Monitoring the ocean current in the Tsushima and the Tokara Straits by using submarine cables

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Abstract. We have been measuring the voltage differences by using submarine cables in the Tsushima and the Tokara Straits. The aim of these measurements is to estimate the volume transports of the ocean currents through those straits. The voltage differences are compared with the corresponding sea level and air pressure differences between straits. Especially in the Tsushima Strait, the voltage difference is consistent with the air pressure difference as well as the sea level difference.

1 Introduction

When sea water as a good conductor flows in the geomagnetic field, an voltage difference is induced across the flow. Faraday mentioned this phenomenon soon after discovering his famous law of electromagnetic induction. Several attempts have been made to measure a voltage difference across a strait for monitoring the ocean current.

The Nippon Telegraph and Telephone West Corporation allowed us to use some submarine cables, which were replaced with optical fiber cables and retired a few years ago, for monitoring the ocean currents. We began to measure the voltage difference between Nogita and Iki on November 1, 1996. Nogita is located in northern Kyushu and about 20Km distant from Fukuoka city. The brief history of our measurement is shown below.

Nov. 1, 1996	Nogita–Iki
Nov. 10, 1998	Nogita–Iki-Tsushima
Jan. 21, 1999	Kagoshima–Naze and Kagoshima–Yaku-Shima
Sept. 9, 1999	PC at Kagoshima station failed.
May 16, 2000	PC was replaced.

Fig. 1 shows the locations of submarine cables used for the measurement and the locations of tidal stations of the Hydrographic Department of Japan Coast Guard. The Kuroshio and a part of the Tsushima Warm Current cross these cables. At the tidal stations the sea levels and the air pressures are measured.

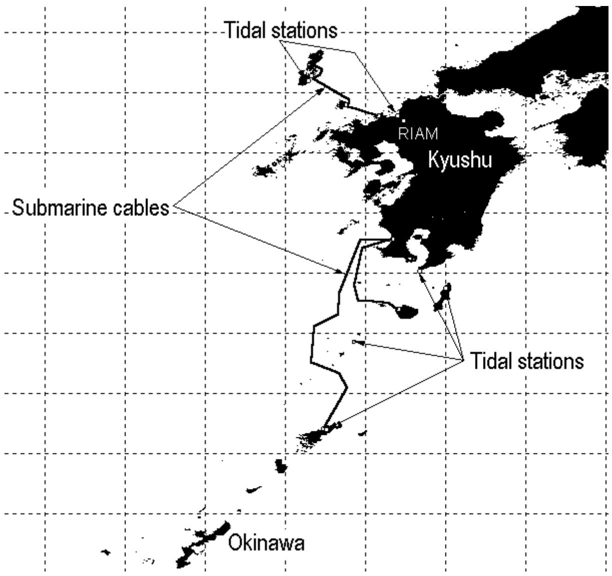

Fig. 1. Locations of Submarine Cables and Tidal Stations.

2 Measurement

We have been measuring the voltage differences in the Tsushima and in the Tokara Straits. The locations of submarine cables and tidal stations are shown in Fig. 1. These cables are no longer in use for the telecommunication. The properties of these cables are show in Table. 1.

The measuring system at Kagoshima (Nagayoshi) station is shown in Fig. 2. Kagoshima station is located in southern Kyushu and is the termination of the submarine cables from Yaku-Shima

Table. 1. Properties of submarine cables.

interval	type	cable length
Nogita–Iki	CS-36M-S	52.709Km
Iki–Tsushima	CS-36M-S	82.046Km
Kagoshima–Yaku-Shima	CS-36M-D1	204.564Km
Kagoshima–Naze	CS-36M-D1	470.352Km

and Naze. The voltages are measured every 5 seconds by two digital multimeters (Keithley Model 2000). These multimeters are connected to a PC running under Linux operating system as shown in Fig. 2. Ten minutes average values of the voltages are calculated to reduce high frequency noise and stored in the PC every 10 minutes. We can get the voltage data any time by means of the telephone line. The measuring system at Iki station is similar to this system except that PC is running under the MS-DOS.

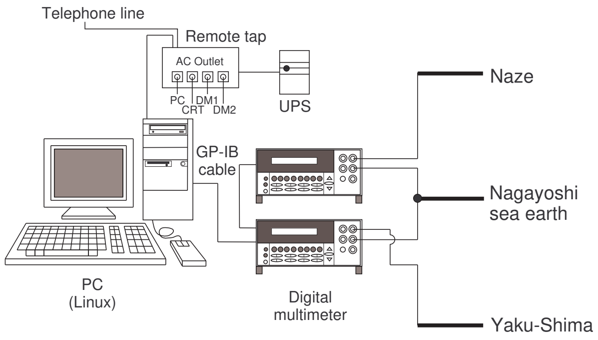

Fig. 2. Schematic Diagram of Measuring System at Kagoshima (Nagayoshi) Station.

3 Data

First we show the sea level difference between Hakata (Fukuoka city) and Izuhara (Tsushima) by solid line and the voltage difference between Nogita and Tsushima by broken line in Fig. 3. There is no tidal station in Iki. Therefore the voltage differences between Nogita and Iki and between Iki and Tsushima are added to calculate the voltage difference between Nogita and Tsushima. Both lines in Fig. 3 are 25 hours moving averages, therefore the tidal components are eliminated. It seems that the agreement of both data is fairly good in Fig. 3. This may mean that the current is geostrophic. If you go over this figure, however, you will find out that the amplitude of the voltage has been gradually decreasing against the sea level difference. The raw data of the voltage and the sea level difference, which include the tidal component, are show in Fig. 4. It is obvious that the amplitude of the voltage has been decreasing while the one of the sea level difference is steady. Though we cannot explain the reason why such a decrease occurs at present, we guess the change of conductivity of the sea water and the seabed causes this phenomenon.

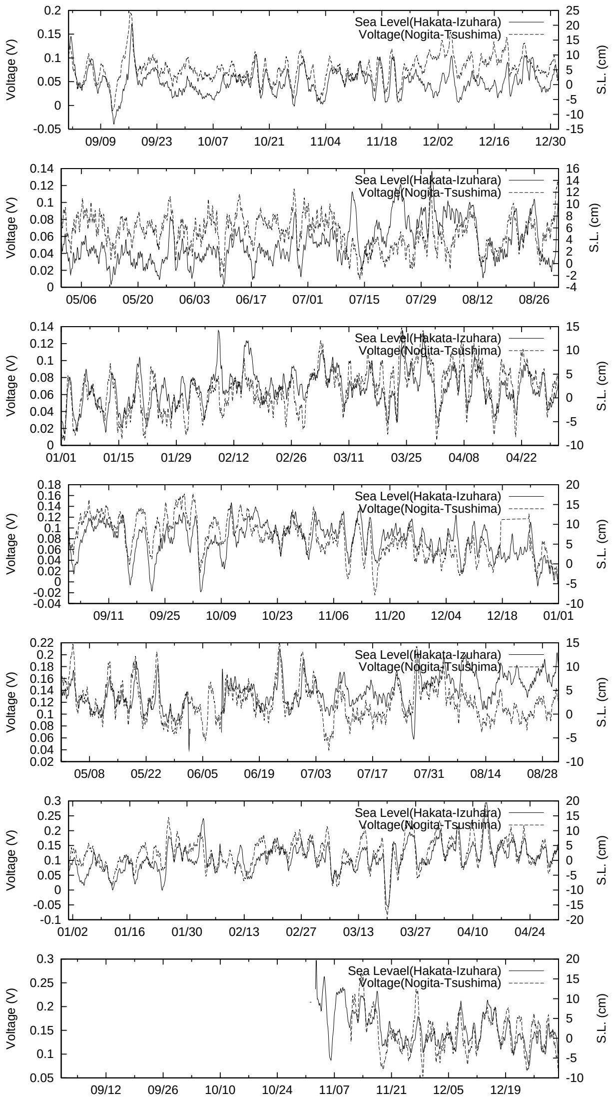

Fig. 3. Comparison of Voltage and Sea Level Differences in the Tsushima Strait from Nov. 1998 to Dec. 2000. The positive voltage corresponds to the north-eastwards current.

Second we show the air pressure difference between Hakata and Izuhara by solid line and the voltage difference between Nogita and Tsushima by broken line in Fig. 5. The air pressure difference is mean daily values and the voltage difference is same as in Fig. 3. It seems that the agreement of both data is fairly good in Fig. 5 as well as in Fig. 3. This may mean that the Tsushima Warm Current in the East Channel is strongly affected by the air pressure or the corresponding wind.

Third we show the sea level difference between Nishinoomote and Naze by solid line and the voltage difference between Naze and Yaku-Shima by broken line in Fig. 6. Nishinoomote is located in southern Tane-ga-Shima which is an island near Yaku-Shima. There is no datum from September 4, 1999 to May 15, 2000 because of failure of the PC at Kagoshima station. We are measuring voltage differences between Kagoshima and Yaku-Shima and between Kagoshima and Naze as shown in Fig. 1, however, it is doubtful that the voltage of the sea earth at Kagoshima station corresponds to the ground since it is shared with a relay equipment of optical fiber submarine cables operating actively. To eliminate the effect of the sea earth at the Kagoshima station, we use the voltage difference between Naze and Yaku-Shima which is calculated by subtracting the voltage difference between Kagoshima and Naze from the one between Kagoshima and Yaku-Shima. Both lines in Fig. 6 are 25 hours moving averages. The agreement of both data is not so bad in Fig. 6.

Last we show the air pressure difference between Nishinoomote and Naze by solid line and the voltage difference between Naze and Yaku-Shima by broken line in Fig. 7. The voltage data are same as in Fig. 6 and the air pressure data are mean daily values. It seems that the Kuroshio is affected by the air pressure difference or the corresponding wind same as in the Tsushima Strait.

4 Conclusion

By comparing the voltage data with the sea level and the air pressure differences, we showed that the voltage data reflect the ocean current signal very well. Our measurement is continuing and the voltage data are increasing every day. Hence we have

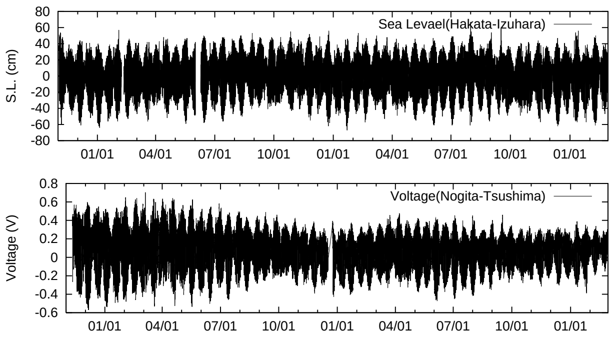

Fig. 4. Comparison of Voltage and Sea Level Differences in the Tsushima Strait from Nov. 1998 to Feb. 2001. (Raw data)

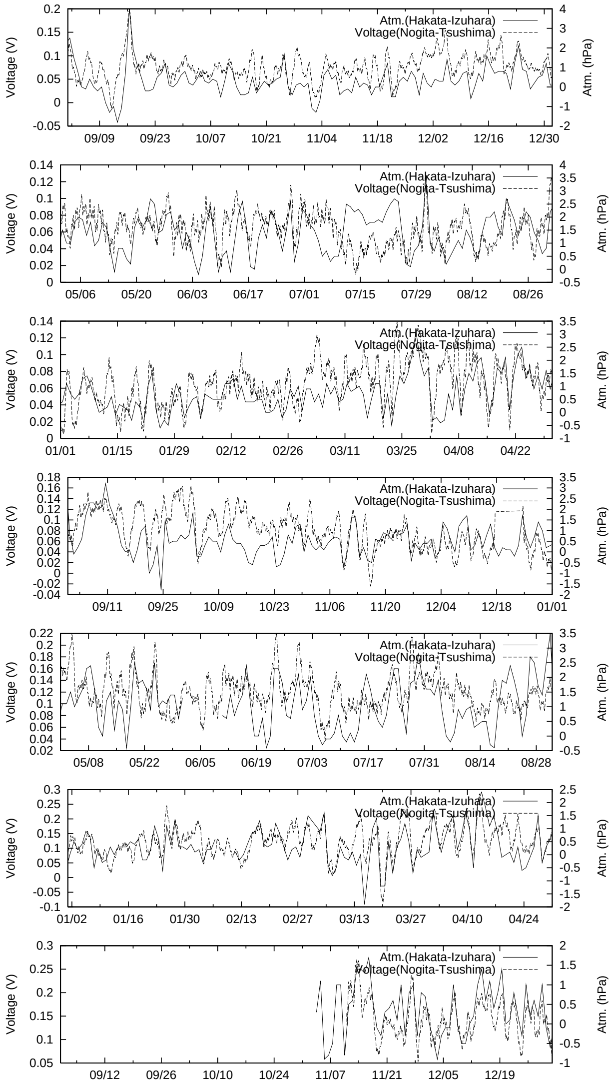

Fig. 5. Comparison of Voltage and Air Pressure Differences in the Tsushima Strait from Nov. 1998 to Dec. 2000.

to calibrate our voltage data with ADCP data and other measured current data to estimate the volume transports of the currents across the cables.

Our voltage data updated every day are shown on our web site, http://amami.riam.kyushu-u.ac.jp/~hashimot/index-e.html.

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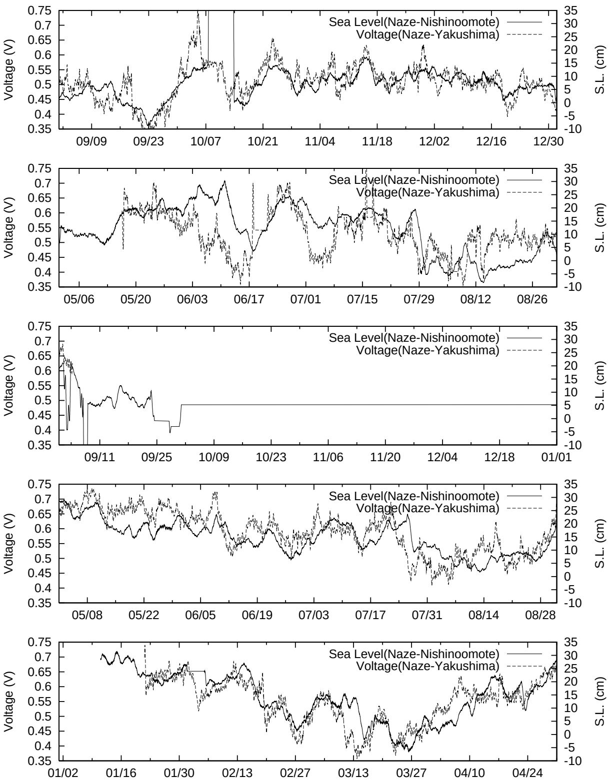

Fig. 6. Comparison of Voltage and Sea Level Differences in the Tokara Strait. (Lower three figures are from Jan. to Sept. 1999, and upper figures are from May to Dec. 2000.) The positive voltage corresponds to the eastwards current.

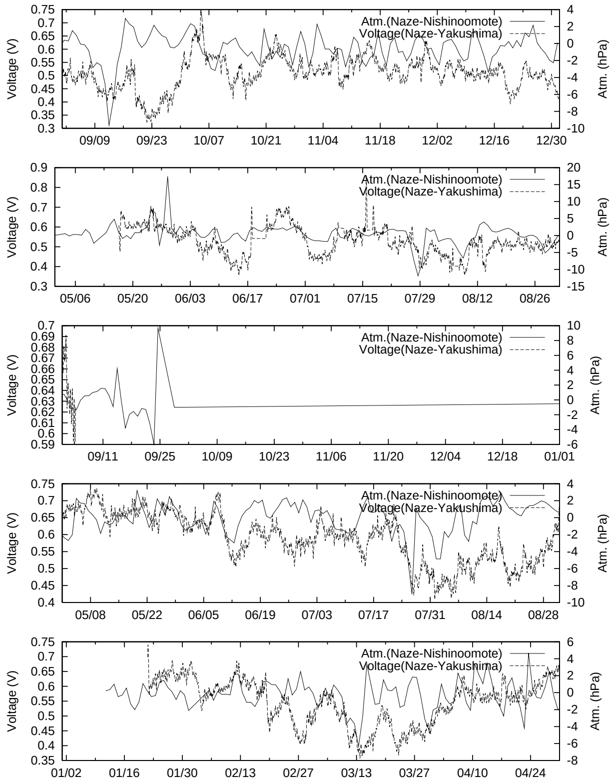

Fig. 7. Comparison of Voltage and Air Pressure Differences in the Tokara Strait. (Lower three figures are from Jan. to Sept. 1999, and upper figures are from May to Dec. 2000.)

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