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▪ Natural Conditions Characterizing Sea Level Variations around Japan

Sea levels vary in a wide range of time scales from a few minutes to several tens of years within directly measurable limits, and even over several tens of thousand years in geological records. In short time scales less than one day, sea levels can fluctuate with very large amplitudes due to meteorological reasons (storm surges) and seismological reasons (tsunamis). Since Japan is located along the northwestern periphery of the western North Pacific, where tropical cyclones pass most frequently in all the oceans on the globe, it is one of the countries most prone to tropical cyclone strikes and storm surges associated with them. The geographical location also means that Japan resides on or very close to one of the belts of the most frequent occurrences of huge earthquakes and tsunamis. Thus Japan has suffered huge disasters from these natural hazards through its history. Therefore, one of the major purposes of sea level observations in Japan is to monitor storm surges and tsunamis on a real-time basis.

In medium time scales from several days to several tens of years, sea levels vary mainly for oceanographic reasons. For example, “Kuroshio”, one of the greatest western boundary currents found in the western Pacific Ocean flowing northeastward past Japan, sometimes affects sea levels along the Japan coasts on time scales of days to months by the meandering of its path or return current or countercurrent.

Sea level observation is indispensable to monitor and analyze these phenomena.

▪ Tide Gauges

Japan Meteorological Agency (JMA) uses Fuess (float) type tide gauges with digital encoders at 37 tide stations, acoustic tide gauges at 33 stations and a hydraulic pressure sensor at the Minami-tori-shima tide station. Those instruments measure the sea level with a resolution of 1cm. Newly developed acoustic tide gauges have been installed at the 13 GLOSS Core Network (GCN) stations in Japan except Minami-tori-shima, and put into operation since January 2006, after a one-year testing phase.

▪ National Sea Level Observation Network

The principal purpose of sea level observations of JMA is to watch storm surges and tsunamis which Japan has suffered since ancient times. Later, monitoring of long-term sea level rise caused by global warming has been added to the purposes.

In Japan, tide stations are operated by several national and local governmental organizations including JMA, Japan Coast Guard (JCG) and Geographical Survey Institute (GSI). These three organizations run 71, 30 (including Syowa tide station in the Antarctic) and 25 tide stations

respectively. The real-time data at about 200 tide stations operated by these organizations are gathered into JMA to aim at disaster prevention.

Among the stations, 14 tide stations of JMA and Syowa tide station are registered at the GCN (see Fig.1 and Table1).

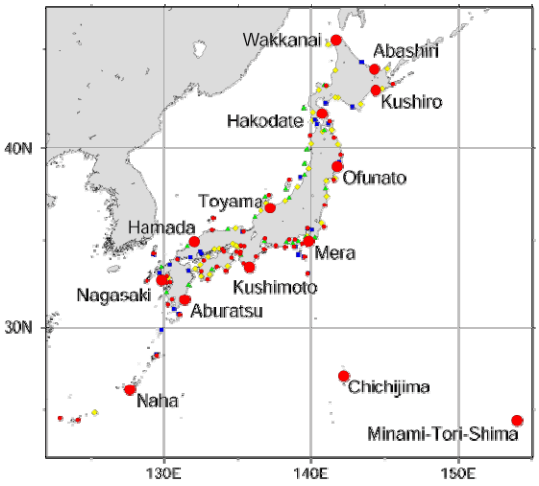

Fig.1: Tide stations in Japan. JMA (red circles, large circles registered in GLOSS Core Network), JCG (blue squares), GSI (green triangles), Other Organizations (yellow diamonds).

STATION NAME	CODE	LAT	LON
ABASHIRI	AS	44 01N	144 17E
ABURATSU	AB	31 35N	131 25E
CHICHIJIMA	CC	27 06N	142 11E
HAKODATE	HK	41 47N	140 43E
HAMADA	HA	34 54N	132 04E
KUSHIMOTO	KS	33 29N	135 46E
KUSHIRO	KR	42 58N	144 22E
MERA	MR	34 55N	139 49E
MINAMI-TORI-SHIMA	MC	24 18N	153 58E
NAGASAKI	NS	32 44N	129 52E
NAHA	NH	26 13N	127 40E
OFUNATO	OF	39 01N	141 45E
TOYAMA	TY	36 46N	137 14E
WAKKANAI	WN	45 24N	141 41E
SYOWA		69 00S	39 34E

Table1: Tide stations registered at GCN

▪ Sea Level Data Acquiring and Processing

All of the tide stations of JMA make measurements at approximately one-second interval. Observational data except those at Minami-tori-shima are transmitted to the headquarters of JMA through a public IP network on a real-time basis. The data observed at the Minami-tori-shima tide stations are transmitted to the JMA headquarters via the Data Collection Platform (DCP) system of the Geostationary Multi-functional Transport Satellite (MTSAT-1R) every 10 minutes. The data collected by the JMA headquarters are distributed to the local meteorological observatories every 15 minutes. The time interval of the data distribution will be shortened to every 5 minutes since this summer.

JMA also processes the data to produce hourly sea level data and monthly mean sea level data. Hourly data of the GCN 14 stations are sent to GLOSS Fast Data Center at Hawaii University and monthly mean sea level data at the all tide stations of JMA are sent to PSMSL.

Hourly sea level data are provided from JMA within 1-2 days of the calculation at:

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

where YYYY, MM, CD stand for year, month and the code of a station, respectively. The code of each station is shown in Table 1.

Real-time data at six stations are also distributed to all over the world by using GTS line

connection for tsunami monitoring.

JMA analyzes hourly data to determine tidal harmonic constants for the calculation of astronomical tides and posts them on its website.

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

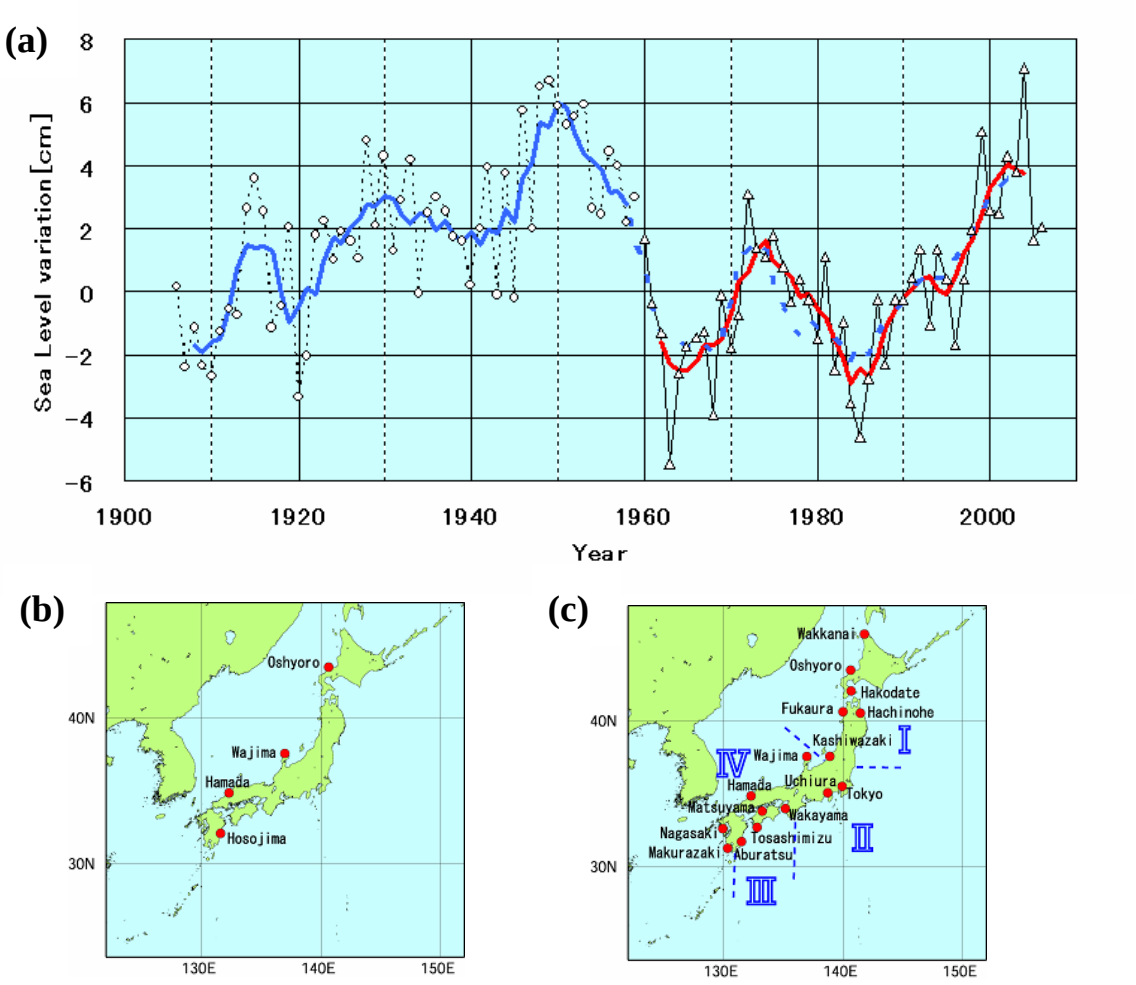

Fig. 2: Time series of the annual mean sea level anomaly around Japan and maps of tide stations used in the analysis

(a) Time series of annual mean sea level. The dotted black line is MSL averaged for the four stations shown in (b) and the blue line represents the 5-year running mean. The thin black and red lines indicate MSL of the 16 stations shown in (c) and its 5-year running mean, respectively.

(b) Location of tide stations of which the data are used in the calculation of MSL for 1906 to 1959

(c) The same as (b) but for the period from 1960 onward

There are eleven tide stations in Japan that have measured sea level for more 100 years. We have selected four stations (Fig. 2(b)) in which the effect of land movements on observed sea levels are considered to be small among the eleven stations.

For the period from 1960 onward, sixteen stations (Fig. 2(c)) are chosen for the better spatial representativeness. In calculating the MSL for the period, we first divided the sea area around

Japan into four regions, within which the characteristics of sea level variation are similar, and calculated MSL for each region. Then, the time series for the four regions are averaged and indicated in Fig. 2(a) as the thin black line. In Fig. 2(a), all MSL values are reduced to the mean value from 1971 to 2000.

The result indicates a sea level fluctuation with approximately twenty-year period is distinguished, and had its maximum around the year of 1950. Also, sea level has been continuously rising since the middle of 1980's and has almost reached the level in 1950's recently.

For the clearer understanding of the mechanism of sea level variations, JMA has been carrying out quantitative analysis of such a sea level variation using sea level and crustal movements observed at these stations, oceanographic data by research vessels, and the results of numerical ocean models, etc.

▪ 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 hundred tide stations in Japan including GCN stations and other oceanographic data are available at the JODC website:

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