Difficulties in Making Sense of Downscaling

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Outline

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Criticising Downscaling

Alternative Concepts

Revisiting Criticism and Alternatives

Summary and Comments

I don’t want to use downscaling because

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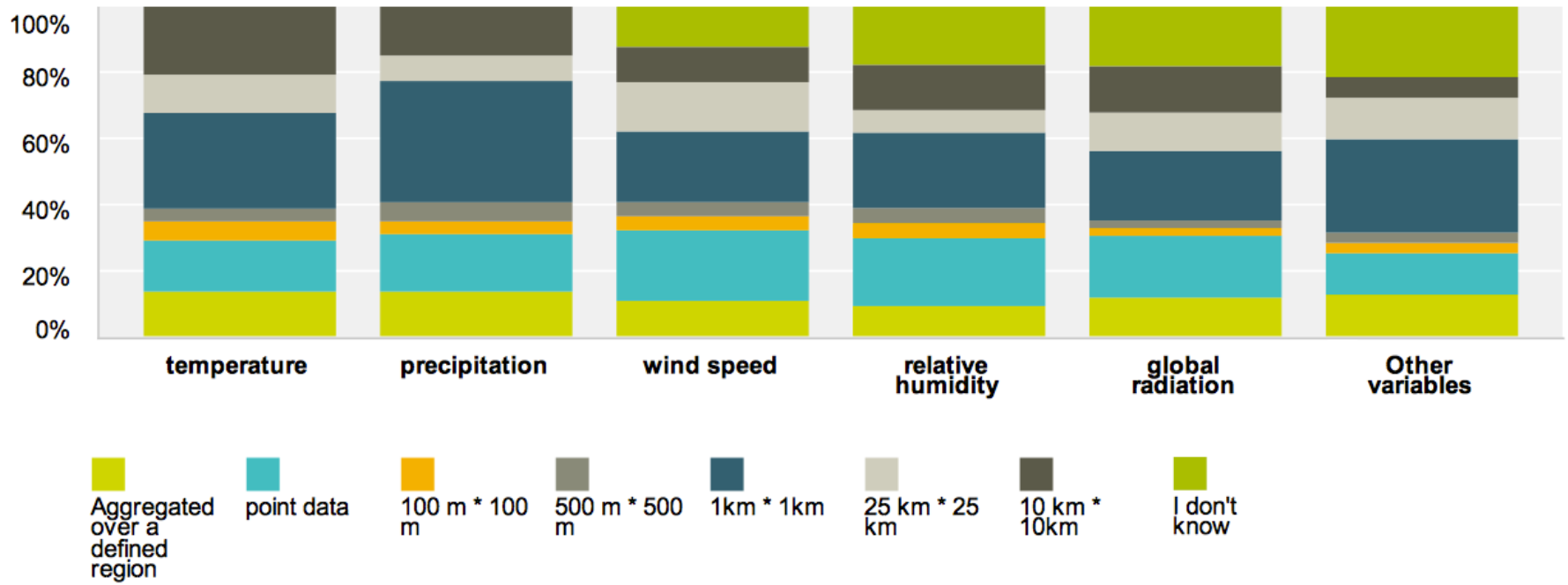
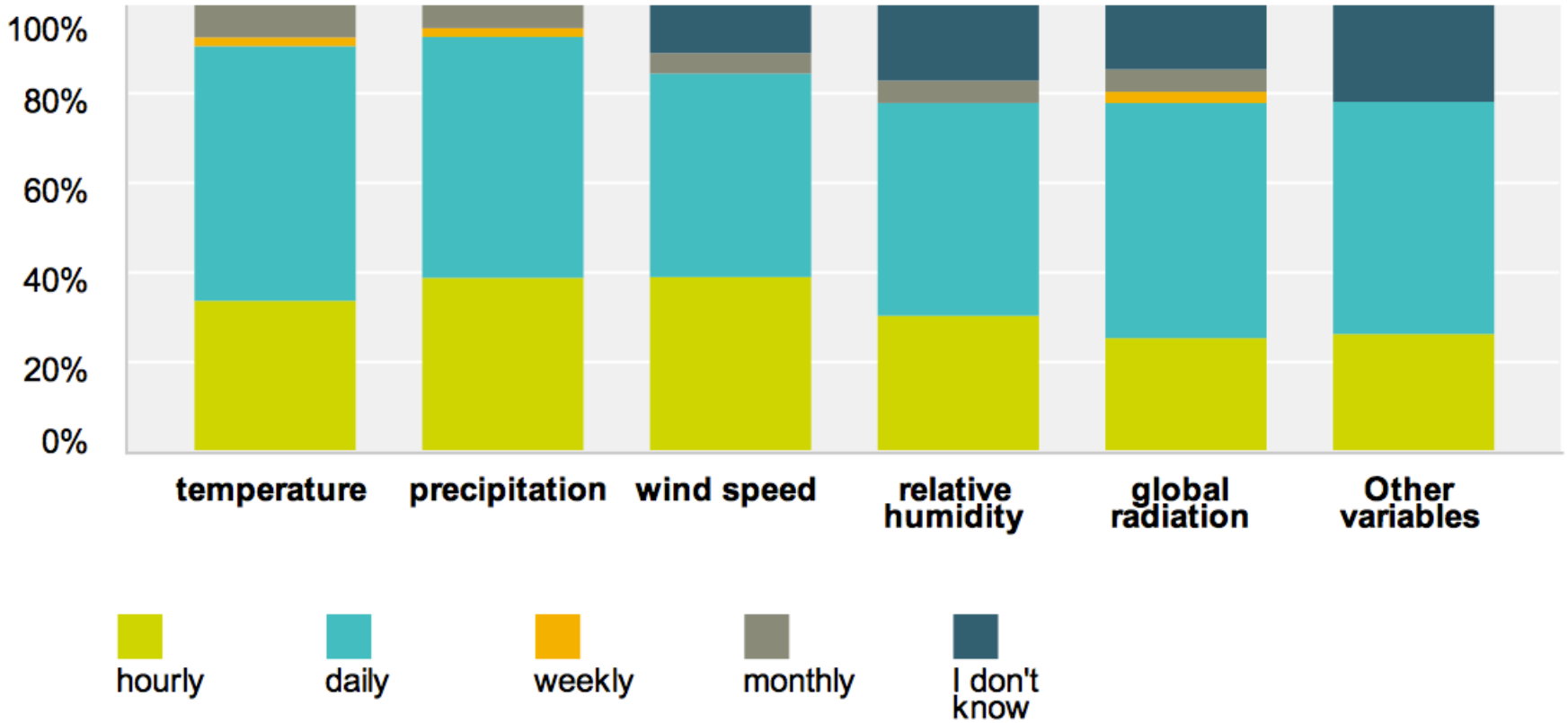
- the resolution is too coarse
- I am fine with bias corrected GCMs
- the results of different methods contradict each other
- it adds another layer of uncertainty
- I don’t want to use model data at all but rather rely on first principles
- ...

Spatial resolution too coarse



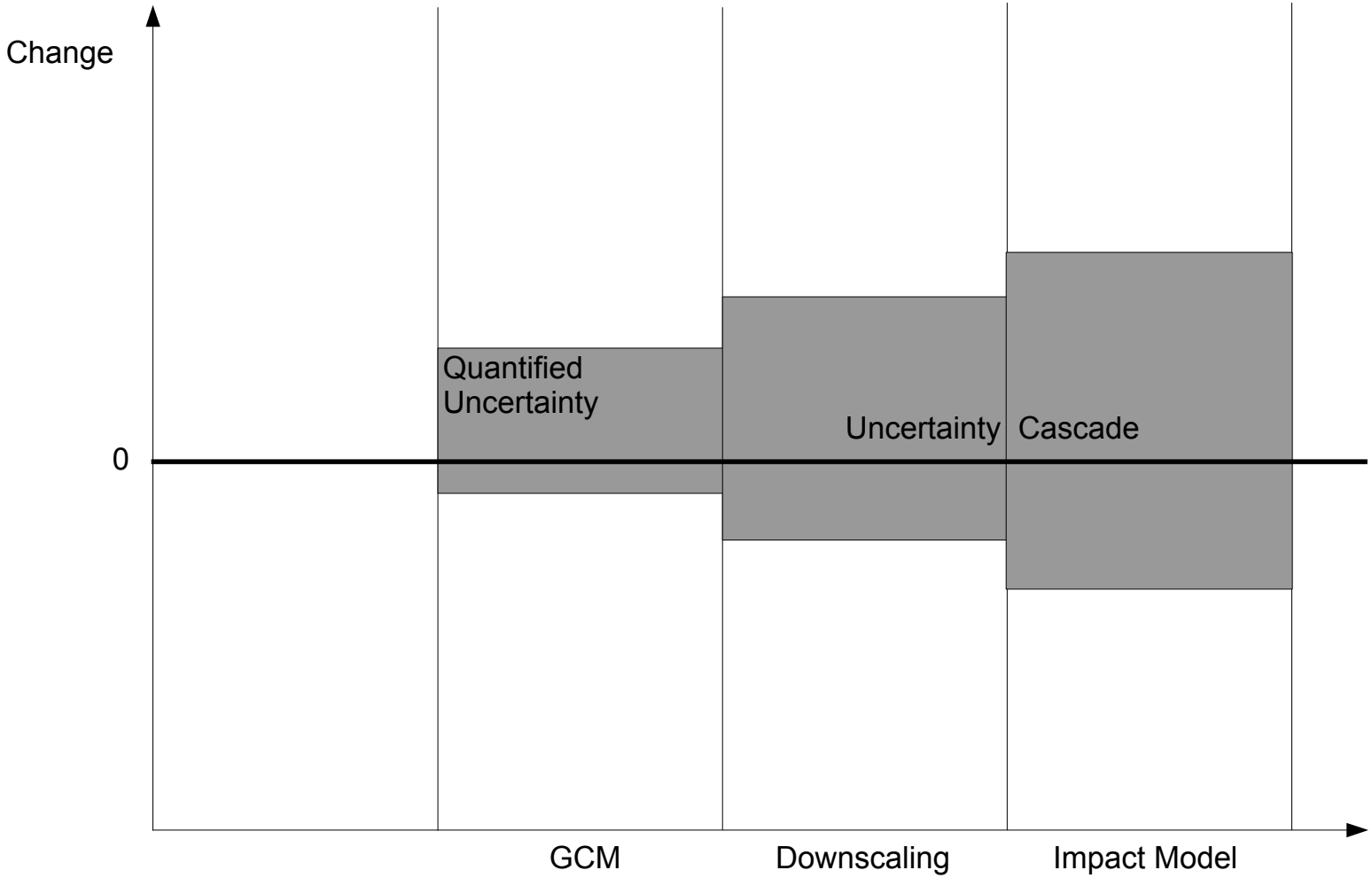
Roessler et al., VALUE end user survey

Temporal resolution too coarse



Roessler et al., VALUE end user survey

Uncertainty Cascade



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Response Surfaces/Decision Scaling, etc.

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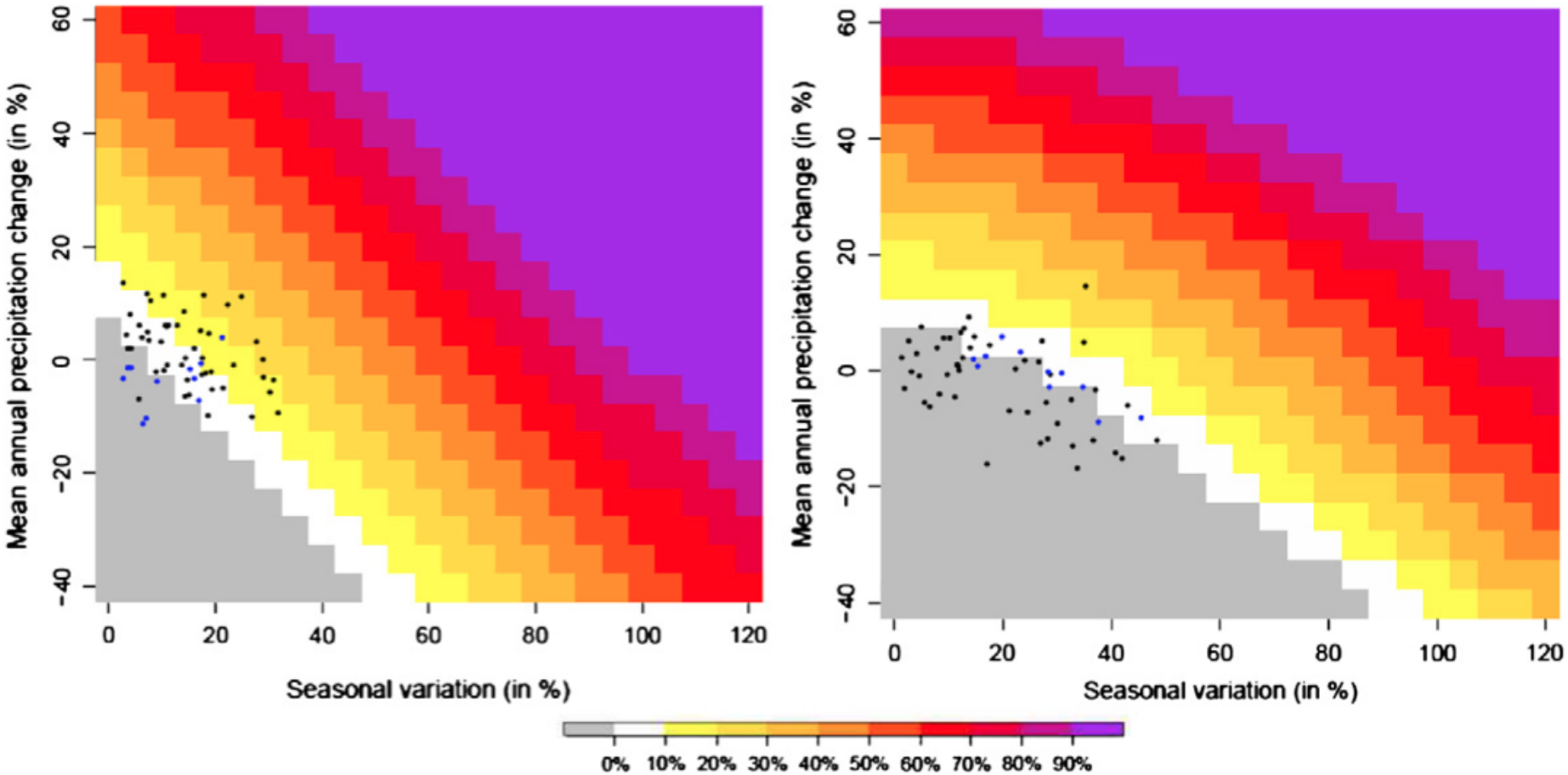
1. Drive impact model with large range of stochastic simulations;
2. based on results, construct response surface to infer sensitivity of change on different input variables;
3. compare bias corrected set of GCMs with response surface.

e.g., Prudhumme et al., 2010; Brown et al., 2012

Example 1: change in peak runoff

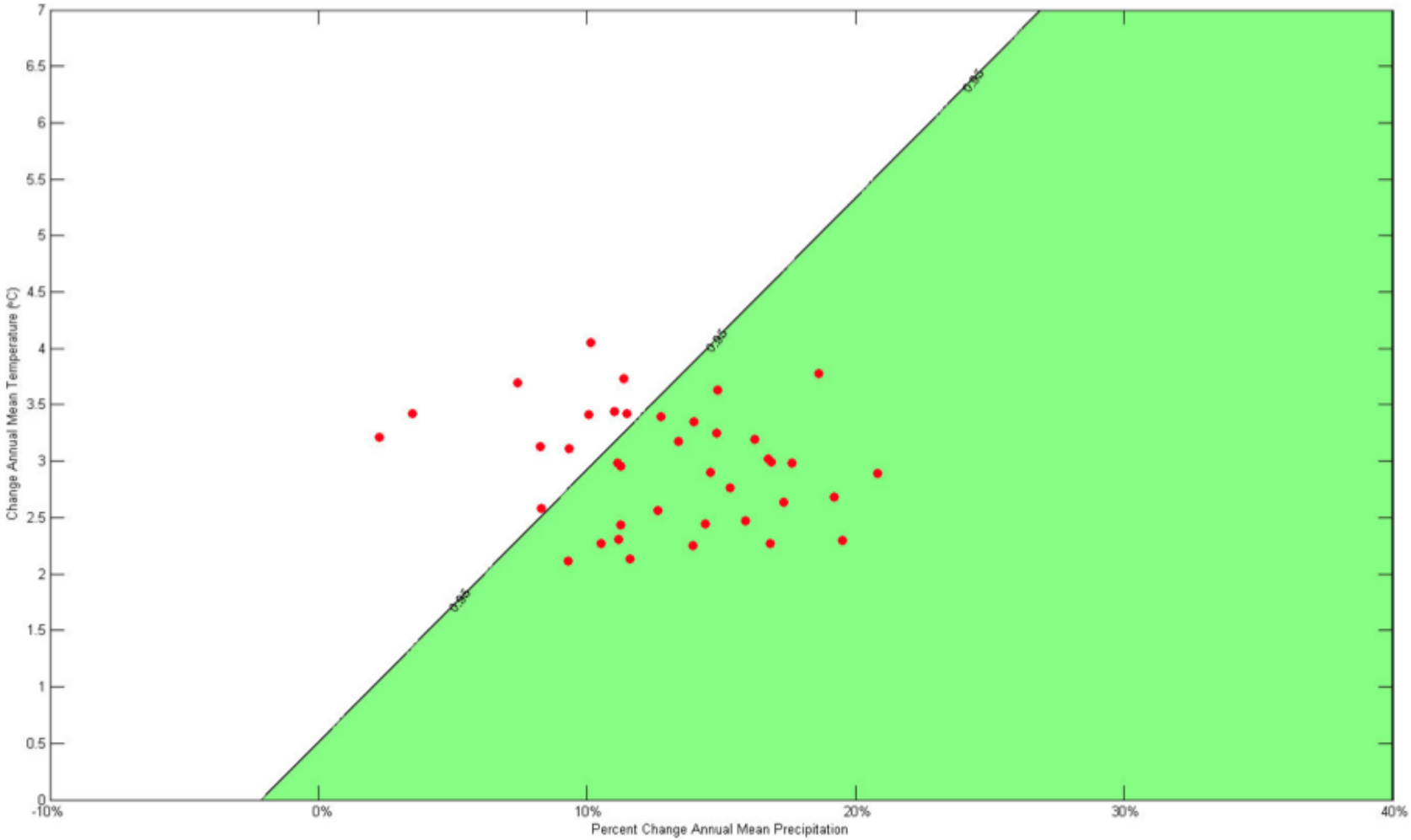
Left: NE Scotland; right: SE England



Prudhomme et al., 2010

Example 2: reservoir reliability

Green: no adaptation action required; white: action required



Brown et al., 2012

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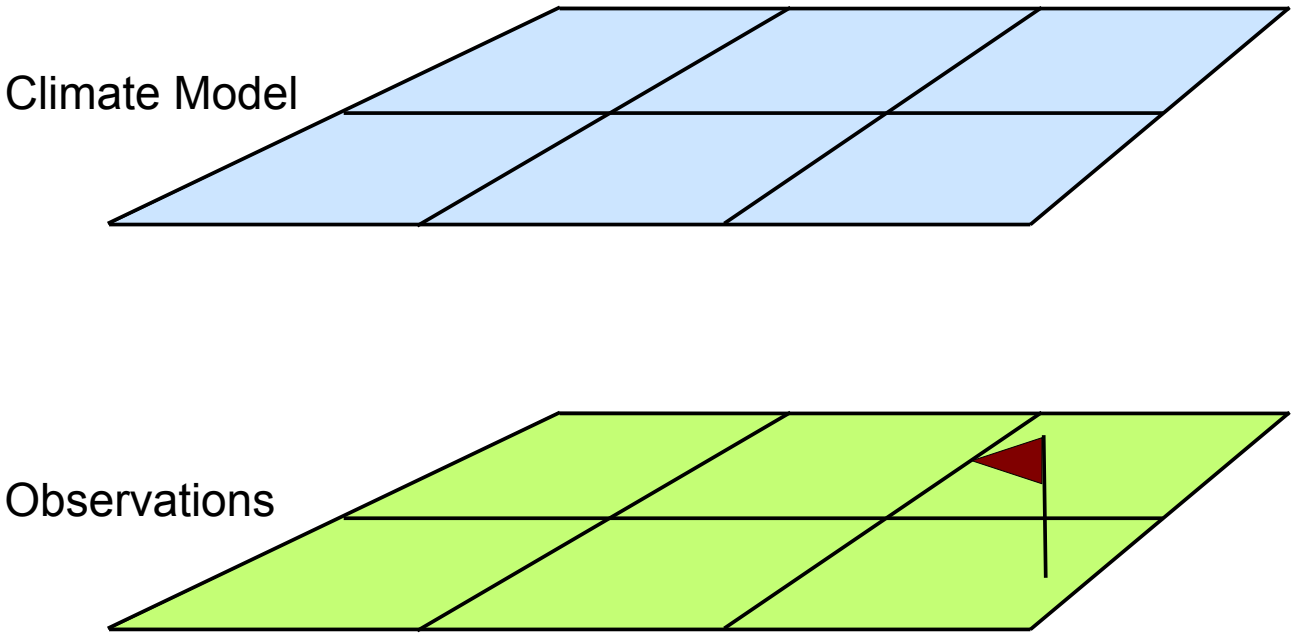
Representativeness Problems

Bias Correction Settings

Pure bias correction vs. bias correction plus downscaling



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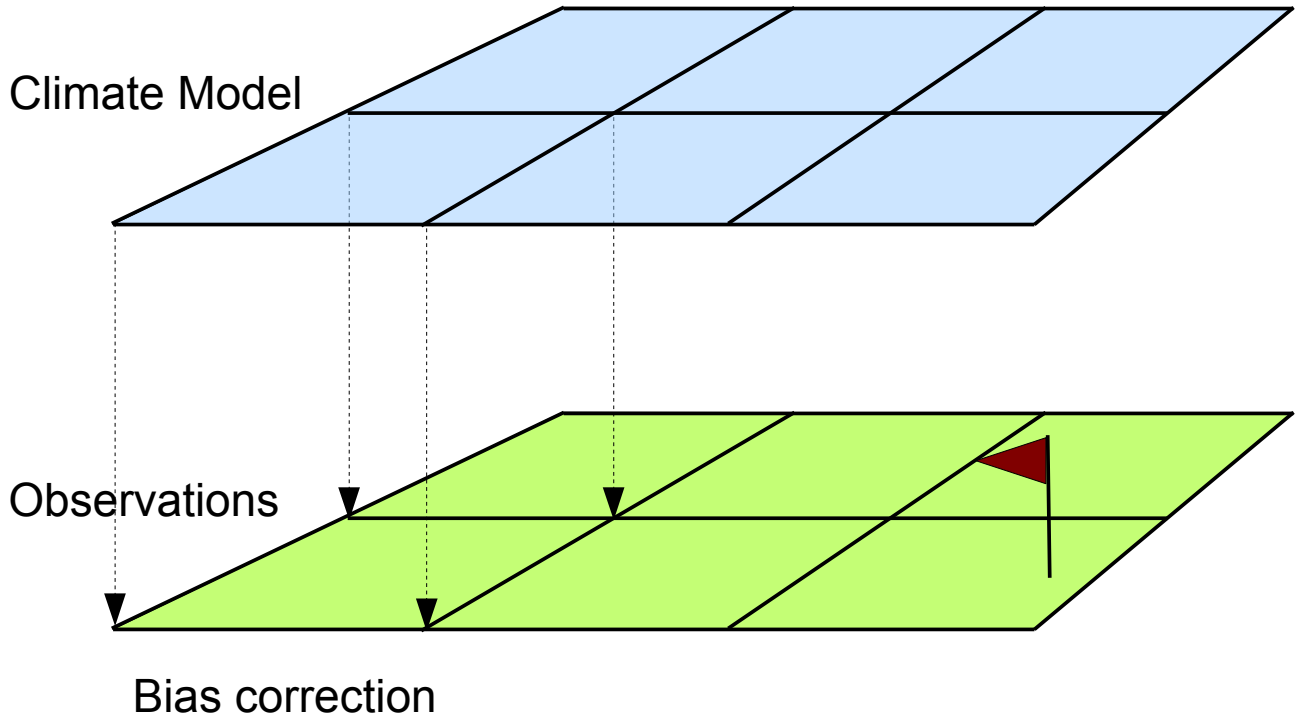

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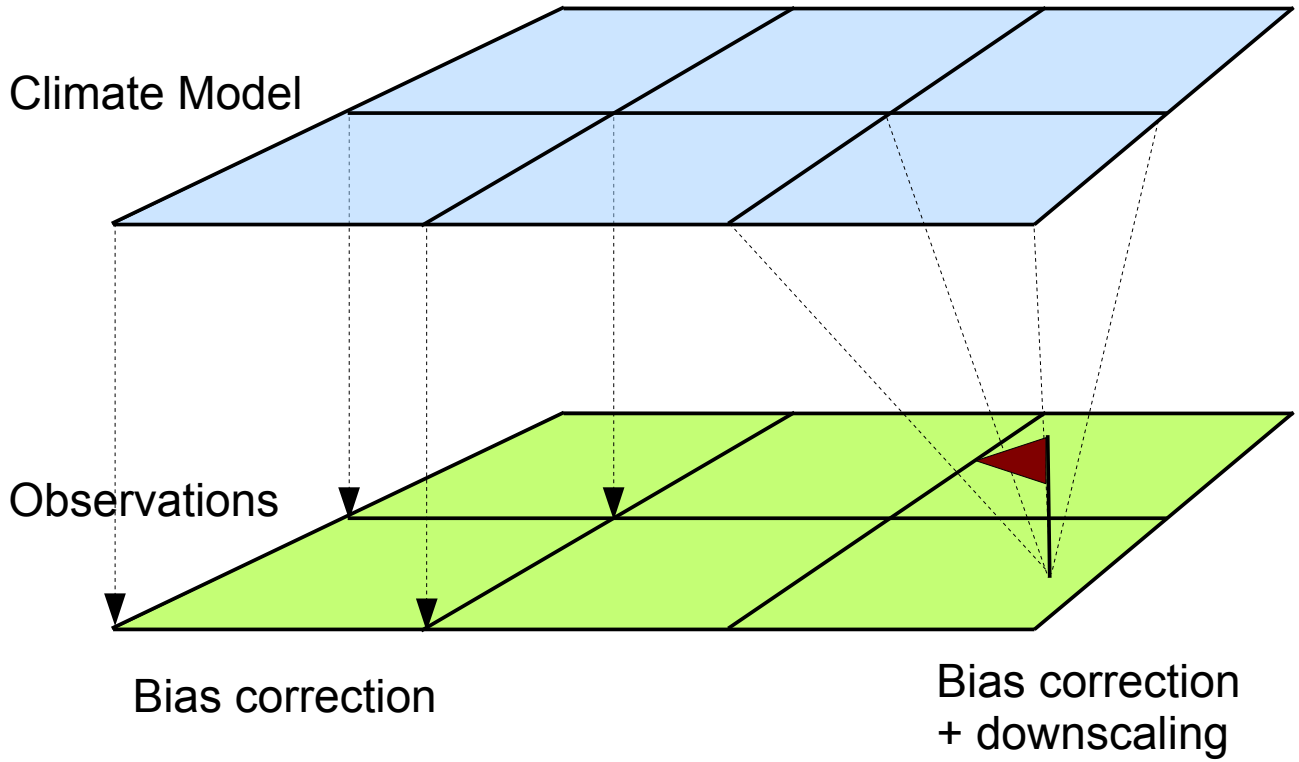

Representativeness Problem

One Grid Box State $\leftrightarrow$ Several Local States

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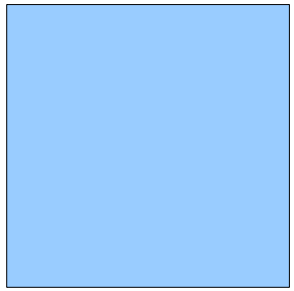
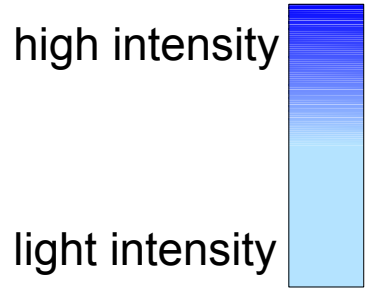
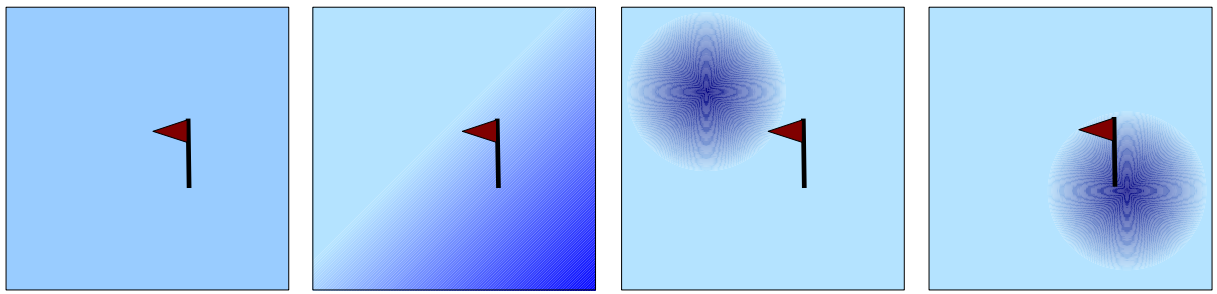
Climate Model



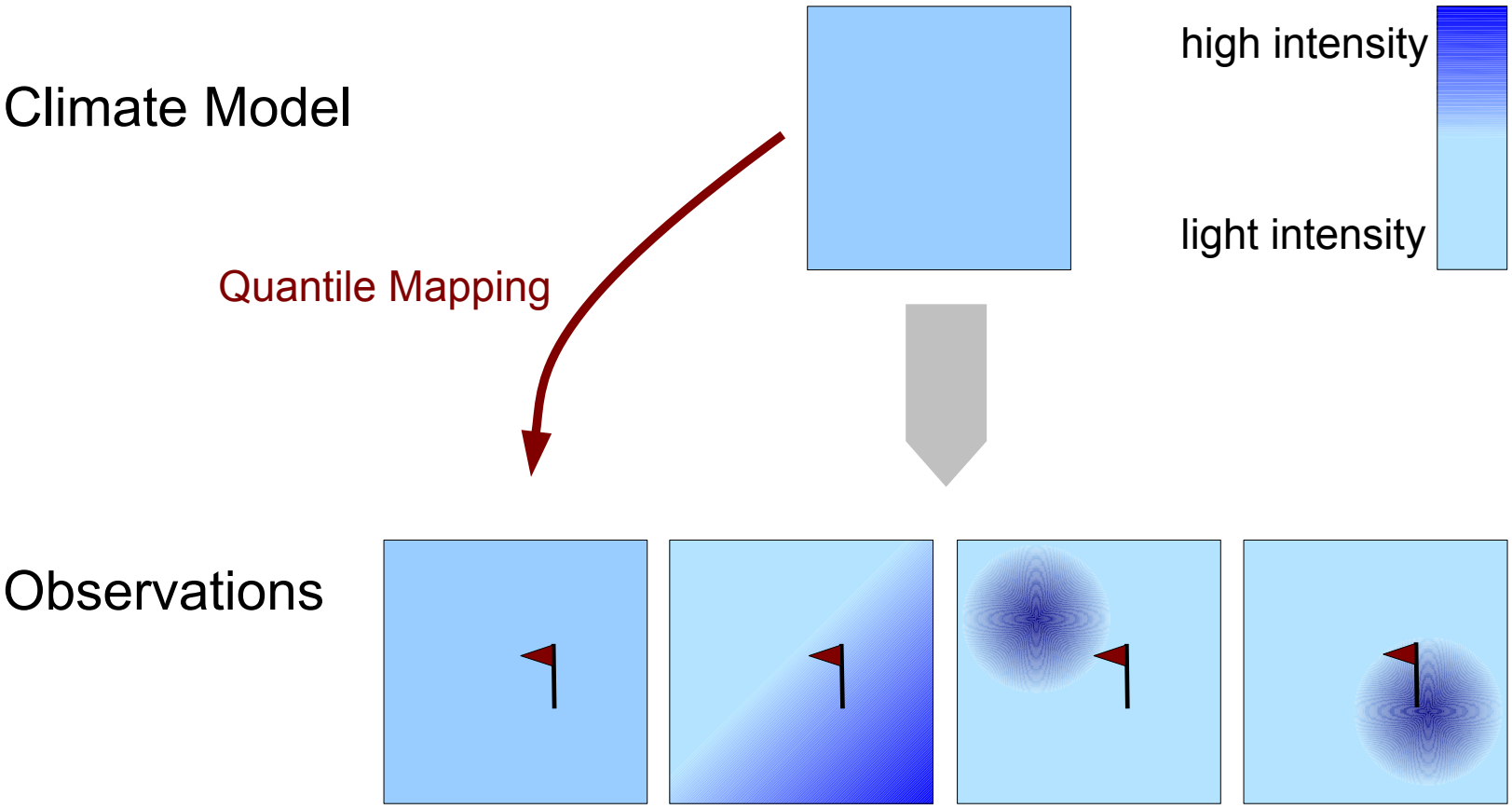


Observations



Grid box variability does not explain all local variability

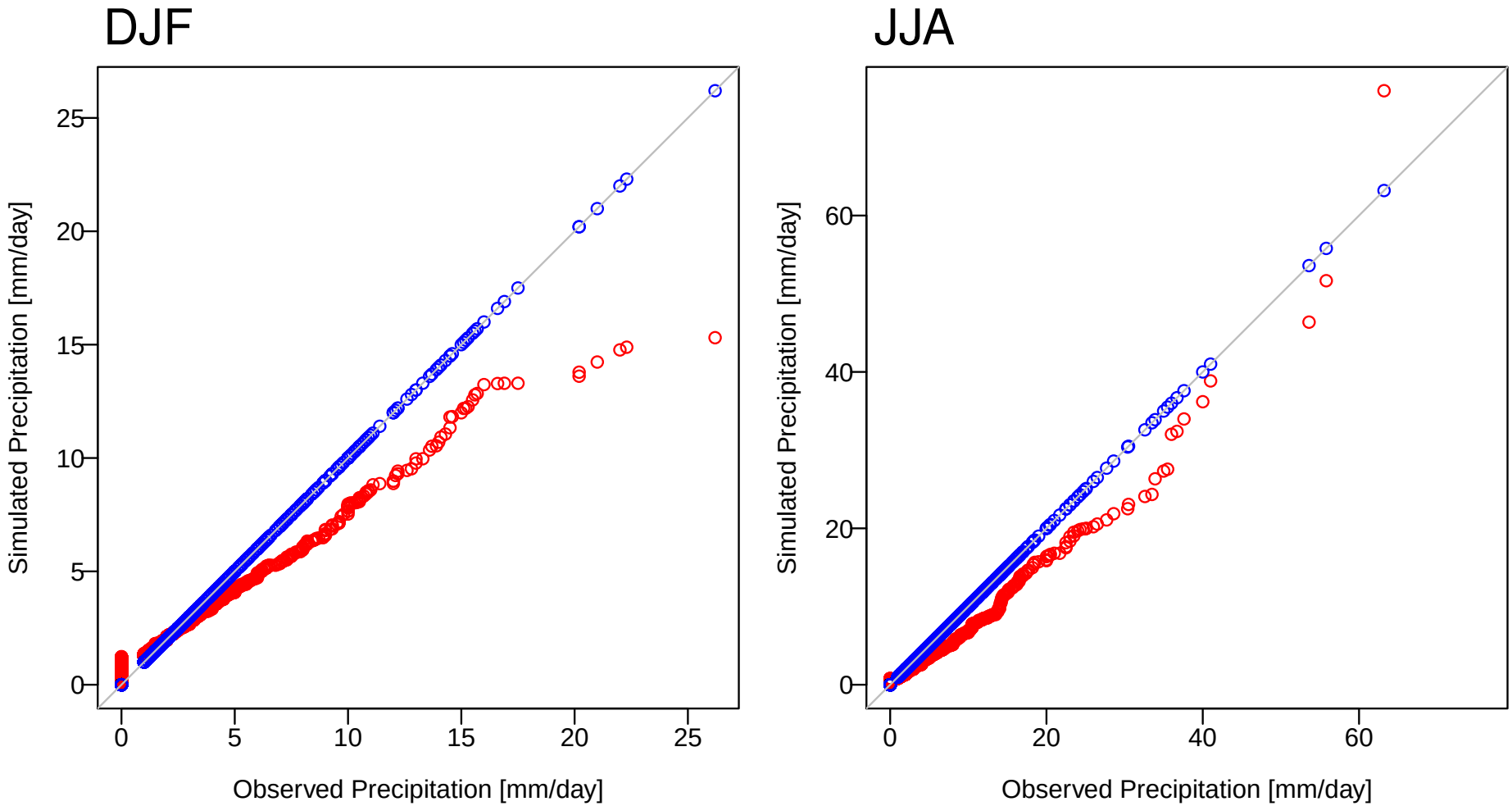
Bias correction does not add random variability



Bias correction is deterministic

Quantile mapping

applied to 20 gauges in Harz mountains

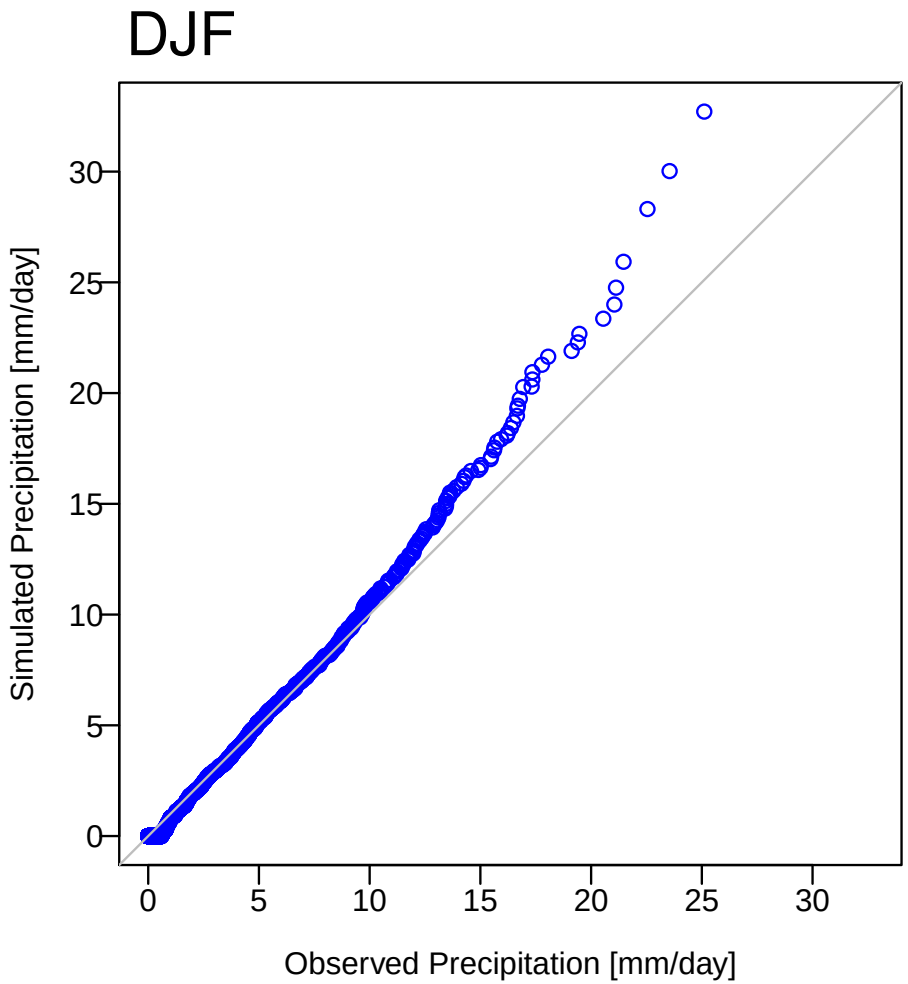


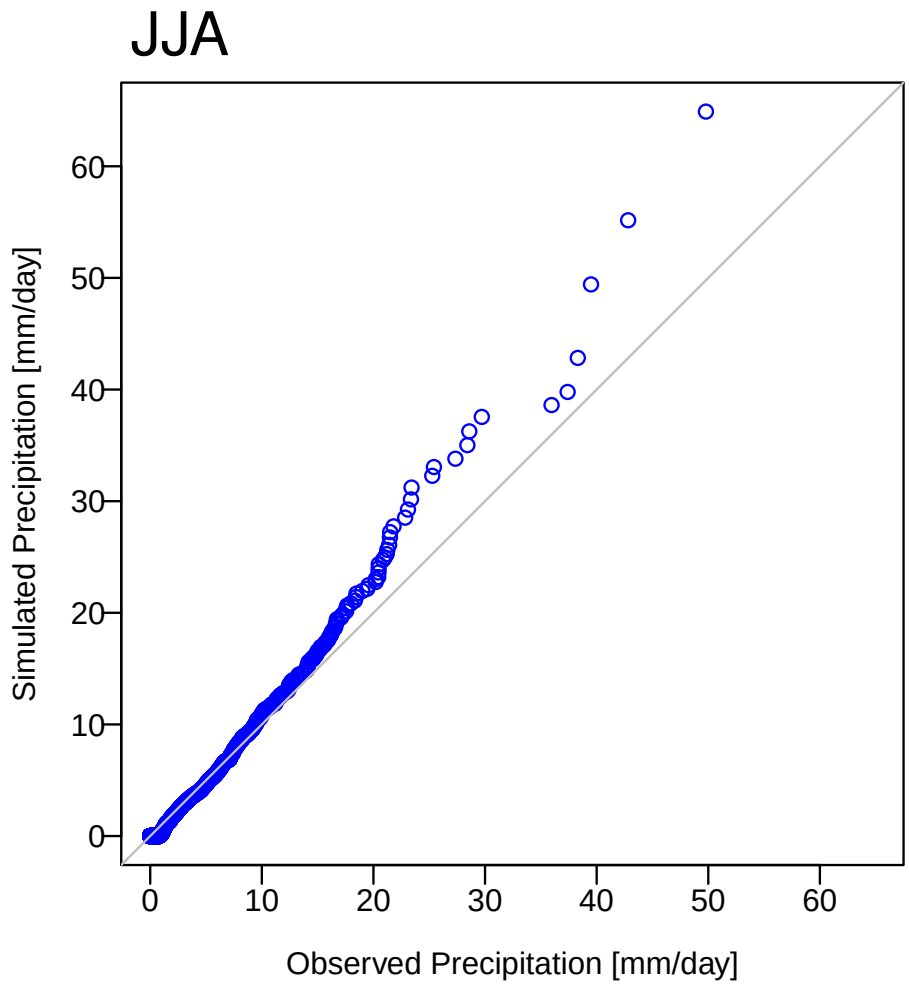
red: uncorrected, blue: corrected

Maraun, J Climate, 2013

QM effect at grid scale

QM overcorrects the area drizzle effect and inflates area extremes





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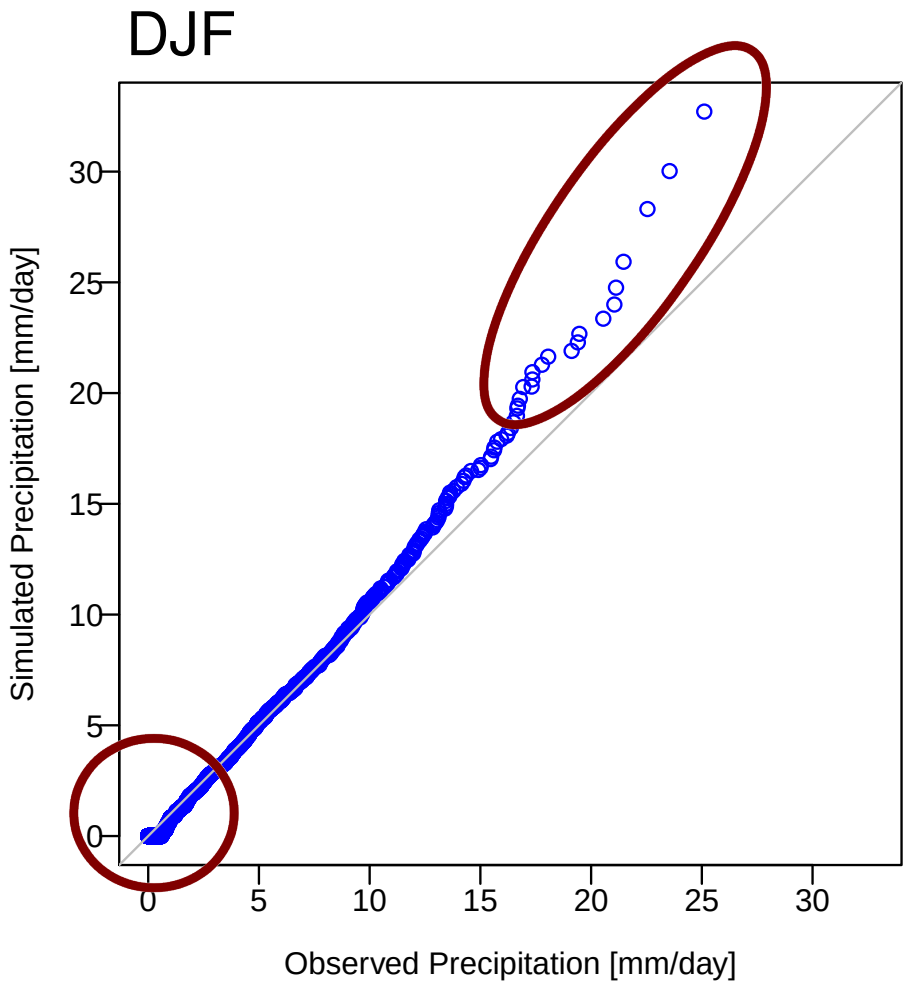
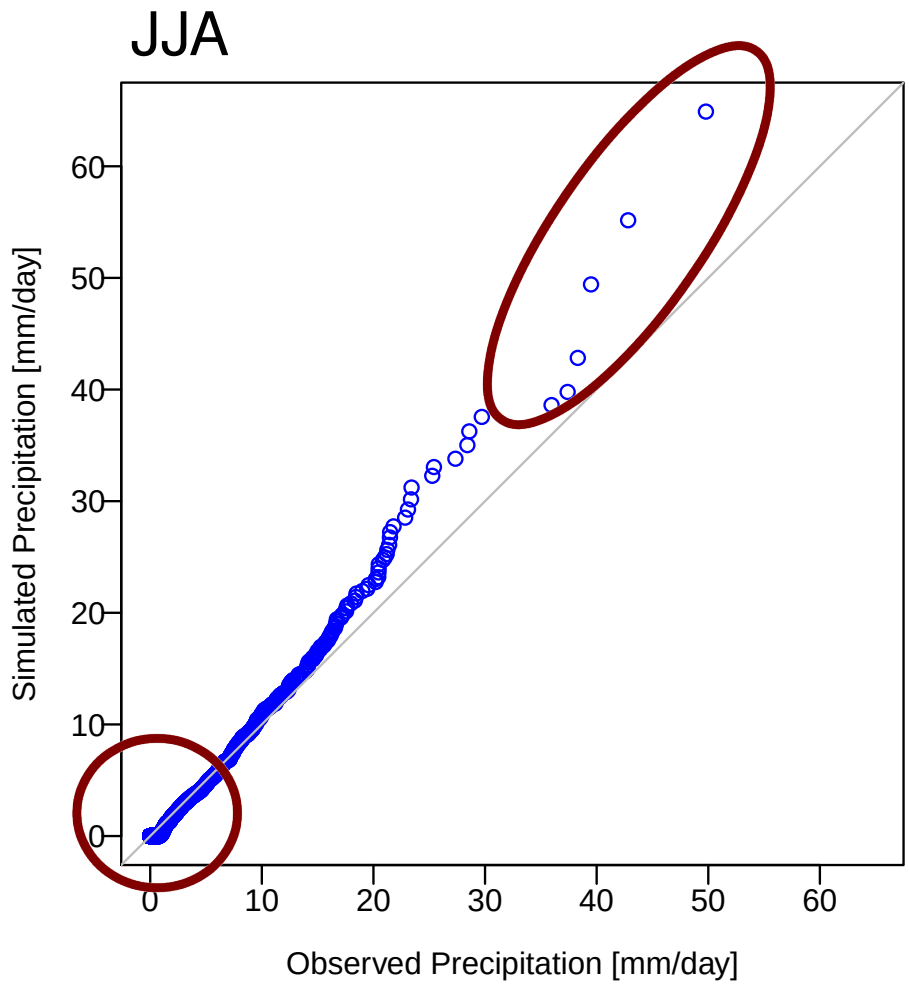
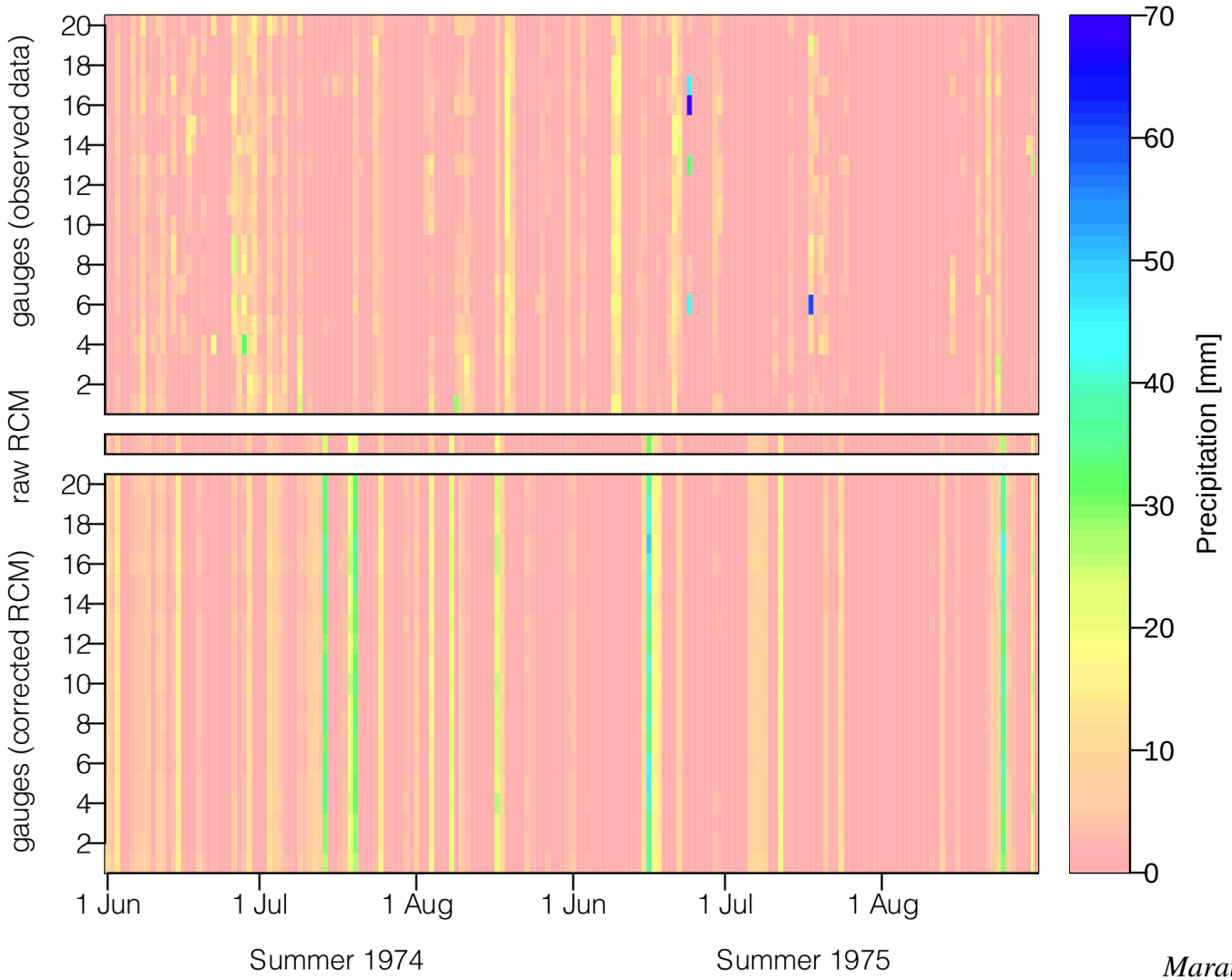




Maraun, J Climate, 2013

Illustrating the Problem

REMO grid box precipitation mapped onto 20 rain gauges



Maraun, J. Climate, 2013

Potential Solution

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Stochastic Bias Correction

- Correct systematic biases
- Add local scale random variability
- “Bias correction weather generator”

Wong et al., 2014; Eden et al., 2014

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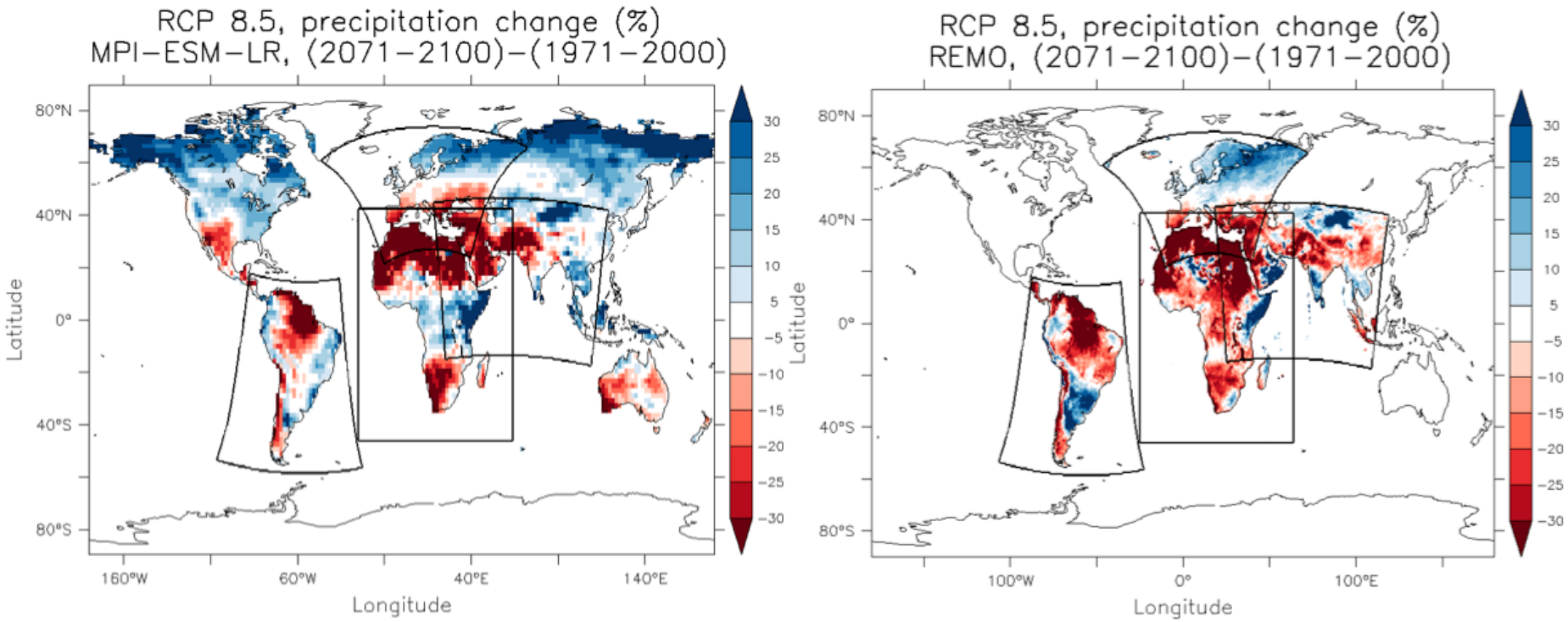
Added Value of Downscaling

Downscaling Changes Change

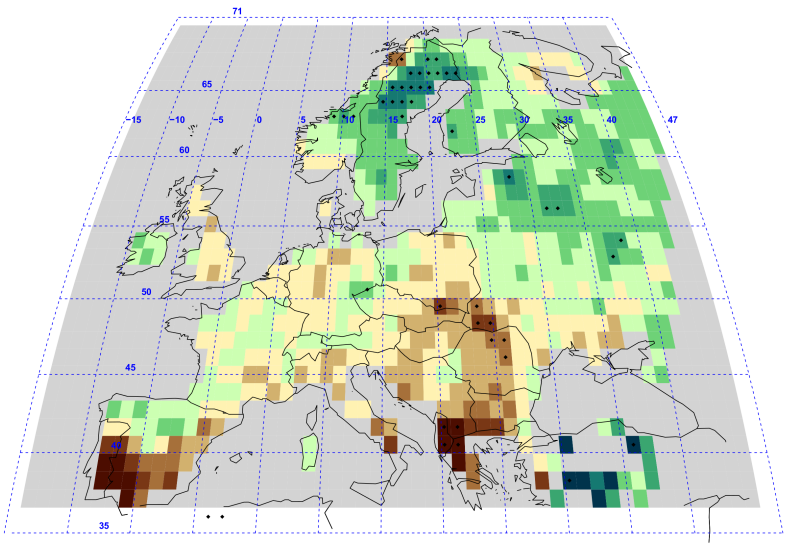


Teichmann et al., 2013

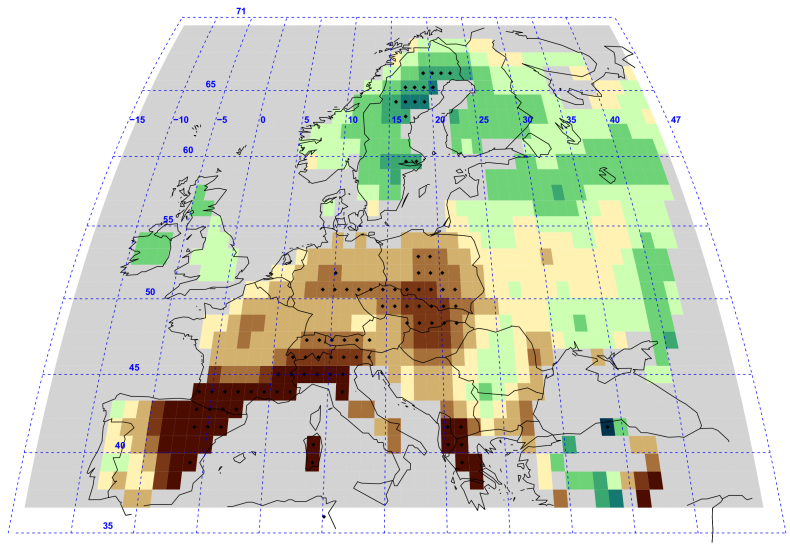
Do RCMs add value to simulated trends

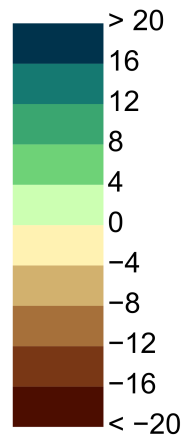
Precipitation Trends in Europe, JJA, 1960-2002 [percent per decade]

EOBS



ERA40





courtesy O. Wulff

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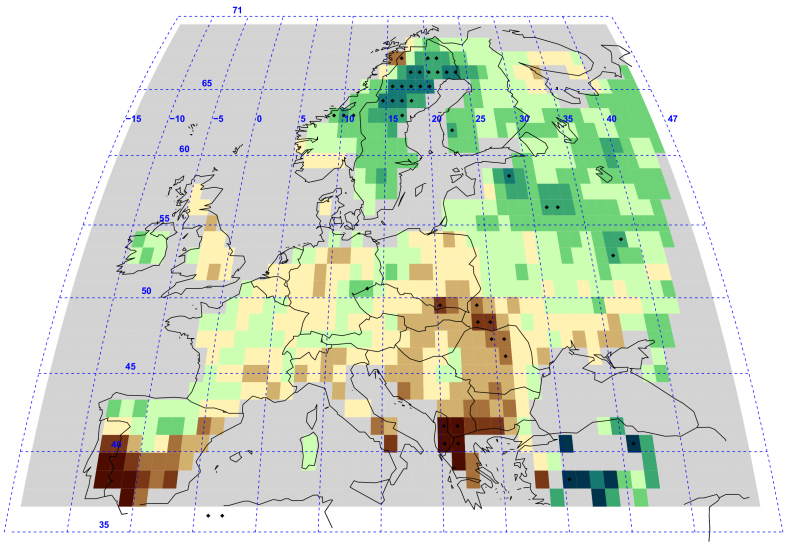
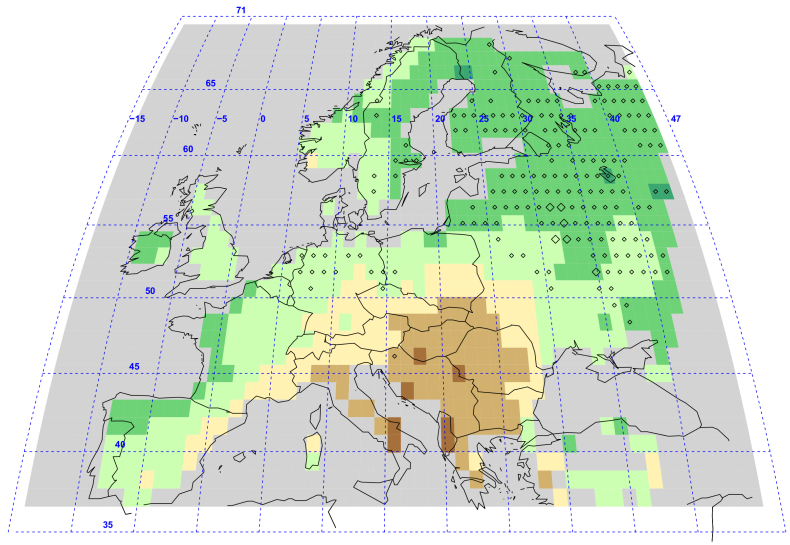
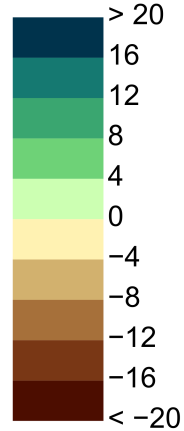


RCM ensemble

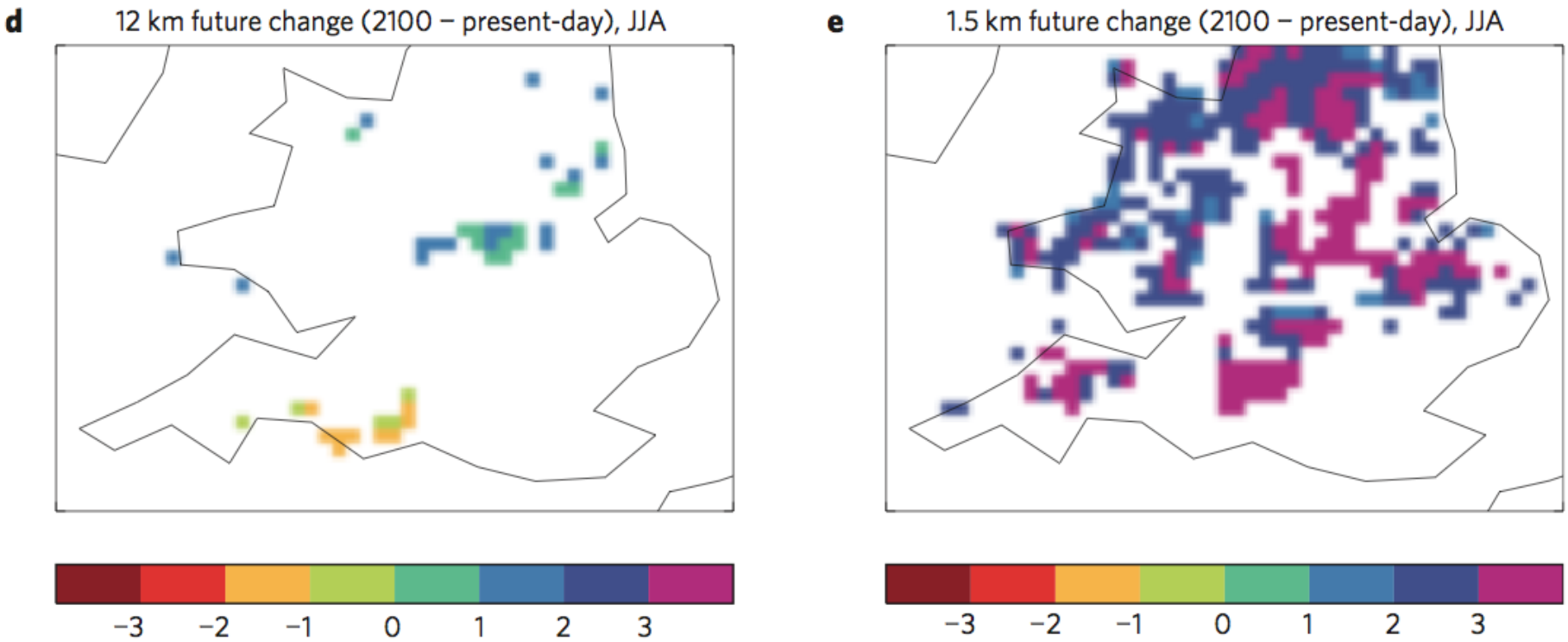




courtesy O. Wulff

State-of-the-art might be not good enough

e.g., for hourly precipitation extremes

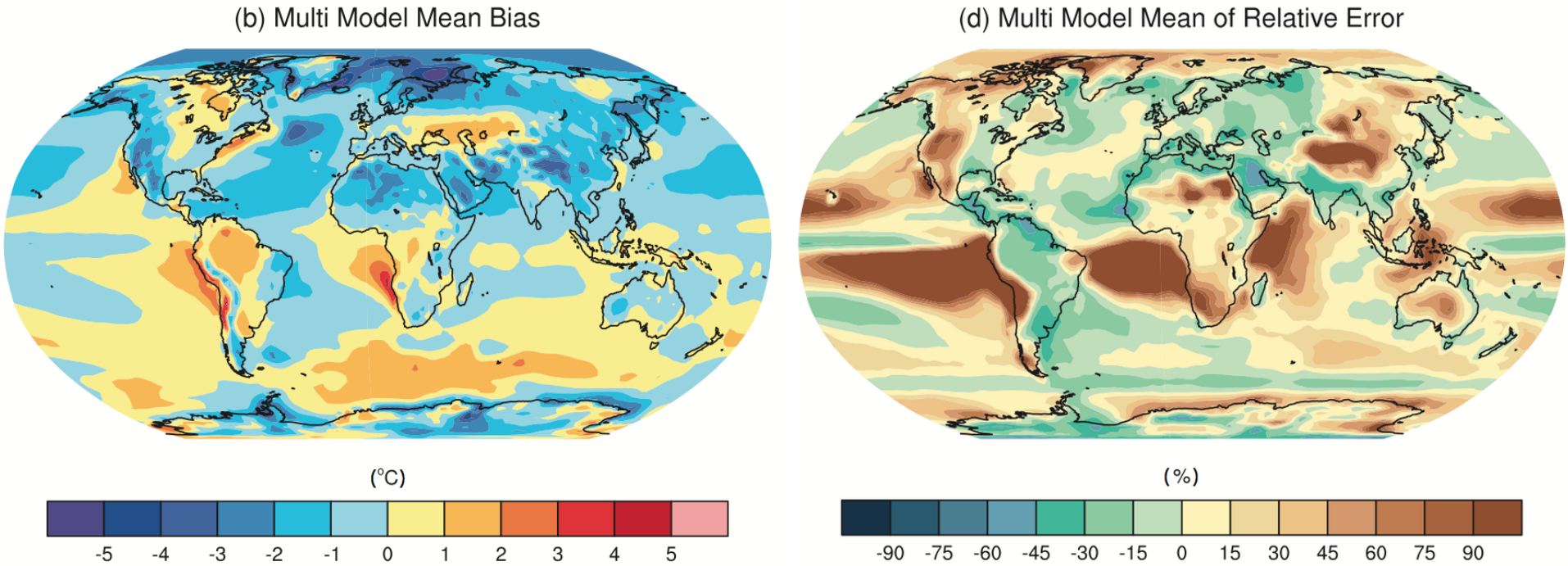


Kendon, 2013

GCM Biases and their Correction

Temperature and precipitation biases

CMIP5, multi-model mean



Flato et al., IPCC AR5, 2013

Temperature and precipitation biases

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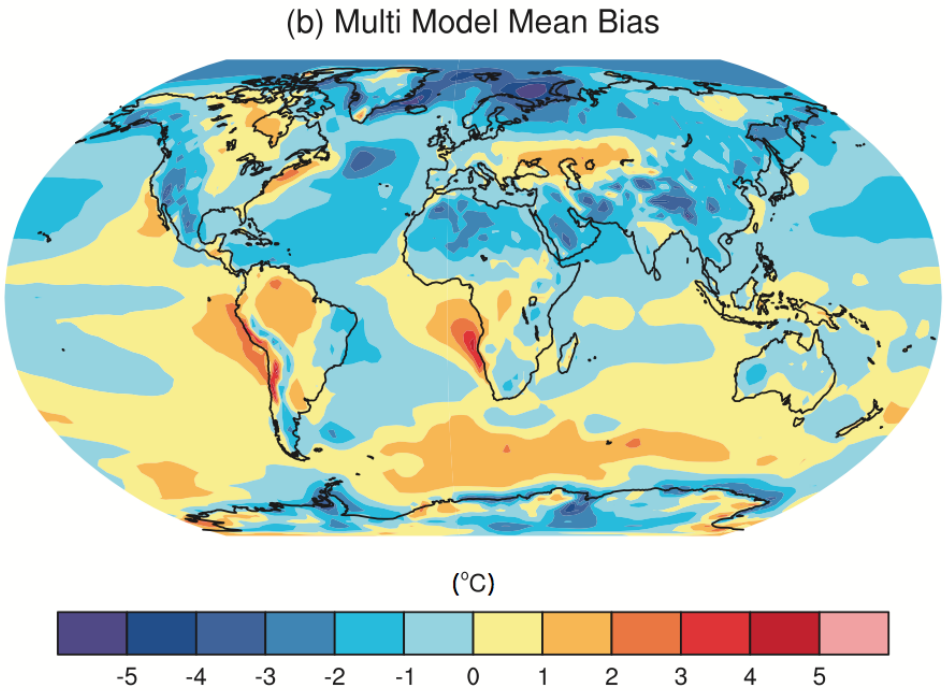
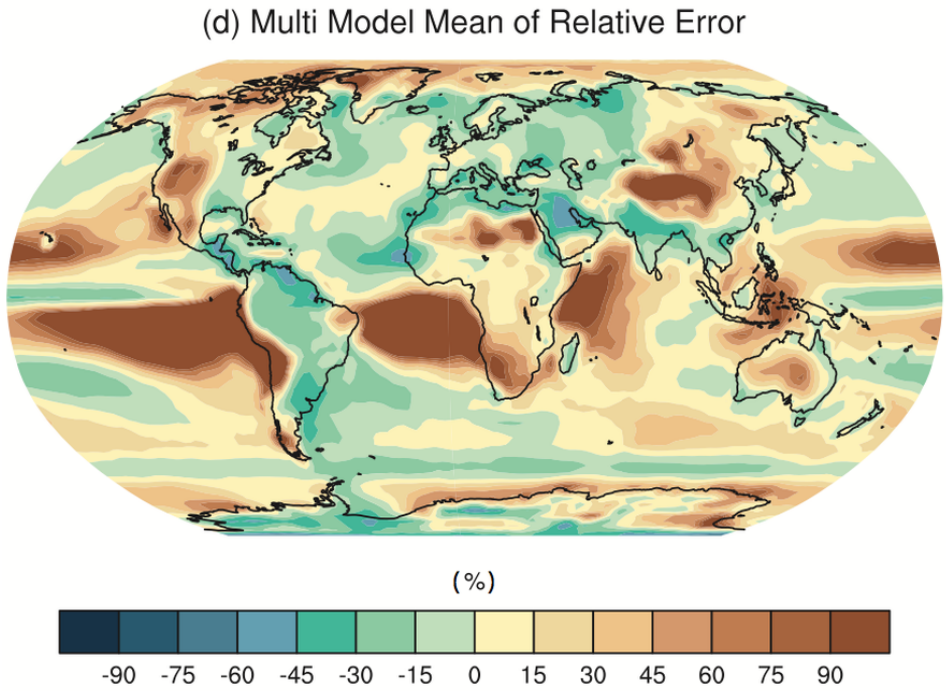




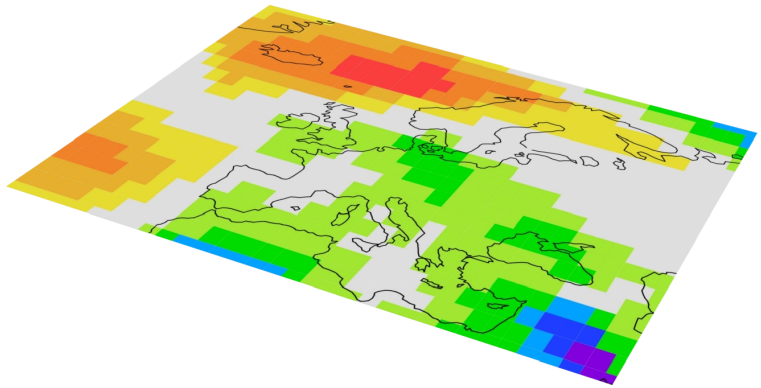
GCM biases are often expressions of fundamental process misrepresentations

Flato et al., IPCC AR5, 2013

Widespread “approach”

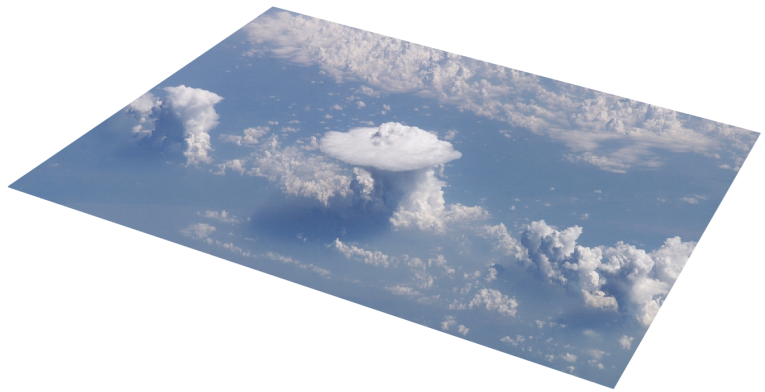
Map GCM output locally onto observed climate

Distribution



GCM

Bias Correction



Distribution

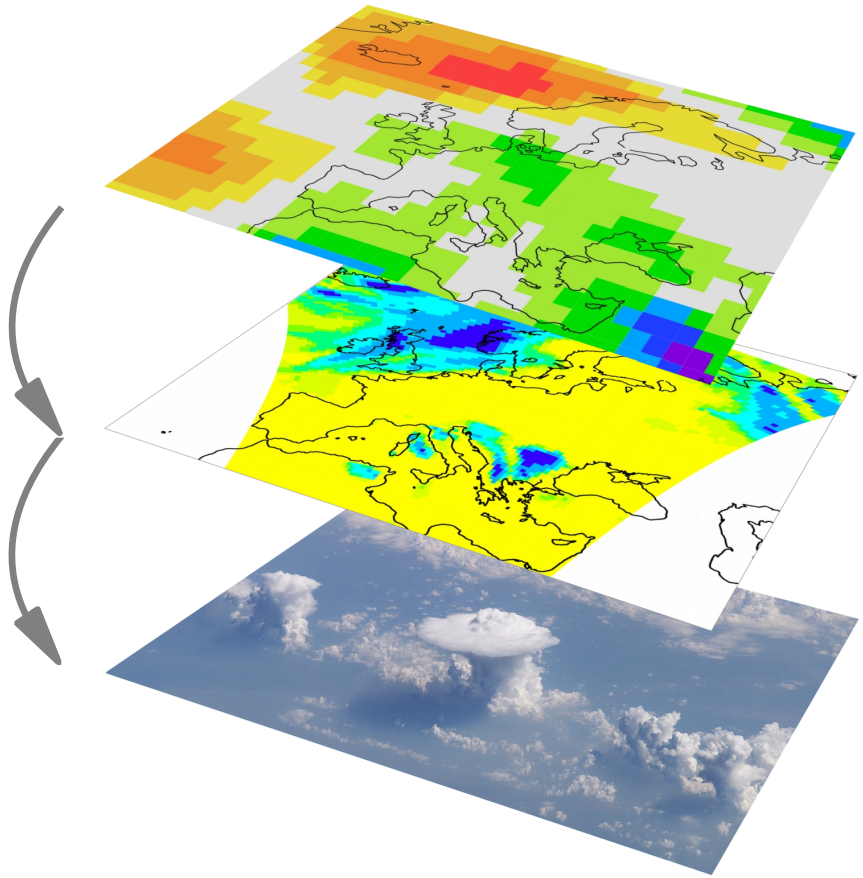
Observations

Common variant

Dynamical downscaling plus bias correction

Dynamical Downscaling

Bias Correction



GCM

RCM

Observations

Gedankenexperiment

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- Bias correction attempts to correct model misspecifications
- Increase misspecifications as far as possible

$$\Downarrow$$

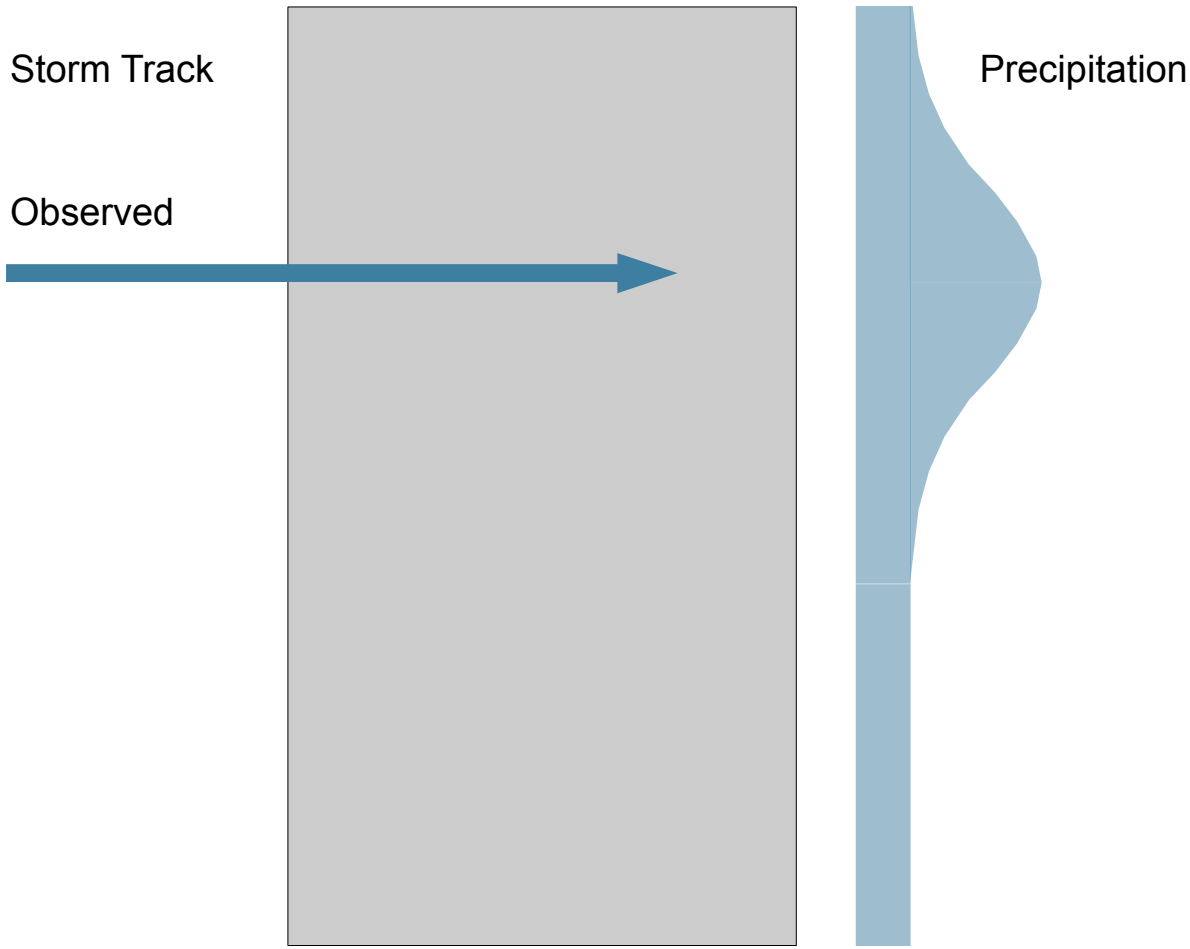
energy balance model

Bias correcting an energy balance model to infer regional changes obviously doesn't make sense.

So, where are the limits?

Origins of BC in weather forecasting

Biases emerge locally from parameterisation errors and topography



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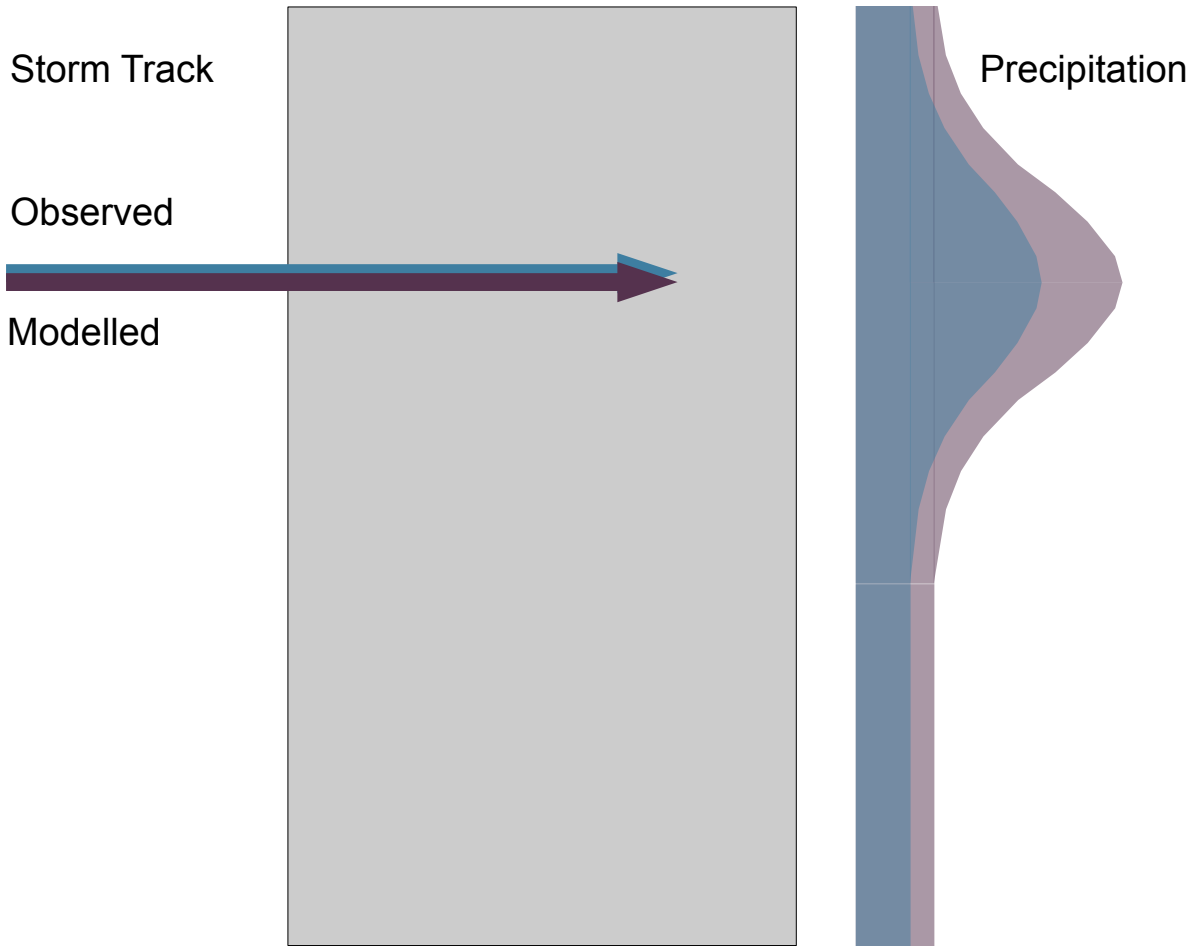

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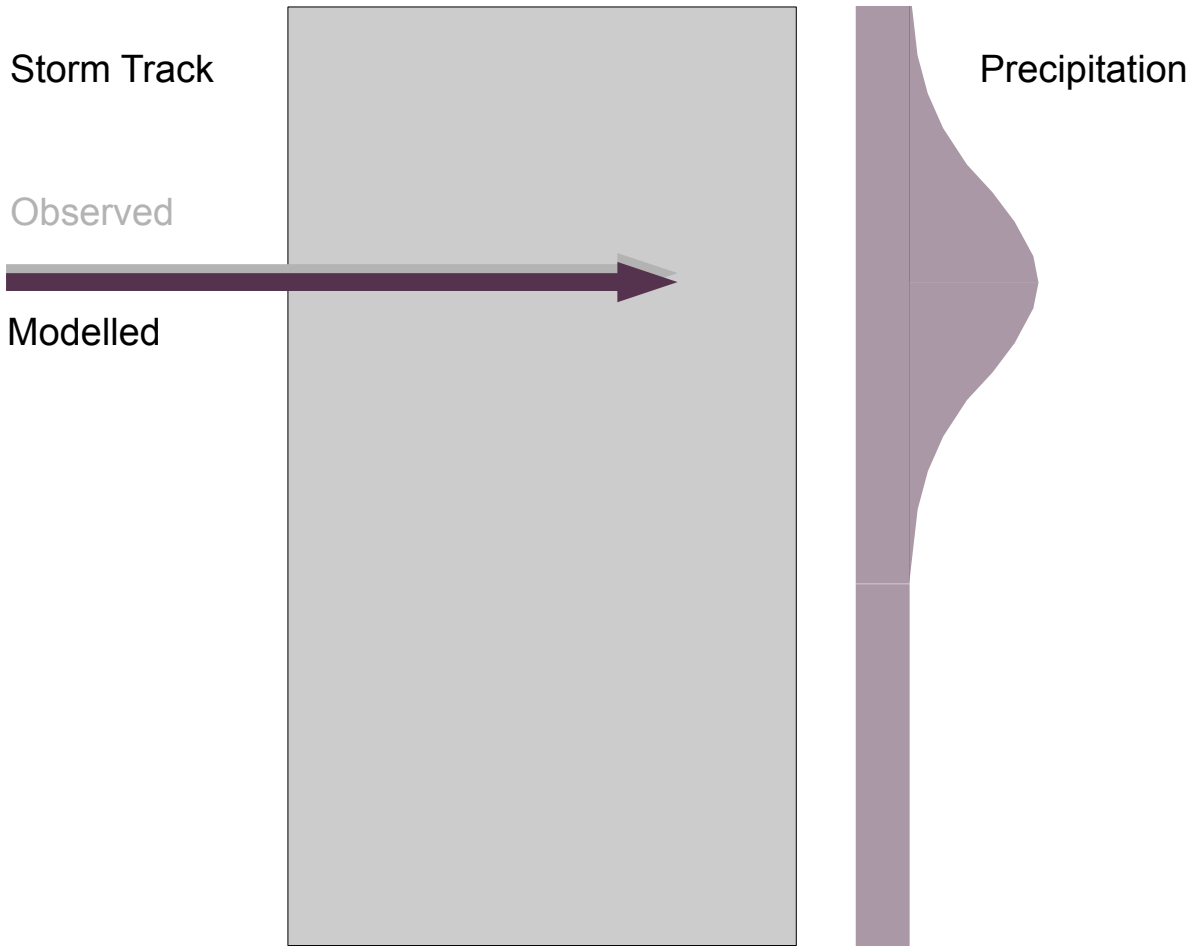
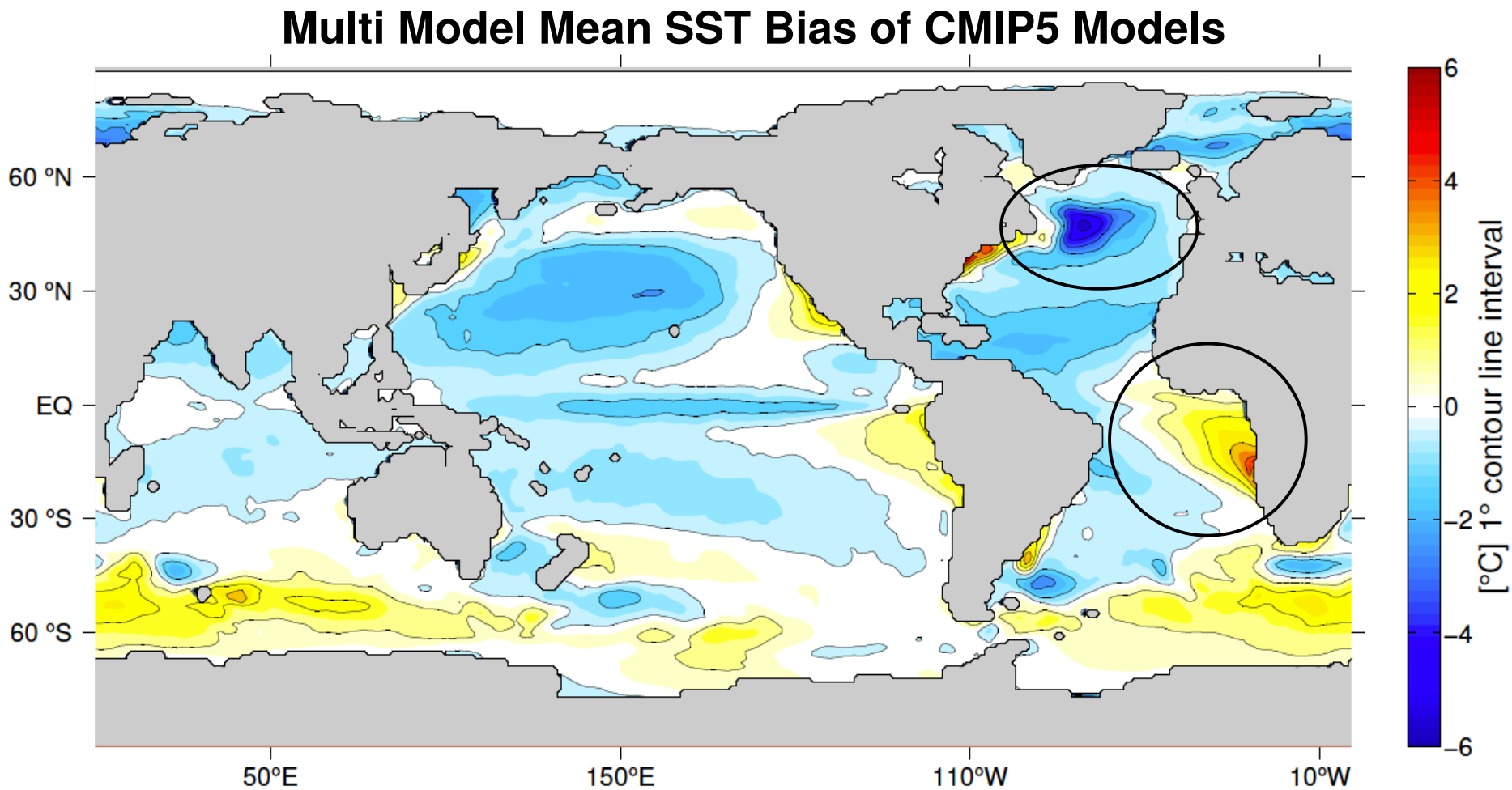


In climate simulations, things are different

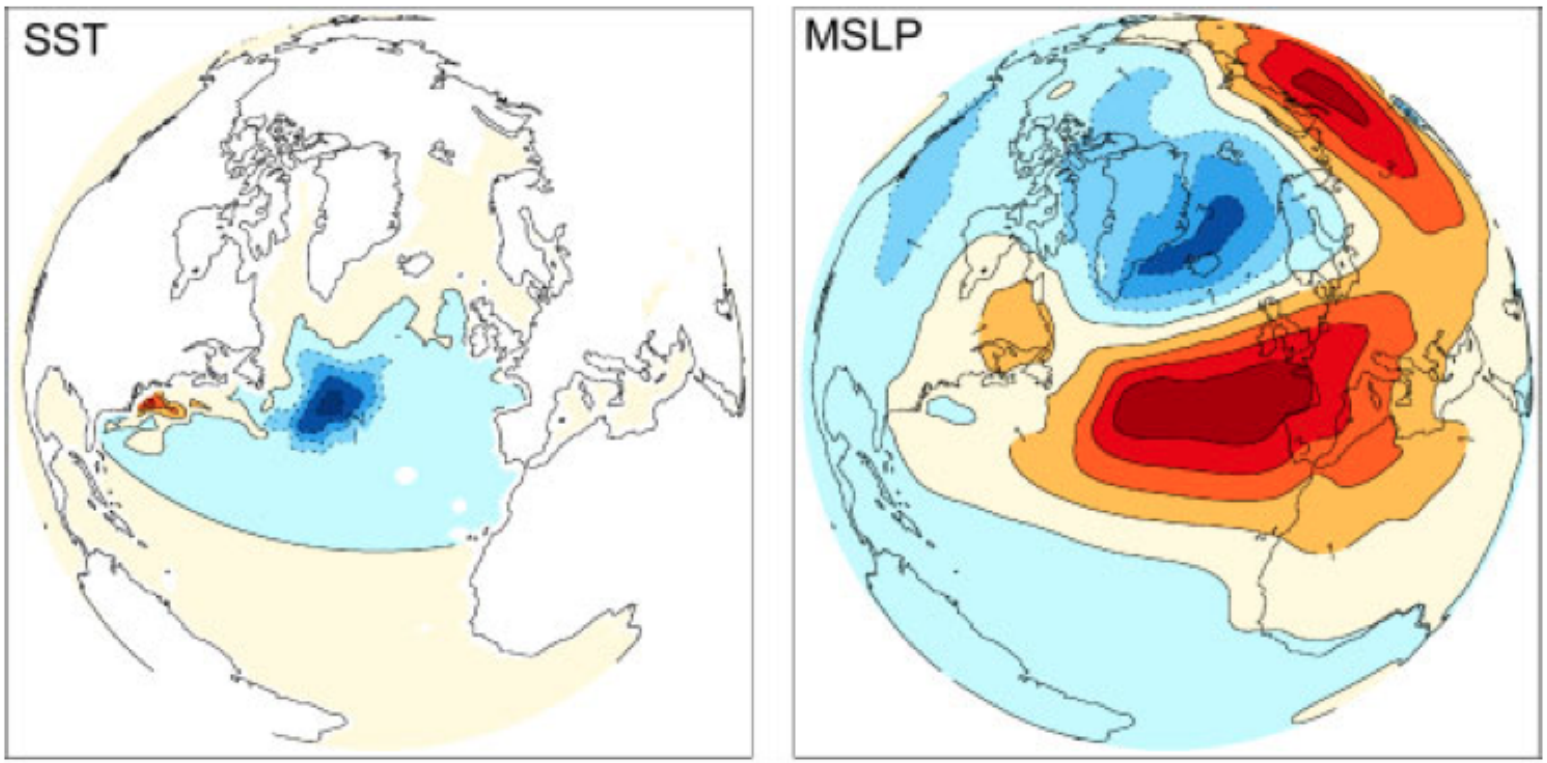
Common SST Biases of GCMs



courtesy S. Steinig

Impacts of GCM biases

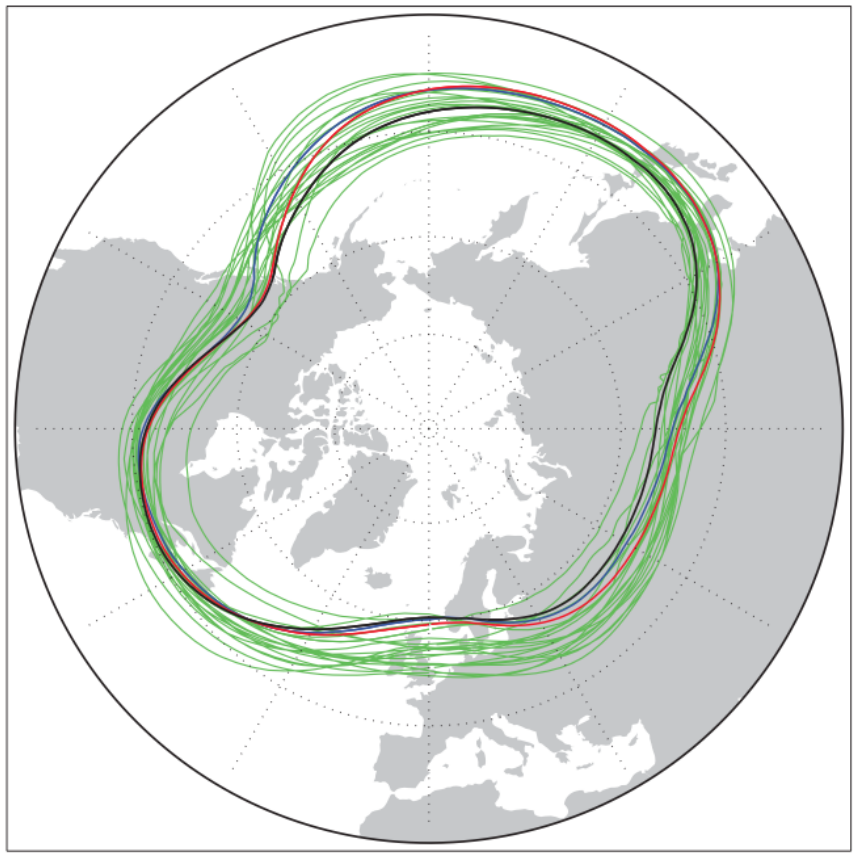
on large-scale circulation



left: imposed SST anomaly; right: DJF SLP response

Keeley et al., QJRMS, 2012

Displaced storm tracks

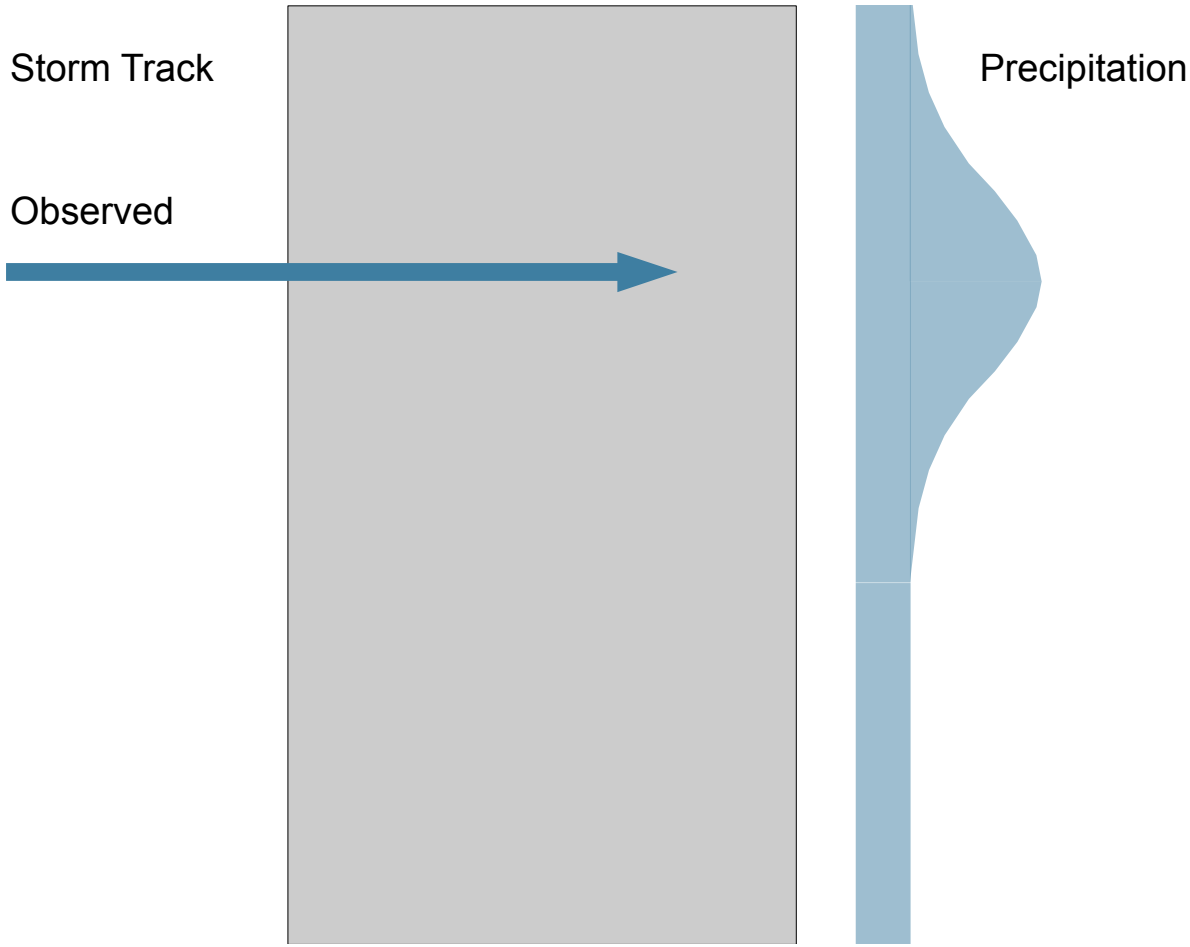


black: ERA40; green: CMIP3 models; red, blue: two high resolution models

Woollings, Phil Trans R. Soc, 2010

Bias correction of global climate models

Biases results from local errors, but also large scale errors



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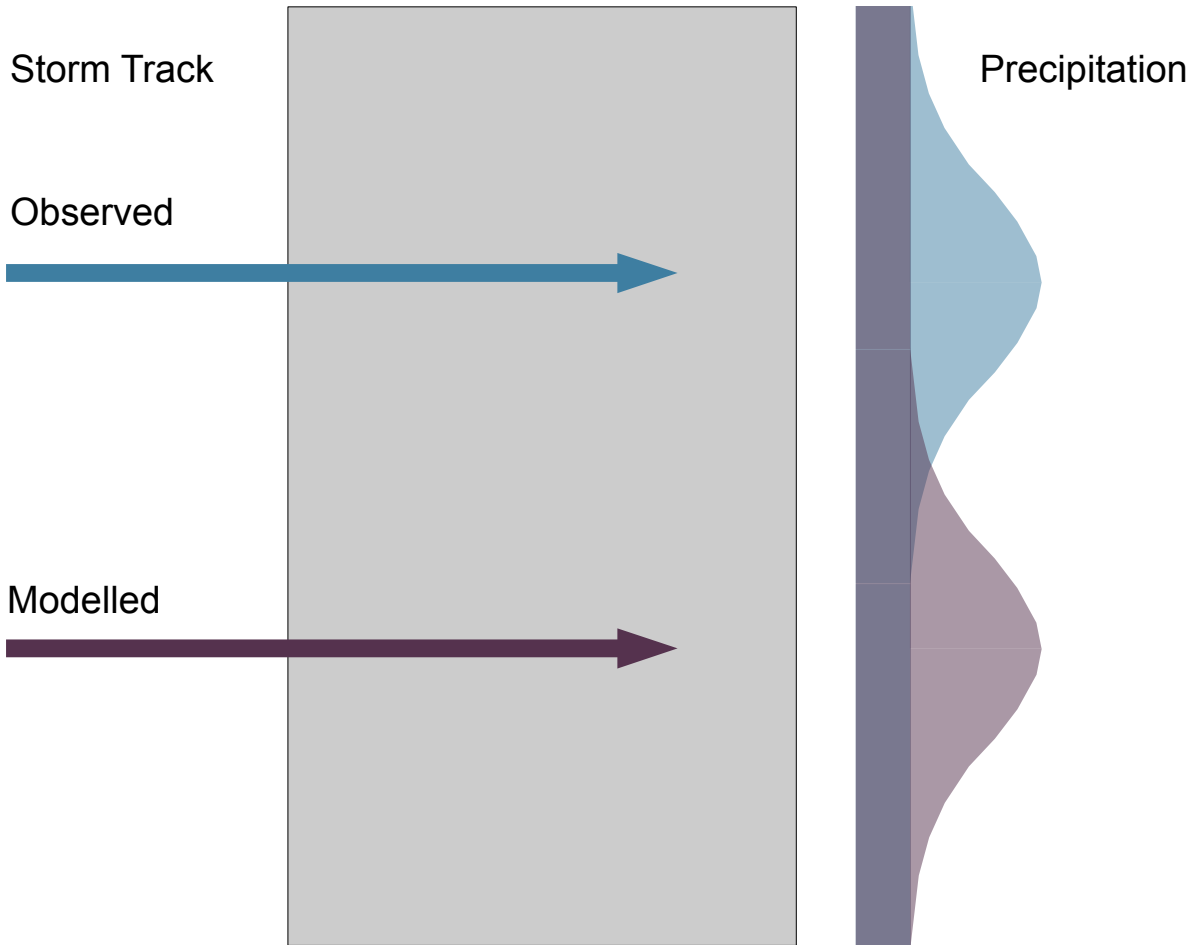

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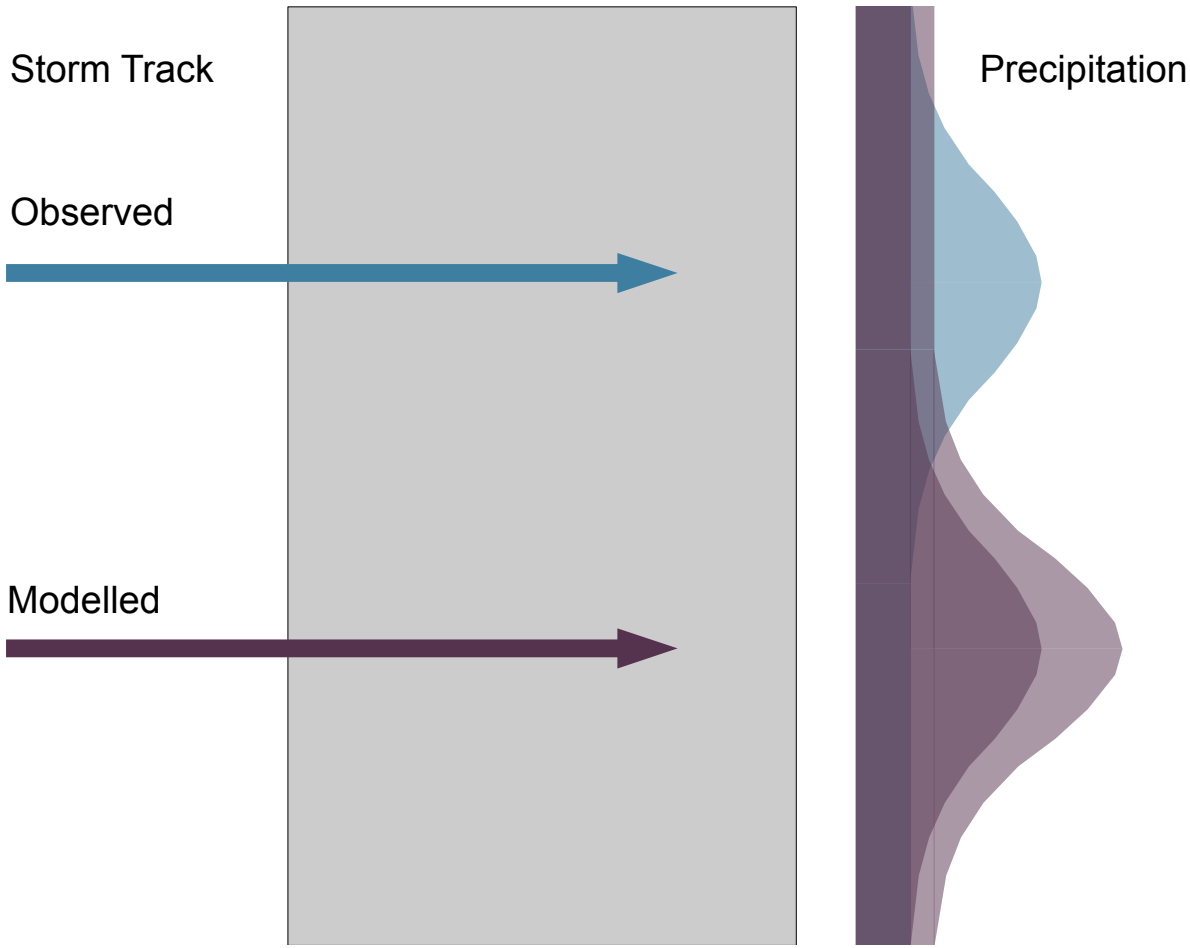

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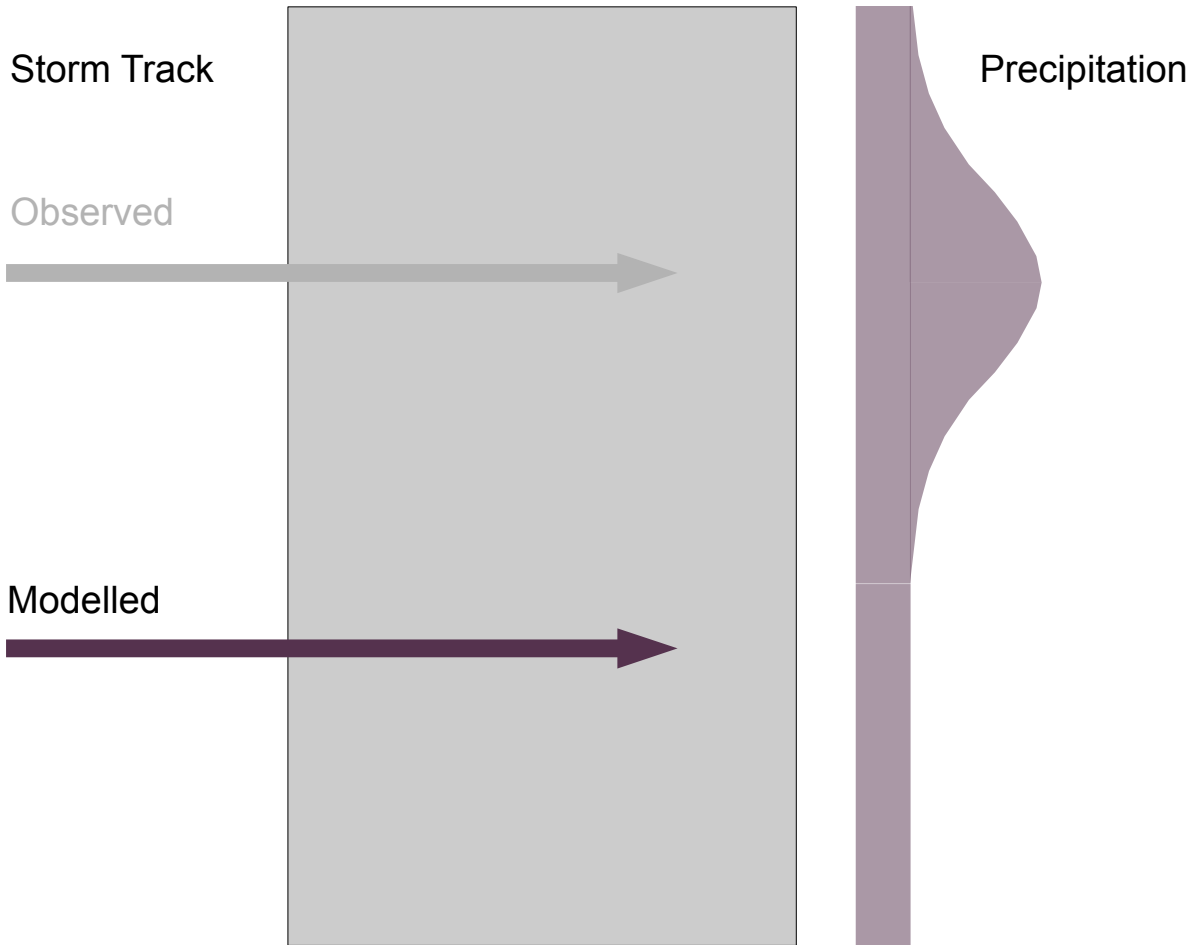

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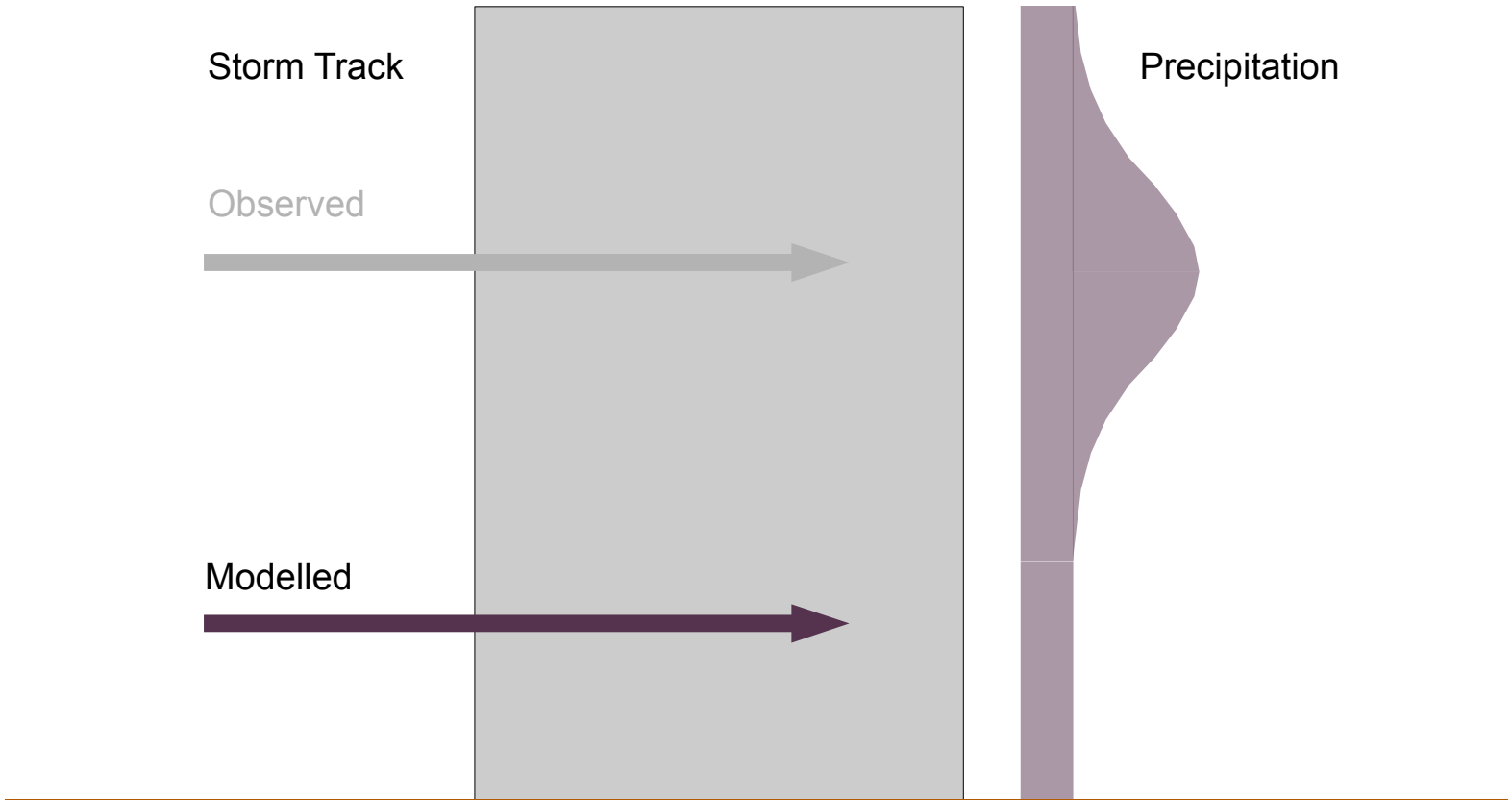
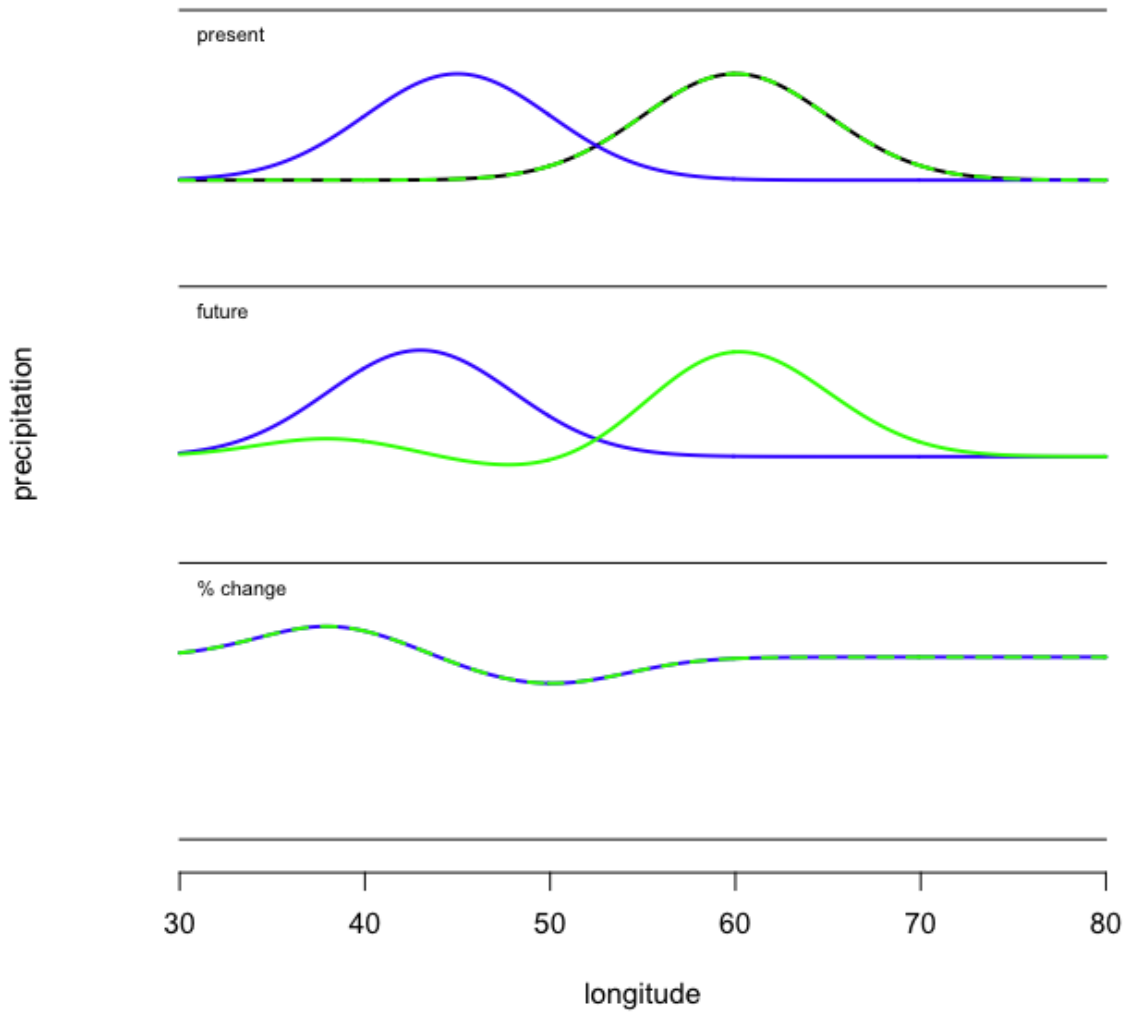


We get rain without storms and vice versa

Potential problems of GCM bias correction

Southward displaced stormtrack, southward shift in the future



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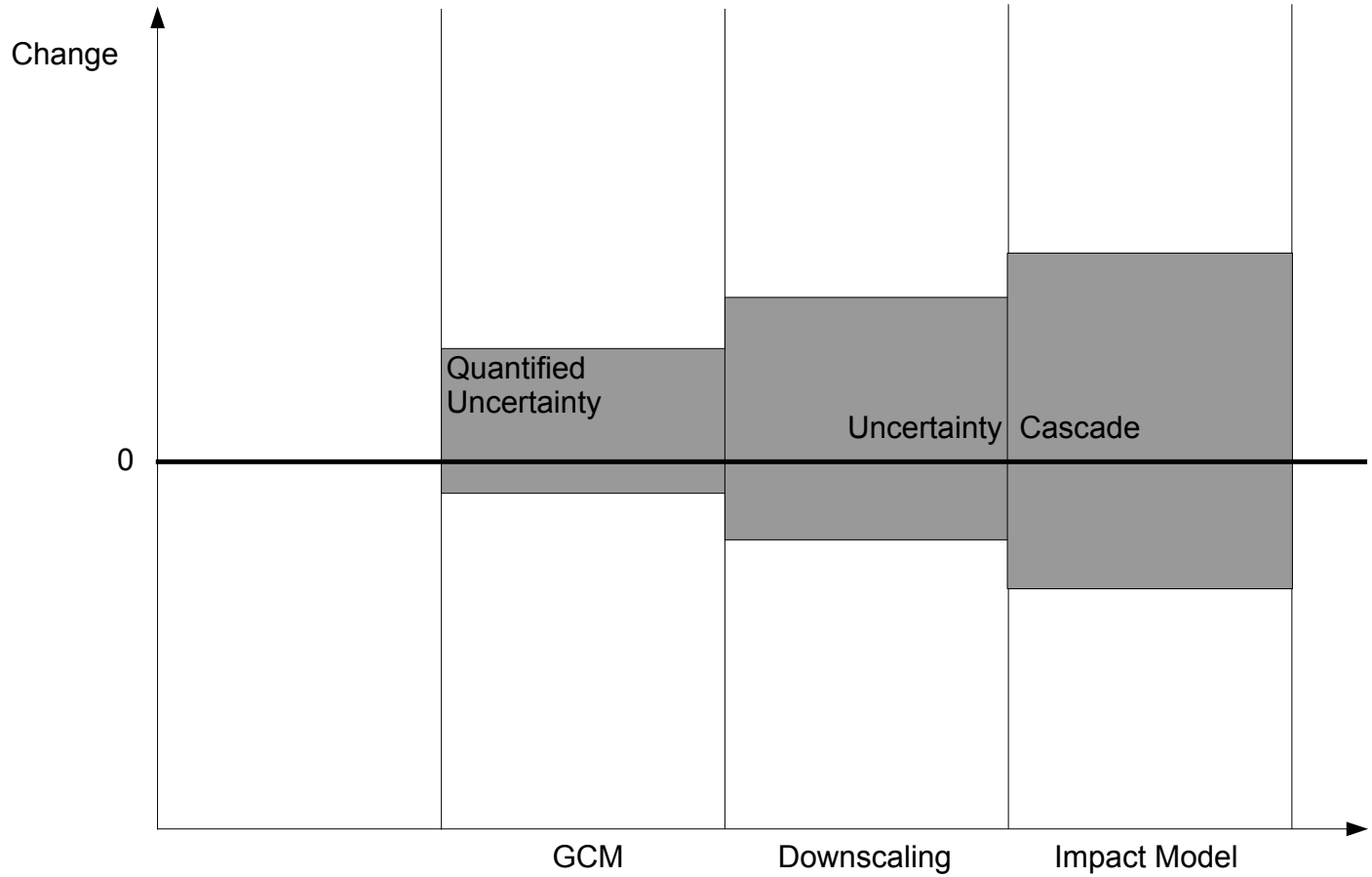
Final Remarks

Revisiting the uncertainty cascade

Downscaling does not[1] add but quantifies uncertainties



[1] in case of proper validation

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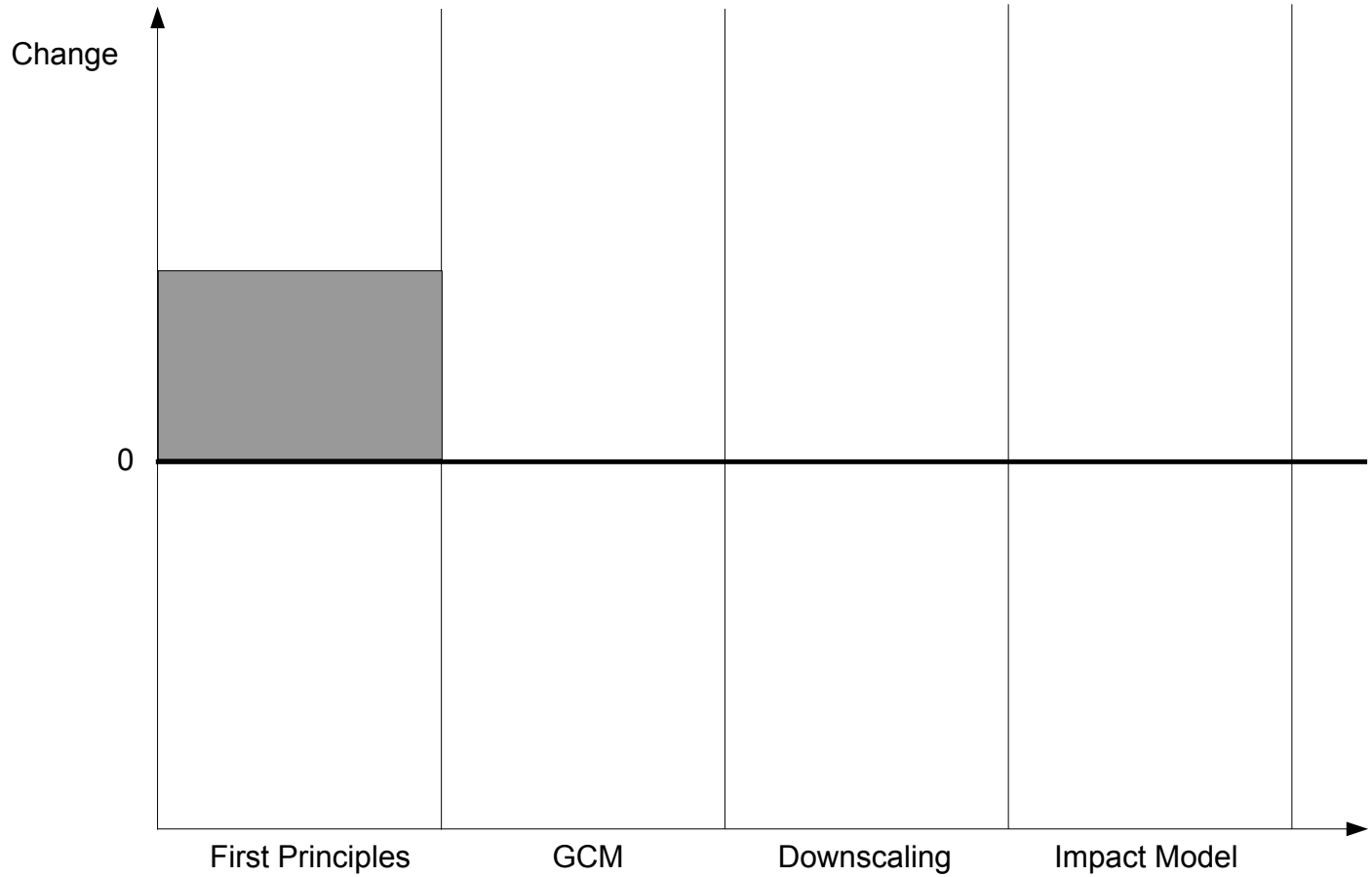

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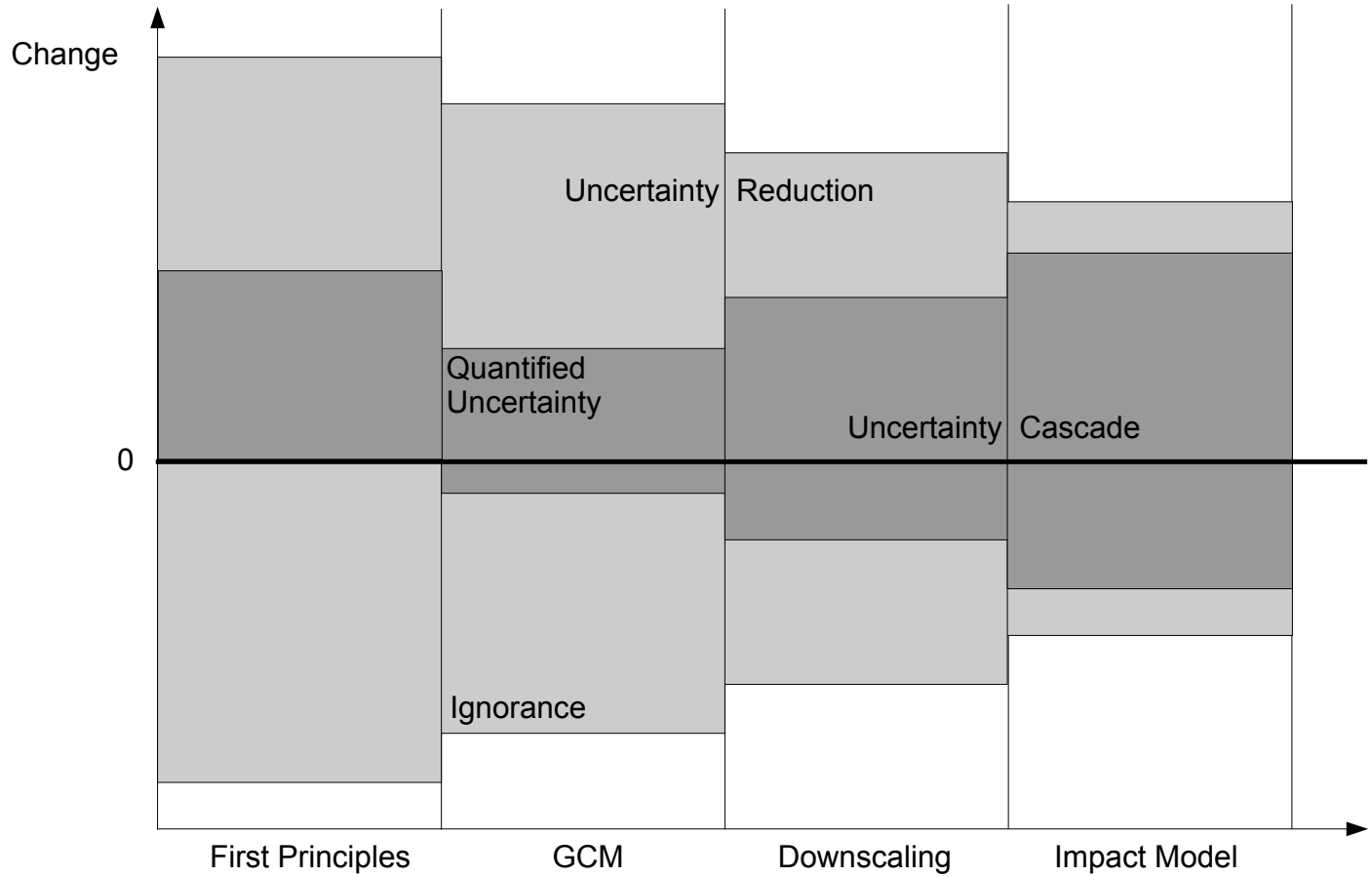

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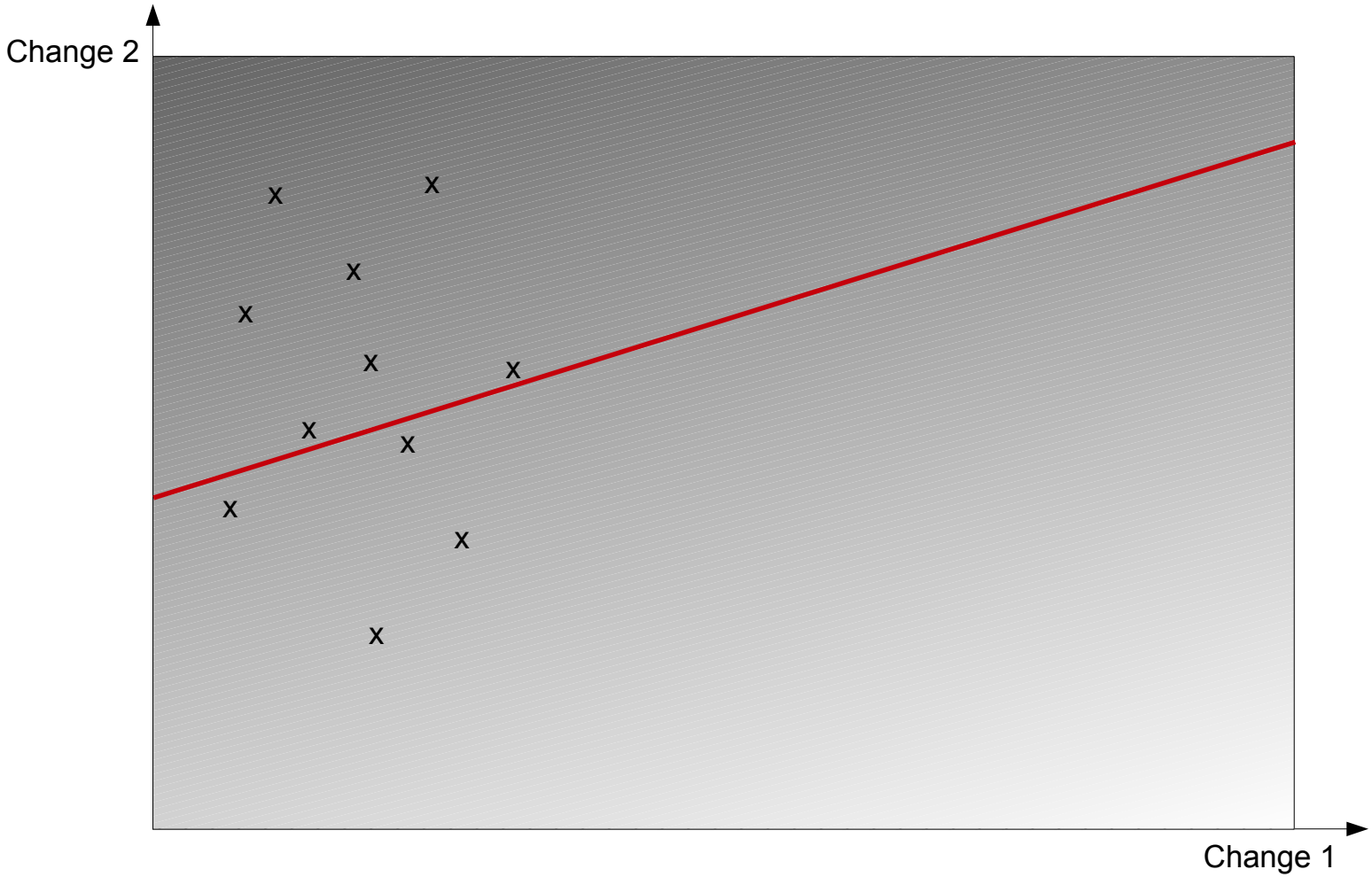
Missing relevant sensitivities



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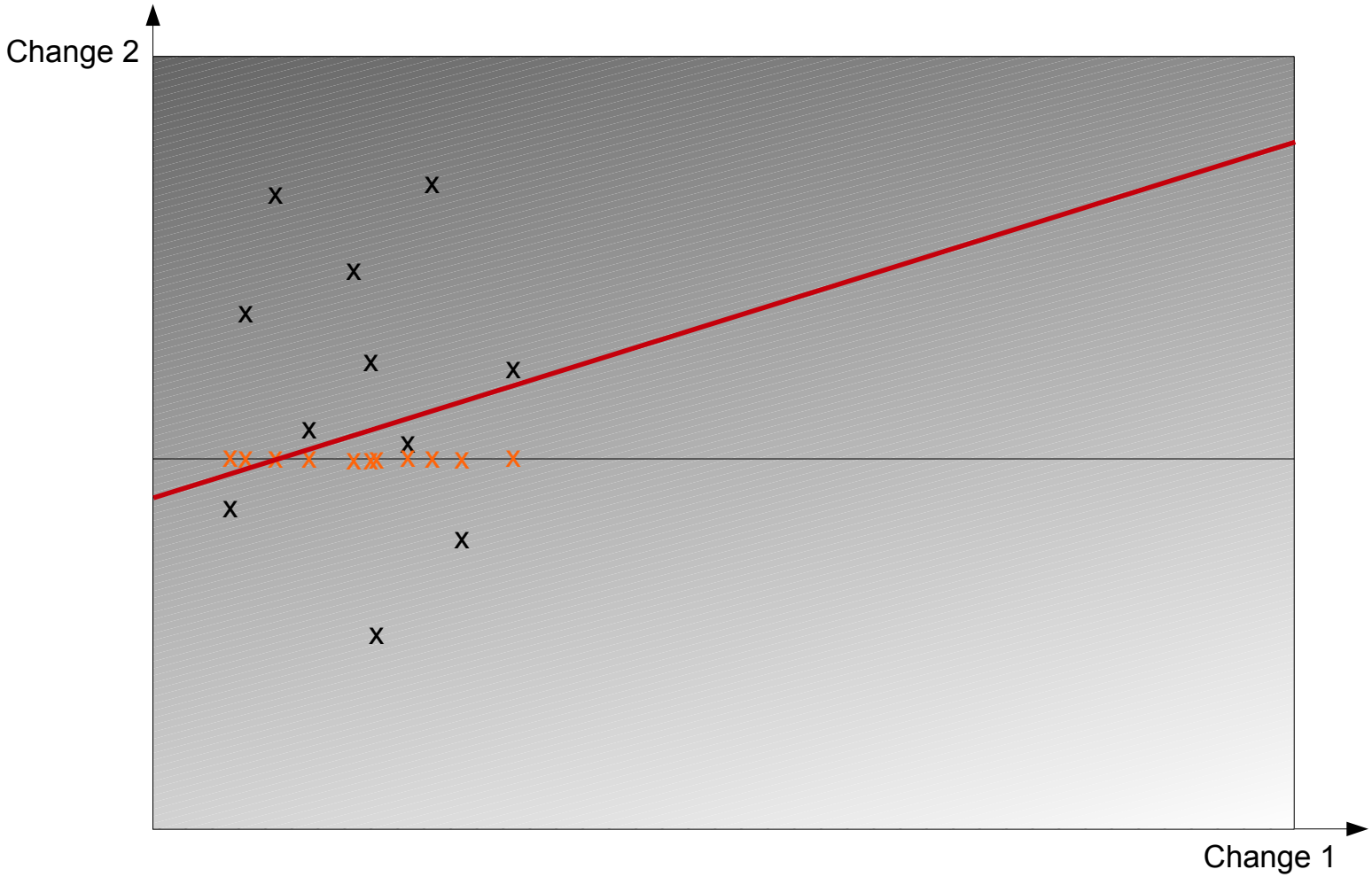

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Need for/limitations of downscaling

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- GCMs represent area averages
- GCMs might not represent the right climate change signal because of regional effects
- GCMs misrepresent crucial processes

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  (Can in principle be overcome by downscaling)
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  (Cannot be overcome by downscaling)

- None of these problems can be overcome by response surfaces

Comments

- Response surfaces are no alternative to downscaling.
- Response surfaces are a useful tool:
  to assess and identify (important) sensitivities
  to extrapolate beyond simulations
  to formally decouple input and output.
- All relevant sensitivities need to be considered!
- You need good weather generators to create response surfaces!
- We do not have no knowledge, but how to relate this to reality?

Pragmatic Suggestion

Combine bottom-up and top-down approaches

- Downscaling to inform creation of response surfaces
- Downscaling to compare potential regional future climates with response surfaces

- Essential:
  Does my GCM sufficiently well represent relevant processes?
  Is my downscaling appropriate for my context?

- We need to understand about which impacts we can say something about future change, and which not.
- We need to understand where downscaling is necessary or not.

Thank you for your attention!