Sabine Undorf[1,2] SABINE.UNDORF@MISU.SU.SE, Andrew Ballinger[1], Nicolas Freychet[1], and Gabriele C. Hegerl[1]
[1] School of GeoSciences, University of Edinburgh, Edinburgh, UK
[2] Department of Meteorology and Bolin Centre for Climate Research, Stockholm, Sweden

Constraining European climate projections with regression-based optimal detection and attribution methods

Motivation

- Uncertainty quantification in climate projections is essential for policy decisions
- Much of the uncertainty on multi-decadal and longer time scales comes from that in the magnitude of the climate response to forcing
- The spread in ensemble projections (e.g. from climate model intercomparison projects) might over- or underestimate this uncertainty

-> Constrain the forced response in future projections using observed climate change

This is the ASK method (Allen et al., 2000; Stott & Kettleborough, 2002).

Key assumptions

- A model's over/underestimation of a climate variable's response to a specific forcing (combination) is the same in the past and in the future
- The responses to the single forcings used are linearly additive
- The models' spatio-temporal pattern of response is correct and the observations free of uncertainty (may be relaxed by accounting for model error and using observational ensembles)
- Big strength: The true signal is allowed to be outside the simulated model range

Methodological choices: Which scaling factors to apply to the future?

Forcings. The past includes anthropogenic (ANT) and natural (NAT: volanic, solar) forcings. Future projections have ANT only. ANT is made up of different forcing factors (mainly greenhouse gases (GHG) and aerosols (AA)).

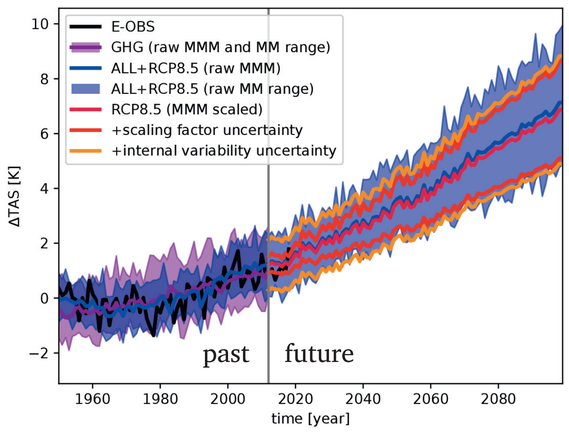
- Use ANT-only scaling factors - but ratio GHG vs. aerosol forcing might vary over time and their scaling factors might differ
- Use GHG-only scaling factors - but: future projections include aerosols, too
- better: Recompose future projections from single-forcing projections as will be available in CMIP6 (DAMIP; Gillet et al., 2016)

Region. To constrain change over a smaller region, use regional (e.g., CEU, MED, NEU; low signal to noise ratio) or larger-scale (e.g., EU) information? If different, (why) do the models get the pattern of change wrong? Here: Use regions combined (CEU+MED+NEU) as compromise.

Other. Check additional sensitivity to historical time period; observational dataset; regression method (optmisation, truncation); model ensemble etc.

ASK method: The concept

- The historical record is composed of the response to forcing and internal climate variability
- Estimate the forced response as the multi-model mean (MMM) of historical simulations (internal variability averages out)
- Determine how far the forced response can be scaled and still be consistent with the observations given internal variability (detection and attribution; D&A)
- Apply the resulting range of scaling factors to the MMM projections



The application

- Near-surface temperature (TAS) and precipitation (PR) averaged over the continental European (EU) region made up of the SREX regions (Field et al., IPCC, 2012)
- E-OBS v19.0e (Haylock et al., 2008) observations and historical and RCP8.5 simulations from CMIP5 (Taylor et al., 2012) models with GHG- and/or NAT-only runs
- historical: 1950-2012 summer (JJA) means; projections for the change from 1995-2014 to 2041-2060
- D&A: total least-squares regression (Allen & Stott, 2003; as in Polson et al., 2013) on 2-signal (ALL&NAT or ALL&GHG) 5-year running-mean time series, optimised using PCA-whitening with truncation (Allen & Tett, 1999)

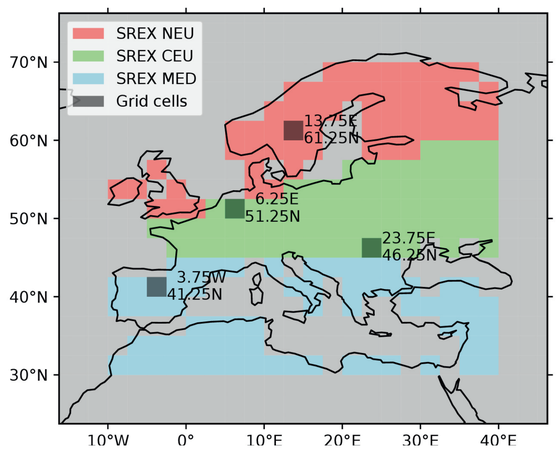
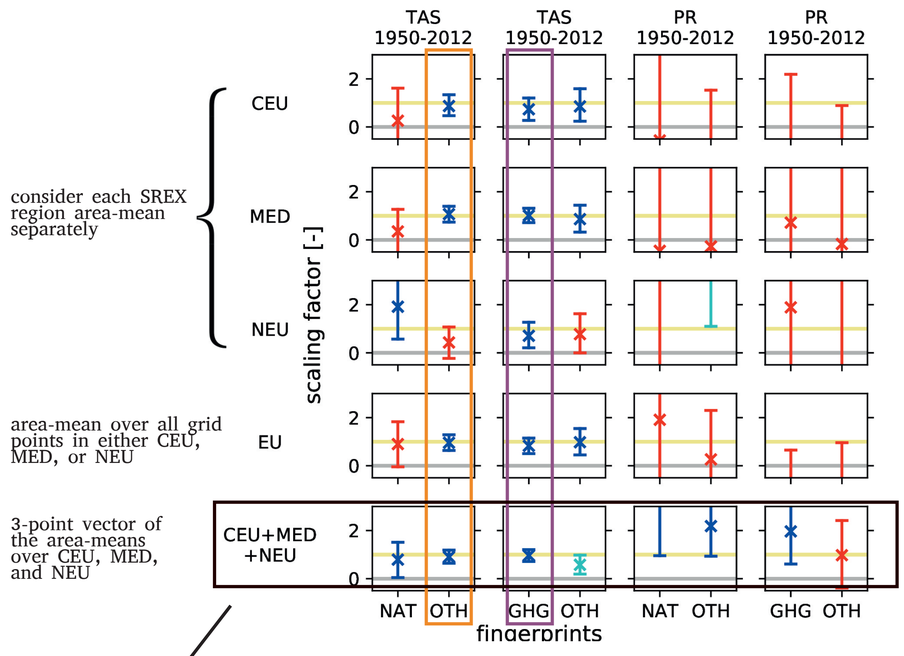


Figure from Lukas Brunner et al., 2019, Environmental Research Letters 14 124010

Detection and attribution results

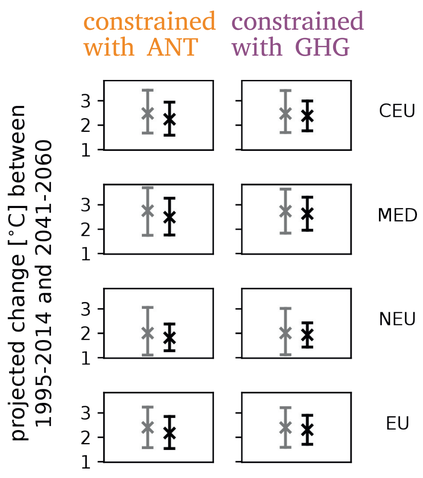


Temperature (TAS)
Both the combined anthropogenic and the GHG-only signal are detected at 95% confidence (scaling factor range>0) in the observed changes in all regions

Precipitation (PR)

- forced change detected for observations of the regions combined (CEU+MED+NEU)
- larger scaling factor ranges than for temperature
- models underestimate the response to forcing? (scaling factor range includes >>1)

Projection results



- Compare the raw multi-model ensemble range (includes internal variability) with the **constrained forced response** (MMM; free of uncertain future internal variability)
- Projected temperature change range over all regions is narrowed compared to the raw multi-model range, with the best estimates tending to be lower than the raw MMM

Conclusions

- The ASK method applies established D&A techniques to constrain future climate projections with observed changes in the respective variable in response to historical forcing
- The method is conceptually simple but not trivial to implement; expertise is required for deciding on methodological details and to interpret the results
- The availiability of single-forcing projections as part of CMIP6 (along with larger ensemble sizes and a longer observed record) is expected to avoid current limitations of the method's constraining potential