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Institute for Atmospheric
and Climate Science

Robustness and uncertainties in temperature and precipitation over CMIP generations

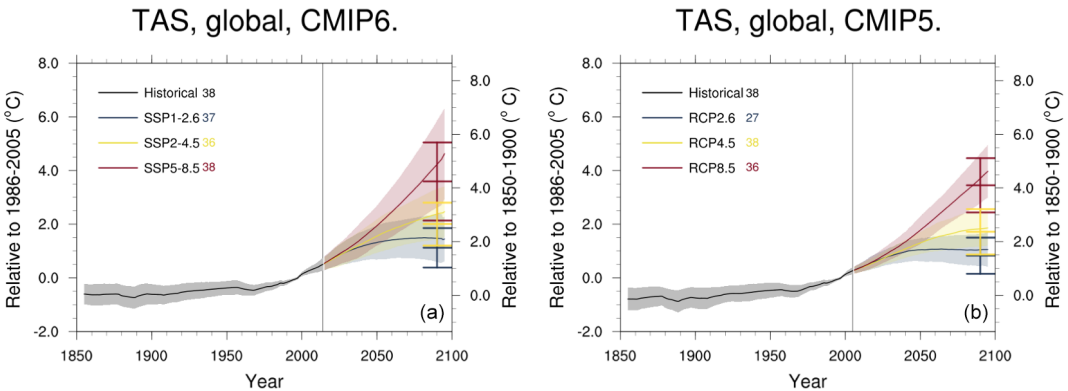
Ruth Lorenz, Anna Merrifield, Lukas Brunner, Reto Knutti

CRESCENDO General Assembly, March 15–17 2021

Motivation

”New generation of more complex climate models running scenarios to be used in the next IPCC Report expected to provide more detailed and more certain projections“ (Knutti & Sedláček 2013, NCC)

→ The same expectation exists for CMIP6



Tebaldi et al. 2021, ESD

Research questions

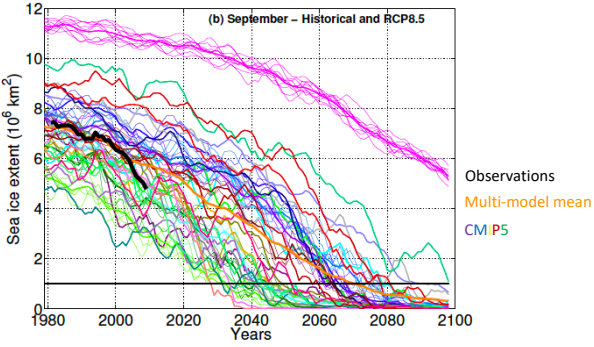
How to make the best use of the climate model projections we have?

Does weighting multi-model ensembles improve our understanding of uncertainties?

How does robustness and uncertainty change from CMIP3 over CMIP5 to CMIP6?

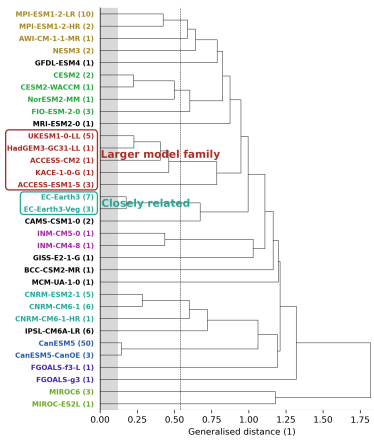
Why do we need to weight climate model projection ensembles?

Some models are better than others



Massonnet et al. 2012

Models are not independent



How can we weight climate model projection ensembles?

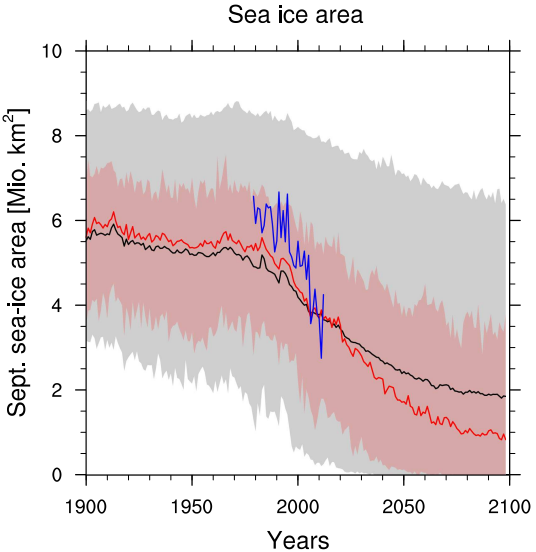
Performance based methods, Bayesian methods, detection & attribution based methods, machine learning methods etc.

Goal: Expertly vetted uncertainty
Incorporate model evaluation into multi-model assessment, use emergent relationships linking present behaviour to future changes → meaningful ensemble.

$$w_i = e^{-\frac{D_i^2}{\sigma_D^2}} \Big/ \left(1 + \sum_{j \neq i}^{M} e^{-\frac{S_{ij}^2}{\sigma_S^2}}\right)$$

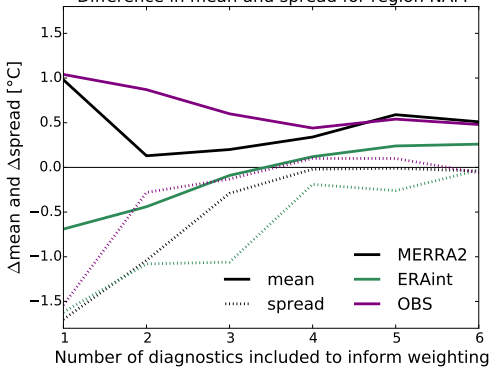
Decreases weight if model is similar to others

Increases weight if distance to observations is small

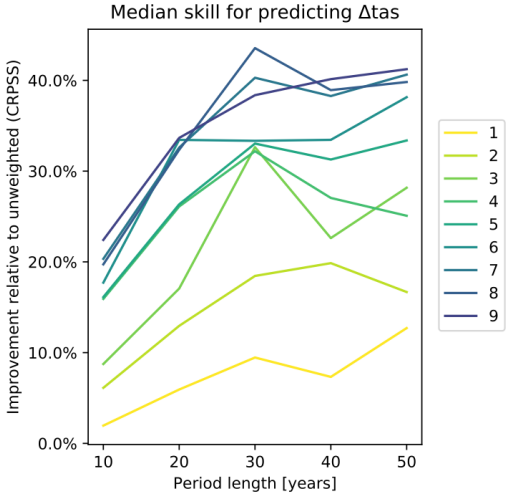


Knutti et al. 2017

Weighting needs to be based on multiple diagnostics

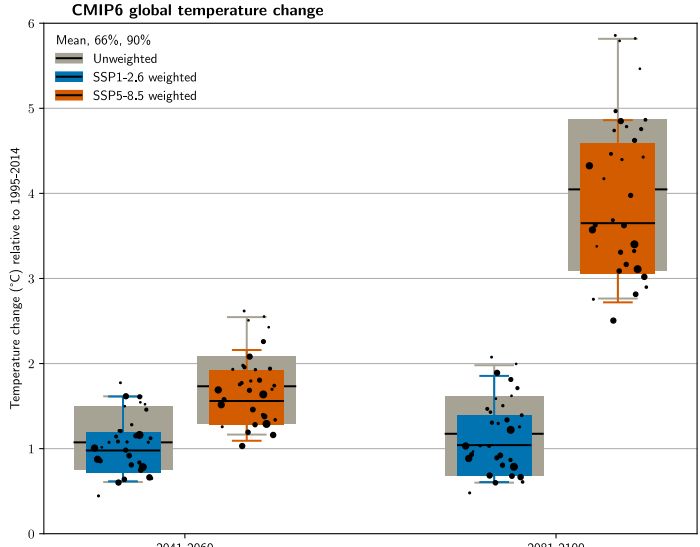


Lorenz et al. 2018, JGR



Weighting global temperature projections from CMIP6

- Used temperature (tas) and surface pressure (psl)
- Independence: 35 year climatologies tasCLIM, pslCLIM
- Performance: 50% tasTREND and 50% anomaly- and variance based diagnostics (about 13% tasANOM, 13% tasSTD, 13% pslANOM, and 13% pslSTD)
- *Brunner et al. 2020, ESD*



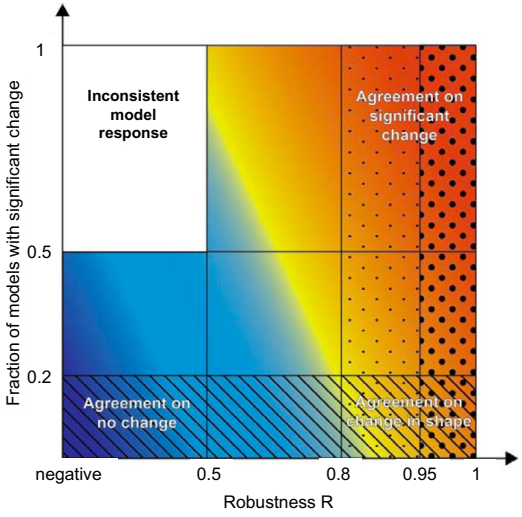
How to measure robustness?

Inspired by signal-to-variability ratio in ranked probability skill score (Knutti & Sedláček, 2013).

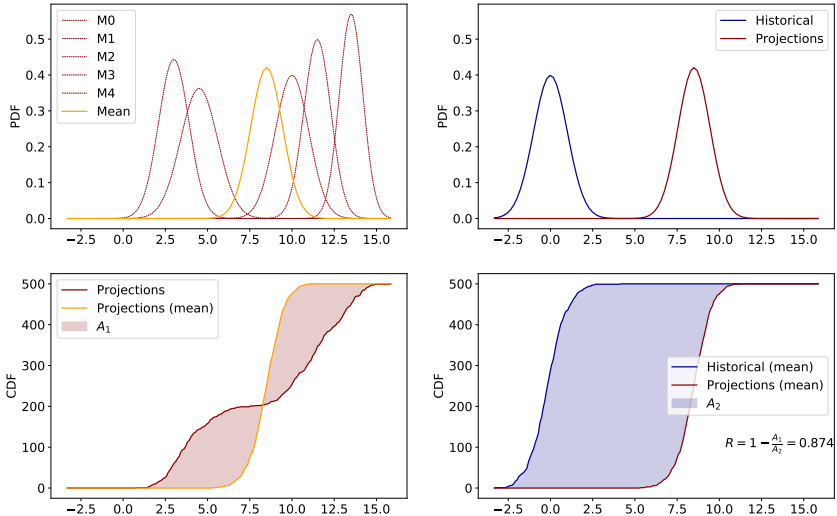
Includes:

- Magnitude of change
- Sign
- Natural variability
- Inter-model spread

$R = 1 \rightarrow$ perfect model agreement (higher model spread or smaller signal decreases R)
$R \approx 0 \rightarrow$ model spread is comparable to signal
$R < 0 \rightarrow$ spread is much larger than signal

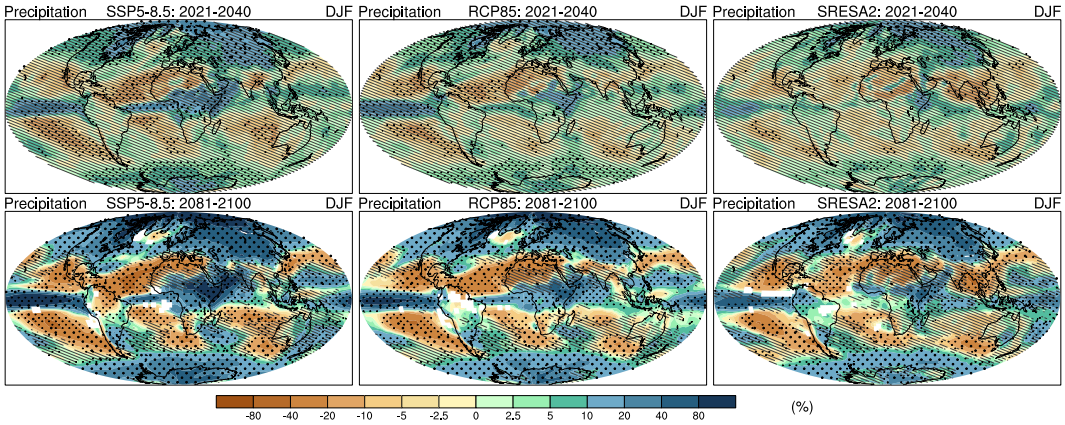


Robustness measure R

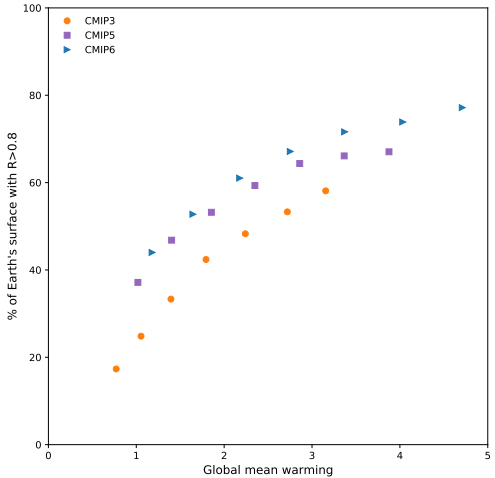


Precipitation

CMIP6 CMIP5 CMIP3



Robustness in precipitation versus global mean warming



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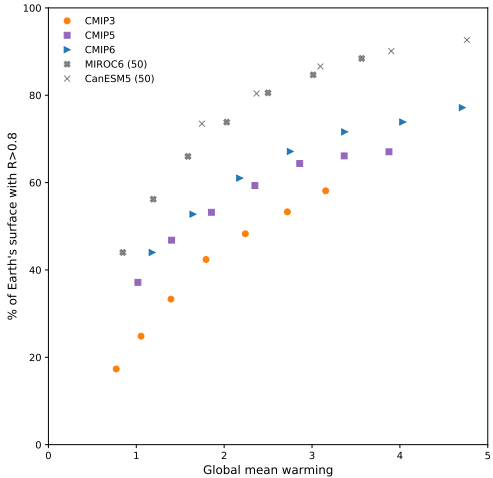
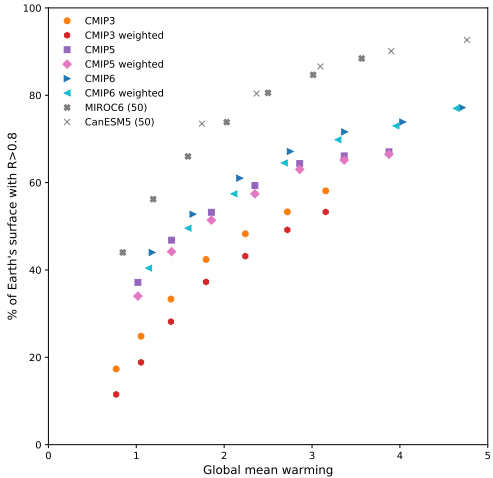


Robustness in precipitation versus global mean warming



Conclusions

- Equal weight to each available model projection is suboptimal due to different model performances and lack of independence
- Weighting is a more formal way to estimate uncertainties consistent with past trends and mean climate (even in cases where weighting does not reduce uncertainties)
- Robustness (as defined here) increases over CMIP generations
- Overall global model agreement on mean precipitation does not improve by defining global weights (but might in some region, for other variables, if metrics are well chosen)

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Questions?

Ruth Lorenz
rlorenz@ethz.ch