Contribution of atmospheric dynamics to changes in European temperatures

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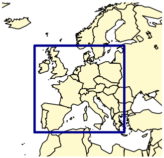
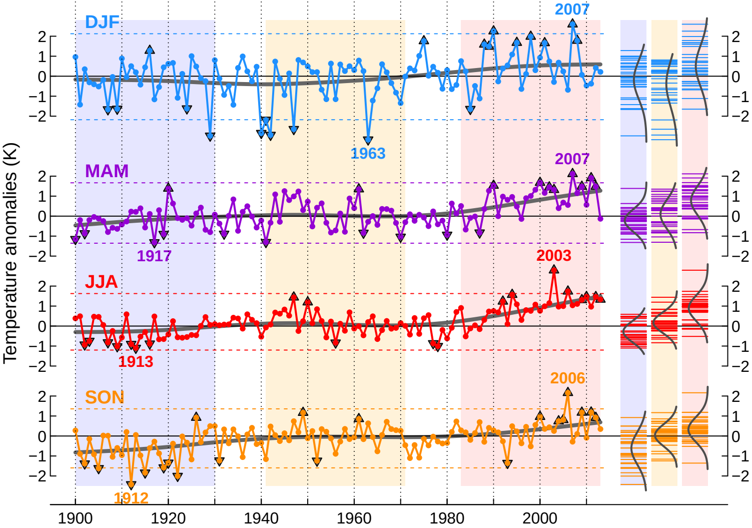
PEPER Workshop | Aussois, Dec 15-19, 2013

Changes in European temperatures 1/3

- Observations: all seasonal records broken in the last 10 years.



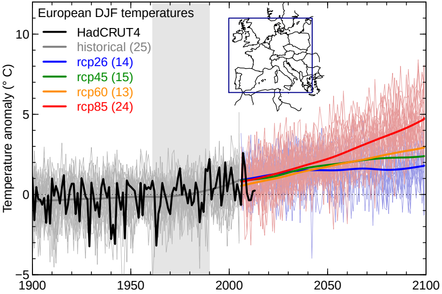


Updated from Cattiaux (2010), HadCRUT4 data.

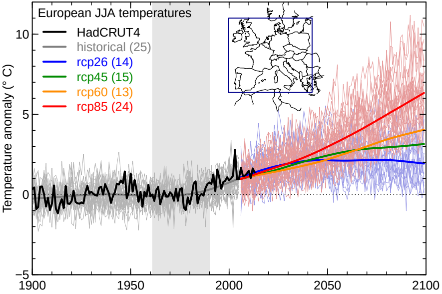
Changes in European temperatures 2/3

- Observations vs. present-day & future climate simulations (CMIP5 models).

Winter (DJF)



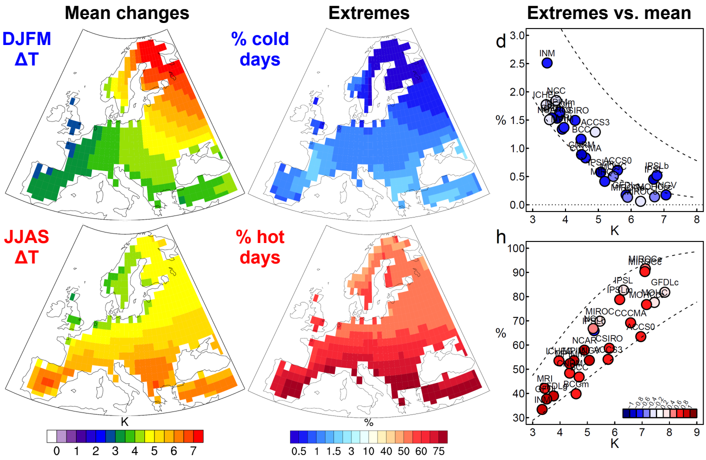
Summer (JJA)



Updated from Stott et al., 2004, *Nature*.

Changes in European temperatures 3/3

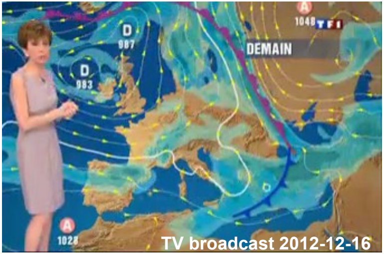
- Late-21C changes in cold/hot days (wrt. 10^{th}/90^{th} present-day percentiles).



2070–2099$_{R85}$ vs. 1979–2008 changes | Cattiaux et al., 2013a, *Climate Dynamics*.

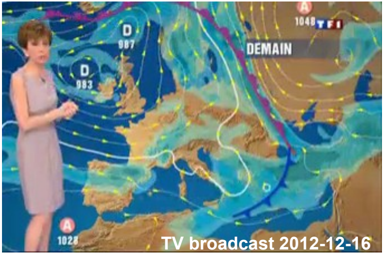
What does drive European temperatures?

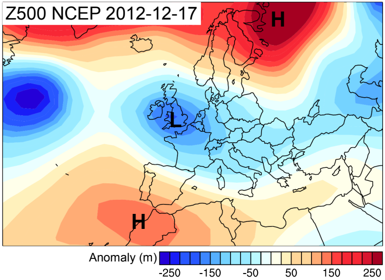
- Role of atmospheric dynamics (particularly for extremes).

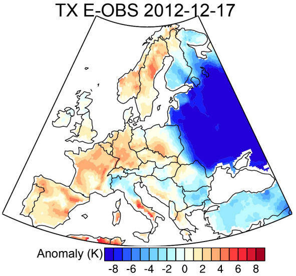


What does drive European temperatures?

- Role of atmospheric dynamics (particularly for extremes). Here: Z500.







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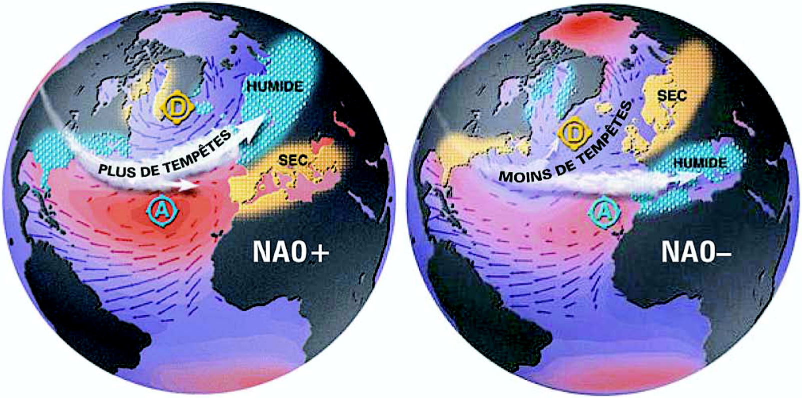
The North Atlantic Oscillation (NAO)

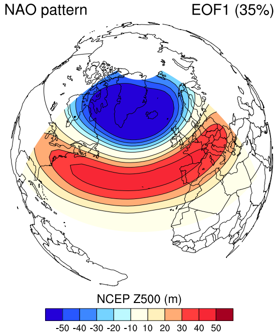
- First mode of variability, linked to fluctuations in the jet stream.

Van Loon & Rogers (1978), Jones et al. (1998), Hurrell (2003), Osborn (2005), among others.

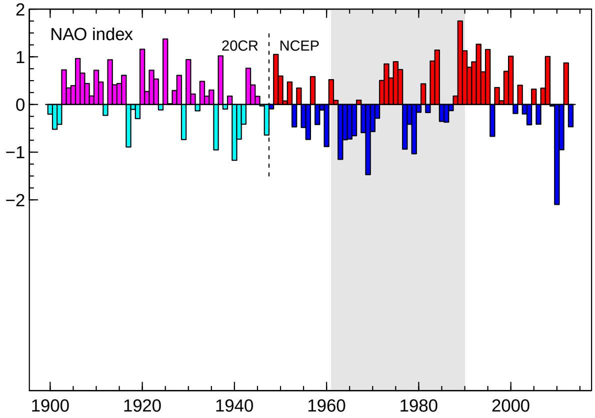


NAO indices and European temperatures

- Index derived from PCA of a circulation variable (here Z500).

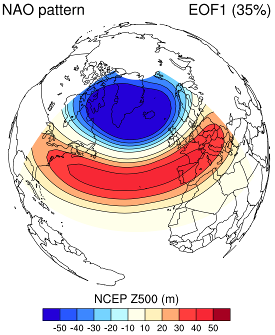


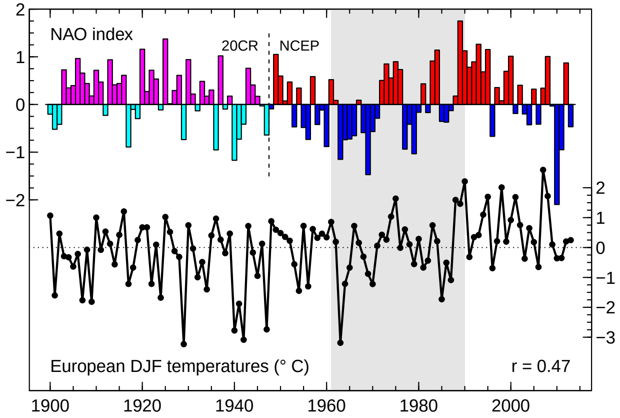
Z500 20CR & NCEP
(EOF 1979–2008)



NAO indices and European temperatures

- Index derived from PCA of a circulation variable (here Z500).
- Explains ∼25 % of variance of European DJF temperatures.



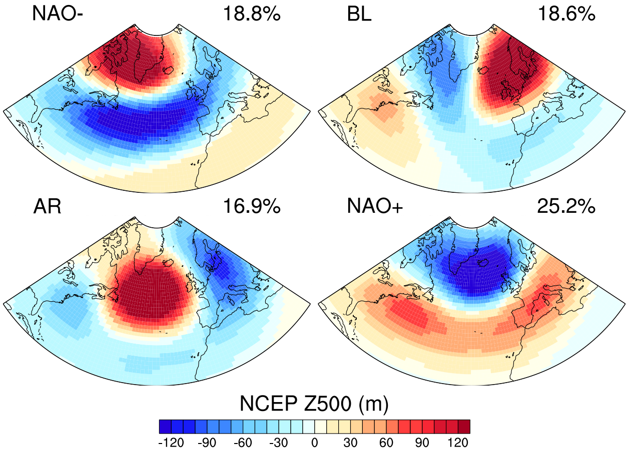


Z500 20CR & NCEP (EOF 1979–2008) + T HadCRUT4.

Beyond the NAO: the weather regimes

- Recurrent patterns derived from Z500 clustering (here *k-means*).

Legras & Ghil (1985), Vautard (1990), Michelangeli et al. (1995), Cassou (2008).



Z500 NCEP2 (DJFM 1979–2008) | Cattiaux et al., 2013a, *Climate Dynamics*.

WRs and European temperatures 1/3

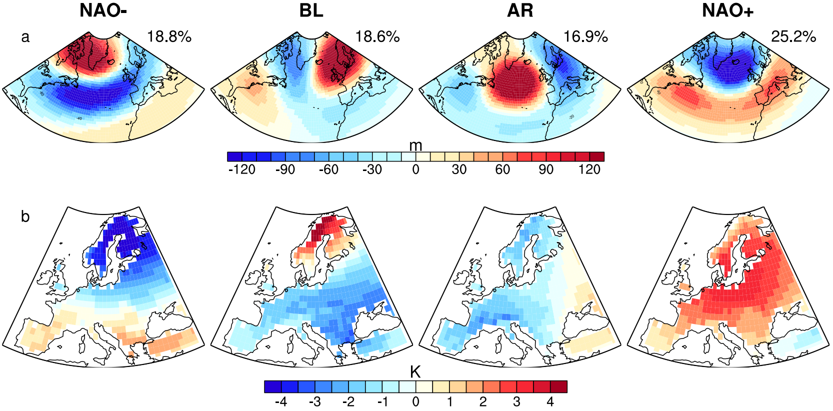
- Temperature composites: $\overline{T} = \sum_k f_k \cdot t_k = \sum_k f_k \cdot \Phi(z_k)$.

$f_k \rightarrow$

z_k

$\downarrow \Phi$

t_k



Z500 NCEP2 & T EOBS (DJFM 1979–2008) | Cattiaux et al., 2013a, *Climate Dynamics*.

WRs and European temperatures 2/3

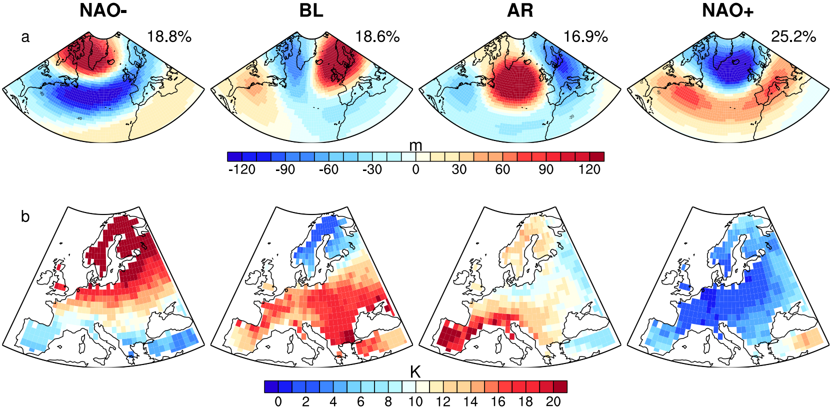
- Conditional prob. of q10 exceedance: $P^{10} = \sum_k f_k \cdot p_k^{10} = \sum_k f_k \cdot \Phi(z_k)$.

$f_k \rightarrow$

z_k

$\downarrow \Phi$

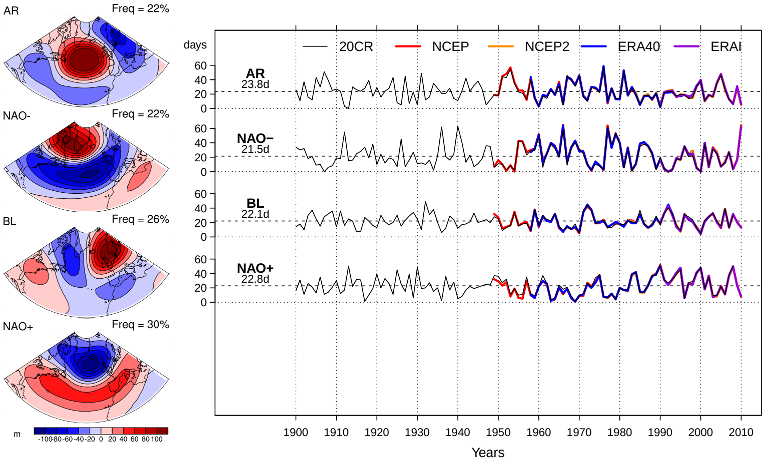
p_k^{10}



Z500 NCEP2 & T EOBS (DJFM 1979–2008) | Cattiaux et al., 2013b, *Climate Dynamics*.

WRs and European temperatures 3/3

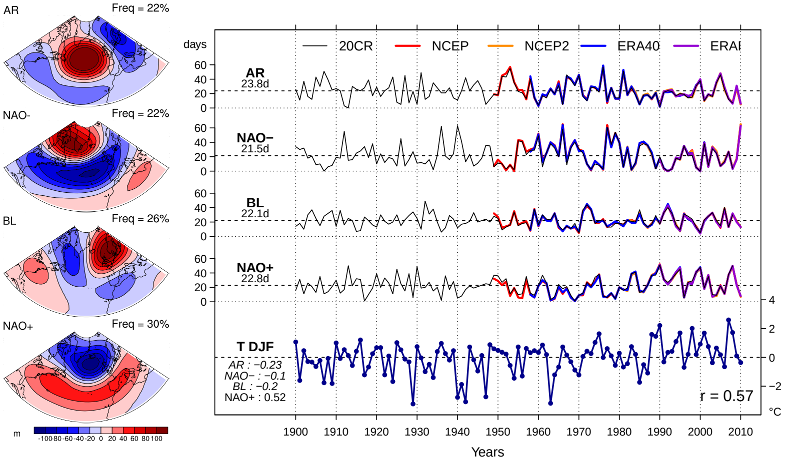
- Seasonal frequencies of occurrence of each regime.



Z500 (5 reanalyses) & T HadCRUT4 | Updated from Ouzeau et al., 2012, *Geophys. Res. Lett.*

WRs and European temperatures 3/3

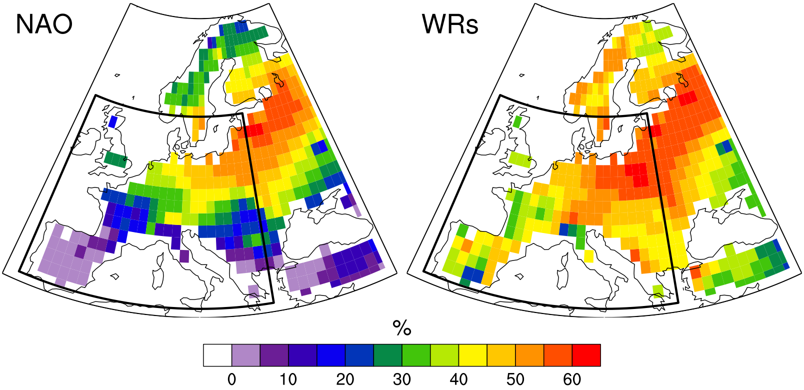
- Seasonal frequencies of occurrence of each regime.
- Explain ~35 % of variance of European DJF temperatures.



Z500 (5 reanalyses) & T HadCRUT4 | Updated from Ouzeau et al., 2012, *Geophys. Res. Lett.*

WRs vs. NAO for European temperatures

- Higher fraction of explained variance of winter temperatures.



Z500 NCEP & T EOBS – Estimated over DJFM 1979–2008.

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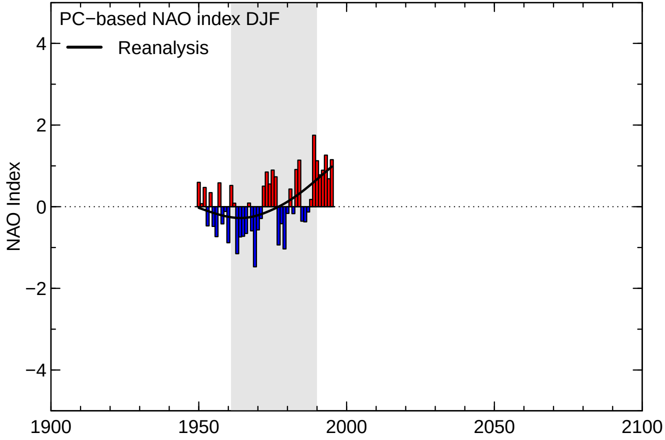
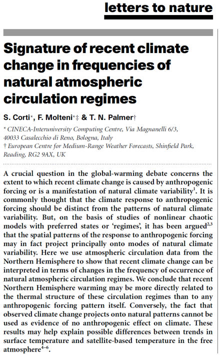
Trends in the NAO

- 1950–1995: NAO+ signal





letters to nature

Signature of recent climate change in frequencies of natural atmospheric circulation regimes

S. Corti*, F. Molteni*‡ & T. N. Palmer†

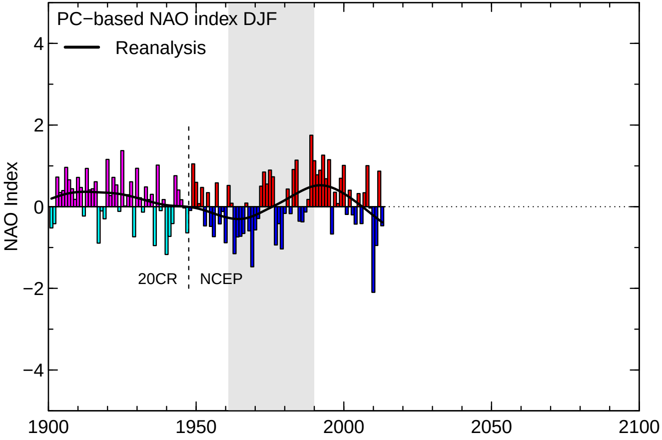
* CINECA-Interuniversity Computing Centre, Via Magnanelli 6/3, 40033 Casalecchio di Reno, Bologna, Italy
† European Centre for Medium-Range Weather Forecasts, Shinfield Park, Reading, RG2 9AX, UK

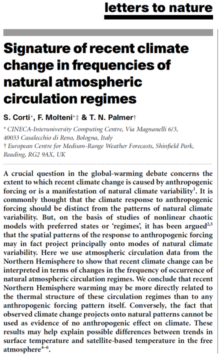
A crucial question in the global-warming debate concerns the extent to which recent climate change is caused by anthropogenic forcing or is a manifestation of natural climate variability[1]. It is commonly thought that the climate response to anthropogenic forcing should be distinct from the patterns of natural climate variability. But, on the basis of studies of nonlinear chaotic models with preferred states or 'regimes', it has been argued[2,3] that the spatial patterns of the response to anthropogenic forcing may in fact project principally onto modes of natural climate 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 observed climate change projects onto natural patterns cannot be used as evidence of no anthropogenic effect on climate. These results may help explain possible differences between trends in surface temperature and satellite-based temperature in the free atmosphere[4–6].

Corti et al., 1999, Nature.

Trends in the NAO

- 1950–1995: NAO+ signal | 1900–2013: no clear signal

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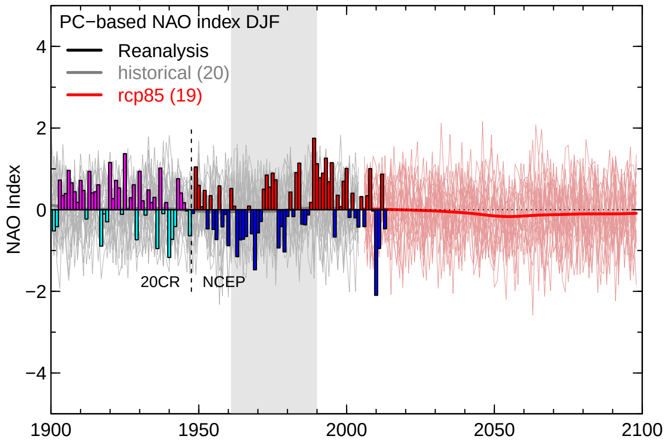
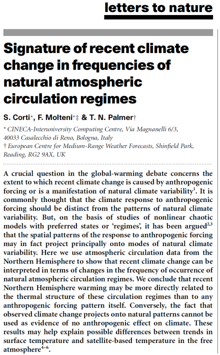
Trends in the NAO

- 1950–1995: NAO+ signal | 1900–2013: no clear signal | 21C: ??



Z500 NCEP + 20CR + CMIP5 models.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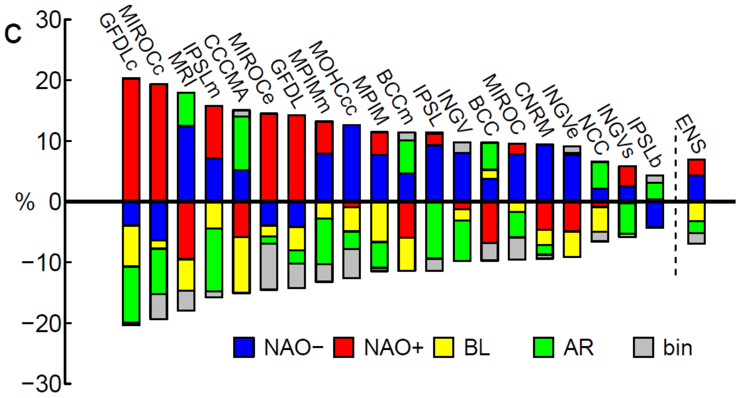
Corti et al., 1999, Nature.

Late-21C changes in WRs frequencies (f_k)

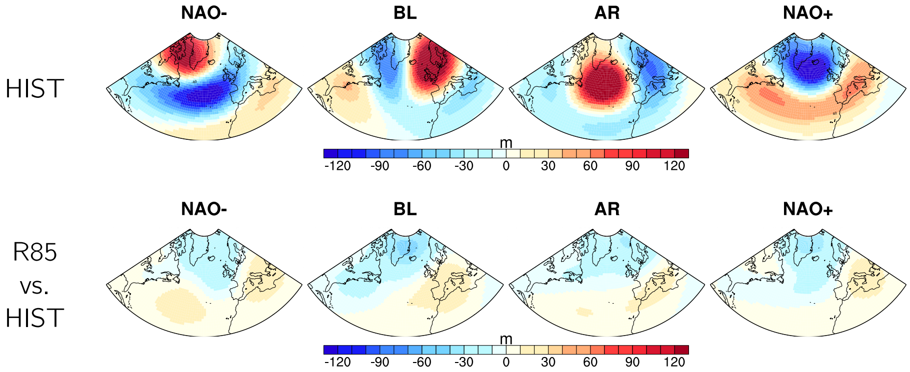
- Model-dependent changes. General increase in NAO− and decrease in BL.



Z500 DJFM 2070–2099$_{R85}$ vs. 1979–2008 | Cattiaux et al., 2013a, *Climate Dynamics*.

Late-21C changes in WRs structures (z_k)

- 2070–2099$_{R85}$ vs. 1979–2008: within-class changes project onto NAO+.



Z500 DJFM 2070–2099$_{R85}$ vs. 1979–2008 | Cattiaux et al., 2013a, *Climate Dynamics*.

Contents

Linking WRs to temperatures: some maths

Recall $\overline{T} = \sum_k f_k \cdot \Phi(z_k)$,

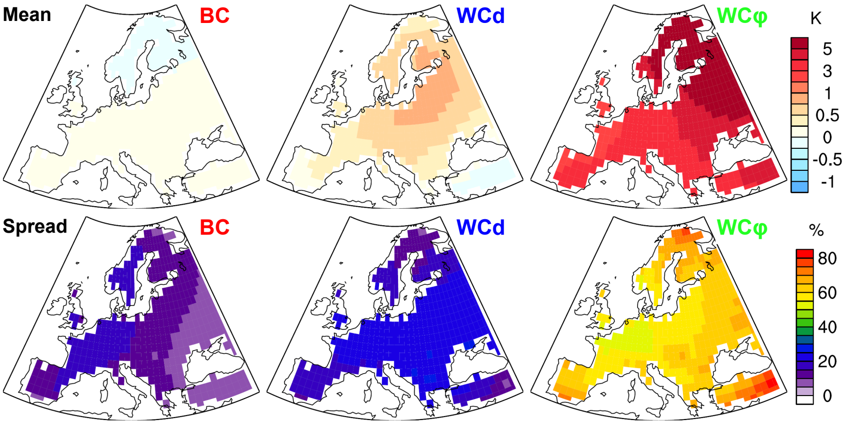
$$\Rightarrow \Delta^{R85-HIST}\ \overline{T} = \sum_k \Delta f_k \cdot \Phi(z_k) + \sum_k f_k \cdot \Phi(\Delta z_k) + \sum_k f_k \cdot \Delta\Phi(z_k) + \varepsilon$$

- Δf_k Contribution of changes in regimes' frequencies (BC).
- Δz_k Contribution of changes in regimes' structures (WCd).
- $\Delta\Phi$ Contribution of non-dynamical processes (WCΦ).
- ε Residual (second-order terms).

Cattiaux et al., 2013b, *Climate Dynamics*.

Linking WRs to temperatures: some maps

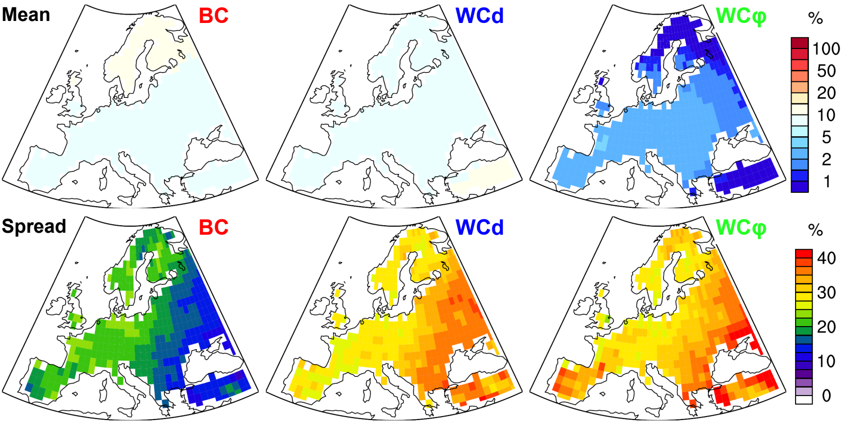
- WRs contribution: minor on mean warming, substantial on uncertainties.



Cattiaux et al., 2013a, *Climate Dynamics*.

Linking WRs to temperatures: some maps (extremes)

- WRs contribution: minor on P^{10} changes, substantial on uncertainties.



Updated from Cattiaux et al., 2013a, *Climate Dynamics*.

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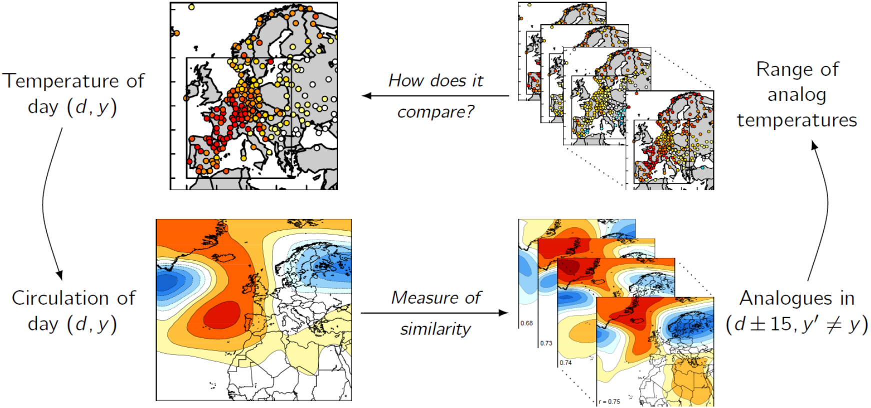
Flow-analogues and temperatures: methodology

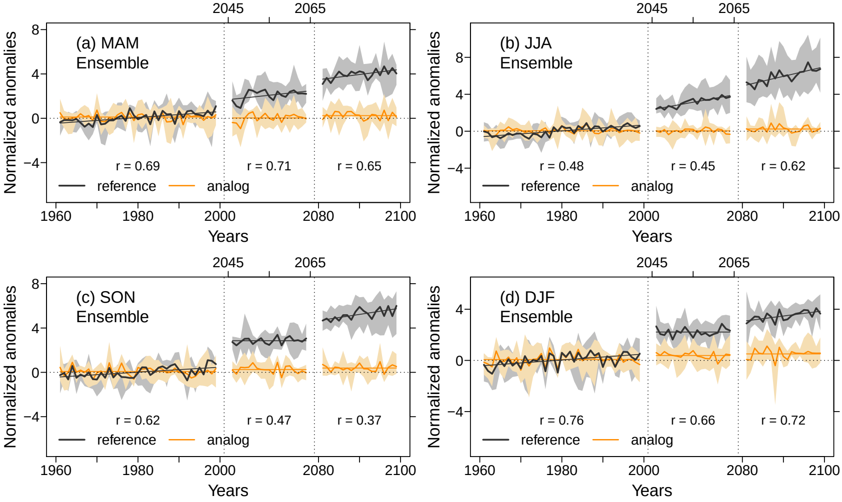
- Searching for analog synoptic situations in the past.



Method from Lorenz, 1969, *J. Atm. Sci.*

Flow-analogues for 21C temperatures

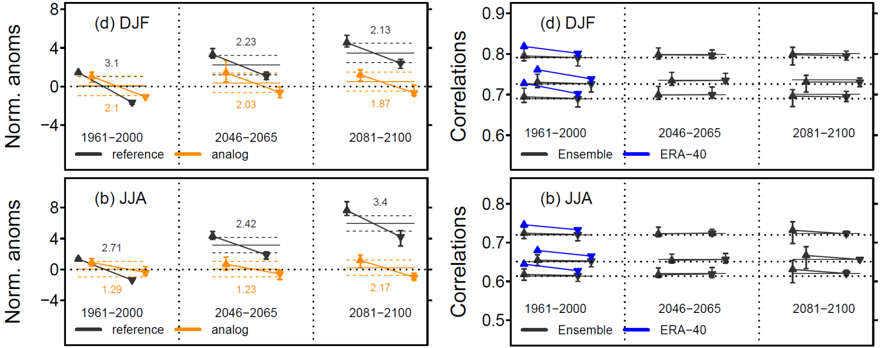
- Analogues remain correlated, but miss the long-term warming.



T CMIP3 (SRES A2) | Cattiaux et al., 2011, *Climate Dynamics*.

Flow-analogues for 21C temperatures (extremes)

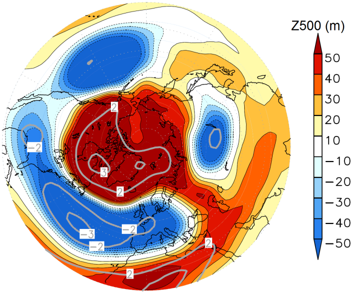
- Circulations of future extremes ∼ circulations of present extremes.

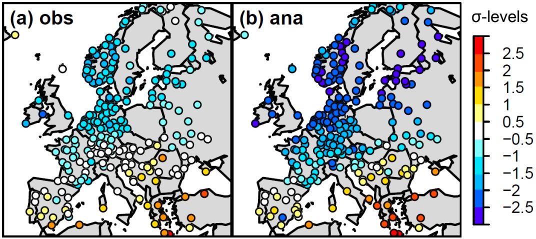


T CMIP3 (SRES A2) | Cattiaux et al., 2011, *Climate Dynamics*.

Already warmer for analog synoptic patterns 1/2

- Example of winter 2010, comparable to glacial winters 1940 & 1963.

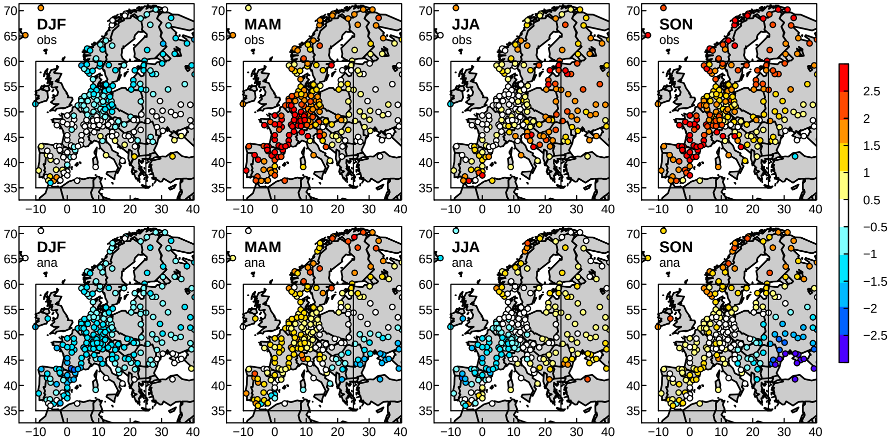




Z500 NCEP & T ECA (stations) | Cattiaux et al, 2010, *Geophys. Res. Lett.*

Already warmer for analog synoptic patterns 2/2

- Example of year 2011, warmest year on record but 10th in analogues.



T ECA (stations) | Cattiaux and Yiou, 2012, *Bulletin Amer. Meteorol. Soc.*

Concluding remarks

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Summary

- Atmospheric dynamics: main driver of European temperatures variability.

$\longrightarrow$ *Can be described through PCA & clustering.*

- Minor contribution to recent & projected European warming.

$\longrightarrow$ *But substantial contribution to uncertainties (model + internal var.).*

Concluding remarks

Summary

- Atmospheric dynamics: main driver of European temperatures variability.

⟶ *Can be described through PCA & clustering.*

- Minor contribution to recent & projected European warming.

⟶ *But substantial contribution to uncertainties (model + internal var.).*

In progress / prospects

- Baroclinicity in the response of atmospheric dynamics to climate change.

⟶ *Role of Arctic amplification (sea ice decline). 3D-analogues? 3D-regimes?*
Cattiaux & Cassou, 2013, *Geophys. Res. Lett.*

- Methods to be applied to other regions and/or other variables.

⟶ *E.g. analogues & weather regimes for U.S. temperatures.*
Cattiaux & Yiou, 2013, *B.A.M.S.*; Lucas-Picher & Cattiaux, in prep.