Global Ocean Waves and Storm Surge Changes Under a Warming Climate

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INTRODUCTION

Impact assessments of climate change on coastal hazard risk are conducted in order to evaluate how coastal communities should adapt their coastal defense systems and other mitigation measures going forward. In this context, global mean sea level rise has been well-studied for several decades now. In addition, to mean sea level rise, it is important to estimate future changes in extreme sea levels due to storm surges and ocean waves for coastal adaptation purposes. This study aims to estimate the climate change impacts on both global waves and storm surges under an extremely high-resolution Global Climate Model (GCM) forcing continuously over 150 years, starting from the mid-20th century and extending to the end of the 21st century as the climate warms. This allows us to gain a consistent and temporally seamless understanding of past and projected future changes to global waves and storm surges.

METHODOLOGY

The results of climate projection experiments conducted by the Japanese Atmospheric Global Climate Model (MRI-AGCM) were used for global storm surges and ocean wave projections. MRI-AGCM can realistically reproduce global distributions of intense TCs, partly through the use of a fine horizontal spatial resolution of 0.1875°. The climate simulation was performed from historical to future periods continuously (1950 to 2099).

The global storm surge simulation was conducted by version 55 of the Advanced CIRCulation model. The unstructured grid is applied in order to simulate the storm surge from the open ocean to coastal water. The computational domain covers the globe composed of 2.40 million grid points.

The global ocean wave simulation was conducted by WAVEWATCH III. WAVEWATCH III was forced by hourly U10, and monthly sea ice concentration. Global ocean wave simulations were conducted by 2-way nesting with four domains on structured grids.

RESULTS

The linear trends of global annual maximum significant wave height (Hs) and storm surge from 1950 to 2099 are shown. Figures 1 (a) and (b) are the spatial distributions of the trend of Hs and storm surge, respectively. Regarding Hs, the positive and negative trends can be seen depending on the region. The spatial distribution is consistent with the changes in TC passing frequency. In the western North Pacific and the Southern Hemisphere, the decreases in TC frequency are notable, and the corresponding negative trend of annual maximum Hs is also larger. On the other hand, in the eastern North Pacific and the eastern North Atlantic, Hs is projected to increase under the increases in TC frequency.

The trend of annual maximum storm surge is plotted along the coastal grid points in Figure 1(b). The spatial pattern is similar to that of Hs. The storm surge tends to decrease along the East Asia coast, Japan coast, and the Gulf of Mexico, where TC frequency decreases. The Japanese Pacific coast shows negative 10 to 20 cm/century trends.

Extreme events less probable than annual maxima are now discussed. Figures 1(c) and (d) show changes in Hs and storm surge in the 50-year return level between future (2015-2099) and historical climates (1950-2014). The spatial patterns (Figure 1(c)(d)) are similar to those of the linear trends (Figure 1(a)(b)), but the spatial pattern is noisy, and the magnitudes of change are larger. Previous studies indicated that intense TCs would be increased in a warmer climate. However, depending on the region, our results show that less probable extreme waves and surge events associated with intense TCs are not necessarily intensified in a warming climate. This is partly because of the favorable environmental conditions for intense TCs in the first half of the historical climate

CONCLUSIONS

The spatial pattern in the trend of annual maximum sea surface heights and wave heights is predominantly driven by changes in tropical cyclone frequency. Future tropical cyclone frequencies are projected to decrease in the western North Pacific, and the annual maximum sea surface heights and wave heights show decreasing trends (-20cm/century and -200cm/century). Although highly intense tropical cyclones are enhanced in the warmer climate, highly extreme storm surges and wave heights do not necessarily increase due to the large natural variability.

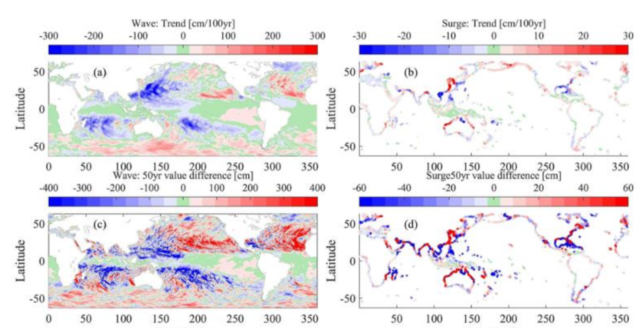

Figure 1: The projected changes in wave heights and storm surges. (a)(b) The trend of annual maximum H_s and storm surge (unit: cm/century), (c)(d) The projected changes from the past to future in H_s and storm surge in 50 years return level (unit: cm).