Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

Uncertainties of Regional Climate Projections

Sven Kotlarski
Federal Office of Meteorology and Climatology MeteoSwiss, Zurich

4th VALUE Training School: **Validating Regional Climate Projections**
Trieste, October 2015

OUTLINE

Part 1 **Overview**

Part 2 **Model Uncertainty**

Parts 3,4,5 **Joanna Wibig**
Douglas Maraun

Marco

«Hey, this was a **cool** *training school, yeah!! Learned a lot! Back at home I applied all this stuff. Did a really cool and relevant downscaling application for my new job in a* ***local government****.*

Took the ***RCP8.5*** *(the most likely emission scenario) and the* ***GCM ECHAM5*** *(really, the best performing GCM in the literature!). Downscaled* ***two 10-year time slices*** *for today and the future with the RCM* ***RCA*** *(was very easy, a friend of mine is familiar with this model and gave me useful instructions)!*

Then fed precip into a ***hydrological model*** *for my local basin. Already the control run produced* ***massive floods*** *(must have missed them in the past)! For the future period* ***flood frequency and magnitude are extremely high****!!!*

Told my boss: This is ***frightening****!*
Should immediately ***evacuate*** *parts of that basin!!»*

What's wrong here??

UNCERTAINTIES!!

Climatic Change (2010) 100:77–85
DOI 10.1007/s10584-010-9841-6

The drama of uncertainty

Linda O. Mearns

?

Uncertainty Basics

- Global and regional climate projections are subject to **inherent uncertainties** (just like weather forecasts)
- In sequential applications, uncertainties **propagate** along the modeling chain
- Some uncertainties are, in principle, reducible. Others are not!
- Projection uncertainty can be **substantial** and needs to be accounted for by users!

The Major Sources of Projection Uncertainty

Scenario Uncertainty

Estimates of future emissions of greenhouse gases and aerosols involve strong assumptions and are **unsure**!

Model Uncertainty (Response Uncertainty)

In response to the same radiative forcing, different models simulate different changes in climate.

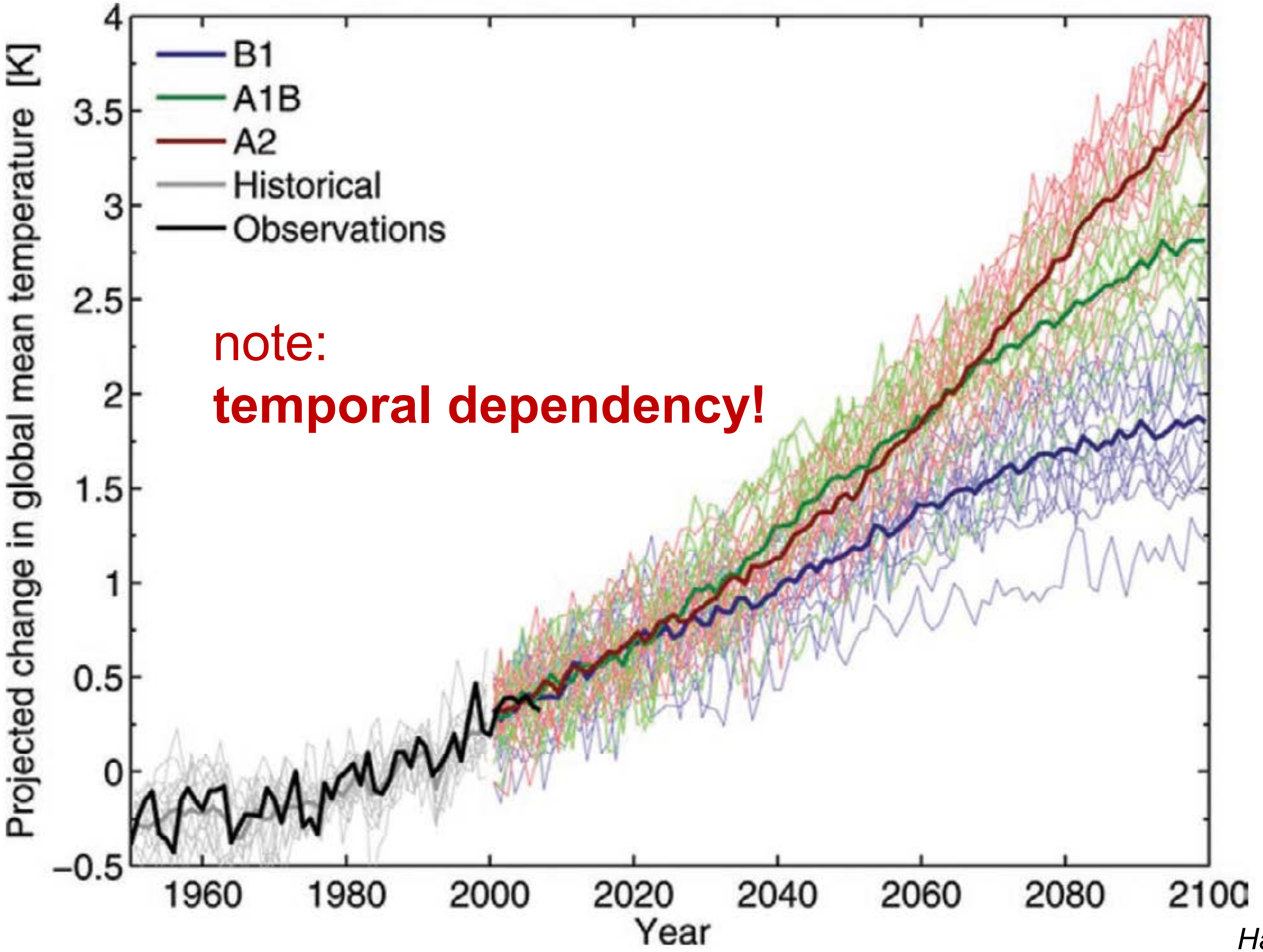
Internal Climate Variability

Uncertainty due to natural climate fluctuations that arise in the **absence** of external forcings.

Uncertainties and «surprises» in external forcings apart from emissions

Postprocessing / Interface to subsequent models

Uncertainty in Global Temperature Projections



Hawkins & Sutton, 2009

Uncertainty Quantification: Ensembles

EMISSION SCENARIO ENSEMBLES

- **Carry out multiple projections assuming different emission scenarios**

MULTI MODEL ENSEMBLES

- **Combine multiple projections from different models**
- **Ideally: models independent of each other** (typically not given!)
- **Intermodel variability as a measure of uncertainty**

PERTURBED PHYSICS ENSEMBLES

- **Combine different simulations of the same model but with perturbed versions of the original model physics**
- **More systematic sampling possible** (multi model ensembles: *opportunistic* ensembles)
- **Intramodel variability as a measure of uncertainty**

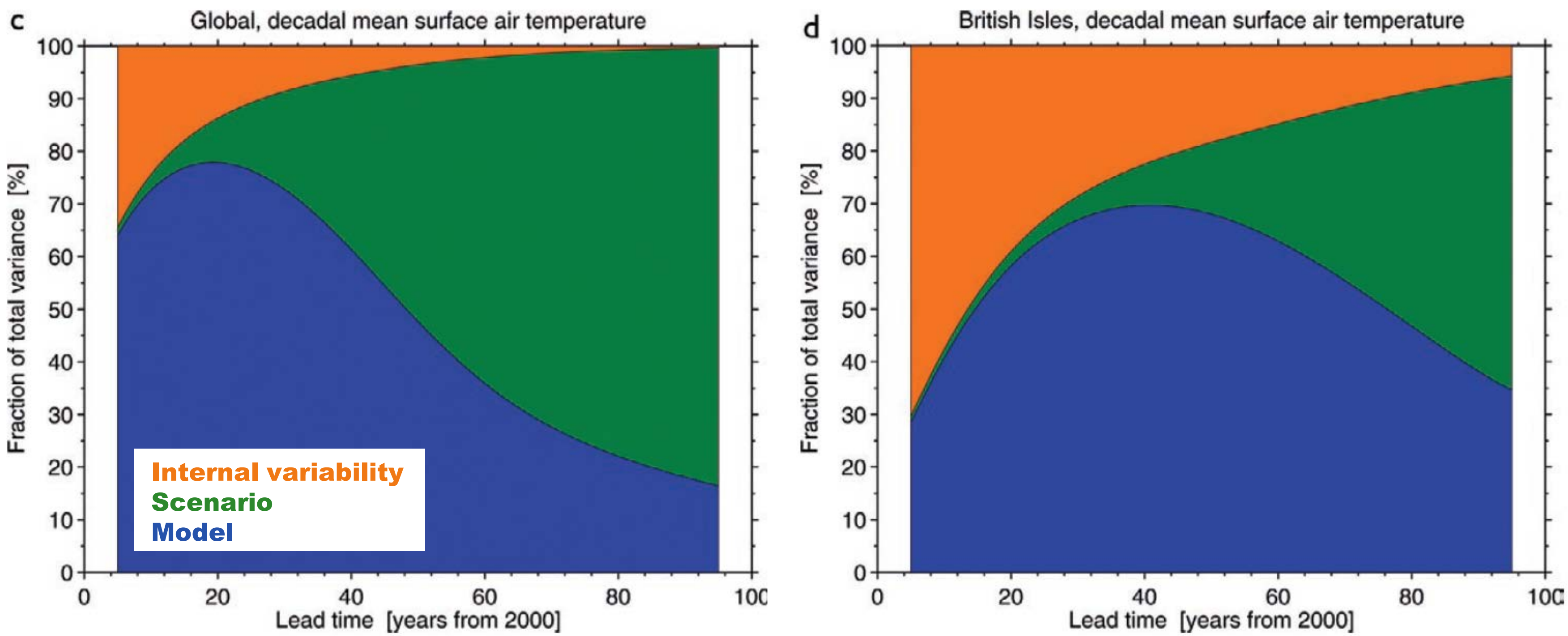
INITIAL CONDITION ENSEMBLES

- **Sampling of internal climate variability**

Relative Importance of Uncertainty Sources

Strongly depends on

- **Variable considered**
- **Spatial scale / region considered**
- **Lead time considered**



Hawkins & Sutton, 2009

OUTLINE

Part 1 Overview

Part 2 Model Uncertainty

Parts 3,4,5 Joanna Wibig Douglas Maraun

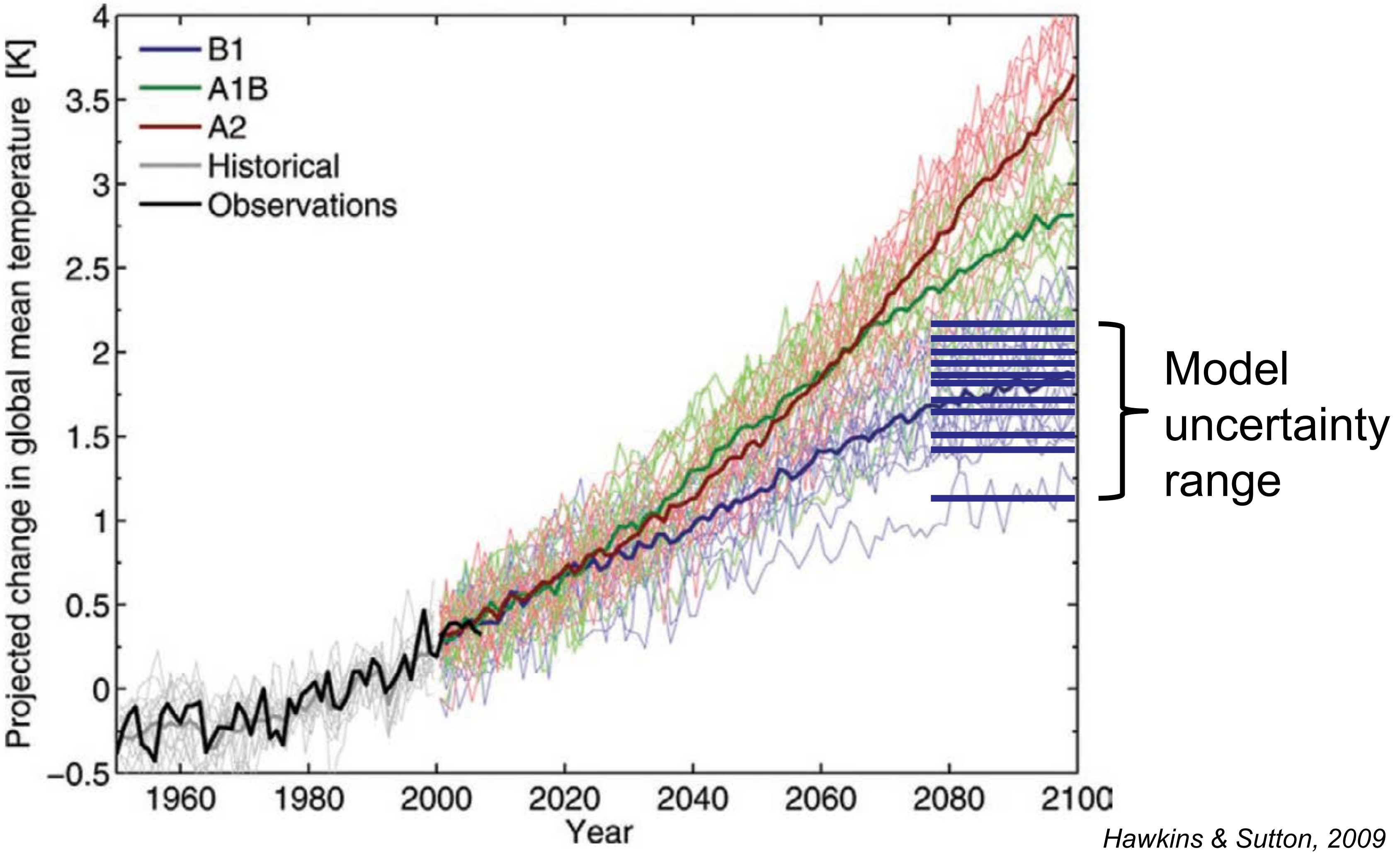
Overview: Model Uncertainty / Response Uncertainty

1. Take two climate models, **A** and **B**
   (alternatively: two variants $\mathbf{A_1}$ and $\mathbf{A_2}$ of the same model **A**).

2. Apply them in a climate projection context under the **exactly same experimental protocol**, particularly with the same external forcings (GHG and aerosol scenarios).

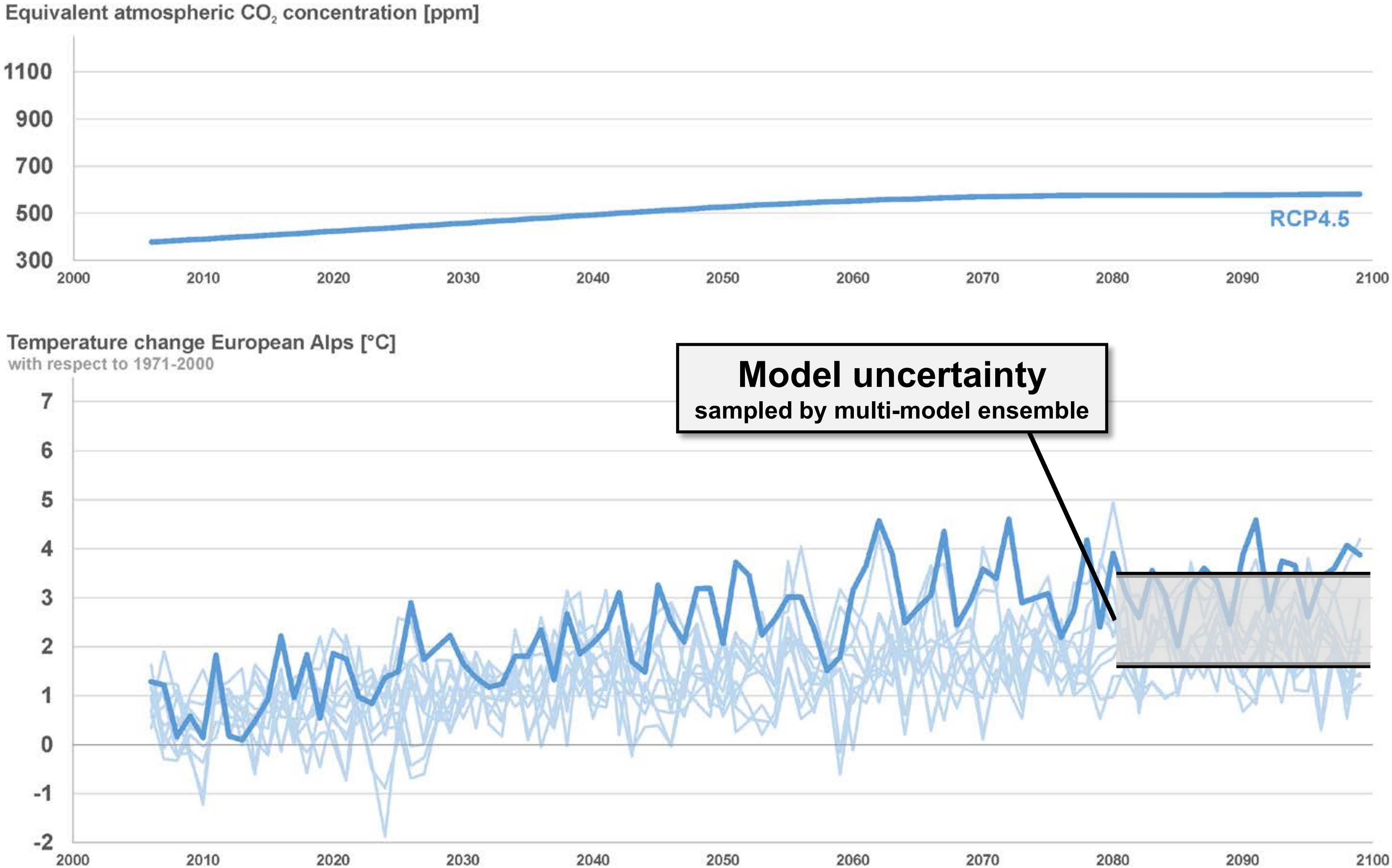
➡ The results from **A** and **B** will surely differ from each other! I.e., there's an **uncertainty in the simulated response** of the climate system to a certain change in GHG and aerosol concentrations.

Model Uncertainty: Examples (1)



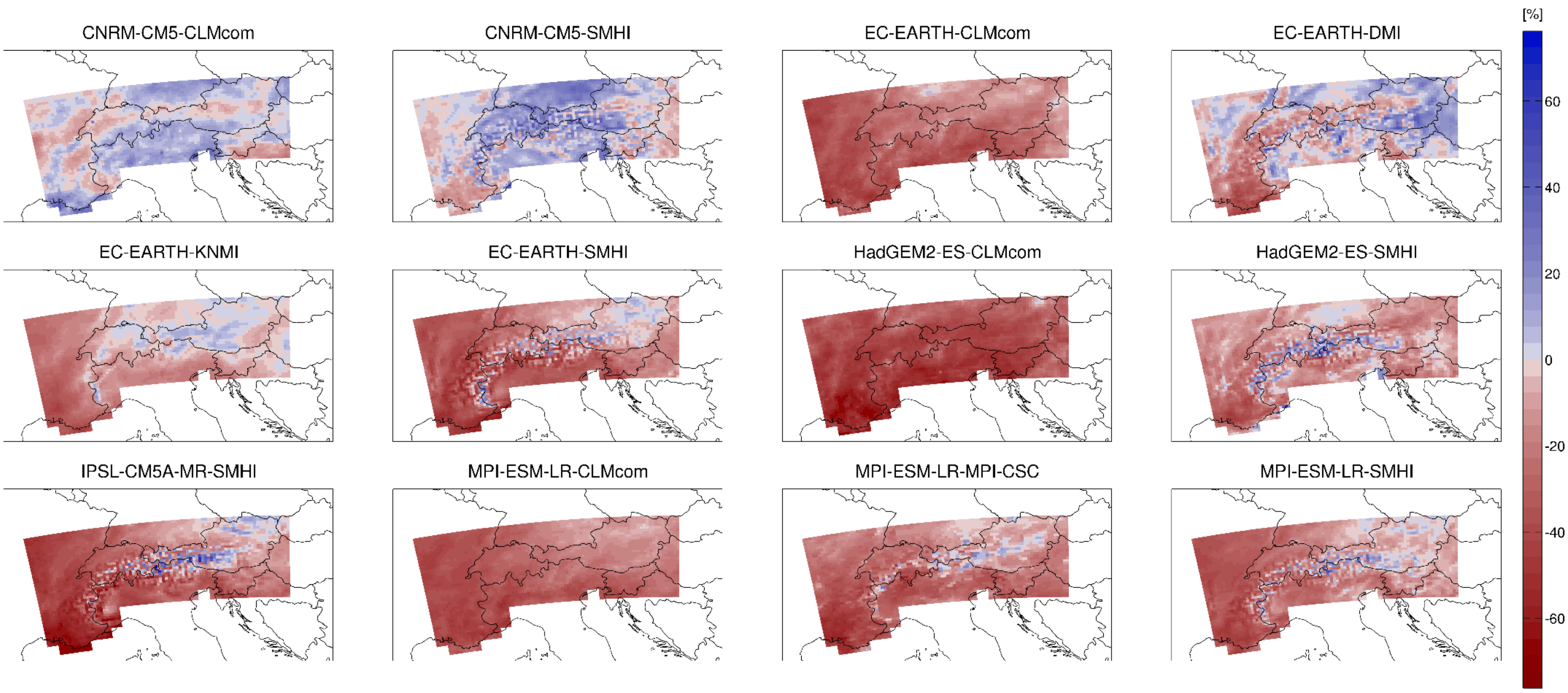
Hawkins & Sutton, 2009

Model Uncertainty: Examples (2)



Model Uncertainty: Examples (3)

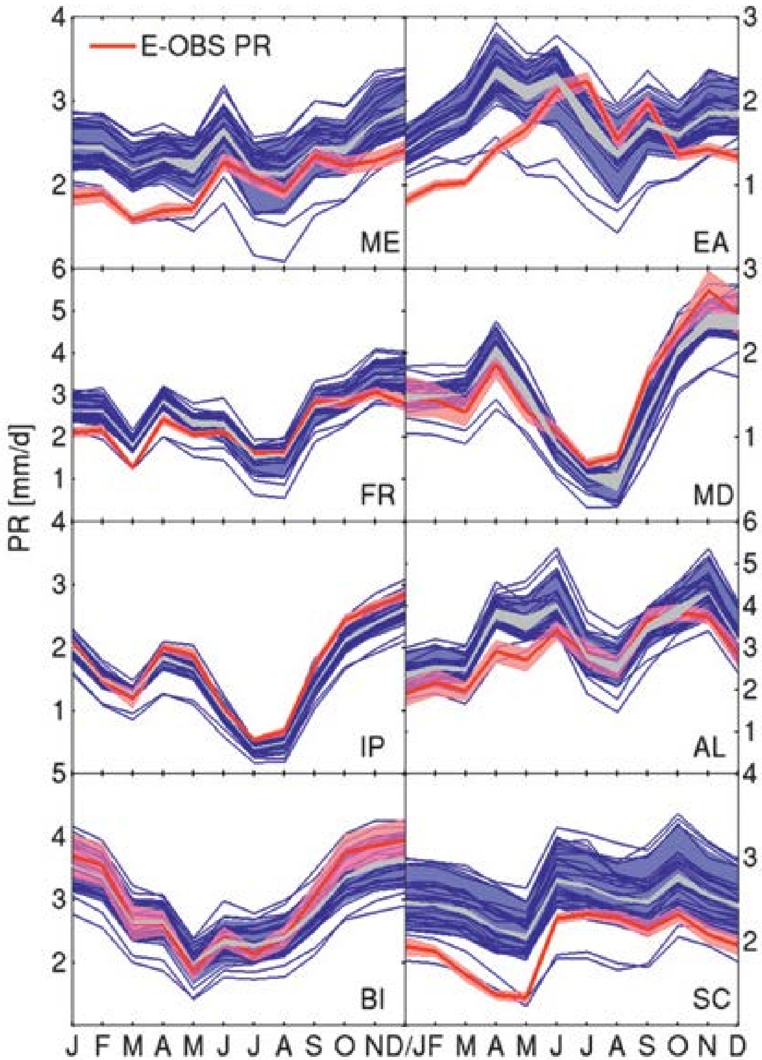
Mean **summer precipitation change** until end of 21st century in the EUR-11 scenarios
High emission scenario (RCP8.5)



Winter et al., 2015, unpublished

Model Uncertainty: Examples (4)

Mean annual cycle (1991-2000) of **precipitation** in the perturbed physics ensemble over the eight sub-domains



Bellprat et al., 2012a

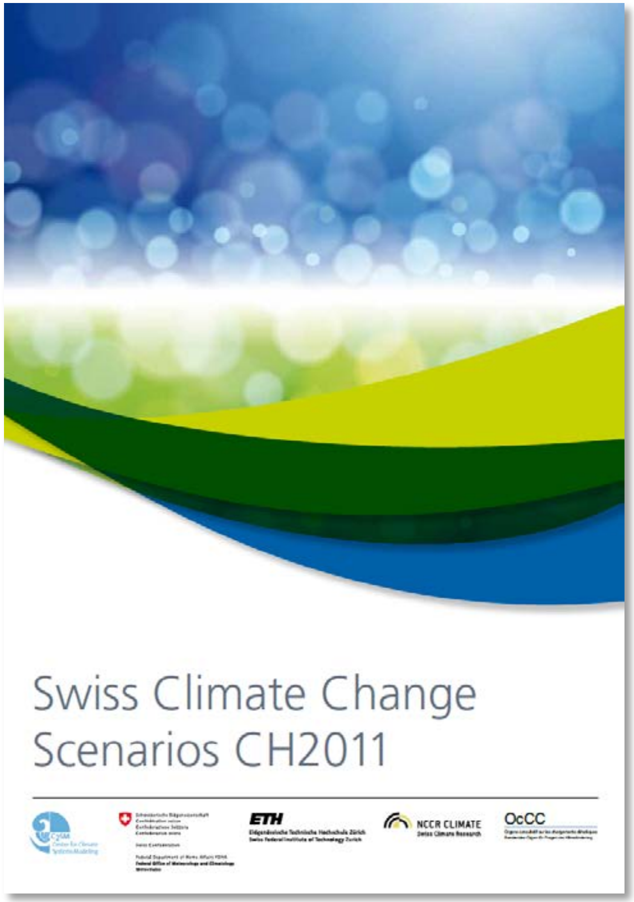
Model Uncertainty: Sources (e.g., IPCC AR5)

- Climate models as **strongly mathematical simplified representations** of the climate system
- Simplification choices vary from model to model in terms of algorithmic structures, numerics, formas and values of parameterizations, number and kinds of coupled processes included, etc.
- **Structural uncertainties**: numerical technqiues, forms of parameterizations, choices of fixed or varying boundary conditions
- **Parametric uncertainties**: Choices made in setting the parameters that control the various model components

Model Uncertainty: Quantification

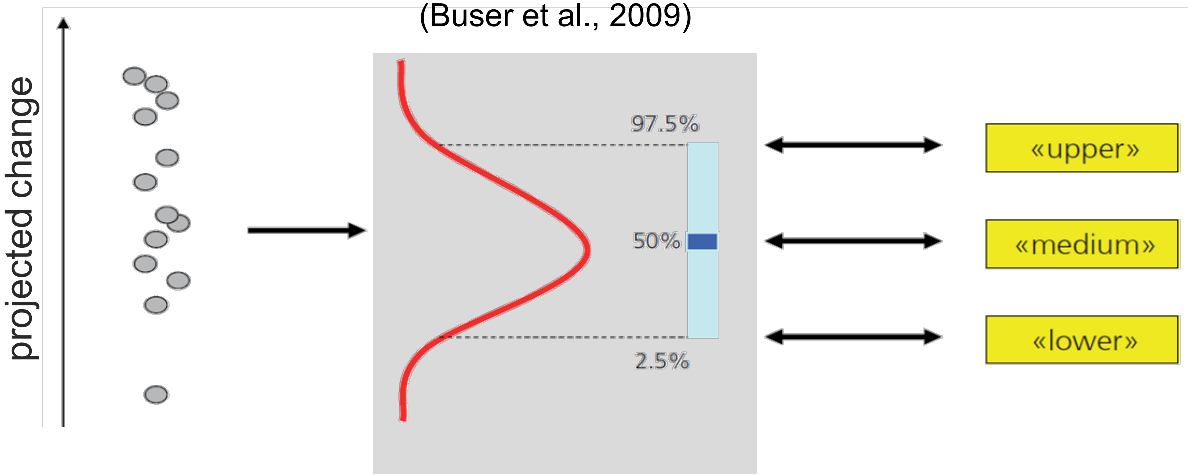
- **Multi model ensembles** (MMEs)
- **Perturbed physics ensembles** (PPEs)
- **Take care:** Neither MMEs nor PPEs can be assumed to represent an adequate sample of all the possible choices one could make in building a climate model.
- **MMEs**: Very often "ensembles of opportunity", sampling a limited uncertainty space. Model developments not independent! (e.g. Knutti 2010) Also: Important aspects might be neglected by **all(!)** models of an MME.
- **PPEs**: Systematic construction possible, but choice of parameters targeted for perturbation subjective, and often biased towards atmospheric parameters.

Model Uncertainty Quantification
The CH2011 Swiss Climate Change Scenarios



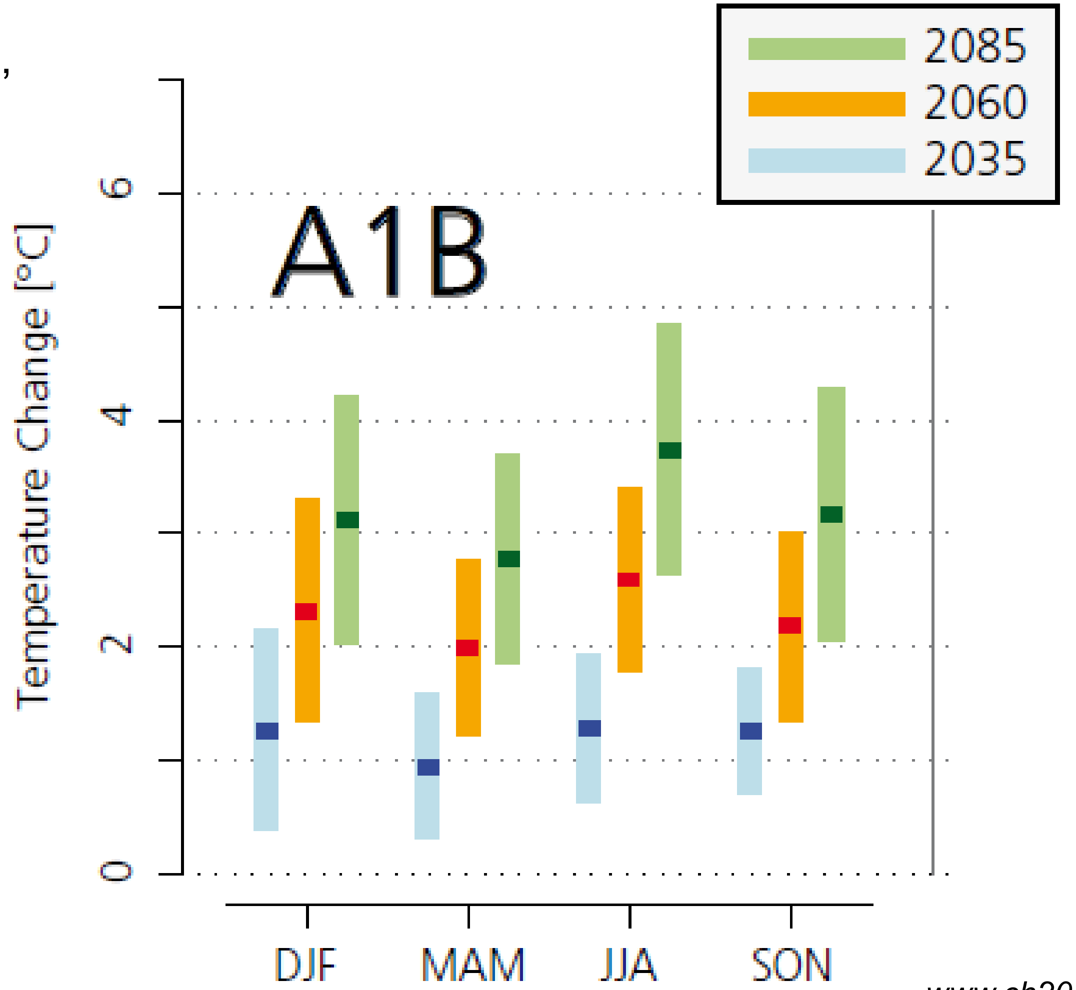
www.ch2011.ch

Probabilistic
Bayesian framework
(Buser et al., 2009)



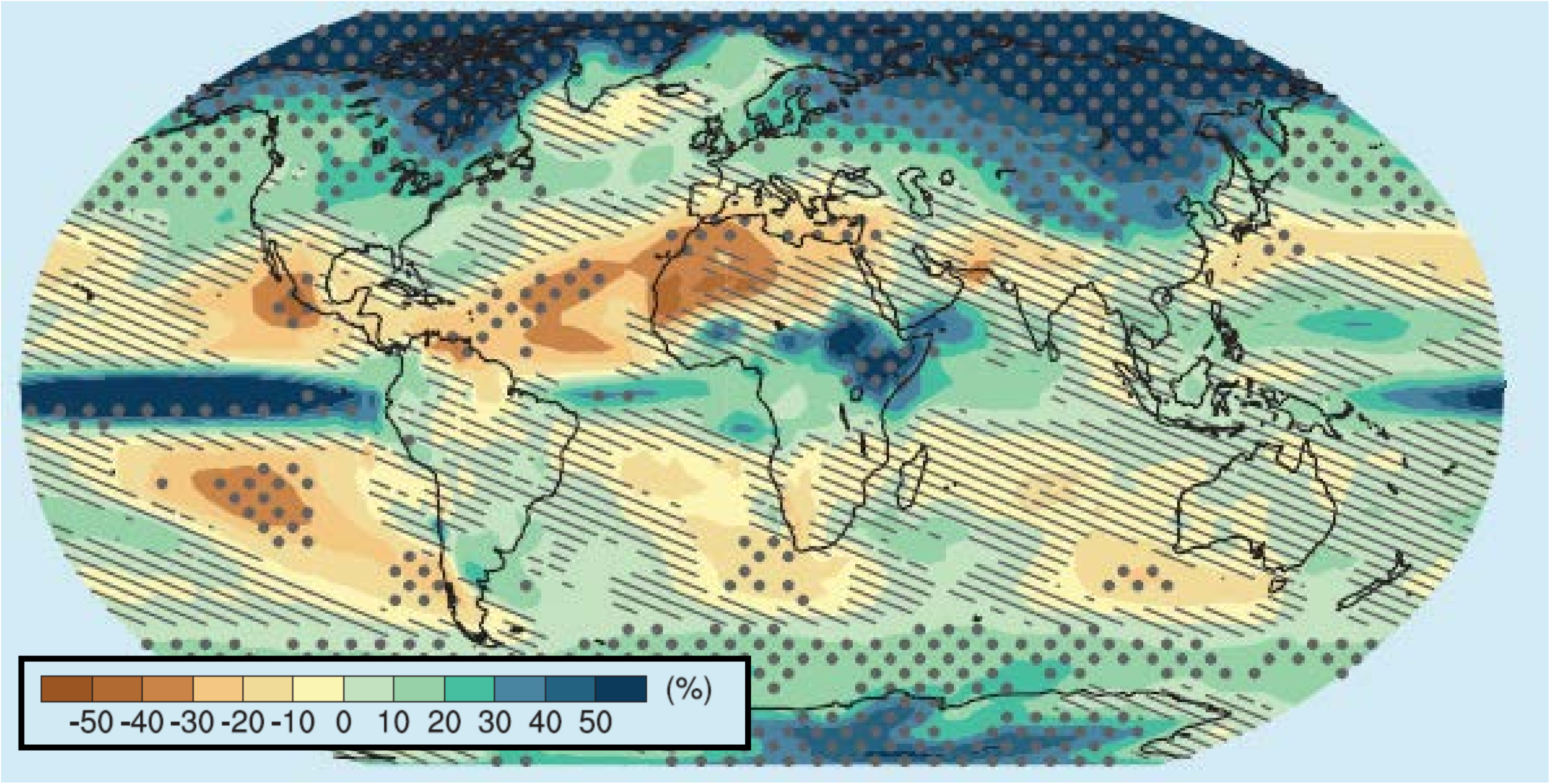
Model Uncertainty Quantification
The CH2011 Swiss Climate Change Scenarios

Range of temperature change,
Northeastern Switzerland



www.ch2011.ch

Illustrating Model Uncertainty in Maps



IPCC AR5, Chapter 12

Projected change in DJF precipitation for 2081–2100, relative to 1986–2005 from CMIP5 models. 39models. **Stippling**: Multi-model mean change > 2 SDs of IV **and where at least 90% of models agree on the sign of change**.

The Good Message

In principle, model uncertainty / response uncertainty is reducible!