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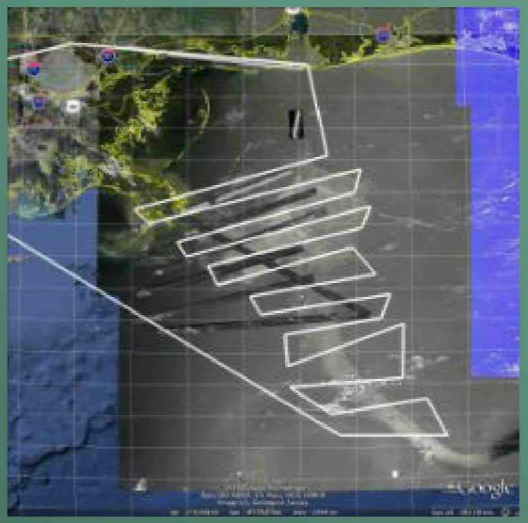
MASS BALANCE 101

Victor F. Labson, Ph.D.
Director - Crustal Geophysics and Geochemistry Science Center
US Geological Survey
Denver, Colorado
Phone 1(303)236-1312, fax 1(303)236-1229
e-mail vlabson@usgs.gov



U.S. Department of the Interior
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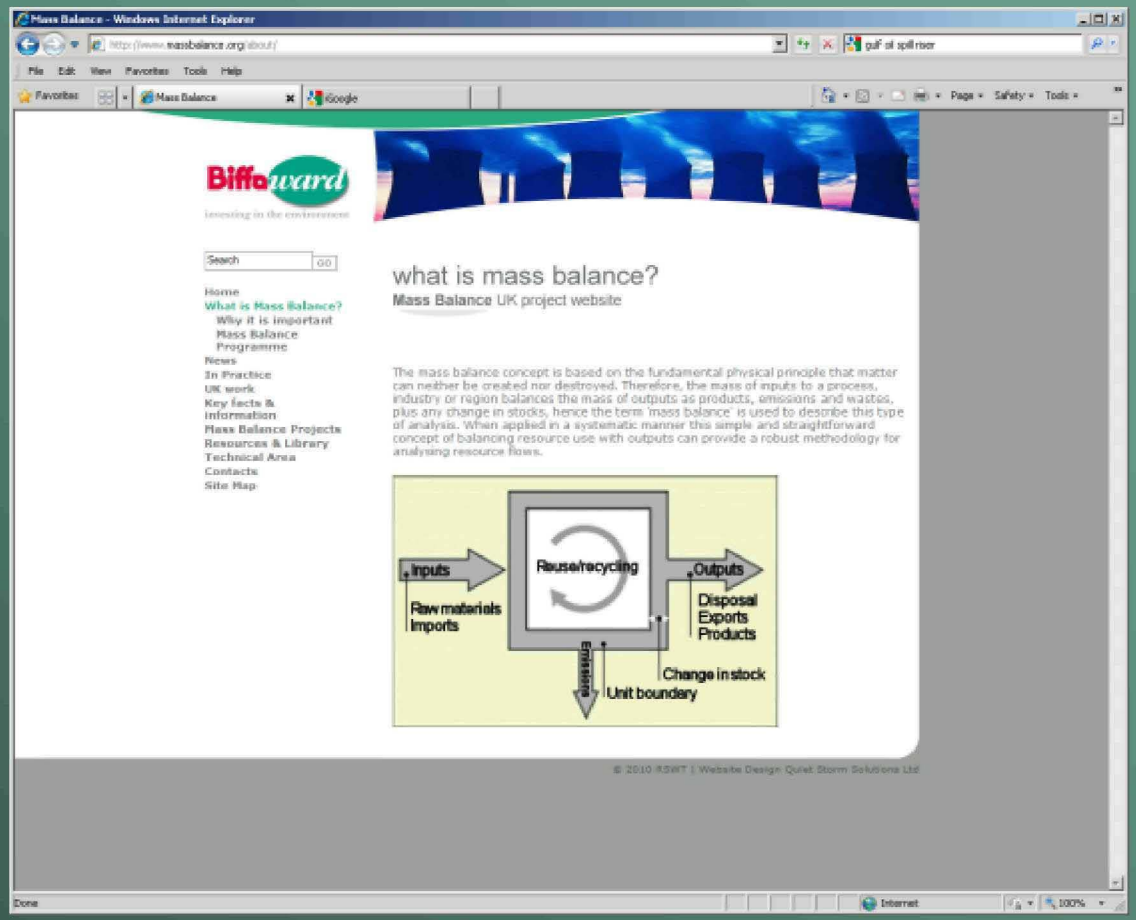
What is Mass Balance?

The mass balance concept is based on the fundamental physical principle that matter can neither be created nor destroyed.

www.massbalance.org



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Mass Balance – Forward and Inverse

- Mass Balance run in a forward direction starting from a discharge rate can be used to compute a daily and cumulative **Oil Budget**
- Run in reverse Mass Balance starts with an oil budget and computes a **Discharge Rate**
- The two are the same if all sources of available oil are accounted for and all losses are quantified.

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Mass Balance – Accounting

- In an industrial process where all inputs, outputs, and losses are known, Mass Balance is simple accounting
- In a deep water oil spill, inputs, outputs, and losses are not all known and may need to be assumed
- The same assumptions need to be used in both the forward and inverse oil spill mass balance for the results to be comparable.

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Mass Balance – Measured and Computed

- **Oil Budget** uses a measured discharge rate and computes available oil at the sea-surface

- **Mass Balance** uses measured available oil at the sea-surface and computes a discharge rate

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Mass Balance – Assumptions

- Losses due to:
  - Natural dispersion
  - Oil/water ratio in skimmed oil
  - Beached oil
  - Chemical dispersion - sea-bottom and sea-surface
  - Biodegradation
  - Evaporation and dissolution

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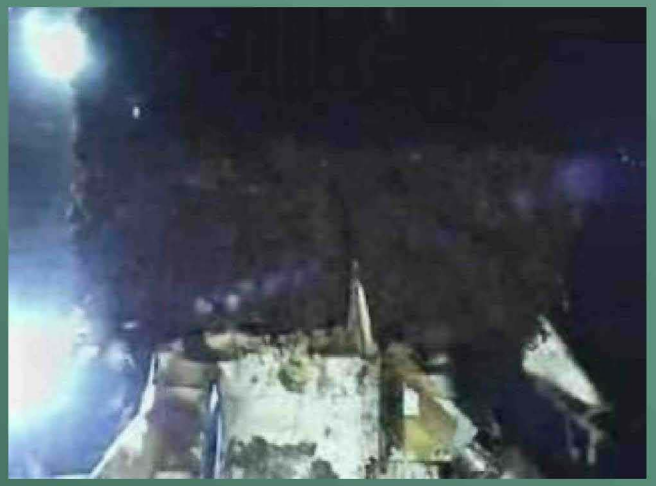
Mass Balance – Oil Budget Calculation

- Start with a measured discharge rate
- Subtract contained oil
- Subtract naturally and chemically dispersed oil
- Subtract evaporated oil
- Subtract skimmed oil
- Subtract burned oil
- Subtract beach collection



- **RESULT = Available oil**

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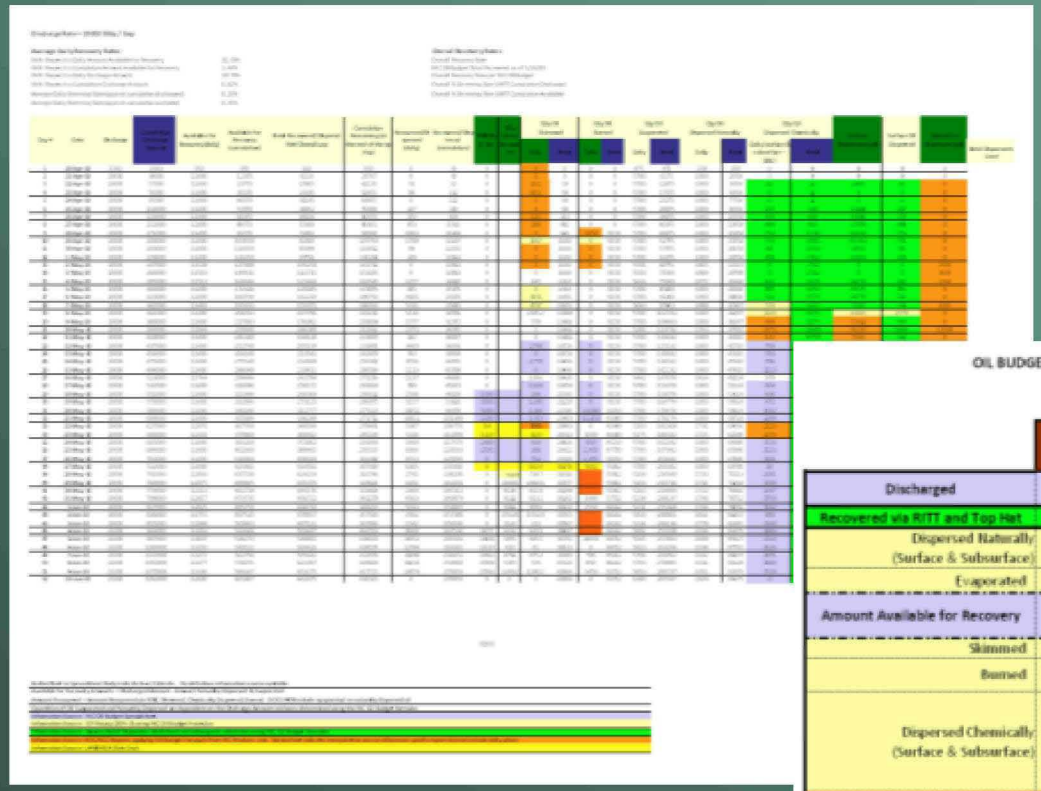
Mass Balance – Oil Budget Calculation



OIL BUDGET (Best Estimate) EXECUTIVE SUMMARY

Last Update: 6/18/2010

	Cumulative Total	Current Assumptions
Discharged	1,071,000	19K bbls/day discharged until 6/4/10 - 21K bbls/day after that
Recovered via RITT and Top Hat	91,835	Based on actual oil amount recovered
Dispersed Naturally (Surface & Subsurface)	93,579	10% by volume of surface oil
Evaporated	280,737	50% per volume of available surface oil
Amount Available for Recovery	604,849	
Skimmed	68,440	10% of oily water collected is oil
Burned	91,792	Based on surface area and thickness calculations on site before burning
Dispersed Chemically (Surface & Subsurface)	53,626	Surface: oil dispersed = dispersant X 3 Surface: dispersant impacts 25% of treatable oil Subsurface: oil dispersed = dispersant X 5
Total Dispersant Used	17,463	note: converted fm gals to bbls - total taken from last operational report
Remaining	390,991	

1 bbl = 42 gals

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Mass Balance – Discharge Rate Calculation

- Start with a measured sea-surface oil volume
- Add beach collection
- Add burned oil
- Add skimmed oil
- Add evaporated oil
- Add naturally and chemically dispersed oil
- Add contained oil

- Divide by number of days of oil discharge

- **RESULT = Average Daily Discharge Rate**

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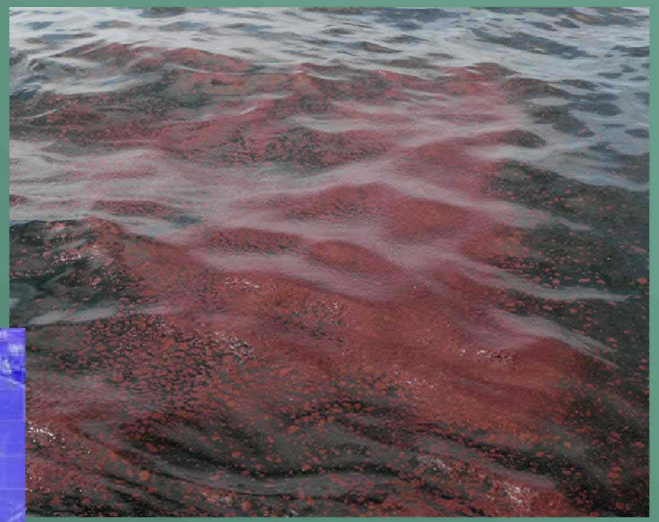
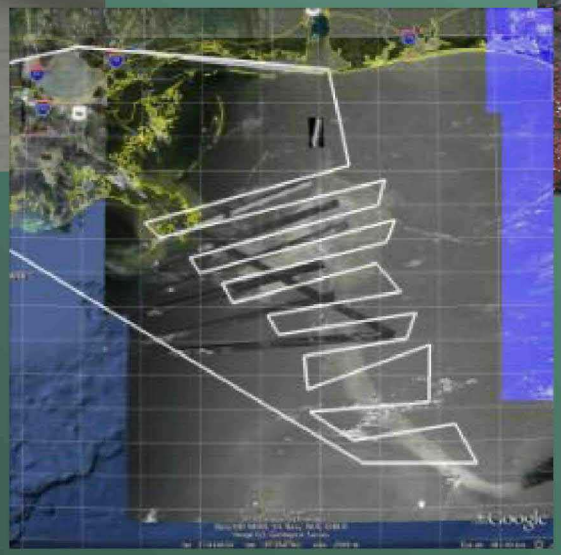
Mass Balance – Discharge Rate Calculation





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Mass Balance – Discharge Rate Calculation

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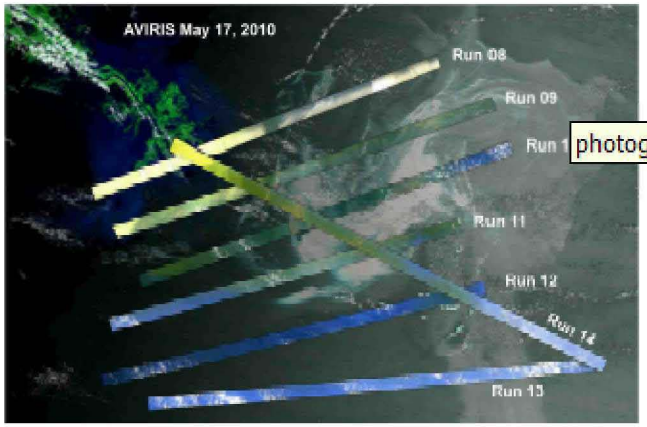
Estimated Minimum Discharge Rates of the Deepwater Horizon Spill—Interim Report to the Flow Rate Technical Group from the Mass Balance Team

By Victor F. Labson, Roger N. Clark, Gregg A. Swayze, Todd M. Hoefen, Raymond Kokaly, K. Eric Livo, Michael H. Powers, Geoffrey S. Plumlee, and Gregory P. Meeker



photograph

Open-File Report 2010–1132

U.S. Department of the Interior
U.S. Geological Survey

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http://pubs.usgs.gov/of/2010/1132/

Mass Balance – Discharge Rate Calculation

Low minimum	High minimum	Explanation
66,000	120,000	2 percent area "thick" oil from imagery
33,500	67,000	10 percent area "dull" oil
29,500	59,000	88 percent area "sheen" oil
129,000	246,000	Total observed on surface
23,500	23,500	skimmed oil
11,500	11,500	burned oil
164,000	281,000	Subtotal as of May 17, 2010
109,000	185,000	40 percent evaporation and dissolution
273,000	466,000	Total estimated as of May 17, 2010
12,500	**21,500**	**Daily average per 21.7 days**
67,000	114,000	assumed subsea dispersion
340,000	580,000	estimated leaked as of May 17

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Overflights

NASA ER-2 with AVIRIS leaving Houston for Gulf overflight.

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Overflights

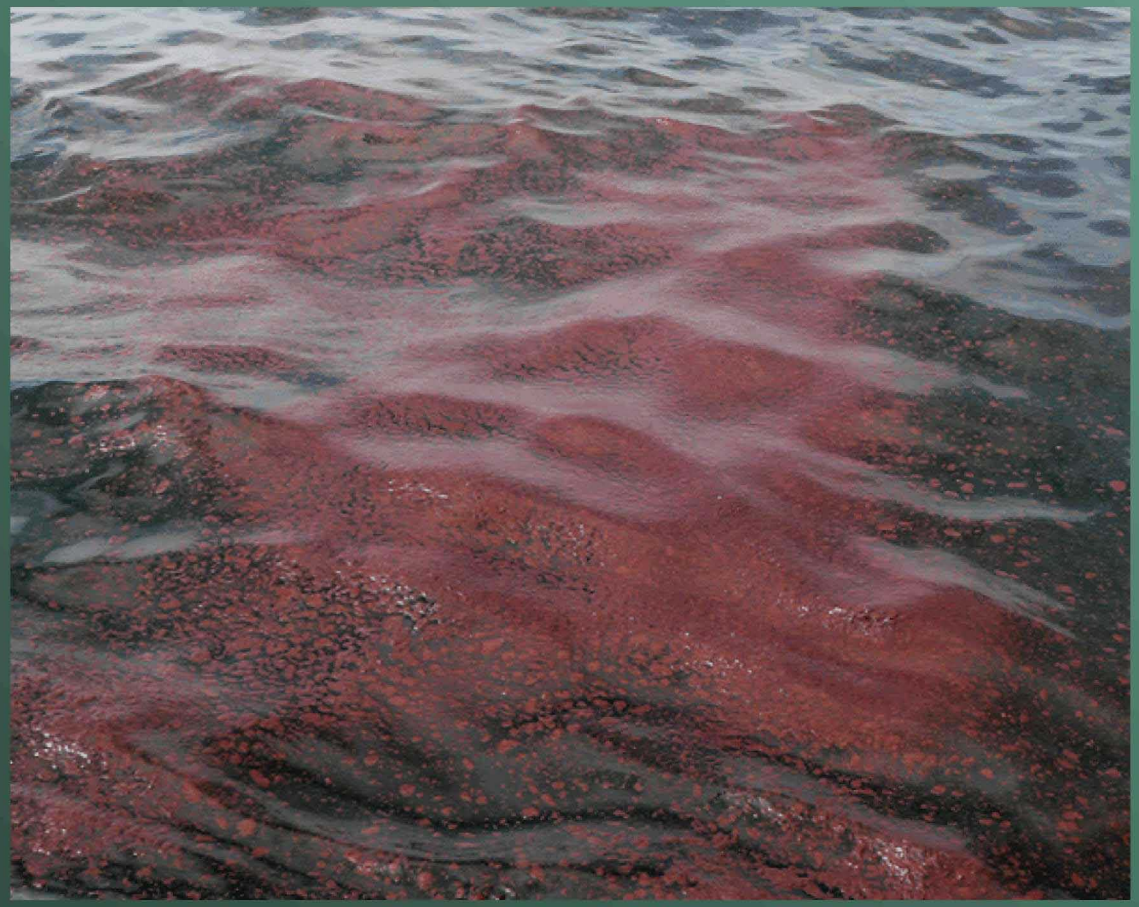

Image of oil emulsion from the Gulf of Mexico oil spill. Photograph taken on May 7, 2010, by Gregg Swayze/Sonia Gallegos during calibration sample collection cruise.

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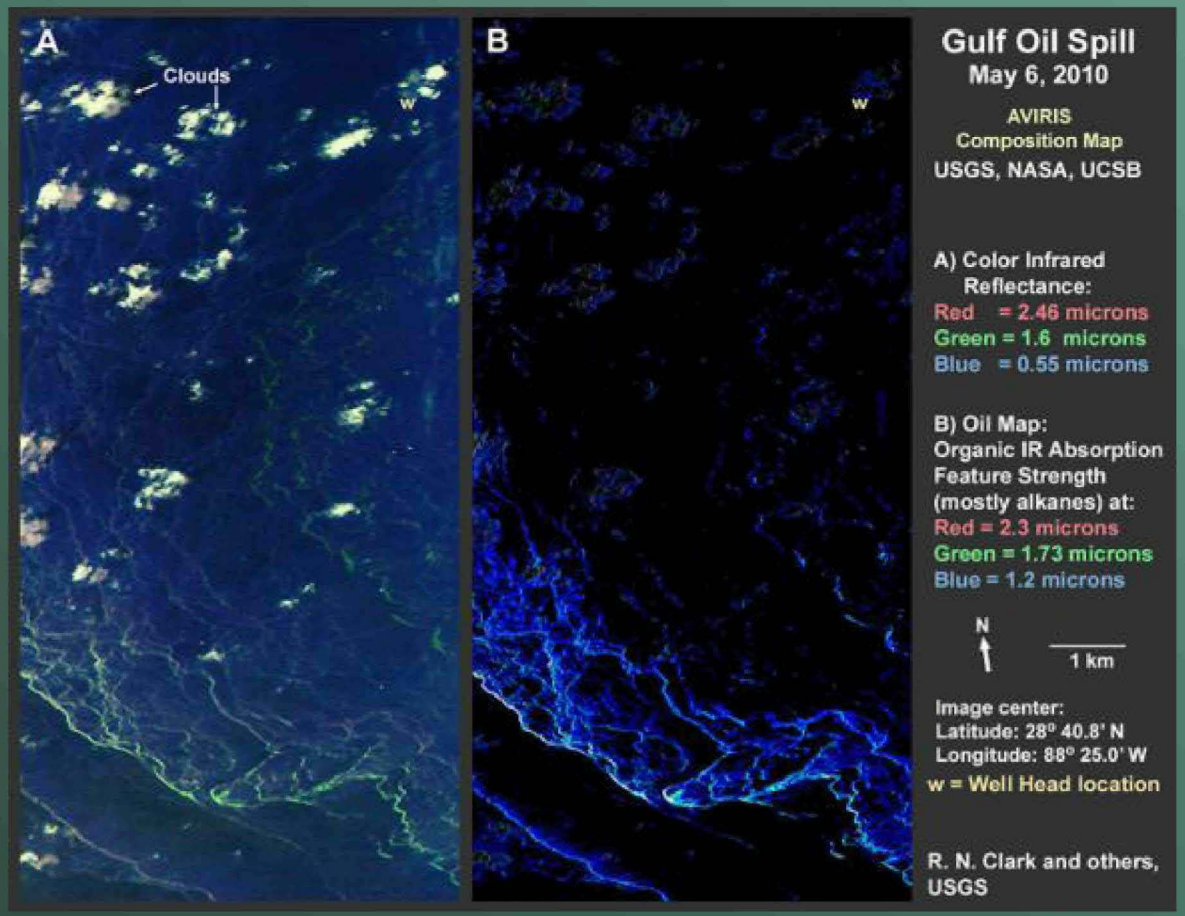
Overflights



Qualitative map of potentially thick oil in vicinity of well head.

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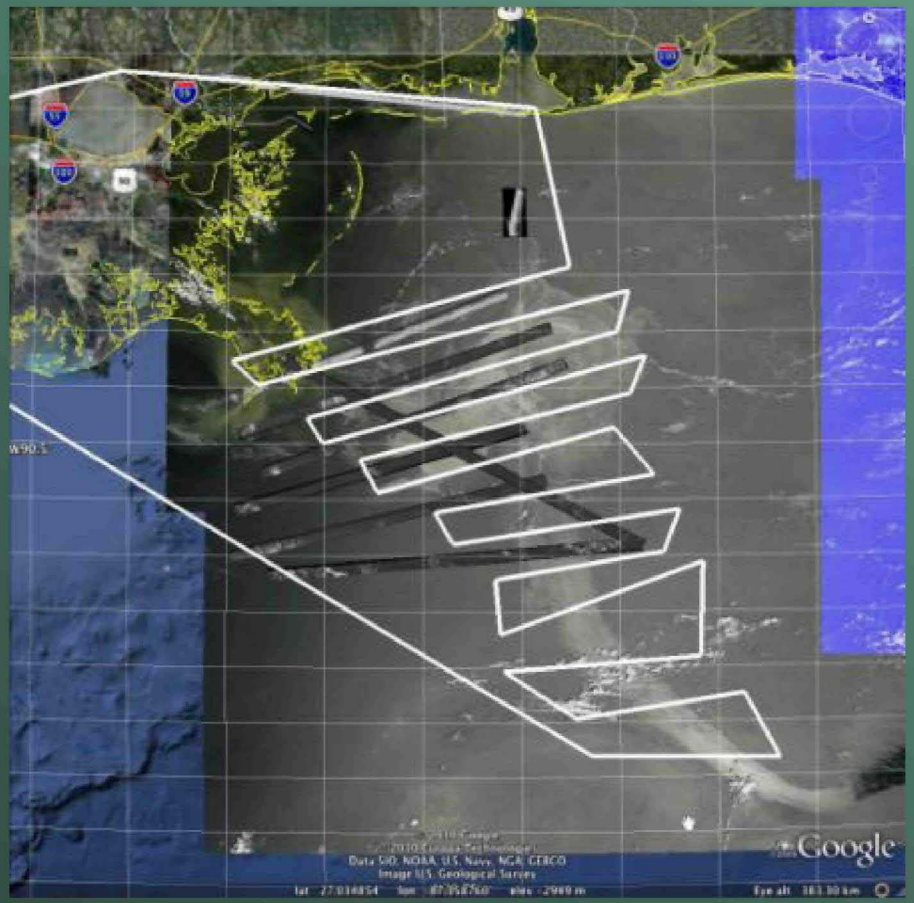

Quick look images of May 17 flight on May17 MODIS image. White lines are May 18 flight plan. May 17 was flown at 28,000 feet for better resolution. May 18 at 45,000 feet for wider coverage

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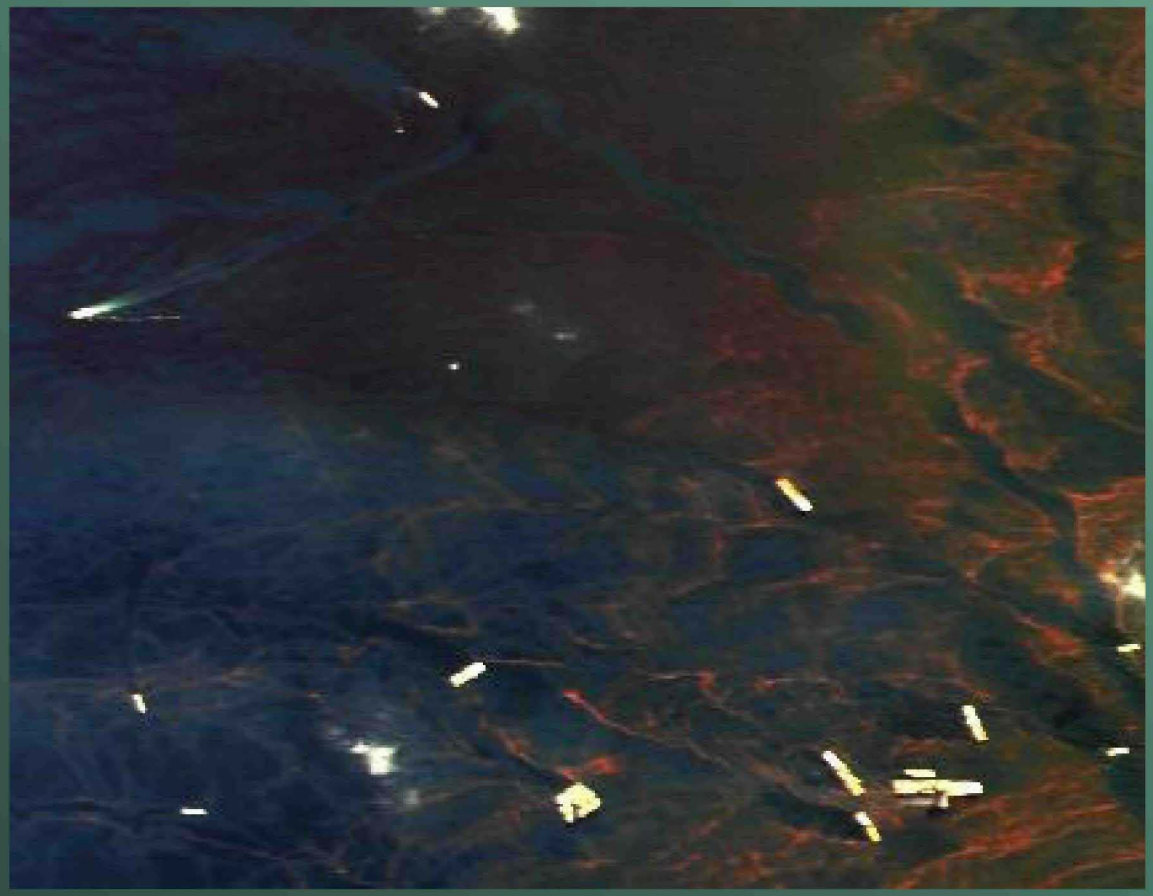
Overflights



May 17 AVIRIS quick-look color composite.

Note ship tracks through oil.

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Imaging Spectroscopy

- Imaging Spectroscopy is a hyperspectral visible and infrared remote sensing method which maps chemical composition
- AVIRIS is much like a digital camera which measures visible and near-infrared light in 224 bands in a vast number of pixels
- Every chemical compound has a unique spectrum, or combination of reflection or absorption, analogous to our sensitivity to color in the visible spectrum

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Imaging Spectroscopy

- AVIRIS is a NASA instrument housed at the Jet Propulsion Laboratory
- Measures in pixels from 2 meters on a side to over 20 meters depending on mission plan
- Chemical compounds are identified by matching to a spectral library of laboratory measurements of chemical compounds and mixtures of compounds
- Resulting mapping reminiscent of Star Trek Tricorder, except this one is real

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A Method for Quantitative Estimation of the Volume of Sea-Surface Oil

MODIS image showing the spill. AVIRIS has covered the central circular area with some of the extension to the southwest. No one can tell how much oil this image represents.

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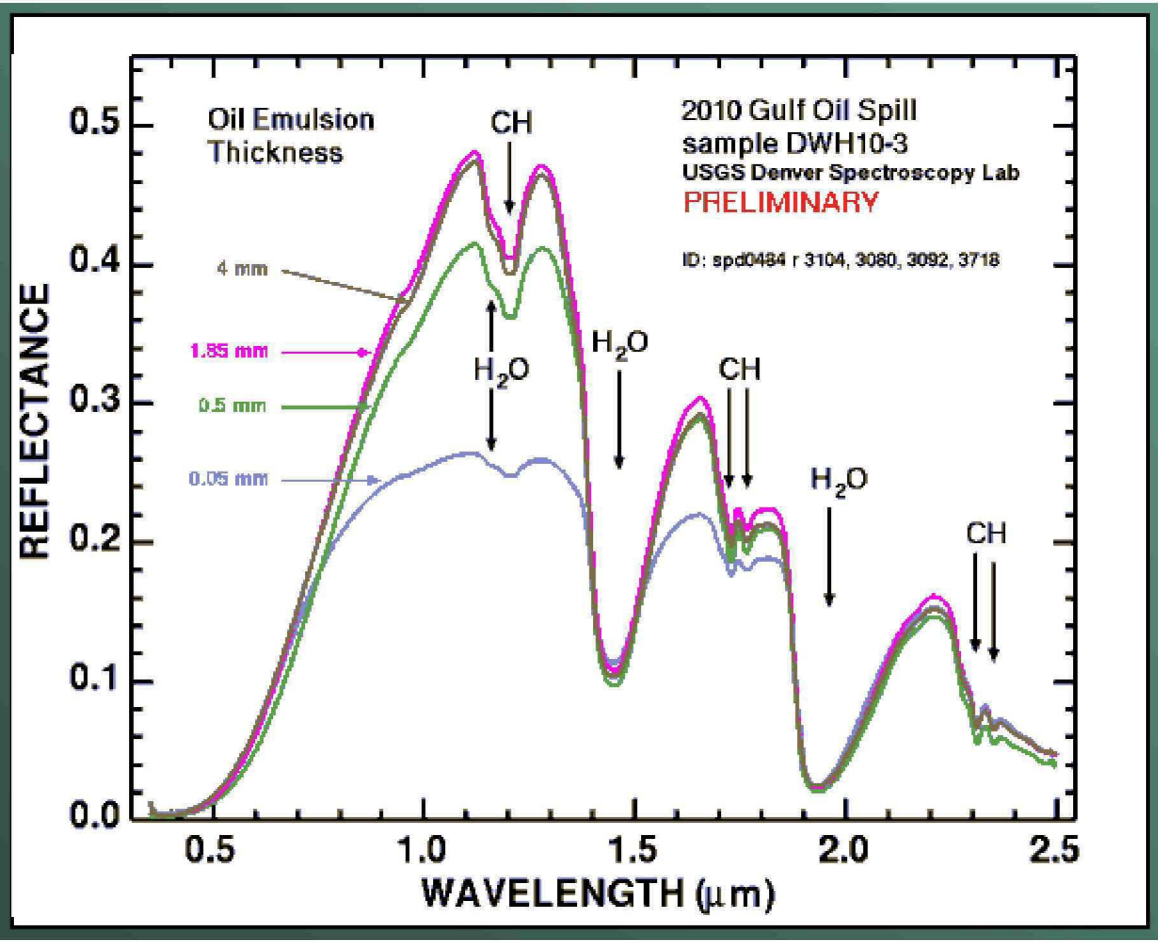
A Method for Quantitative Estimation of the Volume of Sea-Surface Oil



Infrared spectral change with thickness of oil emulsion from the Gulf of Mexico oil spill. Sample collected May 7, 2010.

This property allows us to do the volume estimate.

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A Method for Quantitative Estimation of the Volume of Sea-Surface Oil

- Several oil-seawater emulsion samples collected from spill on May 7, 2010
- Field spectra measured of spill at the locations from which samples were collected
- Laboratory spectra also measured of samples
- Samples are being analyzed for organic chemical composition at USGS Menlo Park labs (R. Rosenbauer), and metals in USGS Denver labs

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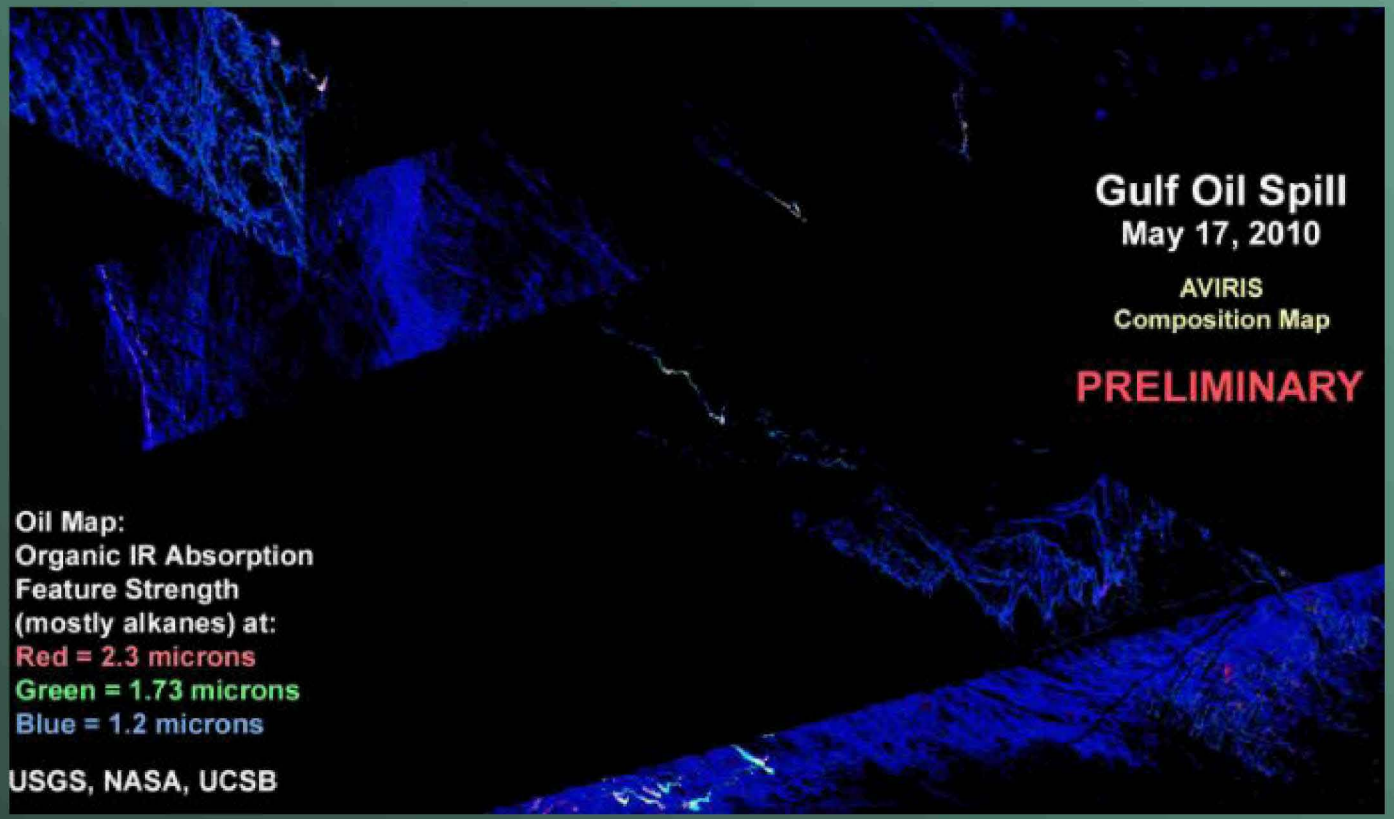
A Method for Quantitative Estimation of the Volume of Sea-Surface Oil



First look, May 17 AVIRIS composition map.

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Additional oil-seawater samples needed from ocean plume

- For reflectance spectroscopy and chemical analysis
- Link laboratory chemical analyses to lab, field spectra and AVIRIS data, to enhance AVIRIS mapping of plume chemical composition
- Help understand chemical evolution of plume in the ocean prior to landfall
  - Degradation, transformation of oil
  - Transfer of heavy metal and organic contaminants to sea water

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Future studies - 2 phase science plan

- **Phase 1 (June-early July 2010):**
  - AVIRIS will be mobilized to the Gulf to fly low altitude detailed mapping of the threatened and impacted coastal areas
  - Deep-sea transects for characterization and calibration.
  - Coordinated, contemporaneous, seaborne sampling and spectral calibration data collection
  - Laboratory analysis of transect oil samples.

- **Phase 2 (July 2010):**
  - High altitude, regional AVIRIS data collection
  - Sea-surface oil volume mapping
  - Determination of sea-surface oil weathering

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