

## High Resolution Surface Characterization from Marine Radar Measurements

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### LONG-TERM GOALS

The long term goal of this proposed project is to improve our understanding of how radar-based measurements from shipborne or spaceborne sensors can be used to represent the phase-resolved surface wave field (PRSWF) for driving highly-nonlinear numerical surface wave models that predict the evolution of the PRSWF.

### OBJECTIVES

The specific scientific objectives of this study, to be carried out in collaboration with the Hi-Res DRI investigators, are:

- 1) To compare wind stress measurements from the ASIS buoys during the SW06 experiment with aerodynamic roughness parameterizations from Donelan *et al.* (2004) and Powell *et al.* (2003).
- 2) To compare array measurements of surface elevation data from ASIS with surface elevation maps from the inverted WaMoS radar data. Determine error characteristics as a function of sea state and wave field complexity.
- 3) Apply new SAR technology to estimate small scale wind and surface roughness fields and surface elevation maps from high resolution SAR images.

### APPROACH

Marine X-Band radar data collected during the SW06 experiment will be used:

- a) Radar imaging of the wave field and translation of the images into time series of 3-dimensional "elevation maps" of the surface using ship-based radar sensors.
- b) Data of the wave field and atmospheric properties above the wave field from two ASIS buoys to generate data sets that could be compared to wave models and radar both in the spectral and phase-resolved domains, and leads to a better understanding how the wind profile, fluxes, aerodynamic roughness vary with respect to differing wind and wave conditions.
- c) Selected high resolution SAR and EO images of the ocean surface to examine small scale variability in the wind fields and ocean surface elevation maps during different sea state and wind conditions.

| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     | Form Approved<br>OMB No. 0704-0188                               |                                                     |                                    |
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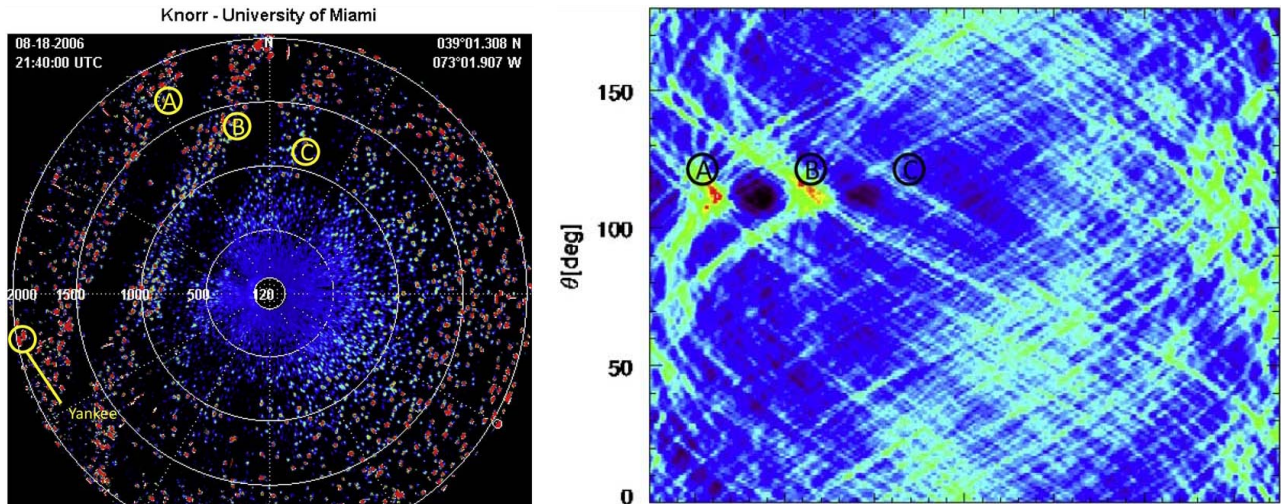
## WORK COMPLETED

- 1) Two workshops were held in Miami to resolve data issues and provide timeseries data to MIT for inclusion in their phase-resolved surface wave field (PRSWF) model.
- 2) Collection of Cosmo-SkyMed and TerraSAR-X SAR data during the Hi-Res field experiment of the southern California coast.
- 3) Improvements to the surface elevation inversion algorithm.
- 4) Development of a new wind algorithm.

## RESULTS

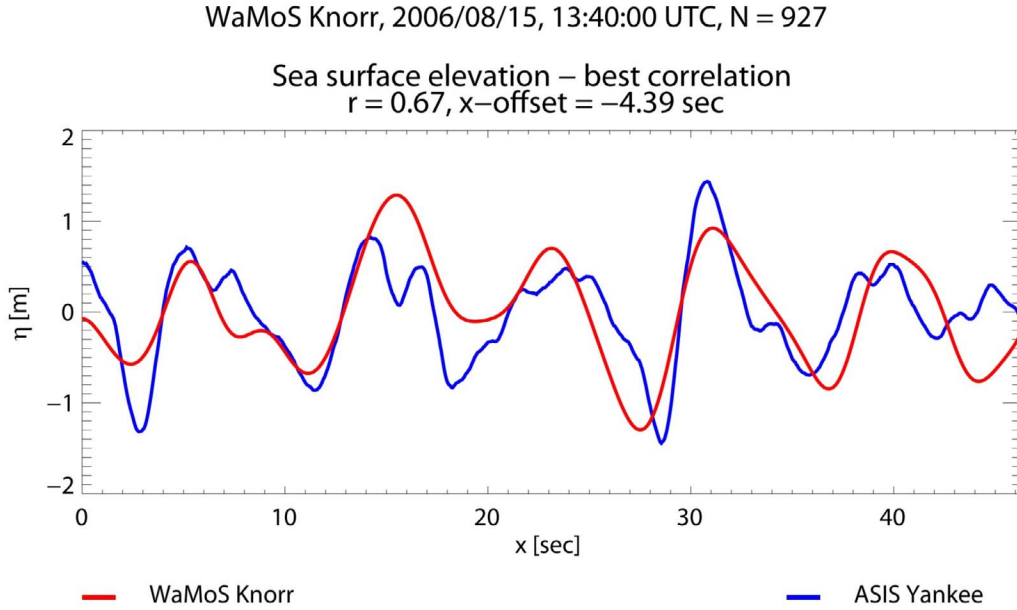
Ramos et al. (2009) described the application of nautical X-Band radars to measure internal wave (IW) properties. A methodology based on the use of Radon transform (RT) techniques is applied to detect internal wave related features from backscatter image sequences is introduced to compute properties such as direction of propagation, non-linear velocity ( $c_0$ ), distance between solitons ( $L_{cc}$ ) and number of solitons per packet. This methodology was extensively applied to several events recorded by a ship-mounted X-Band radar system (WaMoS) during the NLIWI experiment in 2006. Results from the comparisons to simultaneous measurements taken at neighboring oceanographic moorings indicated that  $c_0$  can be estimated with a *RMS* error of  $0.06 \text{ ms}^{-1}$ , which corresponds to a mean relative error of -1.4%. Similarly,  $L_{cc}$  can be estimated with a *RMS* error of 98 m, which is associated with a mean relative error of 14.6%. This latter error estimate, however, is likely to be overestimated, because it reflects strongly the separation between sampling stations as  $L_{cc}$  was shown to be highly dependent on propagation distance. The accuracy of the results shows that X-Band systems are well suited to measure internal wave properties offering some advantages over SAR and other in situ devices.

Figure 1 shows a marine radar display onboard the R/V Knorr on 18 August 2006 at 21:40:00 UTC. Marine radar data was collected continuously and data after each antenna revolution ( $\sim 2$  seconds) was stored for post-processing.



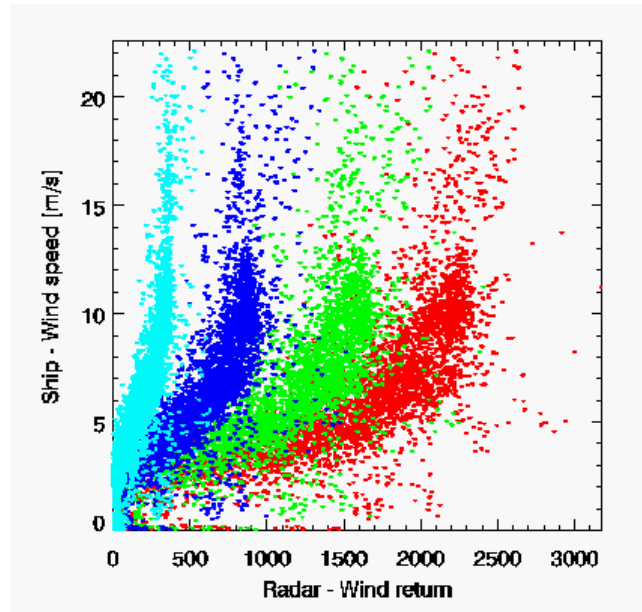
**Figure 1: Left: Homogeneous backscatter power image from sample taken on board R/V Knorr on 21:40 UTC 18 August 2006. Markers identify three IWs and Yankee is the location of the ASIS buoy. Right: Backscatter power image (homogeneous) of image on left in normalized Radon space.**

Figure 2 presents how critical time synchronisation is when inverting marine radar backscatter data to surface elevation maps. Also knowing detailed ship position and speed and heading is needed to remove from radar signal.



**Figure 2: Correlation between surface elevation data from the wavestaffs of ASIS Yankee buoy and the inverted marine radar backscatter onboard the R/V Knorr.**

Figure 3 shows results from the new wind algorithm using marine X-Band radar data collected during the NLIWI experiment and Tropical Storm Ernesto. This algorithm can readily provide near real time winds up to 15 m/s from a moving ship. Additional algorithm development is needed to extent this range to 20 m/s.



**Figure 3: Scatter plot of the average radar return in four different range sectors determined from Knorr imagery collected in the period from August 14 to September 13, 2006.**

## **IMPACT/APPLICATIONS**

Enhanced skills in these areas would lead to the goal of improved predictions of the PRSWF around surface vessels and contribute to the safety and effectiveness of naval operations and sea keeping in moderate to high winds and sea states.

## **TRANSITIONS**

None.

## **RELATED PROJECTS**

None.

## **PUBLICATION**

Ramos, R.J., B. Lund, H.C. Graber, 2009: Determination of Internal Wave Properties from X-Band Radar Observations. *Ocean Engineering*, **36** (14), 1039–1047.