MEGAWAT

Megadroughts in the water towers of Europe - from process understanding to strategies for management and adaptation

Abstract

Climate change is increasing the frequency of megadroughts, i.e. multi-year extreme droughts such as the dramatic decade-long drought that has hit central Chile since 2010, leading to a state of emergency and dramatic consequences for water resources, ecosystems and the economy. A surge of recent research has responded to the increase in extreme events worldwide, raising awareness of the major disruptions associated with them. Megadroughts are rare and much is still unknown about their drivers, future occurrence and impacts. Most recent research efforts have focused on identifying past events from a variety of paleo records, and understanding their broad climatic causes. The recent, satellite-era megadroughts and their impacts have been investigated only in lowlands, and little is known about their consequences in mountainous regions and about the role that the mountain cryosphere, and glaciers in particular, play in compensating for lack of rainfall and excess evapotranspiration. Europe has experienced megadroughts in the past, and is experiencing droughts and heatwaves with increasing frequency, as testified by the recent heatwaves and droughts of 2003, 2018 and 2022, each more amplified in their consequences than the one before.

The main goal of this project is twofold. First, we address fundamental gaps in our knowledge of the hydroclimatic causes of extreme droughts, to provide a new understanding of meteorological droughts and their impact on land-surface interactions and the water cycle of Europe's water towers, focusing on cascading and compound effects. Second, we develop and demonstrate new adaptation strategies to cope with the extreme length, extent and intensity of future megadroughts.

We focus on Europe's mountains and their downstream areas, and adopt a catchment/basin scale approach to identify megadrought impacts and seek fundamental solutions to water management. Europe's mountains represent its water towers, with the capacity to buffer droughts initially thanks to their storage of water in the form of snow, glaciers and permafrost. Once those storage elements have been substantially depleted however, as in a drought of increasing length, the system will reach a threshold, or tipping point, after which the droughts will be amplified and the functioning of the water-ecosystem is jeopardised.

We build on current research characterising megadroughts in mountain regions worldwide to identify extreme droughts that have happened in Europe in the instrumental period. We then use weather system and trajectory diagnostics to understand the atmospheric processes involved in such events, and use this novel understanding to develop new GCM future simulations that provide extreme drought storylines using ensemble resampling. We will downscale these scenarios to the very high spatio-temporal resolution needed for hydrological impact studies (e.g. 250 m, hourly) and create a novel open access database at Europe-wide scale. We will then use a state-of-the-art, hyper-resolution land-surface model to simulate the cryosphere-hydrosphere-biosphere response to the most extreme droughts of the instrumental past, and to future megadroughts across Europe. We will investigate how persistent precipitation anomalies are amplified as a function of catchment characteristics and memory, and identify the mountain dependent European regions most vulnerable to megadroughts. We will examine the role of glaciers and the mountain cryosphere in buffering extreme droughts and identify cryosphere-biosphere tipping points and thresholds. The new understanding of catchment response to climate anomalies will be used to develop stress-test scenarios for the European mountains under unprecedented, but plausible future drought conditions. Finally, we will provide innovative solution-based adaptation and water resources management strategies.

Our project responds to this timely call by addressing Topic 1 and 2.

Project coordinator: **Francesca PELLICCIOTTI**

INSTITUTE OF SCIENCE AND TECHNOLOGY AUSTRIA - AUSTRIA

Project partners

- CONSIGLIO NAZIONALE DELLE RICERCHE - ITALY
- EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH - SWITZERLAND
- FUTUREWATER SL - SPAIN
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Contact

Francesca PELLICCIOTTI
francesca.pellicciotti@wsl.ch

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