EUROPEAN COMMISSION

questions

- Who is responsible for the quote that air pollution might trigger an ice age?
  - Scientists
  - Journalists
- Does it make sense to have a UNFCCC (for climate change) and a UNCLRTAP (for air pollution) ? Y/N
- Main reason for implementing clean energies is:
  - Climate stabilization in the long term (> 100 years)
  - Climate stabilization in the short term (< 50 years)
  - Air pollution abatement
  - Job creation
  - Energy Security.

Tackling Air Pollution and Climate Change:

A Bumpy Road Towards the Common Good

Frank Raes, John Van Aardenne, Frank Dentener, Silvia Kloster,
Rita Van Dingenen, Elisbaetta Vignati, Elina Marmer, Lazlo Sabo, Peter Russ

Joint Research Centre, European Commisison

John Seinfeld

California Institute of Technology

and many others

Max Planck Institute for Meteorology, Hamburg (DE)
ETH, Zurich (CH)
Wageningen University, Wageningen (NL)
International Institute for Applied Systems Analysis, Laxenburg (AU)

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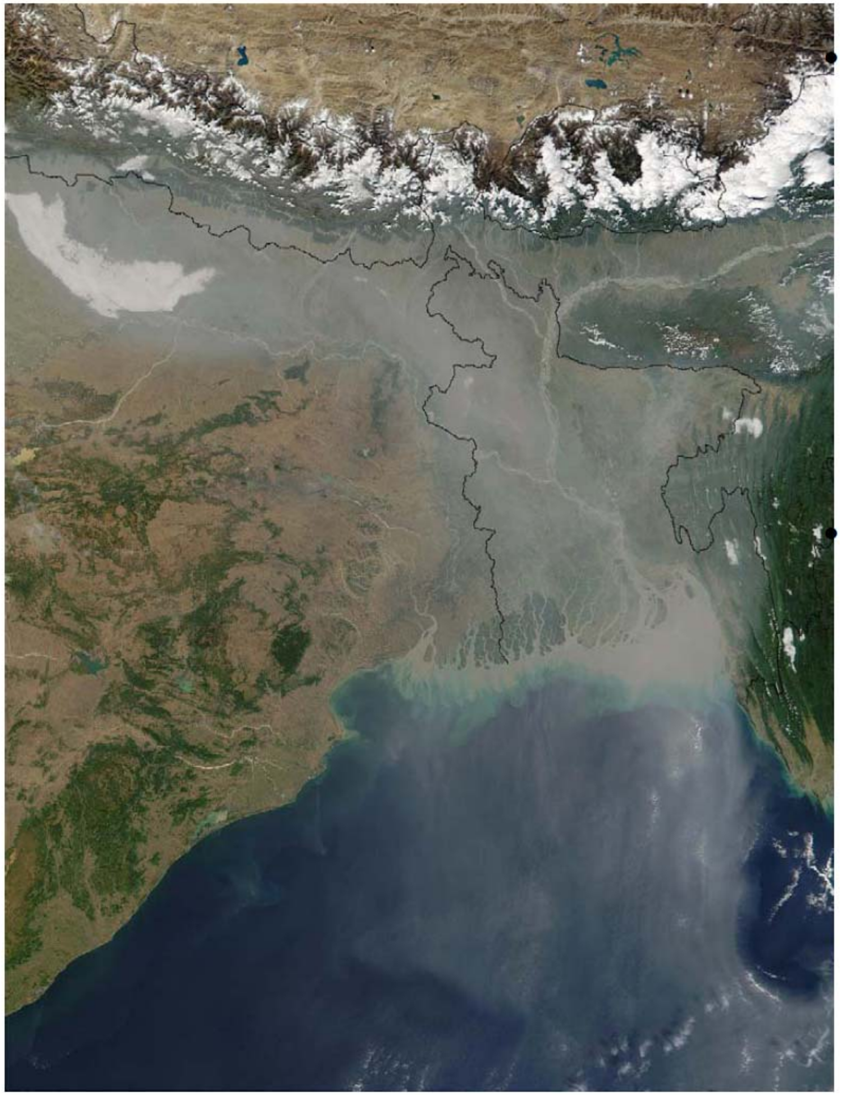
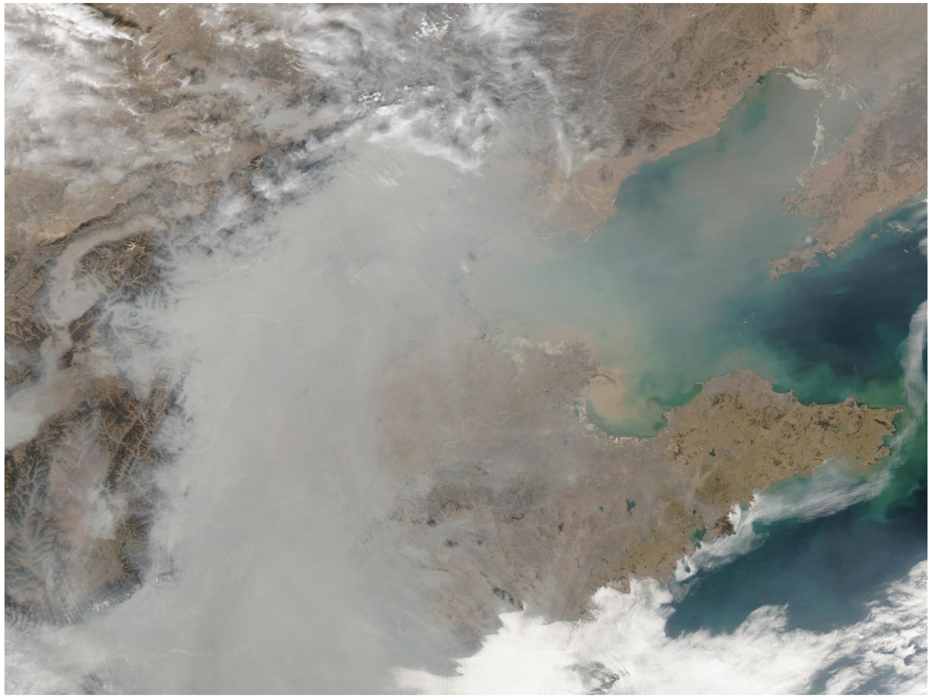
current air pollution

INDIA Ganges



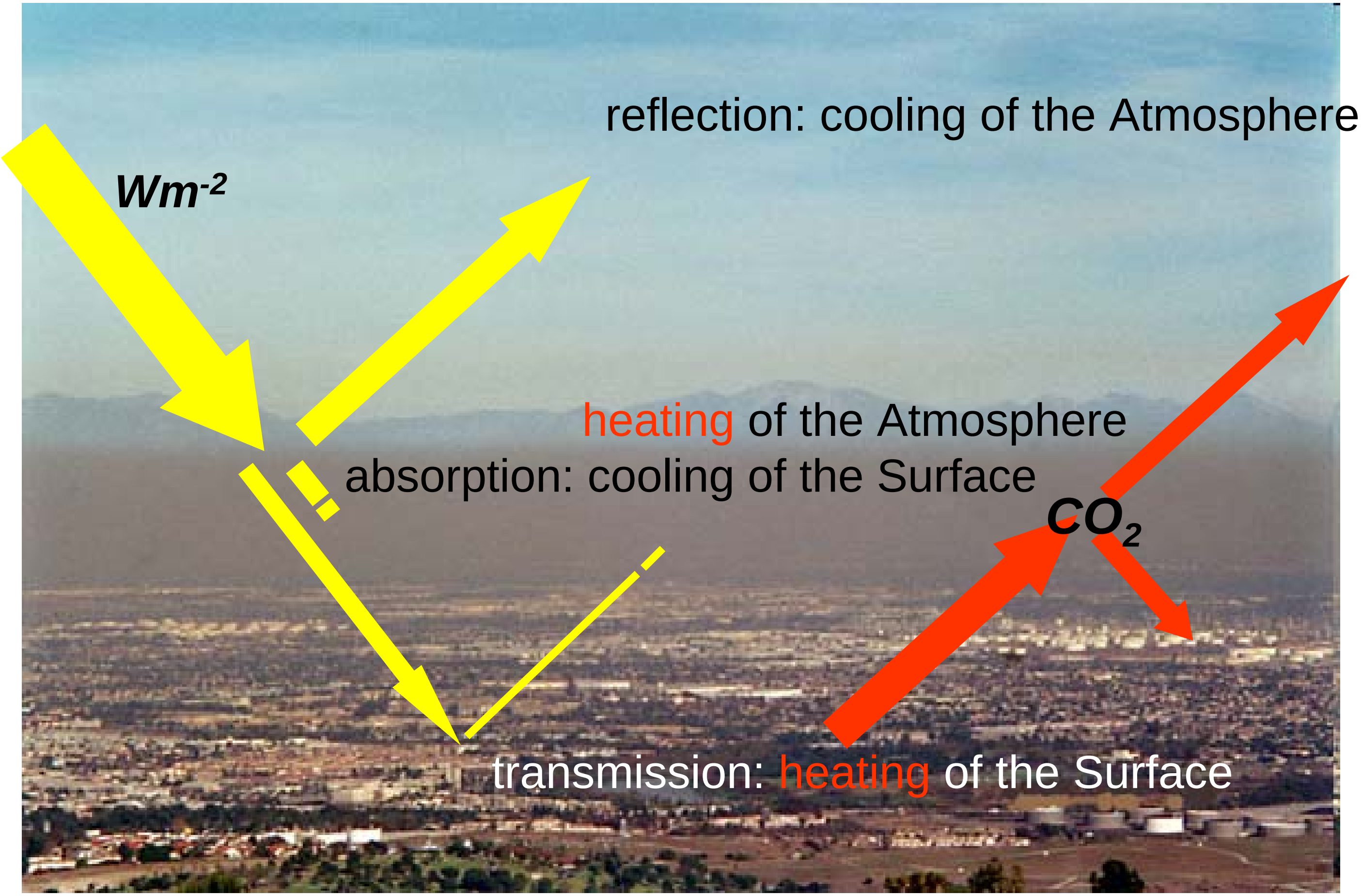
NASA

CHINA Beijing



NASA

air pollution and radiation transfer

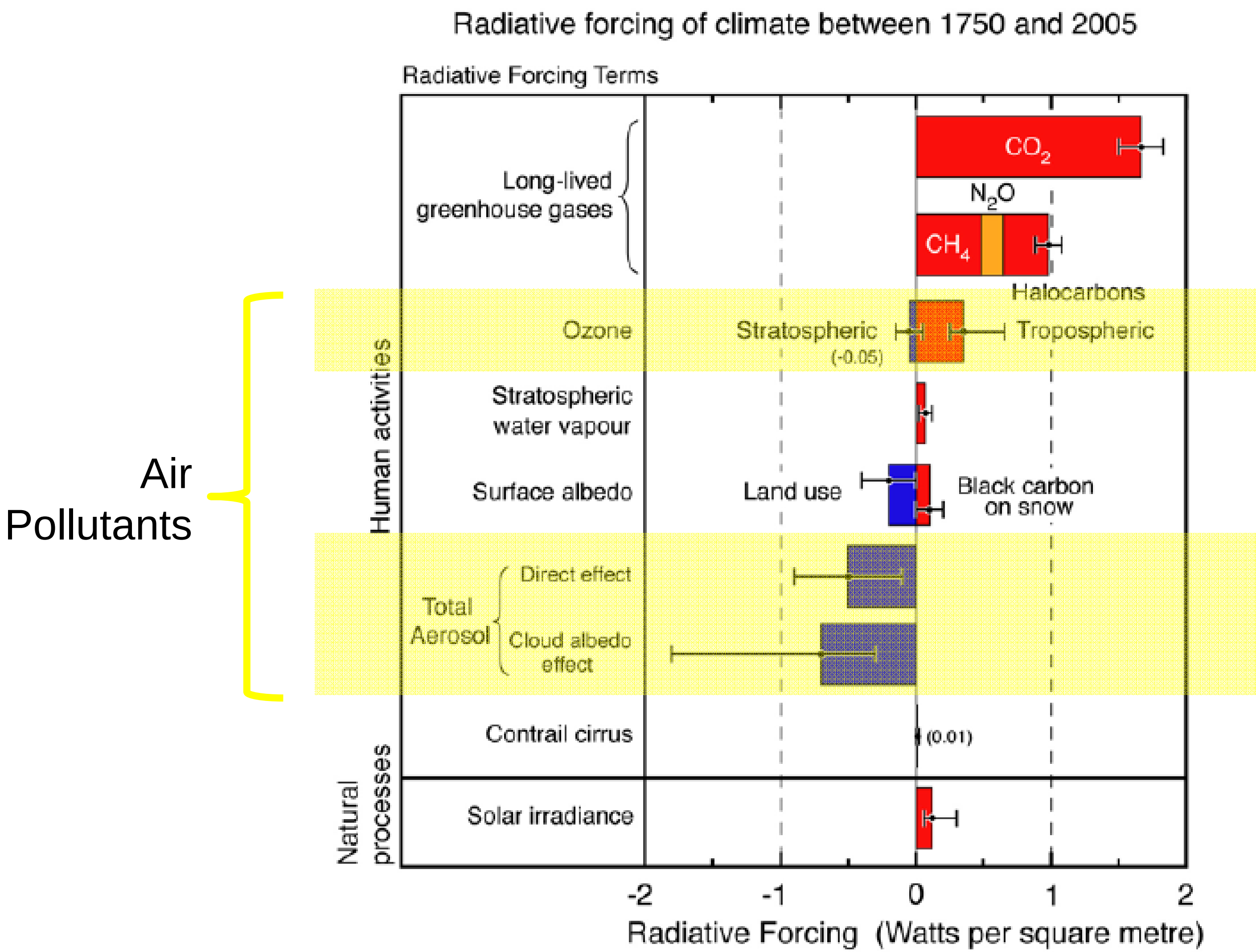


Mark Jacobson

USA San Jose

JRC EUROPEAN COMMISSION

air pollution / climate link: the past



IPCC 4AR (2007)

EUROPEAN COMMISSION JRC

Category	CO_2 concentrat at stabilisa (2005 = 37 ppm)[b]	CO_2 eq [b)] concentration at equilibrium	aking year CO_2 issions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	global mean temperature increase at equilibrium	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 - 490	2000 – 2015	-85 to -50	2.0 - 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes:

a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).

b)

In 2005 CO_2 concentration = 379 ppm (CO_2)

CO_2 equivalent concentration = 375 ppm (CO_2+ CH_4+ N_2O+O_3+ aerosols)

CO_2 equivalent concentration = 455 ppm (CO_2+ CH_4+ N_2O …)

IPCC 4AR Climate Change 2007 Synthesis Report Table 5.1

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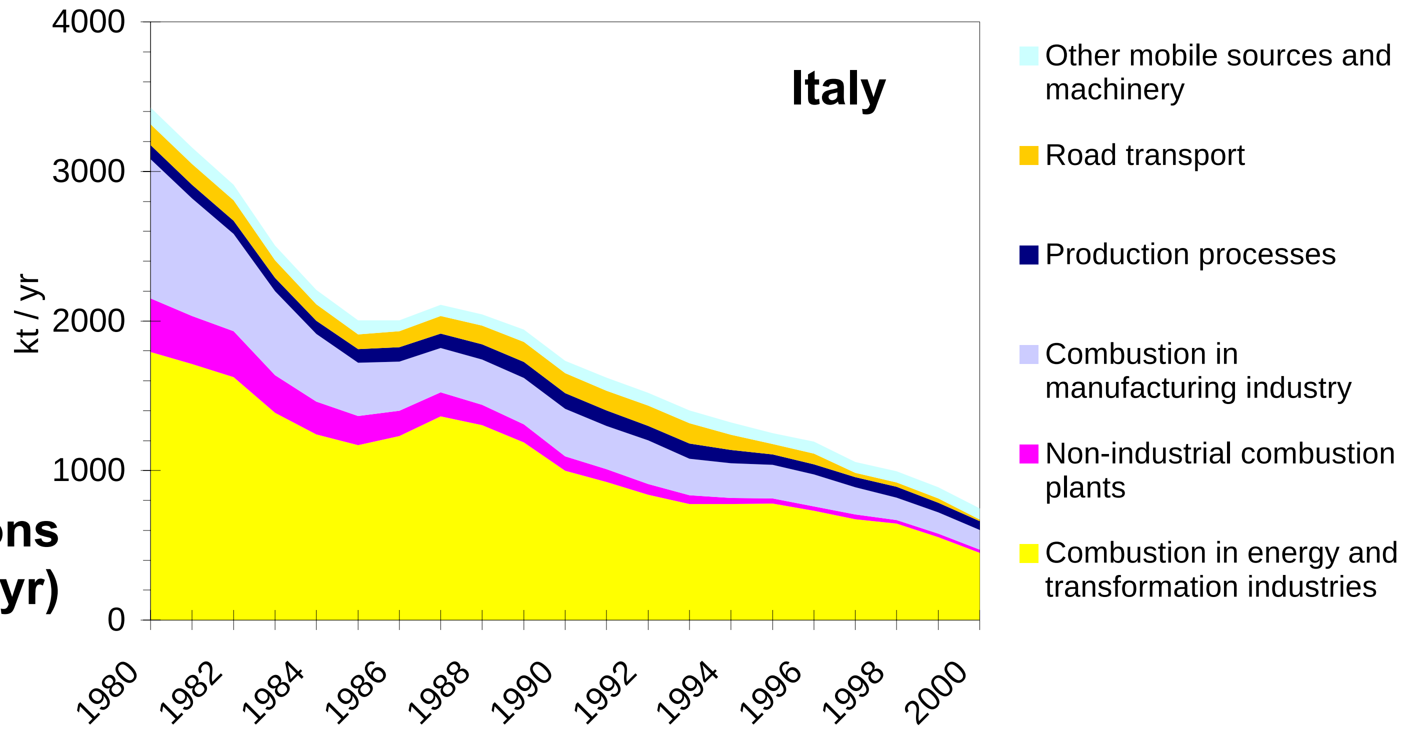
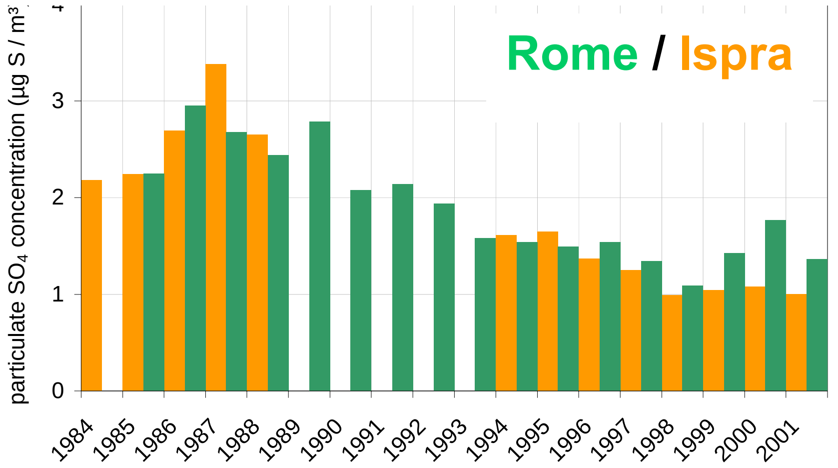
air pollution emission reductions in Italy

SO_2 emissions (kt / yr)



sulfate concentrations (μgr/m-3)



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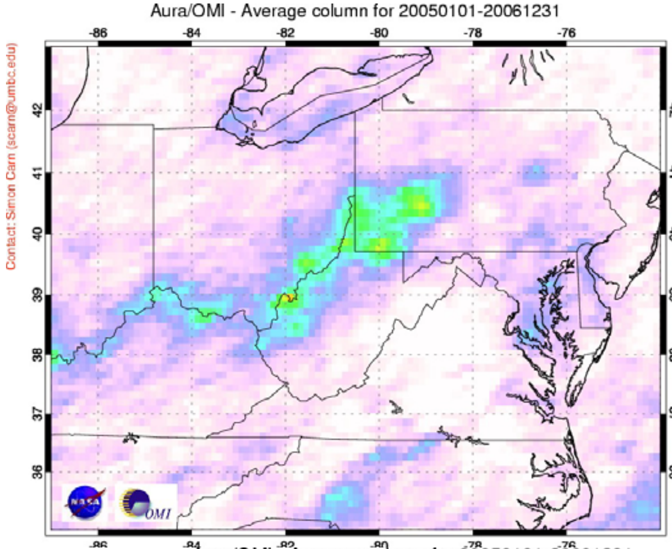
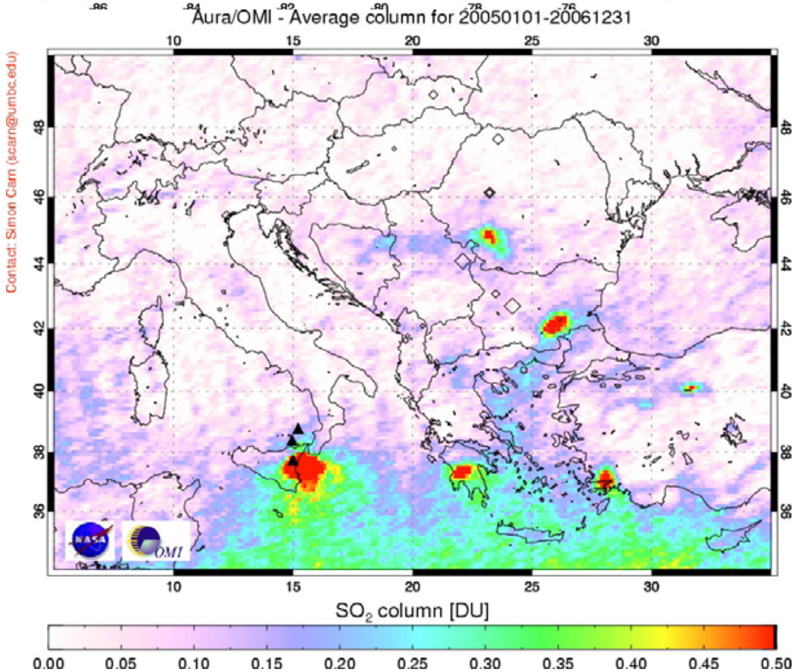
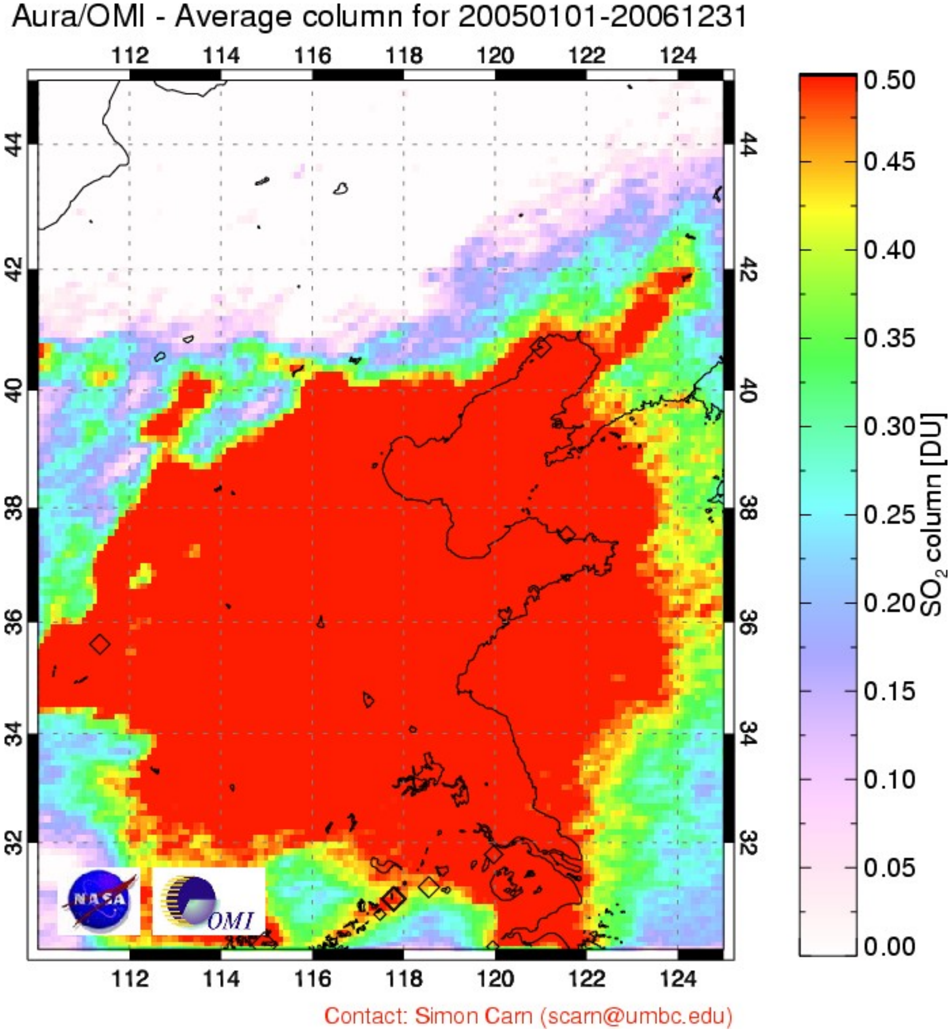
SO_2 concentration over US, Europe and China







2005-2006

NASA Aura/OMI
Column burdens

JRC
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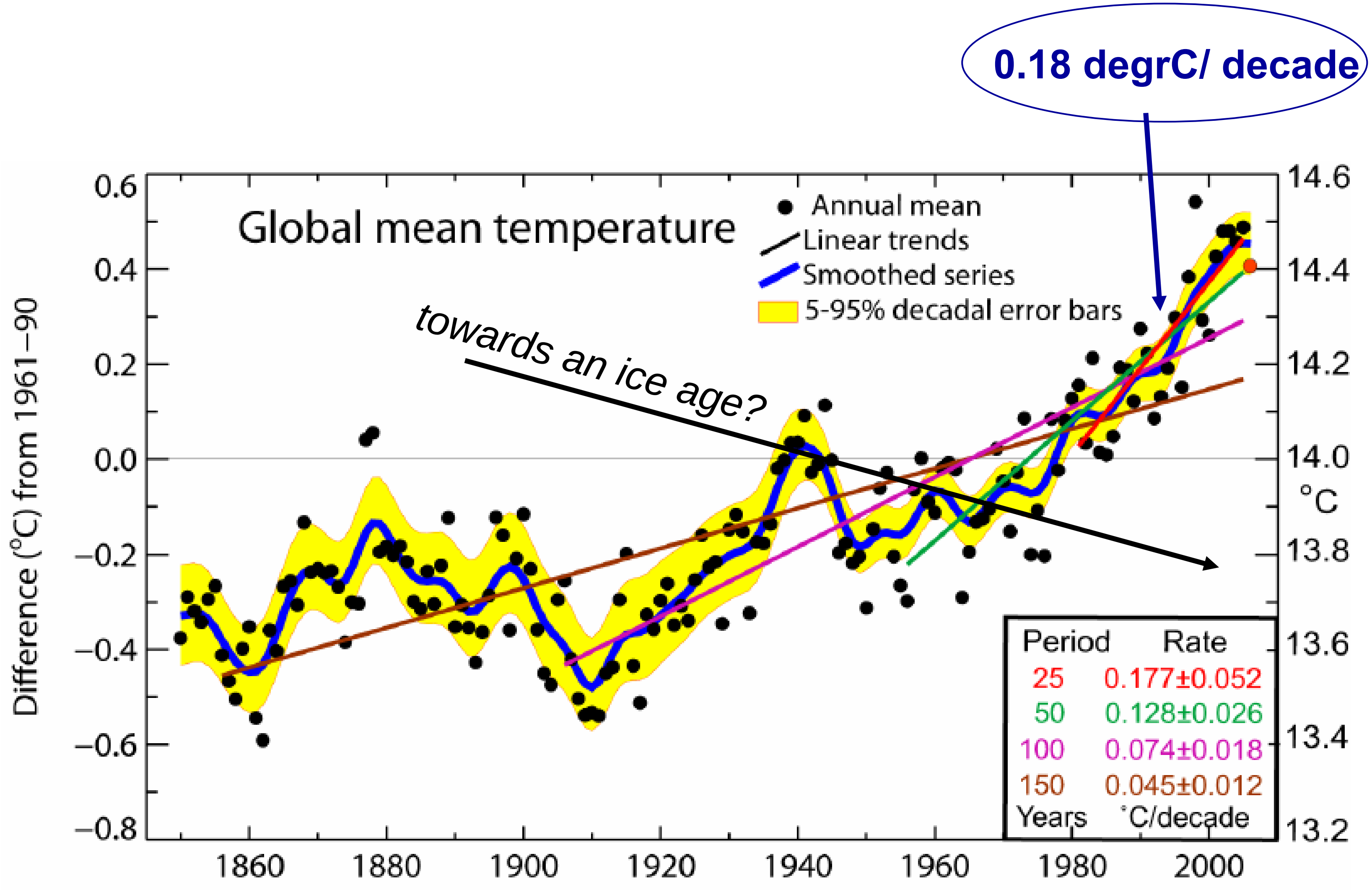
air pollution / climate link: the past



IPCC 4AR (2007)

air pollution / climate link: the past

Hemispheric mean temperature, difference from 1961-90 (degrC)

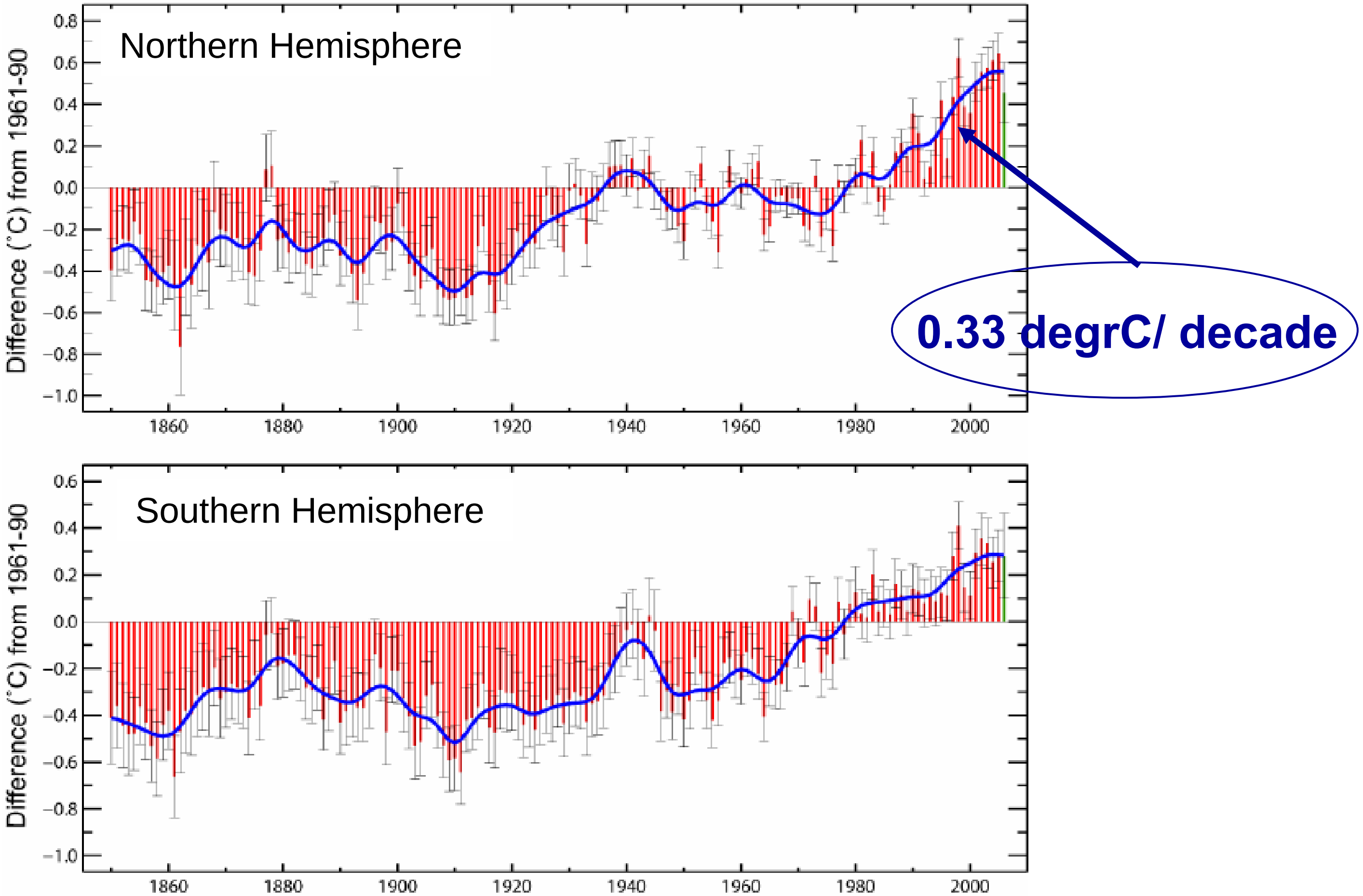


Figure 3.6. Global and hemispheric annual combined land surface air temperature and SST anomalies (°C) (red) relative to the 1961 to 1990 mean, along with 5 to 95% error bar ranges, from HadCRUT3 (adapted from Brohan et al., 2006). The blue decadal smoothing is described in Appendix 3.A. The preliminary value for 2006 is given as a green bar.

IPCC 4AR (2007)

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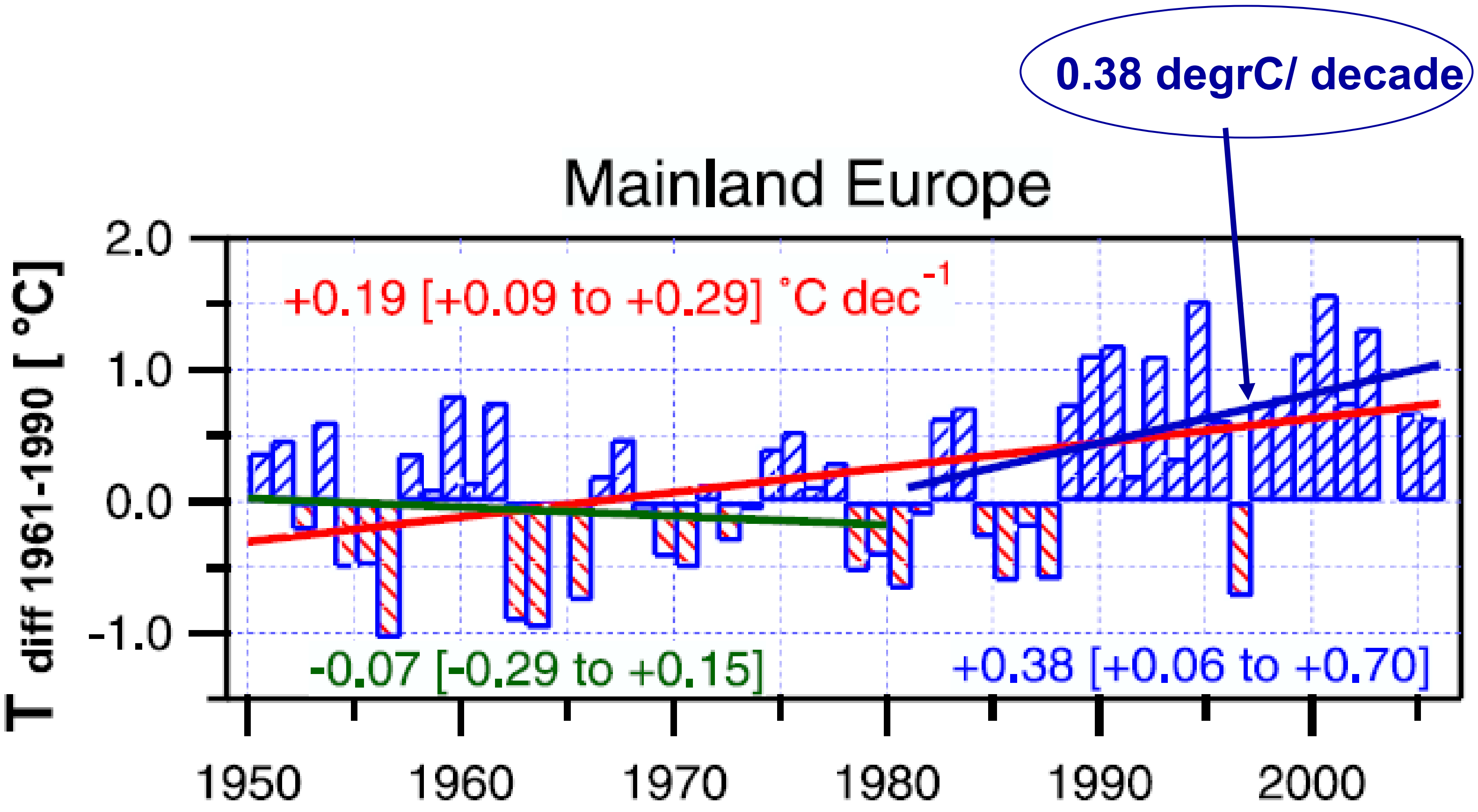
air pollution / climate link: the past



“Of the rapid temperature rise since 1980s …,about 2/3 are … likely forced by aerosol decline.”

Philipona et al, 2009, GRL

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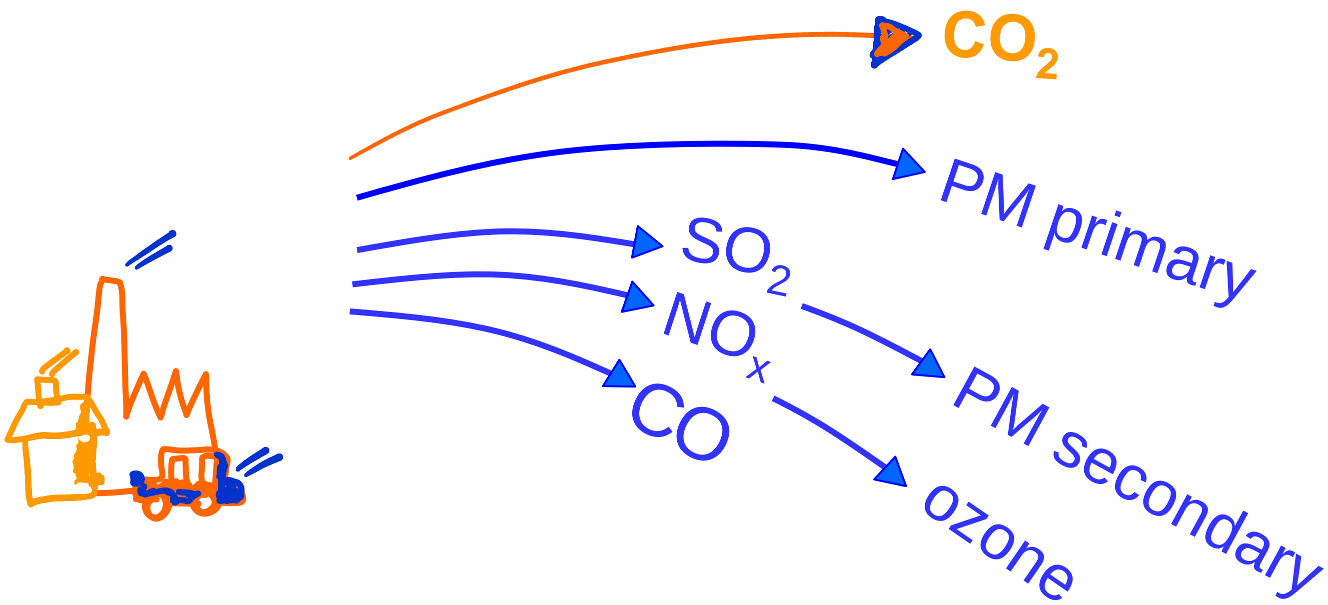
two problems, a common cause



fossil fuel use

climate change
air pollution

AIR POLLU

policies

AP's are rea

- AP's are sh
- local / regio
- national / re
- immediate r

- end-off-pipe
-(structural cl

EU15
75% reduction of
50% reduction of
50% reduction of

CLIMATE CHANGE

policies

CO2 is not reactive

- CO2 is long lived
- global problem
- global policies
- results decades from now

-structural / behavioral measures
- (end-off-pipe control, CCS)

EU15
8% reduction of CO2 : 1990 > 2010
20% reduction of CO2 1990 > 2020

- integrated AP and CC policy means:

  to define, in each world region, the right mix of technical and non-technical control measures, in order to be:

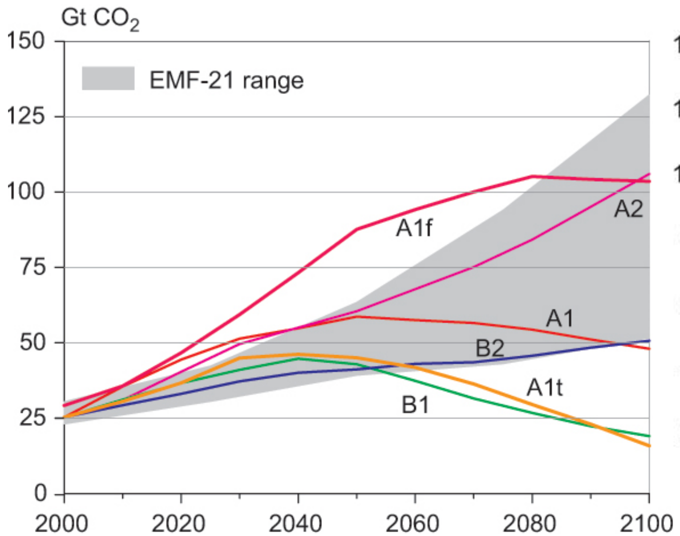
  – environmentally effective
    - reduce effects of air pollution on health and ecosystems
    - avoid dangerous climate change
  – cost-effective
  – socially equitable
    - allow for development and poverty reduction

EUROPEAN COMMISSION JRC

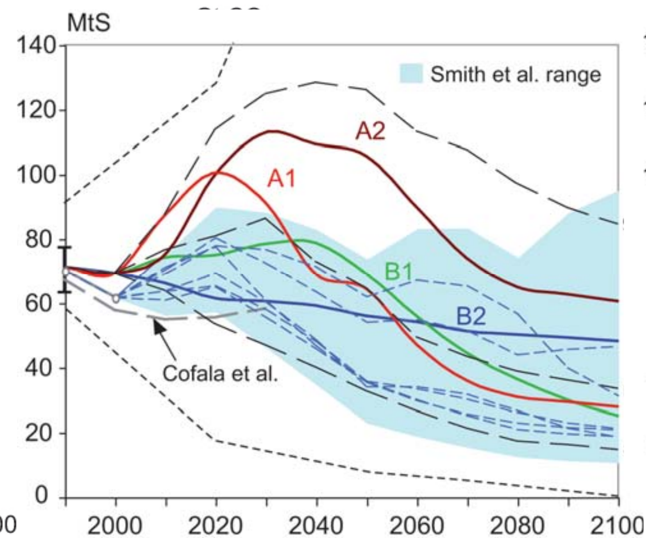
IPCC GHG and AP future emission scenarios

without extra policies

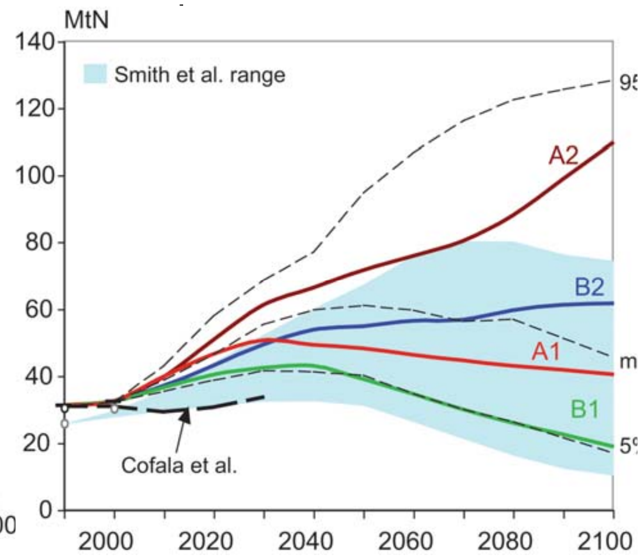
CO_2



SO_2



NO_x

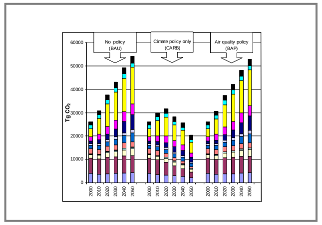


IPCC 4AR WG3

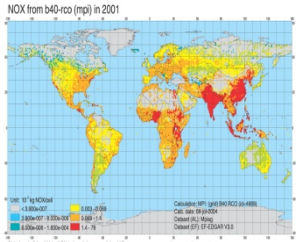
JRC GHG and AP future emission scenarios

with extra policies

AP control technologies
(GAINS JRC)

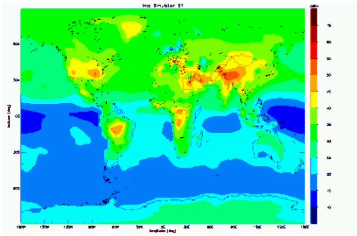


global scenarios
of
energy market
+
CC policy
(POLES JRC)

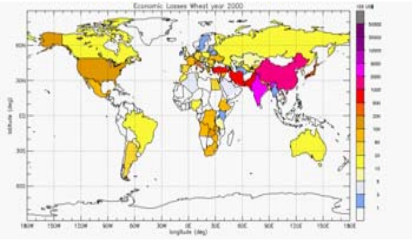


emissions
of
CO_2 &
air pollutants,

present &
future
(EDGAR JRC)



air pollution
&
climate
(TM5 CTM)
(ECHAM5 GCM)



impacts
&
economic costs
(JRC in house)

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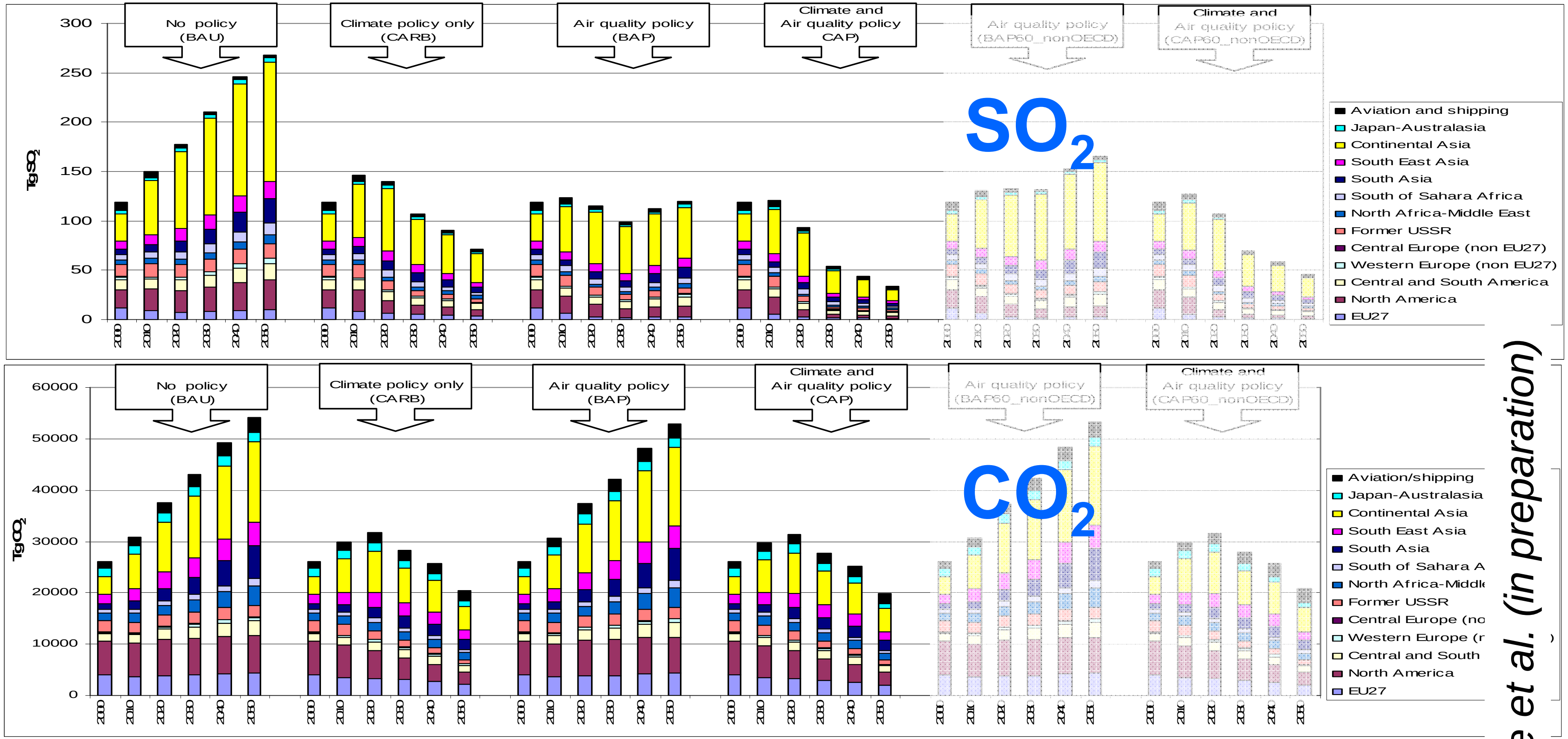
JRC GHG and AP future emission scenarios

with extra policies



BAU *(implement current legislation)*

CC only *(25% CO2 reduction by 2050, globally)*

AP only *(~EU standards globally)*

CC + AP

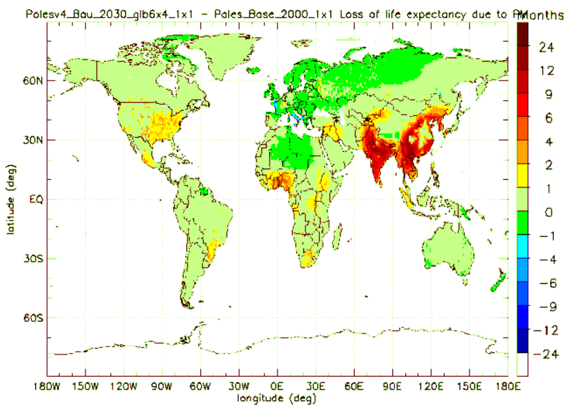
Van Aardenne et al. (in preparation)

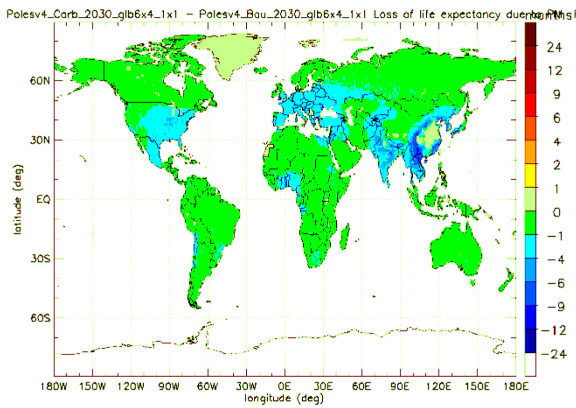
changes in health impacts
between 2000 and 2030

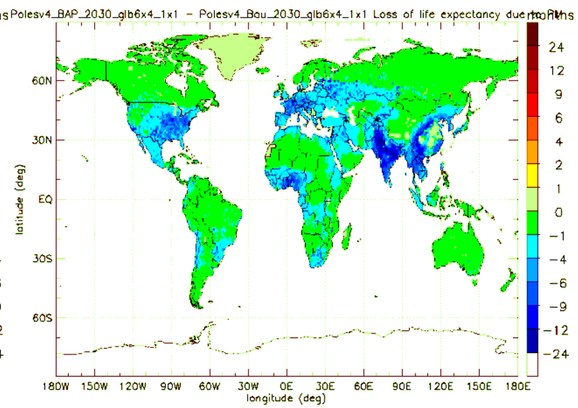
BAU — loss of life expectancy between 2000 and 2030 without additional policies (months)

CC only — effect of CC-only policy by 2030 compared to BAU

AP only — effect of AP-only policy by 2030 compared to BAU

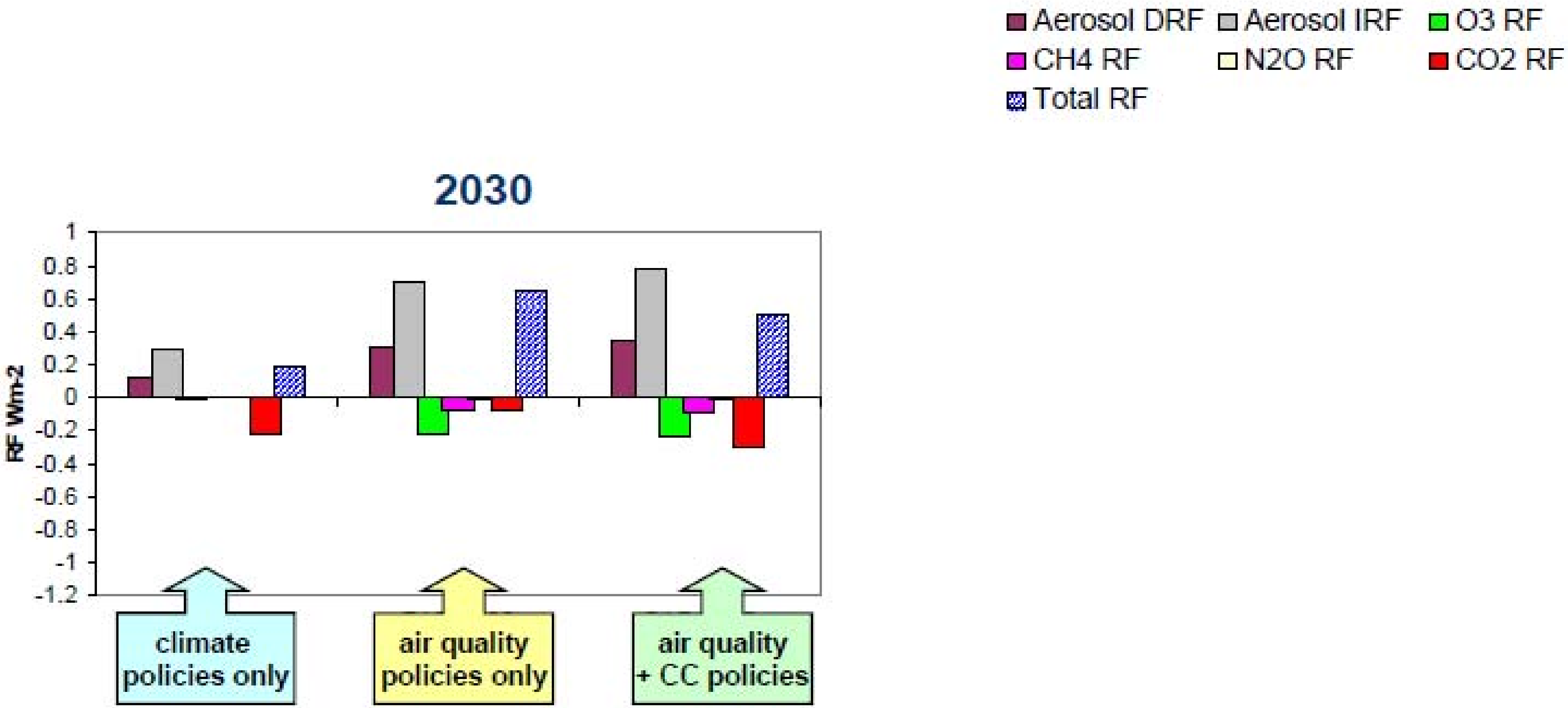






changes in radiative forcing *because* of policies

Effect of policies in 2030 compared to BAU in 2030

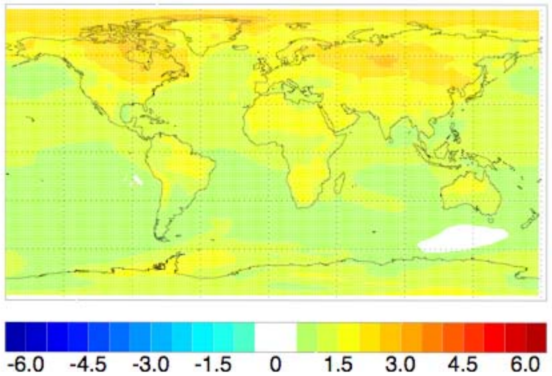


changes in surface temperature
between 2000 and 2030ies

50% of equilibrium temperature

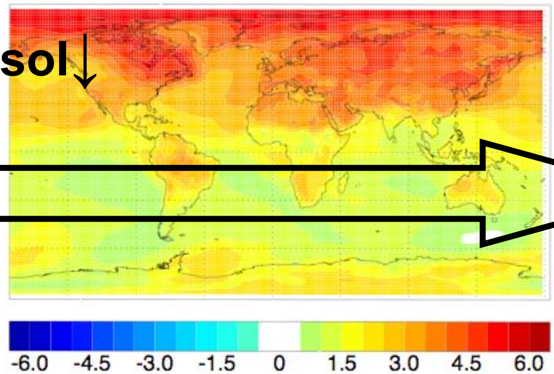
GHG↑

ΔT =
***0.6* °C**



GHG↑+Aerosol↓

ΔT =
***1.1* °C**



***0.3 - 0.4* °C/decade globally**
***0.7 – 0.8* °C/decade locally**

GHGs: SRES B2 scenario
Aerosols: IIASA MFR scenario

Kloster et al., 2009, Climate Dynamics (in press, available on-line)

changes in surface temperature

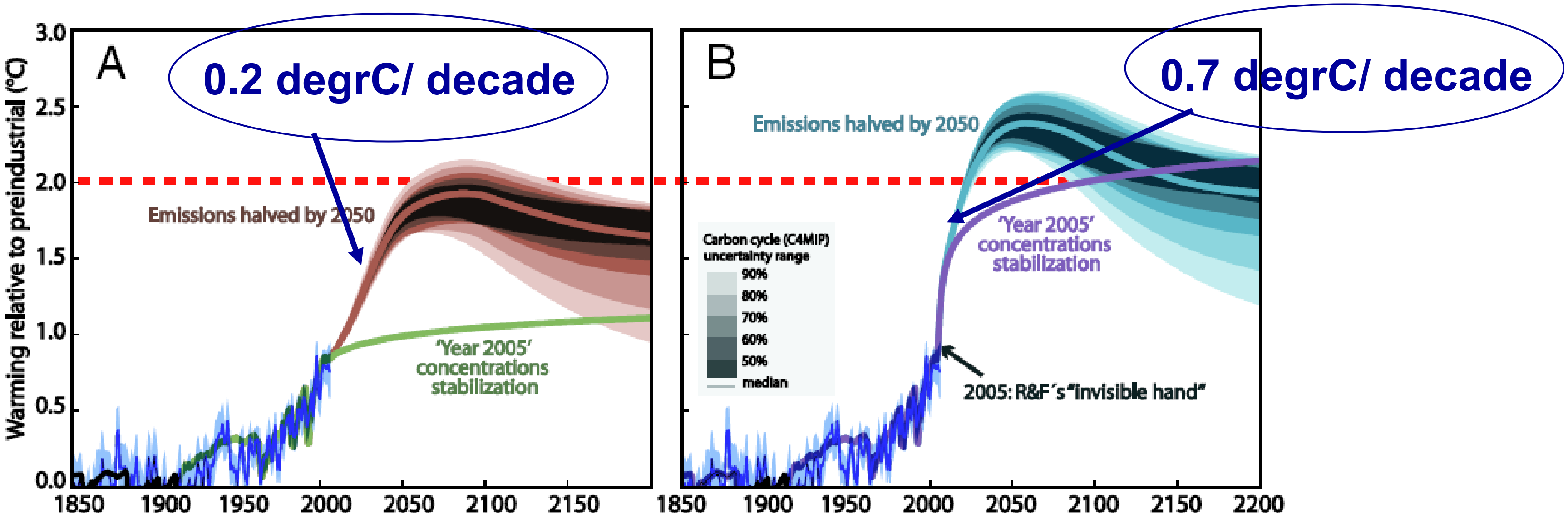
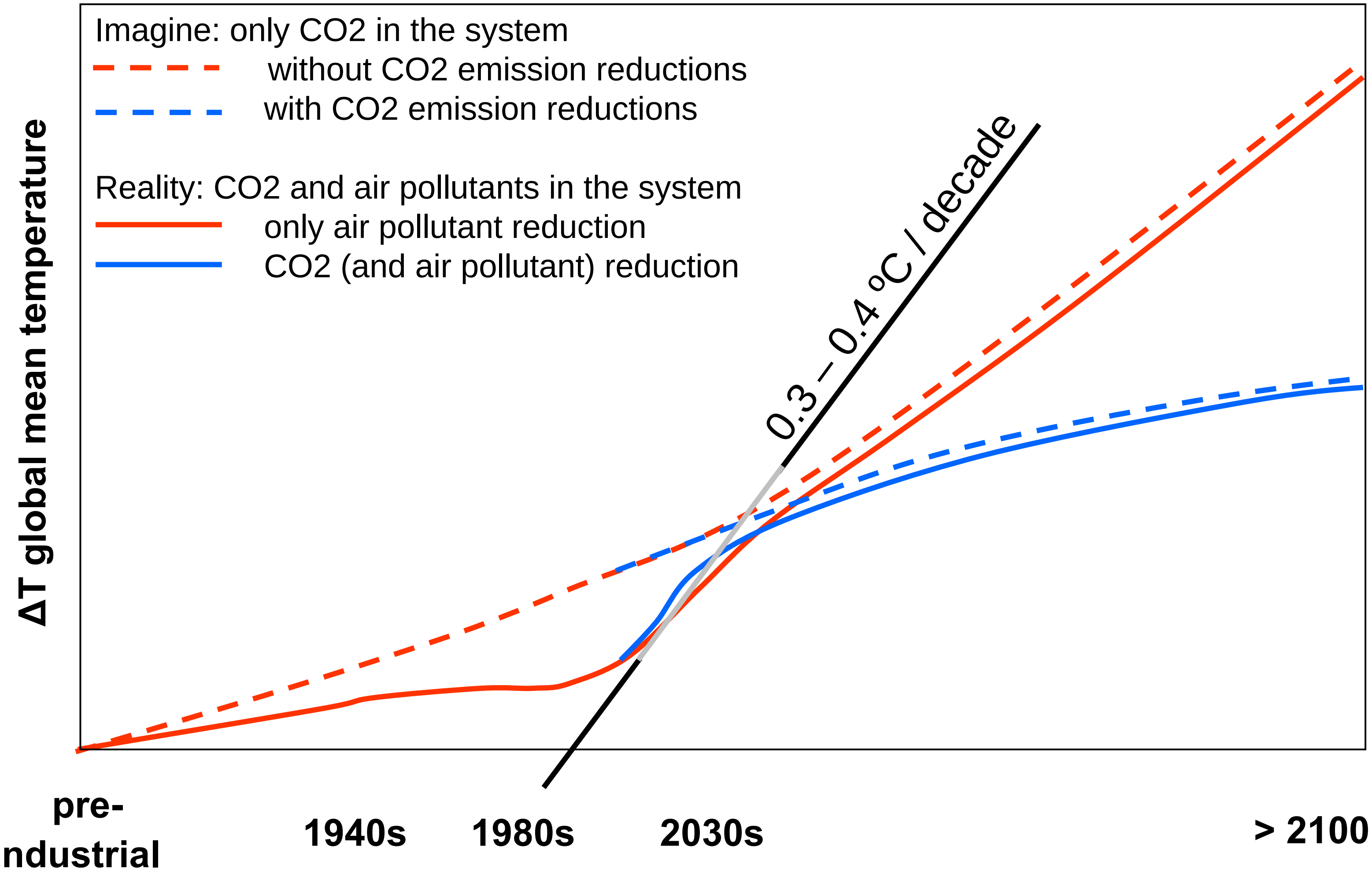


Fig. 1. Comparison of GMT development as resulting from fixing concentrations at 2005 levels [''concentrations stabilization scenario'' (CSS)] and halving global Kyoto-GHG emissions by 2050 relative to 2000 levels [''mitigation scenario'' (MS)], respectively. (*A*) Freezing of current air pollution and GHG levels in CSS, and concomitant gradual decrease of air pollution in MS. (*B*) The ''invisible hand'' of R&F (1) eliminates all forcings except those of long-lived GHGs and tropospheric ozone in 2005, i.e., aerosol cooling vanishes, in both CSS and MS. Climate sensitivity is chosen as 3°C throughout; other climate parameters (such as those affecting ocean inertia) are calibrated toward HadCM3; carbon cycle parameters are varied for representing the range of ten C4MIP models (14) by using MAGICC 6.0 (13). Historical observations of GMT are taken from HadCRUT3v (15).

Schellnhuber, PNAS, 2008

the overall picture: a bumpy road ahead



Raes and Seinfeld, 2009, Atm. Env. (in press, available on-line)

conclusions

- Reducing the use of fossil fuels (structural/behavioral changes, CC policy) and reducing emissions from fossil fuels (end-of-pipe control, AP policy) are required immediately to tackle air pollution and climate change.
- CC policies have co-benefits for air pollution (and others)
- AP policies are still required, to tackle air pollution in all world regions
- AP policies are expected to lead to a faster global and regional warming, mainly because of the reduction of aerosols.
- CC policies that aim at climate stabilization in the long term (> 50 years), will lead to a faster warming in the short term (< 30 years).
- Communicate well about why we do what: make distinction between short-term and long-term benifits and disbenifits of AP and CC policies
- The problem of a faster warming in the short term might be alleviated by focusing *also* on reductions of short-lived warming agents: black carbon aerosols, CH_4 and tropospheric ozone (*Hansen's alternative scenario*)

we need

geo-renovation

rather than

geo-engineering

thanks

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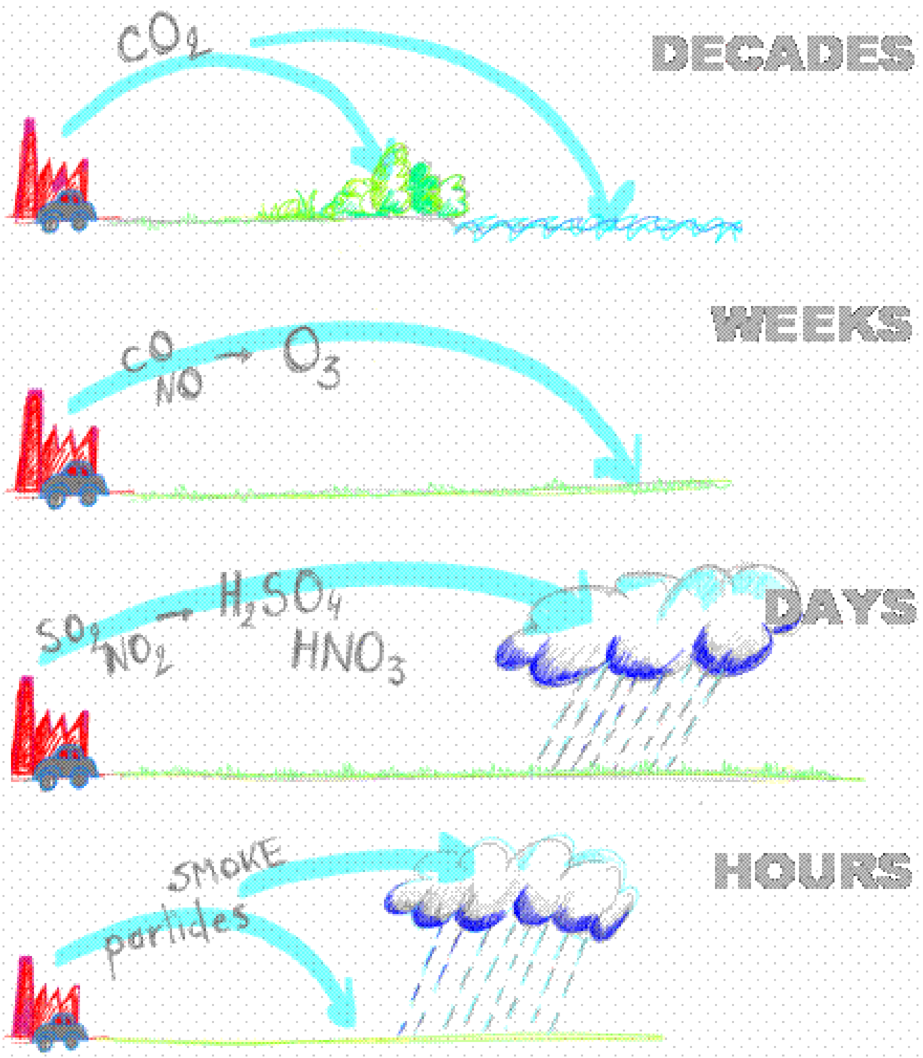
atmospheric life times of GHGs and APs

Air
Pollutants



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NO_2 concentrations worldwide

1997-2002

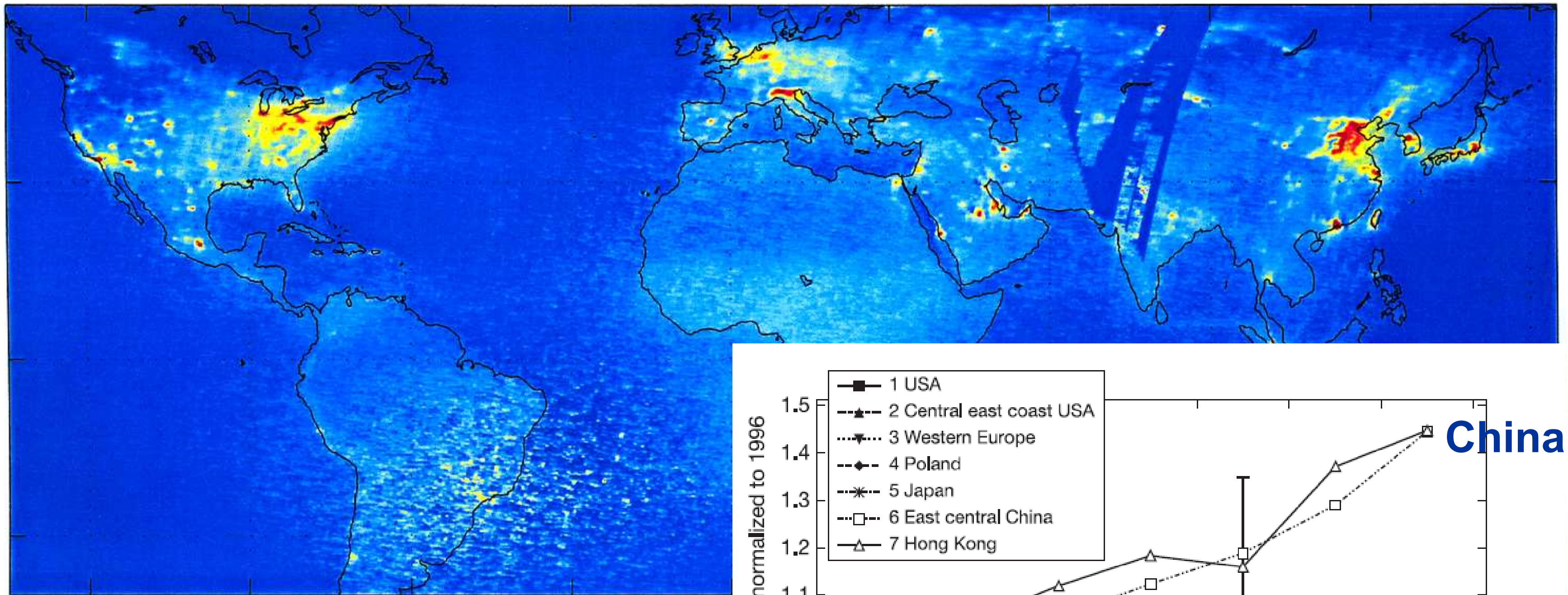
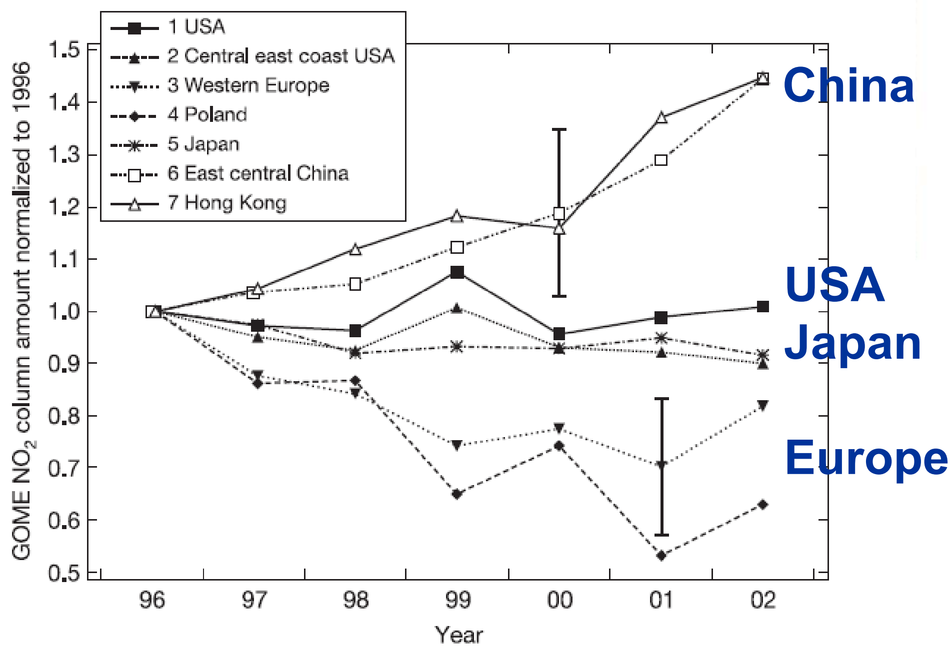


Figure 5: Global mean of tropospheric NO_2 VCD, using narrow viewing mode pixels only (

ESA SCIAMACHY

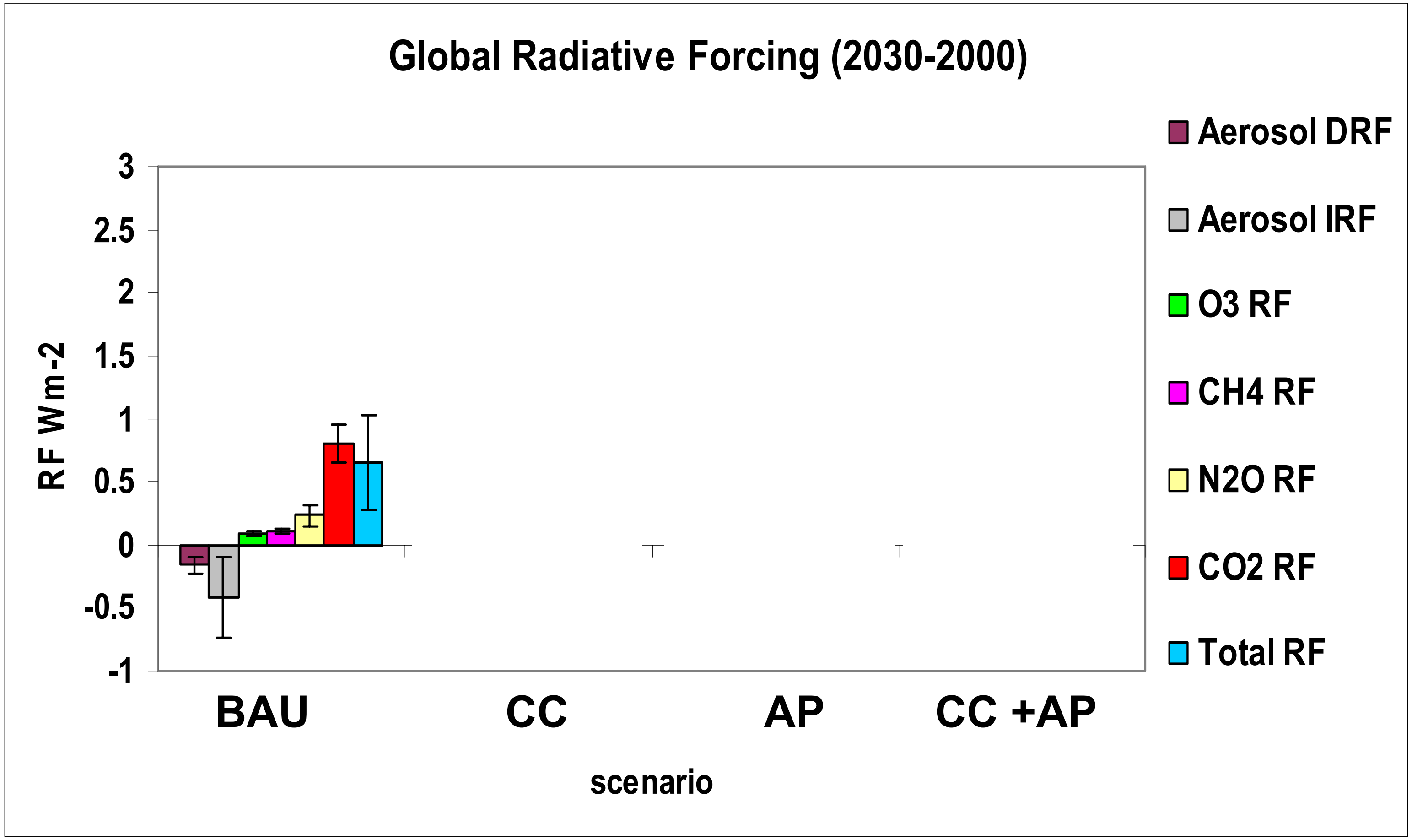
Column burdens



Richter et al. Nature 2005

EUROPEAN COMMISSION JRC

changes in radiative forcing
between 2000 and 2030



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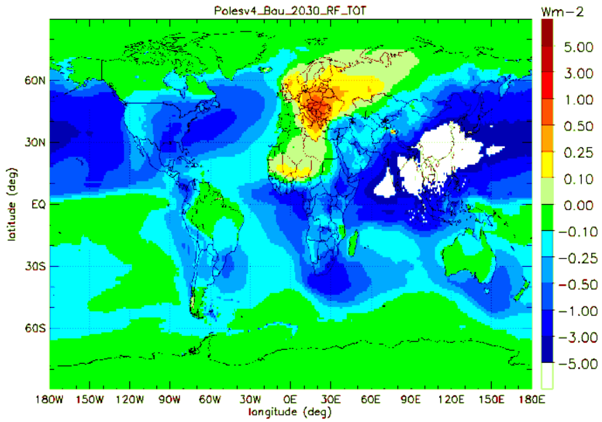
changes in radiative forcing due to aerosols
between 2000 and 2030

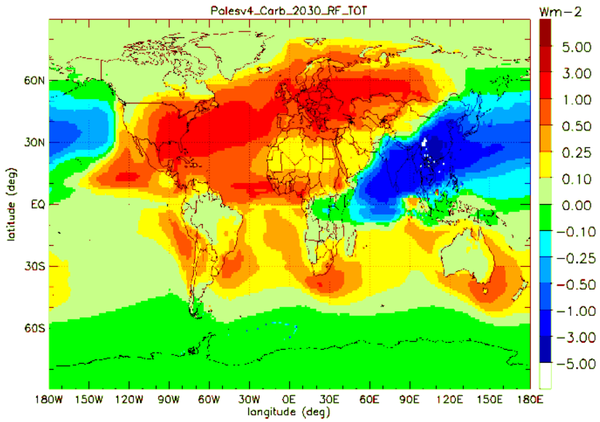
BAU

TOA radiative forcing between 2000 and 2030 without policies (W/m2)



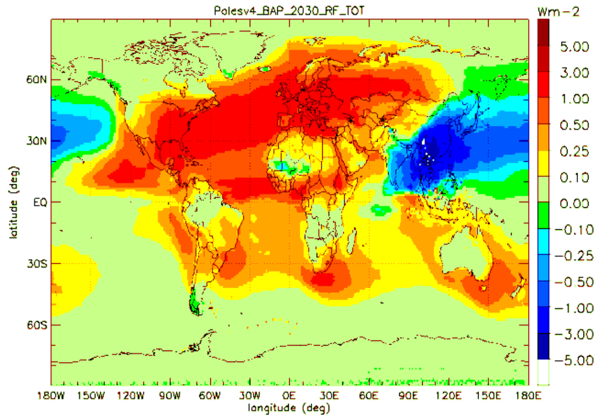
CC only

TOA radiative forcing between 2000 and 2030 with CC policies only (W/m2)



AP only

TOA radiative forcing between 2000 and 2030 with AP policies only (W/m2)



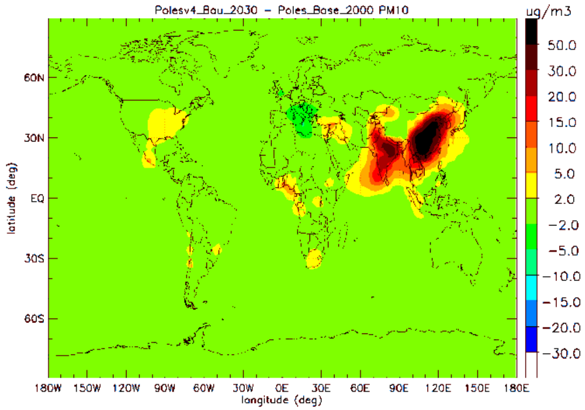
Van Aardenne et al. (in preparation)

EUROPEAN COMMISSION JRC

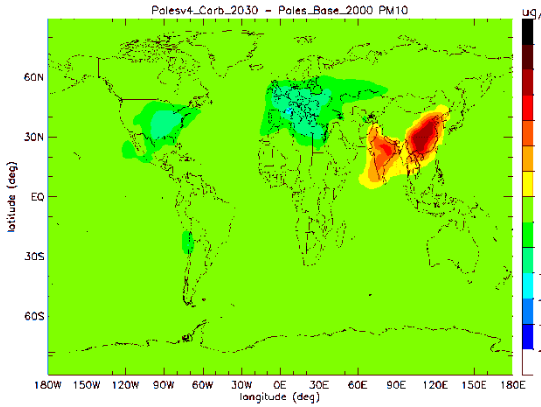
changes in air pollutant fields
between 2000 and 2030

PM10 (surface)

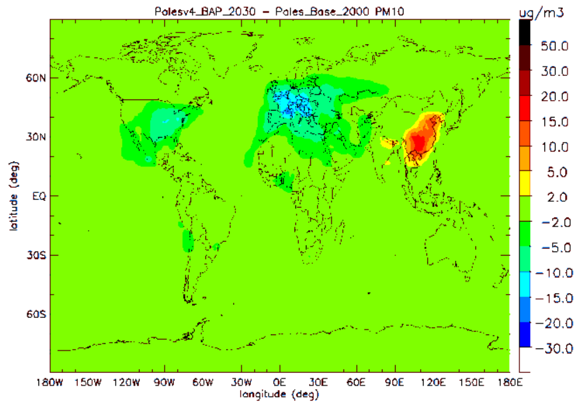
BAU



CC policy only



AP policy only



Van Aardenne et al. (in preparation)

Italo Calvino (1923-1985)

SIX MEMO'S FOR THE NEXT MILLENNIUM

1- Lightness
2- Quickness
3- Exactitude
4- Visibility
5- Multiplicity
6- Consistency

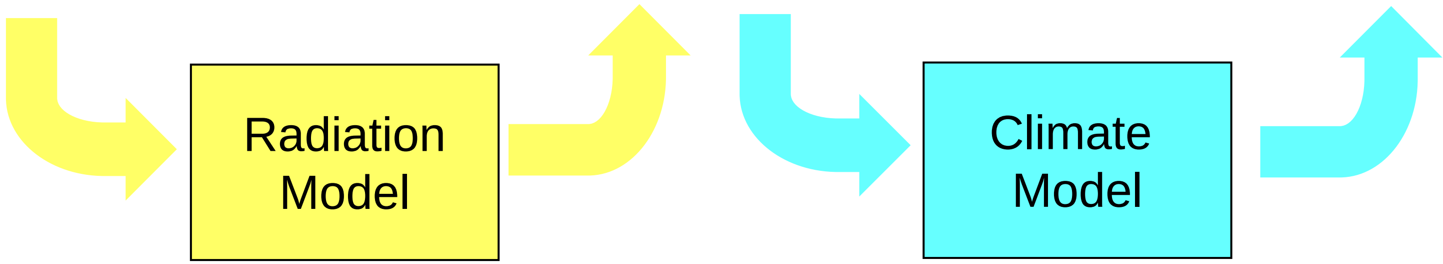
change in greenhouse gas and air pollutant *concentrations*

effect on Earths radiation balance: **"radiative forcing (Wm^{-2})**

effect on climate:
- **Temperature (ºC)**
- precipitation

immediate response

response time of decades



climate sensitivity

0.81 (0.41 – 1.2) ºC/ Wm-2
3.7 (2 – 4.5) ºC for doubling CO_2

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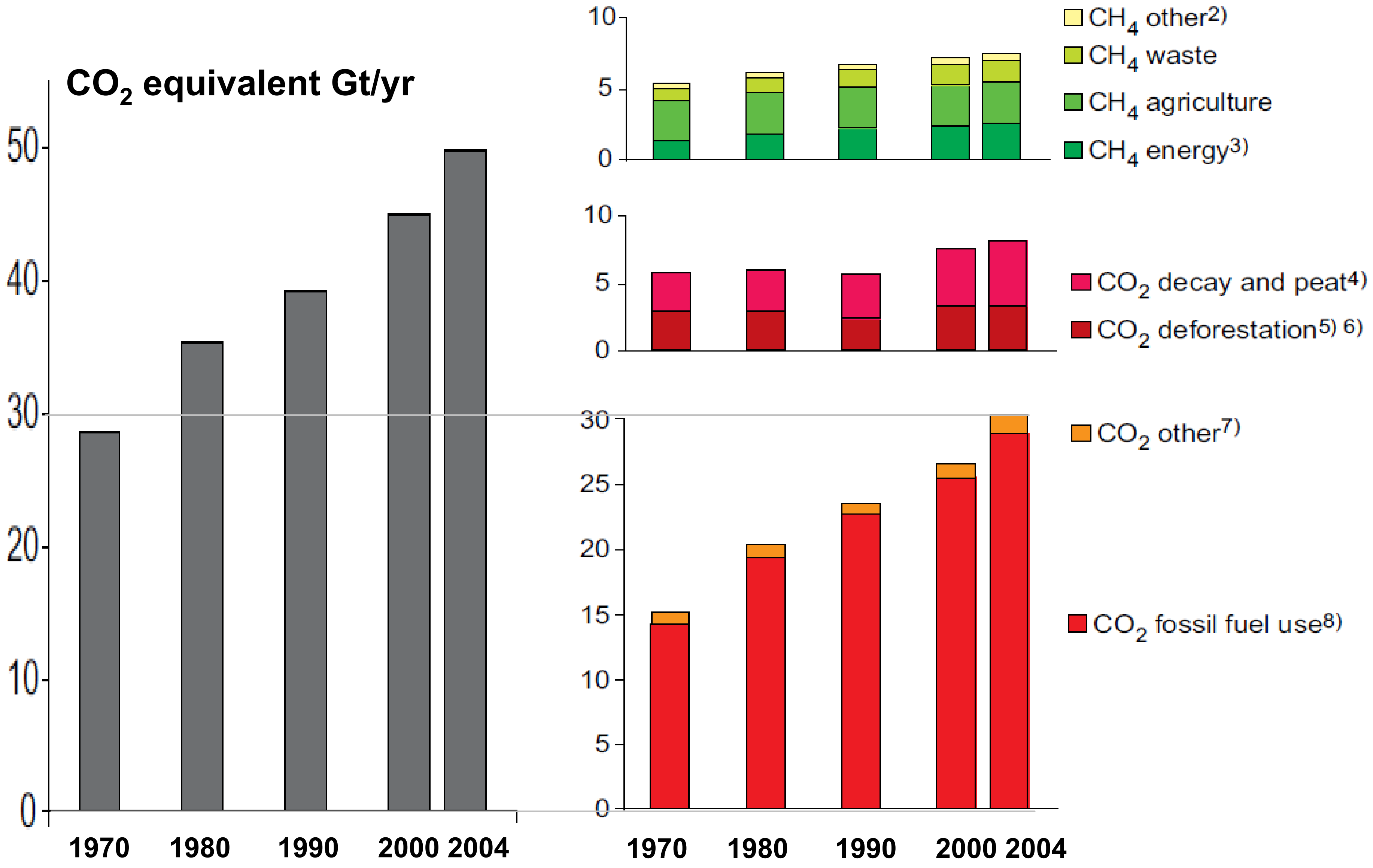
past emissions of greenhouse gases



IPCC 4AR WG3

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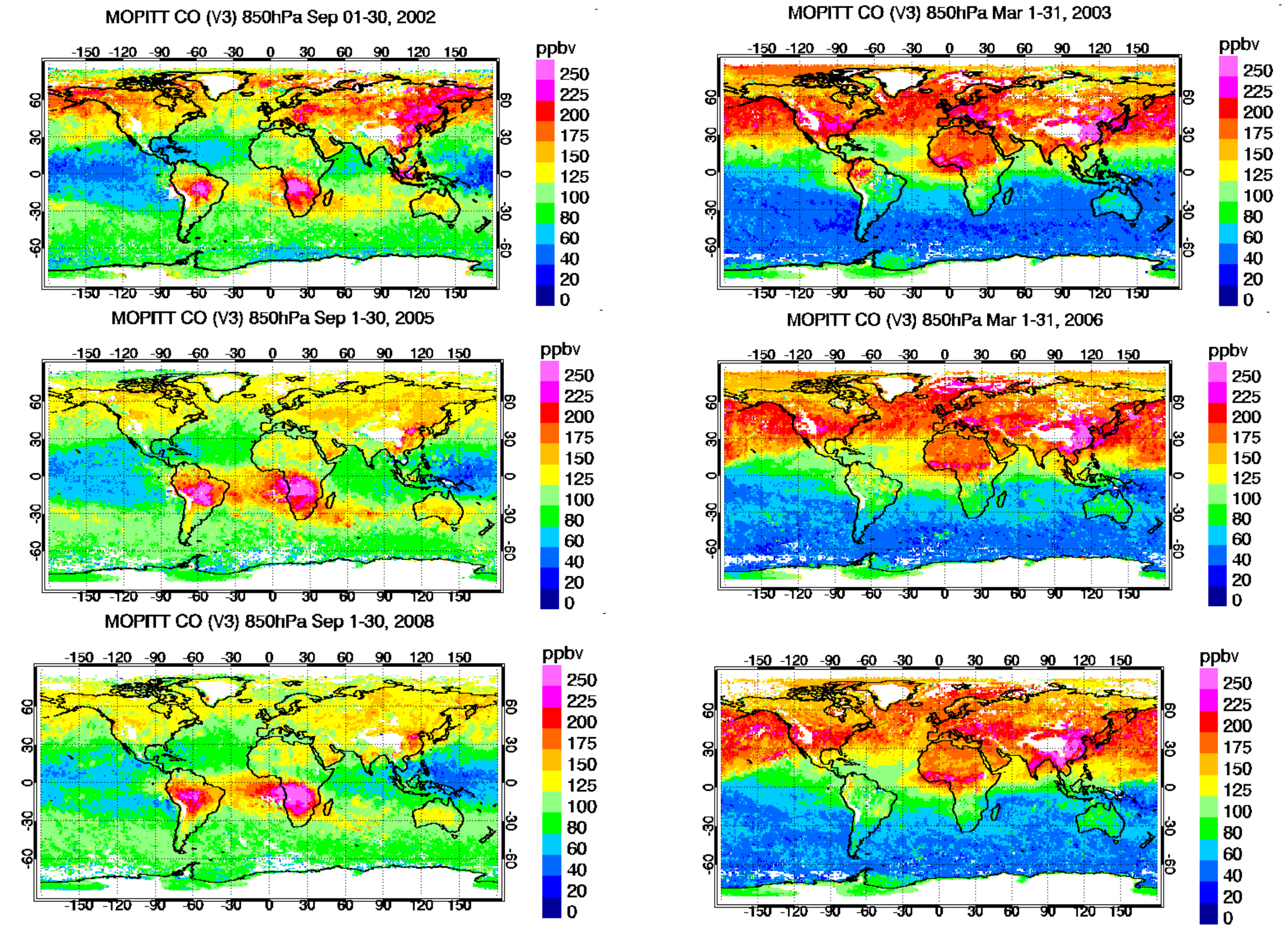

Gridded at 1x1deg from MOP02-200809??-L2V5.*.hdf (apriori fraction < 50%)

Gridded at 1x1deg from MOP02-200903??-L2V5.*.hdf (apriori fraction < 50%)

NASA / MOPITT CO http://www.acd.ucar.edu/mopitt

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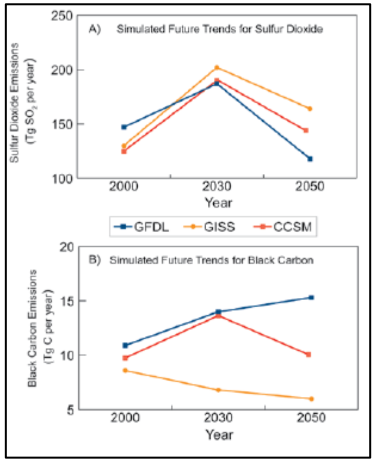
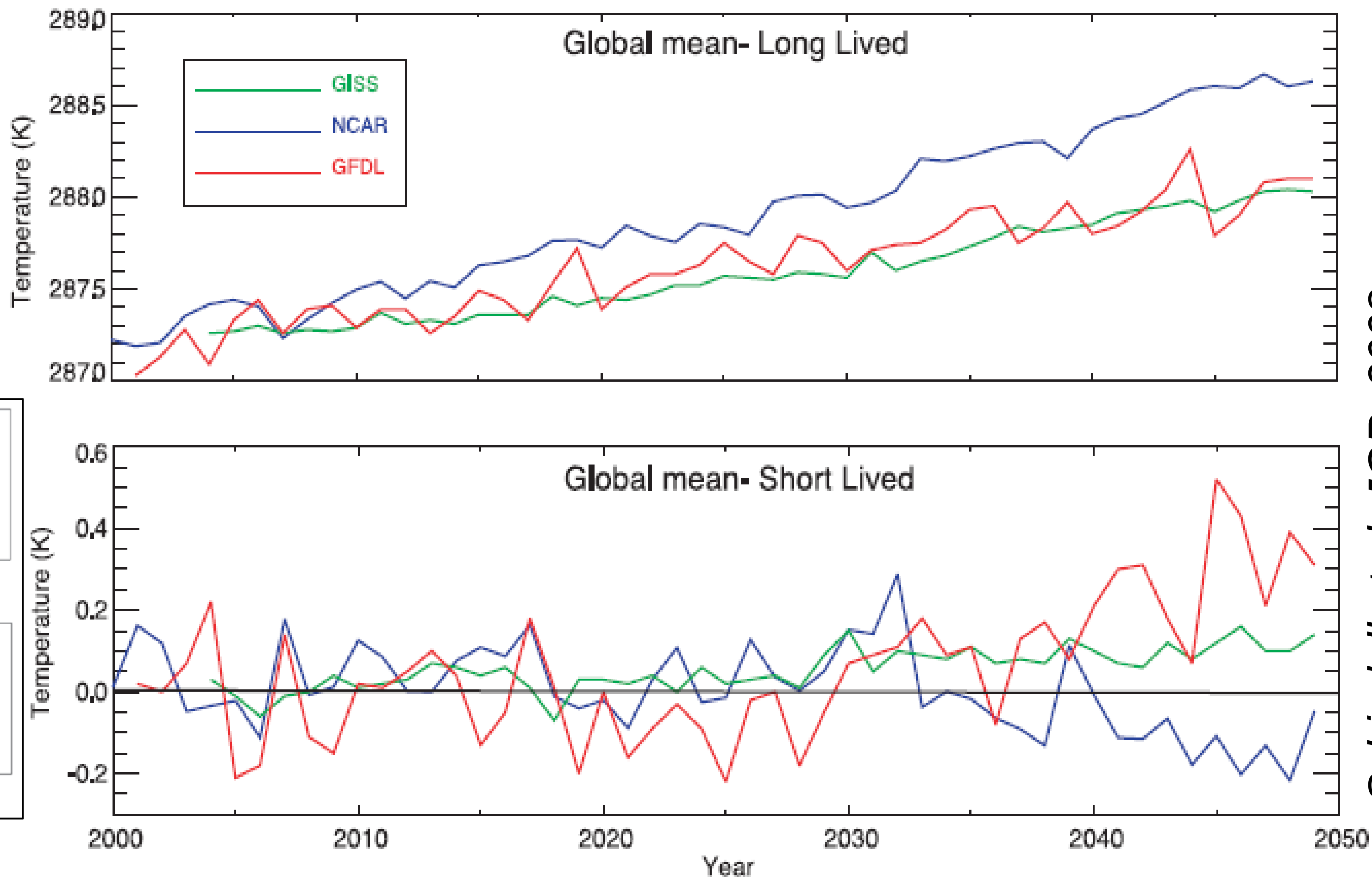
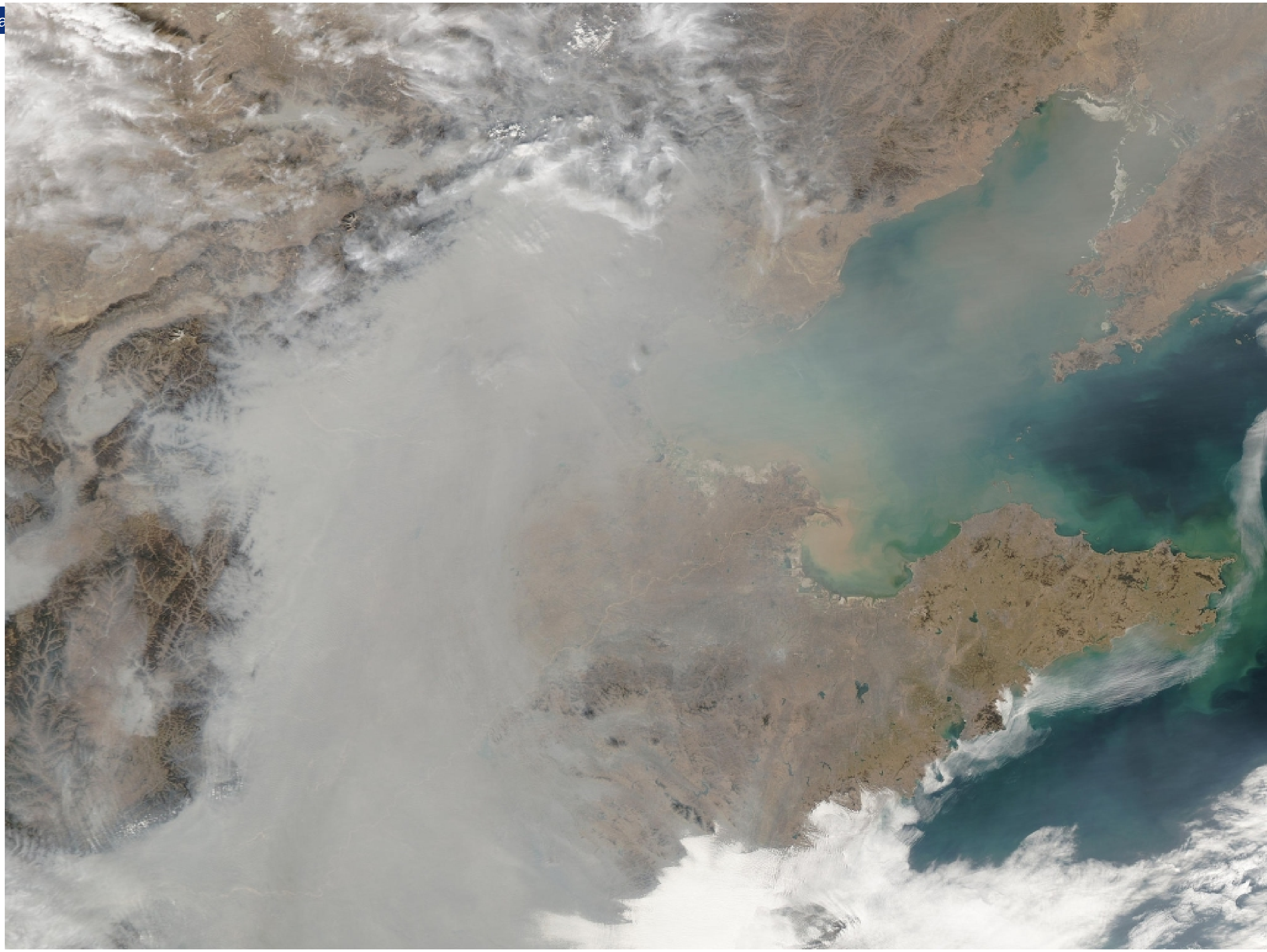




Schindell et al.,JGR, 2008

Figure 5. Global mean annual average temperature in the simulations with time-varying long-lived species only (top) and due to short-lived species based on the ((long-lived+short-lived)-long-lived) difference (bottom). Results are ensemble means for GFDL and GISS.

the direct” radiative effect of aerosols



absorption an scattering in urban haze
Beijing area

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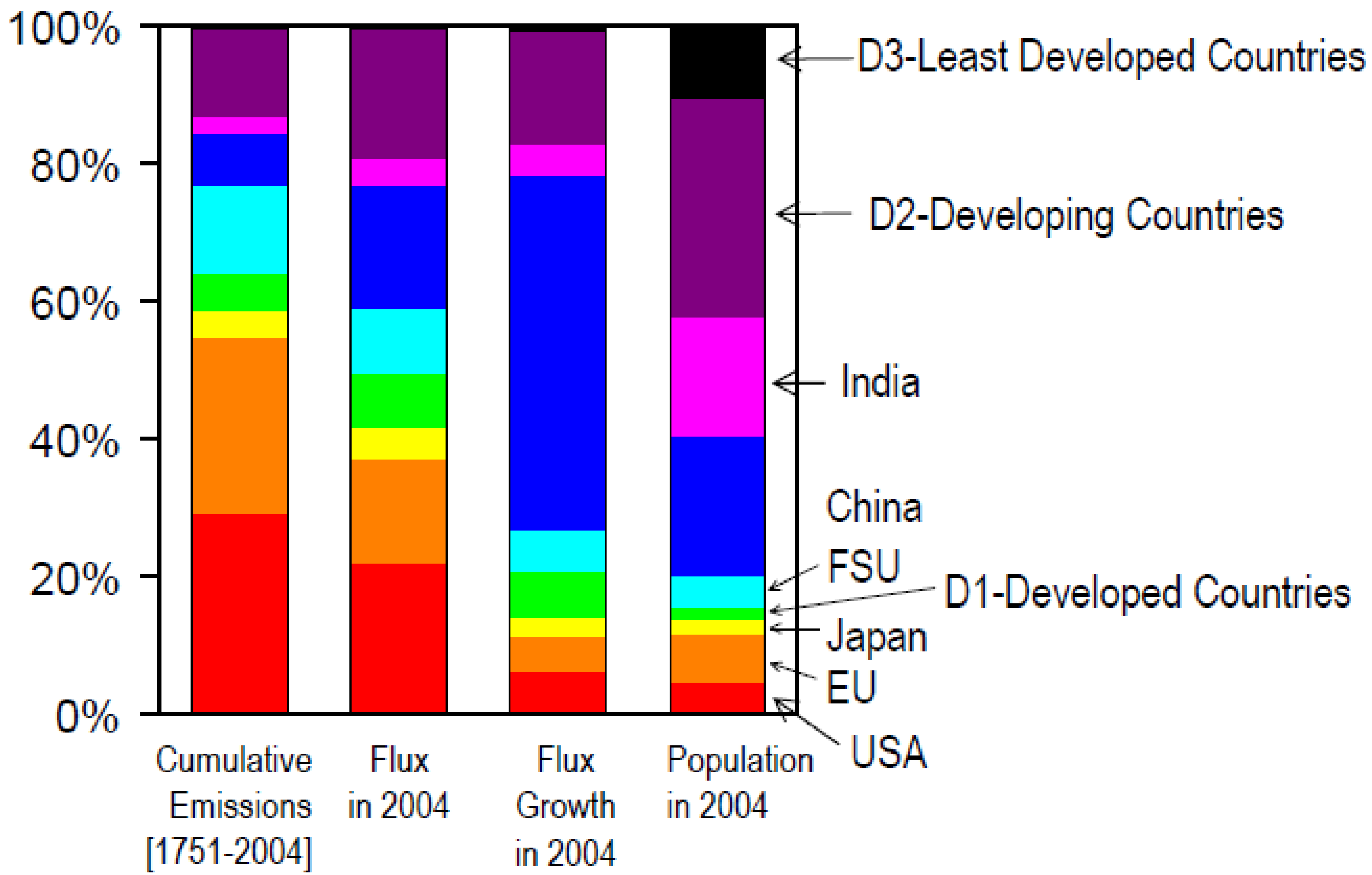
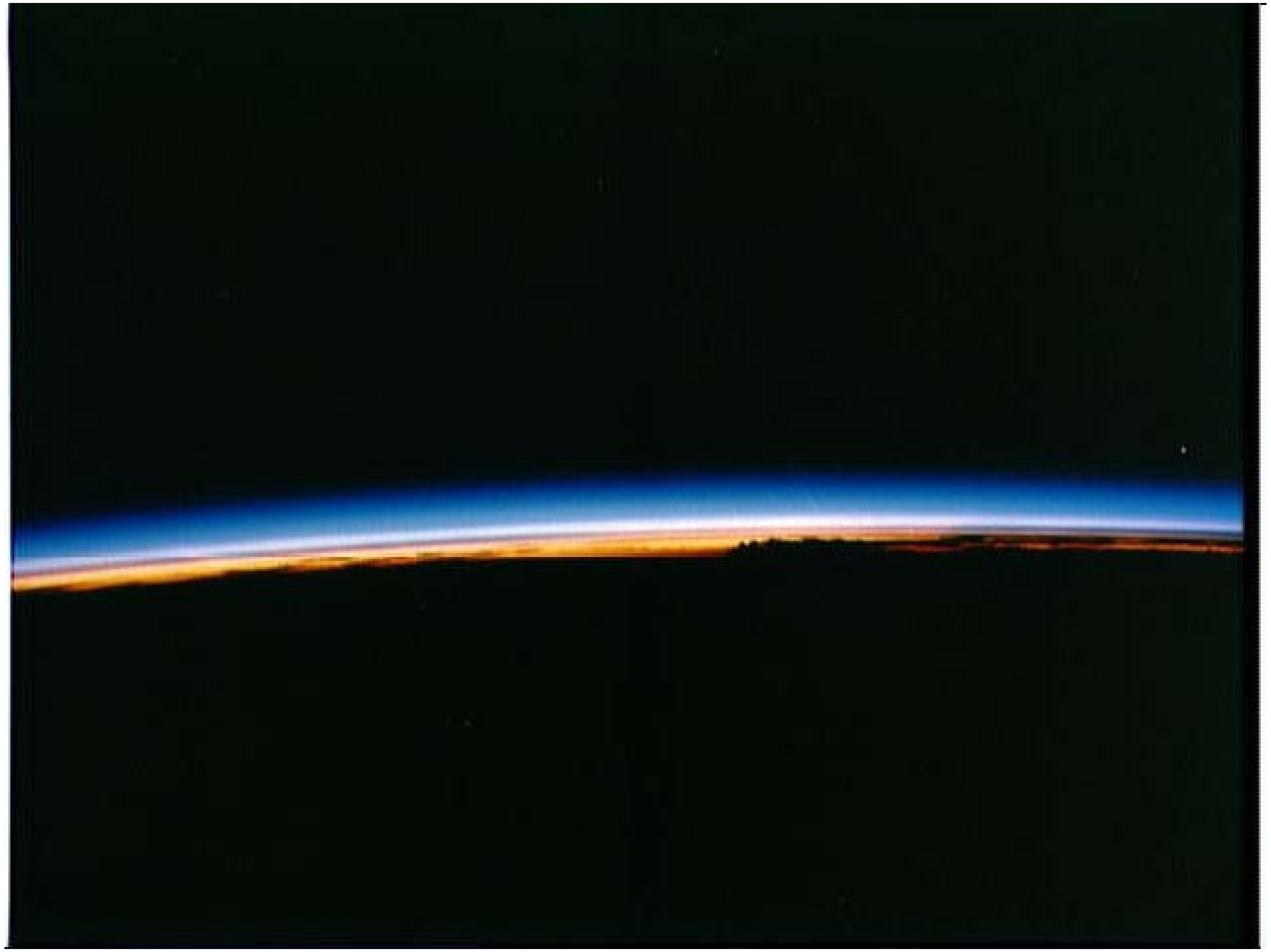
regional share of fossil fuel emisisons



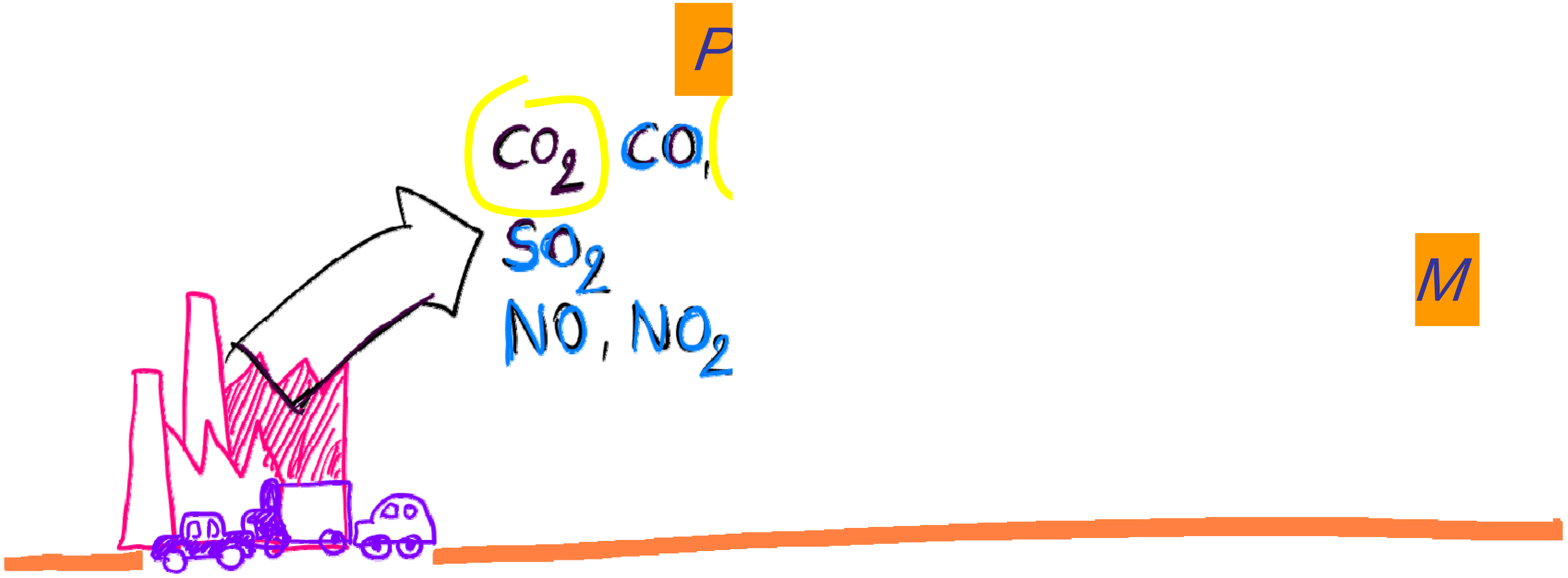
Raupach et al. PNAS 2007 / Global Carbon Carbon, 2008

EUROPEAN COMMISSION JRC

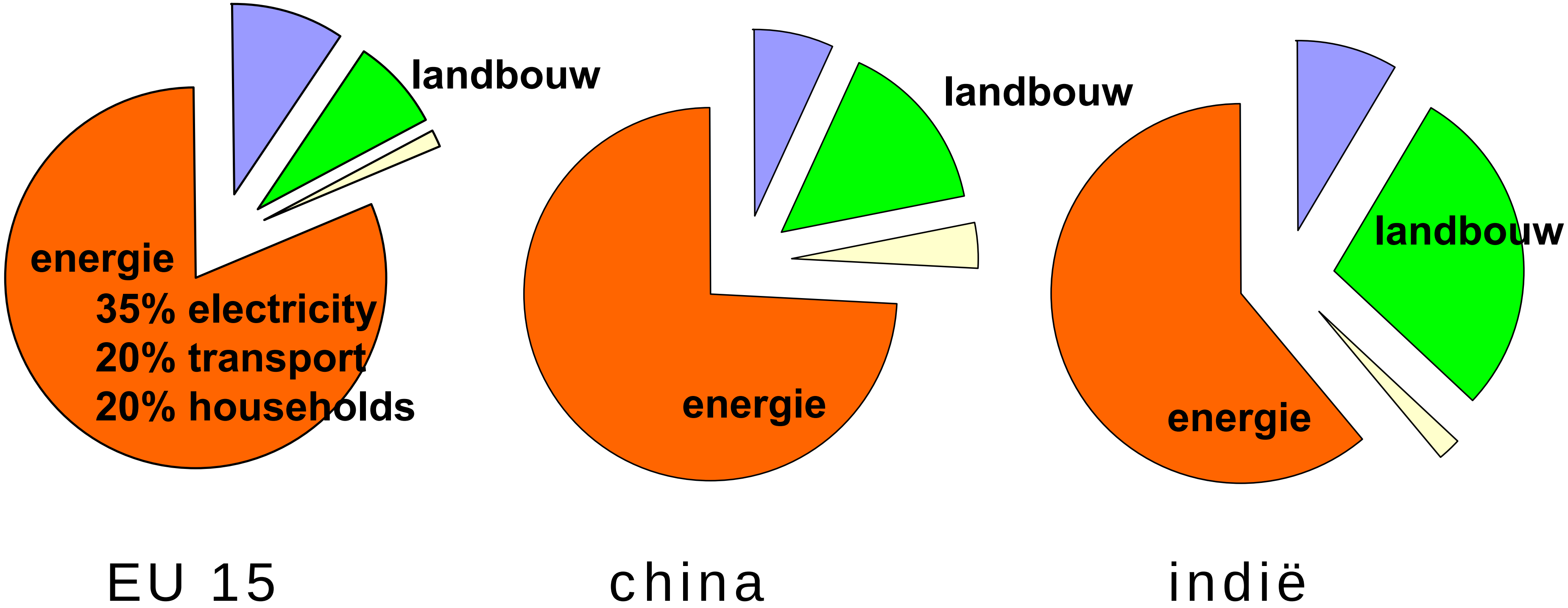


This is what the atmosphere looks like viewed edge on from space. The image is of a small cross-sectional area, note the small curvature of the surface, yet the atmosphere is a small part of the whole. Looking closely, you can see tall thunderstorm clouds silhouetted against an orange layer of atmospheric gases backlit by the sun just below the horizon. Above this layer is the clear blue of the stratosphere and the blackness of space.
From NASA Space Shuttle Flight 6 on 4 April 1983.

Air pollutants and greenhouse gases from fossil fuel burning



broeikasgas uitstoot per sector



QUESTIONS:

- What are the effects of air pollution control policies on climate ?

- What are the effects of climate change mitigation policies on the level of air pollutants

- Are there co-benifits of one policy for the other?

Calculations with TM5 Chemical Transport Model

fixed 2000 meteorology (no AP – Climate feed backs)
atmospheric chemistry
aerosol species do not interact

We calculate
- Fields of air pollutants :ozone
  particulate matter (sulfate, BC, OC, SS, dust)
- Effects on human health , natural ecosystems and agriculture
- Effects of TOA radiative forcing (through off-line calculation)

-for year 2000
-for years 2030 and 2050 under various policy scenarios
  -Business as usual for APs and GHGs **(BAU)**
  -Only climate policies **(CC only)**
  -Only air pollution reduction policies **(AP only)**
  -Climate and air pollution policies **(CC + AP)**

QUESTIONS:

- What are effects of GHGs and aerosols on surface temperature and precipitation?

- Are GHG and aerosol effects additive?

- What is the climate sensitivity to changing GHGs, to changing aerosols, to changing both?

$$\lambda = \Delta T / RF \qquad (^{\circ}C/W/m^2)$$

- What is the hydrological sensitivity to changing GHGs, to changing aerosols, to changing both?

$$h = \Delta precip / \Delta T \qquad (\%/^{\circ}C)$$

Calculations with ECHAM5 General Circulation Model

on-line atmospheric chemistry

aerosol species *do* interact

We calculate

- Fields of air pollutants :ozone
  particulate matter (sulfate, BC, OC, SS, dust)
- Effect on radiative forcing,
- Effects on temperature and precipitation

-for year 2000 (equilibrium calculation)

-for year 2030 (equilibrium calculation)

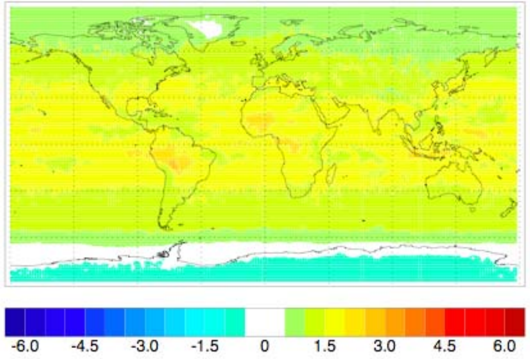
- Only GHG increase according to B2 (**GHG↑**) ***(SRES B2)***
- Only air pollution reduction polcies (**AE↓**) *(MFR everywhere)*
-‘GHG increase + aerosol decrease (**GHG↑ + AE↓**)

changes in radiative forcing
between 2000 and 2030

Total sky TOA radative forcing

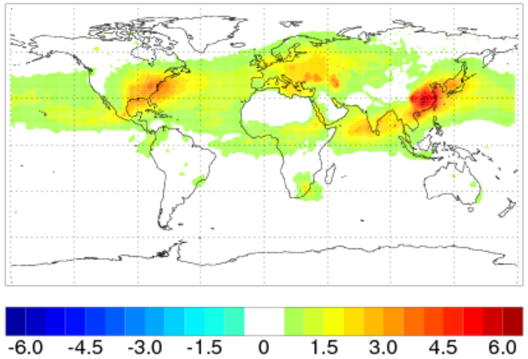
GHG↑

RF= 1.53 W/m2



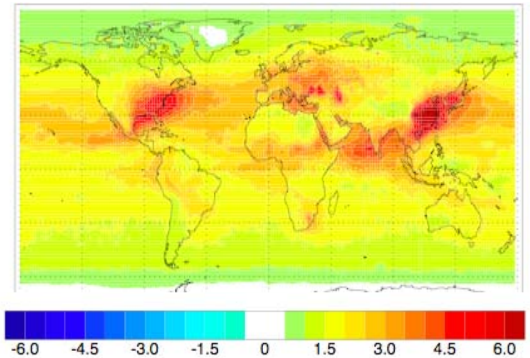
AE↓

RF= 1.13 W/m2



GHG↑+AE↓

RF = 2.66 W/m2



GHGs: SRES B2 scenario
Aerosols: IIASA MFR scenario

Kloster et al. Atmos. Chem. Phys., 2008

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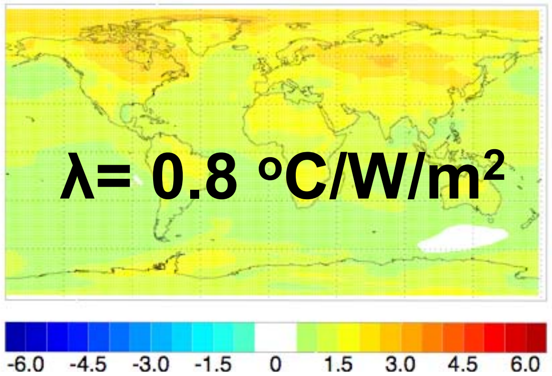
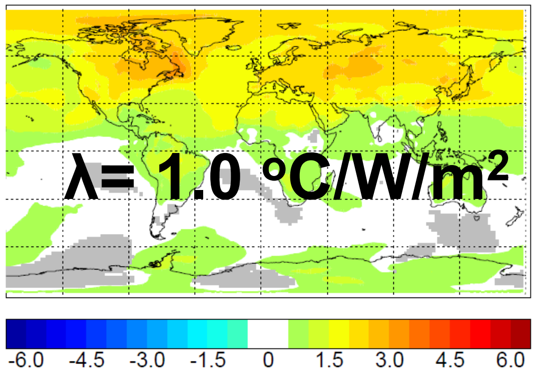
changes in surface temperature
between 2000 and 2030

GHG↑

ΔT =
***1.20* °C**



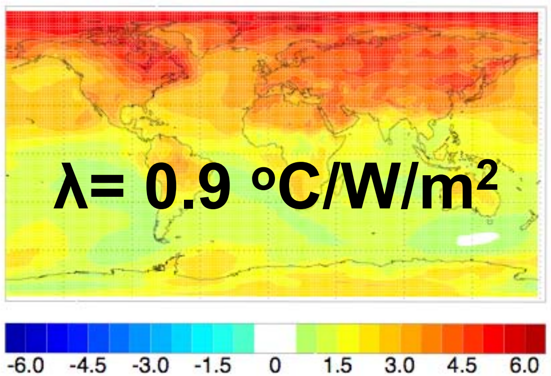


AE↓

ΔT =
***0.96* °C**

GHG↑+AE↓

ΔT =
***2.18* °C**



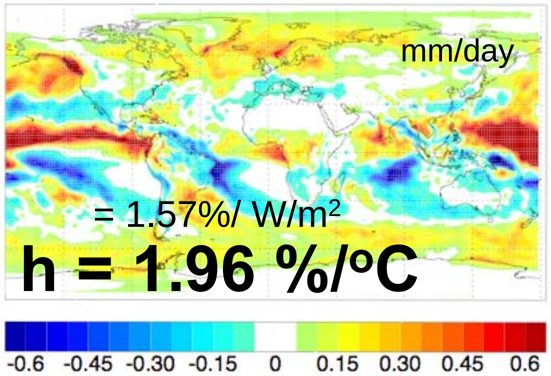
GHGs: SRES B2 scenario
Aerosols: IIASA MFR scenario

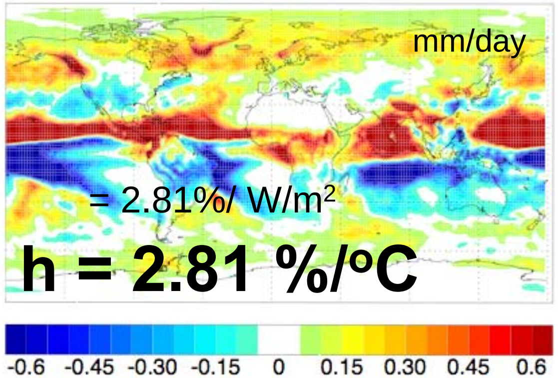
Kloster et al. Climate Dynamics (in press) 2009

changes in precipitation
between 2000 and 2030

GHG↑

Δprecip = +2%



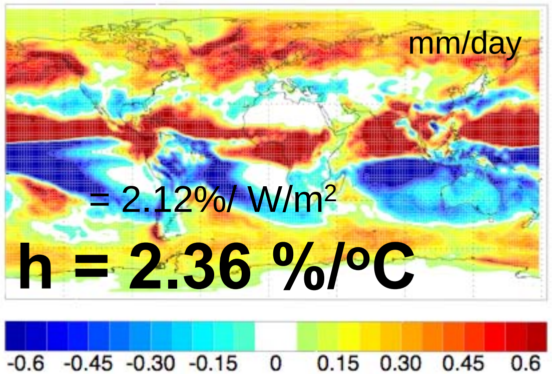


AE↓

Δprecip = +3%

GHG↑+AE↓

Δprecip = +5%



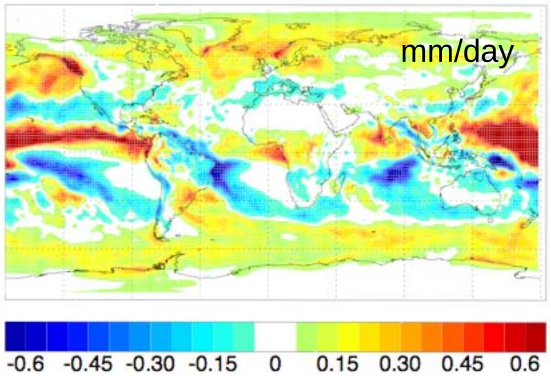
GHGs: SRES B2 scenario
Aerosols: IIASA MFR scenario

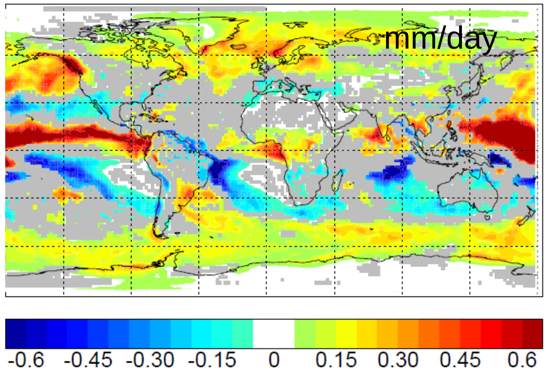
Kloster et al. Climate Dynamics (in press) 2009

changes in precipitation
between 2000 and 2030

GHG↑

Δprecip = +2%

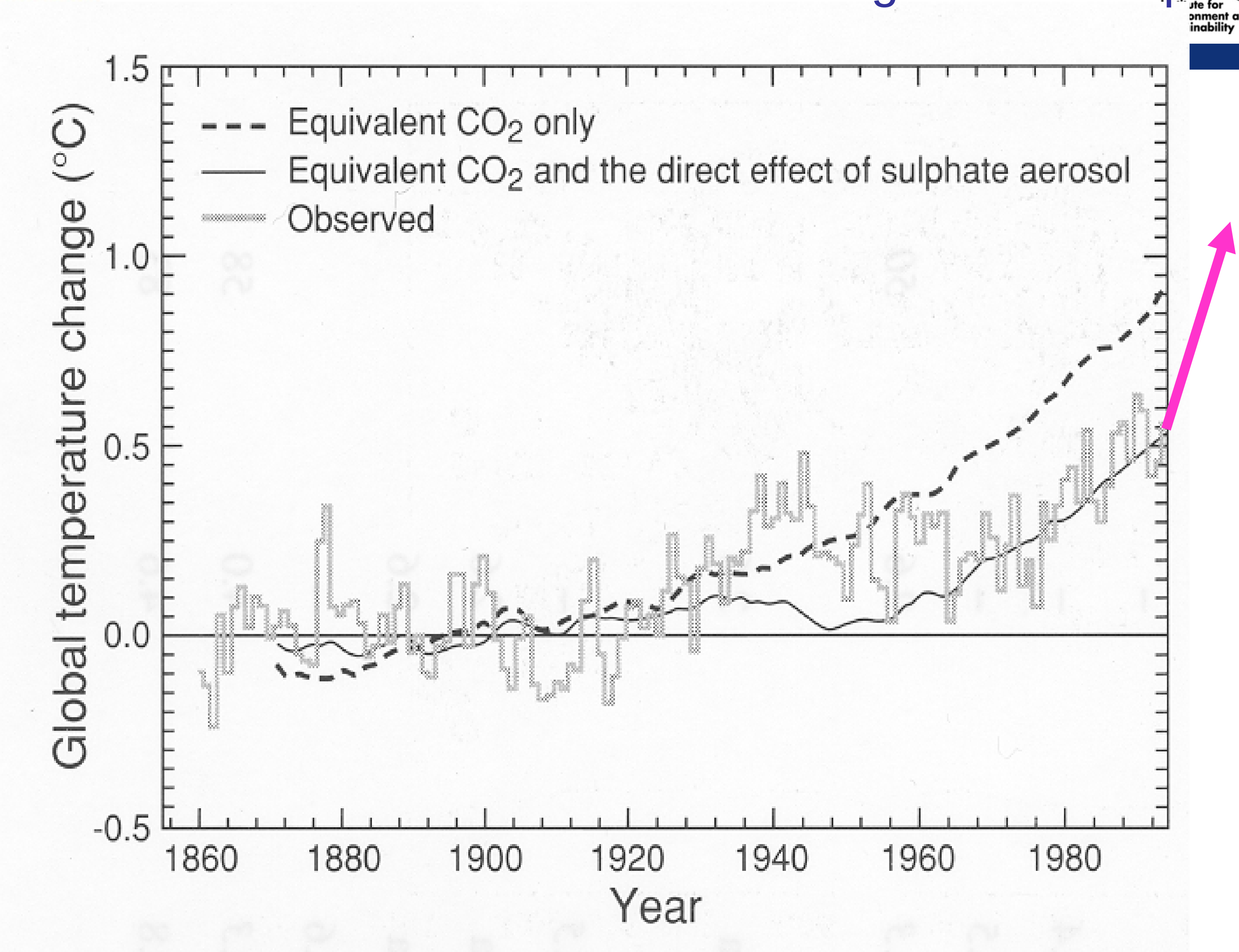




changes with increases above 95% significance level only

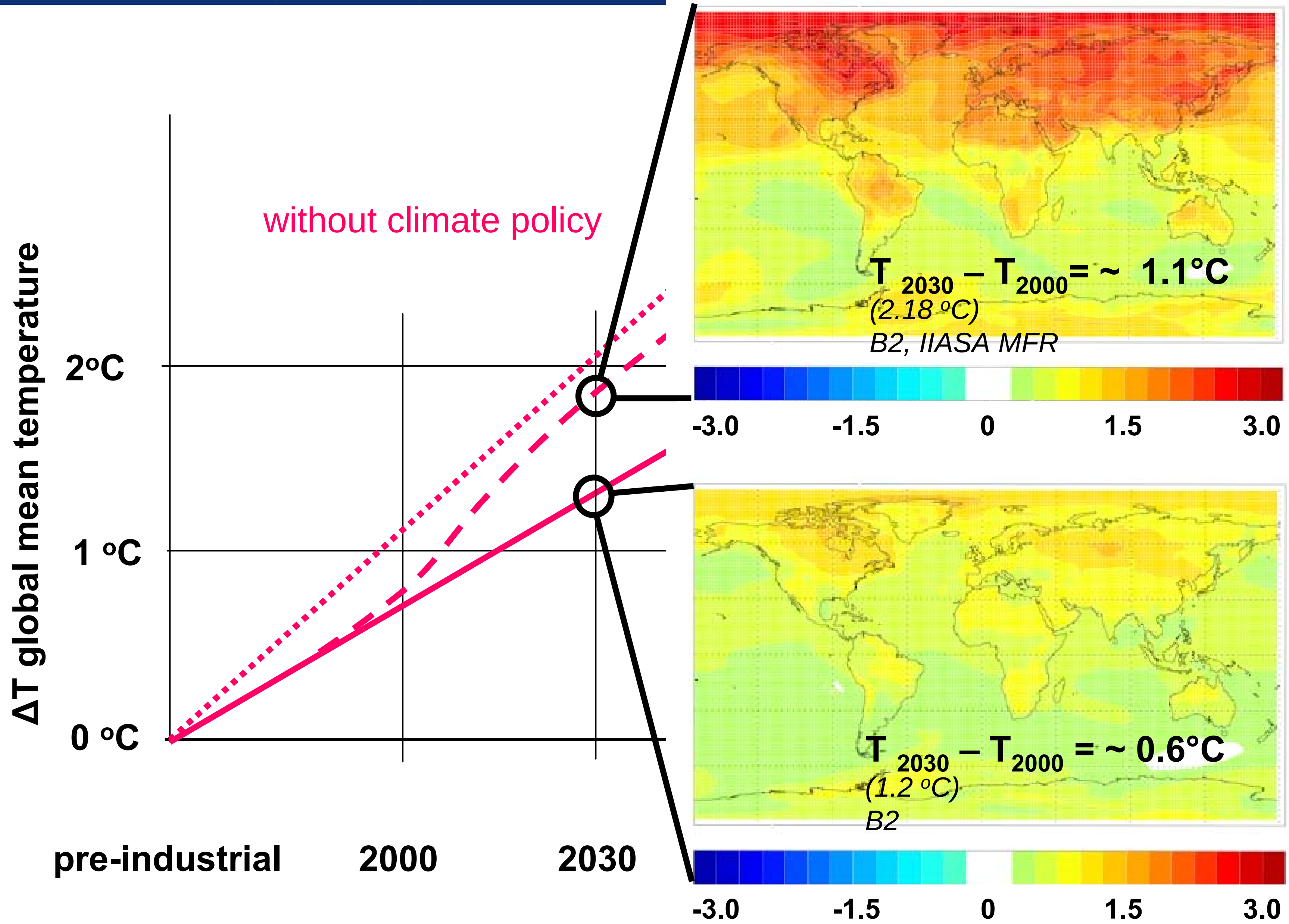
Kloster et al. Climate Dynamics (in press) 2009

effect of aerosols on on global temperatur

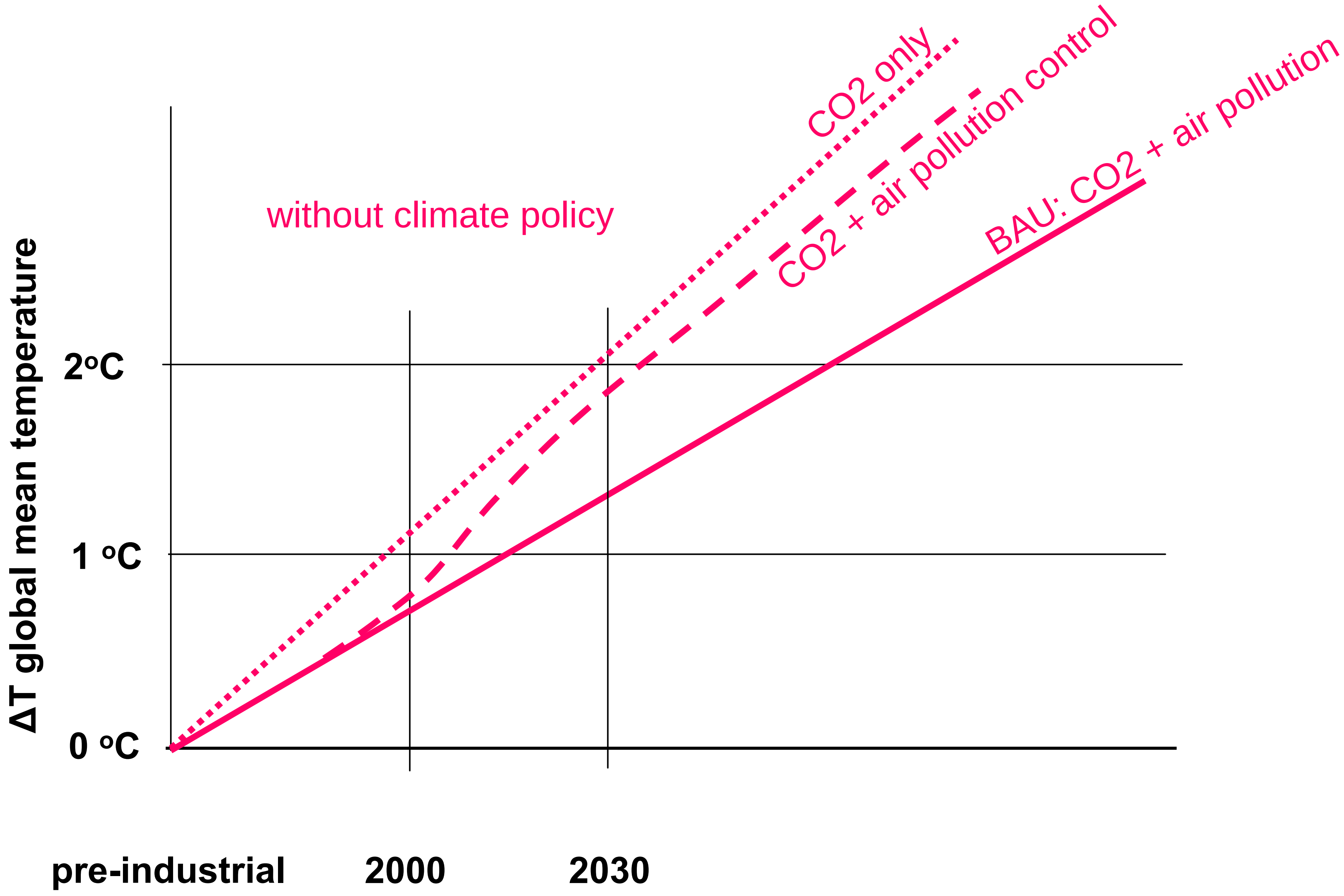


IPCC, 1995

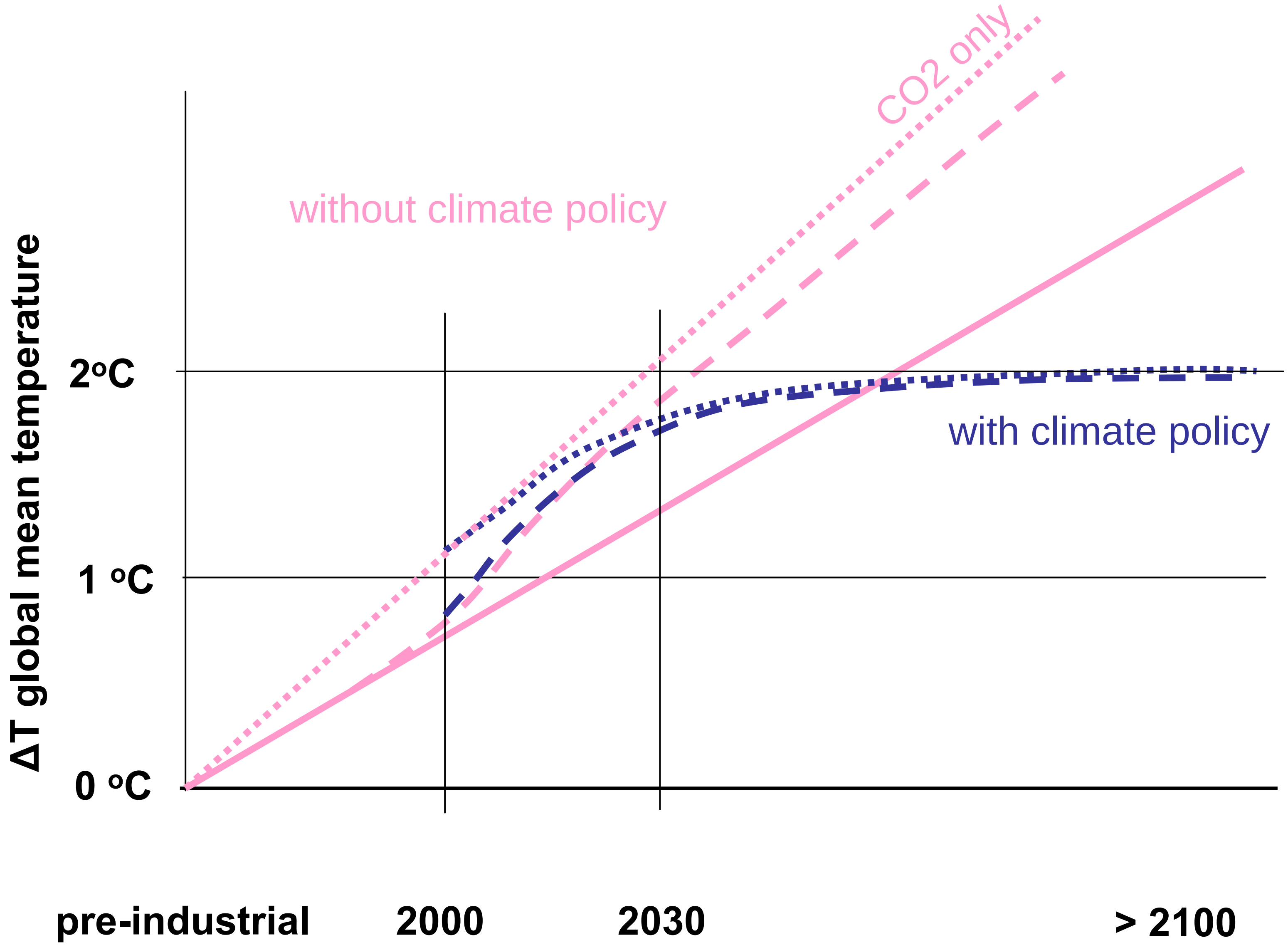
the overall picture



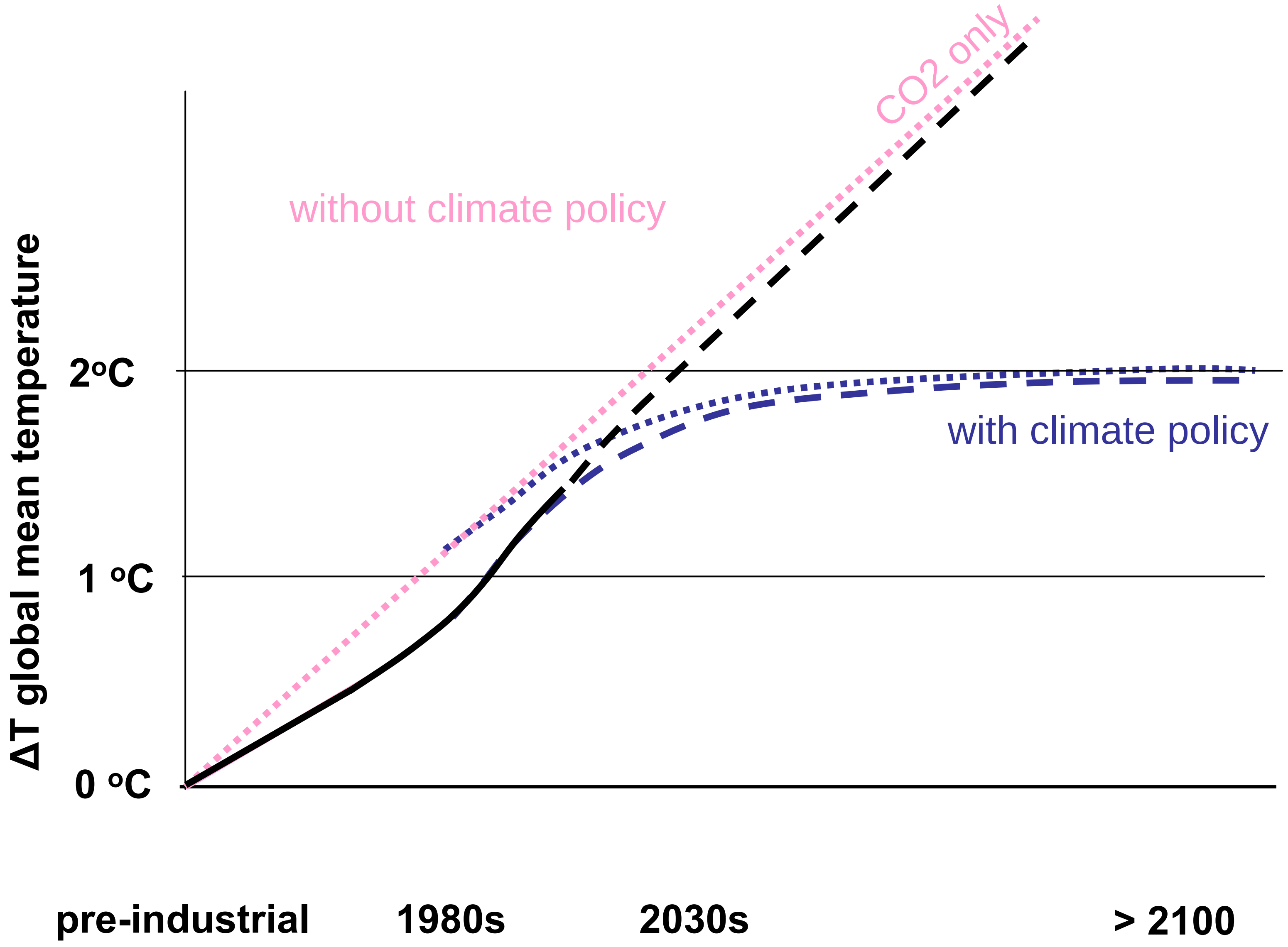
the overall picture



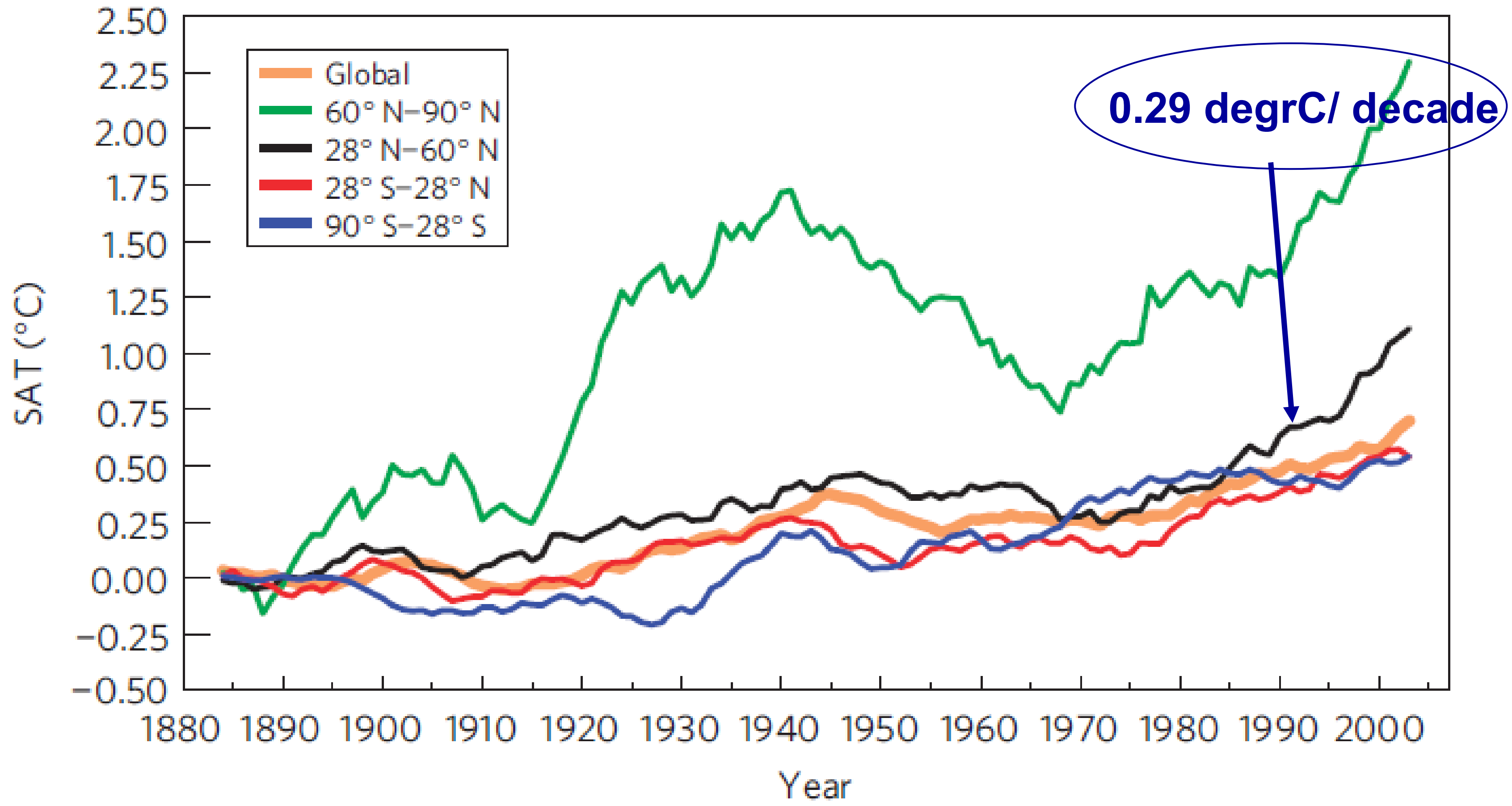
the overall picture



the overall picture

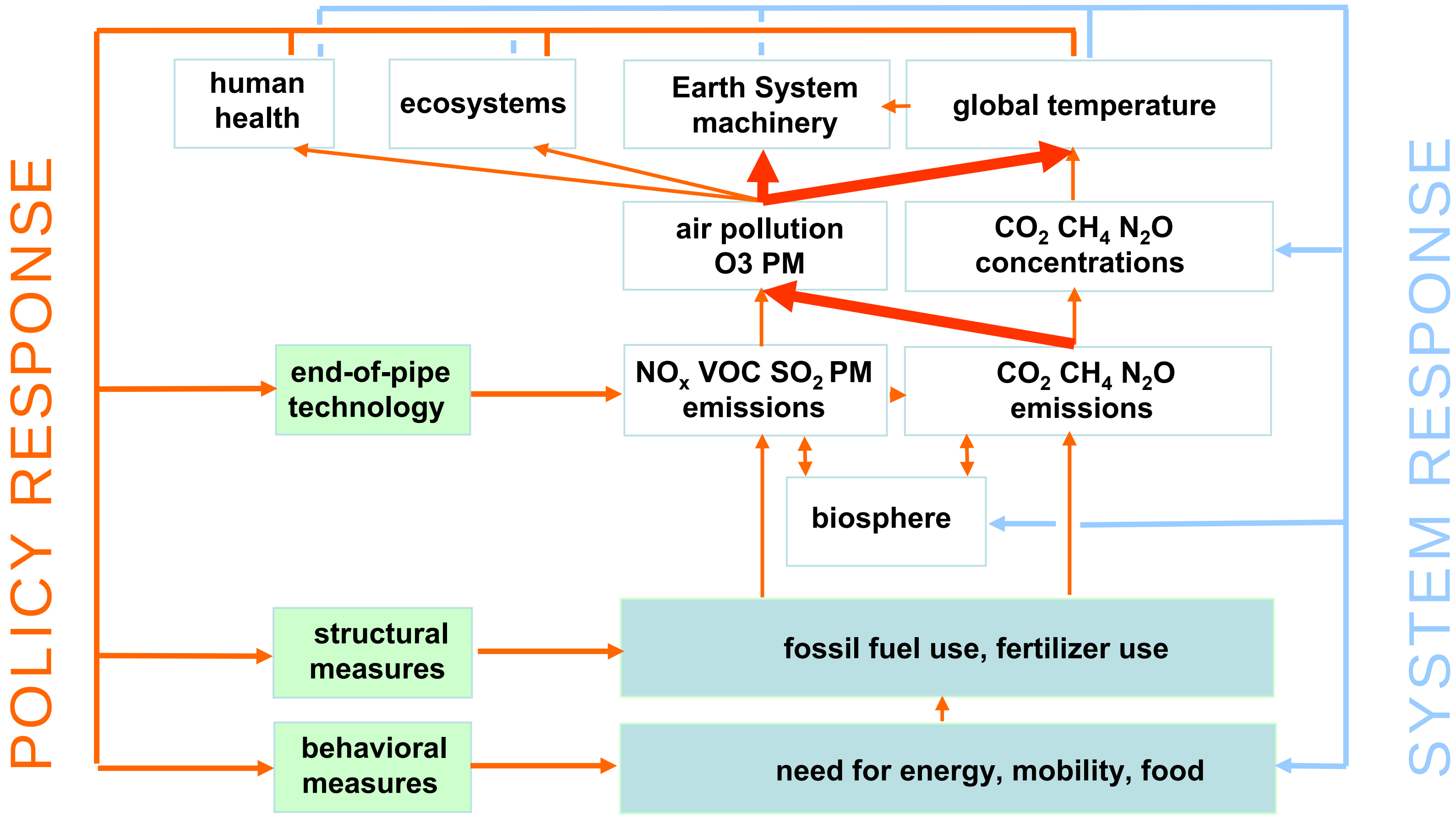


Global and zonal mean temperature, difference from 1880-90 (degrC)



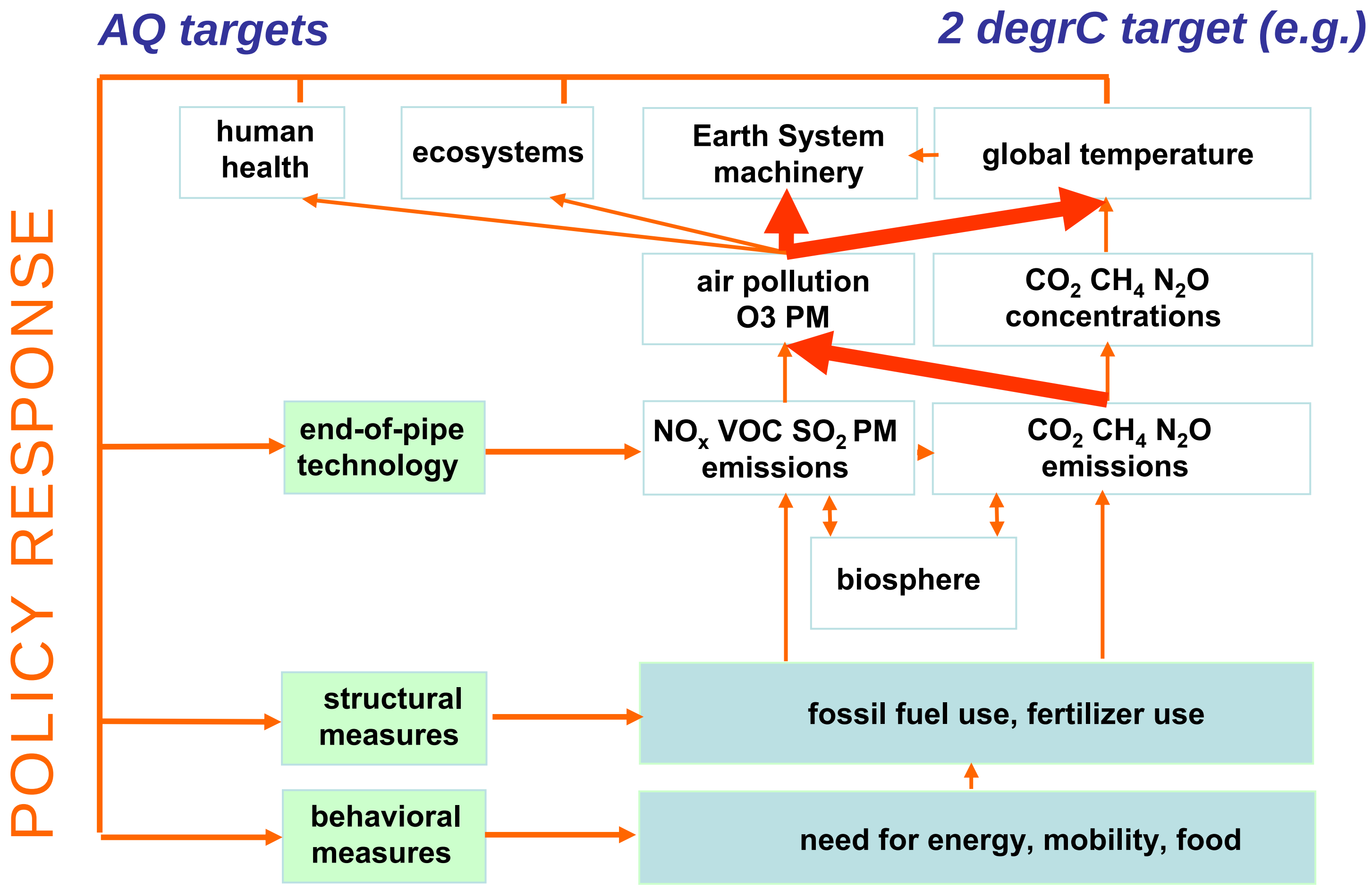
Schindell et al., 2009, Nature Geosciences

integration AP and CC policies



Raes (2006) IGBP Newsletter Nr 65

integration AP and CC policies



Raes (2006) IGBP Newsletter Nr 65

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changes in APs and GHG concentrations
between 2000 and 2030

% change	GHG↑	AE↓	GHG↑ +AE↓
sulfate	+4	-35	-32
Black carbon	+6	-17	-13
Organic carbon	+6	-6	-1
Sea salt	+2	+1	+3
Dust	+7	-7	-1
CO2	+21	0	+21
CH4	+36	0	+36
N2O	+8	0	+8

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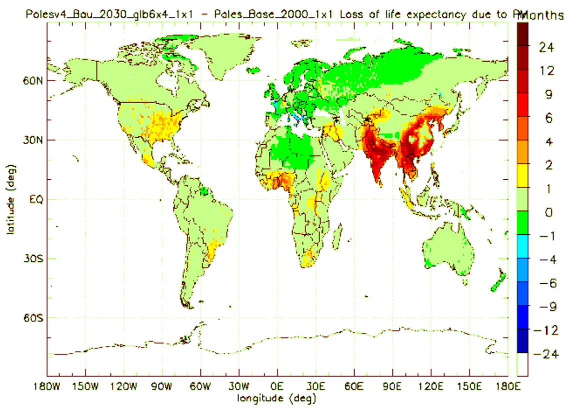
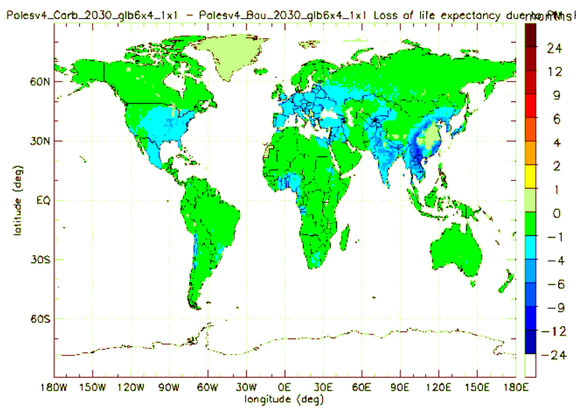
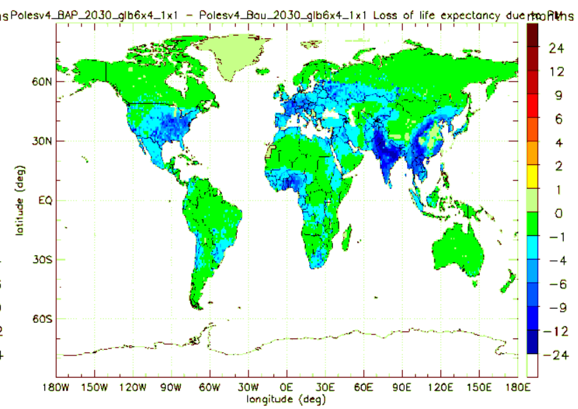
changes in health impacts
between 2000 and 2030

BAU	CC only	AP only
loss of life expectancy between 2000 and 2030 without additional policies (months)	effect of CC-only policy by 2030 compared to BAU	effect of AP-only policy by 2030 compared to BAU







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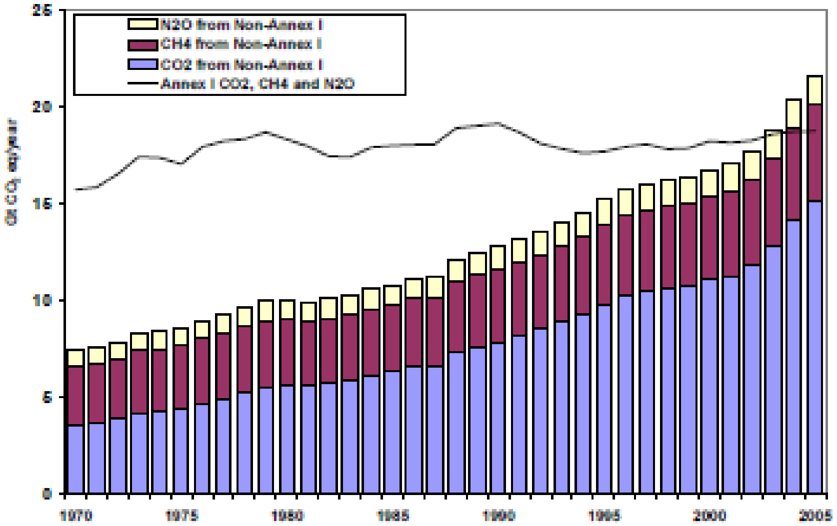
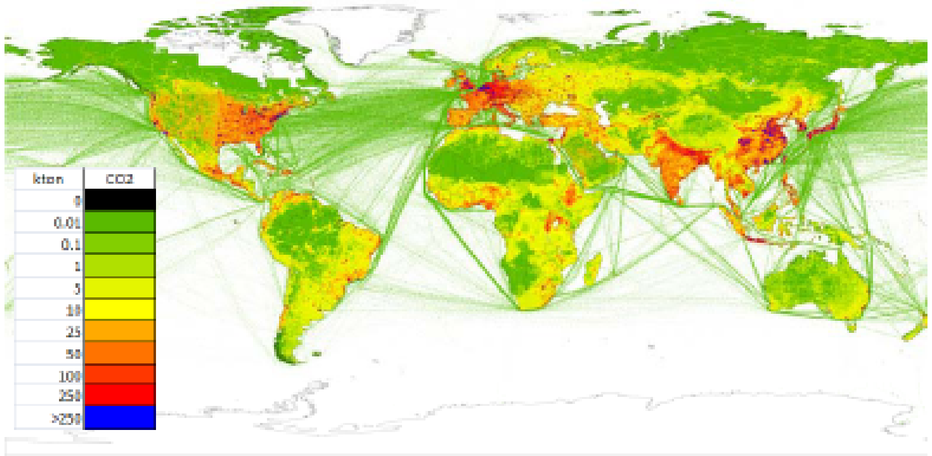


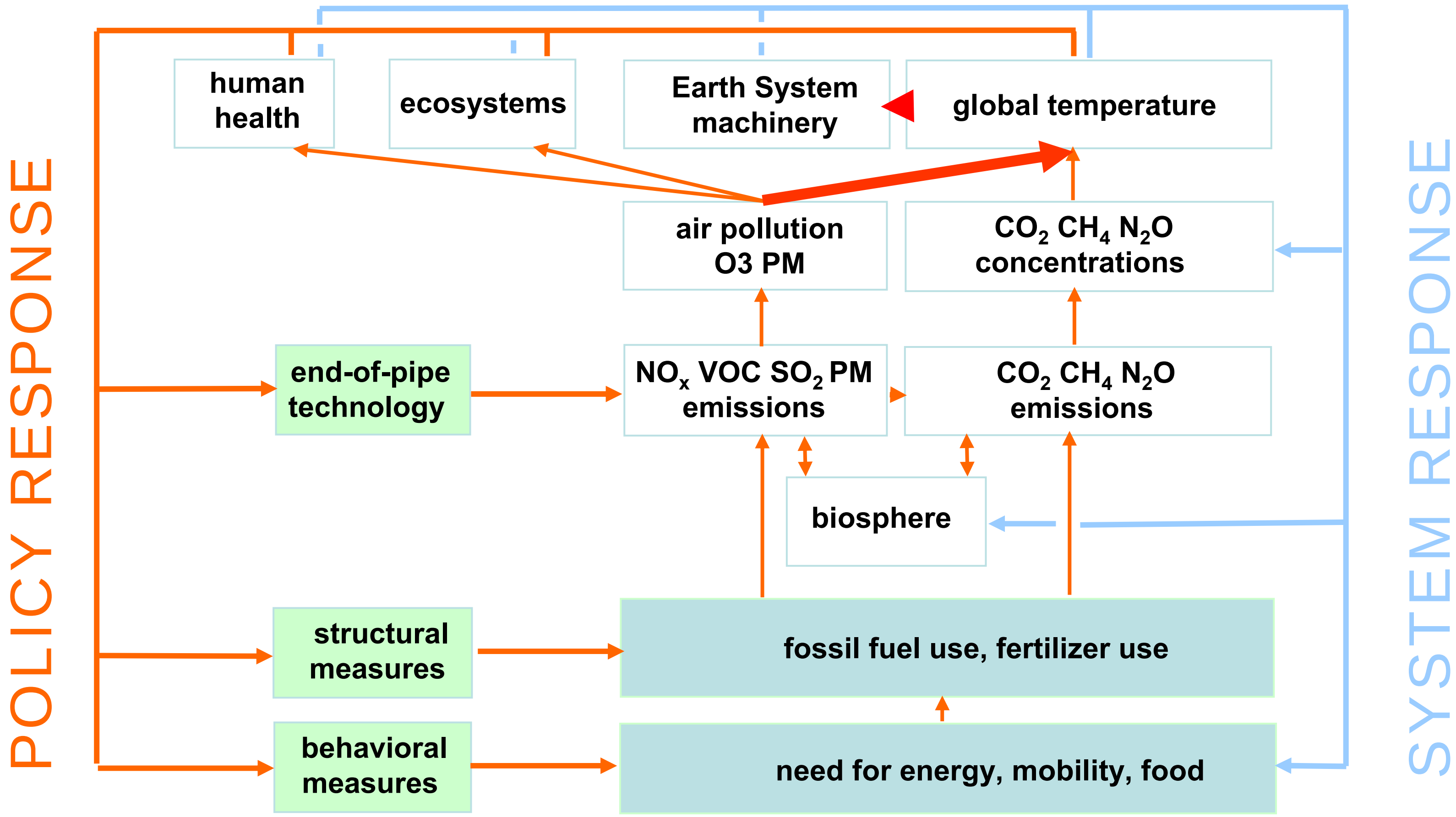


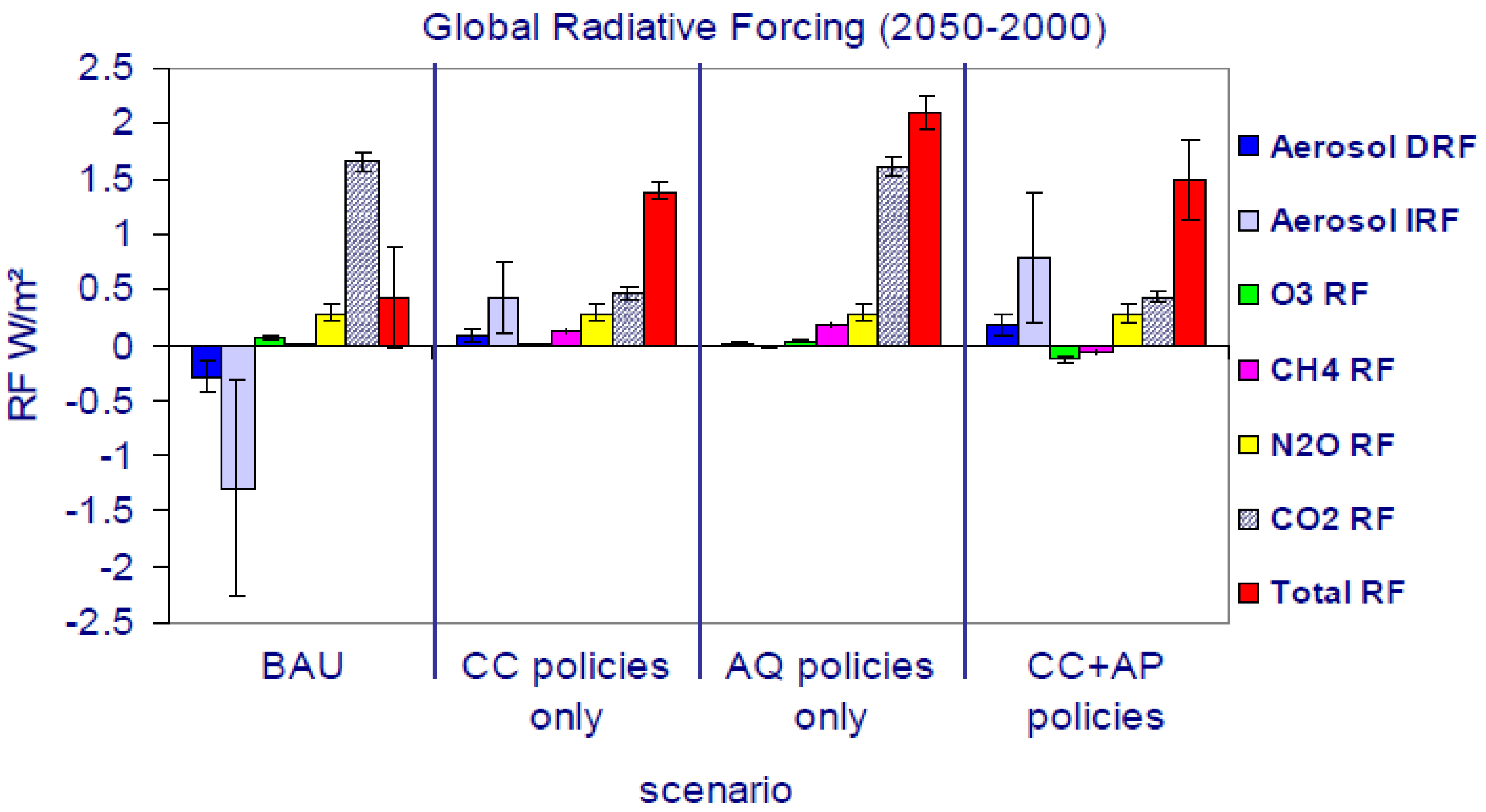
EDGAR v4.0:
Global anthropogenic emissions of greenhouse gas emissions 1970-2005 by world country.

EDGAR v4.0:
Global anthropogenic CO_2 emissions in 2005 allocated to 0.1º grid cells (excl. aviation).

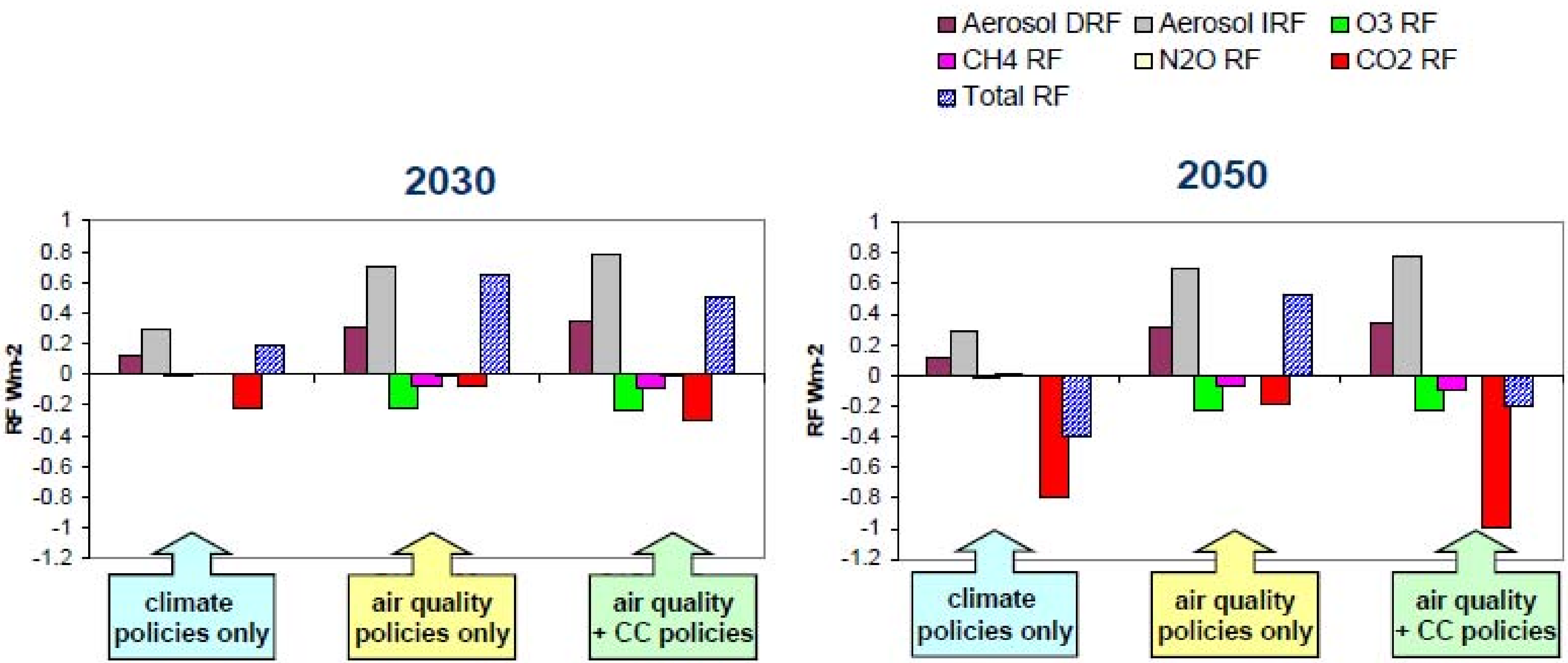
EDGAR
EMISSION DATABASE FOR GLOBAL ATMOSPHERIC RESEARCH

the air pollution - climate link

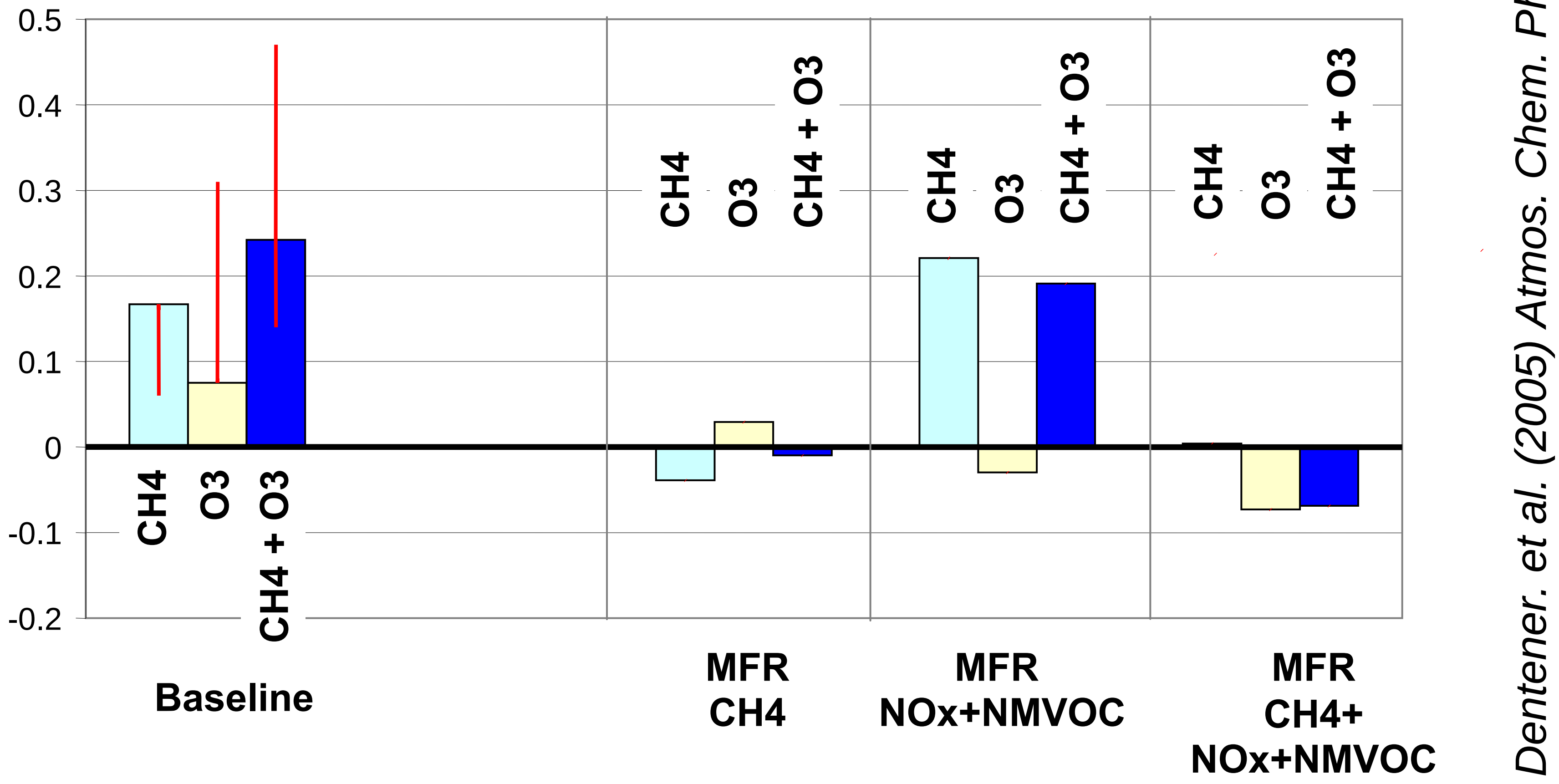



Global Radiative Forcing (2050-2000)
RF W/m2
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
Aerosol DRF
Aerosol IRF
O3 RF
CH4 RF
N2O RF
CO2 RF
Total RF
BAU
CC policies only
AQ policies only
CC+AP policies
scenario

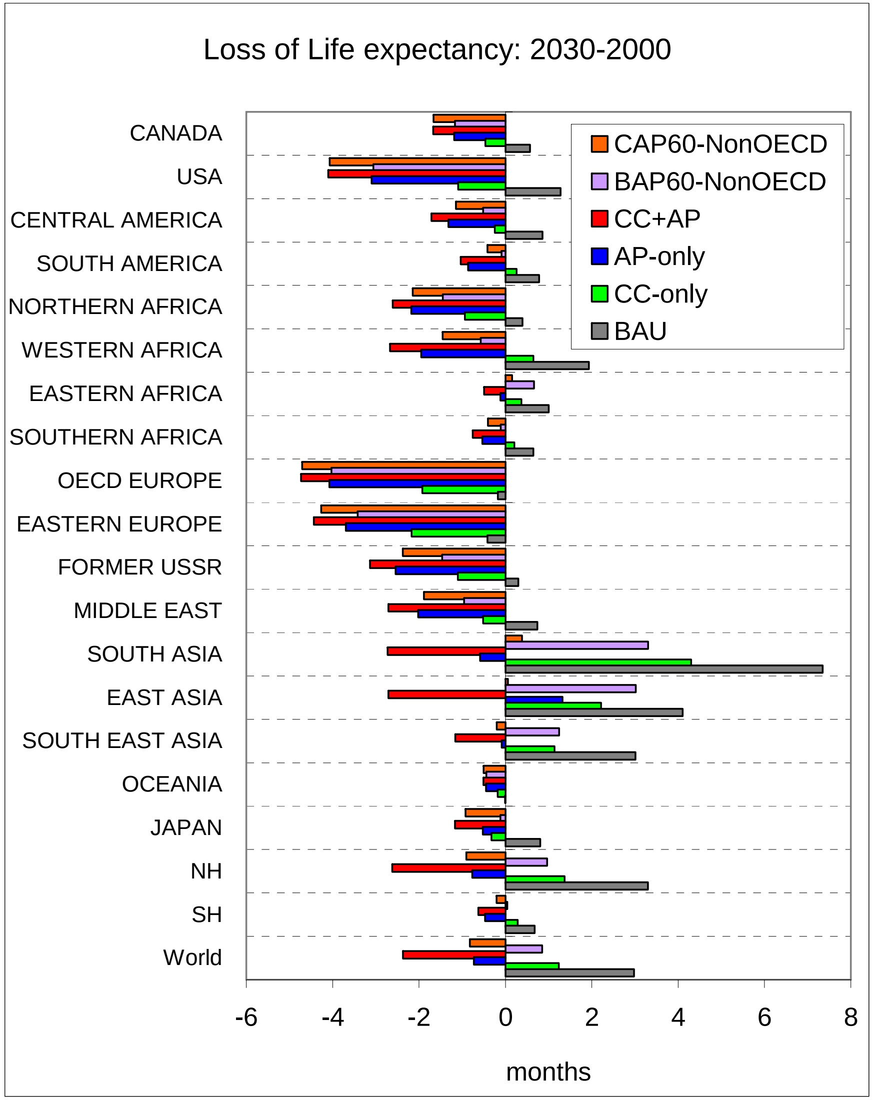
Effect of policies in 2030 and 2050 compared to BAU in 2030 and 2050



Change in global mean radiative forcing 2000-2030 [W/m²]



The red error bars indicate the uncertainty ranges identified in IPCC TAR


Loss of Life expectancy: 2030-2000
CANADA
USA
CENTRAL AMERICA
SOUTH AMERICA
NORTHERN AFRICA
WESTERN AFRICA
EASTERN AFRICA
SOUTHERN AFRICA
OECD EUROPE
EASTERN EUROPE
FORMER USSR
MIDDLE EAST
SOUTH ASIA
EAST ASIA
SOUTH EAST ASIA
OCEANIA
JAPAN
NH
SH
World
CAP60-NonOECD
BAP60-NonOECD
CC+AP
AP-only
CC-only
BAU
-6
-4
-2
0
2
4
6
8
months

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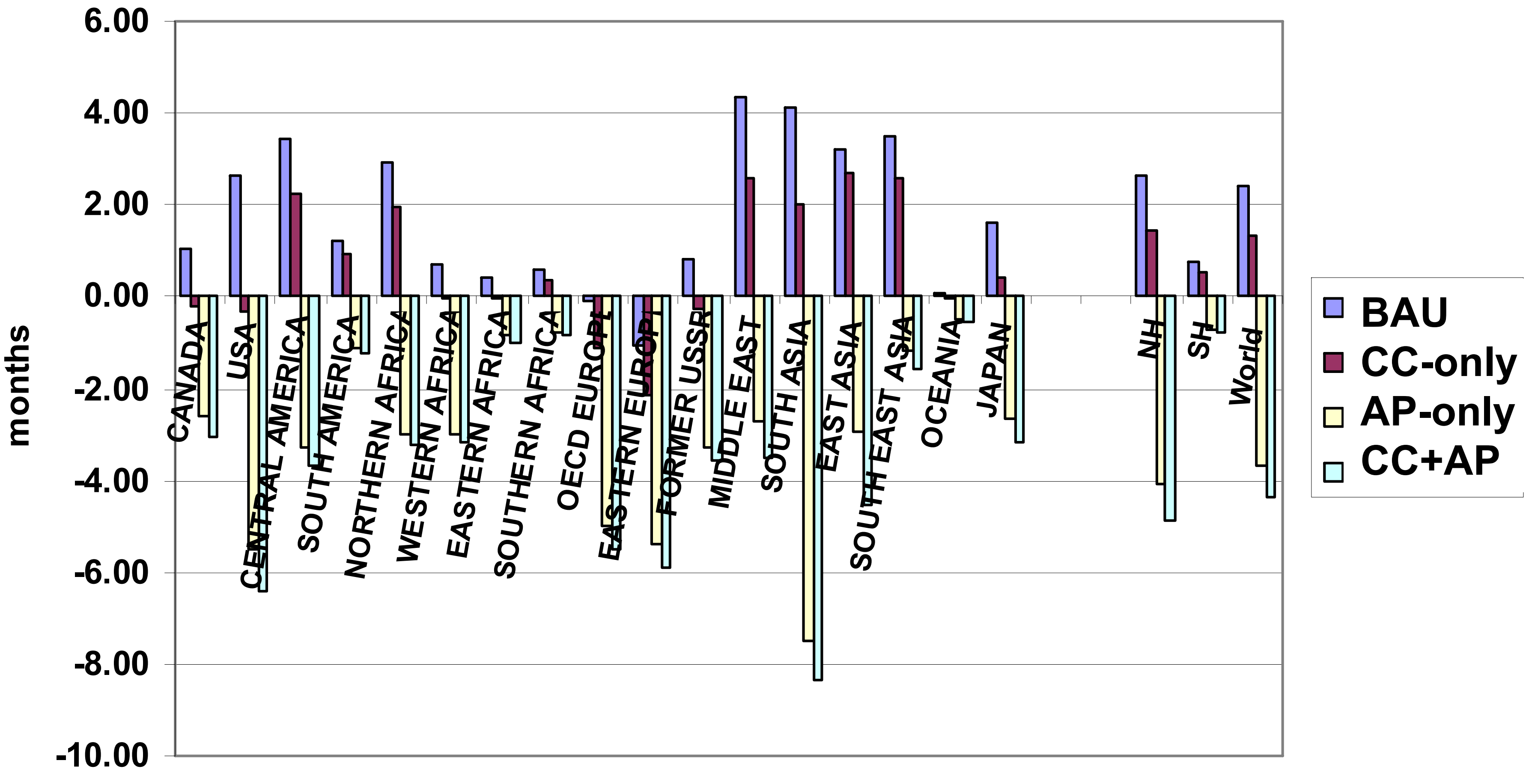
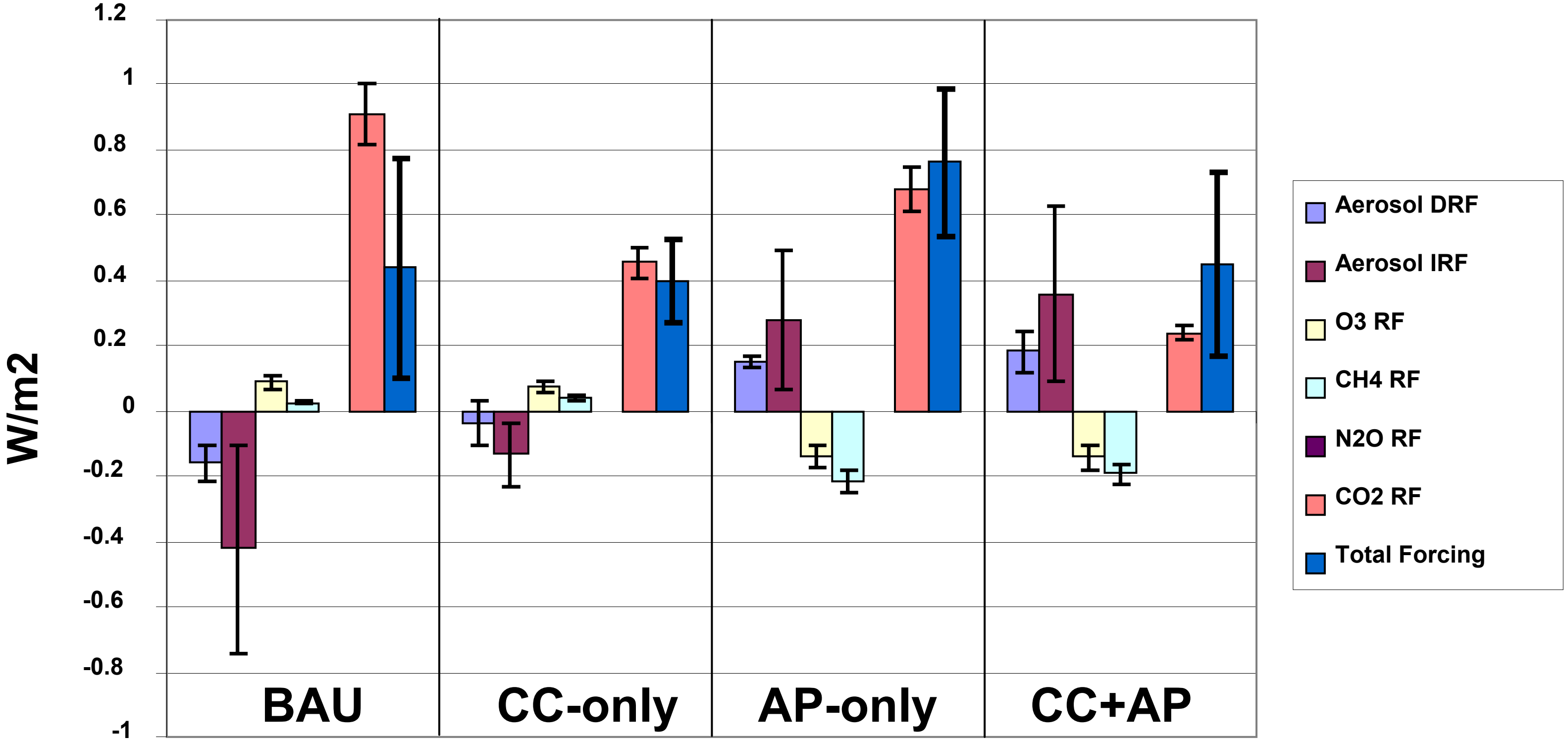
integrated energy, CC and AP modelling

additional loss of life expectancy due to PM between 2000 and 2030 in various scenarios



additional global radiative forcing between 2000 and 2030 in various scenarios



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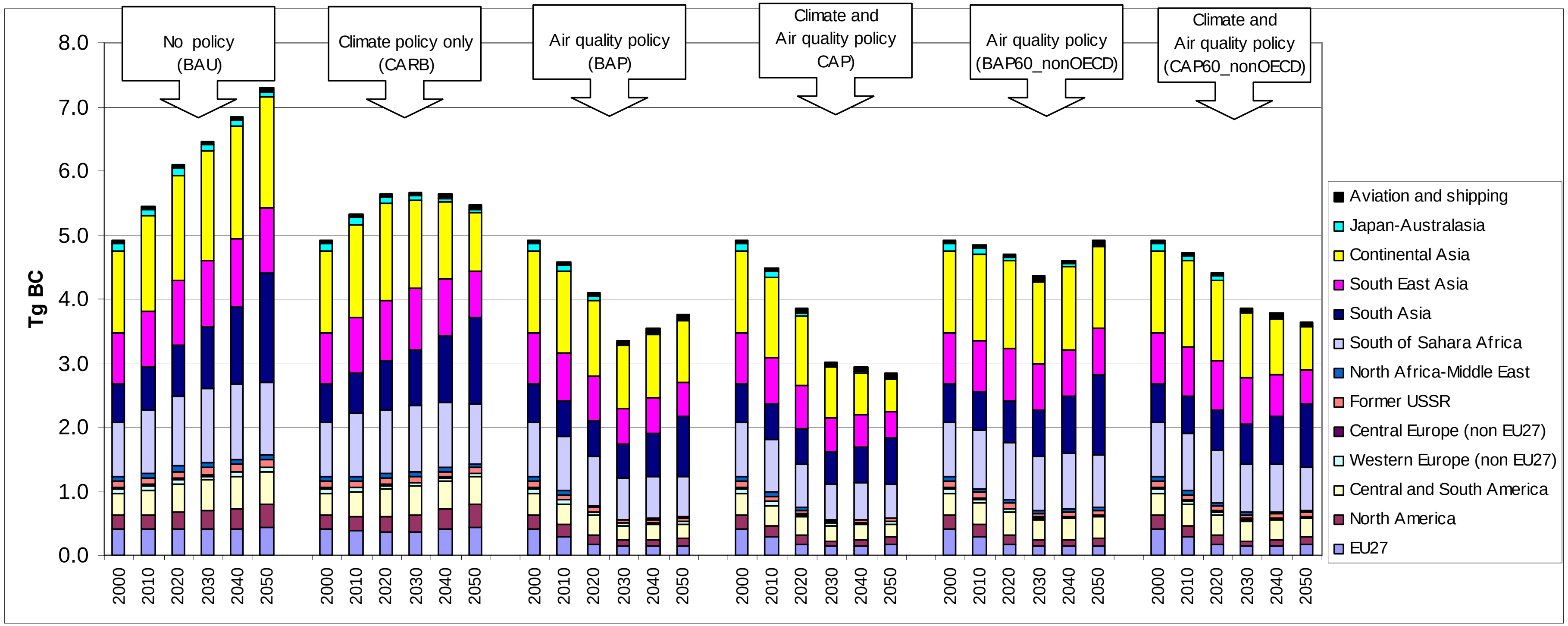


BC Tg BC yr-1

integration AP and CC policies

- integrated AP and CC policy means:

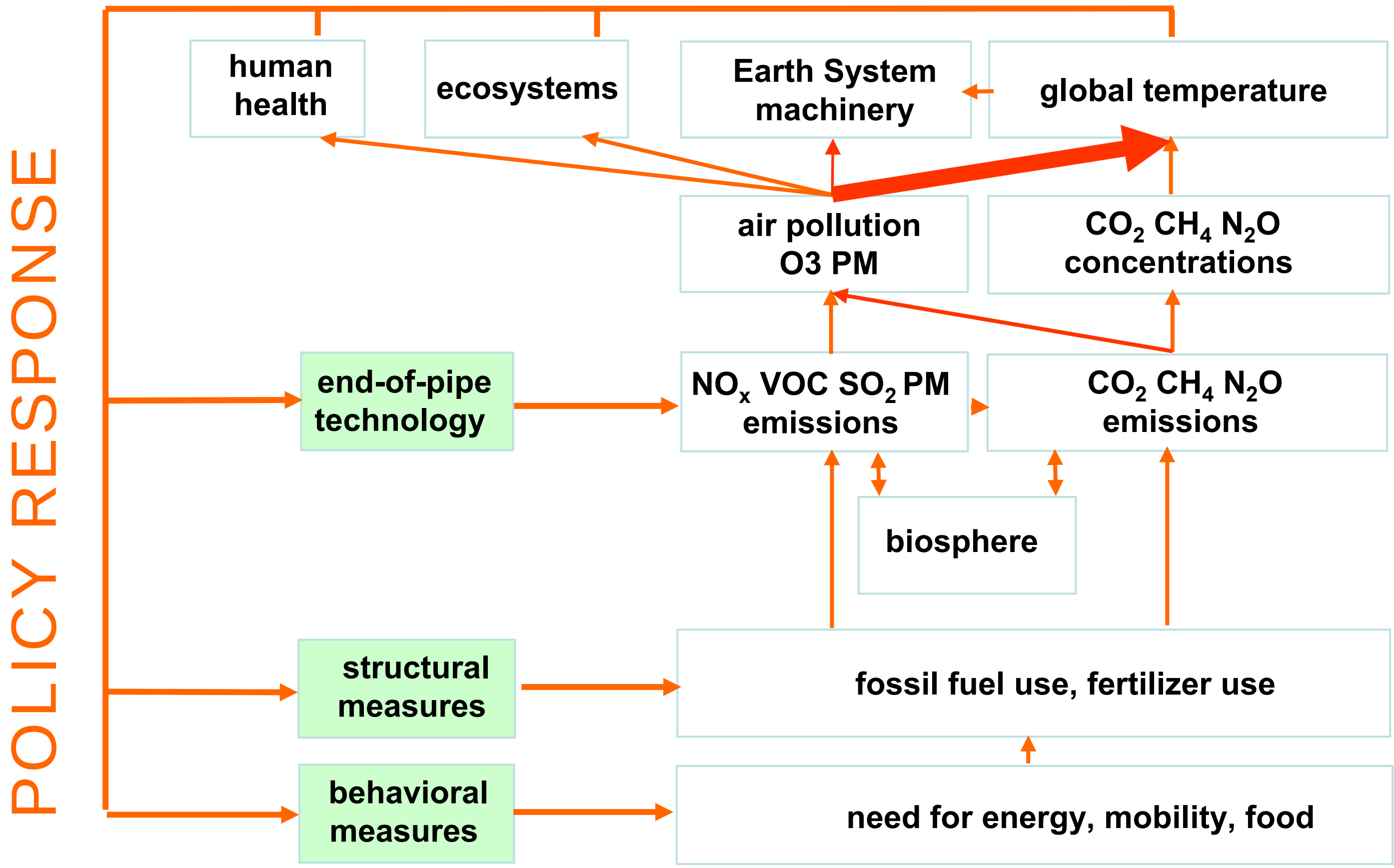
  to define, in each world region, the right mix of technical and non-technical control measures, in order to be:

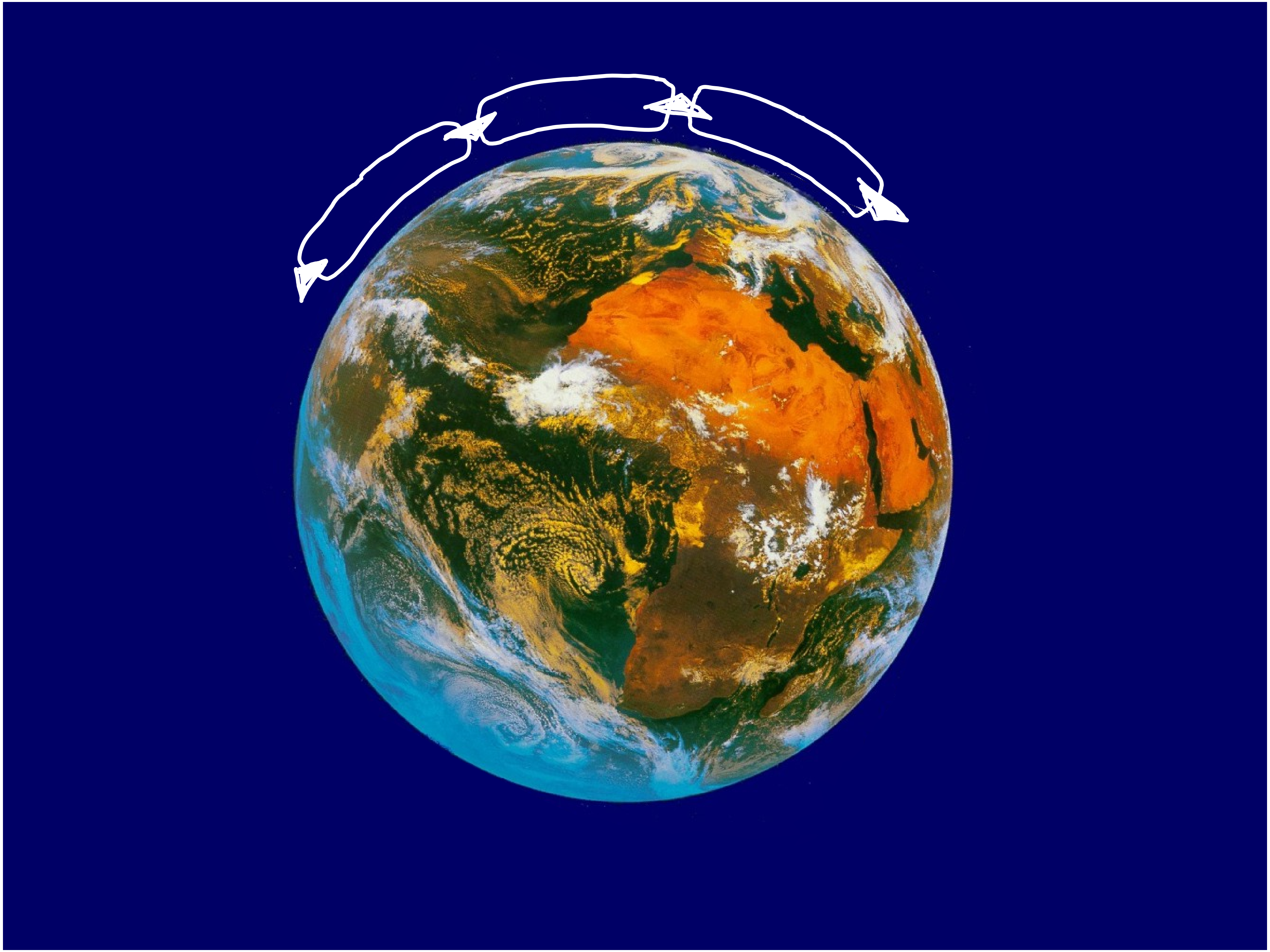
  – socially equitable
    - allow for development and poverty reduction

  – cost-effective

  – environmental effective
    - reduce air effects of air pollution
    - avoid dangerous climate change

the aerosol (PM) climate link





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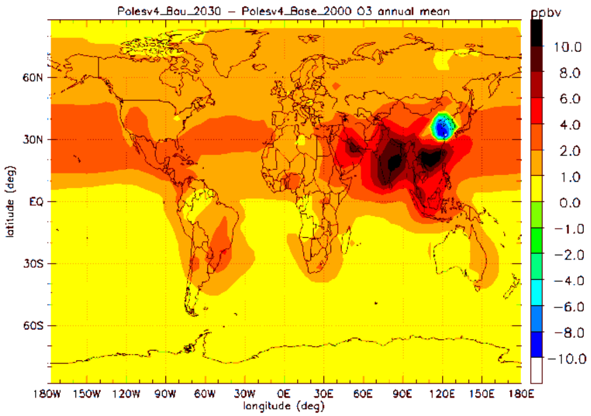
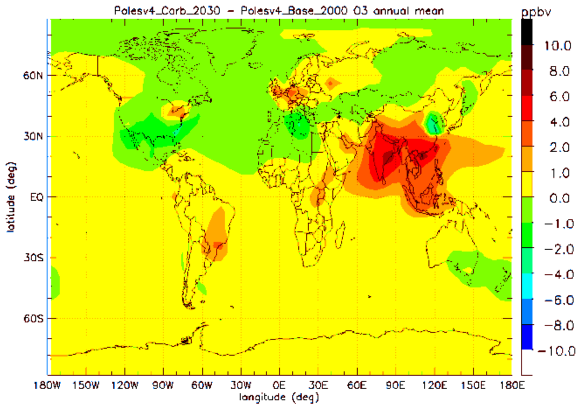
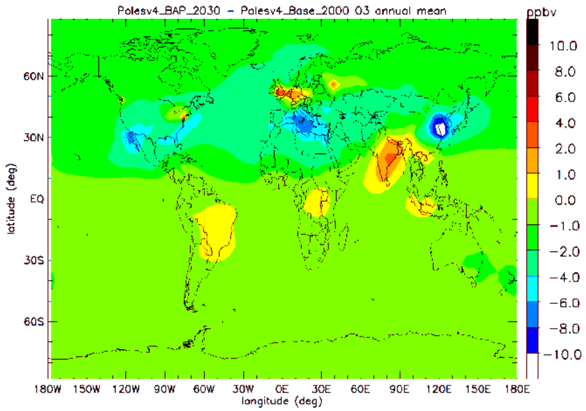
changes in air pollutant fields
between 2000 and 2030

BAU | **CC only** | **AP only**

Ozone (surface)







PM10 (surface)