



**PhD SDC**

SUSTAINABLE DEVELOPMENT  
AND CLIMATE CHANGE



# CLIMATE-TREND ANALYSIS OF AIR TEMPERATURE AND PRECIPITATION IN THE EXTENDED ALPINE REGION (1961-2020)

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# Outline

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EEAR-Clim Dataset

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1961-2020 trend analysis

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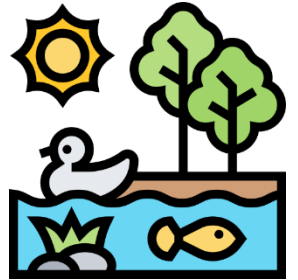
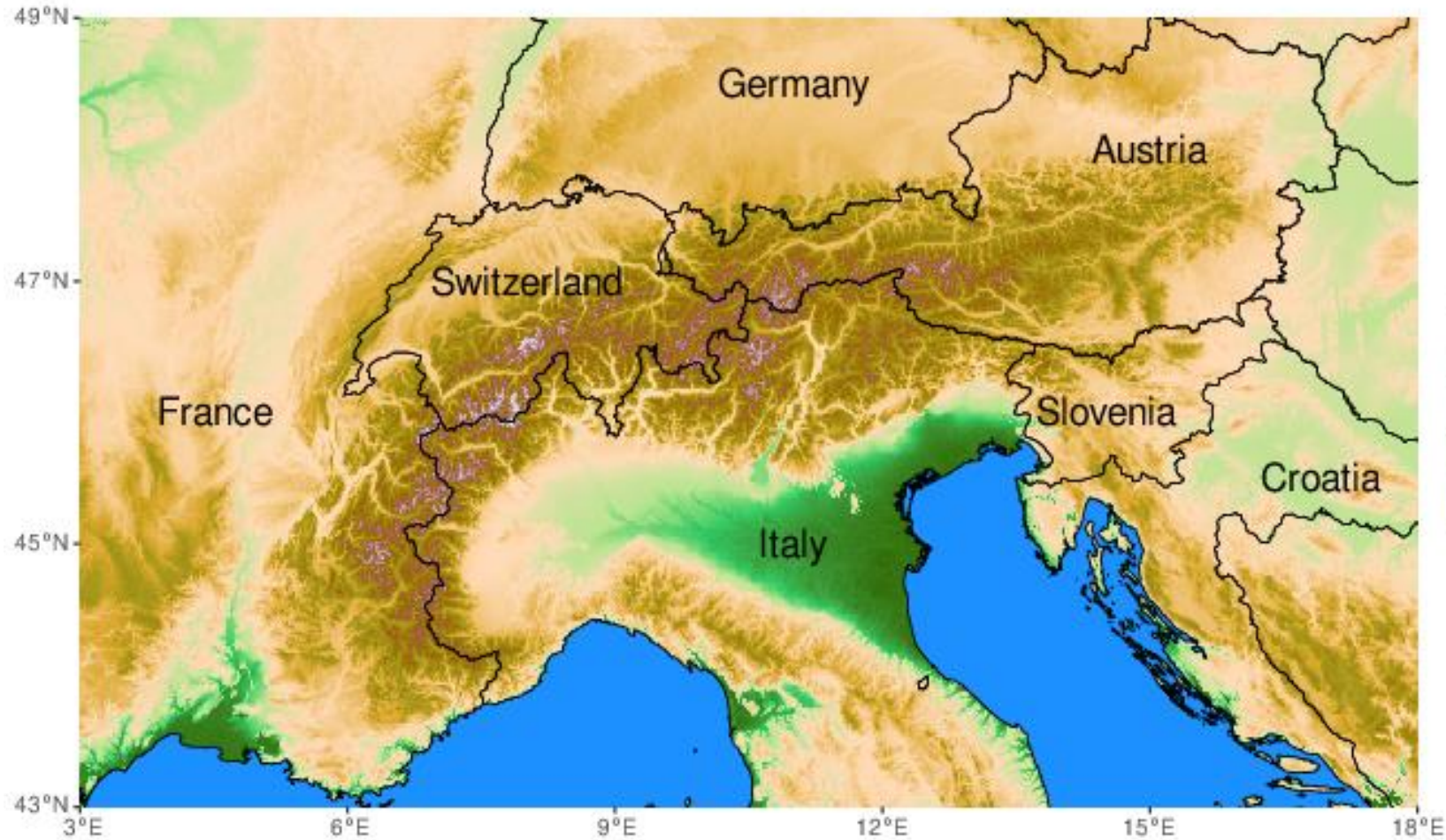
Elevation-dependent climate change

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Regionalization

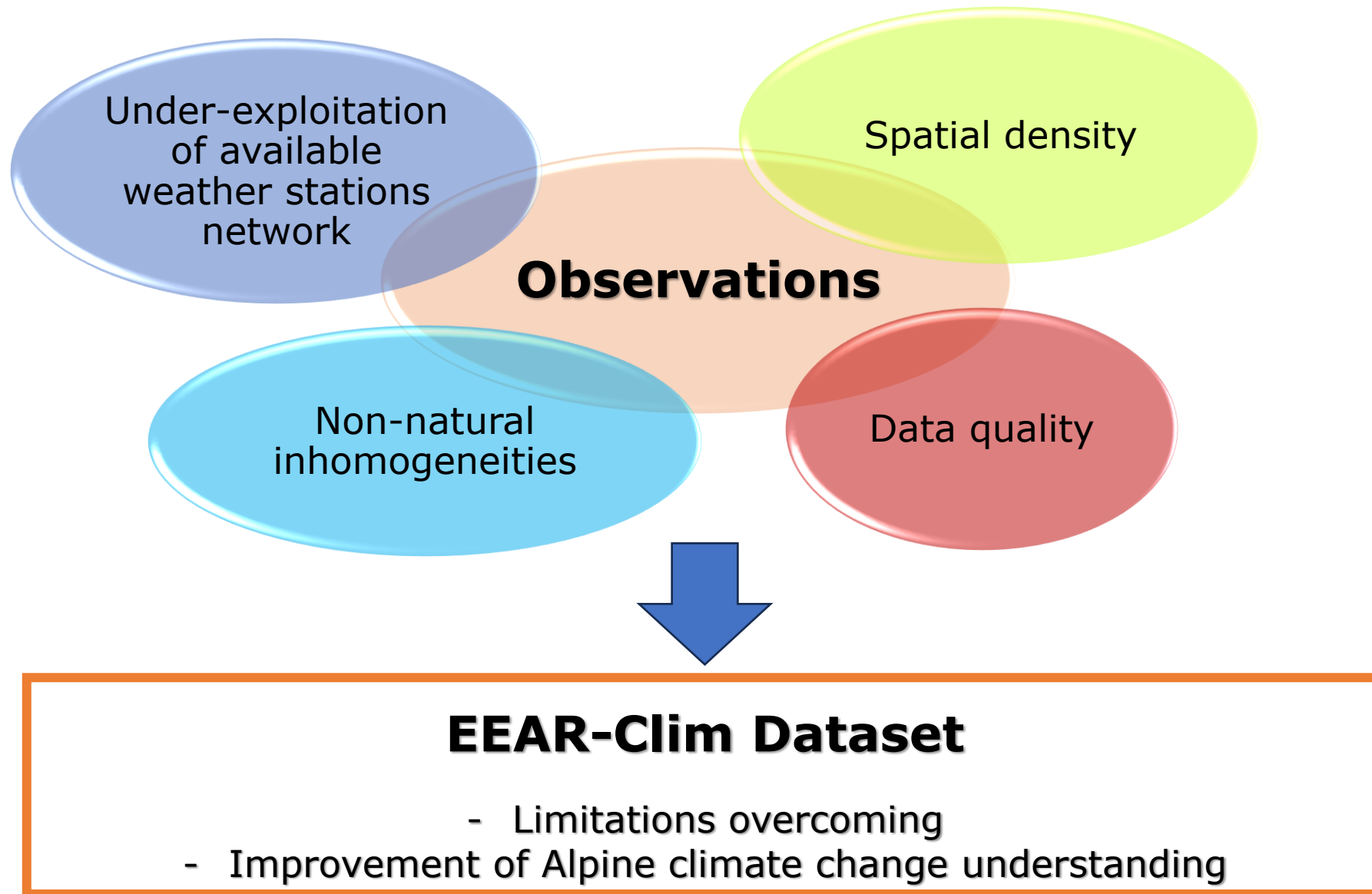


# Study Area

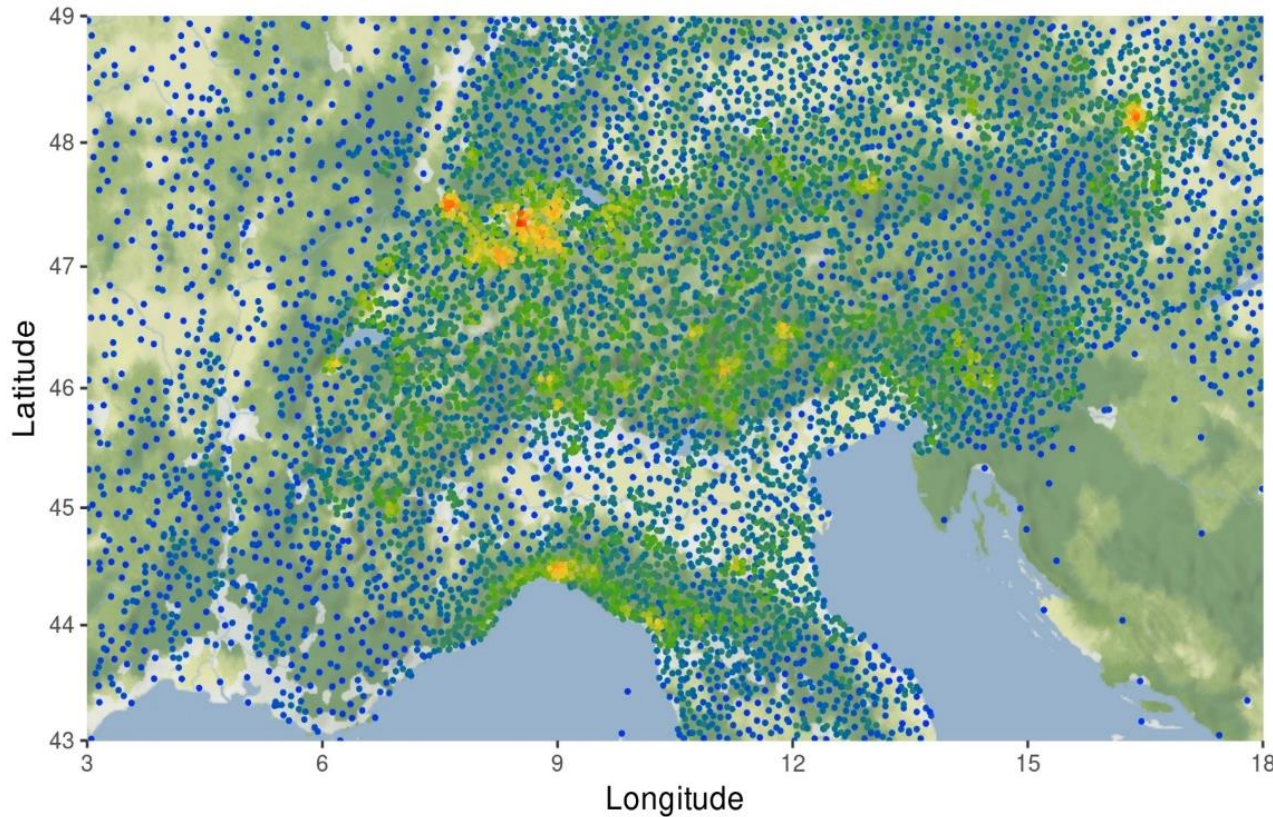


**Extended European Alpine Region (EEAR)  
(3–18° E / 43–49° N)**

# Introduction



# EEAR-Clim Dataset



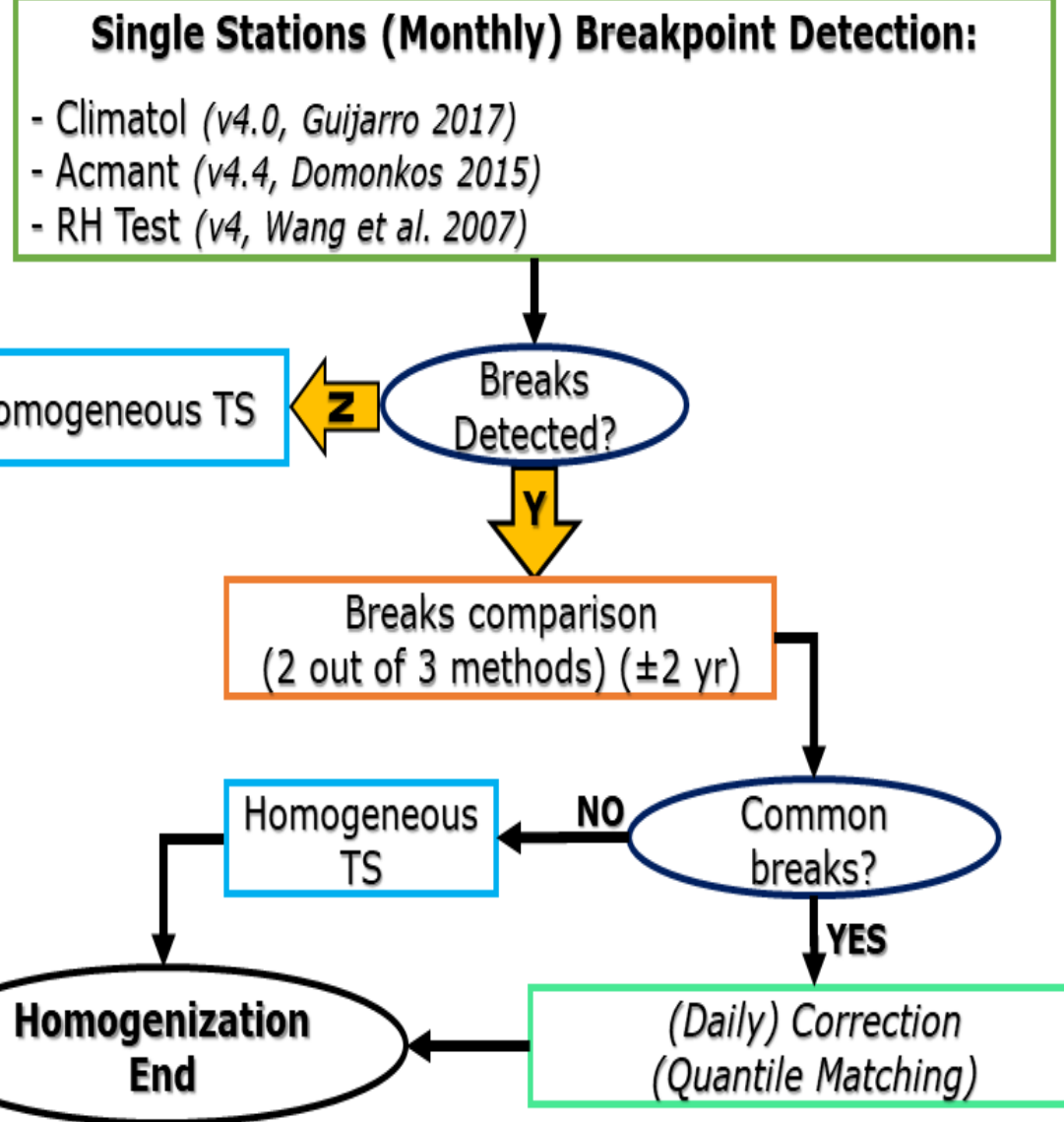
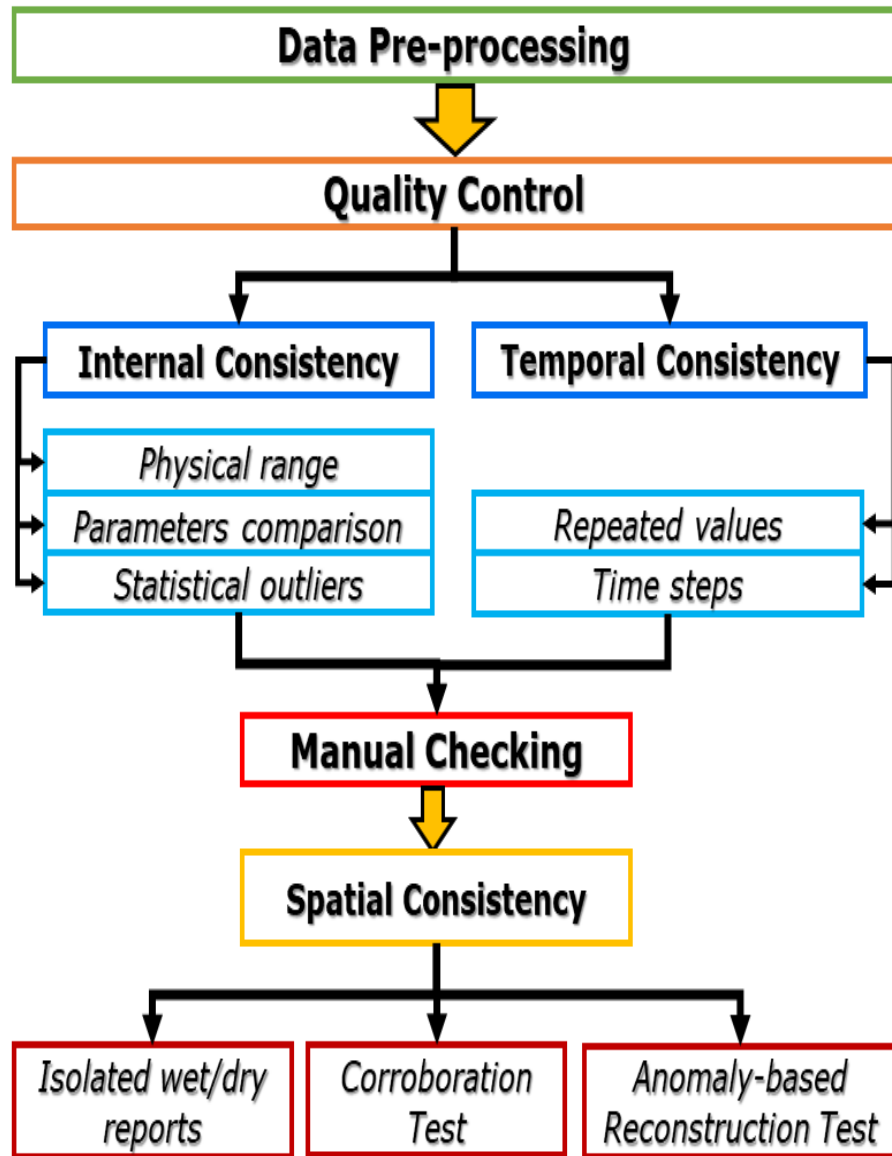
R=10 km

- ~ 10K stations
- 1763-2020
- Daily data
- 1.5 stations/10 km
- 0-4500 m a.s.l.

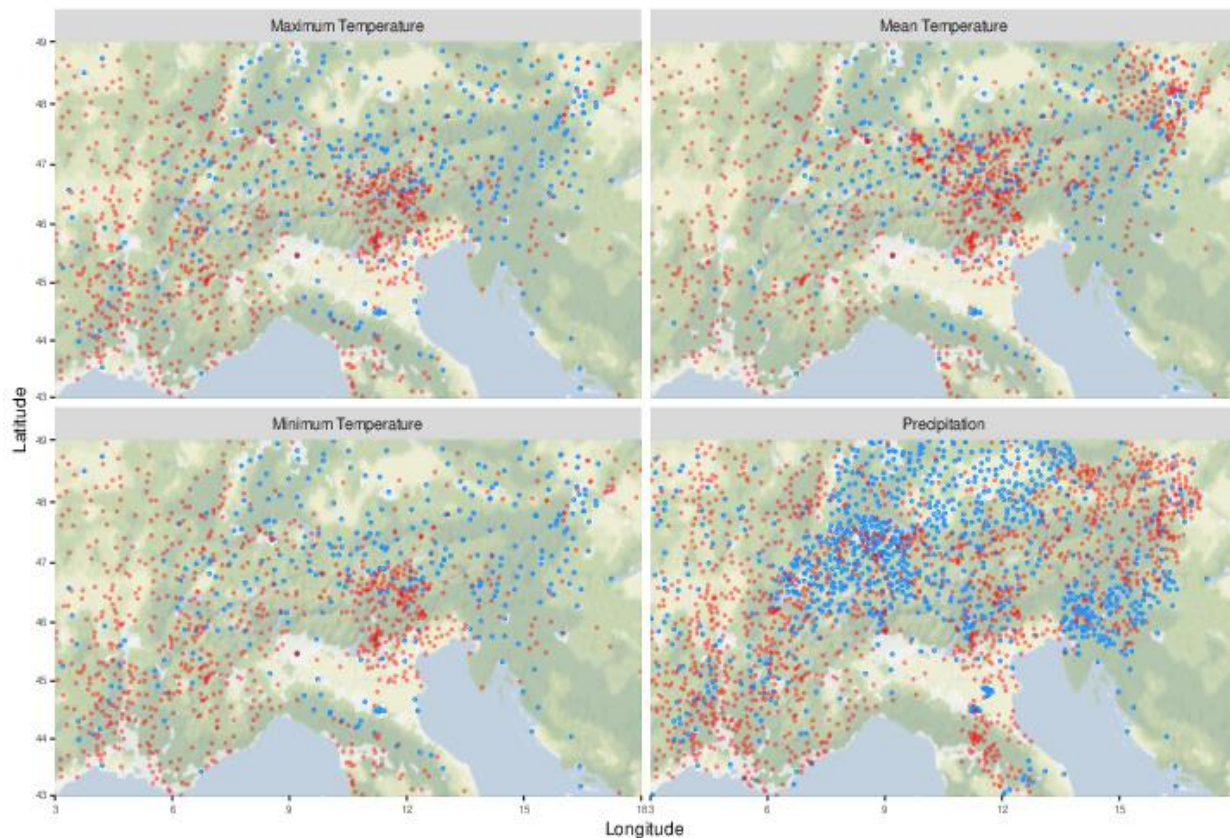
- ✓ 5486 Thermometers
- ✓ 7869 Rain gauges
- ✓ 3235 Hygrometers
- ✓ 2449 Anemometers
- ✓ 4526 Snow gauges
- ✓ 1349 Radiometers



# Quality Control and homogenization



# Trend analysis (1961-2020)



1961 - 2020  
1991 - 2020

## TREND ANALYSIS

THEIL-SEN'S SLOPE

MANN-KENDALL TEST

ETCCDI INDICES

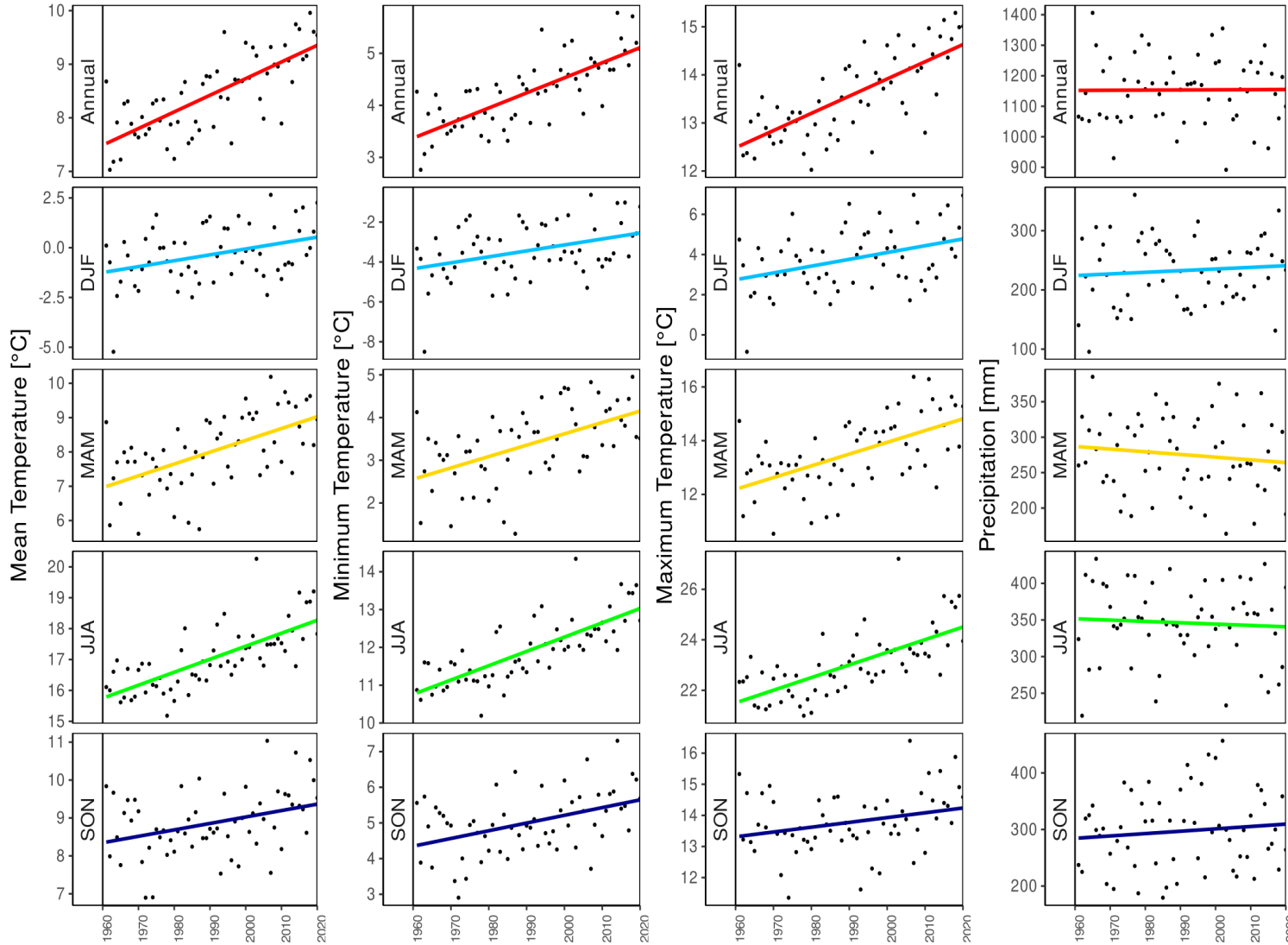
- Summer days (SU)
- Tropical nights (TR)
  - Icing days (ID)
  - Frost days (FD)
- Growing season length (GSL)
- Heavy rainy days (R20mm)
  - Wet spells (CWD)
  - Dry spells (CDD)

- Cold days (TX10p)
- Warm days (TX90p)
- Cold nights (TN10p)
- Warm nights (TN90p)
- Warm spells (WSDI)
- Cold spells (CSDI)
- Very wet days (R95p)
- Extremely wet days (R99p)

## STATIONS SELECTION:

- Valid Month: 5/3 rule
- Valid Year: min. 9 valid months (not cons.)
- 80% Valid Years (Max 4 consecutive years missing)

# Trend analysis



Conf. level:

**99%**

**95%**

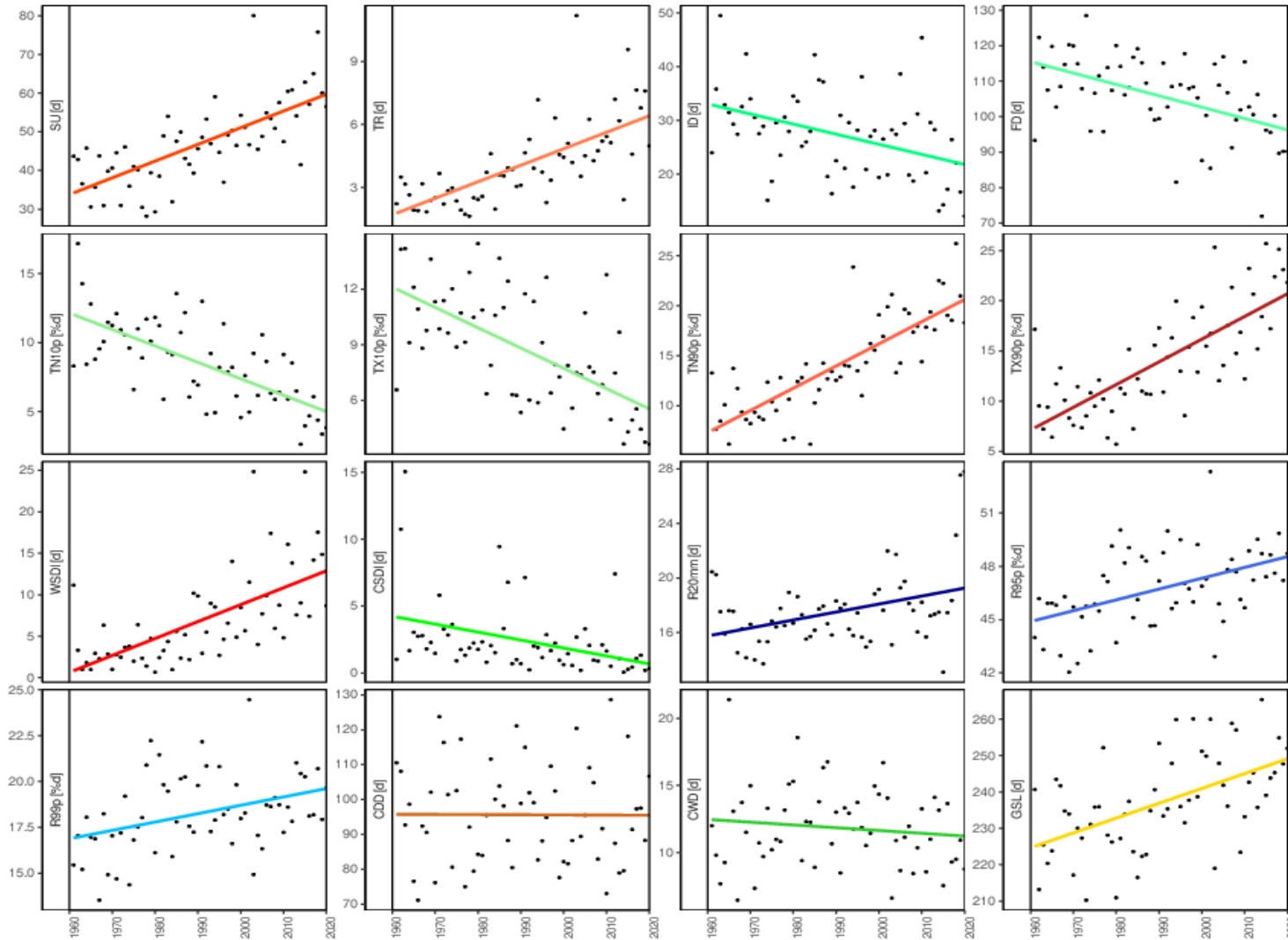
**90%**

## Trend per decade

PERIOD	T [°C]	Tmin [°C]	Tmax [°C]	P [mm]
Annual	0.32	0.29	0.39	0.22
DJF	0.27	0.24	0.30	1.67
MAM	0.34	0.27	0.44	-1.55
JJA	0.41	0.36	0.48	-0.48
SON	0.18	0.21	0.16	1.49
Jan	0.32	0.33	0.36	0.72
Feb	0.20	0.16	0.30	-0.24
Mar	0.35	0.27	0.45	-3.37
Apr	0.40	0.28	0.50	-3.71
May	0.36	0.29	0.42	0.28
Jun	0.41	0.38	0.50	-1.74
Jul	0.41	0.36	0.50	0.30
Aug	0.48	0.40	0.58	-1.23
Sep	0.09	0.12	0.10	7.05
Oct	0.16	0.24	0.09	4.80
Nov	0.27	0.30	0.27	-2.21
Dec	0.36	0.40	0.37	2.39



# Trends of extremes



Conf. level:

**99%**

**95%**

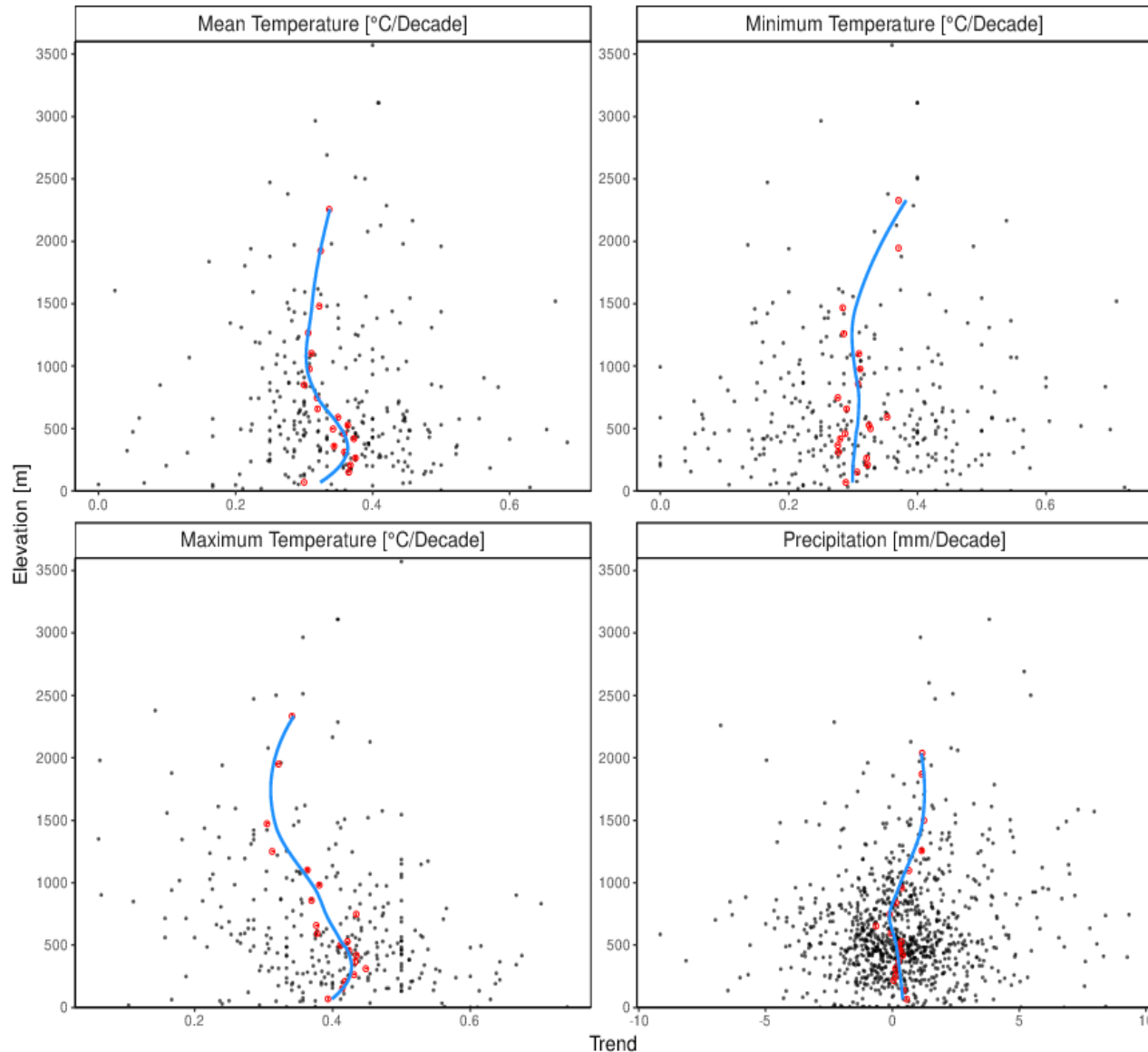
**90%**

## Trend per decade

Index	Trend	Index	Trend
GSL (d)	4.11	TN10P (%d)	-1.22
SU (d)	4.14	TN90P (%d)	2.20
ID (d)	-1.94	CSDI (d)	-0.35
TX10P (%d)	-1.15	R20MM (d)	0.38
TX90P (%d)	2.25	R95P (%d)	0.60
WSDI (d)	1.68	R99P (%d)	0.44
TR (d)	0.71	CDD (d)	-0.24
FD (d)	-3.20	CWD (d)	-0.15

INDEX	DJF	MAM	JJA	SON
TN10p	-0.92	-0.81	-1.59	-0.77
TN90p	1.19	1.98	3.23	1.77
TX10p	-0.88	-1.05	-1.60	-0.53
TX90p	1.94	2.42	2.92	1.08
R95p	0.59	1.00	0.45	0.27
R99p	0.55	0.79	0.79	0.20

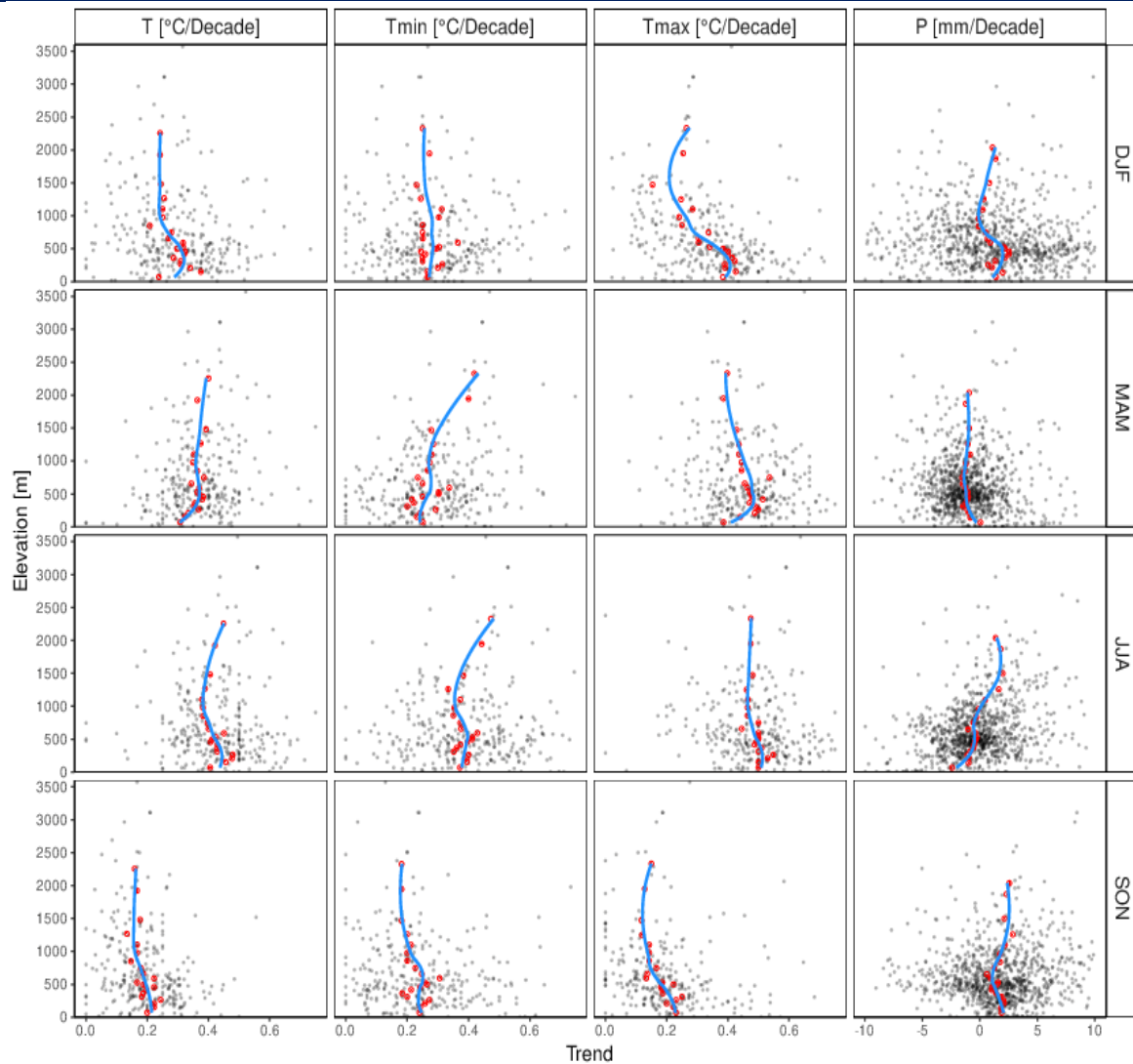
# Elevation trends



- Aggregation in 20 overlapping classes including the same amount of points
- Consistency of class limits among all variables
- Evaluation of EDW/EDPC rates by linear regression of median points
- 8 ETCCDI percentile-based indices

— LOESS fit  
● Median points

# Elevation trends



Conf. level: **99%** **95%** **90%**

## Trend per decade and km

PERIOD	T [°C]	Tmin [°C]	Tmax [°C]	P [mm]
Annual	-0.19	0.25	-0.58	5.93
DJF	-0.45	-0.12	-1.00	-5.56
MAM	0.22	0.72	-0.37	-0.88
JJA	-0.13	0.23	-0.23	17.98
SON	-0.31	-0.35	-0.49	5.13
Jan	-0.82	-0.68	-1.38	9.90
Feb	0.14	0.58	-0.60	-13.18
Mar	0.01	0.53	-0.77	-5.67
Apr	0.63	1.34	0.13	3.19
May	0.21	0.43	0.04	-2.23
Jun	0.12	0.40	0.04	20.56
Jul	-0.51	0.08	-0.52	-0.22
Aug	-0.19	0.46	-0.22	27.86
Sep	-0.48	-0.39	-0.61	-3.00
Oct	-0.85	-0.86	-0.42	3.88
Nov	-0.03	0.14	-0.24	-6.95
Dec	-0.52	-0.19	-1.30	4.64

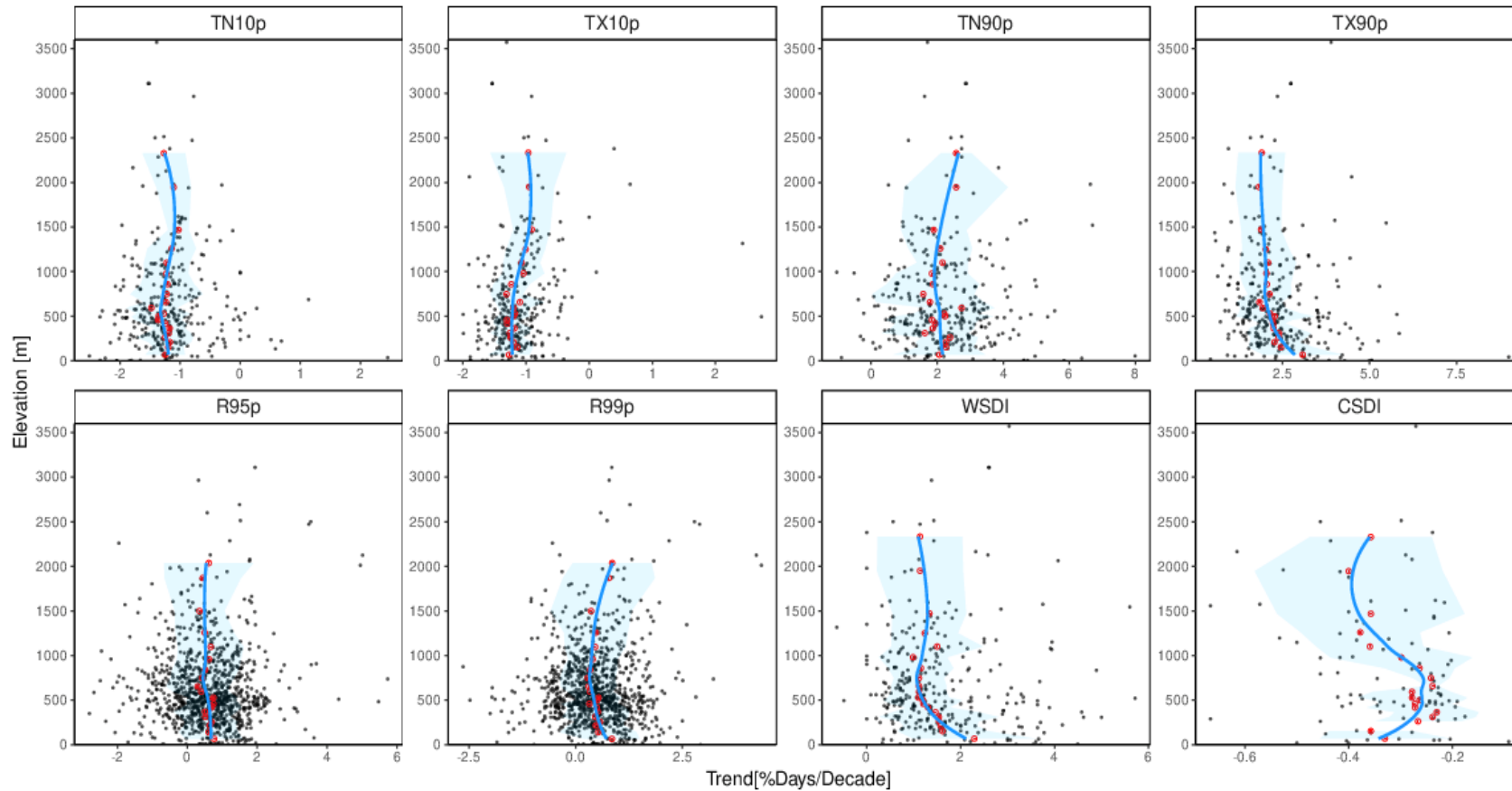
-EDW  
-EDPC  
+EDW  
(T, Tmin)

+EDPC

-EDW



# Elevation trends of extremes



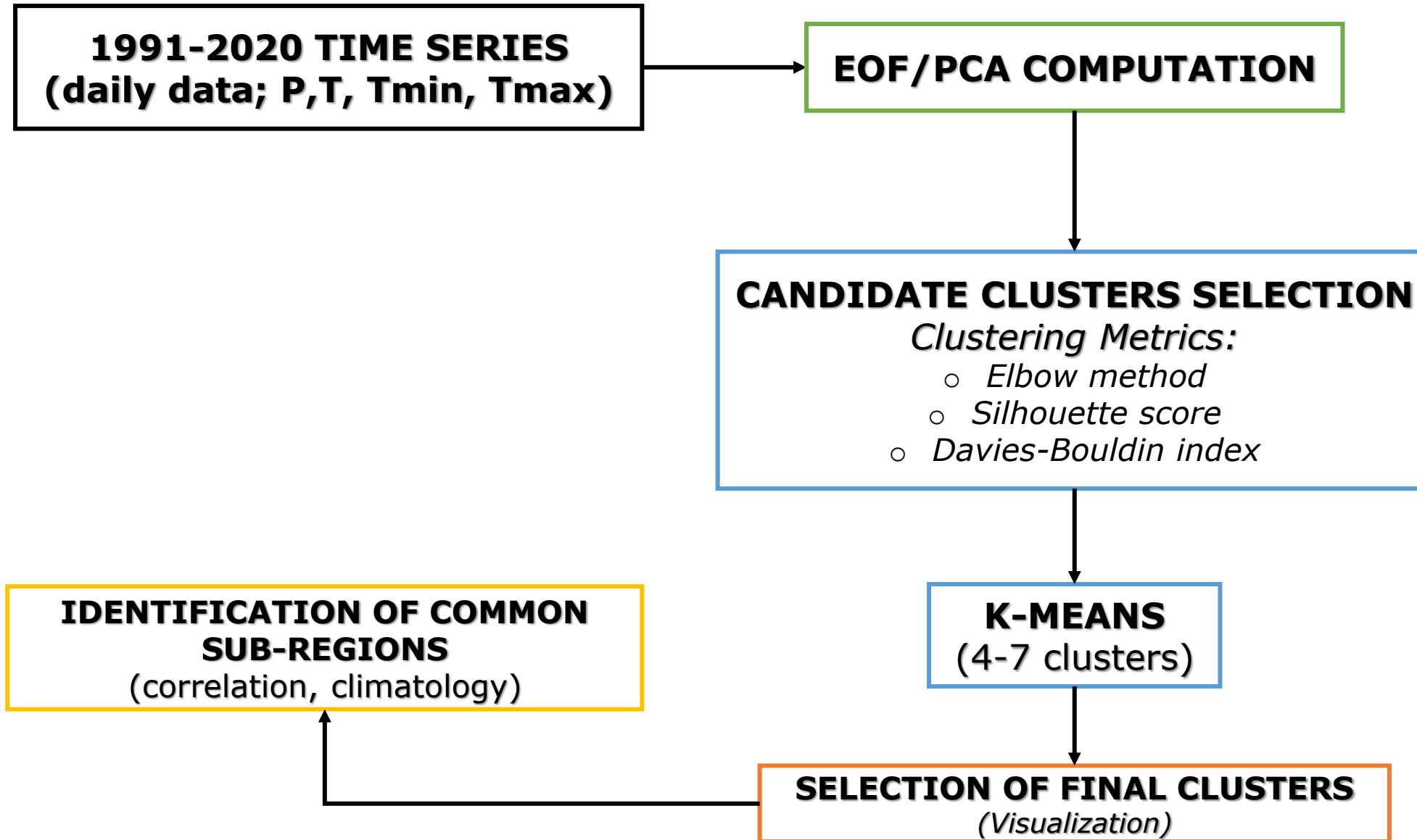
Index	Rate [%d]
TN10P	0.49
TX10P	1.65
TN90P	1.58
TX90P	-3.25
R95P	-0.96
R99P	0.71
WSDI	-2.37
CSDI	-0.55

- Warm nights (TN90p) follow Tmin
- More persistent warming conditions at lower elevations
- Increase of extreme precipitation (R99p) at high elevations

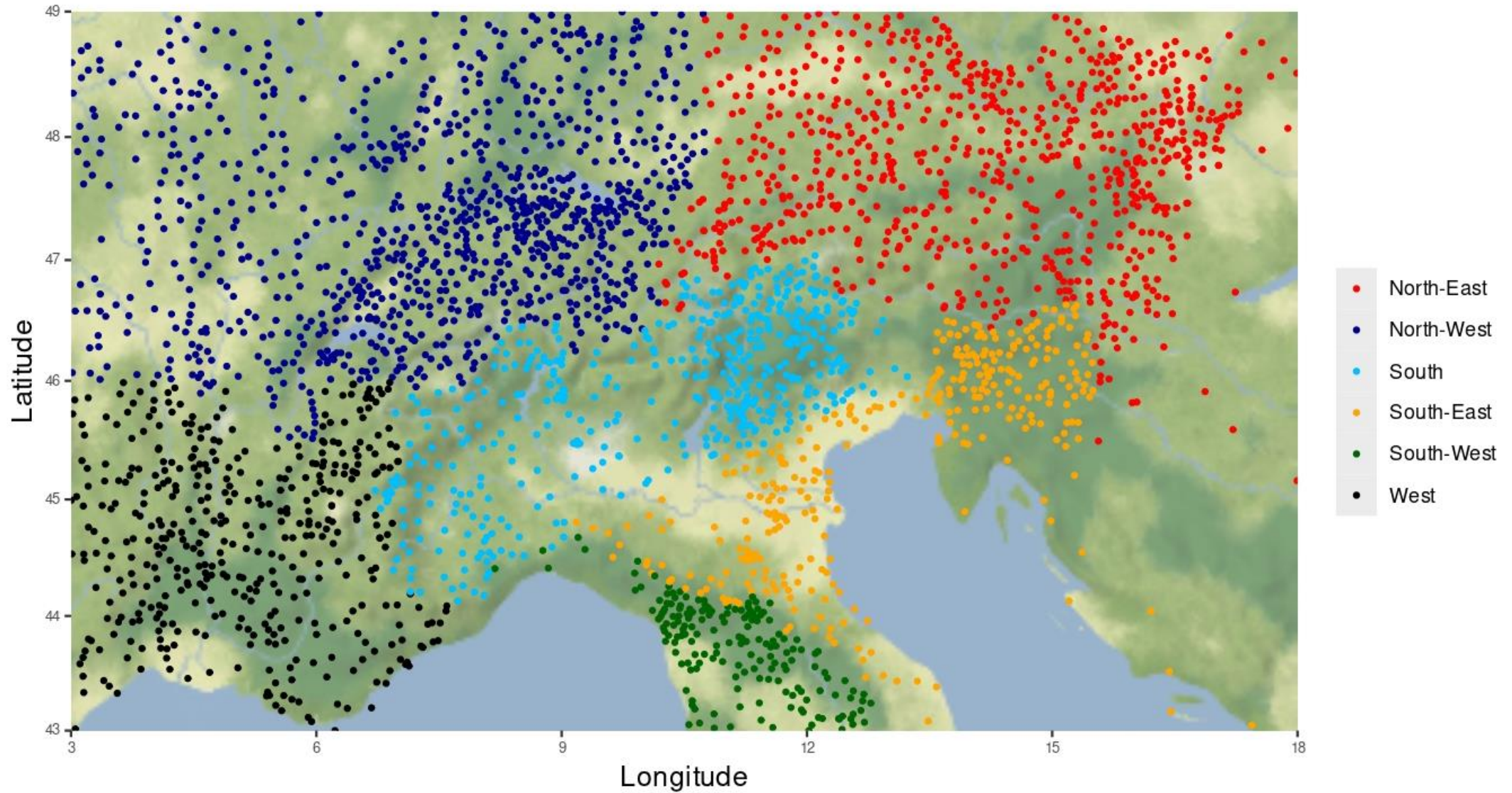
**Conf. level:**

99% 95% 90%

# Regionalization

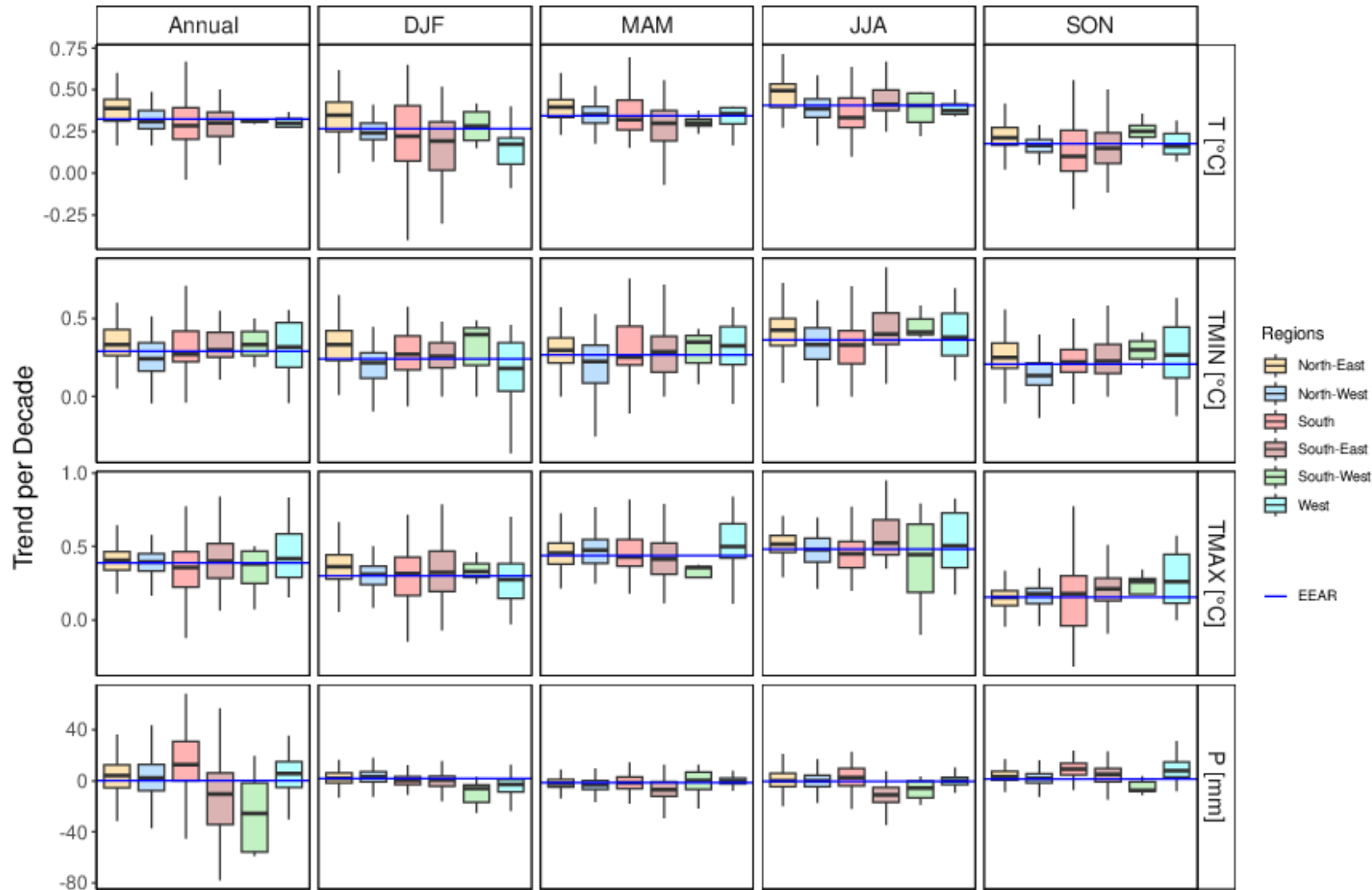


# Sub-regions



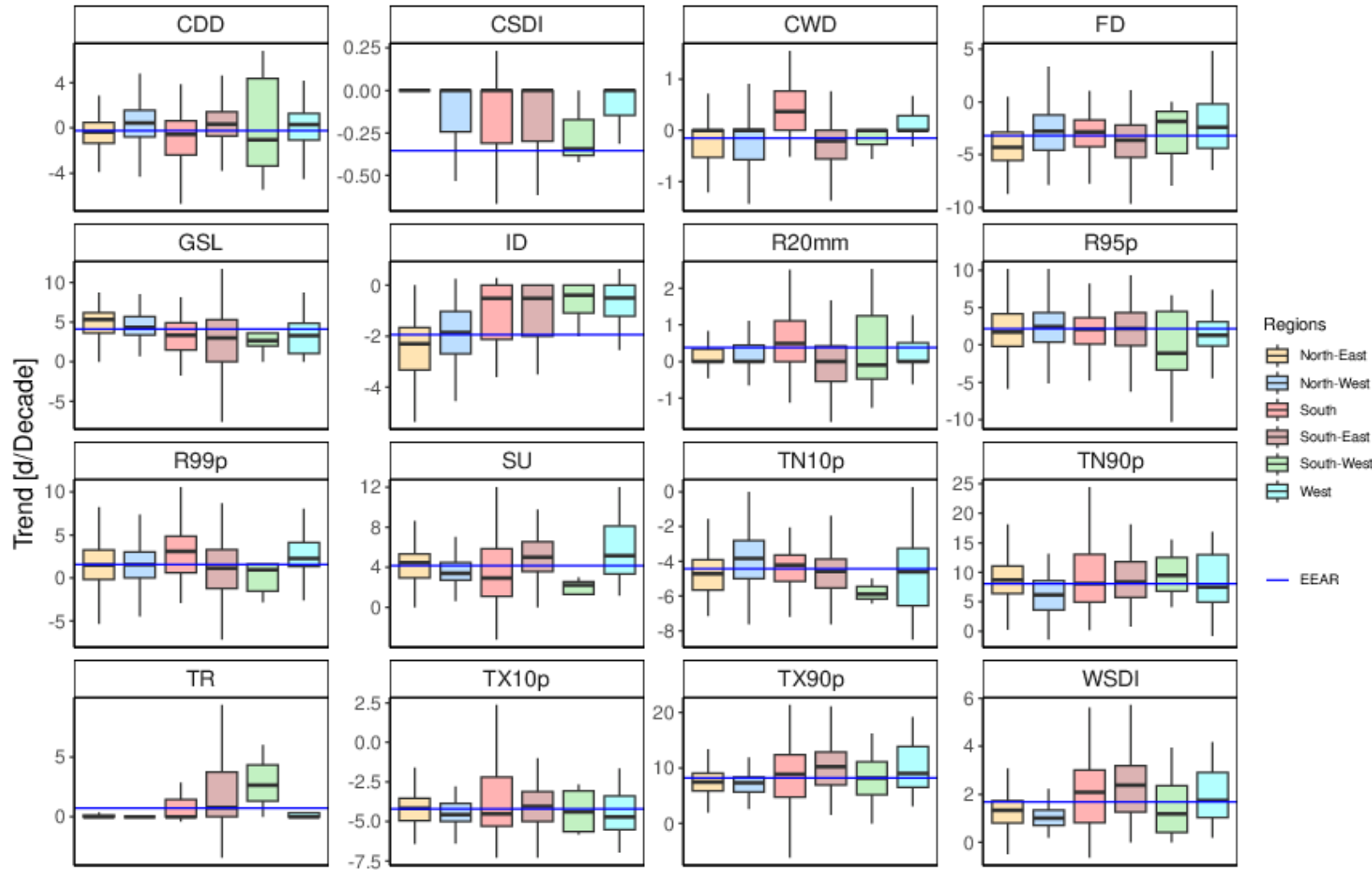


# Regional trends



- Warming above the average in NE (Tmin) and SE (Tmax, JJA)
- Trends around the average or far from average but not significant elsewhere
- -P (significant) in JJA for SW and SE regions

# Regional trends



- Significant (partially) trends for R95p (S) and R99p (SE)
- Southern regions:
  - increased persistent warming
  - Increased frequency of extreme rainfalls
- Reduced cold extremes over NE

# Conclusions

- *Development of a new and unprecedented observational dataset for the Alpine region, addressing key issues*
- *Trend analysis shown a significant average increase of air temperature about 2°C over 1961-2020. Warming conditions more persistent over Southern Alps and North-East*
- *Different EDW patterns for T<sub>min</sub> and T<sub>max</sub>: -EDW in autumn, + EDW in spring*
- *Positive EDPC in summer with drier conditions in the South. Extreme rainfall events increased, especially over Southern Alps*



# Perspectives

- ❑ *The dataset will be soon available in open repository as raw, quality checked and homogenized data*
- ❑ *Trend and climate analysis will be extended to other variables, providing a more complete picture of climate changes over Alpine region*
- ❑ *Dataset interpolation at high spatial resolution and release of the gridded product*