

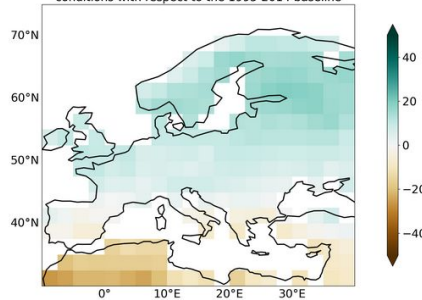
Constraining Future European Climate from GCMs

Methods, Results, and Ways Forward

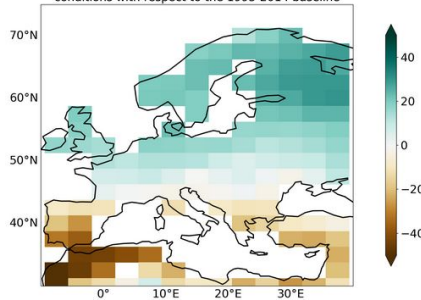
Lukas Brunner | DACH Qualitätskontroll-Methoden Treffen | February 4th 2022

Many thanks to all collaborators!

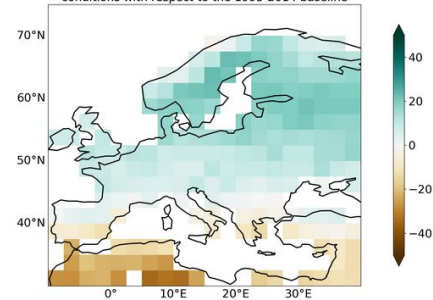
ClimWIP cons djf relative precipitation projections (%) - 50th percentile projected changes between 2041-2060 mean conditions with respect to the 1995-2014 baseline



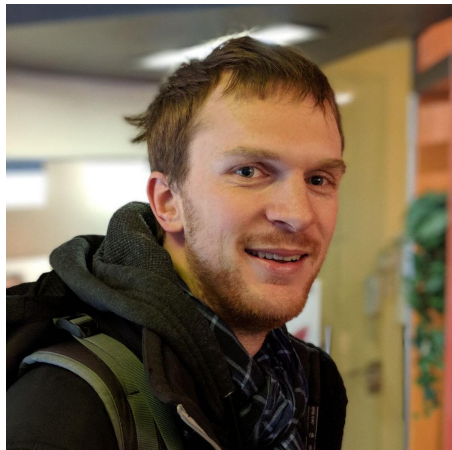
UKCP cons djf relative precipitation projections (%) - 50th percentile projected changes between 2041-2060 mean conditions with respect to the 1995-2014 baseline



REA cons djf relative precipitation projections (%) - 50th percentile projected changes between 2041-2060 mean conditions with respect to the 1995-2014 baseline



About me



- Studied Physics in Graz
- PhD in Graz, Edinburgh, Oslo
- PostDoc in Zürich
- Senior Scientist in Vienna

More:

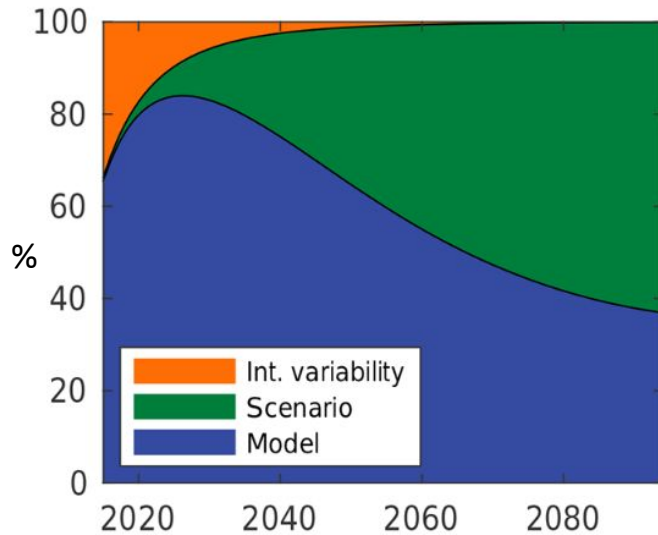
lukasbrunner.github.io

ETH zürich

EUCLP

European Climate Prediction system

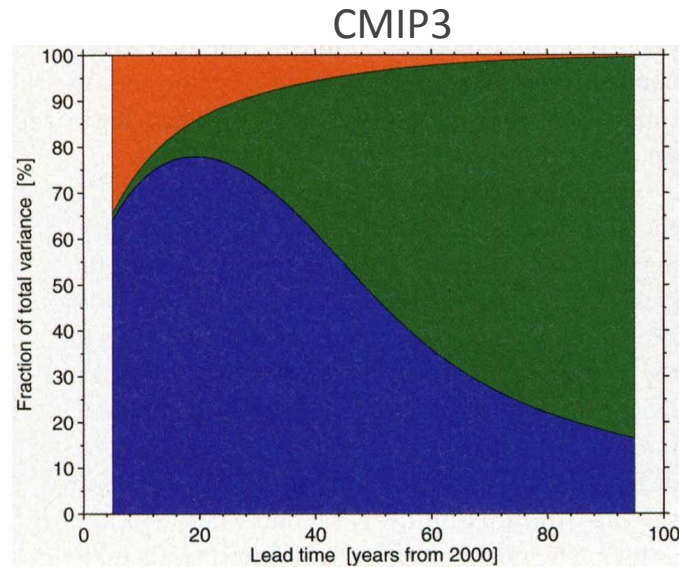
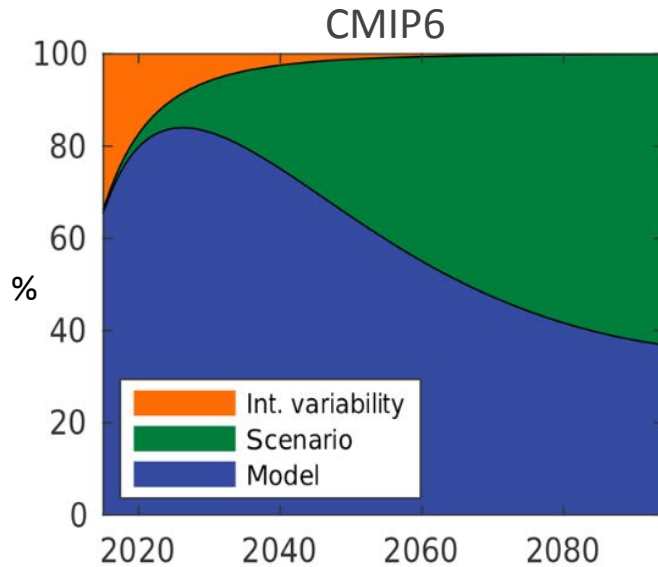
Uncertainty in projections of future climate



Fractional uncertainties in global, decadal mean temperature from CMIP6

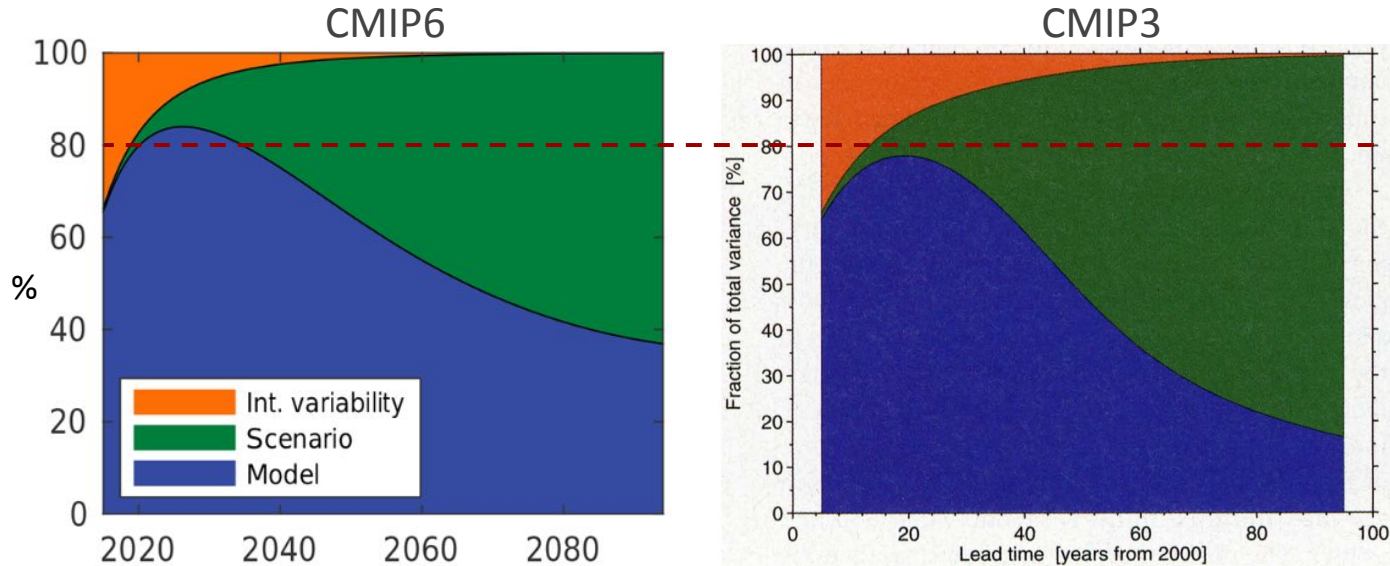
Lehner et al. (2020)

Changes in the distribution of uncertainty



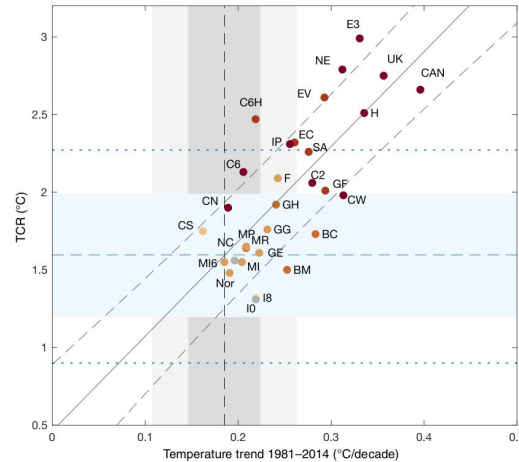
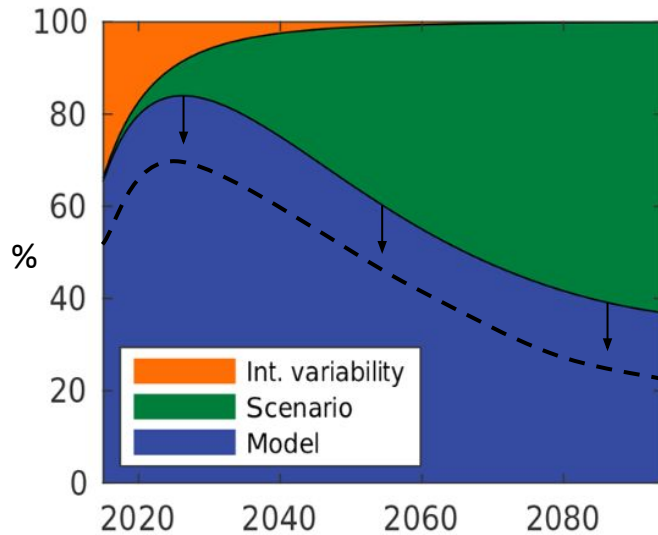
Lehner et al. (2020)
Hawkins & Sutton (2009)

Changes in the distribution of uncertainty



Lehner et al. (2020)
Hawkins & Sutton (2009)

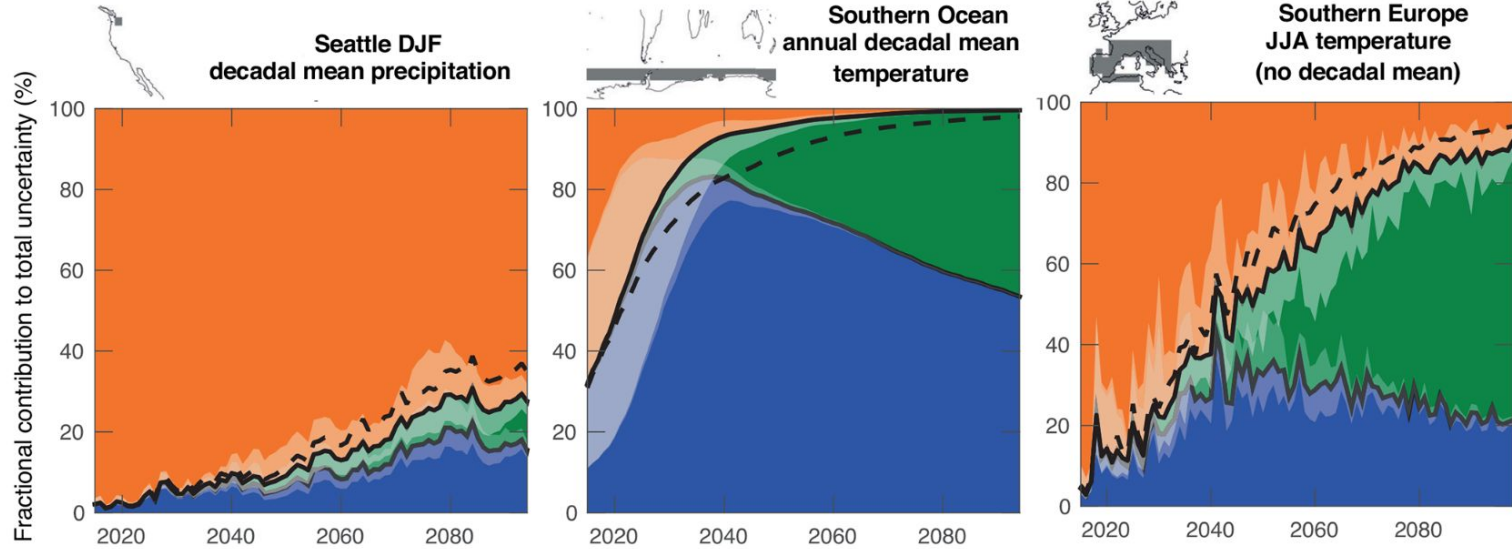
How to quantify (and reduce) model uncertainty?



Emergent constraint:
models with too much
historical warming show
higher TCR

Lehner et al. (2020)
Tokarska et al. (2020)

Uncertainty in projections of regional climate



Lehner et al. (2020)

A weighting scheme that can be applied global or regional

Earth Syst. Dynam., 11, 995–1012, 2020
<https://doi.org/10.5194/esd-11-995-2020>
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Earth System
Dynamics



Reduced global warming from CMIP6 projections when weighting models by performance and independence

Lukas Brunner¹, Angeline G. Pendergrass^{2,1,a}, Flavio Lehner^{1,a}, Anna L. Merrifield¹, Ruth Lorenz¹, and Reto Knutti¹

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Geosci. Model Dev., 10, 2379–2395, 2017
<https://doi.org/10.5194/gmd-10-2379-2017>
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Geoscientific
Model Development



Skill and independence weighting for multi-model assessments

Benjamin M. Sanderson¹, Michael Wehner², and Reto Knutti^{3,1}

¹ National Center for Atmospheric Research, Boulder, CO, USA

² Lawrence Berkeley National Laboratory, Berkeley, CA, USA

³ Institute for Atmospheric and Environmental Research Letters

Correspondence to:

Received: 18 November 2016

Revised: 8 June 2017

LETTER

Quantifying uncertainty in European climate projections using combined performance-independence weighting

Lukas Brunner¹, Ruth Lorenz¹, Marius Zumwald^{1,2}, and Reto Knutti¹

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Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1029/2017JD027992

Key Points:

- Model weighting slightly reduces summer warming signal over central North America
- More than one predicting diagnostics should be used to inform the weighting
- Shortwave radiation trend, mean precipitation, and SST variability are possible constraints on projections of summer maximum temperature

Prospects and Caveats of Weighting Climate Models for Summer Maximum Temperature Projections Over North America

Ruth Lorenz¹, Nadja Herger², Jan Sedláček¹, Veronika Eyring^{3,4}, Erich M. Fischer¹, and Reto Knutti¹

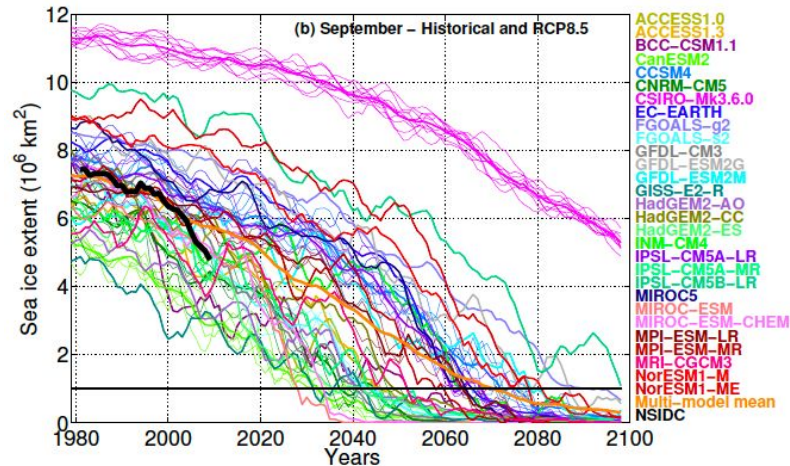
¹ Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland, ² ARC Center of Excellence for Climate System Science and Climate Change Research Center, UNSW Australia, Sydney, New South Wales, Australia,

³ Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany,

⁴ Institute of Environmental Physics (IUP), University of Bremen, Bremen, Germany

Weighting climate models by regional performance

Is a model “fit for purpose” given a specific target?



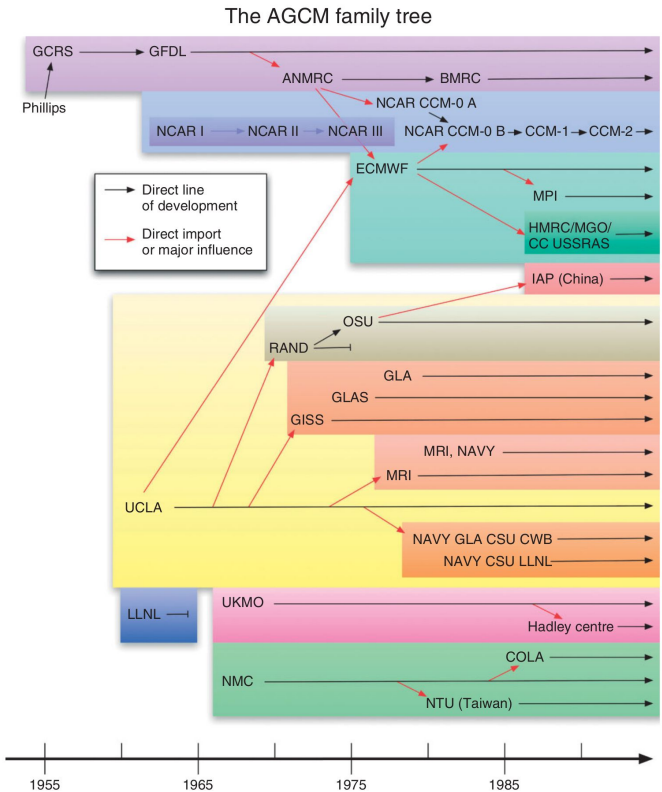
We might want to trust models less if they are “far away” from observations
→ **weighting by performance**

September Arctic sea ice extent in CMIP5 historical / RCP8.5 runs and observations. Massonnet et al. (2012)

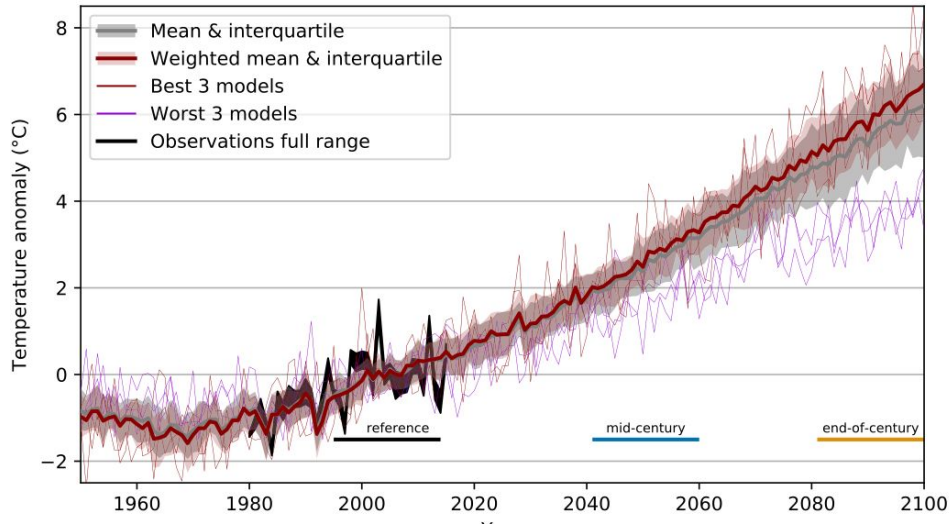
A word about model independence

- Multi-model studies often draw on all available models
- the CMIP multi-model ensembles are not designed to only include independent models (‘ensembles of opportunity’)
 - Several models are closely related (one different component, resolution)
 - Models have been branched from each other
 - Some models share components

→ **weighting by independence**



Weighted changes in Mediterranean summer temperature



- weighted distribution shows **stronger warming**
- The interquartile range is reduced by 24% by the end of the century

Weighted **Mediterranean summer temperature** anomaly (relative to 1995-2014) based on 37 CMIP5 models (79 realizations). Brunner et al. (2019)

Does the weighting improve 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
(counter-example: the climatology has no sharpness)

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

Quality

Does the weighting improve projections?

What Is a Good Weighting? - we don't know the 'truth'

- ✗ **Accuracy**: level of agreement between **weighted projection** and 'truth'
- ✗ **Skill**: accuracy relative to the **unweighted projection**
- ✗ **Reliability**: average agreement between **weighted projections** and 'truth'
- ✓ **Sharpness**: tendency of the **weighted projections** to reduce model uncertainty compared to the **unweighted projections**

- ? **Consistency**: is **weighting** consistent with other methods
- ✓ **Value**: degree to which the **weighted projection** helps users

Consistency: is weighting consistent with other methods?

No coordinated framework to compare methods exist.

They might differ for a range of reasons independent of the methods itself:

- region (global vs Europe)
- season and time period
- models included
- uncertainties included...



The collage features several scientific articles:

- Left Column (Top):** "Calculation of Average, Uncertainty Range, and Reliability of Regional Climate Change from AGCM Simulation via the 'Reliability Ensemble Averaging' (REA) Method" by Fujino et al. (18 Jul 2012).
- Left Column (Middle):** "A Representative Democracy to Reduce Interspersivity in a Multimodel Ensemble" by Bennett et al. (18 Jul 2012).
- Left Column (Bottom):** "Skill and Independence weighting for multi-model assessments" by Ingleton et al. (2019).
- Right Column (Top):** "Estimates of Uncertainty in Projections of Global Mean Surface Temperature" by Knutti et al. (13 Mar 2017).
- Right Column (Middle):** "A new statistical approach to climate change detection and attribution" by Ribes et al. (2017).
- Right Column (Bottom):** "The Max Planck Institute Grand Ensemble: Enabling the Exploration of Climate System Variability" (2019).

Logos for EGU, AGU100, and Scientific Reports are also visible.

Comparing (top) methods and (right) apples and oranges right: CC-BY M. Johnson



A consistent framework for method comparison

- 8 groups contributing methods to quantify uncertainty
- European temperature & precipitation changes in 8 regions
- winter (DJF) and summer (JJA)
- same horizontal resolution

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

LUKAS BRUNNER,^a CAROL MCSWEENEY,^b ANDREW P. BALLINGER,^c DANIEL J. BEFORT,^d MARIANNA BENASSI,^e BEN BOOTH,^b ERIKA COPPOLA,^f HYLKE DE VRIES,^g GLEN HARRIS,^b GABRIELE C. HEGERL,^c RETO KNUTTI,^h GEERT LENDERINK,^g JASON LOWE,^b RITA NOGHEROTTO,^f CHRIS O'REILLY,^d SAÏD QASMI,^h AURÉLIE RIBES,^h PAOLO STOCCHI,^{f,i} AND SABINE UNDORF^{e,j}

^a Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland

^b Met Office Hadley Centre, Exeter, United Kingdom

^c School of GeoSciences, University of Edinburgh, Edinburgh, United Kingdom

^d Atmospheric, Oceanic and Planetary Physics, Department of Physics, University of Oxford, Oxford, United Kingdom

^e Fondazione Centro Euro-Mediterraneo sul Cambiamento Climatico, Bologna, Italy

^f The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy

^g Royal Netherlands Meteorological Institute, De Bilt, Netherlands

^h CNRM, Université de Toulouse, Météo-France, CNRS, Toulouse, France

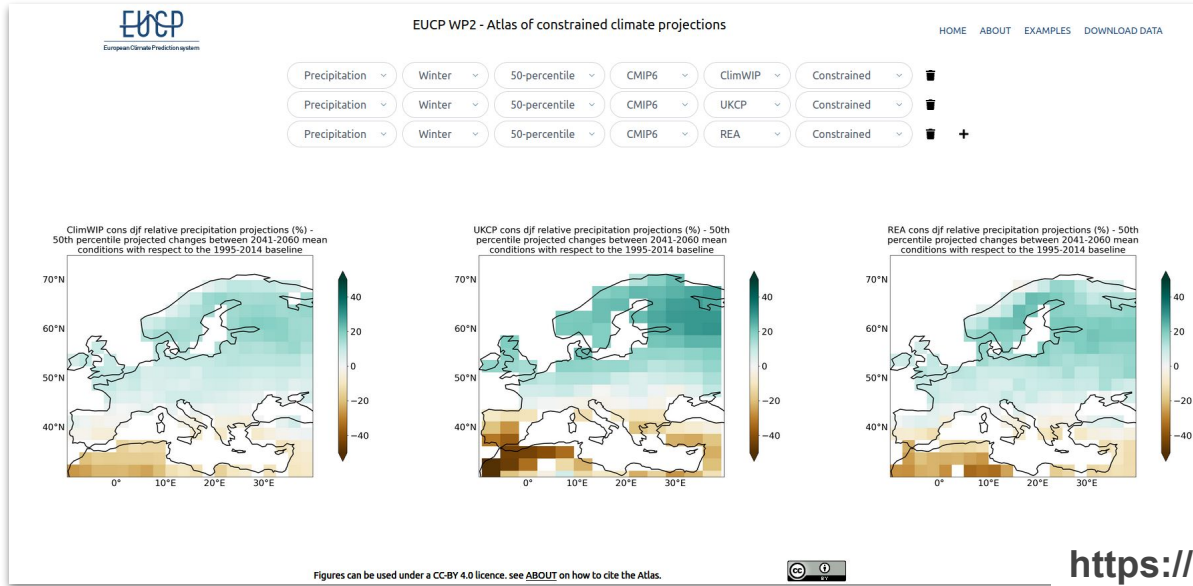
Institution name	Method acronym	Method name	References
ETH Zurich (Switzerland)	ClimWIP	Climate Model Weighting by Independence and Performance	Knutti et al. (2017b); Lorenz et al. (2018); Brunner et al. (2019) ^a
International Centre for Theoretical Physics (Italy)	REA	Reliability ensemble averaging	Giorgi and Mearns (2002, 2003) ^b
University of Edinburgh (United Kingdom)	ASK	Allen–Stott–Kettleborough	Allen et al. (2000); Stott and Kettleborough (2002); Kettleborough et al. (2007)
Centre National de Recherches Météorologiques (France)	HistC	Historically constrained probabilistic projections	Ribes et al. (2020, manuscript submitted to <i>Sci. Adv.</i>) ^c
Met Office (United Kingdom)	UKCP	U.K. Climate Projections (UKCP) Bayesian probabilistic projections method	Sexton et al. (2012); Harris et al. (2013); Sexton and Harris (2015); Murphy et al. (2018)
University of Oxford (United Kingdom)	CALL	Calibrated large ensemble projections	O'Reilly et al. (2020)
Royal Netherlands Meteorological Institute (Netherlands)	BNV [†]	Bootstrapped from natural variability	See the online supplemental material
Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (Italy)	ENA [‡]	Ensemble analysis of probability distributions	See the online supplemental material

^a Source code available online (<https://github.com/lukasbrunner/ClimWIP>).

^b Source code available online (<http://doi.org/10.5281/zenodo.3890966>).

^c Method tool available online (<https://saidqasmi.shinyapps.io/bayesian/>).

Atlas of regional changes



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

How should this information be handled by users?

*Our results raise a number of questions about how information from multiple methods can be communicated, combined, or applied, in particular for cases where **constrained distributions disagree**.*

- considering the decision context
- using agreeing methods
- combining methods outputs
- combining methods before applying them
- selecting methods based on a consistent skill measure

Brunner et al. (2020)

How should this information be handled by users?

*Our results raise a number of questions about how information from multiple methods can be communicated, combined, or applied, in particular for cases where **constrained distributions disagree**.*

- considering the decision context
- using agreeing methods
- **combining methods outputs** O'Reilly et al. (in preparation)
- **combing methods before applying them** Hegerl et al. (2021)
- **selecting methods based on a consistent skill measure** O'Reilly et al. (in preparation)

Does the weighting improve projections?

What Is a Good Weighting? - we don't know the 'truth'

- × **Accuracy**: level of agreement between **weighted projection** and 'truth'
- × **Skill**: accuracy relative to the **unweighted projection**
- × **Reliability**: average agreement between **weighted projections** and 'truth'

Brunner et al. (2020)

Summary and outlook

- The importance of model uncertainty depends on the case
- Different methods exist to constrain regional climate uncertainty
- These methods provide multiple lines of evidence but they are not always consistent
- Work is ongoing to provide objective method skill measures

Resources:

- **Atlas:** <https://eucp-project.github.io/atlas>
- **Storyboards:** <https://eucp-project.github.io/storyboards>
- **KCC (Bayesian constraining):** <https://saidqasmi.shinyapps.io/bayesian>
- **ClimWIP (Model weighting)** implementation on **ESMValTool**:
https://docs.esmvaltool.org/en/latest/recipes/recipe_climwip.html

Literature

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