4th International Workshop on Modeling the Ocean (IWMO-2012), Yokohama, Japan.

Three-dimensional unsteady wave-driven littoral currents

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Abstract:

The multi-scale asymptotic theory by McWilliams *et al*. (2004) with a vortex-force formalism is extended appropriate for strong current regimes applicable to wave-driven nearshore currents around surf zones. The wave-averaged, three-dimensional primitive equations for current and tracers are derived and implemented in ROMS with appending non-conservative parameterizations that account for momentum transfer and mixing associated with depth-induced wave breaking and bottom friction (Uchiyama *et al.*, 2010). A set of the narrow-banded WKB wave ray refraction equation and wave action balance equation is tightly coupled with the slowly evolving currents to provide wave-induced forcing. The coupled system is then applied to the Duck94/SandyDuck field datasets to reproduce three-dimensional unsteady longshore and rip currents. We demonstrate that realistic surfzone topography with shallow incident wave angles leads to unstable rip currents consisting of abrupt ejection of the inner-surfzone water to enhance cross-shore mixing, whereas shear instability of longshore currents, also known as shear waves, is induced by obliquely incident waves.

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Oceanic dispersion of cesium-137 off the north-eastern Pacific coast of Japan

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Abstract:

The 2011 earthquake off the Pacific coast of Tohoku, Japan, and the associated tsunami caused a severe nuclear accident at the Fukushima Daiichi Nuclear Power Plant (1F), leading to radioactive materials leaking into the ocean. We conducted a retrospective, double-nested high-resolution numerical experiment to evaluate oceanic dispersion of the leaked radioactive ^{137}Cs in the coastal marginal sea to successfully reproduce fluctuations of the measured ^{137}Cs concentration. Following the method proposed by Tsumune *et al.* (2011), a total amount of the ^{137}Cs from 1F is estimated quantitatively. Alongshore distribution of the concentration is found to be highly inhomogeneous with lower ^{137}Cs concentration distributed widely at the south of 1F, while medium concentration in the nearshore area at the north of 1F. The probability density function (PDF) of ^{137}Cs concentration suggests that hotspots exist along the Sanriku coast, a rias coastline located north of 1F. According to the previous work by Tsumune *et al.* (2011), ^{137}Cs leaked from 1F is reported to be transported offshore rather quickly. Defining two control volumes centered at 1F, a budget of ^{137}Cs flux is diagnosed. Time-integrated ^{137}Cs fluxes at the northern and southern (alongshore) boundaries indicate apparent outgoing tendency, while the net cross-shore flux at the eastern boundary (100 km offshore) almost vanishes or even has an incoming flux, suggesting that ^{137}Cs tend to remain in the coastal area with mostly being transported alongshore back and forth.

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Effects of wave-current interaction on development of rip currents

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Abstract:

Haas *et al*. (1997) found that the offshore extent of rip currents can be significantly reduced if the current effects on waves (CEW) are considered. Subsequently, Yu and Slinn (2003, hereafter YS03) suggested that it could be led by change of the work done by radiation stress. Since radiation stress is also affected by CEW, it has been an open question that how CEW acts to suppress rip currents. Weir *et al*. (2011) analyzed rip currents with a vortex force formalism to answer this question. They showed that rip currents are modulated due to the wave ray bending associated with offshore-headed rip currents. However, they limited themselves in the asymptote where alongshore topography does not change that much, and didn't consider momentum balance modified by CEW.

In the present study, a two-dimensional shallow-water model based on Regional Oceanic Modeling System (ROMS) with wave effects through the vortex-force formalism, coupled with a set of wave ray equations (Uchiyama *et al*., 2009), is used to examine dynamic effects essential to development of rip currents. In prior to the analyses, the numerical experiment conducted by YS03 is revisited to confirm the validity of the present modeling framework. Then multiple terms attributed to CEW in the wave action and wavenumber conservation equations affecting the offshore evolution of rip currents are explored. The result reconfirms that the wave ray bending by currents is substantial to evolution of rip currents among others. If CEW is taken into consideration, wave ray bending occurs with a modified wavenumber field that changes the alongshore pressure gradient force and the cross-shore component of acceleration due to wave breaking through wave shoaling, leading to the reduction of the extent of rip current.

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Oceanic responses to surface gravity waves in the Southern California Bight

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Abstract:

Influences of surface gravity waves on inner-shelf circulations in the Southern California Bight is investigated by using a quadruple nested high-resolution modeling framework based on ROMS (Regional Oceanic Modeling System) along with double nested SWAN (Simulating Waves Nearshore) and WRF (Weather Research and Forecasting). The wave effects on the circulation includes an interaction between waves' Stokes-drift and Coriolis force (Stokes-Coriolis effect), a correlation between Stokes-drift and background relative vorticity (vortex force), momentum transport to the currents by depth-induced wave breaking, Bernoulli pressure head, etc.

The primary momentum balance occurs between the pressure gradient and Coriolis forces, consistent with the geostrophic balance at a small Rossby number. However, Stokes-Coriolis effect comes in at the same order of magnitude if waves are considered. Advective momentum and vortex force are rather small, while increased to dominate over Stokes-Coriolis effect in the nearshore area outside of the surfzone. It is also found that turbulent kinetic energy associated with mesoscale and submesoscale momentum fluctuation is strongly affected by waves, in particular in the nearshore area for the latter. Therefore, waves are found to play a substantial role in changing the dynamic balance in the bight.