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An Experimental Study of Unsteady Flows Generated in Kojima Lake

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The global positioning system (GPS) is utilized for analysis of flows in the water environment. A float equipped with a GPS unit is designed to drift on the surface of the water. Its driving force is the fluid resistance exerted on a pair of rectangular plates. While it travels over the surface, the GPS unit evaluates its position every second, and spatiotemporal data that specify its motion are transmitted to be recorded. Results of experiments conducted to study unsteady flows generated in Kojima Lake are introduced.

Key words: *water environment, global positioning system*

1 INTRODUCTION

A GPS unit evaluates its position analyzing signals transmitted from the GPS satellites. More accurate results can be obtained with an additional feature to analyze signals transmitted from a radiobeacon, which is called the differential GPS. We conducted experiments to examine flows in the water environment with a float equipped with a differential GPS unit, which we call the GPS-float. The GPS-float is designed to drift on the surface of the water. The driving force of the GPS-float is the fluid resistance exerted on a pair of rectangular plates. Those plates are set crosswise in order to receive the fluid resistance as uniformly as possible, and fixed to one end of a bar, while the other end is connected to a buoyant body of the GPS-float, and they are submerged in the water, while the buoyant body stays on the surface. While the float travels, the GPS unit evaluates its position once every fixed time interval, *e.g.* every second, analyzing signals transmitted from the GPS satellites and a radiobeacon. Those spatiotemporal data concerning the motion of the GPS-float are transmitted with a wireless modem, and they are in turn received with a receiver to be recorded for an analysis. An illustration of the GPS-float is given in Figure 1.

In the following sections, we introduce some experimental results. Those experiments were conducted to study unsteady flows generated in Kojima Lake. Kojima Lake is an artificial lake created by isolating a part of Kojima Bay with a bank. There are six gates that connect Kojima Lake and Kojima Bay. Those gates are opened when it is necessary to discharge the water in Kojima Lake to Kojima Bay in order to control the water level of Kojima Lake, and such a discharge of the water generates an unsteady flow in Kojima Lake. We conducted experiments to study such unsteady flows. In particular, we introduce results obtained in experiments conducted on May 23, 2002 and June 25, 2002. Figures 2 and 3 show photographs of the GPS-float in the experiments on May 23, 2002 and

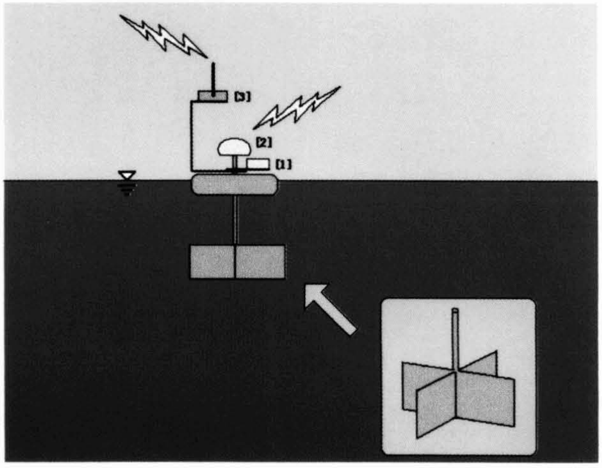

Figure 1: Illustration of the GPS-float; [1]: the GPS unit, [2]: the GPS antenna, [3]: the wireless modem.

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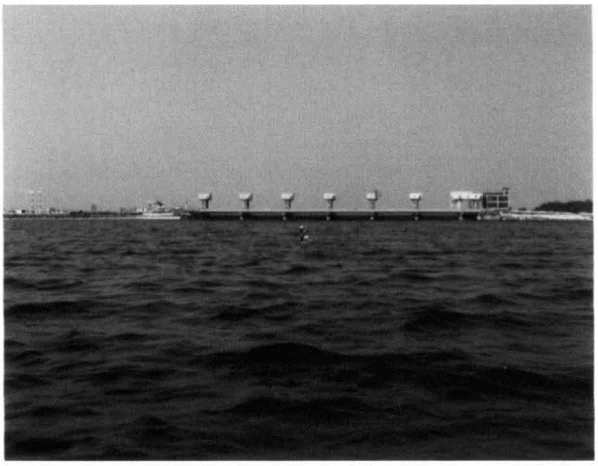

Figure 2: The experiment conducted in Kojima Lake on May 23, 2002.

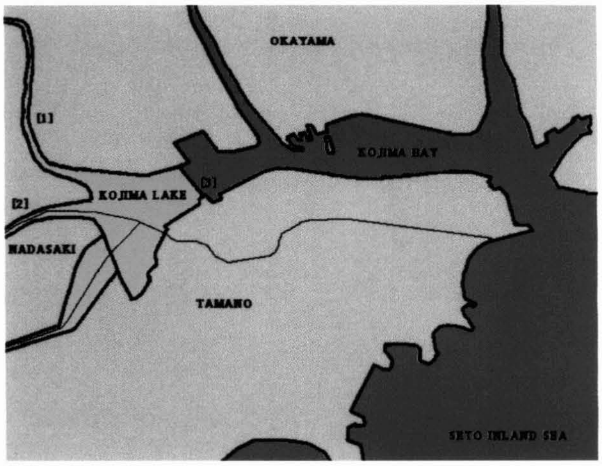

Figure 4: Kojima Lake and its vicinity; [1]: Sasagase River, [2]: Kurashiki River, [3]: the gates.

Figure 3: The experiment conducted in Kojima Lake on June 25, 2002.

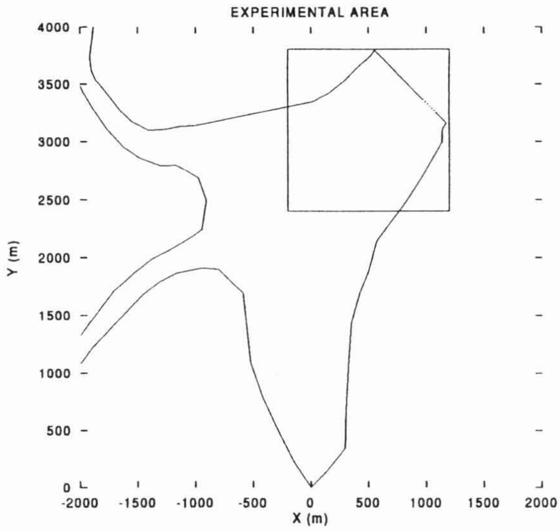

Figure 5: An area where the experiments were conducted.

June 25, 2002, respectively.

2 EXPERIMENTS USING THE GPS-FLOAT

Seto Inland Sea separates Shikoku Island from the main island of Japan. Okayama prefecture lies in the main island and faces Seto Inland Sea. We conducted experiments using the GPS-float to study unsteady flows generated in Kojima Lake in Okayama prefecture. Kojima Lake is an artificial lake created by isolating a part of Kojima Bay which connects with Seto Inland Sea. There are two rivers that serve as the primary water source for Kojima Lake: Sasagase River and Kurashiki River. An illustration of Kojima Lake and its vicinity is given in Figure 4. There are six gates that connect Kojima Lake and Kojima Bay. Each of those gates is 24 m wide. They are opened when the discharge of the water from Kojima Lake to Kojima Bay is necessary in order to control the water level of Kojima Lake. Such a discharge generates an unsteady flow in Kojima Lake. We introduce results of experiments conducted to study such unsteady flows on May 23, 2002, and June 25, 2002. Those results are given in terms of the trajectories of the GPS-float, and they lie in the box shown in Figure 5.

On May 23, 2002, the gates were opened approximately from 4:10 am to 6:50 am GMT. The discharge of the water through the gates generated an unsteady flow in Kojima Lake, and we conducted an experiment to study the unsteady flow. Figure 6 shows the temporal change of the water level of Kojima Lake from 4:00 am to 7:00 am GMT on May 23, 2002. It also shows the temporal changes of the tide level of Kojima Bay, the water levels of Kurashiki River and Sasagase River. Those water levels are in accordance with a local standard (Awabiura Point). The gates

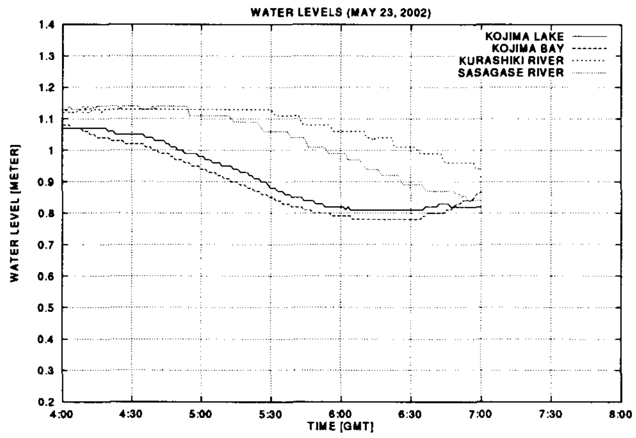

Figure 6: The temporal changes in the water levels of Kojima Lake, Kurashiki River, Sasagase River, and the tide level of Kojima Bay on May 23, 2002.

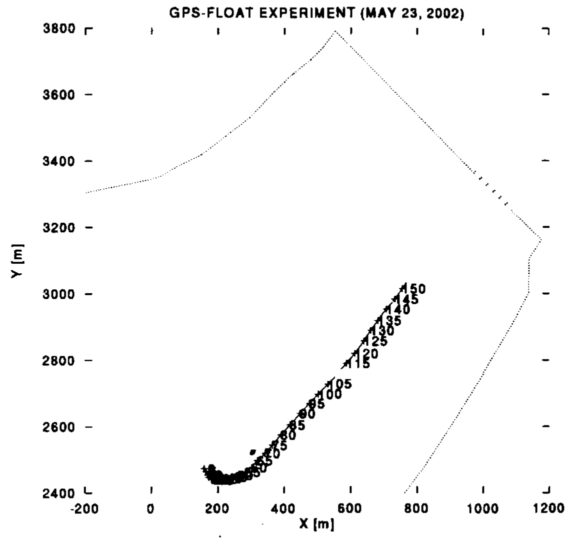

Figure 7: The trajectory of the GPS-float obtained in the experiment on May 23, 2002.

were opened when the tide level of Kojima Bay became as low as the water level of Kojima Lake, and they were closed when they became almost equal. While the gates were open, the water level of Kojima Lake lowered approximately by 0.25 m while the tide level of Kojima Bay also lowered approximately by 0.23 m. We conducted an experiment using the GPS-float to study the unsteady flow generated by the discharge of the water. Figures 7 shows the trajectory of the GPS-float, which shows its movement from 4:7:00 to 6:43:14 GMT. Time elapsed (minute) after the gates were opened is also indicated. The GPS float traveled an approximate distance of 934.0967 m, and its average velocity was approximately 0.0997 m/s.

We conducted an experiment also on June 25, 2002, when the gates were opened approximately from 5:00 am to 7:40 am GMT. Figure 8 shows the temporal changes of the water levels of Kojima Lake, Kurashiki River, Sasagase River, the tide level of Kojima Bay from 5:00 am to 8:00 am GMT on June 25, 2002. While the gates were open, the water level of Kojima Lake lowered approximately by 0.72 m while the tide level of Kojima Bay also lowered approximately by 0.7 m. The GPS float traveled an approximate distance of 821.8722 m, and its average velocity was approximately 0.1895 m/s. Figures 9 shows the trajectory of the GPS-float, which shows its movement from 6:11:55 to 7:24:14 GMT.

3 CONCLUSION

The GPS-float is designed to study flows in the water environment experimentally (Watanabe 1999, 2000 (2), 2002 (1), (2), Watanabe, et al. 2001). On the other hand, the flows in the water environment can be studied by analyzing the equation governing the dynamics of the flow (Watanabe 1999, 2000 (1), (2), 2002 (1), (2), Watanabe, et al. 2001). Since the driving force of the GPS-float is the fluid resistance exerted on a pair of rectangular plates, one can simulate its motion by solving its momentum equation provided the fluid resistance is specified, and, the fluid resistance can be determined by solving equations that govern the dynamics of the flow (Watanabe 1999, 2000 (2), 2002 (1), (2), Watanabe, et al. 2001). Thus experimental results obtained using the GPS-float can be introduced into numerical studies to examine their correspondence with numerical results.

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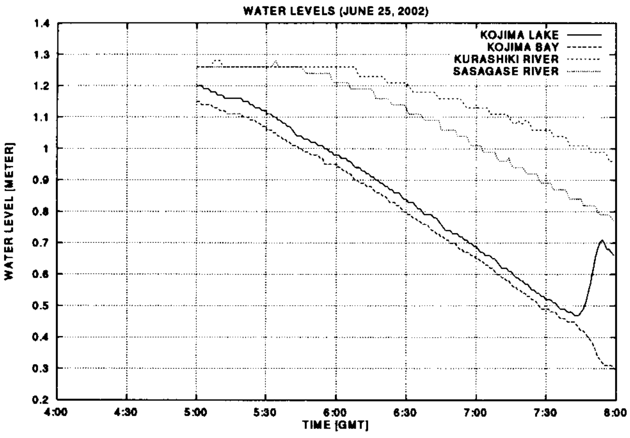

Figure 8: The temporal changes in the water levels of Kojima Lake, Kurashiki River, Sasagase River, and the tide level of Kojima Bay

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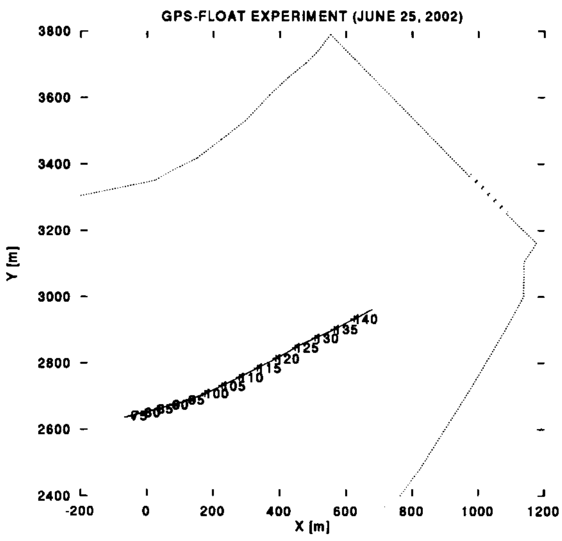

Figure 9: The trajectory of the GPS-float obtained in the experiment on June 25, 2002.