

# **OBSERVATIONS OF WAVES AND CURRENTS NEAR SHORE**

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## **LONG-TERM GOAL**

The goal is to understand the forms and dynamics of the flows near shore. These flows are forced by a combination of wave breaking, winds, and topographic effects. Of particular interest here is the occurrence, form, and dynamics of rip currents. (Here, "rip currents" are loosely defined as narrow, offshore-directed flows extending some distance seaward from the surfzone.)

## **SCIENTIFIC OBJECTIVES**

We wish to establish the conditions under which rip currents occur, and which particular aspects of the environment are most relevant to their dynamics. For example, they are often (but not always) associated with cuts in nearshore bars or channels oriented perpendicular to the coast. Similarly, they are often associated with waves incident nearly normally onto the beach, being somewhat less common when the waves are incident at a steep angle. They often vary irregularly in strength and location, making it difficult to formulate a sampling strategy. Thus, at a practical level, the objective of this project is to make horizontal velocity measurements over an area of sufficient size to resolve the time-space variability of these phenomena. The velocity observations must also be coordinated with measurements of the bottom topography, incident wave field, and wind. Finally, the measurements must extend over a length of time sufficient to experience a variety of conditions.

## **APPROACH**

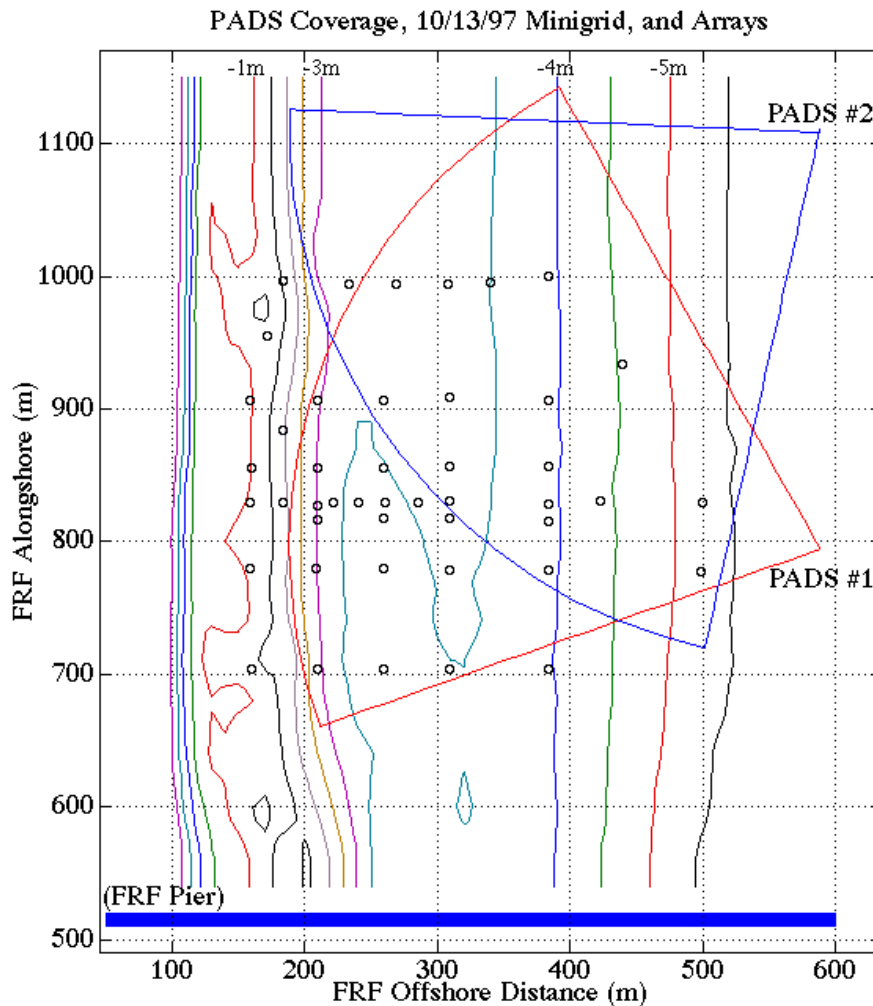
A pair of Phased-Array Doppler Sonars (PADS) were deployed at Duck, NC, as part of the SandyDuck experiment (figure 1). These instruments each provide a radially-directed component of velocity over an area up to 400m radius by 90 degrees in azimuth. Within the overlapping area covered by both systems, both horizontal components of velocity can be estimated. The spatial resolution is about 8 m in range by 6 degrees; so (for example) at 200m range the sample area is about 8 by 20 meters. The sonars transmit every 0.75s, with each ping simultaneously sampling over all angles; thus surface waves as well as the mean flow can be resolved. Two-ping averages are recorded, providing a usable sample rate of 2/3 Hz, with about 7 cm/s RMS velocity error in each range-angle bin. Simultaneously, one-minute averages are formed, sampled, and stored at 30 second intervals; these averages are intended to resolve the "background flow," including infragravity waves, shear waves, and rip currents, with nominally 1 cm/s RMS velocity error (in practice, additional errors arise from imperfect beamforming, etc.). Some supporting measurements (tilt, heading, 4-point pressure arrays) were facilitated by equipment purchased under the DURIP (N00014-95-1-1075). All data are coordinated, via GPS time-stamping, with other measurements of waves, currents, bottom topography, etc., as carried out by other participants at SandyDuck. This will enable detailed comparisons between the

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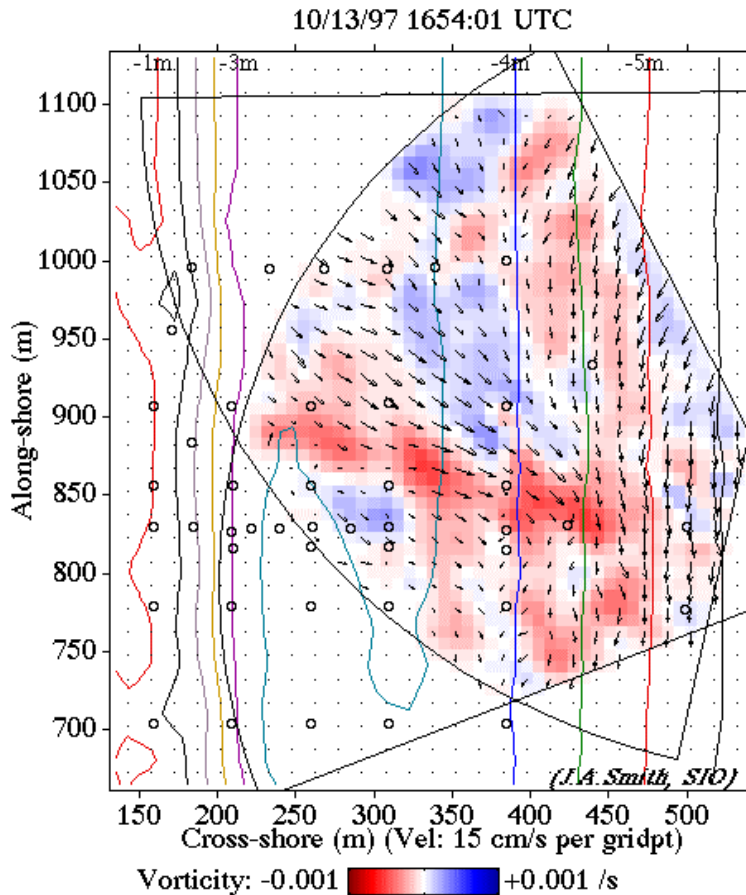
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**Figure 1.** SandyDuck experimental site, showing the (maximum) area covered by the Phased Array Doppler Sonars (PADS). The circles show locations of frames with current meters near or in the area. North is about  $17^\circ$  to the right of up. The location is the Field Research Facility of the US Army Corps of Engineers, in Duck, North Carolina.

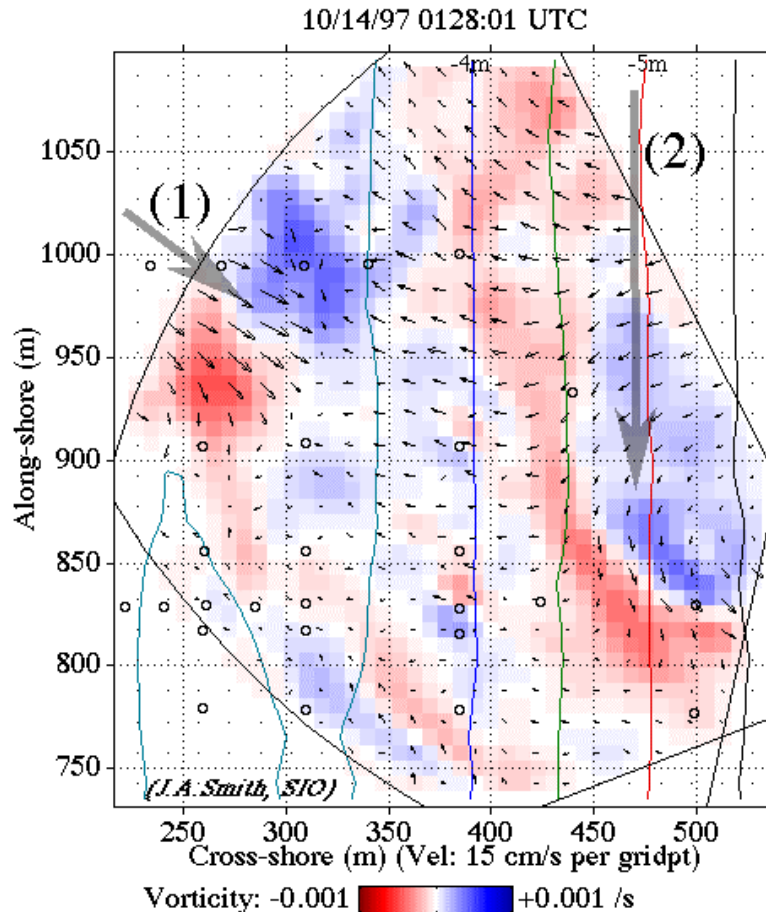
quasi-continuous coverage from the PADS and the currents measured at a variety of points in or near the PADS area (see figure 1, circles). Efforts have begun to compare currents measurements with R. Guza, S. Elgar, and F. Fedderson (all at SIO), and also with A. J. Bowen and A. Hay (Dalhousie). Vertical current profiles were measured in a couple locations within the sonar field of view as well, one by J. Haines (USGS), and another by P. Howe (USF). In addition to the current and wave measurements of these groups, there are winds and directional wave spectra provided by C. Long (FRF staff, USACE). Bottom topography was measured each day (weather permitting) by M. Leffler and crew (also at the FRF/USACE). Consistency checks such as the degree of transport divergence in the measured fields will be carried out. It is expected that variations in the Stokes' transport of the incident waves will contribute a significant amount to the overall balance, as the waves refract over the non-uniform bottom and eventually break.



**Figure 2.** Horizontal velocity vector estimates (small black arrows) and the associated field of vorticity (color contours), estimated over the area covered by both PADS. A long “rip current” appears to originate near the gap in the nearshore bar at 1000 m alongshore, and extends far enough offshore to join with offshore flow to the South. The vorticity pattern, though somewhat noisy, appears to flank the rip current fairly uniformly. In the movie sequence, vorticity “patches” seem to approach from the upper right, pressing in toward the lower left and shutting off the rip current.

## WORK COMPLETED

Construction and modification of the two phased-array Doppler sonars was completed, and they were deployed in late summer (1997; see figure 1). Both systems were operational by September 7th. They continue to function, with recovery planned in early November. To date, some 58 days worth of data have been collected, including 41 days with both systems working. Algorithms to optimally combine the data have been devised, implemented, and tested. The first “dual-Doppler” views of horizontal flows were produced on October 8th, 1997. Sequences of these combined estimates produce “movies” of the 2-dimensional flow field, along with the associated fields of acoustic backscatter intensity (bubble cloud density), and estimates of vorticity. Such movies are being routinely produced as the experiment proceeds. In storm conditions, the sonar measurements can be severely attenuated by the breaking surf (c.f., Smith 1993, Thorpe and Hall 1993). Although the loss of range seriously reduces the area covered, and hence the overall utility of the measurements in these conditions, it will be of interest to document the range versus conditions, both to determine when the measurements are useful, and (perhaps) as a measure of the severity of wave breaking.



**Figure 3.** Two “vorticity features” observed with the PADS. The left feature (#1) is a small rip current, probably originating near the gap in the sandbar (as above). This extends some distance into the domain as suggested by the gray arrow, but then fades. The right hand feature (#2) resembles a “vortex pair” as is sometimes seen in models. This moves through the domain from top to bottom, along the trajectory roughly described by the gray arrow. The intensity of the feature is fairly constant, and it appears to leave behind a “trail” of red (-) vorticity along the -4.5 meter depth contour.

## PRELIMINARY RESULTS

There are times with meandering alongshore flow, and other times where the flow is surprisingly straight and uniform. Some periods exhibit clear indications of rip currents (figure 2), others do not. Vorticity estimates from the data appear realistic, with the expected “red-blue” contrasting vorticity flanking a rip current (figure 2; figure 3, feature #1). A feature suggestive of a “vortex pair” propagating South along an isobath was also observed on one occasion (figure 3, feature #2). It is not known yet how common these are, nor how long they might last. This latter “rip current” feature extends some distance into the measurement domain and simply fades; in contrast, the “vortex-pair” feature passes from the North to South boundary of the domain without obvious reduction in intensity.

## IMPACT/APPLICATION

Exchanges of mass and momentum between the surf-zone and water farther offshore are thought to occur mainly via horizontal flow patterns (Shepard and Inman 1950). The narrow offshore-directed

portions of this flow pattern are often referred to as "rip currents." These phenomena are thought to influence the movement and sculpting of sand near shore (Holman and Bowen 1982), and could be important in the off-shore transport of sand (Smith and Largier 1995). The dynamics and form of rip currents are still not well known, despite decades of interest. It is thought that 5 factors are important in determining the form and dynamics of near shore flows:

- 1) Instabilities of the along-shore flow (vorticity waves);
- 2) Along-shore variability in wave height & direction;
- 3) Edge waves;
- 4) Bottom topography (preexisting sandbars, cuts, etc.);
- 5) Wind.

These 5 factors should be well characterized by the combined effort of SandyDuck investigators, over times long enough to experience a variety of conditions. In particular, we experienced incident wave fields with a variety of incident angles, heights, and directional spreads, and at different angles to the wind.

The means by which we have viewed the velocity and vorticity fields in this study is novel. Patterns suggestive of vortex dynamics (e.g., a self-propagating vortex pair) have been observed in the nearshore environment for the first time. The PADS measurements are a natural complement to the discrete arrays of high-precision current meters, pressure sensors, (etc.) deployed within and near the surf-zone. The combined data set spans an area from the shoreline out to some 500 to 700 m, with a similar extent alongshore. As the data are analyzed, much will be learned about the dynamics and form of the currents near shore.

## **RELATED PROJECTS**

In addition to the collaborations listed in the Approach section, I hope to collaborate with modelers J. Allen, D. Slinn, and J. Kirby. I also hope to compare some aspects of the flow and bubble fields with the video work of R. Holman and T. Lippmann.

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