Vulnerability of Mediterranean water resources under high-end climate change. Recent development and challenges ahead, from regional to local scales.

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Keywords: High-end climate impacts; Water resources; Mediterranean; Climate services; Adaptation
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Preference for Oral Presentation.

Persistent hydroclimatic trends have prevailed over the Mediterranean region for centuries. These trends are particularly intensified during the last few decades (Cook et al., 2016). Recent advances in detection and attribution studies have provided increased confidence on the causality of anthropogenic climate change on the emerging hydro-climatic and environmental changes (Gudmundsson et al., 2017). At the same time, climate projections indicate that given the current emission pathway, the target of limiting global warming to well below 2^{o}C is being increasingly difficult to achieve and making a much more substantial warming increasingly plausible (Berry et al., 2017; Papadimitriou et al., 2016). In a global context, several Mediterranean countries, mostly on the southern and eastern parts of the region, are facing moderate to high vulnerability to freshwater stress. Figure 1, adopted partly by Koutroulis et al., (2019) illustrates a ranking of country level aggregated freshwater vulnerability of the recent past (1981-2010), and changes in vulnerability at a Global Warming Level (GWL) of 4^{o}C relative to preindustrial, according to different financial and demographic developments as formulated by the framework of shared Socio Economic Pathways (SSPs). By examining changes in future freshwater vulnerability, it is foreseen that Mediterranean will more probably be among the regions with the largest increase in freshwater vulnerability considering high-end climate change.

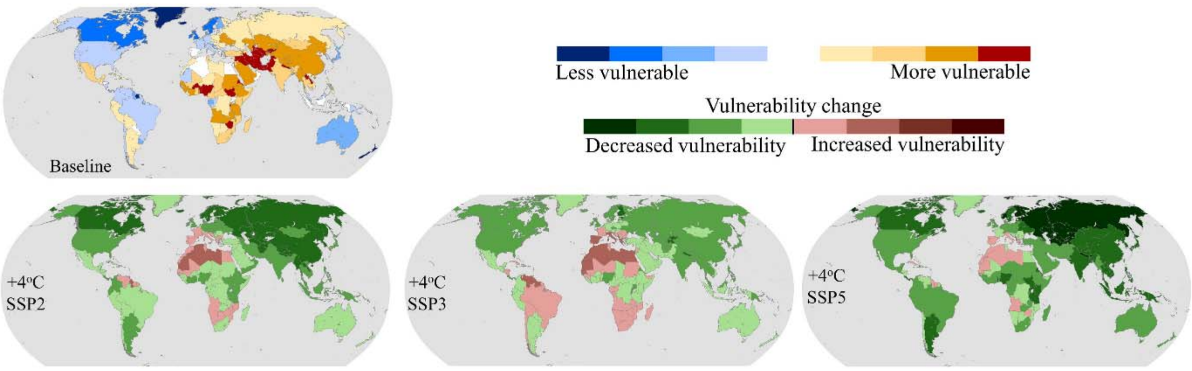

Figure 1: Country level aggregated freshwater vulnerability of the baseline period (top panel), and changes in vulnerability at a Global Warming Level (GWL) of 4^{o}C relative to preindustrial according to SSP2 (left), SSP3 (middle) and SSP5 (right). The average year of crossing the 4^{o}C GWL is 2073 (2068-2090) according to simulations from two high resolution GCMs driven from a CMIP5 subset of GCMs under RCP8.5. The figure is based on results included in Figure 5 from the study by Koutroulis et al., (2019).

This is a combined result of a relatively high sensitivity to water stress, a varying level of adaptation capacity between the Mediterranean surrounding countries and an increased exposure, as simulated by a set of high-resolution global climate models (GCMs), (projecting a high consensus of a drying trend for the area). The increase in exposure is mostly attributed to reduced water availability as a result of decreased precipitation, increased temperature and evaporative demand, and lower levels of runoff and soil water resources. Runoff is the product of complex hydrologic processes and a representative indicator of watershed response. The level of the decrease, or increase in runoff production can be a valuable proxy of future water availability and served, amongst others, as an indicator of exposure. Climate model simulations denote a robust decrease in mean annual precipitation over Mediterranean, which is projected to be more pronounced for higher levels of warming. Similar patterns of runoff changes are simulated by the JULES land surface model at the regional scale as shown in Figure 2 which illustrates changes in mean annual runoff production compared to the recent past (1981-2010) at the global warming level of +4^{o}C relative to preindustrial. There is strong confidence (100% model agreement) of decreases in mean runoff (-5% to -50%) for several parts of the Mediterranean. While global and regional scale studies can serve as valuable sources of information on the direction of projected changes, information of higher detail is needed when moving to the examination of impacts at the local level. Crete Island is lying at the size range of local scale assessments as presented by Koutroulis et al., (2016) on the cross sectoral impacts on water availability at +2°C and +3°C. One of the findings was that a severe decrease of local water resources is foreseen for all the considered scenarios of interlinked climatic and socioeconomic changes. At the GWL of 3°C according to RCP8.5 (crossed from 2047-2076) the current water deficit of 25% is shaped to 37% considering socioeconomic developments consistent to SSP3.

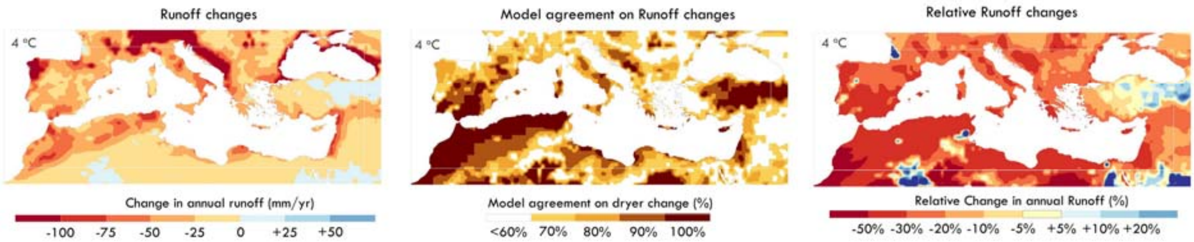

Figure 2: Changes in mean annual runoff production (in absolute and relative values) at a Global Warming Level (GWL) of 4°C relative to preindustrial and the corresponding degree of agreement towards a dryer change for a set of high-resolution climate projections as simulate by the JULES land surface model.

The prospect of a dryer future is expected to cause unfamiliar impacts to several sectors and in particular to the agricultural. Under the prospect of increasing variability and rising water demands, a prior knowledge of precipitation and temperature anomalies, available a few months ahead could be a key information for farmer, stakeholders and managing authorities for drought risk assessment and management. In an attempt to introduce seasonal hydro-meteorological forecasts in local water management Grillakis et al., (2018) developed a site level application with the aim to improve such kind of forecast and make it useful for basin scale applications. Based on hindcasts for precipitation and temperature from the European Centre for Medium-Range Weather Forecasts (ECMWF) System 4 and Met Office GloSea5 systems they tested their forecast skill up to seven months ahead and their ability to capture a limited number of historical streamflow drought events. The results show that both systems provide a skillful ensemble streamflow prediction for one month ahead, with the skill decreasing rapidly beyond that, outlining that several advancements need to be done towards the provision of operational near term predictions at the local scale.

Acknowledgements:
Part of the research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under grant agreement no 603864 HELIX (www.helixclimate.eu) and IMPACT2C under grant agreement no 282746 (www.atlas.impact2c.eu), and from the Horizon 2020 Framework Programme through the project IMPREX (grant agreement no. 641811 www.imprex.eu).

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