Introduction to Climate Risk

BEE 6940 Lecture 3

February 06, 2023

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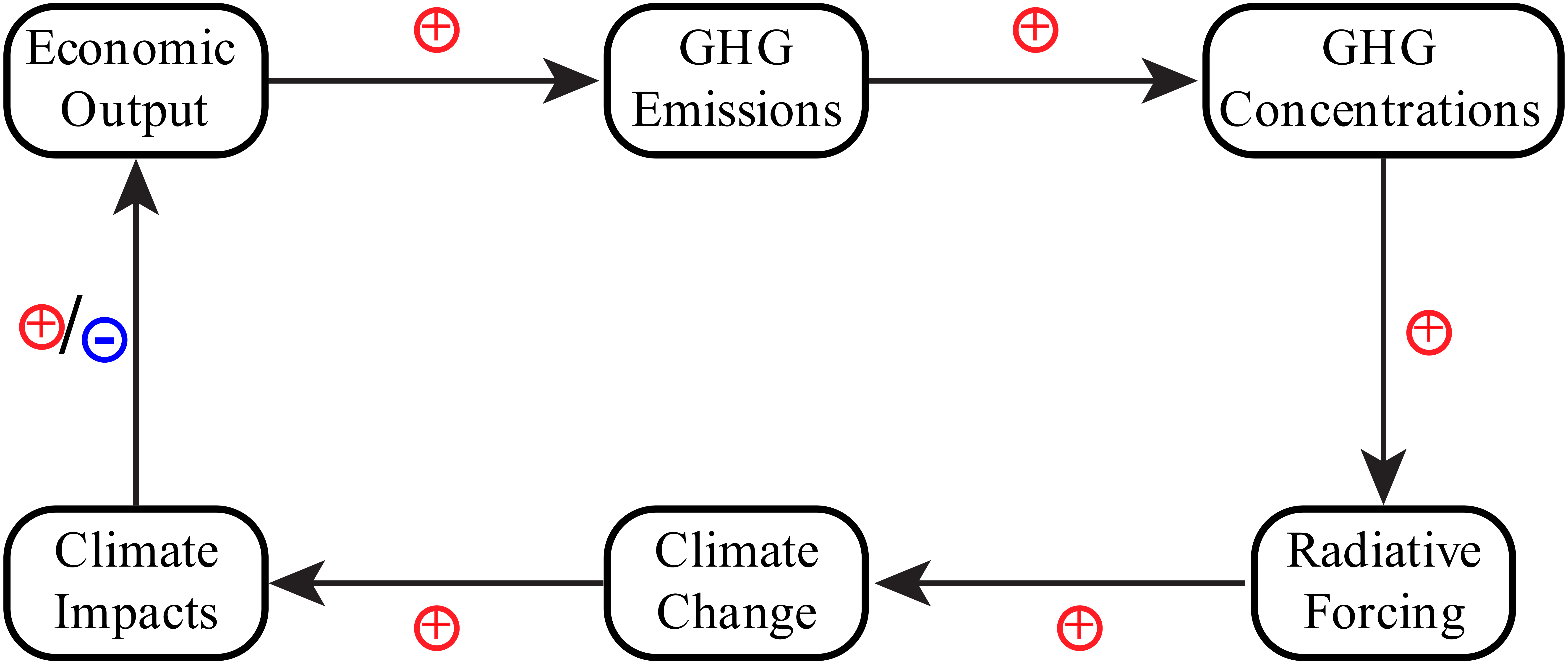
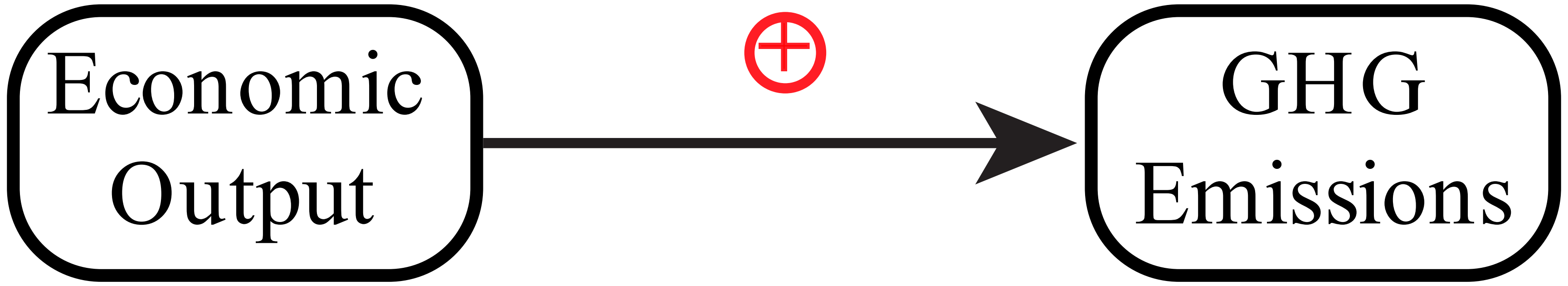
Climate Risk Management

Climate Change Feedback Loop



Adapted from Keller et al (2021)

Feedback Component: Emissions



Key Dynamics: economic output, emissions intensity

Some relevant uncertainties:

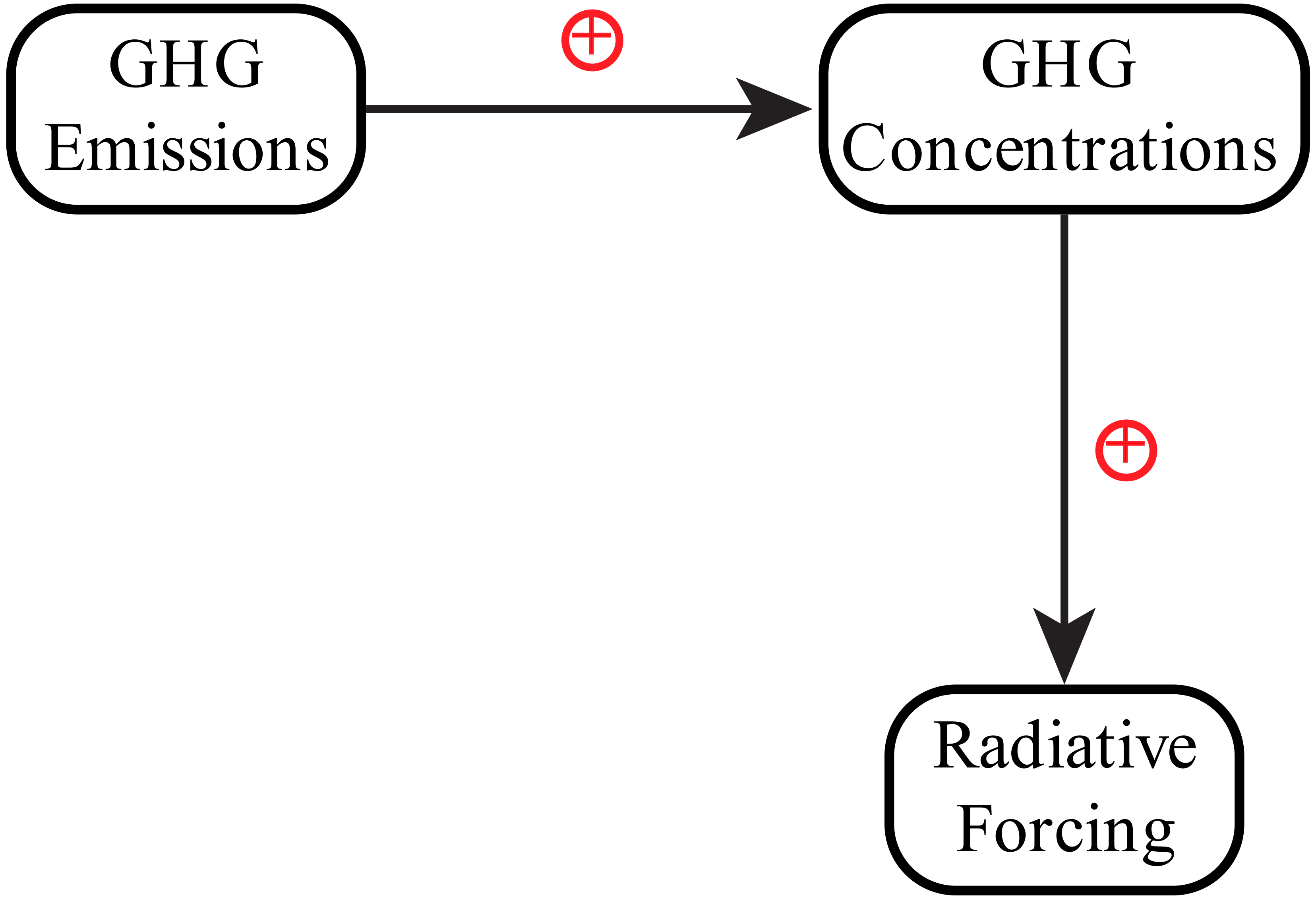
- Economic Growth
- Population Growth
- Technological Change

Feedback Component: Carbon Cycle

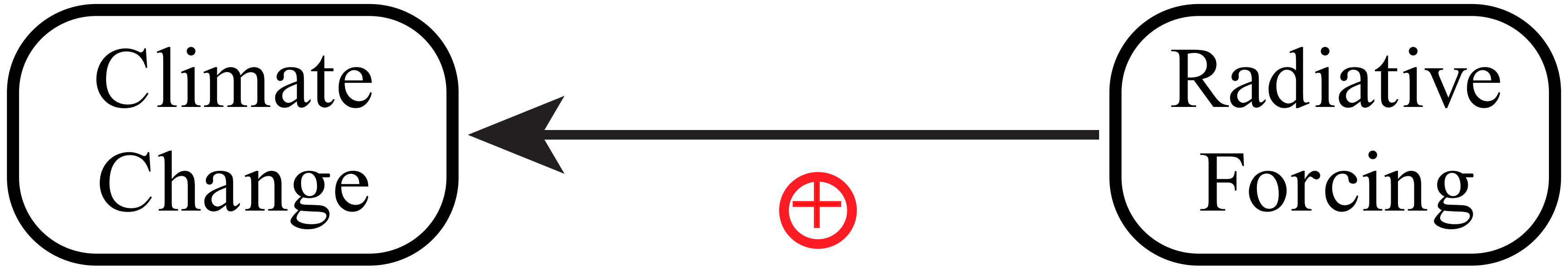
Key Dynamics: carbon storage/diffusion, fertilization/respiration

Some relevant uncertainties:

- Temperature sensitivities
- Total carbon sinks/sources



Feedback Component: Climate



Key Dynamics: greenhouse effect, transient heat transfer, albedo

Some relevant uncertainties:

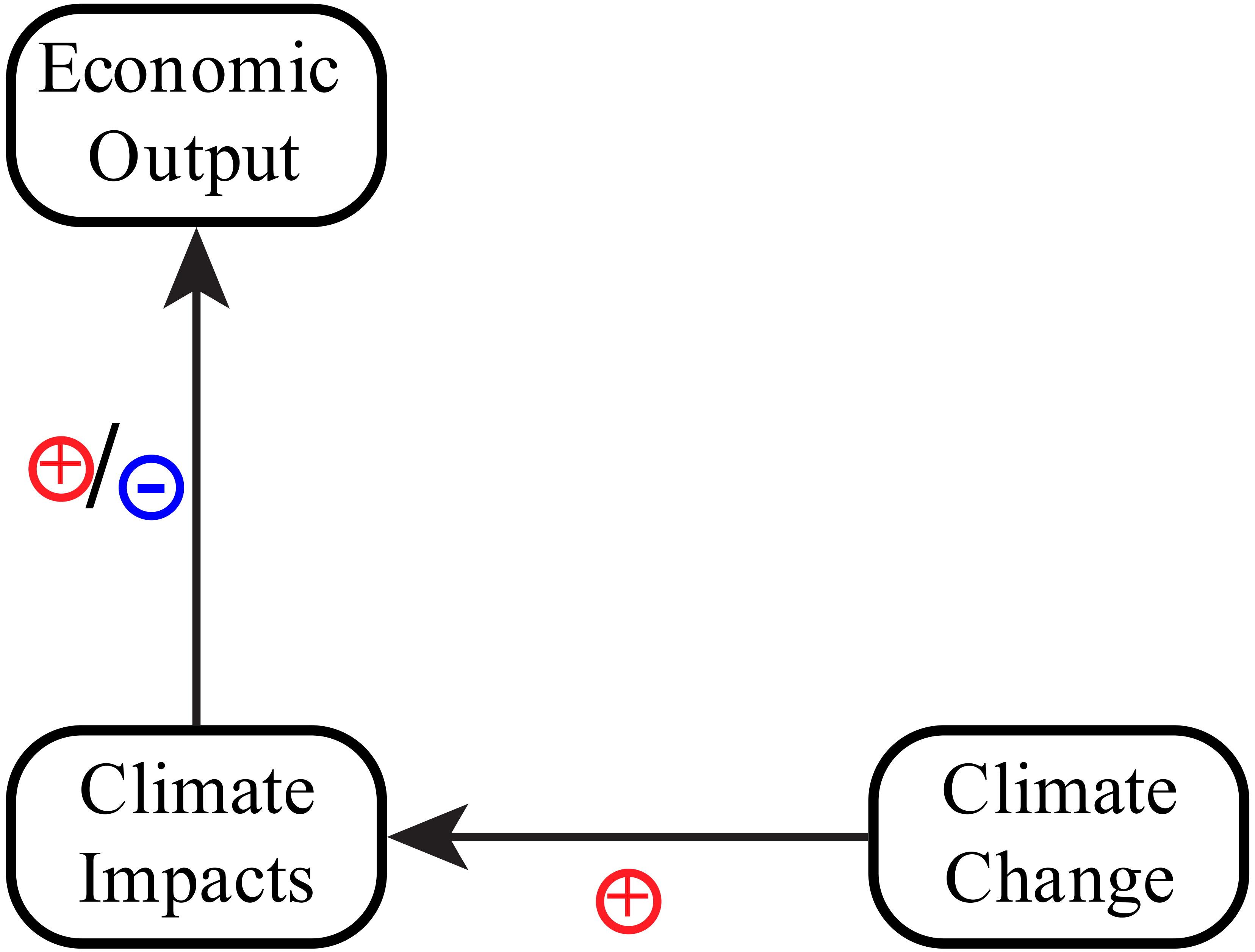
- Equilibrium climate sensitivity
- Ocean heat uptake
- Aerosol-cloud cooling

Feedback Component: Impacts

Key Dynamics: climate dynamics, human-natural system interactions

Some relevant uncertainties:

- Atmospheric/ocean circulations
- Human responses

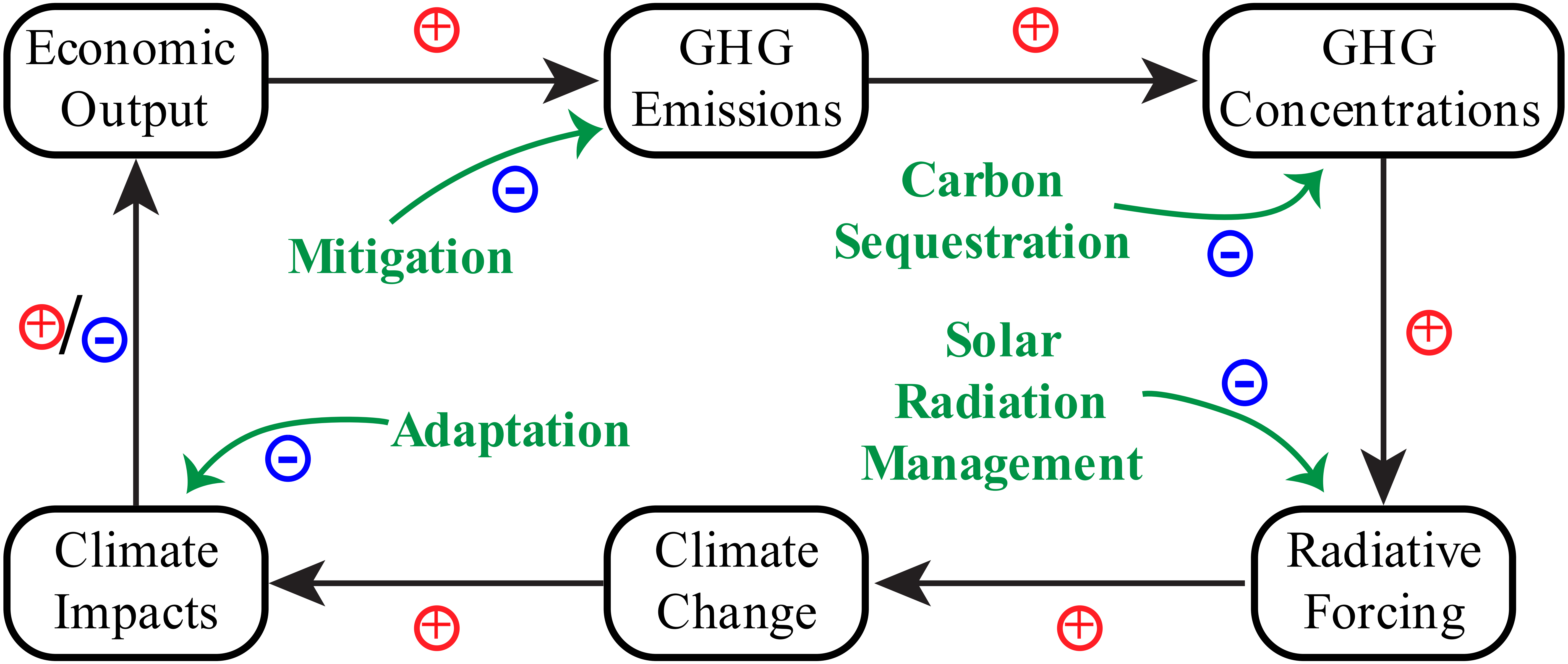


Climate Risk Management

Climate risk can be the result of any (or several!) of these processes.

This makes risk management potentially complicated: there are several possible intervention points, with (often uncertain) downstream implications.

Climate Risk Management Levers



Adapted from Keller et al (2021)

Climate Risk Management Levers

Climate risk management involves choosing among/between this portfolio of approaches, based on a number of factors, including:

- **Relevant uncertainties**
- **Differing spatial/time scales**
- Costs/**benefits**
- **Reliability**
- Stakeholder preferences and values

Climate Risk: Types of Uncertainties

To make things more complicated: climate-relevant uncertainties include both "well-characterized" and "deep" uncertainties, and these uncertainties can be *dynamic*.

- **"Well-characterized" uncertainties**: Those for which we can broadly agree on probability distributions (*e.g.* climate sensitivity)
- **"Deep" uncertainties**: Those for which there is no consensus distribution (*e.g.* future economic growth)

Climate Risk: Types of Uncertainties

To make things more complicated: climate-relevant uncertainties include both "well-characterized" and "deep" uncertainties, and these uncertainties can be *dynamic*.

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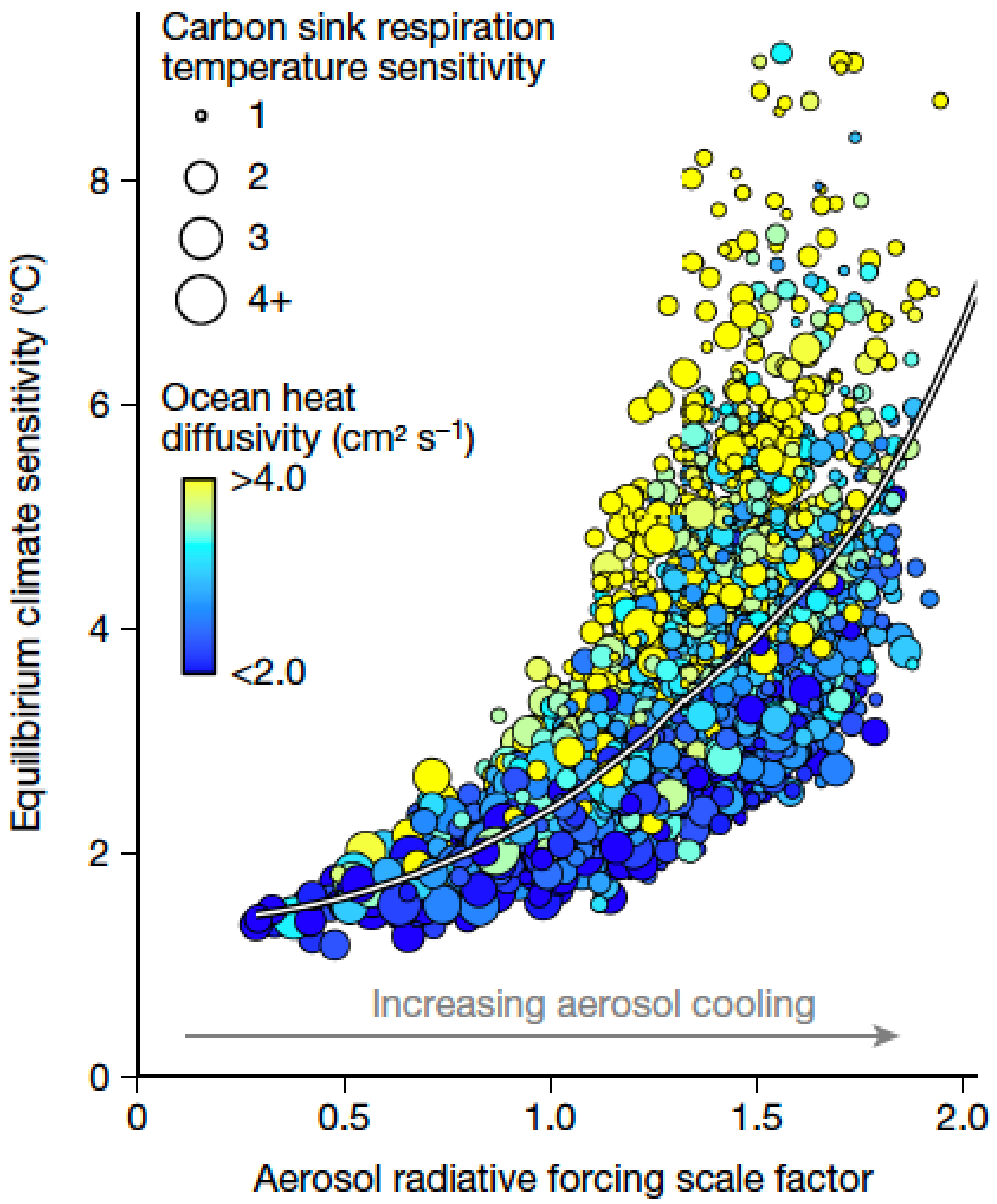
- **"Deep" uncertainties**: Those for which there is no consensus distribution (*e.g.* future economic growth)

More on deep uncertainty later...

Impact of Correlated Uncertainties

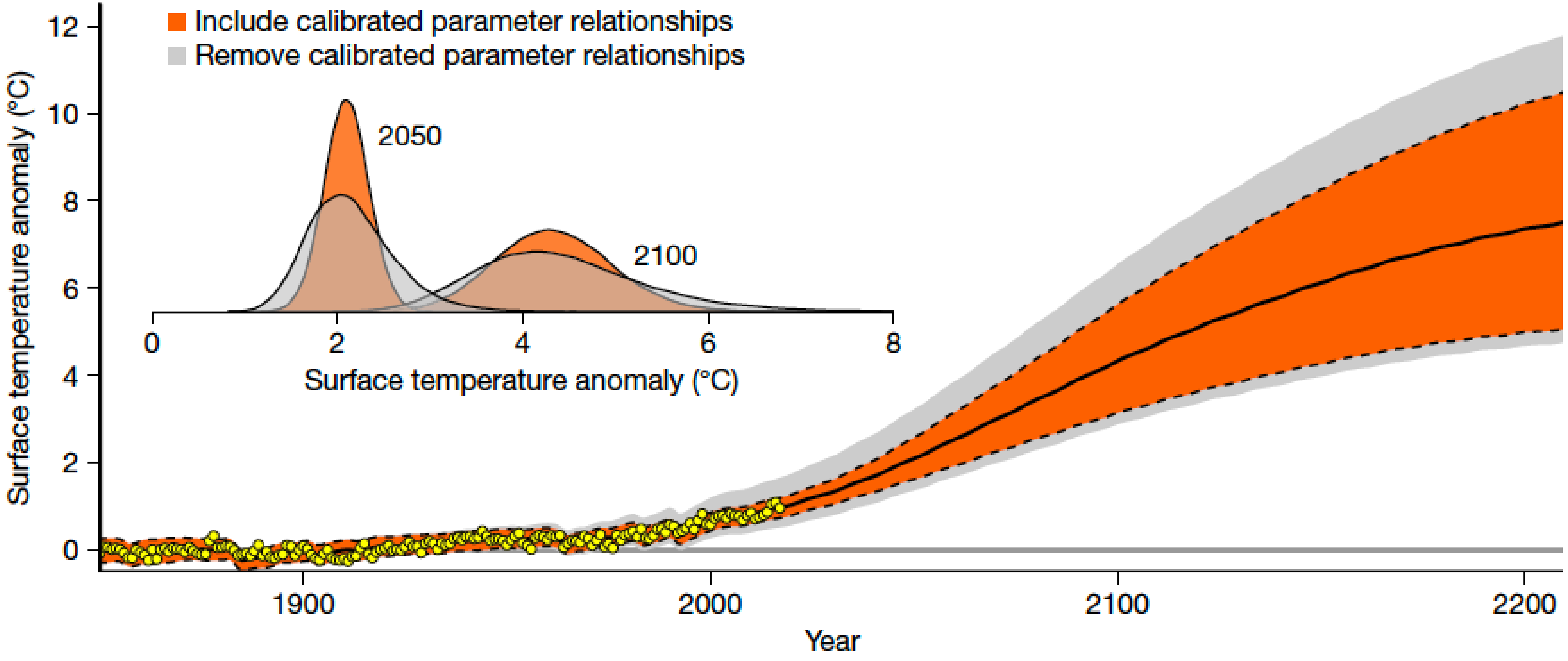
Many relevant uncertainties, even those that are well-characterized, are subject to **correlations**, which can complicate standard statistical approaches assuming independence.



Source: Errickson et al (2021)

Impact of Correlated Uncertainties

Neglecting these correlations can impact projections!



Source: Errickson et al (2021)

Key Takeaways (Climate Risk Management)

- Climate risk is the result of the climate change feedback loop.
- Many relevant uncertainties and processes.
- Several categories of management strategies (levers).
- Subject to deep, dynamic, and correlated uncertainties
- Varying stakeholder preferences.

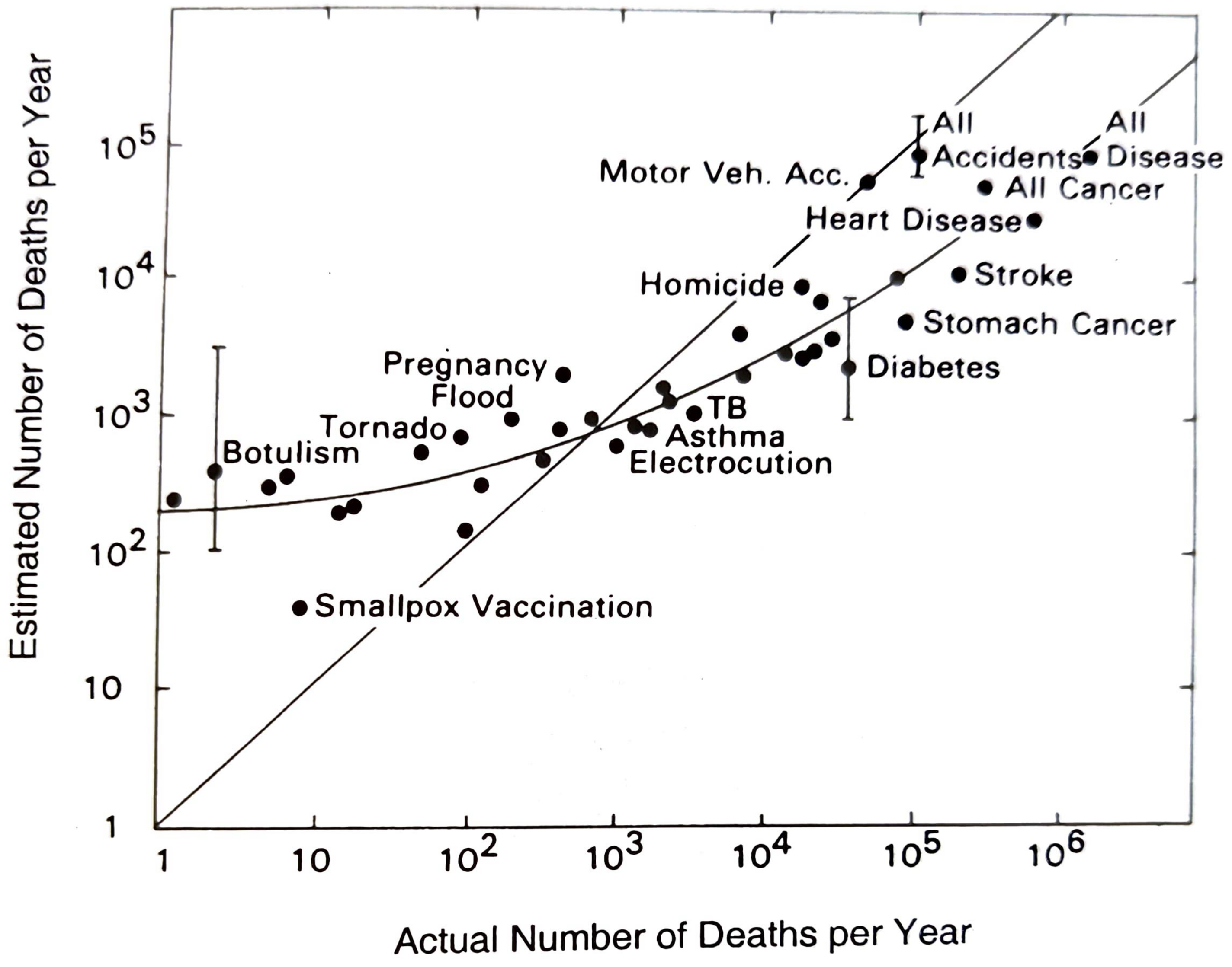
Role of Risk Analysis

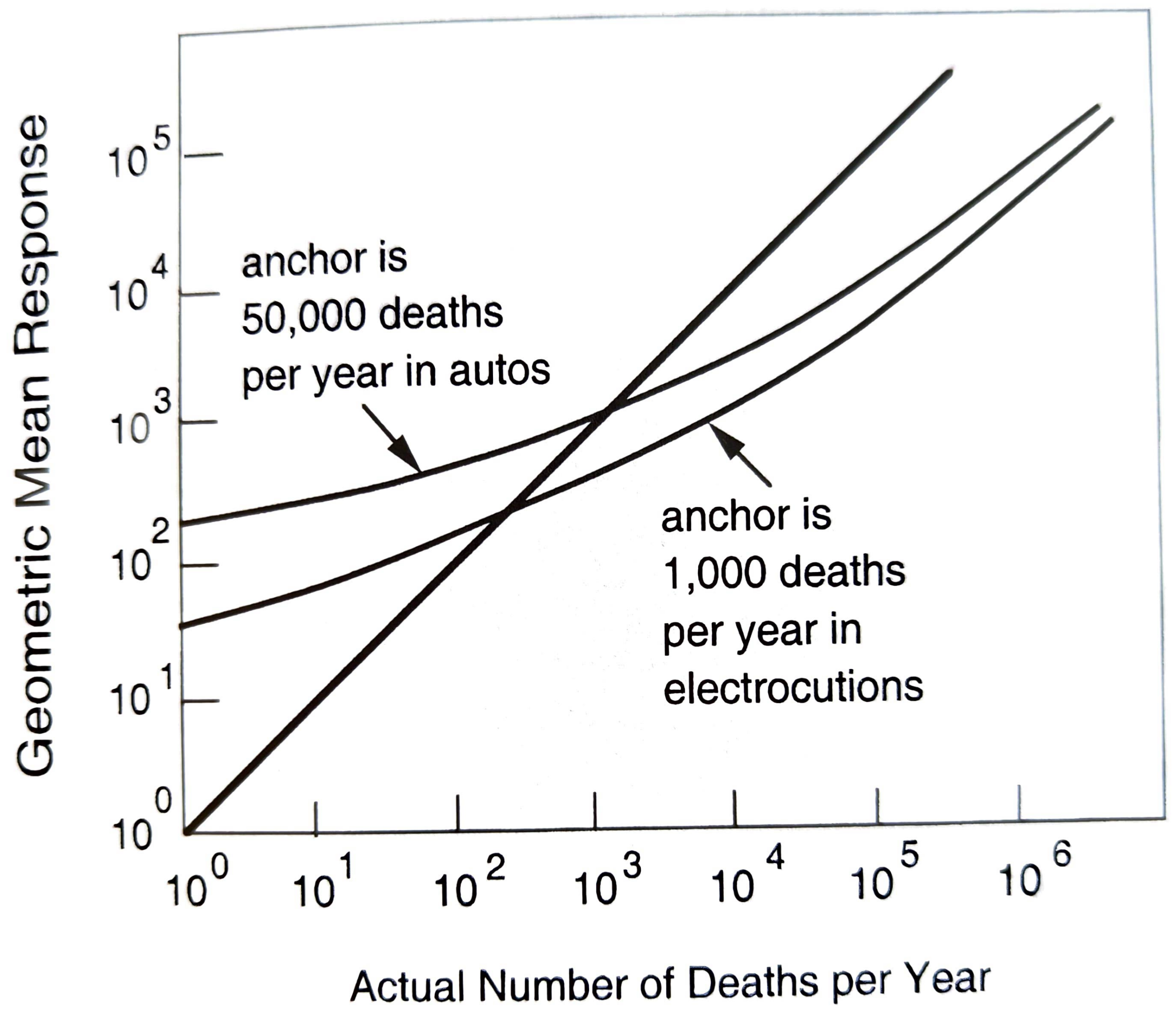
Risk Analysis for Decision Support

The key goal of risk analysis is providing information to help navigate risk management decisions, which may involve differing:

- Perceptions of exposure/vulnerability
- Assessments of hazard probabilities
- Utilities of anticipated losses

Hazard Assessments Are Uncertain





Source: Morgan et al (2002), Risk Communication: A Mental Models Approach
Adapted from Lichtenstein et al (1978)

Diminishing Marginal Value of Utility

> *"There is no doubt that a gain of a thousand ducats is more significant to the pauper than to a rich man though both gain the same amount."*
>
> *— D. Bernoulli (1738), reprinted 1954*

Economists are no longer welcome in Hell.

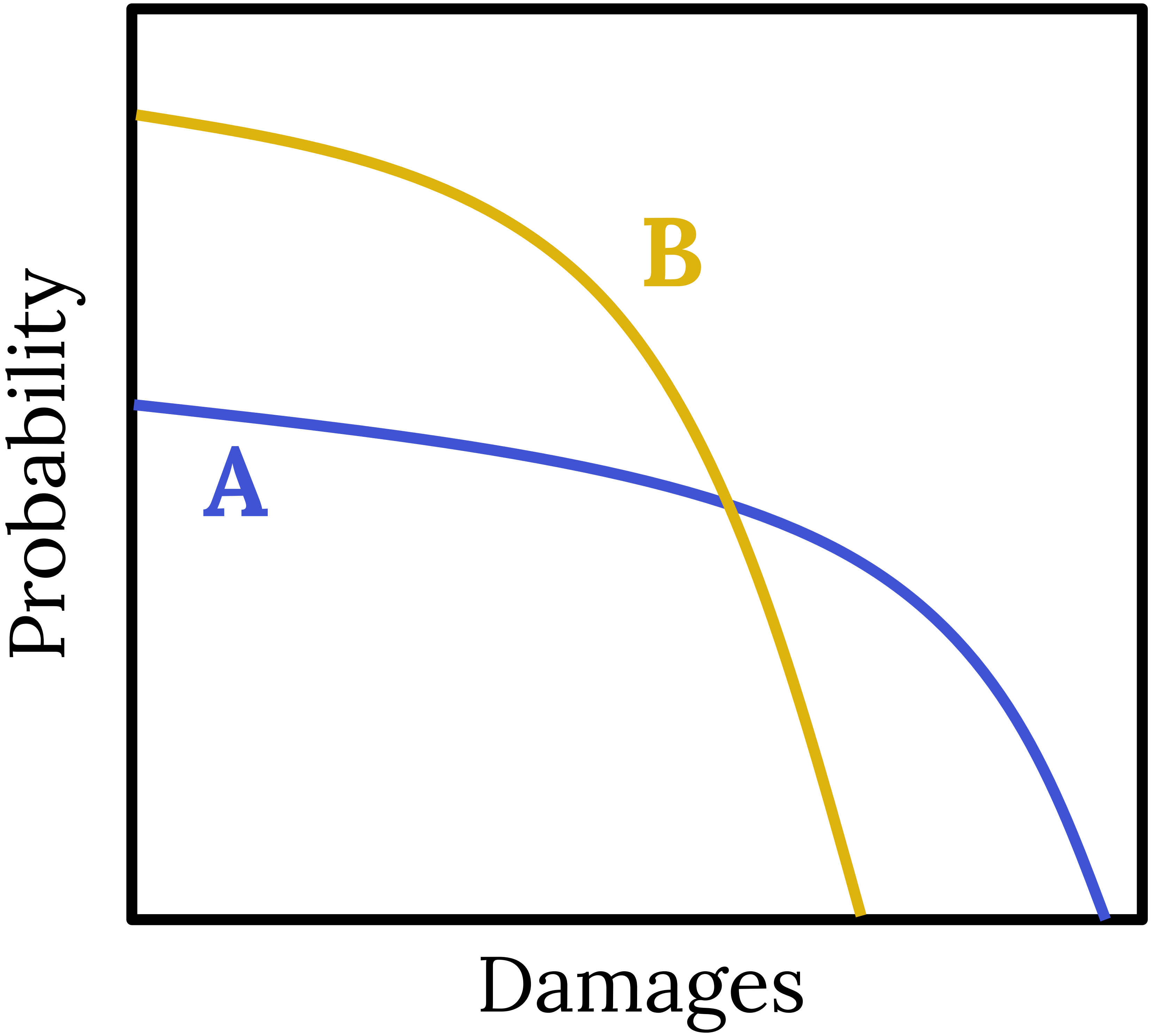
Risk Tolerance Can Be Subjective!

Source: SMBC 05/17/2013

Comparison of Two Risk Profiles

Two risk curves:

- **A**: Increased probability of higher damage events
- **B**: Increased probability of lower damage events



Attitudes Towards Risk

Two scenarios:

1. A certain payout of X?
2. An uncertain payout of $X - d$ or $X + d$, both equally likely?

Attitudes Towards Risk

Two scenarios:

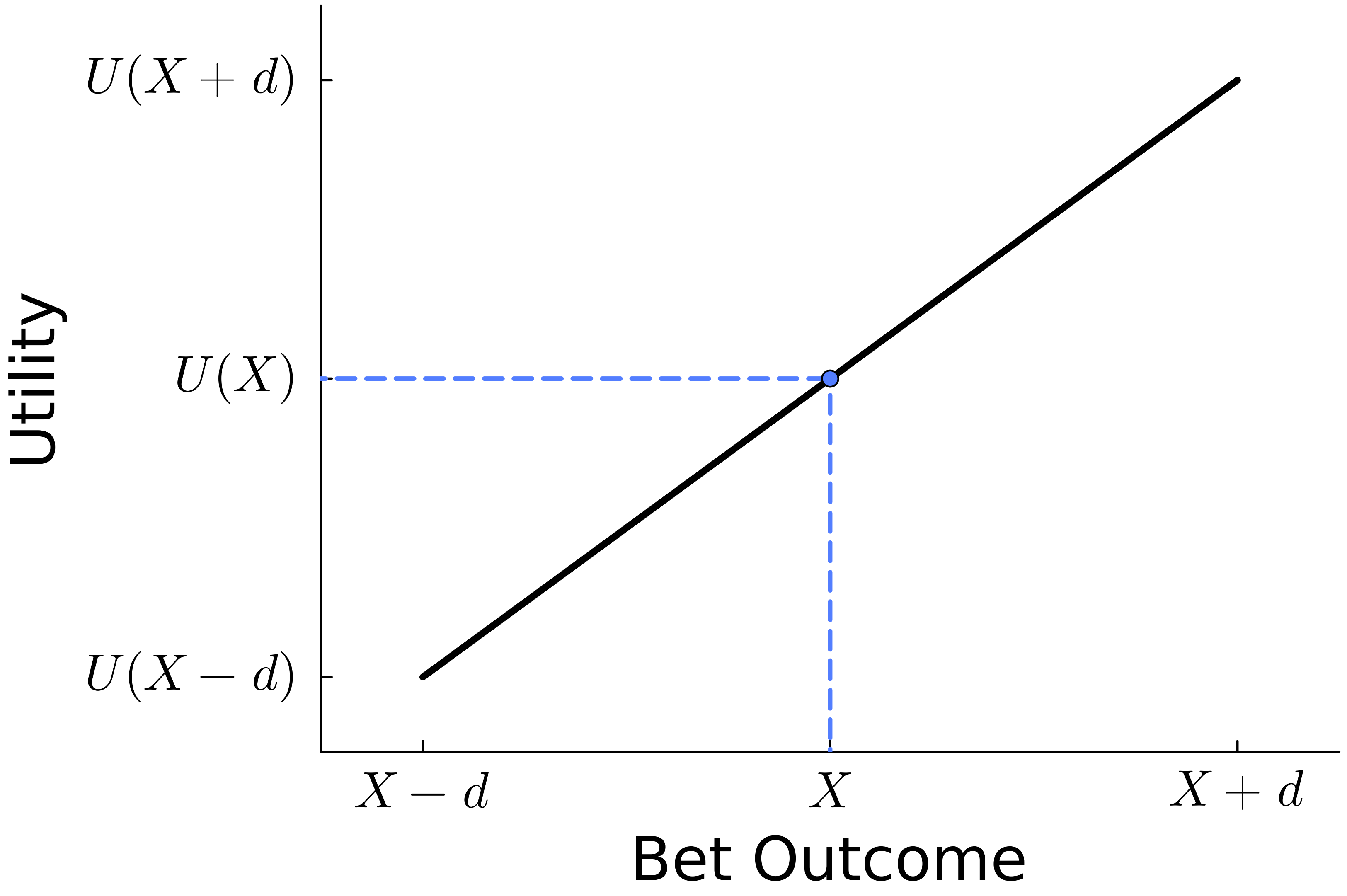
1. A certain payout of X?
2. An uncertain payout of $X - d$ or $X + d$, both equally likely?

Note that both of these "bets" have the same expected payout X. But there are a variety of responses!

Risk Neutral

Linear utility function:

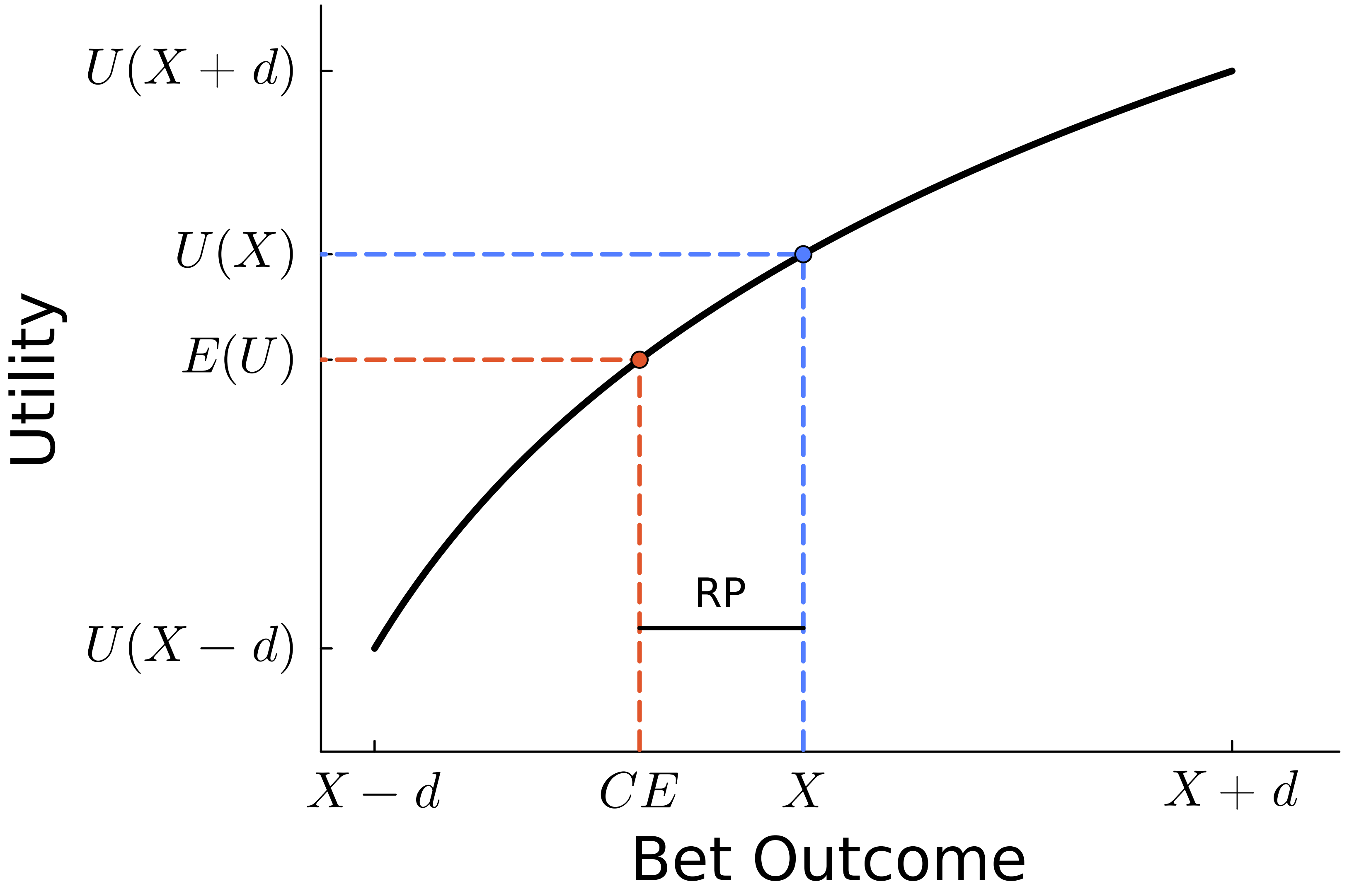
- Expected utility matches expected bet outcome.



Risk Averse

Concave utility function:

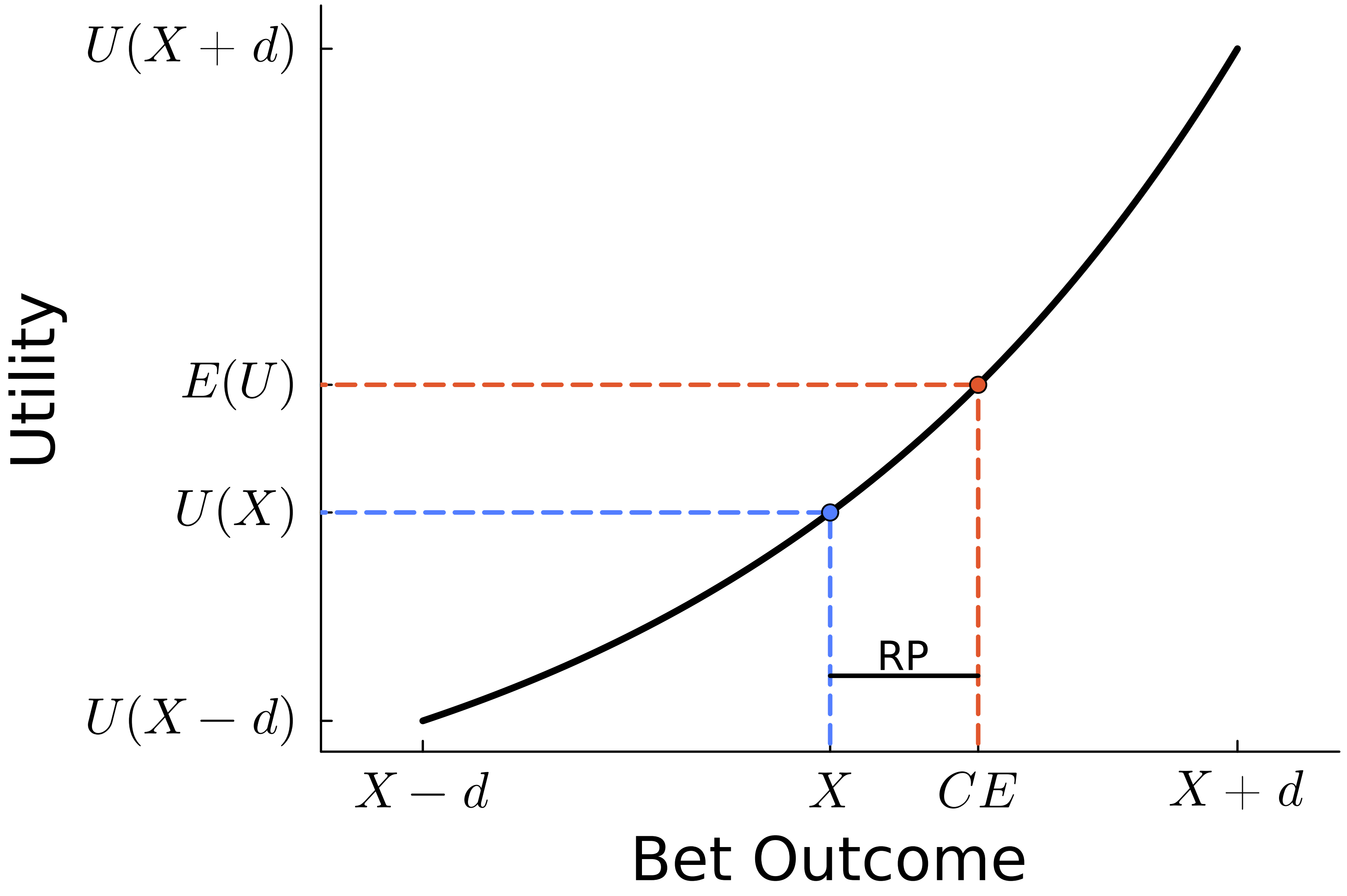
- Greater utility impact from the downside of the bet than upside.
- *Risk Premium (RP)*: "penalty" that would be acceptable to avoid the uncertainty of the gamble.



Risk Seeking

Convex utility function:

- Greater utility impact from the upside of the bet than downside.
- *Risk Premium (RP)*: "bonus" that would be needed to avoid taking the bet.



Takeaways from Expected Utility Theory

- Can use expected utility to rank preferences; what value does an agent assign to outcomes
- Risk-averse/neutral/seeking behaviors reflect tolerance for uncertainty.

Expected Utility and Risk Analysis

Many value-laden questions about utility and risk:

- *Whose* utility should we consider?
- How do we aggregate utilities?
- Do people even have well-defined and consistent utility functions and preferences?
- Is utility-maximization (*rational agent assumption*) actually an appropriate perspective or an accurate description of risk-averse/risk-seeking behavior?
- How can we capture inequities or injustices? Should we?

Expected Utility and Deep Uncertainty

Expected utility theory requires the ability to calculate expectations, which requires probabilities.

But climate risk, as we've seen, involves *deep* uncertainties. What are the implications?

Deep Uncertainty

"Unknown Unknowns"

> *Reports that say that something hasn't happened are always interesting to me, because as we know, there are **known knowns; there are things we know we know**. We also know there are **known unknowns; that is to say we know there are some things we do not know**. But there are also **unknown unknowns — the ones we don't know we don't know**. And if one looks throughout the history of our country and other free countries, it is the latter category that tends to be the difficult ones.*
>
> — *Donald Rumsfeld, former U.S. Secretary of Defense, 2002*

Translating the Word Salad

- **Known Knowns**: Certainty
- **Known Unknowns**: "Shallow" Uncertainty
- **Unknown Unknowns**: "Deep" Uncertainty or ambiguity

Climate Change and Deep Uncertainty

There are many deep climate-relevant uncertainties, including:

- socioeconomic development $\Rightarrow$ emissions;
- technological change;
- politics and policy;
- certain geophysical processes (*e.g.* Antarctic MICI/MISI);
- human-system responses

Scenarios

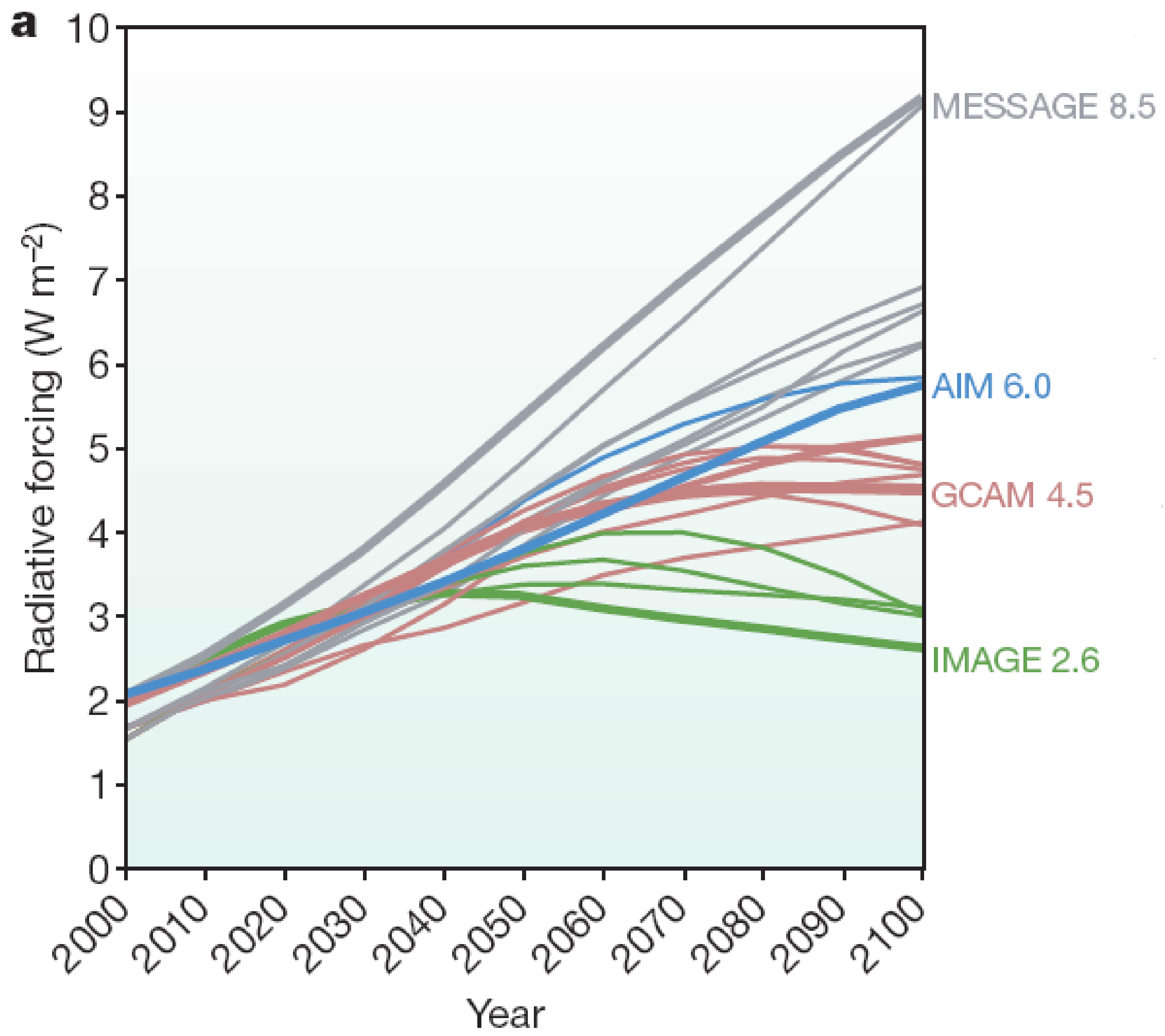
Deep uncertainties are often represented using *scenarios* or future *states of the world*.

For some, "scenario" implies narrative coherence: we will not require this.

Scenarios of Future Climate Change

Future changes to the climate (from socioeconomic development and emissions) are an example of scenario usage.

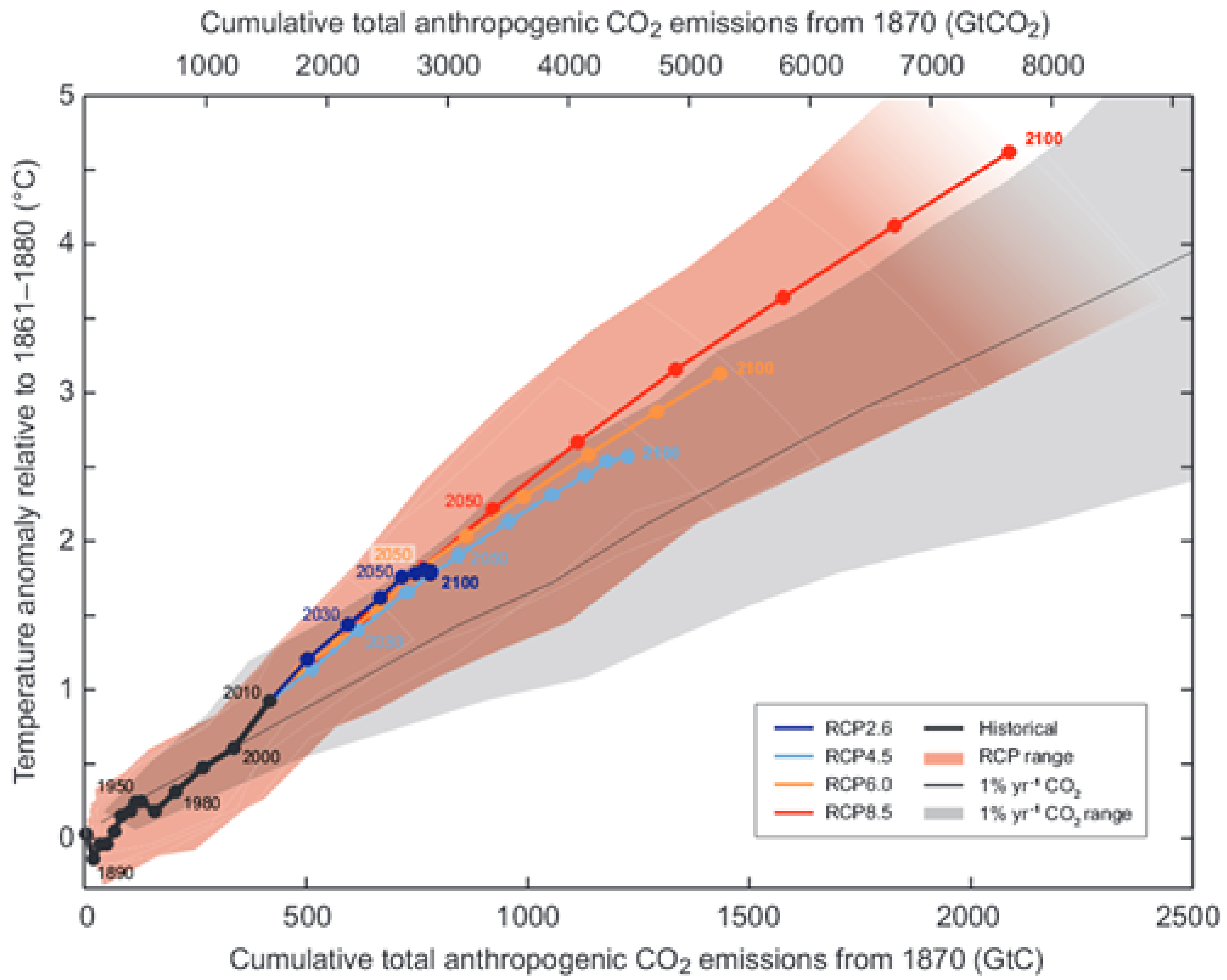
Representative Concentration Pathways



The **Representative Concentration Pathways** (RCPs) are scenarios of future radiative forcing.

Source: Moss et al (2010) via Skeptical Science

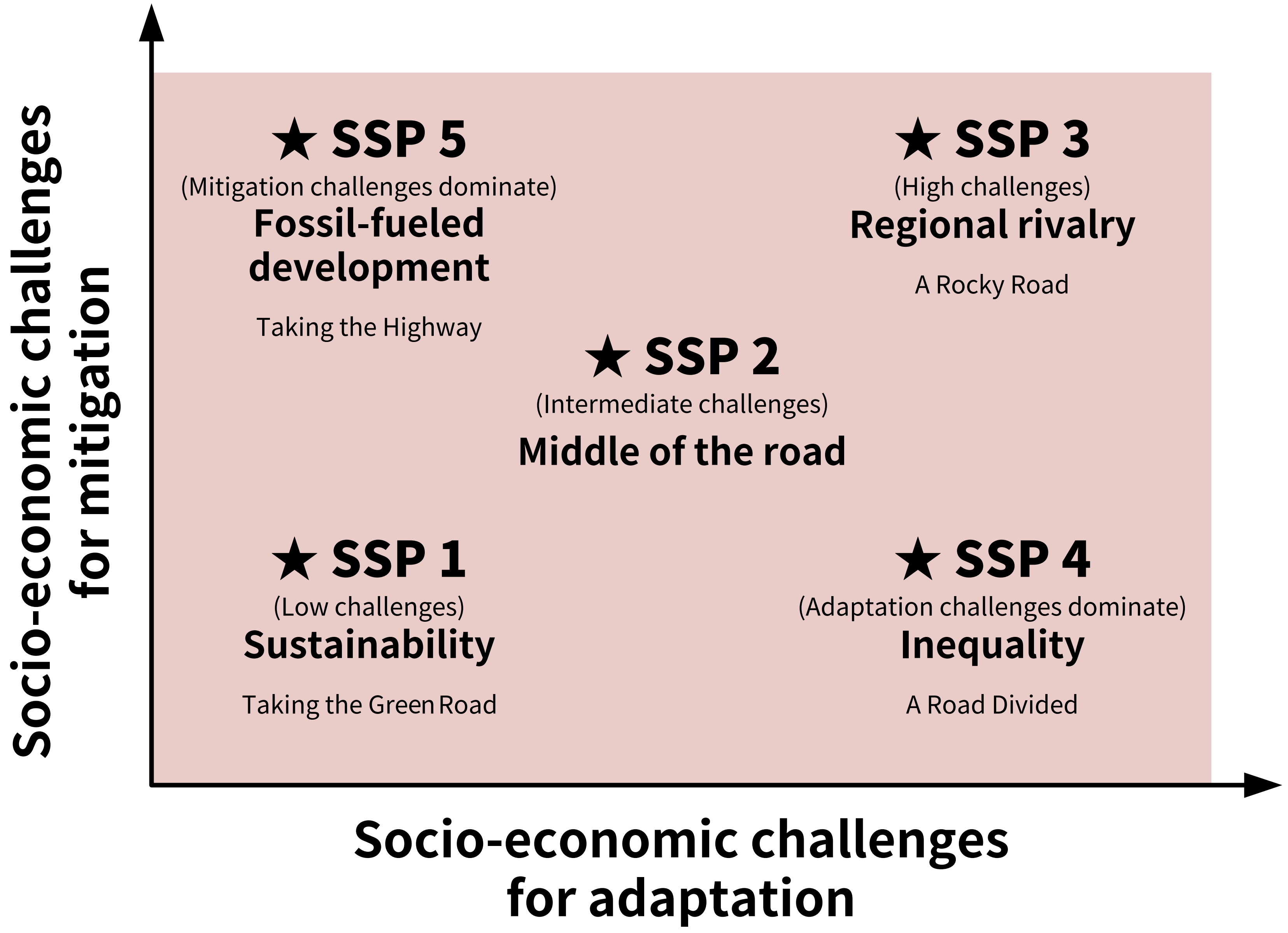
Future Warming Is Largely The Result of Cumulative Emissions



Source: IPCC AR5

Key idea: Considering a *plausible range* of emissions also covers a plausible range of future warming, with less emphasis on the particular pathway.

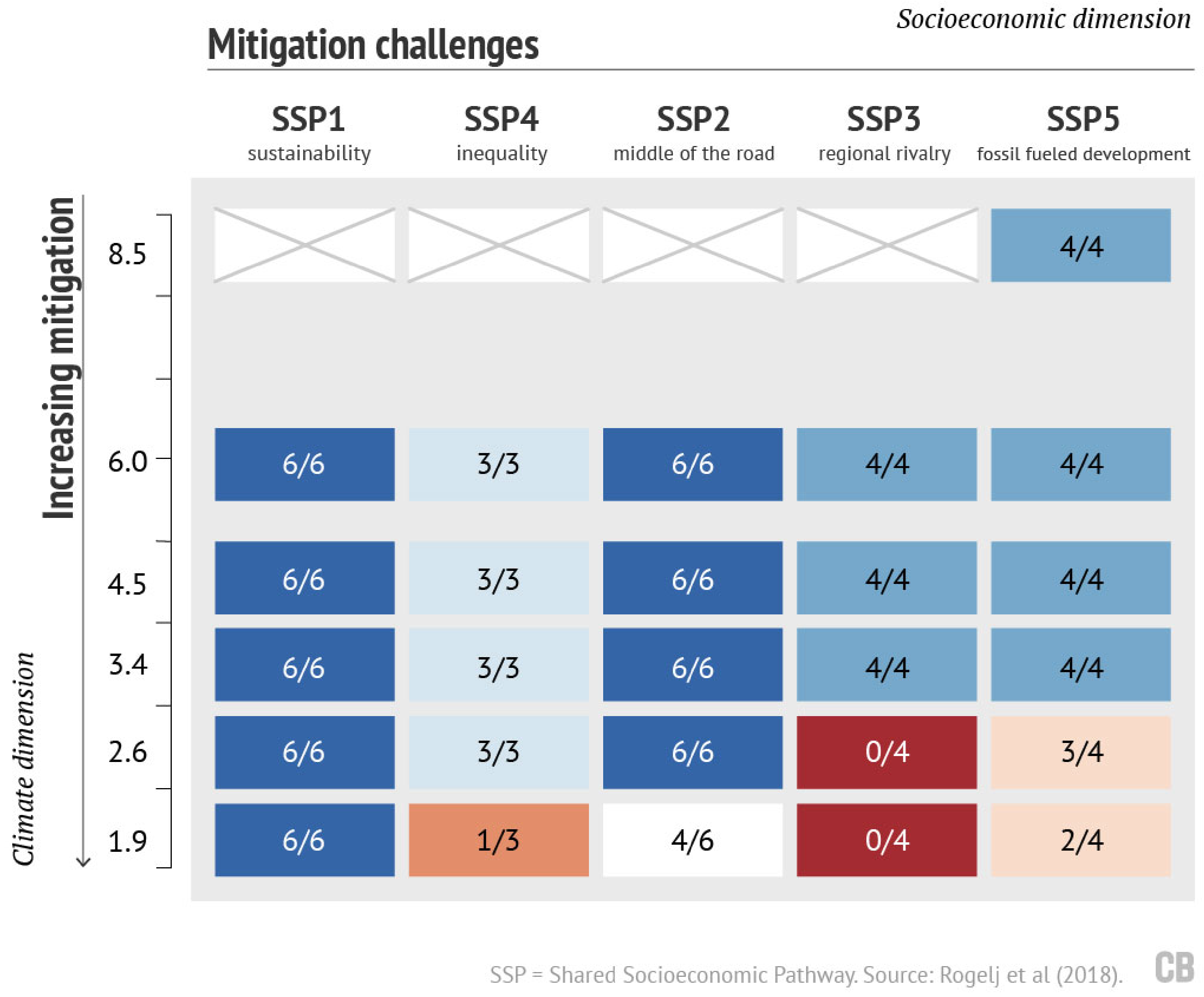
Shared Socioeconomic Pathways



The **Shared Socioeconomic Pathways** (SSPs) are scenarios of future socioeconomic development.

Source: O'Neill et al (2014) via Wikipedia

Latest Generation of Scenarios: SSP-RCPs

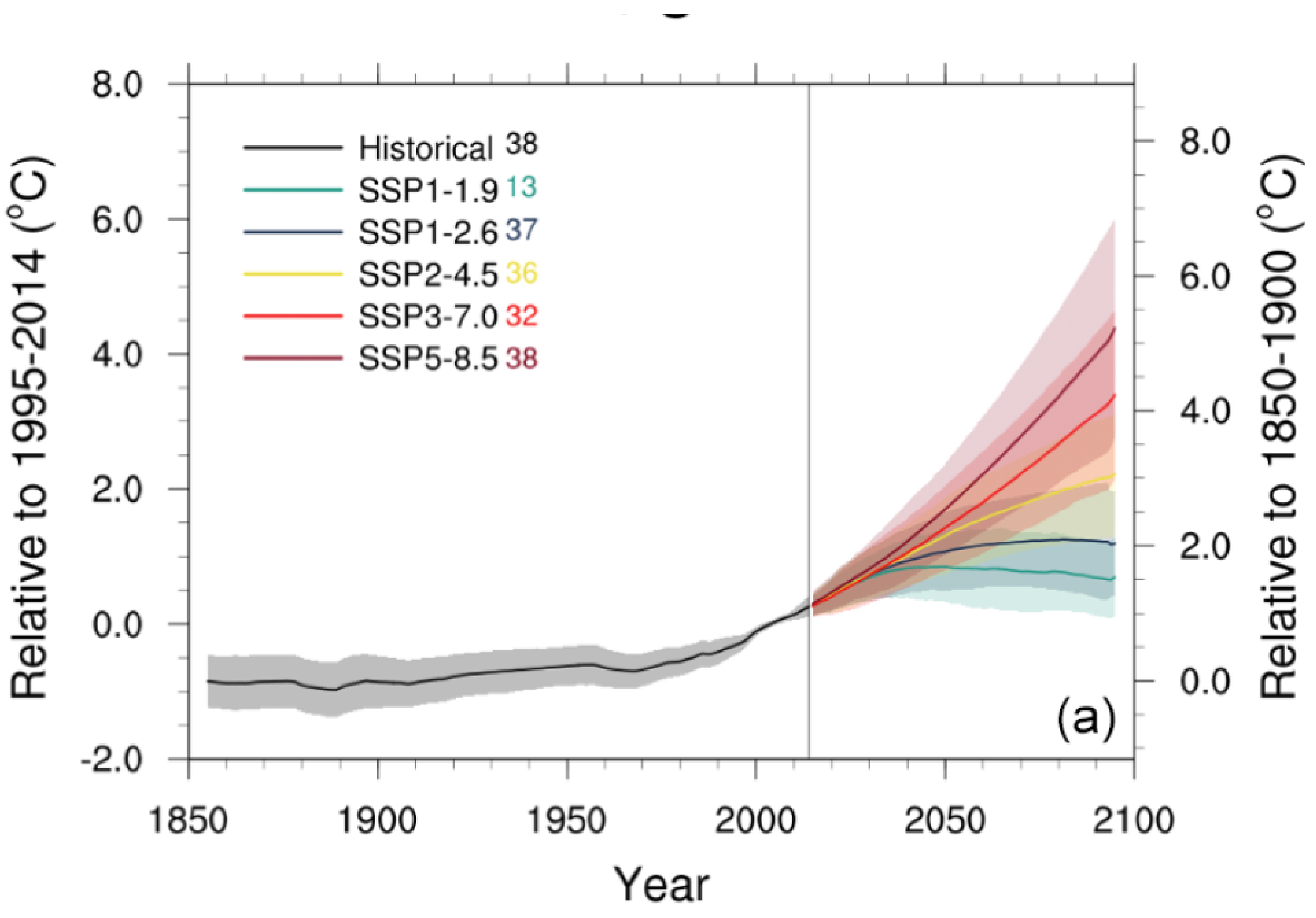


New scenarios (for IPCC Assessment Report 6): combine SSPs and RCPs for more "realistic" emissions scenarios.

Source: Carbon Brief

These Scenarios Are Used to Run Global Climate Models

Global Climate Models (GCMs) are very computationally complex, so their runs are often limited to these scenarios.



Source: Tebaldi et al (2021)

Simple Climate Models vs. GCMs

So-called "simple" climate models can be used to fill in the gaps (more on this in your lab), as they can run more rapidly at the expense of simplified dynamics/more aggregated output.

Decision-Making and Deep Uncertainty

Deep Uncertainty and Utility

How do people make decisions under deep uncertainty?

Let's consider a famous experiment (published in 1961) by Daniel Ellsberg.

Two Urn Game

Consider two urns, each containing 100 balls. **Urn A** has 50 red, 50 black balls, **Urn B** is an unknown mix.

You are offered the following bets:

- **Bet 1A**: get $\$1$ if red ball drawn from Urn A, else $\$0$.
- **Bet 2A**: get $\$1$ if black ball drawn from Urn A, else $\$0$.
- **Bet 1B**: get $\$1$ if red ball drawn from Urn B, else $\$0$.
- **Bet 2B**: get $\$1$ if black ball drawn from Urn B, else $\$0$.

The Ellsberg Paradox (Part 1)

Participants in this experiment were indifferent between 1A and 2A, which is consistent with expected utility theory.

But they also strictly preferred 1A to 1B and 2A to 2B, even though there was no reason to expect that Urn 2 was stacked against them.

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But they also strictly preferred 1A to 1B and 2A to 2B, even though there was no reason to expect that Urn 2 was stacked against them.

Interpretation: People have an aversion to deep uncertainty.

One-Urn Game

Now there is only one urn, with *30 red balls* and *60 (black or yellow) balls* (in unknown proportions)

Four bets:

- **Bet A**: you win $\$100$ if you draw a red ball;
- **Bet B**: you win $\$100$ if you draw a black ball;
- **Bet C**: you win $\$100$ if you draw a red or yellow ball;
- **Bet D**: you win $\$100$ if you draw a black or yellow ball;

The Ellsberg Paradox (Part 2)

Ellsberg found subjects prefer Bet A to Bet B. This is consistent with the Two Urn game: deep uncertainty aversion.

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Expected utility theory implies that people's preferences are reflective of their beliefs about probabilities.

But the combination of these two bet preferences is **inconsistent** with any consistent assignment of probabilities!

Implications for Climate Scenarios

The decision to make climate scenarios (SSPs/RCPs) probability-free is defensible (though was debatable at the time, see Schneider et al (2001)).

However:

- Debate over scenario plausibility;
- "Misuse" of scenarios;
- Overemphasis of RCP 8.5 in impacts literature (*availability heuristic*);
- Aversion to deep uncertainty.

Wrap-Up and Upcoming Schedule

Key Takeaways

- Climate risk evolves along the climate change feedback loop.
- Risk analysis/management complicated by presence of correlated and deep and dynamic uncertainties.
- Aversion to deep uncertainty, decision heuristics can complicate use of probability-free scenarios.

Upcoming Schedule

Wednesday: Discuss Morgan & Keith (2008) and lab on using simple climate models.

Next Monday: Overview of coastal flood risk management problem.