Changes in dynamical and physiscal processes in explaining recent extreme events

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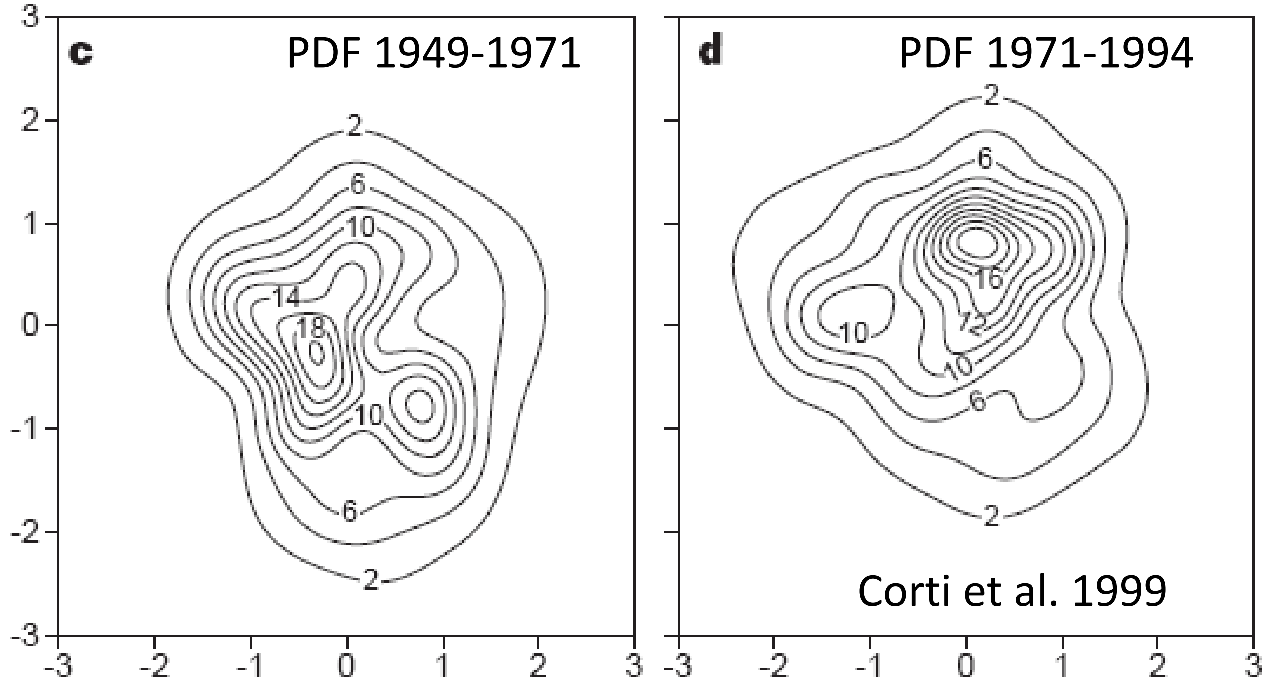
Structure of presentation

- 1. Formalism and methods
- 2. Changes in daily extremes from observations and analogues
- 3. Changes in winter monthly precip – an exemple using large atmospheric ensembles
- 4. Changes in summer temperature anomalies and the role of SM vs. Flow
- 5. Remaining issues and concluding remarks

The starting point: can flow changes explain thermal changes?



variability. Here we use atmospheric circulation data from the Northern Hemisphere to show that recent climate change can be interpreted in terms of changes in the frequency of occurrence of natural atmospheric circulation regimes. We conclude that recent Northern Hemisphere warming may be more directly related to the thermal structure of these circulation regimes than to any anthropogenic forcing pattern itself. Conversely, the fact that

Since then

- Several studies addressing possible long term flow changes and impacts on extremes (eg Lennard et al 2015; Horton et al., 2015, …)
- NAO has gone down then up again lately
- Artic sea ice effects / blocking debate after a few cold winters

- …But the atmosphere is still warming and we still have difficulties characterizing:
  - The changes in flow patterns (too many d-o-fs)
  - The link of such changes to EE changes
  - Europe particularly difficult due to a mixture of drivers

Changes in flow and in extremes

Region		DJF 05	DJF 95	DJF O	DJF P	DJF M	MAM 05	MAM 95	MAM O	MAM P	MAM M	JJA 05	JJA 95	JJA O	JJA P	JJA M	SON 05	SON 95	SON O	SON P	SON M
Europe	Sat						−		+			−	+	±	+	+					
	Ice	+										−	+			+	−	+			−
Western Asia	Sat							+				−	+	±		−	−	+	−	−	
	Ice		+	=	+	+	−	+				−	+	±		+	−	+	−		
Central Asia	Sat						−	+				−					−				
	Ice	+	−	±	+		−	+				−	+				−				
Eastern Asia	Sat											−	+				−	+	±		
	Ice	+	−				+	−				−	+				−	+			
Western N. America	Sat		−				+														−
	Ice		−				+	−										−		+	
Central N. America	Sat	−						+				−					−		+		
	Ice	−										−	+				−	+			
Eastern N. America	Sat	−					−					−		±	−	±	−	+	+		
	Ice	−	+			−	−					−	+	±		−	−	+	+		

500 hPa circulation pattern occurrence (O), persistence (P) and maximum duration (M)	Robust change Equivocal
Reanalyses surface temperature extremes Cold (05) and Hot (95)	Cooling Equivocal Warming
1979–2013 (sat) and 1990–2013 (ice) trends	(+) positive (–) negative

Weather patterns changes and associated changes in extreme temperatures

No significant result for winter

In summer, 27% of extreme changes due to more EE ridges

Z500 used, could induce biases (T included by thermal expansion)

Horton et al., 2015

Formalism

$$P(T > T_0) = \sum_{flows\ F} \underbrace{P(T > T_0|F)}_{\text{Physics}} . \underbrace{P(F)}_{\text{Dynamics}}$$

Change:

$$Pc(T > T_0) = \sum_{flows\ F} Pc(T > T_0|F) . Pc(F)$$

Decomposition of changes

$$\Delta P(T > T_0) =$$

$$\sum_{flows\ F} \Delta P(T > T_0|F)\,.\,Pc(F) + \sum_{flows\ F} P(T > T_0|F)\,.\,\Delta Pc(F)$$

Change in marginal T distribution (physics)

Change in flow F distribution (dynamics)

Both can be due human influence

Natural variability should mostly affect the Change in F

Can we detect a flow-induced change in daily extreme events?

The flow analogue methodology

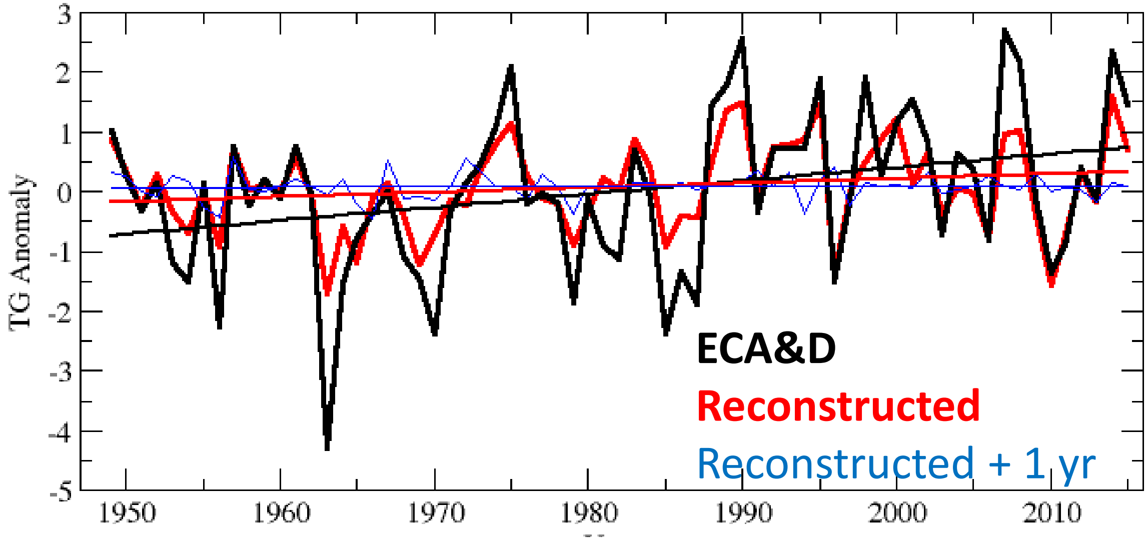
Estimates the marginal distribution $P(T > T_0|F)$

- Take NCEP SLP (daily) 1948-2015
- Take T, Pr from ECA&D 1948-2015
- Reconstruct a daily temperature series from the 10 best flow analogue dates, the « marginal distribution »
- Calculate seasonal statistics (average, freq. Of extremes) from reconstructed data and compare with original data
- Analogue dates taken from the data base of A2C2

A2C2 Atmospheric flow Analogues for Climate Change

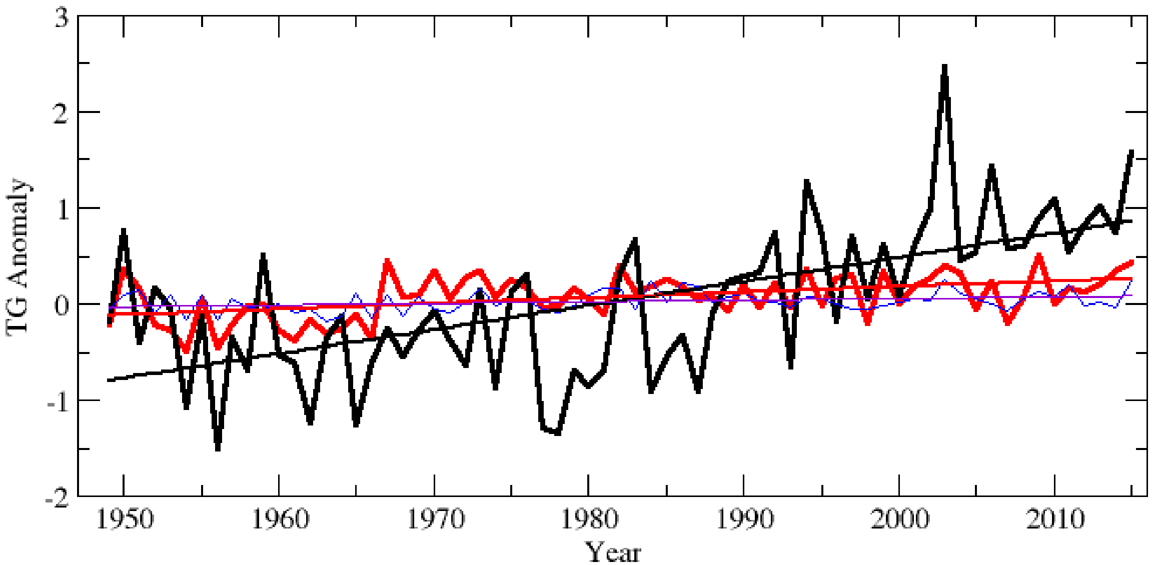
Mean temperature trends and flow contribution

(Vautard & Yiou, 2009, GRL; updated until 2015)



Winter

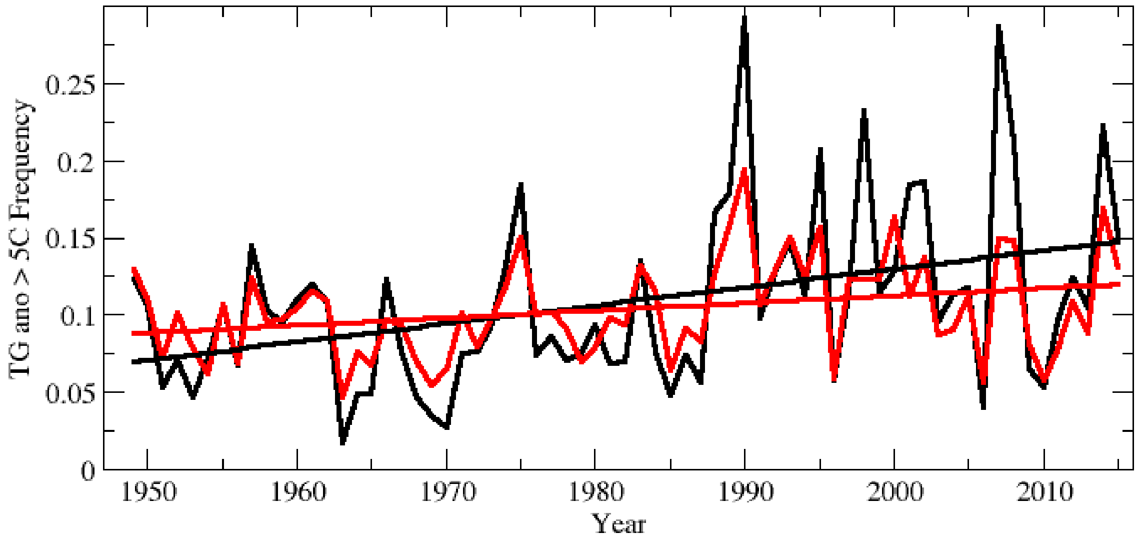
Slope ratio ~2.9



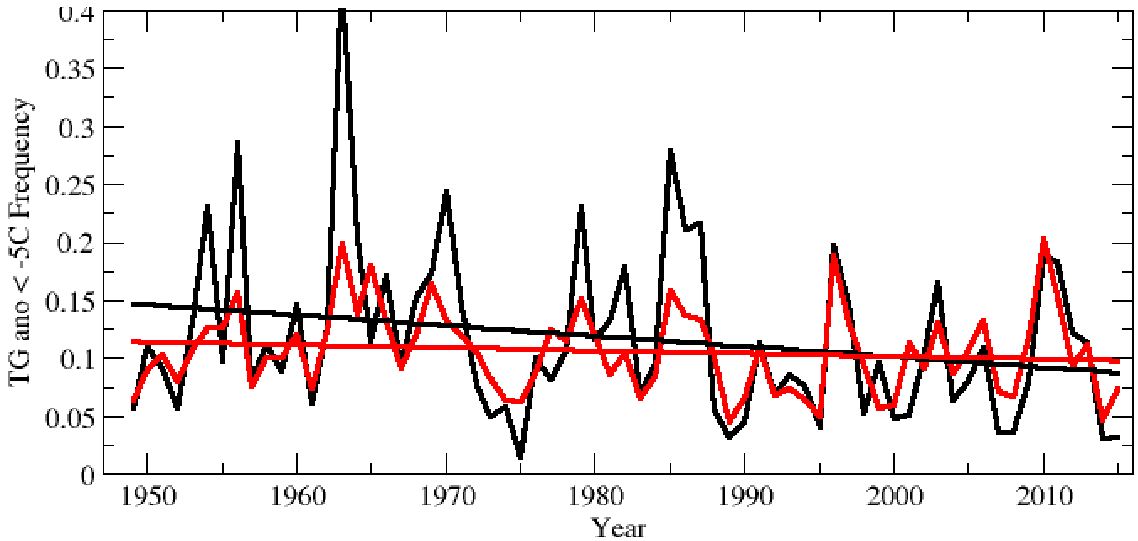
Summer

Slope ratio ~4.3

Winter extremes (*freq.* ano>5°C)

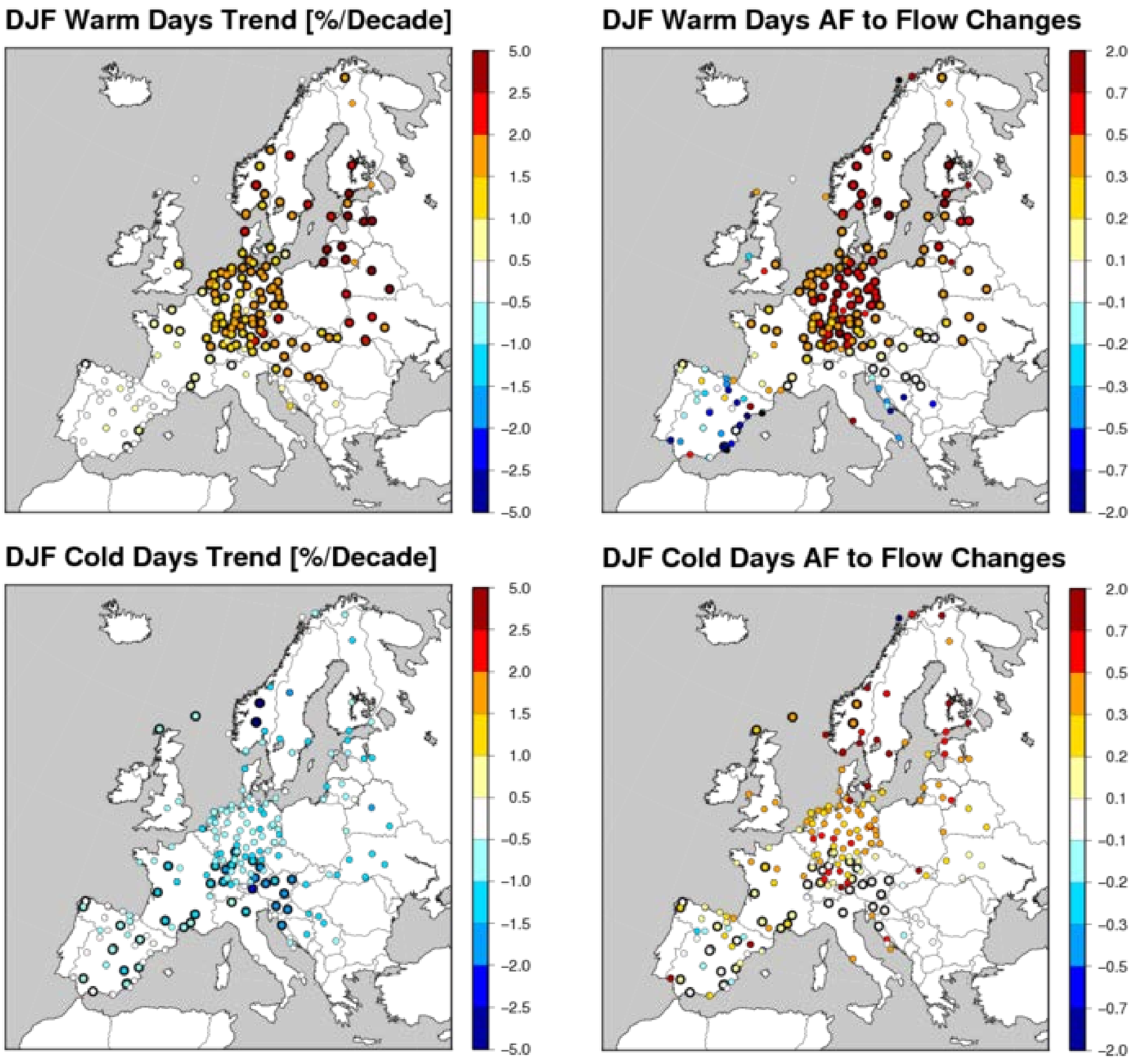


Warm extremes



Cold extremes

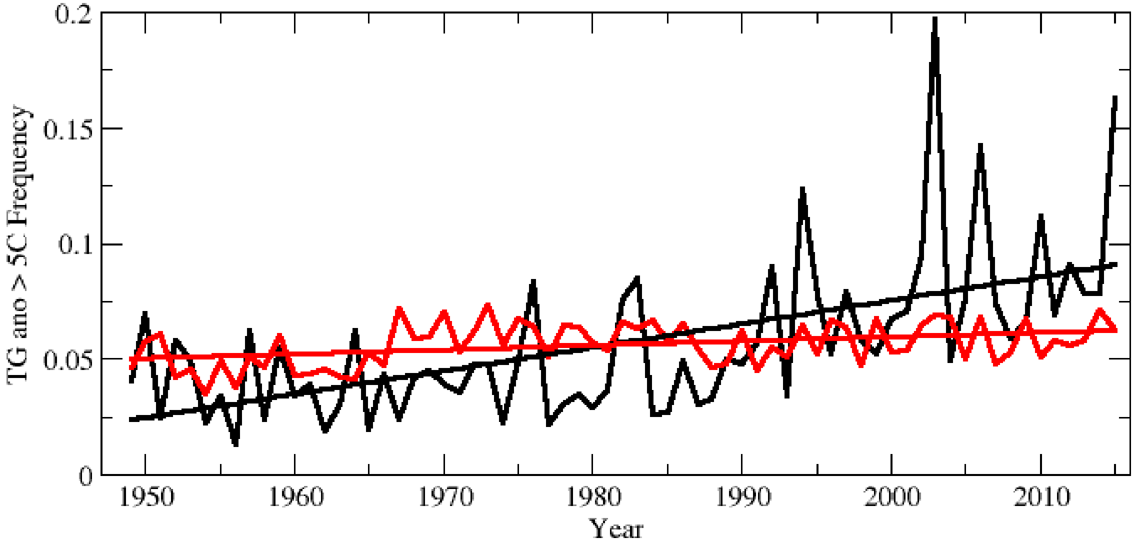
Winter extremes trends & Flow Attributable Fraction



A clear contribution (~50%) of circulation changes in winter warm days in N Europe [more favorable weather patterns]

In N Europe changes in circulations favor a decrease of cold extremes, but less in S Europe where the decrease is most significant
→ Crucial role of thermodynamics

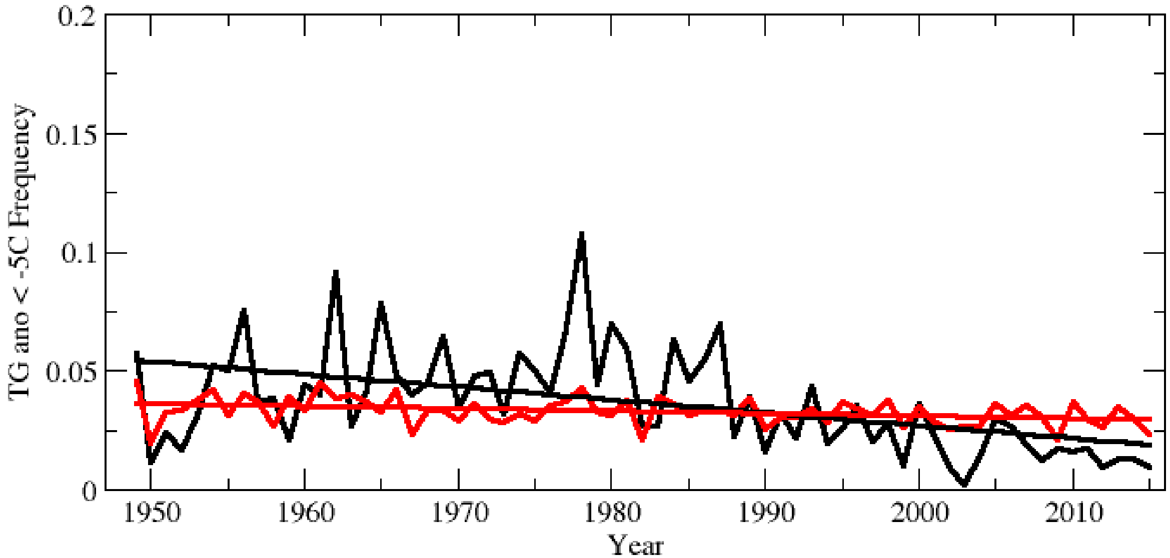
Summer extremes (*freq.* ano>5°C)



Warm extremes

Role of thermodynamics large, including SM feedback, possible SST role

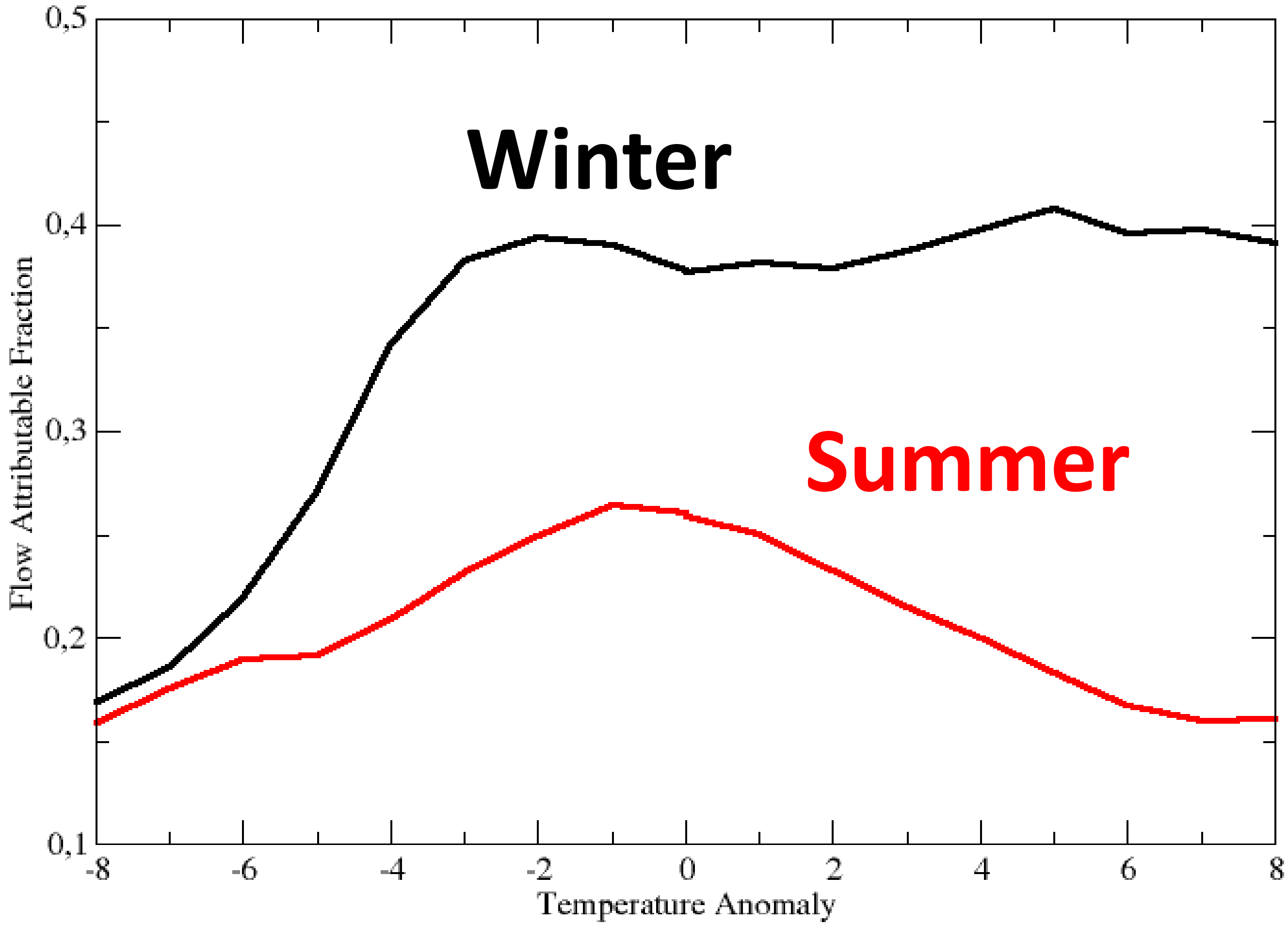
But SLP not suited to characterize summer flows



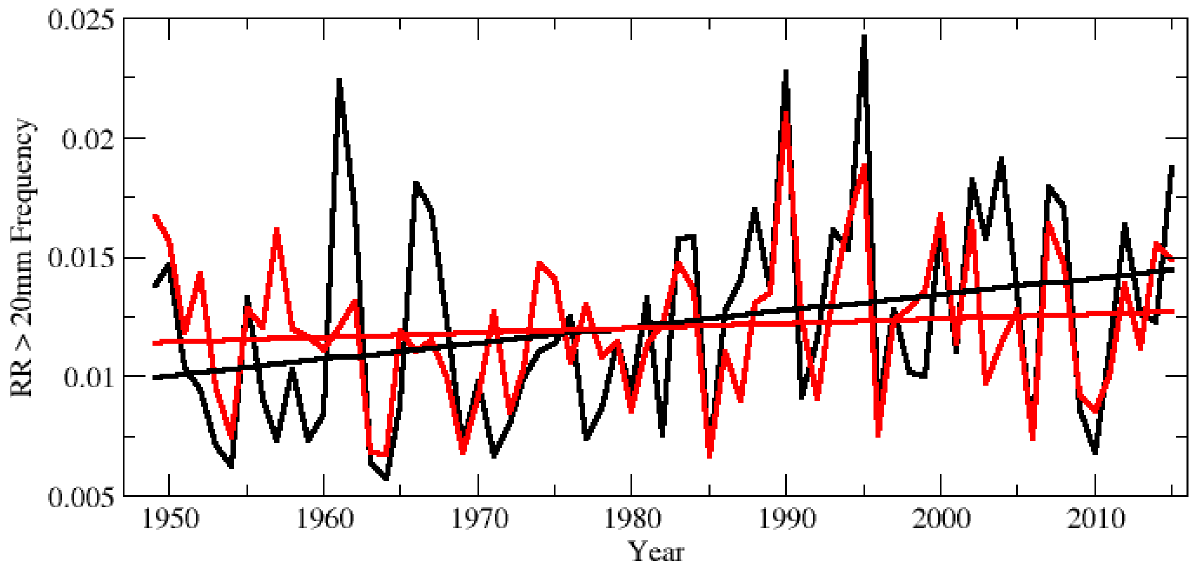
Cold extremes

Same behavior

Flow attributable fraction of extreme temperatures frequency trend



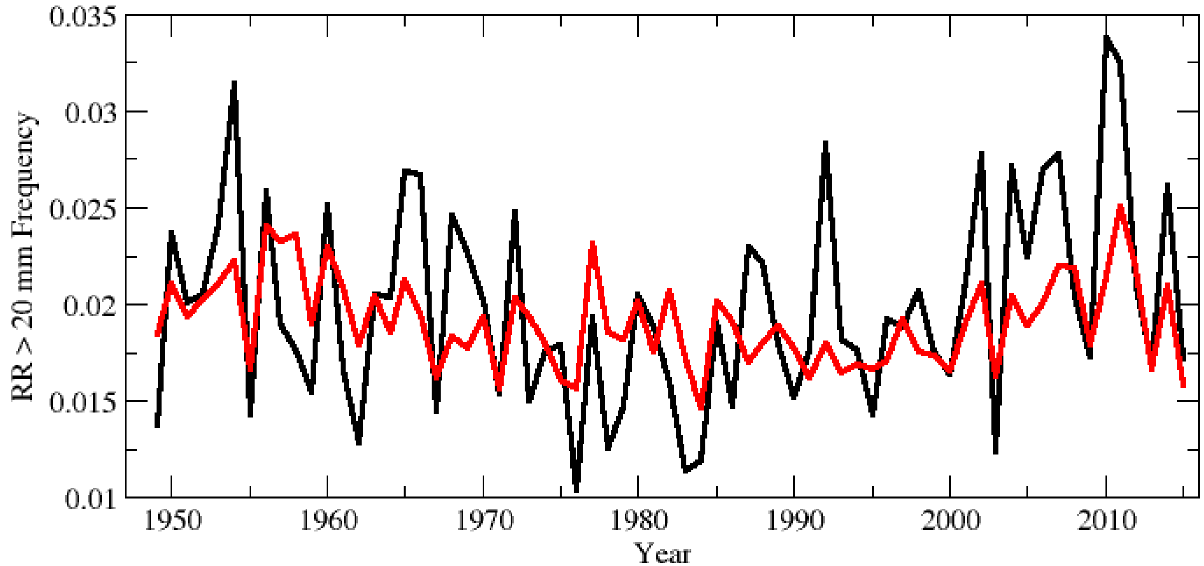
Heavy rain (RR>20 mm)



Winter

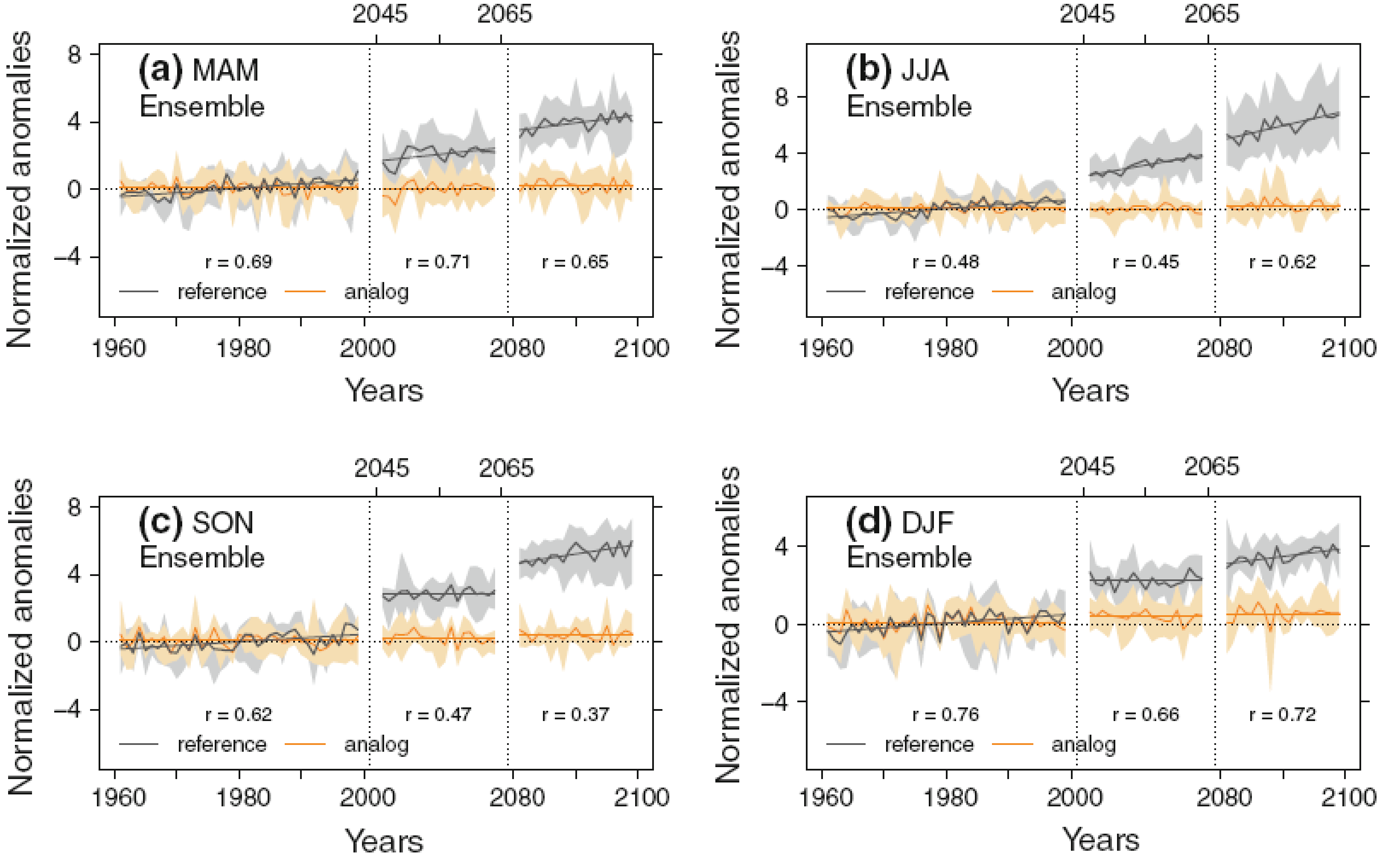
Role of thermodynamics large, including SM feedback

Patterns difficult to establish



Summer

Why do we care about contributions? Future projections (here CMIP3)



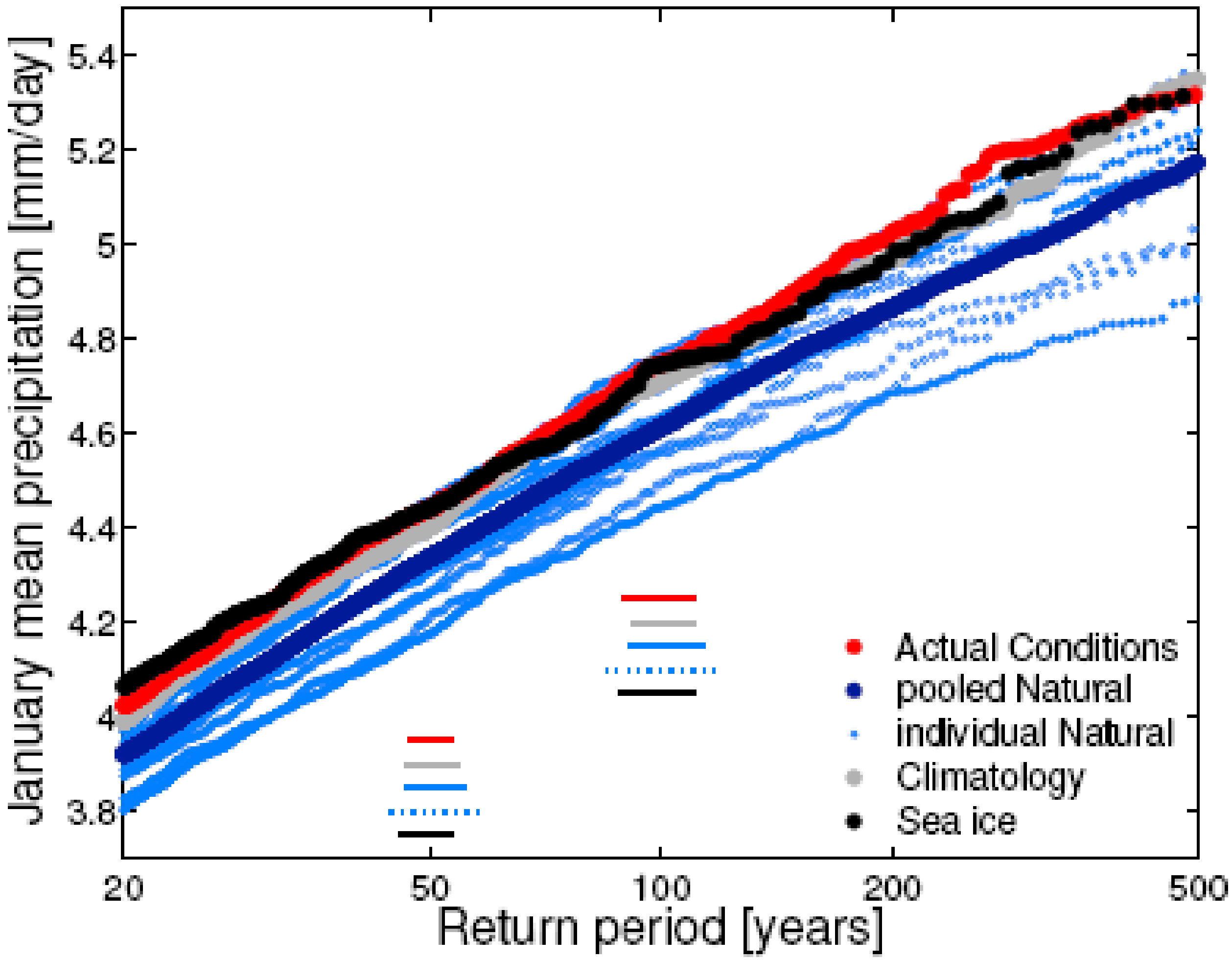
Cattiaux et al. (2012)

Single event – Monthly amounts

The example of the exteme amount of JAN 2014 in Southern UK

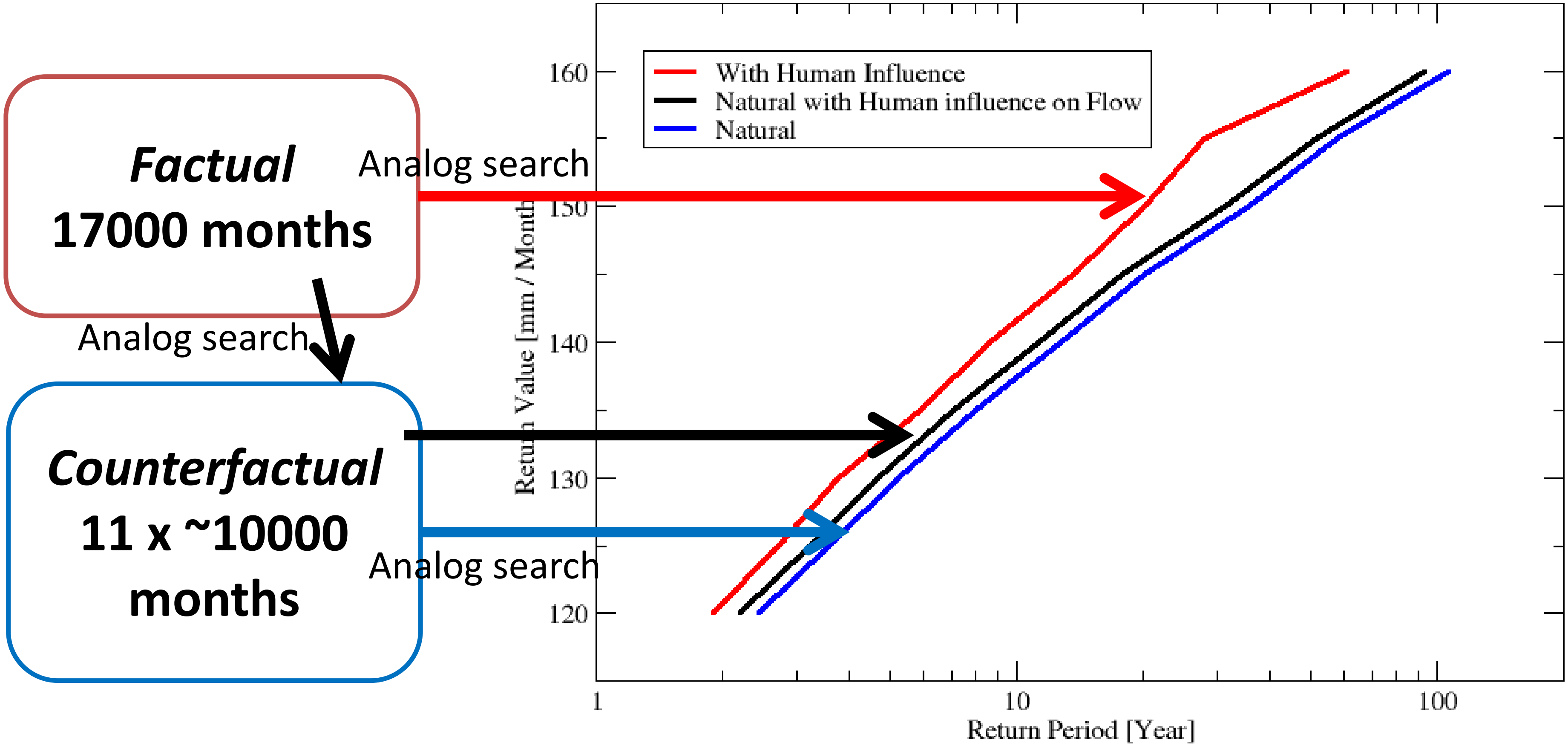
Large ensemble from Oxford experiments
17000 JAN Months for factual world
~110000 JAN months for counterfactual world

Precipitation: models needed with long simulations



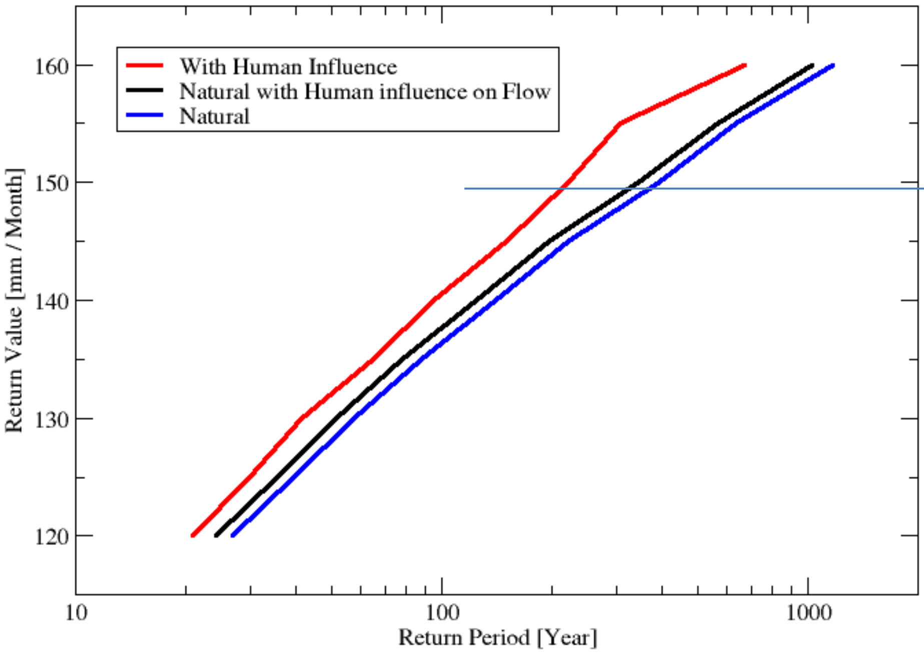
Schaller et al., 2015, in revision

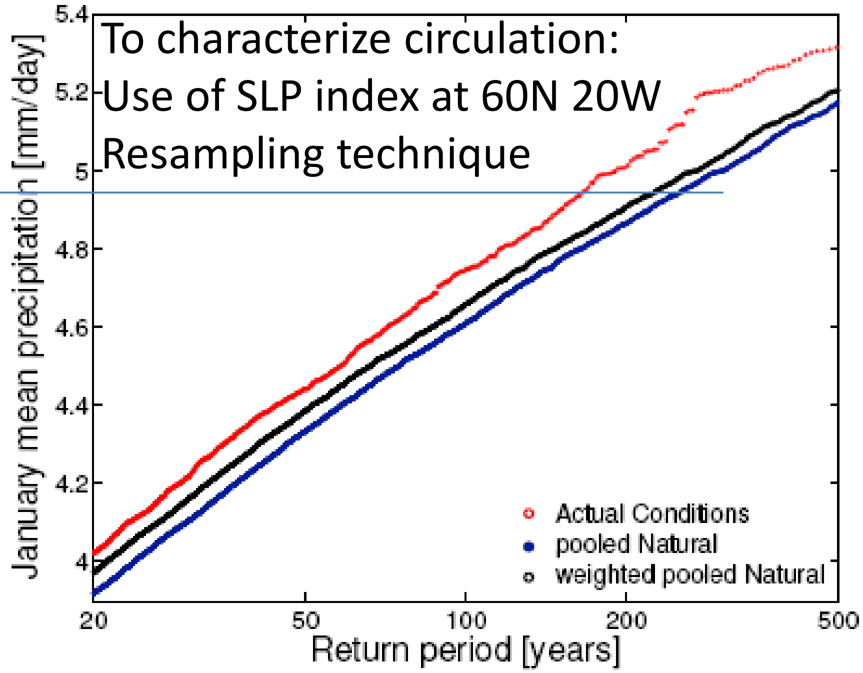
Dynamical contribution: use of monthly analogues



Dynamical contribution ~20%

Role of circulation changes





Schaller et al., 2015, submitted

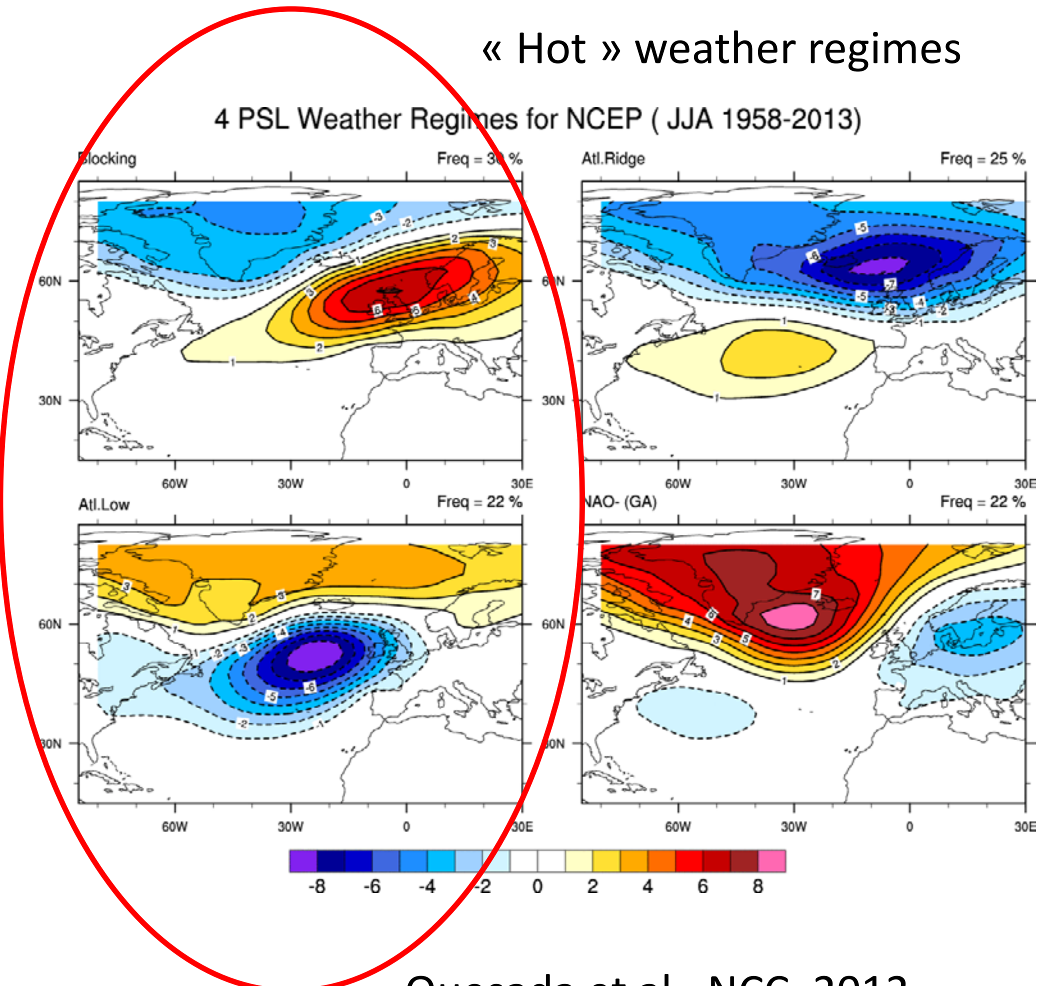
Role of initial soil moisture vs. flow in explaining summer anomalies and extremes

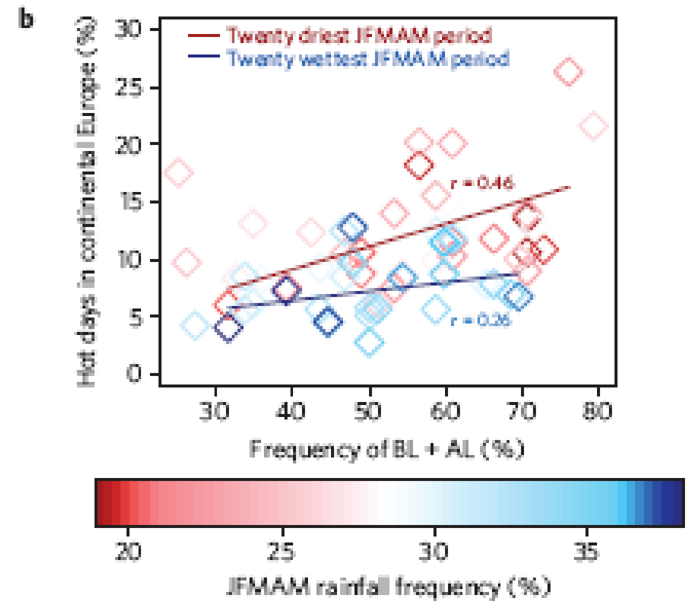
Nudged modeling experiments

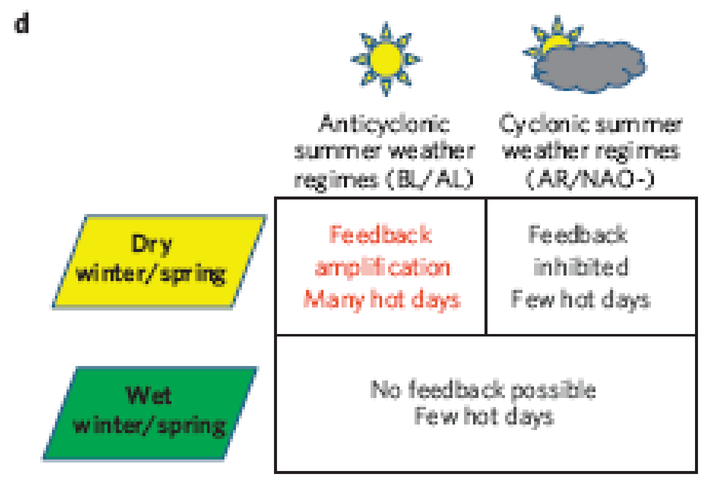
A. Stegehuis, B. Quesada, M. Vogel,
S. Seneviratne, M. Hirschi, P. Yiou

Soil moisture increase the sensitivity ot temperatures to blocking anticyclones

« Hot » weather regimes





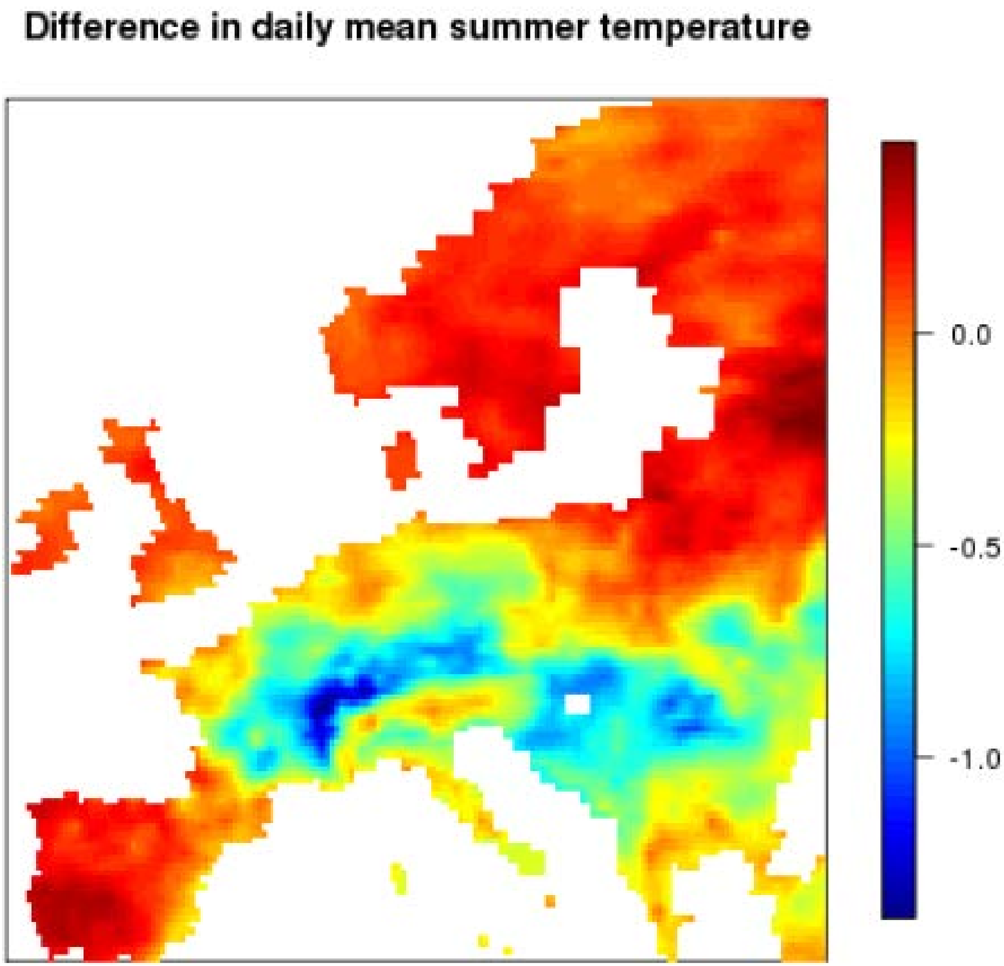


Quesada et al., NCC, 2012

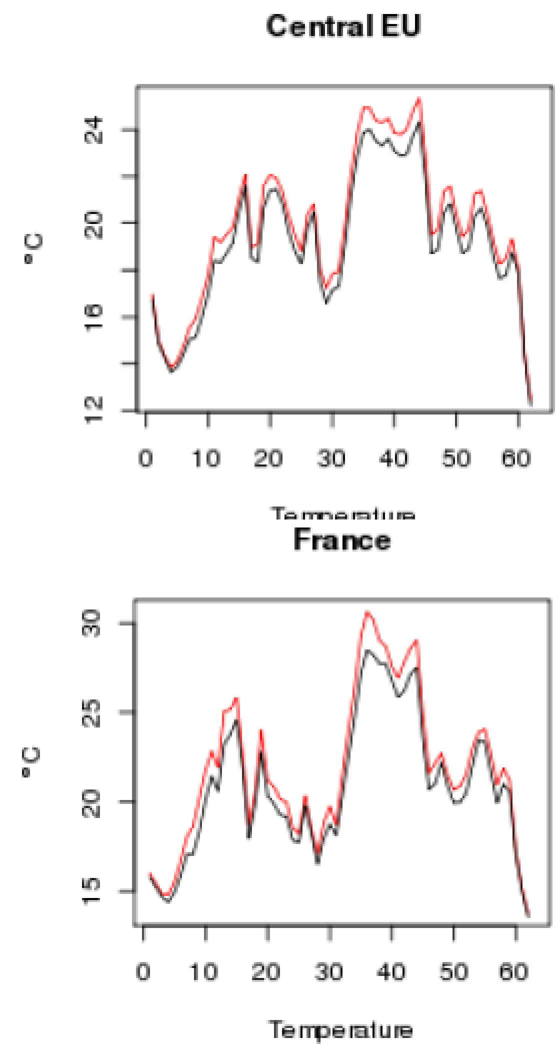
Flow vs. ISM: Experimental design

- Perform a CTRL regional experiment (WRF) run with controled circulation (wind spectral nudging above boundary layer)
- Simulate each summer of Year Y with
  (1) The CTRL soil moisture of Year Y and winds of each of all 32 years, also SSTs
  (2) The winds of Year Y and soil moisture of each of 32 years
- Calculate the differences Tc-<T1> and Tc-<T2> (resp. « flow contribution » and « SM contribution)
- Initial SM on 30 June
- Temperatures averaged over July & August

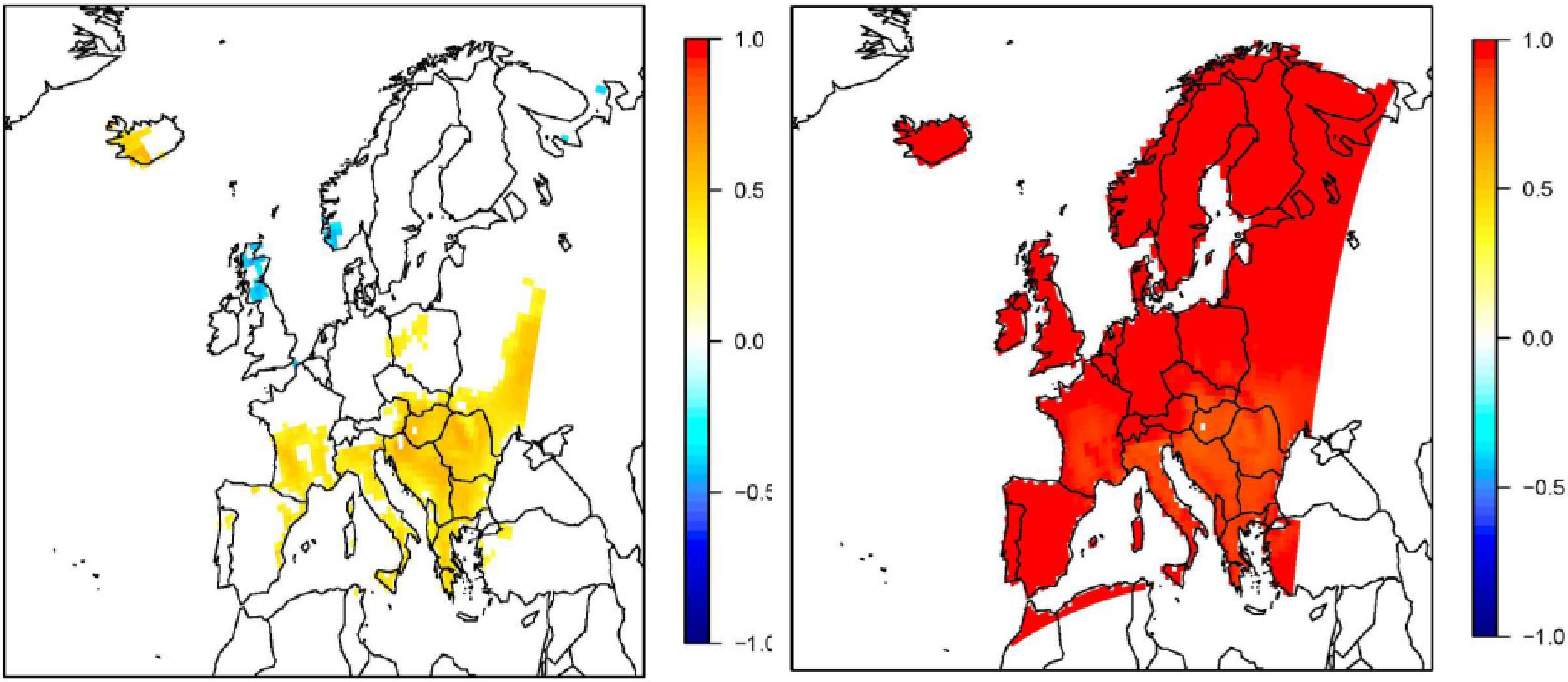
Example : ISM contribution of JA 2003



Opposite of ISM contribution

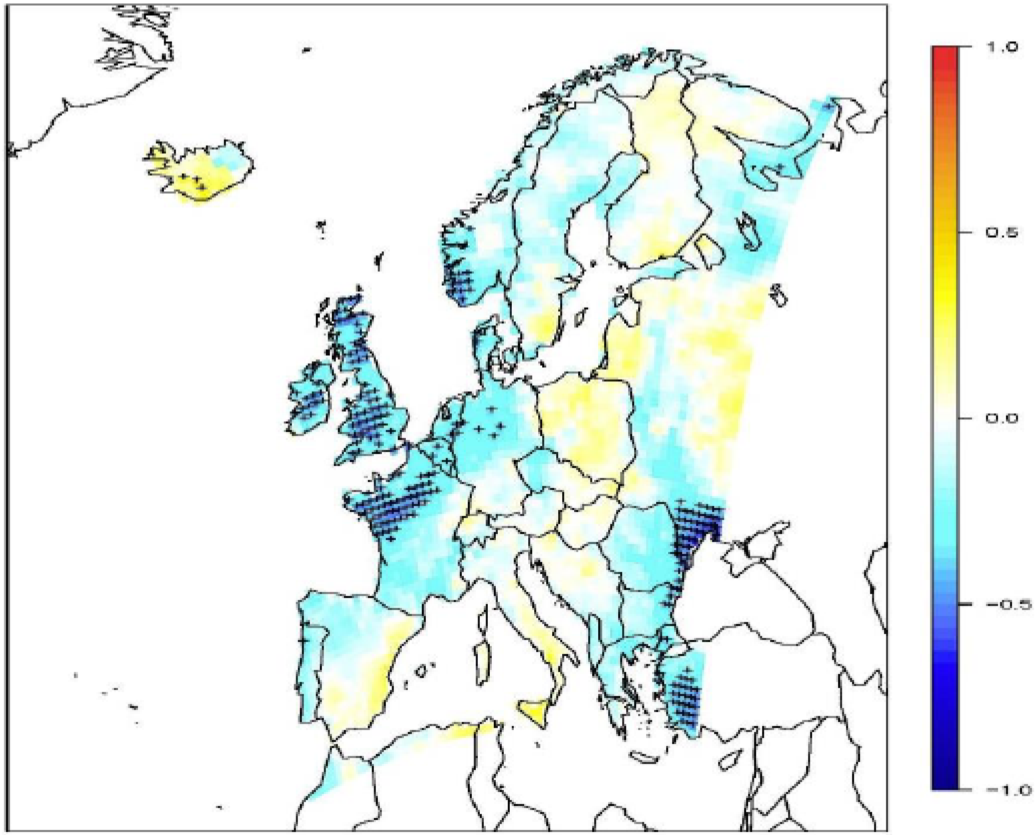


Correlations (*r*) between T anomay and each contribution



Initial (30 Jun) SM Contribution **Circulation (+oth) Contribution**

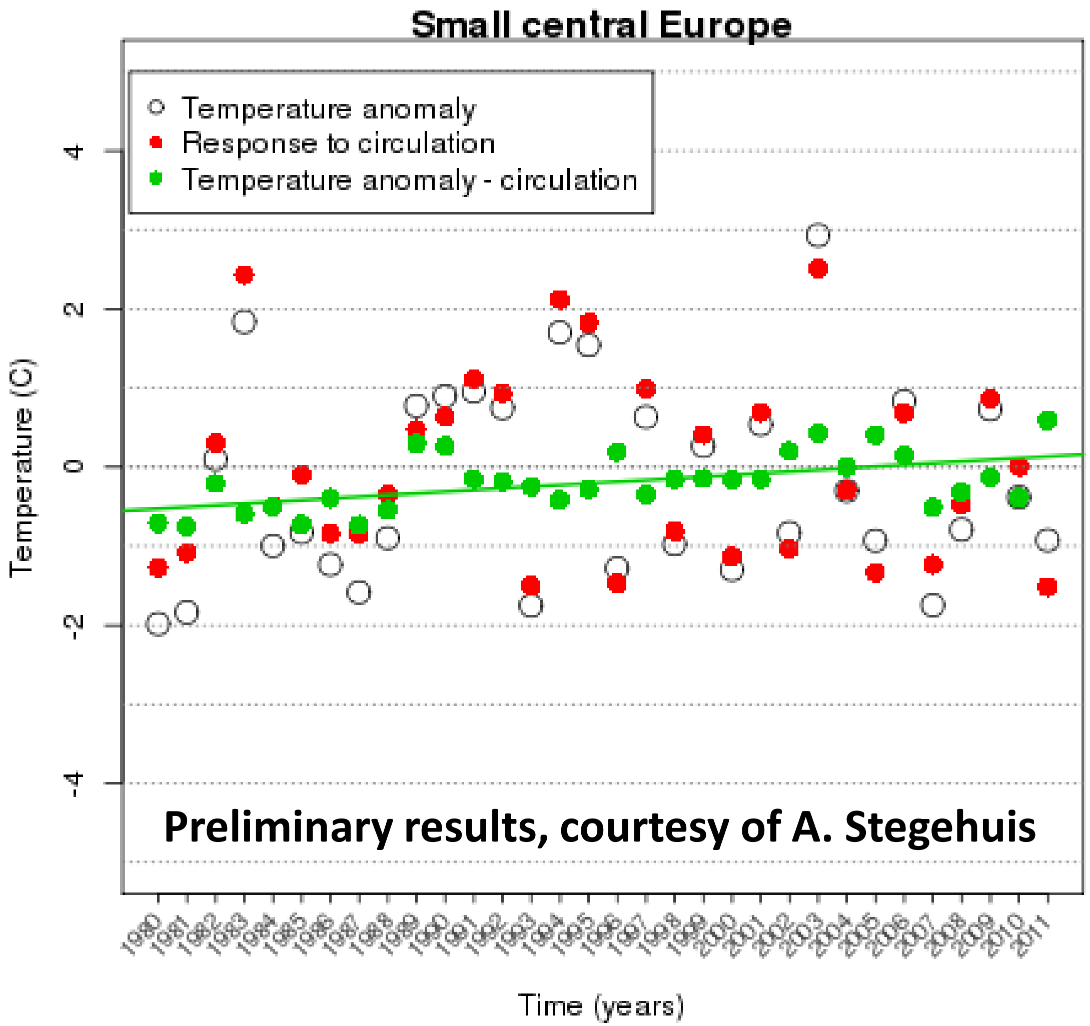
Feedback on circulation?



Correlation between the temperature anomaly and its difference with the sum of the two responses

Negative
→ the sum of responses overestimate the anomaly
→ Negative feedback

Increasing contribution of initial soil moisture?



Main conclusions (for Europe)

- Dynamical contribution of changes in T and Pr extremes exists and varies between 15% and 40% depending on season, higher in winter

- Inconsistent conclusions for summer HWs between studies and experiments regarding role of circulation and other drivers

- Dynamical contribution should become much less in the future as compared to thermodynamics; signal may be emerging in soil moisture contribution changes

Some remaining issues
Key challenges

- What are the flow patterns that change most in frequency and what are those that change extremes?

- Sort out heat waves & drought issues: better characterize land/sea-atmosphere exchanges, soil moisture, SST, snow, time and spatial scales of interaction, long-lived anticyclones

- Link between circulations and changes with most damaging extremes: heavy hourly precip, hail, lightnings etc

Cross-community opportunities

- ExtremeX: evaluate the contribution of various drivers of recent extremes; distinguish dynamics and physics using spectral nudging experiments

- Hourly precipitation extremes (leading to flash floods):
  - Share observations
  - Cloud resolving climate model experiments, CORDEX framework for coordinated experiments

Thanks for your attention!!