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The Influence of Anthropogenic Climate Change on (drivers of) Multi-Year Droughts in North-Western Europe

Thomas J. Batelaan[1,2], Karin van der Wiel[2], and Niko Wanders[3]
[1]Wageningen University and Research, Meteorology and Air Quality Group, Nijmegen, The Netherlands (thomas.batelaan@wur.nl)
[2]Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands
[3]Department of Physical Geography, Utrecht University, Utrecht, The Netherlands

The summer of 2018 in North-Western Europe was exceptionally warm and dry, which negatively impacted many sectors. The drought of 2018 was followed by the dry summer of 2019 and the dry spring of 2020. Such multi-year droughts bring unique challenges to the agricultural sector, water authorities and society, and require different adaptation strategies compared to 'normal' single-year droughts. The succession of these dry years raises a question: is it pure coincidence that North-Western Europe experienced such a multi-year drought, or are there physical processes that cause multi-year droughts? Furthermore, in the present era it is obvious to ask whether anthropogenic climate change will amplify multi-year droughts in the region.

We aim to find drivers of multi-year droughts by using *ERA5 reanalysis* data and state-of-the-art *Large Ensemble simulations* from seven climate models. We select multi-year droughts in these datasets based on the *Standardised Precipitation and Evapotranspiration Index* and compare drought characteristics in the 1991-2020 reference period with multi-year droughts towards the end of the century. The models show a strong increase in multi-year drought risk from present-day to the end of the century. The frequency of multi-year droughts near doubles and the median duration of selected drought events increases from 16 months to 50 months. Model differences are substantial, mostly due to differences in temperature trends, but all models agree on the increase in multi-year drought risk. Internal variability is large, indicating a large ensemble approach is indeed required to study this problem.

Next we discuss geophysical drivers of multi-year droughts. Slow-varying ocean processes (through sea surface temperatures) and land processes (through soil moisture) are investigated as potential sources of meteorological conditions that lead to multi-year droughts. We consider the full Earth system, including ocean-land-atmosphere feedbacks, as potential forcing for these events. Summarizing, we will show that anthropogenic warming has potentially large impacts on the frequency, duration and therewith societal risk of multi-year droughts, warranting detailed studies of this topic.