NASA Assets Used to Detect, Monitor and Measure the Deepwater Horizon Oil Spill

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NASA's response to the BP Deepwater Horizon Gulf of Mexico oil spill has several facets. NASA is using its satellite-mounted instruments to routinely monitor the oil slick, and the agency has also deployed several aircraft with remote sensing instruments.

The **Moderate Resolution Imaging Spectroradiometer (MODIS)** instruments aboard both the Terra and Aqua satellites provide large-scale visible and infrared synoptic views of the oil slick. MODIS has a relatively large measurement swath (2300km) and thus each MODIS instrument is able to view the entire slick twice a day (day and night) with 250m horizontal resolution (see Fig 1). Terra MODIS typically passes over the Deepwater Horizon site between 1600 – 1730 UTC (11:00 am – 12:30 pm CDT), whereas daytime Aqua MODIS passes over the region between 1830 – 2000 UTC (1:30 pm – 3:00 pm CDT). MODIS views of the oil slick are restricted by the presence of clouds, so the slick may be obscured or partially obscured on cloudy days.

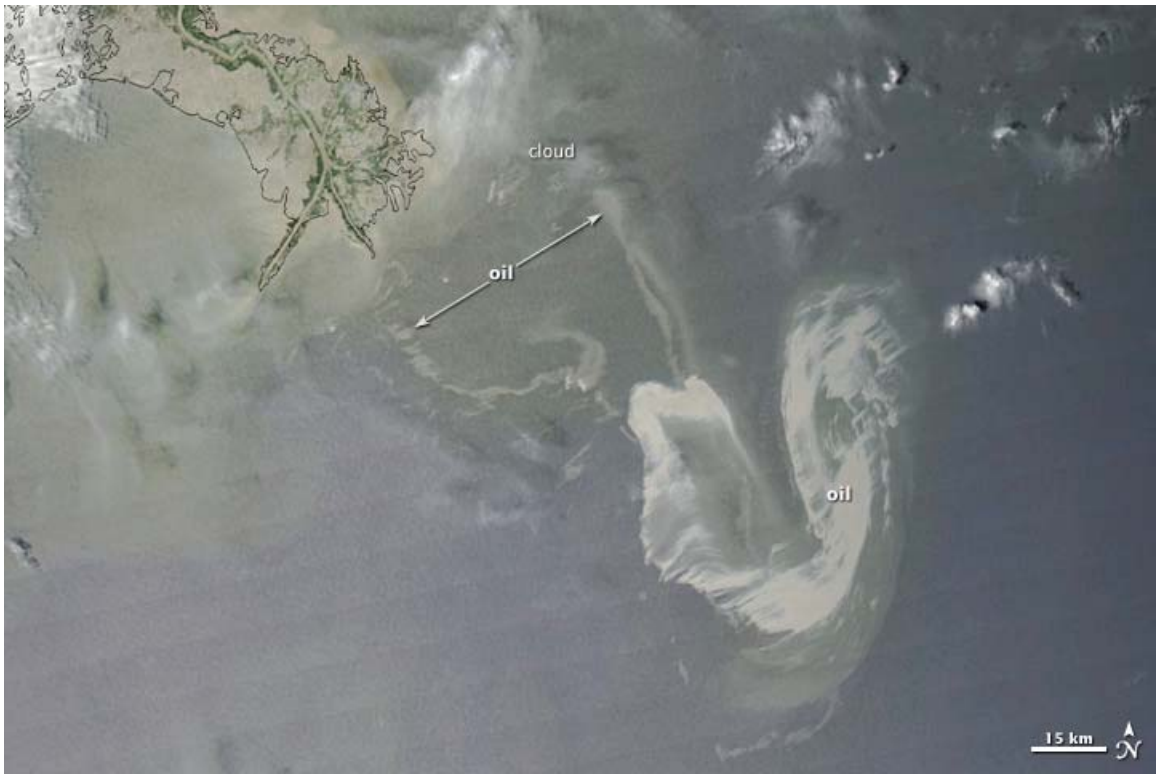

Fig 1. MODIS image of slick on 9 May 2010

The extent of the oil slick is most easily viewed and tracked using the visible channels or through a combination of channels but it can also be detected at night in the infrared. The MODIS instrument is sensitive enough to detect changes in surface temperatures between oil / water emulsion and the surrounding Gulf of Mexico waters (Fig 2).

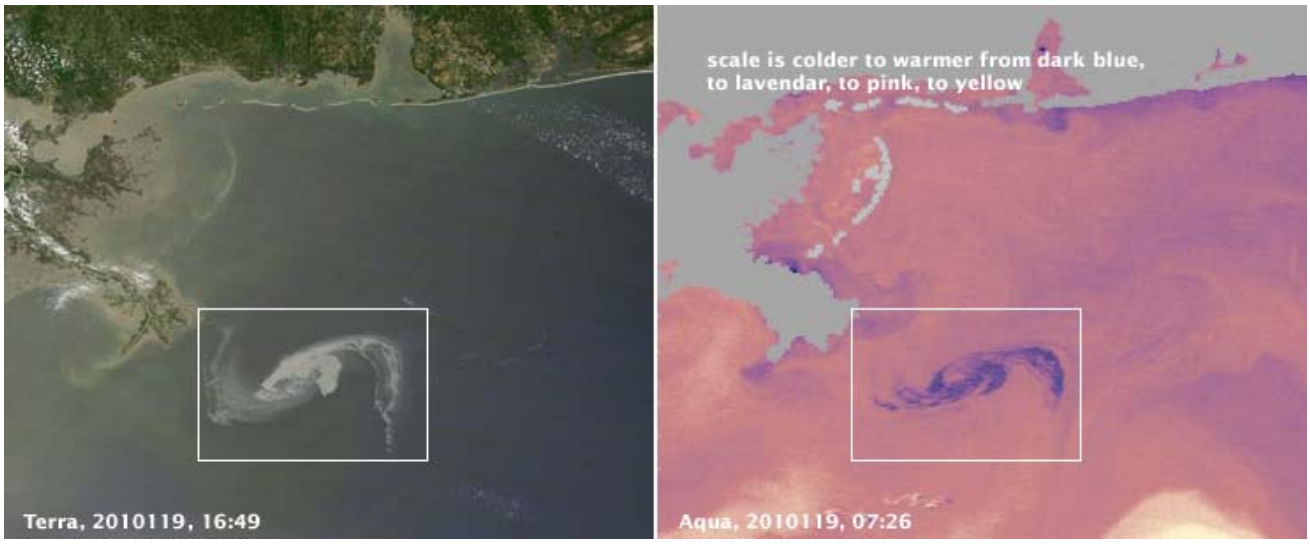

Fig 2. MODIS visible and infrared views of the slick on 29 April 2010

In addition to the MODIS instruments, the Japanese **Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)** on Terra is also viewing the slick. ASTER has visible/near infrared, thermal infrared and shortwave infrared sensors. ASTER has a much narrower swath field of view (60 km) but with higher spatial resolution (15m to 90m). Because it has a much smaller FOV, ASTER does not observe the slick daily and even when it does it only see a portion of the widespread slick. For example, since 1 May 2010 ASTER has viewed segments of the slick on 1 May, 3 May, 8 May, 10 May, 14 May and is scheduled to view it again on 17 May and 19 May 2010.

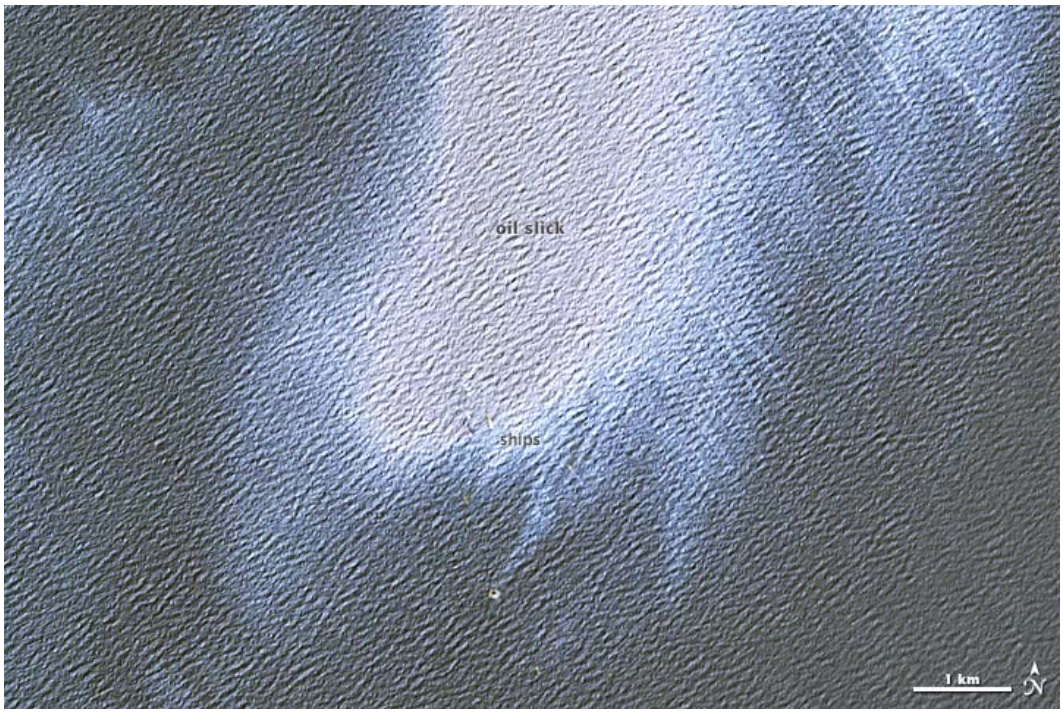

Fig 3. ASTER view of portion of slick on 1 May 2010

Oil colors the surface of the Gulf of Mexico in this detailed satellite image, acquired by ASTER on 1 May 2010. A false-color image is made from both visible and infrared light, but the slick looks similar to its appearance in natural-color images made solely from visible light. The most concentrated areas of oil are silver with slightly lighter concentrations radiating out in streaks of white. The water is black, though even the dark water is tainted with white, hinting at oil on the water's surface throughout the image.

Other satellite assets include the **Advanced Land Imager (ALI) and Hyperion instruments on NASA's Earth Observing-1 (EO-1)** satellite with even finer resolution 10-30m and swath FOV of 8-37 km. Like ASTER its narrower FOV limits its observations of the slick to every two to five days.


Fig. 4 EO-1 Advanced Land Imager view of the slick on 25 April 2010

All of these observations are being transferred to the interagency Hazardous Data Distribution System (HDDS) operated by the US Geological Survey, Sioux Falls, SD. The HDDS archives and distributes data from NASA, NOAA, USCG, USGS, DHS and many other agencies and organizations who are responding to contain the slick and develop recovery efforts.

Other NASA satellite instruments that have viewed the slick are the **Multi-angle Imaging Spectroradiometer (MISR)** on Terra and the **Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)** on the joint NASA-France CALIPSO satellite. The MISR is collocated on the Terra satellite with MODIS and ASTER.

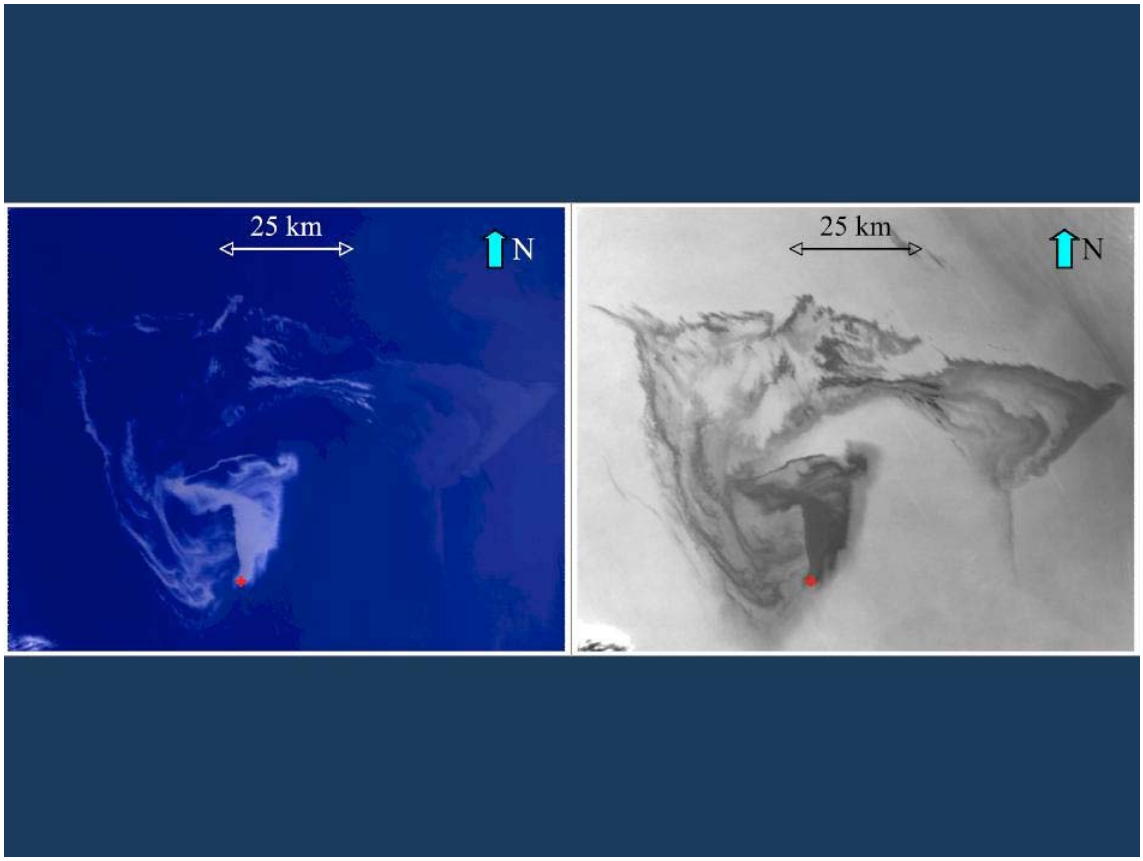

Fig 5. Multi-angle Imaging Spectroradiometer (MISR) on Terra

In figure 5, the image on the left is an enhanced view of the oil slick at 275 meter resolution from MISR's nadir-viewing camera. In this image the slick is about 200 km southeast of New Orleans, LA. The red symbol indicates the approximate position of the Deepwater Horizon platform and the source of the oil slick. Oil is lighter than water and will float on top of the water surface, suppressing small waves and changing the way the surface reflects light. This change in the reflection of sunlight makes the oil slick appear lighter blue on the darker blue waters of the Gulf of Mexico. Some clouds are visible in the extreme lower left corner of the image. The image on the right (Fig 5) is a multi-angle composite image of the oil spill showing the ratio between the reflectance of the aftward viewing camera and the forward viewing camera. The uncontaminated water appears much lighter.

NASA's spaceborne instruments are primarily detecting the extent (presence) and locations of the slick. NASA also has airborne instruments that can provide much higher resolution observations and have the ability to make frequent passes over the shoreline, wetlands and the oil slick. At the request of NOAA, NASA is flying the ER-2 aircraft with the **Airborne Visible Infrared Imaging Spectrometer (AVIRIS)** and the **Cirrus Digital Camera System** (~1.5 m resolution) The ER-2 is a high altitude plane (can fly up to 65,000 ft) that is collecting data along the coastal zone from Texas to Florida (primarily at 45,000 ft) and over oil spill primarily at 28,000 ft. The AVIRIS instrument cannot view the slick through clouds so flights are

restricted to relative cloud free days. Figure 6 shows the combined track of the four ER-2/AVIRIS flights during the period 6-15 May 2010.

Figure 6. ER-2 flight tracks from 6 May, 10 May, 11 May and 13 May 2010. The Deepwater Horizon well head is symbolized by the fire icon in the center of the image.

The AVIRIS team led by Robert Green, Michael Eastwood, and Ian McCubbin of Jet Propulsion Laboratory are measuring how the water absorbs and reflects light in order to map the location and concentration of oil, which has separated into a widespread, thin sheen and ribbons of concentrated oil streams. Satellites can document the overall extent of the oil but have difficulty distinguishing between the sheen and concentrated ribbons and patches of oil and oil. AVIRIS should be able to identify the oil concentrations. After each flight, the AVIRIS team is generating calibrated radiance cubes of the 224 spectral channels and transferring the radiance data sets to the USGS-Denver where Roger Clark/USGS is using experimental algorithms to identify the oil mass and volumes of oil observed in the AVIRIS scenes.

The intent is for the USGS-derived oil concentration product to be provided to the NOAA Office of Response and Restoration for use as inputs into the NOAA oil trajectory models. Trajectory models help guide recovery efforts by showing which locations are most likely to need resources, such as lengths of boom, to protect the shoreline.

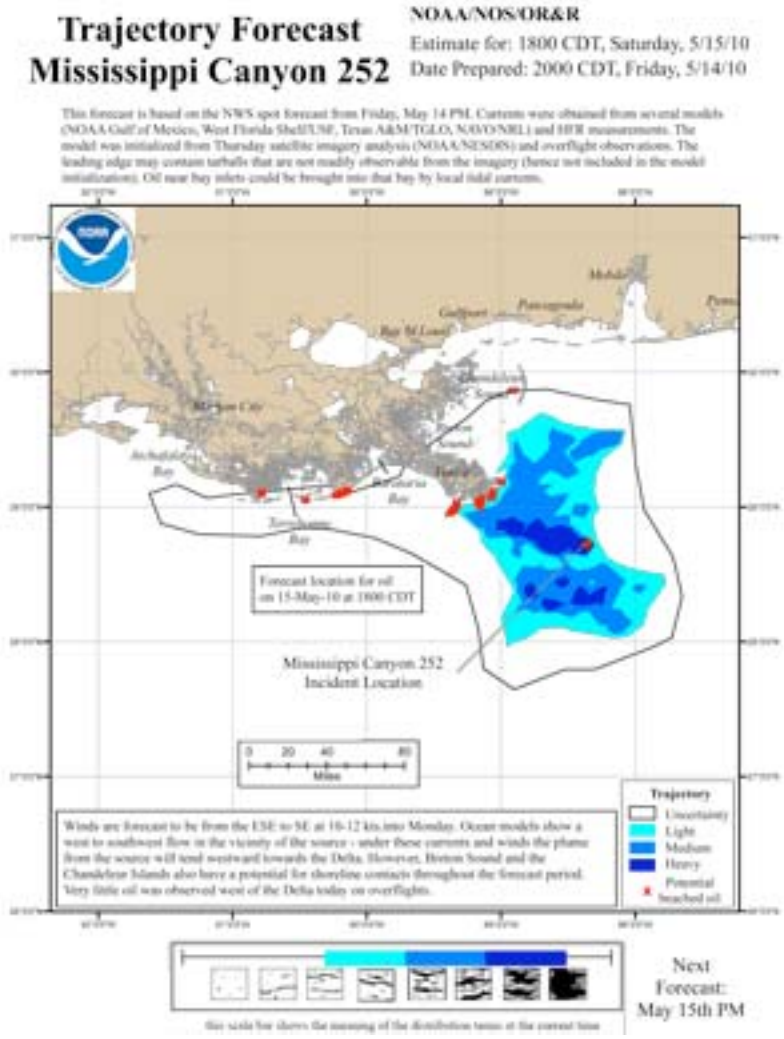

Fig. 7. Trajectory model valid for 15 May 2010 prepared by the NOAA National Ocean Service / Office of Response and Restoration

NASA airborne researchers also plan to measure changes in vegetation along the coastline and assess where and how oil may be affecting marshes, swamps, bayous, and beaches that are difficult to survey on the ground. The combination of satellite and airborne imagery will assist the federal and state agencies in documenting changes in the ecosystem. It is critical to make observations of the coastal zone before the oil inundation. Subsequent post-inundation measurements will enable the assessment of the extent of the oil infiltration into the coastal wetlands and its ecological impact.

NASA is also deploying the **Unmanned Aerial Vehicle Synthetic Aperture Radar** (UAVSAR) to study ecosystem response and recovery. The UAVSAR instrument, which currently flies on a manned Gulfstream-III aircraft, will be used to estimate the impacts of the oil on the coast and marshes, and as an input parameter to understand how the marshy ecosystem responds and recovers. Yunling Lou and Cathleen Jones / JPL will lead the UAVSAR efforts and analyses. The approach is to monitor the region on seasonal to annual time scales in order to differentiate ecosystem response of oil impacted areas from nominal seasonal behavior. A combined high resolution data set composed of hyperspectral measurements and polarimetric SAR data will provide a unique scientific tool for comparison with *in situ* observations and use in modeling efforts. The UVASAR is due to arrive in Pensacola FL around 18 May and will conduct two or three flights (12-14 flight hours) over the LA-MS-AL-FL coastal zone and over the slick. Subsequent flights in late May / early June after the oil impact and then again in late summer and early winter will measure the impact of the oil on the coastal ecosystems.

Selected NASA satellite data sets images (e.g., MODIS, ASTER, EO-1), AVIRIS calibrated radiances and quick-looks, and the Cirrus Digital Camera System (DCS) images are being archived daily at the Hazardous Data Distribution System (HDDS) at the U.S. Geological Survey's Earth Resource Observations and Science data center in Sioux Falls, SD. The HDDS is serving as the interagency data distribution system where Gulf Oil Spill scientists and first responders have access to several layers of data, images, and quick-looks as appropriate for their level of interest and image analysis capabilities. The satellite data are also archived within the NASA Earth Science Data and Information System (ESDIS) Distributed Active Archive Centers (DAACs) while the AVIRIS data are archived at JPL.

NASA AVIRIS and DCS Quick Look images are generated at JSC in approximately 3-6 hrs for AVIRIS and approximately 2 hrs for the DCS. These are then sent via the Internet to HDDS. All raw data is sent to JPL under the normal AVIRIS flight disk process, which ships disks to the AVIRIS Data Facility several times a week. The immediate priority is providing quick look geo-tiffs and radiance data to USGS for first responders and spectroscopy lab analysis.

Calibrated AVIRIS radiance cubes are generated at JSC in 6-12 hrs following the end of each flight. They are then transferred via the Internet to HDDS and to the USGS Spectroscopy Lab in Denver. Transfer times vary depending on the size of the data set (6 hrs for 20 Gbytes). In addition, radiance data cubes are overnight expressed to NGA.

USGS sends the NASA data to first responders in the form of images. In subsequent analyses, the USGS Spectroscopy Lab converts the data to reflectance for generation of oil volume estimates.

NASA ER-2/AVIRIS flights

Sortie Date and Number	Flight Hours
5/7/2010 Transit and first images - Sortie 100915	9.9 (4.5 Transit)
5/10/2010 Sortie 100916	7.2
5/11/2010 Sortie 100917	4.0
5/13/2010 Sortie 100918	5.1
Planned Sortie 5/17/2010	7.2

NASA has also flown LaRC B-200 King Air with both the High Spectral Resolution Lidar (HSRL), from NASA Langley and the Research Scanning Polarimeter (RSP), from NASA's Goddard Institute for Space Studies in New York. The purpose is to help determine oil thickness and density and the density of phytoplankton near the surface. The HSRL flight is ultimately a verification method for the similar lidar instrument on the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite.

Sortie Date and Number	Flight Hours
5/10/2010 Sortie R 218 B	2.8
5/11/2010 Sortie R 218 B	3.3