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Interdecadal variability and linear trend of sea level around Japan in the 20th and 21st centuries

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Sea level variability along the Japanese coast during the 20th century (observed tide gauge data)

- Bidecadal and simultaneous variability along the coast and no significant trend during the 20th century (*Figs.3 and 4)*
- Caused by changes in the wind stress fields over the North Pacific (*Figs.S1 and S2*)

Future projection of sea level around Japan (WCRP CMIP3 multi-model data set)

- Change from the1960-1999 mean to the 2060-2099 mean in the sea level east of Japan due to the northward shift and the intensification of the Kuroshio Extension (KE) is comparable to the global mean steric sea level rise (*Fig.5*).
- An uncertainty of the sea level change east of Japan is induced by the differences of changes in the KE resulting from those of the sea level pressure (SLP) over the eastern part of the North Pacific, which is corresponding to the area of a large spread of SLP among models.
- The eastern part of the North Pacific is the key area to get a successful projection of the sea level east of Japan.

1. Introduction

Japan islands are located at the latitude of the boundary between the subtropical and subpolar gyres in the North Pacific and the area where the strong Kuroshio and Oyashio currents meet. Therefore, sea level change along the Japanese coast could be greatly influenced by the ocean circulation change on various time scales. In this study, interdecadal variability and linear trend of sea level along Japanese coast in the 20th and 21st centuries are examined.

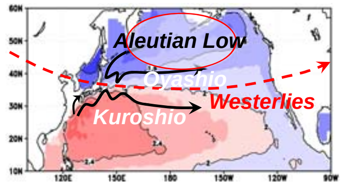

Fig.1 Schematic map of atmosphere and ocean circulations in the North Pacific. Contours and colors: annual mean climatology of dynamic sea surface height (m).

2. Sea level change along the Japanese coast in the 20th century

Historical tide gauge data show bidecadal variability and simultaneous variation of sea level along the Japanese coast (Figs.3 and 4, Senjyu et al., 1999, Yasuda and Sakurai, 2006). There is no significant trend during the 20th century (Fig.4).

Data Tide gauge data along the Japanese coast are archived by the Coastal Movements Data Center (CMDC) in Japan. We use the tide gauge stations that the rate of the crustal movement is less than 2 mm/year as tectonically stable (Fig.2). We also use the AVISO satellite altimetry data (CLS, 2010) during 1993-2008.

(Mechanisms of the interdecadal variability are discussed in Figs.S1 and S2.)

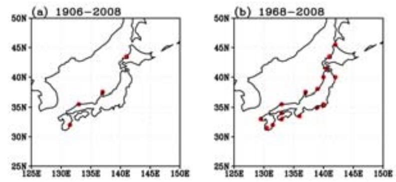

Fig.2 Tide gauge stations used in this study. (a) 4 stations for 1906-2008. (b)16 stations for 1968-2008.

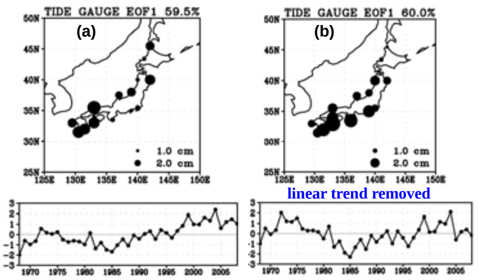

Fig.3 (a) EOF1 of the sea level variability along the Japanese coast during 1968-2008. (b) Same as (a) but for results for trend-removed data.

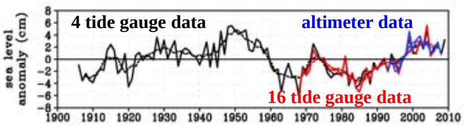

Fig.4 Anomalies of sea level averaged along the Japanese coast and AVISO sea surface height averaged in 30-46N, 128-146E. Dashed line: 5-year running mean values.

3. Future projection of the sea level around Japan

due to the ocean circulation change or the global mean sea level rise?

Data: **WCRP CMIP3 multi-model data set (15 CGCMs)**

Future Change:

[20C] (20c3m: 1960-99 mean) ⇒ [21C] (SRESA1B: 2060-99 mean)

Multi-model ensemble means (MMEs) indicate the future change in the sea level associated with the intensification and the northward shift of the Kuroshio Extension (Fig.5). The similarity of the patterns between the sea level change and the Sverdrup stream function change indicates that the change in the wind stress and sea level pressure results in the sea level change (Fig.5). Sea level change east of Japan due to the ocean circulation change is not negligible compared to the global mean steric sea level rise (17.8cm).

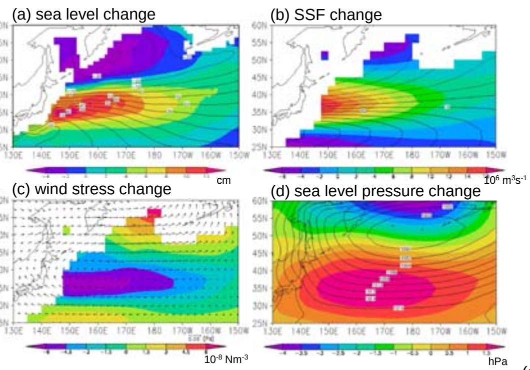

Fig.5 Future change in the MME mean fields ([21C] minus [20C]: colors). (a) sea level due to ocean circulation change, (b) Sverdrup stream function (SSF), (c) surface wind stress (vectors) and wind stress curl, and (d) sea level pressure. Contours: [20C] climatology.

It remains a large uncertainty of the sea level change east of Japan (Fig.6). Composite analyses show that models with a larger northward shift (intensification) of the KE have a northward shift (an intensification) of the Aleutian Low (Figs.7 and 8). An uncertainty of the sea level change east of Japan is induced by sea level pressure change over the eastern part of the North Pacific. This region is corresponding to that of a large standard deviation of SLP among models (Figs.8 and 9). Therefore, the eastern part of the North Pacific is the key region to get a successful projection of the sea level east of Japan.

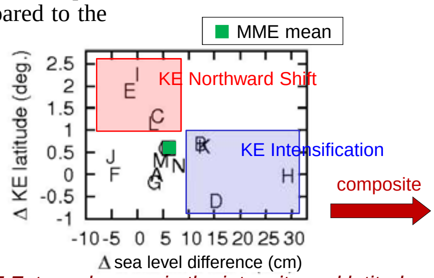

Fig.7 Future changes in the intensity and latitude of the Kuroshio Extension (KE) in each model. KE intensity: meridional sea level difference (34N minus 42N). KE Latitude: the maximum meridional sea level gradient.

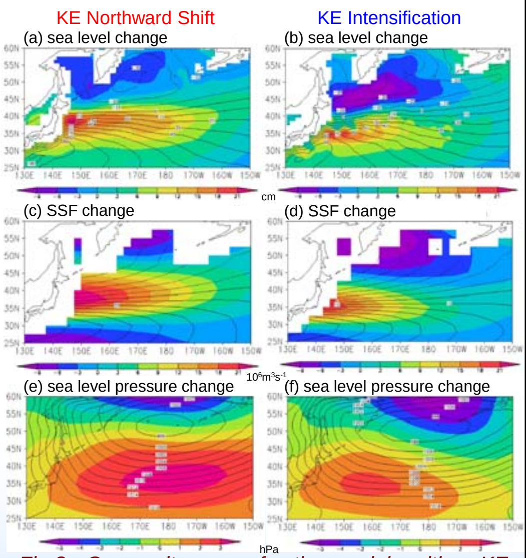

Fig.8 Composite maps for the models with a KE larger northward shift (left) and a KE intensification (right). (a,b) sea level, (c,d) Sverdrup stream function (SSF), and (e,f) sea level pressure in [21C] relative to [20C] (color). Contours: composite maps in [20C].

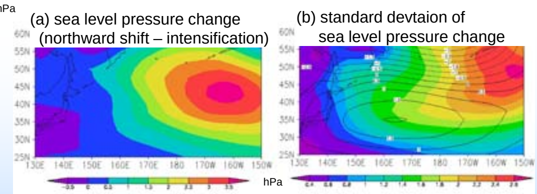

Fig.9 (a) Difference in the SLP future change between the KE northward shift (4) models and the KE intensification (4) models. (b) Standard deviation of the SLP future change among 15 models (color). Contours: the MME mean SLP future change.

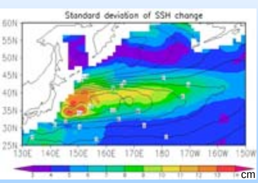

Fig.6 Standard deviation of the future change in the sea level among models (colors). Contours: MME mean sea level change.

Sueyoshi and Yasuda (to be submitted)

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