Tyndall, climate change, certainty and uncertainty, and IPCC

Jean-Pascal van Ypersele, IPCC Vice-chair (speaking in personal capacity)

and Philippe Marbaix

Earth & Life Institute
Université catholique de Louvain
(Louvain-la-Neuve, Belgium)

www.climate.be and www.ipcc.ch
vanyp(@)climate.be

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Thanks to the Belgian Federal Science Policy Office for its support

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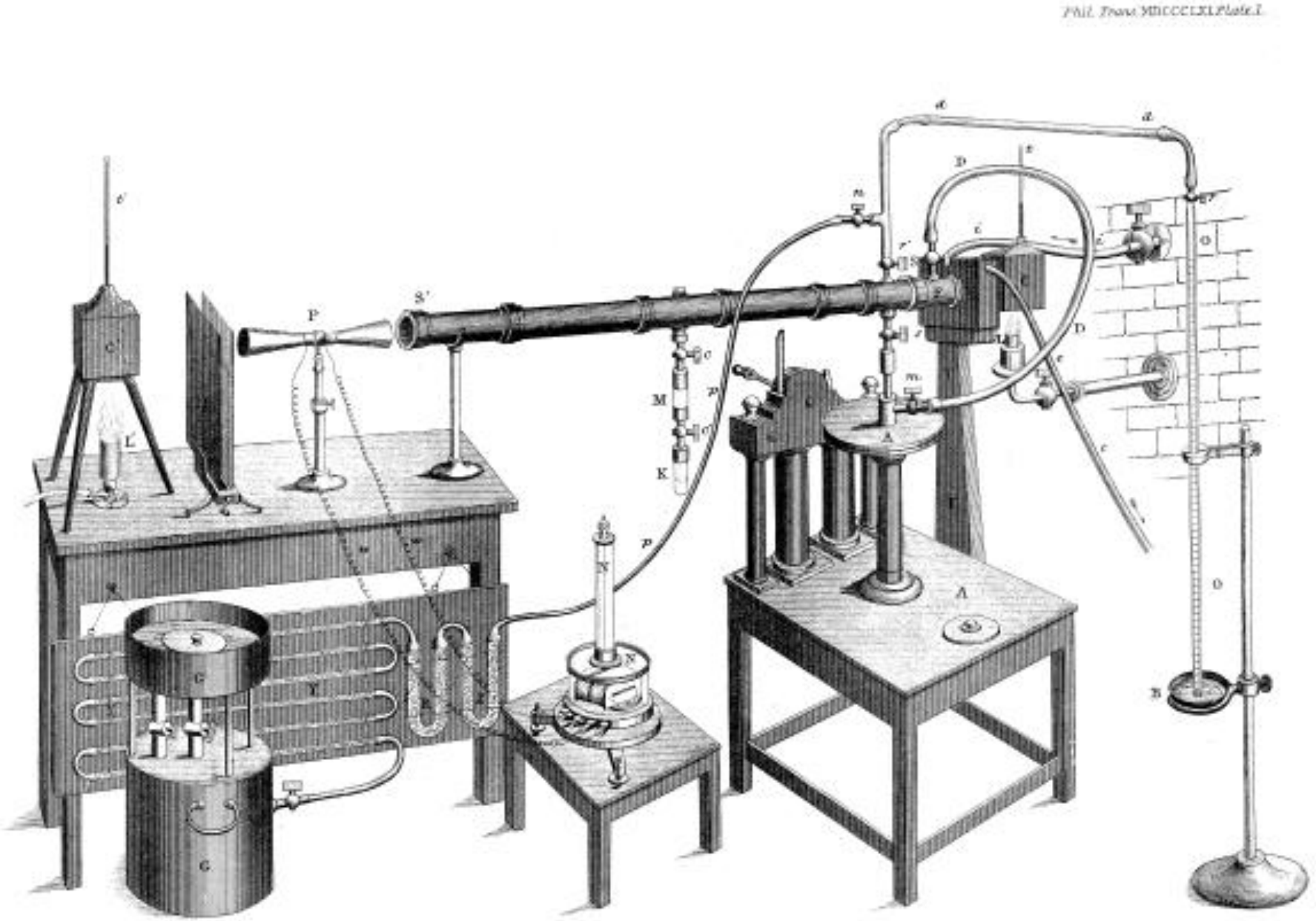


Tyndall (1861)

Tyndall and uncertainty

- "Approximate results were easily obtainable, but I aimed at exact measurements"
- "… a perfect galvanometer is the result"
- "… during the seven weeks just referred to, I experimented from 8 to 10 hours daily"… but these experiments, though more accurate, must unhappily share the fate of the former ones."
- "I am unable at the present moment to range with certainty oxygen, hydrogen, nitrogen, and atmospheric air in the order of their absorptive powers, though I have made several hundred experiments…"

Source: Tyndall Lecture (1861)

Tyndall and uncertainty

- **"It is exceedingly probable that the absorption of the solar rays by the atmosphere, as established by M. Pouillet, is mainly due to the watery vapour contained in the air."**
- **"Every variation of this constituent (aqueous vapour) must produce a change in climate. Similar remarks would apply to the carbonic acid diffused through the air."**

Source: Tyndall Lecture (1861)

Tyndall and uncertainty

- **"… a slight change in [atmospheric] variable constituents would suffice for … different amounts of heat preserved to the earth at different times. Such changes in fact may have produced all the mutations of climate which the … geologists reveal"**
- **"However this may be, the above facts above cited remain; they constitute true causes, the *extent* alone of the operation remaining doubtful"**

Source: Tyndall Lecture (1861)

Uncertainty

« The term “uncertainty” implies anything from confidence just short of certainty to informed guesses or speculation.

Lack of information obviously results in uncertainty, but often, disagreement about what is known or even knowable is a source of uncertainty.

Some categories of uncertainty are amenable to quantification, while others cannot be expressed sensibly in terms of probabilities »

S. H. Schneider, *Uncertainty is prevalent in the climate change debate* (www.climatechange.net)

Greenhouse effect once was speculative…

- The idea of "greenhouse effect" appeared progressively:
  - E. Mariotte, 1681: *Sun's light and heat easily pass through glass and other transparent materials, heat from other sources does not*
  - de Saussure, 1760, uses the analogy of a greenhouse
  - J. Fourier, 1824: summarize his and previous works on heat and the temperature of the Earth
  - Substance responsible for heat absorption not known

Sources: IPCC AR4, and
J.R. Fleming, Historical Perspectives on Climate Change, OUP 1998

J Fourier, 1824

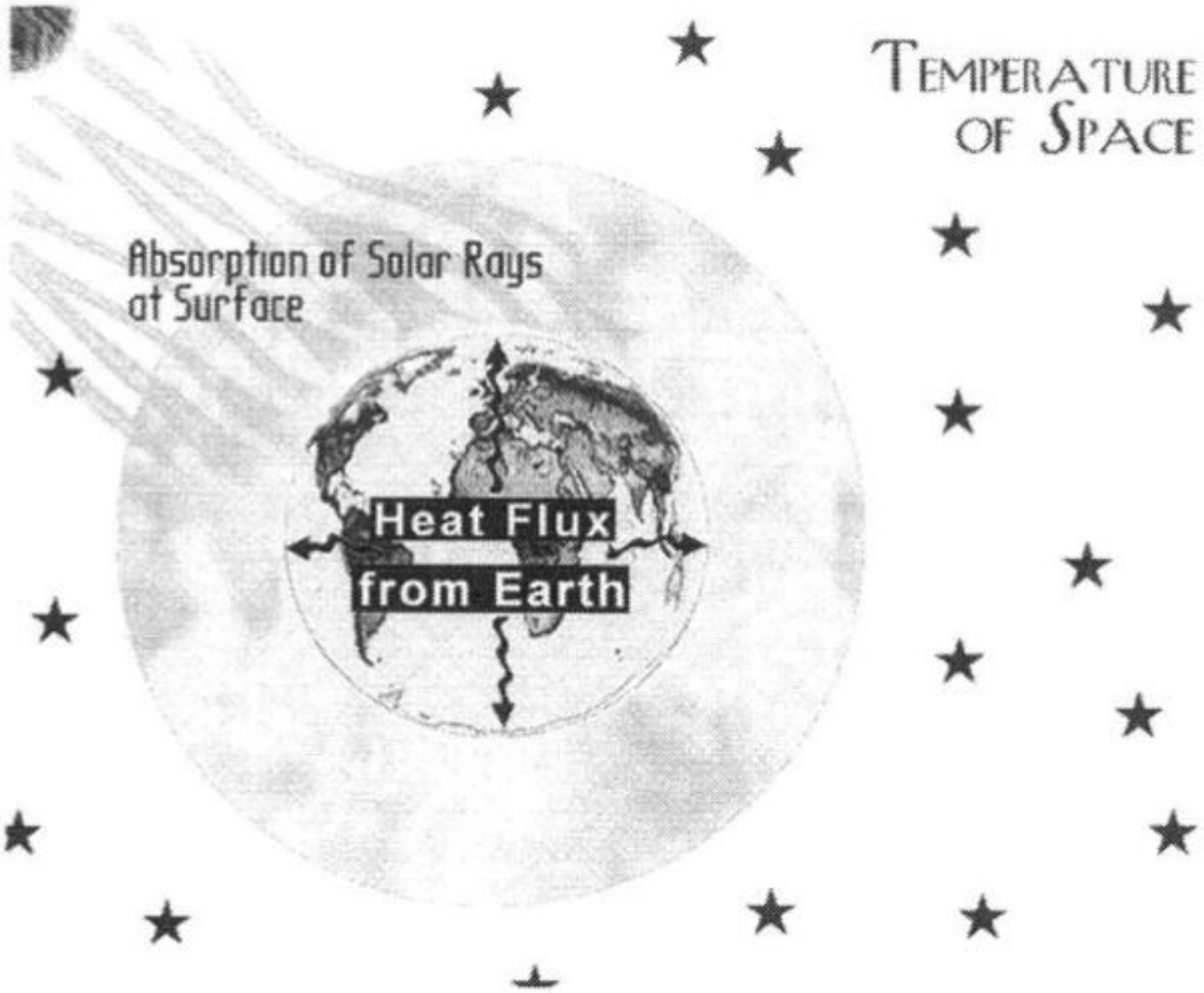


Fig. 5-1. The three heat sources influencing terrestrial temperatures (Fourier).

Source: J.R. Fleming, Historical Perspectives on Climate Change, OUP 1998

Many 19th century scientists contributed knowledge on climate change

- Tyndall, 1861: experiments on IR absorption; he also notes that changes in the amount of CO_2 and H_2O could explain past climate changes
- Other important contributions, e.g. T. C. Chamberlin (water vapour feedback…),…
- Arrhenius, 1896: suggests that a 40% increase or decrease in the atmospheric abundance of CO_2 might trigger the glacial advances and retreats.

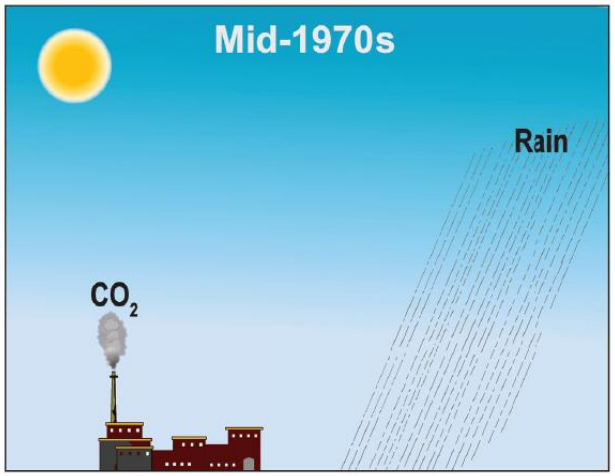
Sources: IPCC AR4, and
J.R. Fleming, Historical Perspectives on Climate Change, OUP 1998

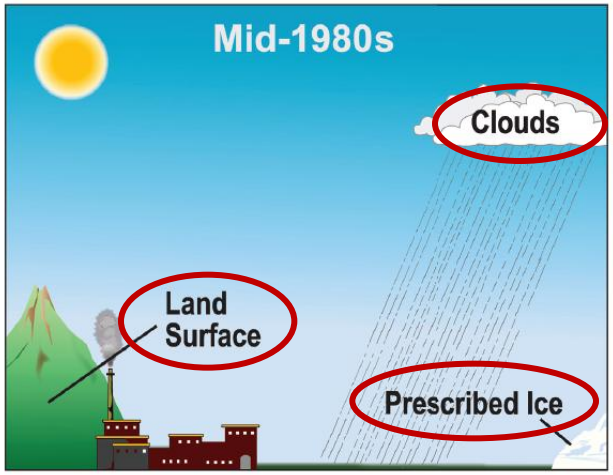
Early 20st century : uncertainty still fundamental

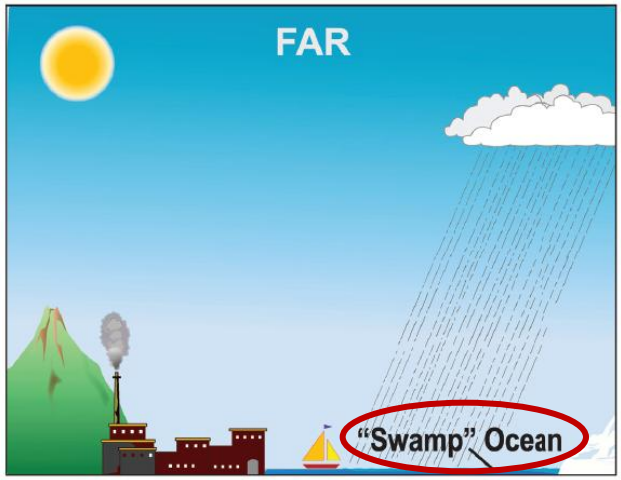
- Arrhenius suggests that doubling CO_2 implies +5°C global warming; thinks that this might be beneficial (e.g. more food…)
  - But knowledge on the details of IR absorption by CO_2 still appears limited by that time (see e.g. Fleming, OUP 1998), so that Arrhenius quantitative result may have partly resulted from compensation of errors (J-L. Dufresne, 2009)
  - At the time, doubt still significant on the role of CO_2: K Angstrom (1900) suggests that CO_2 and H_2O absorb in the same spectral region, …

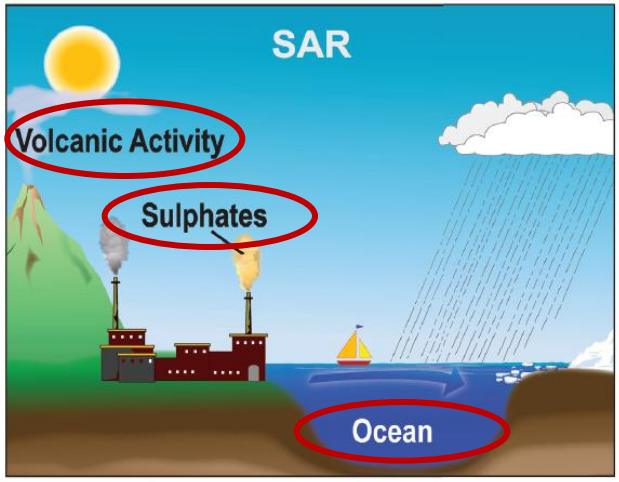
(1) http://www.lmd.jussieu.fr/~jldufres/publi/2009/HDR_JLD.pdf

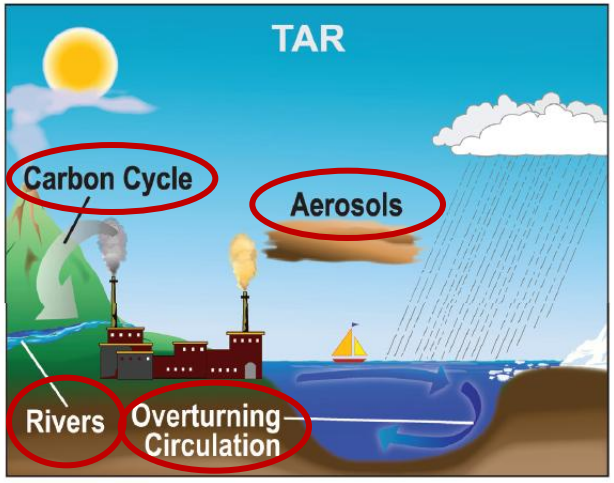
Additional physics incorporated in successive climate models

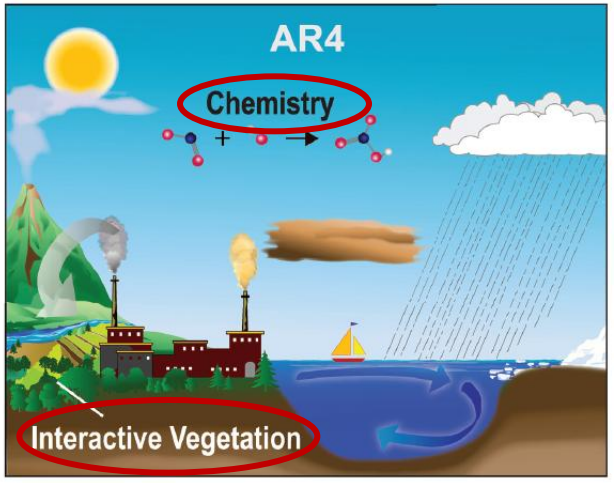












Box 2
Examples of sources of uncertainty

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

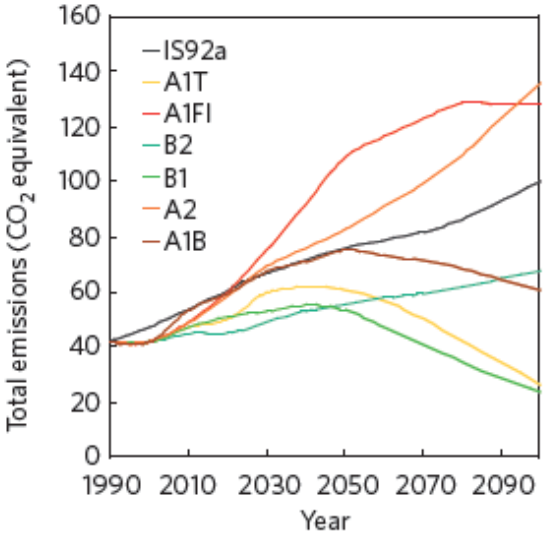
4. Known processes but unknown functional relationships or errors in the structure of the model
5. Known structure but unknown or erroneous values of some important parameters
6. Known historical data and model structure, but reasons to believe parameters or model structure will change over time
7. Uncertainty 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.

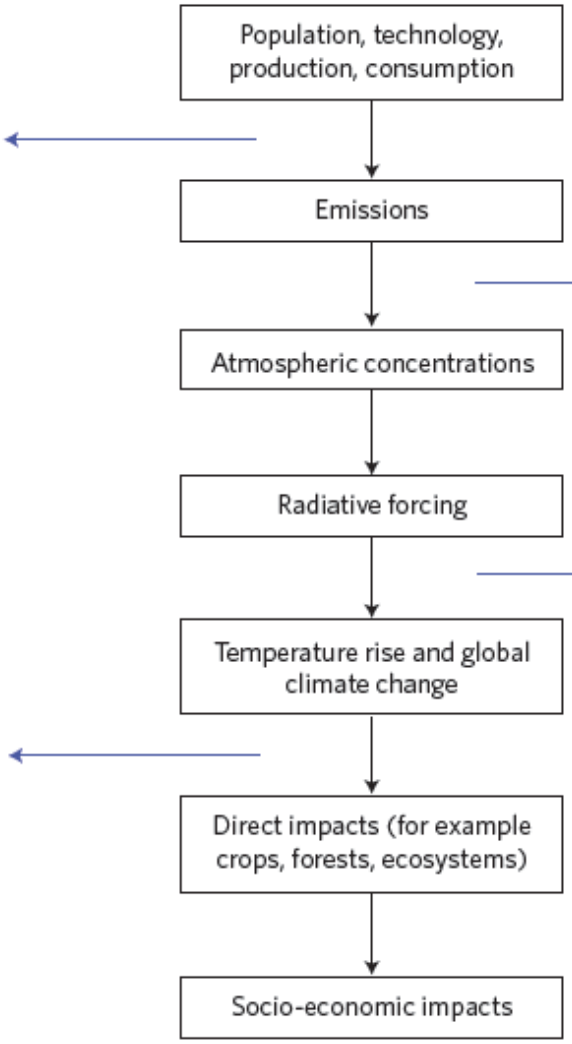
Other sources of uncertainty

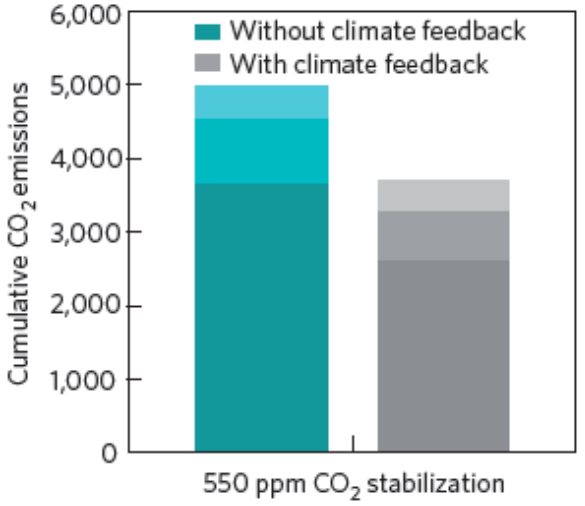
9. Ambiguously defined concepts and terminology
10. Inappropriate spatial/temporal units
11. Inappropriateness of/lack of confidence in underlying assumptions
12. Uncertainty due to projections of human behavior (e.g., future consumption patterns, or technological change), which is distinct from uncertainty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

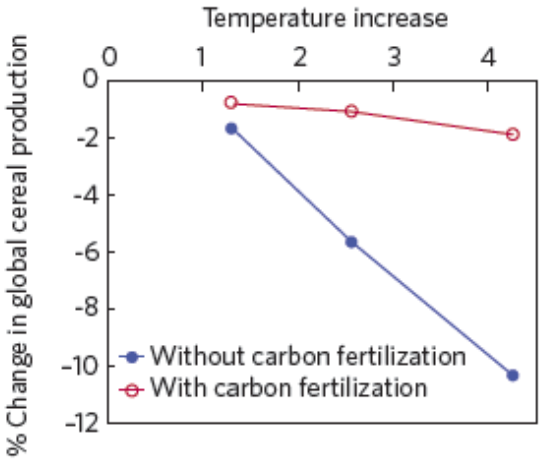
(IPCC TAR Guidance paper, 2001)

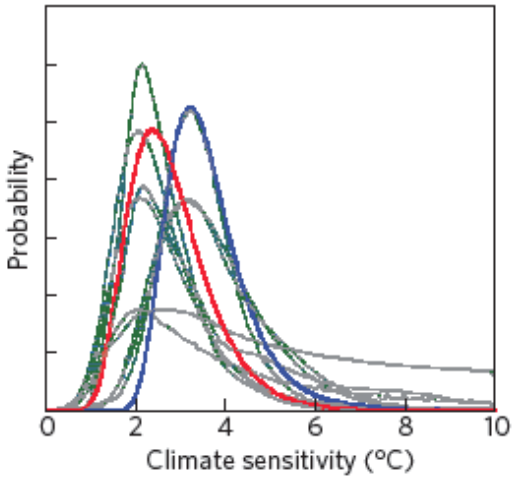
“Cascade of Uncertainty”







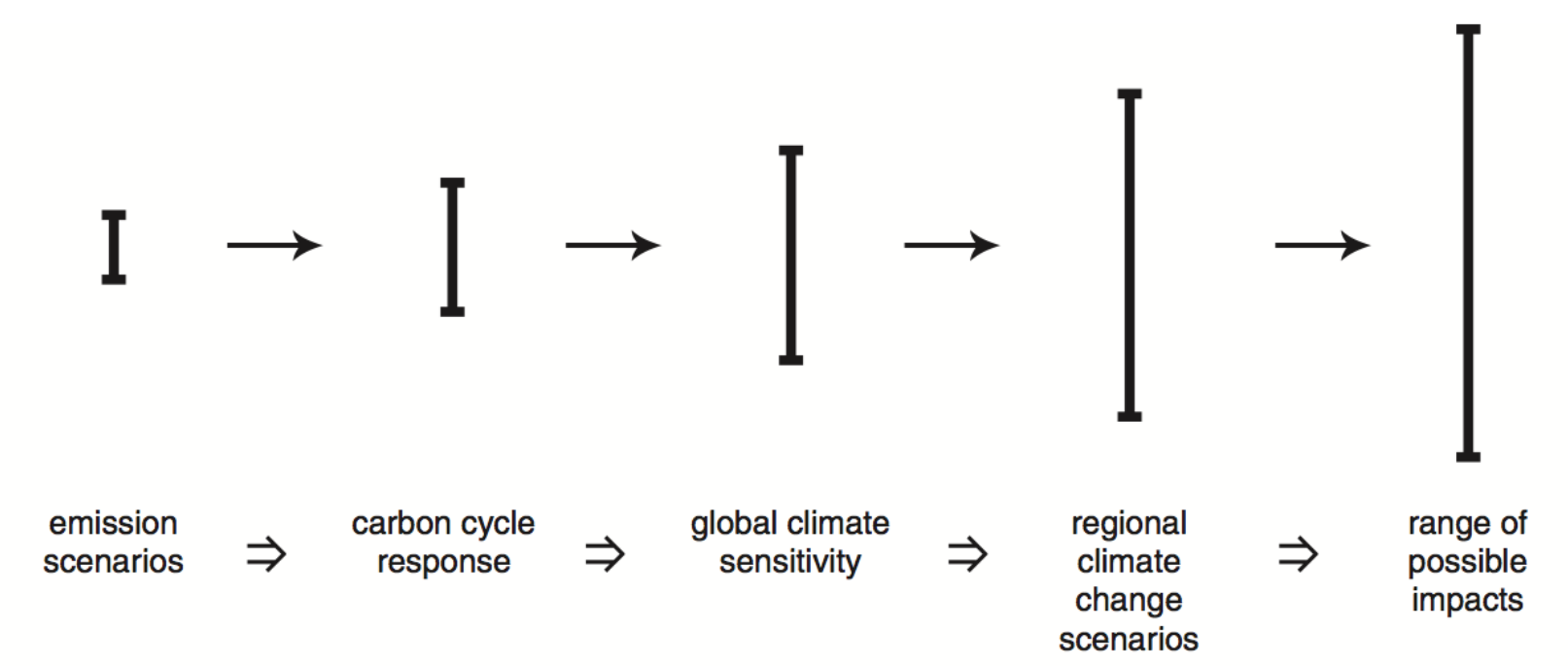




Pidgeon and Fischoff 2011

Slide courtesy of Richard Moss

Explosion of uncertainty



S. H. Schneider, J. Lane, 2006 (Modified after R.N. Jones, Climatic Change 45, 403–419, 2000)

Why the IPCC ?

Established by WMO and UNEP in 1988

to provide policy-makers with an objective source of information about

- causes of climate change,
- potential environmental and socio-economic impacts,
- possible response options.

Jean-Pascal van
(vanypersele@astr.ucl.ac.be)

What did the First IPCC Assessment Report (FAR) say?

Jean-Pascal van Ypersele
(vanypersele@astr.ucl.ac.be)

We are certain of the following: **(from IPCC WGI (1990))**

- 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

1.0.4 *With regard to uncertainties, we note that:*

(from IPCC WGI (1990))

- There are many uncertainties in our predictions particularly with regard to the timing, magnitude and regional patterns of climate change, especially changes in precipitation.

  - These uncertainties are due to our incomplete understanding of sources and sinks of greenhouse gases and the responses of clouds, oceans and polar ice sheets to a change of the radiative forcing caused by increasing greenhouse gas concentrations.

  - These processes are already partially understood, and we are confident that the uncertainties can be reduced by further research. However, the complexity of the system means that we cannot rule out surprises.

Working Group 1 SAR, 1995

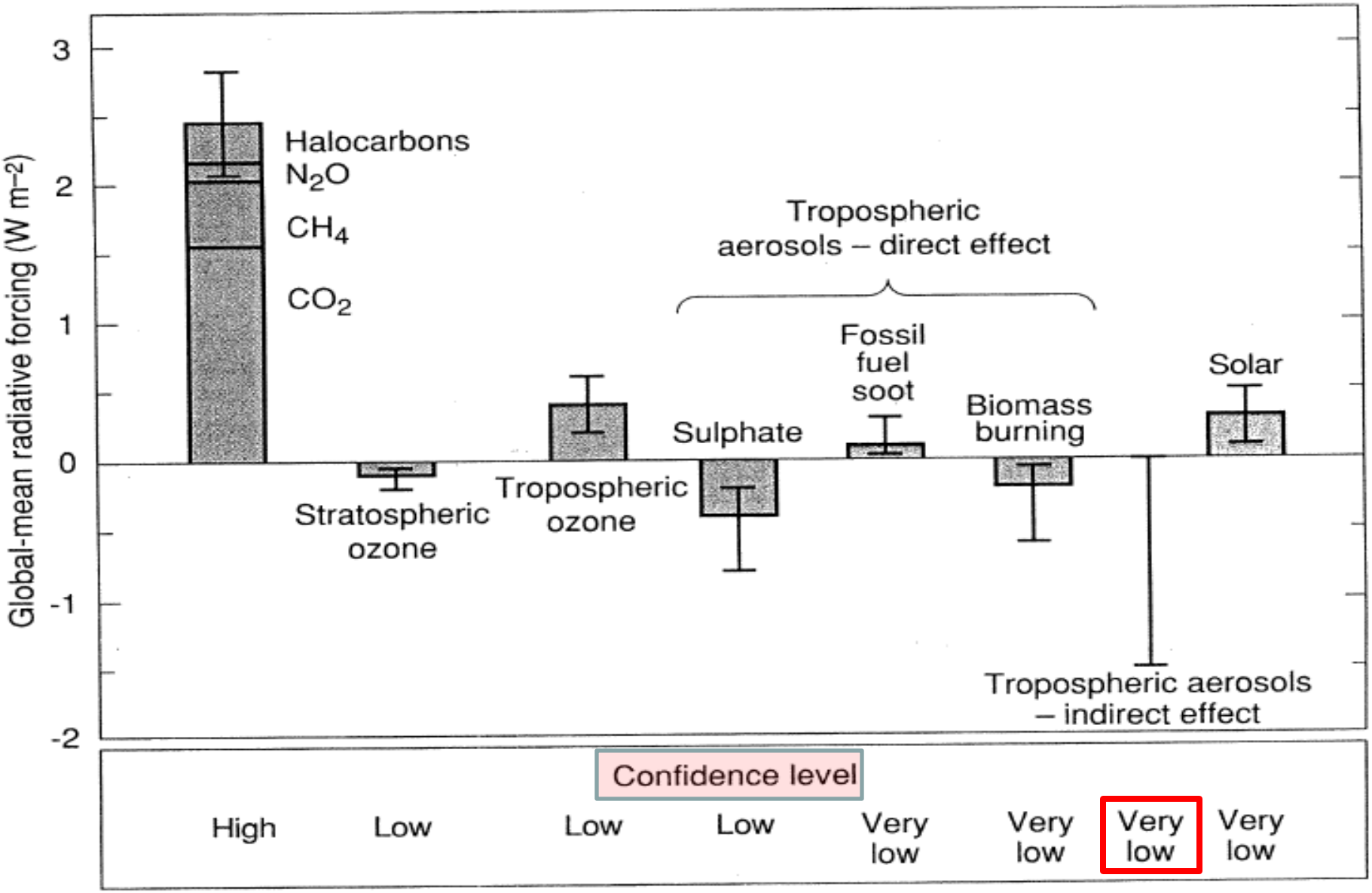
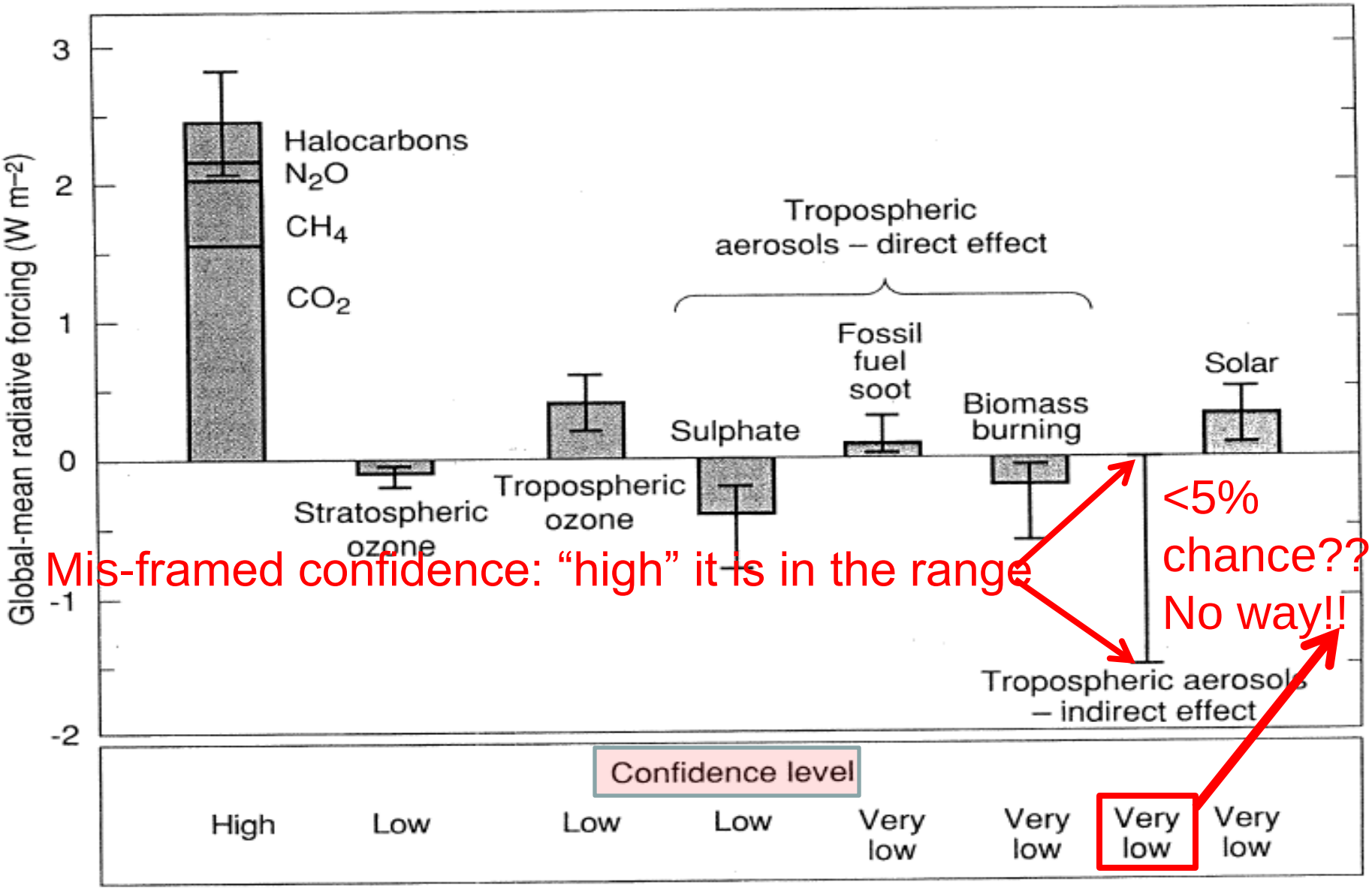


Figure 2.16: Estimates of the globally and annually averaged anthropogenic radiative forcing (in Wm^{-2}) due to changes in concentrations of greenhouse gases and aerosols from pre-industrial times to the present day and to natural changes in solar output from 1850 to the present day. The height of the 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.

Working Group 1 SAR, 1995

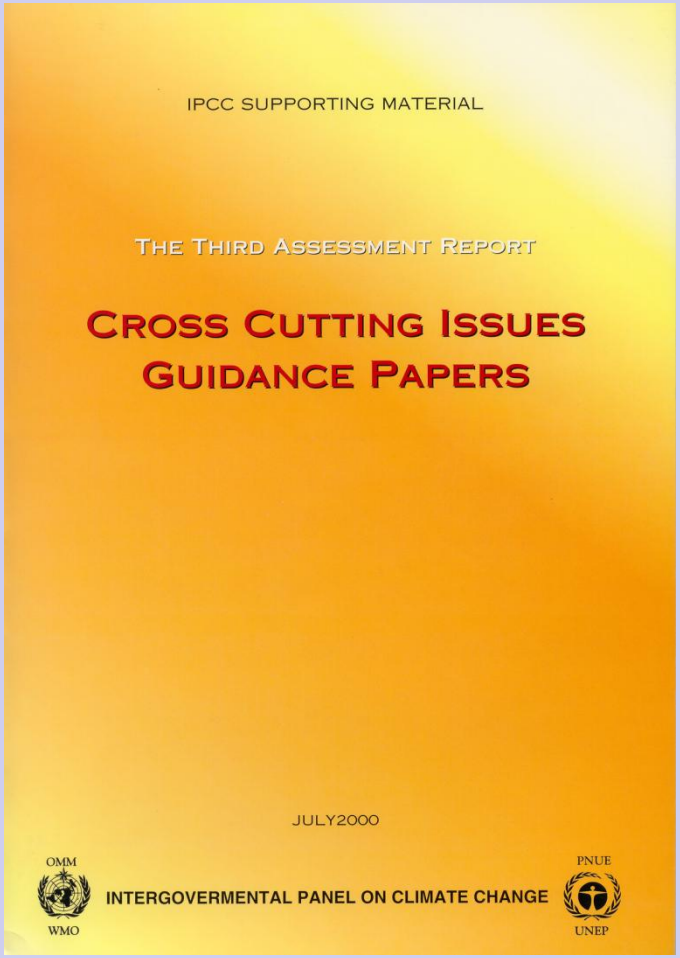


Mis-framed confidence: "high" it is in the range

<5% chance??
No way!!

IPCC TAR Uncertainty Guidance

- Approximately 40 contributors & reviewers
- 2 rounds of drafting, review, and revision
- Addressed both “internal” (uncertainty assessment) and “external” (communication aspects) challenges
- Proposed standardized language



(Based on a slide by Steve Schneider at the IPCC expert meeting on uncertainty, July 2010)

Two Key Challenges Addressed

1. For cases when an uncertain parameter is needed and limits in data or understanding preclude standard statistical approaches, provide advice on improving internal process of making "expert judgments"
2. To address challenge that words mean different things to different people, provide approach for calibrating and standardizing communication (both internal and external audiences)

Recommended Process

1. *Identify the most important factors and uncertainties that are likely to affect the conclusions*.
2. *Document ranges and distributions in the literature*
3. M*ake an initial determination of the appropriate level of precision*
4. C*haracterize the distribution of values that a parameter, variable, or outcome may take*
5. R*ate and describe the state of scientific information (using recommended terminology)*
6. *Prepare a "traceable account" [of all aggregations]*
7. OPTIONAL: *Use formal probabilistic frameworks for assessing expert judgment*

Communication: Mapping Words to Probabilities

This figure shows the range of probabilities that people assign to words, absent any specific context

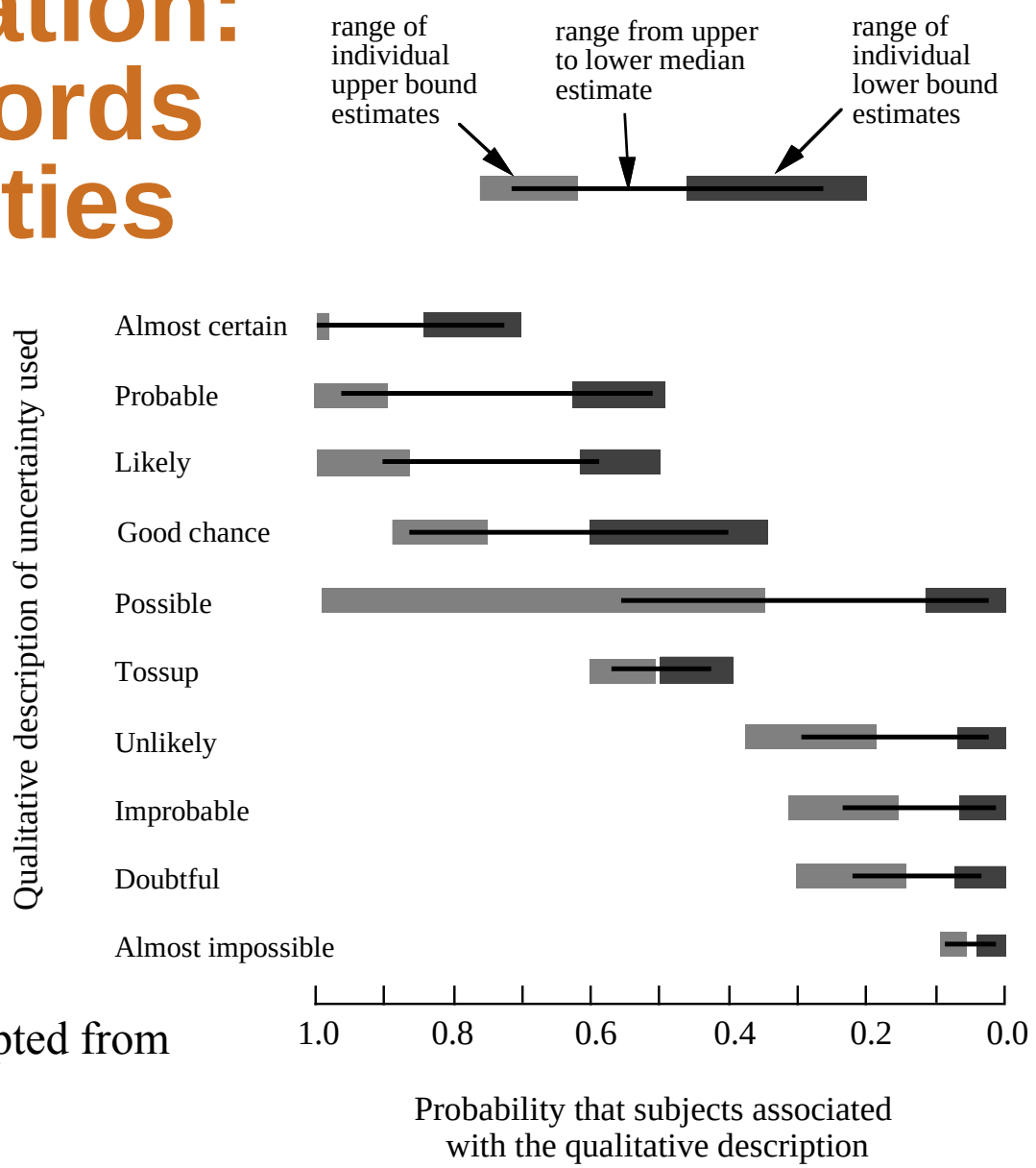


Figure from G. Morgan, adapted from Wallsten et al., 1986

Rating Confidence

- Two sets of confidence terms were proposed
  - Quantitative scale proposed as IPCC standard
  - Qualitative scale proposed as “supplement”
- Idea for confidence “radar plots”

(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)

Likelihood vs Confidence

Likelihood

The chance of a defined outcome occurring in the physical world.

Is estimated, using appropriate information about probability and expert judgment.

Level of Confidence

The degree of understanding and/ or consensus among experts.

Is a statement about the basis for the expert judgment.

In this Summary for Policymakers, the following terms have been used to indicate the assessed likelihood, using expert judgement, of an outcome or a result: *Virtually certain* > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Unlikely* < 33%, *Very unlikely* < 10%, *Extremely unlikely* < 5% (see Box TS.1 for more details).

In this Summary for Policymakers the following levels of confidence have been used to express expert judgements on the correctness of the underlying science: *very high confidence* represents at least a 9 out of 10 chance of being correct; *high confidence* represents about an 8 out of 10 chance of being correct (see Box TS.1)

(From IPCC AR4 WGI, 2007)

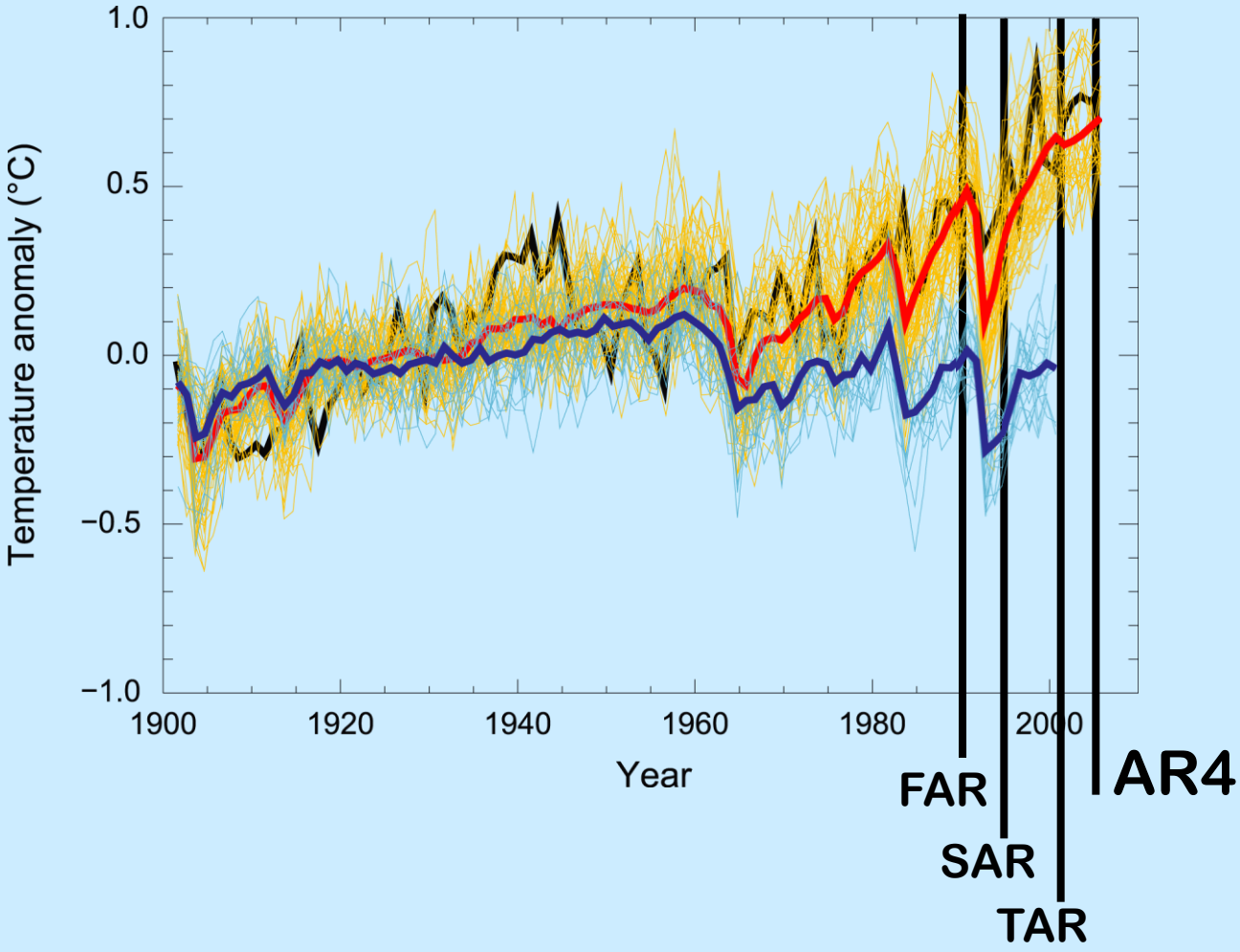
A Progression of Understanding: Greater and Greater Certainty in Attribution

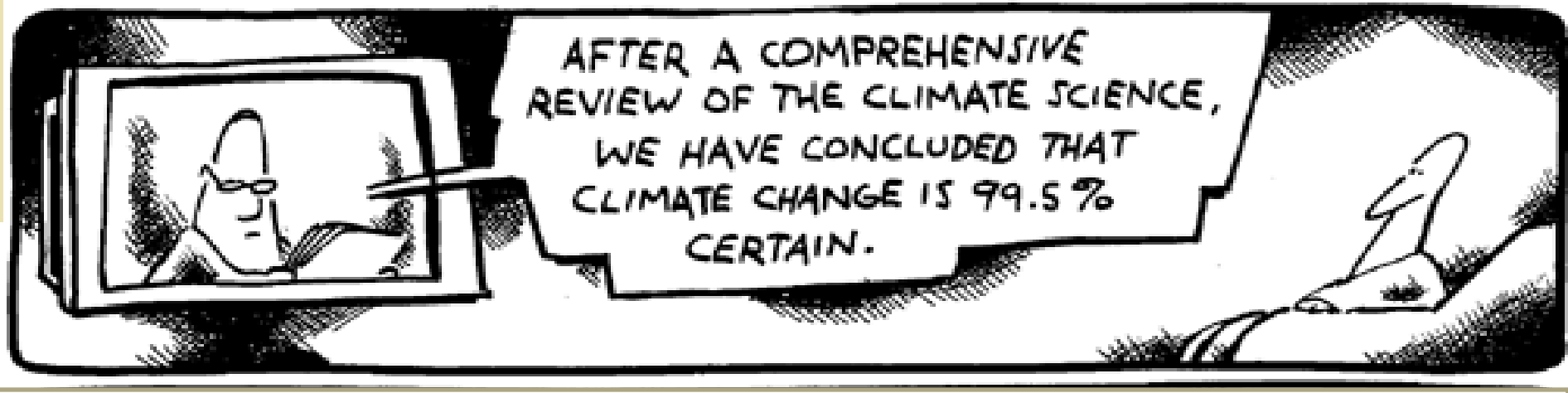
FAR (1990): "unequivocal detection not likely for a decade"

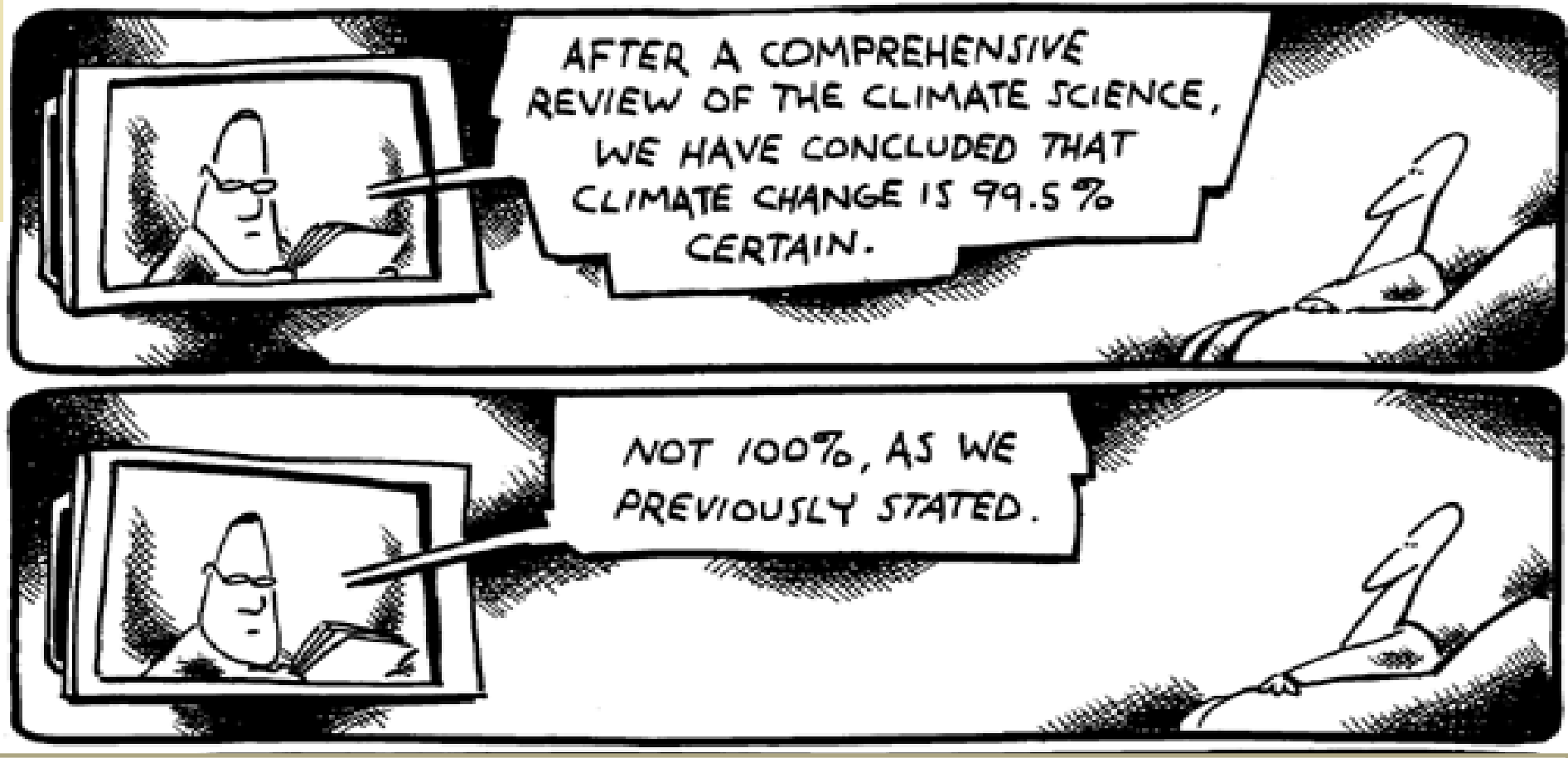
SAR (1995): "balance of evidence suggests discernible human influence"

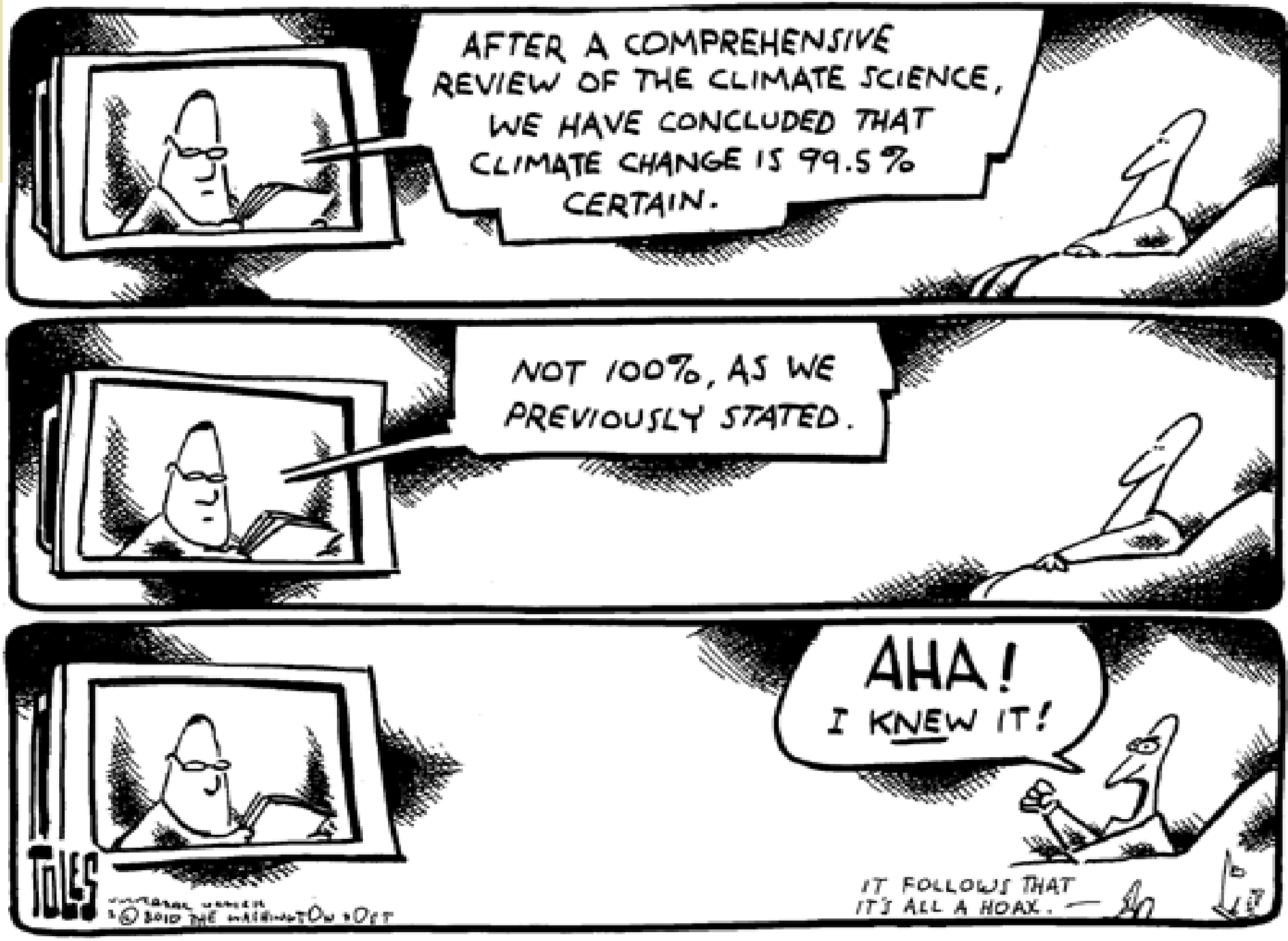
TAR (2001): "most of the warming of the past 50 years is likely (odds 2 out of 3) due to human activities"

AR4 (2007): "most of the warming is very likely (odds 9 out of 10) due to greenhouse gases"

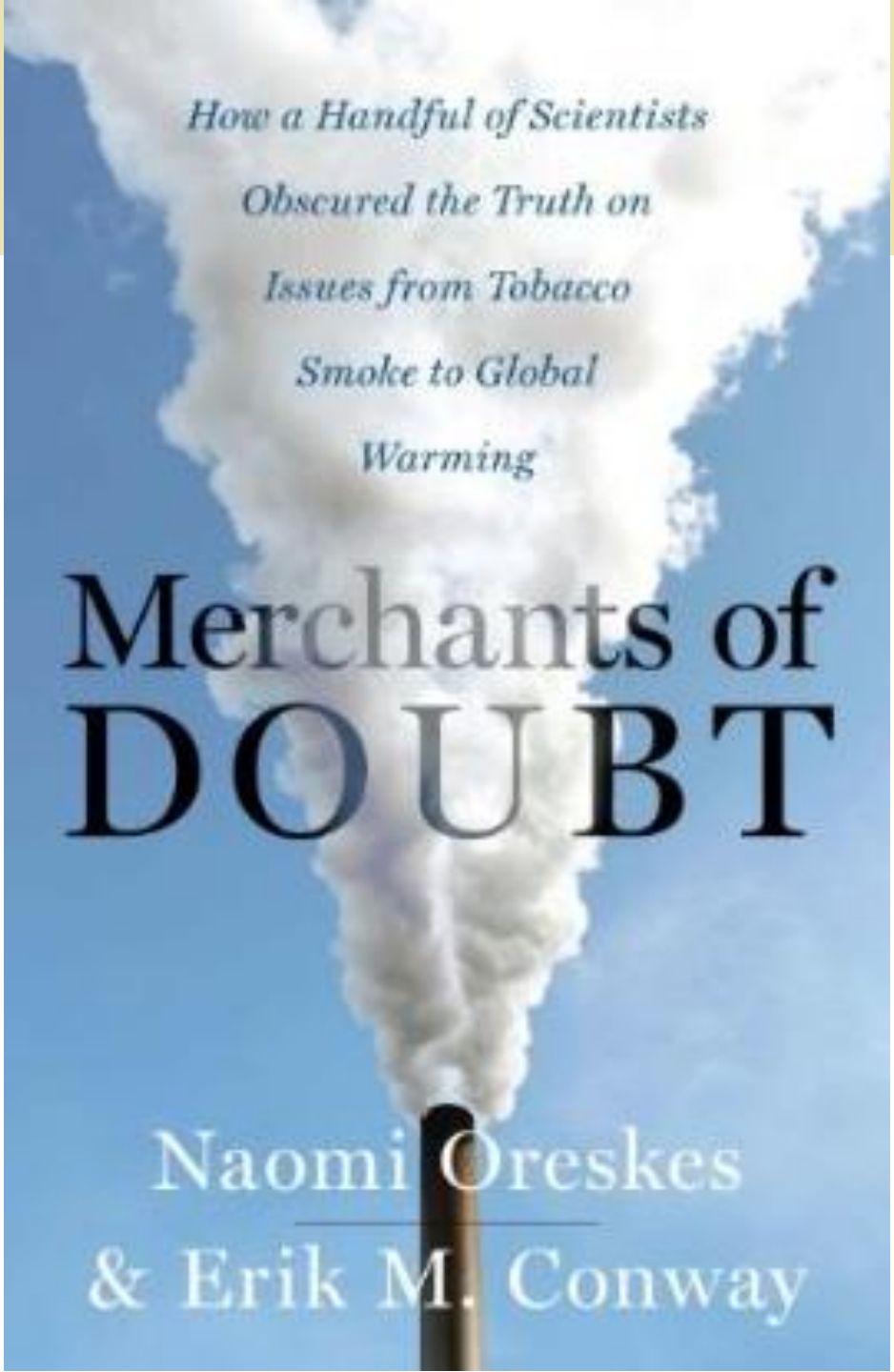



AFTER A COMPREHENSIVE REVIEW OF THE CLIMATE SCIENCE, WE HAVE CONCLUDED THAT CLIMATE CHANGE IS 99.5% CERTAIN.


AFTER A COMPREHENSIVE REVIEW OF THE CLIMATE SCIENCE, WE HAVE CONCLUDED THAT CLIMATE CHANGE IS 99.5% CERTAIN.
NOT 100%, AS WE PREVIOUSLY STATED.



(From one of Steve's presentations)


How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming
Merchants of DOUBT
Naomi Oreskes
& Erik M. Conway

Development of AR5 Guidance

July 2010:

IPCC Cross-Working Group Meeting on Consistent Treatment of Uncertainties

Jasper Ridge Biological Preserve, Stanford, CA

WG II Technical Support Unit · c/o The Carnegie Institution
260 Panama Street · Stanford · California 94305 · USA
telephone +1 650 462 1047 · fax +1 650 462 5968 · email tsu@ipcc-wg2.gov · **www.ipcc-wg2.gov**

WMO UNEP

Development of AR5 Guidance

Decision:

- Update AR4 Guidance to improve distinction and transition between different metrics and consistent application across WGs

Result:

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

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Degree of Certainty for Findings

Two metrics based on evaluation of evidence and agreement:

- Level of *confidence* in the validity of a finding
  - Qualitative
- *Quantified measures of uncertainty* in a finding
  - Expressed probabilistically

Evidence and Agreement

Evaluation

EVIDENCE and AGREEMENT

- Type
  - e.g., mechanistic understanding, theory, data, models, expert judgment
- Amount
- Quality
- Consistency

Provide a ***traceable account*** of evaluation of evidence and agreement in chapter text.

Evidence and Agreement

Summary Terms for Evaluation

- Evidence: “limited,” “medium,” “robust”
- Agreement: “low,” “medium,” “high”

Draft Guidance Note for LA of the AR5 on Consistent Treatment of Uncertainties

1. *Basis of confidence in terms of level of evidence and degree of agreement*:

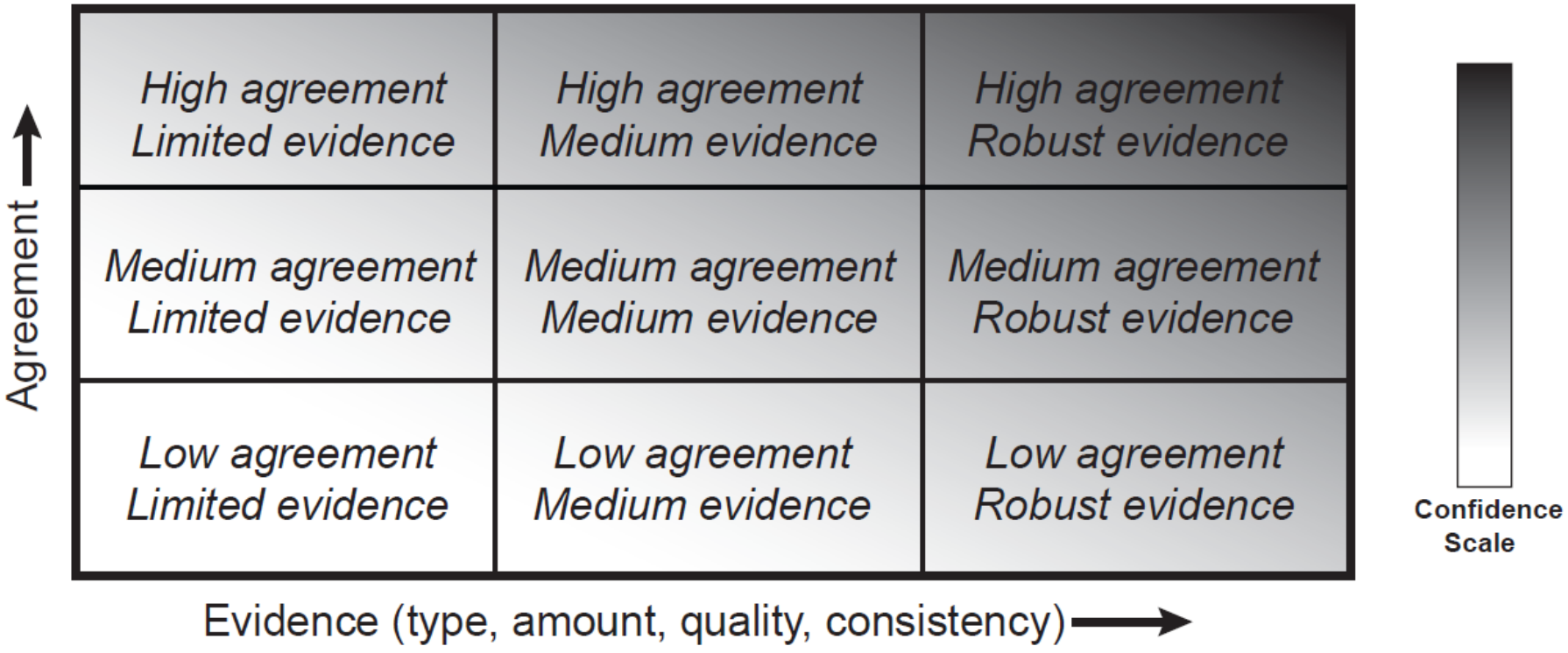
- high agreement + robust evidence → level of confidence/quantified measure of uncertainty
- high agreement *or* robust evidence → confidence/quantify uncertainty when possible
- *low* agreement + *limited* evidence → summary terms for evaluation of evidence

degree of certainty in findings that are conditional on other findings should be evaluated and reported independently

Confidence

Validity of Finding

Confidence synthesizes evaluation of evidence and agreement into a judgment about the validity of a finding.



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Confidence

Levels of Confidence

Confidence synthesizes evaluation of evidence and agreement into a judgment about the validity of a finding.

"Very high"
"High"
"Medium"
"Low"
"Very low"

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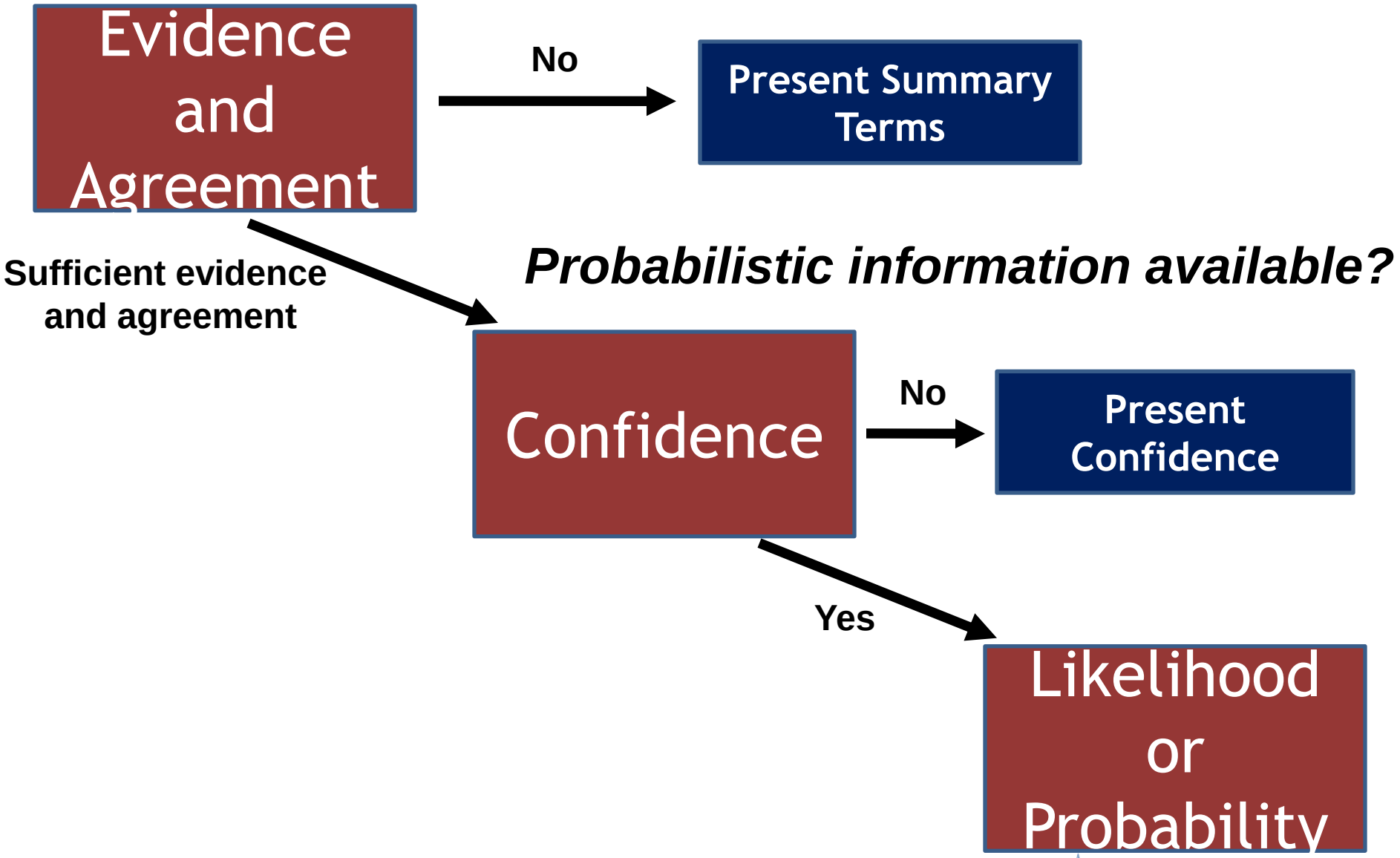
Degree of Certainty for Findings: Process



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Likelihood or Probability

Probabilistic estimate

Likelihood expresses a probabilistic estimate of the occurrence of a single event or of an outcome lying in a given range.

Term	Likelihood of the outcome
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

Use more precise probability ranges when appropriate.

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Draft Guidance Note for LA of the AR5 on Consistent Treatment of Uncertainties

« In summary, communicate uncertainty carefully, using calibrated language for key findings, and provide traceable accounts describing your evaluations of evidence and agreement in your chapter »

We are stuck with uncertainties in the climate world.

- Or, as Barrie Pittock wrote: « Uncertainty is inevitable, but risk is certain »

Citizens Get:
[FROM EXPERTS]

- WHAT CAN HAPPEN?
- WHAT ARE THE ODDS

"Risk" [Conseq X Prob]

- (HOW DO YOU KNOW?) ← Explanation

Citizens Give:

- VALUE JUDGEMENTS ON HOW TO TAKE RISKS, DECIDE WHO PAYS, ETC.

"Risk management"

- CERTIFY OPENNESS OF EXPERT ASSESSMENT PROCESS
- AGENDA FOR EXPERT ASSESSMENT

S. H. Schneider, Communicating on the State and Local Level: How Can Scientists Support Policy-Makers?, 2010

Policy process as **multistep process**

- **Technical analysis**: scientific facts are assembled and analyzed to estimate the likelihood of various potential consequences (risk of 'selective inattention')

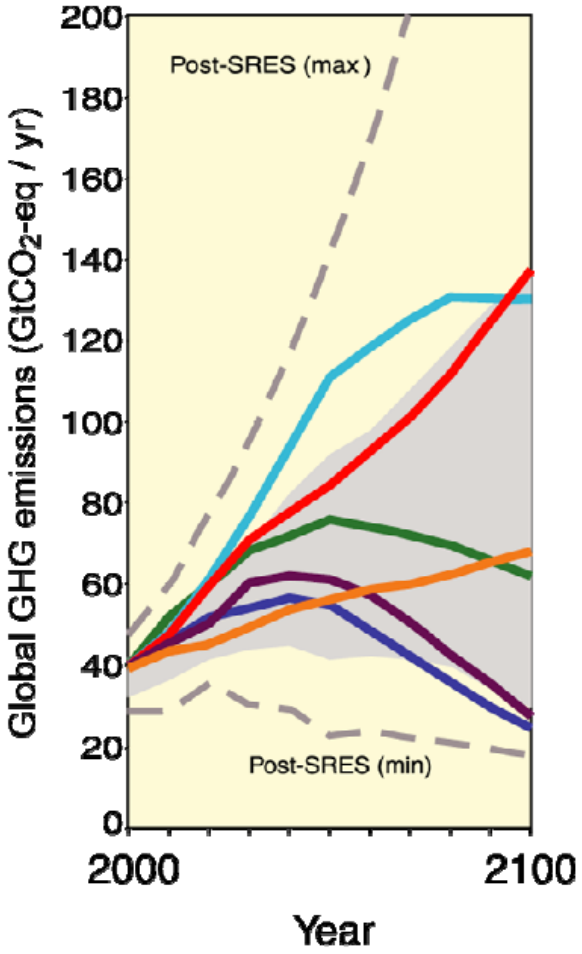
- **Policy analysis**: an effort is made to examine scientifically the varying consequences that might be associated with a range of alternative policies

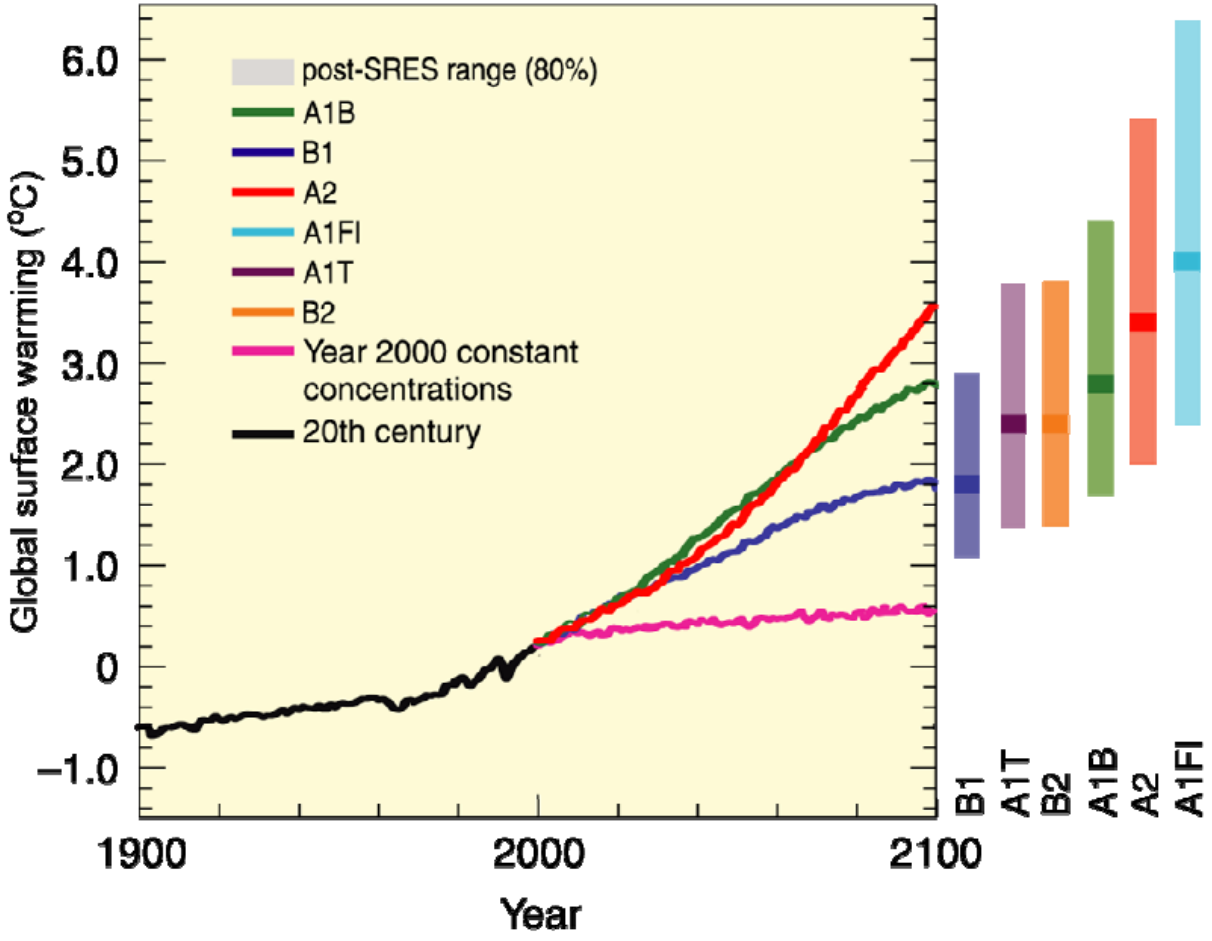
- **Policy choice**: choosing a mix of option

Science can contribute only to **policy analysis**, not to **policy choice**

S. H. Schneider, 1989

The main uncertainty on 2100 climate is related to the political will to be (or not to be) on a given emission trajectory





NB: écart par rapport à la moyenne 1980-1999

Jean-Pascal van Ypersele
(vanypersele@astr.ucl.ac. Source: IPCC, AR4 (2007)

A gamble we must not loose

- As we cannot afford to lose the "planetary gamble" Steve Schneider discussed in "Laboratory Earth", it will remain extremely important for scientists and the IPCC to understand, qualify, and communicate uncertainties in the best way, so that good decisions can be taken.

Jean-Pascal van Ypersele
(vanypersele@astr.ucl.ac.

But uncertainty cannot be an excuse for inaction…

- …In the same way that Tyndall admirably continued his experiments “from 8 to 10 hours daily”, seven weeks in a row, even if he was uncertain of the results he would obtain.

Jean-Pascal van Ypersele
(vanypersele@astr.ucl.ac.

Useful links:

- www.ipcc.ch : IPCC
- www.climatechange.net : Steve Schneider (interdisciplinary) site
- www.climate.be/vanyp : my slides and other documents

Thank you for your attention

Jean-Pascal van Ypersele
(vanypersele@astr.ucl.ac.be)