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Contribution of circulation changes to recent and future temperature extremes in Europe

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Introduction

European temperatures have increased in recent years. In particular all seasonal temperature records have been broken since 2000. According to climate projections, this warming is expected to continue in future years.
The North-Atlantic dynamics is the main driver of temperature variability in Europe. Here we investigate how large-scale circulation contribute to both recent and projected extremes.

Recent warming and extremes in Europe

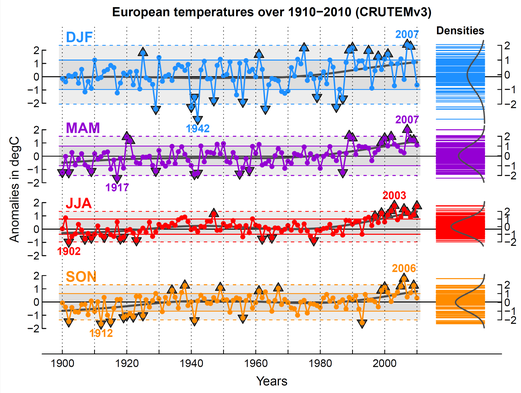


Figure 1. Seasonal T2m from CRUTEMv3 anomalies. Gray shadings indicate σ-levels. Long-term trends are obtained by splines with 5 df.

Strong warming in Europe over recent decades (Fig 1), max. for JJA, min. for SON.

All seasonal warm records have been broken in the 2000s.

- JJA 2003: « well-known » dramatic heat-wave.

- SON 2006: exceptionally mild autumn, comparable in amplitude to JJA 2003.

- DJF 2009/10: one of the coldest winter of the last two decades.

The exceptionally mild autumn 2006

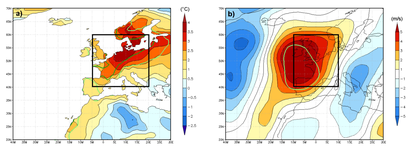


Figure 2. T2m (left) and V500 (right) anomalies of SON 2006, from NCEP re-analyses.

T2m anomaly: on average 2.5K (3.2 σ), and exceeding 5K over North-Western Europe (Fig 2).

Associated with a record-persistence of southly flow: record of V-wind at 500mb (V500, Fig 2).

Daily V500/T2m relationship shifted upward during SON 2006 (Fig 3).

The atmospheric circulation explains about 50% of the SON 2006 T2m anomaly.

Seasonal V500/T2m relationship (r = 0.7) misses the recent warming (Fig 4).

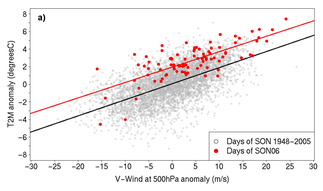


Figure 3. Scatterplot of daily anomalies of T2m vs. daily anomalies of V500, for all SON days (gray) and SON 2006 (red). Linear regressions are significant.

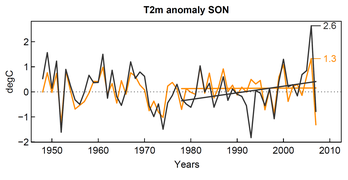


Figure 4. T2m anomalies (black) and linear regression from V500 anomalies (orange) for SON 1948-2007.

From Cattiaux et al. 2009 (GRL).

Winter 2009/10: A cold extreme in a warming climate

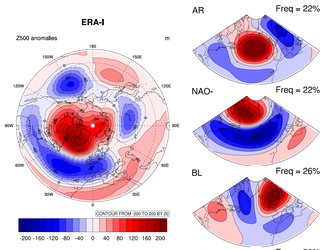


Figure 5. Z500 anomaly of DJF 2009/10, from ERA-Interim reanalyses.

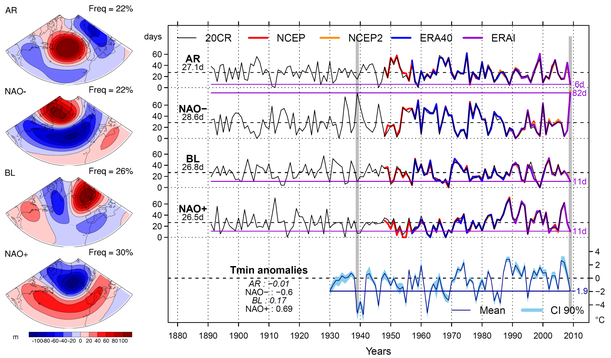


Figure 6. Seasonal (DJFM) mean frequencies of weather regimes occurrences computed from different reanalysis. Weather regimes are plotted on the left. DJFM Tmin anomalies from ECA&D in-situ observations are added, and respective correlations with regimes occurrences indicated.

Extremely persistent (record) negative phase of the AO (whole hemisphere) and/or the NAO (North-Atlantic, Fig 5).

Weather regimes: 85% of days in NAO- regime. Closest winter: 1939/40 (Fig 6).

Tmin anomaly above 50°N: -1.9K (-1σ), not exceptional relative to 20th century. For comparison, winter 1939/40: -5.3K (Fig 6).

Flow-analogues: similar large-scale circulations were associated with colder temperatures in the past 60 years. (Fig 7a-c).

Winter 2009/10 could have been a cold extreme without global warming.

The discrepancy between observed and analog temperatures is consistent with the recent long-term warming (Fig 7d).

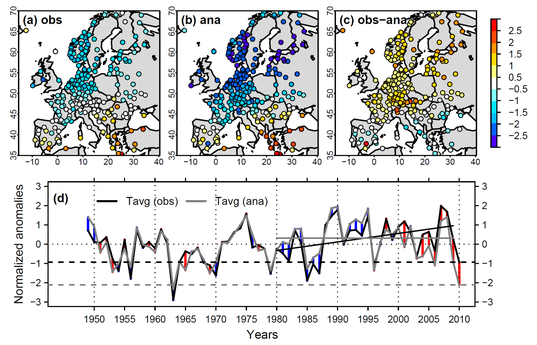


Figure 7. Tmean anomalies of DJF 2009/10 from (a) ECA&D observations and (b) estimates from flow-analogues, represented in σ-levels .
(c) Difference between (a) and (b).
(d) Spatial averages of observed (black) and analog (gray) Tmean over DJF 1948-2010, with linear trends over 1980-2010 added.

From Cattiaux et al. 2010 (GRL) and Ouzeau et al. 2011 (GRL).

Future extremes in CMIP3 projections

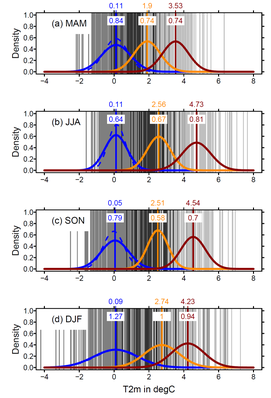


Figure 8. Seasonal changes in European T2m distributions between 1961-2000 (blue), 2046-2065 (orange) and 2081-2100 (red), as simulated by CMIP3 models*. ERA-40 in dashed.

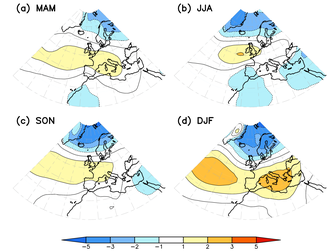


Figure 9. Seasonal changes in mean SLP between 2081-2100 and 1960-2000, as simulated by CMIP3 models.

In addition to the mean T2m increase, changes in variability: increase (decrease) in summer (winter, Fig 8).

Large-scale circulation: tendency towards NAO+ conditions, especially in winter (Fig 9).

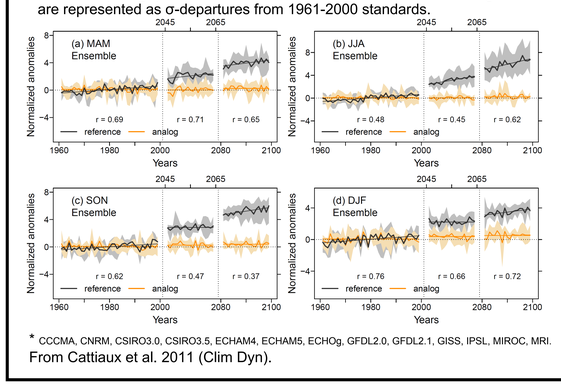
The mean European warming is not explained by dynamical changes.

Circulations associated with warm/cold extremes remain unchanged in future projections.

Flow-analogues applied to CMIP3: mean T2m increases are disconnected from circulation changes. Only a minor contribution of the NAO+ increase in winter (Fig 10).

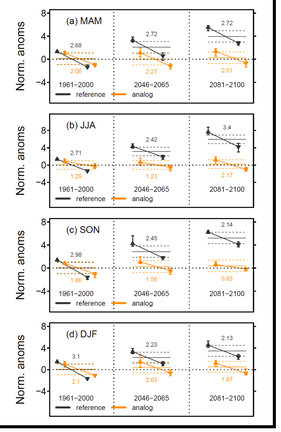
Future extremes remain associated with same circulations as present-day extremes. A part of the variance increase (decrease) in summer (winter) could be explained by the dynamics (Fig 11).

Figure 10. Seasonal T2m from CMIP3 projections (black) and flow-analogue estimates (orange) for the 3 time slices. Shadings indicate model range. T2m are represented as σ-departures from 1961-2000 standards.



* CCCMA, CNRM, CSIRO3.0, CSIRO3.5, ECHAM4, ECHAM5, ECHOg, GFDL2.0, GFDL2.1, GISS, IPSL, MIROC, MRI.
From Cattiaux et al. 2011 (Clim Dyn).

Figure 11. Averages over extremely warm (triangle) and cold (inverted triangle) seasons, for both projected (black) and analog (orange) T2m, and for each season and each time period. Horizontal lines indicate means +/-1σ of Fig. 10. Values are differences between warm and cold seasons in σ-levels.



References

This poster has been made from results of the following articles:

- Cattiaux, J., R. Vautard, P. Yiou (2009), Origins of the extremely warm European fall of 2006, *Geophys. Res. Lett.*, 36, L06713.

- Cattiaux, J., R. Vautard, C. Cassou, P. Yiou, V. Masson-Delmotte, F. Codron (2010), Winter 2010 in Europe: A cold extreme in a warming climate, *Geophys. Res. Lett.*, 37, L20704.

- Ouzeau, G., J. Cattiaux, H. Douville, A. Ribes, D. Saint-Martin (2011). European cold winter of 2009/10: How unusual in the instrumental record and how reproducible in the arpege-climat model?, *Geophys. Res. Lett.*, 38, L11706.

- Cattiaux, J., P. Yiou, R. Vautard (2011). Dynamics of future seasonal temperature trends and extremes in Europe: A multi-model analysis from CMIP3, *Clim. Dyn.*, published online.

Conclusions

Recent temperature extremes in Europe are associated with exceptional conditions of large-scale circulation. However, temperatures have been regularly warmer than expected from the sole atmospheric dynamics, especially during autumn 2006 and winter 2009/10.

According to climate projections, this inconsistency amplifies in future years, so that the European warming can not be explained by changes in circulations occurrences. The atmospheric dynamics nevertheless remains the main driver of the temperature variability, and could in particular contribute to projected changes in seasonal extreme events.