Changes in African extreme precipitation and storm structure since 1981 revealed by satellite observations

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- Extreme precipitation causes **floods, erosion, landslides, debris flows**, and many other hazards, with numerous casualties and large damage

Germany 2021







- Highly vulnerable to extreme precipitation
- Poor ground observations

- Annual maximum daily precipitation (RX1)
- 100-year daily precipitation

We examine changes in **extreme precipitation** in **Africa** since 1981 using **satellite observations** and a **new statistical approach**

- Uses all available data (*vs* extremes only)
- Less assumptions needed
- Increased accuracy in presence of estimation errors (especially for extremes)
- Decreased stochastic uncertainty

CHIRPS version 2 [Funk & al 2015]

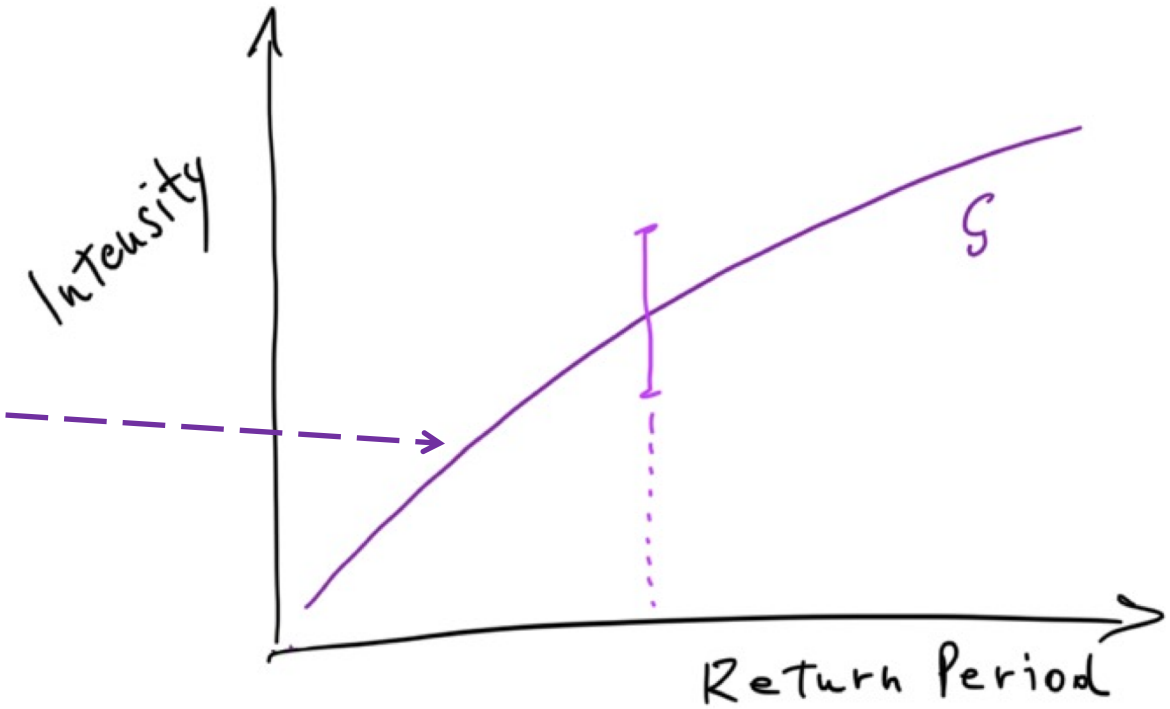
- High spatial resolution (0.05°)
- Long temporal coverage (1981-2019)
- Good quality according to multiple studies

What do we mean by extreme precipitation?

- We focus on extremes of interest for **hydraulic design, risk management, insurance business, adaptation strategies**
  - Yearly non-exceedance probability (i.e., probability *in time*) (not to be confused with precipitation percentiles)

- for example the **100-year event**:
  - 1% yearly exceedance probability
  - exceeded on average once in 100 years

- Well described by the **distribution** ζ of daily **annual maxima (RX1)**



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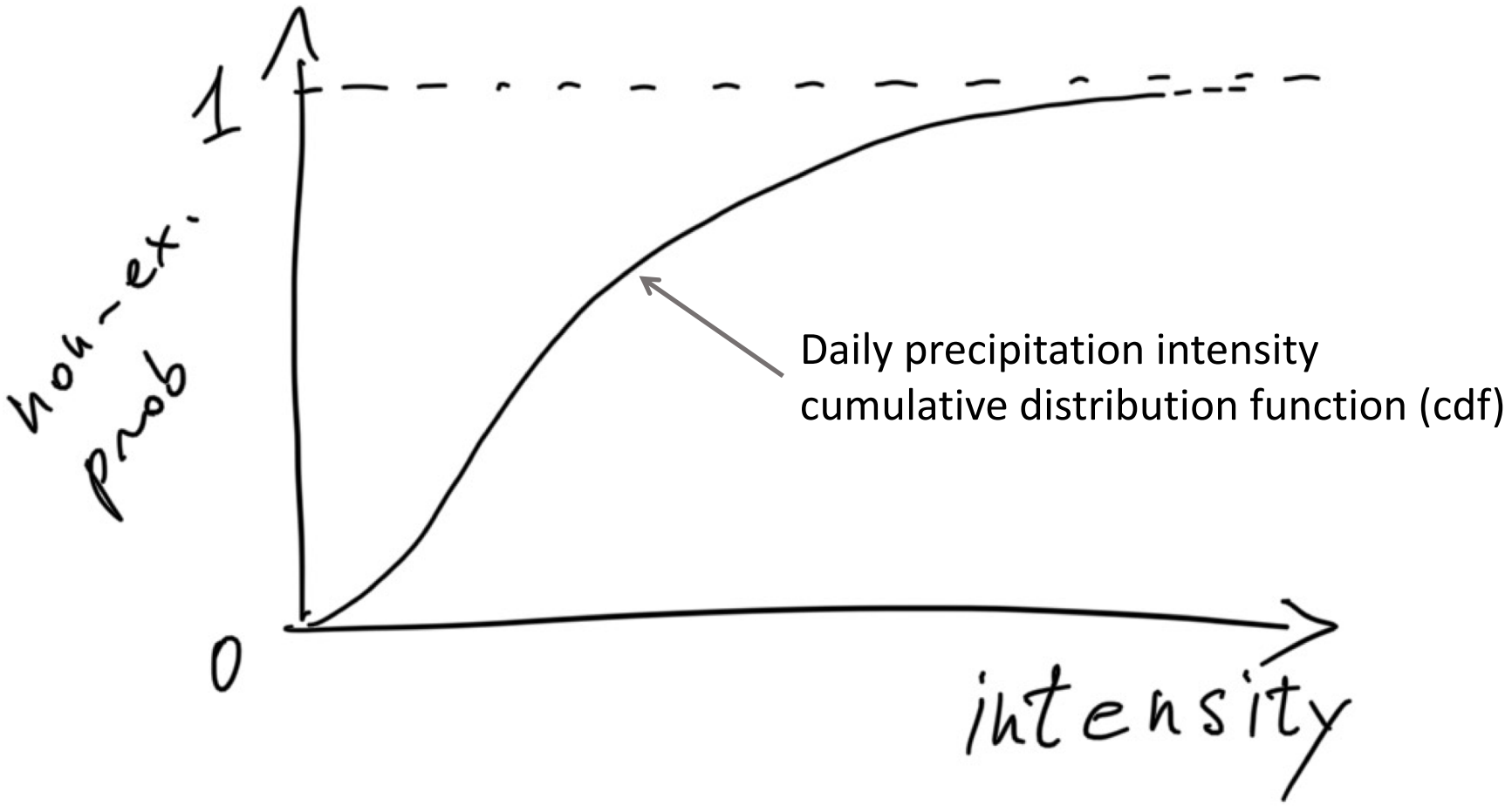

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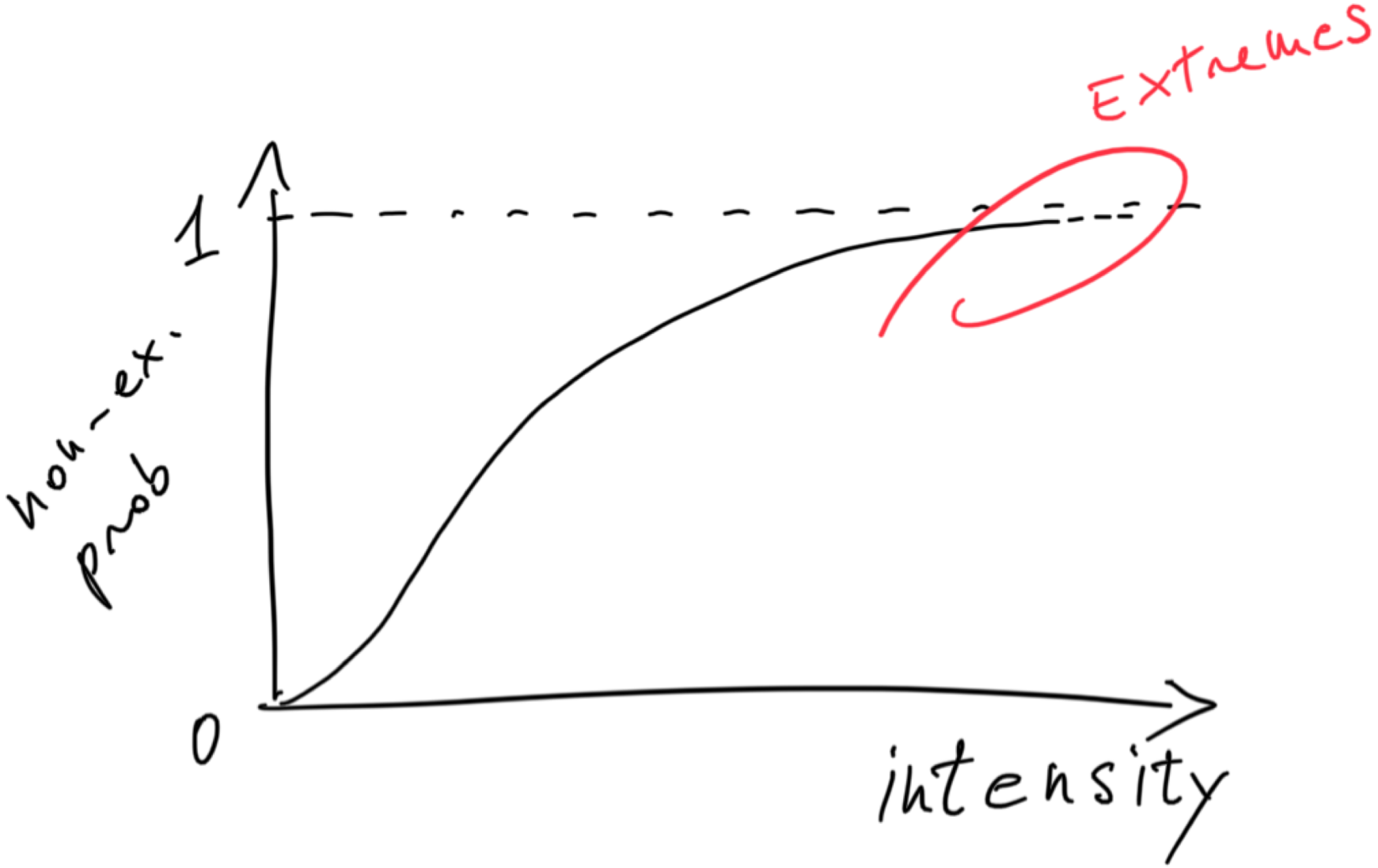

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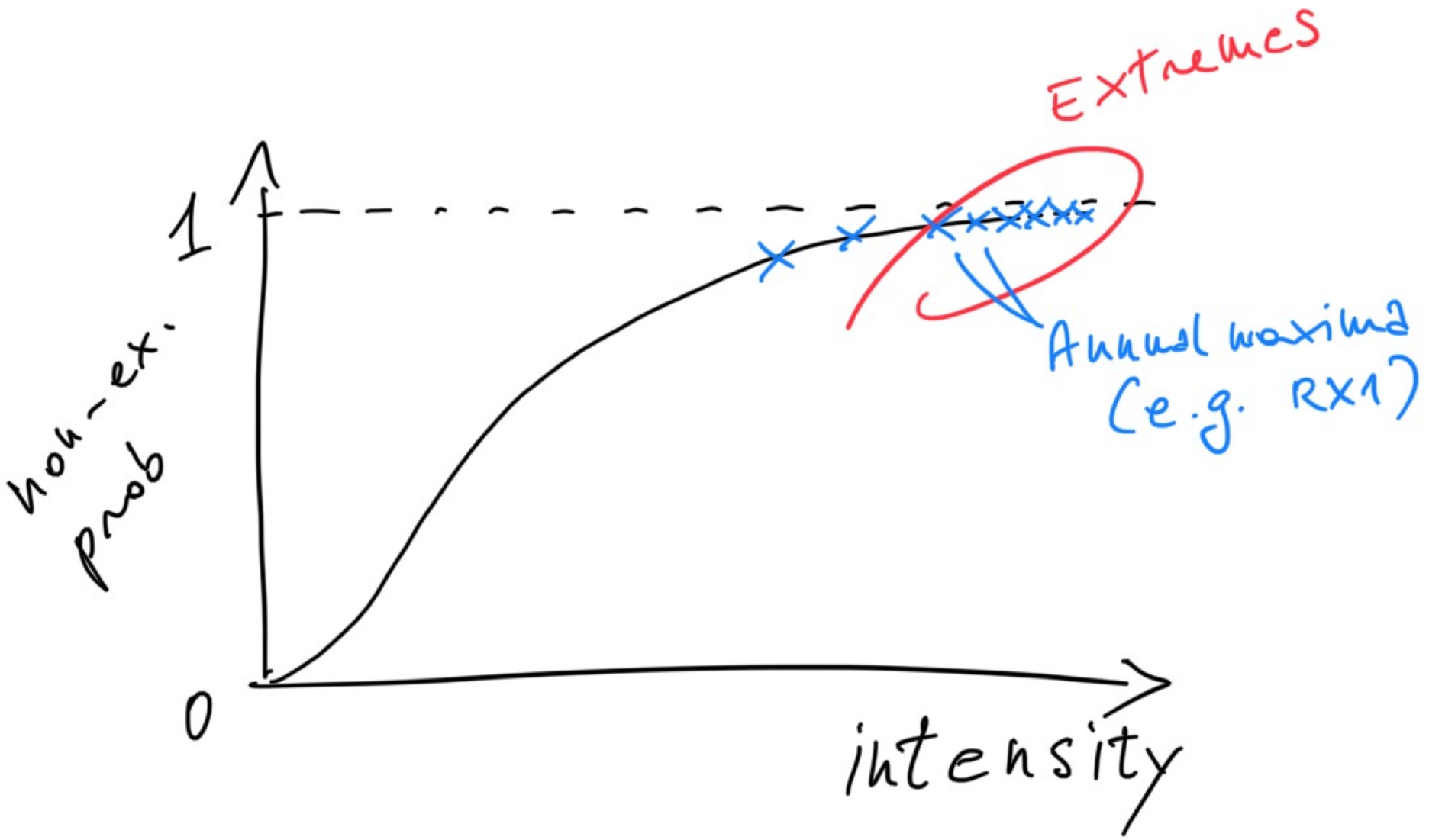

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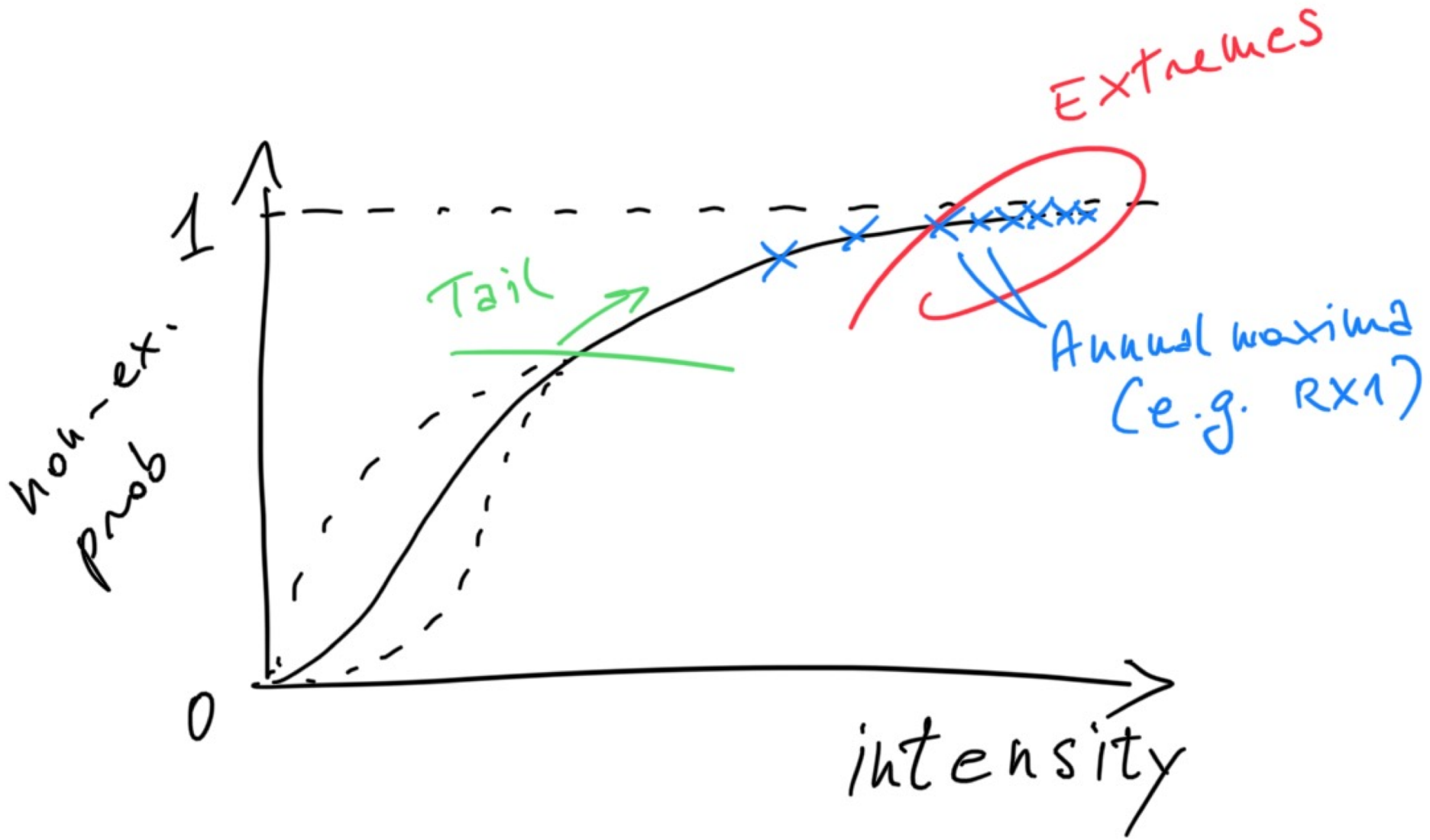


- If the **tail of the daily intensity distribution (F)** is known, the distribution of annual maxima becomes:

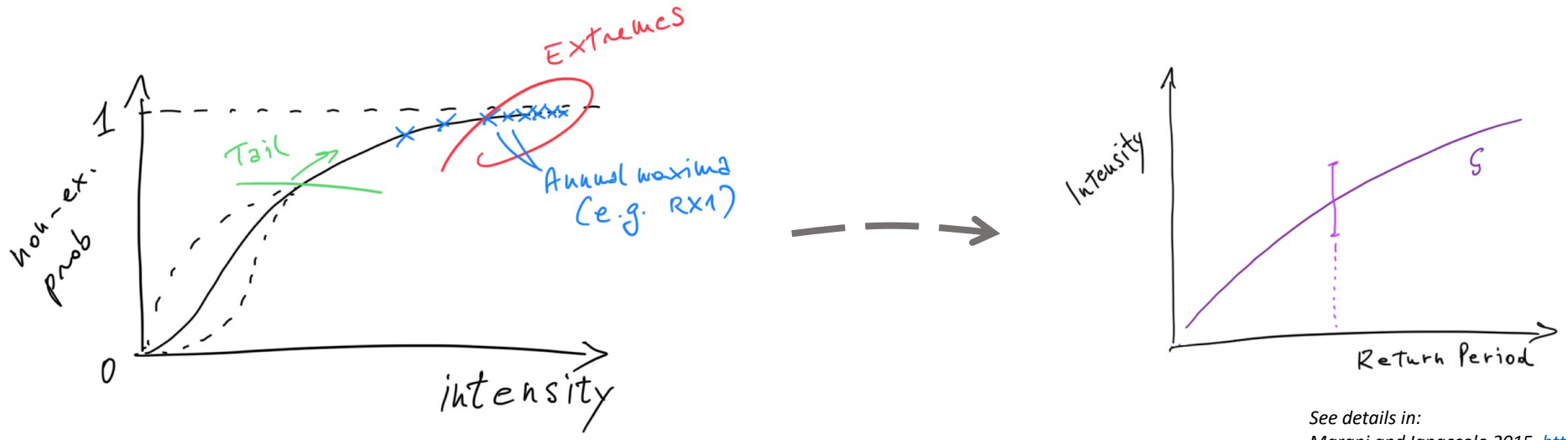
$$\zeta(x) = F(x; \lambda, \kappa)^n$$

x: daily intensity of interest

λ, κ: parameters of a **stretched exponential distribution*** (Weibull)

n: average number of wet days per year

$\zeta(x)$: yearly non-exceedance probability of x



*ask me more/meet me in the breakout room

See details in:
Marani and Ignaccolo 2015, https://doi.org/10.1016/j.advwatres.2015.03.001
Marra & al 2020, https://doi.org/10.1029/2020GL090209
Serinaldi & al 2020, https://doi.org/10.1016/j.advwatres.2020.103686

Observed trends in RX1 (CHIRPS2, 1981-2019)

- Verify our a
  rain gauge b
  (GPCC Full Da
- Use CHIRPS
- Extract RX1
- Quantify te
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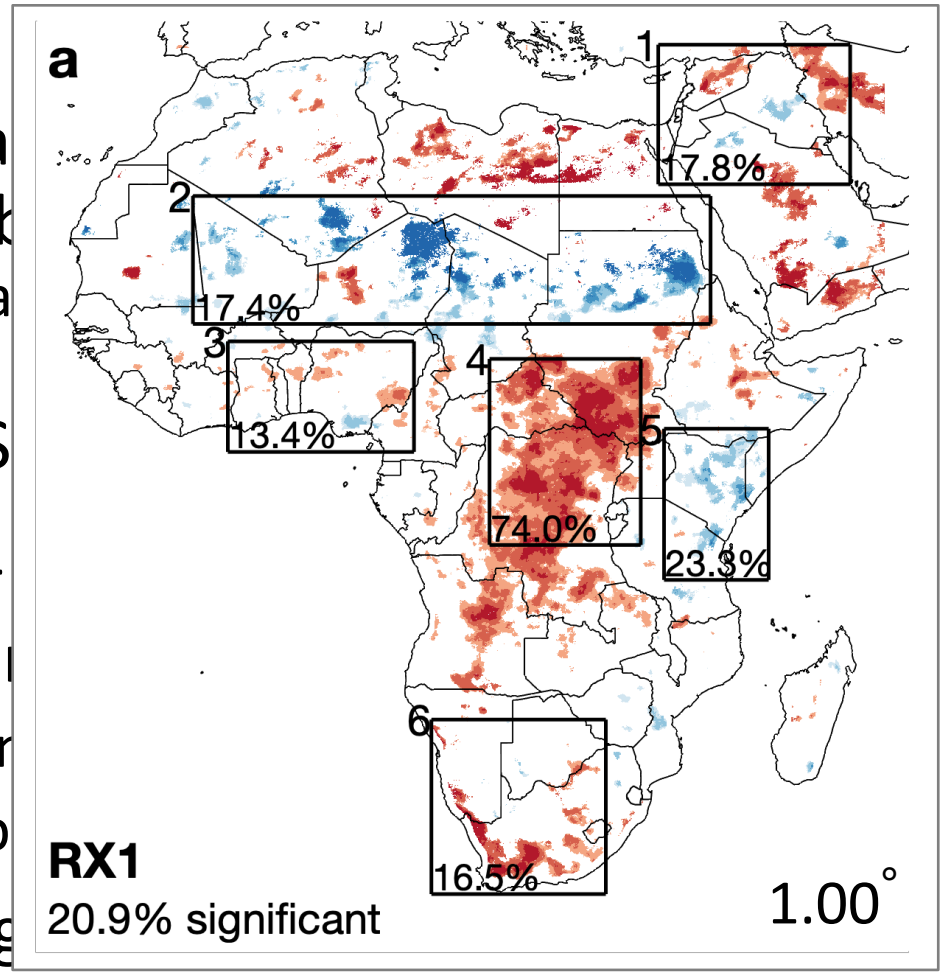
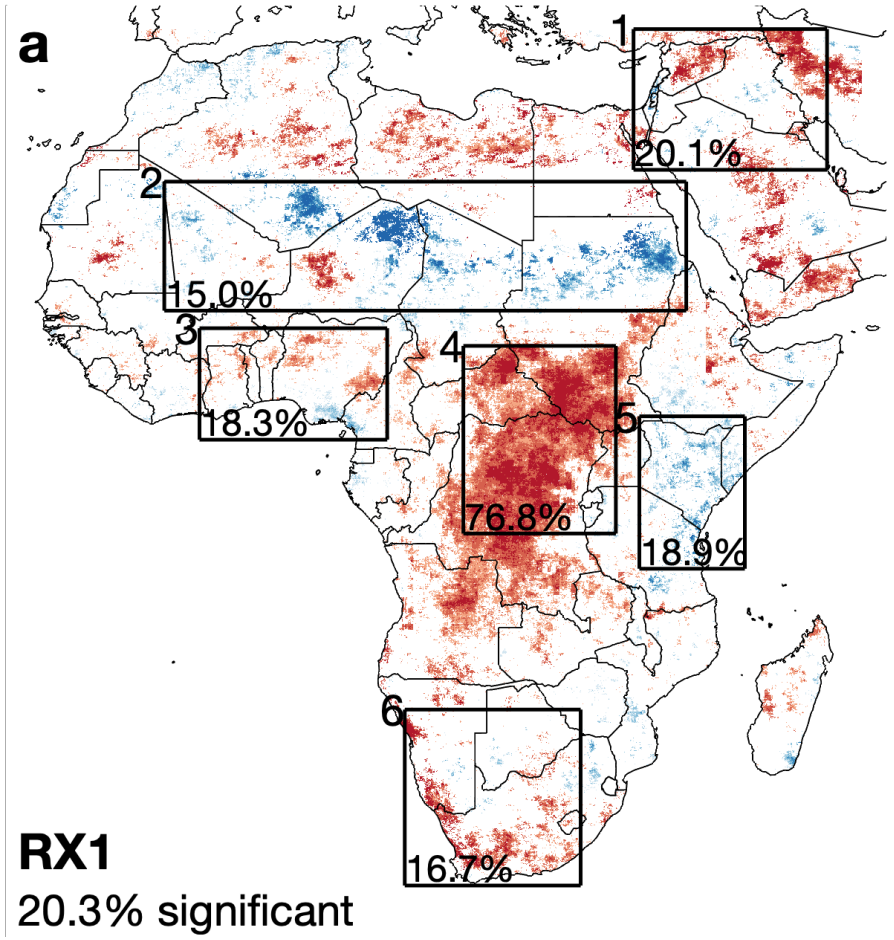
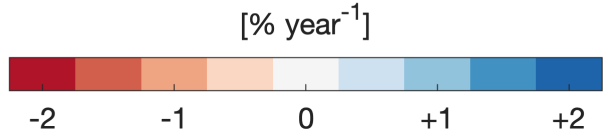




Trend linear slope
Only-significant trends
($\alpha = 0.05$) are shown



**ask me more/meet me in the breakout room*

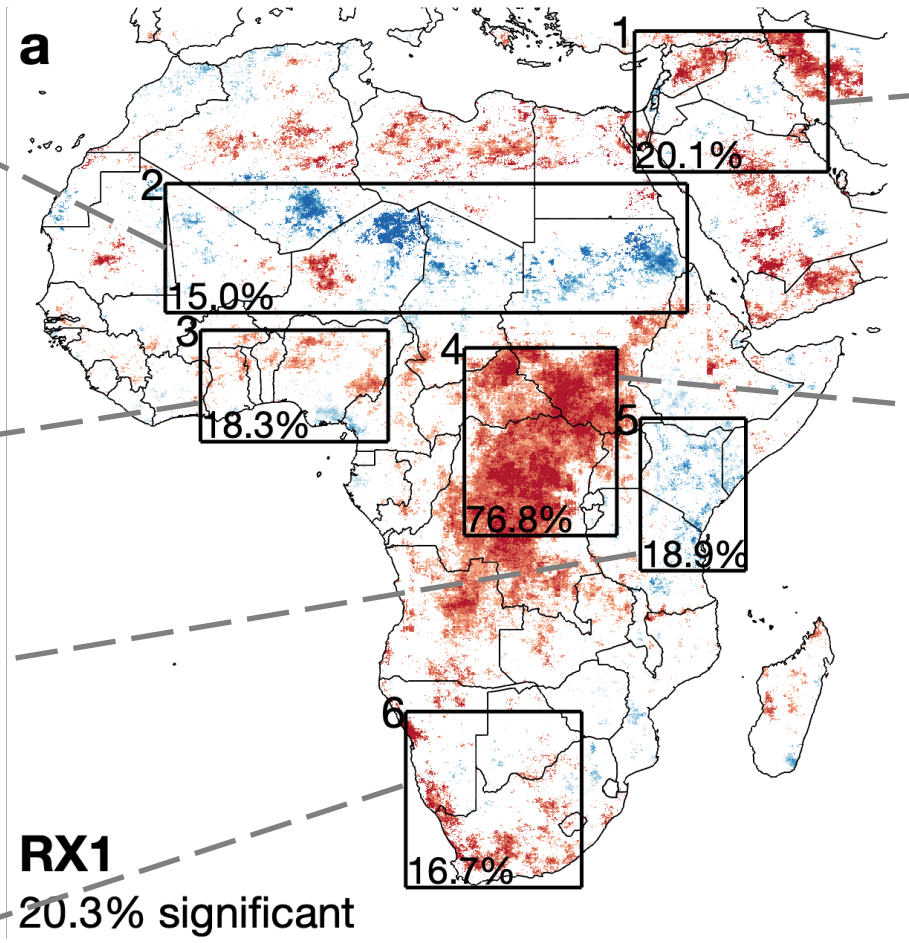
Different responses in different areas

(2) Sahel
- recovery after dry period (60-80s), related to warming of North Atlantic *[Nicholoson & al 2018]*
- in line with GPCC

(3) West Equatorial Africa
- diverse signals
- poor agreement with gauges*

(5) Kenya
- increase attributed to the Oct-Dec season *[Cattani & al 2018]*

(6) South Africa
- in line with GPCC* and previous studies *[Ndebele & al 2019; Jury 2020]*



(1) Middle East
- decrease in the fertile crescent
- good agreement with gauges*

(4) Congo
- in line with drying trend
- increased convection, moisture transported higher with less humidity available for rainfall *[Raghavendra & al 2018]*
- the area is not gauged so artifacts in the sat product cannot be excluded

**ask me more/meet me in the breakout room*

Only-significant trends ($\alpha = 0.05$) are shown

Cattani & al 2018, https://doi.org/10.3390/rs10060931
Jury 2020, https://doi.org/10.17159/wsa/2020.v46.i3.8654
Ndebele & al 2019, https://doi.org/10.1002/joc.6314
Nicholson & al 2018, https://doi.org/10.1016/j.gloplacha.2017.12.014
Raghavendra & al 2018, https://doi.org/10.1016/j.atmosres.2018.05.028

Modelled trends in RX1 (CHIRPS2, 1981-2019)

- Estimate our model parameters
- Quantify temporal trends in parameters
- Estimate trends in the RX1 based on the model* (RX1 modelled)

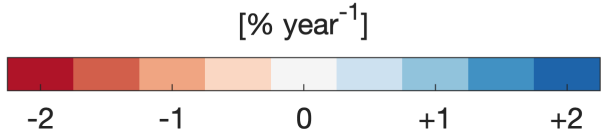
- Repeat censoring annual maxima from the parameter estimation (RX1 modelled censoring RX1)
  - Independent validation

Modelled

The results are still not published, so we cannot upload some of the figures.
Please contact me via email to have the full presentation.

Correlation with observed trends

Trend linear slope
Only-significant trends ($\alpha = 0.05$) are shown



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Trends derived from the model: 89% of explained variance in the observed trends

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Model by censoring annual maxima: 72% of explained variance

Trend linear slope
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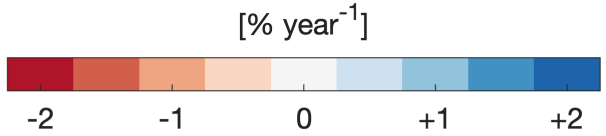

- Ignoring the observed RX1, the model still reproduces 72% of the variance in their trend
  - **Works even if observed RX1 are not trusted**
  - We can trust it to get info on **more extreme events** (such as the 100-year events)

Trends in the 100-year events

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RX1

Trend linear slope
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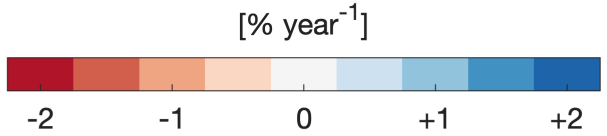

- Modelled trends in the 100-year events at 0.05° and 1.00° resolution
- Similar patterns, **different magnitudes**

Different change rates: **local (0.05°)** vs **mesoscale (1°)**
(related to spatial structure of extreme storms)

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- Almost no cases with opposite trends
- Implications for hydrological design (areal reduction factors)

Different change rates: **RX1 (annual max)** vs **100-year events**

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Both significant
are shown

- **100-year events changed faster** than RX1
  (both increased and decreased)

Key points

- Novel framework for quantifying changes in extremes
  - 89% of explained variance
  - Works even if extremes are NOT well observed (72% of explained variance)
  - Allows us to attribute the change to specific parameters* (n. of wet days, tail heaviness)
- Changes in extremes at multiple scales (related to storm structure)
  - Extremes both increased and decreased in Africa → large regional differences
  - Storms seem to have smoothed
- Changes in the 100-year event
  - 100-year events changed faster than RX1 (both increased and decreased)

Thanks for your attention!

questions and discussions are welcome

meet me in the breakout room

or contact us [*f.marra@isac.cnr.it*](mailto:f.marra@isac.cnr.it)

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