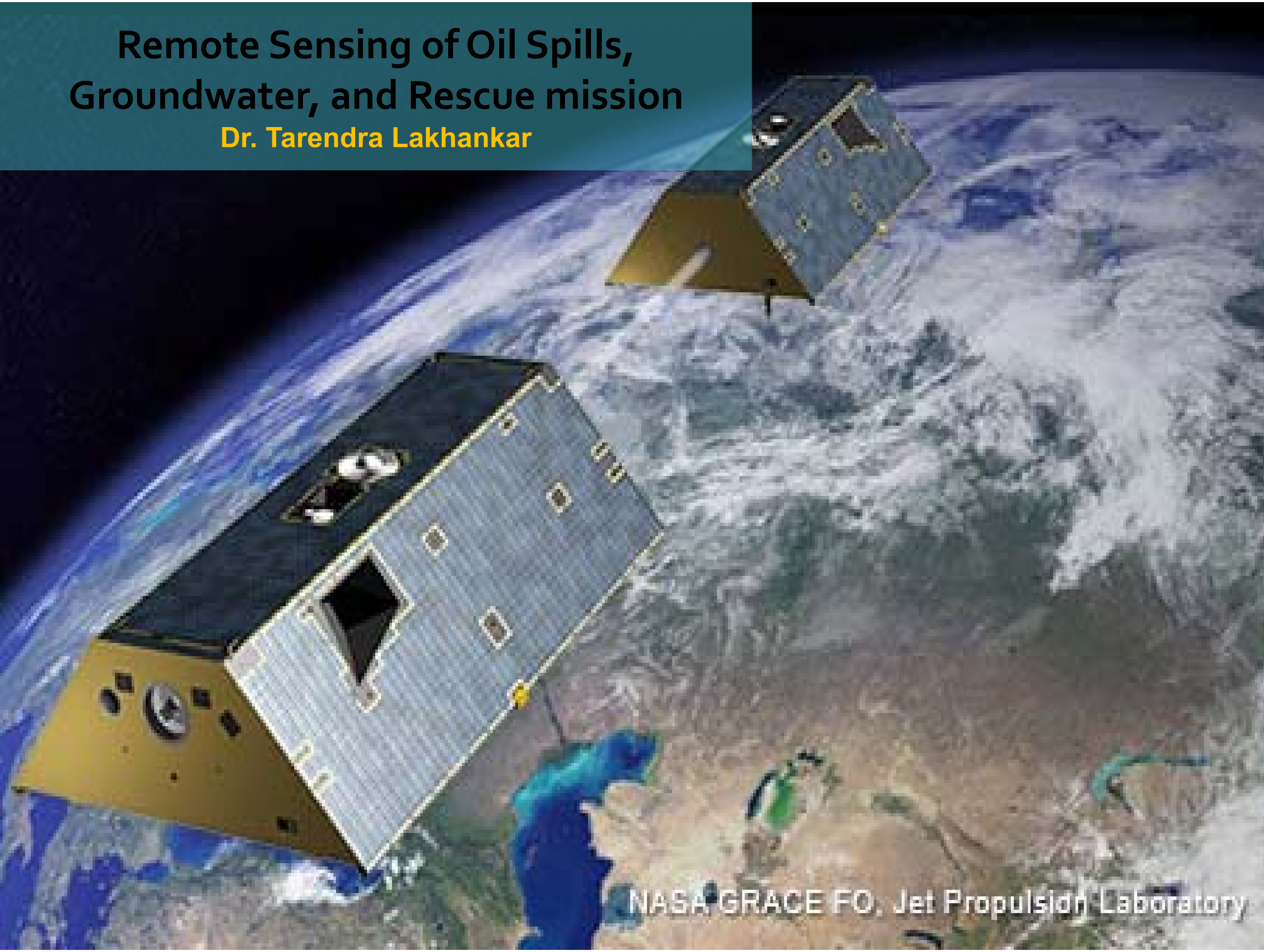
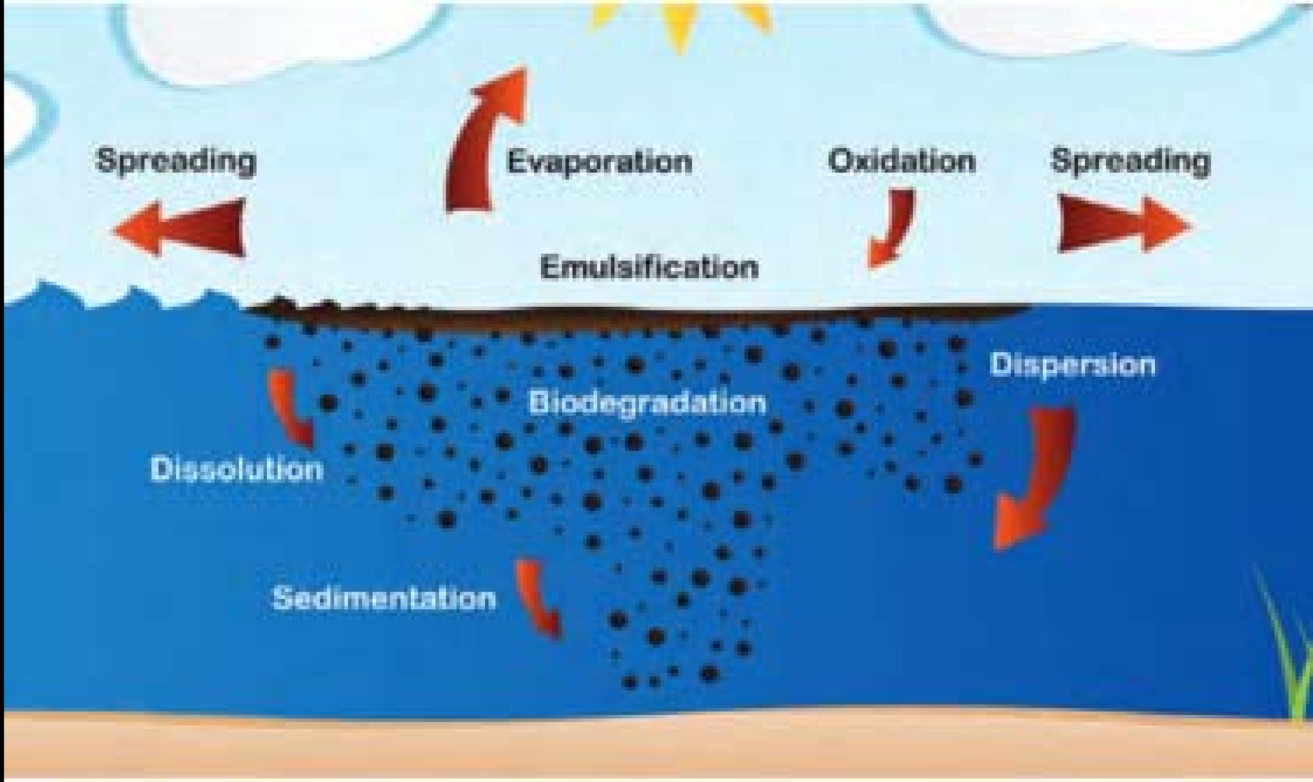
Remote Sensing of Oil Spills, Groundwater, and Rescue mission

Dr. Tarendra Lakhankar



Oil Spills

- An oil spill is the release of a liquid petroleum hydrocarbon into the environment, especially the marine ecosystem, due to human activity, and is a form of pollution.
- The oil release can be accident and illegal discharge.



Oil spills at sea are generally much more damaging than those on land, since they can spread for hundreds of nautical miles in a thin oil slick which can cover beaches with a thin coating of oil. These can kill seabirds, mammals, shellfish and other organisms they coat.

Largest oil spills

Spill / Tanker	Location	Date	Tonnes of crude oil (thousands)[a]	Barrels (thousands)	US Gallons (thousands)
Kuwaiti Oil Fires[dubious – discuss][b]	Kuwait	January 16, 1991 – November 6, 1991	136,000	1,000,000	42,000,000
Kuwaiti Oil Lakes [c]	Kuwait	January 1991 – November 1991	3,409–6,818	25,000–50,000	1,050,000–2,100,000
Lakeview Gusher	Kern County, California, USA	March 14, 1910 – September 1911	1,200	9,000	378,000
Gulf War oil spill [d]	Kuwait, Iraq, and the Persian Gulf	January 19, 1991 – January 28, 1991	818–1,091	6,000–8,000	252,000–336,000
Deepwater Horizon	United States, Gulf of Mexico	April 20, 2010 – July 15, 2010	560–585	4,100–4,900	189,000–231,000
Ixtoc I	Mexico, Gulf of Mexico	June 3, 1979 – March 23, 1980	454–480	3,329–3,520	139,818–147,840
Atlantic Empress / *Aegean Captain*	Trinidad and Tobago	July 19, 1979	287	2,105	88,396
Fergana Valley	Uzbekistan	March 2, 1992	285	2,090	87,780
Nowruz Field Platform	Iran, Persian Gulf	February 4, 1983	260	1,900	80,000
ABT Summer	Angola, 700 nmi (1,300 km; 810 mi) offshore	May 28, 1991	260	1,907	80,080
Castillo de Bellver	South Africa, Saldanha Bay	August 6, 1983	252	1,848	77,616
Amoco Cadiz	France, Brittany	March 16, 1978	223	1,635	68,684
Taylor Energy	United States, Gulf of Mexico	September 23, 2004 – Present	210–490	1,500–3,500	63,000–147,000
Torrey Canyon	England, Cornwall	March 18, 1967	119	872	36,635

Use of oil spill Remote sensing

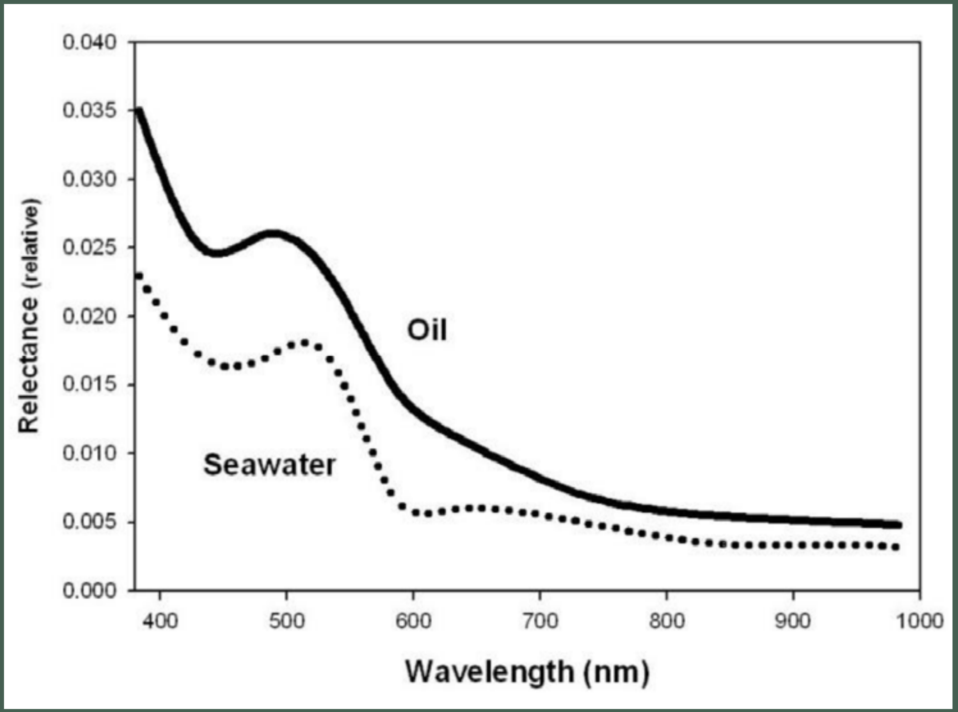
- Enforcement of ship discharge laws
- Surveillance and general slick detection
- Provision of evidence for prosecution
- Mapping of spills for various reasons
- Direction and support to oil spill countermeasures
- Determination of slick trajectories

Remote Sensing Methods

- Visible
- IR
- Ultraviolet
- Microwave
  - RADAR / SAR
  - Passive Microwave
- Laser fluorosensor

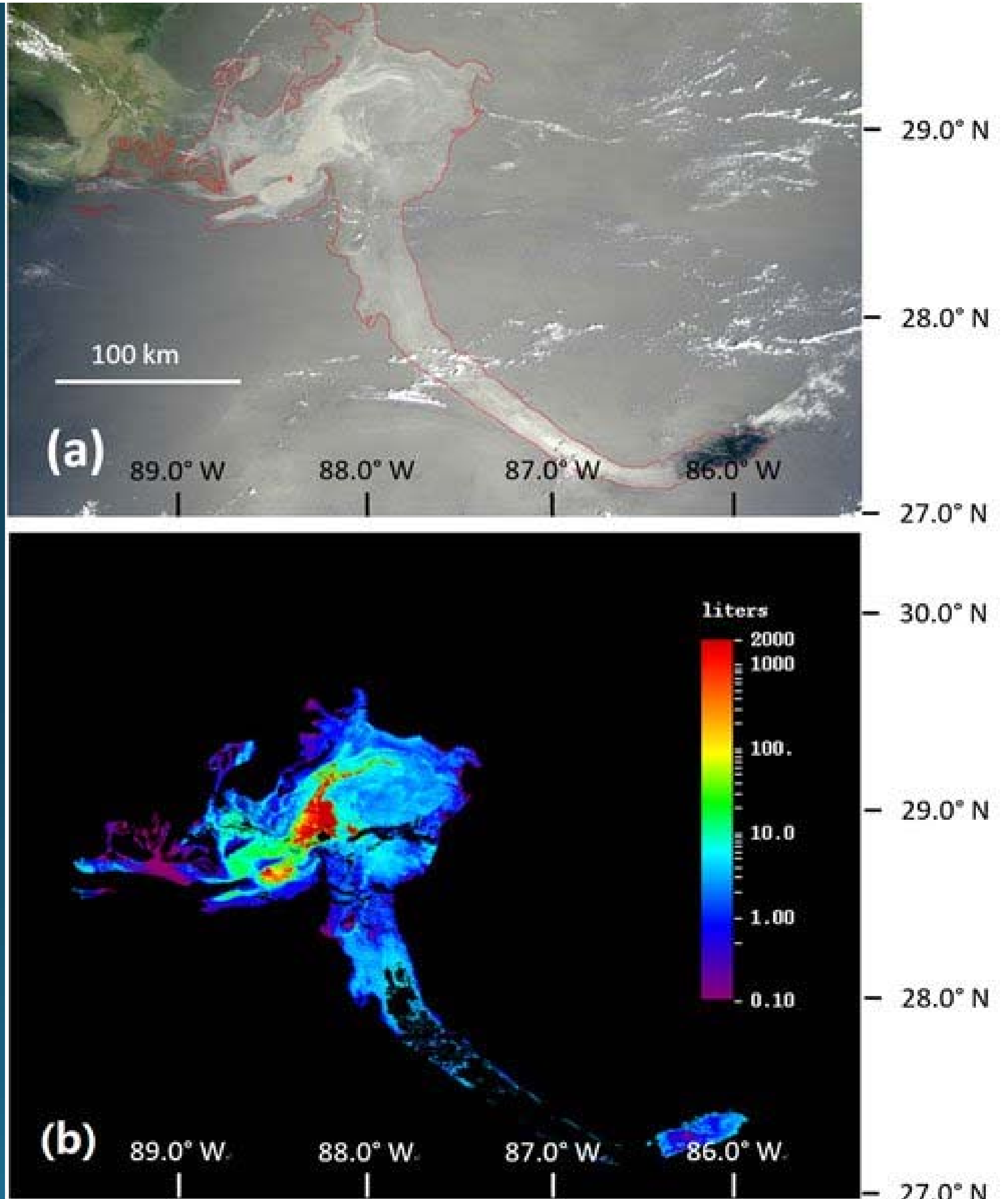
Visible Remote Sensing

- In the visible region of the electromagnetic spectrum (approximately 400–700 nm), oil has a higher surface reflectance than water but shows limited nonspecific absorption tendencies.
- The presence of oil may slightly alter water spectra, and Oil sheen shows up silvery and reflects light over a wide spectral region down to the blue.
- As there is no strong information in the 500–600-nm region, this region is often filtered out to improve contrast.
- Sun glint and wind sheens can be mistaken for oil sheens.



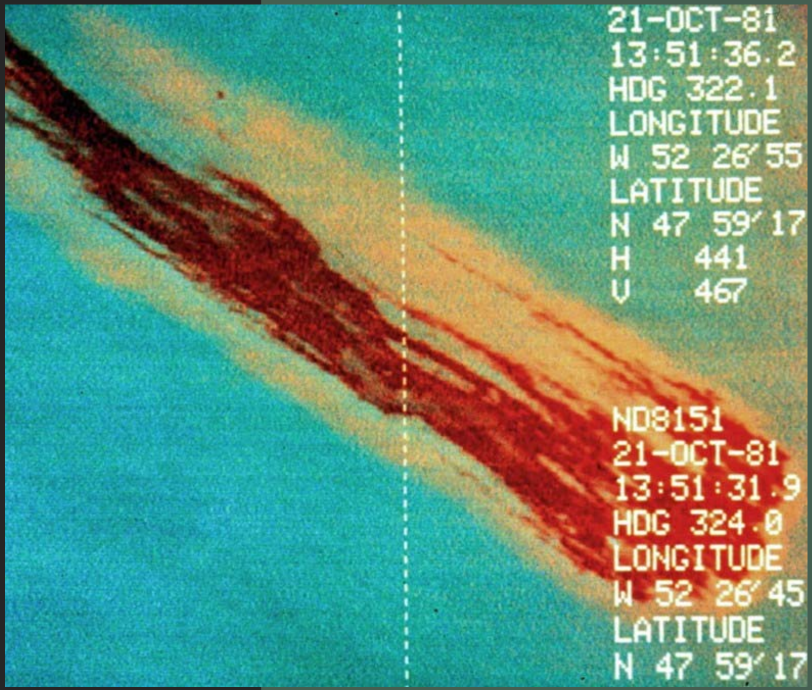
MODIS Data

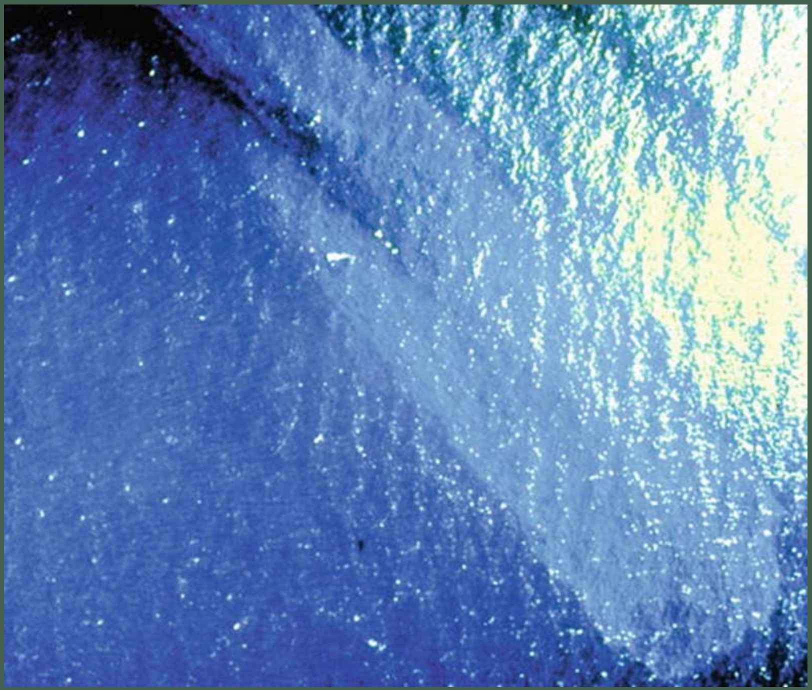
- MODIS satellite image from May 17, 2010, shows oil slicks (outlined in red) from the Deepwater Horizon oil spill.
- Image (a) shows the oil slicks outlined in the red circle and have enhanced contrast due to both sun glint and water circulations.
- Image (b) is a surface oil volume map derived from the MODIS data.



Infrared Remote Sensing

- Infrared offers some potential as an oil spill sensor.
- In daytime oil absorbs light and remits this as thermal energy at temperatures 3 to 8 K above ambient.
- Infrared Remote Sensing suffer from problems such as the inability to discriminate oil on beaches, among weeds, debris or sediment, and under certain lighting conditions.
- Furthermore, water-in-oil emulsions are often not detected in the infrared.





The same slick as shown in both figure, but in the visible (right side), the contrast between the oil and sun glint is poor.

Ultraviolet Remote Sensing

- Oil shows a high reflectance of sunlight in the ultraviolet range. Ultraviolet sensors can be used to map sheens of oil as oil slicks display high reflectivity of ultraviolet (UV) radiation even at thin layers (<0.1 μm).
- Overlaid ultraviolet and infrared images are often used to produce a relative thickness map of oil spills.
- Ultraviolet data are also subject to many interferences or false images such as wind slicks, sun glints, and biogenic material.
- Since these interferences are often different than those for infrared sensing, combining IR and UV can provide a more positive indication of oil than using either technique alone.

Laser fluorosensor

- The laser fluorosensor is a useful instrument because of its unique capability to identify oil on backgrounds that include water, soil, weeds, ice and snow.
- It is the only sensor that can positively discriminate oil on most backgrounds.
- The laser fluorosensor also allows for positive identification and discrimination between oil types
- Laser fluorosensors employ a UV laser operating between 308 and 355 nm.

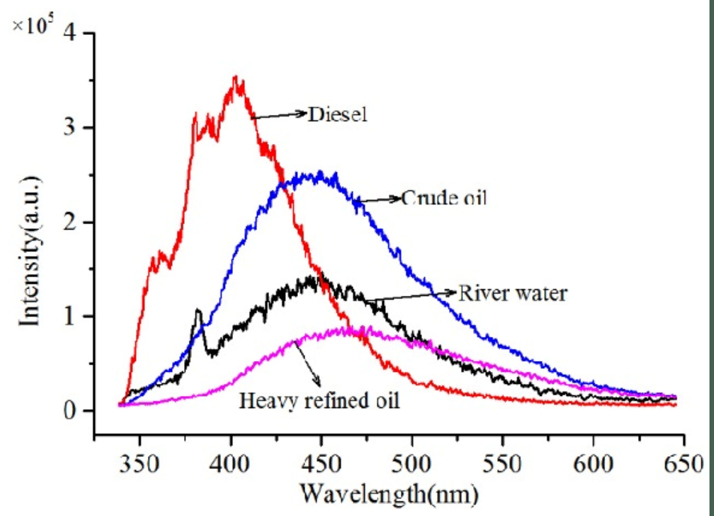
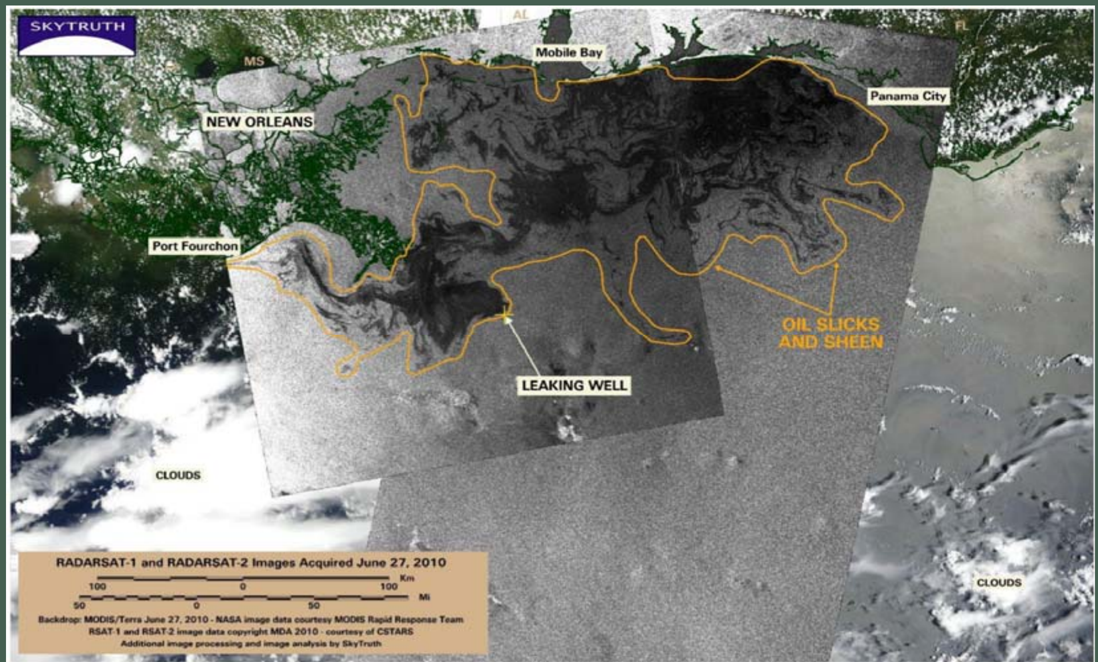


Figure 6 The typical fluorescence signal of the developed laser fluorosensor obtained in the field

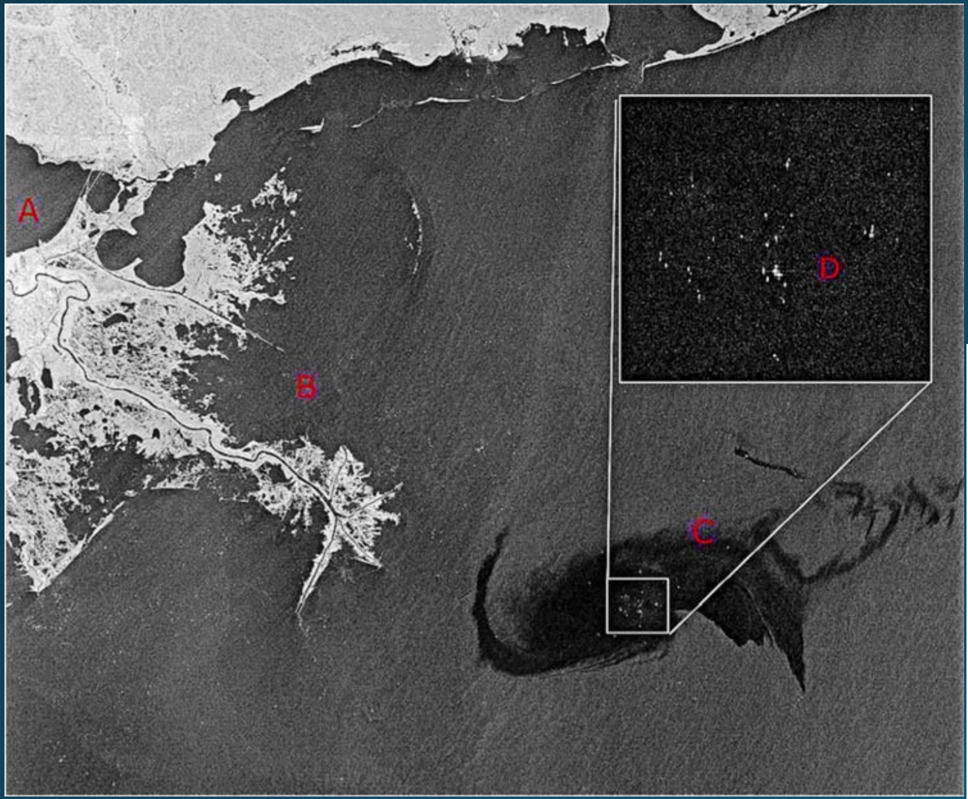
RADAR or SAR Data

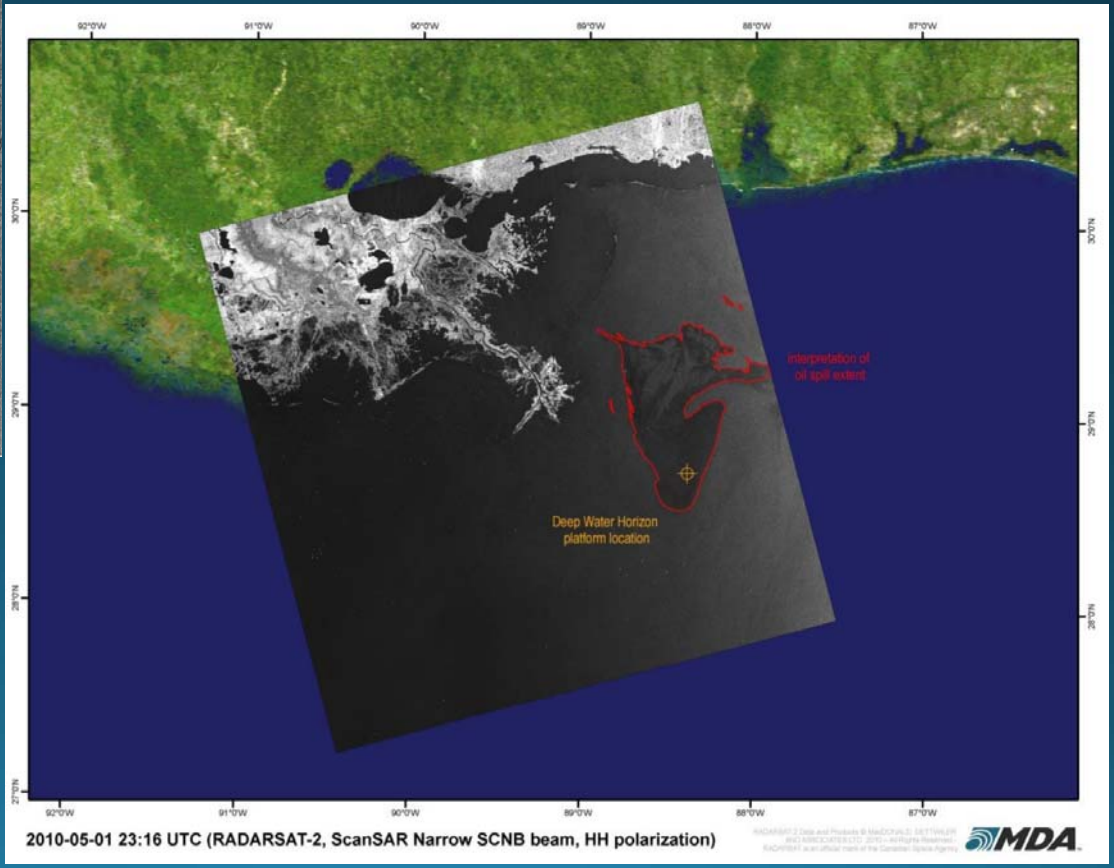
- Oil spills become visible on radar images as dark areas relative to the surrounding area because they reduce the radar backscattering. Other feature includes: the position/shape of the dark area, and the texture of the dark feature.
- Also, radar detects oil on water only in that oil will dampen water-surface capillary waves under low to moderate wave/wind conditions.
- Radar offers the only potential for large area searches, day/night and foul weather remote sensing.
- Satellite-borne radar sensors are useful however their frequency of overpass and lesser spatial resolution, render them useful for mapping large spills or assisting in major ship and platform discharge monitoring.



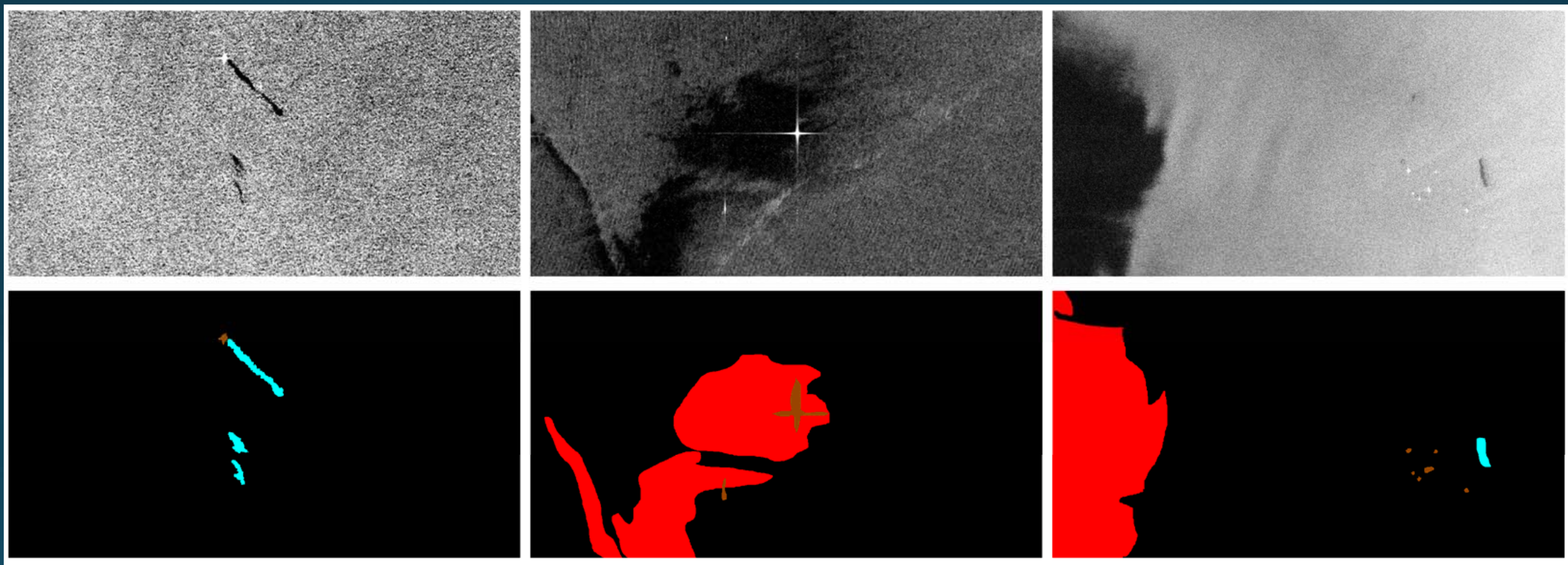
RADARSAT-1 and -2 combined image of the Gulf oil spill.

Radarsat-2 imagery of the Deepwater Horizon spill. The square shows an expanded view of the center of the spill area and the bright dots are ships working to control the spill.





SAR images and corresponding ground truth masks of oil spill



Sensor Suitability for Various Oil Spills Mission

Sensor	Support for Cleanup	Night & Fog Operation	Detection of Oil with Debris	Oiled Shoreline Survey	Spill Mapping	Ship Discharge Surveillance	Enforcement and Prosecution
Still Camera	2	n/a	1	2	2	2	2
Video	2	n/a	1	2	2	2	2
Night Time Vision Camera	3	4	1	n/a	2	2	2
IR Camera (8-14µm)	4	2	1	n/a	3	3	3
UV Camera	2	n/a	n/a	n/a	3	2	1
UV/IR Scanner	4	2	1	n/a	4	2	2
Multi-spectral Scanner	1	n/a	n/a	1	2	1	1
Radar	n/a	4	n/a	n/a	4	3	2
Microwave Radiometer	1	3	n/a	n/a	2	2	1
Laser Fluorosensor	4	3	5	5	1	5	5

Key: n/a = not applicable; numerical values represent a scale from 1 = poorly suited to 5 = ideally suited

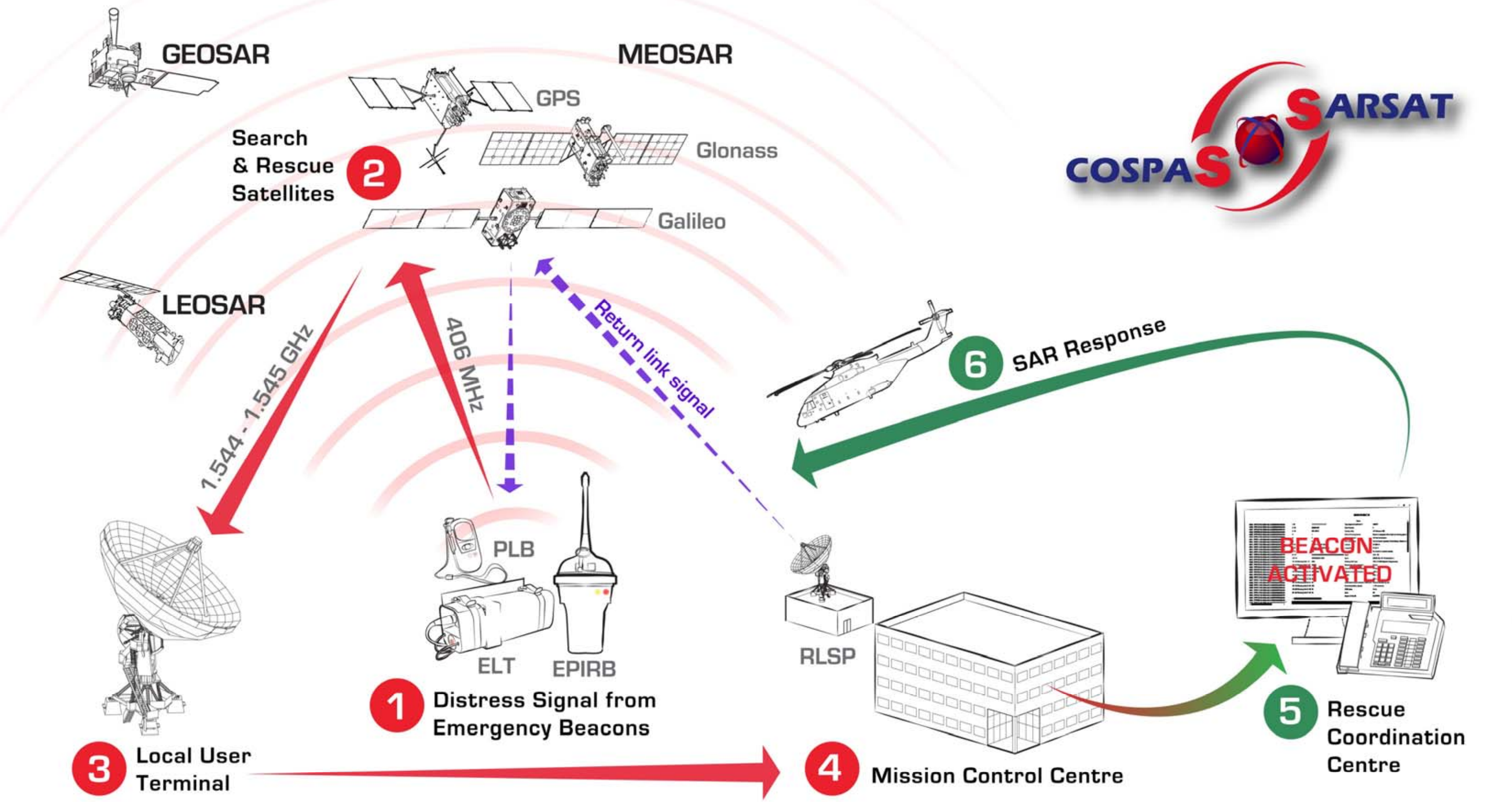
Rescue Mission

https://en.wikipedia.org/wiki/International_Cospas-Sarsat_Programme

Cospas-Sarsat

- Cospas-Sarsat is an international, humanitarian search and rescue system that uses satellites to detect and locate emergency beacons carried by ships, aircraft, or individuals.
- The system consists of a network of satellites, ground stations, mission control centers, and rescue coordination centers.
- With a 406 MHz beacon, a distress message can be sent to the appropriate authorities from anywhere on Earth 24 hours a day, 365 days a year.
- The Cospas-Sarsat system provides a tremendous resource for protecting the lives of aviators and mariners that was unthinkable prior to the Space-Age.

Cospas-Sarsat



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» SARSAT Meetings
» Real Time Cospas-Sarsat Satellite Tracking
» Monthly EPIRB Inspection Procedure
» SARSAT Statistics
» Warning on Unapproved Beacon Batteries
» Partners
» Cospas-Sarsat
» NSARC
» USCG SAR Office
» Air Force RCC
» NASA SAR Program
» Alaska RCC

Search and Rescue Satellites

Low-Earth Orbiting Search And Rescue (LEOSAR) Satellites

- NOAA Polar Orbiting Environmental Satellites (POES) – known as 'SARSAT'
- ESA/EUMETSAT Polar Orbiting Meteorological Satellites (MetOp) – known as "SARSAT"

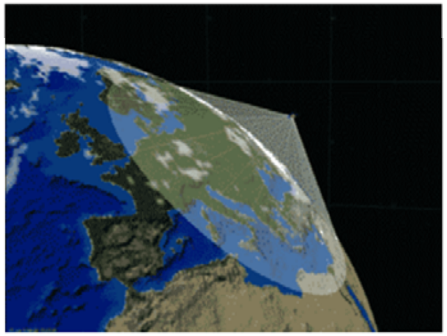
Geostationary Orbiting Search And Rescue (GEOSAR) Satellites

- NOAA Geostationary Orbiting Environmental Satellites (GOES)
- ISRO Indian National Satellite (INSAT)
- ESA Metosat Second Generation (MSG)

Medium-altitude Earth Orbiting Search and Rescue (MEOSAR) Satellites

- United States' Global Positioning System Satellites (GPS)
- Russia's Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS) Satellites
- European Space Agency GALILEO Global Positioning Satellites

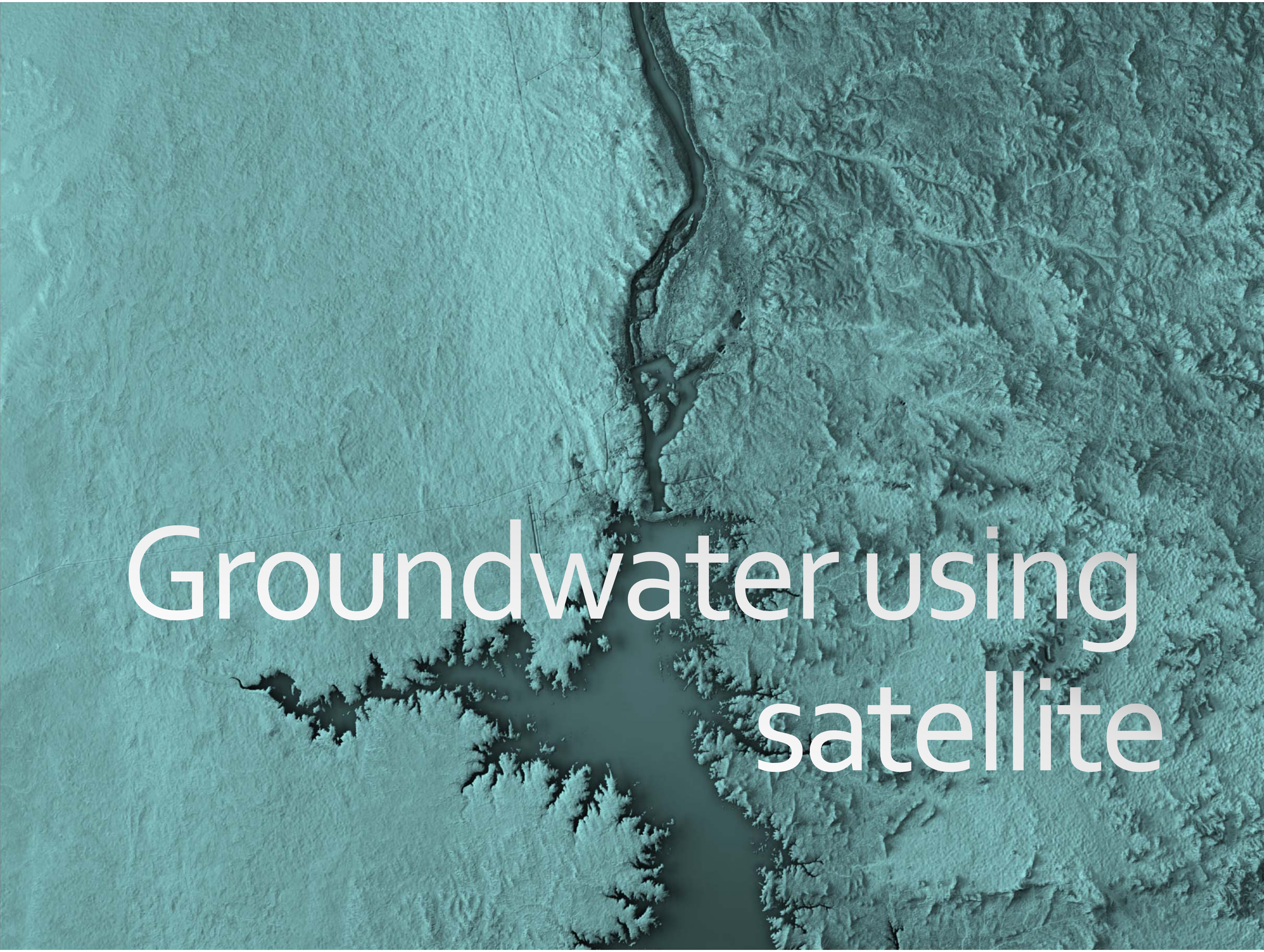
Low-Earth Orbiting Search And Rescue (LEOSAR) Satellites

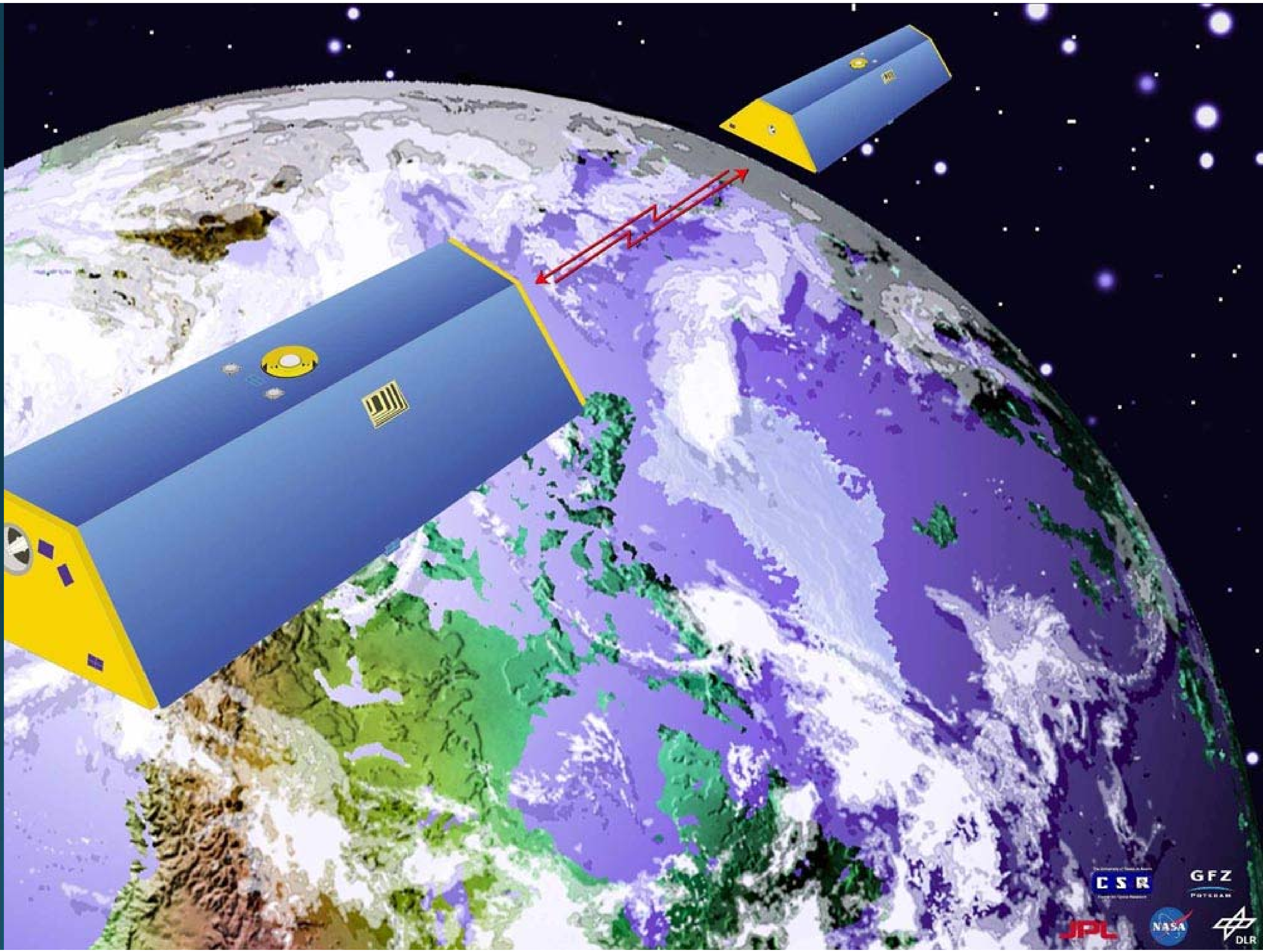


Low-earth orbiting (LEO) satellites provide the ability to detect and locate 406 MHz alerts worldwide. SARSAT is an instrument package flown aboard the NOAA series of environmental satellites operated by NOAA's National Environmental Satellite, Data and Information Service (NESDIS).

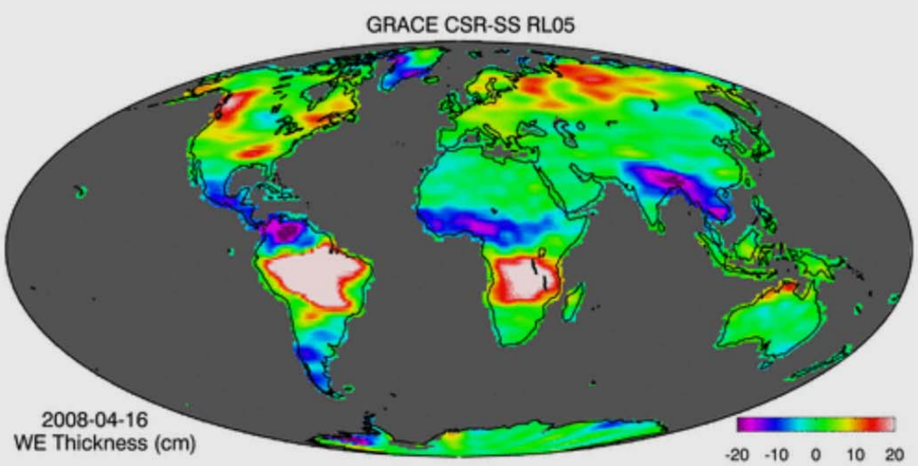
Low-earth orbiting (LEO) satellites orbit at an altitude of approximately 850 kilometers and orbit the Earth once every 102 minutes. Their orbits are inclined 99 degrees from the equator. Typically, each satellite monitors the earth for various weather and climate data. Yet, each satellite also carries a Search and Rescue Repeater (SARR) which receives and retransmits 406 MHz signals anytime the satellite is in view of a ground station. Also carried is a Search and Rescue Processor (SARP) which receives 406 MHz transmissions, provides measurements of the frequency and time, then retransmits this data in real-time. The satellite also stores each 406 MHz signal it receives and continuously downloads this data for up to 48 hours ensuring ground stations around the world receive it. That is, if the satellite was not in view of a ground station when it received a beacon signal, the next ground station that sees that satellite will receive the data. This provides global coverage for 406 MHz distress signals. The SARR is provided by the Canadian Department of National Defence and the SARP is provided by the French Center National D'Etudes Spatiales (CNES).

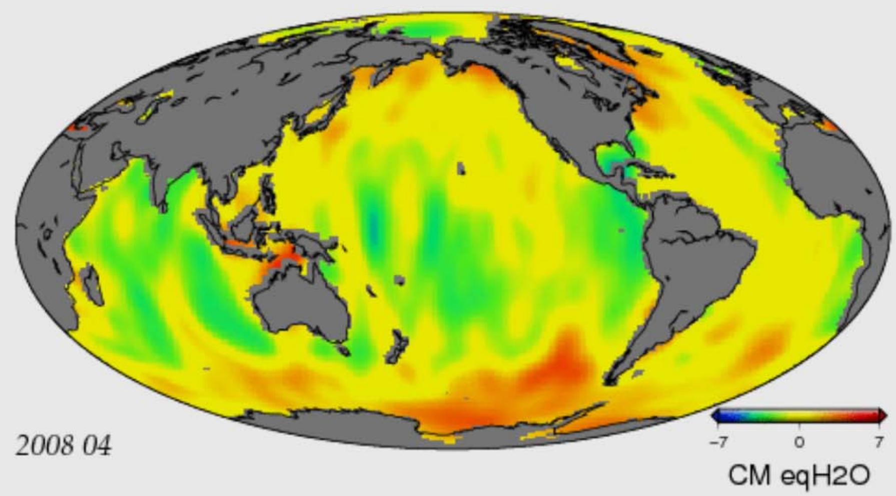
Groundwater using satellite




CSR
GFZ
JPL
NASA
DLR

GRACE





The GRACE twin satellites, launched 17 March 2002, are making detailed measurements of Earth's gravity field changes and revolutionizing investigations about Earth's water reservoirs over land, ice and oceans, as well as earthquakes and crustal deformations. The two GRACE satellites have completed more than 13 years of continuous measurements!

GRACE is a collaboration of the US and German space agencies (NASA and DLR). GRACE ground segment operations are currently co-funded by the GFZ German Research Centre for Geosciences and the European Space Agency (ESA). NASA, ESA, GFZ and DLR are supporting the continuation of the measurements of mass redistribution in the Earth system. The key partners in the design, construction and launch of the mission have been the Jet Propulsion Laboratory, the University of Texas Center for Space Research, GFZ German Research Centre for Geosciences, as well as Astrium GmBH, Space Systems Loral (SS/L), Onera and Eurockot GmBH.

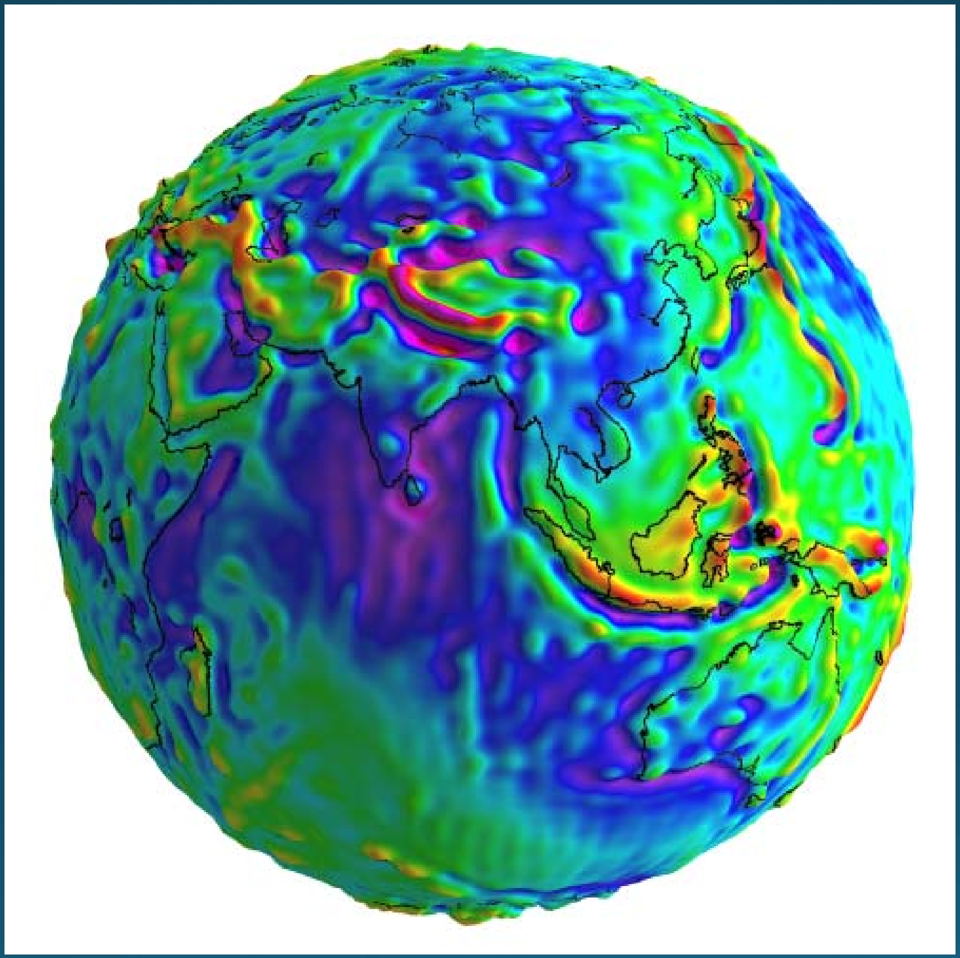
Why 'GRACE Tellus'?

Tellus refers to the Roman goddess of the planet Earth. In English it offers a wordplay, so we can ask "What can GRACE, and time changes in gravitational acceleration TELL US about our changing planet?" Incidentally, Tellus was also "a citizen of ancient Athens who was thought to be the happiest of men." (Source: Wikipedia)

GRACE-FO Mission

- The Gravity Recovery and Climate Experiment Follow-on (GRACE-FO) mission is a partnership between NASA and the German Research Centre for Geosciences (GFZ). GRACE-FO is a successor to the original GRACE mission, which began orbiting Earth on March 17, 2002.
- Launched on May 22, 2018, GRACE-FO continues the work of tracking Earth's water movement to monitor changes in underground water storage, the amount of water in large lakes and rivers, soil moisture, ice sheets and glaciers, and sea level caused by the addition of water to the ocean.

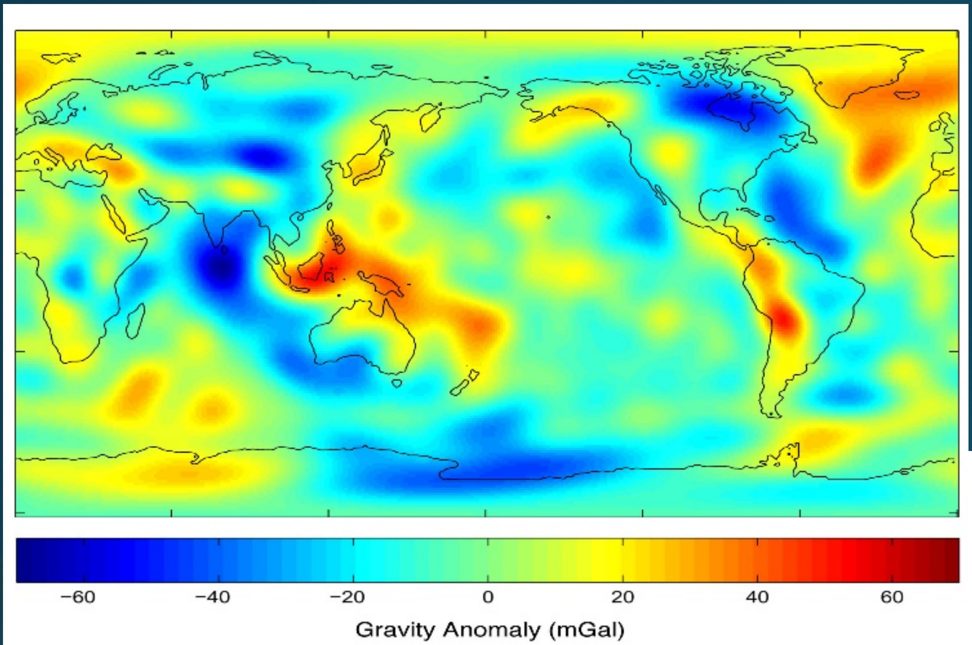
The Beauty of Earth Science



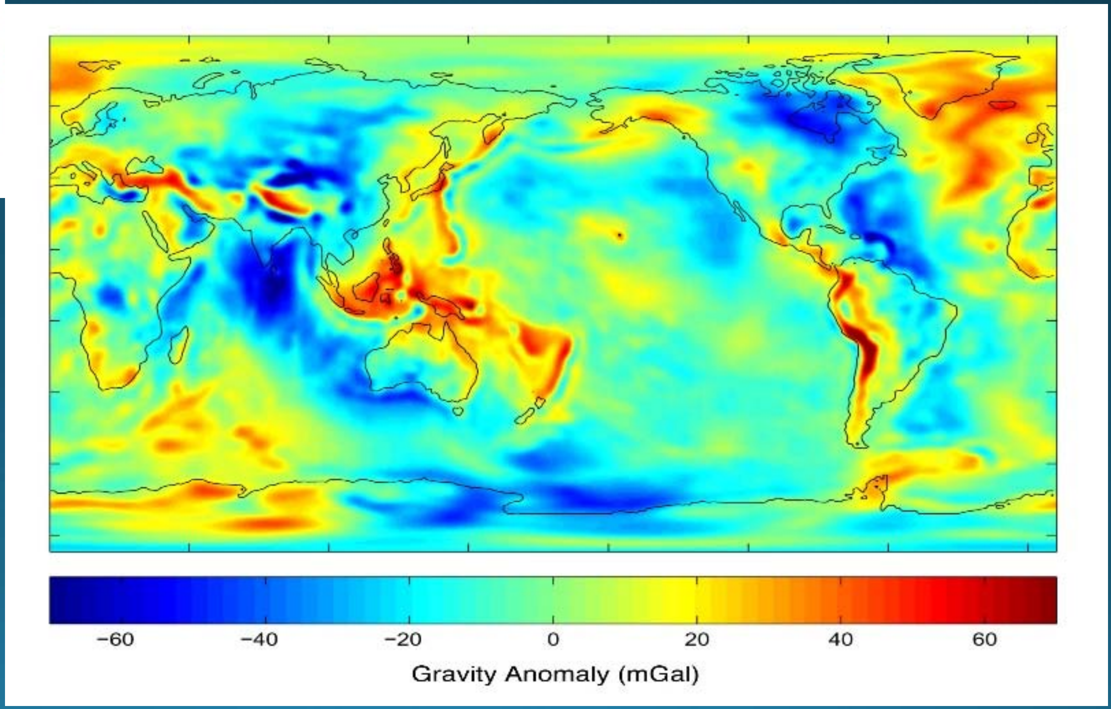
Based on the gravity model EIGEN-GL04C, a combination of GRACE and LAGEOS, plus gravimetry and altimetry surface data

Progress in Gravity Field Resolution

Decades of tracking to geodetic satellites



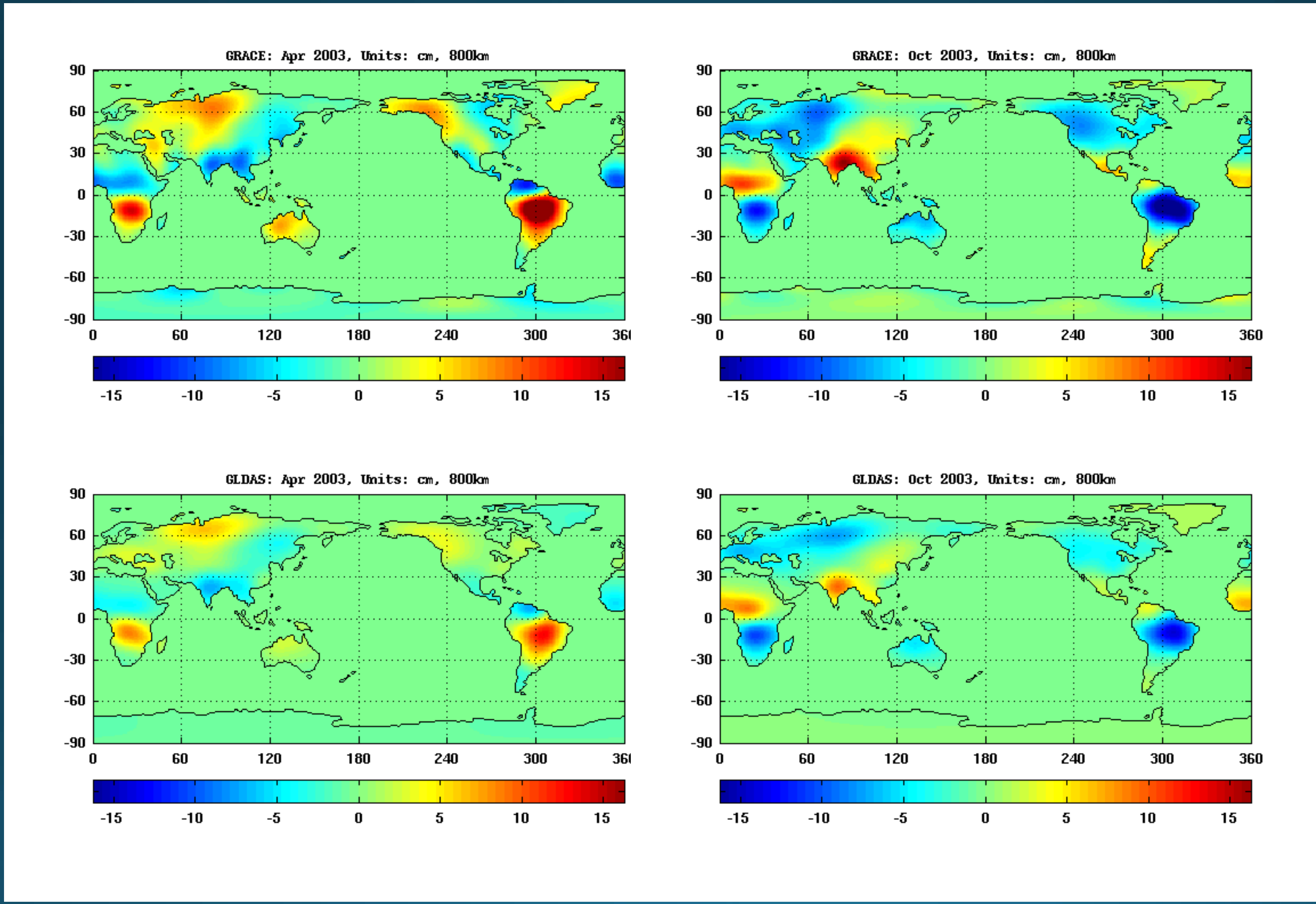
111 days of GRACE data



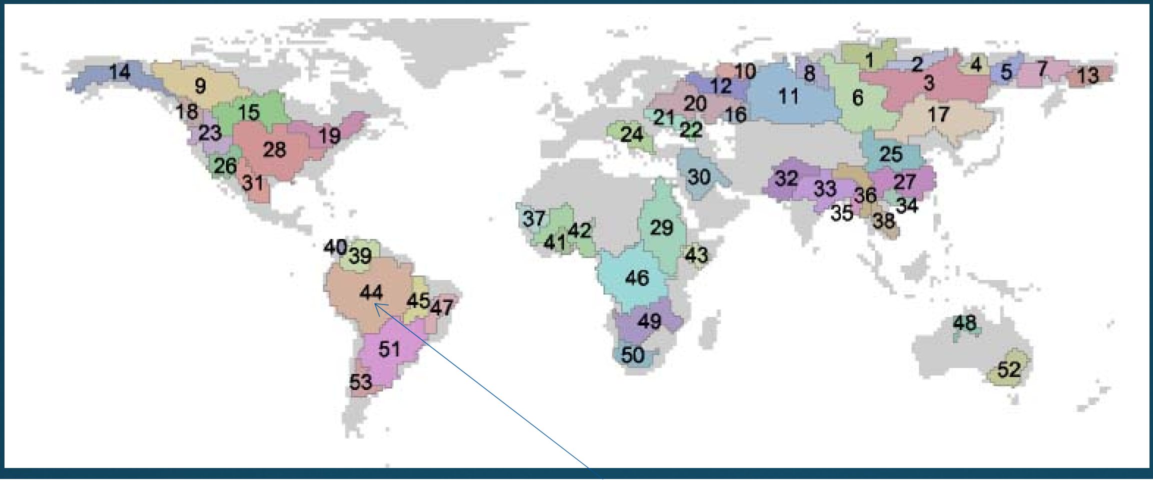
GRACE Main Products

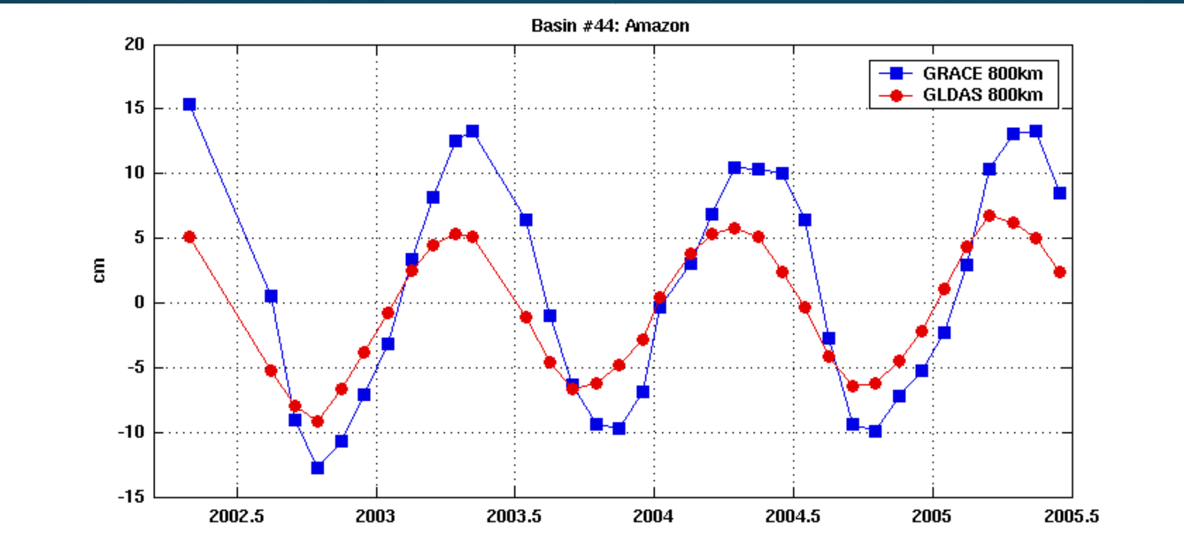
- Time-variable gravity field solutions at approximately monthly intervals.
- Static mean gravity fields (e.g., GGM01C, GGM02C, EIGEN-GL04C …).
- In forms of fully normalized spherical harmonics (or Stokes coefficients) up to degree and order 120 (for time-variable fields).
- From three processing centers, CSR, GFZ, and JPL.
- Supporting data products, GAC, GAB, GAA, and etc.

Global Water Storage Change from GRACE

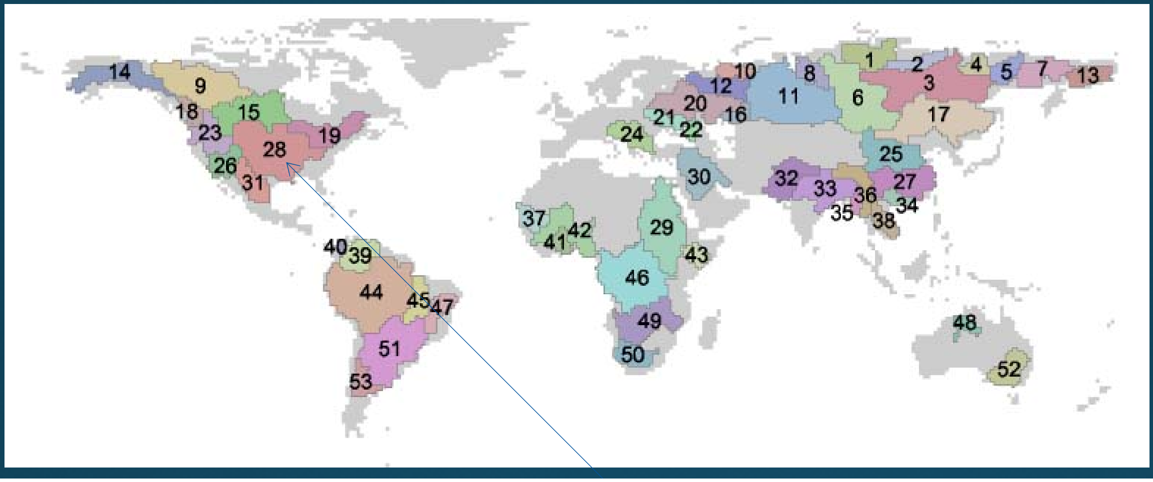


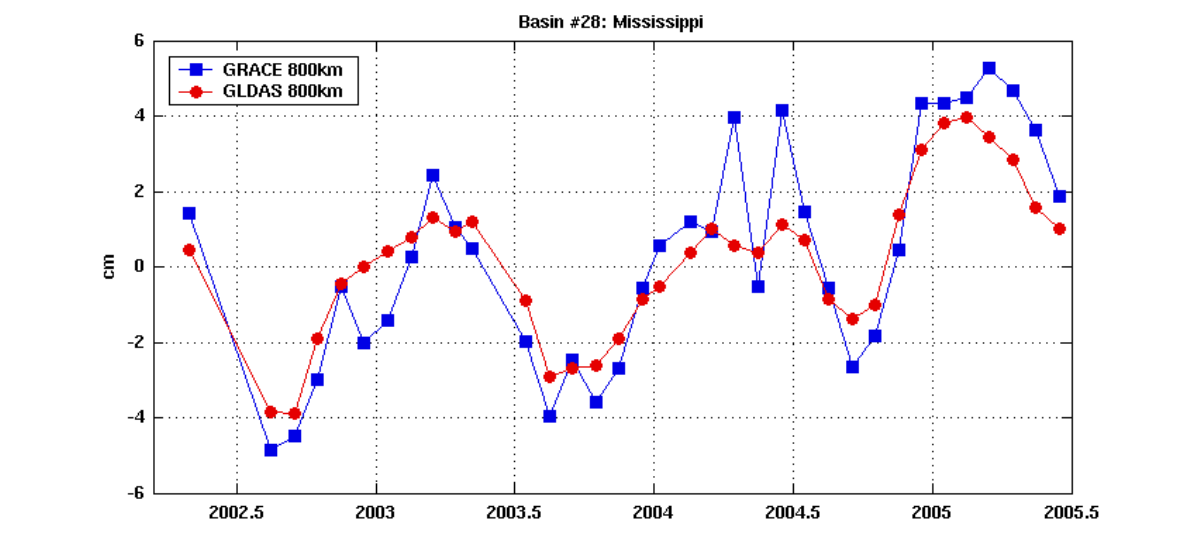
GRACE/GLDAS Comparison in Amazon



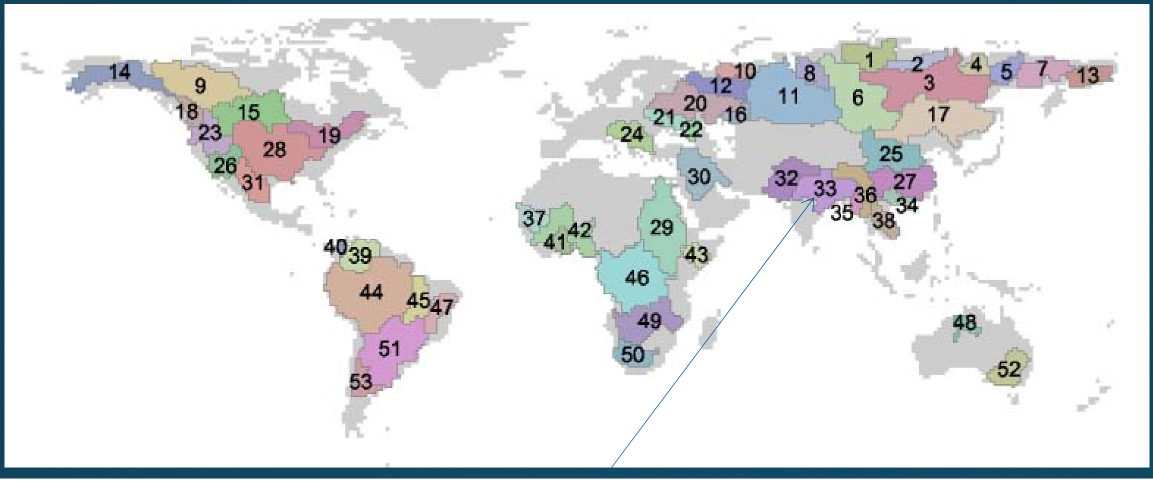


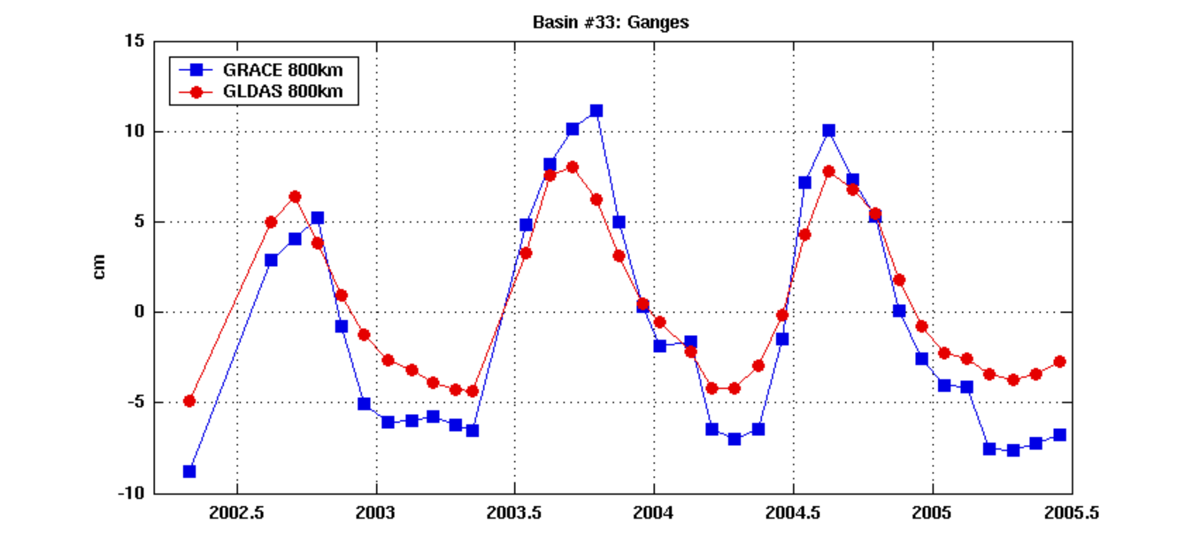
GRACE/GLDAS Comparison in Mississippi





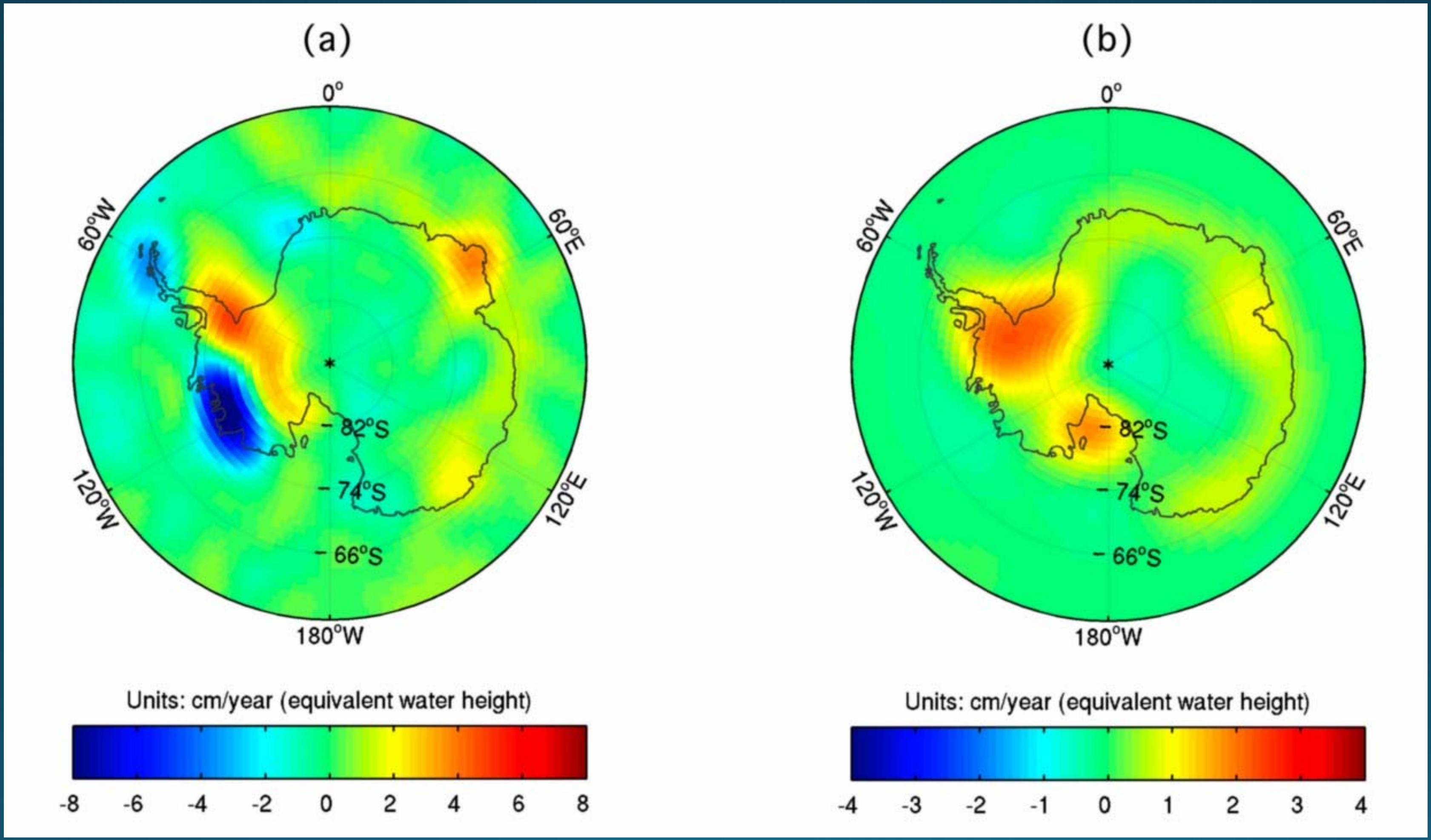
GRACE/GLDAS Comparison in Ganges





GRACE-observed mass change rates (in cm/year of water height) over Antarctica, P4M6 + 300 km Gaussian smoothing.

PGR effects (in mass equivalent) over Antarctica from the IJ05 PGR model, P4M6 + 300 km Gaussian smoothing.



(Please note the different color scales, ± 8 vs. ± 4.)

New Drought Indicators Based on GRACE Satellite Observations

Matthew Rodell, Code 617, NASA GSFC; Bailing Li and Hiroko Beaudoing, ESSIC and Code 617, NASA GSFC

Drought costs the U.S. economy upwards of $8 billion per year. The U.S. Drought Monitor (USDM) is the nation's premier decision support tool for drought assessment, used by farmers, disaster aid officials, agricultural commodities interests, and even *USA Today*. Previously, the USDM authors had lacked information on groundwater storage conditions and had little objective information on soil moisture, two key indicators of drought. Through this project, those two information gaps are being filled, and the USDM authors are now testing the new drought indicators presented here as inputs to their maps.

Drought may be defined as a deficiency, relative to the long term average, of water stored on and in the land, including surface waters, soil moisture, and groundwater. The latter two variables are difficult to measure over large scales using conventional, ground-based techniques. Thanks to satellite observations from NASA's Gravity Recovery and Climate Experiment (GRACE) mission, such data are now becoming available. However, GRACE's spatial and temporal resolutions are low, there is a data latency of 2-3 months, and GRACE does not differentiate one form of land water storage from another. By synthesizing GRACE with other observations within a sophisticated numerical model of land surface water and energy processes, we are able to generate weekly data fields of wetness conditions in the soil and shallow aquifers, with the resolution and timeliness necessary for operational drought monitoring (Figure 1). Maps of these data fields are available from **http://www.drought.unl.edu/MonitoringTools.aspx**

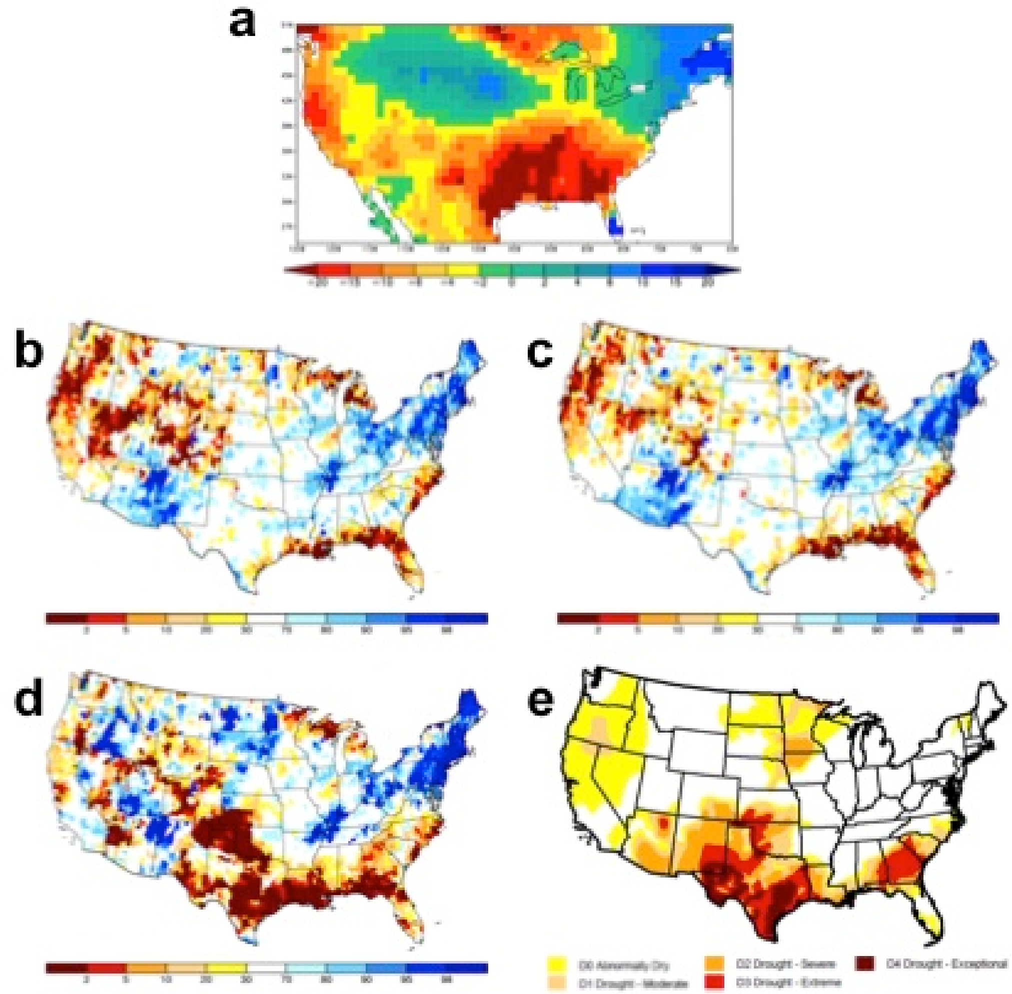
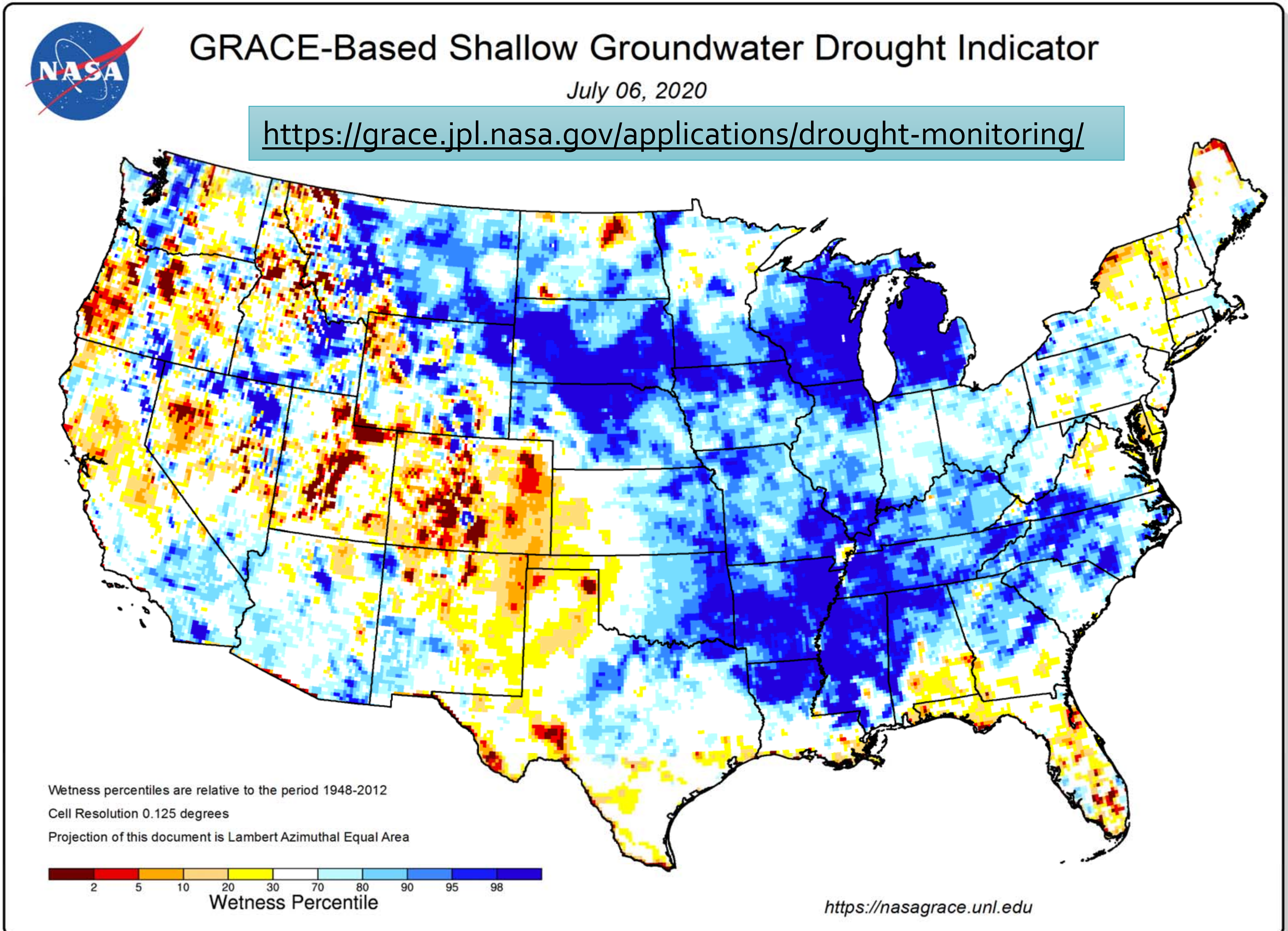


Figure 1: (a) GRACE terrestrial water storage anomalies (cm equivalent height of water) for November 2011; (b-d) surface soil moisture, root zone soil moisture, and groundwater drought indicators from GRACE data assimilation (wetness percentiles relative to the period 1948-present) for 26 December 2011; (e) U.S. Drought Monitor product for 27 December 2011.


GRACE-Based Shallow Groundwater Drought Indicator
July 06, 2020
https://grace.jpl.nasa.gov/applications/drought-monitoring/
Wetness percentiles are relative to the period 1948-2012
Cell Resolution 0.125 degrees
Projection of this document is Lambert Azimuthal Equal Area
2 5 10 20 30 70 80 90 95 98
Wetness Percentile
https://nasagrace.unl.edu