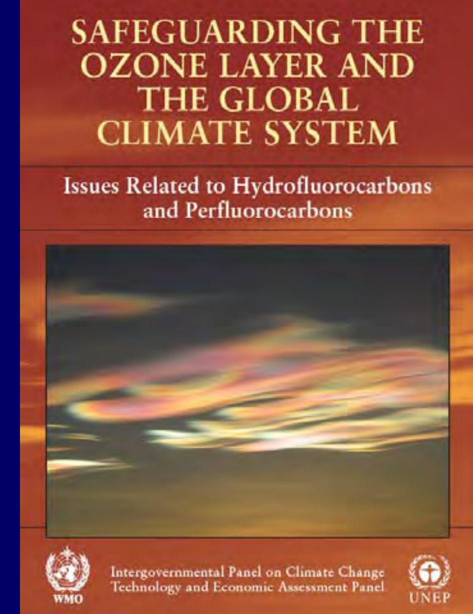
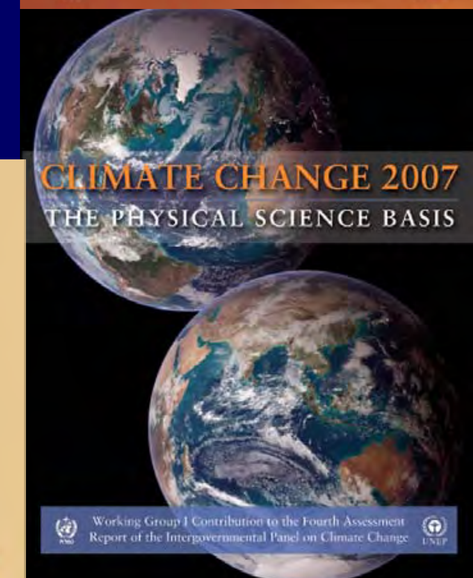
Some Highlights of ESRL Contributions to Assessments

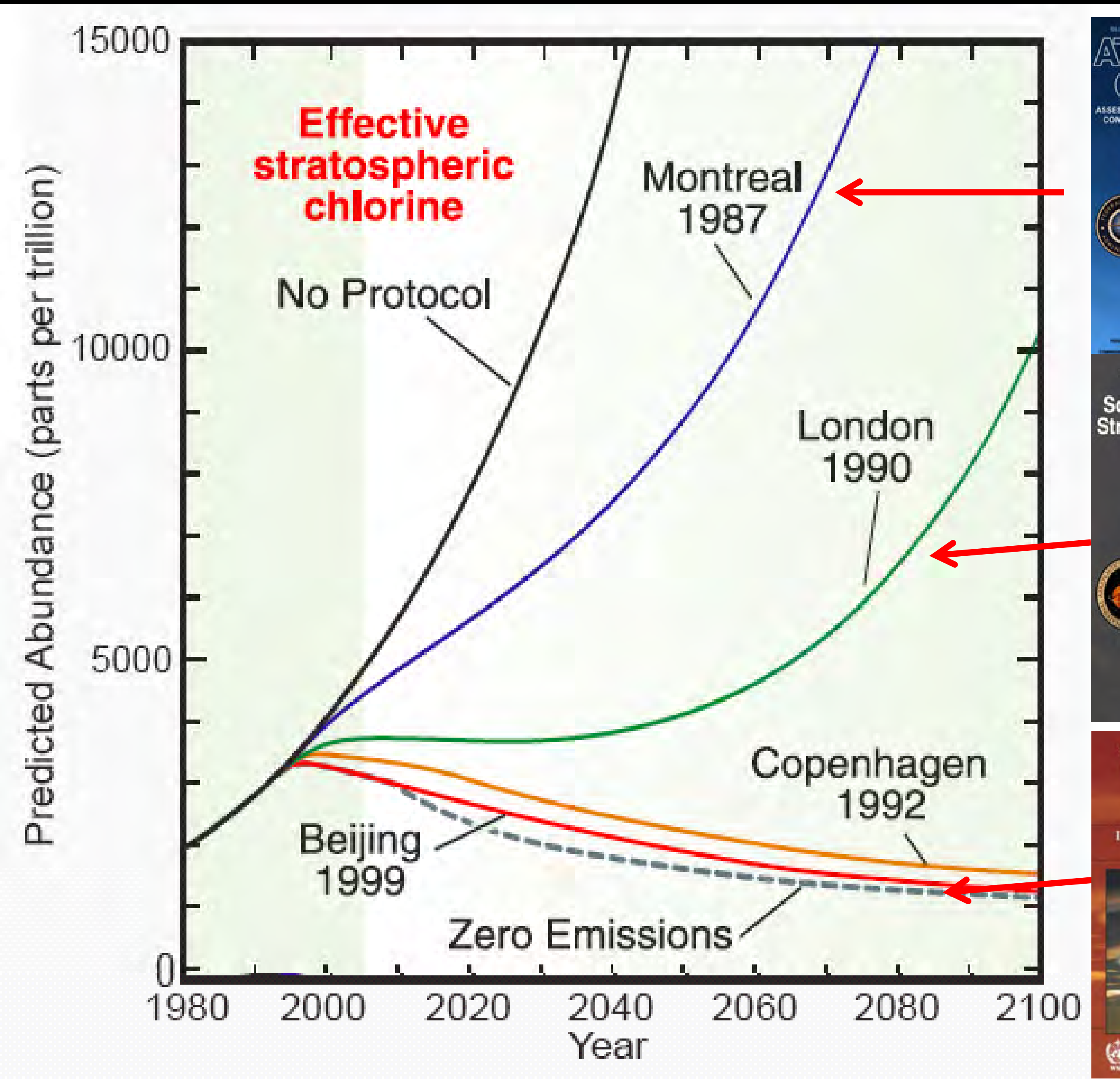
Susan Solomon

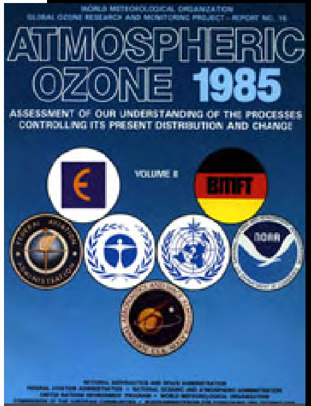
1. Introduction and Background: what is assessment, and what is successful assessment?
2. WMO/UNEP Ozone Assessments
3. Other Assessments (e.g., CCSP, AQ, IPCC special report on ozone/climate)
4. IPCC WG1 AR4
5. Summary and Outlook for the Future



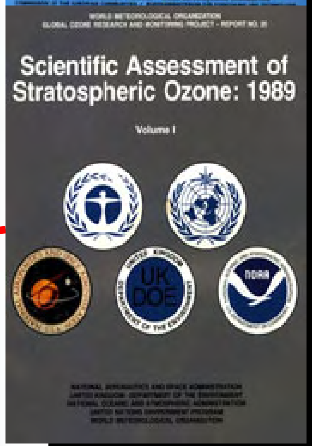


What is an Assessment? Science Input to Key Policy Decisions

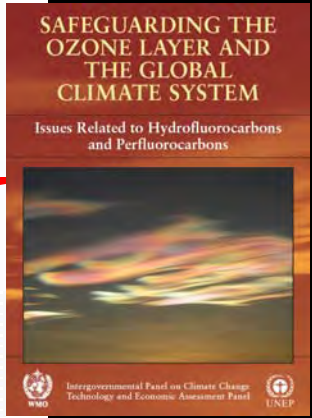




Ozone hole discovered



Ozone hole explained; also depletion in mid-lats



HCFC accelerated phaseout; climate coupling

Elements of a Successful World-Class Assessment

Assessment processes slowly build strength and impact over time (e.g., the 20 years of ozone assessment and ozone policy) through:

- Hard-hitting and policy-relevant science advances
- A strong process of rigorous review, author selection, and approval, stringently followed
- Strong leadership capable of engendering the support and confidence of the science community and of the policy community
- Content that is useful and credible both to the policy community and to the science community
- Connection to policy process

Major messages and findings
of
Science Assessment of Ozone Depletion-2006

World Meteorological Organization
Global Ozone Research and Monitoring Project—Report No. 50

SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2006

Cochairs:

Ayité-Lô Ajavon (Togo)
Daniel L. Albritton (USA)
Robert T. Watson (USA)

Scientific Steering Committee:

Marie-Lise Chanin, CNRS, France

Susana Diaz, CAIC, Argentina

John Pyle, Univ. of Cambridge, UK

Theodore Shepherd, Univ. of Toronto, Canada

A. R. Ravishankara, NOAA, USA

National Oceanic and Atmospheric Administration
National Aeronautics and Space Administration
United Nations Environment Programme
World Meteorological Organization
European Commission

The 2006 Science Assessment

- Worldwide effort involving over 300 scientists from Article-5 and non-Article 5 countries - as Co-chairs, Lead Authors, Co-authors, Contributors, and Reviewers

- Delivered to the Parties in response to their request (Terms of Reference, 15th MOP, Decision XV/53, November 2003)

- Fully reviewed three times by the international scientific community

- Is the sixth in the series of the SAP's scientific assessments for the Parties.   ESRL has played major roles in all of these reports, which have guided ozone policy decisions.

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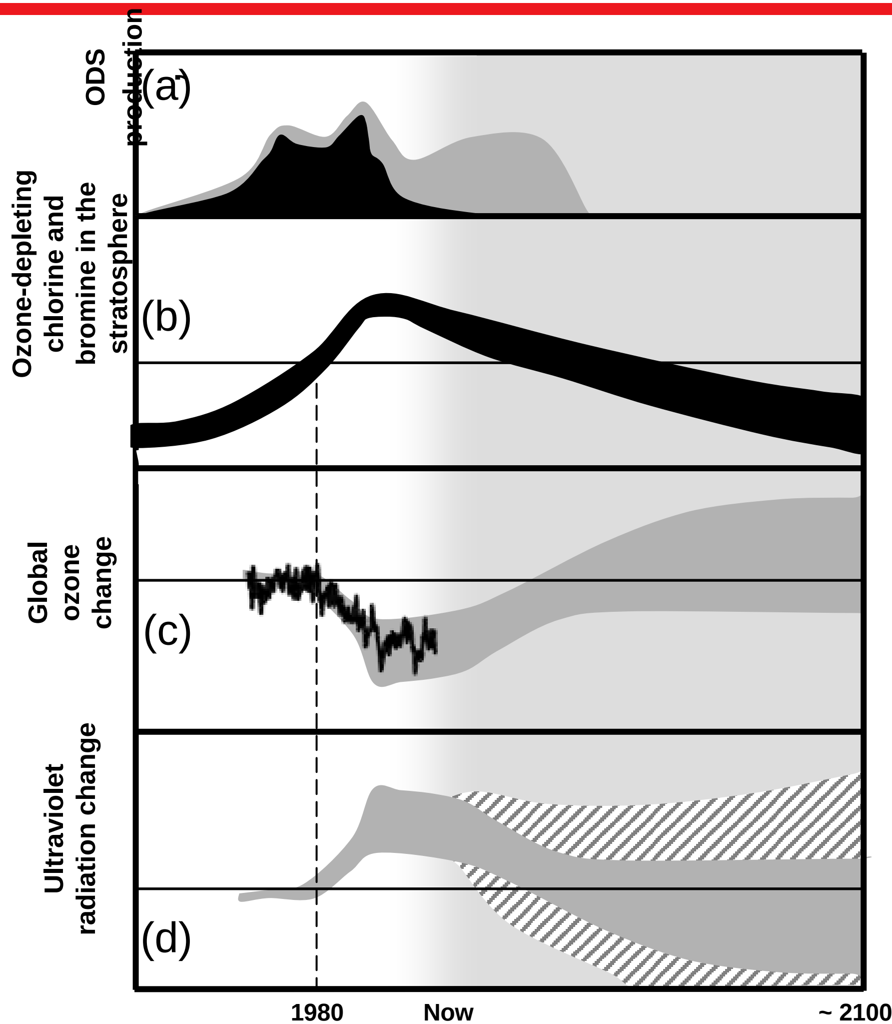
What color will the 2010 volume be?

1989 1991 1994 1998 2002 2006

The Major Findings and Conclusions of the 2006 Science Assessment



ODS production

ODS in the atmosphere

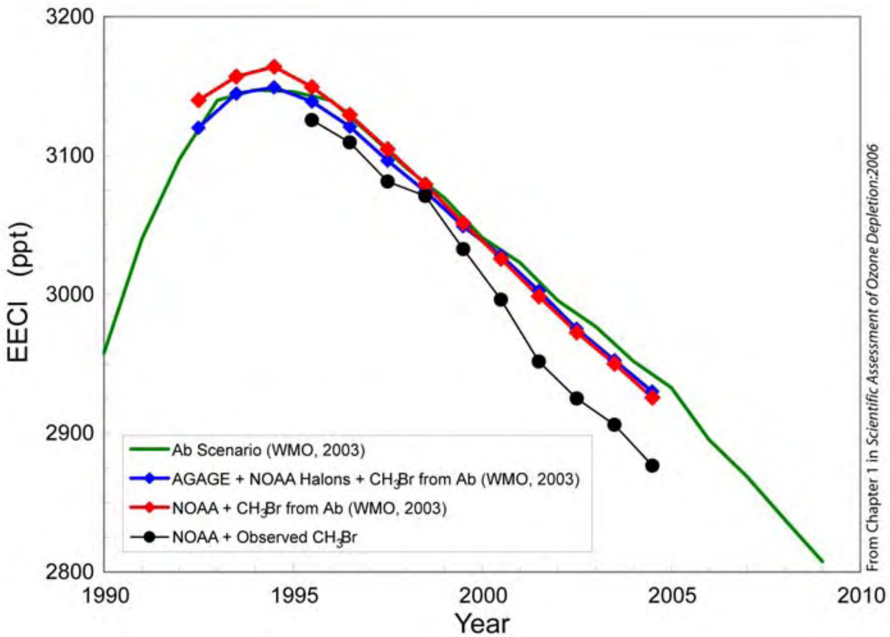
Ozone levels- measured and predicted

UV levels- measured and predicted

The Montreal Protocol is working!

We have entered the "accountability phase" with this issue!

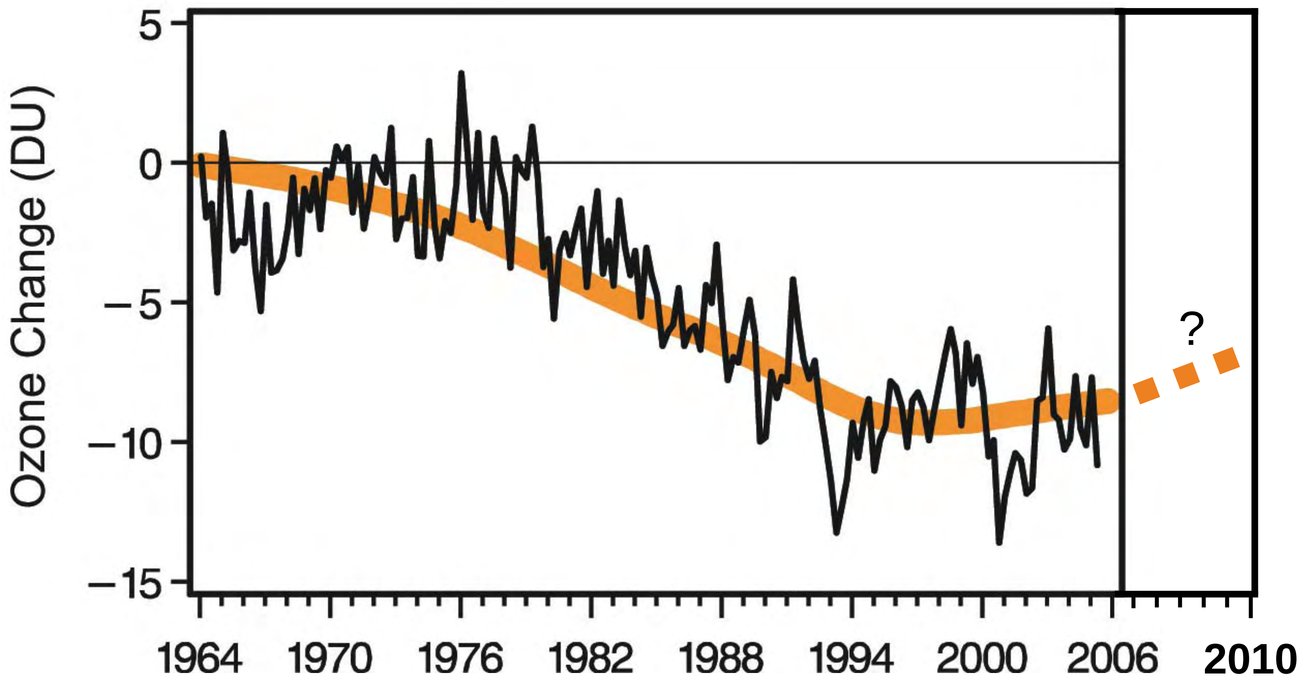
Some Key ESRL Science Inputs



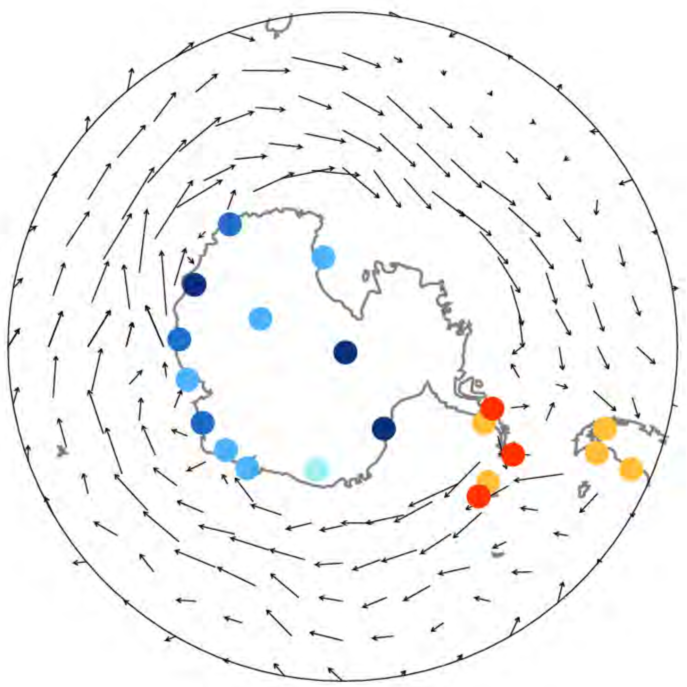
The Protocol Is Working: ODS Changes

Some Key ESRL Science Inputs

There are early signs that the ozone layer is starting its expected recovery



Some Key ESRL Science Inputs



Changes in ozone affect temperature and circulation of the stratosphere and troposphere. Important to discussions of how much halocarbon warming may or may not have been offset by ozone cooling.

Some Key ESRL Science Inputs

Table 8-2. Direct Global Warming Potentials for selected gases.

Industrial Designation or Common Name	Chemical Formula	Radiative Efficiency [1] ($W\ m^{-2}\ ppbv^{-1}$)	Lifetime (years)	Global Warming Potential for Given Time Horizon		
				20 years	100 years	500 years
Carbon dioxide	CO_2	1.41×10^{-5} [2]		1	1	1
Nitrous oxide	N_2O	3.03×10^{-3}	114 [3]	289	298	153
Chlorofluorocarbons						
CFC-11	CCl_3F	0.25	45	6,730	4,750	1,620
CFC-12	CCl_2F_2	0.32	100	10,990	10,890	5,200
CFC-13	$CClF_3$	0.25	640	10,800	14,420	16,430
CFC-113	CCl_2FCClF_2	0.30	85	6,540	6,130	2,690
CFC-114	$CClF_2CClF_2$	0.31	300	8,040	10,040	8,730
CFC-115	$CClF_2CF_3$	0.18	1700	5,310	7,370	9,990
Hydrochlorofluorocarbons						
HCFC-21	$CHCl_2F$	0.14	1.7	530	151	46
HCFC-22	$CHClF_2$	0.20	12.0	5,160	1,810	549
HCFC-123	$CHCl_2CF_3$	0.14	1.3	273	77	24
HCFC-124	$CHClFCF_3$	0.22	5.8	2,070	609	185
HCFC-141b	CH_3CCl_2F	0.14	9.3	2,250	725	220
HCFC-142b	CH_3CClF_2	0.20	17.9	5,490	2,310	705
HCFC-225ca	$CHCl_2CF_2CF_3$	0.20	1.9	429	122	37
HCFC-225cb	$CHClFCF_2CClF_2$	0.32	5.8	2,030	595	181
Hydrofluorocarbons						
HFC-23	CHF_3	0.19 [4]	270	11,990	14,760	12,230
HFC-32	CH_2F_2	0.11 [4]	4.9	2,330	675	205
HFC-41	CH_3F	0.02	2.4	323	92	28
HFC-125	CHF_2CF_3	0.23	29	6,340	3,500	1,100
HFC-134	CHF_2CHF_2	0.18	9.6	3,400	1,100	335
HFC-134a	CH_2FCF_3	0.16 [4]	14.0	3,830	1,430	435
HFC-143	CH_2FCHF_2	0.13	3.5	1,240	353	107
HFC-143a	CH_3CF_3	0.13	52	5,890	4,470	1,590
HFC-152	CH_2FCH_2F	0.09	0.60	187	53	16
HFC-152a	CH_3CHF_2	0.09	1.4	437	124	38
HFC-227ea	CF_3CHFCF_3	0.26 [4]	34.2	5,310	3,220	1,040
HFC-236cb	$CH_2FCF_2CF_3$	0.23	13.6	3,630	1,340	407
HFC-236ea	CHF_2CHFCF_3	0.30	10.7	4,090	1,370	418
HFC-236fa	$CF_3CH_2CF_3$	0.28	240	8,100	9,810	7,660
HFC-245ca	$CH_2FCF_2CHF_2$	0.23	6.2	2,340	693	211
HFC-245fa	$CHF_2CH_2CF_3$	0.28	7.6	3,380	1,030	314
HFC-365mfc	$CH_3CF_2CH_2CF_3$	0.21	8.6	2,520	794	241
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	0.40	15.9	4,140	1,640	499
Chlorocarbons						
Methyl chloroform	CH_3CCl_3	0.06	5.0	506	146	45
Carbon tetrachloride	CCl_4	0.13	26	2,700	1,400	435
Methyl chloride	CH_3Cl	0.01	1.0	45	13	4

Some Key ESRL Science Inputs

Table 8-6. Comparison of scenarios and hypothetical cases[a]: the year when EESC drops below the 1980 value for both midlatitude and polar vortex cases, and integrated EESC differences (midlatitude case) relative to the baseline (A1) scenario. Note that the polar recovery times have not been given in previous Assessments; interpretation of any comparison between these numbers and recovery times given in previous Assessments requires an understanding of the large role played by the different transport times from the troposphere to the stratospheric midlatitude and polar vortex regions.

Scenario and Cases	Percent Difference in integrated EESC relative to baseline scenario for the midlatitude case		Year (x) when EESC is expected to drop below 1980 value	
	Midlatitude			Antarctic vortex[b]
	$\int_{1980}^{x} EESC\,dt$	$\int_{2007}^{x} EESC\,dt$		
Scenarios				
A1: Baseline scenario			2048.9	2065.1
Cases[a] of zero production from 2007 onward of:				
P0: All ODSs	−8.0	−17.1	2043.1	2060.3
CFCs	−0.1	−0.3	2048.8	2065.0
Halons	−0.2	−0.5	2048.8	2065.1
HCFCs	−5.5	−11.8	2044.4	2062.2
Anthropogenic CH_3Br	−2.4	−5.1	2047.9	2063.7
Cases[a] of zero emissions from 2007 onward of:				
E0: All ODSs	−19.4	−41.7	2034.0	2049.9
CFCs	−5.3	−11.5	2045.0	2060.3
CH_3CCl_3	−0.1	−0.2	2048.9	2065.1
Halons	−6.7	−14.4	2045.6	2061.9
HCFCs	−7.3	−15.7	2043.7	2061.8
CCl_4	−1.3	−2.9	2048.5	2064.9
Anthropogenic CH_3Br	−2.4	−5.1	2047.9	2063.7
Cases[a] of full recovery of the 2007 banks of:				
B0: All ODS	−12.9	−27.8	2040.8	2056.7
CFCs	−5.2	−11.3	2045.1	2060.4
Halons	−6.7	−14.3	2045.7	2062.0
HCFCs	−1.9	−4.1	2048.4	2064.8
CH_3Br sensitivity:				
Same as A1, but CH_3Br anthropogenic emissions set to 20% in 1992[c]	3.1	6.6	2050.6	2067.7
Same as A1, but zero QPS production from 2015 onward	−1.5	−3.2	2047.9	2063.7
Same as A1, but critical-use exemptions continued at 2006 level	1.9	4.0-4.7	2050.1	2067.0

[a] Importance of ozone-depleting substances for future EESC were calculated in the hypothetical "cases" by setting production or emission to zero in 2007 and subsequent years or the bank of the ODS to zero in the year 2007 alone. These cases are not mutually exclusive, and separate effects of elimination of production, emissions, and banks are not additive.

[b] This metric specifically for Antarctic polar vortex ozone depletion has not been shown in any previous ozone Assessment.

[c] In the baseline scenario, this fraction was assumed to be 30% in 1992, with a corresponding emission fraction of 0.88 of production. In this alternative scenario, an anthropogenic fraction was assumed to be 20%, with an emission fraction of 0.56 of production. In both scenarios, the total historic emission was derived from atmospheric observations and a lifetime of 0.7 years.

The Preparation of the 2010 Ozone Science Assessment

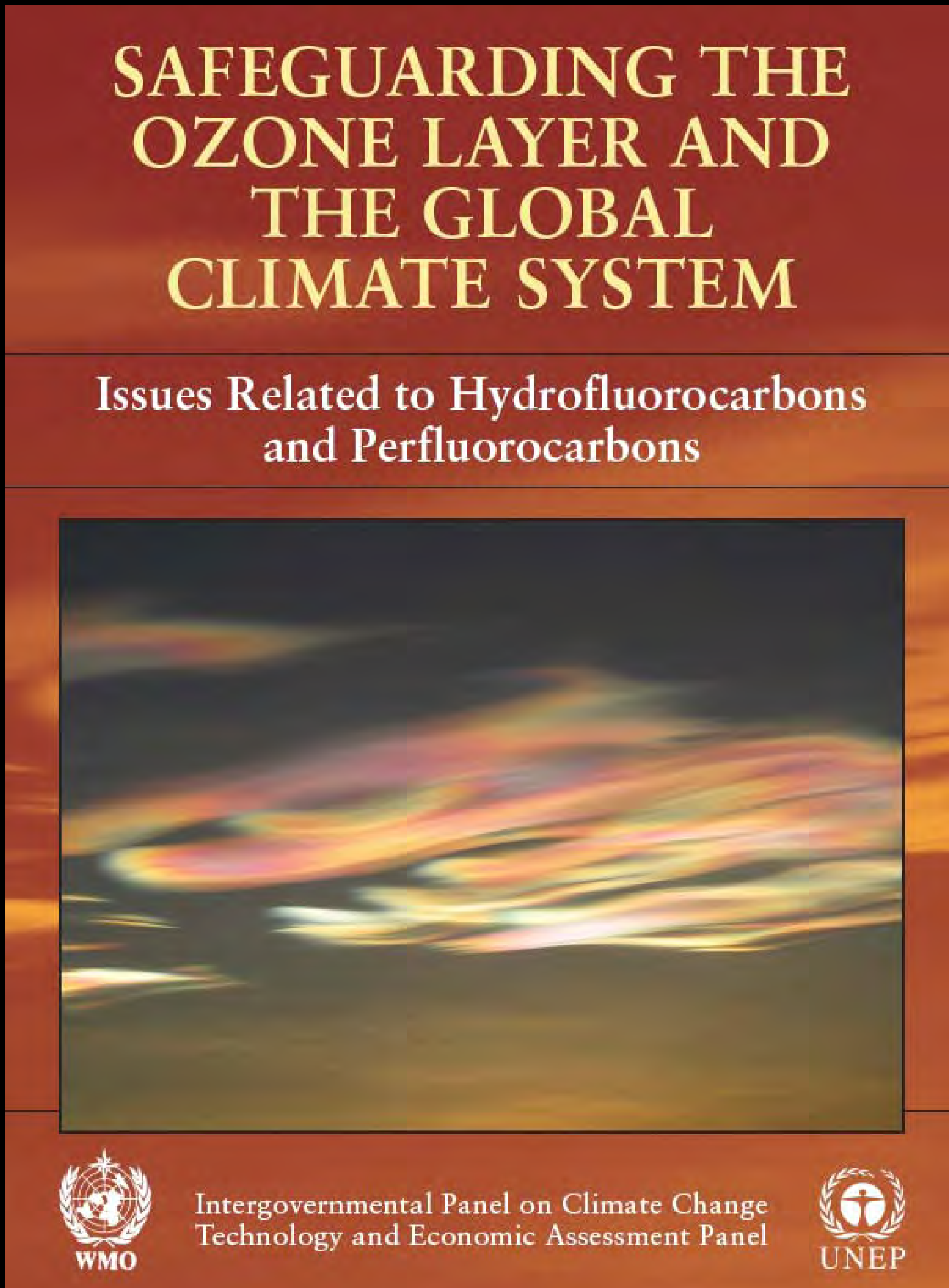
Co-Chairs: A. R. Ravishankara, J. A. Pyle, P. Newman, Ayité-Lô Ajavon

The Terms of Reference from the Parties TBD,but expect elements of the following at least:

- **Assess ozone's impact on climate change**
- **Assess how much benefit to the ozone layer and the climate is obtained by the early HCFC phaseout**

….

Key Technical Support: Christine A. Ennis, ESRL CSD



A Surprising Element in The Search for Options: Ozone-Climate Interactions

IPCC (2005)

Solomon, co-chair IPCC WG1

Support by WG1 TSU

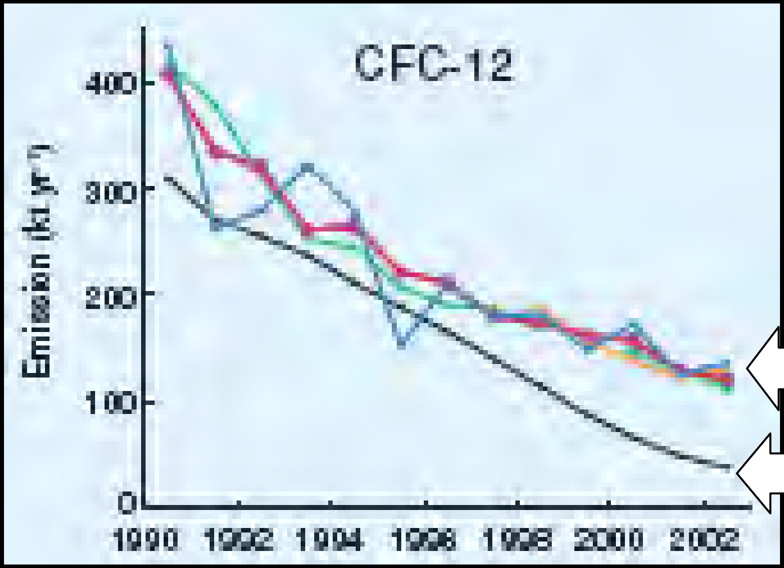
ESRL authors and reviewers

Special Report has shown many win-win solutions

Halocarbon Emissions

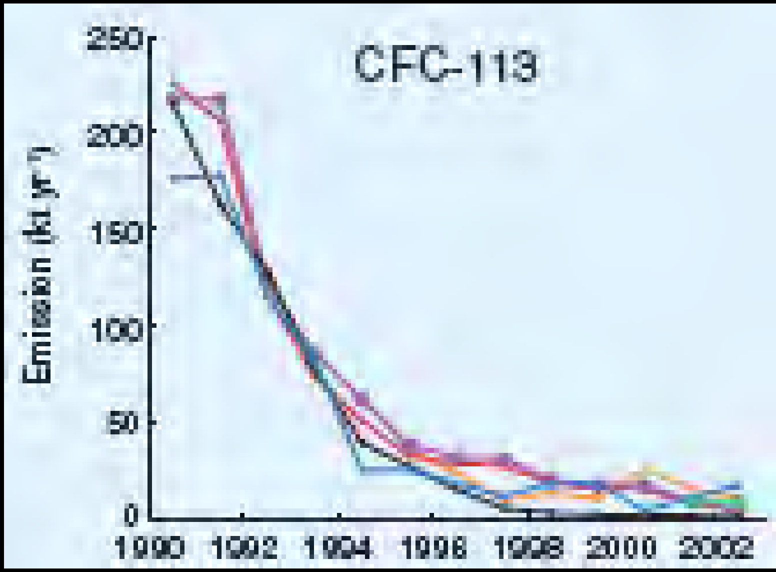
- Continuing emissions of CFC-11 and CFC-12 from banks…values in 2002 about a third of the maxima in late 1980s. Why? Banks in existing equipment (refrigeration, AC, foams, etc.)

- Contrast with e.g., CH3CCl3 and CFC-113, where emissions are now <5% of the max. Why? Solvents - so limited banks.



Observed

Expected



•Current CO_2-equivalent emissions [Table TS-2]:

1.5-1.9 Gt for CFCs

0.53-0.56 Gt for HCFCs

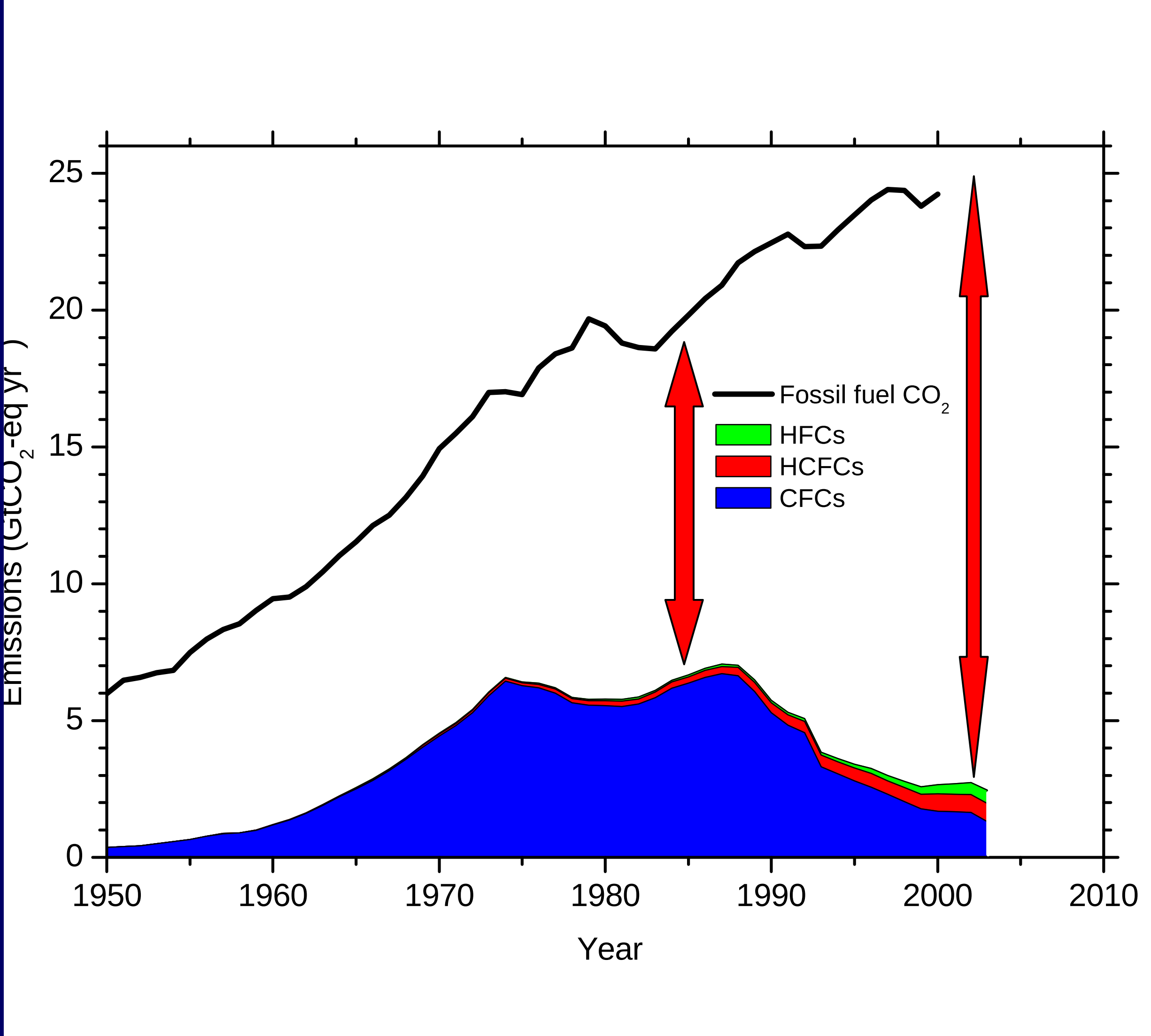
0.36 Gt for HFCs

Halocarbon Emissions

Combined CO_2-equivalent emissions from halocarbons:

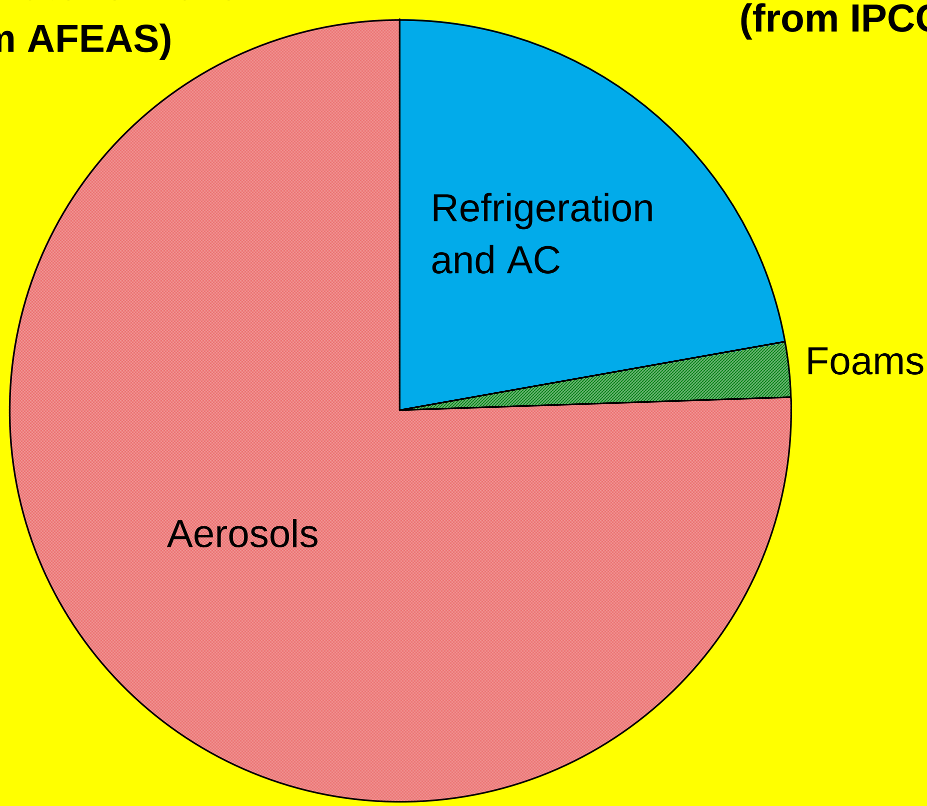
~7.5 Gt near 1990, about 33% of that year's CO_2 emissions from global fossil fuel burning

~2.5 Gt near 2000, about 10% of that year’s CO_2 emissions from global fossil fuel burning (25 Gt)

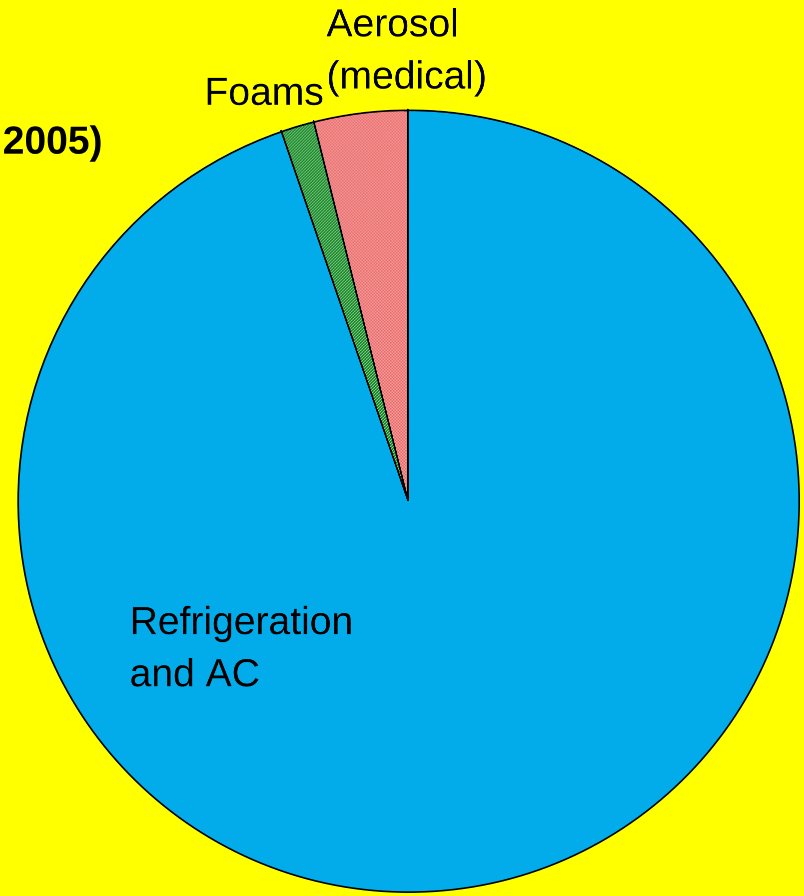


Change in use of CFCs: from 'leaky' to 'tight'

CFC-12 Emission Estimate for 1975 (from AFEAS)

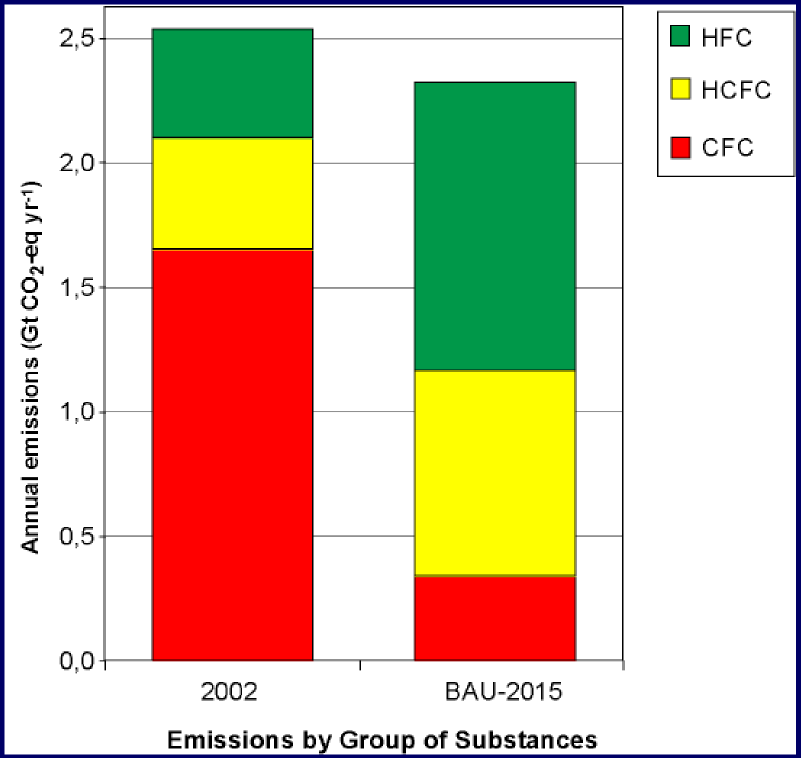


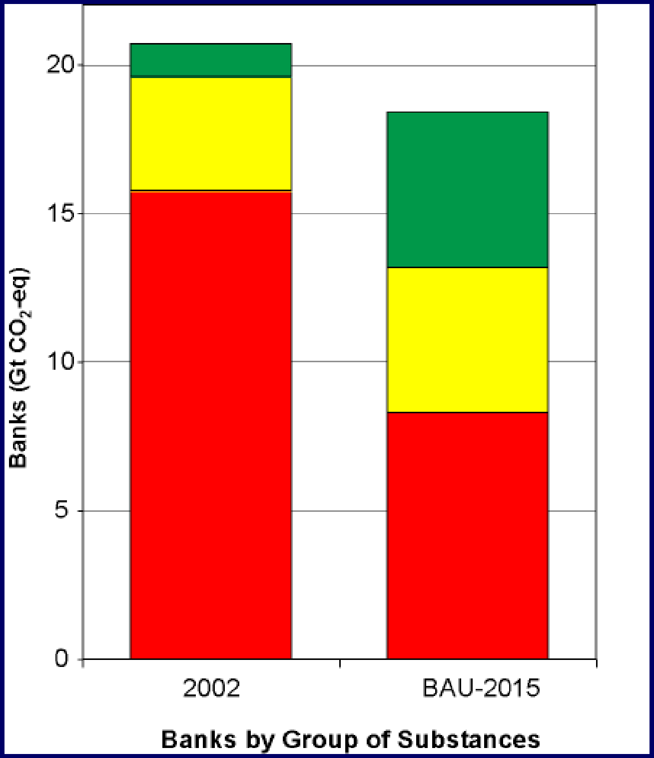
2002 (from IPCC 2005)



This change implies a large change in the role of banks

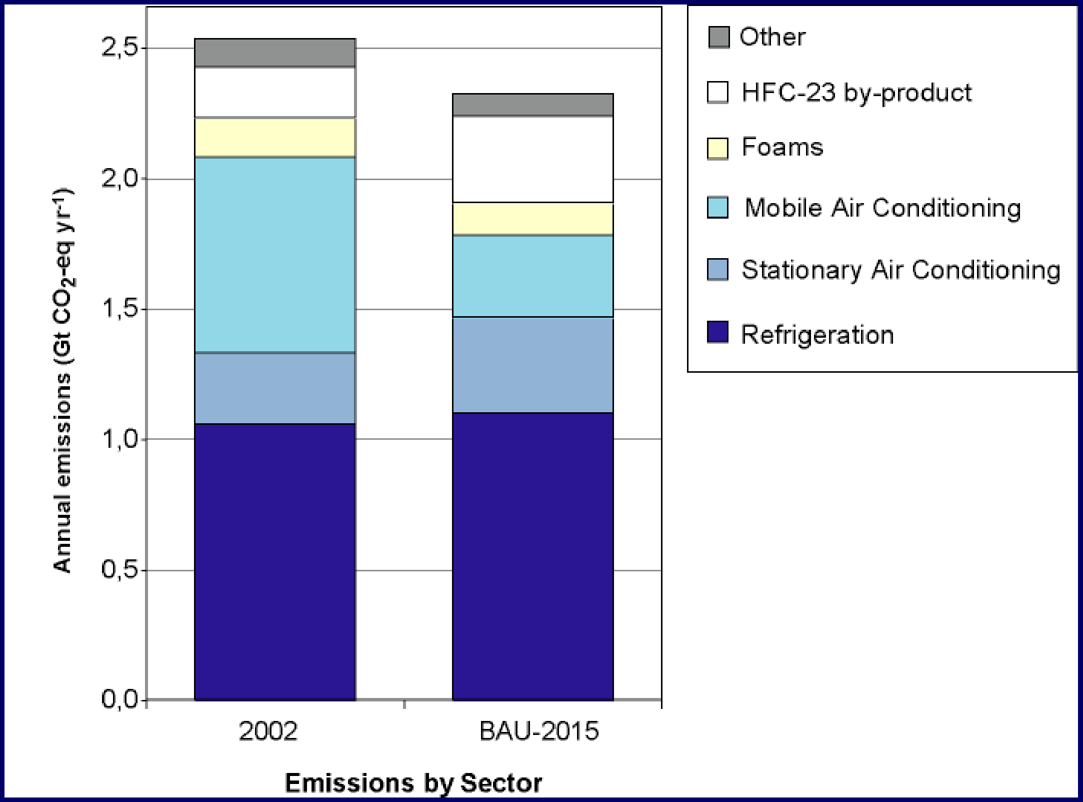
Business-as-usual banks and emissions

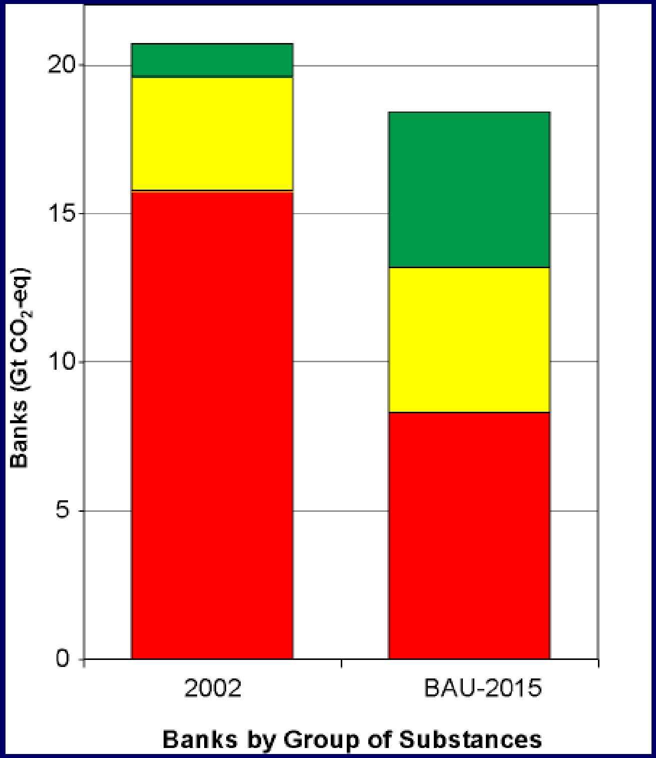




- Large bank of CFCs. Growing banks of HCFCs and HFCs in future (up to 10 Gt CO2 eq in 2015). What about the banks?
- New early phaseout of developing country HCFC-22 production addressed the very thorny problem of HFC-23 emission as a by-product, illuminated in SROC.

Business-as-usual banks and emissions





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- New early phaseout of developing country HCFC-22 production addressed the very thorny problem of HFC-23 emission as a by-product, illuminated in SROC.

CCSP: Connecting with our national process

SAP 2.4 will use the findings from the latest assessments to convey the implications of ozone depletion on the US and to establish the US contributions to this global issue in so far as possible.

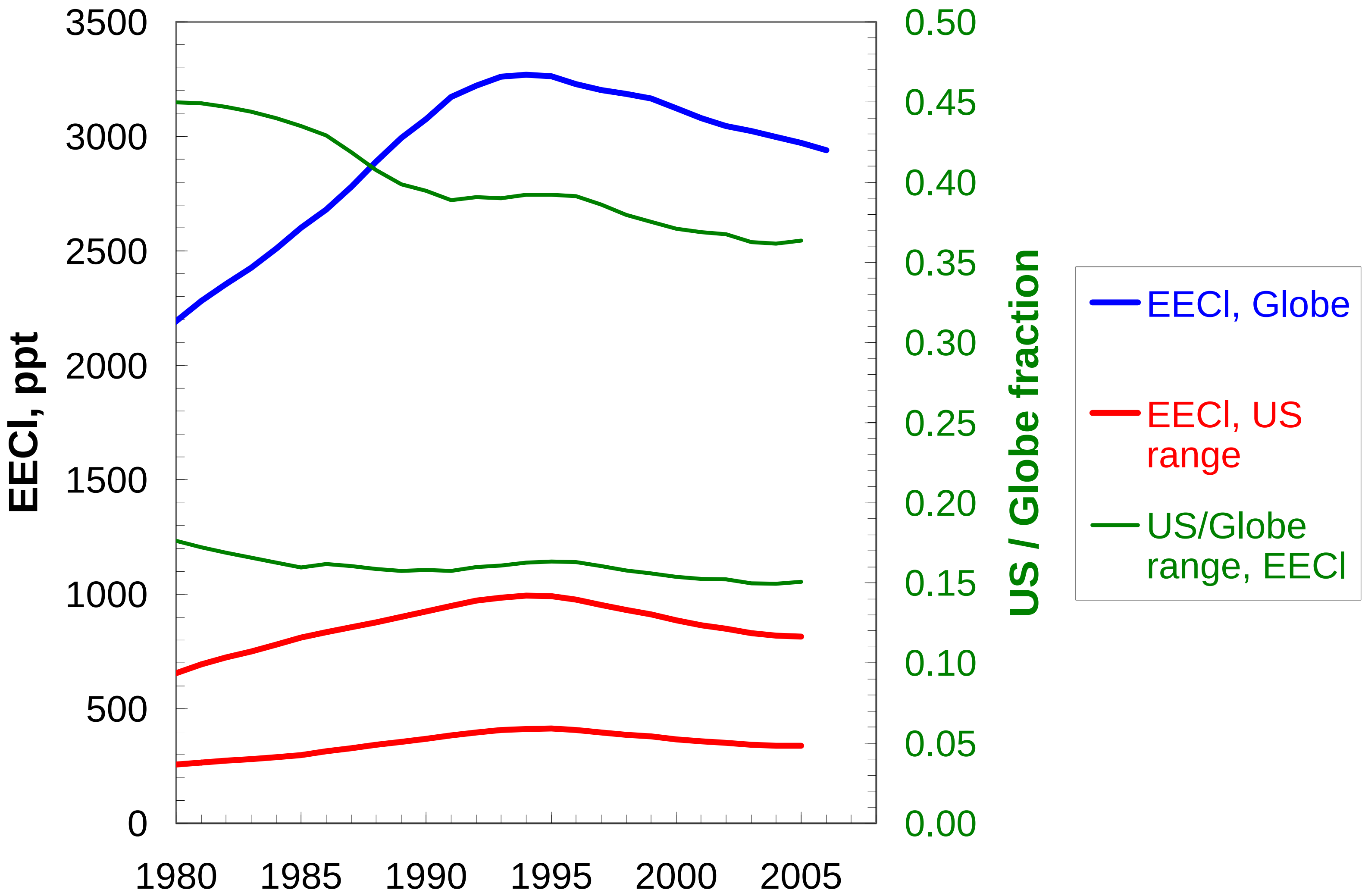
- **Primary sources of information are the IPCC/TEAP "Special Report on Ozone and Climate (SROC; 2005) and the WMO/UNEP O_3 Assessment (2007).**
- **It will utilize new information that has become available since the publication of these two international assessments, such as the IPCC Fourth Assessment Report (2007) and a few recent peer reviewed publications.**

SAP 2.4 provides a good example of how we can take advantage of the international assessments (for which we contribute science and assessment time) for our specific (i.e., national) needs.

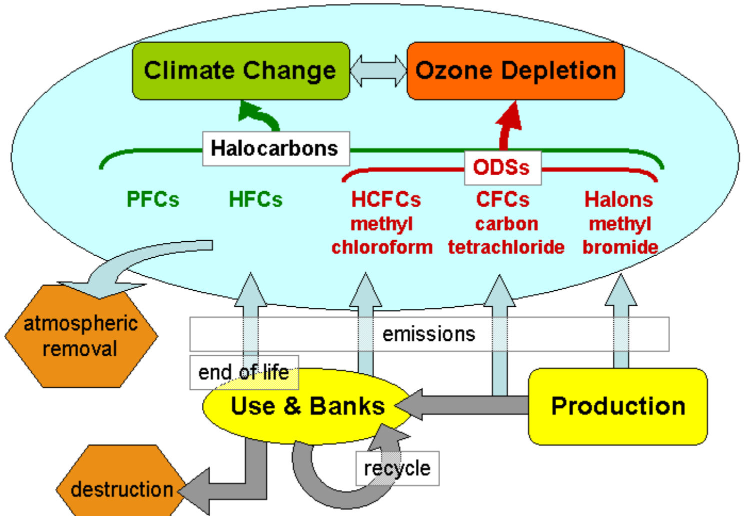
Author Team and Their Roles:

Dr. A. R. Ravishankara, NOAA	**Overall Lead**
Dr. Michael J. Kurylo, NASA	**Overall Lead**
Dr. Richard M. Bevilacqua, NRL / DoD	Scientific Content
Dr. Jeff Cohen, USEPA	Scientific Content
Dr. John S. Daniel, NOAA	Scientific Content
Dr. Anne R. Douglass, NASA	Scientific Content
Dr. David W. Fahey, NOAA	Scientific Content
Dr. Jay R. Herman, NASA	Scientific Content
Dr. Terry Keating, USEPA	Scientific Content
Dr. Malcolm K. Ko, NASA	Scientific Content
Dr. Stephen A. Montzka, NOAA	Scientific Content
Dr. Paul A. Newman, NASA	Scientific Content
Dr. V. Ramaswamy, NOAA	Scientific Content
Dr. Anne-Marie Schmoltner, NSF	Scientific Content
Dr. Richard S. Stolarski, NASA	Scientific Content
Dr. Ken W. Vick, USDA	Scientific Content

Key Finding: The US contribution to stratospheric chlorine



Some Other Issues



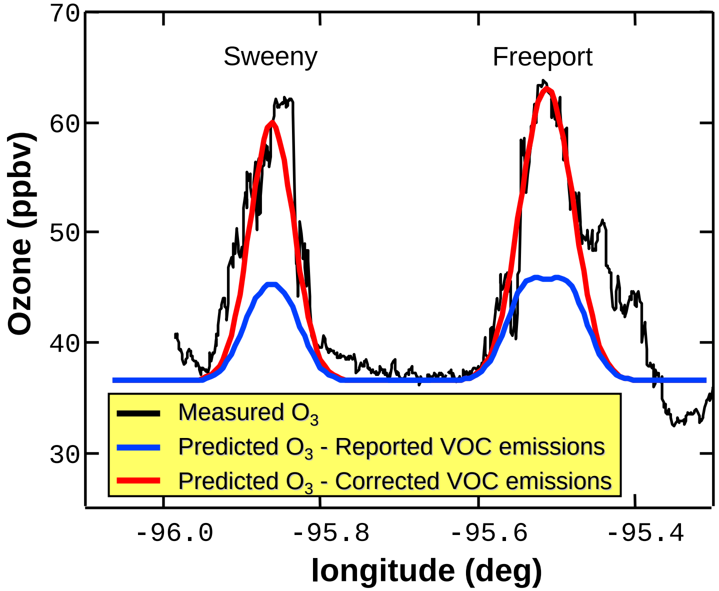
- How large is the US contribution to the banks, and to 'leakage' from the banks (i.e., the future?)
- How much of the US bank is 'accessible' (e.g., auto garage supplies are more accessible than foams in existing buildings)? Recovery and destruction of CFC banks could be an option for further protection of ozone and climate.

Texas Regional Air Quality Assessment

What did we do?

NOAA led two major field experiments in East Texas, in 2000 and 2006, to learn the causes of high ozone levels in the region. This work was highlighted in subsequent assessments provided to the State of Texas at their request.

NOAA science shows petrochemical plants have a greater impact on Houston's O_3 problem than previously believed.



What did we establish through research/assessment?

Texas emission inventories substantially underestimated (by a factor of 10 - 100) routine emissions of reactive petrochemicals (especially very reactive alkenes).

What was the policy impact?

The State of Texas modified its "NO_X only" emission reduction strategy to include reductions in reactive VOCs from petrochemical plants.

What was the economic impact?

The more effective option for managing ozone precursor emissions in Houston is estimated to save the State of Texas over $ 9 Billion and ~ 65,000 jobs by 2010. (G. Tolley and B. Smith, Cleaning Up Houston's Act: An Evaluation of Alternative Strategies, University of Chicago)

What's next?

The policy-relevant findings from the 2006 experiment and the subsequent assessment (major lead: Dave Parrish) are currently being considered in the development of follow-on regulations for ozone precursors in East Texas (including not only Houston but also Dallas, Beaumont/Port Arthur).

20 Years of IPCC WG1

Governments require information on climate change for negotiations

The IPCC formed in 1988 under auspices of the United Nations

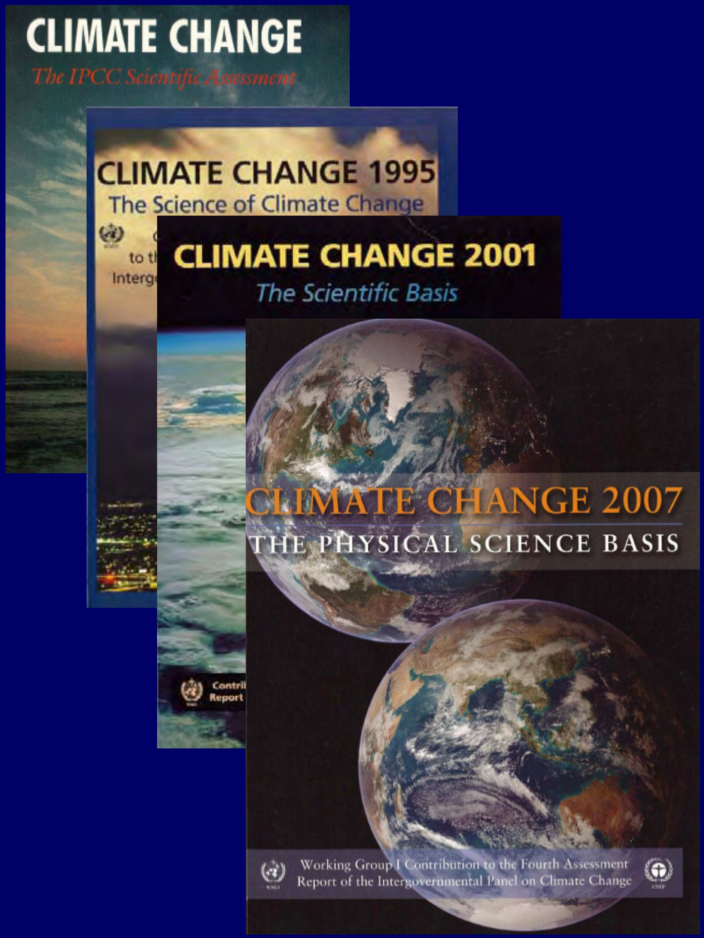
Function is to provide assessments of the science of climate change as input to the United Nations Framework Convention on Climate Change (UNFCCC)

Substance and leadership of IPCC WG1 reports in the hands of scientists

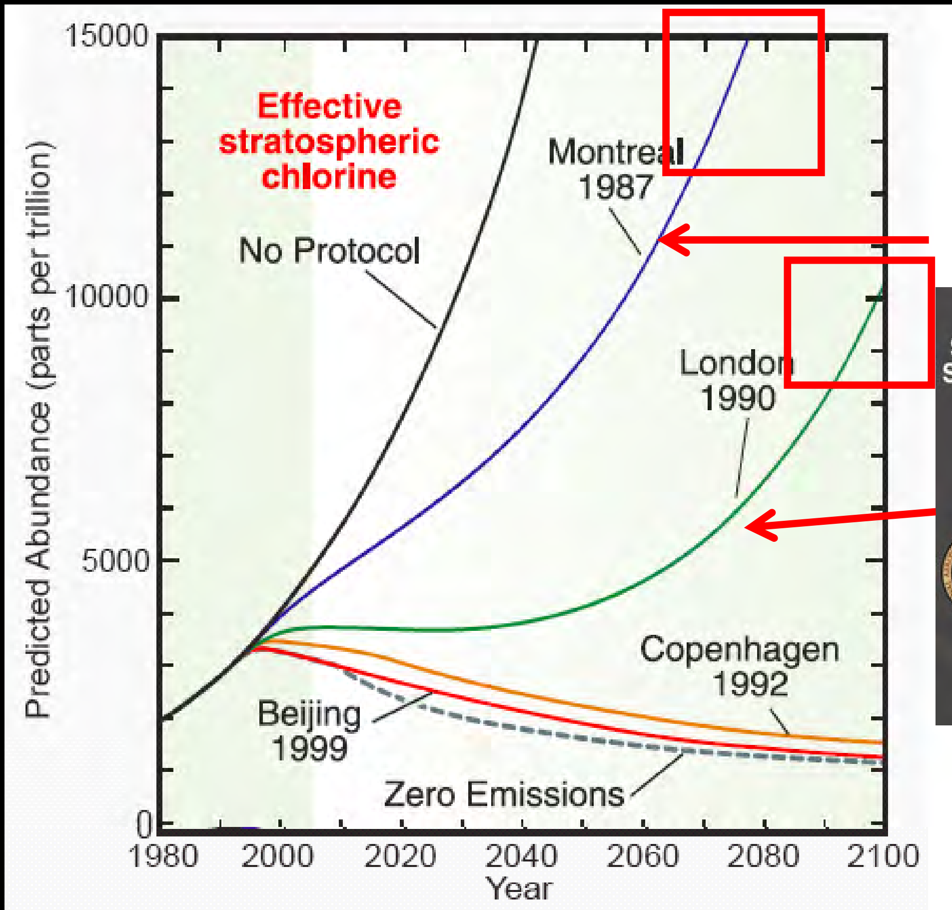
Input to actions in Rio de Janeiro and Kyoto

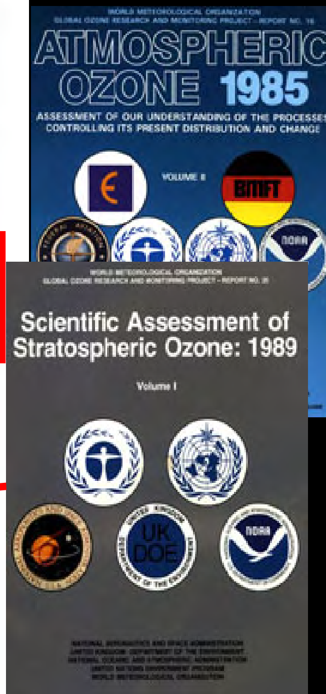
Acceptance of science foundation in Bali - a starting point on a long road ahead

Next IPCC assessment?   TBD, discussion in Budapest, April, 2007



Are Future Science Assessments Needed for Climate Policy, As In Ozone Policy?





Ozone hole discovered

Ozone hole explained; also depletion in mid-lats

Currently, Kyoto implies less global (all countries) emission reduction than the original Montreal agreement in 1987.

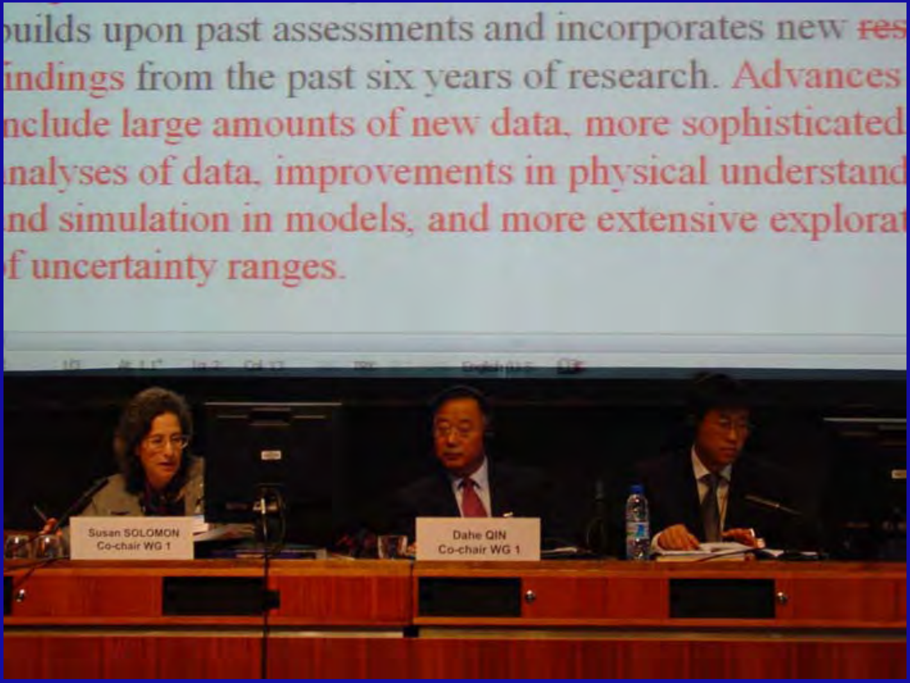
What is needed regarding climate science and assessment to inform e.g. possible future 50-80% emission reductions?

Preparation and Review of the IPCC WG1 AR4

- Each report is an assessment of the state of understanding based upon peer-reviewed published work. IPCC assesses published research but does not do research.

- Each assessment goes through multiple reviews and revision and re-review over a period of years.

- Informal draft prepared, comments sought from 6-12 outside experts for each chapter (Oct 2004 - Mar 2005). Formal first order draft (FOD) reviewed by about 600 reviewers worldwide (Sept -Nov 2005). Formal second order draft (SOD) re-reviewed by about 600 experts worldwide and by dozens of governments (April-May 2006). Govt comments on revised Summary for Policy Makers (Oct-Nov 2006). WG1 received and considered over 30000 comments in total.



- Summary for Policy Makers approved word-by-word by 113 govts in Paris in Feb, 2007. Provides a unique set of robust findings agreed by all governments.

- Co-chairs: Solomon and Qin

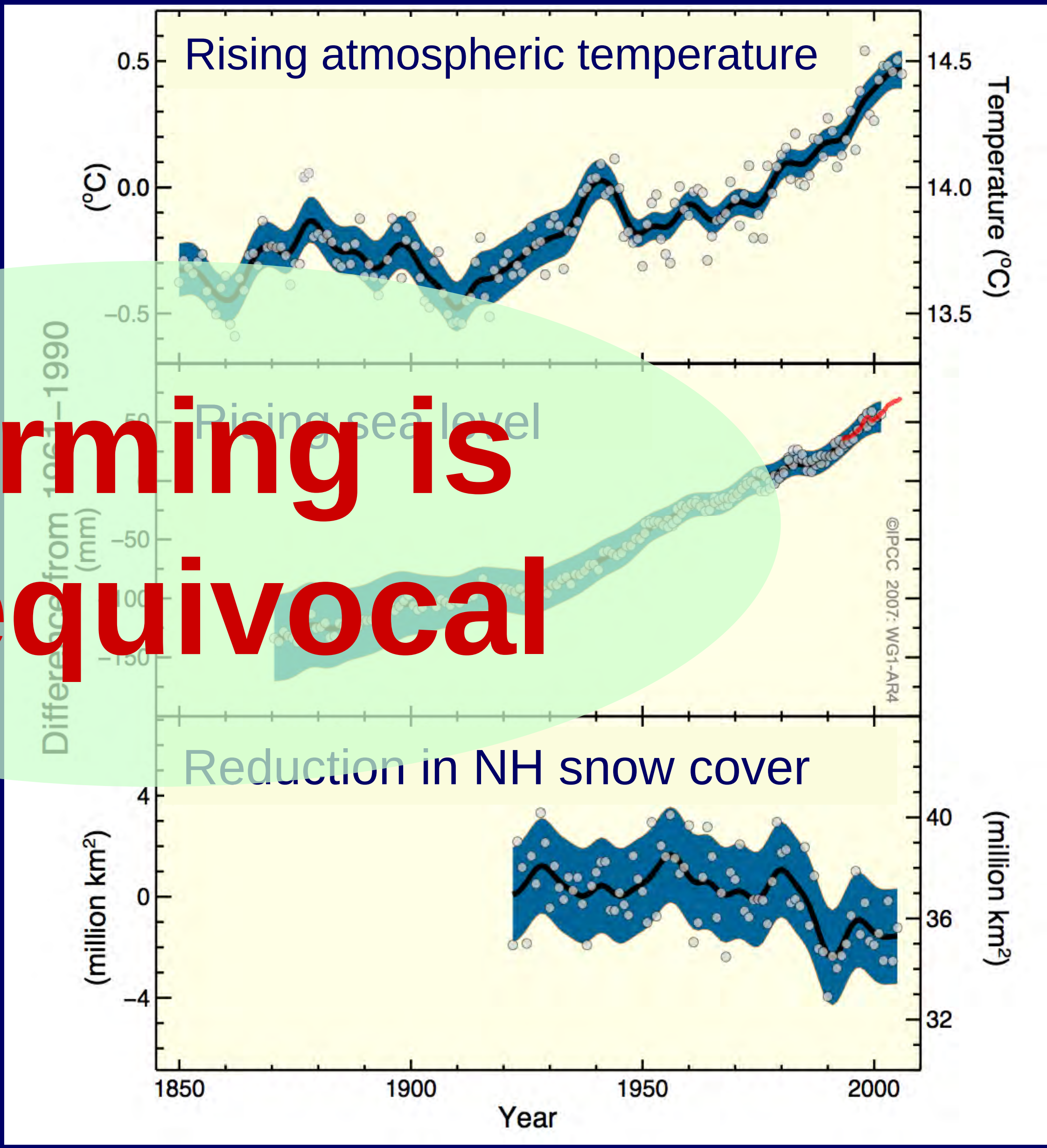
- Technical Support: IPCC WG1 Technical Support Unit (Manning, Marquis, Averyt, Tignor, Miller)

- Many ESRL authors and reviewers
- Bringing the discipline of science to policy

Many Changes Signal A Warming World

And……

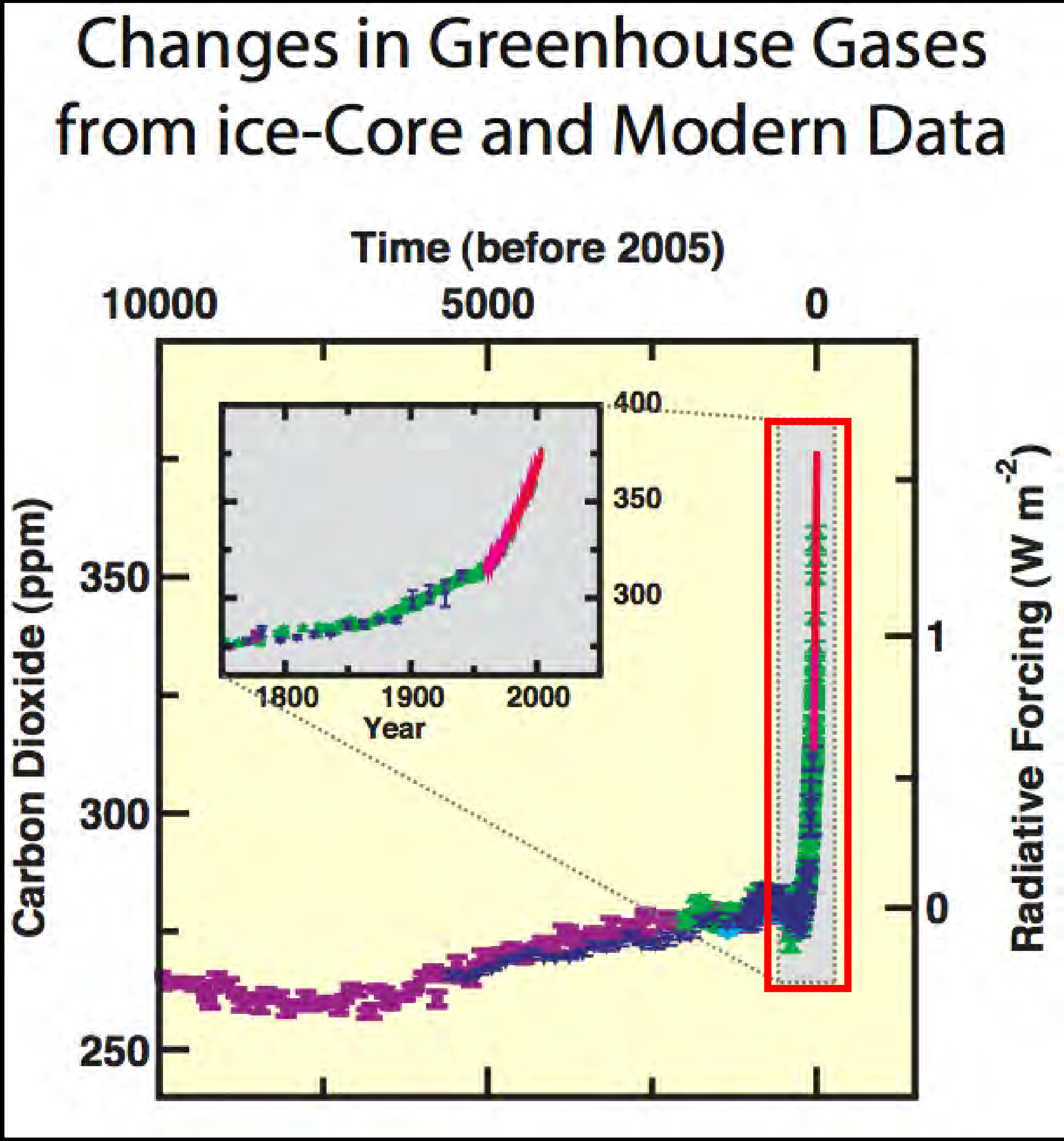
- Atmospheric water vapor increasing
- Glaciers retreating
- Arctic sea ice extent decreasing
- Extreme temperatures increasing
- …………



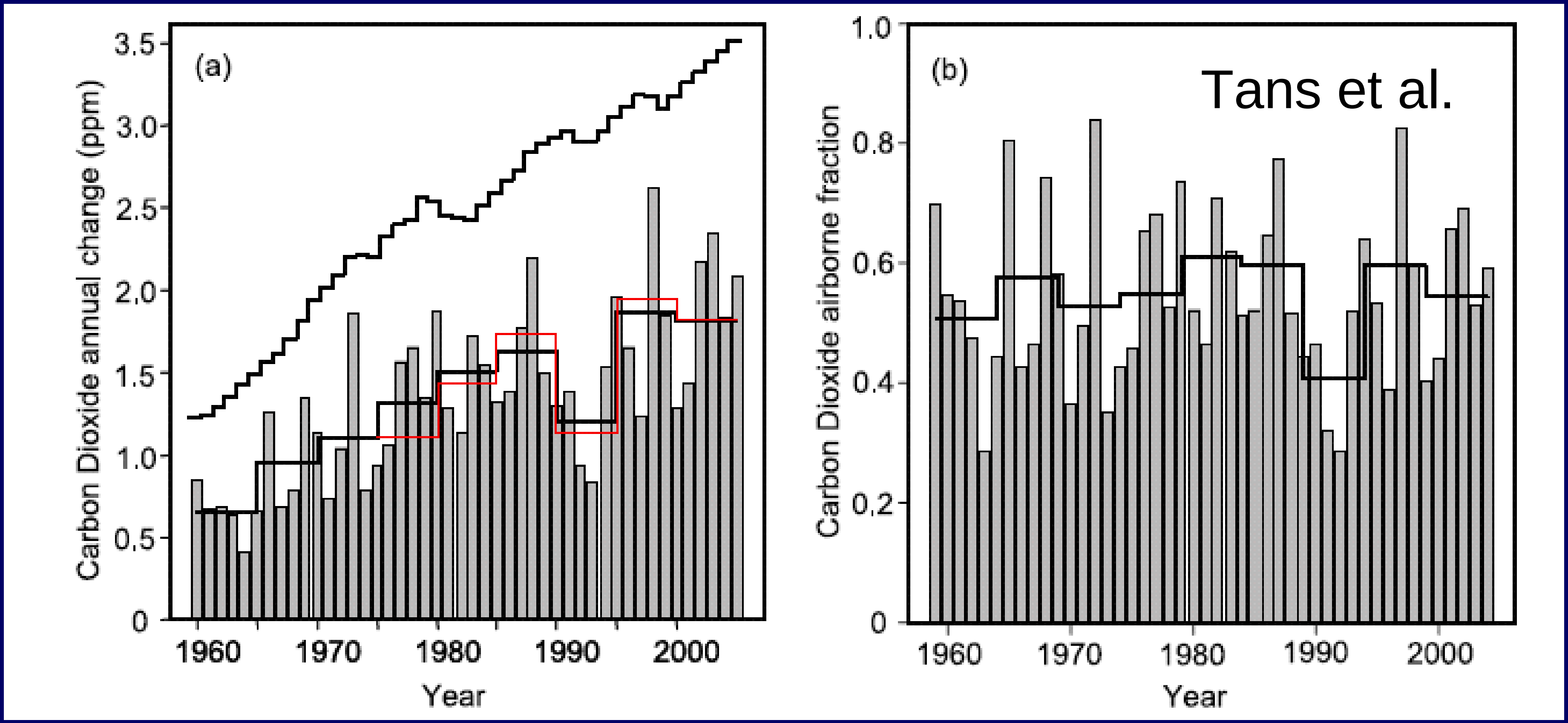
Warming is Unequivocal

Human and Natural Drivers of Climate Change: Unprecedented [IPCC, 2007]

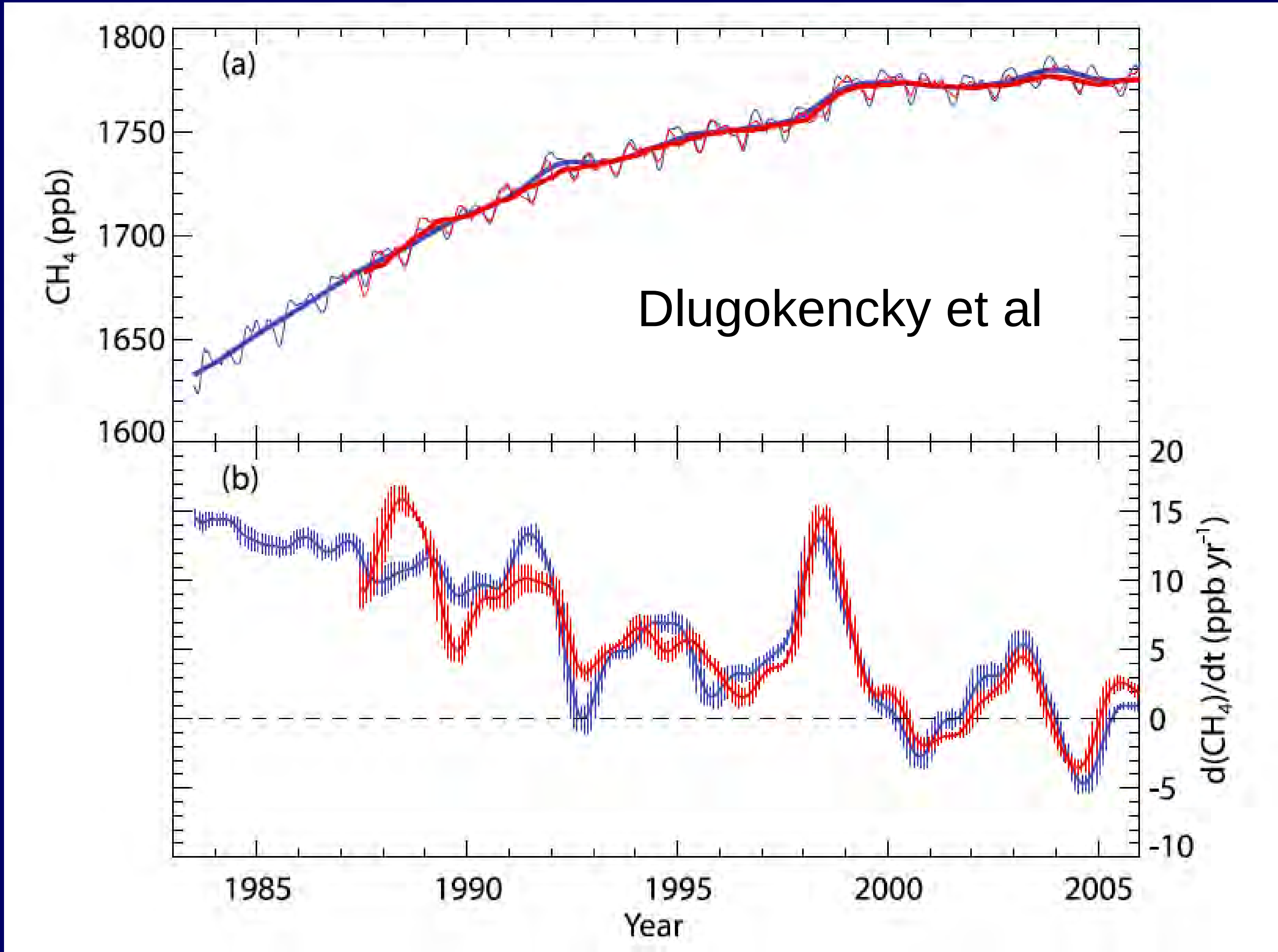
- Dramatic rise of CO_2 in the industrial era, changing the energy budget, and ‘forcing’ the climate in a new way not experienced in many thousands of years.



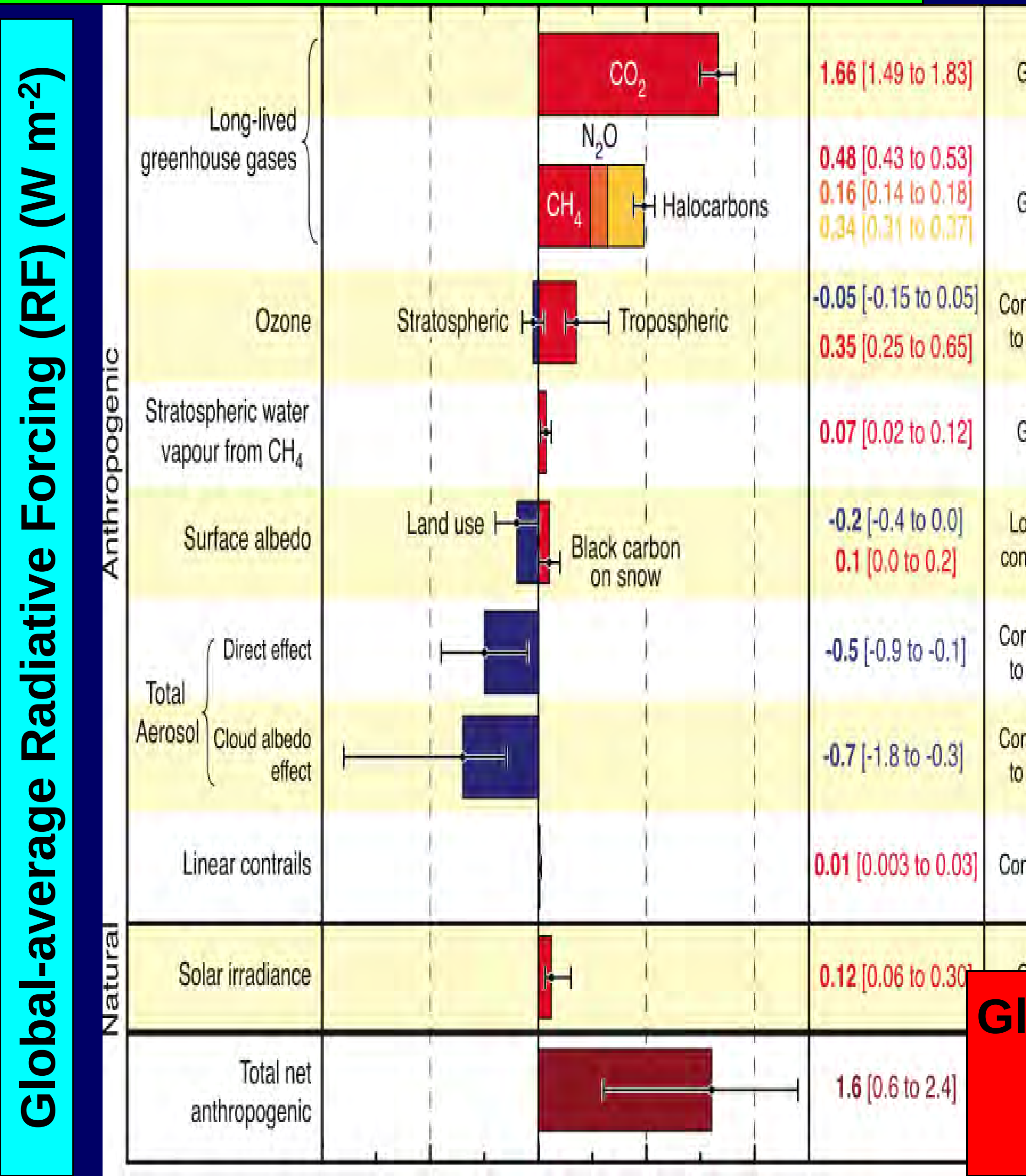
Interpreting Trends and Changes in Carbon Dioxide, Methane, Nitrous Oxide, and a Host of Other Gases



Interpreting Trends and Changes in Carbon Dioxide, Methane, Nitrous Oxide, and a Host of Other Gases



Drivers of Climate Change [1750 to Present-day]



Seminal ESRL contributions include:

Key observations and interpretation of CO_2, N_2O, CH_4, halocarbons, strat and trop ozone, aircraft, stratospheric water, and aerosol forcings.

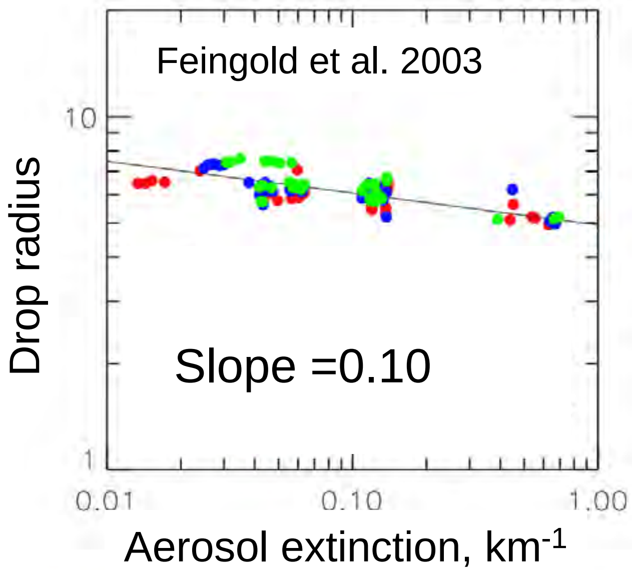
Also: Lab and modelling of RT, lifetimes, GWPs.

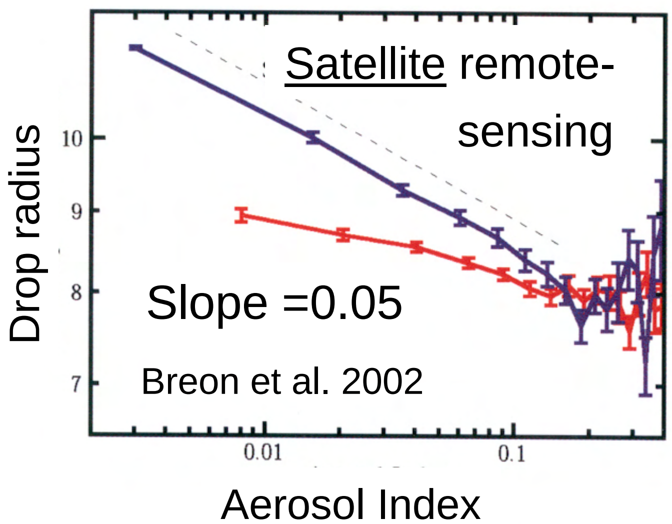
And more…

Global-mean Anthro RF positive
➔Warming influence
[*very high confidence*]

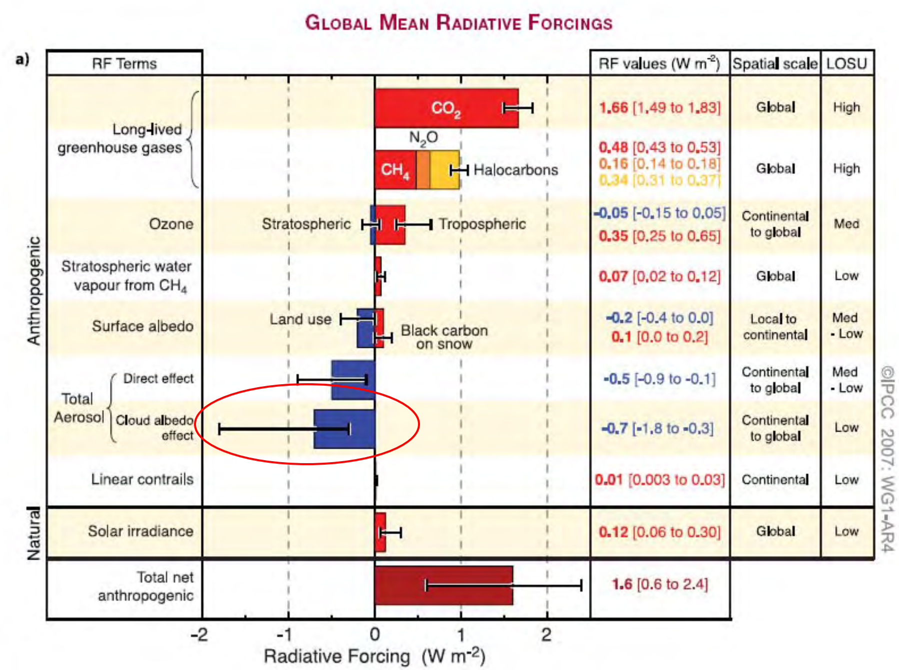
Measurements of Aerosol-Cloud Interactions: Implications for the Aerosol First Indirect Effect

Surface remote-sensing





Slope determined by:
aerosol number conc., size/composition
cloud turbulence, etc.



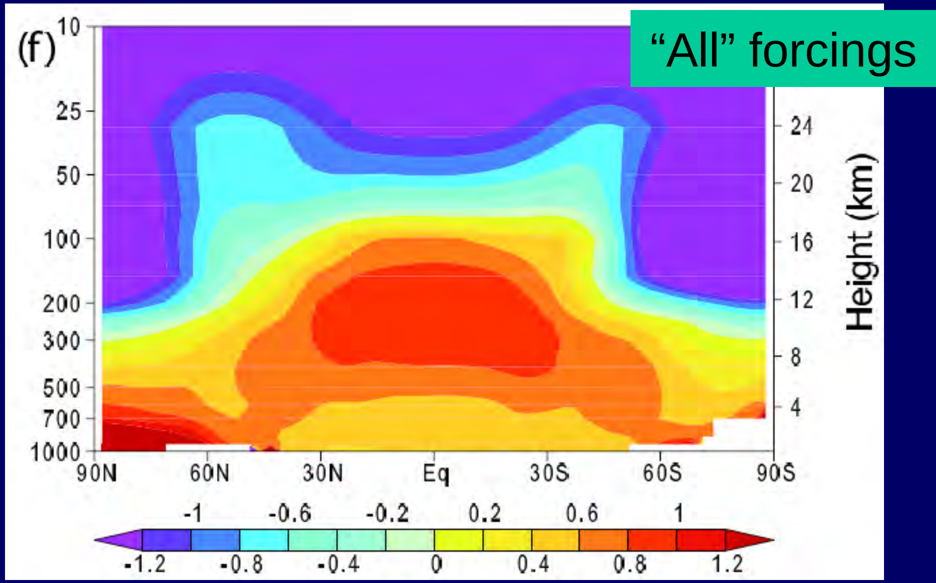
Estimate of the aerosol first indirect effect in the AR4 considered surface as well as satellite-derived slope of drop radius-aerosol relationship

Attribution and Patterns of Forcing

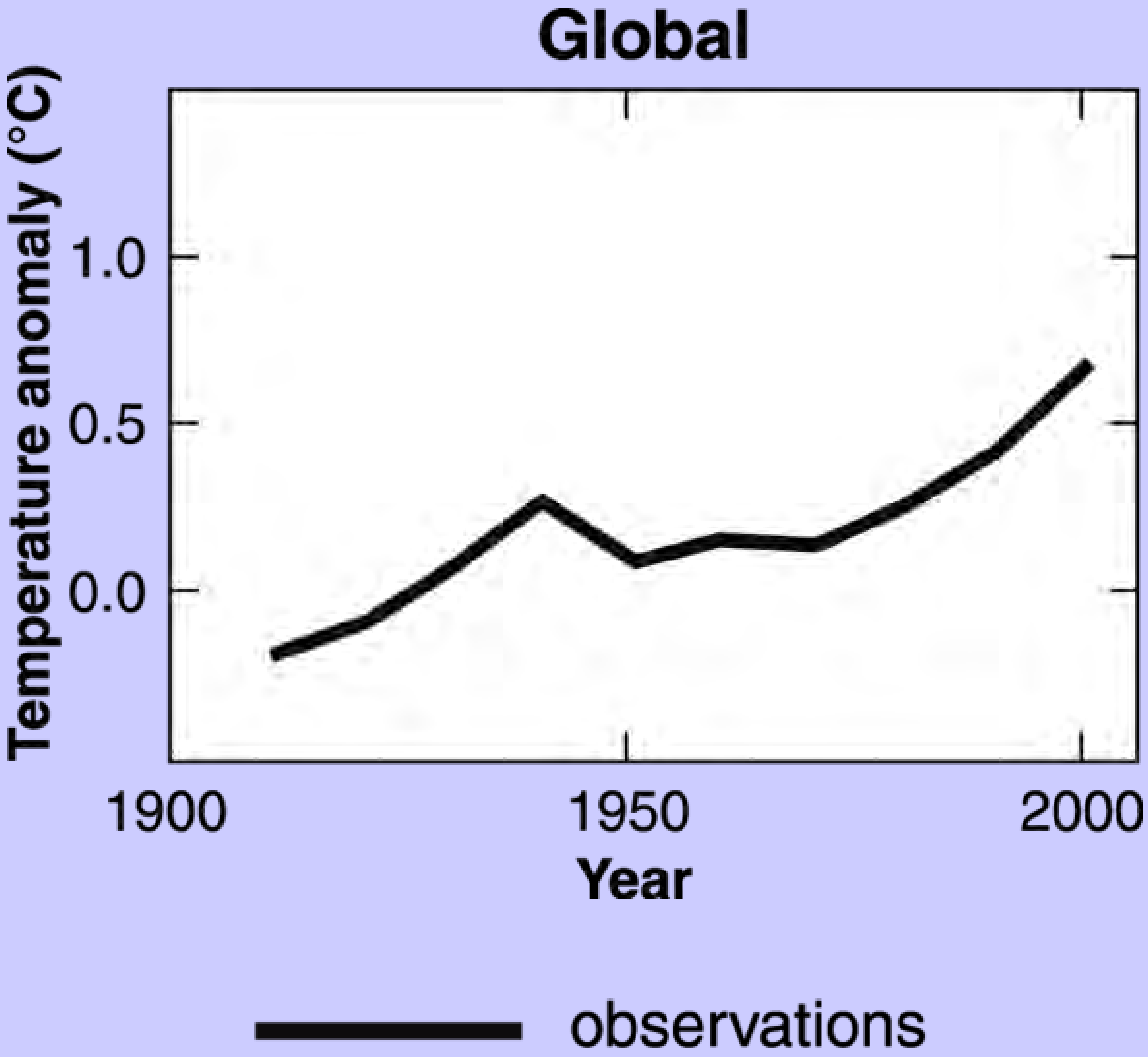
- Attribution is linked to time-space patterns of responses to the array of forcings (e.g, aerosol effect on NH/SH ratio, ozone effect on stratosphere/troposphere ratio….)

- Simulation of the observed pattern and relationship to forcings in space and time (including stratospheric ozone, tropospheric ozone, aerosols, volcanoes, etc.) is key to the success of climate attribution.

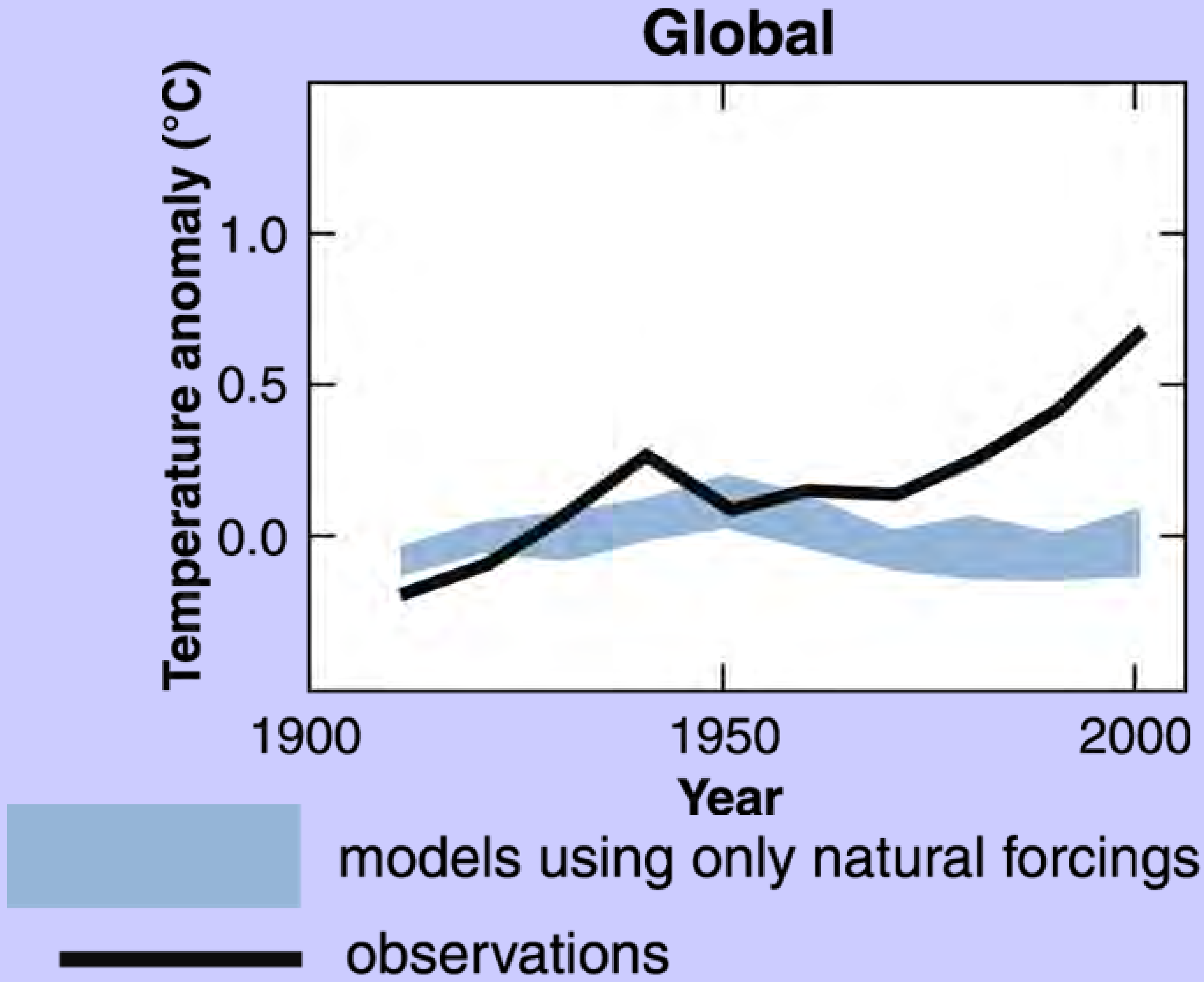
- A rigorous statistical process in which forcing patterns are a fundamental input.



Are Humans Responsible?



Are Humans Responsible?



Are Humans Responsible?

IPCC (1995):

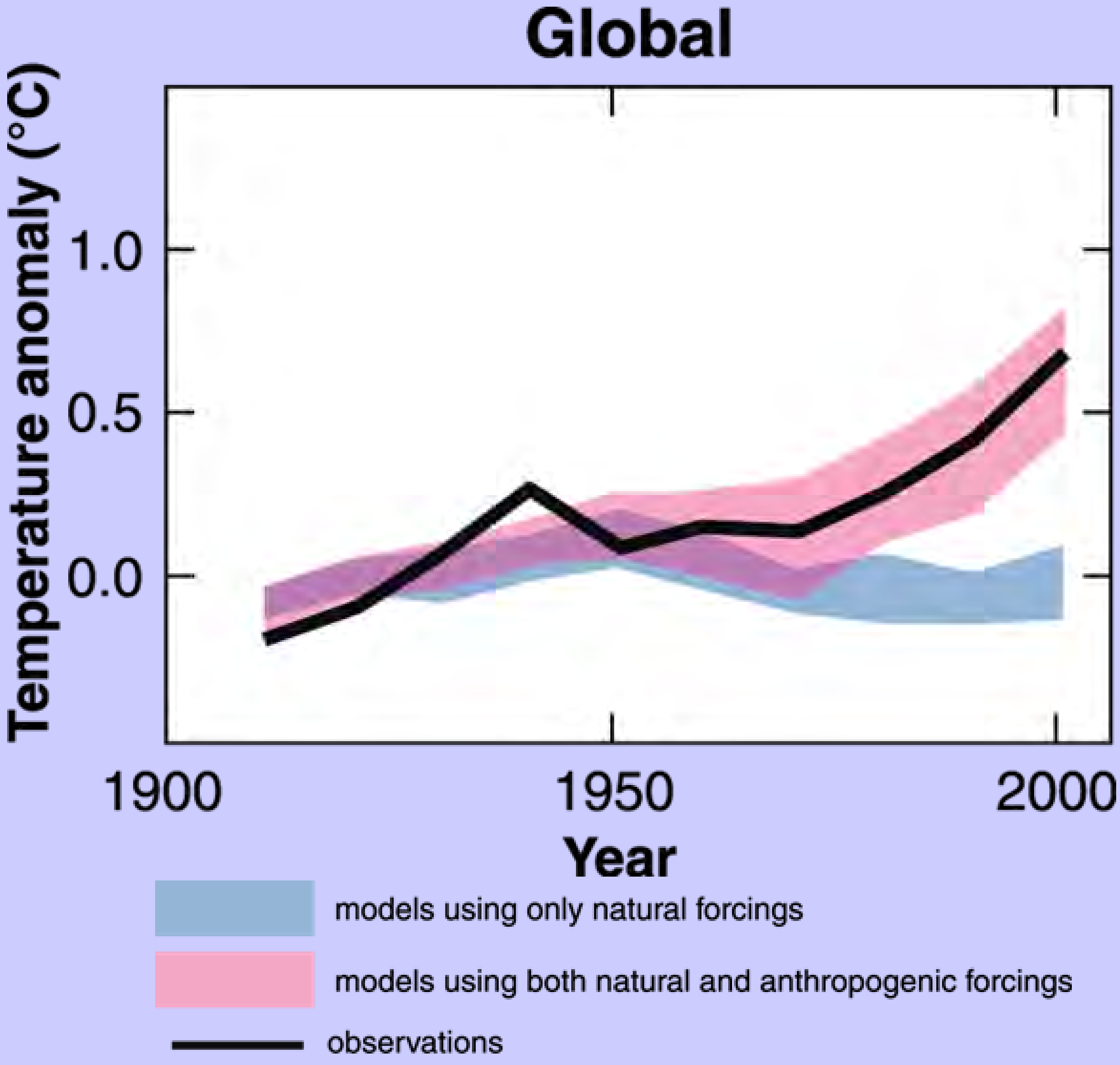
"Balance of evidence suggests discernible human influence"

IPCC (2001):

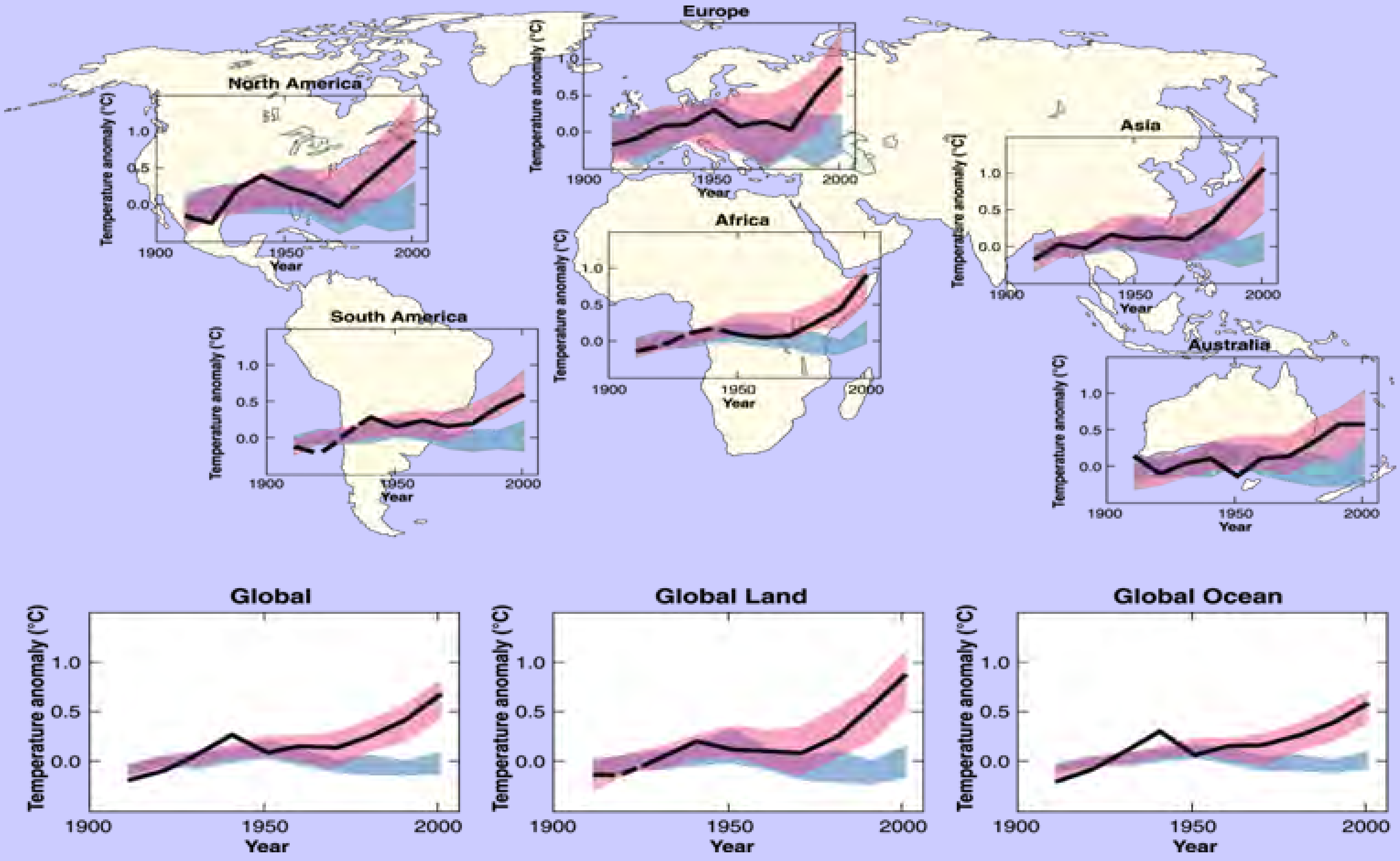
"Most of warming of past 50 years *likely* (odds 2 out of 3) due to human activities"

IPCC (2007):

"Most of warming *very likely* (odds 9 out of 10) due to greenhouse gases"



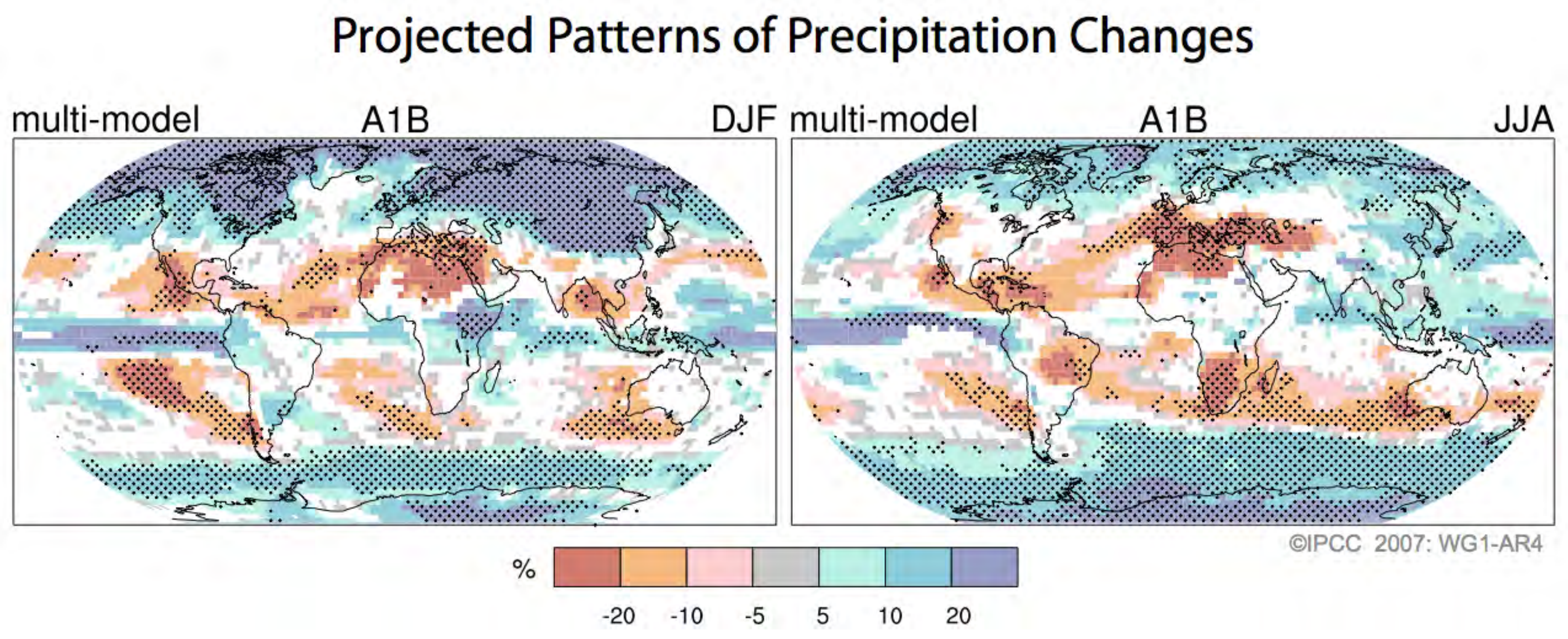
Continental Attribution



Continental scale warming is *likely* (2 out of 3 odds) due to increases in anthropogenic greenhouse gases

Future: More regional -> more info on forcings in <u>space and time</u> essential

Projections of Future Changes in Climate



New in AR4: Rainfall in the SPM at a new level of prominence. Projected drying in much of the subtropics, more rain in higher latitudes, continuing the broad pattern of rainfall changes already observed. Some places projected to get up to 20% drier, some 20% wetter, in this BAU scenario.

Future: Understand relationships of rainfall, heat waves, sea ice…..to GHG, ozone, aerosols...the forcing/attribution/projection challenge is just beginning. Many opportunities/needs for ESRL.

Summary and Outlook

• ESRL has played a key role in shaping science assessments, and the assessments in turn have shaped our work and ourselves.

• ESRL has heritage and leadership in international and national science assessment processes: how to do the challenging task of science assessment that affects public policy

• ESRL science inputs in observations, lab studies, and analysis/modelling have been major in the areas of ozone depletion, climate change, and AQ

• ESRL is well placed to continue to make major contributions to future assessments needed to inform policy decisions in the 21st century.