

The Effectiveness of Using MODIS Products to Map Sea Surface Oil

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Abstract-This project describes the effectiveness of using standard Moderate Resolution Imaging Spectroradiometer (MODIS) imagery and products, produced by NASA and distributed through the Distributed Active Archive Centers (DAACs), to monitor and map oil on the surface of the Gulf of Mexico from the oil release at the Deepwater Horizon site. With twice daily coverage of the Gulf of Mexico and the rest of the world, MODIS is well suited to monitor the effects of these types of incidents on the sea surface. MODIS imagery has been widely used by many federal, state, and local agencies, as well as the media and non-government groups to illustrate the distribution and movement of surface oil. The MODIS products evaluated for their effectiveness in mapping and monitoring oil and the sea surface include: imagery, sea surface temperature (available for nighttime and daytime temperatures), chlorophyll concentration, particulate organic/inorganic carbon, chromophoric dissolved organic matter index, diffuse attenuation coefficient, and remote sensing reflectance. These products were chosen because they are available on a daily basis. Some MODIS standard products are only available as eight-day composites which would not be as useful for monitoring a feature as dynamic as oil moving on the sea surface. MODIS standard products are produced by applying atmospheric corrections and algorithms to selected bands of MODIS data. The bands primarily used for ocean products are bands 8-16 which have a spatial resolution of 1 km. Additional products may be evaluated. The Deepwater Horizon oil rig exploded and caught fire on April 20, 2010. The drilling platform sank several days later. The well ruptured at the seafloor, 5000 feet below the sea surface, and began leaking a combination of crude oil and natural gas. As of July 15, 2010, the oil leak was capped. The Deepwater Horizon site is located approximately 58 miles southeast of the mouth of the Mississippi River in southeastern Louisiana. The effectiveness of the MODIS products was determined by comparing the MODIS data with surface water samples and digital photography taken aboard the research vessel *Pelican* between May 5 and May 15, 2010 within the Gulf of Mexico. During that scientific mission, the presence or lack of surface oil was reported, coordinate locations were recorded, and water and oil samples were collected. The majority of these samples were taken within 10 miles of the Deepwater Horizon site, while some were taken up to 72 miles away. During the research trip aboard the *Pelican*, the surface oil was not consistently present in some areas, but tended to shift due to wind and currents. Particular sites have a useful temporal aspect since they were repeatedly visited for sampling. Sun glint areas on MODIS true color imagery make surface oil especially evident. It is anticipated that the MODIS standard products will detect the oil on the sea surface that is not evident in the visible portion of the imagery spectra.

I. INTRODUCTION

The Deepwater Horizon oil well rupture of April 20, 2010 resulted in oil leaking from the well at the seafloor. The resulting surface oil needed to be tracked to facilitate oil skimming and collection, verification of models and other public information needs. The availability of public MODIS (Moderate Resolution Imaging Spectroradiometer) imagery and some standard products on a daily level is well suited for use in assessing the extent of the surface oil. MODIS is a passive sensor, therefore the imagery does require relatively cloud free conditions and frequently produces images with sun glint which may affect processing for standard products. MODIS imagery has previously been used in relation to oil spills [1,2,4,5,7], and a major resource used is MODIS imagery that has sun glint. The effectiveness of MODIS imagery and ocean standard products was assessed for a time period of May 5 to May 15, 2010 for seas in the area of the Deepwater Horizon well rupture within the Gulf of Mexico. This time period corresponded with a trip of the research vessel *Pelican* for the National Institute for Underwater Science and Technology (NIUST) from which surface water samples and photography were taken within and outside of oil contaminated areas. Fig. 1 shows the location of the samples.

II. METHODOLOGY

MODIS imagery was acquired from the MODIS Rapid Response System and Ocean Color Web for the time period and assessed for cloud cover and sun glint conditions. MODIS ocean standard products were acquired from Ocean Color Web and the University of South Florida MODIS direct broadcast. The daily ocean standard products analyzed were sea surface temperature (available for nighttime and daytime temperatures), chlorophyll concentration, particulate organic/inorganic carbon, chromophoric dissolved organic matter index, diffuse attenuation coefficient, and remote sensing reflectance. These standard products were examined for anomalies in proximity to the Deepwater Horizon site. If a possible relationship between an anomaly and the oil site was evident, the NIUST samples were used to confirm the presence or lack of oil on the surface. Imagery was also used to visually verify the position of the oil in relation to the anomaly.

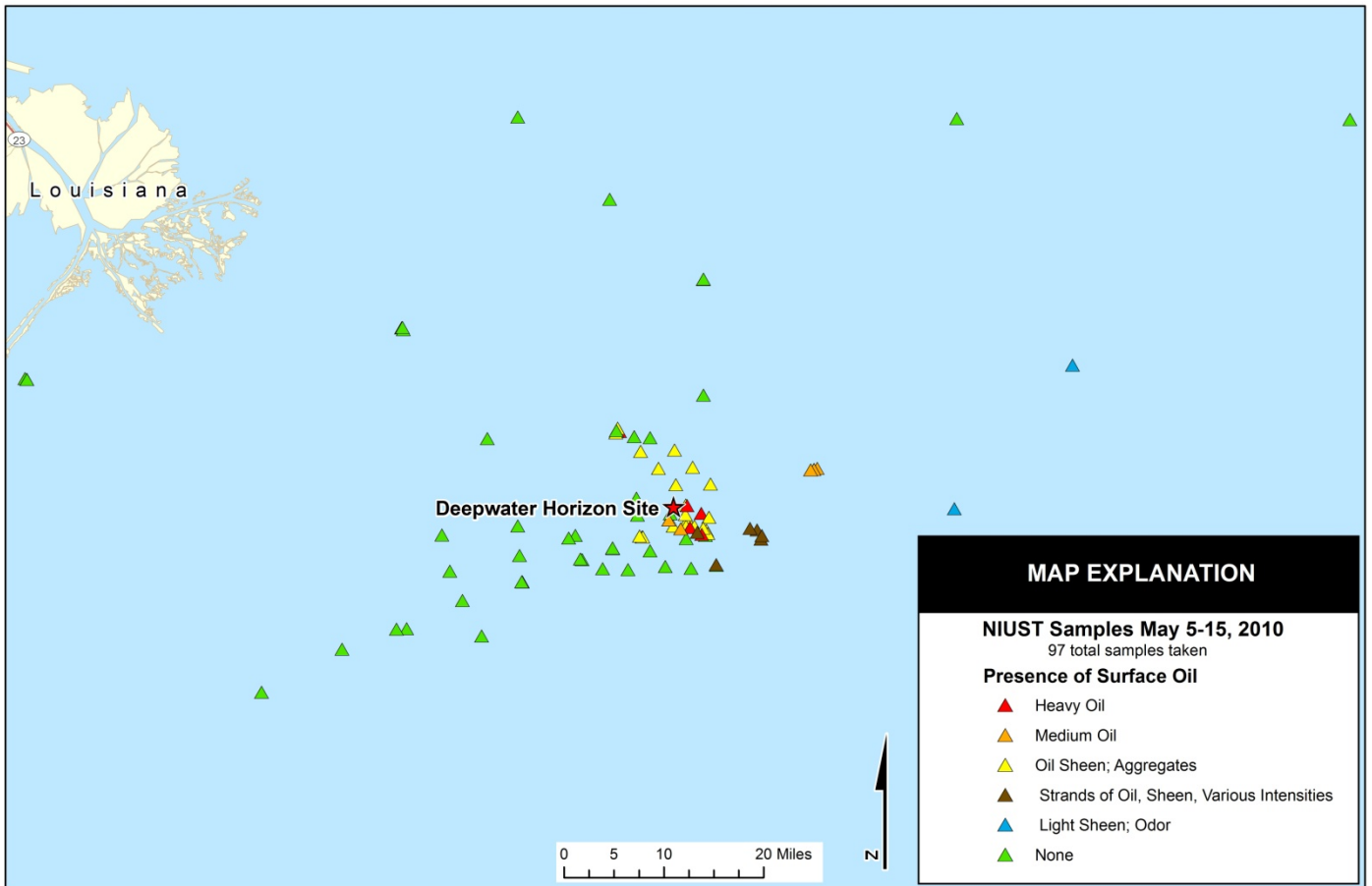


Fig. 1. Location of NIUST samples taken from May 5-15, 2010 in the Gulf of Mexico.

Methods for using remote sensing to map oil have involved different types of imagery and products and combinations. Reference [2] used a combination of Synthetic Aperture Radar (SAR), Medium Resolution Imaging Spectrometer (MERIS), and MODIS because SAR lacks the temporal resolution of MERIS and MODIS. The use of optical sensors, namely infrared, is the most commonly used oil detection tool because it is relatively less expensive than radar, however radar seems to be very effective [3].

III. DATA

A. Sea surface temperature

The sea surface temperature standard product (nighttime and daytime) does not seem well suited to consistently detect surface oil. Cloud cover, even very thin, can affect data availability. Within the May 5-15, 2010 time period, the surface oil does not appear to be thick enough to cause a difference between the sea surface temperature and the oil temperature. A reason for this could be due to the use of booms and other oil collecting methods. Reference [7] suggested that if the oil is thin, it is in thermal equilibrium with the surrounding water and will not show a difference in temperature. During the Deepwater Horizon oil well leak, oil has been visible from sea surface temperature differences [4], but this instance appeared to be at a time of very thick surface oil on April 29, 2010.

B. Chlorophyll concentration

Mixed results were seen with the chlorophyll concentration product. Fig. 2 shows an unusual “tail” that sweeps down east of the Deepwater Horizon site on May 12, 2010. It is uncertain if this difference in chlorophyll concentration is indicating oil or an increase in algae. Cloud cover and a lack of a sun glint make the oil difficult to see on true color imagery, however, the general shape of the tail and the location are consistent with the surface oil seen on MODIS Aqua imagery from the previous day [Fig. 3]. When compared to the surface samples taken by the NIUST researchers near the Deepwater Horizon site, a positive correlation may exist, but it is not conclusive. The high concentration of chlorophyll east of the mouth of the Mississippi River in this area seems atypical and no report of an algal bloom from NOAA could be found. Using this standard product alone would not be effective for monitoring surface oil.

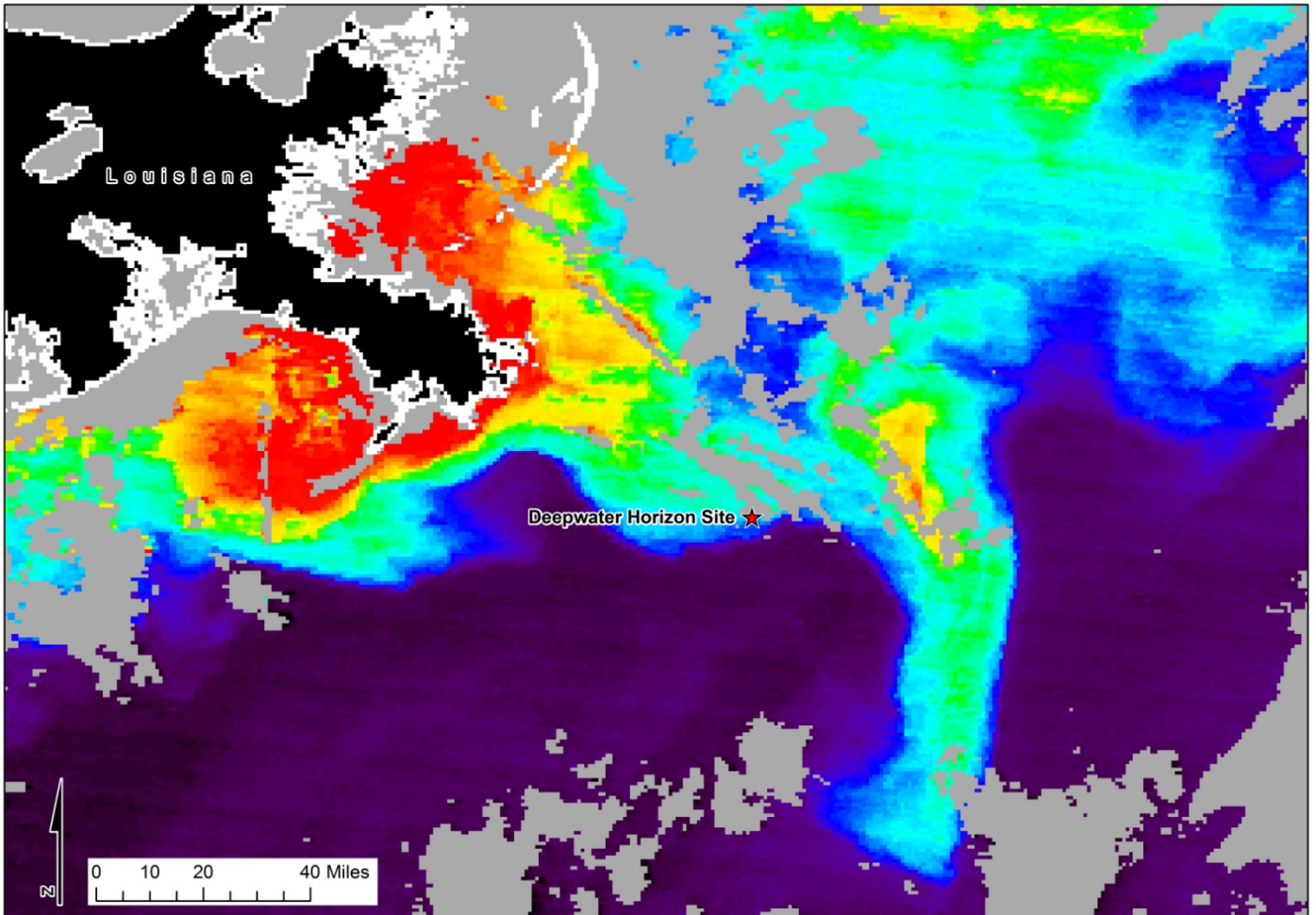


Fig. 2. Chlorophyll concentration from MODIS Terra on May 12, 2010. Red to violet is high to low concentration. Data from University of South Florida.

C. Other MODIS standard products

The remaining standard products that were examined (particulate organic/inorganic carbon, chromophoric dissolved organic matter index, diffuse attenuation coefficient, and remote sensing reflectance) seemed inadequate for detecting surface oil. A large factor in this inadequacy is from a lack of data resolution. Fig. 4 shows the particulate inorganic carbon concentration for May 12, 2010, with the Deepwater Horizon site represented with the red star. A possible increase in concentration is seen to the southeast of the site, but the resolution is lower than other MODIS products at 4 km and this makes it difficult to delineate anomalous features. Possible connections between surface oil and particulate organic carbon, remote sensing reflectance at 547 nm and 531 nm, and diffuse attenuation coefficient were seen but could not be confirmed due to the low resolution data products.

IV. LIMITATIONS

Several limiting factors may be affecting the ability of MODIS data and standard products for mapping and monitoring the effects of the oil release in the Gulf of Mexico. These include cloud cover, surface oil thickness, and lower resolution of some of the data products, which were mentioned before, but specifically, dispersant use. In addition, the use of dispersants during the May 5-15, 2010 cruise could be contributing to the lack of sufficient surface oil that could be detected from the standard MODIS products. When sea surface temperature was effective in showing surface oil on April 29, 2010 [4], major dispersant use had not occurred. By May 6, 2010, aerial spraying of dispersant had begun. The dispersal of the oil may have reduced the oil thickness and changed the optical properties of the oil so that it is not as detectable as in previous studies. Fig. 5 shows a band of sea surface oil in the Gulf of Mexico that is dispersing into much smaller particles. This is an area that merits further research to determine better sensors and products to detect dispersed oil at the surface.

V. CONCLUSIONS

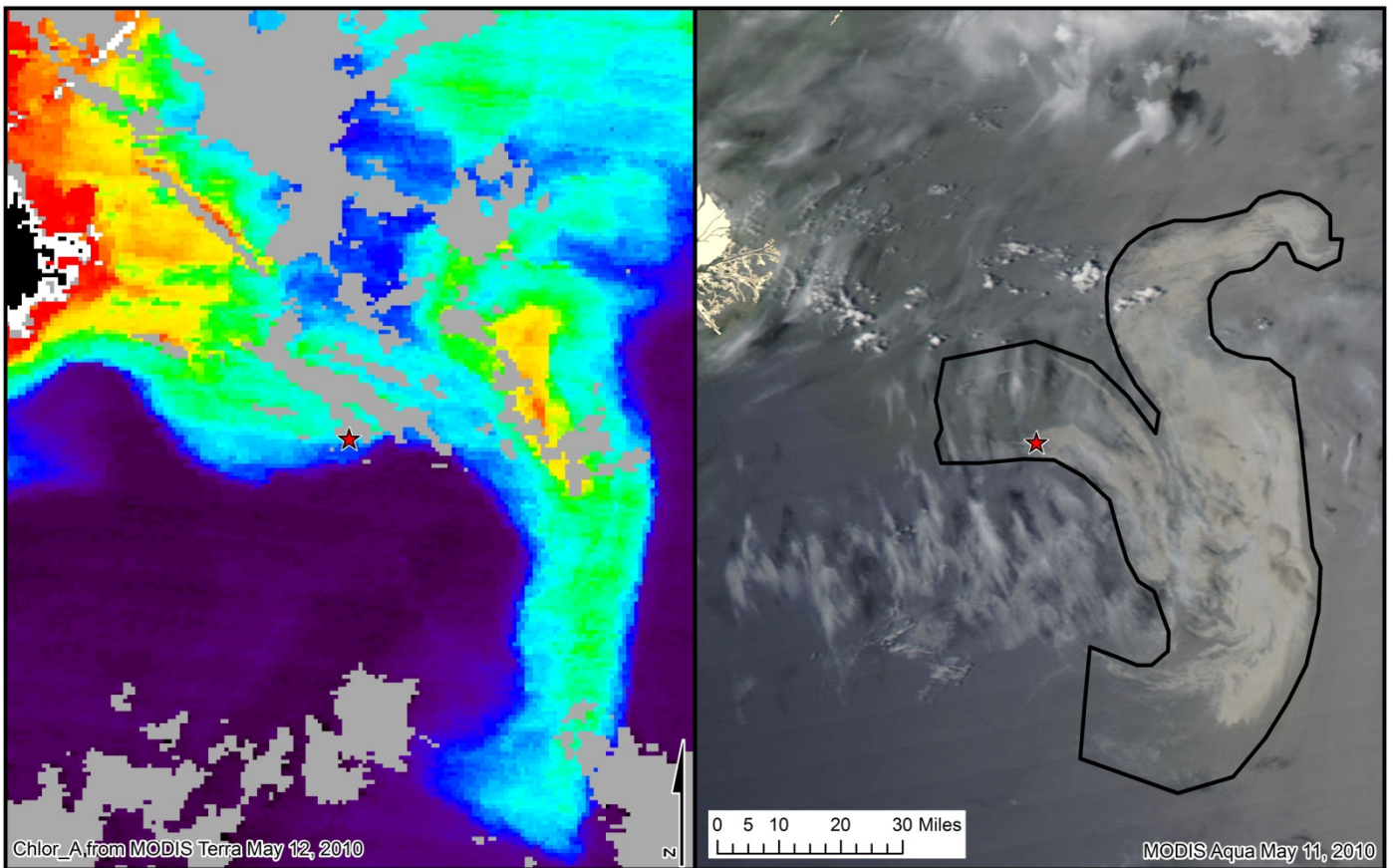


Fig. 3. Comparison of chlorophyll concentration from May 12, 2010 to approximate oil area (outlined in black) from May 11, 2010. Deepwater Horizon site is the red star.

The use of publicly available daily MODIS standard products was not as effective for mapping sea surface oil for the Deepwater Horizon oil well rupture, the biggest oil disaster in history. Reference [5] was more successful in using direct broadcast MODIS imagery to delineate oil on Lake Maracaibo, Venezuela. Using combinations of resources such as SAR and

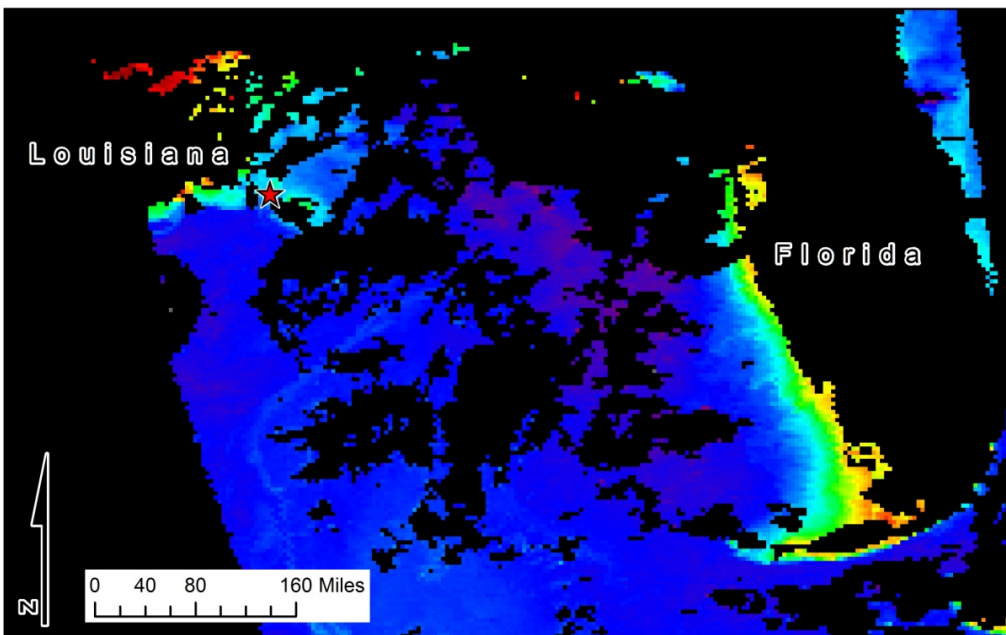


Fig. 4. Particulate inorganic carbon concentration from MODIS Terra May 12, 2010. Red to violet is high to low concentration. Data from Ocean Color Web. Deepwater Horizon site is the red star.

high temporal resolution satellite imagery is very effective at mapping surface oil and rather economical as well. The most consistent method for detecting the oil in this Deepwater Horizon oil disaster has been using sun glint on true color imagery. The use of satellite imagery is not as accurate as other methods of oil spill detection like airborne methods (laser fluorosensors, IR/UV sensors, microwave radiometer sensors, and others) [6], but that does not mean that it should be discounted or not be used in conjunction with other methods. Further investigation into how dispersants affect the properties of oil on water is needed.



Fig. 5. Contact zone of blue-green Gulf water and oil from the Deepwater Horizon well floating at the surface, approximately 1km from the position of the Deepwater Horizon site. Large aggregates are visible in the blue-green water, apparently separating from the oil. Image taken aboard the R/V *Pelican* in the Gulf of Mexico on May 7, 2010.

ACKNOWLEDGMENTS

We acknowledge the support of the US National Oceanic and Atmospheric Administration, the US National Science Foundation, and the US National Aeronautics and Space Administration. We also thank the Captain and crew of the R/V *Pelican* for their efforts.

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