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CLIM XTREME Climate Change and Extreme Events

Characterization of unprecedented precipitation extremes based on episodic downscaling of a large CCLM ensemble

Hendrik Feldmann, Alberto Caldas-Alvarez, Florian Ehmele, Joaquim G. Pinto

Institute of Meteorology and Climate Research – Department Troposphere Research (IMK-TRO)

@rnd.de Ahr flooding 7-2021 Schuld

@rnd.de Erft flooding 7-2021 Erftstadt

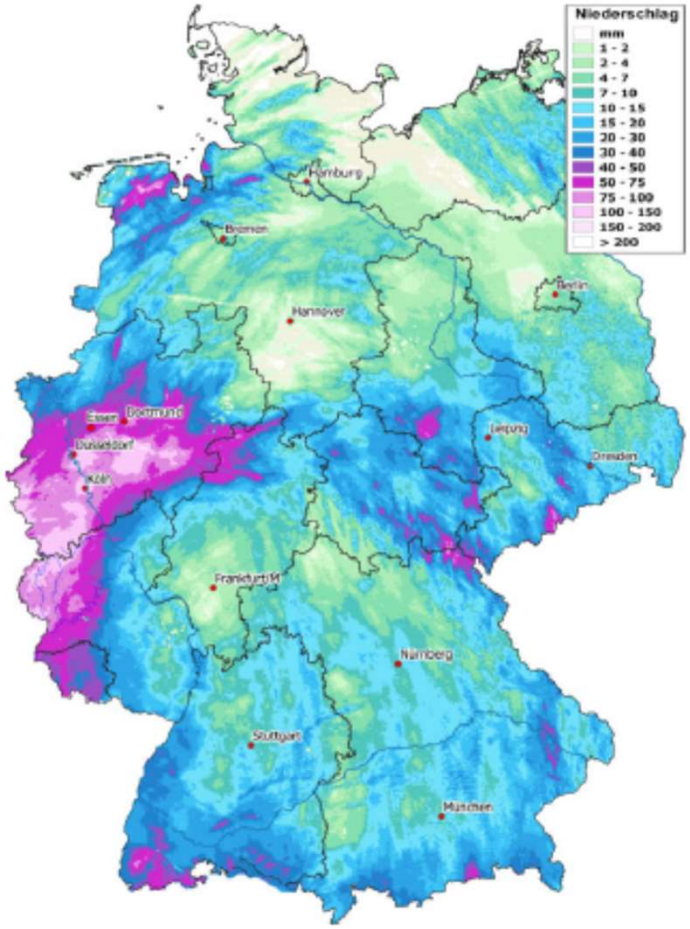
Outline

- Motivation
- THE LAERTES-EU large RCM Ensemble
- Identification and Comparison of Extreme Precipitation Events
- Episodic Downscaling of Extreme Precipitation Events
- Conclusions and Outlook

Motivation:

- Extreme meteorological events can cause the loss of human lives and huge damages
- The observational record is too short to reliably estimate the return level of events with a return period of 100 years or longer under current climate conditions
  - This information is needed for specification of critical infrastructures or for the refinancing of insurance companies
- **Recent example: flooding event Ahr/Erft/Meuse connected to low pressure system “Bernd” 13.-15. July 2021**

Flooding Event „Bernd“ 13. – 15. July 2021

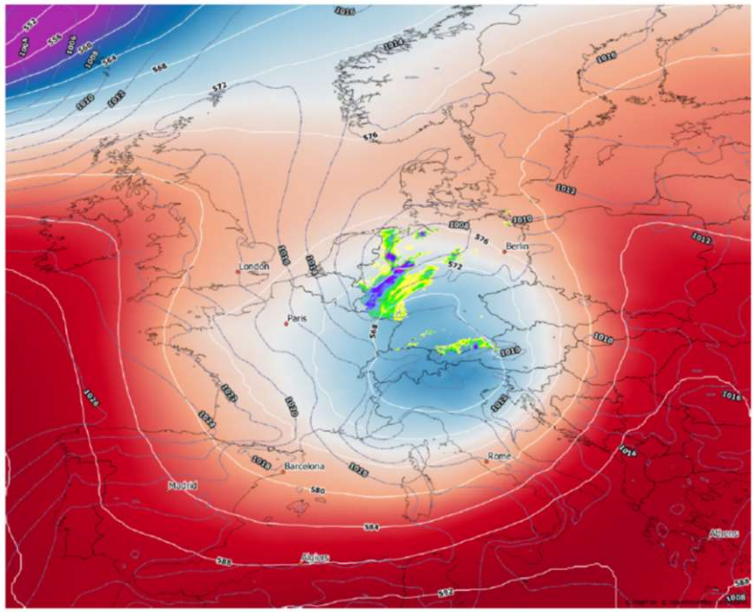


c) 13/14.07.2021

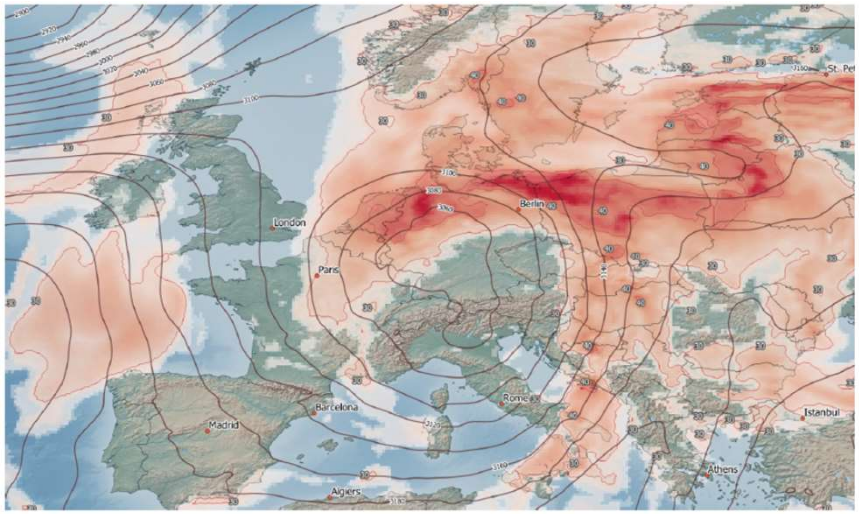
Source: CEDIM FDA Report (https://www.cedim.kit.edu/2926.php)

Flooding Event „Bernd“ 13. – 15. July 2021

14.07.2021 12 UTC 500hPa Geopotential, Sea Level Pressure [hPa] GEM and RADOLAN Radar Intensity



14.07.2021 12 UTC 700 hPa Geop. Height and Precipitable Water [mm]



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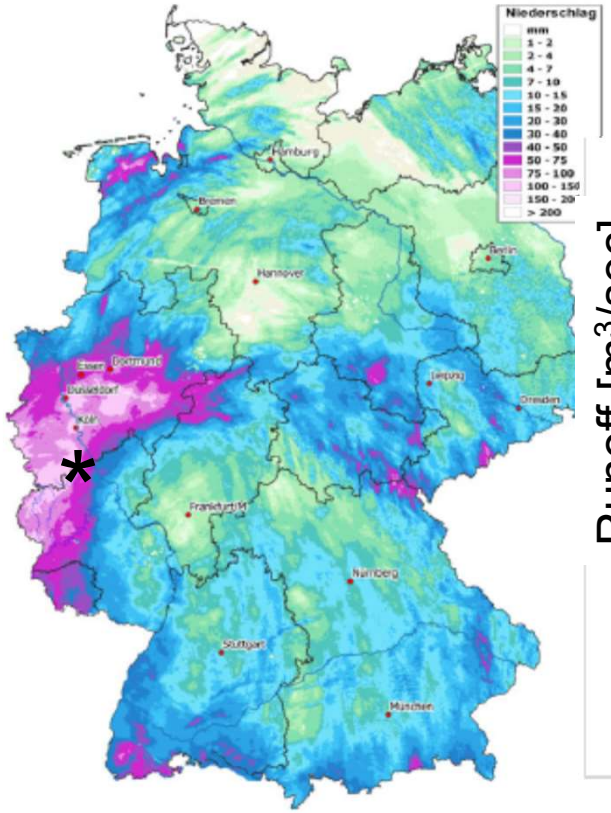

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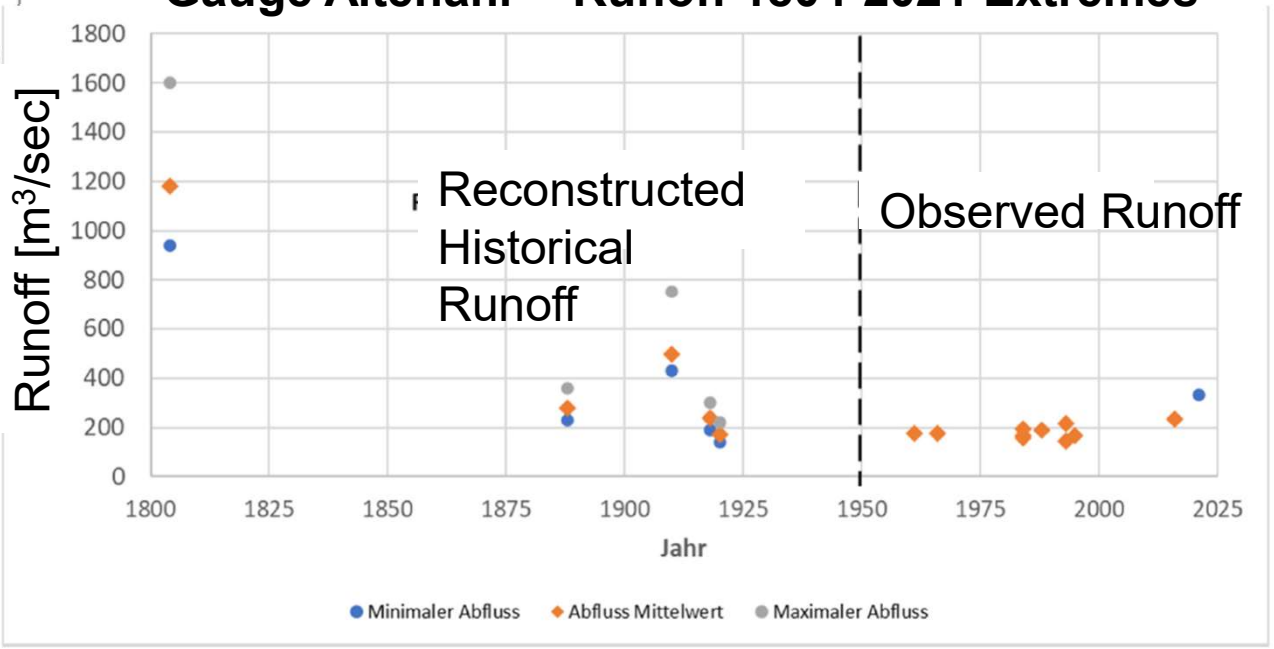


Source: CEDIM FDA Report (https://www.cedim.kit.edu/2926.php)

The large MiKlip CCLM Ensemble LAERTES-EU

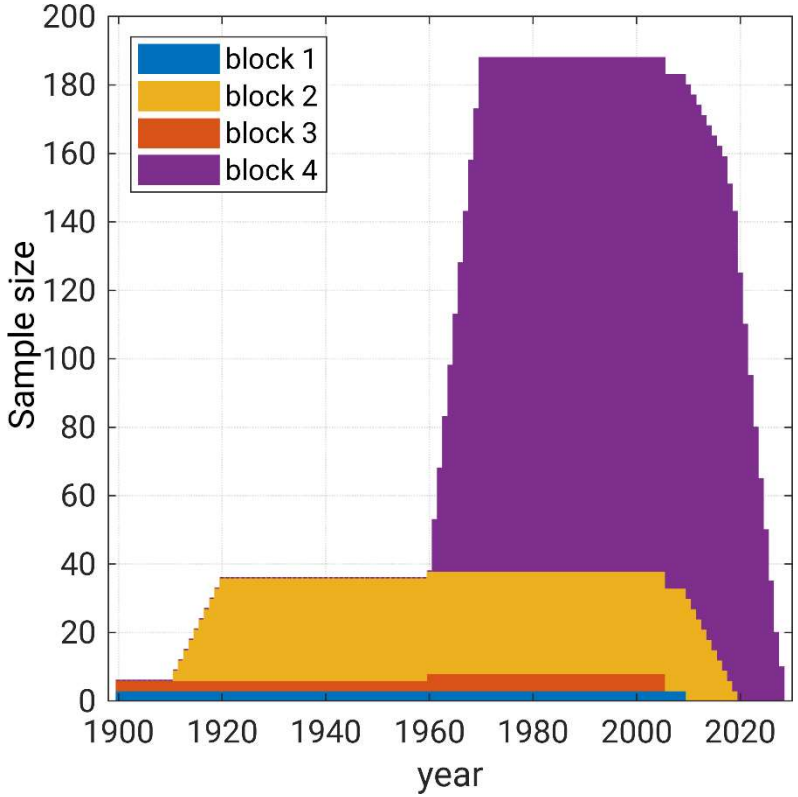
Assessment of extremes with very long return periods in the large RCM ensemble (MiKlip/“LAERTES-EU“)

MiKlip LAERTES-EU regional decadal hindcast ensemble

- EURO-CORDEX Domain
- CCLM5, 0.22° resolution
- initialized 10-year hindcast simulations
  - Yearly starting dates 1960-2019 (1910-2009)
  - 10 (+5+3) members/start years
- forced by MPI-ESM-HR/LR

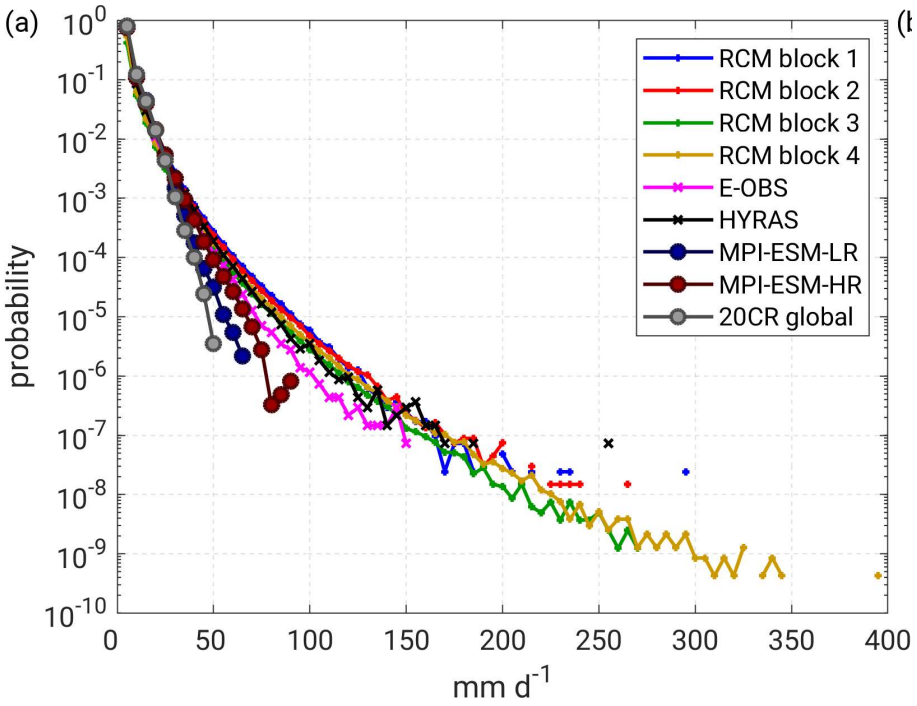
► > 10.000 simulation years for present day climate

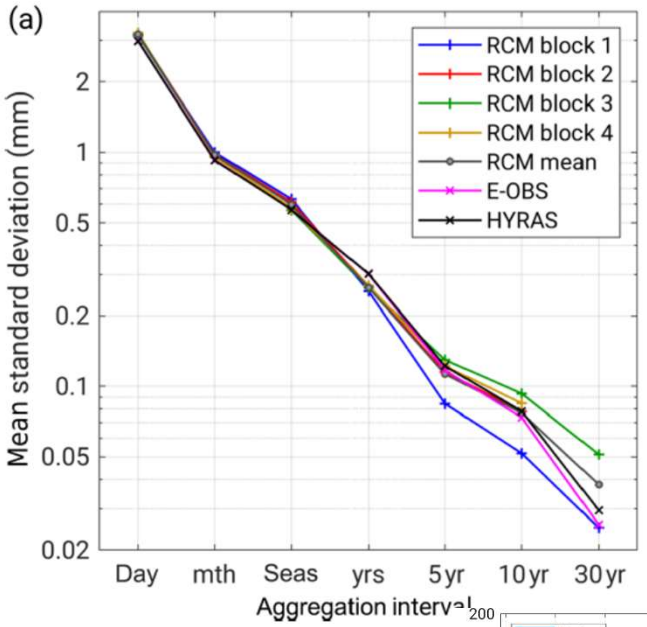
e.g. a 10-year return value can be based on 1000+ events, a 100-year return value on > 100 events

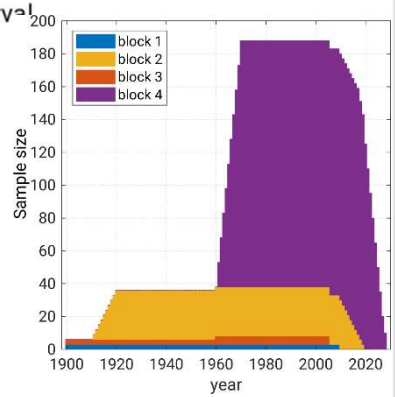


from: Ehmele et al., 2020

Evaluation of extreme precipitation in the large RCM ensemble (MiKlip/“LAERTES“)



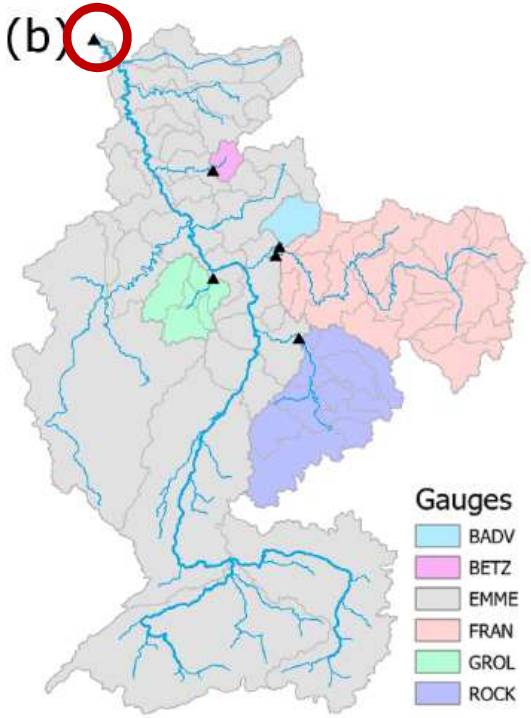


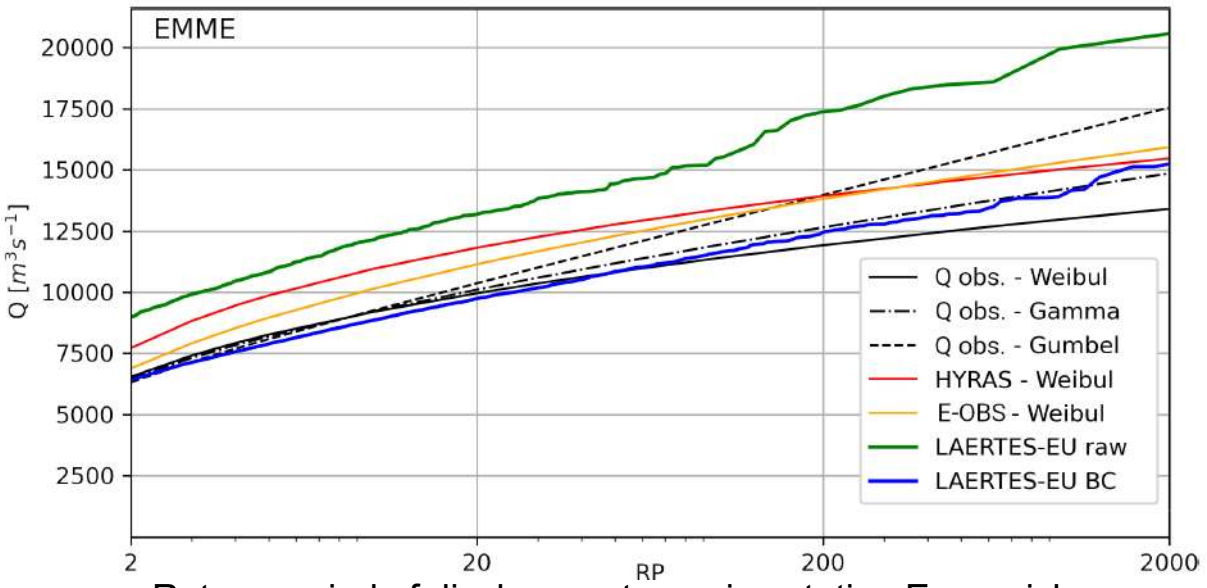


from: Ehmele et al., 2020

Long return periods of river discharge

Hydrological modelling driven by the LAERTES Ensemble





Return period of discharge at gauging station Emmerich

Rhine catchment
O = Gauging Station Emmerich
A = 159,555 km^2

from: Ehmele et al., 2021

Identification and Comparison of Extreme Preciptation Events

Event Selection and Quantification

The Precipitation Severity Index (PSI)

(derived from Leckebusch et al., 2008; Pinto et al., 2012; Piper et al., 2016)

Considers **intensity**, **coverage** and **persistence** of heavy precipitation. Only intensities over the 80-perc are included.

$$PSI_T = \sum_{i=1}^{N} \sum_{j=1}^{M} \sum_{t=T-t_\alpha}^{T} \frac{RR_{ijt}}{RR_{perc_{ij}}} \cdot \prod_{\tau=t}^{T} I\left(RR_{ij\tau}, RR_{perc_{ij}}\right)$$

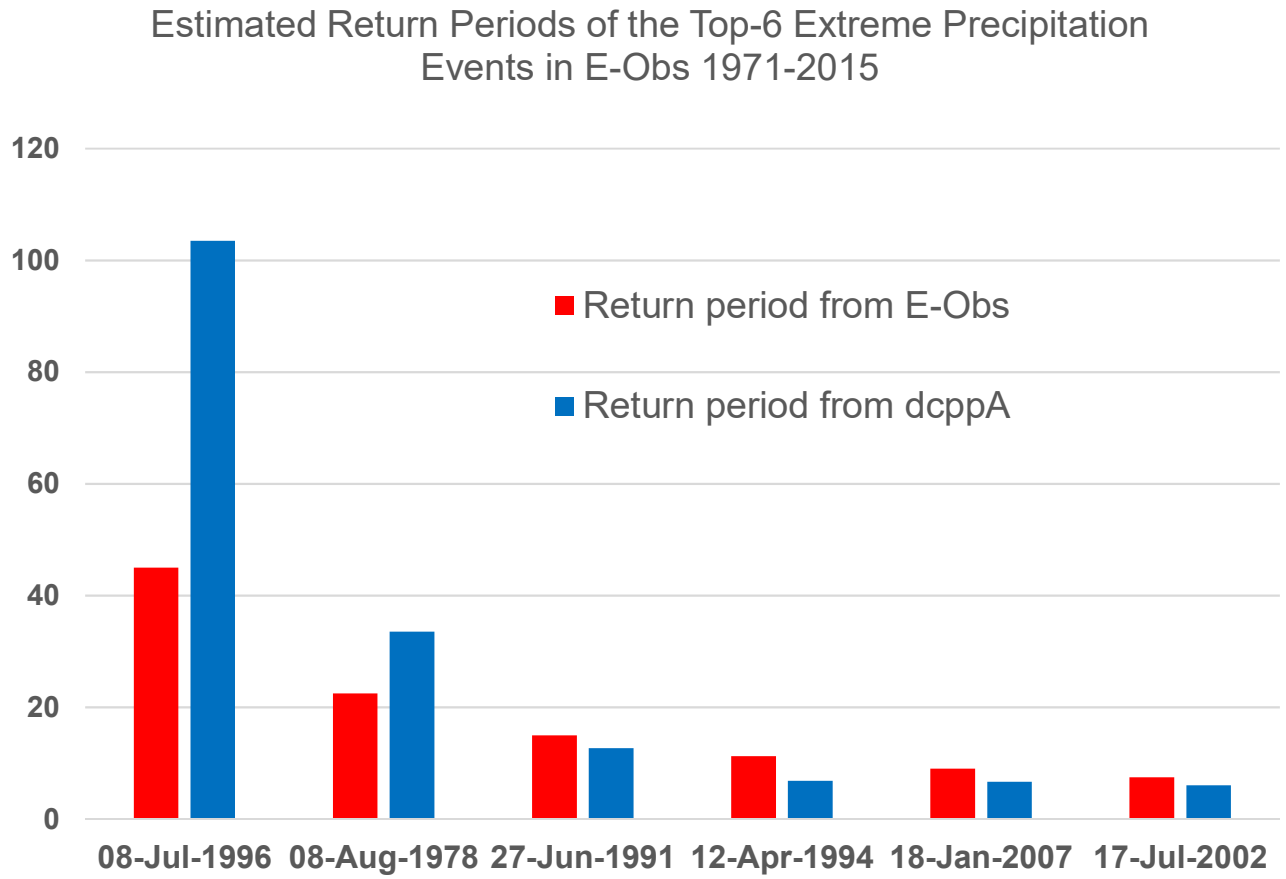
$$I\left(RR_{ij\tau}, RR_{perc_{ij}}\right) \begin{cases} 0 \; if \; RR_{ij\tau} < RR_{perc_{ij}} \\ 1 \; if \; RR_{ij\tau} \geq RR_{perc_{ij}} \end{cases}$$

T=Time step t_α=Accumulation (days), max 2

M y-dim RR_{ijt}=24-h prec. at grid point (i,j) at time (τ)

N x-dim $RR_{perc_{ij}}$= Percentile of precip (period)

Estimation of Return Periods* of Observed Extreme Precipitation Events

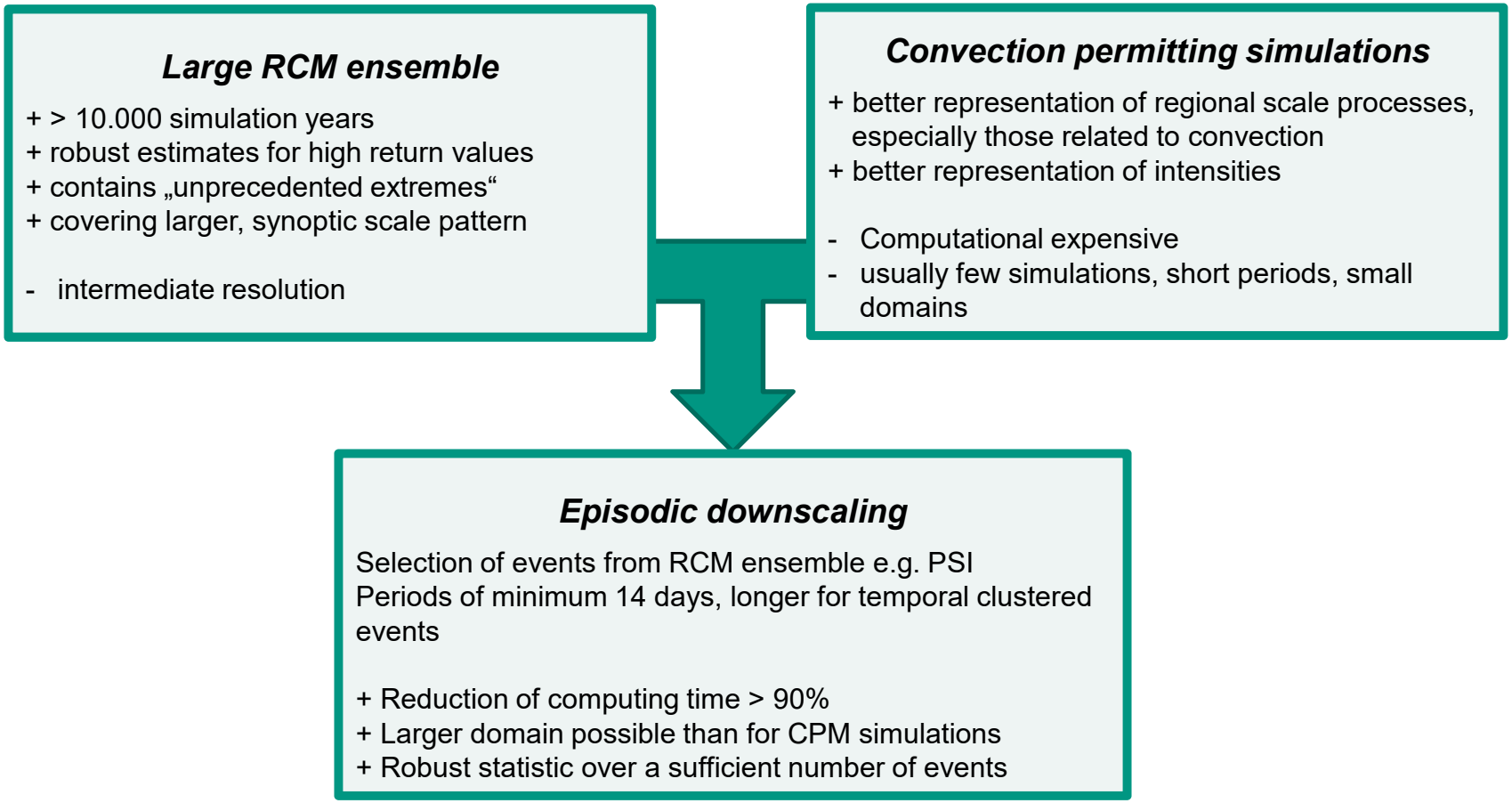


dcppA = LAERTES-EU Block 4

* via plotting position

Episodic Downscaling

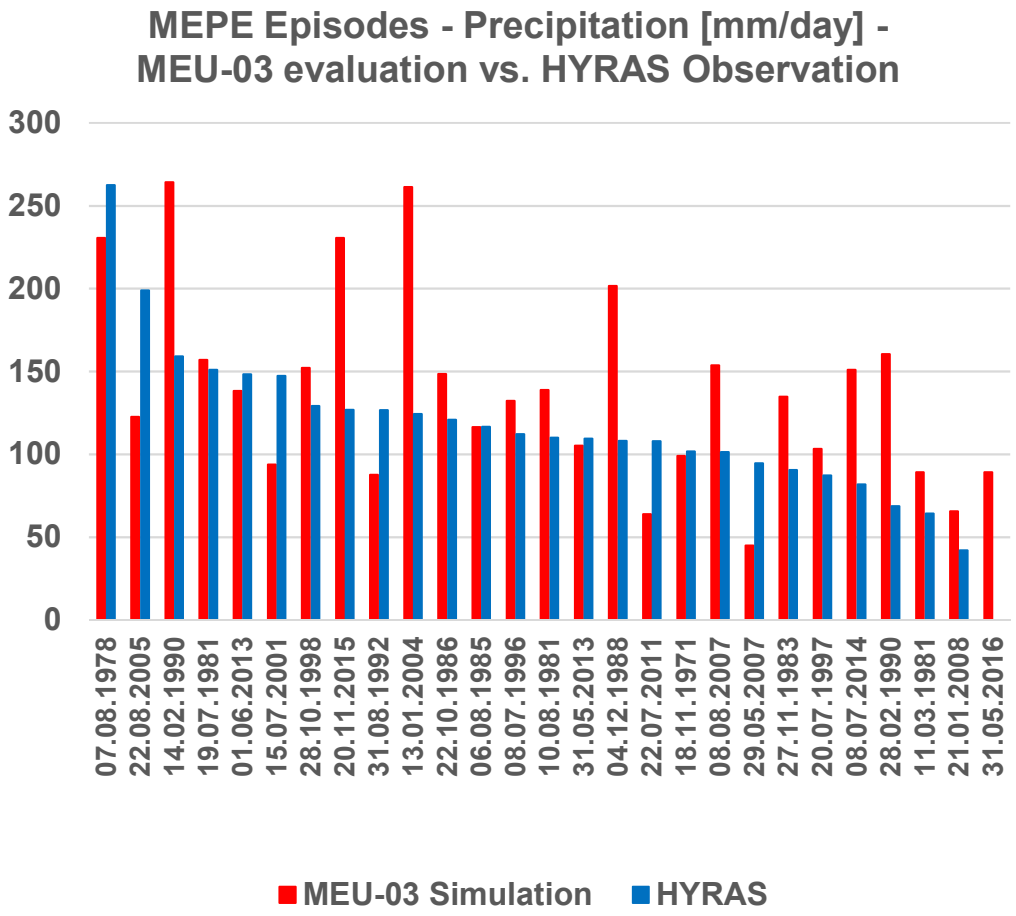
Concept


Large RCM ensemble
+ > 10.000 simulation years
+ robust estimates for high return values
+ contains „unprecedented extremes“
+ covering larger, synoptic scale pattern
- intermediate resolution
Convection permitting simulations
+ better representation of regional scale processes, especially those related to convection
+ better representation of intensities
- Computational expensive
- usually few simulations, short periods, small domains
Episodic downscaling
Selection of events from RCM ensemble e.g. PSI
Periods of minimum 14 days, longer for temporal clustered events
+ Reduction of computing time > 90%
+ Larger domain possible than for CPM simulations
+ Robust statistic over a sufficient number of events

Evaluation and added value of episodic downscaling

Top20 observed extreme events 1961-2016

EUR-22 ERA40/Interim simulation and MEU-03 episodic downscaling



	Average maximum daily precipitation	Average area mean precipitation
HYRAS	119 mm	14,5 mm
MEU-03	140 mm +18,0%	12.4 mm -14.6%
EUR-22	71 mm -40.6%	13.0 mm -10.4%

Example for a High return-period event

13.06.2015 (11.-17.06.) dcppA_hindcast2013_R10

Event 13.05.2015 dcppA_hindcast2013_R10

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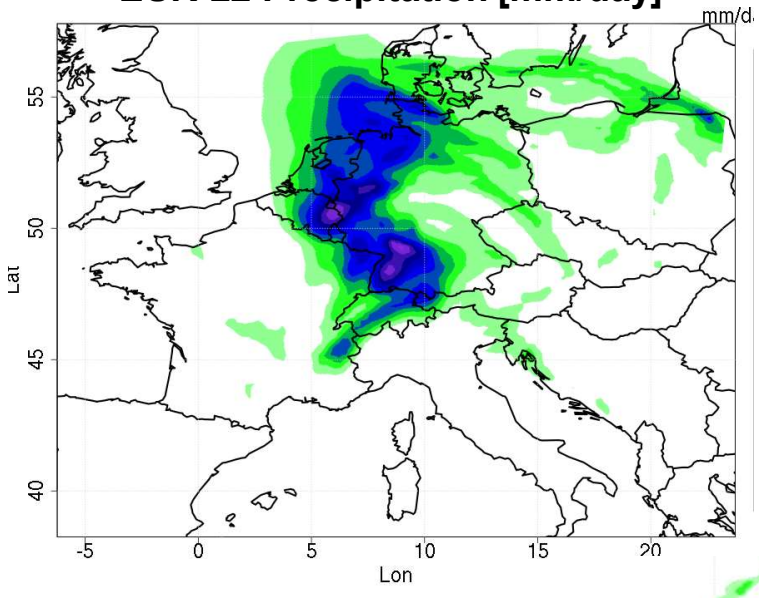
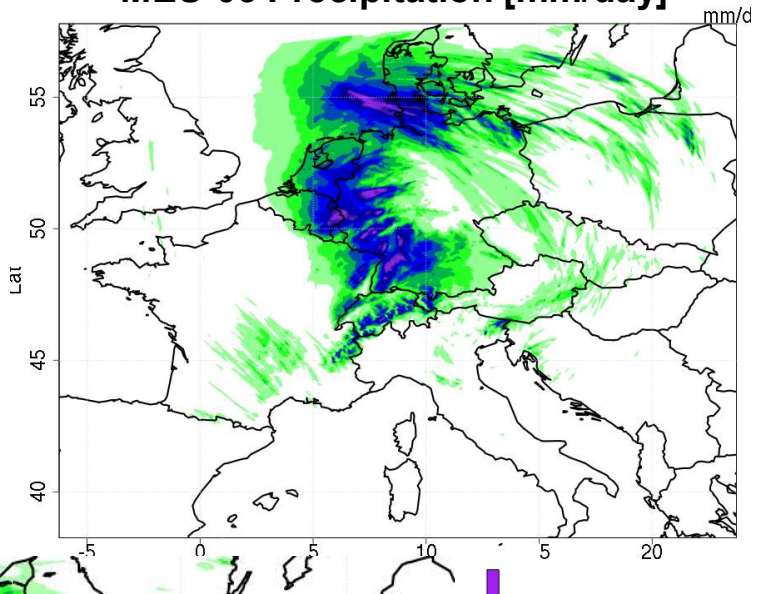
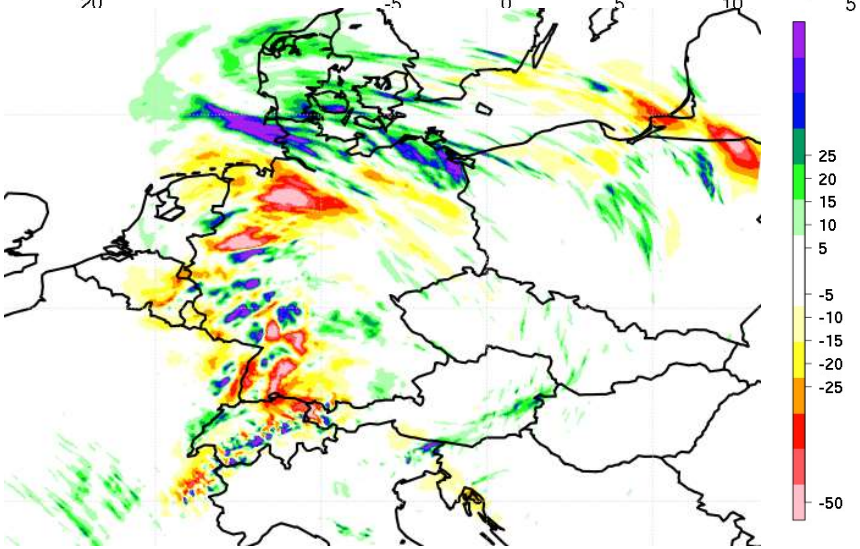
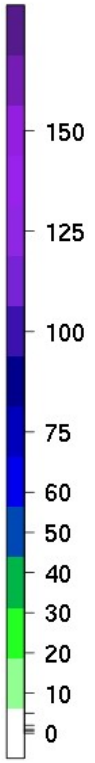
EUR-22 Precipitation [mm/day]



MEU-03 Precipitation [mm/day]







MEU-03 ~ 3km resolution
EUR-22 ~ 25 km resolution

Difference MEU-03 - EUR-22

- **Total precipitation amounts very similar**
- **MEU-03 smaller regions affected (lower mountain ranges)**
- **with higher peak intensities**

Event 13.05.2015 dcppA_hindcast2013_R10

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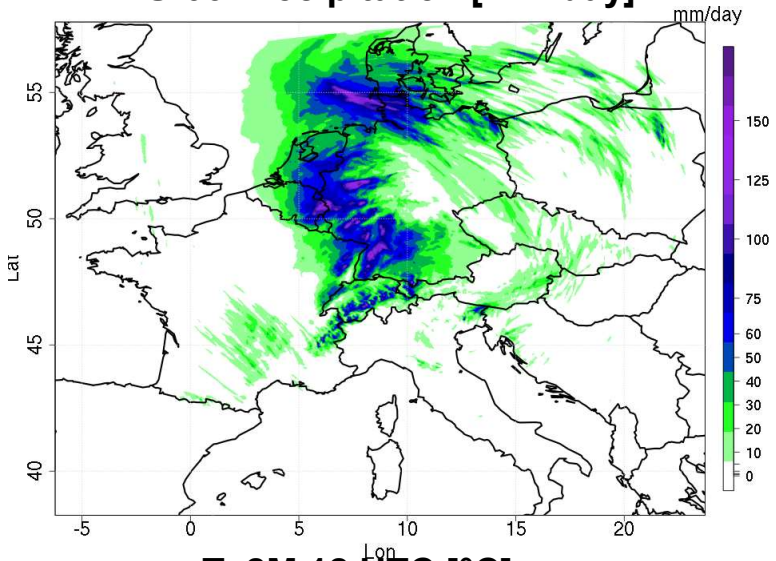
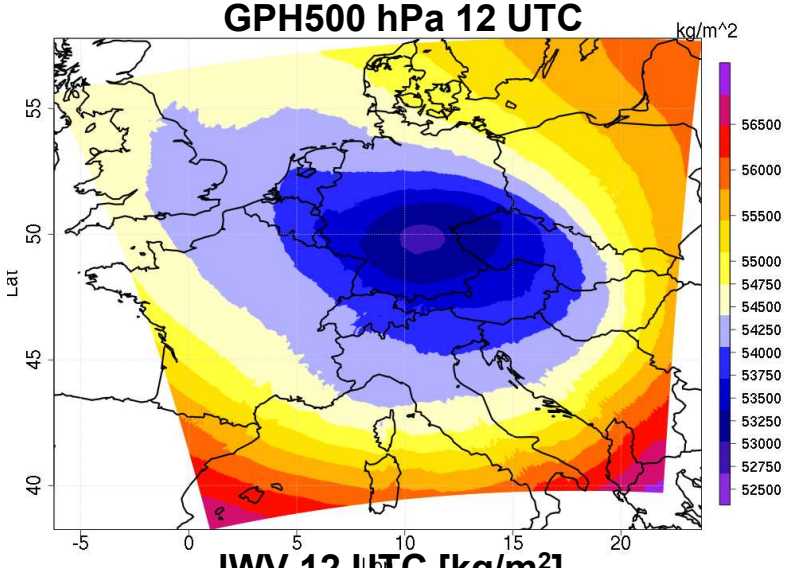
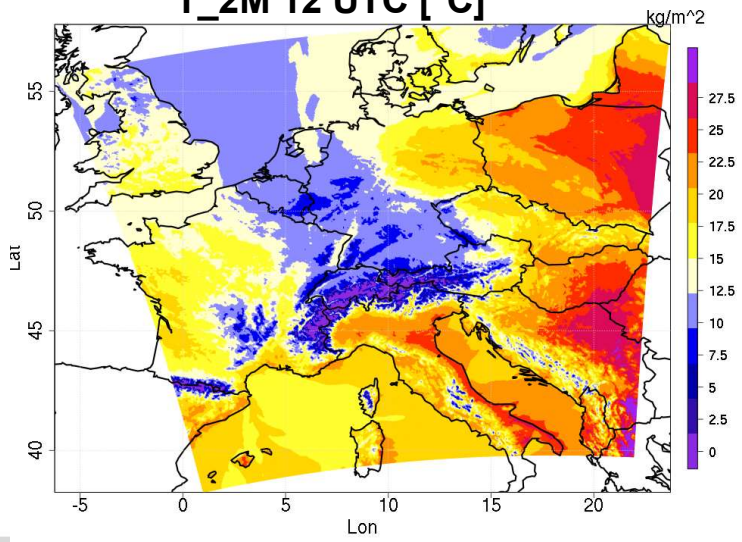
MEU-03 Precipitation [mm/day]



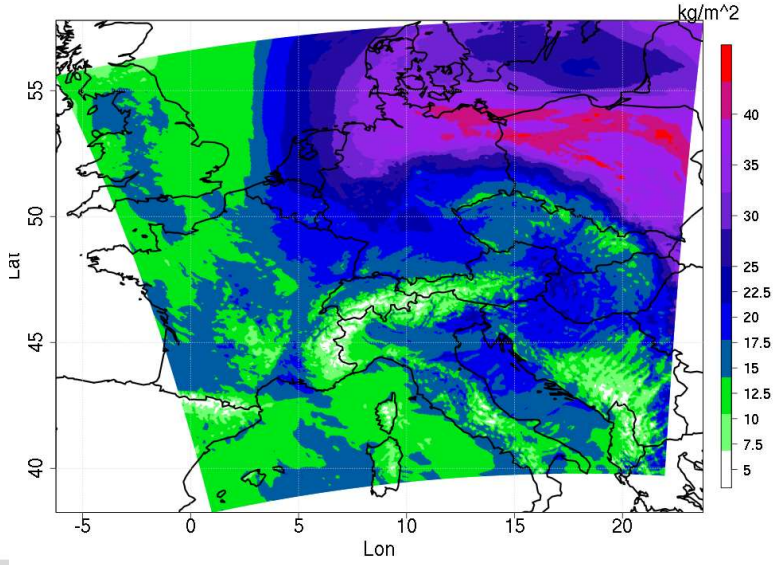
GPH500 hPa 12 UTC



T_2M 12 UTC [°C]



IWV 12 UTC [kg/m²]



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Conclusions/Outlook

- The large RCM ensemble with >10.000 simulation years allows for a characterization of extreme events with return periods > 100 years
  - The ensemble has been evaluated with respect to extreme events and the temporal variability on a wide range of time-scales
- The PSI index is a suitable metric to identify and quantify extreme precipitation events in gridded observations, reanalysis and climate simulations
- The combination of the large ensemble, the PSI index and the episodic downscaling enables a statistically robust characterization of high-RP events beyond the limits of the observational record
- It is planned to apply the method to the MPI Grand Ensemble to assess the temporal evolution of extreme events under climate change

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Thank you for your attention