LARGE-SCALE EXPERIMENTS ON WAVE-INDUCED SHALLOW TURBULENT COHERENT STRUCTURES

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RESEARCH MOTIVATION

There are numerous reports of large-scale "whirlpools" being generated in the near-shore during tsunami events (Borrero *et al.,* 2015). These features, termed tsunami-included turbulent coherent structures (TCS), form due to flow separation at sharp coastline features. During the 2011 Tohoku tsunami, the generation of a large-scale TCS was captured at port Oarai in a helicopter footage (Lynett *et al.*, 2012). The TCS was spinning for tens of minutes, entraining boats in the high-speed rotational flow, until it was washed away by the next incoming wave. TCS generation can potentially control the hazard for small amplitude tsunami waves in ports and harbors (Borrero *et al.,* 2015; Kalligeris *et al.*, 2016).

EXPERIMENTAL SETUP

The generation and evolution of a wave-induced TCS was recreated in Oregon's tsunami wave basin using appropriate scaling (Figure 1). A simplified image of a port was created by building an impermeable breakwater across the width of the basin at an angle, leaving a gap with the sidewall (channel). The wavemaker motion was kept simple, releasing a single asymmetrical N-wave pulse. The wave-induced current was accelerated through the channel and flow separation generated a stable TCS on the wavemaker side. The experiments translate to a 1:27 prototype scale: a ~2.7 km long wave with a leading elevation amplitude of 55 cm, and a period of ~ 3.7 min. Therefore, this physical experiment has the rare property of keeping both the length and time reasonably scaled. Surface velocities and free surface elevation were inferred from optical tracking (PTV) of surface tracers (Figure 2). The methodology was validated using Acoustic Doppler Velocimetry (ADV) and wave gauge data respectively.

ANALYSIS

Through this quantitative dataset, we were able to study the circulation growth of the experimental TCS and compare it with past studies on dipole formation in tidal inlets and 3D vortex ring formation. The structure of the resulting monopolar shallow coherent vortex was assessed through its velocity components in cylindrical coordinates (relative to the TCS center), so as to characterize its surface velocity profile through other known geophysical vortices. Kinematic energy decay of the primary (azimuthal) velocity component due to bottom friction and the spatial growth of the vortex structure were compared with analytical models. The kinematic decay of the secondary flow components was used to examine the time-scale of flow transition to quasi-two-dimensional.

The quantitative dataset can be used for numerical model validation, while the results of this study offer insights to the complex dynamics of tsunami-induced coherent structures in a well-controlled environment that have important applications for prototype scale ports and harbors in tsunami-prone areas.

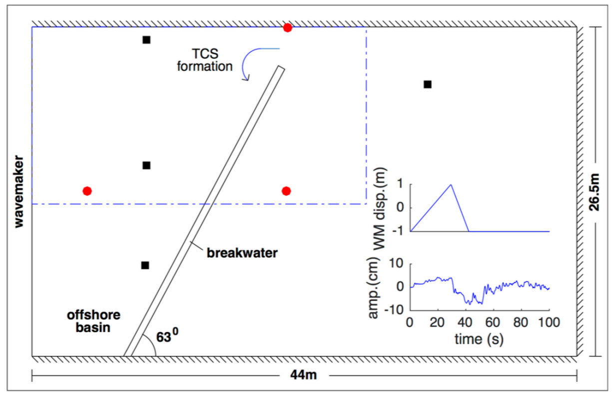

Figure 1 - The experimental setup in the tsunami wave basin. Red dots denote ADV locations and squares denote the location of the overhead HD cameras. The inset figures show the wavemaker motion time-history (top) and the surface elevation (bottom) near the face of the wavemaker.

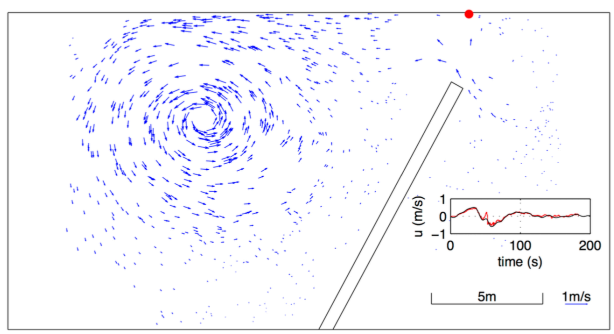

Figure 2 - PTV-extracted surface velocity vectors ~2.2min after the start of the experiment. Inset shows a comparison between the ADV- measured velocity in the x-direction (black curve) and the velocity of the nearest tracer (red curve) measured at the location shown with the red dot.

REFERENCES

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