Numerical simulation of typhoon events in Sekisei Lagoon, Okinawa, Japan using a coupled ocean-wave model

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Sekisei Lagoon is the site of Japan's largest coral reef area and is an important target site for conservation. However, it is affected to varying degrees by typhoons which approach yearly during the summer and autumn seasons. To closely investigate typhoon-driven hydrodynamics in Sekisei Lagoon, a modeling setup was developed using a nested Regional Ocean Modeling System (ROMS) configuration with an outer coarse scale regional model at 1.5 km grid resolution, and an inner model focused on the Sekisei Lagoon domain with a grid resolution of 300 meters. The inner model was configured using the Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST) modeling framework in order to couple the ROMS ocean model with the Simulating Waves Nearshore (SWAN) wave model. Initial conditions and ocean boundary forcing for the regional model were derived from the global 1/12° Hybrid Coordinate Modeling System analysis data (HYCOM GLBv0.08), and tidal forcing was added using data from the 1/30° OSU Topex/Poseidon Global Inverse tidal solution (TPXO9). Meteorological forcing was derived from Japan Meteorological Agency-Grid Point Value (JMA-GPV) mesoscale model results, and SWAN boundary forcing for the inner model was derived using outputs from the 5-km JMA Coastal Wave Model (CWM) for locations around the Yaeyama Islands where Sekisei Lagoon is located.

The modeling setup was run for specific typhoon events as well as for relatively calmer periods, and model performance was evaluated by comparing simulation results with in-situ observations from sensor deployments around Sekisei Lagoon conducted during the summer months of 2014, 2015, and 2016, as well as from a long term continuous monitoring setup in the Shiraho Reef area in Ishigaki Island. Modeled significant wave heights and peak wave periods at wave sensor locations for relatively calm periods had comparable ranges, but exact temporal trends could not yet be reproduced well. During modeled typhoon passages, trends in significant wave height, such as the timing of increase as the typhoon approached and the maximum wave height reached, were well-reproduced for a wave sensor located at the southeastern part of Sekisei Lagoon. However, the comparison was relatively poor for wave sensors deployed at the northwestern part of the lagoon and offshore of Shiraho Reef on the eastern side of Ishigaki Island, particularly in terms of the timing of wave height increase. In terms of simulating water temperature, running the inner ROMS model without SWAN resulted in Wilmott skill index (Wilmott 1981) scores ranging from 0.72 to 0.95 and root mean-square errors ranging from 0.46 to 1.52 deg C when compared with field observations conducted around Sekisei Lagoon from May to November in 2016. Modeling runs for the coupled ROMS-SWAN model were of shorter duration, but the simulated water temperatures showed some notable differences with the ROMS only case for some locations, suggesting that the influence of wave-driven flows on water temperature trends may need closer investigation.

Adjustments to the modeling setup are ongoing, especially in terms of more properly resolving bathymetric features, as some parts of the domain are characterized by complex barrier and fringing reef structures. Parameter tuning is also being conducted in relation to the physical processes considered in the SWAN wave model, such as the influence of bottom friction and depth-induced wave breaking. With further improvement, this modeling setup may serve as a potentially useful tool to gain further insight into the ways typhoons affect the hydrodynamic conditions in Sekisei Lagoon, as well as estimate potential damage levels, given that typhoon tracks and intensities vary. Even for the non-typhoon case, the setup

may also be useful to help clarify the influence of waves on the overall circulation in the area.

Keywords: hydrodynamics, typhoon, ocean model, wave model, coral reef, sensors