

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 on or very close to 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 on a real-time basis.

On a temporal scale ranging from days to decades, sea levels vary due to oceanographic and other factors. By way of example, "Kuroshio", which is a strong western boundary current in the western 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 190 stations are sent to JMA in real time and published on its website (Fig. 1, Table 1).

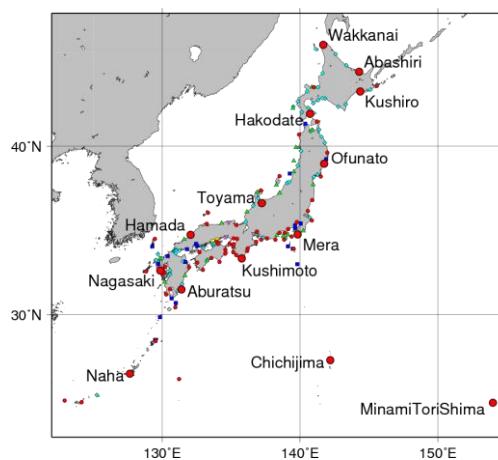


Fig. 1: Tide stations in Japan

JMA (red dots; large dots representing GCN registration), JCG (blue squares), GSI (green triangles), PHB (light-blue diamonds), WDMB (yellow squares), others (inverted purple triangles)

Table 1: JMA website data on 190 tide stations in Japan

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

No.	Location	organi zation	Latitude	Longitude	Type of sensor	No.	Location	organi zation	Latitude	Longitude	Type of sensor
101	Tsuruga	PHB	35°40'	136° 4'	float	146	Kanda	PHB	33°47'	130°59'	float
102	Wakayama	JMA	34°13'	135° 9'	radar	147	Aohama	PHB	33°57'	131° 1'	float
103	Kainan	GSI	34° 9'	135°12'	float	148	Moji	PHB	33°57'	130°57'	float
104	Gobo	JMA	33°51'	135°10'	radar	149	Sunatsu	PHB	33°54'	130°53'	float
105	Shirahama	JMA	33°41'	135°23'	radar	150	Hiagari	PHB	33°55'	130°53'	float
106	Kushimoto	JMA	33°29'	135°46'	radar	151	Hakata	JCG	33°37'	130°24'	float
107	Uragami	JMA	33°34'	135°54'	radar	152	Karatsu	PHB	33°28'	129°58'	float
108	Osaka	JMA	34°39'	135°26'	radar	153	Kariya	GSI	33°28'	129°51'	float
109	Tannowa	JMA	34°20'	135°11'	radar	154	Oura	JMA	32°59'	130°13'	radar
110	Kobe	JMA	34°41'	135°11'	radar	155	Hiradoseto	PHB	33°22'	129°35'	float
111	Himeji (Shikama)	Other	34°47'	134°40'	float	156	Sasebo	JCG	33° 9'	129°43'	float
112	Sumoto	JMA	34°21'	134°54'	radar	157	Kogo	PHB	32°43'	129°50'	float
113	Tsuiyama	Other	35°39'	134°50'	float	158	Nagasaki	JMA	32°44'	129°52'	radar
114	Maizuru	JMA	35°29'	135°23'	radar	159	Kuchinotsu	JMA	32°36'	130°12'	radar
115	Sanban	WDMB	34°36'	133°59'	pressure	160	Izuhara	JCG	34°12'	129°18'	float
116	Uno	JMA	34°29'	133°57'	radar	161	Tsushimahitakatsu	JMA	34°39'	129°29'	radar
117	Otoshima	WDMB	34°30'	133°41'	pressure	162	Gonoura	PHB	33°45'	129°41'	float
118	Kure	JCG	34°14'	132°33'	float	163	Fukue	JMA	32°42'	128°51'	radar
119	Hiroshima	JCG	34°21'	132°28'	float	164	Beppu	PHB	33°18'	131°30'	float
120	Tajiri	GSI	35°36'	134°19'	float	165	Oita	JCG	33°16'	131°41'	float
121	Sakai	JMA	35°33'	133°15'	radar	166	Saiki	JMA	32°57'	131°58'	radar
122	Hamada	JMA	34°54'	132° 4'	radar	167	Kumamoto	PHB	32°45'	130°34'	float
123	Saigo	JMA	36°12'	133°20'	radar	168	Yatsushiro	PHB	32°31'	130°34'	float
124	Takamatsu	JMA	34°21'	134° 3'	radar	169	Hondoseto	PHB	32°26'	130°13'	float
125	Yoshima	PHB	34°23'	133°49'	float	170	Reihoku	JMA	32°28'	130° 2'	radar
126	Aoki	PHB	34°22'	133°41'	float	171	Hosojima	GSI	32°26'	131°40'	float
127	Tadotsu	PHB	34°17'	133°45'	float	172	Miyazaki	PHB	31°54'	131°27'	float
128	Komatsushima	JMA	34° 1'	134°35'	radar	173	Aburatsu	JMA	31°35'	131°25'	radar
129	Awayuki	JMA	33°46'	134°36'	radar	174	Shibushi	PHB	31°29'	131° 7'	float
130	Murotomisaki	JMA	33°16'	134°10'	radar	175	Odomari	JCG	31° 1'	130°41'	float
131	Kochi	JMA	33°30'	133°34'	radar	176	Kagoshima	JMA	31°36'	130°34'	radar
132	Susaki	PHB	33°23'	133°18'	float	177	Makurazaki	JMA	31°16'	130°18'	radar
133	Kure	GSI	33°20'	133°15'	float	178	Akune	GSI	32° 1'	130°11'	float
134	Tosashimizu	JMA	32°47'	132°58'	radar	179	Nishinoomote	JCG	30°44'	131° 0'	float
135	Matsuyama	JMA	33°52'	132°43'	radar	180	Tanegashima	JMA	30°28'	130°58'	radar
136	Uwajima	JMA	33°14'	132°33'	radar	181	Nakanoshima	JCG	29°51'	129°51'	float
137	Kurushimakoro	PHB	34° 7'	132°59'	float	182	Naze	JCG	28°24'	129°30'	float
138	Tokuyama	JCG	34° 2'	131°48'	float	183	Amami	JMA	28°19'	129°32'	radar
139	Ube	PHB	33°56'	131°15'	float	184	Nakagusukuwanko	PHB	26°20'	127°50'	float
140	Chofu	PHB	34° 1'	131° 0'	float	185	Okinawa	GSI	26°11'	127°49'	float
141	Deshimatsu	PHB	33°56'	130°56'	float	186	Naha	JMA	26°13'	127°40'	radar
142	Tanokubi	PHB	33°55'	130°55'	float	187	Minamidaito	JMA	25°52'	131°14'	radar
143	Oyamanohana	PHB	33°55'	130°54'	float	188	Hirara	PHB	24°49'	125°17'	float
144	Haedomari	PHB	33°57'	130°53'	float	189	Ishigaki	JMA	24°20'	124°10'	radar
145	Susa	GSI	34°38'	131°36'	float	190	Yonaguni	JMA	24°27'	122°57'	radar

▪ **An overview of Gauge Technology in the Network**

JMA's 72 monitoring facilities consist of 70 radar tide gauge stations, one Fuess (float)-type tide gauge station with digital encoders, 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 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 March at http://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	

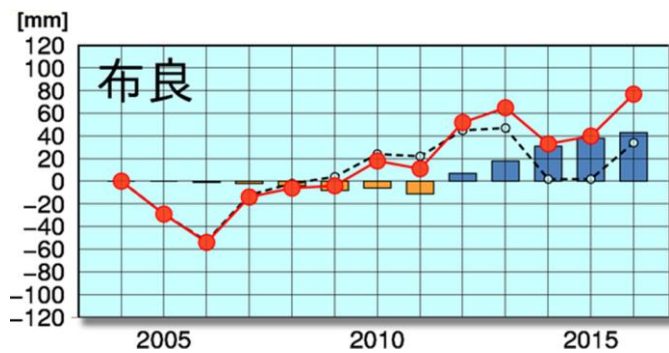


Fig. 2: Corrected sea level data for Mera
 Solid red line: corrected sea level data; dashed black line: pre-correction data;
 bars: crustal movement against a 2004 zero baseline

▪ **An overview of Data Availability**

Near-real-time tide data (with five-minute latency) from 189 tide stations other than Minamitorishima are posted on the JMA website (in Japanese) at <http://www.jma.go.jp/jp/choi/>.

Sea level variations caused by storm surges, tsunamis and other influences can also be monitored here.

Figure 3 shows an example of Omaezaki observation data.

Initial estimations on hourly sea level data are provided by JMA within a few

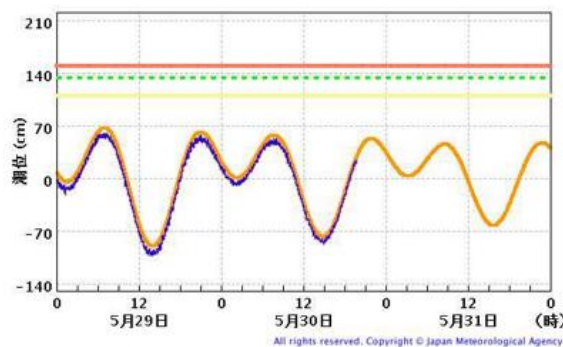


Fig. 3: Omaezaki sea level observations for May 29 – 30, 2017.
 Dark blue line: observation data
 Orange line: astronomical tides
 Red and yellow lines: criteria for storm surge warnings and advisories, respectively
 Dotted green line: maximum observed sea levels

days of raw-data checking. These can be found at:

http://www.data.jma.go.jp/gmd/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:

<http://www.data.jma.go.jp/gmd/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/index.html>

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 (http://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 1981 – 2010 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 of these regions (variations shown in Fig. 4 (a)).

The results indicate that sea levels peaked around 1950 and sea level 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.

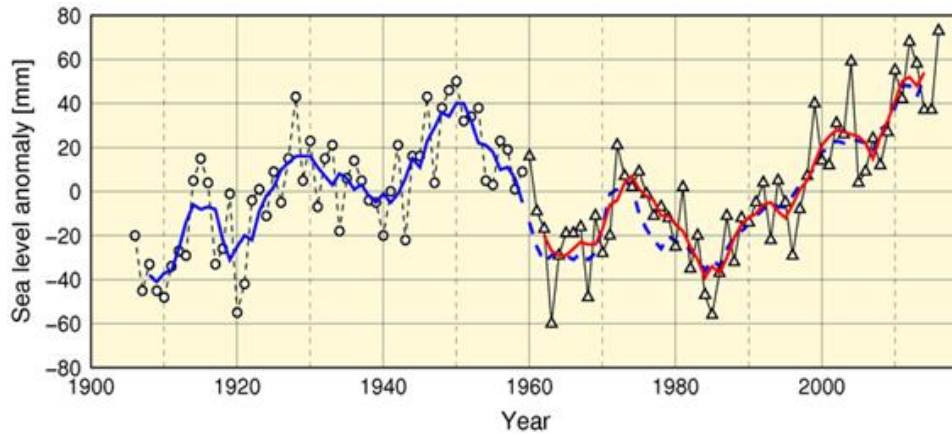


Fig. 4 (a): Time-series representation of annual mean sea level values around Japan. The blue line indicates the five-year running mean of sea level anomalies at four stations, and the red line shows the same for the four regions.

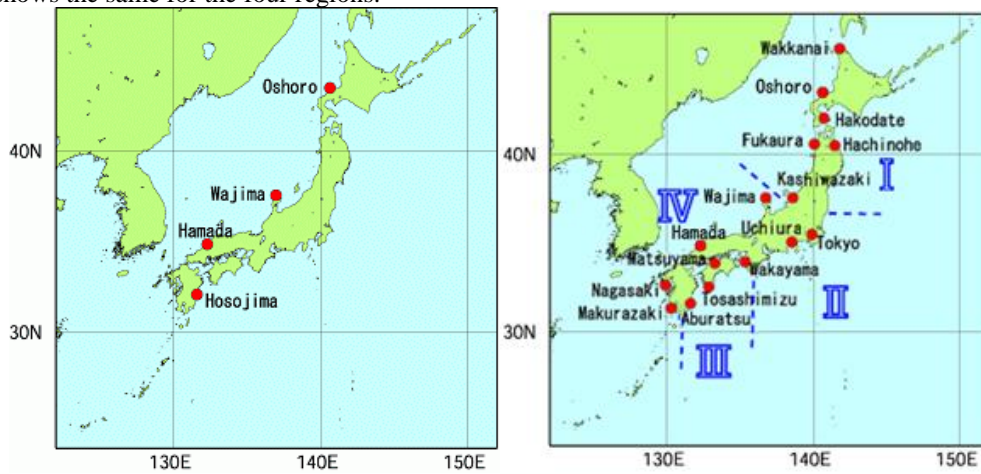


Fig. 4 (b) and 4 (c): Location of tide stations

▪ JMA's Historical Tide Gauge Dataset

In March 2017, JMA published a historical tide gauge dataset on its website. It consists of hourly data, monthly mean data and annual mean data beginning in December 1924 (Fig. 5), with original hourly data created from 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

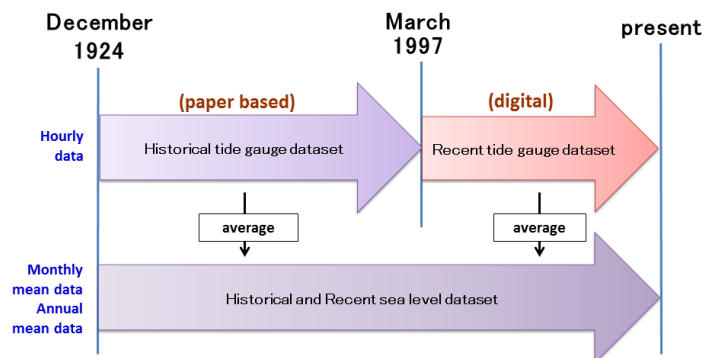


Fig. 5: Periods for historical (December 1924 to March 1997) and recent (1997 onward) tide gauge data provided on JMA's website

The above data are provided as detailed below.

Original:

http://www.data.jma.go.jp/gmd/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:

http://www.data.jma.go.jp/gmd/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

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

Monthly and annual means:

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

CD: station code (Table 2)