Proc. NIPR Symp. Antarct. Geosci., 4, 100–107, 1990

TIDES AND TIDAL CURRENTS IN THE ANTARCTIC SEA OBSERVED AT SYOWA STATION, EAST ANTARCTICA

Minoru ODAMAKI and Katsujiro OKA

Hydrographic Department, Maritime Safety Agency, 3-1, Tsukiji 5-chome, Chuo-ku, Tokyo 104

Abstract: Tidal currents were observed at the Kita-no-seto Strait near Syowa Station for 15 days from January to February, 1982 by the 23rd Japanese Antarctic Research Expedition. The observed currents show a semidiurnal type in contrast with the tides at Syowa Station showing a mixed type. Judging from the amplitude and phase lag distributions around Antarctica, M2 tidal wave is understood as a standing wave which has a node near the Station. Therefore, the disagreement of the characteristics is interpreted as that the vertical oscillation (tide) is reduced and the horizontal movement (tidal current) becomes significant around the node.

K1 tidal wave is understood as a progressive wave which is trapped to the Antarctic coast and traveling from east to west once a day around Antarctica. This understanding agrees with the fact that the phase lag of K1 tidal current at the Strait is close to that of K1 tide at Syowa Station.

1. Introduction

According to GILL (1979), the tide in the Antarctic Sea is explained with the combined oscillation of direct forcing and free tides. The direct forcing tide is generated directly by gravitational force and the free tide is induced by the oscillation of the other sea tide through the boundary condition. Particularly the former tide is expected to be developed in the Antarctic Sea where the tidal wave propagates zonally around the earth, and the latter tide is expected to have a great influence on the other sea tide. Therefore, the tides and tidal currents are not remarked only as local phenomena but also as functions of the global ocean tide.

At Syowa Station the tidal current observation was made successfully first in 1982 while the tidal observation has been continued since 1961 by the Japanese Antarctic Research Expedition (JARE) Project. In this paper, we report the results of observations and discuss their relation to the whole tidal oscillation in the Antarctic Sea.

2. Tidal Current Observation

The tidal current at the Kita-no-seto Strait was observed during 15 days from January to February, 1982, by JARE-23 (OKA and FUCHINOUE, 1984). Kita-no-seto Strait is a small channel located about 500 m north of Syowa Station, East Ongul Island (Fig. 1a), and its width is about 200 m and its depth about 10 m. The current meter (Bergen model 4 of AANDERAA) was moored at 5 m below the ice surface

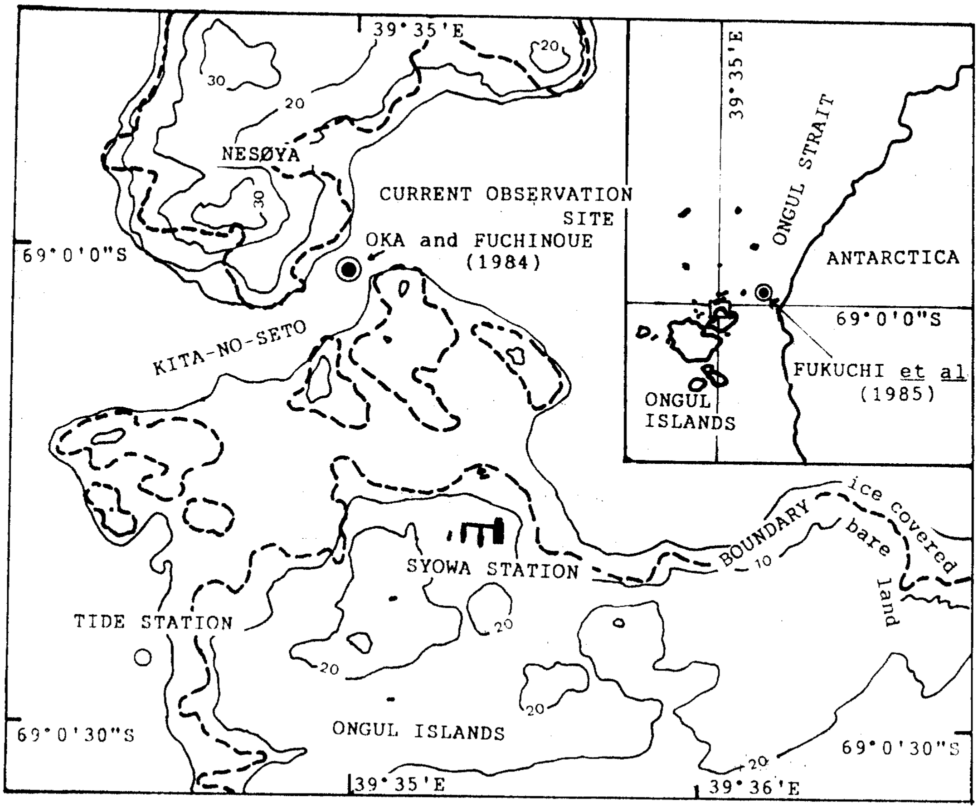

Fig. 1a. Locations of Syowa Station, Kita-no-seto and Ongul Straits. See Fig. 2.

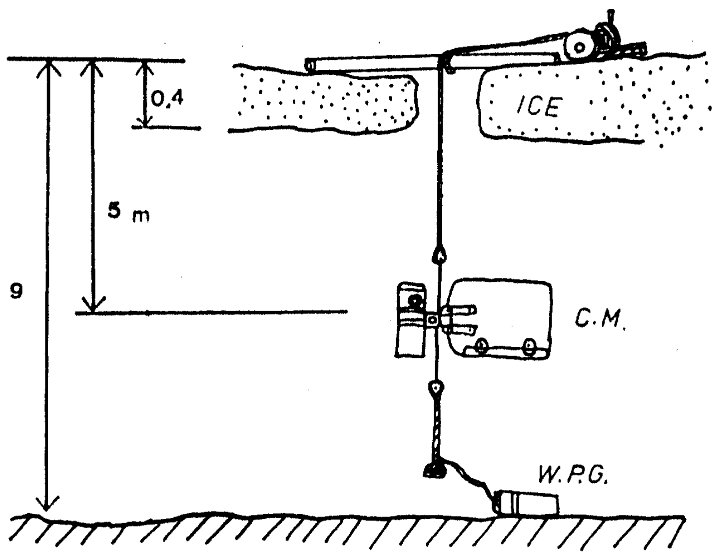

Fig. 1b. Total mooring system for the tidal current observation at the Kita-no-seto Strait. Current meter (CM) was attached at 5 m below the sea surface and water pressure gauge (WPG) was set on the sea bed.

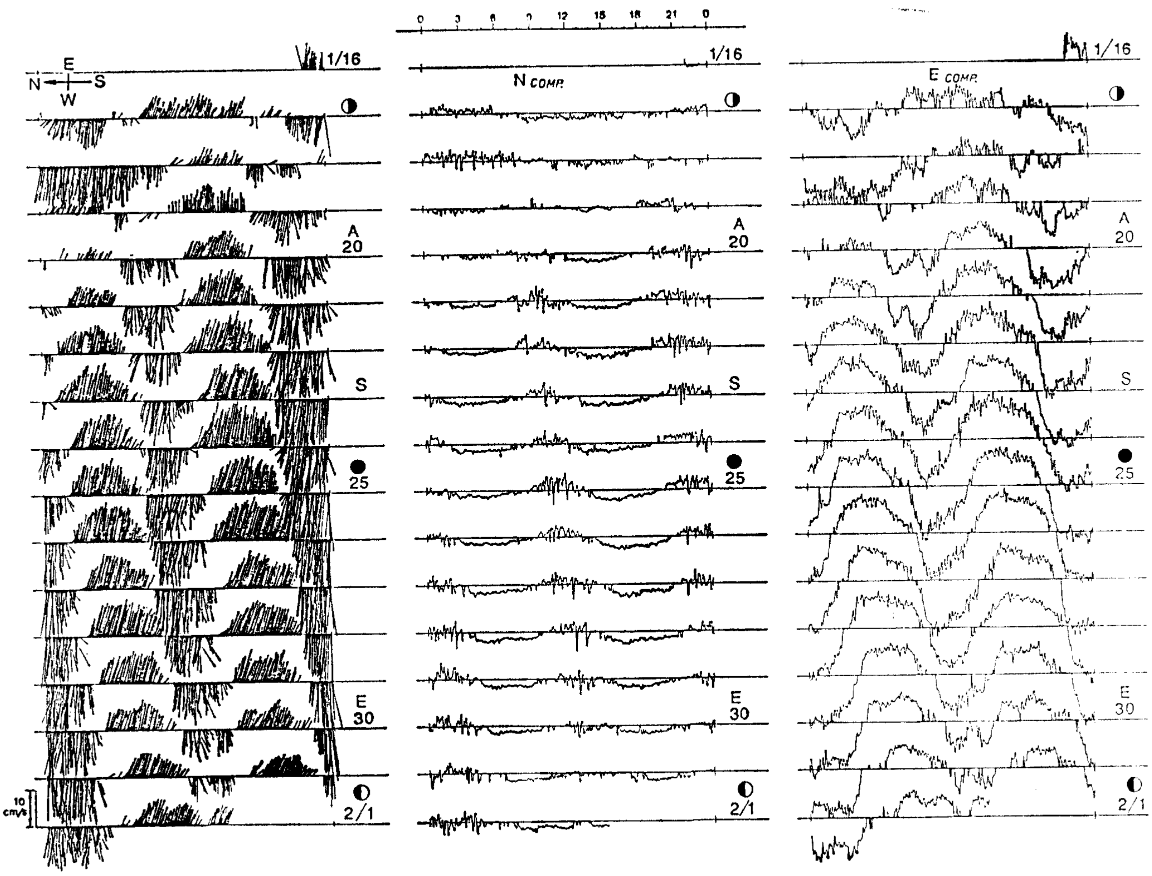

Fig. 1c. Tidal current observed at the Kita-no-seto Strait from January 16 to February 1, 1982. Left: Current vector stick-diagram, center: north-south component, and right: east-west component in north- and eastward positive. Each line shows record for one day. Symbols ◐, ●, ◑, A, S, and E indicate conditions of moon, first quarter, new, last quarter moons, apogee, at the southernmost, and on the equater, respectively.

attached to a rope hung through the digged ice hole (Fig. 1b). The pressure type tide gauge was set on the sea bottom, but did not work well owing to disorder.

Figure 1c shows the stick-diagram of the observed current, in which upward and lefthand correspond to east and north components, respectively, and each line shows currents for one day. Tidal current changed the direction twice a day for the whole observed period. The maximum tidal current occurred in the spring tide about 1 day after the day of new moon, January 25. Thus the tidal current has the characteristics of semidiurnal type.

3. Harmonic Constants of Tide and Tidal Current

Tidal current harmonic constants are calculated with 15 day harmonic analysis program (ODAMAKI, 1981), and the harmonic constants of 4 principal components, M2, S2, K1 and O1, are shown in Table 1. Tidal harmonic constants of Syowa Station (ODAMAKI and KURAMOTO, 1989), and tidal current harmonic constants of the Ongul Strait, which are calculated by the authors from the 15 days of 1 year data observed by

Table 1. Harmonic constants of tides and tidal currents around Syowa Station.

Place	M2			S2			K1			O1		
Tide: Syowa Station (39°35′E, 69°00′S)												
	23 cm	165°		19 cm	181°		22 cm	4°		23 cm	352°	
	Direction, amplitude (cm/s), phase (°)											
Tidal current: Kita-no-seto Strait (39°35′00″E, 69°00′00″S)												
L*	278	6.6	298	279	6.3	306	279	2.3	19	273	1.0	218
S**	8	0.2	208	9	0.2	216	9	0.0	109	3	0.0	128
Tidal current: Ongul Strait (39°40′42″E, 68°59′46″S)												
L	6	4.3	268	22	2.5	287	321	1.6	159	293	2.6	283
S	96	0.6	358	112	0.9	17	51	0.4	69	23	0.5	193

* Long axis, ** Short axis of the tidal current ellipse.
Phase lags are referred to the local transit time.

FUKUCHI *et al.* (1985), are also listed.

At the Kita-no-seto Strait the amplitudes of semidiurnal tidal currents are larger than those of diurnal ones, but at Syowa Station the analysis for the tide shows opposite sense. Therefore, the diurnal inequality appears larger in tide than that in tidal current. Difference of phase lags between tidal current and tide attains to about 130° for M2, but only 15° for K1. Furthermore it is noteworthy that the amplitude of O1 tide is superior to that of K1 at Syowa Station, and the amplitude of O1 tidal current is superior to that of K1 at the Ongul Strait.

4. Tidal Wave in the Antarctic Sea and the Position of Syowa Station

Figure 2 shows tide stations around Antarctica (HORI and INBE, 1968; ODAMAKI and KURAMOTO, 1989). The following results have a little ambiguity for the lack of data in the area from 90°W to 180°W.

Figure 3a shows the distributions of amplitude and phase lag for M2 tide in the zonal sea region surrounding Antarctica. The amplitude takes maximum in the Weddell Sea and minimum in the adjacent sea of the Enderby Land. The phase changes twice from 0° to 360° in a round. In the place between Stns. 18 and 19 the phase changes abruptly and the amplitude takes minimum, which means the existence of a node of tidal oscillation around there. Syowa Station (Stn. 20) is located just west of the node. In the vicinity of node, tidal current amplitude becomes large and its phase delays about 90° compared with the tide. As listed in Table 1, at the Kita-no-seto Strait and at the Ongul Strait, the amplitudes of the M2 tidal currents are larger than those of the other components and their phase differences to the M2 tide are 130° and 100°, respectively. These facts are consistent with the characteristics of node.

Figure 3b is the same as Fig. 3a but for S2 tide. Similar to M2 tide, the node is detected near Stn. 18. Therefore, the characteristics of S2 tidal currents at the Kita-no-seto Strait and at the Ongul Strait can be explained with the existence of the node same as those of M2. However, the phase of S2 tide changes 3 times from 0° to 360° in a round, and it is very different from that of M2 tide which changes twice.

Figure 3c is the same as Fig. 3a but for K1 tide. Its amplitude does not vary in

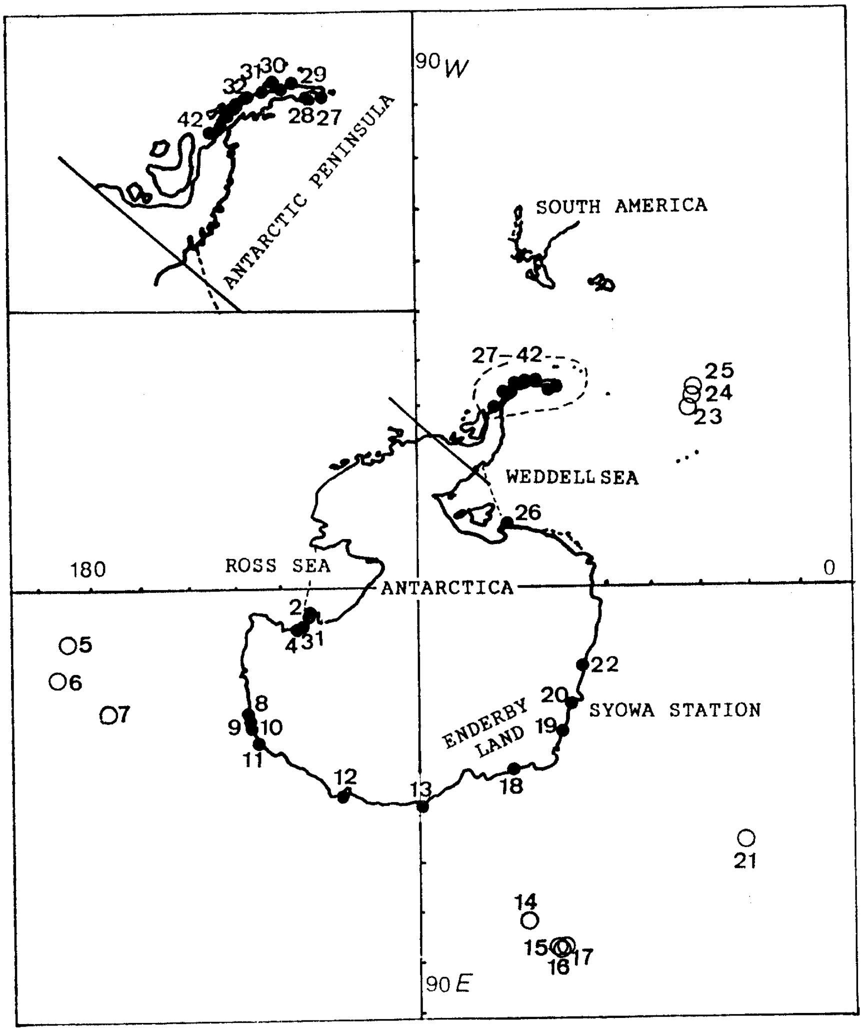

Fig. 2. Locations of tide stations around Antarctica. Dots are the stations on the coast of Antarctica and circles are those at islands.

the pattern as those of M2 and S2 tides. The fact that the amplitudes on the coast of Antarctica are always larger than those at the islands in the surrounding sea, means that the K1 tidal wave is trapped near the coast. Its phase changes linearly from east to west and coincides with the value of longitude, measuring positive to west and negative to east. This phase distribution means that the K1 tidal wave has the characteristics of fundamental mode with one crest and one trough in the zonal sea surrounding Antarctica moving at the same speed as the Earth's rotation. In the case of progressive wave, its phase of tidal current should be the same as that of the tide. Certainly the phase difference between the K1 tidal current and the K1 tide is only 15° at the Kita-no-seto Strait and 25° at the Ongul Strait.

Figure 3d is the same as Fig. 3a but for O1 tide. The characteristics are almost the same as those of the K1 tide. However, the observed phase difference between tide and tidal current is rather large, 140° at the Kita-no-seto Strait and 70° at the Ongul Strait, which does not agree with the explanation of progressive wave as in the case of K1.

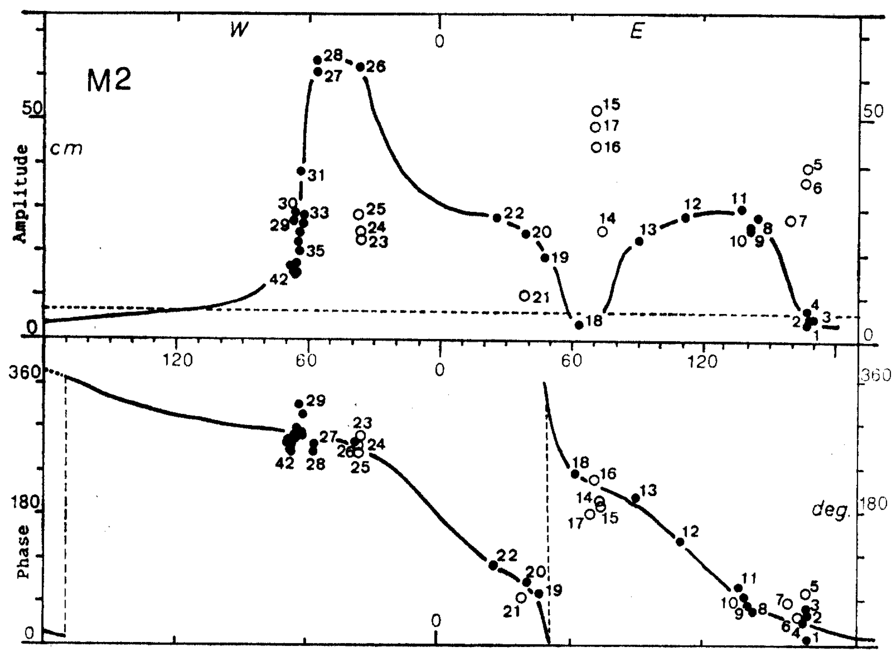

Fig. 3a. Amplitudes (upper) and phase lags referred to Greenwich (lower) for M2 tide around Antarctica. Numerals correspond to the station numbers in Fig. 2. Dashed line in the upper part indicates the M2 amplitude of equilibrium tide along 60°S, 6.1 cm.

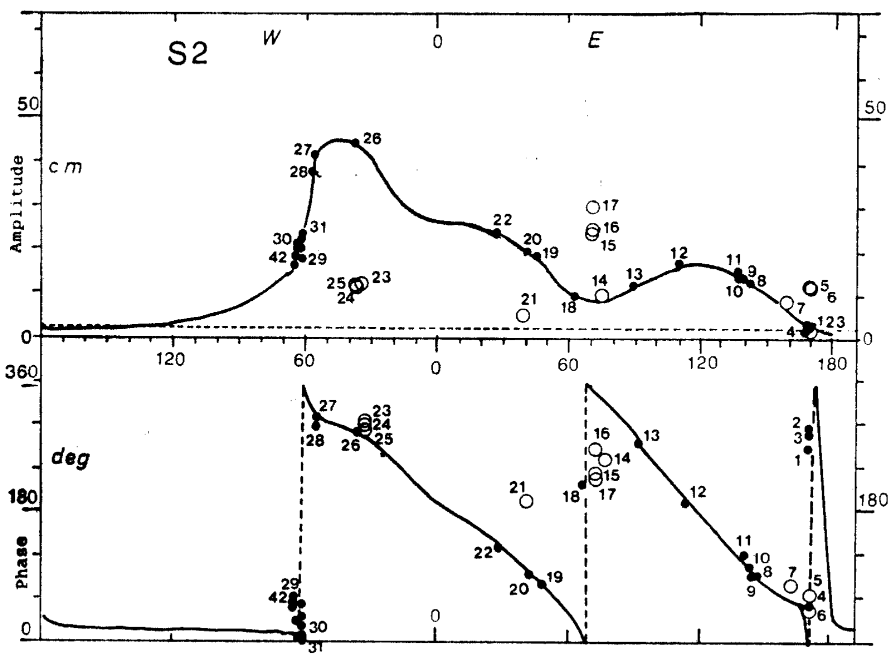

Fig. 3b. Same as Fig. 3a but for S2. Dashed line indicates the S2 amplitude of equilibrium tide, 2.8 cm.

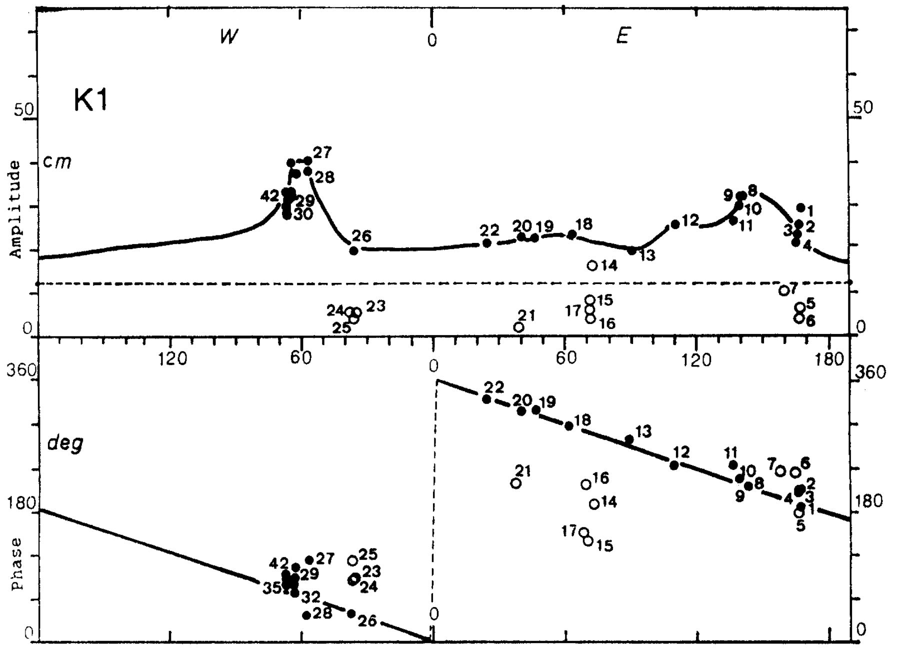

Fig. 3c. Same as Fig. 3a but for K1. Dashed line indicates the K1 amplitude of equilibrium tide, 12.3 cm.

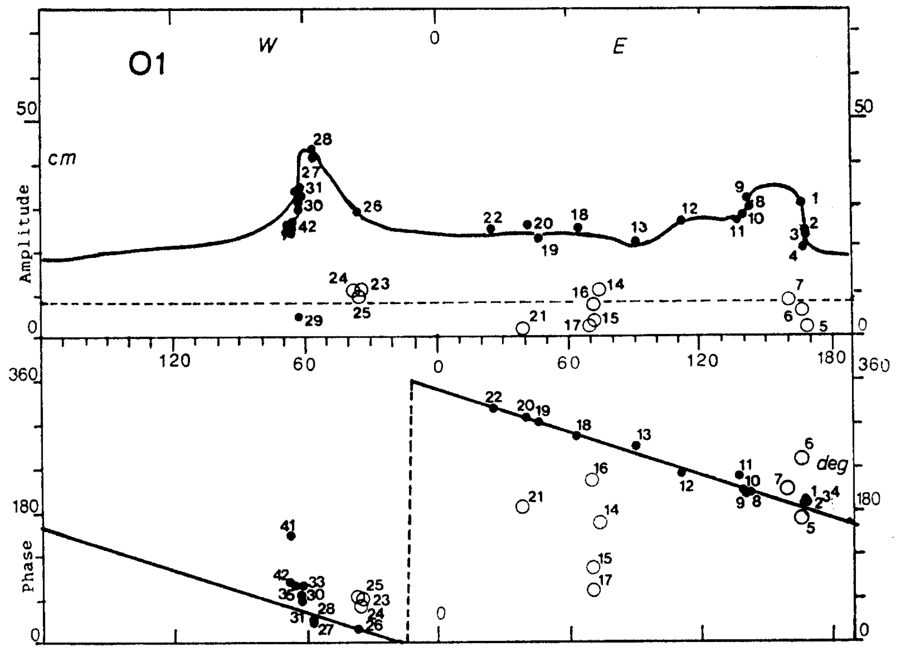

Fig. 3d. Same as Fig. 3a but for O1. Dashed line indicates the O1 amplitude of equilibrium tide, 8.8 cm.

5. Conclusion

The nodes of the M2 and S2 tidal waves are detected around 60°E near Syowa Station. The characteristics of tidal currents at the Kita-no-seto Strait and at the Ongul Strait, and their disagreement with the tide such as the diurnal inequality are successfully explained by the existence of these nodes.

HUTHNANCE (1983) discussed the diurnal tide in the southern ocean concerned with that in the Atlantic. He pointed out that the diurnal tidal wave is the Kelvin wave strongly trapped to the coast and traveling steadily around Antarctica. The amplitude and phase distributions of K1 and O1 tides in this paper support his explanation. The observed K1 tidal current is almost in phase with the K1 tide, which again confirms his steady propagating tidal wave model.

HUTHNANCE (1983) suggested that O1 period is close to a natural period of the Antarctic Sea (30 hours) so that the O1 tide exceeds the K1. It is evident that the O1 tidal amplitude leads the K1 at Syowa Station, and the O1 tidal current amplitude leads the K1 at the Ongul Strait. However, the O1 tidal current does not lead the K1 at the Kita-no-seto Strait and is not in phase with the O1 tide at the Ongul Strait, which remains to be explained in future work.

Acknowledgments

We should like to thank the JARE-23 members for their efforts to observe the tidal current, all the JARE members for their efforts to continue the tide observation at Syowa Station, and the reviewers for their kind comments on our manuscript.

References

FUKUCHI, M., TANIMURA, A., OTSUKA, H. and HOSHIAI, T. (1985): Tidal current data in the Ongul Strait, Antarctica, from April to December 1982 (JARE-23). JARE Data Rep., **102** (Oceanography 5), 57 p.

GILL, A. E. (1979): A simple model for showing effects of geometry on the ocean tides. Proc. R. Soc. London, **A367**, 549–571.

HORI, S. and INBE, E. (1968): Tides at Syowa Station. Nankyoku Shiryô (Antarct. Rec.), **32**, 48–54.

HUTHNANCE, J. M. (1983): Simple models for Atlantic diurnal tides. Deep Sea Res., **30**, 15–29.

ODAMAKI, M. (1981): Saishô jijôhô ni yoru chôseki•chôryû no tanki chôwa bunkai no hitotsu no kokoromi (A new trial on the harmonic analysis for short period observation of tide and tidal current, using the least square method). Suirobu Kenkyû Hôkoku (Rep. Hydrogr. Res.), **16**, 71–82.

ODAMAKI, M. and KURAMOTO, S. (1989): Nankyokukai ni okeru chôseki (Tides in the Antarctic Sea). Nankyoku no Kagaku, 8. Kaiyô (Science in Antarctica, 8. Oceanography), ed. by Kokuristu Kyokuchi Kenkyujô. Tokyo, Kokon Shoin, 36–62.

OKA, K. and FUCHINOUE, S. (1984): Oceanographic data of the 23rd Japanese Antarctic Research Expedition from November 1981 to April 1982. JARE Data Rep., **91** (Oceanography 3), 38 p.

(Received April 3, 1990; Revised manuscript received May 8, 1990)