Surface Circulation Estimation Using Image Processing and Computer Vision Methods Applied to Sequential Satellite Imagery*

Abstract

Two methods of automating the process of ocean feature tracking for estimating surface currents in coastal areas are outlined. These methods involve pattern recognition and have certain advantages over the more familiar maximum cross-correlation technique of Emery et al. (1986). The first method requires three steps in its application–pattern selection, pattern recognition, and geometrical calculations–to determine both the cross- and the along-isotherm displacements. The second method calculates certain surface motion parameters, including rotation and translation in Hough parameter space. Each method is applied to sequential AVHRR IR satellite imagery off the U.S. east coast. Finally, some of the practical problems encountered in the application of these methods are described.

Introduction

Oceanographers and environmentalists need objective, rapid, and accurate methods to track features in satellite images in order to estimate surface circulation. Emery *et al.* (1986) adapted cloud motion algorithms to estimate sea surface velocity from AVHRR imagery. Their method demonstrated statistical reproducibility, but is time consuming and cannot determine the along-isopycnal transport or circular (rotational) velocities.

We have adopted pattern recognition methods to determine sea surface velocities. This methodology can potentially provide more and accurate information in the study of both cross- and along-isopycnal transport and allows the estimation of coherent surface velocity fields from a minimal set of observations. The models have been developed with computer vision and pattern recognition concepts, which involve artificial intelligence techniques. Briefly, a set of point correspondences, with shape invariance under motion, yields a set of parameters that carry the motion information. Several methods to obtain the motion of these parameters have been developed. Among these is the approach using Singular Value Decomposition, which proves to be very efficient. Similarly, the point or feature correspondence between images has been extensively studied in image processing in the area of temporal image compression using motion compensation. Two of these methods have been adapted to the sea surface motion framework and implemented with actual imagery off the U.S. east coast where eddies and other mesoscale ocean features often occur between the continental shelf and the Gulf Stream.

Many of the surface velocity estimates using feature tracking have been acquired along the U.S. west coast where the oceanic processes and features are quite different from those encountered along the U.S. east coast. Our initial efforts have focused on the Slope Water region just beyond the New York Bight where feature tracking has not been used extensively. We believe that the new pattern recognition methods will significantly improve our ability to determine actual velocity fields – both cross- and along-isopycnal transport – to determine the trajectory of oil spills, to carry out more effective search and rescue efforts, and to perform other environmental analyses of the surface flow in the region. The results of this research will also provide a better understanding of the sub-mesoscale circulation, therefore allowing us to obtain a better understanding of the physical processes in this coastal region, and improving our ability to use artificial intelligence techniques applied to remote sensing for coastal environmental studies.

In the following discussion, we present only a brief outline of these methods for automated features tracking, followed in each case by an example, i.e., pilot study, of their application. These methods will be described in greater detail in forthcoming studies.

Methodology

The Ordered Statistical Edge Detection Method

The method described in this section is a three-step process: pattern feature selection in using Ordered Statistical Edge Detection, pattern recognition and selection of the feature most closely matching the pattern feature from objects found in a search area in a subsequent image, and geometric calculations to compute cross and along frontal displacement direction and magnitude.

Pattern Feature Selection

Assuming that surface thermal patterns are well-conserved over the typical periods between successive satellite images

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