Estimation of storm surge caused by a typhoon with the maximum potential intensity in the Seto Inland Sea, Japan

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Introduction

It is considered that the global warming causes sea level rises and enhances intense tropical cyclones, thereby resulting in an increase in disaster risk around coastal area.

Here, we evaluate the long-term oceanic-origin sea levels and project sea level rises based on the observed tide station data and the IPCC AR4 outputs. Furthermore, we estimate the future potential storm surge by combining the Maximum Potential Intensity (MPI) (Emanuel, 1988) theory and the outputs of the IPCC AR4, against Typhoon Chaba which caused severe storm surge in the Seto Inland Sea (SIS), Japan.

Past Long-term Change in Sea Level

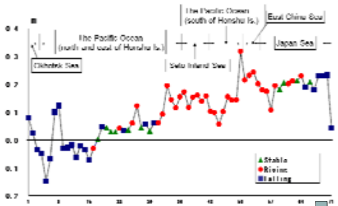
The number of the tide stations around Japan is 100 or more.

20 tide stations have long time records (more than 60 years)

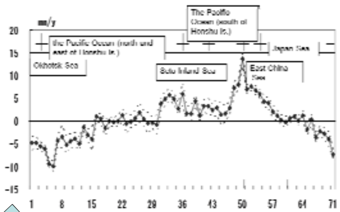
10 tide stations have more than 100 years records

Here, 71 tide records around Japan are analyzed to estimate the long-term change in mean sea level, after extracting the crustal movement using the leveling data directly.

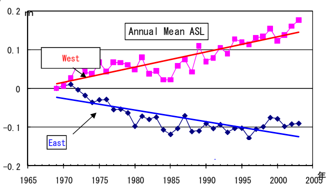
Change in Mean Sea Level around Japan during 1998-2003



Change in Absolute Sea Level around Japan during 1998-2003

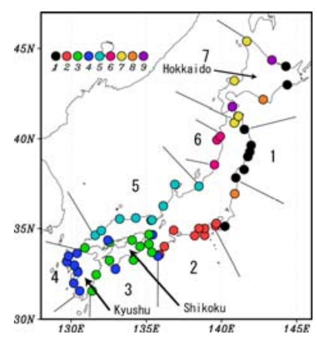


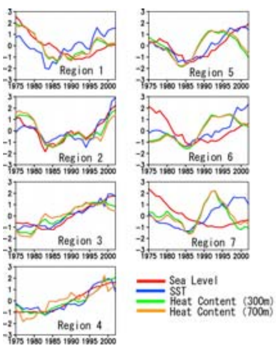
Extract the crustal movement



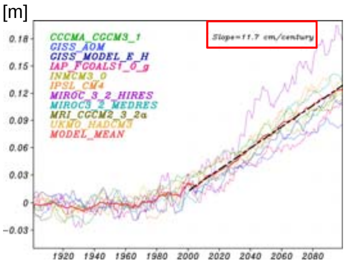
In eastern Japan:
a negative trend of 3.1 mm/yr
In western Japan:
a positive trend of 2.4 mm/yr

Future Change in Sea Level



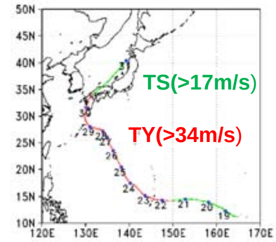


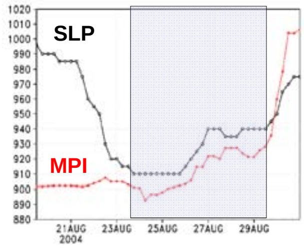
[m]



We classify Japan's coast into seven regions by applying cluster analysis to the sea level data. Changes in sea level correlate well to those in SST and heat content for regions 2, 3, and 4. Based on the linear regression model, we predict changes in sea level for region 3 in the 21st century using SSTs predicted data from global warming experiments under the IPCC SRES A1B scenario.

Typhoon Chaba

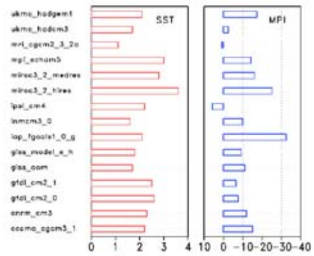




During 23-29 August 2004, the observed central pressure of Typhoon Chaba evolves nearly to its maximum potential intensity. The similar tendency is found in other tropical cyclones statistically (Emanuel, 2000).

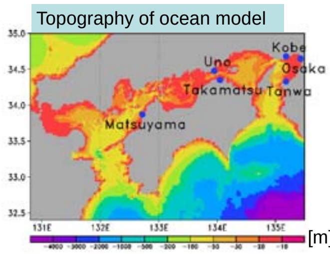
Projection of Storm Surge induced by Typhoon Chaba under Global Warming

In order to estimate the maximum storm surge under the global warming, we assume that Typhoon Chaba may develop the intensity to the MPI even under the global warming. Using the output of the IPCC AR4, we estimate the MPI in the 2090's at the time that Typhoon Chaba reached its maximum intensity.



Difference in SST (℃) and MPI (hPa) between the 20cm3 (1980-1999) and SRESA1B(2081-2100) for each IPCC AR4 output.

Topography of ocean model



The storm surge model is similar to the POM. Horizontal resolution is 0.025°, with three vertical sigma levels. The surface pressure fields is defined by the formula of Fujita (1952).

$$P_S(r) = P_\infty - \frac{P_\infty - P_C}{\sqrt{1+(\frac{r}{r_0})^2}}$$

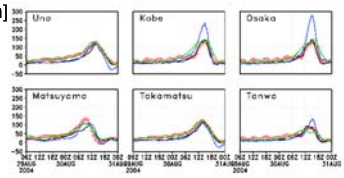
The parameter r_0 is determined based on the weather chart. The surface winds are derived from the surface pressure profile, adding a typhoon moving speed as asymmetrical component.

The future P_c under global warming is estimated as follows:

$$P_C^F(t) = \left(P_C^P(t_0) + MPI^F(t_0) - MPI^P(t_0)\right)\frac{P_C^P(t)}{P_C^P(t_0)}$$

, where t_0 is the time that Typhoon Chaba reached its maximum intensity. The suffix P and F indicates the corresponding variables in the future and present climate. The latter is derived from the JMA Best track data and reanalysis data (JRA25). The track, the moving speed, and the size is assumed to be same as observed in the present climate.

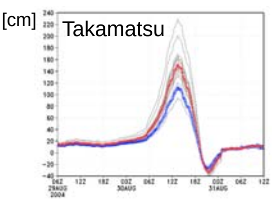
[cm]



Time series of storm surge (cm) at several stations. Red lines are for observation, while blue lines are for the model with the simple typhoon model. Black and green lines are the storm surge of the model driven by the JMA operational meso scale model prediction data and the model output data simulated with the WRF model, respectively.

The significant discrepancies in the model (blue lines) at Kobe and Osaka are due to the wrong wind direction of the simple typhoon model.

[cm]



Storm surge (cm) induce by Typhoon Chaba under global warming at Takamatsu. Red line is model ensemble mean. Blue line is the simulated storm surge by using the JMA best track data.

Summary and Discussion

We have estimated the potential flood risk in the Seto Island Sea, Japan, under the global warming scenario. In 2100, the increase in sea level is about 10 cm, while the storm surge induced by Typhoon Chaba has increased by about 40 cm, suggesting an increase in disaster risk around coastal area in future.

However, the simple typhoon model can not give reasonable atmospheric fields, in particular, around the coastal ocean with complex topography and midlatitude. Therefore, it is necessary to estimate storm surge by using sophisticated atmospheric models.