Rip Currents Onshore Submarine Canyons

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Award Number: N00014-02-1-0238

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Award Number: N00014-02-WX2-0662

LONG-TERM GOALS

The long-term goals of this research are to understand the dynamics of rip currents generated by large-scale variations in alongshore pressure gradients and wave forcing, and the impact of rip currents on nearshore bathymetry. These goals will be accomplished collaboratively using field observations and numerical models, and will be pursued as part of the Nearshore Canyon Experiment (NCEX) held in fall of 2003.

OBJECTIVES

1. Develop computationally fast and efficient Particle Image Velocimetry (PIV) imaging methods for rapidly and accurately analyzing video data for surface current measurements in and around the surf zone. Apply the PIV methods to video data obtained from past experiments and the planned 2003 NCEX experiment.

2. Prepare for and participate in the 2003 NCEX experiment, specifically to obtain observations of surface currents in and around a rip current, alongshore variations in surf zone width, wave breaker angle, and runup elevations, and beach profiles and submarine topography.

3. Provide observations of surf zone surface currents, shoreline run-up, breaker angle, and surf zone width to collaborative studies utilizing data assimilation methods to model nearshore circulation (PI's Ozkan-Haller, Shore, Lippmann, and Kaihatu) and nearshore wave breaking (PI's Walker and Haller).

APPROACH

Three primary field measurements are supported by this grant. The first are observations of surface current velocities spanning the scales of a rip current (obtained from new PIV analysis of high-resolution shore-based digital video cameras; Holland, *et al.*, 2001). The second are observations of large-scale (5-km) alongshore variations in wave breaking patterns and shoreline positions; good proxies for the spatial and temporal forcing of alongshore pressure gradients in the surf (obtained from established analysis methods of an array of shore-based video imagery). The third are observations of

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2003		**00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE
Rip Currents Onshore Submarine Canyons

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Ohio State University,Civil and Environmental Engineering & Geodetic Science,,Byrd Polar Research Center, 1090 Carmack Rd.,,Columbus,,OH,43210

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**8**	

the large-scale (sand bar) seabed morphology (obtained from recently developed nearshore survey systems). These observations will be contributed to the NCEX team for other studies, for comparison with other data, and for input and verification of numerical models.

An array of nine analog video cameras were deployed close to La Jolla, CA along the edge of the 50-m high bluffs of Scripps, Black's, and Torrey Pines beaches for 2 months in the fall of 2003 as part of the Nearshore Canyon Experiment (NCEX). An example image obtained during the early period of NCEX is shown in Figure 1. Two distinct rip currents are visible, driven possibly by strong alongshore variations in wave energy at group time scales. The ground coverage of the video array spans approximately 3 km alongshore and extends approximately 500-1000 m seaward (Figure 2). The video data is being transmitted directly to a receiving station at the end of Scripps pier and digitized in real time during the experiment. Square regions of the ocean surface approximately 8 m by 8 m are interrogated with PIV techniques to determine drift velocities of passive foam and bubbles, giving instantaneous surface current estimates. Each analyzed pair of camera images were separated by 1/3 second. Mean flows were calculated over varying time intervals of 5-30 minutes, resulting in flow patterns associated with large scale circulation influenced by rip currents.

Figure 1. Left image shows a wide-angle view of the surf zone during the early part of NCEX. The flow patterns associated with the two distinct rip currens can be quantified with PIV techniques. Right image shows a high-resolution narrow-angle view focused on a single rip current (visible in the upper part of the image).

In addition, shore normal transects of pixel intensity time series spaced approximately 250-m alongshore are being sampled continuously during daylight hours. The data are stored in timestack images that can be used to detect wave breaking distributions and shoreline run-up. Analysis will follow using established techniques and data made available to modelers as soon as possible following NCEX.

We are also obtaining high-resolution video imagery of a subset of the NCEX field site in order to focus on detailed observations of a single rip current (Figure 1). These measurements are being obtained using color digital cameras sampling intermittently at 6 Hz. Three cameras have been deployed at the National Marine Fisheries Building overlooking the Scripps Canyon. In addition, a field camera is relocated at one of two bluffs looking directly offshore from vantage points north of the fisheries building. Owing to general experience at the field site, large rip currents often form in these regions such that the high resolution sampling will allow for observations of surface current time series at sampling frequencies fast enough to capture individual incident wave transformation across the width of the surf zone, as well as detail the mean flow patterns associated with rip currents that may form in the area.

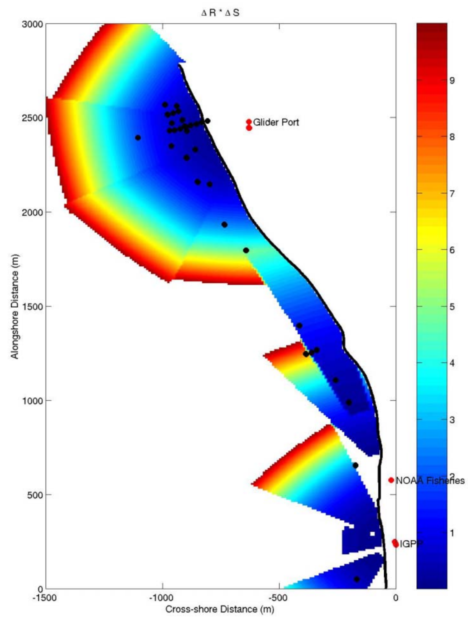

Figure 2. Map of the video footprints during NCEX derived from the geometry solutions of the 9-camera array deployed along the bluffs of La Jolla. The color contours indicate the resolution of the images. Good PIV surface velocities can be obtained in blue-tinted regions that span the 3 km field site. The locations of some of the in situ instrumentation are shown with black dots.

WORK COMPLETED

Much of our focus has been in preparation for and deployment at NCEX, and follows two distinct lines. The first is preparing and deploying the video-related field hardware, video-data transmission system, and bathymetric survey equipment. The deployed video array consists of 9 cameras that transmit data over wireless RF link to a central receiving station where they are time-stamped, digitized in real time, and archived. The bathymetric survey system has been completed and is presently being used at the field site.

The second line of work has focused on development of data processing software to sample the video data for wave breaking distributions, run-up, wave angle, and surface currents. Software exists from previous experiments to produce timestack imagery that can be subsequently analyzed for breaker position and runup excursion. Software also exists (called VISSER) to sample pixel time series in small arrays to measure average wave angle. Software utilizing PIV methods to measure surface currents over large portions of the surf zone have been developed and are presently being used to quantify surface flow patterns during NCEX over the 3 km region spanned by the video array. Owing to the computationally intensive algorithms necessary in the PIV methods, time considerations become important when processing live video feeds. Significant improvements over the past year have shortened the time to process a single pair of images by an order of magnitude, and depending on the density of measurements desired, can be accomplished with reasonable accuracy in just a few seconds. In addition, we have improved processing techniques to automatically determine shoreline and sandbar locations, wave direction, and inferred bathymetry on an hourly basis. These data are available online at: http://visser.nrlssc.navy.mil/BLACKY/.

Surf zone velocities can also be obtained from Microwave Doppler radar that relies on small-scale ocean surface roughness. Comparison of radar and video data show high correlation in regions of large radar backscatter that corresponds to broken and unbroken waves propagating across the surf zone (Puleo, *et al.*, 2002). Correlation coefficients between radial velocities sampled using the two methods at multiple locations across the surf zone typically exceeded 0.5 (maximum of 0.60) when high frequency (> 0.25 Hz) noise is excluded. Similarly, spectra were found to be coherent at the 95% level with a nearly zero phase shift near the broad spectral peak between 0.02 and 0.25 Hz. The PIV method is capable of estimating swash zone surface velocities when sufficient image texture is present, whereas the smooth water surface in the swash zone was not conducive to radar signal reflectivity.

RESULTS

Regions where alongshore currents converge cause strong, often narrow, seaward flowing rip currents that extend seaward up to many surf zone widths. The often sediment-laden rip currents are visible by the contrast between the lighter intensity foam and bubbles generated by breaking waves in the surf (Figure 1). These rip currents are not stationary in time and space and thus require spatially large arrays of instruments. As part of this research we have developed video image processing methods to quantify the surface flow patterns over the large scales of the surf zone. This image analysis methodology is known as Particle Image Velocimetry (PIV). In our application, surface flow can be mapped by observing time series of advection displacements in a similar manner as the seeded laboratory experiments.

To verify the surface flow measurements, we compared our PIV-based surface velocities with an *in situ* vertical array of bi-directional flow meters deployed by Thornton and Stanton (Naval Postgraduate School) during the 1994 Duck94 field experiment. The surface flow averaged over 70 minutes compares well with the subsurface flow (Figure 3) out to distances up to 400 m from the camera.

In addition to mean surface flow estimates, the PIV data can resolve oscillatory wave motions where the resolution of the image footprint is good (Figure 2). Where the infragravity and shear waves are strong, arrays of PIV estimates can be used to estimate the alongshore wavenumber distribution of the motions across the surf zone. Example wavenumber-frequency spectra from the 1997 SandyDuck experiment are shown in Figure 4.

When the fluctuations induced by individual wave propagation are removed, a smooth pattern of the wave-averaged flow can be produced with good confidence (Figure 3). Wave-averaged quantities are directly applicable to data assimilation models under development by collaborators (PI's Ozkan-Haller, Shore, Lippmann, and Kaihatu). Mean flows averaged over longer periods can also be obtained. An example 6-hour average from the middle of the NCEX array is shown in Figure 5. The flow pattern shows a strong meander of the flow near the head of the Scripps Submarine Canyon that impinges very close to the coastline.

Bathymetry and foreshore profiles were also obtained during NCEX, and can be found at http://cdip.ucsd.edu/models/ncex/bathy/mini_grid/index.html.

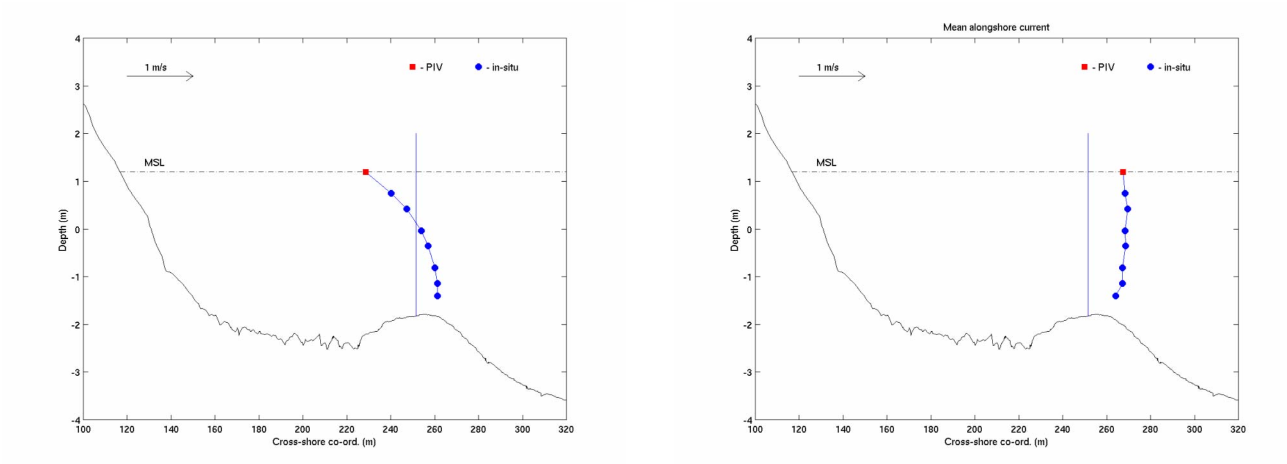

Figure 3. Comparison of mean cross-shore (left panel) and alongshore currents (right panel) between video-based surface measurements (red squares) and a vertical array of in situ flow-meters (blue circles). Velocity estimates are relative to the vertical line that indicates the location of the vertical stack of flow meters and the center of the PIV interrogation window. The bathymetry profile and water level are also shown.

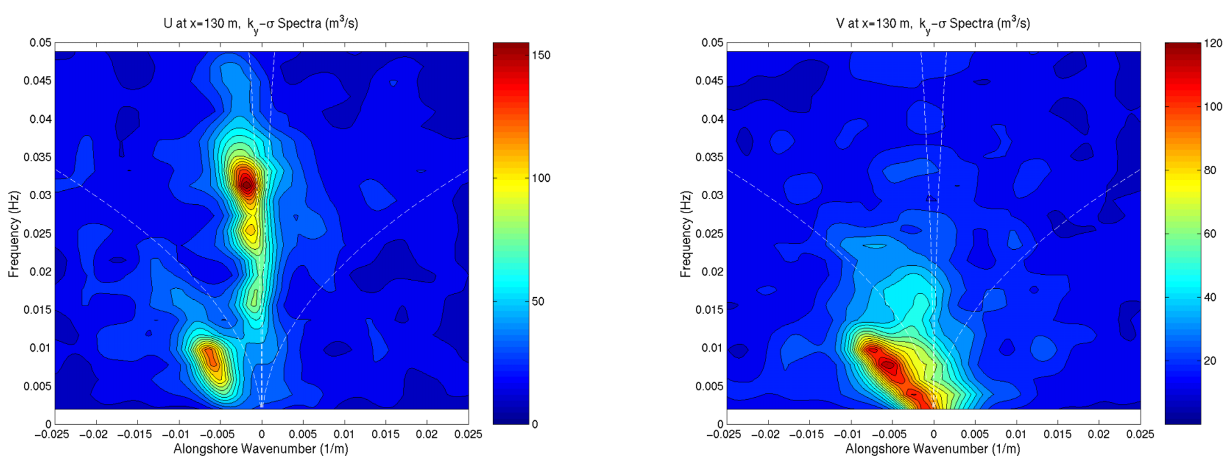

Figure 4. Wavenumber-frequency spectra derived from an alongshore array of surface current estimates for the cross-shore (left panel) and alongshore (right panel) component of the flow obtained during the SandyDuck experiment. The arrays were within about 50 m of the shoreline, and show strong shear and infragravity wave energy.

IMPACT/APPLICATIONS

Improvements in the sampling and modeling of wave breaking have lead to improved models for ensemble-averaged wave transformation and the forcing for mean flow. Development of remote sensing methods for measuring surface currents over large areas of the surf zone can be used to verify circulation models in the nearshore where *in situ* instrumentation is difficult to deploy.

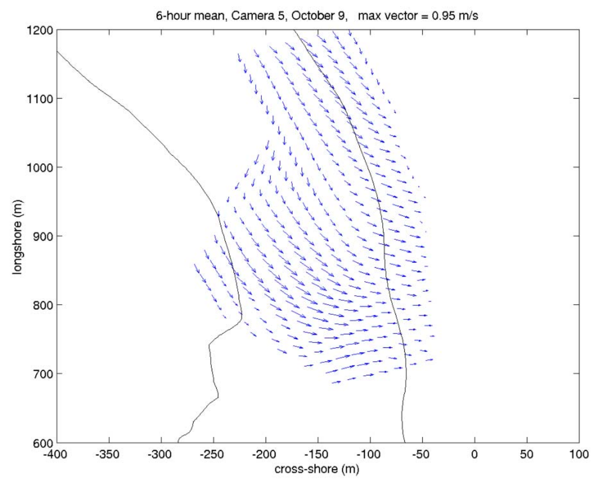

Figure 5. Surface flow pattern averaged over a 6 hour period early in the NCEX experiment. The shoreline and 5 m depth contours are shown (the shoreline is to the right in the image). The observations reveal a strong meander in the mean flow field persistent over the 6 hour run.

TRANSITIONS

Many of the surf zone characterization techniques relating to this effort are being transitioned under the NRL Littoral Environmental Nowcasting System program for eventual Naval operational use.

RELATED PROJECTS

Video data analysis of the 1990 Delilah, 1994 Duck94, 1996 MBBE, 1997 SandyDuck, and 2001 RIPEX experiments are being examined in collaboration with other ONR-funded scientists making *in situ* observations of wave and current properties.

REFERENCES

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Puleo, J. A., G. Farquharson, S. J. Frasier, and K. T. Holland, 2002, Comparison of optical and radar measurements of surf zone velocities, *J. Geophys. Res.*, submitted.

PUBLICATIONS

Puleo, J. A., G. Farquharson, S. J. Frasier, and K. T. Holland, 2002, Comparison of optical and radar measurements of surf zone velocities, *J. Geophys. Res.*, submitted.