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Utilizing Remote Sensing to Detect Deepwater Horizon Oil Spill Properties

Amanda Kristedja

Abstract

This paper focuses on the detection of oil spills using satellite information. For this research project, the focus will be primarily on the Deepwater Horizon Oil Spill, which is the largest accidental oil spill. In order to detect an oil spill, the chlorophyll $a$ content must be observed with data from the SeaWiFs at 9km and the MODIS-aqua at 9km and 4km. There is conflicting evidence of whether or not chlorophyll a concentration is positively correlated with the presence of an oil spill. This will be further investigated in the experiment. Also, by utilizing the MODIS instrument aboard the terra and aqua satellites, the amount of solar radiation during the day can be measured, particularly at the wavelength 443nm. Also related to the reflectance of the area of the oil spill is the sea surface temperature. The sea surface temperature can be measured by the MODIS-aqua and MODIS-terra at 9km during the day and night. It is hypothesized that high levels of dissolved organic matter also suggest the presence of an oil spill. Measurements from the SeaWiFs at 9km and the MODIS-aqua at 9km and 4km can be analyzed to show the levels of dissolved organic matter. The measurements of these specific parameters help to detect oil spills as well as to show the effects that oil spills have on the surrounding environment. For this study, measurements from these satellites over the Gulf of Mexico are taken before, during, and after the occurrence of the Deepwater Horizon Oil Spill that occurred between April and July 2010. These measurements show that there are positive correlations between the presence of an oil spill and both the chlorophyll a concentration and reflectance of the oil spill. In contrast, sea surface temperature was found to be lower in the area of the oil spill. Evidence from colored dissolved organic matter in the affected area proved to be inconclusive.

Keywords: Oil Spill, Deepwater Horizon Oil Spill, MODIS-aqua, MODIS-terra, Chlorophyll

1. Introduction

Oil spills are a hazard introduced to the Earth by human activity. Oil spills are a pollutant specifically called liquid petroleum hydrocarbon. Sources of oil spills include oil platforms and rigs in the middle of the ocean as well as leaking from a crude tanker and other large ships. Although there are natural occurring oil seeps, these are usually over land rather than ocean and are not as much of a concern as the spills that are a result of human activity. Some environmental effects include the injuries and deaths of marine life. Also, if the oil sits on top of the water, it can hinder the sun's rays from reaching plant life and phytoplankton that reside on the Earth's ocean floor. Oil-consuming bacteria exist in nature and help in the process of removing the oil from the area. However, this is a slow process that merely acts as a cleaning agent, but does not prevent any of the harm to the marine life. Human efforts to clean these oil spills are present as well. There are many methods of extracting the oil from the ocean, yet some of them require specific conditions and others actually contribute to pollution.

Having the ability to detect oil spills is one of the first steps to eradicating them. If the presence of an oil spill is unknown, nothing can be done to stop it or slow its spread throughout the ocean. The most efficient way known to detect oil spills is with remote sensing.
The purpose of this paper is to present the results of the study of remote sensing detection of oil spills. There are several remote sensing sensors and instruments that are able to detect the presence as well as environmental effects of accidental oil spills. This study specifically analyzes data retrieved from sensors provided by NASA to analyze the Deepwater Horizon Spill. Data-processed images supplied by NASA from the year before the oil spill and the time frame of the oil spill are the basis of this study.

2. Deepwater Horizon Oil Spill

The Deepwater Horizon Oil Rig located in the Gulf of Mexico exploded on April 20th, 2010. The explosion killed 11 men and injured 17. In addition to human lives being compromised, the marine life and plant life in the surrounding area suffered greatly for months. The oil spill also endangered some species of birds and turtles native to the area. Oil causes animals to drown, die from hypothermia, become hydrated or even constrict their movement, causing them to die. Those animals that did survive the effects of the oil spill now have to live in a destroyed habitat. These consequences of the oil spill were immense due to the fact that this spill is the largest oil spill since the beginning of human extraction of oil. On July 15th, the oil spill was finally stopped after it had already leaked 4.9 million barrels of crude oil. The oil rig was owned by the oil and gas company, British Petroleum, more often referred to as BP. Therefore, BP was claimed as responsible for the cost of damage as well as the cleanup of the oil.

The removal of the oil spill was not as simple as with other oil spills due to its size. The original plan was to burn large portions of the oil away. However, because of the size, conditions, and the amount of environmental damage expected, the burning option was not executed until later. When conditions allowed burning of the oil, this method was used as well. Since burning of the oil was not available at the beginning of the oil spill, BP employed numerous machines remove the oil. These machines were designed to separate oil from water, which greatly helped to reduce the amount of oil. Skimmers were also originally banned at the start of the oil spill. Skimmers are small devices that float over areas with oil and extract the oil from the water, but later a skimmer was brought to the site without any significant results. The most interesting method of removing the oil was the oil eating microbes which were genetically engineered to digest oil. Unfortunately, the effects of this effort were not significant. In addition, since these microbes are a form of bacteria, it has been announced that the microbes are the possible cause of strange skin rashes found in people that live in the area. The most effective methods of removing the oil from the Gulf of Mexico were the burning of the oil and the separation of oil and water via machines.

3. Instruments and Parameters

The source of data for this experiment is NASA’s online application, Giovanni, that allows anyone to analyze visual representations of remote sensing data. In order for this site to be useful, some level of understanding of the sensors and parameters is necessary. Giovanni has multiple interfaces, called instances that are grouped by scientific community. The instance that specifically applies to this study is ocean color radiometry. Within this instance there are multiple sensors which are each capable of measuring varying parameters. The four sensors which are used in this experiment are SeaWiFS at 9km, MODIS-aqua at 9km, MODIS-aqua at 4km, and MODIS-terra at 9km. The four parameters of interest for this study are: chlorophyll a content, colored dissolved organic matter, reflectance, and sea surface temperature. The SeaWiFS and MODIS-aqua instruments both have the capability to measure chlorophyll a content, colored dissolved organic matter (CDOM), and reflectance at 443nm. In addition to those three parameters, MODIS-aqua has the ability to measure the sea surface temperature, along with MODIS-terra.

These four parameters were chosen for this study to confirm the hypothesis that they indicate an oil spill. One hypothesis is that in the presence of an oil spill, the chlorophyll a content increases. One particular research experiment "did not find significant differences in the chlorophyll a concentration of the polluted and reference sediments" (Riaux-Gobin). However, in another experiment that deals with the effects of oil on chlorophyll a content, results showed that oil was a cause of increase in chlorophyll a content (Fabregas). For this discrepancy in the effect of oil spills on chlorophyll a content, this parameter is included in this study to try and retrieve more
conclusive data about the relationship between chlorophyll a content and the presence of an oil spill. Another hypothesis is that the amount of colored dissolved organic matter also increases. Another experiment found that "the dissolved organic matter concentration of the ground water increased to 50mg C L−1 adjacent to the oil spill" (Ryan). Also, the reflectance should be higher in the area of an oil spill due to the physical properties of the oil. Oil, especially on the surface of the water, has sheen to it, causing the sunlight to be reflected back into the atmosphere and towards the satellites. Sunlight penetrates the surface of clean ocean water, therefore having a lower reflectance than that of an oil spill. As a result of an increase in reflectance, the sea surface temperature should be lower in areas of an oil spill and higher in the surrounding areas of clean ocean water. Since oil spills reflect the sunlight and reflectance and absorption are opposites of each other, oil spills do not absorb the sunlight, hence resulting in a lower temperature.

Through the Giovanni website the information can be arranged in several different ways. For this study, time-averaged Latitude-Longitude maps are produced from data from these parameters and instruments. These maps show the data in the form of a color scale over the actual map of the area. The dark purple color indicates the least concentration of that particular parameter, while the red color indicates the highest concentration of the parameter. Each map needs to be interpreted differently depending on the parameter and the highest level of concentration listed for that image. This type of map was chosen for this study because we want to compare the location as well as the varying levels of concentration of the parameters of interest. These maps display the information in a much more meaningful way rather than observing a table of values of concentrations of each parameter.

4. Results

The time-averaged Latitude-Longitude maps generated from the SeaWiFS at 9km, MODIS-aqua at 9km, and MODIS-aqua at 4km, MODIS-aqua at 4km for each specific parameter, area, and time frame, were very similar to each other. However, the MODIS-aqua at 4km seemed to give the best image each time, so most of the images provided are from the MODIS-aqua at 4km. The sea surface temperature parameter was the one parameter that was not available on MODIS-aqua at 4km. It was only available on MODIS-aqua at 9km and MODIS-terra at 9km. MODIS-terra at 9km gave the best results for the sea surface temperature. The results discussed in this paper consider all of the maps from each of the sensors, but for visual purposes, the images provided for each parameter will only be from one sensor.

The time-averaged Lat-Lon maps for the chlorophyll a content were generated and analyzed from the data from the instrument MODIS-aqua at 4km. For the desired time frame, the only maps able to be produced were from select months from the year before and the year of the occurrence of the oil spill: April 2009, April 2010, May 2010, and June 2010. When comparing April 2009 and April 2010, it is clear that there is more chlorophyll content near the site of the explosion of the oil rig as well as towards the shore closest to the oil rig. The maps from May 2010 and June 2010 show higher concentrations of chlorophyll a near the shore closest to the oil rig, but not as much near the actual oil rig. The maps also display higher concentrations of oil between the site of the oil spill and the coast of Florida.
Figure 1.1: Chlorophyll a concentration for April 2009. Instrument: MODIS-aqua at 4km
The time-averaged Lat-Lon maps for the sea surface temperature were generated from data from the MODIS-terra instrument. Maps were created for each month, April to June, for the year before oil spill and the year the oil spill occurred were generated. Comparing April 2009 and April 2010, it is evident that the sea surface temperature off the coast is cooler in 2010 than it was in 2009. When comparing the two maps from May, the same result was evident. However, the overall temperatures in May were higher than they were in April for both years. When looking at the maps generated from June for both years, the cooler temperatures were slightly farther away from the coast in the year 2010.
Figure 2.1: Sea surface temperature (day) for April 2009. Instrument: MODIS-terra at 9km.
Figure 2.2: Sea surface temperature (day) for April 2010. Instrument: MODIS-terra at 9km.

Reflectance at 443nm also had Lat-Lon maps generated from the MODIS-aqua at 4km. The two maps for April show less reflectance near the shores and more reflectance towards the middle of the ocean. The maps for May 2009 and June 2009 were not available, but the maps for May and June of 2010 showed much brighter reflectance a small distance off the coast than in the map for April.
Figure 3.1: Reflectance at 443nm for April 2010.
Instrument: MODIS-aqua at 4km.
Figure 3.2: Reflectance at 443nm for May 2010. Instrument: MODIS-aqua at 4km.

Lat-Lon maps were generated from the parameter CDOM, or colored dissolved organic matter from data retrieved from the instrument MODIS-aqua at 4km. April 2009 shows higher concentrations of dissolved organic matter along the coast. April 2010 shows a similar pattern, except concentrations near the coast are not nearly as high as that of April 2009. However, the overall concentration of dissolved organic matter was much lower in 2010. The maps for May 2009 and June 2009 are unavailable, but the maps from May and June of 2010 show significant less concentrations of dissolved organic matter. June 2010 showed almost no dissolved organic matter at all in most of the region.
Figure 4.1: Colored dissolved organic matter for April 2010
Instrument: MODIS-aqua at 4km.
5. Discussion

Most of the results of this experiment were consistent with the hypothesis. The images above are a few of the images from each parameter that were part of this study.

The images displaying the chlorophyll $a$ concentration showed higher concentrations near the oil rig at the beginning of the spill, then in later months, the chlorophyll concentration increased more toward the shore and traveled east towards the shores of Florida. This pattern matches the movement pattern of the oil due to the ocean currents and winds. Therefore, it can be concluded that the hypothesis that chlorophyll $a$ concentration is higher in the presence of oil.

The maps generated for sea surface temperature display cooler temperatures in the area of the oil spill, just as predicted. Both April and May showed cooler temperatures towards the coast which is where the oil spill was located during these months. The images provided demonstrate that the sea surface temperature is indeed cooler where the oil spill is located. June 2010 showed slightly cooler temperatures farther away from the coast because the oil spill had diminished, spread out, and traveled farther away from the shores.

The maps of the reflectance show brighter colors in the areas of the oil spill because the oil spill reflects more sunlight than the surrounding ocean. The images available show the first two months of the oil spill. As you can
see, the overall reflection in June 2010 is higher than in May 2010, especially in oil-ridden areas. The black color of the oil would normally absorb sunlight. However, in this case, the physical properties of the oil cause it to be more reflective than the clean, oil-free ocean surrounding it. This is consistent with the results of the study which display that the presence of oil and reflectance of that area are positively correlated.

The parameter that did not give results as confirming as the others is the colored dissolved organic matter. This could be due to the efforts to remove the oil, so therefore the amount of dissolved organic matter is lower in the months of May and June. Another possible reason for the lack of results from CDOM is that it might be at the wrong wavelength. Another sensor might be able to detect the increase in CDOM at a different wavelength. The dispersants released in the affected area might interfere with the satellite information, causing the CDOM to decrease rather than increase. Further investigation into this parameter would give more conclusive results.

Overall, this experiment was successful in choosing the appropriate sensors in combination with the parameters. It can be concluded that chlorophyll, sea surface temperature, and reflectance are all factors that alter due to the presence of an oil spill. The chlorophyll a content and reflectance both increase with the presence of an oil spill while the sea surface temperature is actually lower over the oil spill. The colored dissolved organic matter is a parameter in which other experiments might find different results due to the instruments and the information available.

6. Future Research

This study is just a beginning to what could be a very advantageous experiment. If this study were to continue, there are many of different factors to consider. More data would need to be collected in order to make the experiment more reliable.

I would explore other sensors available, not just from the Giovanni website. These other sensors might have access to information about other parameters that could contribute to detecting oil spills.

Alternate locations of interest would be analyzed to collect more data and possibly confirm that the four parameters used in this study actually detect oil spills. This would eradicate the possibility results that were coincidental. Other large oil spills from history would be investigated using the same parameters from the same instruments as well as any extra that might produce results. Some other possible locations to study would be any other significant oil spills that occur or any oil leaks produced by crude tankers or ships.

Using in situ measurements, measurements taken on site, of areas of current oil spills would be able to confirm the data from the satellites. However, in situ measurements would only be possible to collect from future oil spills.

Overall, this study could potentially be very advantageous. After extensive research, scientists could use these satellites to detect any oil spills that are undetectable by the human eye. If these usually undetected oil spills can be detected early on, measurements can be taken to start removing the oil from the environment immediately. This could potentially save many of marine and plant life that are often affected by oil spills.

References

