Analysis of Climatological Drivers of Low-Flow Events
Using Large Ensemble Climate Projections in Hydrological Bavaria*

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Modelling hydrological Bavaria

Hydrological model data

The data are composed of ten hydrological simulations of the WaSiM model, each of which is driven by a member of the single model initial condition large ensemble CRCM5-LE.

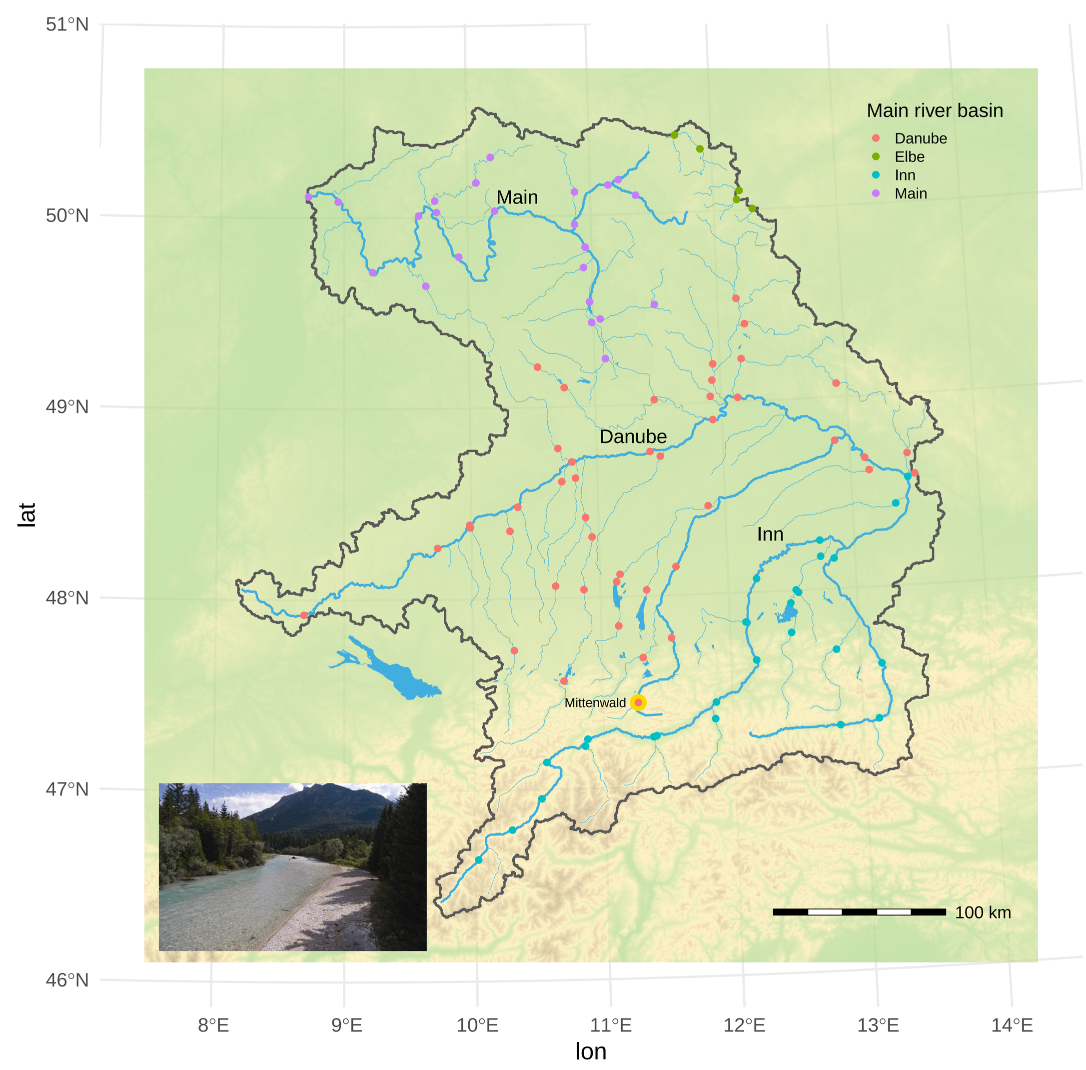

Figure 1: *Hydrological Bavaria is divided into 98 catchments with virtual gauges that act as measuring stations.*

Definition of Low-Flows and drivers

$$NM7Q^s = \frac{1}{310} \sum_{(y,m) \in Y \times M} \frac{1}{7} \min_{\forall t \in T^{(y,m,s)}} \left(\sum_{k=t-6}^{t} Q_k \right)$$
, where s := hydrological season, Y:= 1990-2020, M = set of available model members, and × := Cartesian product

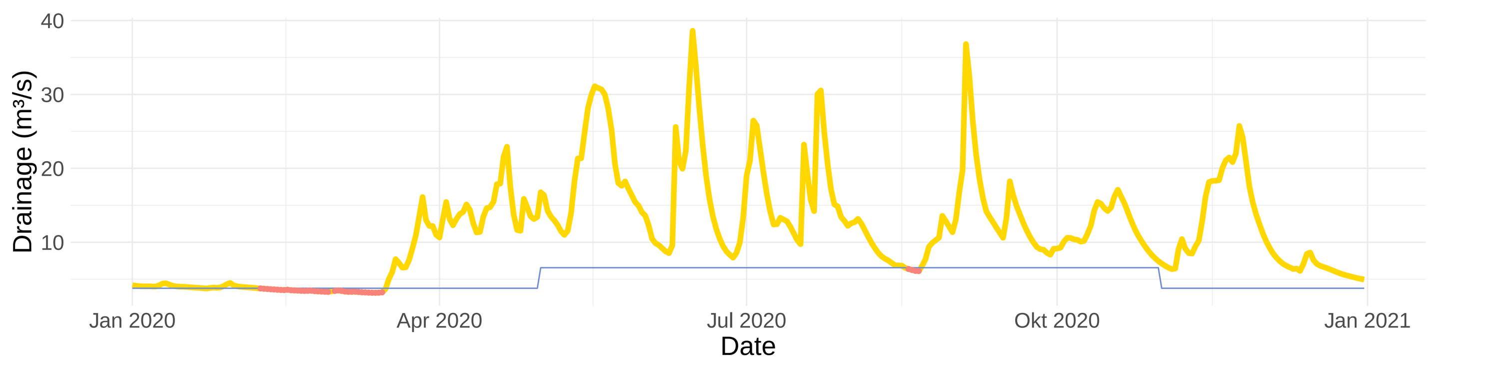

Figure 2: *The NM7Q and the respective drainage for gauge Mittenwald at Isar in member kbe. The seasonal NM7Q is defined as the lowest 7-day mean of drainage averaged over 31 years and all members and acts as an indicator of hydrological dryness.*

Model formula and variable description

$$Y^{(m,g,s)} \sim X^{(m,g,s)}$$
, where m := model member, g:= gauge, s:= hydrological season

Group	Variable	Explanation	Unit
Y	Low flow	Seasonal NM7Q indicating a low-flow event	0 = no event 1 = event
	Drainage	Daily mean of drainage	m^3/s
X	Precipitation	Daily sum of precipitation	mm
	Temperature	Daily mean of temperature	°C
	Soil water	Daily mean of soil water	%
	Snow storage	Daily mean of snow Storage	mm
	Relative humidity	Daily mean of relative humidity	%
	Radiation	Daily mean of Radiation	Wh/m2

Table 1: Time varying hydrological data available per gauge and per member.

Linear Effects over Bavaria

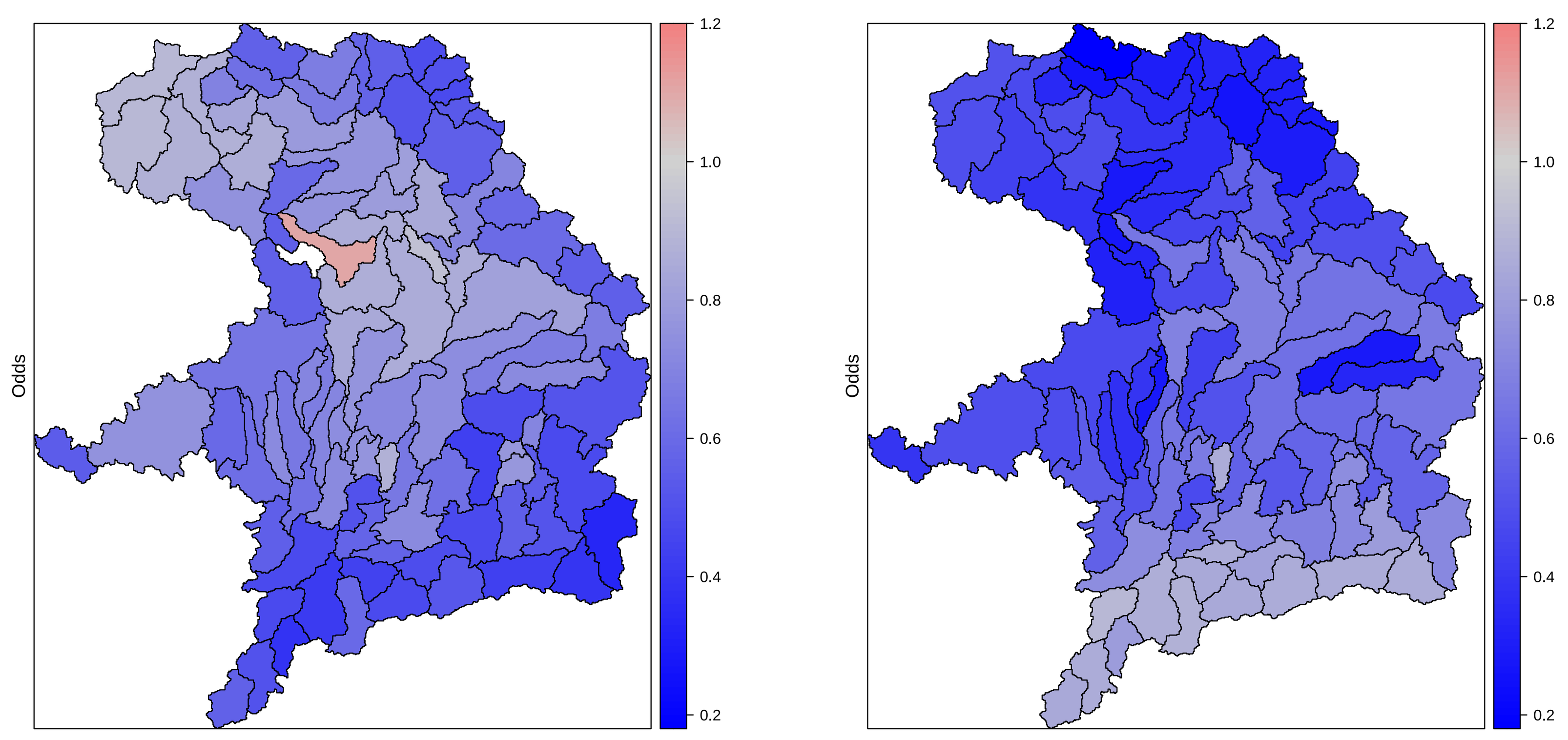

Figure 3: *Depiction of the average effects corresponding to a 1 mm increase in precipitation during the summer (left) and winter (right) seasons on the odds of low-flow events in each catchment.*
Interpretation: *There is a seasonal inversion in the impact of precipitation on alpine and northern non-alpine regions. During the summer, precipitation has a more pronounced preventive effect on low-flow occurrences in alpine regions. Conversely, in the winter, the mitigating effect of precipitation on low-flow events in the Alps is lessened, likely due to the part of the precipitation falling as snow.*

Scenario Analysis

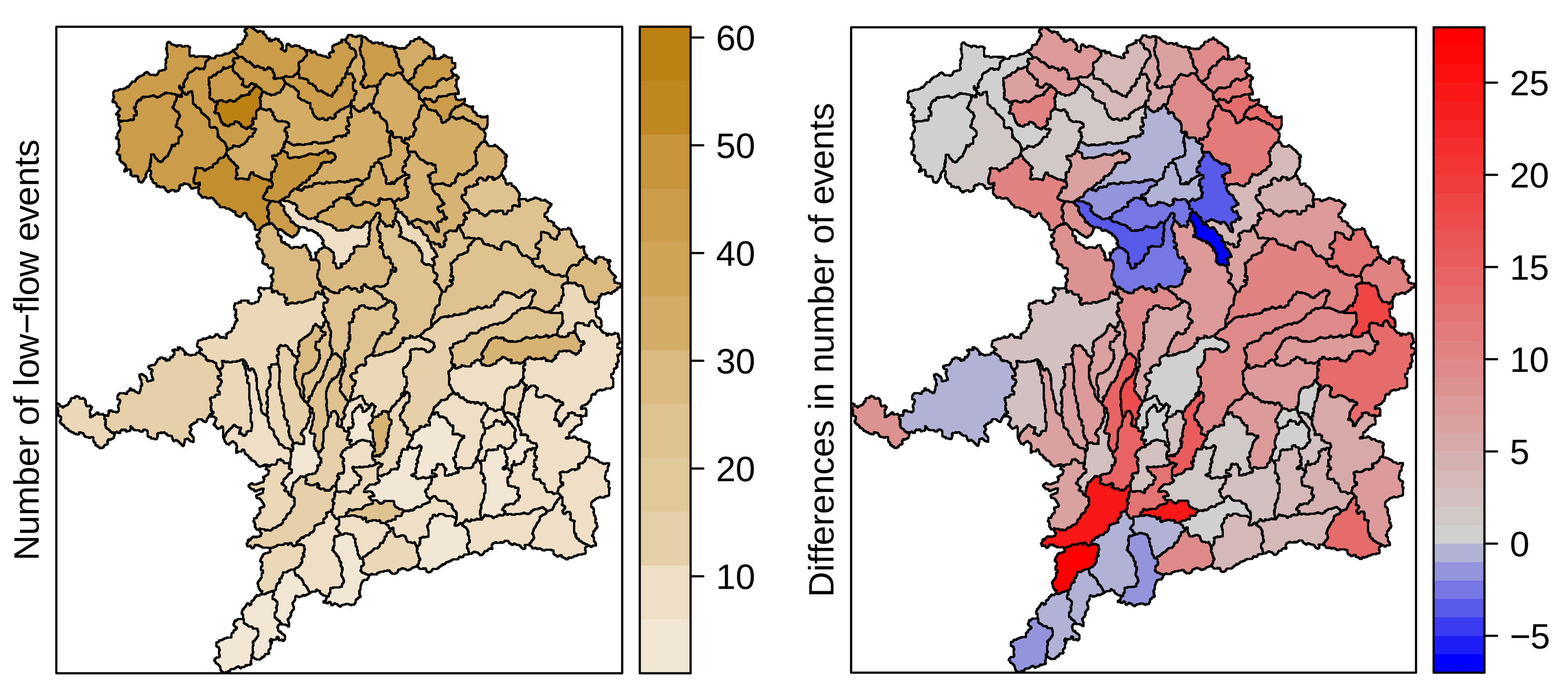

Figure 4: *This illustrates the number of predicted low-flow events for the summer of 2010 based on unmodified data (left), and the difference in the number of days under a climate scenario featuring a 3 °C increase in temperature, a 50% reduction in precipitation, and the absence of snow storage (right). The predicted number of events amplifies across large portions of hydrological Bavaria under this climate scenario, with some catchments witnessing a drastic increase of up to 27 additional low-flow days.*

Additive Effects for Mittenwald

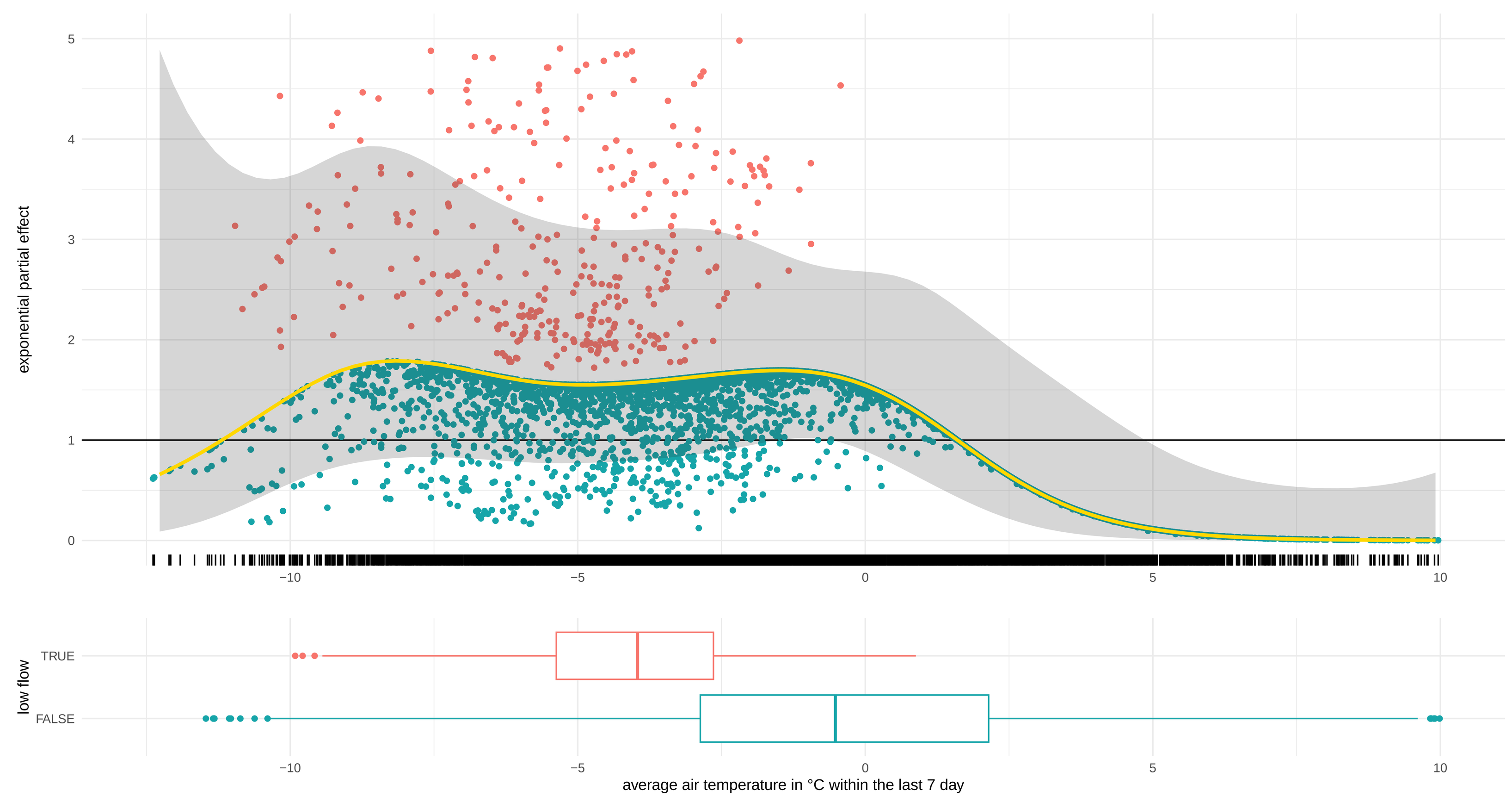

Figure 5: *The lower graphic illustrates the distribution of average air temperatures, conditioned on low flow events. The upper plot provides a visualization of the exponentially smooth effect of temperature on the occurrence of these low flow events, complete with confidence intervals and partial residuals.*
Interpretation: *Caution should be exercised when interpreting the smooth term for temperatures below -10 degrees. This is due to the paucity of low flow events, and thus limited observations at these temperature levels. C.p., for increasing temperatures below 0 °C, the expected chance of low flows exhibits a gentle decline. Once temperatures exceed 0 °C, the expected likelihood of low flow events sharply decreases towards zero. This trend can be attributed to snow melting during winter in alpine gauges, thus reducing the chance of low flow occurrences.*

Challenges & Opportunities

Challenges

- Time-lag → adapted rolling averages for covariates
- Seasonality → Split in hydrological seasons
- Regionality → Catchment-specific effects
- Compound events → Interactions
- 10 simulated climate members → separate modelling

Opporunities

- Couple gauge drainage by Gaussian processes or hierarchical Bayesian modelling
- Evaluate model data on measured data
- Seasonality by dynamic time warping
- Climate change trend analysis

*This project, currently in progress, is under the purview of students. The geographic aspects are overseen by Alex Sasse and Andrea Böhnisch, while the statistical components are under the guidance of Henri Funk and Helmut Küchenhoff.

References

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