Numerical simulation of typhoon events in Sekisei Lagoon, Okinawa, Japan

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Typhoons of sufficient intensity have been known to cause damage to coral reef ecosystems but may also bring benefit in the form of typhoon-induced cooling, which can mitigate against thermal stress. Sekisei Lagoon is the site of Japan's largest coral reef area and is also impacted to varying degrees by typhoons which approach yearly during the summer season. To closely investigate typhoon-driven hydrodynamics in Sekisei Lagoon, selected typhoon events were modeled 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. Ocean boundary forcing for the regional model was derived from global 1/12° Hybrid Coordinate Modeling System analysis data (HYCOM GLBa0.08). Meteorological forcing was derived from Japan Meteorological Agency-Grid Point Value (JMA-GPV) mesoscale model results. Model performance was evaluated by comparing simulation results with in-situ observations from sensor deployments around Sekisei Lagoon conducted during the summer months of 2013, 2014, and 2015. Sensor positions and durations varied between the deployments, but typhoon event field data at specific locations was available for model comparison for parameters such as water velocity, water level, temperature, and wave height. Analyses of field observations during typhoon passages revealed various typhoon related trends, such as sudden temperature downshifts, potentially destructive wave conditions, and enhanced water flow velocity, especially through channels. The timing, magnitude, and spatial patterns of such trends varied depending on typhoon track and intensity, and the ability of the model to reproduce these observed trends was assessed. The model results were then analyzed further in terms of modeled 3-D spatiotemporal trends both within the Sekisei Lagoon domain and the surrounding ocean areas to clarify the dominant physical processes involved in each specific event, such as the effects of strong vertical mixing due to typhoon winds, wind-driven currents, and the possibility of typhoon-driven upwelling of cold, bottom waters from offshore. The results of this investigation may give further insight into the ways in which typhoons affect the hydrodynamic conditions in Sekisei Lagoon, which are related to many aspects of the coral reef ecosystem, such as coral health and susceptibility to bleaching, larval dispersal, and physical damage from waves. Such information may help guide coral reef ecosystem management and conservation efforts to more properly account for the effects of typhoons.

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

