The Impact Assessment of Global Warming on the Heavy Rainfall during Baiu Season in Japan Taking into Account the Events in July 2018 and 2017

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Abstract: We estimated the future change of heavy rainfall during Baiu season considering the events in July 2017 and 2018. The meso-β heavy rainfall like the event in 2017 will increase and the amount of water vapor inflow prone to meso-α widespread and long-lasting heavy rainfall like the event in 2018 will also increase in the future.

Keywords: climate change, heavy rainfall, Baiu season, multi-scale analysis, high resolution model

1. Background and Objectives

In 2017, the localized heavy rainfall event occurred at narrow area in Northern Kyusyu district of Japan and killed over 40 people (BHR17). In 2018, the heavy rainfall event also occurred over broad area in Western Japan for a few days and killed over 200 people (BHR18). Both of two events were record-breaking from the different spaciotemporal scale. As the warming trend becomes more significant, it is an urgent issue to assess the impact of global warming on the heavy rainfall during Baiu season for the purpose of adaptation for climate change.

The typical heavy rainfall during Baiu season (Baiu heavy rainfall) is a phenomenon of back-building type, whose feature is to continuously generate the cumulus carrying the rain at same area and build a rainband, in the meso-β scale (20~200km) under atmospheric conditions of Baiu front in a scale relatively larger than the meso-α scale (200~2000km). BHR17 was a meso-β back-building type while BHR18 was widespread and long-lasting event. For the impact assessment of global warming on Baiu heavy rainfall of several scale respectively, it is important to capture the characteristics of Baiu heavy rainfall from multiple spatial scales. Thus, we aimed to comprehensively assess the global warming impact on Baiu heavy rainfall considering BHR17 of meso-β and BHR18 of meso-α.

2. Data and the characteristics of two events

2.1 Data

In the SOUSEI Program in Japan, 5-km-mesh non-hydrostatic regional climate model (NHRCM05) was developed by nested in 20-km-mesh MRI_AGCM3.2S (AGCM20) under the scenario of RCP8.5 (IPCC, 2013). NHRCM05, which outputs 30-minutes precipitation, enables us to obtain the meso-β Baiu heavy rainfall as precipitation output. NHRCM05 and AGCM20 have four SST ensembles, called c0 ~ c3. Moreover, Mizuta et al. (2016) performed a huge ensemble experiments, of which the dataset is called as d4PDF. d4PDF has outputs of 20-km-mesh model (d4PDF20) with 50 and 90-ensembles of the present (1951-2010) and future (2051-2110) climate, respectively. d4PDF enables us to estimate probabilistic future changes. On the other hand, for analysis of recent extreme events, we used a composite rainfall data from X- and C-band polarimetric radar (CX composite), which has 250-m-mesh and 1-min resolution and can estimate the quantity of rainfall with high accuracy. We also use the data of Meso scale model (MSM) by Japan Meteorological Agency, which has 5-km-mesh resolution.

2.2 The characteristics of two events: the event in 2018 and 2017

Both of BHR18 and BHR17 were unprecedented events from different spaciotemporal scale. The feature of BHR18 was widespread, long-lasting, and relative weak precipitation while that of BHR17 was very localized and high intensive precipitation. Figure 1 shows the accumulated amount of precipitation made from CX composite and 10-days averaged atmosphere of sea level pressure (SLP) and water vapor flux made from MSM of these two events. The duration for accumulation is 60 hours for BHR18 and 24 hours for BHR17. The area highlighted by red dashed line in left figure of BHR18 is corresponding to the area of accumulated precipitation showed in left figure of BHR17. We can see BHR17 was very localized event occurred at narrow area compared with BHR18. Moreover, in terms of atmospheric circulation, Okhotsk high was westward protruding and Pacific high was northward protruding in BHR18 while Pacific high was very westward protruding in BHR17 and rich vapor invaded from the southwest into Japan.

3. Results

3.1 Future change of the frequency of meso-β Baiu localized heavy rainfall: a review

Osakada and Nakakita (2018a) investigated the future change of meso-β Baiu heavy rainfall by directly picking up the events from precipitation output from June 1st to August 31st of NHRCM05. Figure 2 shows that result. We can see that meso-β Baiu heavy rainfall like BHR17 will increase almost everywhere in Japan. Especially, Hokkaido, Tohoku or Hokuriku, where have seldom experienced meso-β Baiu heavy rainfall in present climate, will face a new risk of meso-β Baiu heavy rainfall in the future. Moreover, Osakada and Nakakita (2018a) also showed that the occurrence frequency of atmospheric pattern of westward protruding Pacific high and southwesterly water vapor inflow as shown in the right of Figure 1 will also increase in the future using a huge ensemble of d4PDF20.

3.2 Future change of accumulated precipitation

Osakada and Nakakita (2018b) showed that the accumulated amount of meso-β Baiu heavy rainfall will increase in the future using the heavy rainfall database picked up by Osakada and Nakakita (2018a). Then, we applied the same analysis to BHR17 and BHR18. For BHR18, we picked up some meso-β scale heavy rainfall events that meet the criteria used in Osakada and Nakakita (2018b) highlighted as black circle in the left of Figure 1. The criteria are based on the rain over 50mm/h (refer to the detail as Osakada and Nakakita, 2018b). The result is shown in Figure 3.

Blue triangles (red circles) mean Baiu heavy rainfall events picked up from present (future) climate of NHRCM05 and colorful squares represent the past events. Black squares show BHR18 and pink shows BHR17. The black squares are located below among the events in present climate, which means that BHR18 was not rare even in present climate from meso-β scale. It is indicated that we need to capture the feature of BHR18 from larger scale than meso-β. On the other hand, the pink square is located above among present climate and middle among future climate, which means that BHR17 was very extreme in present climate and would not be so rare even in future climate.

3.3 Future change of water vapor inflow

Then next, we analyzed the future change of the amount of water vapor inflow into Japan. Water vapor inflow *F* is defined as sum of the value of normal vector that pass through N. Lat. 30 from E. Lon.128 to E. Lon.138 and normal vector that pass through E. Lon. 128 from N. Lat.30 to N. Lat. 33 by setting north and east as positive. We analyzed the sum of *F* for 3-days because BHR18 lasted for over 3-days. We calculated the sum of *F* for 3-days using d4PDF20 from June to August, and the Figure 4 shows the relative frequency of the sum of *F* for 3-days.

The amount of water vapor when BHR18 occurred is located around the tail of distribution in present, in short, abundant water vapor continuously flowed in Japan during BHR18 and that conditions was very rare in present climate. Moreover, the amount of BHR18 is considerably different from that of BHR17 and will relatively frequently occur in future climate. The amount of daily water vapor of BHR18 is also much different from that of BHR17 (not shown).

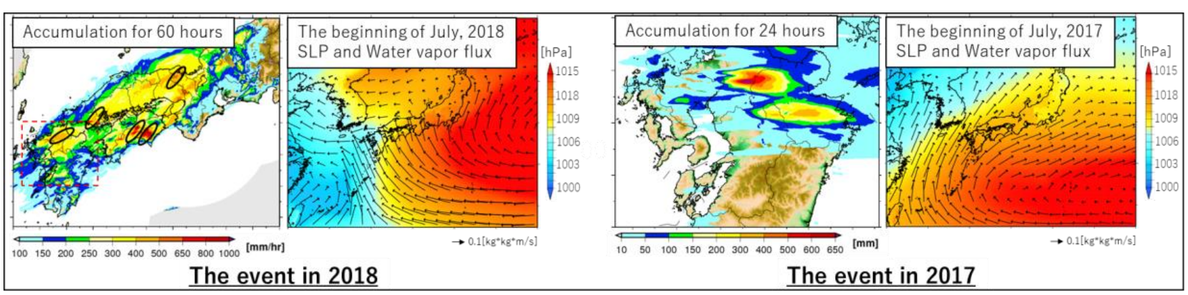

Figure 1. The amount of accumulated precipitation from CX composite and 10-days averaged atmospheric conditions from MSM of sea level pressure (color) and water vapor flux (arrow) for the event in 2018 and 2017.

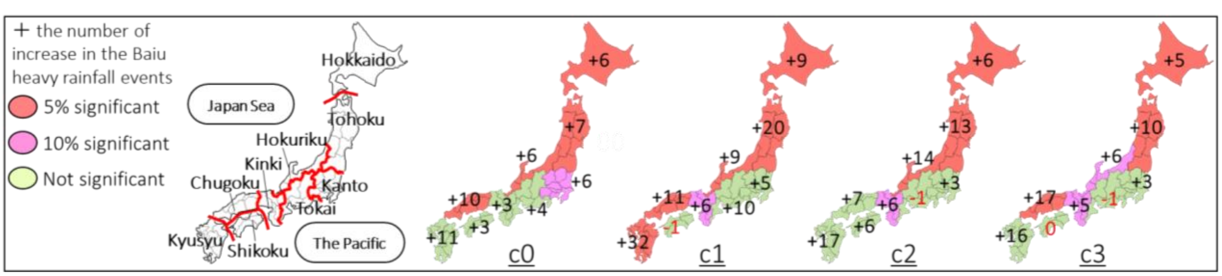

Figure 2. Future change of meso-β Baiu heavy rainfall obtained from NHRCM05 (Osakada and Nakakita, 2018a).

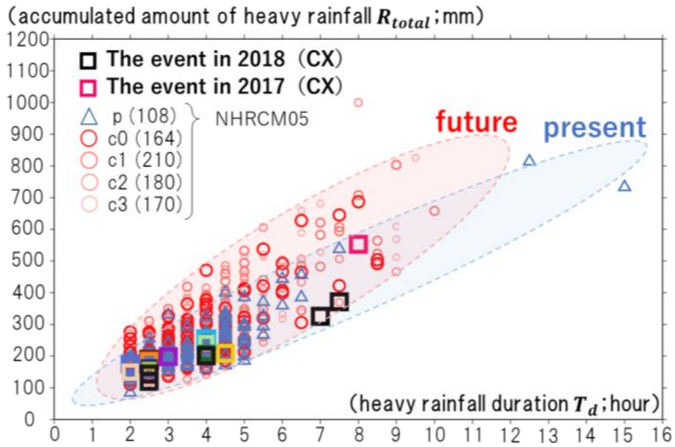

Figure 3. The future change of accumulated amount of meso-β Baiu heavy rainfall.

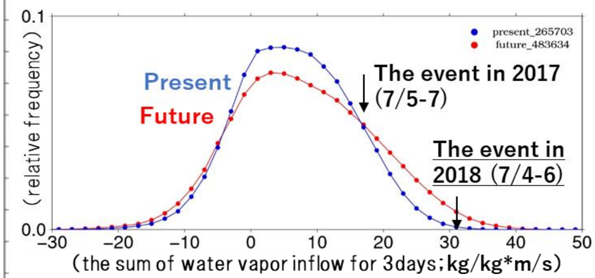

Figure 4. The relative frequency of 3days water vapor inflow from d4PDF20.

3.4 Future change of atmospheric pattern

As described above, Osakada and Nakakita (2018a) investigated the occurrence frequency of atmospheric patterns prone to meso-β Baiu heavy rainfall like BHR17 and showed that its frequency will increase in the future by using a clustering method called as SOM. We also estimated the future change of atmospheric pattern when BHR18 occurred and found that its frequency will not increase in the future (not shown). However, this analysis is still insufficient in terms of statistically significance so deeper analysis is needed as a future work.

4. Summary and future work

In this research, we investigated the global warming impact on Baiu heavy rainfall considering two extreme events in 2018 and 2017 occurred in Japan. The frequency of meso-β Baiu heavy rainfall like BHR17 will increase and the atmospheric pattern of BHR17 will also more frequently occur in future (Osakada and Nakakita, 2018a). Moreover, the accumulated amount of heavy rainfall for BHR17 was rare among the present climate and would not so rare among the future climate. On the other hand, for BHR18, the accumulated amount of heavy rainfall from meso-β scale was not rare even among the present climate. However, the amount of water vapor inflow into Japan was very extreme among the present climate while that of BHR17 was not extreme.

As above, the abnormality and the future change of these two events were totally different in terms of spaciotemporal scale. As future work, we need to deeply investigate the future change of widespread and long-lasting heavy rainfall like BHR18 by directly checking the precipitation output of NHRCM05 and estimating the future change of atmospheric patterns.

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