

Attributing Typhoon Heavy Rainfall to Global Warming Using Meta-Earth Technology

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Typhoon is a great concern in our society. However, its randomness and natural variability of climate system hinder to estimate precisely the impacts of human-induced global warming on the changes in the frequency of typhoon heavy rainfall. This study shows that the frequency of typhoon heavy rainfall has increased over southeast China, Korean peninsula, and Japan and decreased in the southern part of the northwest Pacific. Based on Meta-Earth experiment, which intercompares simulations including and excluding human-induced greenhouse gas emissions, we first proved that such changes in the frequency of typhoon heavy rainfall has been caused by the human-induced global warming.

Background

Floods and landslides caused by typhoons pose a significant threat to human society. Therefore, changes in the floods caused by typhoons are important information for various fields such as disaster prevention, insurance, agriculture, and tourism. According to future simulations using climate models, it is predicted that future typhoons will be affected by global warming, and the frequency of floods caused by typhoons has also been reported to have changed over the past few decades in various parts of the world. However, typhoon activity is greatly influenced by randomness or natural variability in the climate system, so it is not clear whether the observed changes in the past were due to natural variability or the effects of global warming caused by human activities.

Contents

In this study, it was found from observational data that the frequency of typhoon-induced heavy rains (hereinafter referred to as typhoon rains) in the North Pacific region including the Korean Peninsula and Japan has significantly changed over the past 50 years. Furthermore, it was revealed that the observed changes cannot be explained by warming caused by human activity, using climate model simulation so-called Meta-Earth.

Figure 1 (left) shows the frequency change of typhoon rains over the past 50 years (1961 to 2015) based on observational data in the North Pacific region. In the coastal areas of East Asia (southeastern China, Taiwan, southern Korean peninsula, and Okinawa to eastern Hokkaido in Japan), the frequency of typhoon rains is increasing, while in the region below the 22 degree north, there are many areas where the frequency of typhoon rains has decreased. This shows that the change in typhoon rains within the North Pacific region is not uniform. Climate models can not only reproduce past climate experiments but also remove the warming effect caused by human activity, so the effect of warming caused by human activity on typhoon rains was investigated by comparing the frequency of typhoon rains in different virtual Earths (i.e., warming and non-warming Earths) using Meta-Earth experiments. Figure 1 (right) shows the frequency change of typhoon rains estimated using Meta-Earth experiments. The effect of warming can be seen to increase the frequency of typhoon rains in coastal areas of East Asia while decreasing the frequency in a wide area of low latitudes. This geographical distribution is consistent with the characteristics shown in Figure 1 (left), indicating that the observed changes in the frequency of typhoon rains are influenced by warming caused by human activity.

To confirm that the spatial patterns of observation and simulation are not due to chance or natural variability but a necessary result of anthropogenic climate change, Meta-Earth experiments and fingerprint analysis were used. Figure 2 shows the signal of the anthropogenic climate change fingerprint for observational data and non-warming Earth experiments, respectively. Non-warming Meta-Earth considers the range of variability due to chance and natural variability by using 50 ensembles of 50-year simulation data with slightly changing initial states (i.e., a total simulation period of 2500 years). The anthropogenic climate change fingerprint in the non-warming Earth mostly remains around 0, while the signal of the anthropogenic climate change fingerprint in the observational data shows a strong increasing trend since the 1970s. The comparison between observational data and non-warming Earth simulations concludes that the changes in the frequency of typhoon rains are a result of anthropogenic climate change.

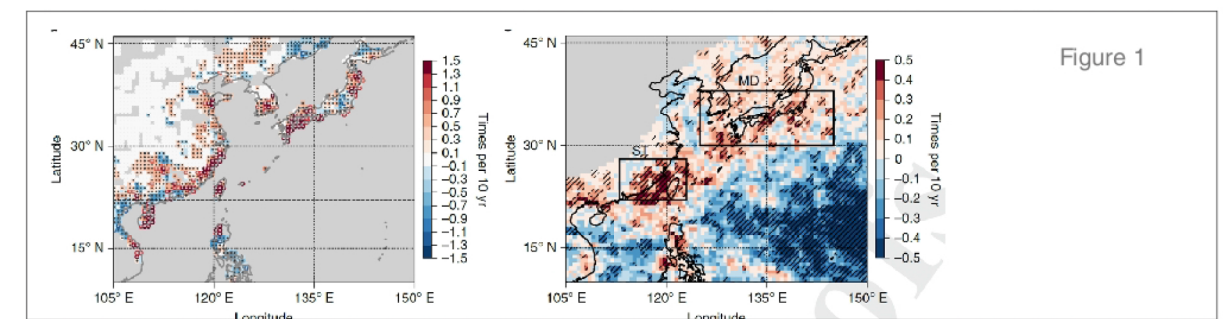


Figure 1

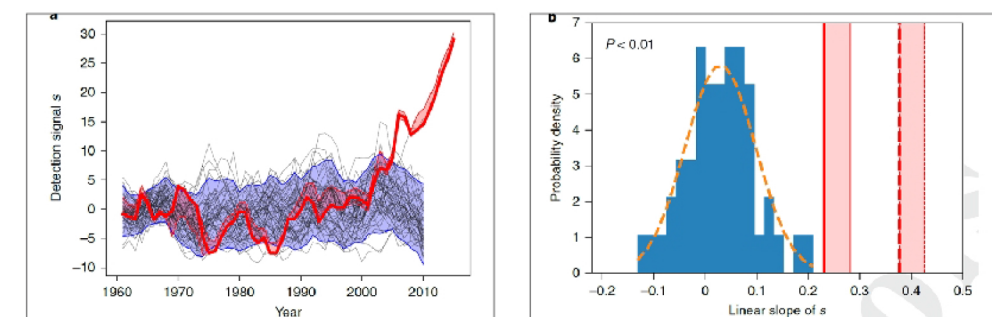


Figure 2 Figure 3

Expected effect

This study reveals that the impact of human-induced global warming is already evident in the frequency changes of typhoons heavy rains in the northwestern Pacific region. The study focuses on the northwestern Pacific region, which is one of the most active regions in the world for typhoons, and where many populous coastal areas and mega-cities with significant economic scale are located. To optimize the cost-effectiveness of climate change measures, accurate assessments of the climate change impact are essential in various fields. This study presents crucial insights into the impact of climate change, particularly on typhoons in the East Asian region. Typhoons are extreme weather events that have been increasingly frequent in recent years and are expected to persist. Understanding and evaluating the effects of climate change on these events is vital for developing effective strategies to mitigate their impact.

Research outcomes

- [Paper 1] Utsumi, N. and H. Kim (2022) Observed influence of anthropogenic climate change on typhoon heavy rainfall, *Nature Climate Change*, 12, 436–440 [Impact Factor = 28.862]
- [Paper 2] Shioyama, H., M. Watanabe, H. Kim and N. Hirota (2022) Emergent constraints on future precipitation changes, *Nature*, 602, 612–616 [Impact Factor = 69.504]

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