

# Chapter 4-2

## Great Gyres and Lake Water Overturn in Lake Biwa

### Abstract

Due to being a governing physical element for the movement and diffusion of heat and matter in lake water, water currents in Lake Biwa are closely related to physical, chemical and biological processes and water quality formation processes. There are mainly currents caused by great gyres and periodic currents caused by internal waves in the lake.

**Keywords:** Water current, Great gyres, Internal waves, Lake water overturns

### 1. Great Gyres in Lake Biwa

In the summer of 1925, the Kobe Marine Observatory discovered three great gyres in Lake Biwa. The first gyre is the largest in the three and is stable and appears as a quasi-steady flow over the long stratified period from spring to autumn in the North Basin, making it the most important lake current system in the lake. The first gyre moves water mass in a counterclockwise direction and its detailed structure (Fig. 4-2-1) was illustrated in 1994 from observations by the Lake Biwa Research Institute. The cause of the first gyre can be explained by the Wind-forming Theory (a theory that indicate that the gyre is driven by winds) and the Thermoforming Theory (a theory that indicate that the gyre is driven by heat). Both theories can explain the occurrence of the first gyre moving in a counterclockwise direction. Since there are still doubts as to which of the two theories is correct, the formation cause of the gyres in the lake remains a mystery. It should be noted that the existence of a gyre in winter has also been discovered recently.

### 2. Periodic Currents Caused by Internal Waves

After inclination of the thermocline of the North Basin of Lake Biwa by strong winds, oscillations in the thermocline occurs as it attempts to return to its original horizontal position. These oscillations are called internal waves.

The most notable internal waves in Lake Biwa are internal Kelvin waves and

internal Poincare waves. The internal Kelvin waves propagate in a counterclockwise direction in a period of approximately two days during the summer due to the balance between the inclination of the thermocline and the effects of the rotation of the earth with their larger amplitudes near the lakeshore. At a position, the current caused by these waves rotate with time in a counterclockwise direction. On the other hand, the amplitudes of the internal Poincare waves are larger near the center of the lake with a period of approximately 16 to 18 hours in summer. The current caused by these waves rotates with time in a clockwise direction.

### 3. Lake Water Overturn in Lake Biwa

The lake water overturn in Lake Biwa is a physical phenomenon that equalizes the water temperature from the surface to the bottom due to full perpendicular mixing of the lake water down to the deep lake bottom in mid-winter. Lake Biwa's water overturn supplies water with a high concentration of dissolved oxygen from the surface layer to the deep lake bottom, which is an extremely important phenomenon not only for organism living on the lake bottom, but also for water quality in the environs of the lake bottom and is called "the deep breath of Lake Biwa."

#### 4. Global Warming and the Delay of the Water Overturn in Lake Biwa

As global warming advances, water circulation type changes have been observed in lakes around the world. Lakes such as Lake Ikeda in Kagoshima Prefecture have been transformed from a full monomictic regime to a partial monomictic regime. The record warm winter of 2006-2007 resulted in delay of the “deep breath of Lake Biwa”, because the lake water overturn that normally occurs

between January and February in average years finally took place at the end of March. This delay resulted in that the dissolved oxygen concentration near the deep lake bottom was very low in autumn of 2007. Further advances in global warming in the future will present the danger of changing the extent of the lake water overturn, resulting in progressive hypoxia on the deep lake bottom of Lake Biwa.

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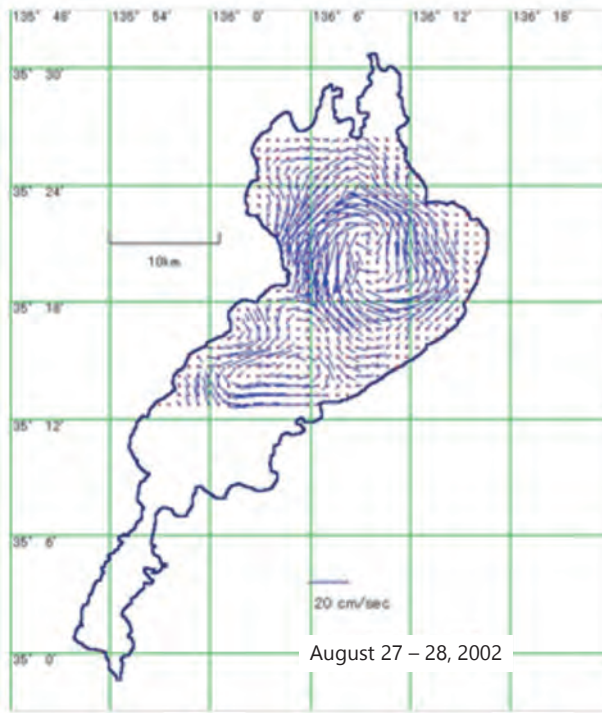


Fig. 4-2-1 The first gyre in the North Basin of Lake Biwa (August 2002)

**Thermocline:** A thin but distinct layer in which temperature changes much more rapidly with depth than it does in the layers above or below, formed during summer as a boundary between the warm water of the surface layer and the cold water in deep waters. The surface water layer and deep water layers divided by a thermocline normally feature significant differences not only in water temperature, but also in organisms and water quality.