Potential Impact of Small Scale Supersonic Transport Aircraft on the Atmosphere: Climate and Ozone Layer

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Outline

- The physical basis of climate change
- The impact of air traffic on climate
- Assessments of supersonic transport: HSCT, IPCC, SCENIC
- Impact of small scale supersonic transport aircraft (S4TA)
- Conclusions

The physical basis of climate change: IPCC

- Scientific intergovernmental body set up by UN
- Consists of governments (review) and scientists (author+review)
- Aims at providing decision-makers and others interested in climate change with an objective source of information about climate change
- Regular reports 1990, 1995, 2001, 2007: ~550 authors ~400 reviewer per WG)
- Special reports (e.g. on air traffic 1999)
- 3 working groups

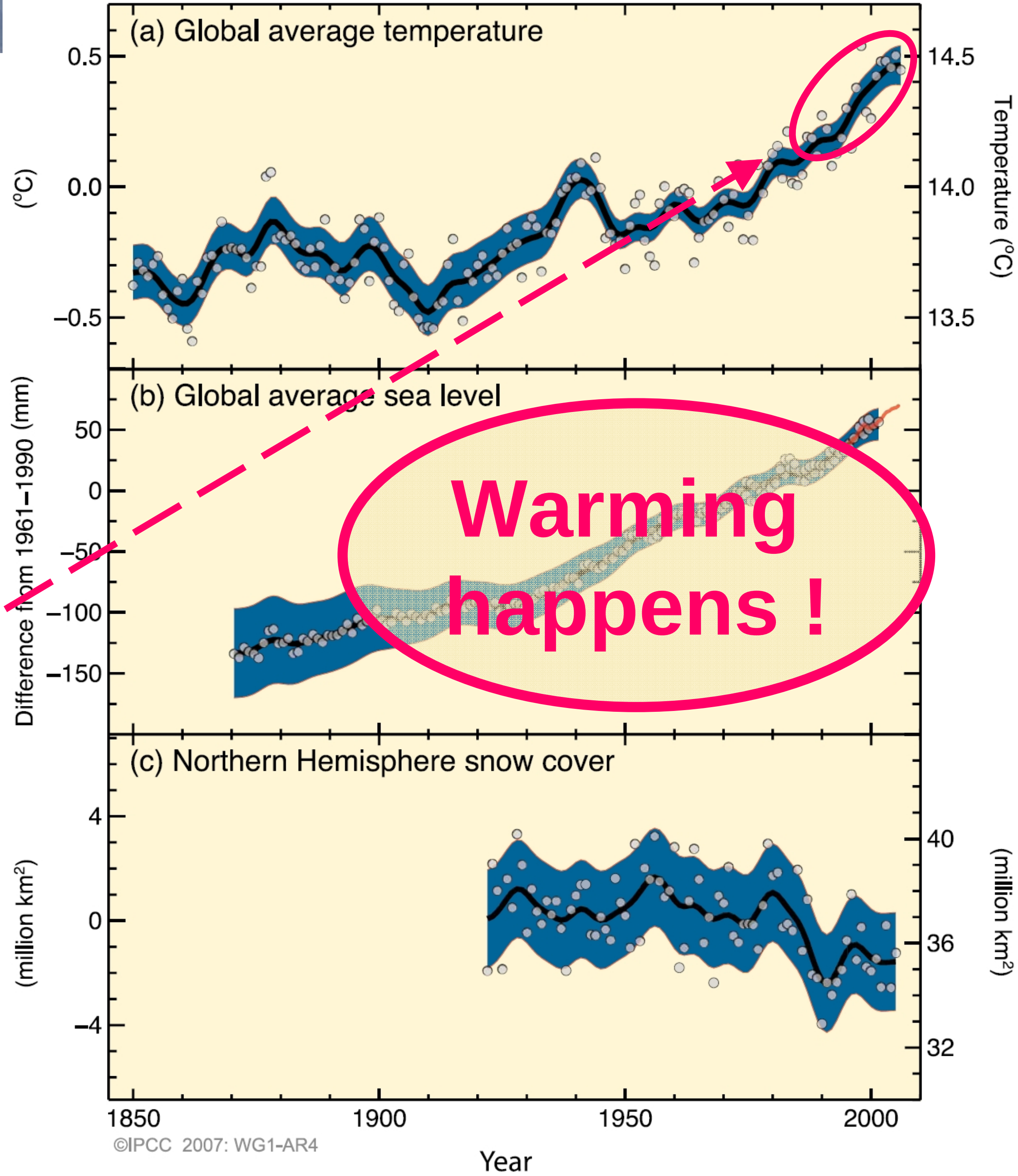
The Physical Science Basis	Impacts,Adaptation & Vulnerability	Mitigation of Climate Change
FAQs	FAQs	FAQs
Summary for policy makers	Summary for policy makers	Summary for policy makers
Technical summary	Technical summary	Technical summary
Detailed report	Detailed report	Detailed report

} line-by-line approval (FAQs, Summary for policy makers)

} 2 stage expert & government review (Technical summary, Detailed report)

www.ipcc.ch

Observed changes in global mean surface temperature, global mean sea level and Northern Hemisphere snow cover

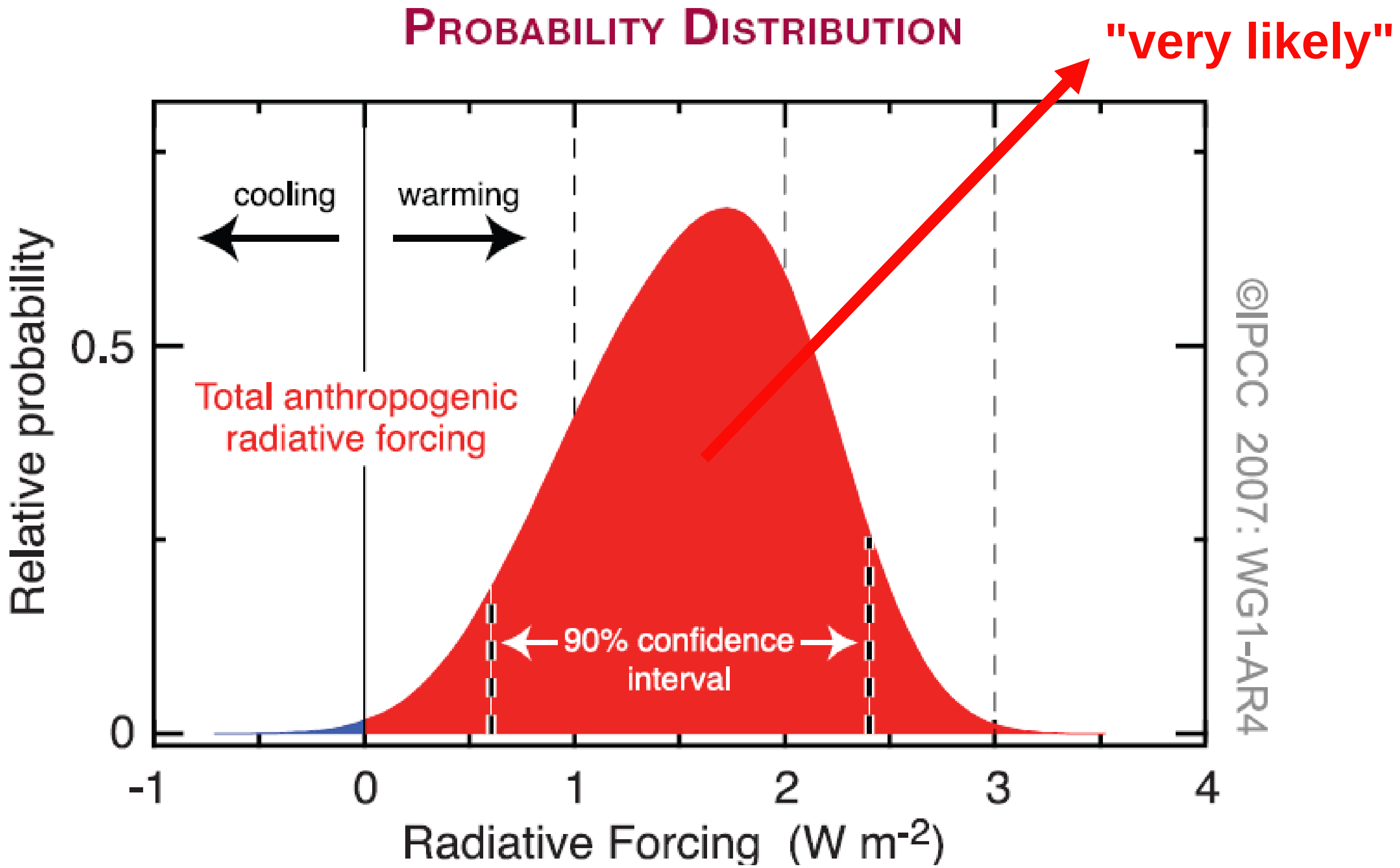


The 12 warmest years of the instrumental period:

1998, 2005, 2003, 2002, 2004, 2006, 2001, 1997, 1995, 1999, 1990, 2000

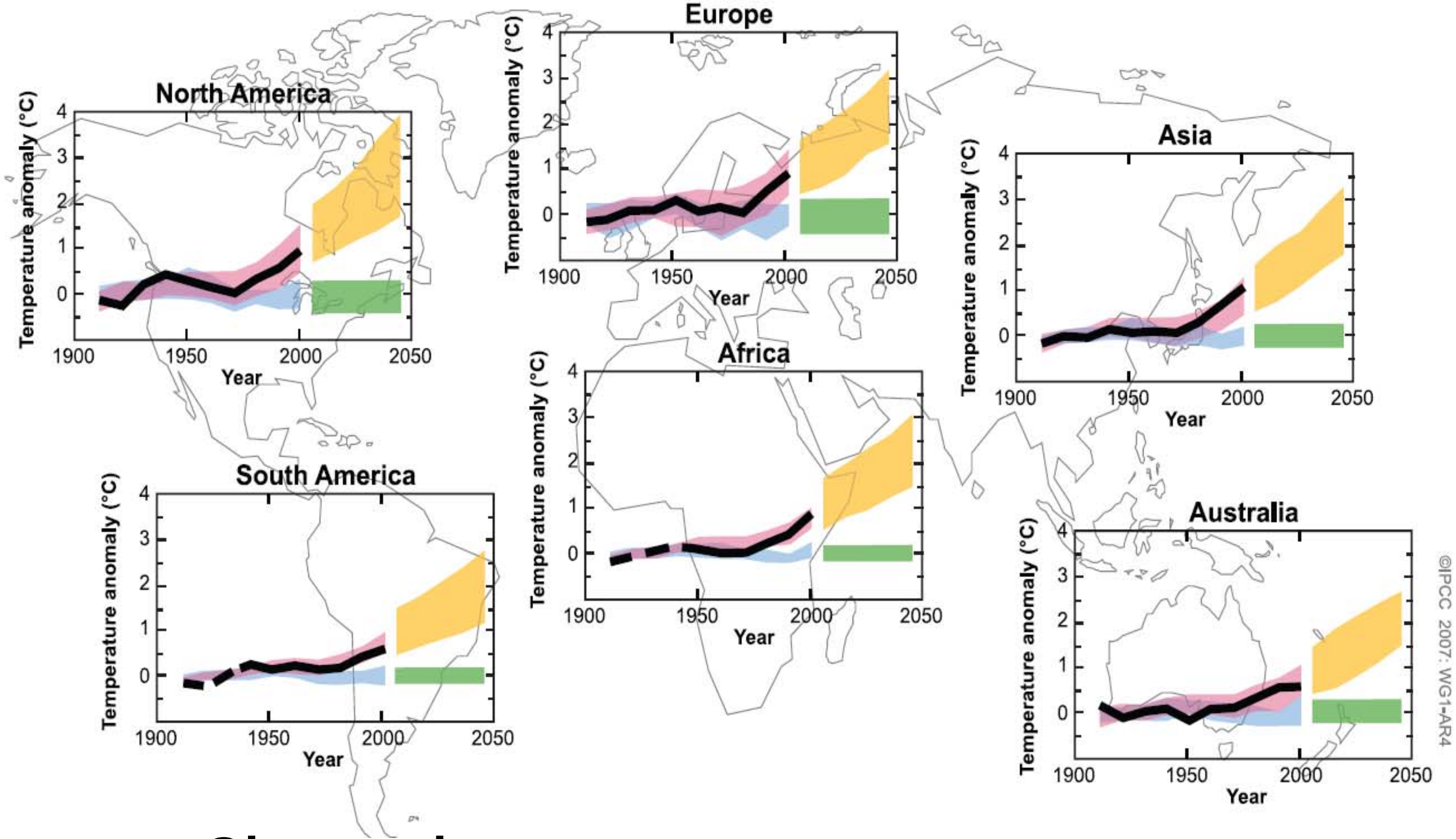
IPCC, 2007, SPM

How sure are we that a warming happens?



IPCC, 2007, SPM

Continental Surface Temperature Anomalies: Observations and Projections



Observations

Natural Variability

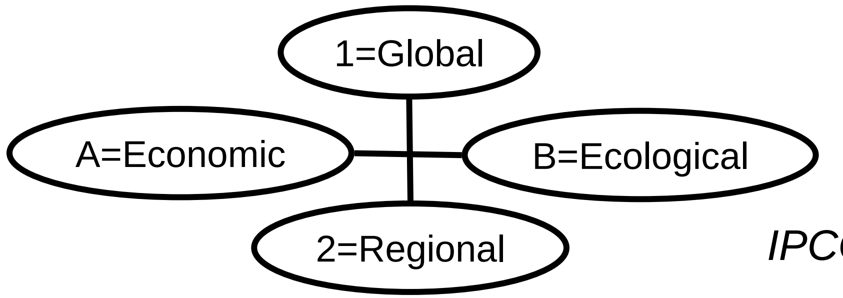
+ Anthropogenic Impacts

IPCC, 2007, SPM

Main results - Physical basis

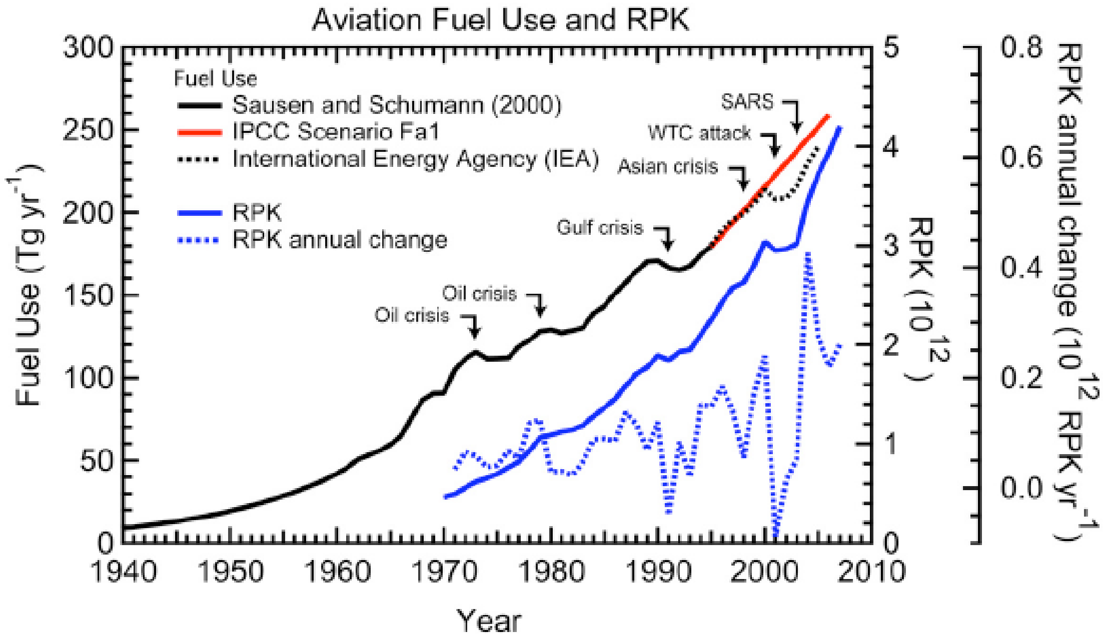
- Warming happens !
- GHGs increase
- Most of the warming *very likely* caused by increase in GHGs
- Projected warming in 2100 compared to

	pre-industrial	2000
constant concentration 2000:	1.1°C	0.6°C
A1B = rapid growth, global, new techs, fuel mix	3.3°C	2.8°C
A2 = heterogeneous world, local approaches	4.1°C	3.6°C
B2 = information economy, sustainable	2.9°C	2.4°C
A1FI = A1, but only fossil fuels	4.5°C	4.0°C



IPCC, 2007, SPM

Evolution of air traffic 1940 to 2005



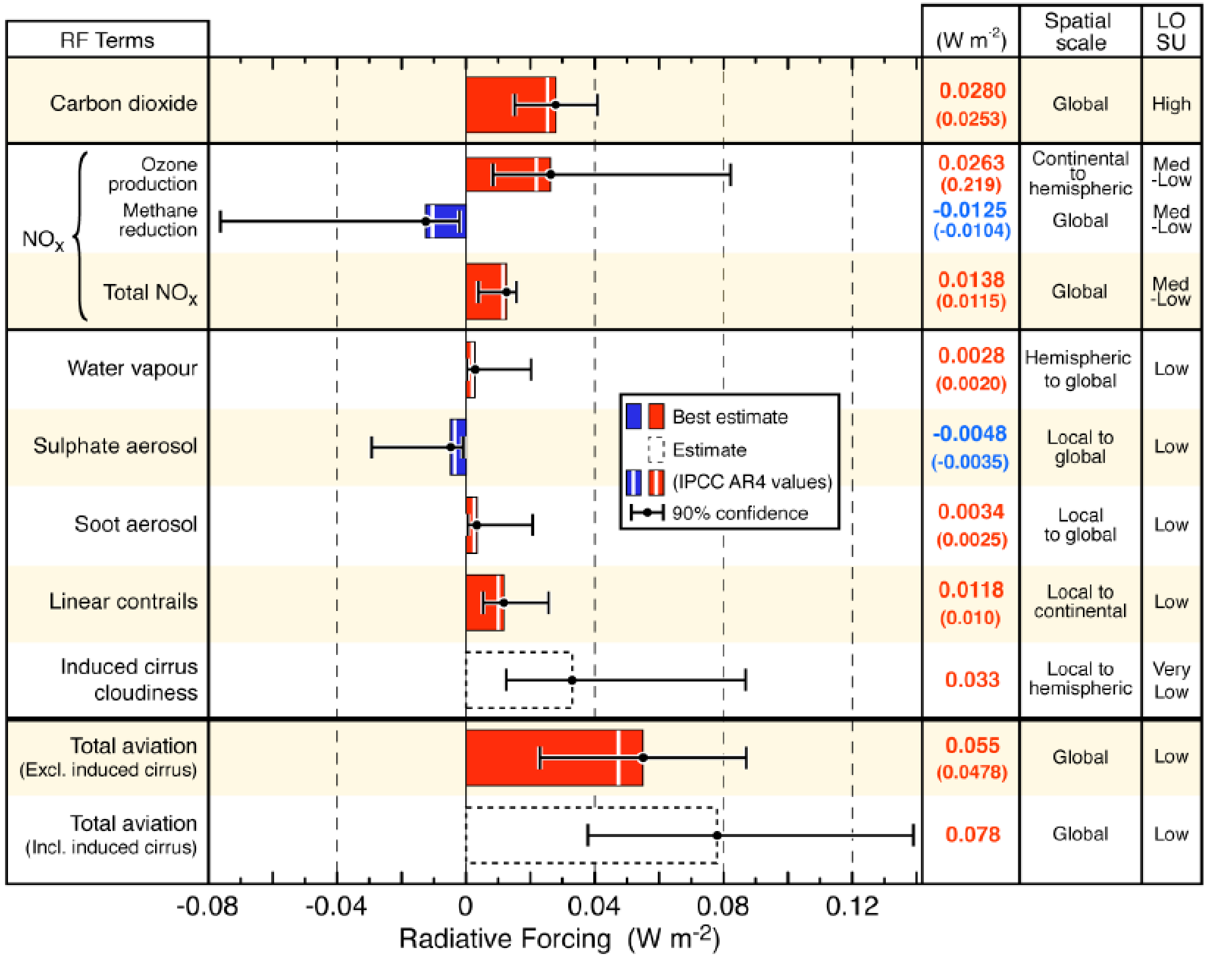
More than linear increase in transport demand

Crises reduce air traffic for a short time period.

Lee et al., 2009

Climate impact of current air traffic (2005)

Aviation Radiative Forcing Components in 2005



Lee et al., 2009

Main contributors:

CO_2

NO_x

Contrails

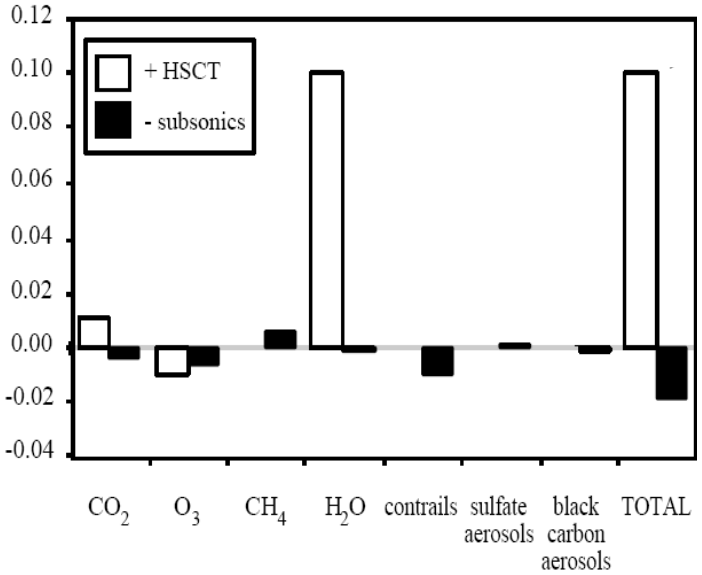
3.5-5.0% of warming attributed to air traffic

Supersonic transport:
Fleets (Large/Small Aircraft) regarded in previous projects:

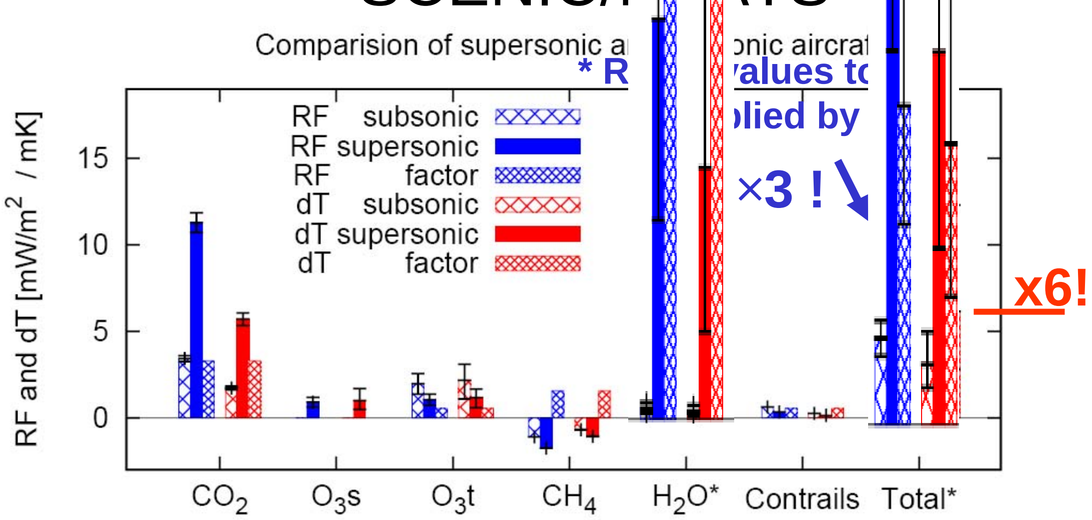
Project	Concept	Time of full fleet	Mean Cruise Altitude [km]	Number Aircraft	PAX	Speed [Mach]	Fuel [10^9 kg/a]	Climate impact (RF) [mW/m^2]
HSRP 1999	Boeing	2015	18-21	500	~300	2.4	82	not calculated
IPCC 1999	Boeing	2050	17-20	1000	309	2.4	137	100
NASA 2002	Boeing	2015	15,17,19	500	10	<<2.4	1-4	not calculated
SCENIC 2007	Airbus	2050	16-19	500	250	2.0	62	40
HISAC 2009	Dassault Alenia Sukhoi	2050	15-16	250	8	1.6-1.8	0.4	0.1

Climate impact of large-scale supersonic tran ort

IPCC 99



SCENIC/I ATS



Grewe and Stenke, 2008

- Main contributors: H_2O and CO_2

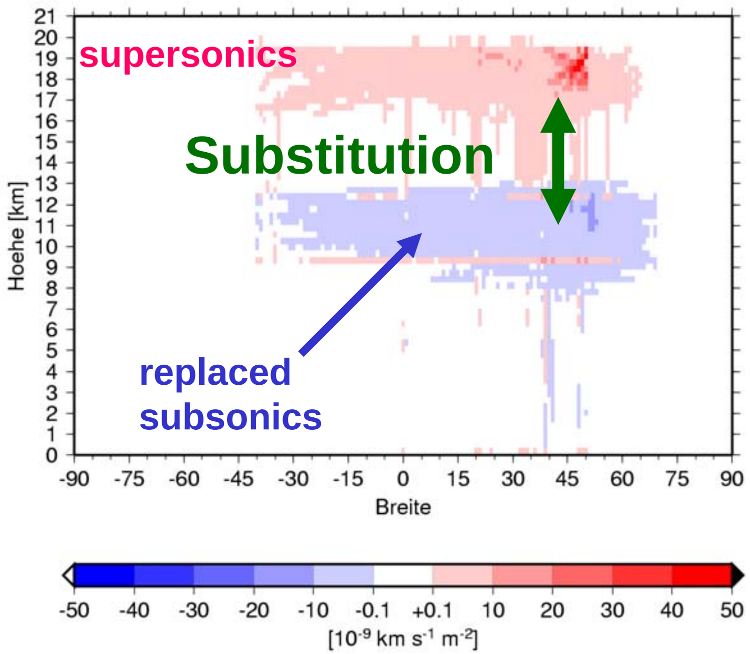
- Large-Scale Supersonic Transport Aircraft have a 6 time larger climate impact.

- Non-CO_2 effect ranges from 5 (SCENIC) to 10 (IPCC99)

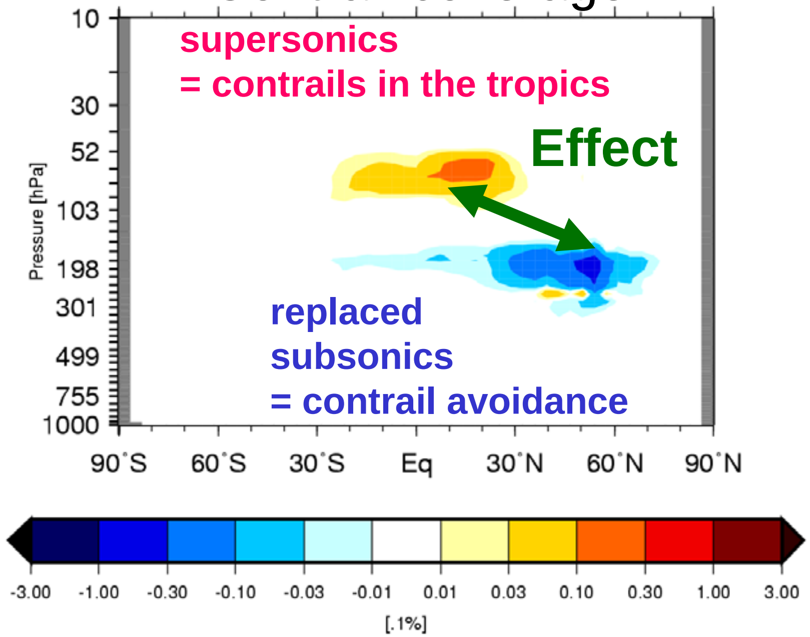
Do supersonics avoid contrails?

Substitution of subsonic large scale aircaft by supersonics:

Difference in flown kilometers



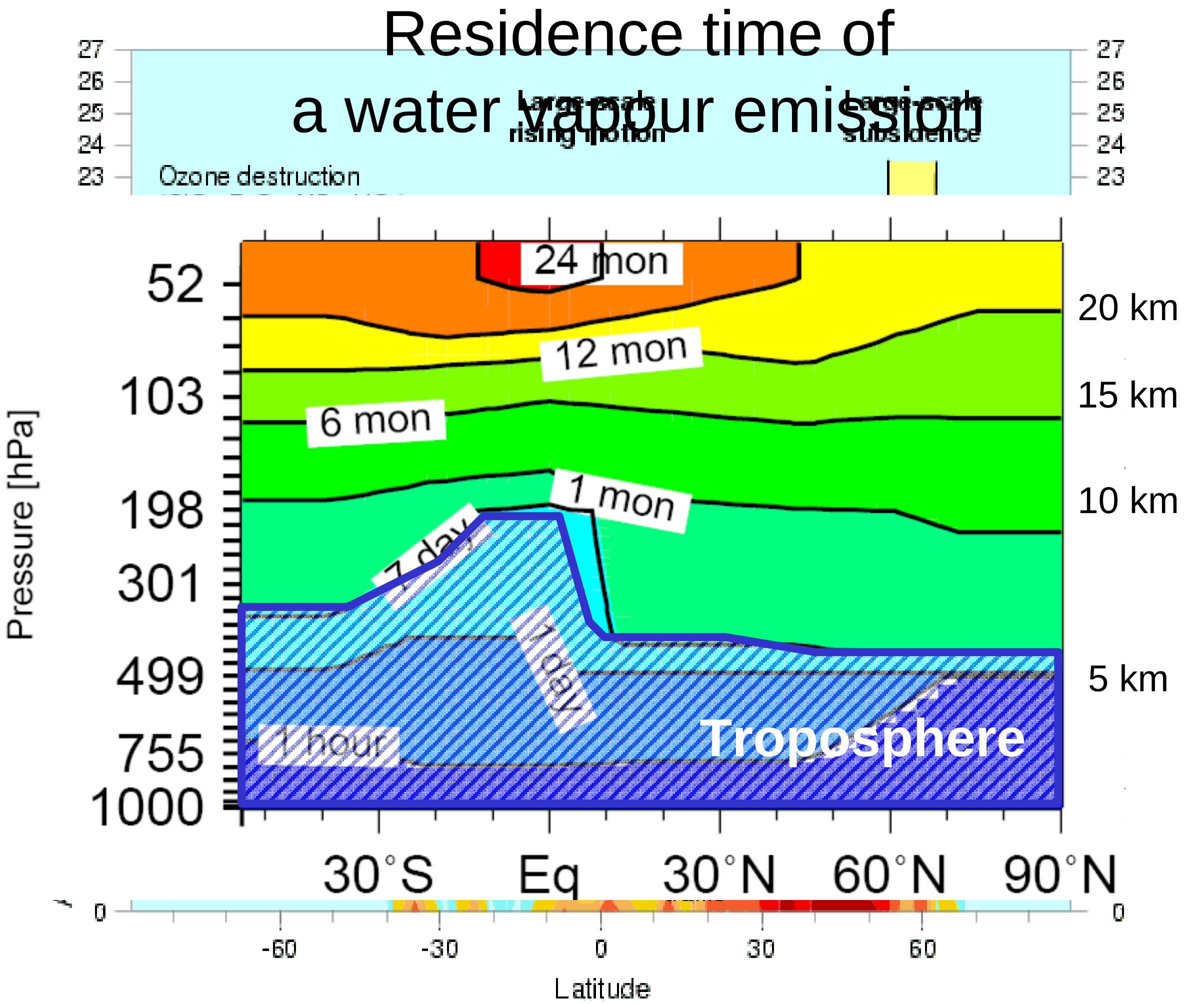
Contrail coverage



No! Just a shift to the tropics!

Stenke et al., 2008

Genererell Circulation and Air Traffic Emissions

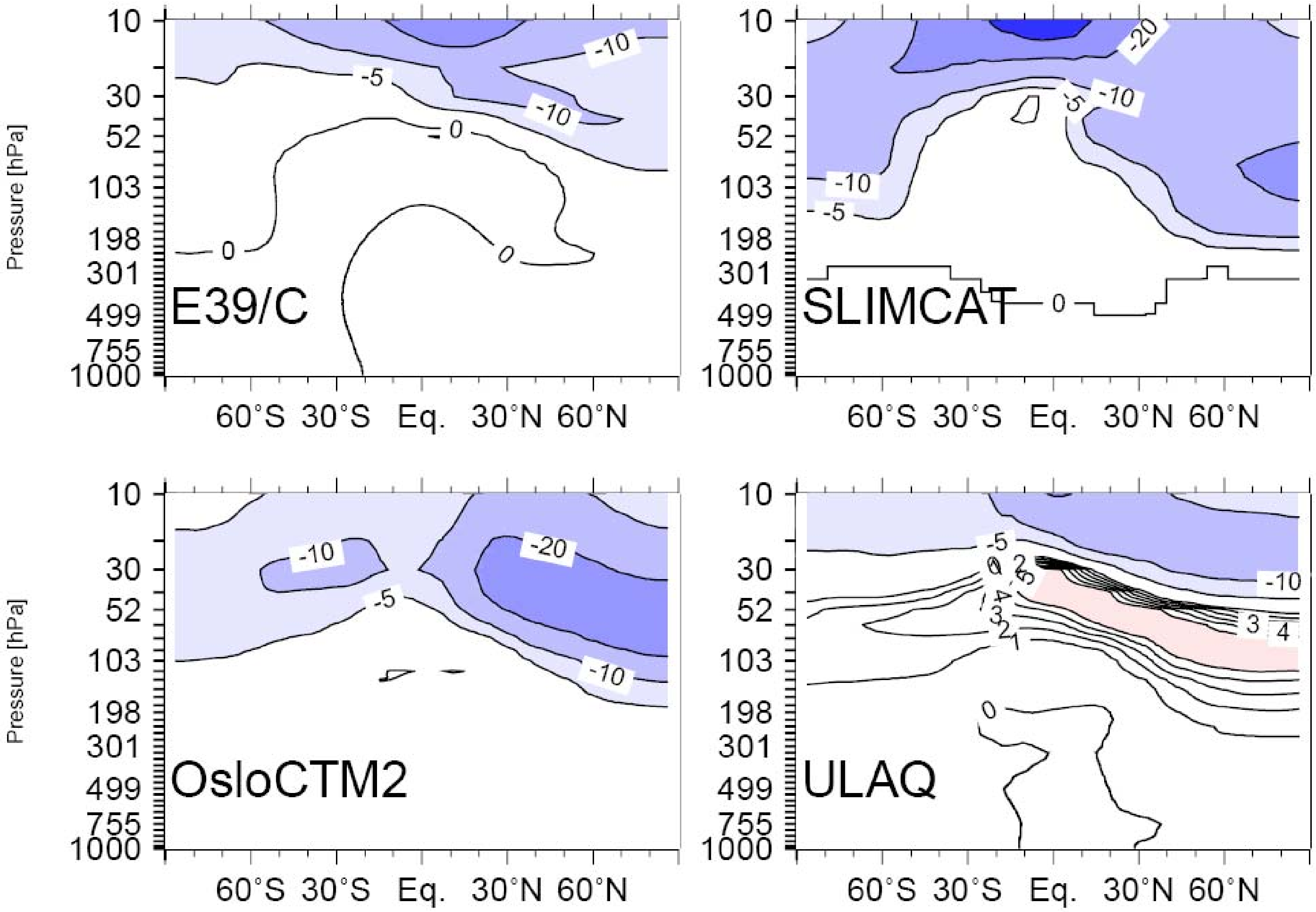


Residence time of species emitted by supersonic transport increases with

- increasing altitude
- decreasing latitude

Grewe and Stenke, 2008

SCENIC: Impact on the ozone layer [ppbv]



Considerable ozone depletion by the regarded SCENIC fleet

SCENIC: ~0.3 %

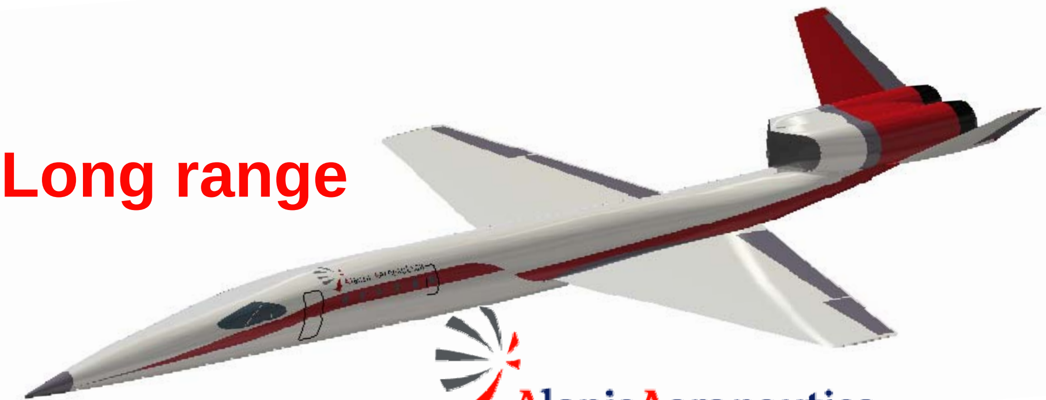
CFCs: ~3%

Description of HISAC S4TA

Low boom

Low weight

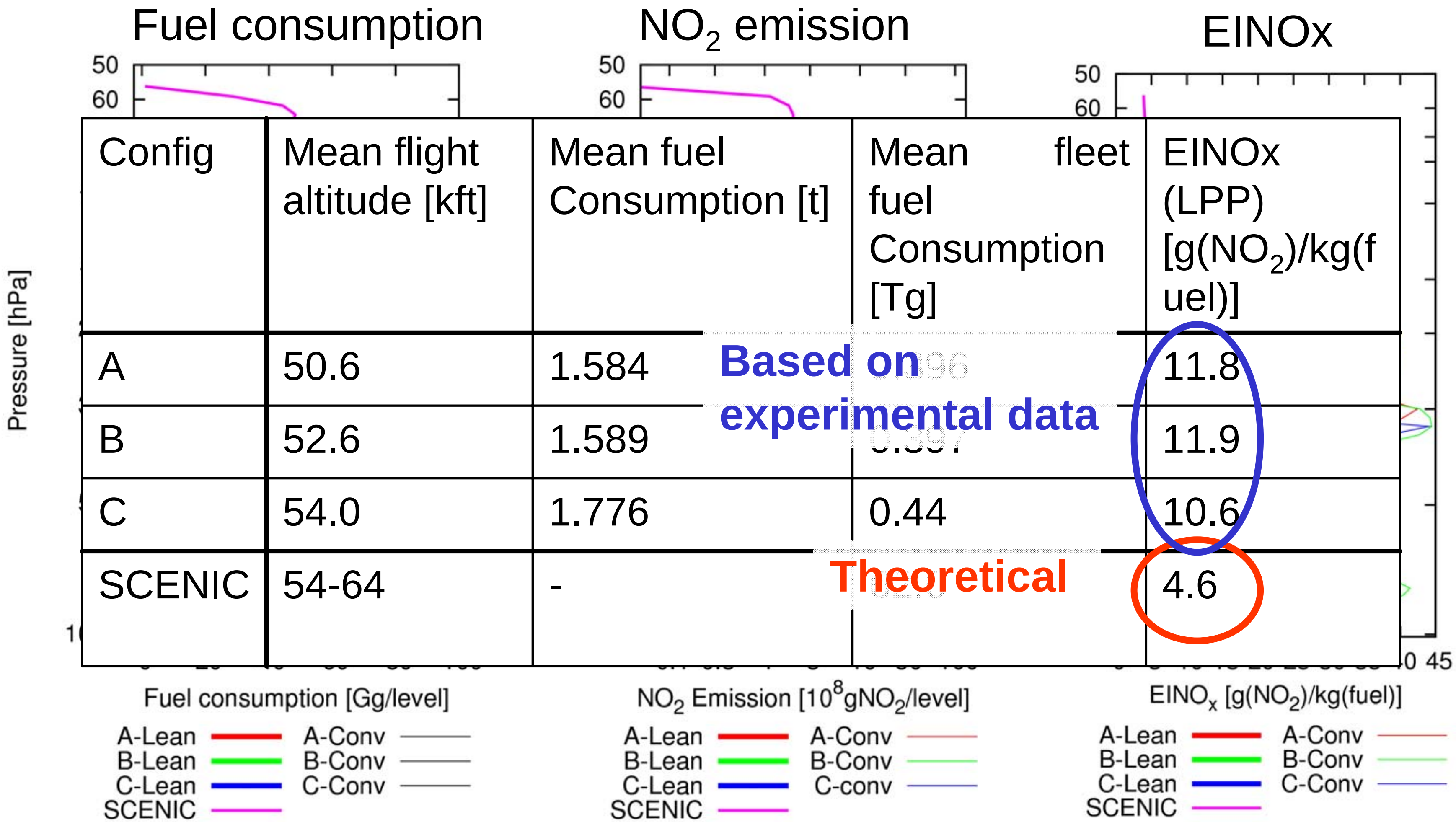
Long range



Methodology:

- 4 flight trajectories for 4 different geographical regions from Pole to Tropics
- Calculation of emissions along the flight trajectories with 2 combustion chamber technologies
- Calculation of concentration changes
- Calculation of climate impact

HISAC fleet emissions



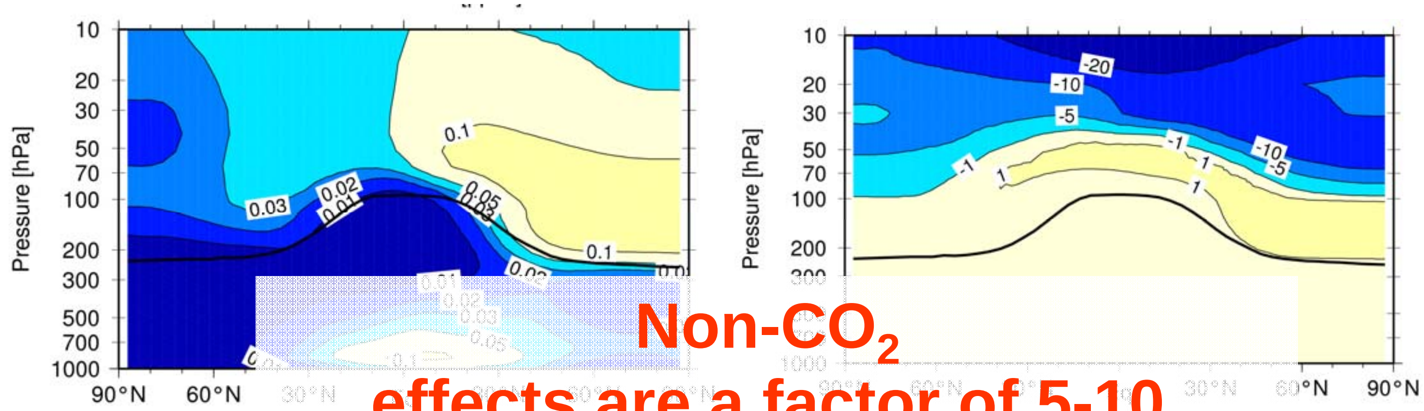
Config	Mean flight altitude [kft]	Mean fuel Consumption [t]	Mean fleet fuel Consumption [Tg]	EINOx (LPP) [g(NO_2)/kg(fuel)]
A	50.6	1.584	[illegible]	11.8
B	52.6	1.589	0.397	11.9
C	54.0	1.776	0.44	10.6
SCENIC	54-64	-	[illegible]	4.6

Based on experimental data (A, B, C)

Theoretical (SCENIC)

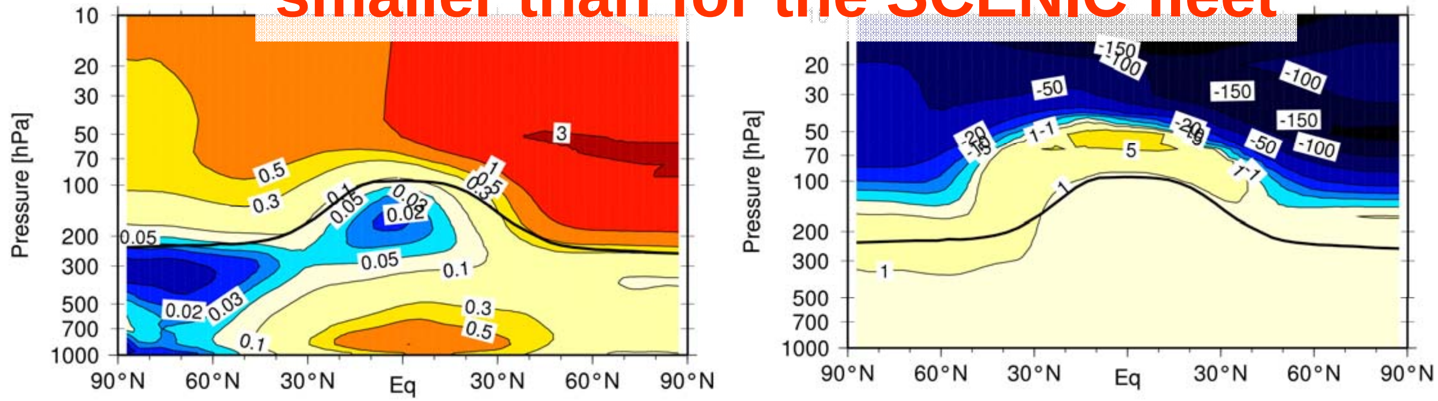
Atmospheric impact of a HISAC fleet

Water vapour [ppbv] | Ozone [pptv]



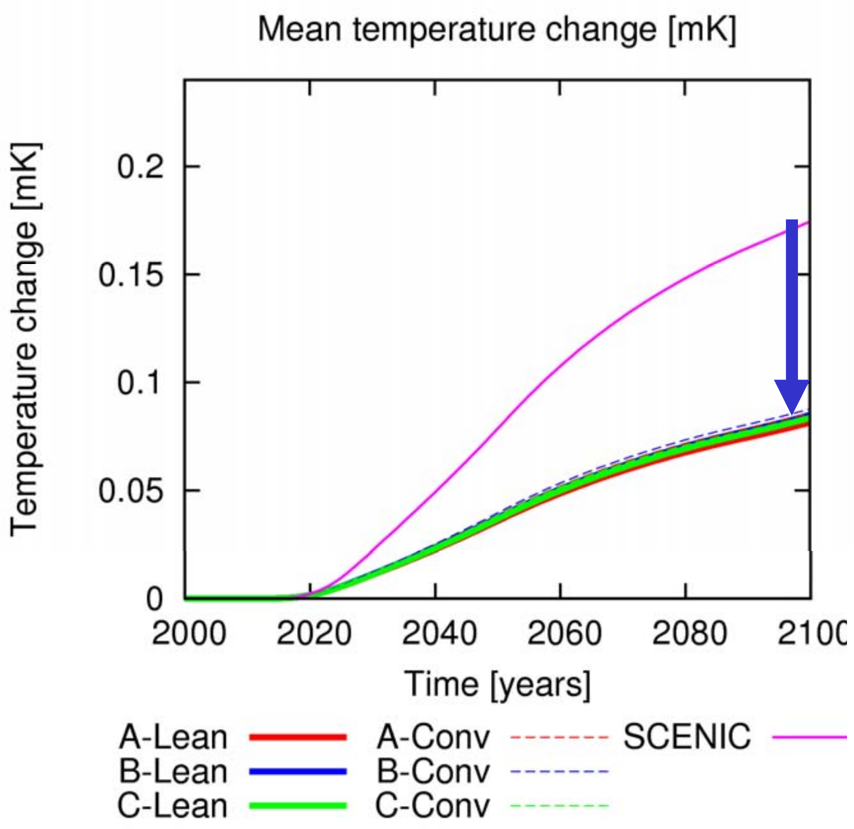
HISAC

Non-CO_2 effects are a factor of 5-10 smaller than for the SCENIC fleet



SCENIC scaled to HISAC fuel consumption

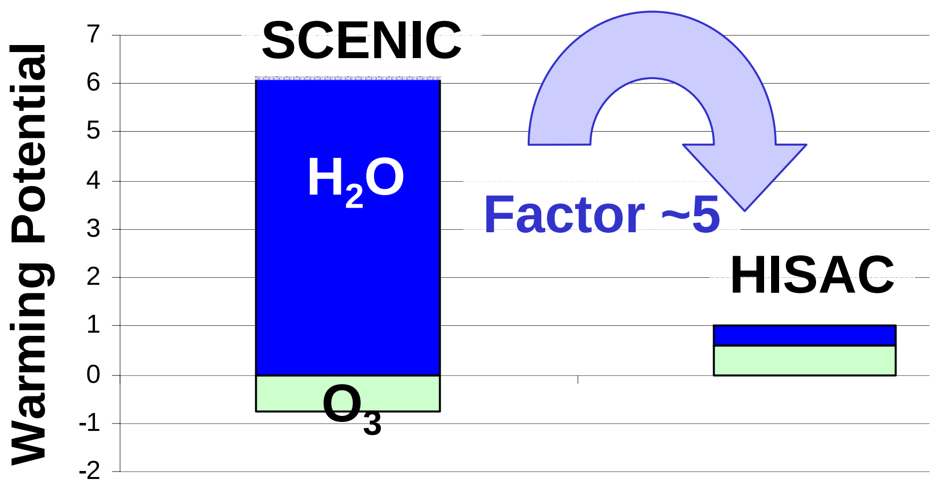
Climate impact



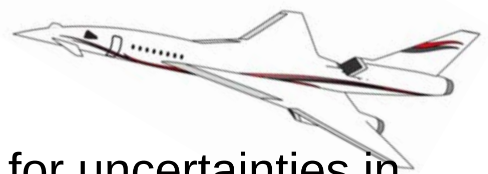
50% reduction of the climate impact by reducing non-CO_2 effects.

= impact of lower cruise altitude wrt SCENIC

warming(non-CO_2):warming(CO_2)

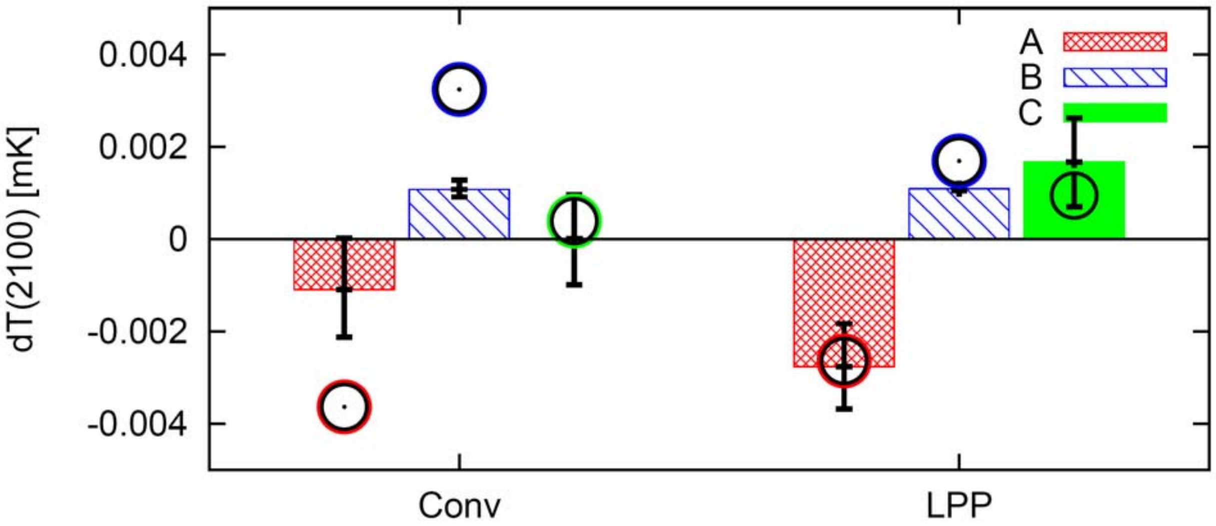


Aircraft specifications impact on climate



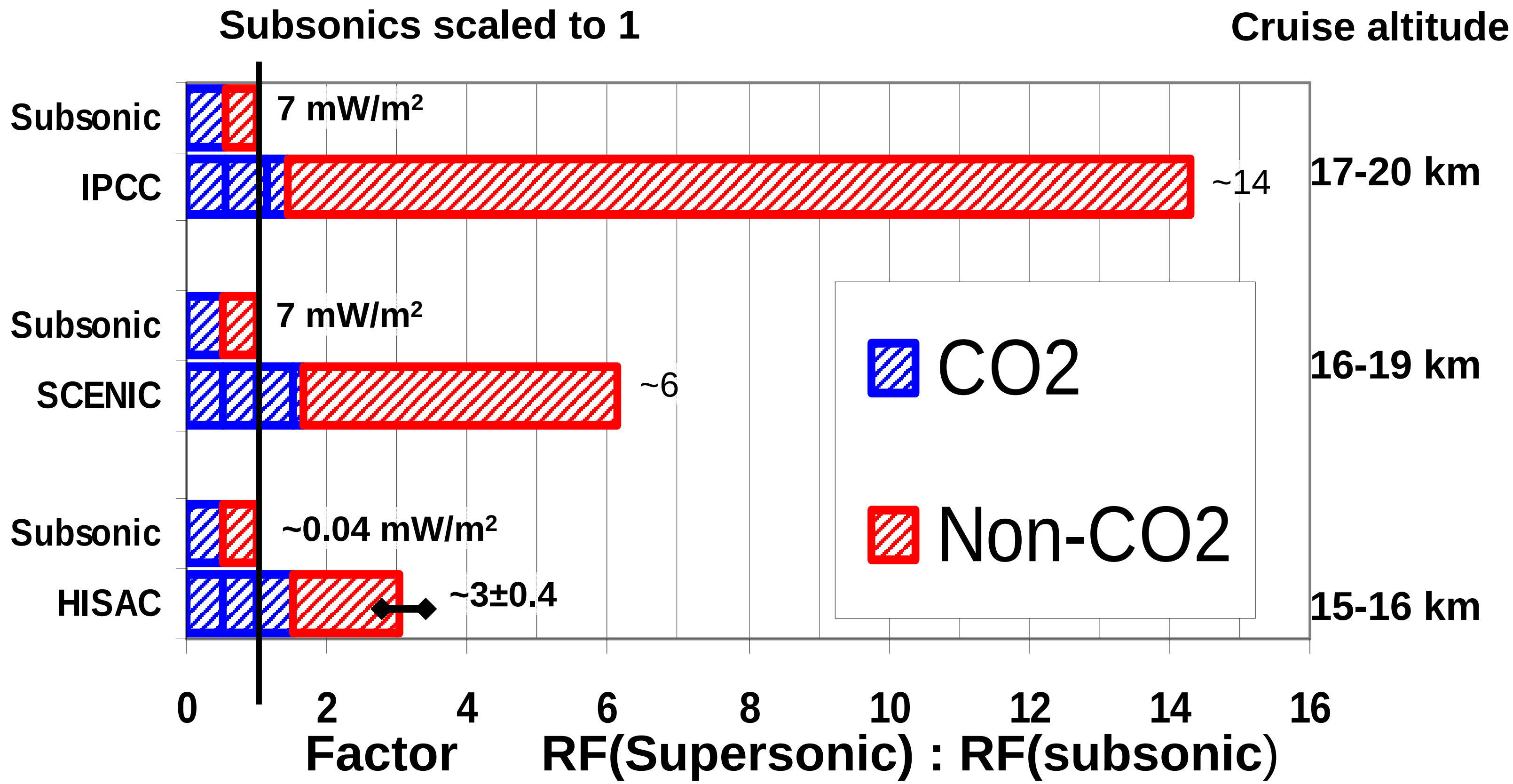
- Differences small
- Configuration A has minimal climate impact
- Uncertainty range based on Monte-Carlo Simulation for uncertainties in atmospheric processes (residence time, radiation, climate sensitivity)

Climate Impact of Configurations A, B, C



Ozone layer:
Estimated depletion:
CFCs: ~ 3%
SCENIC: ~ 0.3 %
HISAC: ~ 0.0005%

Direct intercomparison of sub- and supersonic transport



At low cruise altitudes a factor of 3 is achievable

= 2 times more climate impact than respective subsonic aircraft

Summary

- Climate impact and ozone depletion of a fleet of Small Scale Supersonic Aircraft are considerably smaller than for supersonic fleets considered previously for 3 reasons (factor 400-1000):
  - Smaller fleet size (Factor 2-4)
  - Smaller aircraft = less fuel consumption (Factor ~40)
  - Lower flight altitude = smaller Non-CO_2 effects (Factor ~5)

- Climate impact and ozone depletion larger than for respective subsonic aircraft.

- No explicit results available for a direct intercomparison of subsonic and supersonics ⇒ Estimates for the difference: Factor 3±0.4