Learning of weather-type transitions for risk assessment

by Hoffmann et al.

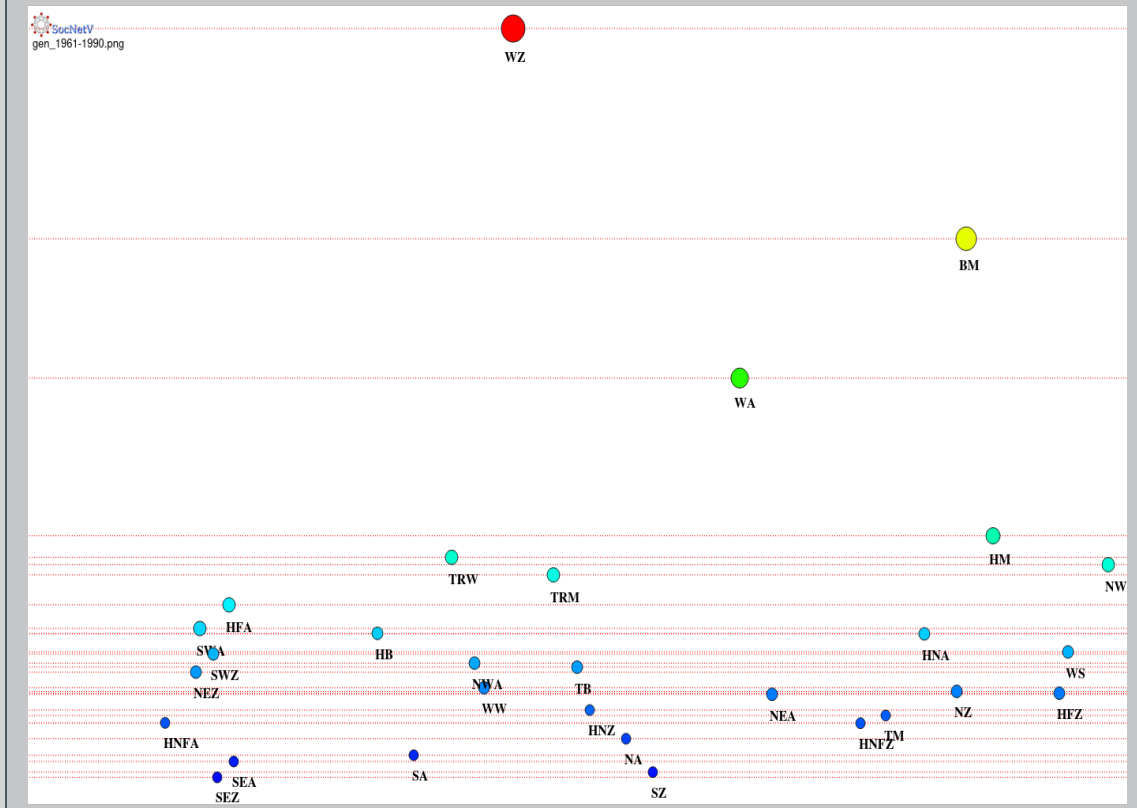
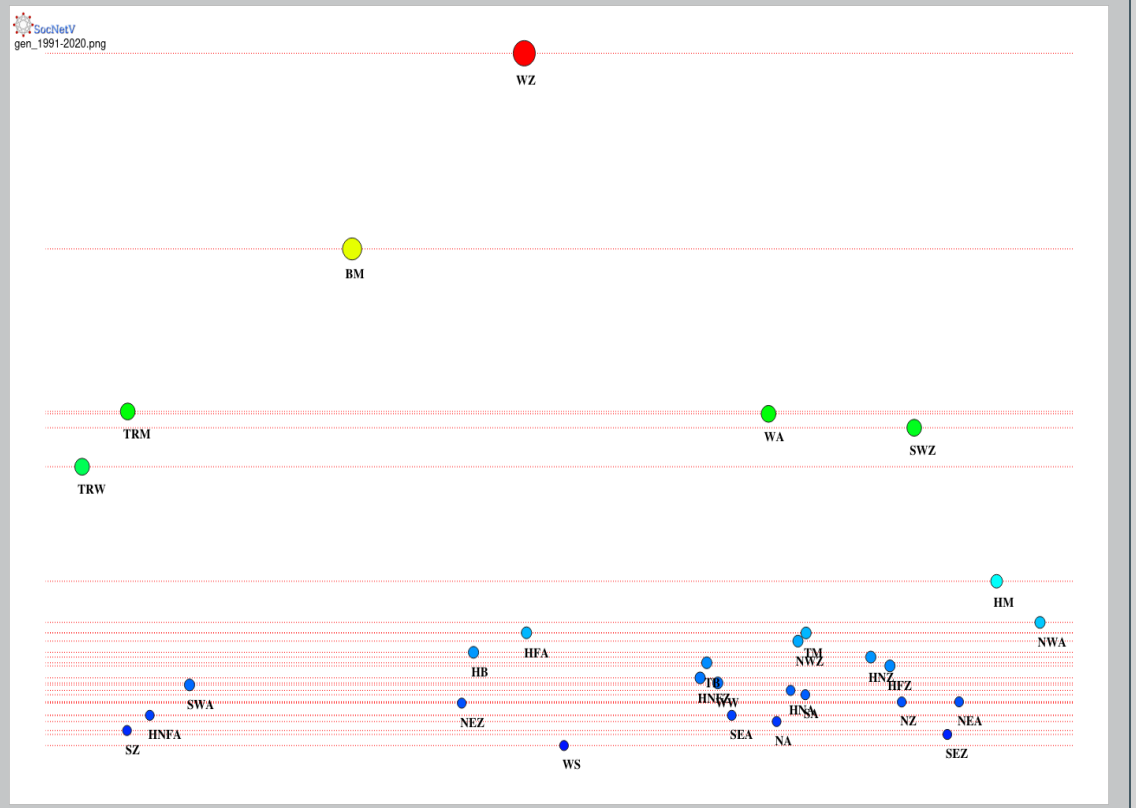
Research Question

Have observed changes in circulation patterns over Europa already contributed to a higher risk of climate extremes?

The answer is yes!

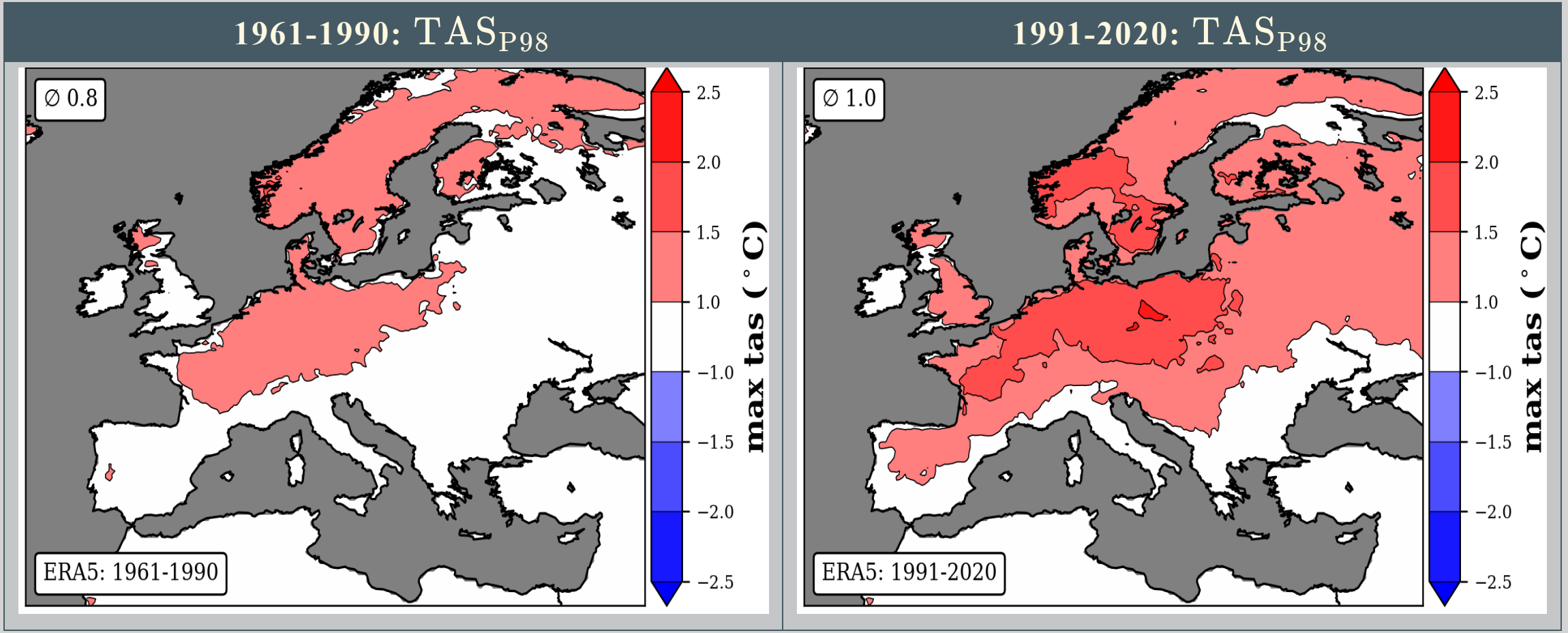
Centrality of circulation patterns

New dominate circulation patterns: TRM, TRW, SWZ

1961-1990 (past)	1991-2020 (present)
	

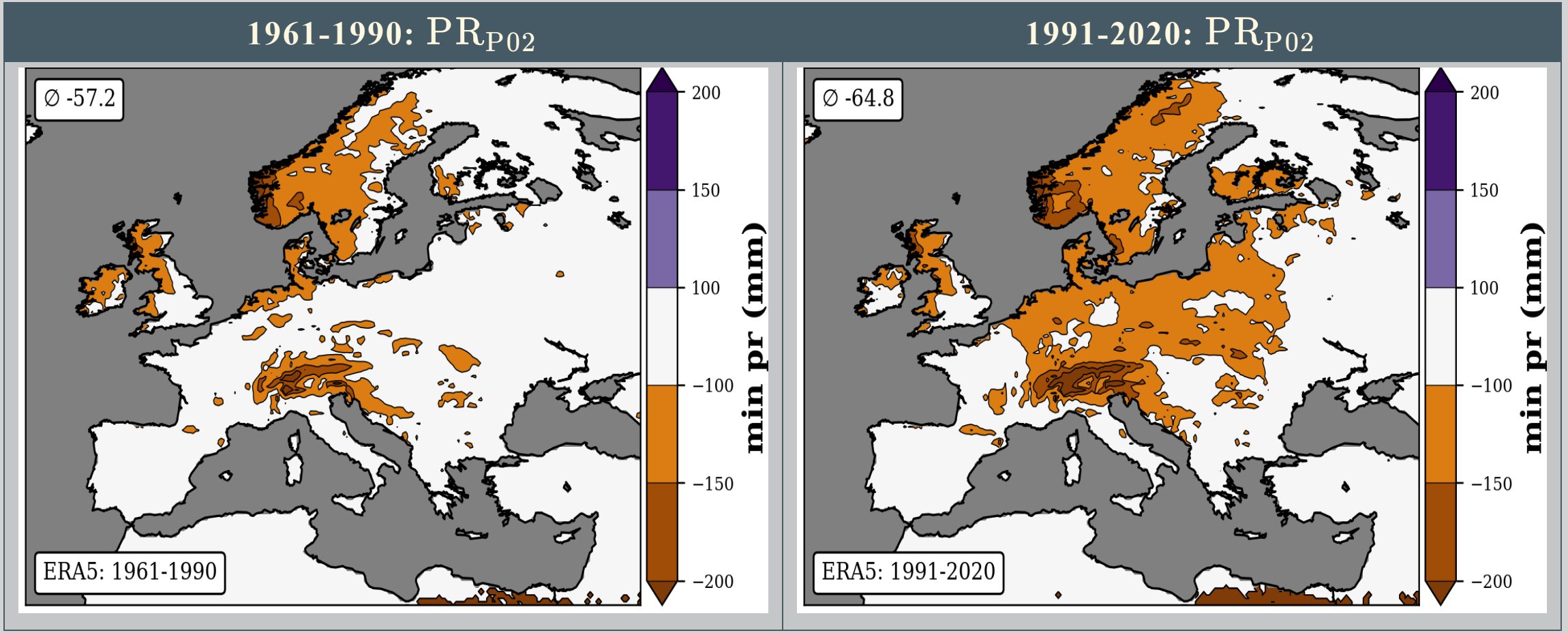
Hot Summers

50-year events getting hotter in Central Europe alone caused by dynamical factors



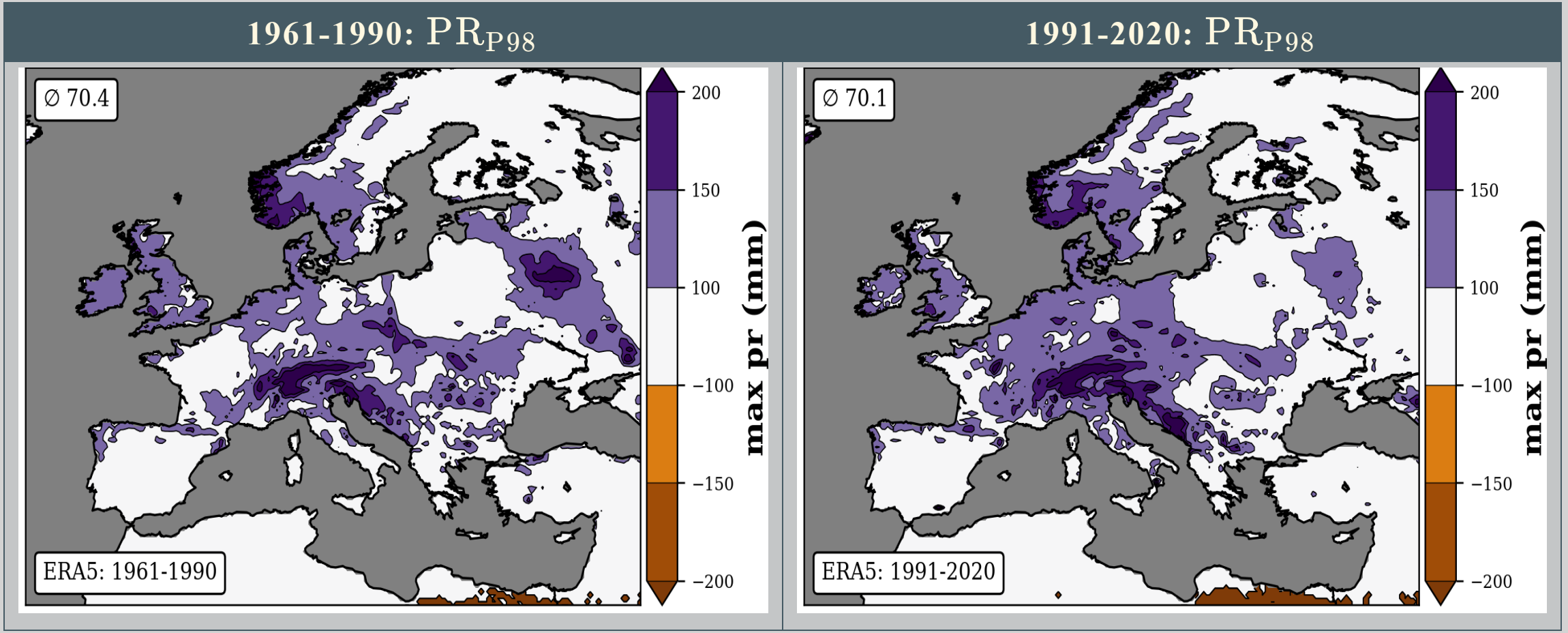
Dry Summers

50-year events getting drier in Central Europe alone caused by dynamical factors



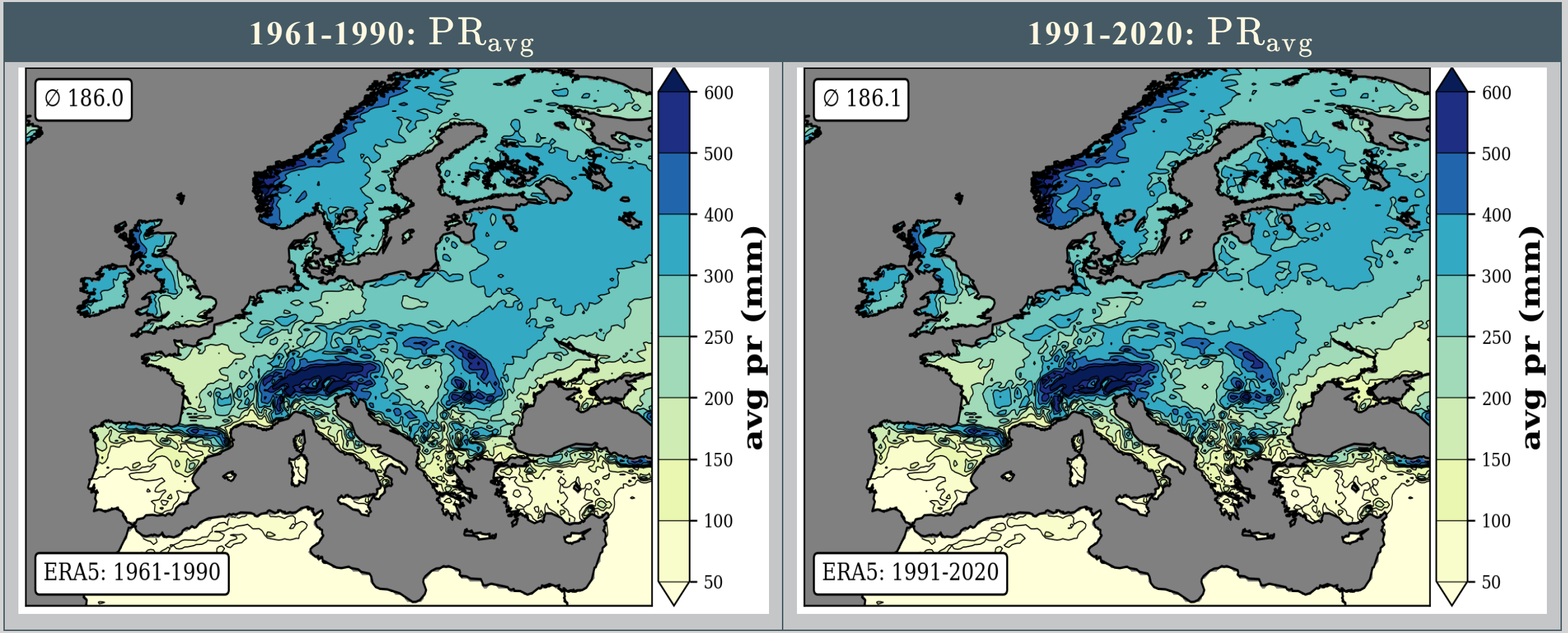
Wet Summers

50-year events getting wetter in Central Europa alone caused by dynamical factors



Mean Summers

No changes in mean values alone caused by dynamical factors



How we come to this result?

We learn from past and present weather-type transitions, generate possible sequences and translate it to physical risks.

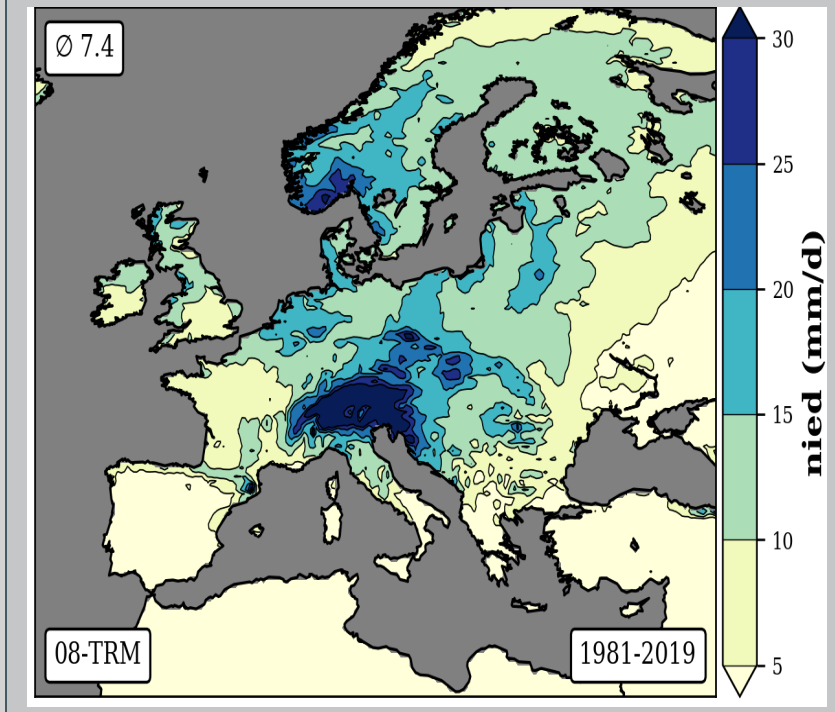
Data and Methods

- **Data:**
  - **1961-2020:** daily European weather-types (GWL Großwetterlagen)
  - **1981-2019:** daily fields of temperature and precipitation from ERA5 reanalysis data
- **Processing:**
  - **1981-2019:** long-term mean daily temperature and precipitation per weather-type and month
- **Method:**
  - Random forest (decision tree) $P_{k,k'}^{(m)} = (GWL_t = k | GWL_{t+1} = k')$
  - **1961-1990/1991-2020:** Learning/Training GWL transitions
  - **2001-3000/2001-3000:** Testing GWL transitions
  - translation into meteorological quantities (mean daily weather)
- **Diagnostic:**
  - 1000 years of summer means
  - 98th (50-year return period) for hot and wet
  - 02th (50-year return period) for dry

Mean GWL Weather

Long-term daily mean temperature and precipitation for each GWL and month

Europe: TRM-Aug



Potsdam: all GWL and all Months

obs: 1961-1990

	WA	WZ	WS	WW	SWA	SWZ	NWA	NWZ	HM	BM	TM	NA	NZ	HNA	HNZ	HB	TRM	NEA	NEZ	HFA	HFZ	HNFA	HNFZ	SEA	SEZ	SA	SZ	TB	TRW
Dec	2.1	5.8	2.5	0.6	1.2	1.3	0.6	2.2	2.2	2.9	0.2	0.1	1.1	0.6	0.4	0.9	1.5	0.2	0.3	0.5	0.5	0.1	0.2	0.4	0.3	0.5	0.4	0.4	0.4
Nov	1.5	6.3	0.8	0.7	1.0	1.3	1.1	1.0	2.4	1.9	0.5	0.1	0.9	0.3	0.0	1.1	2.1	0.1	0.4	0.3	0.5	0.2	1.0	0.1	0.3	0.8	0.3	0.5	2.0
Oct	2.6	5.0	0.8	0.7	1.7	1.6	0.3	0.9	3.6	3.6	0.7	0.0	0.2	0.2	0.3	1.0	1.0	0.1	0.1	0.8	0.2	0.0	0.0	1.1	0.5	1.5	0.8	0.5	0.8
Sep	2.7	5.8	0.3	0.5	0.8	1.6	1.6	0.6	2.1	4.2	0.4	0.1	0.1	0.9	0.1	0.9	1.1	0.3	0.4	1.1	0.5	0.0	0.0	0.0	0.0	0.6	0.3	0.7	1.9
Aug	2.9	4.3	0.6	0.3	1.4	0.5	0.4	1.4	1.9	3.8	0.4	0.5	0.7	0.5	0.8	0.4	1.6	1.0	1.0	1.3	0.8	0.5	0.9	0.2	0.0	0.1	0.0	0.7	1.9
Jul	2.8	4.6	0.5	0.6	0.7	0.6	0.8	2.7	1.9	3.4	0.2	0.0	0.6	0.8	0.4	1.4	1.7	0.3	0.7	1.4	0.6	0.9	0.3	0.0	0.0	0.0	0.0	1.0	1.4
Jun	1.6	4.1	1.4	0.7	0.8	0.5	0.6	1.1	1.4	2.6	0.9	0.7	0.7	1.0	0.8	1.2	0.9	1.2	1.2	0.7	0.7	0.3	0.7	0.4	0.1	0.1	0.1	0.8	2.1
May	0.4	3.2	0.8	0.7	0.5	1.8	0.2	1.3	1.4	2.0	1.2	0.2	1.0	1.0	1.7	0.8	0.5	1.0	0.8	1.6	1.1	0.6	1.0	0.3	0.3	0.7	0.0	1.4	2.8
Apr	0.4	2.2	0.9	0.7	0.4	1.6	0.1	2.0	1.7	2.6	1.9	0.5	1.5	0.6	0.7	1.8	1.3	0.5	0.5	0.4	0.3	0.2	2.1	0.4	0.3	0.8	0.2	0.6	2.4
Mar	1.6	5.5	0.8	0.9	1.1	0.9	1.2	1.8	1.1	2.2	0.8	0.0	0.7	0.5	0.8	0.9	1.1	0.3	0.6	2.0	0.7	0.4	0.3	0.9	1.1	0.0	0.3	0.7	1.5
Feb	0.6	5.0	1.4	0.9	0.8	0.9	0.2	1.5	2.0	2.3	1.0	0.1	0.4	0.9	0.6	1.4	0.6	0.2	0.0	0.6	0.6	0.7	0.9	1.2	1.5	0.6	0.6	0.2	0.5
Jan	1.8	6.4	1.7	1.3	0.9	1.6	0.2	1.9	1.7	3.0	0.0	0.2	1.2	0.6	0.6	0.5	0.9	0.0	0.3	0.3	0.4	0.2	1.5	1.0	0.7	0.6	0.6	0.5	0.2

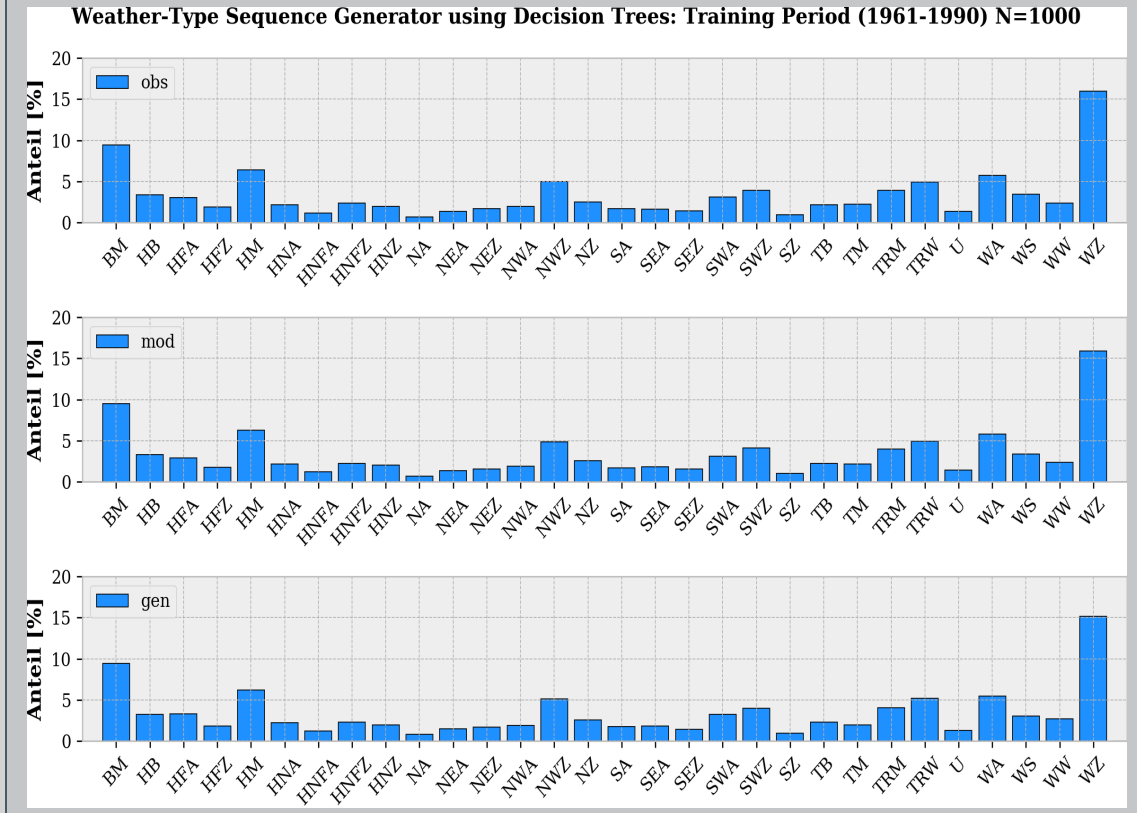
These values are assigned to the 1000yr generated GWL sequences for the past and present conditions.

No new daily extremes are generated, but seasons!

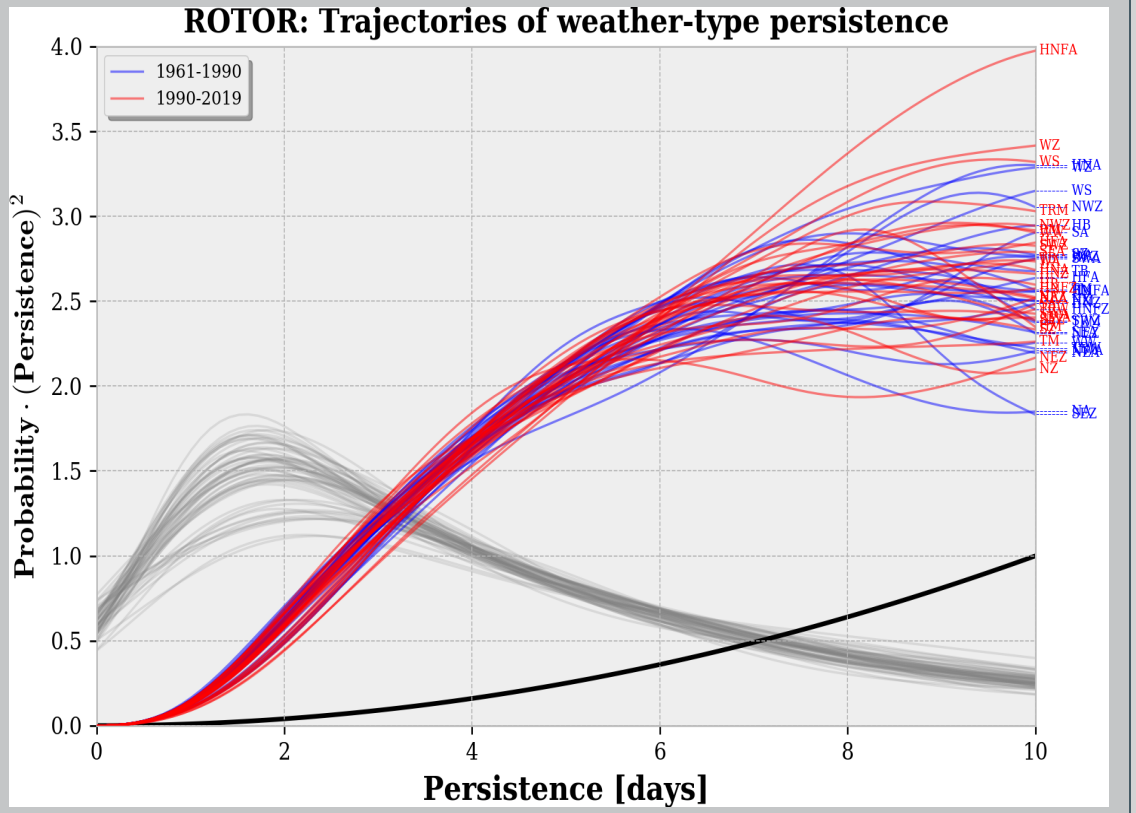
Weather-Type (GWL) Frequency and Persistence

HNFA (Omega-like Patterns) and TRM (Trough Central Europe) become more persistent

Frequency



Persistence



Conclusions

- hydroclimatic extremes are mainly triggered by the stagnation of critical circulation patterns
- observed dynamical changes already show new dominant circulation patterns over Europe
  - *Trough Central Europe:* TRM
  - *Trough Western Europe:* TRW
- the dominance of weather patterns is determined by the frequency and the persistence
- this alone cannot explain the warming but the increase of hydroclimatic extremes
- extreme hot, dry and wet summer seasons over Central Europe have become more frequent by dynamical factors
- possible but not observed weather-type transitions are trained by learning decision trees
- this is helpful for hydroclimatic risk assessment