

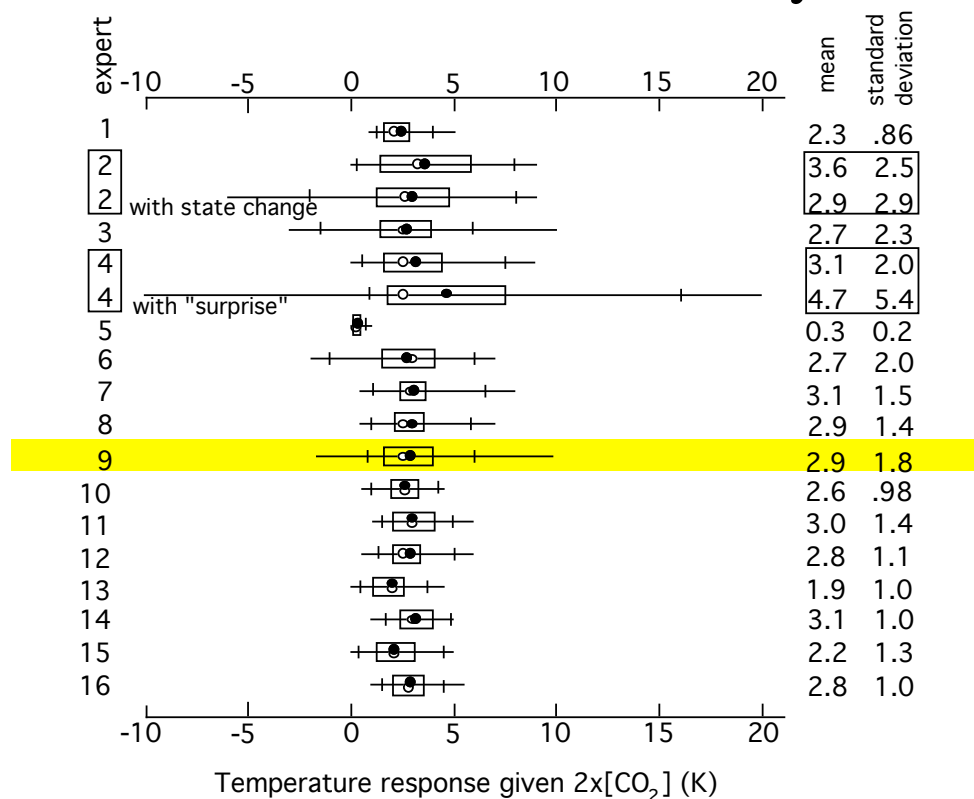
Probabilistic Estimation of “Dangerous” climate change.

[Please, do not take model-dependent “results”
literally, but please consider the framework
seriously!]

Stephen H. Schneider
Aspen Global Change Institute
13 March 2004

An example:

David Keith and I conducted a set of expert elicitations among 16 leading climate scientists in 1994. The figure summarizes their estimates of climate sensitivity for a $2\times\text{CO}_2$ climate change.



At the end of the interview, after the experts had designed a $\$10^9/\text{yr}$ 15yr research program designed to *reduce* this and other key uncertainties, we asked the experts to tell us how they thought their estimates of climate sensitivity might change.

Overall...

...the experts estimated that, after a \$10⁹/yr 15 year research program designed to *reduce* the key uncertainties we'd been discussing, the chances that the uncertainty in their best estimate of climate sensitivity might *grow* by > 25% ranged from a low of 8% to a high of 40%!

Like all experienced scientists, they knew that research does not always reduce uncertainty.

Source: Morgan and Keith, 1995.

Expert Number	Chance climate sensitivity uncertainty grows >25% after a 15yr. \$ 10 ⁹ /yr research program
1	10
2	18
3	30 (Note 1)
4	22
5	30
6	14
7	20
8	25
9	12
10	20
11	40
12	16
13	12
14	18
15	14
16	8

Note 1: Expert 3 used a different response mode for this question. He gave a 30% of an increase by a factor of ≥ 2.5 .

Variations of the Earth's surface temperature: years 1000 to 2100

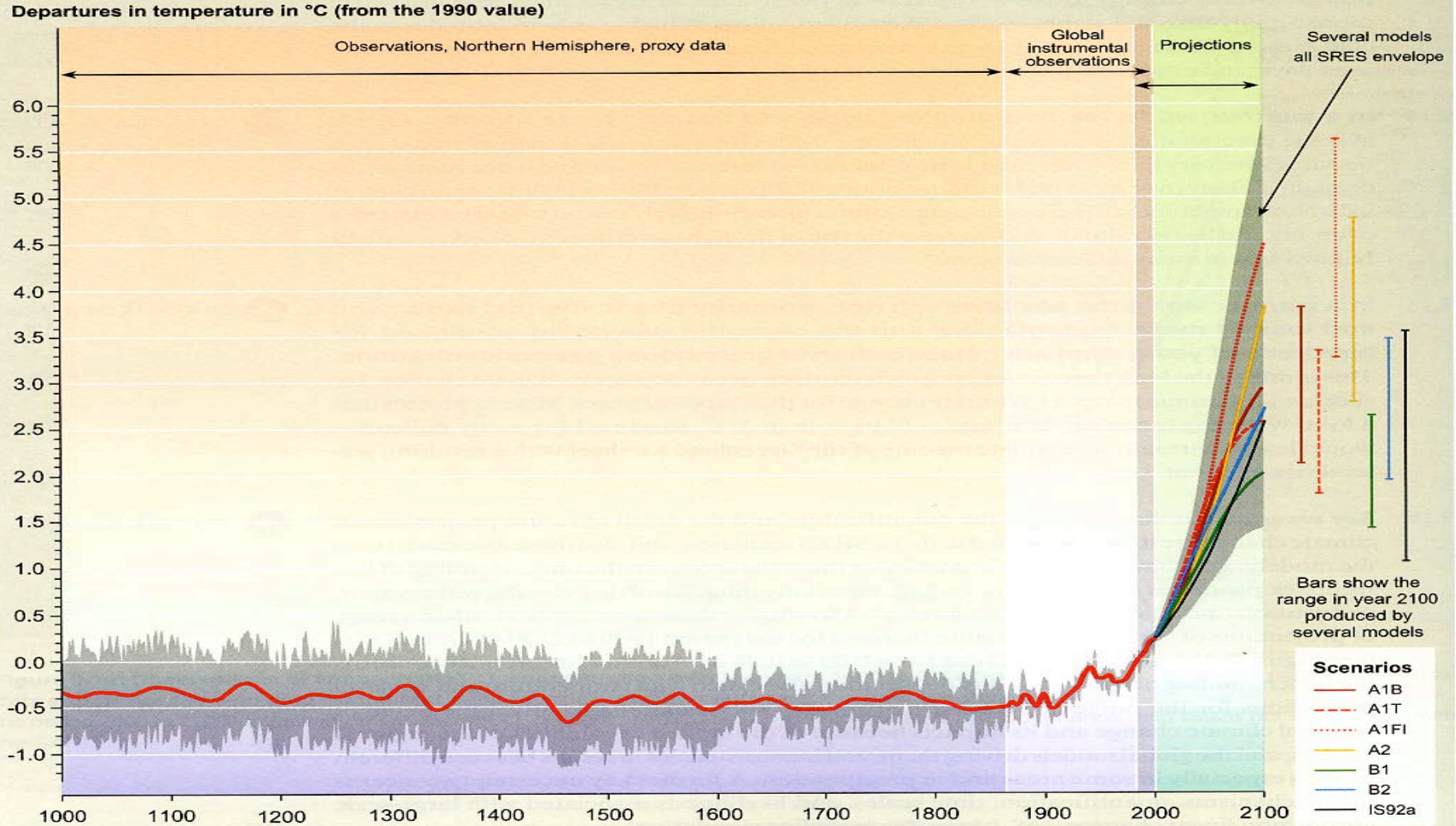


Figure 9-1b: Variations of the Earth's surface temperature: years 1000 to 2100. Over the period 1000 to 1860, observations are shown of variations in average surface temperature of the Northern Hemisphere (corresponding data from the Southern Hemisphere not available) constructed from proxy data (tree rings, corals, ice cores, and historical records). The line shows the 50-year average, and the grey region the 95% confidence limit in the annual data. From the years 1860 to 2000, observations are shown of variations of global and annual averaged surface temperature from the instrumental record. The line shows the decadal average. Over the period 2000 to 2100, projections are shown of globally averaged surface temperature for the six illustrative SRES scenarios and IS92a as estimated by a model with average climate sensitivity. The grey region "several models all SRES envelope" shows the range of results from the full range of 35 SRES scenarios in addition to those from a range of models with different climate sensitivities.

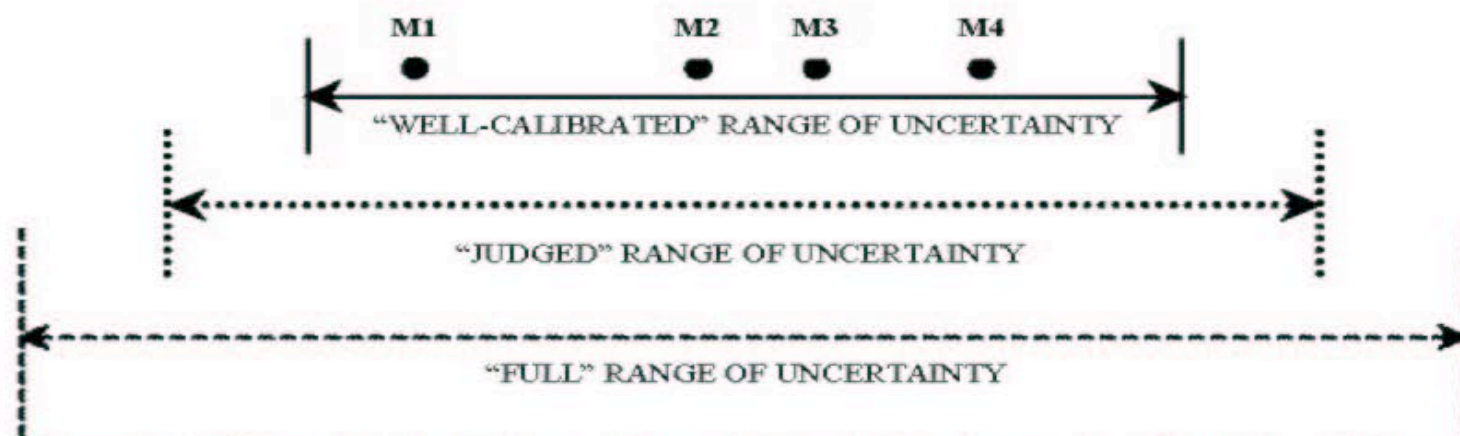
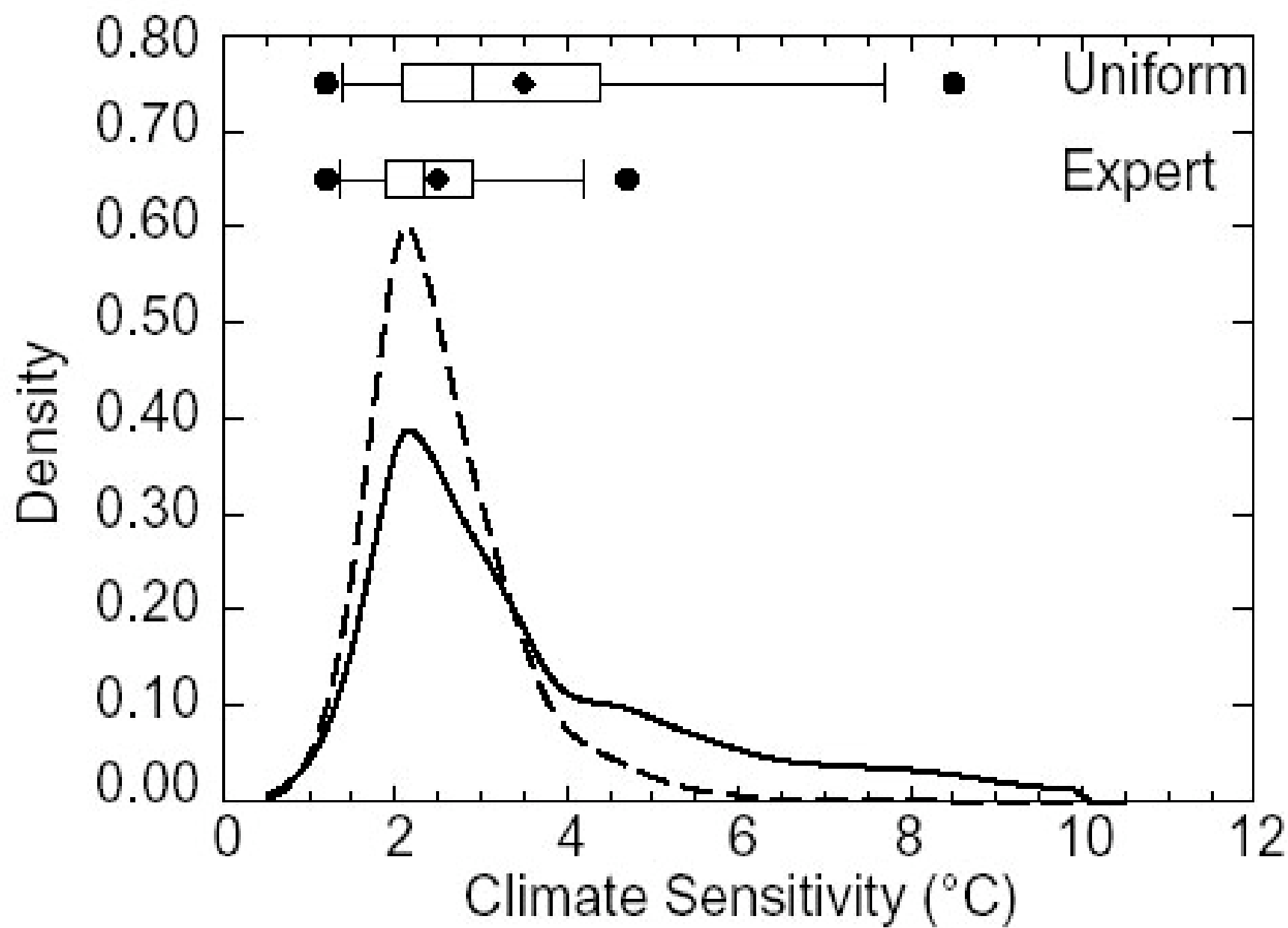
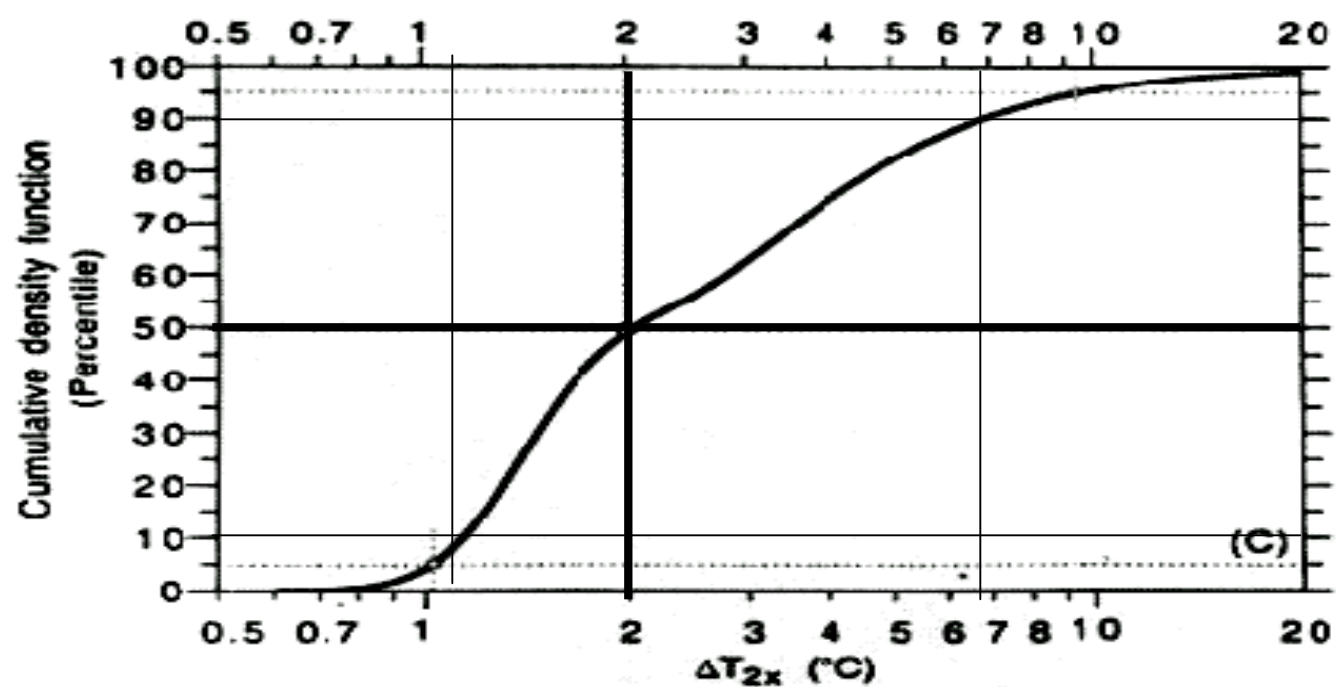
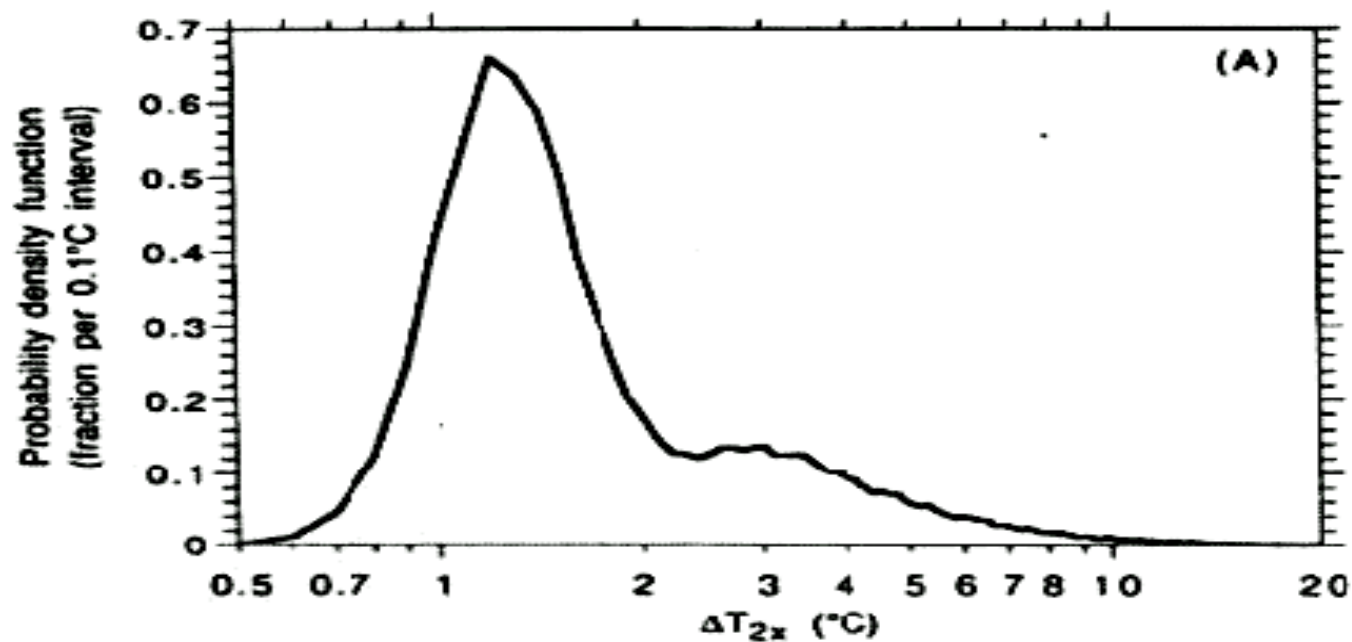
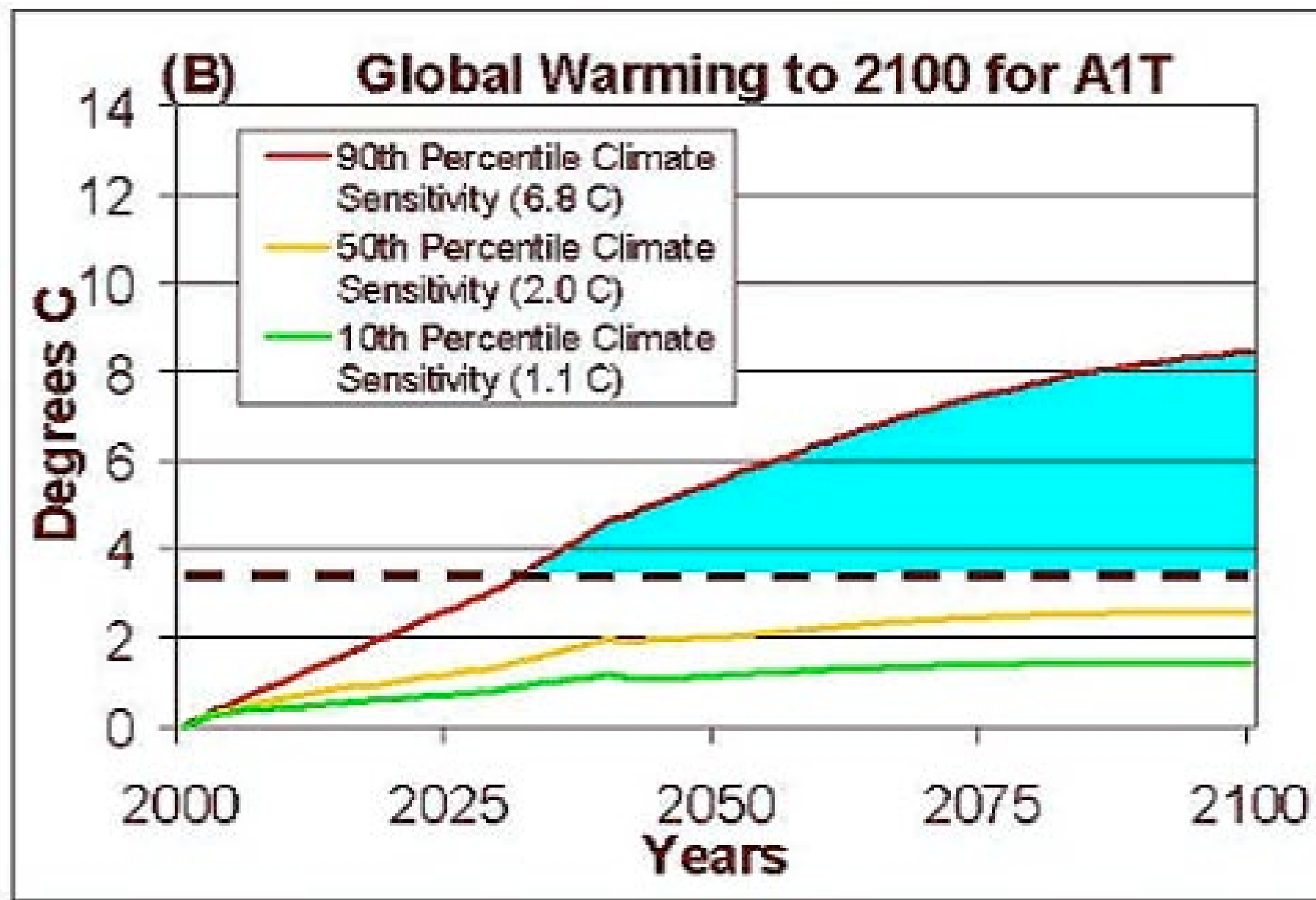


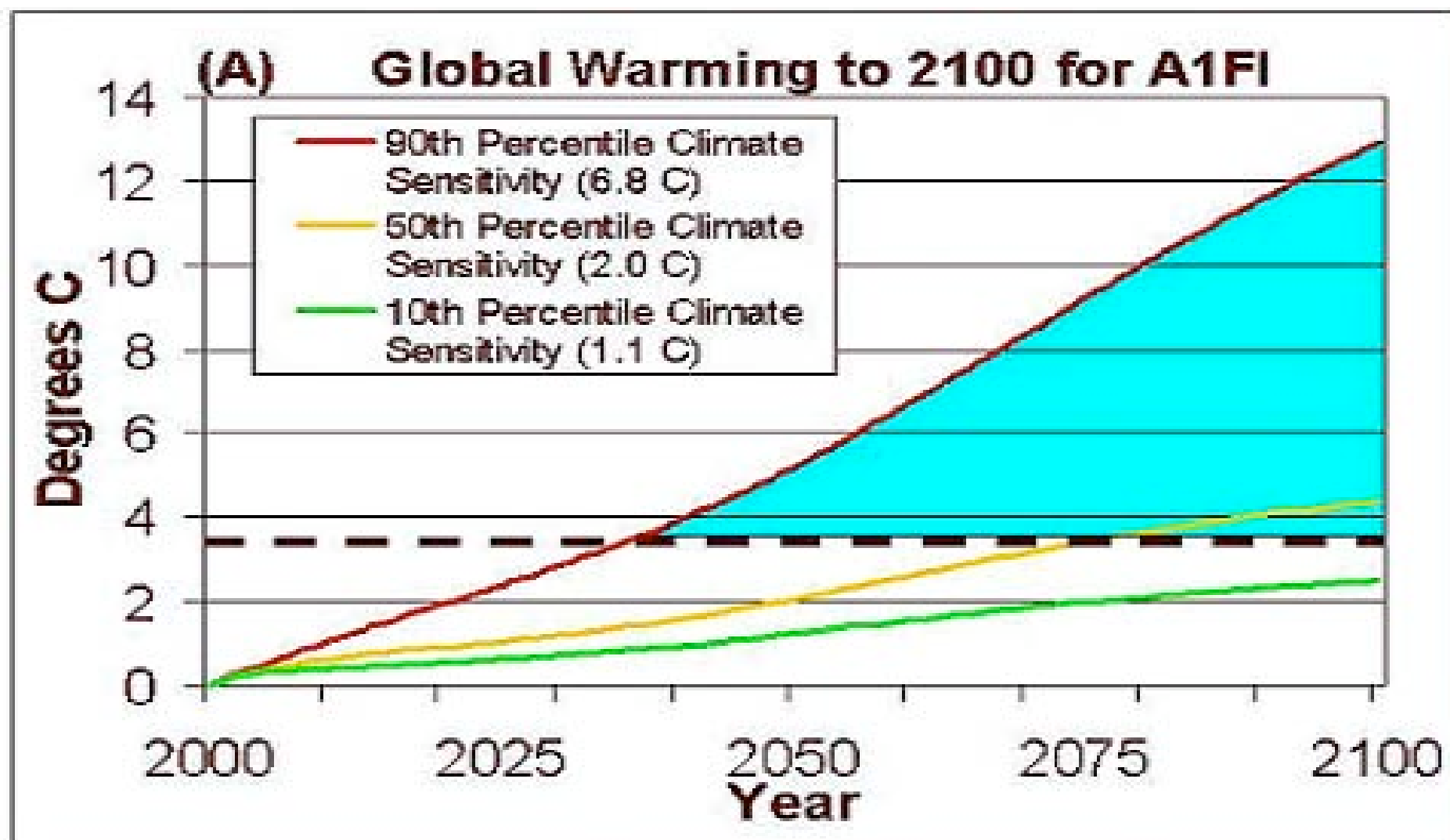
Figure 2. Schematic depiction of the relationship between “well-calibrated” scenarios, the wider range of “judged” uncertainty that might be elicited through decision analytic survey techniques, and the “full” range of uncertainty, which is drawn wider to represent overconfidence in human judgments. M1 to M4 represent scenarios produced by four models (e.g., globally averaged temperature increases from an equilibrium response to doubled CO₂ concentrations). This lies within a “full” range of uncertainty that is not fully identified, much less directly quantified by existing theoretical or empirical evidenceⁱ. (from Schneider and Kuntz-Duriseti, 2002).

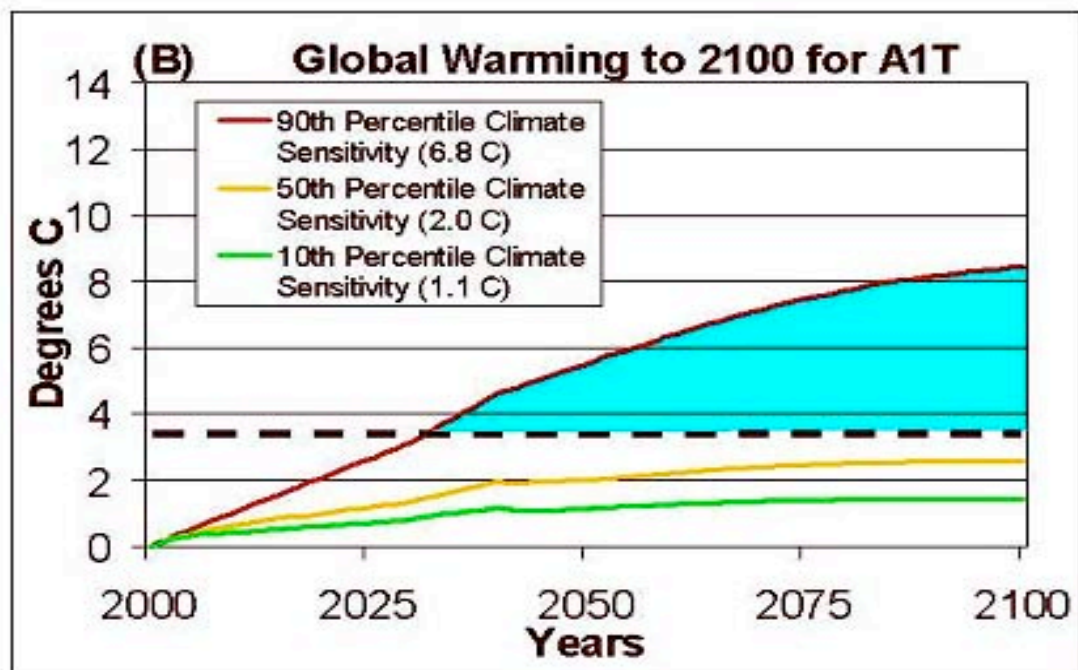
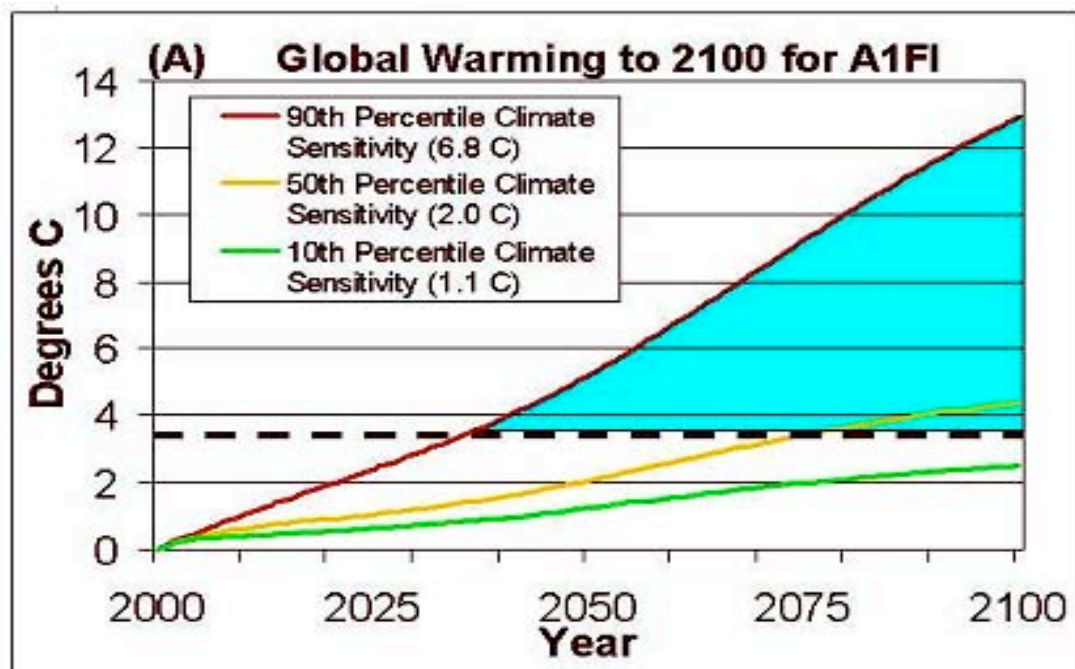
ⁱ Jones, R.N., 2000: Managing uncertainty in climate change projections: Issues for impact assessment. An editorial comment. *Climatic Change* 45(3-4): 403-419.











Article 2 of the UN Framework Convention on Climate Change (UNFCCC) states that: “The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, **stabilization of greenhouse** gas concentrations in the atmosphere at a level that would prevent **dangerous anthropogenic interference** with the climate system”. The Framework Convention on Climate Change further suggests that “Such a level should be achieved **within a time frame** sufficient

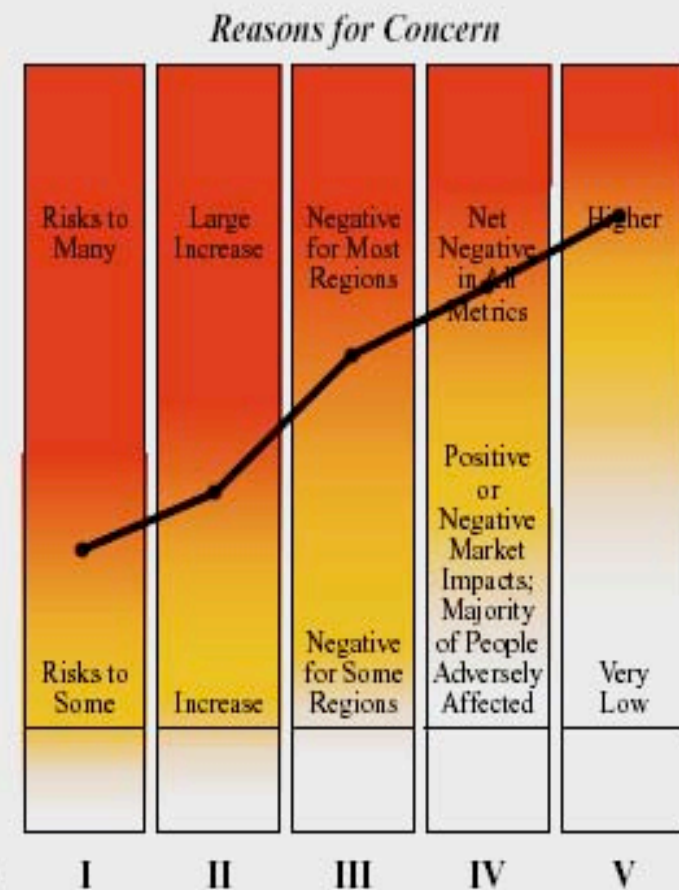
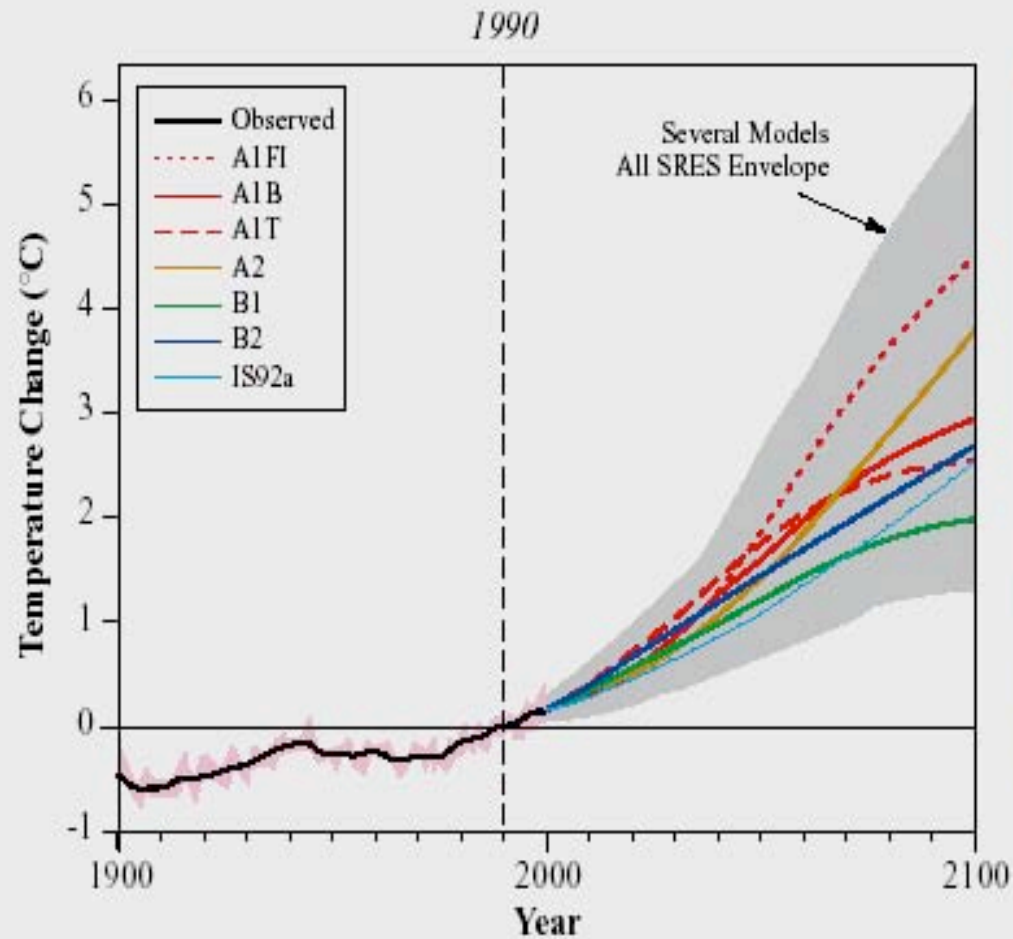
- to allow ecosystems to adapt naturally to climate change,
- to ensure that food production is not threatened and
- to enable economic development to proceed in a sustainable manner.”

What is the probability of dangerous climate change?

This elicits three fundamental questions:

- What is “dangerous” climate change?
- What sorts of climate change scenarios are out there, and how do we assign probabilities to them?
- What “solutions” have been proposed, and how are they affected by projected probabilities and consequences (or lack thereof)?

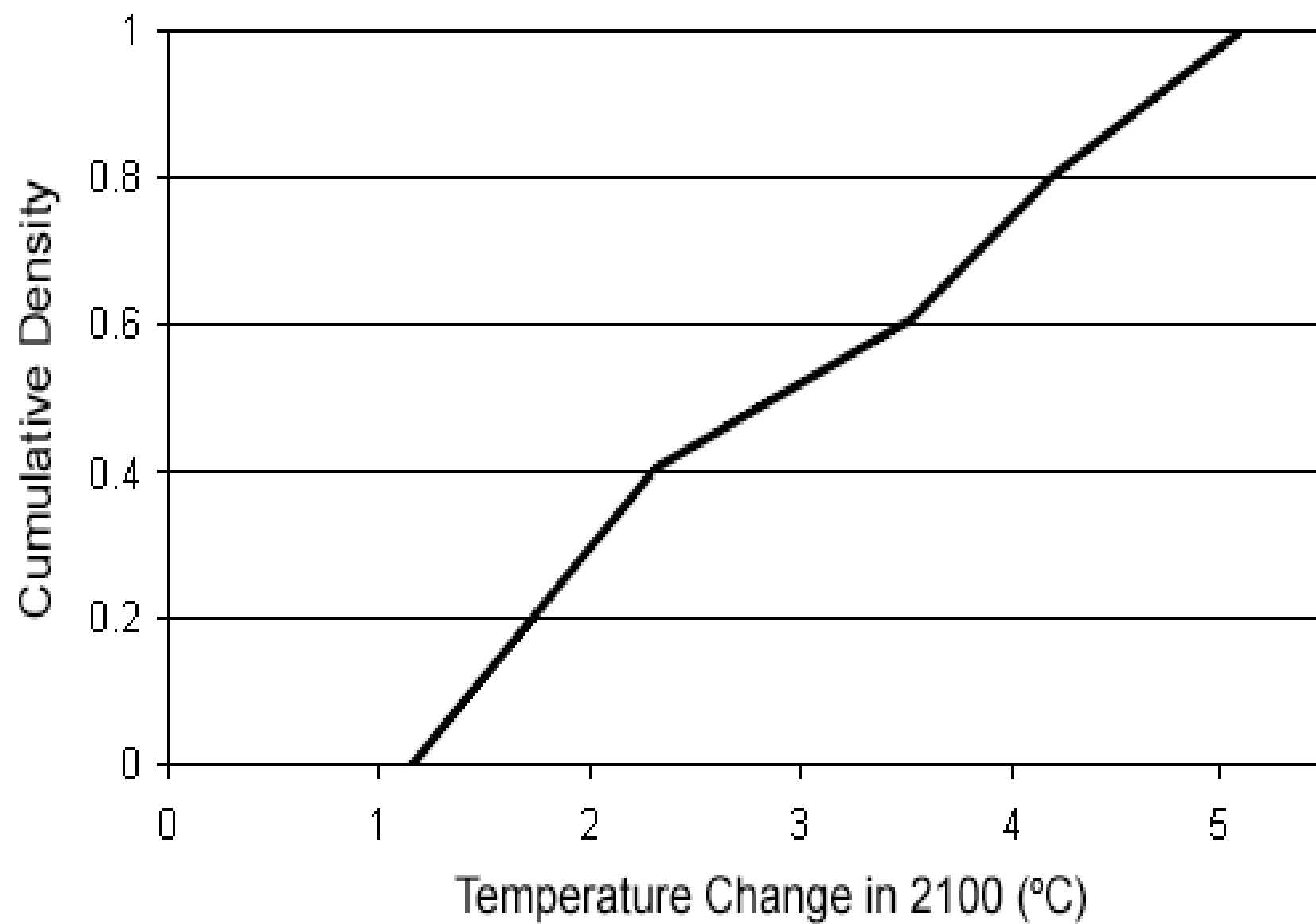
Reasons for Concern About Climate Change Impacts.

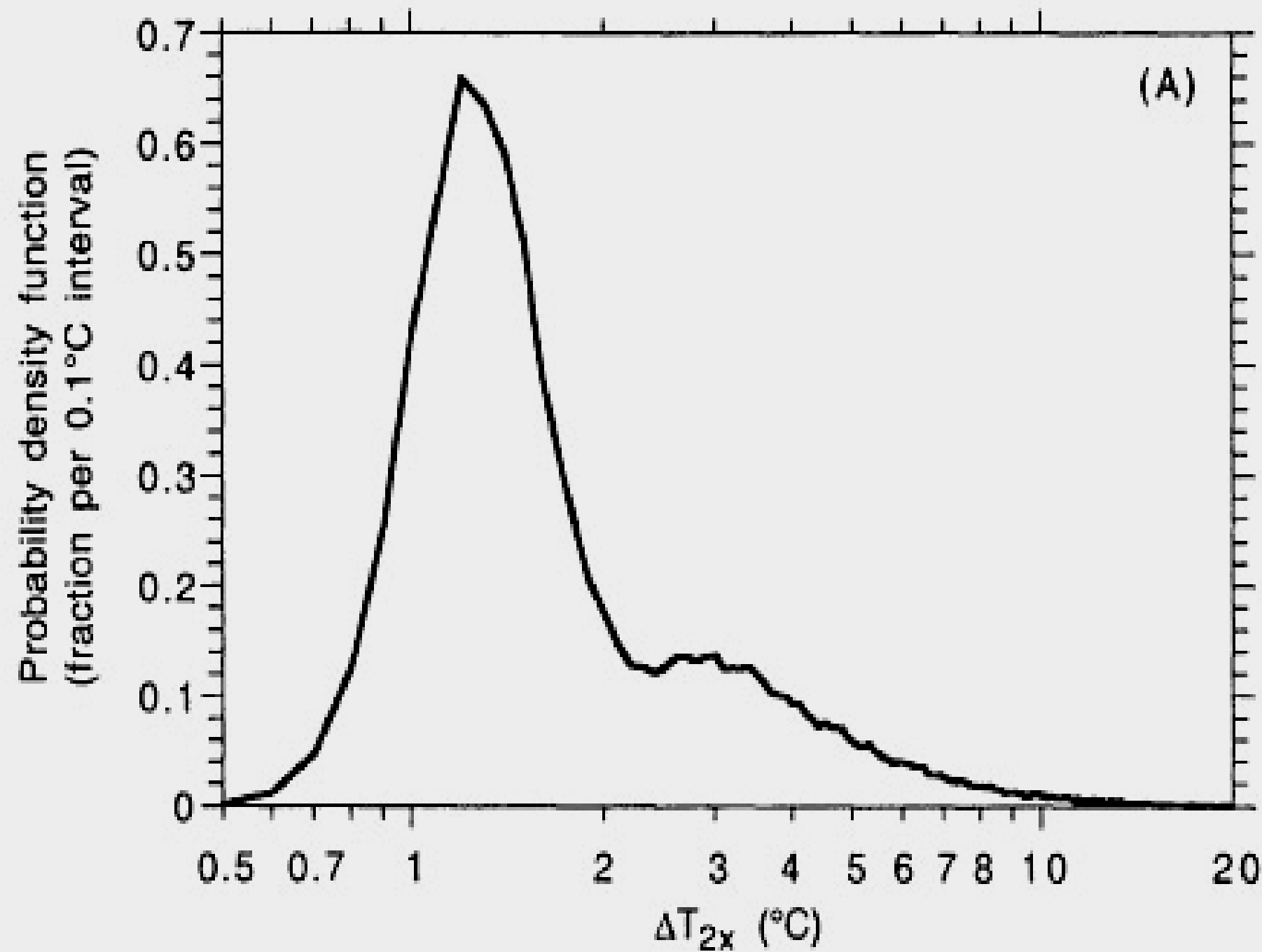


- | | |
|-----|---|
| I | Risks to Unique and Threatened Systems |
| II | Risks from Extreme Climate Events |
| III | Distribution of Impacts |
| IV | Aggregate Impacts |
| V | Risks from Future Large-Scale Discontinuities |

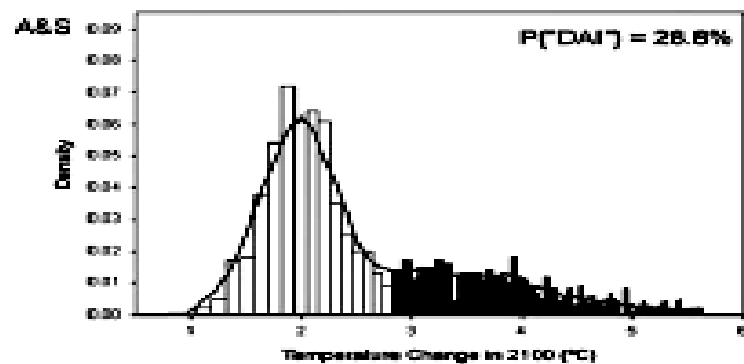
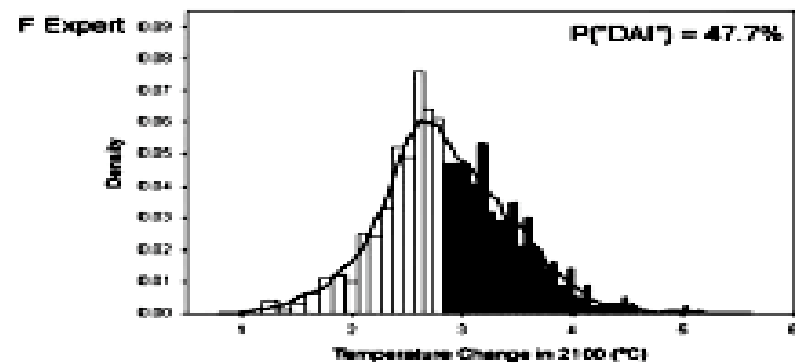
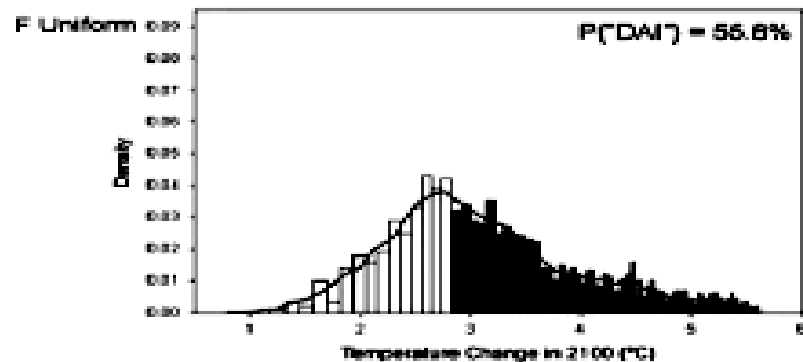
“Traceable account” (Moss-Schneider, 2000) of aggregation process:

Each “Reason for Concern” independent and equally important (no differential weights), and degrees of “dangerousness” accumulate across the five dimensions. Other aggregations/weighting needed, and should be important goals of impacts research in the context of Article 2

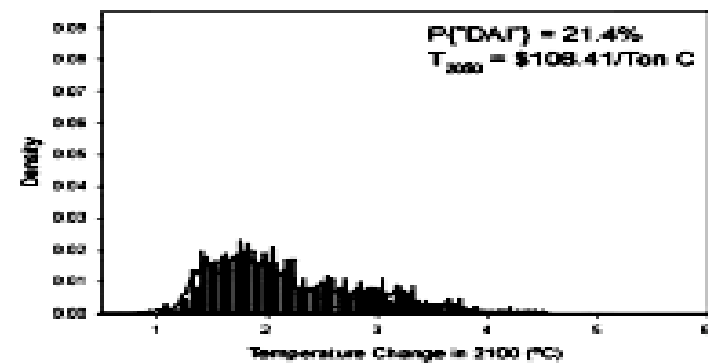
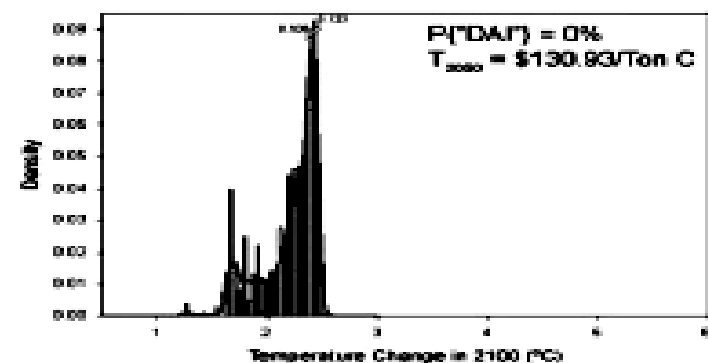
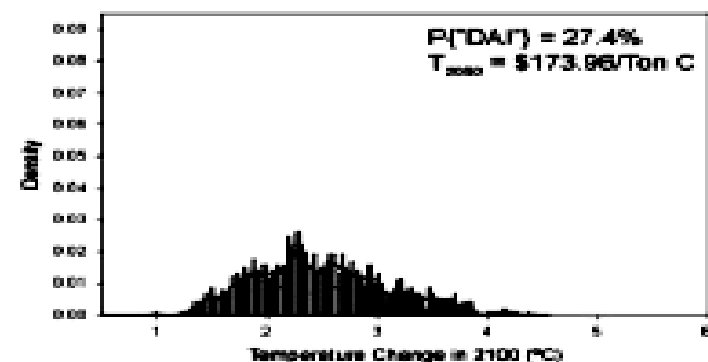




a) Single Monte Carlo



b) Joint Monte Carlo



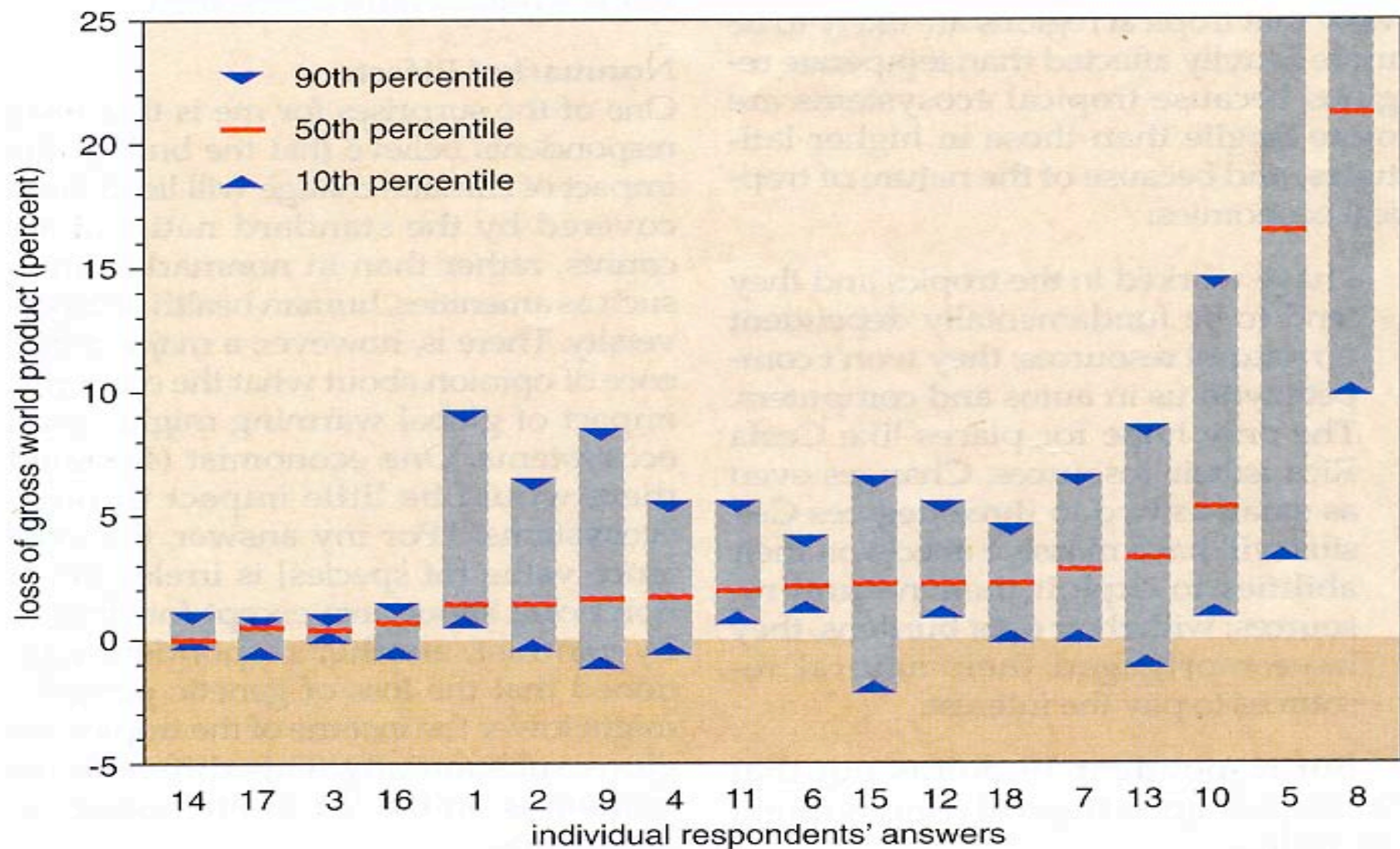
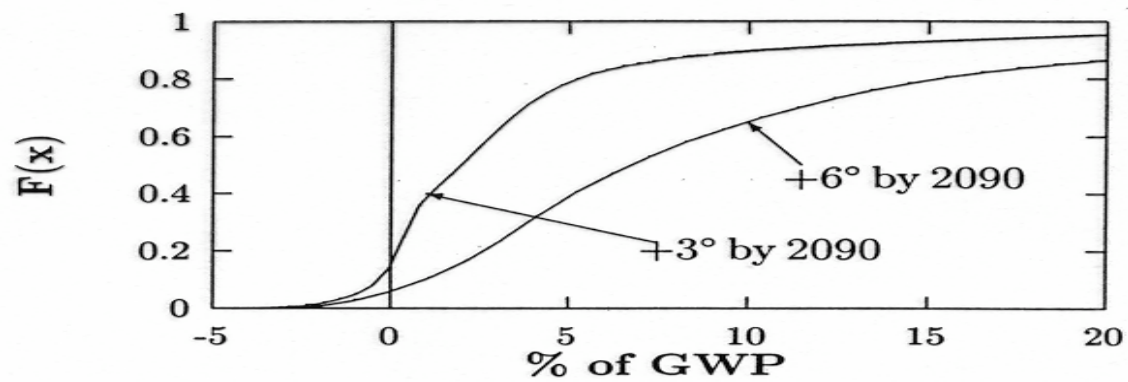
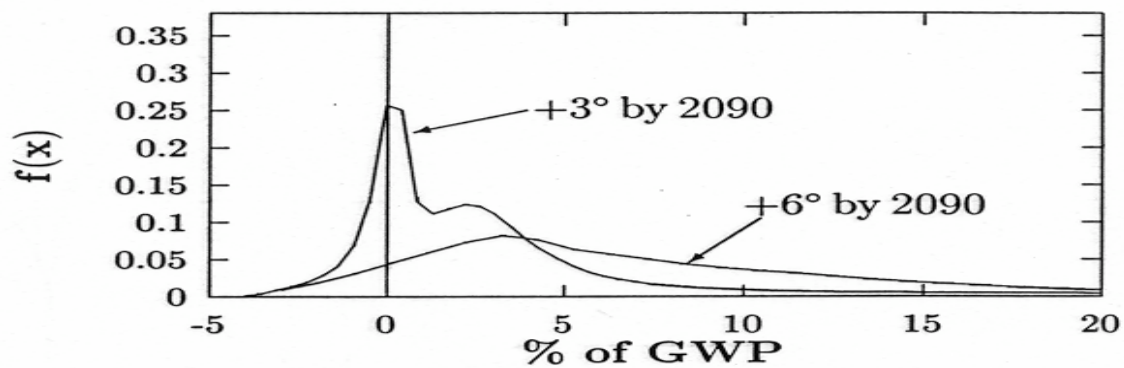


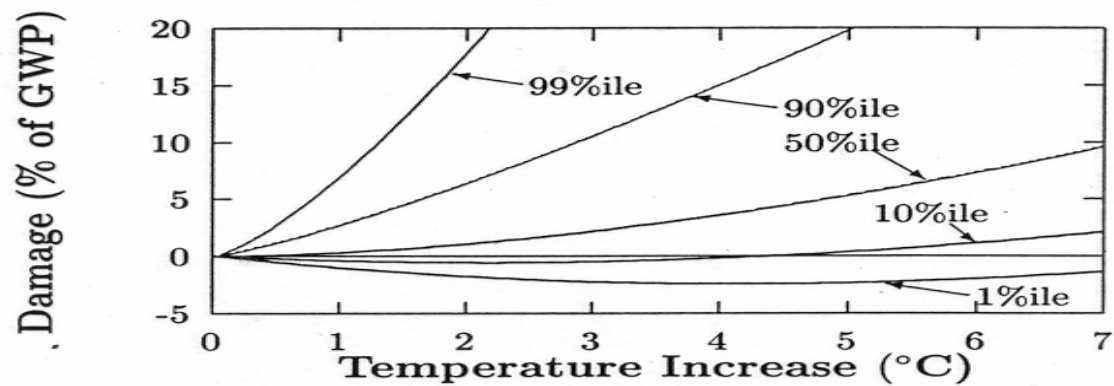
Figure 5. Respondents were queried on the distribution of impacts for scenario A. The 90th percentile is the level of impacts for which a respondent believes that the odds are 9 to 1 that the actual outcome will better. Each respondent's best guess of impacts is shown as the 50th percentile. From the ranges of these estimates can be inferred some measure of each respondent's degree of uncertainty about the economic impact of a 3-degree warming by 2090.



(a)

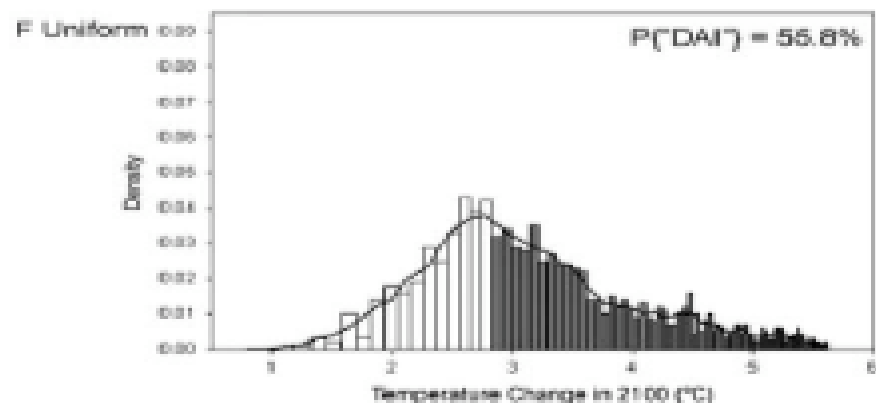


(b)

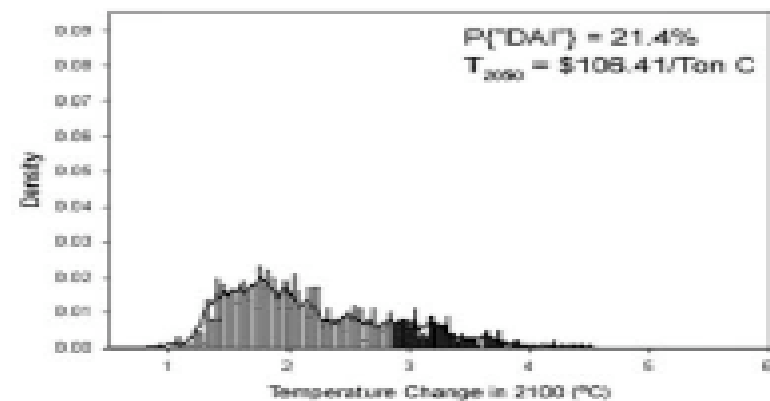
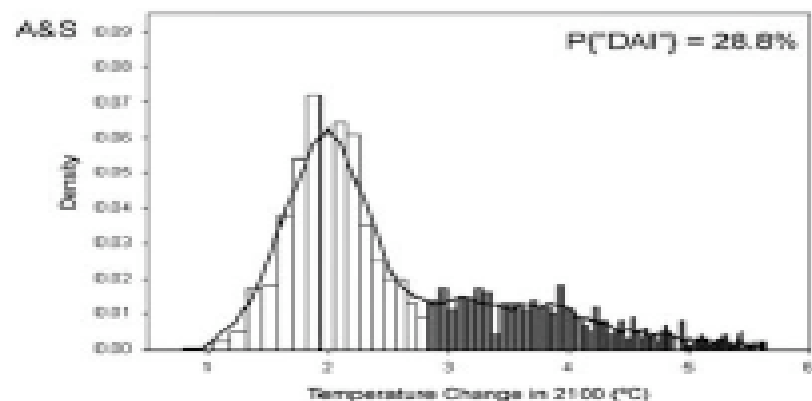
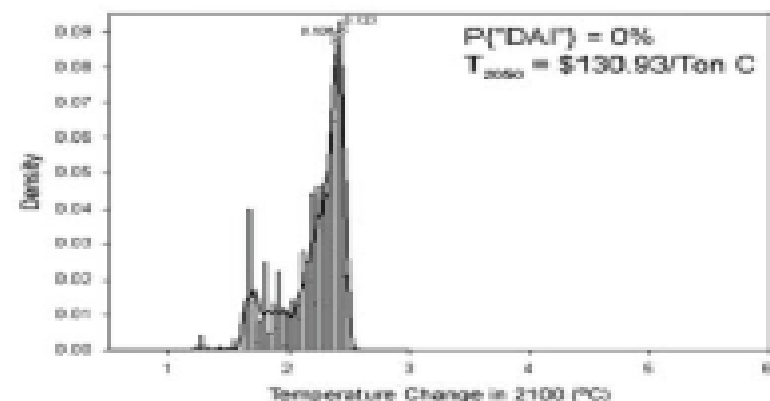
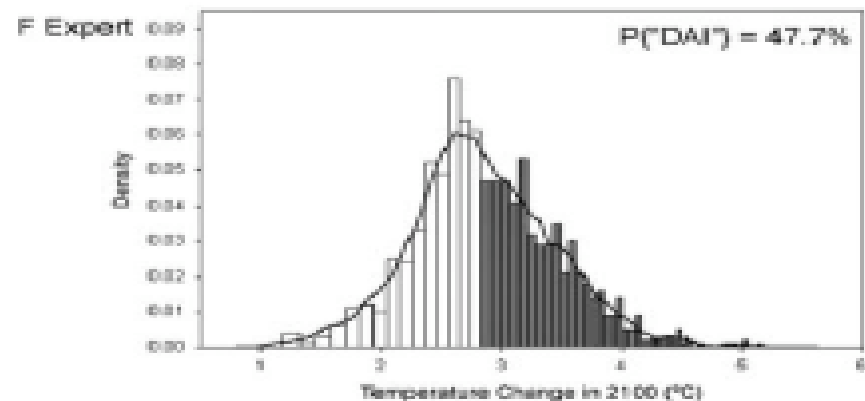
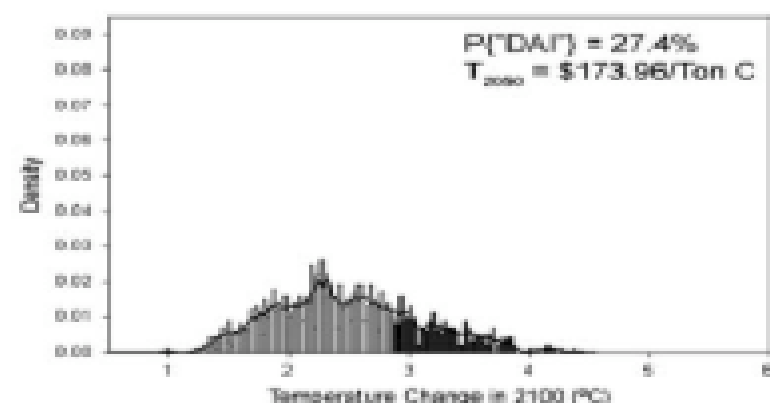


(c)

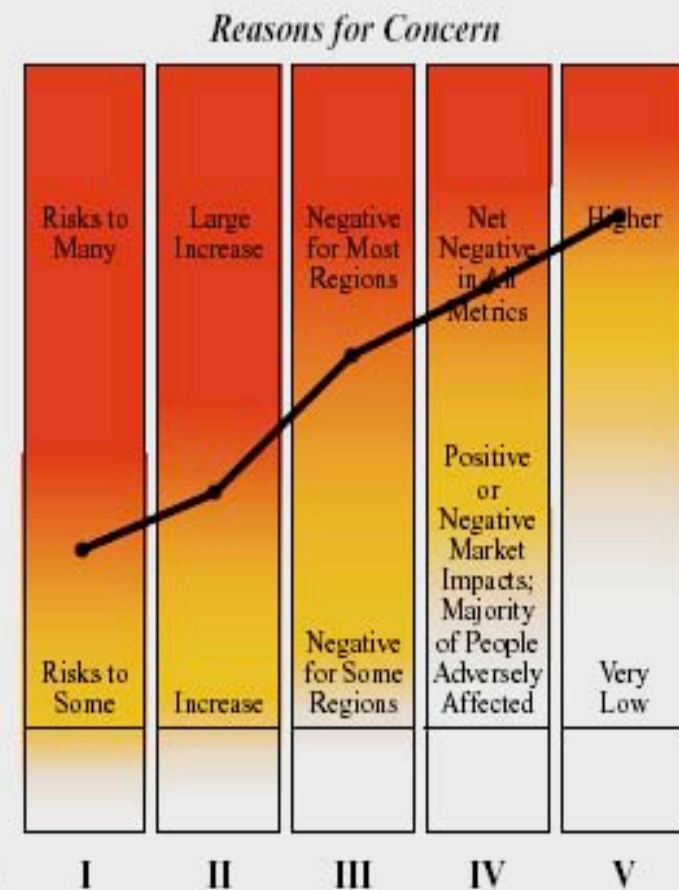
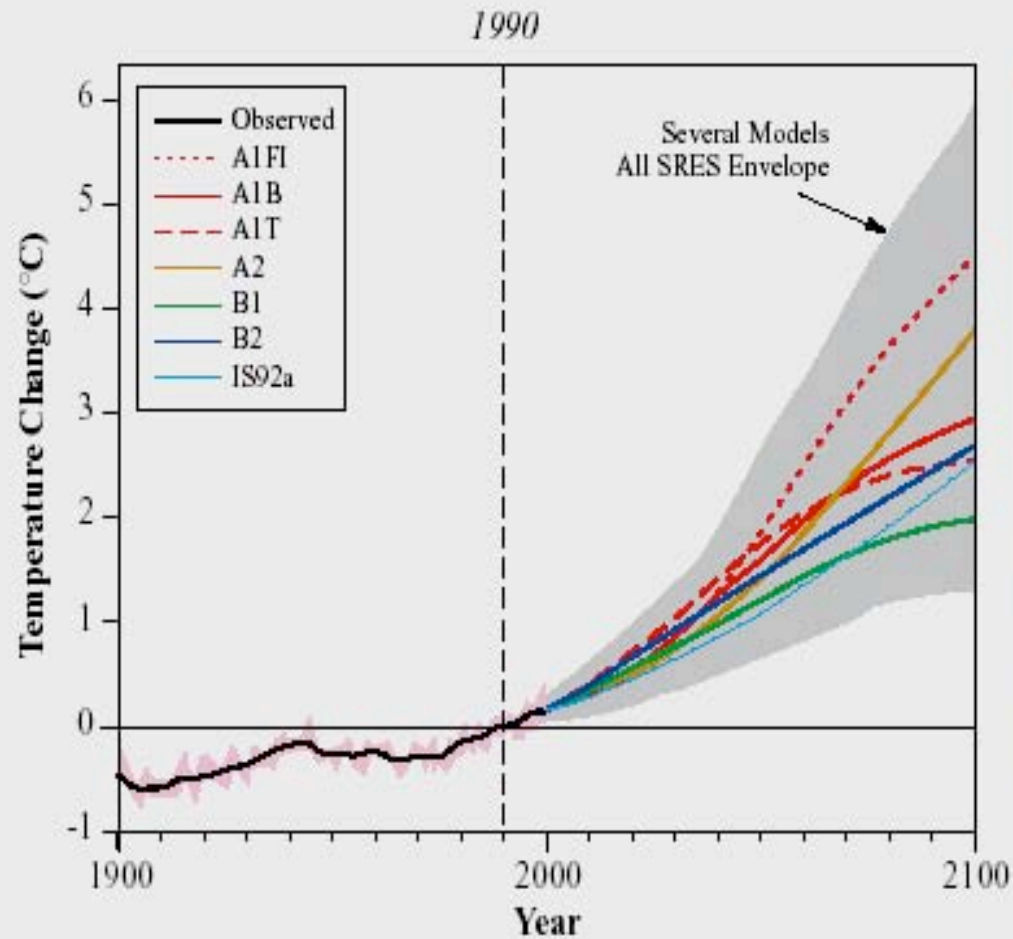
a) Single Monte Carlo



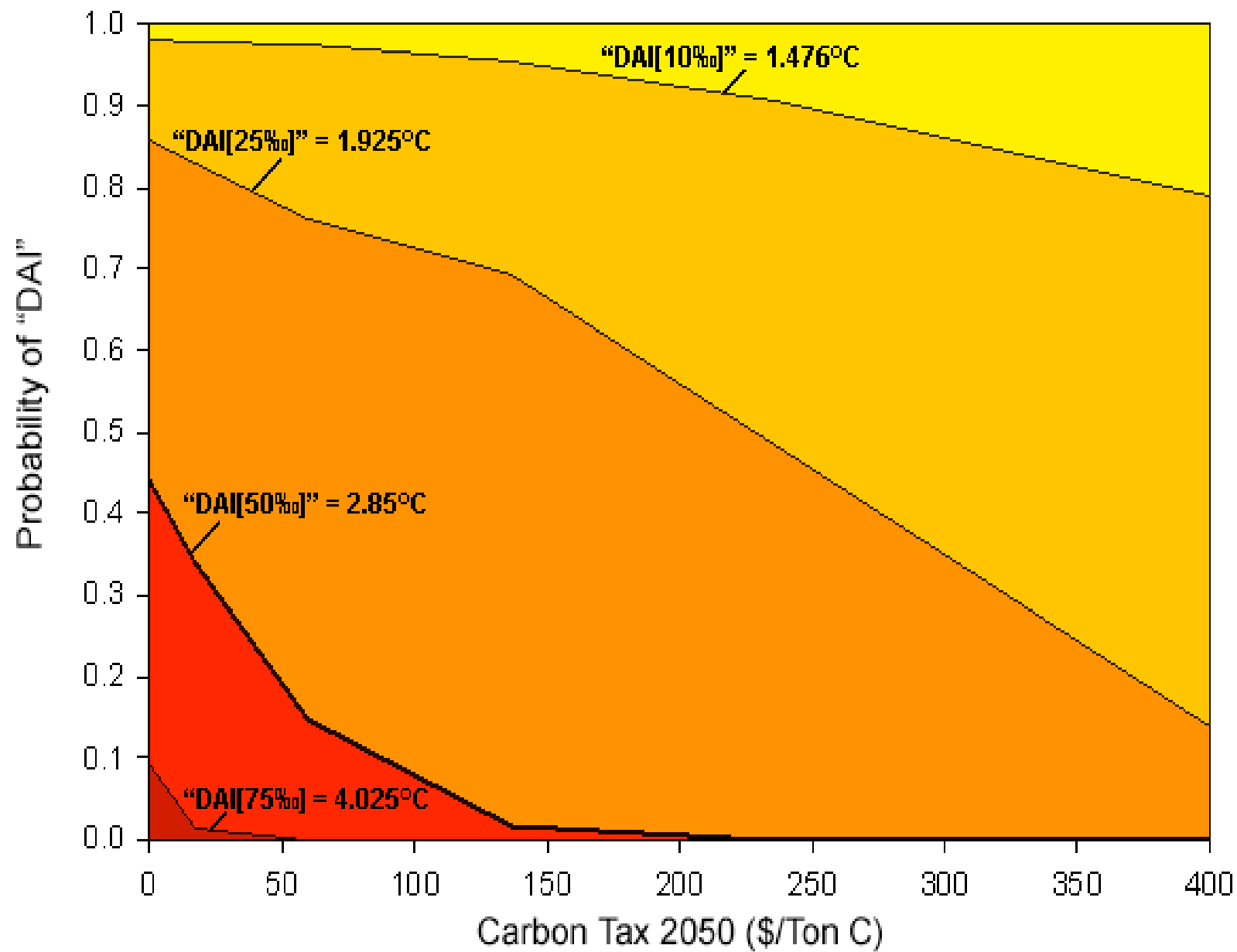
b) Joint Monte Carlo

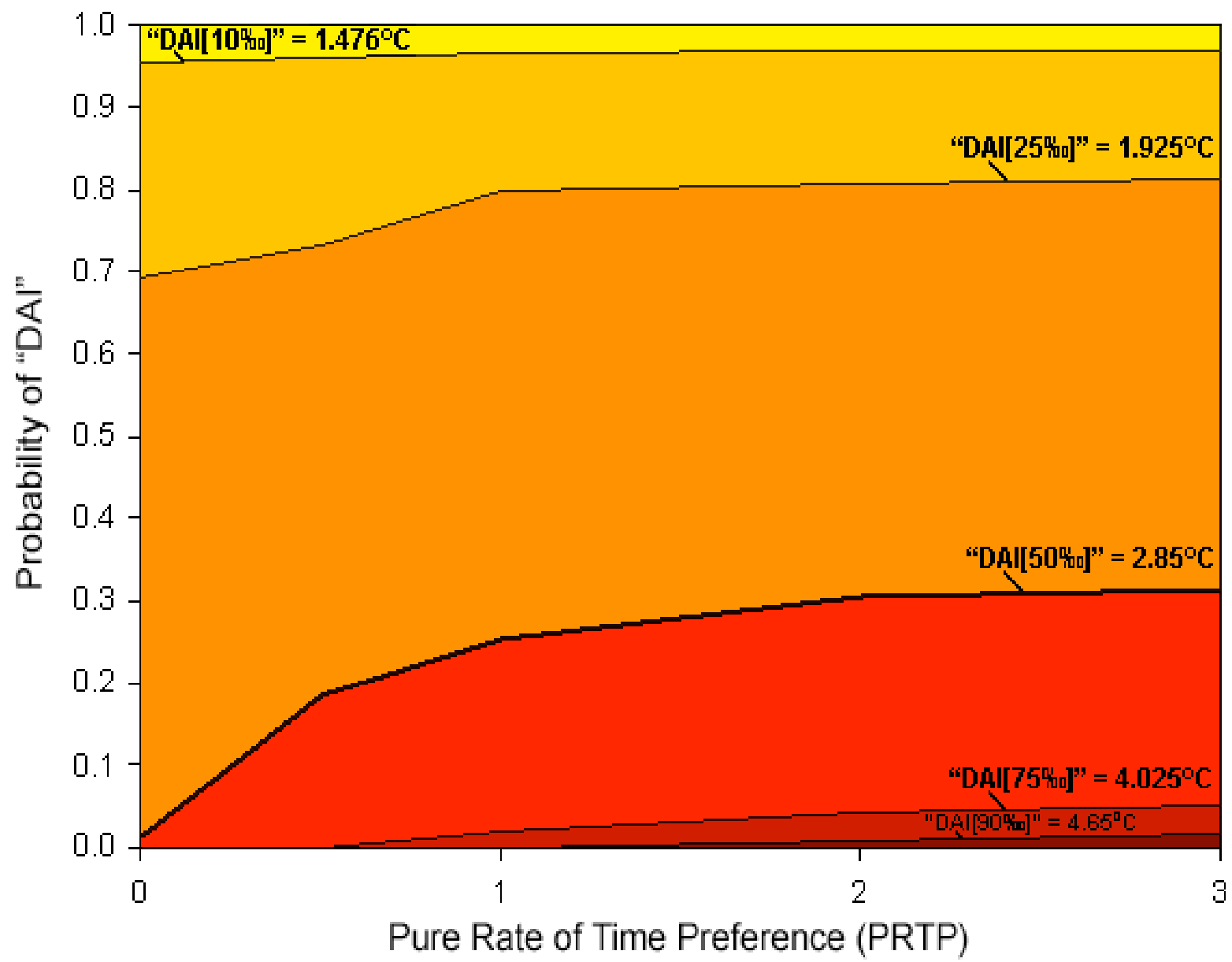


Reasons for Concern About Climate Change Impacts.



- | | |
|-----|---|
| I | Risks to Unique and Threatened Systems |
| II | Risks from Extreme Climate Events |
| III | Distribution of Impacts |
| IV | Aggregate Impacts |
| V | Risks from Future Large-Scale Discontinuities |





QUESTIONS AND
COMMENTS PLEASE

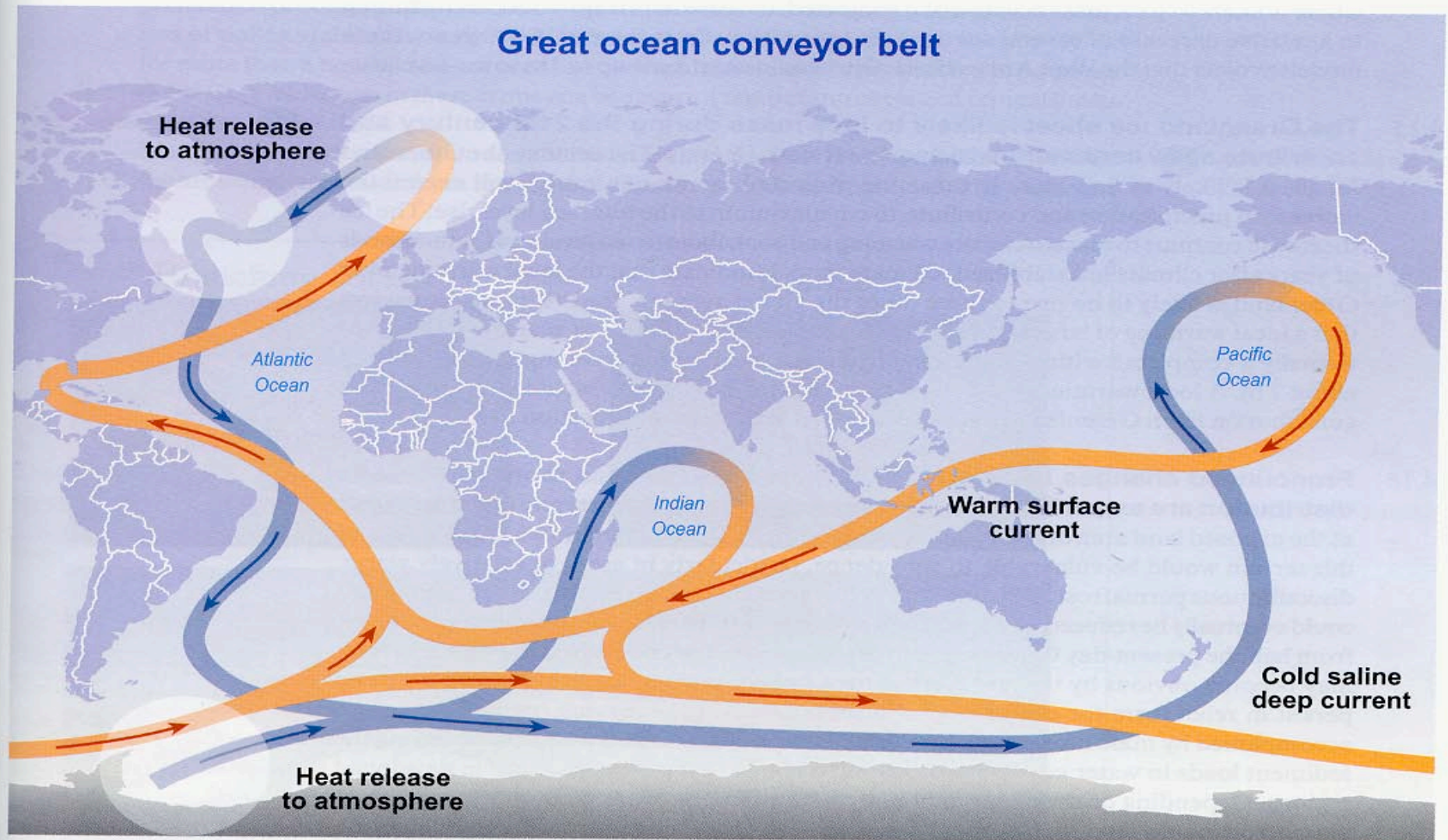


Figure 4-2: Schematic illustration of the global circulation system in the world ocean consisting of major north-south thermohaline circulation routes in each ocean basin joining in the Antarctic circumpolar circulation. Warm surface currents and cold deep currents are connected in the few areas of deepwater formation in the high latitudes of the Atlantic and around Antarctica (blue), where the major ocean-to-atmosphere heat transfer occurs. This current system contributes substantially to the transport and redistribution of heat (e.g., the poleward flowing currents in the North Atlantic warm northwestern Europe by up to 10°C). Model simulations indicate that the North Atlantic branch of this circulation system is particularly vulnerable to changes in atmospheric temperature and in the hydrological cycle. Such perturbations caused by global warming could disrupt the current system, which would have a strong impact on regional-to-hemispheric climate. Note that this is a schematic diagram and it does not give the exact locations of the water currents that form part of the THC.

Thermohaline Catastrophe Behavior

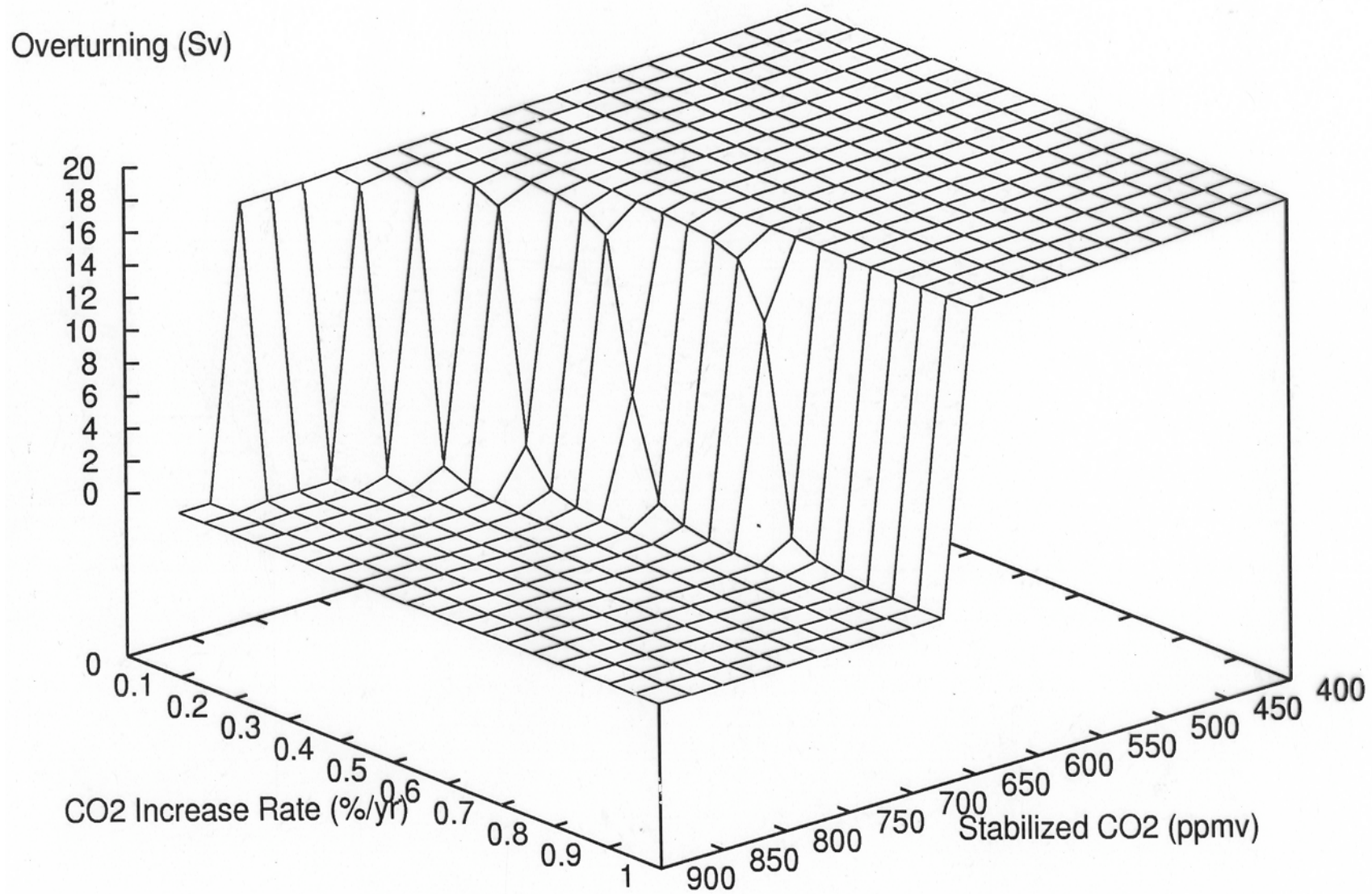
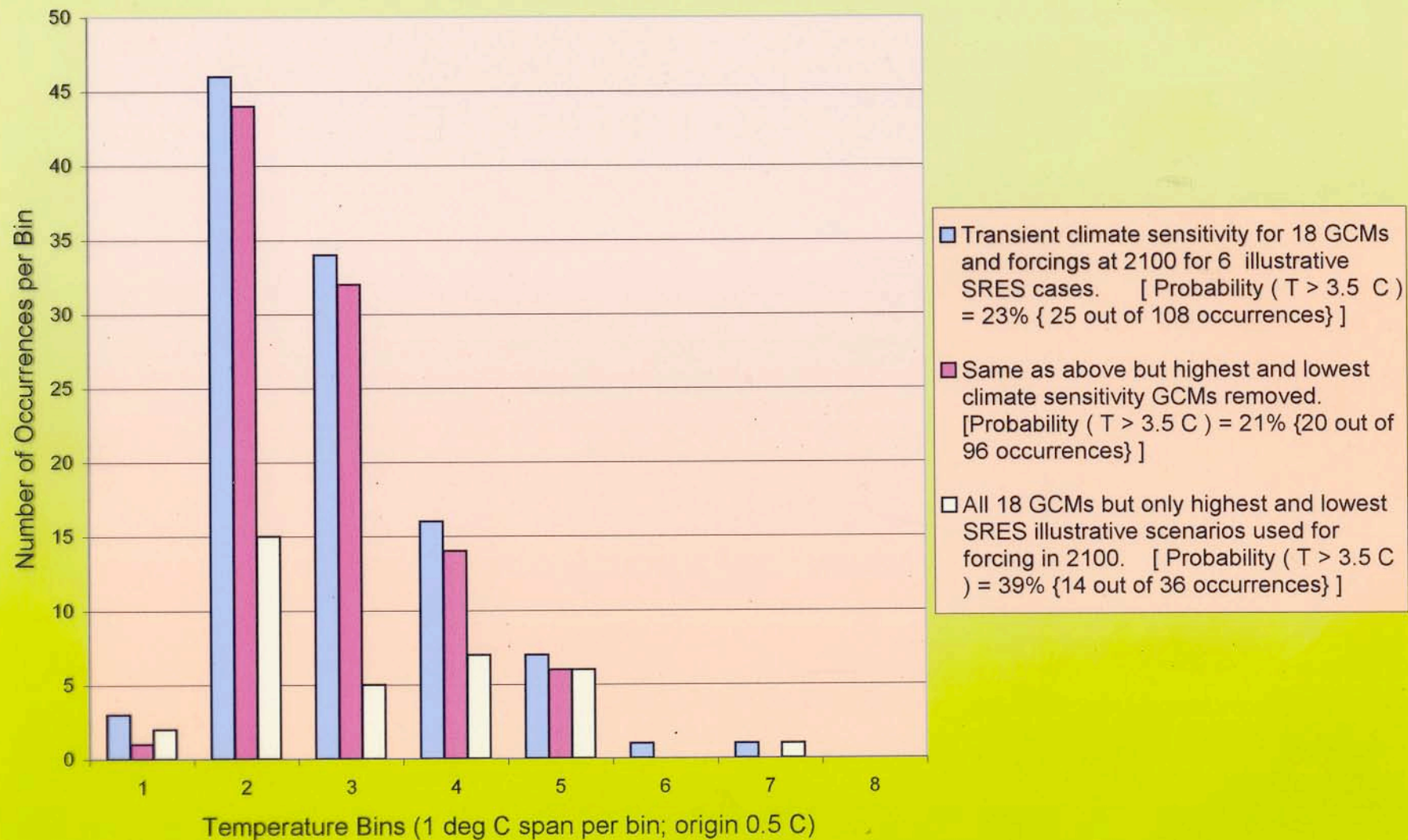


Figure 11

Type 1 versus Type 2 errors and their consequences

Decision	Forecast proves false	Forecast proves true
Accept forecast—policy response follows	Type I error	Correct decision
Reject or ignore forecast—no policy response	Correct Decision	Type 2 error

"Frequency" of 2100 Temperature Increases



The inadequacy of qualitative language

Qualitative uncertainty language (i.e., words such as "likely" and "unlikely") is inadequate for use in policy and decision making because:

- the same words can mean very different things to different people;
- the same words can mean very different things to the same person in different contexts;
- important differences in experts' judgments about mechanisms (functional relationships), and about how well key coefficients are known, can be easily masked in qualitative discussions.

Words mean different things to different people

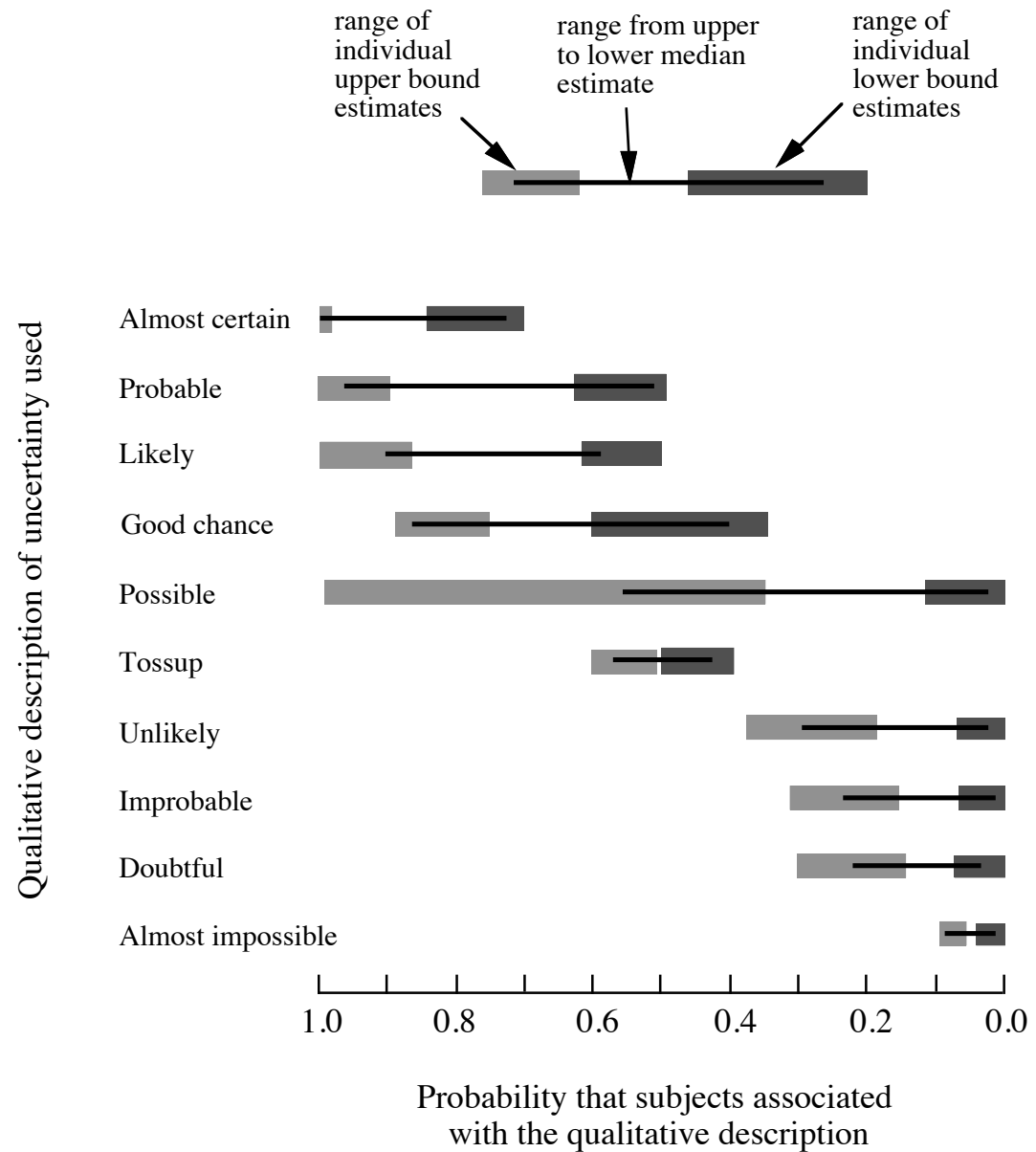


Figure adapted from Wallsten et al., 1986

Ex Com of EPA SAB

The minimum probability associated with the word "likely" spaned four orders of magnitude.

The maximum probability associated with the word "not likely" spaned more than five orders of magnitude.

There was an overlap of the probability associated with the word "likely" and that associated with the word "unlikely"!

Figure from Morgan, 1998.



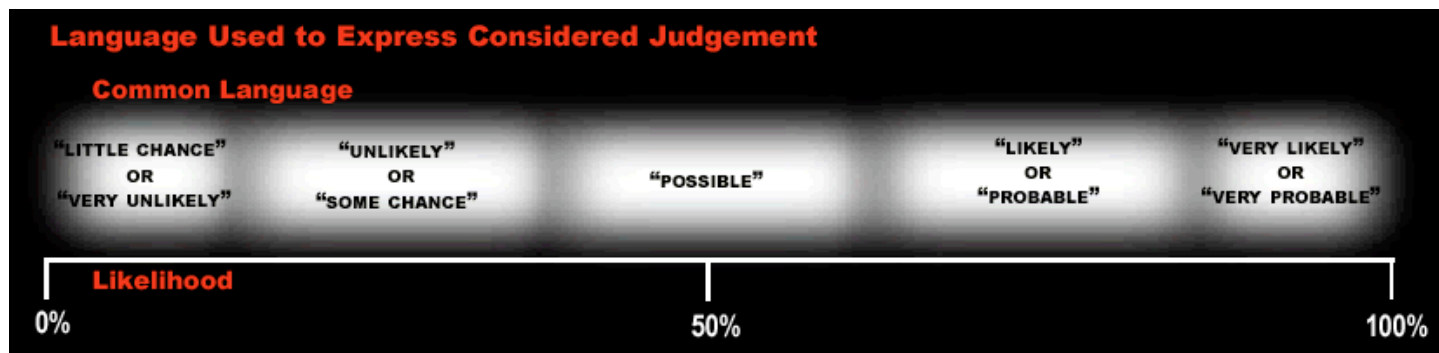
The bottom line

Without at least some quantification, qualitative descriptions of uncertainty convey little, if any, useful information.

The climate assessment community is gradually learning this lesson.

As he'll shortly explain, Schneider and colleagues have worked to get a better treatment of uncertainty incorporated in the past and current rounds of IPCC. Progress is uneven, but awareness is growing. Individual investigators are pushing the process along.

At Morgan's insistence, US national assessment synthesis team gave quantitative definitions to five probability words and tried to use them consistently throughout the overview report.



THE THIRD ASSESSMENT REPORT

CROSS CUTTING ISSUES GUIDANCE PAPERS

JULY 2000

Box 2

Examples of sources of uncertainty

Problems with data

1. Missing components or errors in the data
2. “Noise” in the data associated with biased or incomplete observations
3. Random sampling error and biases (non-representativeness) in a sample

Problems with models

4. Known processes but unknown functional relationships or errors in the structure of the model
5. Known structure but unknown or erroneous values of some important parameters
6. Known historical data and model structure, but reasons to believe parameters or model structure will change over time
7. Uncertainty regarding the predictability (e.g., chaotic or stochastic behavior) of the system or effect
8. Uncertainties introduced by approximation techniques used to solve a set of equations that characterize the model.

Other sources of uncertainty

9. Ambiguously defined concepts and terminology
10. Inappropriate spatial/temporal units
11. Inappropriateness of/lack of confidence in underlying assumptions
12. Uncertainty due to projections of human behavior (e.g., future consumption patterns, or technological change), which is distinct from uncertainty due to “natural” sources (e.g., climate sensitivity, chaos)

(1.00)
“Very High Confidence”
(0.95)
(0.95)
“High Confidence”
(0.67)
(0.67)
“Medium Confidence”
(0.33)
(0.33)
“Low Confidence”
(0.05)
(0.05)
“Very Low Confidence”
(0.00)

Figure 3. Scale for Assessing State of Knowledge

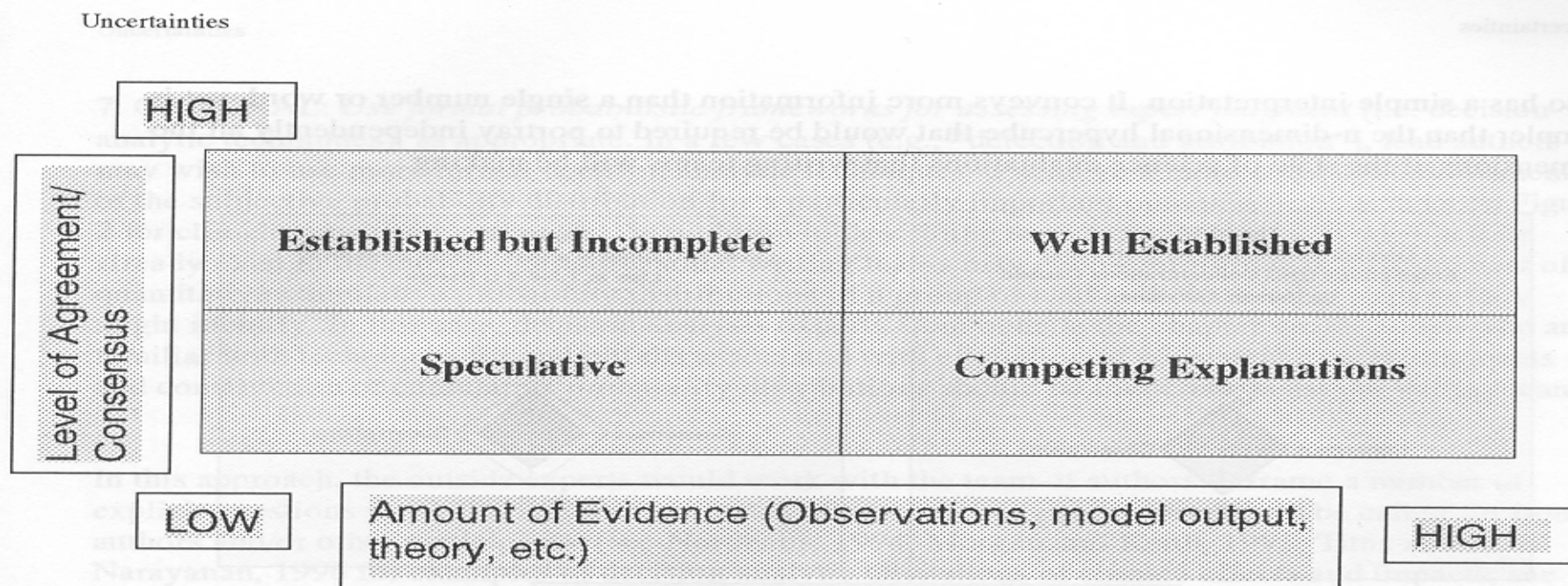


Figure 4. Supplemental Qualitative Uncertainty Terms.

Key to qualitative “state of knowledge” descriptors:

Well-established: models incorporate known processes; observations largely consistent with models for important variables; or multiple lines of evidence support the finding)

Established but Incomplete: models incorporate most known processes, although some parameterizations may not be well tested; observations are somewhat consistent with theoretical or model results but incomplete; current empirical estimates are well founded, but the possibility of changes in governing processes over time is considerable; or only one or a few lines of evidence support the finding

Competing Explanations: different model representations account for different aspects of observations or evidence, or incorporate different aspects of key processes, leading to competing explanations

Speculative: conceptually plausible ideas that haven’t received much attention in the literature or that are laced with difficult to reduce uncertainties or have few available observational tests

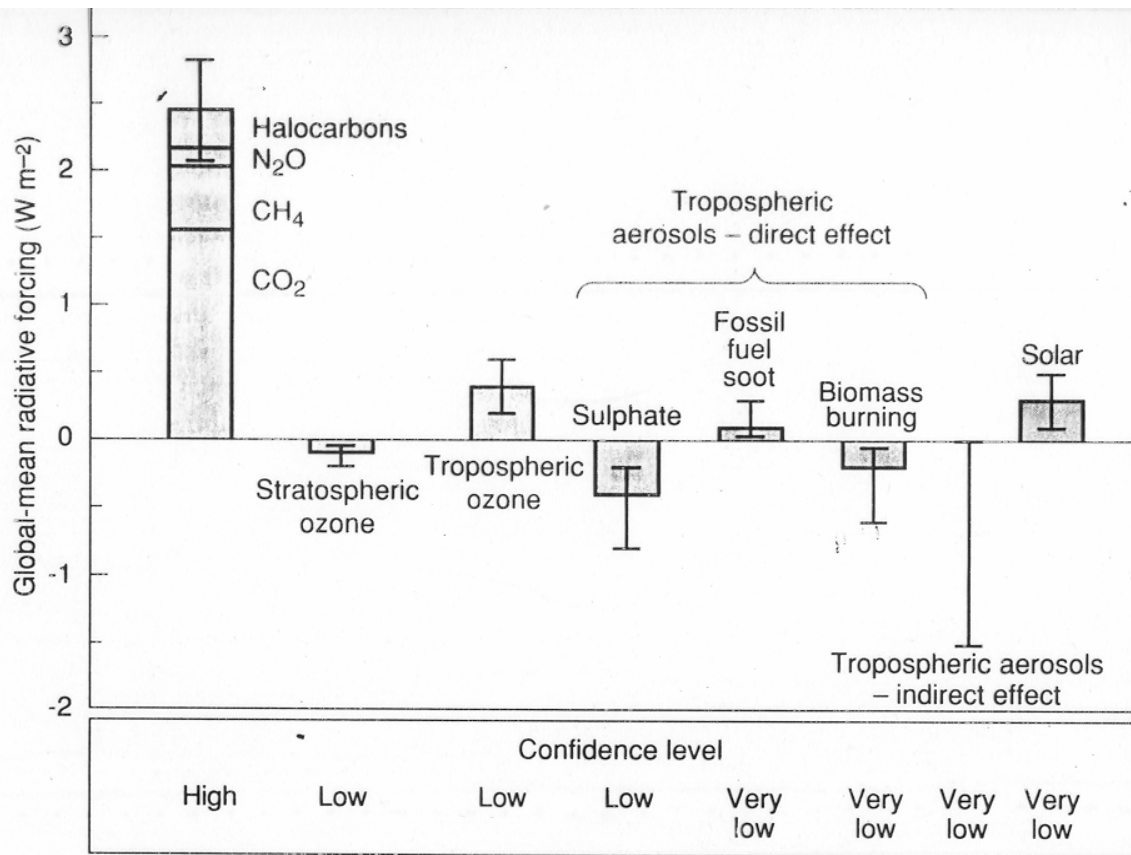


Figure 2.16: Estimates of the globally and annually averaged anthropogenic radiative forcing (in W m^{-2}) due to changes in concentrations of greenhouse gases and aerosols from pre-industrial times to the present day and to natural changes in solar output from 1850 to the present day. The height of the rectangular bar indicates a mid-range estimate of the forcing whilst the error bars show an estimate of the uncertainty range, based largely on the spread of published values; our subjective confidence that the actual forcing lies within this error bar is indicated by the "confidence level". The contributions of individual gases to the direct greenhouse forcing is indicated on the first bar. The indirect greenhouse forcings associated with the depletion of stratospheric ozone and the increased concentration of tropospheric ozone are shown in the second and third bar respectively. The direct contributions of individual tropospheric aerosol components are grouped into the next set of three bars. The indirect aerosol effect, arising from the induced change in cloud properties, is shown next; our quantitative understanding of this process is very limited at present and hence no bar representing a mid-range estimate is shown. The final bar shows the estimate of the changes in radiative forcing due to variations in solar output. The forcing associated with stratospheric aerosols resulting from volcanic eruptions is not shown, as it is very variable over this time period; Figure 2.15 shows estimates of this variation. Note that there are substantial differences in the geographical distribution of the forcing due to the well-mixed greenhouse gases (CO_2 , N_2O , CH_4 and the halocarbons) and that due to ozone and aerosols, which could lead to significant differences in their respective global and regional climate responses (see Chapter 6). For this reason, the negative radiative forcing due to aerosols should not necessarily be regarded as an offset against the greenhouse gas forcing.

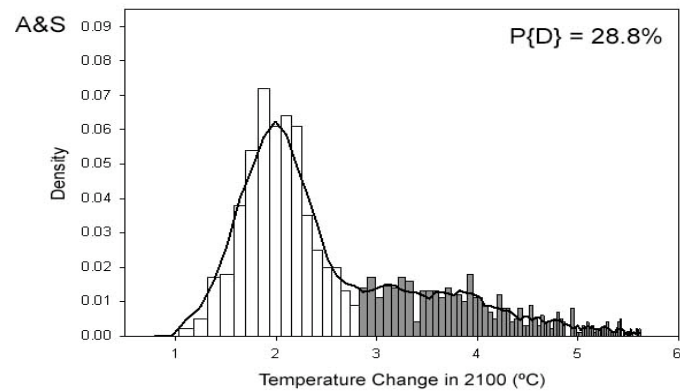
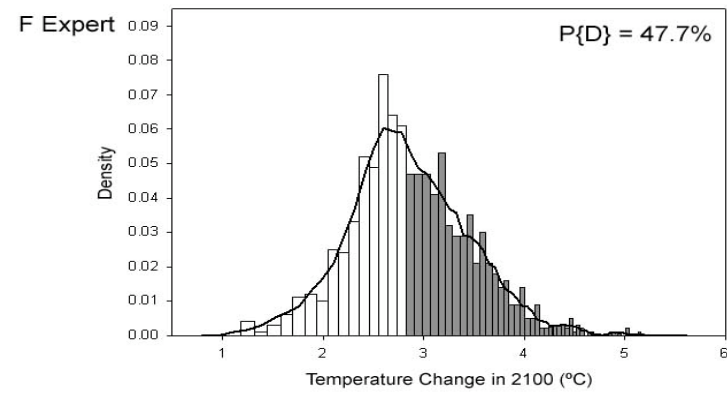
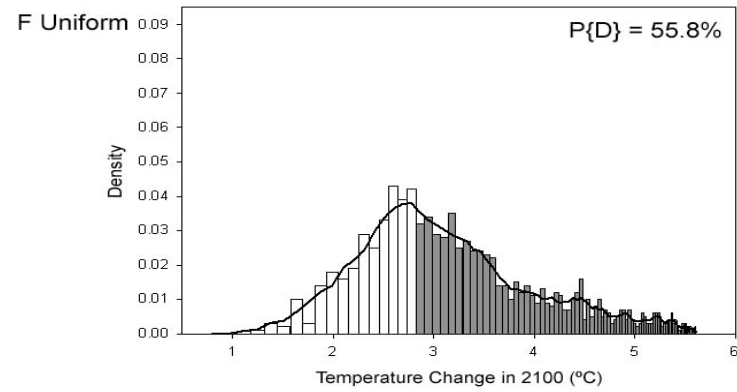
(IPCC)
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THE THIRD ASSESSMENT REPORT

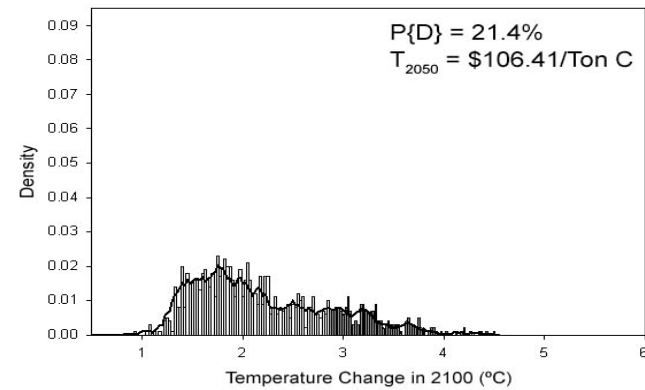
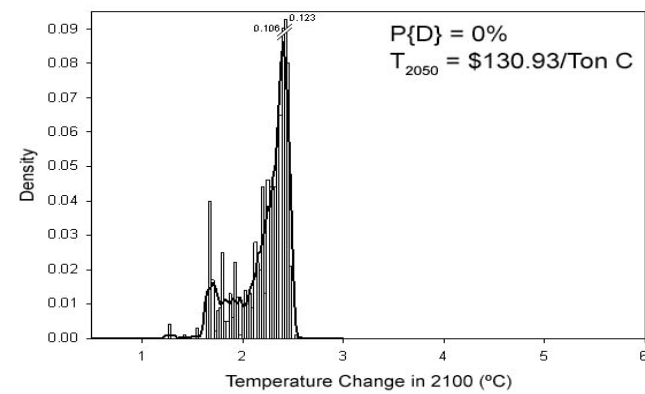
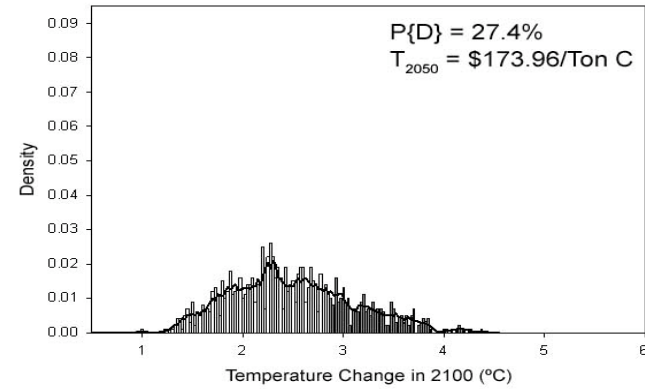
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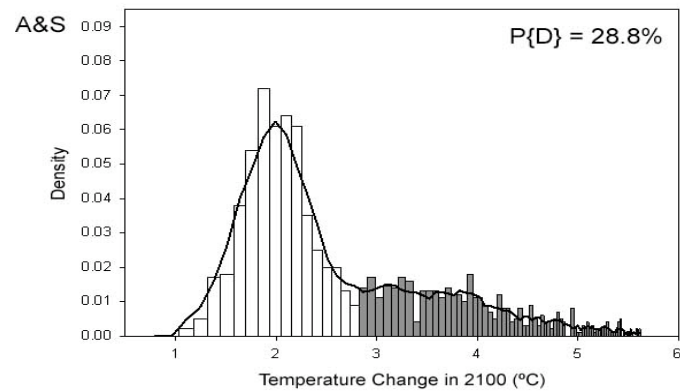
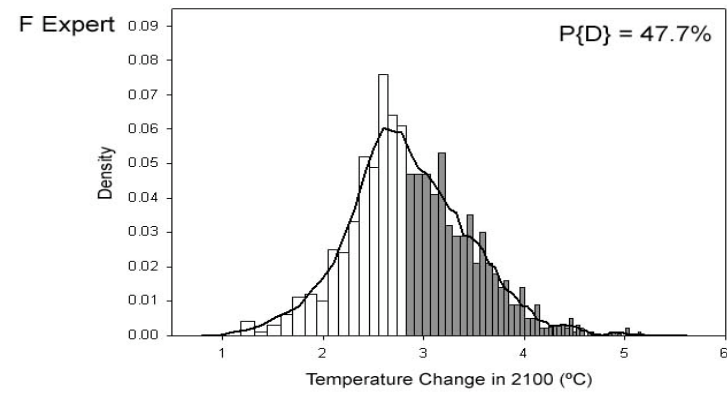
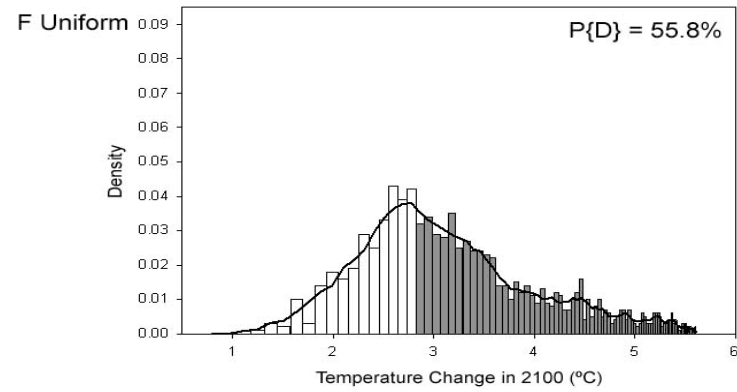
a) Single Monte Carlo



b) Joint Monte Carlo



a) Single Monte Carlo



b) Joint Monte Carlo

