Consequences of the Typhoon 18 (Sep. 2013) and associated runoff on Lake Biwa

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Abstract. On September 16 2013, typhoon 18 hit the prefecture of Shiga, and was associated with heavy rains and strong wind on Lake Biwa's watershed. The heavy rain provoked intense river run-off, leading to a substantial discharge of suspended material into the lake. Through the use of an unstructured numerical model, we assessed the dynamics involved in the dispersion of material in Lake Biwa during the event of Typhoon 18. The results of the model have been checked against observations, and suggest the generation of upwellings during the typhoon event, some of which were located at a river's mouth. These upwellings at river's mouth are likely to have facilitated the particles to remain at the surface instead of plunging below the surface layer. When the major upwelling, in the northernmost part of the lake went, re-equilibrated the resulting currents advected materials in a direction opposite to the wind.

Keywords: typhoon, rain, run-off, water quality, particle tracking.

1. Introduction

Lake Biwa is a source of freshwater for 14 millions inhabitants in the Kyoto/Osaka region in Japan, to which approximately 300 inlets provide water, but only one outflow. Due to its great number of inlets, the quality of Lake Biwa's water is sensitive to river run-offs and their discharge.
Lake hydrodynamics play a substantial role in the fate of pollutant ([1], [2]), along with environmental and meteorological events. Impact of river run-offs on water quality and the dispersion of pollutant has been studied with the influence of normal meteorological forcings ([3], [4]). [3] alluded to an impact of wind-induced internal waves on the transport of pollutants several days after the discharge in a stratified fjord lake. [4] illustrated the direct impact of wind forcing on the residential time of particles in an embayment of Lake Geneva.
However, river run-offs and associated material discharge can occur during extreme meteorological events, such as a typhoon. With the likelihood of an increase of extreme meteorological events (IPCC report), such situation needs to be studied.
For this presentation we focus on the effect of Typhoon 18 (Typhoon Man-Yi, hereinafter) on Lake Biwa water, when the water is stratified (presence of a rapid change of temperature in the vertical). The passage of the Typhoon Man-Yi (2013-09-16) over Japan was associated with strong wind and heavy rains in the vicinity of Lake Biwa. Flooding of the inlets followed with an extreme discharge of suspended material into Lake Biwa. To understand the physical processes involved in the transport of material during this extreme meteorological event, we employed the numerical model SUNTANS ([5]), forced with observed meteorological parameters from governmental institutions. To track the particles route we employ a particle-tracking program.

2. Simulation settings

The numerical simulation was performed using the three-dimensional numerical simulator SUNTANS ([5]). The simulation spans from September 1st 2013 to September 30th 2013 including a 14 days spin-up period. The unstructured grid that represents Lake Biwa possesses a horizontal resolution of 270m on average and a vertical resolution of 1m.

In the simulation of river run-offs we limit ourselves to eleven major rivers located in the Northern basin of Lake Biwa. To reproduce the impact of Typhoon Man-Yi on the water of Lake Biwa, we force the simulation in applying observed wind stress, river discharge and heat fluxes. Meteorological data are taken from five meteorological stations around the lake, managed by the Japanese Meteorological Agency. River discharge data of Ane river were obtained from the Water Bureau's website. Due to the lack of data from other rivers we perform the simulation assuming identical discharge time series for each river discharge.

3. Consistency

The consistency of our numerical simulation was assessed by comparing the simulated temperature time series against observed temperature monitoring in the center of the lake (Figure 1). We also assessed the consistency of the simulation by comparing surface temperature distribution against available SST data from satellite. The comparison between observed temperature and simulated suggests the numerical model to reproduce consistently the dynamics.

As a surrogate for the suspended material discharged from the rivers, we released numerical particles from the rivers when the river run-off occurred. Particle tracking results provided similarities with RGB satellite images. These results suggest that we can explain the dynamics involved in the propagation of particles during the Typhoon Man-Yi.

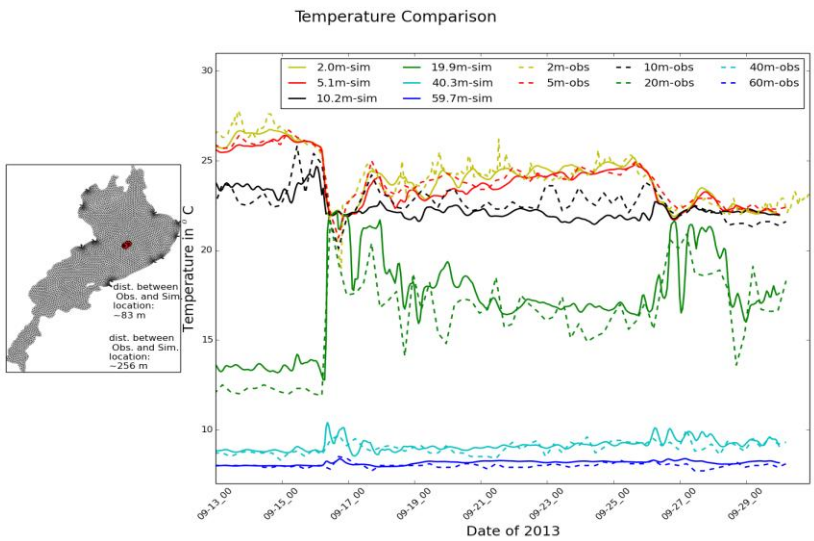

Figure 1: Left-hand side: grid used in the simulation with the locations of the monitoring stations (red circles) and closest points in the simulation (black circles). The distance between the locations is written. Right-hand side: comparison of simulated temperature time series (solid lines) against observed temperature time series (dash lines)

4. Results and Discussions

The results of the simulations allude to a generation of upwellings (a major and minor ones) due to the strong wind from typhoon Man-Yi (Figure 2), somewhat more pronounced in the simulation. During the typhoon suspended material / particles were released into the lake with water that was less dense than the lake's water, in some parts (southernmost upwelling in Figure 2). This situation occurred because cold water from deeper parts was brought to the surface by wind-induced upwellings (water from rivers at 23 C whereas water at the upwelling is about 16 C on September 16 10:00 in Figure 2), thus run-off water transport would be impacted by the thermal front. Figure 2 illustrates the particles remaining at the same area for 11 hours, therefore highlighting the increase of residence time of the particles due to the thermal front.

When the typhoon ceases, the water body went back to a thermally stable condition (warm water on top and cold water in the bottom), the material was then transported by the induced currents (Northward), see Figure 3, with a direction opposite to the wind (Southward). In the case of typhoon Man-Yi, the simulation results suggest that material from eastern rivers remain in the eastern side, whereas the particles that originated from the rivers on the western side are transported on both sides of the lake.

From simulation results, divergent currents caused by the major upwelling decreasing, caused a patch of particles to spread and create what looks like a "tiger tail". This "tiger tail" represents a small surface of the lake with a high concentration of particles surrounded by water with low-concentration of particles. Thanks to the particle tracking method we can establish the origin of the particles that make up the "tiger tail". In the case of typhoon Man-Yi, the particles came from two rivers on the western side of the lake.

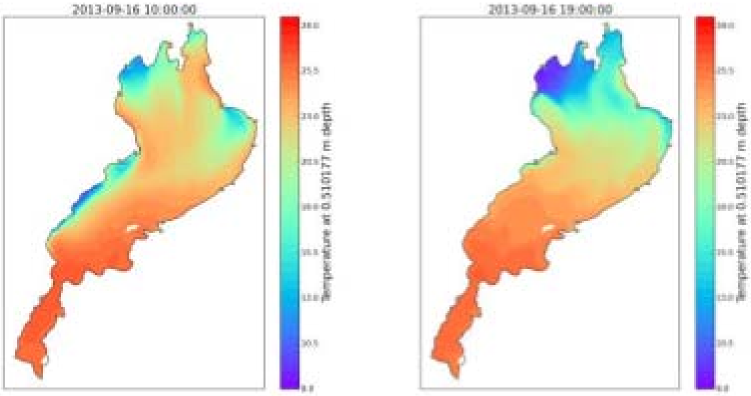

Figure 2 Surface temperature during the typhoon on September 16th 2013 at two different time stamps during the typhoon18.

Figure 3 Particle distribution from one river on the lower west side of the lake. The two panels on the left-hand side are during the Typhoon Man-Yi. The panel on the right-hand side represents the particle distribution after typhoon

5. Conclusions

To understand the response of Lake Biwa extreme winds and heavy rain caused by typhoon Man-Yi in 2013 September 2013, we used results from a simulation that consistently reproduced this event. We show that the strong winds not only affected the distribution of material throughout Lake Biwa directly but also had a delayed impact by generating upwellings at several places in the lake.

The results of the simulation allude to an increase of residence time caused by the thermal front, generated by the discharge of water and the wind-induced. Moreover, the simulation also suggested that the consecutive upwellings spread the materials in the Northern part of Lake Biwa in less than a day.

In a context of improving the water quality in lakes and other water bodies, knowing the path of pollutants and/or materials is paramount. During extreme meteorological events (as studied here) substantial discharge of materials into water bodies can occur. However, these extreme meteorological events generate complex dynamics in large water bodies, such as upwellings and thermal fronts, that can affect the transport material / pollutant in accelerating or slowing down their propagation.

Acknowledgements

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