Is Western Europe warming much faster than expected?

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CERFACS & NCAR/CGD/CAS.
Motivation

Western Europe is warming much faster than expected

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- 2m-temperature (SAT) trends 1950 – 2007

- Compare Observations with CMIP3
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- 2m-temperature (SAT) trends 1950 – 2007
- Compare Observations with CMIP3
- Discrepancy between models and observations
- Model and forcing biases rather than internal variability
Outline

- Observations
- A climate variability paradigm for attribution
- A simple approach to estimate variability related to a change in atmospheric circulation
- Use the CESM1 large ensemble (Kay, Deser et al. 2015) to estimate the possible influence of internal variability on past temperature trends over Europe
- Summary
Observed temperature time series

°C

a) DJF

1900 1920 1940 1960 1980 2000

b) JJA

DJF

JJA
Observed temperature trends: 1963-2012

°C / 50 years

DJF

°C

JJA

°C
## Climate variability paradigm

### 4 components of variability

<table>
<thead>
<tr>
<th>Forced</th>
<th>Free</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermodynamical</td>
<td>Dynamical</td>
</tr>
</tbody>
</table>
Dynamical / thermodynamical SAT components

- Dynamical component: due to a change in atmospheric circulation
- The thermodynamical component is simply defined as the residual (Total – Dynamical)
- Intrinsically linked to a certain extent
- How to estimate the dynamical component?
Get the dynamical component using analogues

- World with constant external forcing
- CESM1 2000-years PiCntrl simulation
- Use large-scale circulation analogues
- SLP monthly means

January SLP
Year 576
Dynamical component using analogues

January SLP
Year 576

Step 1: Select $N$ closest analogues among all Jan.
Dynamical component using analogues

January SLP
Year 576

Step 2: Randomly draw $M$ out of $N$
Step 3: Find best linear fit coefficients

January SLP
Year 576

$$\approx a_1 + a_2 + a_3 + a_4 + a_5$$

hPa
Step 4: SAT linear combination using the $a_i$
Step 5: Iterate steps 2, 3, 4

\[ K = 1, \ldots, N_{\text{iter}} (=15) \]

\[ K = 1 \]

\[ K = 15 \]

°C
Step 5: Iterate steps 2, 3, 4

\[ K = 1, \ldots, N_{iter} (=15) \]

Step 6: take the average of the \( N_{iter} \) values

\[ K = 1 \]

\[ K = 15 \]

°C
SAT thermodynamical component

Thermodynamical component
Influence of internal variability on SAT trends

Model framework: use the CESM1 large ensemble (30 members, HISTorical 1920-2012)

1. Focus on the 1963-2012 period
2. Focus on winter season (DJF)
3. Reconstruct HIST monthly SLP from PiCntrl closest analogues
4. Derive monthly SAT dynamical component for all months of all HIST members
5. Use paradigm to partition 50-yr trends
Winter SAT 1963-2012 trends

CESM1 Ens.Mean  

1.2 °C / 50 years

Obs  

1.8 °C / 50 years
All CESM1 trends

°C / 50 years
All CESM1 trends

°C / 50 years
Total trends

Member 7

Member 12

0 °C / 50 years

2.5 °C / 50 years
Dynamical component

Member 7

Member 12

-0.56 °C / 50 years

1.1 °C / 50 years
Thermodynamical component

Member 7

Member 12

0.56 °C / 50 years

1.4 °C / 50 years
Member 12: free and forced components

- Total: 2.5 °C/50yr
- Free: 1.3 °C/50yr
- Forcéd: 1.2 °C/50yr

Maps showing the distribution of temperature changes over Europe with color gradients indicating different temperature changes.
Dynamical and thermodynamical free components

Dynamical

Thermodynamical

0.9 °C / 50 years

0.4 °C / 50 years
EOFs of the trends thermodynamical component

EOF1 45%

EOF2 14%

Snow frac.
Dynamical adjustment and time of emergence

Total SAT

Dynamically-adjusted
Observations: trend attribution

°C / 50 years
Western Europe is warming (1.8 K / 50 years in winter)
Analysis of CESM1 LE suggests a possible large contribution from internal variability (same magnitude as the forced response)
Main contribution comes from the dynamical component
Dynamical adjustment increases signal to noise ratio (more in winter than summer) and advances time of emergence
Spread in internal thermodynamical component related to the ocean state and land-atmosphere interactions (snow effect dominant in winter)
No discrepancy between CESM1 and observations
Dynamically adjusting observations suggests that half of the observed trend could be due to unpredictable decadal changes in atmospheric circulation
Thermodynamical component: ocean
Thermodynamical component: snow
Trend attribution: member 12
Trend attribution: member 7
Reliability in space

Period 1950-2007: Observations SAT (GISS)
⇒ Use SAT regression on global mean temperature
  \[ \text{SAT}(x,y,t) = B(x,y) \cdot \text{SAT}_{\text{glob.mean}} + \epsilon(x,y,t) \]
⇒ Percentile of observed B in model CMIP3 values
Reliability: CMIP5

Period 1950-2007: Observations SAT (GISS)
⇒ Use SAT regression on global mean temperature
\[
\text{SAT}(x,y,t) = B(x,y) \cdot \text{SAT}_{\text{glob.mean}} + \varepsilon(x,y,t)
\]
⇒ Percentile of observed B in CMIP5
• Use monthly data
• Use a large regional domain (e.g. North America), m grid points
• **Algorithm**

=> Start with SLP of Jan. 1920 of the first HIST member and look for the \(N_a\) closest SLP analogues among all (1200) PICNTRL January

⇒ Even a 1200-year period is not enough to get good enough analogues.

⇒ Use the Constructed Flow Analogue (CFA) method (Van den Dool 1994)

⇒ Draw randomly \(N_b\) analogs among the \(N_a\)

⇒ Let \(X_h\) be the Jan. 1920 monthly SLP from HIST, \(X_{c,i=1,Nb}\) the \(N_b\) analogues from PICNTRL. We estimate \(\beta\) such as: \(X_h \approx X_{ca} = X_c \cdot \beta\)

⇒ \(X_{ca}\) constructed analogue as a linear combination of the \(N_b\) closest analogues (dims of \(X_c\): \(m \times N_b\), \(X_{ca}\): \(m \times 1\) and \(\beta\): \(N_b \times 1\))

⇒ Estimate \(\beta\) as \([ (X_c^T \cdot X_c)^{-1} \cdot X_c^T ] \cdot X_h\) (Moore-Penrose pseudo_inv)

⇒ Reconstruct any other monthly variable (SAT, PR) using \(\beta\)

⇒ Repeat previous steps \(N_i\) times

⇒ Do that for all months and all members from HIST
Europe DJF temperature: member 12
Sensitivity to number of analogues