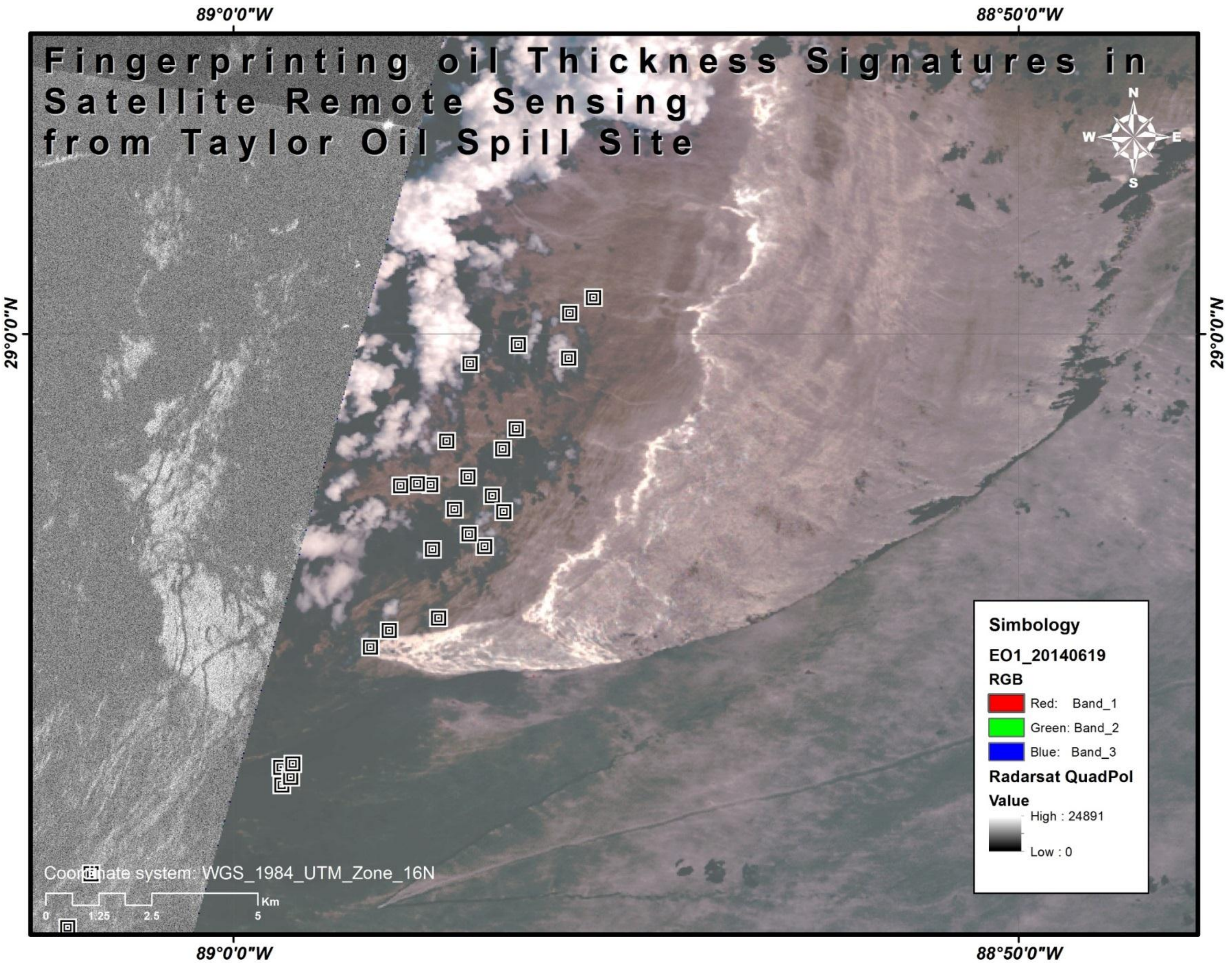
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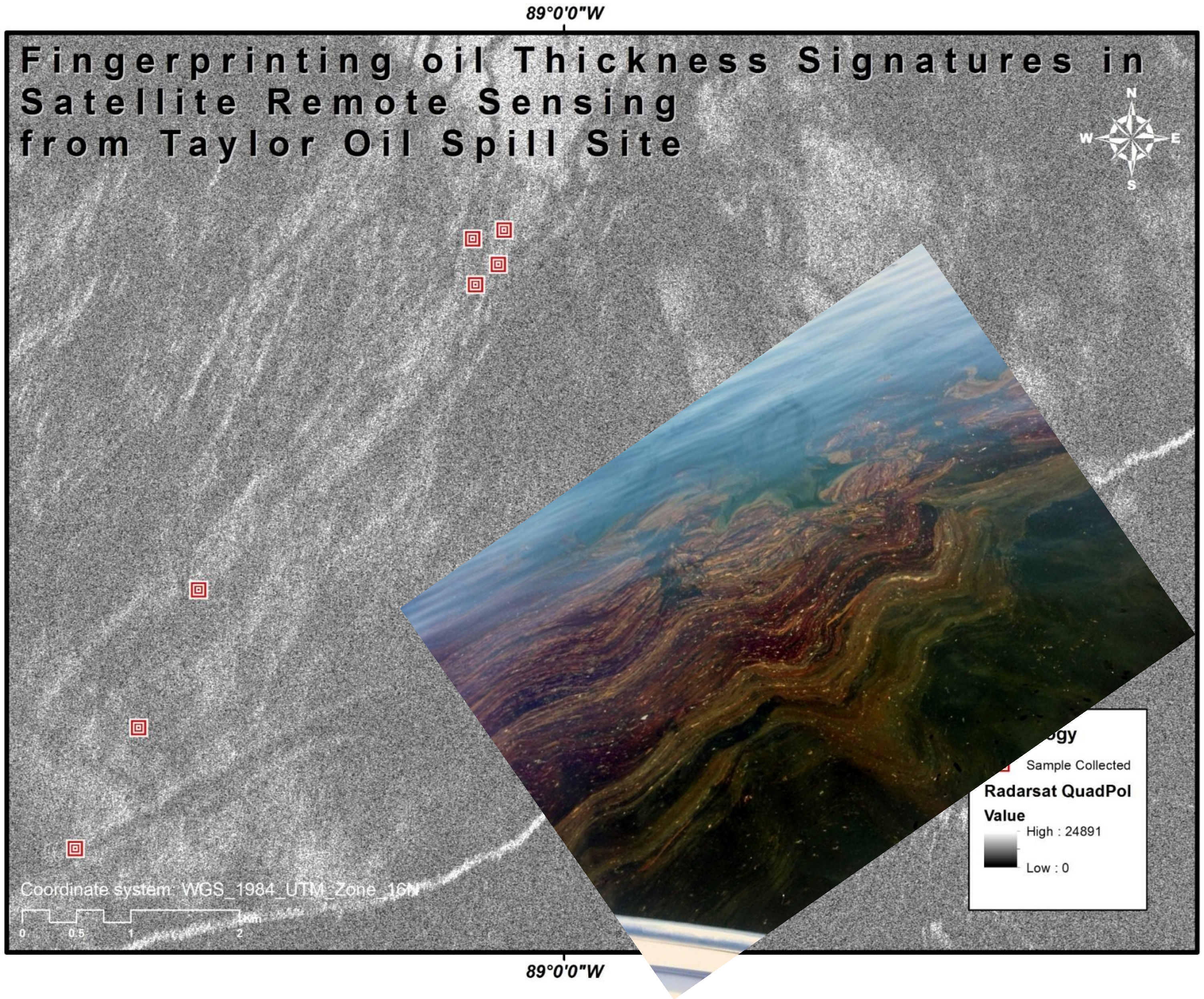
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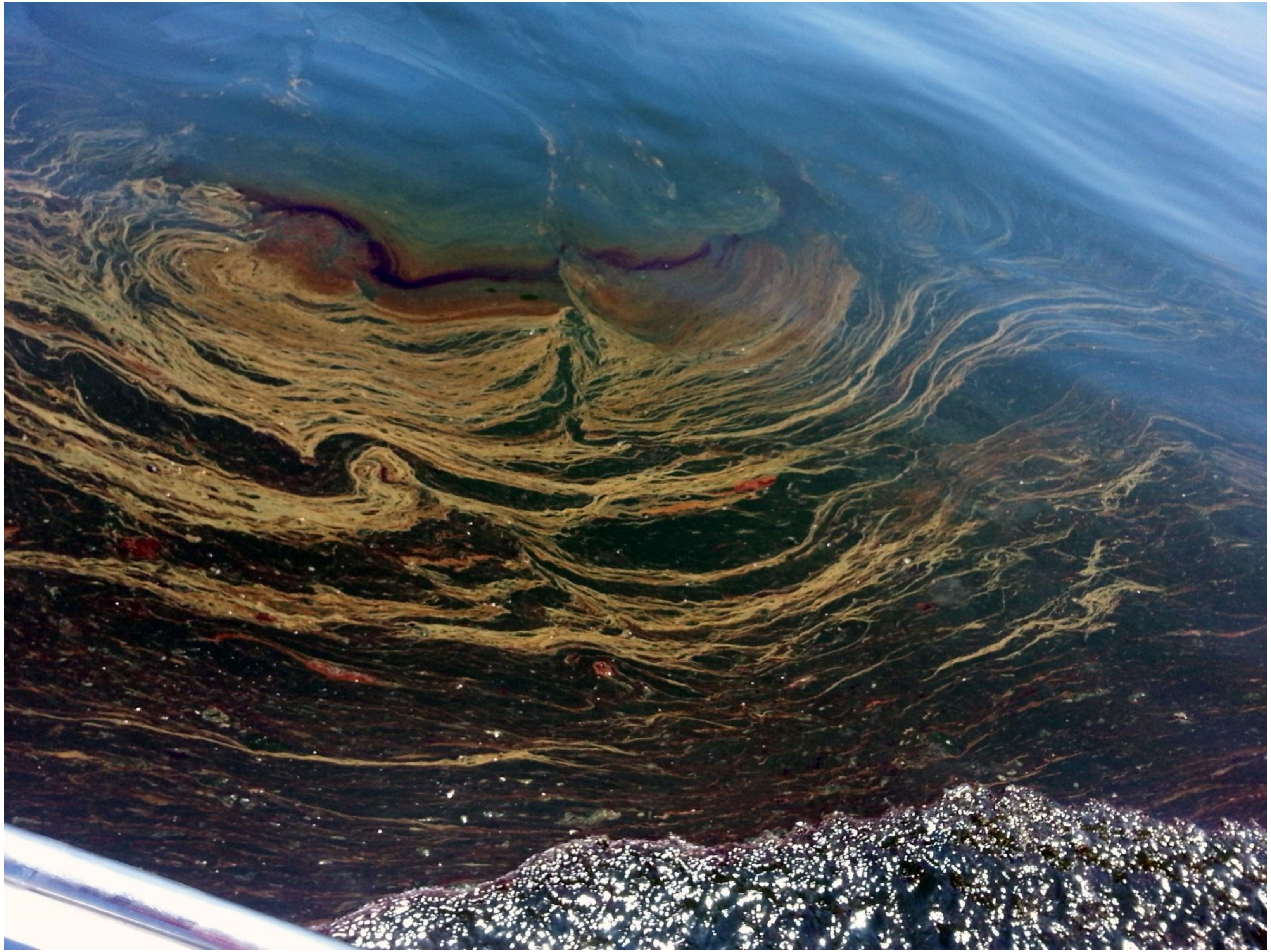
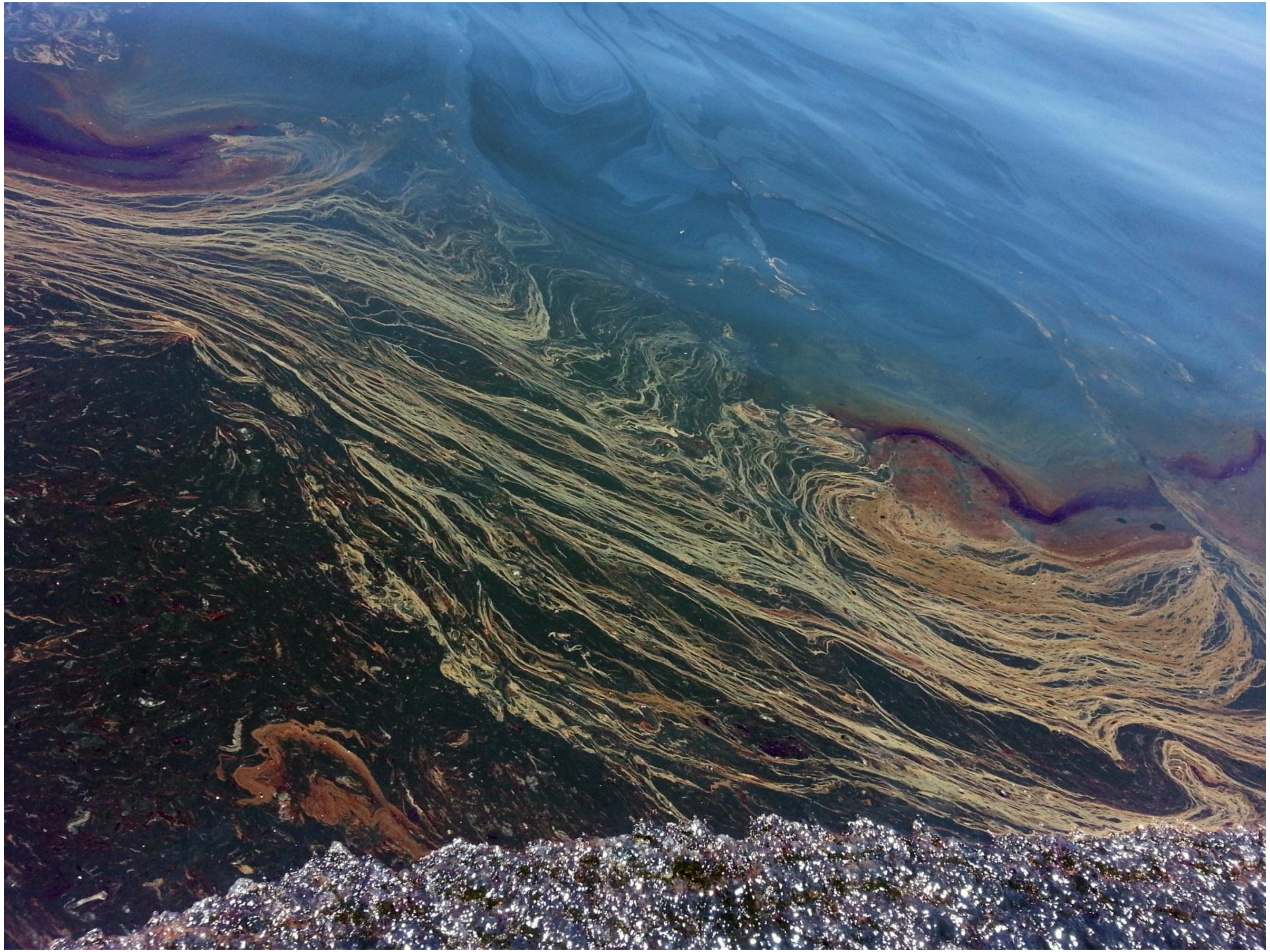
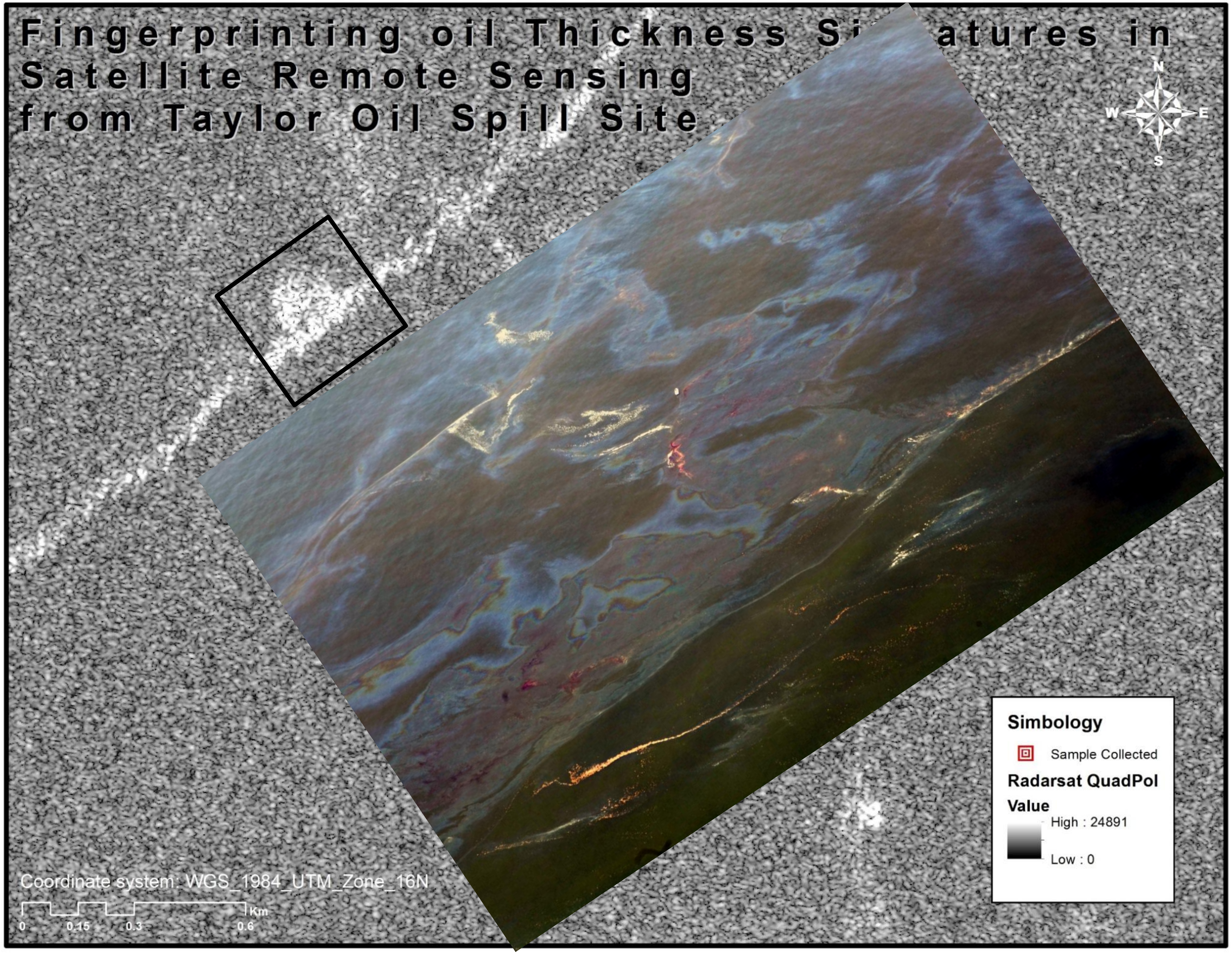
89°0'0"W







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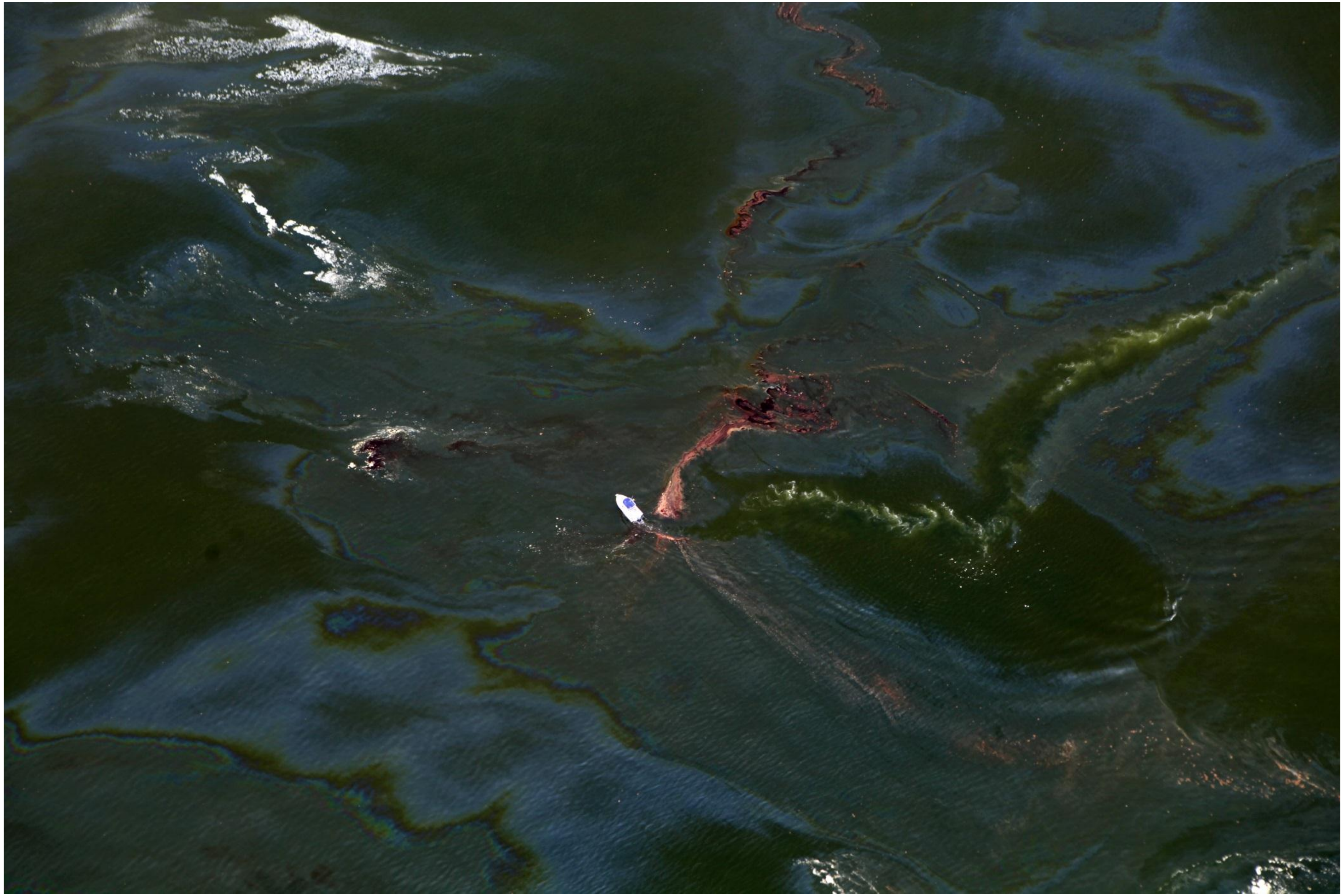

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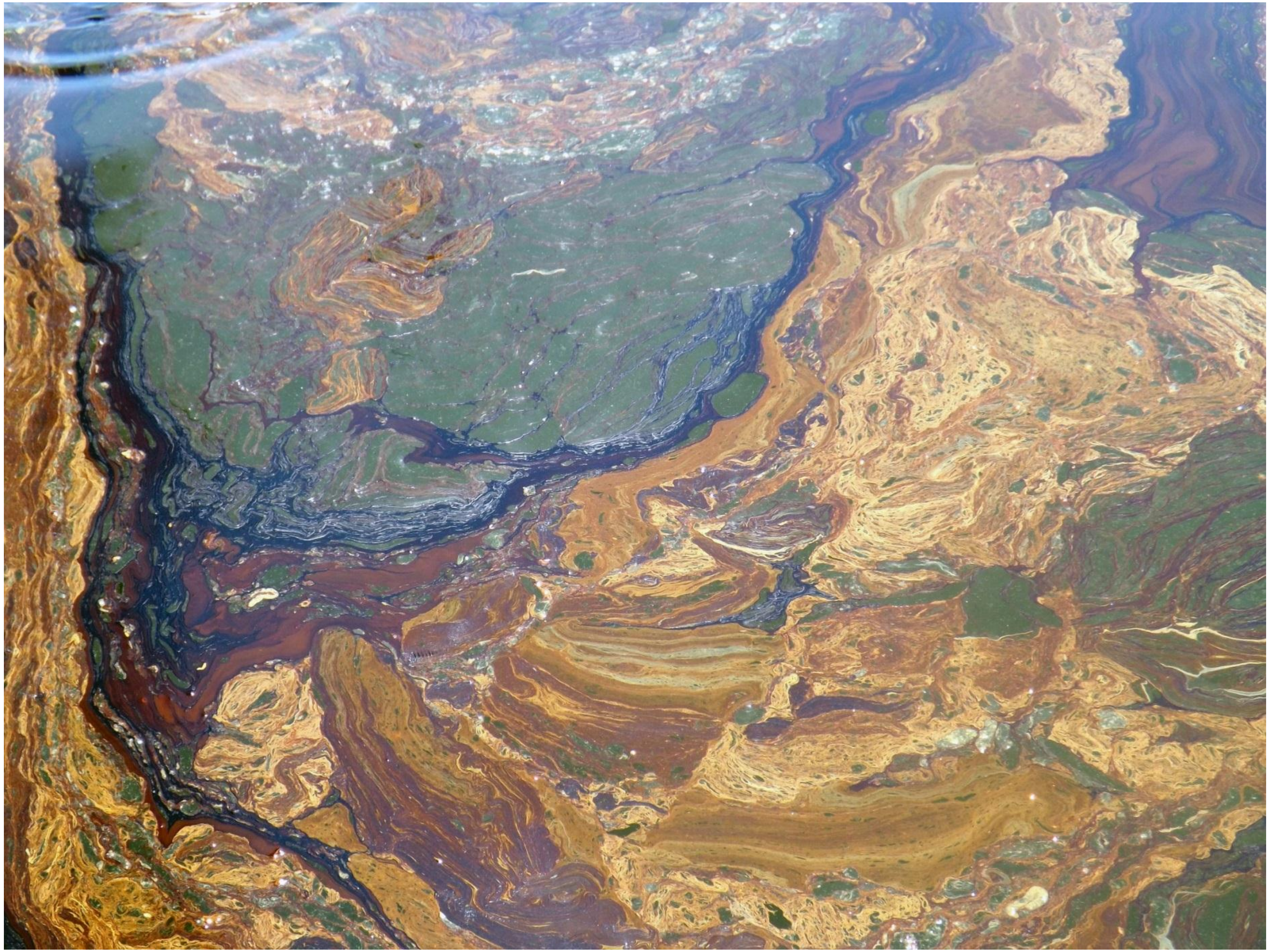

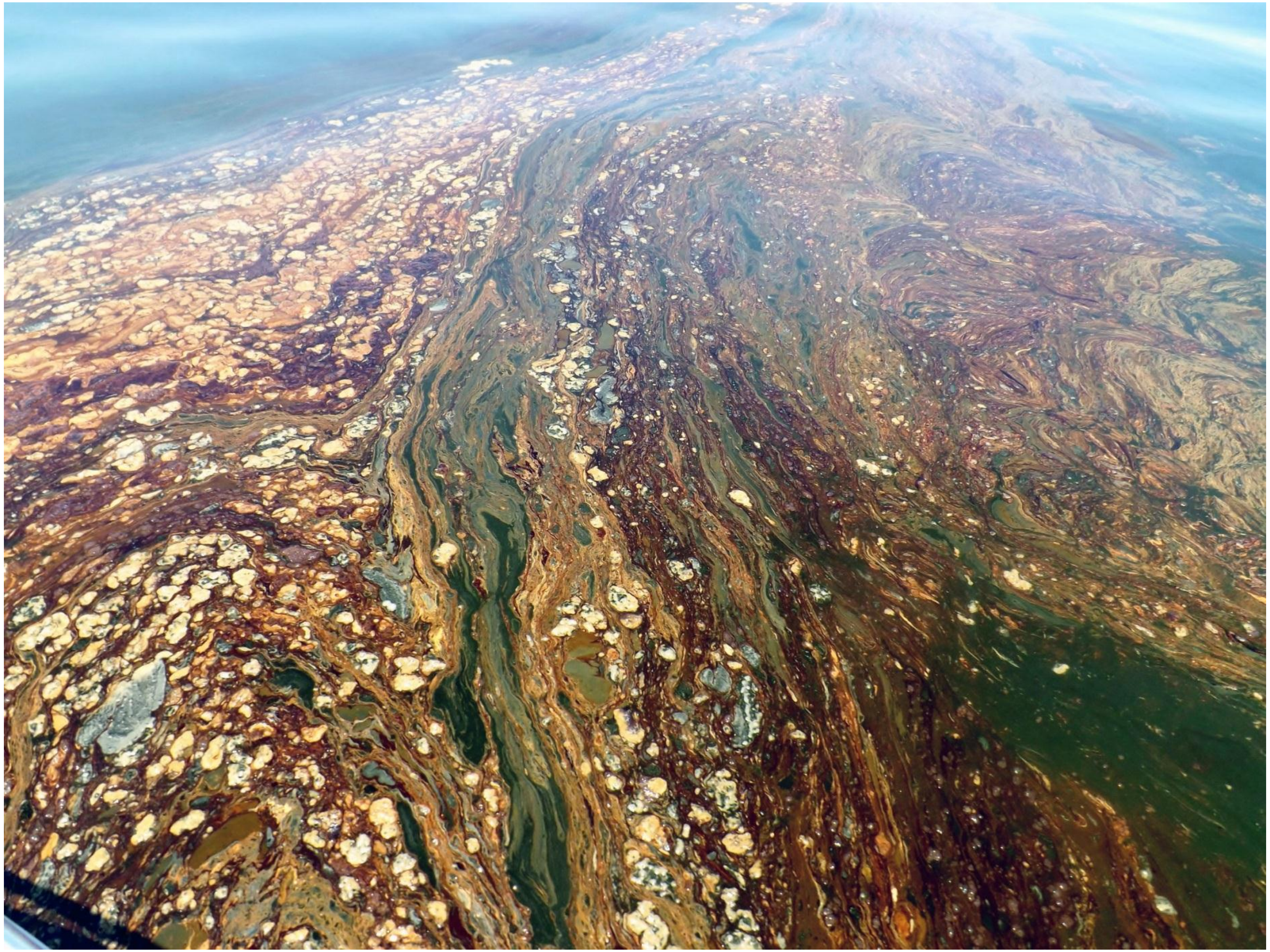

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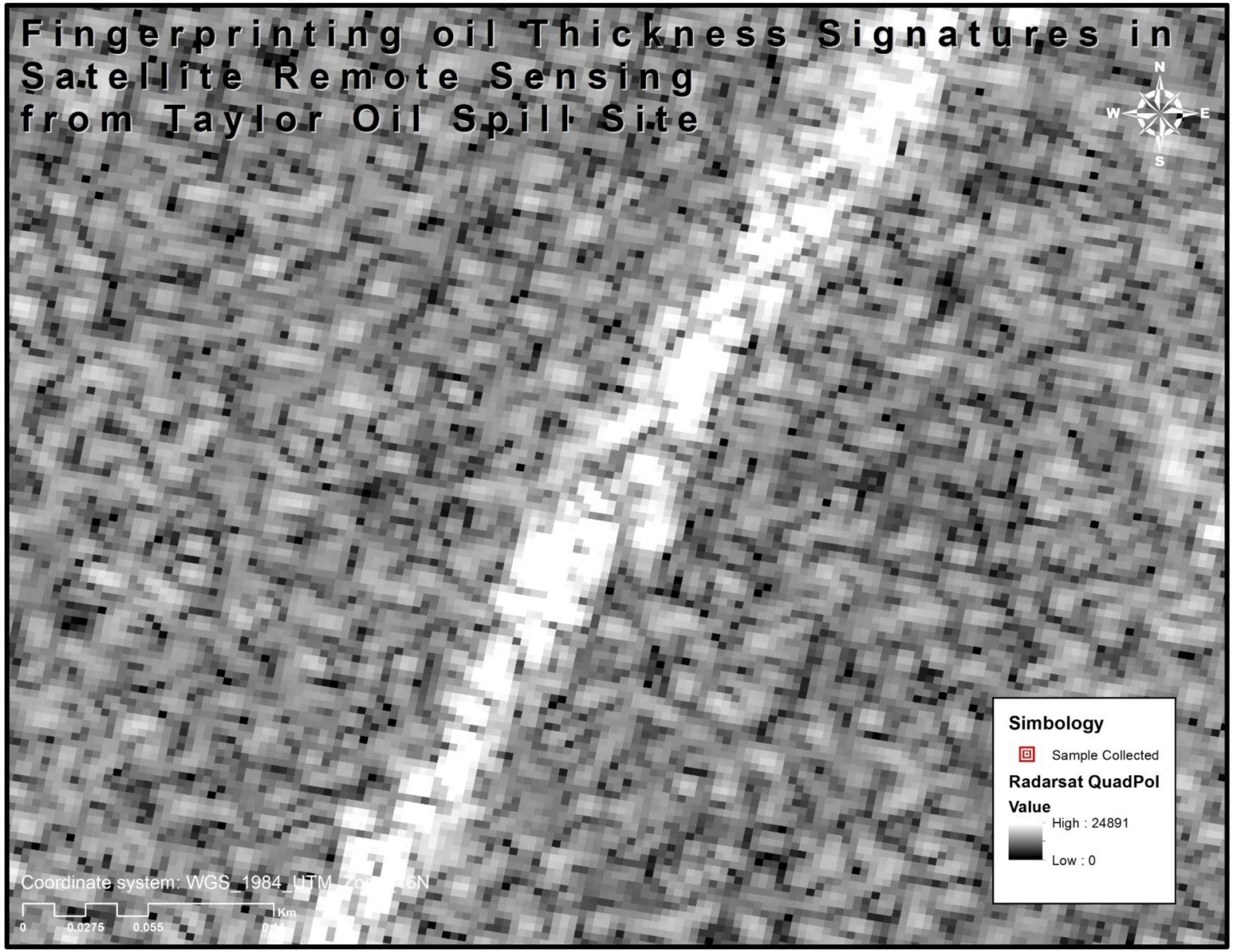
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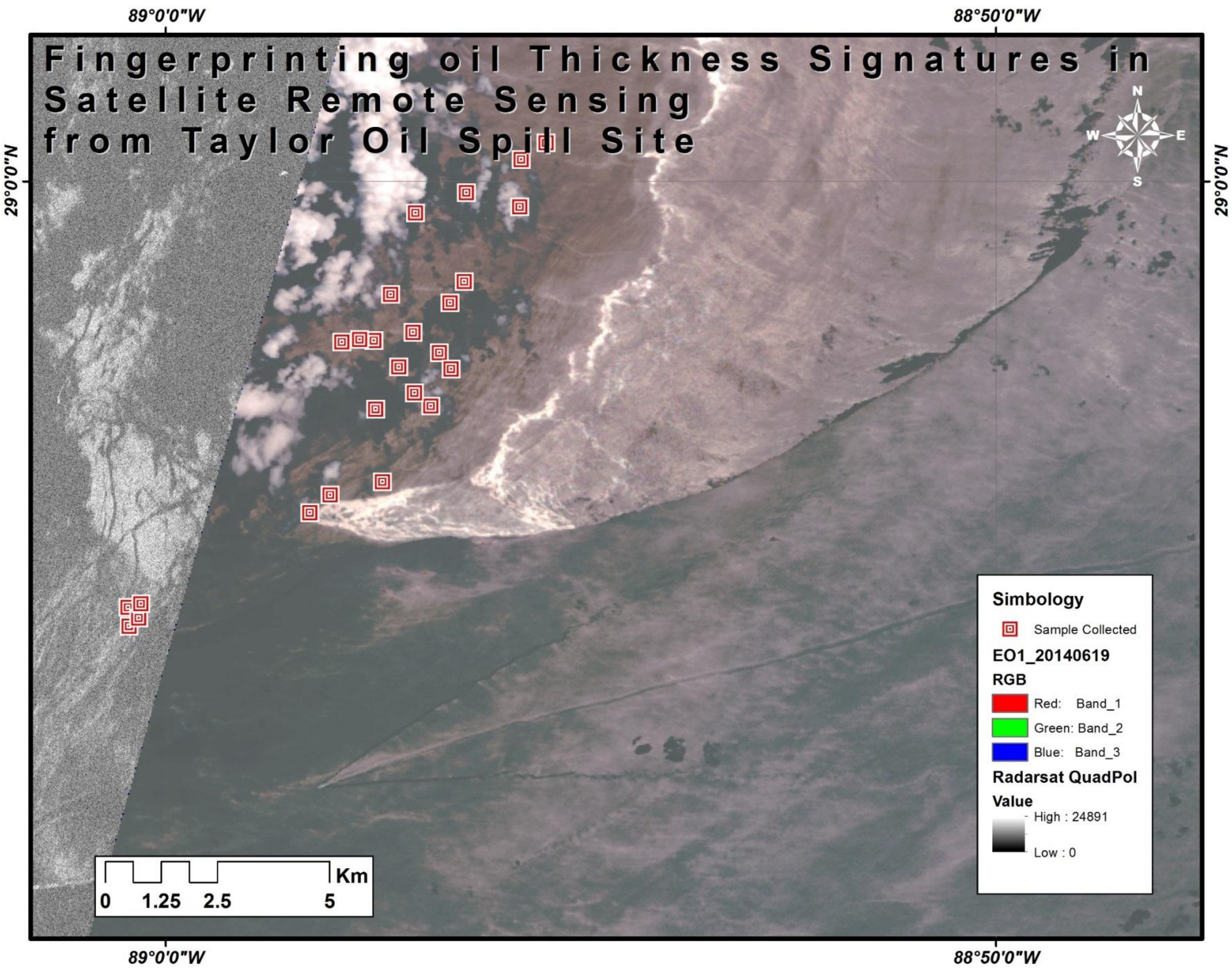

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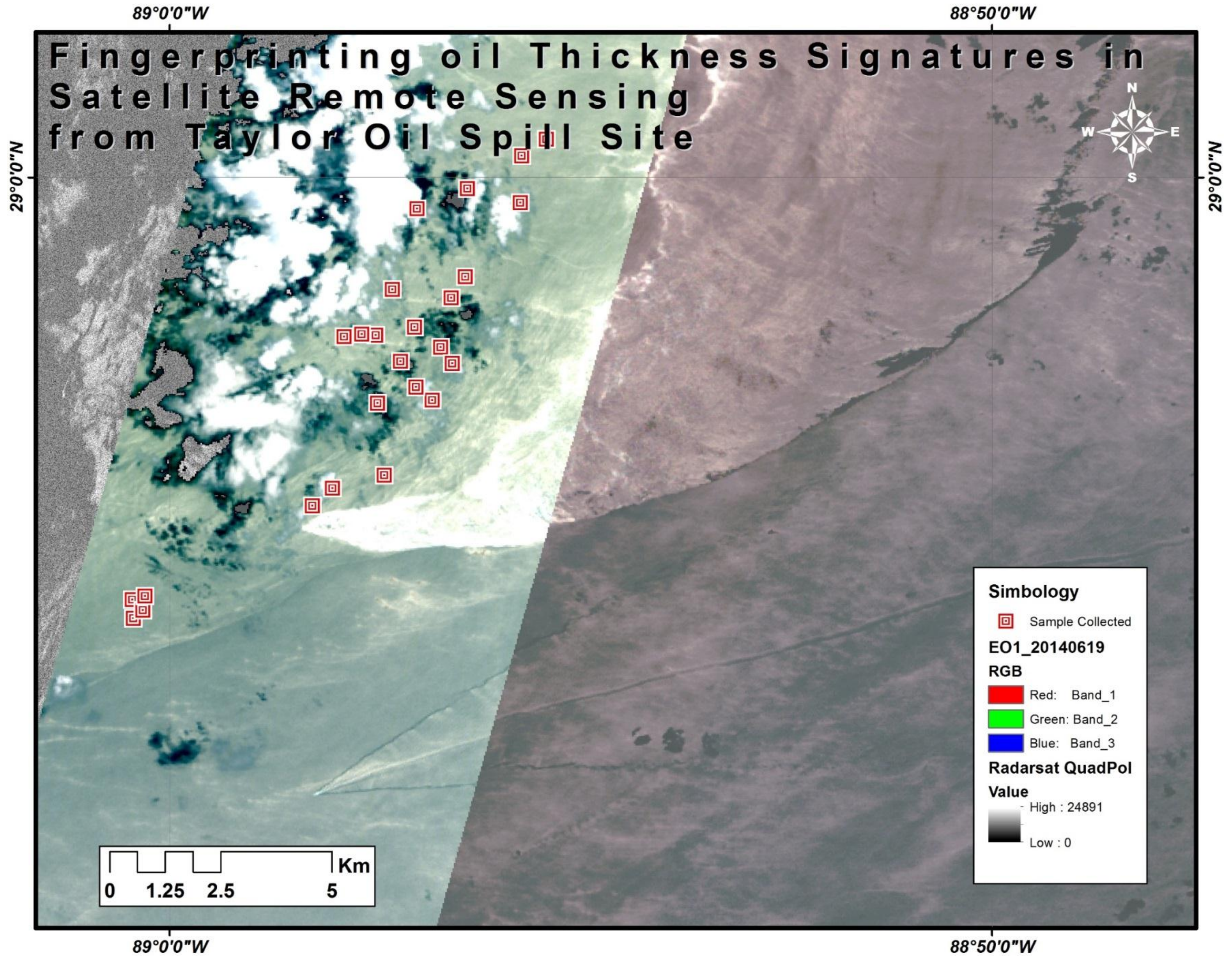

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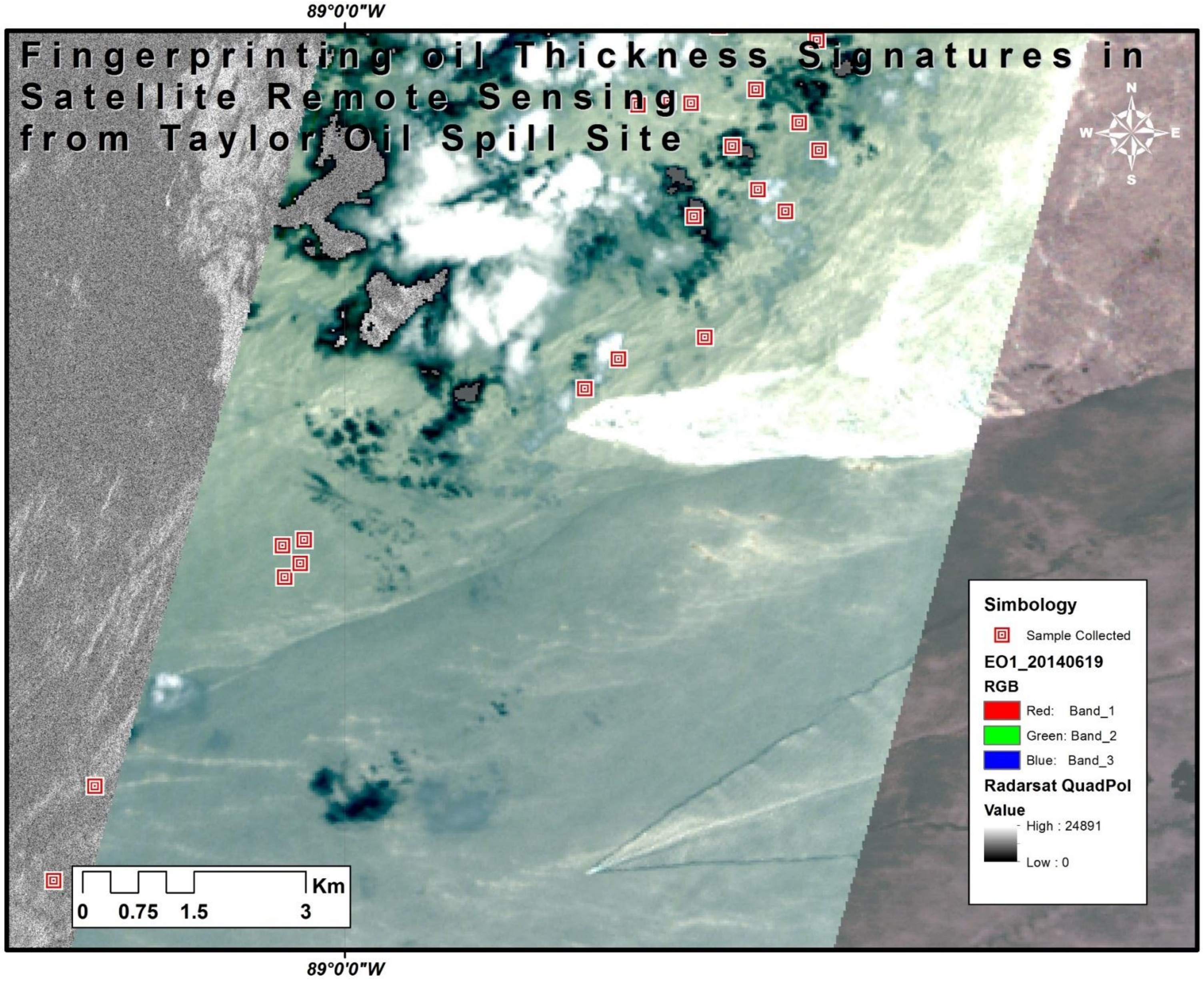
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Green: Band_2
Blue: Band_3
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Low : 0
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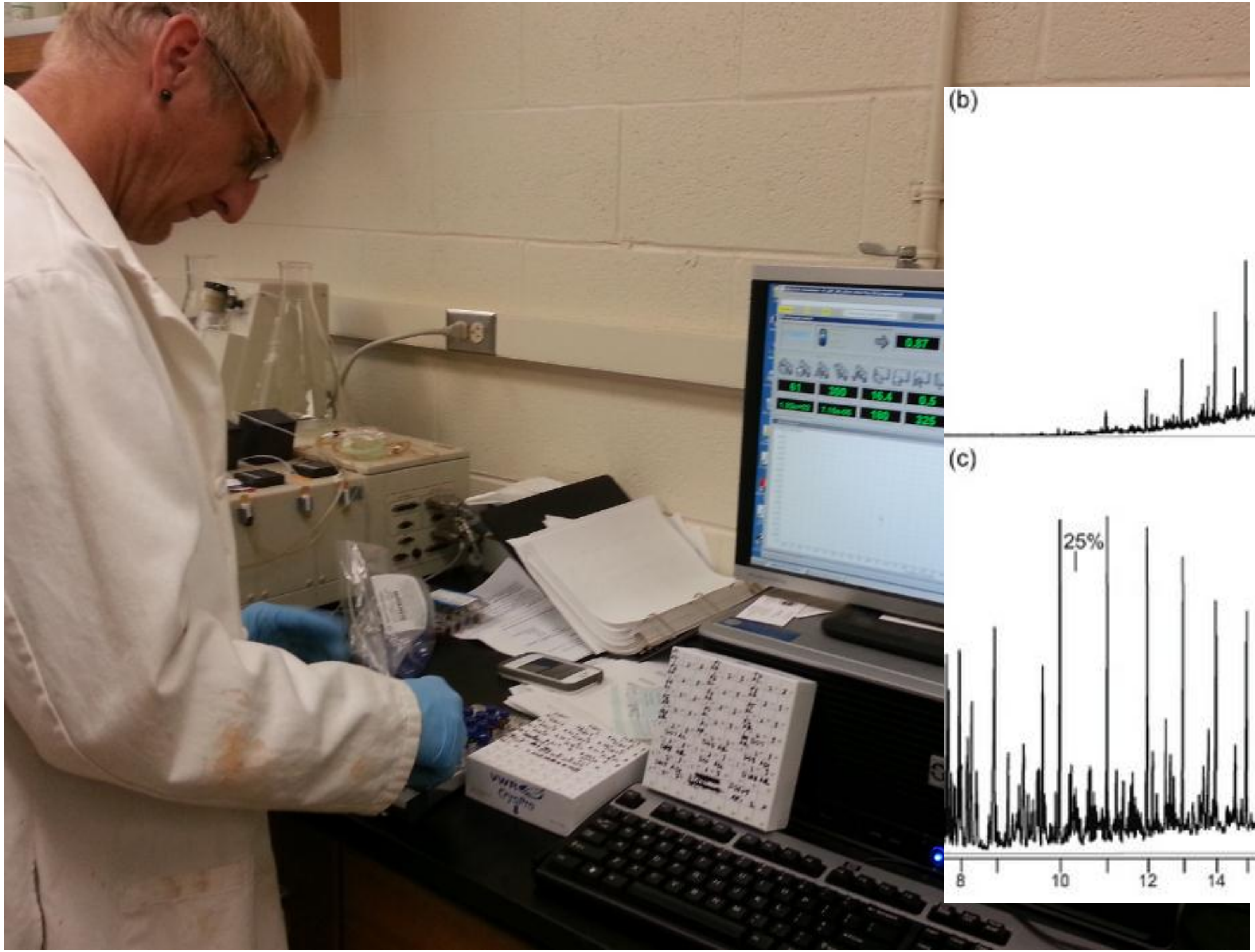
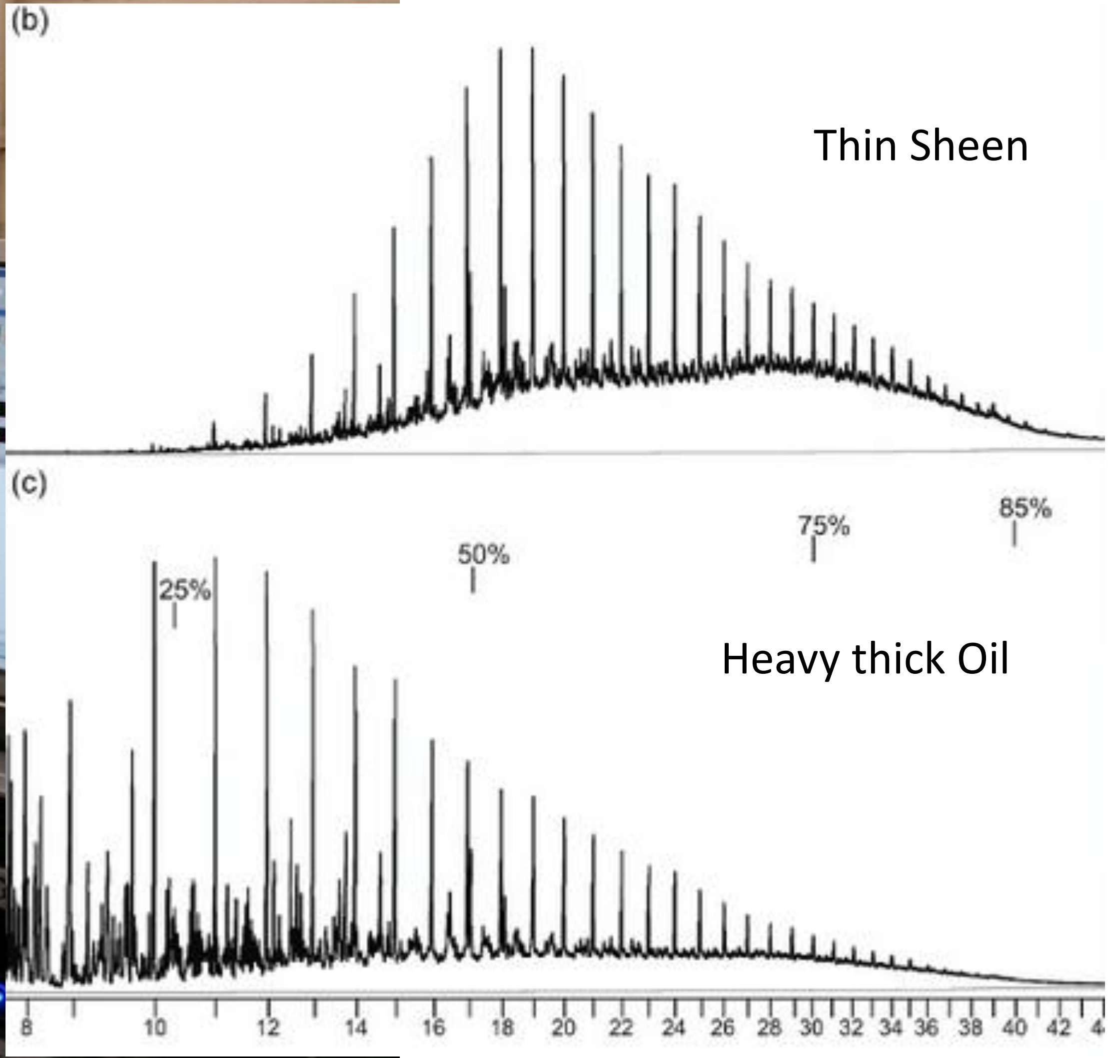
Chemical and spectral analysis of oil samples





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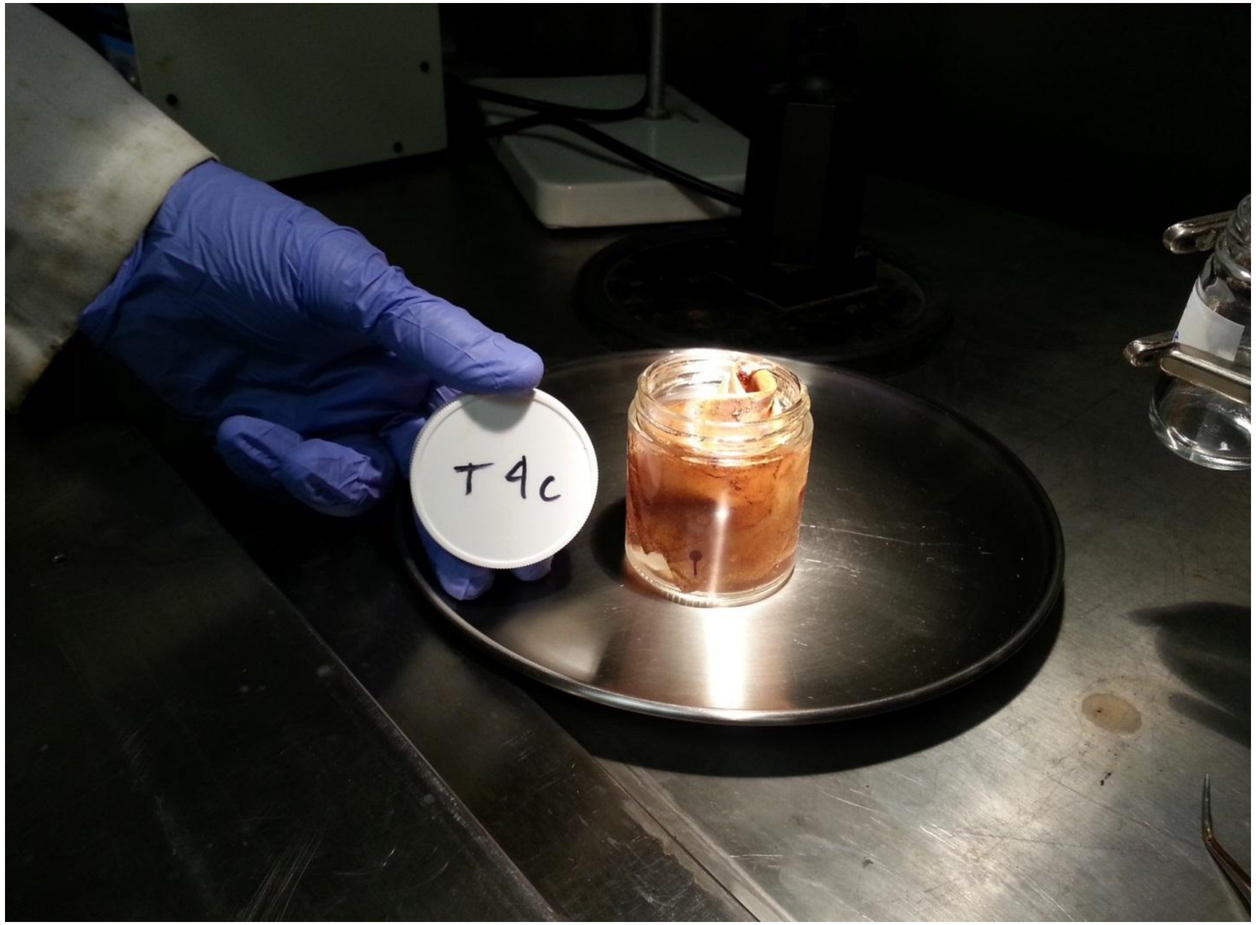
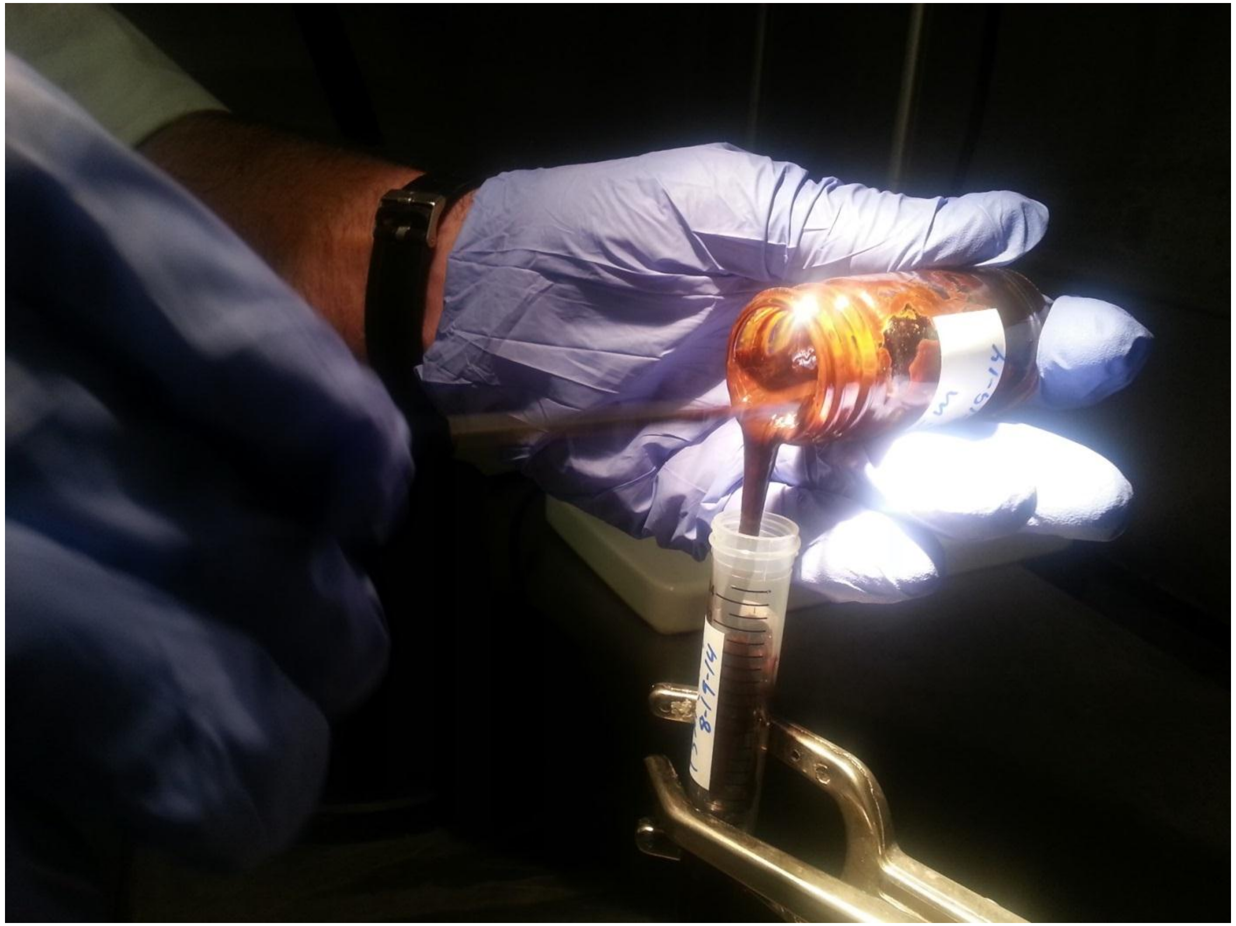
Spectral Analysis





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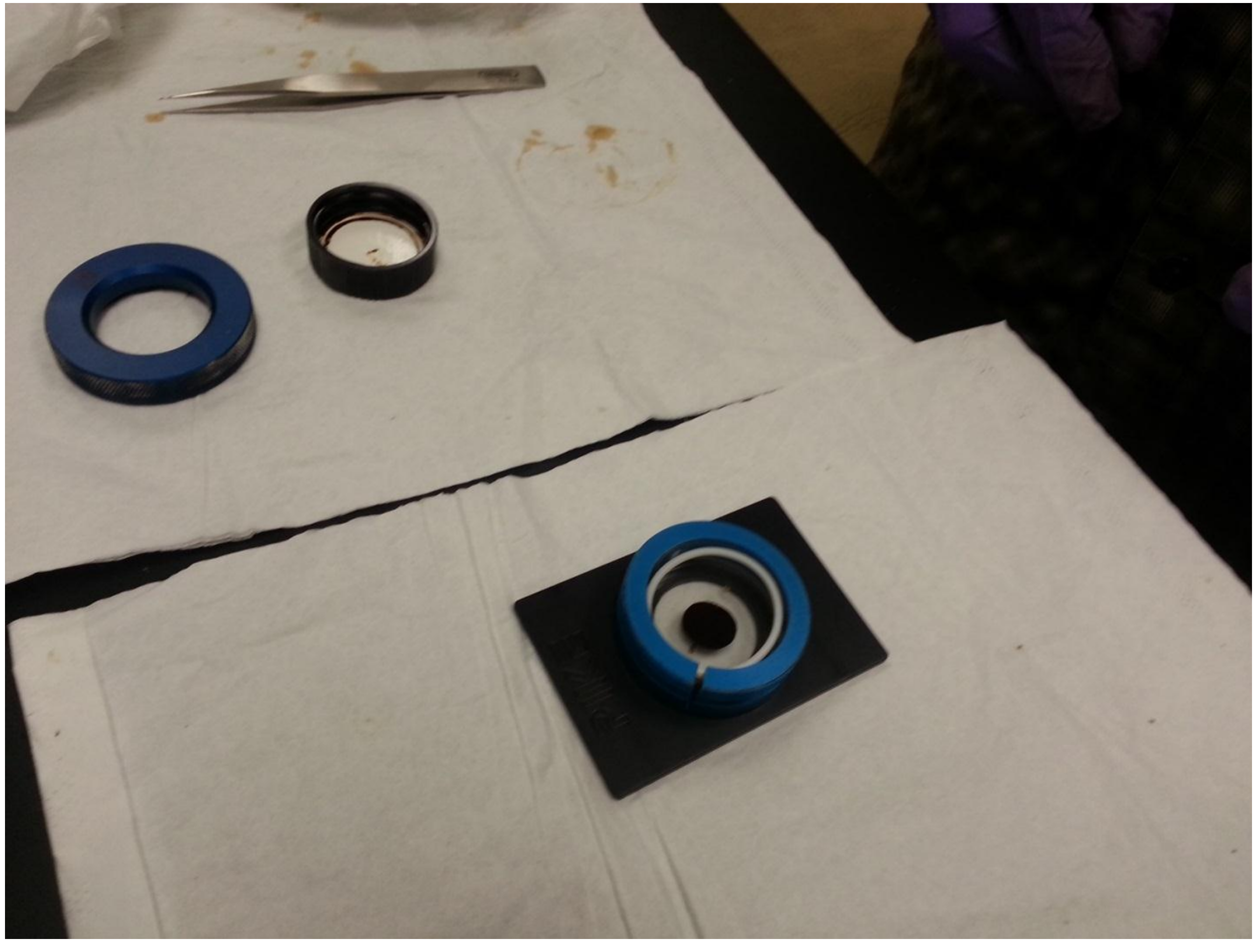
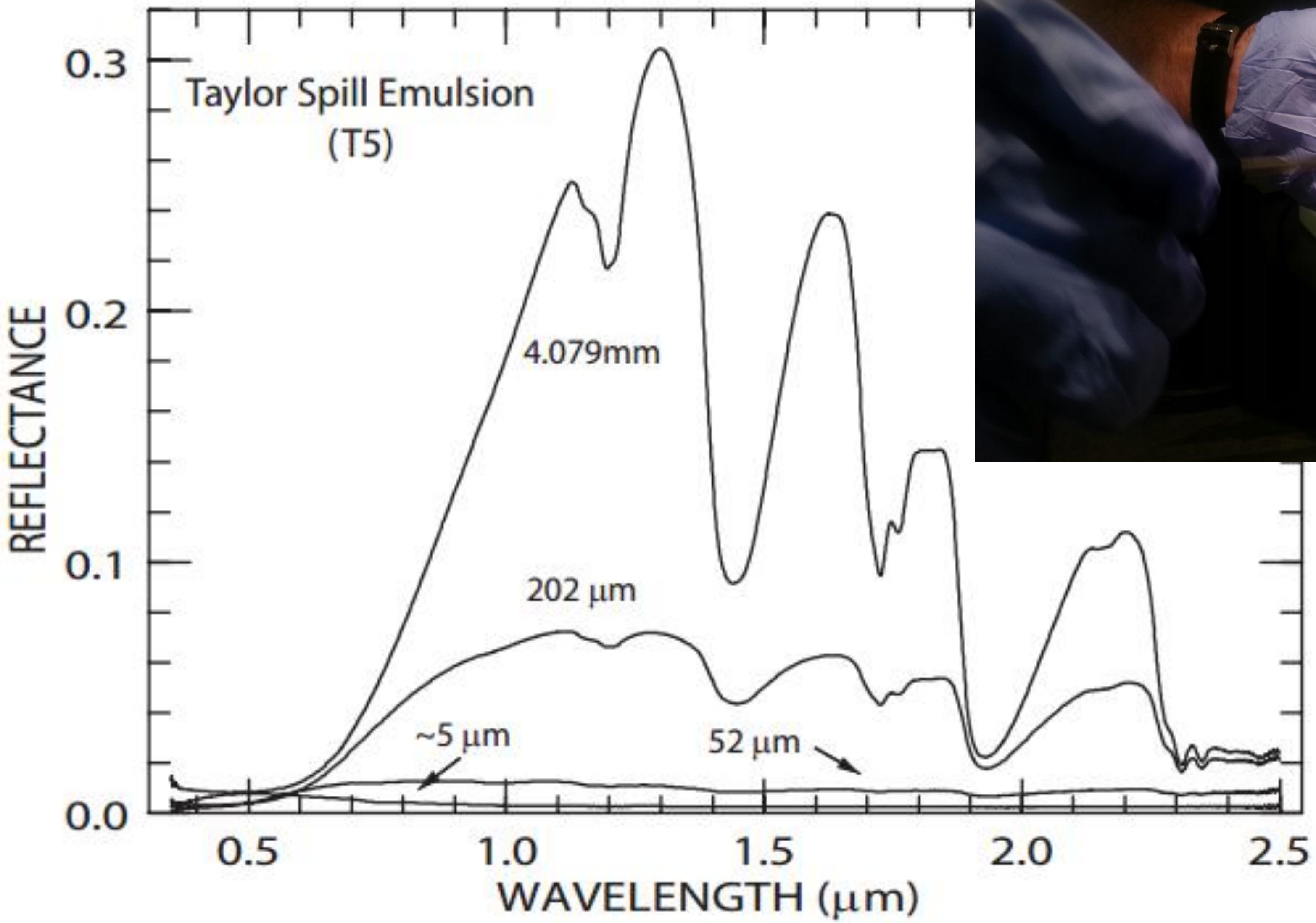
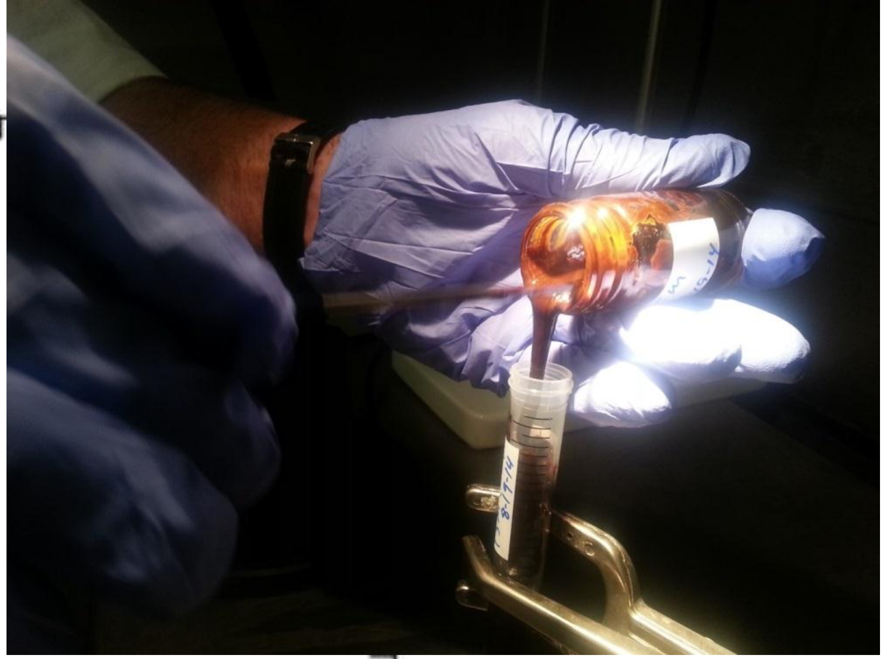
Spectral Analaysis







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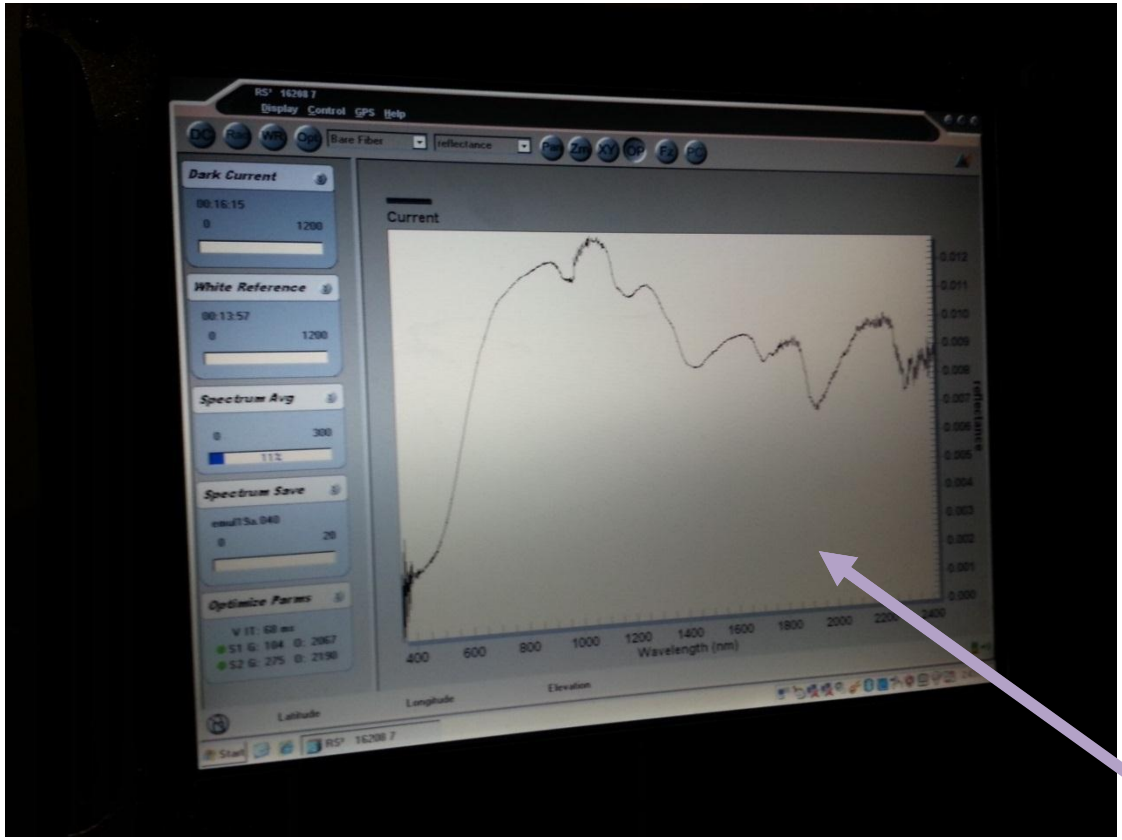
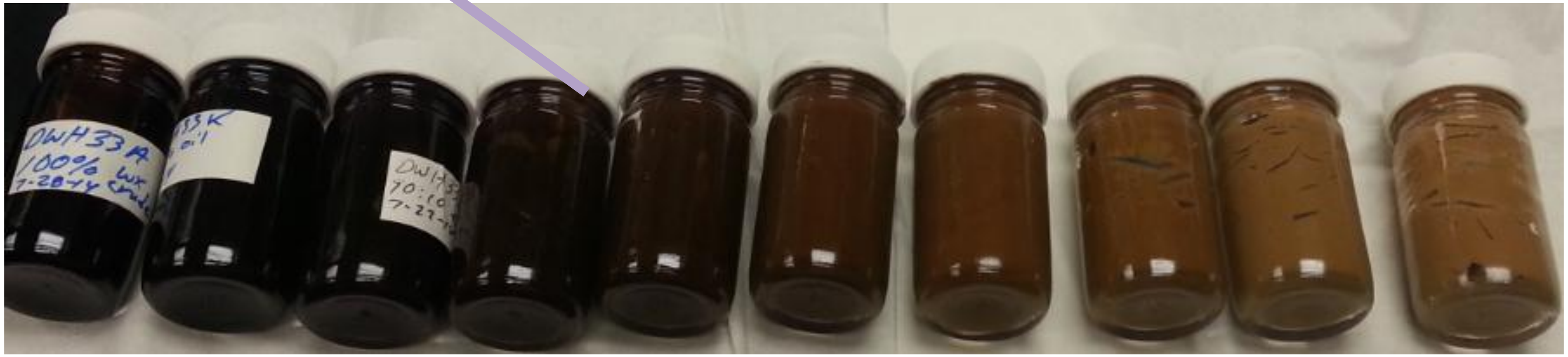
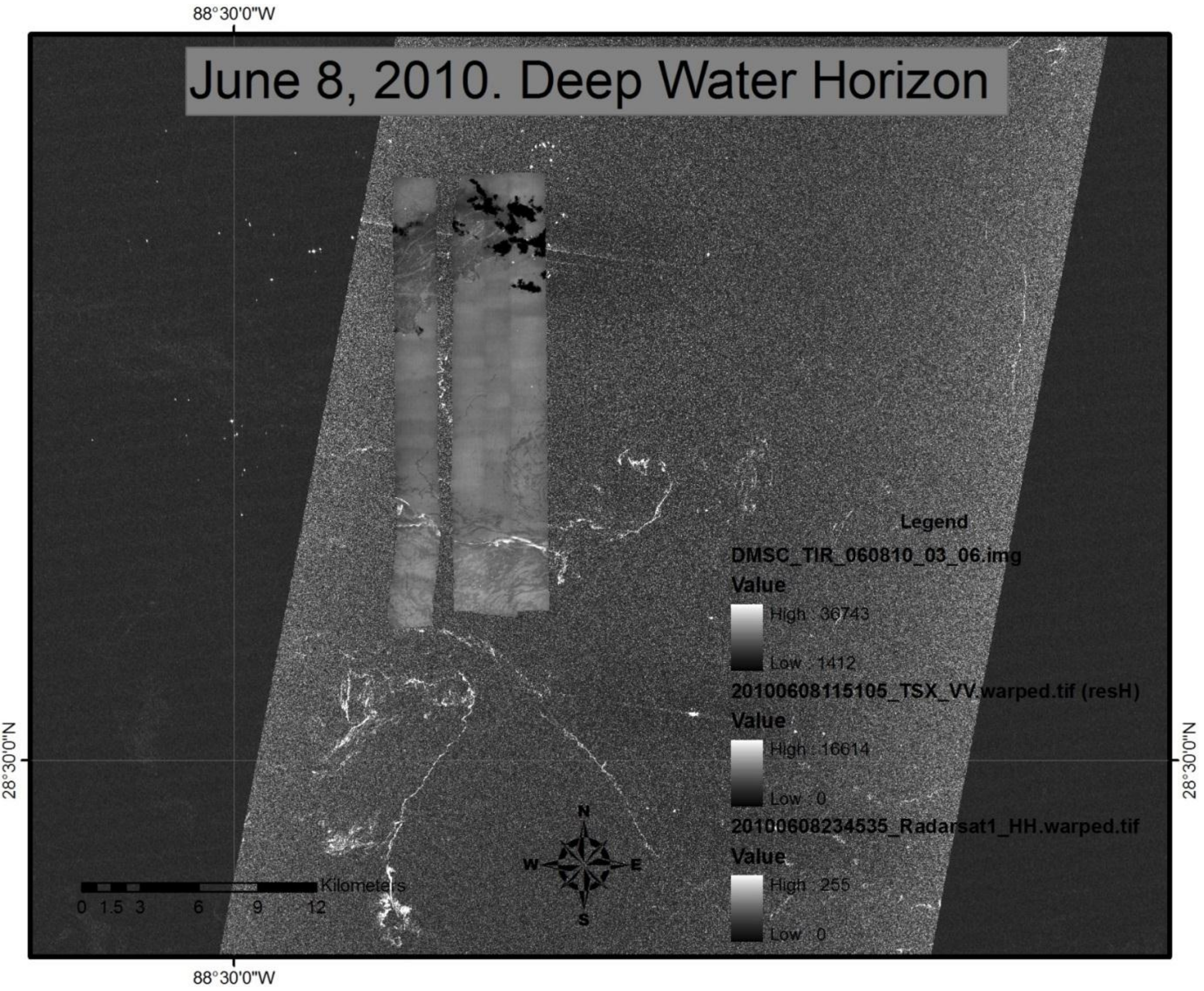
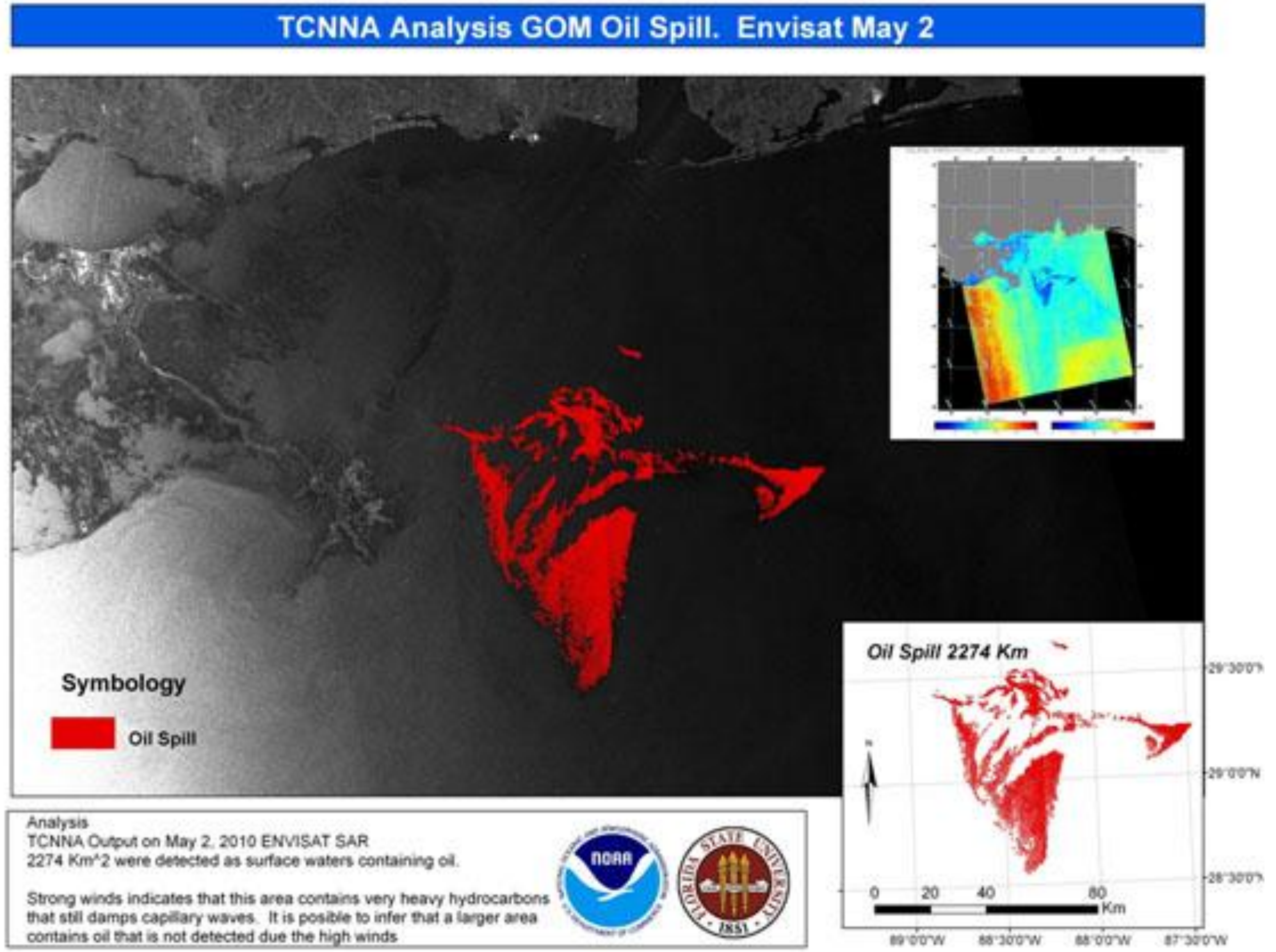

Dark Current
White Reference
Spectrum Avg
Spectrum Save
Optimize Parms
Current
Wavelength (nm)
reflectance



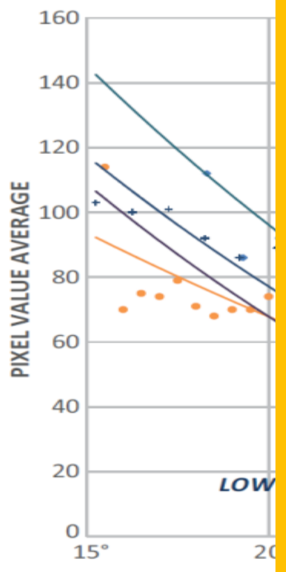


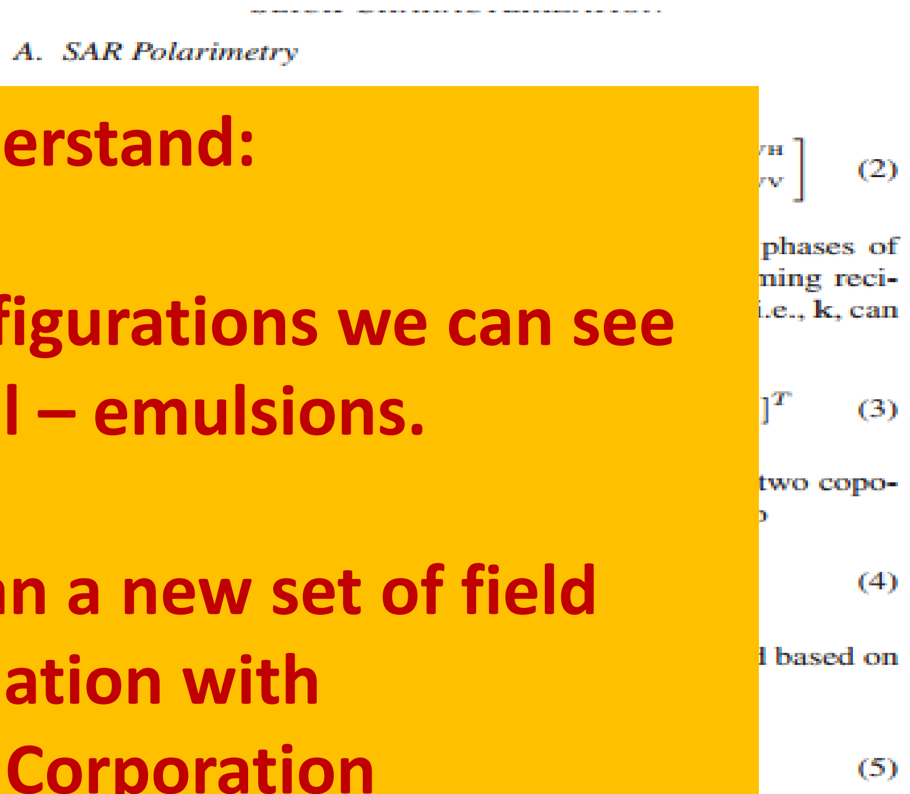


Use of SAR to detect floating oil. Wind Range: 0 to 12m/s

Further Steps

Develop a geophysical model that process and classifies SAR imagery
For detection of thick patches of emulsified oil




A. *SAR Polarimetry*

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We still need to understand:

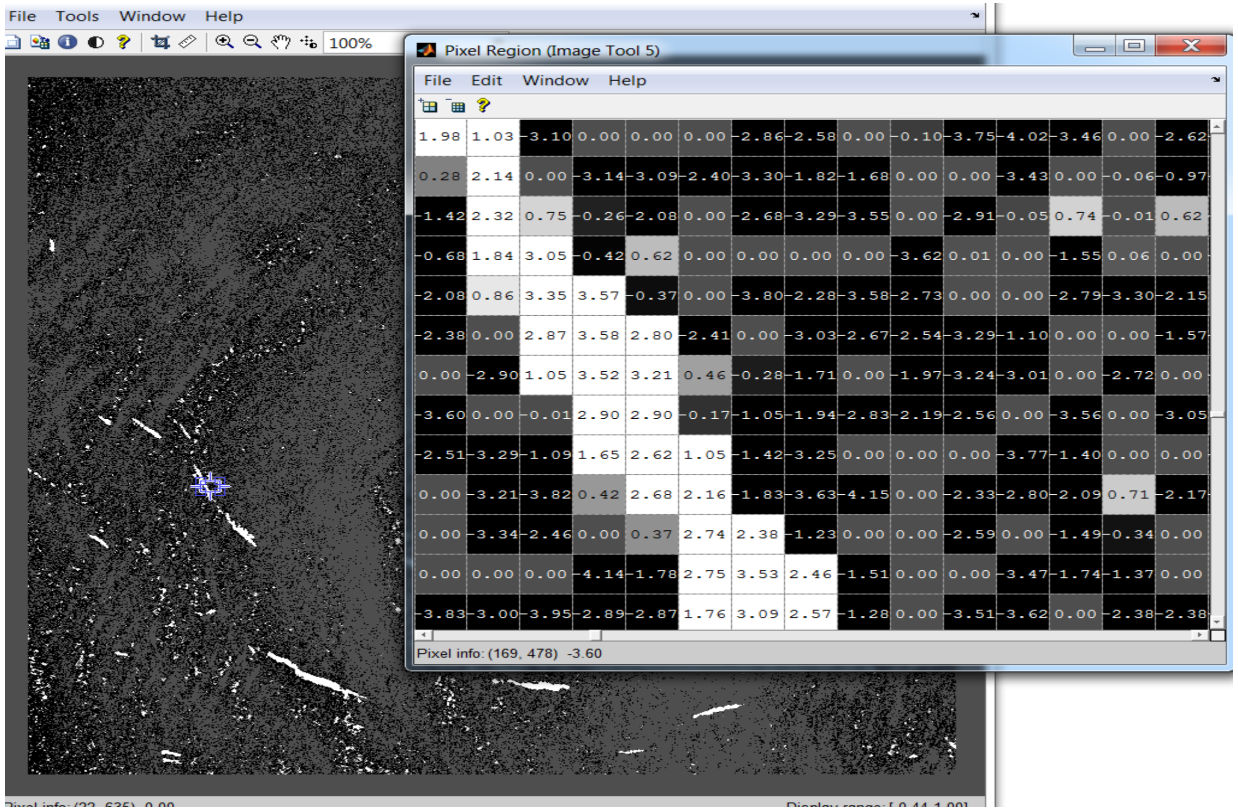
Under which ambient-sensor configurations we can see and we can not see the oil – emulsions.

To accomplish this, we have plan a new set of field expeditions in coordination with
NASA, NOAA, and MDA Corporation

New Output Model

Binary Output Oil-Not Oil

Probability Oil Function



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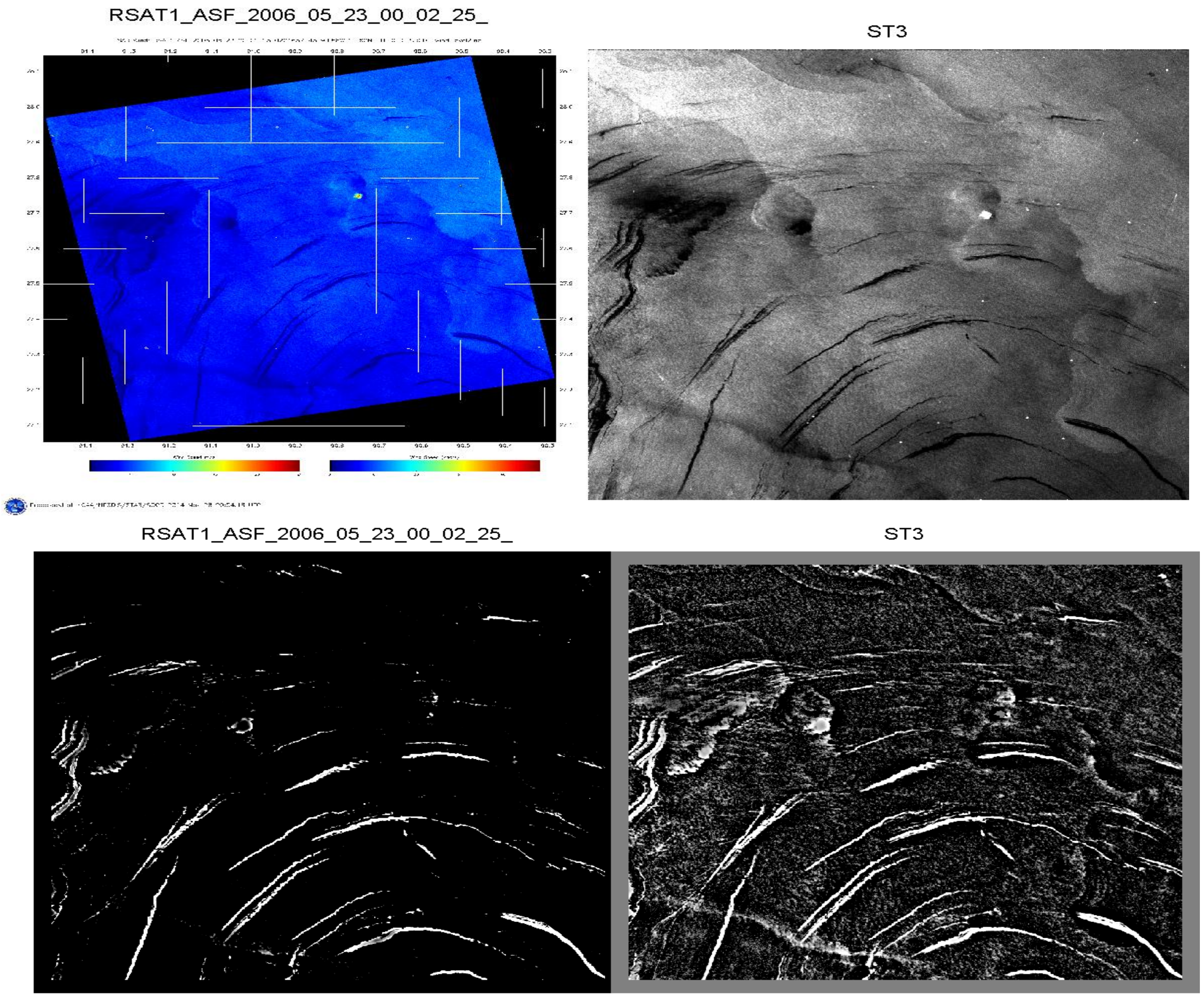
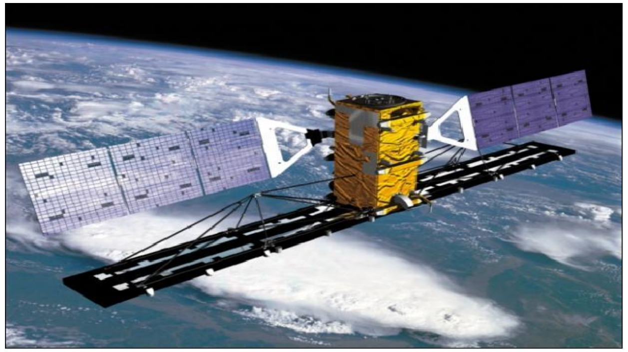
Oil with weather features:
Ideal winds





Sources of SAR data

Satellite	Launch (Lifetime)	Freq	Polarization	Resolution	Swath
TerraSAR-X	2007	X	Full-Pol	1 – 30 m	5 – 200 km
Radarsat-2	2007	C	Full-Pol	3-100 m	20 – 510 km
Cosmo-SkyMed (4)	2007(2)/2008/2010	X	HH, VV	1 -100 m	10 – 200 km
TanDEM-X	2010	X	Full-Pol	1 – 30 m	5 – 200 km
ALOS-2	2014	L	Full-Pol	1-100 m	25 – 350 km
Sentinel-1A	2014	C	HH, VV, VH, HV*	5-20 m	80 – 400 km
CSK- 2nd Gen (2)	2015	X	Full-Pol	0.8 – 20 m	10 – 200 km
PAZ	2015	X	Full-Pol	1-30 m	5 – 200 km
Sentinel-1B	2016	C	HH, VV, VH, HV*	5-20 m	80 – 400 km
RCM (3)	2018	C	Dual / Compact	5 – 50 m	20 – 350 km
NI-SAR	2020	L	Full-Pol / Compact	3 – 50 m	240 km

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Conclusion:

- The capability of SAR to detect oil emulsions sheds light on the monitoring and assessment of further oil spills. Not only to detect presence/absence of oil, but its relative thickness. This is of great importance on the planning and coordination of response operations.

THANKS!

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