RIBASIM Danube:
Modeling water allocation in the Danube Basin with a focus on low-flow conditions

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Introduction

- **Basin**: The transboundary Danube river basin encompasses 19 riparian countries, covering a total area of 801,463 km² with diverse topographic and climatic characteristics
- **Key stakeholder**: International Commission for the Protection of the Danube River (ICPDR)
- **Climate change** is leading to alterations in low-flow conditions and droughts, while societal factors like urbanization are intensifying these challenges
- The **upper Danube** is particularly influenced by glaciers and snow, which are significant for low flows during summer. The **lower Danube** is expected to face increased drought risk in combination with rising agricultural water demand$_{(1)}$
- **Focus area** in the upper Danube: Austrian free-flowing section east of Vienna, a critical bottleneck for navigation at Regelsbrunn, where measurements (e. g. dredging) are undertaken to ensure navigation during low-flow conditions$_{(2)}$
- **Tool**: River Basin Simulation (RIBASIM) model is a node-link model from Deltares for simulating and balancing water availability, allocation and use

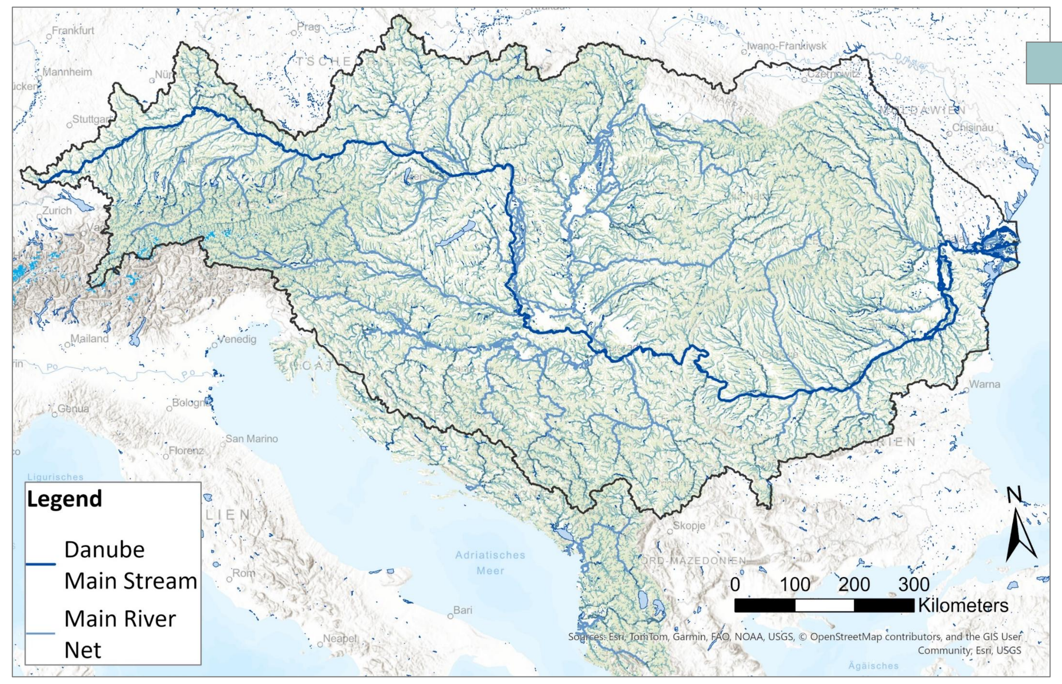

Figure 1: Danube Basin with the River Net, Source: EU-Hydro River Net$_{(3)}$

Methodology

- Variable **inflow** nodes are based on the wflow_sbm model, a grid-based rainfall-runoff model (Deltares). Daily discharges are determined from defined sub-basins for the period 2010 to 2020. RIBASIM timestep is set to a resolution of 10 days
- On the **demand side** the focus was on the Danube main stream with different type of explicit nodes (Tab. 1). Critical low flow nodes, essential for minimum flow for navigation and e-flow were also included

Table 1: Overview of the different types of nodes and examples for the Danube network

Symbol	Type of Nodes	Examples
	Fixed Irrigation (Fir)	▪ Marchfeld (AT) ▪ Dolj (RO)
	General District (GD)	▪ Nuclear Power Plant Paks (HU) ▪ Thermal Power Station Simmering (AT)
	Public Water Supply (PWS)	▪ Vienna (AT) ▪ Budapest (HU) ▪ Belgrad (SRB)
	Industrial Water Supply (IWS)	
	Low Flow (LF)	▪ Navigation Bottleneck Regelsbrunn (AT) ▪ E-flow Lobau (AT)

- Plausibility check and **sensitivity analysis**: Simulated discharges, demands, supplied demands (i.e. water use), and shortages for the period 2010 to 2020 were verified
- **Future scenario**: Glacier retreat was estimated on the basis of Weber et al. (2010) and its effects in the upper Danube during low-flow conditions were analyzed$_{(4)}$

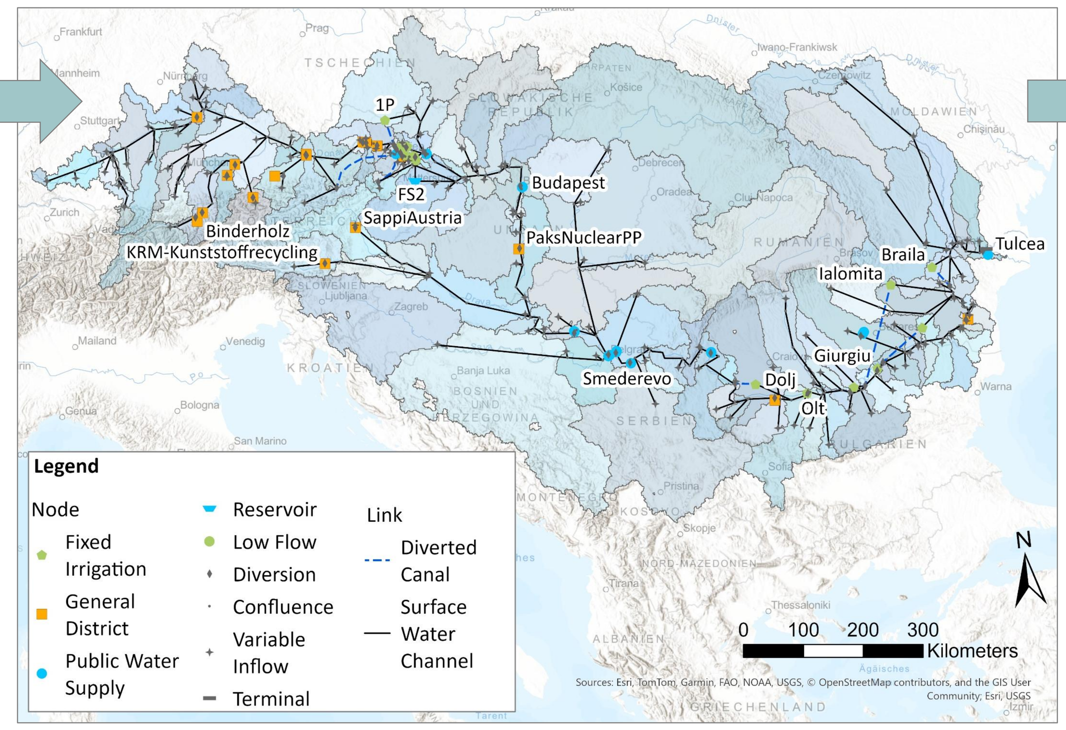

Figure 2: RIBASIM Network and Danube sub-basins of wflow_sbm

(Preliminary) Results & Discussion

- **Reference period** 2010-2020:
  - Reasonable discharges show seasonal fluctuations and lower discharges in low-flow conditions (Fig. 5)
  - Priority order: The different demand nodes are set to the same level to show a realistic structure and to represent the principle "first come, first served"
  - Shortages occur at the LF node Regelsbrunn as well as in PWS in Bucharest at Mures mainly in summer periods
- **Demands**: The comparison of the demand for each node type leads to large differences in the demand and consumption of water (Fig. 3 and 4). Due to the input of explicit demands, a complete capture is limited

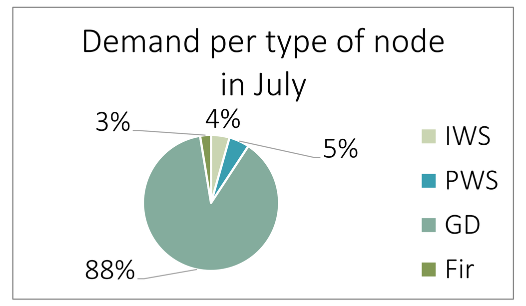

Figure 3: Share of demand per type of node in July

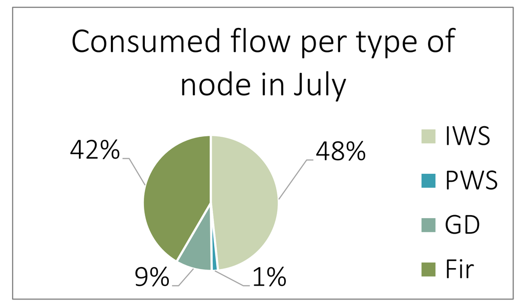

Figure 4: Share of consumed flow per type of node in July

- **Model assumptions** were made, such as constant industrial demands

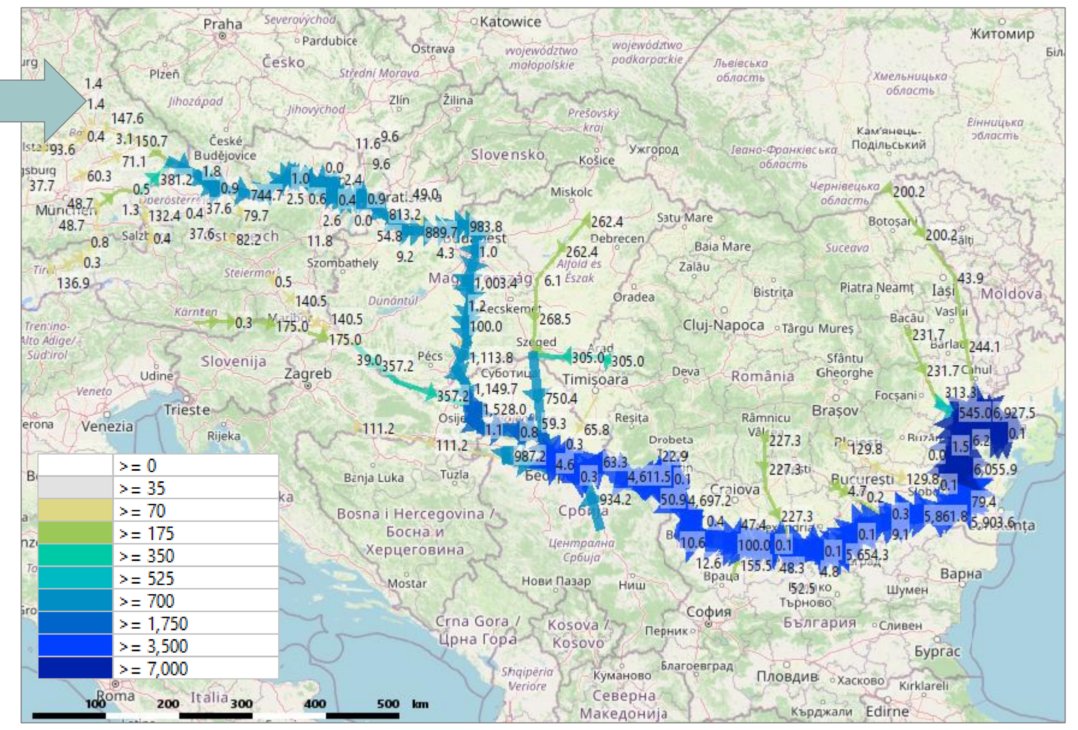

Figure 5: RIBASIM Discharge results of the reference period in m³/s (01-08-2018)

- **Glacier retreat in the focus area**: : Free-flowing Austrian Danube east of Vienna (Regelsbrunn)
- **What-if scenario**: Analysis of a dry year (2018) in Regelsbrunn in a scenario with fully retreated glaciers. The detailed Map in Figure 8 gives an insight
- **Calculation** of glacier retreat: The average ice melt runoff from 1991 to 2000 is transferred to the reference period from 2010 to 2020. The share of glacier area per sub-catchment and the seasonality of the melting process, which is shown in Figure 6, are taken into account

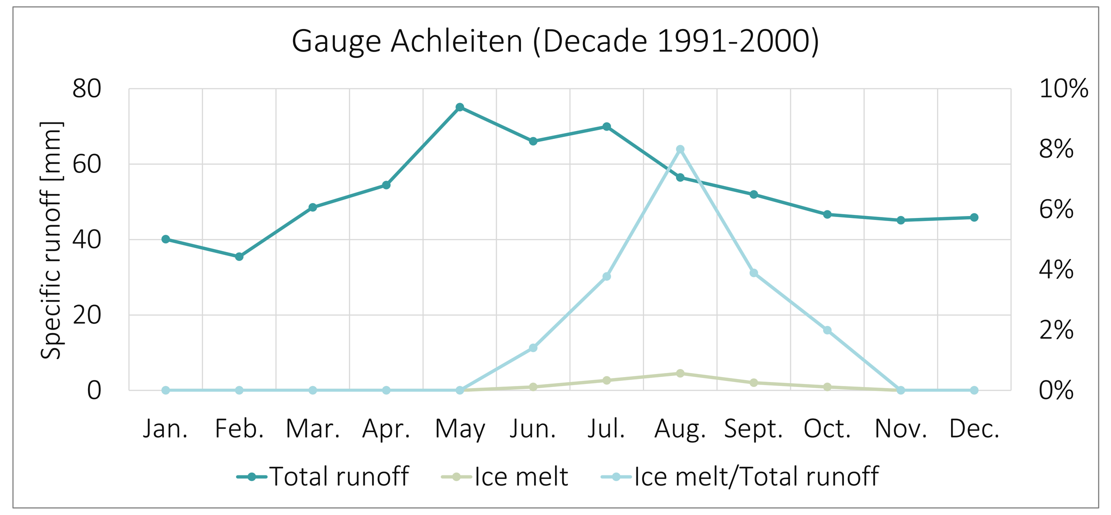

Figure 6: Specific total and ice melt runoff and the perecentage of ice melt to total runoff modified after Weber et al. (2010)

- **Selected preliminary results**:
  - intensified low-flow conditions in summer especially in dry years (Fig. 7)
  - the peak share of discharge over the running period is in August (Fig. 9)

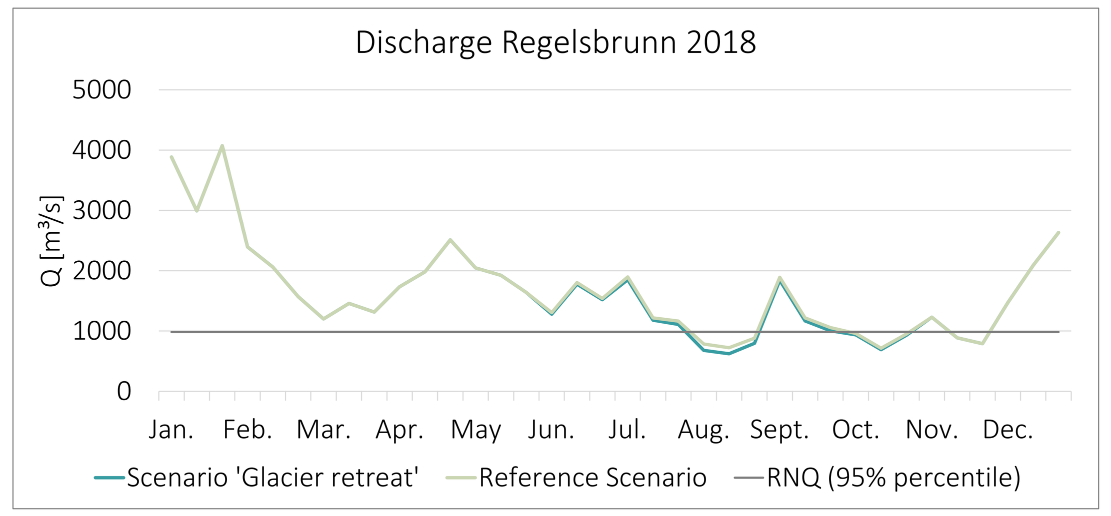

Figure 7: Hydrograph of Regelsbrunn in 2018 with and without ice melt and the 2.5 m limit

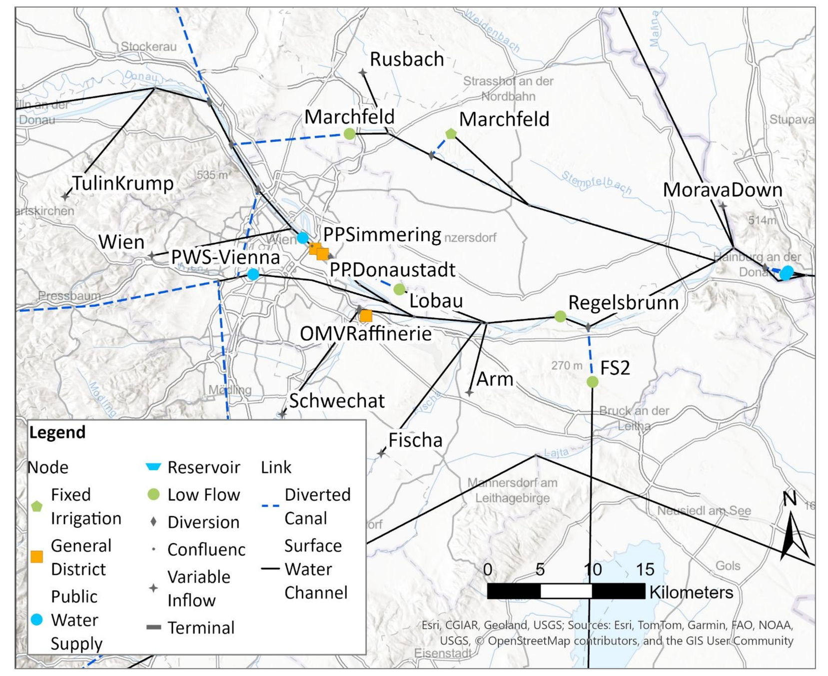

Figure 8: Detailed RIBASIM Network in the area of Vienna

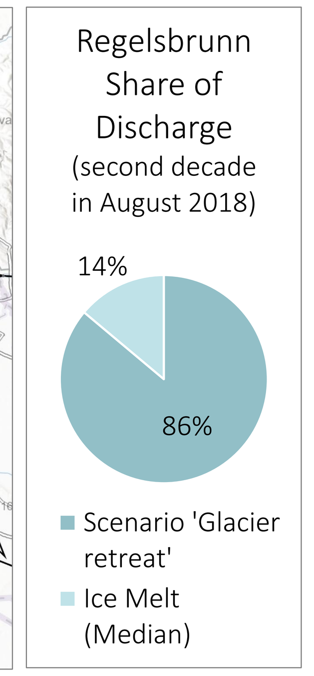

Figure 9: Share of ice melting discharge to the reference discharge

Conclusion & Outlook

- Based on the model, the **hotspots for shortages** during periods of drought and low-flow can be more effectively identified
- Basis for establishing a **management tool** for the stakeholders to adapt to and mitigate future risks on the Danube
- **Data availability**: Need for comprehensive data collection on local water needs across the river basin and increased cross-border cooperation to address water management challenges in the Danube basin
- **Next steps**:
  - **Additional scenarios** with increased pressures on the water demand side, additional management scenarios and climate change scenarios
  - **Further focus areas** in the lower Danube especially with the fact of increased drought risk
  - **Include** Hydropower plants, river bed incision and scenario combinations (worst case)

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