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Elucidating the impact of global warming levels to agricultural droughts in Europe

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Global warming may exacerbate future soil moisture droughts and bring societies and natural systems to their limits by inducing significant environmental changes and large socio-economic losses. Little is know, however, about the effects of global mean temperature increases of 1-3 K on soil moisture droughts and their extreme characteristics.

Unprecedented high-resolution hydrological simulations are performed with multiple models to provide the first pan-European quantification of the areas and durations of future droughts at a spatial resolution of 5 km from 1950 until 2100. This multi-model ensemble comprises four hydrologic models (HMs: mHM, Noah-MP, PCR-GLOBWB, VIC) which are forced by five CMIP-5 Global Climate Models (GCMs: GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, NorESM1-M) under three RCP scenarios (RCPs: 2.6, 6.0, and 8.5). This results in a 60-member ensemble. The contribution GCM/HM uncertainties were analyzed based on a sequential sampling algorithm proposed by Samaniego et al. (2016). This study is carried out under the umbrela of the EDgE project funded by the Copernicus Climate Change Service (edge.climate.copernicus.eu) and the HOKLIM project funded by the German Ministry of Education (BMBF) (www.ufz.de/hoklim).

The droughts that will result under a global mean temperature increase of 3 K will affect a maximum area that is 40 % (± 24 %) greater, and these extensive droughts will affect 42 % more people, than the droughts that will result under a global mean temperature increase of 1.5 K. Similarly, drought duration increases by a factor of three between these two warming levels. An event like the 2003 drought will become two times more frequent under a warming of 3 K. Redefining the reference period modifies the drought threshold and allows to quantify the extent of required climate change adaptation. For example, adapting to a temperature increase of 3 K implies adjusting to an increase in aridity of up to 8 % (i.e., 35 mm), which is comparable to the soil water deficit during the 2003 event. Consequently, any event of this magnitude will be too small to be classified as a drought in the future. Our results highlight that adaptation measures must contend with levels of aridity that are unprecedented in the historic record.

The overall ensemble uncertainty is dominated by the GCMs in comparison to the hydrologic/land-surface models (HMs). There are, however, marked regional differences. The contribution of GCMs is particularly high in the Continental and Atlantic regions but in Scandinavia, the Southern Alps and partly the Mediterranean, the HMs contribute at least as much to the uncertainty as GCMs. In cold regions, this might be related to the significant effect of snow processes. The rate of snow melt and accumulation varies substantially among the HMs. In semi-arid regions such as the Mediterranean, the soil water restriction to evapotranspiration also varies among HMs. This process substantially influences how fast soils dry and thus drought development.

References

1. EDgE: http://climate.copernicus.eu/edge-end-end-demonstrator-improved-decision-making-water-sector-europe

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3. Samaniego, L., et al. (2016). Propagation of forcing and model uncertainties on to hydrological drought characteristics in a multi-model century-long experiment in large river basins. Climatic Change, 141(3), 435–449.