J2.6 SONAR MEASUREMENTS IN THE GULF STREAM FRONT ON THE SOUTHEAST FLORIDA SHELF COORDINATED WITH TERRASAR-X SATELLITE OVERPASSES

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1. INTRODUCTION

Synthetic aperture radar (SAR) has proved itself as an effective tool for imaging the sea surface (Alpers et al., 1999, Velotto et al., 2010, Soloviev et al., 2010a). Fine scale features of both natural and anthropogenic origin can appear on SAR imagery (Soloviev et al., 2010b). Continuously evolving SAR technology has provided new advances in resolution and processing. These advances allow for better imaging of the sea surface and identification of smaller scale features.

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 (Soloviev et al., 2010b). With a new generation of SAR satellites (*TerraSAR-X*, *ALOS PALSAR*, *RADARSAT*-2, *COSMO SkyMed*) our ability to identify small-scale features in the upper ocean from space increases.

In this work, we review a subset of *TerraSAR-X* images in the Straits of Florida collected in conjunction with sonar measurements; the latter can potentially reveal three dimensional structures in the upper layer of the ocean.

2. MEASUREMENTS AND ANALYSIS

For this study, SAR imaging has been combined with field measurements in order to better characterize features seen in the imagery. Field measurements were collected using a Valeport Midas 606 CTD profiler and a Humminbird 1197c sonar unit with a GPS antenna and a quad beam transducer operating in 83 kHz, 200 kHz, and 455 kHz frequencies. In order to increase spatial resolution, a reduced depth range was set for some of the sonar profiles. Detailed bottom topography collected by the U.S. Naval Oceanographic Office in 2001 has been used to identify acoustic artifacts caused by “late echoes” (Blondel, 2009).

Measurements were collected from a research vessel equipped with a retractable mount, pictured below in Figure 1, during the time just after the satellite overpass. Wave parameters were collected from a bottom mounted Nortek AWAC.

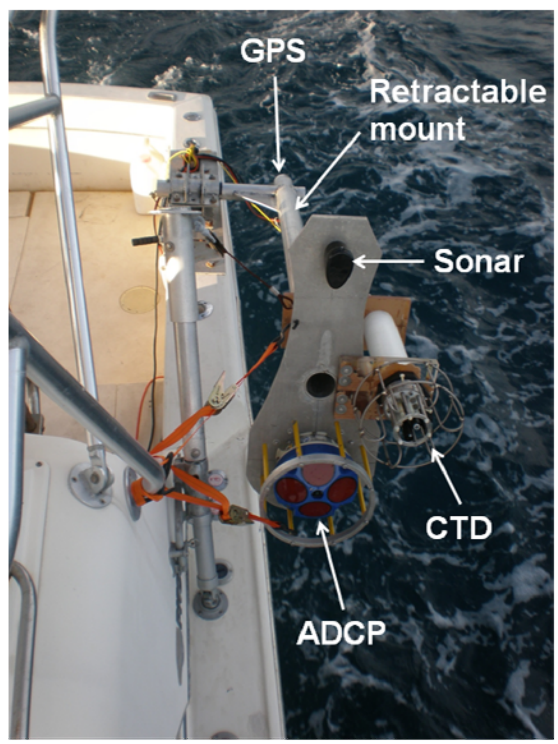

Figure 1: Retractable mount for sonar, GPS, ADCP, and CTD instruments.

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Two cases from recent field studies will be examined; one on June 10th and the other on June 15th 2010. On June 10th the wind speed was U_{10} = 4 m/s with a thunderstorm line moving offshore from the coast. On June 15th the wind conditions were calm (U_{10} = 0.5 m/s). The directional spectra of surface waves on June 10th and 15th are shown in Figure 2 and Figure 3 respectively.

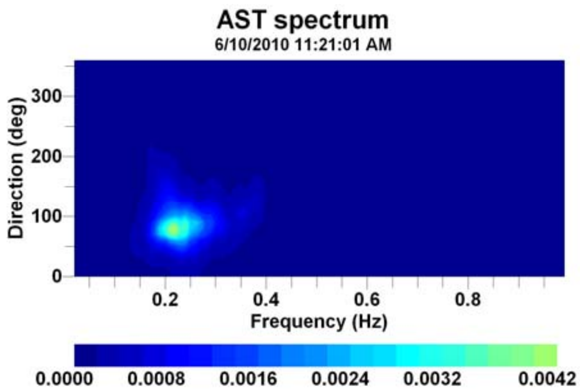

Figure 2: Surface wave directional spectra for June 10th, 2010 11:21UTC. Wave directions are reported as direction "from". Units for the spectrum are m^2/(Hz*Deg). Significant wave height is 0.39 m.

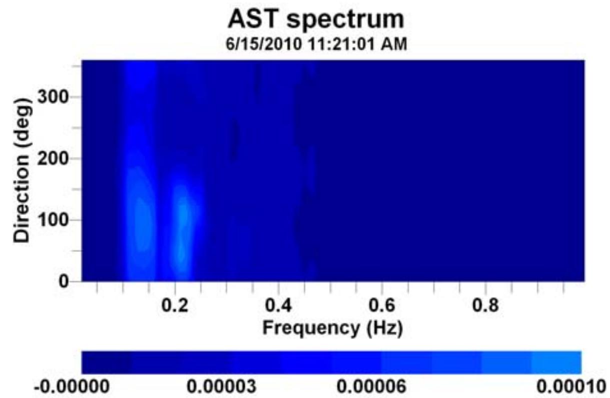

Figure 3: Same as in Figure 2, but for June 15th, 2010 11:21UTC. Significant wave height is 0.12 m.

The first case on June 10th was conducted in low wind speed conditions with a TerraSAR-X overpass occurring at 11:17 GMT. Figure 4 shows the sonar backscatter plot from June 10th displaying a thermocline feature located at approximately 20 meters depth. This feature was identified through two CTD casts which indicated a temperature drop at 20 meters, as shown in Figure 5.

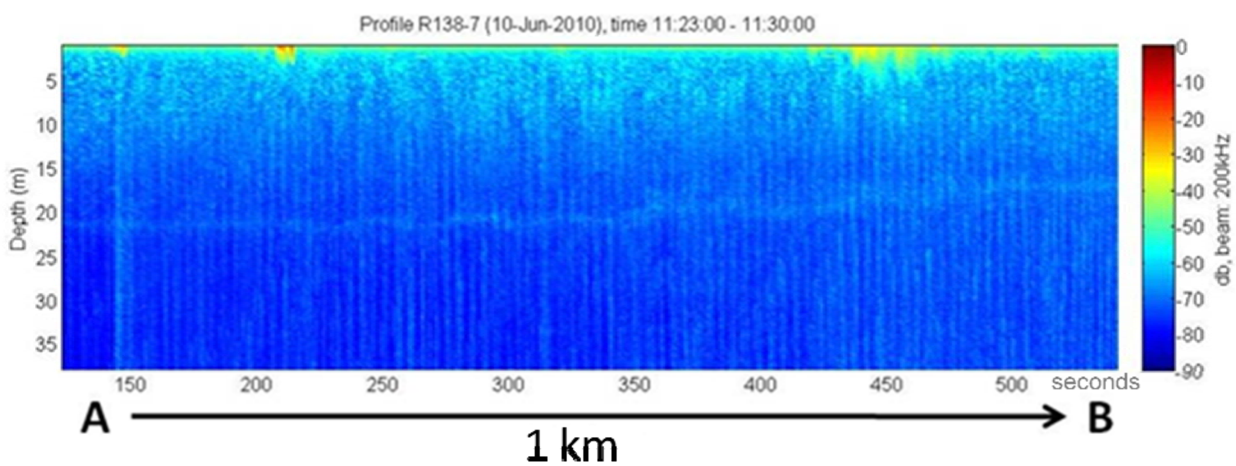

Figure 4: Sonar plot taken from 11:23 to 11:30 GMT on June 10th, 2010. This sonar transect was collected by travelling towards shore a distance of 1.6km from point 'A' to 'B' as shown on the plot and the SAR image. Plot shows a thermocline located at aproximately 20 meters depth.

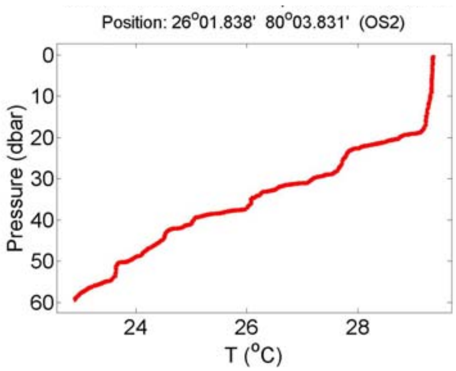

Figure 5: CTD cast profile of temperature vs. pressure taken on June 10th, 2010 indicating a thermocline located at 20 meters depth.

The dual polarimetric SAR imagery from June 10th can be seen in Figure 6, and shows a distinct boundary between the coastal and offshore waters. It is believed this feature was caused by a progressing line of thunderstorms coming from the coast as seen in a picture taken during the cruise in Figure 7.

The second case on June 15th was conducted in calm weather conditions in conjunction with a TerraSAR-X overpass at 11:25 GMT. The dual polarimetric SAR image in Figure 8 shows a number of slicks visible in the coastal waters. Also visible in the image is a boundary between the coastal and offshore waters, which is characterized by eddie formations, indicating the edge of the Gulf Stream. During our field measurements, we observed the offshore waters to be slick as indicated in Figure 9.

Slicks were also observed during the field measurements as can be seen from the photos in Figure 10 and Figure 11. Additionally, sonar measurements made directly after the satellite overpass indicate a frontal boundary that surfaces at the approximate location of a slick visible on the SAR image. The sonar plot in Figure 13 shows the horizontal transect taken from point 'A' to point 'B' on the SAR image from 11:30 to 12:00 GMT. The frontal features 3 as well as microstructure 2, as shown in Figure 13, were associated with re-stratification of the upper layer of the ocean as indicated by the CTD cast shown in Figure 12.

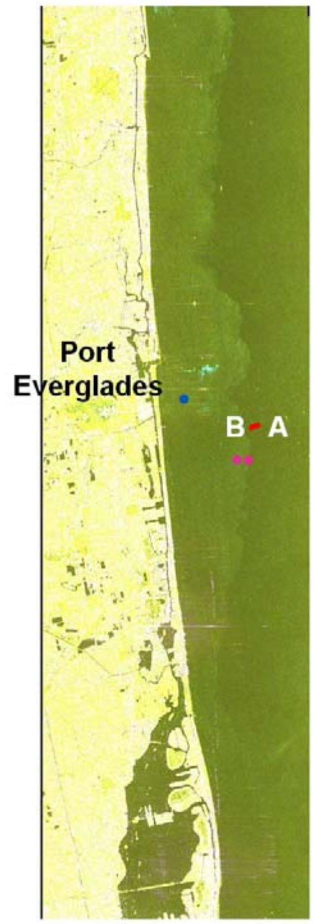

Figure 6: TerraSAR-X image acquired on June 10th, 2010 (11:17 GMT). SAR data was acquired in dual polarimetric mode (HH-VV combination), with HH for red color, VV for green color, HH-VV for blue color. Location of CTD casts is indicated by purple dots, AWAC by blue dot, and track of boat by red line between 'A' and 'B'.

Figure 7: Picture displaying the encroaching thunderstorm taken from the research vessel on June 10th, 2010.

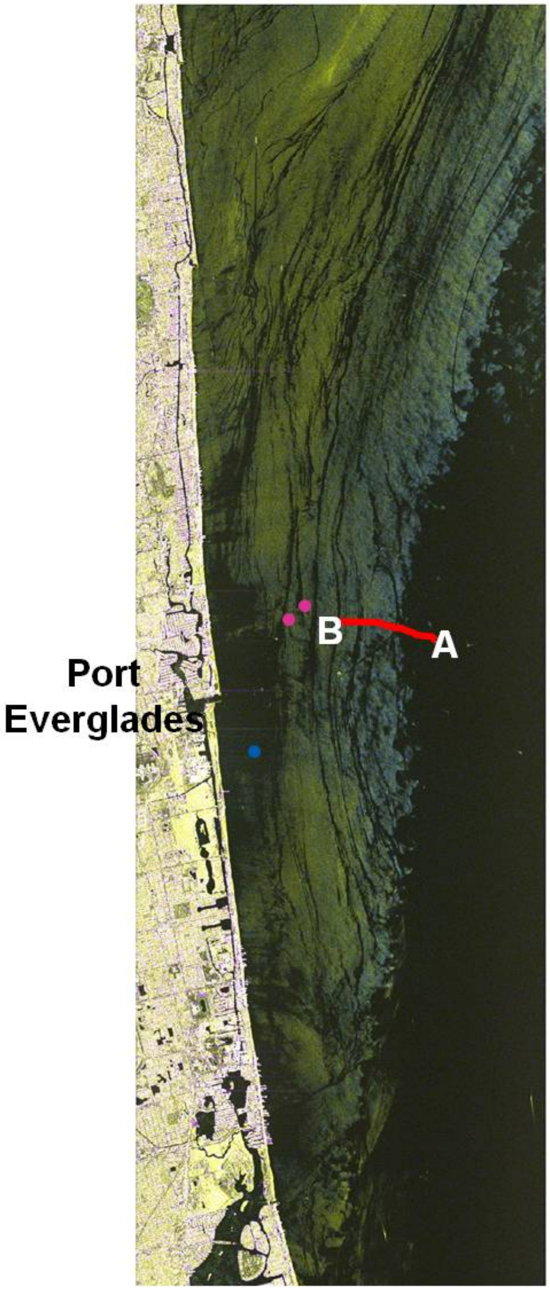

Figure 8: TerraSAR-X polarimetric image acquired on June 15th, 2010 (11:25 GMT). SAR data was acquired in the same method described in Figure 6. Location of CTD casts is indicated by purple dots, AWAC by blue dot, and track of boat by red line between 'A' and 'B'.

Figure 9: Photo taken on June 15th, 2010 indicating the slick appearance of the offshore waters.

Figure 10: Photo taken on June 15th, 2010 indicating a coastal slick feature with meanders and eddies forming on the offshore edge (photo right).

Figure 11: Photo taken on June 15th, 2010 indicating a coastal slick feature.

3. CONCLUSIONS

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. Visibility of the fine ocean structure in SAR depends on local weather conditions and presence of surfactants.

In July 2010, we continued experiments in the Straits of Florida during TerraSAR-X, RADARSAT 2, and ALOS PALSAR satellite overpasses in collaboration with the German Aerospace Center and the Bedford Institute of Oceanography. Results are being analyzed.

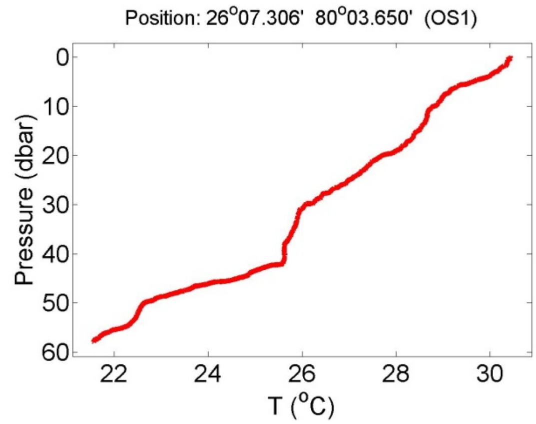

Figure 12: CTD cast from June 15, 2010 indicating stratification in the upper layer.

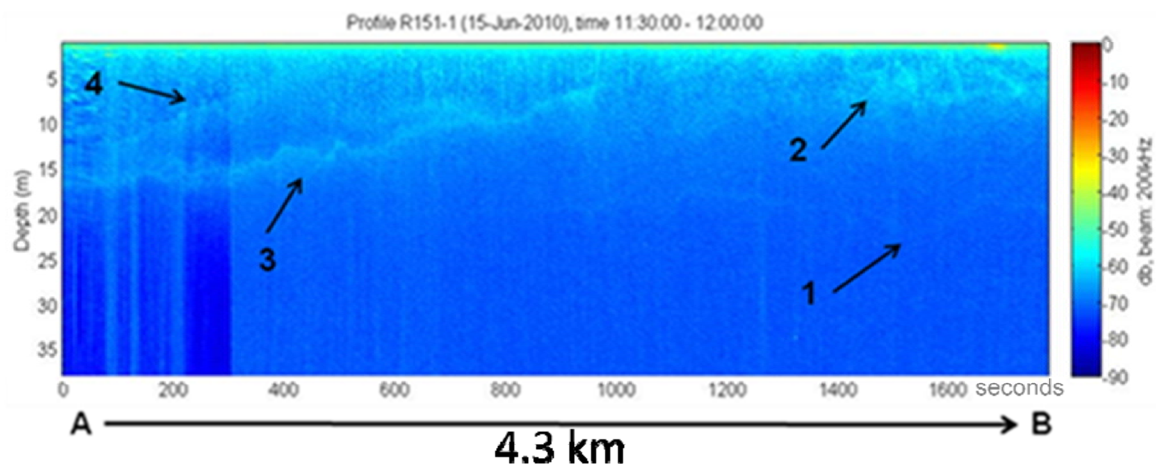

Figure 13: Horizontal sonar cross-section showing a front surfacing. This sonar transect was collected by travelling towards shore a distance of 7.1 km from point 'A' to 'B' as shown on the plot and the SAR image. Features indicated on the plot are as follows: 1-thermocline, 2-microstructure in the near surface layer, 3-frontal interface, 4-acoustic artifact relating to bottom reflection due to late echoes (see Section 2 for details).

4. REFERENCES

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