Regional Climate Uncertainty: Sources and Assessments

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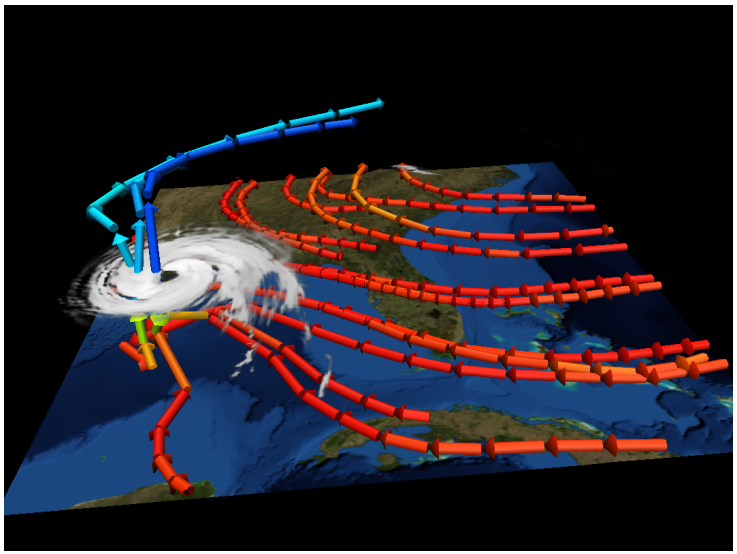
NESL/MMM

Take Home Messages

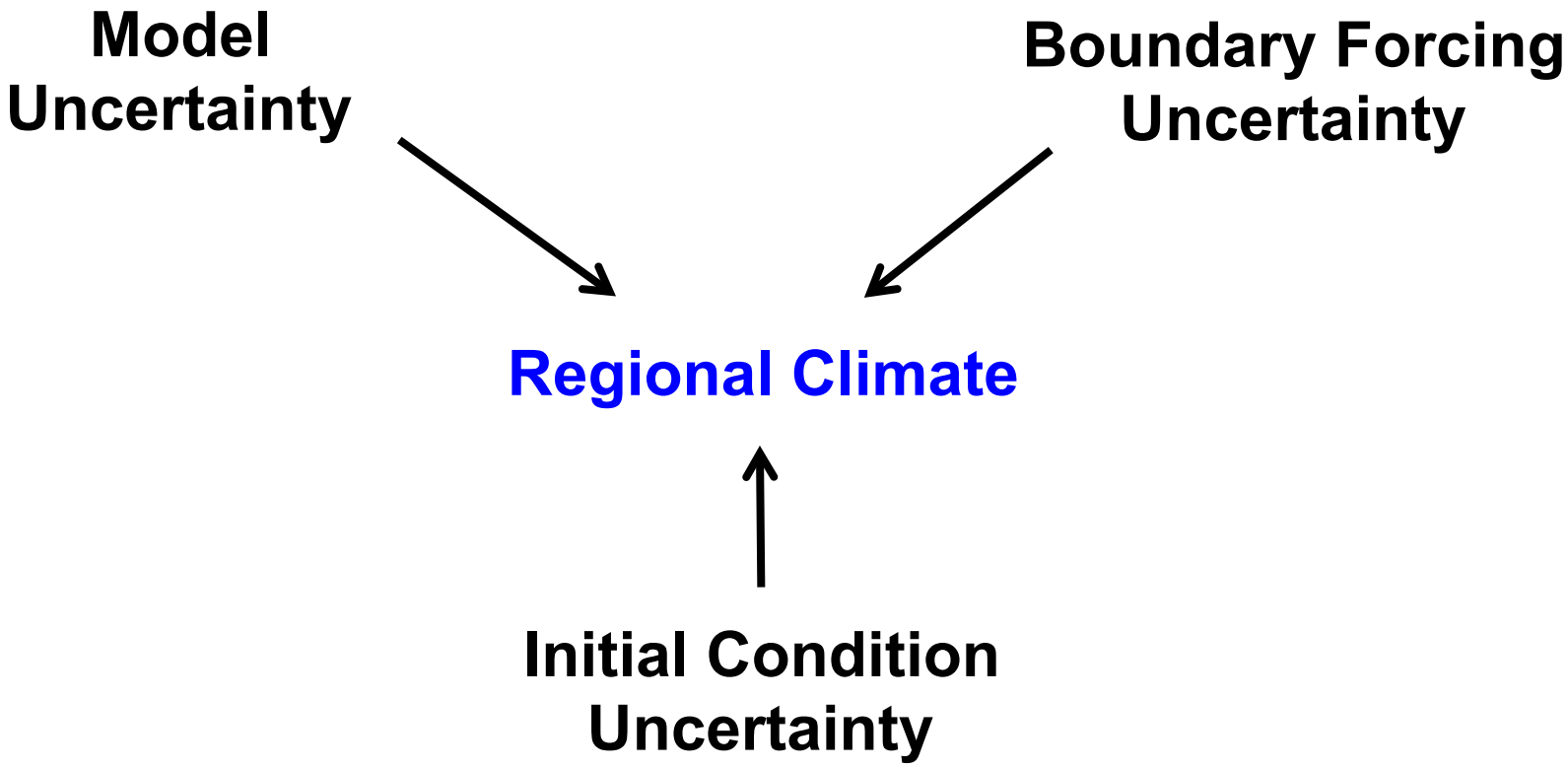
- There are many sources of regional climate uncertainty.
- Uncertainty varies with scale and variable.
- Combined statistical-dynamical modeling can provide practical and useful information on uncertainty.

Overarching Goal

Develop capacity to assess confidence in assessments and predictions of regional climate and high-impact weather statistics.



Uncertainty Sources



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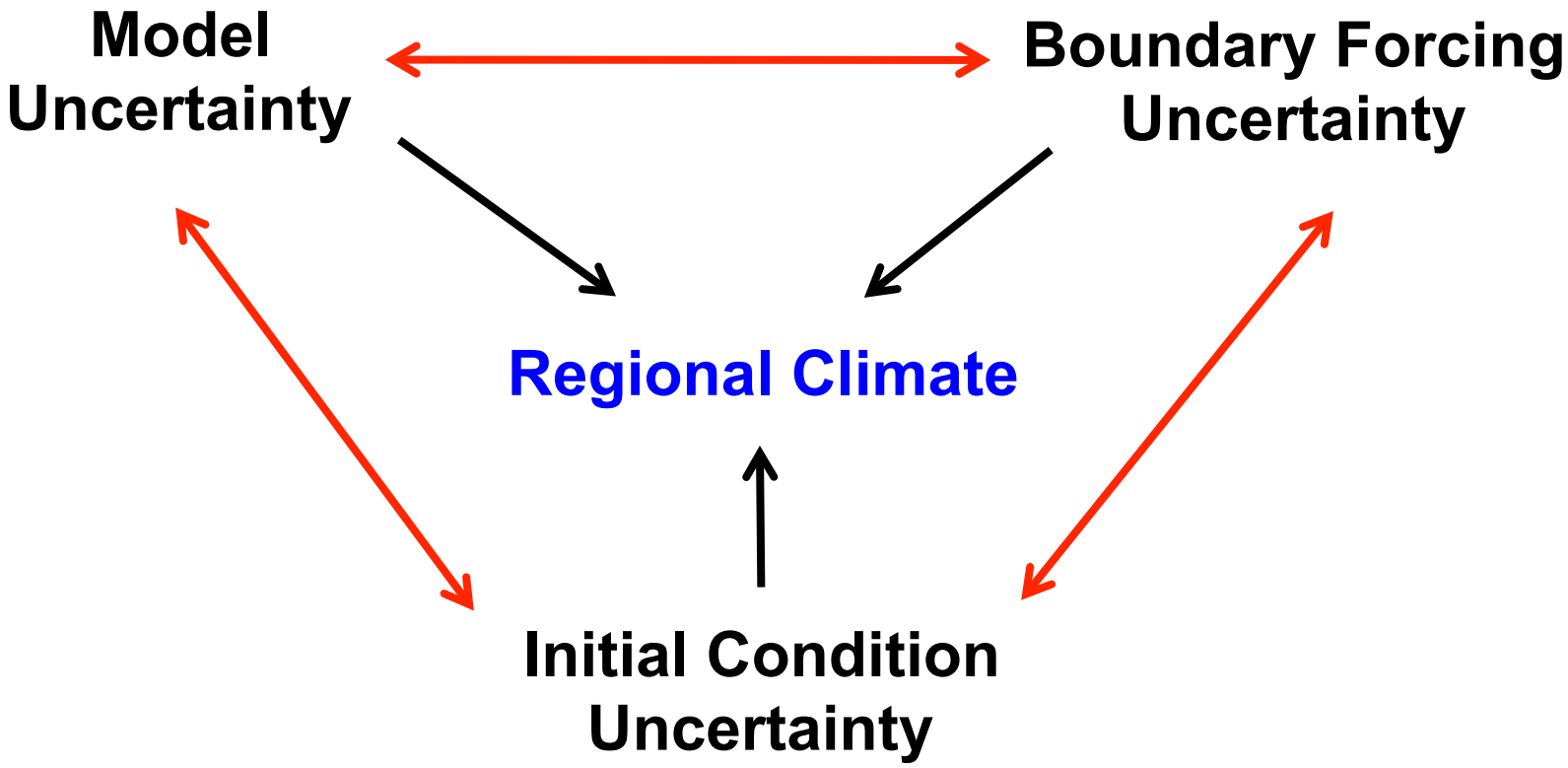

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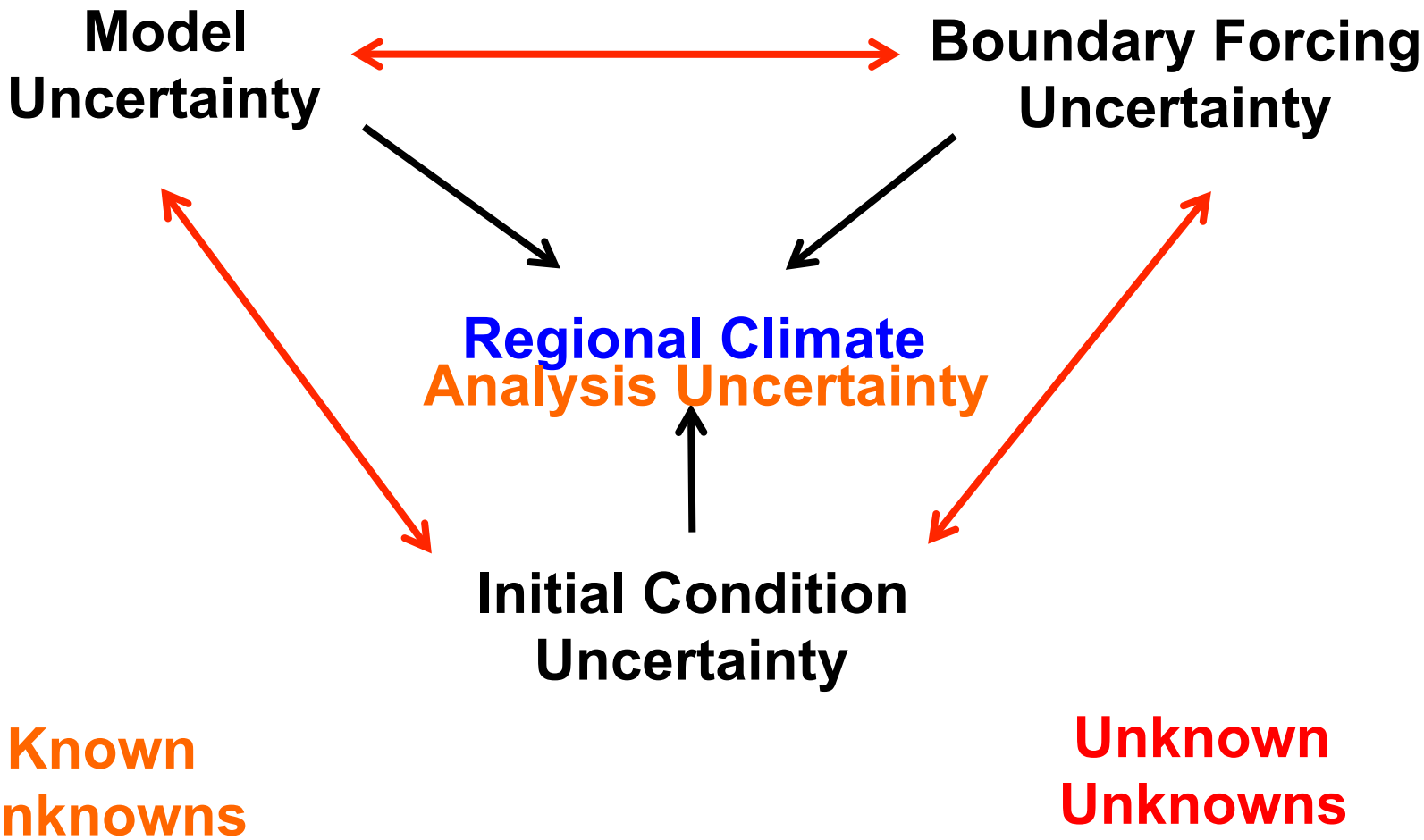
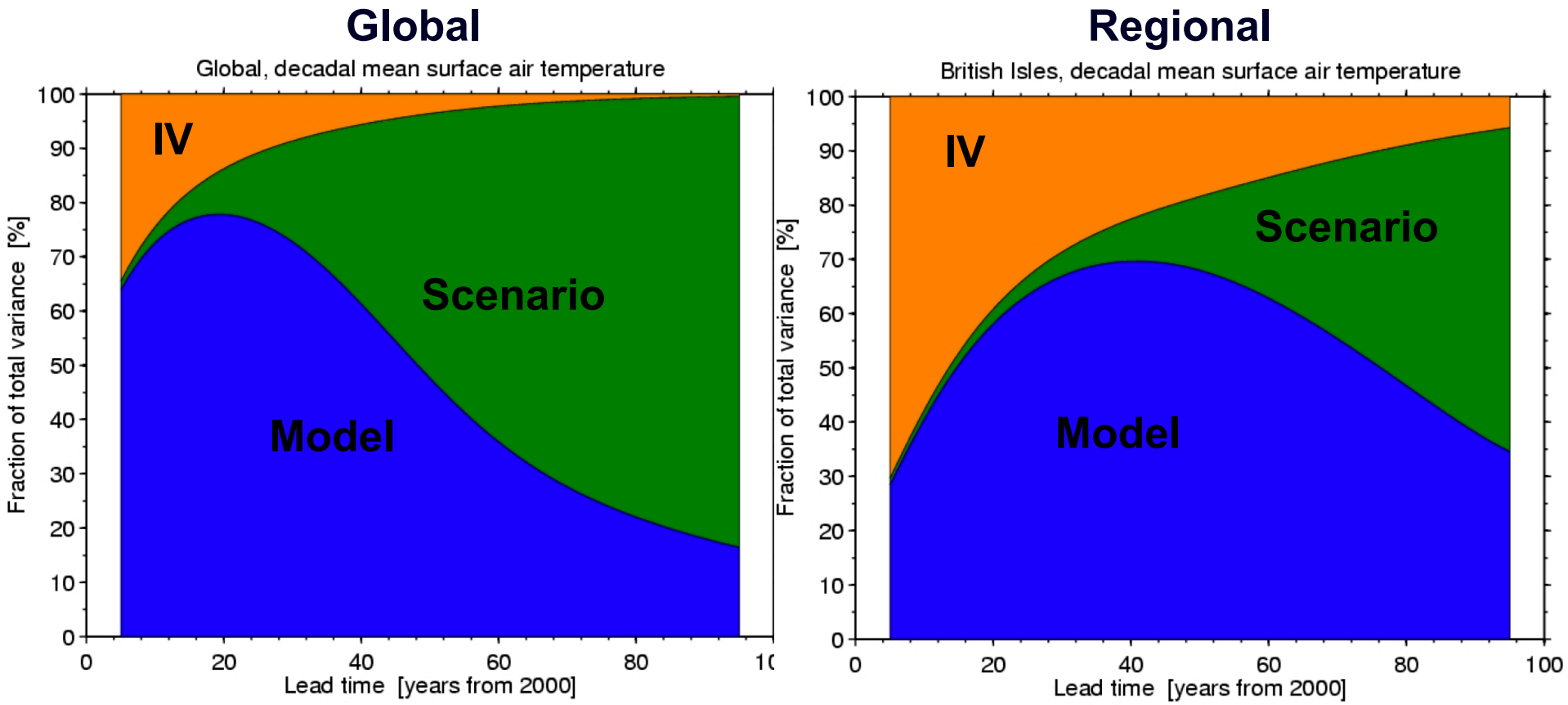


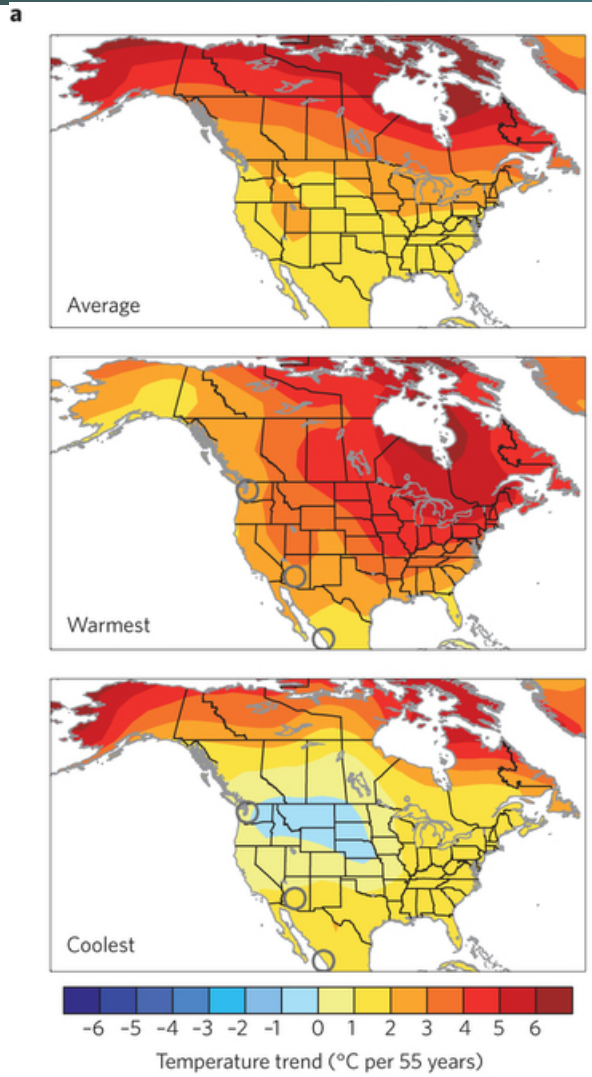
Importance of Scale



- The dominant uncertainty source varies with scale.

Hawkins, Ed, Rowan Sutton, 2009: The Potential to Narrow Uncertainty in Regional Climate Predictions. *Bull. Amer. Meteor. Soc.*, 90, 1095–1107.

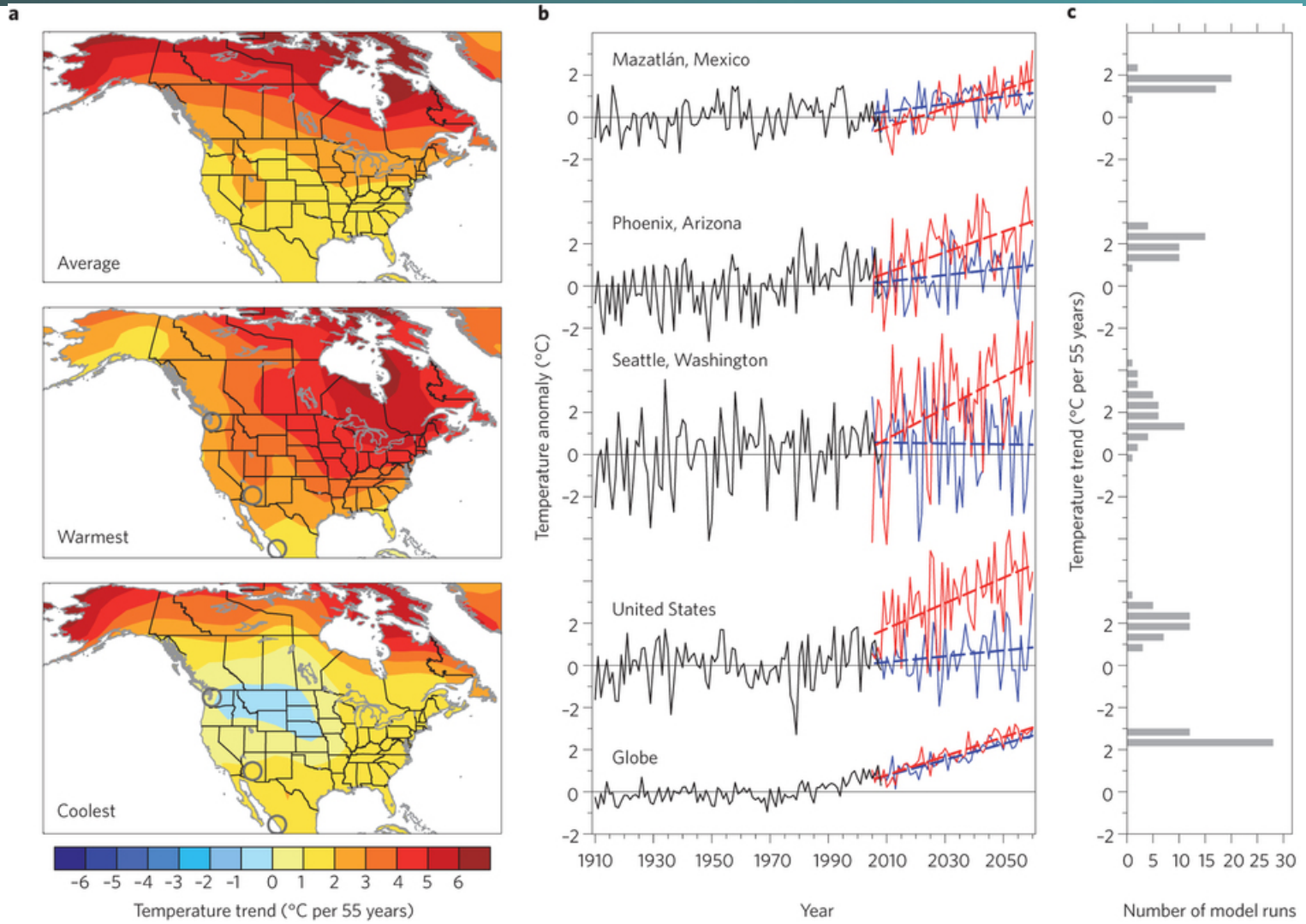
Initial Condition Uncertainty and Scale



55-year temperature trends (2005-2060) from a 40 member initial condition global ensemble.

Deser, C., R. Knutti, S. Solomon, and A. S. Phillips, 2012: Communication of the role of natural variability in future North American climate. *Nat. Clim. Change*, **2**, 775-779.

Initial Condition Uncertainty and Scale



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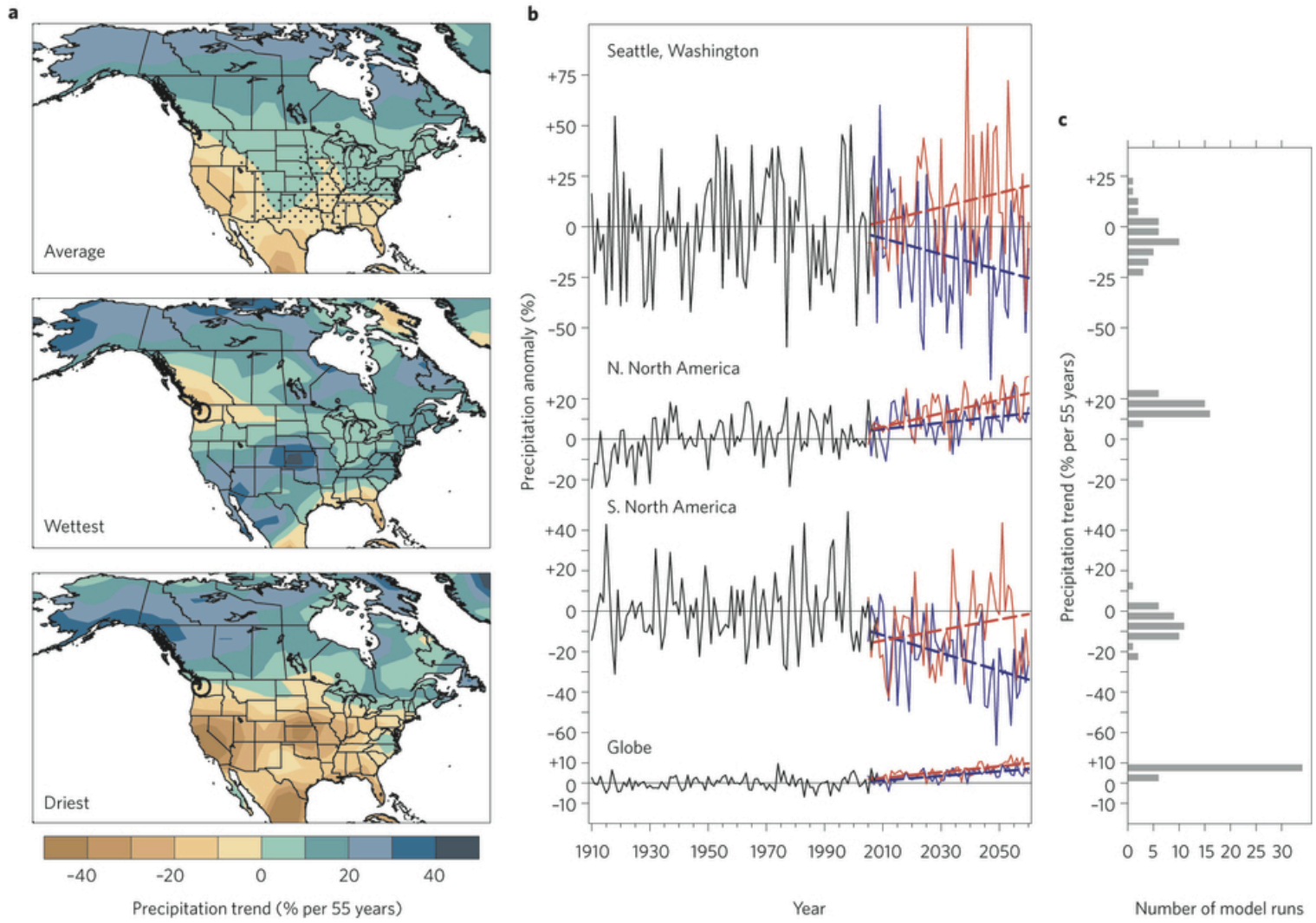
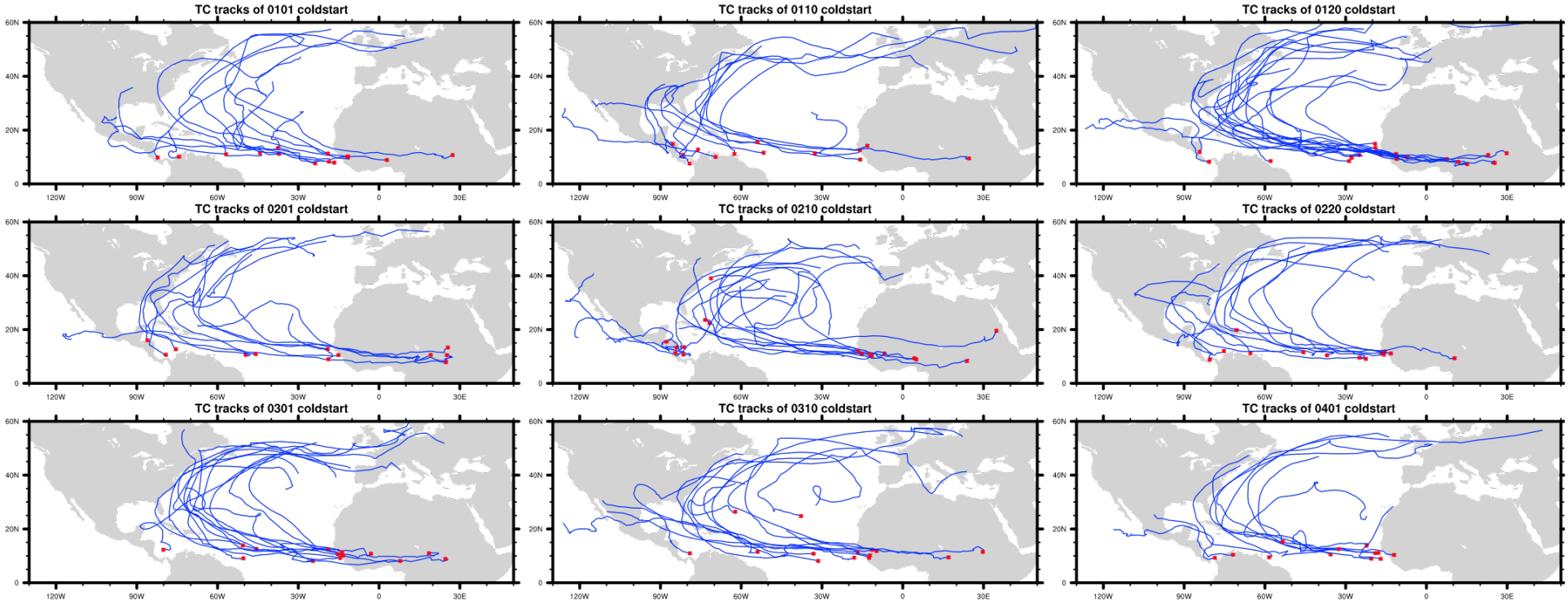
Importance of Variable



- Uncertainty depends on the variable of interest.

Initial Condition Uncertainty of High-Impact Weather

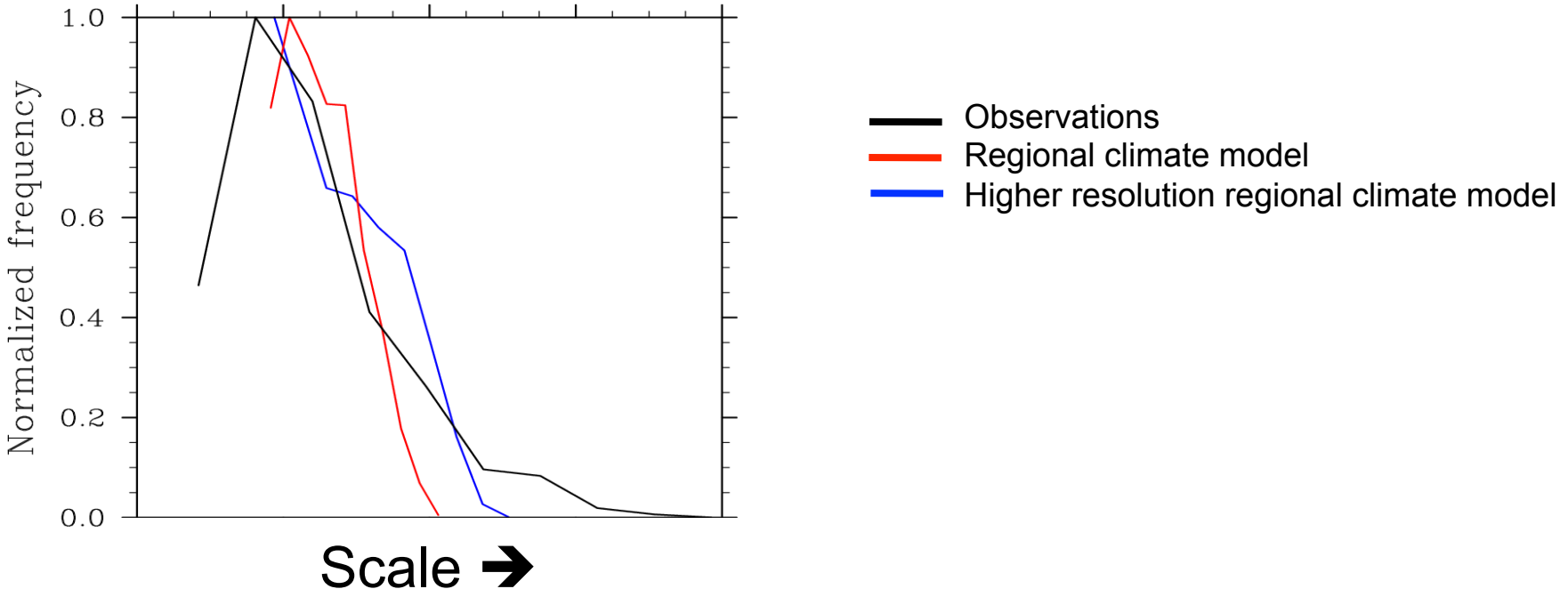
9-member initial condition regional model ensemble.



Range in number of tropical cyclones: 13 – 20.

Model Uncertainty

A typical weather system PDF

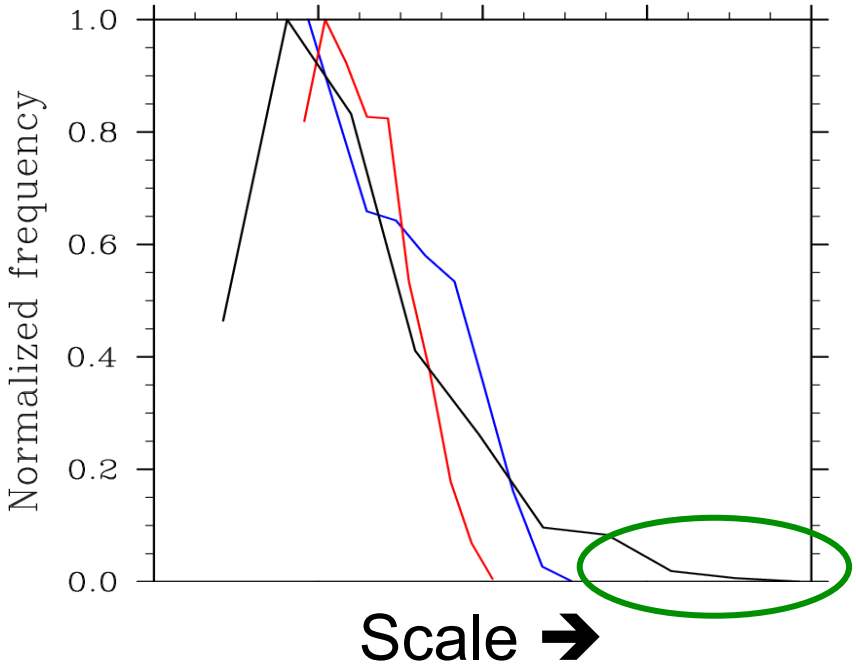


The Problem: Typical regional climate models do not capture the extremes. Truncated at high end due to:

- *resolution* – cannot resolve the relevant physical processes;
- *capacity* – do not include the relevant physical processes;
- *rarity* – cannot be run long enough to sample the tail.

Model Uncertainty

A typical weather system PDF



Observations
Regional climate model
Higher resolution regional climate model

Societal impact α rarity

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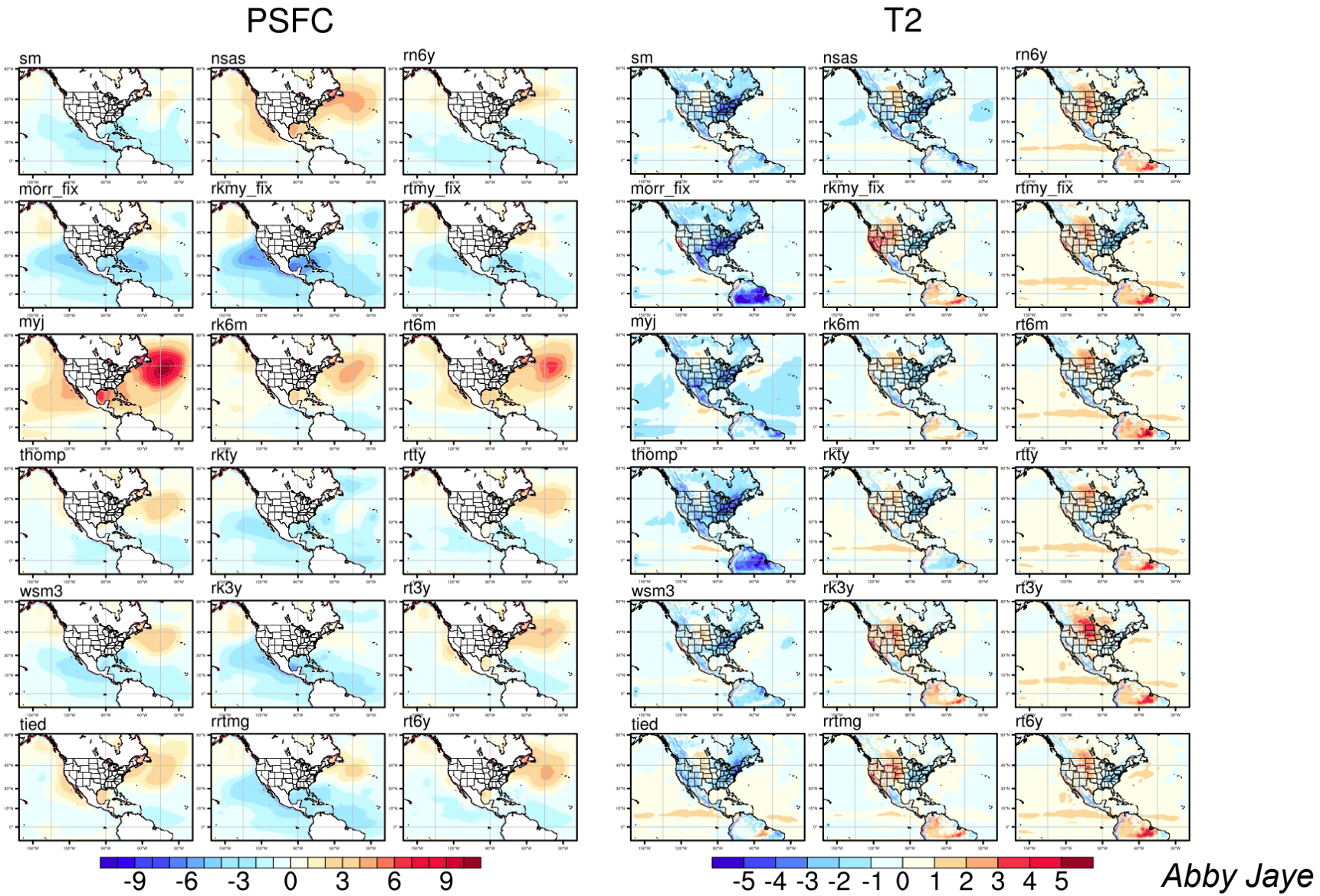
Model Uncertainty

In addition we may need to treat:

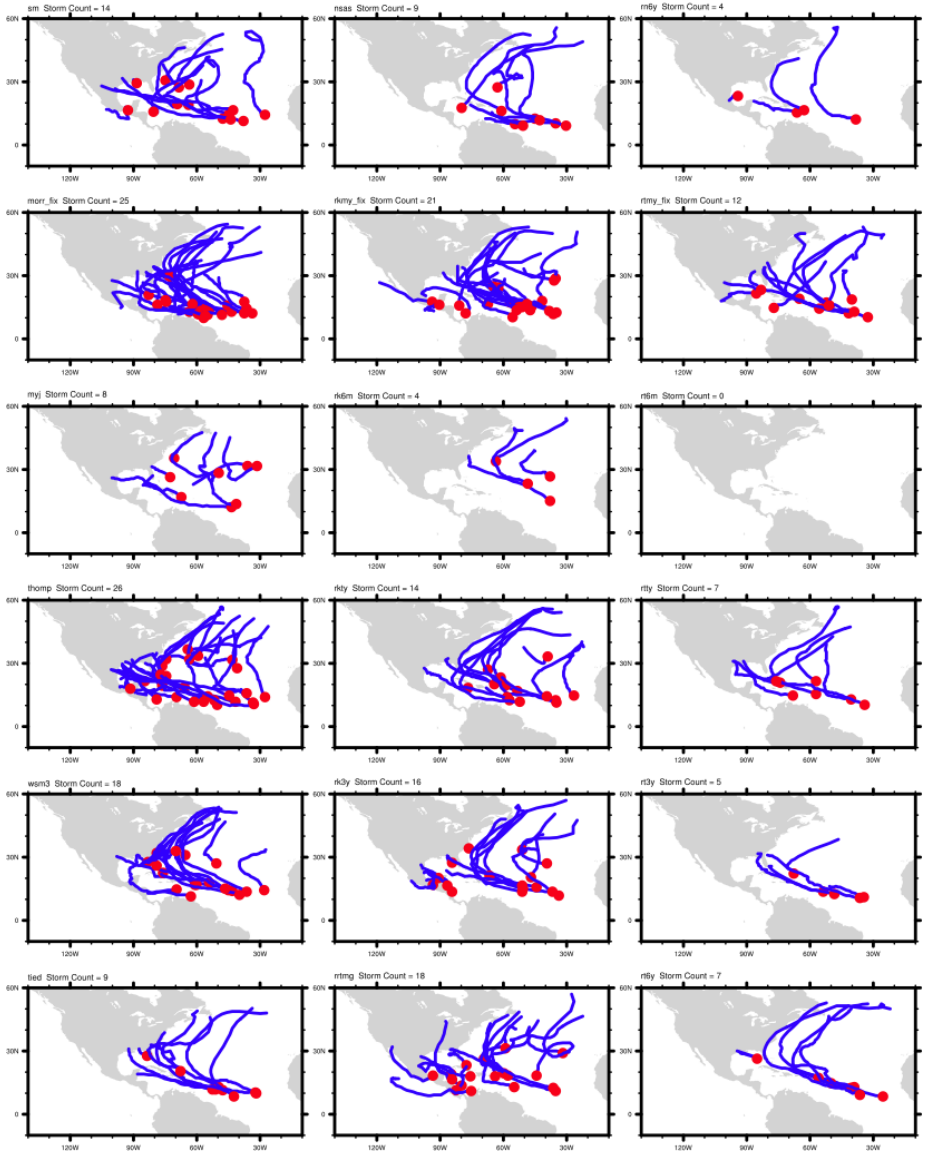
- *errors in location* – e.g. error in the mean mid-latitude storm track.
- *errors in frequency* – wrong distribution function.
- *errors in physical mechanisms* – right answer for the wrong reason.

Model Physics Uncertainty



Abby Jaye

Model Physics Uncertainty



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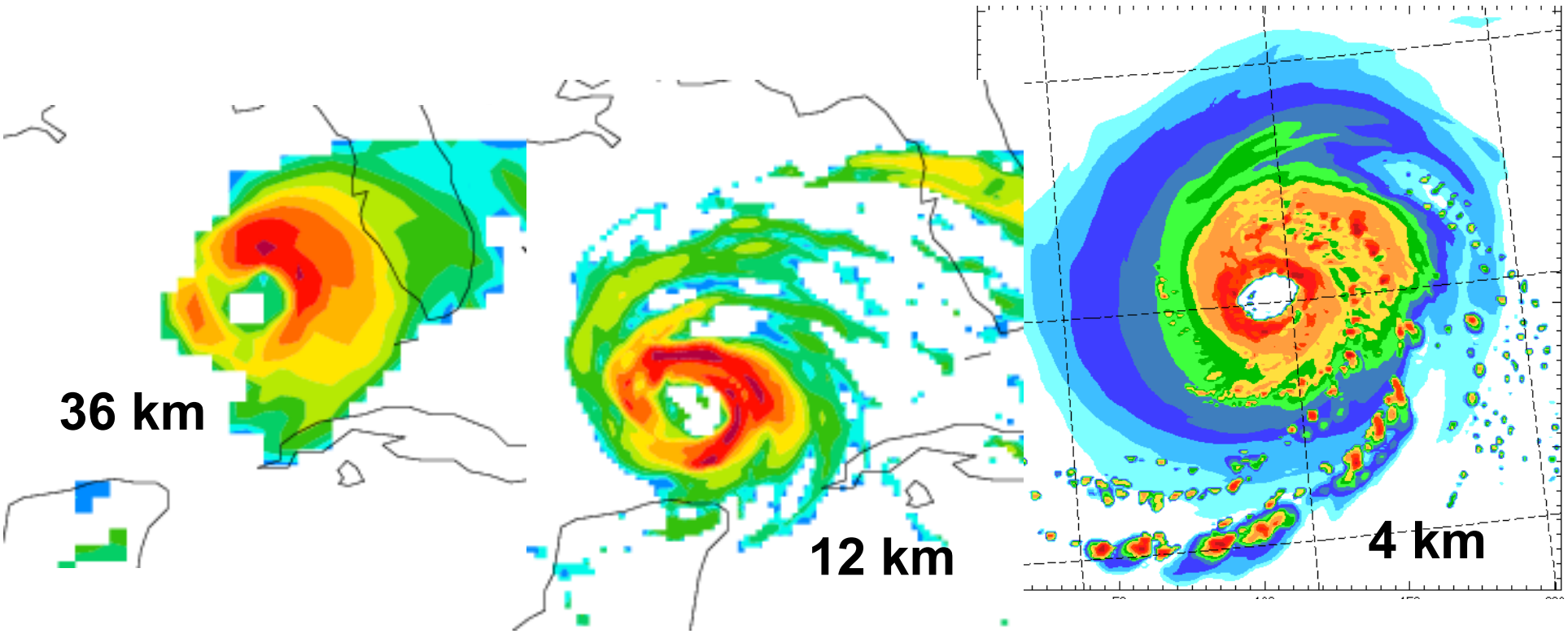
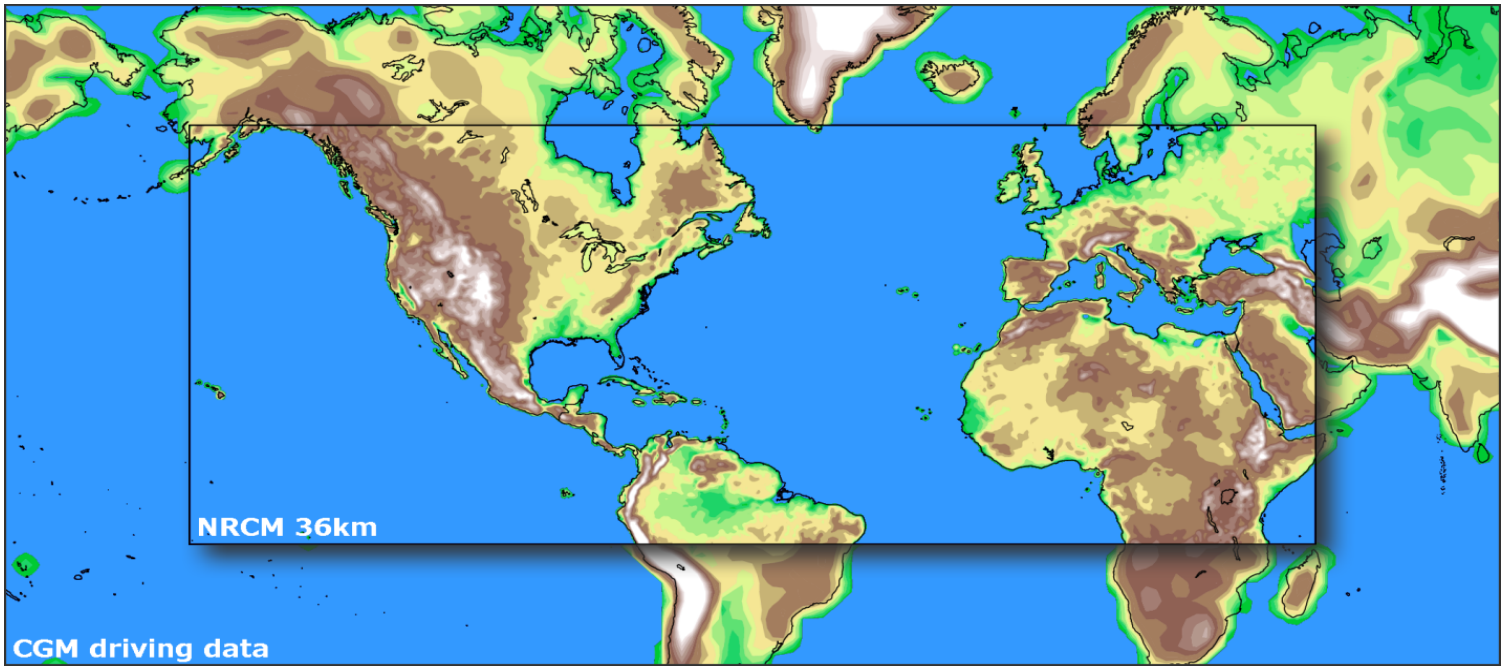
Uncertainty and Resolution



- Uncertainty due to missed processes: spiral rainbands, formation mechanism, strength of ocean coupling, upscale impacts.
- May impact future changes.

Uncertainty and Domain Size



- Uncertainty due to missed regional climate processes.

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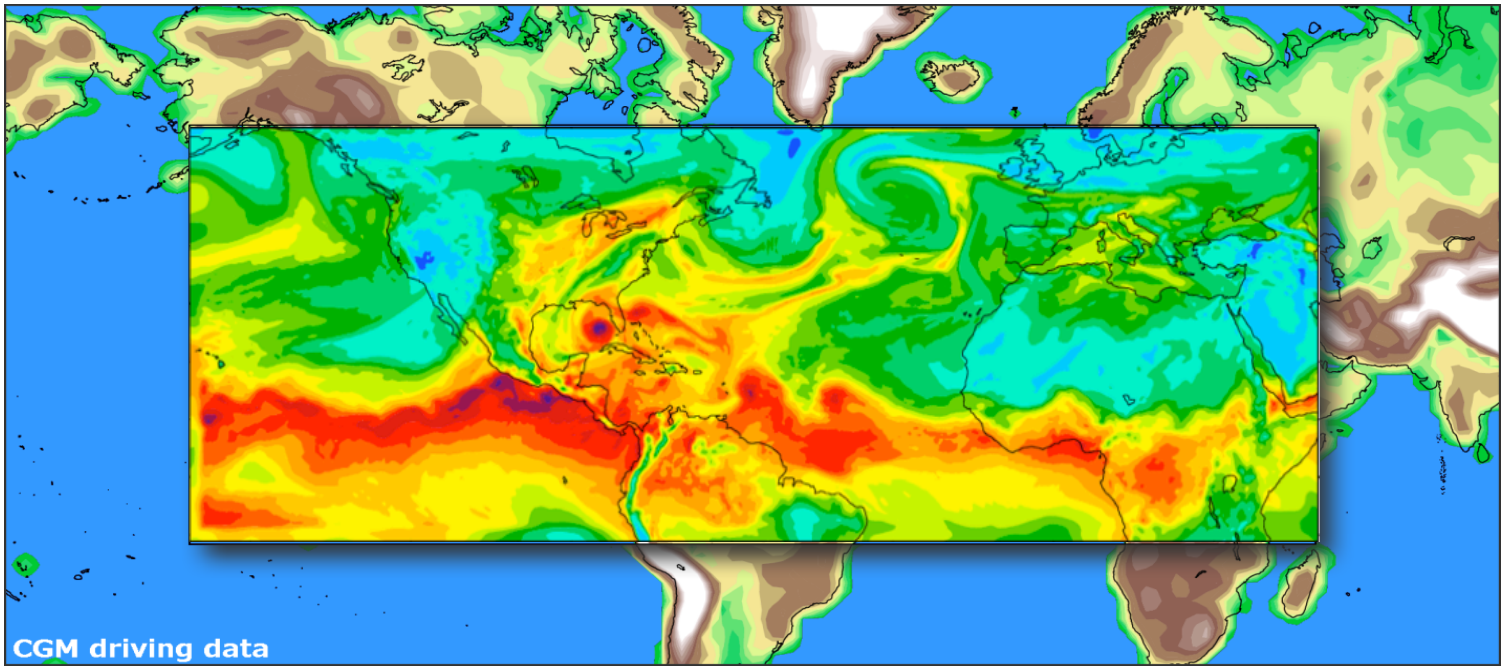

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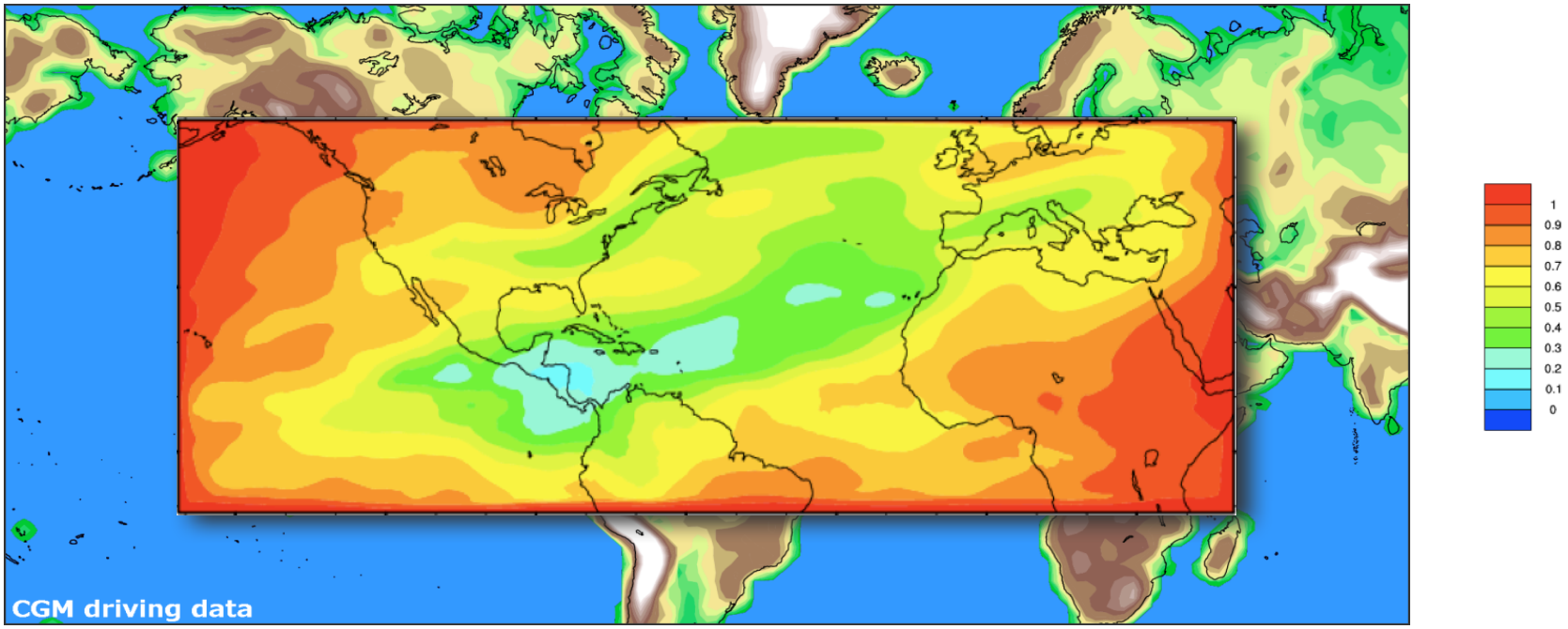
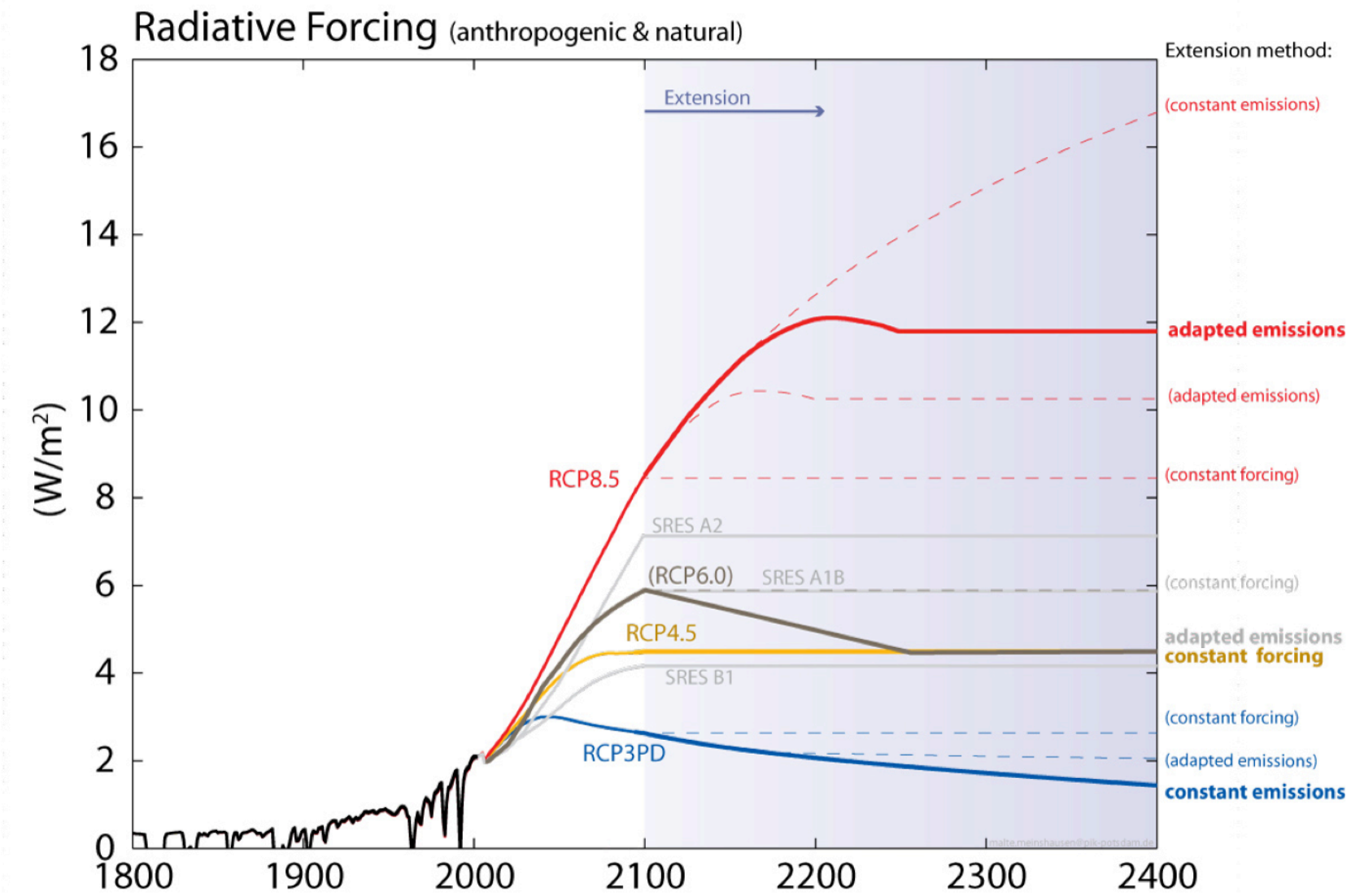
Uncertainty and Domain Size



- Large domain allows large departure from driving data and large ensemble spread.

Boundary Condition Uncertainty



Boundary Condition Uncertainty

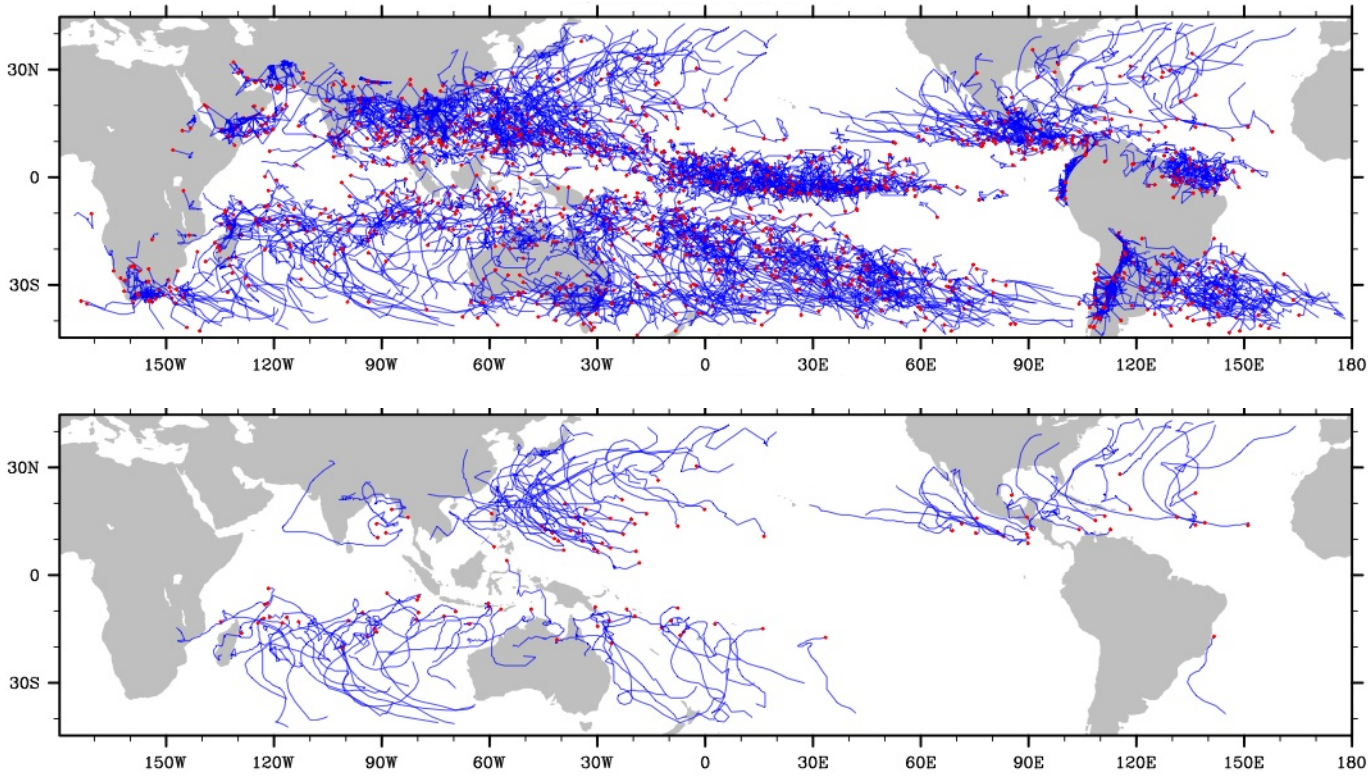
Climate Response:

- Which global climate model?
- Which ensemble member?

- Downscaling assumption: no remote small-scale process acts upscale to impact region of interest.

- How to handle non-stationary climate bias?

Analysis Uncertainty



Relaxed Tracking Criteria
1468 tracks/yr

Strict Tracking Criteria
106 tracks/yr

- Number of cyclones is highly sensitive to tracking criteria.

Asuka Suzuki-Parker

Computational Limitations

Challenge: Assess uncertainty with finite computational capacity.

A balance between competing multiplicative demands:

$$C \sim L^2 * N_V * T * N_e / (Dx^3 * Dz)$$

- **Domain size**
- **Complexity**
- **Length of integration**
- **Ensemble size**
- **Resolution (incl. time step)**

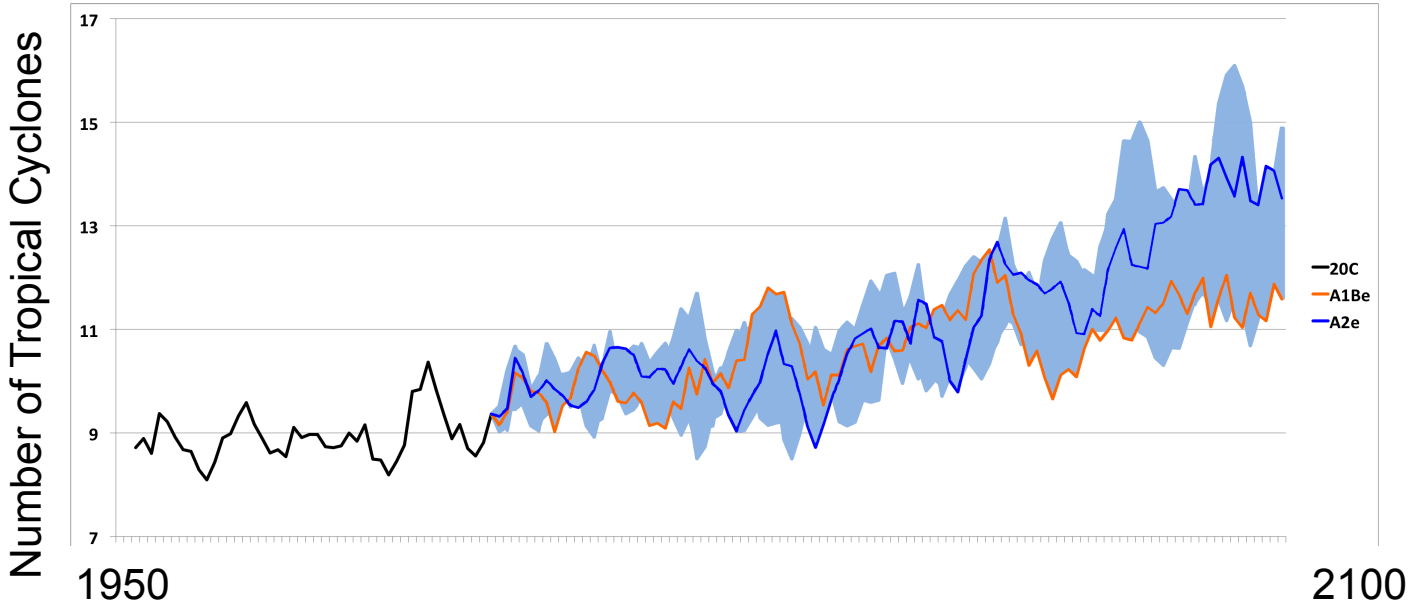
One Approach: Expand the dimensions through statistical means.

Example: Tropical Cyclone Numbers

Example: Assess spread in predicted Atlantic tropical cyclone numbers using an empirical/statistical downscaling approach.

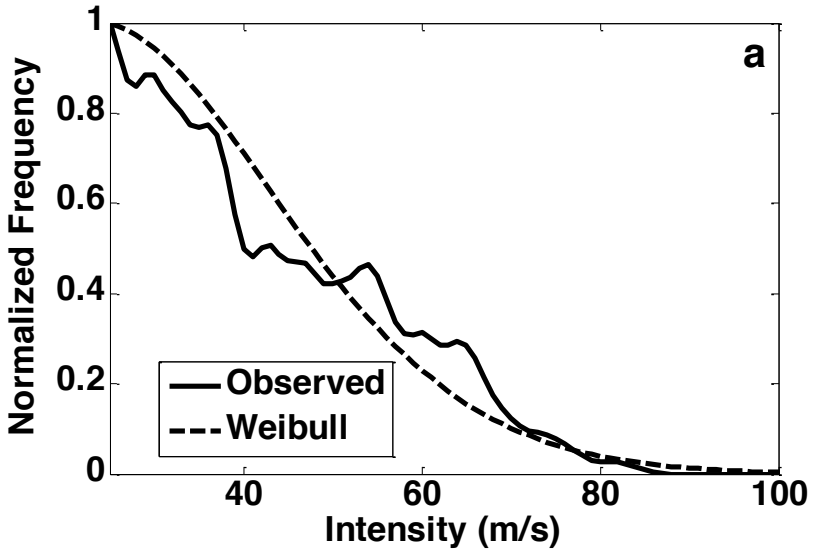
Cyclone Genesis Index:

$$CGI = \left(\frac{V_{pot}}{70} \right)^3 \left(1 + 0.1 V_{shear} \right)^{-2}$$

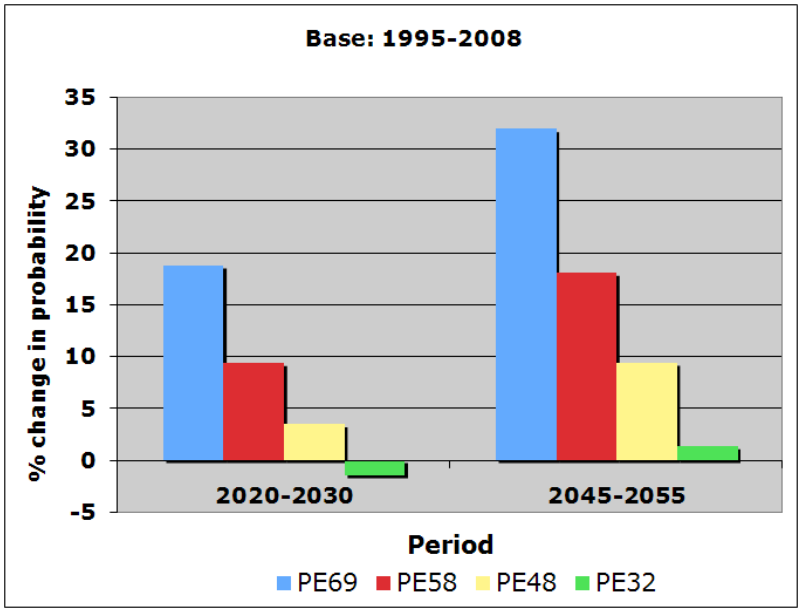


Example: Tropical Cyclone Intensity

Approach: Assess future changes in intense hurricanes by fitting an extreme value distribution to the observations . . . . .



. . . . and applying modeled future change to the fitted distribution.



PE69=Cat5, PE58=Cat4-5,
PE48=Major Hurricanes, PE32=Hurricanes

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Done, J.M., G.J. Holland, C.L. Bruyere (more) , 2012: Modeling high-impact weather and climate: Lessons from a tropical cyclone perspective. NCAR Technical Note NCAR/TN-490+STR. http://nldr.library.ucar.edu/repository/collections/TECH-NOTE-000-000-000-854