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Review

State of the art satellite and airborne marine oil spill remote sensing: Application to the BP *Deepwater Horizon* oil spill

Ira Leifer [a,*], William J. Lehr [b], Debra Simecek-Beatty [b], Eliza Bradley [c], Roger Clark [d], Philip Dennison [e], Yongxiang Hu [f], Scott Matheson [e], Cathleen E. Jones [g], Benjamin Holt [g], Molly Reif [h], Dar A. Roberts [c], Jan Svejkovsky [i], Gregg Swayze [d], Jennifer Wozencraft [h]

[a] *Marine Science Institute, University of California, Santa Barbara, CA, United States*
[b] *NOAA Office of Response and Restoration, Seattle, WA, United States*
[c] *Geography Department, University of California, Santa Barbara, CA, United States*
[d] *US Geological Survey, Denver, United States*
[e] *Department of Geography and Center for Natural and Technological Hazards, University of Utah, Salt Lake City, UT, United States*
[f] *NASA Langley Research Center, Hampton, VA, United States*
[g] *Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States*
[h] *US Army Corp of Engineers, Kiln MS, United States*
[i] *Ocean Imaging Corporation, Solana Beach, CA, United States*

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A B S T R A C T

The vast and persistent *Deepwater Horizon* (DWH) spill challenged response capabilities, which required accurate, quantitative oil assessment at synoptic and operational scales. Although experienced observers are a spill response's mainstay, few trained observers and confounding factors including weather, oil emulsification, and scene illumination geometry present challenges. DWH spill and impact monitoring was aided by extensive airborne and spaceborne passive and active remote sensing.

Oil slick thickness and oil-to-water emulsion ratios are key spill response parameters for containment/cleanup and were derived quantitatively for thick (>0.1 mm) slicks from AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) data using a spectral library approach based on the shape and depth of near infrared spectral absorption features. MODIS (Moderate Resolution Imaging Spectroradiometer) satellite, visible-spectrum broadband data of surface-slick modulation of sunglint reflection allowed extrapolation to the total slick. A multispectral expert system used a neural network approach to provide Rapid Response thickness class maps.

Airborne and satellite synthetic aperture radar (SAR) provides synoptic data under all-sky conditions; however, SAR generally cannot discriminate thick (>100 μm) oil slicks from thin sheens (to 0.1 μm). The UAVSAR's (Uninhabited Aerial Vehicle SAR) significantly greater signal-to-noise ratio and finer spatial resolution allowed successful pattern discrimination related to a combination of oil slick thickness, fractional surface coverage, and emulsification.

In situ burning and smoke plumes were studied with AVIRIS and corroborated spaceborne CALIPSO (Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation) observations of combustion aerosols. CALIPSO and bathymetry lidar data documented shallow subsurface oil, although ancillary data were required for confirmation.

Airborne hyperspectral, thermal infrared data have nighttime and overcast collection advantages and were collected as well as MODIS thermal data. However, interpretation challenges and a lack of Rapid Response Products prevented significant use. Rapid Response Products were key to response utilization—data needs are time critical; thus, a high technological readiness level is critical to operational use of remote sensing products. DWH's experience demonstrated that development and operationalization of new spill response remote sensing tools must precede the next major oil spill.

* Corresponding author.
E-mail address: Ira.Leifer@bubbleology.com (I. Leifer).

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Contents

1. Introduction

1.1. Overview

Marine petroleum affects the environment, economy, and quality of life for coastal inhabitants leading to concerns that include resource exploration, recovery, transportation, and resultant oil spill contingency planning, mitigation, and remediation (Jensen et al., 1990). Traditionally, remote sensing has played a secondary support role in oil spill response and monitoring. However, recent technological advancements and sensor availability have enabled a more important role for remote sensing. During the *Deepwater Horizon* (DWH) spill, several remote sensing technologies rapidly moved up the technological readiness scale (Ramirez-Marquez & Sauser, 2009), propelled by the spill's scale and urgency.

In this review, we summarize and discuss the role of remote sensing technologies used in the DWH response with varying degrees of effectiveness. This paper has five sections: 1) oil spill processes relevant to oil spill response and remote sensing interpretation, 2) passive oil-spectroscopy and remote sensing, 3) active oil remote sensing, 4) remote