MEAN SEA-LEVEL OBSERVED AT SYOWA STATION, EAST ANTARCTICA

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Abstract: Hydrographic Department of Maritime Safety Agency, Japan, has continued tidal observation at Syowa Station as part of the Japanese Antarctic Research Expedition project since 1966. The tidal observation system and data processing manner are described in this paper. Using the well-controlled data from 1981 to 1987, monthly mean sea-levels are analyzed and show the trend of the falling at the rate of about 1 cm/year. Furthermore, it is also shown that the seasonal change of mean sea-level at Syowa Station is larger than those at other stations around the Antarctic Sea.

1. Introduction

The 1st Japanese Antarctic Research Expedition (JARE-1) party observed sea-level for a few days in 1956 by using a tide pole in order to establish the datum level at Syowa Station. The JARE-5 party succeeded in tidal observation by using a tide gauge in 1961, but reliable record was obtained for only one week. Since 1966, Hydrographic Department has continued tidal observation as part of the JARE project using a pressure type tide gauge. However, the tide gauge of mechanical pressure sensor in early days had many problems, so the tidal record had breaks until a record over one year was obtained in 1975. The tidal record has been continued since 1975 using a strain gauge sensor, but there were problems in monitoring mean sea-level in the early stages. One reason was that the drift of the gauge zero was large (Odamaki and Kuramoto, 1989). Another tide gauge using a strain gauge sensor was carefully installed in 1981, and has been able to monitor MSL. Recently, the tide gauge has aged so that its replacement was started in 1987 (Michida, 1988).

In this paper, the tidal observation system at Syowa Station is described, and the observed long-term trend of the MSL from 1981 through 1988 is reported.

2. Tidal Observation System

The tide station has been located in the Nisi-no-ura Cove (Fig. 1) since 1976. Figure 2 shows the tide gauge of the previous type (SWL-7, Kyowa Shoko Co., Ltd.) which measures absolute pressure using a strain gauge. The electrical output is transmitted and recorded in the analogue recorder installed in the tidal observation hut. The range of tidal record is 1.8 m and its accuracy is 1.0% to the full scale, *i.e.* 0.036 m.
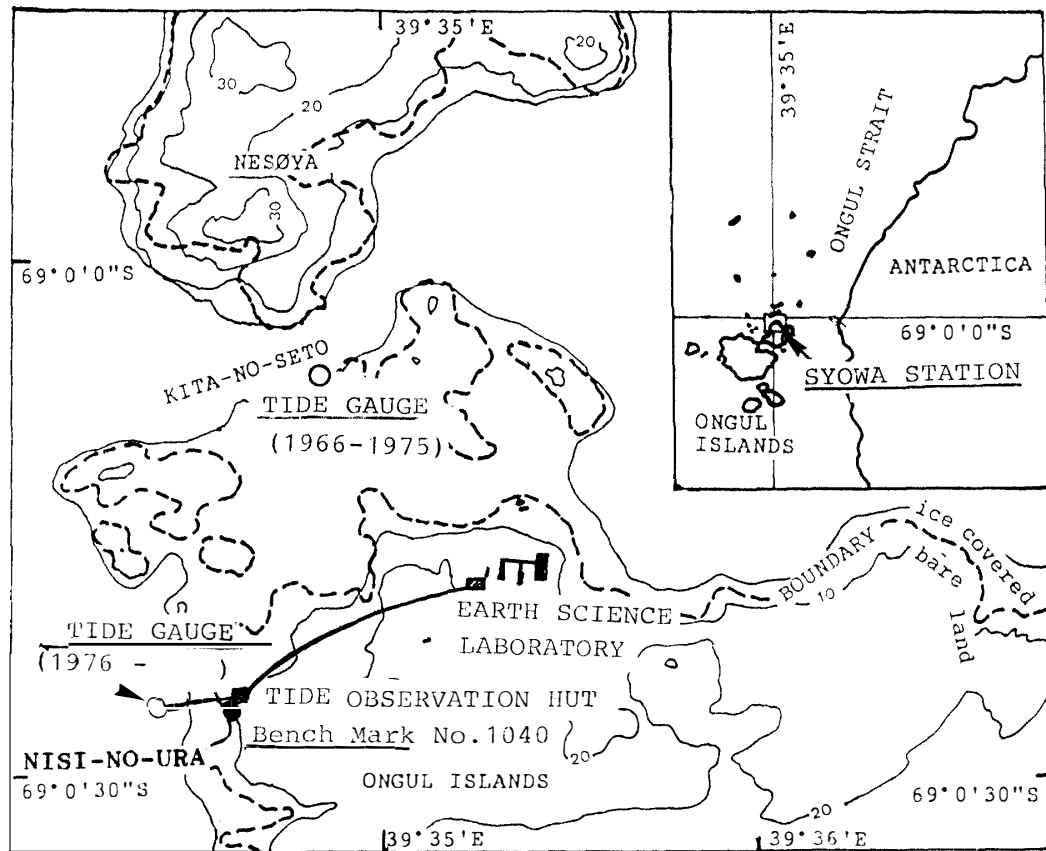
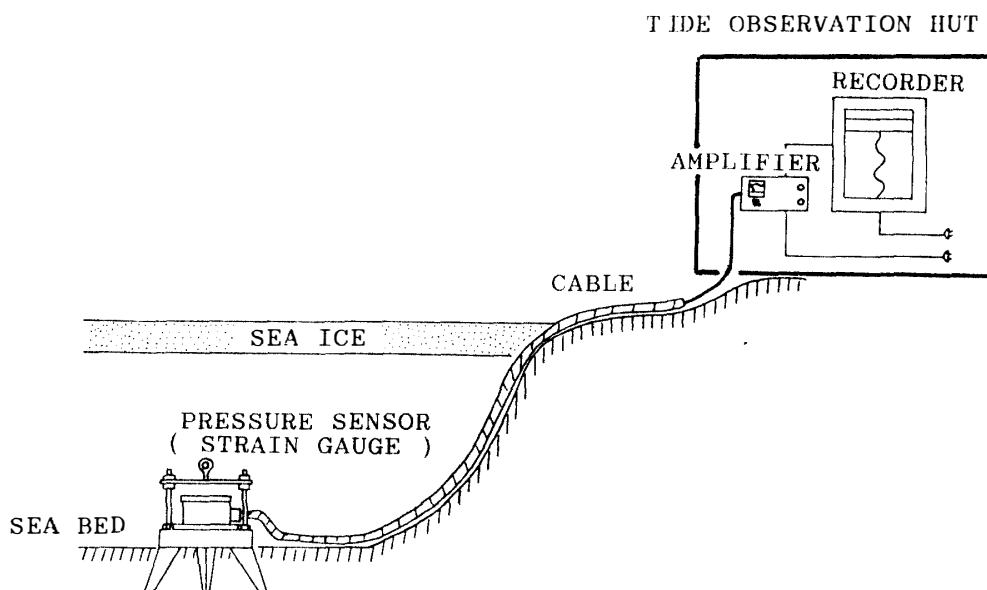*Fig. 1. Location of Syowa Station and tide gauge.*

Fig. 2. Former tidal observation system using the strain gauge (SWL-7, Kyowa Shoko Co., Ltd.). Recorder and amplifier are installed in the hut. Absolute pressure is measured in this system.
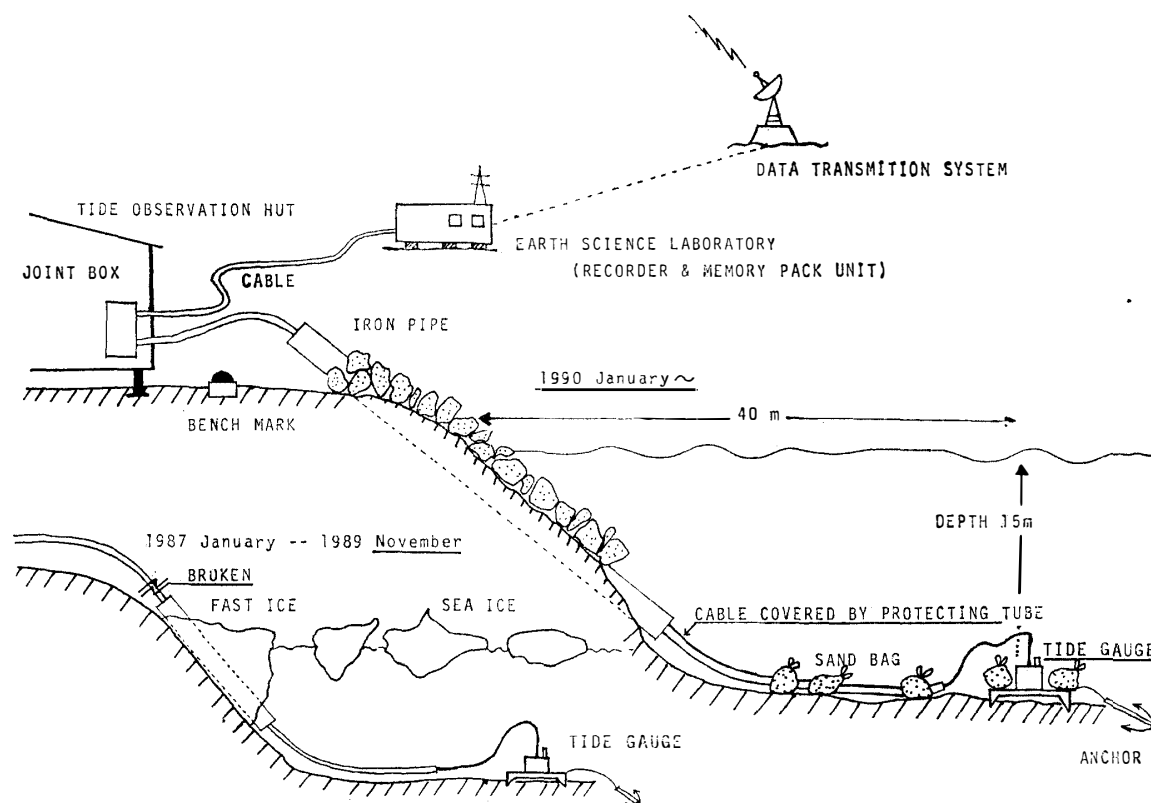
Fig. 3. New tidal observation system using the quartz oscillator (QWP-801, Meisei Electric Co., Ltd.). Tidal data are recorded in the earth science laboratory and transmitted to Japan through satellite communication system. Relative pressure compensated with the atmospheric pressure is measured.

Another system of this type was installed in 1981, and has operated up to the present.

Figure 3 shows the new tidal observation system (QWP-801, Meisei Electric Co., Ltd.) starting to be replaced in 1987. The tide gauge was fixed at the sea floor of 15 m depth with anchors and sand bags. In this system, the relative water pressure compensated for the atmospheric pressure is measured with quartz oscillator. Range of the sensor is 0–5 m and its accuracy is 0.1% to the full scale, i.e. 0.005 m. The data sampled 5 times per second are averaged over one min and recorded on solid IC memory every 10 min. The first system installed in January 1987 stopped working in November 1989, and the second system installed in January 1988, also stopped in November 1988. This is probably due to troubles in the communicating cables, attacked by the sea ice in the surf zone. The third system, installed in January 1990, has operated to the present (May 1991).

It should be noted that the tide gauge of the previous type (SWL-7) measures absolute pressure, and while that the tide gauge of the present type (QWP-801) measures relative pressure.

3. Check of the System and Data Processing

Tide gauges of pressure type are vulnerable to changes in sensitivity, and to drift in the datum, so that calibration is essential to get reliable sea-level data for long

periods.   At Syowa Station, sea ice opens for a few weeks in January, and this is the
only chance to carry out calibration.   Practically, the tidal records (*x*) are compared
with the actual water height readings (*y*) for one tidal cycle using the tide pole which is

Table 1.   Results of calibration of tide gauge.

Date	Sensitivity *a*	g0 *b*	Atmospheric pressure *c*
y/m/d	m/m	m	mb
1981/1/20	0. 8158	4. 116	992. 9
1982/1/25	0. 8565	4. 112	995. 6
1983/1/14	0. 7820	4. 015	991. 9
1984/1/ 3	0. 815	4. 118	988. 9
1985/1/ 8	0. 8202	4. 010	991. 8
1986/1/25	0. 7719	4. 044	993. 0
1987/1/16	0. 768	4. 043	999. 5

$y=ax+b$
    y; reading of tide pole referred to a fixed point,
    x; reading of tide gauge,
    a; sensitivity, b; zero point of tide gauge,
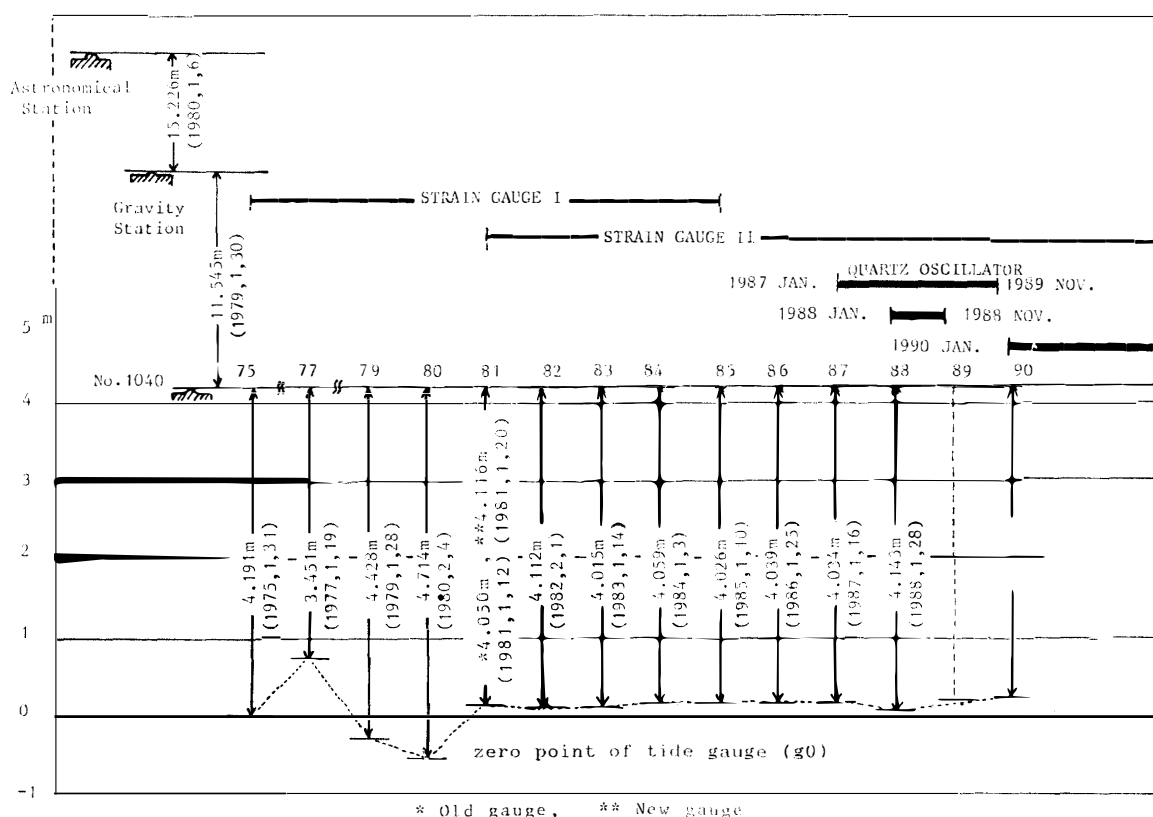 c; daily mean atmospheric pressure of observed day.

Fig. 4.   Drifts of zero point of tide gauge referred to the fixed point (BM No. 1040).   In 1981, a new
tide gauge was operated.   In some years, such as 1989, a check of datum was not carried out
because of concentrated sea ice cover.   Since 1987, renewing of tide gauge has started.
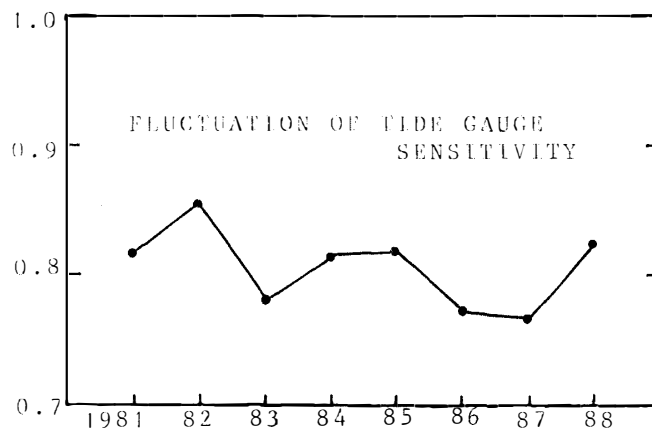
Fig. 5. Fluctuation of tide gauge sensitivity.

Table 2. Monthly mean sea-level (MMSL) and atmospheric pressure (MMAP).

	1	2	3	4	5	6	7	8	9	10	11	12	Mean
1981													
MMSL	***.* 157.1	166.5	173.9	184.2	183.0	172.8	170.4	176.1	170.9	169.9	162.3	171.6	
MMAP	986.0	989.6	990.5	986.4	986.9	994.8	993.3	986.2	981.3	983.3	981.3	987.6	
1982													
MMSL	155.5	166.8	173.9	182.3	179.2	180.4	174.3	170.5	167.2	160.0	153.8	141.1	167.1
MMAP	991.2	986.7	976.7	979.0	983.4	981.7	986.4	986.2	978.5	987.4	991.0	997.5	985.7
1983													
MMSL	140.4	150.6	167.3	177.8	180.6	177.0	179.4	182.5	177.9	172.9	168.2	157.6	169.4
MMAP	993.9	991.0	985.7	984.9	990.9	987.9	982.4	982.8	980.0	980.2	982.4	986.9	985.6
1984													
MMSL	154.6	159.6	171.6	181.6	184.7	188.3	183.0	178.2	178.9	175.8	163.6	154.0	172.8
MMAP	991.8	989.2	983.0	985.6	991.7	991.0	989.2	990.5	982.3	982.0	987.6	996.6	988.5
1985													
MMSL	154.7	171.0	178.9	181.1	182.9	178.5	180.3	175.1	173.1	169.9	162.5	155.2	171.9
MMAP	993.0	986.6	987.1	986.8	988.3	990.6	976.2	983.2	980.3	980.4	978.8	983.4	984.6
1986													
MMSL	146.8	149.9	162.6	179.5	175.4	169.9	174.8	167.3	172.2	161.2	156.7	147.6	163.7
MMAP	990.0	994.1	988.6	980.6	993.9	991.9	981.0	987.8	973.2	979.6	982.2	983.7	985.6
1987													
MMSL	141.9	145.2	162.7	172.6	173.0	172.9	172.1	175.4	168.4	167.5	168.1	149.1	164.1
MMAP	995.1	988.6	985.3	985.4	990.5	988.5	991.7	978.4	988.1	979.6	978.0	988.8	986.5
1988													
*MMSL	141.3	140.3	149.0	153.7	152.8	143.0	157.3	145.0	137.0	133.6	142.7	140.6	144.7
Averaged MMSL and MMAP from 1981 to 1987													
MMSL	148.9	157.2	169.1	178.4	180.0	178.6	176.7	174.2	173.4	168.3	163.3	152.4	168.4
MMAP	992.6	988.9	985.1	984.7	989.3	988.4	986.0	986.0	981.2	981.5	983.3	988.3	986.3

* MMSLs in 1988 are observed using the new tide gauge equipped quartz oscillator which measures relative pressure (water pressure). From 1981 to 1987 MMSLs are observed using the old tide gauge equipped strain gauge which measures absolute pressure (water and atmospheric pressure).

referred to the base of bench marks (BM). We assume the linear relation, $y=ax+b$, where "a" is sensitivity in unit m/m, and "b" is the relative height of zero point of tide gauge (g0) to the tide pole. The g0 is related to the BM (No. 1040) which is founded on the base rock. Constants "a" and "b" obtained in each calibration using the least squares method are shown in Table 1, and daily mean atmospheric pressure in the last column. As shown in Fig. 4, the g0 values before 1980 fluctuated considerably. Since 1981, the fluctuation of g0 has not been more than 10 cm. As shown in Fig. 5, the sensitivity has fluctuated by around 0.8 (m/m) in each year.

Measured hourly sea-level data are published as the JARE Data Report series by the National Institute of Polar Research. Since 1986 they have been corrected by multiplying interpolated sensitivity in each month, so that a small discontinuity appears between the last value of the month and the first value of the following month. The data are not corrected for the fluctuation of g0. Before 1985 the data were corrected assuming a constant sensitivity throughout the year, so that the data have the discontinuity between the Data Reports of one year to the next.

Using the data from January 1980 to December 1988, through which datum levels were nearly stable, monthly mean sea-levels (MMSL) have been re-calculated according to the present manner of correction and are shown in Table 2. Monthly mean atmospheric pressures (MMAP) are added to the table, and the values in the bottom lines represent the averaged values for each month from 1981 through 1987.

4. Monthly and Annual Mean Sea-Level at Syowa Station

Long-term MSL variation at Syowa Station is shown in Fig. 6. Small circle indicates MMSL and large circle indicates annual mean sea level (AMSL). They are referred to the Level 4.191 m below the BM No. 1040 and not corrected for the g0
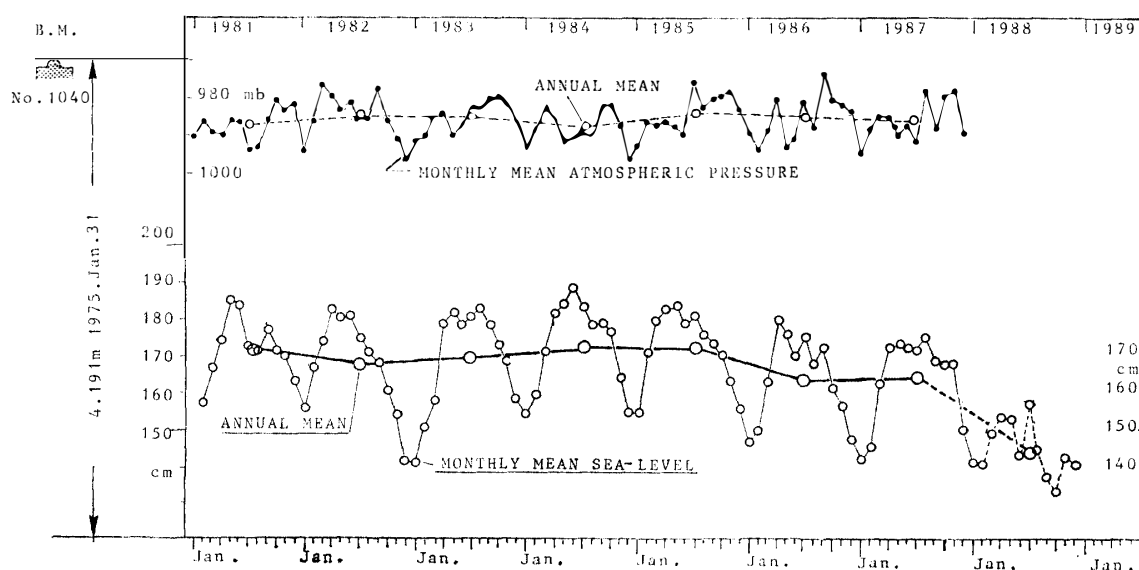

Fig. 6. *Long-term mean sea-level variation at Syowa Station. Small circles indicate monthly mean sea-levels and large circles annual mean sea-levels. Small dots in the upper part indicate monthly mean atmospheric pressures which are plotted as decreasing upward.*

fluctuation. Small dots in the upper part of Fig. 6 indicate MMAPs. In 1988, MMSLs show apparently a different tendency from those of the former several years, but in fact the tide gauge was changed to measure water pressure corrected with the atmospheric pressure. Before 1987 MMSLs were measured as the absolute pressure which includes water and atmospheric pressures. Therefore the difference of MMSL between 1988 and the former years shows the influence of atmospheric pressure.

Figure 7 shows averaged seasonal changes of MMSLs and MMAPs. Averaged MMSL is lowest in January, and rises rapidly from February to April. It reaches its highest value in May. Then it goes down gradually from June to October. It falls quickly in November and December, and is lowest in January. The range of MMSL from the lowest to the highest is about 30 cm.

Figure 8 shows AMSL picked up from Fig. 6. Thick full line in the figure shows the least square regression line calculated with the data from 1981 to 1987;

$$\begin{array}{cccc} & \text{cm} & \text{cm/year} & \text{cm} \\ \text{AMSL} & = -0.95 & \times & (\text{Year} - 1980) + 172.5. \end{array}$$

Although AMSL in each year is scattered in the range of about 10 cm, AMSL is concluded to fall at the rate of about 1 cm/year.
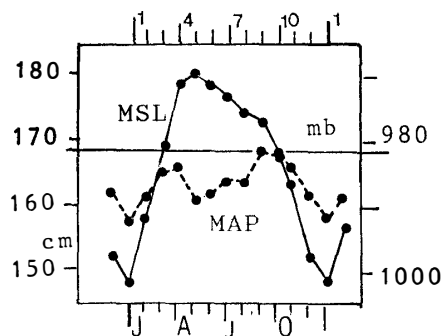

Fig. 7. Seasonal change of monthly mean sea-level (full line) and atmospheric pressure (broken line) averaged from 1981 to 1987.
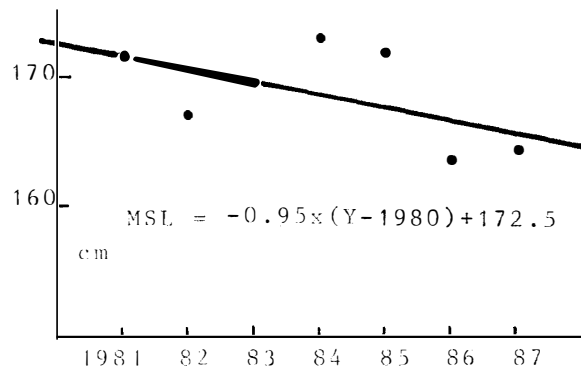

Fig. 8. Regression line of annual mean sea-level.

5. Concluding Remarks

As shown in Fig. 6, MMAPs vary in the range of about 20 mb. Assuming 1.0 cm/mb for barometric factor, the influence of MMAP appears to be of the order of 20 cm fluctuation of MMSL. As shown in Fig. 7, the averaged MMAP value reaches its highest two times in one year, in January and May, and its seasonal change is quite different from that of the MMSL. Therefore, the definite difference of MMSL between 1988 and other years shown in Fig. 6, is concluded due to the change from absolute pressure to relative pressure.

According to the ADMIRALTY, U.K., Tide Table (1989), seasonal changes of MSL in the ports of the southern hemisphere, such as Cape Town and Cape Horn, are much

Fig. 9. Comparison of seasonal change of mean sea-levels.
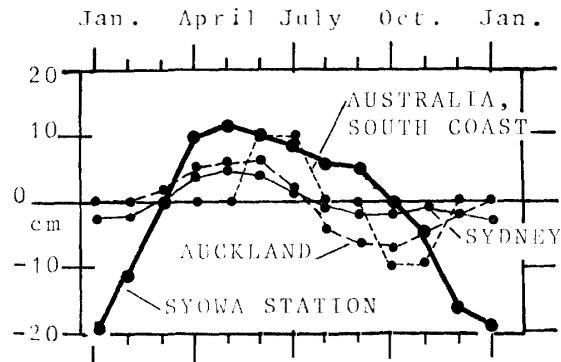
smaller than those at Syowa Station. Tidal record in the Macquarie Island (GUNSON, 1988) does not show the seasonal change. As shown in Fig. 9, seasonal change of MSL at Syowa Station is still large compared with those of the ports of Australia and New Zealand. Though the reason of this difference is not clear, it is possibly concerned with ocean dynamics, such as the Antarctic circumpolar current.

The tendency of the annual MSL falling at Syowa Station shows a good agreement with the explanation of the eustatic sea-level change, that in most of the southern oceans a rapid initial response to the glacial melting of 5000 years ago in the form of a rising relative sea-level is followed by a slow fall of sea-level and relative land uplift to the present time (CLARK, 1980; PUGH, 1987).

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Data Source

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(b) Meteorological data Syowa Station

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