Assessment of Future Landslide Risk in Japan Using Large Ensemble 5-km Regional Climate Projections

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Background

Beyond our experiences, in recent decades, extreme rainfall events have broken new records of peak rainfall intensity and accumulated amounts, and most events have consequently triggered massive and devastating floods and landslide disasters across Japan. Analysis of historical rain gauge observations indicates a statistically significant increase in the intensity and frequency of extreme precipitation on hourly, 3-hour, and daily scales. Not only examining historical rainfall trends, understanding future climate trends under global warming is also of importance for ensuring a safer and more sustainable living environment. To explore future trends in extreme precipitation over the Japanese archipelago, a 720-year ensemble dynamical downscaling was recently conducted using a regional climate model with a 5-km grid spacing under the warming scenarios of 2K and 4K increases (Kawase et al., 2023). This dataset, known as the Database for Policy Decision Making for Future Climate Change (abbreviated as d4PDF_5km), predicts that annual maximum daily and hourly precipitation are enhanced over Japan due to global warming, and local-scale heavy precipitation is also projected to increase in frequency and intensity under the 4K warming scenario. Combined with historical observation and future climate projections, these projected future rainfall features are likely to intensify the risk of future landslide occurrences. In light of this condition, we aim to statistically assess the future risk of landslides in a changing climate by using the d4PDF_5km dataset and the method of current landslide early-warning system on each 1-km grid across Japan. This study aims to reveal the spatiotemporal distributions of landslide risk nationwide and across different regions in terms of geological factors of plate tectonics and lithology.

Data and method

The study analyzes two datasets, including Radar/Raingauge-Analyzed Precipitation published by JMA (referred to as Radar-AMeDAS) and the climate model experiments d4PDF_5km. The historical observation data of Radar-AMeDAS covers 23 years (1998-2010) at a spatiotemporal resolution of 5-km per 1-hour. With the same spatiotemporal resolution, d4PDF_5km datasets are simulated based on four scenarios, including present climate with sea surface temperature (SST) without a warming trend (HIST_NAT), present climate (HIST), RCP2.6 (+2K), and RCP8.5 (+4K). Each scenario contains 12 ensemble members based on variable SST patterns extracted from CMIP5 simulations. The landslide risk is assessed using the current thresholds in the landslide early warning system (see Wu et al., 2020 for details).

Analysis results

With the large ensemble of d4PDF_5km, the analysis can be statistically reliable and significant. Our analysis quantitatively reveals that landslide risk is increasing in in western Japan during early summer (July) and in eastern Japan during later summer (September). Notably, a slight increasing landslide risk exhibits in the summer in Hokkaido, the northern region of Japan that is historically less experienced rainfall-triggered landslide. Also, the change of frequency distribution of hourly rainfall in the 100-yr return period highlights the feature of future extreme rainfall patterns.

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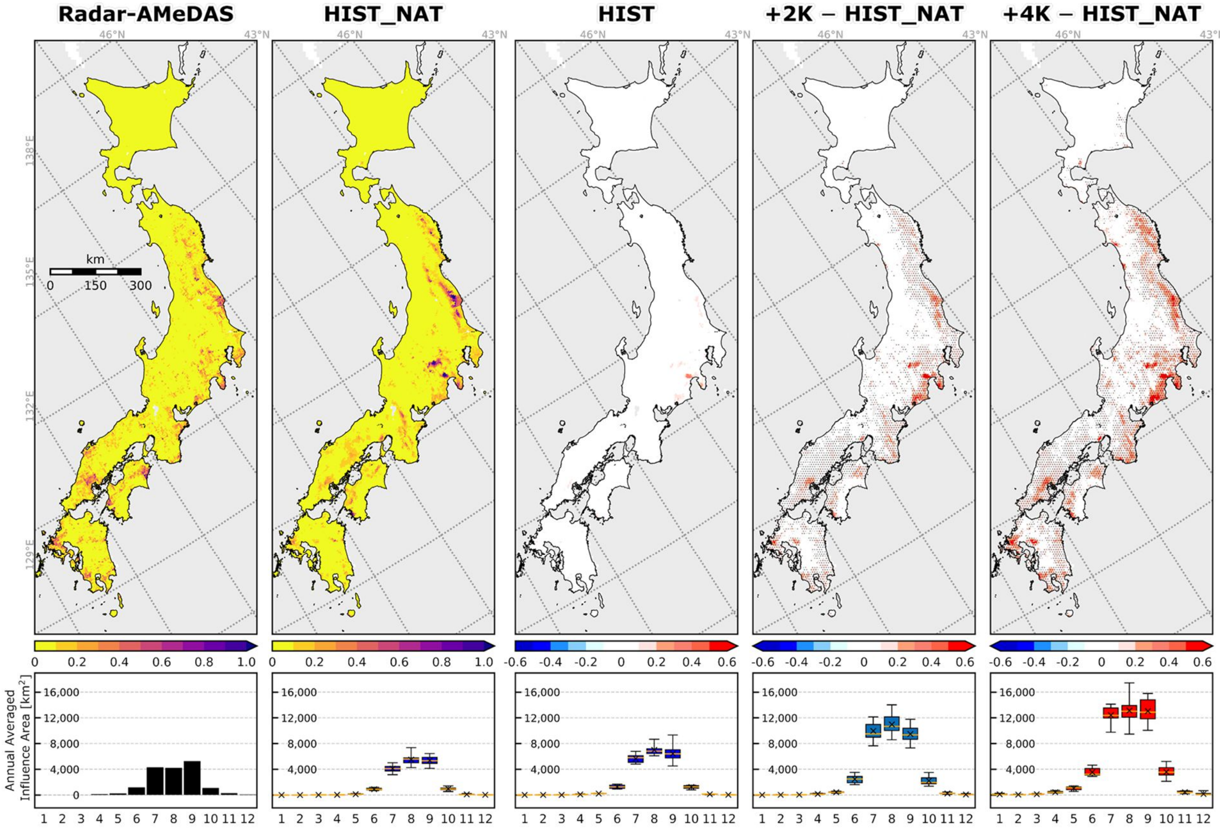

Fig. 1 Annual averaged landslide occurrence under the historical observation (Radar-AMeDAS), and climate model experiments (HIST_NAT); the deviations of NIST, 2K+, 4K+ from the HIST_NAT. The lower low shows the annual averaged affected area in each month.

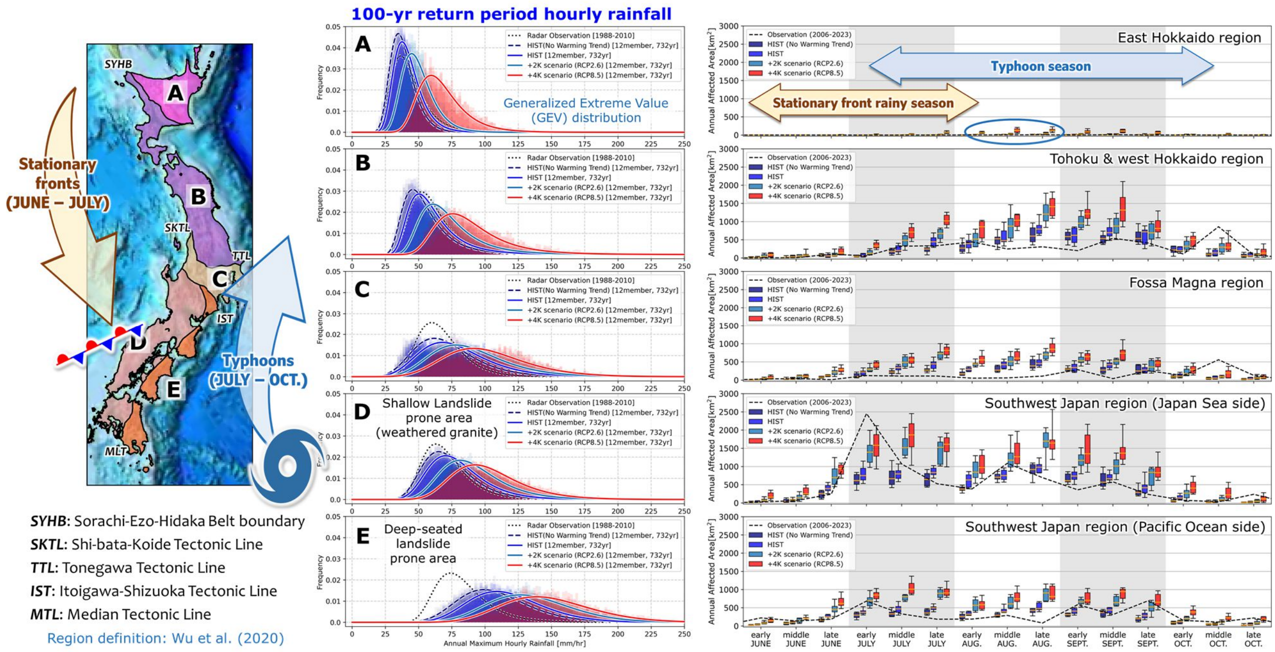

Fig. 2 The frequency distribution of hourly rainfall in the return period of 100-yr in variable regions in terms o geological factors of plate tectonics and lithology. The most righthand side shows the annual averaged affected area in early, middle, and late periods of each month in the rain season (June to October).

References

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