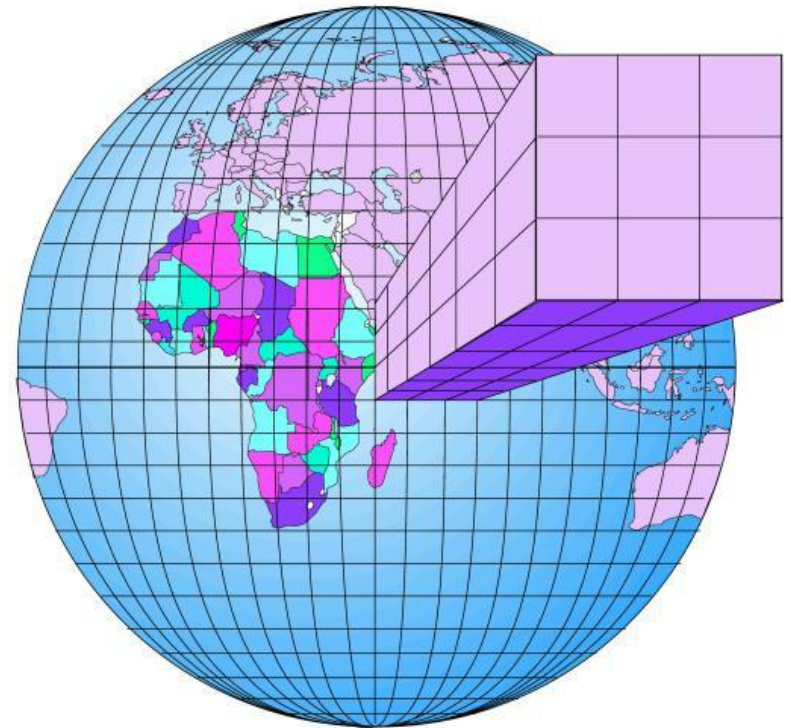
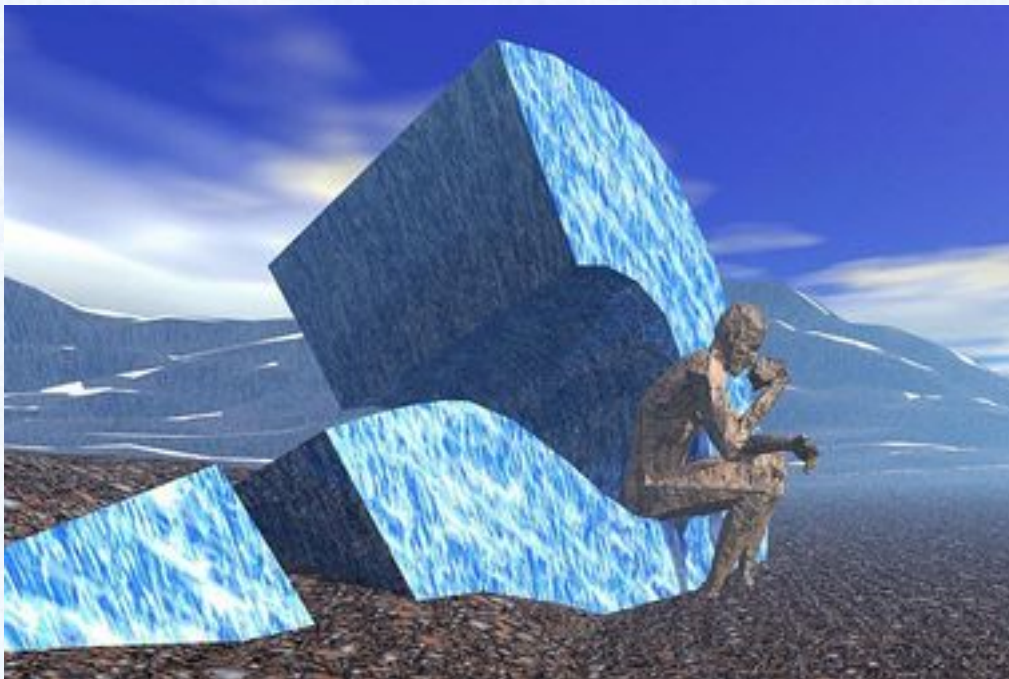


Climate models: Fit for what purpose?

Judith Curry

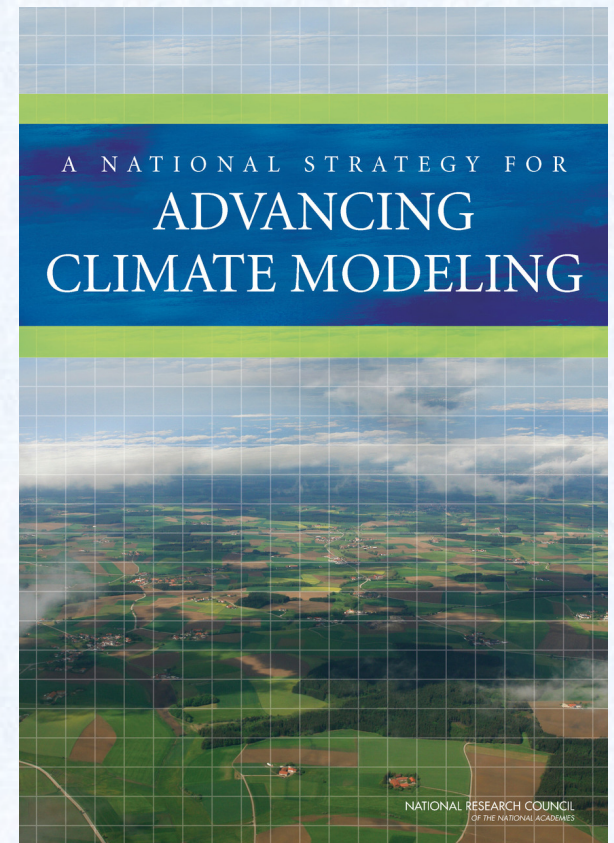


Current path for advancing climate modeling

Priority should be given to climate modeling activities that intersect the space where:

- (i) addressing societal needs requires guidance from climate models
- (ii) progress is likely, given adequate resources.

This does not preclude climate modeling activity focused on basic research questions or “hard problems,” but is intended to allocate efforts strategically.



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Confidence in climate models

Basis for confidence:

- Theoretical physical basis of the models
- Ability to reproduce observed mean state and some variability
- Successes of numerical weather prediction

Basis for model developer 'comfort':

- history of model development
- reputations of the modeling groups and individuals
- consistency among model simulations

Knutti (2007) "So the best we can hope for is to demonstrate that the model does not violate our theoretical understanding of the system and that it is consistent with the available data within the observational uncertainty."



Rising discomfort with climate models

- Prediction capability can't be evaluated for decades-century
- Circularity in arguments validating climate models against observations, owing to tuning & prescribed boundary conditions
- Impenetrability of the model and formulation process; extremely large number of modeler degrees of freedom
- Insufficient exploration of model & simulation uncertainty
- Lack of formal model verification & validation, which is the norm for engineering and regulatory science
- Concerns about fundamental lack of predictability in complex nonlinear system
- Concerns about epistemology of models of open, complex systems



Model credibility and fitness for purpose

Credibility: linked to the model and simulations themselves (expertise and trust)

Fitness for Purpose: suitability and confidence with regards to the (potentially) many uses of the model and simulations.

The user will treat simulation results as 'fit' when there is enough evidence that it fulfills its intended purpose, so that useful decisions can be made about the system of interest.



Climate models: fit for decision support?

CO2 mitigation policies:

- GCMs have a role to play, but large ensembles from lower order models with interactive carbon cycle may be the better solution for determining sensitivity

Regional climate change:

- Little to no skill here; increased resolution not helping
- Dynamical & statistical downscaling adds little value, beyond accounting for local effects on surface variables
- Many extreme weather events not explicitly simulated
- Depends on poorly simulated modes of natural internal variability



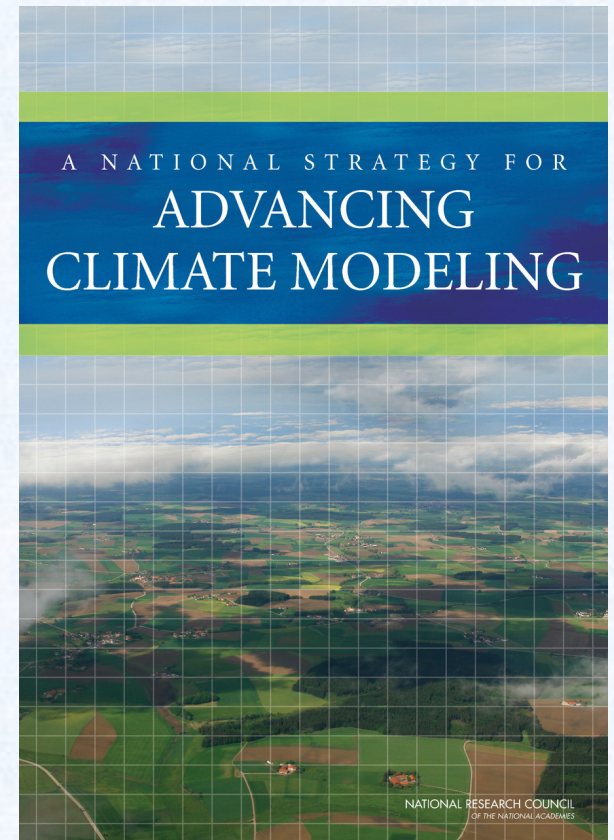
Current path for advancing climate modeling

Model improvements:

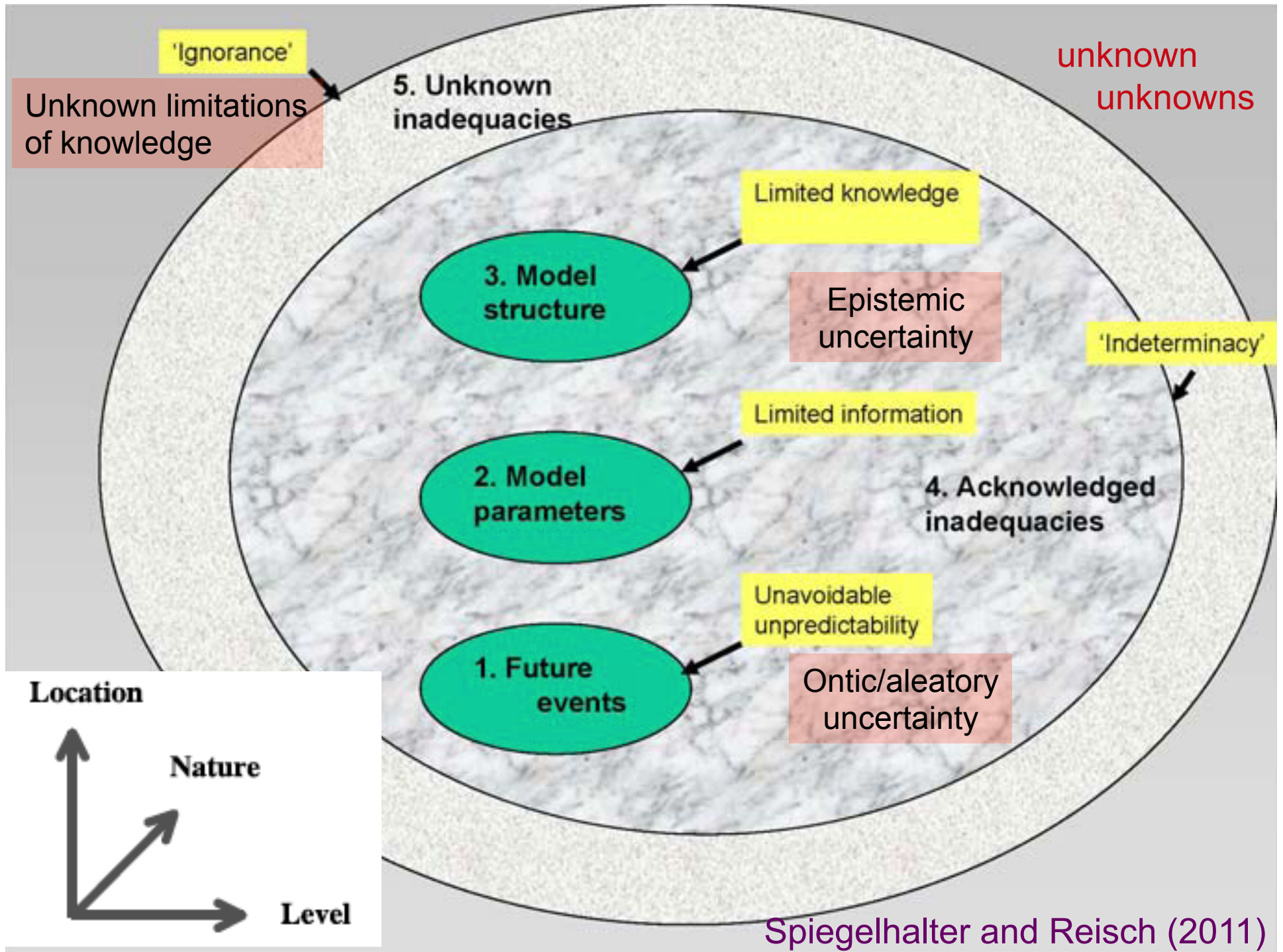
- (i) increasing model complexity
- (ii) improved physics, parameterizations, and computational strategies, increased model resolution, and better observational constraints
- (iii) improved co-ordination and coupling of models at global and regional scales

Uncertainty strategy focuses on:

- Model weighting in multi-model ensembles
- Parameter optimization
- Reducing uncertainty
- Communicating uncertainty



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Are GCMs especially policy useful?

Main advantage:

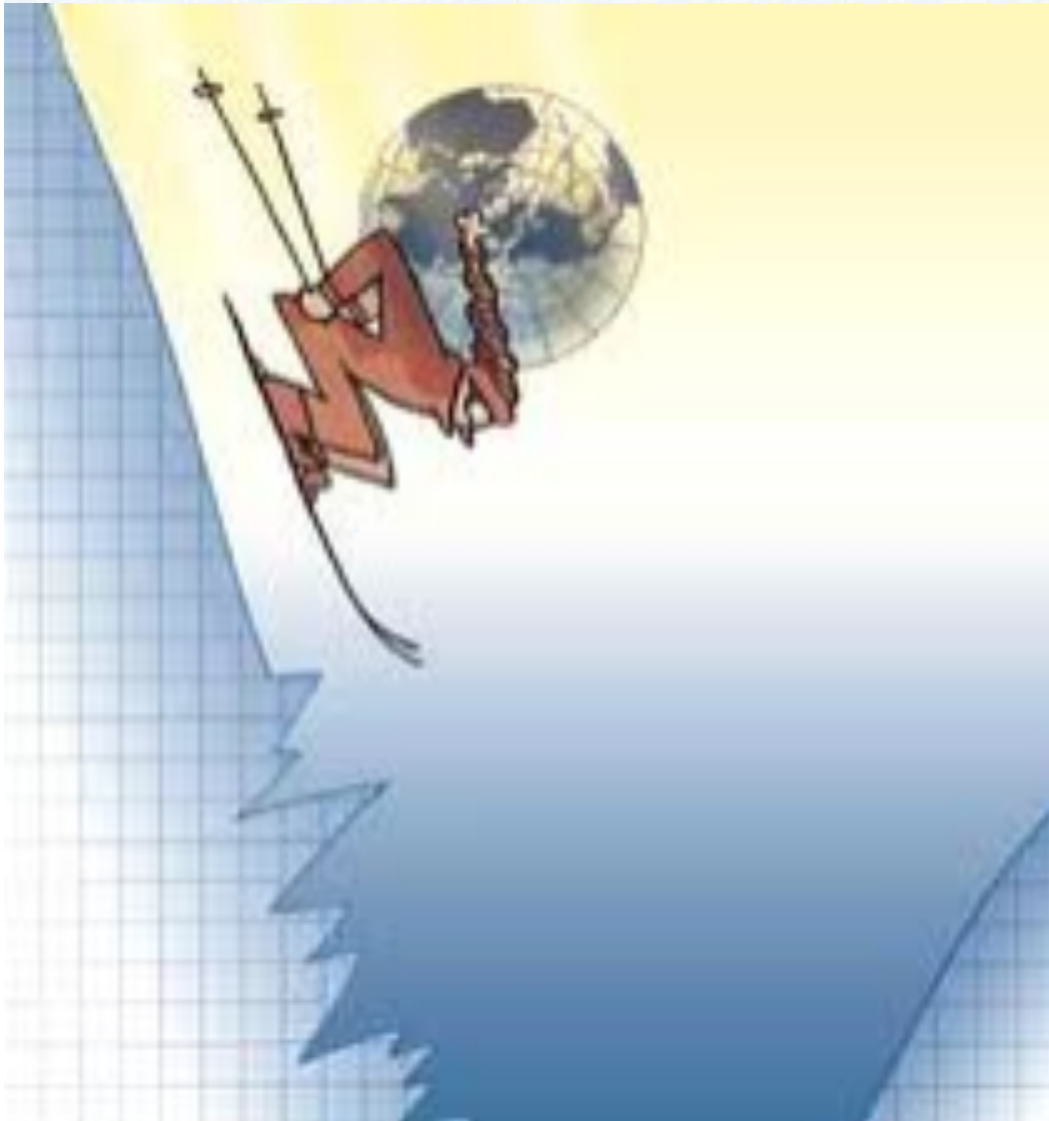
- (unrealized) *potential* to provide regional climate change scenarios
- perception that complexity = scientific credibility

Disadvantages:

- demands massive computing and personnel resources
- slow to incorporate new scientific insights or understanding
- precludes conducting extensive sensitivity and uncertainty analyses
- precludes rapid exploration of different model assumptions and policy scenarios
- not user friendly for advisory scientists or policy makers



Decision making under uncertainty



The decision-analytic framework influences how climate models are used and developed.

The current focus on the precautionary principle and optimal decision making is driving climate model development & applications in directions for which they are not fit.

Optimal decision making: linear model

more research → less uncertainty →
political consensus → meaningful action

Classical decision analysis can suggest statistically optimal strategies for decision makers when:

- uncertainty is well characterized
- model structure is well known



Key climate policy dilemma

Whether betting big today with a comprehensive global climate policy targeted at stabilization will:

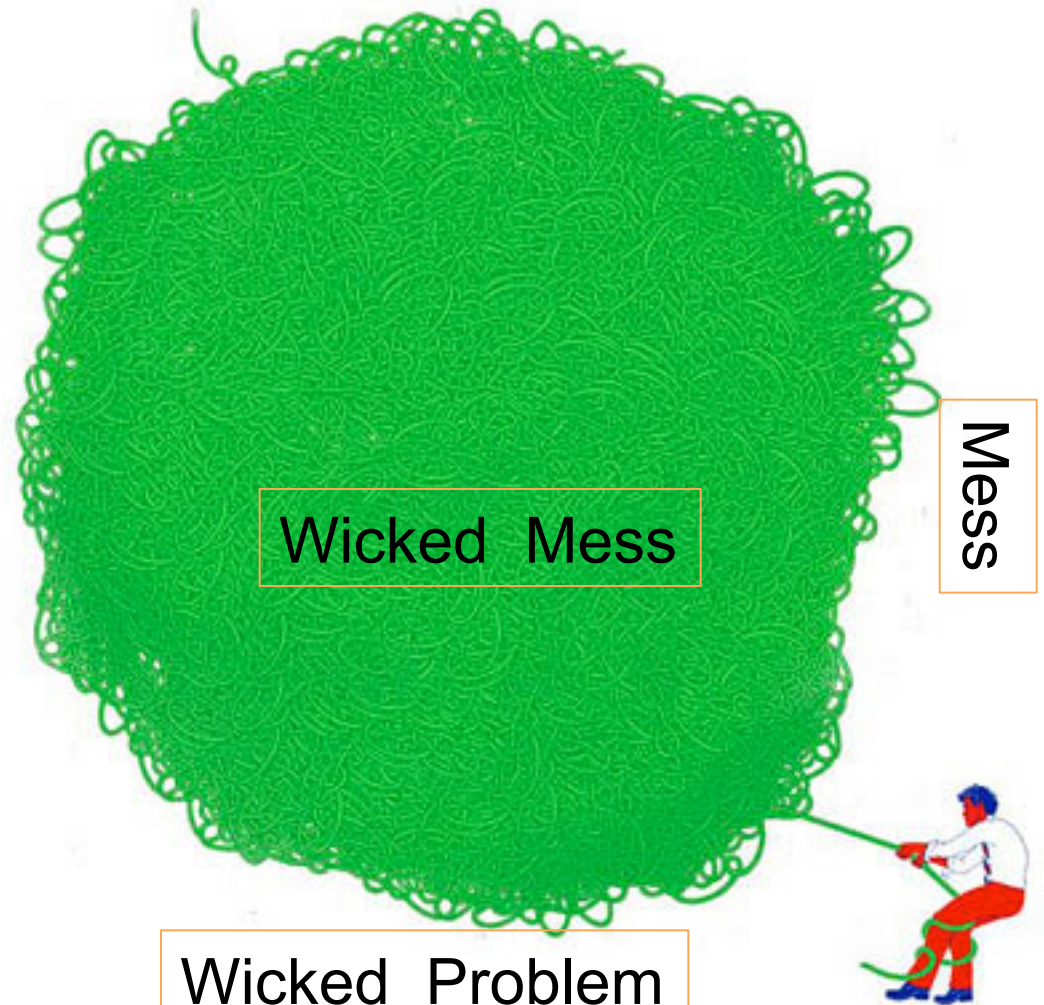
- fundamentally reshape our common future on a global scale to our advantage
- OR -
- quickly produce losses that throw mankind into economic, social, & environmental bankruptcy



Tame Problem



versus



Mess

Wicked Mess

Wicked Problem

Decision making under deep uncertainty

Bammer & Smithson 2008

Deep uncertainty is characterized by situations in which:

- phenomena are characterized by high levels of ignorance and are poorly understood scientifically
- modelling and subjective judgments must substitute extensively for estimates based upon experience with actual events and outcomes
- ethical rules must be formulated to substitute for risk-based decisions.

Understanding uncertainty and areas of ignorance is critical information for the decision making process



Options for decision makers confronted with deep uncertainty:



"OK, all those in favour of delegating decision-making, shrug your shoulders"

- Wait and see
- **Delay, gather more info**
- **Target critical uncertainties**
- Enlarge the knowledge base for decisions
- **Precautionary principle**
- Adaptive management
- Build a resilient society

Robust decision making

Robustness is a strategy that seeks to reduce the **range of possible scenarios** over which the strategy performs poorly:

- uses available information to distinguish reasonable from unreasonable choices
- is flexible and can be adjusted quickly to new information
- considers unlikely but not impossible **scenarios** without letting them dominate the decision



Scenario Thinking – Robust Decisions

- Scenarios are provocative and plausible accounts of how the future might unfold.
- The purpose is not to identify the most likely future, but to create a map of uncertainty of the forces driving us toward the unknown future.
- Scenarios help decision makers order and frame their thinking about the long-term while providing them with the tools and confidence to take action in the short-term

climate change • extreme weather events

population increase • land use changes

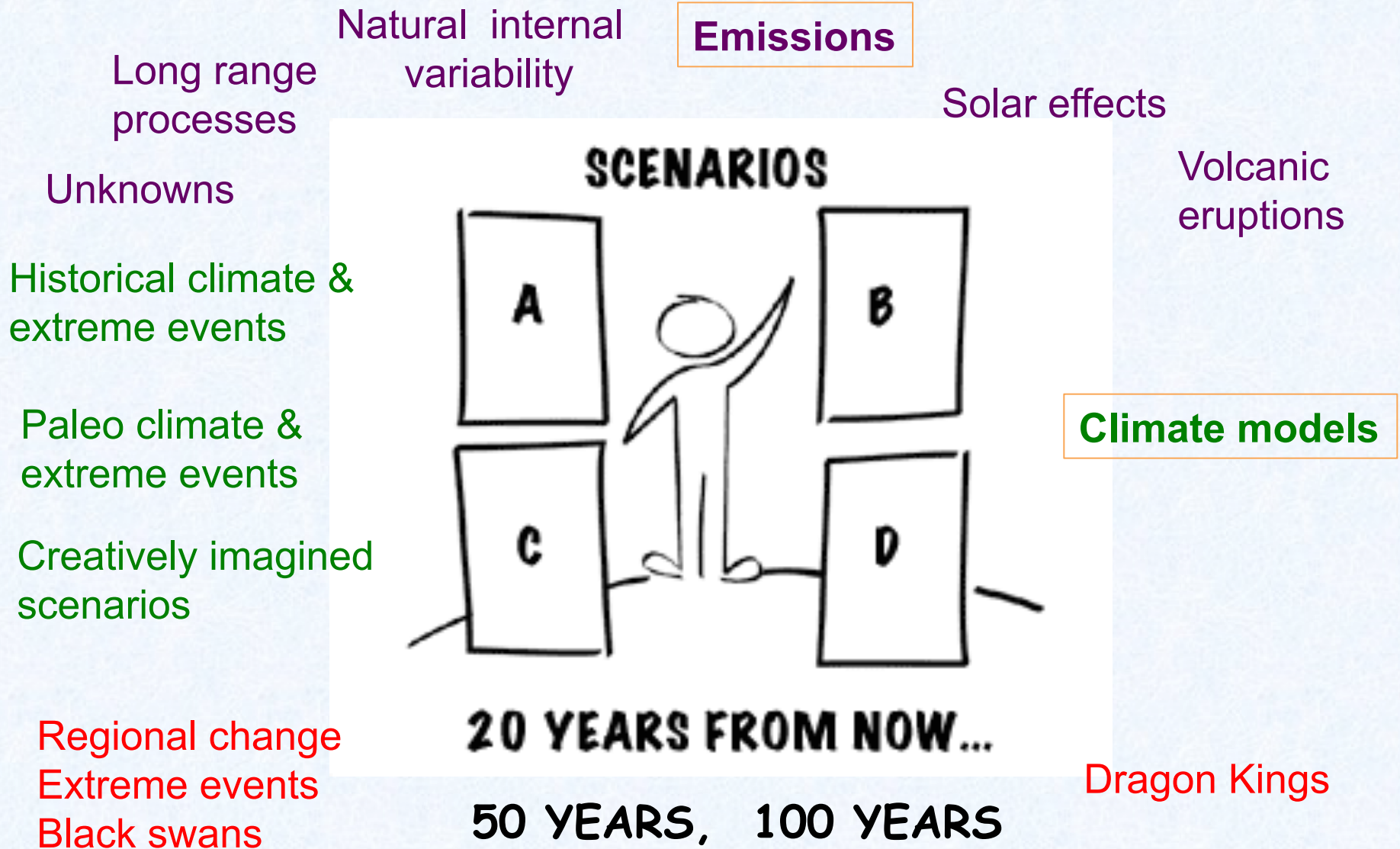
technology • economics



alternative policy options



Scenarios of future climate



Decision makers: “Tell us what you DON’T know”



**Black
swan**

- 2004/2005 U.S. hurricane landfalls
- Heavy snowfall + cold last winter
- Russian heatwave/Pakistan flood



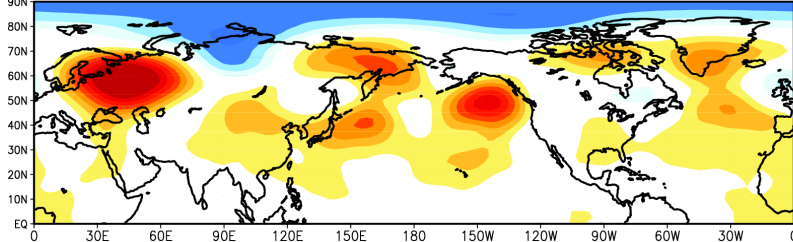
**Dragon
King**

- “Tipping points”
- Abrupt climate change

Outlook for the Russian Heat Wave

Observations

NCEP 500GPH [m] Jul10–Aug10 2100

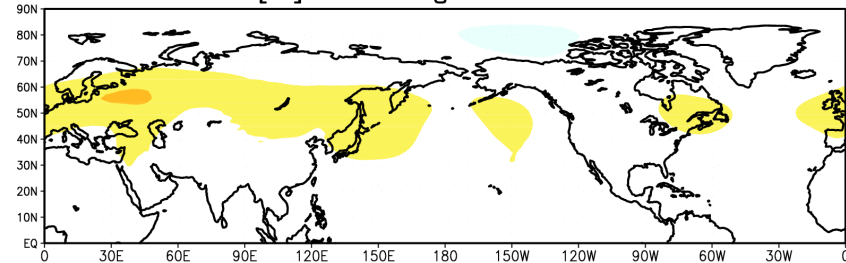


➤ Sub-Seasonal Time Scale (Days 10-40):

- ✓ CFAN's clustering of ensembles based on the best match to hemispheric 500 hPa pattern for first two weeks of the forecast captures well the geopotential anomalies pattern up to 40 days in advance.
- ✓ The 500 hPa geopotential height represents the signature of the blocking pattern associated with the Russian heat wave.

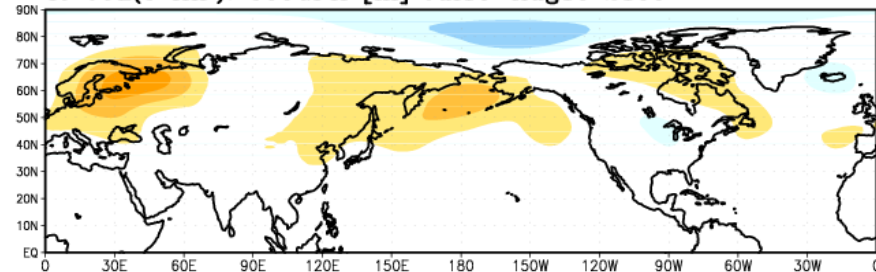
Ensemble Mean

IC JUL: 500GPH [m] Jul10–Aug10 2100



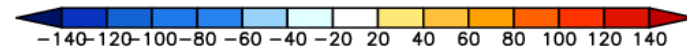
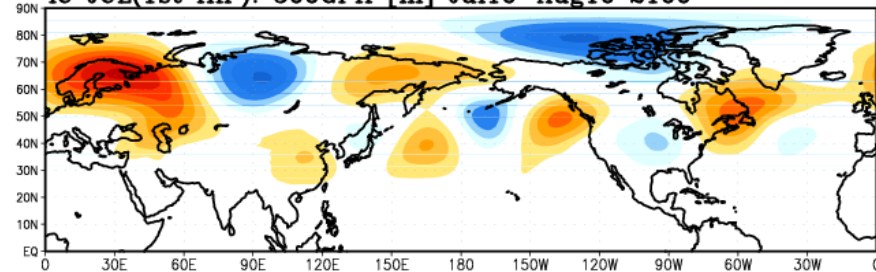
Clustering: Top 5 Verifying July 1-14

IC JUL(5 HIP): 500GPH [m] Jul10–Aug10 2100



Clustering: Top 1 Verifying Jul 1-14

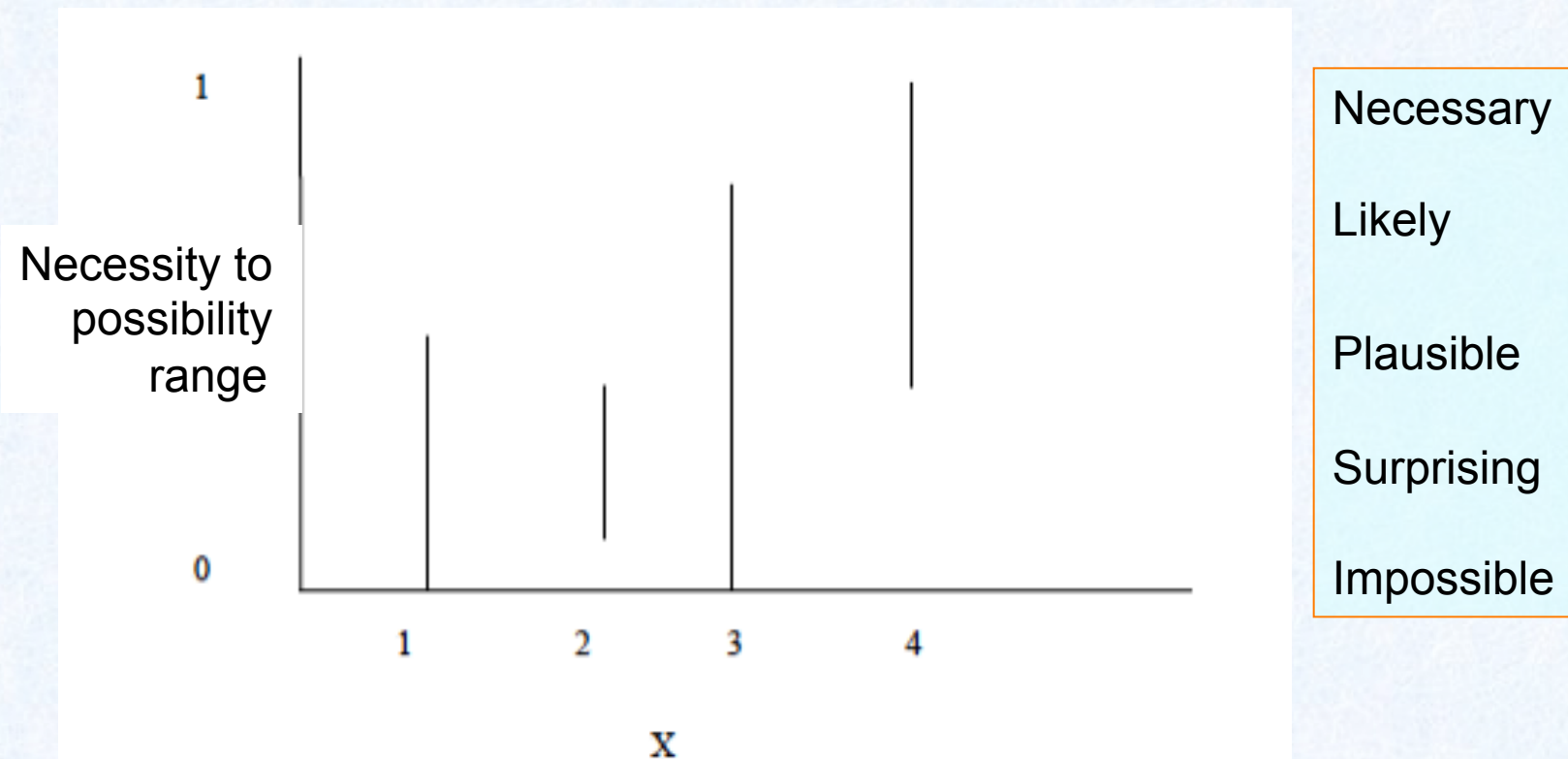
IC JUL(1st HIP): 500GPH [m] Jul10–Aug10 2100



Possibility distribution

Possibility theory is an imprecise probability theory.

A *possibility distribution* distinguishes what is plausible versus the normal course of things versus surprising versus impossible.



Summary

The objective of improving climate models for societal needs is based upon three dubious premises:

- climate models are **fit** for this purpose
- climate models are **useful** for this purpose
- climate models are the **best choice** for this purpose

GCMs are currently incapable of simulating:

- Regional climate variability and change
- Network of teleconnection climate regimes on DEC-CEN timescales
- Predictions of emergent phenomena, e.g. abrupt climate change

It is unlikely that the current path of development will improve this

Fundamental issues for climate models: with the focus on societal needs and the large investment in IPCC production runs, climate models are becoming less fit for the purpose of increasing our understanding of the climate system

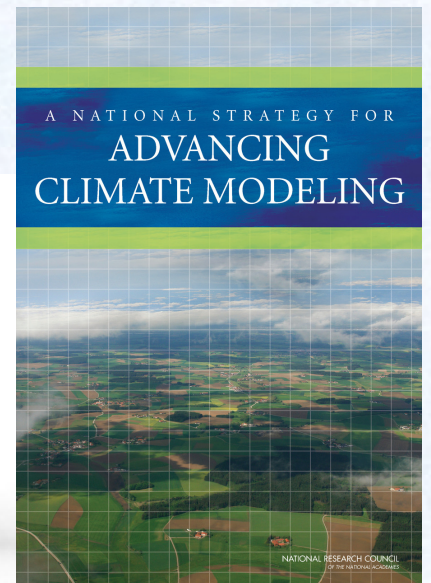
Recommendations

Re-orient the science-policy interface to decision making under deep uncertainty, robust decision making and scenario thinking

Re-orient climate modeling development and applications to support the creation of a broad range of future scenarios

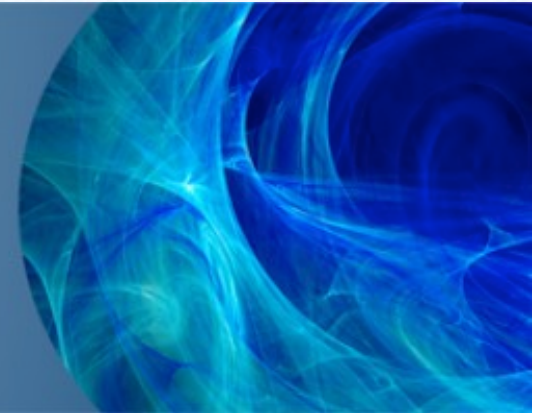
- refocus climate model development to emergent phenomena, extreme events, and natural internal variability
- emphasis on ensemble size

More complete exploration of climate model uncertainty, including unknowns and model structural uncertainty



<http://judithcurry.com>

Climate Etc.



‘uncertainty monster’ at the
science-policy interface

