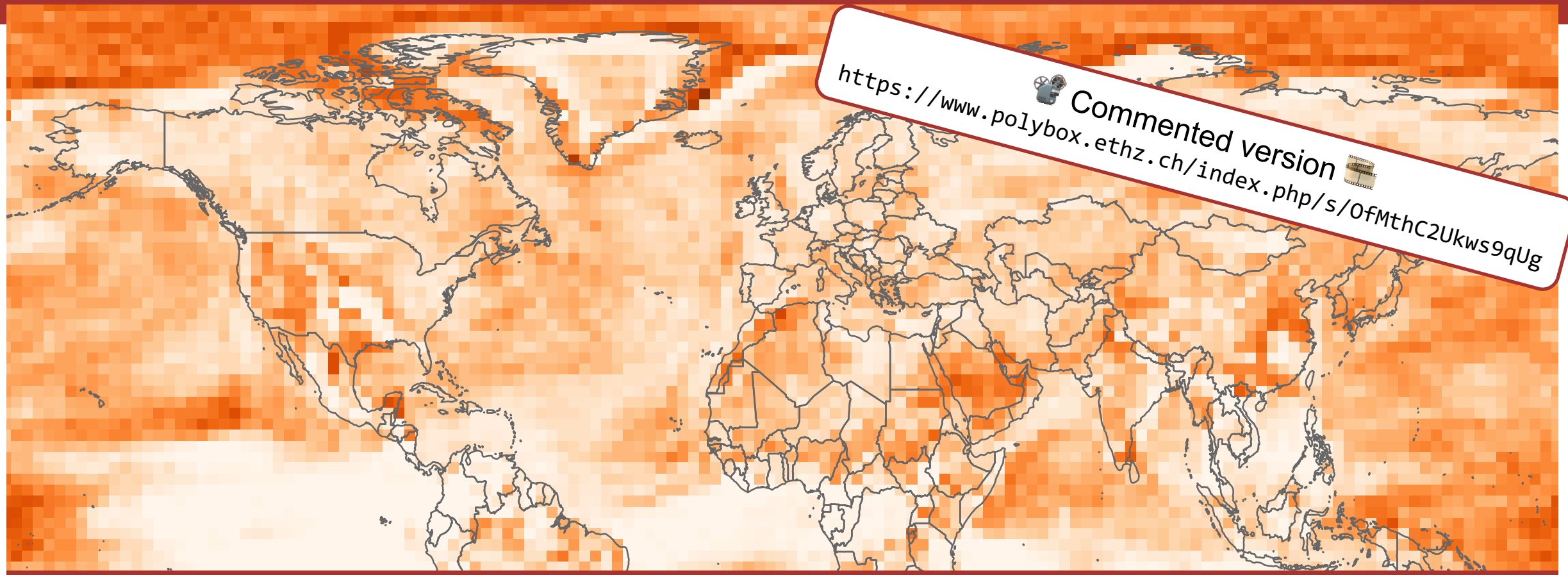
ETH zürich



The Challenge of Estimating High Return Levels with Short Records under Large Internal Variability

EGU Session on Large Ensembles

IAC Institute for Atmospheric and Climate Science

CC BY

Claire the Climate Scientist
Motivation



Model:

- CESM 1.2.2 (2° Resolution)
- Pre-industrial control run
- and further CMIP6 models

Target variable:

- Tx7d (Maximum 7d temperature mean)
- and Rx1d & Rx5d (max 1-/5-day precipitation)

Research focus:

- Return level and return period estimates for Maxima under different
  - time series durations t_{sub} or
  - block sizes m

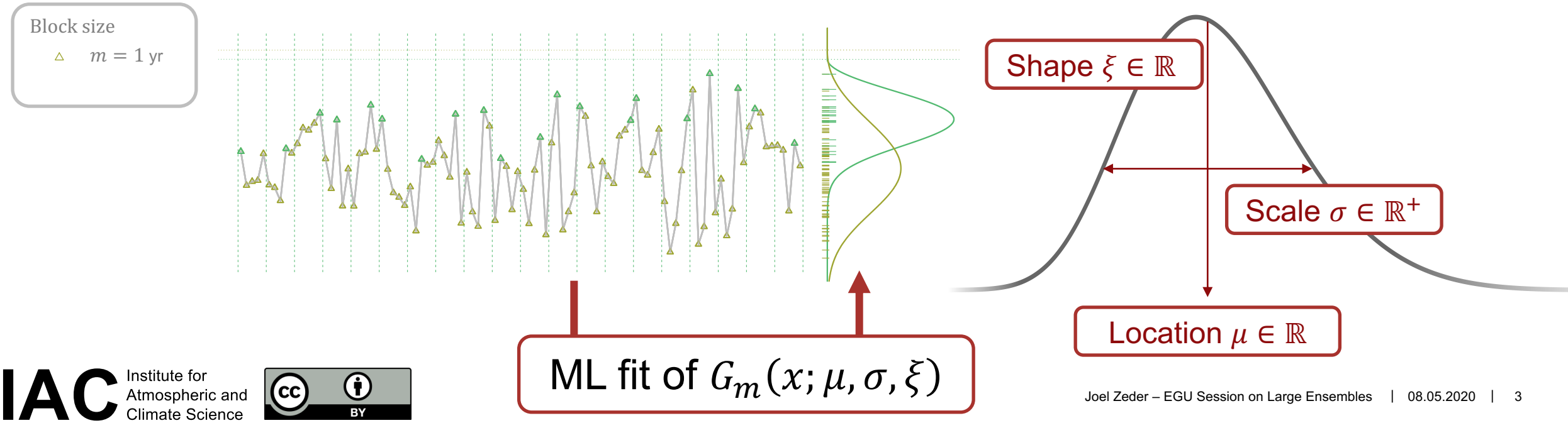
CC BY



Generalised Extreme Value Distribution $G(x; \mu, \sigma, \xi)$

Recap in Extreme Value Theory

- Statistical distribution of maxima taken from blocks (length m) of iid data
- E.g. highest daily temperature in consecutive five year blocks ($m = 5\text{yr}$) from 1901 to 2000 ($t_{sub} = 100\text{yr}$), i.e. 1901-1905, 1906-1910, …, 1996-2000



IAC Institute for Atmospheric and Climate Science

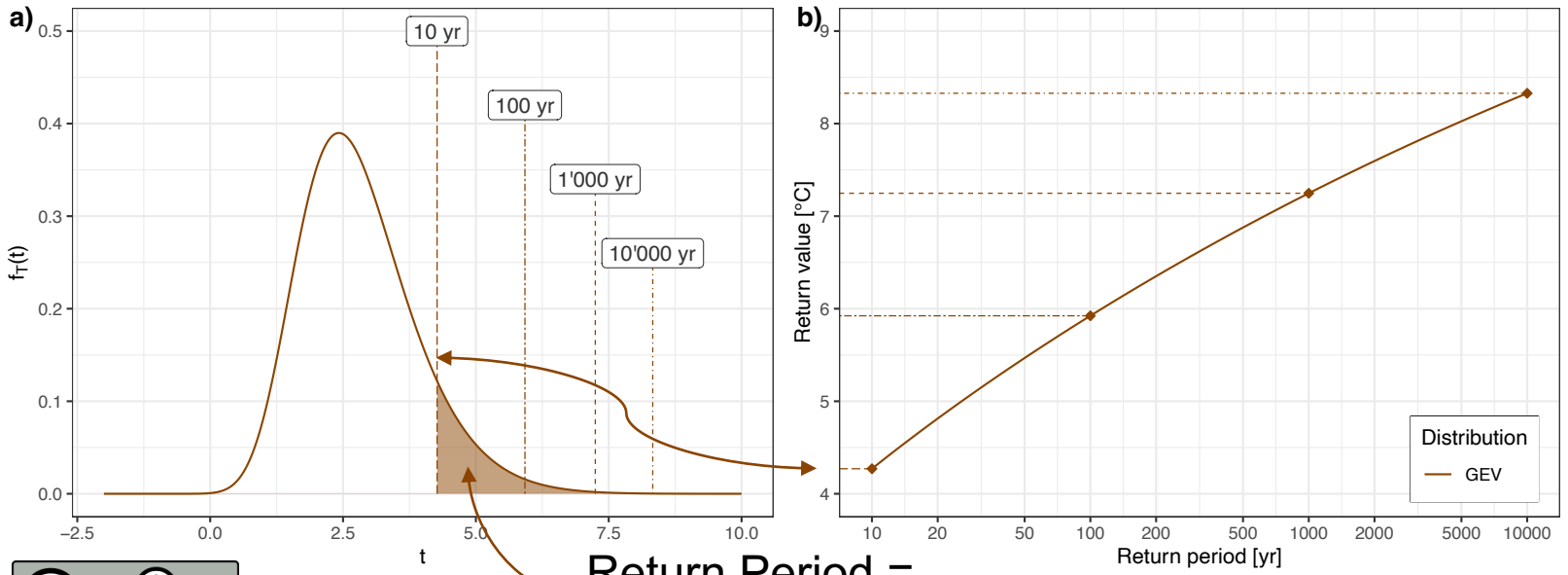
CC BY

Generalised Extreme Value Distribution $G(x; \mu, \sigma, \xi)$

Recap in Extreme Value Theory

- Having estimated the model parameters $\hat{\mu}, \hat{\sigma}, \hat{\xi}$, we can infer the respective return levels z_p for specified return periods $1/p$:

$$\hat{z}_p(\hat{\mu}, \hat{\sigma}, \hat{\xi}) = \hat{\mu} - \frac{\hat{\sigma}}{\hat{\xi}}[1 - (-\log(1-p))^{-\hat{\xi}}]$$



Return Period = 1/Exceedance Probability

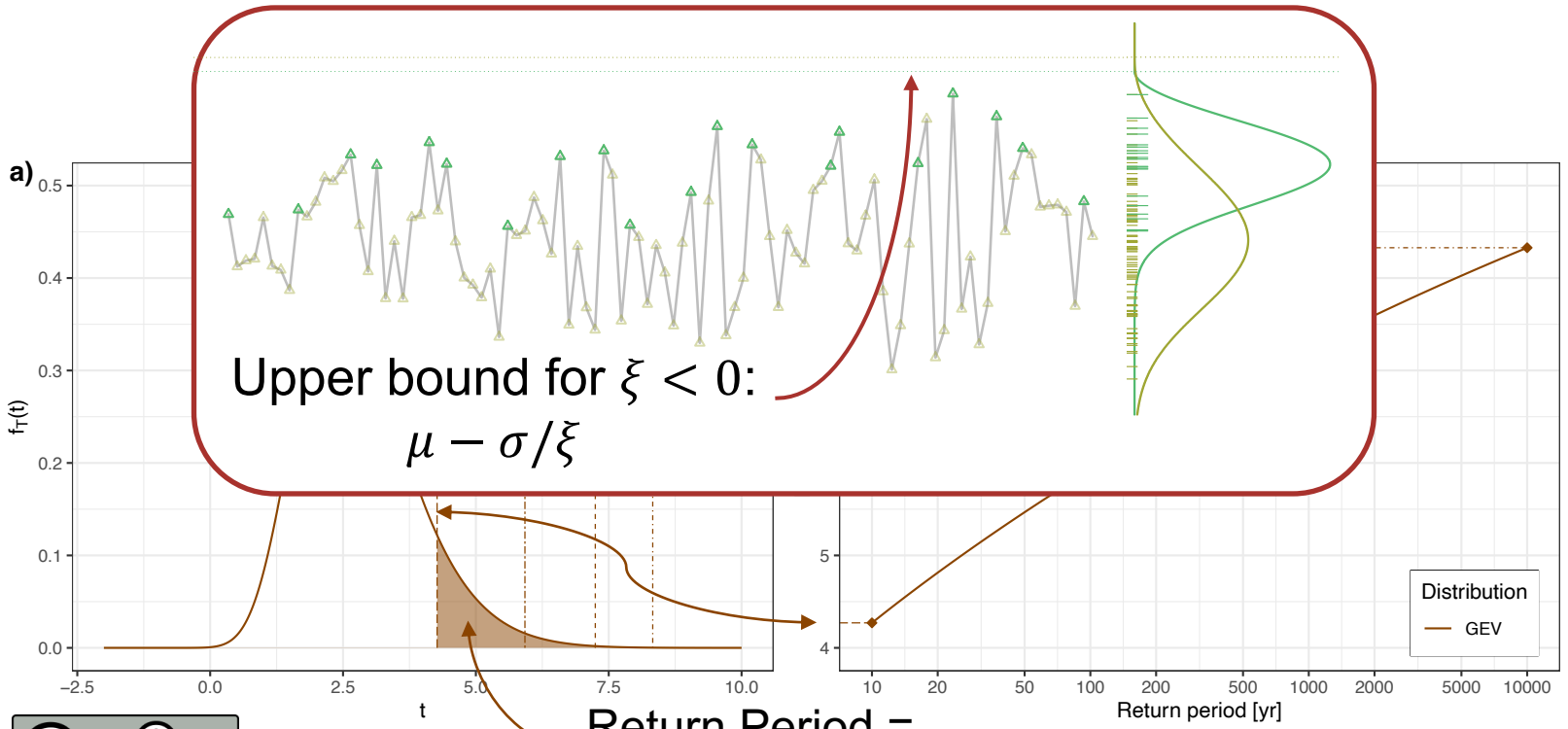
IAC Institute for Atmospheric and Climate Science

CC BY

Generalised Extreme Value Distribution $G(x; \mu, \sigma, \xi)$

Recap in Extreme Value Theory

- Having estimated the model parameters $\hat{\mu}, \hat{\sigma}, \hat{\xi}$, we can infer the respective return levels z_p for specified return periods $1/p$:



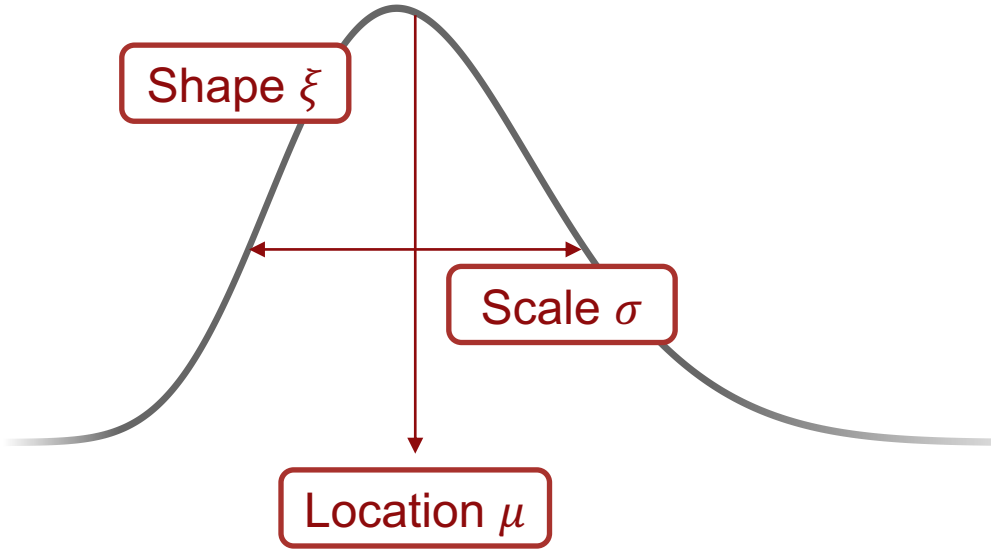
CC BY

Research Objective

How do estimates of model parameters (μ, σ, ξ), return values $(100/200/500/1000\mathrm{yr})$ and exceedance probabilities (i.e. return periods) depend on

- block size $(m = 1, 5, 20\mathrm{yr})$ and
- time series length $(t_{sub} = 50, 100, 500, 1000\mathrm{yr})$

under the influence of internal variability?



CC BY

Extremes in a Stationary (Model) Climate

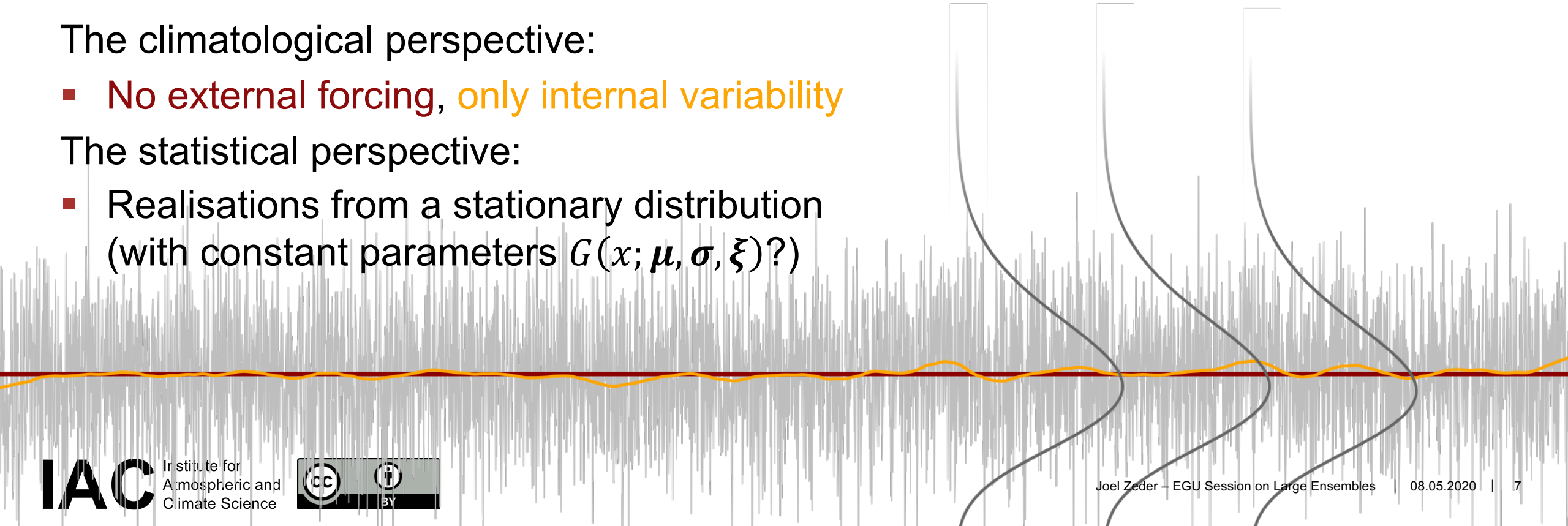
Focus on internal variability → Analyse extremes in stationary model climate

The climatological perspective:

- No external forcing, only internal variability

The statistical perspective:

- Realisations from a stationary distribution (with constant parameters $G(x; \boldsymbol{\mu}, \boldsymbol{\sigma}, \boldsymbol{\xi})$?)



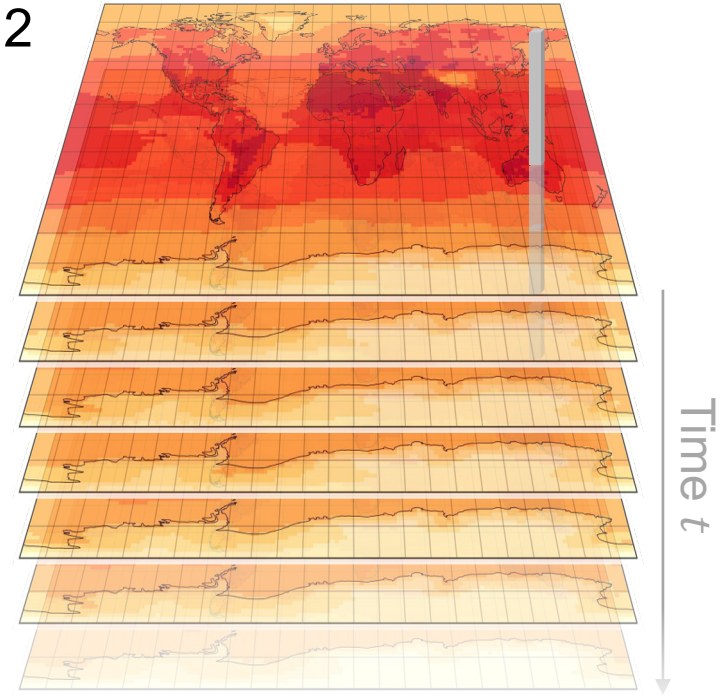
CC BY

Claire the Climate Scientist
Motivation



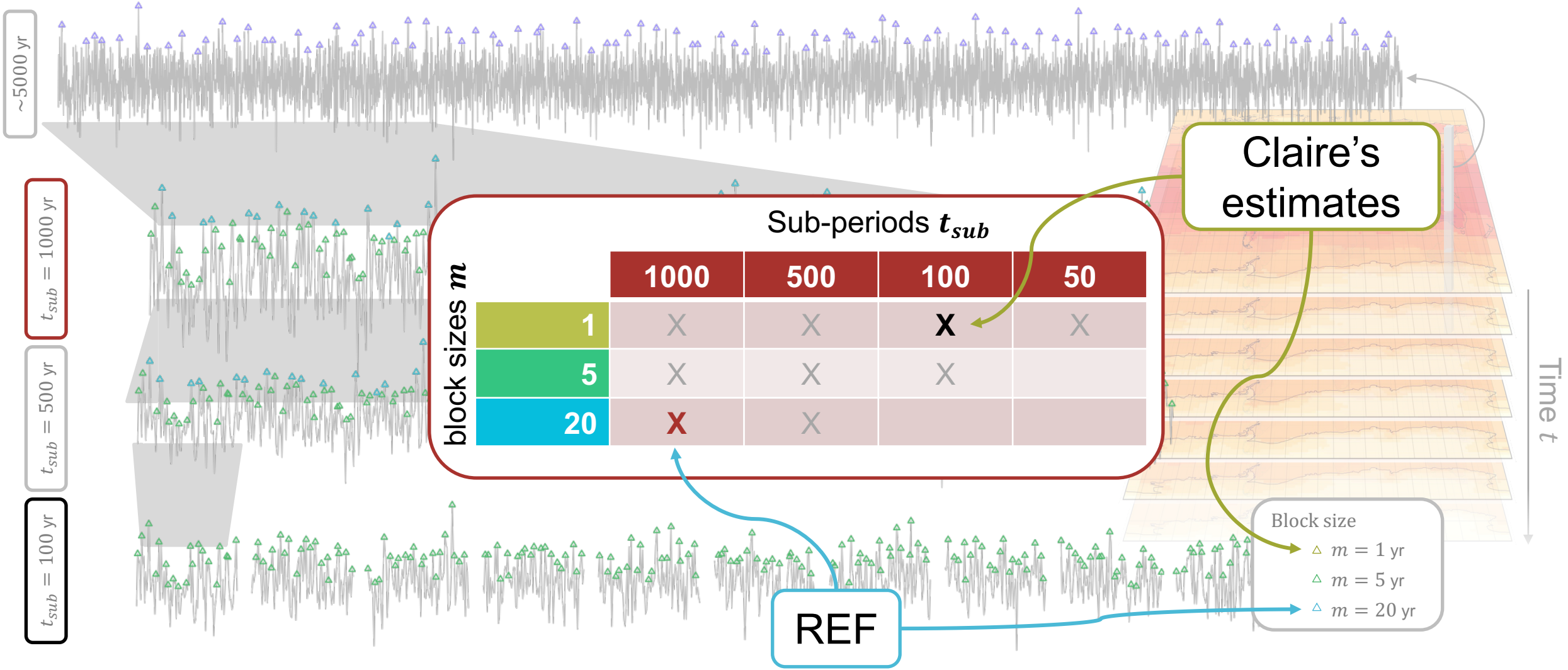
Data form CESM12 pre-industrial control run:

- 7day maxima of surface temperature
- at each grid point
- for ~5000yr model years



CC BY

Sub-periods t_{sub} and block sizes m

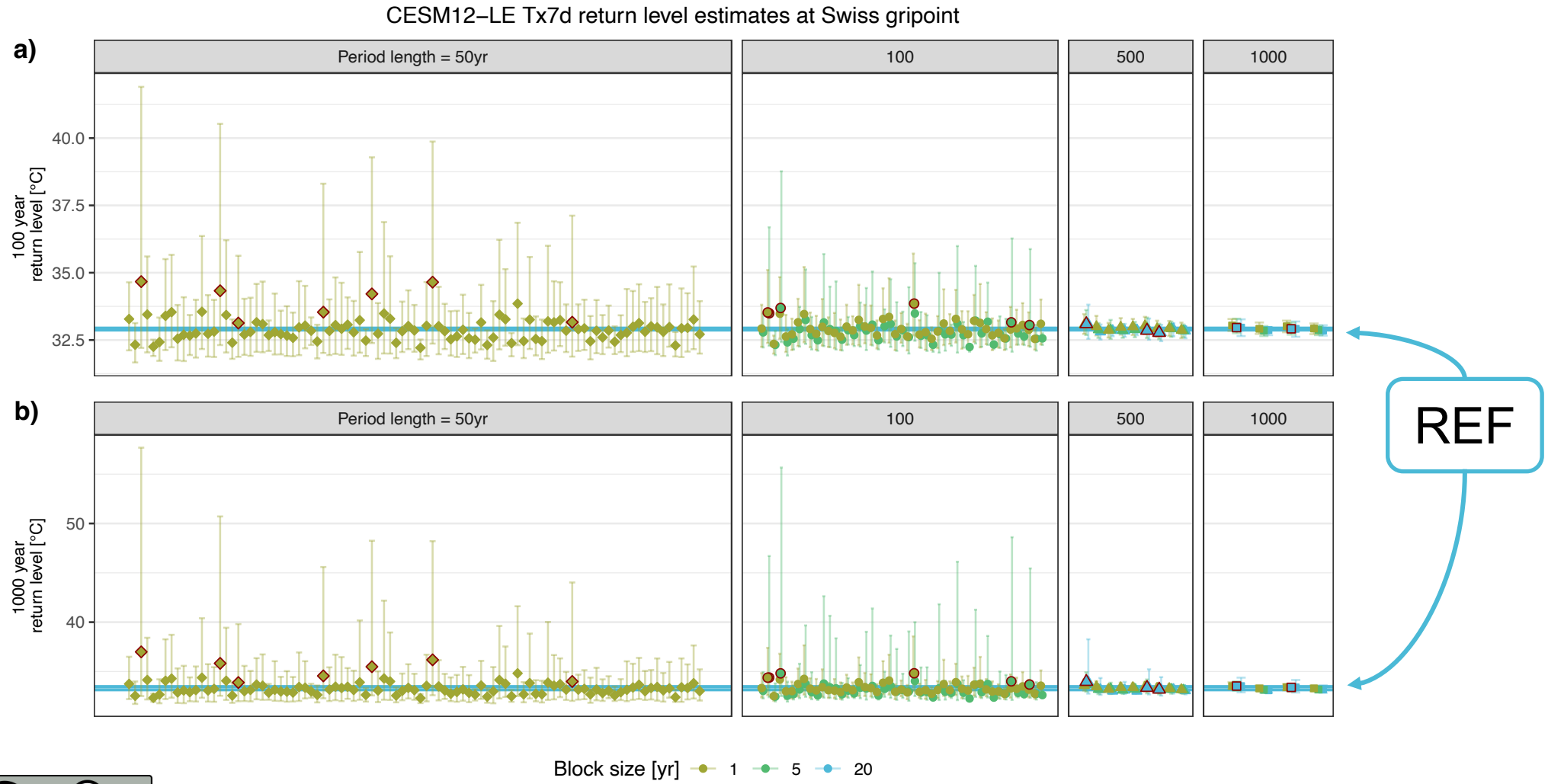


CC BY

Estimated Tx7d GEV return levels at Swiss grid point

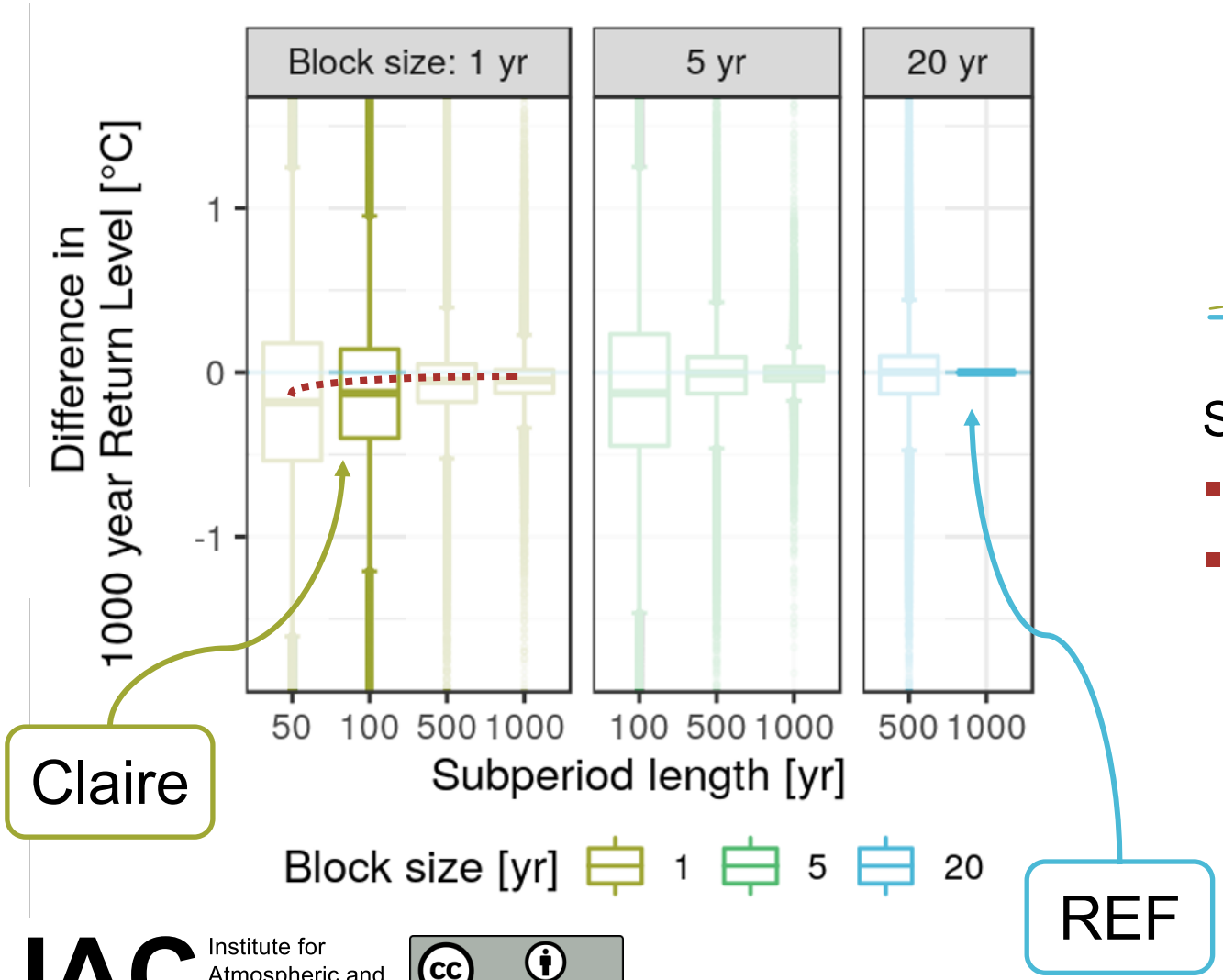
100 year
return level [°C]

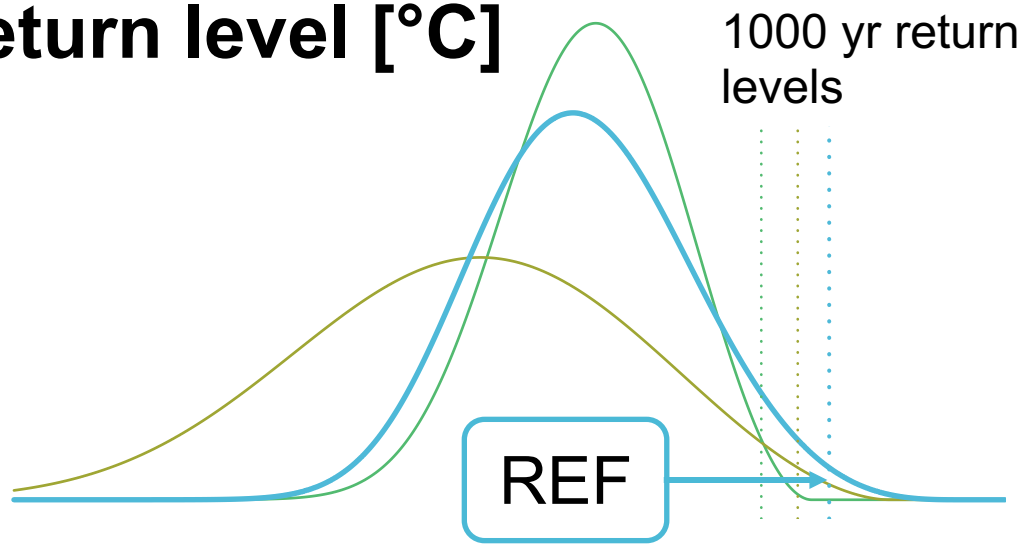
1000 year
return level [°C]



CC BY

1. Systematic underestimation of return level [°C]





Small systemic underestimation of return levels

- observable for shorter sub-periods t_{sub}
- not so much for smaller block sizes m

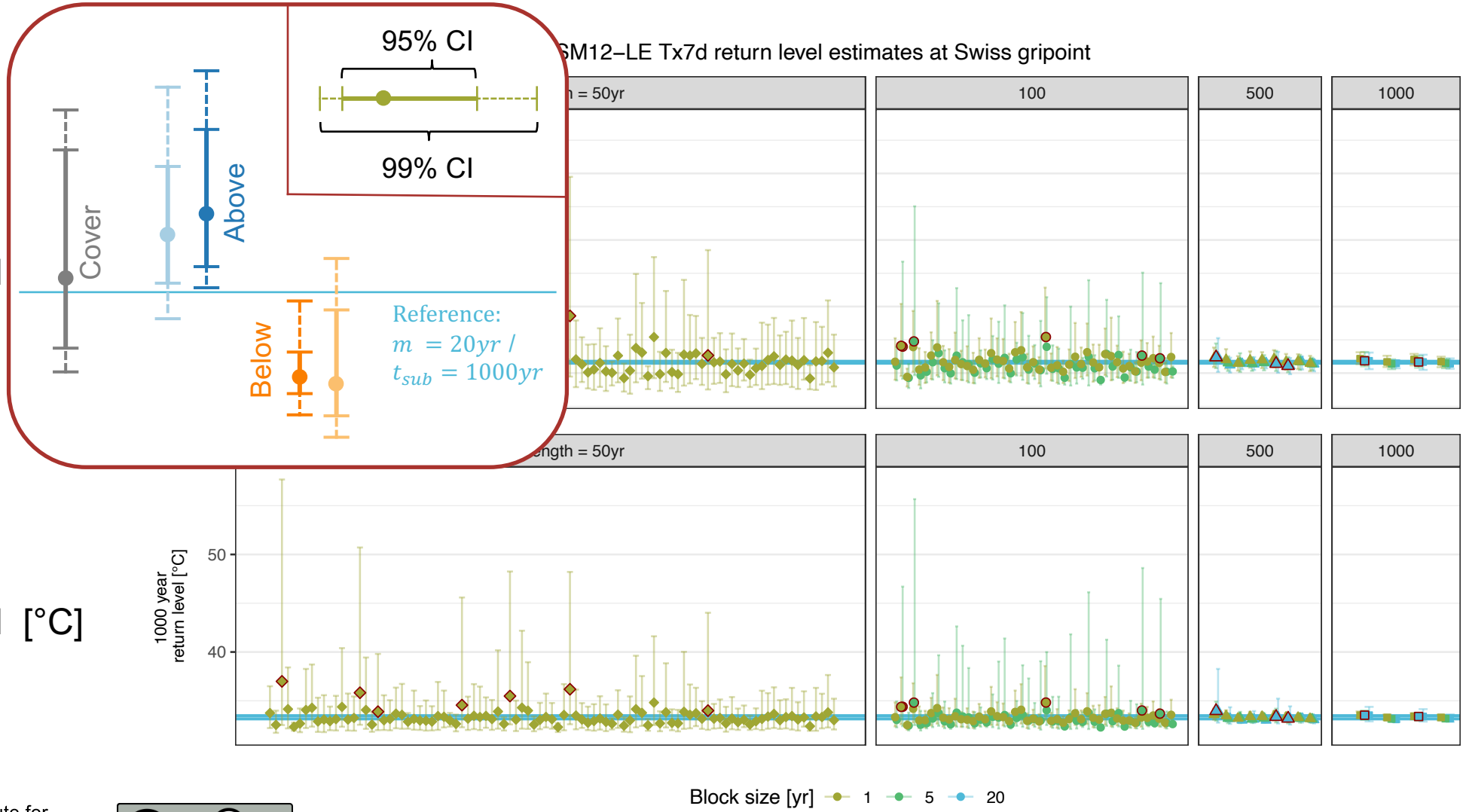
IAC Institute for Atmospheric and Climate Science

CC BY

CI of estimated Tx7d GEV return levels at Swiss grid point

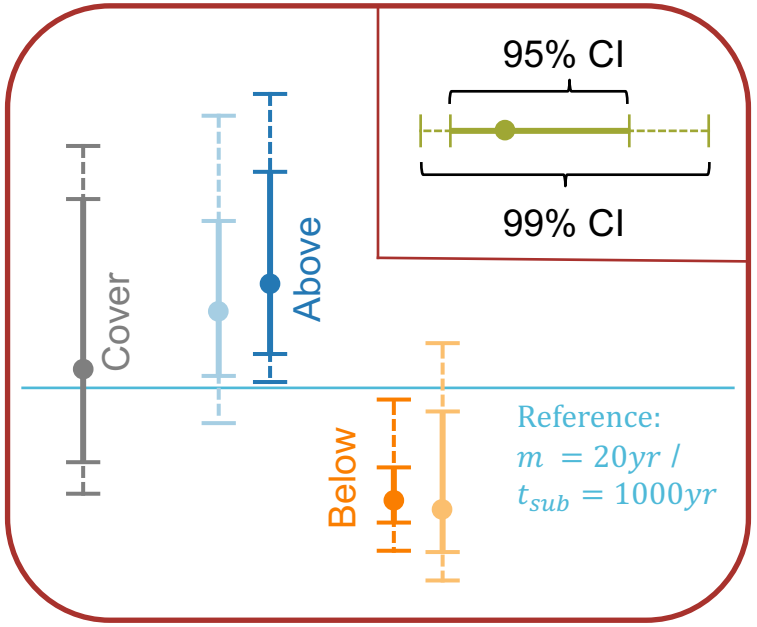
100 year return level

1000 year return level [°C]

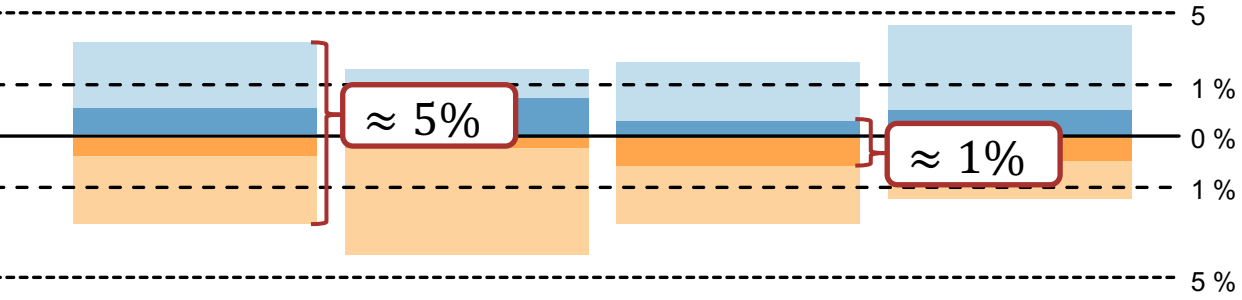


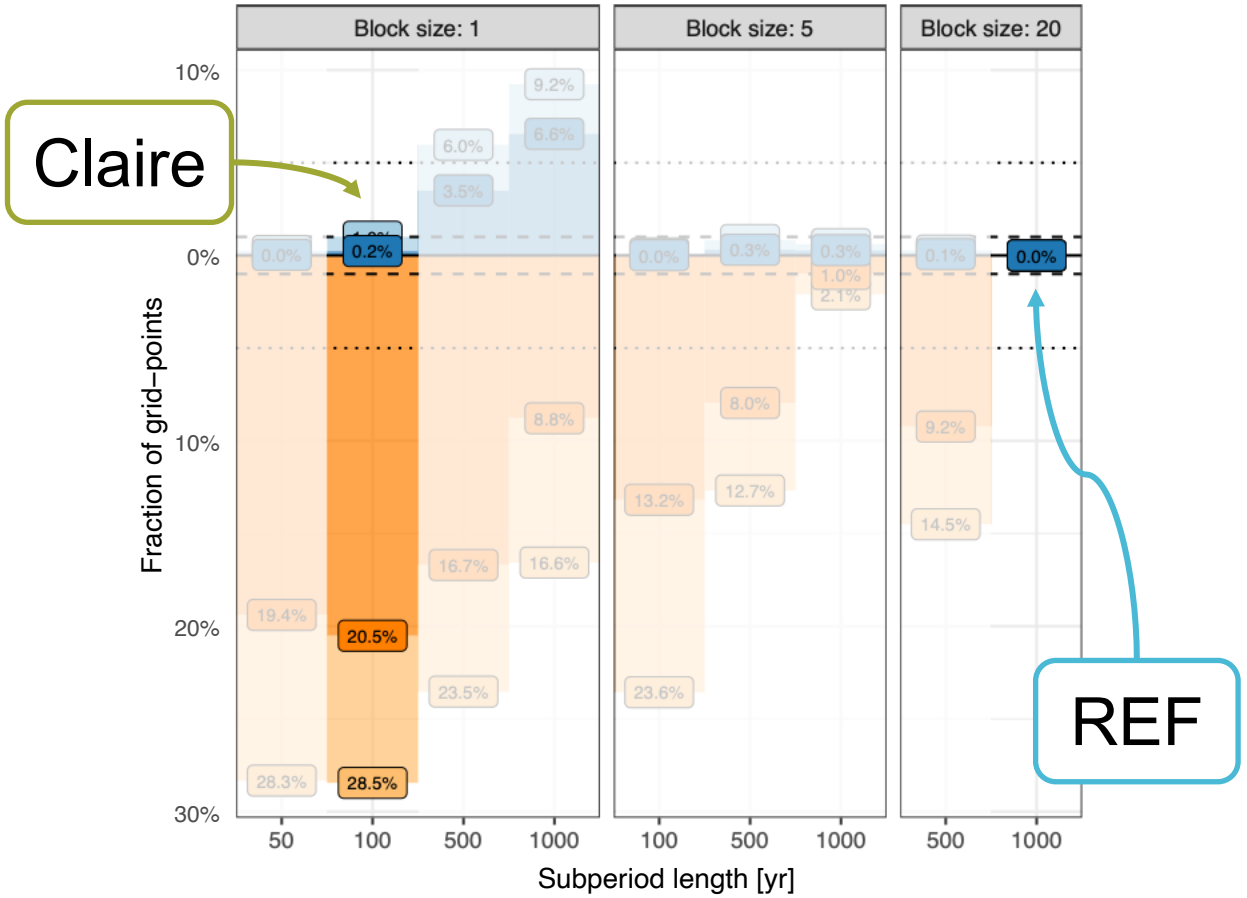
CC BY

2. CI coverage of 1000yr return level reference estimate



Expectation from theory:





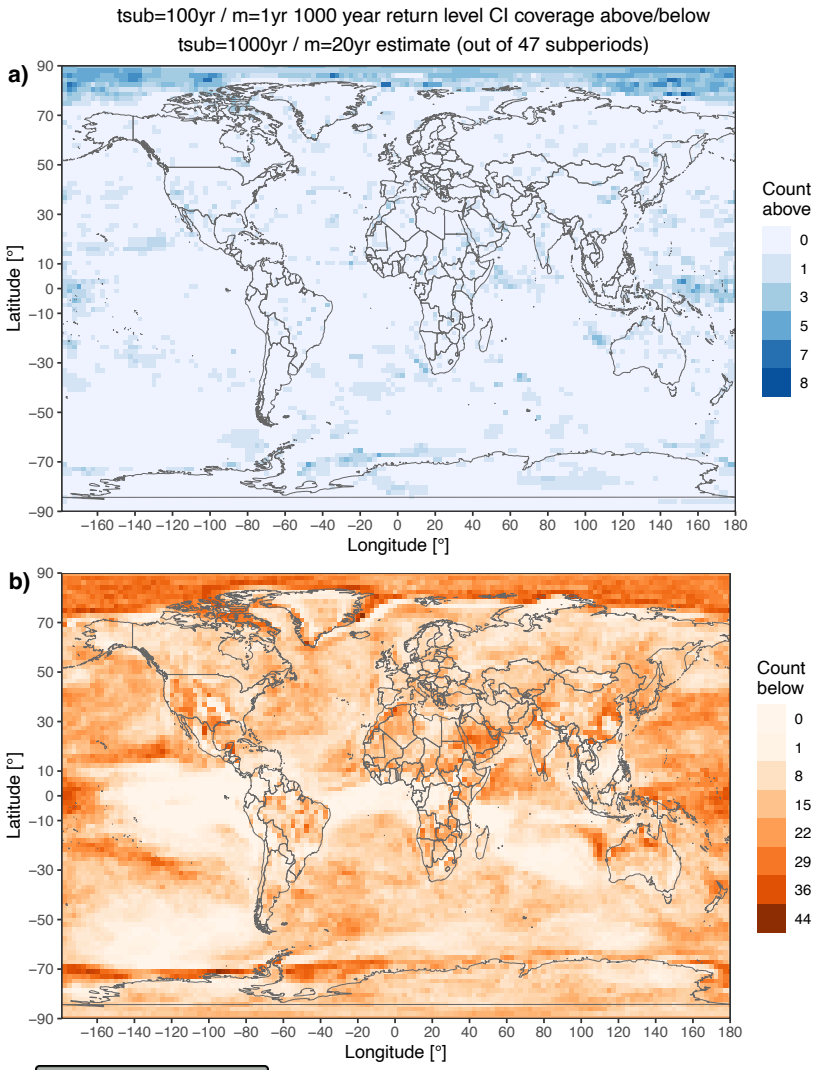
1000 year return level CI comparison with tsub=1000yr / m=20yr parameter:

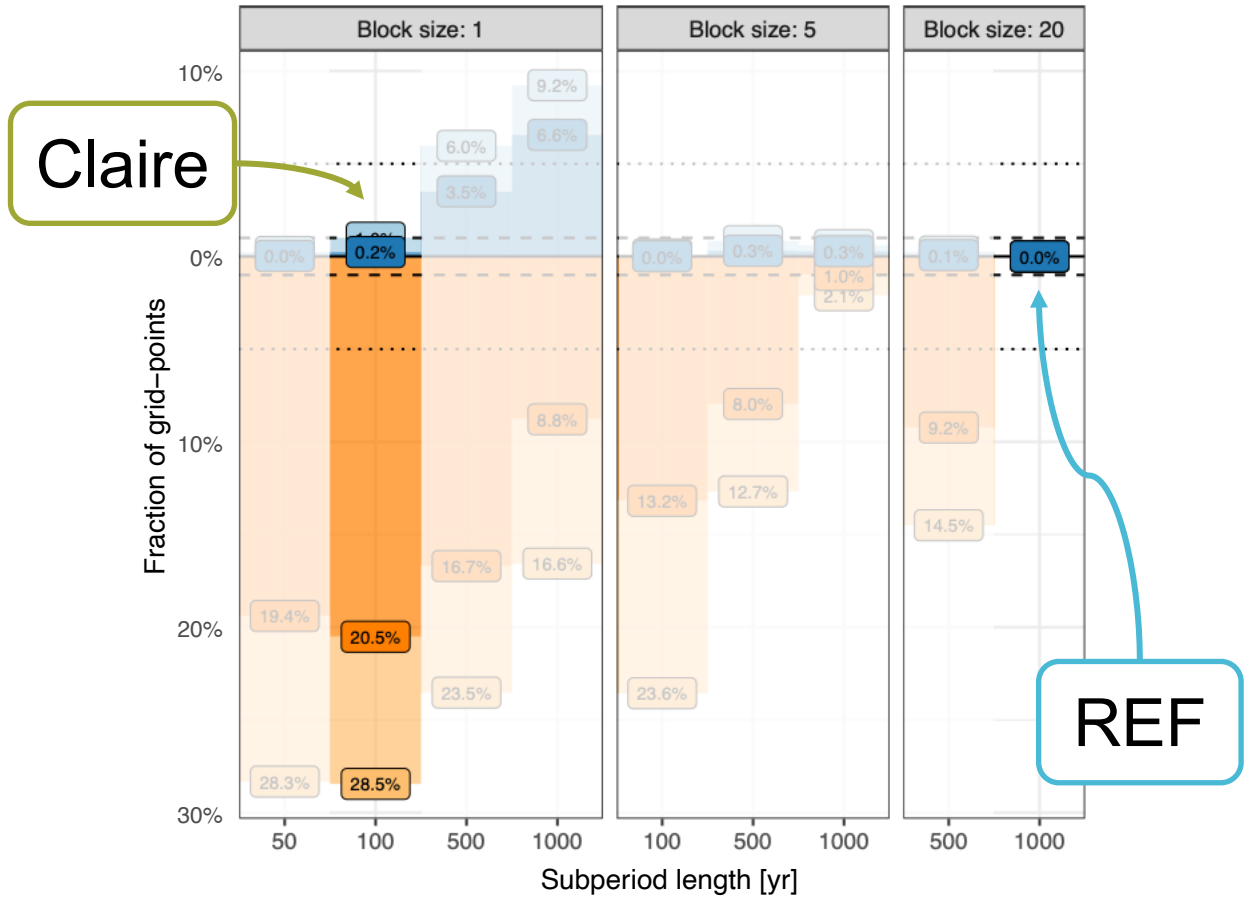
Above parameter (95% CI)
Above parameter (99% CI)
Below parameter (95% CI)
Below parameter (99% CI)

IAC Institute for Atmospheric and Climate Science

CC BY

2. CI coverage of 1000yr return level reference estimate





1000 year return level CI comparison with tsub=1000yr / m=20yr parameter:

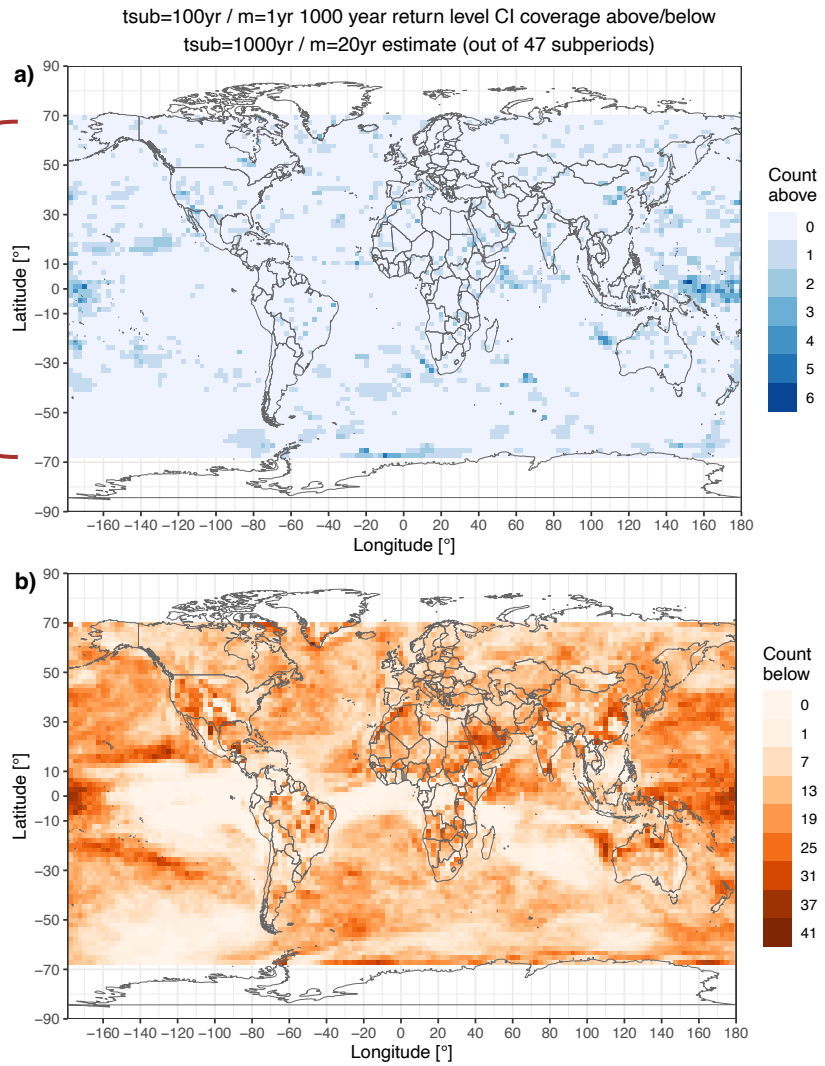
Above parameter (95% CI) | Below parameter (95% CI)
Above parameter (99% CI) | Below parameter (99% CI)

IAC Institute for Atmospheric and Climate Science

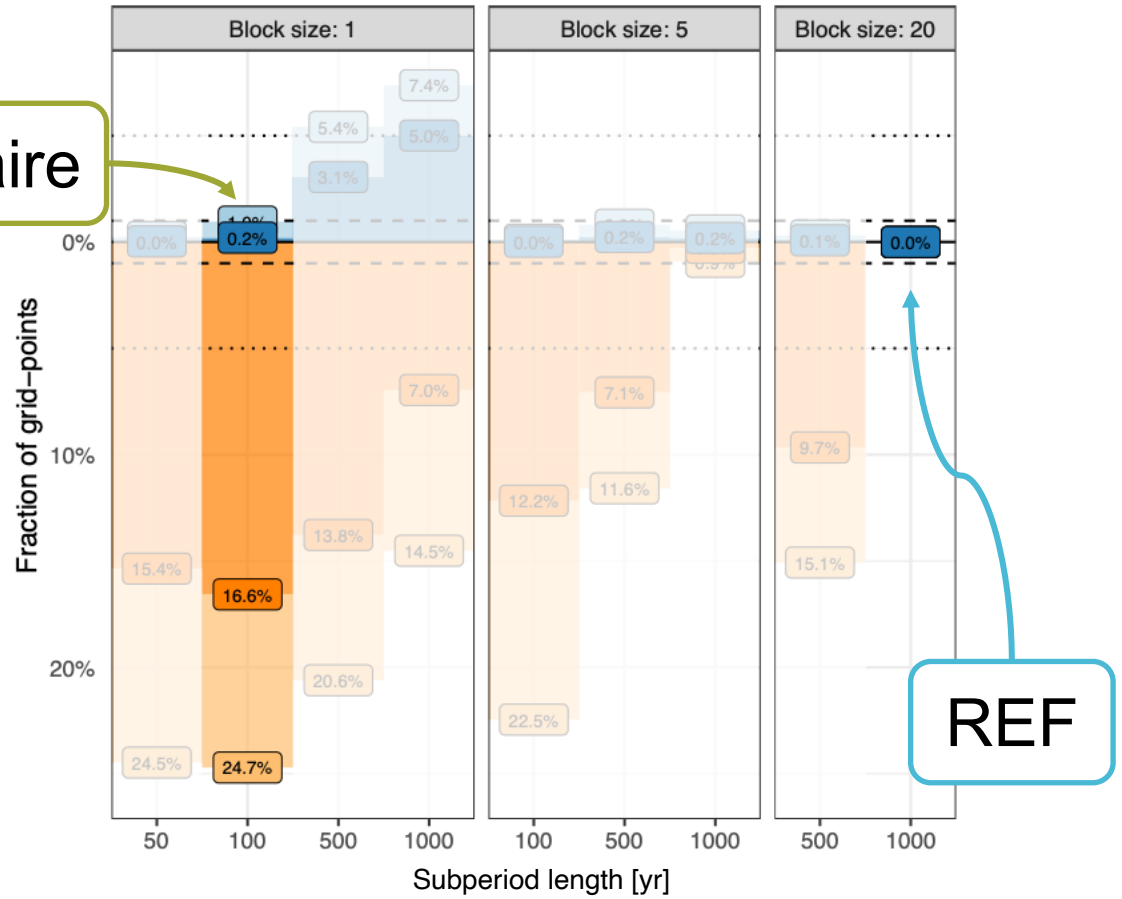
CC BY

2. CI coverage of 1000yr return level reference estimate

Only low latitudes



Claire



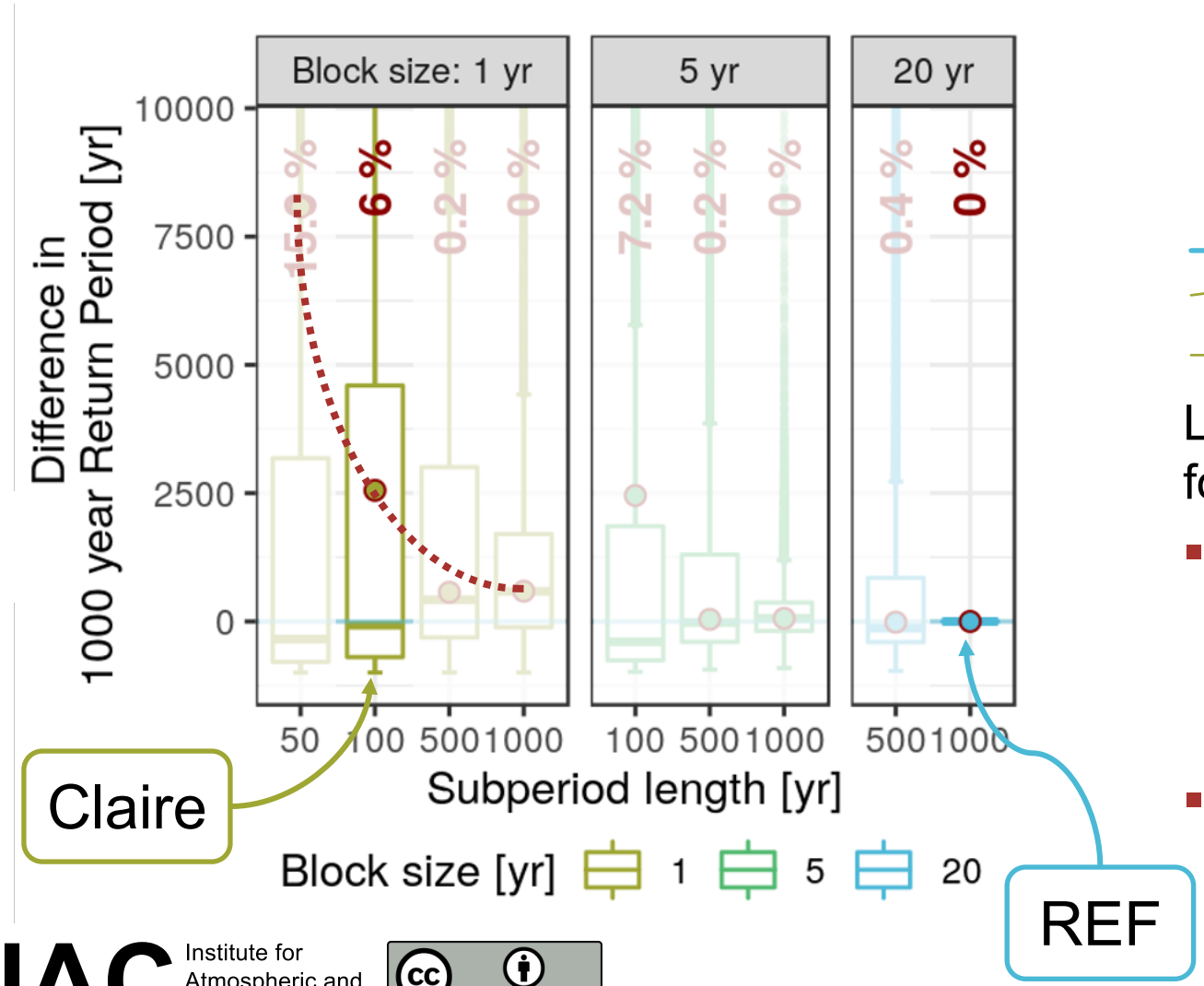
1000 year return level CI comparison with tsub=1000yr / m=20yr parameter:

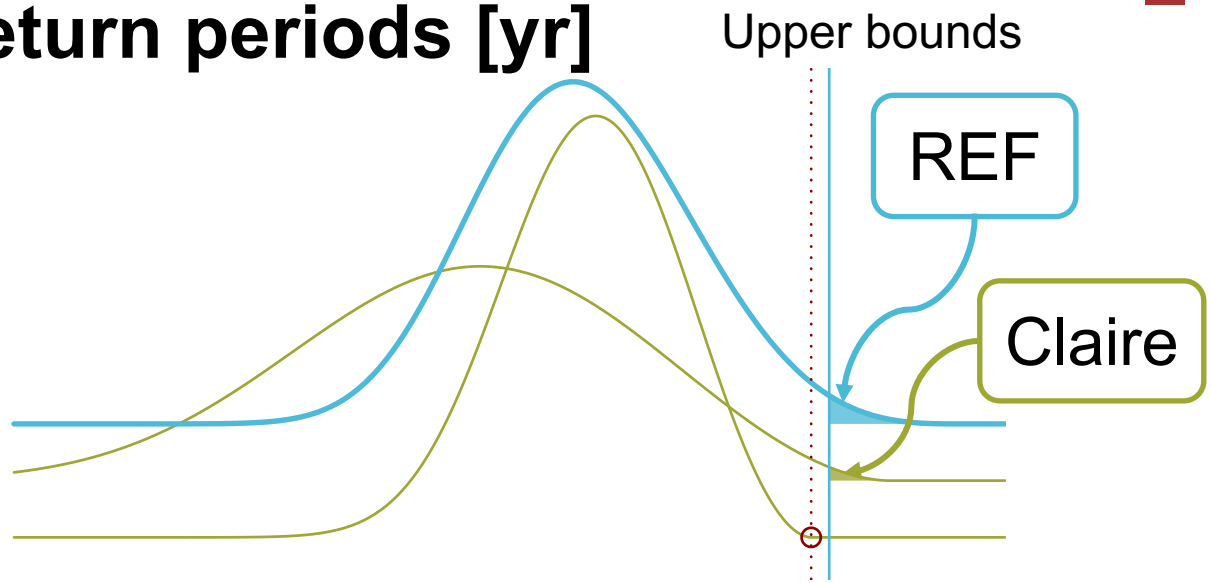
Above parameter (95% CI)
Above parameter (99% CI)
Below parameter (95% CI)
Below parameter (99% CI)

IAC Institute for Atmospheric and Climate Science

CC BY

3. Systematic underestimation of return periods [yr]





Large systemic overestimation of return periods for high return levels in the reference data:

- The median return period of a 1000 yr reference return level is estimated to be a ~3500 yr return level for $t_{sub} = 100yr$ and $m = 1yr$ fits.
- In 6% of $t_{sub} = 100yr$ and $m = 1yr$ fits, the 1000 yr reference return level has a return period of infinity.

IAC Institute for Atmospheric and Climate Science

CC BY

Conclusions and Outlook

Even under stationary conditions,

- ✓ high return values are often underestimated and return periods are overestimated by fitting on small block sizes and short time series.
- ✓ Confidence intervals are often not covering the refence value and thus underestimate uncertainty of the estimate.

The same findings can be concluded for transient LE CESM12 data, other CMIP6 control run simulations and using $m = \mathbf{5}\mathrm{yr}$ / $t_{sub} = 1000\mathrm{yr}$ estimates as reference.

Outlook:

- ❑ Extend analysis to non-stationary **transient** LE simulations.

CC BY

Thank you very much for your attention

- Joel Zeder, PhD Candidate
  joel.zeder@env.ethz.ch / @JoelZeder
- Dr. Erich Fischer, Senior Scientist
  erich.fischer@env.ethz.ch / @erichfischer

ETH Zurich
Climate Physics Group of Prof. Reto Knutti
Institute for Atmospheric and Climate Science
Universitätstrasse 16
8092 Zurich
Switzerland





Also have a look at the presentation of Claudia Gessner, working on a similar project:

https://meetingorganizer.copernicus.org/EGU2020/EGU2020-1628.html

CC BY