

論文の要旨

題目 Innovative study on non-tidal environmental variations of the Seto Inland Sea by the external forcing (外部強制により瀬戸内海に発生する非潮汐周期環境変動に関する先端的研究)

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The Seto Inland Sea is the largest inland sea in Japan, facing the Pacific Ocean with the Kuroshio Current at the western and eastern inlets (the Bungo and Kii Channels, respectively) and surrounded by three of the Japanese main islands (Honshu, Kyushu and Shikoku). All regions of the inland sea are characterized by strong tidal current which flows among one thousand islands and developed as fishing grounds. Part of the Kuroshio Current intrudes into the Seto Inland Sea sporadically through the Bungo and Kii Channels and significantly influences the inland sea environment. However, direct observation of the Seto Inland Sea throughflow has never been attempted. The throughflow is a splendid target of the reciprocal sound transmission method using coastal acoustical tomography (CAT) because long-term measurement by other methods are hopeless.

Hiroshima Bay, located in the western part of the Seto Inland Sea, is the biggest oyster aquaculture field in Japan. The bay is elliptical, with a north-south length of 50 km and an east-west length of 10 km. The northern part of the bay is semi-enclosed (for about 10 km) by the coast of Hiroshima City on the northern side and three islands (Miyajima, Etajima and Ninoshima) on the southern side. Dynamic events such as anomalous sea level rises (ASLRs), internal seiches and coastal upwelling are known to occur in Hiroshima Bay after typhoon-derived northerly wind attacked. The measurement of such dynamic events is quite difficult without using a multi-station of CAT, distributed to surround the bay.

All the previous inverse analyses on a horizontal slice for CAT were performed to reconstruct current structures using function expansion inverse method. In this study, the grid-segmented inverse method as a method suitable for the horizontal-slice inversion with a limited number of data (five in this study) instead of the well-used function expansion method is first applied to the variations of

temperature structures, reconstructing the horizontal-slice structures of coastal upwelling and the associated internal tides. In the analysis of travel time data, the range-averaged current must require reciprocal travel time data and strict clock accuracy, whereas the range-averaged sound speed (temperature) can be calculated with strict positioning accuracy from one-way travel time data. The accurate position is very important for temperature calculation, so the new position correction method is newly proposed. Data gaps can be greatly reduced by using one-way data. Station-to-station ranges were corrected in such a way that sound speed (determined from one-way travel time data) was equal to sound speed calculated from a couple of CTD (conductivity-temperature-depth) data sets on each transmission line. In addition, all station positions were adjusted to make focal points at the geographical positions of the transducers.

This thesis is intended to study the environmental changes of the Seto Inland Sea (Aki-nada Sea and Hiroshima Bay) by the external forcing such as the Kuroshio and typhoon. The Seto Inland Sea throughflow and the anomalous sea level rise (ASLR) associated with coastal upwelling, internal tides and internal seiches in Hiroshima Bay are environmental events to be studied.

The net transport through the Seto Inland Sea, associated with the intrusion of the Kuroshio Current from the Pacific Ocean, is focus to study. Direct measurement of the net transport has been successfully accomplished during February-November 2012 using reciprocal sound transmissions in the Akinada Sea, the western part of the inland sea while accurate transport was estimated only during mid-April to late July and mid-September to October. The nearest tidal gauge data and long-wave theory are used to estimate the net transport. The net westward transport averaged monthly for the accurately observed period of six months was $13,107 \pm 2,544 \text{ m}^3\text{s}^{-1}$. This result implies that the inland sea water is exchanged with Pacific water in 778 days (2.1 years).

Nontidal sea level changes, generated in Hiroshima Bay of the Seto-Inland Sea, Japan are studied over all time scales from the subtidal (2d to 1month) to interannual (>2a). The total sea level variation produces the standard deviation (STD) of 12.5 cm. The interannual component of the sea level variation in Hiroshima Bay oscillates with an STD of 3.4 cm, forming a long-term trend of 4.9 mm/a. The STD of the sea level variation is 9.8 cm for the seasonal component (8month to 2a) and 4.7 cm for the intraseasonal one (1month to 8months). Significant sea level variations with an STD of 4.2 cm also occur in the subtidal range. Special attention is paid to the subtidal sea level changes.

It is found that the upwelling and the associated transient sea level changes, generated along the north coast of Hiroshima Bay (opened southward) by the strong northerly wind, play a significant role in the subtidal sea level changes. The transient sea level changes are over 10 cm in most cases when caused by typhoons which pass the Pacific Ocean off the Kii Peninsula, located at about 400 km east of Hiroshima Bay. The reasonable sea level changes are evaluated by the balance of pressure forces which works at the onshore and offshore boundary of the study domain.

Temperature variations caused by a typhoon were measured in the northern part of Hiroshima Bay by four CAT systems. The horizontal distributions of depth-averaged temperature from 0 to 8 m were mapped at 10 min intervals between the 11 and 25 September 2013. The horizontal distributions of a coastal upwelling and the associated diurnal internal tides were reconstructed well by regularized inversion based on the grid segmented method, using one-way travel time data along five successful sound transmission lines. The corrections increased the accuracy of temperature measurements to make temperature errors as small as 0.073–0.079 °C. The high accuracy made it possible to map the temperature structure with a variation range of less than 0.05 °C. An upwelling grew from 16 to 17 September, due to a typhoon-derived northerly wind. The diurnal internal tide resonated with the semidiurnal external tide, which was pronounced after the upwelling decayed (18 September), around the time the spring tide occurred. The upwelling and mixing fractions were formulated. These fractions increased continuously as the upwelling grew. Complete mixing was observed during the upwelling's mature phase.