IMPACTS OF INCIDENT WAVE CONDITIONS AND NEARSHORE BATHYMETRY ON SURFZONE VORTICITY

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INTRODUCTION

Nearshore circulation patterns such as rip currents and eddies transport bacteria, sediment, and people across and along the surf zone, affecting beach safety, coastal morphology, and marine wildlife (Grant et al. 2005). Recent phase-resolving modeling studies suggest nearshore circulation patterns and the associated vorticity are linked to bathymetric and incident wave conditions. Persistent eddies correspond to the length scales of the underlying bathymetric variations (order 100 m), whereas small-scale (order 10 m) vorticity increases with wave directional spread (O'Dea et al. 2021, Baker et al. 2021). However, these numerically generated hypotheses have not been tested with field observations, largely due to the challenge of instrumenting the surf zone with sufficient spatial resolution (Holman & Haller 2013). Here, remote sensing techniques provide high spatial resolution estimates of surface flows in the surfzone for a range of conditions, allowing hypotheses about the impacts of bathymetry and incident waves on surfzone vorticity to be examined with field data.

OBSERVATIONS

Observations were collected at the USACE Field Research Facility on the Atlantic Ocean in Duck, NC during several experiments spanning 2013-2023. Remote sensing algorithms Particle Image Velocimetry and Optical Current Meter (Chickadel et al. 2003) were applied to optical imagery to track the motion of naturally occurring foam on the ocean surface, generating two-dimensional surface flow estimates every 3.2 m across several hundred meters of the coast. Imagery was collected from cameras on a 40-m-high tower overlooking the beach and from cameras on drones flown over the surf zone. Remote and in situ flow estimates are similar ($r^2 > 0.8$ for alongshore flows). Bathymetry was surveyed intermittently throughout each experiment, and an offshore wave buoy measured incident waves.

DISCUSSION

Preliminary examination of the estimated flows indicates agreement with previous numerical model results (O'Dea et al. 2021, Baker et al. 2021). Persistent circulation occurs at length scales corresponding to the scales of alongshore bathymetric variability (e.g., holes, bumps, and channels in the seafloor). For a case of strong alongshore inhomogeneity (Figure 1), the spatial scales of bathymetric variation peak at ~100 m (red curve, Figure 2), similar to the energetic spatial scales of the vorticity estimated from the remotely sensed currents (black curve, Figure 2). In contrast, for a case of alongshore uniform bathymetry, the spectral levels of long wavelength (>~50 m) vorticity are decreased (not shown).

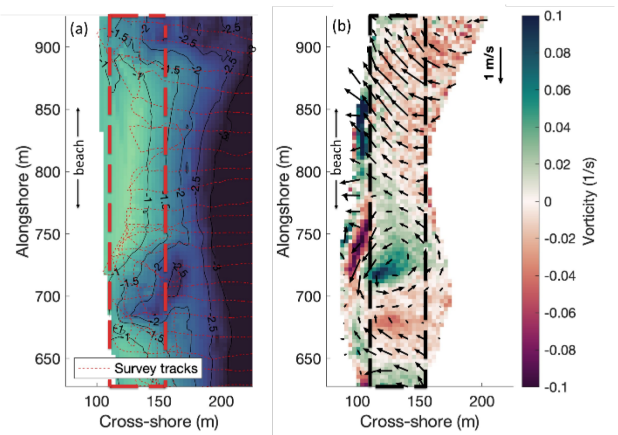

Figure 1 - Color contours of (a) bathymetry (contour curves every 0.5 m) and (b) vorticity (scale on the right) as a function of cross- and alongshore coordinates. The thin red dotted curves in (a) are the path of the survey vehicle. Arrows in (b) are remotely sensed 1-hour mean current vectors that point in the direction of flow with length proportional to speed. The spatial density of estimates has been reduced by 75% as a visual aid. The thick red and black dashed boxes in (a) and (b) indicate the area of spectral analysis (Figure 2).

Additionally, the spectral levels of long wavelength vorticity (>~50 m) are not sensitive to the averaging period (10-60 min) of the currents, whereas short wavelength (<~30 m) vorticity decreases as the averaging period of the currents increases, indicating a dependence on more transient conditions (e.g., wave breaking).

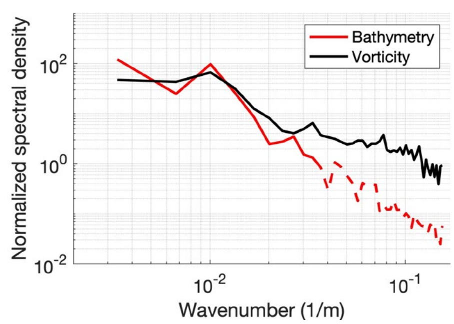

Figure 2 - Normalized spectral density of bathymetry (red curve) and vorticity (black curve) for a case with strong alongshore inhomogeneity (Figure 1) averaged along alongshore rows between cross-shore coordinate 112 and 163 m (the surf zone, dashed boxes in Figure 1) versus wavenumber. The dashed portions of the bathymetry curve are from interpolated data.

This analysis will be expanded to additional field observations, examining the relative importance of both incident wave conditions and bathymetry in determining vorticity at varying temporal and spatial scales.

REFERENCES
Baker, et al. (2021), J. Geophys. Res. Oceans, 126.
Chickadel, et al. (2003), J. Geophys. Res., 108, 3364.
Grant, et al. (2005), J. Geophys. Res., 110, 20.
Holman, Haller (2013), Annu. Rev. Mar. Sci., 5, 95-113.
O'Dea, et al. (2021), J. Geophys. Res. Oceans, 126.

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