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HYPERSPECTRAL IMAGE ANALYSIS FOR OIL SPILL MITIGATION

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1. ABSTRACT

During the last several decades, the Chesapeake Bay has suffered from several large spill events threatening coastal habitats and species. Chesapeake Bay's resources remain vulnerable as they share the coastal areas with major interstate commerce routes, underground pipelines, extensive development, large industrial facilities, and heavy shipping traffic to the ports of Norfolk and Baltimore. In order to effectively protect communities and species in jeopardy, fast and accurate determination of oil spill hazard areas is needed, particularly if monitoring large quantities of oil spilled. Where oil-handling infrastructure is aging, this need is amplified. This research addresses remote sensing, especially Hyperspectral image analysis applicable to the Chesapeake watershed. This case study is a prototype of oil spill leaks in Patuxent River in Maryland, and the associated image analysis for detecting oil spills using hyperspectral imagery and the effect on soil, water, wetland, and vegetation contaminated by oil spill. Space-borne and airborne images, as an effective survey tool, are the main source for getting real-time data. In the event of an oil spill, this information can be retrieved in short time to help authorities to plan the quickest route to the spill and formulate an effective environmental protection plan, that could be a way to reduce damages. Hyperspectral sensor affords the potential for detailed identification of materials and better estimates of their abundance. This can eliminate the false alarms of features that have the same color and appearance of oil, such as large algae blooms or jellyfish. Such phenomena may be identified by visual interpretation as a suspected oil spill using some conventional sensors. Some other types of light fuel, such as gasoline and diesel, cannot be identified visually because of their changing appearance with time. Hyperspectral sensing can record over 200 selected wavelengths of reflected and emitted energy. With this spectral information one can exploit the spectral signature of oil and also to distinguish between different types of oil (crude or light oil). HSI observations with high spectral and spatial resolution can be used to detect oil based on the spectral signature matching to identify the level of oil contamination of polluted areas in the shoreline, which are necessary for determining proper cleaning processes.

2. MOTIVATIONS

In this research some of these problems can be minimized when using more advanced methodology to identify oil spill based on the spectral signature matching not by visual interpretation of the image. New techniques such as HIS should be used in order to make the proper distinctions between oil types (crude or light oil) and to properly identify natural phenomenon; The results of this research show that with HSI spectral information, the signature of oil can be used to detect minute concentrations of hydrocarbon (crude oil) on the sea and it can distinguish between different types of oil (crude or light oil). Part of this study also includes the monitoring of oil slicks movements, dispersion in water, and identifying spills on the shoreline. The work under progressing will emphasize the oil contaminates in wetland, soil, vegetation, and grass in Patuxent River basin in Chesapeake Bay due to oil pollution. The Linear un-mixing technique will be used to distinguish between mixing signatures of different materials polluted with oil.

3. PROBLEM STATEMENT

A number of remote sensing systems are available (e.g., side-looking airborne radar, laser fluorescence, microwave radiometer, infrared-ultraviolet line scanner, SAR, ERS 1, 2 and LANDSAT satellite systems). However, problems associated with each of these systems preclude their exclusive use during oil spills. Although remote sensing data can be a valuable tool in the response effort, results from different sensors can vary widely. This problem is particularly apparent during major spills, when many interpretative analyses for satellite images are based on oil color or oil film appearance on water. Many of these analysis techniques have problems identifying and quantifying oil floating on the sea. As the spill progressing, a surprising number of false positive sightings may be seen. Ice, internal waves, kelp beds, natural organics, pollen, plankton blooms, cloud shadows, jellyfish, algae, and guano washing off rocks all appear as oil (Pavia and Payton 1983, McFarland et al. 1993). Weather conditions are one of the limitations when using some sensors such as radar imagery, are the on-scene weather and difficulties inherent in estimating area of coverage. Waves will increase natural dispersion during the early parts of the spill, break the surface tension that causes the oil to look "slick," and mix some of the oil into the surface layer temporarily. Observers should note that as the wind speed increases, the ability to detect the oil decreases (Ministry of Transport 1992). Visual observation of submerged oil is extremely difficult unless the water is very clear and shallow. Spill characteristics appear differently under low light conditions and under strong winds conditions. Observations in an up-sun direction are typically difficult to interpret. Glare due to very low sun angles and sunlight directly overhead can make observations particularly difficult due to poor contrast between the oil sheen and water. After oil spends even a short time floating on the ocean surface, it starts to change its physical characteristics due to various physical, biological, and chemical processes. The false reports obscure knowledge of the actual location and description of the spill. In additional to other factors that make some conventional remote sensing techniques unreliable.

4. MAJOR OBJECTIVE

The HSI technique is used to detect oil spill and determine characteristics of the substance spilled, and to make predictions of the spread or mitigation success. The tasks involved are:

1. **Predict oil spill spread direction and flow rate characteristics:** Hyperspectral Image Analysis for oil spills must be fast and timely for operational environmental monitoring. The airborne HSI temporal image process predicts how oil spills disseminate within a particular body of water, under current environmental conditions, and where it might affect sensitive sites, such as coastal wetlands.

2. **Identify shoreline features and the severity of oil spills:** With its high spectral and spatial resolution, HSI can be used to identify shoreline features, and areas damaged due to spilled oil. Areas impacted are environmentally sensitive, e.g. wetlands with shallow water, sea-grass, salt marshes, tidal-flats, waterways, or sandy beaches with significant biodiversity therein.

3. **Determine the pollutant type**: The oil characteristics (e.g. oil type) are important to help the cleanup crews identify the best cleanup method, the environmental impacts of burning oil, and for modeling techniques (to predict the flow path, dispersion rates, and time before the slick hits the shoreline). For example, an oil type can be crude or light oil and the evaporation rate of the light fuel is faster than crude oil, but it could be more toxic for the marine species.

5. METHODOLGY

Hyperspectral sensors such as the Airborne Imaging spectro-radiometer for applications (AISA) enabled the construction of an effective, continuous reflectance spectrum for every pixel in the scene. These systems can be used to discriminate among earth surface features. Hyperspectral sensors afford the potential for detailed identification of materials and better estimates of their abundance. This can eliminate the false alarms of features, which may be identified by mistake as a suspected oil spill with other conventional sensors. Hyperspectral sensing can record over 200 selected wavelengths of reflected and emitted energy. With this spectral information one can exploit the spectral signature of oil to detect minute concentrations of hydrocarbon on the sea surface. And also to distinguish between different oil types (crude / light oil) and Applications of the hyperspectral sensing include determination of contaminated soil wetlands, shallow water, sand beaches, and shoreline which enables the identification of features with high spatial and spectral resolution.

6. SCOPE OF RESEARCH

It was demonstrated from our preliminary results by using Spectral Angle Mapper classification technique, that signatures for different types of crude oil can be matched as long as a sample has high concentration of hydrocarbons and does not match for light oils such as diesel or gasoline and benzene. The model is unreliable for distinguishing between different types of crude oil, also for small oil spills. The classified image indicated features similar to oil was appeared in areas covered with shadows and areas used for storing coal (inside the Maryland Power station), the results confirmed that materials have the same chemical composition such as coal (carbon), has the same signature of oil.

7. HYPERSPECTRAL DATA AND SENSORS

The AISA Airborne imaging Spectrometer: It is a push-broom style, hyperspectral system measuring up to 288 bands of continues visible an IR wavelengths. Fifty bands were selected from 268 bands, for our image processing. The data was derived from the Pipco oil company project for pollution protection of Patuxent River in Maryland.
For high spatial and spectral resolution requirements, the Airborne Imaging Spectroradiometer for Applications (AISA) sensor system gets more information out of each pixel of data - more detail, finer imagery and faster turnaround than from other multi-spectral systems or traditional methods of monitoring. The use of AISA data for identifying spectral signatures for oil spill and oil contaminated areas, can be more successful than traditional methods. Time sequence images of the oil can guide efforts in real-time by providing relative concentrations and accurate locations. Environmentally sensitive sites such as wetland can be quickly and accurately mapped, measured, and characterized. AISA can be used to build a spectral library for oil spill on water and land for areas, which contaminated by oil. The Spectral signature can be used for identifying shoreline features specially areas which are environmentally sensitive, and determine the level of oil contamination (heavy or moderate) areas onshore. This can be useful for focusing cleanup processes.

7. HYPERSPECTRAL IMAGE PROCESSING USING ENVI

The spectral Angle Mapper (SAM) technique is used for identifying oil spills in water and shoreline. Real time analysis of the images allows field checks in the rapidly changing water conditions due to wind, current and tides. Signature matching method can be used to extract specific spectral signatures in order to build a spectral library for different oil types on water, wetland, and vegetation contaminated by oil spill, also to determine the level of oil contamination onshore. The linear un-mixing signature method will be useful to identify contaminated coastal features, for distinguish between mixed signatures for different materials, such as grass, water, and soil contaminated with oil.
The ability to collect and analyze very narrow bands of light allows hyperspectral images to separate water from aquatic vegetation, point source pollution, and turbidity, particularly, in the areas which are environmentally sensitive, such as wetlands, sand beaches, sea-grass, tidal-flats, tidal rivers, and the water quality. This can be useful for focusing cleanup and oil spill mitigation processes.
This scenario utilizes HSI analysis, applied to the Chesapeake Bay watershed. The following represents one example of an oil spill in the Patuxent River in Maryland, and what the associated image analysis using HSI data makes possible.

8. HYPERSPECTRAL IMAGE PROCESSING TECHNIQUES

1. Extract reflectance Spectra and create end the end-member collection
2. Spectral matching with the reference signature
3. Spectral Angle Mapper (SAM) classification
4. Class images and rule images (image masking)& matching with image Features
5. Comparing the rule image results with ground truth

9. SPECTRAL ANGLE MAPPER (SAM) METHOD

Spectral Angle Mapper (SAM) Classification is a physically based spectral classification that uses the N-dimensional angle to match pixels to reference spectra. The algorithm determines the spectral similarity of two spectra by calculating the angle between them. The advanced image processing software, ENVI, is used for image analysis.

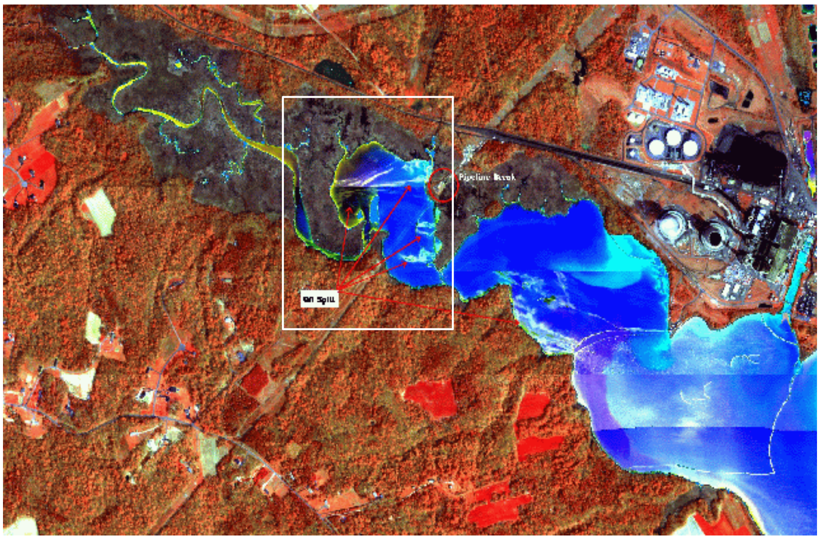


Figure (1) shows an AISA hyperspectral image in Patuxent River for an oil spill due to a petroleum pipeline break. Also the contaminated offshore areas (Maryland April 2000)

9.1 EXTRACTING OIL SPECTRUM

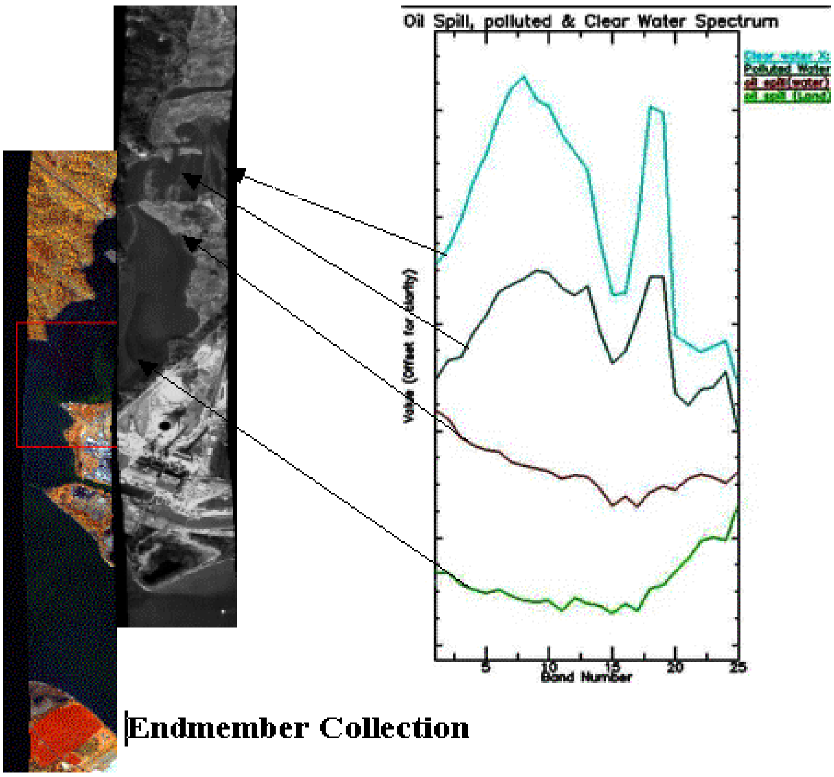
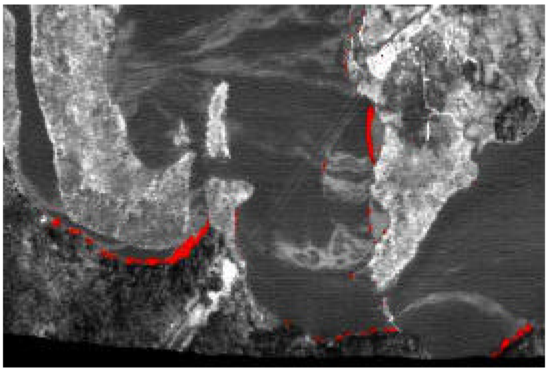


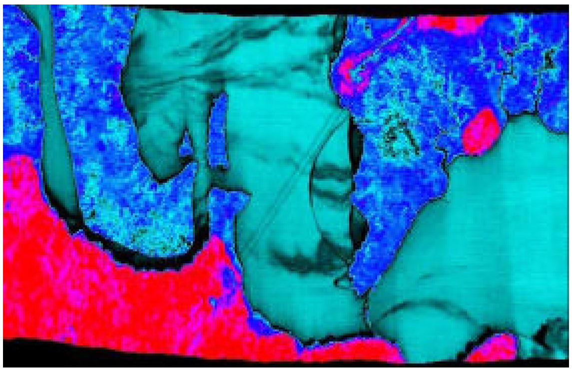
Figure (2)

Results of Spectrum Matching: The direct identification of specific materials via the extraction of the specific spectral features using ground truth. The oil signature was extracted from on the image using pictures was taken to the site in the same time of the event happened. By matching the Oil Spill Spectrum with the reflected signature of Iranian crude oil (from experimental on lab), used as a reference spectrum of crude oil. The four depressions represent the oil absorption at wavelength of 400 and 700 um. The water spectrum shape appeared with steep slob different from oil, so it is easy to discriminate between both materials.

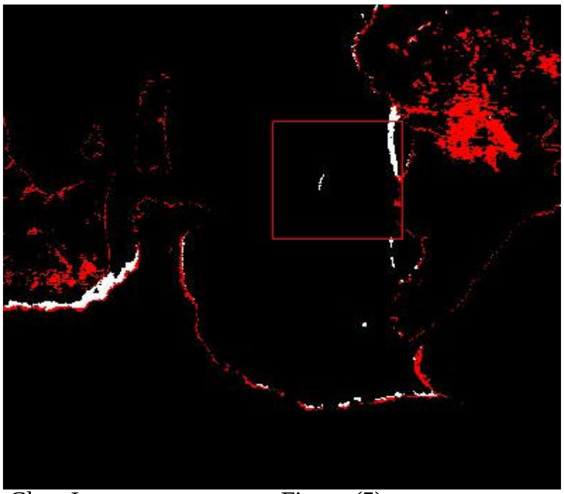
9. 2 HYPERSPECTRAL IMAGE ANALYSIS RESULTS FOR DETECTING OIL SPILL



Figure(3) Red Color Represents Oil On Water



Figure(4) Oil and Polluted Water Appeared In Black



Class Image Figure (5)

Figure (6)

Figure (5) Shows Two Classes, White Indicted The Oil Spill In Water,
It Appears Close To The Shore Outline, Red Color Represents Oil On Land Due To Pipeline Break.
Figure (6) Picture Used As Ground Truth For Comparing Results, Was Taken On The Same Time of the event.

10. SUMMERY AND CONCLUSIONS

1. Using Hyperspectral imagery, as an advanced remote sensing technology, is more reliable to minimize the limitations of conventional remote sensing techniques for detecting oil spill, These limitation such as weather difficulties, changing in oil appearance with time, image glare due to sun angle, and Natural phenomena that have the same appearance of oil spill.
2. The results of this research show that the signature matching method is more accurate than the conventional techniques, which based on the visual interpretation of oil color and appearance in the satellite images.
3. HSI spectral information is used to distinguish between different types of oil (crude/ light). The signature of oil is used to detect minute concentrations of hydrocarbon (crude oil).
4. For oil spill image analysis, Spectral Angle Mapper classification is more accurate than other supervised classification techniques. When the training samples is selected from the image based on the pixels color, the classification may be mislead by the analyst, signatures matching technique can distinguish between materials based on the chemical composition not by visual appearance, this allows more accurate classification
5. Hyperspectral Image is fast and timely for operational environmental monitoring for oil compared with space-borne systems. The airborne HSI temporal image process predicts how oil spills disseminate within a particular body of water, under current environmental conditions, and where it might affect sensitive sites, such as coastal wetlands.

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