https://doi.org/10.20575/00000044
Polar Data Journal, Vol. 7, 1–12, January 2023

Hydrographic Data of the 61st Japanese Antarctic Research Expedition from January 2019 to February 2020

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(Received April 14, 2022; Accepted November 21, 2022)

Abstract: The Japan Coast Guard (JCG) conducts bathymetric surveys, and tidal observations for producing nautical charts around Syowa Station in Antarctica. This report describes the results of the bathymetric survey around Lützow-Holm Bay from January to February 2020 and the effects of tidal observations at Syowa Station, Antarctica, from January 2019 to December 2019.

1. Background & Summary

The Japan Coast Guard conducts bathymetric surveys and tidal observations around Syowa Station in Antarctica to obtain bathymetric data for charting purposes. Nautical charts are necessary for ensuring the safety of ship navigation. Within the framework of the Hydrographic Commission on Antarctica (HCA) of the International Hydrographic Organization (IHO), each member country conducts hydrographic surveys and publishes charts for its assigned area. Tidal observation also contributes to the understanding of sea level rise caused by global warming, ground deformation, and earthquake disaster prevention measures through tsunami observation.

In 2009, a multibeam echo sounder (SeaBeam 3020 Icebreaker, ELAC, Inc.) was equipped with the second-generation SHIRASE. This enabled the acquisition of highly accurate seafloor topographic data. The bathymetric survey using the multibeam echo sounder was suspended from 2014 to 2018 due to a failure of the echo sounder. The multibeam echo sounder was repaired and the survey resumed in 2019.

Tidal observation at the Syowa Station has been conducted continuously since 1965. Since 1975, tidal observation has constantly been observed at the Nishi-no-Ura Tide Station on East Ongul Island using quartz-oscillator water level gauges (Matsumoto and Mine, 1982)[1] (Odamaki *et al.*, 1991)[2]. The quartz-oscillator water level gauges and tidal observation equipment have been updated several times. This paper reports the results of the bathymetric survey conducted around Lützow-Holm Bay in January and February 2020 and the tidal observations at the Syowa Station, Antarctica. The tide gauge data were recorded during the 60th Japanese Antarctic Research Expedition (JARE-60) from January to December 2019.

2. Location

We surveyed in two areas around Lützow-Holm Bay (Fig. 1). One was surveyed in Lützow-Holm Bay, northwest of Syowa Station, between 68°51'S–68°55'S and 38°47'E–39°02'E on January 30. The other was surveyed off Lützow-Holm Bay, between 66°45'S and 67°08'S and 35°10'E and 36°33'E on February 5.

Tidal observations were carried out at East Ongul Island. Two quartz-oscillator water level gauges, which measure the height of the sea surface by pressure, were installed at Nishi-no-Ura, East Ongul Island, and were in operation from January to December 2019. The main tide gauge (QWP-8-203D-K, Meisei Electric Co., Ltd.) was installed on the seabed at a depth of about 12 m in Nishi-no-Ura during the JARE-59 summer period (Watanabe, 2019)[3]. The other backup tide gauge (QWP-8-203D-K, Meisei Electric Co., Ltd.) was installed on the seafloor at a depth of about 10 m in Nishi-no-Ura during the JARE-56 summer period (Shimomura, 2016)[4]. The tidal observation system, which consists of a power supply, a processing unit, and a recording unit, is installed in the Earth Science Laboratory, Syowa Station, about 600 m away from Nishi-no-Ura (Fig. 2). The tide gauge and the tidal observation system are connected by cables.

3. Methods

Bathymetry data were acquired using a multibeam echo sounder (SeaBeam 3020 Icebreaker, ELAC, Co.) installed on the SHIRASE and recorded by a data recorder (Hydrostar ONLINE, Bureau Veritas, Co.). The bias values for the mounting angles of the multibeam echo sounder were determined in 0.01-degree increments by a performed patch test.

The data was then processed with a data processor (Caris HIPS and SIPS Ver. 11, Teledyne

CARIS) for following various corrections and noise editing. The ship's positioning was carried out by GPS and POS/MV (Applanix Co.). The sound velocity correction was done using XCTD observation data. The tidal correction was applied in Lützow-Holm Bay using the tide gauge data of the Nishi-no-Ura tide station. No tidal correction was applied outside the bay since the depth error caused by the tide is relatively tiny at deep waters of 4000 m. The surface sound velocity correction was done using data from sound velocity measurement (SV & P, AML Oceanographic Co.). The draught correction was done using the waterline readings value by the SHIRASE draught scale, which was video recorded.

The bathymetric surveys were conducted with full bathymetric coverage and an overlap ratio of at least 35% for each adjacent survey line.

The tide gauge data was measured by a strain pressure gauge (SWL-7, Kyowa Shoko Co., Ltd.) at the beginning of the tide observation. Since 1991, the relative pressure (water pressure minus atmospheric pressure) has been measured by the quartz-oscillator water level gauge with an air vent (QWP-8, Meisei Electric Co., Ltd.) to observe the tide level. The tide gauge data in this report was observed by a quartz-oscillator water level gauges with air vent (QWP-8-203D-K, Meisei Electric Co., Ltd.) installed at JARE-59, with an observation range of 0 to 20 meters and an accuracy of 0.01 meters. The tide gauge data is sampled once every two seconds, and the average value for 30 seconds is recorded on the hard disk drive of the recording unit in the Earth Science Laboratory. The detailed methodology of the tidal observation is described in Odamaki *et al.* (1991)[2], which is described in detail in "2. Tidal Observation System".

4. Data Records

First, I report the results of the bathymetric survey. After processing the obtained bathymetry data by the data processor, I color-coded the data by the depth and mechanically plotted the depth and isobaths using ArcGIS 10.5 (ESRI). Figure 3 shows the survey results conducted in Lützow-Holm Bay on January 30. Figure 4 shows the survey results conducted off Lützow-Holm Bay on February 5.

Next, I report the results of the tidal observations obtained by the quartz-oscillator water level gauges installed at JARE-59 from January 2019 to December 2019. During this winter period, the tide station was maintained by the winter period of JARE-60; hourly tide gauge data were extracted from the 30-second tide gauge data, and daily and monthly mean sea levels were calculated from the hourly data, respectively. The results are shown in Table 1. Tidal harmonic analysis using the least squares method was also performed using 369 days of tidal data, and the calculated tidal harmonic constants are shown in Table 2. The tidal harmonic analysis is a calculation to determine the amplitude (H) and the lag (K) of each oscillation, assuming that the tidal variation consists of a superposition of multiple cosine oscillations, each oscillation is called a constituent tide, and the amplitude (H) and lag (K) determined by the tidal harmonic analysis. In this report, the amplitude (H) and the lag (K) of each constituent tide were calculated using the least-squares method to minimize the difference between the estimated and measured values for 60 different constituent tides. The method using tidal harmonic constants is effective in the analysis and forecasting of tidal phenomena. (Marine Survey Technical Manual - Oceanographic and Meteorological Surveys - 4th Edition, 2005)[5]

5. Technical Validation

The bathymetry data were calculated by the CUBE (Combined Uncertainty and Bathymetric Estimator) processing in Caris HIPS and SIPS Ver.11. The CUBE processing is a processing method for outputting statistically likely high-density CUBE bathymetry from all the large amount of raw bathymetry soundings obtained by multibeam echo sounder and their uncertainties (Sumiyoshi *et al.*, 2020)[6], and is one of the standard methods for modern hydrographic surveys. The grid sizes of the CUBE bathymetry were set to 4 m in Lützholm-Bay and 128 m outside the bay, depending on the beam footprint, a measure of the spatial resolution of the multibeam echo sounder.

Total Propagated Uncertainty (TPU), a comprehensive evaluation of the error factors of each sensor related to bathymetry, was used as the uncertainty (Uncertainty), which is an index for evaluating the precision of each bathymetry sounding. The TPU is calculated by considering error factors such as the precision of the multibeam echo sounder, the precision of surface sound velocity and sound velocity profile observations, the precision of tide level observations, the precision of positioning and motion, and the precision of draft measurements.

Each step of the CUBE process was checked to ensure it was correctly performed. We confirmed that no significant systematic errors were generated in the CUBE bathymetry by displaying the CUBE bathymetry in three dimensions and showing the isobath contours. Manual editing of noise soundings affecting the automatically calculated statistical CUBE bathymetry was performed.

The typical uncertainties of the resulting CUBE bathymetric data are 3.2 ±0.1 m in Lützow-Holm Bay (depth range of approximately 130–320 m) and 12 ±5 m outside the bay (depth range of approximately 3,800–4,500 m).

The calibration of the quartz-oscillator water level gauge is performed by visual observation of sea level change using a temporary measure during the summer period. In JARE-61, tidal observations for calibration were conducted from January 12 to 14, 2020 at Nishi-no-Ura Cove, East Ongul Island. From the calibration results, it was confirmed that the variation of zero level and sensitivity ratio of the quartz-oscillator water level gauge was within the measurement accuracy. A vertical offset of 500 cm below the top of benchmark No. 1040 was applied to the tidal data in this report. It has been used as the observation datum level for tidal observations since February 1, 2001 (Kinoshita and Nosaka, 2005)[7]. (Figure 5)

6. Figures

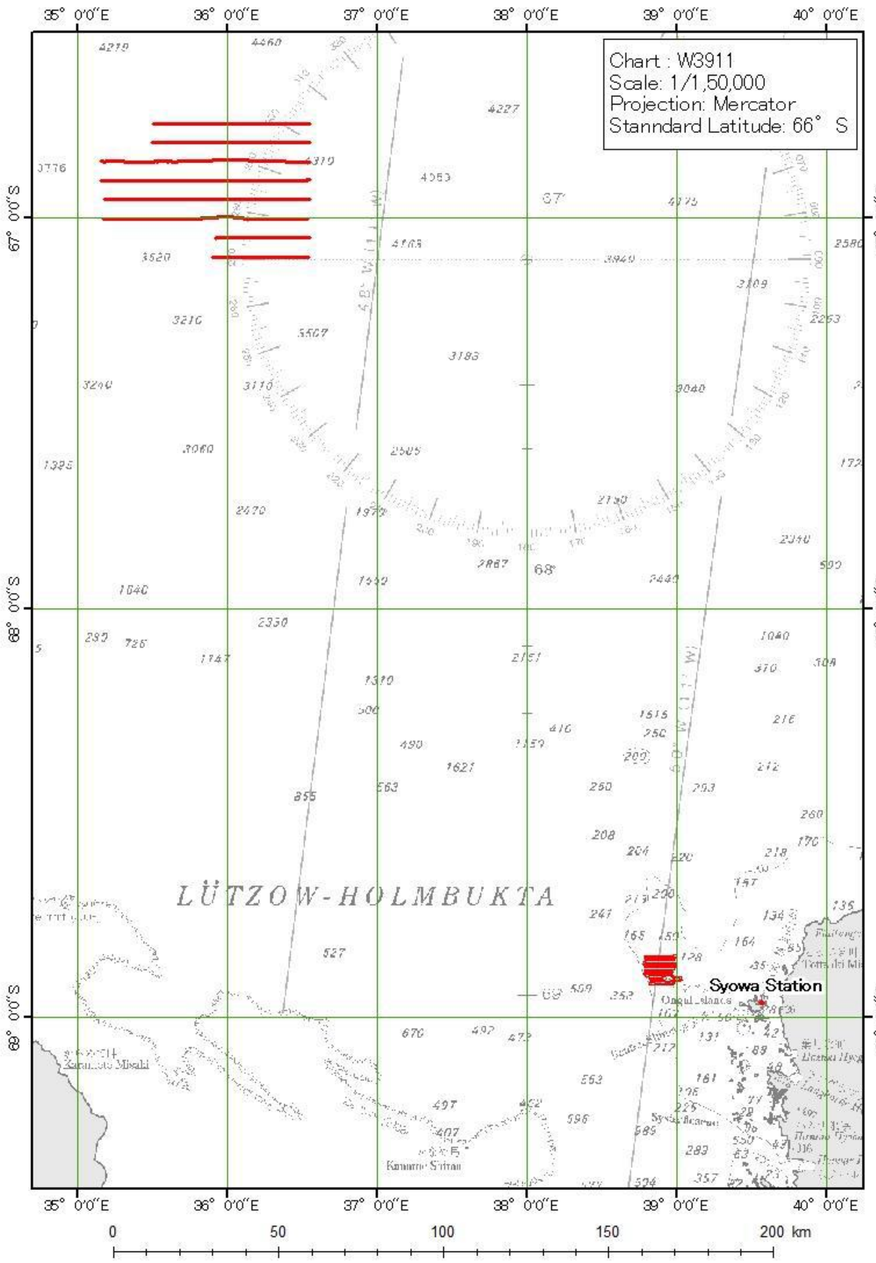


Figure 1. Ship track map of bathymetric surveys in the Lützow-Holm Bay and approaches.

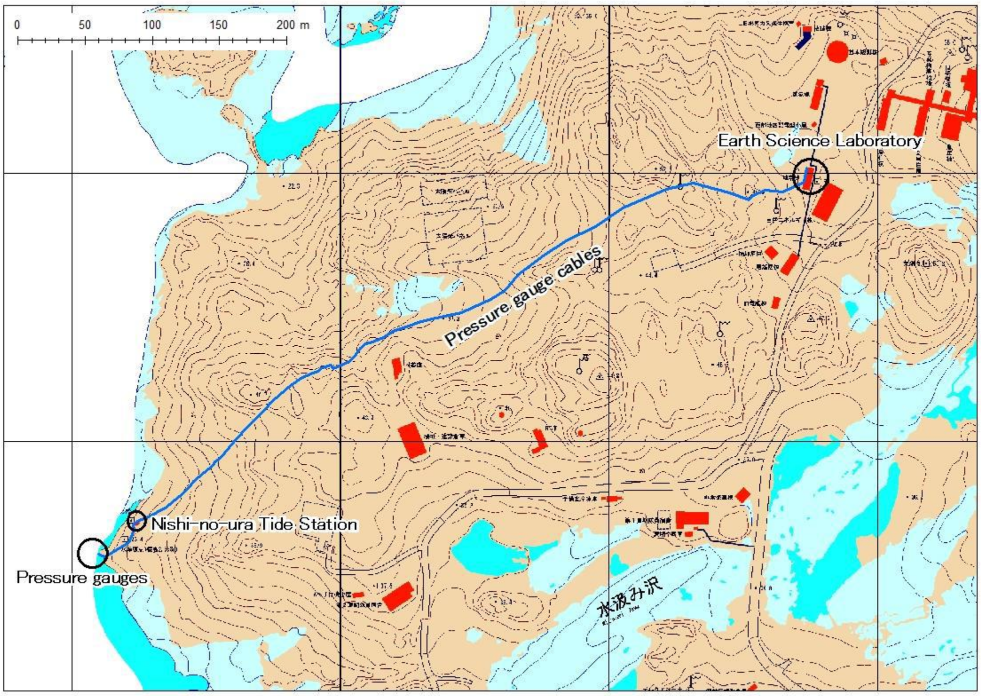


Figure 2. Location map of tidal observations at Syowa Station.

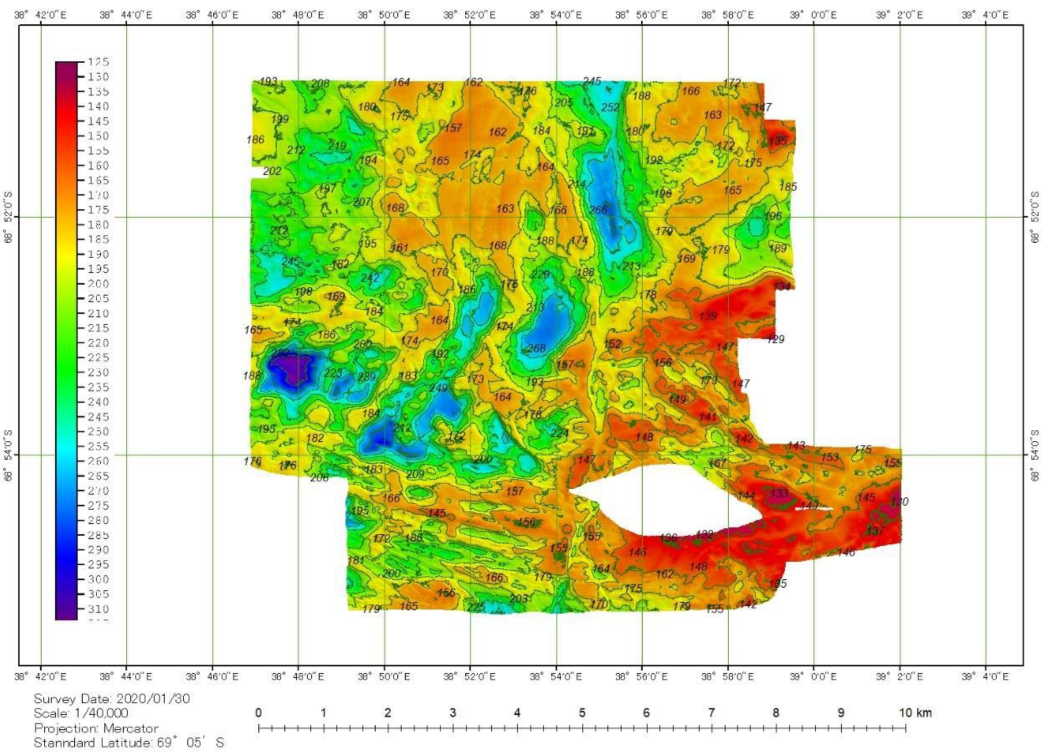


Figure 3. Bathymetric chart in the Lützow-Holm Bay.

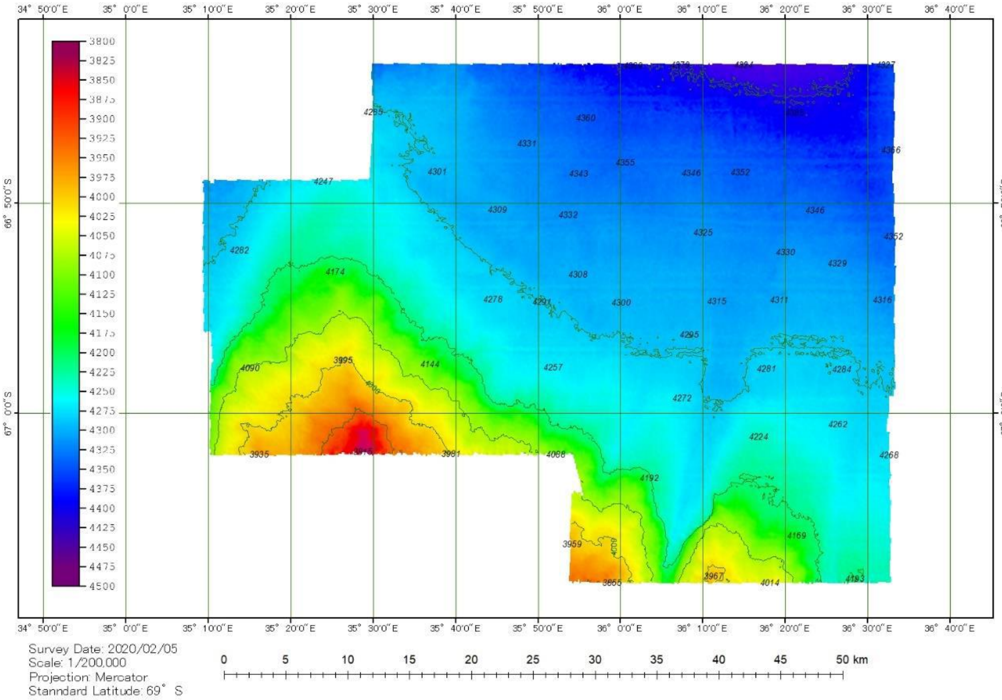
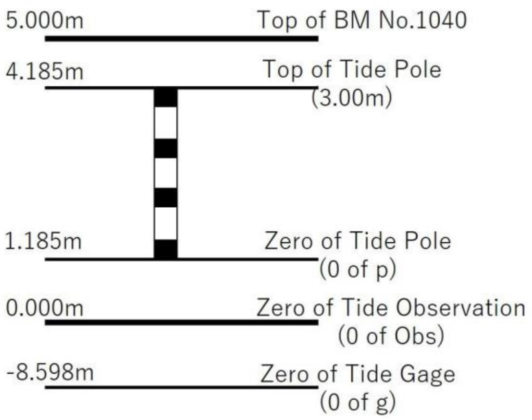


Figure 4. Bathymetric chart off the Lützow-Holm Bay.



Tidal observation at Syowa station,Nishi-no-Ura

Latitude: 69-00-28 S

Longitude: 39-34-13E

Time Zone: Syowa Station Local Time (UTC+3h)

System: Hydraulic type (Subtracting the atmospheric pressures)

Tide gauge: QWP-8, Meisei Denki Co Ltd.

Visual tidal observation with a temporal tide pole gauge

Sensor channel: No.2

Reduction ratio: 0.97

Intercept: –9.783 m

The length of tide pole: 3.00 m

Observational day : 2020/01/12–2020/01/14

Figure 5. Tide Level Diagram at Syowa Station, Nishi-no-Ura.

7. Tables

Table 1. Hourly tidal observation 2019 at Syowa Station.

The 24-hour total and mean tides, 25-hour total and mean tides, and monthly mean tides listed in this table are calculated using hourly tide levels from Tide gauge data (URL: “https://jdoss1.jodc.go.jp/vpage/tide.html”) posted at JODC. All data are available in Supplemental Tables. http://id.nii.ac.jp/1434/00000044 > Supplemental Tables

Station : Syowa Station
Latitude : 69° 00′ 28″ N
Longitude : 39° 34′ 13″ E
Duration : Jan. 1 - Jan. 31 , 2019
Unit : Centimeter

The zero of the tide gauge:
500 cm below the bench mark No.1040

	Time																								(24H)		(25H)	
Date	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Sum	Mean	Sum	Mean
1	267	271	271	269	264	254	238	223	212	206	205	212	225	242	259	274	283	285	281	274	268	263	263	265	6074	253	6345	254
2	271	276	281	282	278	270	252	233	214	200	195	199	210	228	251	272	286	296	296	290	279	270	266	268	6163	257	6435	257
3	272	278	285	290	290	282	264	244	220	199	185	181	191	208	232	259	281	293	298	297	287	273	267	264	6140	256	6407	256
4	267	273	281	289	293	288	274	253	227	203	183	172	175	191	215	243	269	288	297	299	292	278	268	262	6080	253	6343	254
5	263	269	279	289	296	296	287	268	241	214	189	171	169	180	202	232	259	282	298	304	298	287	276	267	6116	255	6379	255
6	263	268	279	292	302	307	301	286	262	232	202	180	170	175	192	218	246	271	290	300	298	289	277	268	6168	257	6429	257
7	261	262	271	284	297	306	303	291	273	245	216	189	171	171	182	205	230	258	279	291	295	287	276	267	6110	255	6369	255
8	259	255	261	275	290	301	304	298	283	258	231	204	182	174	180	200	222	246	269	285	291	288	279	270	6105	254	6368	255
9	263	256	257	270	286	298	304	303	294	274	247	221	200	188	187	198	217	240	260	277	287	287	278	269	6161	257	6423	257
10	262	255	250	257	270	284	292	294	289	276	255	230	209	195	189	196	210	227	247	265	277	280	275	268	6052	252	6313	253
11	261	253	249	252	261	274	285	292	292	285	271	252	235	222	216	218	227	240	256	272	283	289	288	282	6255	261	6528	261
12	273	264	257	254	258	266	275	282	285	281	272	259	245	234	225	223	226	232	244	256	266	271	271	266	6185	258	6444	258
13	259	250	242	236	236	241	247	254	259	259	257	251	244	236	231	230	232	235	243	254	262	267	271	271	5967	249	6232	249
14	265	259	253	245	242	244	246	249	254	257	259	260	259	260	260	259	258	258	260	265	270	272	274	276	6204	259	6478	259
15	274	269	263	255	248	242	238	236	237	240	243	248	253	258	263	266	269	268	265	265	268	267	266	269	6170	257	6441	258
16	271	268	262	257	248	237	228	219	214	214	217	223	233	244	257	266	273	275	272	267	265	264	261	261	5996	250	6260	250
17	264	266	265	261	252	240	226	210	199	193	193	199	211	230	249	266	279	284	284	278	272	267	263	261	5912	246	6176	247
18	264	269	272	270	264	253	999	999	999	999	999	999	999	999	238	263	284	296	299	296	289	280	272	269				
19	271	275	281	285	282	273	256	231	205	181	165	161	168	188	216	245	273	294	304	304	298	287	275	269	5987	249	6257	250
20	270	277	286	293	298	296	280	257	227	195	172	158	159	175	200	231	265	291	308	314	311	301	288	278	6130	255	6406	256
21	276	281	291	302	312	315	306	286	257	222	188	164	153	159	179	209	243	273	294	308	310	301	290	278	6197	258	6467	259
22	270	272	282	295	308	318	315	303	281	248	212	181	159	153	164	188	218	248	275	293	300	296	287	274	6140	256	6403	256
23	263	260	266	280	297	313	320	317	303	278	244	210	182	167	166	182	207	232	257	277	287	287	279	266	6140	256	6393	256
24	253	244	244	254	271	289	302	308	305	290	265	236	208	187	179	185	201	223	246	265	279	282	276	264	6056	252	6308	252
25	252	240	232	235	248	267	282	293	297	292	279	258	234	214	201	198	207	222	240	258	270	275	271	261	6026	251	6275	251
26	249	237	225	219	225	239	254	265	275	279	275	264	250	237	224	220	224	231	245	260	270	276	278	273	5994	250	6256	250
27	262	251	241	230	227	234	243	252	262	269	273	272	264	258	253	249	248	251	256	266	275	277	278	275	6166	257	6431	257
28	265	255	245	234	225	223	223	227	234	242	247	253	257	259	261	265	267	267	270	274	279	282	283	283	6120	255	6400	256
29	280	273	265	257	248	240	231	226	226	227	230	236	244	250	257	264	269	269	269	269	268	269	268	267	6102	254	6369	255
30	267	264	260	254	246	235	224	214	207	203	207	213	223	239	255	269	281	286	286	283	280	278	275	276	6025	251	6303	252
31	278	280	280	279	275	265	250	234	221	210	206	208	218	235	254	273	288	297	299	295	288	281	275	273	6262	261	6537	261
1	275																											
																									Monthly Mean	254.4	cm(30day)	

Table 2. Harmonic 1 constants at Syowa Station.

Syowa Station(Nishi-no-Ura)

Position : Lat. 69-00-28S , Lon. 39-34-13E

Epoch and Duration of Analysis:

- Epoch : 2019/01/01
- Central Date : 2019/07/04
- Duration in Days: 369 days
- Missing Hour : 45 hours

Mean Sea Level : 261.9 cm

Harmonic Constants :

	H(cm)	K(deg)	G(deg)		H(cm)	K(deg)	G(deg)
SA	8.81	76.72	76.85	M2	25.24	160.75	168.56
SSA	1.58	75.49	75.74	MKS2	0.15	175.29	183.35
MM	0.80	252.12	253.75	LAM2	0.26	163.23	172.45
MSF	2.25	84.57	87.62	L2	1.33	150.71	160.15
MF	3.17	155.12	158.41	T2	1.23	164.01	174.74
2Q1	0.95	320.35	319.34	S2	20.47	176.23	187.09
SIG1	0.99	338.29	337.50	R2	0.16	232.59	243.57
Q1	5.55	338.90	339.53	K2	5.90	176.55	187.65
RHO1	0.94	343.28	344.12	MSN2	0.10	10.24	22.73
O1	24.50	349.78	352.04	KJ2	0.30	27.44	40.18
MP1	0.32	321.66	324.17	2SM2	0.23	112.02	125.93
M1	1.52	350.16	354.07	MO3	0.11	196.97	207.04
CHI1	0.35	13.08	17.22	M3	0.24	259.80	271.52
PI1	0.48	6.21	11.39	SO3	0.06	327.44	340.56
P1	7.38	356.71	362.02	MK3	0.04	218.26	231.63
S1	0.16	52.45	57.88	SK3	0.43	332.26	348.68
K1	22.20	357.29	362.84	MN4	0.22	52.04	66.03
PSI1	0.17	335.68	341.36	M4	0.43	106.40	122.03
PHI1	0.34	343.14	348.94	SN4	0.04	116.98	134.01
THE1	0.20	347.46	354.43	MS4	0.17	181.41	200.08
J1	0.90	356.57	363.76	MK4	0.04	214.66	233.58
SO1	0.22	351.23	359.83	S4	0.07	210.69	232.41
OO1	0.58	329.01	337.86	SK4	0.09	190.54	212.50
OQ2	0.03	168.93	171.81	2MN6	0.08	20.58	42.38
MNS2	0.12	347.48	350.61	M6	0.15	93.88	117.32
2N2	0.38	106.80	111.34	MSN6	0.08	148.90	173.75
MU2	0.58	104.76	109.52	2MS6	0.31	188.47	214.95
N2	4.26	147.12	153.29	2MK6	0.08	199.52	226.25
NU2	0.81	162.49	168.88	2SM6	0.10	251.50	281.03
OP2	0.04	338.27	345.83	MSK6	0.06	253.76	283.54

H(cm): Amplitude

K(deg): Phase lag:

The time from the time when the moon passes directly above to the storm surge.

G(deg): Modified phase lag:

The time from the time the moon passes Greenwich longitude to the storm surge. Effective for comparing retard angles at different points.

Author contributions

The author conducted a bathymetric survey, and tidal observations for the calibration, and maintained the tide gauge in the summer period of JARE-61.

Acknowledgments

The author would like to express her gratitude to all the people of JARE-60, JARE-61, and SHIRASE for their support and valuable and appropriate advice. I express my sincere appreciation to Mr. Mitsuteru Kuno and Mr. Michiharu Shibata of the JARE-61 summer party who conducted the bathymetric survey with me. I express my sincere appreciation to Ms. Nayuta Matsumoto of the JARE-60 wintering party, maintained the tide gauges at Syowa Station throughout the year.

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Data Citations

All observation data are located at website run by Japan Oceanographic Data Center. JODC website URL: https://www.jodc.go.jp/jodcweb/JDOSS/index.html.

Bathymetry data URL: https://jdoss1.jodc.go.jp/vpage2017/JAREdepth.html.
Download Methods: Check “JARE61” and click “get data”.

XCTD data URL: https://jdoss1.jodc.go.jp/vpage/scalar.html.
Download Methods:
1. Check “Latitude” and “Longitude”.
2. Check “Observed date” and set the observation date to November 1, 2019–March 31, 2020.
3. Check “Data type” and check “Temperature” and “Salinity”. Do not check “Do”.
4. Click “Detailed setup”.
5. Check “Organization code” and select “Japan Coast Guard / Hydrographic and Oceanographic Department (01100)”.
6. Check the “Latitude and longitude is setting.” at the top of the figure. Left-click in the figure to select the range 20°S 70°S 30°E 160°E and release your finger to select the range. Click “Search” in the upper right corner of the figure to display the observation points in the figure.
7. Check the “Tip on” at the top of the figure. Move the cursor over the observation point to display detailed information about that point.
8. Display only the data you want to download and click “get data”.

Tide gauge data URL: https://jdoss1.jodc.go.jp/vpage/tide.html.
Download Methods:
1. Left-click on the map and move the mouse to the Syowa Station (69°0.467′S 039°34.217′E).
2. Click on the light blue inverted triangle (Tide station managed by the Japan Coast Guard).
3. Check “2019” and click “get data”.