Present-day biases and future changes in intra-seasonal variability of European temperatures

A multi-model analysis from CMIP5 and CFMIP2

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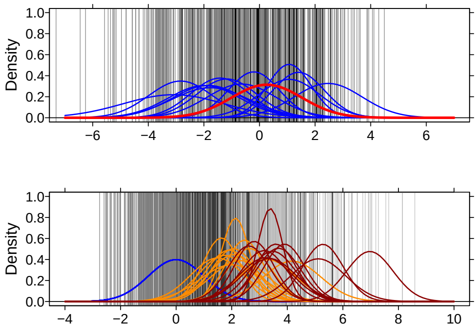
Motivations

European temperatures in CMIP3 models (DJF).



ERA-40 1961–2000 2046–2065 2081–2100

Understanding. . .

- Present-day biases, both in mean state & variability (extremes).
- Uncertainties in future projections (sensitivity to enhanced radiative forcing).

How?

By decomposing biases / changes into dynamical (weather regimes) and physical contributions.

Multi-model analysis?

Data available up to now (now = May 2011)

Variables (daily data required)

- Surface temperature (*tasmin*, *tasmax*). Ref: E-OBS, interpolated from ECA&D stations (Haylock et al., 2008).
- Z500 (*zg*). Ref: NCEP2 reanalysis (Kanamitsu et al., 2002).
- Surface radiative fluxes (*rlds*, *rlus*, *rsds*, *rsus*...). Ref: SRB data (NASA/GEWEX).

EUCLIPSE models available up to now

- CNRM-CM5.
- IPSL-CM5A-LR.

Experiments available up to now

- AMIP-type (*amip*, *amipFuture*), period 1979–2008.
- + IPSL-CM5A-LR: *historical*.

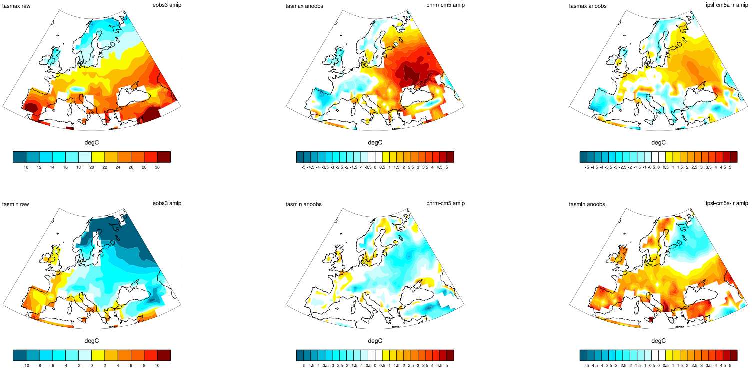
Present-day mean seasonal biases

(*amip* vs. ref over 1979–2008)

E-OBS (raw) | CNRM-CM5 (bias) | IPSL-CM5A-LR (bias)

JJAS *tasmax*

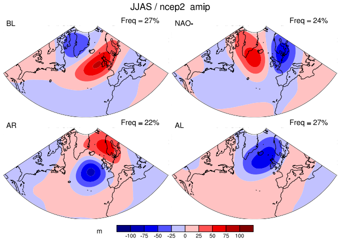
DJFM *tasmin*



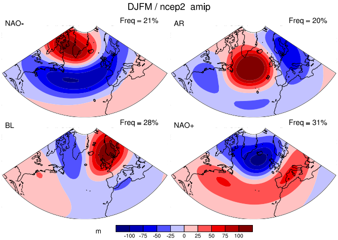
Methodology (Michelangeli et al., 1995)

- preferential states of daily NAE atmospheric circulations.
- clustering on the n first EOFs of detrended Z500 anomalies. JJAS: $n = 20$; DJFM: $n = 15$ (90% of variance).
- each day is attributed to one regime (Euclidean distance).

JJAS



DJFM

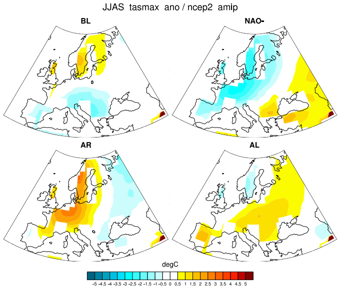


NCEP2, 1979–2008.

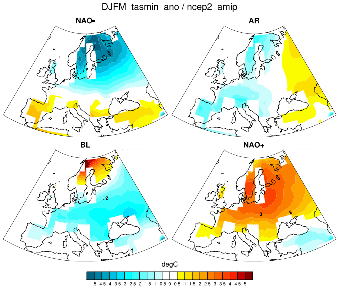
Intra-class mean temperatures t_k

- $t_k = \frac{1}{N_k} \sum_{i \in \Omega_k} T_i$, with Ω_k the N_k days spent in WR_k.
- Overall $\bar{T} = \frac{1}{N} \sum_i T_i = \sum_k f_k t_k$, with $f_k = \frac{N_k}{N}$ frequency of WR_k.

JJAS *tasmax*



DJFM *tasmin*



EOBS, 1979–2008, based on NCEP2 classification.

Inter-class / intra-class contributions to ΔT

Some maths

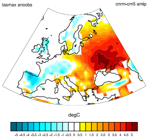
Recall $\bar{T} = \frac{1}{N}\sum_i T_i = \sum_k f_k t_k$
(aka Bayes formula: $P(X) = \sum_k P(Y_k)P(X|Y_k)$).

$$\begin{aligned}
\Delta T &= \bar{T}^m - \bar{T}^0 = \sum_k f_k^m t_k^m - \sum_k f_k^0 t_k^0 \\
&= \\
&= \dots \\
&= \\
&= \sum_k (f_k^m - f_k^0) t_k^0 + \sum_k f_k^0 (t_k^m - t_k^0) + \sum_k (f_k^m - f_k^0)(t_k^m - t_k^0) \\
&= \underbrace{\sum_k \Delta f_k \cdot t_k^0}_{Inter-class} + \underbrace{\sum_k f_k^0 \cdot \Delta t_k}_{Intra-class} + \underbrace{\sum_k \Delta f_k \cdot \Delta t_k}_{Residual}
\end{aligned} \tag{1}$$

Inter-class / intra-class contributions to ΔT

Some maps (present)

$$\Delta^{m-0} T = \sum_k \Delta f_k \cdot t_k^0 + \sum_k f_k^0 \cdot \Delta t_k + \sum_k \Delta f_k \cdot \Delta t_k$$



amip−ref
CNRM-CM5
JJAS *tasmax*

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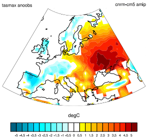

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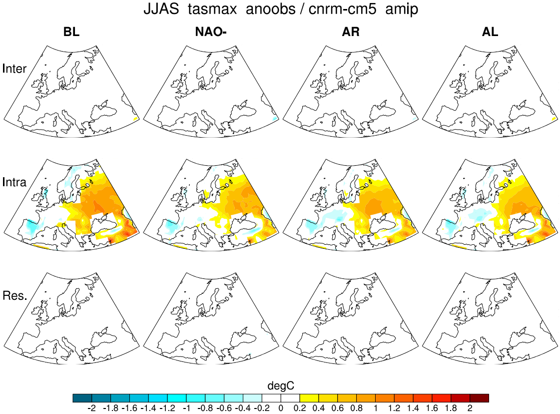
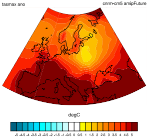


Inter-class / intra-class contributions to ΔT

Some maps (future)

$$\Delta^{F-P} T = \sum_k \Delta f_k \cdot t_k^0 + \sum_k f_k^0 \cdot \Delta t_k + \sum_k \Delta f_k \cdot \Delta t_k$$



amipFuture−amip
CNRM-CM5
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Inter-class / intra-class contributions to ΔT

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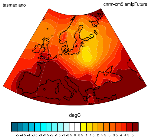

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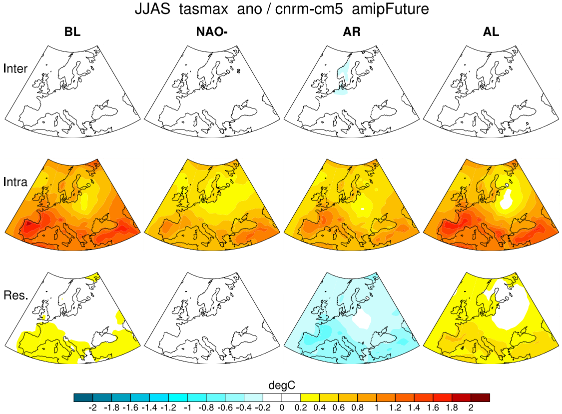
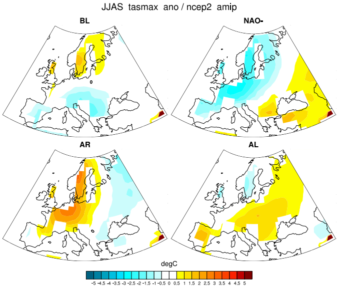


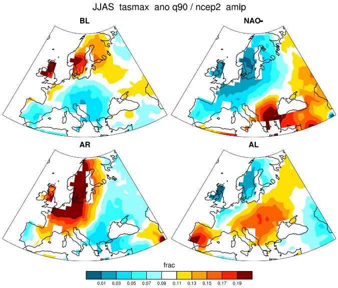
Days above/below $90^{th}/10^{th}$ temperature quantiles

- $p_k^{90} = \frac{n(T>T^{90})_k}{N_k}$, with N_k the number of days spent in WR_k.
- Overall $P^{90} = 10\% = \sum_k f_k p_k^{90}$, with f_k frequency of WR_k.

JJAS *tasmax*



JJAS P^{90} (*tasmax*)

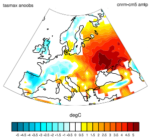


EOBS, 1979–2008, based on NCEP2 classification.

Inter-class / intra-class contributions to ΔP^{90}

Some maps (present)

$$\Delta^{m-0} P^{90} = \sum_k \Delta f_k \cdot p_k^0 + \sum_k f_k^0 \cdot \Delta p_k + \sum_k \Delta f_k \cdot \Delta p_k$$



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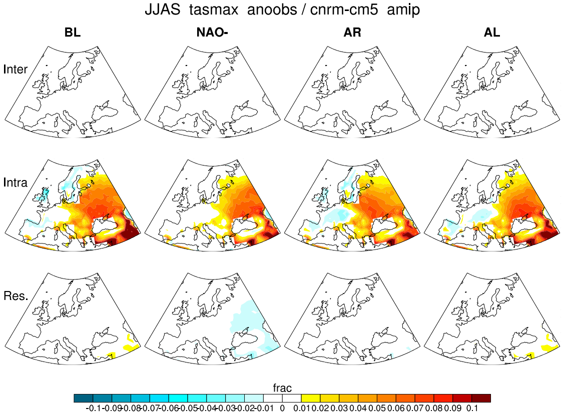

Inter-class / intra-class contributions to ΔP^{90}

Some maps (future)

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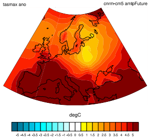

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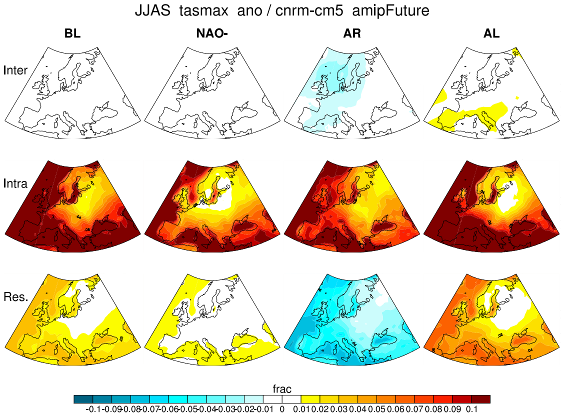


Concluding remarks

Summary

- Methodology for decomposing biases / future changes in both mean and extreme temperatures into dynamical & physical contributions.
- First results for CNRM-CM5 (*amip*):
    - ΔT almost exclusively due to intra-class contributions.
    - Intra-class ΔT can vary from one regime to another, and have to be linked to biases in radiative fluxes and processes.

Prospects

- Better understanding of intra-class biases:
    - Estimating the dynamical part due to the weather regimes methodology.
    - Investigating surface energy budgets (contributions of clouds, albedo, snow etc.).
- Apply the methodology to (at least) all EUCLIPSE models, and gather the multi-model information (e.g., highlight general features).

Thanks for your attention.
Questions?

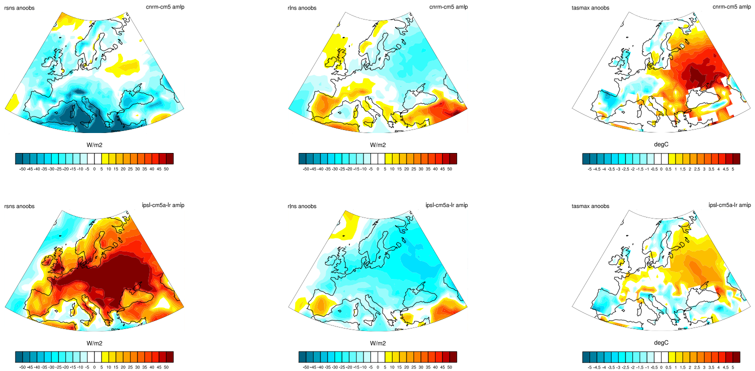
Mean radiative biases

(*amip* vs. ref over 1979–2008, JJAS)

SW net (↓) | LW net (↓) | *tasmax*

CNRM-CM5

IPSL-CM5A-LR



Relative to SRB data, 1984–2007. Two different radiative biases, two different atmospheric physics. . .

. . . two different temperature biases.