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Strong increase in the flood frequency of the River Meuse in response to Holocene and future climate and land use change: a new perspective for long-term modelling

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Although long-term changes in climate and hydrological systems can have profound socio-economic impacts, it is difficult to examine such changes due to the lack of long-term observations. Even in river basins with relatively long time-series of observed discharge, records dating back longer than a century are scarce. Hence, hydrological models used to simulate the effects of future climate change are calibrated and validated against relatively short (decadal to one century) discharge records. Given that future climate is expected to change beyond the climate variability of the 20^{th} Century, the application of these models to the future is problematic. To address this problem we have coupled a climate model (ECBilt-CLIO-VECODE) and a hydrological model (STREAM) in order to simulate flood frequencies of the Meuse river (northwest Europe) in two long time-series: 4000-3000 BP (natural situation), and 1000-2100 AD (includes land use and human-induced climate change). The climate model is forced by changes in greenhouse gas concentrations, orbital parameters, volcanic aerosols, and solar irradiance; for the 21^{st} Century the model is forced according to SRES emissions scenarios A2 and B1. For 4000-3000 BP we assume that the basin was almost fully forested; for 1000-2000 AD we reconstructed land use based on historical sources; for the 21^{st} Century land use was based on EURURALIS scenarios

A2 and B1. For 4000-3000 AD the recurrence time of large high-flow events (discharge > 3000 m^3s^{-1}) is 77 years; for 1000-2000 AD the recurrence time increases to 65 years. On this timescale almost all of the increase can be ascribed to the effects of land use change (especially deforestation). The simulation results are in agreement with (qualitative) proxy records available from the basin, and are therefore validated to some extent against conditions different to those of the 20^{th} Century. Hence, this method provides added confidence to the results under future climate change scenarios. In the 20^{th} Century the recurrence time of large high-flow events is 40 years; the simulation results of the 21^{st} Century show a strong shortening of this recurrence time to 20 and 25 years under the A2 and B1 scenarios respectively. On this timescale almost all of the change can be attributed to the effects of climate change, and mainly increased precipitation (mean and intensity), especially in the winter half-year. The magnitudes of extreme high-flow events (recurrence time = 1250 years) were estimated by fitting Gumbel plots to the simulated annual maximum discharges for the periods 1000-2000 AD (4072.9 m^3s^{-1}), 20^{th} Century (4136.6 m^3s^{-1}), 21^{st} Century (A2 scenario) (4615.2 m^3s^{-1}), and 21^{st} Century (B1 scenario) (4350.2 m^3s^{-1}). The results suggest that the potential for serious flooding will be significantly greater in the 21^{st} Century than during the last century.