LONG-TERM GOALS

The long-term objective is to develop field-verified models for the wave fields, circulation patterns, and morphological evolution near inlets.

OBJECTIVES

The primary objective of our recent work is to develop, test, and improve models for nearshore processes near and within inlets.

APPROACH

Our approach is to collect field observations to test existing hypotheses, to discover new phenomena, to provide ground truth for remote sensing studies, to initialize and test data assimilative models that invert for bathymetry, and to calibrate, evaluate, and improve models for inlet hydrodynamics and morphological evolution.

WORK COMPLETED

i) Field Observations
In summer 2015, current meters and pressure gages were deployed in Vineyard Sound and Katama Bay on the southern shore of Martha’s Vineyard (Fig. 1). We also performed several days of drifter releases to obtain observations to assimilate into models for the circulation, and we surveyed the remnant ebb shoal, shoreline, and bay near the inlet mouth. The inlet was breached in 2007, migrated east 2 km, and closed in 2015. The data are being used by PhD students Mara Orescanin (recently defended her dissertation) and Julia Hopkins (advanced to candidacy) to investigate the effects of tides, waves, and bathymetry on circulation and morphological evolution in and near Katama Bay and Inlet.
ii) Modeling
In August Mara Orescanin defended her thesis in which she used an ADCIRC model to investigate the
effects of the changing inlet configuration on the circulation in the inlet and bay (Orescanin et al. 2015). Julia Hopkins is investigating inner shelf hydrodynamics and nearshore morphological change
near the inlet mouth using a SWAN-Delft3D-Flow model (Hopkins et al. 2015). In collaboration with
ONR team members, we have been using field observations in combination with numerical model
simulations to learn about inlet processes. Our observations of waves and currents were used to calibrate
and test numerical simulations of the circulation patterns at New River Inlet (Chen et al. 2015). Drifter
trajectories were compared with model simulations (NearCOM and COAWST) of the flows in the
strong currents at New River Inlet (Spydell et al. 2015). Simulations with Delft3D accurately
reproduced the dominant alongshore momentum balance estimated from observations collected near a
deep submarine canyon near La Jolla, CA (Hansen et al., 2015). The model results suggest that
nonlinear advective terms can be important in the momentum balance, and accounting for advection
provides better estimates of bottom friction.
(iii) Remote Sensing
We compared lidar with pressure-sensor observations of waves in the inner surf and swash zones (Brodie et al. 2015). The lidar observations are similar to those made with pressure gages, and have much higher spatial resolution, allowing edge-wave modes, reflection, and wave statistics to be examined in unprecedented spatial detail. In addition, the lidar provides estimates of the beach bathymetry during wave run down. We used our observations at New River Inlet to calibrate and test radar estimates of wave propagation from offshore, across the ebb shoal, to the beach (Diaz Mendez et al. 2015). In addition, we used the observations to develop radar-based estimates of breaking wave heights in the surf zone near the inlet mouth (Goncharenko et al. 2015).

RESULTS

Observations of waves, currents, and bathymetry in combination with numerical models are being used to investigate hydrodynamics and morphodynamics on the complex inner shelf and shoreline near Katama Bay, Martha’s Vineyard, MA (Fig. 2).

Figure 2. Bathymetry (color contours, scales on the right) and nested grids (black rectangular outlines) for (a) the full model domain, (b) the region near the shoreline of Martha’s Vineyard, and (c) the inner grid near the shoreline. Open (7 m depth) and filled (2 m depth) circles are locations of colocated wave and current sensors. The 7 m depth sensors are labeled with their distance (km) from the eastern-most sensor located at x = 0 km (open circle with “X”). The sensor at x = 8.8 km was in 12 m depth. The yellow circle in (a) is NOAA buoy 44097 (~50 m depth). Spatial resolutions (1000, 200, 40, and 13 m) are shown in the lower right-hand corner of each grid. [Map of Cape Cod and the islands showing nested grid boundaries and the locations of wave and current sensors.]
The currents on the inner shelf (~7 m depth), onshore of the Muskeget Channel (Fig. 2b) are > 1.0 m/s near the inlet and decrease to < 0.2 m/s 10 km to the west (Figure 3). The model predictions of the inner-shelf currents are skillful (compare red with black curves in Fig. 3), except for an underprediction of westward flows at the eastern edge of the model domain (Fig. 3c). We hypothesize the discrepancy between model and data at that location may be owing to inaccurate modeling of the westward tidal flows that separate from the shoreline in this area. Small inaccuracies in bathymetry or model parameters may result in a spatial displacement of the simulated separation zone relative to the observations.

Model simulations of wave heights and directions on the inner shelf (~7 m depth, Fig. 4) and surfzone (~2 m depth, not shown) also are accurate, including the large (~70°) observed modulation of wave directions (Fig. 4f). Waves propagating across the continental shelf to the shoreline cross the strong (> 3 m/s) tidal currents flowing through Muskeget Channel (Fig. 2b) and the complicated bathymetry south of Martha’s Vineyard (Fig. 2). To determine if the modulations in wave direction are caused by changes in refraction owing to tidally-varying water depth or by changes in interactions between waves and the strong, tidally-varying Muskeget Channel currents, the model was run with and without wave-current interaction. When there is no wave-current interaction, the model does not simulate the observed tidal modulations in wave direction (compare red with blue curves in Fig. 5a and red with black in Fig. 5b). In contrast, the model with refraction from both wave-current interaction and bathymetry (blue in Fig. 5) and the model with wave-current interaction only (green in Fig. 5) simulate the observed tidal modulations of direction.

Figure 3. Observed (black curves) and modeled (red curves) 1-hr mean depth-averaged (a-c) east and (d-f) north velocity in 7-m water depth versus time at locations (Fig. 2) x = (a,b) 10.8, (c,d) 3.3, and (e,f) 0.3 km. RMSE values (normalized by the data range) are given in the upper right-hand corners. [Modeled currents are similar to the observed flows.]
Figure 4. Observed (black curves) and modeled (red curves) 3-hr (a-c) significant wave height and (d-f) wave direction in 7-m water depth versus time at locations (Fig. 2) x = (a, d) 10.8, (b, e) 3.3, and (c, f) 0.3 km (distances are relative to the sensor at x = 0 km). Grey curves are the observed offshore (50 m depth) wave heights and directions. RMSE values (normalized by the data range) are given in the upper right-hand corners. [Model simulations of wave heights and directions are accurate.]

Figure 5. (a) Wave direction versus time at x = 0.3 km and (b) energy density of the time series of wave direction versus frequency for observations [black curve, (b) only] and simulated by the model including tidal currents and water depth changes (blue curves), currents, but no depth changes (green curves), and depth changes, but no tidal currents (red curves). [The model without wave-current interaction does not predict the observed ~70° tidal modulation of wave directions. Including wave-current interaction results in skillful model predictions.]
With student Julia Hopkins, we have been testing the model’s ability to simulate morphological evolution, especially during storms. Julia spent summer 2015 at TU Delft (The Netherlands) modeling the shoreline change we observed near Katama Inlet during Hurricane Irene. Sediment transported by large waves and strong currents caused the inlet and associated ebb shoal to migrate eastward ~100 m, with more than 2 m of accretion at the eastern end of the sand spit (Norton Point) separating Katama Bay from the Atlantic Ocean (green ovals in Fig. 6), 2 m of erosion in the new location of the inlet channel (black ovals in Fig. 6), and 2 m of erosion (red ovals, Fig. 6) and 2 m of accretion (white ovals, Fig. 6) as the ebb shoal migrated eastward with the inlet. These preliminary results suggest the model simulates the erosion and accretion in Katama Inlet caused by Hurricane Irene (Fig. 6).

**IMPACT/APPLICATIONS**

The simulations suggest that the observed tidal modulations of wave direction are caused primarily by current-induced refraction. Consequently, breaking wave-driven alongshore currents (and the associated sediment flux) may change direction (or strengthen and weaken) with the tide, even when offshore wave conditions are constant.

Field observations in a range of nearshore environments have been used to test and improve model predictions for waves, circulation, and morphological change, as well as to provide ground truth for remote sensing of littoral areas.

**RELATED PROJECTS**

The observations of waves and currents near New River Inlet are being used as ground truth for remote sensing studies (MURI and other colleagues), and the observations from the inner shelf, surfzone, and inlet channel(s) at New River and Katama Inlets are being used to test and improve models for wave propagation, circulation, and morphological evolution, and to initialize and test models that invert for the underlying bathymetry.
Many investigators are using our observational databases to test components of models (e.g., the NOPP nearshore community model, DELFT3D, ADCIRC, COAWST, nonlinear wave propagation schemes) for nearshore waves, currents, and bathymetry, and as ground truth for remote sensing studies. Since 2006, more than 100 scientists, engineers, postdoctoral researchers, and students, have accessed our data distribution WWW site [http://science.whoi.edu/users/elgar/main.html] to download time series and processed data products for their studies. In FY15 several journal papers used data we gathered in Duck, NC in 1994 (!), and more than 20 people (including investigators from U.S. and international universities, government and DoD laboratories, and private companies) downloaded data from the Duck94, SandyDuck, NCEX, SWASHX, WORMSEX, STIFEX, and RIVET1 projects.

Some of the work discussed here was in collaboration with Dr. Elgar's NSSEFF project to study morphological evolution in littoral areas.

REFERENCES


Hopkins, Julia, Steve Elgar, and Britt Raubenheimer, Observations and model simulations of wave-current interaction on the inner shelf, *J. Geophysical Research, sub judice.*

Orescanin, M., Steve Elgar, and Britt Raubenheimer, Changes in bay circulation in an evolving multiple inlet system, *Continental Shelf Research, sub judice.*


PUBLICATIONS


Hopkins, Julia, Steve Elgar, and Britt Raubenheimer, Observations and model simulations of wave-current interaction on the inner shelf, *J. Geophysical Research, sub judice*. [refereed]

Orescanin, M., Steve Elgar, and Britt Raubenheimer, Changes in bay circulation in an evolving multiple inlet system, *Continental Shelf Research, sub judice*. [refereed]

**HONORS/AWARDS/PRIZES**

Britt Raubenheimer, Woods Hole Oceanographic Institution, promoted to senior scientist