Interreg
Danube Region

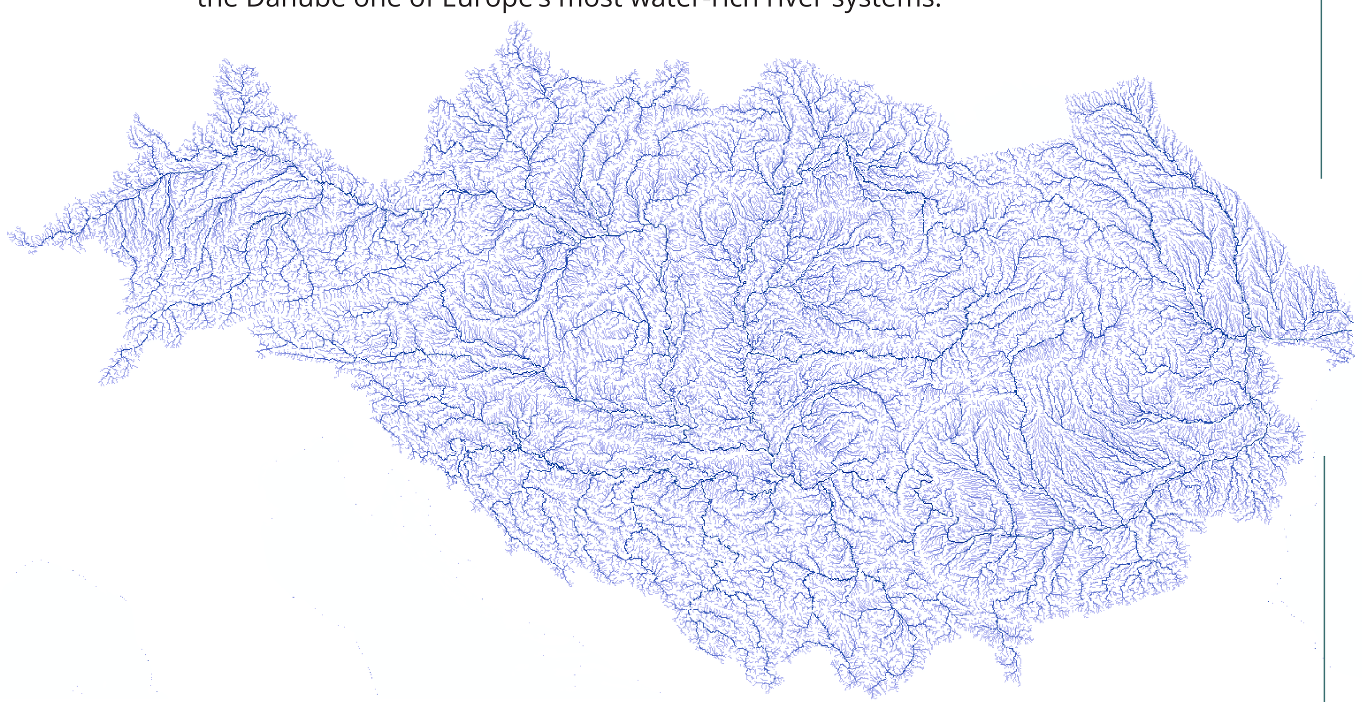
Co-funded by
the European Union

Danube Water Balance

Basin-wide hydrological modelling of the Danube River Basin

The Danube Water Balance project, funded by the Interreg Danube Region Programme and implemented by a transnational consortium of research institutions, water authorities and NGOs from 12 countries, develops a harmonised water balance model for the entire Danube River Basin. The project applies the open-source Community Water Model (CWatM) developed by International Institute for Applied Systems Analysis (Austria) and extended together with the project partners to meet basin-specific needs.

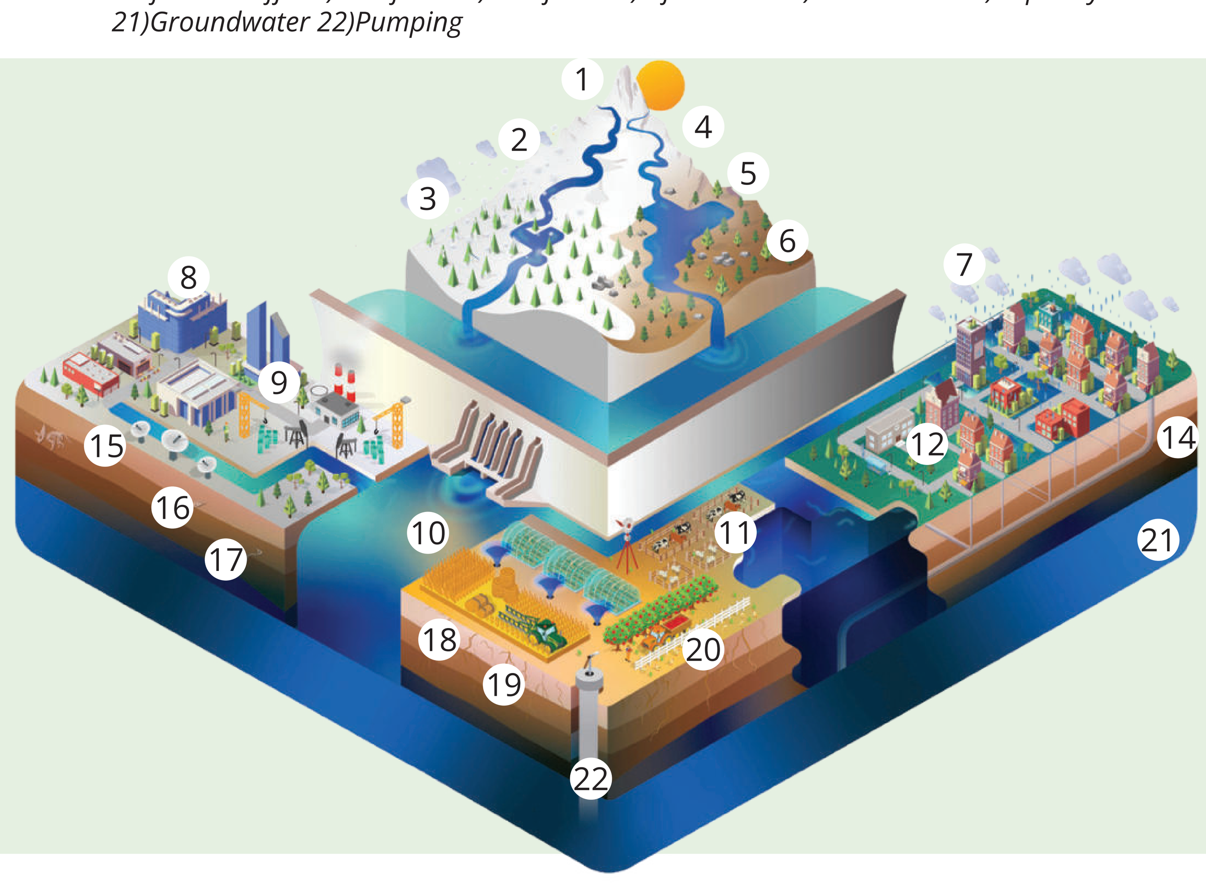
The Danube River Basin (DRB) is the second largest river basin in Europe, covering 801,463 km^2 across 14 countries. The Danube flows 2,857 km from Germany to the Black Sea. Mean annual precipitation within the basin ranges from 500 to 2,500 mm/year, generating approximately 210 km^3/year of renewable water resources. The long-term average discharge at the river mouth is around 6,500 m^3/s, making the Danube one of Europe's most water-rich river systems.



Community Water Model (CWatM)

CWatM operates at 1 arc-minute (~1 km) spatial resolution and daily temporal resolution, combining global and regional datasets (precipitation, temperature, land cover, digital elevation). The model simulates all major components of the water cycle: precipitation, evapotranspiration, soil moisture, snowpack, runoff and river discharge.

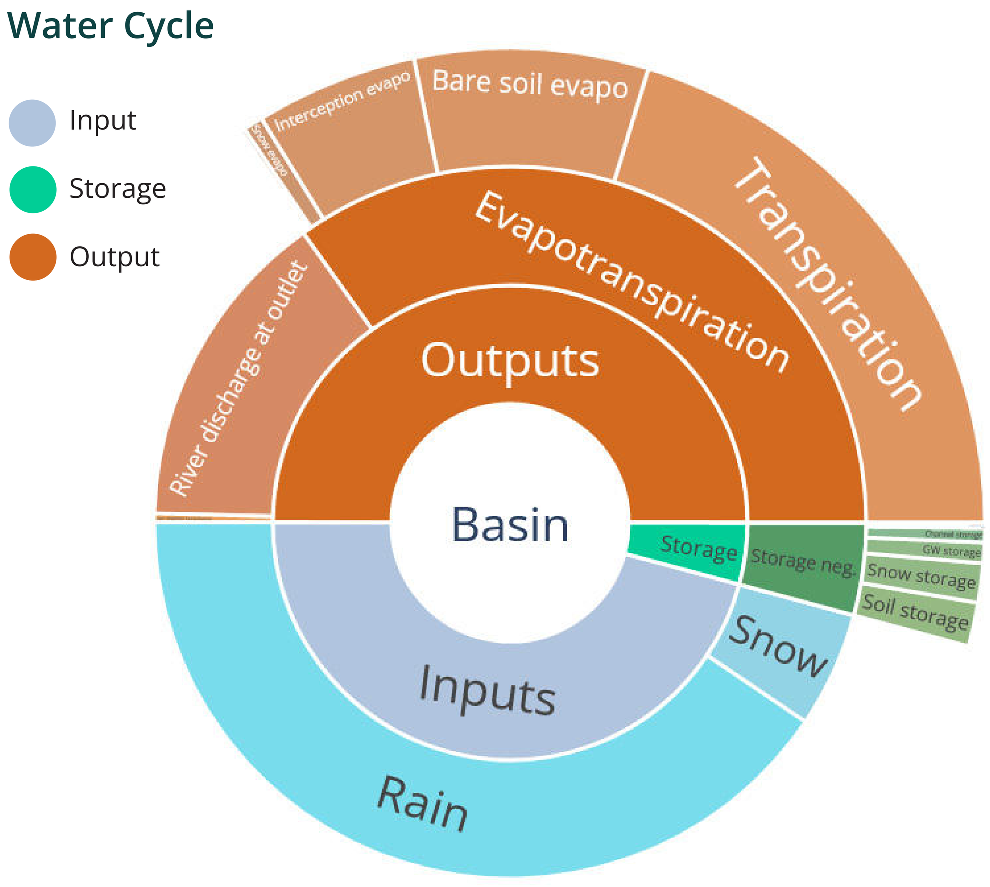
1) Glacier 2)Snow 3)Interception 4)Lake 5)Transpiration 6)Evaporation 7)Reservoir 8)Desalination 9)Industry 10)Agriculture 11)Livestock 12)Households 13)Rainfall 14)Soil 15) Surface runoff 16)Interflow 17)Baseflow 18)Infiltration 19)Percolation 20)Capillary rise 21)Groundwater 22)Pumping



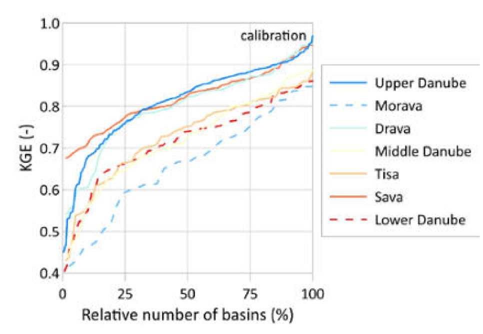
The hydrological model CWatM
- can be used globally (0.5°,5') and regionally (5',30" 1km)
- is open source in python
- it uses globally freely available data
- it includes the major hydrological processes

+Danube - CWatM coupling with
- Open Global Glacier Model
- MODFLOW Model

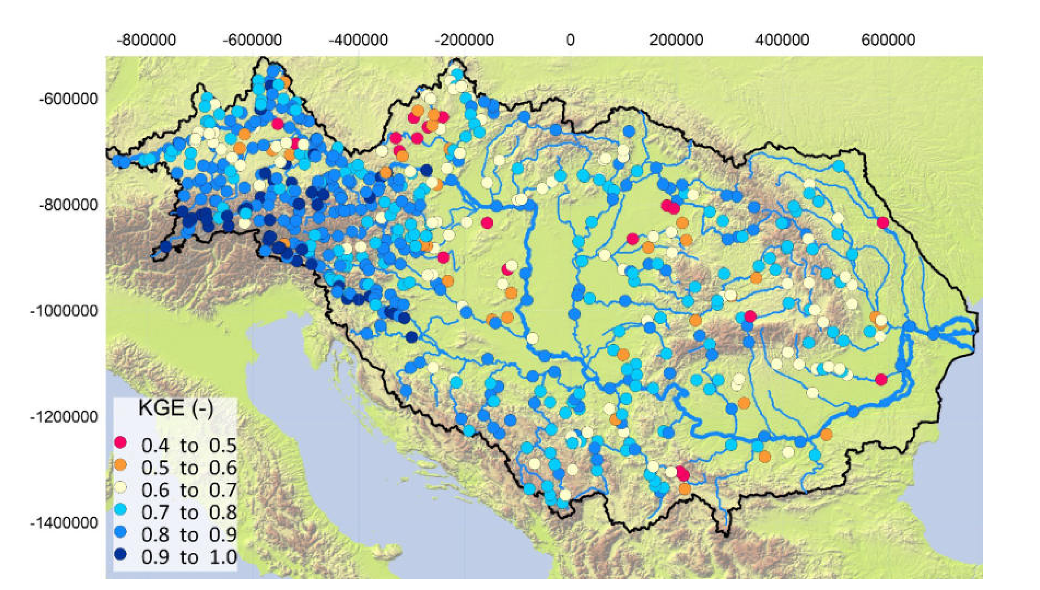
Water Cycle



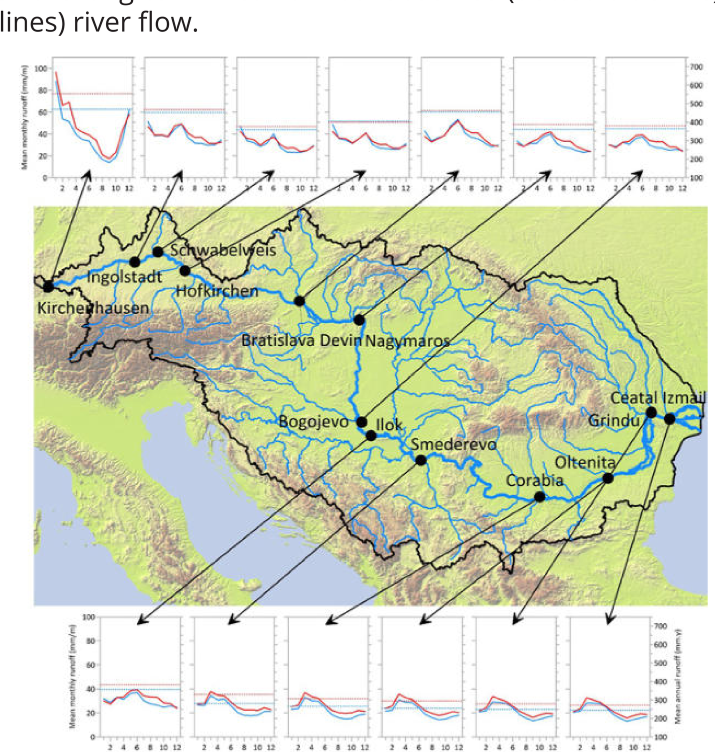
Calibration



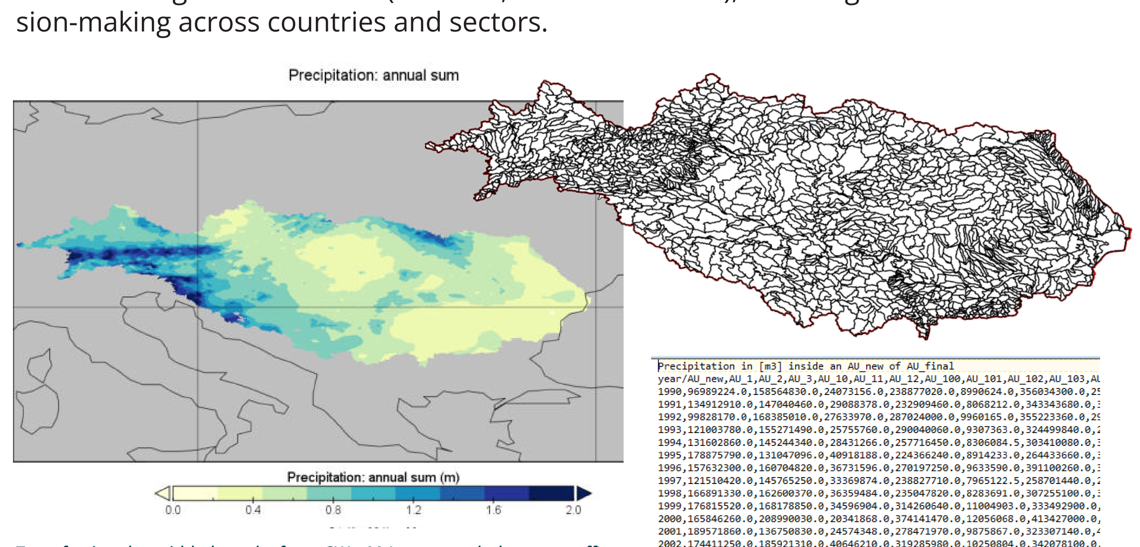
Calibration was performed using discharge observations from 645 gauging stations. An upstream–downstream calibration scheme and multi-objective optimisation (modified Kling-Gupta Efficiency, KGE) were applied. The model achieves an average KGE of 0.79, demonstrating high reliability in reproducing historical streamflow.



CWATM model efficiency at selected gauging stations along the Danube River Basin in the calibration period. The line plots show the long-term mean monthly simulated (solid red line) and observed (solid blue line) flow. The dotted lines show the difference between the long-term mean annual observed (dotted blue line) and simulated (dotted red lines) river flow.

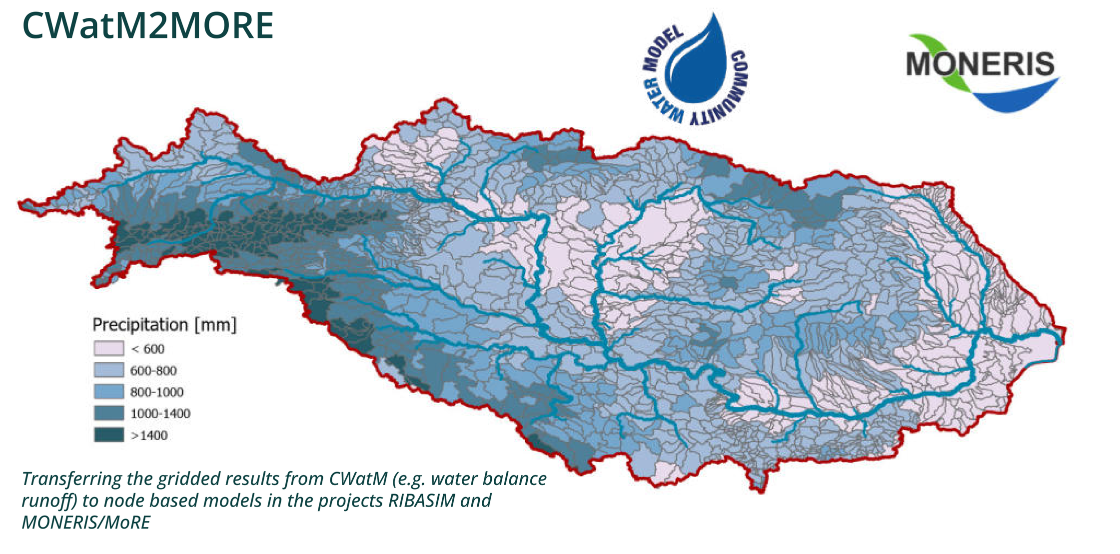


Outputs are available as gridded time series and are further linked to basin-wide water management models (RIBASIM, MONERIS/MoRE), enabling consistent decision-making across countries and sectors.

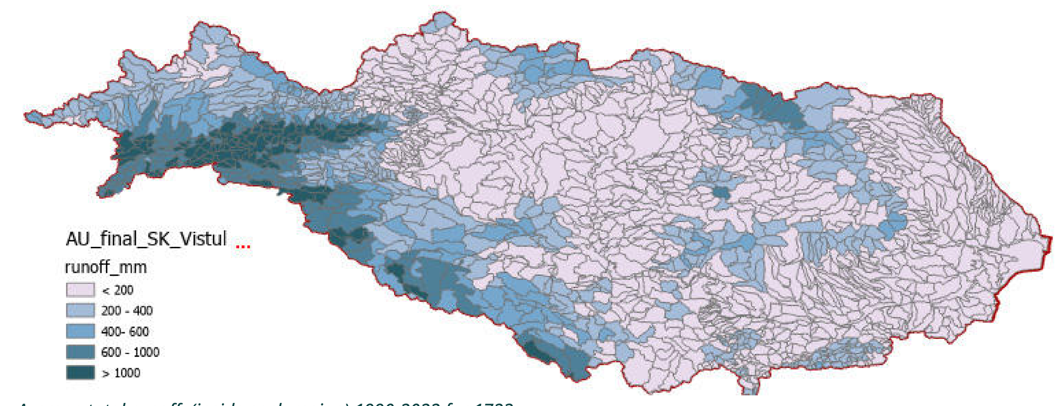


Transferring the gridded results from CWatM (e.g. water balance runoff) to node based models in the projects RIBASIM and MONERIS/MoRE

CWatM2MORE



Transferring the gridded results from CWatM (e.g. water balance runoff) to node based models in the projects RIBASIM and MONERIS/MoRE



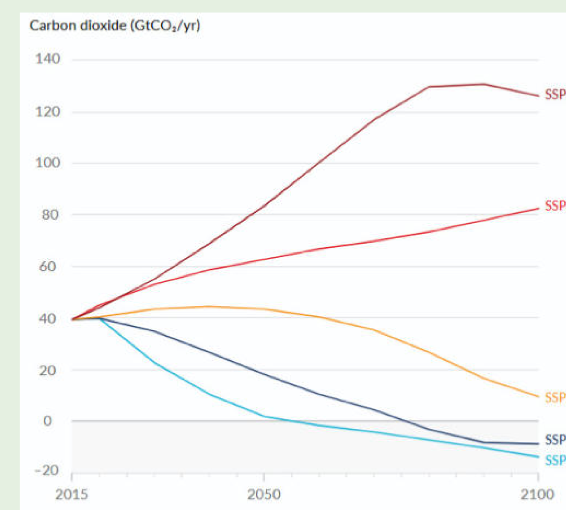
Average total runoff (inside each region) 1990-2022 for 1723 regions of the Danube from CWatM

Climate Change

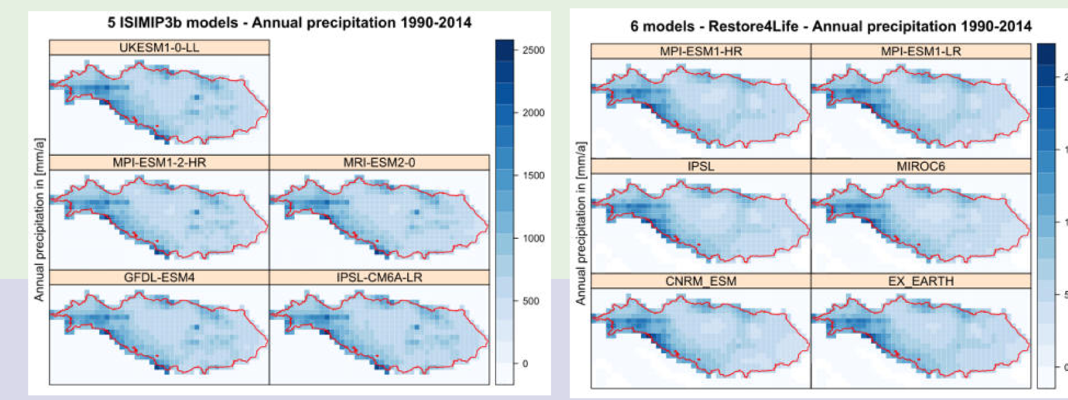
EXTERNAL DATA

Scenario building & Energy Future

annual emissions of CO_2 (IPCC, 2021: Climate Change 2021: The Physical Science Basis)

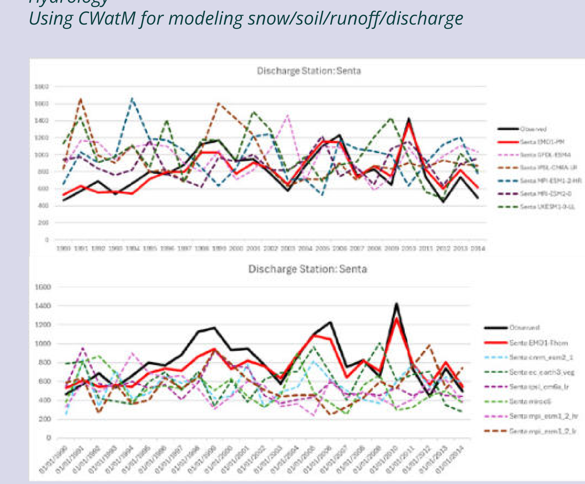


Meteorology
General Circulation Model (5+6 GCMS) – Downscaling and Bias-correction (ISIMIP3b, Restore4Life)

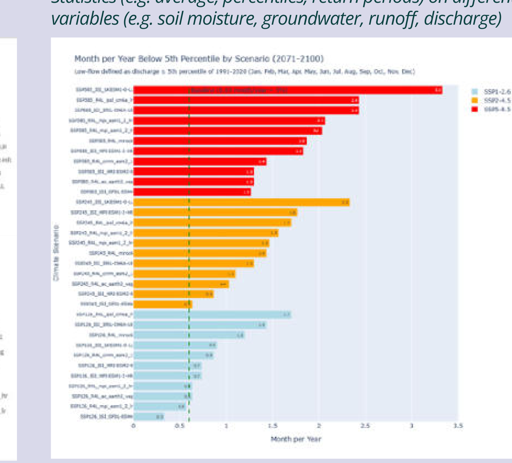


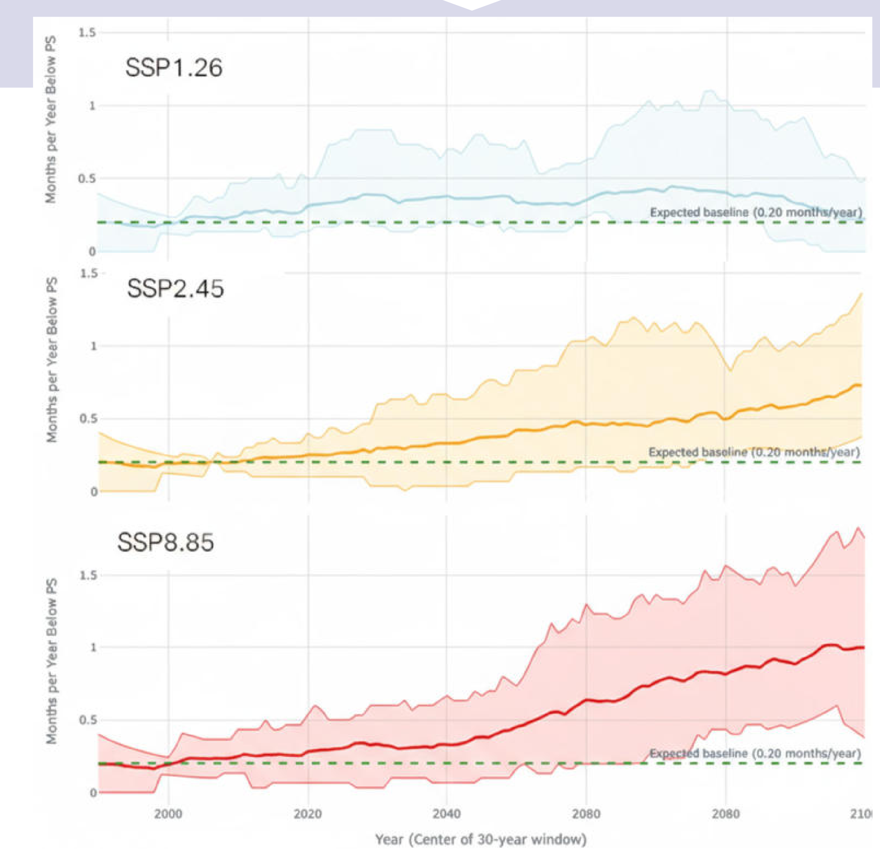
DANUBE WATER BALANCE

Hydrology
Using CWatM for modeling snow/soil/runoff/discharge



Analysis
Statistics (e.g. average, percentiles, return periods) on different variables (e.g. soil moisture, groundwater, runoff, discharge)





Change of number of dry month (5th percentile) of soil moisture (non-irrigated) from 1990-2100 in different SSPs for areas in the Morava basin which are currently irrigated

Interpretation

This is one (draft) result for CC at the example of the Morava basin: CWatM results- here we look in detail:
- Soil moisture (0-30 cm soil layer)
- Non-irrigated crop- and grassland soil moisture
- Only cells withs are currently irrigated
- Only month from June- September
- Evaluating dry month (5th percentile)

During the mid-century, SSP126 shows a peak in the moving average and a bigger range of single GCM results. By the end of the century, it reaches almost the same status as the reference period. It seems this can be called a stable soil-moisture pattern with some (random) dry and wet periods.
In contrast, SSP245 and, even more so, SSP585, exhibit a clear trend in the moving average and in the range of the GCMs. Between 1990 and 2020, all SSPs have, on average, 6 (of 120 June-Sept. months altogether in 30 years) dry months (≤ P5). By the end of the century, according to SSP585, there will be 20 dry months, which means a higher need for irrigation.

The Danube Water Balance project supports evidence-based water governance and contributes to a shared understanding of water availability in the Danube River Basin.

More information:
https://interreg-danube.eu/projects/danube-water-balance

GENERAL DIRECTORATE OF WATER MANAGEMENT