Optical Imaging of the Nearshore

Rob Holman
COAS-OSU
104 Ocean Admin Bldg
Corvallis, OR 97331-5503
phone: (541) 737-2914 fax: (541) 737-2064 email: holman@coas.oregonstate.edu

Award #: N00014-02-1-0154
http://cil-www.coas.oregonstate.edu:8080

LONG-TERM GOAL

The long term goal of neashore processes research has been to develop a predictive understanding of the fluid dynamics of a random wave field shoaling over the complicated bathymetry of a natural beach, and the response of the beach to those overlying wave and current motions. Traditionally, this has involved forward prediction based on models and seed data. However, it has now been broadly recognized that prediction of nonlinear systems such as the nearshore will inevitably fail at long time scales, so that knowledge of a coastal environment will depend on frequent data updates, likely acquired through innovative remote sensing techniques.

OBJECTIVES

Over the last decade, our scientific focus has been on the development and implementation of an extensive, robust optical sampling capability for nearshore processes (the Argus Program) and documentation of the plethora of new phenomenology that were observed. Our current work sees a re-focussing on understanding the physics of electro-optical imaging, an assumed prerequisite to full exploitation of optical signals. We wish to develop a physics-based model for the Modulation Transfer Function (MTF) relating optical radiance to underlying geophysical variables. Thus, observations will shift from a basis in contrast (for waves) and morphology (patterns of sand) to actual time series of sea surface elevation and bathymetry. This work includes both optical processes outside the surf zone where radiance is based on Fresnel reflection from a sloping and wavey sea surface as well as radiance for breaking-induced foam. Of particular recent interest is the potential for direct estimation of radiation stress gradients through optical measures.

APPROACH

Our principle implementation of optical remote sensing has been through the Argus Program, a collection of remote stations located at strategic sites around the world with an hourly sampling program for a variety of fluid and bathymetric variables. The development of Argus techniques has been based on a series of ground-truth opportunities, generally based at the Field Research Facility at Duck, NC. In the fall of 2003, Argus will play an important role in the next such field effort, at the Nearshore Canyon Experiment (NCEX), in Southern California. In anticipation, and to allow a build up of capability prior to that experiment, a new Argus Station was installed at the site in the fall of 2001 (http://cil-www.coas.oregonstate.edu:8080/ncex/ncex.html).

In addition, the Coastal Imaging Lab is continuing a regular GPS survey program at our home site at Agate Beach, Oregon. This involves monthly surveys of a 3 km stretch of beach at spring low tide. This provides not only an excellent data set in its own right, but also provides ground truth data for the local Argus station and for occasional LIDAR overflights.

WORK COMPLETED

A major activity this year has been the installation of the NCEX Argus Station and initial configuration and testing of pixel instruments for this site (Figure 1). This array features a number of cross-shore transects for wave celerity and bathymetry estimation, as well as the more useful longshore current instruments and alpha arrays measuring the wave angle of incidence. Since none of the three cameras of this station have clear ground control points in view, we have developed pattern-based registration techniques for calculating the required sub-pixel image geometry solutions.

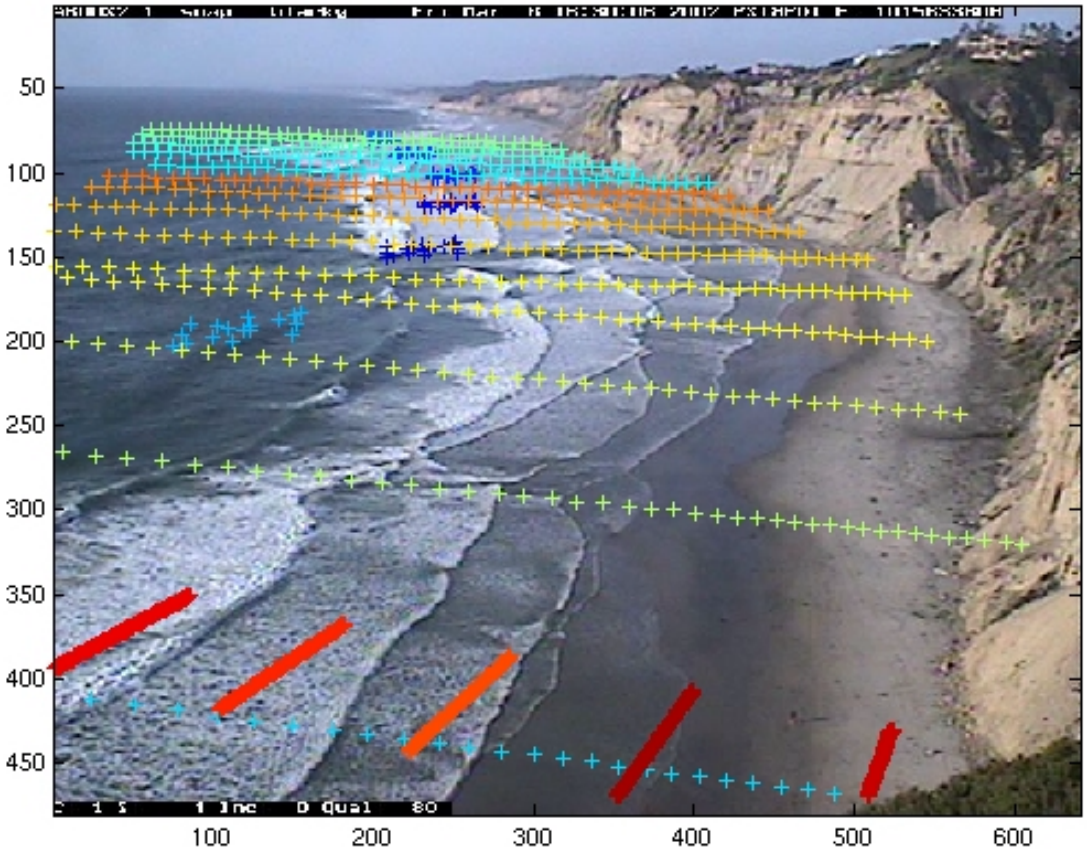

Figure 1. Initial pixel instrument array at Black's Beach, CA. Cross-shore lines allow bathymetry estimation, alongshore (red) lines provide estimates of the longshore current, offshore pixel "blobs" measure wave angle of incidence. [View of Black's Beach with superimposed symbols indicating array of pixels to be sampled].

The time exposure results of the first ten months have been assembled into movie loops in both oblique and rectified view and made available on the web (e.g. http://cil-www.coas.oregonstate.edu:8080/ncex/blacky.merge.small.avi where "merge" and 'c1' give rectified and oblique images, respectively; 'avi' and quicktime ('.mov') are available; and 'small' and 'big' specify movie resolution; note that 'c1' is only available in small). The plethora of rip channels and occasional bars should provide a challenge for modeling as well as field sampling.

We have completed work on the "Optical Current Meter" technique for measuring longshore currents optically. Ground-truth comparisons from the SandyDuck field experiment show the technique to be unbiased with a 10 cm/sec rms deviation from ground truth, some of which is not error but is associated with a wind-driven surface shear layer (Figure 2; [*Chickadel et al.*, in review]).

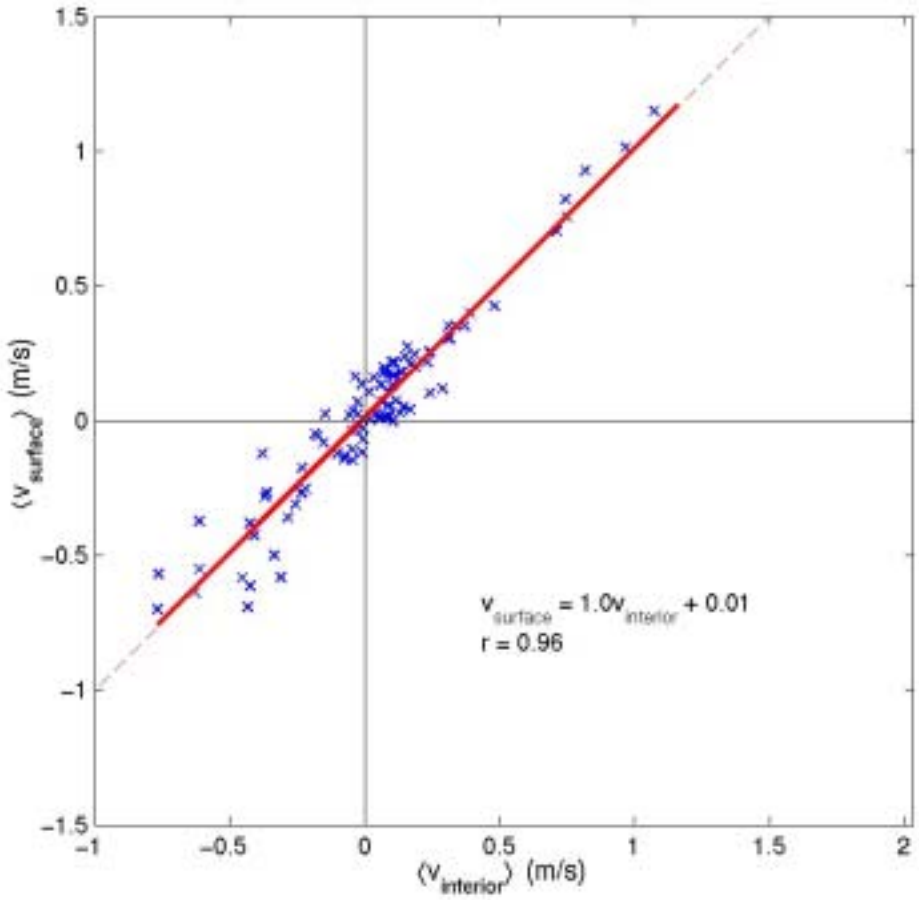

Figure 2. Test of the optical current meter, comparing optical estimates of mean longshore current ($V_{surface}$) to ground truth measurement ($V_{interior}$) from the SandyDuck field experiment (ground truth provided courtesy of R.T. Guza and S. Elgar). The optical technique is unbiassed, with an rms error of 10 cm/sec (some of which is true, wind-generated shear). [Data cluster along the 1:1 line, spanning a range from –1 to about +1 m/sec]

We have continued our work on describing and understanding large scale nearshore morphology. *Alexander and Holman* [in review] describes a technique for quantification of nearshore shorelines and bar systems with a set of simple, continuous variables (an improvement of the discrete state descriptors commonly in use). Results from four disparate field sites (Duck, NC; Agate Beach, OR; Egmond, The Netherlands; and Palm Beach, Australia) were systematically compared. *Ruessink et al.* [in press] and *Ruessink et al.* [in review] describe comparisons from a set of long term bathymetric data sets. Sand bars were found to obey certain universal relationships with respect to their amplitude and rate of offshore progression.

IMPACT/APPLICATION

The development of a robust set of optical remote sensing techniques opens many doors. From the point of view of the U.S. nearshore processes research effort, Argus data continues to provide surprising and wide-ranging data that are available quickly on the web. Long time series, such as can really only be collected by a program like Argus, have proved themselves invaluable to understanding previously unsuspected inter-annual variability in the nearshore. We expect that Argus will have a large impact on the upcoming NCEX field program both due to the long record of morphological variability from the site in the experiment build-up phase, as well as due to the range of fluid measurements that will complement and supplement the in-situ arrays during the actual experiment.

The impact of Argus on society is becoming increasingly apparent. In addition to the 11 sites run by the Coastal Imaging Lab, there are now an additional 13 sites being operated by others worldwide. Argus is the focus of a three year EU program (CoastView), designed to integrate Argus into everyday Coastal Zone Management practices.

TRANSITIONS

Argus technology has been embraced by NRL-SSC in a program run by Dr. Todd Holland. We continue to have strong collaboration with his group, including cooperative work associated with the VISSER station at Camp Pendleton and a second station, jointly installed in the past year, at Waveland, MS. Skills and ideas in handling EO data developed due to Argus interest have lead to the PI spending substantial lengths of time either at Navoceano, or at OSU, working directly on problems of implementation of nearshore remote sensing to Naval needs. The PI is also involved in the LRS program and continuing interactions with government and contractor scientists. We continue collaboration with the U.S. Army Corps of Engineers both through Bill Curtis at Vicksburg and through the FRF on a variety of Argus issues. Argus is now becoming “mainstream” in Europe with the beginning of the CoastView EU program for the integration of Argus into standard Coastal Zone Management practice.

RELATED PROJECTS

1 - Joint work with Dr. Todd Holland, NRL-SSC
2 - Collaboration and data sharing of pixel time stack data with Dr. Jim Kaihatu or NRL-SSC
3 – Collaboration with Craig Cobb of the WSC at Navoceano on nearshore remote sensing
4 – LRS program collaboration
5 – EU CoastView Program (2002 – 2005)
6 – Numerous collaborations with the Field Research Facility

REFERENCES

Alexander, P.S., and R.A. Holman, Quantitative analysis of nearshore morphological variability based on video imaging, *Marine Geology*, in review.

Chickadel, C.C., R.A. Holman, and M.F. Freilich, An optical technique for the measurement of longshore currents, *Journal of Geophysical Research*, in review.

Ruessink, B.G., R.A. Holman, and K.M. Wijnberg, Interannual nearshore bar behavior: an inter-site comparison, in *Proceedings of Coastal Dynamics*, ASCE, Lund, Sweden, in press.

Ruessink, B.G., K.M. Wijnberg, R.A. Holman, Y. Kuriyama, and I.M.J. van Enckevort, Inter-site comparisons of interannual nearshore bar behavior, *Journal of Geophysical Research*, in review.

PUBLICATIONS

Alexander, P.S., and R.A. Holman, Quantitative analysis of nearshore morphological variability based on video imaging, *Marine Geology*, in review.

Chickadel, C.C., R.A. Holman, and M.F. Freilich, An optical technique for the measurement of longshore currents, *Journal of Geophysical Research*, in review.

Haxel, J.H., and R.A. Holman, The sediment response of a dissipative beach to variations in wave climate, *Marine Geology*, in review.

Ruessink, B.G., R.A. Holman, and K.M. Wijnberg, Interannual nearshore bar behavior: an inter-site comparison, in *Proceedings of Coastal Dynamics*, ASCE, Lund, Sweden, in press.

Ruessink, B.G., K.M. Wijnberg, R.A. Holman, Y. Kuriyama, and I.M.J. van Enckevort, Inter-site comparisons of interannual nearshore bar behavior, *Journal of Geophysical Research*, in review.

PATENTS

None