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A Multi-dimensional Safe Operating Space Evaluation Framework for Regional Water Resources Systems

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Water resources face increasing pressure globally and regionally driven by rising water, energy and food demand, resulting in extensive resource abstraction and severe environmental consequences, including diminished water quantity and quality, groundwater depletion, and ecosystem degradation. The escalating impacts of climate change further compound these challenges by altering water availability and intensifying extreme events like droughts and floods. Addressing these issues necessitates the urgent establishment of a Safe Operating Space (SOS) for water systems, ensuring reliable and clean water supply for human activities and ecosystems in a changing climate and society.

While various analytical frameworks have emerged to assess components of the water resources SOS, predominantly at a global scale (e.g., water planetary boundaries), their adoption in local and regional water management remains limited. Existing frameworks often lack comprehensive acknowledgement of relevant local and regional dimensions, including hydrological, infrastructure, ecological, and human processes. Moreover, spatial and temporal granularity tends to be insufficient for providing locally and regionally relevant information and for effectively engaging and supporting stakeholders. This is particularly evident in regions with high exposure to water scarcity where the complexity of infrastructure development and resource management is high. To bridge this gap, there is a crucial need to define the SOS framework at decision-relevant spatial scales, involving integrated efforts in data collection and modelling while also fostering a continuous dialogue with stakeholders to facilitate local and regional knowledge exchange.

Our goal is to define and understand the SOS for water systems at local and regional scales to support the co-design of actionable management pathways. We propose a multi-dimensional SOS evaluation framework for local and regional water resources systems (SOS-Water) with four key components: 1) co-development of future scenarios and pathways, 2) integration of water system models (e.g., global hydrological models) and local and regional impact models, 3) identification of

water system indicators for impact assessment with associated failure thresholds, and 4) determination of the multi-dimensional SOS for water systems. The SOS for the local and regional water systems is initially computed under baseline conditions, representing the status quo, and subsequently evaluated under diverse climate and socio-economic scenarios and management pathways. The multi-dimensional SOS, derived from the integrated modelling system, depicts performance for each indicator under varying conditions and is reinforced with different hierarchized objectives defined by the stakeholders through an inclusive and iterative participatory approach. Here, we will present the conceptual structure of the SOS-Water framework and some preliminary results of its evaluation for the Jucar River Basin (Spain), which is subject to significant water scarcity due to ongoing climate-induced impacts.