Uncertainty visualization in the climate change discourse:

from the IPCC reports to climate web portals

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Thomas Nocke
Potsdam Institute for Climate Impact Research

Outline

- Uncertainty typology
- Uncertainties in IPCC climate data visualizations
  - spatial
  - temporal
  - abstract
- Uncertainty presentation on interactive climate visualization platforms
- Conclusion

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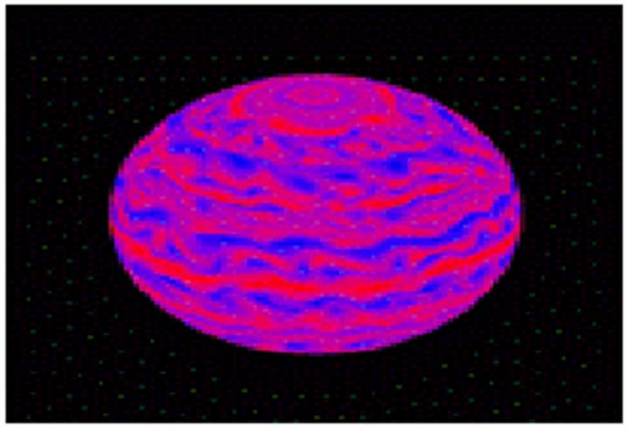
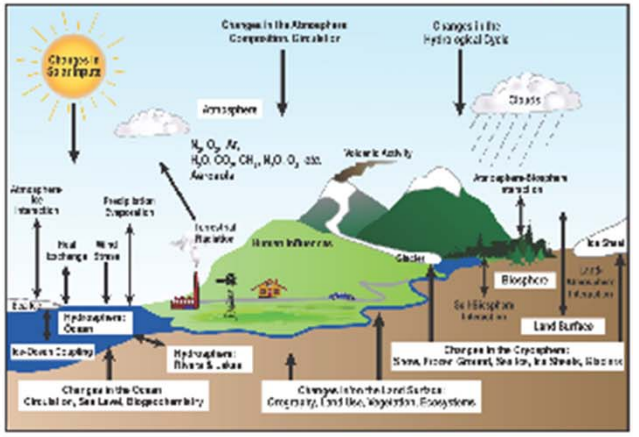
Uncertainty Typology (1)

- Natural stochastic



- Epistemic (knowledge not yet sufficient)



- Human reflexive (predictions about society will affect decision)

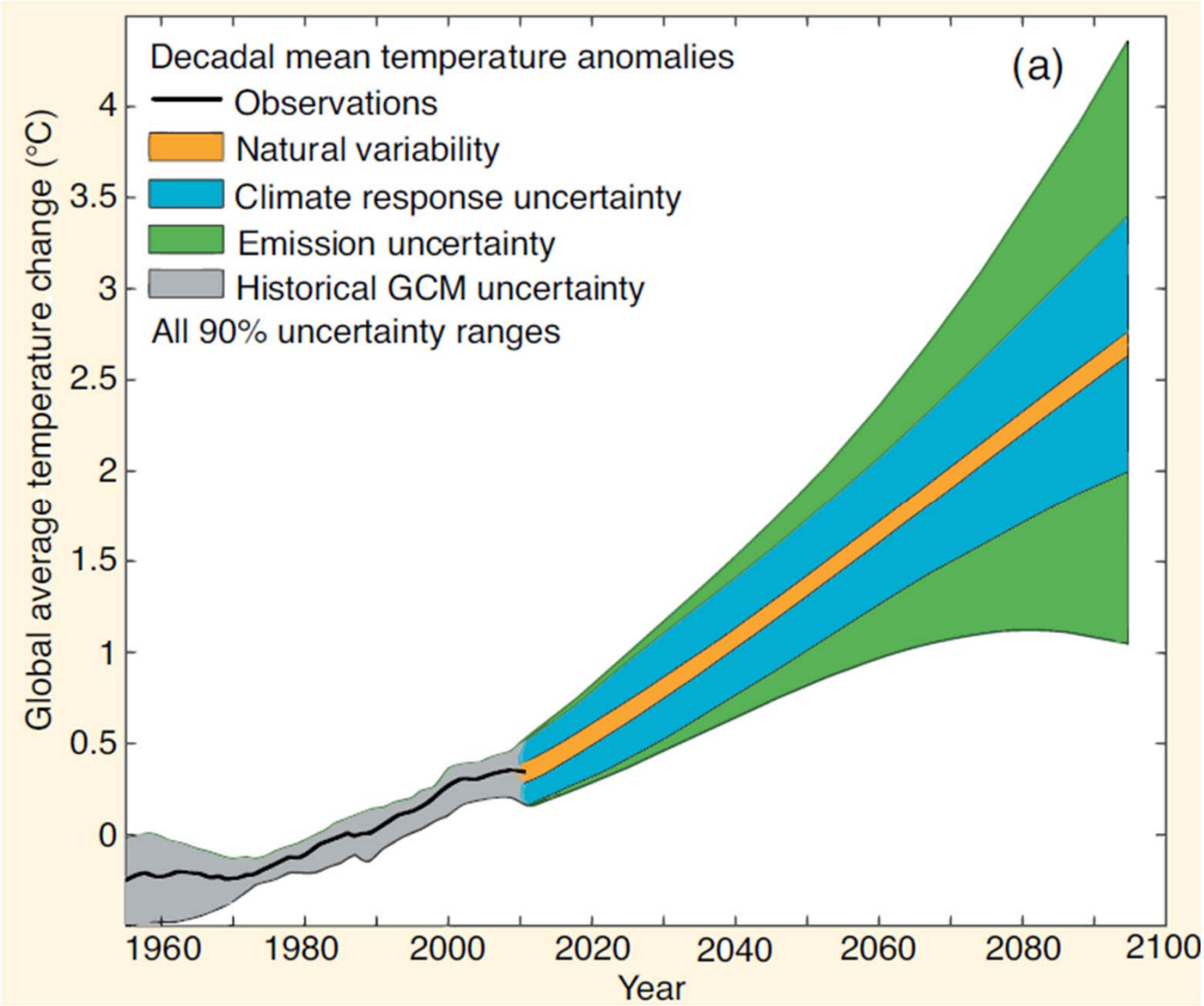
[Dessai & Hulme 2004]

Uncertainty Typology (2)

Table 1. A simple typology of uncertainties

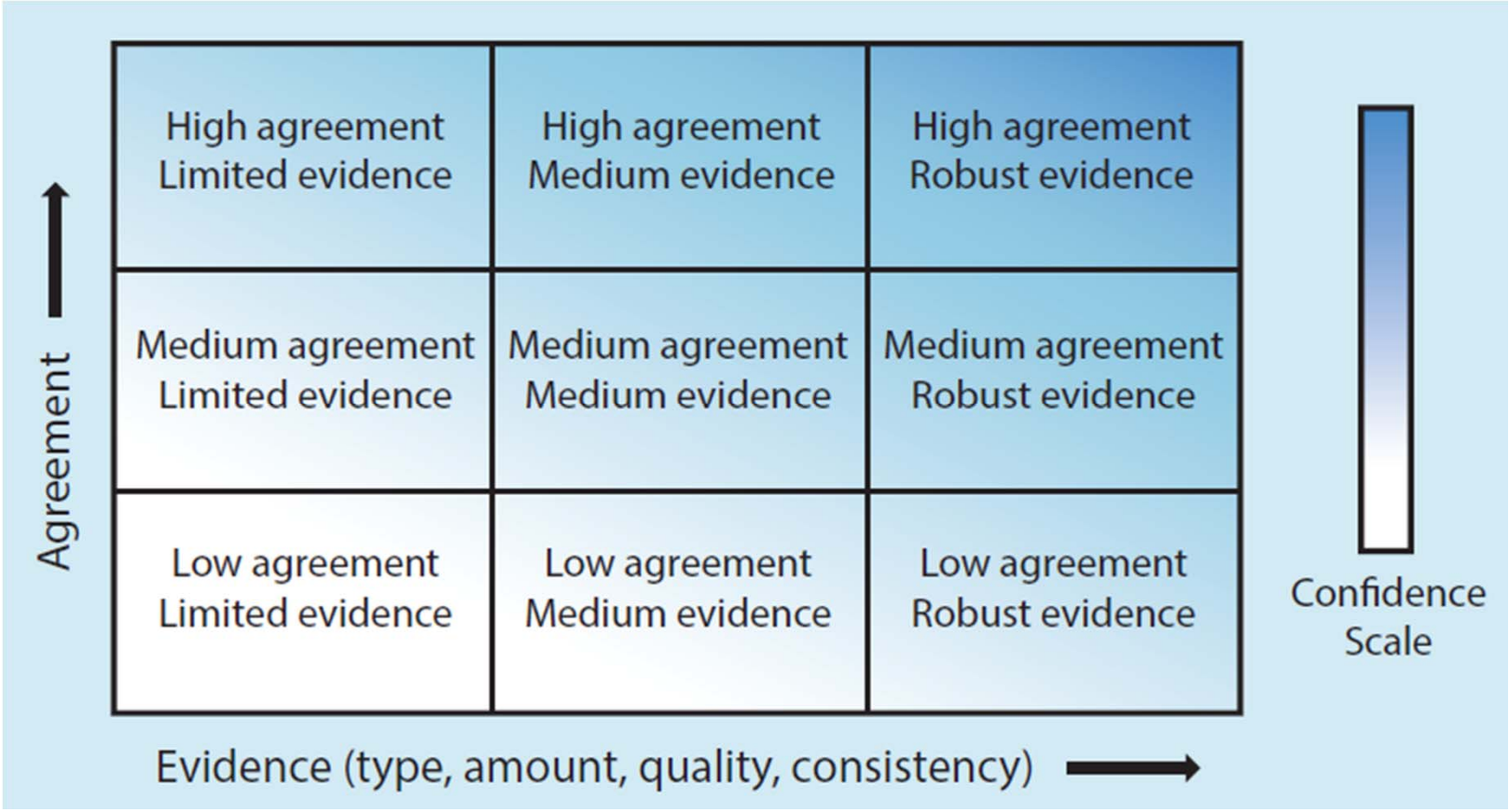
Type	Indicative examples of sources	Typical approaches or considerations
Unpredictability	Projections of human behaviour not easily amenable to prediction (e.g. evolution of political systems). Chaotic components of complex systems.	Use of scenarios spanning a plausible range, clearly stating assumptions, limits considered, and subjective judgments. Ranges from ensembles of model runs.
Structural uncertainty	Inadequate models, incomplete or competing conceptual frameworks, lack of agreement on model structure, ambiguous system boundaries or definitions, significant processes or relationships wrongly specified or not considered.	Specify assumptions and system definitions clearly, compare models with observations for a range of conditions, assess maturity of the underlying science and degree to which understanding is based on fundamental concepts tested in other areas.
Value uncertainty	Missing, inaccurate or non-representative data, inappropriate spatial or temporal resolution, poorly known or changing model parameters.	Analysis of statistical properties of sets of values (observations, model ensemble results, etc); bootstrap and hierarchical statistical tests; comparison of models with observations.

[Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties, 2005]



"Schematic diagram showing the relative importance of different uncertainties, and their evolution in time." [IPCC AR5 WG1 Ch. 1]

IPCC uncertainty typology (1)



"A depiction of evidence and agreement statements and their relationship to confidence." [IPCC AR5 WG1 TS]

IPCC uncertainty typology (2)

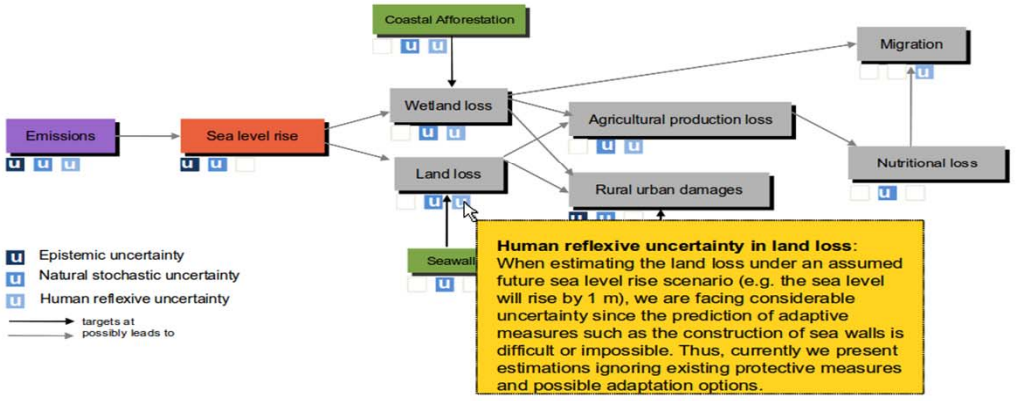
Term*	Likelihood of the outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

IPCC uncertainty terminology [IPCC AR5 WG1 TS]

Communication of Spatial Uncertainty

[Reinke & Hunter 2002]:

1. Notification (about the existence)
2. Identification (i.e. describing the type of uncertainty and its spatial extent)
3. Presentation of the quantitative information
4. Enabling an evaluation of the relevance of the uncertainty



Uncertainty identification example (cigrasp web portal)

Uncertainty Communication Situations

- Target auditorium:
  - scientific field specialists
  - stake holders / policy makers
  - general public
- Media:
  - interactive visualization tools
  - print media
  - web portals

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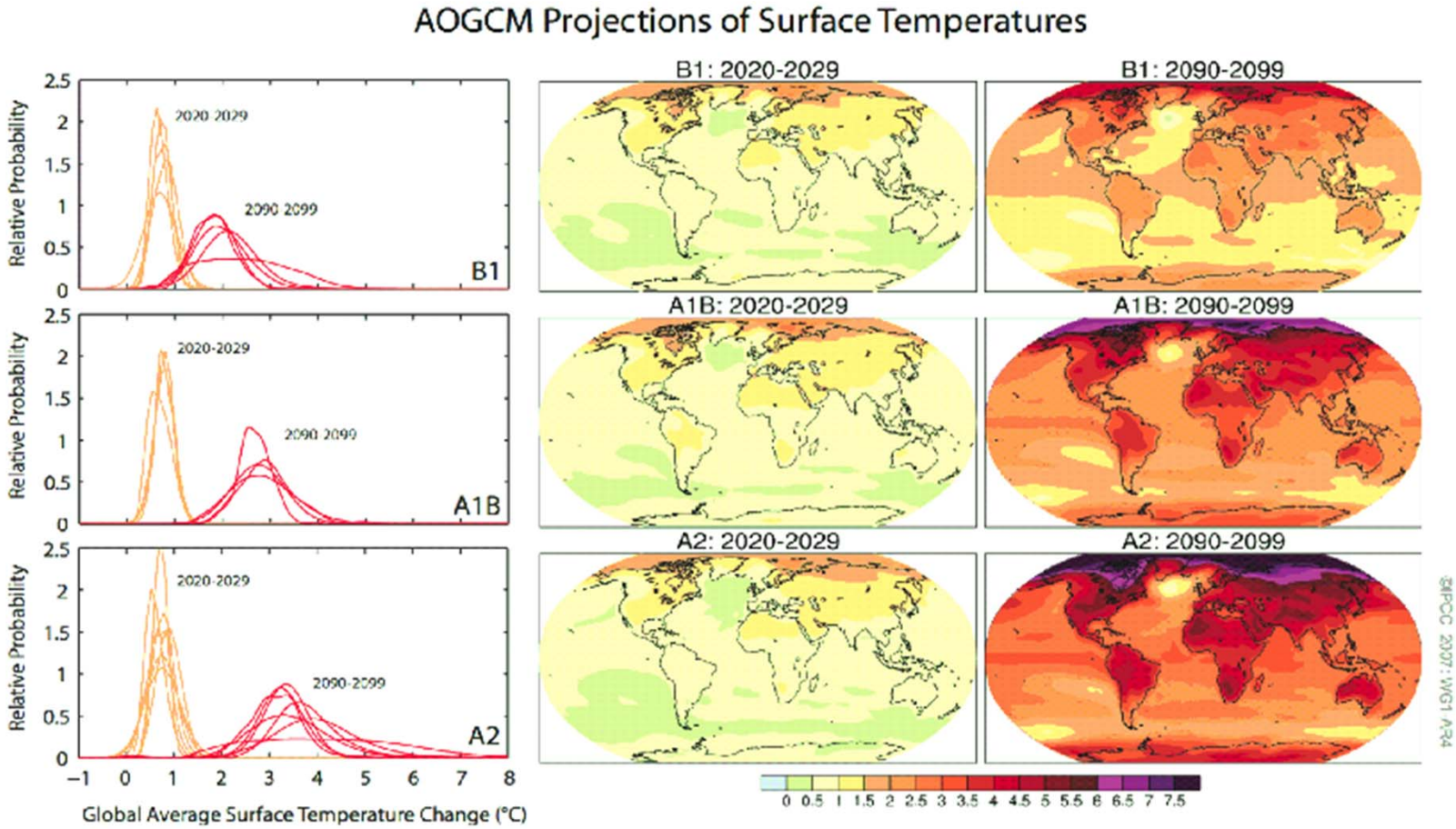
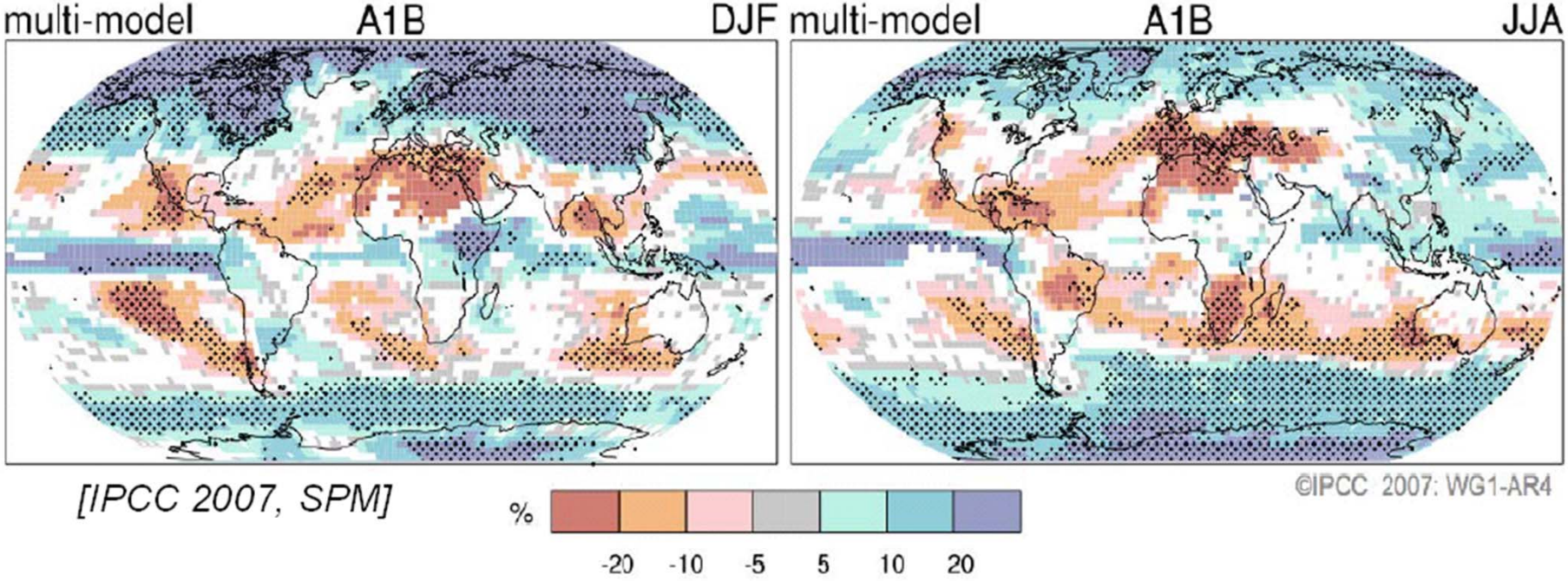
- separate maps



[IPCC 2007, Summary Report for Policy Makers]

- combined maps (texture), continuing

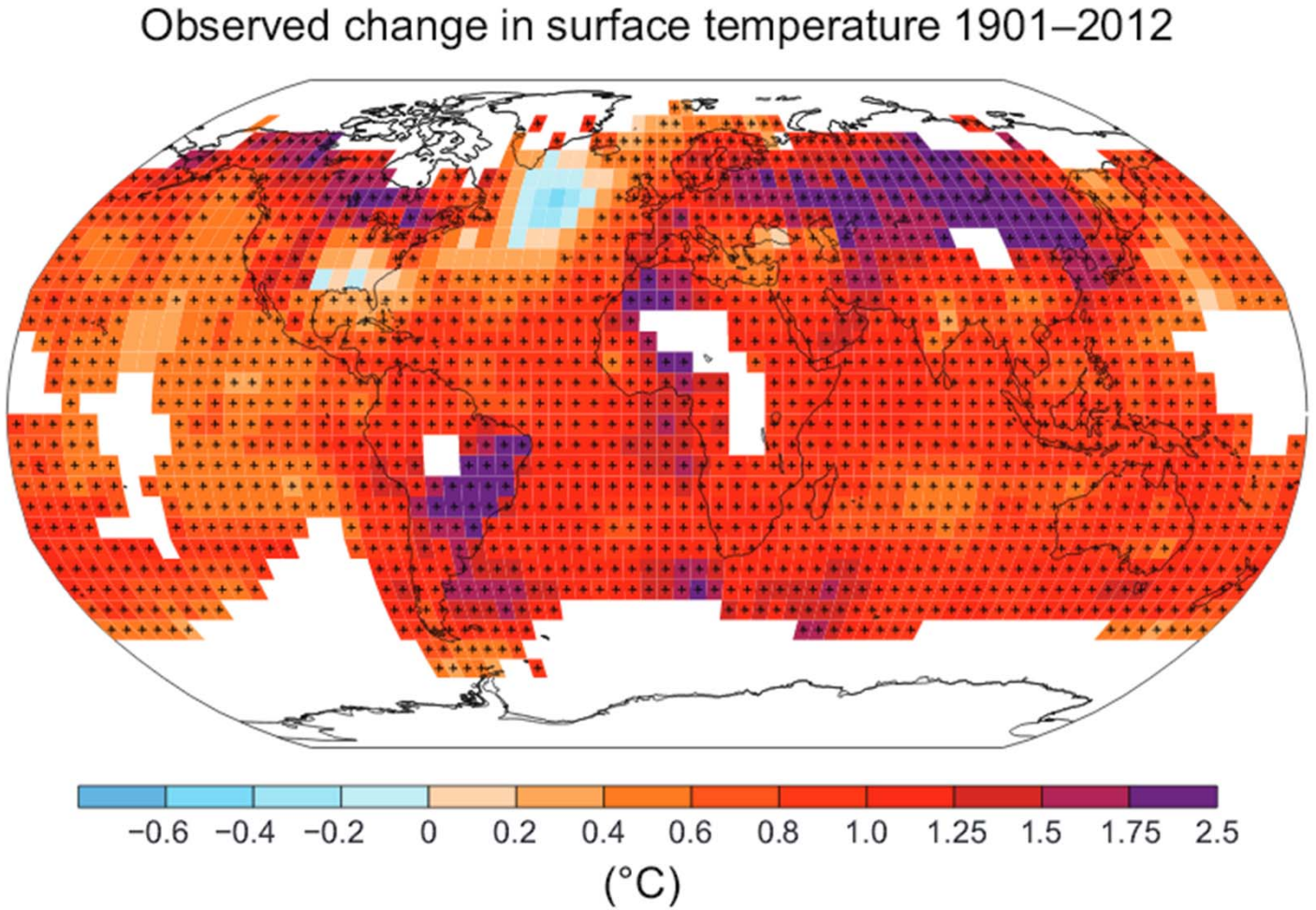


[IPCC 2007, SPM]

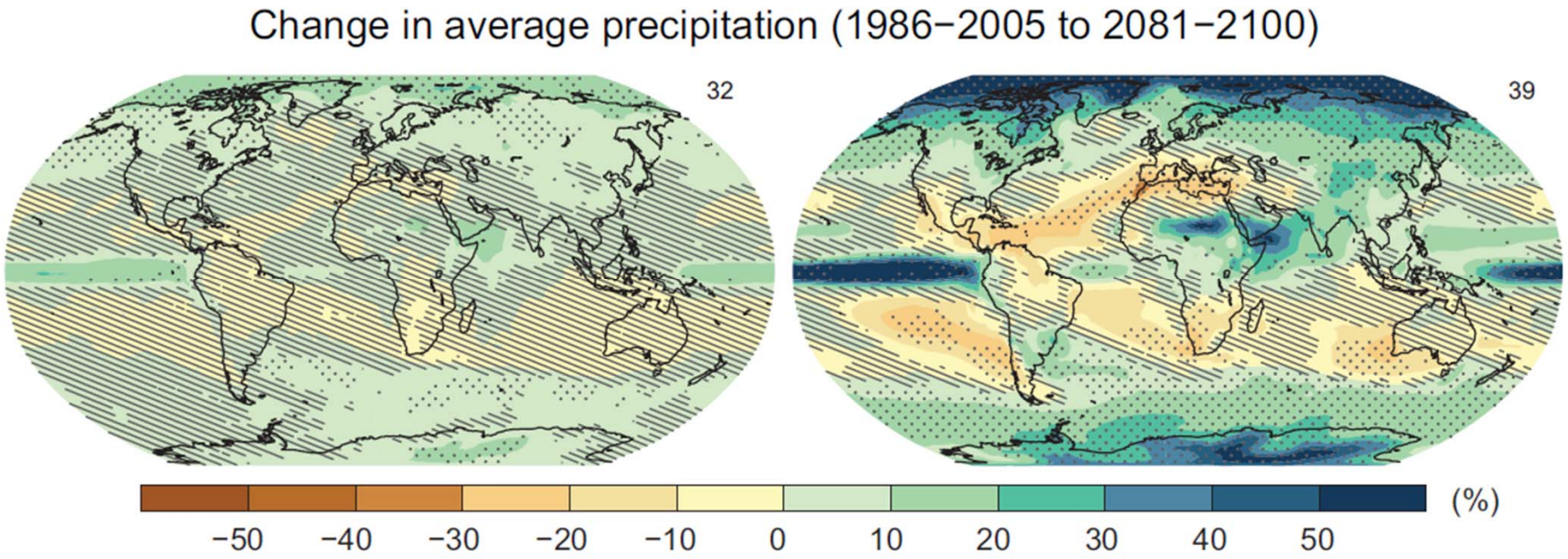
Relative precipitation change (2100 to 1990)

Scenario: A1B

dotted regions: strong model homogeneity
white regions: strong model differences

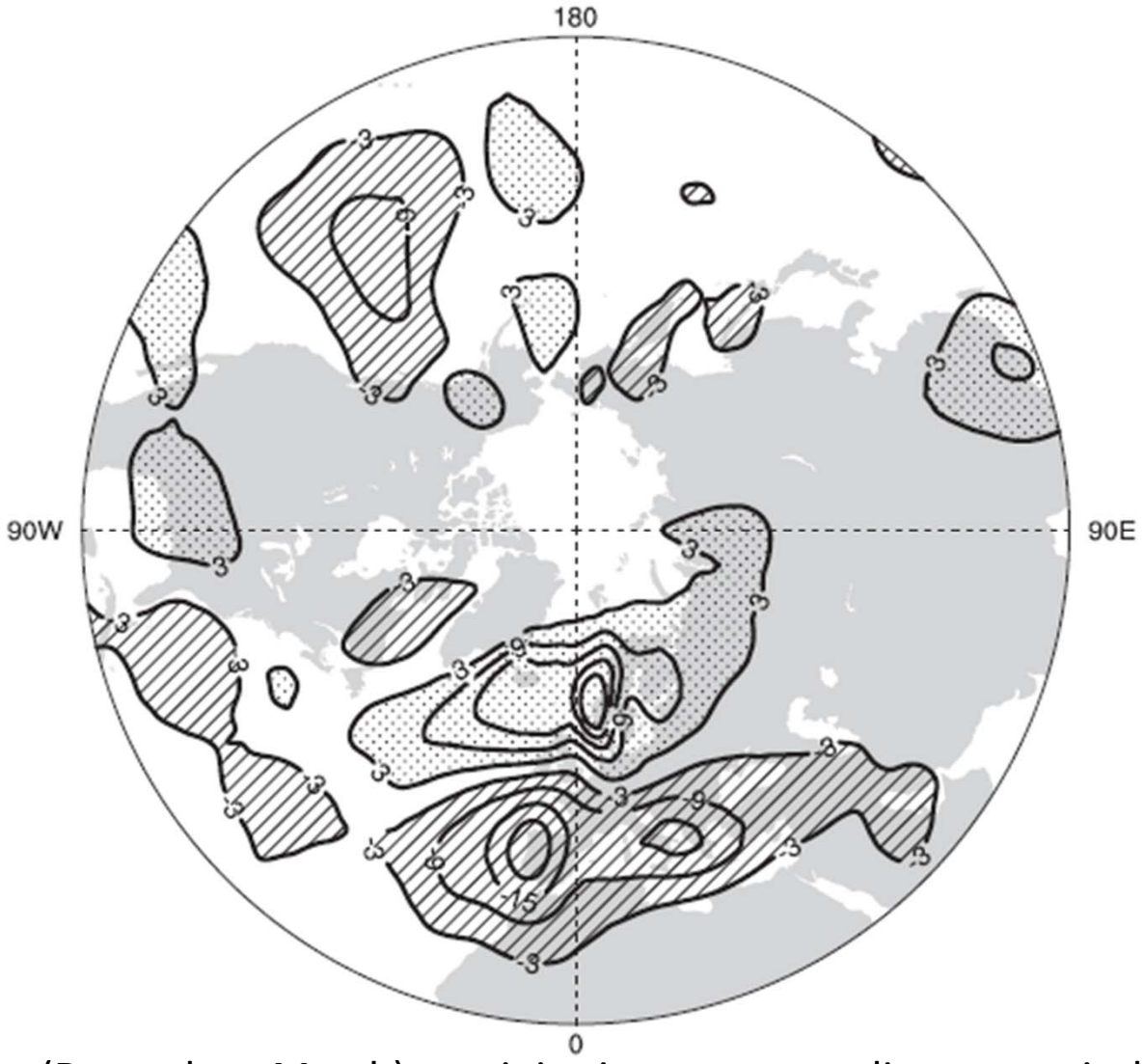


IPCC AR5-WG1 SPM report



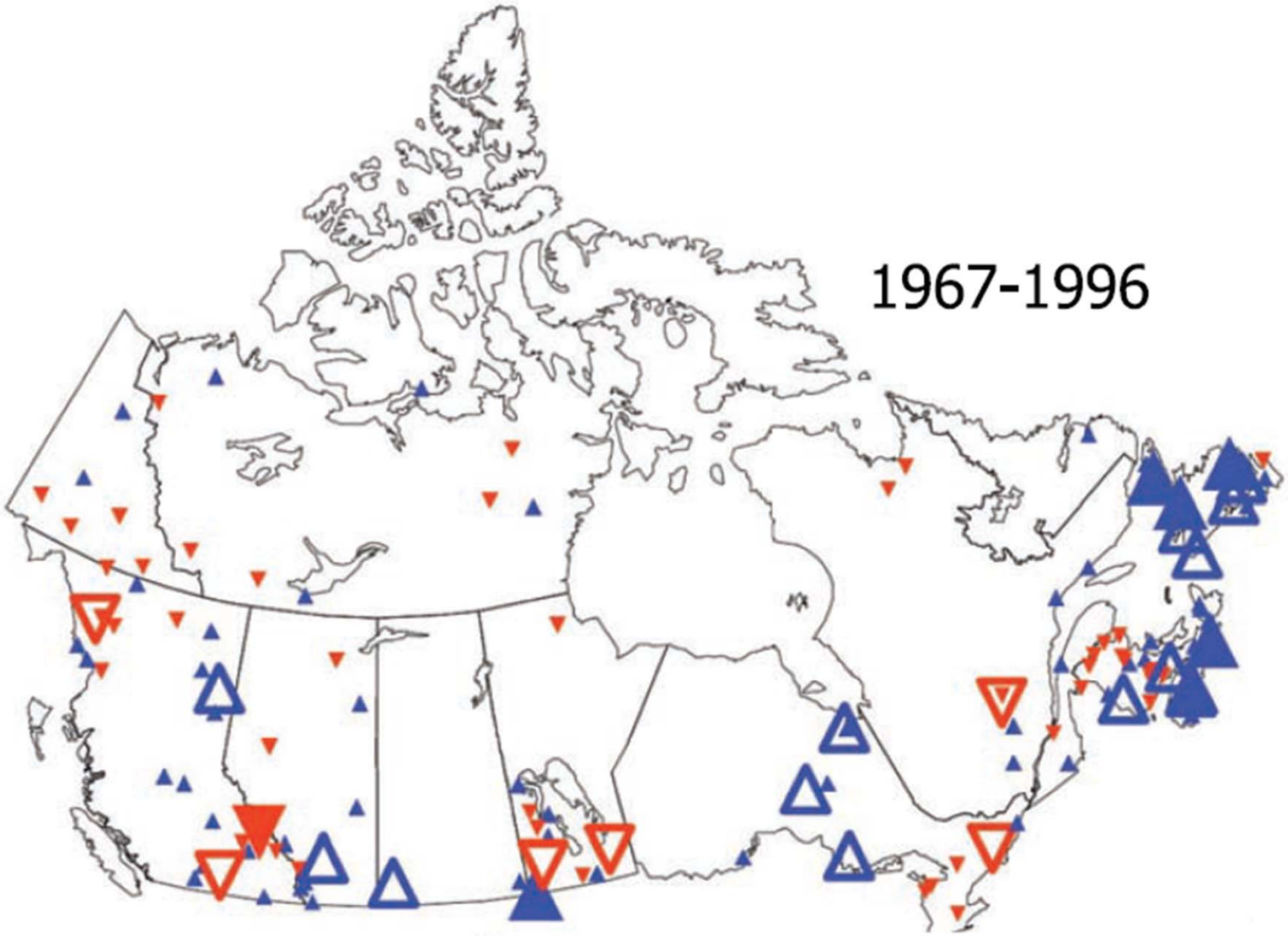
" […] hatching indicates regions where the multi-model mean is small compared to natural internal variability (i.e., less than one standard deviation of natural internal variability in 20-year means). Stippling indicates regions where the multi-model mean is large compared to natural internal variability (i.e., greater than two standard deviations of natural internal variability in 20-year means) and where at least 90% of models agree on the sign of change […]"

IPCC AR5-WG1 SPM report



Changes in winter (December–March) precipitation corresponding to a unit deviation of the NAO index over 1900 to 2005. […] *Stippling indicates values greater than 0.3 mm per day and hatching values less than –0.3 mm per day.*

IPCC AR4-WG1 Ch. 3



“Trends in river ice cover duration in Canada. Upward pointing triangles indicate lengthening of the ice cover period while downward triangles indicate shortening of the ice cover period. Trends significant at the 99 and 90% confidence levels are marked by larger filled and hollow triangles, respectively. Smaller triangles indicate trends that are not significant at the 90% level” (IPCC AR4 WG1 Ch. 4, Zhang et al., 2001).

- combined maps (bivariate color mapping)

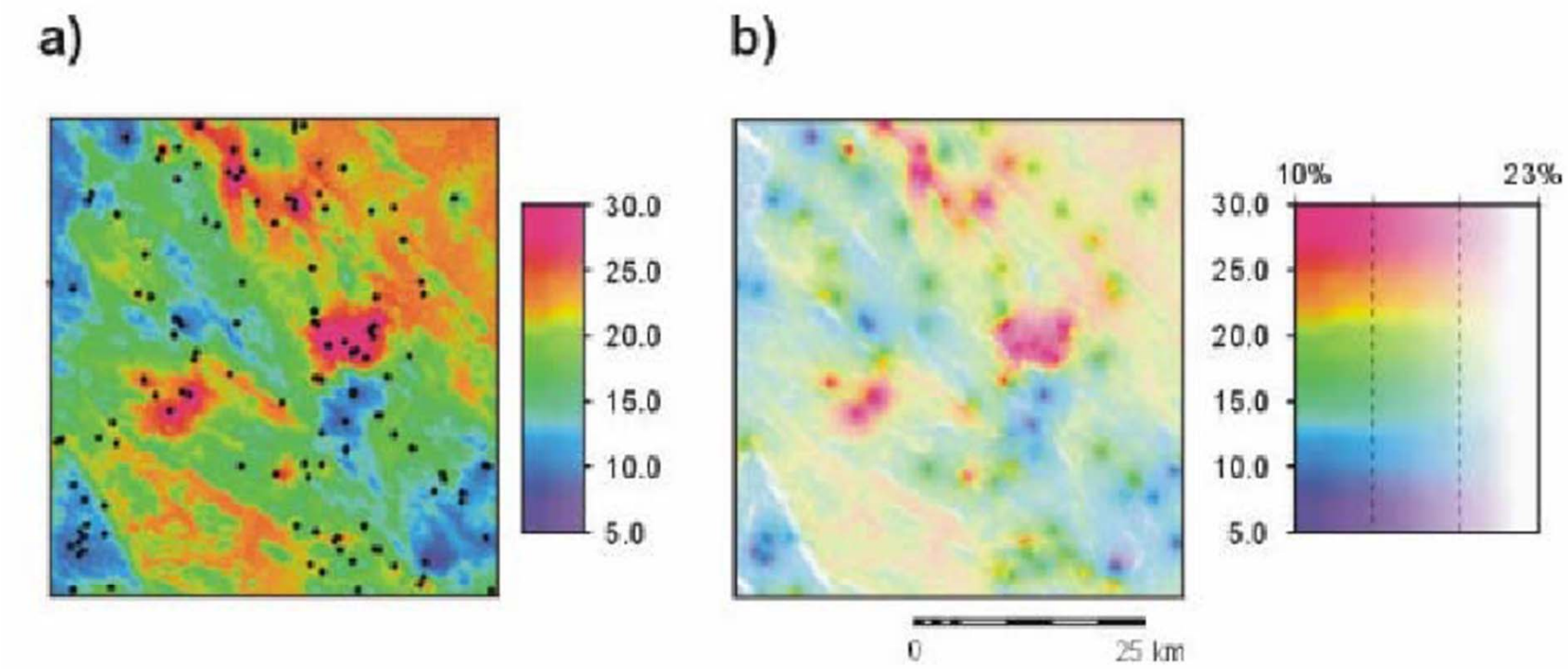
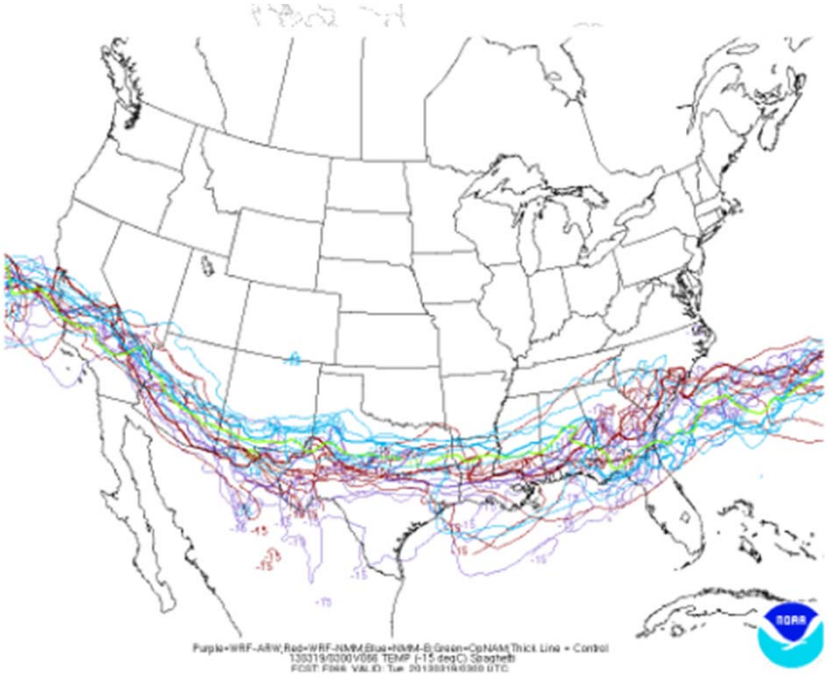


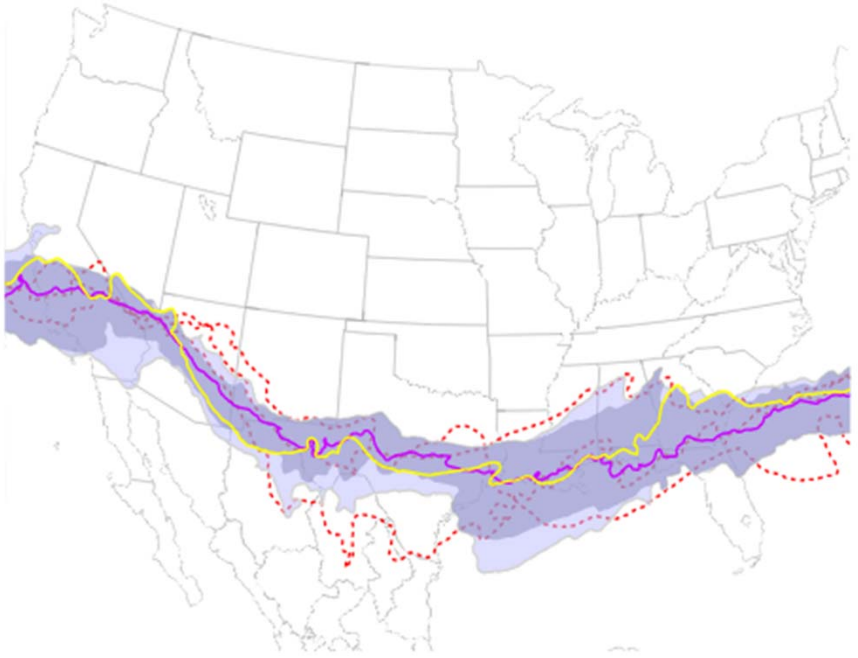
Fig. 2. Visualisation of uncertainty for a quantitative variable (topsoil thickness) interpolated using regression-kriging: (a) the common pseudo-colour legend used in many GIS packages and (b) two-dimensional legend with uncertainty coded with the whiteness.

[Visser et al. 2006]

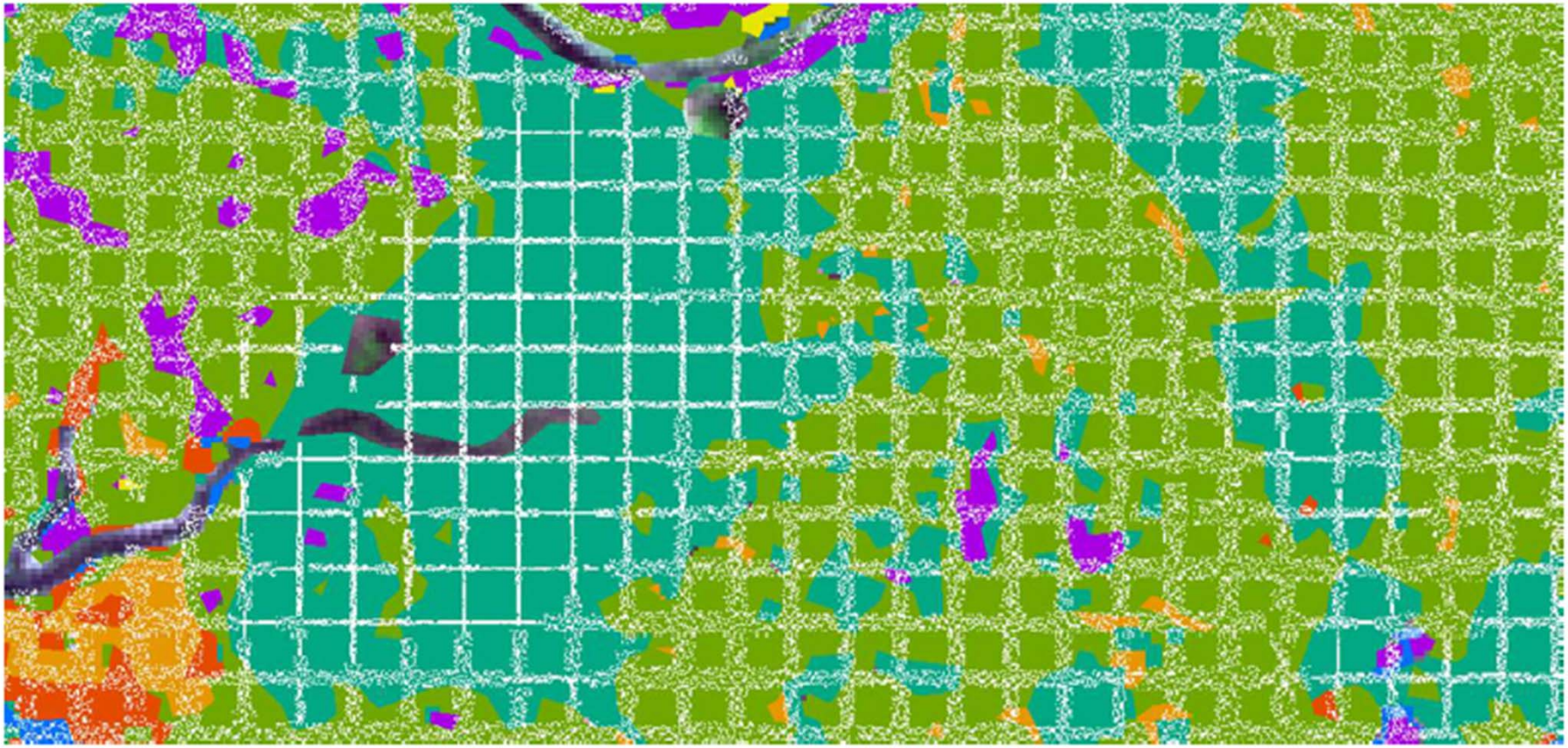
- Contour boxplots [Whitaker et al. 2013]



Original “spaghetti” image



Combination of “statistical areas” and outlier preservation



Annotation lines
[Kinkeldey et al. 2013]

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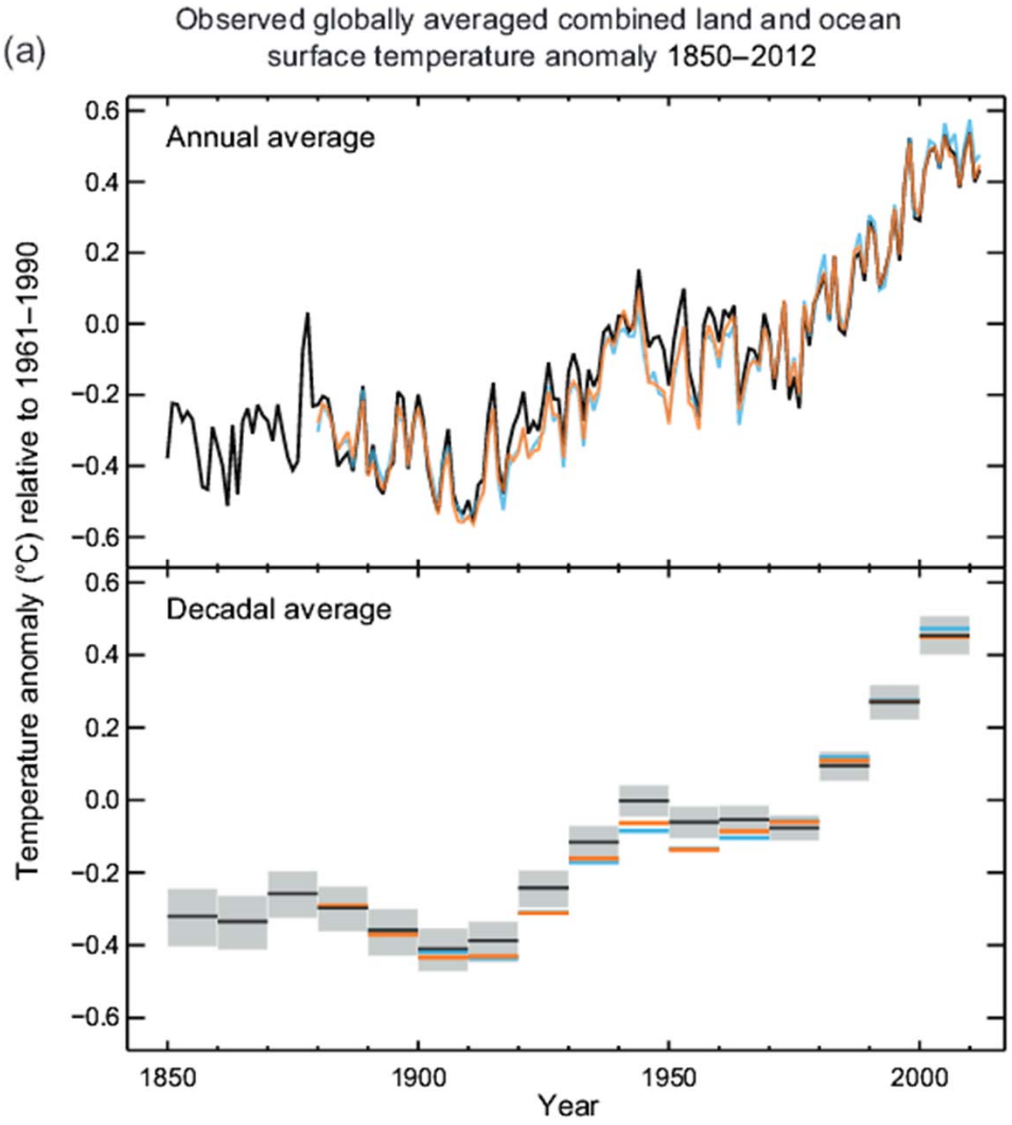
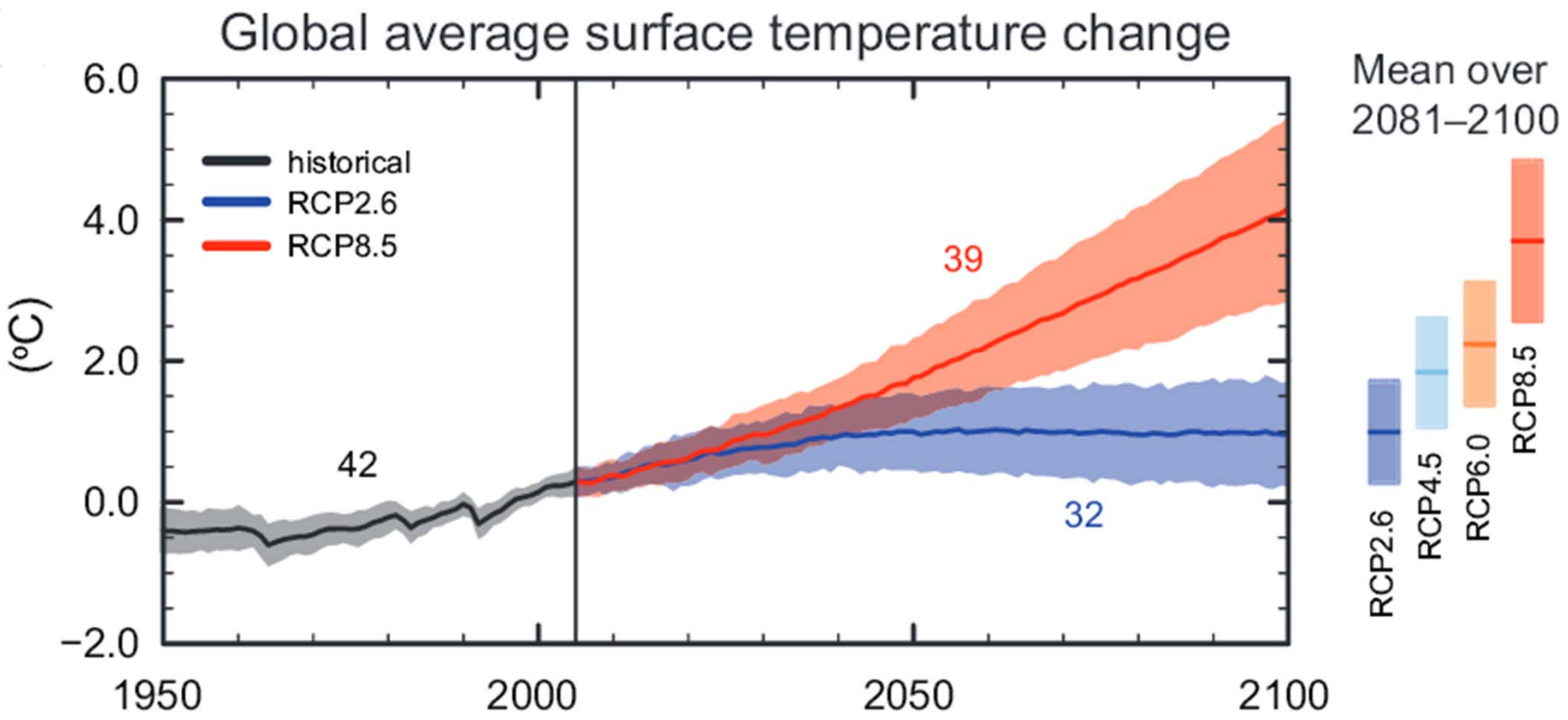
- “Time chart spagetti” und decadal bandwidth

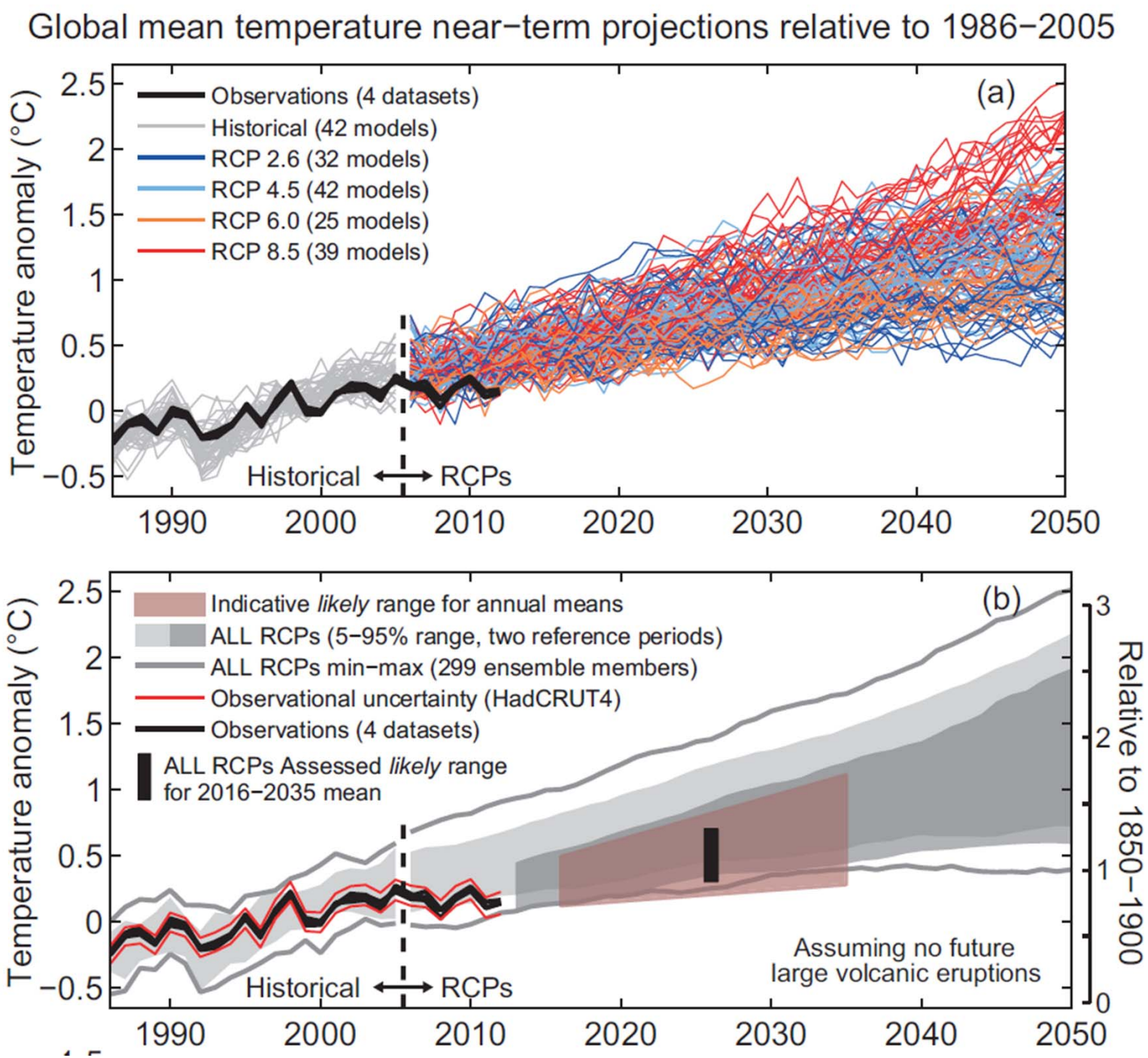


IPCC AR5-WG1 SPM report

- Temporal bandwidth representation using area coloring

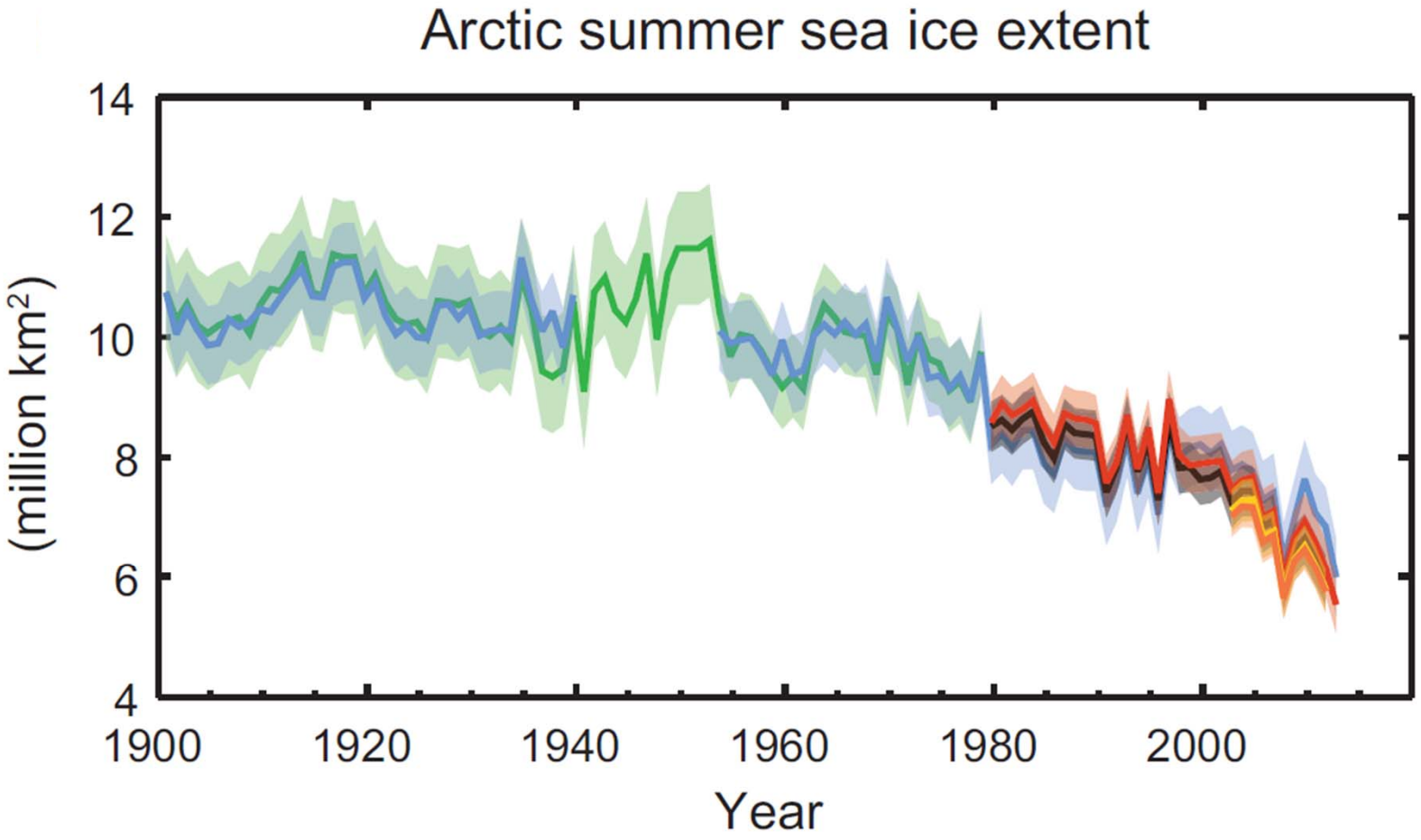


[IPCC AR5-WG1]



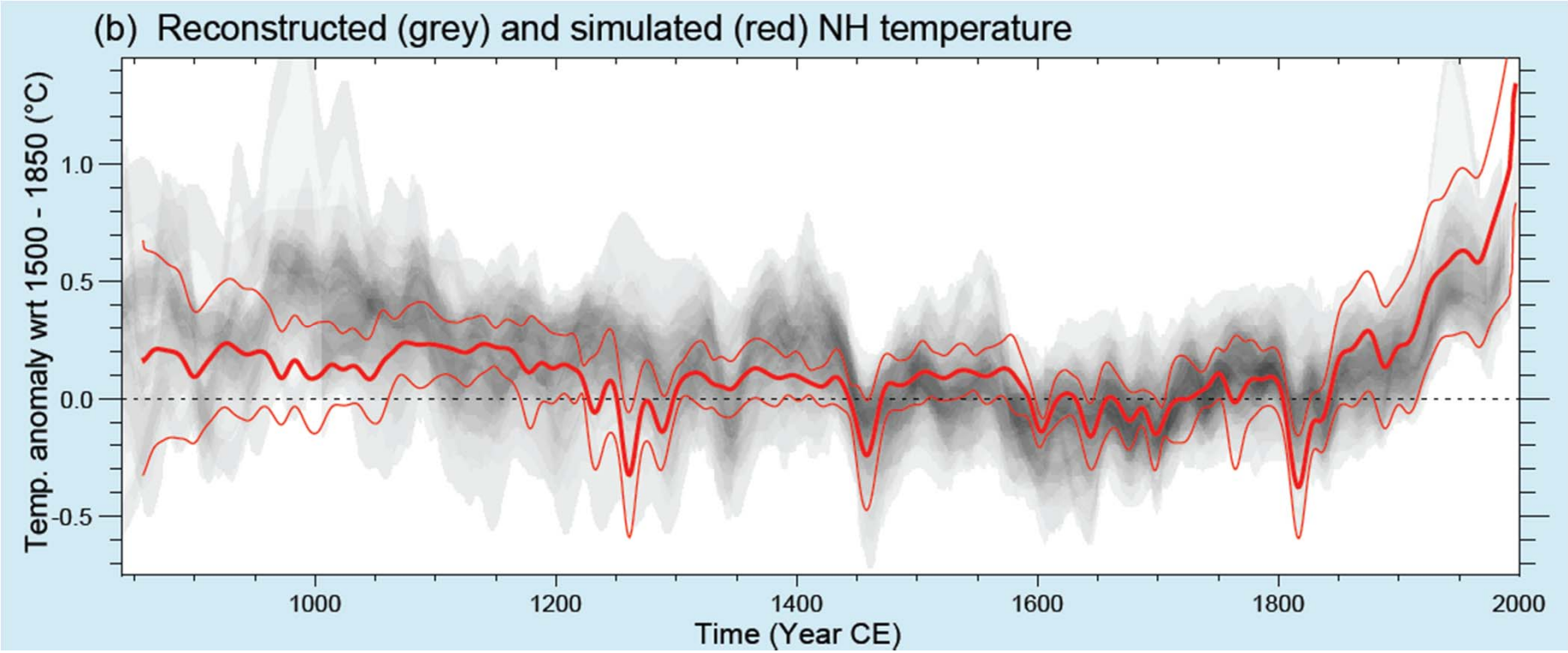
[IPCC AR5 WG1 TS]

- Temporal bandwidth representation using area coloring (multiple time series)



[IPCC AR5-WG1]

- Temporal bandwidth representation (mixed)



[IPCC AR5-WG1 TS]

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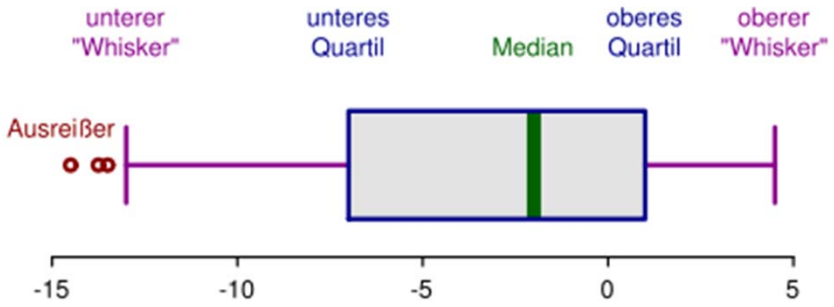
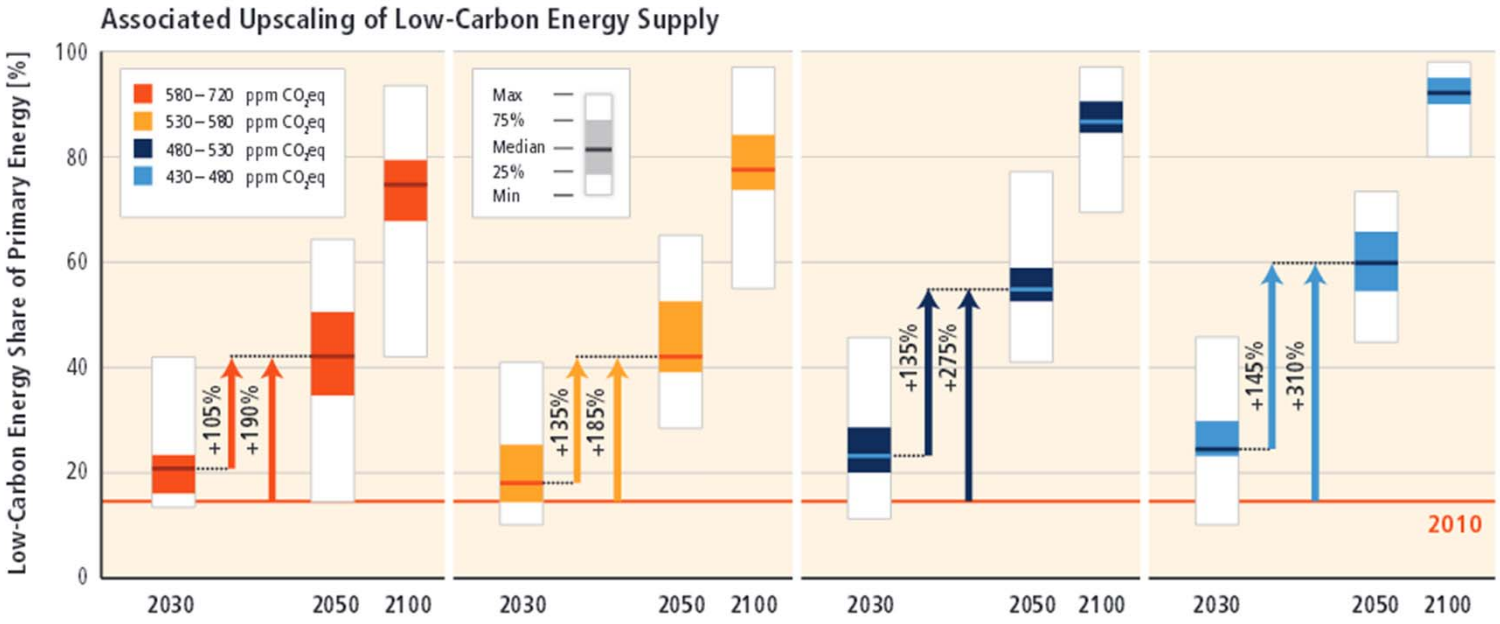
- Box plots

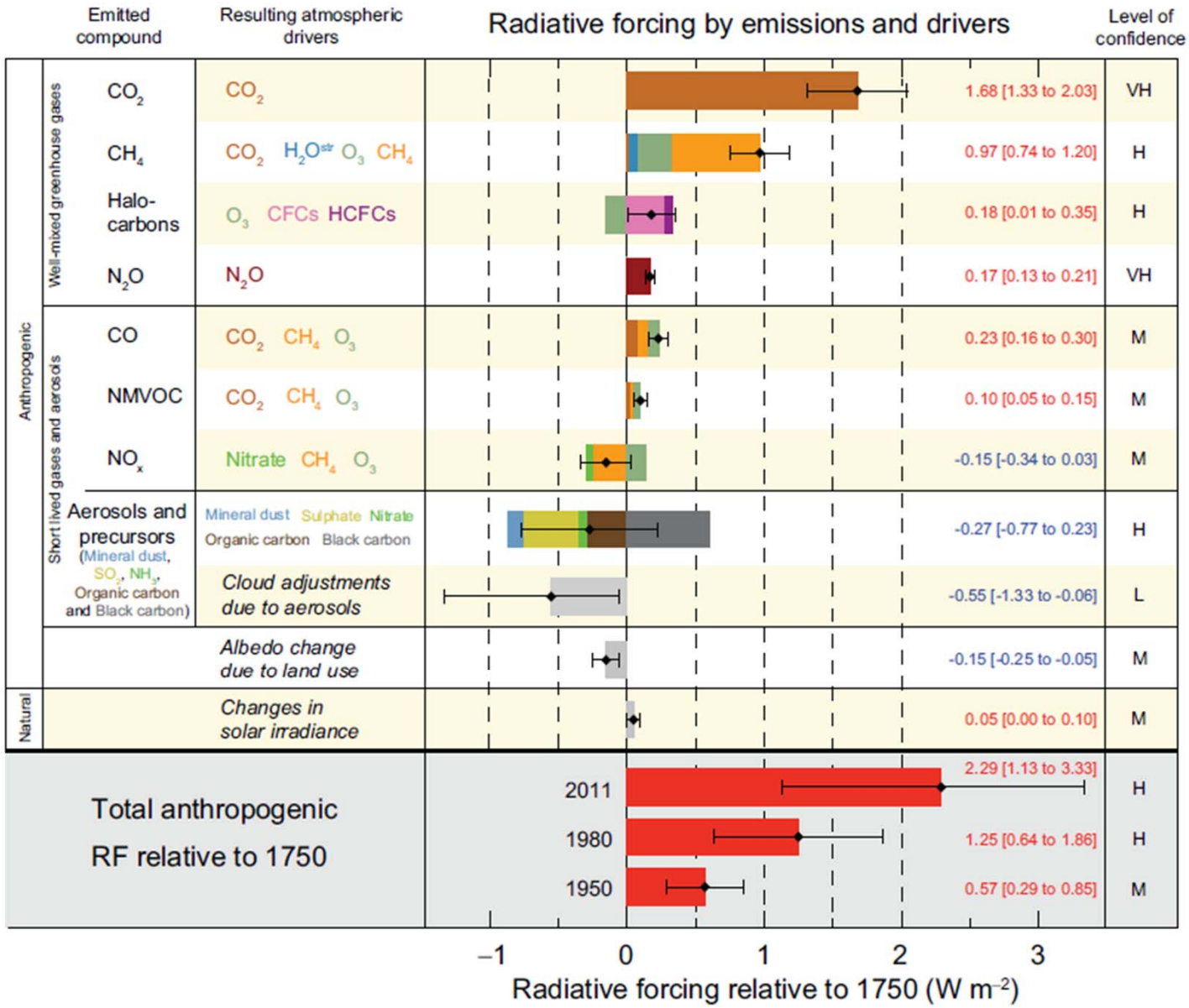


[Wikipedia, 2014]

Simplified box plots [IPCC AR5 SPM WGIII]

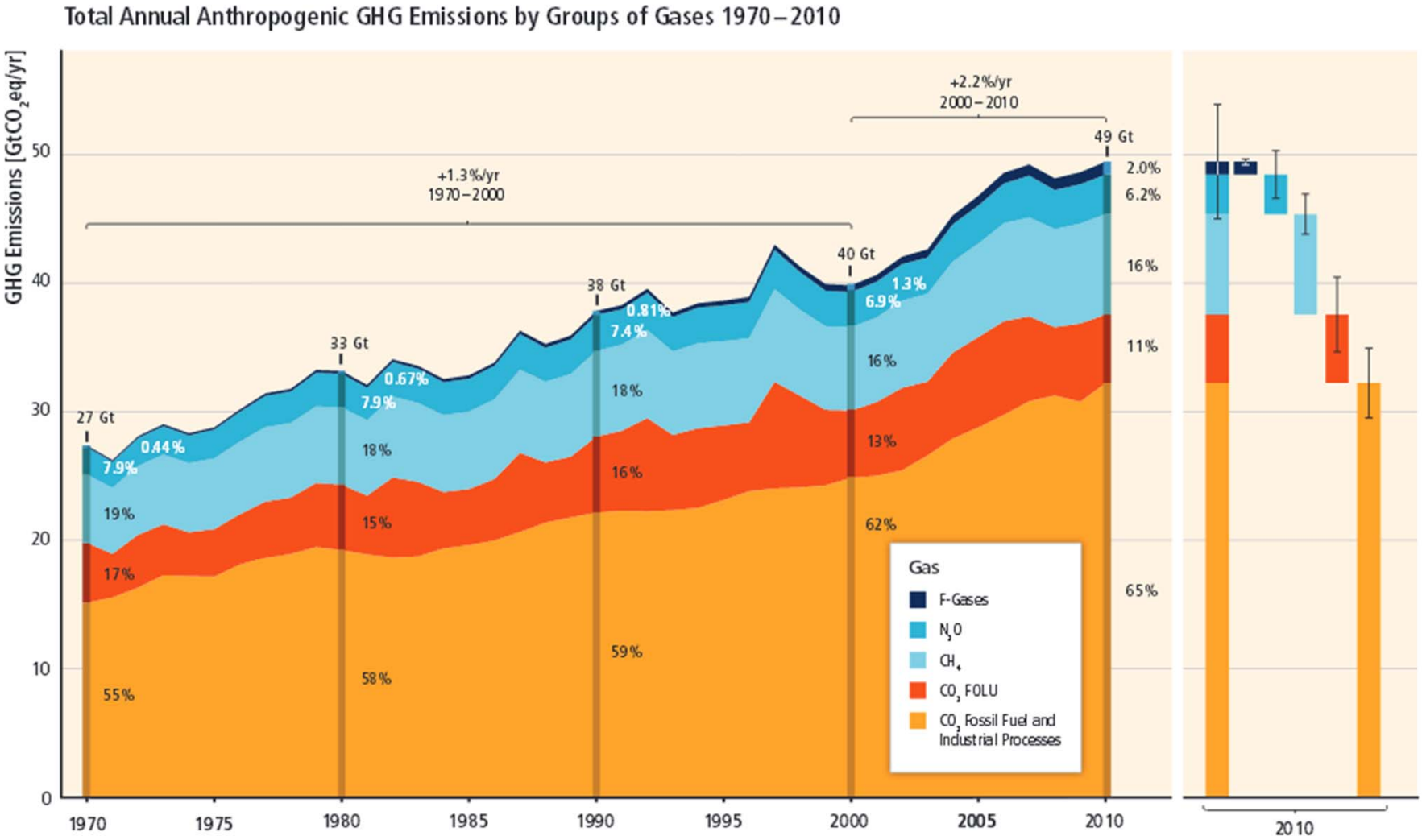


- Uncertainties in bar charts (1)



Additional whiskers at the bar charts [IPCC AR5 SPM WGI]

- Uncertainties in bar charts (2)



Uncertainties in stacked bar charts (right) [IPCC AR5 SPM WGIII]

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Interactivity in uncertainty visualization

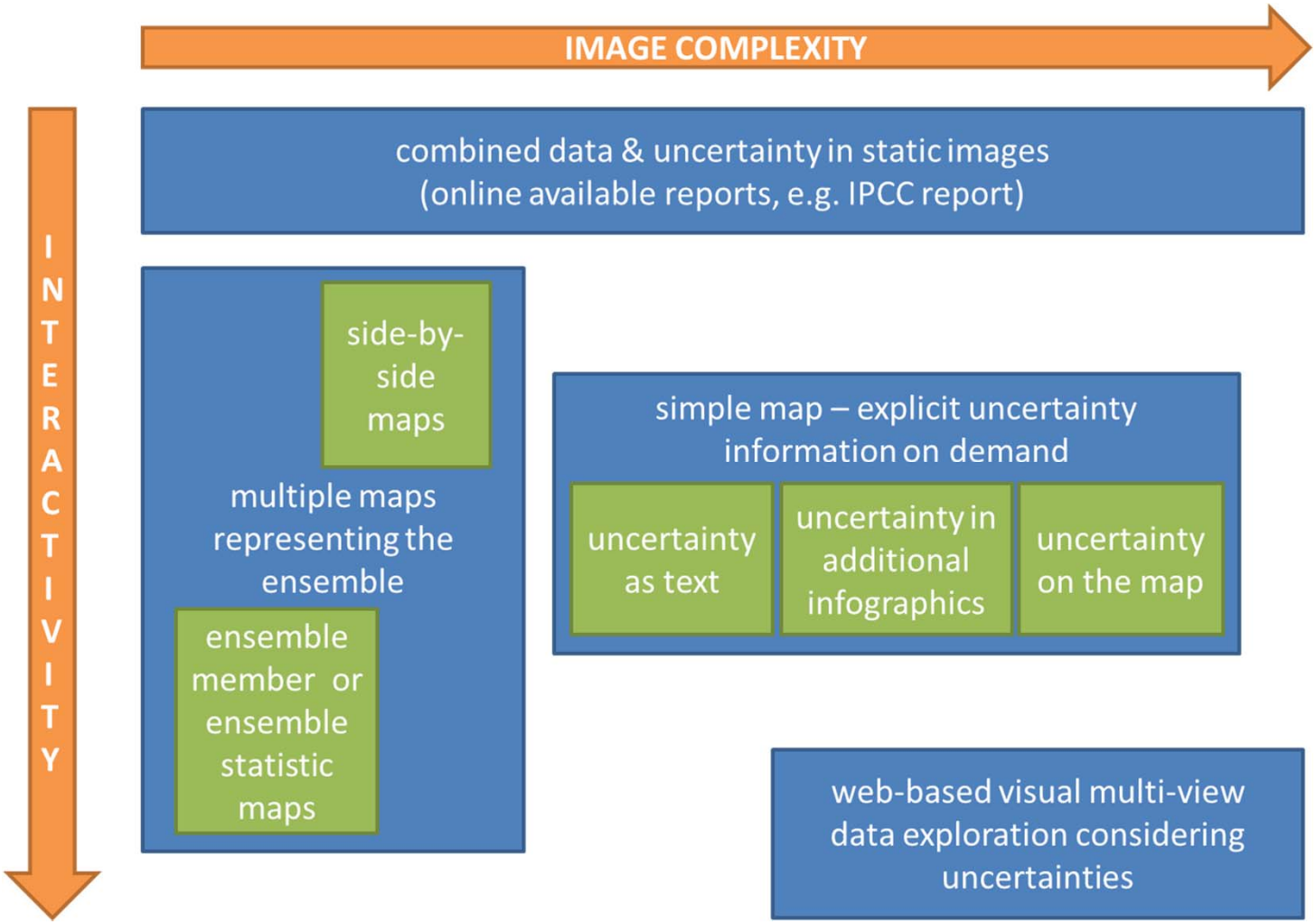
- **Possibility to represent more (uncertain) information on demand**

  "A Graphic is not drawn once and for all" [Bertin, 1981]

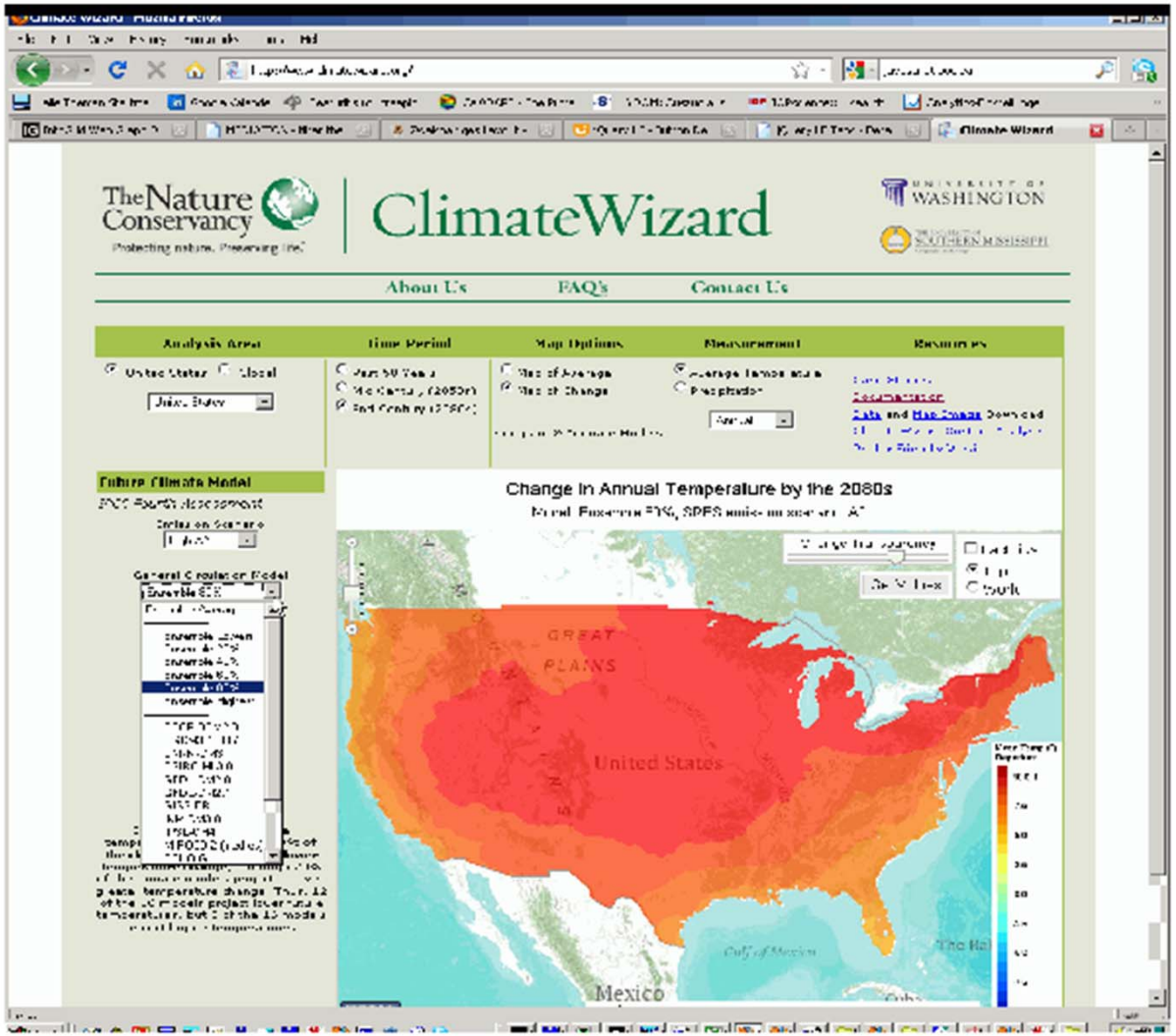
  "Overview first, Zoom and Filter, then details on demand" [Shneiderman, 1996]

- **System / tool classes:**
  - Linked multi-view interactive visual analysis tools
  - Multi-view interactive expert support presentation tools
  - Climate online portals

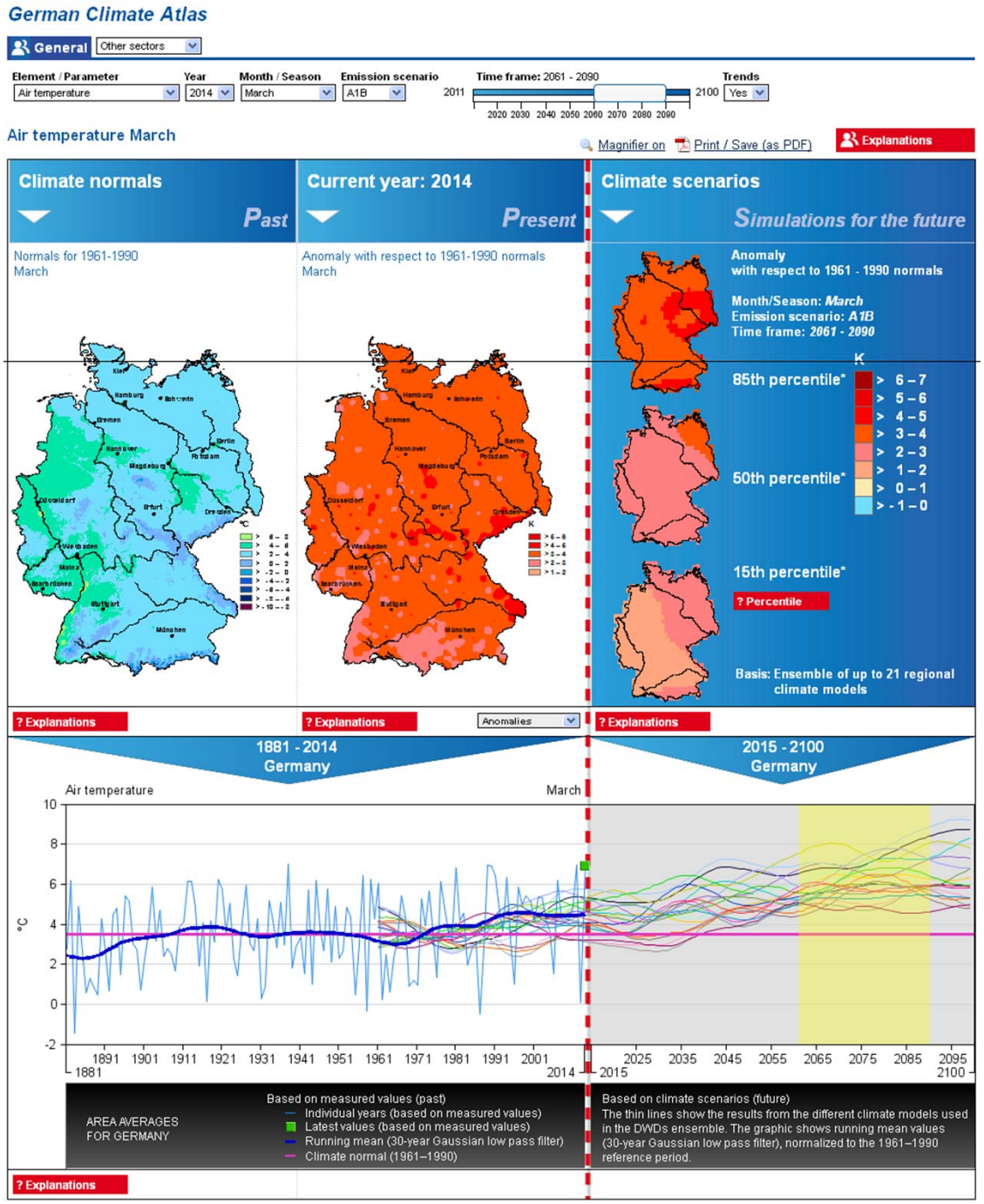
Classification of climate web portal uncertainty visualizations



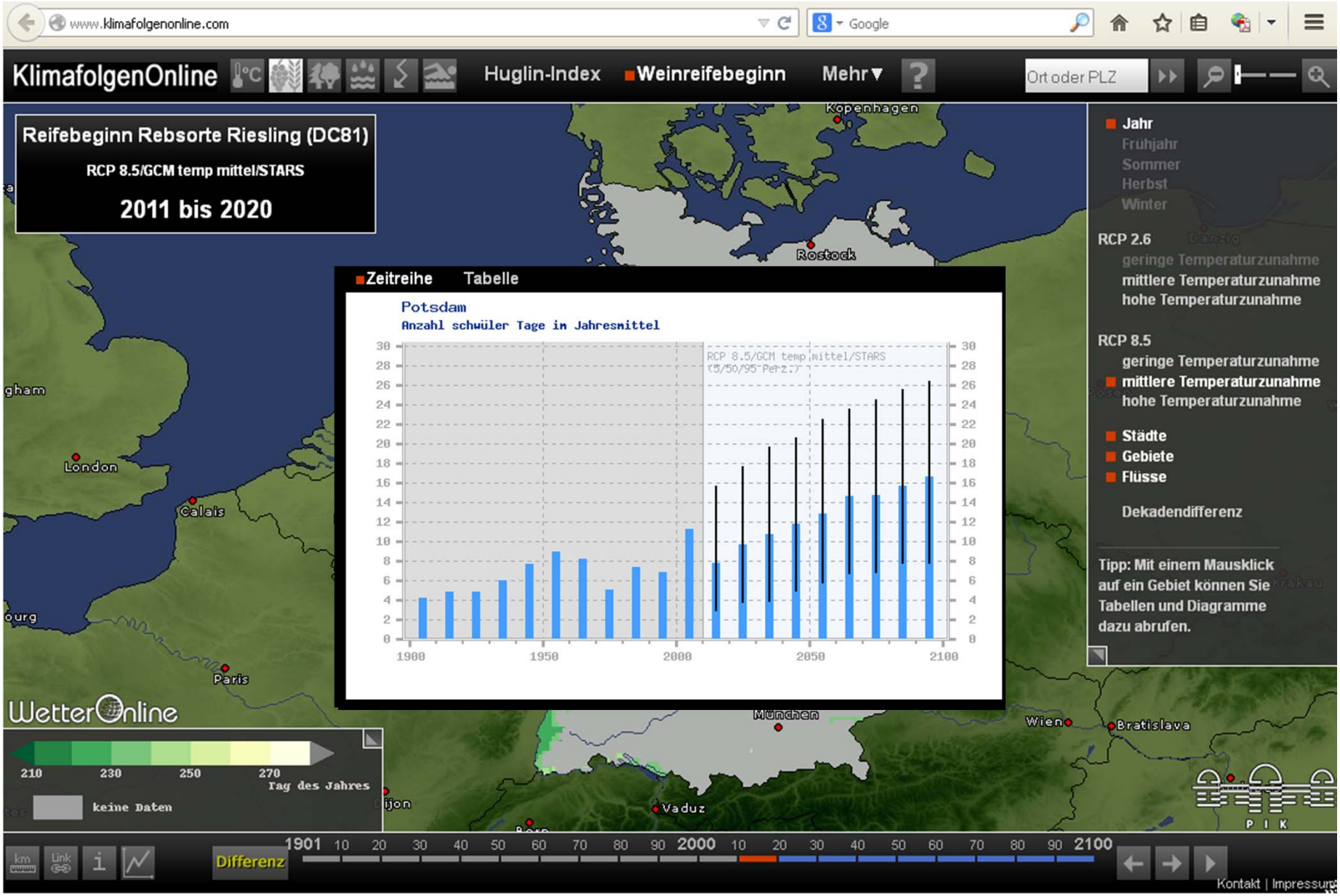
Representation technique: display statistical measures on a map



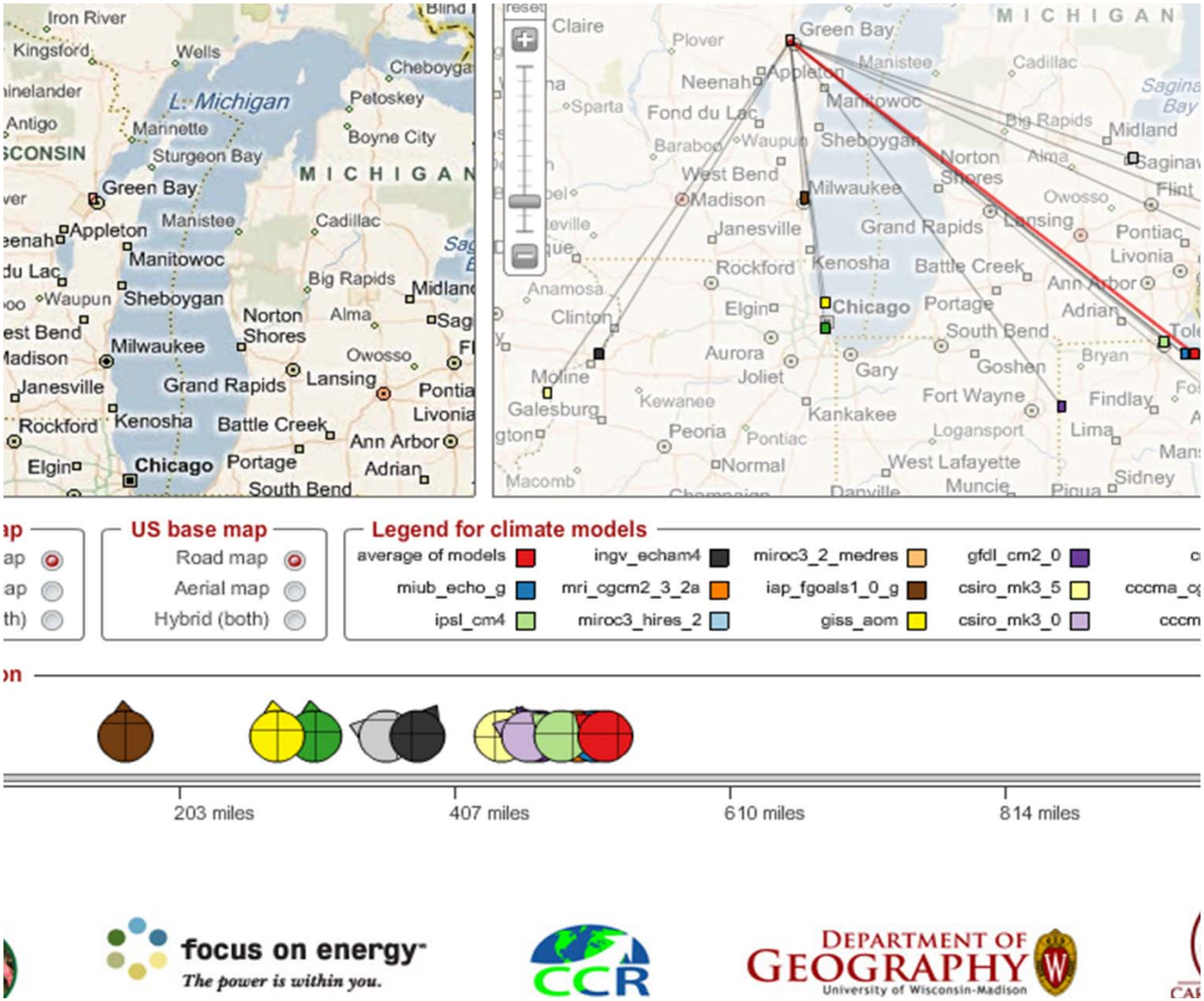
http://www.climatewizard.org/



German Climate Atlas by German Weather Service (DWD)



ClimateImpactsOnline.com web portal



Presentation of the model heterogeneities for a certain location (in the future) by depicting (present) climatically comparable places (Wisconsin Climate Analogs)

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Conclusion

- Problem of (quantitative) uncertainty visualization:
  - more complex representation which
    - can result in viewer overload
    - can result in longer perception times
    - are no longer intuitively interpretable without reading longer textual explanantions
  - more representations
    - limitations for print media

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nocke@pik-potsdam.de

References

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