Projected changes in the variability and extremes of European summer temperatures

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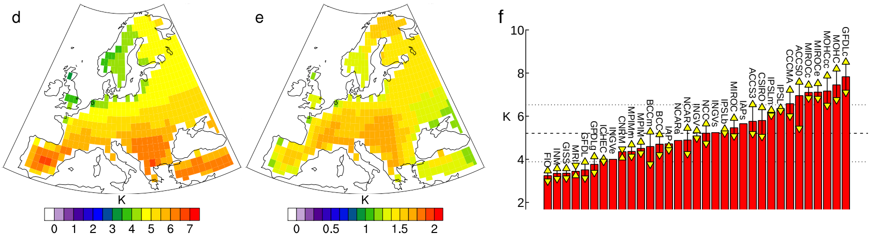
Motivations 1/2

- Europe is projected to warm, especially in summer.

Example of JJAS 2070–2099 vs. 1979–2008 in RCP8.5 (33 CMIP5 models):

Multi-model mean Inter-model spread Individual models



Motivations 2/2

- Evidences for increase in intra-seasonal and/or inter-annual variability:
  - in recent observations – Parey et al. 2010, Schär et al. 2004, Yiou et al. 2009;
  - in regional climate projections – Fischer and Schär 2009, Kjellström et al. 2007;
  - in CMIP3 global climate projections – Cattiaux et al. 2011.
- Soil drying and atmospheric circulation suggested as physical drivers.
- Both mean and variability contribute to warm extremes.

Our aim:

- document changes in **intra-seasonal variability in CMIP5**;
- identify **physical drivers** and understand the model discrepancies;
- quantify contributions of mean and variance to changes in **heat waves**;
- investigate observational **constraints** to reduce future uncertainties.

What we did E3P project

- **Variability – focus on day-to-day and within-day variations:**
  - Inter-diurnal temperature variability:

$$\mathrm{ITV} = \frac{1}{n_d - 1} \sum_{d=1}^{n_d - 1} |\mathrm{ITD}_d| = \frac{1}{n_d - 1} \sum_{d=1}^{n_d - 1} |T_{d+1} - T_d|$$

  - Diurnal temperature range:

$$\mathrm{DTR}_d = T_d^x - T_d^n.$$

- **Heat waves – definition of events**
  - At least 3 days with $T > T98$ over at least 30% of our domain.

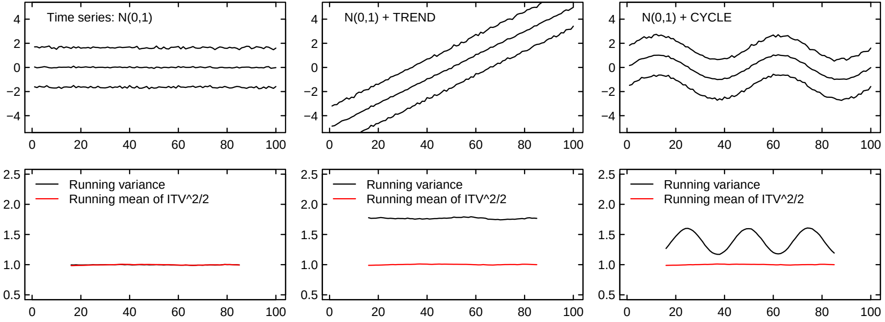
- **Data:**
  - 34 CMIP5 models, historical and future simulations (3 RCPs);
  - changes assessed as differences between 1979–2008 and 2070–2099;
  - EOBS temperatures for evaluation over 1979–2008;
  - 10 historical runs of CNRM-CM5 for internal variability.

Why ITV?

- Day-to-day absolute variations are linked to the daily variance:

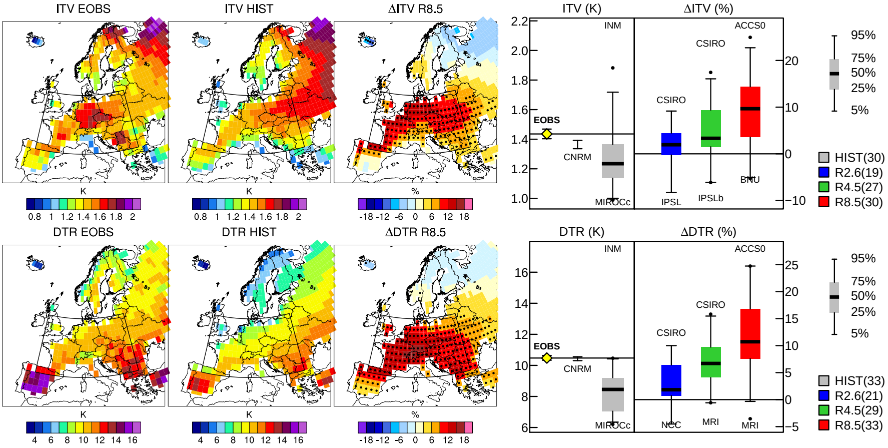
$$|\mathrm{ITD}_d| = |T_{d+1} - T_d| = \sqrt{2}\,\sigma(T_{[\![d,d+1]\!]})$$

- Contrarily to the variance, the ITV is not sensitive to long-term variations:



Based on 1000 random simulations of white noises.

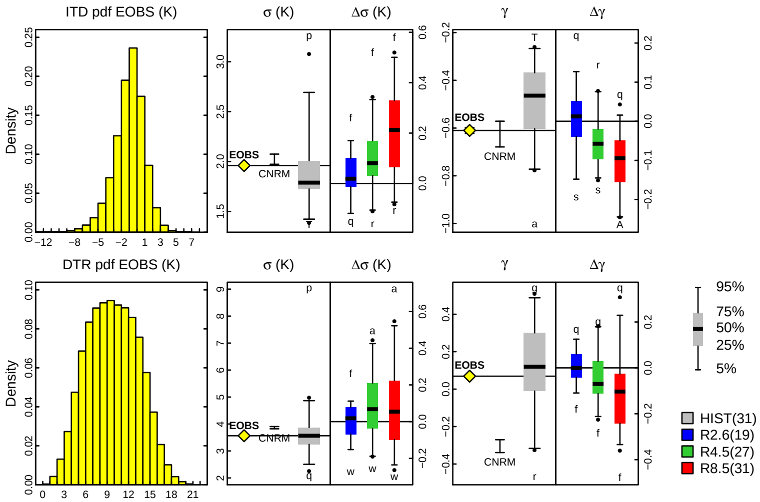
ITV & DTR changes The mean



- Increase consistent with Kim et al. 2013, Lindvall & Svensson 2014 (global).

ITV & DTR changes The pdf

- Widening of the ITV distribution vs. shift of the DTR distribution.



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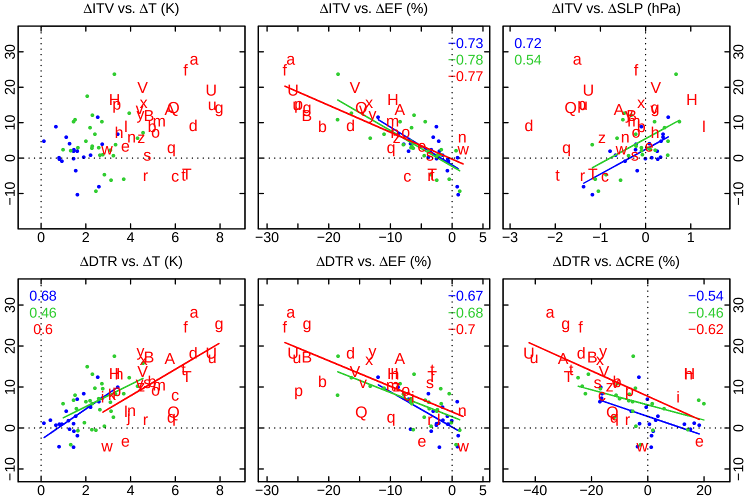
Drivers of the variability increase

- Role of soil drying, circulation (ITV) and cloudiness (DTR).



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Circulation vs. other drivers Methodology

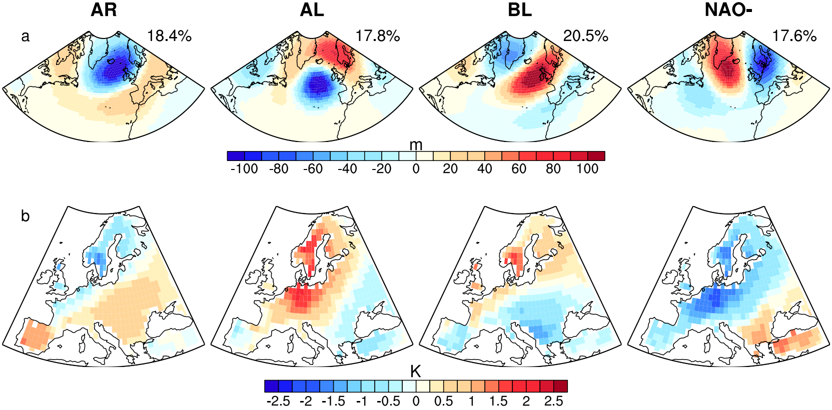
- For X the ITV or DTR: $\overline{X} = \sum_k f_k \cdot x_k = \sum_k f_k \cdot \Phi(z_k)$.

$f_k \rightarrow$

$\boxed{z_k}$

$\downarrow \Phi$

$\boxed{x_k}$

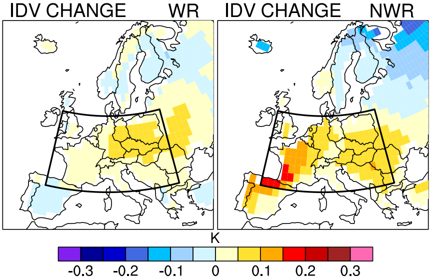


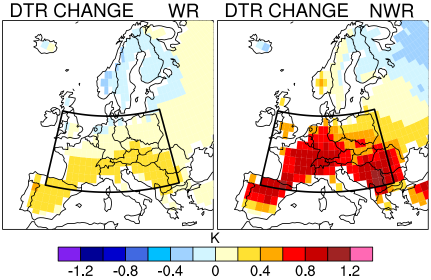
Data: Z500 NCEP2 & DTR EOBS | Methodology: Cattiaux et al., 2013, *Clim. Dyn.*

Circulation vs. other drivers Results

- For X the ITV or DTR: $\overline{X} = \sum_k f_k \cdot x_k = \sum_k f_k \cdot \Phi(z_k)$.

$$\Delta\overline{X} = \underbrace{\sum_k \Delta f_k \cdot \Phi(z_k) + \sum_k f_k \cdot \Phi(\Delta z_k)}_{\text{Weather Regimes (WR)}} + \underbrace{\sum_k f_k \cdot \Delta\Phi(z_k)}_{\text{Non WR}} + \varepsilon$$





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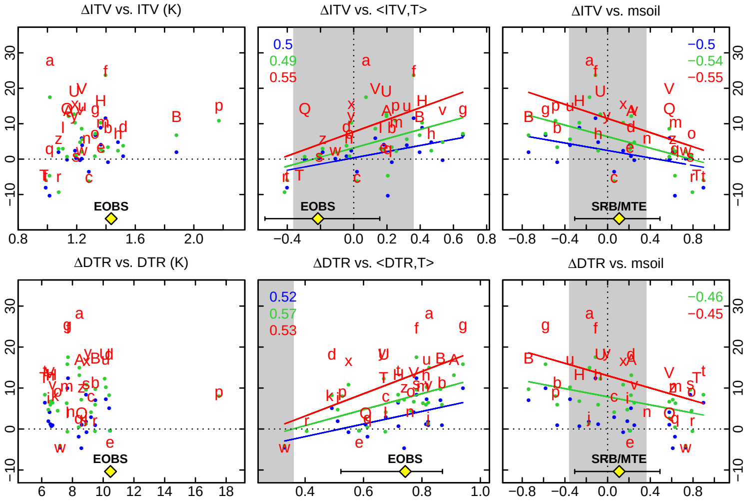
Can we reduce future uncertainties?

- **Emerging constraints** in inter-annual present-day correlations.



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Heat waves

Heat waves More details on the methodology

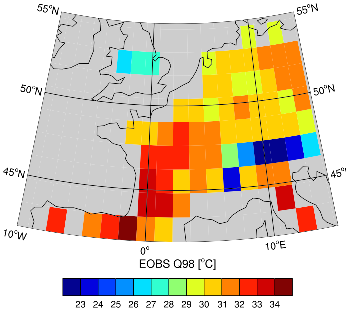
- **Heat wave definition:**

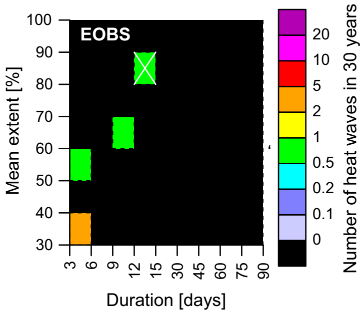
For each model, an event is at least 3 consecutive days with at least 30% of grid points where *Tmax* exceeding the 98th percentile of the MJJASO 1979–2008 distribution.

- **Heat wave characteristics:**

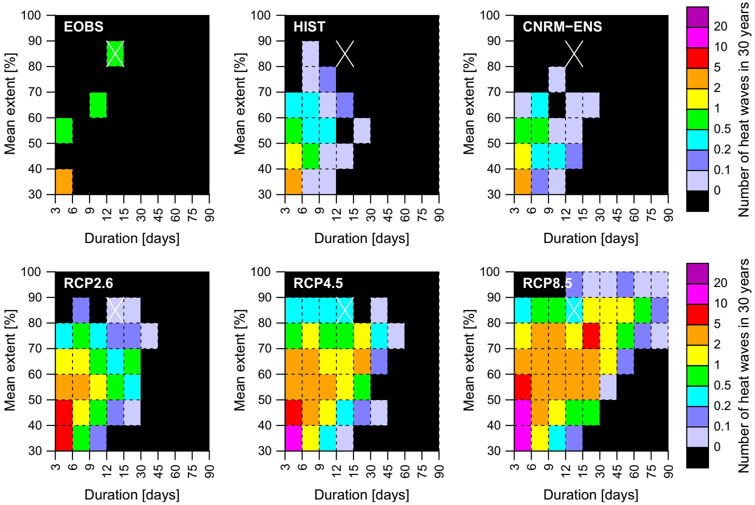
Number, duration (days), intensity (K), extent (%), and severity (product of all).

Example : 7 events in EOBS 1979–2008, with August 2003 the most severe.





Changes in heat waves characteristics 1/2



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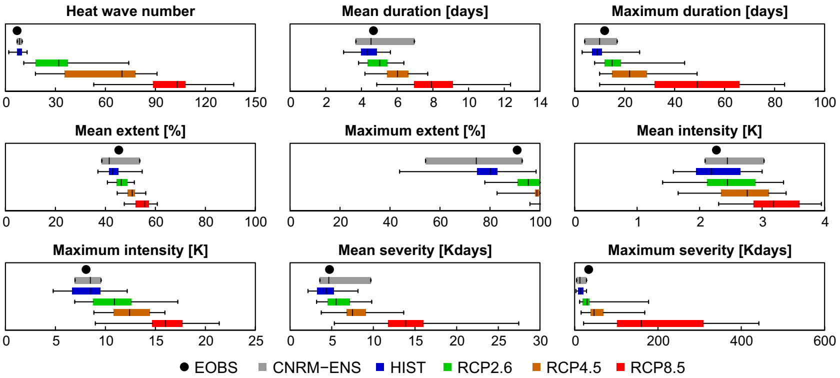
Changes in heat waves characteristics 2/2

- Increase in all *statistics* of heat waves.
- Uncertainties due to scenario, model and internal variability.



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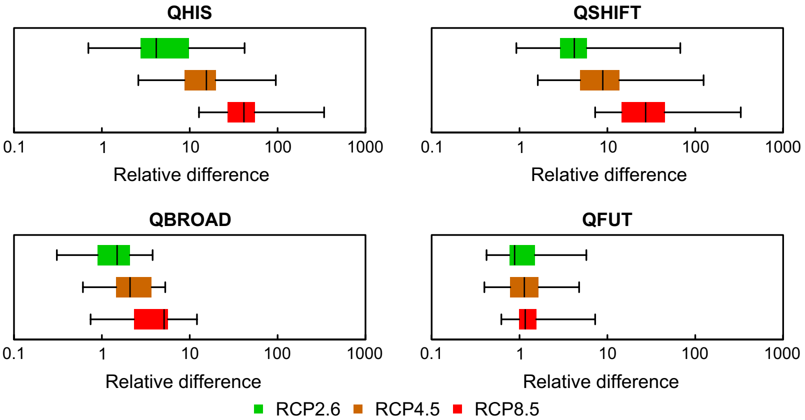
Contribution of mean and variability

Contribution of mean: threshold $QSHIFT = Q98_{FUT} - \Delta Q50$

Contribution of variability: threshold $QBROAD = Q98_{FUT} - \Delta(Q98 - Q50)$



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Summary

- ✓ Increase in short-term European summer temperature variability,
- ✓ Associated with soil drying, circulation changes (ITV) and cloudiness reduction (DTR).
- ✓ Contributes to the increase in heat wave severity.
- ✓ Emerging constraints in inter-annual present-day correlations.

⟶ Detection and attribution of present-day trends?

⟶ Sensitivity experiments to quantify the contributions of the different drivers (+ explore others, e.g. changes in horizontal temperature gradients)?

⟶ Life-cycle analysis of heat waves? Schoetter et al., in revision for *GRL*.

Cattiaux, J., H. Douville and Y. Peings (2013), European temperatures in CMIP5: present-day biases and future uncertainties, *Clim. Dyn.*, 41 (11-12), 2889-2907. doi :10.1007/s00382-013-1731-y.

Cattiaux, J., H. Douville, R. Schoetter, S. Parey and P. Yiou (2015), Projected increase in diurnal and inter-diurnal variations of European summer temperatures, *Geophys. Res. Lett.*, online. doi:10.1002/2014GL062531.

Schoetter, R., J. Cattiaux and H. Douville (2015), Changes of western European heat wave characteristics projected by the CMIP5 ensemble, *Clim. Dyn.*, online. doi :10.1007/s00382-014-2434-8.

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