DOMINANT OSCILLATIONS OF SUBSURFACE SEA WATER TEMPERATURE AND RESIDUAL TIDE LEVEL AT MIYAKE ISLAND

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Abstract

The continuous records of subsurface sea water temperature were obtained by means of submarine cable off Miyake Island in the southern sea of Japan. The record between September 3 to October 2 in 1968 and the hourly residual tide level data were analysysed applying the standard method of spectral analysis.

The spectra of the water temperature of 100 meters depth revealed a dominant sharp peak at the frequency of 0.08 cph (semi-diurnal period) and one weak peak at the frequency of 0.04 cph (diurnal period). The root mean square amplitudes of these peaks were 3.6°C and 2.1°C, respectively.

In the residual tide level spectra, two dominant peaks were also observed at the frequency of 0.04 and 0.08 cph, too. These oscillations were of the order of 10 cm in root mean square amplitude.

Coherence between the water temperature of 100 m depth and the residual tide level was very high. These two time series had good response between 0.07 to 0.09 cph.

The results suggest that vertical water motion with semi-diurnal and diurnal periods occured in association with internal wave which may be caused by meteorological disturbance such as typhoons. Also the short period variation of the Kuroshio may have close relation with these oscillations.

1. Introduction

In order to monitor the variations of the oceanic conditions, submarine cable with thermistors as temperature sensors has been laid off the west coast of Miyake Island (Fig. 1.). Subsurface temperatures near the sea bottom at the depths of 3 m and 100 m are being recorded on shore.

The tide station is located at the same place as the recorder. The value of daily mean sea level have been used to monitor the change of oceanic conditions associated with the variation of the Kuroshio in this region.

This report is an interim study concerning the dominant oscillation of subsurface water temperature and residual tide level, and the relations between these oscillations and internal tide wave and the short period variation of the Kuroshio.

2. Data

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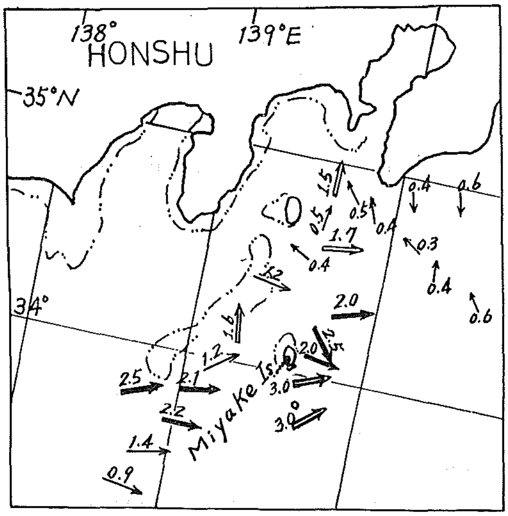

Fig. 1 Location of Miyake Island and surface currents Sept. 19～30, 1968.

The subsurface temperatures were observed at the fixed depths of 3 m and 100 m by means of thermistors connected with submarine cable, so that the temperature measured is the one near the sea bottom. The location of the submarine cable and the tide station is shown in Fig. 1.

Continuous temperature records were read every hour with the accuracy of 0.1°C. The residual tide level was defined as the residue obtained by substracting predicted tide level computed with 18 harmonic constituents from observed tide level. The accuracy of the residue is about 1 cm. The period of data analyzed was from September 3 to October 2, 1968.

The hourly value of the subsurface water temperature and residual tide level are shown in Fig. 2. Remarkable semi-diurnal oscillation having amplitude of 10 cm in the residual tide level is observed. Also in the temperature at 100 m record oscillations with amplitude of more than 4°C are observed. Temperature at 3 m shows generally very smooth variations.

The dominant oscillations which appeared in temperature of 100 m depth ware very remarkable from September 8 to 12 and from 23 to 25. At that time the typhoons No. 13 and No. 15 of 1968 passed to the south of Miyake Island. Therefore, the dominant oscillations may have been caused by these typhoons which accompanied strong northeast wind.

According to the observation of the oceanic currents, the Kuroshio was flowing to the south of Miyake Island at this time and the northern boundary of the Kuroshio may have reached here (Fig. 1.).

Invertion of water temperature between 3 m and 100 m depth was observed on October 2, but it must be noted that two sensors are about 2.2 km apart horizontally.

The subsurface water temperature and the residual tide level can be regarded

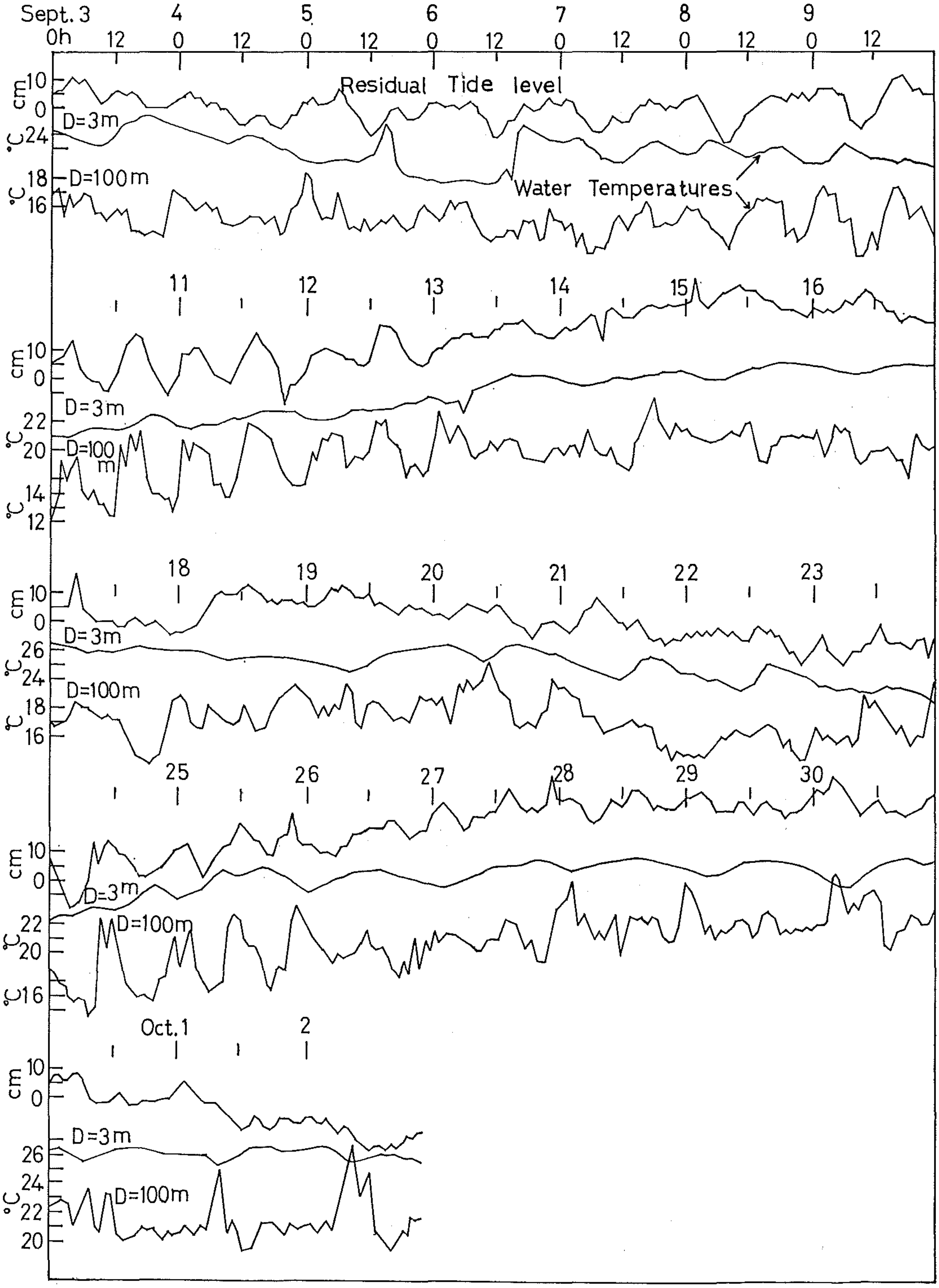

Fig. 2 Time variation of subsurface sea water temperatures and of residual tide level at Miyake Island in 1968.

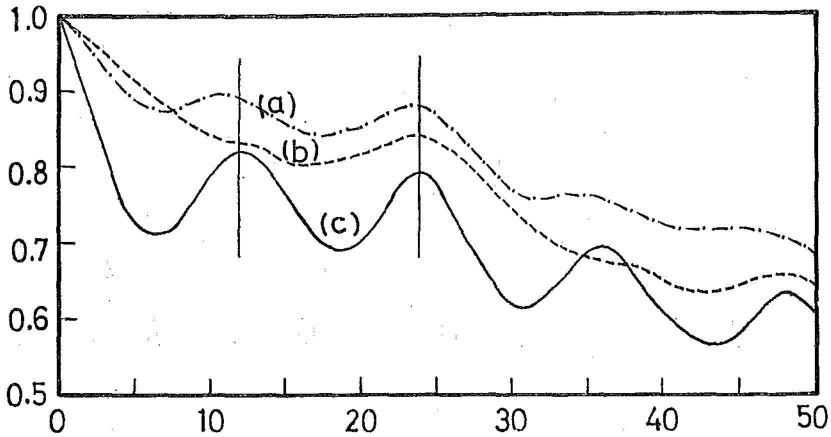

Fig. 3 Auto-correlations of subsurface sea water temperatures and hourly residual tide level.
(a) Hourly residual tide level.
(b) Subsurface water temperature of 3 m depth.
(c) Subsurface water temperature of 100 m depth.

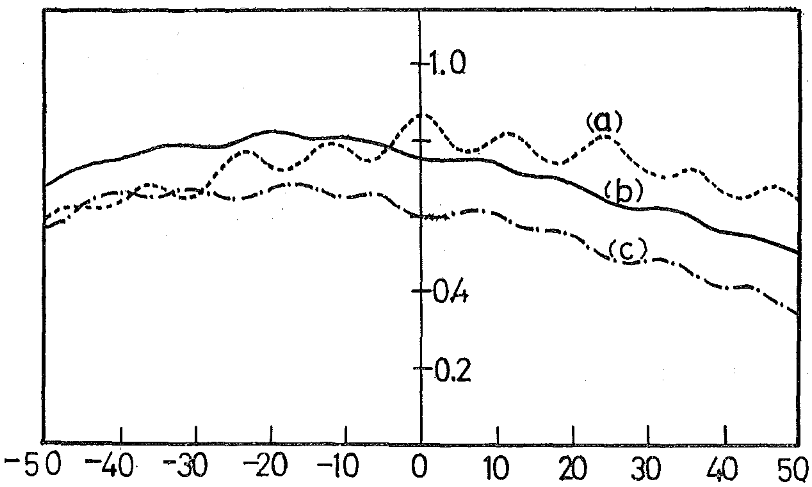

Fig. 4 Cross-correlations of subsurface water Temperature and hourly residual tide level.
(a) Between water temperature of 100 m depth and hourly residual tide level.
(b) Between water temperature of 3 m depth and of 100 m depth.
(c) Between water temperature of 3 m depth and hourly residual tide level.

as time serieses and assumed to be approximately Gaussian processes. Then the standard methods of spectral analysis can be applied to these data (Blackman and Tukey, 1968).

3. Auto-correlations and cross-correlations

Auto-correlations and cross-correlations are shown in Fig. 3 and 4. Significant values of auto-correlation are found for the curve of the water temperature at 100 m depth. The peaks are seen at about 12 h and 24 h.

A weak peak is present for the curve of the temperature at 3 m depth at 24 h. The auto-correlation of the residual tide level shows the presence of oscillations at about 12 h and 24 h.

Significant cross-correlation is seen between the water temperature at 100 m depth and the residual tide level at about 12 h and 24 h. The cross-correlation between the water temperature of 100 m depth and 3 m depth, and between 3 m water temperature and residual tide level are very small.

4. Auto-power spectra

The auto-power spectra of the water temperatures and the residual tide level are shown in Fig. 5 and 6.

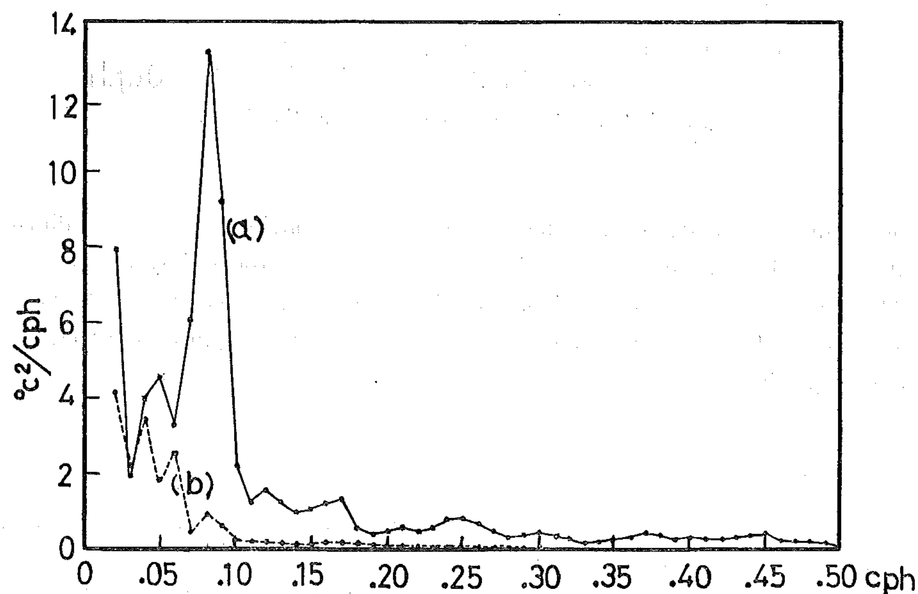

Fig. 5 Auto-spectra of subsurface water temperature.
(a) 100 m depth. (b) 3 m depth.

The auto-power spectrum of the water temperature at 100 m depth has a dominant sharp peak at the frequency of 0.08 cph with the root mean square amplitude of 3.6°C. A sub-peak with the root mean square amplitude of 2.1°C is found

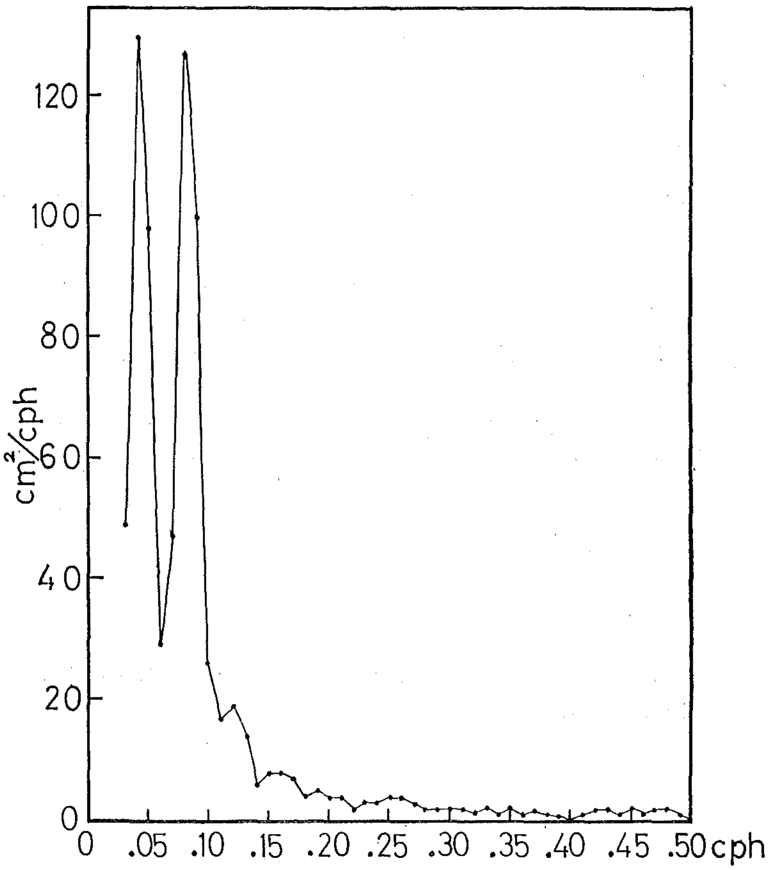

Fig. 6 Auto-spectrum of hourly residual tide level.

at the frequency of 0.04 cph. These peaks indicate obviously that semi-diurnal and diurnal oscillations of water motion exists in the sea around Miyake Island.

The auto-spectrum of the residual tide level shows two dominant peaks at the frequency of 0.04 and 0.08 cph, too. The root mean square amplitudes are 11.4 and 11.3 cm, respectively.

5. Cross spectra

Cross spectra are shown in Fig. 7, 8 and 9. The cross spectrum between the residual tide level and the water temperature of 100 m depth indicates statistically significant correlation. Coherence is strong, power is large and phase lag is around 0 degree at the frequency of 0.04 and 0.08 cph. The power of the dominant peak is 35 cm·°C/cph at the frequency of 0.08 cph. Subpeak power at 0.04 cph is 14 cm·°C/cph.

The cross spectra between the water temperature of 3 m depth and the residual tide level is not significant. Coherence is high at the middle frequency, but this feature is not statistically significant, because the cross power is small.

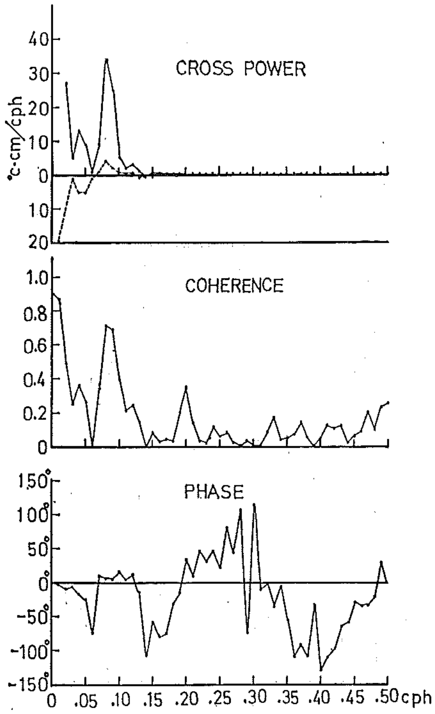

Fig. 7 Cross-spectrum between subsurface water temperature of 100 m depth and hourly residual tide level.

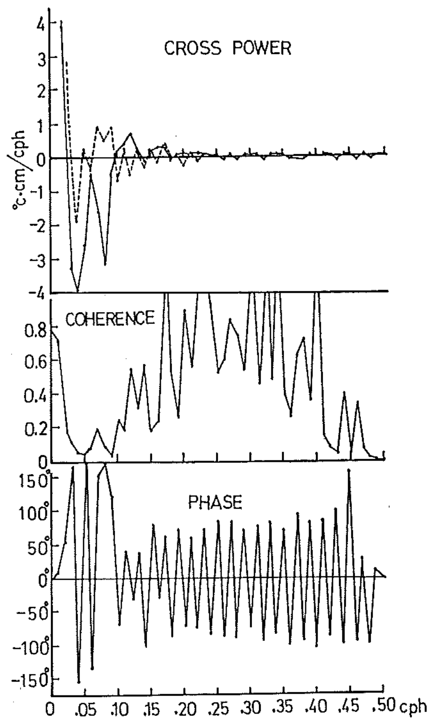

Fig. 8 Cross-spectrum between Subsurface water temperature of 3 m depth and hourly residual tide level.

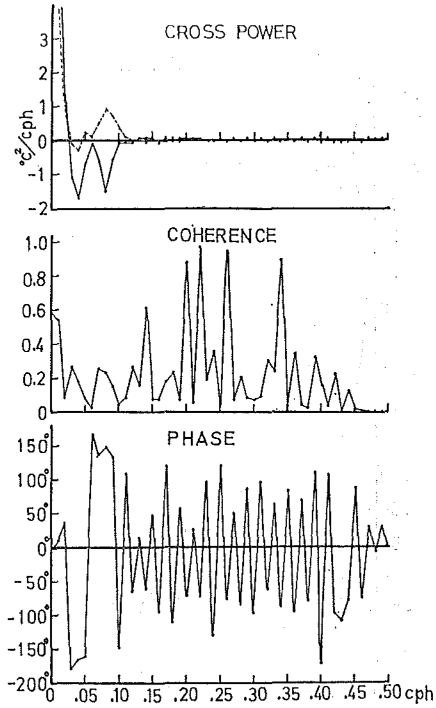

Fig. 9 Cross-spectrum between subsurface water temperature of 3 m depth and of 100 m depth.

6. Discussions

As the cause of these dominant oscillations, astronomical tide, internal wave with tidal periods, inertial wave and the short period change of the Kuroshio are taken into consideration.

According to the calculation of the residual tide level, the principal tide components of semi-diurnal and diurnal tide are removed by 96 percent. Lee and Cox (1966) observed short period variation of water temperature at the depths extending from the surface to the bottom. They reported that the variation of water temperature off California is dominated by semi-diurnal periodicity and suggested the existence of the vertical motions of ocean water associated with internal tide wave with amplitude of about 10 m.

Konaga (1965) reported that the internal wave observed in the southern sea of Japan has the characteristic period of tide or inertial motion. The frequency of the inertial wave is 0.046 cph at longitude of 34° N. This frequency is nearly equal to the observed frequency of 0.04 cph and it is not possible to separate these two oscillations by the present calculation.

Shoji and Nitani (1966, 1970) reported that the velocity of the Kuroshio changed with the periods of semi-diurnal and diurnal. The amplitude of the change was 0.25 knots Compared with the mean velocity of 2 knots. This change of the velocity of the Kuroshio is sufficient to account fort he change of the residual tide level.

As mentioned above, the northern boundary of the Kuroshio was flowing near Miyake Island. The possibility that these peaks are caused by the variation of the Kuroshio can not be denied.

However, it seems certain that the generation of dominant oscillations was primarily caused by the typhoon with strong wind as description section 2.

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