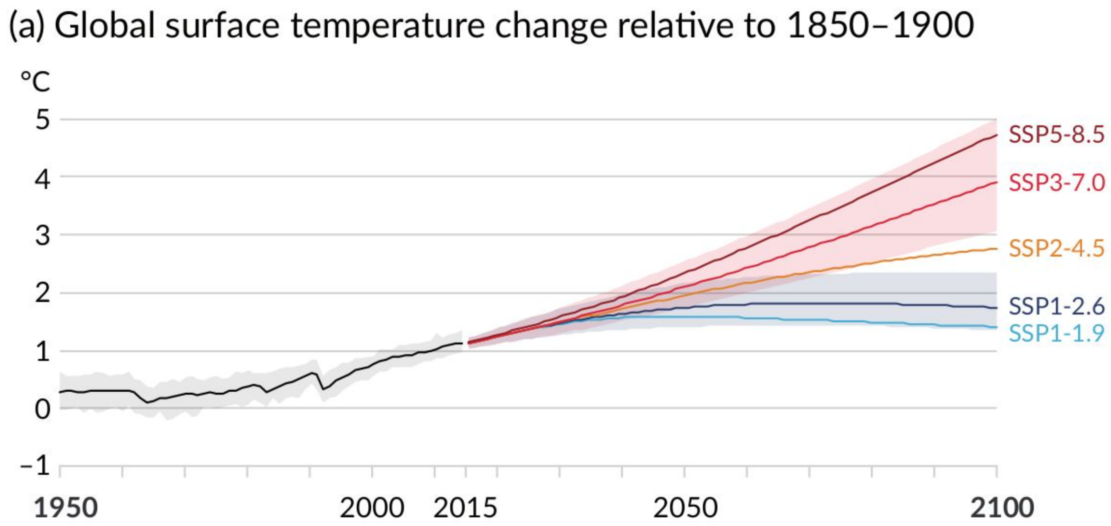
Separating Uncertainties in Projections of Future Climate – Importance, Lessons, and Solutions

Lukas Brunner | CliMatters Workshop | February 3rd 2022

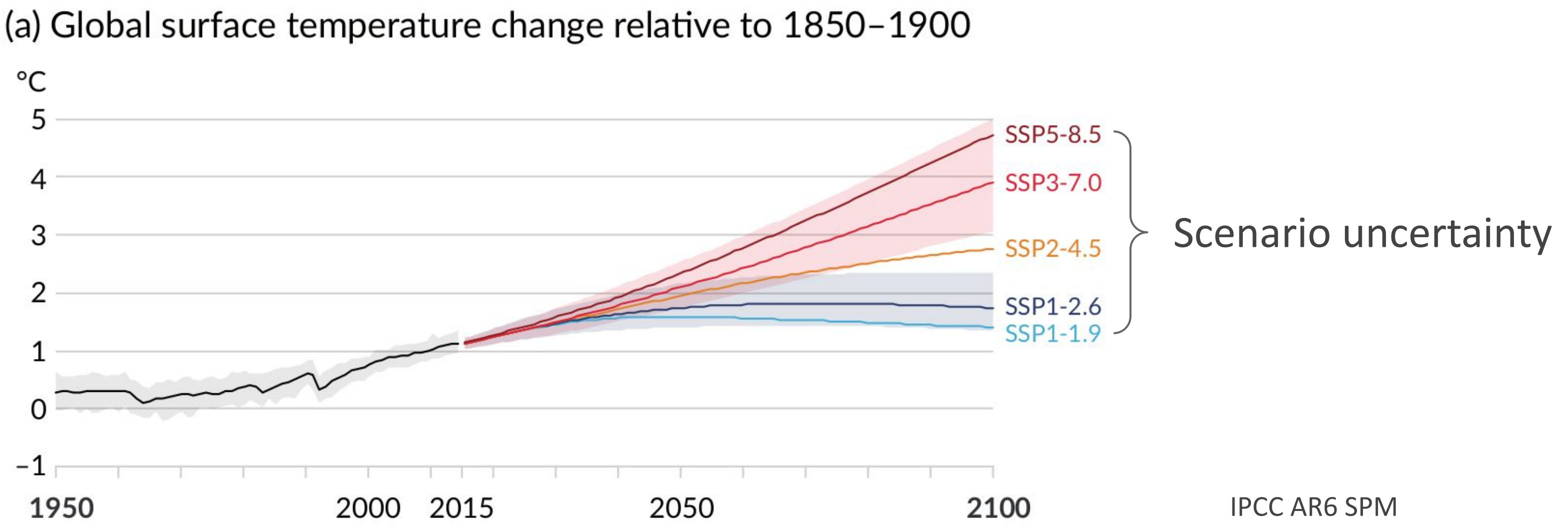
Many thanks to all collaborators!

Sources of uncertainty in projections of future climate



IPCC AR6 SPM

Sources of uncertainty in projections of future climate



IPCC AR6 SPM

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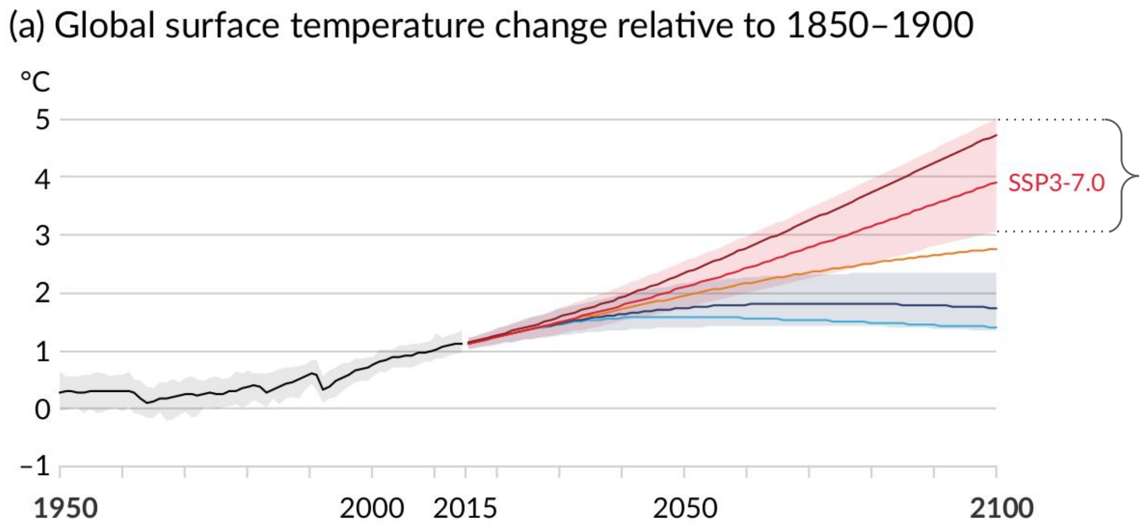
Sources of uncertainty in projections of future climate



Model uncertainty and internal variability

IPCC AR6 SPM

Interactions between uncertainties

Interaction between uncertainties I: robust changes

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The multi-model mean potentially hides the interaction between model uncertainty and internal variability

Precipitation change in the period 2081-2100 relative to 1986-2005 (SRES-A2 / RCP8.5 / SSP5-8.5). Brunner et al. (in preparation)

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Interaction between uncertainties I: robust changes

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figure

Robustness is a combination of the change signal in each model and the difference between models → **Model uncertainty**

Each model can show **significant** change → **internal variability**

Areas with low robustness but high significance are marked as **inconsistent**

Precipitation change in the period 2081-2100 relative to 1986-2005 (SRES-A2 / RCP8.5 / SSP5-8.5). Brunner et al. (in preparation)

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Interactions between uncertainties II: some lessons from EUCP

Challenge: compare different methods to constrain uncertainty in future changes

Comparing Methods to Constrain Future European Climate Projections Using a Consistent Framework

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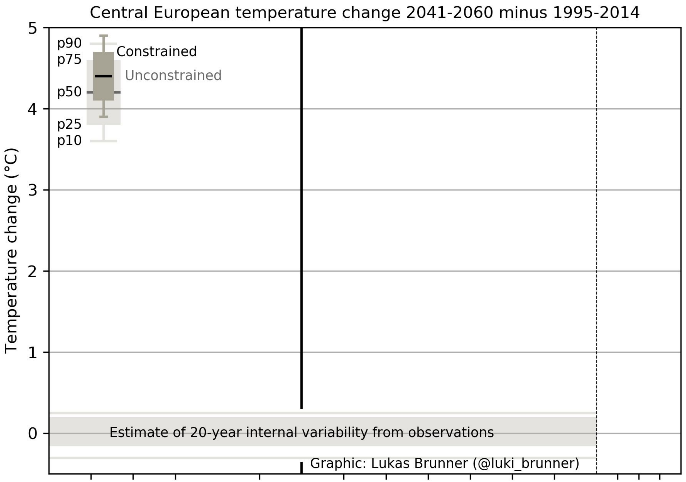
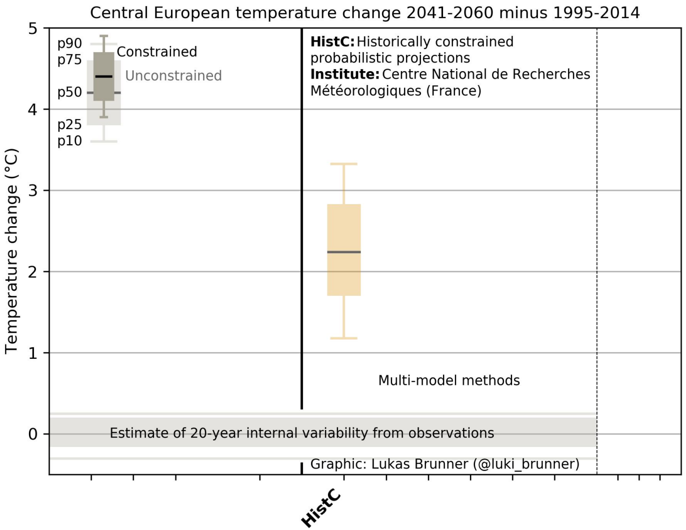
Comparing constrained projections from different methods



Brunner et al. (2020)

Comparing constrained projections from different methods



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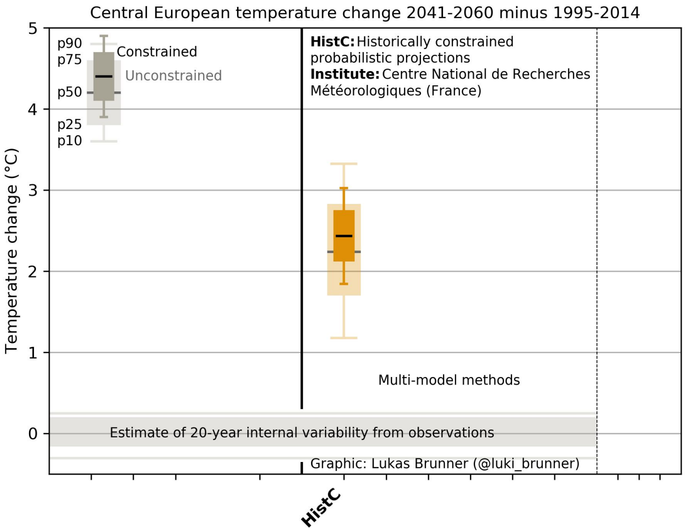

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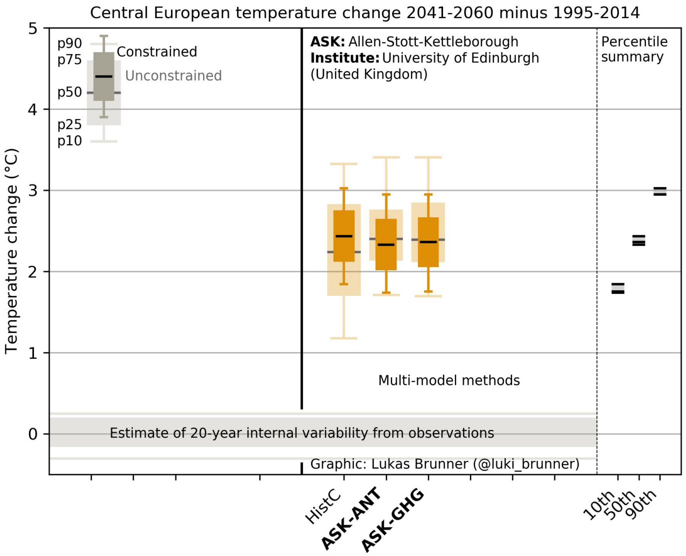

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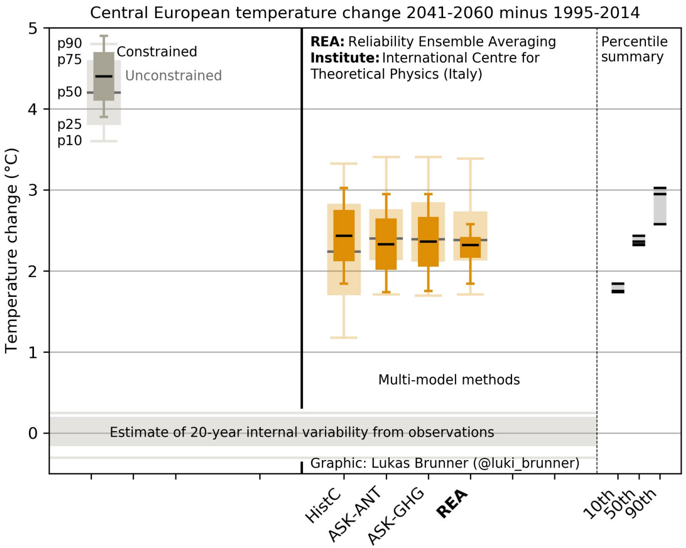

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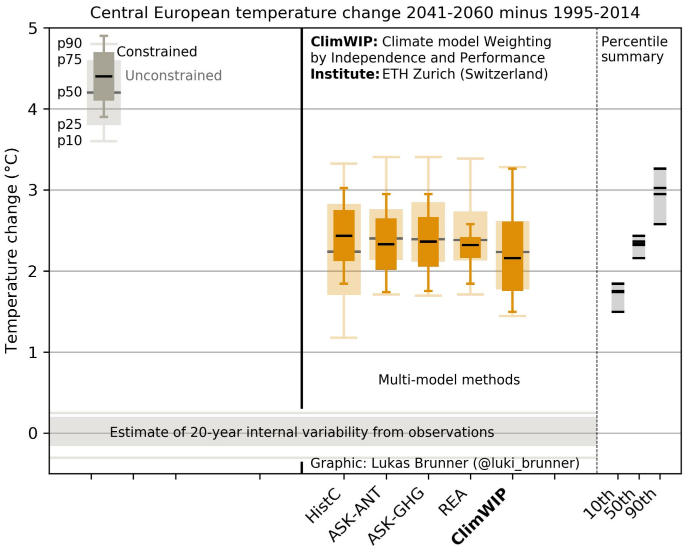

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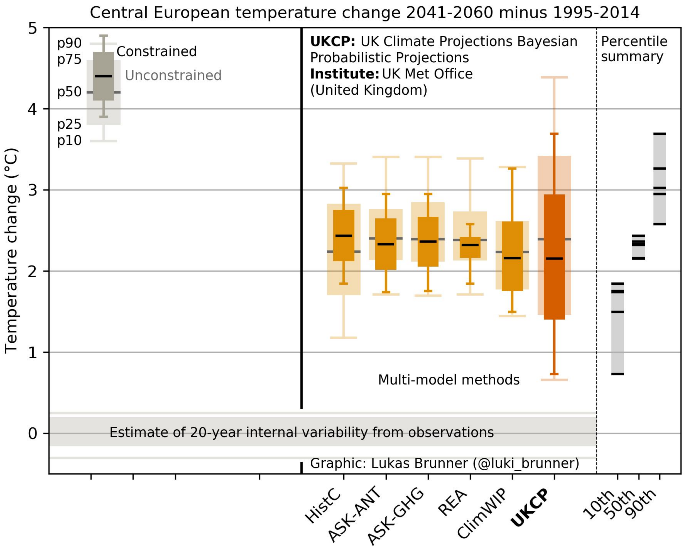

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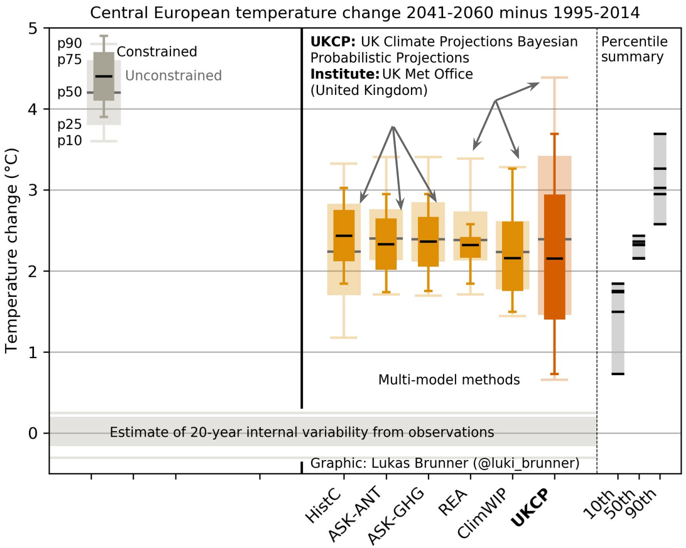
Comparing constrained projections from different methods

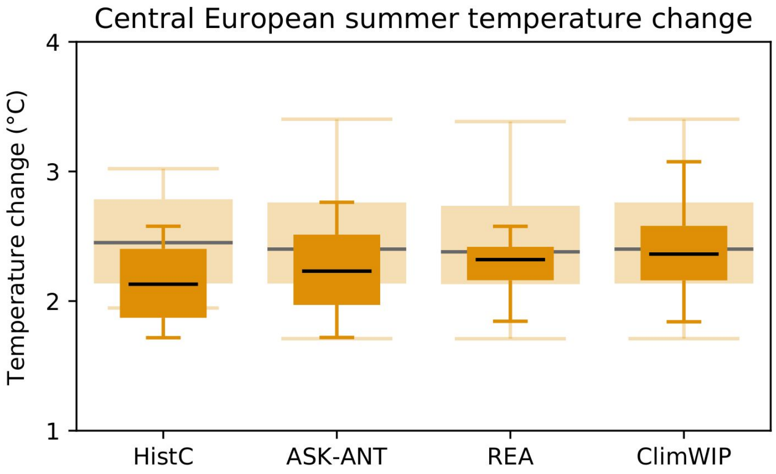


Why are the **unconstrained** projection uncertainties different?

- different models used
- handling of multiple ensemble members
- internal variability included
- parameter uncertainty included
- calculation of percentiles (Gaussian assumption)

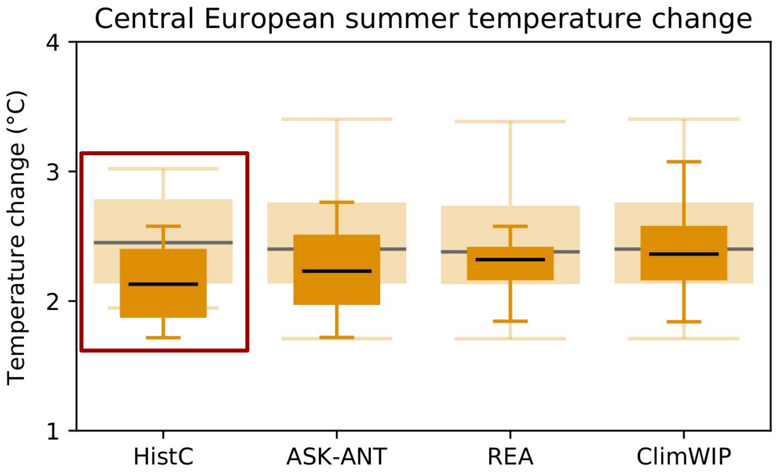
Brunner et al. (2020)

Consistency versus methods available



- ✔ same model pool
- ✔ internal variability included
- ✔ no parameter uncertainty

Consistency versus methods available



✔ same model pool
✔ internal variability included
✔ no parameter uncertainty

✘ calculation of percentiles
✘ separation of internal variability and model uncertainty

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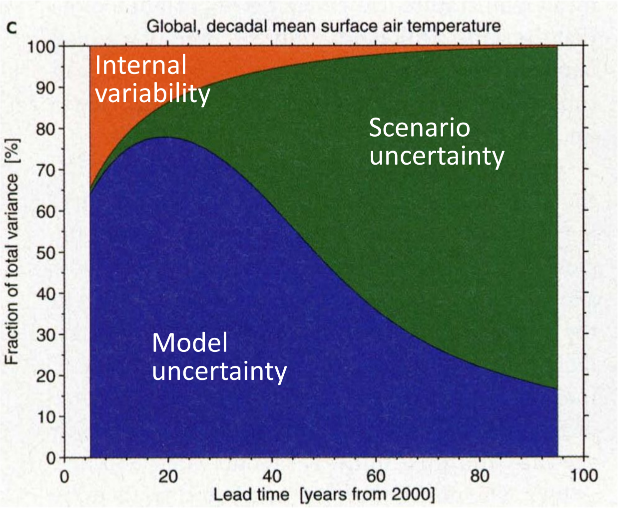
Separating uncertainties

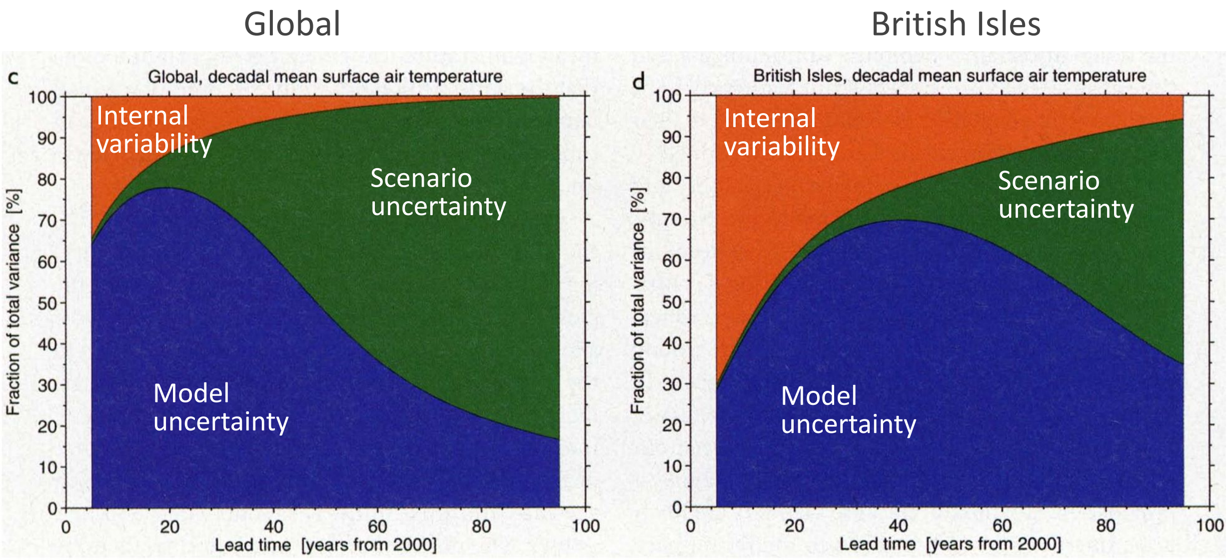
Fractional contributions to total uncertainty (CMIP3)



Total uncertainty =
Invernal variability +
Scenario uncertainty +
Model uncertainty

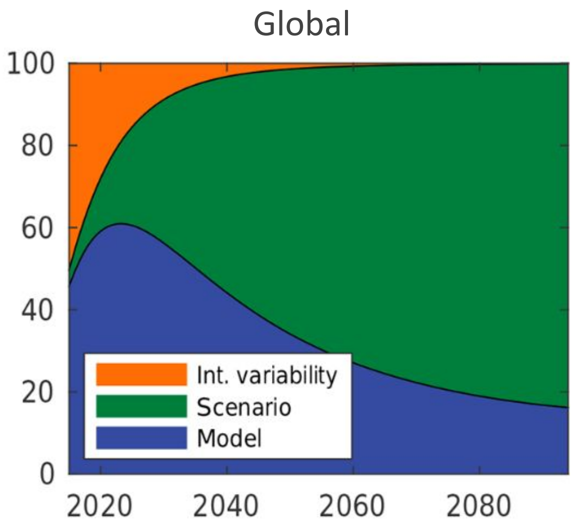
Hawkins and Sutton (2009)

Fractional contributions to total uncertainty (CMIP3)



Hawkins and Sutton (2009)

Fractional contributions to total uncertainty (CMIP5)

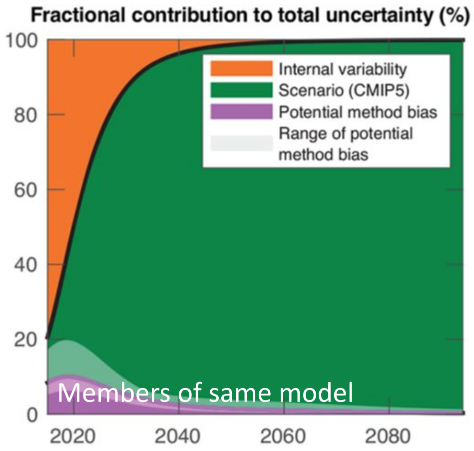


Lehner et al. (2020)

Quantifying method bias using large ensembles

The model uncertainty for a single model should be zero by definition!

Global



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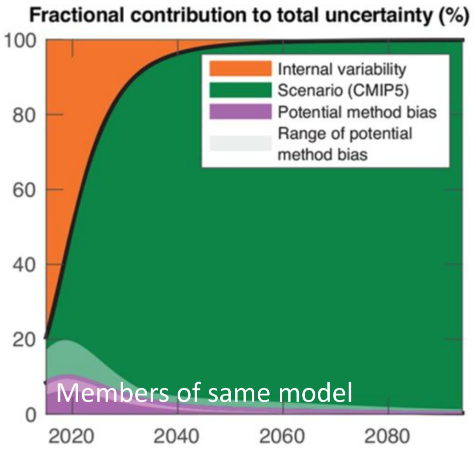
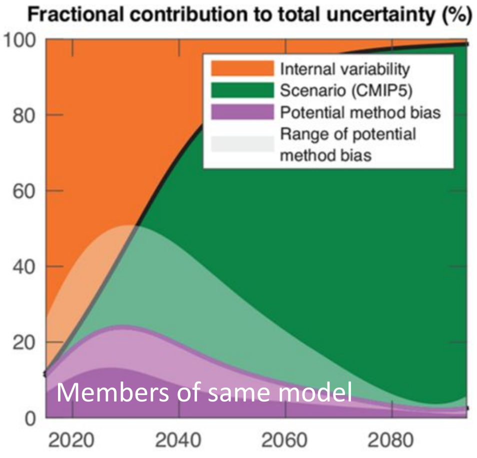
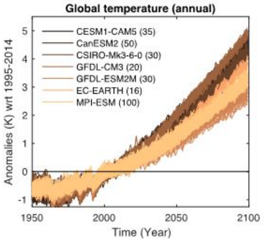


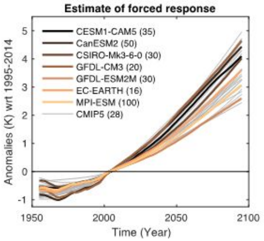
British Isles

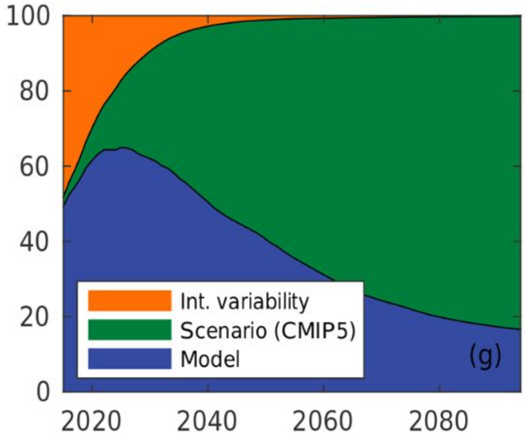


Lehner et al. (2020)

Estimating the forced response directly using large ensembles







Lehner et al. (2020)

Summary and Conclusions

- 3 main sources of uncertainty in projections of future climate
  - scenario uncertainty
  - **model uncertainty**
  - **internal variability**
- Model uncertainty & internal variability can be hard to separate but their interaction is important, e.g., for
  - **robustness of future changes**
  - **consistent comparison of expected changes**
- Large ensembles (SMILEs) can help to better quantify the contributions from different sources of uncertainty

Literature

- IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. In Press.
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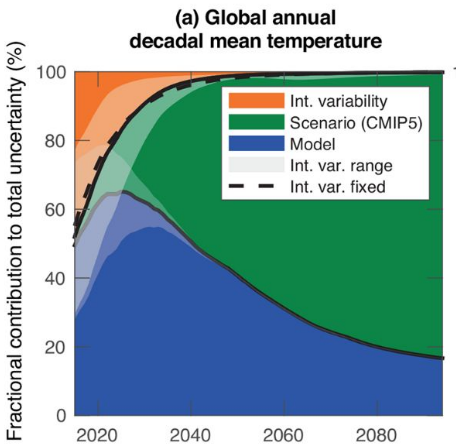
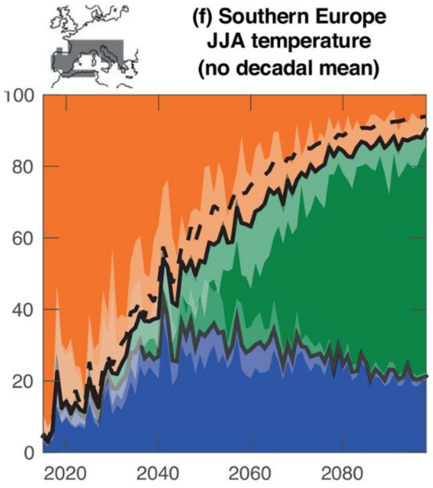
- Hawkins, E., & Sutton, R. (2009). The Potential to Narrow Uncertainty in Regional Climate Predictions. Bulletin of the American Meteorological Society, 90(8), 1095–1108. https://doi.org/10.1175/2009BAMS2607.1
- Lehner, F., Deser, C., Maher, N., Marotzke, J., Fischer, E. M., Brunner, L., Knutti, R., & Hawkins, E. (2020). Partitioning climate projection uncertainty with multiple large ensembles and CMIP5/6. Earth System Dynamics, 11(2), 491–508. https://doi.org/10.5194/esd-11-491-2020

Estimating changes in internal variability





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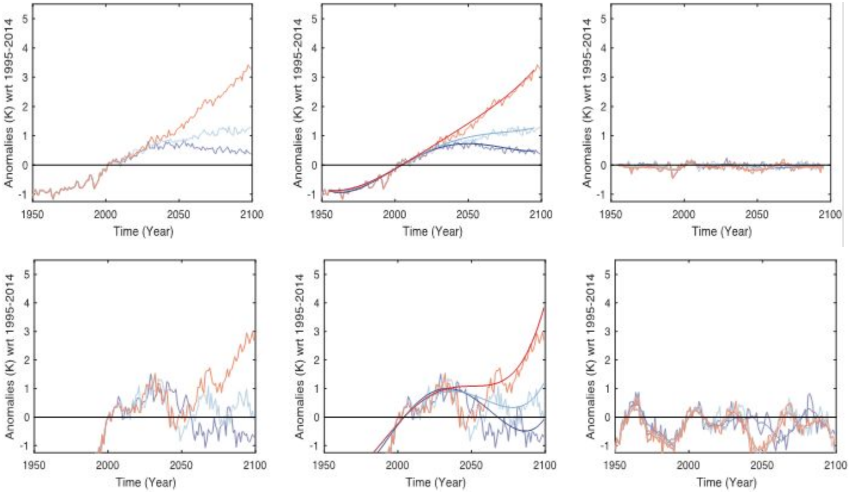
Potential method bias

Is a 4th order polynomial appropriate to estimate the forced response?



Global, decadal mean temperature

Southern Ocean, decadal mean temperature. Courtesy: FL

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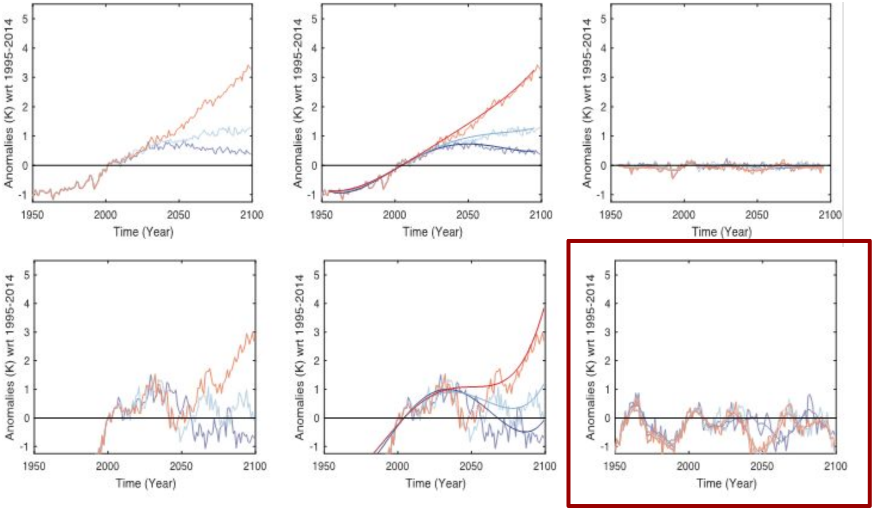
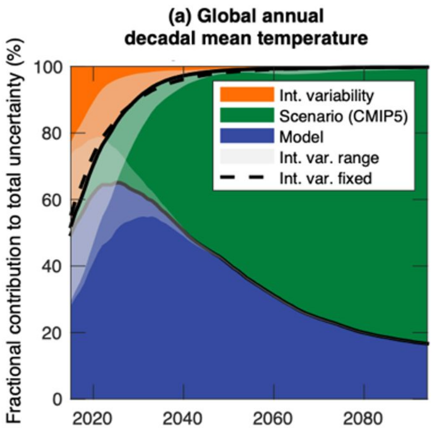


Global, decadal mean temperature

Southern Ocean, decadal mean temperature. Courtesy: FL

Estimating the amplitude of internal variability

What is the correct value for internal variability?

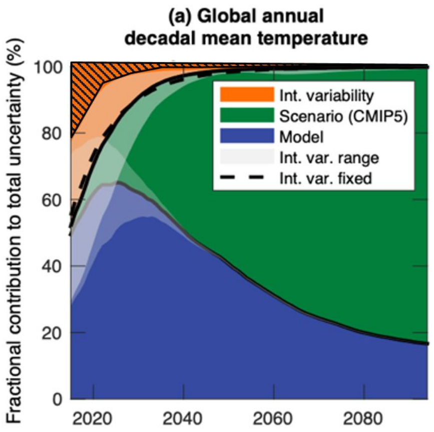


Different models give different estimates of internal variability

Lehner et al. (2020)

Estimating the amplitude of internal variability

What is the correct value for internal variability?

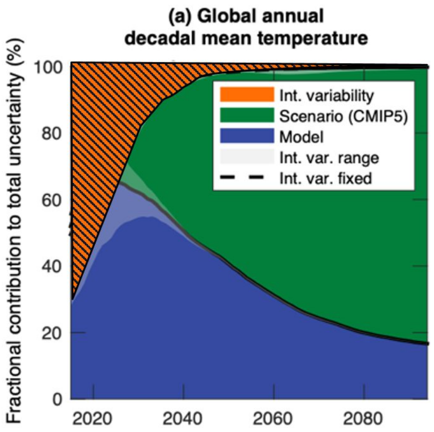


Model with low internal variability (EC-Earth)

Lehner et al. (2020)

Estimating the amplitude of internal variability

What is the correct value for internal variability?

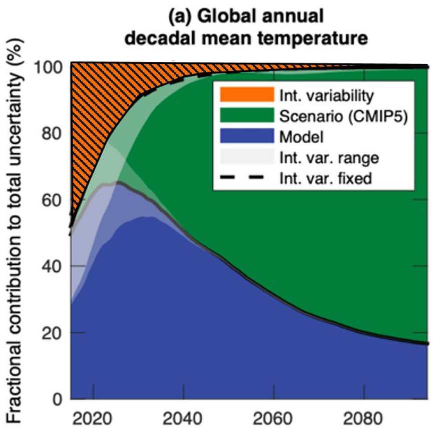


Model with high internal variability (GFDL-CM3)

Lehner et al. (2020)

Estimating the amplitude of internal variability

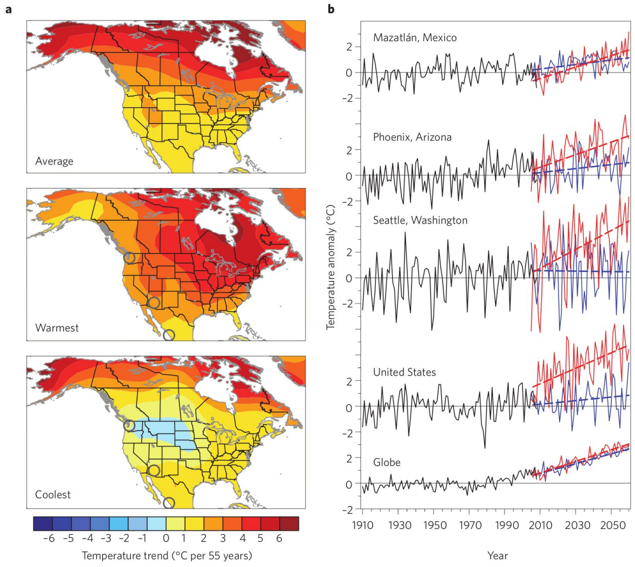
What is the correct value for internal variability?



Multi-model mean internal variability

Lehner et al. (2020)

Effects of internal variability



Locally internal variability can lead to differences in trends even within one model

Deser et al. (2012)