Heavy rainfall variation under warming and cooling climates for quantifying fluvial geomorphic response in SE-Hokkaido

*Takahisa Furuichi[1,2], Masaru Inatsu[3]

1. Forestry and Forest Products Research Institute, 2. University of the Sunshine Coast, 3. Hokkaido University

General circulation models (GCMs) predict rainfall intensity and distribution in the future but also have a potential to reconstruct those in the past, which in previous studies have been assessed by sample- and point-based proxy data such as pollen records and isotope signatures. The quantitative and spatial estimates of the rainfall by GCMs should allow quantitative analysis of past, as well as of future, fluvial geomorphic processes triggered by heavy rainfall. To illustrate the estimates, we focus on southeastern Hokkaido, Japan, where vast alluvial fans and fluvial terraces formed in the past and rainfall-induced landslides, debris flows and floods recently caused disasters. Large ensemble climate simulation data were provided with a 60-km x 60-km resolution and employed to estimate the variation in frequency and intensity of the heavy rainfall (> 50 mm/d) and extreme rainfall (> 150 mm/d). Four climate scenarios of (1) the preindustrial era as NAT, (2) the historical record from 1950 to 2010 as HIST, (3) the 2 ℃ warming relative to 1850 as 2 ℃ and (4) the 4 ℃ warming relative to 1850 as 4 ℃, were applied. Ensemble-mean annual counts of the grid-points with the heavy rainfall increased by the 2 ℃ and the 4 ℃, compared with NAT. Linear extrapolation of the estimates into the negative temperature change suggests that the heavy rainfall could not occur under a colder climate with its global-mean temperature below approximately -6 ℃ relative to the NAT situation. Both ensemble-mean area-averaged rainfall intensity in a heavy rainfall event and the frequency of the extreme rainfall event increase by the 2 ℃ and the 4 ℃. Patterns of rainfall distribution and sea level pressure indicate that the heavy rainfall events are consistently caused by southeasterly influx of warm moisture-laden air from the western North Pacific, partly due to typhoons. These findings should allow better quantitative analysis of future fluvial geomorphic processes in southern Hokkaido, where a substantial amount of sediments that was accumulated in the past cold climate remains in the catchments. The findings also indicate quantitative paleoclimatic pictures that the heavy rainfall (> 50 mm/d) likely occurred during Marine Isotope Stage (MIS) 3 and 4 in southeastern Hokkaido, which presumably induced effective hillslope and fluvial processes, but unlikely occurred during MIS 2.

Keywords: climate change, d4PDF, heavy rainfall, fluvial landform

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