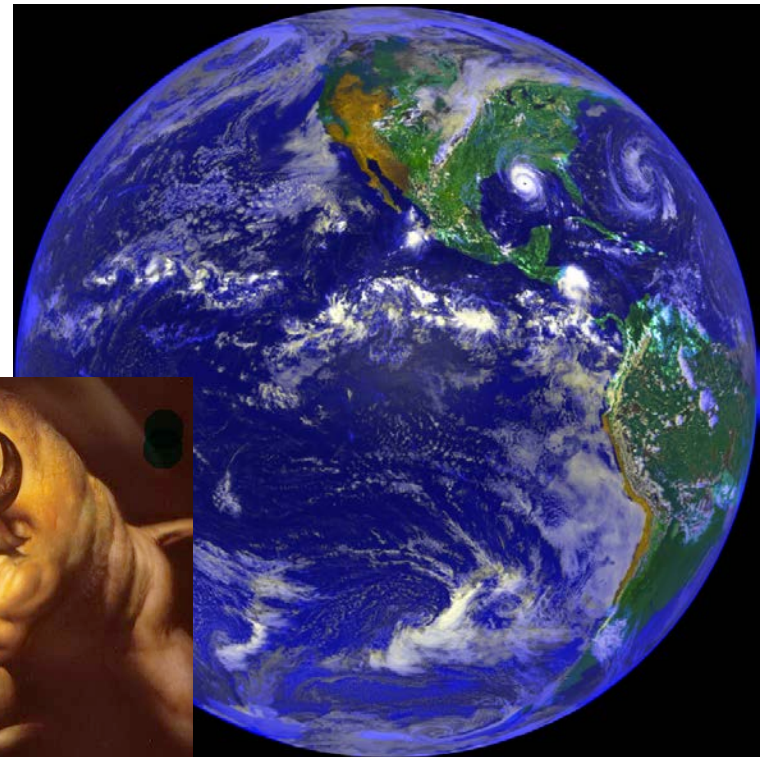


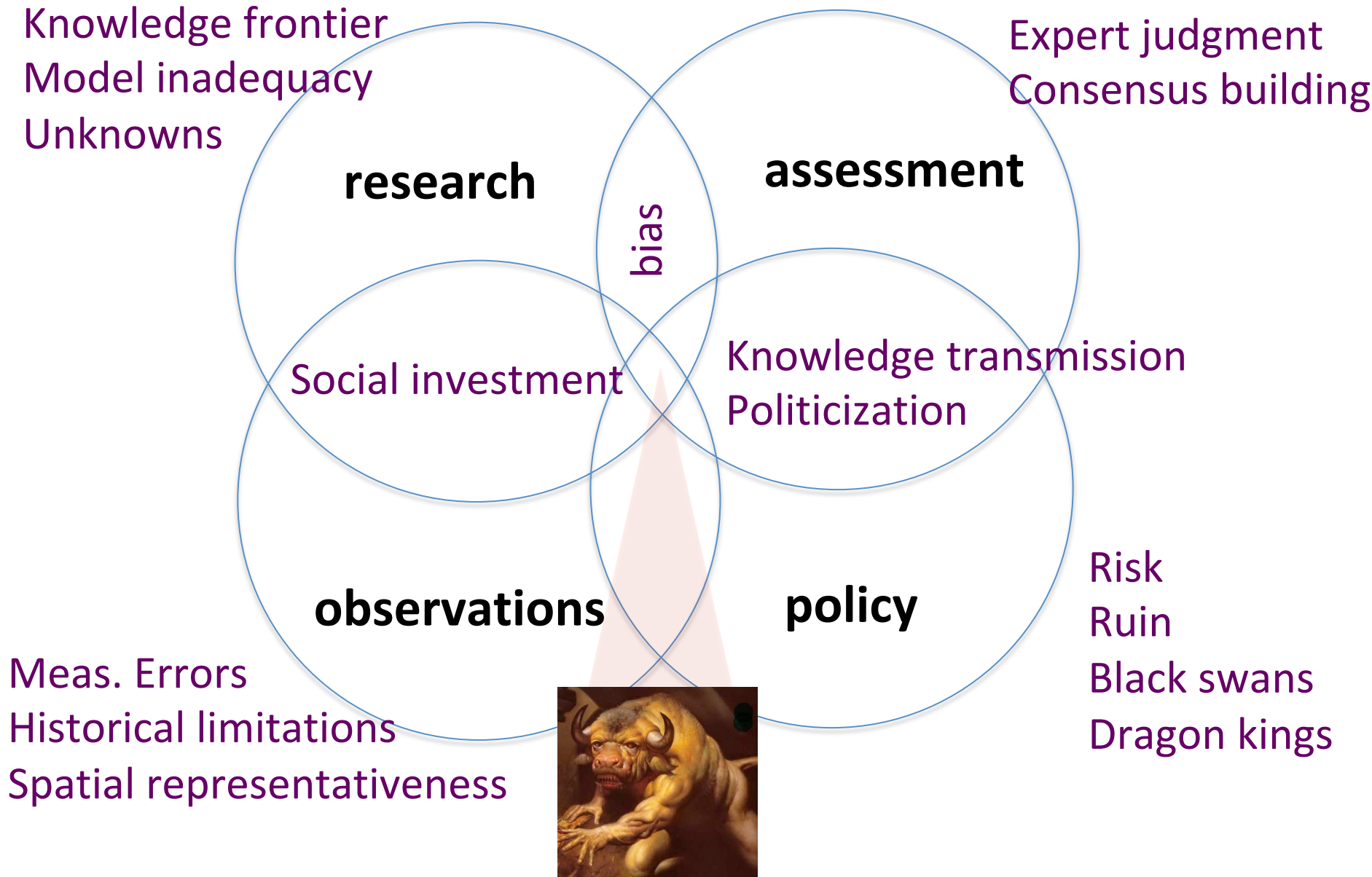
Climate Change & the Uncertainty Monster

Judith Curry

Climate Forecast Applications Network



Uncertainty and the science – policy interface



Uncertainty Monster

The “monster” is a metaphor used in analysis of the response of the scientific community to uncertainties at the science-policy interface.

Confusion and ambiguity associated with:

- knowledge versus ignorance
- objectivity versus subjectivity
- facts versus values
- prediction versus speculation
- science versus policy



Genealogy of the Uncertainty Monster

Monster theory: monster as symbolic expressions of cultural unease that pervade a society and shape its collective behavior

Monster metaphor of Dutch philosopher Martintje Smits: co-existence of public fascination and discomfort with new technologies

Uncertainty monster of Dutch social scientist Jeroen van der Sluijs: ways in which the scientific community responds to the monstrous uncertainties associated with environmental problems



Uncertainty monster coping strategies

Monster hiding. Never admit error strategy motivated by a political agenda or fear of being judged as poor science.

Monster exorcism. Reducing uncertainty through more research.

Monster simplification. Subjectively quantifying and simplifying the assessment of uncertainty.

Monster detection. Scientists, auditors, merchants of doubt.

Monster assimilation. Giving uncertainty an explicit place in the contemplation and management of environmental risks.



Understanding the uncertainty monster

Reasoning about climate uncertainty.

Climatic Change (2011)

Climate science and the uncertainty monster.

Bull Amer Meteorol. Soc. (2011)

Nullifying the climate null hypothesis.

WIREs Climate Change (2011)

Climate change: No consensus on consensus.

CAB Reviews (2013)

Climate uncertainty and risk.

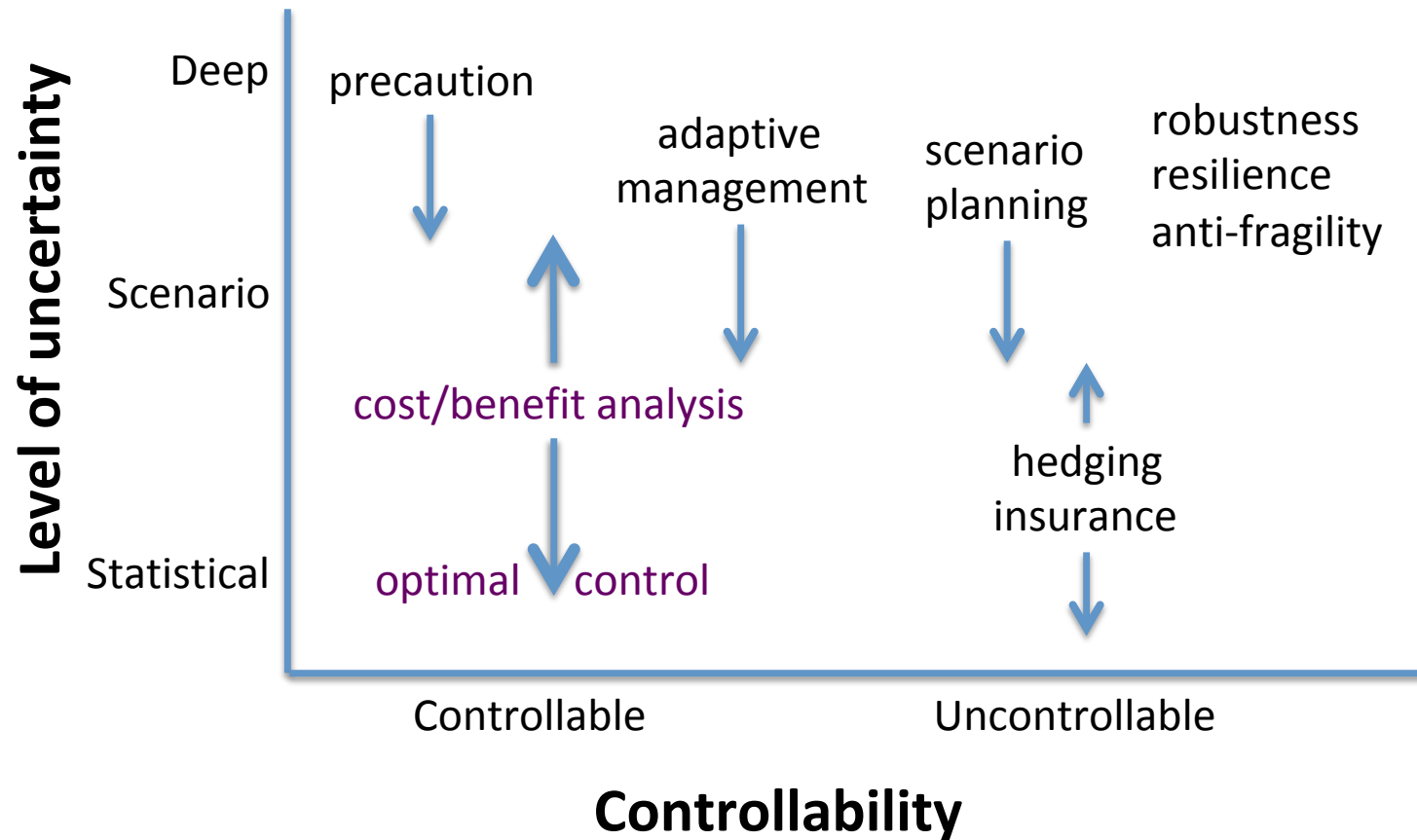
CLIVAR Variations. (2018)

Sea level rise: what's the worst case?

(in prep)



Decision – analytic frameworks



Should we have confidence in future projections from climate models?

The IPCC AR4 provided the following conclusion:

“There is **considerable confidence** that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above.”

Is this level of confidence in climate model projections justified?



Epistemic status of climate models

Climate model simulations represent possible climate futures

Climate models cannot falsify or verify possible climate futures

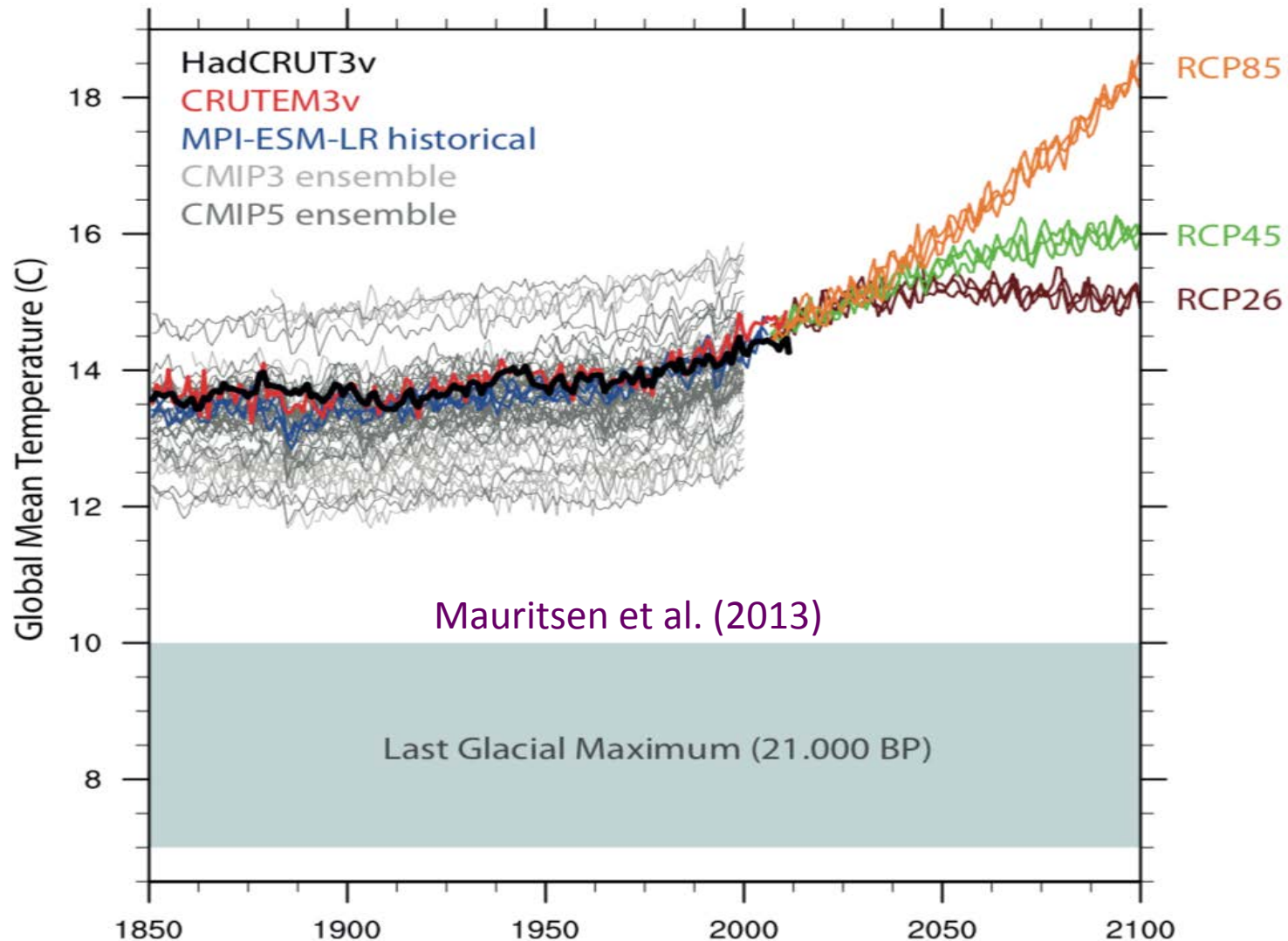
Are climate models consistent with background knowledge?

- Climate models make assumptions that we know to be false
- **Climate models have been known to produce realistic simulations of some variables**

Verified possibilities requires that climate models are imperfect credible worlds with regard to some of their projections



How much confidence should we have in climate models?



Scenarios of climate futures

Existing climate models do not allow exploration of all possibilities that are compatible with our knowledge of the basic way the climate system actually behaves.

Some of these unexplored possibilities may turn out to be real ones.

Scientific speculation on plausible, high-impact scenarios.

The **worst-case scenario** is the most extreme scenario that cannot be falsified as impossible based upon our background knowledge.



Quality of Evidence

Guyatt et al. 2008

High quality	Further research is very unlikely to change our confidence in the estimate of effect
Moderate quality	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
Low quality	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate
Very low quality	Any estimate of effect is very uncertain

Possibility verification

Gregor Betz

Strongly verified possibility – basic theoretical considerations, empirical evidence

Corroborated possibility - it has happened before

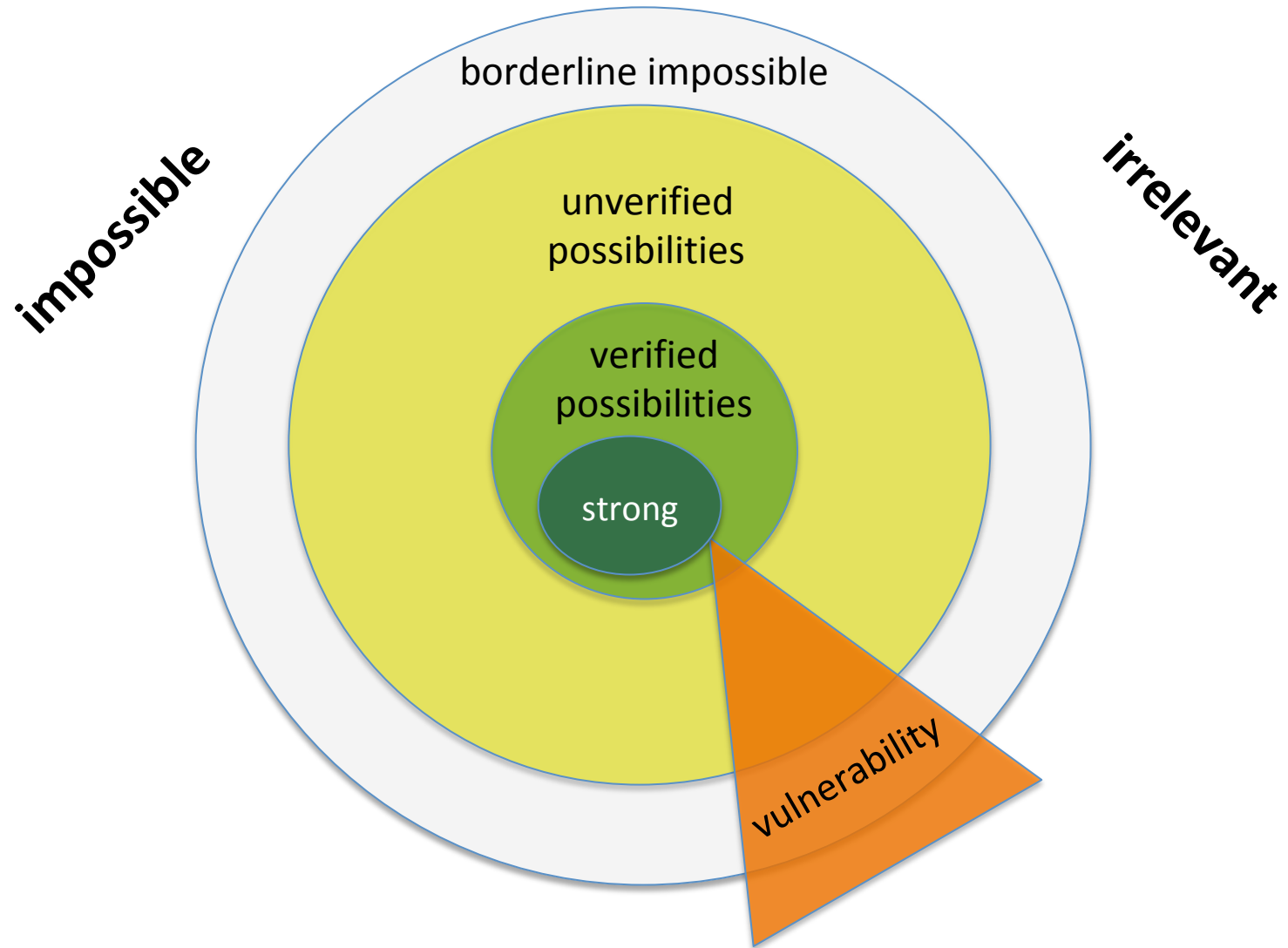
Verified possibility – consistent with relevant background knowledge

(Un)verified possibility - climate model simulation

Borderline impossible – consistency with background knowledge is disputed (**‘worst case’** territory)

Impossible – inconsistent with relevant background knowledge

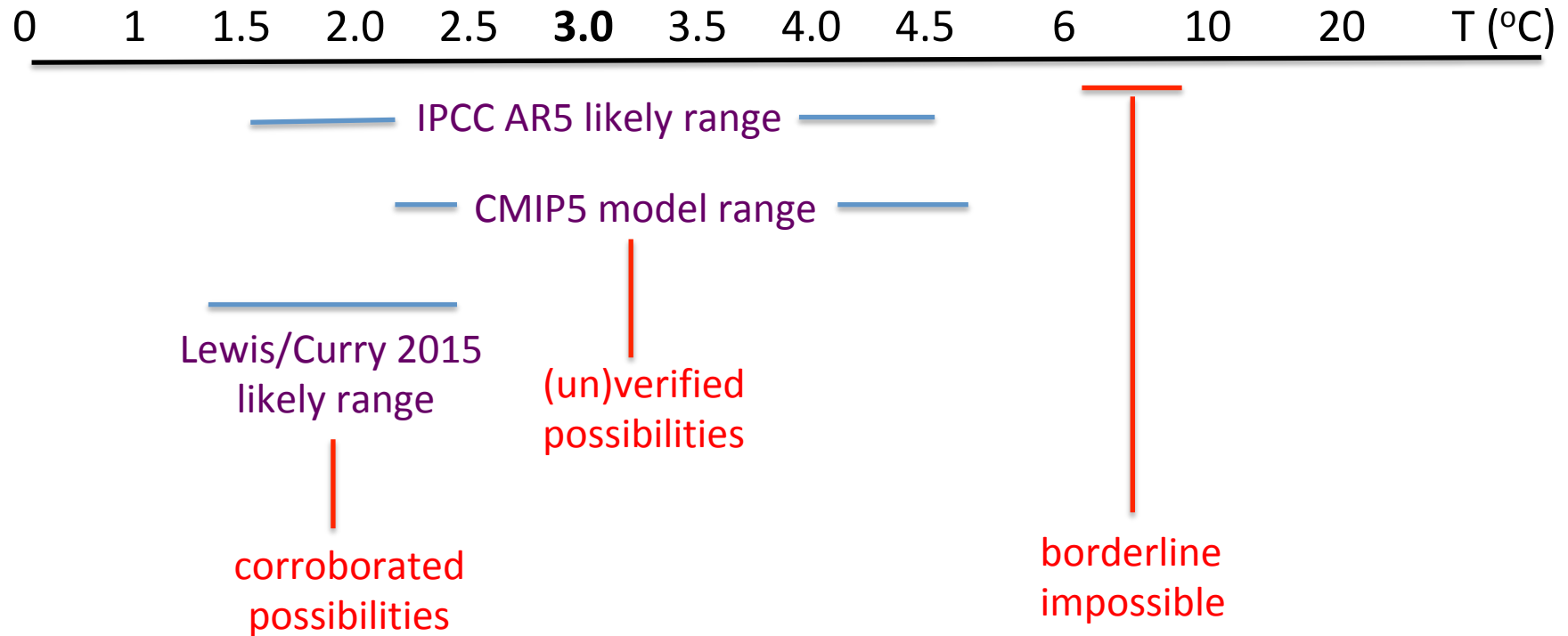
Classifying possibilities



All possibilities (with appropriate classification)
are useful for policy making

Equilibrium Climate Sensitivity to Doubled CO₂

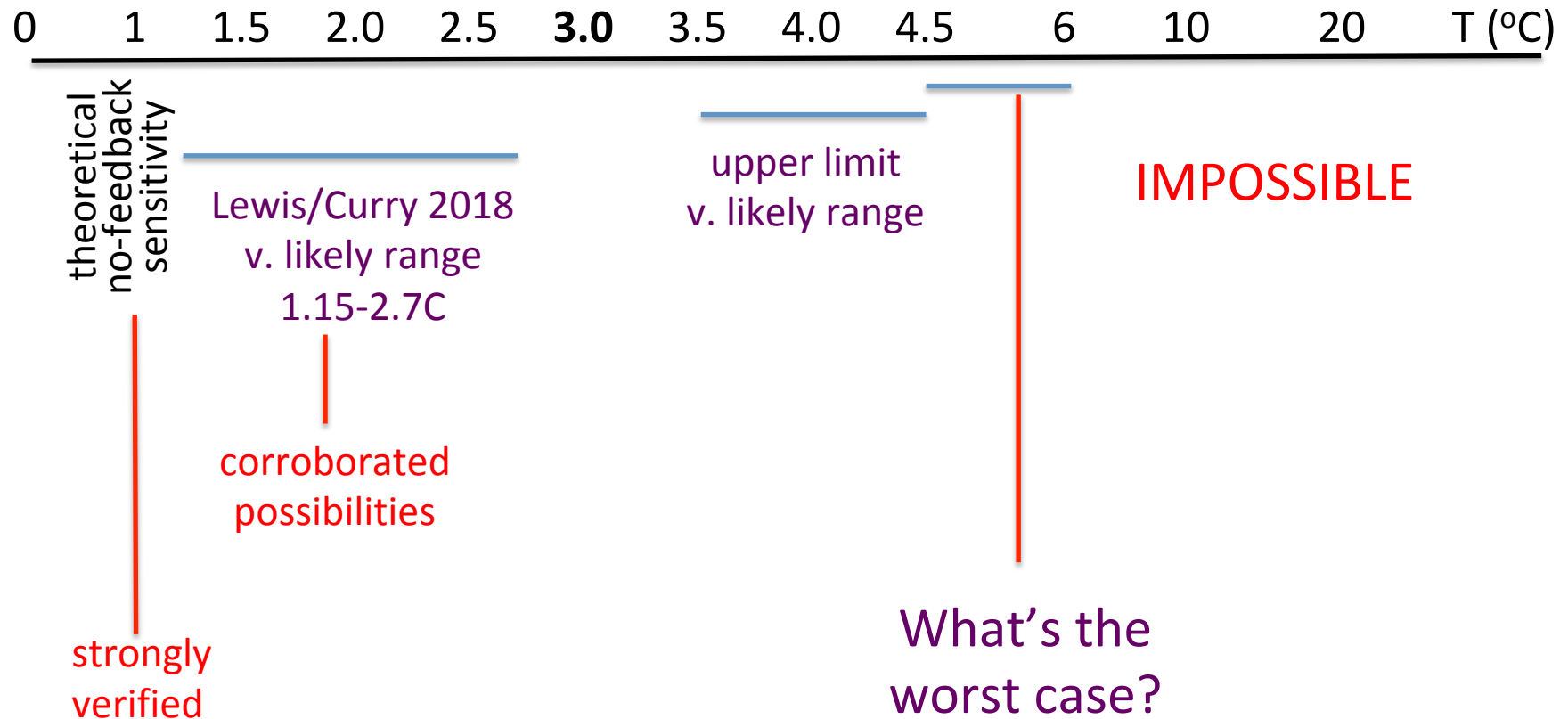
IPCC AR5 perspective



IPCC AR5 SPM: “No best estimate for equilibrium climate sensitivity can now be given because of a lack of agreement on values across assessed lines of evidence and studies.”

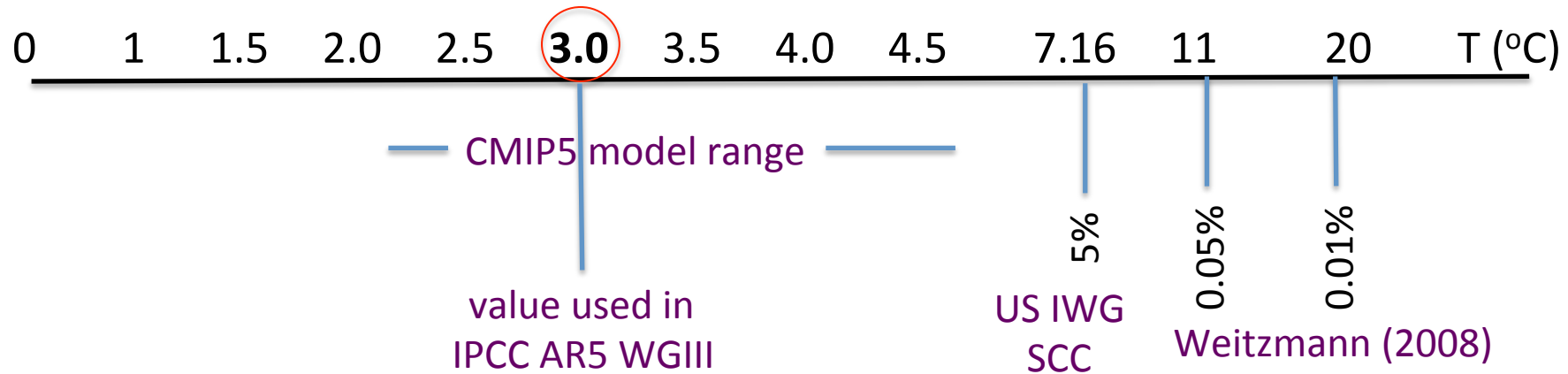
Equilibrium Climate Sensitivity to Doubled CO₂

JC's perspective



Equilibrium Climate Sensitivity to Doubled CO₂

Perspective from economists and the social cost of carbon



Social cost of carbon is driven by extreme values of climate sensitivity



Worst case scenario versus 'fat tail'

Uncertainty status of equilibrium climate sensitivity:

scenario/deep uncertainty; Level 4 uncertainty

→ **no basis for developing a PDF** (no mean, weakly defended upper bound)

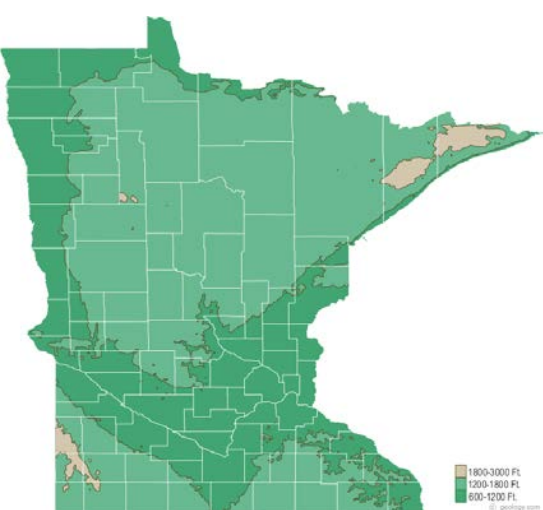
Statistically-manufactured 'fat tails,' with arguably impossible values of climate sensitivity, are driving calculations of the **social cost of carbon**

→ ***Monster creation***

The best that we can do is bound the range:
best case, worst case scenarios

lopping off
the 'fat tail'





On trial in MN: Social Cost of Carbon

A 1990s law requires the MN Public Utilities Commission (PUC) to establish externality values for CO₂ and other power plant pollutants to help guide utility planning decisions.

The PUC adopted the federal Social Cost of Carbon (SCC)

PUC/SCC was challenged by energy companies and industry groups in a recent trial

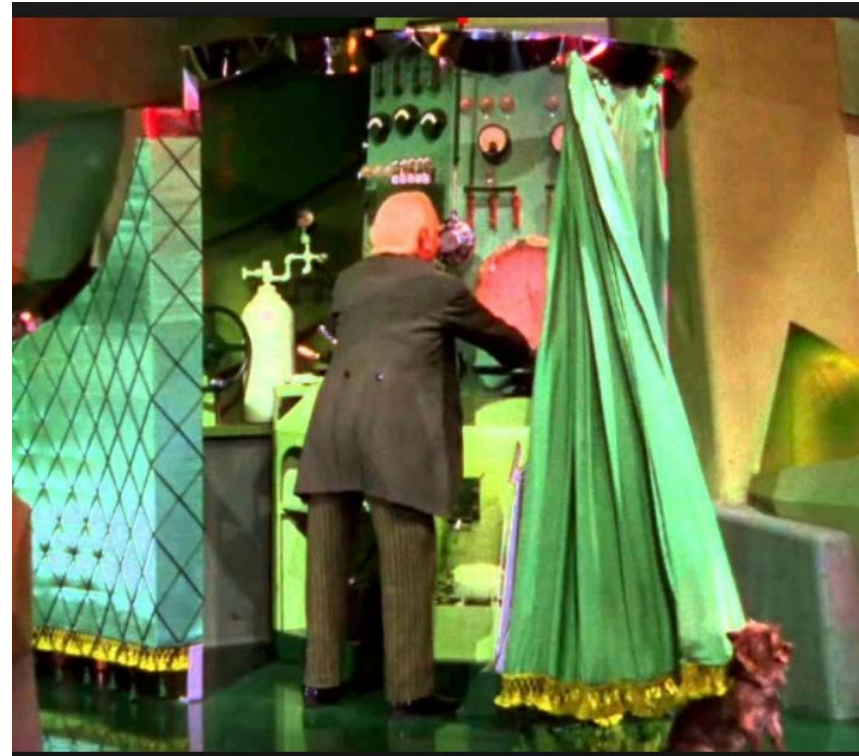
Pindyck: Use & Misuse of Models for Climate Policy

“Pay no attention to the man behind the curtain!” – Wizard of Oz

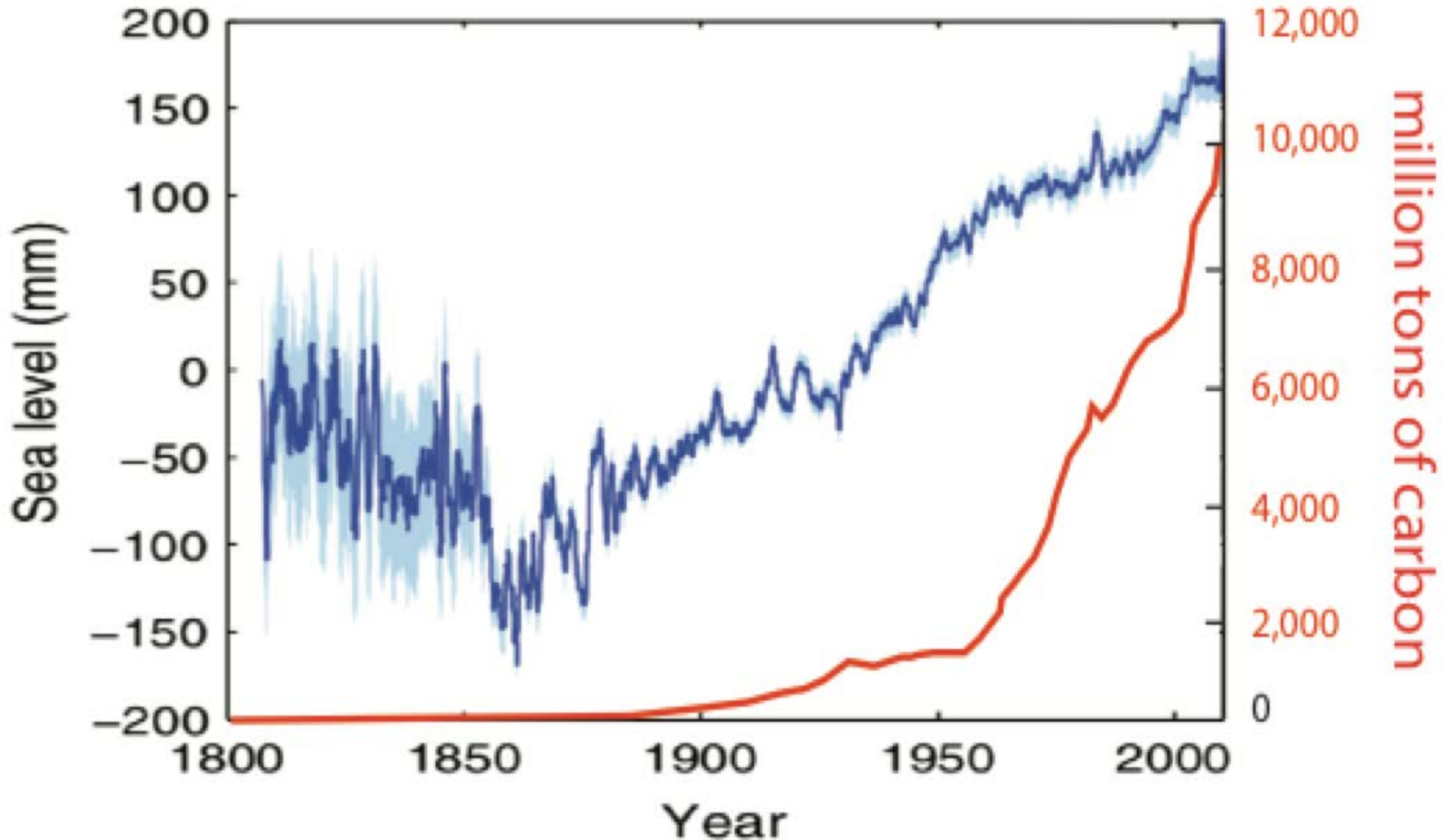
“Building and using elaborate models might allow us to think that we are approaching the climate policy problem more scientifically, but in the end, like the Wizard of Oz, we would only **be drawing a curtain around our lack of knowledge.**”

Instead:

- Focus on **catastrophic outcomes**
- Avoid the pretense that we know the damage function, climate sensitivity, etc.
- Use expert opinion to determine the inputs to a simple model



Is CO₂ the 'control knob' for sea level rise?



“In looking for causes, I have applied the ‘Sherlock Holmes procedure’ of eliminating one suspect after another. The procedure has left us without any good suspect. Thermal expansion was the candidate of choice at the time of the first IPCC review. *The computed steric rise [from warming] is too little, too late, and too linear.*” – Walter Munk

Predicting sea level rise: 2100

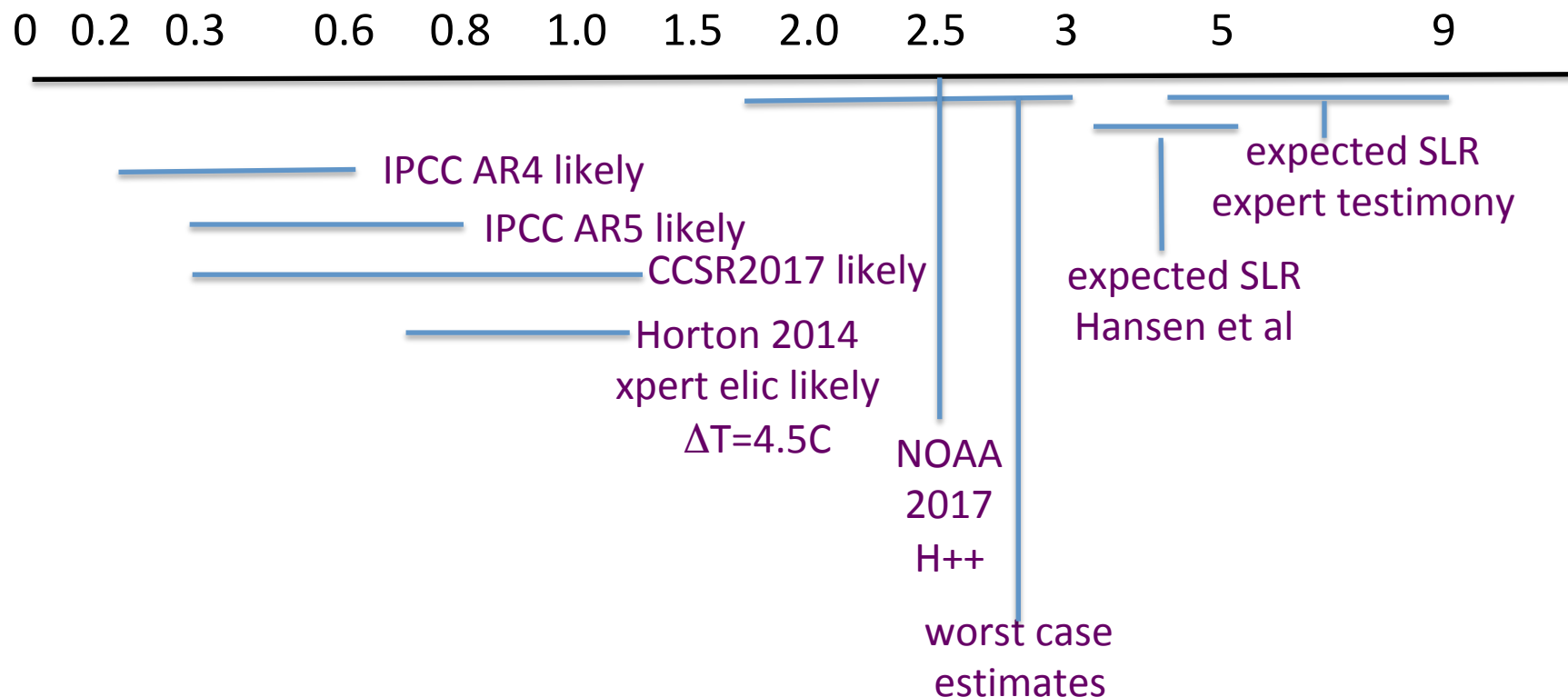
“We are in the uncomfortable position of extrapolating into the next century without understanding the last.” – Walter Munk

Projections of future sea level rise:

- Semi-empirical approaches based on past relationships of sea level rise with temperature
- Process-based methods using models
 - Thermal expansion from ocean warming: derived directly from the global climate model simulations
 - Changes in glacier and surface mass balance: regional models; empirical relations
 - Contributions from ice sheet dynamics: ice sheet models, expert judgment, and/or statistical projections.

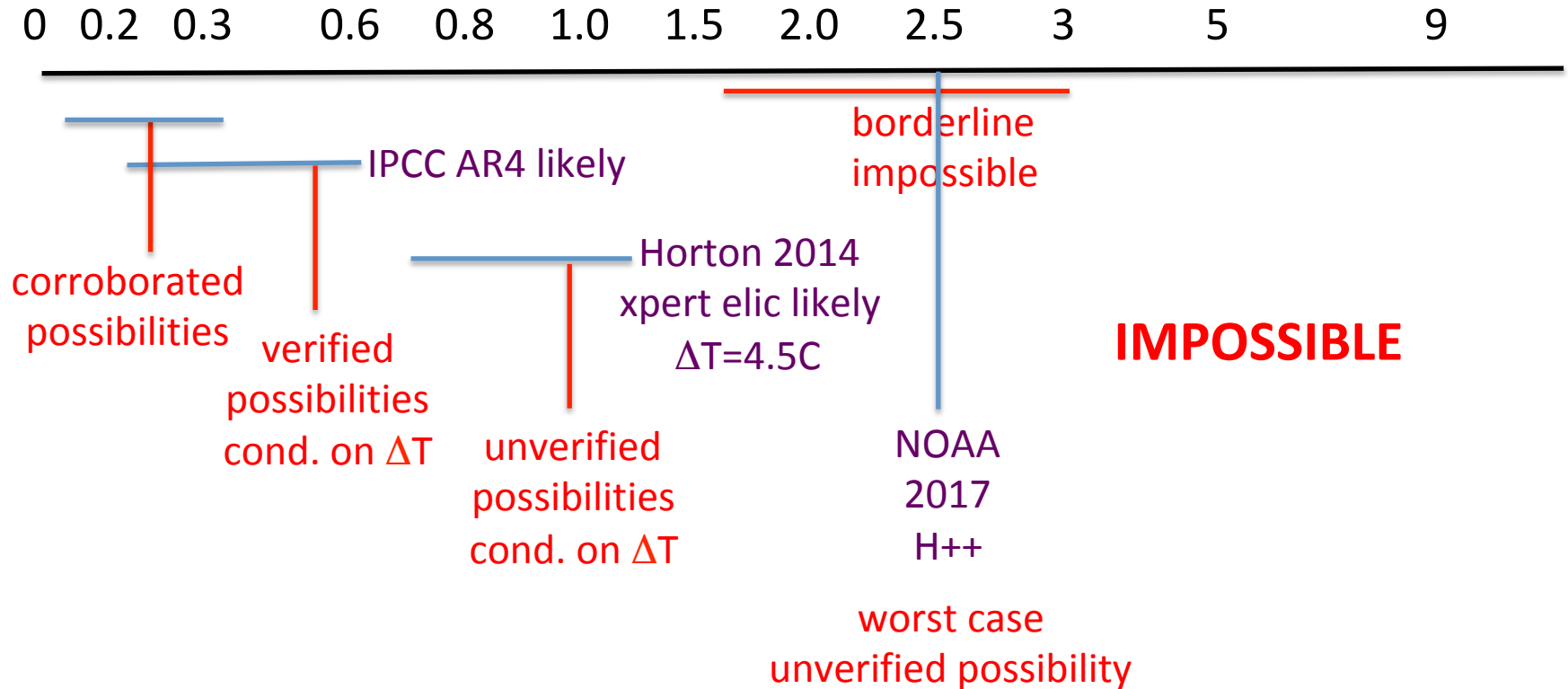
Global sea level rise: 2100 (m)

Expert assessments



Global sea level rise: 2100 (m)

JC perspective



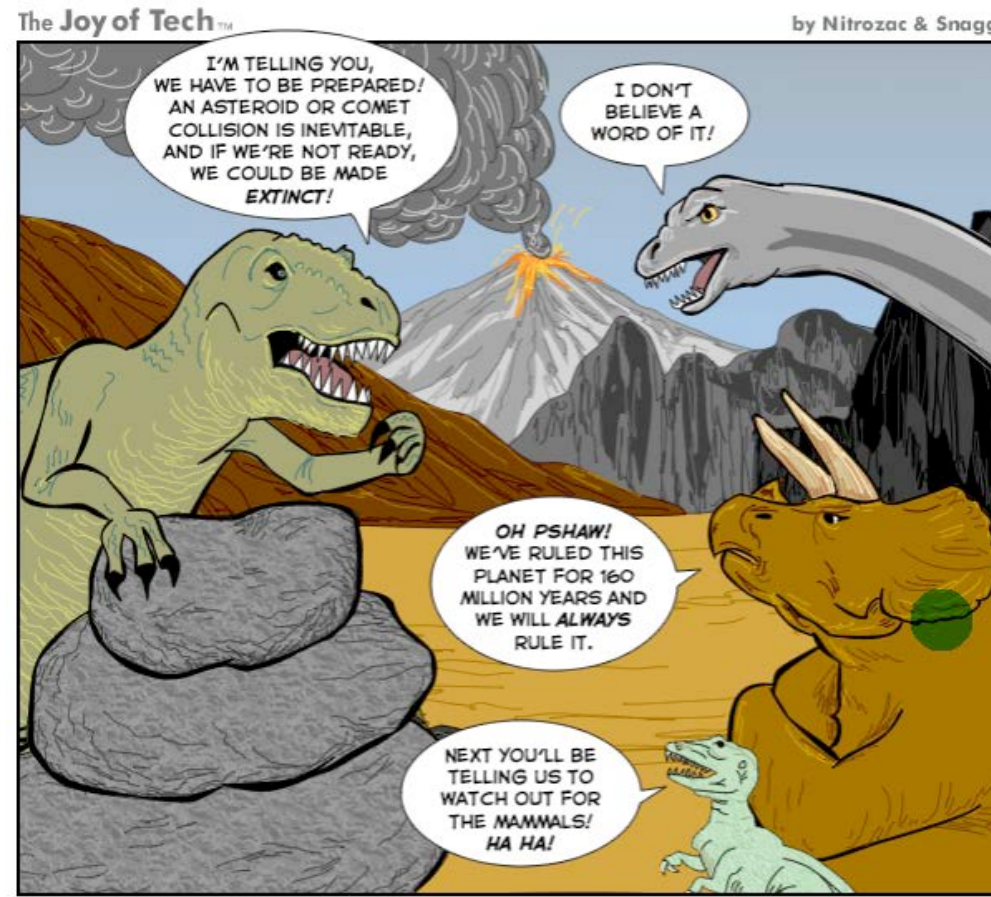
Sea level rise 2100: What's the worst case?

Estimates of worst case range from 1.6 m to 3.0 m

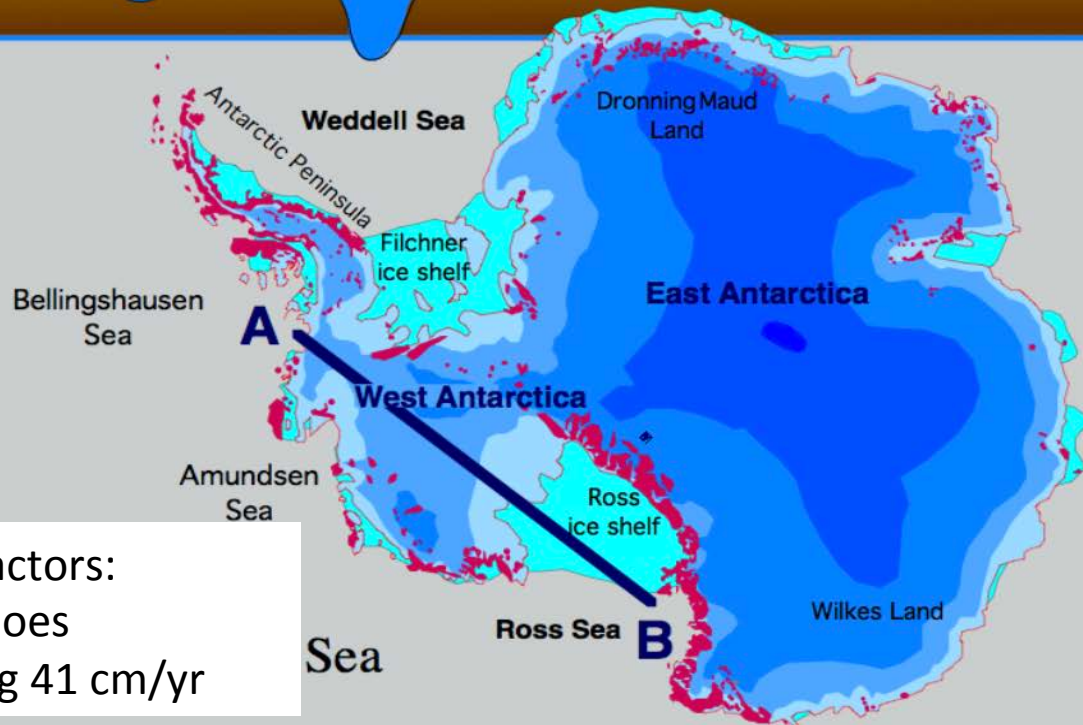
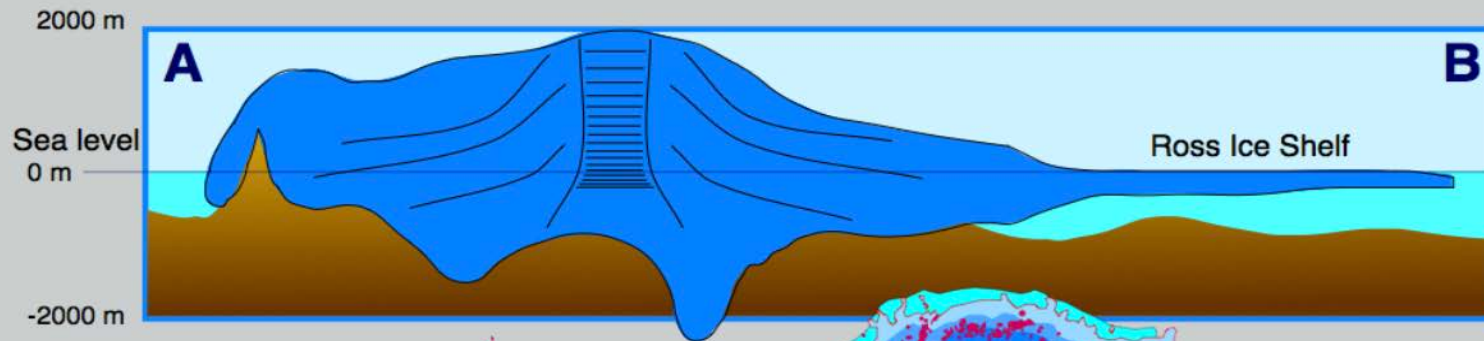
NOAA H++ scenario 2.5 m: probability of 0.05%

Probability for worst case is misleading: unknown probability

'Worst case' scenario is driving infrastructure planning and lawsuits



West Antarctic Ice Sheet (WAIS)

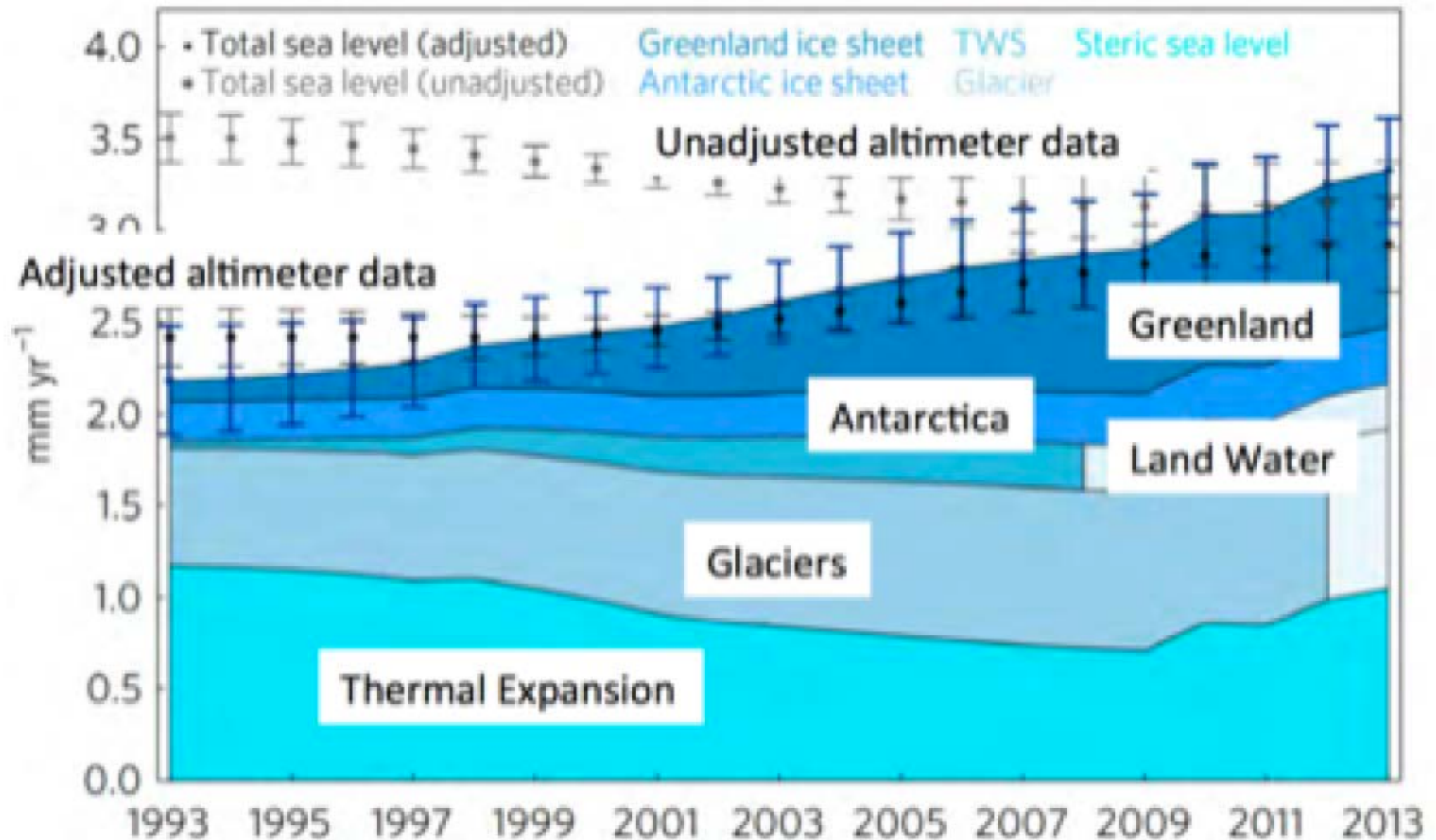


Confounding factors:

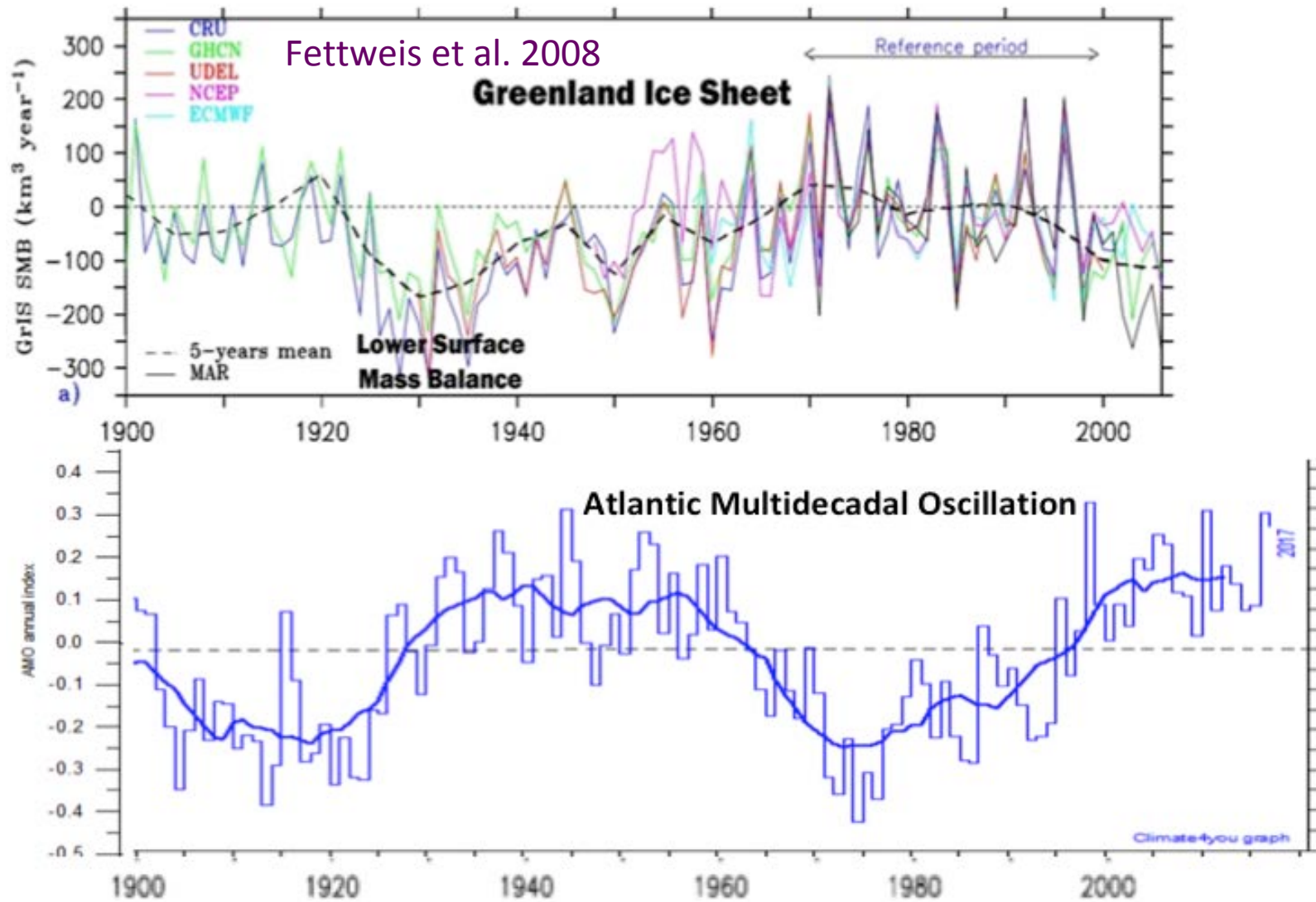
- 138 volcanoes
- WA is rising 41 cm/yr

- Complete collapse would raise sea level by **10 feet**
- IPCC AR5: **medium confidence** would not exceed several tenths of a meter of sea level rise during the 21st century (**~8 inches**)

What is causing recent sea level rise?



Greenland melting and the AMO



Framing error: 'unknown knowns'

Unknown knowns: known 'neglecteds'. Known processes or effects that are neglected for some reason.

Climate change problem framed too narrowly: driven by CO₂

Predictions of 21st C sea level change – known neglecteds:

- Solar variability and solar indirect effects
- Volcanic eruptions
- Natural internal variability (large-scale ocean circulations): impact on glacier/ice sheet mass balance Greenland
- Geothermal heat sources: Greenland, Antarctica
- Geologic uplift: Greenland, Antarctica

Black versus white swans

Human-caused climate change

- CO₂ is the primary climate 'control knob'

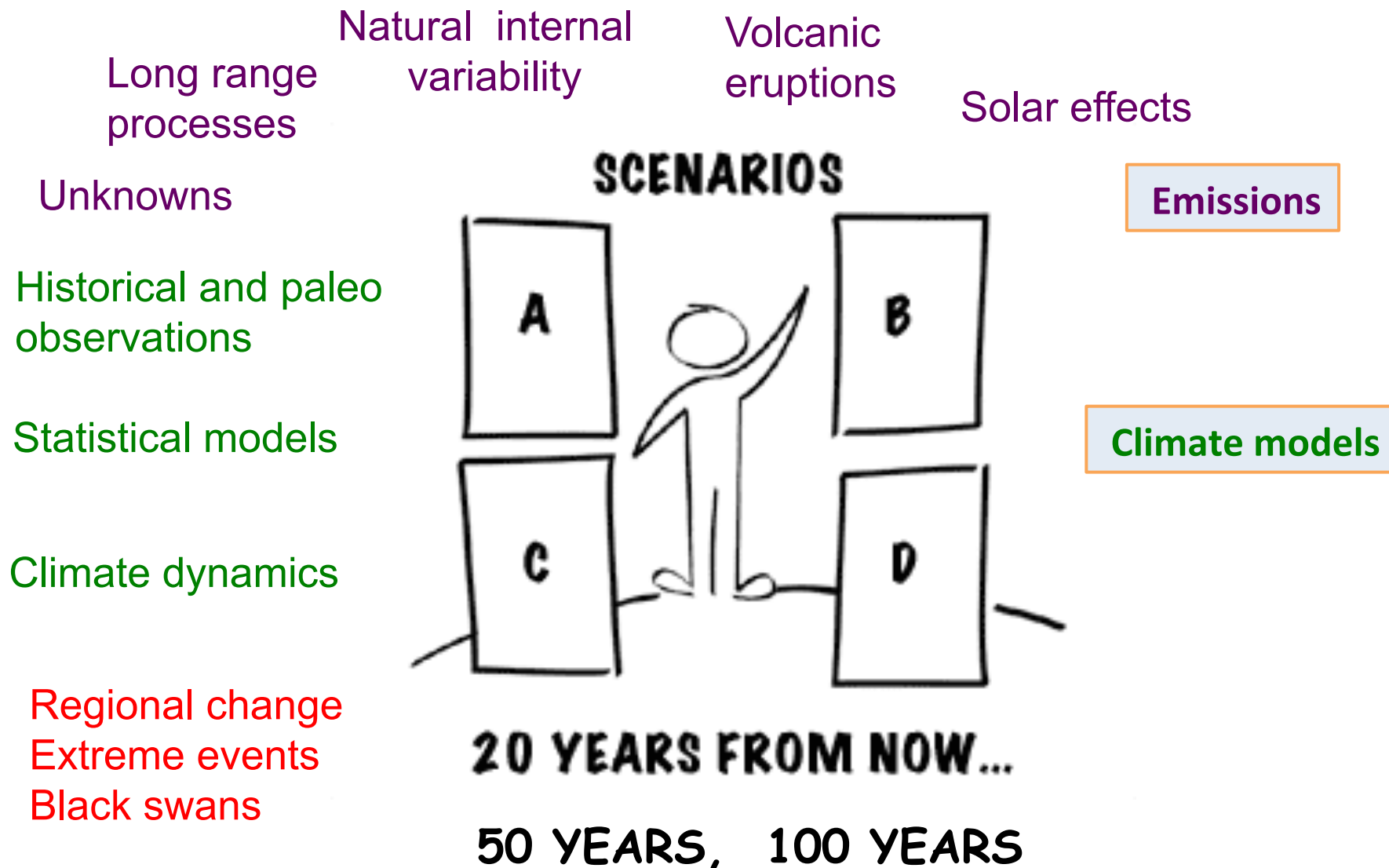


Natural climate variability

- Highly **complex** dynamical system
- **No** simple cause and effect
- Climate **shifts** naturally in unexpected ways.



Scenarios of future climate



Are GCMs the best tool for developing scenarios of future climate change?

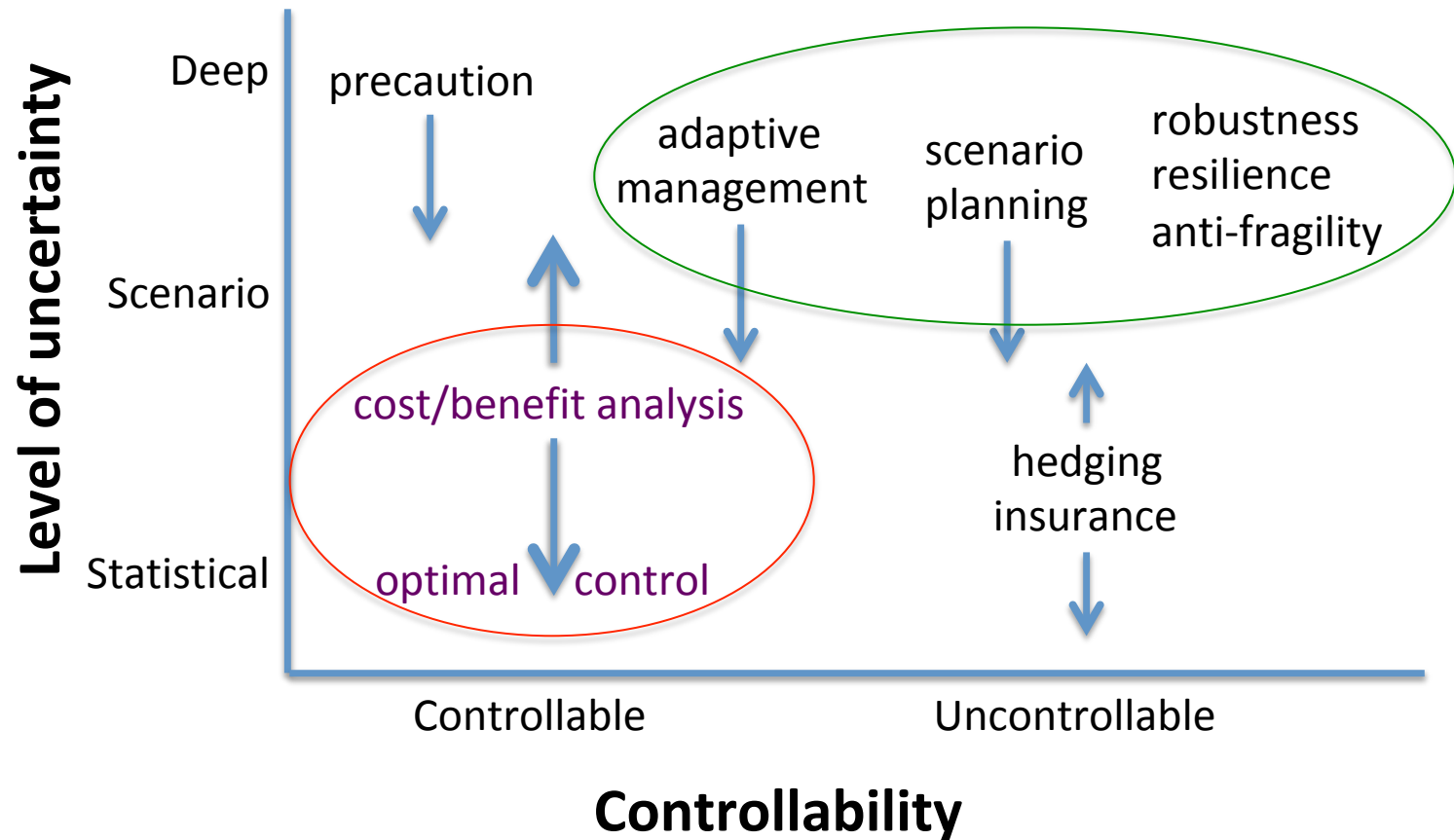
Challenges:

- GCMs do not simulate the full likely range of climate sensitivity, nor full range of climate-relevant processes
- current GCMs inadequate for simulating natural internal variability on multidecadal time scales
- computational expense precludes adequate ensemble size
- GCMs currently have no skill in simulating regional climate variations

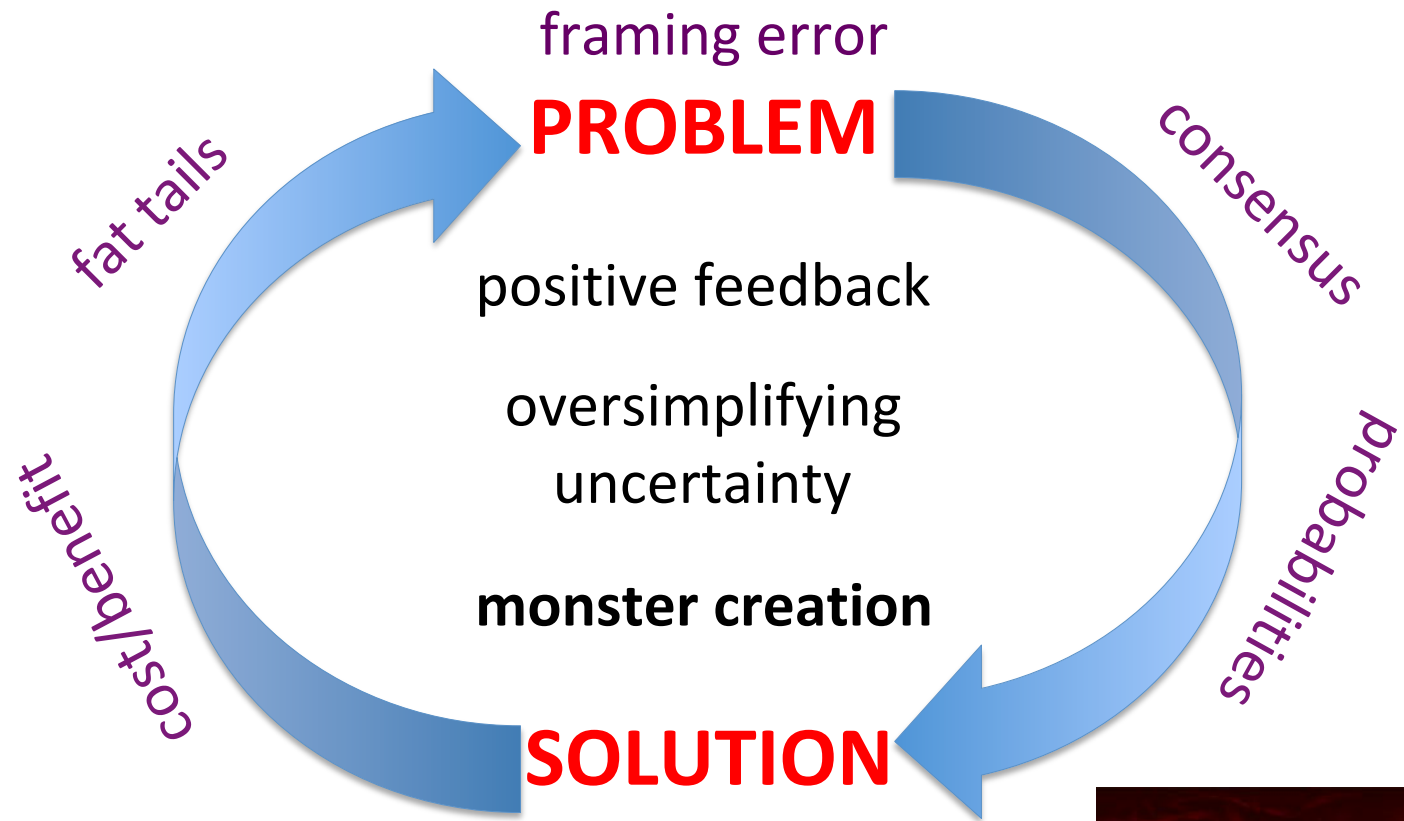
Alternative scenario generation methods

- Hybrid models: integrate GCMs, process models, empirical models, expert judgment (un)verified possibilities
- Climatology (historical, paleoclimate) (verified possibilities)
- Extrapolation of recent trend (corroborated possibilities)
- Dynamic climatology empirical model (Suckling/Smith) (verified possibilities)
- Network-based dynamic climatology (Wyatt & Curry) (verified possibilities)
- Secular global warming as a multiplier effect (conditionally verified)
- “What if” scenarios relative to vulnerability threshold
- Sensitivity analyses (unverified possibilities)

Decision – analytic frameworks



Oversimplification → alarmism



policy cart b4
scientific horse

enraged monsters



A tamed uncertainty monster



“Being open about uncertainty should be celebrated: in illuminating where our explanations and predictions can be trusted and in proceeding, then, in the cycle of things, to amending their flaws and blemishes.” - Bruce Beck

<http://judithcurry.com>

Climate Etc.

- Climate science
- Uncertainty
- Communications
- Social psychology
- Philosophy of science
- Policy and politics
- Ethics
- Energy tech & policy

