Towards a better understanding of changes in European temperature extremes

A multi-model analysis from CMIP5/CFMIP2

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Motivations

Temperature extremes?

- Extremely warm/cold days: Tmax/Tmin above/below the $90^{th}/10^{th}$ centile of a reference pdf (e.g., observations or *historical* runs).
- Highest impacts, responses not necessarily scaled on the mean.

Questions

- Uncertainties in GCMs: Large-scale circulation? Soil processes? Cloud feedbacks?
- How to separate dynamical *vs.* non-dynamical contributions?

Multi-model data (9 GCMs so far)

CMIP5: *historical* (1979–2008) & *rcp85* (2070–2099): 8 GCMs.
CFMIP2: *amip* & *amipFuture*: 4 GCMs.

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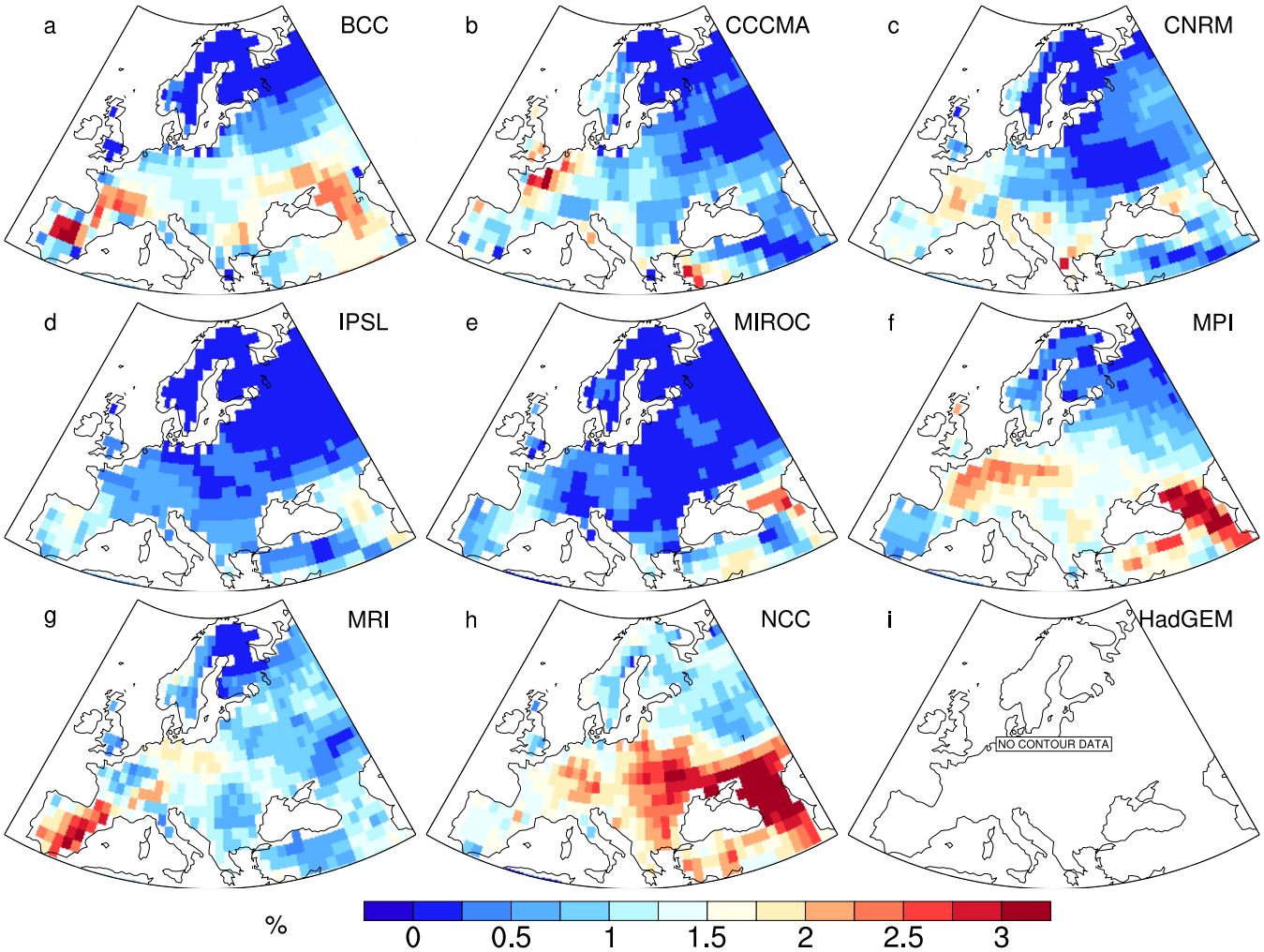
Future changes in wintertime cold days

Probability of exceeding $Q_{10}^{historical}$ in *rcp85* (PQ10)



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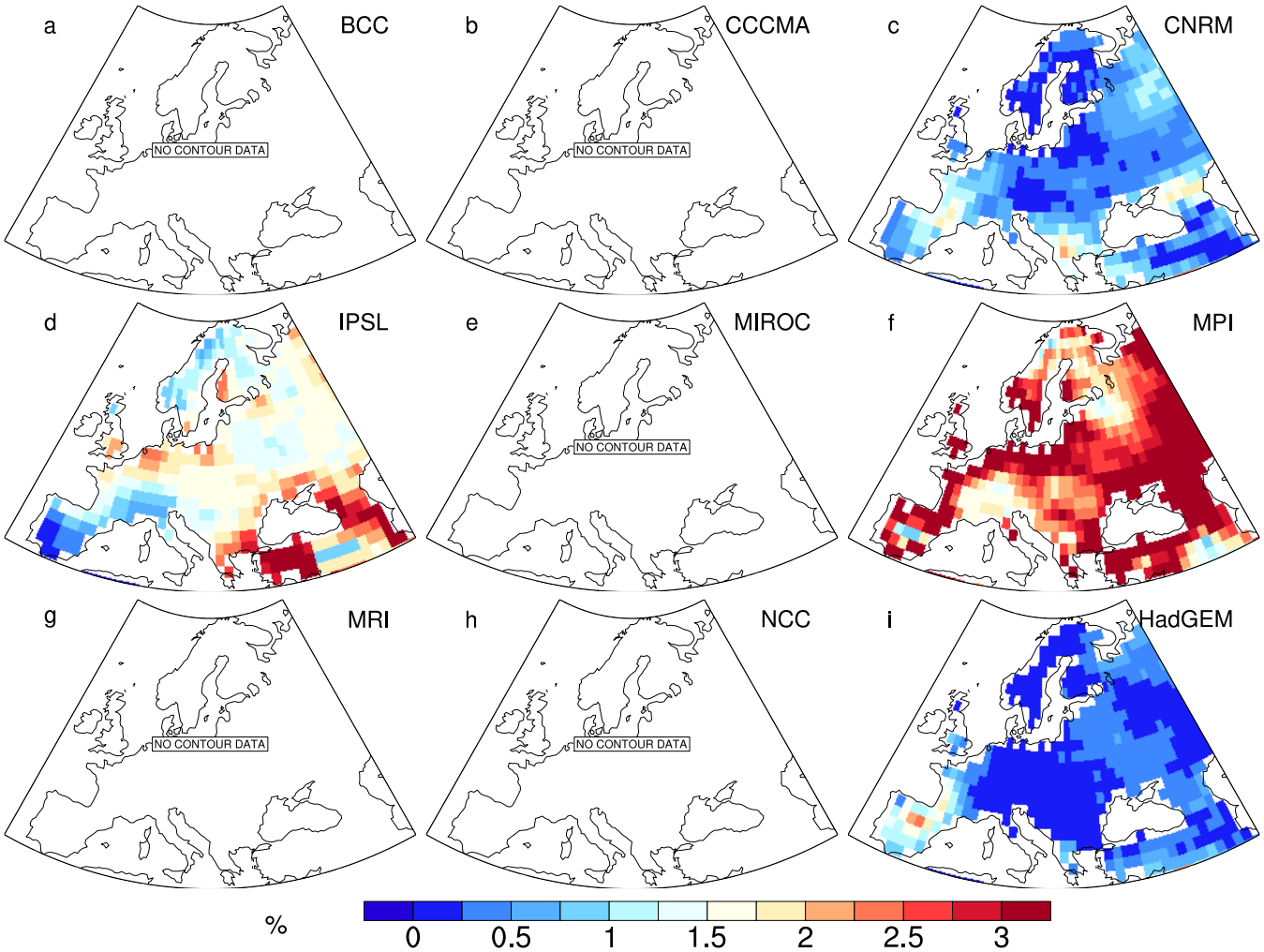
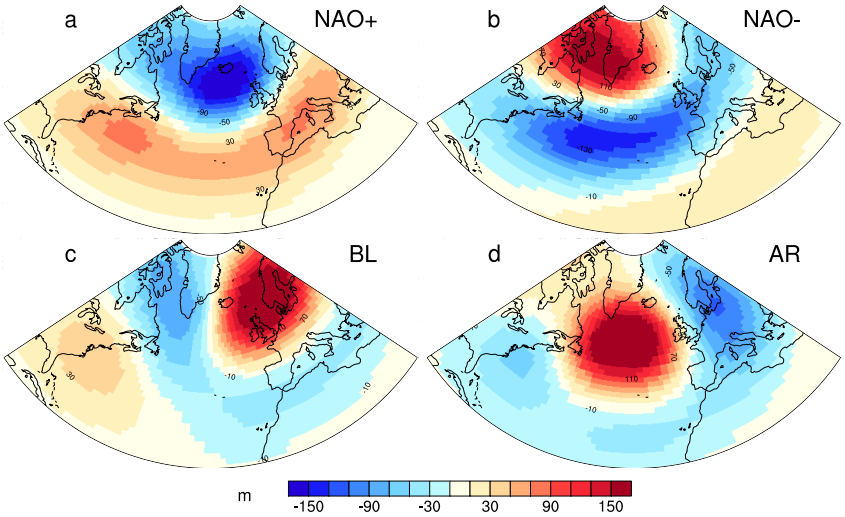


European temperatures & North-Atlantic dynamics

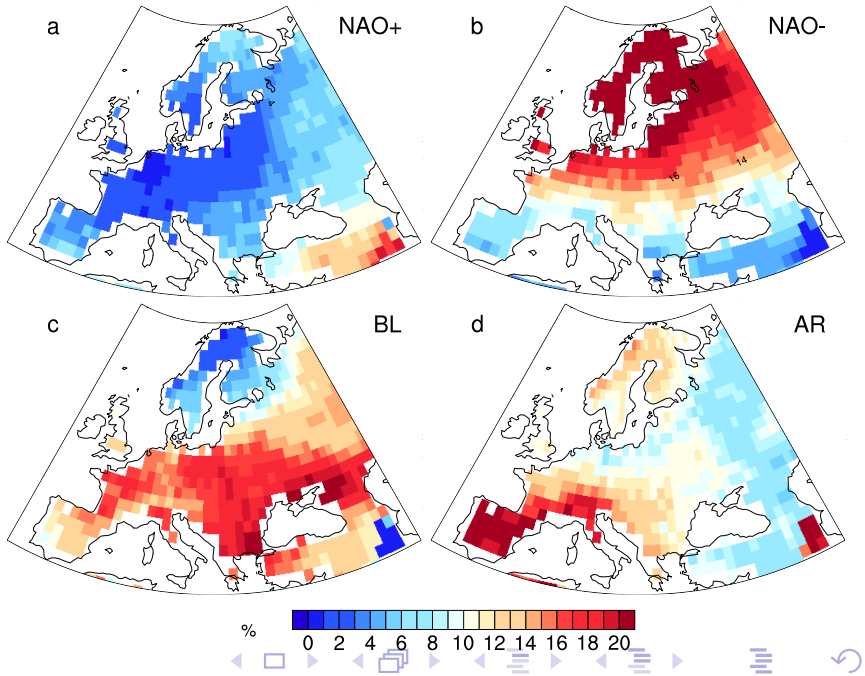
Weather regimes

- Clustering of daily *Z500* anomalies. (e.g., Michelangeli et al., 1995)
- Temperatures well discriminated among the 4 classical regimes.
- $\overline{\mathrm{PQ10}} = \sum_k P(\Omega_k) \cdot P(T < T_{10} \mid \Omega_k)$.

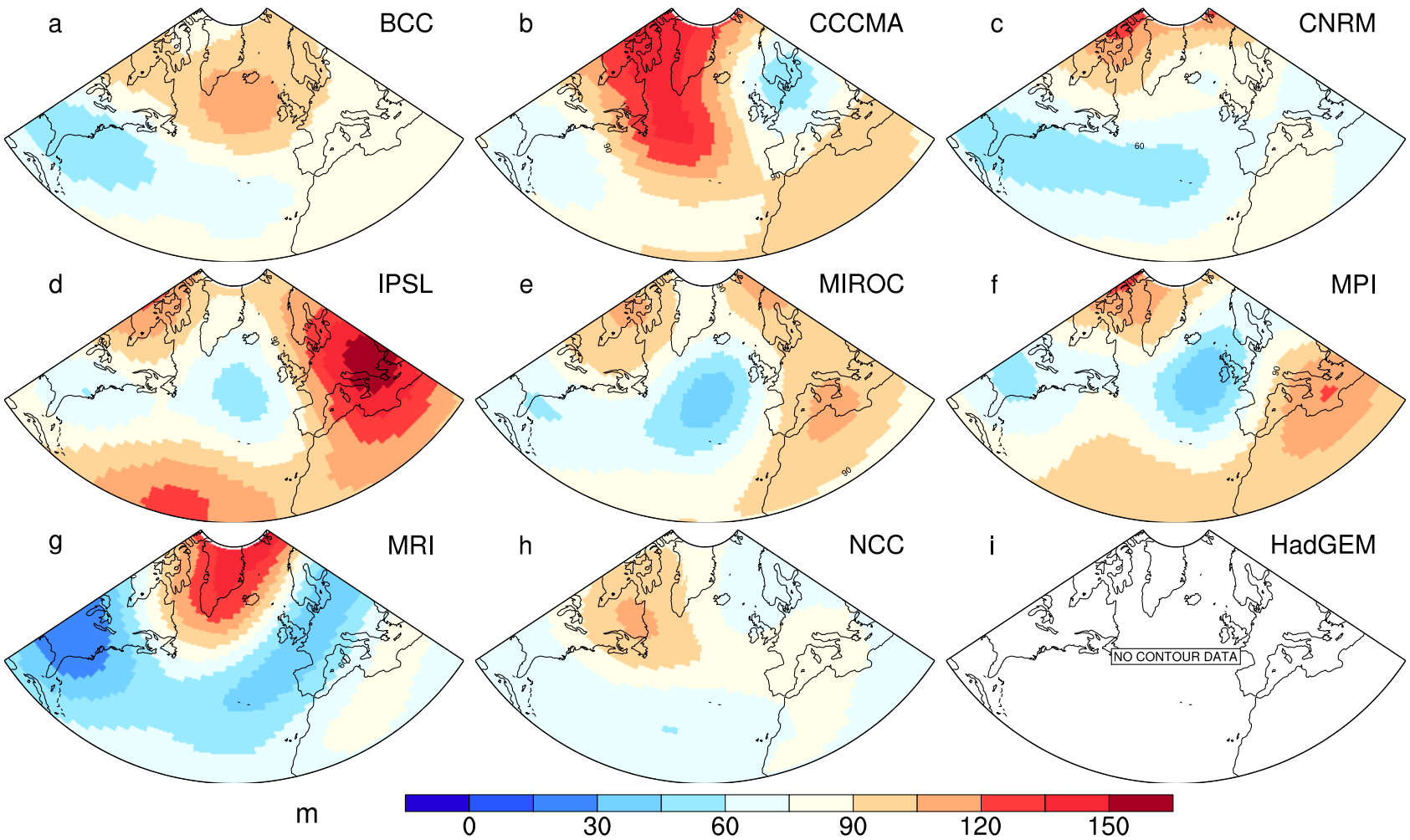
Z500 (NCEP2)



PQ10 (E-OBS)



Future changes in mean Z500



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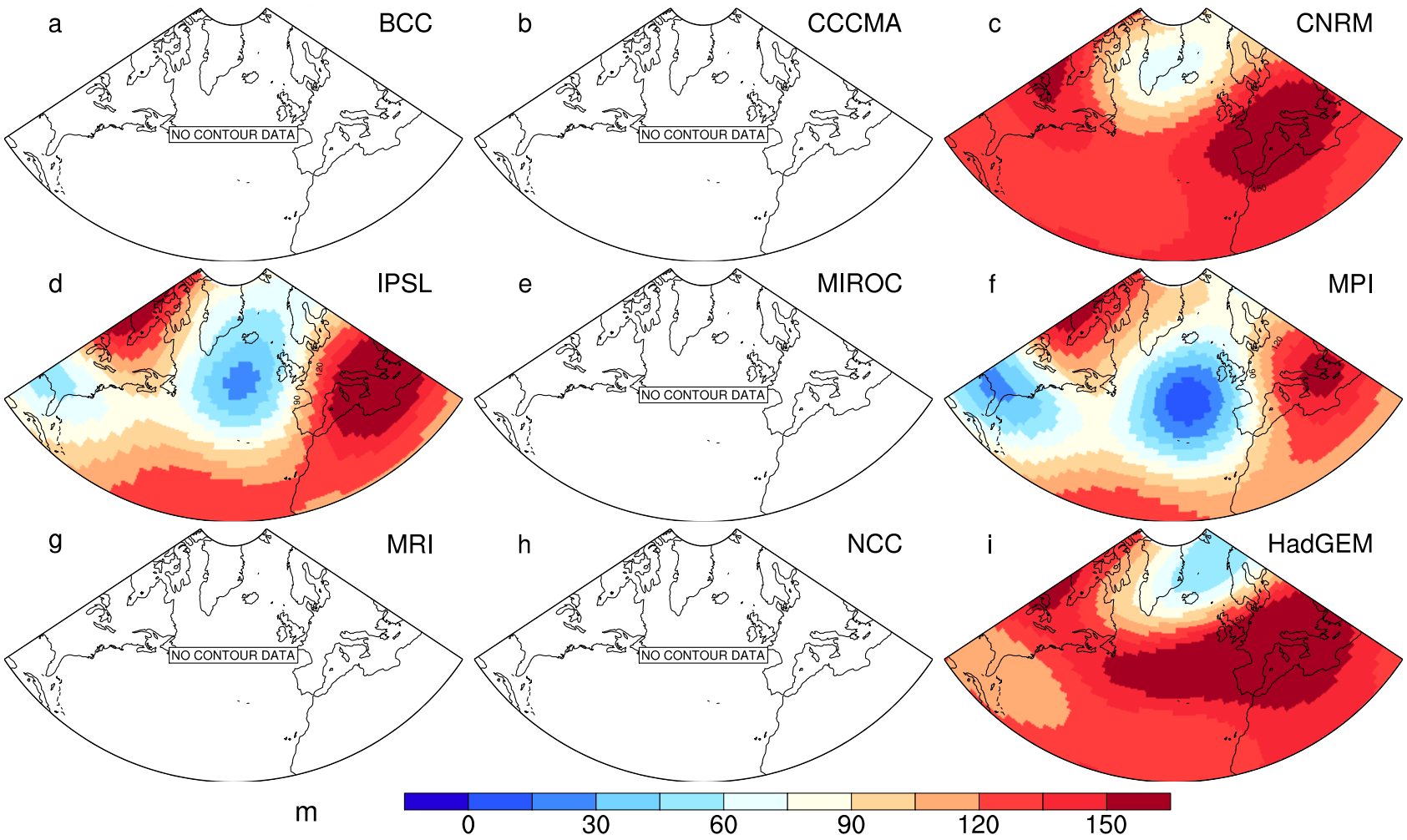

Evaluating dynamical contributions

Contribution of changes in regimes frequencies:

$$\overline{X} = \sum_k f_k x_k \quad \Rightarrow \quad \Delta^{F-P}\overline{X} = \overline{X}^F - \overline{X}^P = \sum_k f_k^F x_k^F - \sum_k f_k^P x_k^P$$

$$= \underbrace{\sum_k \Delta f_k \cdot x_k^P}_{BC} + \underbrace{\sum_k f_k^P \cdot \Delta x_k}_{WC} + \underbrace{\sum_k \Delta f_k \cdot \Delta x_k}_{RES}$$

Contribution of changes in regimes structures:

$$\forall k \; x_k = \Phi(d_k) \quad \Rightarrow \quad \Delta x_k = \Phi^F(d_k^F) - \Phi^P(d_k^P) = [\Phi^F(d_k^F) - \Phi^P(d_k^F)] + [\Phi^P(d_k^F) - \Phi^P(d_k^P)]$$

Final breakdown

$$\Delta^{F-P}\overline{X} = \underbrace{\sum_k \Delta f_k \cdot \Phi^P(d_k^P)}_{BC} + \underbrace{\sum_k f_k^P \cdot \Phi^P(\Delta d_k)}_{WCd} + \underbrace{\sum_k f_k^P \cdot \Delta\Phi(d_k^F)}_{WC\Phi} + RES$$

Cattiaux et al., *SI Clim. Dyn.*, submitted.

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Evaluating the term $\Phi^P(d_k^F)$

I.e. the mean value of X that would produce present-day physics from future circulations.

One way to do it: consider

$$\Phi^P(d_k^F) \equiv \Phi^P(\widetilde{d_k^P}) \quad ,$$

where $\widetilde{d_k^P}$ are the flow-analogs of d_k^F sampled among the present-day circulations d_k^P.

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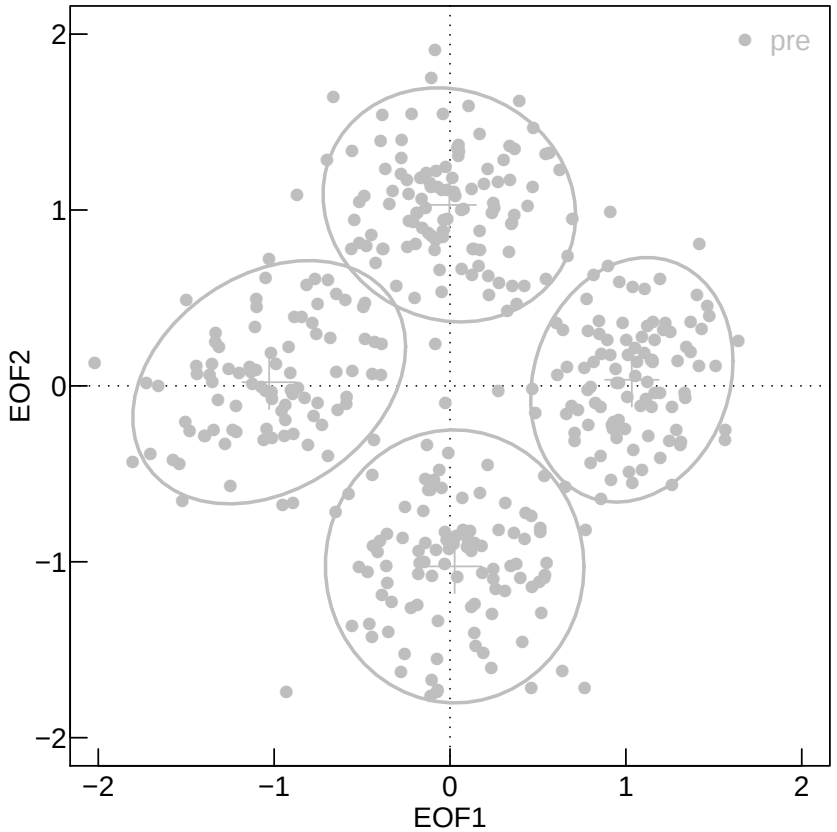
See, e.g., Lorenz (1969) for flow-analogs.



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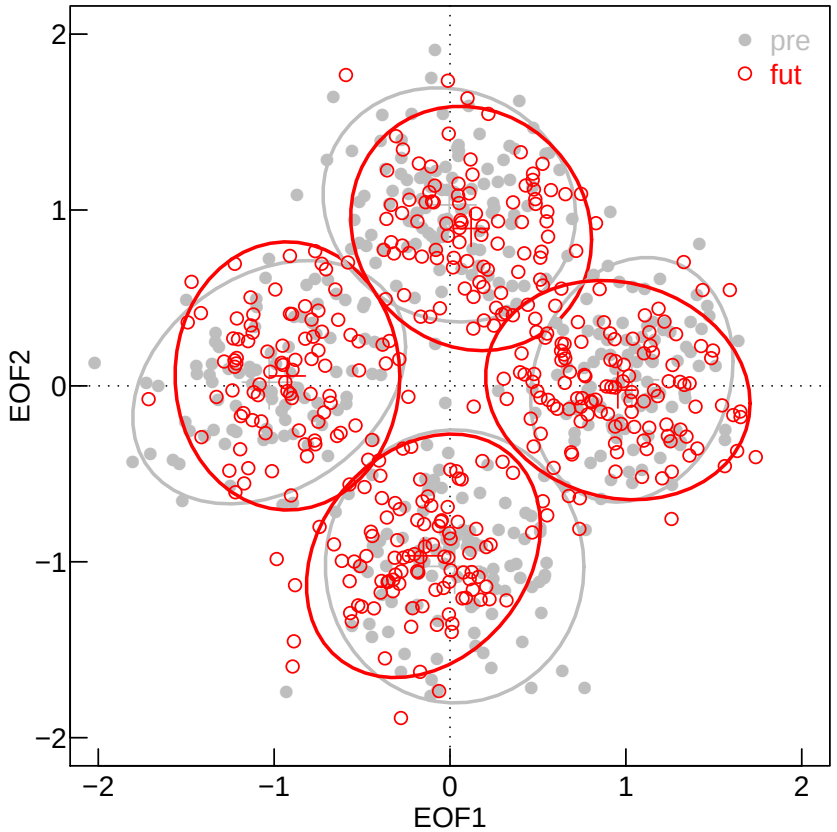

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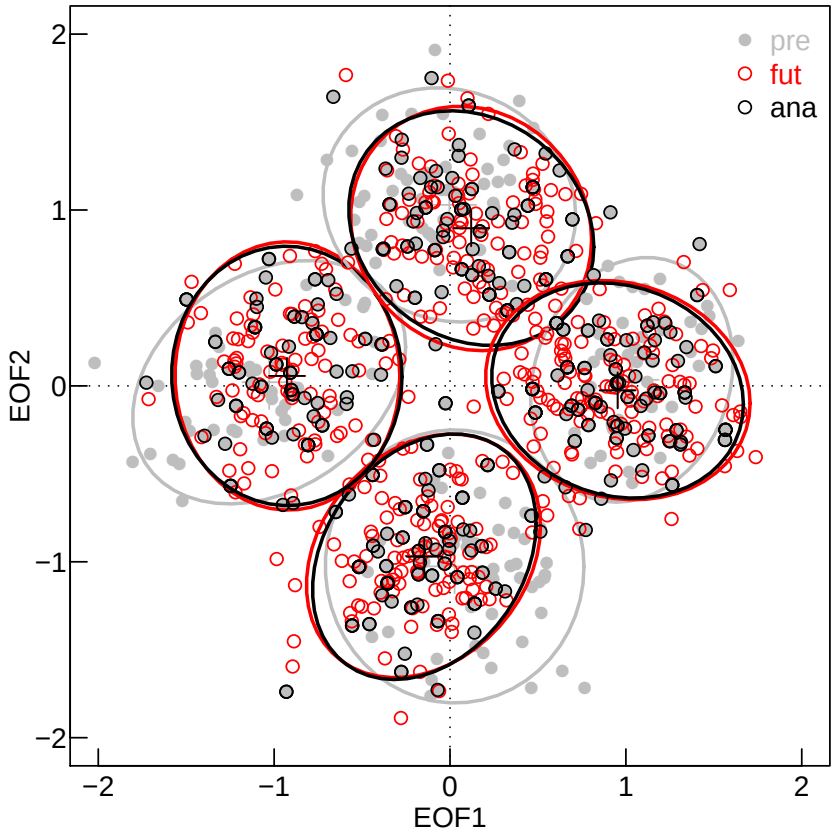

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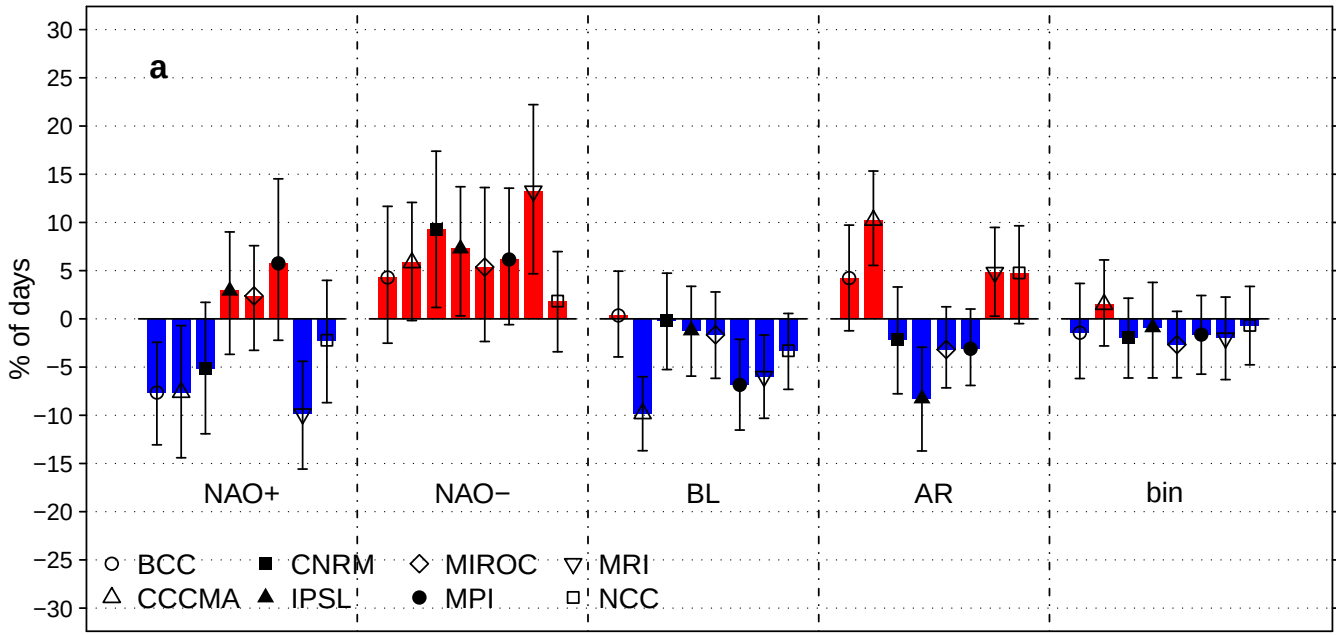
Changes in regimes frequencies

rcp85 vs. historical



- Increase of NAO−, while all previous CMIP concluded to increase of NAO+. . . (Boé, 2007; Cattiaux, 2010; Najac, 2008; Stephenson et al., 2006; van Ulden and van Oldenborgh, 2006, among many others)
- Opposite behaviour for CNRM in *amip*-type runs.
  Run forced by SST derived from *rcp85*? *amipFuture* in other GCMs?

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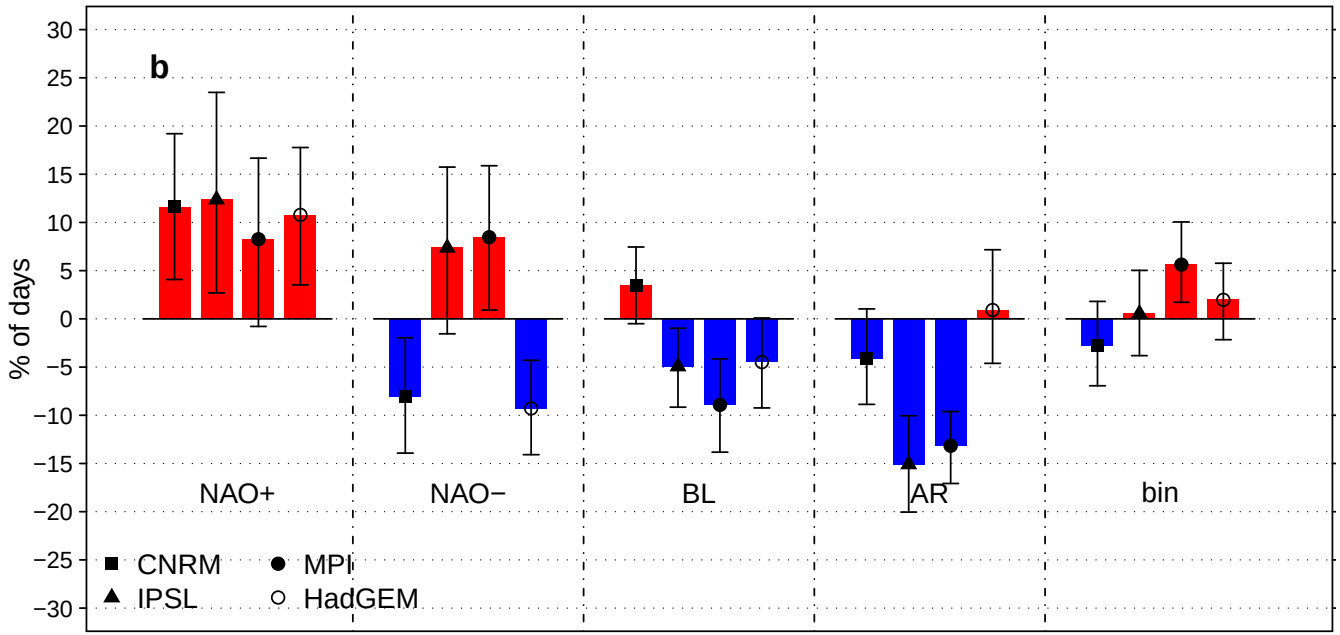
amipFuture vs. amip



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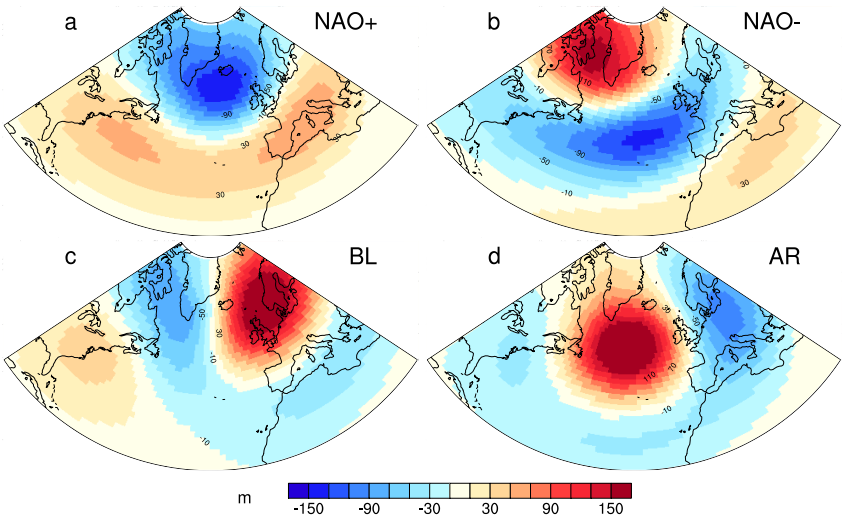
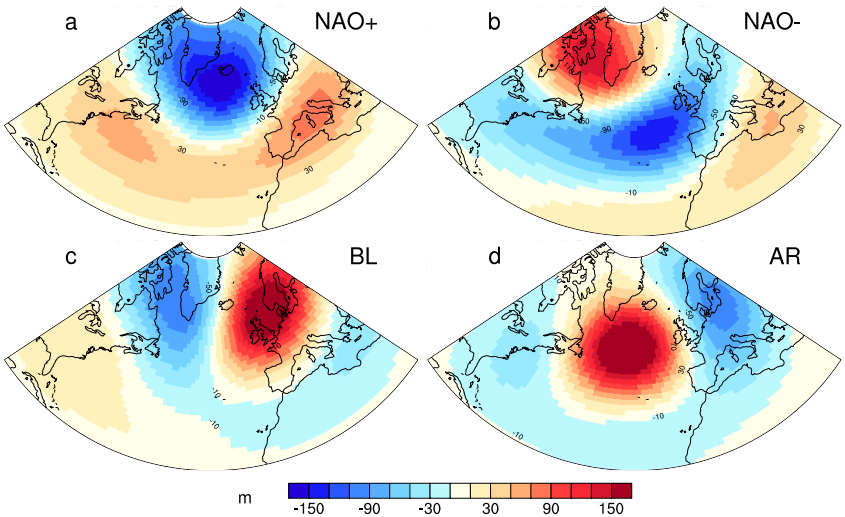
Changes in regimes structures

$\overline{d_k^P}$, ensemble mean (*historical*)



$\overline{\widetilde{d_k^P}}$, ensemble mean (*historical* analogs of *rcp85*)



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- ...but a general increase of westerlies (or decrease in easterlies) for all regimes.

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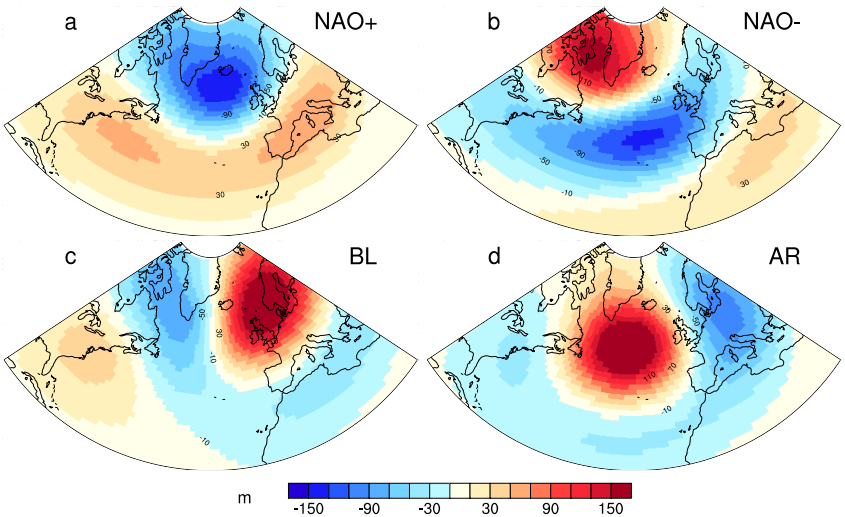

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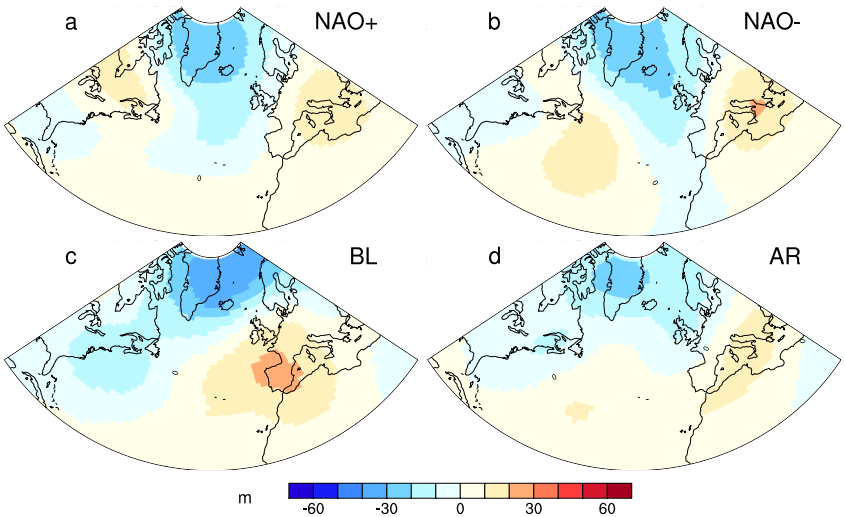

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Contributions to temperature extremes

Mean changes

Ensemble mean of each term in:

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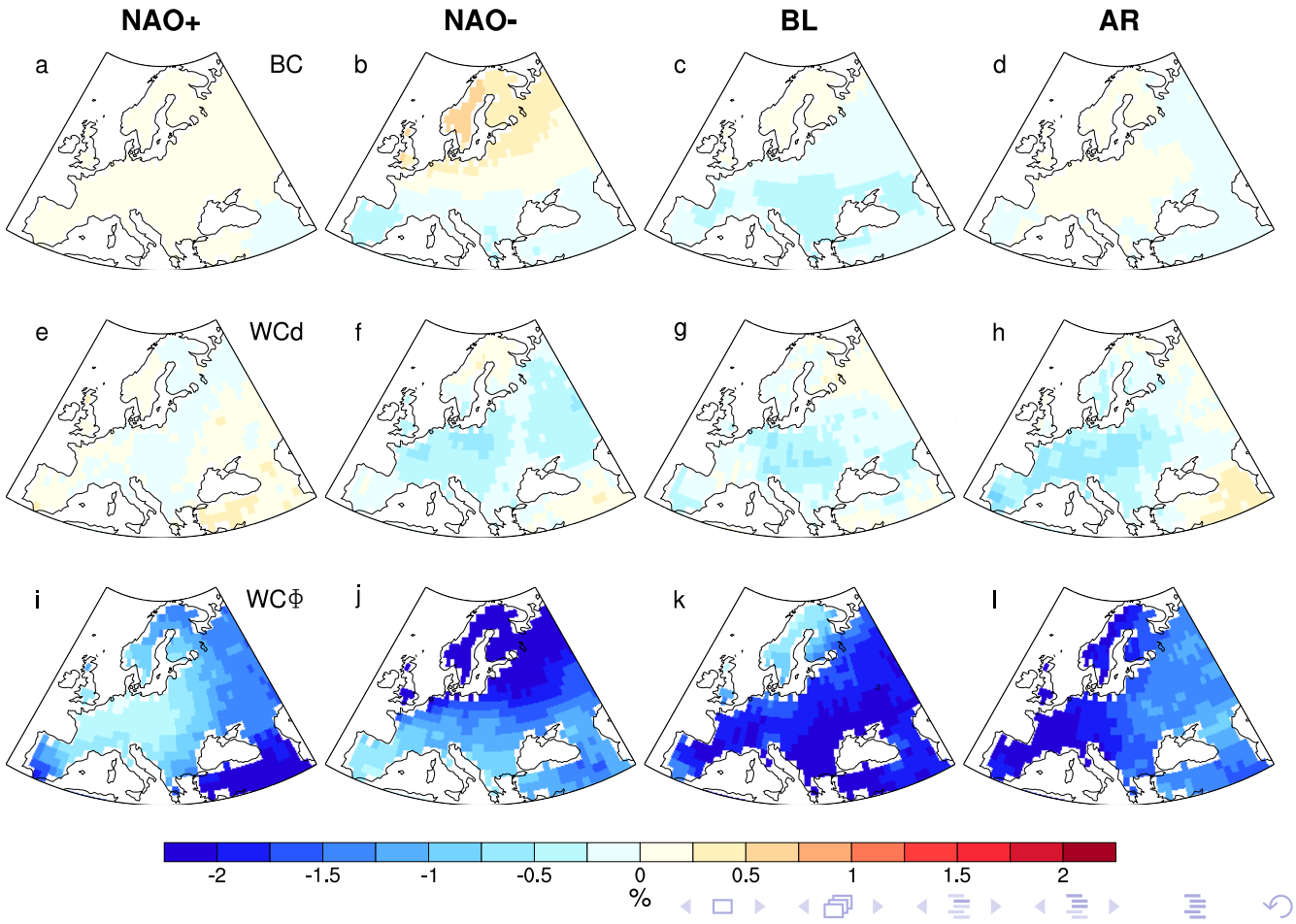
Regimes frequencies (Δf_k)

Regimes structures (Δd_k)

Non-dynamical processes ($\Delta\Phi$)



Contributions to temperature extremes

Uncertainties

Ensemble standard deviation of each term in:

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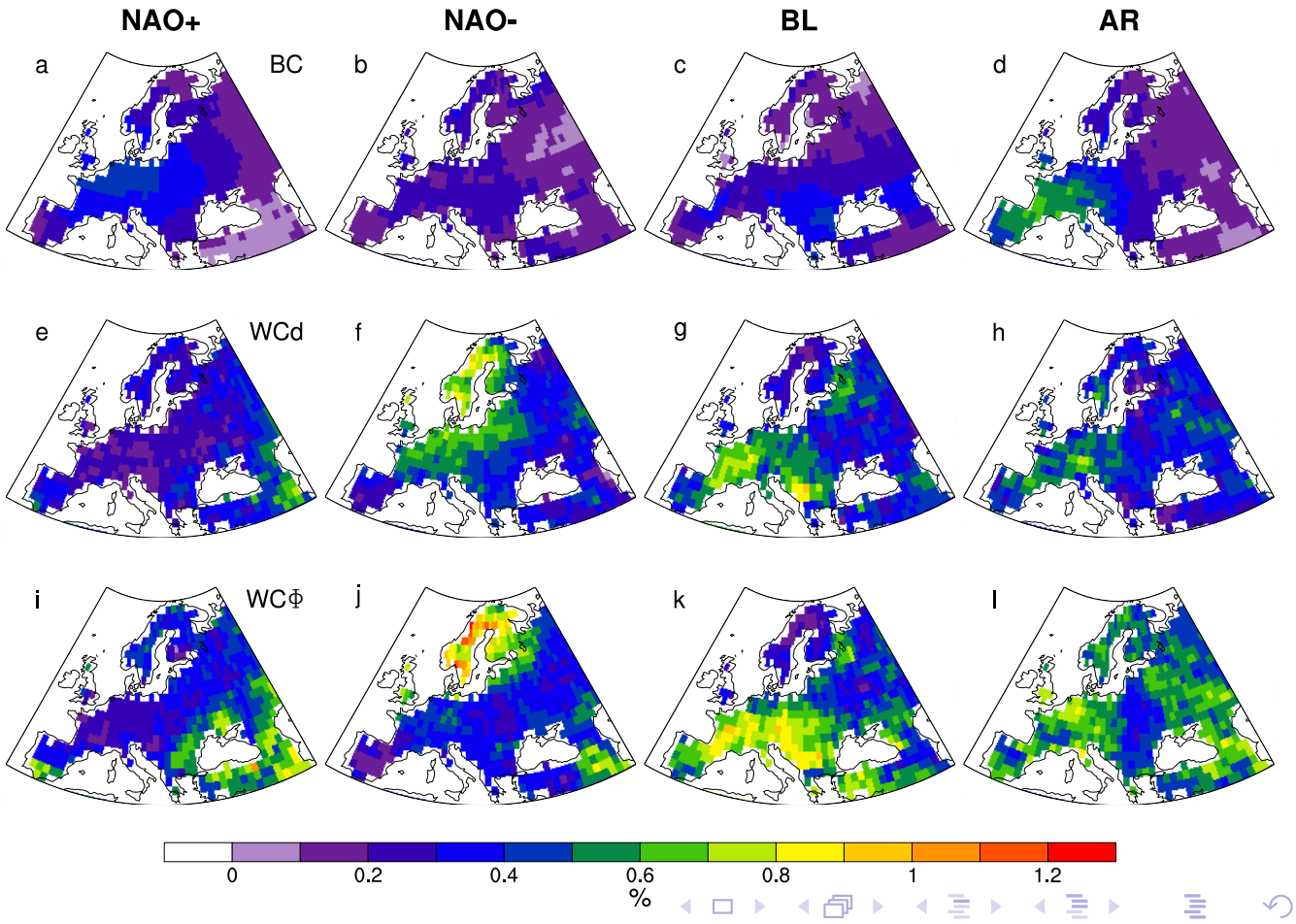

Concluding remarks

Summary

- Original methodology to separate dynamical *vs.* non-dynamical contributions to temperature changes.
- CMIP5: surprising future increase in NAO− conditions (to be confirmed...).
- Dynamical contribution: minor on mean changes, substantial on uncertainties.

Work in progress...

- Understanding of physical contributions: radiative budgets, heat fluxes, surface variables...
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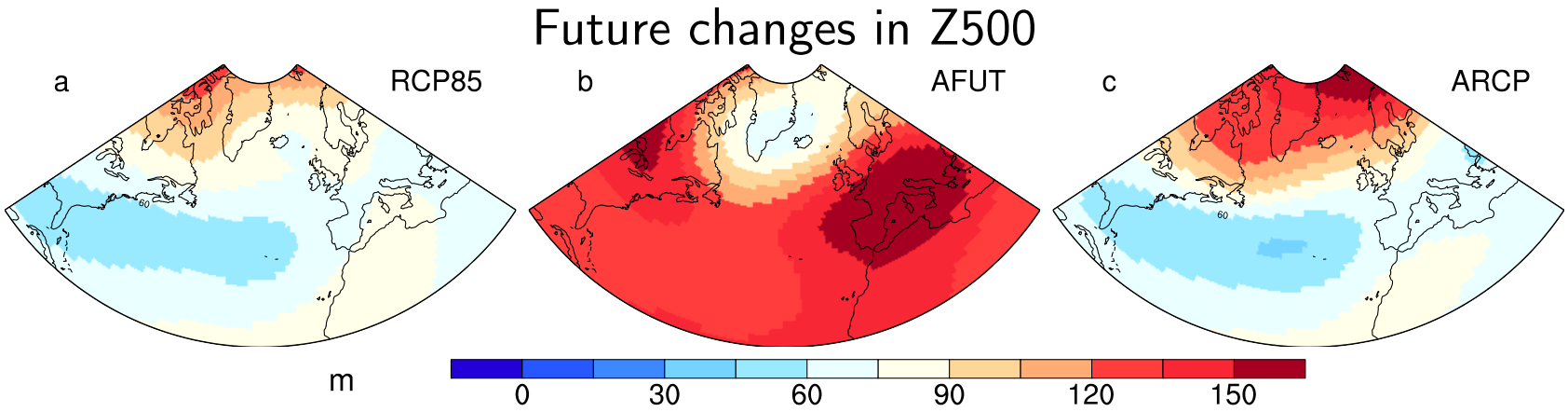
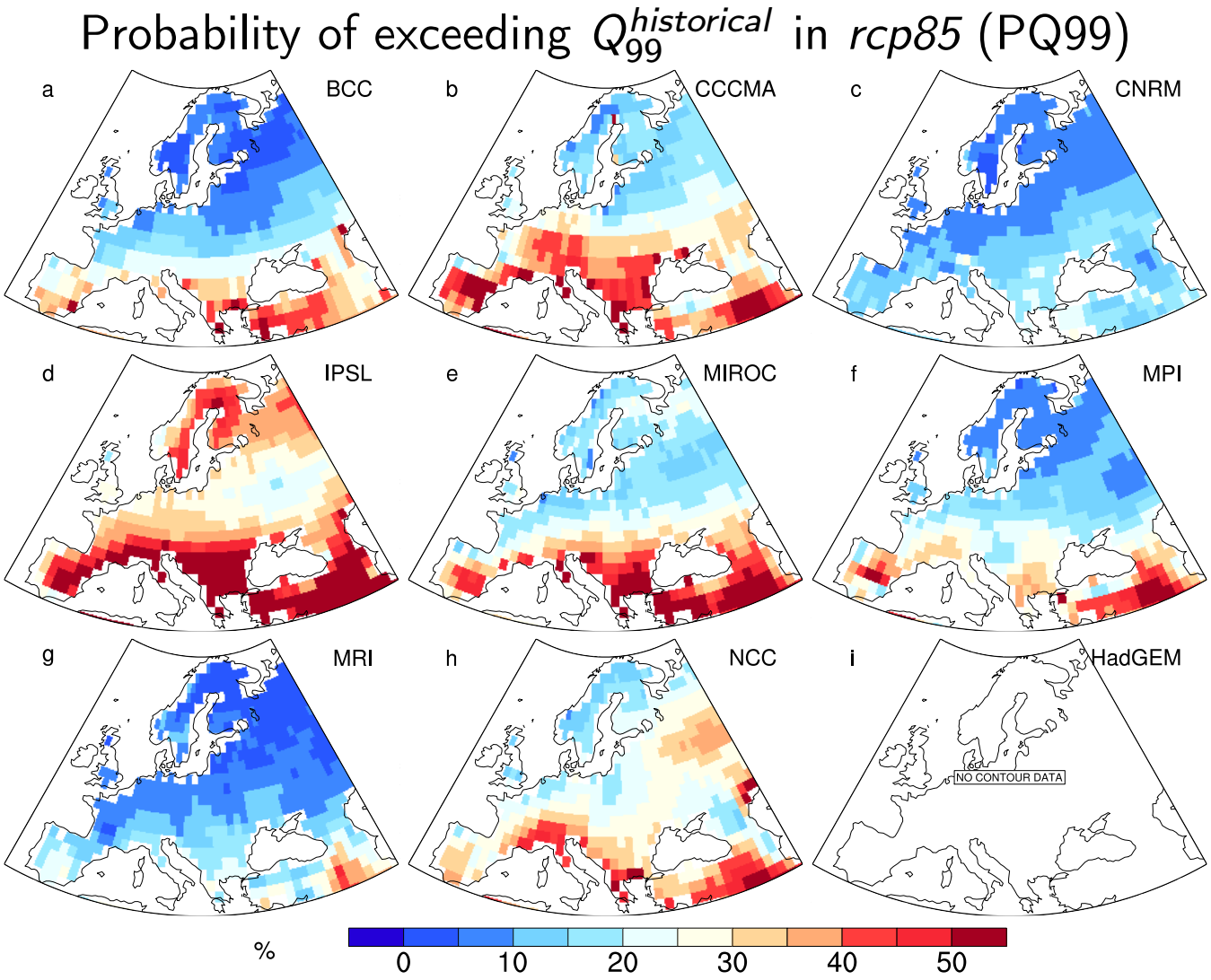
CNRM-CM5: Future increase of NAO+? NAO−?

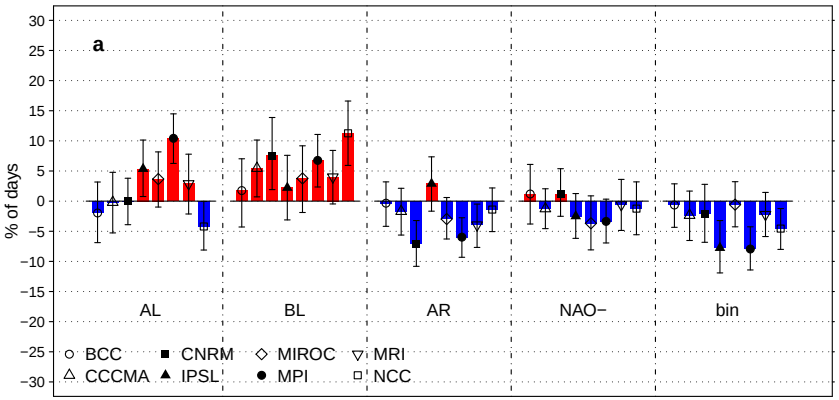


Future changes in summertime hot days

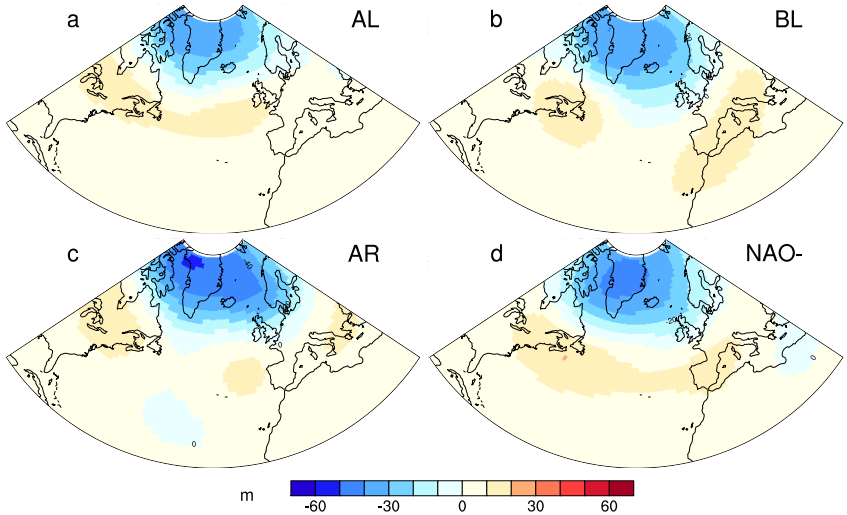


Changes in regimes frequencies and structures

Frequencies
(*rcp85*−*historical*)



Structures
(*rcp85* analogs vs. *historical*)



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Regimes structures (Δd_k)

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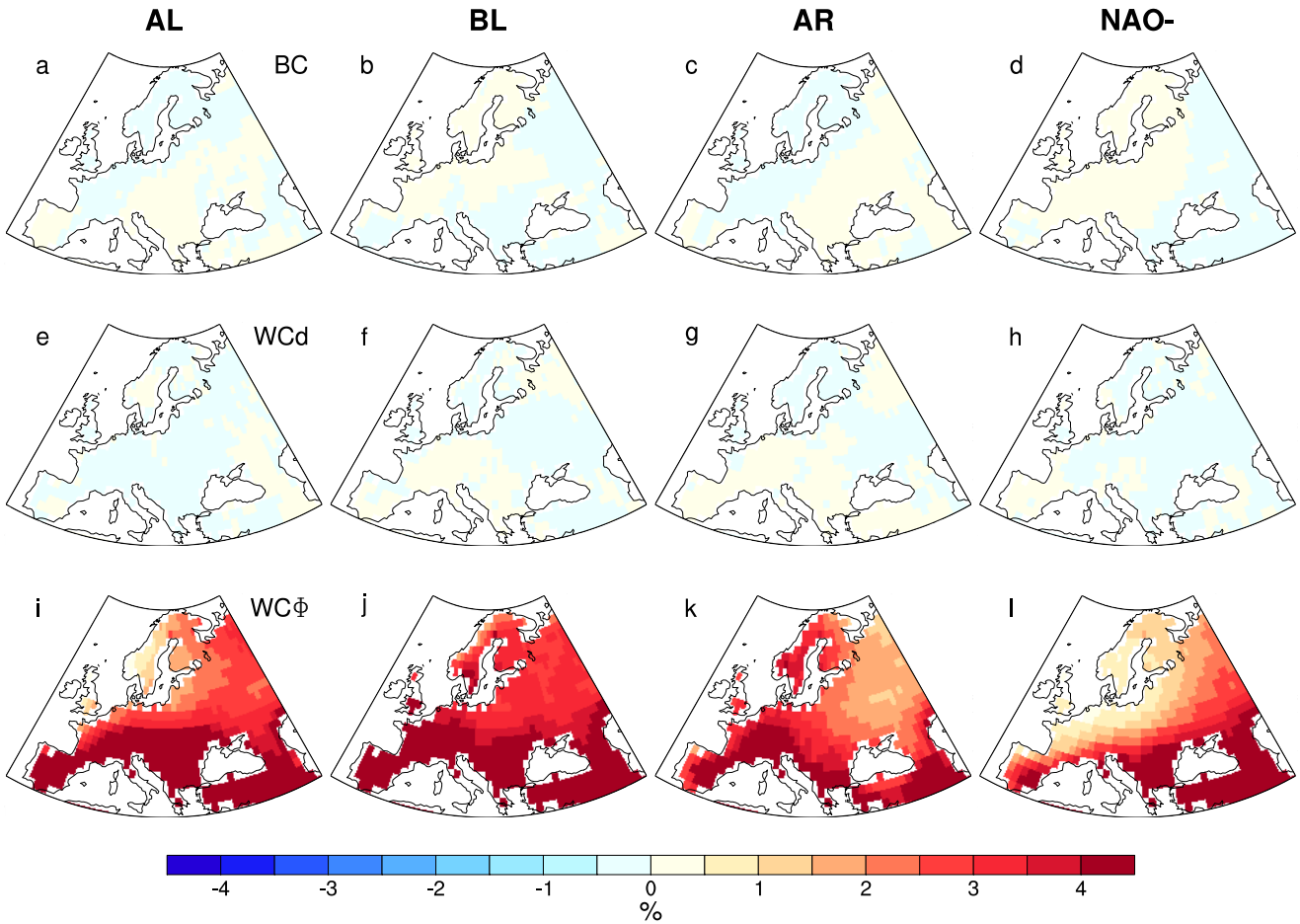

Contributions to summertime temperature extremes

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