High-resolution flow-simulation in Typhoon 21, 2018: tremendous loss of water plants in South Lake Biwa

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The typhoon 21 (Jebi) of Category 5 landed in Japanese main island on September 4 in last year (2018) and catastrophically damaged in mainly west Japan. The typhoon generated the extreme fluctuation of the water level observed in the south basin of Lake Biwa and induced the massive loss of aquatic plants, especially submerged macrophytes in the whole basin. The similar water level fluctuation was first observed in 2nd Muroto Typhoon in September 16, 1961. In recent years, the widespread exuberance of the aquatic macrophytes was often emergent in the south basin, which can severely affect water quality and biota in the lake bed. On the positive side of the aquatic macrophytes, they can absorb the nutrients dissolved in the lake to purify water and spawning ground for freshwater fishes such as carp and crucian. The massive loss of aquatic macrophytes can greatly impact the water environment in the south basin. It is anticipated that the climate change can induce the intense typhoons, understanding the massive loss mechanism of water macrophytes is essential to manage the lake water quality in the near future. This study investigates the physical processes of massive loss of aquatic macrophytes in the south basin based on the high-resolution flow simulation in Lake Biwa to reproduce the extreme fluctuation of the water level in the period of the typhoon 21 attack. We employed the prognostic, three-dimensional, unstructured-grid Finite-Volume Community Ocean Model (FVCOM). This model uses an unstructured triangular grid and provides better flexibility to fit the irregular coastal geometry and bathymetry in the Lake Biwa. The finite-volume approach ensures the conservation of mass necessary to reproduce water level fluctuation in the lake under conditions of a strong atmospheric disturbance. Reanalysis meteorological Grid Point Value datasets of the Meso-Scale Model datasets produced by the Japan Meteorological Agency were input into the FVCOM as mean hourly air temperature, precipitation, cloud cover, relative humidity, dew-point temperature, and wind speed. Hourly-mean data of river inflow to the lake and outflow from the Seta weir located in the south basin were input to the simulation. The initial conditions of water temperature used in the lake simulation were produced by the observational data obtained in August 2018. The simulations began from an initial state of rest, starting 28 August 2018 and was conducted for 2 weeks. Water level data to validate the simulated water level were downloaded from the Water Information System operated by the Ministry of Land, Infrastructure, Transport and Tourism of Japan. The simulation reproduced the extreme fluctuation of the water level, indicating that correlation coefficient between simulated and observed data was more than 0.9. When the water level pronouncedly decreased approximately 1 meter in the typhoon approach near the Lake Biwa, the northward current stronger than 1 m/s was formed in the whole south basin. The bottom shear stress and the drag force on the aquatic submerged macrophytes were calculated based on the simulated data. The bottom shear stress was smaller than critical shear stress suggesting little scouring in the basin bed. On the other hand, the drag force was larger in the areas of the higher vegetation height of submerged macrophytes, indicating that the map of the drag force was similar to the horizontal distribution of the macrophytes loss. These results suggested that the stronger horizontal flow induced by the typhoon wind formed the large drag force on the higher submerged macrophytes leading to uprooting and washout over the speed limit. The south wind over the 20 m/s blowing above the lake surface can induced the flow stronger than 1 m/s to uproot the submerged macrophytes.

Keywords: Lake Biwa, water plants, flow-simulation, Typhoon