Visualizing projected Climate Changes - the CMIP5 Multi-Model Ensemble

Michael Böttinger 1), Veronika Eyring 2), Axel Lauer 2), and Karin Meier-Fleischer 1)

1) Deutsches Klimarechenzentrum (DKRZ)
2) German Aerospace Center (DLR)
Background: CMIP5

- CMIP = The Coupled Model Intercomparison Project
- WCRP/WGCM established CMIP as a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models (AOGCMs)
- CMIP5 = fifth phase of CMIP, simulations carried out w.r.t. IPCC AR5
The CMIP5 Multi Model Ensemble

- ~ 25 Modeling groups
- ~ 40 different models/configurations

Sources of uncertainty:
- Internal climate variability
- Model uncertainty: different
  - representation of processes
  - climate sensitivity
- Scenario uncertainty

CMIP5 – The RCP Climate Change Scenarios

RCPs = Representative Concentration Pathways (*RCP6.0 omitted*)

Source: Van Vuuren et al., 2011 (modified)
CMIP5 - Projected Changes in the the 2m-Temperature

Source: IPCC AR5, TS Figure 15

Global surface temperature change (°C)

-2 0 2 4 6 8 10 12

1850 1900 1950 2000 2050 2100 2150 2200 2250 2300

Year

- historical
- RCP2.6
- RCP4.5
- RCP6.0
- RCP8.5

39 25 42 12 12

42 models

Source: IPCC AR5, Figure 12-09

Annual mean surface air temperature change (RCP4.5: 2081-2100)

Source: IPCC AR5, TS Figure 15

Böttinger et al. – Visualizing the CMIP5 Multi-Model Ensemble 28.04.2017
Uncertainty versus Robustness

- **Uncertainty**
  - What we don’t know
  - Communicate some result plus some uncertainty range (model spread)

- **Robustness**
  - What we know (= positive)
  - Determine which part of the data (i.e. projected signals) is statistically significant
Overlayed Stippling and Hatching indicating Robustness

(a) Change in average surface temperature (1986–2005 to 2081–2100)

RCP 2.6

RCP 8.5

Stippling indicates multi-model mean is more than two standard deviations of natural internal variability in 20-yr means; hatching indicates multi-model mean is less than one standard deviation of natural internal variability in 20-yr means, and where at least 90% of models agree on the sign of change.

Source: IPCC AR5, SPM Figure 8
Animation: Overlayed Stippling indicating Robustness
Our Approach I

2m Temperature change mapped on topography

- Data Processing with ESMValTool (Eyring et al., 2016, doi:10.5194/gmd-9-1747-2016)
- Visualization performed with the commercial 3D-Tool „Avizo“ (Climatology Edition).
- Relief shading potentially reveals correlations of the data with topographic features.
Our Approach II – Derive Robustness Mask

2m Temperature change

Robustness mask (2 σ)
(black = robust)

> (2 σ)?

Standard deviation σ
500 years PiControl

Böttinger et al. – Visualizing the CMIP5 Multi-Model Ensemble 28.04.2017
Our Approach III – Compositing

2m Temperature change

Robustness mask (2 σ)

Composite:
2m Temperature change and robustness

CMIP5 Multi Model Ensemble: 2m Temperature Anomaly relative to 1986-2005

2031

Böttinger et al. – Visualizing the CMIP5 Multi-Model Ensemble
Clear Colors for Robustness, Grey Shading for Uncertainty
Overlayed Stippling and Hatching to indicate Robustness

RCP2.6 Change in average precipitation (1986–2005 to 2081–2100) RCP8.5

Source: IPCC AR5, SPM Figure 8
Clear Colors for Robustness, Grey Shading for Uncertainty
In literature, robustness of multi-model ensemble data is visualized using stippling/hatching overlays for presenting uncertainty measures to experts and non-experts.

- Stippling/hatching is not well suited for animations.

- Overlaying additional information on the robust part of the visualization might distract the perception of this (probably) more important part.

We propose annotating the uncertain range instead of the robust range for communicating multi-model results to the public.

- Overlay of robustness-information by semi-transparent grey-shading is better suited for animations of uncertainty measures.

The visualizations shown will be used within a video produced by WMO for communication to the public.