Experimental and Numerical Studies of Nearshore Tsunami Dynamics

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The study and understanding of the kinematic properties and turbulent energy associated with a breaking wave is of particular importance when trying to predict wave forces on structures, nearshore mixing and circulations, sediment transport, and ultimately coastal morphology. There have been extensive experimental and numerical studies focused on furthering knowledge of the turbulence that develops as waves interact with an underlying bathymetry and break; these have largely focused on mean flows that are two-dimensional. The goal of this laboratory study was to understand the three-dimensional turbulence and kinematic properties that developed as a solitary wave evolved over an irregular, 3D bathymetry.

A 3-month long laboratory experiment was performed at the Tsunami Wave Basin at Oregon State University to investigate the three-dimensional turbulence and kinematic properties of a breaking solitary wave propagating over an irregular shallow water bathymetry. The bathymetry consisted of a deep water region connected to a shallow shelf via a relatively steep slope. The offshore boundary of the shelf break varied in the longshore direction, such that the shelf had a triangular shape in plan view, with the widest part of the shelf along the basin centerline. This alongshore-variable bathymetry caused the solitary wave the break first at the apex of the shelf, with the plunging breaking then spreading out towards both side walls.

The information presented here provides both insight into long wave evolution over shallow bathymetry and a unique 3D dataset to validate and calibrate numerical models. While extrapolations to geophysical-scale events, such as tsunamis, need be done with great caution, a few relevant conclusions from this experiment can be made. While it is generally accepted that long wave runup is a primary function of the upper beach slope, shallow offshore bathymetry can also play a major, and possibly counterintuitive, role in the inundating wave properties. When considering processes dominated by turbulent dynamics, such as mixing and transport, this experiment indicates that the turbulence created through borefronts and spatial velocity gradients dwarfs that generated through bottom stress, both in an instantaneous and event-averaged sense. Finally, abrupt variations in nearshore bathymetry can lead to unstable shear layers, which are capable of shedding persistent eddies, that in turn can cause localized mixing and transport.