



Institut
*Pierre
Simon
Laplace*



UPMC
PARIS UNIVERSITAS



Réflexion Autour de la Géo-Ingénierie Environnementale

Atelier de Réflexion Prospective

<http://www.arp-reagir.fr>

Certainties and uncertainties: the treatment of clouds and aerosols in the IPCC AR5

Olivier Boucher

Laboratoire de Météorologie Dynamique

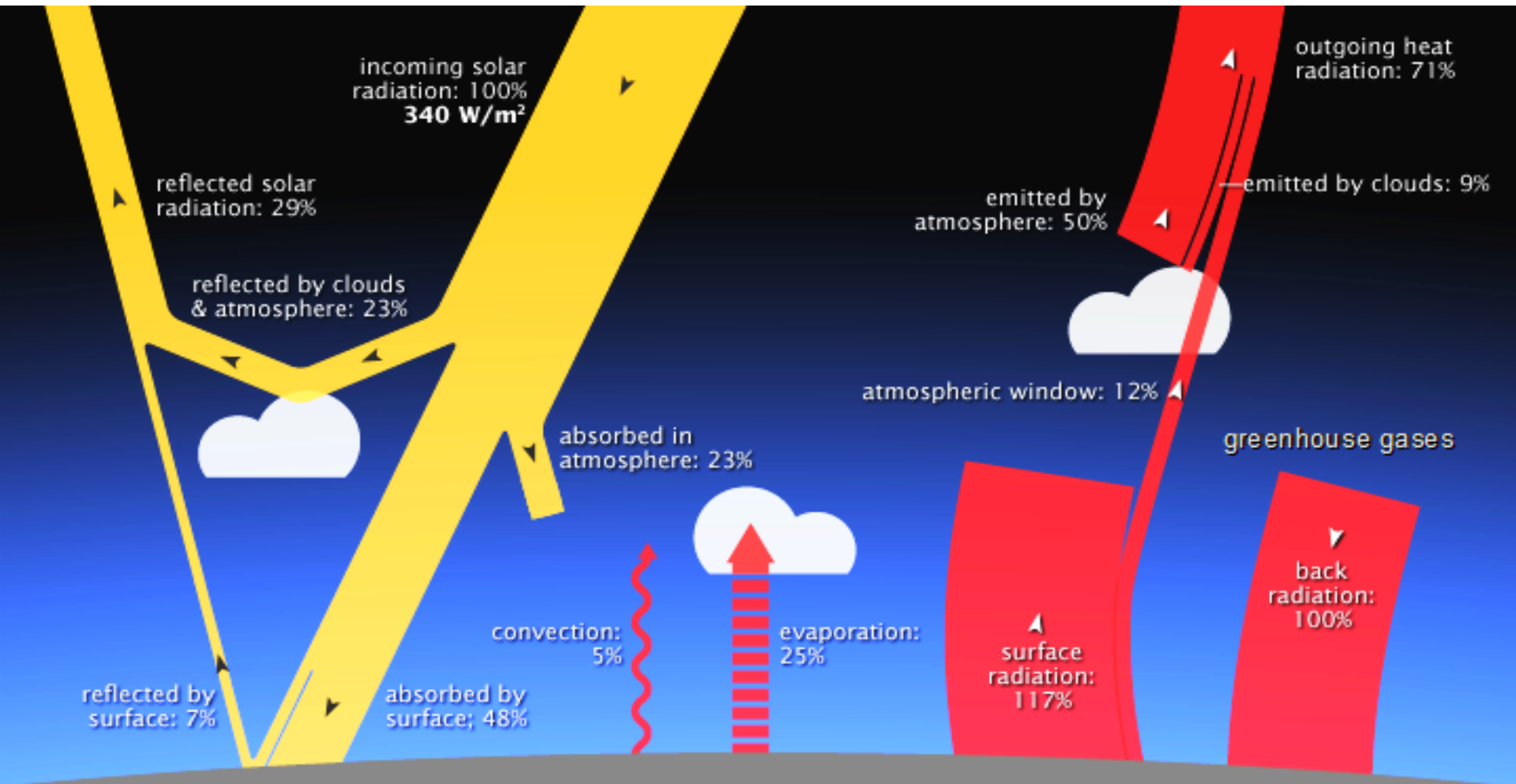
20 November 2014

***International conference on Confidence, Credibility,
and Authority in Climate Sciences and Politics***

Outline of talk

- 1/ A primer on radiative forcing & climate sensitivity
- 2/ Lessons from coordinating IPCC chapter 7
- 3/ Some thoughts on uncertainties
- 4/ Conclusions

The Earth's energy budget

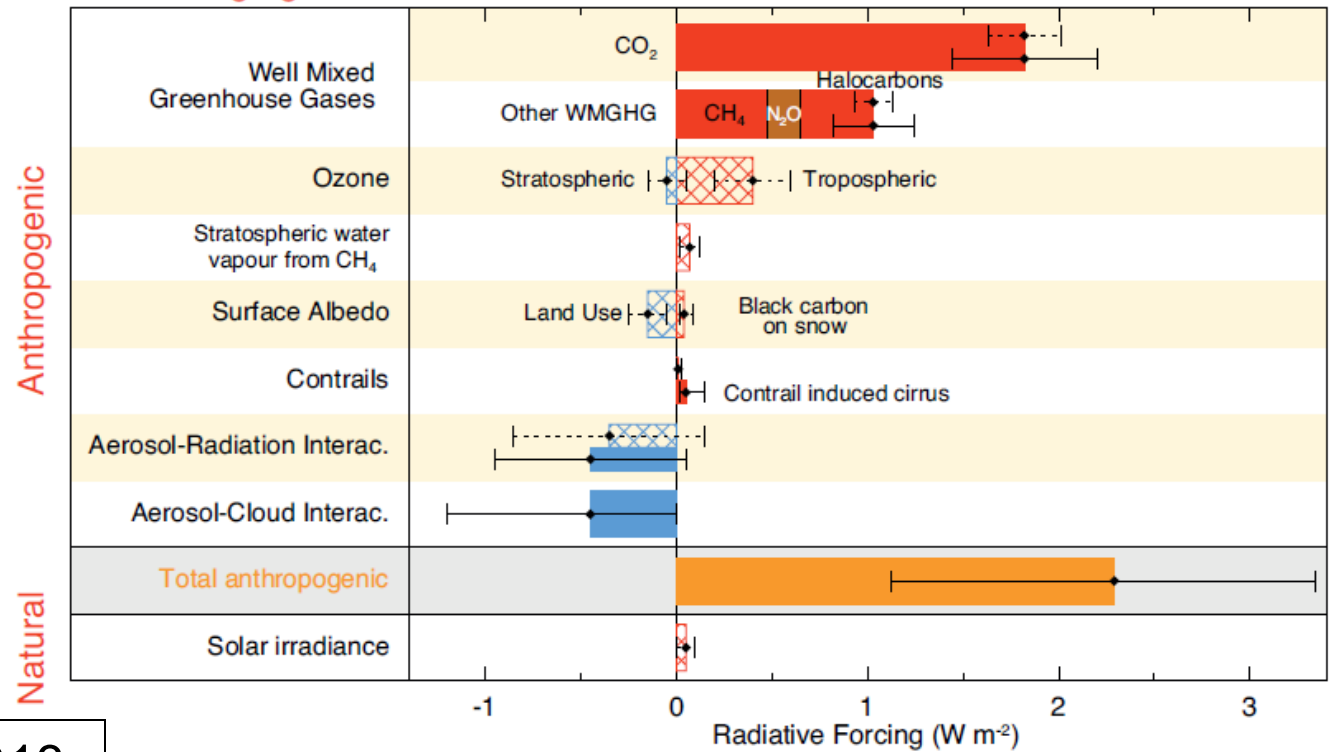


Greenhouse gases
=> warming

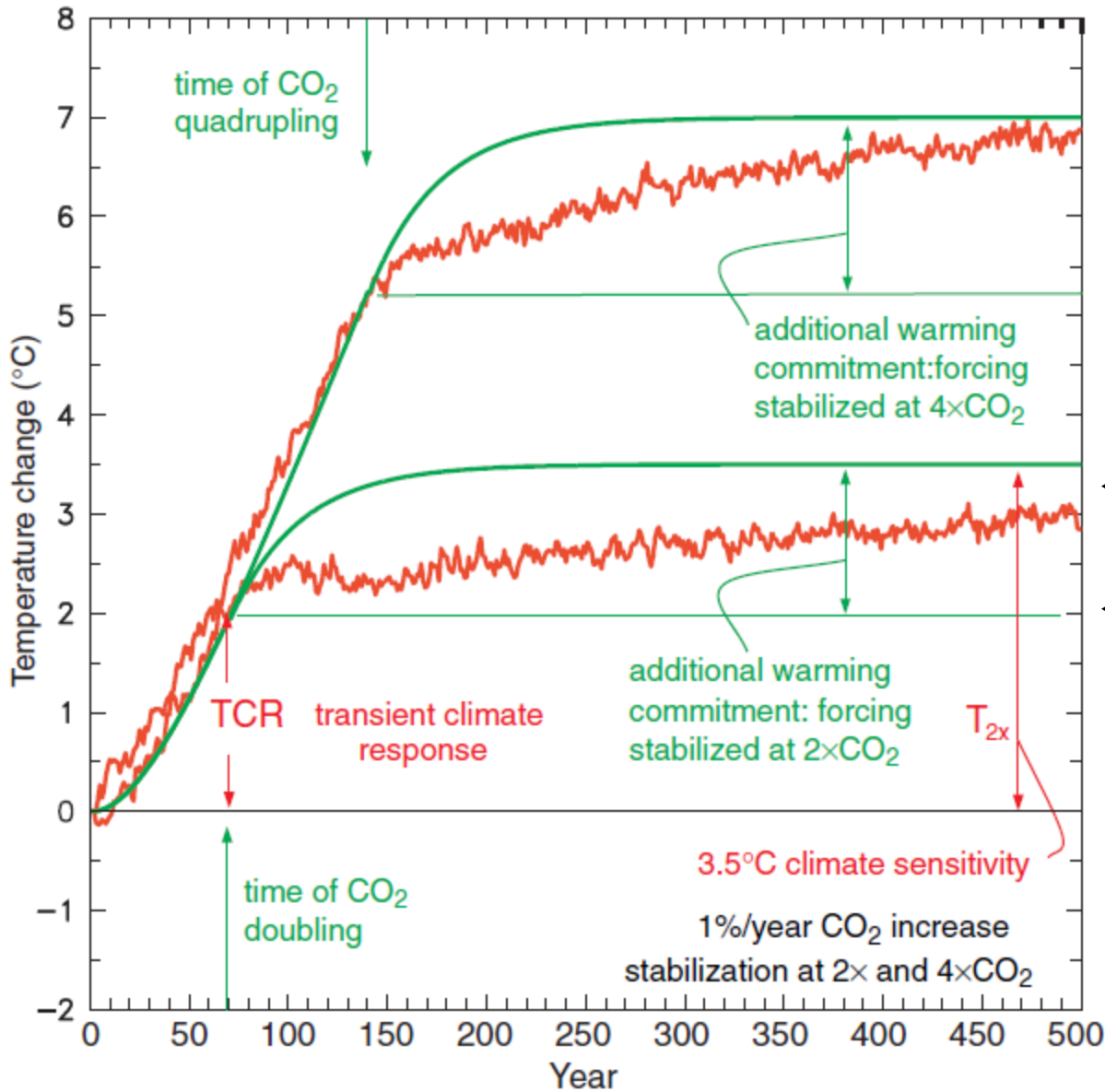


Aerosols
=> cooling

Radiative forcing of climate between 1750 and 2011
Forcing agent



Idealized 1%-per-year increase CO₂ experiment (until 2xCO₂ or 4xCO₂)



← Equilibrium climate sensitivity (ECS)

← Transient climate response (TCR)

Two ways to get to climate sensitivity

1/ **Bottom up** by building a climate model and constraining it with process observations

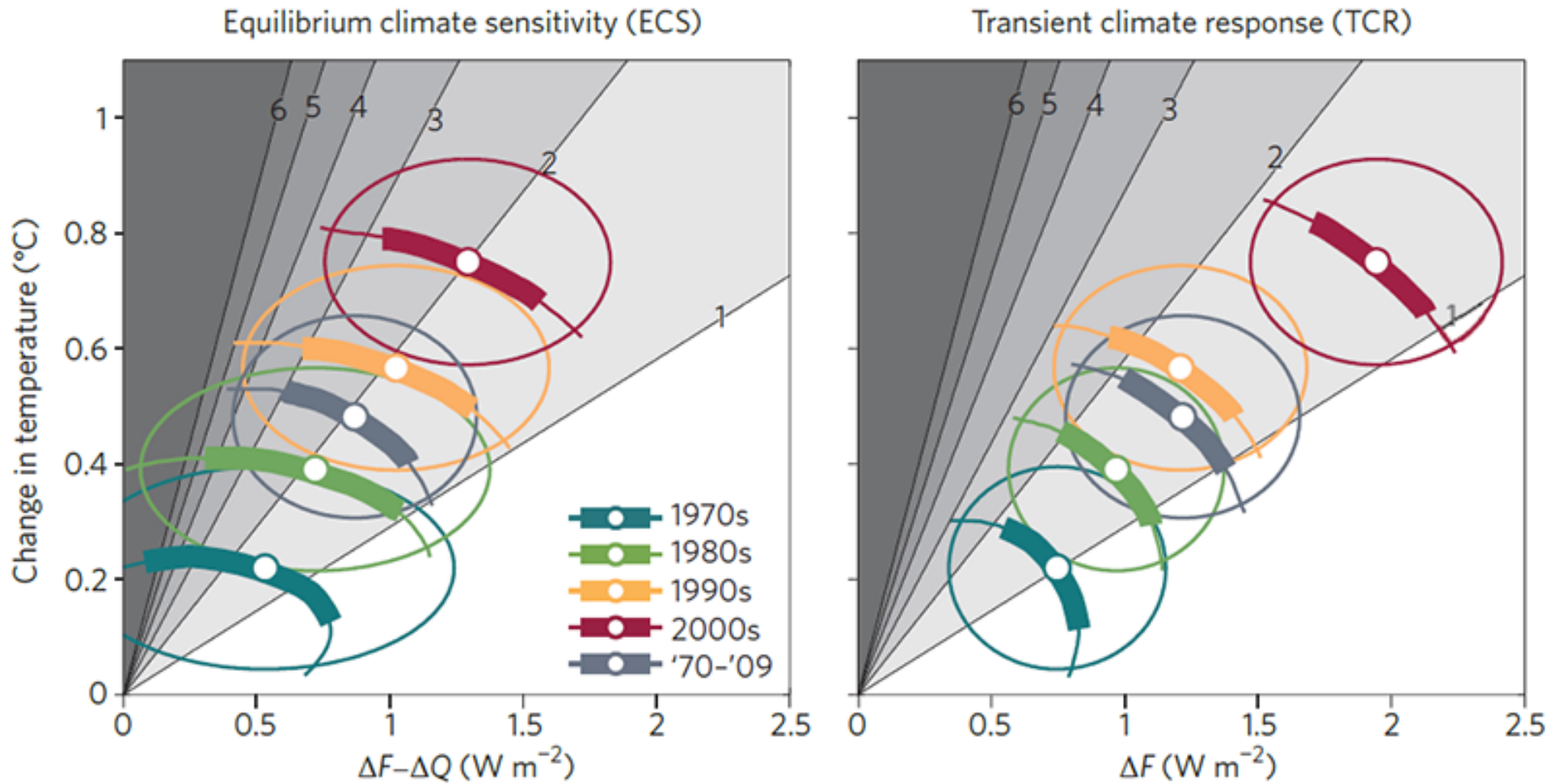
- water vapour and lapse rate feedbacks
- surface albedo feedback
- cloud feedbacks
- heat export to the deep ocean

2/ **Top down** by combining knowledge of surface warming and radiative forcing (and also looking at paleoclimates)

$$\text{TCR} = T_{2x} / F_{2x} = T / F$$

$$\text{ECS} = T / (F - Q)$$

Observational constraint on climate sensitivity



Otto et al., Nature Geoscience, 2013

Two ways to get to climate sensitivity

1/ **Bottom up** by building a climate model and constraining it with process observations

- water vapour and lapse rate feedbacks
- surface albedo feedback
- cloud feedbacks
- heat export to the deep ocean

2/ **Top down** by combining knowledge of surface warming and radiative forcing (and also looking at paleoclimates)

$$TCR = T_{2x} / F_{2x} = T / F$$

$$ECS = T / (F - Q)$$

⇒ Some disagreement between different sources of information

⇒ *high confidence TCR to be likely between 1°C and 2.5°C*

⇒ *medium confidence ECS is likely between 1.5°C and 4.5°C*

Outline of talk

- 1/ A primer on radiative forcing & climate sensitivity
- 2/ Lessons from coordinating IPCC chapter 7
- 3/ Some thoughts on uncertainties
- 4/ Conclusions

Chapter 7 – WGI IPCC AR5

Contents

Front Matter	Foreword	v
	Preface	vi
	Dedication	ix
SPM	Summary for Policymakers	3
TS	Technical Summary	33
Chapters	Chapter 1 Introduction	119
	Chapter 2 Observations : Atmosphere and Surface	159
	Chapter 3 Observations: Ocean	255
	Chapter 4 Observations: Cryosphere	317
	Chapter 5 Information from Paleoclimate Archives	383
	Chapter 6 Carbon and Other Biogeochemical Cycles	465
	Chapter 7 Clouds and Aerosols	571
	Chapter 8 Anthropogenic and Natural Radiative Forcing	659
	Chapter 9 Evaluation of Climate Models	741
	Chapter 10 Detection and Attribution of Climate Change: from Global to Regional	867
	Chapter 11 Near-term Climate Change: Projections and Predictability	953
	Chapter 12 Long-term Climate Change: Projections, Commitments and Irreversibility	1029
	Chapter 13 Sea Level Change	1137
	Chapter 14 Climate Phenomena and their Relevance for Future Regional Climate Change	1217
Annexes	Annex I Atlas of Global and Regional Climate Projections	1311
	Annex II Climate System Scenario Tables	1395
	Annex III Glossary	1447
	Annex IV Acronyms	1467
	Annex V Contributors to the IPCC WGI Fifth Assessment Report	1477
	Annex VI Expert Reviewers of the IPCC WGI Fifth Assessment Report	1497
	Index	1523

“Process” chapter
... which nevertheless
has some importance

Implication of chapter 7 statements

Cloud feedback is positive and **large** => ECS is large

Cloud feedback is **positive and small** or **negative** => ECS is small

Aerosol forcing is **very negative** => TCR is large

Aerosol forcing is **slightly negative** => TCR is small

Assessment on **solar radiation management**

→ Strong implications of Chapter 7 in the overall report
(although of course this is diluted by other *lines of evidence*)

Chapter 7 executive summary

“The net feedback from water vapour and lapse rate changes combined, as traditionally defined, is extremely likely positive (amplifying global climate changes)”.

“The sign of the net radiative feedback due to all cloud types is less certain but likely positive. Uncertainty in the sign and magnitude of the cloud feedback is due primarily to continuing uncertainty in the impact of warming on low clouds.”

“The total ERF due to aerosols ($ERF_{ari+aci}$, excluding the effect of absorbing aerosol on snow and ice) is assessed to be -0.9 (-1.9 to -0.1) $W m^{-2}$ with medium confidence.”

⇒ Slightly inconsistent conclusions in terms of what it tells us on ECS and TCR, which we had to live with

Chapter 7 – Review comments

1st and 2nd rounds of review comments have influenced our thinking and the conclusions of Chapter 7.

Although we have reached consensus within the chapter on all issues, some reviewers would still feel that uncertainties are larger than stated in the IPCC AR5 chapter (especially aerosols).

It is difficult to stick to a pure “bottom up” estimate of aerosol RF.

Expert judgment involved.

OLIVIER BOUCHER AEROSOLS



WE DONT REALLY
KNOW WHAT'S IMPORTANT



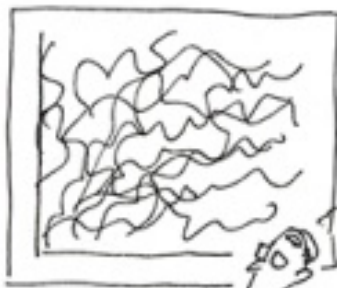
BLACK CARBON
DONT UNDERESTIMATE
THIS GUY!



SPRAY ON, LASTS ALL DECADE,
AND SMELLS COOL!

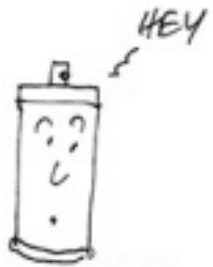


CAN YOU HANG ABOUT
{ WHILE I CHECK
YOU OUT?

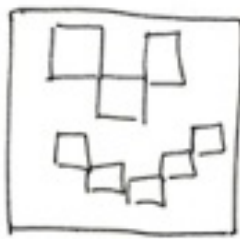


NOT STATE OF THE ART

josh@cartoonsbyjosh.com



AEROSOLS - ARE
THEY IMPORTANT



- HIGH RES
- NEW METHODS
- VERIFY

MEMO
FOR
FUTURE

Q: A CLOUDS + AEROSOLS



NO!
HA

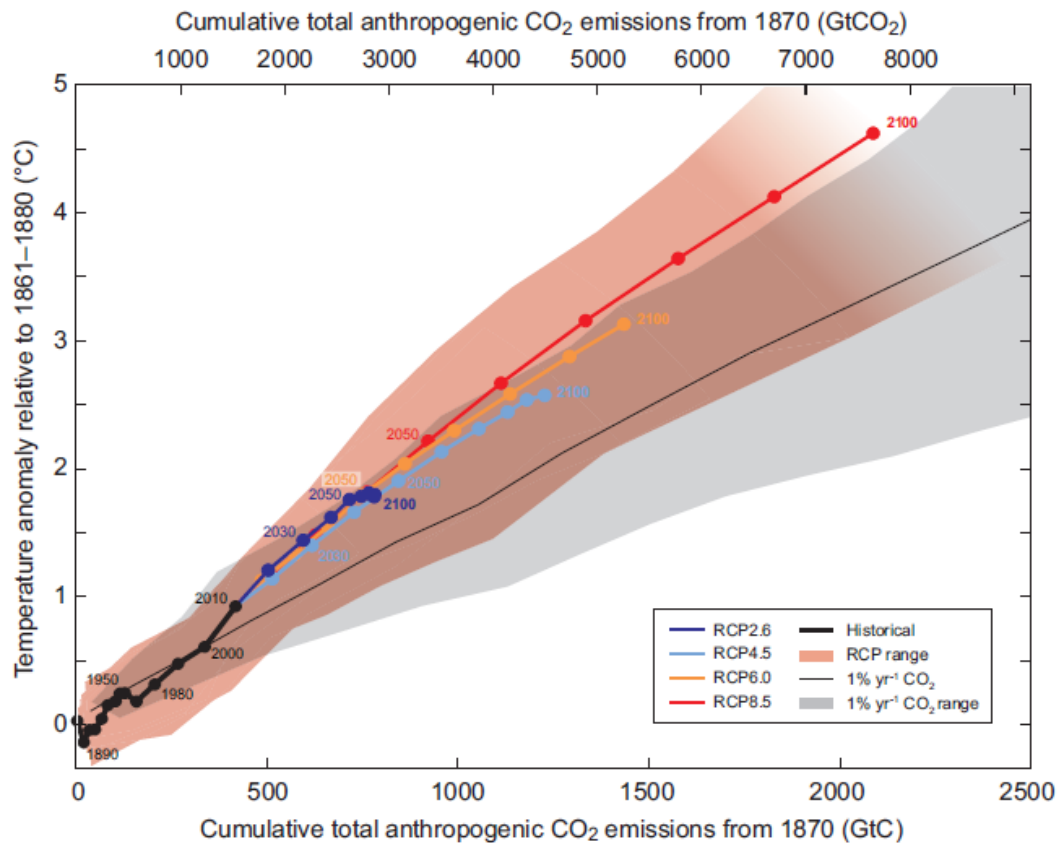
Chapter 7 – Geo-engineering

WGI Chapter 7 was in charge of assessing Solar Radiation Management from a physical science perspective.

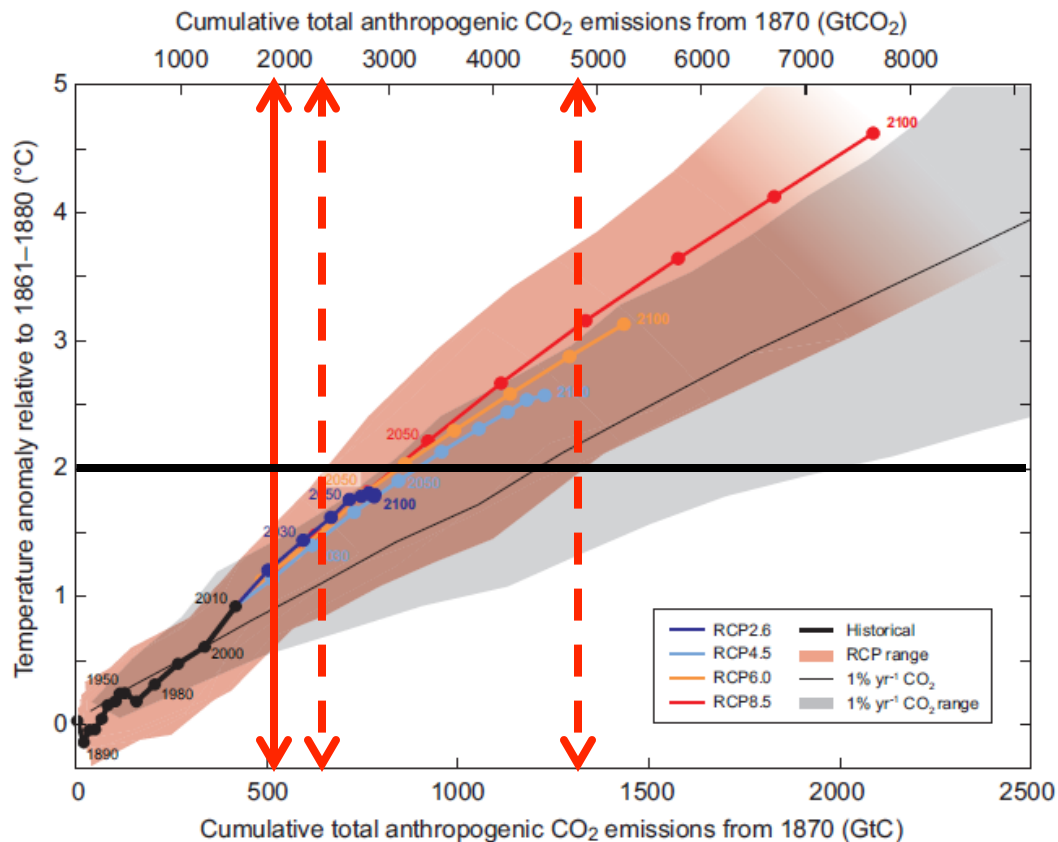
- Sensitive issue!
- Careful wording to avoid meaning being altered if sentence is quoted out of context (i.e. exec summary & SPM).
- Many comments during government review but a lot of comments wanted us to go into WGII and WGIII territory.
- Difficult to treat SRM and CDR together in SPM. We had to resist hard against sweeping statements.
- This highlights the limitations of separate WG approaches.
- Only one comment in the IPCC approval session!

Outline of talk

- 1/ A primer on radiative forcing & climate sensitivity
- 2/ Lessons from coordinating IPCC chapter 7
- 3/ Some thoughts on uncertainties
- 4/ Conclusions

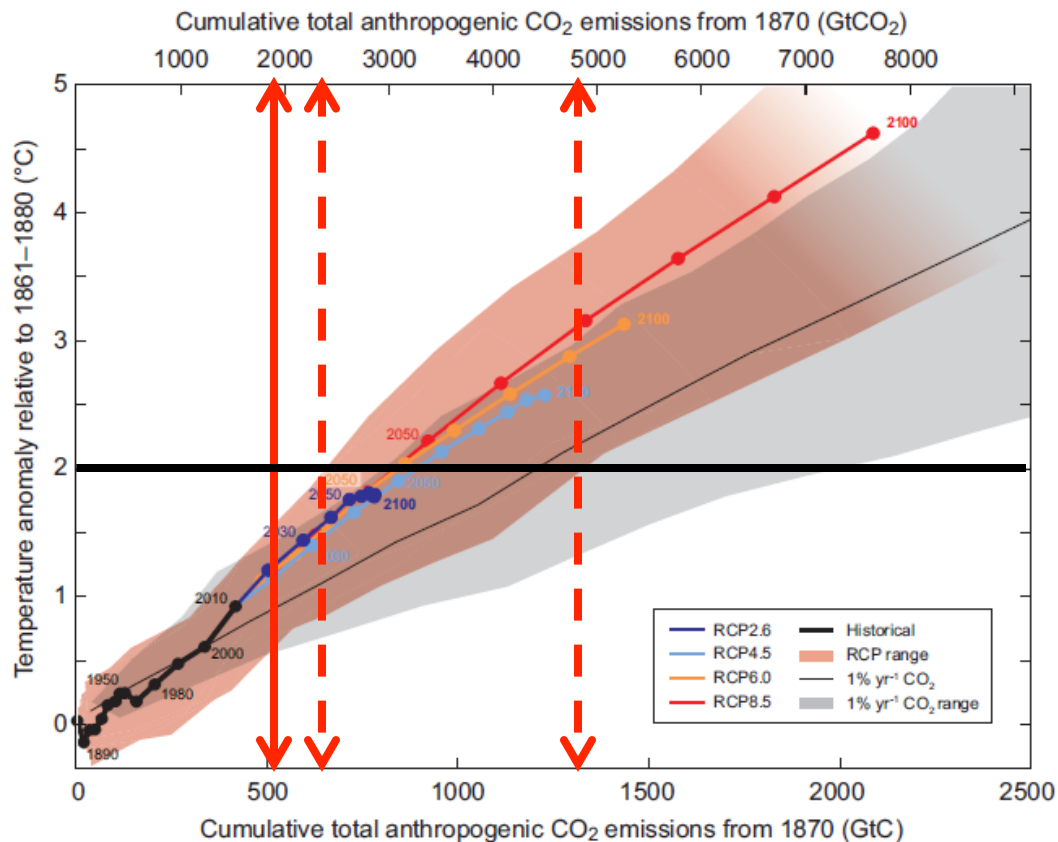


Uncertainties remain large...



Uncertainties remain large...

Limiting the warming caused by anthropogenic CO₂ emissions alone with a probability of >33%, >50%, and >66% to less than 2°C since the period 1861–1880, will require cumulative CO₂ emissions from all anthropogenic sources to stay between 0 and about 5760 GtCO₂, 0 and about 4440 GtCO₂, and 0 and about 3670 GtCO₂ since that period, respectively. These upper amounts are reduced to about 3300, 3010 and 2900 GtCO₂, respectively, when accounting for non-CO₂ forcings as in RCP2.6. An amount of 1890 [1630 to 2150] GtCO₂ was already emitted by 2011. {12.5}



Uncertainties
remain large...
and difficult to
communicate

“ Two-thirds of all the emissions permissible if dangerous climate change is to be avoided have already been pumped into the atmosphere, the IPCC found. ”

The Guardian, 2 Nov 2014

Uncertainties versus risk

Uncertainty: often evaluated within IPCC by assigning a probability distribution to a physical quantity

⇒ IPCC uncertainty language

⇒ Likelihood statements (e.g. *unlikely, likely, very likely*)

Risk = $\sum i$ Probability of event i X Severity of event i

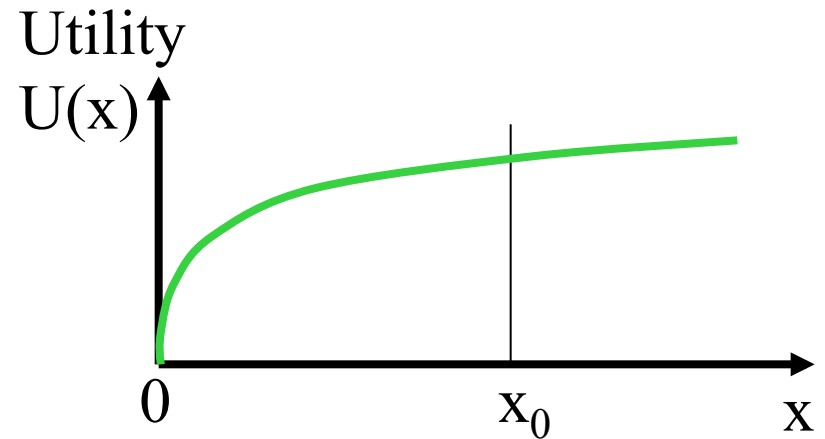
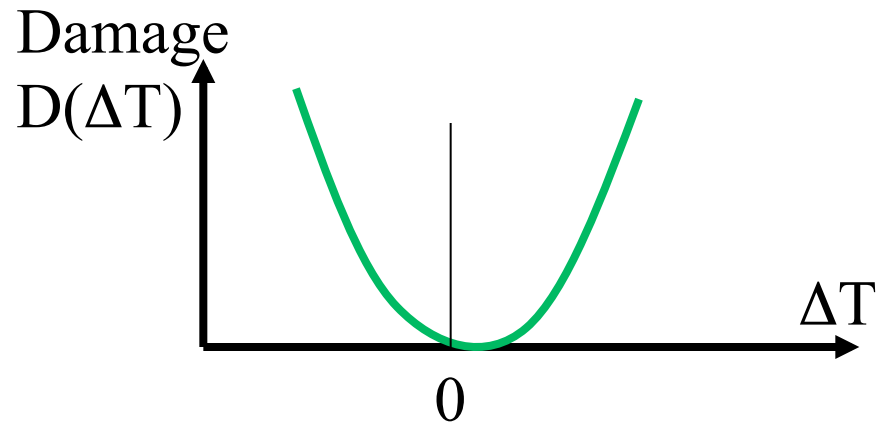
Uncertainties versus risk

Uncertainty: often evaluated within IPCC by assigning a probability distribution to a physical quantity

⇒ IPCC uncertainty language

⇒ Likelihood statements (e.g. *unlikely, likely, very likely*)

Risk = \sum_i Probability of event i X Severity of event i



Uncertainties versus risk

Uncertainty: often evaluated within IPCC by assigning a probability distribution to a physical quantity

⇒ IPCC uncertainty language

⇒ Likelihood statements (e.g. *unlikely, likely, very likely*)

Risk = \sum_i Probability of event i X Severity of event i

⇒ Can we better constrain the upper tail of the PDF of TCR/ECS?

⇒ Can we better estimate potential irreversible changes?

⇒ Can we better estimate the cost of climate change?

⇒ Can we better compare risks of various scenarios?

⇒ Not quite as simple as Pascal's wager

Conclusions

- IPCC is probably as quantitative as it can be on uncertainties. There remains some elements of expert judgment which are recognized as such.
- IPCC is conservative on some aspects (but rightly so).
- Uncertainties remain large, difficult to communicate, and are often omitted at some point in the communication chain (but can it be otherwise?).
- We should think more in terms of risk assessment, which will ultimately lead to weighing different risks.

END

