Analogues of atmospheric circulation to probe rare and extreme events

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Circulation Analogues (1)

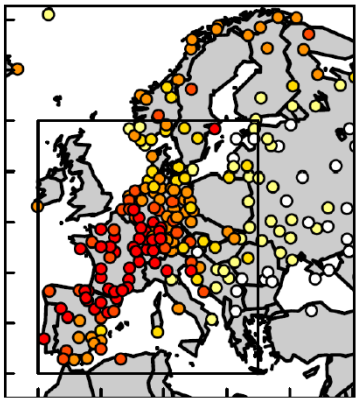
- Find recurring patterns in the atmosphere from:
  - SLP, Z500…
- Relate them with other fields:
  - T, Prec, wind speed
- Estimation of “most probable” climate variable given an atmospheric pattern

Circulation analogues (2)

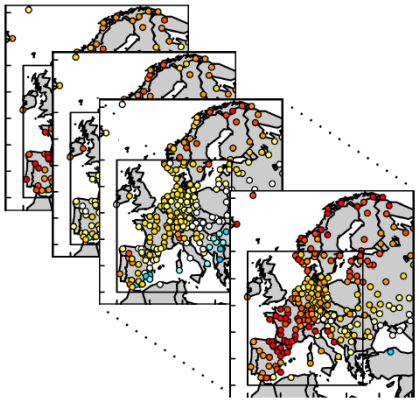
- Use of daily sea-level pressure (SLP) from NCEP reanalyses
- For all days between Jan. 1st 1948 and March 31st 2013, pick the 20 days within 30 calendar days but different year with the closest SLP:
  - Smallest Euclidean distance

Procedure

Temperature of day (d, y)

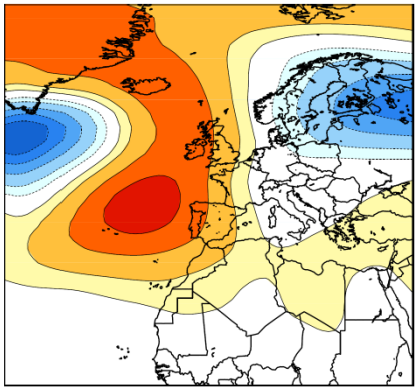


How does it compare?

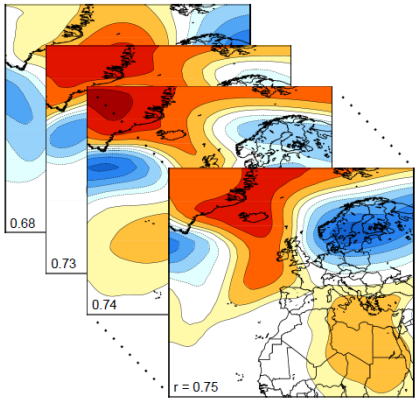


Range of analog temperatures

Circulation of day (d, y)



Measure of similarity



Analogues in $(d \pm 15, y' \neq y)$

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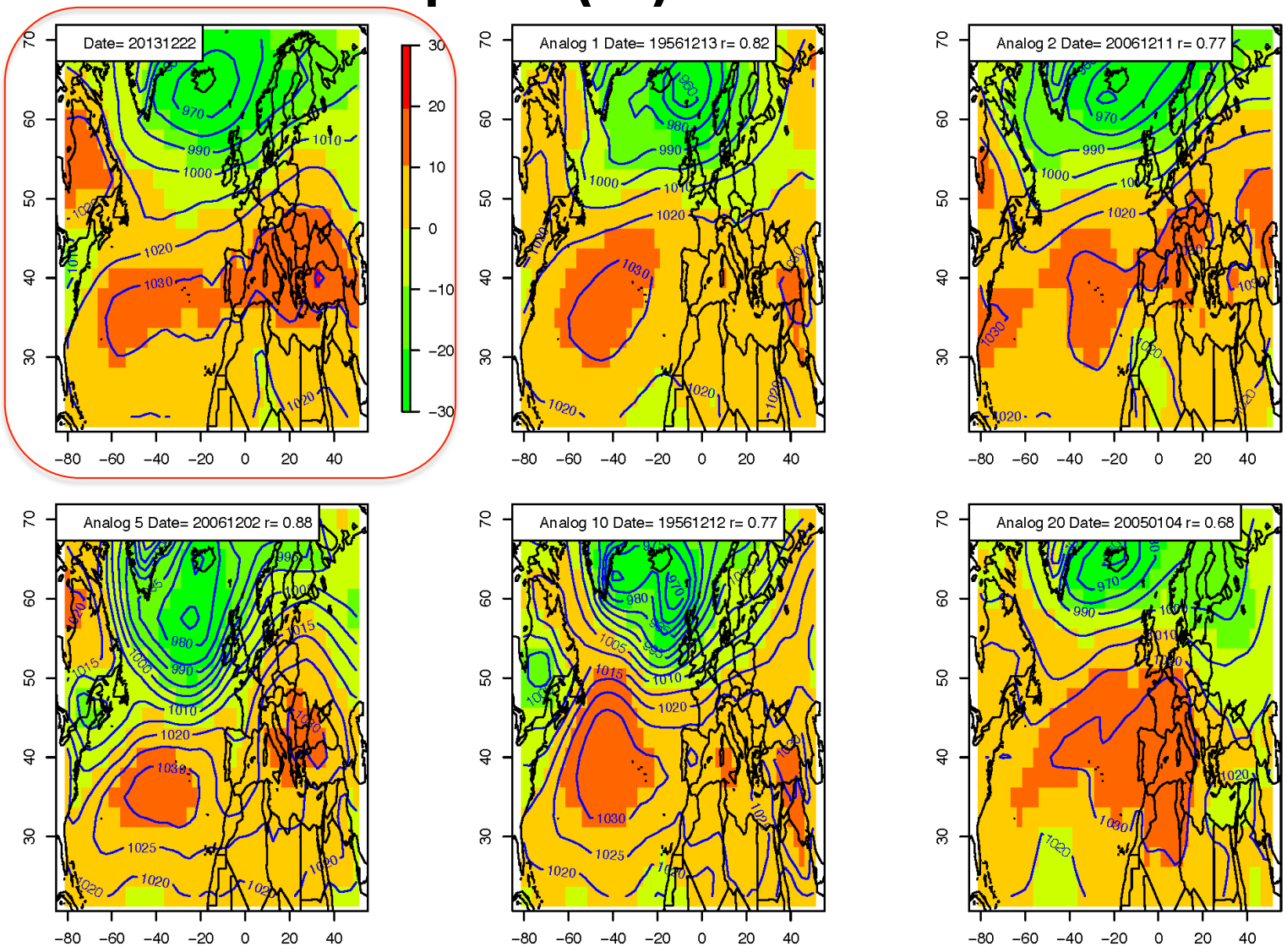
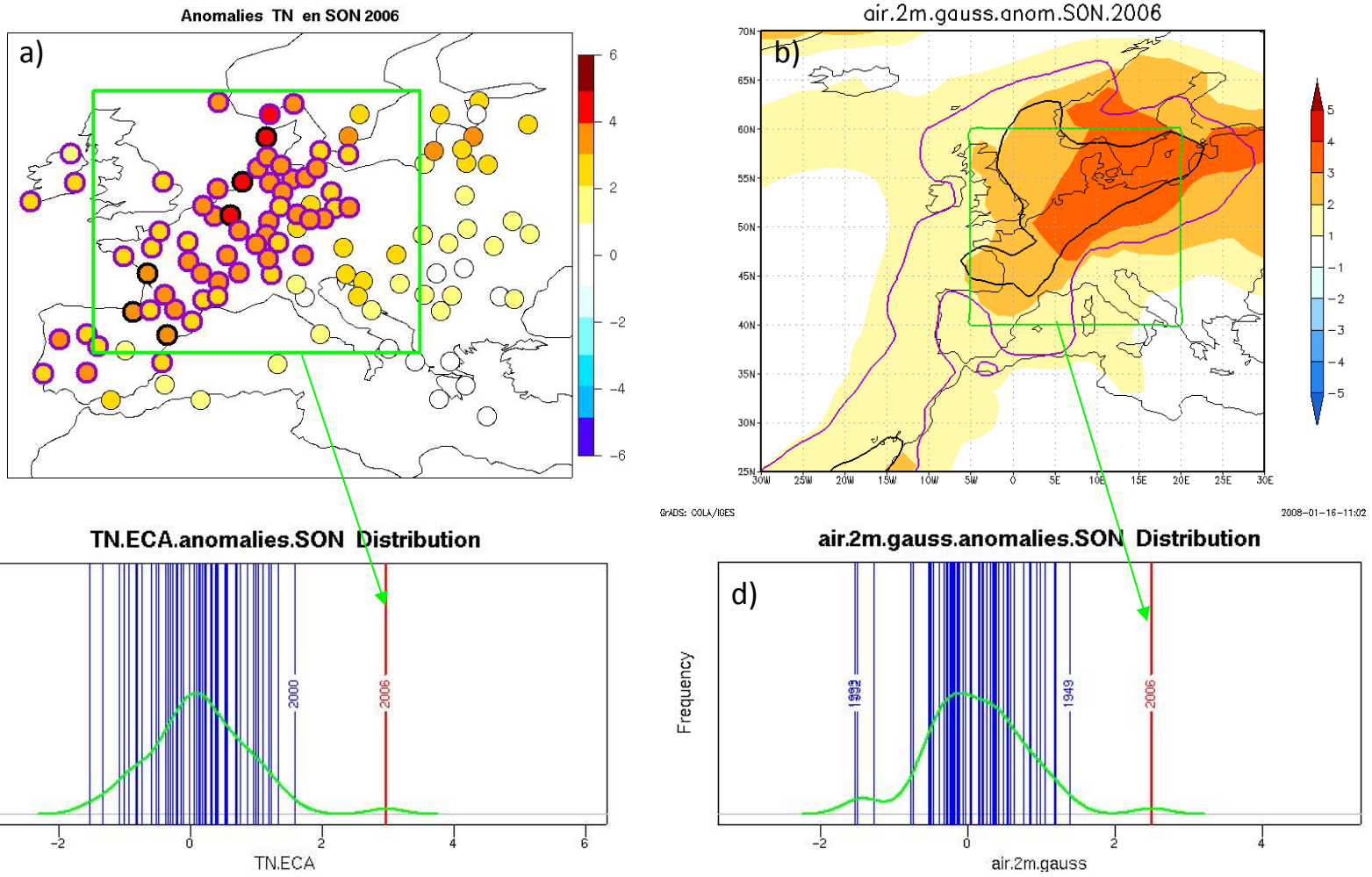
Example (1) Storm Dirk



Temperature analogues

- Average daily minimum temperature (TN) anomalies over Europe
  - ECA&D database (?), UKMO, Météo-France
- Compute the median temperature for 20 circulation analogue days
  - Analogue temperature & spread of analogues
- Same for precipitation (RR)

A European record in 2006



(courtesy of J. Cattiaux)

High temperatures (1)

- How *unusual* was the winter 2006/2007
- Odds that N days (out of S=90) are above all temperature analogues?

$$[T_1(t),...,T_N(t)]: \ N \text{ analogue "copies" of } T(t)$$

$$\Pr(T(t) \geq \max(T_k(t))) \rightarrow \text{Bernoulli}(p)$$

$$N(m) = \#\{T(t) \geq \max_{k=1..N}\left(T_k(t)\right), t \in m\} \rightarrow \text{Binomial}(p,S)$$

(m: month or season with S days)

High temperatures (2)

- Determine parameter p of the binomial distribution for factual and counterfactual "worlds"
- Compare

$$\Pr(N(m) = n)$$

for factual and counterfactual binomial distributions

Probability of high fall/winter high temperatures

Prototype of FAR

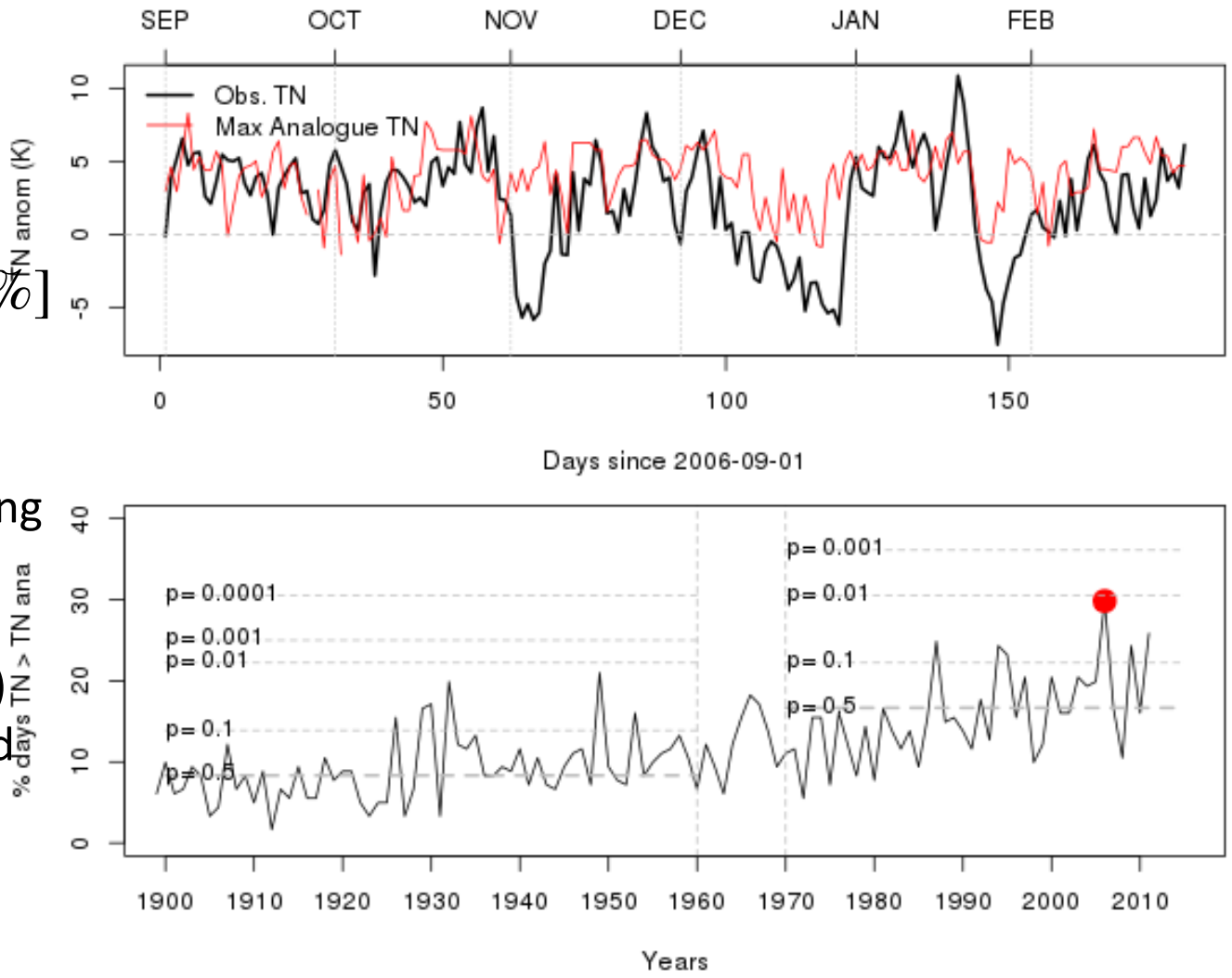
Estimate:

$$1 - \frac{p_0}{p_1} = 97\%[87;98\%]$$

p = probability that T_{obs} exceeds N $T_{analogues}$ during one season

p_1: factual world (NCEP)

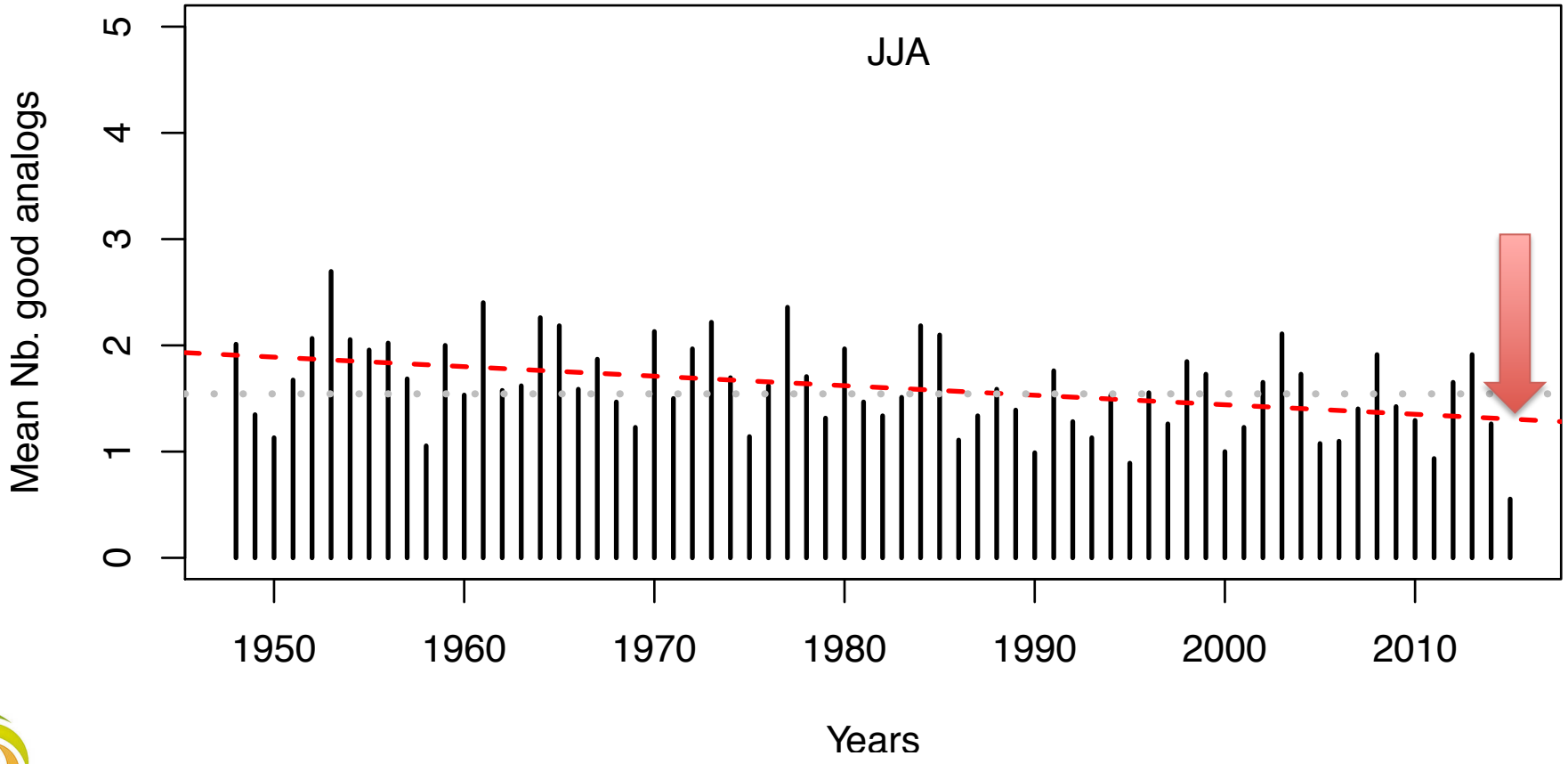
p_0: counterfactual world (20CR)



Probing rare events

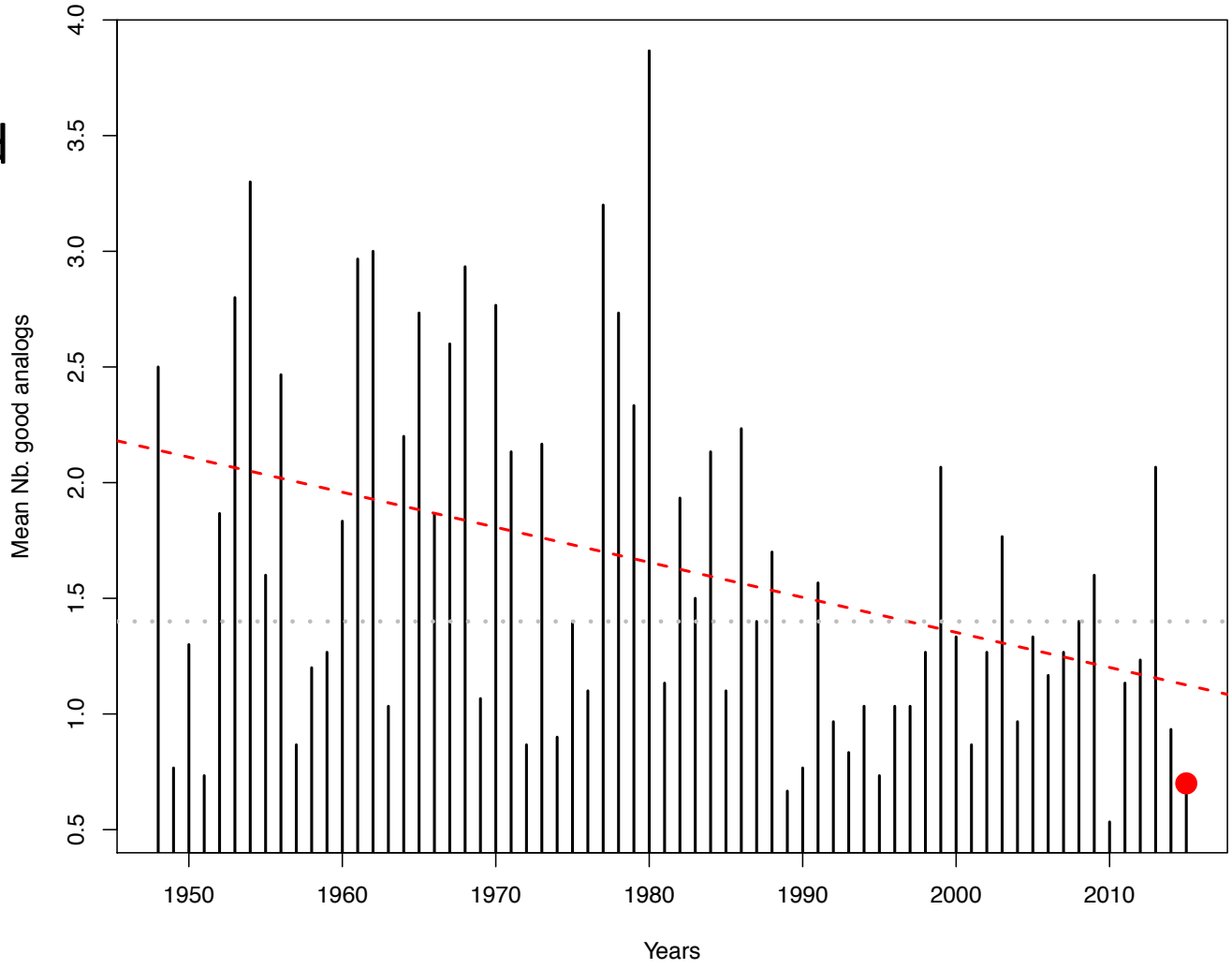
- Not necessarily extreme BUT *unusual* atmospheric circulation types
- Cases with NO or FEW good analogues
- Case of summer 2015
  - Count number of *good* analogues to determine rarity of patterns

JJA 2015


JJA
Mean Nb. good analogs
0
1
2
3
4
5
1950
1960
1970
1980
1990
2000
2010
Years

June2015 heatwave

Average Nb of good analogues in JUNE:
$d < d_0 (=q_{25})$ and
$C > C_0 (=q_{75})$



Conclusions

- Flexible approach to estimate p_0 and p_1 for well defined events (monthly time scales)
  - Conditional on a meteorological trajectory
- Dependence on domain being assessed (North Atlantic vs. European)
- Similar exercise with precipitation (see Robert Vautard's talk)
  - Winter 2013/2014

Thank you

Circulation analogues (1)

- *Reference* database **R**, containing consistent pressure (SLP and/or geopotential heights), temperature, precipitation etc. data during a reference period of observations
  - E.g. Reanalysis data for a fixed period, model control simulation
- *Target* dataset **T**, with only pressure data (SLP or geopotential height)
  - E.g. Observation during a period outside of the reference

Circulation analogues (2)

- We want to infer the value of climate variables (e.g. T, Prec., Wind speed) in the dataset **T**, from information in the database **R**.
- For each day in **T**, find best analogues of pressure in **R**.
  - Minimize distance (Euclidean, Mahalanobis…)