Informing Risk Management Decisions in the Face of Deeply Uncertain Sea-Level Rise Projections.

Or: Are we there yet?

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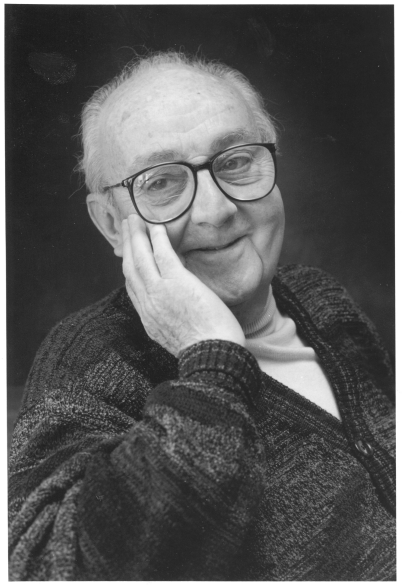
Snowmass Meeting July 30/31 (2013)
Contains some privileged materials, please do not cite or distribute

How are we doing in the eyes of some of our peers?

"[Integrated Assessment] models have crucial flaws that make them close to useless as tools for policy analysis." (Pindyck, 2013)



"all models are wrong, but some are useful." (George Box)

What our models are useful for?

How are we doing in the eyes of the public?
-> Press-coverage of a recent Snowmass meeting

"Can Dr. Evil Save The World?

Last summer, an elite group of scientists, economists and government officials gathered at Snowmass ski resort near Aspen, Colorado, to contemplate the end of the world."

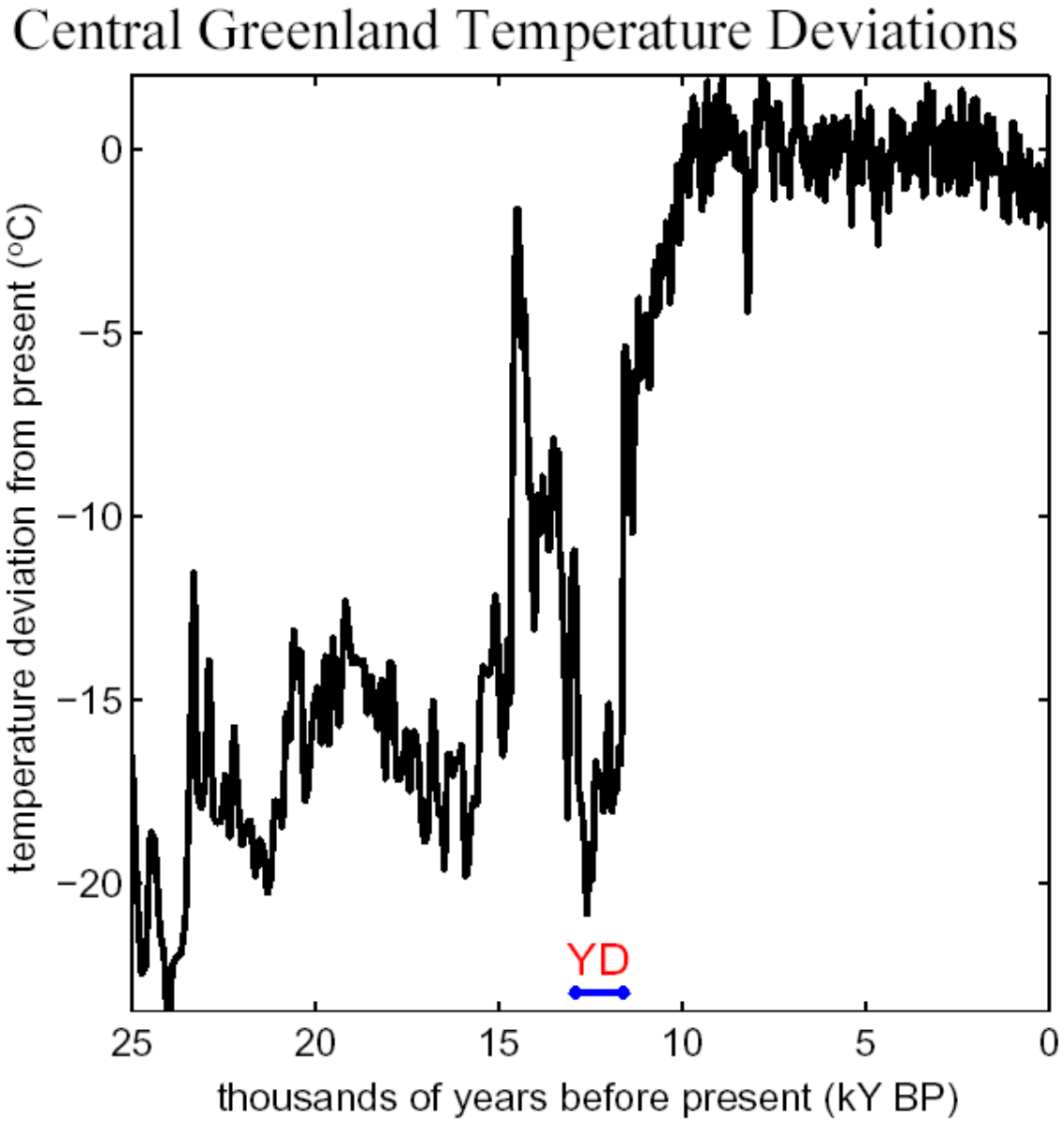
"Weyant, surprised by the "emotional and religious" debate over Wood's proposal, cut off discussion before it turned into a shouting match"

Do we have the education, information, and tools to rationally analyze and discuss climate risk management strategies in the face of potential high-impact events?

What are examples of high-impact events?

Climate Change can be abrupt.

What is one potential mechanism for abrupt climate changes?



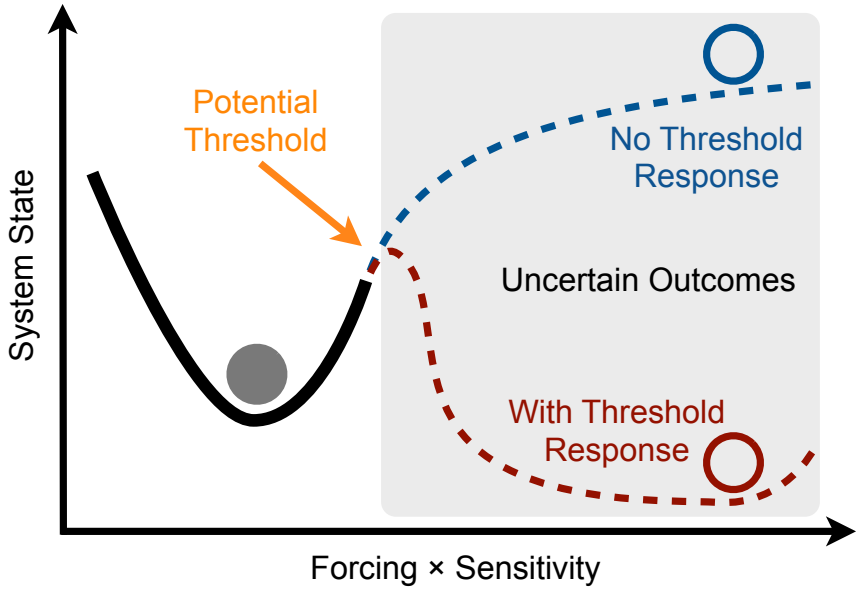
Data from Meese et al. (1994) and Stuiver et al. (1995).
20 year running mean, $\delta^{18}O$-temp conversion based on Cuffey et al., 1995

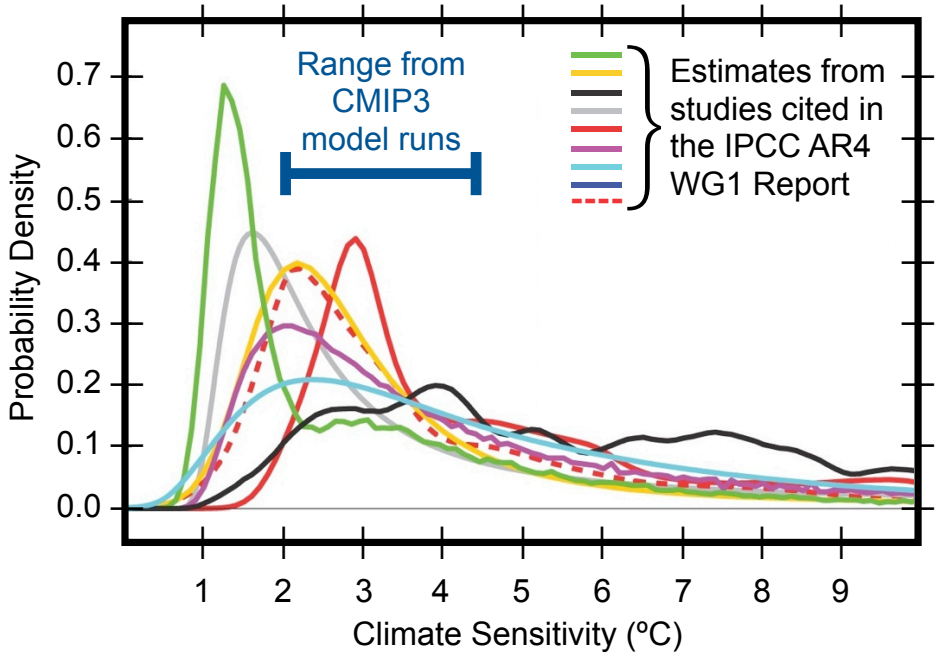
Two interrelated challenges:

(i) Coupled natural and human systems can react with nonlinear and persistent threshold responses.

(ii) Risk estimates about these threshold responses are deeply uncertain.

What are examples of potential threshold responses?
How do IAMs treat them?

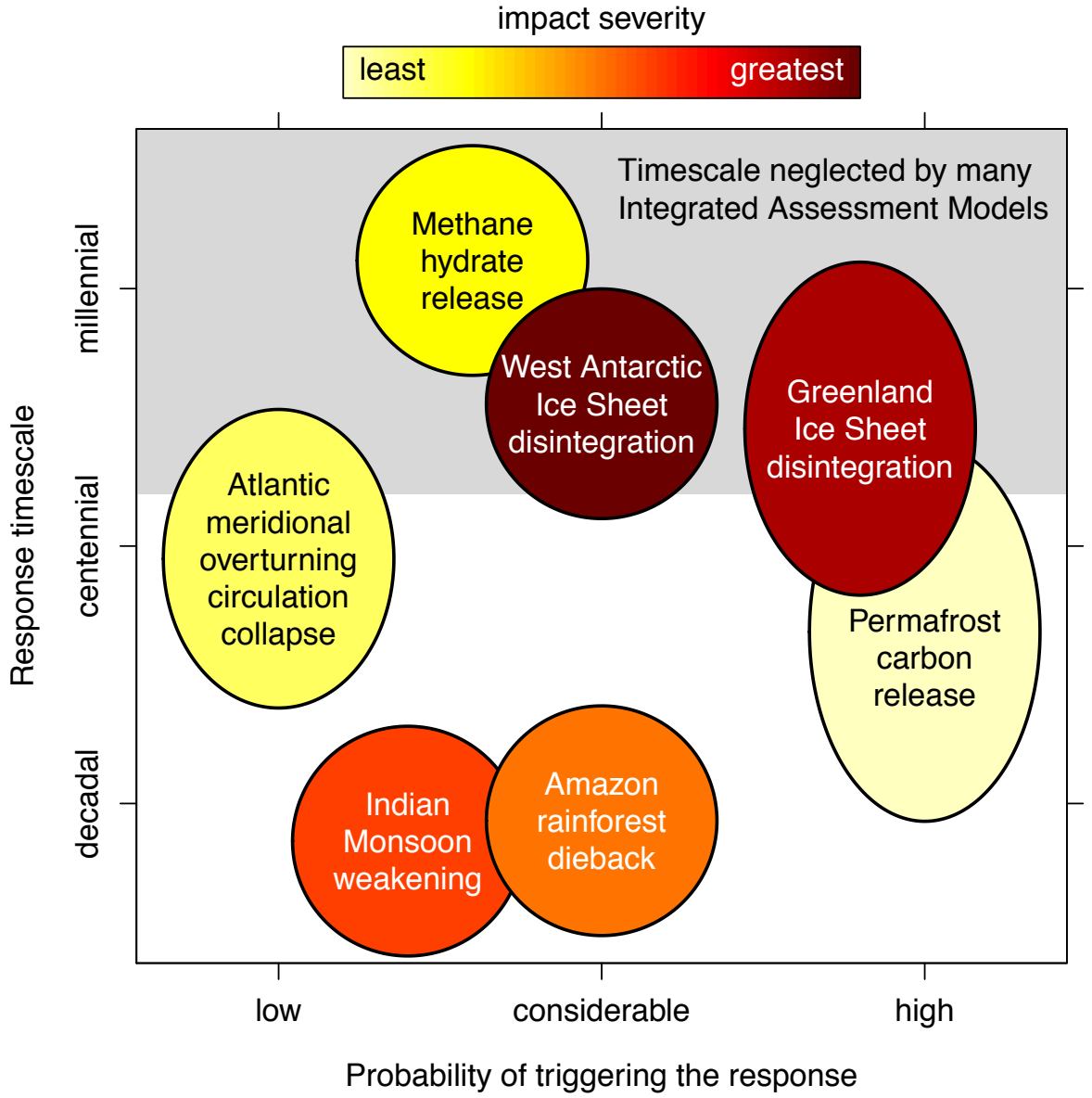




data from Meehl et al. (2007); figure adapted from Randall et al. (2007)

Integrated Assessment models are typically silent on potential climate threshold events.

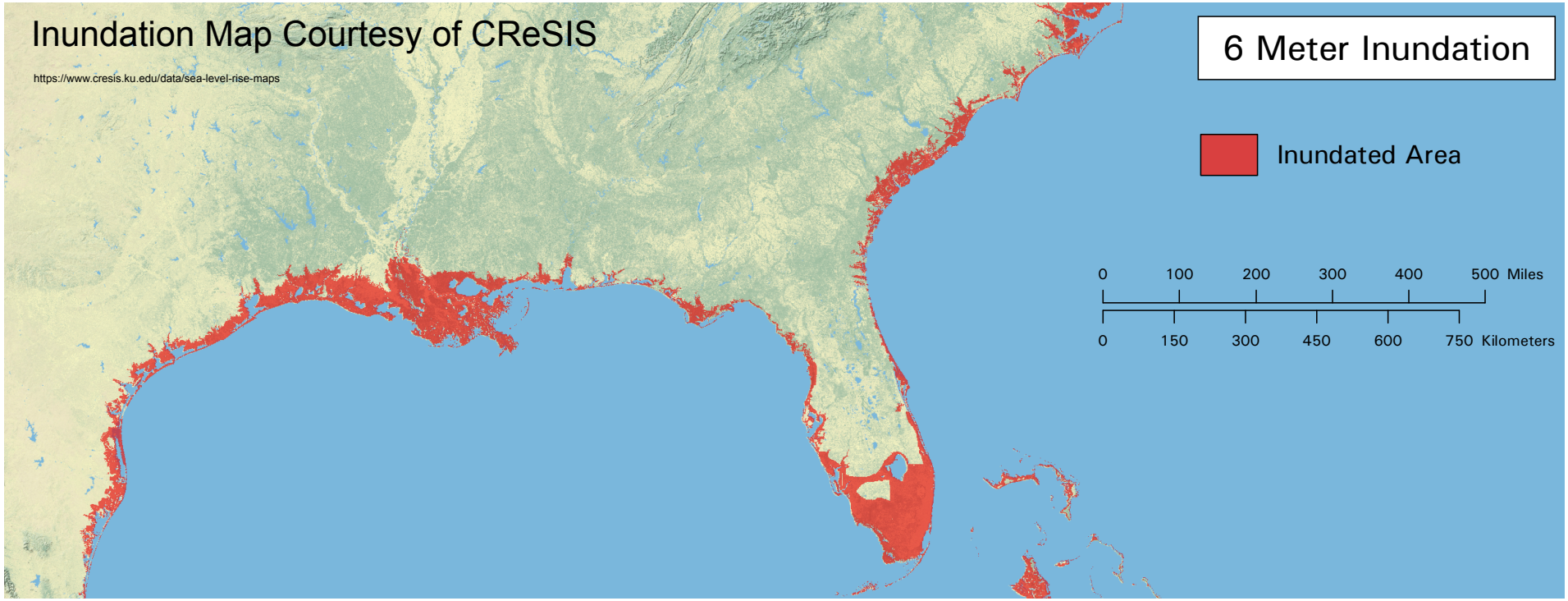
What are potential impacts for one specific example?



Nicholas and Keller (2012), synthesis of published assessments

See talk by Bill

A potential GIS disintegration could eventually raise the global mean sea level by roughly seven meters and impose sizable risks.



Who cares and why?

Decisions to adapt to sea-level rise are made in the face of diverse objectives and risk-management instruments.

See talks by Tad, David, Rob, and Bob.

Port of Los Angeles

- Focus on adaptation.
- Focus on robust economic viability and (relatively low) reliability.
- Relatively short (~ decadal) time-scale.

Tuvalu

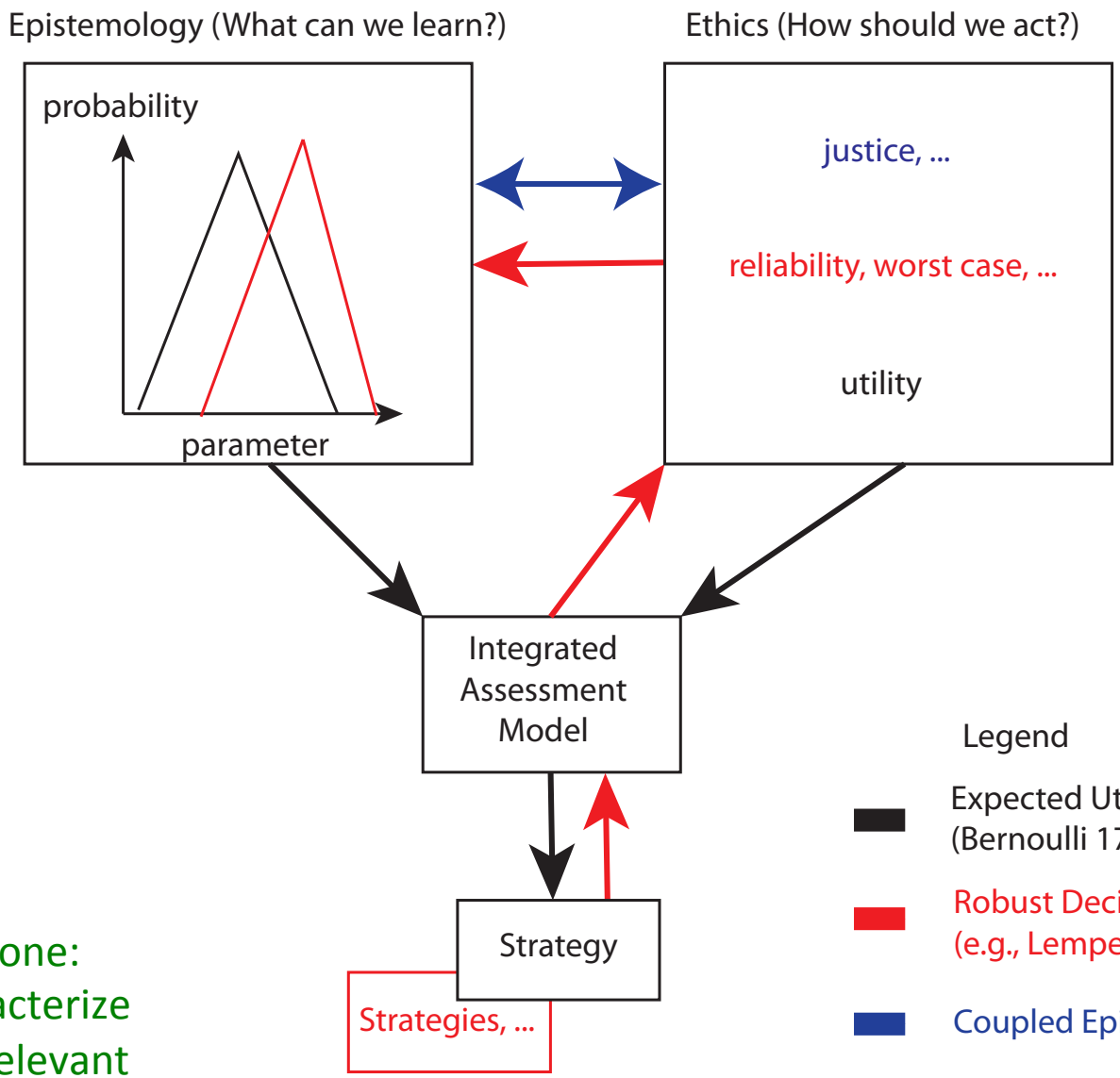
- Interactions of mitigation, adaptation, and geoengineering ("Tuvalu Syndrome").
- Focus on sustainability.
- Decadal to century time-scales.

The Netherlands

- Interactions of mitigation, adaptation, and geoengineering.
- Focus on saving human lives and very high reliabilities (needs deeply uncertain tails of the distribution).

How have such decisions been analyzed?

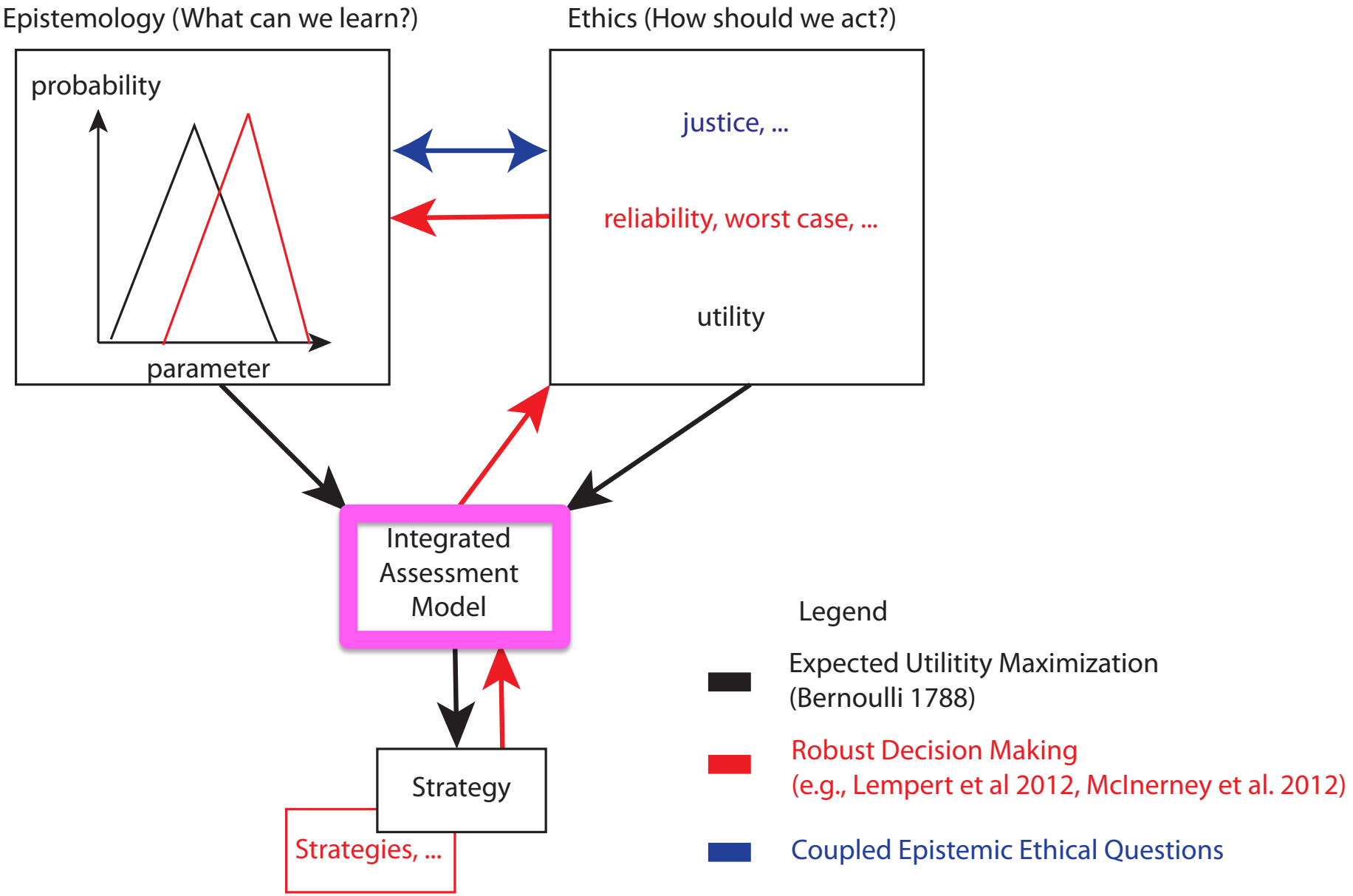
Two approaches to decision analysis.



See talks by David, Rob, and Nancy

Step one: characterize the relevant interactions...

Keller, Tuana, and Lempert (in prep)

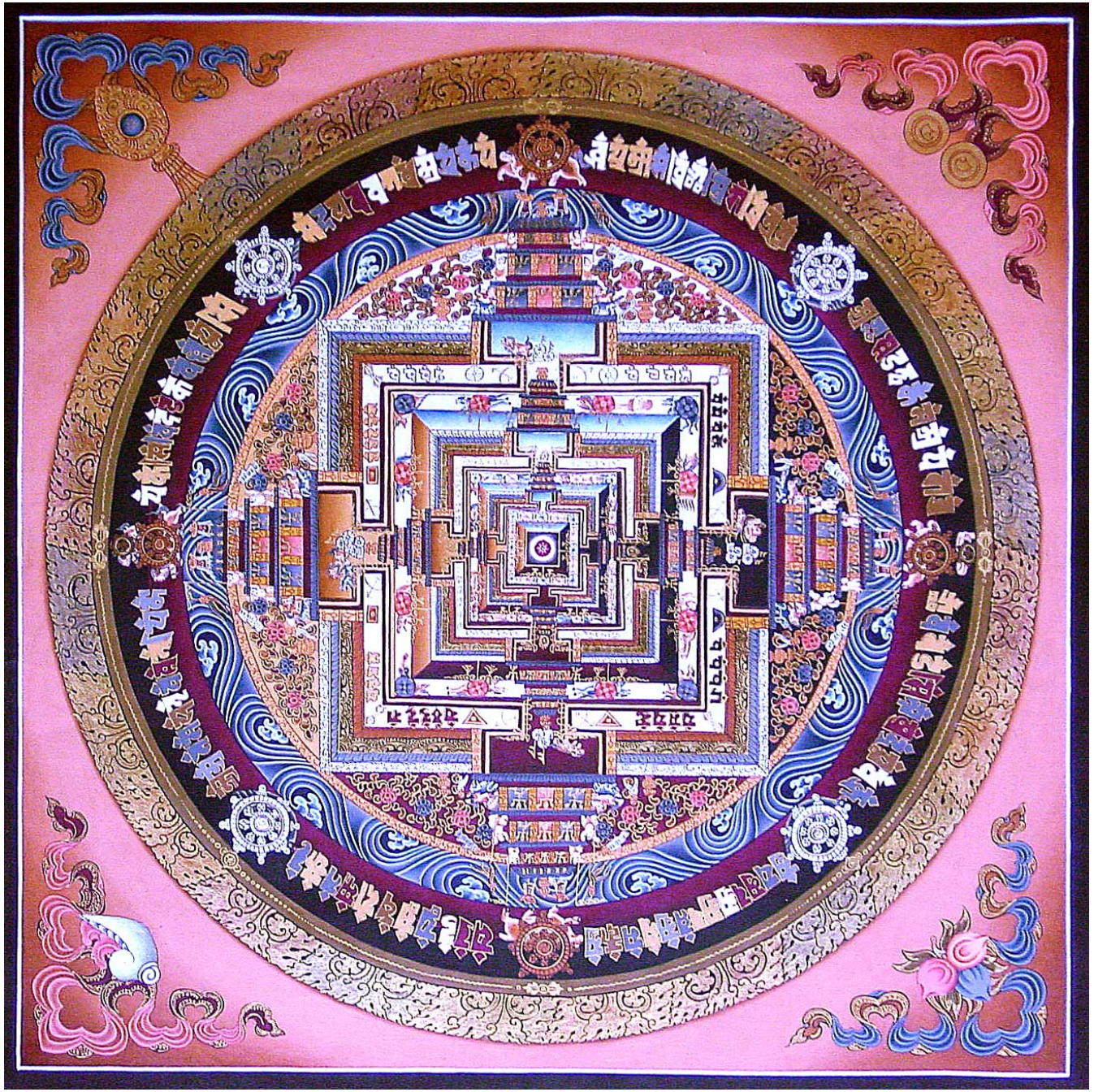


What is a useful model of the relevant interactions?

Keller, Tuana, and Lempert (in prep)

What is a useful model of the relevant interactions?

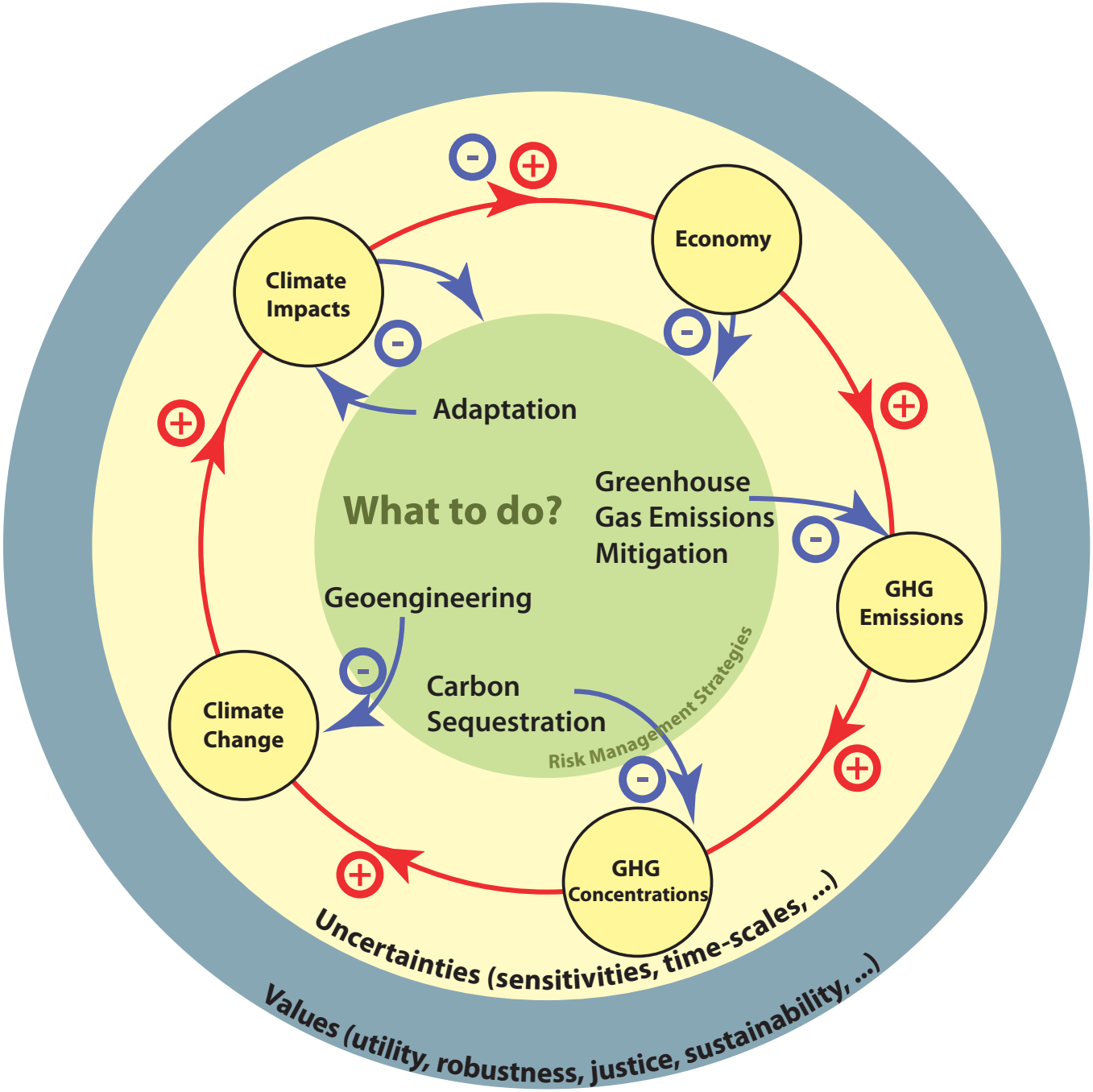
"Mandala […] is a spiritual and ritual symbol in Hinduism and Buddhism, representing the Universe."



Can we come up with more parsimonious model?

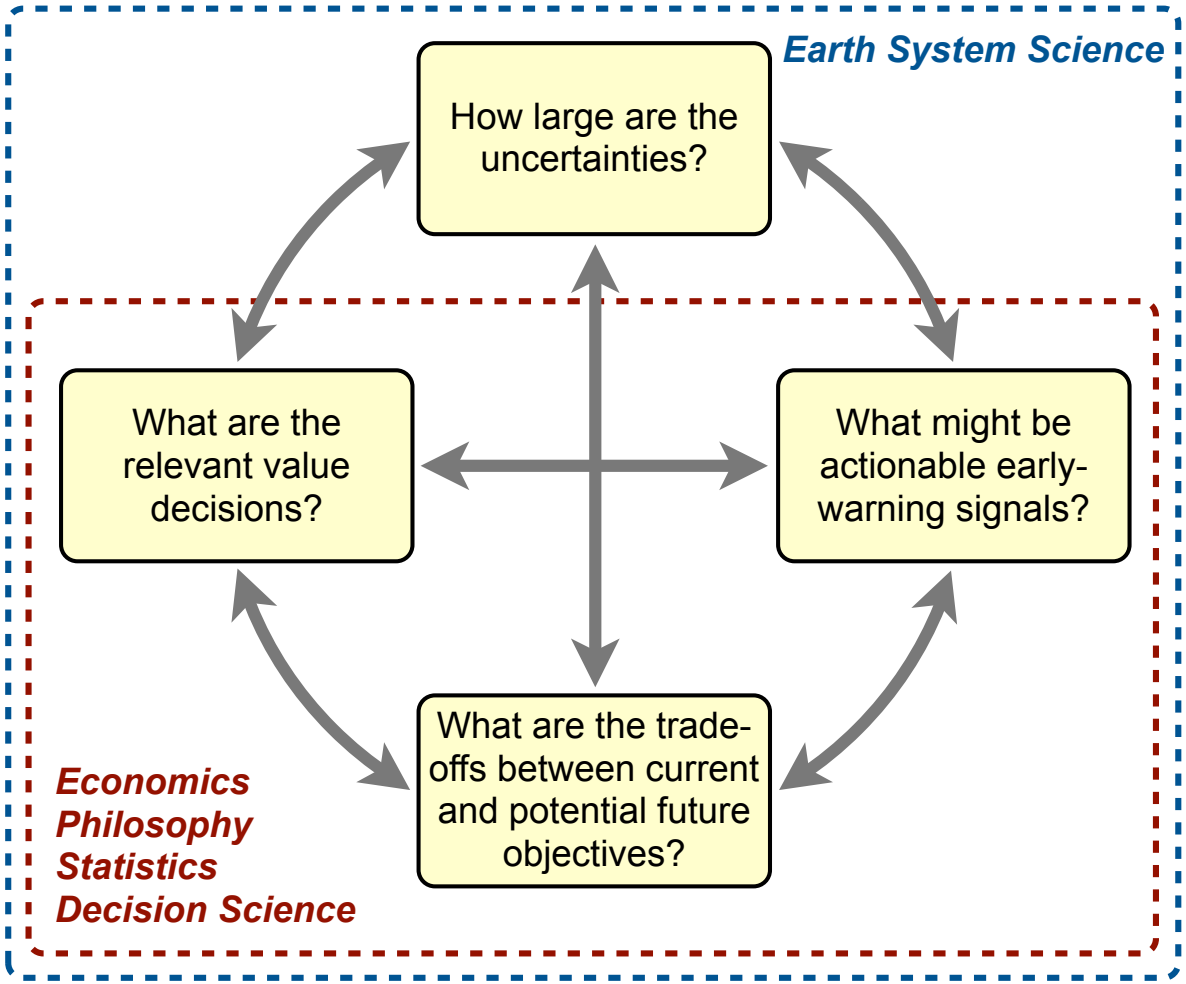
Assessing climate risk management strategies requires the analysis of complex systems with nontrivial interactions.

What are key research questions?



Why are key questions and challenges?

Overarching question: What are sustainable, scientifically sound, technologically feasible, economically efficient, and ethically defensible climate risk management strategies?

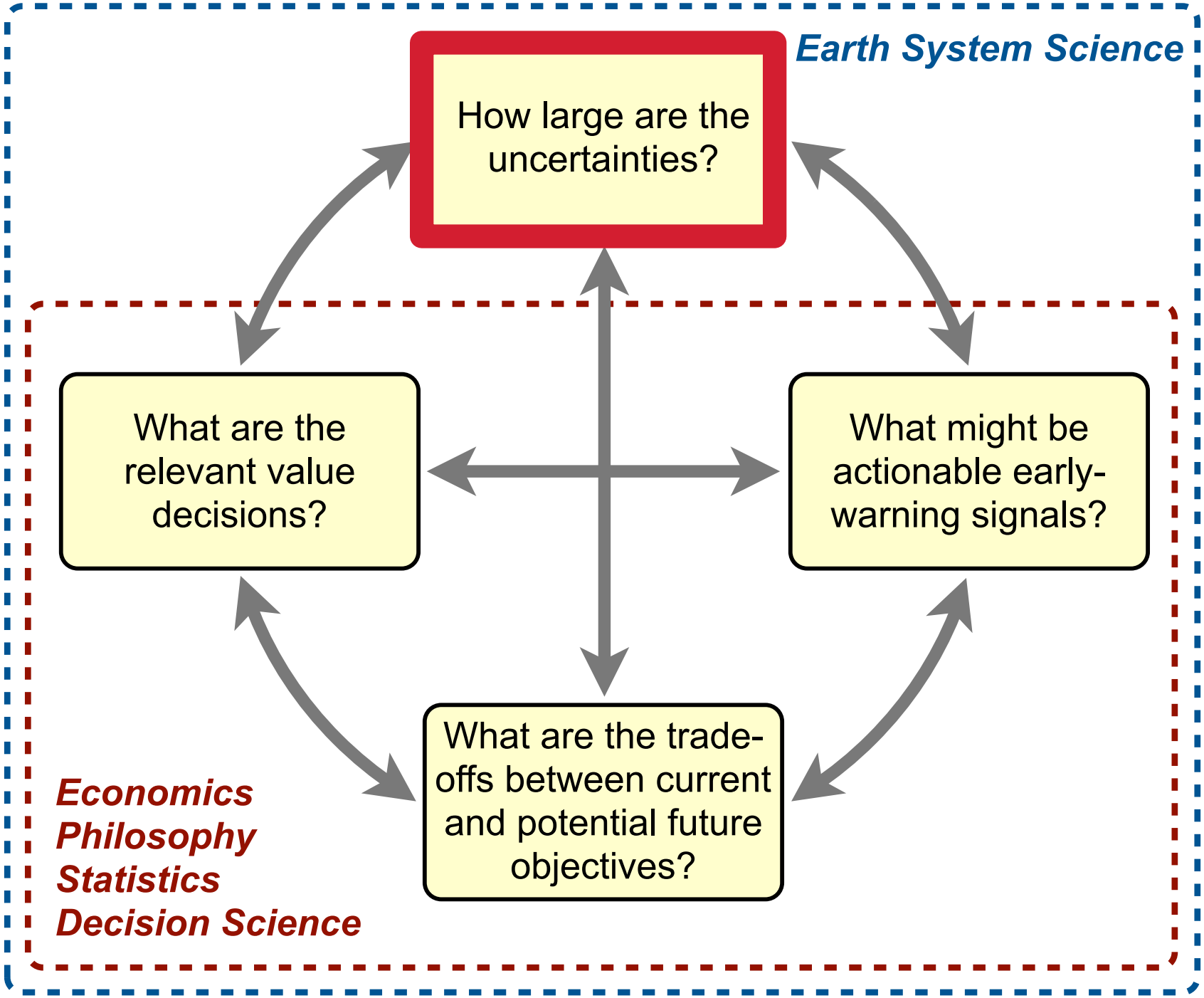


Addressing these questions requires transdisciplinary networks.
How can we build and sustain such networks?

What is SCRiM?

- SCRiM links a transdisciplinary team of scholars at 19 universities and 5 research institutions across 6 nations.
- Cooperative Agreement with NSF over five years and 11.9 million US$.
- Hub at Penn State with many subcontract spokes in the US, as well as national and international partners.
- Scrimhub.org

What are network components?

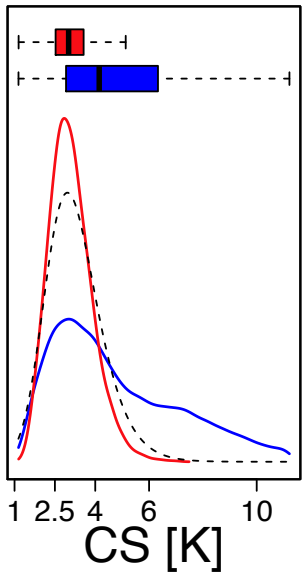

Earth System Science
How large are the uncertainties?
What are the relevant value decisions?
What might be actionable early-warning signals?
What are the trade-offs between current and potential future objectives?
Economics
Philosophy
Statistics
Decision Science

Climate sensitivity estimates typically neglect known unknowns.

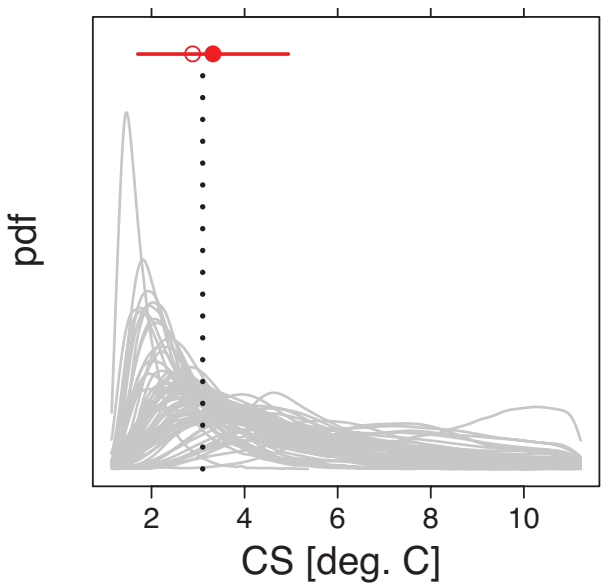
- The "standard approach" is to report sensitivities to priors, and maybe flag neglected uncertainties as caveat (e.g., Olson et al, 2012).
- Published climate sensitivity estimates typically neglect important uncertainties, for example regarding parametric, structural, and prior assumptions.
- Considering these neglected uncertainties can considerably widen the deeply uncertain pdfs (e.g., Olson et al, 2013).
- Given this dynamics, one may expect a widening of reported credible intervals over time ("negative learning").

Do we see evidence for negative learning?

Olson et al. JGR (2012)



Olson et al. JGR (2013)



Current communications of sea-level rise projections are deeply uncertain and often miss important processes and uncertainties.

Alley et al, IPCC, SPM, WG1 (2007)

Table SPM.3. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

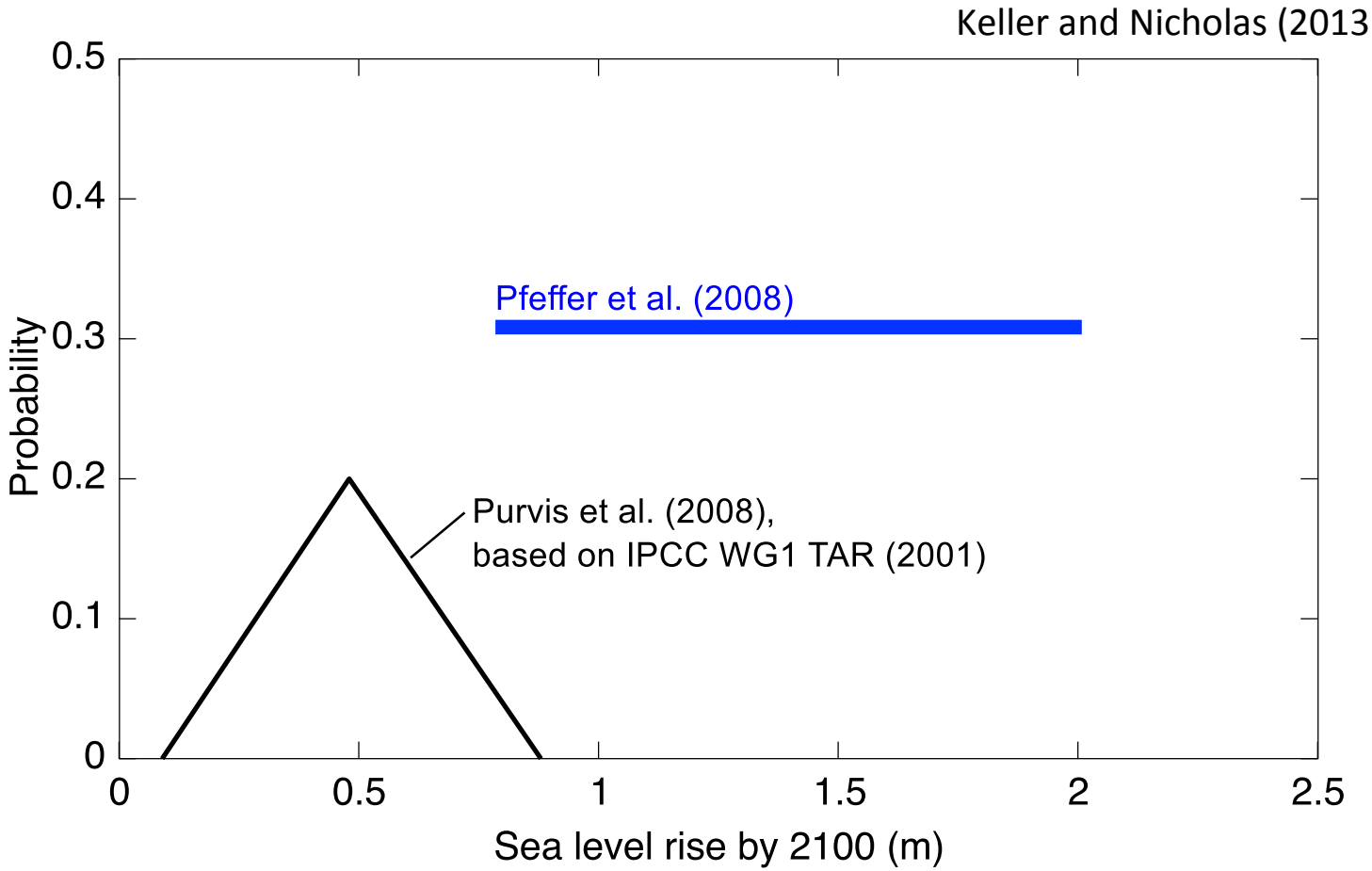
Table notes:

[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).

[b] Year 2000 constant composition is derived from AOGCMs only.

Surely this would not be missed by sophisticated analysts and decisionmakers….

The IPCC projections are often adopted for decision- and risk-analyses at face value and with apparent neglect of key qualifiers.



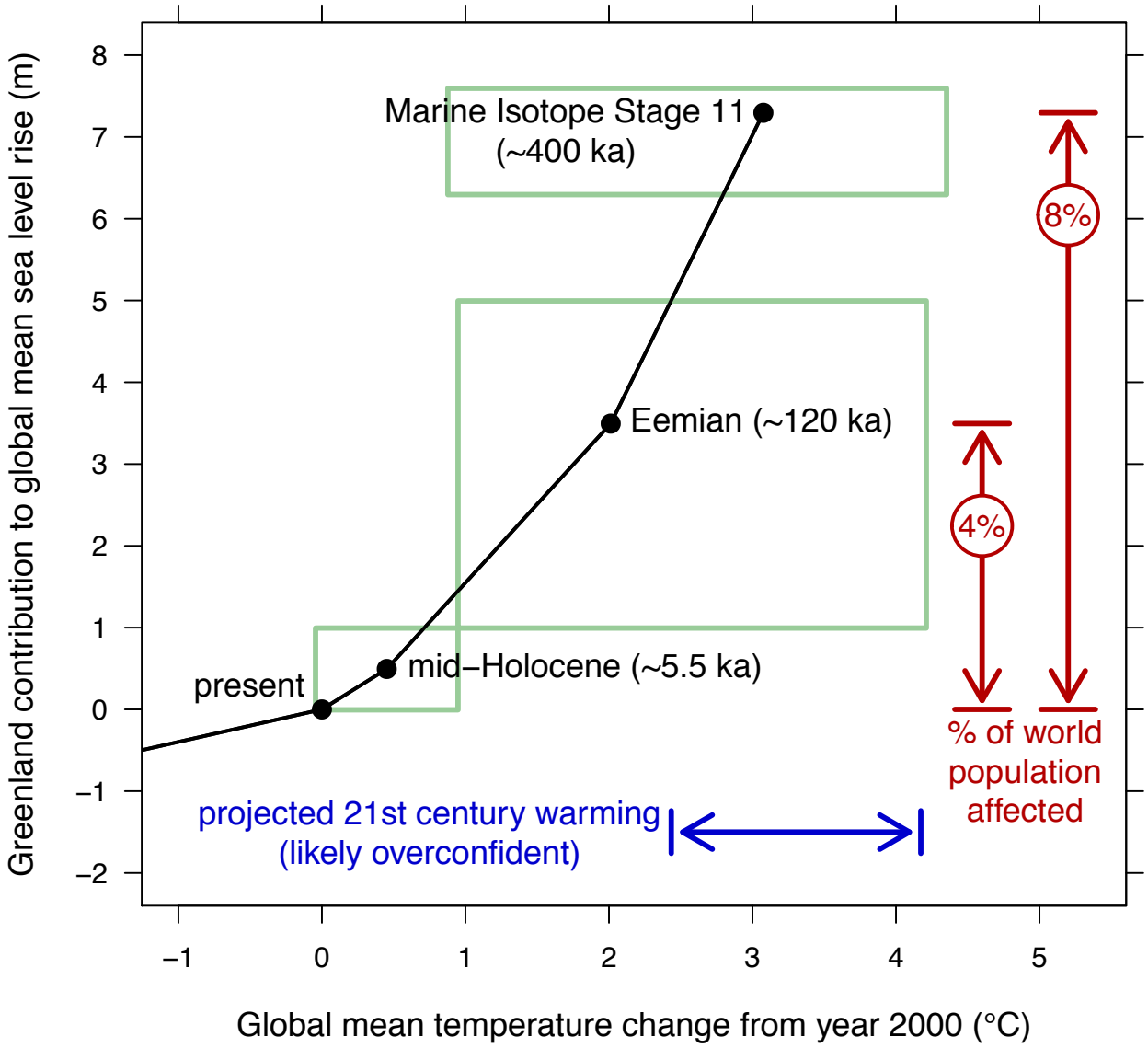
So, is this just a communication problem?

The paleo-record and simple physics suggest that anthropogenic climate forcings cause considerable risks driven by a potential Greenland Ice Sheet (GIS) disintegration.

Paleo-records provide (quasi) equilibrium responses.

What is the time scale of the response?

Lenton et al (2008) states:
"> 300 years".

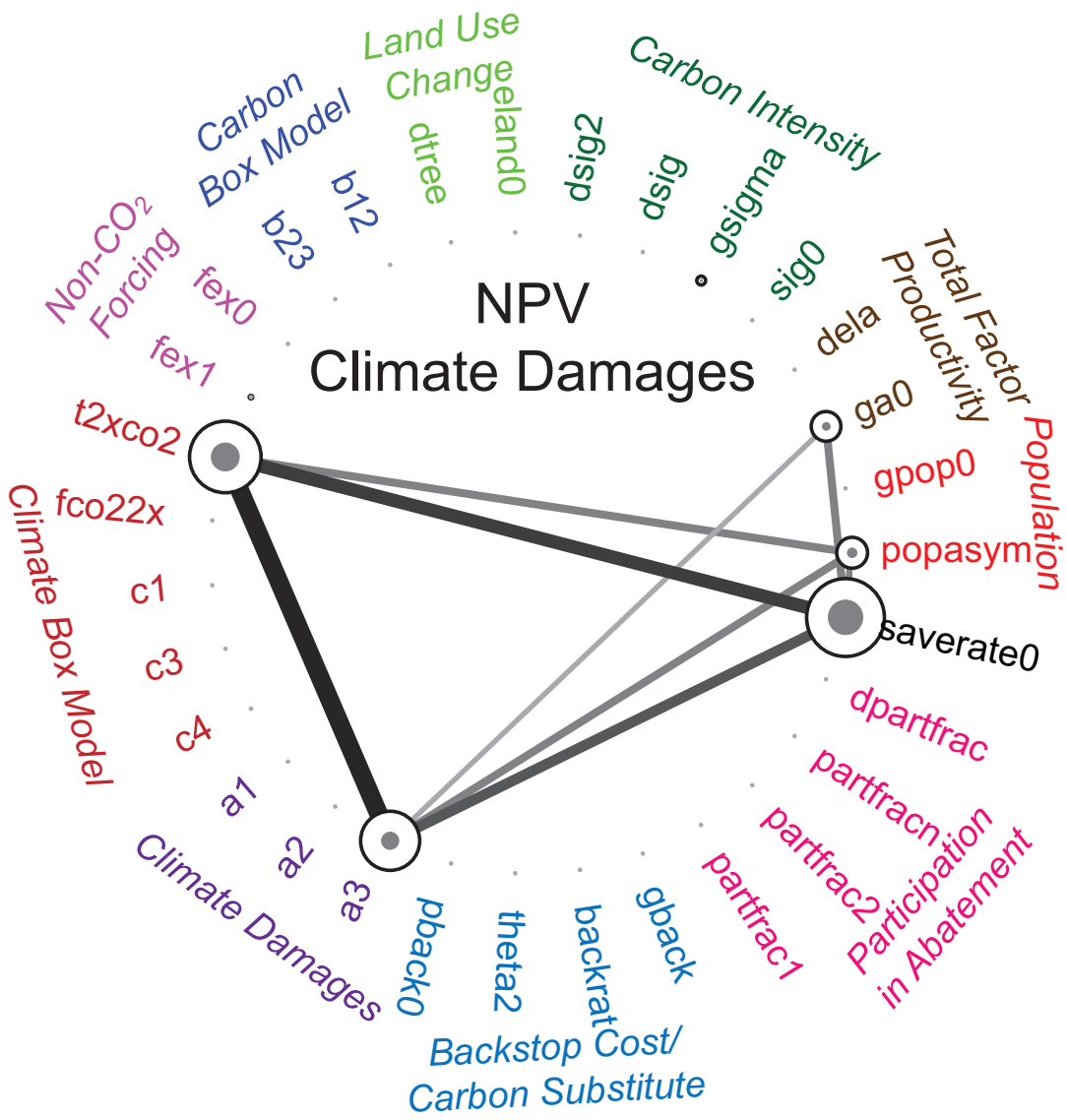


Is ">300 years" a good model?
What are sensitivities and uncertainties?

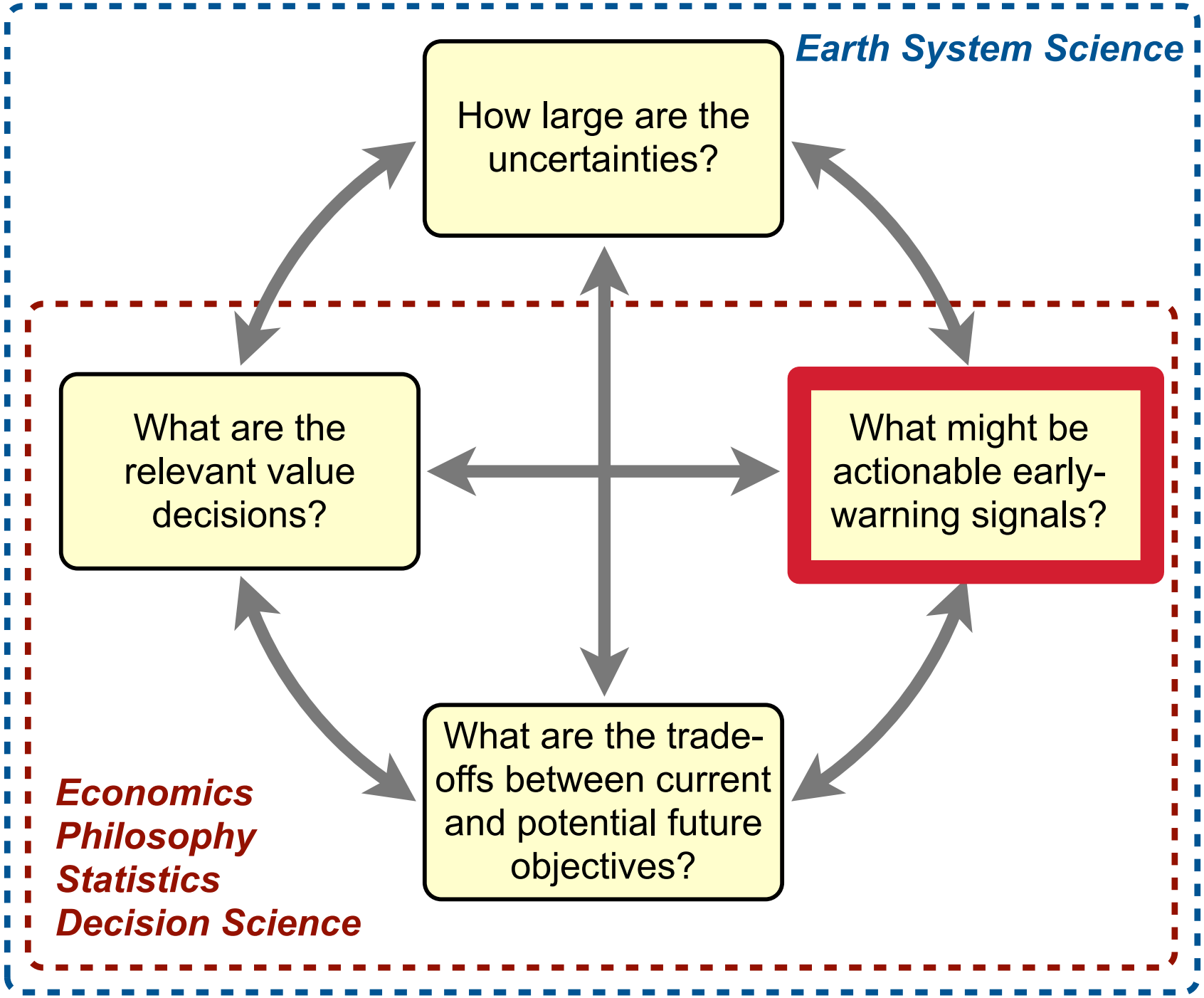
Paleo-data from Alley et al (2010), population data from Li et al (2009), climate projections from Meehl et al (2007).

How to identify the most important uncertainties?

1. Global sensitivity analysis of the DICE model using ~ 8M evaluations (for numerical stability).
2. One-at-a-time sensitivity analyses can miss important nonlinear interaction effects.
3. Aside: changing climate sensitivitity pdf from real data posterior to a uniform prior did not drastically change the plots and conclusions.
4. Parameter importance varies with the performance metric.



Butler, Reed, Fisher-Vanden, Keller, and Wagener (in revision)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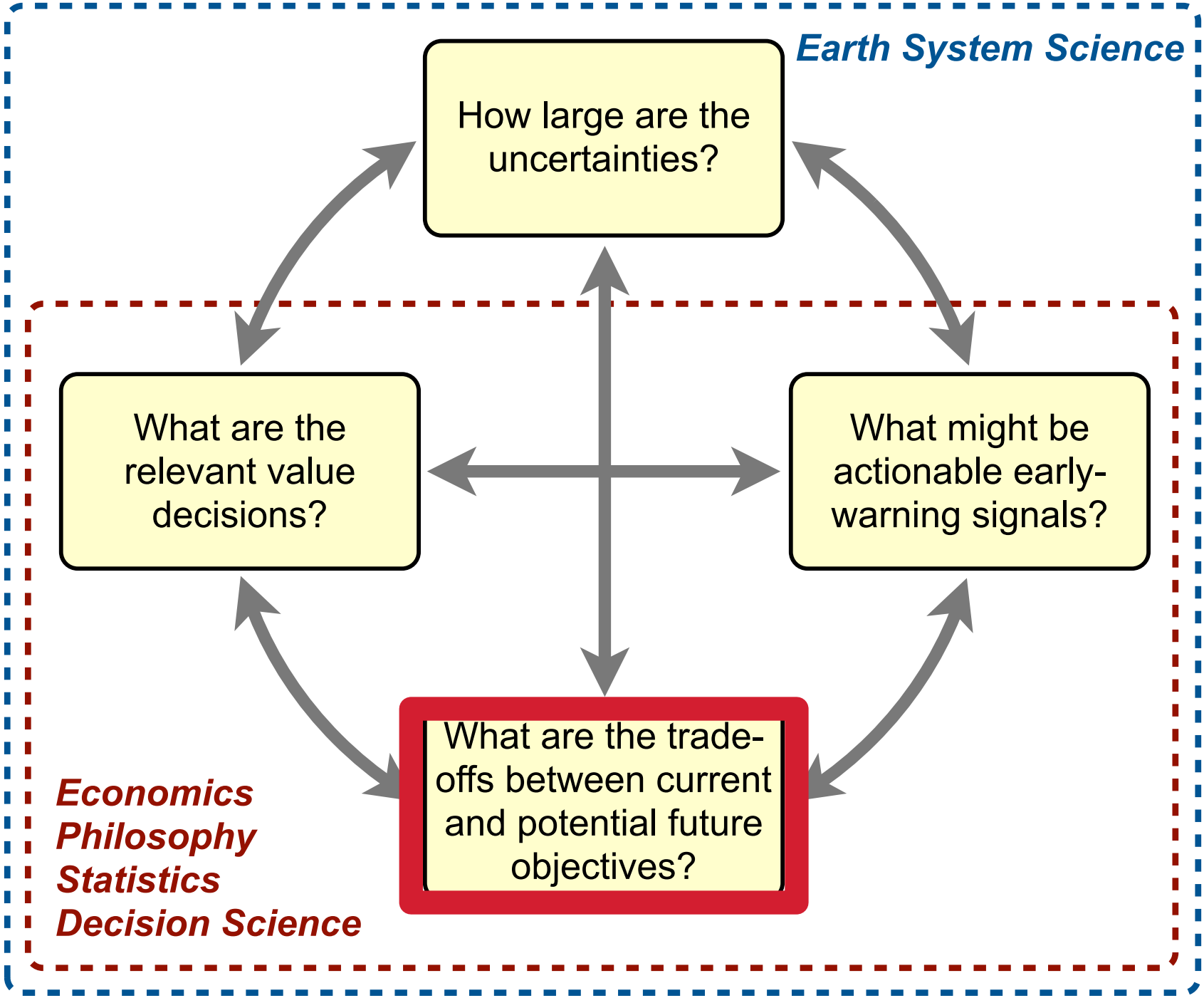
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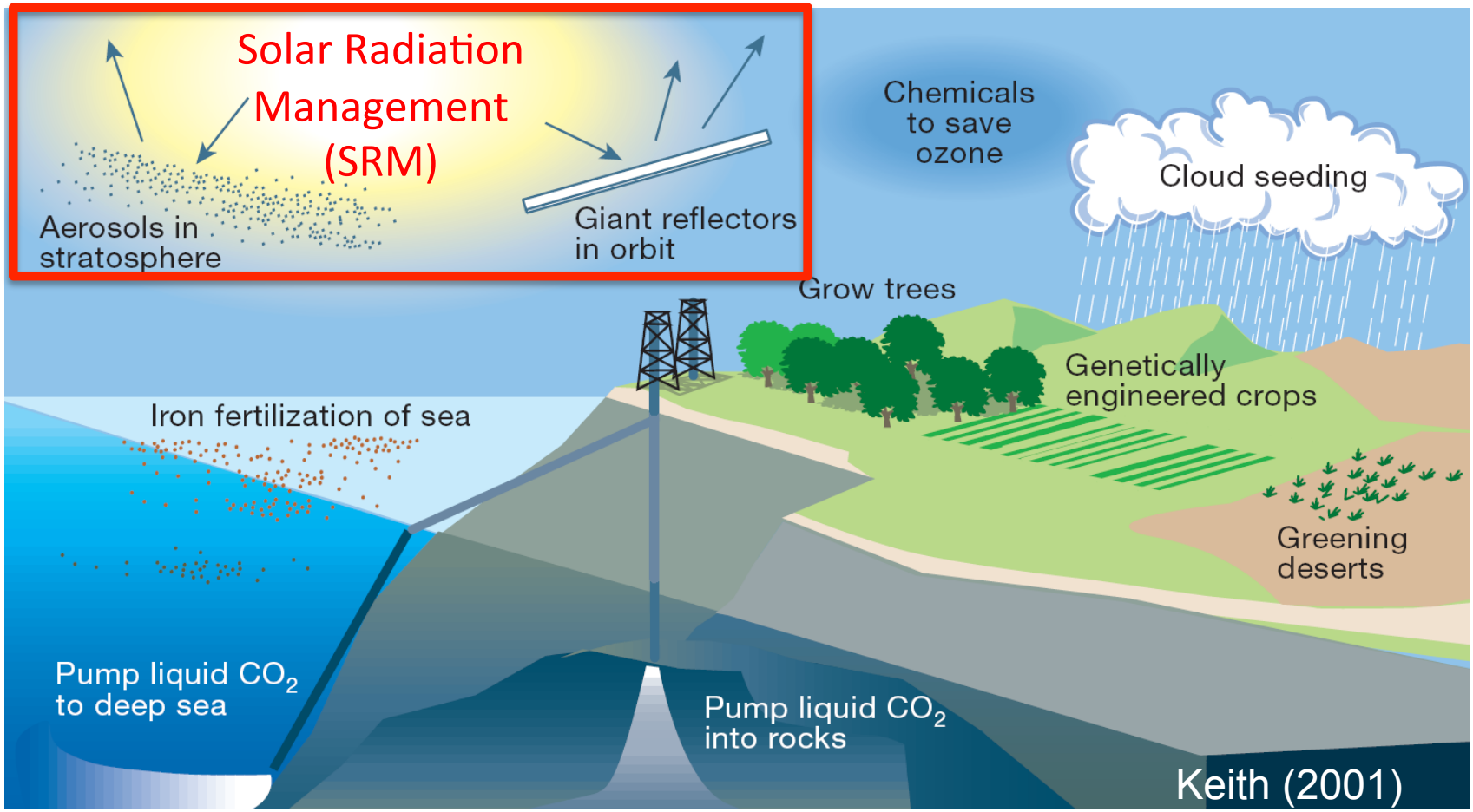
Geoengineering: One of the proposed risk management instruments

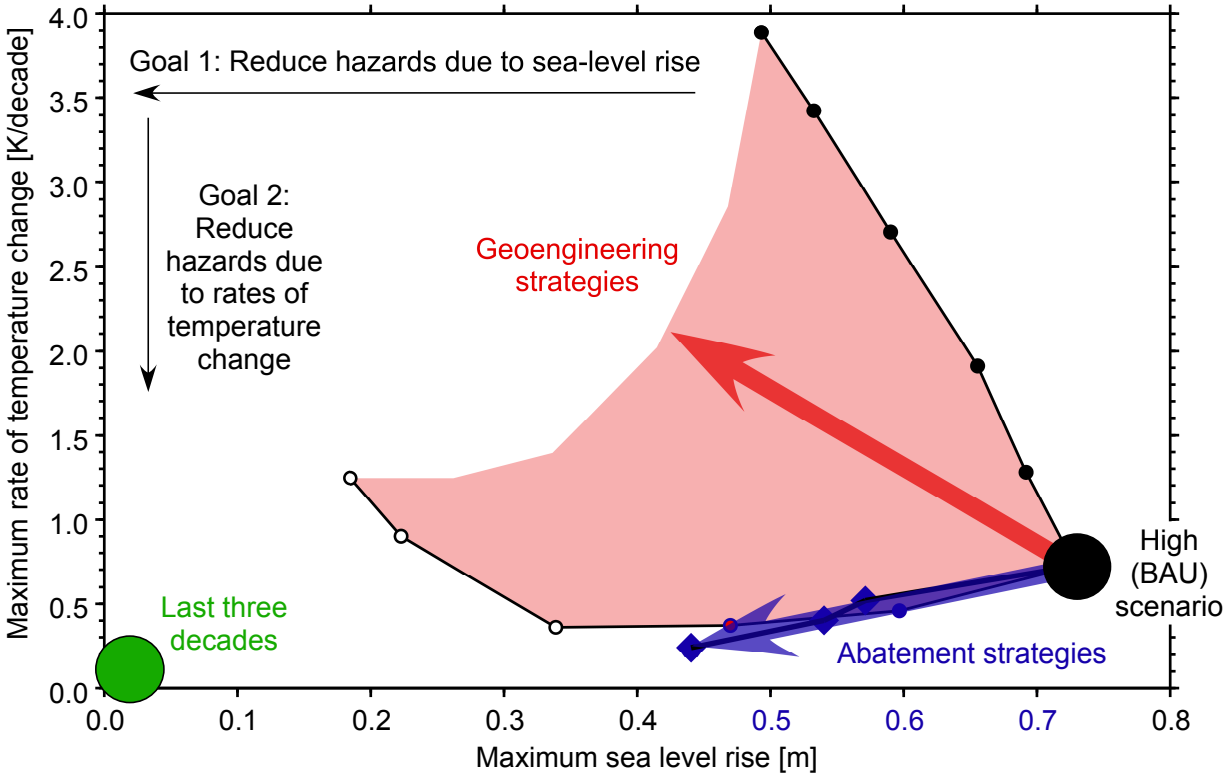


"SRM may be the only human response that can fend off rapid and high-consequence climate impacts." (Keith, Parson, and Morgan, 2010).

What are examples of trade-offs that geoengineering introduces?

There is a potentially strong tension between the objectives of different regions in choosing a geoengineering strategy.

"In a world with similar countries, geoengineering is a Pareto improvement over a policy of only mitigation" (Moreno-Cruz, 2010) => Yes…, but how realistic is this assumption?



What are the effects of
(i) spatial differences in impacts,
(ii) potential threshold responses,
(iii) adaptive capacities, and
(iv) deep uncertainties about Earth system properties, decisionmaking/ethical frameworks?

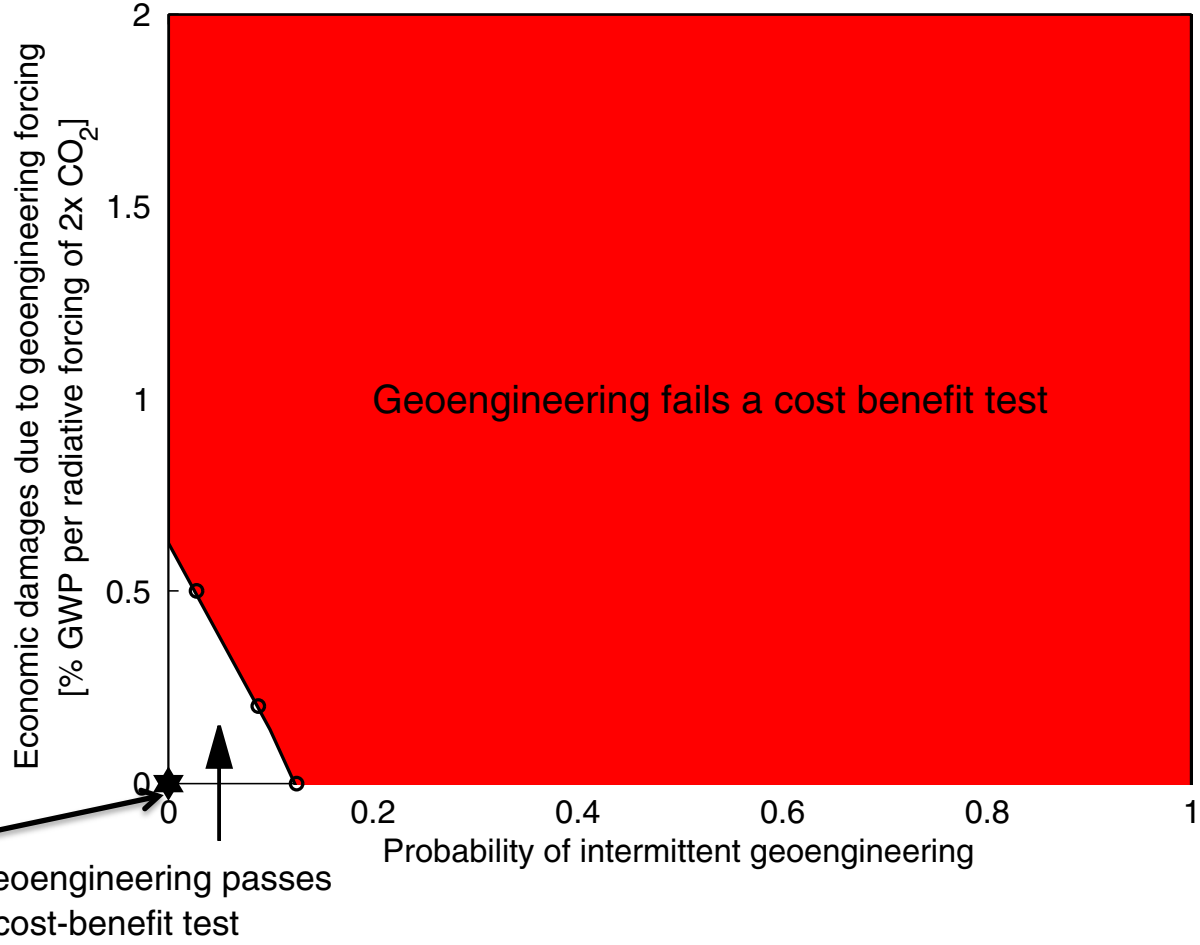
Irvine, Sriver, and Keller, Nature Climate Change (2012)

Does replacing CO_2 abatement with aerosol geoengineering pass a cost-benefit test?

Open questions:

- What are priors for the deeply uncertain model parameters?
- What is the effect of possible learning?
- How fast could we learn?
- What are the effects of parametric and structural uncertainties?
- Are there strategies that perform reasonably well across the deep uncertainties?
- What are trade-offs under different ethical frameworks?

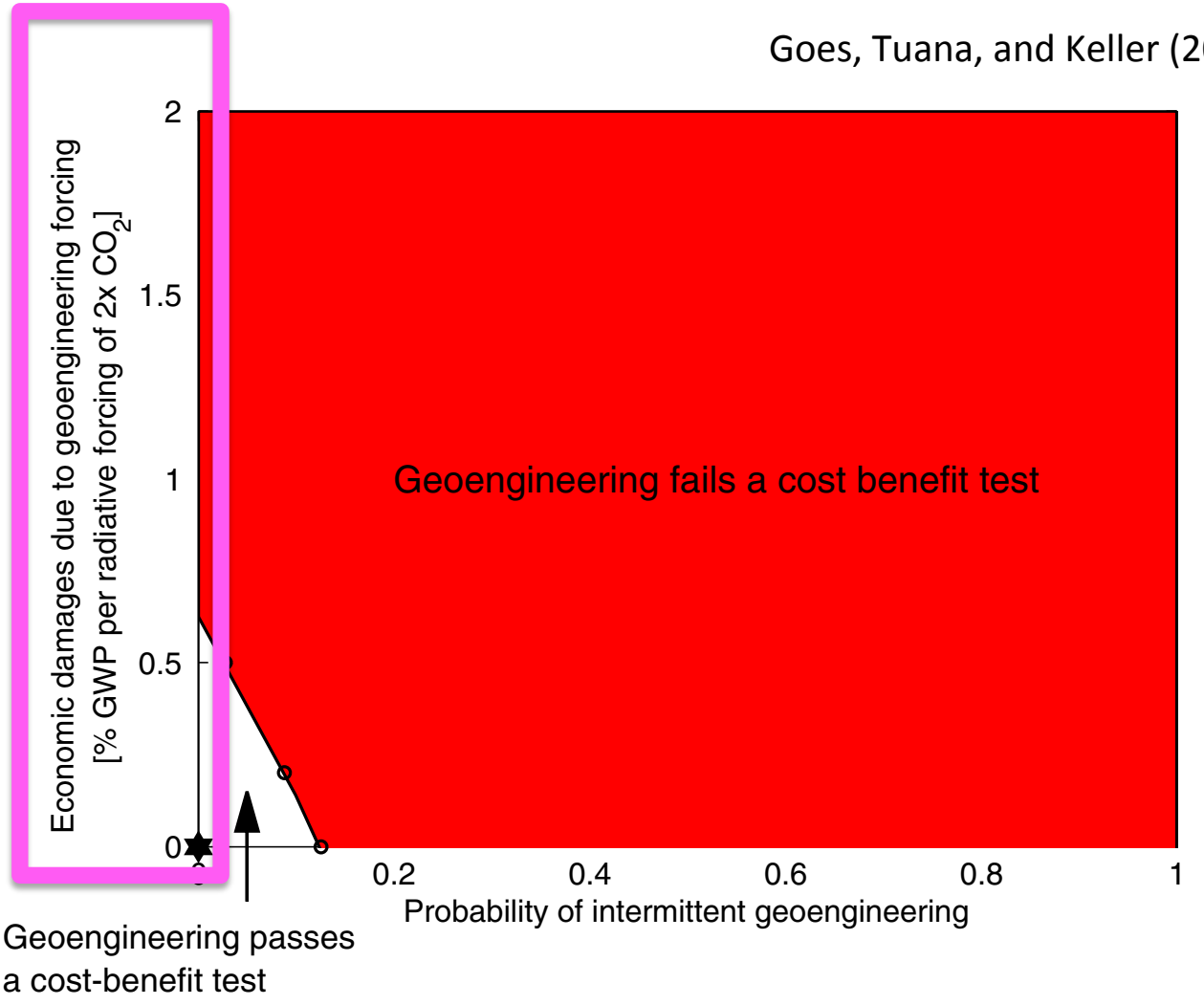
Goes, Tuana, and Keller (2011)



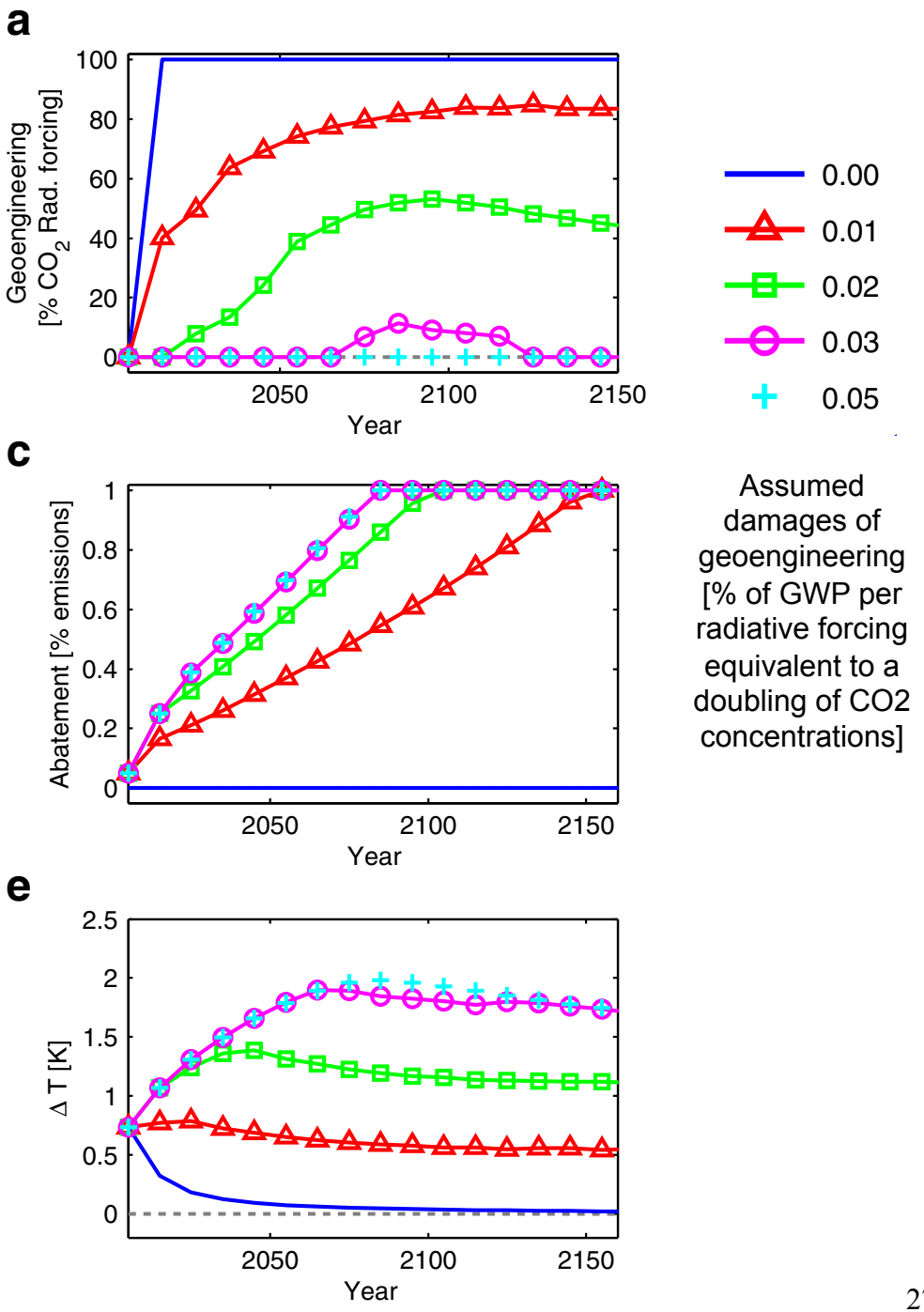
What are dynamic implications for mixed strategies (i.e., a mixture of abatement and geoengineering)?

Goes, Tuana, and Keller (2011)

Focus on sensitivity to one parameter (for now, for simplicity)

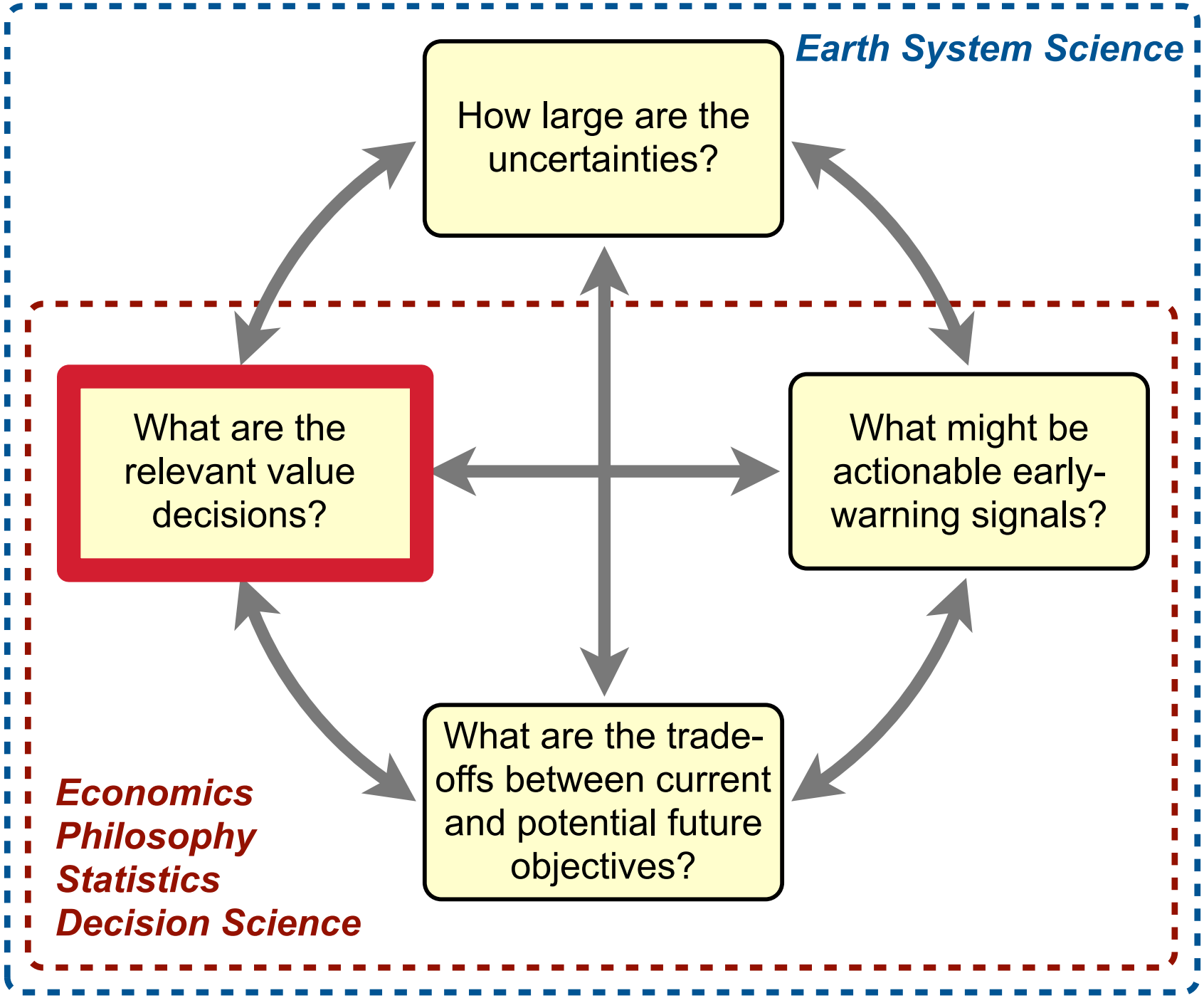


Geoengineering displaces sizable fractions of abatement only for quite optimistic assumption about negative geoengineering side effects.



Assumed damages of geoengineering [% of GWP per radiative forcing equivalent to a doubling of CO2 concentrations]

Goes, Tuana, and Keller (2011)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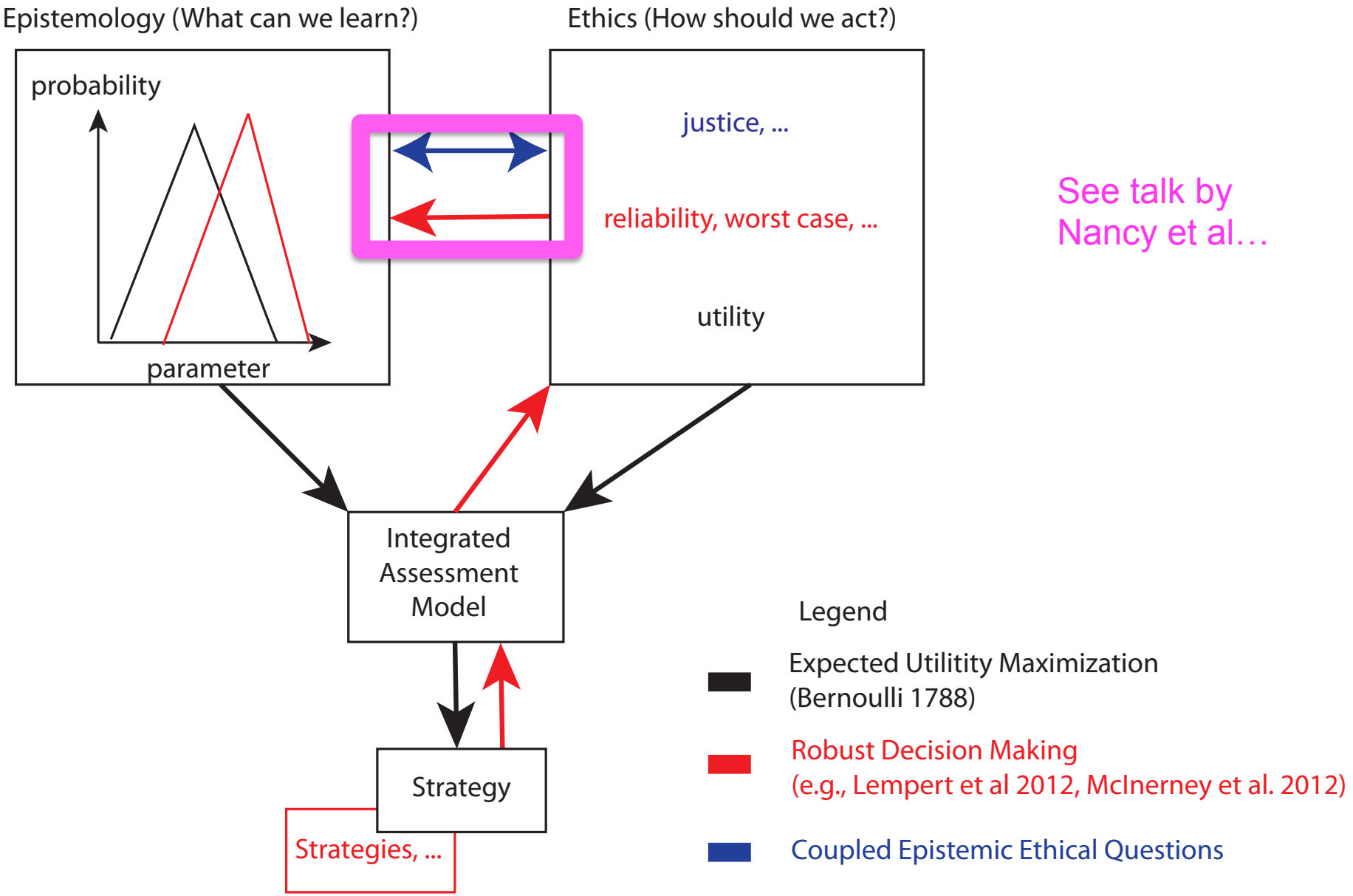
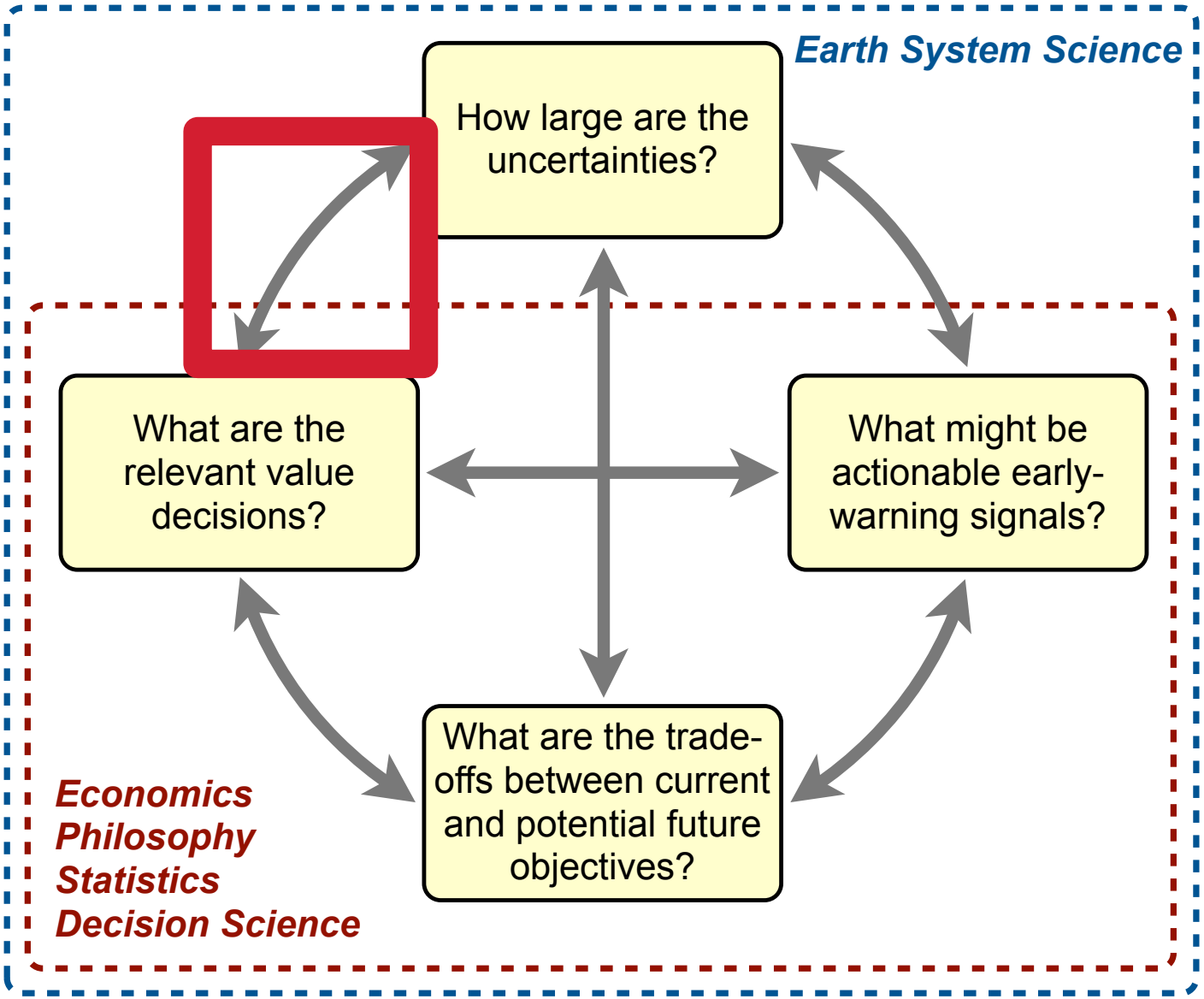
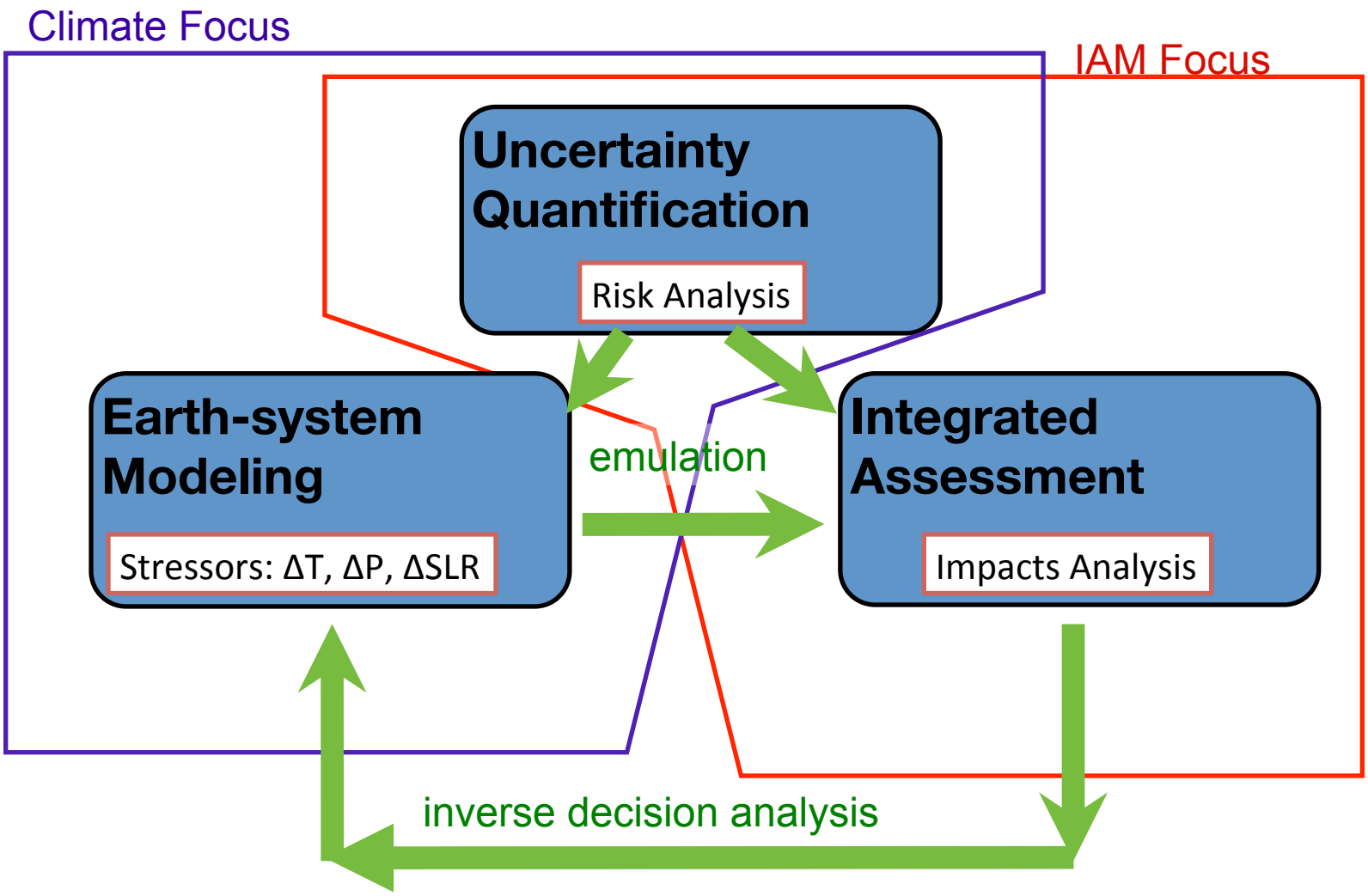


Keller, Tuana, and Lempert (in prep)

Closing the feedback loop

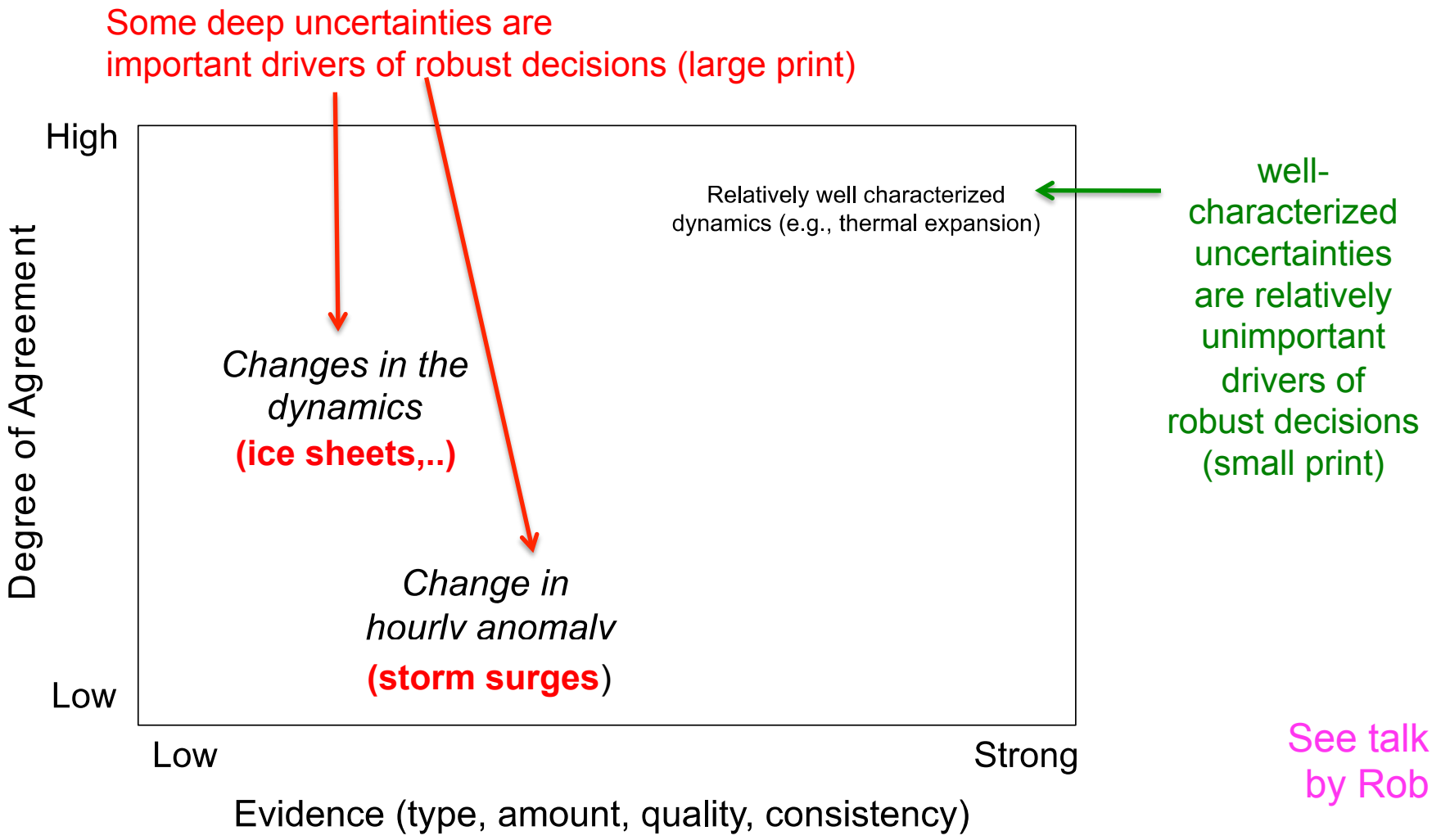


Inverse decision analysis: What are decision-relevant uncertainties?



How does this work in a real-world example?

Which uncertainties are the most important drivers of changes in adaptation strategies to sea-level rise?



See talk by Rob

Lempert, Keller, and Sriver (2012)

Key Points

- Past climate projections often show evidence for overconfidence. One potential reason for this overconfidence is that these projections typically consider only a subset of the decision-relevant uncertainties.
- Inverse decision-analysis and robust decision-making are promising tools to (i) support the mission-orientation of climate science, (ii) point out decision-relevant uncertainties, and (iii) provide decision-support.
- We need to improve education, information, and our tools to better analyze and discuss climate risk management strategies in the face of potential high-impact events.

Thanks to

(Former) PSU students, postdocs, and colleagues:

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- Ryan Sriver
- ….

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- David Budescu
- Robert Lempert
- Damon Matthews
- Peter Irvine
- …

Mentors:

- François Morel
- David Bradford
- Michael Oppenheimer
- …

All errors and opinions are (unless cited) mine.

The Journey ahead

Tad Pfeffer

Threshold behavior in ice sheets- Physical origins of deep uncertainty

Nathan Urban

Characterizing the probability of tail area events in sea-level rise

Bob Kopp

Using the geological past to inform sea-level rise projections

David Johnson

Informing sea-level rise adaptation decisions under deep uncertainty

Robert Lempert

Interplay between adaptation capacity, mitigation, and geoengineering

The Journey ahead

Bill Nordhaus

Modeling irreversible events

Detlef vanVuuren

Representation of geoengineering in Integrated Assessment Models

David Anthoff

Representation of different ethical frameworks in integrated assessment

Granger Morgan

Beyond cost-benefit analysis.

Nancy Tuana

Coupled epistemic ethical issues in analyzing climate risk management strategies