MATCH

Modelling and assessment of contributions to climate change

Final report

Bali, Indonesia

5 December 2007

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ECOFYS

Overview

1. Introduction to the MATCH process
   (Niklas Höhne, Ecofys, Germany)

2. Results

   1. Uncertainties along the cause-effect chain
      (Michael Prather, University of Irvine, USA)

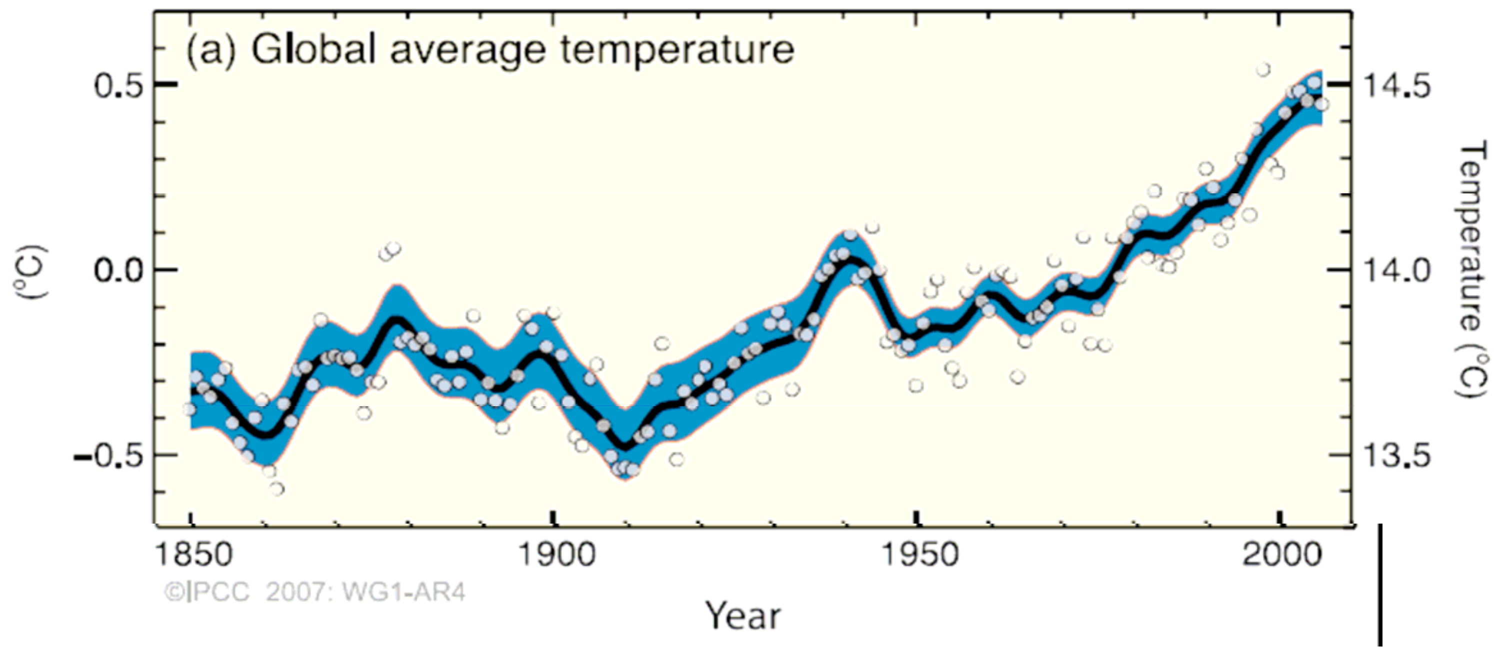
   2. Reconciling historical emissions from forestry
      (Joyce Penner, University of Michigan, USA)

   3. Regions' and countries' contributions to temperature increase
      (Niklas Höhne, Ecofys, Germany)

3. Summary
   (Joyce Penner, University of Michigan, USA)

Main question

What are the contributions of regions, nations or sectors to man-made climate change?



MATCH process

UNFCCC / Kyoto Protocol

- **1997: “Brazilian Proposal”: Industrialized countries should reduce emissions proportional to contribution to temperature increase**

2002

MATCH

Modelling and assessment of contributions to climate change

- **Ad-hoc group**
- **Initiated by Brazil and UK**

SBSTA 17 (Oct 2002)

- **Work should be continued by the scientific community**, in particular to improve the robustness of the preliminary results and to explore the uncertainty and sensitivity
- Be of a standard consistent with the practices of **peer-reviewed published science**.
- The process should be **inclusive**, **open** and **transparent**.
- **Capacity building**: strongly encouraged Parties and institutions to facilitate capacity-building in developing countries, including by hosting scientists from developing countries
- Invited the **scientific community**, including IGBP, WCRP, IHDP and IPCC to provide information on how they could contribute
- Encouraged scientists to **undertake further work**, to make the results of their **work publicly available** and to report progress at SBSTA 20, June 2004 (side event).
- SBSTA decided to **review the progress** at its 23rd session (Nov 2005).

MATCH process

- Assess methods for **calculating the contribution of different emission sources** (e.g. regional, national or sectoral) to climate change
- Provide clear **guidance on the implications** of the use of the different scientific methods, models, and methodological choices
- **Where scientific arguments allow, recommend** one method/model/choice
- **Expert meetings**, workshops and a coordinated modelling exercise
- Prepare **papers** to be published in peer reviewed scientific journals
- **Open and transparent,** www.match-info.net
- **Scientific coordination committee**
- **Funds for developing country experts** (provided by Norway, Germany and UK)
- **Support unit** Ecofys (funded by UK)

MATCH process

Scientific coordination committee

Guoquan Hu	National Climate Center, China
Michel den Elzen	RIVM, Netherlands
Jan Fuglestvedt (Co-chair)	CICERO, Center for International Climate and Environmental Research - Oslo, Norway
Jason Lowe	Met Office, Hadley Centre for Climate Prediction and Research, UK
Joyce Penner (Co-chair)	University of Michigan, USA
Michael Prather	University of California at Irvine, USA
Cathy Trudinger	CSIRO Atmospheric Research, Australia
Murari Lal	IIT, India
José Domingos Gonzalez Miguez	Interministerial Committee on Global Climate Change, Brazil
Niklas Höhne (secretary)	Ecofys, Germany

Participation in addition to SCC

Akinori Ito	Agency for Marine-Earth Science & Technology, Japan
Ana Claudia Nioac de Salles	University of Rio de Janeiro, Brazil
Atsushi Kurosawa	Institute of Applied Energy, Tokyo, Japan
Atul Jain	University of Illinois at Urbana-Champaign, USA
Bård Romstad	CICERO, Oslo, Norway
Ben Matthews	Universite Catholique de Louvain, Belgium
Benito Müller	Oxford University, UK
Brian O'Neil	IIASA, Laxenburg Austria
Christiano Pires de Campos	University of Rio de Janeiro, Brazil
Fabian Wagner	IIASA, Laxenburg, Austria
Gregory Bodeker	National Institute of Water and Atmospheric Research, Wellington, New Zealand
Helcio Blum	University of Rio de Janeiro, Brazil
Ian Enting	The University of Melbourne, Victoria, Australia
John van Aardenne	Joint Research Centre, Institute for Environment and Sustainability, Ispra, Italy
Laila Gohar	Hadley Centre for Climate Prediction and Research, Met office, Exeter, UK
Luiz Gylvan Meira Filho	University of Sao Paulo, Brazil
Luiz Pinguelli Rosa	University of Rio de Janeiro, Brazil
Malte Meinshausen	Potsdam Institute for Climate Impact Research, Germany
Maria Silvia Muylaert de Araujo	University of Rio de Janeiro, Brazil
Martina Jung	Ecofys, Germany
Mathias Friman	Linköpings University, Sweden
Michael Schlesinger	University of Illinois, Urbana, USA
Michiel Schaeffer	MNP/RIVM, Bilthoven, Netherlands
Natalia Andronova	University of Illinois, Urbana, USA
Norichika Kanie	Tokyo Institute of Technology, Japan
Peter Stott	Hadley Centre for Climate Prediction and Research, Met Office, Exeter, UK
Promode Kant	Indira Gandhi National Forest Academy, Dehradun, India
Ragnhild Bieltvedt Skeie	CICERO, Norway
Sarah Raper	University of East Anglia, Norwich, UK
Suzana Kahn Ribeiro	University of Rio De Janeiro, Brazil
Stephen W. Wood	National Institute of Water and Atmospheric Research, Wellington, New Zealand
Wandera Ogana	University of Nairobi, Kenya
Xiaosu Dai	China Meteorological Administration, Beijing, China

Brazil Proposal: Spin-off papers

- **Pinguelli Rosa, Ribeiro 1997:** “The share of responsibility between developed and developing countries in climate change, Greenhouse Gas Mitigation”. In Proceedings from the International Energy Agency Conference on GHG, Vancouver, 1997
- **Pinguelli Rosa and Ribeiro 2001:** “The present, past, and future contributions to global warming of CO2 emissions from fuels”, Climatic Change
- **Den Elzen and Schaeffer 2002:** “Responsibility for past and future global warming: Uncertainties in attributing anthropogenic climate change”, Climatic Change
- **Andronova and Schlesinger 2004:** “Importance of Sulfate Aerosol in Evaluating the Relative Contributions of Regional Emissions to the Historical Global Temperature Change”, Adaptation and Mitigation Strategies for Global Change
- **Pinguelli Rosa, Ribeiro, Muylaert and Campos 2004:** “Comments on the Brazilian Proposal and contributions to global temperature increase with different climate responses - CO2 emissions due to fossil fuels, CO2 emissions due to land use change”, Energy Policy
- **Muylaert, Cohen, Rosa and Pereira 2004** “ Equity, responsibility and climate change” Climate Research
- **Muylaert, Campos and Rosa 2005** “GHG historical contribution by sectors, sustainable development and equity” Renewable and Sustainable Energy Reviews
- **Campos, Muylaert and Rosa 2005** “Historical CO2 emission and concentrations due to land use change of croplands and pastures by country”, Science of the Total Environment
- **Trudinger, Enting, 2005:** “Comparison of formalisms for attributing responsibility for climate change: Non-linearities in the Brazilian Proposal approach”, Climatic Change
- **Den Elzen, Schaeffer, Lucas, 2005:** “Differentiating Future Commitments on the Basis of Countries’ Relative Historical Responsibility for Climate Change: Uncertainties in the ‘Brazilian Proposal’ in the Context of a Policy Implementation”, Climatic Change
- **Enting, 2005:** “Automatic differentiation in the analysis of strategies for mitigation of global change” in: International Conference on Modelling and Simulation
- **Kurosawa, Tomoda 2005:** Brazilian Proposal as Greenhouse Gas Mitigation Criteria”, Kiho Enerugi Sougou Kogaku
- **Rive, Torvanger, Fuglestvedt, 2006:** “Climate agreements based on responsibility for global warming: periodic updating, policy choices, and regional costs”, Global Environmental Change
- **Höhne, Blok, 2005:** “Calculating historical contributions to climate change – discussing the ‘Brazilian Proposal’”, Climatic Change
- **Hu, Dai, Bodeker, Reisinger 2006:** “Numerical simulation study on the scientific and methodological aspects of the Brazilian Proposal”, Acta Meteorologica Sinica
- **Kurosawa, Tomoda 2007:** “Regional Attribution to the Climate Change and Brazilian Proposal” in: Proc. Annual Meeting of Society for Environment Economics and Policy Studies
- **Araújo, Campos, Rosa 2007:** “Historical Manure Management N2O emission and enteric fermentation CH4 emission of domestic livestock by country”. Climate Research
- **Araújo, Campos 2007:** “Land use change sector contribution to the carbon historical emissions and the sustainability case study of the Brazilian Legal Amazon”. Renewable & Sustainable Energy Review
- **Rive, Fuglestvedt 2007:** “Introducing population-adjusted historical contributions to global warming”, Global Environmental Change
- **Müller, Höhne, Ellermann 2007:** “Differentiating Historic Responsibility for Climate Change - Synthesis Report”, submitted

Timeline

May 2006: SBSTA 26 renewed mandate and agreed on timeline

31 October 2007: Submission of the final report to SBSTA

December 2007: In-session special side event at SBSTA 27 to present the work to UNFCCC delegations

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7 March 2008: Countries submit their views on the matter

June 2008: Official consideration by SBSTA 28
or soon thereafter

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2. **Results**

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MATCH results

- **Publication of four joint journal articles**
- **Capacity building** and exchanges also enabled scientific participation of scientists from many countries
- **Historic country level emission datasets** of greenhouse gases stretching back to the 18th century and **datasets** showing a range of typical attribution results (soon on www.match-info.net)
- **On-line models** enabling user experiments with different options were stimulated by MATCH.
  - Java Climate Model (www.climate.be/jcm)
  - FAIR model (www.mnp.nl/fair)
  - CAIT tool (cait.wri.org)

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presentation of MATCH scientific paper to SBSTA 27
at COP-13, Bali, 5 Dec 2007

MATCH
Modelling and assessment of contributions to climate change

From human activities to climate change: uncertainties in the causal chain

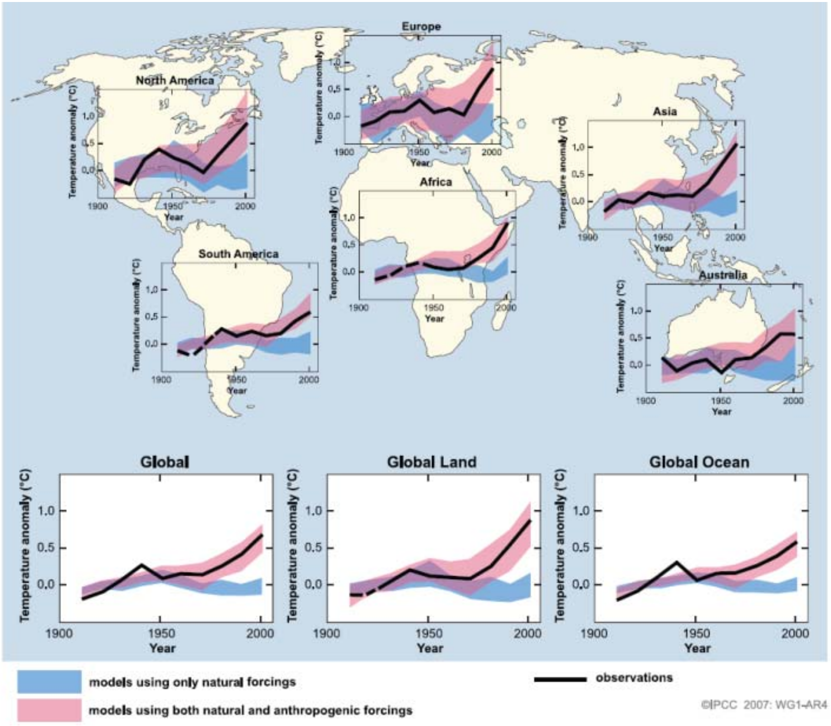
Michael J. Prather[1], Joyce E. Penner[2], Jan S. Fuglestvedt[3], Atsushi Kurosawa[4], Jason A. Lowe[5], Niklas Höhne[6], Atul K. Jain[7], Natalia Andronova[2], Luiz Pinguelli[8], Chris Pires de Campos[9], Sarah C.B. Raper[10], Ragnhild B. Skeie[3], Peter A. Stott[5], John van Ardenne[11], Fabian Wagner[12]

1 University of California, Irvine, USA
2 University of Michigan, Ann Arbor, USA
3 CICERO, Oslo, Norway
4 Institute of Applied Energy, Tokyo, Japan
5 Hadley Center, Met Office, Exeter, UK
6 Ecofys, Cologne, Germany
7 University of Illinois, Urbana-Champaign, USA
8 University of Rio de Janeiro, Brazil
9 PETROBRAS, Rio de Janeiro, Brazil
10 Metropolitan University, Manchester, UK
11 Joint Research Centre, Ispra, Italy
12 IIASA, Laxenburg, Austria

Quantifying the rate at which ***climate is being altered by society as a whole*** (or by individual countries) is the first step in planning how to avoid dangerous climate change.

The rapid warming and associated ***climate change over the 20th century has been attributed to the observed rise in greenhouse gases*** (and not to specific human activities or greenhouse gas emissions).

A thorough and consistent evaluation of the potential errors and uncertainties in going from activity-based emission inventories to consequent climate change is a prerequisite for attributing national climate change.



We develop a new methodology to track the causal chain

from human activities
to greenhouse gas emissions
to changing atmospheric composition
to climate change,

Propagating

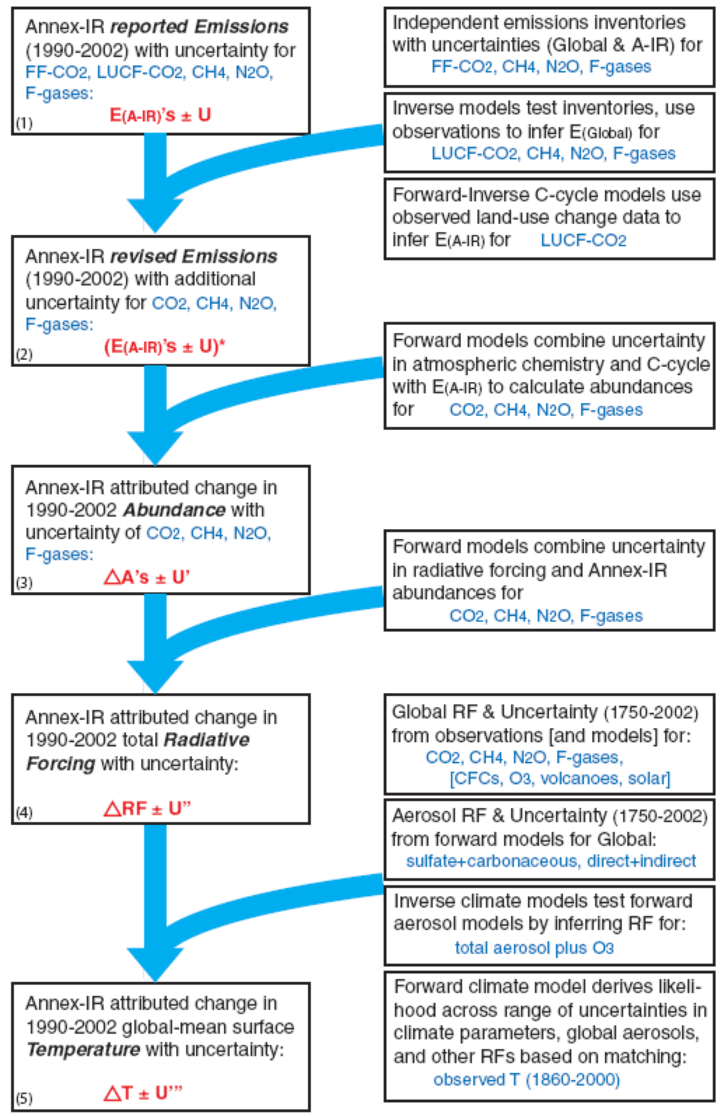
uncertainties at each step.

As a case study, we evaluate the mean surface temperature change attributable to the UNFCCC countries with regular reporting of greenhouse gas emissions for the period 1990-2002 (Annex-IR).

Annual Emissions (Mton CO_2 equivalent) of Kyoto GHGs averaged over 1990-2002.

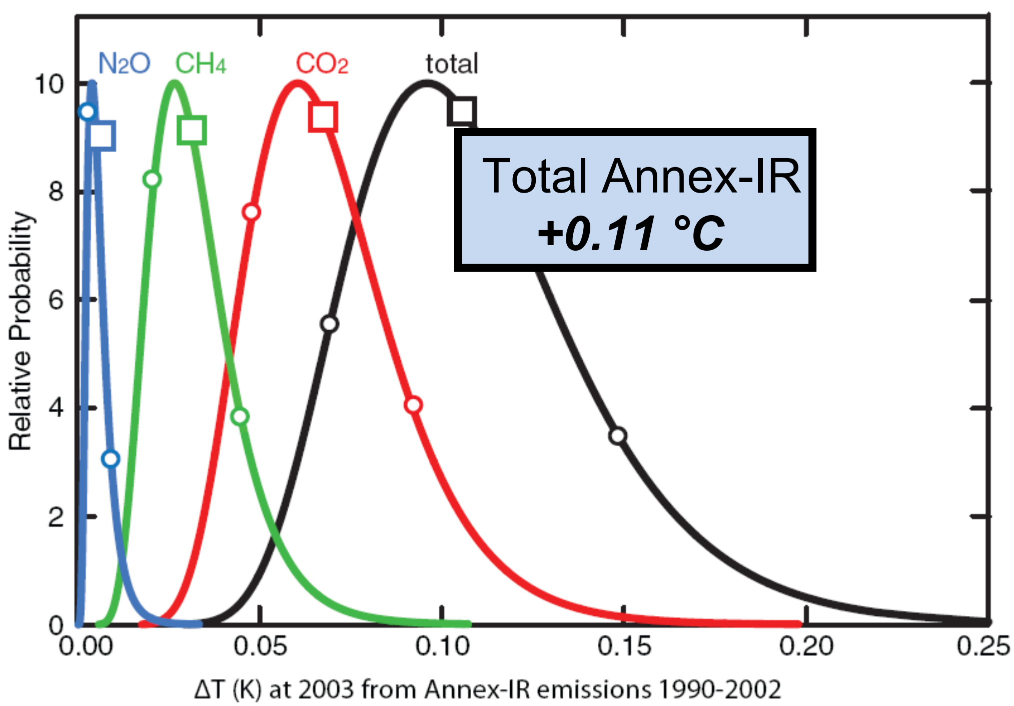
	USA	EU-15	Annex-IR	Global
CO_2 (FF)	5,423	3,308	11,447	22,811
CO_2 (LUCF)	-915	-233	-1,314	7,891
CH_4	629	400	1,378	5,866
N_2O	420	367	970	3,254
PFCs	15	9	44	92
HFCs	69	40	123	155
SF_6	28	12	50	62

UNFCCC reported emissions weighted by IPCC SAR 100-yr GWPs. EU-15 is the sum of EU members prior to 2004. Annex-IR includes all Annex I countries except the former Soviet states. Global emissions are derived from the EDGAR source-inventory database.

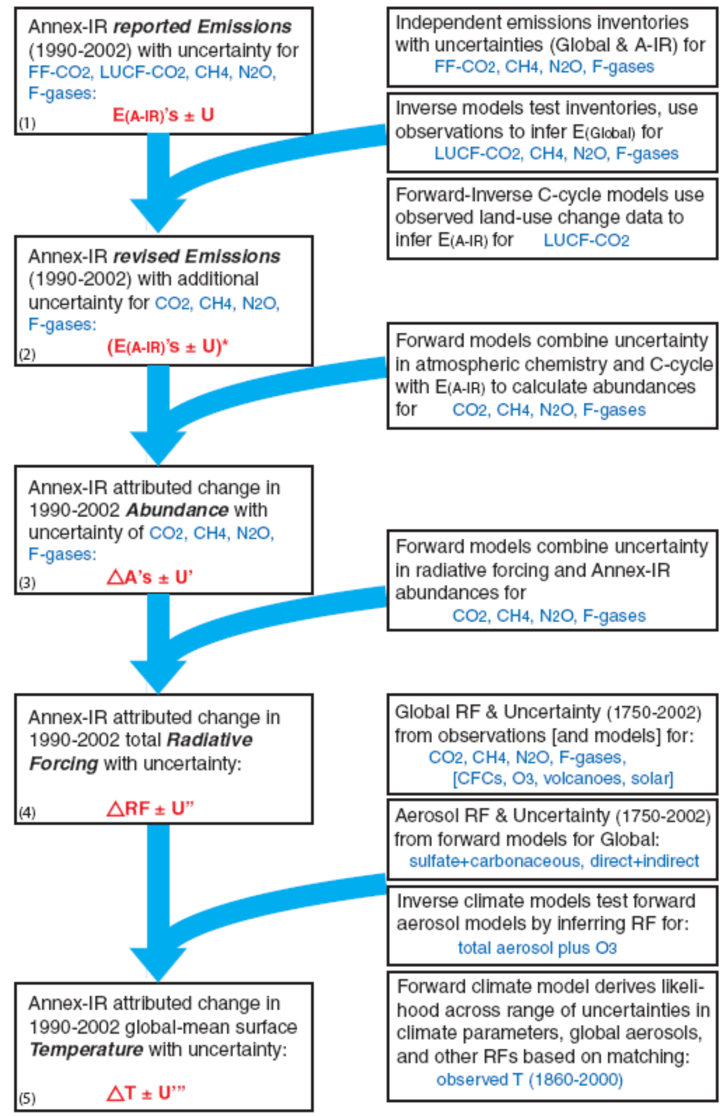


Results

Using models and data sets constrained by current knowledge, we find that ***the surface temperature increase in 2003 caused by Annex-IR 1990-2002 emissions is +0.11 °C***, with a skewed 1-σ uncertainty range of -27% to +32%.



Probability distribution function



The Annex-IR attributed climate change of +0.11 °C can be compared +0.33 °C caused by all countries Kyoto-gas emissions.

Mean Surface Temperature Change (1990-2003)

	ΔT (ºC)	Uncertainty (16% to 84%)
Attributed to 1990-2002 emissions:		
Annex-IR all Kyoto gases	**+0.11**	**(-0.029, +0.034)**
Global Anth. all Kyoto gases	**+0.33**	
Global Anth. Aerosols	**-0.73**	
Observed:		
using trend fit 1981-2003	+0.24	±0.05
using trend fit of 'last 50 years'	+0.09	±0.02

F-gases are included in the total as 2% of that of CO_2 based on equivalent-CO_2 emissions, see Table S2. The period 1990-2003 was not used to fit a temperature trend because volcanic cooling from Mt. Pinatubo gives a large, spurious, short-term trend. Global emissions-driven temperature changes are derived from the integrated ΔRF changes from the best model without uncertainties.

This example is perhaps the best constrained case; for pre-1990 emissions & post-2003 climate change the uncertainties will increase, but emphasises short lived greenhoues gases

(1 ► 2) Collect Reported Emissions and Evaluate with Independent Datasets

(1) Annex-IR ***reported Emissions*** (1990-2002) with uncertainty for $FF\text{-}CO_2$, $LUCF\text{-}CO_2$, CH_4, N_2O, F-gases:

$E_{(A\text{-}IR)}$'s ± U

Independent emissions inventories with uncertainties (Global & A-IR) for $FF\text{-}CO_2$, CH_4, N_2O, F-gases

Inverse models test inventories, use observations to infer $E_{(Global)}$ for $LUCF\text{-}CO_2$, CH_4, N_2O, F-gases

Forward-Inverse C-cycle models use observed land-use change data to infer $E_{(A\text{-}IR)}$ for $LUCF\text{-}CO_2$

(2) Annex-IR ***revised Emissions*** (1990-2002) with additional uncertainty for CO_2, CH_4, N_2O, F-gases:

($E_{(A\text{-}IR)}$'s ± U)*

Annex-IR ***reported Emissions*** (1990-2002) with uncertainty for $FF\text{-}CO_2$, $LUCF\text{-}CO_2$, CH_4, N_2O, F-gases:

(1) **$E_{(A\text{-}IR)}$'s ± U**

Independent emissions inventories with uncertainties (Global & A-IR) for $FF\text{-}CO_2$, CH_4, N_2O, F-gases

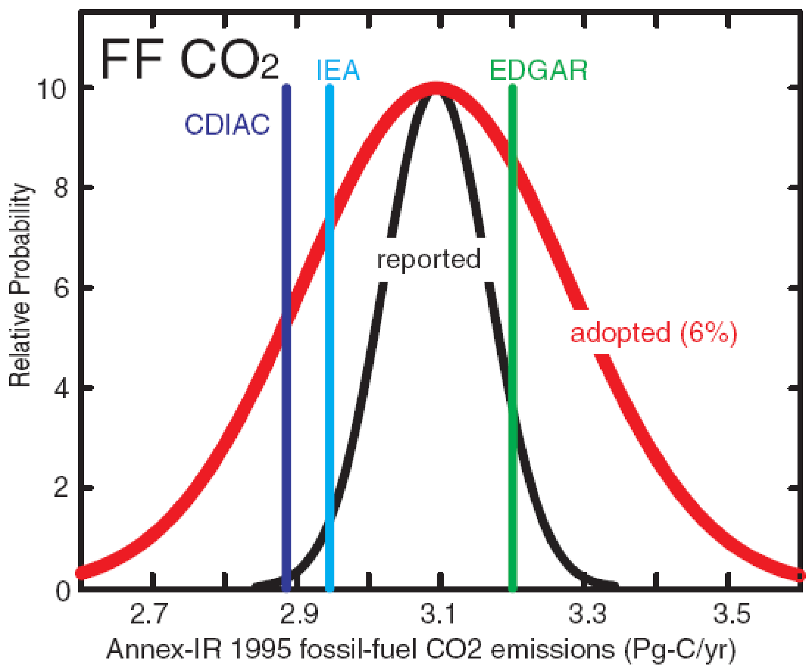
Inverse models test inventories, use observations to infer $E_{(Global)}$ for $LUCF\text{-}CO_2$, CH_4, N_2O, F-gases

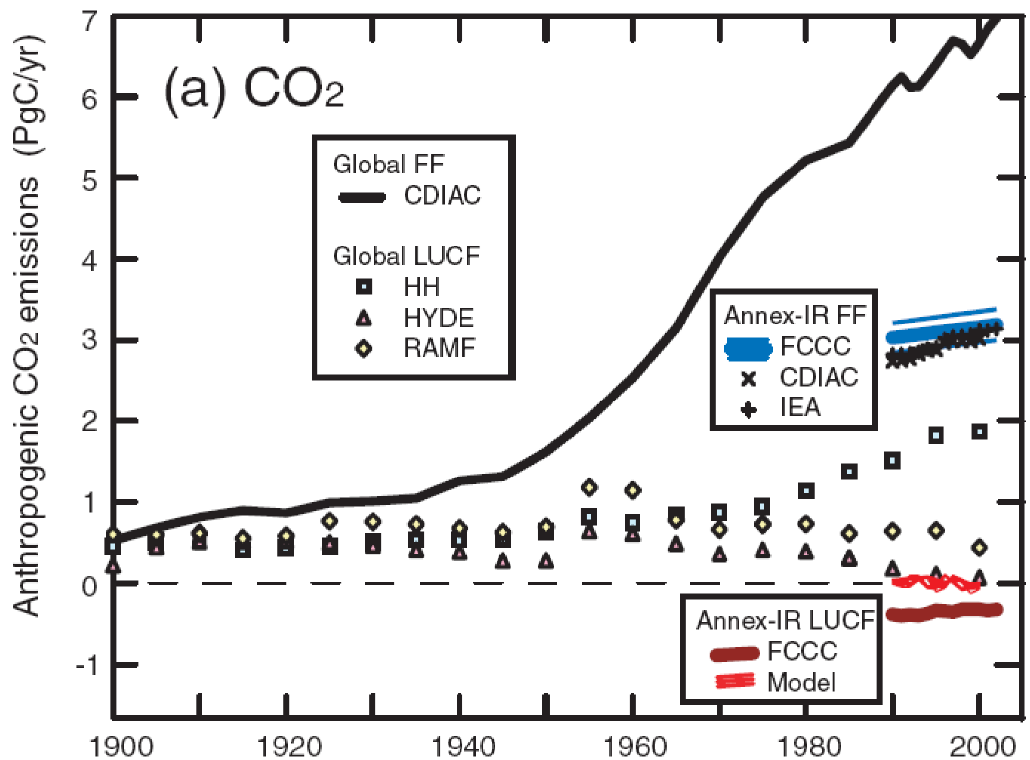
Forward-Inverse C-cycle models use observed land-use change data to infer $E_{(A\text{-}IR)}$ for $LUCF\text{-}CO_2$

Annex-IR ***revised Emissions*** (1990-2002) with additional uncertainty for CO_2, CH_4, N_2O, F-gases:

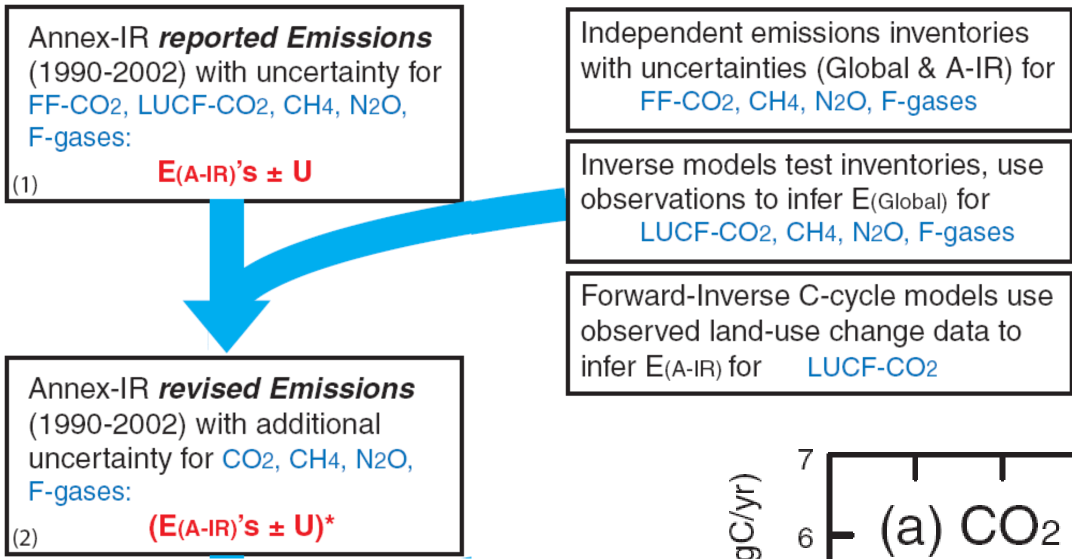
(2) **($E_{(A\text{-}IR)}$'s ± U)***

CO_2 FF

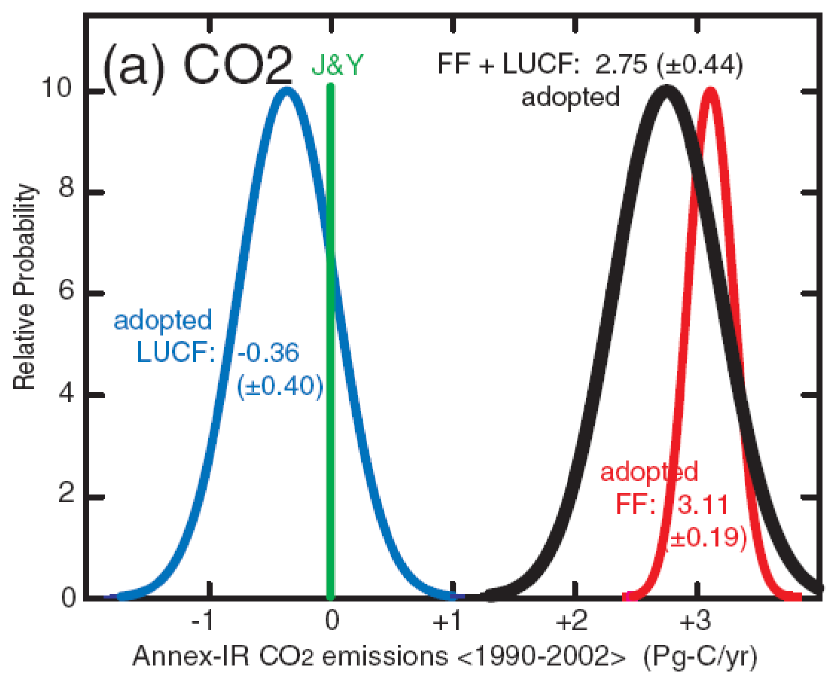




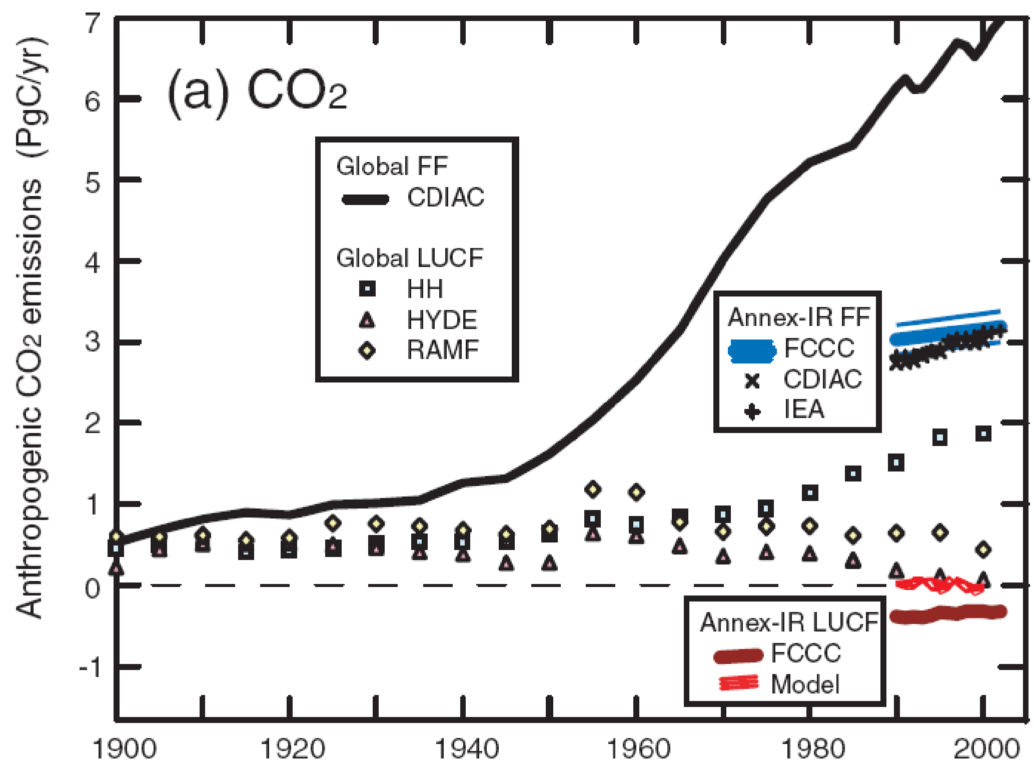
CO_2 FF+LUCF



Annex-IR reported Emissions (1990-2002) with uncertainty for FF-CO2, LUCF-CO2, CH4, N2O, F-gases:
E(A-IR)'s ± U
(1)
Independent emissions inventories with uncertainties (Global & A-IR) for FF-CO2, CH4, N2O, F-gases
Inverse models test inventories, use observations to infer E(Global) for LUCF-CO2, CH4, N2O, F-gases
Forward-Inverse C-cycle models use observed land-use change data to infer E(A-IR) for LUCF-CO2
Annex-IR revised Emissions (1990-2002) with additional uncertainty for CO2, CH4, N2O, F-gases:
(E(A-IR)'s ± U)*
(2)



(a) CO2
J&Y
FF + LUCF: 2.75 (±0.44) adopted
adopted LUCF: -0.36 (±0.40)
adopted FF: 3.11 (±0.19)
Relative Probability
0
2
4
6
8
10
-1
0
+1
+2
+3
Annex-IR CO2 emissions <1990-2002> (Pg-C/yr)



(a) CO2
Global FF
CDIAC
Global LUCF
HH
HYDE
RAMF
Annex-IR FF
FCCC
CDIAC
IEA
Annex-IR LUCF
FCCC
Model
Anthropogenic CO2 emissions (PgC/yr)
-1
0
1
2
3
4
5
6
7
1900
1920
1940
1960
1980
2000

CH_4

Annex-IR ***reported Emissions*** (1990-2002) with uncertainty for $FF\text{-}CO_2$, $LUCF\text{-}CO_2$, CH_4, N_2O, F-gases:

(1) **$E_{(A\text{-}IR)}$'s ± U**

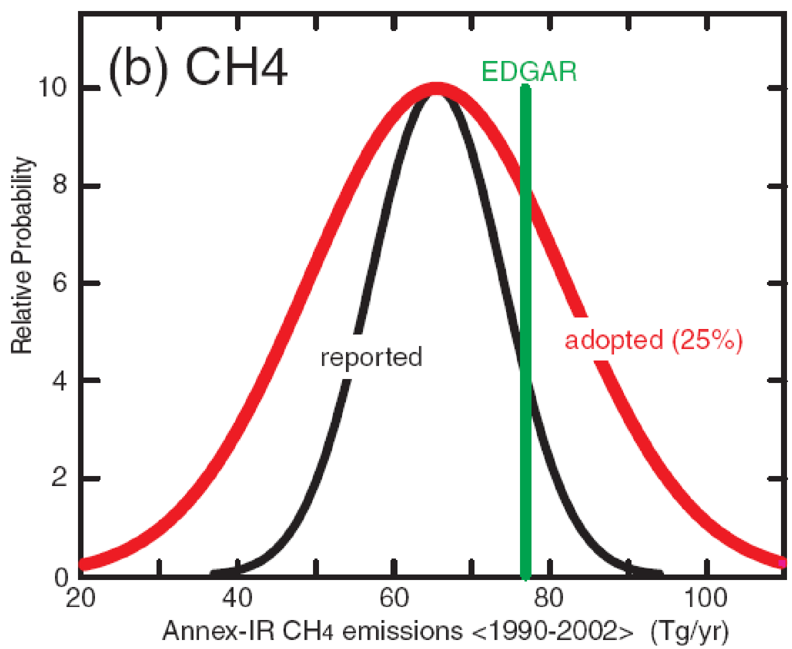
Independent emissions inventories with uncertainties (Global & A-IR) for $FF\text{-}CO_2$, CH_4, N_2O, F-gases

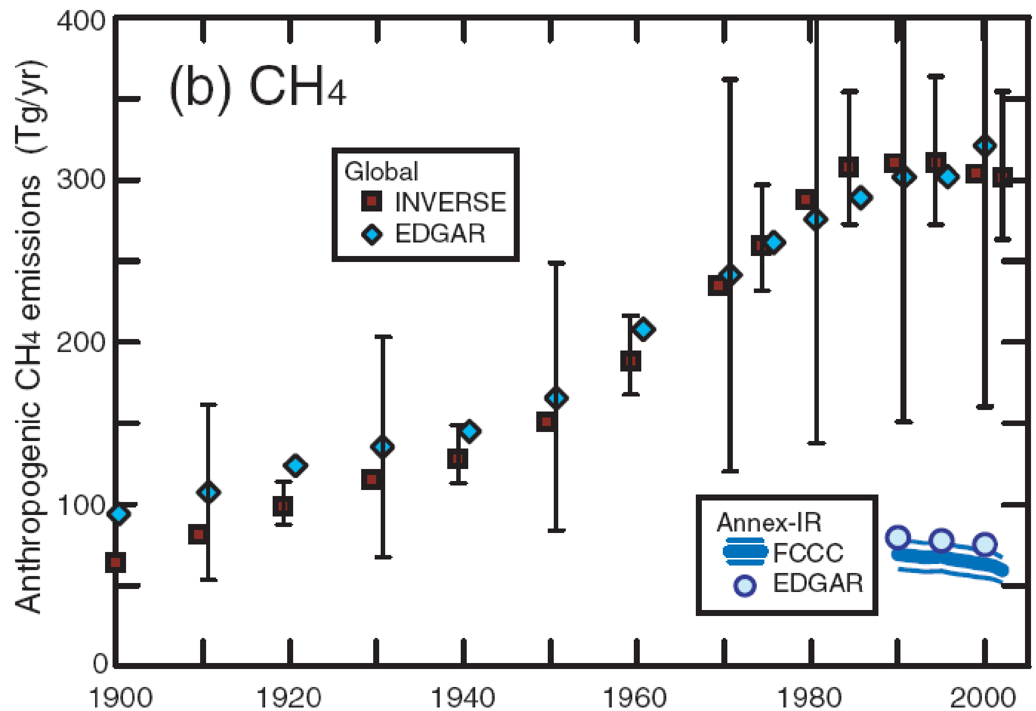
Inverse models test inventories, use observations to infer $E_{(Global)}$ for $LUCF\text{-}CO_2$, CH_4, N_2O, F-gases

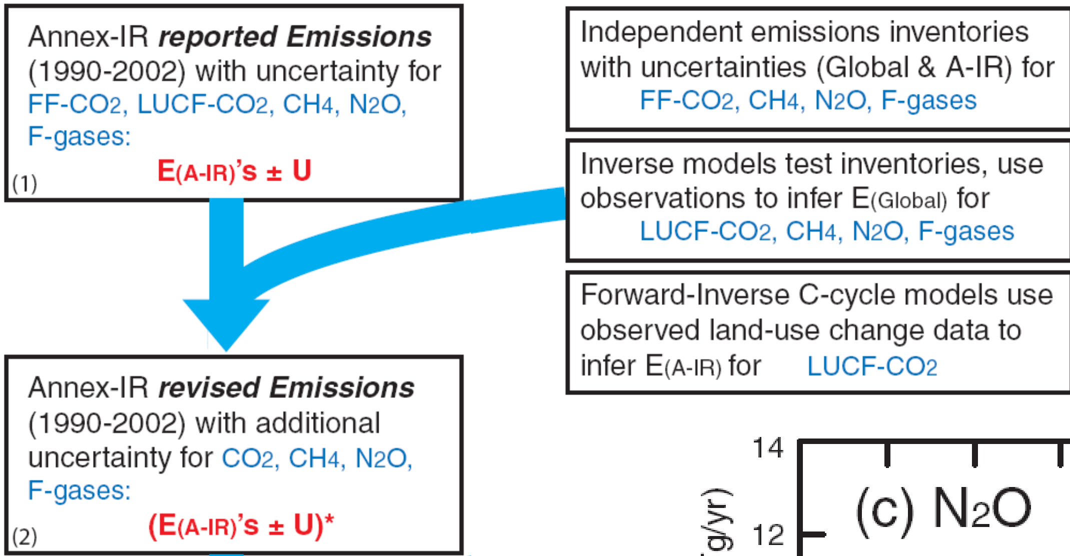
Forward-Inverse C-cycle models use observed land-use change data to infer $E_{(A\text{-}IR)}$ for $LUCF\text{-}CO_2$

Annex-IR ***revised Emissions*** (1990-2002) with additional uncertainty for CO_2, CH_4, N_2O, F-gases:

(2) **($E_{(A\text{-}IR)}$'s ± U)***

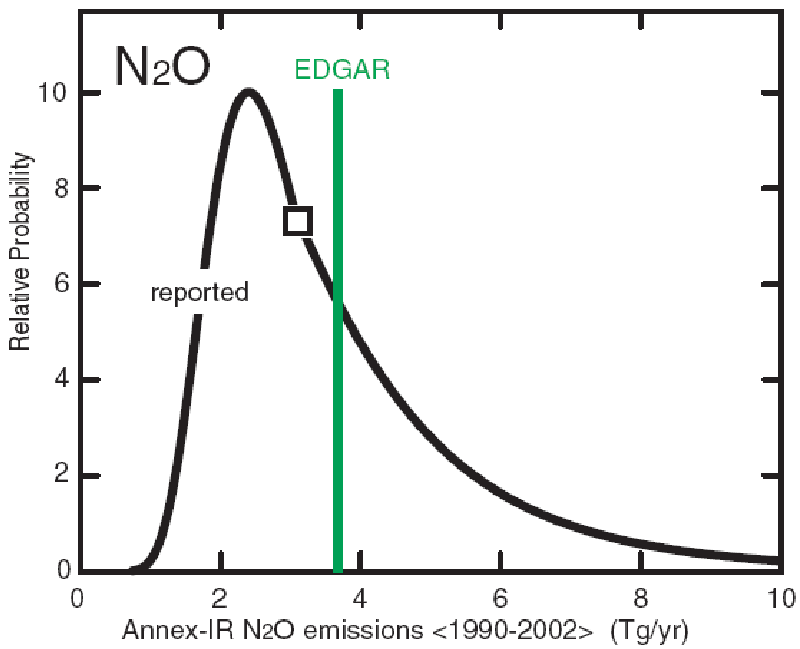




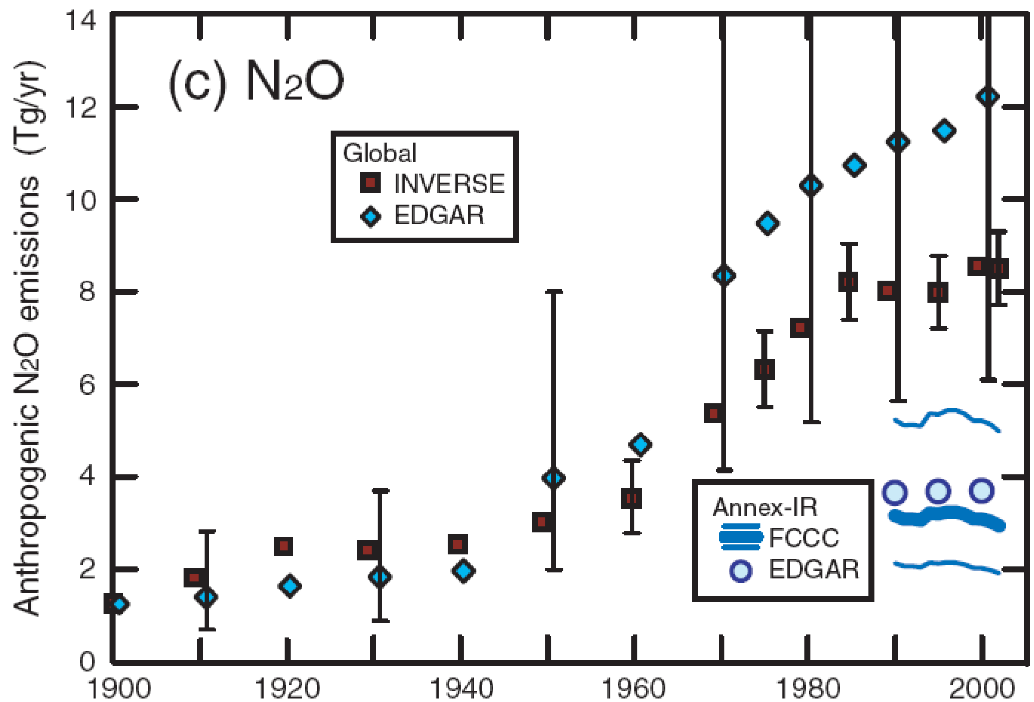


Annex-IR *reported Emissions* (1990-2002) with uncertainty for
FF-CO2, LUCF-CO2, CH4, N2O, F-gases:
(1) E(A-IR)'s ± U
Independent emissions inventories with uncertainties (Global & A-IR) for
FF-CO2, CH4, N2O, F-gases
Inverse models test inventories, use observations to infer E(Global) for
LUCF-CO2, CH4, N2O, F-gases
Forward-Inverse C-cycle models use observed land-use change data to infer E(A-IR) for LUCF-CO2
Annex-IR *revised Emissions* (1990-2002) with additional uncertainty for CO2, CH4, N2O, F-gases:
(2) (E(A-IR)'s ± U)*

N_2O



N2O
EDGAR
reported
Relative Probability
0
2
4
6
8
10
Annex-IR N2O emissions <1990-2002> (Tg/yr)



(c) N2O
Global
INVERSE
EDGAR
Annex-IR
FCCC
EDGAR
Anthropogenic N2O emissions (Tg/yr)
0
2
4
6
8
10
12
14
1900
1920
1940
1960
1980
2000

F gases

(1) Annex-IR ***reported Emissions*** (1990-2002) with uncertainty for FF-CO_2, LUCF-CO_2, CH_4, N_2O, F-gases:

$E_{(A\text{-}IR)}$'s ± U

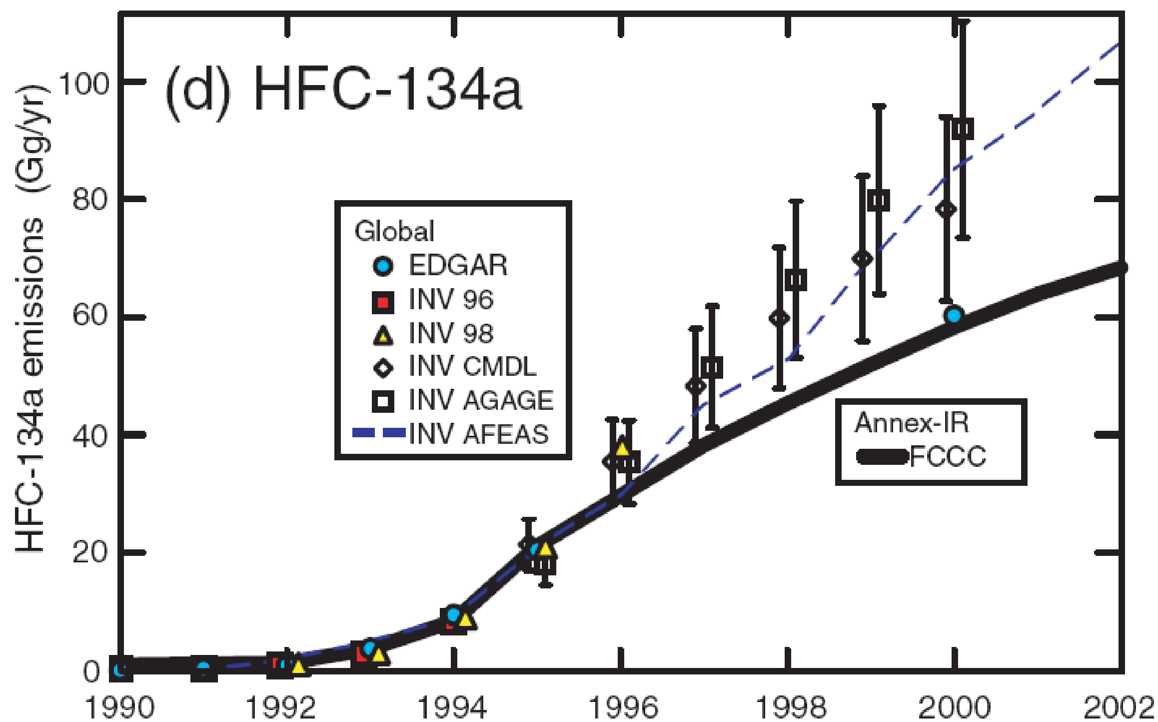
Independent emissions inventories with uncertainties (Global & A-IR) for FF-CO_2, CH_4, N_2O, F-gases

Inverse models test inventories, use observations to infer $E_{(Global)}$ for LUCF-CO_2, CH_4, N_2O, F-gases

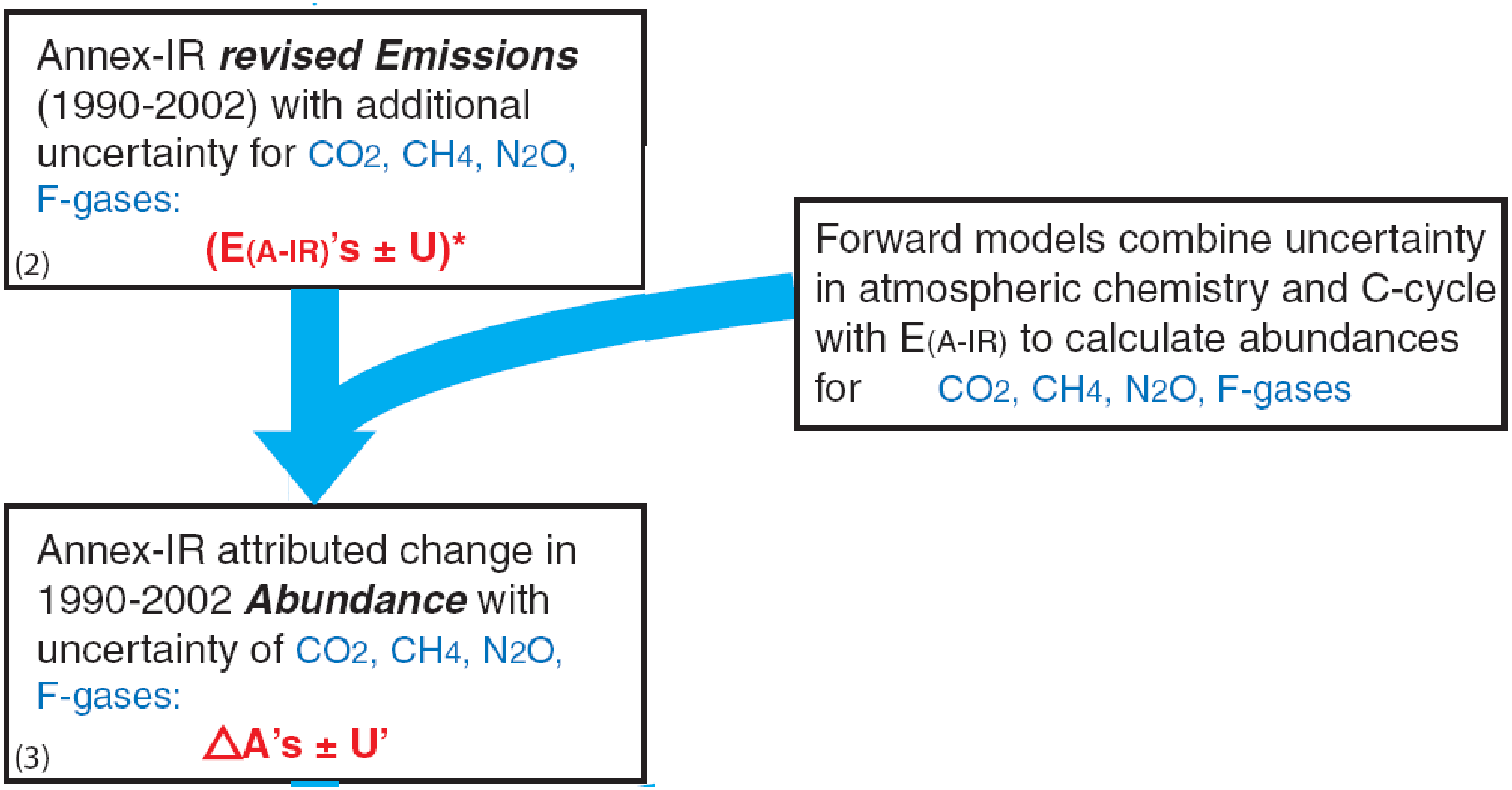
Forward-Inverse C-cycle models use observed land-use change data to infer $E_{(A\text{-}IR)}$ for LUCF-CO_2

(2) Annex-IR ***revised Emissions*** (1990-2002) with additional uncertainty for CO_2, CH_4, N_2O, F-gases:

($E_{(A\text{-}IR)}$'s ± U)*



(2 ► 3) Propagate Uncertainty in Emissions to Atmospheric Abundance



CO_2 annex-IR abundance change

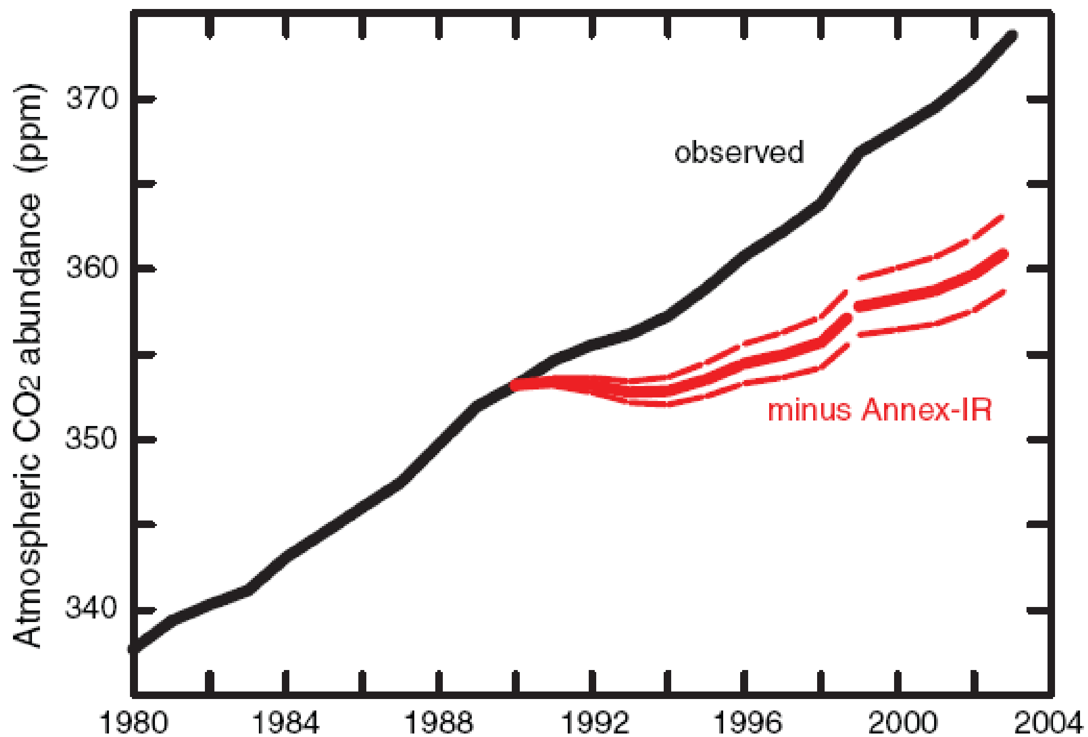
Annex-IR ***revised Emissions*** (1990-2002) with additional uncertainty for CO_2, CH_4, N_2O, F-gases:

(2) **$(E_{(A\text{-}IR)}$'s ± U)***

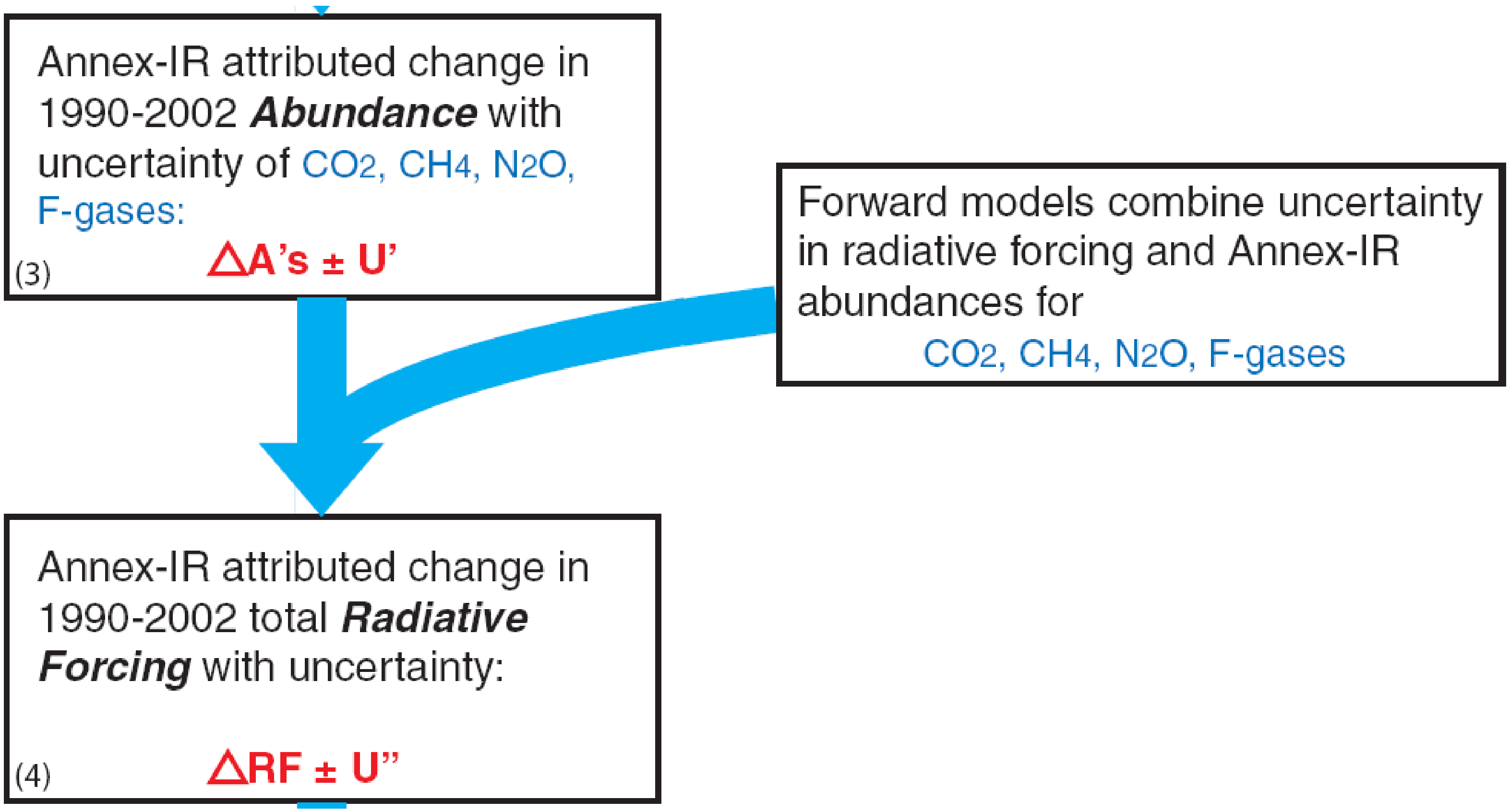
Forward models combine uncertainty in atmospheric chemistry and C-cycle with $E_{(A\text{-}IR)}$ to calculate abundances for CO_2, CH_4, N_2O, F-gases

Annex-IR attributed change in 1990-2002 ***Abundance*** with uncertainty of CO_2, CH_4, N_2O, F-gases:

(3) **ΔA's ± U'**



(3 ► 4) Abundance to Uncertainty in Radiative Forcing



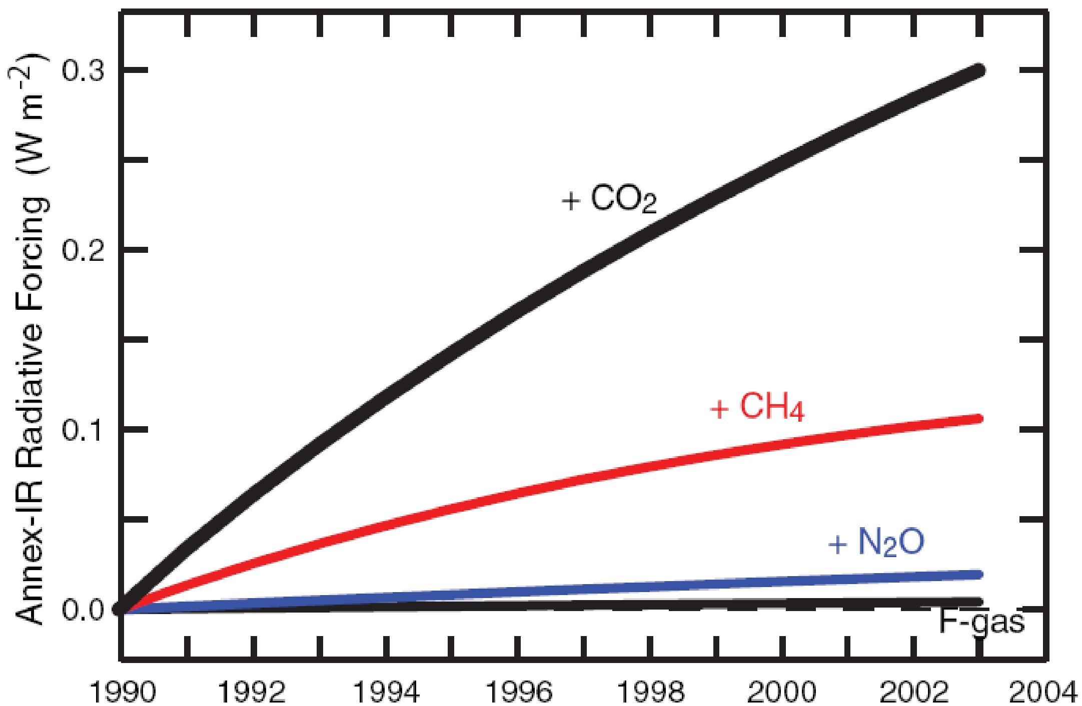
Annex-IR attributed change in 1990-2002 ***Abundance*** with uncertainty of CO_2, CH_4, N_2O, F-gases:

(3) **ΔA's ± U'**

Forward models combine uncertainty in radiative forcing and Annex-IR abundances for CO_2, CH_4, N_2O, F-gases

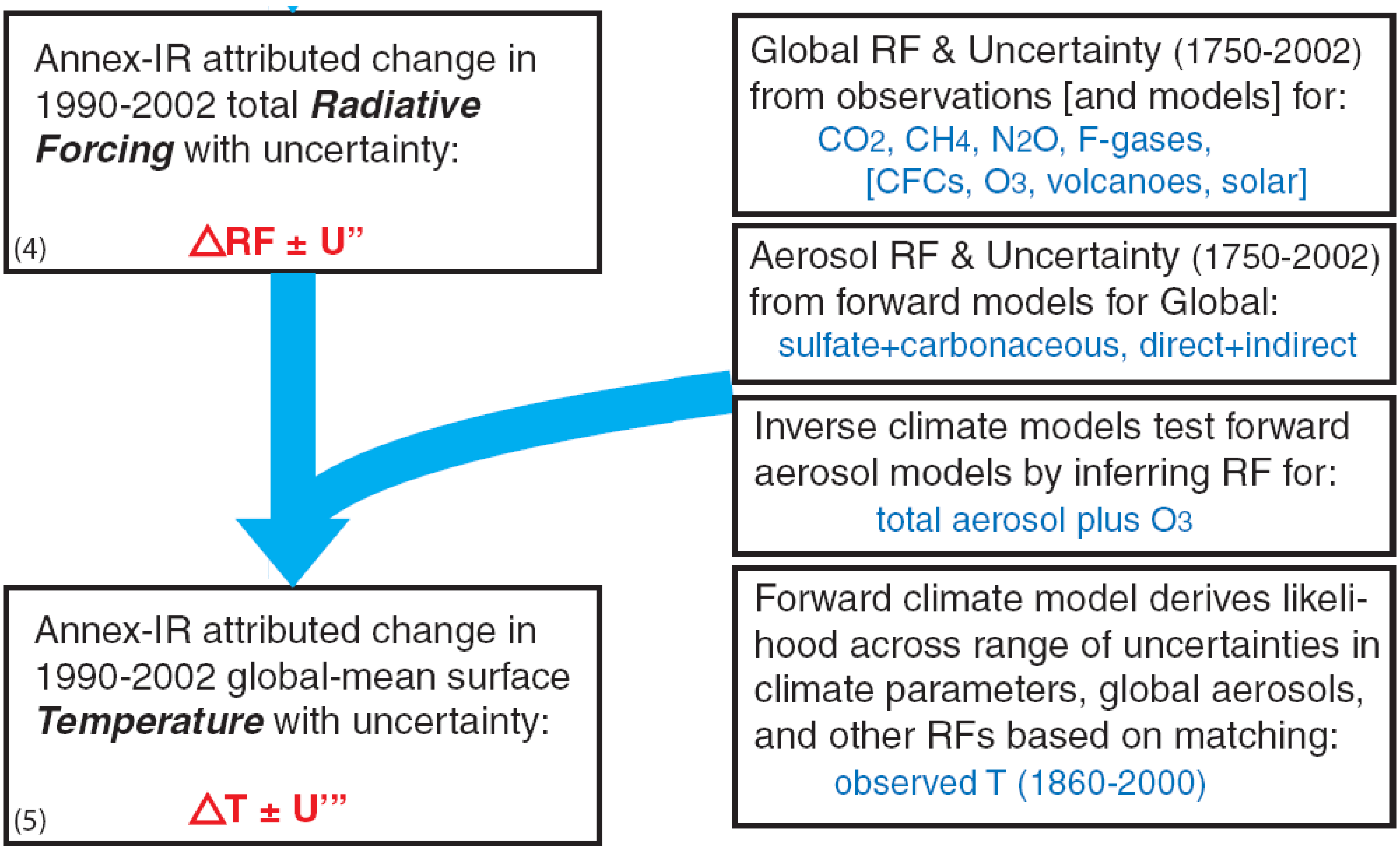
Annex-IR attributed change in 1990-2002 total ***Radiative Forcing*** with uncertainty:

(4) **ΔRF ± U"**



Annex-IR
cumulative total (1990-2002) = 0.3 W/m^2

(4 ► 5) Propagate Uncertainty in Radiative Forcing to Mean Surface Temperature Change



Annex-IR attributed change in 1990-2002 total ***Radiative Forcing*** with uncertainty:

(4) ΔRF ± U”

Global RF & Uncertainty (1750-2002) from observations [and models] for:
CO_2, CH_4, N_2O, F-gases,
[CFCs, O_3, volcanoes, solar]

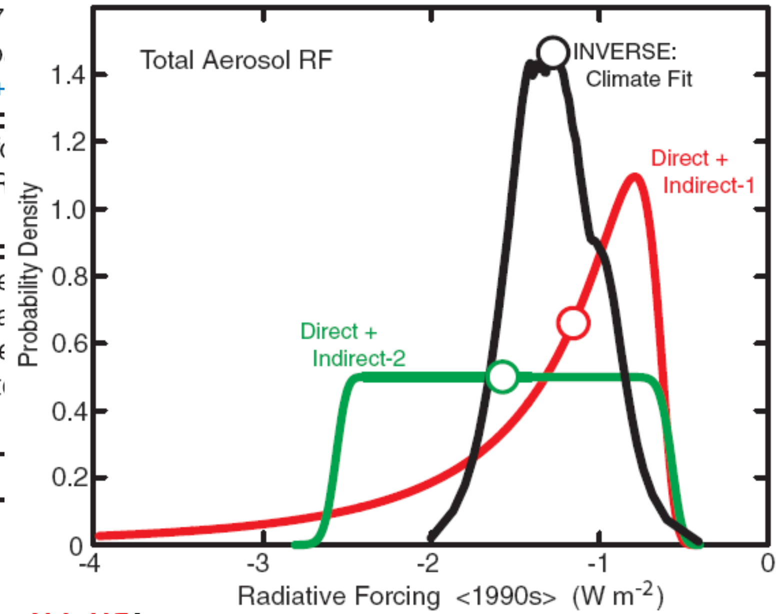
Aerosol RF & Uncertainty (17
from forward models for Glob
sulfate+carbonaceous, direct+

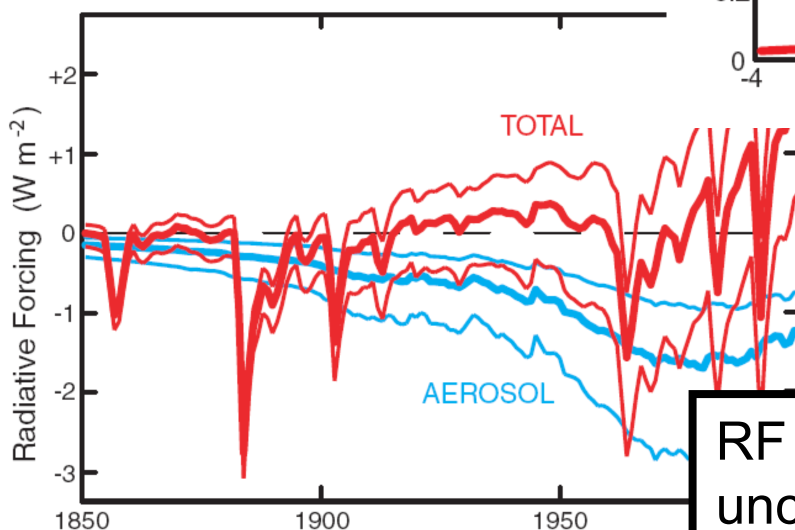
Inverse climate models test fo
aerosol models by inferring R
total aerosol plus O_3

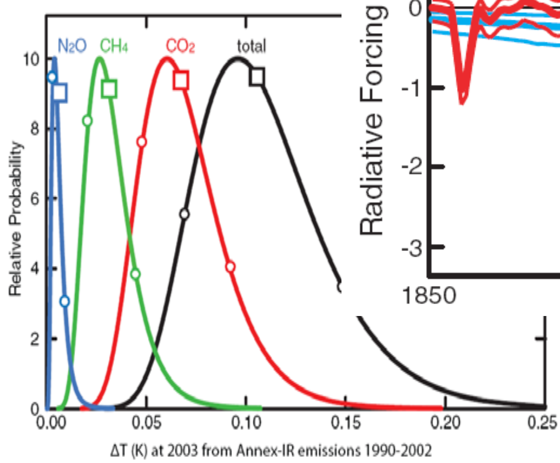
Forward climate model derive
hood across range of uncerta
climate parameters, global ae
and other RFs based on mat
observed T (1860-2000)

Annex-IR attributed change in 1990-2002 global-mean surface ***Temperature*** with uncertainty:

(5) ΔT ± U’”







RF history (hence aerosol RF uncertainty) determine which climate model is more likely (i.e., climate sensitivity).

From human activities to climate change: uncertainties in the causal chain

The effect of ALL anthropogenic emissions of Kyoto GHG from 1990 to 2003 on temperature change in 2003 is 0.33 ºC. The Annex-IR attributed change is 0.11 ºC (±30%).

Thus the Annex-IR relative fraction – for this example & including only the Kyoto GHG – is ***0.33, but with what uncertainty*** ?

Uncertainty in the ratio is clearly ***less than ±30%*** because some of the errors are correlated and will cancel (e.g., conversion of CO_2 abundance to RF), yet some errors are uncorrelated and will not (e.g., different mixes of GHGs).

Until a careful analysis of the scientific uncertainty is made, including uncorrelated errors, our judgment is that the uncertainty in the relative attribution of climate change in this case lies ***between ±10% to ±20%.***

Uncertainty increases as the period of emissions is extended backward to 1900 and/or the climate change evaluation is extended forward to 2100.

Overview

1. Introduction to the MATCH process
(Niklas Höhne, Ecofys, Germany)

2. Results

    1. Uncertainties along the cause-effect chain
    (Michael Prather, University of Irvine, USA)

    2. **Reconciling historical emissions from forestry**
    (Joyce Penner, University of Michigan, USA)

    3. Regions' and countries' contributions to temperature increase
    (Niklas Höhne, Ecofys, Germany)

3. Summary
(Joyce Penner, University of Michigan, USA)

Can we reconcile differences in estimates of carbon fluxes from land-use change and forestry for the 1990s?

A. Ito[1], J. E. Penner[2], M. J. Prather[3], C. P. de Campos[4], R. A. Houghton[5], T. Kato[1], A. K. Jain[6], X. Yang[6], G. C. Hurtt[7], S. Frolking[7], M. G. Fearon[7], L. P. Chini[7], A. Wang[8], and D. T. Price[9]

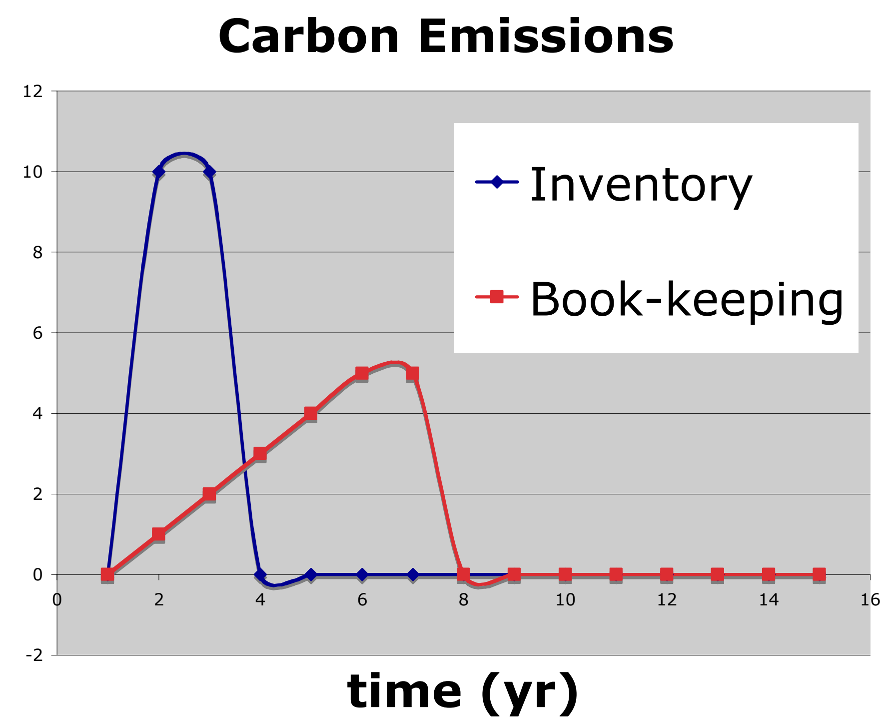
Participants from: Japan, USA, Brazil, Canada

Motivation

- Quantifying net emissions from terrestrial sources is important for meeting stabilization targets
- The UNFCCC-reported LUCF emissions for Annex-IR countries are much larger than estimates from a carbon-cycle model (-0.35 PgC yr^{-1} vs +0.1 to -0.1 PgC yr^{-1})
- The political need for reporting may not match actual carbon emissions or uptake

Methods used to estimate LUCF emissions

- **Inverse models:** can only yield net CO_2 emissions from broad areas, cannot identify processes
- **Bottom-up inventories (e.g. UNFCCC):** do not always include all processes and may not account for delays in emissions
- **Book-keeping methods (e.g. Houghton):** often do not include effects of climate and CO_2 fertilization
- **Biogeochemical models (e.g. Jain):** include ENV effects but may not include all processes



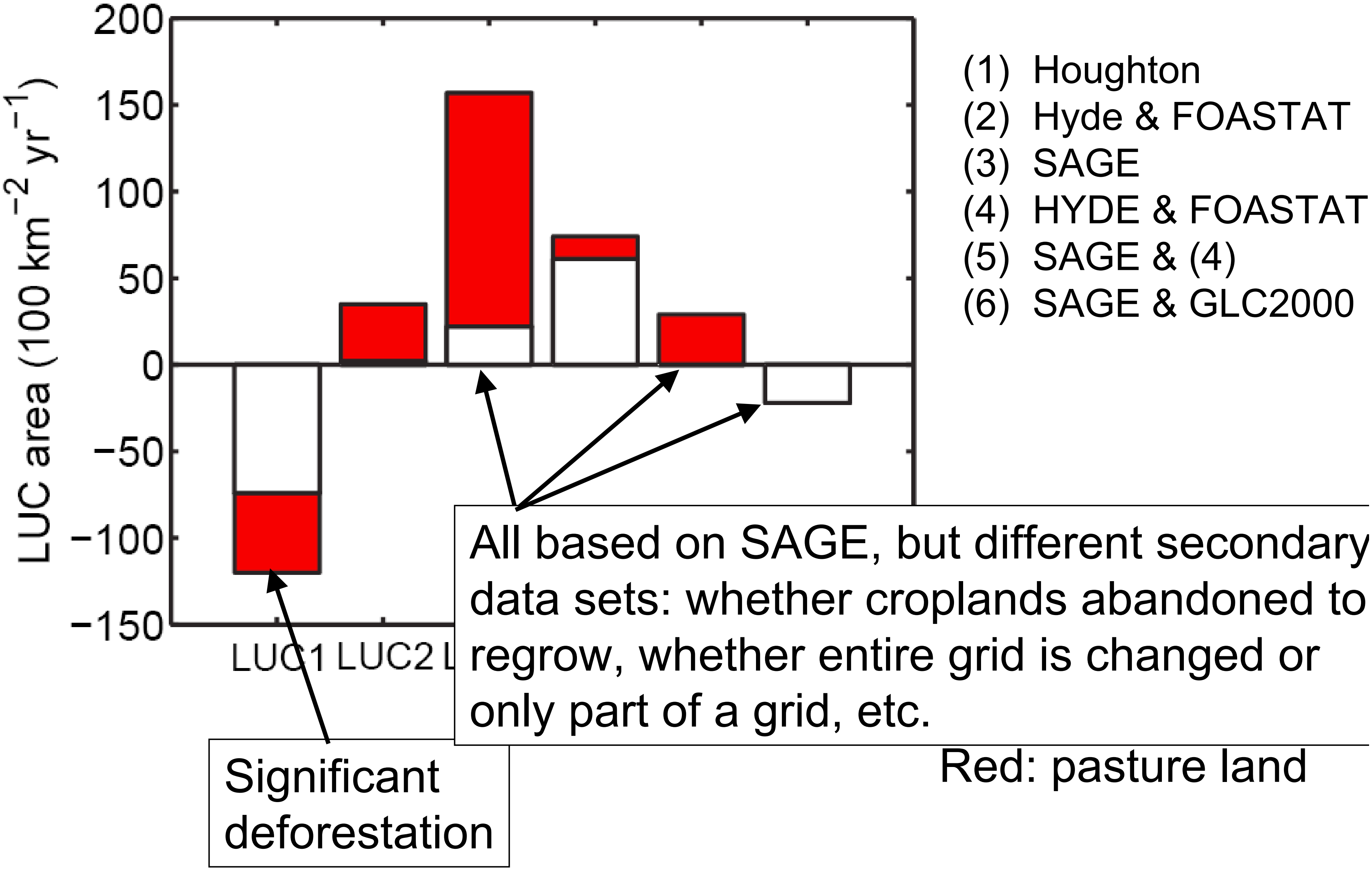
This study

- Compare LUC areas
- Compare carbon pools in different categories
- Compare carbon fluxes and carbon pool changes
- Focused study on estimates for USA and Brazil

Data sets for Land Use Change areas

Namea	Study	Resolution	Data Source
LUC1	Houghton (2006)	Region/country	FAO
LUC2	De Campos et al. (2006)	Country	HYDE & FAOSTAT, 2005
LUC3	Kato et al. (2007)	2.8 °x2.8°	SAGE & HYDE
LUC4	Hurtt et al. (2006)	1°x1°	HYDE & FAOSTAT, 2004
LUC5	Hurtt et al. (2006)	1°x1°	SAGE & LUC4
LUC6	Wang et al. (2006)	0.5°x0.5°	SAGE & GLC2000

Global land use change area in forests



Data sets for carbon pools and emissions

Name	Study	Resolution	Method	LUC
EMI1	Houghton (2006)	Region/country	Book-keeping	LUC1
EMI2	UNFCCC	Country	Inventory	National inventory
EMI3	Olivier and Berdowski (2006)	Country	Inventory	FAO
EMI4	Hurtt et al (2006)	1°x1° USA	Inventory/process	National statistics
EMI5	De Campos et al. (2006)	Country	Book-keeping	LUC2
EMI6	Kato et al. (2007)	2.8°x 2.8°	Process model	LUC3
EMI7	Jain and Young (2005)	0.5°x0.5°	Process model	SAGE
EMI8	This study	Region/country	Consolodated data	N.A.

Comparison of carbon pools

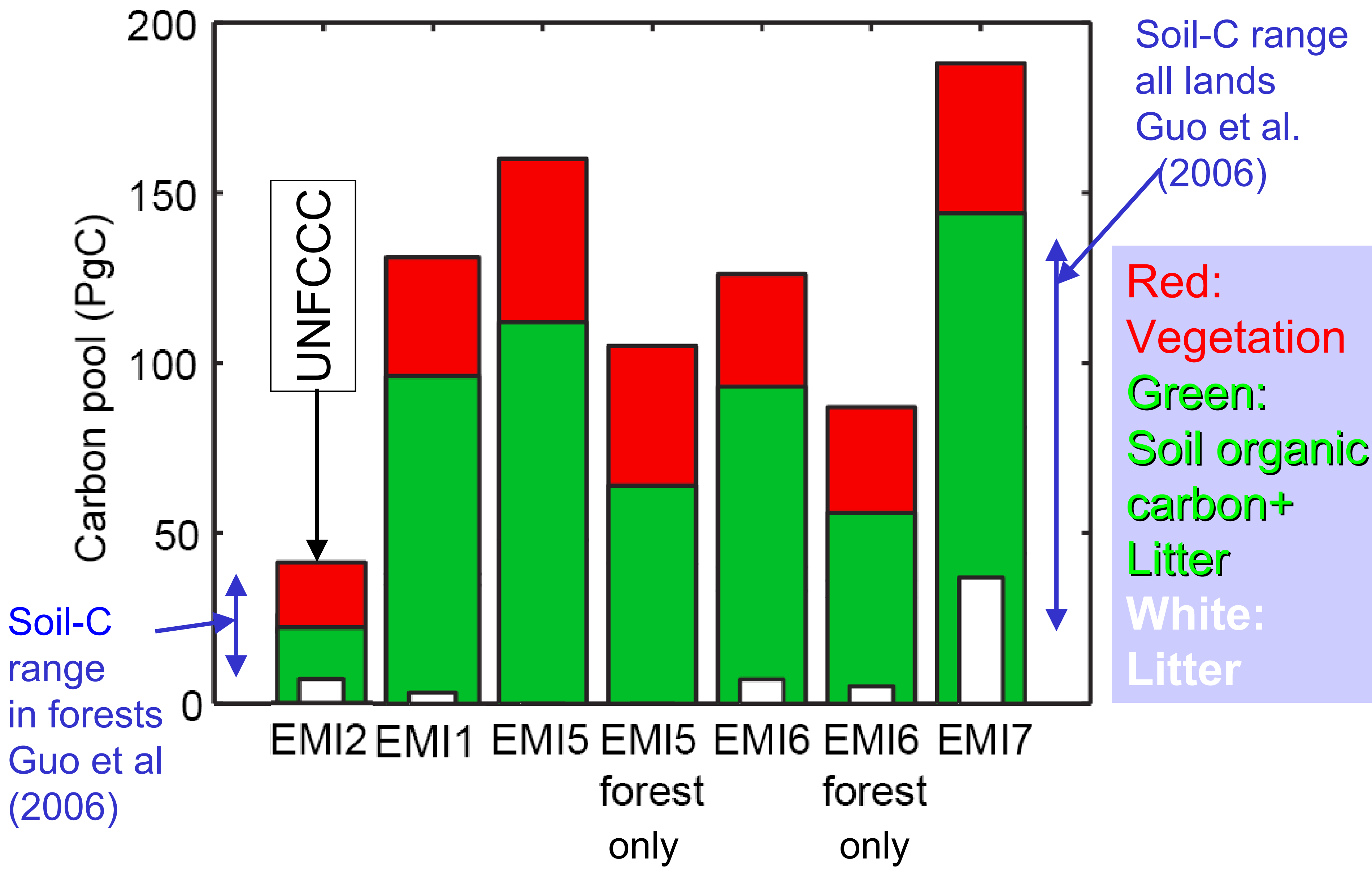
Carbon PgC	**EMI1**	**EMI5**	**EMI6**	**EMI7**
Above ground	516	687	4	90
Woody tree parts			574	678
Non-woody tree (root)			19	42
Non-woody tree (leaf)			118	
Burning	23		0	0
Biofuel				
Paper products			0	1
Long lived product			1	1
Elemental C				1
Decomposable non-woody litter	15	1477	95	7
Resistant litter				471
Microbial biomass	854		1415	34
Humus matter				1314
Global total	**1408**	**2154**	**2227**	**2639**

Different break down of carbon pools will lead to different lifetime and emissions

Carbon fluxes ($PgCyr^{-1}$) from UNFCCC reported countries

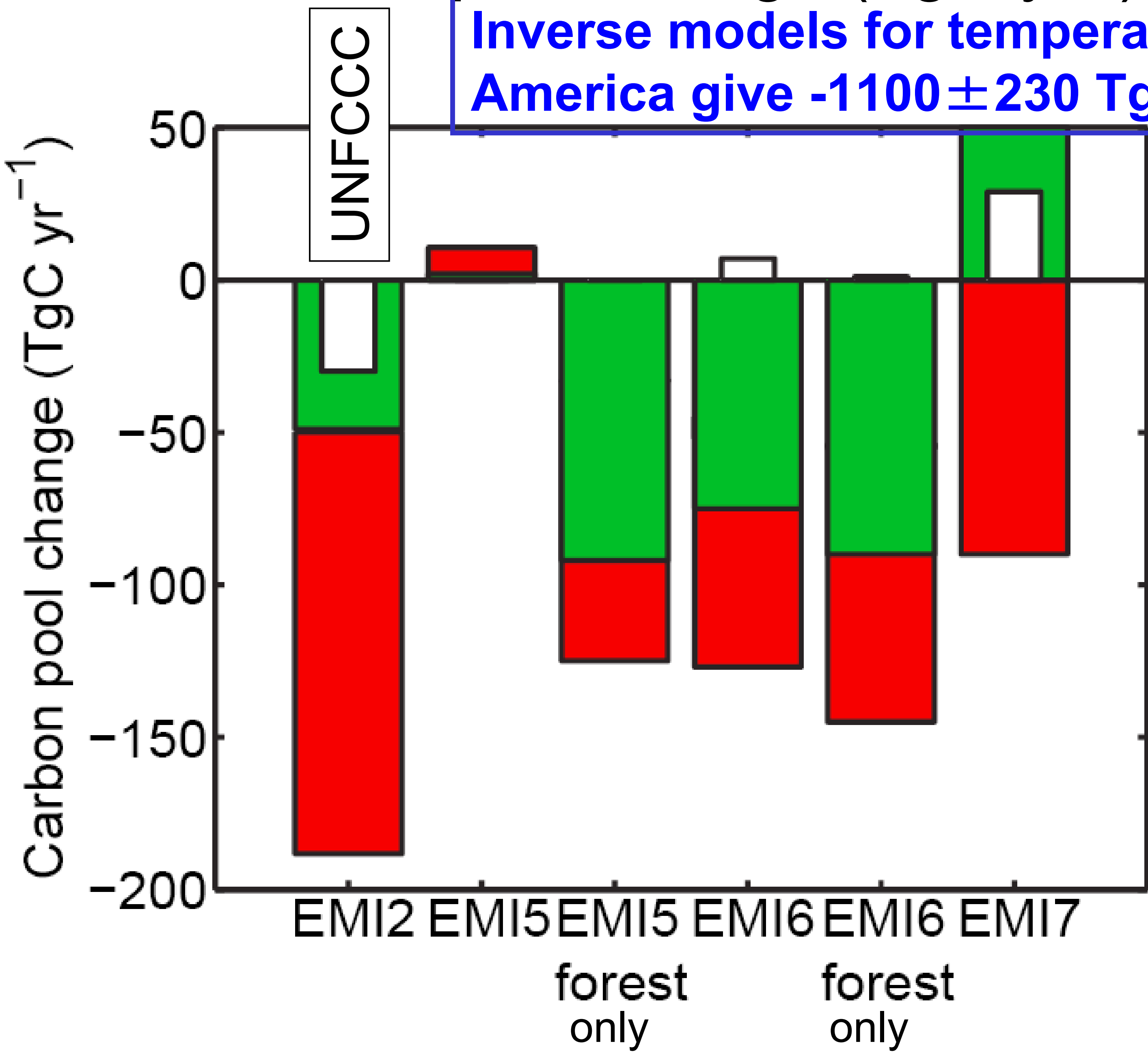
Type of land use change	UNFCCC (EMI 2)	EMI 1 (Bk-keep)	EMI 5 (Bk-keep)	EMI 6 (Biogeoch)	EMI 7 (Biogeoch)
Pasture conv. In forest	113	478	521	-465	NI
Pasture conv. In grassland		1			NI
Crop conv.		633			474
Shifting cultivation		224	NI	NI	NI
Afforestation		-93	NI	NI	NI
Soil emissions	9	NI	NI	NI	NI
Land degradation	NI	2	NI	NI	NI
Logging	-362	177	NI	NI	NI
Fuelwood		86	NI	NI	NI
Fire suppression		-122	NI	NI	NI
Other	0	NI	NI	NI	NI
Climate+CO2 in forest	NI	NI	NI	-690	-1432
Climate+CO2 in nonforest	NI	NI	NI	-238	
Sum	**-240**	**1386**	**521**	**-1393**	**-958**

USA terrestrial carbon pools in 1990s



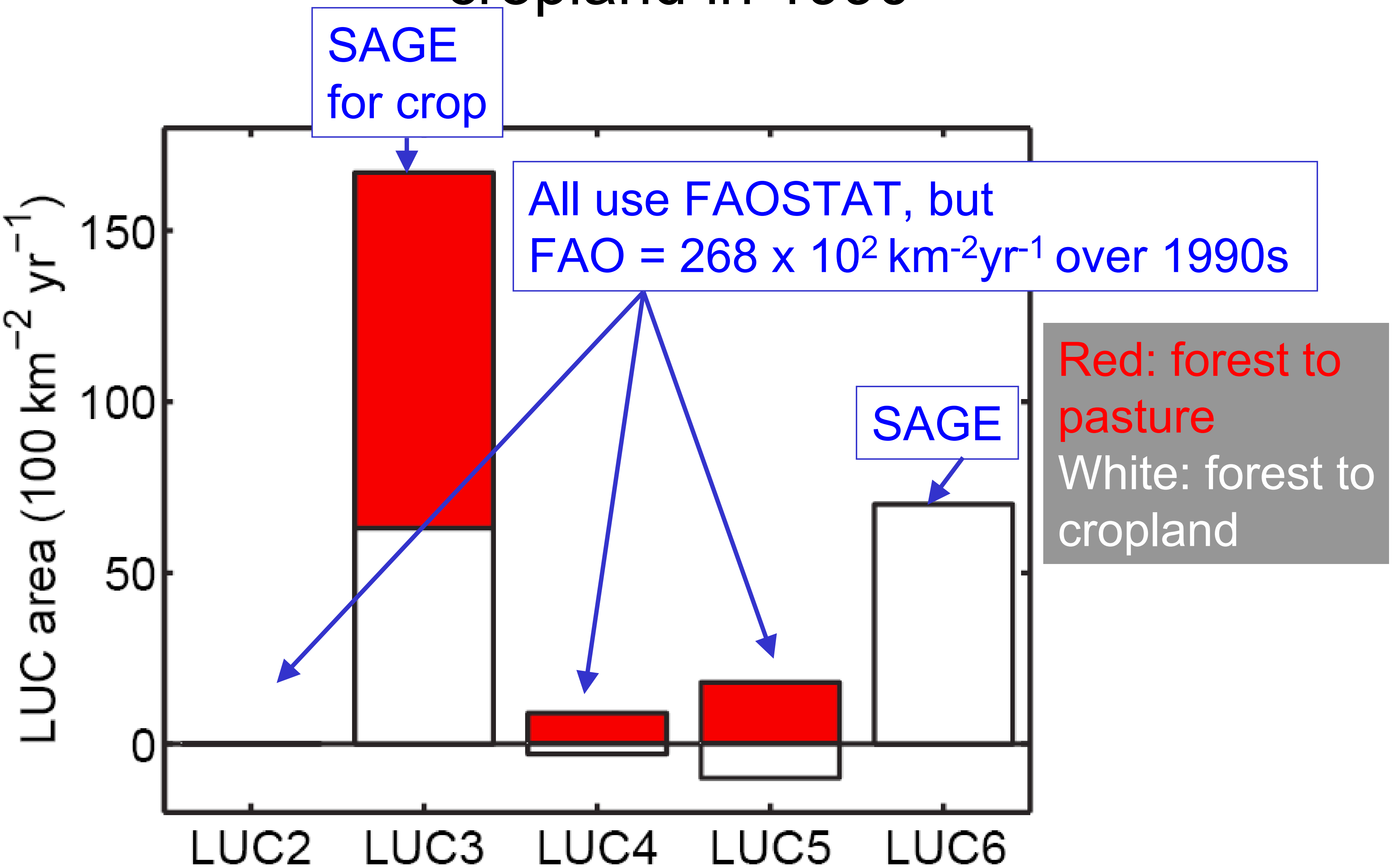
USA Carbon pool change (TgC yr^{-1}) in 1990s

Inverse models for temperate North America give -1100±230 TgC yr^{-1}



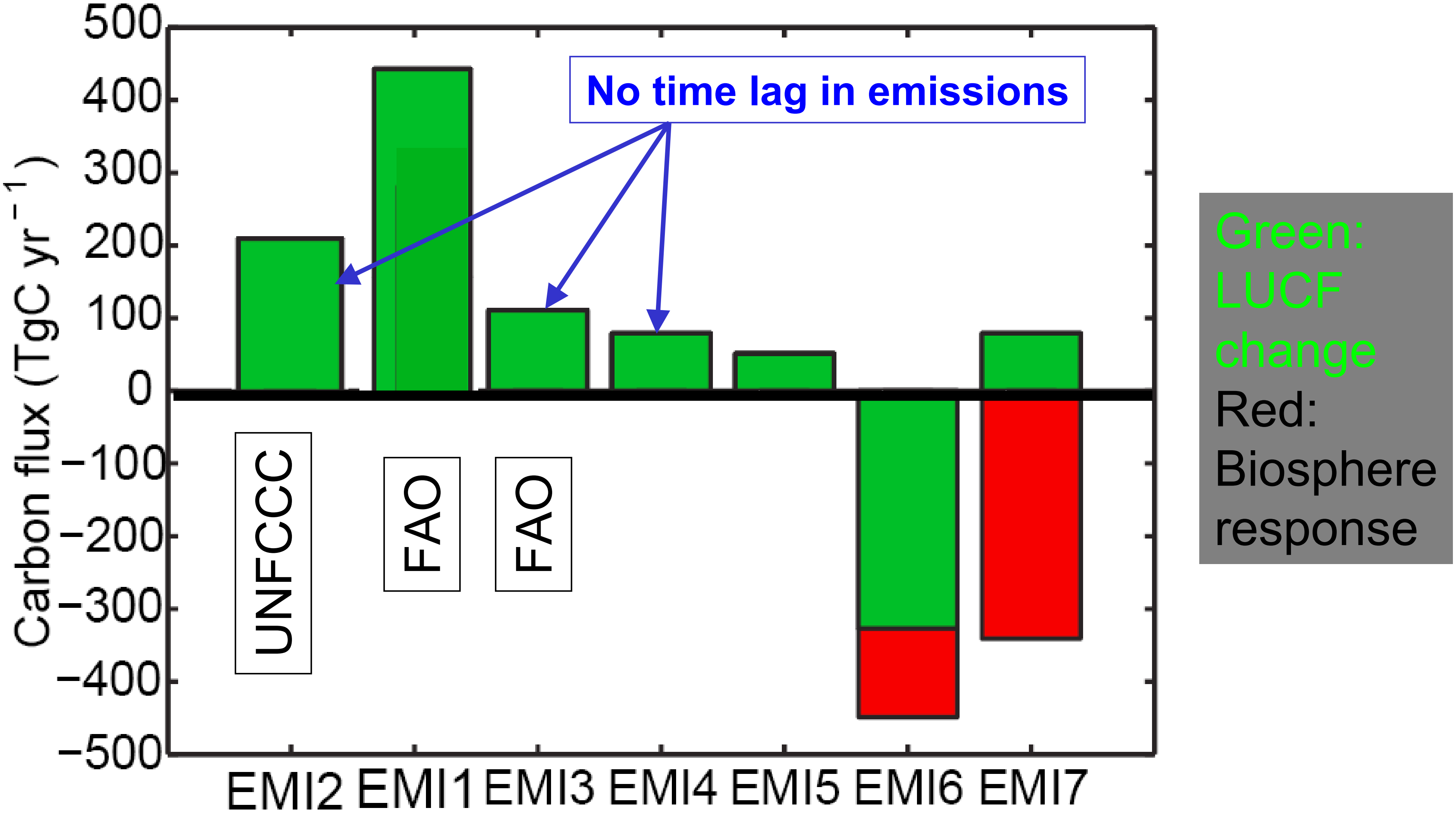
Red: Vegetation
Green: Soil organic carbon+ Litter
White: Litter

Brazil net conversion of forest to pasture and cropland in 1990



Brazil terrestrial C fluxes in the 1990s

The estimated flux for Latin America ranges from 226 (UNFCCC) to 793 TgC yr^{-1} while inverse models estimate 430 ± 860 TgC yr^{-1}



Conclusions

- There are large differences in the processes included in different LUCF data sets

- Climate feedbacks and fertilization could significantly decrease the net global emissions from LUCF but are highly uncertain and, may, to some extent be included in UNFCCC estimates

- We constructed a consolidated estimate of fluxes for Latin America, USA and globally

- There is no easy reconciliation of different fluxes on a global scale, since the cause differs when examined on a country by country basis

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      (Joyce Penner, University of Michigan, USA)

   3. **Regions' and countries' contributions to temperature increase**
      (Niklas Höhne, Ecofys, Germany)

3. Summary
   (Joyce Penner, University of Michigan, USA)

Analysing countries' contribution to climate change: Scientific uncertainties and methodological choices

Environmental Science and Policy 2005

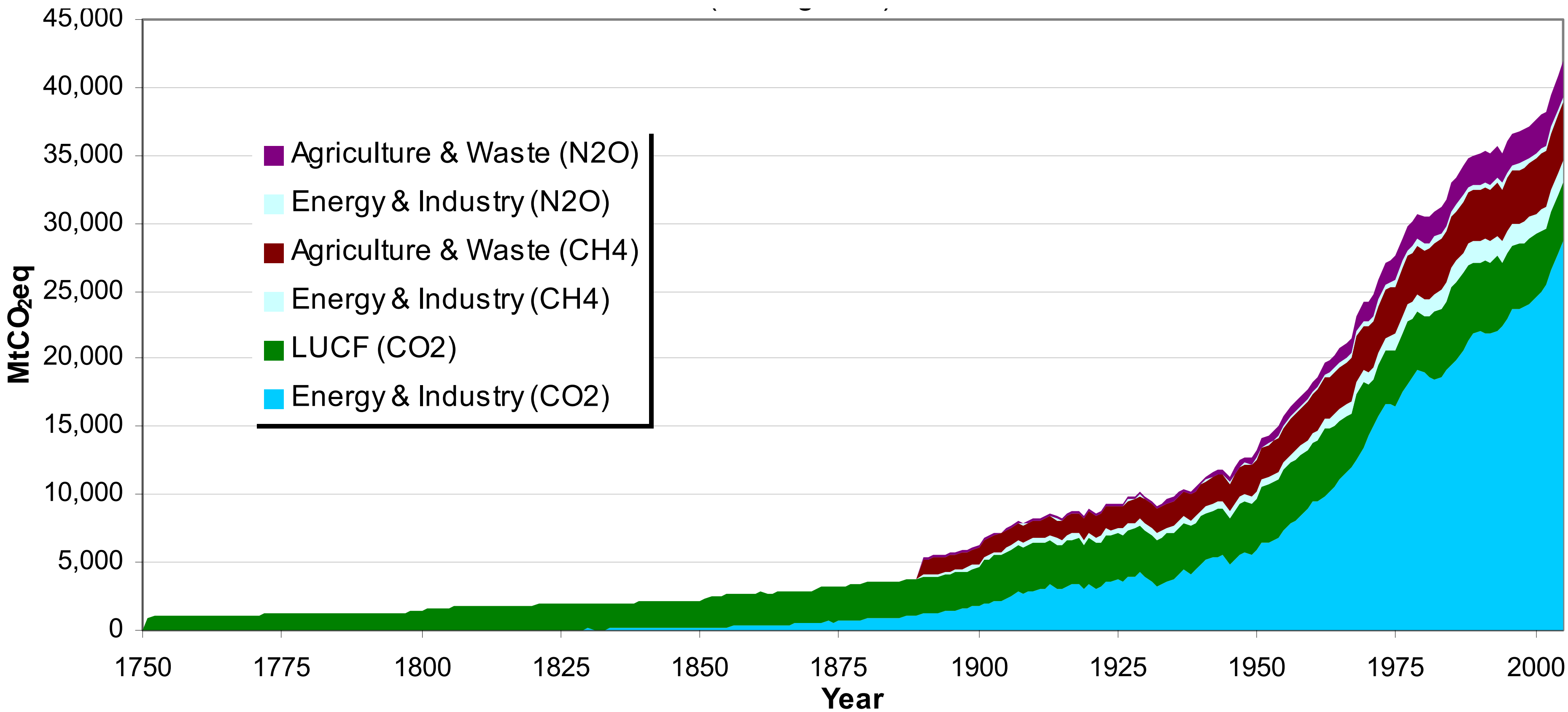
- Michel den Elzen (RIVM, Netherlands)
- Jan Fuglestvedt (CICERO, Norway)
- Niklas Höhne (Ecofys, Germany)
- Cathy Trudinger (CSIRO, Australia)
- Jason Lowe (Hadley, UK)
- Ben Matthews (UCL, Belgium)
- Bård Romstad (CICERO, Norway)
- Christiano Pires de Campos (Brazil)
- Natalia Andronova (UIUC, USA)

Contributions of individual countries' emissions to climate change and their uncertainty

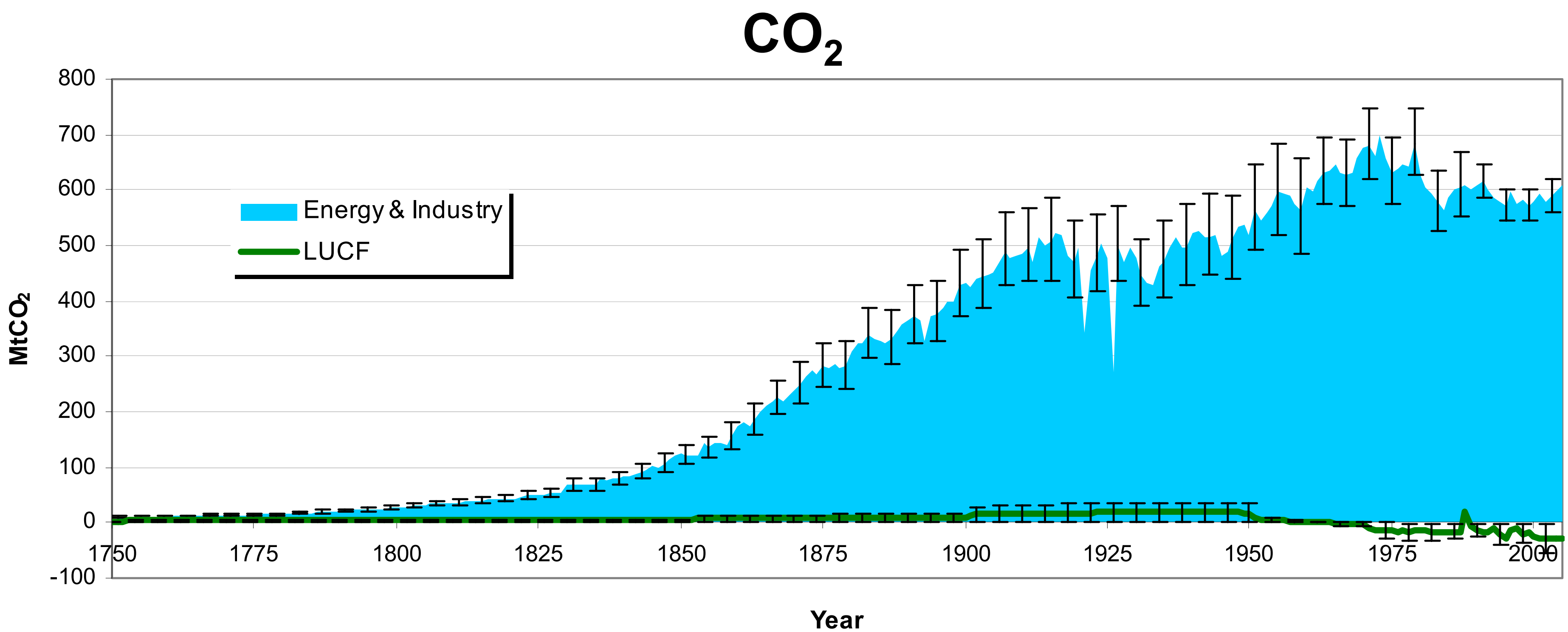
Climatic change (submitted 2007)

- Niklas Höhne (Ecofys, Germany)
- Helcio Blum (IVIG, Brazil)
- Jan Fuglestvedt (CICERO, Norway)
- Ragnhild Bieltvedt Skeie (CICERO, Norway)
- Atsushi Kurosawa (IAE, Japan)
- Guoquan Hu (National Climate Center, China)
- Jason Jowe (Mettoffice, UK)
- Laila Gohar (Mettoffice, UK)
- Ben Mathews (UCL, Belgium)
- Ana Claudia Nioac de Salles (IVIG, Brazil)
- Christian Ellermann (Ecofys, Germany)

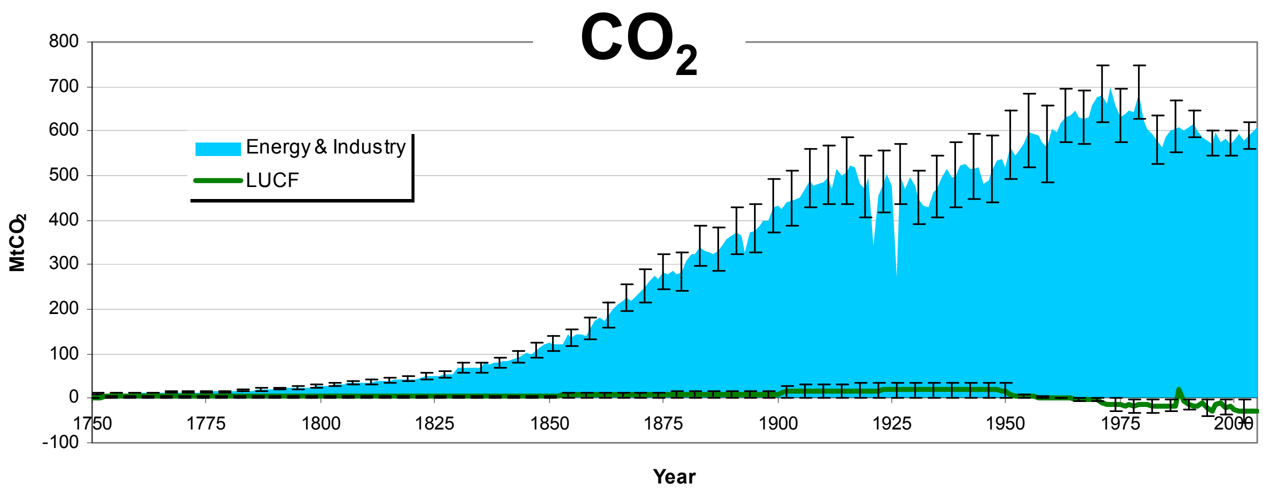
Historical emissions by sector

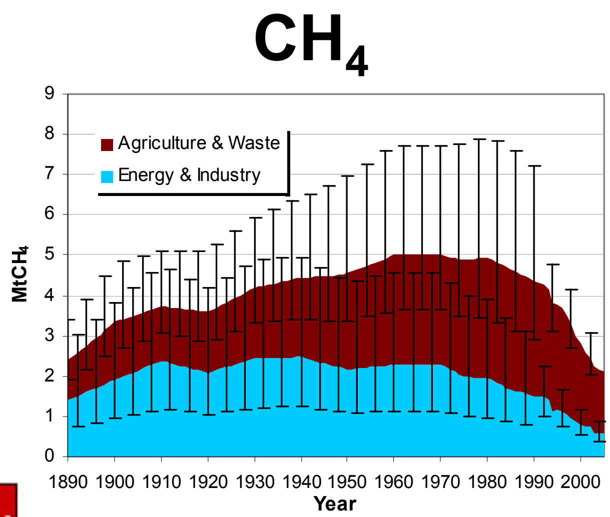


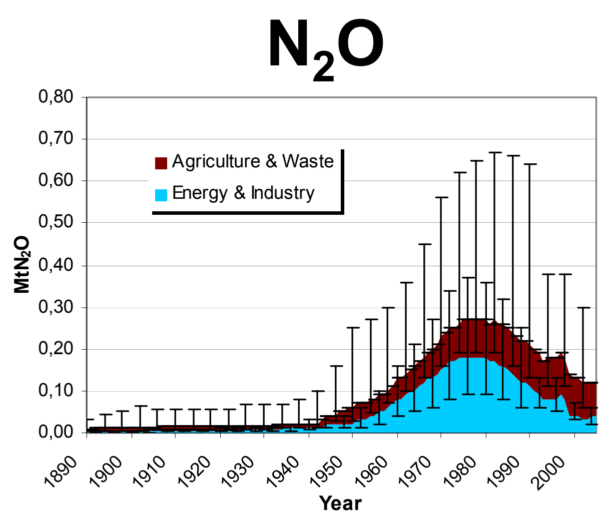
Historical emissions UK

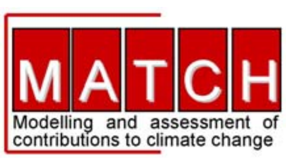


Historical emissions UK



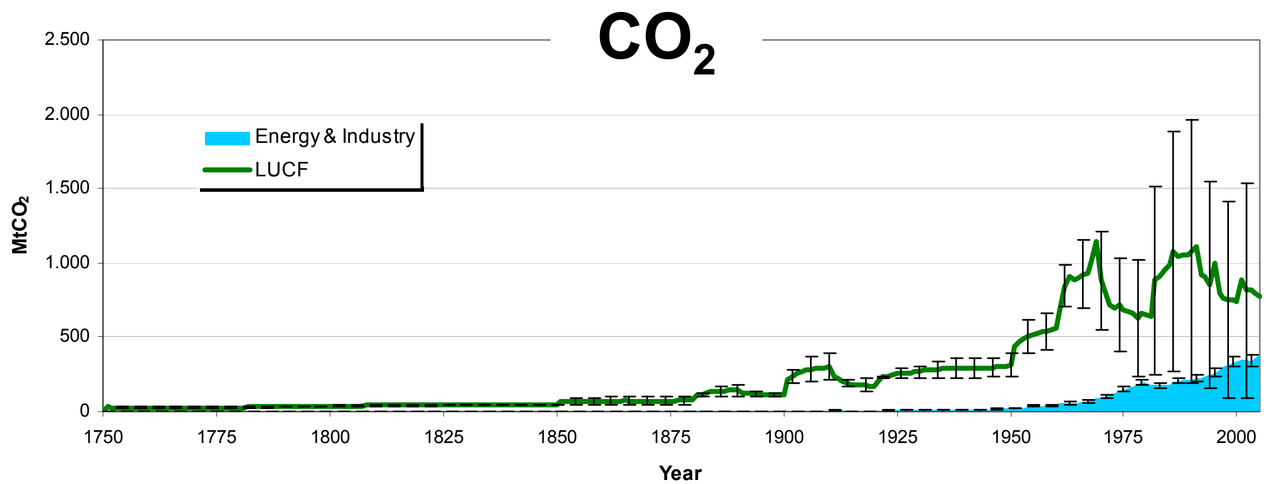


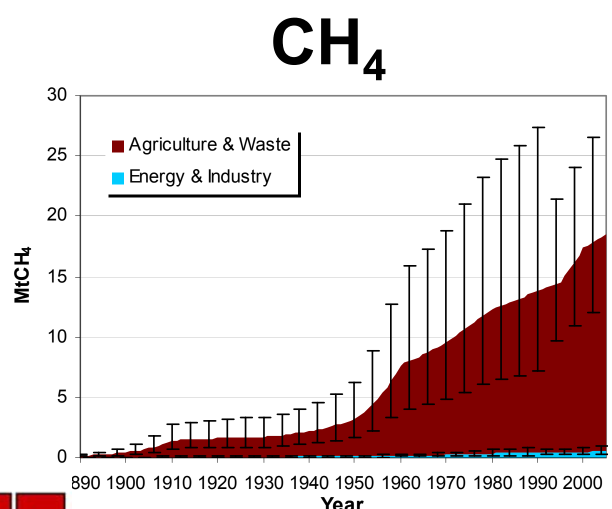


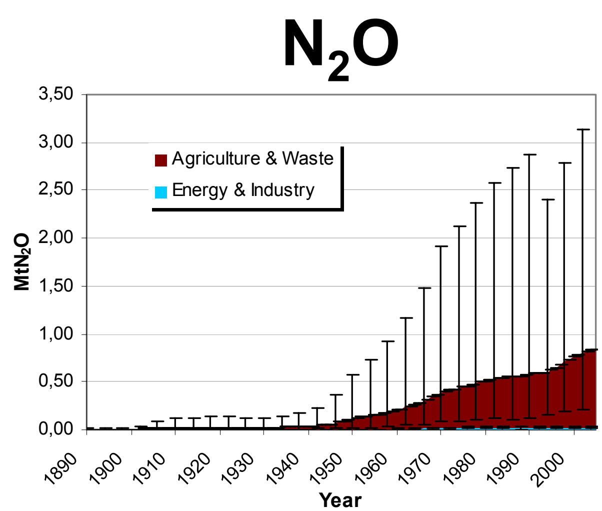


Modelling and assessment of contributions to climate change

Historical emissions Brazil



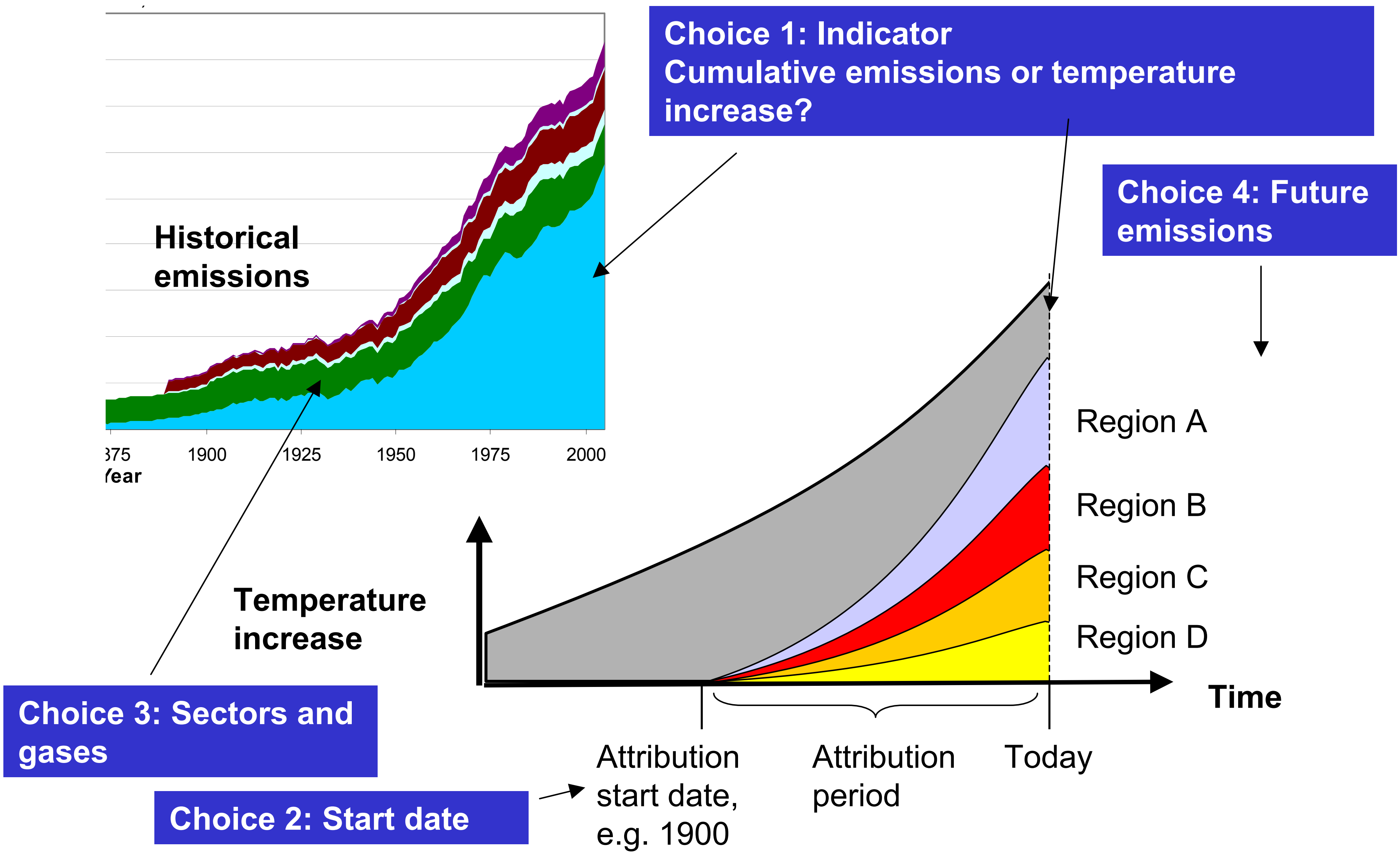




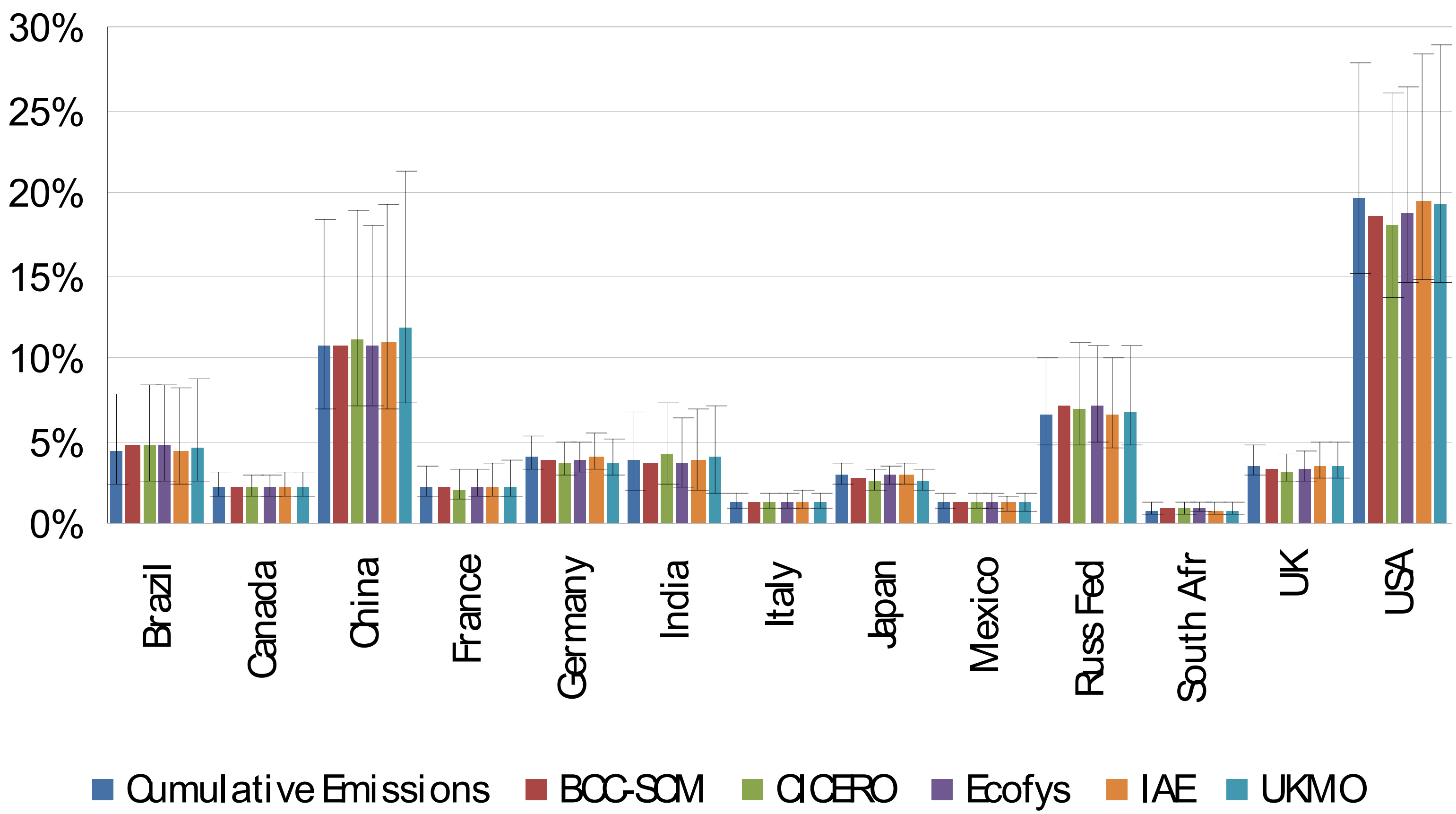
MATCH
Modelling and assessment of contributions to climate change

Modelling and assessment of contributions to climate change

Policy choices

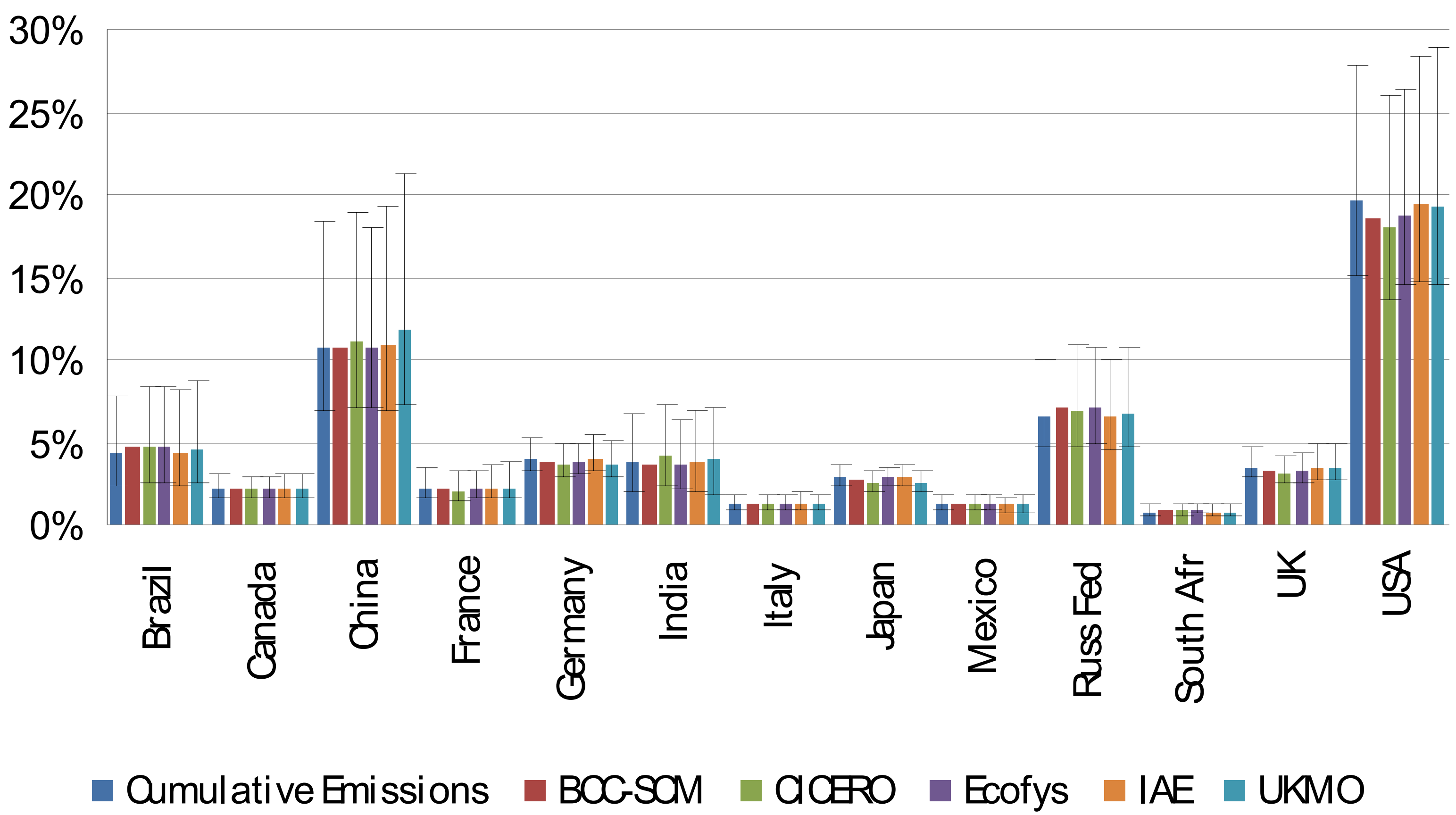


5 models show similar outcomes



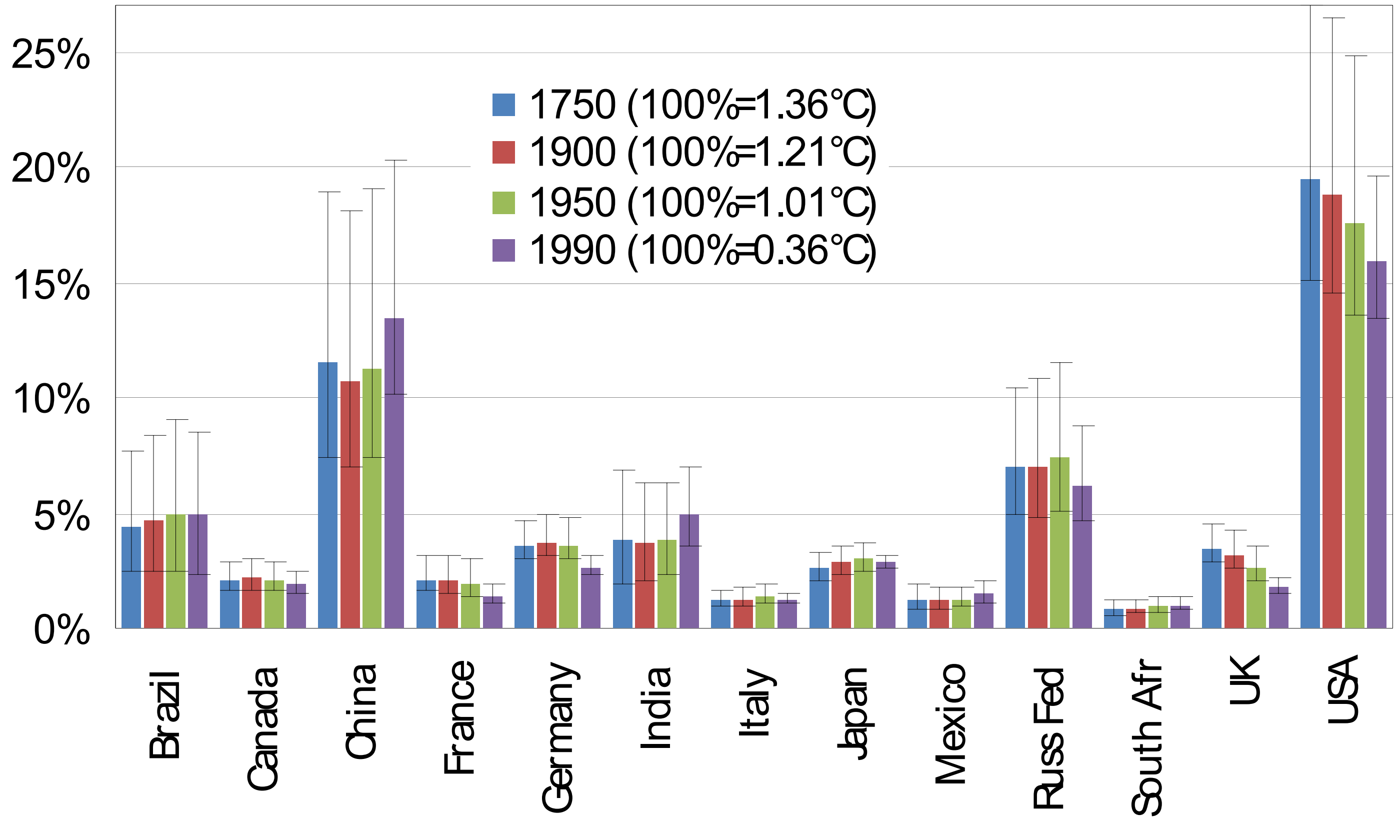
Contribution to temperature increase in 2005 of emissions from 1900 to 2005 of CO_2, CH_4 and N_2O including LUCF

Choice 1: Cumulative emissions vs. temperature from 5 models



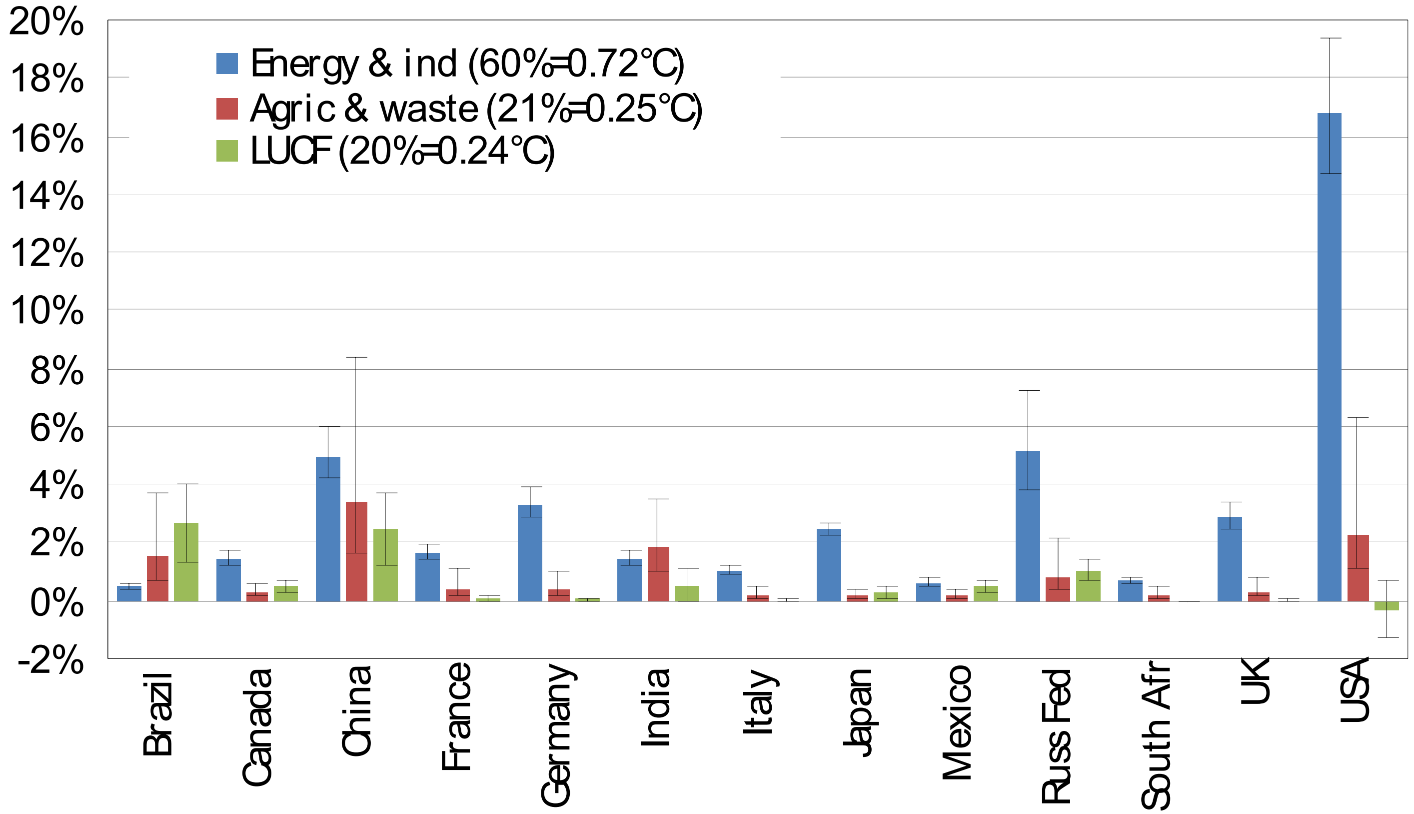
Difference between cumulative emissions and temperature small for long time horizons

Choice 2: 4 start dates, one model



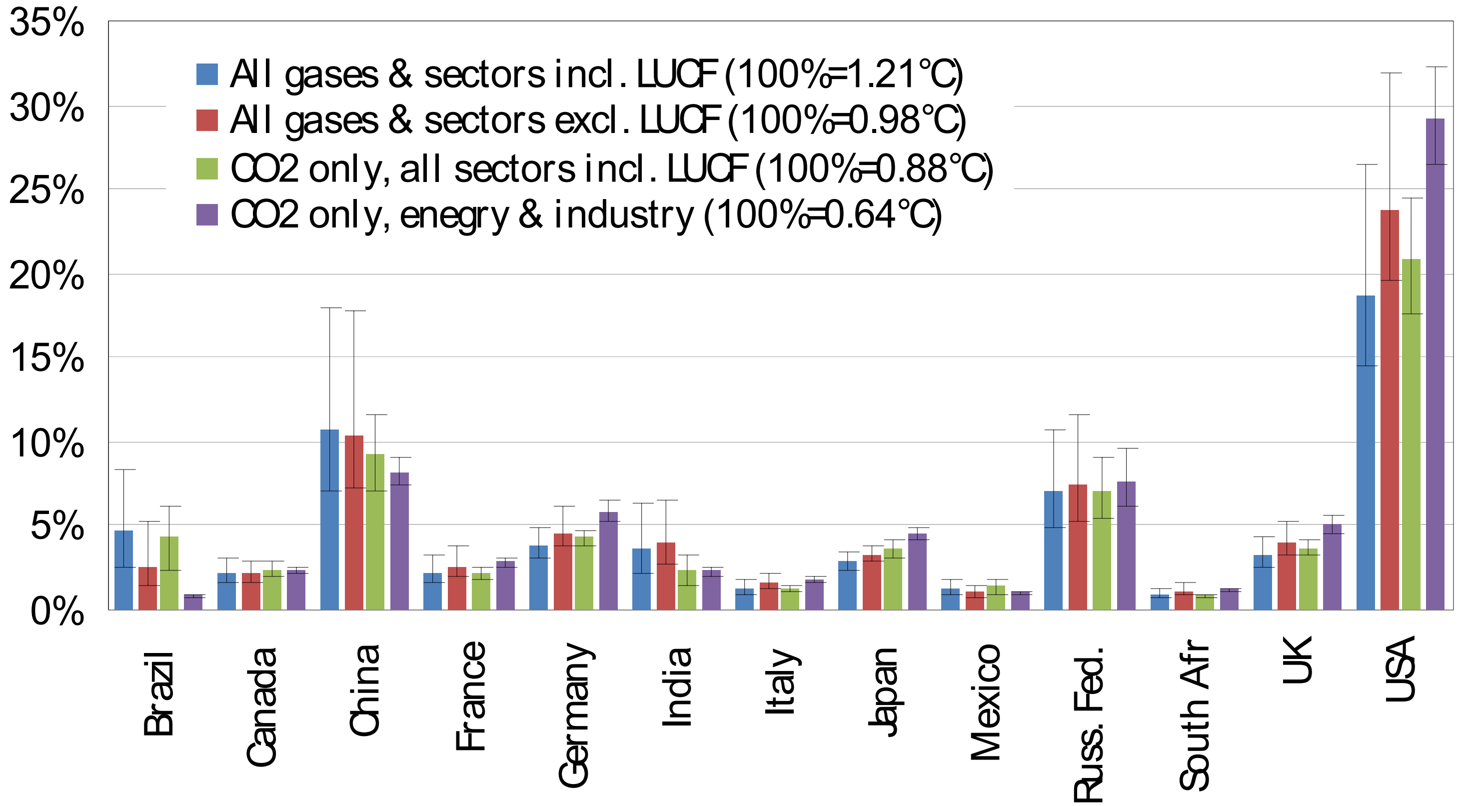
- The difference is large for rapid increase in emissions recently (e.g. China, India) or currently decreasing emissions (e.g. UK)
- Uncertainty increases when moving to earlier emissions

Contribution by sector



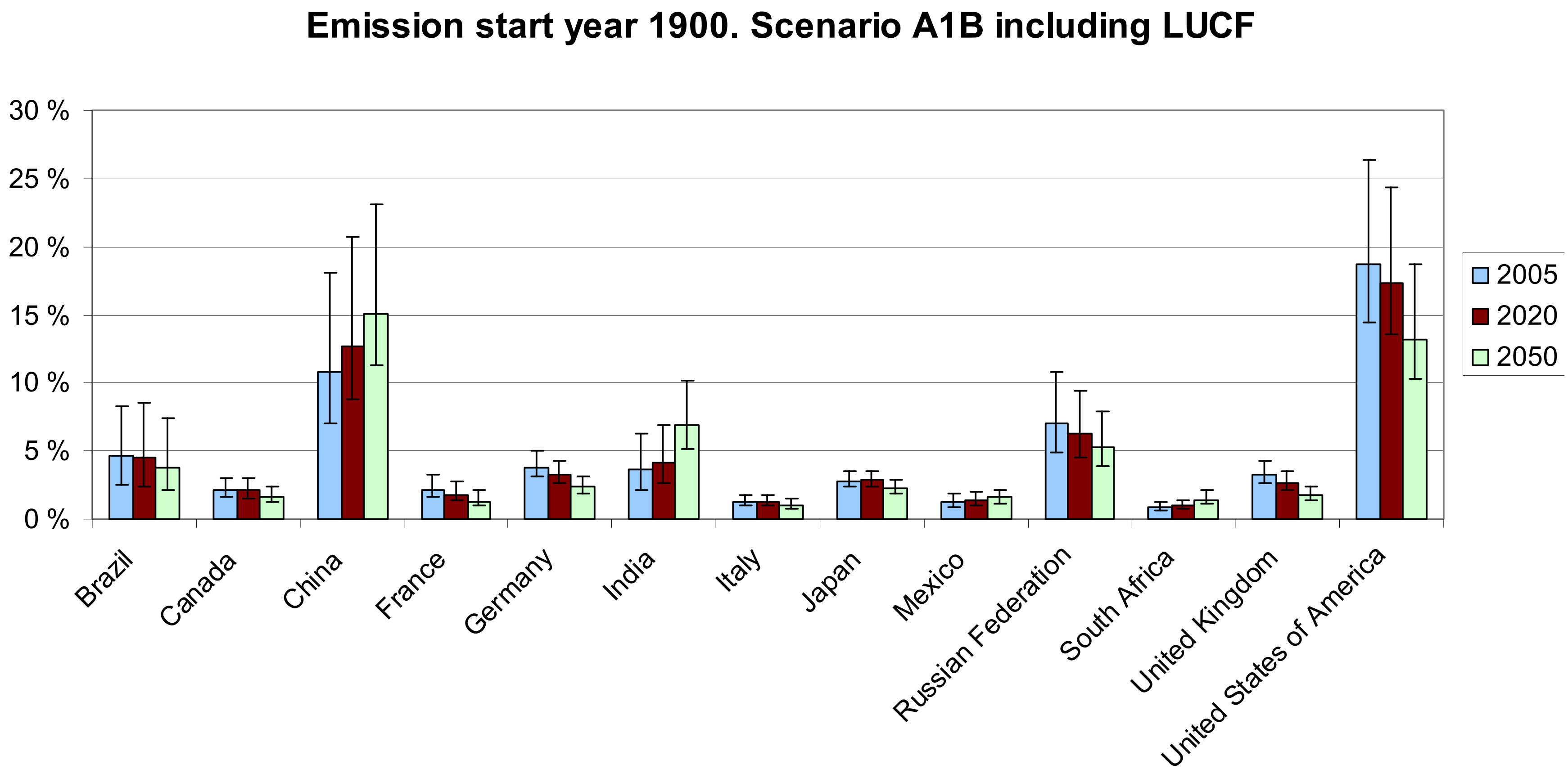
- Energy and industry largest for most countries, except for Brazil
- CO_2 is the dominant gas for most countries, except India, where the contribution of methane to current temperature is higher

Choice 3: Sectors and gases



- Large difference: high emissions from deforestation and/or from CH_4 and N_2O, e.g. Brazil, China and India.
- Uncertainty smaller for the case of CO_2 from energy and industry only

Choice 4: Future emissions



- For industrialized countries contributions decline
- For developing countries contributions increase, exception Brazil

Conclusions

- Country and sector level historical emissions with uncertainty estimates (also electronically)
- Country and sector level contributions for different choices: indicator, start date, sectors and future emissions (also electronically)
- Important factors
  - Uncertainty of historical emissions
  - Choice of the start date
  - Including or excluding LUCF or CH_4 and N_2O
- Less important factors
  - Uncertainty of different simple climate system models
  - Choice between “cumulative emissions” and “temperature increase” for long timeframes
- Still unresolved: LUCF, other uncertainties and finer sectoral resolution
- We hope that the data and results prove useful for designing effective climate change policies

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      (Niklas Höhne, Ecofys, Germany)

3. **Summary**
   (Joyce Penner, University of Michigan, USA)

Conclusions

- Brazil proposal started with a single model demonstration.
- Scientific underpinnings, historical datasets and modelling tools have been developed.
- Choices influence the contribution results. The impact of the decisions depends on the countries' emissions history.
- Uncertainty in the contribution to absolute temperature was shown to be ±30% in the case of recent emissions
- Full results are being peer-reviewed and may be included in future IPCC reports

www.match-info.net