National Report of Japan

Hironori HAYASHIBARA, Japan Meteorological Agency, Japan

Address: 1-3-4 Otemachi, Chiyoda-ku, Tokyo 100-8122, Japan
Email: tide@climar.kishou.go.jp
Tel: +81-3-3212-8341 Ext. 5158
Fax: +81-3-3211-3047

▪ Natural Conditions Characterizing Sea Level Variations around Japan

Sea levels vary in a wide range of time scale from a few minutes to several decades within directly measurable limits, and even over several tens of thousands of years in geological records.

In a short time scale less than one day, sea levels can fluctuate by very large amplitudes due to meteorological factors such as storm surges, and also due to seismological factors represented by tsunamis as well as astronomical tides. Since Japan is located along the northwestern periphery of the Pacific Ocean, where tropical cyclones pass most frequently among all the oceans on the earth, Japan is one of the most storm surge prone countries in the world. Additionally, the geographical location means that Japan is on or very close to a belt where huge earthquakes and tsunamis occur quite frequently. As Japan has suffered huge disasters from these natural hazards through its history, one major purpose of sea level observations in Japan is to monitor storm surges and tsunamis on a real-time basis.

In a medium time scale from several days to several decades, sea levels vary mainly for oceanographic reasons. For example, "Kuroshio", which is a strong western boundary current in the western North Pacific and is flowing northeastward along Japan, sometimes affects sea levels along the Japanese coast on a time scale of days to months by meandering its path or with the warm water intrusion. On the other hand, sea levels vary on a long time scale of several decades, which will be described in later section.

Sea level observations are indispensable to monitor and analyze these oceanographic phenomena.

▪ Tide Gauges of JMA

The original purpose of sea level observations of the Japan Meteorological Agency (JMA) is to watch storm surges and tsunamis that Japan has suffered since ancient times, but these days, sea level data are also used to monitor the long-term sea level rise caused by climate change.

JMA uses radar tide gauges at 63 stations, acoustic tide gauges at 7 stations, Fuess (float) type tide gauges with digital encoders at 2 tide stations and a hydraulic pressure sensor at the Minami-tori-shima (Marcus Island) tide station. Those instruments measure sea levels with a resolution of 1 cm.

▪ National Sea Level Observation Network

Tide stations are operated by several national and local governmental organizations in Japan, including JMA, the Japan Coast Guard (JCG), the Geospatial Information Authority of Japan (GSI), Ports and Harbours Bureau (PHB) and Water and Disaster Management Bureau (WDMB) of Ministry of Land, Infrastructure, Transport and Tourism (MLIT). JMA runs 73 stations and the observed data at more than 200 tide stations operated by Japanese governmental organizations, mainly the ones mentioned above, are sent to JMA in real-time aiming at disaster prevention. Among them, 14 JMA tide stations and the Syowa tide station in the Antarctic are registered at the GLOSS Core Network (GCN) (see Fig. 1 and Table1).

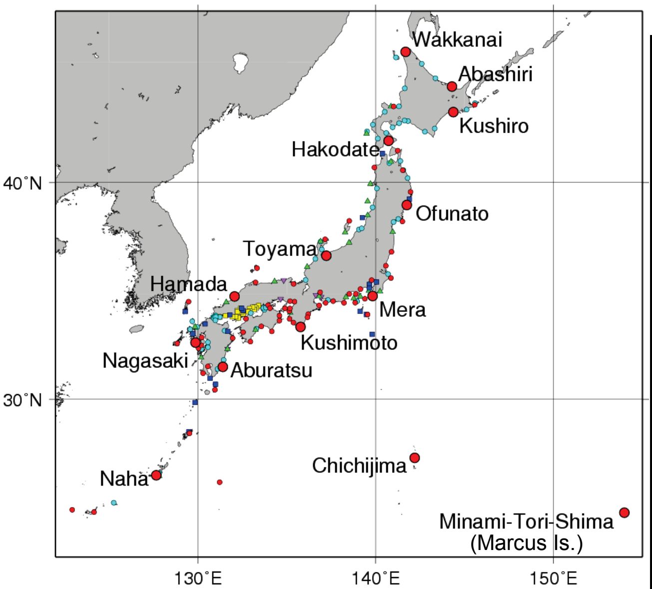

Fig. 1: Tide stations in Japan.
JMA (red circles; large ones registered at GCN), JCG (blue squares), GSI (green triangles), PHB (light blue diamonds), WDMB (yellow squares), Others (purple upside-down triangles).

Table 1: Tide stations registered at GCN

STATION NAME	CODE	LAT	LON
ABASHIRI	AS	44°01'N	144°17'E
ABURATSU	AB	31°35'N	131°25'E
CHICHIJIMA	CC	27°06'N	142°12'E
HAKODATE	HK	41°47'N	140°43'E
HAMADA	HA	34°54'N	132°04'E
KUSHIMOTO	KS	33°29'N	135°46'E
KUSHIRO	KR	42°59'N	144°22'E
MERA	MR	34°55'N	139°50'E
MINAMI-TORI-SHIMA	MC	24°17'N	153°59'E
NAGASAKI	NS	32°44'N	129°52'E
NAHA	NH	26°13'N	127°40'E
OFUNATO	OF	39°01'N	141°45'E
TOYAMA	TY	36°46'N	137°13'E
WAKKANAI	WN	45°24'N	141°41'E
SYOWA		69°00'S	39°34'E

▪ Acquisition, Processing and Dissemination of Sea Level Data by JMA

All the tide stations of JMA make measurements at approximately 1 second interval. Observed data except those at the Minami-tori-shima tide station are transmitted to the headquarters of JMA through a public IP network on a real-time basis. The data at Minami-tori-shima are transmitted to the JMA headquarters via the Data Collection Platform (DCP) system of the Geostationary Multi-Functional Transport Satellite (MTSAT-2) every 10 minutes. The data collected by the JMA headquarters are distributed to local meteorological observatories every 5 minutes. Also, the observed data at 22 stations (including the 14 GCN stations) in Japan are distributed to all over the world through the GTS line in real-time for tsunami monitoring.

Quick estimations of hourly sea level data are provided from JMA within a few days after the quality check of raw data found at:

http://www.data.kishou.go.jp/kaiyou/db/tide/sokuho/YYYYMM/z_hryYYYYMMCD.txt

where YYYY, MM, and CD indicate year, month and the station code, respectively. The code of each station is shown in Table 1. JMA confirms the previous month's data on or around the 20th of each month, and the values may change from quick estimations of them accordingly. The confirmed hourly sea level data are provided at:

http://www.data.kishou.go.jp/kaiyou/db/tide/genbo/YYYY/YYYYMM/hryYYYYMMCD.txt

JMA also processes these confirmed data to produce monthly mean sea level data. The confirmed hourly sea level data of the 14 GCN stations are sent to the GLOSS, University of Hawaii Sea Level Center, and monthly mean sea level data at the 55 JMA tide stations are sent to the Permanent Service for Mean Sea Level (PSMSL).

- **Monitoring Storm Surges and Tsunamis**

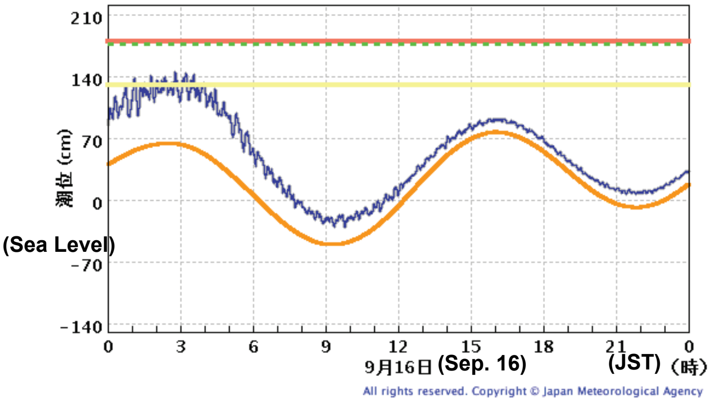

Fig. 2: Observed sea level at Uragami tide station during typhoon Man-yi in September, 2013.
The dark blue line indicates the observed data and the orange line is the astronomical tide. The red and yellow lines are the criteria for the storm surge warning and advisory, respectively. The dotted green line is the highest observed sea level in the past.

Near real-time tide data (5 minutes latency) from 187 tide stations are posted (in Japanese) on the JMA web site for disaster prevention:

http://www.jma.go.jp/jp/choi/

Fig. 2 is an example of a storm surge observed at Uragami tide station during typhoon Man-yi in September, 2013, posted on the JMA web site at that time. Real-time sea level observations play an important role for storm surge warnings/advisories, tsunami observation information and tide information.

- **Monitoring Long-Term Sea Level Changes**

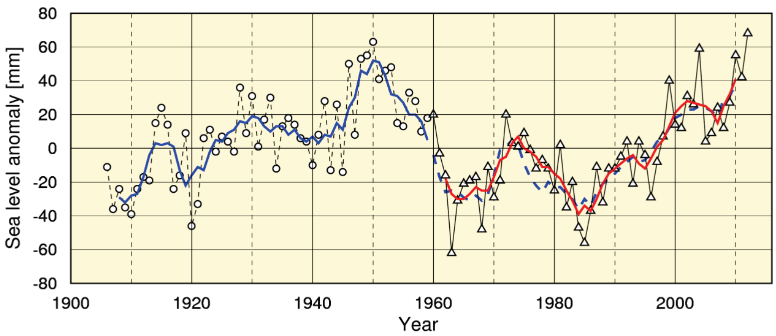

Fig. 3 (a): Time-series representation of annual mean sea level values around Japan. The blue line indicates the 5-year running mean of sea level anomalies at the 4 stations, while the red line shows this value for the 4 regions.

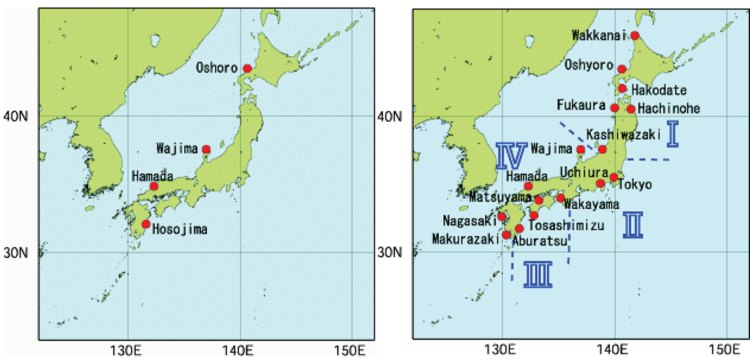

Fig. 3 (b) and 3 (c): Location of tide stations

Long-term sea level changes are monitored using the tide gauge data. Fig. 3 (a) shows the time series representation of annual mean sea level anomalies for each year, obtained using the 1981 – 2010 average as the normal.

There are 11 tide stations in Japan that have measured sea levels for more than 100 years. 4 stations among them, assessed as being affected to a lesser extent by crustal movement, are selected for the period 1906 – 1959 (Fig. 3 (b)), while 16 stations are selected for the period after 1960 for the better spatial representativeness (Fig. 3 (c)). For the period after 1960, cluster analysis was first applied to sea level observation data for the selected stations along the Japanese coast, then the Japanese coast were divided into the 4 regions shown in Fig. 3 (c) according to sea-level variation characteristics, the annual mean sea level anomalies were averaged for the 4 regions, and the variations were plotted in Fig. 3 (a).

The result indicates sea levels had their maximum around the year of 1950, and a sea level variation with approximately twenty-year period is dominant until the 1990s. Also, a rising trend in sea levels has been seen with a near-10-year variation since the 1990s.

For clearer understanding of the mechanism of sea level variations, JMA has been carrying out oceanographic observations by research vessels, numerical ocean modeling, a quantitative analysis of such sea level variations combining sea level and crustal movement data observed at these stations, and so on. As for the crustal movement data, GSI is conducting continuous real-time observations of crustal movements at the GPS-based control stations, which network is called GEONET (GPS Earth Observation Network System) and consists of about 1,200 stations in Japan. In cooperation with GSI, GPS systems are also equipped at all the Japanese GCN stations except Minami-tori-shima and Syowa.

▪ Online Databank for Oceanographic Data

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

http://www.jodc.go.jp/index.html