ESSENTIAL DIRECTIONS FOR CLIMATE CHANGE RESEARCH

Atmospheric Composition and Radiative Forcing

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TOP-LEVEL ISSUES IN CLIMATE CHANGE SCIENCE

- How *much* will the climate change, and how *fast* will it change?
- What are the drivers of climate change?

  Changing atmospheric composition.
- How are drivers of climate change quantified?

  Radiative forcing F— change in radiative flux component (W m^{-2}).
- Prediction of future climate change, *e.g*., for temperature, requires:
  - Predictive capability for *future radiative forcing* and
  - Knowledge the *climate sensitivity* $\lambda = \Delta T / F$.
- How can climate sensitivity be determined?
  - Climate models evaluated by performance on *prior climate change* and/or
  - Empirical determination from *prior climate change*.
- ***Either way, ΔT and F must be determined with known and sufficiently small uncertainty.***

UNCERTAINTY PRINCIPLES

- The "commonly accepted" estimates of the sensitivity for global temperature change for a doubling of CO_2 (4 W m^{-2}) range from 1.5 to 4.5 K (IPCC, 2001), equivalent to (3 ± 1.5) K — a factor of three**!** ***Fractional uncertainty*** $\boldsymbol{\delta\lambda/\lambda = 0.5}$.
  Such an uncertainty is not very useful for policy planning purposes.

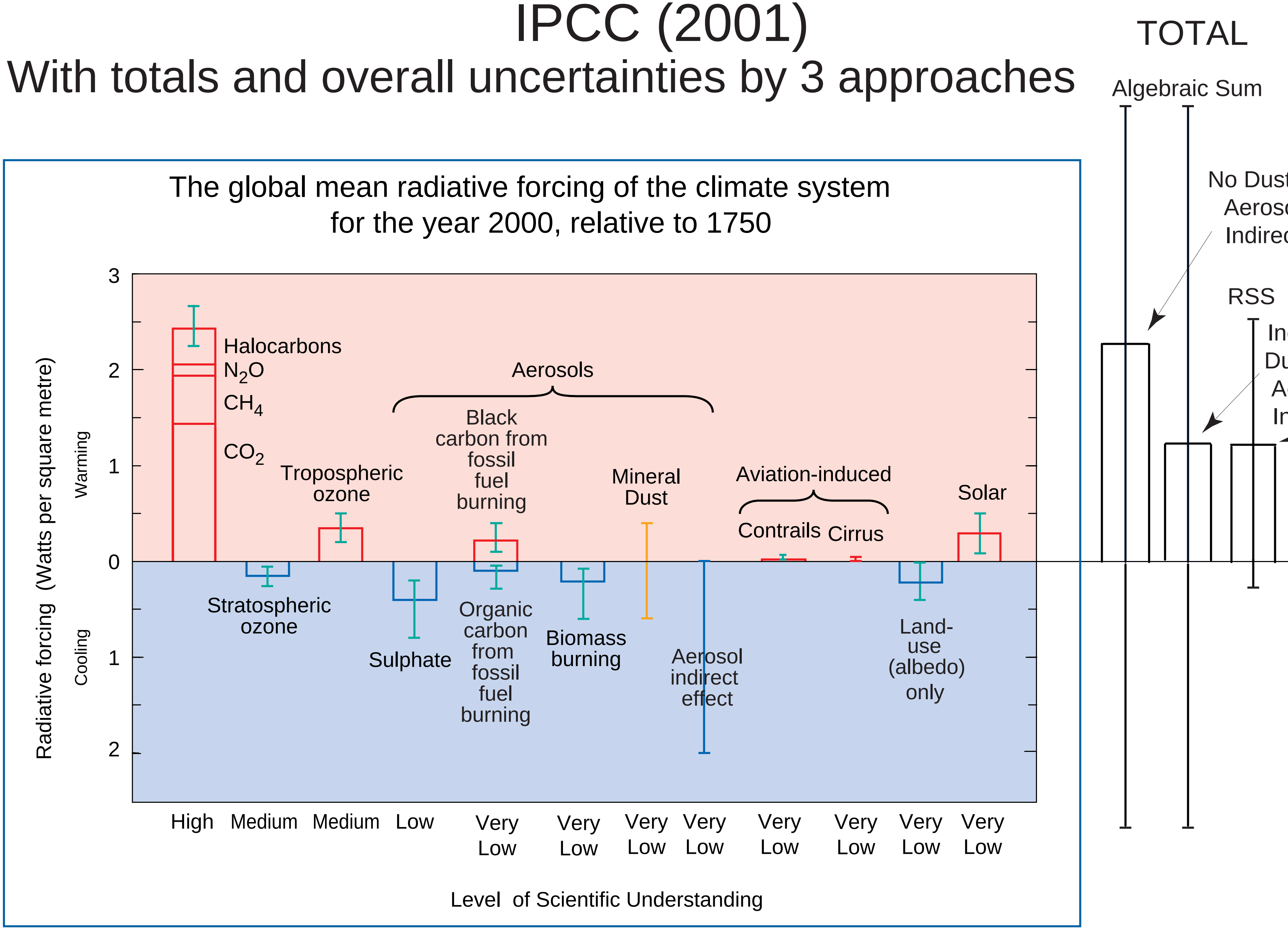
The fractional uncertainty in climate sensitivity λ is evaluated from fractional uncertainties in temperature change ΔT and forcing F as:

$$\frac{\delta\lambda}{\lambda} = \sqrt{\left(\frac{\delta\Delta T}{\Delta T}\right)^2 + \left(\frac{\delta F}{F}\right)^2}$$

- The increase in global mean temperature over the industrial period is 0.6 ± 0.2 K, *i.e.*, $\delta\Delta T/\Delta T = 0.33$. (IPCC, 2001)
- This uncertainty in response, together with the "commonly accepted" uncertainty range in λ implies uncertainty in forcing $\delta F/F = 0.37$.
  This is wholly inconsistent with present physically based estimates!
- A reasonable target might be $\delta\lambda/\lambda = 0.3$
  This would require $\boldsymbol{\delta F/F = \delta\Delta T/\Delta T = 0.2}$.

RADIATIVE FORCING OVER THE INDUSTRIAL PERIOD IPCC (2001)

With totals and overall uncertainties by 3 approaches



WHY IS UNCERTAINTY IN FORCING SO LARGE?

- ***Uncertainties in knowledge of atmospheric composition***

  Mass loading and chemical and microphysical properties and cloud nucleating properties of anthropogenic aerosols, and geographical distribution.

  To lesser extent, the amount and distribution of tropospheric ozone.

  Other atmospheric constituents are a distant third.

- ***Uncertainties in knowledge of atmospheric physics of aerosols***

  Relating direct radiative forcing and cloud modification by aerosols to their loading and their chemical and microphysical properties.

RESEARCH REQUIREMENTS

- Reducing uncertainty in *climate sensitivity* requires great reduction in the uncertainties in loading and properties and resulting *forcing* of present aerosol relative to preindustrial aerosol:
  - ***Mass loading and chemical and microphysical properties of anthropogenic aerosols and geographical distribution.***
  - ***Relation between aerosol loading and properties and radiative forcing.***
- Prediction of *future climate change* requires developing and demonstrating predictive capability for aerosols and radiation influencing gases:
  - ***Sources and sinks of long-lived greenhouse gases and predictive capability for their concentrations as a function of emissions.***
  - ***Sources and sinks of aerosols and predictive capability for their concentrations and properties as a function of emissions.***

REQUIREMENTS FOR THE STRATEGIC PLAN

The *Strategic Plan for the Climate Change Science Program* must explicitly recognize the need to:

- ***Determine the climate sensitivity with sufficient accuracy and confidence to permit decision making and planning to limit emissions and/or to develop strategies to adapt to future climate change.***

Achieving this objective will require:

- ***Accurate knowledge of the forcing of climate change over the industrial period.***
- ***Predictive capability for future forcing of climate change, including concentrations of radiation influencing trace gases and concentrations composition, and microphysical properties of aerosols.***

Development of these capabilities is the ***sine qua non*** of a successful Climate Change Prediction Program.

The *Strategic Plan* ***must*** give this objective highest priority.

COMPARE THE DRAFT STRATEGIC PLAN

Products and Payoffs (Chapter 5, pp. 60-61) lack focus and specificity:

- Improved description of the global distributions of aerosols
- Improved estimate of the indirect climate effects ... of aerosols.
- More accurate detection and attribution ...
- Better understanding and description of uncertainties...

These products and payoffs should be replaced by ***much more specific and targeted objectives***.

Questions 3, 4, and 5 of Chapter 5 — regional pollution, stratospheric ozone depletion, and couplings — ***must be viewed as secondary*** to the first order issues of climate sensitivity and decreasing the uncertainty in forcing.

IMPLICATIONS

Because greenhouse gases build up in the atmosphere, ultimately the warming influence of GHGs will become dominant over any cooling influence of aerosols.

If the magnitude of aerosol negative forcing is anywhere near the high end of the present uncertainty range,

Then total forcing over the industrial era is much smaller than greenhouse gas forcing, and therefore

Climate sensitivity is much greater than has been inferred previously.

Hence the importance of decreasing uncertainty in climate sensitivity.