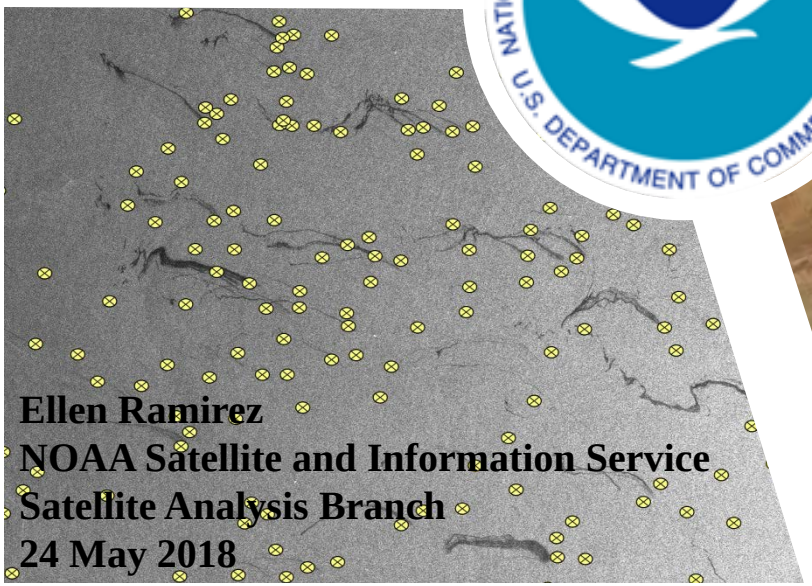
Detection of Marine Oil from Multispectral Satellite Imagery and Synthetic Aperture Radar



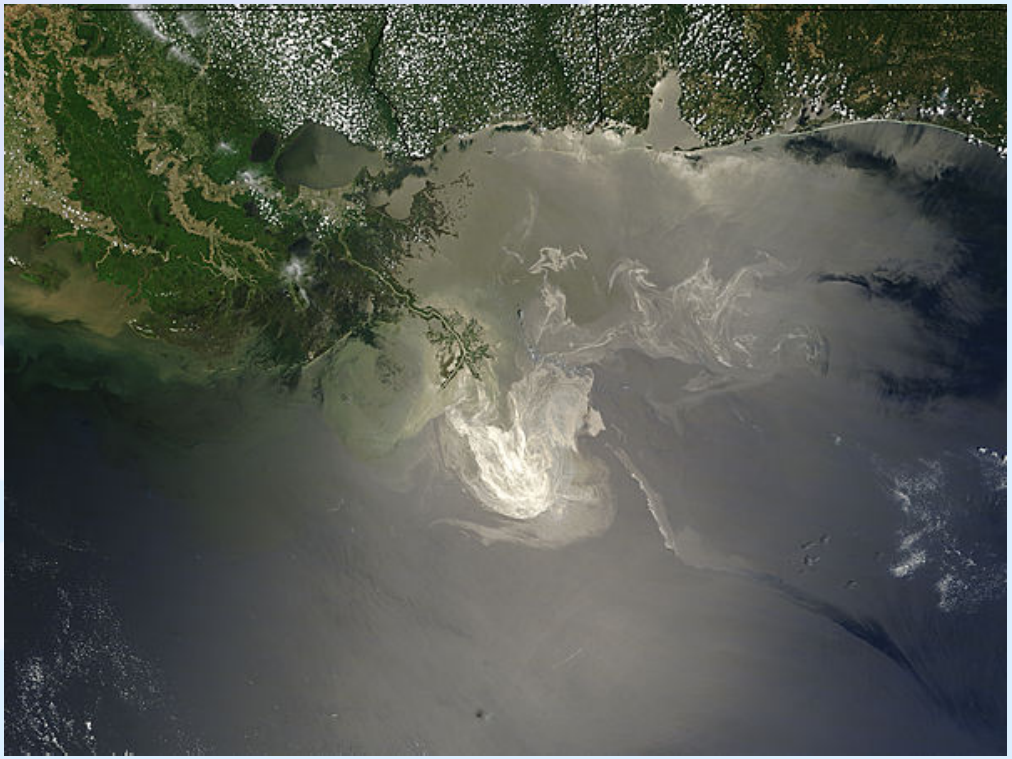
Ellen Ramirez
NOAA Satellite and Information Service
Satellite Analysis Branch
24 May 2018

The Satellite Analysis Branch (SAB)

- Part of the U.S. National Oceanic and Atmospheric Administration (NOAA) Satellite and Information Service
- Based on the outskirts of Washington D.C. in College Park, MD
- Staffed 24 hours a day, 7 days a week
- **Mission:** Operate new proof of concept satellite analysis techniques needed to support disaster mitigation and warning services for U.S. federal agencies and the international community.
- 5 operational desks: Tropical cyclones, volcanic ash, heavy precipitation, wildfires, and oil spills

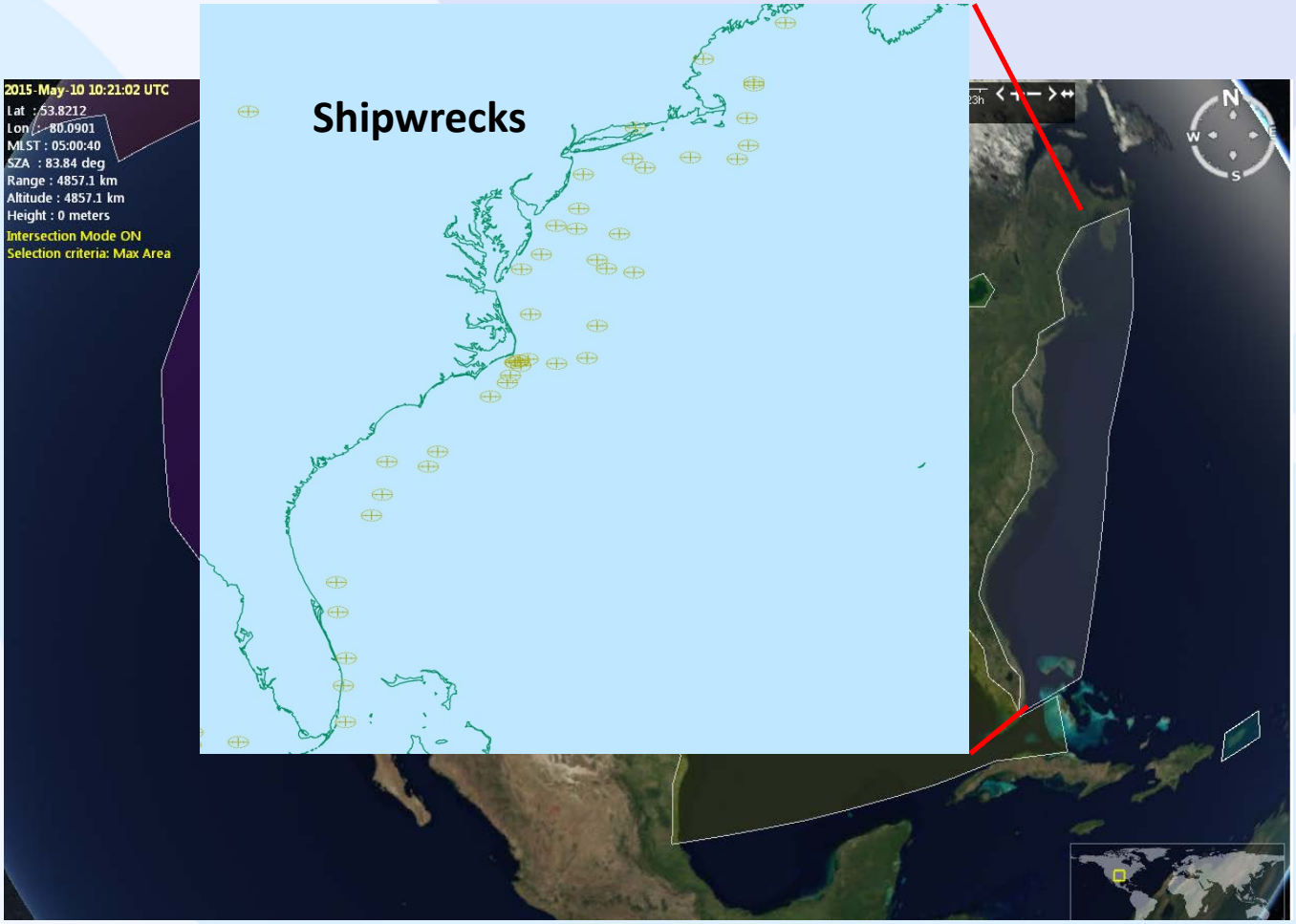
NOAA's Oil Spill Monitoring Program

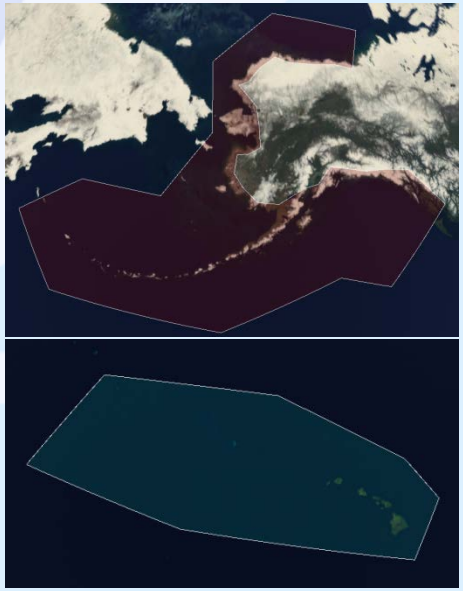
- In 2009 a formal request was made by NOAA's Office of Response and Restoration for satellite support of oil spill emergencies and for assistance in monitoring intentional and accidental crude oil discharges in U.S. waters
- Oil Spill desk became fully operational in 2011.
- Customers/users include the **U.S. Coast Guard, NOAA/ National Ocean Service, the Bureau of Safety and Environmental Enforcement, the Environmental Protection Agency, and State Agencies (e.g. Florida Fish and Wildlife, Texas General Land Office)**
- As of 1 March 2018, Marine Pollution Surveillance Reports (MPSRs) are published to the web and publicly available.



Gulf of Mexico imaged by MODIS in 2010 during the Deepwater Horizon incident

Operational Regions





U.S. water within the Exclusive Economic Zone (EEZ) and their approaches, and internationally when requested.

Routine Satellite Acquisitions

Manmade crude oil slicks occur for two reasons:

1. Accidental discharges. Examples – Exxon Valdez, Deepwater Horizon, platform equipment failure, pinhole leaks in pipelines, damage to platforms/rigs from natural disasters, sunken vessels.

2. Intentional discharges. Examples – Pumping bilge waste at sea instead of paying to properly dispose of the waste in port.

Synthetic Aperture Radar

- Radarsat-2
- Sentinel-1A
- Sentinel-1B

Optical

- Landsat-7
- Landsat-8
- NPP-VIIRS
- Sentinel-2A
- MODIS Terra
- MODIS Aqua

Software Used to Analyze Satellite Imagery and Create Reports

ENVI

Geospatial image analysis program that features spectral interrogation, enhancements and stretches, and target detection, among other tools.

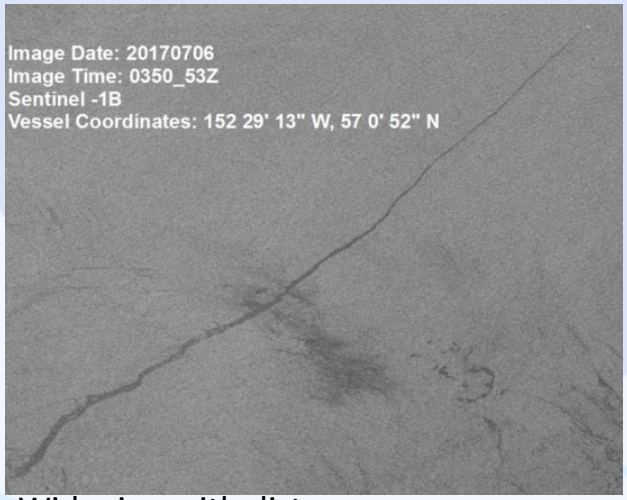
ARC GIS

Geospatial map interface that also allows for imagery analysis as well as the creation of shapefiles that depict the boundaries of the oil

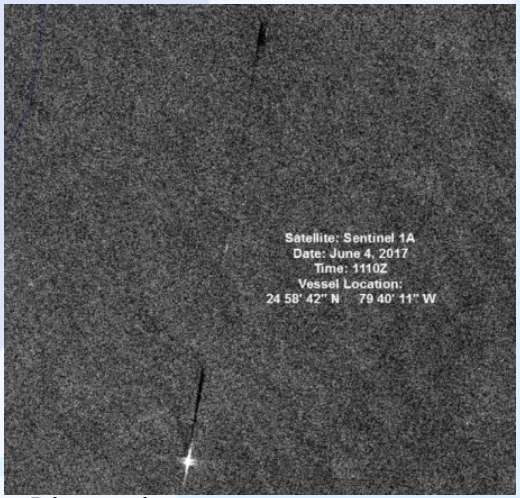
Identifying Oil in Synthetic Aperture Radar

Visual Characteristics of Bilge Dumping

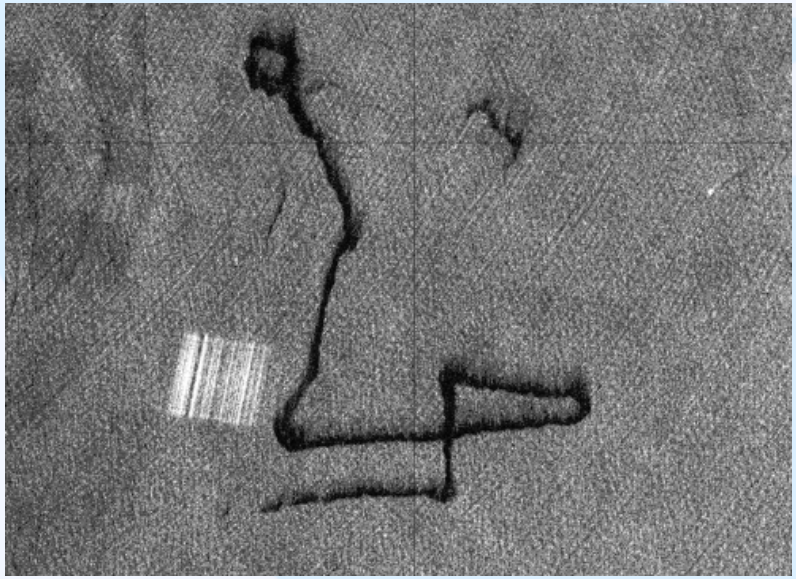
Feathering signature



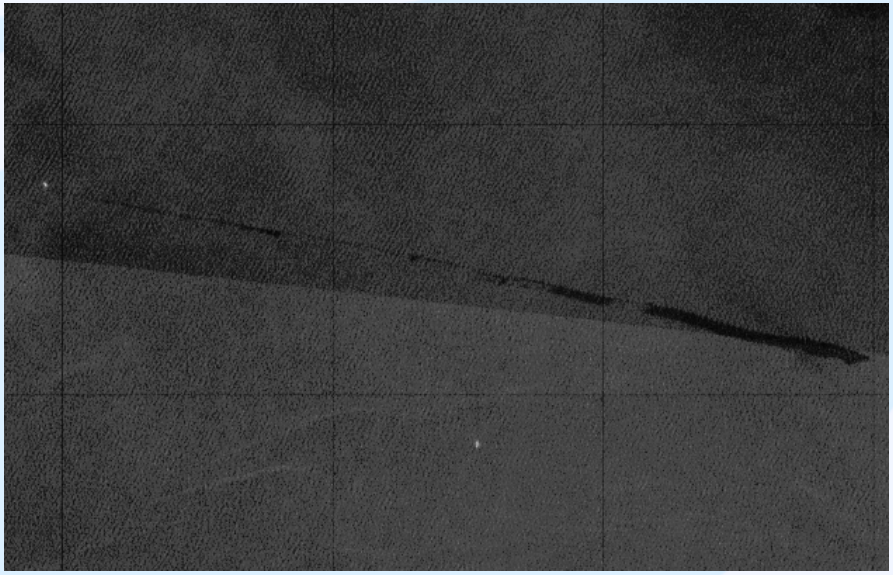
Widening with distance



Discontinuous

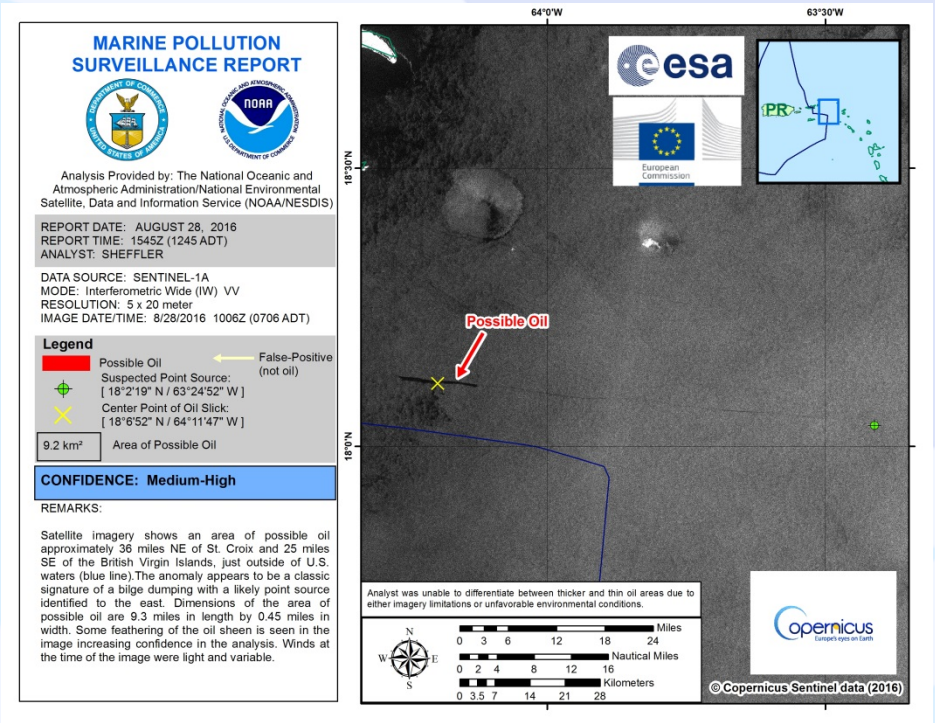


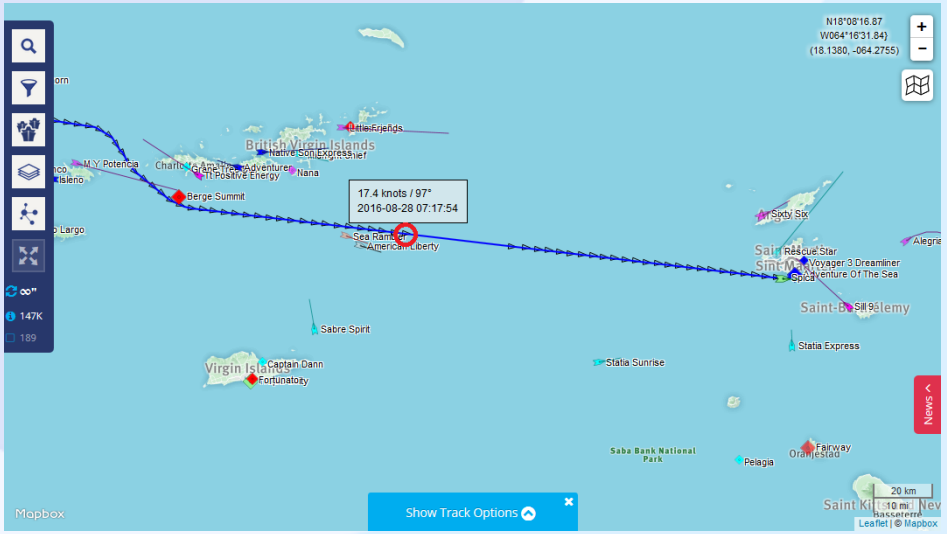
Unnatural turns



Widening with distance

Bilge Dumping Observed in SAR

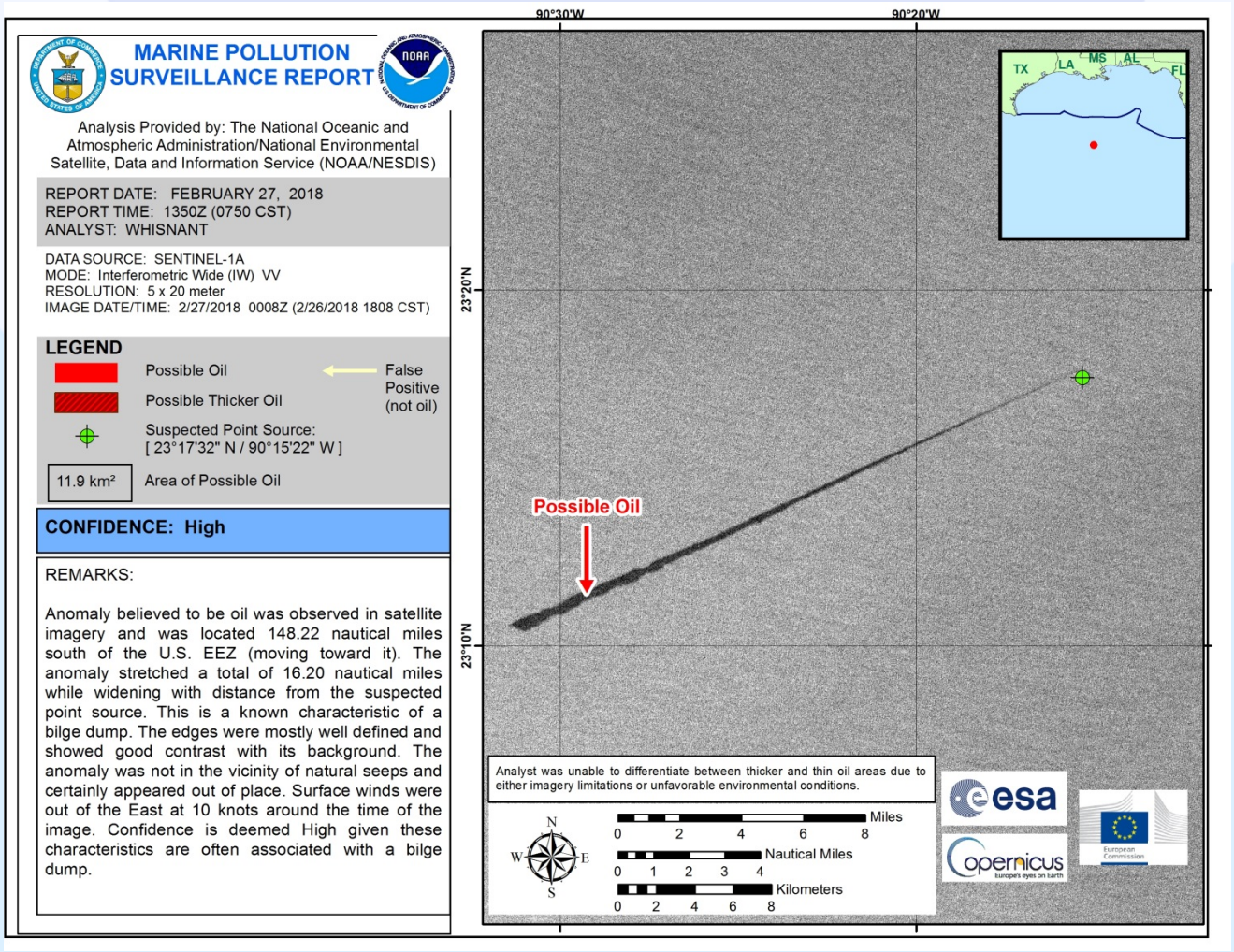




AIS data revealed the beacon was turned off between 0717Z – 0822Z. Sentinel-1A imaged the area at 1006Z.

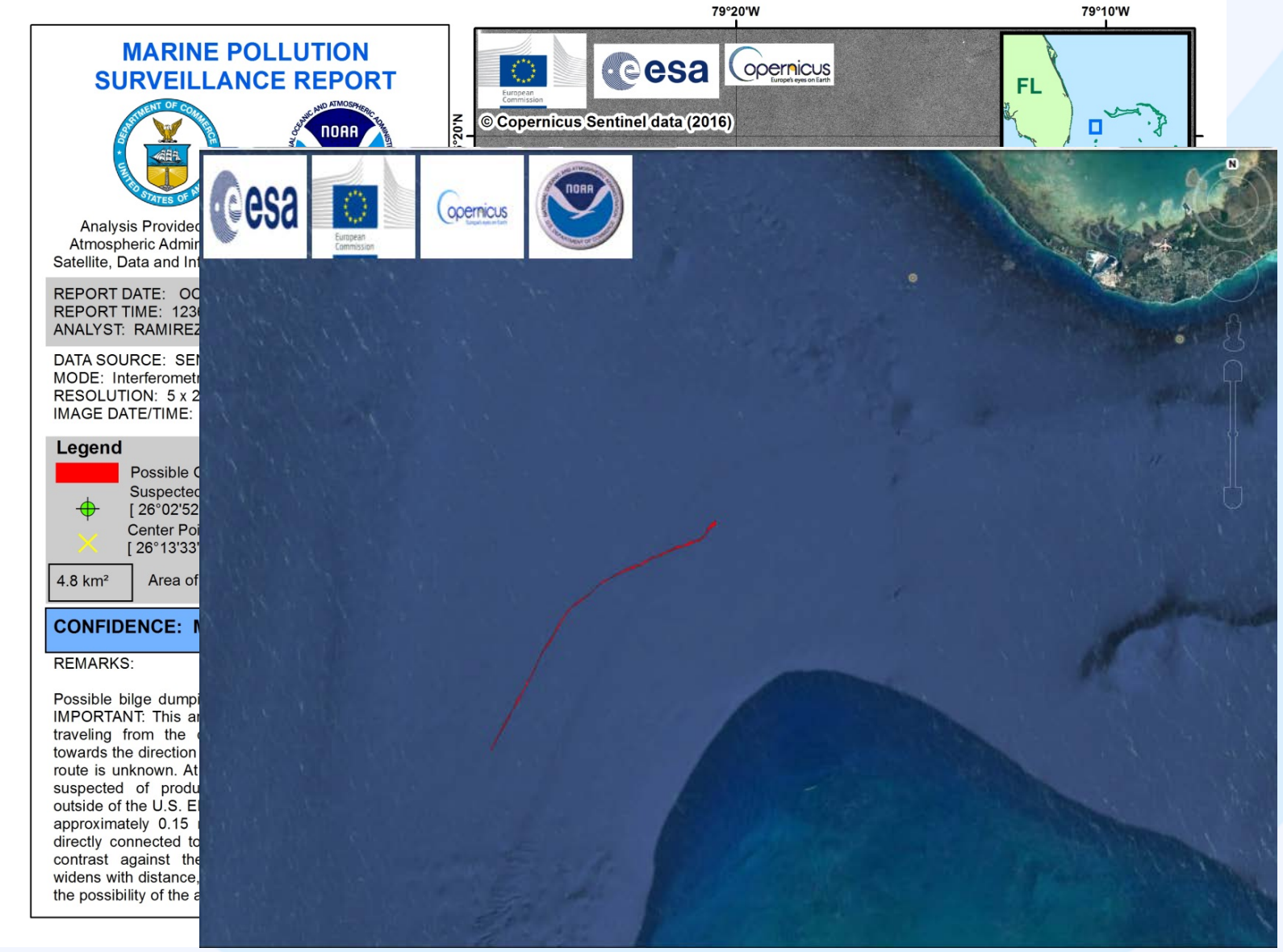
Possible oil discharge was reported by SAB in British Virgin Islands waters from a vessel departing Puerto Rico bound for St. Maarten. The MPSR was picked up by the USCG Sector San Juan and the USCG Maritime Intelligence Fusion Center – Atlantic (MIFCLANT) in Virginia Beach. A cutter investigated and found a light remnant sheen. Coordination was established with the British CG as this is a MARPOL violation (The International Convention for the Prevention of Pollution from Ships).

Bilge Dumping Observed in SAR



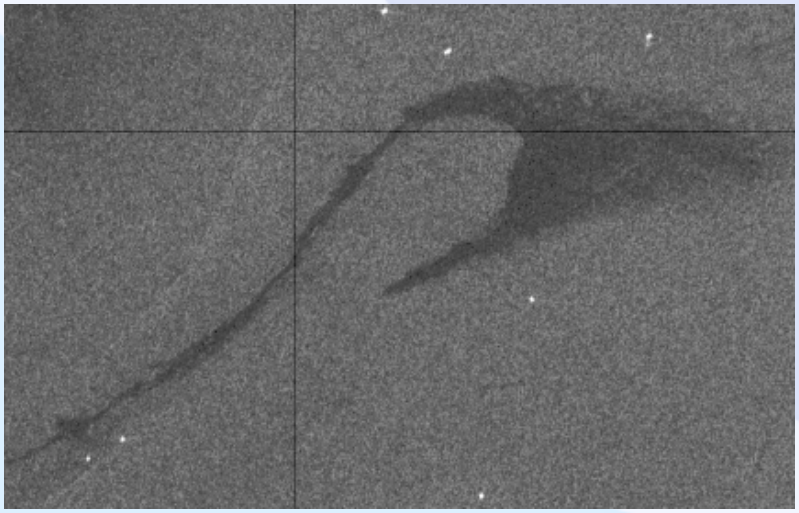
Possible oil discharge was observed in the Gulf of Mexico from a vessel cruising approximately 150 NMI south of the U.S. EEZ. Report was picked up by the USCG Maritime Intelligence Fusion Center – Atlantic (MIFCLANT) in Virginia Beach. The vessel was boarded when it reached port in Savannah, GA on 3 March 2018. We are awaiting feedback on the results of the investigation.

Bilge Dumping Observed in SAR

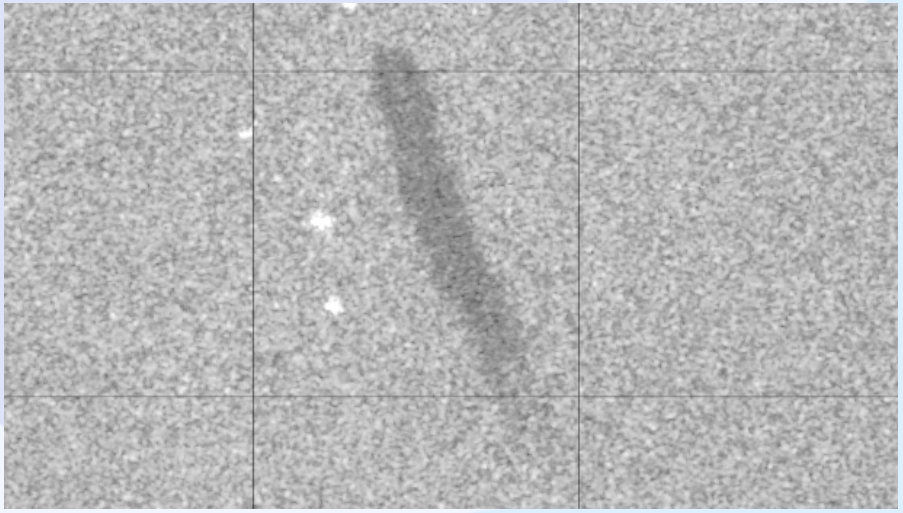


Observing Oil in Synthetic Aperture Radar

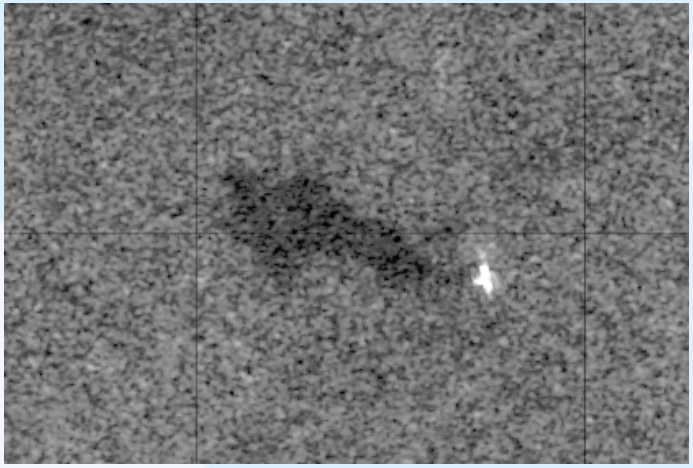
Visual Characteristics of Accidental Discharges



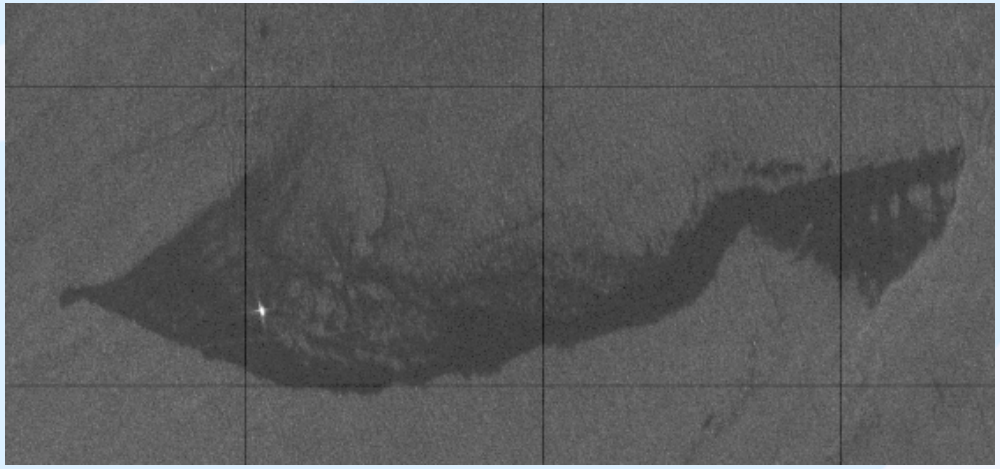
Good contrast



Stands out from any other feature in the image

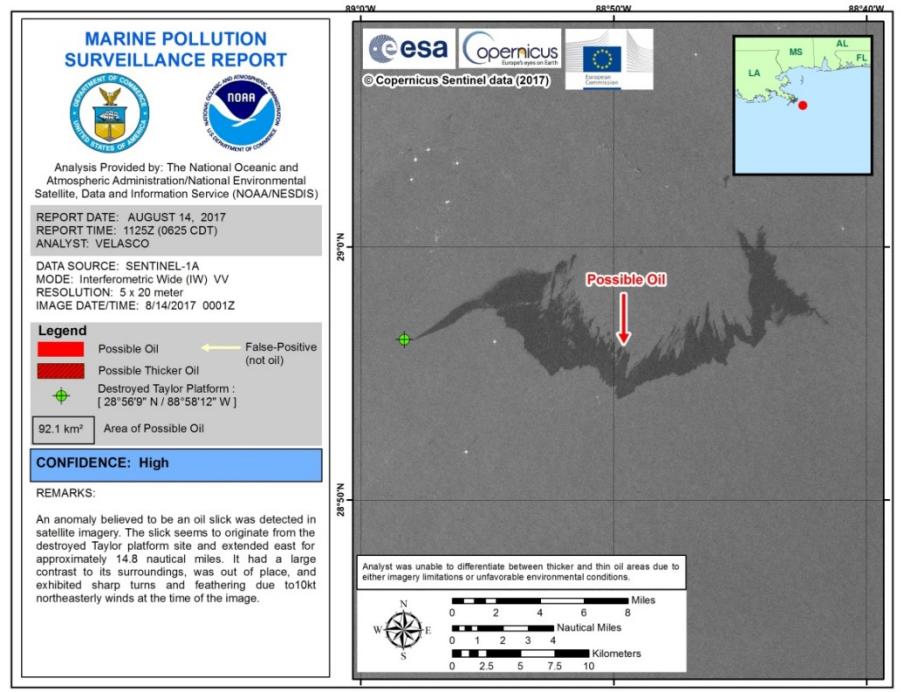


Has a point source

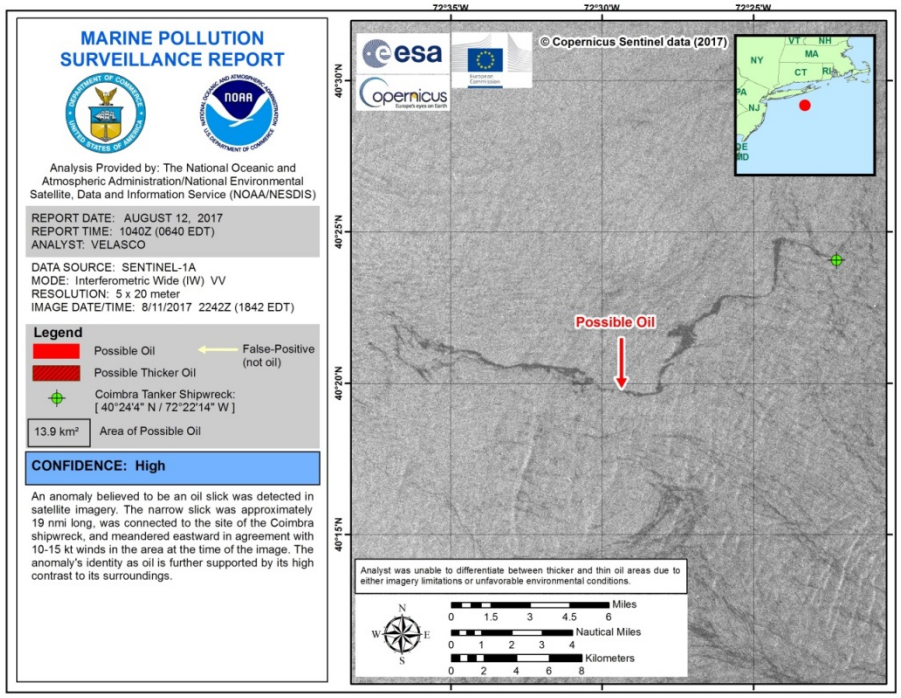


Well defined edges

Marine Pollution Surveillance Report (MPSR)

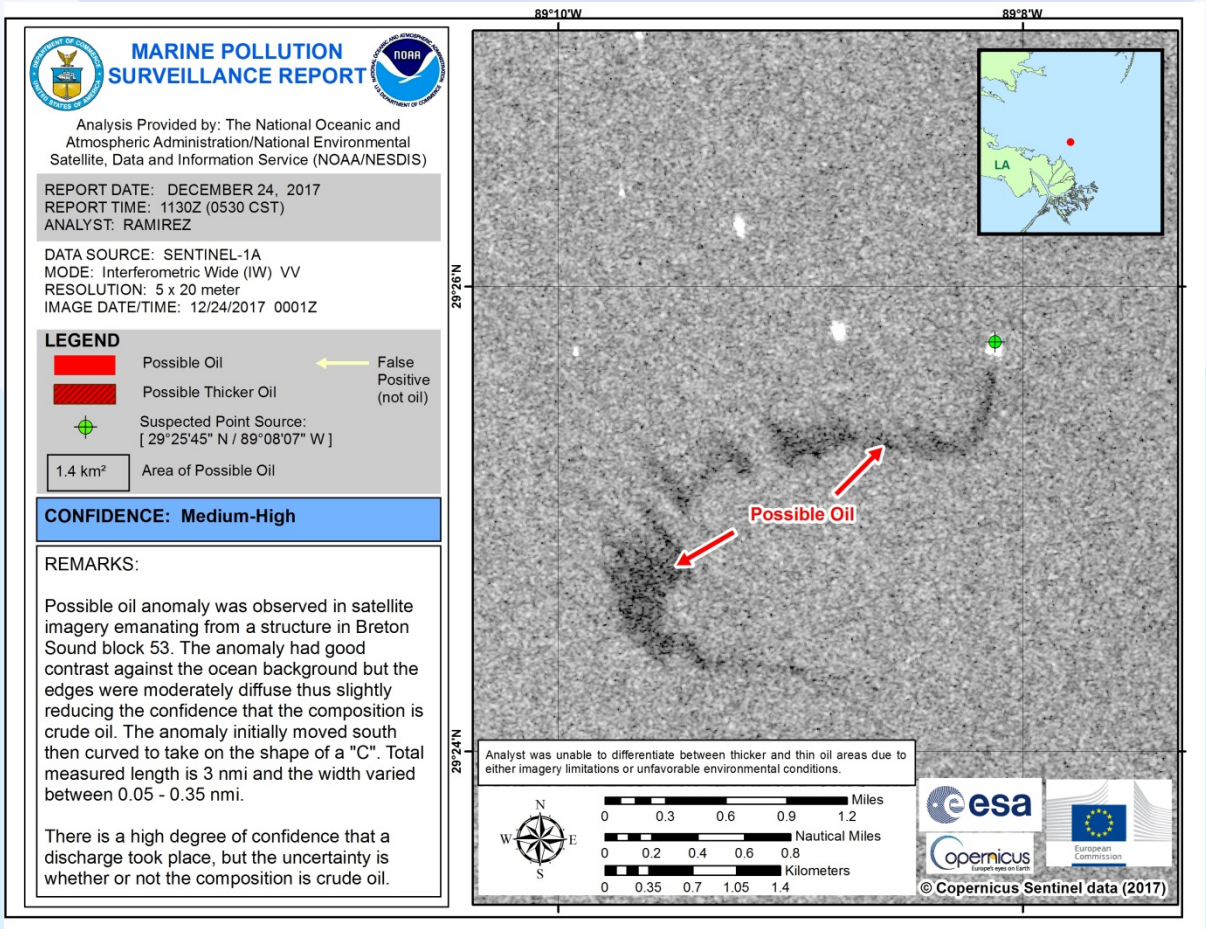


Possible oil discharge was observed in the Gulf of Mexico just offshore from the birds foot delta in Louisiana. This ongoing oil release is the result of a Taylor Energy platform that was damaged by Hurricane Ivan in 2004. Litigation remains ongoing, and each satellite report generated by SAB serves as documentation.



Possible oil discharge was observed south of Long Island, NY. This ongoing oil release is the result of the Coimbra Tanker, which was torpedoed by a U-boat and sank in January 1942. This wreck is part of NOAA's Remediation of Underwater Legacy Environmental Threats (RULET) project, and SAB satellite reports serve as documentation of the ongoing discharge.

Marine Pollution Surveillance Report (MPSR)



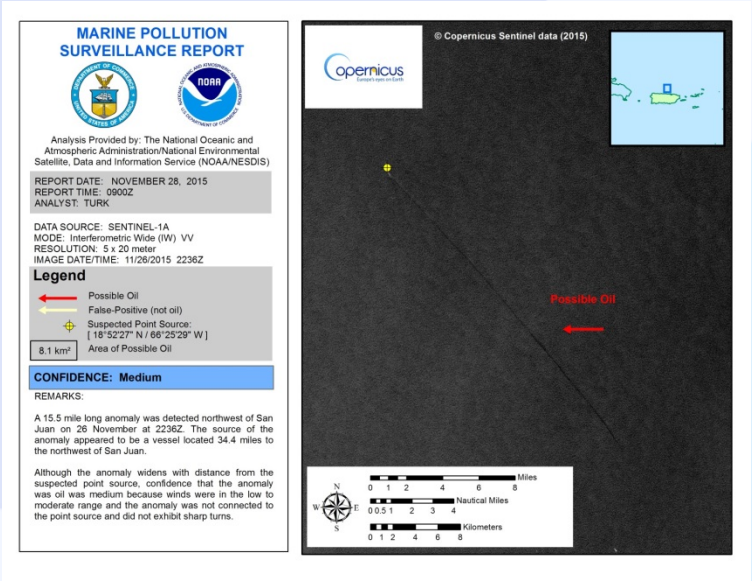
On Sunday morning December 24th, 2017 a three mile long possible oil sheen was detected in the Gulf of Mexico using a 0001Z Sentinel-1A satellite image. The USCG Sector New Orleans determined that the discharge was ongoing and originating from a decommissioned oil production platform. The Coast Guard's Incident Management Division (IMD) opened a Federal Project and contracted OMI Environmental Solutions to assess the incident and install a containment boom on December 25th.

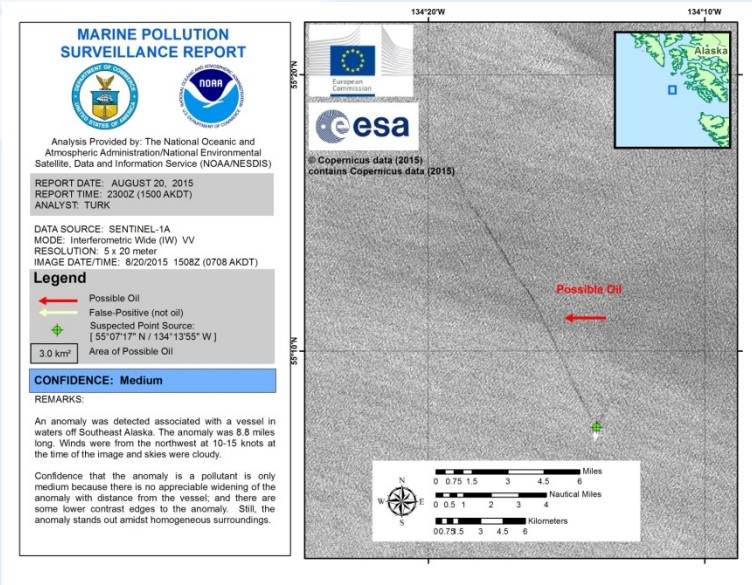
Common Pitfalls for Oil Detection in Synthetic Aperture Radar

- Low wind conditions
- Ship wakes
- Sheltering
- Upwelling
- Biogenic slicks or organic material
- Fishing Activity
- Convective Outflow
- Grease Ice

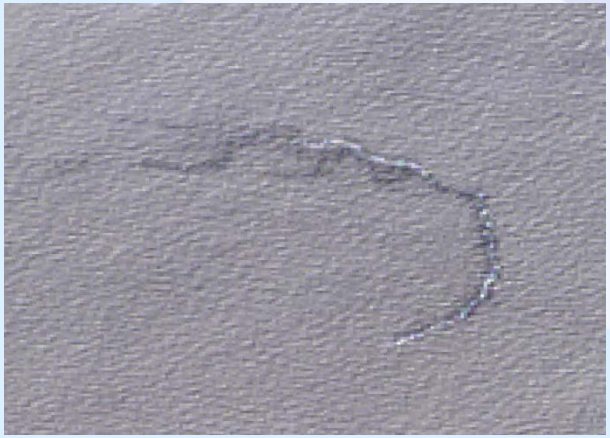
Despite exhibiting good contrast, the anomalies trailing the vessels neither show feathering nor widening with distance and are retroactively assessed to be wakes.

→

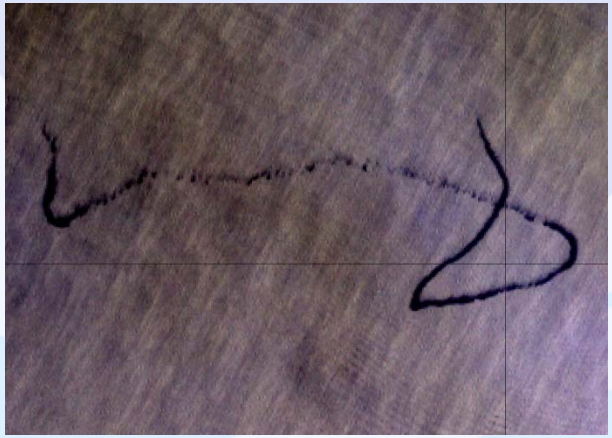




Identifying Oil in Optical Imagery

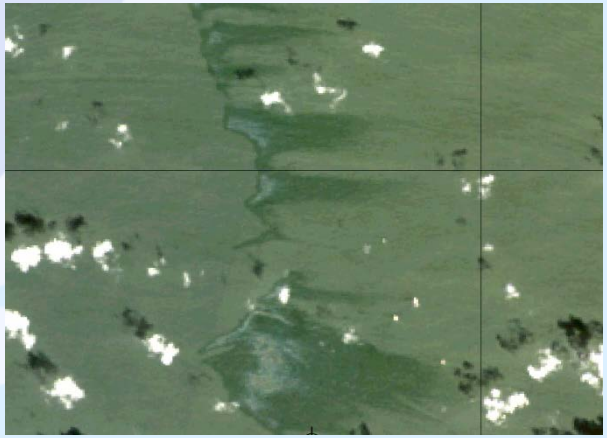


Can appear white and shimmery in sun illumination



Dark anomaly with well defined edges and good contrast against the ocean background

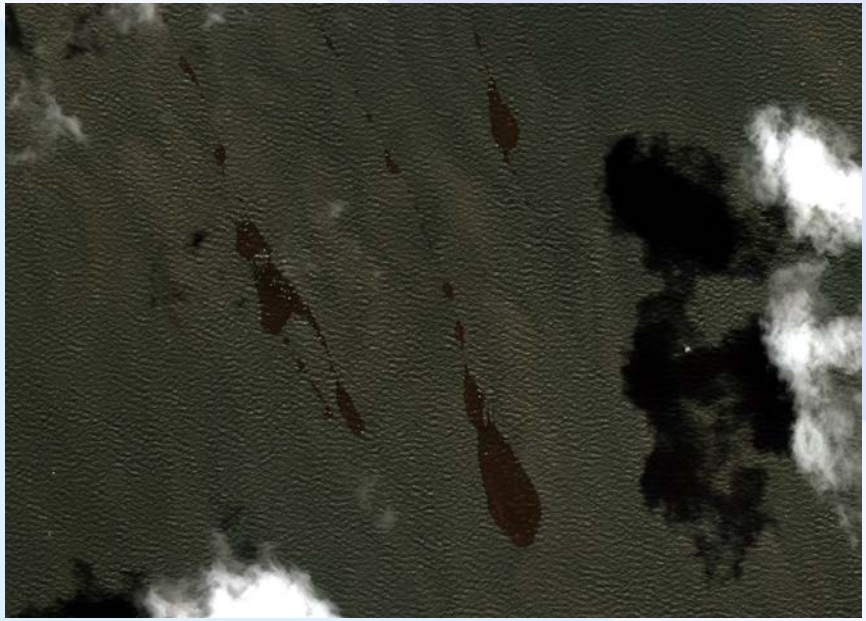
Unnatural turns



Feathering signature

Does not emit in the Near IR portion of the electromagnetic spectrum, as this would be indicative of vegetation (e.g. algal bloom)

Vegetation vs. Oil

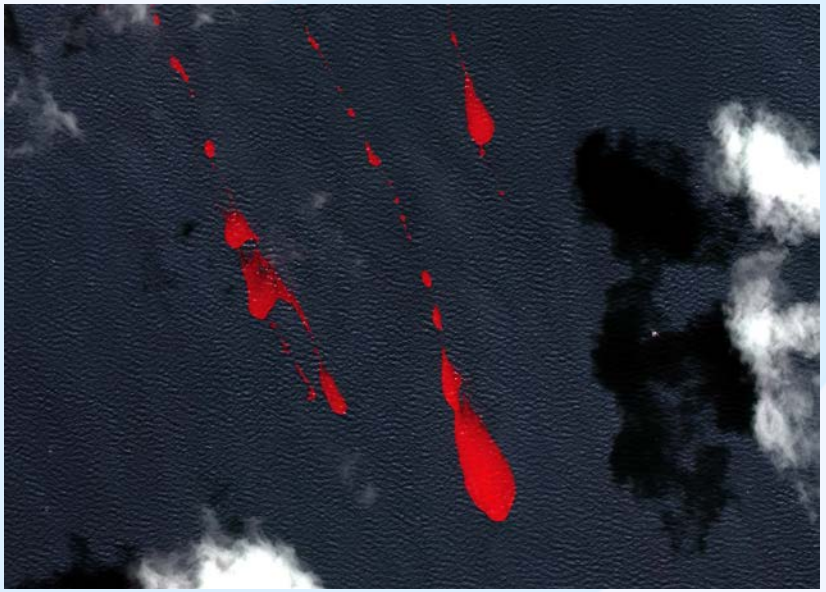


1.5 meter resolution WV2

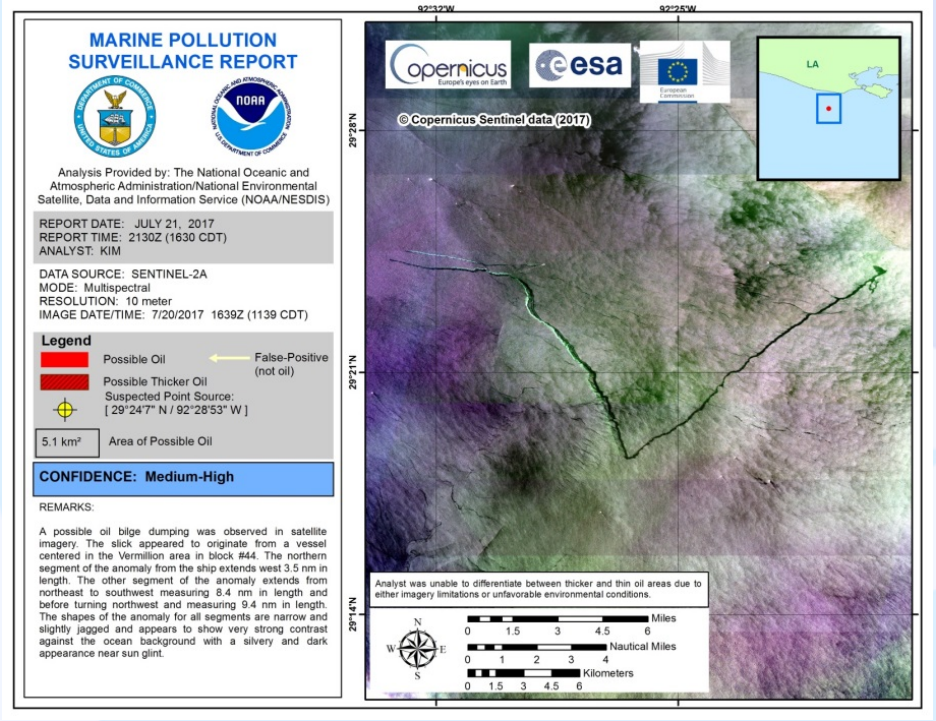
True Color image
(Red-Green-Blue)

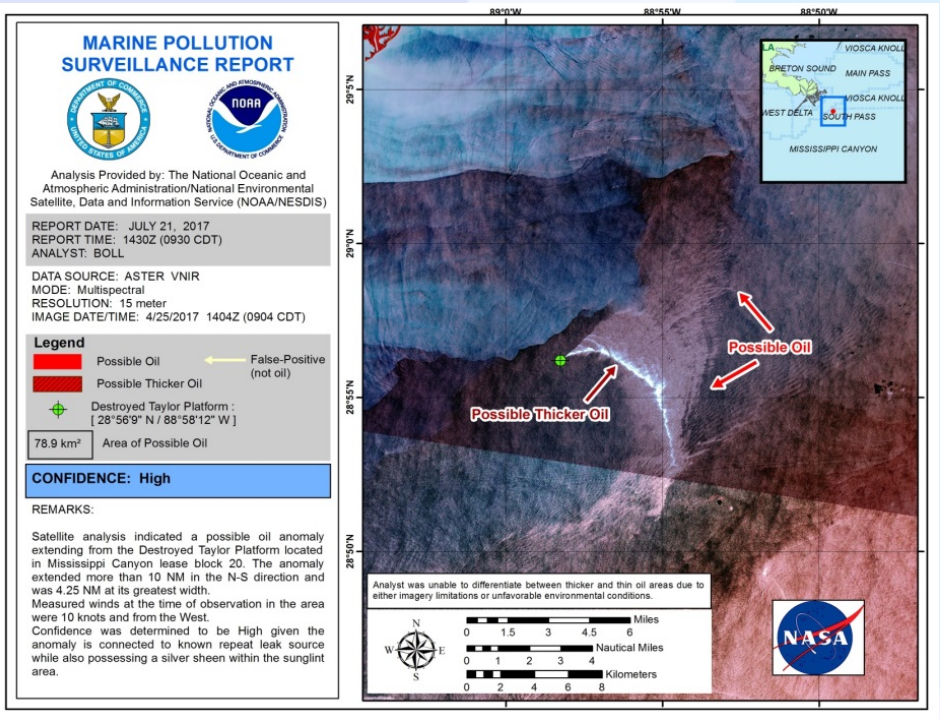
1.5 meter resolution WV2

Vegetation band enhancement
(NearIR-Red-Green)

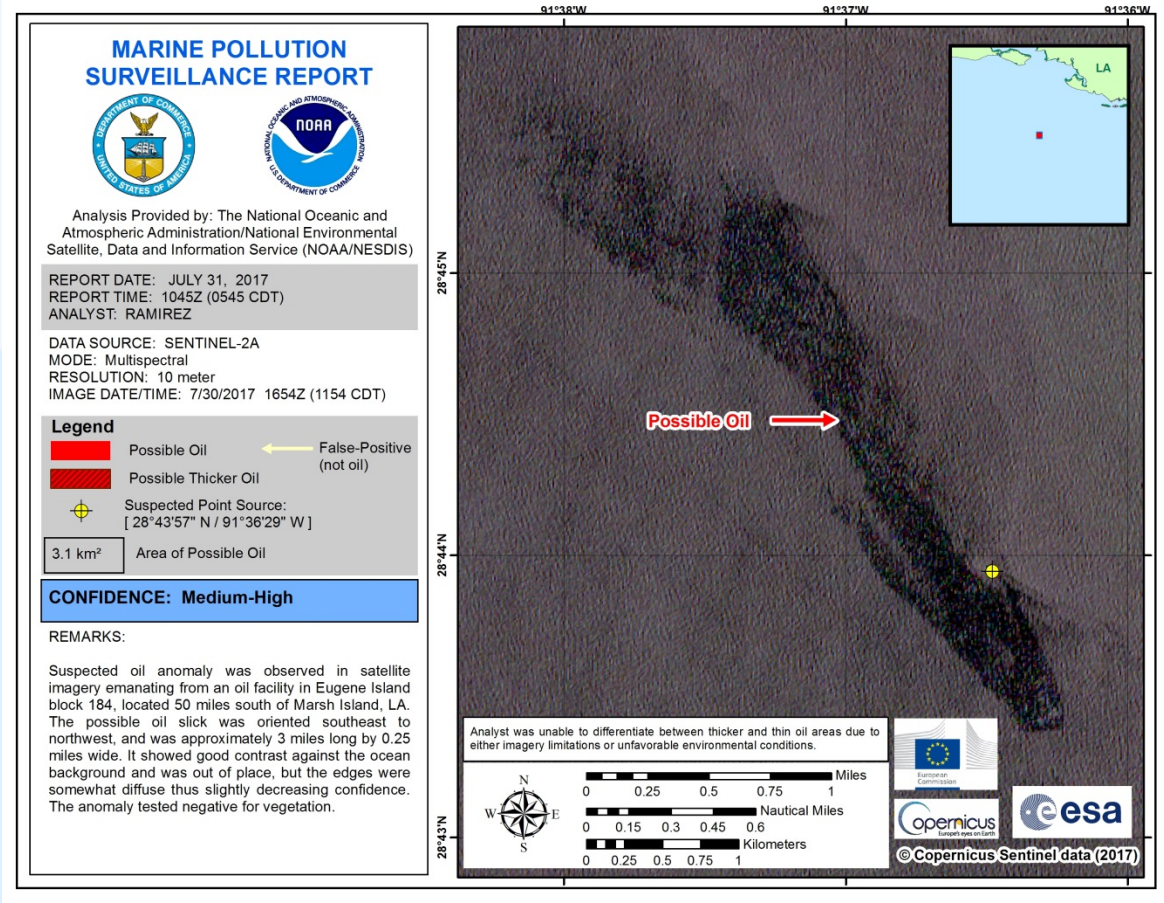


Marine Pollution Surveillance Report (MPSR)
Optical Imagery



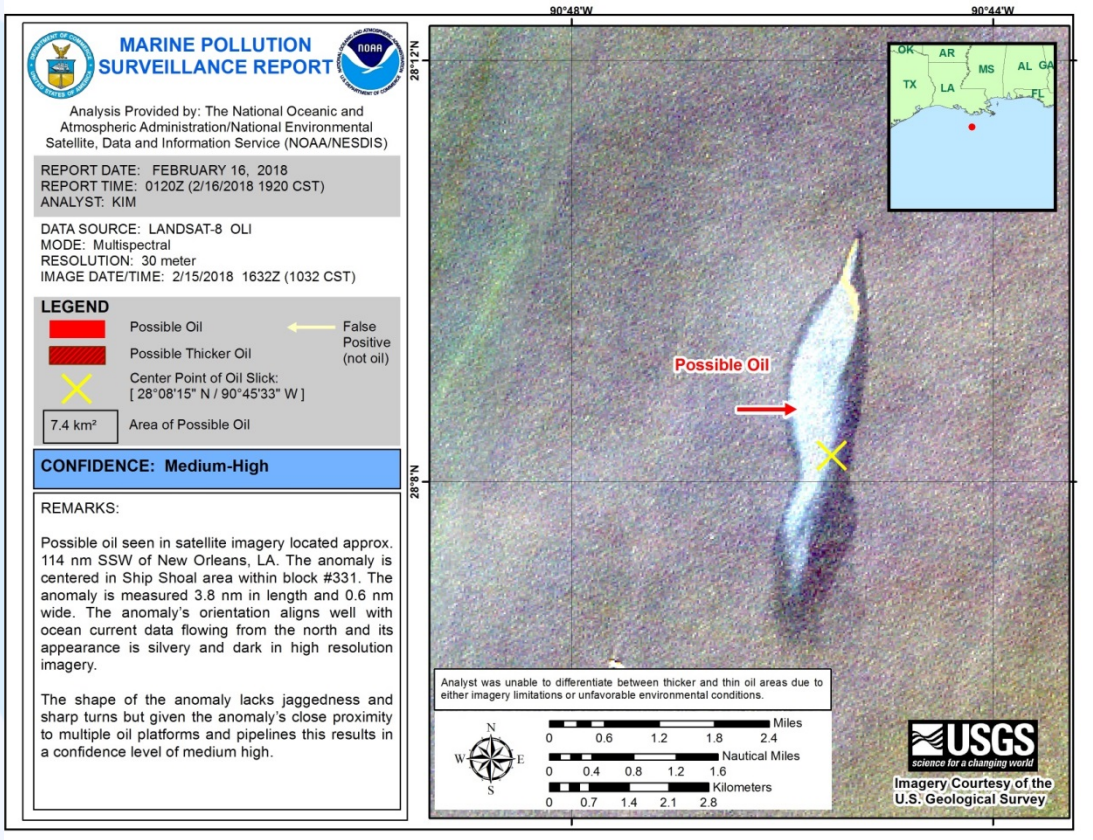


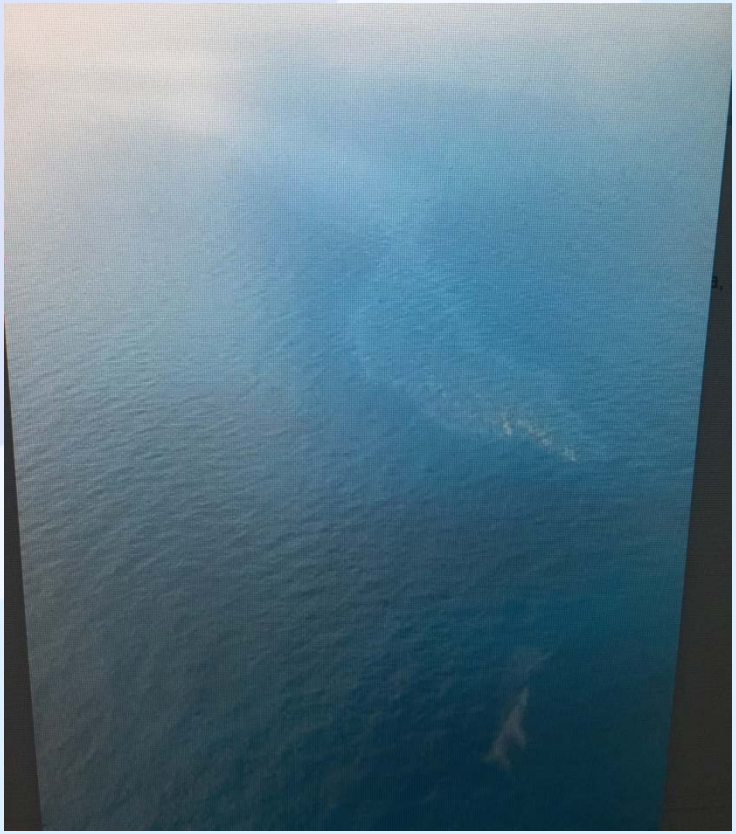
Marine Pollution Surveillance Report (MPSR) Optical Imagery



Early on Monday July 31st the marine pollution analyst in the Satellite Analysis Branch (SAB) detected a three mile long oil sheen in the Gulf of Mexico using a 1654Z Sentinel-2A satellite image. The oil sheen appeared connected to a platform in the Gulf of Mexico. The owner, NorthStar Offshore Group, LLC acknowledged that a sheen was observed but they failed to report it to the National Response Center. The Bureau of Safety of Environmental Enforcement investigated.

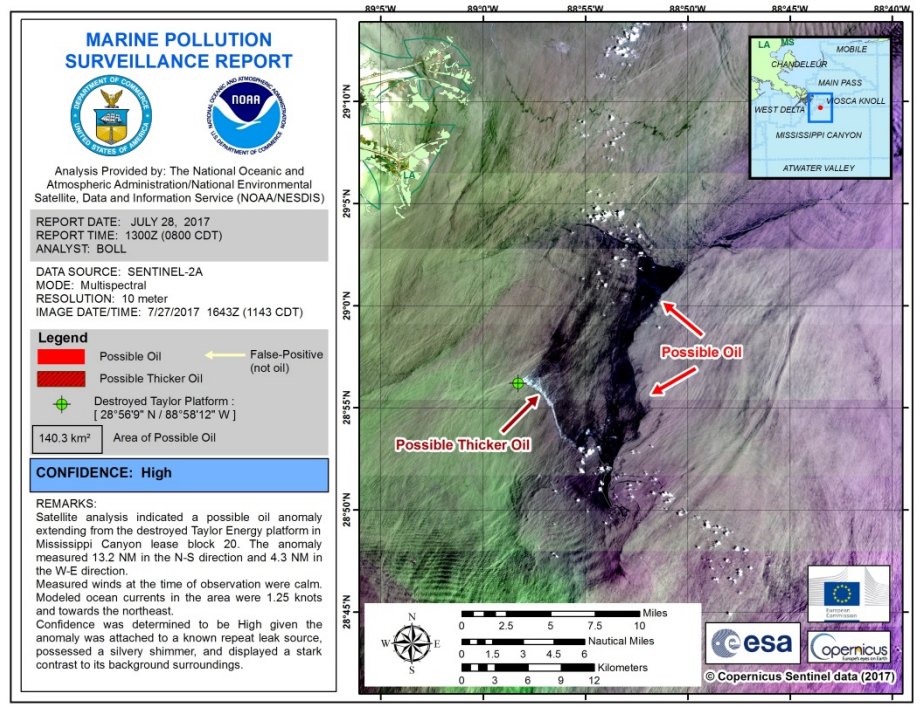
Marine Pollution Surveillance Report (MPSR) Optical Imagery

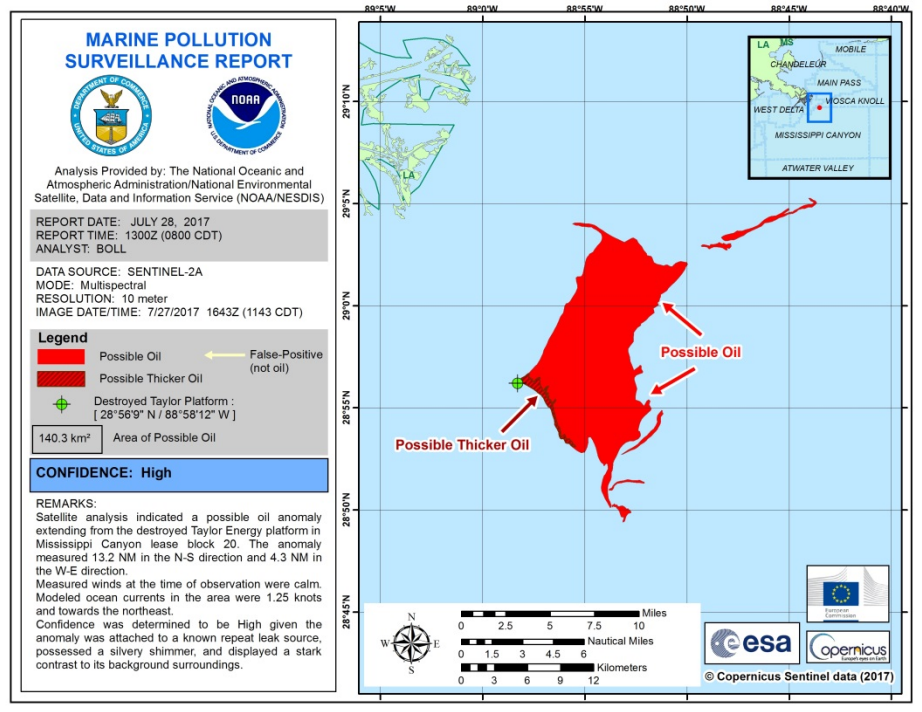




On the evening of February 15th, the marine pollution analyst in the Satellite Analysis Branch (SAB) detected a 3.8 NMI long possible oil sheen in the Gulf of Mexico using a 1632Z Landsat-8 satellite image. In the morning on February 16th the Bureau of Safety and Environmental Enforcement (BSEE) Sector Houma overflew the area and discovered an oil sheen measuring 1 NMI by 200 yards. The oil slick was in the vicinity of numerous pipelines, but its source remains unknown at this time.

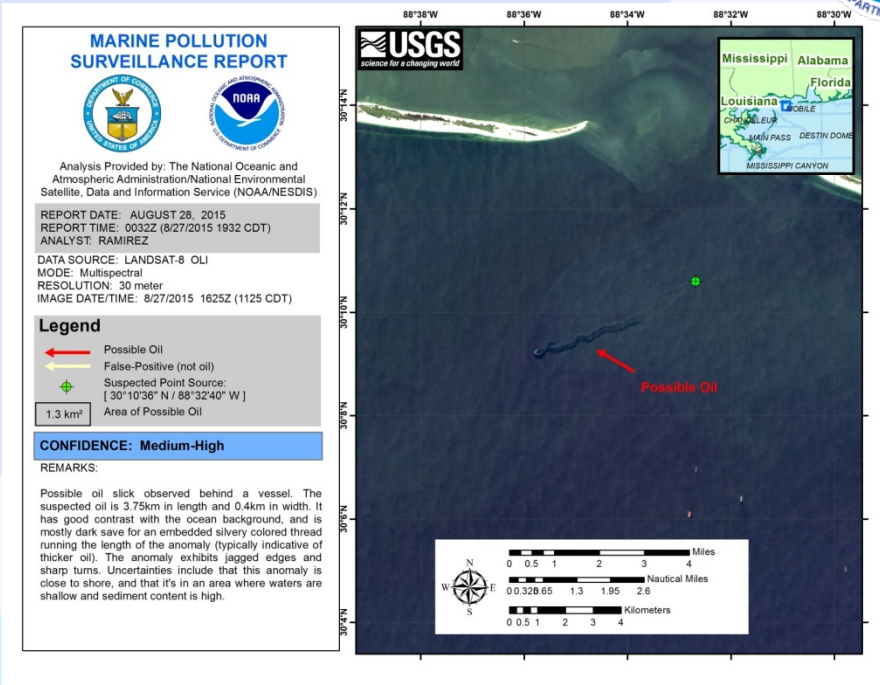
Oil Thickness Assessment





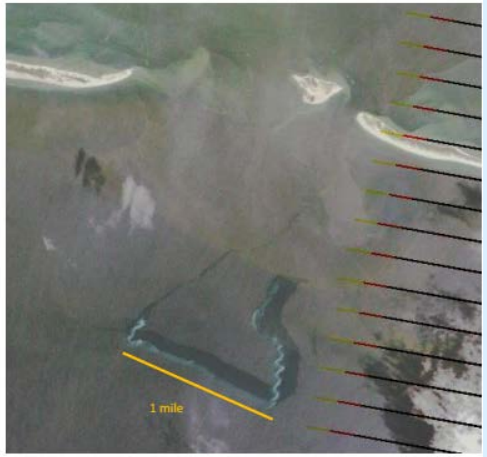
Common Pitfalls for Oil Detection in Optical Imagery

- Bathymetric or “bottom” features
- Fishing activity
- Ship wakes
- Cleaning agents
- Shadows



Similar anomaly 1 year earlier →

True Color



False Color

Confidence Level Assessment

High

- Has a source point, or if not has another report of oil co-located
- Has appreciable widening with distance or feathering or shimmery in sunglint or very sharp unnatural turns
- Anomaly clearly stands out from any other feature in the image

Medium-High

- May or may not have a source point
- Has sharp, well defined edges and good contrast against the ocean background
- Is either removed from or is distinguishable from natural phenomena
- Anomaly moderately stands out from any other feature in the image

Medium

- Has a source point but it is unclear if anomaly is natural (e.g. ship wake), or is in the vicinity of natural phenomena (e.g. vegetation)
- Doesn't have a source point but exhibits moderately sharp edges or moderately sharp turns that appear different from any other feature in the image

Comparison of SAR vs. Optical Imagery

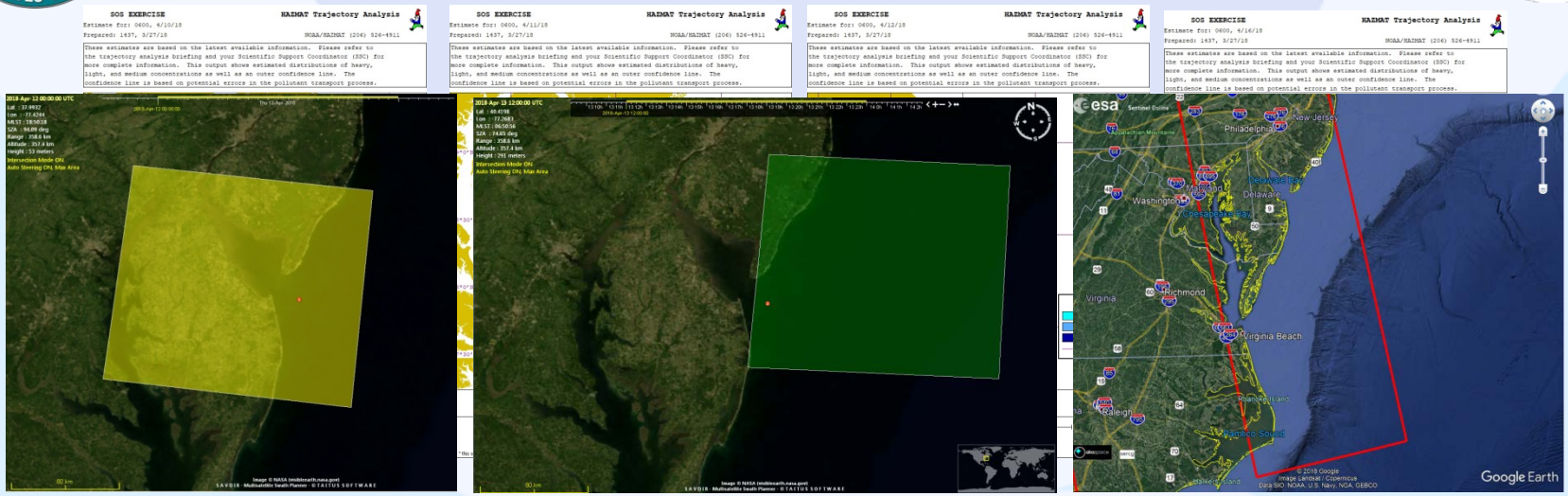
ADVANTAGES	DISADVANTAGES
SAR • Not dependent on daylight • Can see through clouds	SAR • Cannot distinguish oil from vegetation or newly formed ice
Optical • Can test for vegetation • Has color information	Optical • No night time detection • Requires cloud free conditions

Emergency Services

- For moderate spills expected to last more than 1 day, we can request special satellite imagery. There are 3-4 satellite assets that are available to us at no charge on an ad-hoc basis, but typically take 1+ business day to get tasked and acquired.

- For significant spills where the Pollution Recovery Funding Authorization (PRFA) is activated and satellite imagery is added, we can purchase satellite imagery in support of the needs of the FOSC and SSC.

Spill Trajectory April 10-16



Routinely Acquired Imagery

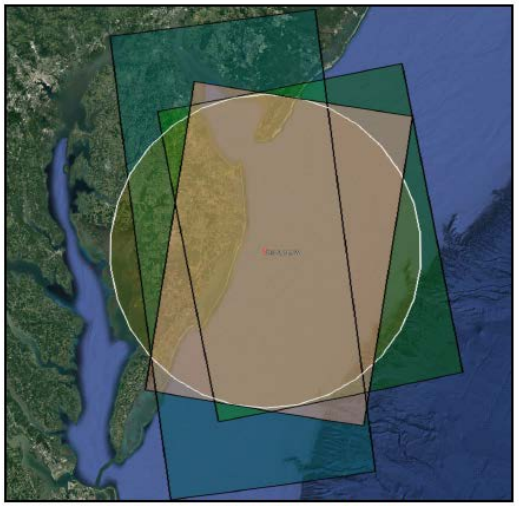
April 11th 1550Z: Sentinel 2A
April 12th 1540Z: Landsat 8
April 13th 1536Z: Landsat 7
April 16th 1548Z: Sentinel 2B
April 18th 2255Z: Sentinel 1A

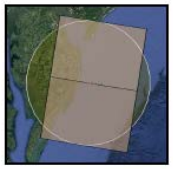
Specially Acquired Imagery (free source)

April 11th 1604Z: Aster
April 12th 1601Z: Worldview2
April 13th 1552Z: Aster
April 13th 1633Z: Worldview3
April 15th 1550Z: Worldview2
April 20th 1558Z: Aster

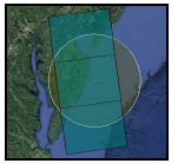
SAR for Purchase

Feasibility for April 12th, 2018

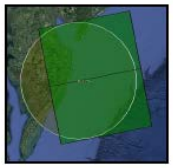




Satellite: COSMO-SkyMed 1
Sensor: ScanSAR (WideRegion)
Scenes: 2
Time: 22:43:40



Satellite: COSMO-SkyMed 1
Sensor: ScanSAR (WideRegion)
Scenes: 3
Time: 10:54:43



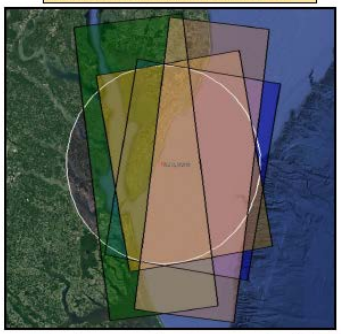
Satellite: COSMO-SkyMed 4
Sensor: ScanSAR (WideRegion)
Scenes: 2
Time: 10:30:46

COSMO-SkyMed ScanSAR (WideRegion) Feasibilities

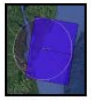
CSTARS

Feasibilities for April 15th, 2018

Satellite: COSMO-SkyMed
Sensor Mode: ScanSAR (WideRegion)



COSMO-SkyMed 2
Scenes: 3
Time: 11:00:32

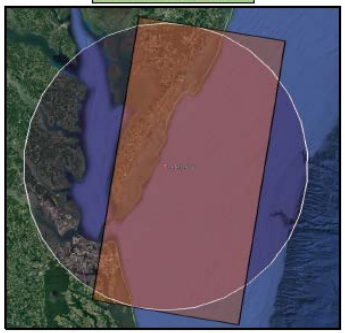


COSMO-SkyMed 2
Scenes: 2
Time: 22:49:58

COSMO-SkyMed 3
Scenes: 3
Time: 22:31:45

COSMO-SkyMed 3
Scenes: 2
Time: 10:42:34

Satellite: TerraSAR-X
Sensor Mode: ScanSAR

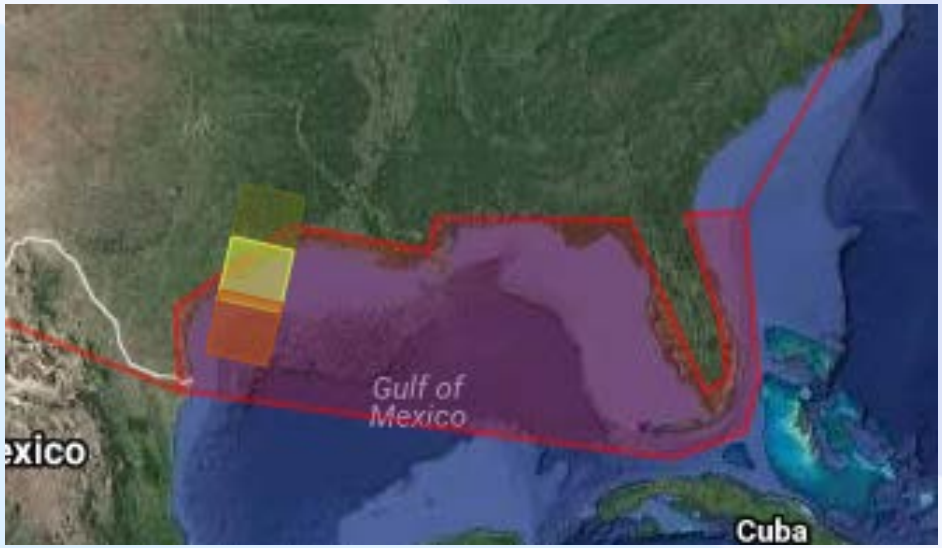


TerraSAR-X
Scenes: 2
Time: 11:06:17

CSTARS

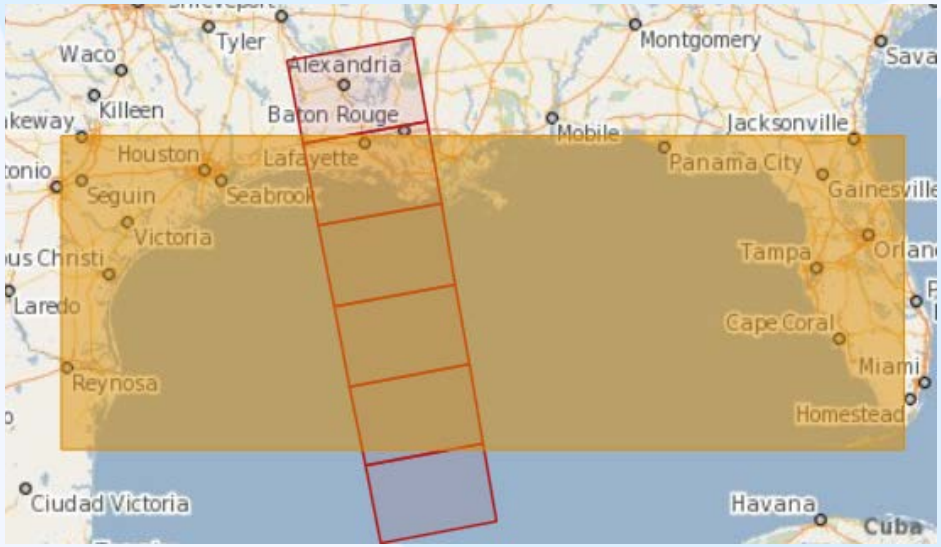
Routine Satellite Revisit Times

- Landsat7/8 – **30m** optical - **16 days**



- Sentinel-2 – **10m** optical - **10 days**

- Sentinel-1 – **5 to 40m** SAR - **12 days**



- MODIS Terra/Aqua – **250m** optical **Everyday**

Routine Satellite Lag Times

- It is important to note that the majority of the satellite imagery we analyze for oil is **non-NOAA** and therefore timely availability, portal maintenance and downtime, and download restrictions are largely out of our control.

Landsat 7/8 – USGS

The Gulf is imaged around 12pm local time and imagery is available 4h after acquisition. (downlinked in South Dakota, uploaded to Earth Explorer).

We are restricted to 2 simultaneous downloads. Downloading, unzipping, analyzing, and report creation and dissemination typically add another 2h.

TOTAL LAG: ~6h

Terra/Aqua – NASA

The Gulf is imaged between 12pm-2pm local time and imagery is available 3h after acquisition.

Downloading, analyzing, and report creation and dissemination typically add another 1h.

TOTAL LAG: ~4h

Sentinel 1/2 – ESA

The Gulf is imaged by Sentinel-1A at 7pm local time. Files are large and we are restricted to 2 simultaneously downloads.

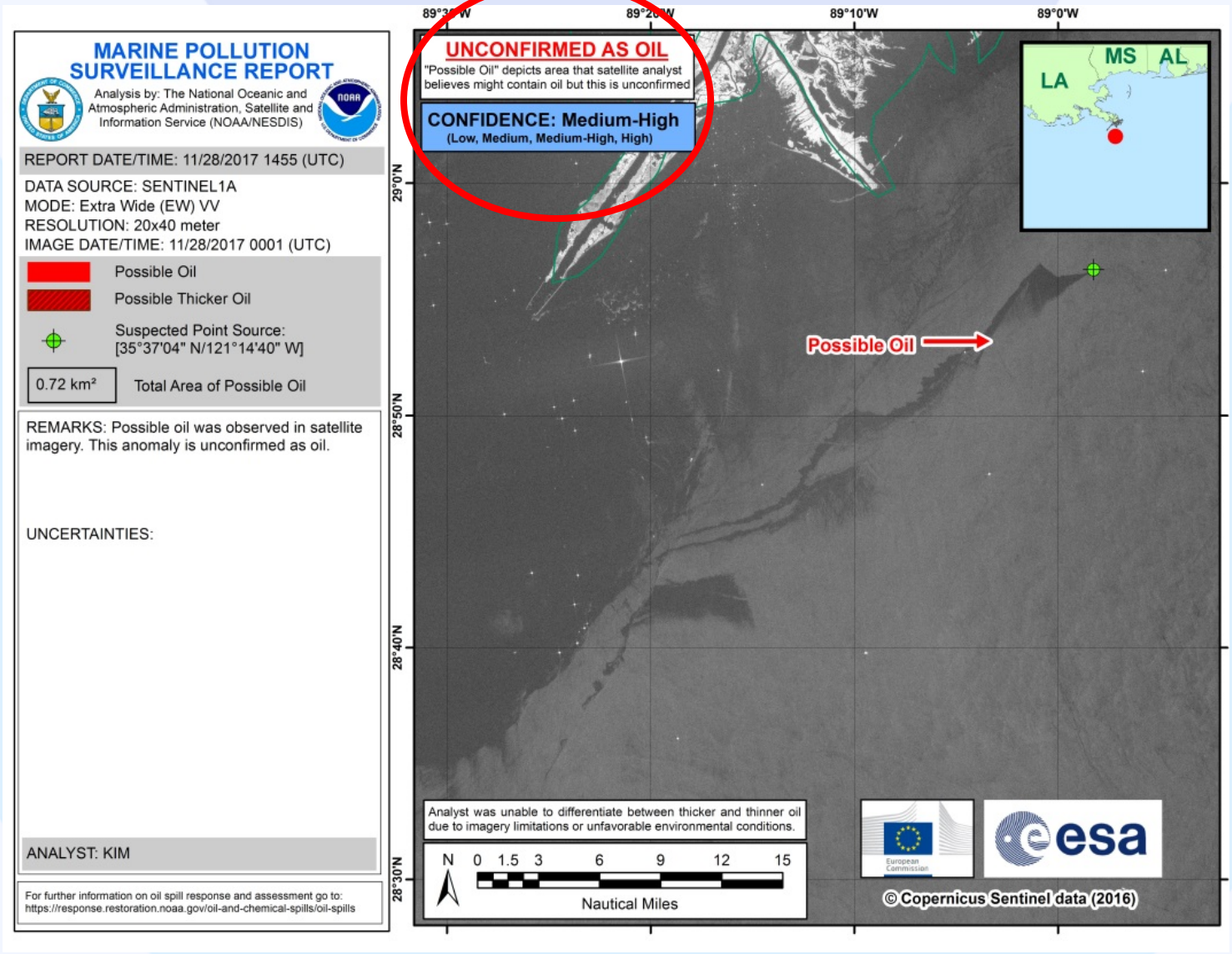
TOTAL LAG: 6-12h

The Gulf is imaged by Sentinel-2A/B at 12pm local time. Files are VERY large and we are restricted to 2 simultaneous downloads.

TOTAL LAG: 12-24h

Changes in 2018

New Report Template



Semi-Automated Email Alert

NOAA/NESDIS MPSR Issued for: Gulf of Mexico Inbox x

Oceanmap Mar 26 (4 days ago)

to Ed, George, Brad, John, Mike, Paige, Scott, Rachel, Stephen.Werndli, Matthew, Steven, Adam, Mike, Doug, Kevin, Daniel, Liza, Amy, Lisa, Brandi, David.Fish, Investigator, Andrew, Stacey.

Dear User,

A possible oil anomaly was observed in satellite imagery. This anomaly is unconfirmed as oil.

REGION: Gulf of Mexico
SUBREGION: N/A
REPORT DATE: 03-26-2018
IMAGE DATE: 03-24-2018
IMAGE TIME: 1629 UTC
SATELLITE: Sentinel 2A
RESOLUTION: 10 meter
COORDINATES: 28°56'16" N 88°58'14" W
AREA: 28.61 square kilometers
CONFIDENCE: High (Low, Medium, Medium-High, High)
REMARKS: Possible oil was observed in satellite imagery. This anomaly is unconfirmed as oil. The slick was believed to be emanating from the destroyed Taylor platform location and was oriented in accordance with winds to the NNE at the time of the image. The anomaly was distinguishable from its homogeneous surroundings and contained a shimmery area that was believed to be relatively thicker oil compared to the darker slick portion of the slick surrounding it. The N-S feathering signature also supported the anomaly's identification as being oil.
UNCERTAINTIES: A more precise areal measure of the anomaly could not be attained due to the feathering and dark ocean background, but it is possible the area was larger than that calculated in this report.

ANALYST: Velasco

Maps and shapefiles can be accessed at: www.ospo.noaa.gov/Products/ocean/marinepollution/

For further information on oil spill response and assessment go to: https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills

IF YOU WOULD LIKE TO SHARE ANY FEEDBACK ABOUT THIS REPORT OR HAVE QUESTIONS, PLEASE CONTACT THE OPERATIONAL ANALYST AT (301) 683-1403 OR SEND TO oceanmap@noaa.gov. REQUESTS TO BE ADDED TO THE EMAIL ALERTS SHOULD ALSO BE SENT TO oceanmap@noaa.gov. EMAIL ALERTS ARE AVAILABLE ONLY TO THOSE INVOLVED IN RESPONSE, ASSESSMENT, RECOVERY, ETC. PLEASE ALLOW UP TO 2 BUSINESS DAYS TO PROCESS THE REQUEST.

Distributions Lists: Atlantic, Gulf of Mexico, Great Lakes, Pacific

To request to be added, email ellen.ramirez@noaa.gov

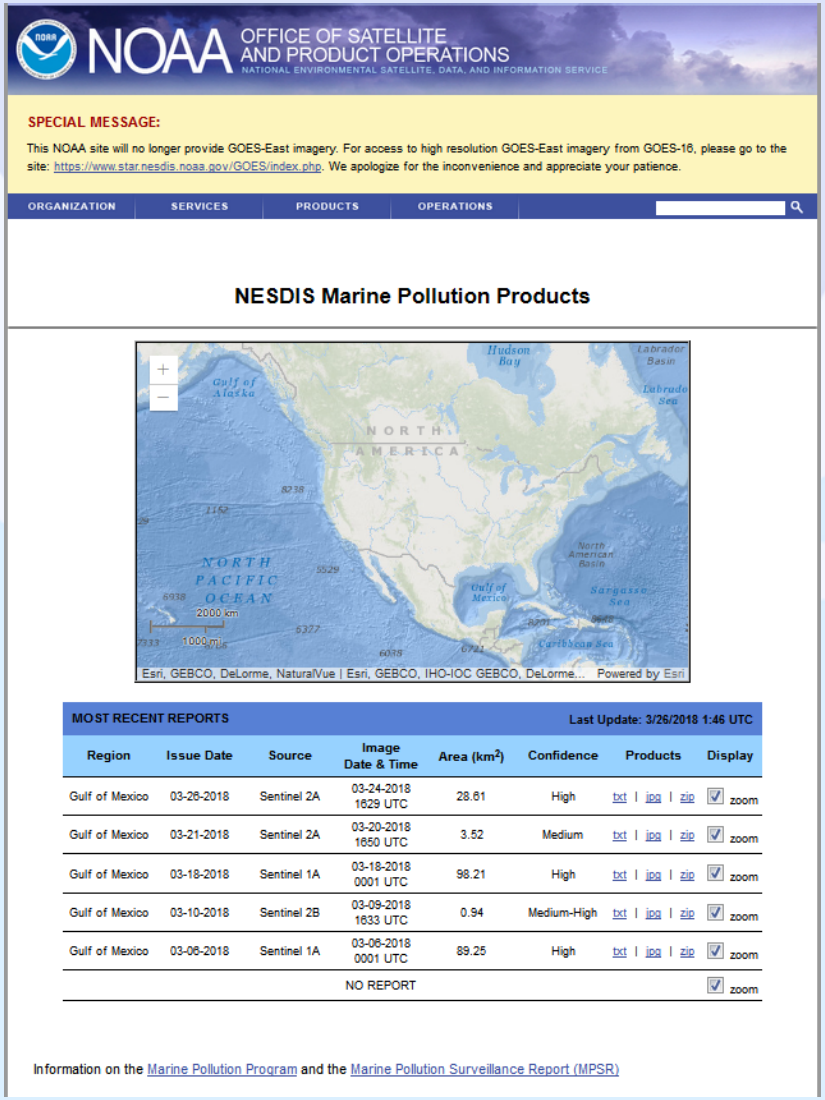
A Note on the National Response Center

- The National Response Center (NRC) is the designated federal point of contact for reporting all oil spills, not NOAA.

- All Marine Pollution Surveillance Reports generate a NRC incident.

- CG/BSEE/EPA/NOAA is by no means required to share feedback with NOAA, but it is of paramount importance to the quality of our program as oil confirmation or false positive confirmation are valuable learning opportunities, and reduce the chance of perpetuating mistakes.

Public Webpage



NOAA OFFICE OF SATELLITE AND PRODUCT OPERATIONS
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE

SPECIAL MESSAGE:

This NOAA site will no longer provide GOES-East imagery. For access to high resolution GOES-East imagery from GOES-16, please go to the site: https://www.star.nesdis.noaa.gov/GOES/index.php. We apologize for the inconvenience and appreciate your patience.

ORGANIZATION | SERVICES | PRODUCTS | OPERATIONS

NESDIS Marine Pollution Products

MOST RECENT REPORTS — Last Update: 3/26/2018 1:46 UTC

Region	Issue Date	Source	Image Date & Time	Area (km²)	Confidence	Products	Display
Gulf of Mexico	03-28-2018	Sentinel 2A	03-24-2018 1629 UTC	28.61	High	txt | jpg | zip	zoom
Gulf of Mexico	03-21-2018	Sentinel 2A	03-20-2018 1650 UTC	3.52	Medium	txt | jpg | zip	zoom
Gulf of Mexico	03-18-2018	Sentinel 1A	03-18-2018 0001 UTC	98.21	High	txt | jpg | zip	zoom
Gulf of Mexico	03-10-2018	Sentinel 2B	03-09-2018 1633 UTC	0.94	Medium-High	txt | jpg | zip	zoom
Gulf of Mexico	03-06-2018	Sentinel 1A	03-06-2018 0001 UTC	89.25	High	txt | jpg | zip	zoom
			NO REPORT				zoom

Information on the Marine Pollution Program and the Marine Pollution Surveillance Report (MPSR)

http://www.ospo.noaa.gov/Products/ocean/marinepollution/

Thank you!

Contact Information:

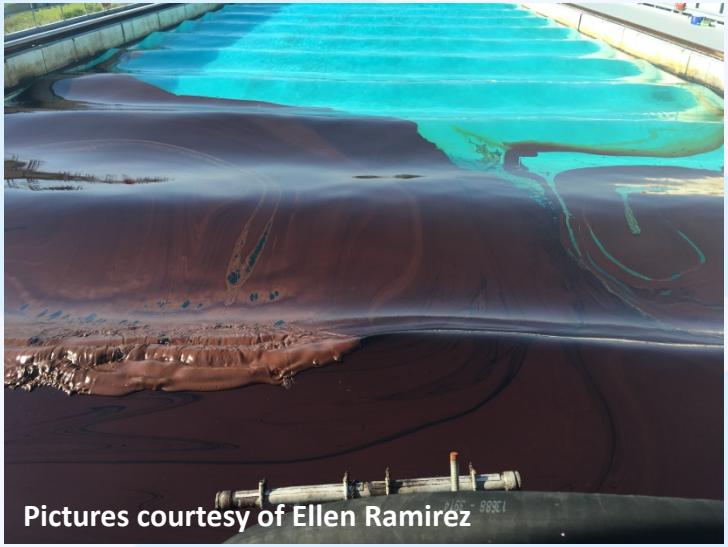
24 x 7 operational marine analyst
(301) 683-1403 or oceanmap@noaa.gov

Ellen Ramirez, Oil Spill Monitoring Operations Lead
ellen.ramirez@noaa.gov

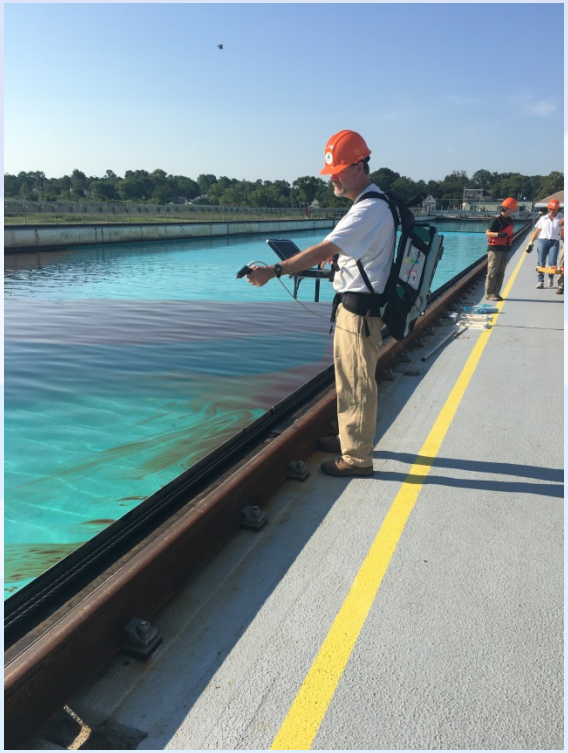
BSEE Funded Research

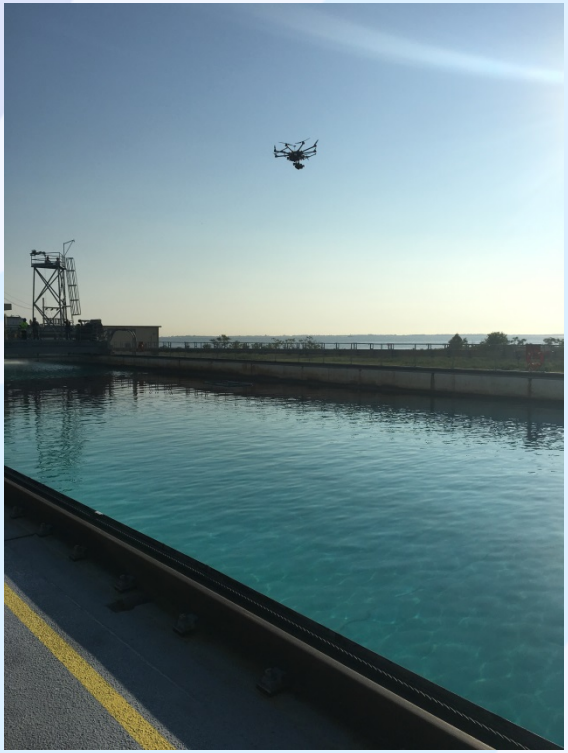
High resolution commercial imagery has been repeatedly requested by the NOAA Satellite Analysis Branch (SAB) from 2015-2017 as part of a joint effort between NOAA and BSEE which has enabled SAB to provide advanced oil analyses that include thickness information.

Ohmsett is the National Oil Spill Response Test Facility, located in Leonardo, New Jersey and stands for Oil and Hazardous Materials Simulated Environmental Test Tank.



Pictures courtesy of Ellen Ramirez





- Phase 1: Characterize the detection of known oil thicknesses and oil-emulsions in a controlled environment, performing multiple tests and calibrations for thermal, optical, and microwave sensors.
- In July 2016 400 gallons of crude oil was released into the salt water tank and waves were applied to simulate mixing in the open ocean.

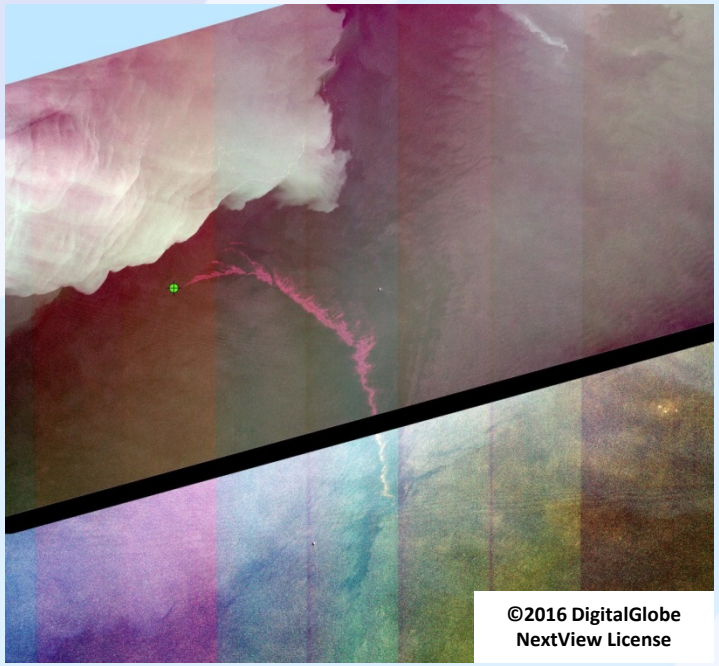
Field Work Continued…

Controlled Spill

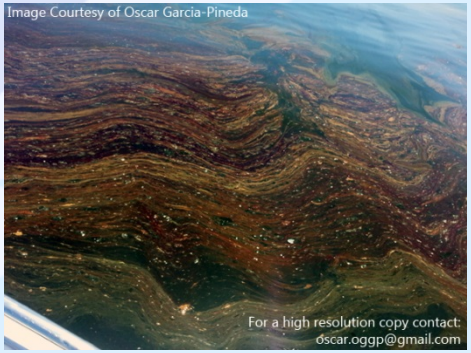
Worldview-3 Images Acquired

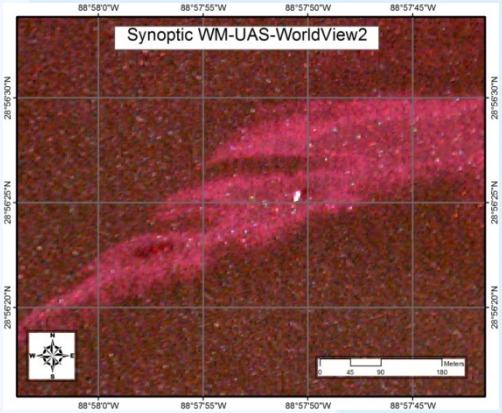
Open Ocean

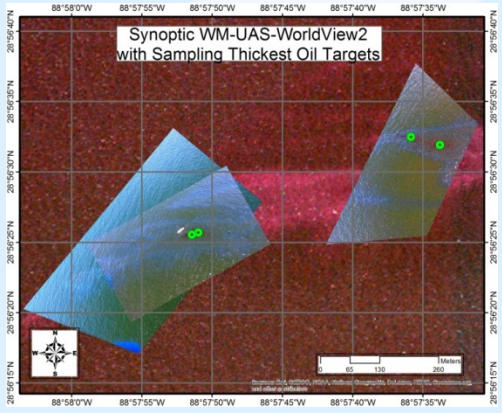
Phase 2: Measure the open water oil thicknesses and oil-emulsions at the damaged Taylor Energy well field surface oiling site performing multiple tests and calibrations for thermal, optical and microwave sensors.

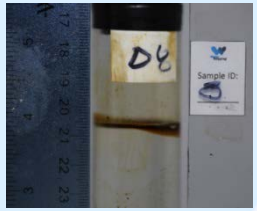


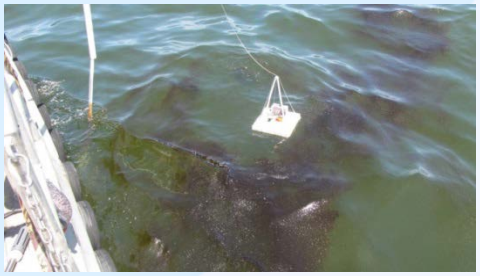
Field Work Continued…



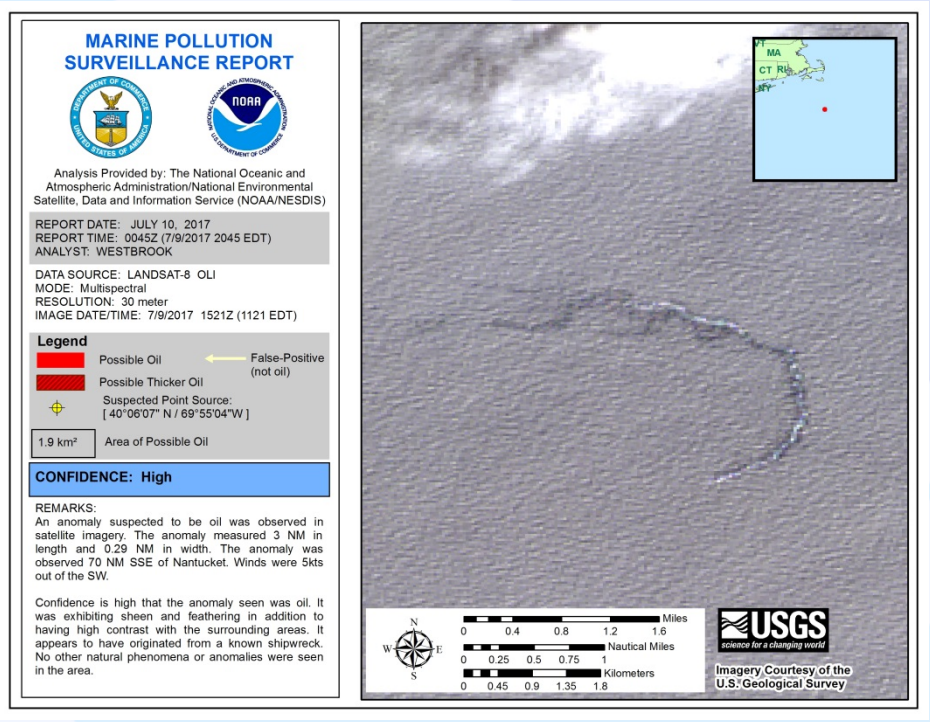




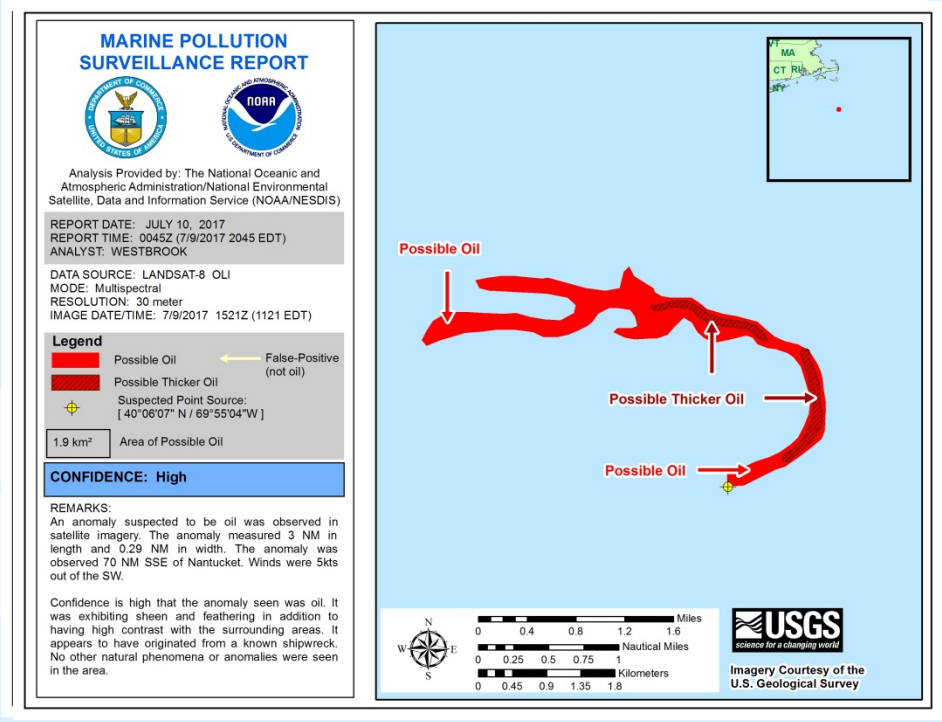




How Does This Translate Into Operations?



Prior to mid 2016, the Marine Pollution Surveillance Reports denoted only the boundary of the entire oil slick



Currently, when possible and using an optical image, the analyst will qualitatively assign areas of “relatively thick” oil based on visual inspection. We can confidently report this because we have high resolution imagery concurrent with field work validation