DEEPWATER HORIZON NATURAL RESOURCE DAMAGE ASSESSMENT
Science Highlights and Research Informing Future Responses and Assessments

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Deepwater Horizon: Setting the Scene

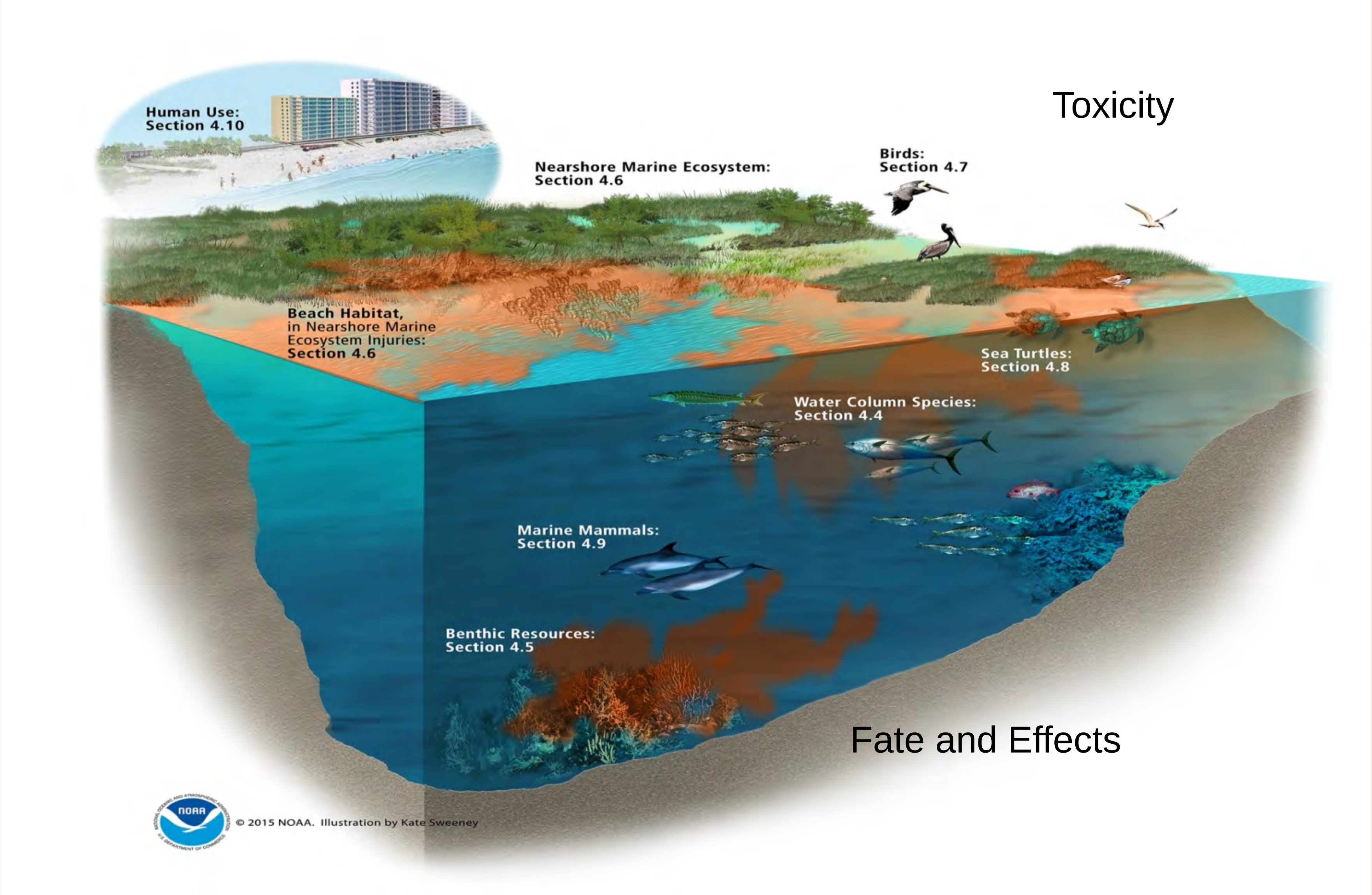
- Largest offshore oil spill in our nation's history (134 million gallons)

- More than 1,300 miles of shoreline fouled by oil,
  5 states affected

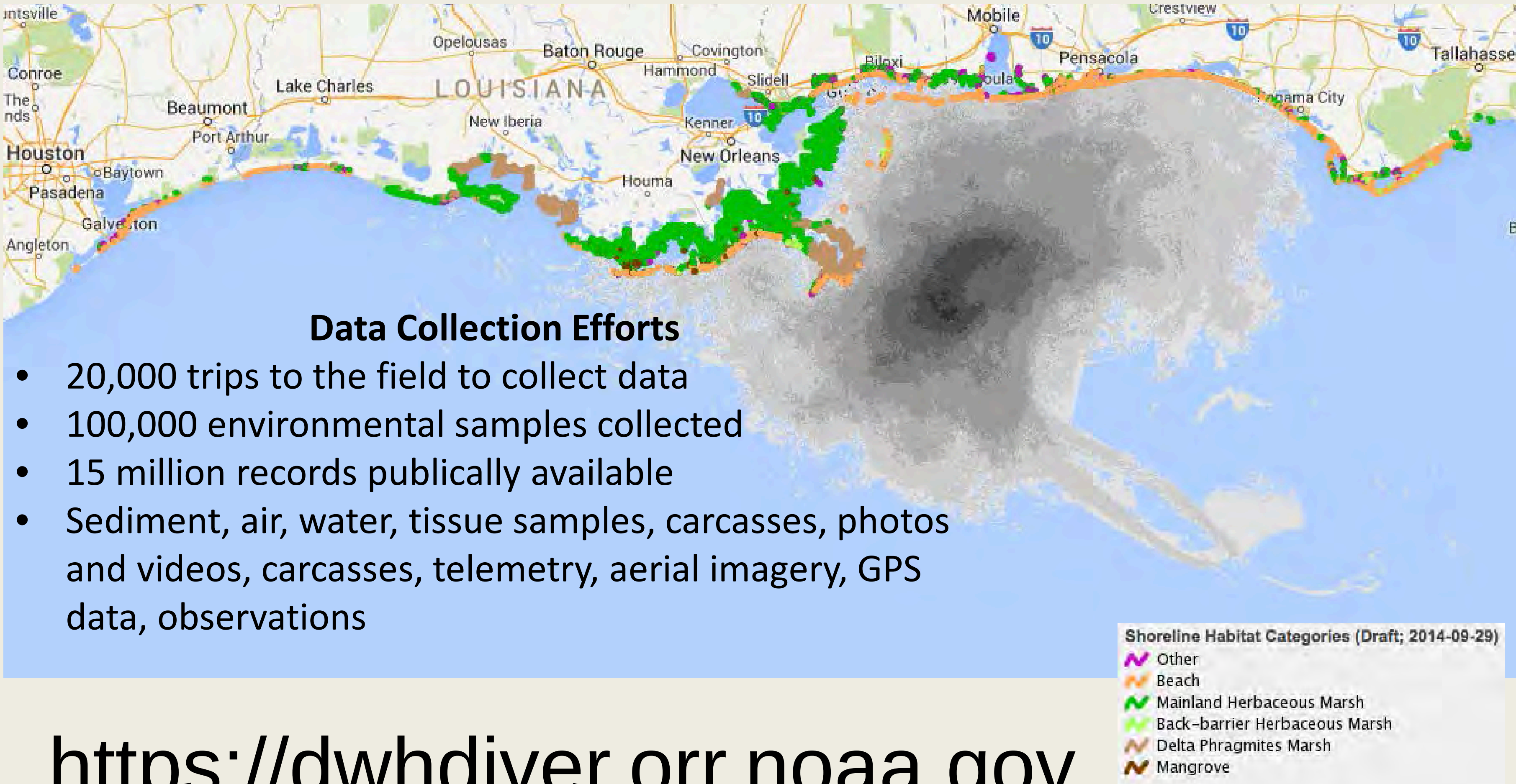
- Oil slicks were observed cumulatively across 43,300 square miles

- Largest NRDA Settlement >$8B for Natural Resource Damages

NRDA Assessment Activities



A Massive Spill, a Massive Response, a Massive NRDA

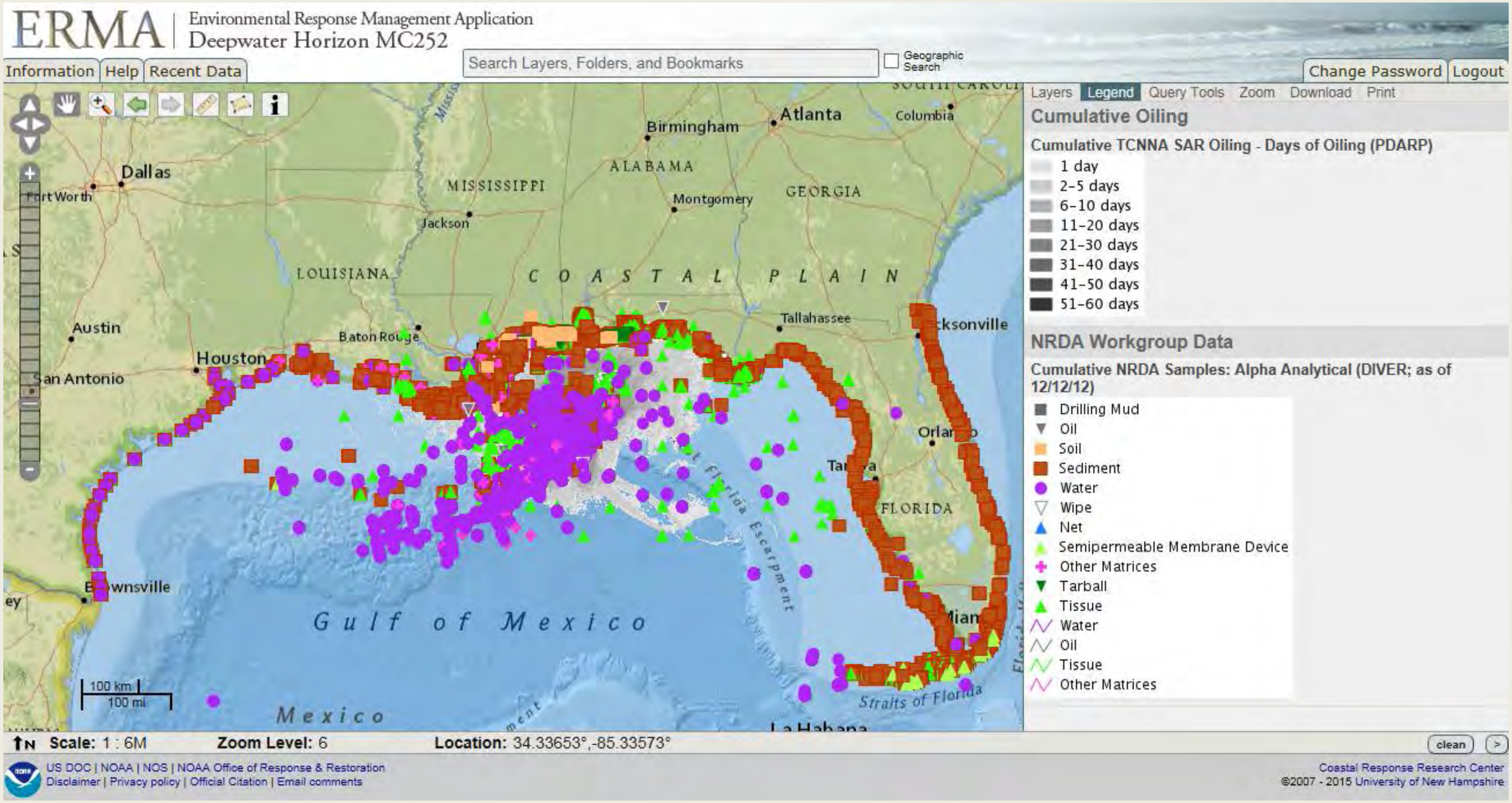


Data Collection Efforts

- 20,000 trips to the field to collect data
- 100,000 environmental samples collected
- 15 million records publically available
- Sediment, air, water, tissue samples, carcasses, photos and videos, carcasses, telemetry, aerial imagery, GPS data, observations

https://dwhdiver.orr.noaa.gov

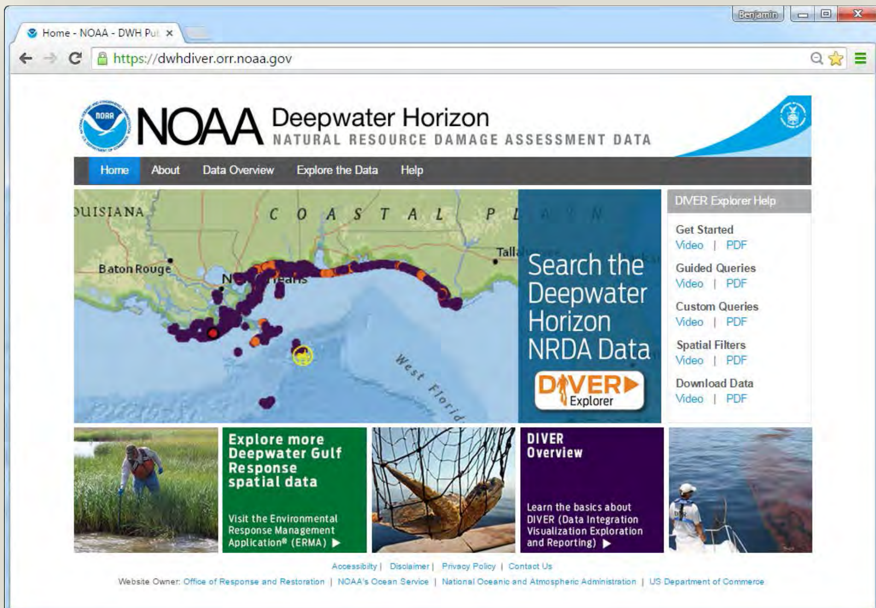
Cumulative NRDA Analytical Samples



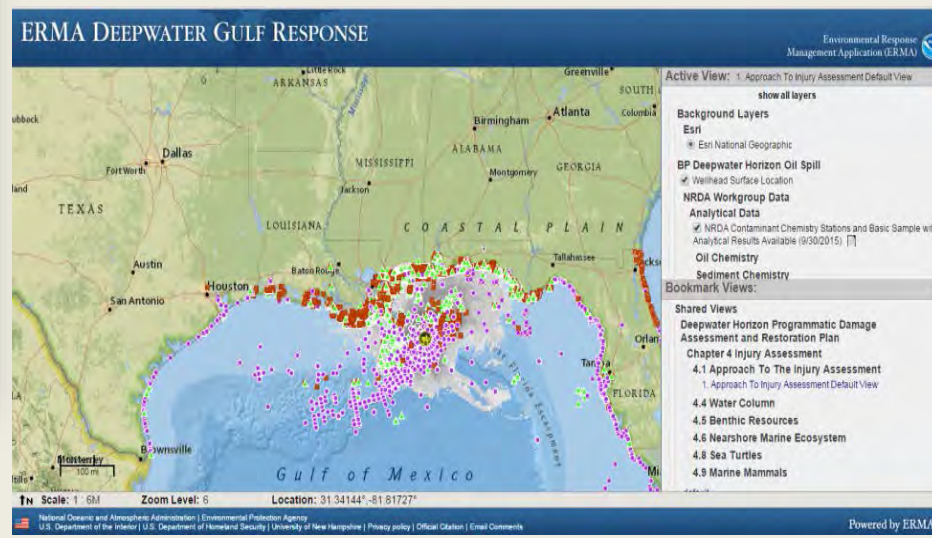
https://erma.noaa.gov/gulfofmexico/erma.html

Where Can I Find the Data?

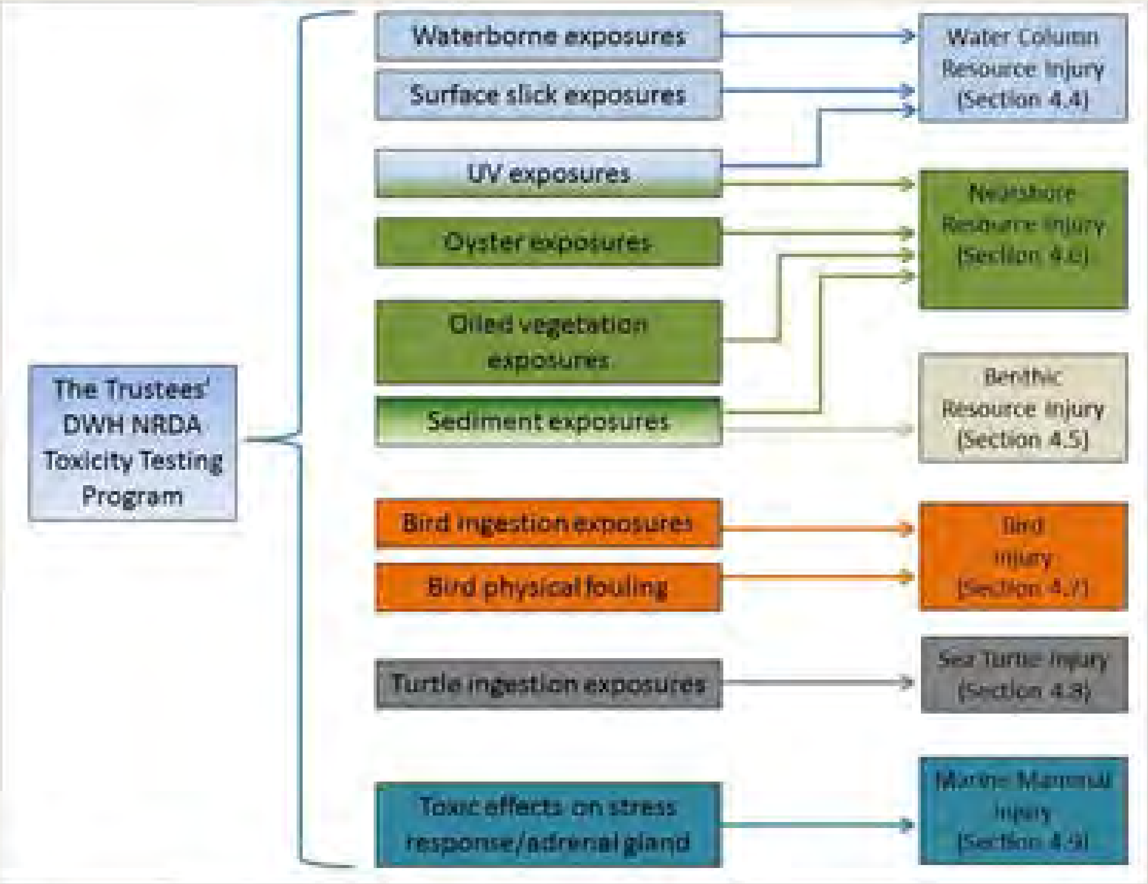
https://dwhdiver.orr.noaa.gov



http://gomex.erma.noaa.gov

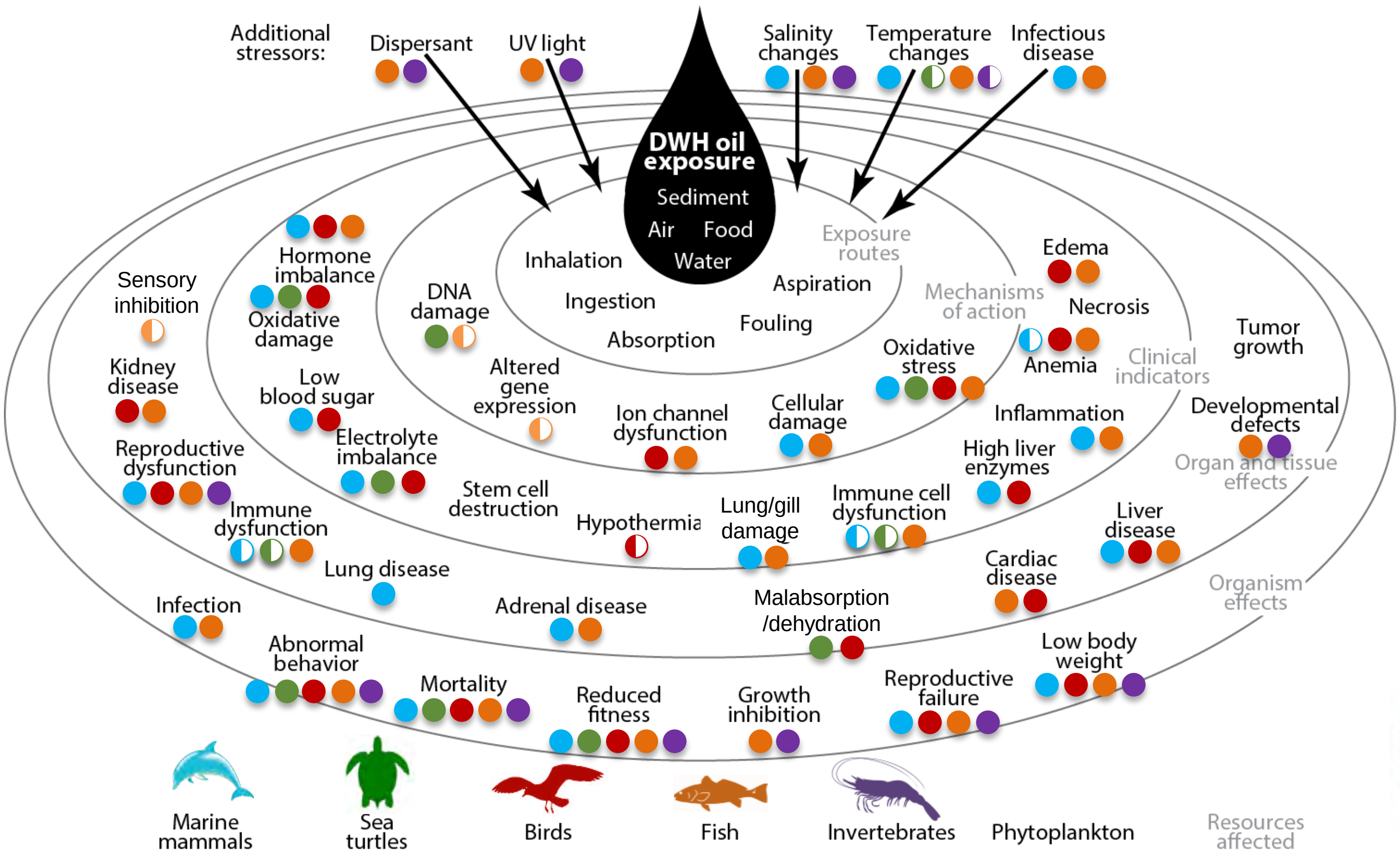


Oil Toxicity Program



Tested 40 species including fish, invertebrates, plankton, 2 freshwater turtle species, birds, and a mammal adrenal cell line study

Physiological Oil Response Constellation

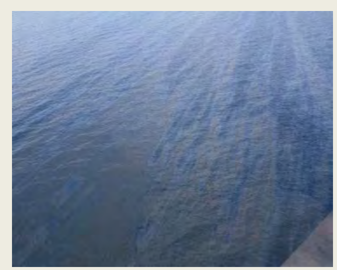


Toxicity Program: Importance of Surface Oil and Sheens with UV

- Thin sheens (1 um or less) toxic to early life stages (ELS) of fish and to invertebrates
- UV enhanced toxicity resulted in 10x to >100x increase in toxicity under ambient UV for semi-transparent inverts, and early life stage fish

Source: *Abt Associates*

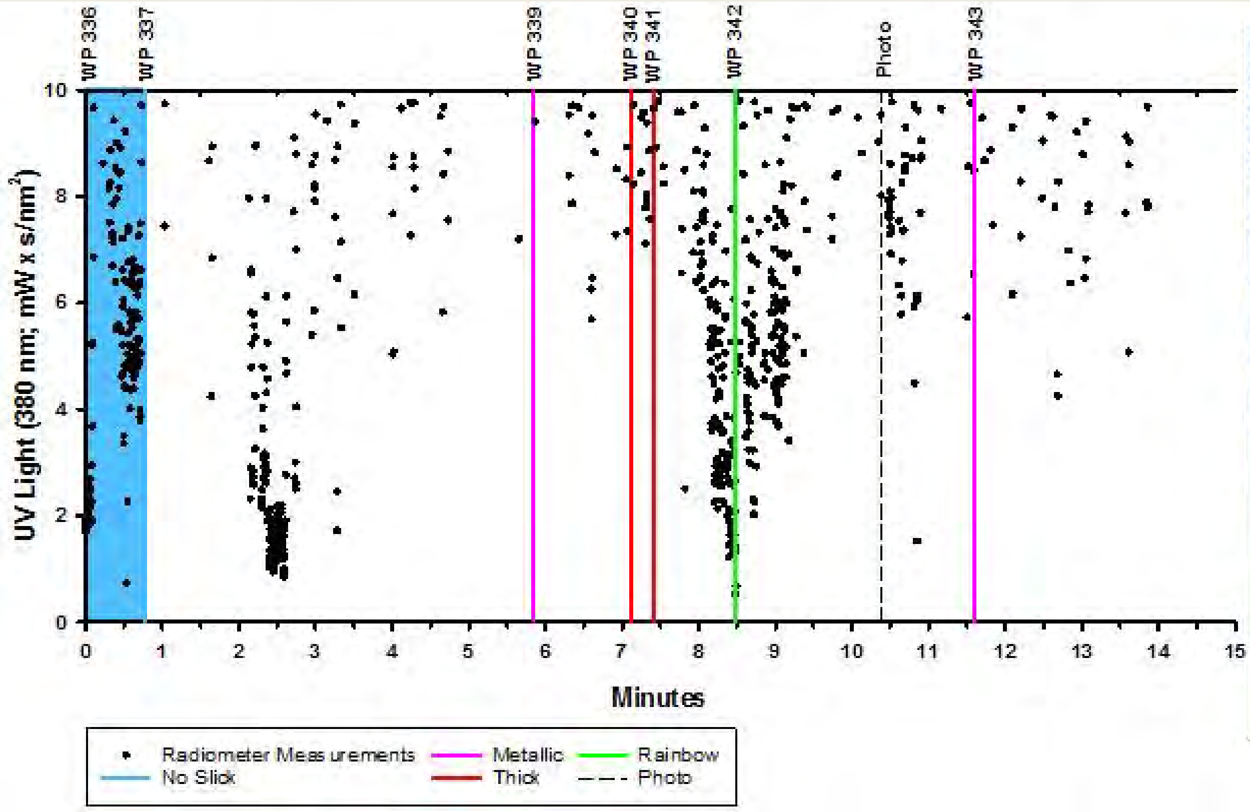
Thin oil sheen generated in a beaker using DWH oil (~ 1um thick) as used in bioassays with fish and invertebrates.



Source: *NOAA*

DWH oil sheen photographed from an airplane

UV Light Attenuation Under Floating Oil:
MC20 Site NGoM



UV light penetration to 1.3–1.5 m on April 25, 2017 beginning at 1:45 p.m. The Biospherical radiometer measured light intensity at various wavelengths, while contained in a protective housing with a UV-transparent lid.

The Role of Surface Oil Observations in Assessments

- Surface oil accumulates and persists in same areas as susceptible natural resources
- Many sensitive early life stages congregate at surface or in surface mixing layer or directly at or on surface
  - Planktonic
  - Neutrally or positively buoyant
- UV light penetrates in surface waters (15-30 m in N. Gulf of Mexico)
- Surface breathing animals (e.g., turtles and mammals and birds) inhale or aspirate oil

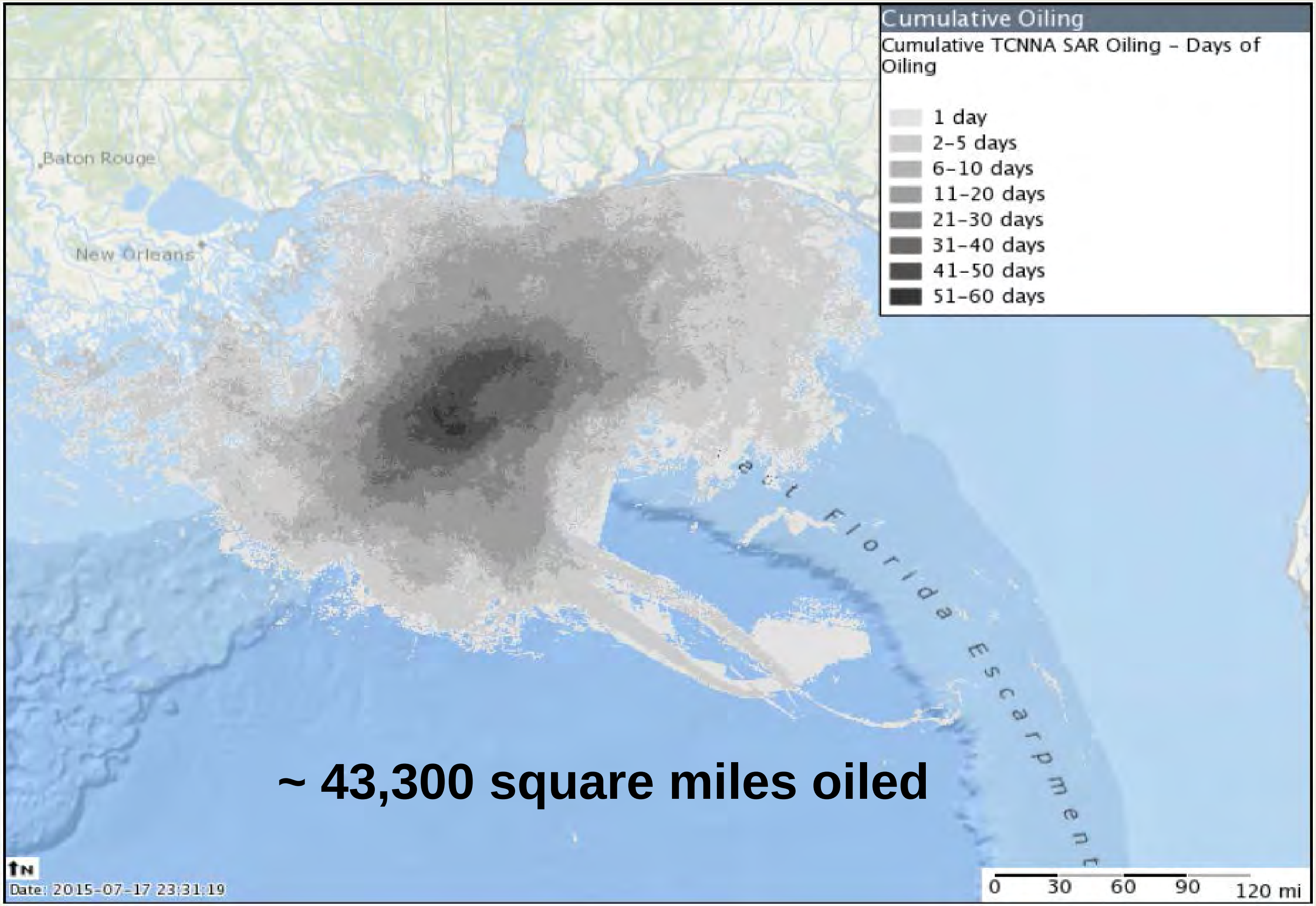
Oil on Water Assessment

- Oil on water products used for all resource category injury quantifications
- Multiple sensors evaluated and used alone or in combination
- Surface oiling "footprints" of exposure
  - Cumulative, daily, weekly, or other timeframes relevant to resources of interest
  - Percent cover of oil, or other information about surface oil 'patchiness'
  - Overlay resource distribution (e.g., turtles, mammals, birds, other, using telemetry, boats, aerial surveys etc) with surface oil
- Information about surface oiling "thickness"

DWH Remote Sensing

- 89 days of satellite SAR based oiling extents
- Over 35 days of aerial SLAR oiling extents
- 25 days of MODIS visible/thermal
- 9 days of Landsat MSS
- 1-3 days of AVIRIS hyperspectral
- Daily (x2) Ocean Imaging aerial DMSC
- 150+ daily overflights (fixed, VTOL, Blimp)
- ***And almost no coordinated ground truth…..***

Cumulative Surface Oiling Footprint (SAR)



DWH Lessons Learned Studies

Damage Assessment Remediation & Restoration Program

BSEE/NOAA Interagency Agreement Summer 2016: Detection of Oil Thickness and Emulsion Mixtures using Remote Sensing Platforms

Goal: Use Lessons Learned from the DWH NRDA applications of remote sensing

- Evaluate remote sensing platforms and sensors for the detection and characterization of surface oil and emulsions
- Coordinate simultaneous *in situ* water and oil collection and characterization for thickness and chemistry
- Validate and enhance DWH NRDA remote sensing work
- Expand the use of remote sensing to meet response and assessment objectives

DWH Lessons Learned Studies

Damage Assessment Remediation & Restoration Program

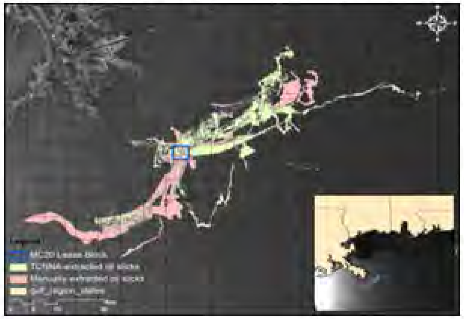
BSEE/NOAA Interagency Agreement Summer 2016: Detection of Oil Thickness and Emulsion Mixtures using Remote Sensing Platforms

Phase One

Controlled Experiment

Phase Two

Marine Validation



Phase Three

Methods and Implementation

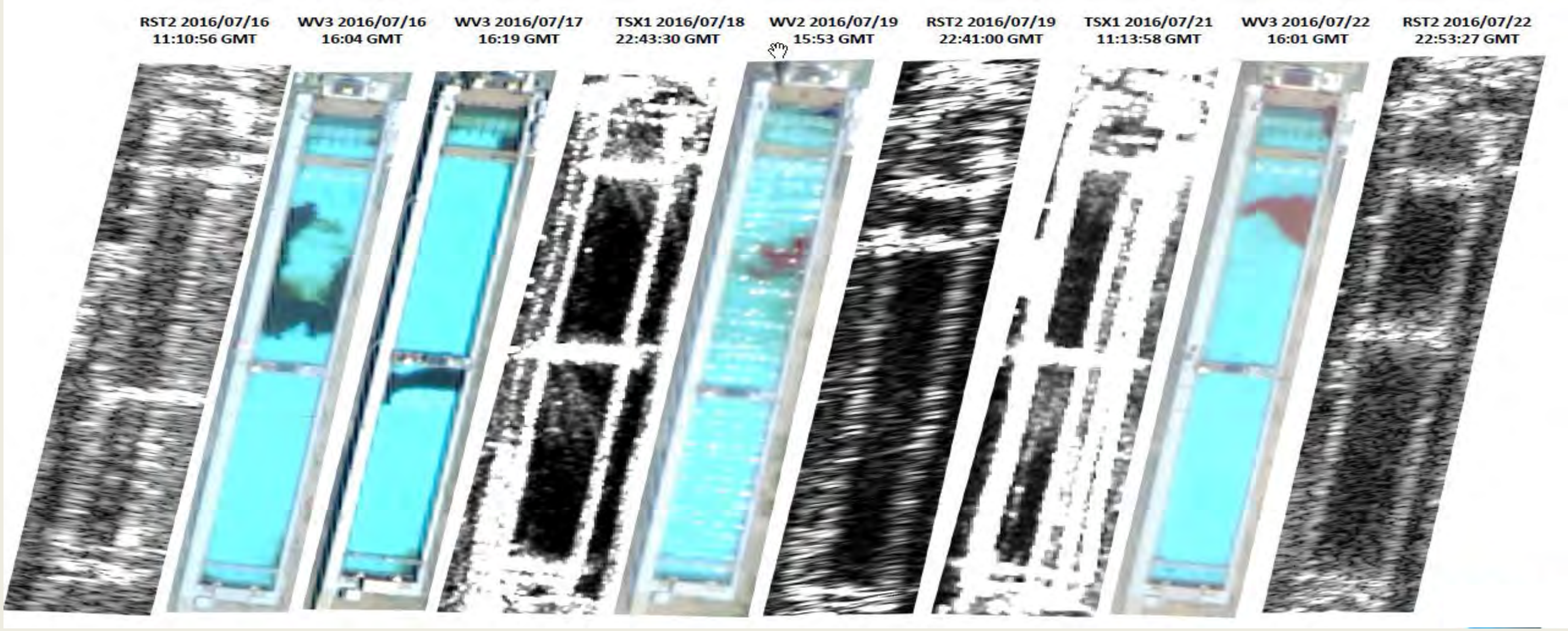
Partners: EPA, NASA, USGS, WHOI, UNT, USF, Abt Consulting, Ocean Imaging, Water Mapping, Fototerra, MDA Canada, MSRC NOAA

GOM Surface Oiling Examples

Sensor Platforms

Satellite Platforms

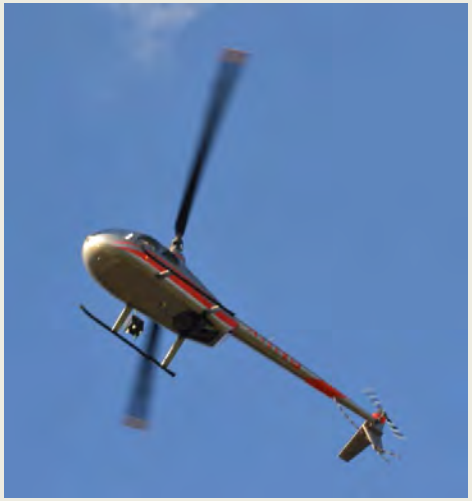
- Radarsat-2 (SAR), TerraSAR-X (SAR), Worldview 2 and Worldview 3 (Visible/NIR)
- RadarSat 2, ALOS-2, Landsat 8



Sensor Platforms

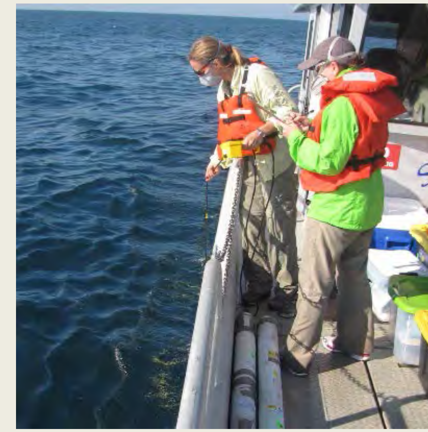
Aerial (manned/unmanned) Platforms

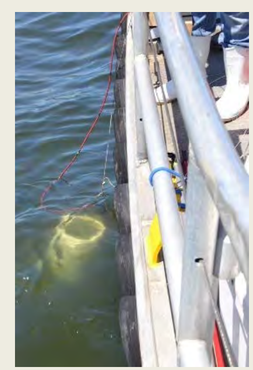
- Fixed wing: Multi-Sensor, dedicated aircraft/ MEDUSA (Fototerra)
- NASA UAV SAR
- Helicopter: UV, RGB, IR/Thermal/ TRACS (Ocean Imaging)
- UAS: RGB, Thermal/FLIR (WaterMapping)
- Spotter aircraft (On Wings of Care)

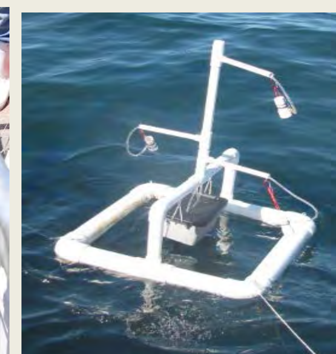


In Situ Sampling

- Oil thickness sampling
  - Sorbent Pads with PVC frame
  - Modified Dip plates
  - WaterMapping sampler: vertical tube collection
- Water Sampling
  - EPA - Real-time Fluorescence monitor (Cyclops) to target water sampling
  - Whole water sampling at multiple depths for TPAH/TPH
  - CTD profiling
  - WHOI - REMUS 100 AUV (fluorometer, CTD, optical)
- Hand held light and UV attenuation
  - Secchi disk, biospherical radiometry (UNT)
- Air Sampling (limited)
  - Helium Diffusion Sampler for VOCs
  - Polyurethane foam sorbent tubes (PUF) for PAHs
  - Hand-held UltraRAE 3000 VOC monitor



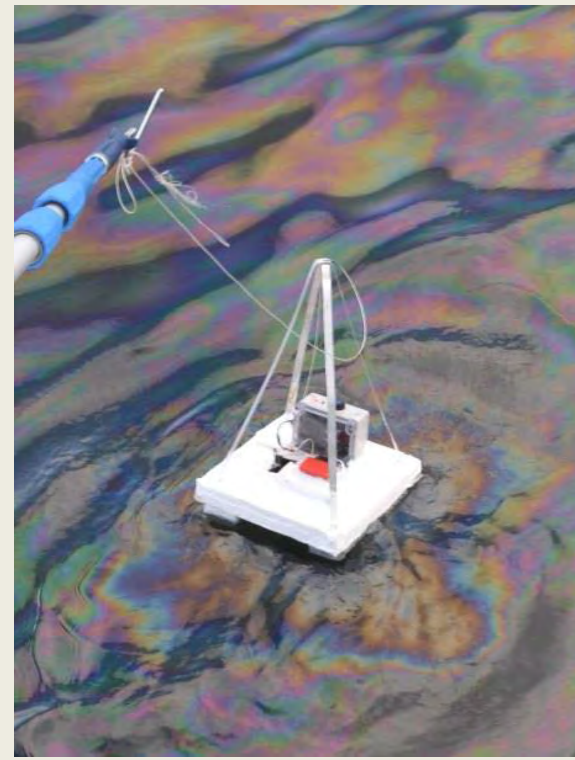




In Situ Oil Thickness Measurement Methods

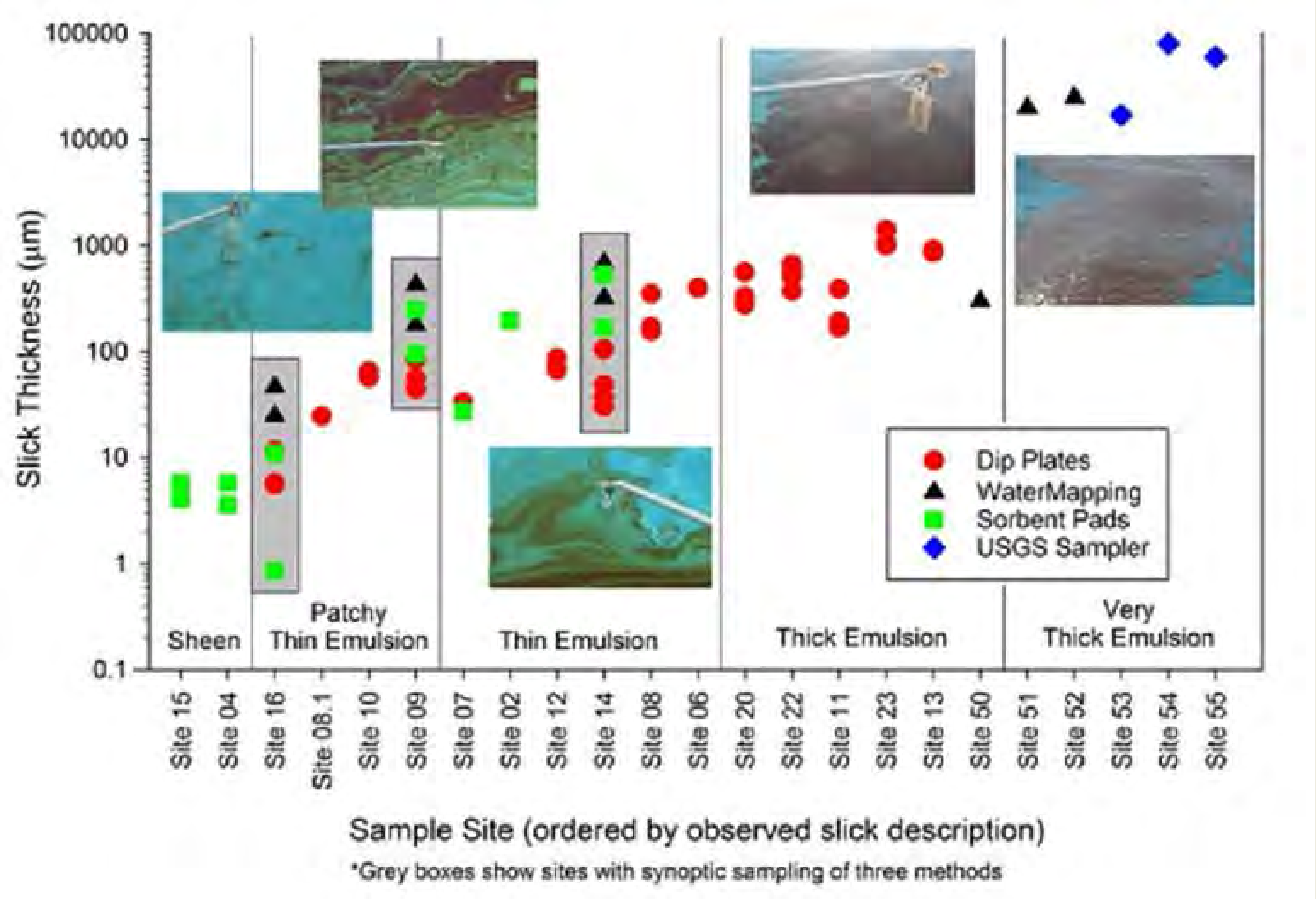
Dip Plate

Sorbent Pad

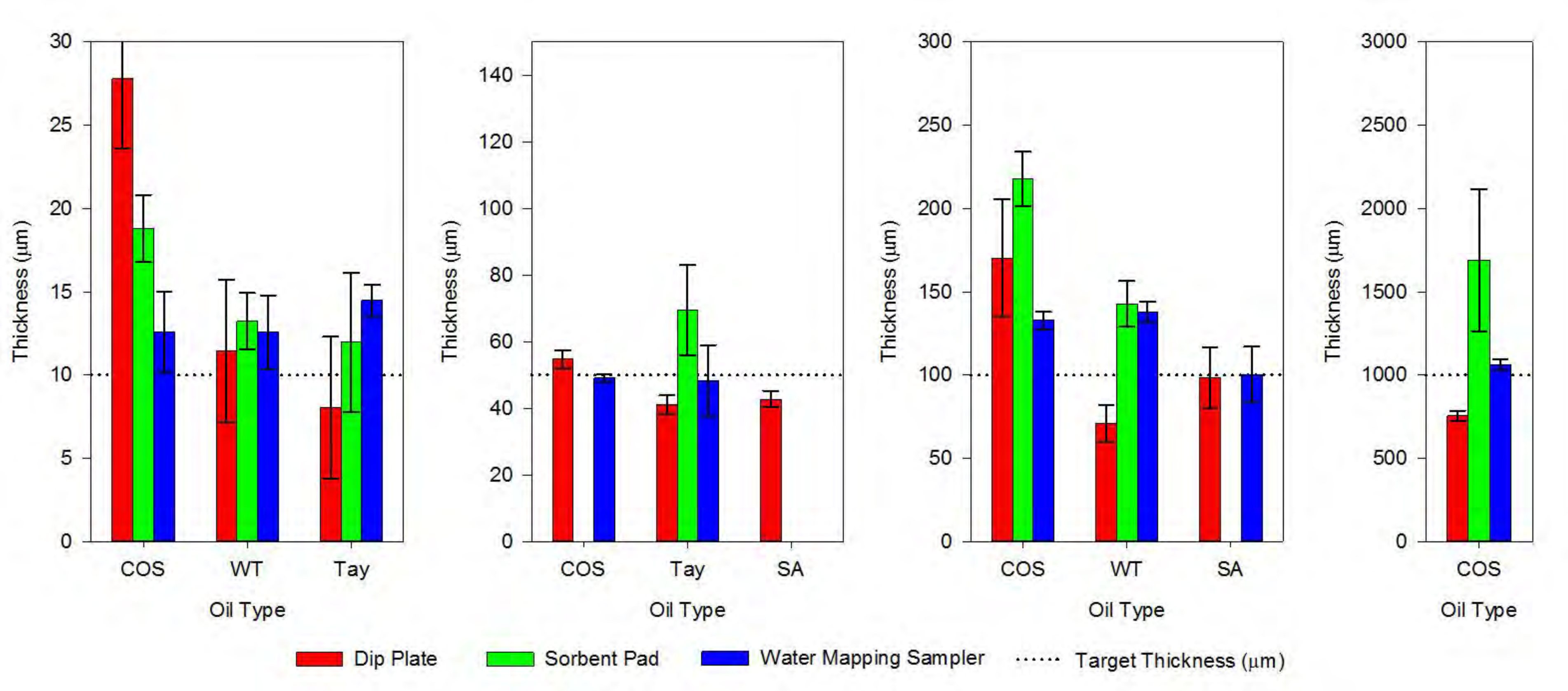


Water Mapping Sampler

Oil Thickness Measurements: Ohmsett DRAFT Results



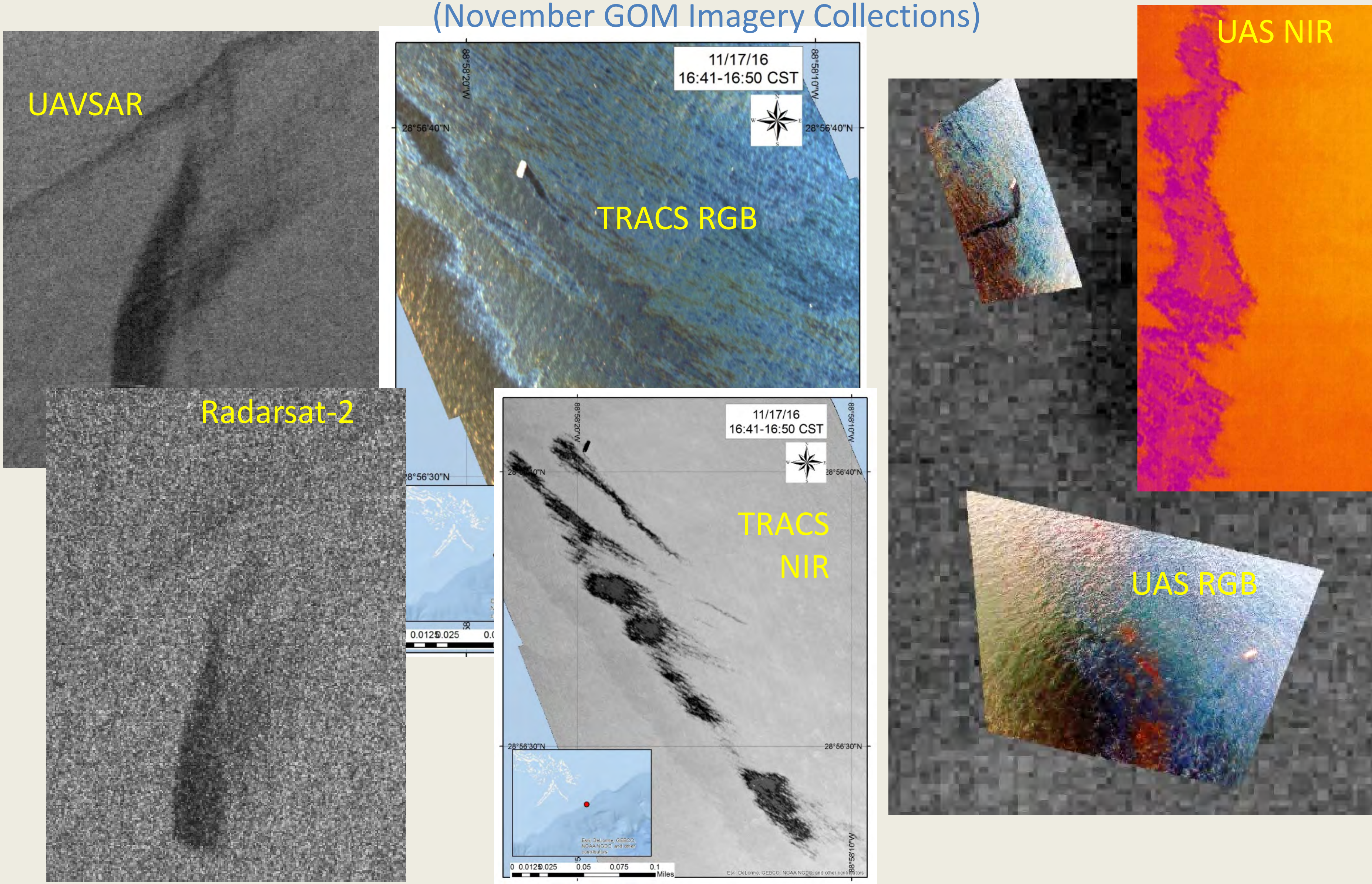
Oil Thickness Measurements: USF Lab DRAFT Results



Comparison of the three slick thickness measurement methods using different oils across a range of slick thicknesses. COS = Canadian oil sands crude, WT = West Texas intermediate crude, Tay = MC20 (Taylor Energy) oil, SA = DWH Slick A.

Comparing Remote Sensing Products

(November GOM Imagery Collections)



Refining Oil Mapping Products

NOAA
Damage Assessment Remediation
& Restoration Program

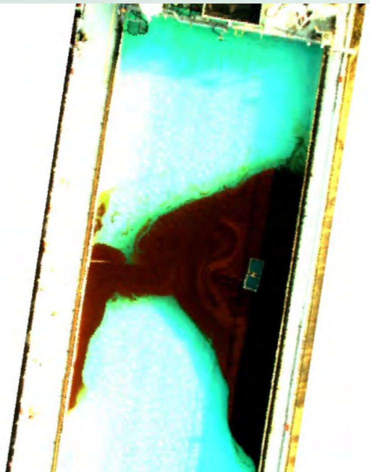
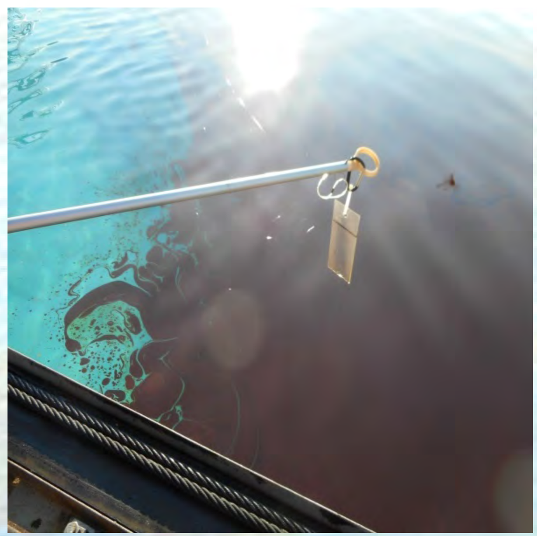
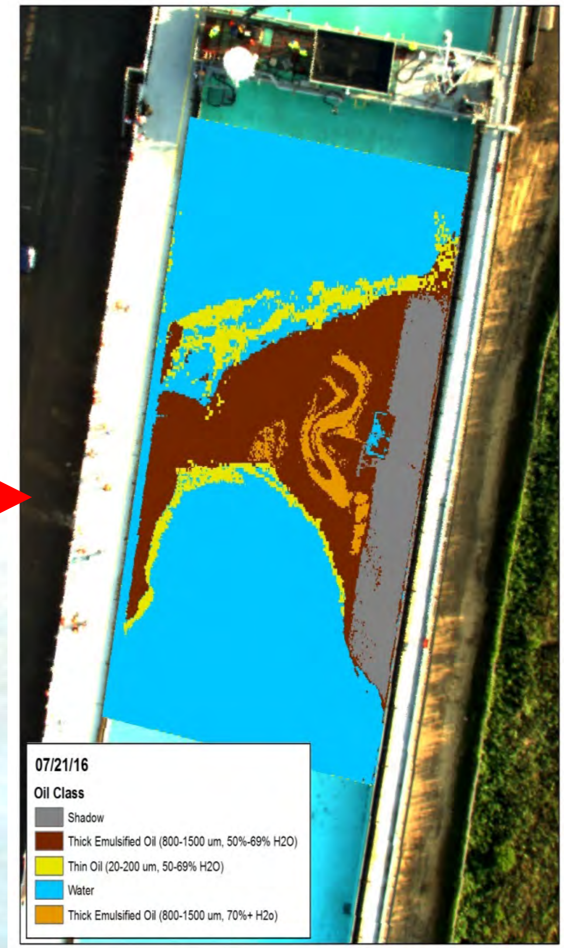
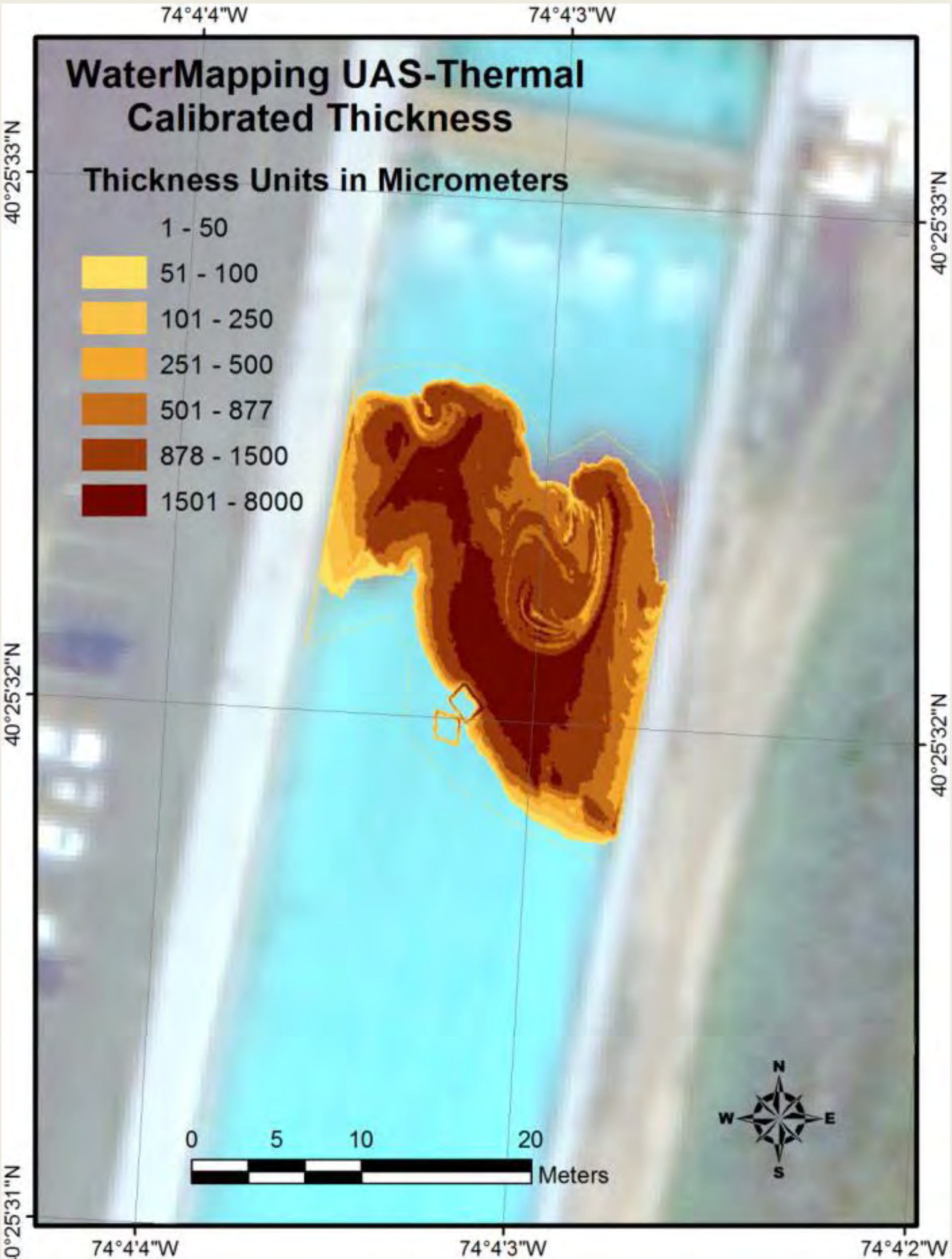


	Plate width (cm)	Plate Surface Area	Total SA (cm^2)	Thickness (cm)	Thickness (um)	Slick Description	Photo #s (Abt camera)	Notes
2	8.2	121.36	485.44	0.040	399	No description (see photos)	NA	
3	NA	#VALUE!	#VALUE!	#VALUE!	#VALUE!	No description	NA	
4	10	208	832	0.056	560	thick emulsion	NA	
5	4	83.2	332.8	0.031	311	thick emulsion	NA	
6	4.5	93.6	374.4	0.033	333	thick emulsion	NA	
7	3.1	64.48	257.92	0.028	278	thick emulsion	NA	
8	8.2	90.2	360.8	0.057	575	thick emulsion	191-194	
9	8.2	90.2	360.8	0.067	665	thick emulsion	NA	
10	8.2	203.36	813.44	0.037	375	thick emulsion	NA	
11	8.2	203.36	813.44	0.051	508	thick emulsion	NA	
12	8.2	203.36	813.44	0.003	33	light emulsion	228	
13	8.2	203.36	813.44	#VALUE!	#VALUE!	very light emulsion	229-230	
14	8.2	121.36	485.44	0.019	192	thick emulsion	NA	
15	8.2	121.36	485.44	0.017	168	thick emulsion	249	
16	8.2	121.36	485.44	0.039	389	thick emulsion	NA	
17	8.2	121.36	485.44	0.006	57	spotty thin emulsion	240-241	
18	8.2	121.36	485.44	0.007	66	spotty thin emulsion	242	
19	8.2	121.36	485.44	0.004	44	spotty thin emulsion	243-244	
20	8.2	121.36	485.44	0.006	56	spotty thin emulsion	245-247	
21	8.2	121.36	485.44	0.008	84	spotty thin emulsion	248	
22	8.2	121.36	485.44	0.002	25	thicker than thin sheen	235-236	
23	8.2	121.36	485.44	0.017	171	thin emulsion	NA	
24	8.2	121.36	485.44	0.016	155	thin emulsion	237-238	
25	8.2	121.36	485.44	0.035	350	thin emulsion (Thicker edge of emulsion due to sprayers)	239	
26	8.2	121.36	485.44	0.007	67	thin emulsion	252	
27	8.2	121.36	485.44	0.007	71	thin emulsion	253	
28	8.2	121.36	485.44	0.009	87	thin emulsion	254	
29	8.2	121.36	485.44	0.106	1055	thick emulsion	255-256	
30	8.2	121.36	485.44	0.141	1408	thick emulsion	257	
31	8.2	121.36	485.44	0.100	1004	thick emulsion	258	

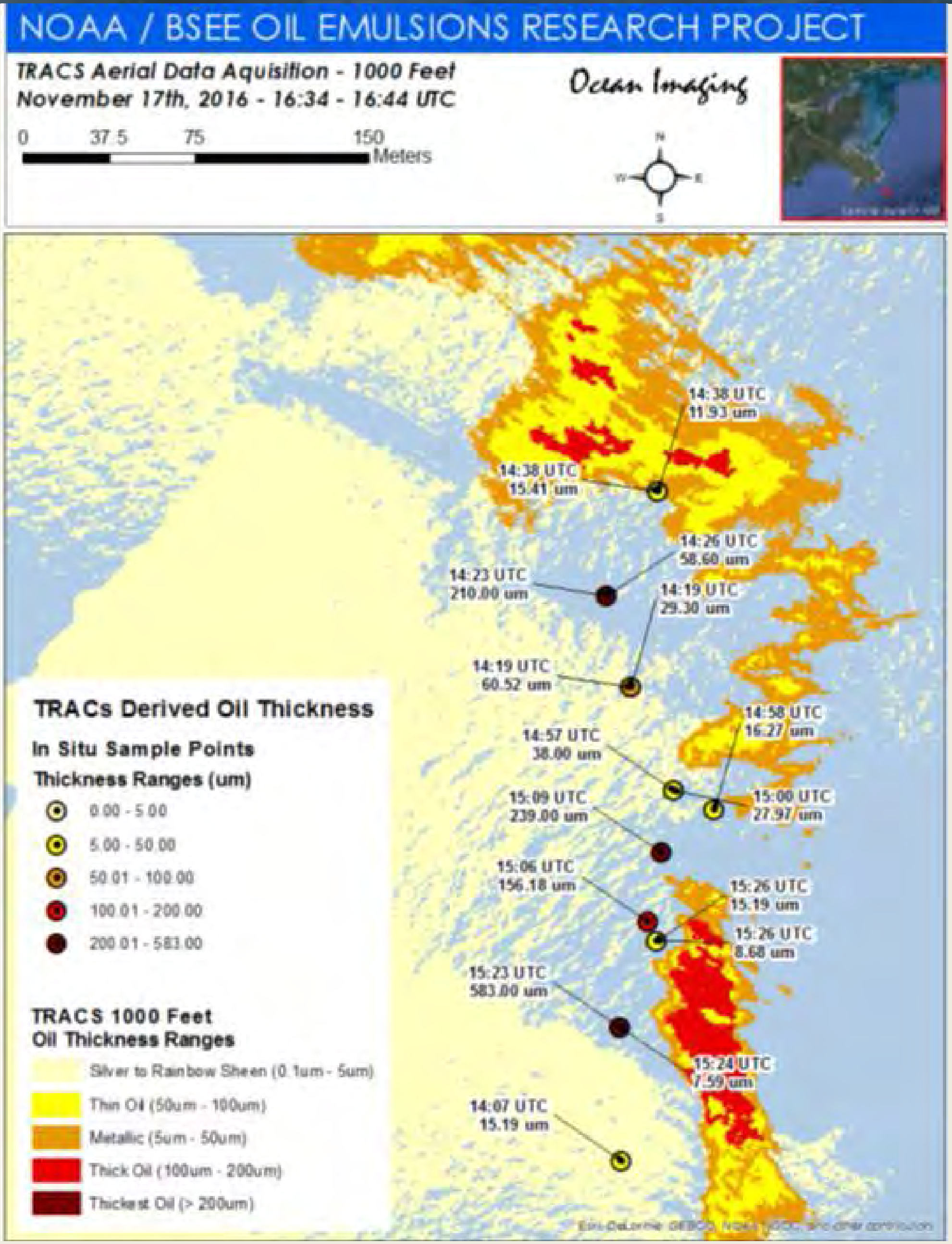




- High confidence, classified TRACS classification of emulsified oil (right) derived from analysis of TRACS imagery, in situ oil thickness measurements, water content, and available photographs (Ohmsett)

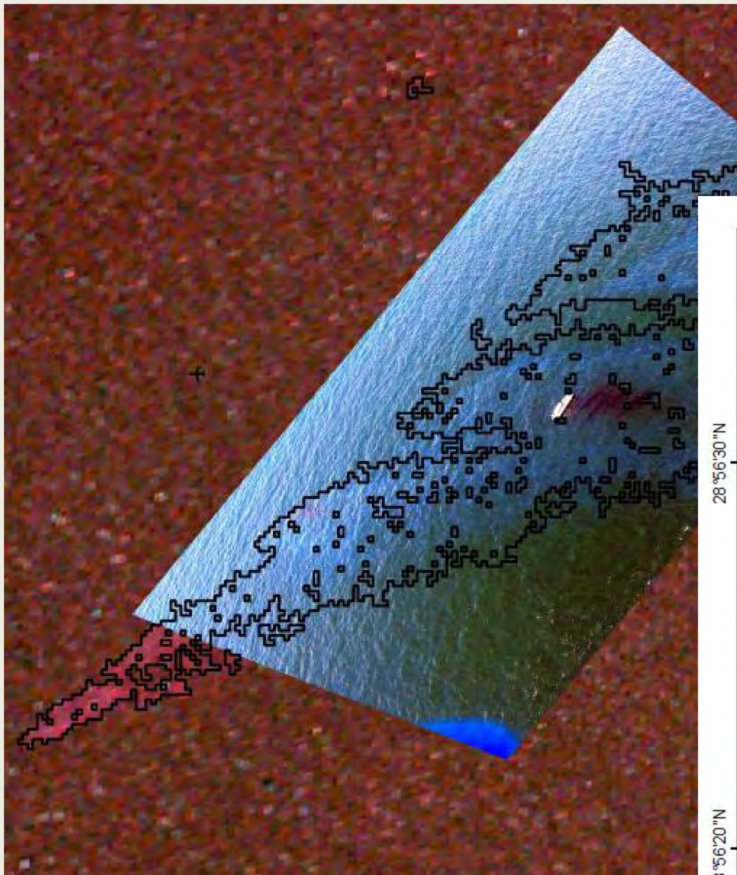


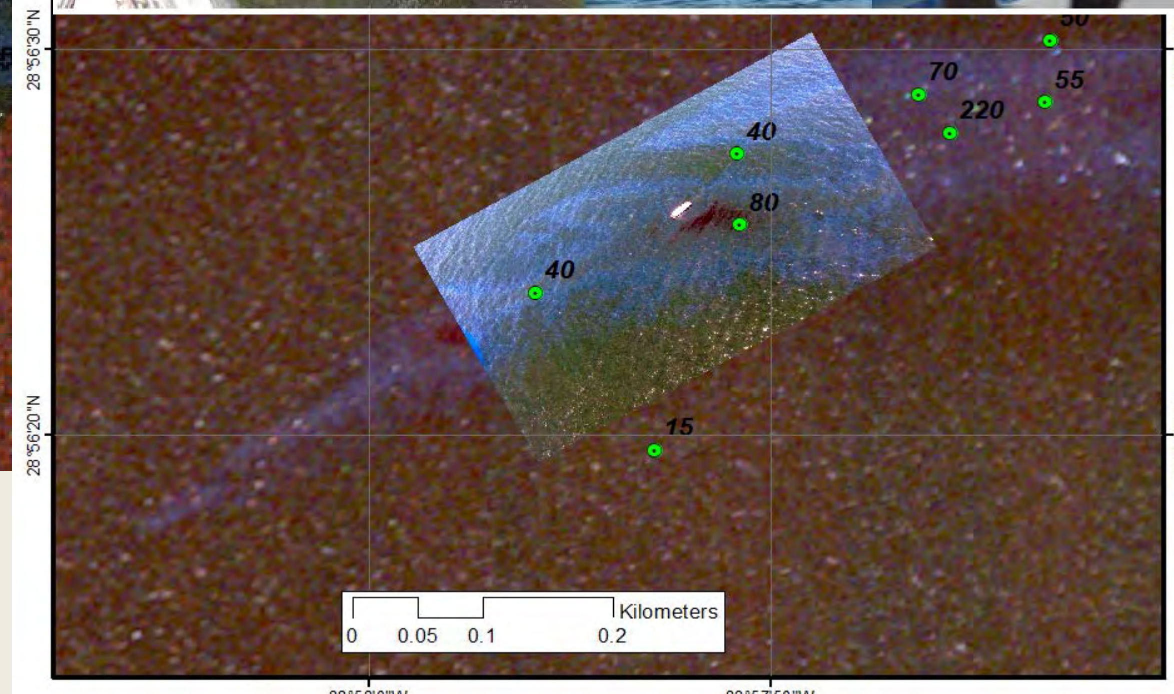
DRAFT Ohmsett oil slick classified into thickness categories based on HD and FLIR thermal IR imagery collected from UAS platform and incorporating thickness data collected from the Ohmsett tank.



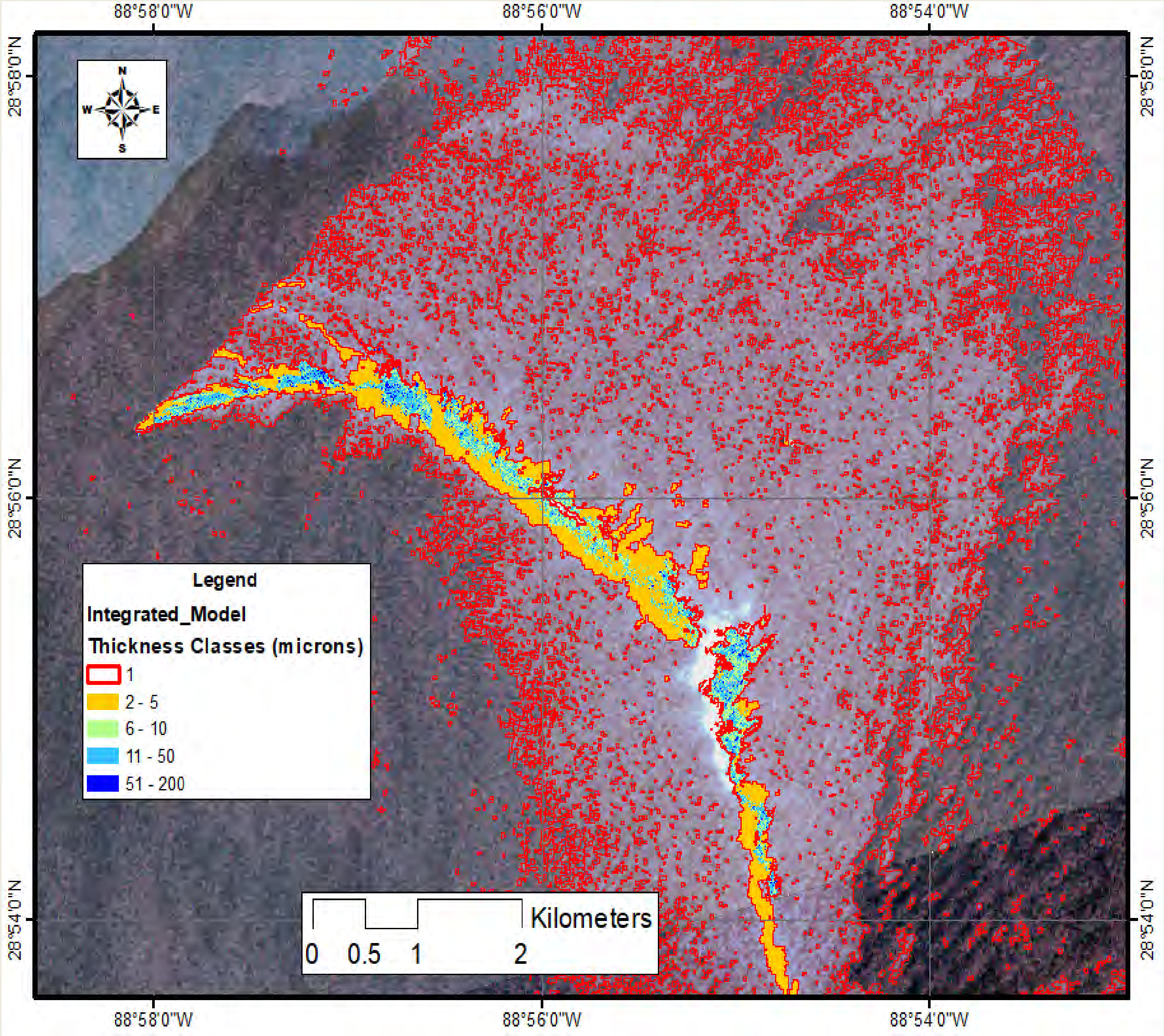
Ocean Imaging's DRAFT classification of oil thickness ranges at MC20 on November 17, 2016, integrating boat-collected data with TRACS remote sensing signatures (MC20)

Projection of UAS and *in-situ* Measurements on Satellite Imagery



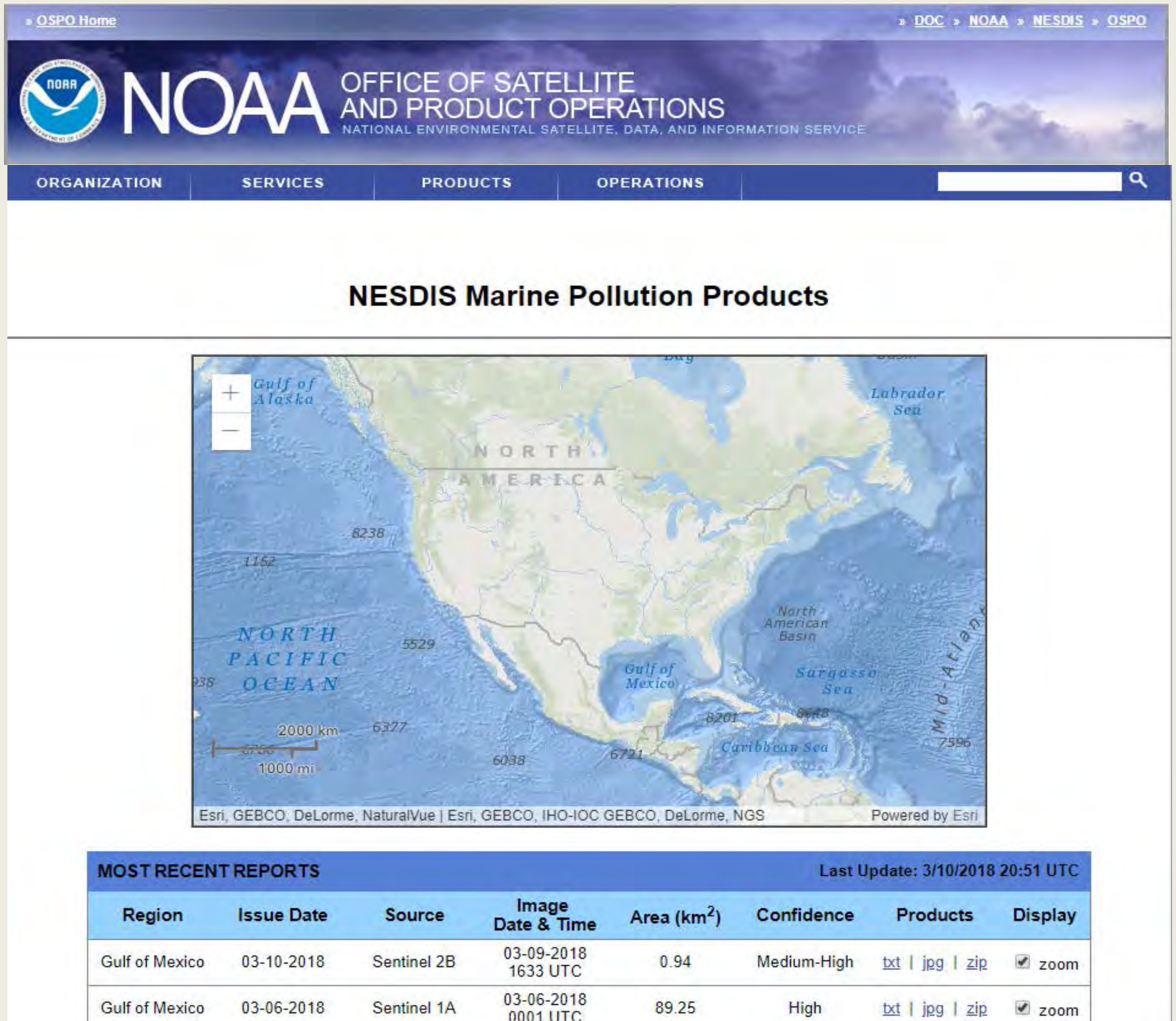


Satellite-UAS-*in-situ* Integrated Model



Now Public: NOAA/NESDIS Marine Pollution Surveillance Reports

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



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NESDIS Marine Pollution Products

MOST RECENT REPORTS — Last Update: 3/10/2018 20:51 UTC

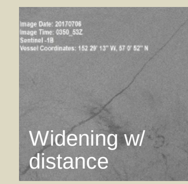
Region	Issue Date	Source	Image Date & Time	Area (km^2)	Confidence	Products	Display
Gulf of Mexico	03-10-2018	Sentinel 2B	03-09-2018 1633 UTC	0.94	Medium-High	txt | jpg | zip	zoom
Gulf of Mexico	03-06-2018	Sentinel 1A	03-06-2018 0001 UTC	89.25	High	txt | jpg | zip	zoom

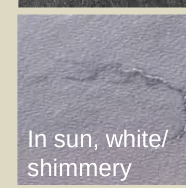
Sensors Employed	Oil Anomaly Signatures

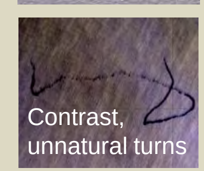
Synthetic Aperture Radar
Radarsat-2
Sentinel-1A
Sentinel-1B

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

Other NESDIS Analysis Reports:
Tropical cyclones, volcanic ash, heavy precipitation, wildfires



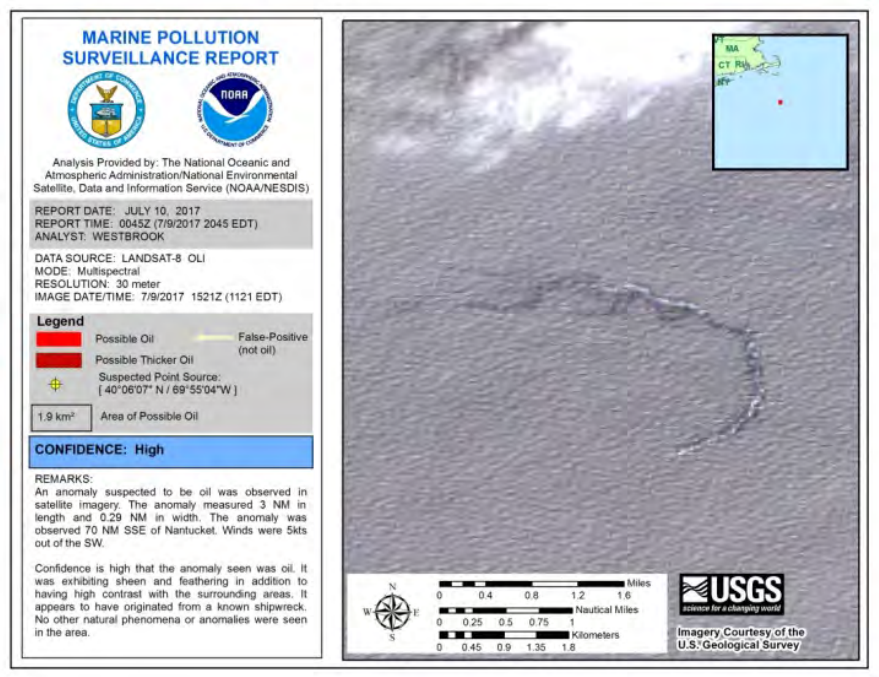


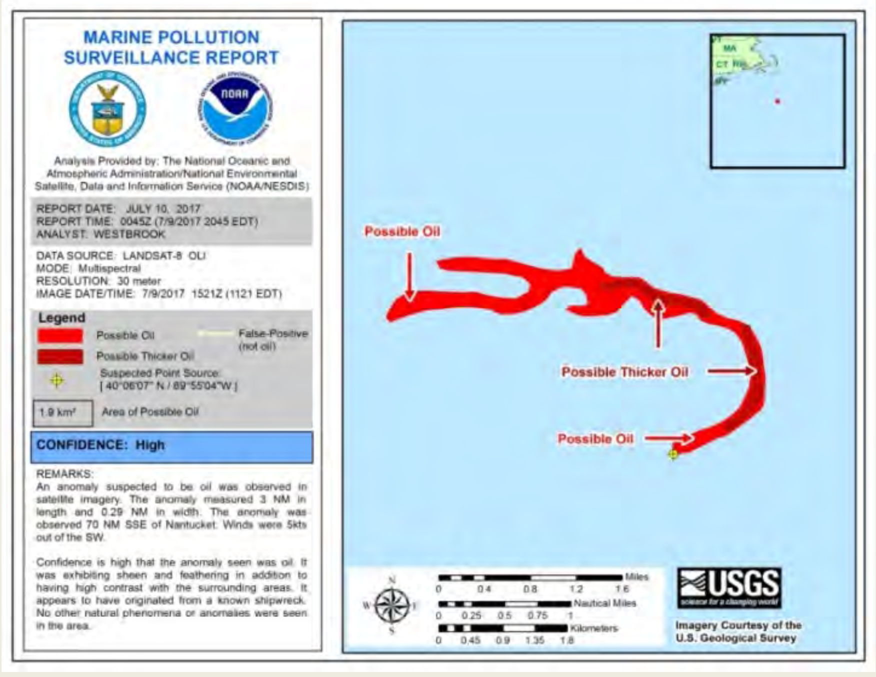


Now Public: NOAA/NESDIS Marine Pollution Surveillance Reports

Enhancements to MPSRs continue

- Relative thickness is reported when discernable from imagery based on visual inspection
- Operational Neural Network algorithm (TCNNA) for more consistent analysis





GoMOSES Workshop

"Recent Advances in Estimating and Measuring Oil Slick Thickness"

Goals:

- Provide forum for discussion of recent and ongoing oil thickness research collective advances.
- Identify achievements and limitations, and application of new tools and methods to future incidents.
- Discuss ways to leverage limited resources and opportunities for conducting research and developing tools and methods.
- Identify priorities and next steps in advancing our ability to characterize floating oil thickness.

GoMOSES Workshop (continued)

"Recent Advances in Estimating and Measuring Oil Slick Thickness"

Format:

- Panelists representing various sectors highlight needs (n=6)
  - Help guiding response efforts by directing limited assets to priority cleanup areas (actionable oil)
  - Aid in the assessment of 'volume released' estimates
  - Support modeling platforms for predicting transport and fate of oil
  - Support natural resource injury determinations
  - Need for 'relative' versus 'quantitative'
- Brief research presentations of study methods, findings, and limitations (n=12 methods presented)
- Moderated discussion including audience
  - Key findings and how they relate to various sector needs
  - Research needs
  - Funding opportunity
  - Opportunities for collaboration

GoMOSES Workshop

“Recent Advances in Estimating and Measuring Oil Slick Thickness”

Next Steps:

- Finalize sensor specifications table
  - Sensor Name, Sensor Type, Platform, GSD* (e.g., 10m/pixel), Scene Footprint Size/Swath Width, Thickness Detection Limits, Accuracy and Precision, Where Tested?, Sea State, Strengths, Weaknesses, TRL, Other Noteworthy Items
- Identify key desirable attributes of sensor packages for dissemination to research community
- Collaboration underway with specific projects, proposals, paper reviews
- Plans for continued discussions and meeting (Clean Gulf? GoMOSES?, IOSC?)

Bottlenose Dolphin Droplet Inhalation and Aspiration: Phase 1

- DWH dolphin health assessments demonstrated significant pulmonary disease, decreased reproductive rates, adrenal impairment and potential cardiac effects

- Unique anatomy and physiology of dolphin's respiratory system and close proximity to oil/water/air interface results in direct inhalation/aspiration of oil and dispersants
  - Vapors, VOCs, liquid oil, aerosols, droplets

- Direct inhalation of water particles (or oil) has never been documented

Bottlenose Dolphin Droplet Inhalation and Aspiration: Phase 1

Research Partners (primaries):

- NOAA, Johns Hopkins (Joe Katz Lab), Baltimore National Aquarium, National Marine Mammal Foundation

Phase 1 Goal:

- Capture dolphin inhalation/aspiration of water particles using advanced laser imaging with high resolution videography
- Accomplished by documenting water droplet and aerosolized particle production and inhalation during an 'on command' surface breathing event pen-side at aquarium

Status:

- Preliminary feasibility assessment complete
- Prototype equipment built and dolphin training underway

Next Steps:

- Lab studies on droplet distribution with oil and dispersants
- Aquarium studies with modified droplet inhalation

BSEE-NOAA FY18 Project Plan

“Three-dimensional mapping of dissolved hydrocarbons and oil droplets using a REMUS AUV”

- Develop a REMUS-600 customized with a suite of oil sensing tools (fluorescence, back scatter, holographic imaging, camera and water sampler) for comprehensive 3-d hydrocarbon mapping.
- Refine data outputs and delivery from the sensors to be compatible with the existing data management and visualization tools used in operations (DIVER, ERMA)).
- Demonstrate the operations readiness of the REMUS via field deployment to quantify and characterize spilled oil (slick and suspended).

DWH NRDA Publications

- >150 peer reviewed publications and counting……
  - Deepsea corals and benthos
  - Marine Mammals
  - Fish Toxicity
  - Sea Turtles
  - Oil in the environment
- Publications available to public: http://response.restoration.noaa.gov/deepwater-horizon-oil-spill/noaa-studies-documenting-impacts-deepwater-horizon-oil-spill.html
- Other resources:
  - http://www.gulfspillrestoration.noaa.gov
  - https://dwhdiver.orr.noaa.gov
  - https://erma.noaa.gov/gulfofmexico/erma.html
  - http://response.restoration.noaa.gov/about/media/where-find-noaa-information-deepwater-horizon-oil-spill.html

Questions?

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https://response.restoration.noaa.gov