**NASA DEVELOP National Program**



NASA Langley Research Center

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Alaska Disasters

Utilizing NASA Earth Observations to Identify Oil Spills and Natural Oil Seeps off the Coast of Northern Alaska

 **Technical Report** 

Rough Draft – June 18, 2015

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# I. Abstract

[Placeholder - do not put anything here until the final draft submission. The abstract in the project summary is where the working draft of the abstract should “live”]

**Keywords**

Alaska, Arctic oil spills, sea ice, natural seeps, synthetic aperture radar, Sentinel-1, ESA Aqua/Terra MODIS, Landsat

# II. Introduction

Satellite data show a dramatic decrease in Arctic sea ice over the last thirty years (Zigmuntowska et al., 2014; Laxon et al., 2013). As a result, maritime transportation activity and energy exploration is expected to increase in the region (National Oceanic and Atmospheric Administration, 2015). A recent development in May 2015 saw the United States Government Bureau of Ocean Energy Management conditionally approve offshore oil exploration north of Alaska. This overall increase in traffic combined with challenges unique to an Arctic environment escalates the risk of oil spills. Perils significant to operations in the Arctic include extended periods of darkness, lack of support infrastructure, and severe environmental conditions (e.g., low temperatures, strong wind and sea currents, sea ice, poor visibility) (Tunaley, 2010). These hazardous conditions make oil spill discovery difficult and recovery efforts dangerous (Bureau of Safety and Environmental Enforcement [BSEE] Arctic Oil Spill Response Research [OSRR], 2015).

An oil spill in the Arctic represents both an ecologic and economic disaster. Oil behavior and fate in freezing environments is complex due to its spreading on and under ice, absorption in snow, containment on and in ice, and spreading over ice-infested water (Fingas and Hollebone, 2003). In addition, lower temperatures slow the rate of dissipation, dispersion, and degradation of hydrocarbons, so oil persists longer and has a higher potential for greater impact to the environment (Tunaley, 2010; Atlas, 1972). The Arctic marine ecosystem is a region of high biological productivity that supports a wealth of life from the water column to the coastal plain and even above, below and within sea ice (National Snow and Ice Data Center [NSIDC], 2015; Geiselman et al., 2012). Biological and environmental damage due to an oil spill can create critical challenges to human health, food security, and the survival of indigenous cultures who depend on Arctic species availability for their livelihood (NSIDC, 2015). As the arctic nations - Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States - continue to grow in commercial shipping, fisheries, tourism, and energy exploration, an oil spill heralds a serious economic disturbance (United States Coast Guard [USCG], 2015; Clark et al., 2010).

In addition to human activities, oil enters the marine environment through natural seepages, a geographically common, natural phenomena active throughout geologic time (Kvenvolden and Cooper, 2003). A natural seep is defined by Hunt (1979) as visible evidence of past or present oil, gas or bitumen leakage on the surface of the earth. A report by Becker and Manen (1988) of the NOAA, National Ocean Service, Alaska Office Assessments Division identifies 29 seepage areas (14 confirmed) that occur within the coastal areas of Alaska. Kvenvolden and Cooper (2003) report that 47% of crude oil entering the marine environment is from natural seeps; therefore, given the deleterious impact oil has on the environment, detecting and monitoring these coastline and oceanic seeps is appropriate.

The USCG, the project partner for this study, faithfully executes its mission in the Arctic to serve and safeguard the public, protect the environment and its resources, and defend the Nation’s interests in the maritime region. US Federal Law requires all citizens to report an oil spill to the National Response Center immediately upon discovery. Once a spill has been reported, the USCG will investigate the location and formulate a clean-up and/or dispersal plan. The USCG currently conducts fly over assessments in an effort to locate any unreported oil spills. Modern remote sensing techniques can assist USCG response personnel in detecting, mapping and monitoring oil spills and natural oil seeps.

Numerous studies have been conducted in an attempt to identify best practices for remote sensing of oil. Due to the complexity of the Arctic environment, remotely sensing the presence of oil in an ice-infested region will likely require a mix of sensors, both passive and active, operating across the electromagnetic spectrum (Fingas and Brown, 2014). Hu et al. (2009) showed that Moderate Resolution Imaging Spectroradiometer (MODIS) imaging is capable of detecting oil slicks based on the same backscattering principles of Synthetic Aperture Radar (SAR). MODIS is also advantageous in that it expands the coverage area and revisit frequency (Hu et al., 2009). A study in 2013 by Polychronis and Vassilia, demonstrated that high resolution satellite images from Landsat 4-5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) work well for detecting oil spills and seeps using an object based method. Brekke and Solberg (2004) report that SAR is the most suitable space-borne sensor for oil detection because of its all-weather/all-day collection capabilities which is especially important in Arctic conditions. Thus, it follows that because of individual sensor limitations (e.g., all-weather, revisit frequency, coverage) and the unique environmental challenges confronting remote sensing in the Arctic, a mixture of sensors is desirable (Tunaley, 2010). A robust suite of spectral imagery from the NASA Earth Observation Systems - Aqua/Terra MODIS and Landsat - combined with radar imagery analysis from European Space Agency Earth Observations - Sentinel-1 - could provide an effective strategic response planning tool for the USCG in the event of an Arctic spill.

The study area of this project is the coastal region of Alaska. The natural oil seep investigation examined spectral and radar data of 14 confirmed natural oil seeps as reported by Becker and Manen (1988) (Figure 1). In conducting the oil spill analysis, the study quickly discovered that imagery-interpretation of oil occurrences is best conducted by analyzing known oil spill events that allow signature verification through ground-truthing (Polychronis and Vassilia, 2013; Suresh et al., 2013). However, there are no reported oil spills in the study area that align with sensor data availability and include the necessary components needed for spectral and radar signature differentiation: oil, ice, and seawater. In light of this, the project included a test study area in the North Sea off the west coast of Norway. At this site, the Norwegian Clean Seas Association for Operating Companies (NOFO) conducted its annual Oil-in-Water (OPV) exercise from June 8-11, 2015 during which they released 130 tons of oil into the ocean. This exercise is conducted yearly in order to develop and maintain oil spill preparedness on the Norwegian shelf (NOFO, 2015).

The Alaska Disasters project addresses the NASA Applied Sciences Program application area, “Disasters”. By familiarizing the project partner, the USCG, with the use of NASA Earth Observation Systems, the organization is able to improve coastal management practices and emergency preparedness and response. Although the SAR data used in this study is provided by the European Space Agency, its effectiveness as an oil detection remote sensing technique showcases the future NASA EOS sensor, NISAR (NASA Indian Space Research Organization SAR) which is expected to launch in 2020 as the first dual frequency radar imaging satellite.

The objective of this study was to evaluate the capabilities of spectral data from NASA EOS, MODIS-Aqua/Terra and Landsat, as well as radar data from the European Space Agency’s Sentinel-1 to detect, map, and monitor oil spills and natural oil seeps within the coastal area of Alaska. Results from this study will help develop an improved remote sensing strategy for managing oil spills and seeps by accurately discriminating oil slicks from the background of a complex Arctic environment. Ultimately, the project aims to inject our final deliverables into the Arctic ERMA in order to facilitate fast visualization of oil seeps or an oil spill situation to improve USCG communication and coordination efforts.

# III. Methodology

**Satellite Remote Sensing and Data Acquisition**

*Surface Reflectance - MODIS- Aqua, MODIS-Terra, Landsat 8 OLI/TIRS*

MODIS-Aqua, MODIS-Terra, and Landsat 8 OLI/TIRS data were retrieved from EarthExplorer operated by the USGS (<http://earthexplorer.usgs.gov>). MODIS-Aqua MOD09GA and MODIS Terra- MYD09GA data provided Bands 1-7 in a daily gridded L2G product in the Sinusoidal projection, including 500m reflectance values and 1km observation and geolocation statistics (Land Processes Distributed Active Archive Center [LPDAAC], 2014). MODIS-Aqua MYD09GQ and MODIS-Terra MOD09GQ data provided Bands 1 and 2 at a 250m resolution in a daily gridded L2G product in the Sinusoidal projection (LPDAAC, 2014). MODIS data was created by reprojecting Bands #, #, # from the aforementioned products from their native Sinusoidal to Universal Transverse Mercator (UTM) using...

Landsat 8 Operational Land Imager/ Thermal Infrared Sensor (OLI/TIRS) carries two push-broom sensors: OLI and TIRS. OLI data provided nine shortwave bands, eight spectral bands at 30m resolution and one panchromatic band at 15m (USGS, 2012). TIRS collected two long wave thermal bands at 100m resolution (USGS, 2012). Landsat 8 OLI/TIRS data was created by projecting Bands #, #, #.

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| --- | --- | --- | --- | --- |
| **Sensor** | **Data**  | **Level** | **Dates** | **Source** |
| **MODIS-Aqua** | MYD09GA- Surface Reflectance Daily: Global 1km and 500mMYD09GQ- Surface Reflectance Daily: Global 250m | L2G |  | [earthexplorer.usgs.gov](http://earthexplorer.usgs.gov) |
| **MODIS-Terra** | MOD09GA- Surface Reflectance Daily: Global 1km and 500mMOD09GQ- Surface Reflectance Daily: Global 250m | L2G |  | [earthexplorer.usgs.go](http://earthexplorer.usgs.gov)v |
| **Landsat 8 OLI/TIRS** | Bands X – Y would fit here or you could add a new column to the table with the band ino  | L1T |  | [earthexplorer.usgs.go](http://earthexplorer.usgs.gov)v |

*Surface Reflectance - Sentinel-1*

Synthetic Aperture Radar (SAR) data were retrieved from the Sentinel-1 Scientific Data Hub operated by the European Space Agency (ESA) (<https://scihub.esa.int/dhus/>). Sentinel-1, launched in April 2014 in a polar, sun-synchronous orbit and carries a C-band SAR instrument. Sentinel-1 is an ideal platform for this study due to its all-weather capability, ability to distinguish open ocean, ice, wind, and waves, and expedient production of 10 *m* resolution images within hours to support emergency response operations (ESA, 2015). Sentinel-1 data was processed...reprojected....

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| **Sensor** | **Data** | **Level** | **Dates** | **Source** |
| **Sentinel-1** |  | S1SLC  |  | [scihub.esa.int/dhus](https://scihub.esa.int/dhus/) |

*Spatial Data - Arctic Emergency Response Management Application (ERMA)*

Spatial data were retrieved from the Arctic ERMA maintained by NOAA (<https://erma.noaa.gov/arctic/erma.html>). Arctic ERMA is a web-based GIS tool that assists emergency responders with environmental incidents by providing real-time and static spatial datasets (NOAA, 2015). Shapefiles were imported into ArcGIS for incorporation into the Natural Oil Seep Static Map product.

**Natural Oil Seep Mapping**

ArcMap product created using Arctic ERMA spatial data, historical data from Becker and Manen (1988), NASA EOS and ESA EO imagery. Final product ingested into Arctic ERMA.

**Oil Spill Detection Method**

ArcGIS, Python Scripting, Arctic ERMA Ingest

Proposed Python Script Workflow:



This should be the focus of the paper - concise, yet explanatory, and highlight the NASA Earth observations utilized and its/their capabilities. Include a paragraph or more for each of the following items. No word cap, but be thoughtful and keep it in the two to six page range.

Content to include:

* Data Acquisition: What data did you get, what level products are they, for what dates did you get images, where did you get the images from, etc.
* Data Processing: What did you do to the data? Were there conversions needed to be able to analyze it? Did you have to mosaic images? Did you have to normalize anything to fit other datasets? Did you run an NDVI, change detection, etc.?
* Data Analysis: How did you analyze the data? What methods did you use?

# IV. Results & Discussion

Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range.

Things to discuss:

* Analysis of Results: What can you tell from your graphs, images, etc.? What does this mean for your project?
* Errors & Uncertainty: What factors could you not account for, what things didn’t work out like you expected they would, etc.
* Future Work: If this project was to be selected for another term, what would be the focus? What other areas would be of interest?

# V. Conclusions

Final conclusions. Word count: 200-600 (~a page).

# VI. Acknowledgments

Insert here. Keep to a concise paragraph or bullets of names. End with the following sentence.

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

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# IV. Appendices

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