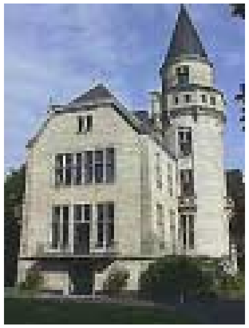


FCCC, Bonn, 4-6 Apr 2002
SBSTA – IPCC/TAR

Michael Prather
University of California at Irvine

Risk and Uncertainties in Anthropogenic

Control over Greenhouse Forcing in the TAR

with a focus on Atmospheric Chemistry

What Greenhouse Agents are listed under Kyoto ?

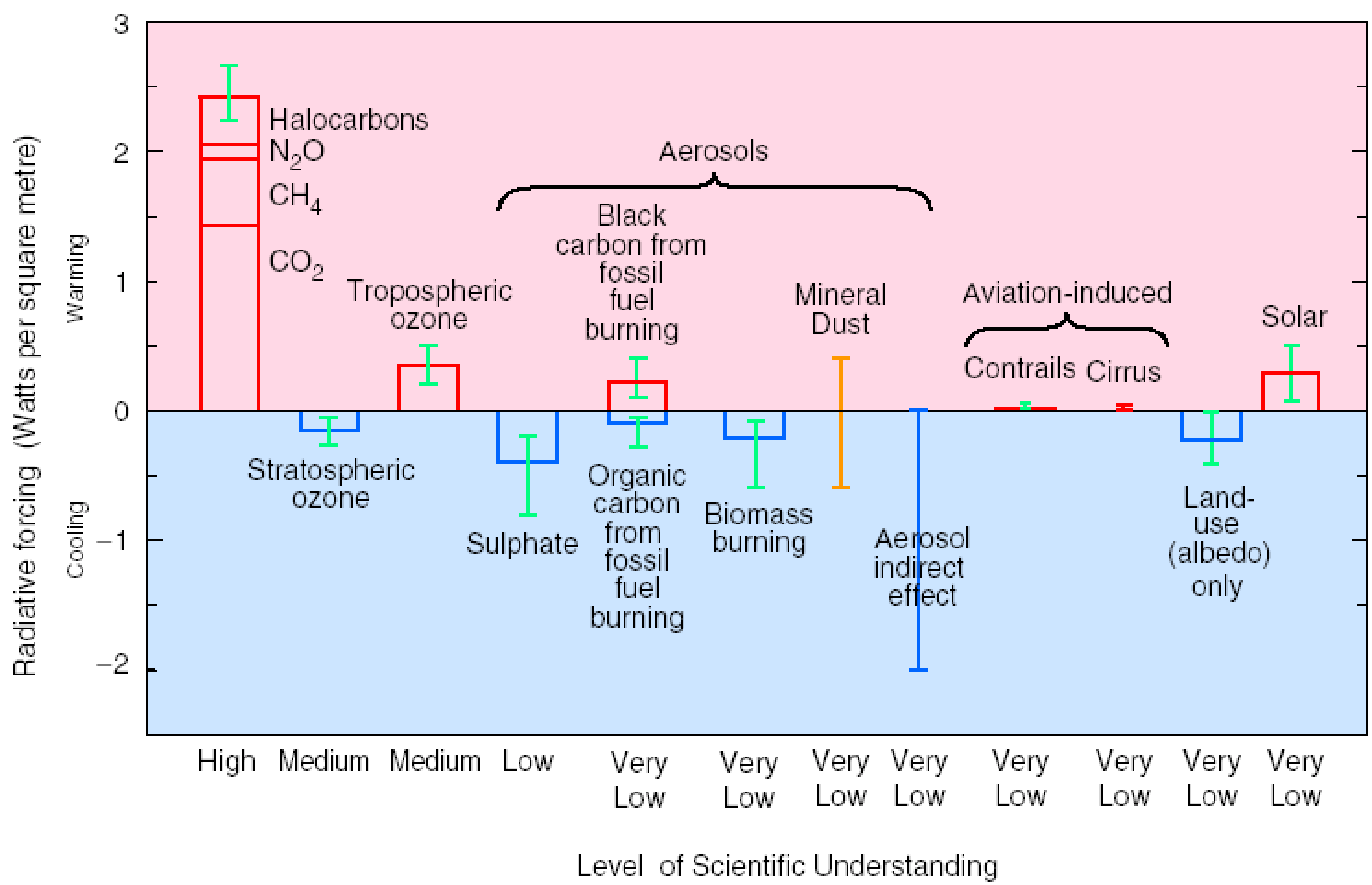
Annex A

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)

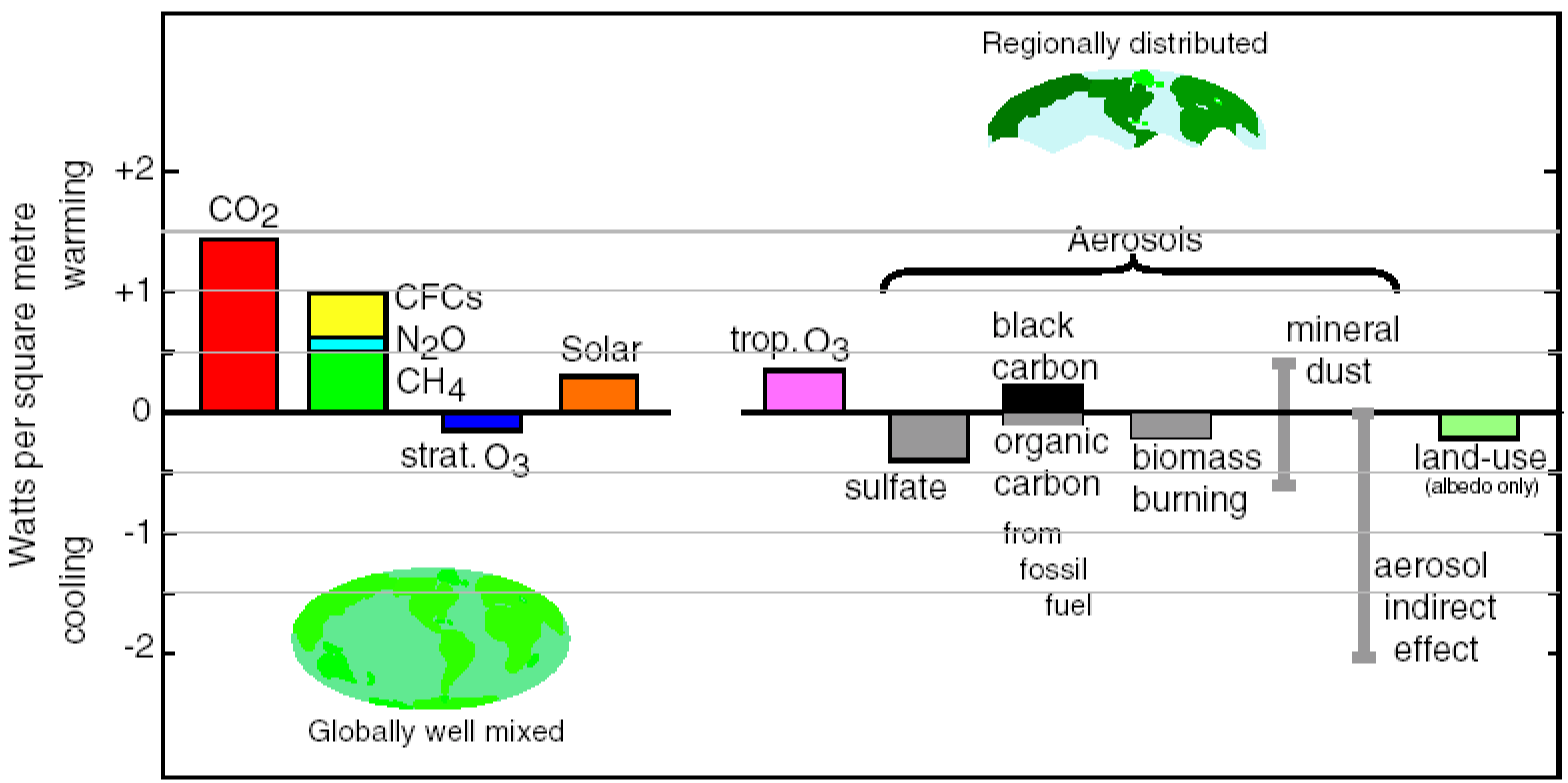
What are not ?

- CFCs & HCFCs *(Montreal - OK)*
- Sulfate Aerosols
- Black & Organic Carbon Aerosols
- Tropospheric Ozone (O_3)
- Carbon monoxide (CO)
- Nitrogen Oxides (NO_X)

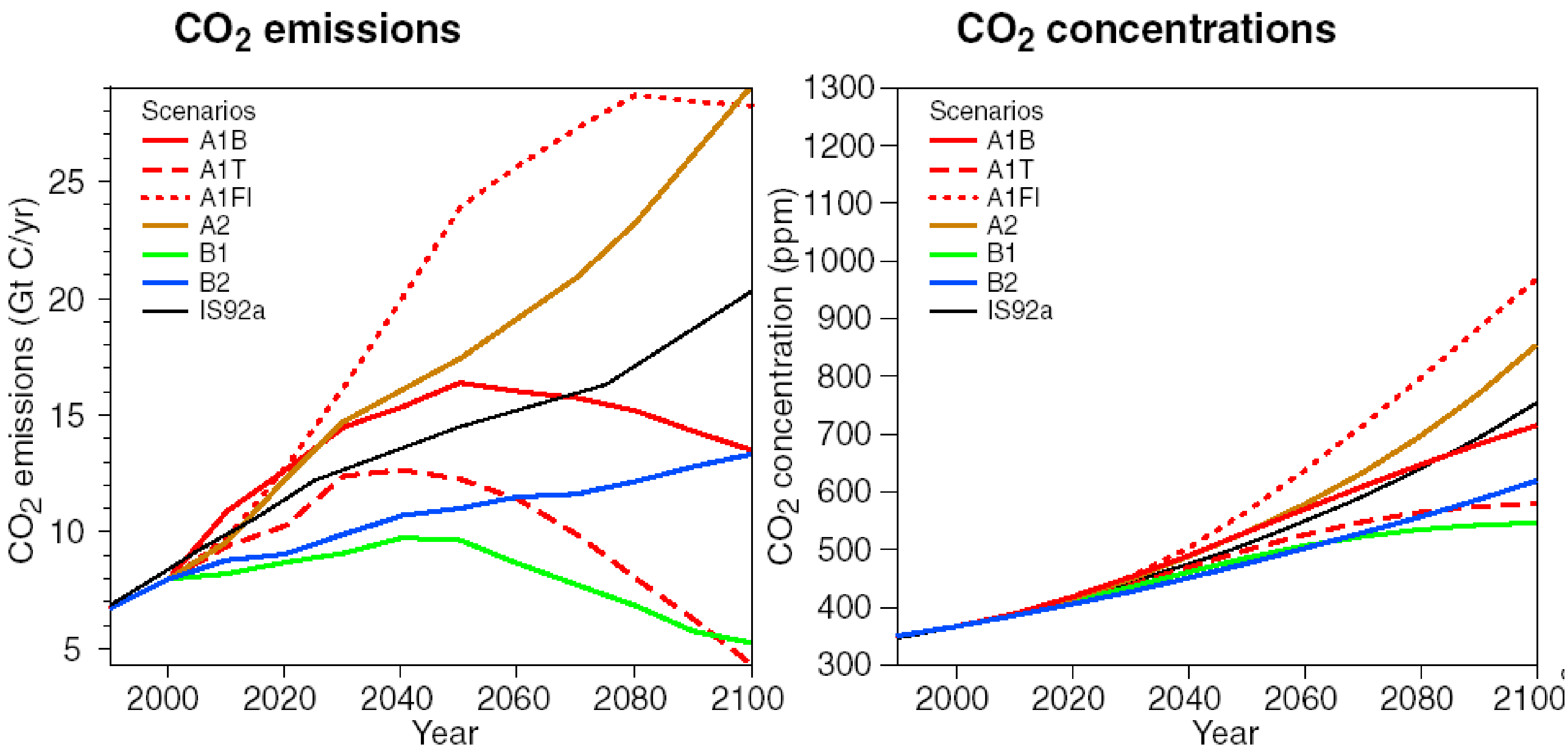
The global mean radiative forcing of the climate system for the year 2000, relative to 1750



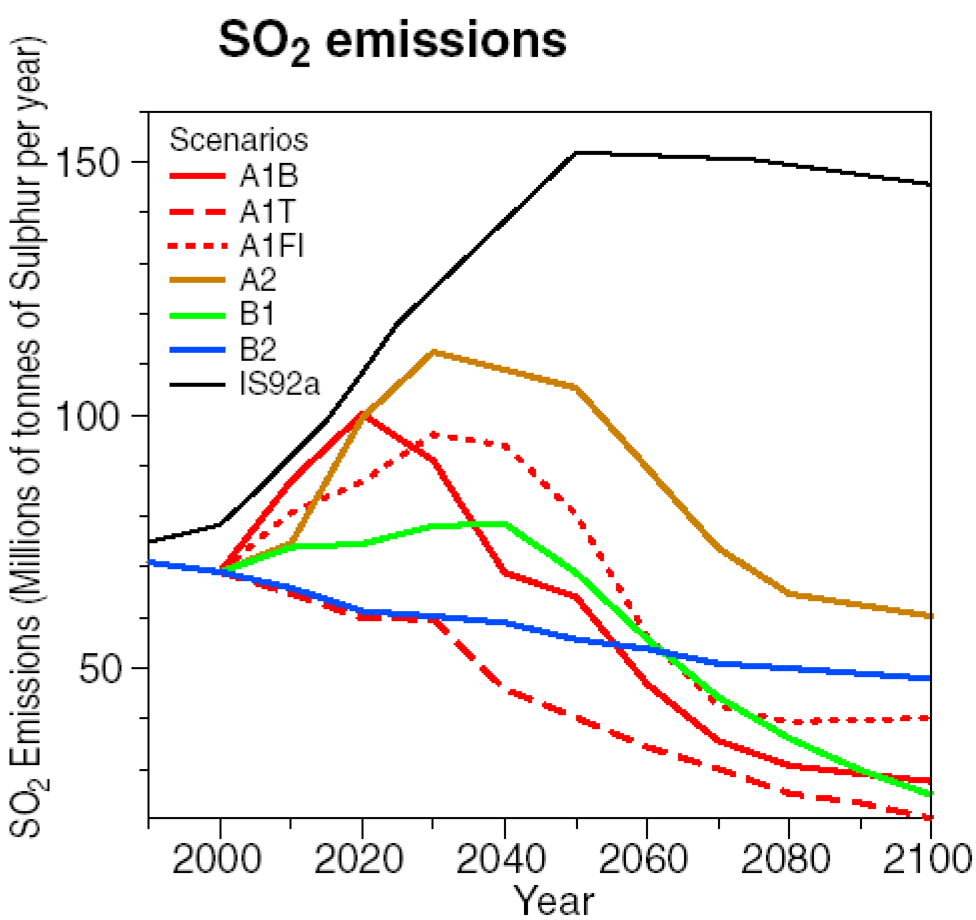
Global Mean Radiative Forcing of Climate for year 2000 relative to 1750



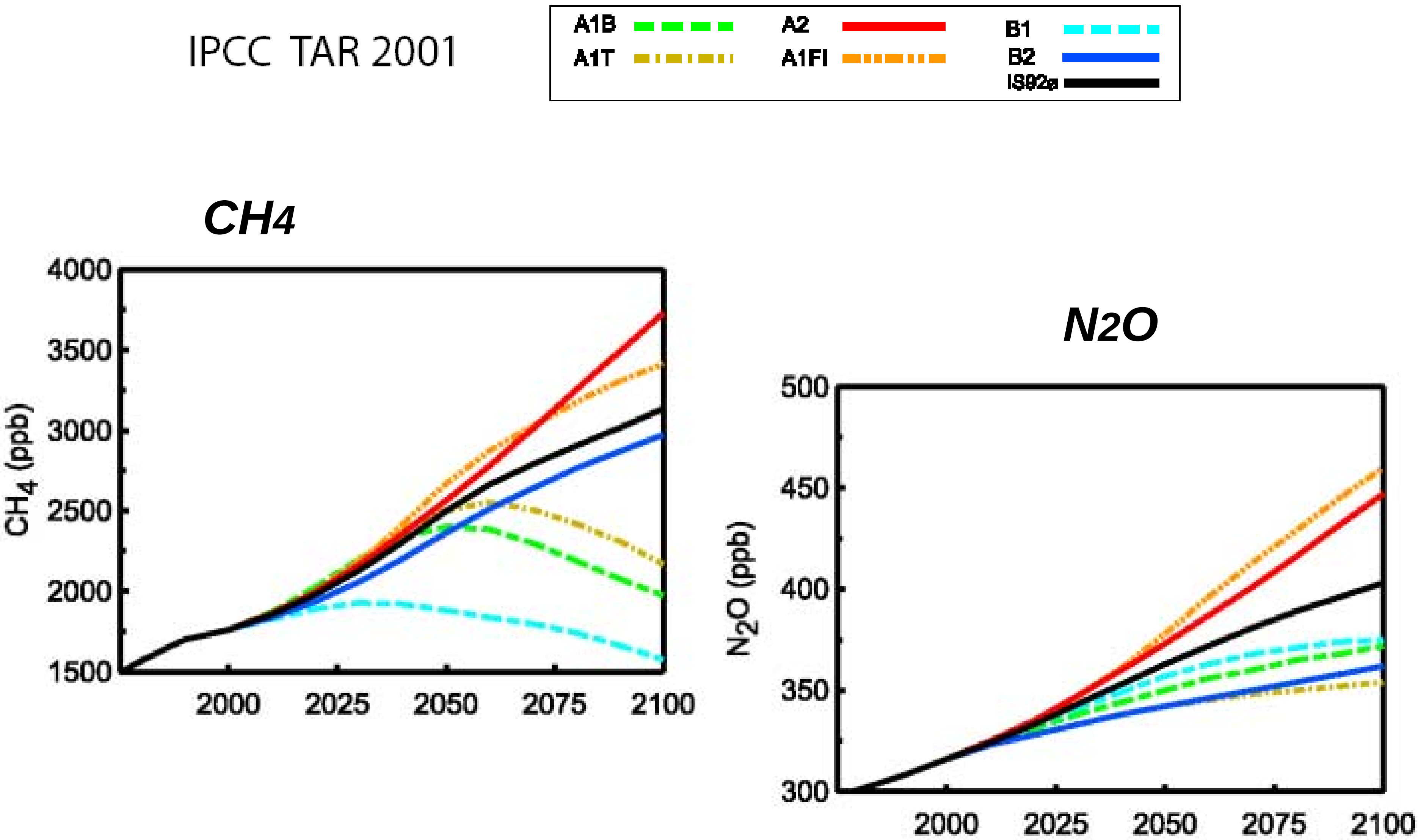
IPCC TAR 2001



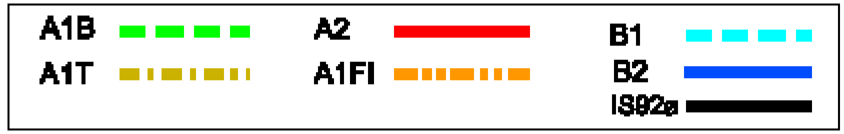
IPCC TAR 2001

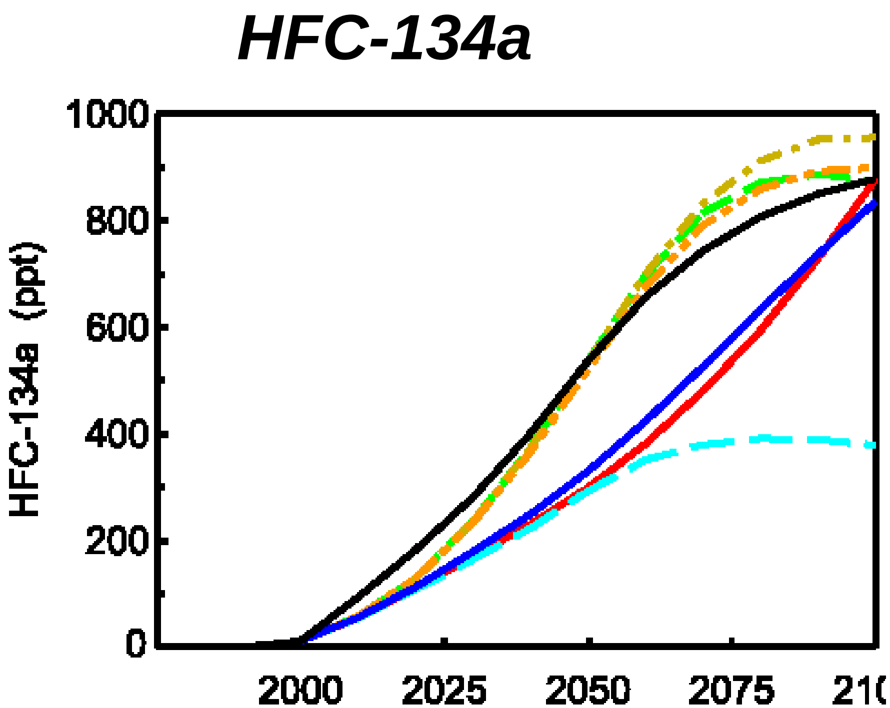


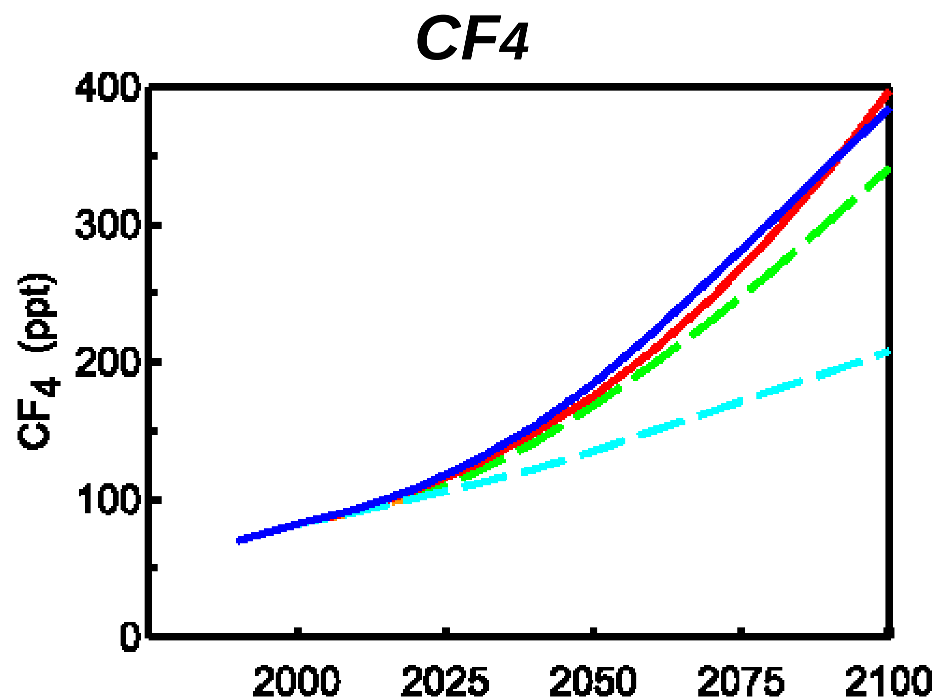
IPCC TAR 2001



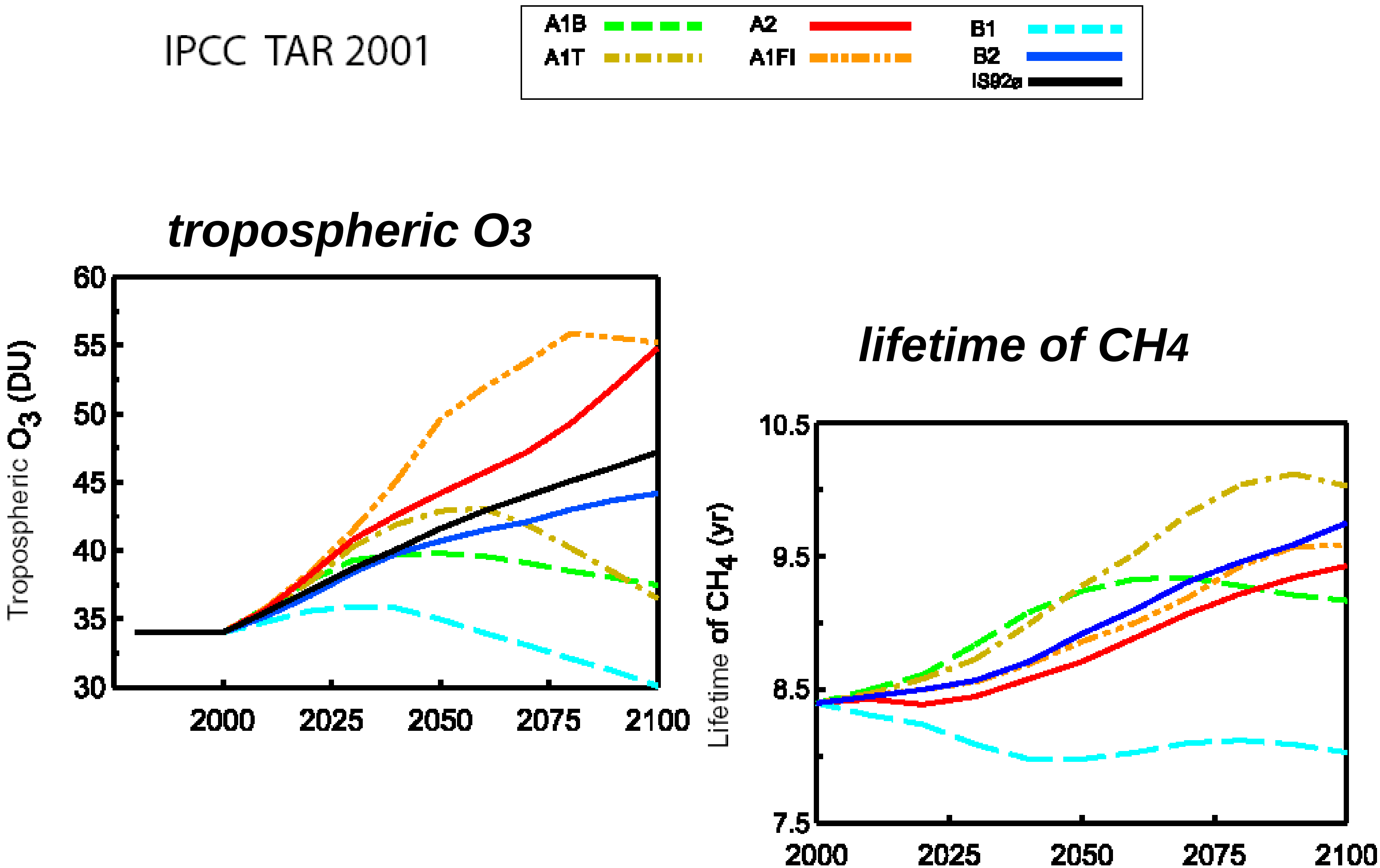
IPCC TAR 2001

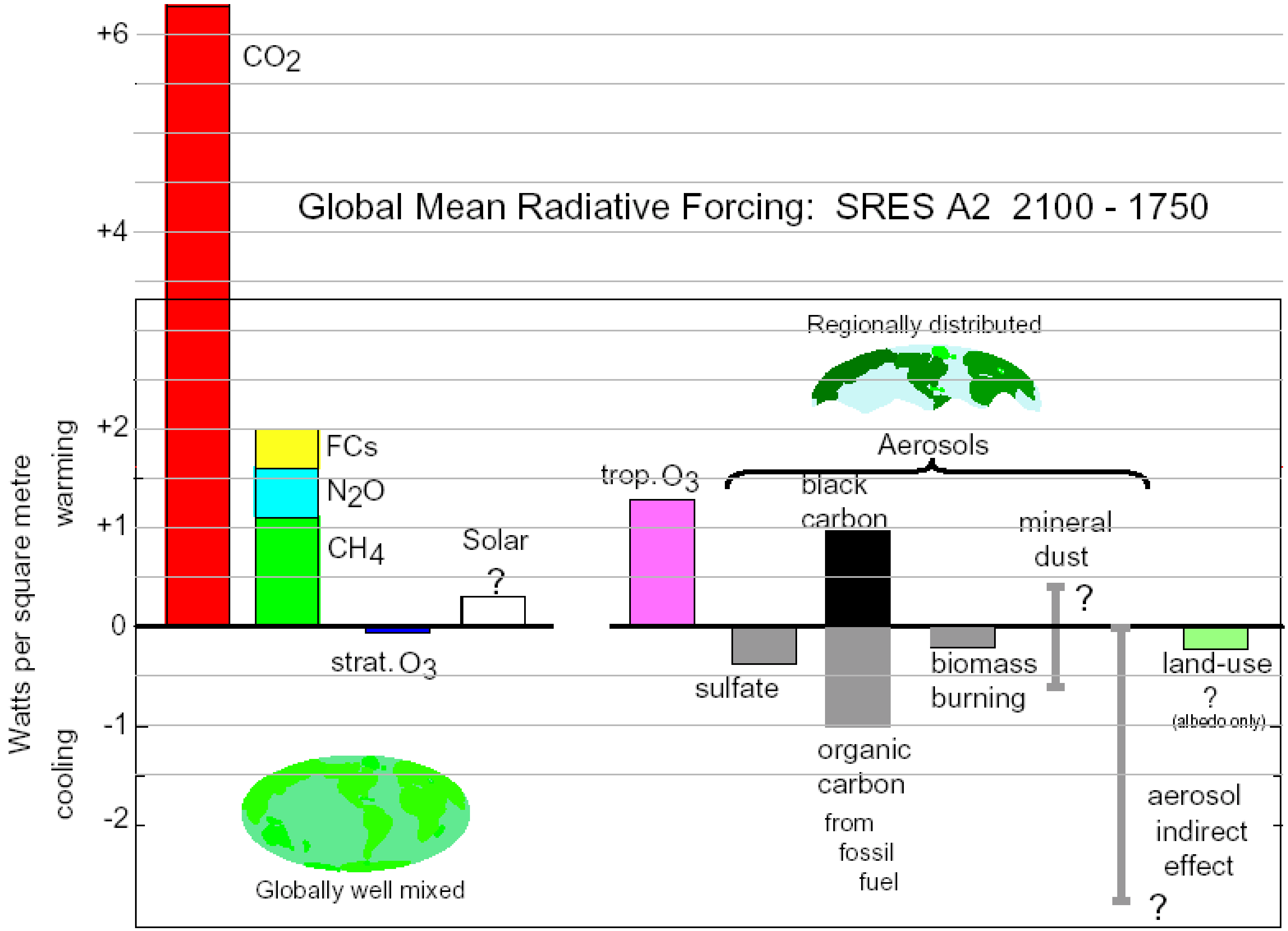






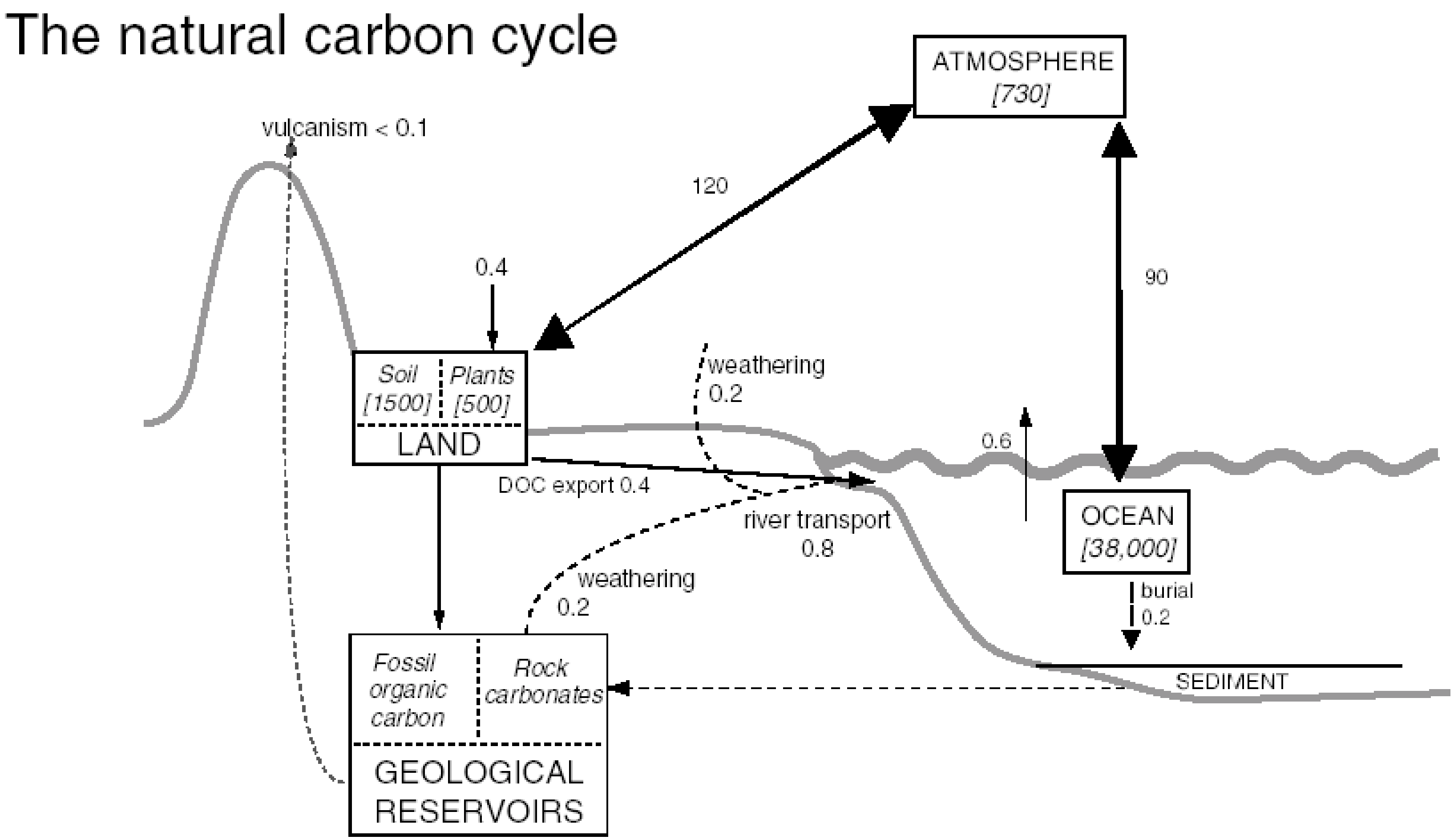
IPCC TAR 2001



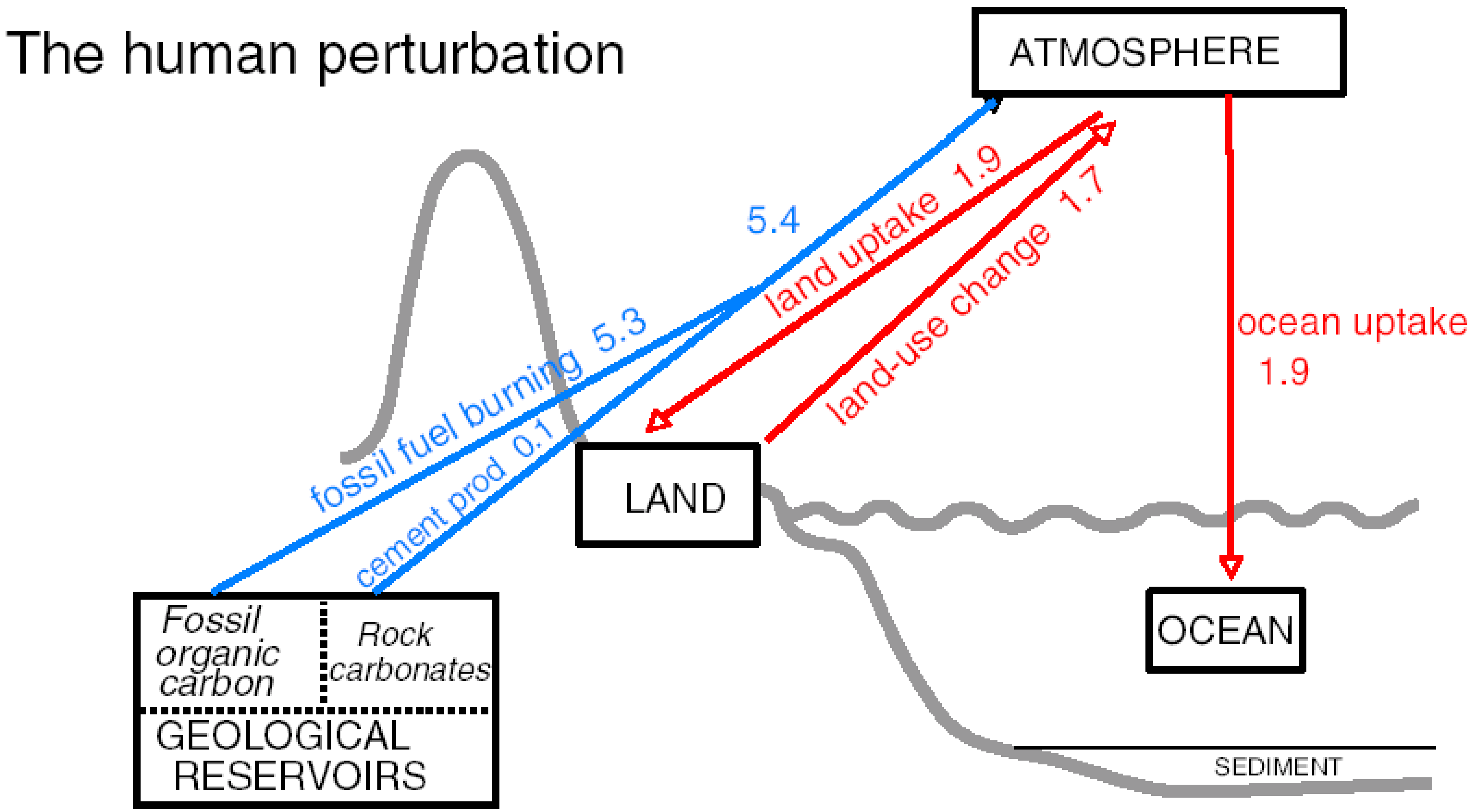


Global Mean Radiative Forcing: SRES A2 2100 - 1750
Watts per square metre
warming
cooling
+6
+4
+2
+1
0
-1
-2
CO2
FCs
N2O
CH4
strat. O3
Solar
?
Globally well mixed
trop. O3
Regionally distributed
Aerosols
black carbon
sulfate
organic carbon from fossil fuel
biomass burning
mineral dust
?
aerosol indirect effect
?
land-use
?
(albedo only)

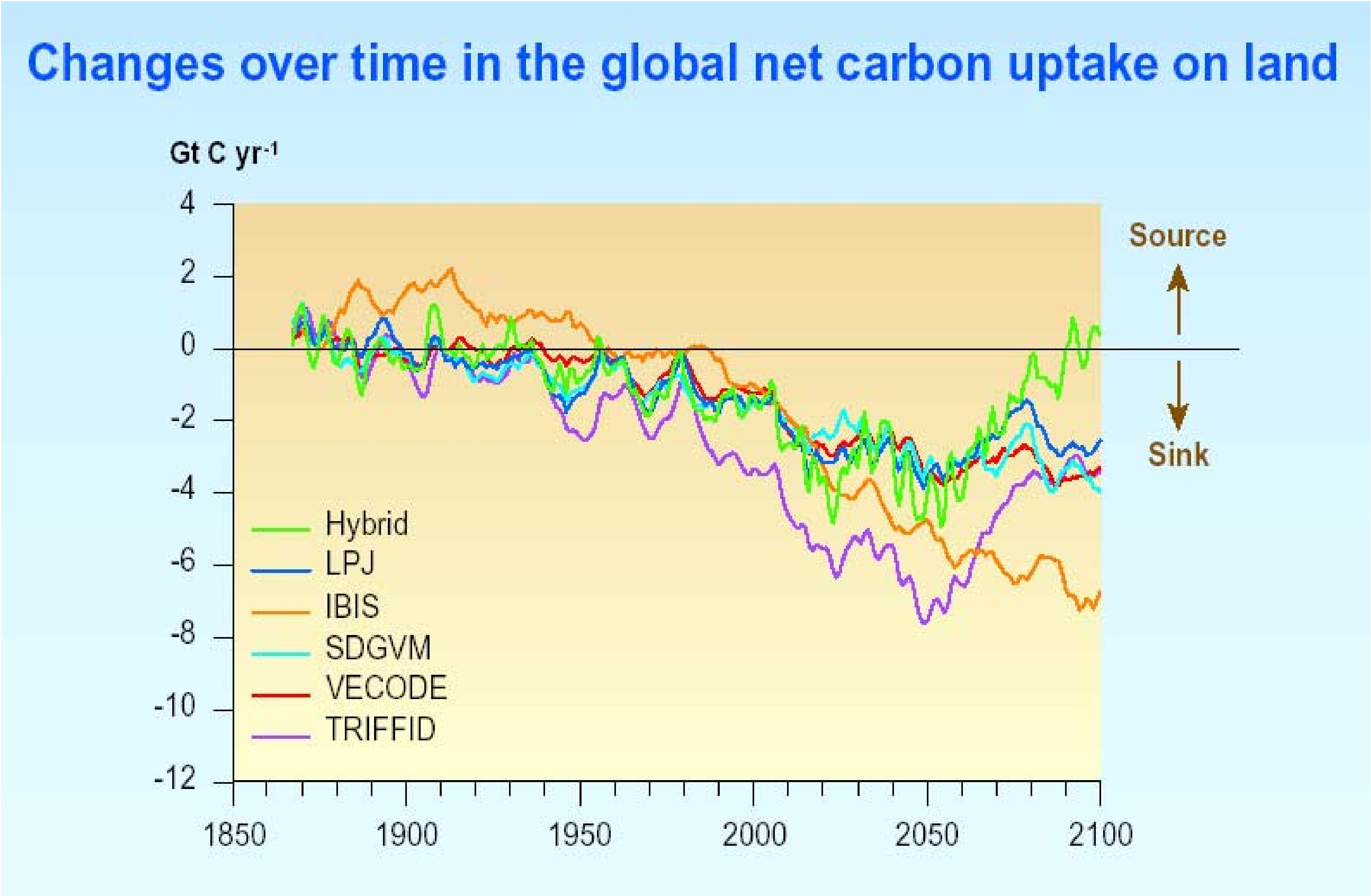
CO_2 – the carbon cycle



CO_2 – the carbon cycle, 1980s



Uptake of fossil CO_2 has possible "saturation" effects



CO2 – the carbon cycle - solutions

<u>Additional land uptake:</u>

TAR ***-*** restore all of the carbon released by historical land-use changes → reduce CO_2 by 40 - 70 ppm.

<u>Active sequestration:</u>

technologies applied to CO_2 reduction

e.g., NAE symposium, 23-24 April 2002, "Complements to Kyoto: Technologies for Controlling CO2 Emissions."

http://www.nae.edu/nae/naehome.nsf/weblinks/BDOR-588Q9A?OpenDocument

Aerosols – direct and indirect forcing (WG1-Ch.5)

Aerosols consist of:

ammonium sulfate and nitrates

sea salt

mineral/soil dust

industrial dust

carbonaceous matter (“brown”)

elemental carbon or soot (“gray”)

The radiative forcing of aerosols through their effect on liquidwater clouds consists of two parts: the 1st indirect effect (increase in droplet number associated with increases in aerosols) and the 2nd indirect effect (decrease in precipitation efficiency associated with increases in aerosols).

Aerosols (Synthesis Report)

The radiative forcing from anthropogenic greenhouse gases is positive with a small uncertainty range; that from the direct aerosol effects is negative and smaller; whereas the negative forcing from the indirect effects of aerosols on clouds might be large but is not well quantified.

These studies include uncertainties in forcing due to anthropogenic sulfate aerosols and natural factors (volcanoes and solar irradiance), but do not account for the effects of other types of anthropogenic aerosols and land-use changes.

Key Uncertainties: Climate forcings due to natural factors and anthropogenic aerosols (particularly indirect effects).

Anthropogenic control of the old GHGases

CH_4 emissions (600 Tg-CH_4/yr)

fossil fuels	17%
biomass burning	5%
landfills	7%
ruminants	14%
rice	9%
pollution (lifetime)	*??%*

N_2O emissions (16 Tg-N/yr)

industrial processes	7%
biomass burning	3%
agriculture	24%
cattle/feedlots	12%

CFC & HCFC emissions (<< 1 Tg/yr)

refrigeration, foam, propellant, cleaning

phased out under Montreal Protocol

Anthropogenic control of the new GHGases

PFCs = CF_4 + ... (13 Gg/yr ++)
anthropogenic*** 100%
aluminum, industrial

SF_6 emissions (6 Gg/yr ++)
anthropogenic 100%
insulation, electrical switches

HFC emissions (100 Gg/yr ++)
anthropogenic 100%
CFC partial replacements

Anthropogenic control of Aerosols

sulfate = SO_2 emissions (110 Tg-S/yr)

fossil fuels	67%
biomass burning	2%

Black Carbon emissions (12 Tg/yr)

fossil fuels	55%
biomass burning	45%

Carbonaceous emissions (140 Tg/yr)

fossil fuels	20%
biomass burning	39%

Anthropogenic control of the pollution gases

CO emissions (2800 Tg-CO/yr)

fossil & domestic fuel	32%
biomass burning	25%

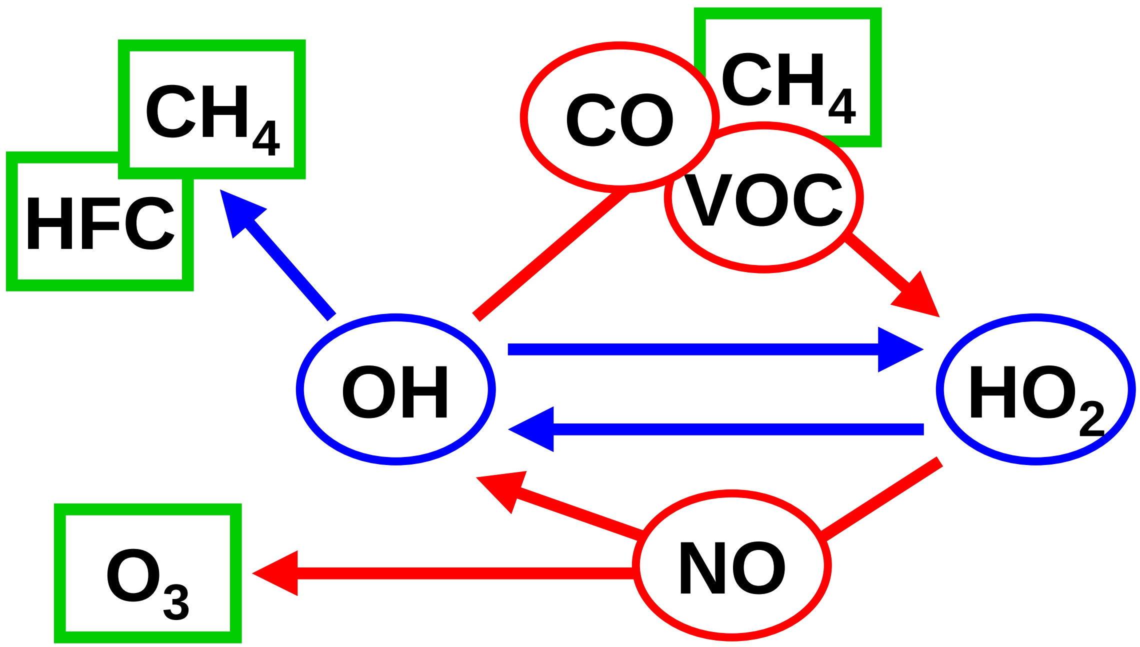
NO_x emissions (52 Tg-N/yr)

fossil fuels	65%
biomass burning	14%
agriculture/soils	12%

VOC emissions (600 Tg-C/yr)

fossil fuel	28%
biomass burning	6%

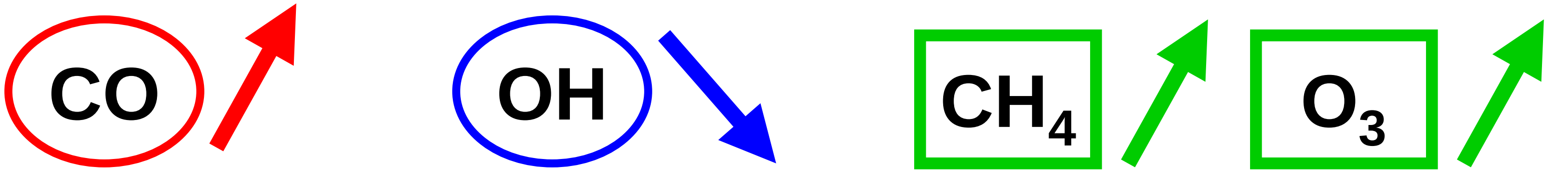
How do non-greenhouse Pollutants impact Climate ?

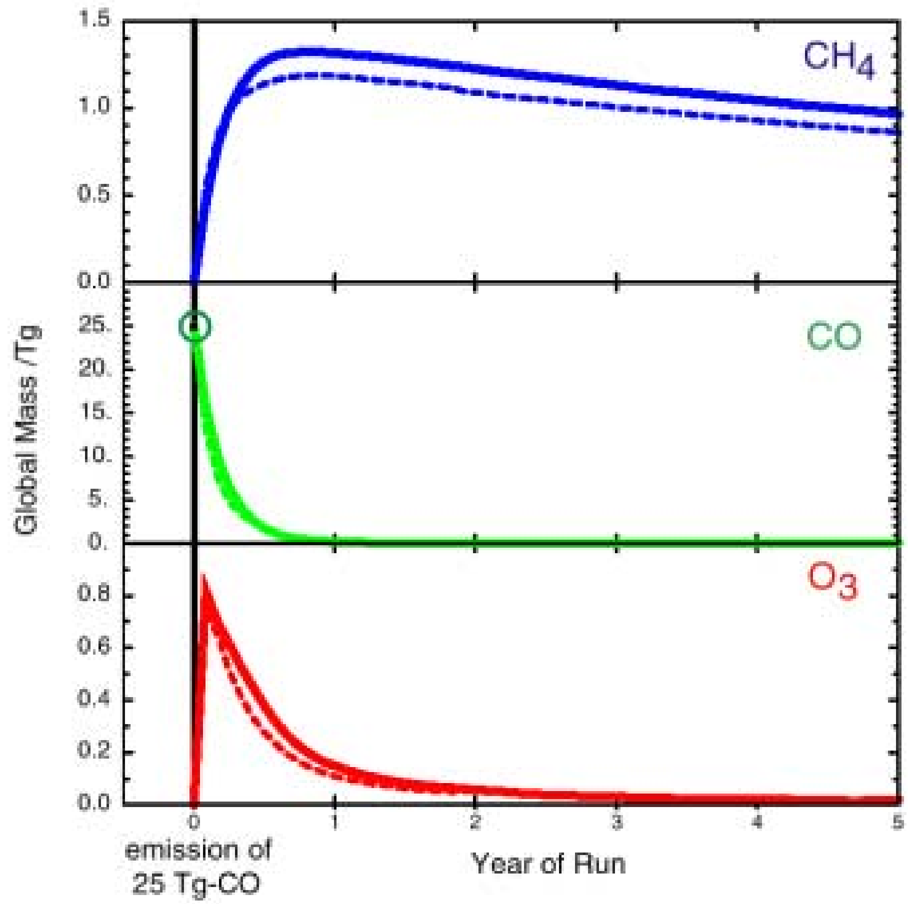


CO, VOC, NO_X *(=NO+NO$_2$)*, & CH_4 control

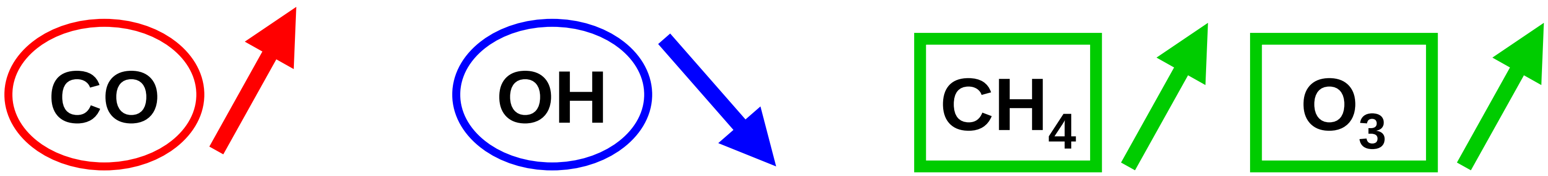
Tropospheric Chemistry

is the sink for CH_4 & HFCs; the source for O_3


CO
OH
CH_4
O_3


CH_4
CO
O_3
Global Mass /Tg
1.5
1.0
0.5
0.0
25.
20.
15.
10.
5.
0.
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
emission of
25 Tg-CO
Year of Run

CO becomes an indirect greenhouse gas



CO emissions are effectively

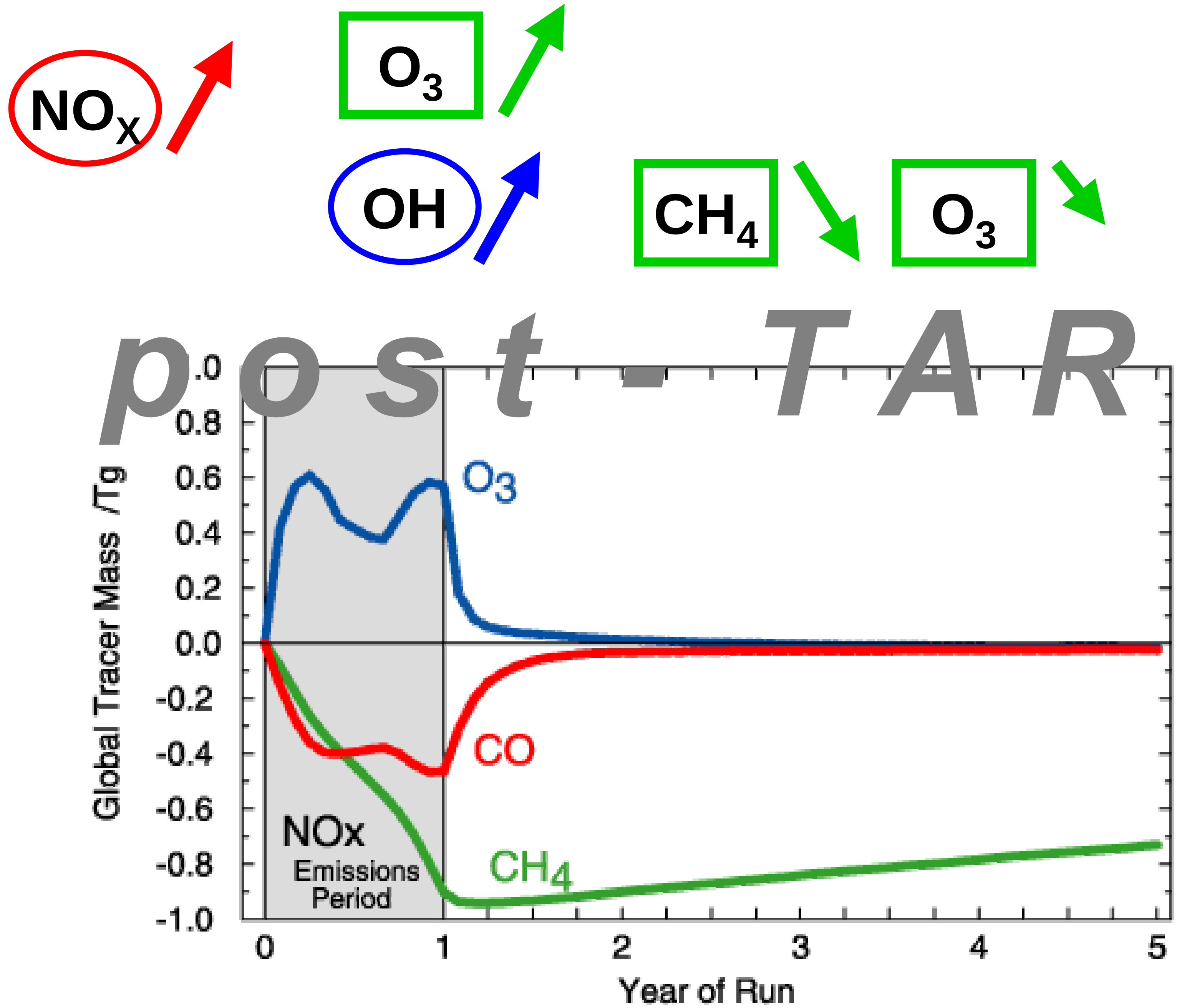
equivalent to CH_4 emissions:

100 Tg-CO = 5 Tg-CH4

(IPCC, TAR)

Effective Reactive Pollutant contribution to CH_4

CH_4	320 $Tg(CH_4)/y$ = direct emission	
NOx	40 Tg(N)/y	⇨ **-** 80 $Tg(CH_4)/y$
CO	1000 Tg/y	⇨ **+** 50 $Tg(CH_4)/y$
VOC	250 Tg/y	⇨ **+** 30 $Tg(CH_4)/y$



NO_X
O_3
OH
CH_4
O_3
post - TAR
Global Tracer Mass /Tg
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
O_3
CO
CH_4
NOx
Emissions
Period
0
1
2
3
4
5
Year of Run

NOx becomes an indirect greenhouse gas

0.5 Tg-N of NOx → short-lived trop-O_3 *vs*. long-lived CH_4 & O_3

depends strongly on location of emissions