

VORTICAL SEA-SURFACE FEATURES GENERATED BY A SUBMERGED BODY IN A CURRENT FIELD

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LONG-TERM GOALS

The long-term goal is to contribute to our understanding of the dynamics of air-sea interacting processes in the presence of a submerged body. In particular, we are interested in characterizing the sea-surface features affected by the eddies shed behind a submerged body in a current field.

OBJECTIVES

Scientific objectives are aimed to quantify the modifications of sea-surface roughness by a submerged body in a current field, and to find a proper algorithm to identify associated vortical surface features. It is anticipated that the results will be beneficial for shallow water mine detection with remote sensors.

APPROACH

Extensive laboratory experiments will be performed at our Wind-Wave-Current Research Facility (WWCRF) under various controlled wind and current conditions. A high-speed CCD camera will first be used to monitor surface features, then a two-dimensional scanning laser slope gauge (SLSG) will be deployed to map the fine sea-surface features. The CCD images during a five-minute record time will be analyzed to provide (1) the number, (2) the location of the first appearance, and (3) the propagation speed of eddies on the water surface. On the other hand, the SLSG data will be processed to provide quantitative descriptions of these features. Furthermore, the observed surface features will be compared with the aqueous flow structure; the latter will be measured with our newly acquired hot-film anemometer. To substantiate our efforts, either radar and/or measurements will be conducted jointly by our collaborators from Naval Research Laboratory (NRL).

WORK COMPLETED

We have conducted a series of experiments under various wind and current conditions. Both CCD imaging of surface features and SLSG mappings of surface slopes were performed. The acquired CCD images were compiled to characterize the vortical surface features. The SLSG slope mapping has provided quantitative information of these features. The slope data were processed to provide movie strips for all experimental conditions; the spectral domain in wave frequency/wave number domain is being performed. In addition, a collaborative experiment with an IR camera by investigators from NRL was initiated.

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RESULTS

Our experiments were conducted with a rigid sphere under wind and no-wind conditions with the aqueous flow's Reynolds number in the range between 7,000 and 40,000. The CCD images indicate that appearance of eddies on the sea surface is Reynolds-number dependent, as shown in Figure 1. Both the number of occurrence during the five-minute observation period and traveling speed of eddies increase with increasing Reynolds number. The influence of depth of submergence is also shown in the figure. The Froude number scaling is thus introduced for proper parameterization of these features. On the other hand, the number of eddy occurrences on the water surface was found to be higher than that shed behind the bluff body. It appears that generation of secondary vortices may also affect the surface roughness.

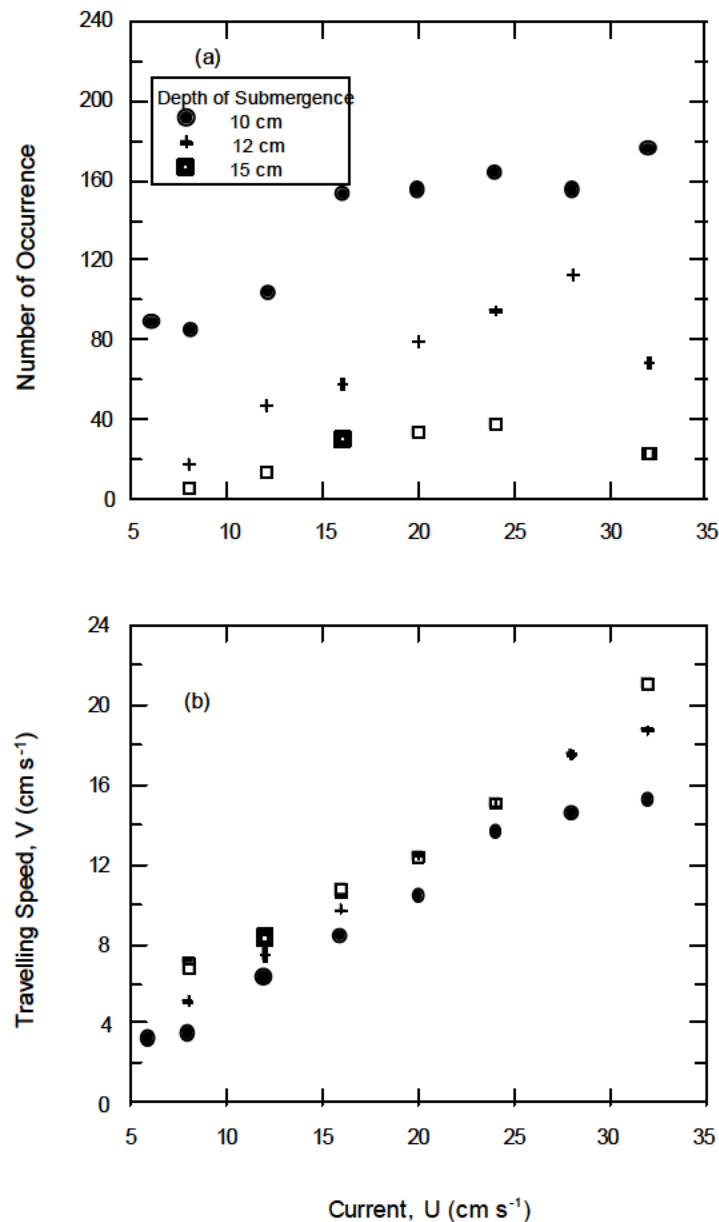


Figure 1. CCD Observations of Eddies on the Water Surface

The vortical features are successfully mapped with our two-dimensional SLSG. The fast scanning speed of the SLSG enables us to obtain the slope mapping of a “frozen” surface. An example of slope mapping by SLSG over an area of 8 cm x 8 cm is presented in Figure 2 with the color bar indicating the total slope in radian. The vortical feature is clearly shown as the bright spot at the upper right corner. The dimples associated with this feature are in centi- to millimeter scale. These fine-scale variations may contribute some influence on radar sea return. The corresponding mean-square slope shown in Figure 2 is equivalent to that at the 3 m s^{-1} wind. The features are likely smeared at high wind conditions; this motivates us to analyze SLSG data in the wavenumber-frequency domain.

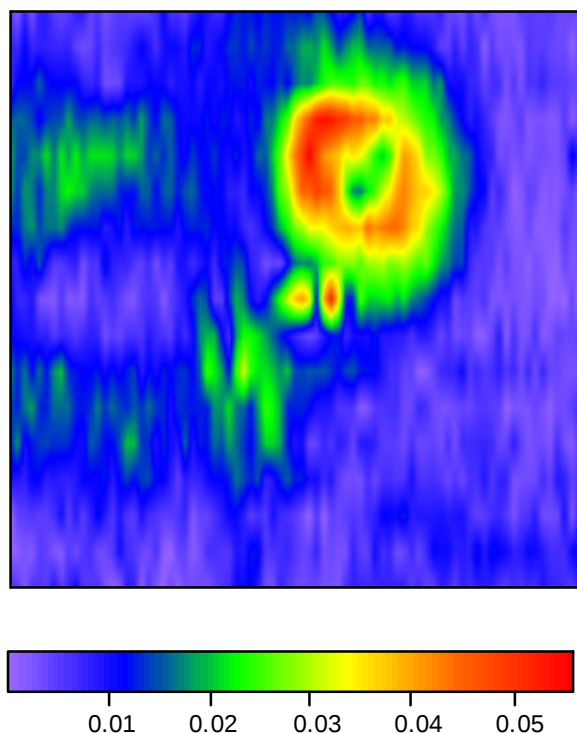


Figure 2. Slope Images as Eddies Appeared on the Free Surface

These eddies also disrupt the thermal boundary layer as they appeared on the water surface. The associated temperature rise is also shown in the IR images obtained at WWCRF by Smith et al. (1997) of NRL.

IMPACT/APPLICATIONS

These surface features offer a unique opportunity for detecting near-shore mines with remote sensors. For example, the imaging radar, which receives signals from the sea-surface features, is a potential candidate for such operation. Our effort in characterizing these features under various environmental conditions is a useful input in developing a proper algorithm.

TRANSITIONS

Collaborative work with investigators from NRL is in progress.

RELATED PROJECTS

The features derived from our CCD images were compared with the thermal signatures obtained by Geoffrey Smith (NRL) and Richard Leighton (NRL). Our SLSG data will also be compared with the numerical results obtained by other investigators.

REFERENCES

Smith, G., R. Leighton, S. Tang, and S. Chen, "The thermal signature of eddies shed from a sphere," ONR Workshop on Free-Surface and Wall Bounded Turbulence and Turbulent Flows, California Institute of Technology, Pasadena, California, February, 1997.

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