netherlands eScience center

# Statistics of extreme weather

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Utrecht 7/12/2020

- **Societal impact**: casualties, disease, migration, agitation, protests

- **Economic impact**: infrastructure damage, productivity loss, crop destruction

- **Ecological impact**: loss of vegetation and widlife, forest fires, pollution

- Scientific impact: test of weather forecast models, but also climate models



Reuters

Attribution: was it due to climate change?

- Due to chaotic nature of atmosphere, events independent after ~20 days

- Approach: extreme value theory, i.e. statistics of maxima of random samples

- Applications in climate science, hydrology, insurance, epidemology, engineering

- If the cumulant of max($X_1$,…,$X_n$) converges upon iterative shifting/scaling…

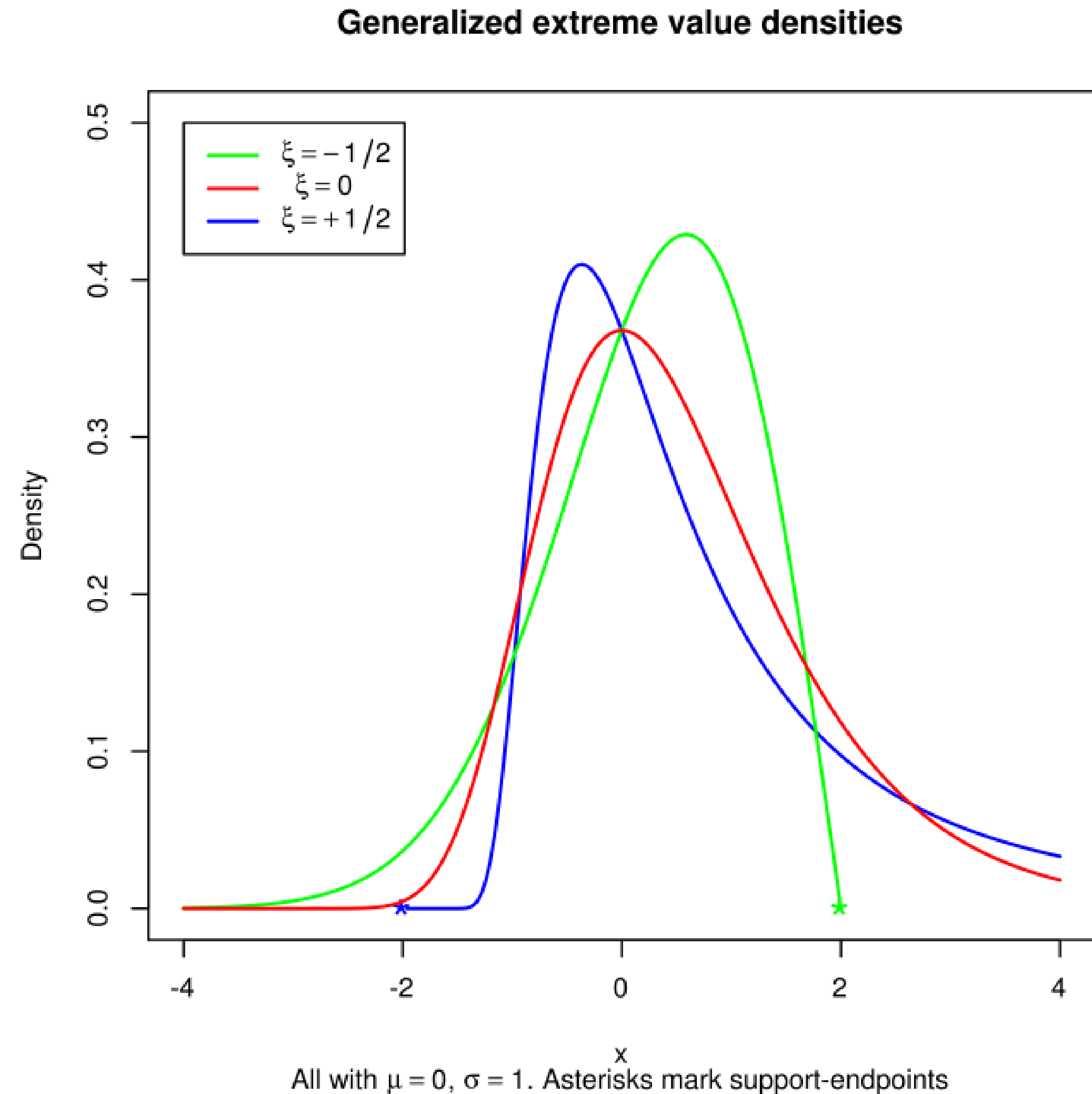$$P\left(\frac{M_n - b_n}{a_n} \leq x\right) \propto G(x), \quad n \to \infty$$

- …it converges to the generalized extreme value (GEV) distribution

$$G(x) = \exp\left(-\left[1 + \xi\left(\frac{x - \mu}{\sigma}\right)\right]_+^{-1/\xi}\right)$$

- $\mu$: location, $\sigma$: scale, $\xi$: shape

- $\xi >$    : Frechet
- $\xi =$    : Gumbel
- $\xi <$    : Weibull



Generalized extreme value densities

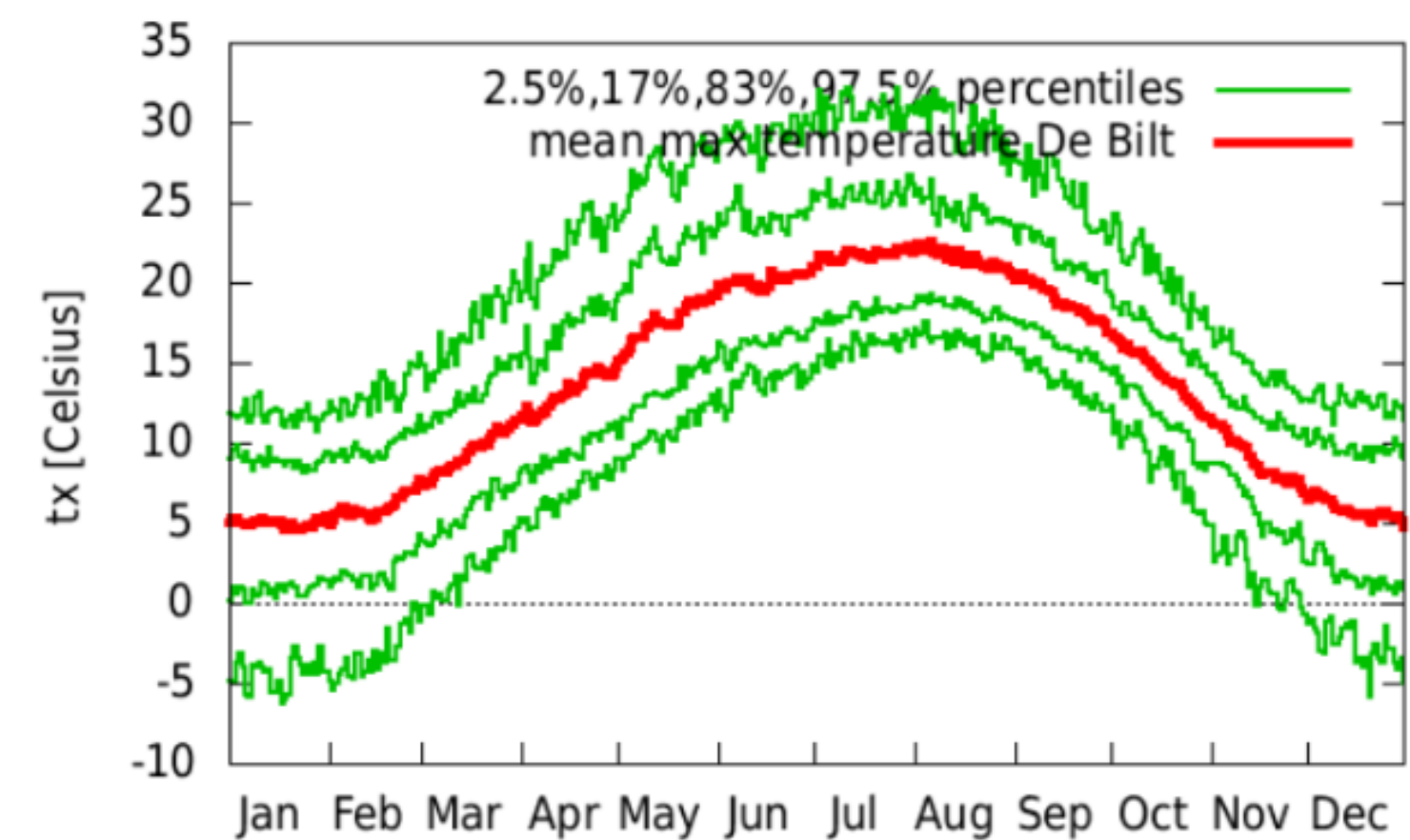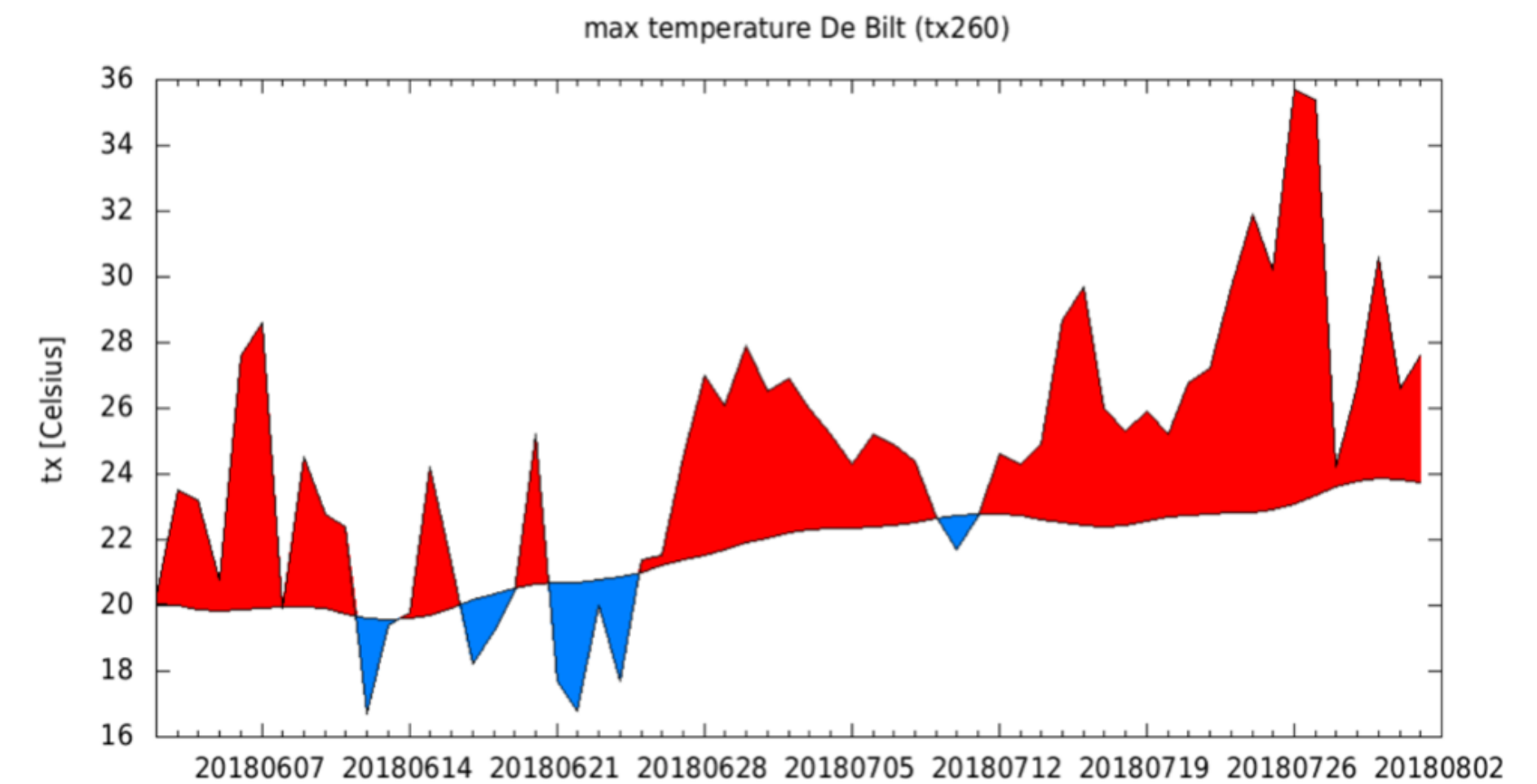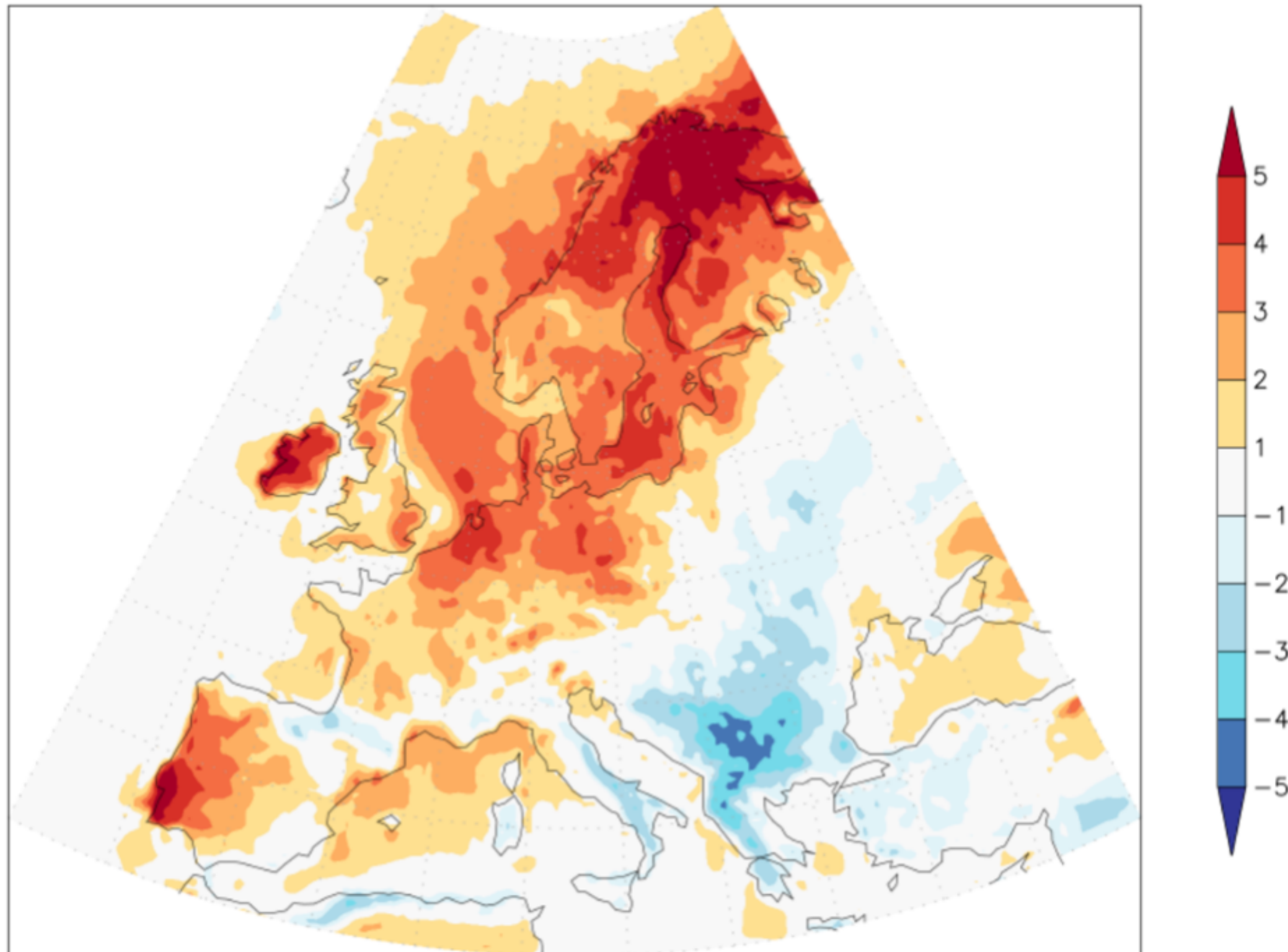All with $\mu = 0$, $\sigma = 1$. Asterisks mark support-endpoints

- Return period: $T_{ret} = \dfrac{1}{1 - G(x)}$

- Return level: $x = G^{-1}(1 - T_{ret}^{-1})$

$$= \mu - \frac{\sigma}{\xi}\left[1 - (-\log(1 - T_{ret}^{-1}))^{-\xi}\right]$$

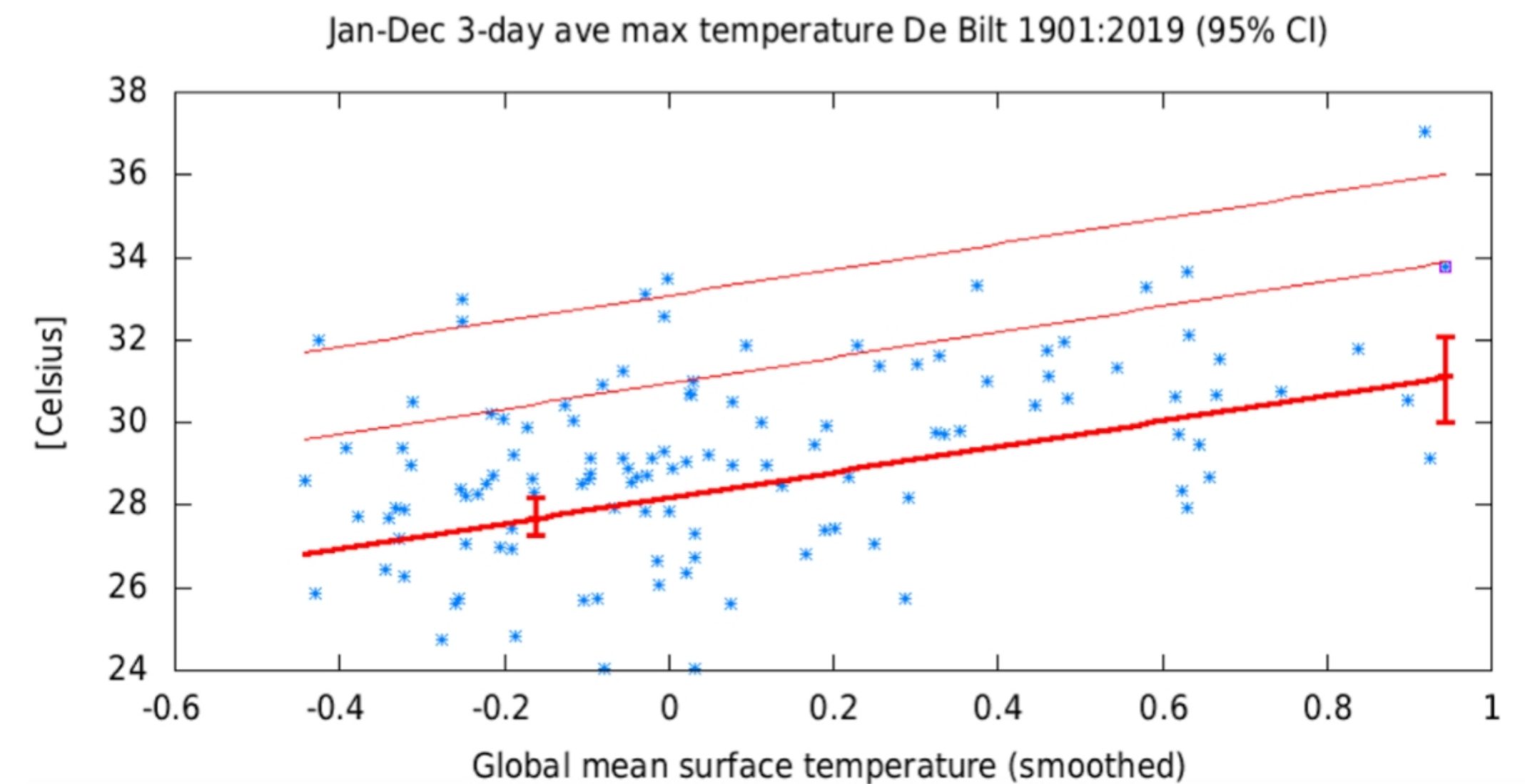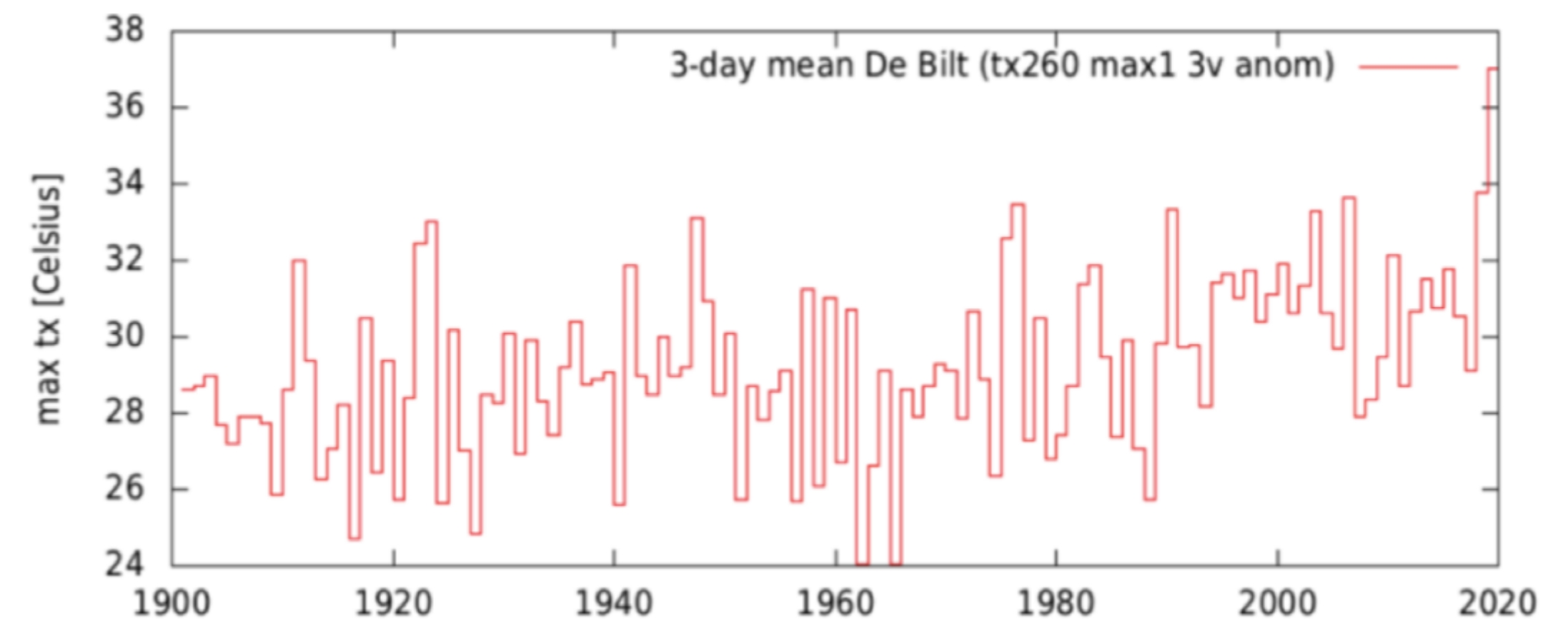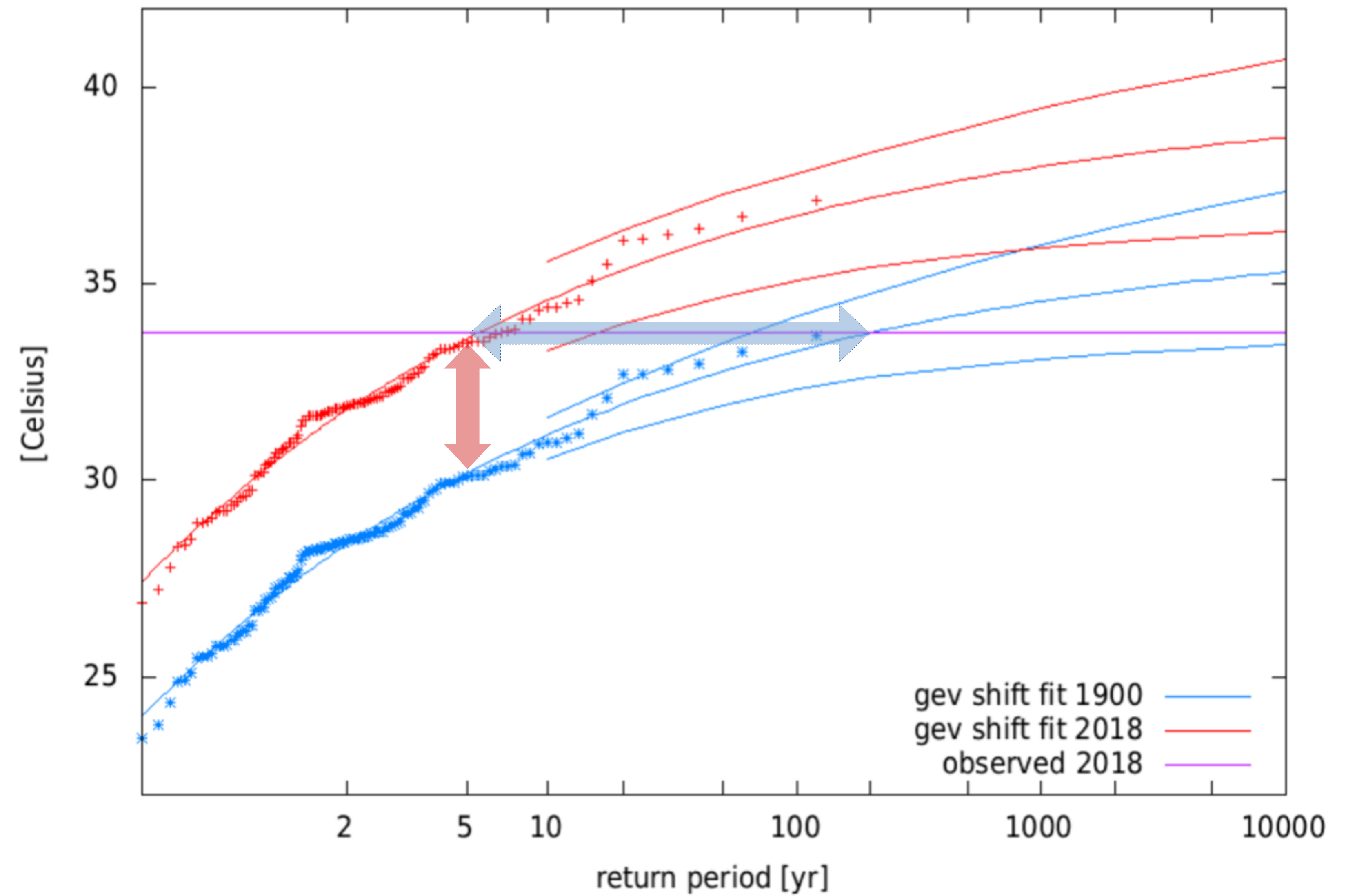- Local weather extremes depend on geographic location and seasonal cycle…

...and climate change



- Assume covariate relation with GMT time series:
  • For temperature →  location prop. to gmt
  • For precipitation → scale prop. to gmt

- Constrained fit gives attribution result

Jan-Dec 3-day ave max temperature De Bilt 1901:2019 (95% CI)

Intensity change $\Delta I$

Probability ratio P

[Celsius]

40

35

30

25

gev shift fit 1900
gev shift fit 2018
observed 2018

2          5    10              100          1000        10000

return period [yr]