

Wavelet Analysis of Satellite Imagery on Coastal Oil Spills

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ABSTRACT

With the aid of satellite remote sensing imagery, it is now possible to monitor the seawater with adequate temporal and spatial coverage for marine pollution and biological productivity. In this paper, we present case studies on two major coastal oil spills, which have been captured by the remote sensing imagery. The detection and tracking of the oil slicks are achieved by means of two-dimensional Gaussian-based wavelet analysis. This work demonstrates that this technique is a useful and promising tool for monitoring of coastal waters.

KEY WORDS: Wavelet analysis, oil spill, SAR, AVHRR, RADARSAT

INTRODUCTION

Satellite remote sensing technology can provide sea surface data with far better spatial and temporal coverage than that of the conventional *in situ* measurements. With the aid of the satellite remote sensing imagery, it is now possible to monitor the seawater, particularly coastal water, with adequate temporal and spatial coverage for marine pollution and biological productivity. In this paper, we present case studies on two major coastal oil spills, which have been captured by the SAR (synthetic aperture radar) and the AVHRR (advanced very-high resolution radiometer) sensors on board several satellites. In both cases, the dispersion route and pattern have been identified by means of two-dimensional Gaussian-based wavelet analysis.

WAVELET ANALYSIS

In a nutshell, the two-dimensional wavelet transform is a form of spatial differentiation. The resulting image is differential image with accentuated amplitude changes. Furthermore, the Laplacian of Gaussian wavelet transform, one of the two employed in this analysis, works as a band-passed filter. Ideally only features with length scale within a chosen band are retained upon transformation.

Two types of wavelets are used in this analysis, the first order derivative and the second order derivative (the Laplacian) of a two-dimensional Gaussian function. The Gaussian has the following form:

$$g(x, y) = -a \exp\left(-\frac{x^2 + y^2}{2a^2}\right)$$

The latter wavelet, due to its characteristic shape, is often referred to as the "Mexican hat wavelet" (Combes *et. al.*, 1989). The wavelet-transformed images, therefore, reflect the properties of the spatial first order derivative and second order derivative of the original image, respectively.

To perform the wavelet transformation, one needs to first choose a suitable a value, which corresponds to the length scale of the Gaussian hump. The general rule of thumb is to choose this value based on 1) the length scale of the feature of interest; and 2) the resolution (or pixel spacing) of the original image.

A differential detection is then carried out to determine the pixel locations of significant differentials so that the feature of interest can be delineated from the background. In this work, both kinds of wavelet-transformed data ($w1$ and $w2$) are examined. An edge is deemed present at pixel (x_0, y_0) if both of the following conditions are met:

- 1) $w1(x_0, y_0)$ exceeds a chosen threshold value T , where $T = [w1(x, y)] + t \times [w1(x, y)]'$, and
[w] : the ensemble average;
[w]' : the standard deviation of the ensemble.
- 2) $w2(x_0, y_0)$ equals to a predetermined value c (typically in the neighborhood of zero).

The choices of t and c rely to a great extent on the knowledge of one has as to where the actual edges lie, which can be achieved by visual inspection.