Applied Methods for Documenting, Reporting, and Assessing Uncertainty

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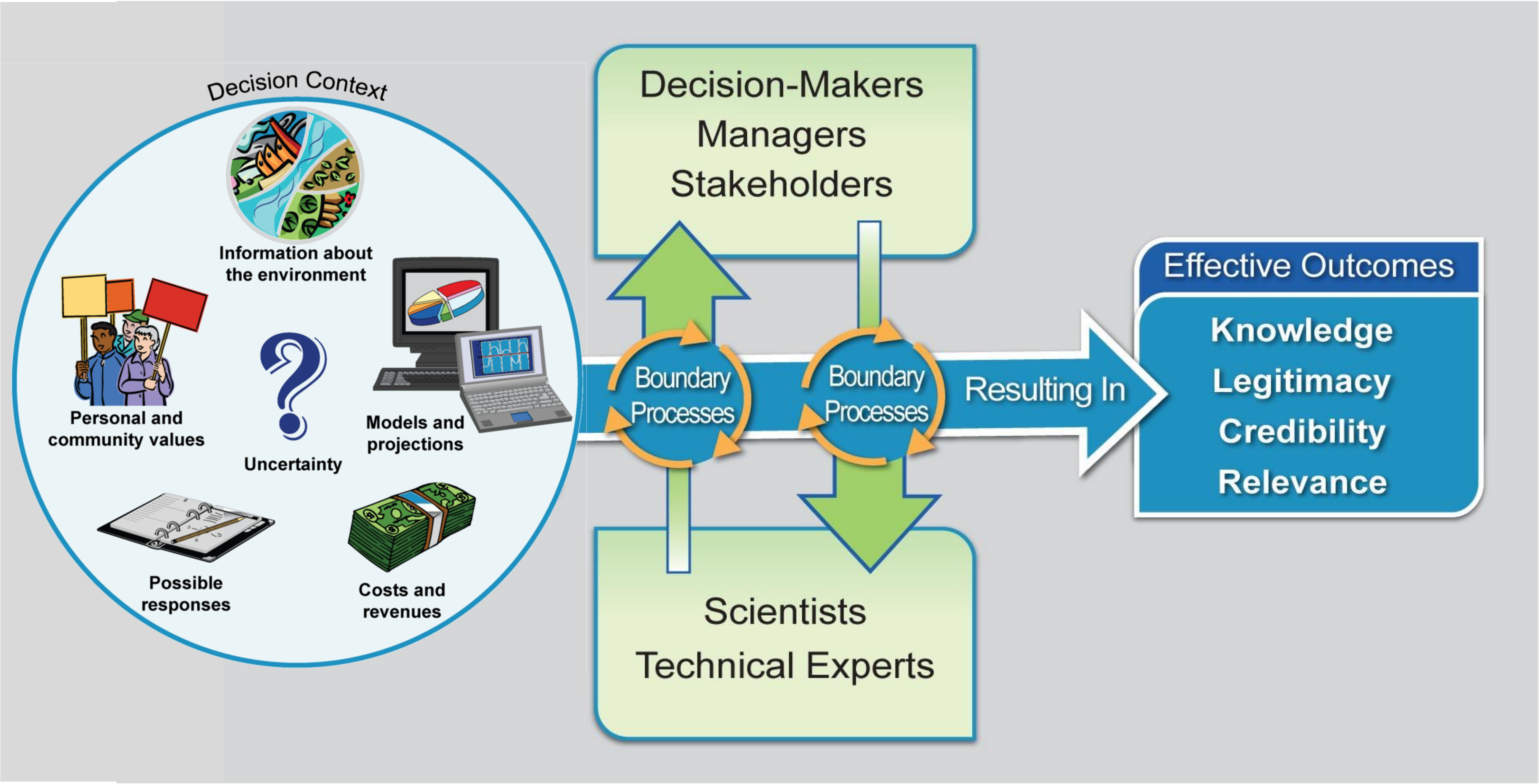
Goal of Scientific Information Production: support decision-making

Three key attributes of information:

- Credibility – creating authoritative, believable, and trusted information
  - Traditional focus of scientists
  - Important, but can overestimate importance of credibility alone
- Salience – creating information relevant to decision making bodies or publics
- Legitimacy – creating information through fair processes, considering appropriate values, concerns, perspectives of different stakeholders

Strong processes critical to cross the boundary from Science to Decision-making

Boundary Processes Linking Decision-Makers and Scientific/Technical Experts

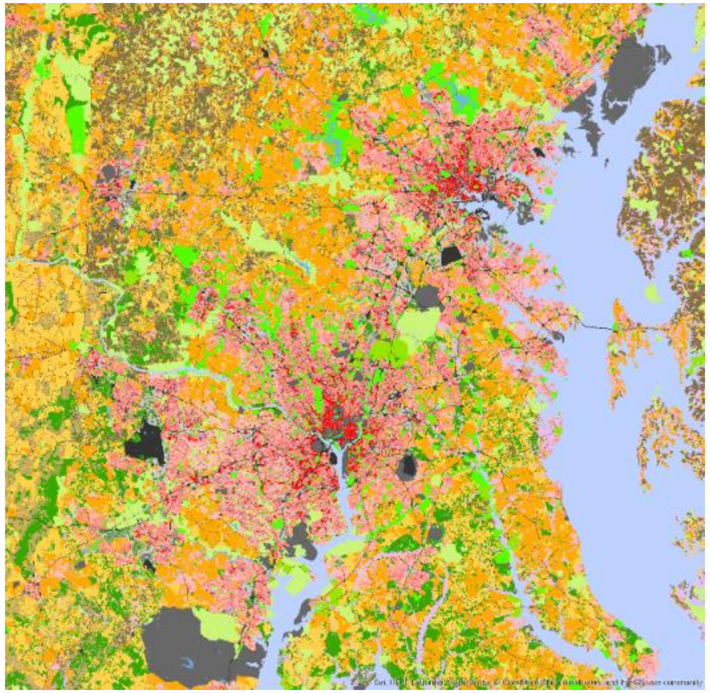


Source: Climate Change Impacts in the United States: The Third National Climate Assessment (Chapter 26)

Importance of Salience

- Information the scientist thinks is relevant may not be the same as what the decision maker considers relevant, and vice versa
- The scientist needs to know what kinds of questions to ask to produce knowledge salient to the decision maker
- Value of Information approaches: may want/need to consider larger contexts

2010



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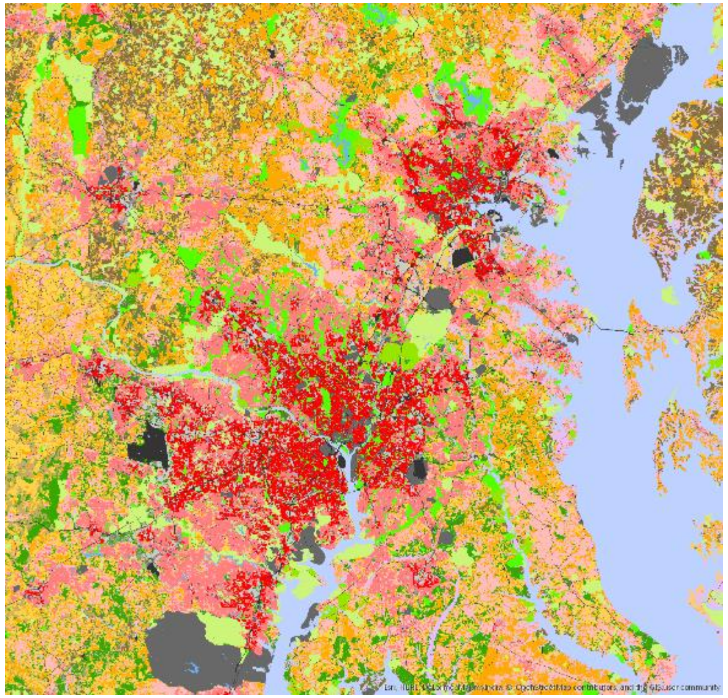


ICLUS: 21st Century Land use: Washington, DC and Baltimore, MD (higher population growth scenario)

Importance of Legitimacy

- Legitimacy is developed through having a fair and open process:
  - For framing problems
  - For setting research agendas
  - For engaging experts in the scientific endeavor
  - For considering policy options
- Legitimacy is also developed through how boundaries are bridged
  - Between decision makers, decision makers with experts, between experts, among all parties
- Saliency or credibility of the information may not matter if the way it is produced is perceived as unfair or not inclusive

CIDA/Decision Scaling

Source: Ranger et al., 2010.

Importance of Credibility

- Science can produce conflicting information and recommendations
- Decision makers judge among information sources based on which are viewed as more plausible and/or accurate
- What are the criteria by which believability or trustworthiness of the information sources will be judged?
  - Holding salience constant, the expert who is most credible will influence the decision making
  - Information that is not credible is likely to be ignored
  - Transparency can play a key role
    - Documentation of conclusions
    - Literature and data – systematic review approaches

Tensions and Complementarities among salience, credibility, legitimacy

Attempts to increase…	Influence salience	Influence credibility	Influence legitimacy
salience	---	↓ by "tainting" science with politics; ↑ by including "place-based" knowledge	↑ or ↓ by increasing the inclusion of different decision makers
credibility	↓ by isolating the science and removing decision maker input; ↑ by including different scientific disciplines who ask different questions	---	↓ by limiting participation and thus decreasing process legitimacy; ↑ by increasing inclusiveness of expertise from formally excluded group
legitimacy	↓ by changing the focus of the resulting information and therefore its usefulness to defined users ↑ by increasing inclusiveness and therefore increasing participation of decision makers	↓ by "tainting" science with politics; ↑ by increasing the inclusion of different knowledges	---

Source: Cash et. al, 2003

What do we mean by uncertainty? (following Knight, 1921)

- Decision making under certainty: m=1

  Max $v(y_{i,1})$

- Decision making under <u>*risk*</u>: $p(\Theta j)$; $j = 1 \ldots m$; $\sum_{J=1}^{m} p(\Theta j) = 1$

  Assuming risk neutrality, then:

  Max $\sum_{J=1}^{m} v(y_{i,j}) p(\Theta_j)$

- Decision making under uncertainty: $p(\Theta j)$ are unknown

- BMP removal efficiency estimates seem like they are between risk and uncertainty
  - Panel needs to document "uncertainties in the published literature (across and within studies)"
  - Also how the Panel came to their conclusions, accounting for scientific uncertainties and variation in empirical findings of removal effectiveness, in a rigorous and transparent way
  - Inevitably will involve expert judgements, which should be fully documented
  - Tailor effort to meet requirement, e.g., using simple approaches may be "good enough"

1st and 2nd IPCC Report (1990 and 1995)

- High Confidence —This category denotes wide agreement, based on multiple findings through multiple lines of investigation. In other words, there was a high degree of consensus among the authors based on the existence of substantial evidence in support of the conclusion.
- Medium Confidence —This category indicates that there is a consensus, but not a strong one, in support of the conclusion. This ranking could be applied to a situation in which an hypothesis or conclusion is supported by a fair amount of information, but not a sufficient amount to convince all participating authors, or where other less plausible hypotheses cannot yet be completely ruled out.
- Low Confidence —This category is reserved for cases when lead authors were highly uncertain about a particular conclusion. This uncertainty could be a reflection of a lack of consensus or the existence of serious competing hypotheses, each with adherents and evidence to support their positions. Alternatively, this ranking could result from the existence of extremely limited information to support an initial plausible idea or hypothesis.

EXECUTIVE SUMMARY

We are certain of the following:

- there is a natural greenhouse effect which already keeps the Earth warmer than it would otherwise be

- emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide These increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface The main greenhouse gas, water vapour, will increase in response to global warming and further enhance it

We calculate with confidence that:

- some gases are potentially more effective than others at changing climate, and their relative effectiveness can be estimated Carbon dioxide has been responsible for over half the enhanced greenhouse effect in the past, and is likely to remain so in the future

- atmospheric concentrations of the long-lived gases (carbon dioxide, nitrous oxide and the CFCs) adjust only slowly to changes in emissions Continued emissions of these gases at present rates would commit us to increased concentrations for centuries ahead The longer emissions continue to increase at present day rates, the greater reductions would have to be for concentrations to stabilise at a given level

- the long-lived gases would require immediate reductions in emissions from human activities of over 60% to stabilise their concentrations at today's levels, methane would require a 15-20% reduction

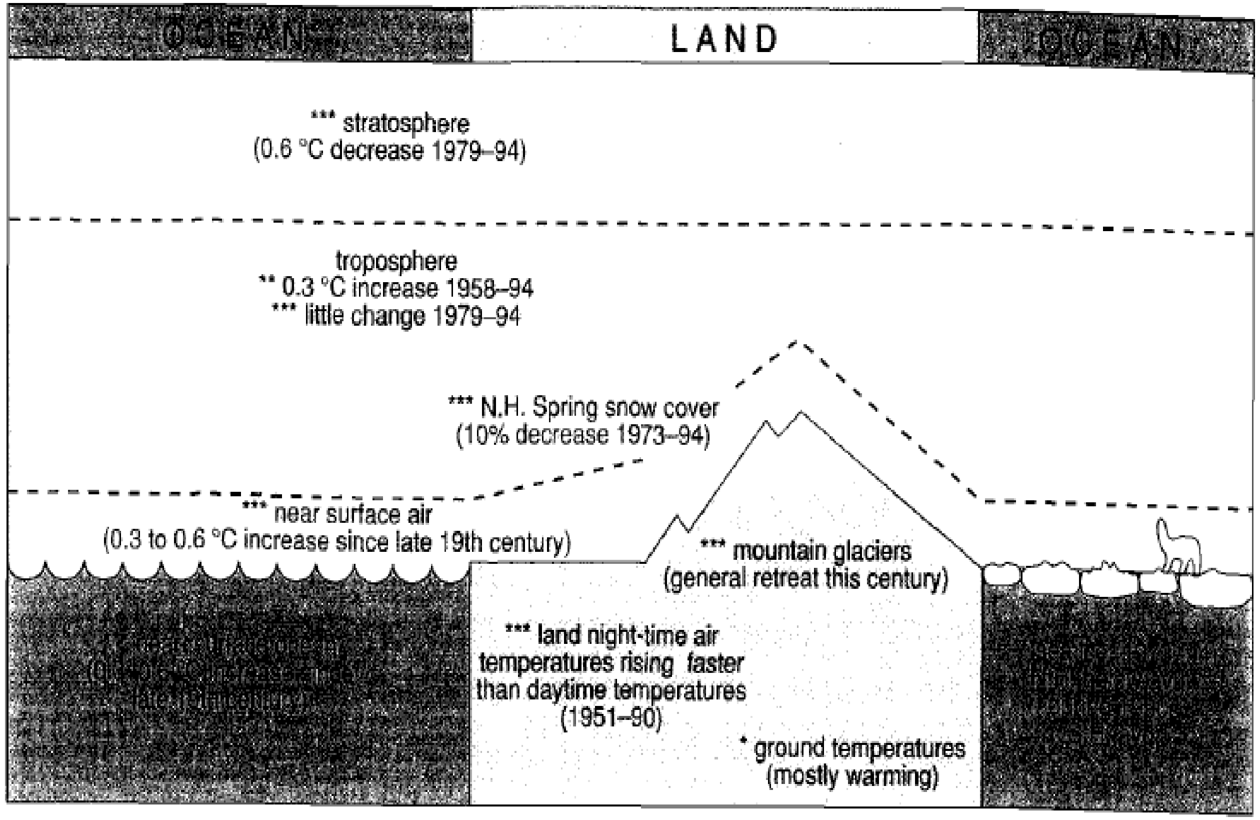
Based on current model results, we predict:

- under the IPCC Business-as-Usual (Scenario A) emissions of greenhouse gases, a rate of increase of global mean temperature during the next century of about 0 3°C per decade (with an uncertainty range of 0 2°C to 0 5°C per decade), this is greater than that seen over the past 10,000 years This will result in a likely increase in global mean temperature of about 1°C above the present value by 2025 and 3°C before the end of the next century The rise will not be steady because of the influence of other factors

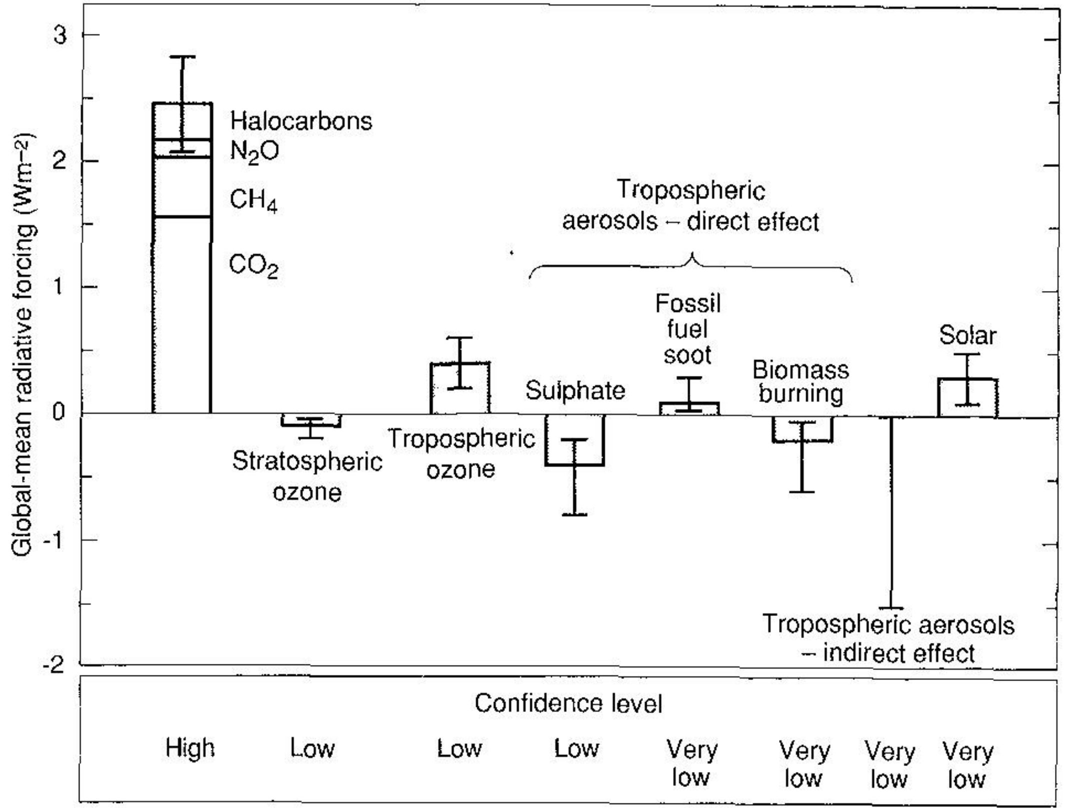
- under the other IPCC emission scenarios which assume progressively increasing levels of controls rates of increase in global mean temperature of about 0 2°C per decade (Scenario B), just above 0 1°C per decade (Scenario C) and about 0 1°C per decade (Scenario D)

2nd IPCC Report (1995)

(a) **Temperature indicators**



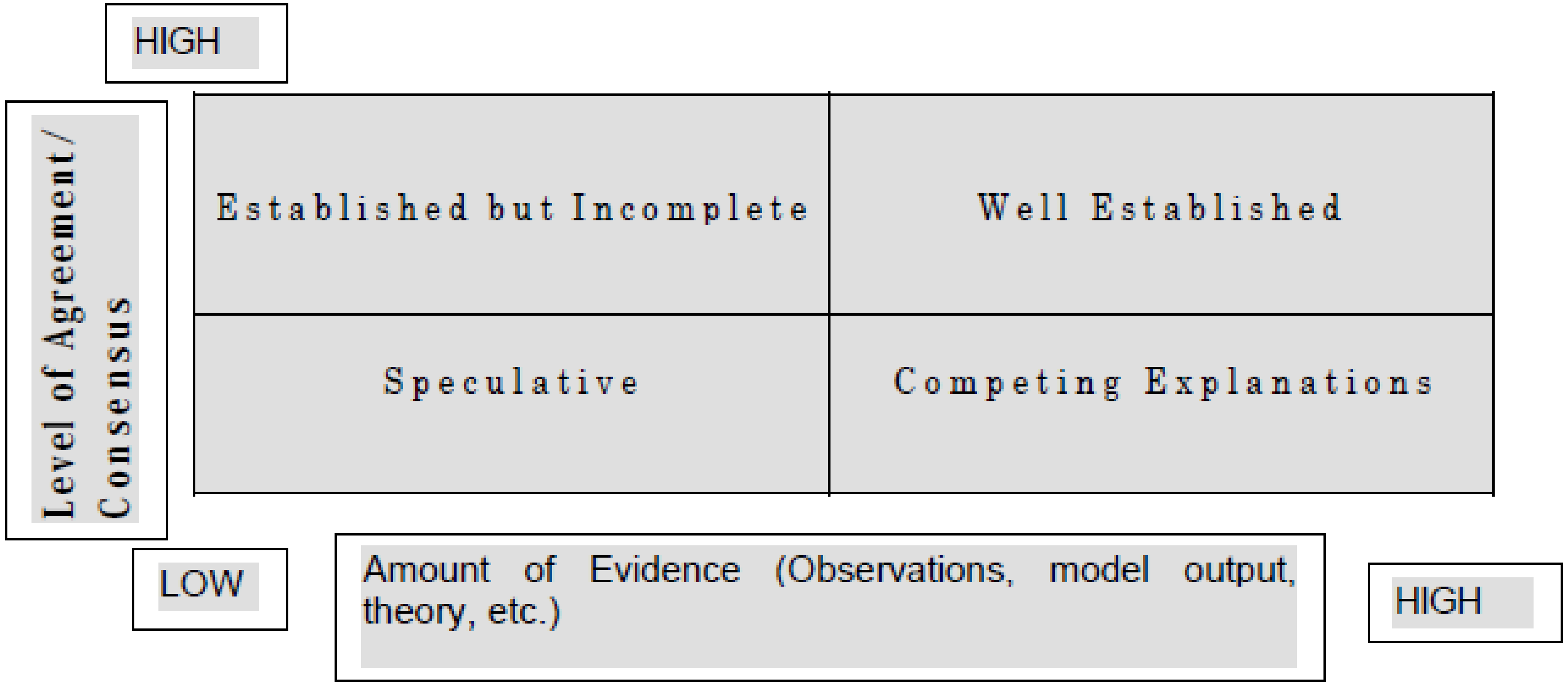
Asterisk indicates confidence level (i.e., assessment): * high, ** medium, * low**



3rd IPCC report: Guidance notes (2000)

(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)

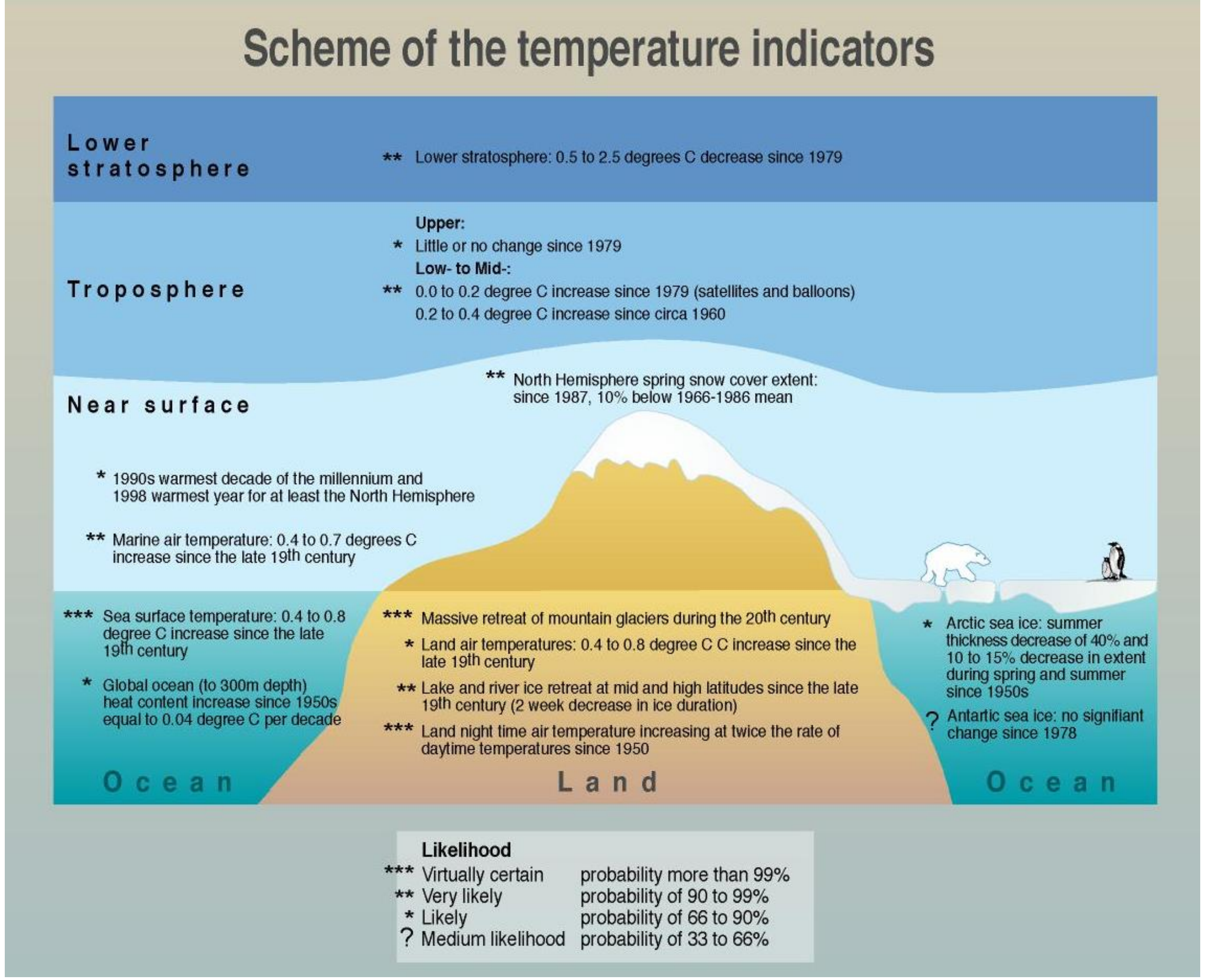
Scale for Assessing State of Knowledge

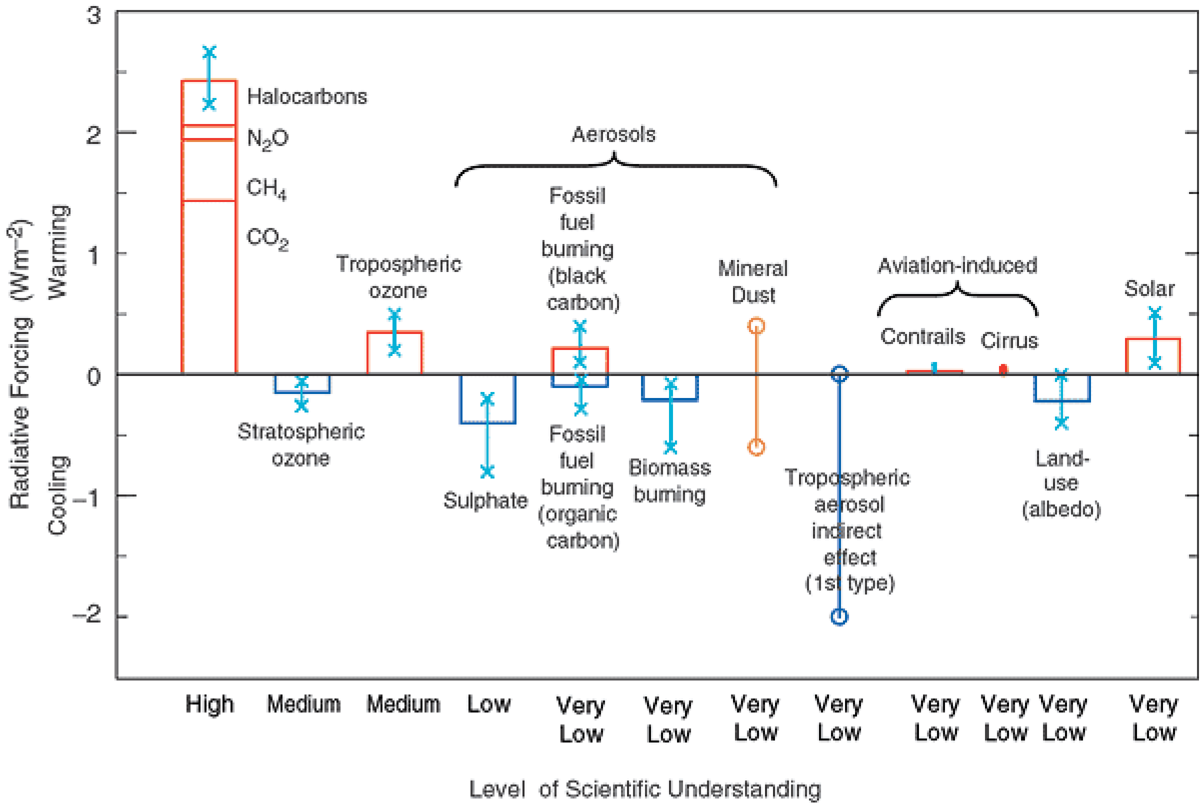


Supplemental Qualitative Uncertainty Terms

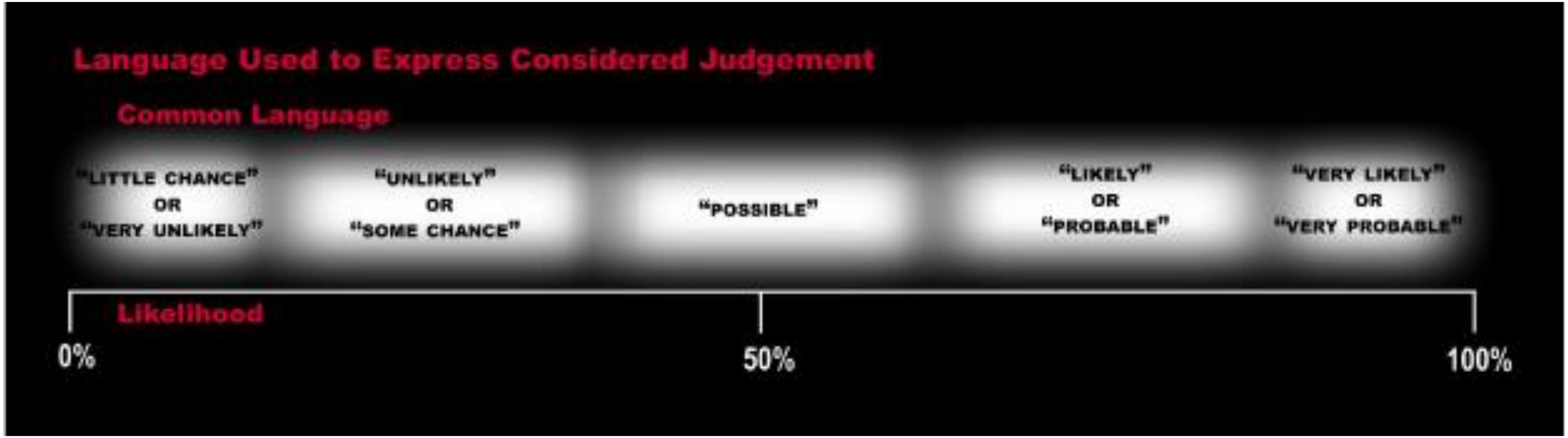
Authors to prepare a traceable account of how estimates were constructed

3rd IPCC Report (2001)





1st National Climate Assessment (1997-2001)



- Relied on "considered judgment" based on historical data, model projections, published scientific literature and other available information
  - Some based on broad scientific consensus as stated by authorities (e.g., IPCC, NRC)
- Not well documented

4^{th} IPCC Report: Guidance notes (2005)

Table 1. A simple typology of uncertainties

Type	Indicative examples of sources	Typical approaches or considerations
Unpredictability	Projections of human behaviour not easily amenable to prediction (e.g. evolution of political systems). Chaotic components of complex systems.	Use of scenarios spanning a plausible range, clearly stating assumptions, limits considered, and subjective judgments. Ranges from ensembles of model runs.
Structural uncertainty	Inadequate models, incomplete or competing conceptual frameworks, lack of agreement on model structure, ambiguous system boundaries or definitions, significant processes or relationships wrongly specified or not considered.	Specify assumptions and system definitions clearly, compare models with observations for a range of conditions, assess maturity of the underlying science and degree to which understanding is based on fundamental concepts tested in other areas.
Value uncertainty	Missing, inaccurate or non-representative data, inappropriate spatial or temporal resolution, poorly known or changing model parameters.	Analysis of statistical properties of sets of values (observations, model ensemble results, etc); bootstrap and hierarchical statistical tests; comparison of models with observations.

What kind of uncertainty is BMP performance?

4th IPCC Report: Guidance notes (2005)

Table 2. Qualitatively defined levels of understanding

Level of agreement or consensus →

High agreement limited evidence	…	*High agreement much evidence*
…	…	…
Low agreement limited evidence	…	*Low agreement much evidence*

Amount of evidence (theory, observations, models) →

Table 3. Quantitatively calibrated levels of confidence.

Terminology	Degree of confidence in being correct
Very High confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Table 4. Likelihood Scale.

Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability of occurrence
Very likely	> 90% probability
Likely	> 66% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Exceptionally unlikely	< 1% probability

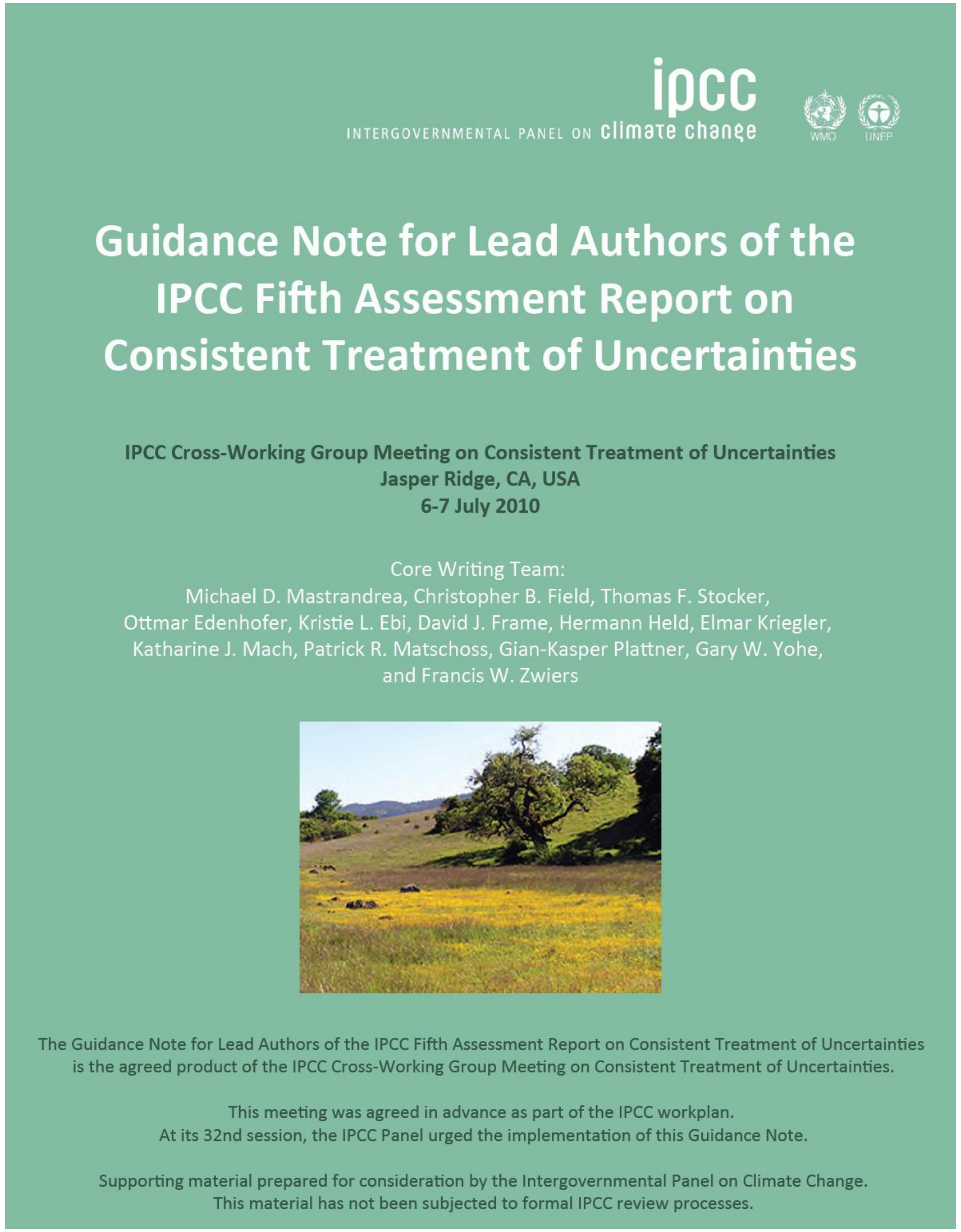
Each of the three IPCC Working Groups used a different approach

2nd US National Assessment (2008) -- SAP4.4: Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources

Agreement →		
	LH Low evidence High agreement	**HH** High evidence High agreement
	LL Low evidence Low agreement	**HL** High evidence Low agreement
	Evidence →	

	Protecting key ecosystem features	Reducing anthropogenic stresses	Representation	Replication	Restoration	Refugia	Relocation
National Forests	HL	HH	LL	LL	HL	HL	HL
National Parks	HH	HH	LL	LL	HH	LL	LL
National Wildlife Refuges	HH	HH	HH	HH	LL	HL	LL
Wild and Scenic Rivers	LH	HH	HH	HH	LL	HH	LL
National Estuaries	LL	HH	LH	LH	HH	LL	N/A
Marine Protected Areas	LH	LH	LH	LH	LL	LH	N/A

- Legitimacy, salience and credibility were all going to be challenges
- Lead Author's drawn from outside EPA (in another Agency or Academic)
- For synthesis, author's asked to assess effective-ness of adaptation option
  - Based on literature, field experience, theory
- Documentation of their conclusions (Handout)
- In some cases, individual chapters formed the core of subsequent adaptation plans
- Not perfect, but fast



ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties

IPCC Cross-Working Group Meeting on Consistent Treatment of Uncertainties
Jasper Ridge, CA, USA
6-7 July 2010

Core Writing Team:
Michael D. Mastrandrea, Christopher B. Field, Thomas F. Stocker, Ottmar Edenhofer, Kristie L. Ebi, David J. Frame, Hermann Held, Elmar Kriegler, Katharine J. Mach, Patrick R. Matschoss, Gian-Kasper Plattner, Gary W. Yohe, and Francis W. Zwiers

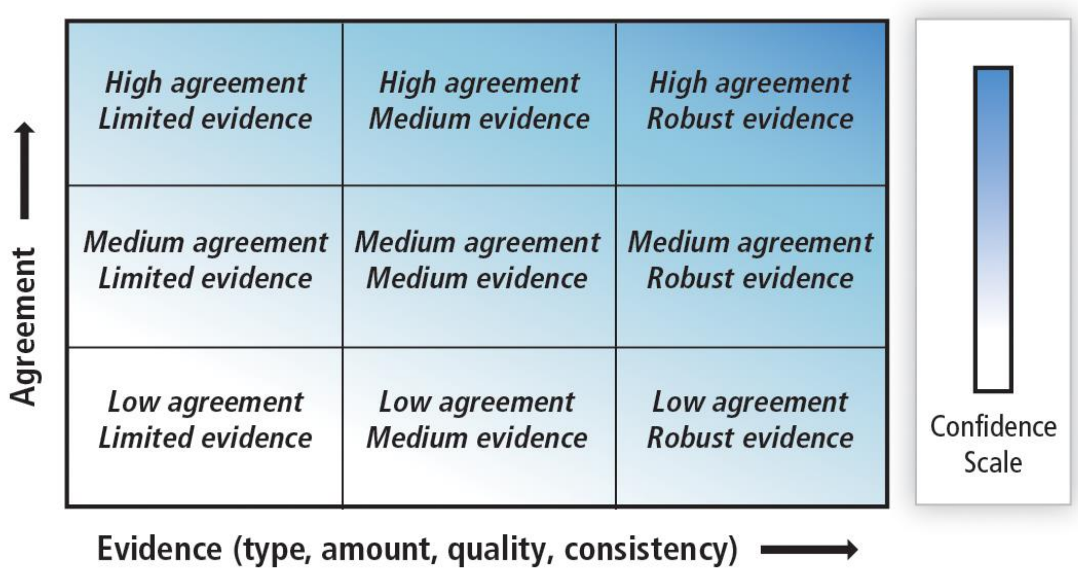
The Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties is the agreed product of the IPCC Cross-Working Group Meeting on Consistent Treatment of Uncertainties.

This meeting was agreed in advance as part of the IPCC workplan.
At its 32nd session, the IPCC Panel urged the implementation of this Guidance Note.

Supporting material prepared for consideration by the Intergovernmental Panel on Climate Change.
This material has not been subjected to formal IPCC review processes.

AR5 relied on two metrics:

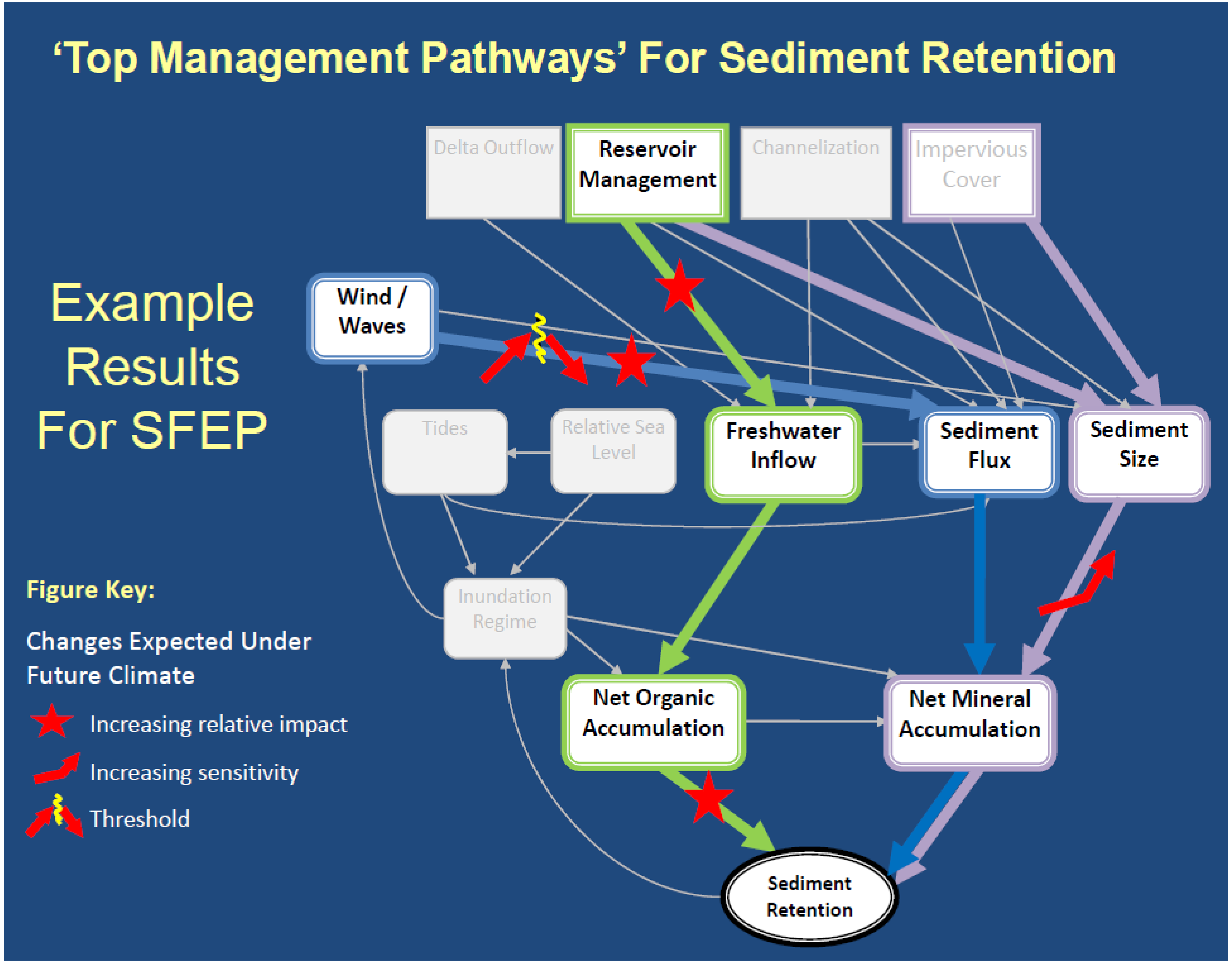
- Confidence in the validity of a finding, based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement. Confidence is expressed **qualitatively**.
- Quantified measures of uncertainty in a finding expressed probabilistically (based on statistical analysis of observations or model results, or expert judgment). (Likelihood)



2016 USGCRP Special Report on Climate Change and Health: Key Findings –Air Quality Impacts Chapter

- Exacerbated Ozone Health Impacts Key Finding 1: Climate change will make it harder for any given regulatory approach to reduce ground-level ozone pollution in the future as meteorological conditions become increasingly conducive to forming ozone over most of the United States [Likely, High Confidence]. Unless offset by additional emissions reductions of ozone precursors, these climate-driven increases in ozone will cause premature deaths, hospital visits, lost school days, and acute respiratory symptoms [Likely, High Confidence].
- Handout on traceable account

Expert elicitation



Multi-disciplinary process using expert judgment to inform decision-making when:

- Empirical data are not yet complete
- Uncertainties are large
- More than one conceptual model can explain available data
- Technical judgments are required to assess assumptions

Not a formal EE, but an approach based on the same principles and elements

Two-day workshops to elicit expert judgments on:

- Conceptual modeling of relationships among physical and biological components of each ecosystem process
- Sensitivities of relationships under a) current conditions and b) two future climate change scenarios
- Potential for threshold shifts under climate change

Have focused on how to characterize and communicate uncertainty and conclusions – but we also need to do a better job on how we got there

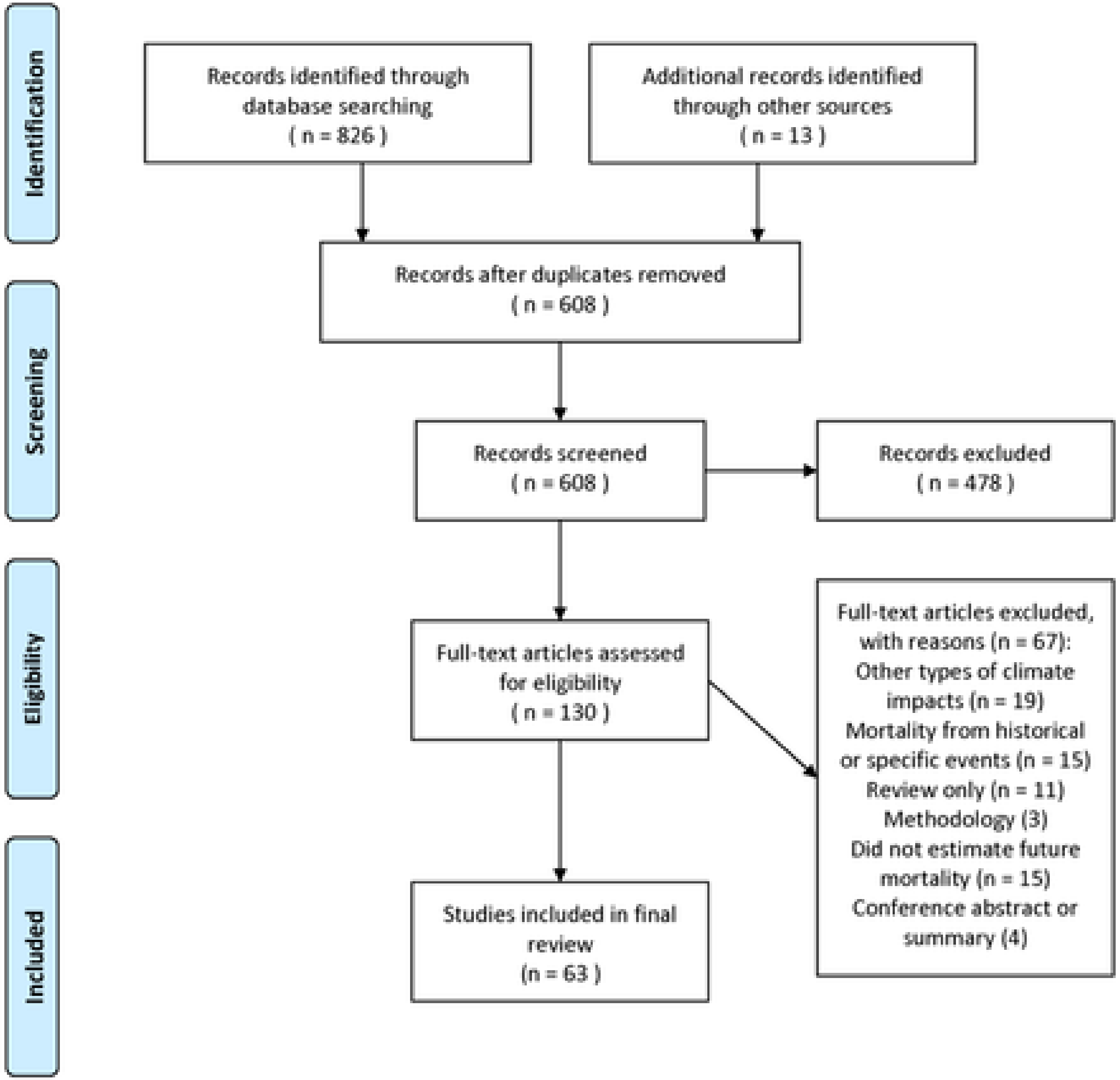
	Traditional Literature Review	Systematic Review
The review question/topic	Topics may be broad in scope; the goal of the review may be to place one's own research within the existing body of knowledge, or to gather information that supports a particular viewpoint.	Starts with a well-defined research question to be answered by the review. Reviews are conducted with the aim of finding all existing evidence in an unbiased, transparent and reproducible way.
Searching for studies	Searches may be ad hoc, and based on what the author is already familiar with. Searches are not exhaustive or fully comprehensive.	Attempts are made to find all existing published and unpublished literature on the research question. The process is well-documented and reported.
Study selection	Often lack clear reasons for why studies were included or excluded from the review.	Reasons for including or excluding studies are explicit and informed by the research question.
Assessing the quality of included studies	Often do not consider study quality or potential biases in study design.	Systematically assess risk of bias of individual studies and overall quality of the evidence, including sources of heterogeneity between study results.
Synthesis of existing research	Conclusions are more qualitative and may not be based on study quality.	Base conclusion on quality of the studies, and provide recommendations for practice or to address knowledge gaps.

Recently have begun seeing systematic review approaches in climate assessments

- Predominantly used in health sciences
- Systematic review is a process, not a static-outcome; can be dynamic, flexible, adaptable to meet needs
- No 'one size fits all' – intent is to increase the transparency and intentionality of methods

Lots of approaches to research synthesis – some qualitative, some quantitative

Could also be used in conjunction with EE, other decision analytic approaches



PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)

PRISMA is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses

Includes a 27-item checklist and a four-phase flow diagram

General concepts and topics covered by PRISMA are relevant to any systematic review – but, some modification of the checklist items or flow diagram may be necessary/desirable

Sanderson M, Arbuthnott K, Kovats S, Hajat S, Falloon P (2017) The use of climate information to estimate future mortality from high ambient temperature: A systematic literature review. PLOS ONE 12(7): e0180369. https://doi.org/10.1371/journal.pone.0180369
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0180369

Proposed components of a systematic review in adaptation research

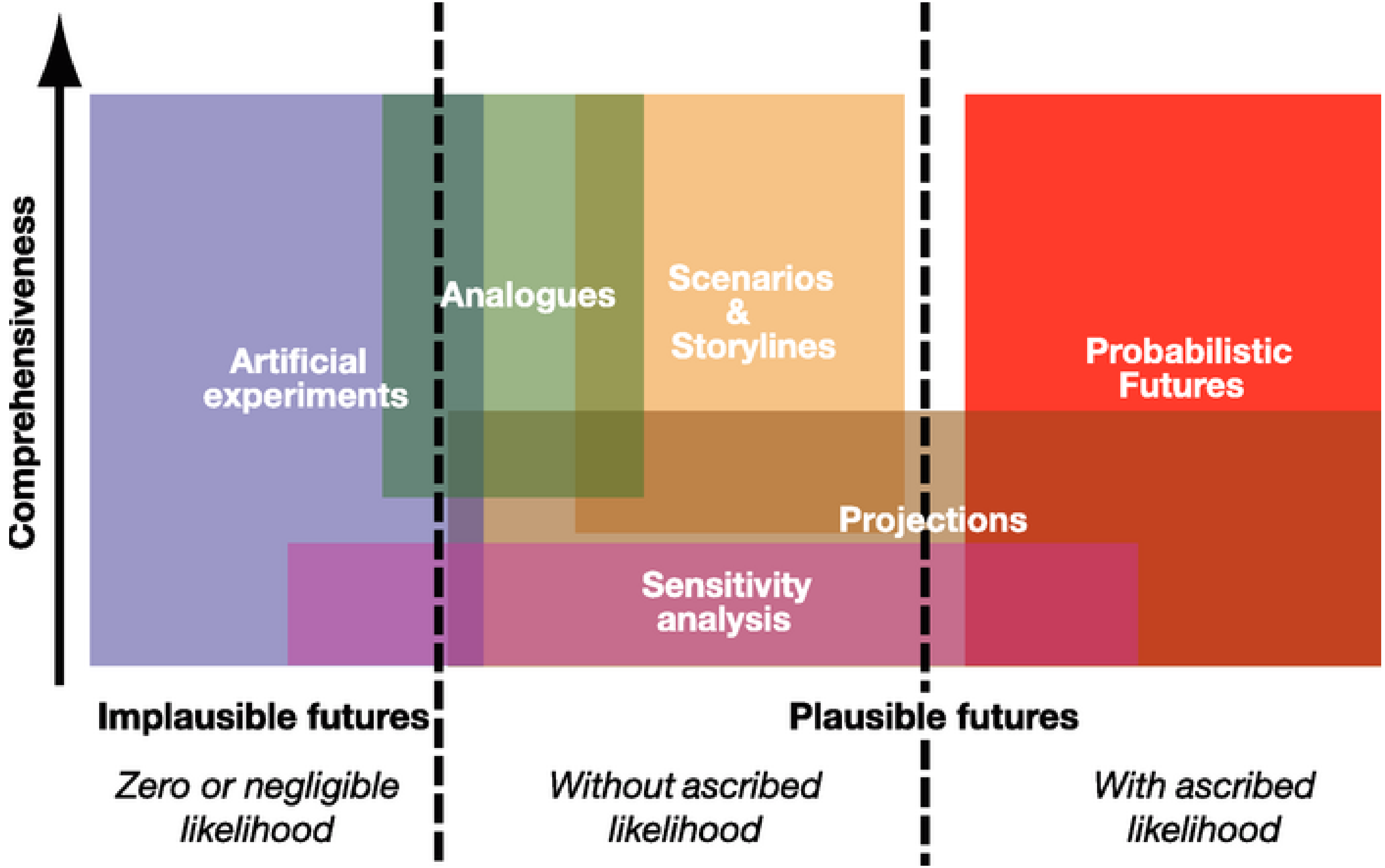
Research question/aim
Explicit aim and objectives of review Including context and scoping of the research problem.
Clear description of theoretical or conceptual approach used to guide the review
Data source and document selection
Justification and description of literature source, and consideration of bias arising from the selection of literature source.
Articulation of search terms and/or detailed description of search process
Description of criteria for inclusion and exclusion
Documentation of literature included and excluded
Analysis and presentation of results
Description of methods for analysis
Critical appraisal of information quality

Berrang-Ford, L., Pearce, T. & Ford, J.D. (2015)


Thank you!
Questions?

- Supplemental Materials

Scenarios


Comprehensiveness
Artificial experiments
Analogues
Scenarios & Storylines
Probabilistic Futures
Projections
Sensitivity analysis
Implausible futures
Plausible futures
Zero or negligible likelihood
Without ascribed likelihood
With ascribed likelihood

Global-Mean Sea Level Rise

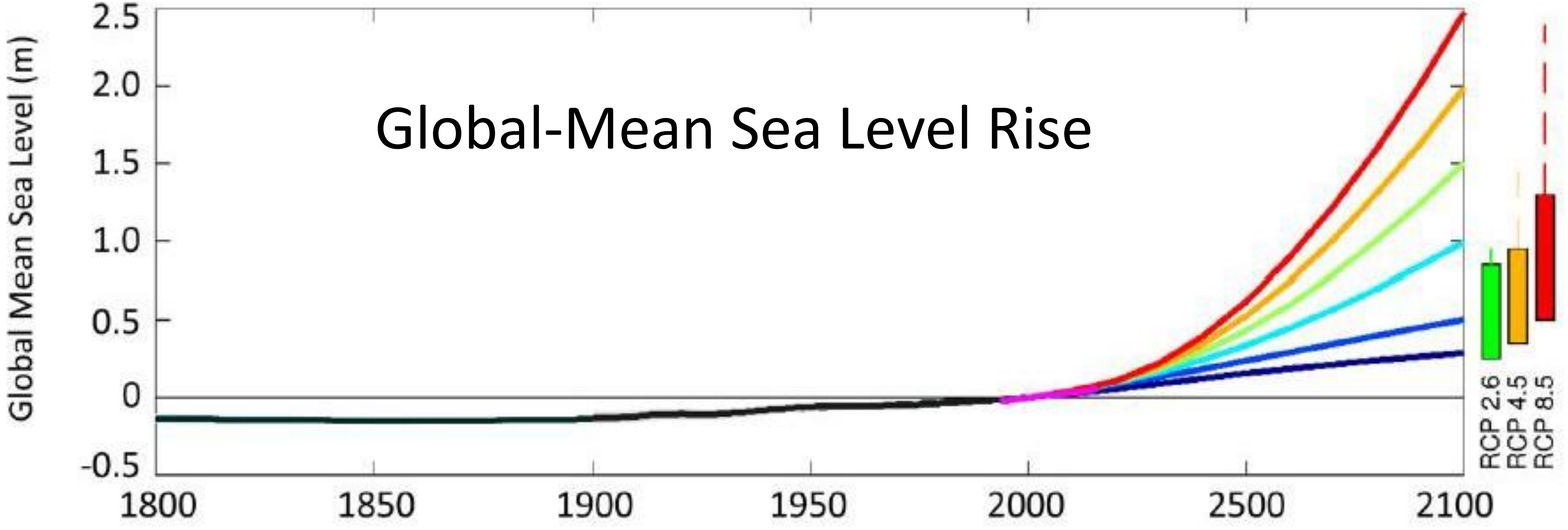
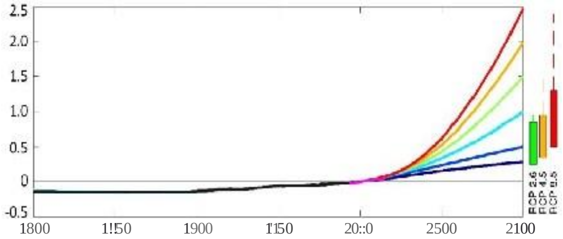


Table 4. Probability of exceeding GMSL (median value) scenarios in 2100 based upon Kopp et al. (2014).

GMSL rise Scenario	RCP2.6	RCP4.5	RCP8.5
Low (0.3 m)	94%	98%	100%
Intermediate-Low (0.5 m)	49%	73%	96%
Intermediate (1.0 m)	2%	3%	17%
Intermediate-High (1.5 m)	0.4%	0.5%	1.3%
High (2.0 m)	0.1%	0.1%	0.3%
Extreme (2.5 m)	0.05%	0.05%	0.1%

Change in Relative Sea Level (RSL):

$$\Delta RSL = \Delta SL_{G} + \Delta SL_{RM} + \Delta SL_{RG} + \Delta SL_{VLM}$$



Regional:
f (oceanographic factors; dynamic SLR)

Regional:
f(changes in Earth's g-field due to ice melt redistribution)

Local:
f(uplift/subsidence, GIA)

1-degree x 1-degree data product for the U.S. (incl. AK, HI, Caribbean, Islands)

Relative Regional Sea Level Rise