National Report of Japan

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▪ Introduction

Japan's location along the northwestern periphery of the Pacific Ocean, which has the highest incidence of tropical cyclones among all the world's oceans, makes it one of the earth's most storm surge-prone nations. The country is also near a belt characterized by relatively frequent huge earthquakes and tsunamis. Based on Japan's history of major disasters caused by such natural hazards, a major purpose of its sea level observations is to monitor storm surges and tsunamis in real-time.

Sea levels vary due to oceanographic and other factors on a temporal scale ranging from days to decades. For example, "Kuroshio," a strong western boundary current in the west of the North Pacific, flows northeastward along Japan, occasionally affecting sea levels along its coastline with a time scale ranging from days to months and path changes or warm-water intrusions.

Sea level observation is indispensable for monitoring and analysis of these oceanographic phenomena.

▪ Sea Level Observation Network in Japan

Tide stations are operated by several national and local governmental organizations in Japan, including the Japan Meteorological Agency (JMA), the Japan Coast Guard (JCG), the Geospatial Information Authority of Japan (GSI), the Ports and Harbors Bureau (PHB) and the Water and Disaster Management Bureau (WDMB) of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Data from 189 stations are sent to JMA in real-time and published on its website (Fig. 1, Table 1).

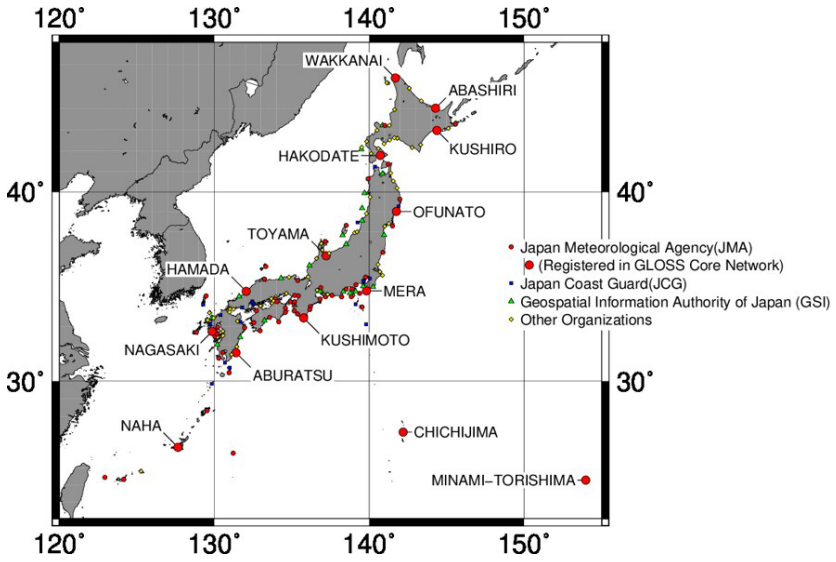

Fig. 1: Tide stations in Japan.

Table 1: JMA website data on 188 tide stations in Japan.

No.	Location	Organization	Latitude	Longitude	Type of sensor	No.	Location	Organization	Latitude	Longitude	Type of sensor
1	Esashi	PHB	44° 56′	142° 35′	float	51	Okada	JMA	34° 47′	139° 23′	radar
2	Kutsugata	PHB	45° 11′	141° 8′	float	52	Miyakejima （Tsubota）	JMA	34° 3′	139° 33′	radar
3	Wakkanai	JMA	45° 24′	141° 41′	radar	53	Chichijima	JMA	27° 6′	142° 12′	radar
4	Rumoi	PHB	43° 57′	141° 38′	float	54	Minamitorishima	JMA	24° 17'	153° 59′	pressure
5	Ishikari-Shinkou	PHB	43° 13′	141° 18′	float	55	Kouzushima	JCG	34° 13′	139° 8′	float
6	Iwanai	PHB	42° 59′	140° 30′	other	56	Miyakejima （Ako）	JCG	34° 4′	139° 29′	float
7	Oshoro	GSI	43° 13′	140° 52′	float	57	Hachijoujima （Kamiminato）	JCG	33° 8′	139° 48′	float
8	Otaru	JMA	43° 12′	141° 0′	radar	58	Katsuura	GSI	35° 8′	140° 15′	float
9	Monbetsu	PHB	44° 21′	143° 22′	float	59	Mera	JMA	34° 55′	139° 49′	radar
10	Abashiri	JMA	44° 1′	144° 17′	radar	60	Chiba	JCG	35° 34′	140° 3′	float
11	Nemuro	PHB	43° 21′	145° 35′	other	61	Choshigyoko	Other	35° 45′	140° 51′	float
12	Hanasaki	JMA	43° 17′	145° 34′	radar	62	Keihinkou	PHB	35° 28′	139° 38′	float
13	Kiritappu	PHB	43° 5′	145° 7′	other	63	Aburatsubo	GSI	35° 10′	139° 37′	float
14	Kushiro	JMA	42° 59′	144° 22′	radar	64	Odawara	JMA	35° 14′	139° 9′	radar
15	Tokachi	PHB	42° 18′	143° 19′	float	65	Yokohama	JCG	35° 27′	139° 39′	float
16	Tomakomai Higashi	PHB	42° 36′	141° 49′	float	66	Yokosuka	JCG	35° 17′	139° 39′	float
17	Tomakomai Nishi	PHB	42° 38′	141° 37′	float	67	Ito	GSI	34° 54′	139° 8′	float
18	Muroran	PHB	42° 21′	140° 57′	float	68	Tago	GSI	34° 48′	138° 46′	float
19	Shiraoi	PHB	42° 31′	141° 19′	float	69	Yaizu	GSI	34° 52′	138° 20′	float
20	Urakawa	PHB	42° 10′	142° 46′	float	70	Shimoda	PHB	34° 40′	138° 58′	float
21	Mori	PHB	42° 7′	140° 36′	other	71	Irozaki	JMA	34° 38′	138° 53′	radar
22	Hakodate	JMA	41° 47′	140° 43′	radar	72	Uchiura	JMA	35° 1′	138° 53′	radar
23	Setana	PHB	42° 27′	139° 51′	float	73	Shimizuminato	JMA	35° 1′	138° 31′	radar
24	Okushiri	GSI	42° 5′	139° 29′	float	74	Omaezaki	JMA	34° 36′	138° 13′	radar
25	Okushiri-Kou	PHB	42° 10′	139° 31′	float	75	Maisaka	JMA	34° 41′	137° 37′	radar
26	Esashi	PHB	41° 52′	140° 8′	float	76	Kinuura	Other	34° 53′	136° 57′	float
27	Aomori	PHB	40° 50′	140° 46′	float	77	Onizaki	GSI	34° 54′	136° 49′	float
28	Asamushi	GSI	40° 54′	140° 52′	float	78	Mikawa	PHB	34° 44′	137° 19′	float
29	Hachinohe Kou	PHB	40° 32′	141° 33′	float	79	Nagoya	JMA	35° 5′	136° 53′	radar
30	Shimokita	JMA	41° 22′	141° 14′	radar	80	Akabane	JMA	34° 36′	137° 11′	radar
31	Hukaura	JMA	40° 39′	139° 56′	radar	81	Yokkaichiko	Other	34° 58′	136° 38′	float
32	Tappi	JCG	41° 15′	140° 23′	float	82	Toba	JMA	34° 29′	136° 49′	radar
33	Mutsuogawahara	PHB	40° 56′	141° 23′	float	83	Owase	JMA	34° 5′	136° 12′	radar
34	Oga	GSI	39° 57′	139° 42′	float	84	Kumano	JMA	33° 56′	136° 10′	radar
35	Akita	PHB	39° 45′	140° 4′	float	85	Kashiwazaki	GSI	37° 21′	138° 31′	float
36	Miyako	JMA	39° 39′	141° 58′	radar	86	Ogi	GSI	37° 49′	138° 17′	float
37	Ofunato	JMA	39° 1′	141° 45′	radar	87	Niigatahigashikou	PHB	37° 59′	139° 13′	float
38	Kamaishi	JCG	39° 16′	141° 53′	float	88	Sado	JMA	38° 19′	138° 31′	radar
39	Kuji	PHB	40° 12′	141° 48′	float	89	Awashima	JCG	38° 28′	139° 15′	float
40	Ishinomaki	PHB	38° 24′	141° 16′	float	90	Niigatanishikou	PHB	37° 56′	139° 4′	float
41	Sendaishinkou	PHB	38° 16′	141° 0′	float	91	Ikuji	WDMB	36° 53′	137° 25′	pressure
42	Ayukawa	JMA	38° 18′	141° 30′	radar	92	Shinminato	PHB	36° 46′	137° 7′	float
43	Nezugaseki	GSI	38° 34′	139° 33′	float	93	Toyama	JMA	36° 46′	137° 13′	radar
44	Tobishima	GSI	39° 11′	139° 33′	float	94	Fushikitoyama	PHB	36° 48′	137° 4′	float
45	Sakata	PHB	38° 55′	139° 49′	float	95	Wajimako	PHB	37° 24′	136° 54′	float
46	Soma	GSI	37° 50′	140° 58′	float	96	Noto	JMA	37° 30′	137° 9′	radar
47	Onahama	JMA	36° 56′	140° 54′	radar	97	Nanao	PHB	37° 3′	136° 58′	float
48	Kashima	PHB	35° 56′	140° 42′	float	98	Kanazawa	PHB	36° 37′	136° 36′	float
49	Oarai	JMA	36° 18′	140° 34′	radar	99	Mikuni	GSI	36° 15′	136° 9′	float
50	Tokyo	JMA	35° 39′	139° 46′	radar	100	Tsuruga	PHB	35° 40′	136° 4′	float

No.	Location	Organization	Latitude	Longitude	Type of sensor	No.	Location	Organization	Latitude	Longitude	Type of sensor
101	Maizuru	JMA	35° 29′	135° 23′	radar	145	Hiagari	PHB	33° 55′	130° 53′	float
102	Tannowa	JMA	34° 20′	135° 11′	radar	146	Aohama	PHB	33° 57′	131° 1′	float
103	Osaka	JMA	34° 39′	135° 26′	radar	147	Moji	PHB	33° 57′	130° 57′	float
104	Himeji (Shikama)	Other	34° 47′	134° 40′	float	148	Sunatsu	PHB	33° 54′	130° 53′	float
105	Tsuiyama	Other	35° 39′	134° 50′	float	149	Hakata	JCG	33° 37′	130° 24′	float
106	Kobe	JMA	34° 41′	135° 11′	radar	150	Saiki	JMA	32° 57′	131° 58′	radar
107	Sumoto	JMA	34° 21′	134° 54′	radar	151	Oita	JCG	33° 16′	131° 41′	float
108	Kainan	GSI	34° 9′	135° 12′	float	152	Beppu	PHB	33° 18′	131° 30′	float
109	Urakami	JMA	33° 33′	135° 54′	radar	153	Kogo	PHB	32° 43′	129° 50′	float
110	Kushimoto	JMA	33° 29′	135° 46′	radar	154	Kuchinotsu	JMA	32° 36′	130° 12′	radar
111	Shirahama	JMA	33° 41′	135° 23′	radar	155	Nagasaki	JMA	32° 44′	129° 52′	radar
112	Gobo	JMA	33° 51′	135° 10′	radar	156	Fukue	JMA	32° 42′	128° 51′	radar
113	Wakayama	JMA	34° 13′	135° 9′	radar	157	Tsushimahitakatsu	JMA	34° 39′	129° 29′	radar
114	Sanban	WDMB	34° 36′	133° 59′	pressure	158	Sasebo	JCG	33° 9′	129° 43′	float
115	Otoshima	WDMB	34° 30′	133° 41′	pressure	159	Izuhara	JCG	34° 12′	129° 18′	float
116	Uno	JMA	34° 29′	133° 57′	radar	160	Hiradoseto	PHB	33° 22′	129° 35′	float
117	Hiroshima	JCG	34° 21′	132° 28′	float	161	Gonoura	PHB	33° 45′	129° 41′	float
118	Kure	JCG	34° 14′	132° 33′	float	162	Karatsu	PHB	33° 28′	129° 58′	float
119	Hamada	JMA	34° 54′	132° 4′	radar	163	Kariya	GSI	33° 28′	129° 51′	float
120	Saigo	JMA	36° 12′	133° 20′	radar	164	Oura	JMA	32° 59′	130° 13′	radar
121	Tago	GSI	35° 36′	134° 19′	float	165	Yatsushiro	PHB	32° 31′	130° 34′	float
122	Sakai	JMA	35° 33′	133° 15′	radar	166	Kumamoto	PHB	32° 45′	130° 34′	float
123	Komatsushima	JMA	34° 1′	134° 35′	radar	167	Hondoseto	PHB	32° 26′	130° 13′	float
124	Awayuki	JMA	33° 46′	134° 36′	radar	168	Reihoku	JMA	32° 28′	130° 2′	radar
125	Yoshima	PHB	34° 23′	133° 49′	float	169	Miyazaki	PHB	31° 54′	131° 27′	float
126	Aoki	PHB	34° 22′	133° 41′	float	170	Hosojima	GSI	32° 26′	131° 40′	float
127	Tadotsu	PHB	34° 16′	133° 45′	float	171	Aburatsu	JMA	31° 35′	131° 25′	radar
128	Takamatsu	JMA	34° 21′	134° 3′	radar	172	Akune	GSI	32° 1′	130° 11′	float
129	Kurushimakoro	PHB	34° 7′	132° 59′	float	173	Kagoshima	JMA	31° 36′	130° 34′	radar
130	Matsuyama	JMA	33° 52′	132° 43′	radar	174	Makurazaki	JMA	31° 16′	130° 18′	radar
131	Uwajima	JMA	33° 14′	132° 33′	radar	175	Tanegashima	JMA	30° 28′	130° 58′	radar
132	Kure	GSI	33° 20′	133° 15′	float	176	Amami	JMA	28° 19′	129° 32′	radar
133	Murotomisaki	JMA	33° 16′	134° 10′	radar	177	Odomari	JCG	31° 1′	130° 41′	float
134	Kochi	JMA	33° 30′	133° 34′	radar	178	Nishinoomote	JCG	30° 44′	130° 60′	float
135	Tosashimizu	JMA	32° 47′	132° 58′	radar	179	Nakanoshima	JCG	29° 51′	129° 51′	float
136	Chofu	PHB	34° 1′	131° 0′	float	180	Naze	JCG	28° 24′	129° 30′	float
137	Susa	GSI	34° 38′	131° 36′	float	181	Shibushi	PHB	31° 29′	131° 7′	float
138	Tanokubi	PHB	33° 55′	130° 55′	float	182	Okinawa	GSI	26° 11′	127° 50′	float
139	Ooyamanohana	PHB	33° 55′	130° 54′	float	183	Naha	JMA	26° 13′	127° 40′	radar
140	Haedomari	PHB	33° 57′	130° 53′	float	184	Nakagusukuwanko	PHB	26° 20′	127° 50′	float
141	Ube	PHB	33° 56′	131° 15′	float	185	Minamidaito	JMA	25° 52′	131° 14′	radar
142	Tokuyama	JCG	34° 2′	131° 48′	float	186	Hirara	PHB	24° 49′	125° 17′	float
143	Deshimatsu	PHB	33° 55′	130° 56′	float	187	Ishigaki	JMA	24° 20′	124° 10′	radar
144	Kanda	PHB	33° 48′	131° 0′	float	188	Yonaguni	JMA	24° 27′	122° 57′	radar

▪ An overview of Gauge Technology in the Network

JMA's 71 monitoring facilities consist of 70 radar tide gauge stations and one hydraulic pressure sensor tide station at Minamitorishima (Marcus Island). The instruments at these sites measure sea levels with a resolution of 1 cm at approximately 1-second intervals.

Sea level observation data (other than those from Minamitorishima) are sent to JMA Headquarters and Osaka Regional Headquarters in real-time via a public IP network. As a backup, Iridium satellite communication capacity is provided. Minamitorishima data are sent via the Data Collection System (DCS) of the Himawari-8 geostationary satellite every 10 minutes. JMA Headquarters dispatches data to local meteorological observatories every 5 minutes.

▪ An overview of the GPS Technology in the Network

GSI conducts ongoing real-time observation of crustal movement at GNSS-based control stations in the GEONET (GNSS Earth Observation Network System) network, which consists of about 1,200 stations across Japan. In support of GSI, GPS systems are also operated at all Japanese GLOSS Core Network (GCN) stations (Table 2) other than Minamitorishima and Syowa.

Information on crustal movement is sent to JMA and used to correct sea level data (Fig. 2). Updates on corrected sea level variations around Japan are provided every year at https://www.data.jma.go.jp/gmd/kaiyou/db/tide/sl_gcntrend/sl_gcntrend.html (in Japanese).

Table 2: Tide stations registered at GCN

Location	Station code
Abashiri	AS
Aburatsu	AB
Chichijima	CC
Hakodate	HK
Hamada	HA
Kushimoto	KS
Kushiro	KR
Mera	MR
MinamiToriShima	MC
Nagasaki	NS
Naha	NH
Ofunato	OF
Toyama	TY
Wakkanai	WN
Syowa	

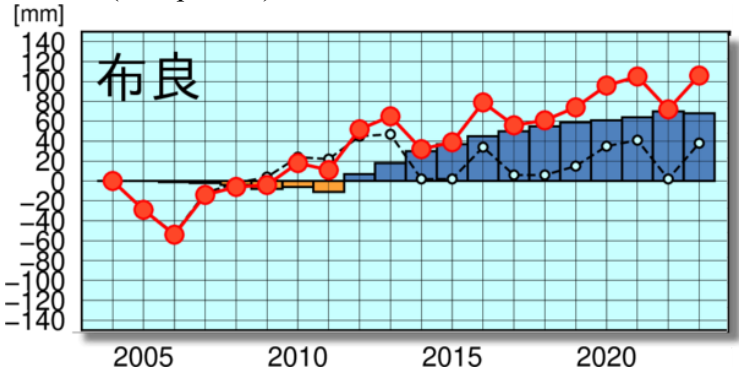

Fig. 2: Corrected sea level data for Mera.
Solid red line: corrected sea level data; dashed black line: pre-correction data.
Bars: the crustal movement against a 2004 zero baseline.

▪ An overview of Data Availability

Near-real-time tide data from 189 tide stations other than Minamitorishima are posted on the JMA website (in Japanese) at: https://www.jma.go.jp/bosai/map.html#5/34.507/135/&contents=tidelevel.

Sea level variations caused by storm surges,

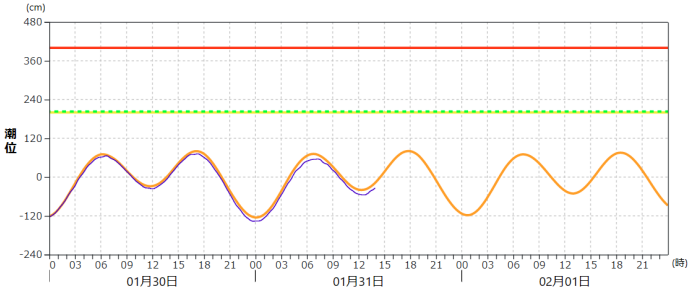

Fig. 3: Tokyo sea level observations for January 30–31 and February 1, 2025.
Dark blue line: observation data.
Orange line: astronomical tides.
Red and yellow lines: criteria for storm surge warnings and advisories, respectively.
Dotted green line: maximum observed sea levels.

tsunamis, and other influences can also be monitored here.
Figure 3 shows an example of Tokyo observation data.

JMA provides initial estimations on hourly sea level data within a few days of raw data checking. These can be found at:

https://www.data.jma.go.jp/kaiyou/data/db/tide/sokuho/{YYYY}{MM}/z_hry{YYYY}{MM}{CD}.txt

YYYY: year, MM: month, CD: station code (Table 2)

JMA creates a finalized data set for the previous month around the 20th of every month. These values may differ from initial estimations and are provided at:

https://www.data.jma.go.jp/kaiyou/data/db/tide/genbo/{YYYY}/{YYYY}{MM}/hry{YYYY}{MM}{CD}.txt

YYYY: year, MM: month, CD: station code (Table 2)

JMA creates monthly mean sea level data based on finalized hourly data. Hourly sea level data from the 14 GCN stations are sent to GLOSS at the University of Hawaii Sea Level Center, and monthly mean data from JMA's 55 tide stations are sent to the Permanent Service for Mean Sea Level (PSMSL).

Oceanographic data and related information obtained by various oceanographic research institutes in Japan are archived at the Japan Oceanographic Data Center (JODC). Hourly sea level data from more than 100 tide stations in Japan (including the 14 GCN stations) and other oceanographic data are available on the JODC website:

http://www.jodc.go.jp/jodcweb/

Observation data from 22 stations, including the 14 GCN stations, are distributed worldwide via GTS in real-time every 10 minutes. The information can be accessed at:

http://www.ioc-sealevelmonitoring.org/list.php

- **Monitoring of Long-Term Sea Level Change**

JMA monitors long-term sea level change using annually updated tide gauge data (https://www.data.jma.go.jp/gmd/kaiyou/english/sl_trend/sea_level_around_japan.html). Figure 4 (a) shows a time-series representation of annual mean sea level deviations from the 1991 – 2020 average.

Sea levels have been monitored for more than 100 years at 11 tide stations in Japan. Data from four of these assessed as being affected to a lesser extent by crustal movement are used for the period from 1906 to 1959 (Fig. 4 (b)), while data from 16 stations are used for the period from 1960 onward for their superior spatial representativeness (Fig. 4 (c)). For the period after 1960, cluster analysis was first applied to sea level observation data from the selected stations along the Japanese coast, which was divided into the four regions shown in Fig. 4 (c) based on sea level variation characteristics. Annual mean sea level anomalies were averaged for each area (variations shown in Fig. 4 (a)).

The results indicate that sea levels peaked around 1950, and variations with a periodicity of approximately 20 years were dominant until the 1990s. A rising trend in sea levels with a near-10-year variation is also observed from the 1990s onward.

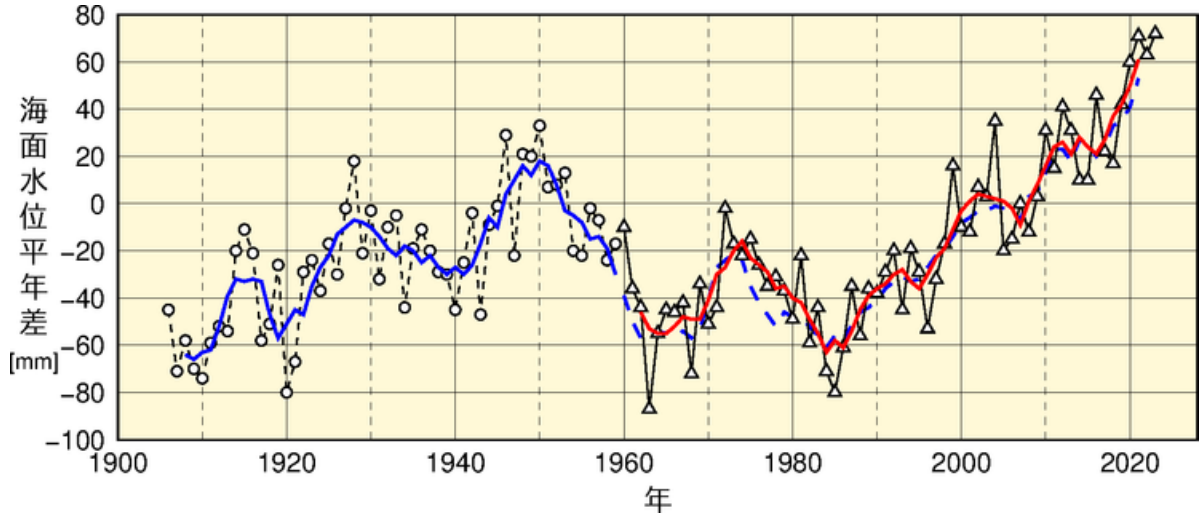

Fig. 4 (a): Time-series representation of annual mean sea level values around Japan. The blue line indicates the five-year running mean of sea level anomalies at four stations, and the red line shows the same for the four regions.

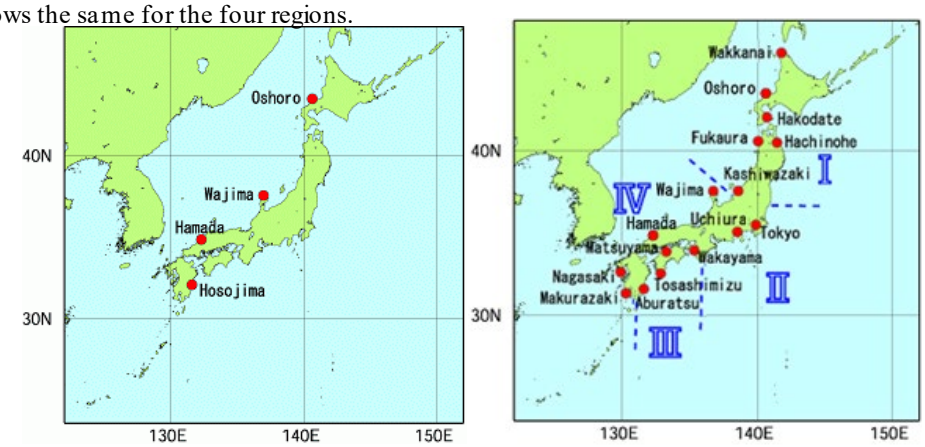

Fig. 4 (b) and 4 (c): Location of tide stations.

▪ JMA's Historical Tide Gauge Dataset

In March 2017, JMA published a historical tide gauge dataset on its website. It consists of hourly, monthly, and annual mean data beginning in December 1924 (Fig. 5), with original hourly data created from the digitization of paper-based sea level records kept by individual observatories. In quality checking of these original data, abnormal values were corrected or excluded to produce a reanalysis dataset. The monthly mean and annual mean data were created by averaging the reanalyzed hourly data.

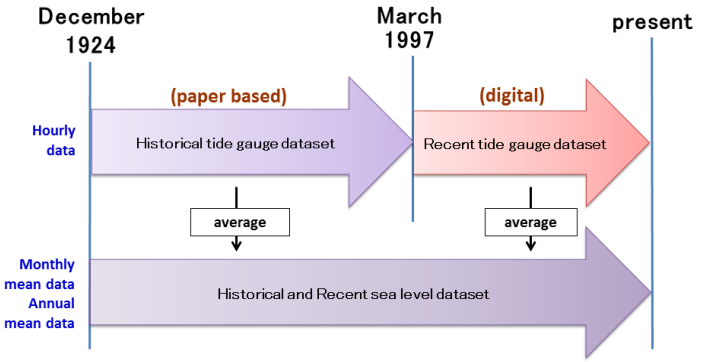

Fig. 5: Periods for historical (December 1924 to March 1997) and recent (1997 onward) tide gauge data provided on JMA's website.

The above data are provided in detail below.

Original:

https://www.data.jma.go.jp/kaiyou/data/db/tide/sea_lev_var/orgdata/{YYYY}/{YYYY}{MM}/org{YYYY}{MM}{CD}.txt

YYYY: year, MM: month, CD: station code (Table 2)

Reanalysis:

https://www.data.jma.go.jp/kaiyou/data/db/tide/sea_lev_var/{YYYY}/{YYYY}{MM}/hry{YYYY}{MM}{CD}.txt

YYYY: year, MM: month, CD: station code (Table 2)

QC flag addition:

Whole-period data can be downloaded at

https://www.data.jma.go.jp/kaiyou/db/tide/sea_lev_var/index_download.php (in Japanese).

Monthly and annual means:

https://www.data.jma.go.jp/kaiyou/data/db/tide/sea_lev_var/msl/{CD}.monthly.txt

CD: station code (Table 2)

- **Three-minute mean of tide level**

JMA changed each point's record high tide level and the three-minute mean of the tide level live commentary from March 2021. Until now, statistics have been compiled using the observed values subjected to a smoothing filter for cutoff period of about three hours. Typhoon Jebi of 2018 caused a major storm surge disaster, mainly along the coast of Osaka Bay in Japan. Since this typhoon moved quickly and the tide level changed rapidly in a short time, the smooth value could not adequately express the tide level at the time of the storm surge. Therefore, to capture the change in tide level more accurately, a smoothing filter for cutoff period of 3 minutes was introduced. JMA recalculated the data from April 1997 onwards, when the digital data on tide levels were organized, and reviewed the record high tide levels. Data before March 1997 are recorded based on tide levels read from analog records, including those based on trace surveys. The list of revised records can be viewed at the following URL (Japanese only: https://www.data.jma.go.jp/kaiyou/db/tide/list2.html).

In addition, the tide level realtime value on the JMA website has also displayed the observation value every 15 seconds; from the viewpoint of disaster prevention, we have changed the value to the 3-minute mean value.

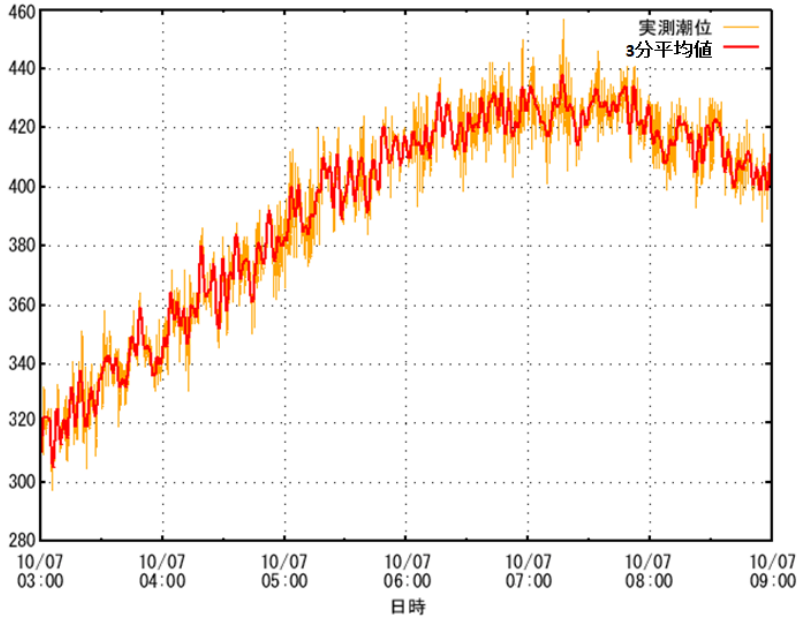

Fig. 6: Tide data of observation and (orange line) 3-minute-mean (red line).