Cover Sheet

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Paper Title:
Japan as a Possible Hot Spot of Flood Damage in Future Climate Illustrated by High-Resolution Climate Modeling Using the Earth Simulator

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Japan as a Possible Hot Spot of Flood Damage in Future Climate Illustrated by High-Resolution Climate Modeling Using the Earth Simulator

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Abstract

A high-resolution coupled ocean atmosphere climate model has been developed and a series of climate change experiments have been conducted to assess the enhancement of flood damage due to climate change over Japan, using one of the world highest computational capabilities, the Earth Simulator. It is projected that summer mean precipitation over Japan is enhanced due to anomalous pressure pattern. Extreme daily precipitation, including that associated with typhoon attacks, would be further enhanced due to the enhancement of atmospheric moisture availability. It is shown that a high-resolution climate modeling is helpful to assess the impact of extreme events in the course of climate change. Taking into account the highly concentrated population and property, Japan could be one of the hot spots of climate change impact in terms of the amount of damaged population and property.

1. Introduction

In 2004, Japan has experienced unprecedented flood damages due to a series of torrential rain events and ten attacks of typhoons (breaking the previous record of six). The total insurance payment for the damages reached approximately 5,000 million US$. This anomalous numbers of extreme rainfall events could be mainly attributable to the natural climate variability and should not simply be interpreted as a manifestation of anthropogenic climate change. However, we could learn from this experience the vulnerability of Japan to

water disasters in terms of the amounts of damaged population and property, due to the highly concentrated population and property in Japan. If it is expected that the frequency and magnitude of extreme precipitation events over Japan increases due to the anthropogenic climate change in near future, Japan should be regarded as one of the hot spots of climate change impact.

The projection of the change in summer precipitation over Japan by climate models has long been difficult, since the summer precipitation over Japan is characterized by complex features such as Baiu front (east Asian monsoon rain band) and typhoons, which have been difficult to be realistically reproduced in coarse resolution climate models. Thanks to the Earth Simulator, which is one of the world highest-performance computational capabilities, we have developed a high-resolution coupled ocean atmosphere climate model and performed climate change experiments, which enables us to simulate the summer precipitation over Japan realistically and to assess the possible flood damage in Japan in future climate with enhanced greenhouse gases concentrations.

2. Model and Experiments

The climate model, called MIROC, has been collaboratively developed by Center for Climate System Research of the University of Tokyo (CCSR), National Institute for Environmental Studies (NIES) and Frontier Research Center for Global Change of Japan Agency for Marine-Earth Science and Technology (FRCGC). The description of the model is found in [1]. The horizontal resolution of the atmospheric part is approximately 120km, while that of the oceanic part is approximately 25km. A series of experiments have been conducted with this model, including the 20th century historical run and SRES A1B and B1 scenario runs for the 21st century. For avoiding the sea surface temperature (SST) errors in the coupled model, atmospheric model runs with prescribed SST are also conducted for the present and 2xCO2 climates, though the SST errors of the coupled model is fairly small (note that the model does not use flux correction).

3. Results

3.1 Regional Climate

For the present day climate, the model realistically reproduced not only the seasonal mean precipitation distribution but also the distribution of extreme daily precipitation over Asia, for example, in terms of 99th percentile as validated against the data of daily precipitation based on satellite observation, GPCP 1DD [2] (figure not shown).

Figure 1 shows the climate change pattern over the Asian-Pacific region in summer (June-July-August) projected by the coupled model. This is the difference between the mean for 2071-2100 in the A1B run and the mean for 1971-2000 in the historical run. The contours, arrows and shades denote the changes in

500hPa height, 850hPa wind and precipitation rate, respectively. The area with dense shade extending from the southeastern edge of China to the southeast of Japan indicates the increase in precipitation over the Meiyu/Changma/Baiu front (east Asian monsoon rain belt). This is affected by two high-pressure anomalies, one is located to the northeast of the Philippines, and the other is over the eastern Siberia and the Sea of Okhotsk. The former is caused by the El Nino-like tropical Pacific warming (larger warming over central to eastern tropical Pacific). It tends to form a low-pressure anomaly to the north of it and provides warm moist air to the rain belt. The latter is caused by the enhanced continental warming and tends to hinder the northward migration of the rain belt.

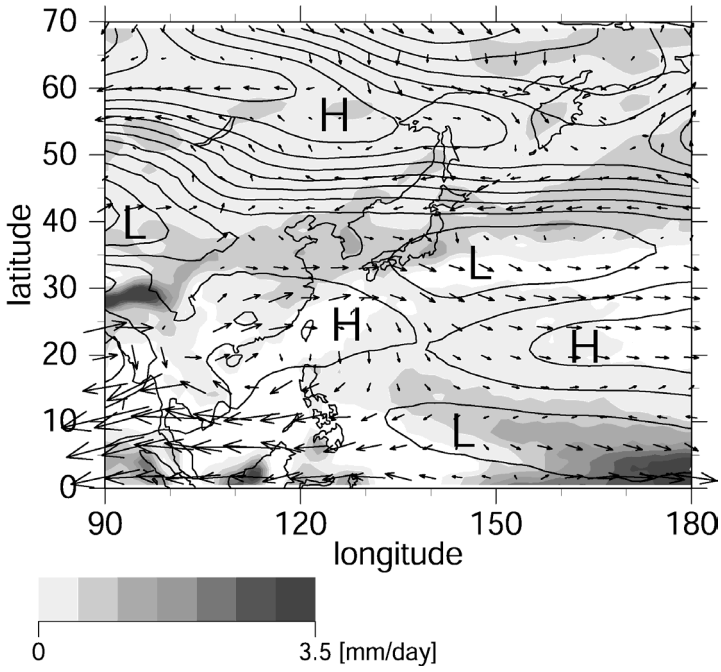

Figure 1. Projected climate change pattern over the Asian-Pacific region. See text for detail.

3.2 Frequency of torrential rain

Figure 2 shows the projected change in the number of days of torrential rain in summer (June, July, August) during the period of 1900 to 2100 in Japan. The A1B run was used for the 21st centuriey. If the daily precipitation of at least one of grids covering the Japanese archipelago exceeded 100mm, it was counted as one day of torrential rain. Though there is a large inter-annual variability, frequencies of torrential rains increased steadily in the 21st century. In general, the chance of extremely heavy precipitation is expected to be increased in the warmed climate due to the increased atmospheric water vapor.

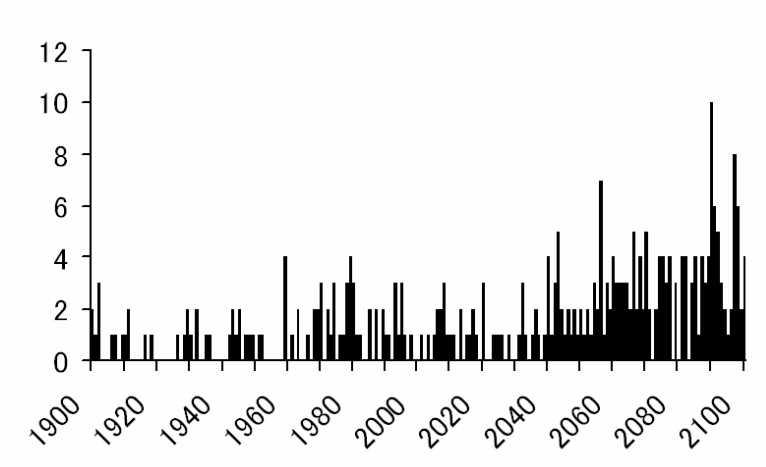

Figure 2. Projected torrential rain frequency over Japan.

3.2 Typhoons

To further examine the enhancement of modeled extreme daily precipitation, simulated typhoon-like disturbances in the atmospheric model runs are defined similarly to [3] and daily precipitation due to typhoon is extracted. Figure 3 shows the daily precipitation that is caused by typhoons averaged over 20 years in a present climate (left) and a doubled CO2 climate (right). The overlaid thin lines are tracks of the simulated tropical cyclones. Although the number of tropical cyclones is even decreased in the doubled CO2 climate over this region, the mean daily precipitation caused by the tropical cyclones is significantly enhanced in the changed climate especially near the south coast of Japan.

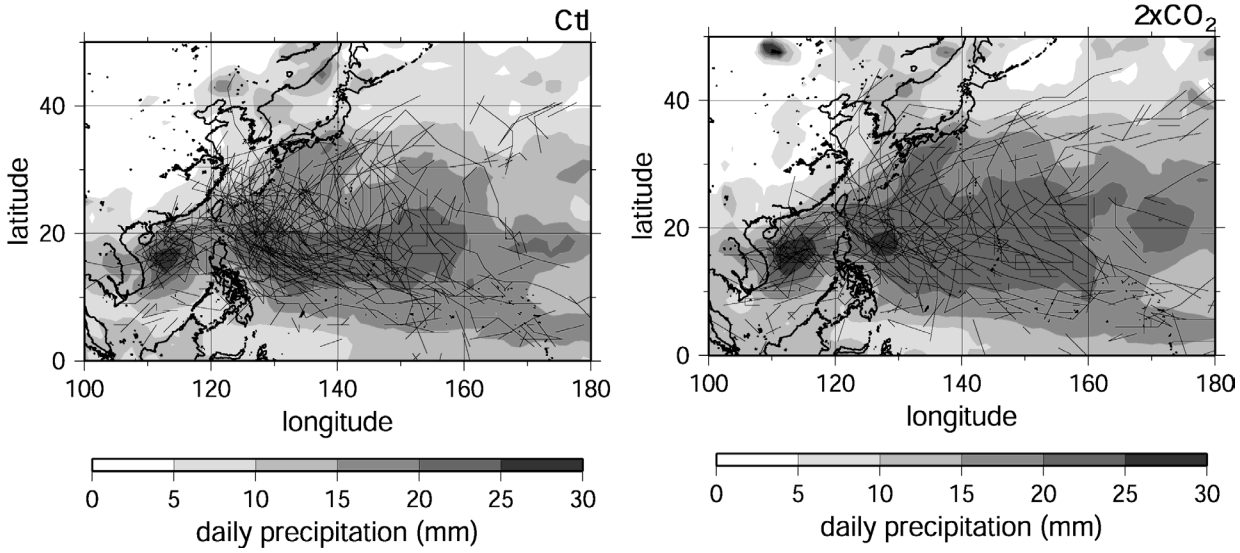

Figure 3. Extracted mean daily precipitation amount due to typhoons (shade). Tracks of typhoons are superimposed with thin line.

4. Conclusion

It was shown from high-resolution climate modeling results that mean precipitation over Japan in summer is expected to be enhanced due to the mean change in pressure pattern and that the intensity of precipitation including that due to typhoons is expected to be further enhanced due to the enhancement of atmospheric moisture availability. The frequency of torrential rain and consequent floods could be doubled in late 21st century compared with in the 20th century, though the uncertainty due to climate change scenarios and modeled climate sensitivity should be taken care of. In general, impact assessment based not only on the projection of mean climate but also on the projection of extreme precipitation is highly demanded to discuss the long-term target of climate stabilization. It is demonstrated that a high-resolution climate modeling is

helpful to investigate the future changes in regional climate and extreme events with some confidence. It is also implied from this study that Japan could be a hot spot of climate change impact in terms of damaged population and property due to the highly concentrated population and property, and some other developed countries might be as well.

References

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