Robust Littoral Characterization using Electro-Optical Sensors

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LONG-TERM GOAL

The long-term goal of nearshore 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 or tidal inlet, and the response of the erodible bottom to those overlying wave and current motions (Holman et al., 1990). Success requires not only knowledge of nearshore physics but also an ability to collect and incorporate input geophysical data required as inputs to numerical models.

OBJECTIVES

Our immediate objectives are to develop and test algorithms for the estimation of required nearshore geophysical variables based primarily on optical signals or on combinations of optical data with other remote sensing modalities. In order to allow proper data assimilation or resulting estimates, we also require methods to estimate confidence intervals.

APPROACH

Since the science objectives and content substantially overlap and the ONR programs have now merged, this report combines results from my core Coastal Geosciences research and that on surf zone radiance originally funded under the Ocean Optics program.

Data collection is key to developing and testing ideas and our program is based on the observation methods and infrastructure of Argus, developed over the past 25 years. We are basing analyses on several sampling opportunities. Surf Zone Optics (September, 2010) provided the main opportunity for focused data collection, modeling effort and multi-sensor data collaborations and included in-situ measurements of incident wave dissipation by Jim Thomson (UW-APL). An upcoming two-month NSF-funded experiment by Steve Henderson and Tuba Özkan-Haller provides a new comparison against an array of in-situ wave height and current sensors. A follow-on experiment to Surf Zone Optics (RIVET) will provide data in a more challenging domain that mixes wave-bathymetry (beach) physics with wave-current interaction. Due to permitting issues, this program has been delayed until May, 2012. To prepare for the sampling and analysis challenges of a wave-current-bathymetry domain

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and to make use of the additional preparation time, we are now collecting at Teignmouth, England, an existing Argus site with strong tidal currents and waves.

While optical signals offer great potential in the surf zone and nearshore, the main obstacle is to measurements is contamination by high-wavenumber wave components since most reflectance processes depend on wave steepness. Thus, effective analysis must be done in the frequency domain and must include automated confidence interval estimation. We have developed an algorithm, cBathy, for the robust estimation of wavenumber and direction for incident frequencies hence bathymetry via he dispersion relationship. This algorithm improves signal to noise using robust signal processing and is being tested against ground truth data sets at two sites and adapted to provide simultaneous mean currents from Doppler measurements (this will be required for RIVET work).

We continue to study the processes of optical radiance in the surf zone, primarily based on data collected in the Surf Zone Optics experiment at Duck, NC. Our hypothesis is that ocean surface optical signals are dominated by Lambertian reflection from layers of surf zone bubbles associated with depth-induced breaking (Walker, 1994). Figure 1 shows a comparison of normalized observed optical reflectance and dissipation measured by a fixed ADCP that was alternately in or seaward of the surf zone depending on tidal elevation. The lower panel compares this tidally-driven variability of dissipation (blue) with optical reflectance (green), showing a reasonable agreement (omitting the fourth day when raindrops spotted the lens). We model the optical signal in terms of the fraction of breaking (Battjes and Janssen, 1978), and are developing corresponding measurement algorithms and error bars. Development of an optical proxy for dissipation will be a powerful aid to model-data assimilation packages.

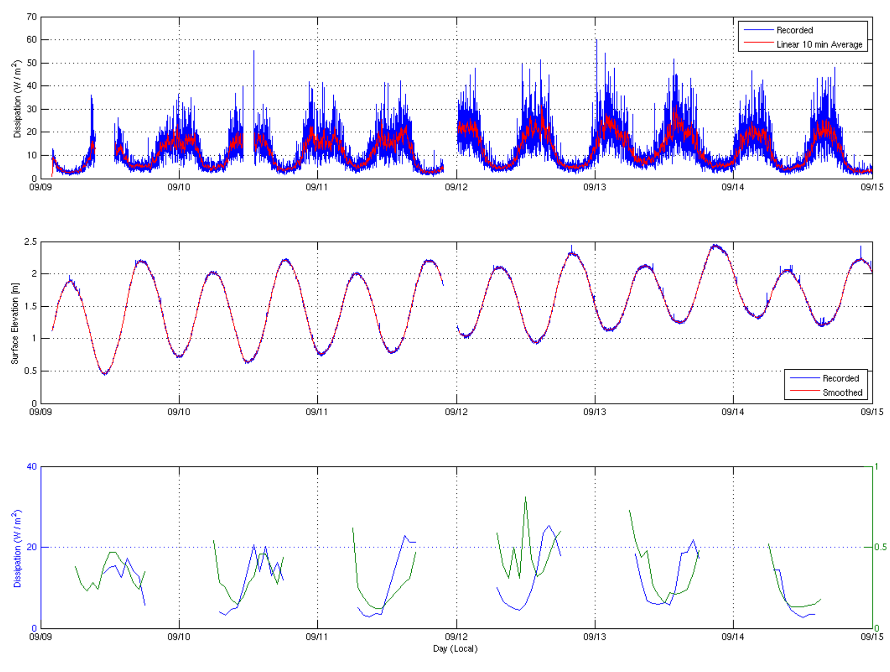

Figure 1. Results from the Surf Zone Optics experiment showing: upper panel) one-minute in-situ dissipation measurements (blue) and their 10-minute averages (red); middle panel) measured tidal elevation (red is smoothed to 10 minutes); and lower panel) 10-minute averaged dissipation at times of Argus time exposure images (blue) and reflectance computed from those images. Other than the fourth day when raindrops contaminate the optical signals, EO and in-situ agree well.

Work on determination of wave heights from optical polarization has been slowed by the problem of short wavelength contamination. Overcoming this issue requires a frequency domain analysis that we are implementing through cBathy. Thus, we need to close out cBathy development prior to finishing our polarization work.

WORK COMPLETED

Over the past year a number of past efforts have come to publication. A simplified model describing the morphodynamics of 2DH sand bars and the role of alongshore variability on cross-shore dynamics has been published (Splinter et al., 2011). The impact of this alongshore variability has been shown to be a non-negligible contributor to cross-shore bar dynamics (1DH dynamics are often assumed).

A method to exploit sparse in situ measurements to improve erroneous estimates of nearshore bathymetry using ensemble data assimilation methods has now been published (Wilson et al., 2010) and forms the basis of continuing work to ingest a variety of remote sensing model inputs.

Work exploiting the combined signatures of breaking waves in optical and radar data to clarify ambiguities in either sensor has finally been published (Catalan et al., 2011).

A new model for the physics by which inundated sand dunes erode has been developed, modeled and tested (Palmsten and Holman, in press).

Several collaborative papers have been published on the physics of natural swash, an important physics problem both for the impact on coastal processes and as a potentially diagnostic variable that can be observed and assimilated into numerical models (Guedes et al., in press; Power et al., in review; Senechal et al., 2011).

A data-driven paper describing the physics of wave propagation across dense mud banks has finally been published (Pereira et al., 2011).

Finally, results of an assessment of the potential for carrying out Argus-like sampling using commercially available UAVs was presented at a workshop and published in a refereed journal (Holman et al., 2011) jointly with NRL-SSC scientists.

RESULTS

A number of research topics regarding the interactions of nearshore hydrodynamics with an erodible bathymetry and foreshore topography have reached fruition. Work has shifted to the problem of surf zone characterization coupling optically-derived geophysical measurements to numerical models and to potential methods for collecting these data. The main focus is on developing analysis methods to defeat high frequency noise and to provide observations coupled with confidence intervals that can be incorporated into data assimilation models.

IMPACT/APPLICATION

Nearshore remote sensing is of obvious importance to Naval Battlespace Characterization as well as to civilian applications in coastal zone management requiring extended observation (beyond the scope and available funding for focused experiments). The continual improvement in signal processing methods to reduce the high frequency noise that often dominates optics makes these methods robust, with well-understood statistics.

TRANSITIONS

The optical remote sensing approaches of Argus have been transitioned or are being further pursued in many ways. Efforts to make Argus available to the world have seen some success but will pushed anew in a potential collaboration with CoastalCOMs. Argus is an accepted tool by the nearshore community throughout the world. Argus technology or spin-offs have been and are being actively used by the U.S Navy through products of the LRS program and, for NSW teams, through products of the research work of Dr. Todd Holland's group at NRL (we remain tightly connected to this group and are part of ongoing research nearshore battlespace characterization). The U.S. Army Corps of Engineers (through the FRF) continues to use Argus for both testing and applied projects. The USGS, particularly through Nathaniel Plant, also embraces Argus as an important tool in coastal monitoring and experimentation.

RELATED PROJECTS

1 – Joint work with Dr. Todd Holland, NRL-SSC on Argus methods, SUAV applications and improved bathymetric approximations for use in Delft3D models on denied beaches.

2 – Numerous collaborations with the USACE Field Research Facility including Morphos and XBeach testing and operations.

3 – Work with USGS on Argus bathymetry methods (Plant) and shoreline vulnerability through foreshore-swash and dune erosion studies.

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