FINE STRUCTURE OF THE UPPER OCEAN FROM HIGH-RESOLUTION SAR IMAGERY AND IN-SITU MEASUREMENTS

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1. INTRODUCTION

Satellite-based radar images of the ocean surface reveal fine features of natural and man-made phenomena in the upper ocean [1–3]. Satellite technology continues to advance as it produces better/higher resolution images of the ocean surface. Fine horizontal features on scales less than the typical scale of the upper ocean mixed layer (about 30–50 m) are often associated with three-dimensional processes. With a new generation of synthetic aperture radar (SAR) satellites our ability to identify such small-scale features in the upper ocean from those images increases [4].

This project is aimed at investigating small-scale features using SAR imagery, including sharp frontal interfaces, wakes of surface ships, and slicks of artificial and natural origin. High resolution SAR images have been collected from the Northern Sea, the Strait of Gibraltar, the Straits of Florida and the coast of Australia. Collection of the ground truth data helps in the understanding of the physical mechanisms behind the patterns visible in the image. Satellite images in the Straits of Florida have often been collected in conjunction with in situ measurements collected with a CTD and the profiling sonar installed on a research vessel or in conjunction with surfactant release experiments.

2. MEASUREMENTS AND ANALYSIS

We have analyzed about 30 high resolution images (beginning at 1m resolution) for occurrence, visibility, and radar contrast of fine features of the sea surface with respect to their parameters (front type, ship speed and size, or slick age) and meteorological conditions. Figures 1–3 show several examples of natural and man-made features

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on the sea surface. The effects of the observed conditions, such as wind speed and direction, image resolution, radar parameters (incident angle, polarization, and wavelength) are included in the analysis.

An asymmetry of the ship wake structure with respect to wind direction revealed on high-resolution SAR images (Fig. 3) has been explained by the interaction of the three-dimensional circulation in the ship wake with the wind field [4–5]. (The Bragg-scattering waves appear to be larger on the upwind side of the ship wake and smaller on the downwind side of the wake; which, on radar images, results in a bright line on the upwind side of the wake and in the dark line on the downwind side of the wake.) In some cases, we have presumably observed a connection between fine features in SAR images (Fig. 1a) and the sharp frontal interfaces in the upper layer of the ocean in sonar images (Fig. 2).

This study supports the view that under certain conditions the three-dimensional structure of the upper layer of the ocean can be inferred from the high-resolution SAR imagery.

3. REFERENCES

[1] L. Fu and B. Holt, "*Seasat Views Oceans and Sea Ice With Synthetic Aperture Radar*", JPL publication 81-120, Feb. 15, 1982.

[2] *SAR Marine User's Manual*, ed. by J. Apel and C. Jackson, US Govt. Printing Office, Washington, DC, 2004. Online at www.sarusersmanual.com.

[3] W. Alpers, L. Mitnik, L. Hock, and K.S. Chen, *The Tropical and Subtropical Ocean Viewed by ERS SAR*, 1999. Online at www.ifm.zmaw.de/fileadmin/files/ers-sar.

[4] A. Soloviev, M. Gilman, K. Young, S. Brusch, and S. Lehner, "Sonar Measurements in Ship Wakes Simultaneous With TerraSAR-X Overpasses", *IEEE Transactions on Geoscience and Remote Sensing,* Digital Object Identifier: 10.1109/TGRS.2009.2032053, 2010.

[5] J.D. Lyden, R.R. Hammond, D.R. Lyzenga, and R.A. Schuchman, "Synthetic Aperture Radar Imaging of Surface Ship Wakes". *Journal of Geophysical Research*, vol. 93, pp. 12293–12303, 1988.

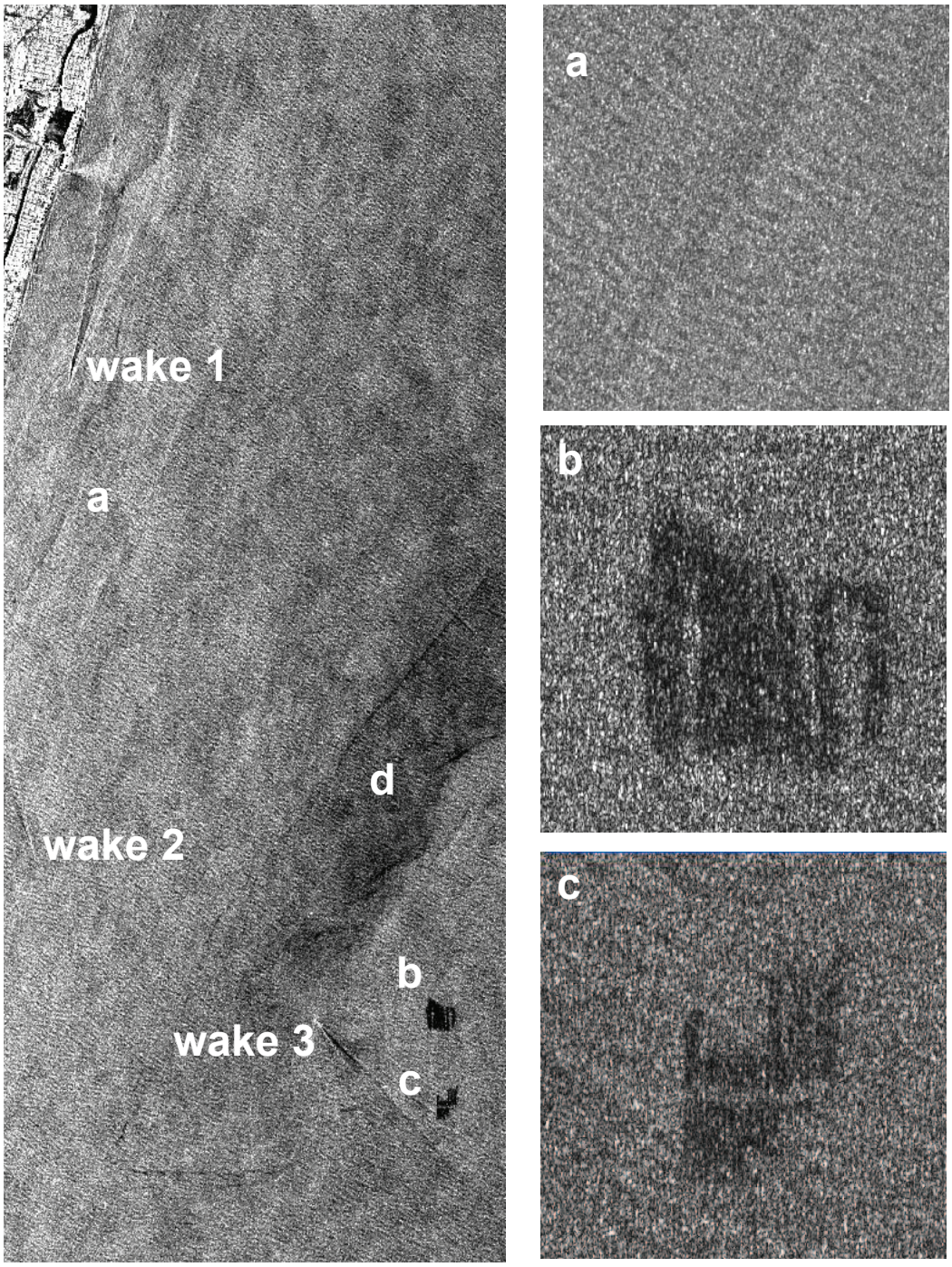

Fig. 1. A TerraSAR-X Stripmap image taken on September 25, 2009, 23:13 UTC (HH channel) off the coast of South Florida. The image reveals different features on the ocean surface: (a) oceanic front; (b) artificial slick, average age 80 min; (c) artificial slick, average age 30 min; d) natural slick of unknown origin. Features a, b, and c are shown in more details in the right column. A few wakes of ships are also visible (wake 1, 2, and 3).

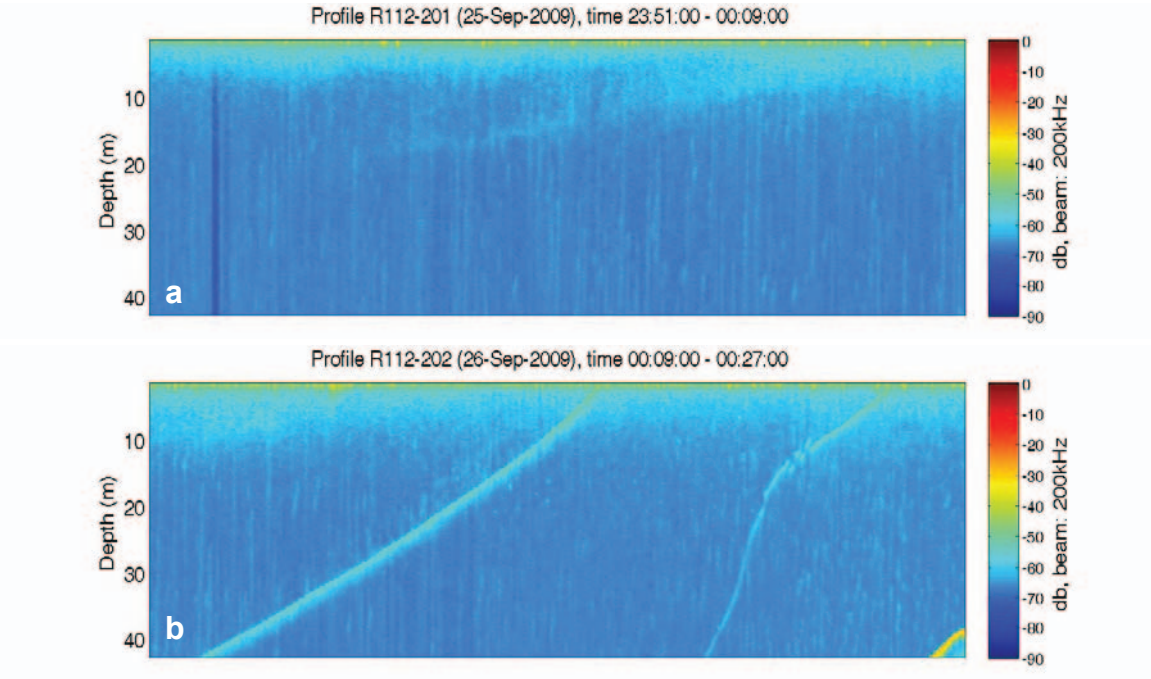

Fig. 2. Sonar profiles made shortly after the satellite overpass in Fig. 1. Crossings of the sharp frontal features associated with the western boundary of the Florida Current are seen in the panel (a) and panel (b). Panel (b) is the continuation of panel (a). Horizontal length of each panel is approximately 2700 m.

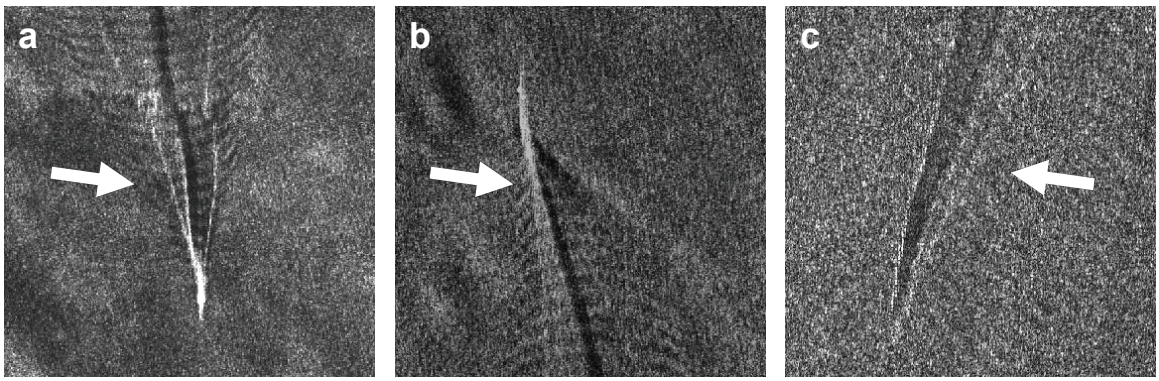

Fig. 3. High-resolution images of ship wakes in the presence of wind across the wake. (a) TerraSAR-X Stripmap image taken on July 02, 2008, 18:14 UTC, in the Gibraltar Straits. The arrow shows a tentative wind direction. The turbulent wake is asymmetric: the upwind boundary is much brighter than the downwind; (b) same image, but the asymmetry is not so well pronounced; (c) “wake 1” from Fig. 1.