Predicting the future of hydrological systems

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INTRODUCTION

Climatic and hydrological patterns in Europe are already difficult to recognize although we are most likely just experiencing the first wave of impacts of global warming. A look at the trends from the last 20 years outlined in the WMO report on the "State of Global Water Resources 2021" indicates a clear negative trend for terrestrial water storage for the European continent. The more recent WMO report "State of Global Water Resources 2022" shows that in large parts of the Danube basin the observed storage in 2022 was "below" or "much below" the reference 2002-2020 period (Fig.1). What remains mostly unknown is how these changes will evolve, what are the associated risks, and how can they be managed.

Adding on top of the inherent complexity of hydrological systems is the uncertainty related to climate change. There are dozens of global climate models (GCMs) which make different predictions, several emission scenarios to choose from, and climate data is constantly changing as the situation develops. So, the question is, how to make up-to-date, reliable, long-term hydrological predictions facing high levels of uncertainty in a dynamic, developing context? How much water in a given catchment can we count on in 20 or 30 years from now, and what will be the variability of the supply? What are the uncertainty bands for the predictions? Which adaptation strategy makes the most sense?

STATUS QUO PARADIGM OF WATER RESOURCES MANAGEMENT PLANNING

Historical measurements → Flow statistics → ~~Extrapolation into the future~~ → Planning

Climate change will redefine the historical hydrological patterns. European economies have been developing based on a relatively stable availability of water resources. Hydrological patterns were documented and systematized using statistics based on decades of in-situ measurement data, which gave a level of understanding which was considered "fit for purpose". This approach does not provide reliable inputs for long term planning any more.

SOLUTION

Long term planning in water management implies th enecessity of consideration of dozens of possible futures. DHI is currently working on a solution which will enable modelers, engineers and planners to make the necessary steps answering the questions above. The heart of the system will be DHI's high end physics-based spatially distributed, integrated hydrological model - MIKE SHE - which will be supported by a set of tools for climate data downscaling and assimilation, probabilistic screening of uncertainty bands, implementation of adaptation measures with special emphasis on Nature Based Solutions, and finally the mission-critical step – **an easily deployable web-based platform which enables effective dissemination of the results to stakeholders and decision-makers** in a comprehensible and interactive way. The overall idea is to provide a "one-stop-shop" tool-kit which will enable solving most of the engineering challenges related to long-term water resource management and planning in a changing climate dealing with inherently high uncertainty.

STEP 1

Climate models & emission scenarios

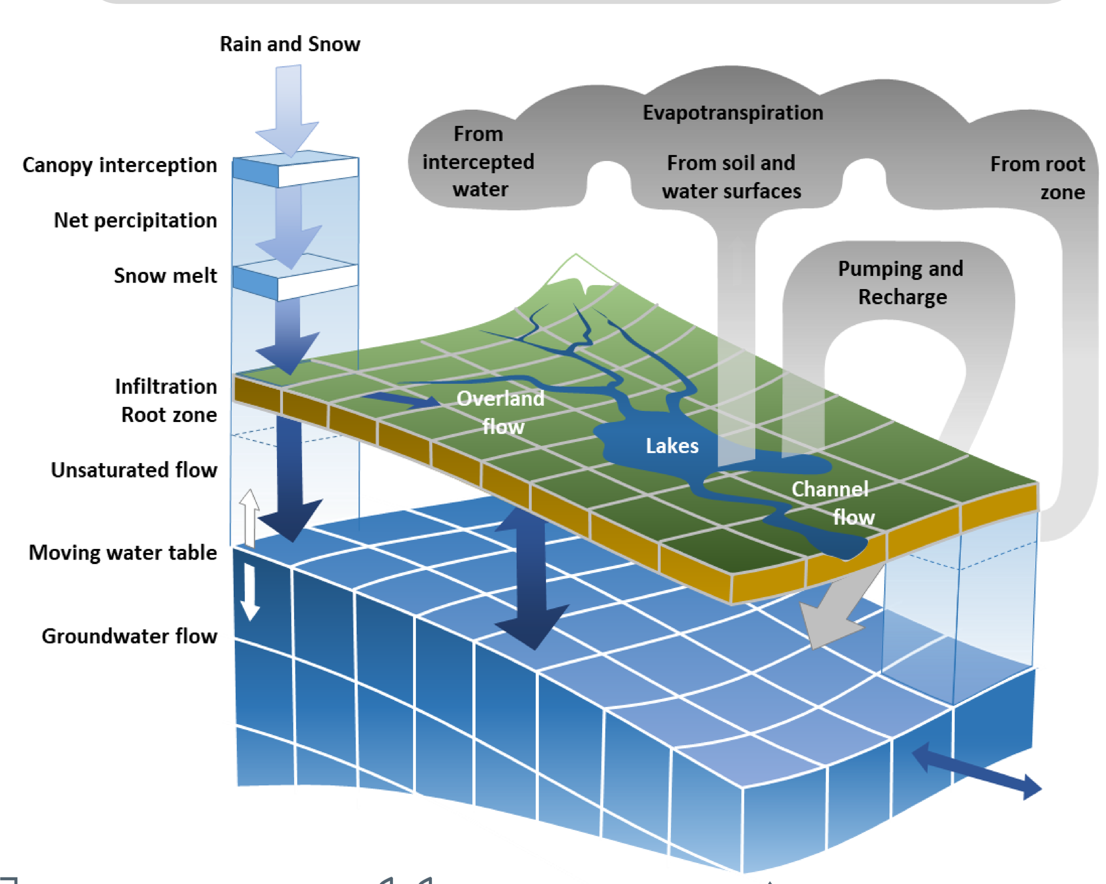
Hydrological input data

STEP 2

Probablilistic screening

STEP 3

Physics-based distributed, integrated hydrological simulations (MIKE SHE)



Understand detailed, vertical soil moisture and vegetation changes

Estimate evapotranspiration and groundwater recharge

Simulate rainfall, snowmelt, runoff and flooding

Understand the impact of land use changes on hydrology

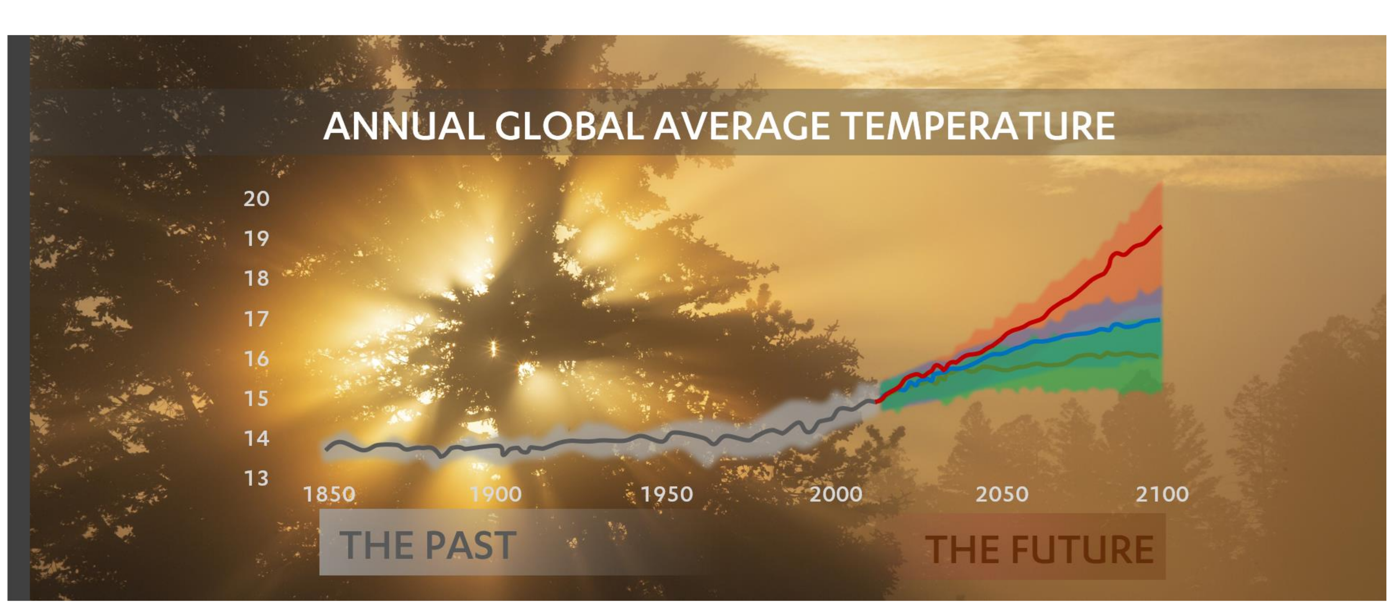
STEP 4

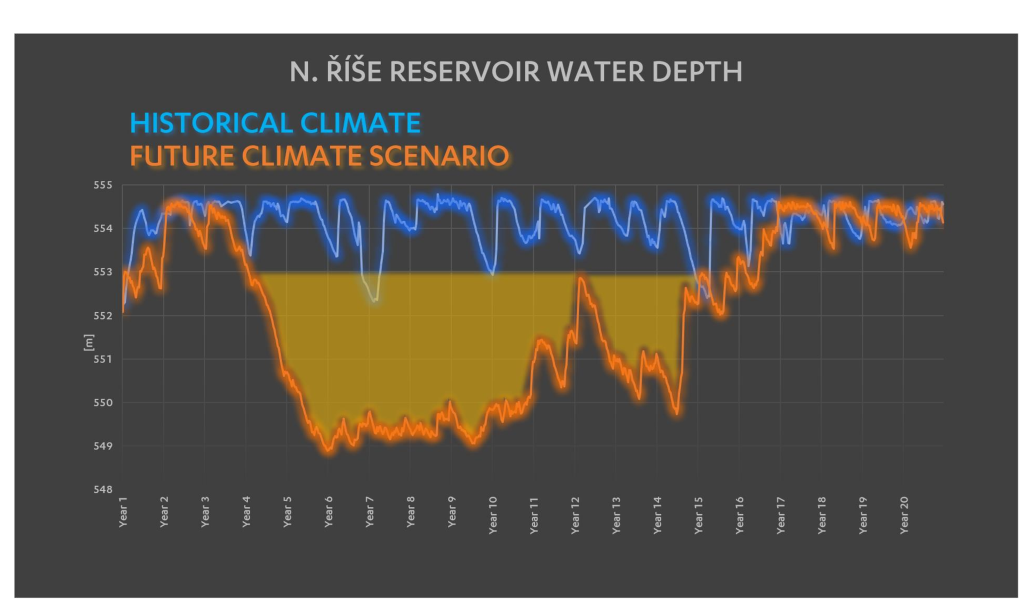
Risk analysis

Testing the efficiency of adaptation strategies

STEP 5

SHARE!
Web based platform for interaction with results and decision suport





An example of a study developed using a similar approach was executed in the Dyje (Thaya) river catchment in Czechia – a part of the Danube basin. The study which covered an area of 12 738 km2 incorporated 1470 km of river models, 55 structures, and 310 water users. The baseline scenario simulation covered the period from 1976 to 2019 followed by simulations of scenarios for the period 2026-2070 including climate change, land use changes and adaptation measures

CONCLUSIONS

- Long term hydrological trends cannot be extrapolated into the future since they have been driven by a climate which does not exist anymore. Thus, there is a need for a change in the paradigm of planning in water resource management to be prepared for a larger variety of future climatic and hydrological scenarios.
- The foundation of such planning should be a solid understanding of the interrelations between climate factors, current and future land use, and responses of the river catchment. The inherent complexity of hydrological processes calls for the application of advanced climate downscaling methodologies and spatially distributed simulation models which include all elements of the hydrological cycle.

References:
[1] WMO 2022 State of Global Water Resources 2021. WMO-No. 1308. Report of the World Meteorological Organization, Geneva.
[2] WMO 2023 State of Global Water Resources 2022. WMO-No. 1333. Report of the World Meteorological Organization, Geneva.
[3] Abbott M.B., Bathurst J.C., Cunge J.A., O'Connell P.E., Rasmussen J. 1986 An introduction to the European hydrological system - systeme hydrologique Europeen, "she", 1: history and philosophy of a physically-based, distributed modelling system. In: Journal of Hydrology, 87 pp. 45-59