DLR Climate Research And Aircraft Technologies

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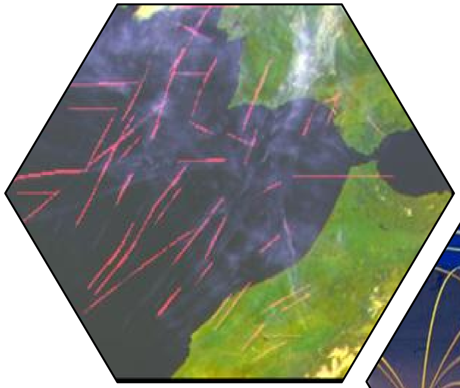
in der Helmholtz-Gemeinschaft

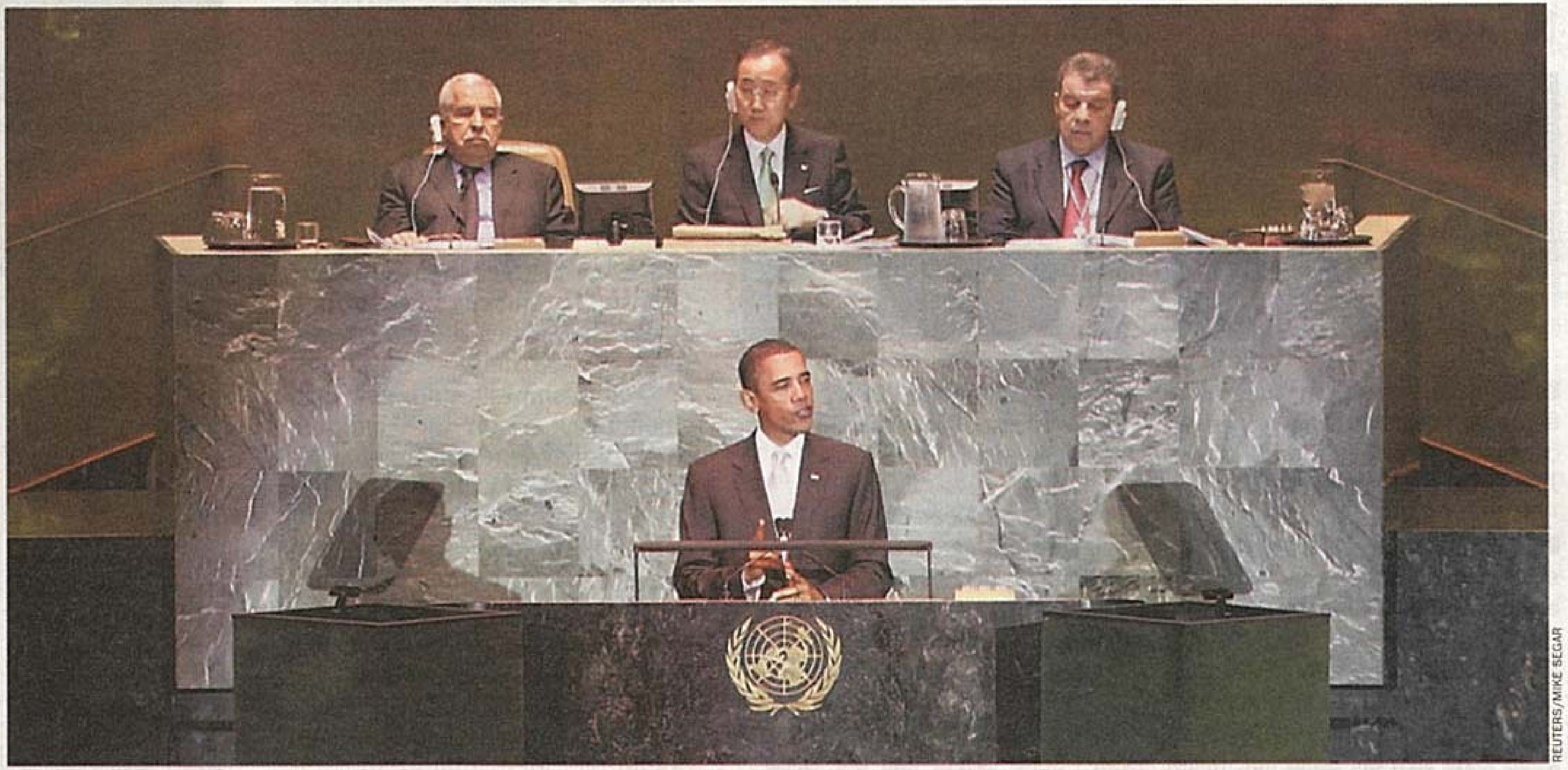
Environment

"The degree of one's emotion varies inversely with one's knowledge of the facts -- the less you know the hotter you get."

Bertrand Russell



Die Welt, 21.September 2009



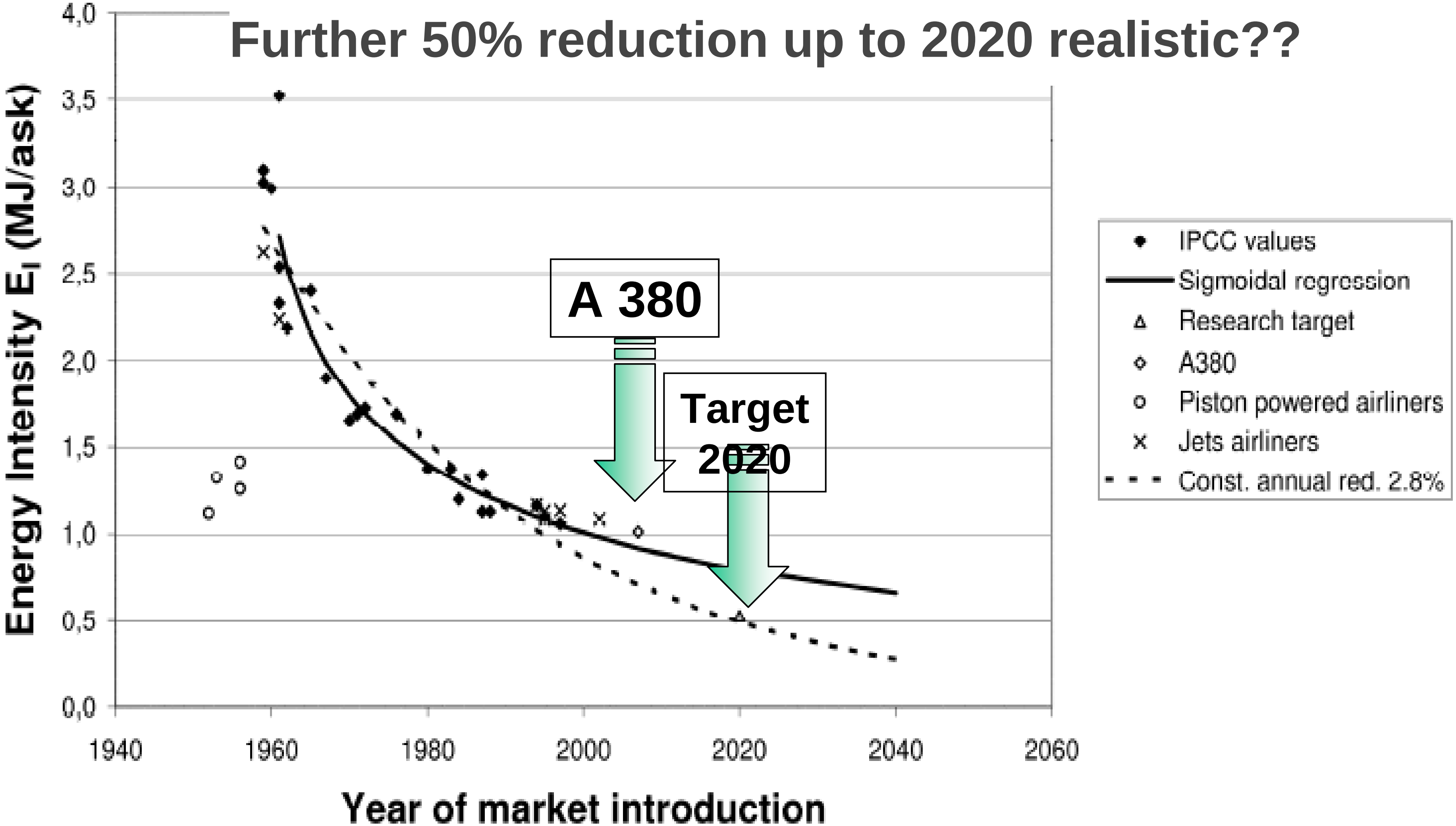
„Unumkehrbare Katastrophe“: Barack Obama spricht vor den Vereinten Nationen in New York, UN-Generalsekretär Ban Ki-moon sitzt hinter ihm

Obama warnt vor Klimakatastrophe

Airlines present climate change proposals to heads of governments

1. Improving carbon efficiency with a 1.5% average annual improvement in fuel efficiency to 2020
   From 2000 to 2006 the fuel burn has decreased by 1,6% per year.
   The total emissions increased in the same period by 2,3% !
2. Stabilizing emissions with carbon-neutral growth from 2020
   Estimated requirement of more than 50% biofuel !
3. Emissions reductions with a 50% absolute cut in emissions by 2050 compared to 2005
   ALL new products from now on need 50% fuel burn reduction.
   Technologies are not available today !

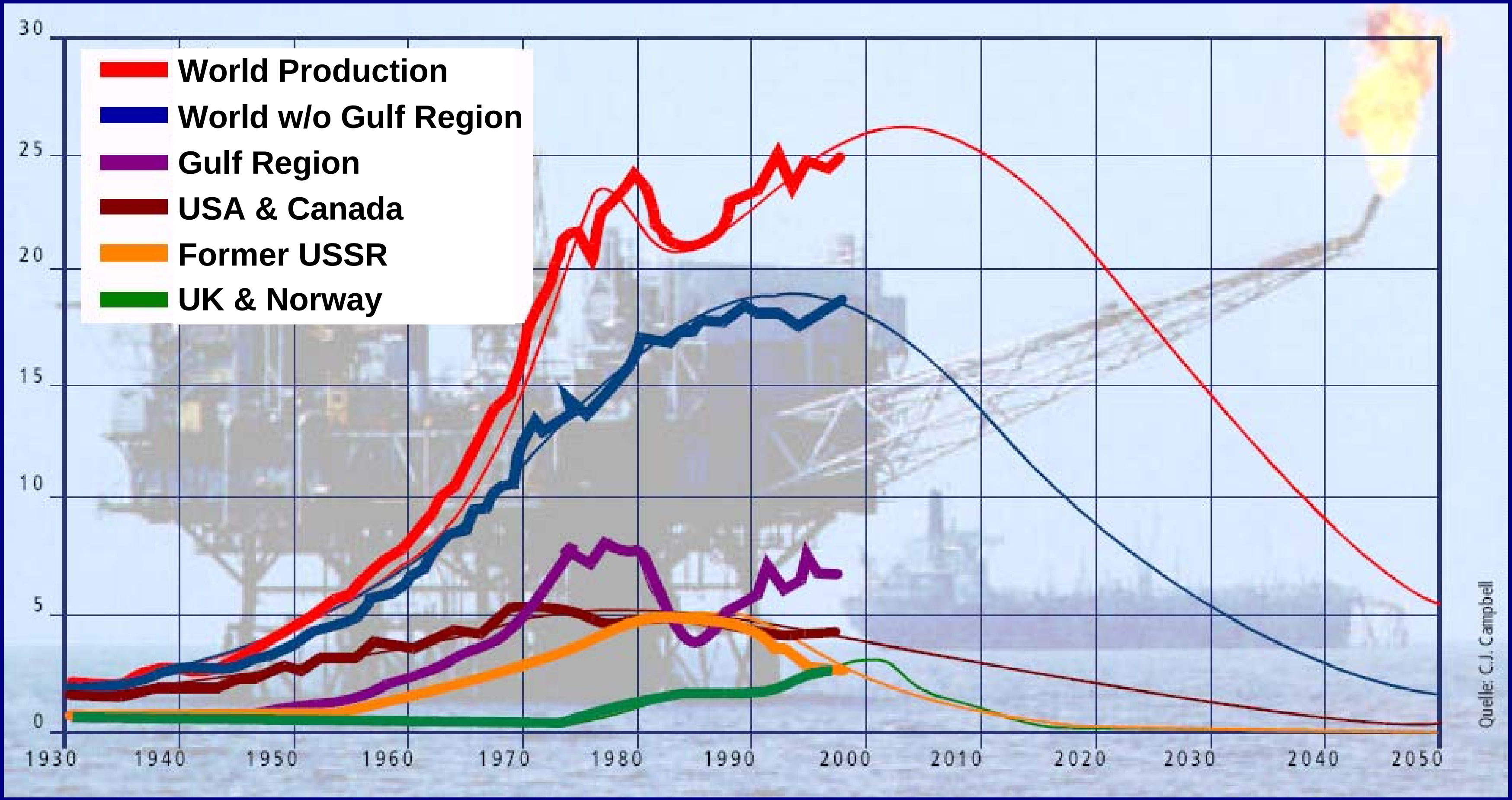
Energy Intensity Reduction for Air Transport



[*Peeters and Middel*, 2006]

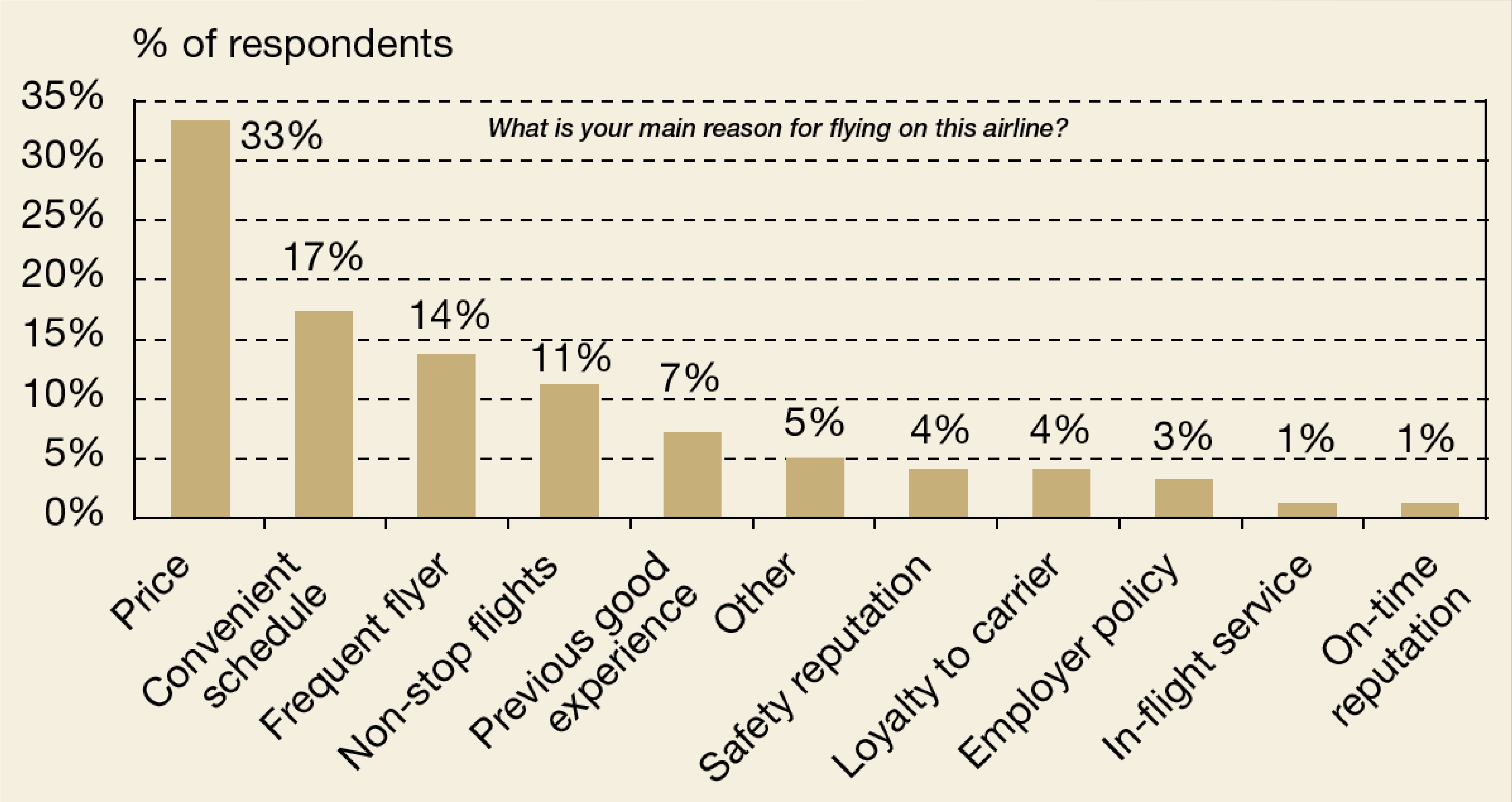
The „Future“ of Fossile Fuels

Oil Production Forecast by Region:

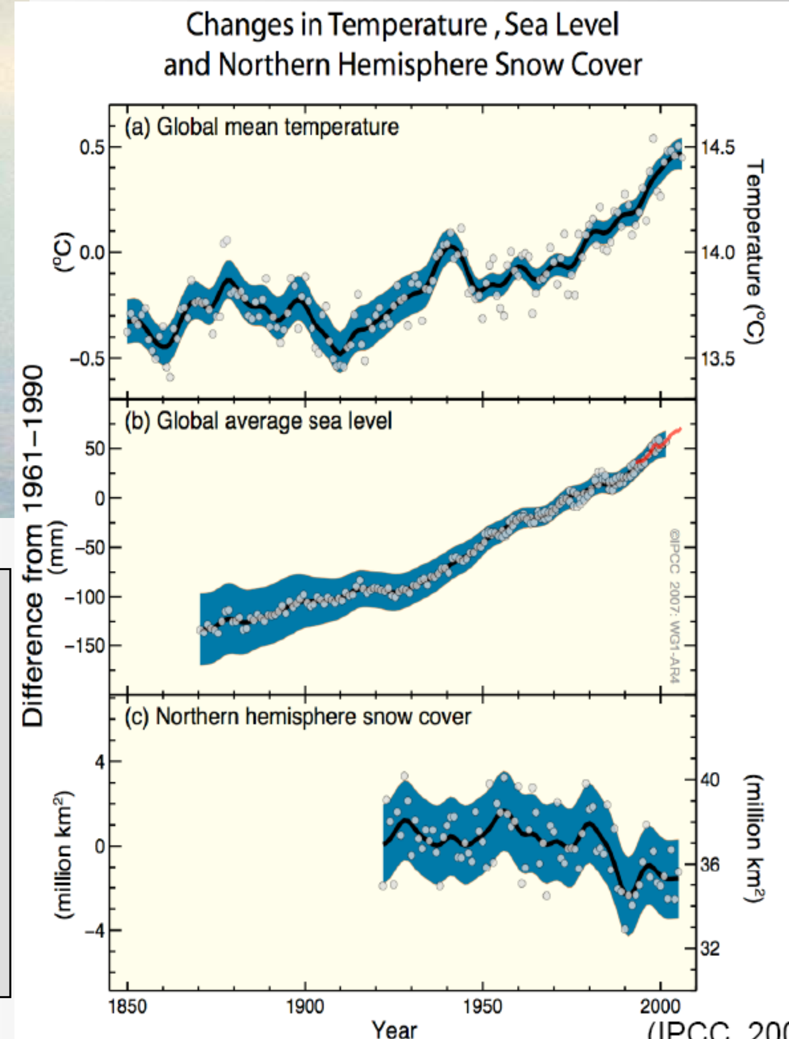


The Passenger

Why do you fly this airline ?



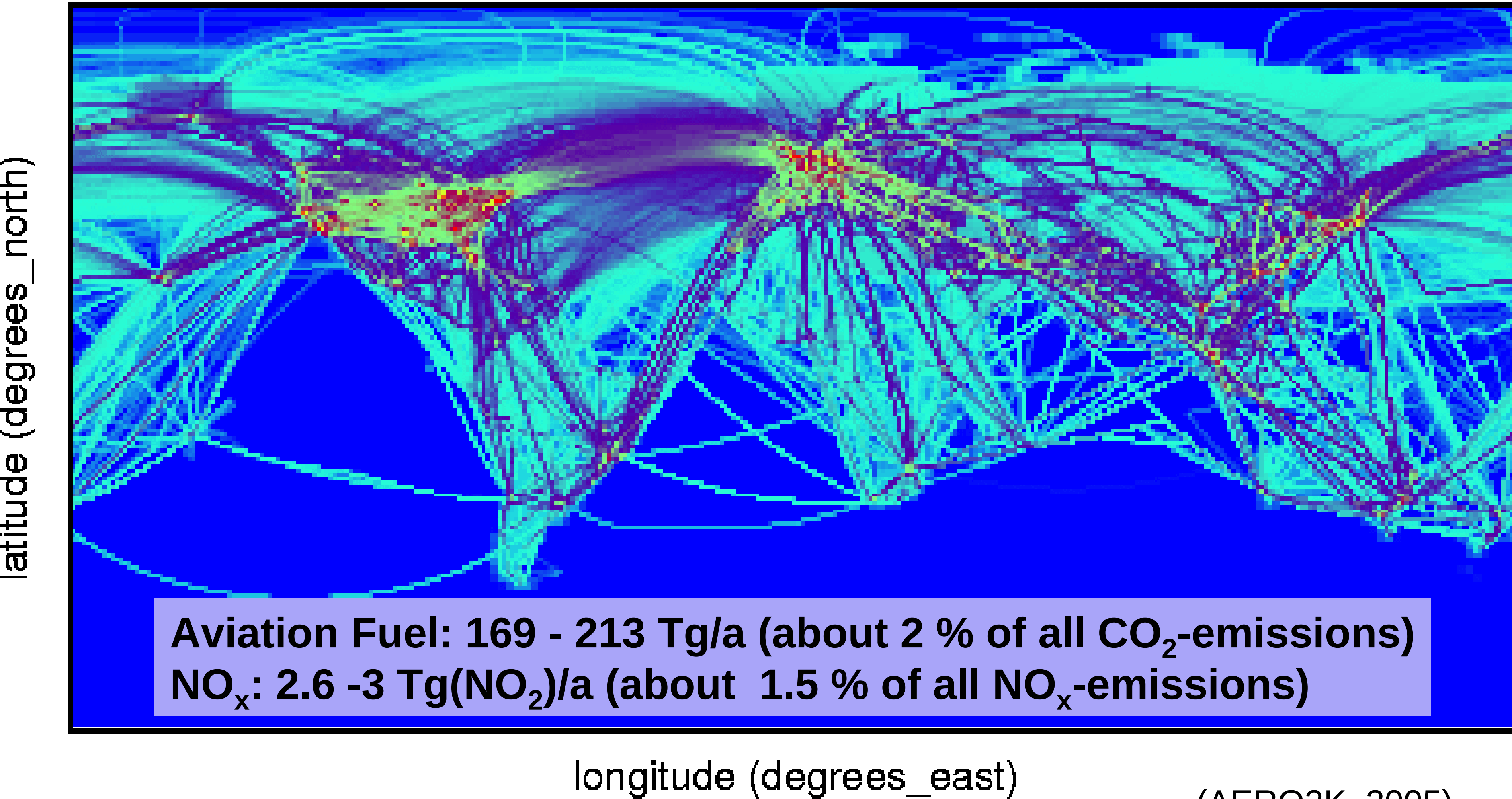
Source: US Department of Commerce



(IPCC, 200

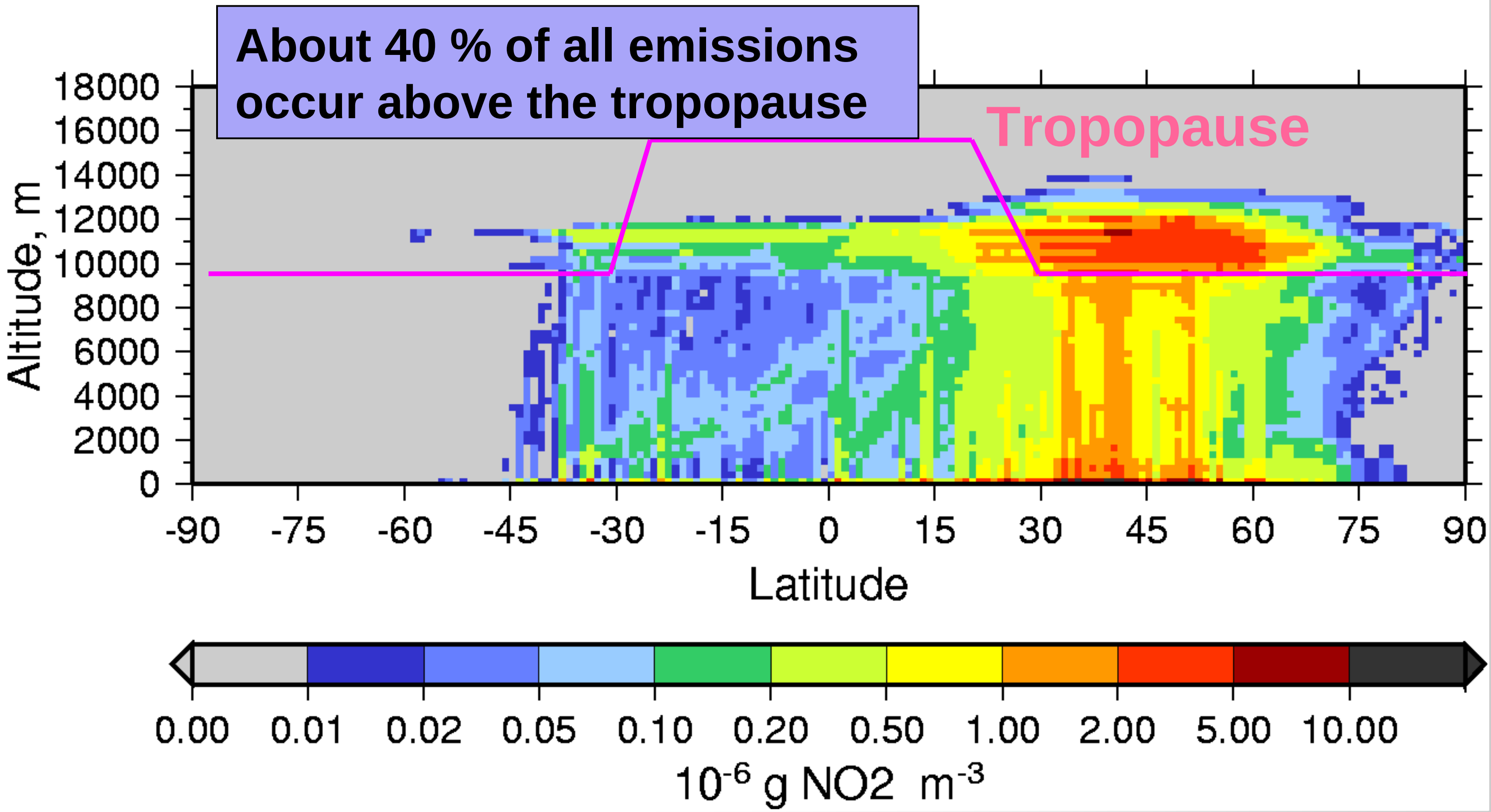
Global air transport contributes about 0,025°C to the total global warming of the earth surface of 0,7°C

Global distribution of aviation emissions



(AERO2K, 2005)

Vertical Distribution of Aircraft Emissions



(AERO2K, 2005)

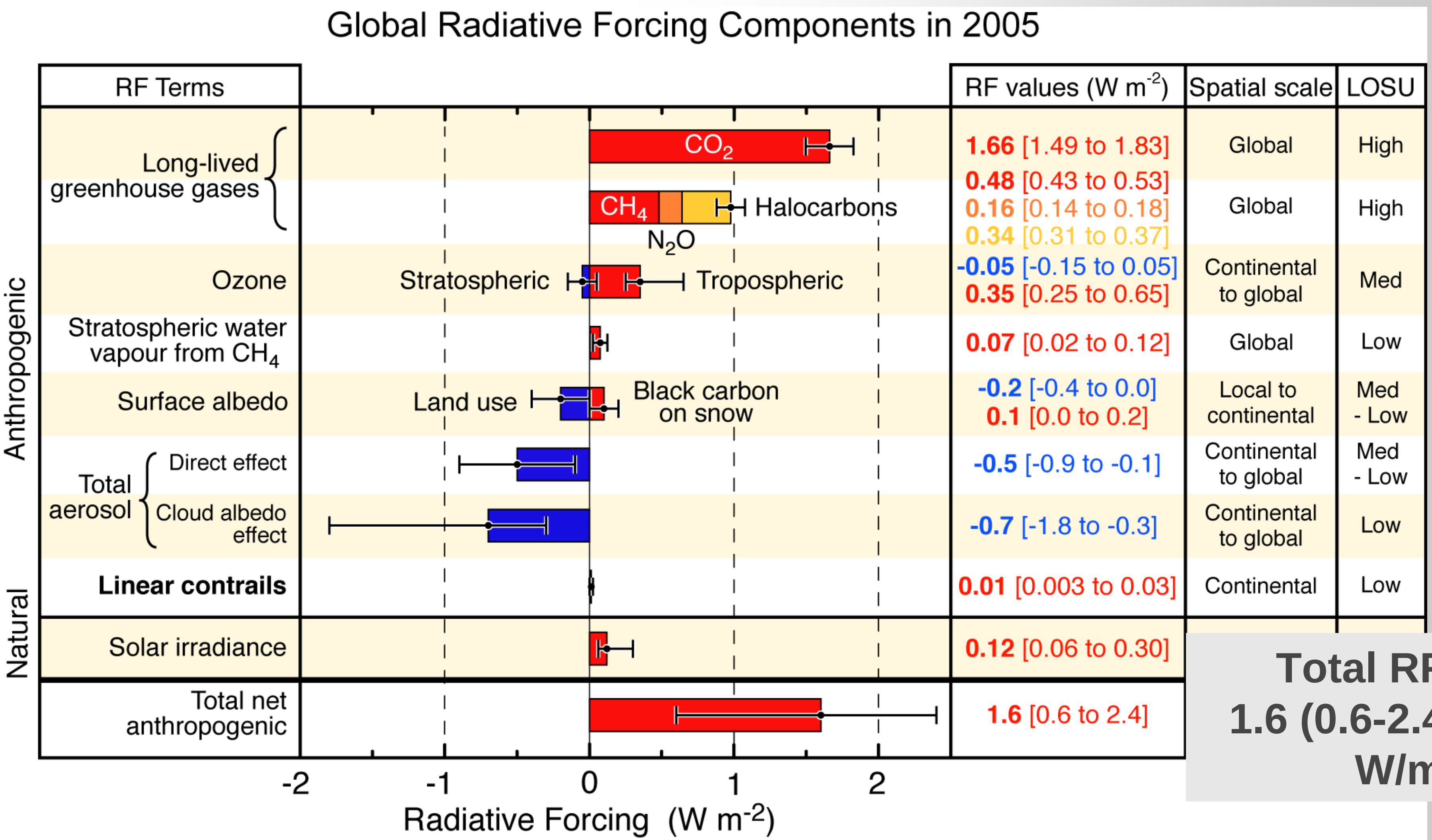
Radiative Forcing

- The dimension for expressing the climate impact is Radiative Forcing, RF.
- Radiative Forcing is measuring the rate of temperature increase due to human activities in Watt per square meter (W/m^2).

Simplified

- 1 W/m^2 results in about 0.8 (0.5 – 1.2) °C global medium temperature on earth surface

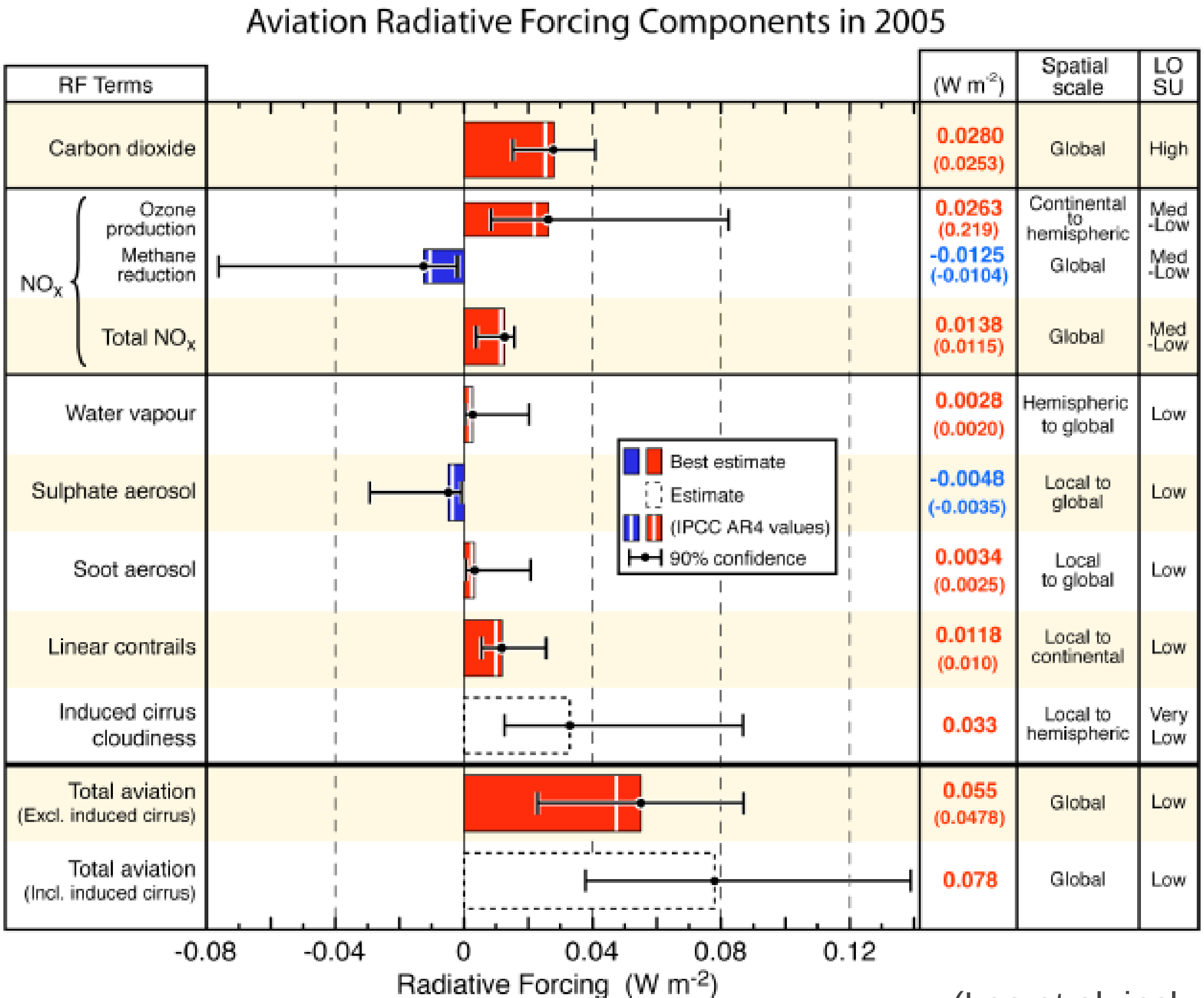
Global Radiative Forcing 1750-2005, from all sources



Total RF: 1.6 (0.6-2.4) W/m²

(IPCC, 2007; Lee et al., 2009)

Global Radiative Forcing 1750-2005, from aviation



Aviation RF contribution

0.04-0.14 W/m²

or 3 – 8 % of total

(Lee et al. including Sausen, DLR, 2009)

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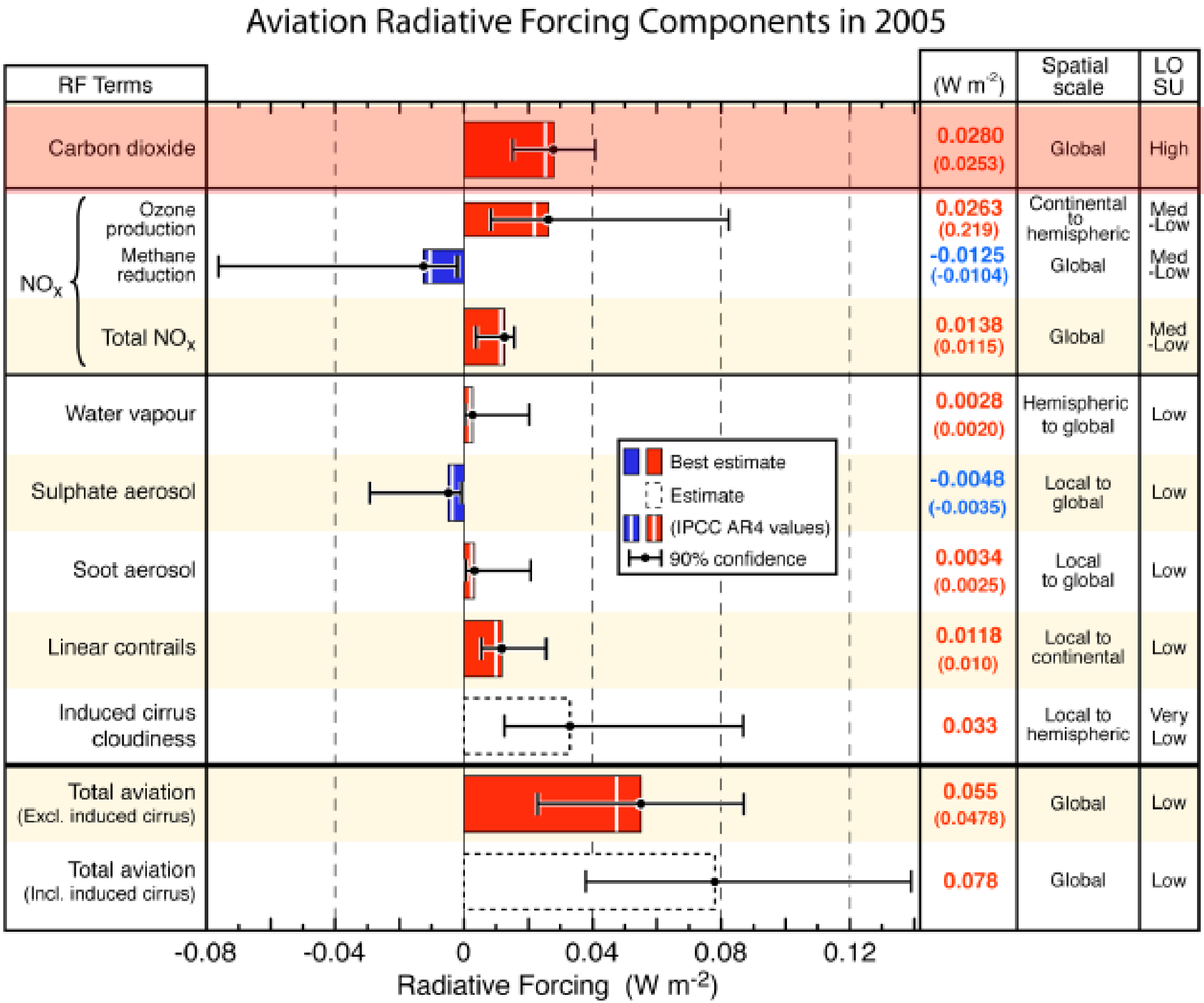
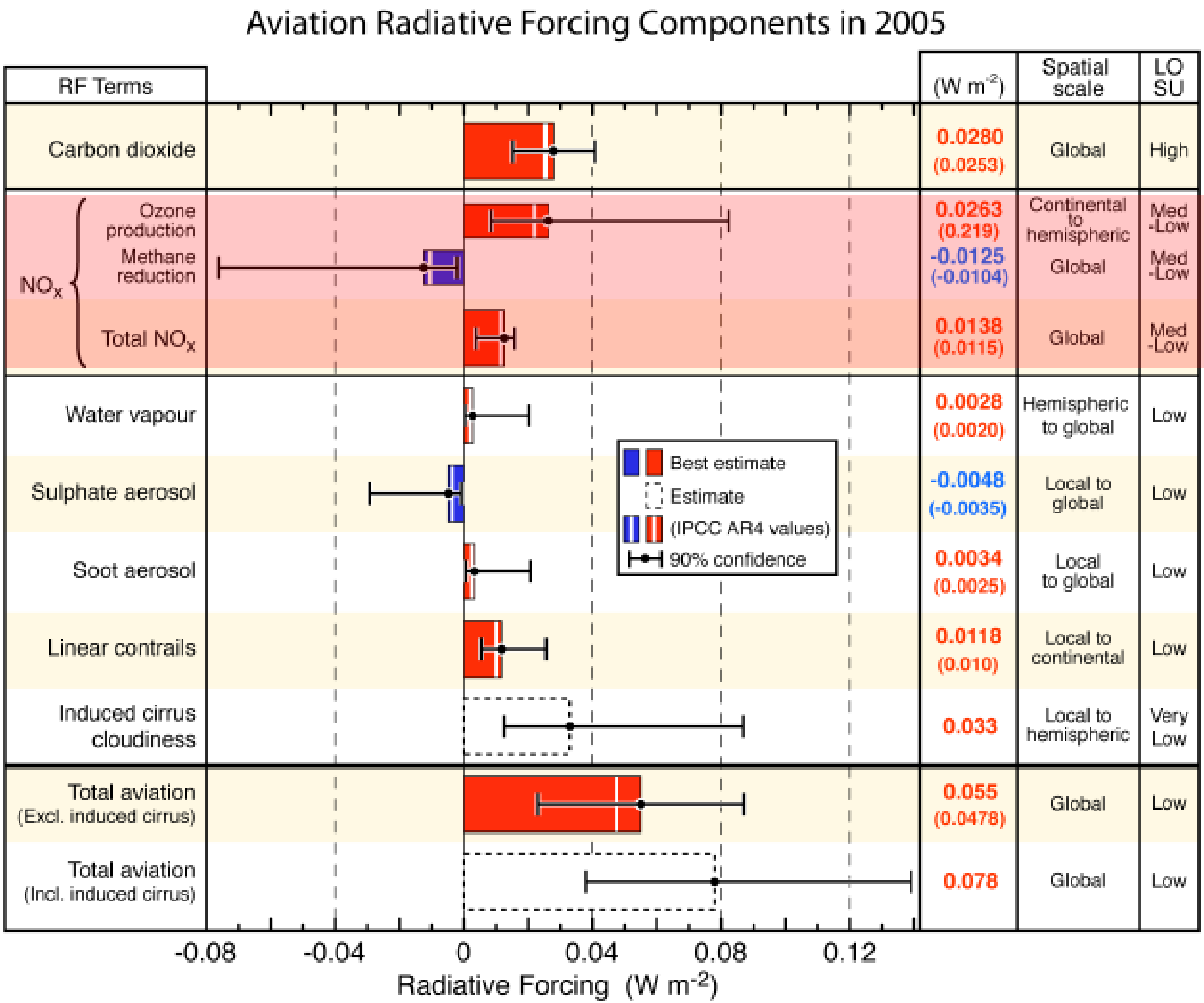
Aviation Radiative Forcing: Main Contributions



RF from aviation CO_2 forms presently about 1/3 of the total aviation RF.

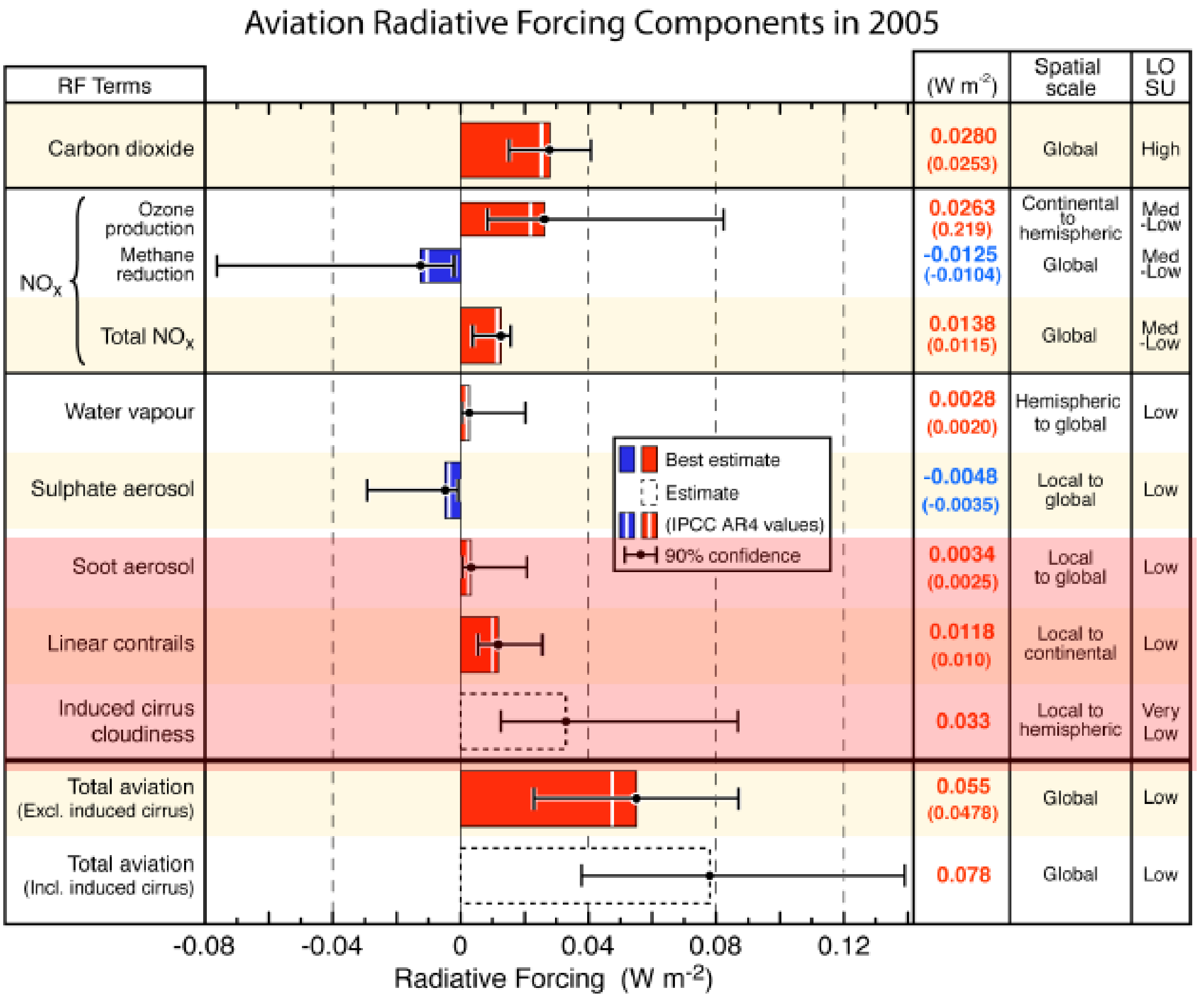
Because of long lifetime, the CO_2-RF keeps growing even for constant emissions

Aviation Radiative Forcing: Main Contributions



Several recent publications indicate larger methane reduction than assessed here, and hence even negative RF-values for total NOx

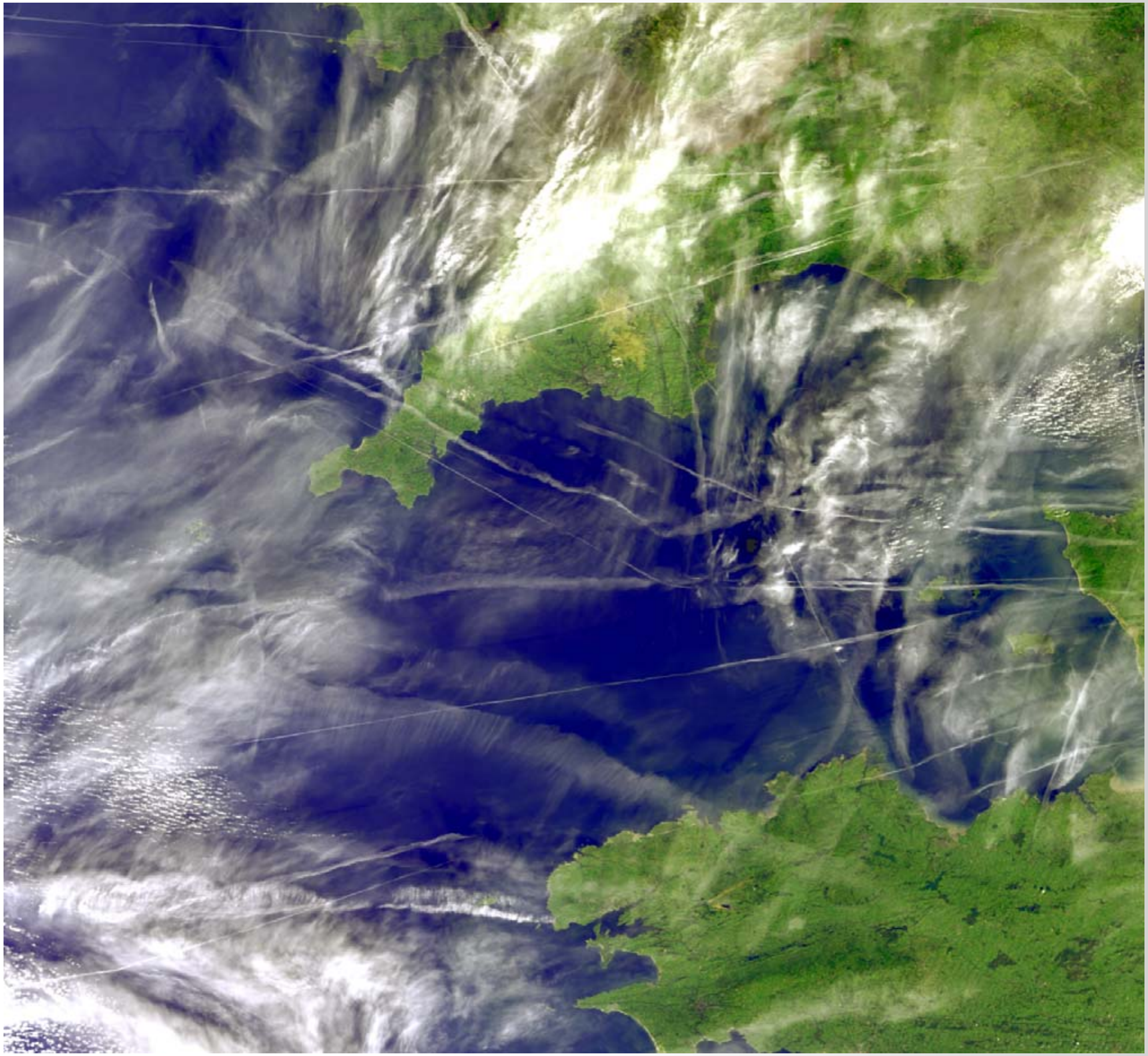
Aviation Radiative Forcing: Main Contributions



Induced cirrus cloudiness depends on soot and contrails.

Outside contrails, soot cause RF<0, inside contrails soot cause RF>0

Contrails and Cirrus



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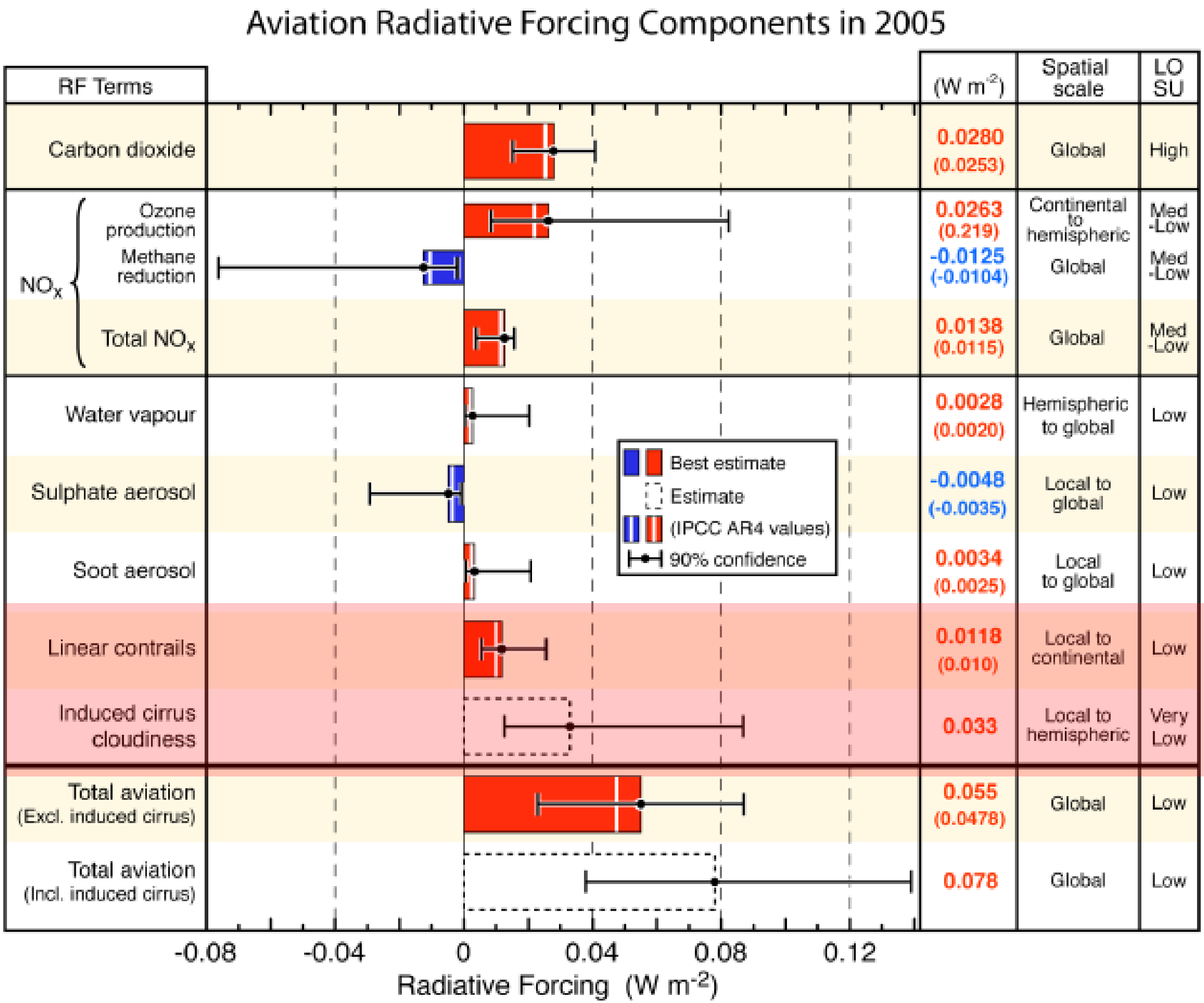
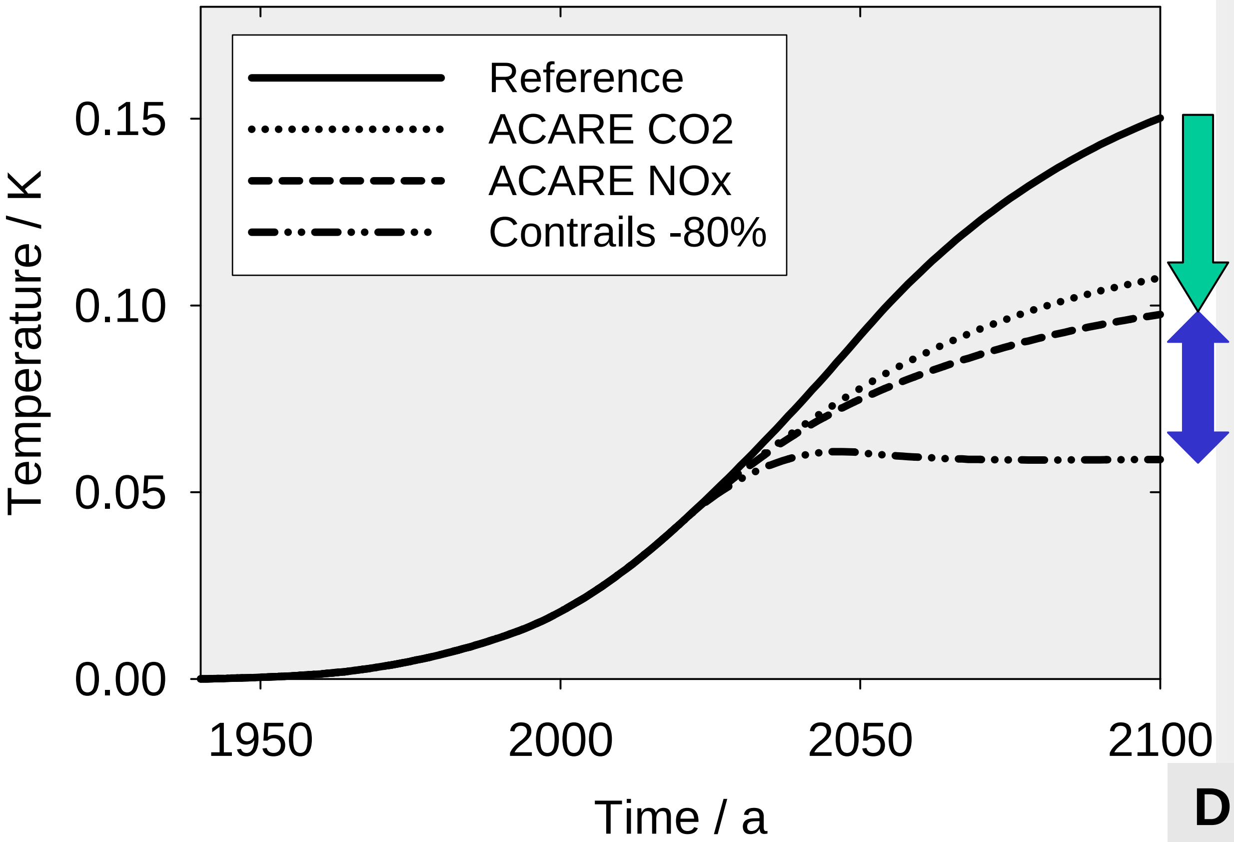
Aviation Radiative Forcing: Main Contributions



Recent DLR-studies show that contrail induced cirrus clouds may cause

RF >0.1 W m^{-2}

The global warming by aviation can be limited only if contrails are reduced in addition to CO_2 (and NO_x)



Reduction by less fuel consumption (CO_2) and NO_x (ACARE goals introduced in 2050)

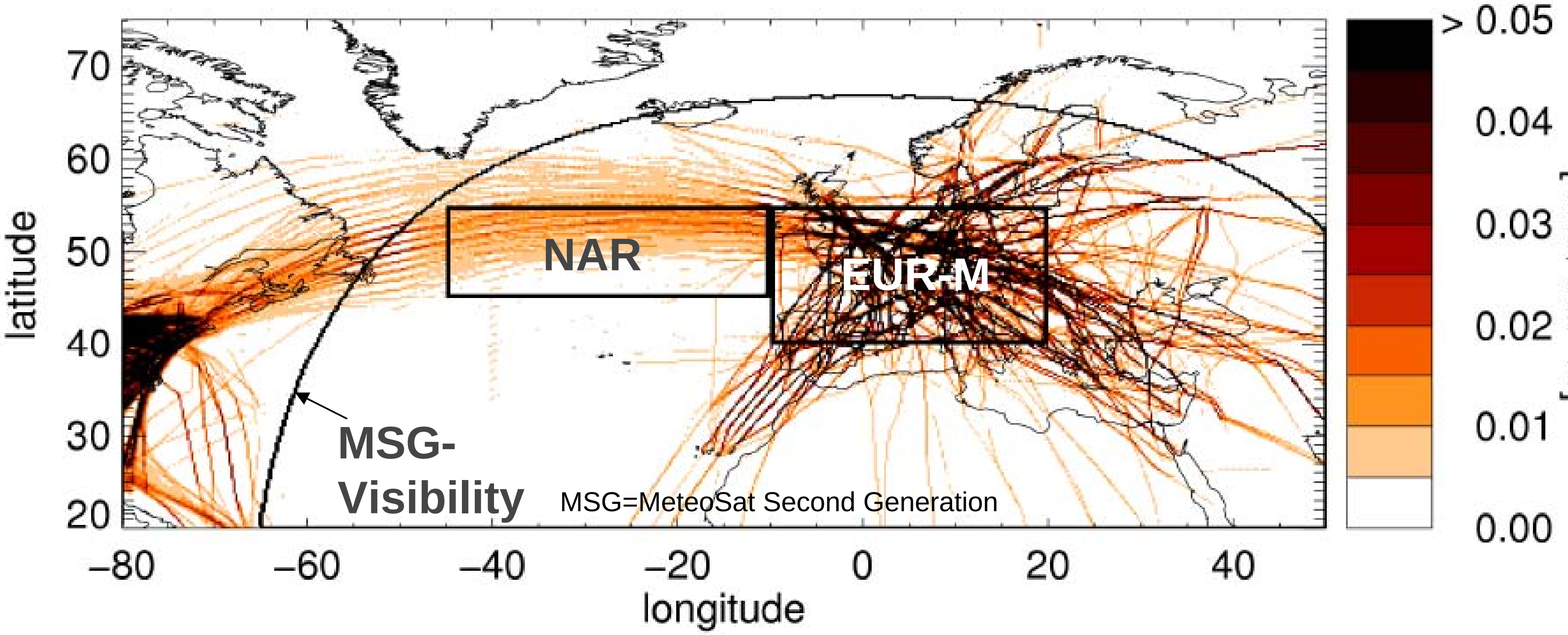
In addition:
80 % less Contrail-Cirrus (if 80 mW/m^2 present value)

DLR-CATS project: reduce the uncertainties and assess mitigation options.

(Schumann, 2008)

The diurnal Traffic and Cirrus cycles in the North Atlantic Region, NAR, provides an Aviation Fingerprint:

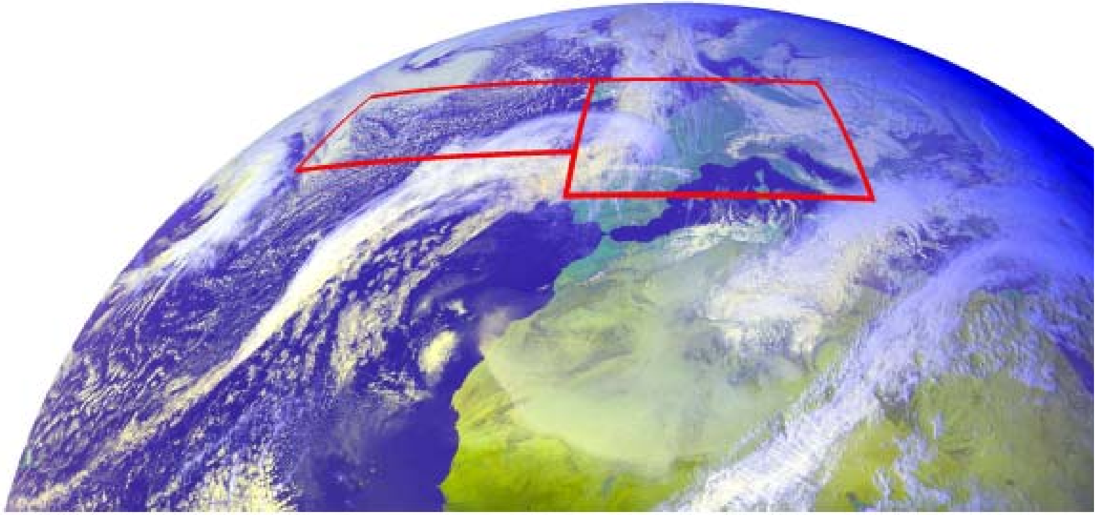
Annual mean Air traffic density (ATD) in km/(km^2 h)



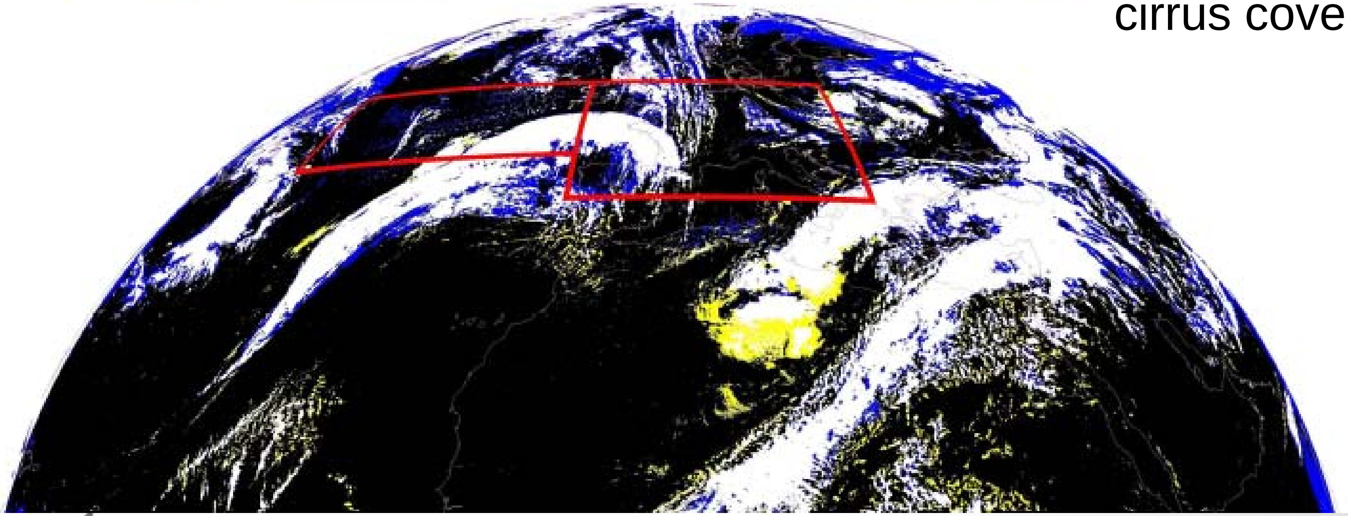
Vertically integrated traffic data above 6 km from EUROCONTROL at 15 min time resolution

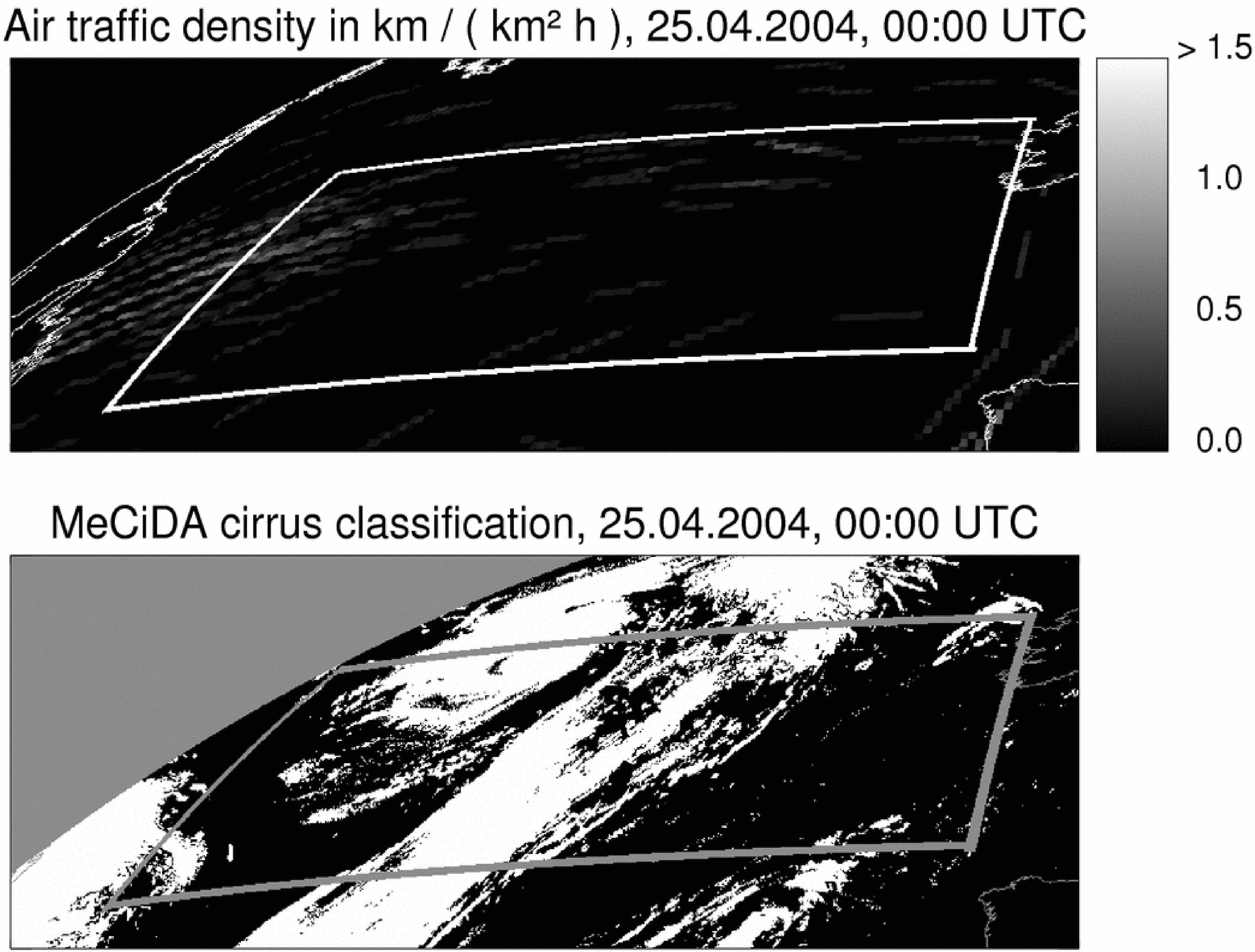
(Graf, Mayer, Mannstein, Schumann et al., DLR, 2009)

Cirrus cover determined from a new (day and night time) Meteosat Cirrus Detection algorithm: MeCiDa



- uses 7 IR channels of SEVIRI
- cirrus detection at day and night.
- combines morphological and multi-spectral threshold tests
- detects optically thin (> 0.4) ice clouds.
- Data include 4 years of 15 min cirrus cover, Feb 2004–Jan 2008

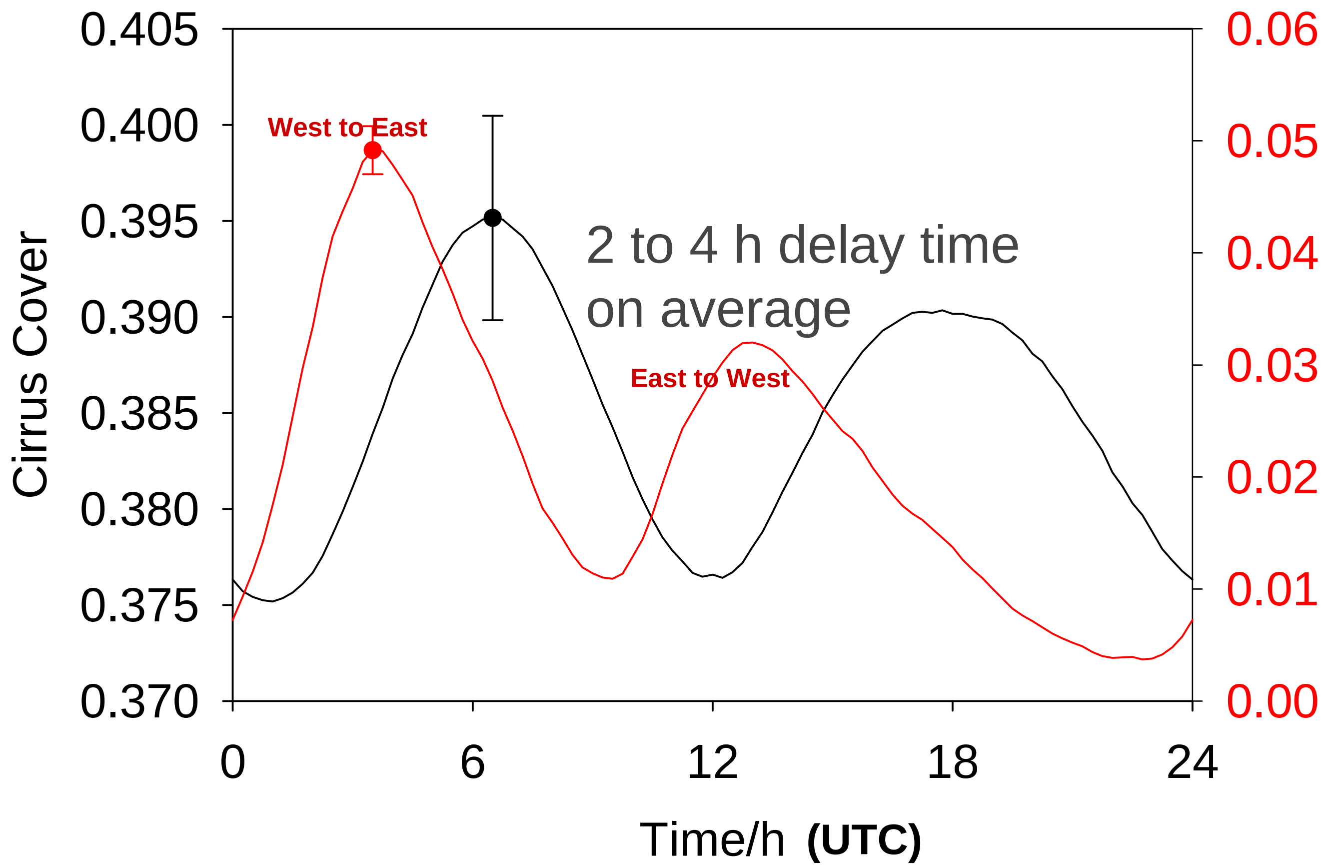




Air traffic density in km / (km² h), 25.04.2004, 00:00 UTC
> 1.5
1.0
0.5
0.0
MeCiDA cirrus classification, 25.04.2004, 00:00 UTC

Air Traffic and Cirrus

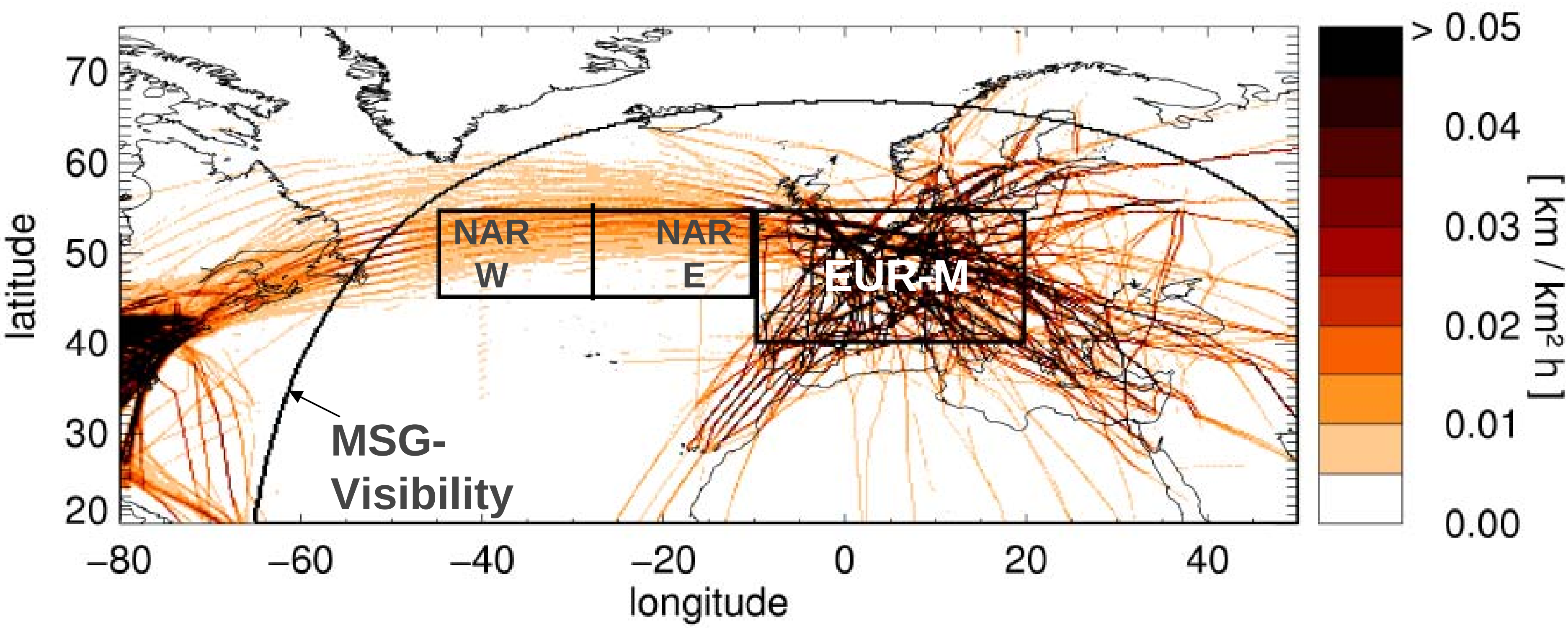
Annual mean cirrus cover and air traffic density (ATD)



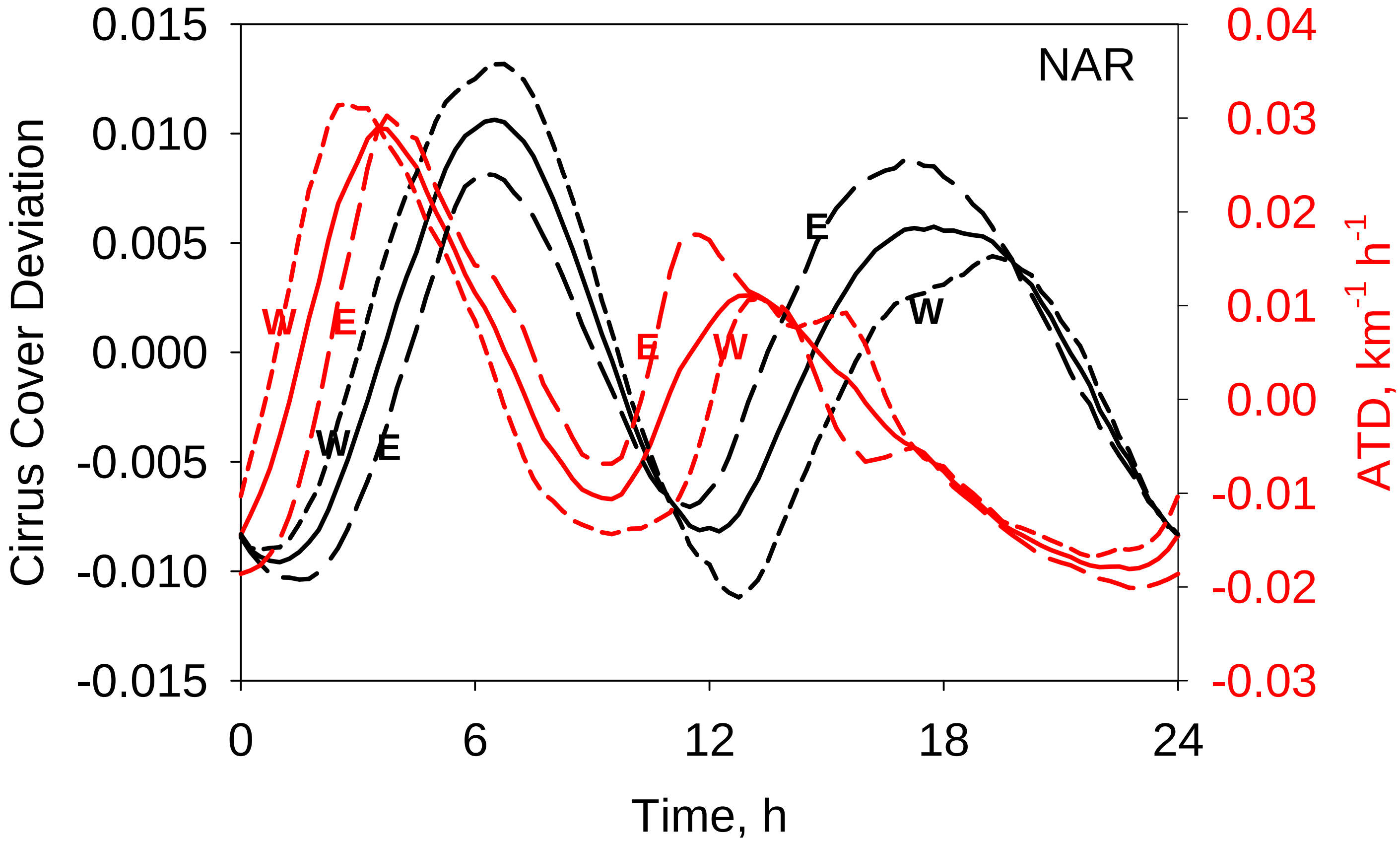
Cirrus cover follows air traffic with 2 to 4 h delay (this is the time to spread contrail cirrus to maximum width and thickness visible for the satellite

The cirrus amplitude is far larger than expected for line-shaped contrails so far.

Split into west and east part of NAR



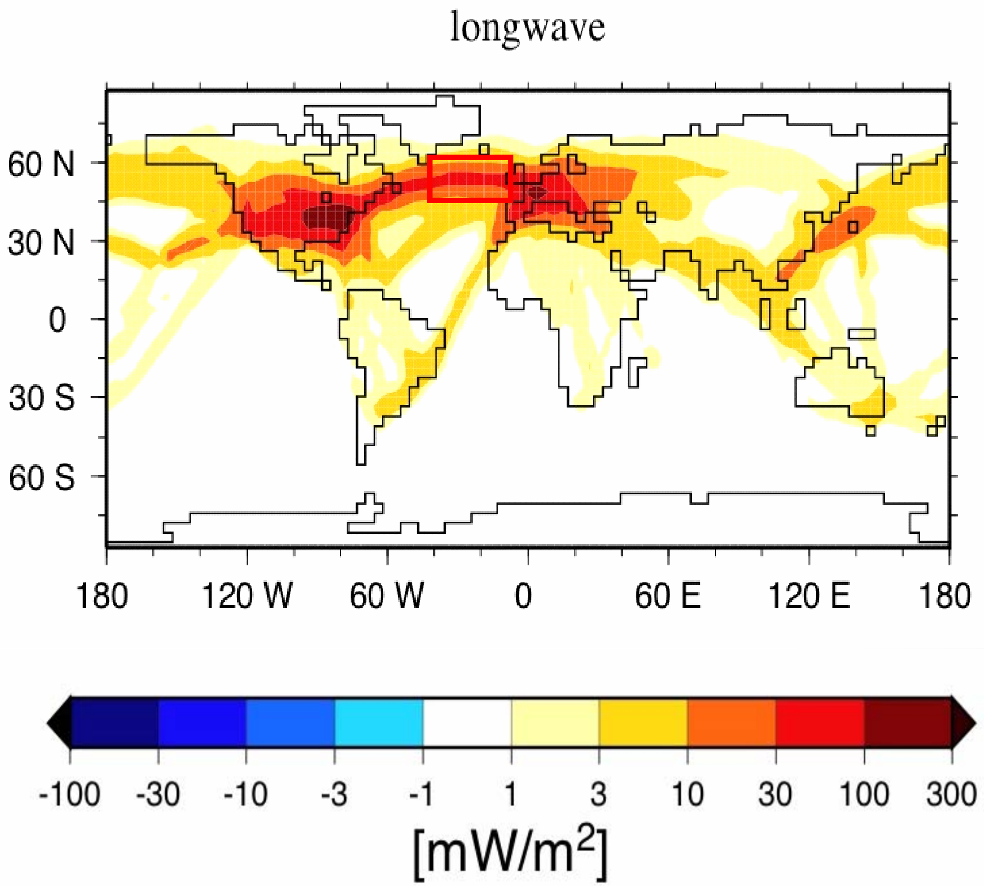
When dividing the NAR into 2 equal 17.5°x10° W-E-subregions: cirrus cover and ATD density are well correlated



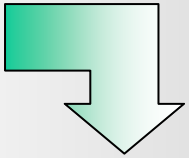
Diurnal traffic and cirrus cycles show correlations in the western and eastern parts separately, which can only be explained by aviation impact on cirrus

Contrails Globally: RF Forcing about 0.1 W/m^2

State of the art: line shaped contrail RF: 17 mW/m^2 in NAR, 0.003 W/m^2 globally.



(Marquart et al., 2003), DLR



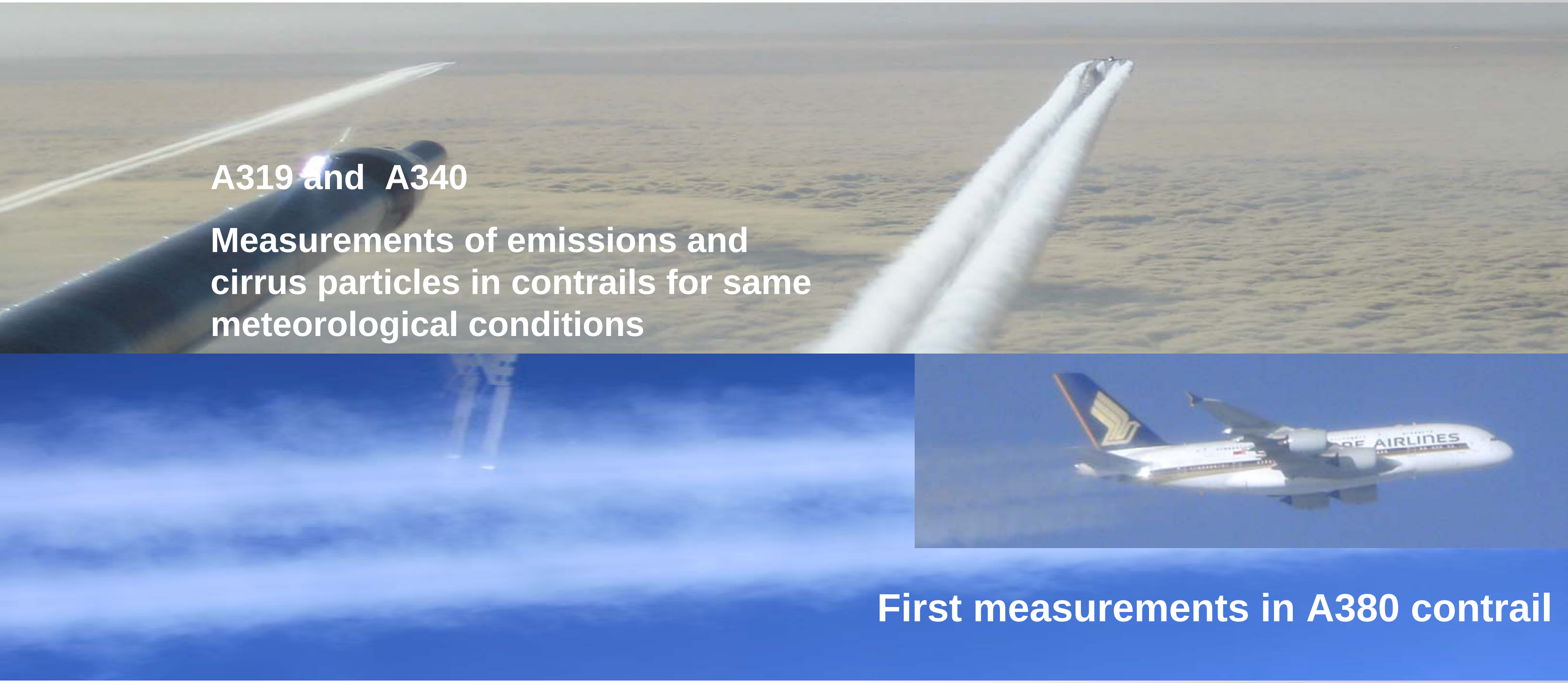
<u>New results show 30 × larger RF values for all contrails than for line-shaped contrails only</u>

Hence global RF ≅ 0.1 W/m^2

Aviation induced cirrus cause a larger climate impact than CO_2, (and NO_x) together!

New measurements with DLR Falcon

Over North Sea behind A319, A340, A380, B737, CRJ2 aircraft



A319 and A340

Measurements of emissions and cirrus particles in contrails for same meteorological conditions

First measurements in A380 contrail

Result: Contrails of larger aircraft compared to smaller ones are thicker and stay longer

More soot causes smaller ice particles which sediment later and therefore cause longer contrails

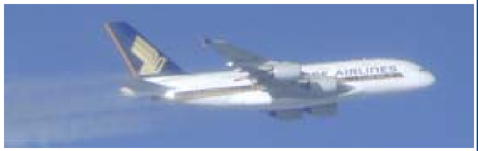
(DLR-CATS + HGF-AEROTROP; Voigt et al., 2009)

A New DLR- Simulation Model

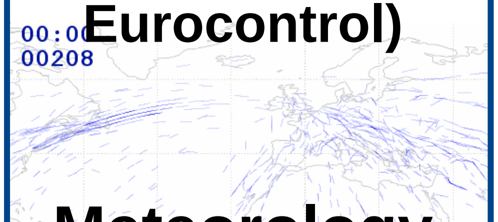
Contrail Cirrus Simulation and Prediction (CoCiP)

Input:

Aircraft
(BADA)

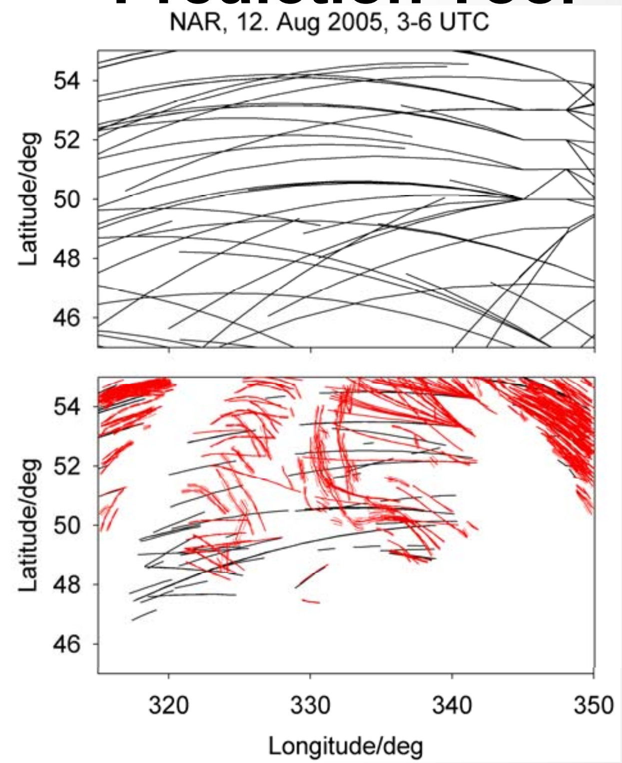


Movements
(ATM data, DFS, Eurocontrol)



Meteorology
(NWP results, ECMWF, DWD)

Contrail Cirrus Prediction Tool



- From regional to global
- Comparable to observations

Output:

Contrail,
life cycle, cover, radiation

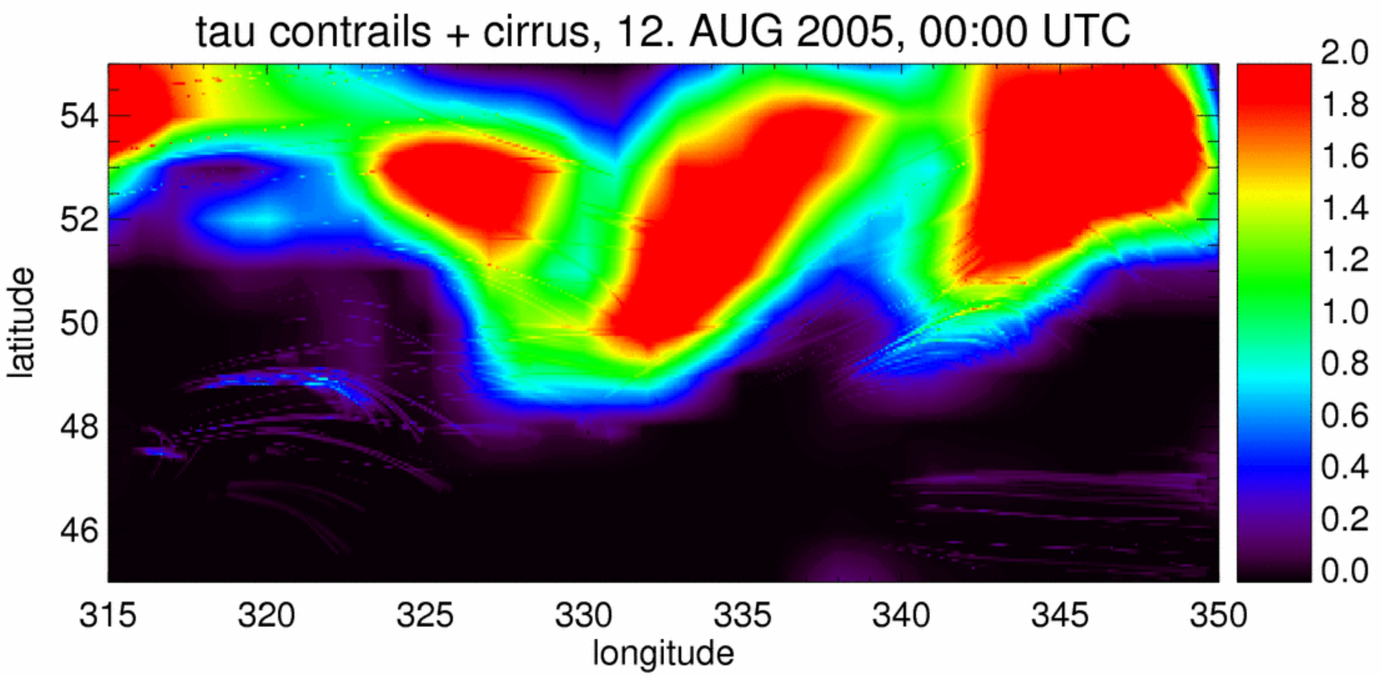
Natural Cirrus

Simulation
(insitu, Lidar, Satellite)

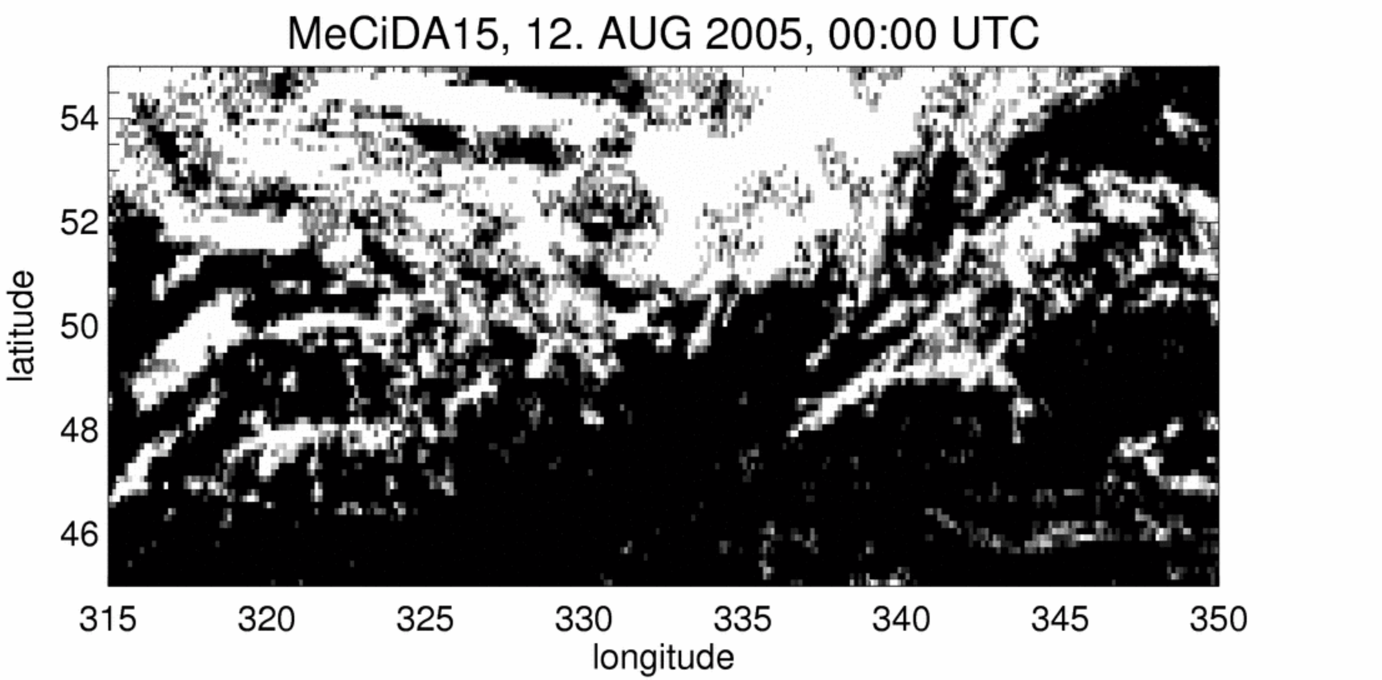
Sensitivity studies

Prediction
Climate impact

(Schumann, 2009)

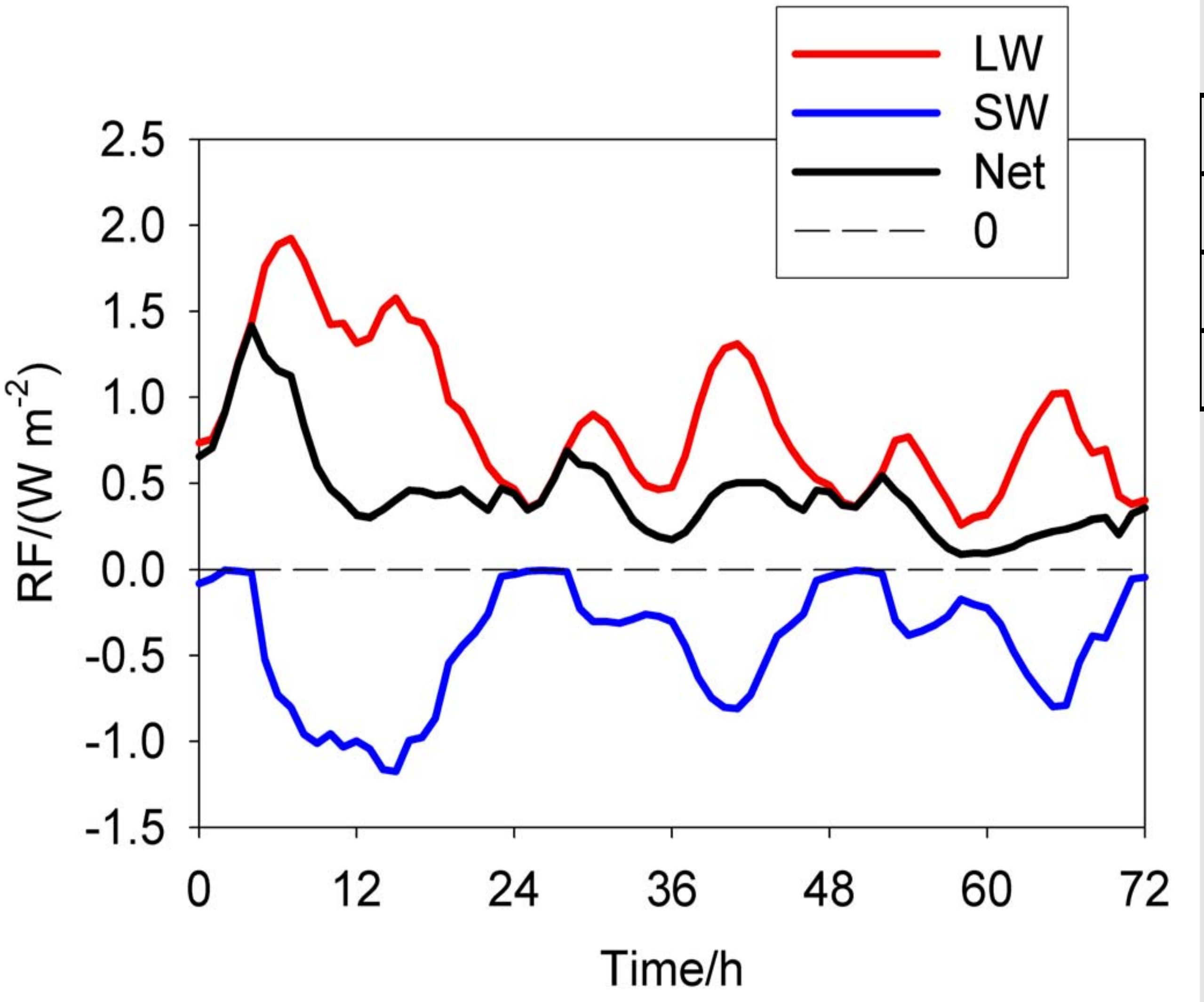


Modeled cloud thickness (tau) show structures



…. comparable to observations

Regional radiative forcing for NAR reference case



[W/m²]	
LW	0.86
SW	-0.42
Net	0.44

all day LW warming

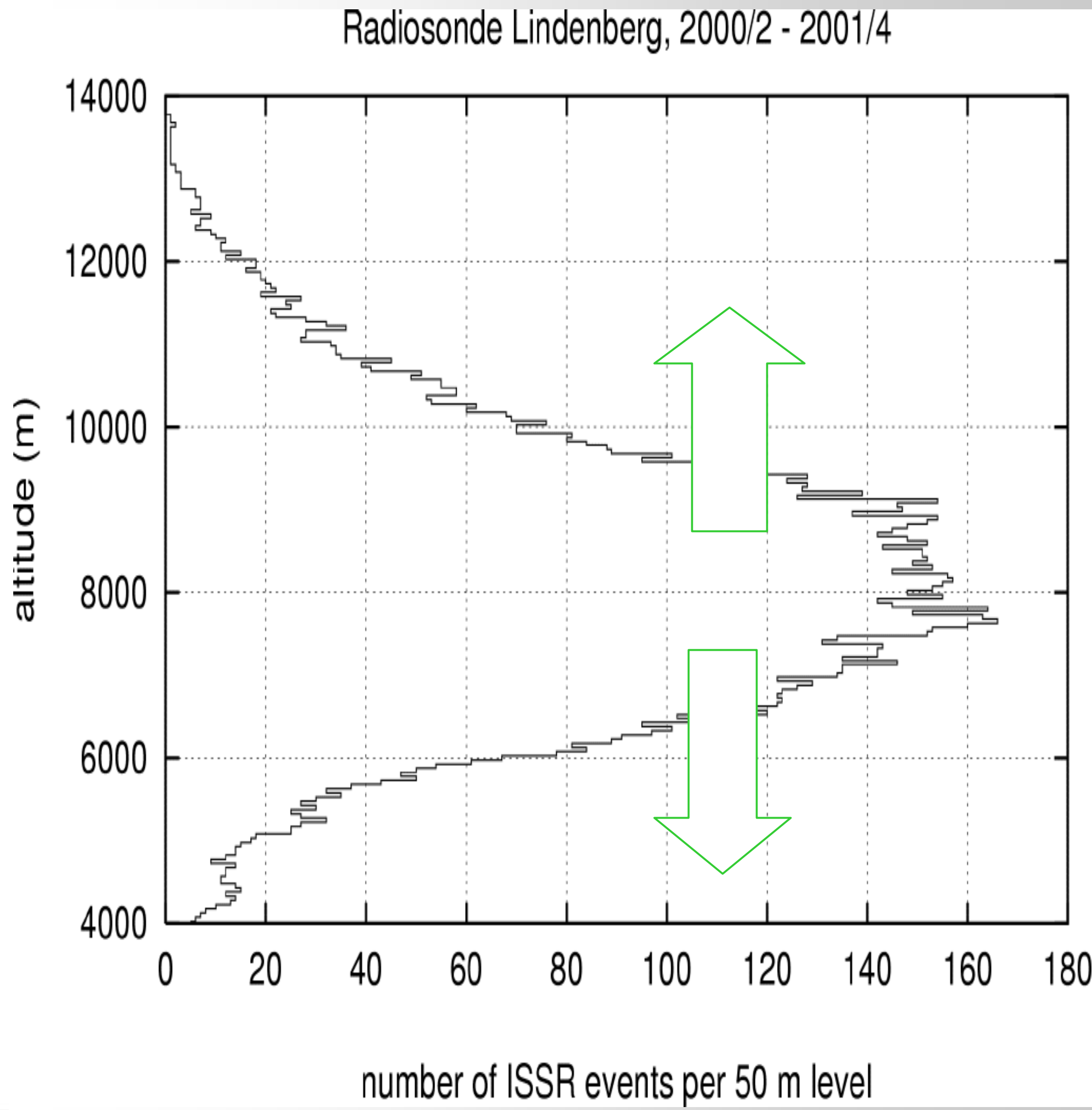
daytime SW cooling

all day net warming in this case

Contrails can be avoided by flying higher or lower in particular humid regions

Vertical distribution of ALL ice super-saturated regions

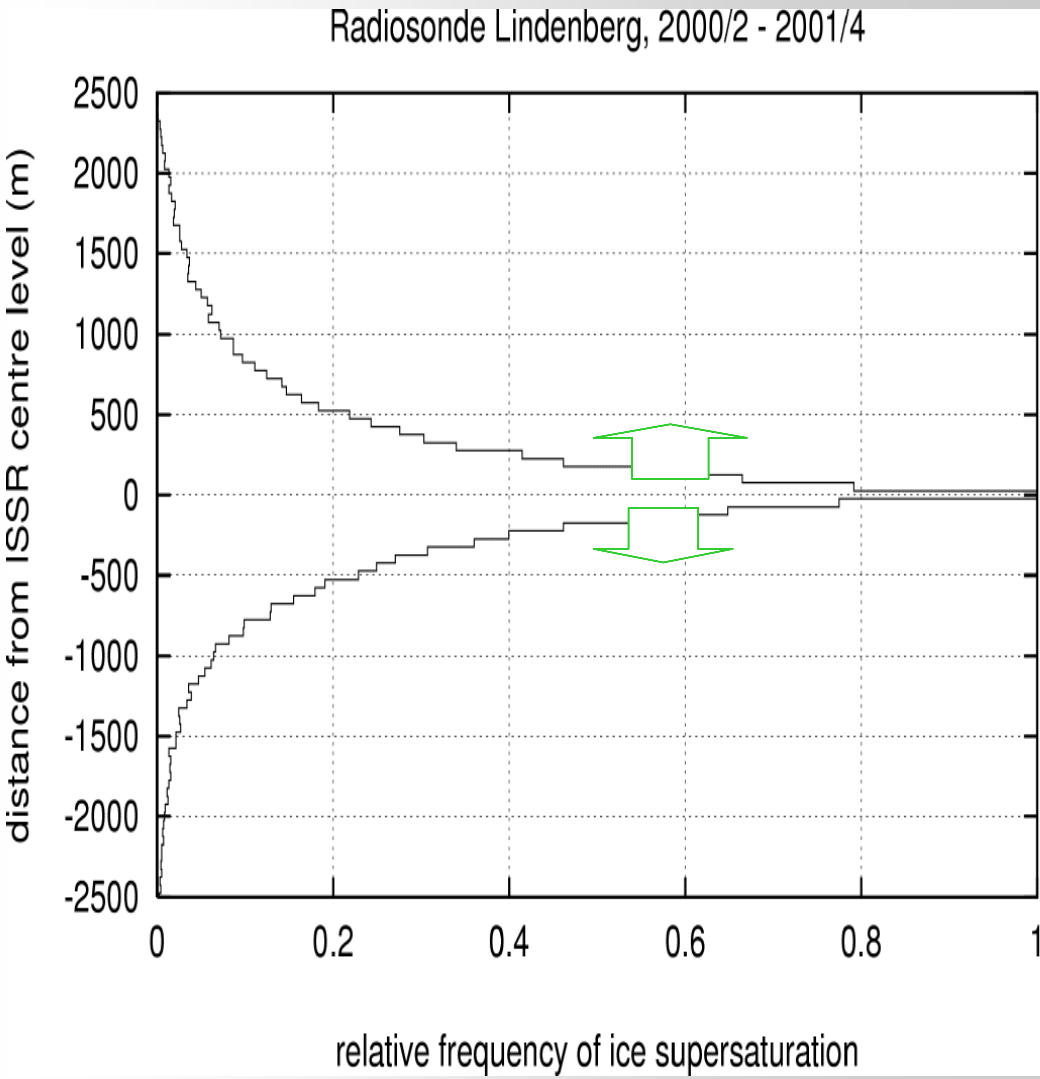
Required altitude change: +-2 km?



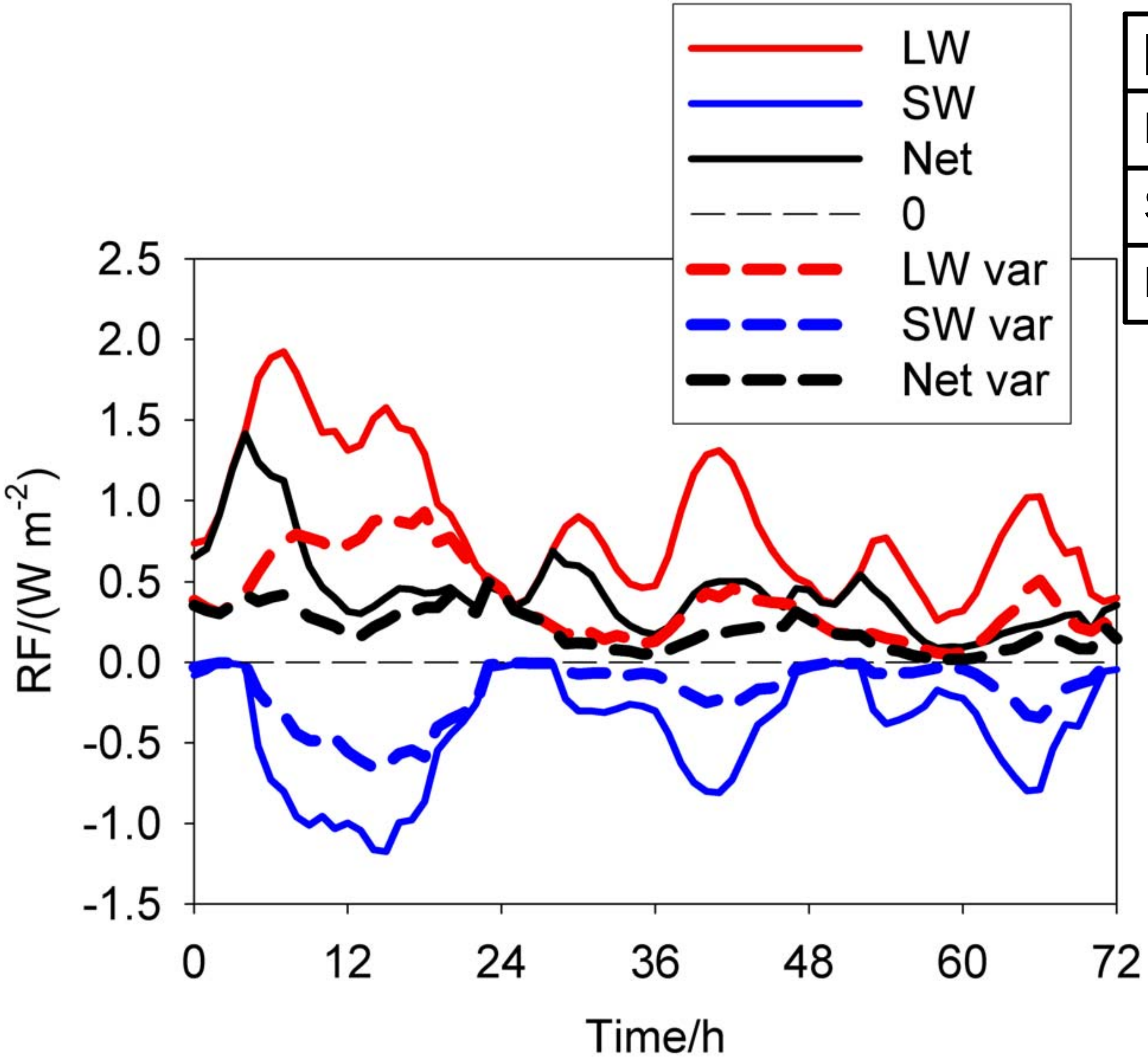
Contrails can be avoided by flying higher or lower in particular humid regions

Vertical distribution of INDIVIDUAL ice-saturated regions

Required altitude change: +-0,3 km?



Flying 600 m higher or lower, minimizing contrails



[W/m²]	fix	var.
LW	0.86	0.38
SW	-0.42	-0.18
Net	0.44	0.20

By adjusting flight levels to minimum humidity, more than 50 % of the contrail heating effect can be avoided

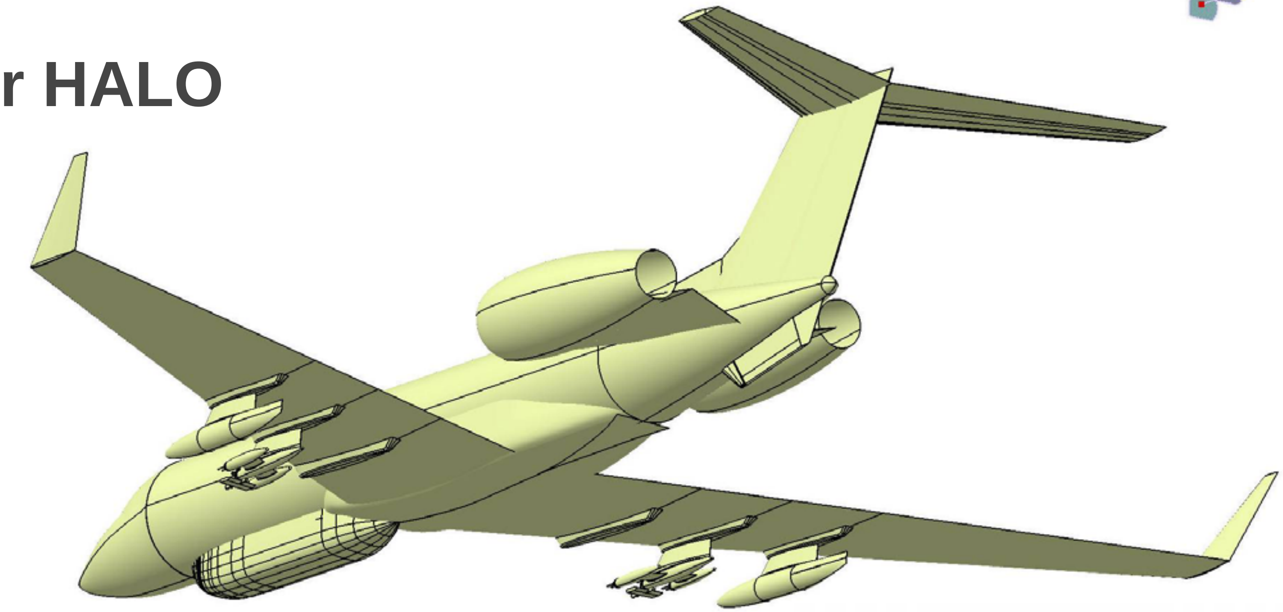
Conclusions for Climate Research

- **The CO_2 impact remains very important for centuries. Hence, Fuels without fossil C emissions are needed**
- **The NOx impact is less important than thought when formulating ACARE objectives in 2000, however, NOx can be an health issue in the airport vicinity**
- **The climate impact of contrail cirrus is larger than estimated so far.**
- **A reduction of soot emissions helps to reduce the climate impact of contrail cirrus.**
- **Contrail cirrus can be reduced by flying higher or lower, depending on the predicted weather situation.**
- **This causes a small CO2-RF-increase and a larger contrail RF-reduction.**
- **Future ATM routing should minimize climate impact from CO_2 and contrails**
- **Limiting global warming to less than 2°C requires quick actions on all warming contributions, including contrails and soot**

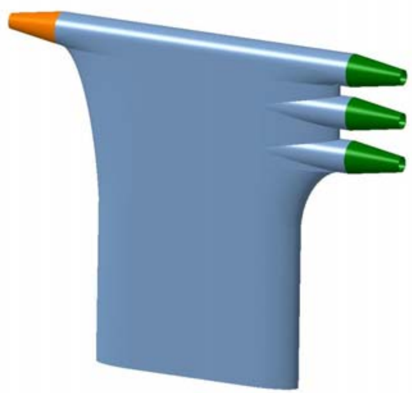
HALO Experiments

HALO Experiments

Instrumentation for HALO



- Far field measurements: LIDAR / GLORIA
- Cloud radar
- Microwave sensor for temperature far field
- Mass spectrometer (SO_2, PAN, HNO_3, ...)
- In-situ trace gas instruments
- Particle probes below wing
- **More than 40 different instruments for first three Demo missions**



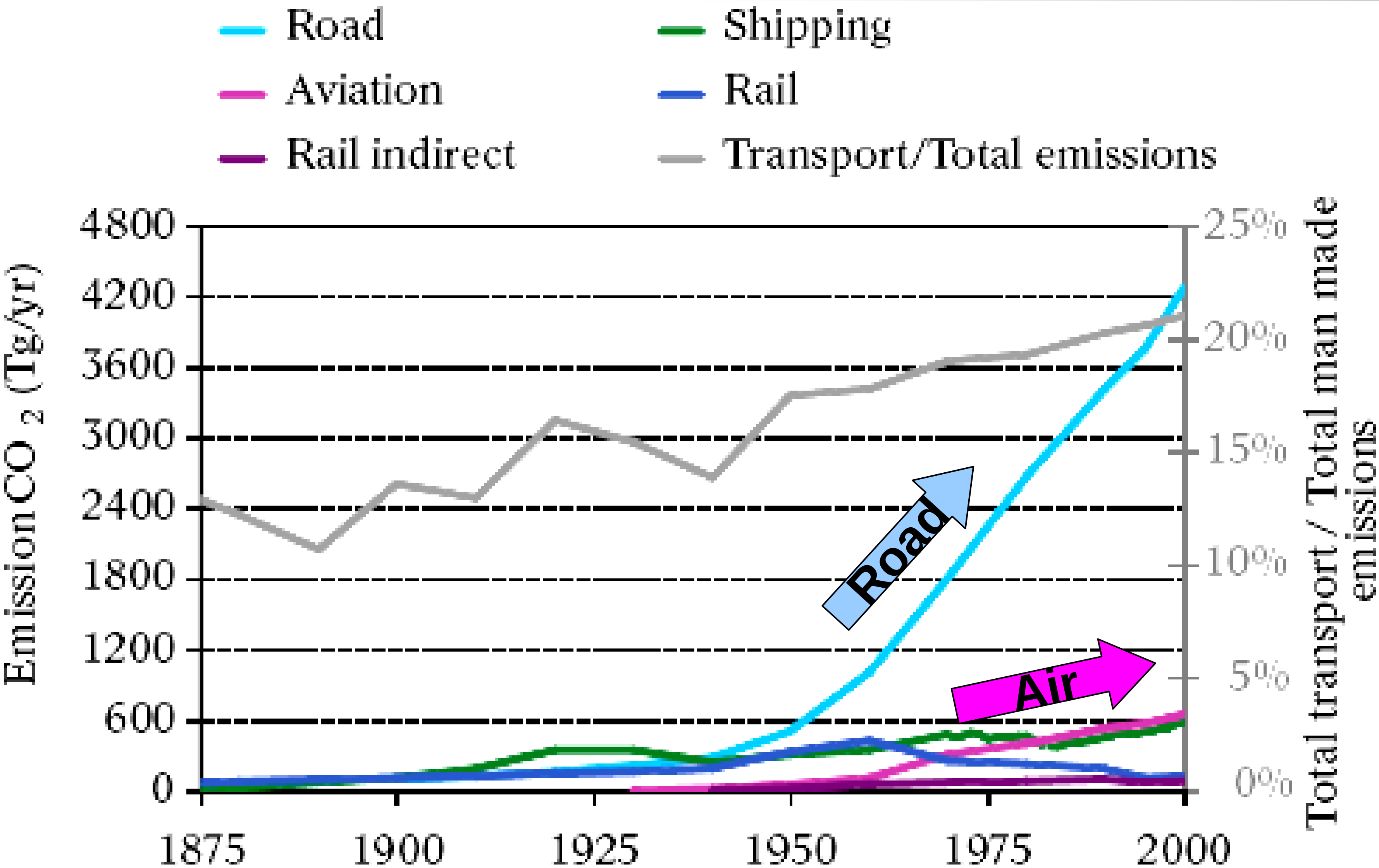
Next steps

DLR project 2008-2012
Climate compatible Air Transport System (CATS)

- Atmospheric research to reduce the existing uncertainties (in particular assessment of the global climate impact of aviation induced cirrus)
- Air transport system research (in particular an integrated simulation and assessment chain for analyses of various mitigation options)
- Finalization of the EU-Project QUANTIFY to assess all traffic impact (aircraft, ships, cars, trains etc.) in 2010.
- EU-Project REACT4C (2009-2011) to explore the feasibility of adopting flight altitudes and flight routes that lead to reduced fuel consumption and emissions, and lessen the environmental impact.

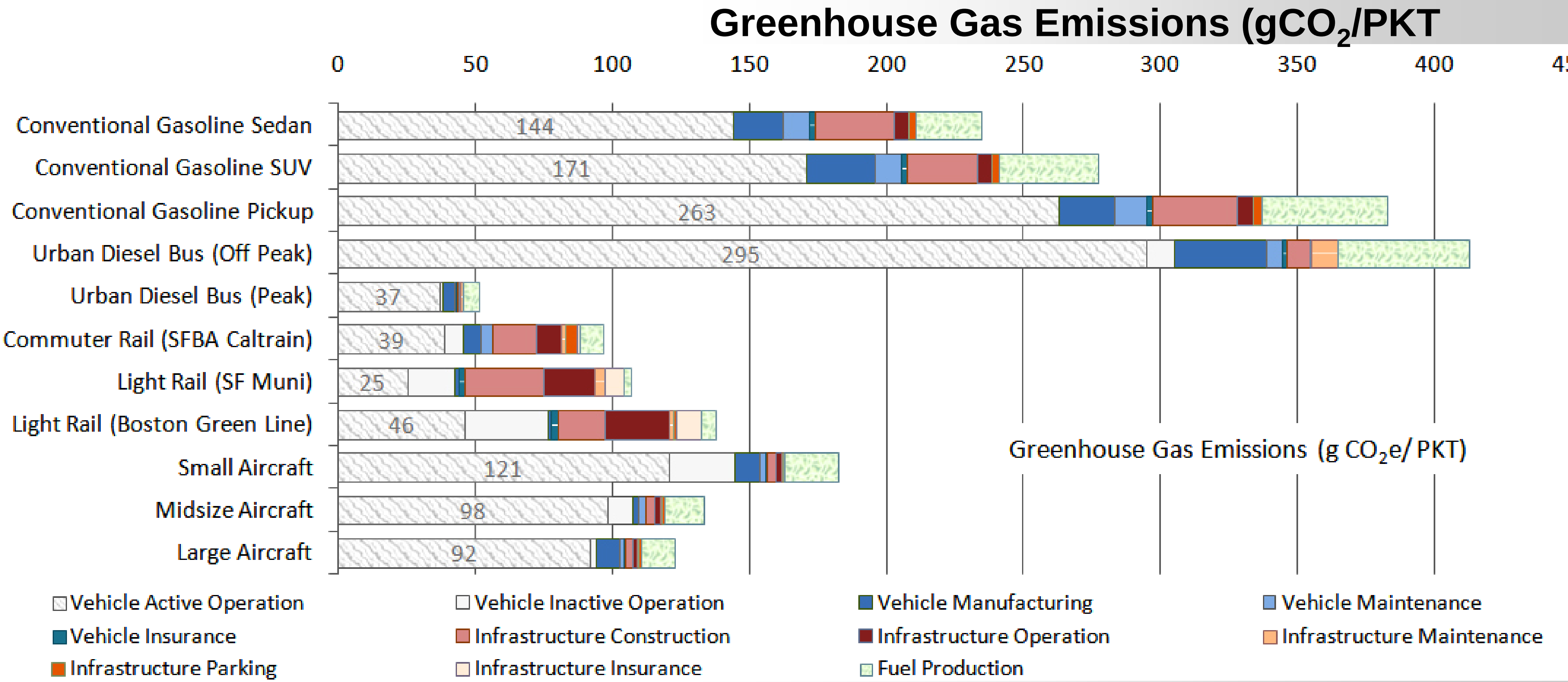
Planned for 2010: HALO ML-CIRRUS experiment to validate the contrail cirrus models

CO_2-Emissions Transport



Fuglestvedt et al., 2007, © PNAS

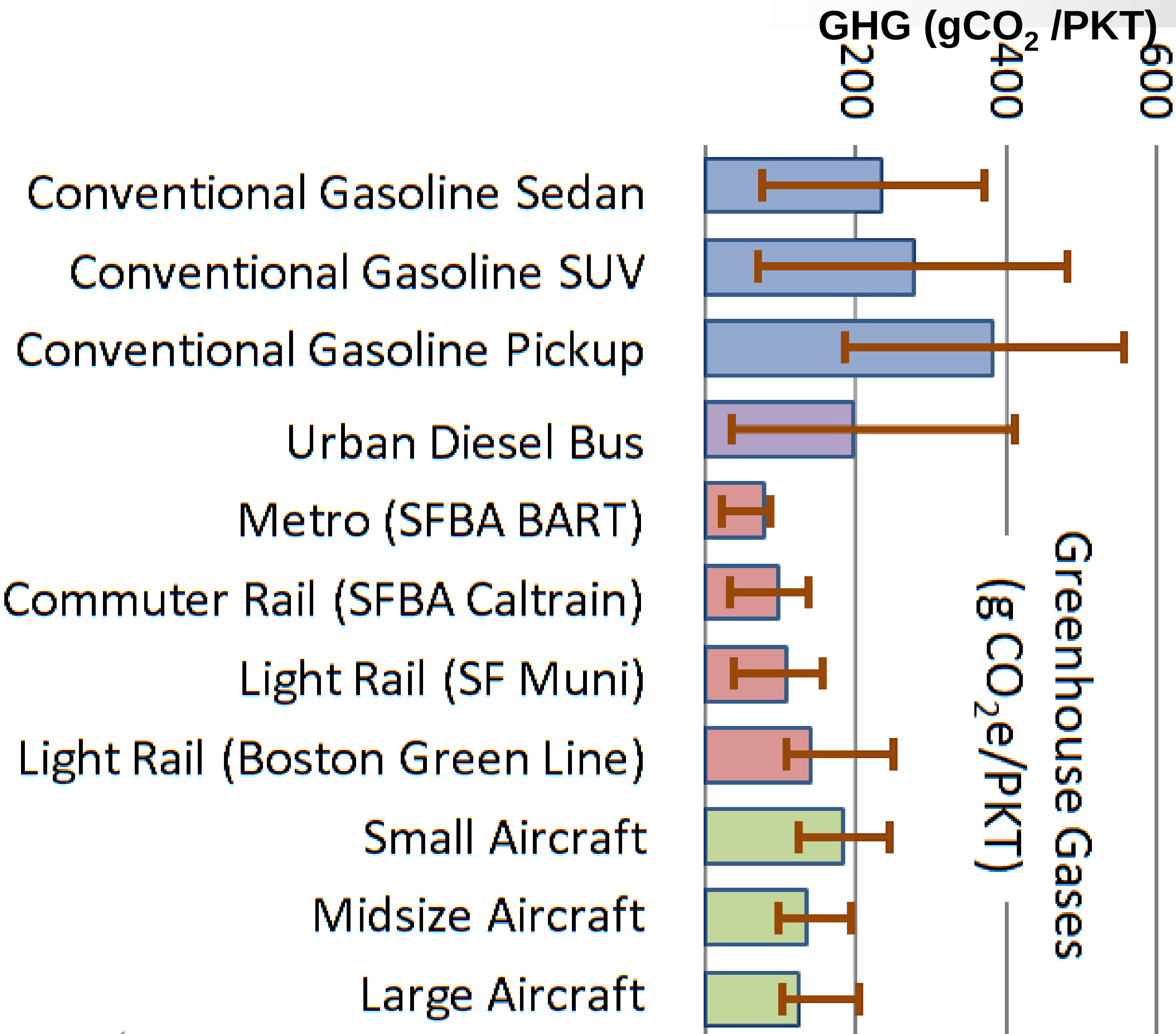
GHG Emissions per PKT for Different Modes of Travel



PKT= Passenger Kilometers Travelled

Chester, Horvarth, 2009

GHG Emissions Sensitivity to Occupancy



Car: 1 and Max Seats

Bus: 5 and 60 PAX

Rail: 25% and 110%

Air: 50% and 100%

Chester, Horvarth, 2009

"However beautiful the strategy, you should occasionally look at the results."

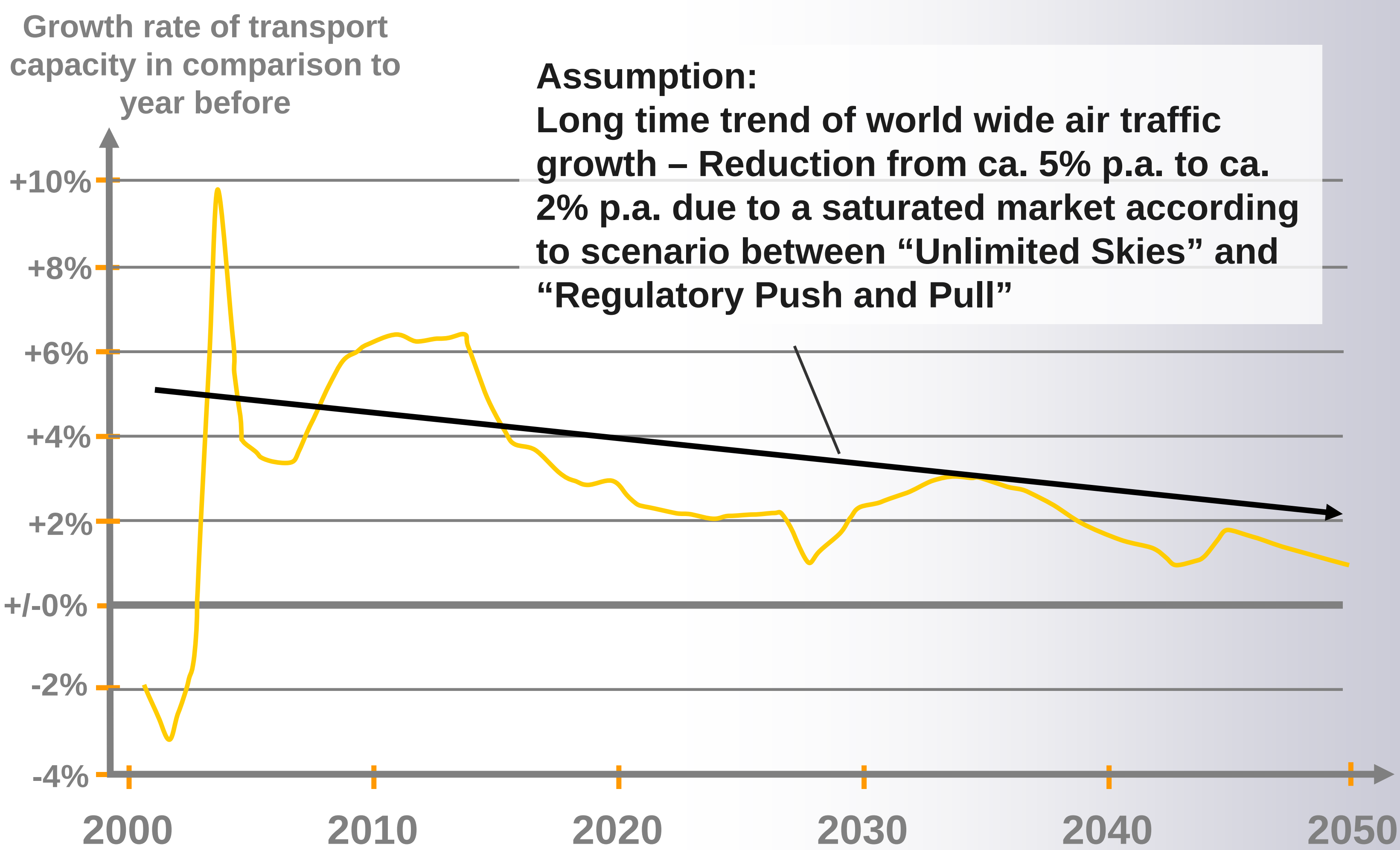
Winston Churchill

How much technology do we really need?

Prognoses

- Traffic Growth between 5% and 3,5%
- Load Factor
- Service Life
- PAX / Freight and Combi-Aircraft
- Blockfuel
- Average Seat Calculation
- Distance pro hour
- Flight-hours per Aircraft
- Considered Aircraft Types:
  - Classic and New Generation,

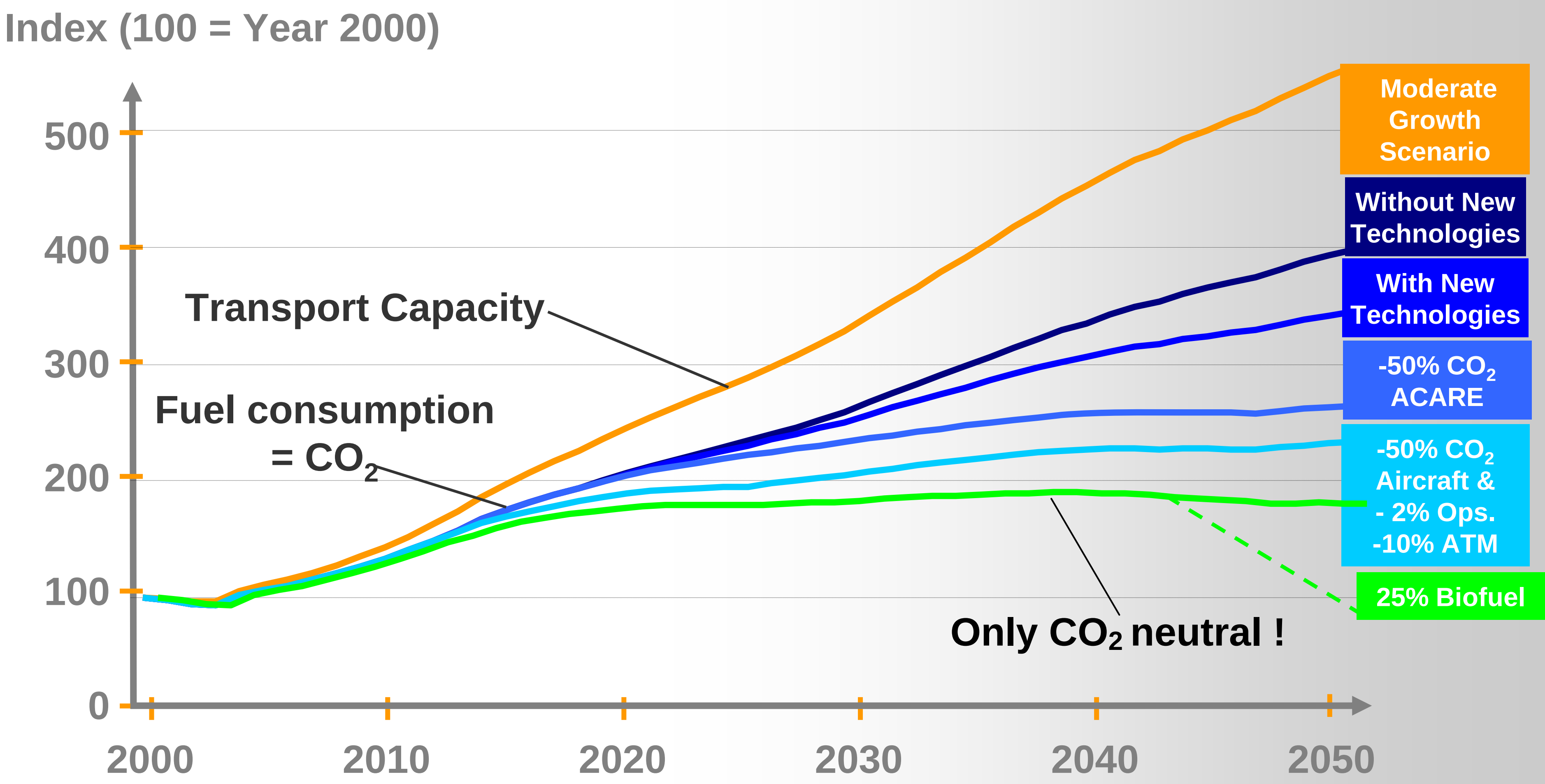
Extrapolation until 2050



(W. Grimme, DLR, 2008)

Technology Impact Fuel Burn

Technology Impact – Extrapolation 2000 - 2050



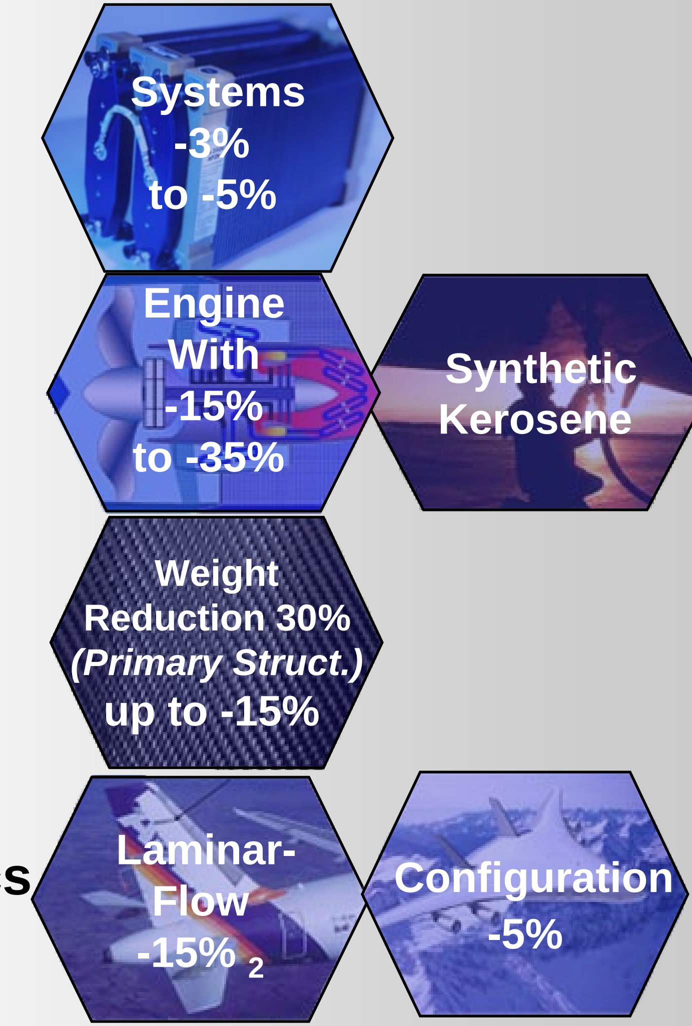
Aircraft Technologies for Fuel Burn Reduction

Systems

Engine

Structures

Aerodynamics

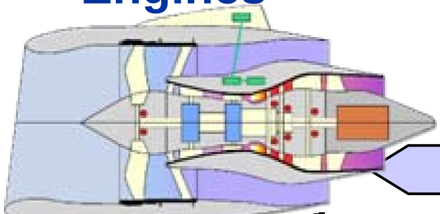


Joint Technology Initiative "Clean Sky"

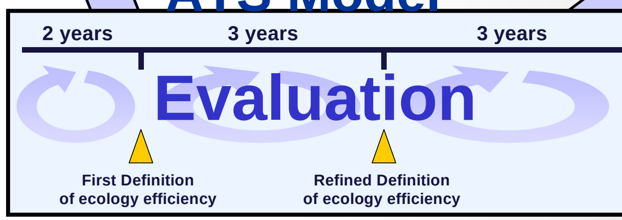
SMART Wing Aircraft

Systems for Green

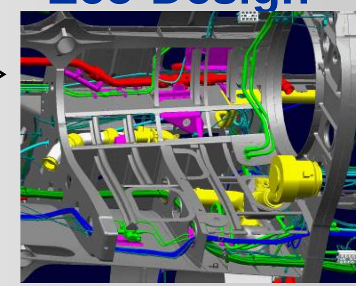
Green Engines



ATS Model



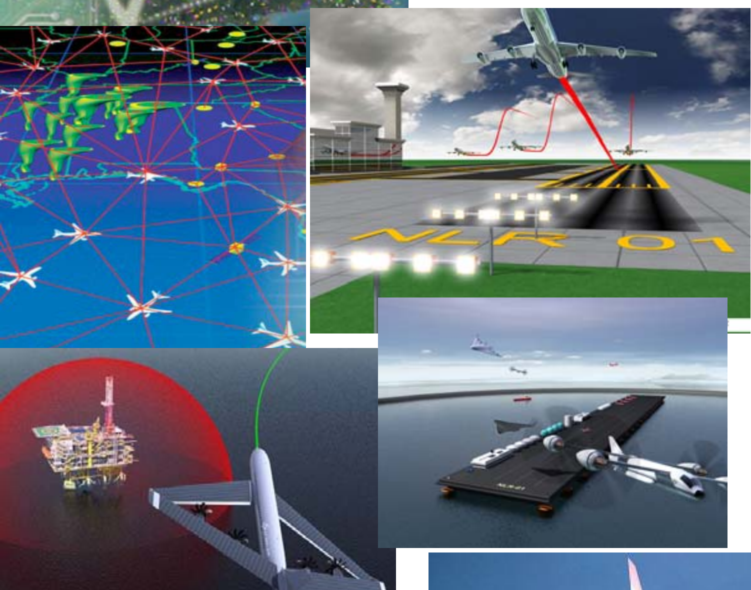
Eco-Design



Green Rotorcraft

Regional Air Transport

Operational Technologies for Fuel Burn Reduction



Flight Guidance

- SESAR
- 4 D Route Planning -3%
- „Free-Flight“ -6%

Operation

- Efficiency. Airlines 10 Years -2%
- Formation-Flight -10%
- Air Refueling (Long Distance) -25%

EU Technology Programmes

Europe today

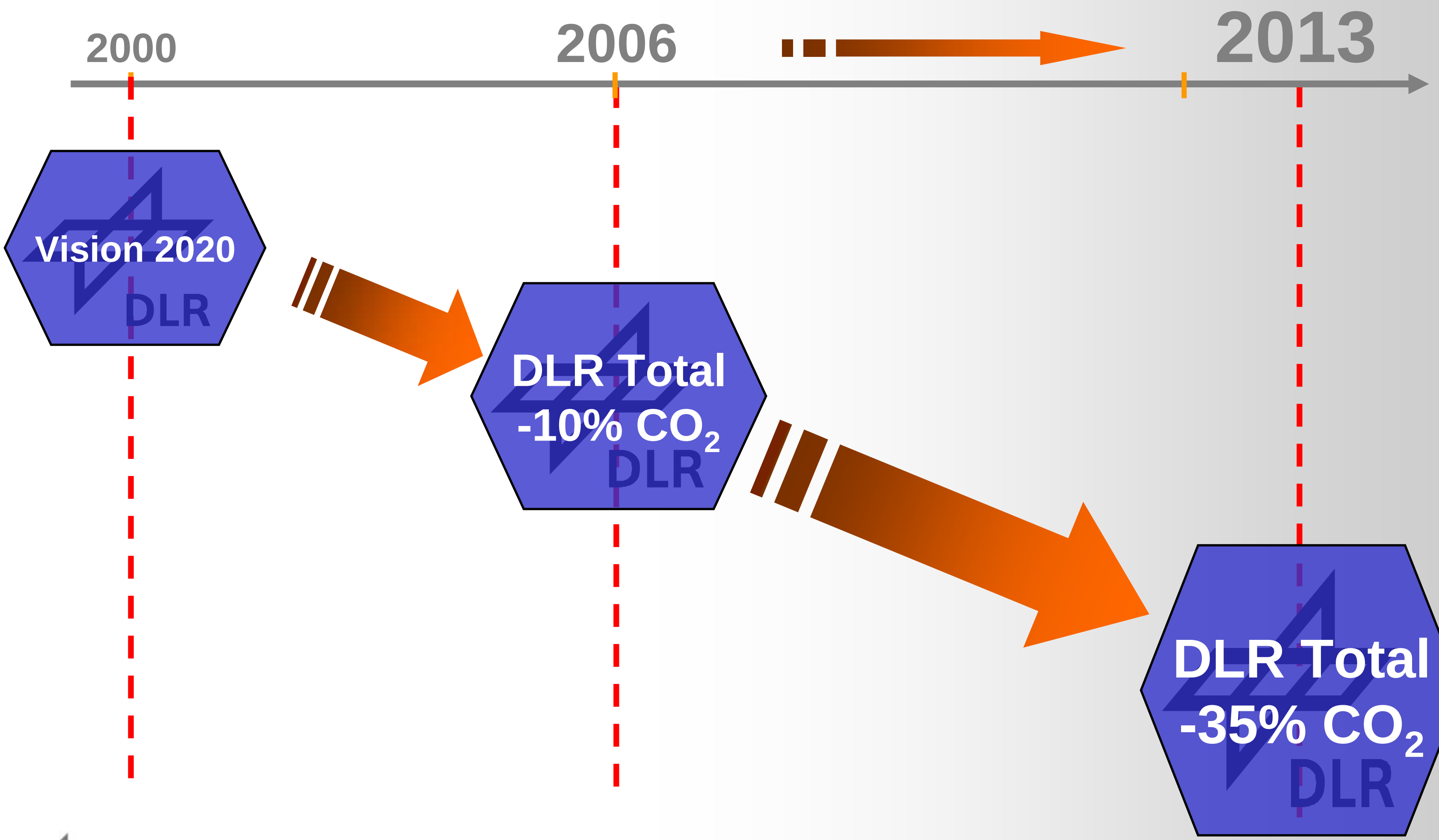
- 25.000 flights per day
- With 5.000 aircraft
- Over 650 sectors
- Between 100 large airports
- With 27 different Air Traffic Management Systems
- For a total ATM costs of 7 billion Euro per year
- Corresponding to 6% of the flight costs

SESA

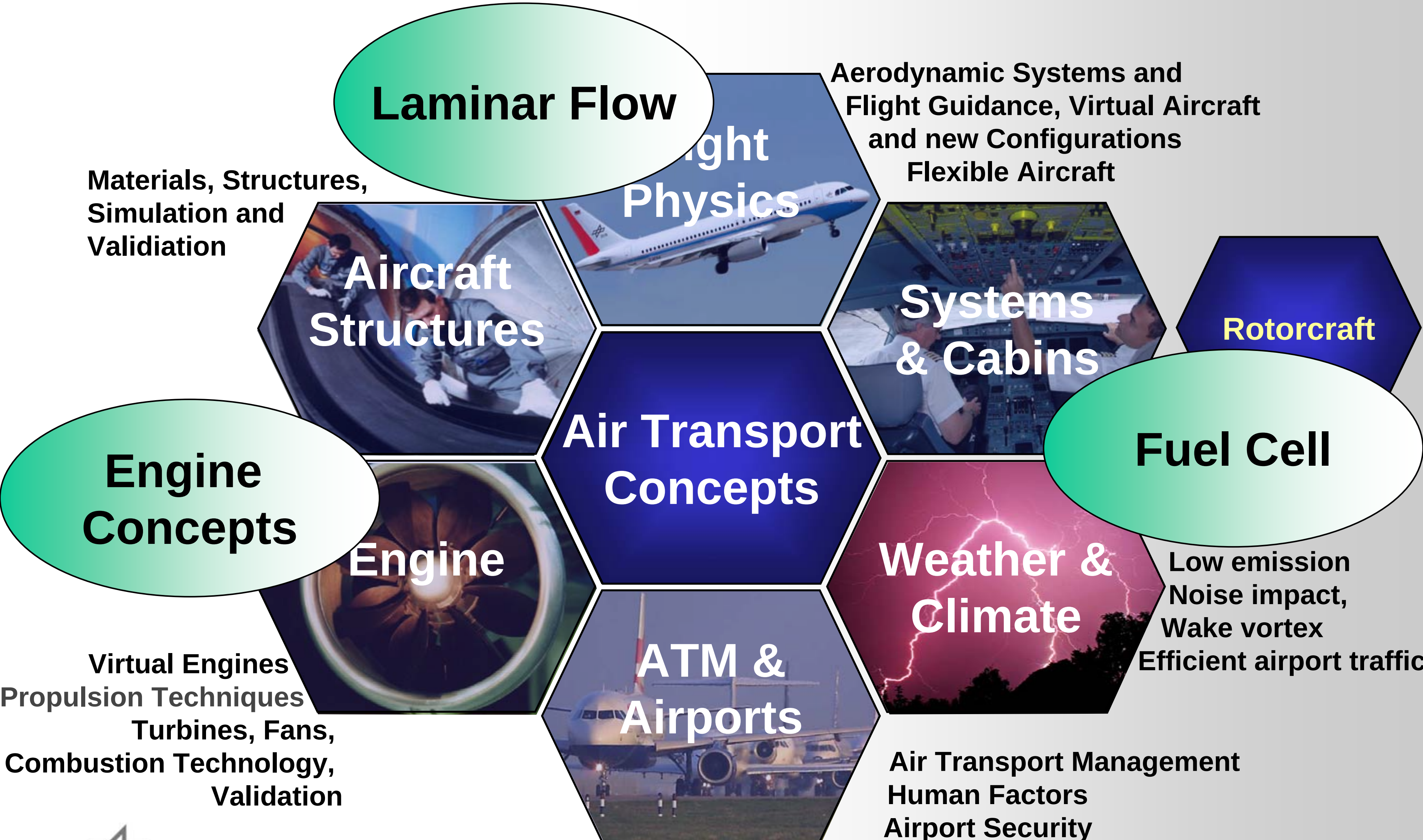
-12%
Fuel Burn

GALILEO

DLR Contribution to Vision 2020



Main Areas of Research at the DLR



Laminar Flow Control: Potential and Challenges

Challenges and Research Topics

- Suction System Complexity
- Anti-Contamination System (Insects)
- De-Icing System
- High-Lift System Wing Design
- Surface Quality & Integrity
- Mass Production Concepts

Potential Savings (aircraft level):

Wing:	- 12%
Tail:	- 3%
Nacelles:	- 1%

Fuselage: not feasible due to high Reynolds numbers

Past and Future Flight Testing on DLR-Research Aircraft

DLR ATTAS

DLR
ATRA A320

High Requirements for Fuel Cell Systems in Aeronautics

- variable outside pressures and temperatures
  up to +13000 m and between -72°C / +56°C
- loads due to aircraft maneuvres (inclination, acceleration)
- vibrations
- installation at sub-atmospheric pressure
- transient operations, e.g. start-up
- fuel supply (kerosine vs. hydrogen)
- cooling
- mission safety

ATRA – Fuel Cell Demonstrator ILA 2008

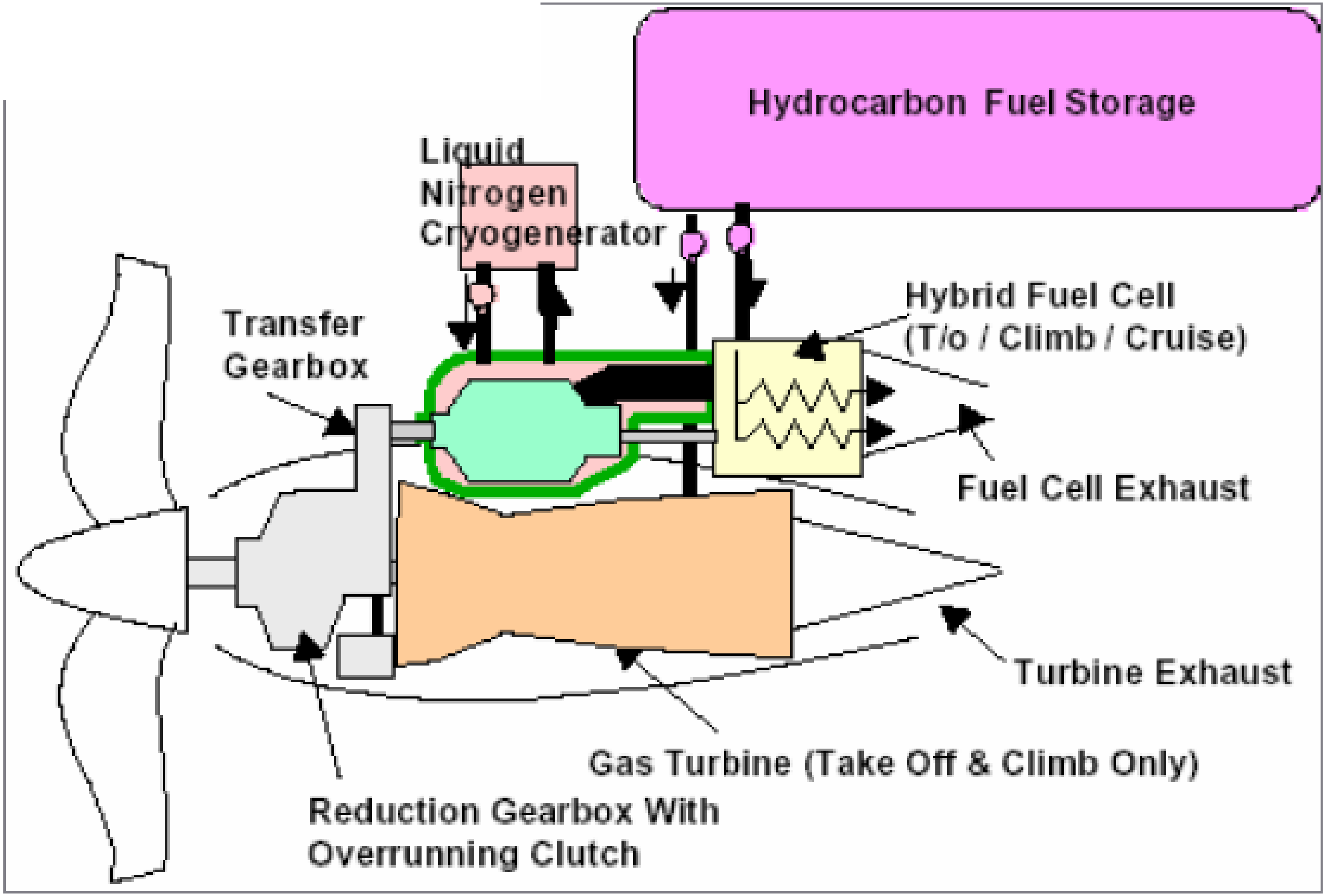
- **Cooperation with Airbus**
- **Qualification of Fuel Cells in Flight**
- Regular **„Ground Demos“:**
  - Electrical Supply of „blue“ hydraulic pump
  - Moving control surfaces
  - Demonstration of operational parameters for active fuel cell system
- **Milestone:** Certified Infrastructur in rear cargo belly for installation of a fuel cell system
- **Ongoing Research:**
  - Powered landing gear

Antares DLR H2 – General Concept

Characteristics

- Empty weight ca. 460kg/1014 lb.
- Weight fuel cell system ca. 60kg
- max. Weightt FC System 100kg
- Maximum Weight DLR H2 750kg
- Range > 750km (> 2000km at 4
- PODs)
- Max. system power ca. 25kW
- Continuous power >20kW
- Max altitude >>4000m/>>12000ft
- Max climb performance (560kg) >
- 2,5m/s (at 25kW)

More Advanced Concept for the 2025 Engine



Coutrot, SAFRAN 2007

Innovation will lead global aviation out of economic slump

The global aviation industry must rely on technological advances to address three of its most pressing challenges

- **the worldwide economy,**
- **the environment,**
- **and global air transportation system modernization**

AIA President and CEO Marion Blakey
April 2009

Conclusions and Outlook

For the operation and the design of aircraft it is thus recommended:

- Air transport growth and CO2 emissions must be decoupled
- Next generation aircraft must then have a 50% fuel bu reduction compared to today's products
- Technologies need to be validated
- Fuels without fossil C emissions are needed

We need to foster creativity and innovation

- Infrastructure
- Pioneering research
- Education / Young Professionals

Can we afford …

- ……..not to wait for the technological window of opportunity?
- ……..to miss the economical window of opportunity?
- …… not to develop a sustainable air transport system?

“In light of the fact that humanity is not able to learn from past mistakes we can not afford to make mistakes in the future.” -

Ernst Ferstl

www.dlr.de

Thank you for listening