Global Climate Change and Aviation - The Challenge

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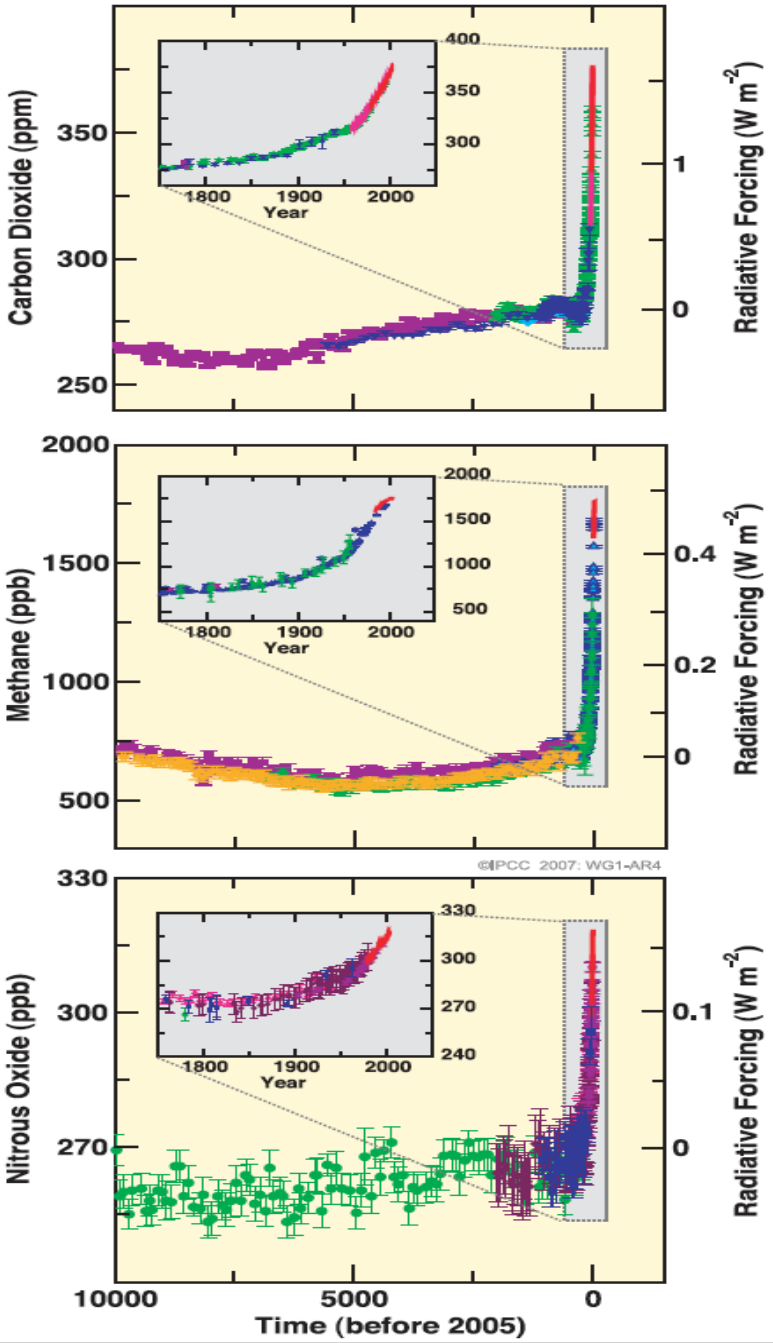
Global warming is a reality

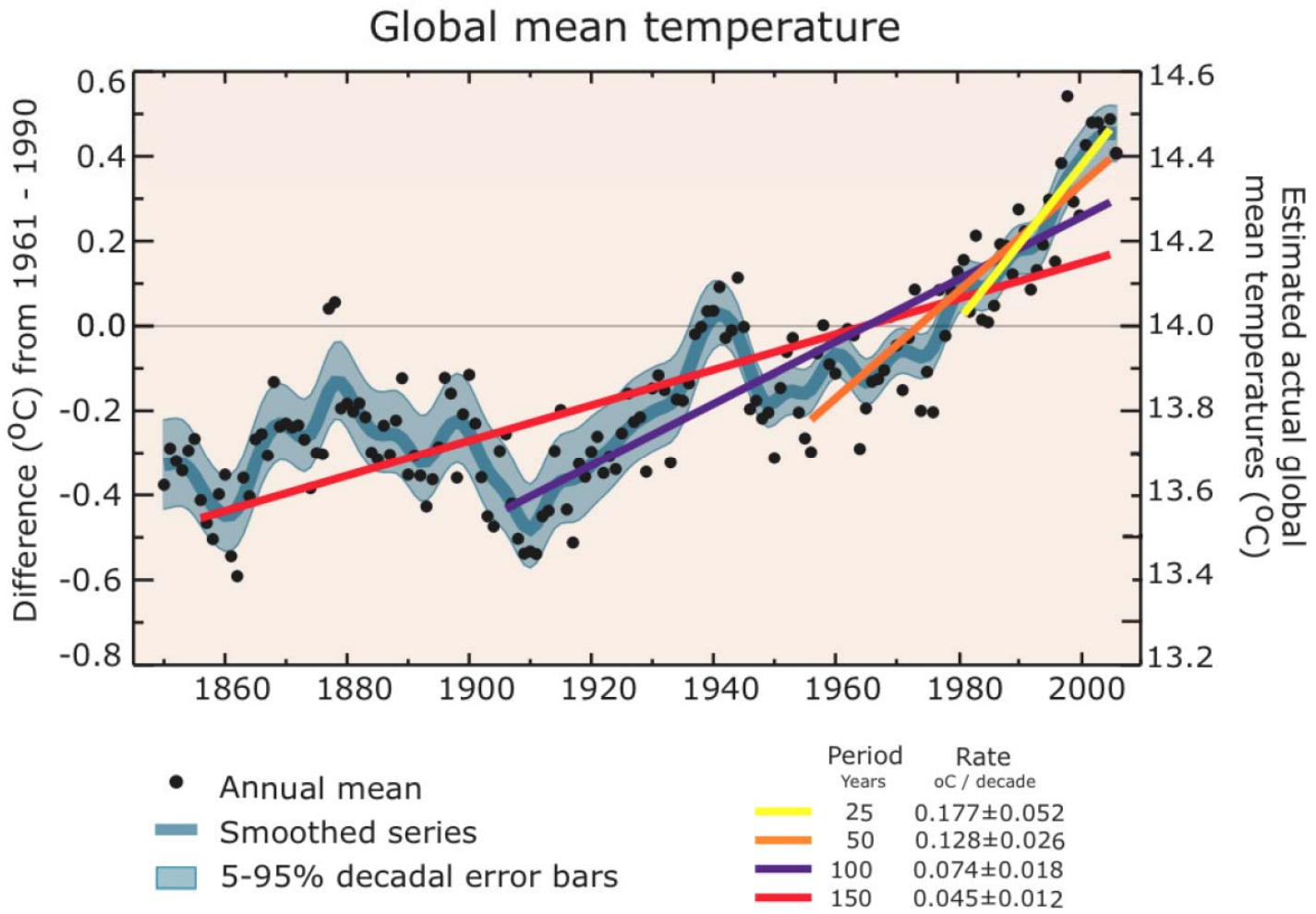
- Strongest CO_2 concentrations increase since 650,000 years
- 0.75°C warmer globally than a century ago
- Human induced radiative forcing of about 1.6 W/m^2
- Most of the global warming of the past half-century is due to increases in greenhouse gases
- The future climate depends on human choices about emissions

CO_2 concentrations increase: unprecedented in the last 10,000 (actually 650,000) years

- Increased Growth rates of Greenhouse gas concentrations (Carbon Dioxide, Methane, Nitrous Oxide) during the last 50 years
- Carbon Dioxide (CO_2) increases caused mainly by burning fossil fuels

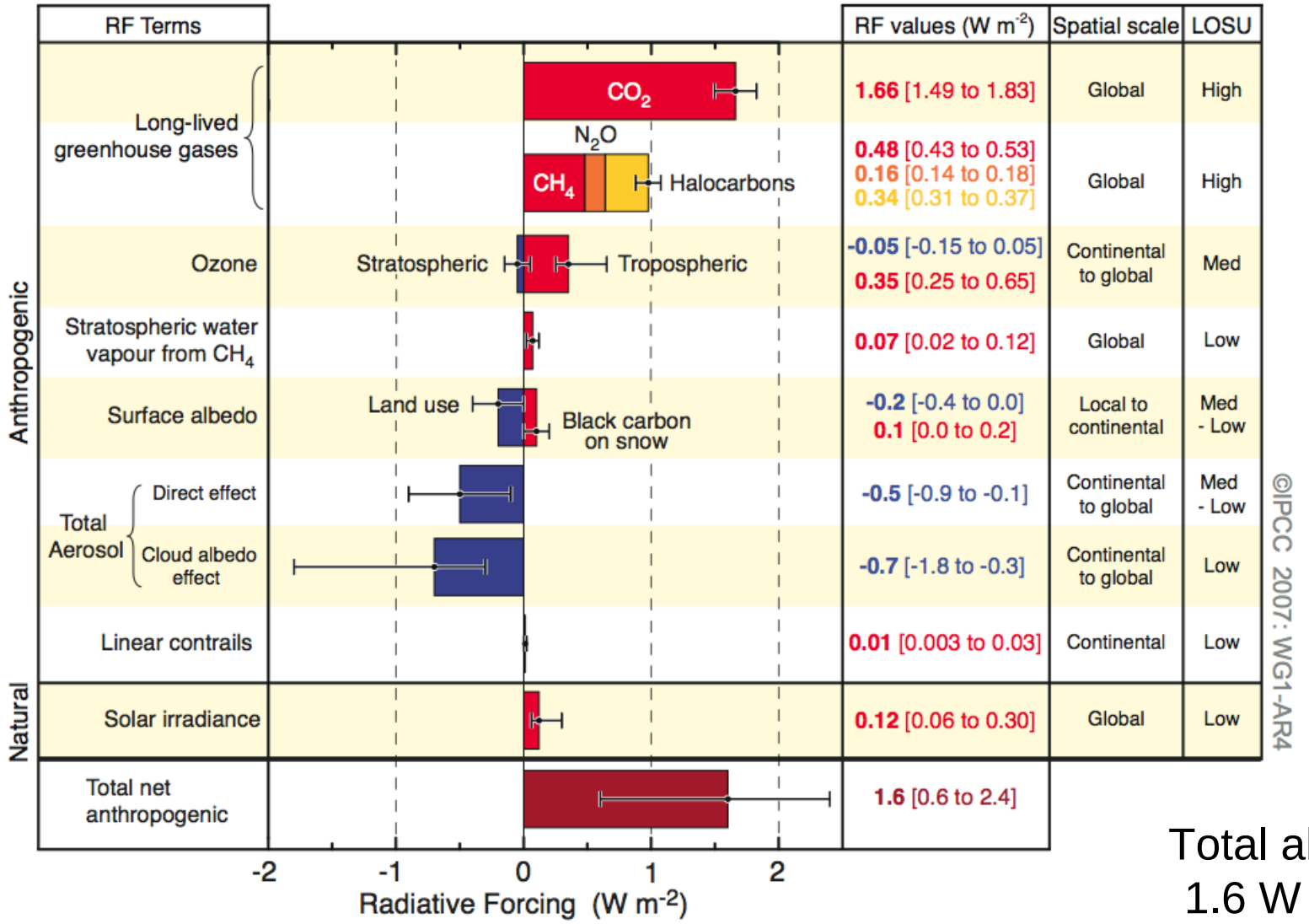


Global mean surface temperature: 0.75°C warmer than it was a century ago



(IPCC, Fig. 3.2)

Large Human Contributions to Radiative Forcing



Aviation:

+

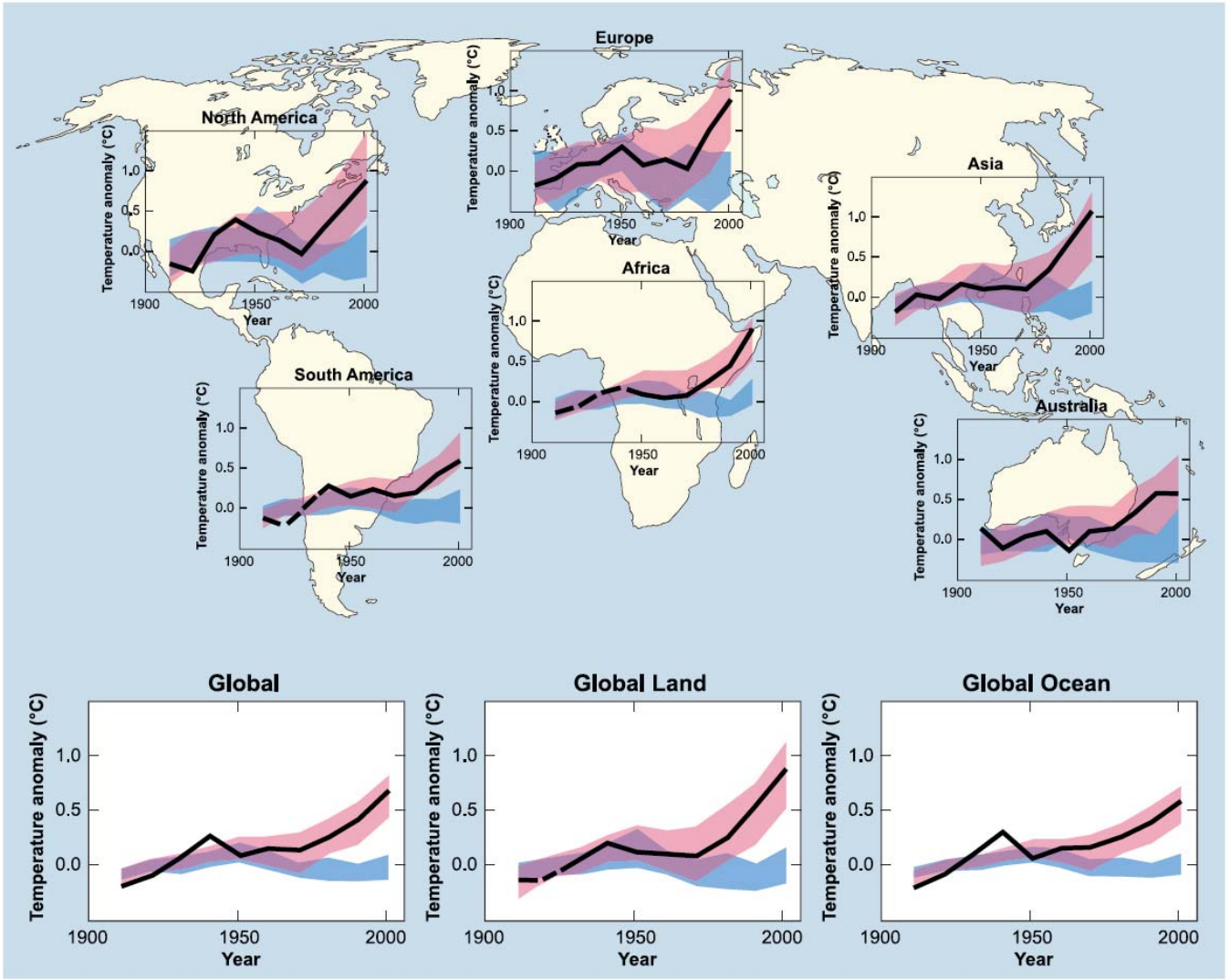
-

+

+

Total about
1.6 W m^{-2}

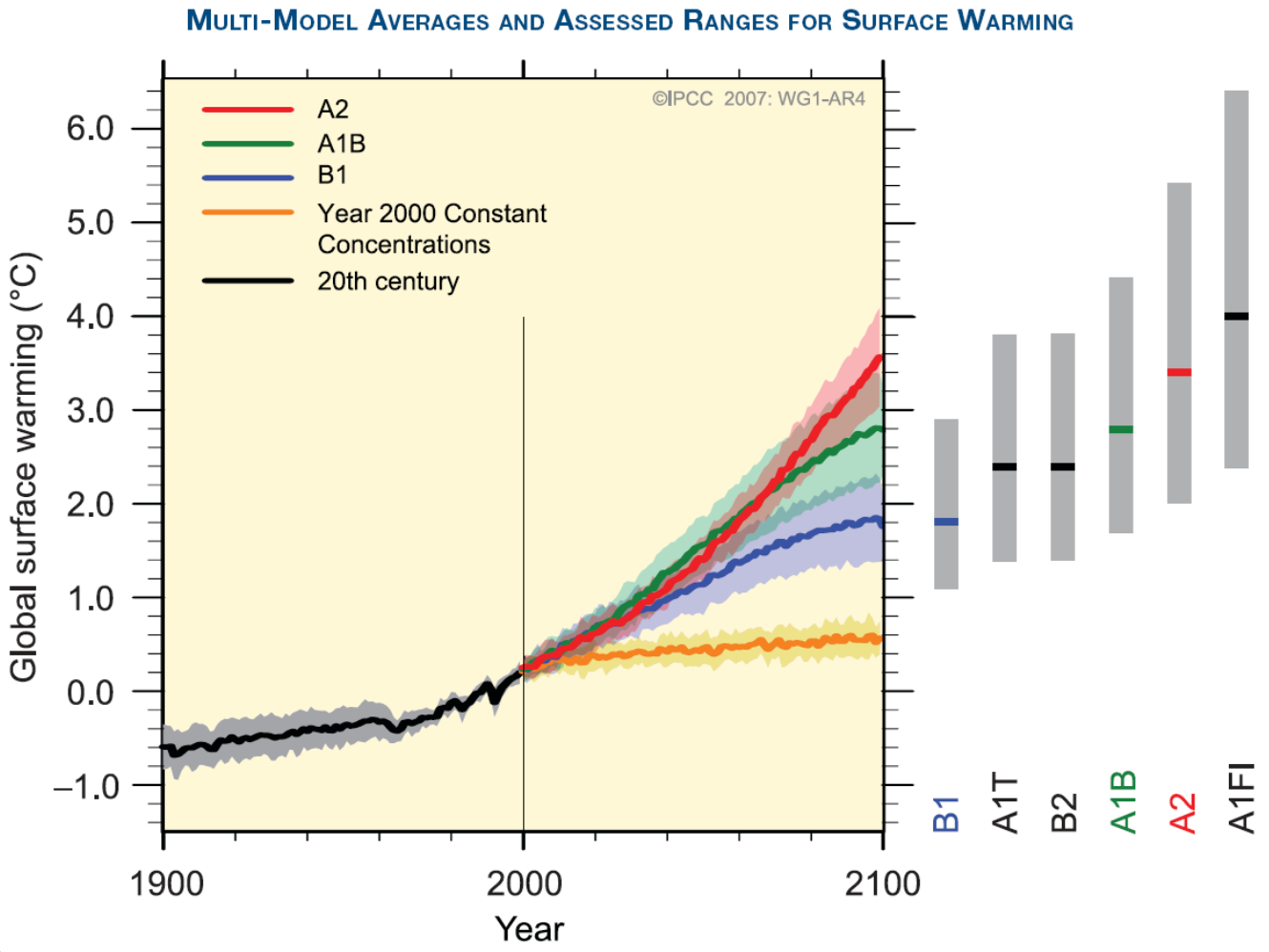
Very likely (>90%) that most of the global warming of the past half-century is due to increases in greenhouse gases



The future climate depends on human choices about emissions

Growth to
600 – 1550 ppmv
CO_2 equiv
(B1 – A1FI)

corresponds to
+1.8°C to +4°C
[likely 2.4-6.4°C]
by 2100



Climate Impact of Aviation

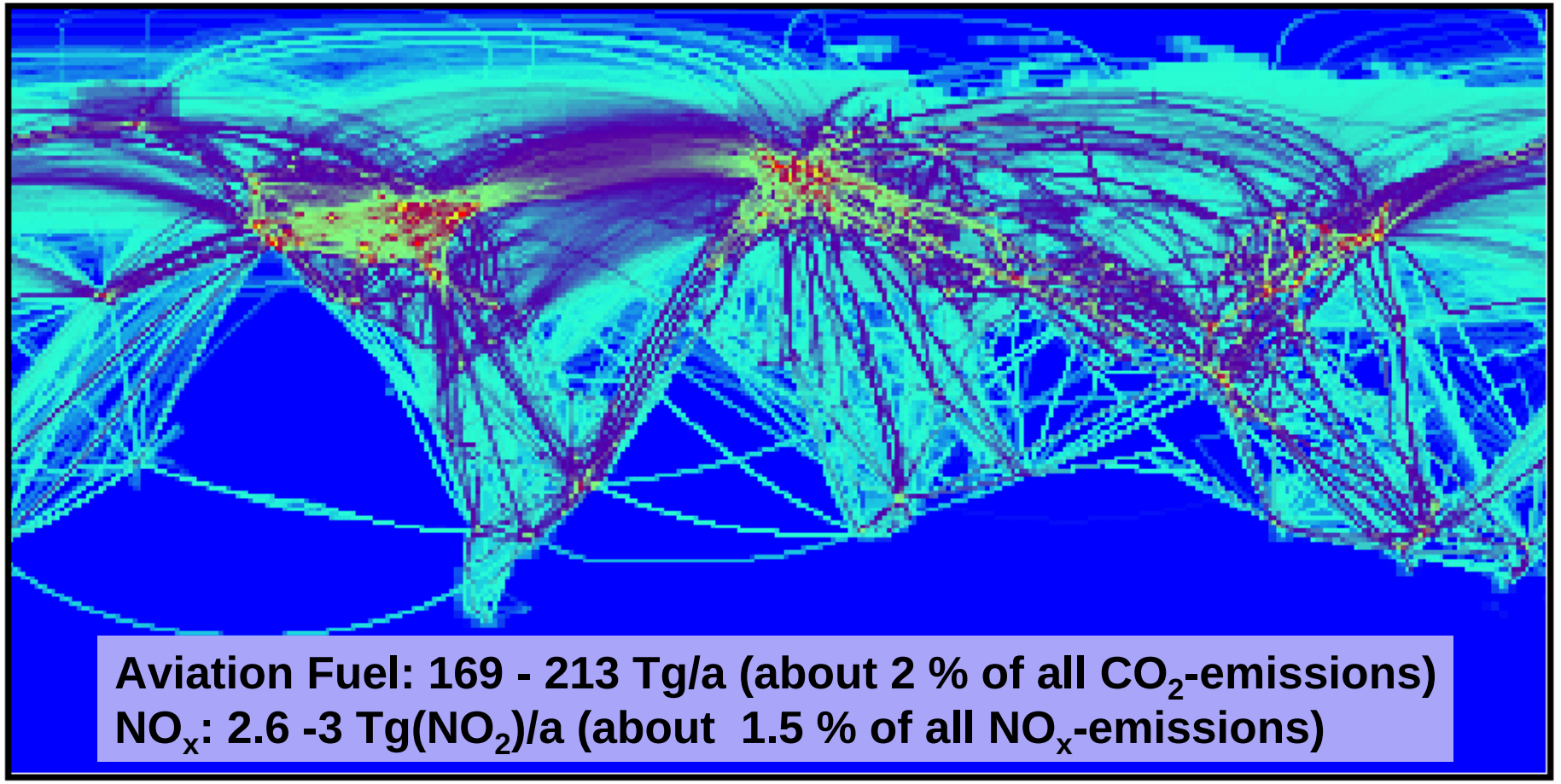
Global aviation contributes to climate change by emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), water vapour, particles, contrails and cirrus changes.

Carbon dioxide is the most important greenhouse gas. Its effect is independent of the altitude at which the emission occurs.

Nitrogen oxides from aviation at subsonic cruise altitudes enhance ozone formation and reduce methane; both are greenhouse gases.

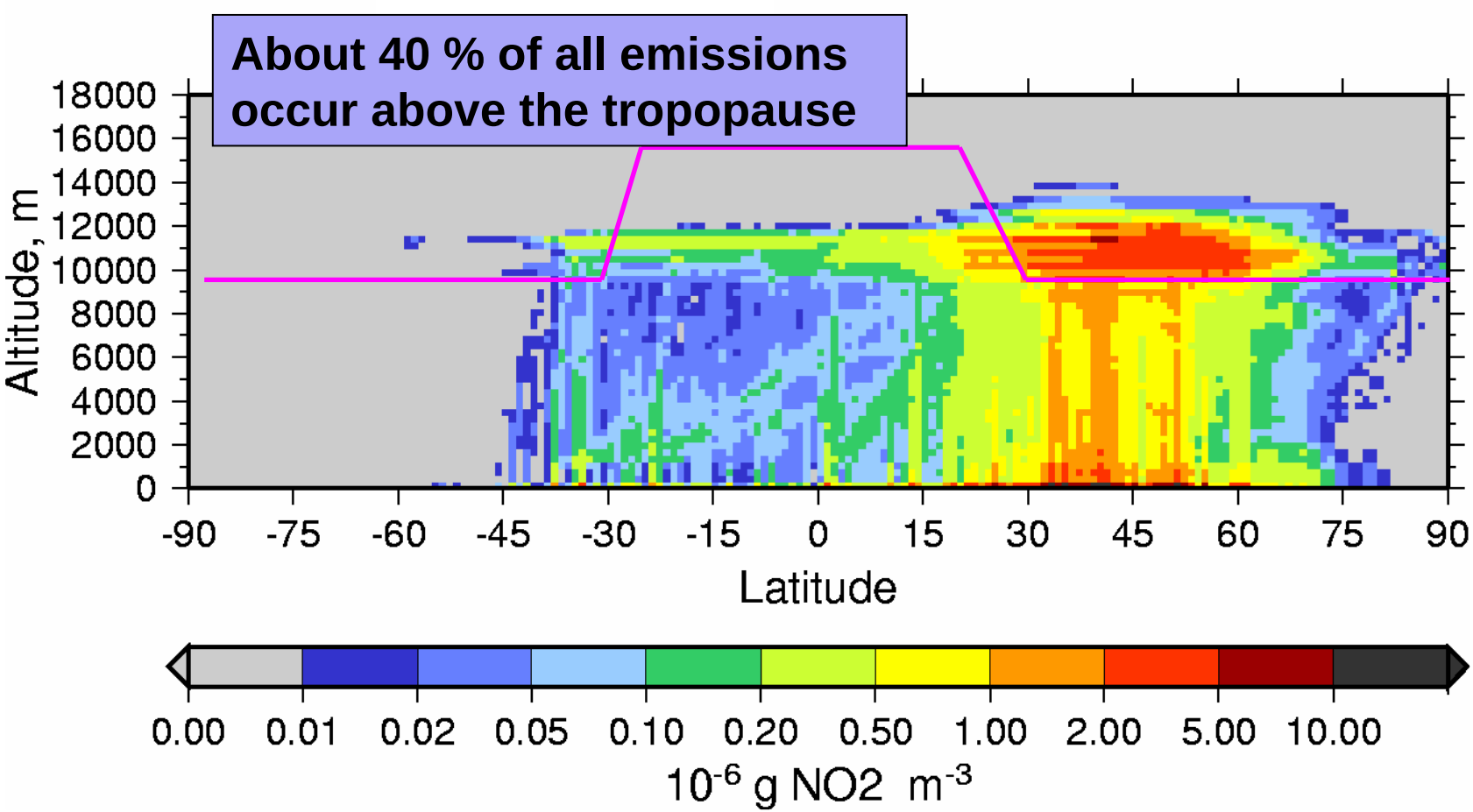
Water vapour and particles (soot etc.) emitted at altitudes near the tropopause can induce contrails and cirrus clouds, likely enhancing the greenhouse effect.

Global distribution of aviation emissions



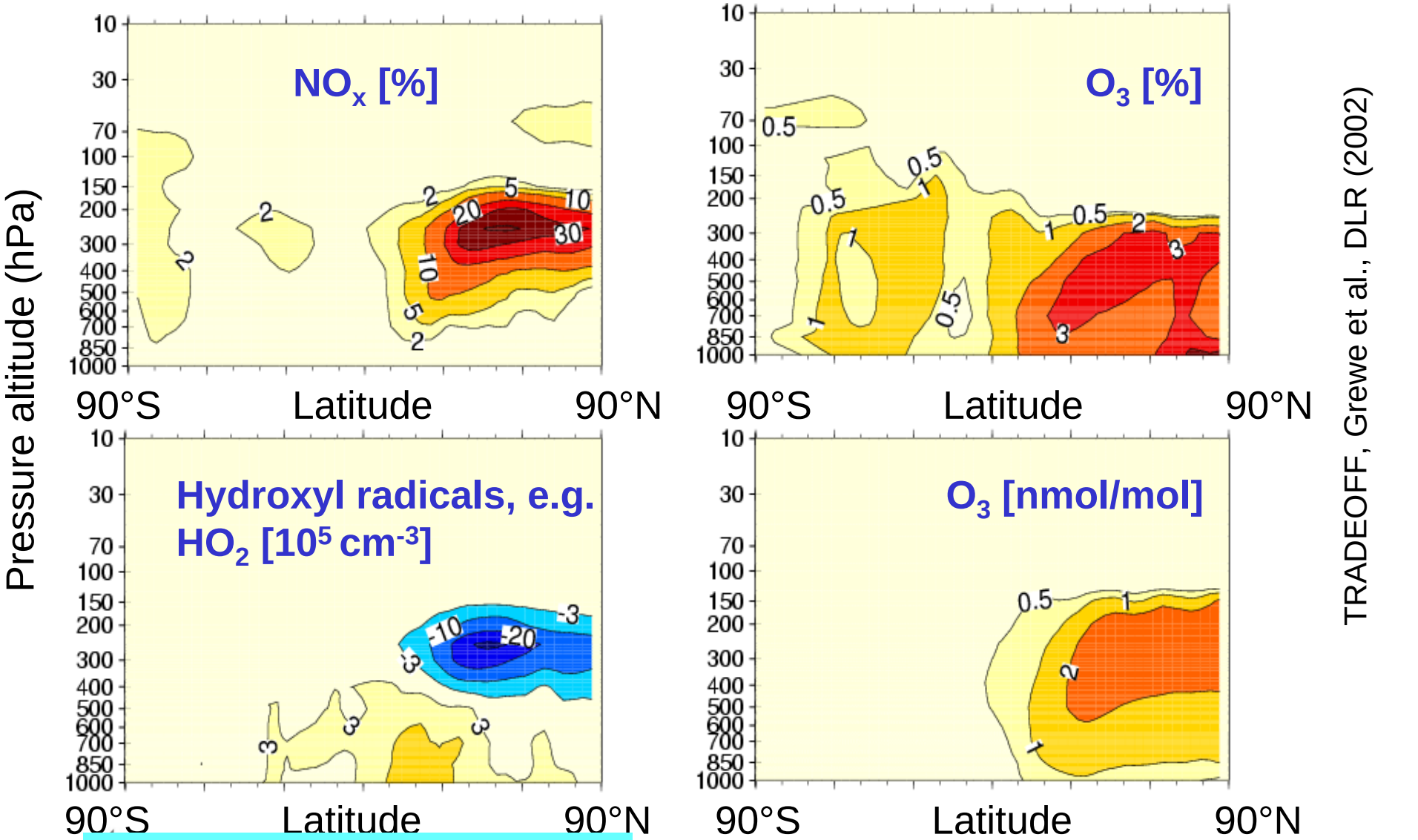
(AERO2K, 2005)

Vertical Distribution of Aircraft Emissions and Tropopause



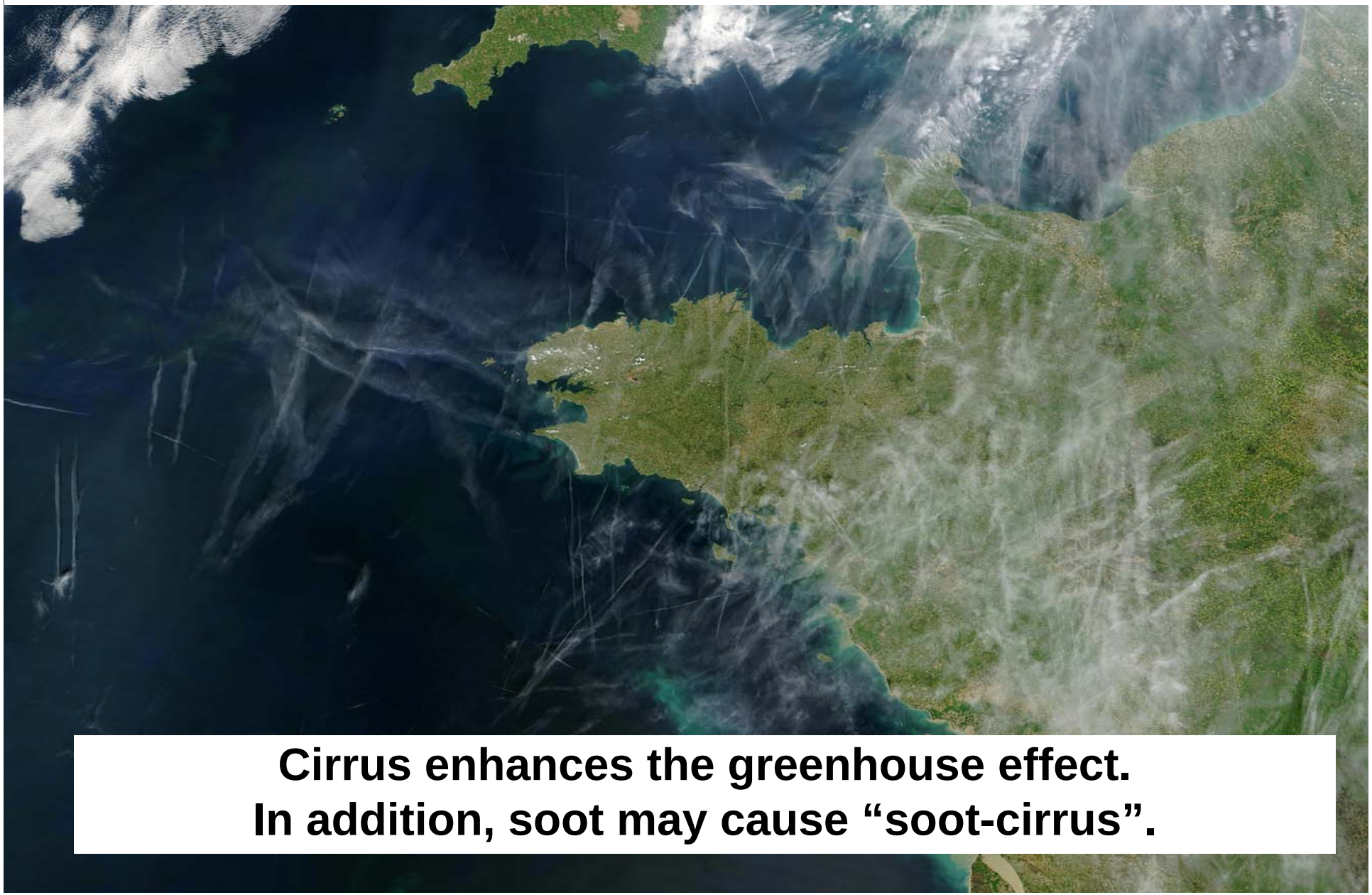
(AERO2K, 2005)

Aviation increases Nitrogen Oxides (NOx), Ozone (O_3) and Hydroxyl Radicals (OH) concentrations in Upper Troposphere



CH_4+OH -> CO + 2 H_2O

Contrails from cruising aircraft and soot cause cloud changes: we see line-shaped contrails evolving into “contrail-cirrus”



Cirrus enhances the greenhouse effect.
In addition, soot may cause “soot-cirrus”.

Contrails and soot from cruising aircraft cause cloud changes which mostly contribute to warming

Contrails are caused by water vapor emissions from aircraft flying in cold and humid air masses

Soot and other particles change contrails and cirrus properties

Line-shaped contrails are detectable from space

The total cirrus change is estimated with still large uncertainty

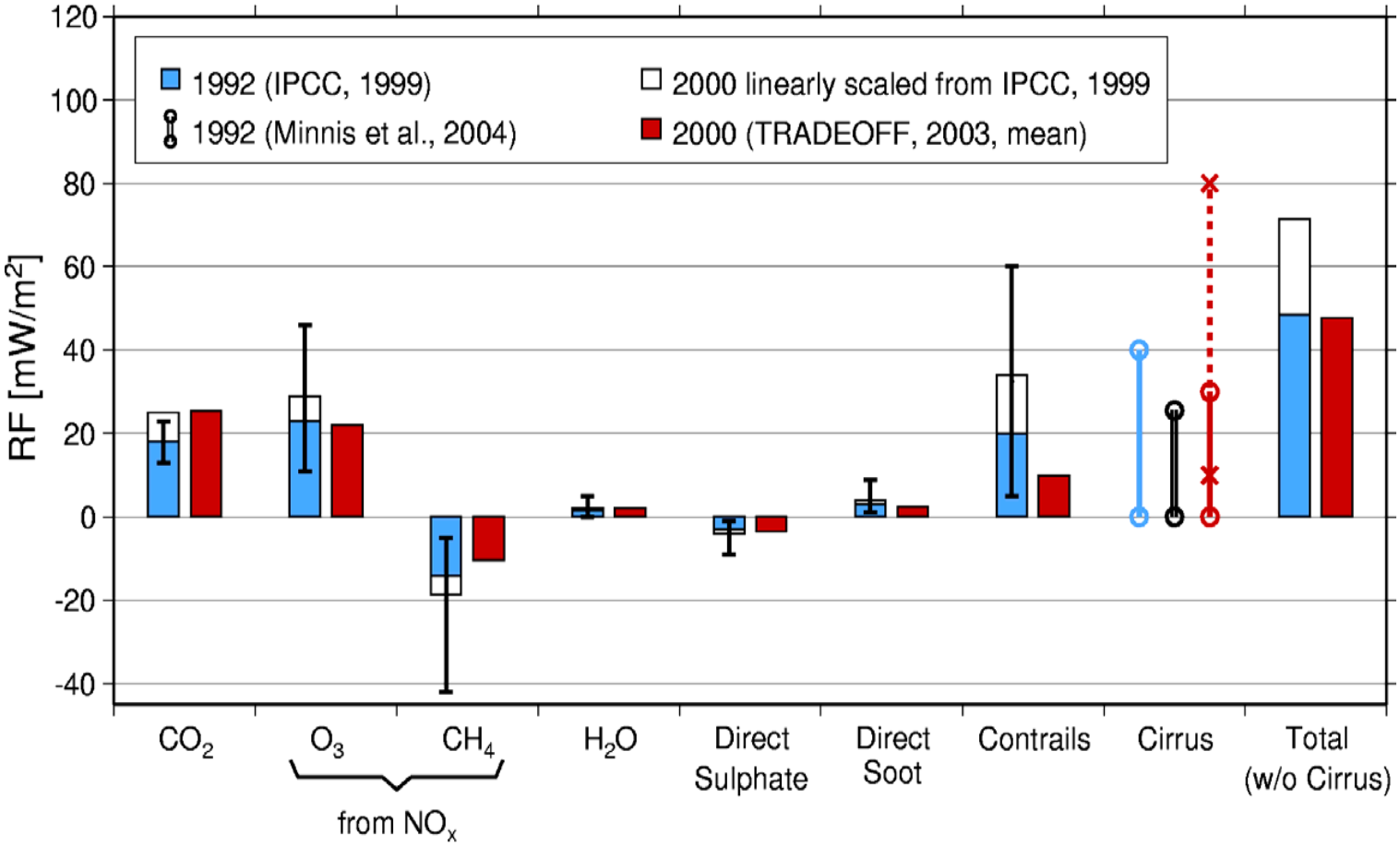
Cirrus and contrails heat during night

They heat or cool during day

Radiative Forcing and Temperature Change induced by Aviation

- **Global aviation contributed to Radiative Forcing so far about 0.05 W/m^2.**
- **These are about 3 % of the total (about 1.6 W/m^2) radiative forcing from all anthropogenic effects**
- **The largest uncertainty comes from aviation contributions to changes in cirrus clouds, which are not included in the total therefore.**
- **Including the presently know uncertainties, the aviation contribution is estimated within the range 2 to 8 %.**
- **Global aviation contributed to the observed global warming of 0.7°C about 0.02-0.03°C (ca. 3-4 %), so far.**

Radiative Forcing until 2000 from Global Aviation

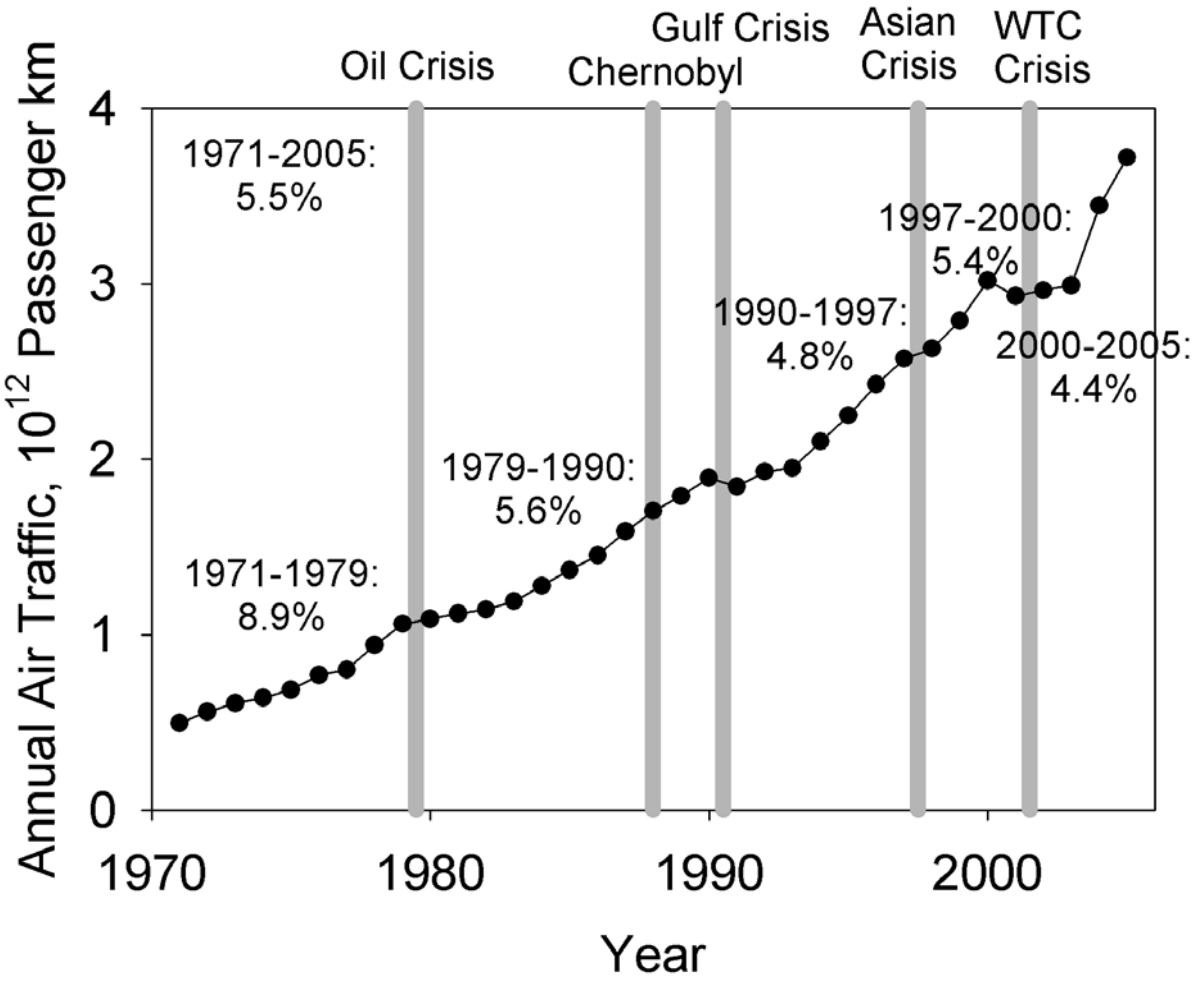


(Sausen et al., TRADEOFF,2005)

Trends

- **Aviation fuel consumption (CO_2 emissions) grew globally by 2-3 % per year from 1990 – 2004.**
- **Aviation NOx emissions grew faster**
- **Further growth of global fuel consumption and global emissions of CO_2 and NOx is to be expected.**
- **Scenarios of civil aviation CO_2 emissions in 2050 show a potential increase by factors 3.3 - 5**
- **If aviation emissions continue to grow while other emissions get reduced, the relative importance of aviation contributions grows**

Trends



1991-2004:

Passenger-km: 4.6 %/a

Freight-km: 6.4 %/a

Kerosene: 2.1 %/a

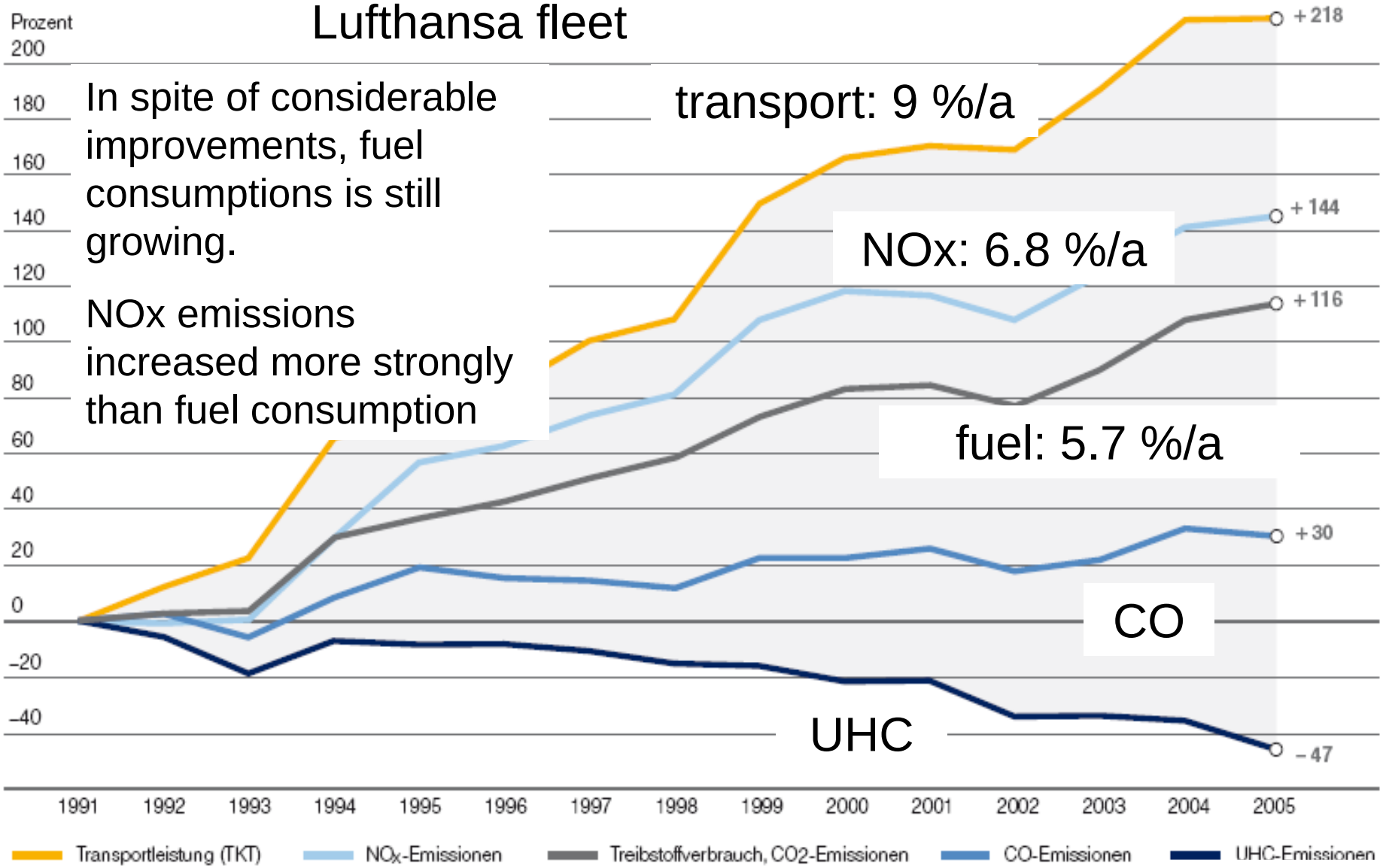
(Schumann, 2007)

Entkopplung von Transportleistung und Umweltbelastung
Veränderung gegenüber 1991 in Prozent, Angaben für die Flotte des Lufthansa-Konzerns

Lufthansa fleet

In spite of considerable improvements, fuel consumptions is still growing.

NOx emissions increased more strongly than fuel consumption

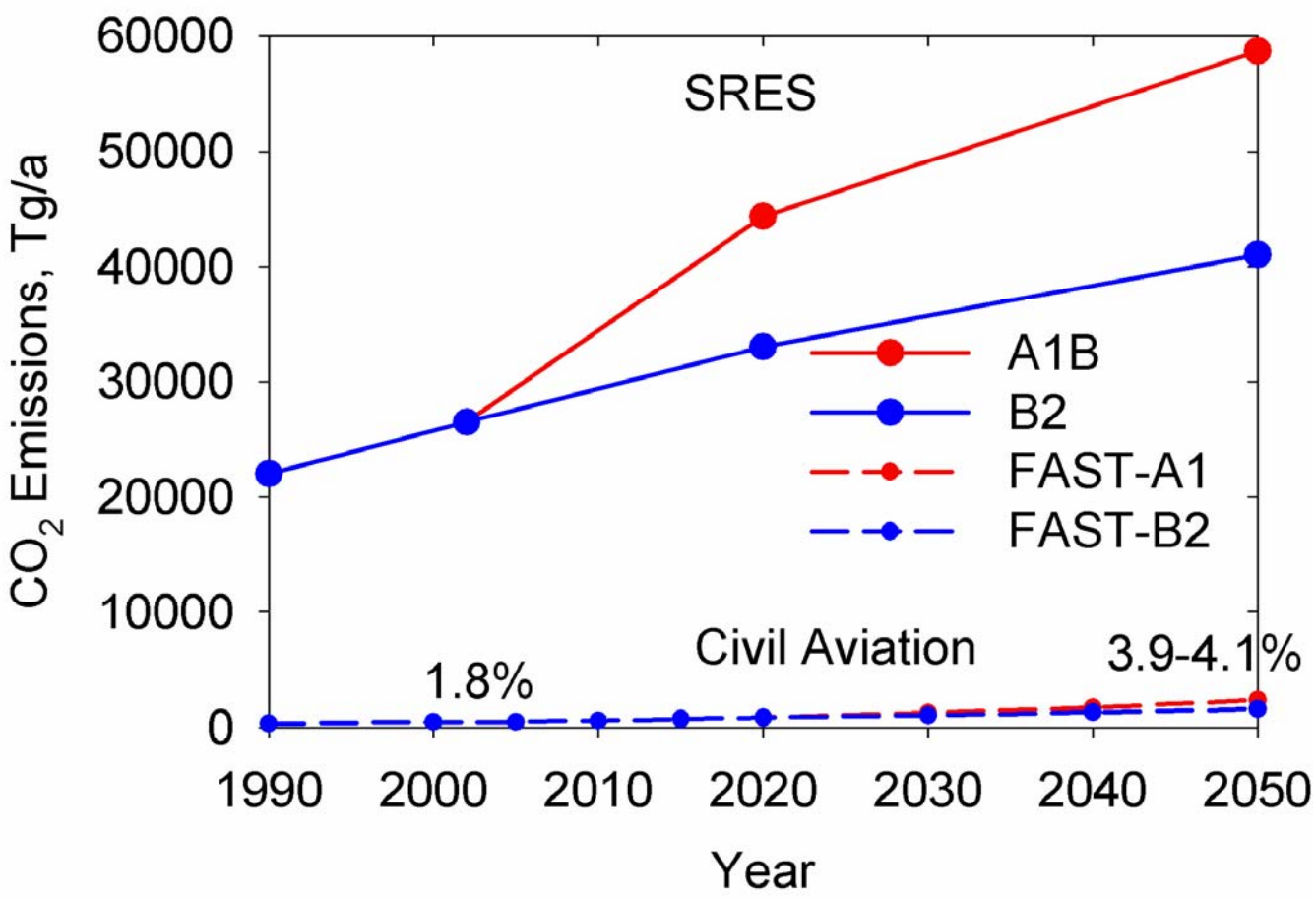


(Lufthansa, 2006)

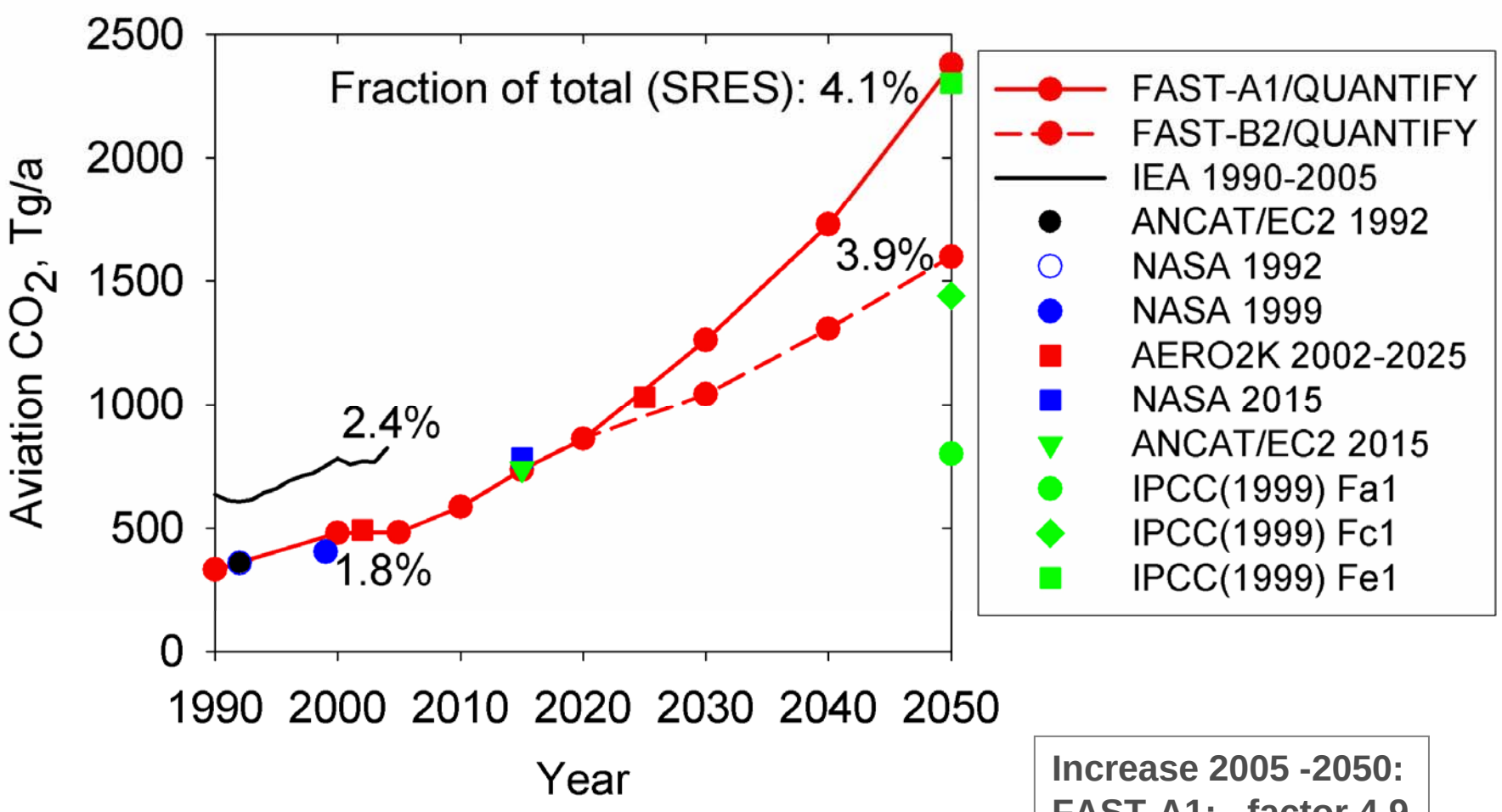
Future Emission Scenarios for CO_2 from all sources

A1B: rapid economic growth, balance across all sources, fast intro. of new technologies, strong globalisation

B2: moderate economic growth, diverse technological change, more oriented towards environmental protection, focus on regional levels

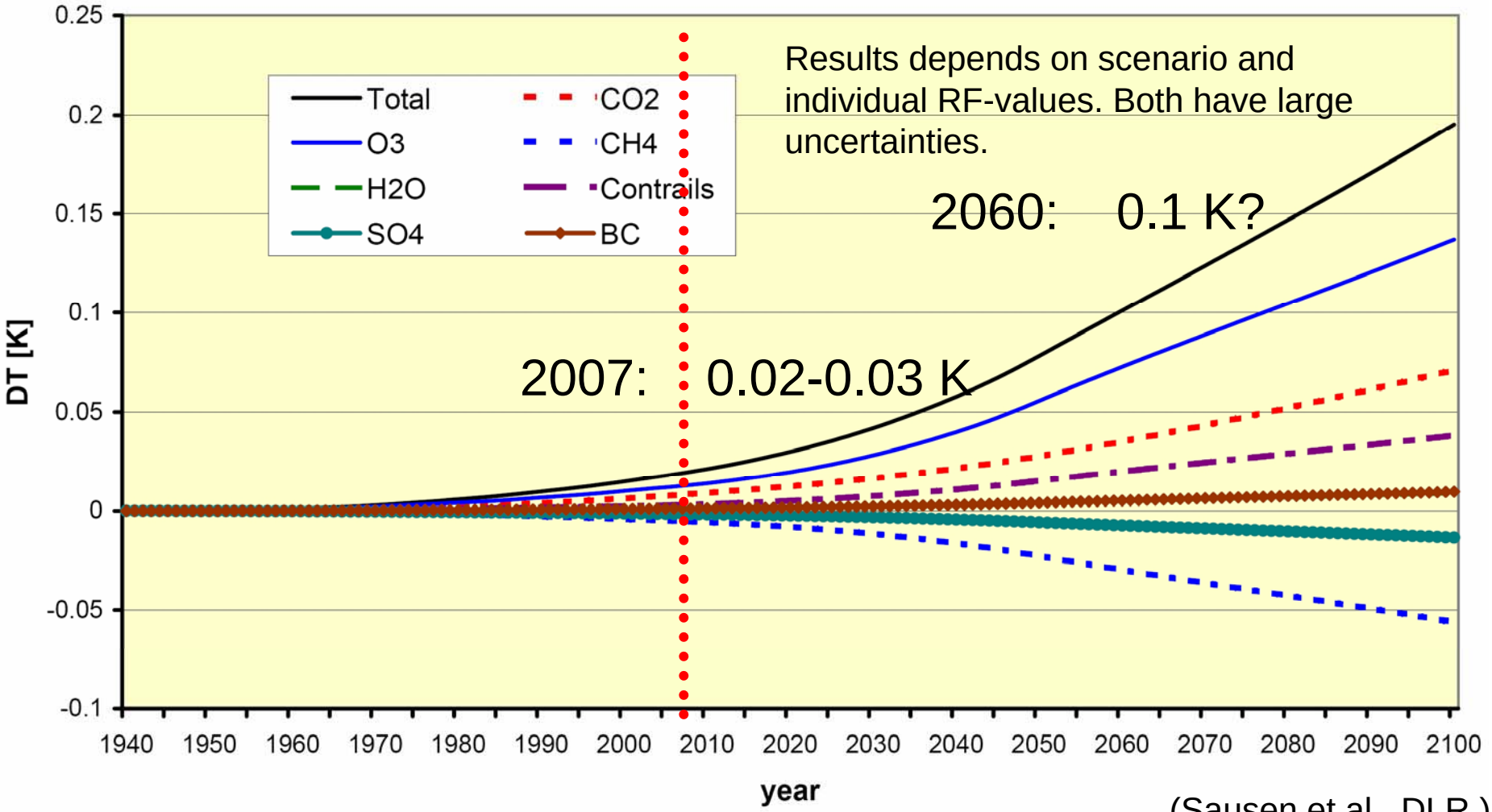


Scenarios: Aviation CO_2 increases in absolute and relative measures



Increase 2005 -2050:
FAST-A1: factor 4.9
FAST-B2: factor 3.3

Global aviation contributed to the observed global warming of 0.7°C about 0.02-0.03°C (~3-4 %), so far



(Sausen et al., DLR.)

Conclusions

Global warming is observed and largely caused by human drivers

Climate protection requires reductions of the total greenhouse gas emissions, including those from aviation

The aviation share in CO_2 emissions is presently about 2 %

Hence, increased fuel efficiency is important (for several reasons)

In addition, cruising aircraft impact climate by NOx and contrails

The aviation share in radiative forcing is presently 3 % (range 2-8%)

Scenarios of aviation CO_2 emissions show potential increase by factors 3.3 – 5 until 2050

NOx and Contrails offer special chances for climate mitigation

Largest uncertainty and possibly largest contribution from contrail cirrus

The contrail issue needs higher attention by ACARE and others