Disruption of the European climate seasonal clock in a warming world

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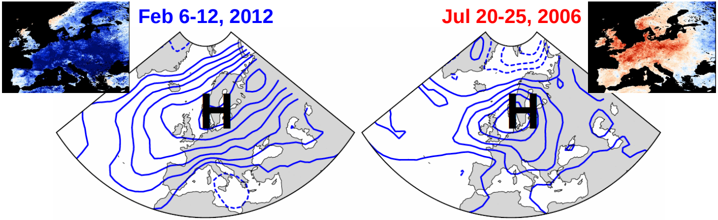
AGU Fall Meeting
San Francisco, Dec 15, 2015

Introduction

- W-European T extremes are associated with persistent H systems (*blockings*).
  Cassou et al. (2005); Schneidereit et al. (2012); Sillmann et al. (2012)...

SLP anomaly – cold spell Feb 2012 vs heat wave July 2006



More on this Friday at session on atmospheric patterns and climate extremes!

Introduction

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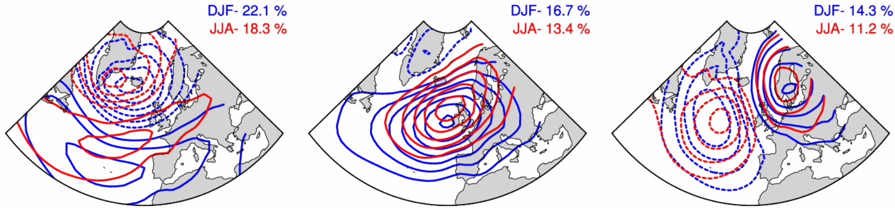
  Cassou et al. (2005); Schneidereit et al. (2012); Sillmann et al. (2012)...
- The Scandinavian blocking is a recurrent pattern throughout the year (EOF 3).
  Barnston & Livezey (1987); Wettstein & Wallace (2010)...

First 3 leading modes of SLP variability for winter and summer



EOF 1, 2 & 3 of daily SLP anomalies | NCEP-NCAR reanalysis 1950–2012

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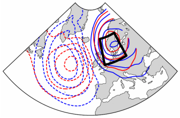
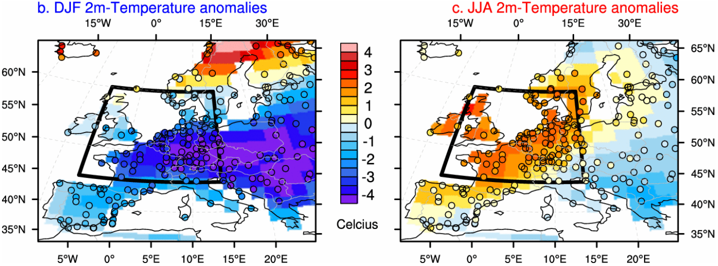
  Rex (1950); Slonosky et al. (2001)...

Winter and summer T anomalies associated with blocking days





Composites of daily T anomalies over days with SLP index $> 1\sigma$
| NCEP-NCAR reanalysis + ECA&D stations 1950–2012

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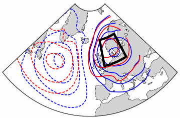
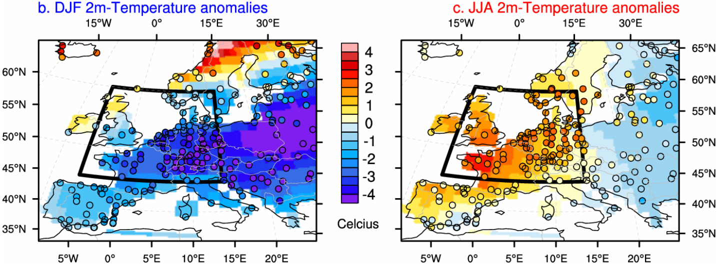
- It blocks the westerlies and induces cold episodes in winter / warm in summer.
  Rex (1950); Slonosky et al. (2001)...
- This season-dependent SLP-T relationship is well captured by climate models.
  Example of CNRM-CM5: Voldoire et al. (2013)

Winter and summer T anomalies associated with blocking days





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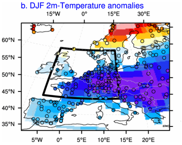
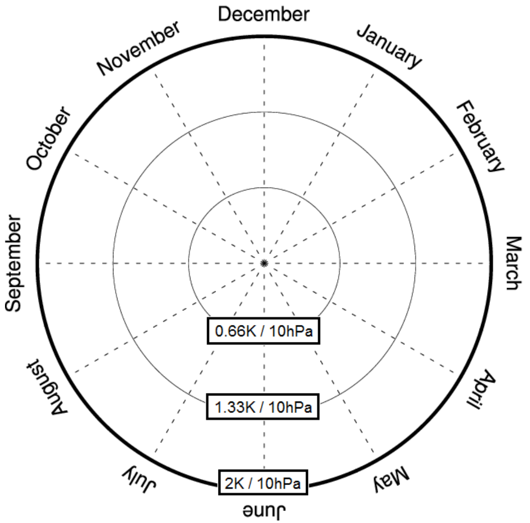
The European *climate seasonal clock*



January
SLP-T regression:
-1.4K/10hPa



July
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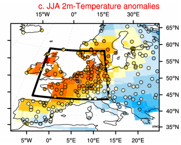
2.0K/10hPa



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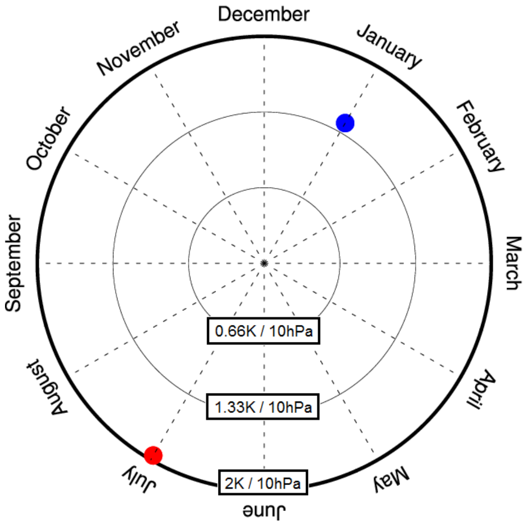

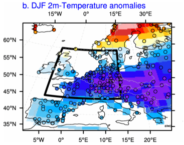

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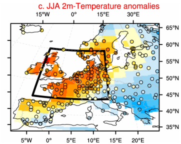

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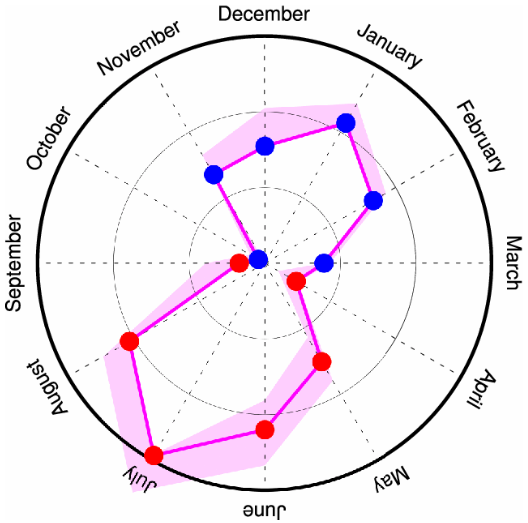

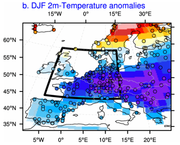

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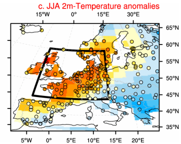

Obs. estimates (20CR/NCEP/ECA&D | 1950–2010)

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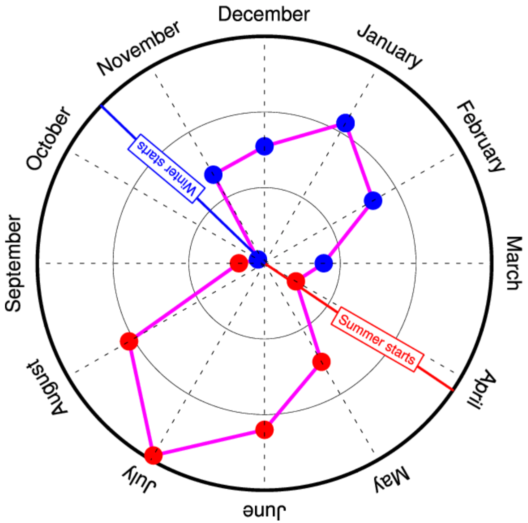

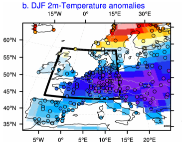

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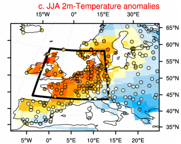

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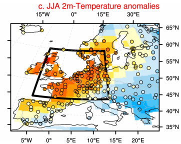

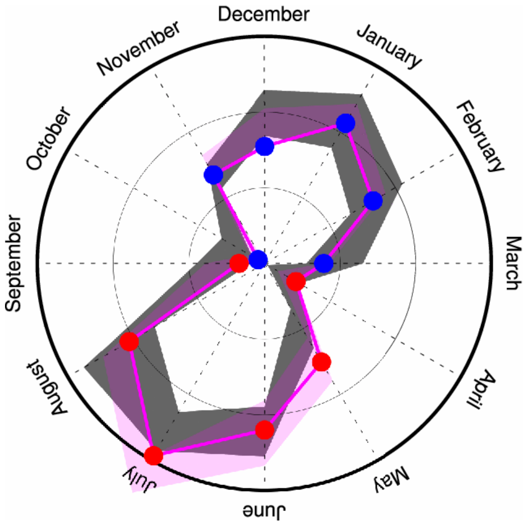

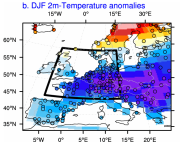

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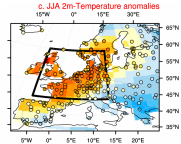
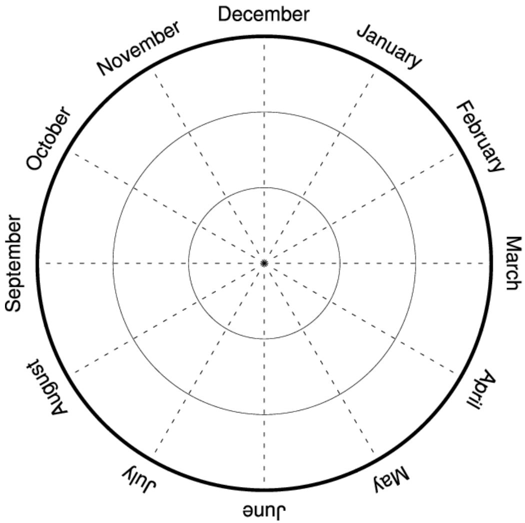
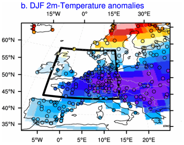
Obs. estimates (20CR/NCEP/ECA&D | 1950–2010)
CNRM-CM5 historical (10 members | 1950–2010)

The seasonal clock in a warmer world







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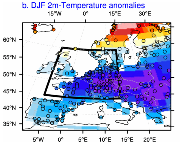
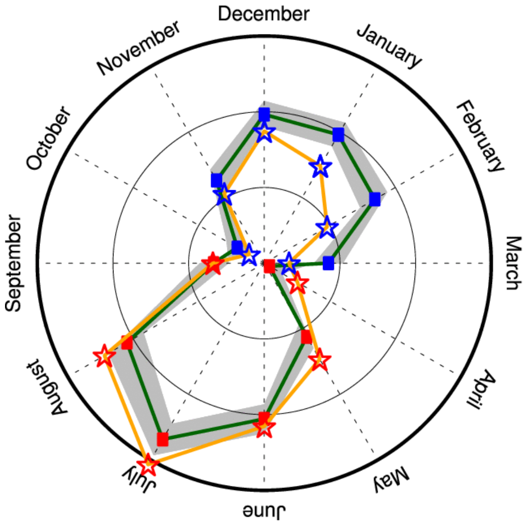
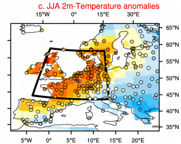


The regression decreases in winter.



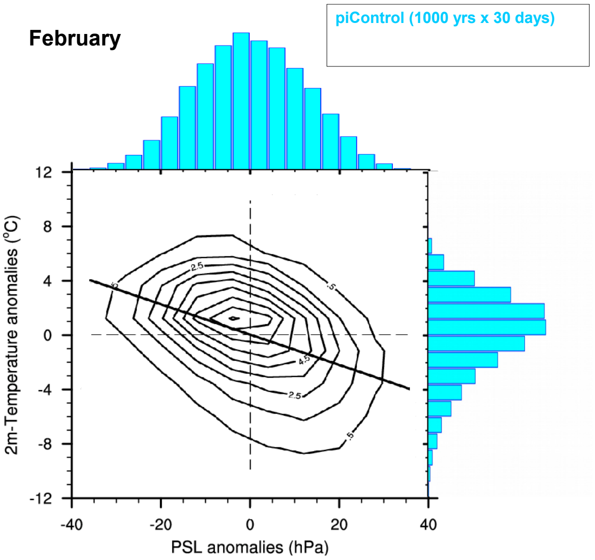
The regression increases in summer.



CNRM-CM5 piControl (1000 yrs) + 90%-level C.I

CNRM-CM5 rcp85 (5-member ens. mean | 2070–2100)

Weaker winter SLP-T regression



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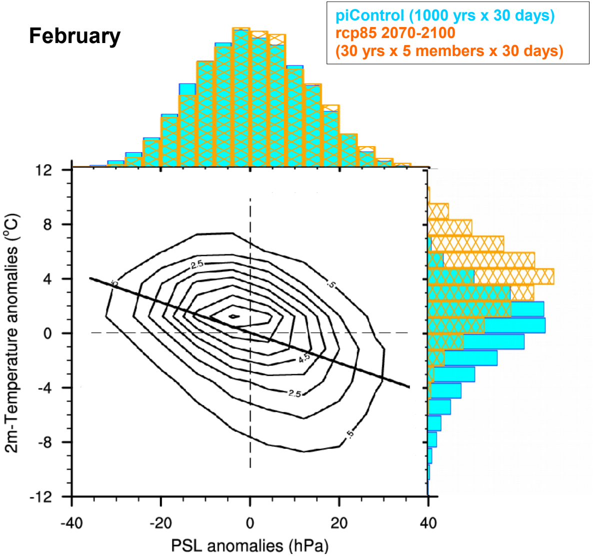

- No major SLP change, warm shift of T pdf.

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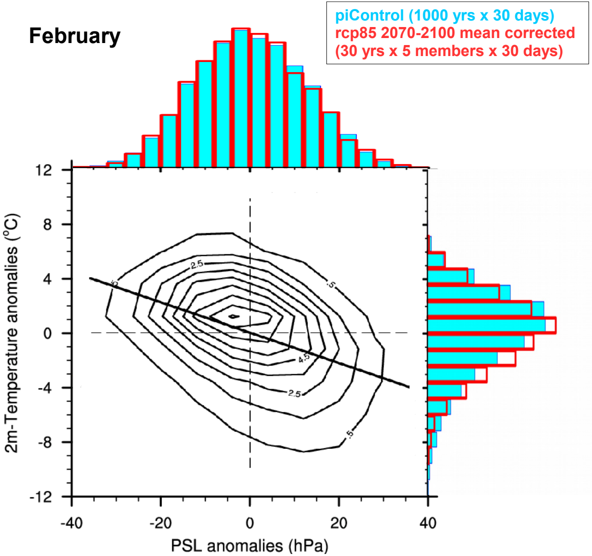

- No major SLP change, warm shift of T pdf.
- Beyond the shift, the T variance decreases.

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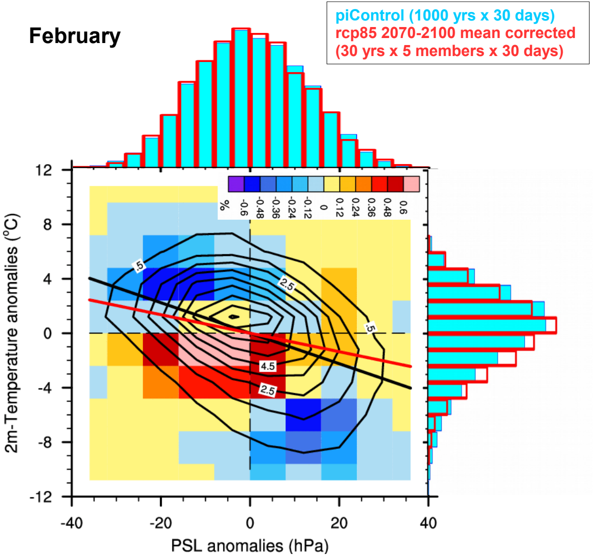
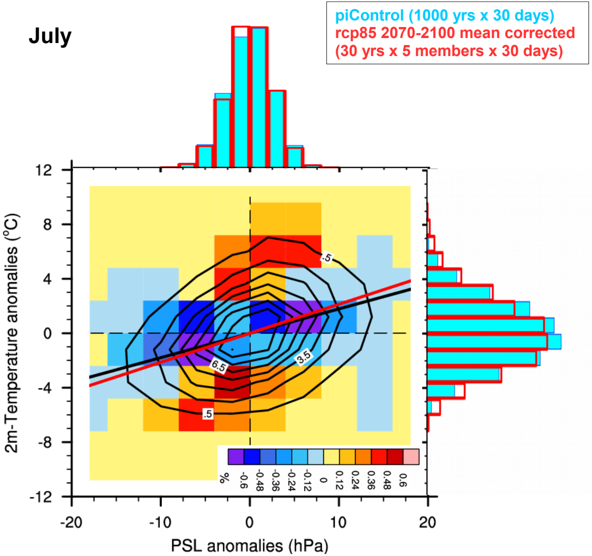


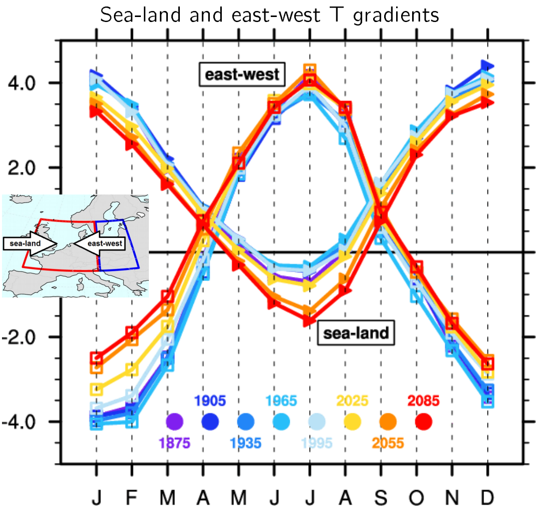
- No major SLP change, warm shift of T pdf.
- Beyond the shift, the T variance decreases.
- T changes are dependent on SLP.
  → Both warm+west & cold+east days become less frequent.

Stronger summer SLP-T regression



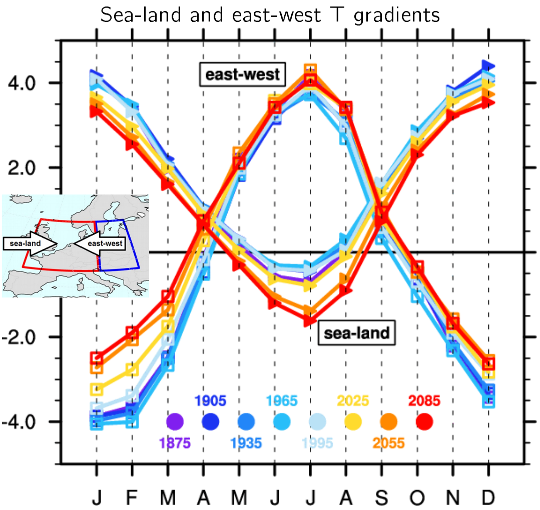
- No major SLP change, warm shift of T pdf.
- Beyond the shift, the T variance increases.
- T changes are less dependent on SLP.
  → Warm or cold days more frequent regardless of circulation.

Changes in zonal T gradients



CNRM-CM5 historical+rcp85 (5-member 30-yr climatologies)

Changes in zonal T gradients



CNRM-CM5 historical+rcp85 (5-member 30-yr climatologies)

- Winter T variance decrease linked to decreases in both gradients.

→ Westerlies less efficient to warm, easterlies less efficient to cool.

Cattiaux et al. (2011); De Vries et al. (2012).

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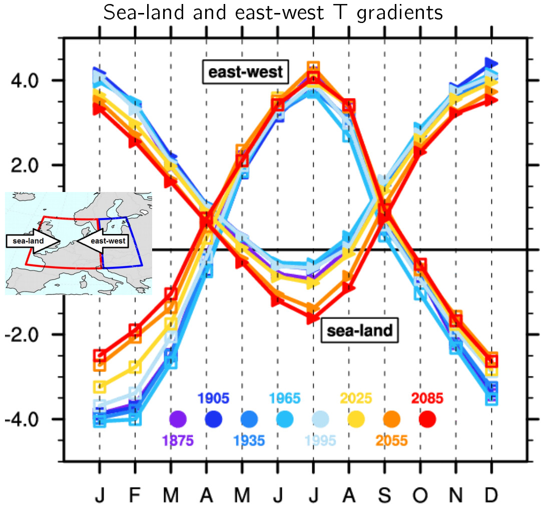

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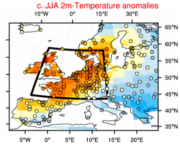
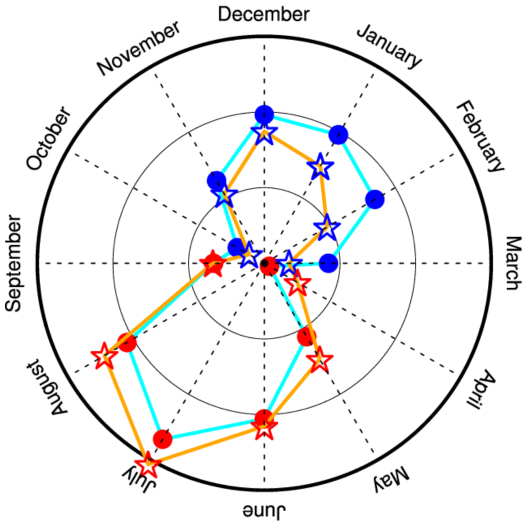
- Summer T variance increase partially linked to the increase in sea-land gradient.

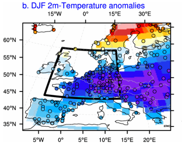
→ Other factors, e.g. local soil drying for hot extremes.

Boé & Terray (2014); Cattiaux et al. (2011,2015); Fischer et al. (2009,2012); Seneviratne et al. (2006)...

Winter/summer onsets in a warmer world



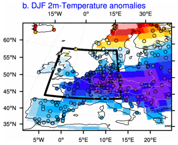


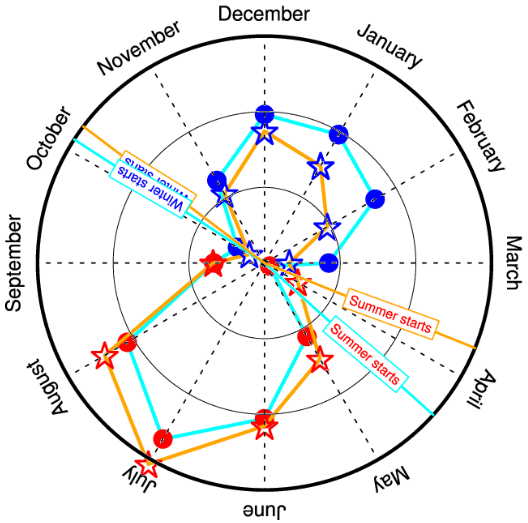


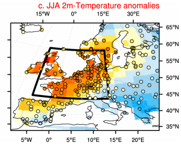
CNRM-CM5 piControl (1000 yrs)
CNRM-CM5 rcp85 (5-member ens. mean | 2070–2100)

Winter/summer onsets in a warmer world

The winter onset is slightly delayed.







The summer starts ∼25 days earlier.

CNRM-CM5 piControl (1000 yrs)

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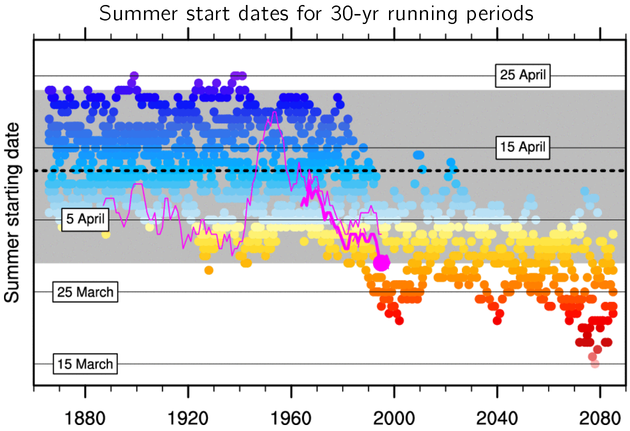
An earlier summer onset

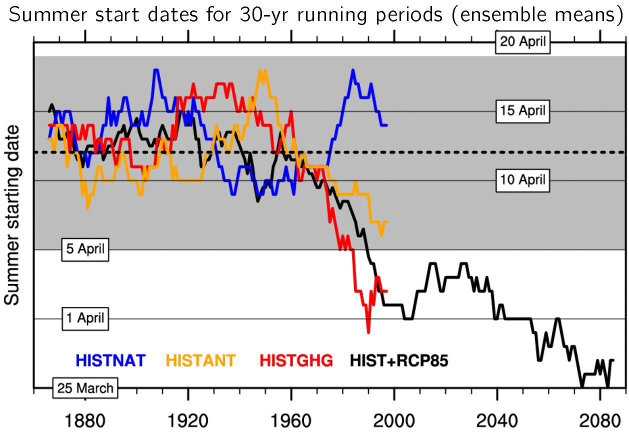
- Observed trend of ~ -2.5 days/decade since the 1960s.



Obs. estimates (NCEP 1948–2014 | 20CR 1870–2012)
CNRM-CM5 piControl 90%-level C.I from 1000 random 30-yr periods
CNRM-CM5 historical+rcp85 (10 members 1850–2005 | 5 members 2006–2100)

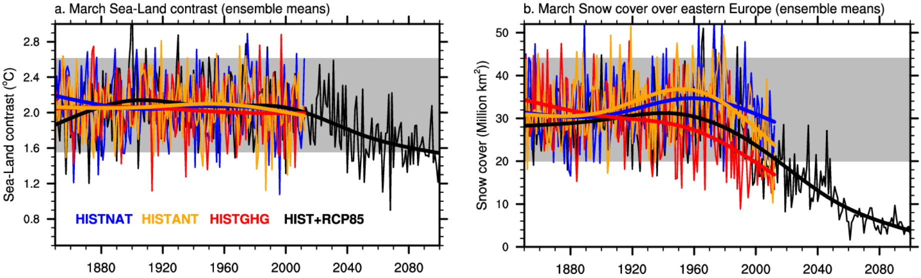
An earlier summer onset – Attribution runs

- ~ −2.5 days/decade is consistent with the expected response to GHG.



CNRM-CM5 historical+rcp85 (5 members 1850–2100)
CNRM-CM5 piControl 90%-level C.I from 1000 averages of 5 random 30-yr periods
CNRM-CM5 historicalNat, **historicalAnt** & **historicalGHG** (5 members 1860–2005 each)

The role of snow cover decline



- ▶ Summer advance explained by the reduced March east-west T gradient linked to snow cover decline.

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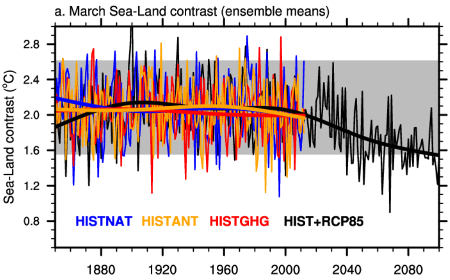

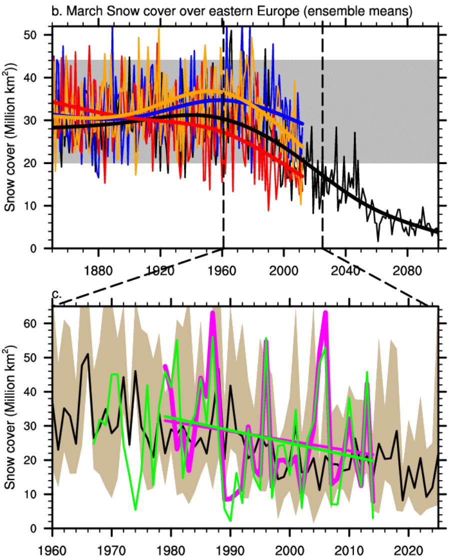

- ▶ Summer advance explained by the reduced March east-west T gradient linked to snow cover decline.
- ▶ CNRM-CM5 snow trend consistent with obs. estimates (1960–2015).

Trend-HIST= [-6/-1] Mkm²/10yr
Trend-MERRA= -2.8 Mkm²/10yr
Trend-NSIDC= -3.7 Mkm²/10yr

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Based on a intrinsic feature of the circulation-temperature relationship.

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Evidences for expected changes in intra-seasonal temperature variability.

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Consistent with the expected response to GHG, and phenological studies e.g. Menzel et al. (2006).

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This work:

Cassou, C. and J. Cattiaux, Disruption of the European climate seasonal clock in a warming world, *Nature Climate Change*, in revision.

+ 2 recent papers on the increase in European summer temperature variability:

Cattiaux, J., H. Douville, R. Schoetter, S. Parey and P. Yiou (2015), Projected increase in diurnal and inter-diurnal variations of European summer temperatures, *Geophysical Research Letters*, 42(3), 899-907.

Douville, H., J. Colin, E. Krug, J. Cattiaux and S. Thao (2015), Mid-latitude daily summer temperatures reshaped by soil moisture under climate change, *Geophysical Research Letters*, in press.