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Decomposing the uncertainties in global drought projection

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Droughts are anticipated to intensify or become more frequent in many parts of the world due to climate change. However, the issue of drought definition, namely the diversity of drought definition, makes it difficult to compare drought projections and hampers overviewing future changes in drought. This issue is widely known and underscored in recent reports of the Intergovernmental Panel on Climate Change, but the relative importance of the issue and its spatial distribution have never been quantitatively evaluated compared to other sources of uncertainty.

Here, using a multi-scenario and multi-model dataset with combinations of three climate change scenarios, four global climate models and seven global water models, we evaluated changes in the frequency of three categories of drought (meteorological, agricultural, and hydrological droughts) by a consistent standardized approach with four different temporal scales of accumulation periods to show how differences among the drought definitions could result in critical uncertainties. For simplicity, this study focuses on one drought index per drought category. Firstly we investigated the disagreement in the sign of changes between definitions, and then we decomposed the overall uncertainty to estimate the relative importance of each source of uncertainty. By a multifactorial ANOVA, uncertainty was decomposed into four main factors, namely drought definitions, climate change scenarios, global climate models and global water impact models, and their interactions.

Our results highlight specific regions where the sign of change disagrees between drought definitions. Importantly, changes in drought frequency in such regions tended to be statistically

insignificant with low ensemble member agreement. Drought definition attributed to18% of the main factor uncertainty at the global scale, and the definition was the dominant uncertainty source over 11% of the global land area. The contribution of difference in the drought category showed a higher contribution to overall uncertainty than the difference in scales. The contribution of scenario uncertainty was the least among the main factors in general, though it is a dominant factor in the far-future in a couple of hotspot regions such as the Mediterranean region. Overall, model uncertainties were the primary source of uncertainty, and the definition issue was less important over large areas. However, definition uncertainty was the primal uncertainty source with significant changes in particular regions, such as parts of high-latitude areas in the northern hemisphere. One needs to pay attention to these regions in overviewing future drought change. Nonetheless, what this study quantified is the relative importance of uncertainty stemming from drought definition that should be avoidable or reducible if one treats drought specifically. Our results indicate that we can reduce uncertainty in drought projections to some extent and get a clearer picture by clarifying hydrological processes or sectors of interest.