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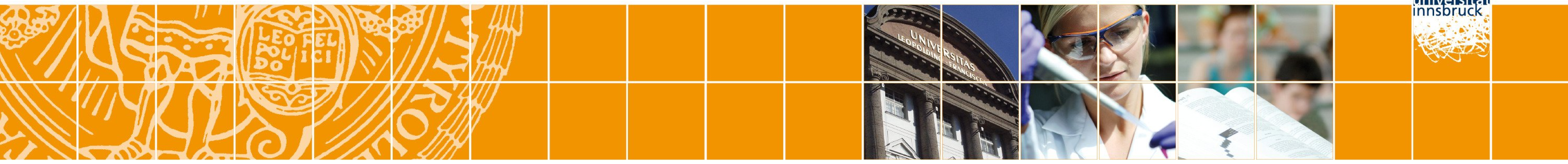

High-Resolution Spatio-Temporal Precipitation Climatology in Complex Terrain

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Introduction

High-resolution spatio-temporal climatologies of precipitation are important for e.g., agriculture, risk assessments, or tourism.
Problem: large proportion of **zero-observations** for high (daily) temporal resolutions (dry days). **A common solution:** decrease the temporal resolution to **monthly** or **yearly** sums to remove zeros (*Goovaerts 2000, Hijmans 2005, ...*).

Our goal

Provide a methodology to create climatologies with:

- **daily** temporal resolution (requires handling of zero-observations)
- **full** climatological **distribution**
- fully **scaleable** spatial domain/resolution
- **no need** for **extensive** or **manual** tuning for new areas

Model Setup

Generalized Additive Model for Location, Scale, and Shape

$$\mathbf{y}^* \sim \mathcal{N}(\mu, \sigma^2), \quad \mathbf{y} = \max(0, \mathbf{y}^*), \quad \mu = \eta_\mu, \quad \log(\sigma) = \eta_\sigma$$

$$\eta = \beta_0 + \underbrace{\beta_1\,\text{alt}}_{\text{altitude}} + \underbrace{f_1(\text{yday})}_{\text{season}} + \underbrace{f_2(\text{long},\text{lat})}_{\text{spatial}} + \underbrace{f_3(\text{yday},\text{long},\text{lat})}_{\text{spatial season}}$$

$\mathbf{y}^*/\mathbf{y}$:	latent/censored response	η:	linear predictor (identical for μ/$\log(\sigma)$)
$\mathcal{N}(\dots)$:	Gaussian distribution	β:	unknown coefficients
$f_k(\dots)$:	non-linear multidimensional functions	yday:	day of the year
μ/σ:	mean and standard deviation	long/lat/alt:	geographical information

Precipitation ($\mathbf{y}$) is physically limited to ≥ 0, which can be considered by an e.g., censored distribution ($\max(0, \mathbf{y}^*)$). A novel Bayesian model framework was used to estimate the unknown coefficients (*R* package **bamlss**, Umlauf 2015).

Data & Data Analysis

Data set

- 110 stations with quality controlled data; 510–2300*m a.m.s.l.*
- 24*h* sums observed at 06*UTC*
- 42 years of data (85% data availability)
- 1′440′000 observations; fraction of zeros $\sim$ 56%

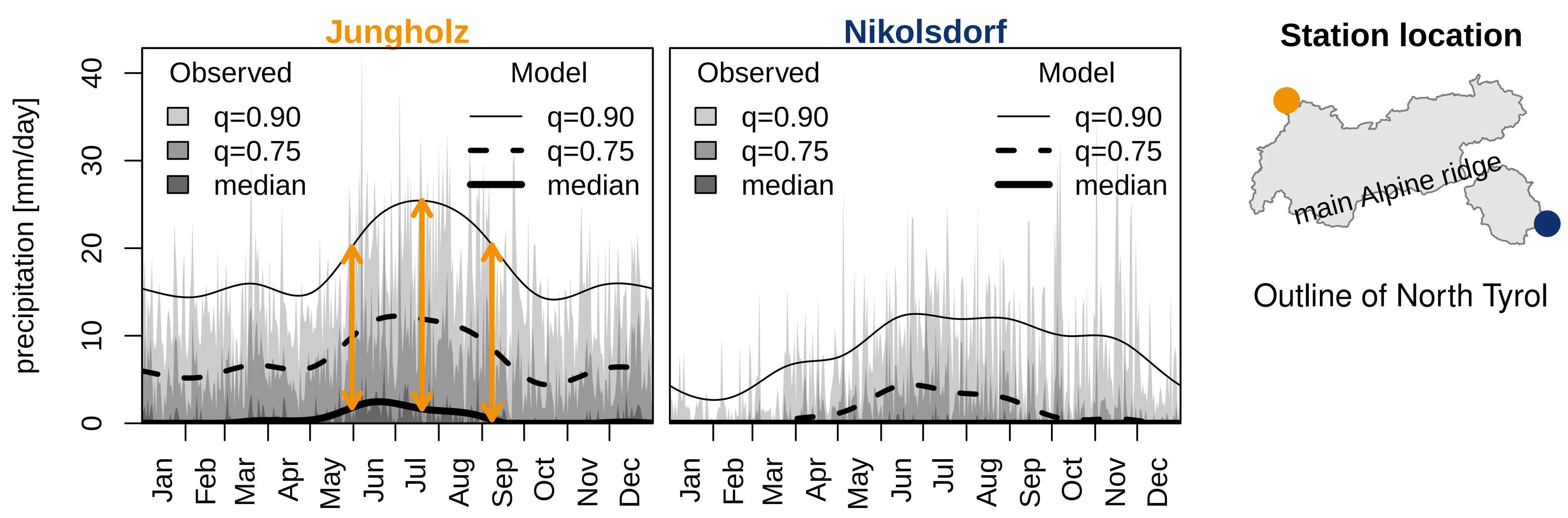

Figure 1 : Two sample stations; 0.90/0.75/0.50 quantiles are shown for both, the daily observed precipitation distribution over the last 33/24 years, and the in-sample fitted spatial climatology on a daily basis (final results).

Features captured by the statistical model

- seasonal pattern vary with location (e.g., north/south; Fig. 1)
- increased amount of precipitation during the summer season (Figs. 1&2)
- independent seasonal pattern for mean (μ) and variance (σ) (↕; Figs. 1&2)
- significantly drier south of the main Alpine ridge (Figs. 1&3)

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Model Results

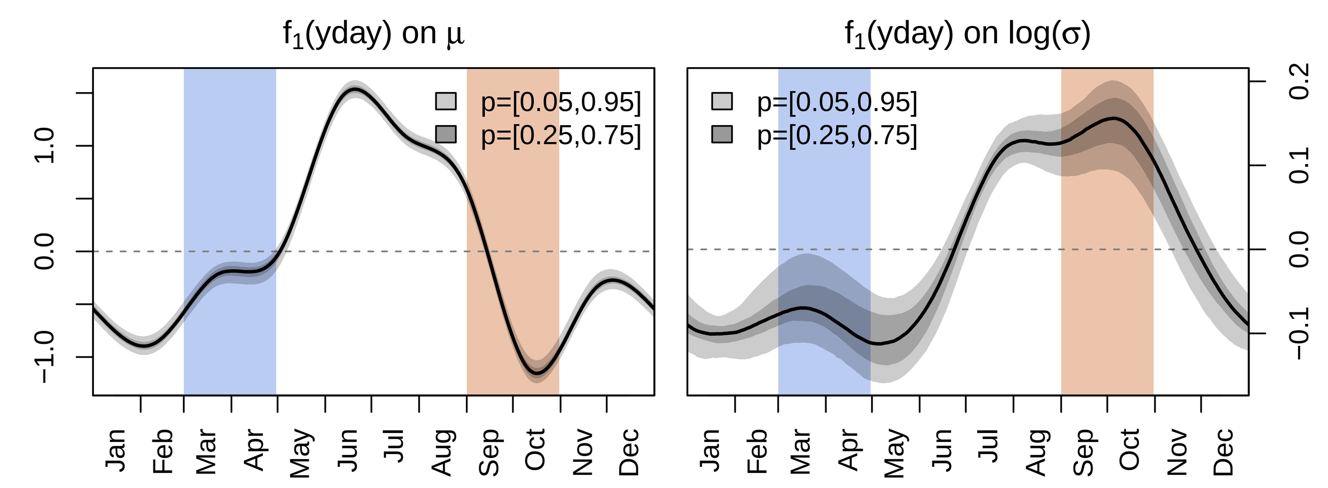

Figure 2 : Centered cyclic seasonal effect f_1(yday). "**April weather**" (*blue*): increasing mean (μ), local maximum of variability ($\log(\sigma)$). **Autumn** (*orange*): strongly decreasing mean (μ) with coincidentally increasing variability ($\log(\sigma)$).

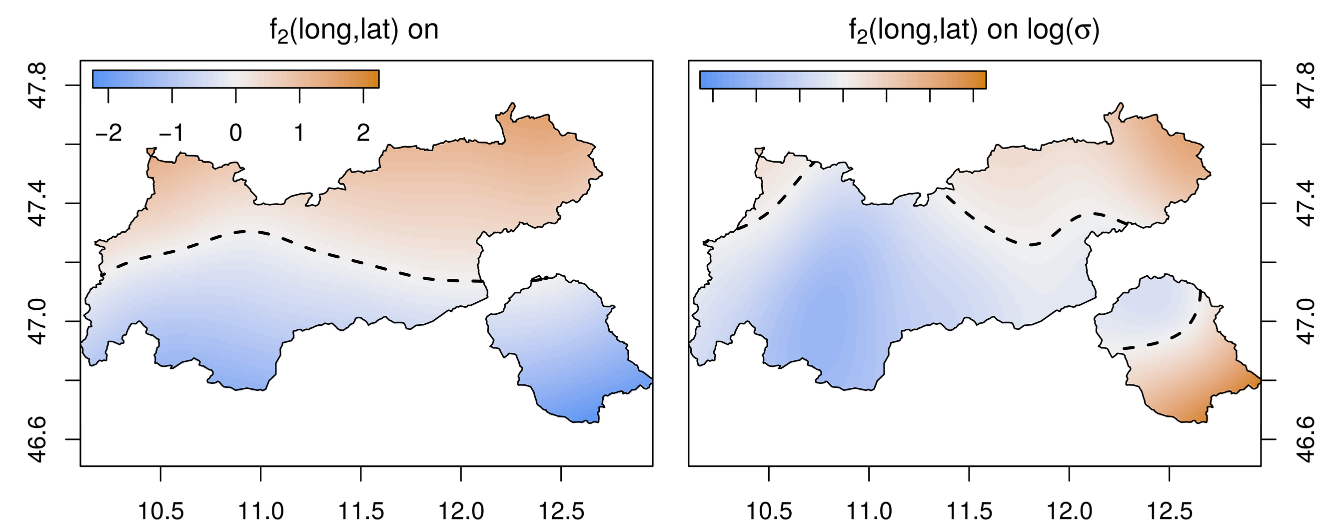

Figure 3 : Centered longitude/latitude effect $f_2(\text{long},\text{lat})$. Mean ($\mu$): positive effect north while dry to the South/inner-alpine regions. Variance ($\log(\sigma)$): weaker variability within the Alps.

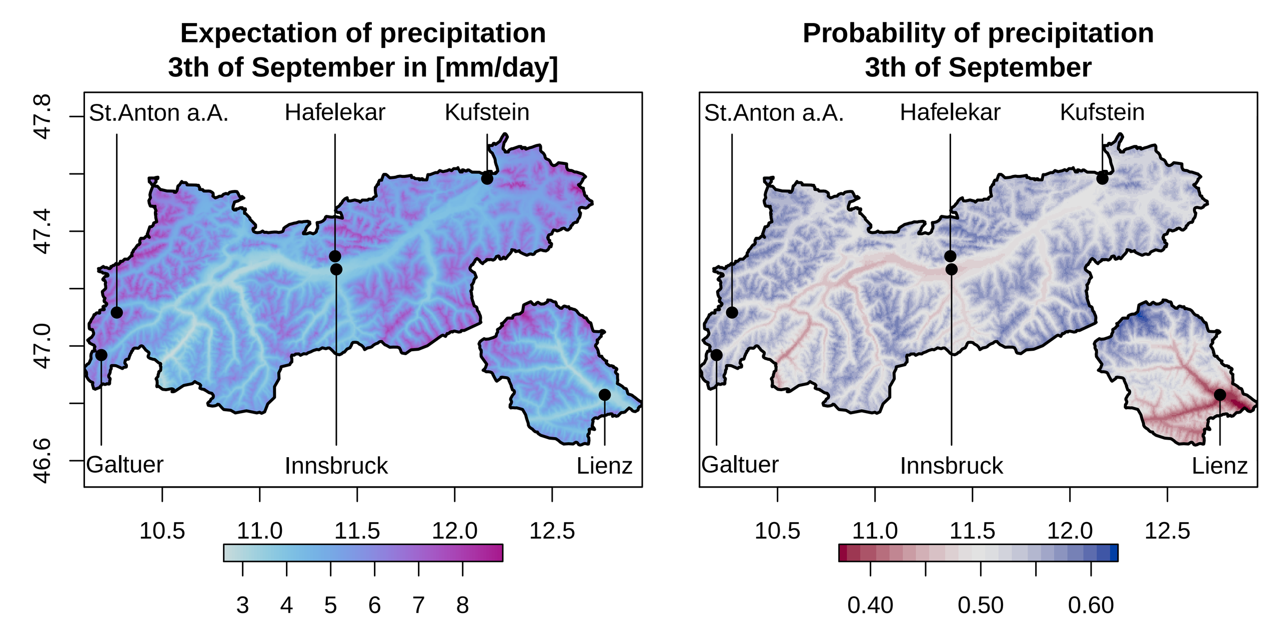

Figure 4 : Estimated expectation (*left*) and probability of precipitation (*right*), 3. September.
Innsbruck: expected precipitation amount: **3.5***mm*, probability of precipitation: **46%**.
Hafelekar: expected precipitation amount: **6.4***mm*, probability of precipitation: **57%**.

Summary & Outlook

Current status

- **zero-observations** properly handled by the **censored distribution**
- highly resolved **spatio-temporal** model; **adaptable** to arbitrary scales
- **full** climatological **distribution**; allows extracting **quantiles**/**probabilities**
- accurate estimate on **station level**
- "simple", **generalized** setup

Planned extensions

- to include additional **covariates** (e.g., terrain dependent features, wind)
- to test different **distributions** (e.g., censored logistic)
- to include **additional stations**
- to **compare** with existing methods

References:
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Umlauf, N., et al., 2015: bamlss: Bayesian Additive Models for Location Scale and Shape (and Beyond). *R package version 0.1-1* (`https://R-Forge.R-project.org/R/?group_id=865`).