Regional block-maxima modelling of precipitation extremes in climate model simulations

AND OBSERVED DATA

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INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

OUTLINE

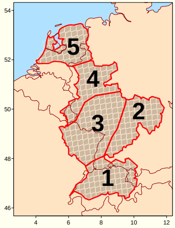
1. Introduction, study area & data
2. Statistical model
3. Assessment of daily and multi-day precipitation extremes in present and future climate for the Czech Republic
4. Model diagnostics
5. Sub-daily precipitation extremes in the Czech Republic
6. Conclusions

INTRODUCTION

- Work iniciated within the ENSEMBLES project - WP5.4 Evaluation of extreme events in observational and RCM data
- Questions:
  - are the precipitation extremes properly represented in the RCM simulations?
  - what are the projected changes in precipitation extremes?
  - how large is the uncertainty associated with the estimation of precipitation extremes and their changes in the climate model data?
- statistical model developed to answer these questions

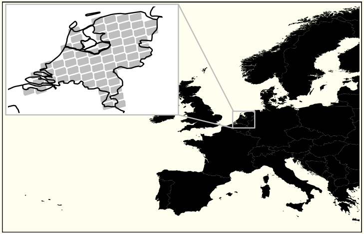
Statistical model applied to assess

- 1-day summer and 5-day winter precipitation extremes in the Rhine basin



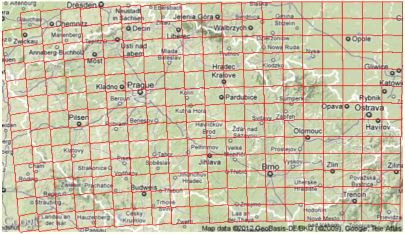
Statistical model applied to assess

- 1-day summer and 5-day winter precipitation extremes in the Rhine basin
- 1-day and 1-hour annual precipitation extremes in the Netherlands



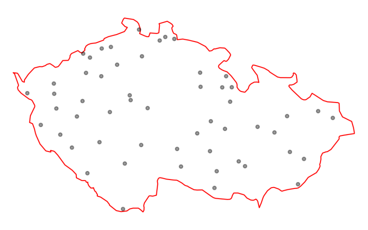
Statistical model applied to assess

- 1-day summer and 5-day winter precipitation extremes in the Rhine basin
- 1-day and 1-hour annual precipitation extremes in the Netherlands
- 1-, 3-, 5-, 7-, 10-, 15-, 20- and 30-day precipitation extremes for all seasons in the Czech Republic



Statistical model applied to assess

- 1-day summer and 5-day winter precipitation extremes in the Rhine basin
- 1-day and 1-hour annual precipitation extremes in the Netherlands
- 1-, 3-, 5-, 7-, 10-, 15-, 20- and 30-day precipitation extremes for all seasons in the Czech Republic
- *Observed sub-daily precipitation extremes (summer half year) in the Czech Republic*



DATA

RCM DATA

model	acronym	source	period
	— ECHAM5 driven —		
RACMO	**RACMO_EH5**	KNMI	1950-2100
REMO	**REMO_EH5**	MPI	1951-2100
RCA	**RCA_EH5**	SMHI	1951-2100
RegCM	**RegCM_EH5**	ICTP	1951-2100
HIRHAM	**HIR_EH5**	DMI	1951-2100
	— HadCM3Q0, HadCM3Q3, HadCM3Q16 driven —		
HadRM	**HadRM_Q0**	Hadley Centre	1951-2099
CLM	**CLM_Q0**	ETHZ	1951-2099
HadRM	**HadRM_Q3**	Hadley Centre	1951-2099
RCA	**RCA_Q3**	SMHI	1951-2099
HadRM	**HadRM_Q16**	Hadley Centre	1951-2099
RCA	**RCA_Q16**	C4I	1951-2099
	— ARPEGE driven —		
HIRHAM	**HIR_ARP**	DMI	1951-2100
CNRM-RM	**CNRM_ARP**	CNRM	1951-2100
ALADIN-CLIMATE/CZ	**ALA_ARP**	CHMI	1961-2100
	— BCM driven —		
RCA	**RCA_BCM**	SMHI	1961-2100

RCM simulations

- $\approx$ 25 km $\times$ 25 km
- SRES A1B
- transient simulations

Definition of maxima

- block maxima, i.e. the largest precipitation amount in a year/season
- various aggregations of data (e.g. 1-day, 5-day ...)

OBSERVATIONAL DATA ($\approx$ 25 km x 25 km)

acronym	source	period
CHMI_OBS	CHMI	1950-2007
E_OBS	KNMI	1950-present

GEV DISTRIBUTION FUNCTION

$$F(x) = \exp\left\{-\left[1+\kappa\left(\frac{x-\xi}{\alpha}\right)\right]^{-\frac{1}{\kappa}}\right\}, \qquad \kappa \neq 0$$

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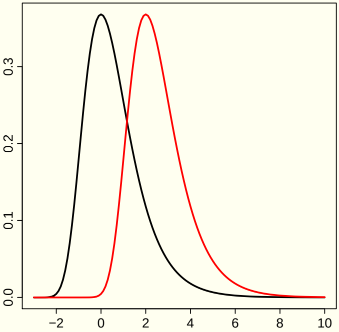
- ξ ... location parameter

PROBABILITY DENSITY FUNCTION



The GEV parameters can

- vary over the region (spatial heterogeneity)
- vary with time (climate change)

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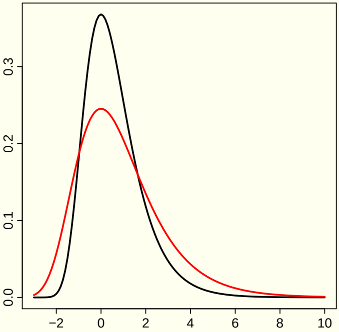

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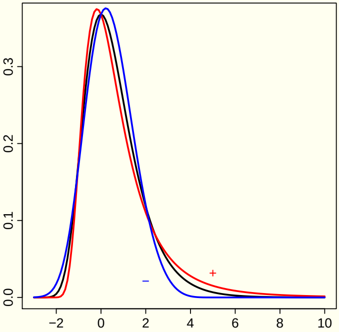


STATISTICAL MODEL

- Index flood method assumes that precipitation maxima over a region are identically distributed after scaling with a site-specific factor

SPATIAL HETEROGENEITY

- ξ varies over the region
- κ, $\gamma = \frac{\alpha}{\xi}$ are constant over the region
  γ is the dispersion coefficient analogous to the coefficient of variation
- T-year quantile at any site s can be represented as

$$Q_T(s) = \mu(s) \cdot q_T, \qquad q_T = 1 - \gamma \cdot \frac{1 - \left[-\log\left(1 - \frac{1}{T}\right)\right]^{-\kappa}}{\kappa}$$

  where q_T is a common dimensionless quantile function (growth curve) and $\mu(s)$ is a site-specific scaling factor ("index flood")

- it is convenient to set $\mu(s) = \xi(s)$

STATISTICAL MODEL

NON-STATIONARITY

- location parameter varies over the region, but with common trend
$$\xi(s,t) = \xi_0(s) \cdot \exp\left[\xi_1 \cdot I(t)\right]$$
where $I(t)$ is the time indicator
- dispersion coefficient and shape parameter are constant over the region, but vary with time
$$\gamma(t) = \exp\left[\gamma_0 + \gamma_1 \cdot I(t)\right]$$
$$\kappa(t) = \kappa_0 + \kappa_1 \cdot I(t)$$

UNCERTAINTY

- assessed by a bootstrap procedure (1000 samples for each RCM simulation, season and duration)

RELATIVE CHANGES

- T-year quantile in time t and location s:

$$Q_T(s,t) = \xi(s,t) \cdot q_T(t)$$

- Relative change between t_2 and t_1 ($t_2 > t_1$) is:

$$\frac{Q_T(s,t_2)}{Q_T(s,t_1)} = \frac{\xi(s,t_2)}{\xi(s,t_1)} \cdot \frac{q_T(t_2)}{q_T(t_1)}$$

$$\xi(s,t) = \xi_0(s) \cdot \exp\left[\xi_1 \cdot I(t)\right] \Rightarrow \frac{\xi(s,t_2)}{\xi(s,t_1)} = \exp\left\{\xi_1 \cdot [I(t_2) - I(t_1)]\right\}$$

$\Rightarrow$ the relative change in quantiles can be written as

$$\frac{Q_T(s,t_2)}{Q_T(s,t_1)} = \exp\left\{\xi_1 \cdot [I(t_2) - I(t_1)]\right\} \cdot \frac{q_T(t_2)}{q_T(t_1)}$$

which does not depend on s.

TIME INDICATOR

Various choices for $I(t)$ are possible:

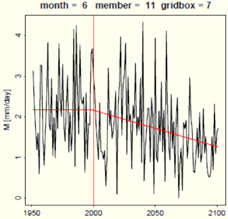
- year t

  e.g., $I(t) = t$, but more complicated functions are needed
- temperature/ temperature anomaly

We use:

- seasonal global temperature anomaly of the driving GCM

CHANGE IN PRECIPITATION



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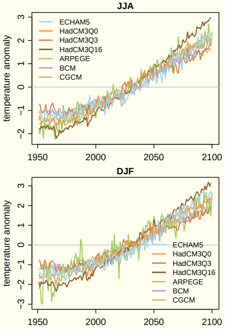
SEASONAL GLOBAL TEMPERATURE ANOMALY



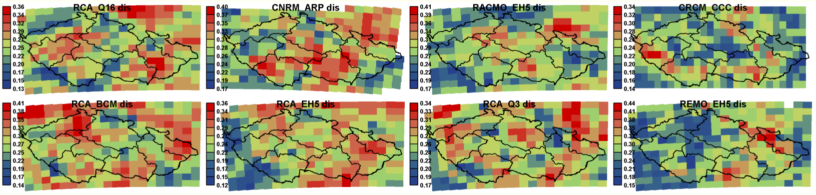
We use:

- seasonal global temperature anomaly of the driving GCM

IDENTIFICATION OF HOMOGENEOUS REGIONS

For each RCM simulation and season we assessed

- the grid box estimates of the GEV parameters for the period 1961-1990 and 2070-2099
- their changes between these two periods
- focus mainly on the dispersion coefficient and changes in location parameter and dispersion coefficient
- formation of homogeneous regions common for all RCM simulations and seasons is challenging



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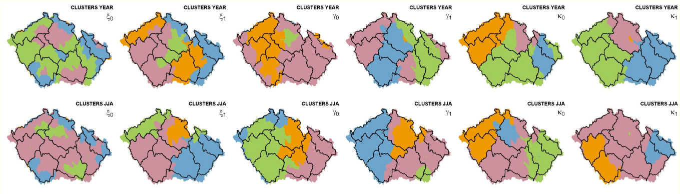
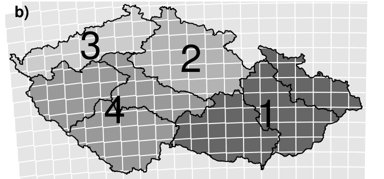


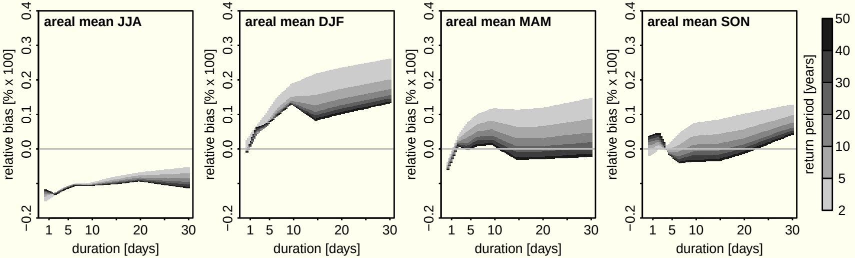
IDENTIFICATION OF HOMOGENEOUS REGIONS

- obviously it is not possible to identify strictly homogeneous regions common for all RCM simulations and seasons
  - however, regional frequency analysis is more accurate than the at-site analysis even in not strictly homogeneous regions
  - allowing more heterogeneity of precipitation maxima in the statistical model improves goodness-of-fit, however, the estimated changes are not much different when compared to the standard model
- it turned out that the regions could be acceptably based on the areas of the eight river basin districts in the Czech Republic
- different groupings of the river basin districts were examined with respect to the lack-of-fit of the statistical model

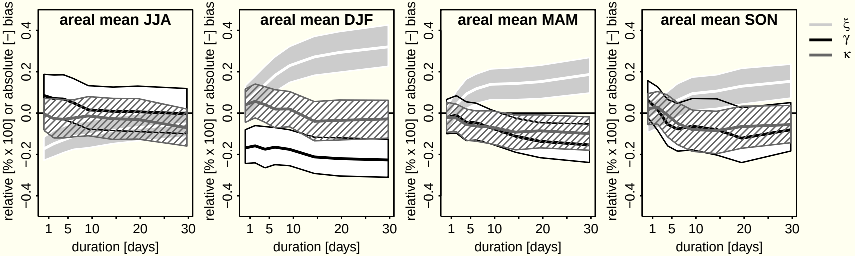


EVALUATION FOR CONTROL CLIMATE

Relative bias in quantiles

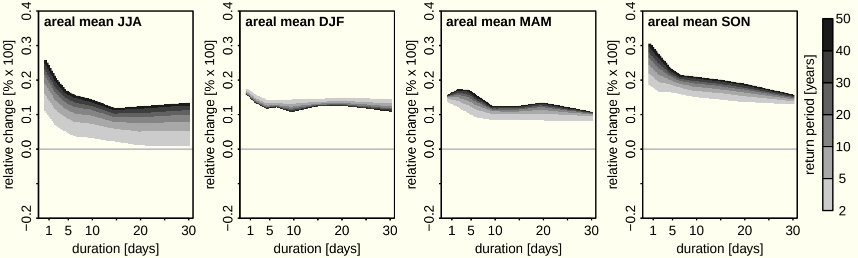


Relative (ξ, γ) and absolute (κ) bias in parameters



CHANGES BETWEEN 1961-1990 AND 2070-2099

Relative changes in quantiles



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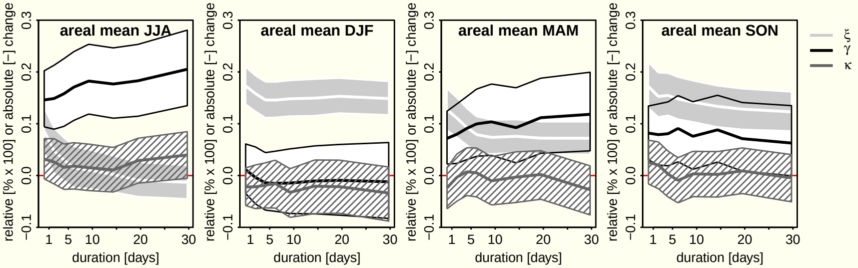
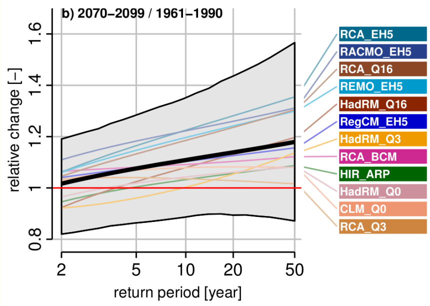
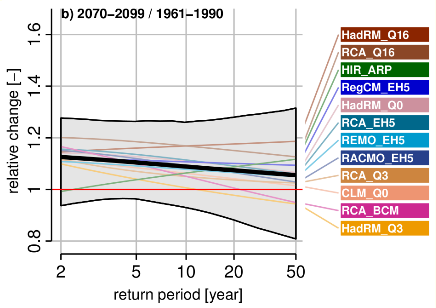


CHANGES IN 1-DAY SUMMER AND 5-DAY WINTER PRECIP EXTREMES, RHINE BASIN





MODEL DIAGNOSTICS

For each grid box we calculate the residuals:

- we transform the seasonal maxima X_t to:

  $$\widetilde{X}_t = \frac{1}{\hat{\xi}(t)} \cdot \log\left[1 + \frac{\hat{\xi}(t)}{\hat{\gamma}(t)} \cdot \left(\frac{X_t}{\hat{\mu}(t)} - 1\right)\right],$$

  which should have a standard Gumbel distribution;

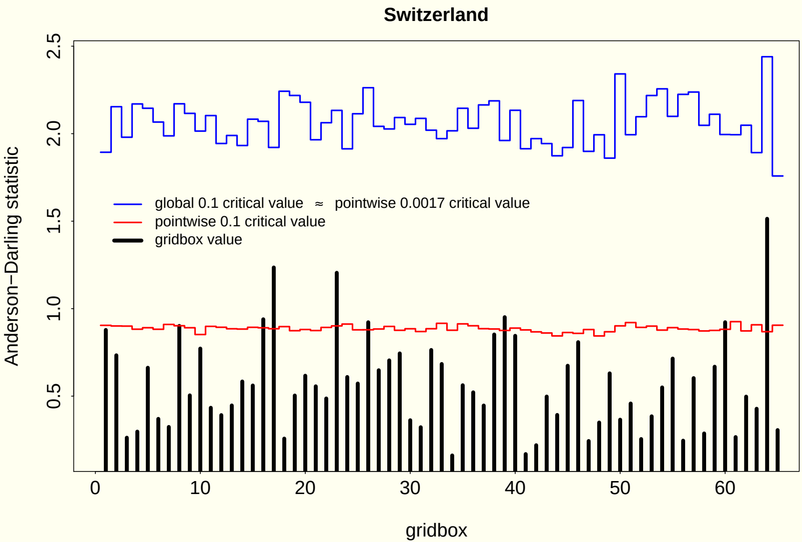
  $$\Pr\{\widetilde{X}_t \leq x\} = \exp\left[-\exp(-x)\right]$$

  if the model is true.
- these residuals can be inspected visually and/or e.g. by the Anderson-Darling statistics:

  $$A^2 = N \int_{-\infty}^{\infty} \frac{[F_N(x) - F(x)]^2}{F(x)[1 - F(x)]} dF(x),$$

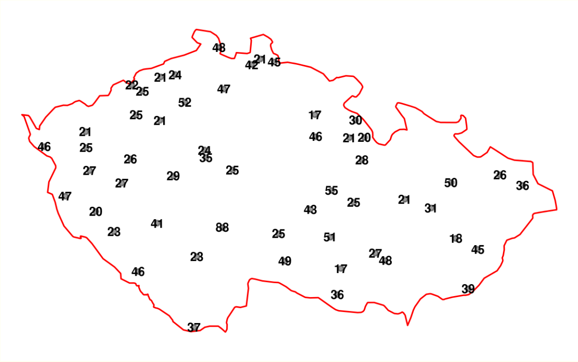
  where $F_N(x)$ is the empirical distribution function of $\widetilde{X}_t$ and $F(x)$ standard Gumbel distribution function.
- critical values can be derived using simulation
- bootstrap procedure based on resampling of standard Gumbel residuals

MODEL DIAGNOSTICS



DATA

- 54 stations, combination of pluviographic (10-min) and automatic (30-min) rain gages, max 7 years overlap
- from 1921-1991 to 2011, May-September
- 33 years on average, in total 1807 station-years

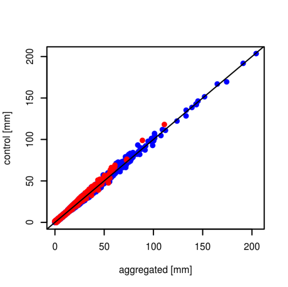


QUALITY CHECK

for both data sources available control daily total - checked against aggregated amount from pluviograph/automatic station

- records for days with difference > 1.5 mm (for totals < 15 mm) or > 10 % marked unreliable
- only years with < 10 % of unreliable data considered

- sources combined
- automatic rain gages on average 5 % underestimation, pluviograph 1 % underestimation
- no correction considered (yet?)



SUB-DAILY PRECIPITATION EXTREMES FOR THE CZECH REPUBLIC

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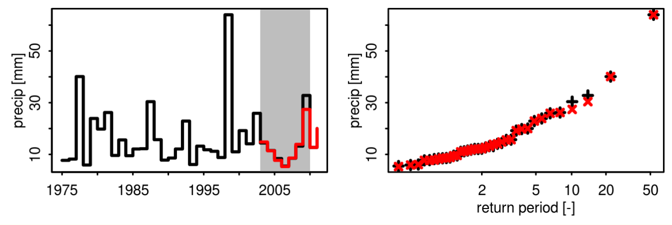
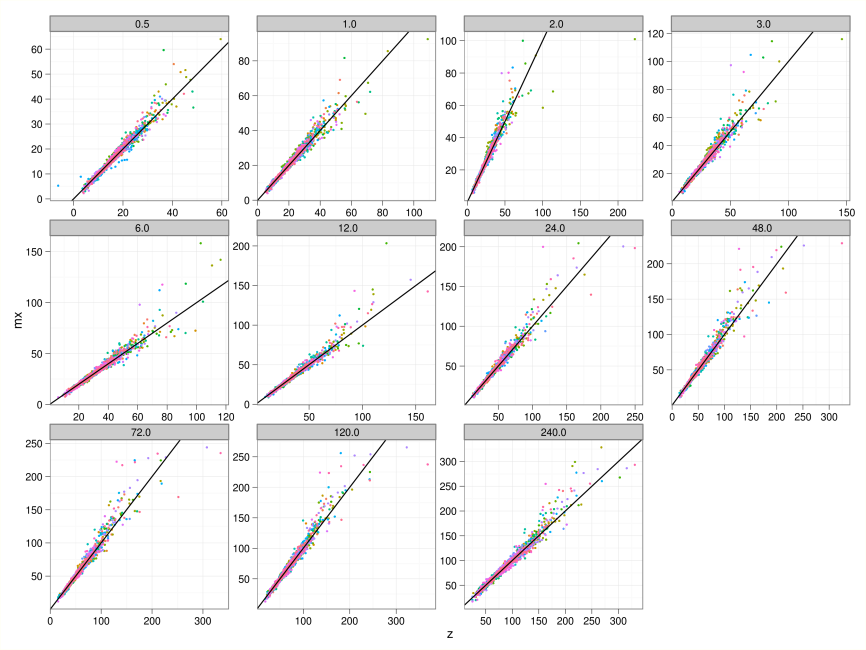


SUB-DAILY PRECIPITATION EXTREMES FOR THE CZECH REPUBLIC

- assessment of 0.5, 1, 2, 3, 6, 12, (24, 48, 72, 120, 240) hour precipitation extremes

- stationary at-site model
- non-stationary index-flood model
- stationary at-site model across aggregations

STATIONARY AT-SITE MODEL



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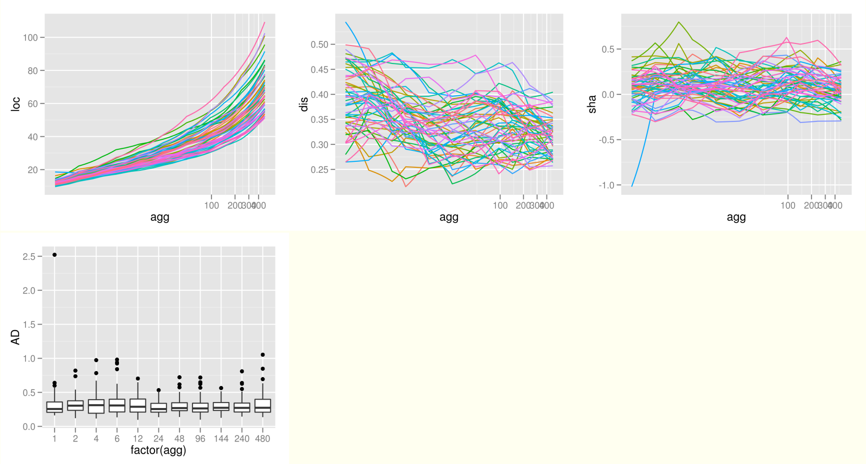
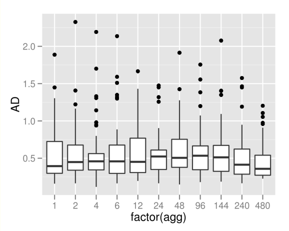


NON-STATIONARY INDEX-FLOOD MODEL

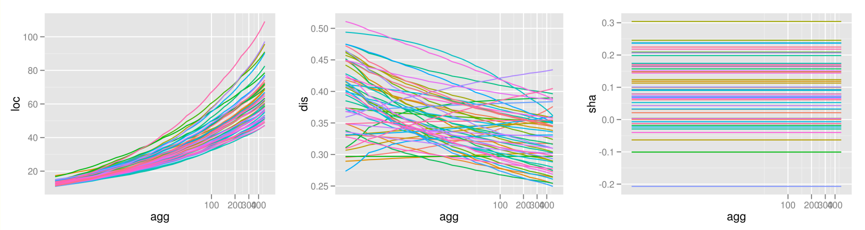
assumed constant shape parameter, location parameter and dispersion coefficient dependent on NH temperature anomaly

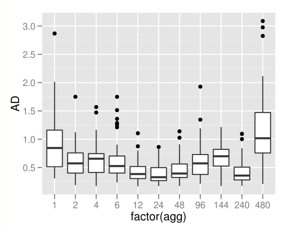


STATIONARY AT-SITE MODEL ACROSS AGGREGATIONS

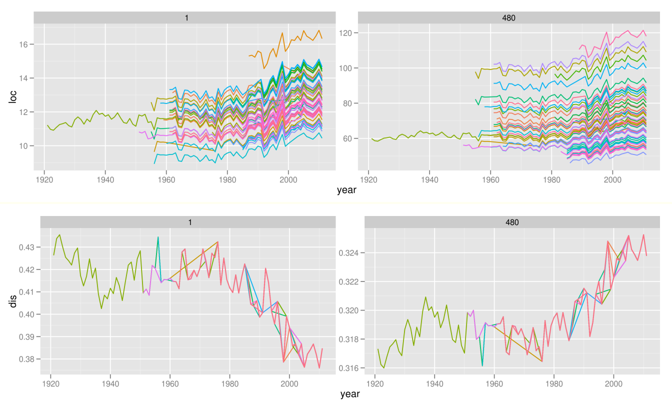
$$\theta = a + b \ln D^c,$$

with θ the GEV parameter, D aggregation and a, b, c parameters.
For the shape parameter assumed constant value for all aggregations.



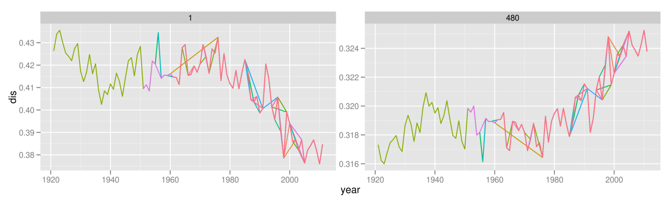


TRENDS



TRENDS


1
480
loc
year
16
14
12
10
120
100
80
60
1920
1940
1960
1980
2000


1
480
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year
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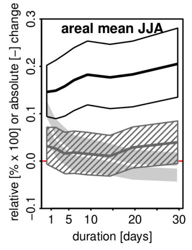
1920
1940
1960
1980
2000


areal mean JJA
relative [% x 100] or absolute [–] change
duration [days]
0.3
0.2
0.1
0.0
−0.1
1
5
10
20
30

CONCLUSIONS

- Regional GEV modelling provides an informative summary of changes in parameters and various quantiles (rather than a single quantile only).
- Taking ξ and γ constant over a region strongly reduces standard errors.
- Consistent parameters across aggregations can be obtained by modification of the model.

Thank you for attention