Identifying future changes of extreme precipitation in Japan using 720-year 5-km-grid regional climate experiments

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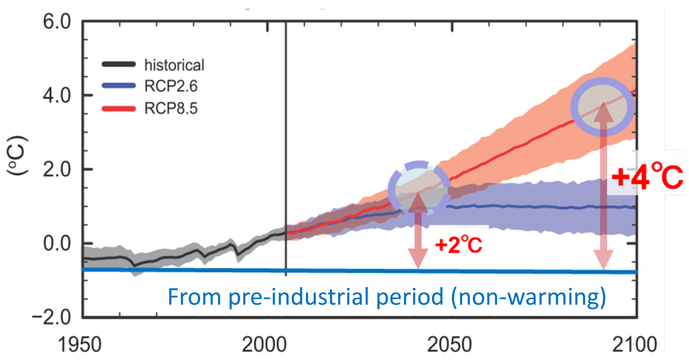
1. Introduction and summary

To evaluate the impacts of global warming on local-scale extreme precipitation in Japan, 720-year ensemble dynamical downscaling is conducted by a regional climate model with a 5 km grid spacing. Comparing the historical and 4K warming climates, the annual maximum daily and hourly precipitation are enhanced over Japan due to global warming. The increasing rate of annual maximum daily precipitation is larger over the coast of the Pacific Ocean in eastern and western Japan and the northern parts of Japan. The periods in which the extreme daily precipitation increases in each region depend on the movement of the Baiu front and the number of typhoons from June through September. The local-scale quasi-stationary band-shaped precipitation system, which is called senjo-kousuitai, is well reproduced in the 5 km experiments and shows increases in frequency and intensity under the 4K warming condition.

Kawase H. et al. 2023, Identifying Robust Changes of Extreme Precipitation in Japan From Large Ensemble 5-km-Grid Regional Experiments for 4K Warming Scenario, JGR-Atmosphere, 128, https://doi.org/10.1029/2023JD038513.

2. Experimental design

■ Database for Policy Decision-Making for Future Climate Change (d4PDF)

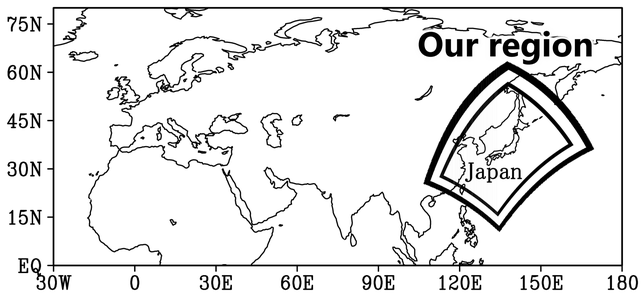


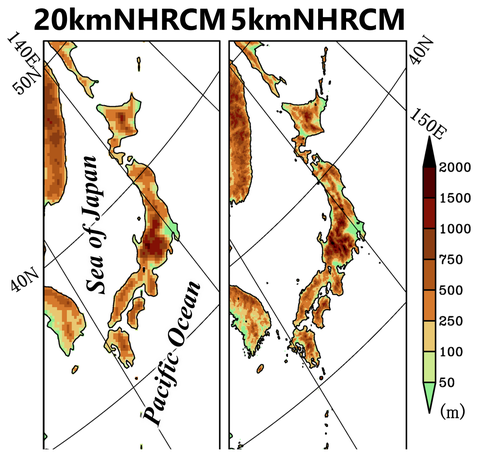
d4PDF is created by 60-km Meteorological Research Institute Atmospheric General Circulation Model (MRI-AGCM) and 20-km Nonhydrostatic Regional Climate Model(NHRCM).

Full set of d4PDF (60km MRI-AGCM)
- **Historical climate simulation:** 1951-2010, 100 ensemble members
- **Non-warming simulation*:** 1951-2010, 100 ensemble members
- **+2K future climate simulation*:** 2031-2090, 54 ensemble members
- **+4K future climate simulation*:** 2051-2110, 90 ensemble members

*Long term trends were eliminated in the non-warming, +2K, and +4K simulations.

■ 5-km dynamical downscaling from d4PDF

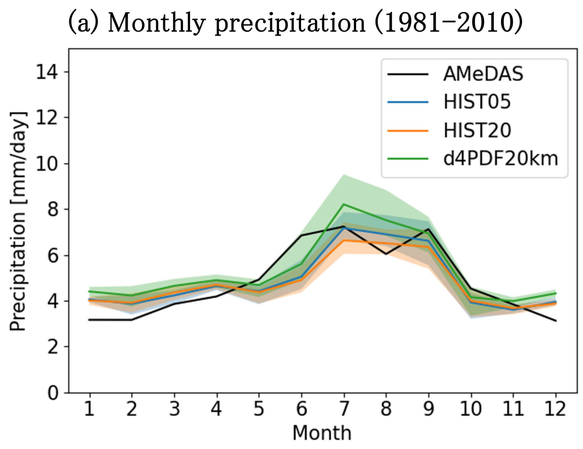


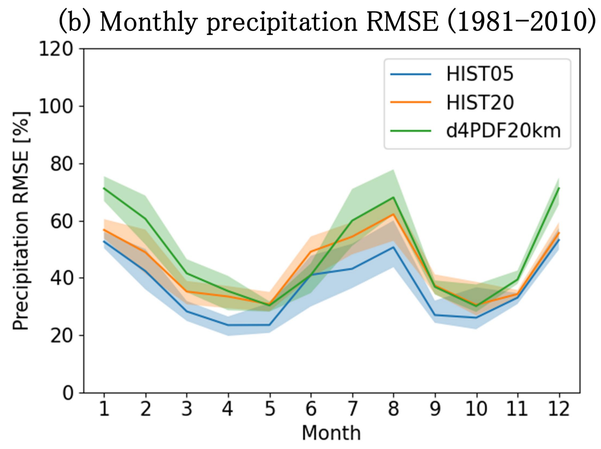


Regional model：NHRCM [Sasaki et al. 2008]
Grid spacing：20km -> **5km** (One-way nesting)
Boundary condition: d4PDF [Mizuta et al. 2017]
Historical run (HIST): 1951-2010 (60yrs), 12 member [Total: 720 years]
Future runs (+4K): 60yrs x 12 member [Total: 720 years]
Integration: Our dynamical downscaling is separately conducted in each 12-month with about 40-day spin-up duration. Continuous time integrations were continued from July 20 and 24 in NHRCM20 and NHRCM05, respectively, to August 31 in the following year, e.g., July 1951 to August 1952 and July 2010 to August 2011.
Land surface: Improved MJ-SiB (iSiB)
Planetary boundary layer: MYNN Level 2.5 (Nakanishi and Niino 2004)
Cumulus convection: KF scheme (Kain and Fritsch 1990; Nakano et al., 2012)

3. Results

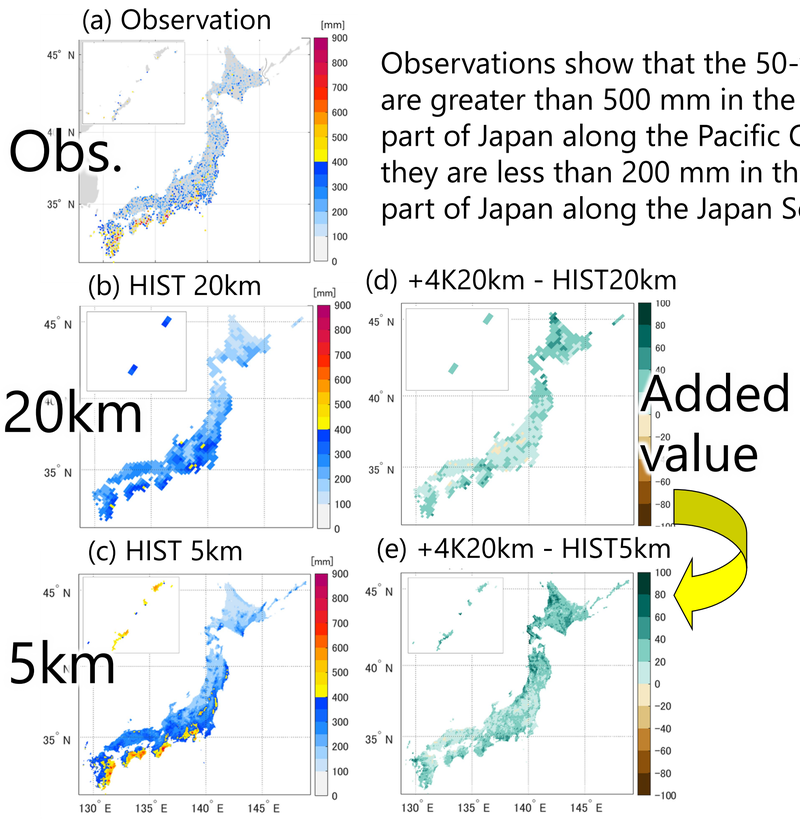
3.1 Biases and RMSEs of monthly precipitation





Black, blue, orange, and green lines show Observation (AMeDAS), HIST5km, HIST20km, and old 20 km simulation in the d4PDF. Shadings represent the variation between the maximum and minimum of ensemble members. Precipitation at the model grid point nearest to the observational station is compared to the observation.

3.2 50-year return values of annual maximum daily precipitation

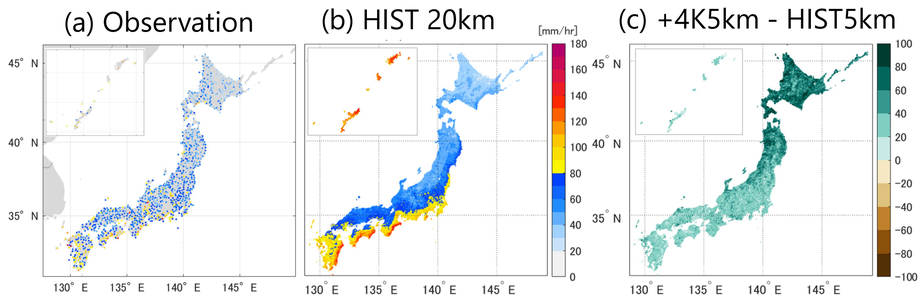


Observations show that the 50-year return values are greater than 500 mm in the southwestern part of Japan along the Pacific Ocean, whereas they are less than 200 mm in the northwestern part of Japan along the Japan Sea.

HIST20 underestimates extreme precipitation, particularly, in the southwestern part of Japan. HIST05 reproduces extreme precipitation fairly well in the southwestern part of Japan.

The +4K20 projection shows that the spatial distribution of future changes in the 50-year return values is similar to that in the +4K05, but the signs of the changes are opposite in the high mountainous areas of central Japan.

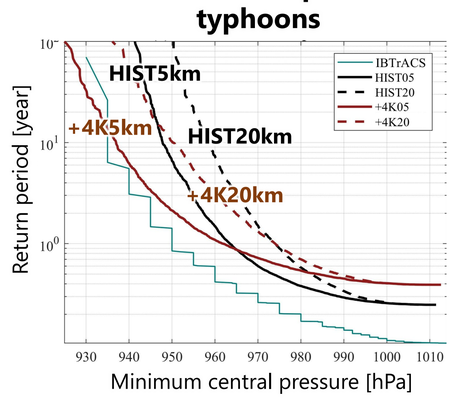
3.3 50-year return values of annual maximum hourly precipitation



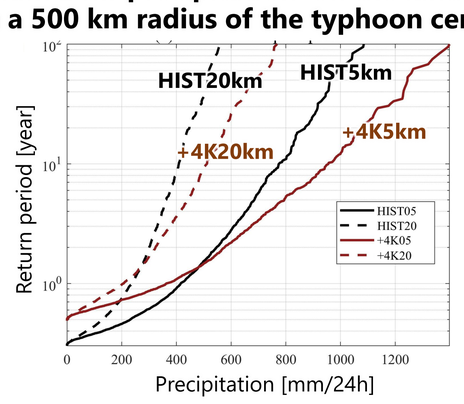
The annual maximum hourly precipitation will increase in the northern part of Japan by 60–100%, while the other regions show moderate increases of 30%, on average.

3.4 Heavy precipitation induced by Typhoon (tropical cyclone)

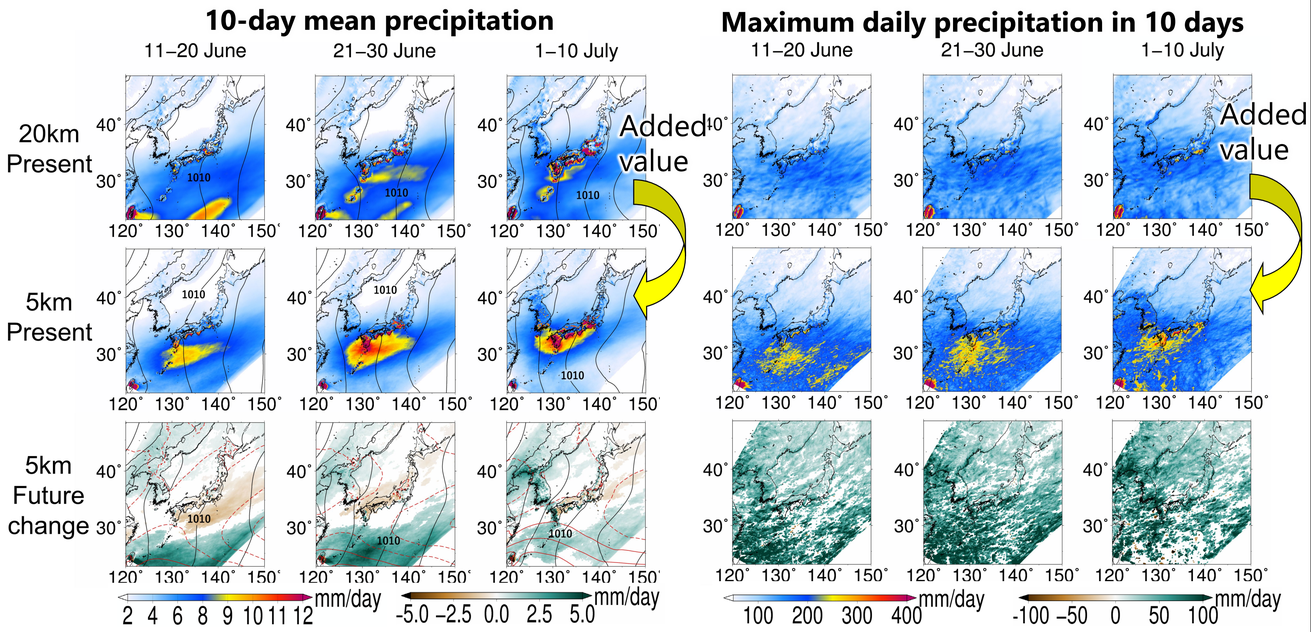
Minimum central pressure of typhoons



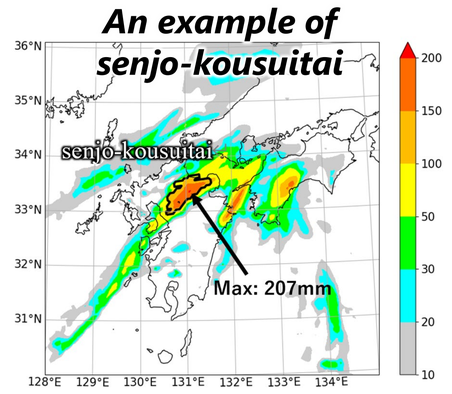
Maximum 24hr precipitation on the land of Japan within a 500 km radius of the typhoon center

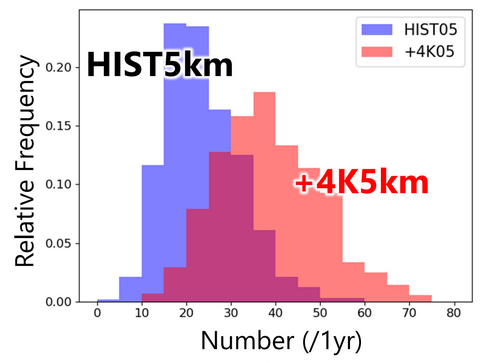


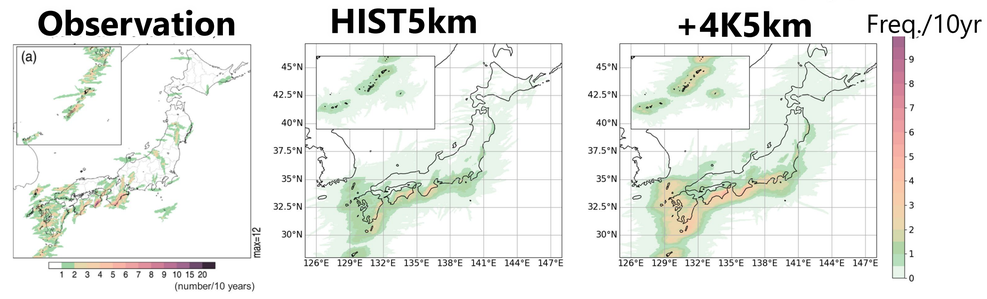
3.5 Heavy precipitation induced by Baiu (Meiyu/Chang-ma) front



3.6 Heavy precipitation induced by quasi-stationary band-shaped precipitation system (Senjo-kousuitai in Japanese)







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