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ETH zürich

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European Climate Prediction system

Constraining European projections

EUCP progress towards a unified method

Lukas Brunner | EUCP final workshop | May 4th 2022

with contributions from all of WP2 & EUCP

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Constraining future projections – IPCC AR6

There are [...] good reasons for basing an assessment of future global climate on lines of evidence in addition to the [unconstrained] projection simulations. However, despite some progress, no universal, robust method for weighting a multi-model projection ensemble is available […]

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Measuring the benefit of constraining projections

From weather forecasting: “What Is a Good Forecast?” Murphy 1993

- **Accuracy**: level of agreement between forecast and truth
- **Skill**: accuracy relative to a reference forecast
- **Reliability**: average agreement between forecasts and truth
- **Sharpness**: tendency of the forecast to predict specific values

} **Quality**

- **Consistency**: forecast is consistent with prior knowledge
- **Value**: degree to which the forecast helps decision makers

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What is good constraining? - we don't know the 'truth'

- **Accuracy**: level of agreement between **constrained projection** and 'truth'
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- **Sharpness**: tendency of the **constrained projections** to predict specific values compared to the **unconstrained projections**

- **Consistency**: **constraint** is consistent over different methods
- **Value**: degree to which the **constrained projection** helps users

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Individual perfect model tests
Brunner et al. 2020a, O'Reilly2020, Ribes et al. 2021

Combined perfect model tests
O'Reilly et al. in preparation

Comparison and combination of methods Brunner et al. 2020b, Hegerl et al. 2021

Muli-User Forum

Application for impact studies
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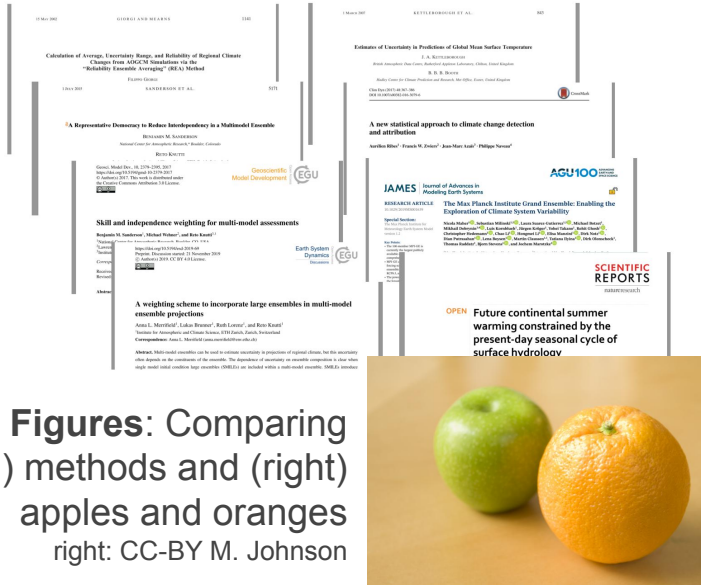
Comparing different constraining methods is not straight-forward

No **coordinated framework** to compare methods exist. They might differ for a range of reasons independent of the methods itself:

- variable (e.g., temperature vs precipitation)
- region and mask (e.g., global vs Europe)
- season, time period, and reference period
- models included (incl. members included)
- uncertainties included (e.g., internal variability)
- reported results (e.g., mean vs median)



Figures: Comparing (top) methods and (right) apples and oranges

right: CC-BY M. Johnson

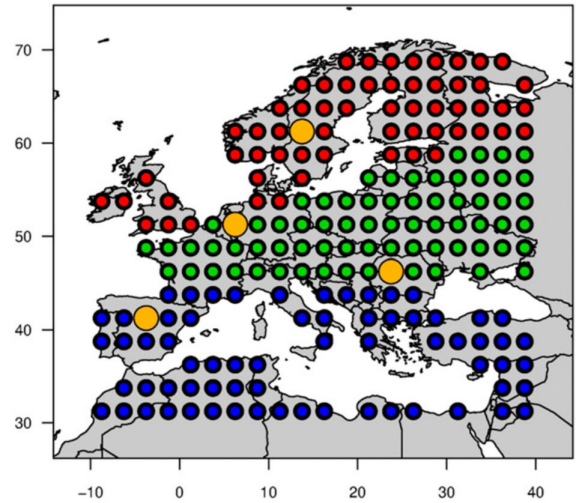
A common framework for method comparison

Goals

- **consistent** over all methods
- **inclusive** to allow as many methods as possible to participate
- **unambiguous** guidelines
- **easy** to apply

Drawbacks

- not the best possible setup for individual methods
- potentially not the most interesting cases scientifically



Brunner et al. 2020b

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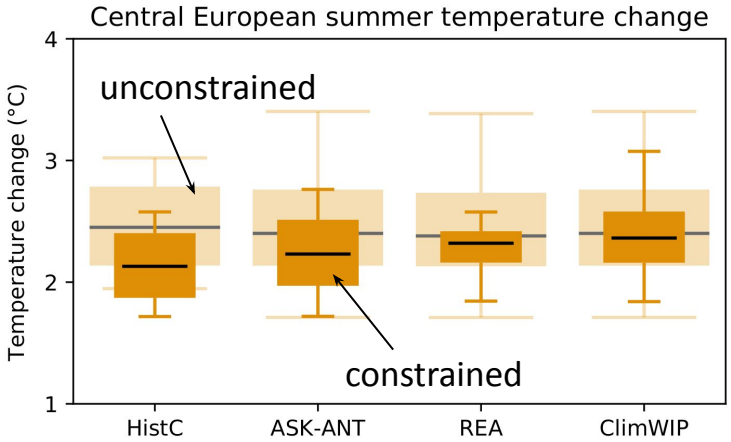
Projections for Central European summer temperature with CMIP5

- Example of most consistent setup
  ⟶ Excludes some methods
- Remaining differences of HistC can be explained:
  - calculation of percentiles
  - different handling of internal variability
- **Methods consistently narrow the uncertainty range and agree on slightly less warming**
  ⟶ not all cases look that nice



2041-60 minus
1995-2014

Brunner et al. 2020b

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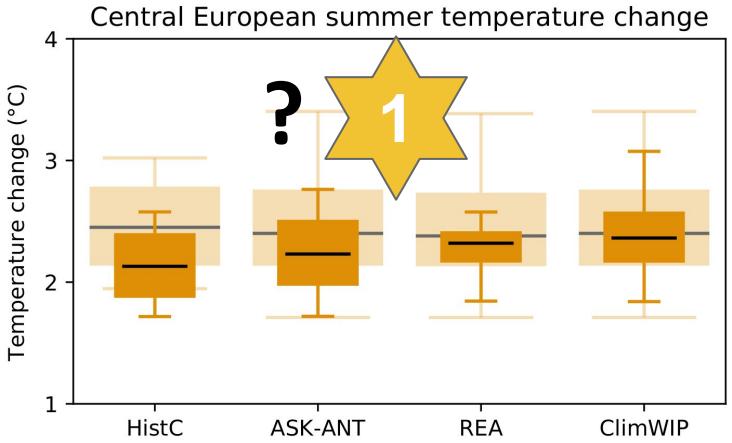
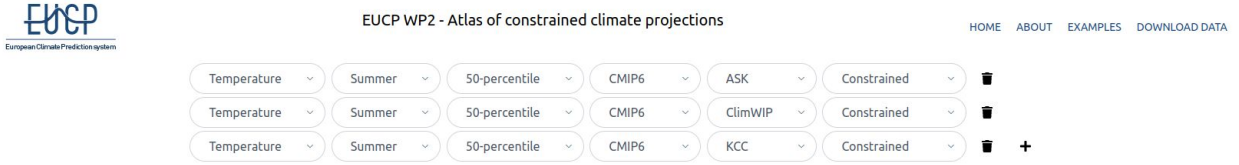
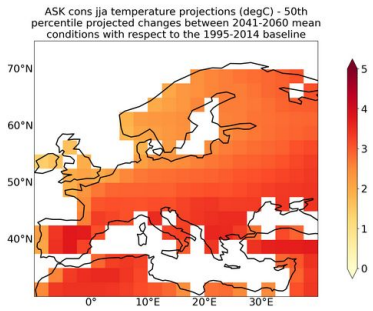
- What's the 'best' method? ⟶ talk by Chris

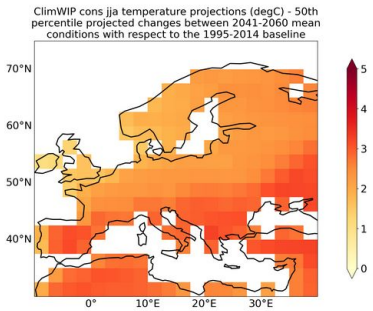


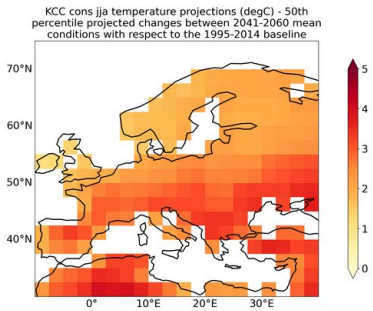
Brunner et al. 2020b

Projections for European summer temperature with CMIP6





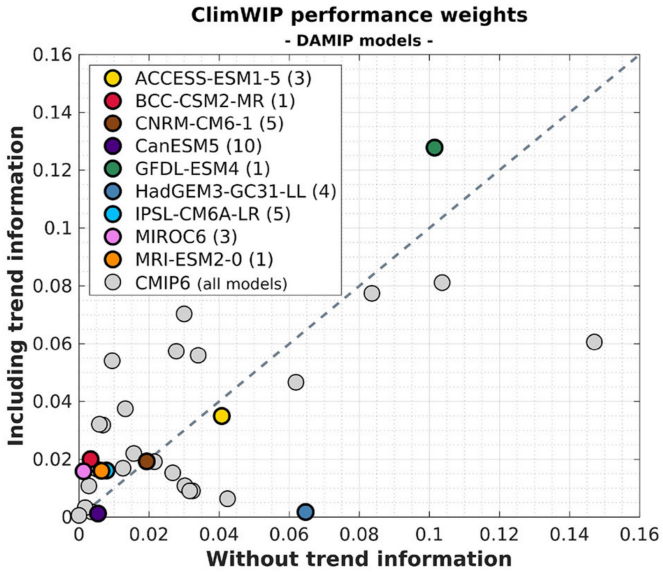




https://eucp-project.github.io/atlas/

→ talk by Peter

Combining different constraints/constraining methods is even less straight-forward



Example: Combining ClimWIP and ASK and interpreting the role of temperature trend

Hegerl et al. 2021

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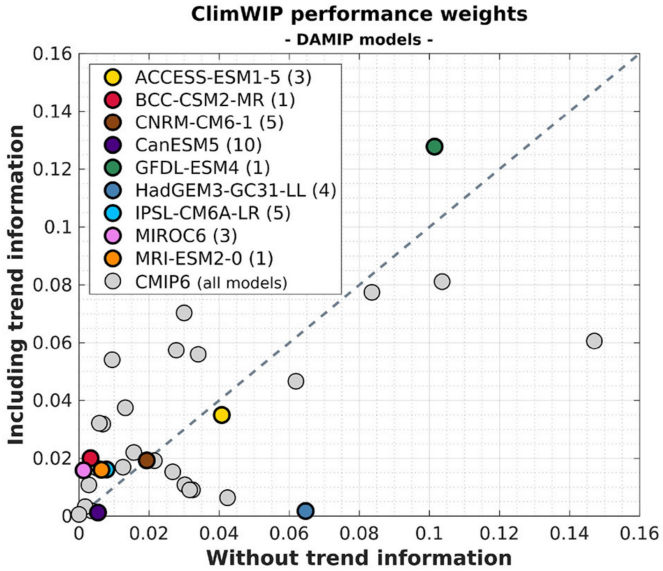

Example: Combining ClimWIP and ASK and interpreting the role of temperature trend

"[...] different information used can pull observational constraints in different directions."

"[We need] to avoid accounting for trends twice when applying the constraints subsequently [...]"

"[...] we need a common and consistent test protocol for skill and reliance to ensure performance."

Hegerl et al. 2021

Conclusions and Outlook

EUCP has contributed to developing more consistent constraints for Europe and globally

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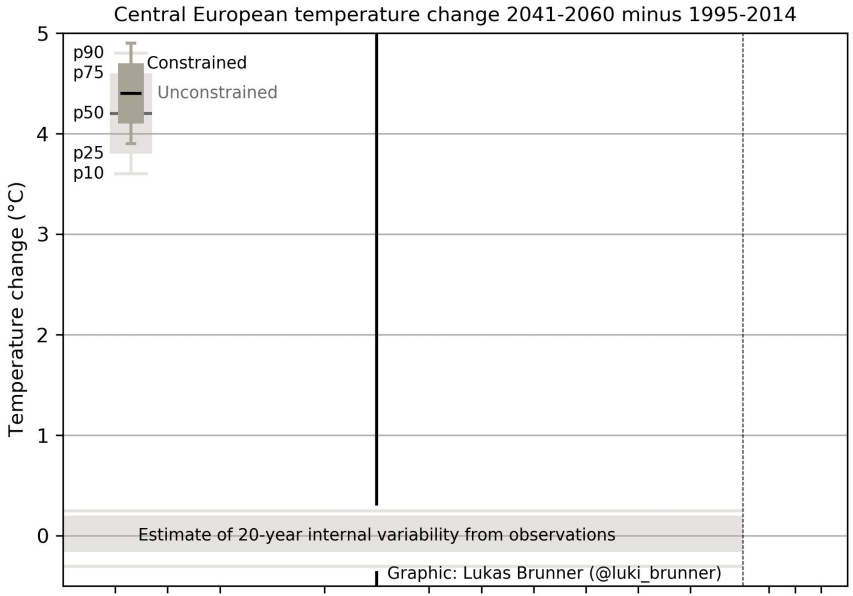
- Ongoing work on a method selection/combination ⟶ talk by Chris O'Reilly et al. in preparation
- New constraining challenges arising with the emergence of storm resolving models
  - border between NWP and climate projections starts to blur
  - climatological time scales not available due to computational limitations
  - new methods to evaluate models on shorter time scales Talk by Lukas at Climate Informatics Conference
    ⟶ "Classifying climate models based on temperature patterns from a single day using a convolutional neural network"

References

- Brunner, L., Pendergrass, A. G., Lehner, F., Merrifield, A. L., Lorenz, R., & Knutti, R. (2020). Reduced global warming from CMIP6 projections when weighting models by performance and independence. Earth System Dynamics, 11(4), 995–1012. https://doi.org/10.5194/esd-11-995-2020
- Brunner, L., McSweeney, C., Ballinger, A. P., Befort, D. J., Benassi, M., Booth, B., Coppola, E., de Vries, H., Harris, G., Hegerl, G. C., Knutti, R., Lenderink, G., Lowe, J., Nogherotto, R., O'Reilly, C., Qasmi, S., Ribes, A., Stocchi, P., & Undorf, S. (2020). Comparing Methods to Constrain Future European Climate Projections Using a Consistent Framework. Journal of Climate, 33(20), 8671–8692. https://doi.org/10.1175/JCLI-D-19-0953.1
- Ribes, A., Qasmi, S., & Gillett, N. P. (2021). Making climate projections conditional on historical observations. Science Advances, 7(4), eabc0671. https://doi.org/10.1126/sciadv.abc0671
- O'Reilly, C. H., Befort, D. J., & Weisheimer, A. (2020). Calibrating large-ensemble European climate projections using observational data. Earth System Dynamics, 11(4), 1033–1049. https://doi.org/10.5194/esd-11-1033-2020
- Hegerl, G. C., Ballinger, A. P., Booth, B. B. B., Borchert, L. F., Brunner, L., Donat, M. G., Doblas-Reyes, F. J., Harris, G. R., Lowe, J., Mahmood, R., Mignot, J., Murphy, J. M., Swingedouw, D., & Weisheimer, A. (2021). Toward Consistent Observational Constraints in Climate Predictions and Projections. Frontiers in Climate, 3(June), 1–22. https://doi.org/10.3389/fclim.2021.678109
- Sperna Weiland, F. C., Visser, R. D., Greve, P., Bisselink, B., Brunner, L., & Weerts, A. H. (2021). Estimating Regionalized Hydrological Impacts of Climate Change Over Europe by Performance-Based Weighting of CORDEX Projections. Frontiers in Water, 3. https://doi.org/10.3389/frwa.2021.713537

Projections for Central European summer temperature with CMIP5

- Most methods show a slightly lower constrained median warming
- Most methods show a reduction in spread
- More agreement in the central estimate than in extremes
- Not fully consistent: unconstrained distributions differ



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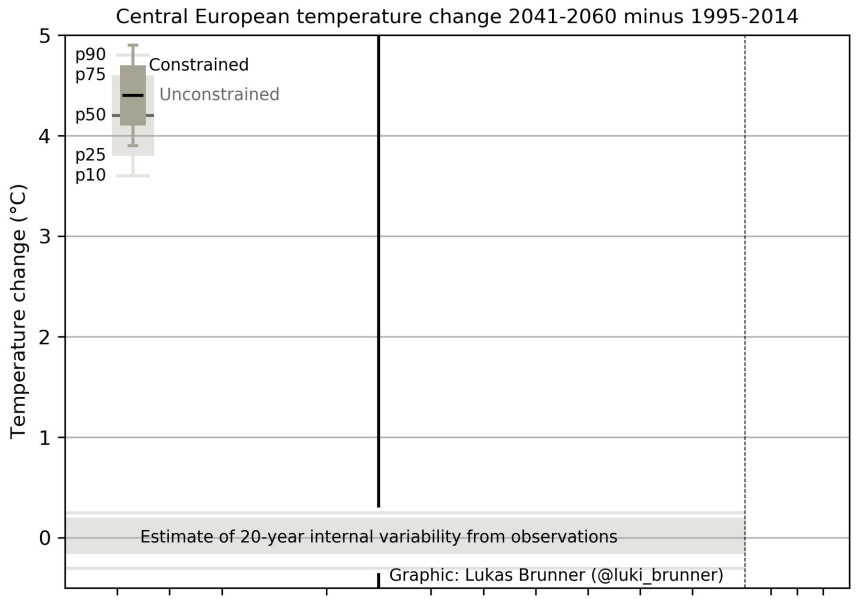

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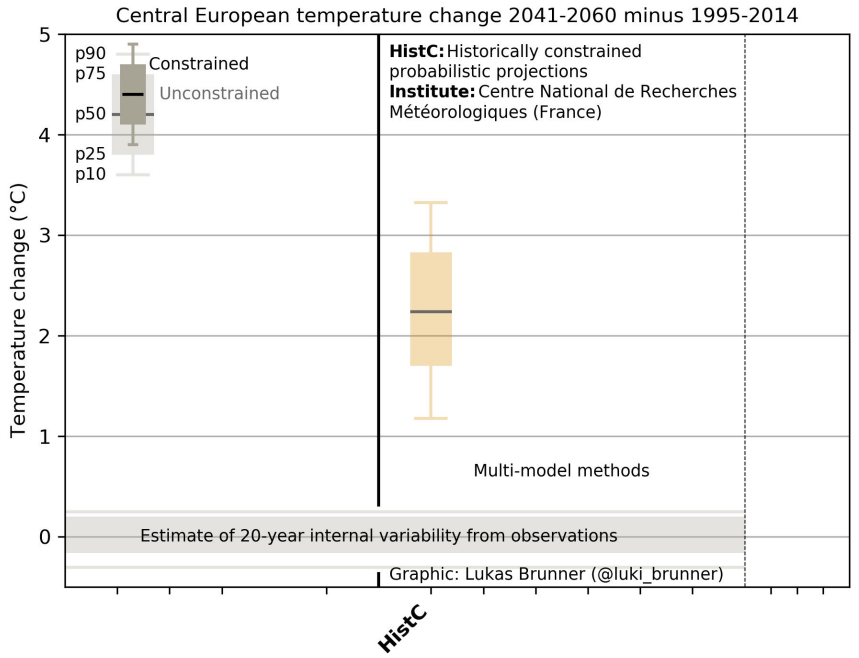

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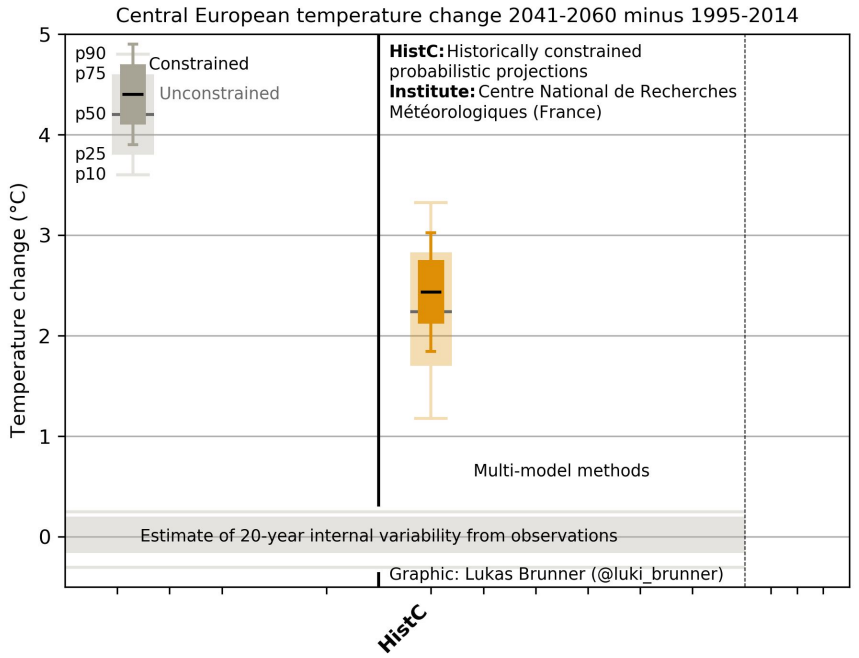

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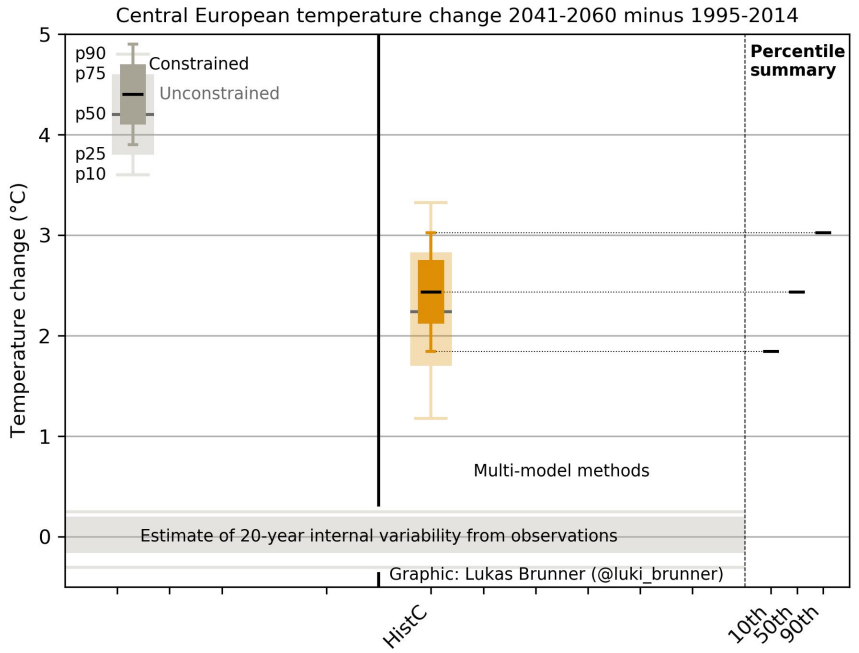

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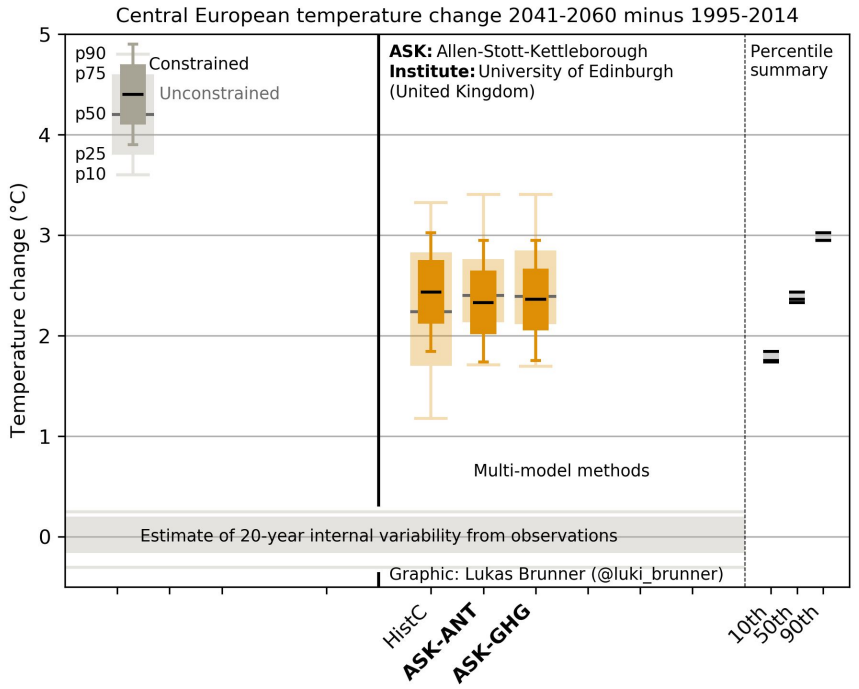

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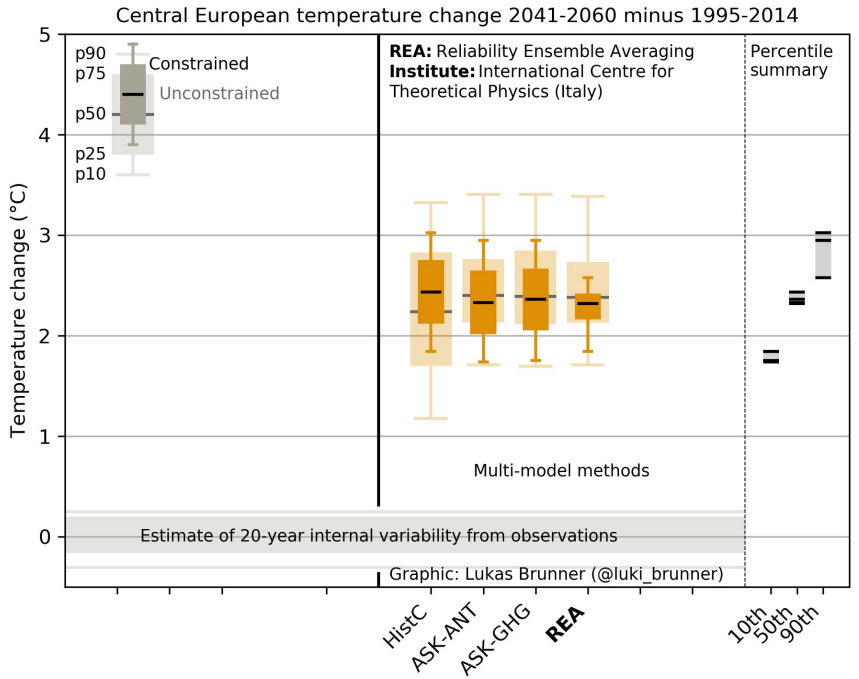

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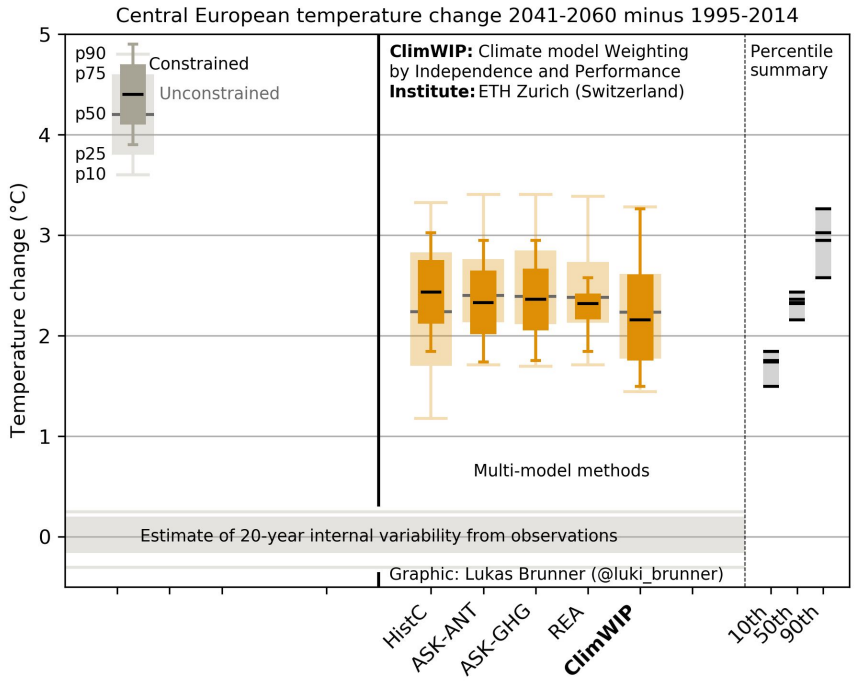

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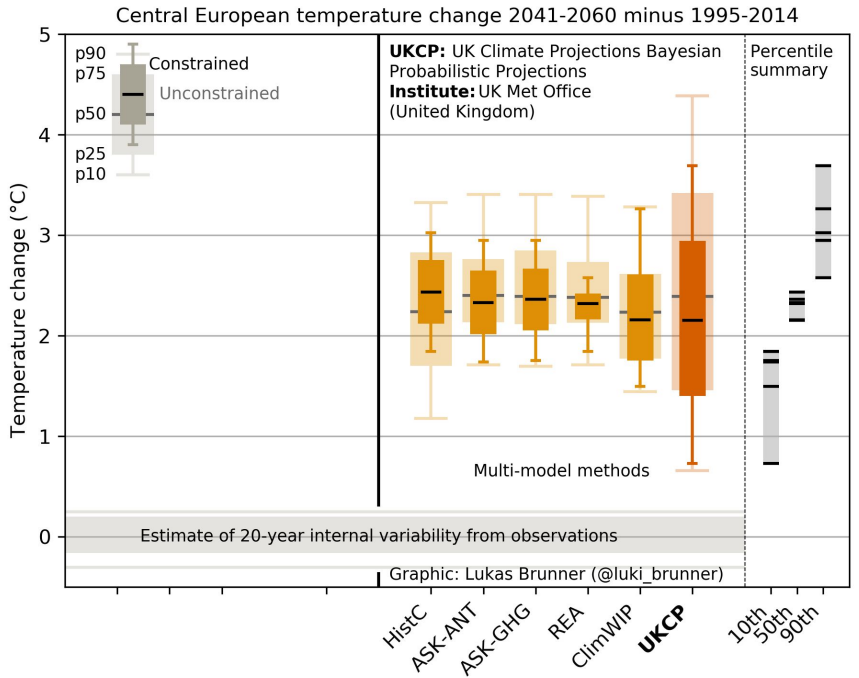

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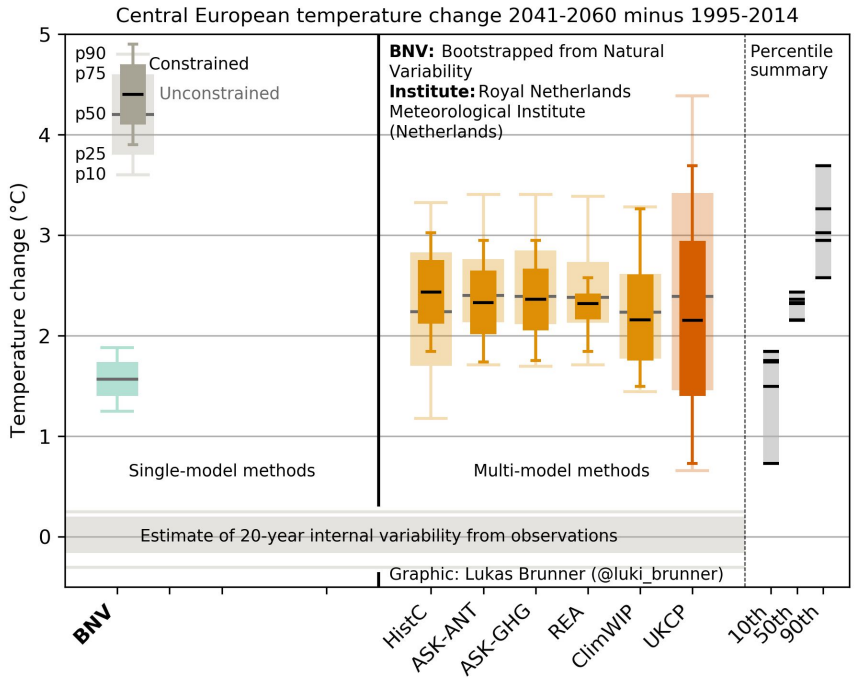

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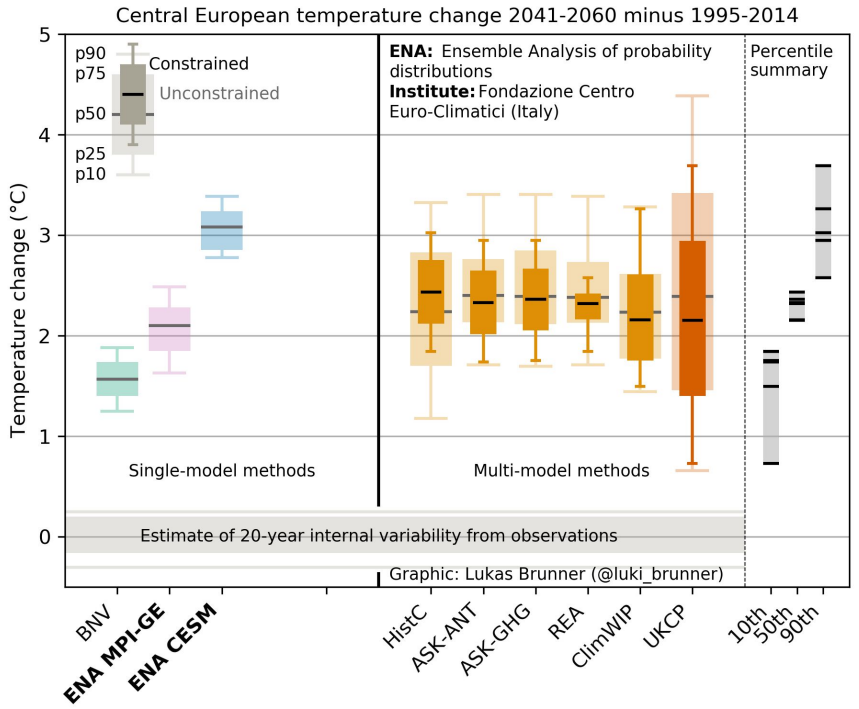

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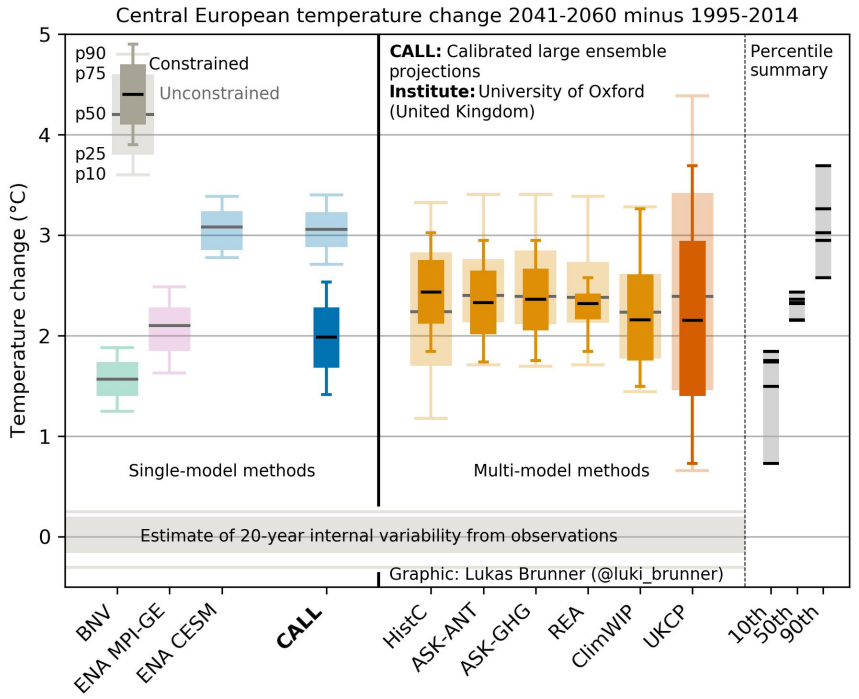

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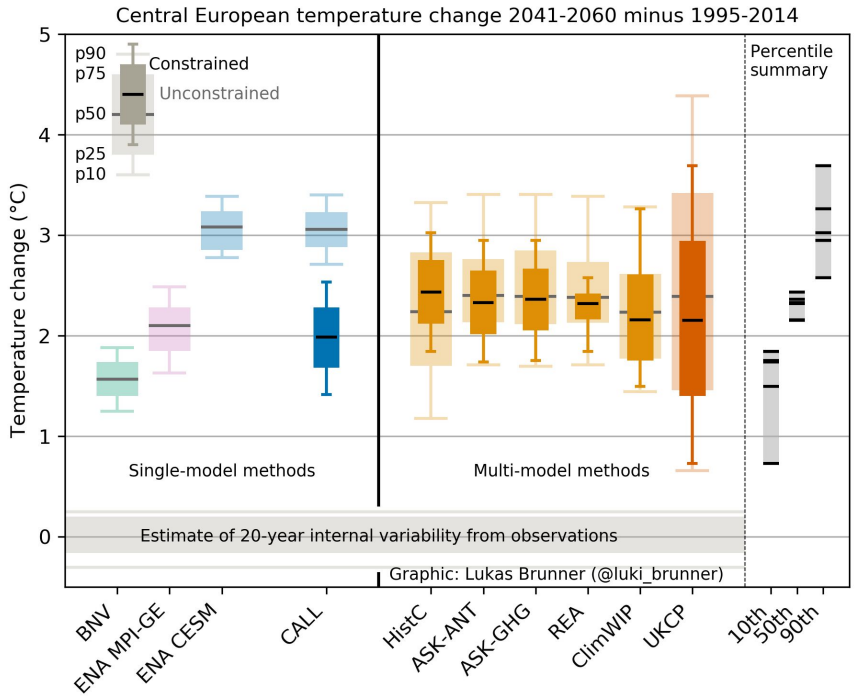

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