# Why particular emphasis on climate impacts of transport

# The research projects QUANTIFY and ATTICA

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Transport Emissions: The Climate Challenge

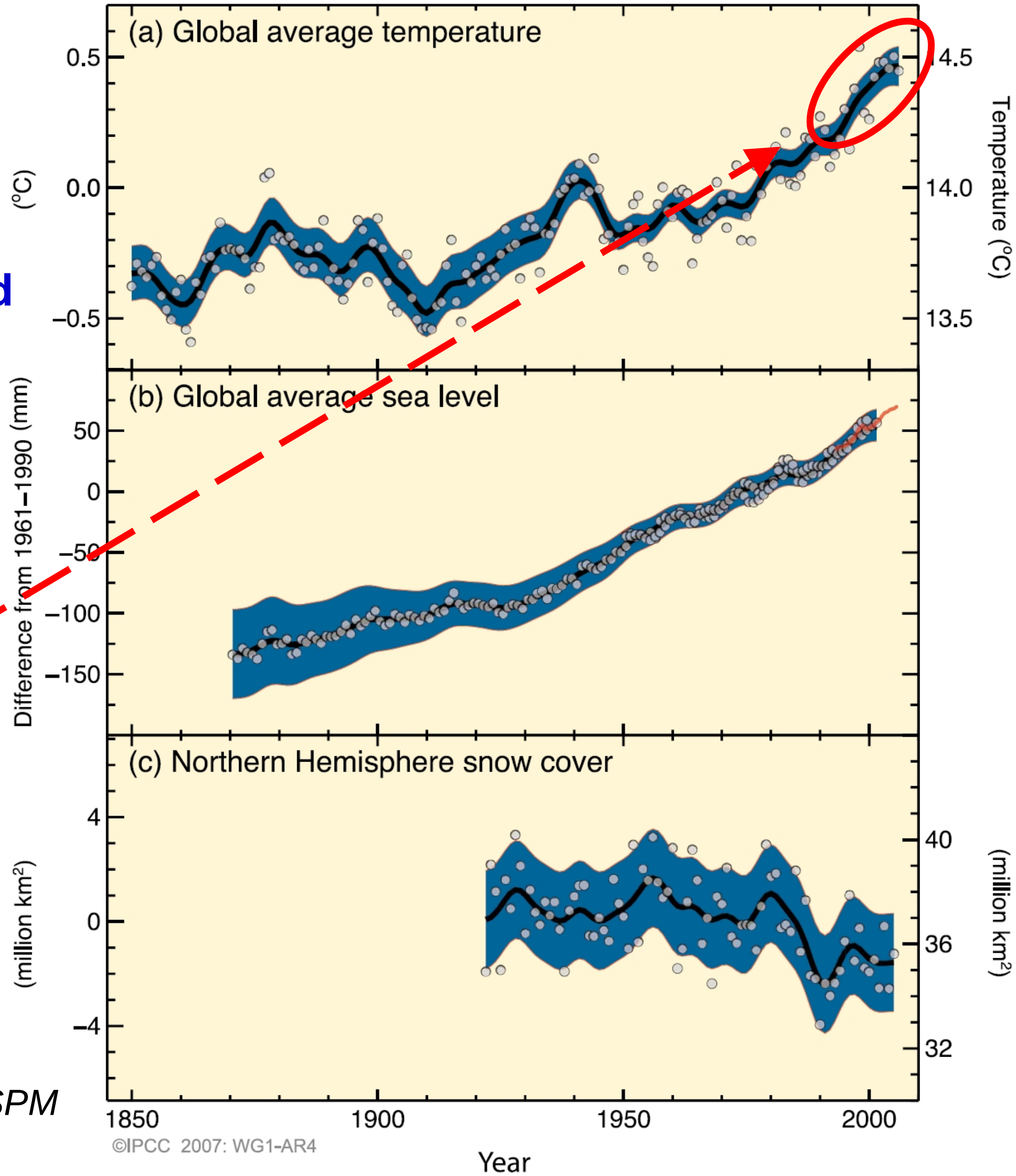
Results from IP QUANTIFY and SSA ATTICA

Brussels, 22 April 2010

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.

in der Helmholtz-Gemeinschaft

## Observed changes of temperature, sea level and Northern Hemisphere snow cover




**The 12 warmest years of the instrumental period (until 2006):**

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

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*IPCC, 2007, SPM*

# Temperature changes for different emission scenarios

## Multi-Model Averages and Assessed Ranges for Surface Warming

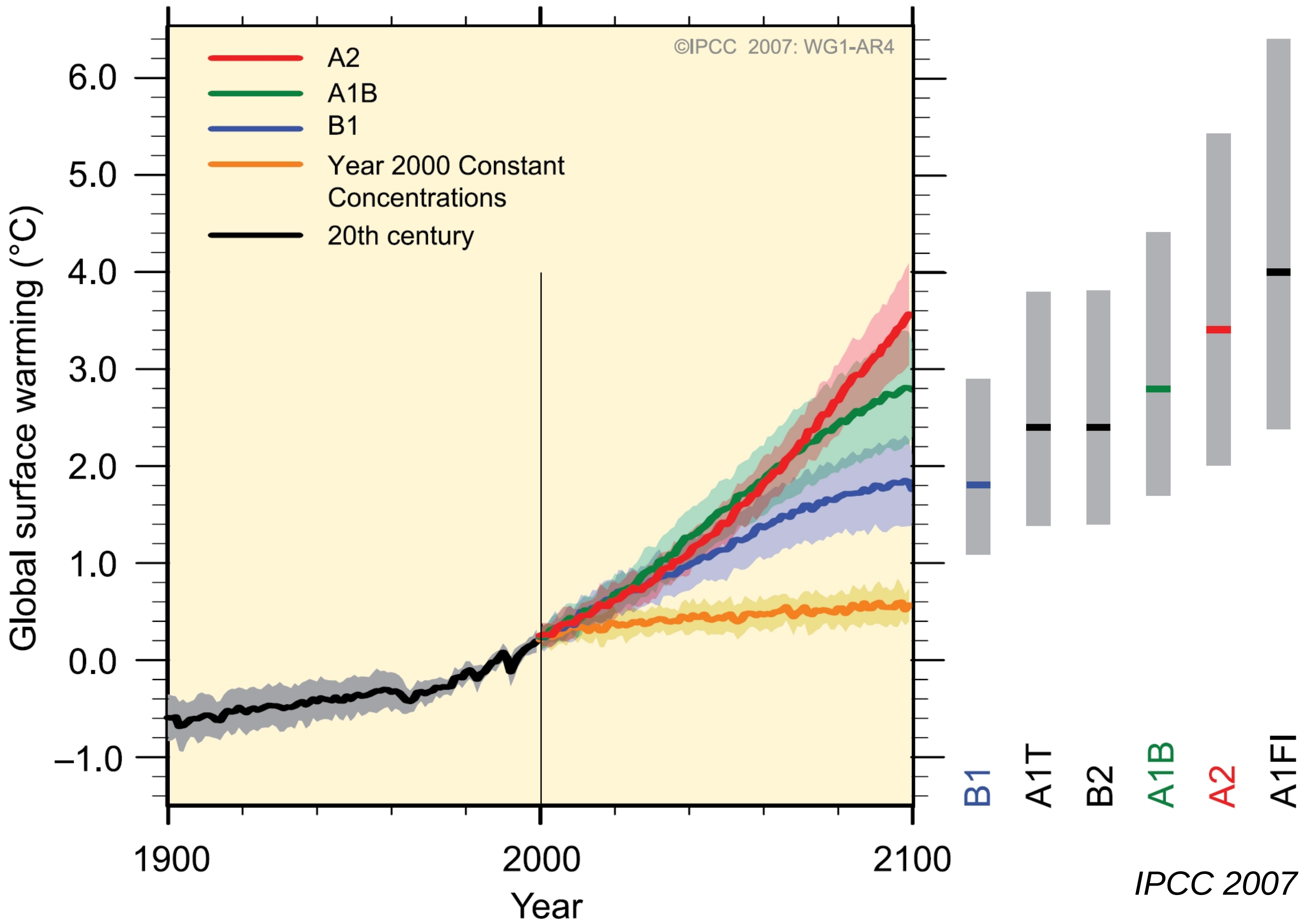



**Figure SPM.5.** *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

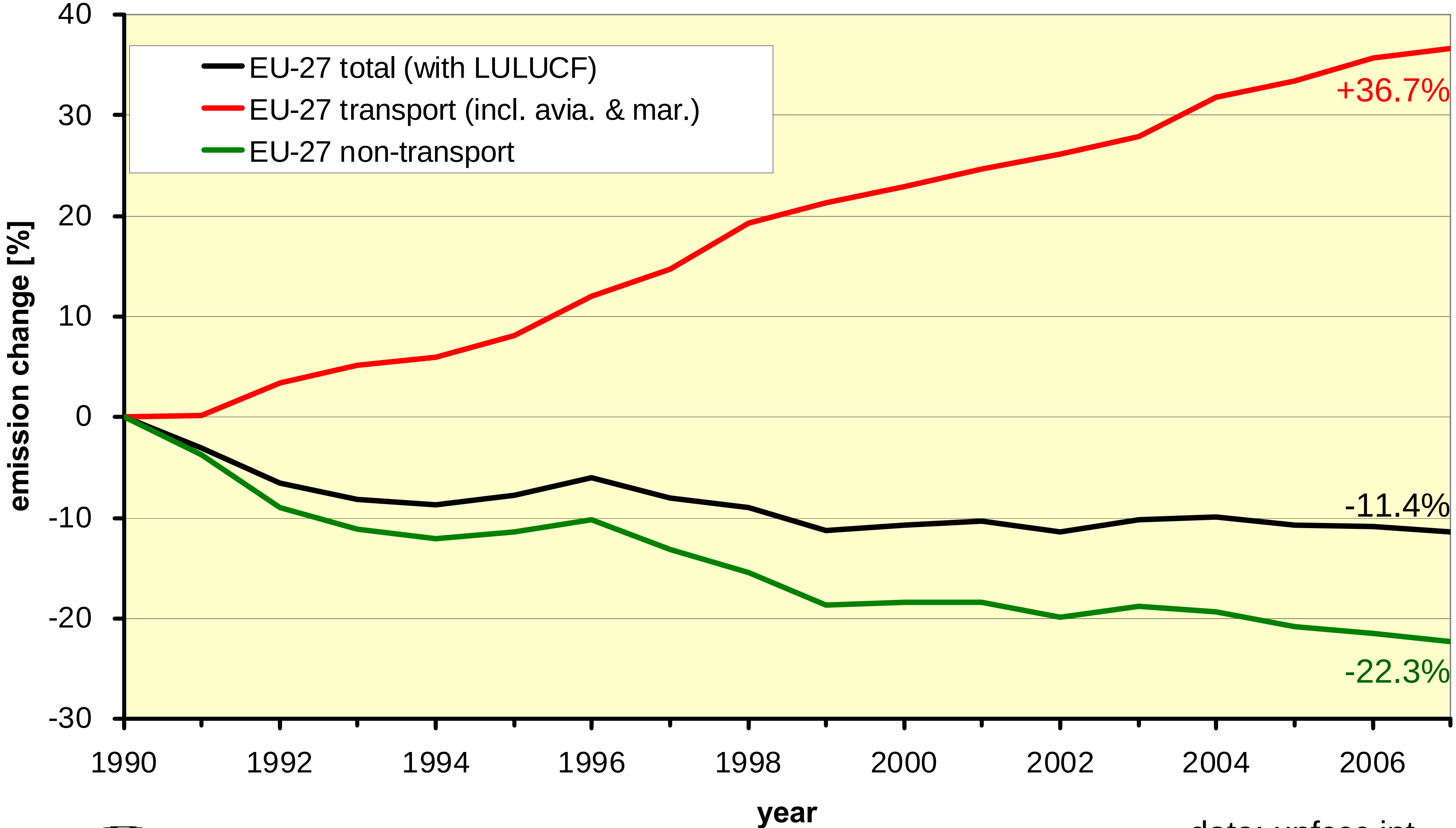
# How can transport impact climate ?

Changes in radiative forcing can be caused by

- the emission of greenhouse gases, including long-lived species like $CO_2$ and $N_2O$, but also of water vapour;

# $CO_2$ equivalent emissions of EU-27 *

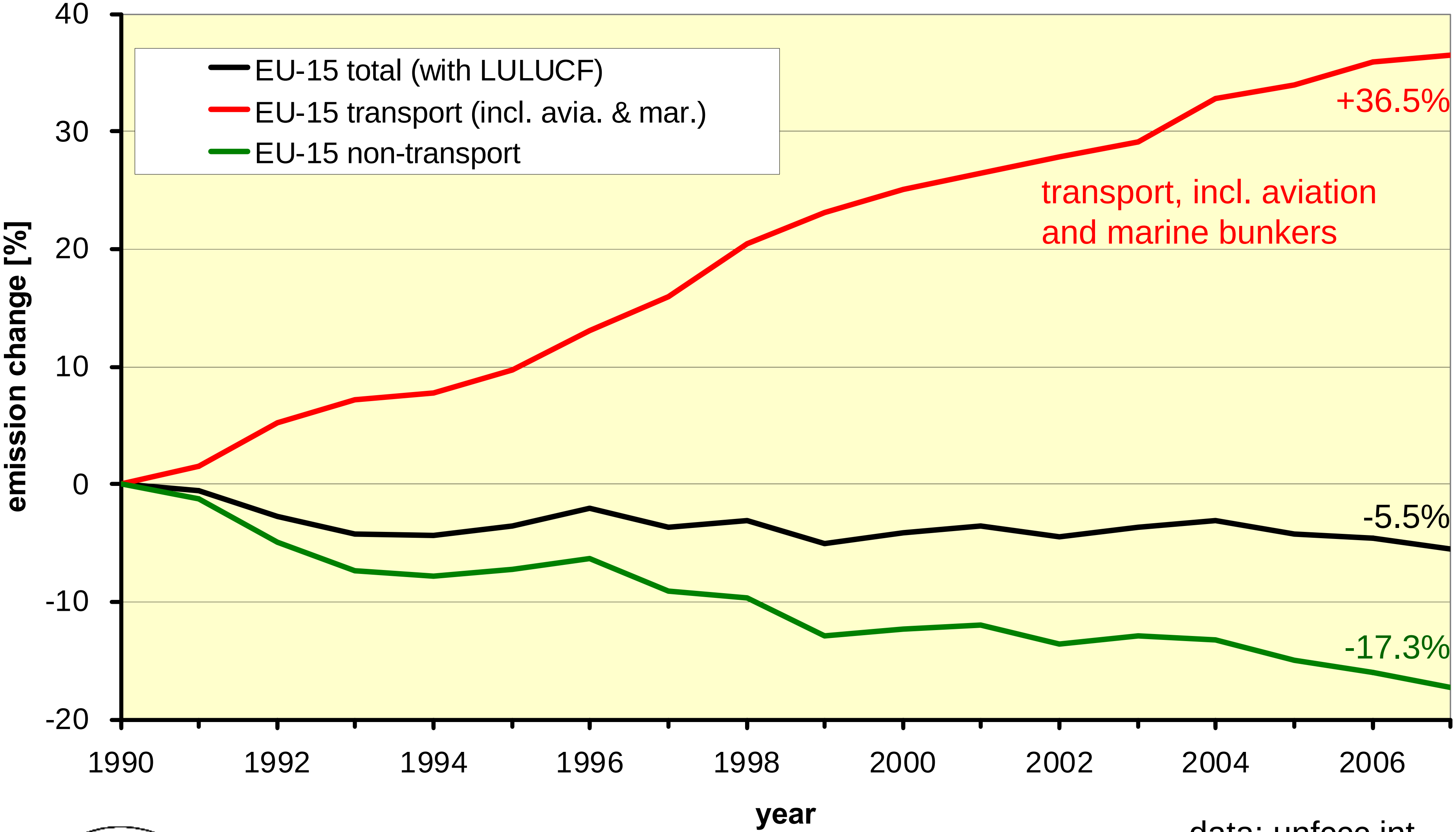
## Change since 1990




data: unfccc.int

* all EU countries except Cyprus and Malta

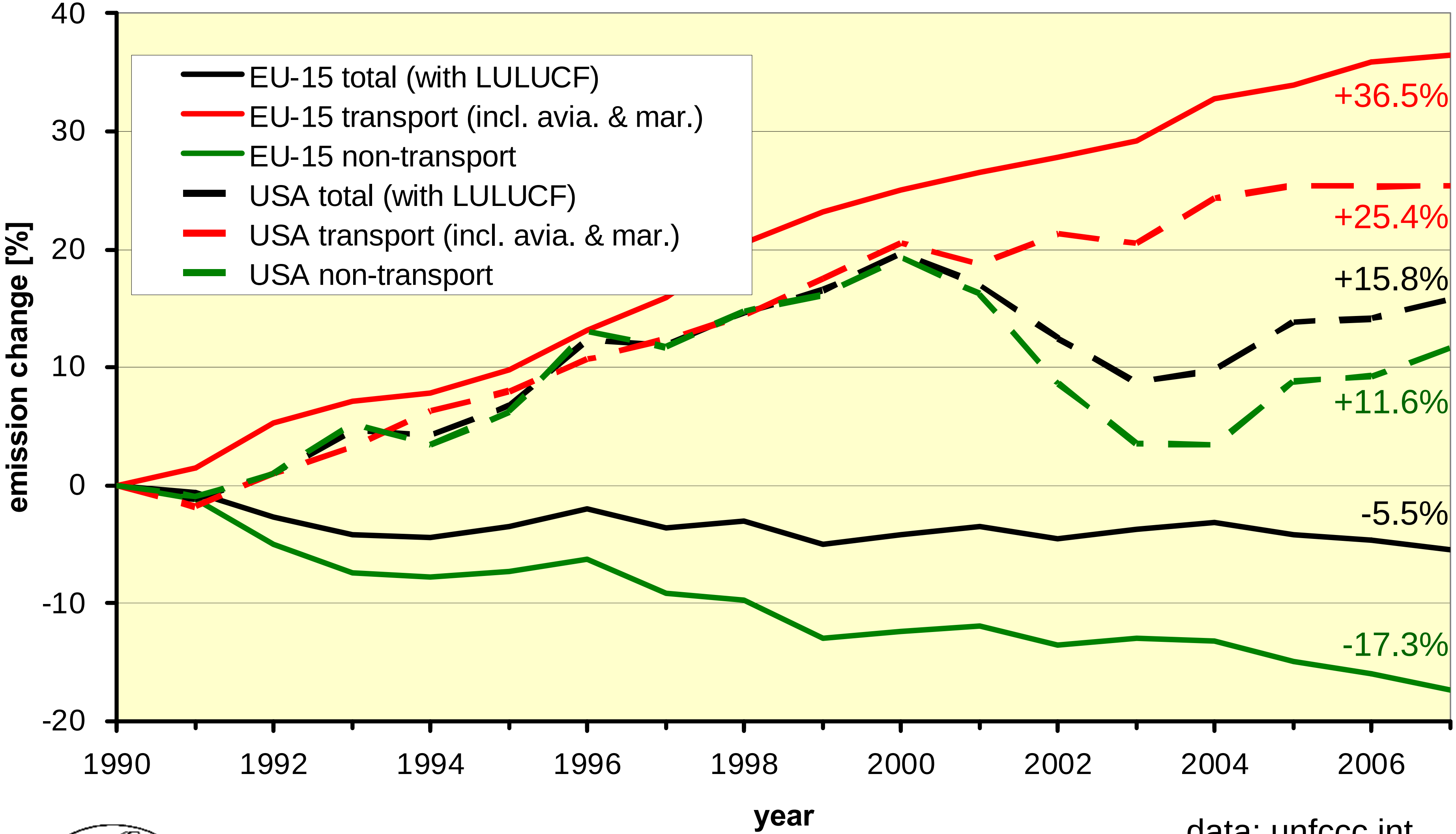
# $CO_2$ equivalent emissions of EU-15
## Change since 1990




data: unfccc.int

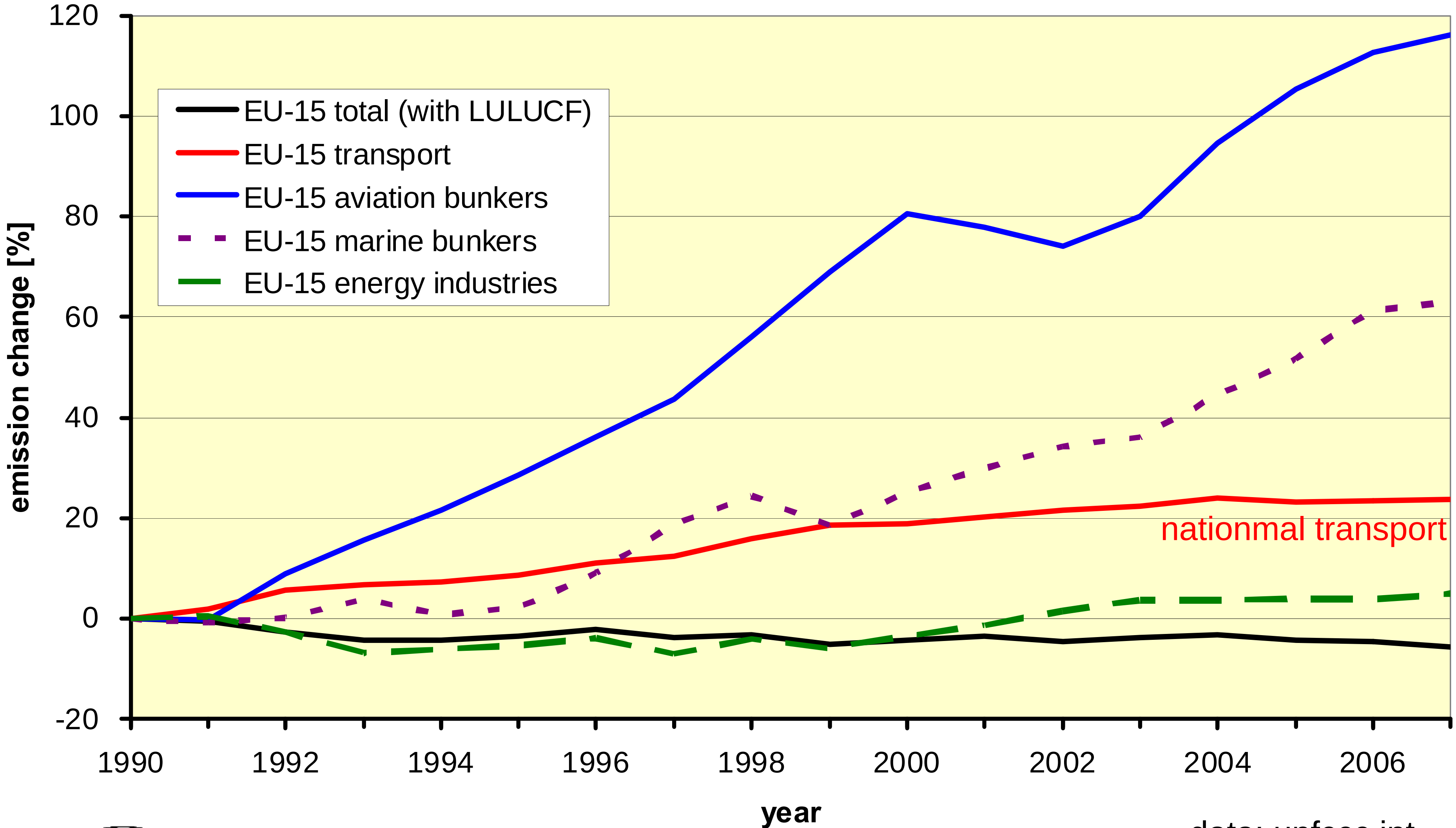
# $CO_2$ equivalent emissions of EU-15 and USA

## Change since 1990




data: unfccc.int

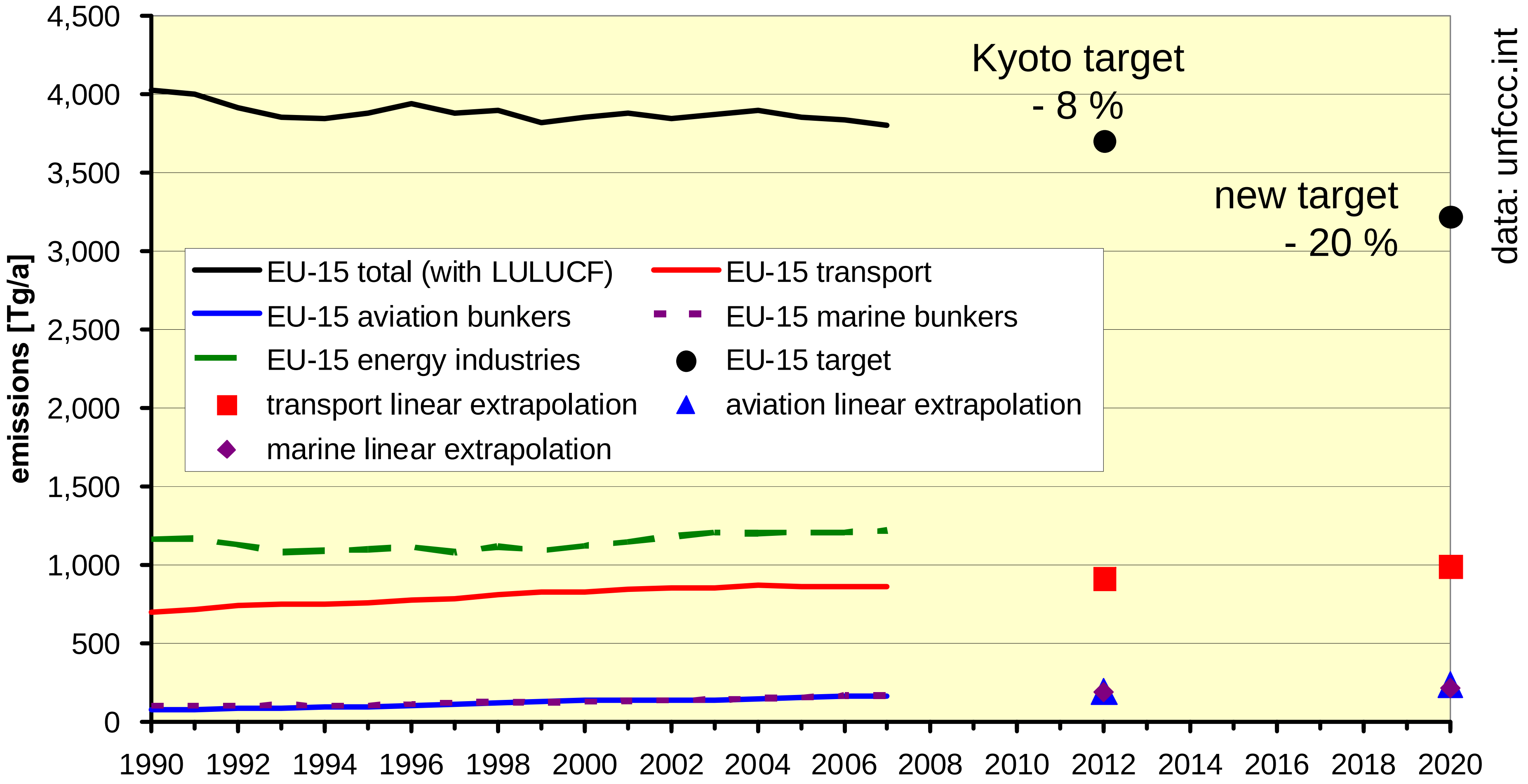
# $CO_2$ equivalent emissions of EU-15
## Change since 1990




data: unfccc.int

# New EU target and consequences for transport:

## Reduction by 20 % relative to 1990




| **transport fractions (1990** | **2007** | **2012** | **2020):** |
|---|---|---|---|
| national transport: 17.4 % | 22.8 % | 24.7 % | 30.9% |
| aviation bunkers: 1.9 % | 4.4 % | 5.3 % | 7.4 % |
| marine bunkers: 2.6 % | 4.5 % | 5.1 % | 6.9 % |

linear growth of transport emissions after 2007

# How can transport impact climate ?

Changes in radiative forcing can be caused by

- the emission of greenhouse gases, including long-lived species like $CO_2$ and $N_2O$, but also of water vapour;

included in the Kyoto Protocol, apart from water vapour

- the emission of ozone precursors, like $NO_x$;
- the emission of particles and their precursors;
- triggering additional clouds (e.g., contrails, contrail cirrus) and
  by modifying natural clouds (e.g., ship tracks).

short-lived effects NOT included in the Kyoto Protocol, but of particular importance for aviation and shipping

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# QUANTIFY

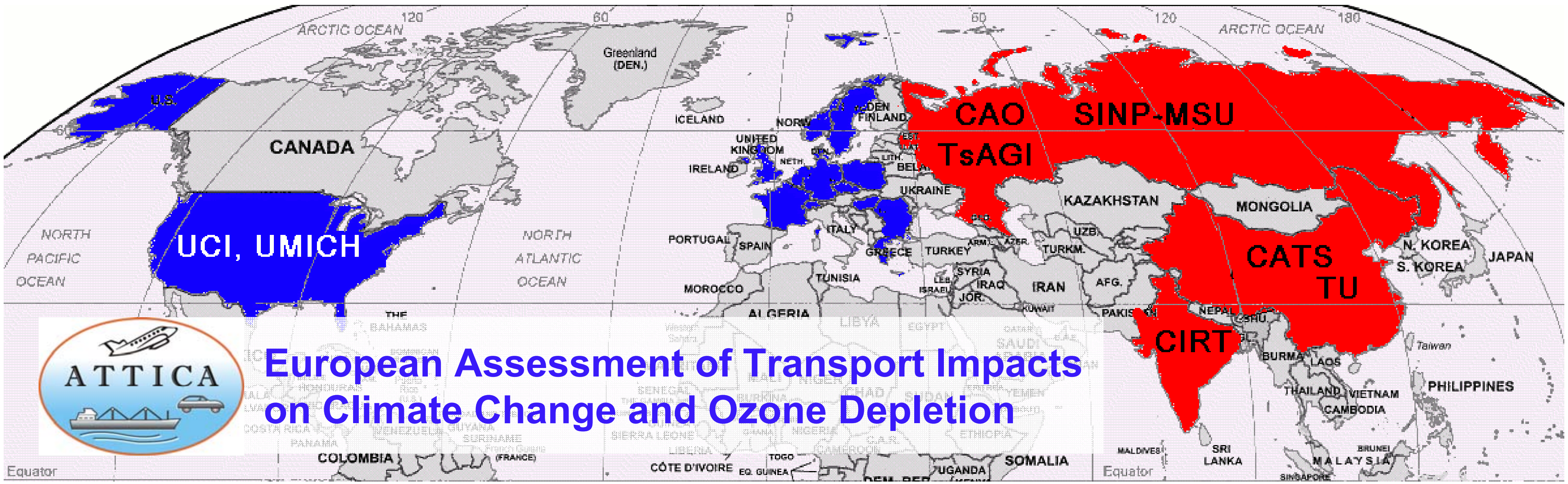
## Quantifying the Climate Impact of global and European Transport Systems

Objective: To quantify the climate impact of the global and European transport systems for the present situation and for different scenarios of future development.

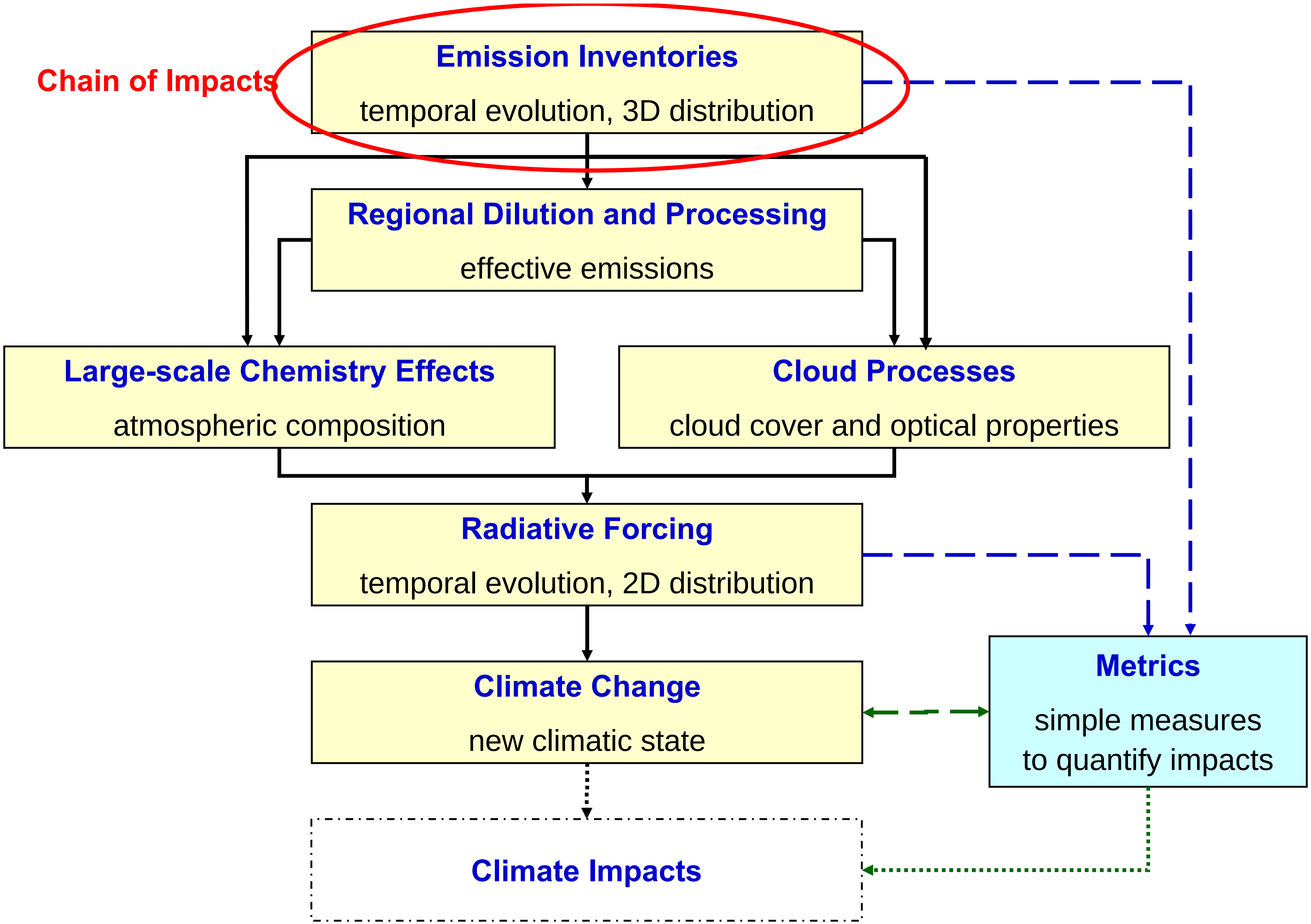
Co-ordinator: Robert Sausen, DLR-IPA
Participants: 41 from 19 countries
Duration: March 2005 to February 2010
Funds: 8.4 M€
Total costs 12.8 M€

**http://ip-quantify.eu**

QUANTIFY-TTC

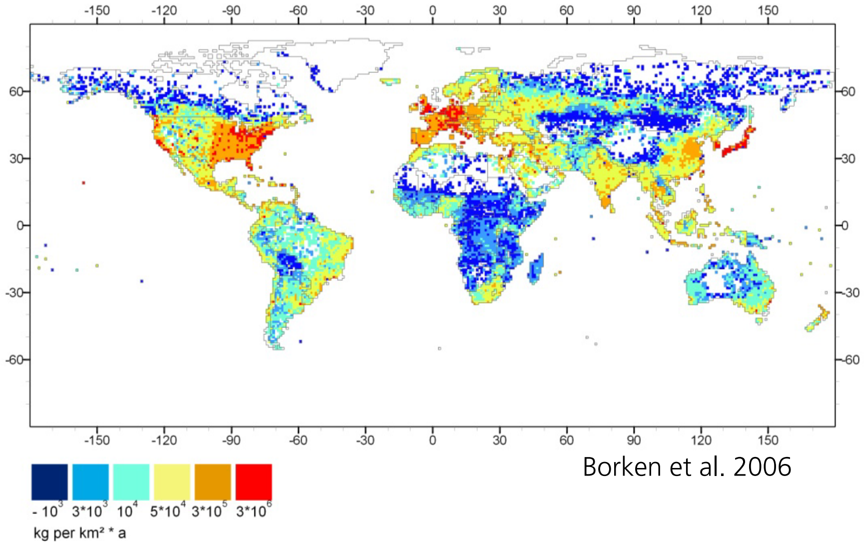


## Chain of Impacts



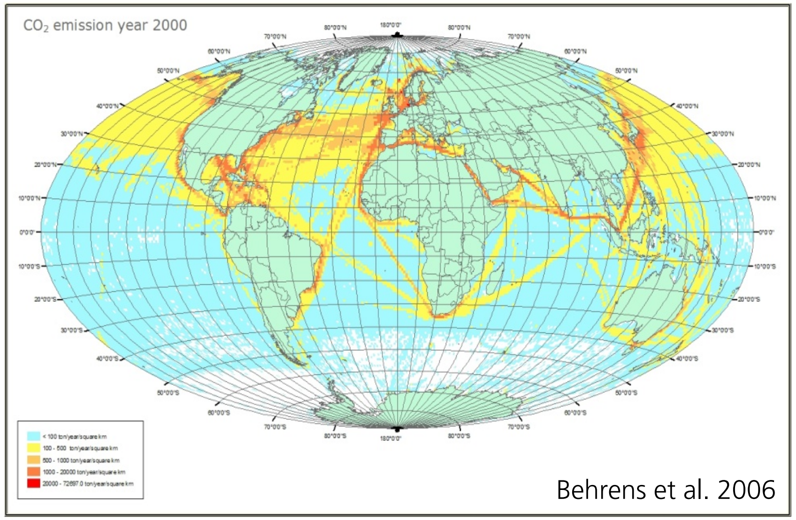
# QUANTIFY emission inventories, $CO_2$

## Road: 1168 Tg C/a



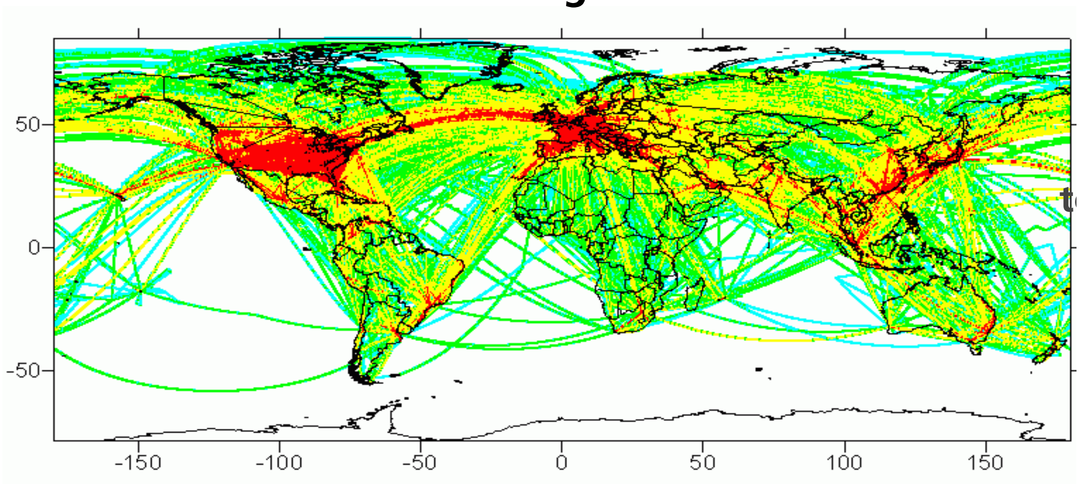

Borken et al. 2006

## Shipping: 152 Tg C/a




Behrens et al. 2006

## Aviation: 131 Tg C/a

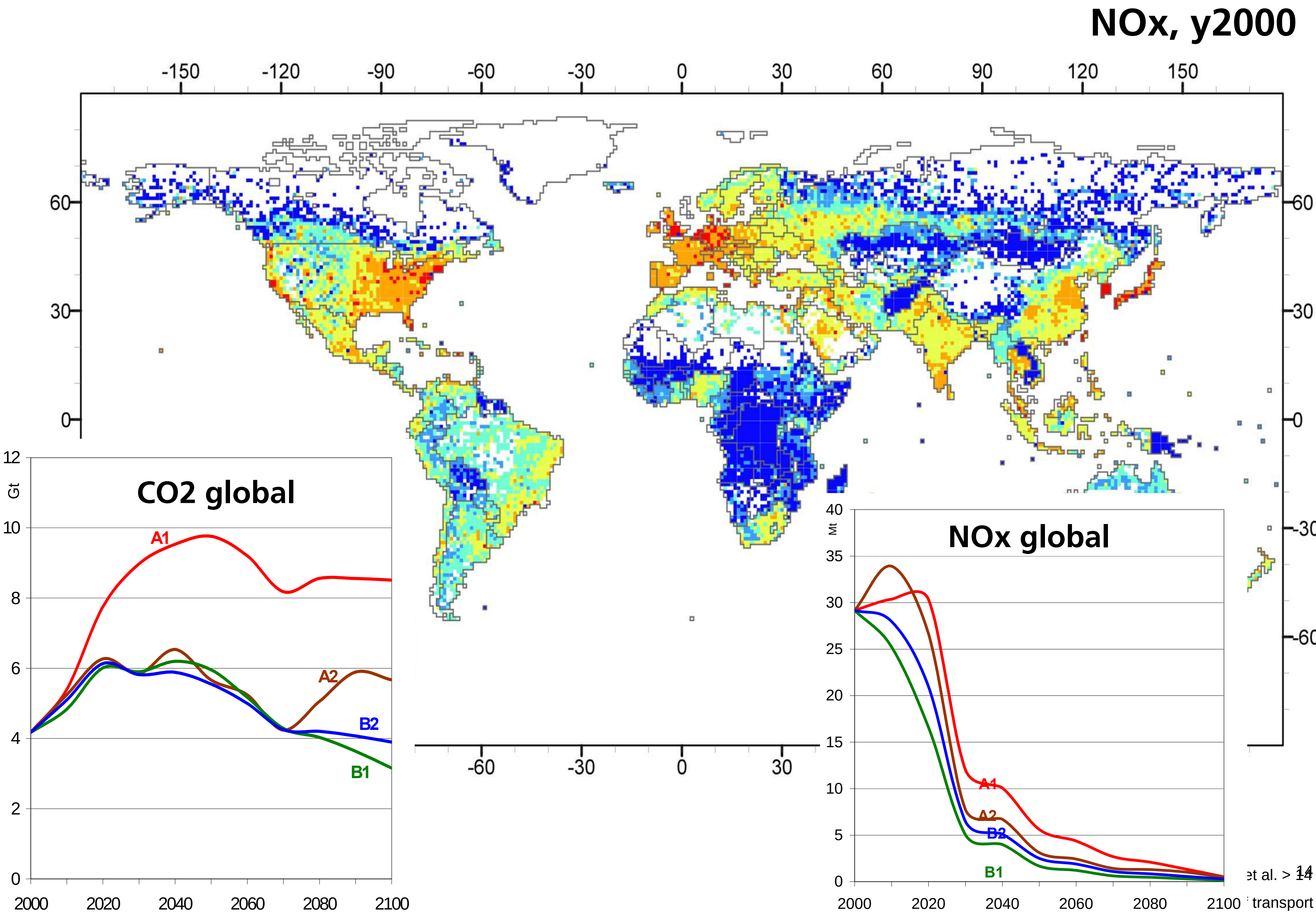



Owen et al. 2006

## More

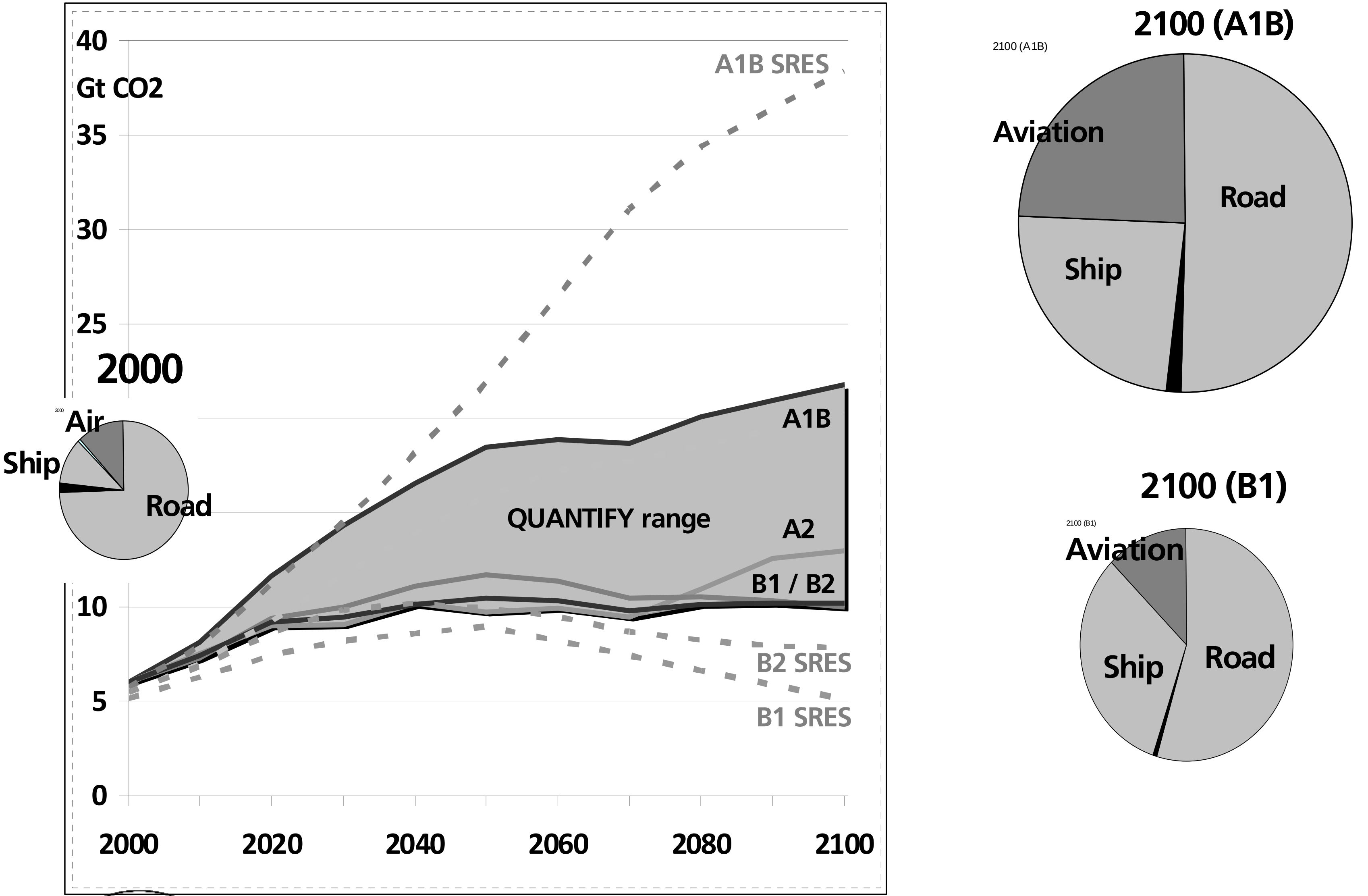
- comprehensive (species),
- accurate (e.g. gridding, emission factors),
- detailed (e.g. by vehical/vessel type)

# Road transport's emission scenarios

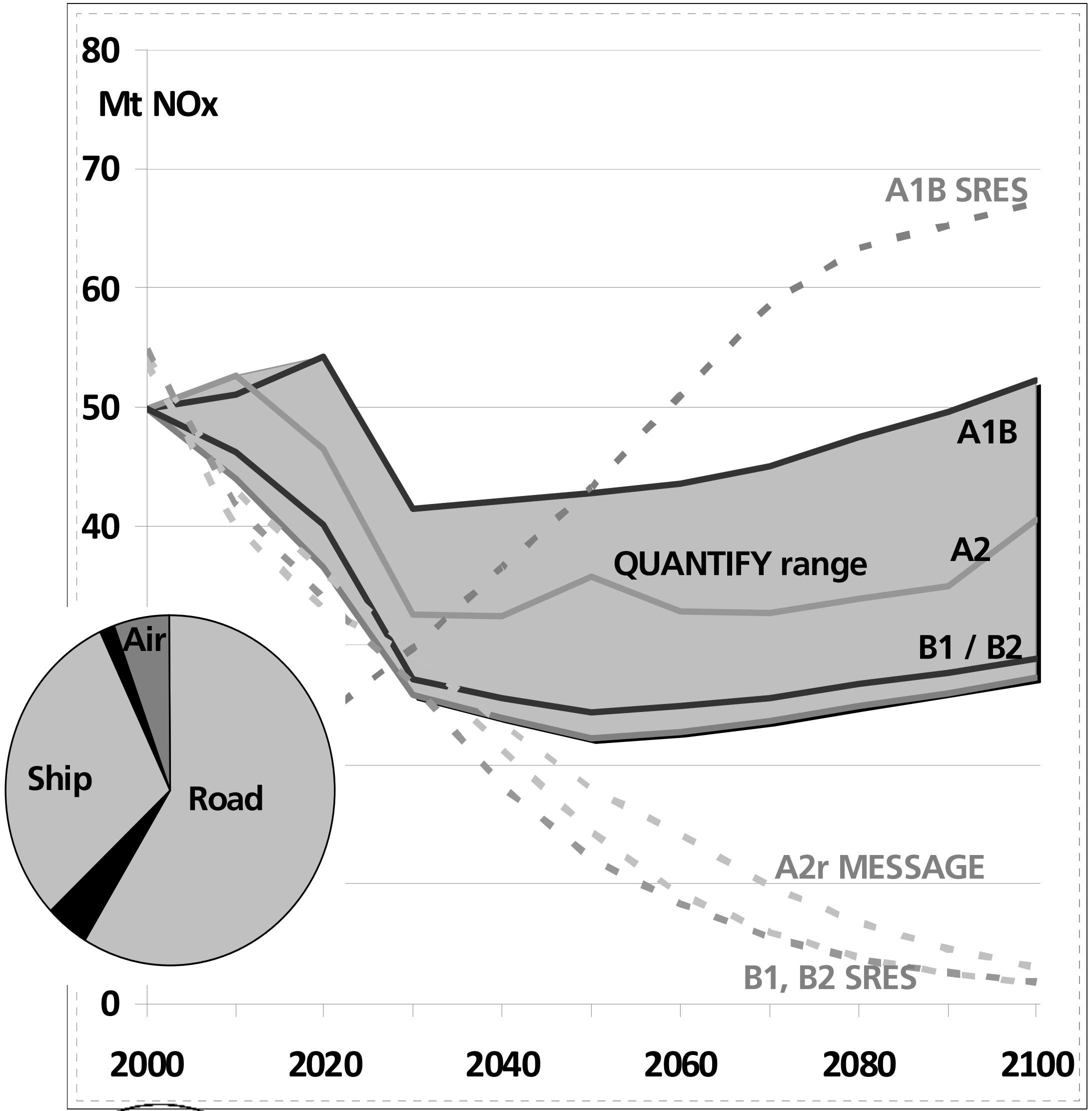


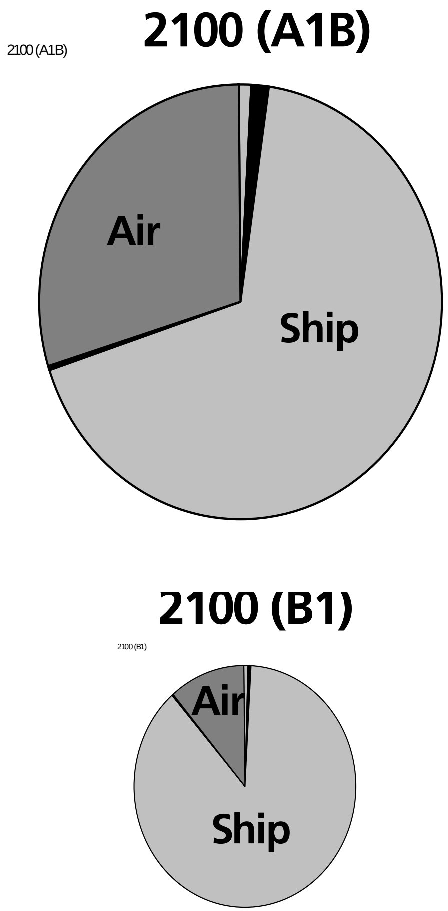

Borken et al. 2006 Data: v20061213

# $CO_2$ emissions transport – all scenarios



# $NO_x$ emissions transport – all scenarios

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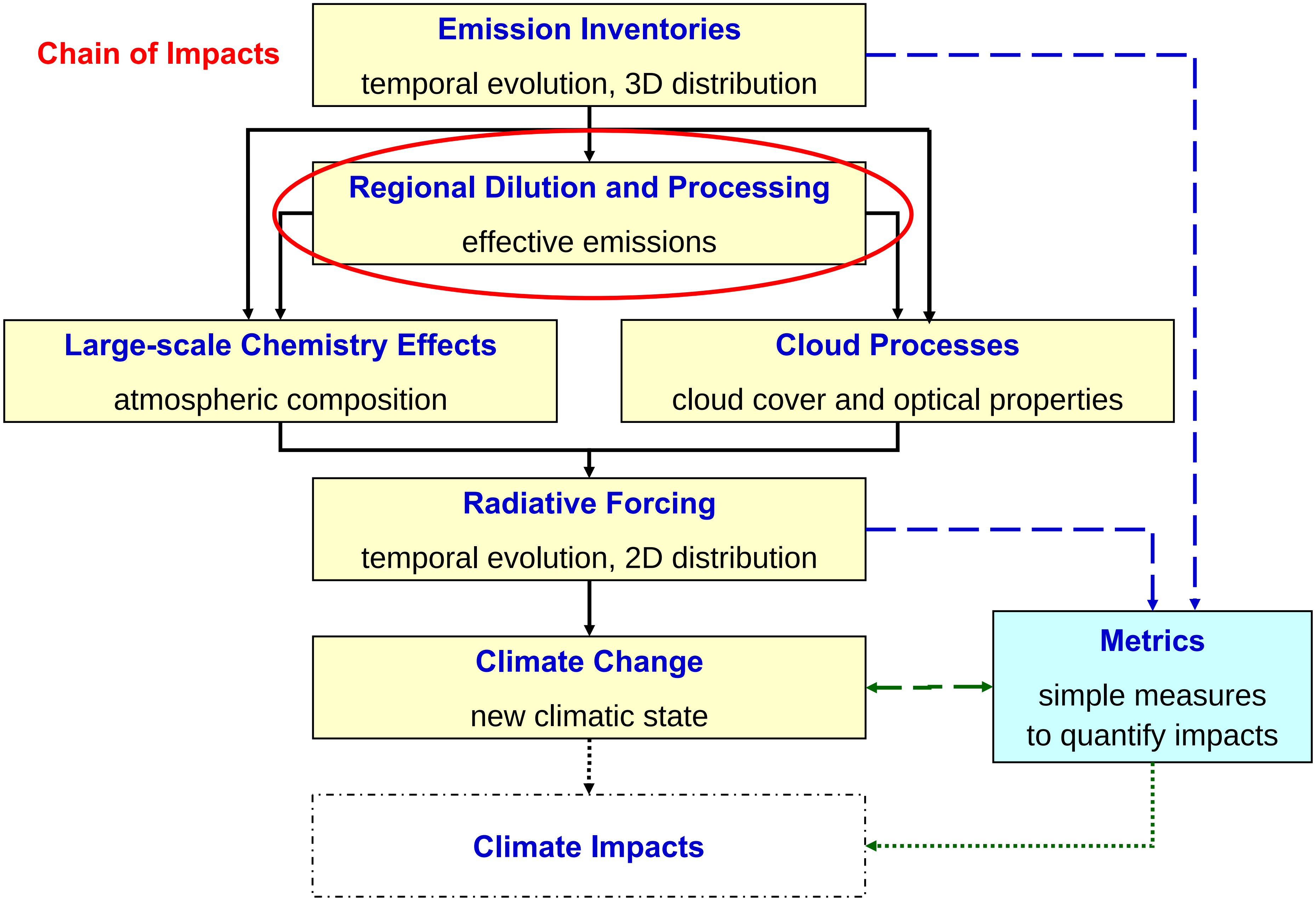
## Chain of Impacts



# The QUANTIFY ship measurement campaign in 2007

**Objectives:**

- To study in detail the dilution processes of plumes and chemical transformations of pollutants generated by shipping from the local scale to the global scale.

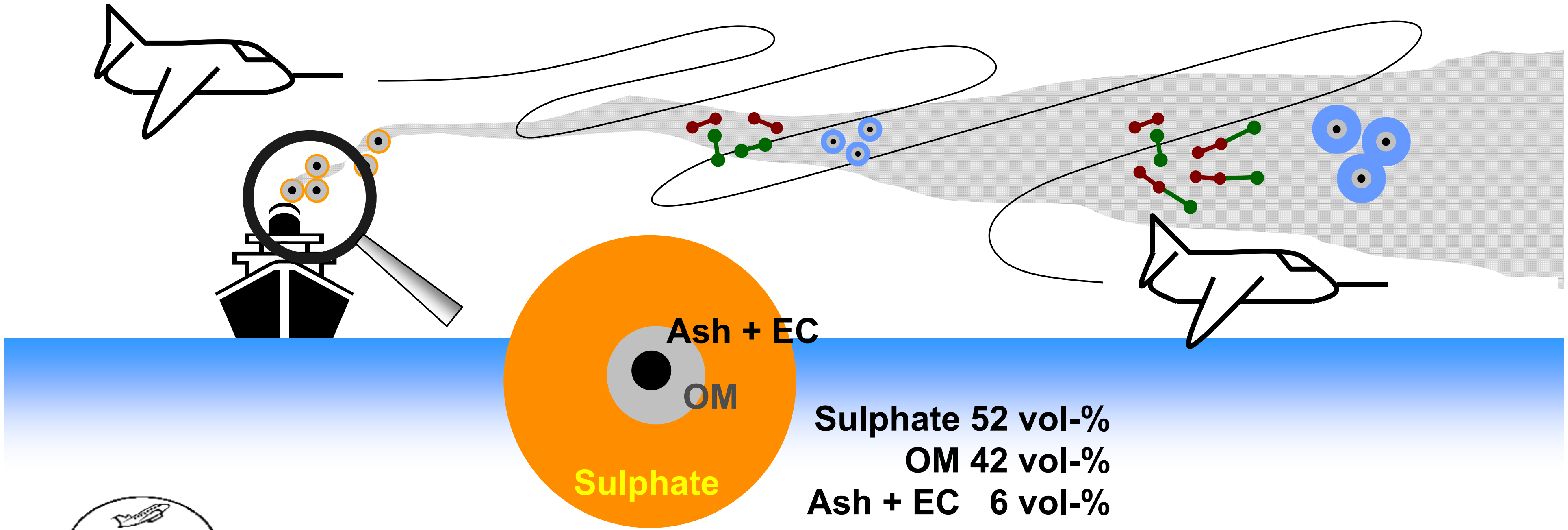
- To calculate and propose parameterisations for "effective emission indices" linking emission inventories to the emissions to be used as input in large-scale models.

# Approach I

1. Conduct aircraft-based **in-situ measurements of plume composition** at various ship exhaust plume ages from 100 s to 1 h.

2. Conduct simultaneous **in-stack measurements of fresh exhaust composition** on board of the same vessel to get initial properties.

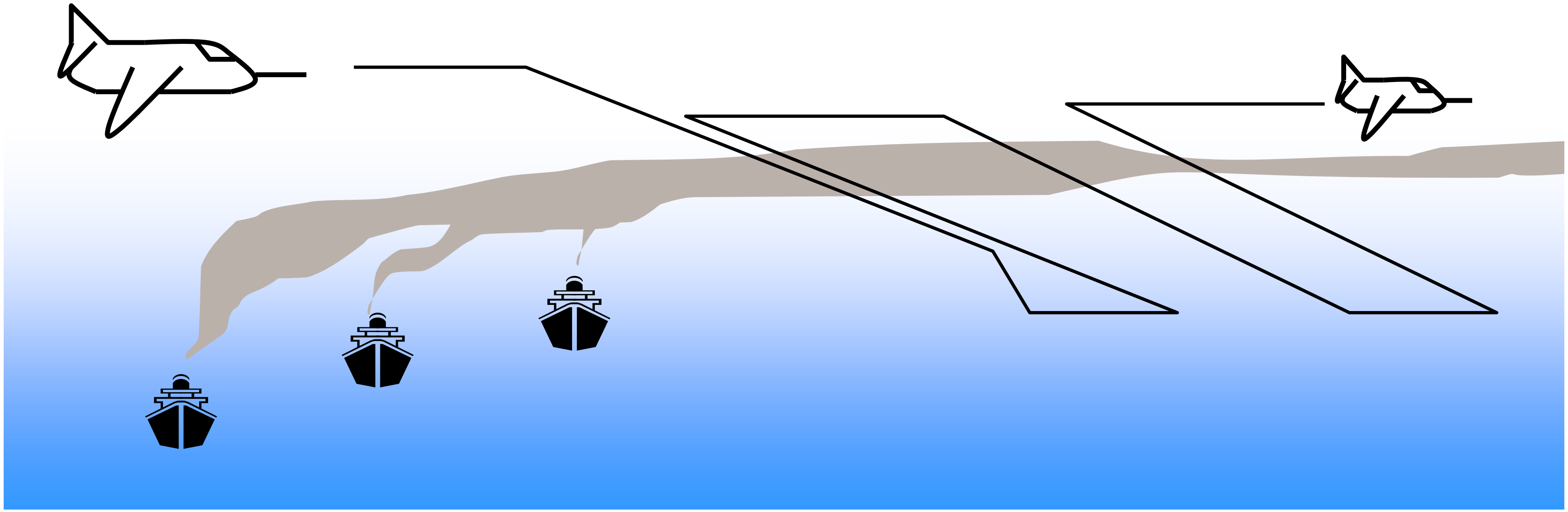
3. Combine **test-rig data for exhaust components** which are not accessible by in-stack measurements to get initial properties.



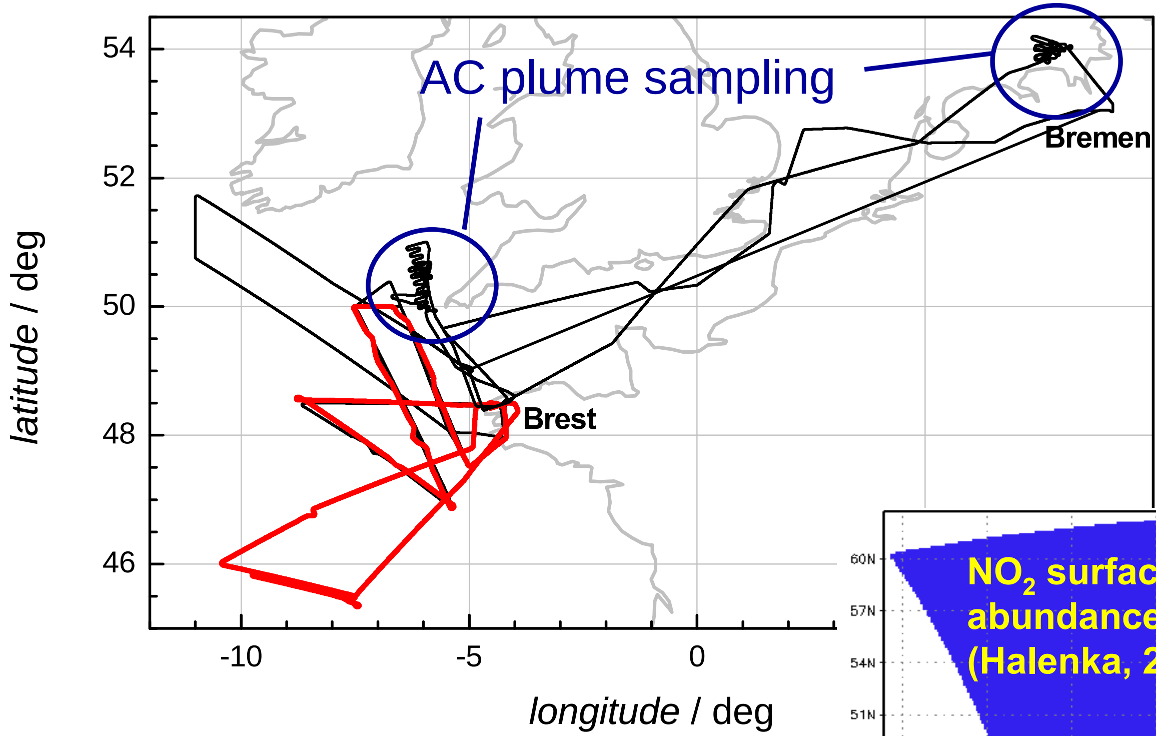

# Approach II

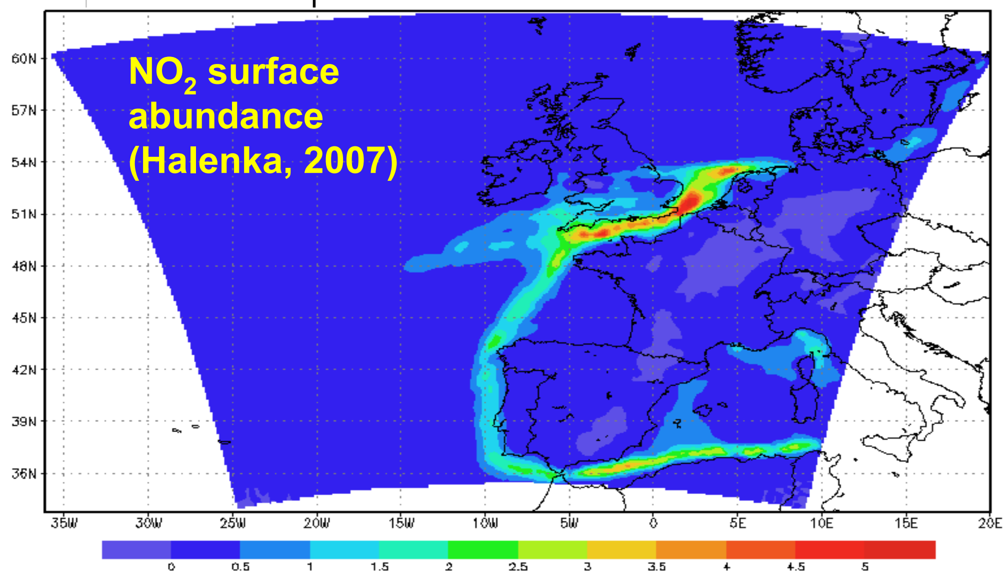
4. Study plume chemistry and physics in highly frequented shipping corridors to quantify the contribution of shipping to the chemical composition of the marine boundary layer (MBL).

5. Determine effective emission indices for key properties as input for regional to global-scale models.



# Target Area




**Falcon base: Brest, F**
**Period: June 2007**

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# Instrumentation

**Test rig studies: Large four-stroke medium speed marine diesel engines**

IP-HERCULES

Total particle mass,
Particle chemical composition:
OC/BC, inorganic ionic species,
Particle size distribution.

Results are used as reference data for plume measurements.

**In-stack measurements on board the vessel Atlantic Conveyor**

**Gases:**
$NO_x$, CO, $CO_2$, HC, $O_2$, $SO_2$, benzene

**Aerosol properties:**
Number concentration (CN)
total particle mass (PM)

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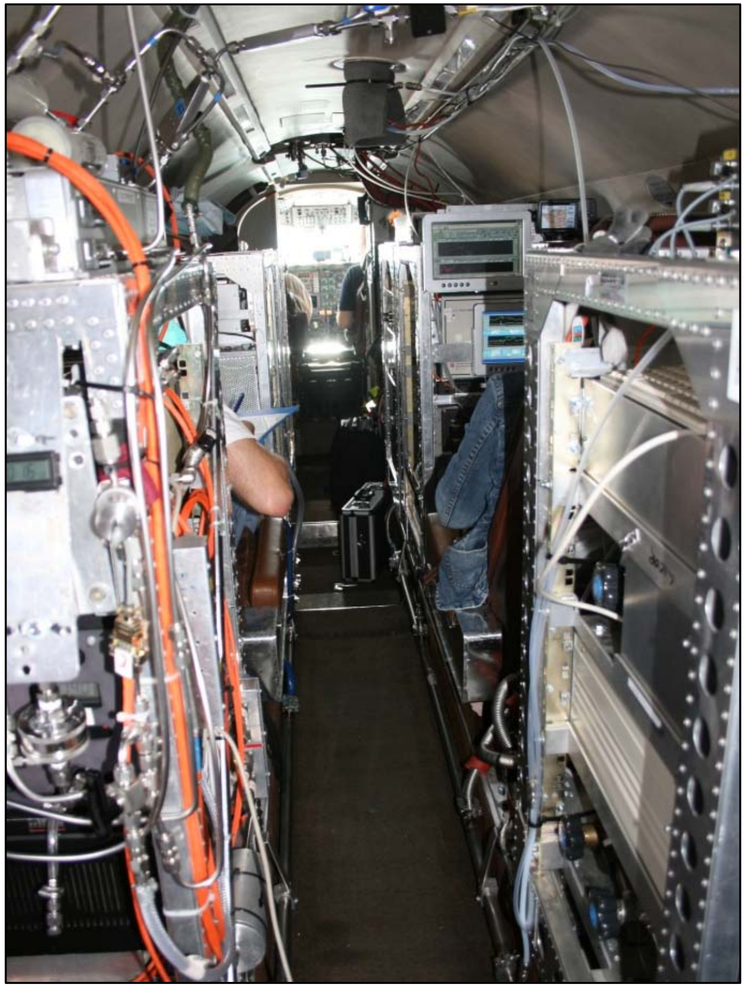
# Falcon Instrumentation



Falcon cabin

**Trace Gases:**

NO/$NO_y$ , $NO_2$, CO, $CO_2$, $CH_2O$, $O_3$, $HNO_3$, $SO_2$, HC

**Aerosol properties:**

Number concentration
Particle size distribution
Non-volatile fraction of aerosol modes
Aerosol absorption and black carbon

**Meteorology:**

T, p, RH, wind

**Forecast products:**

Meteorological forecasts
Chemical forecasts
ENVISAT- SCIAMACHY footprint

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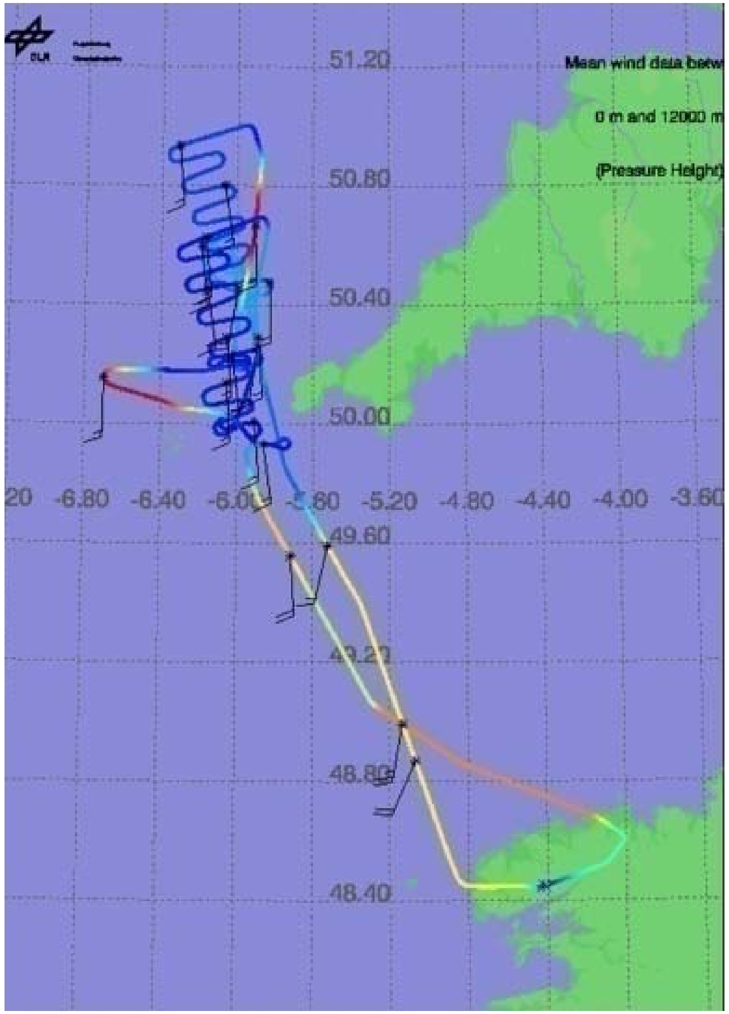
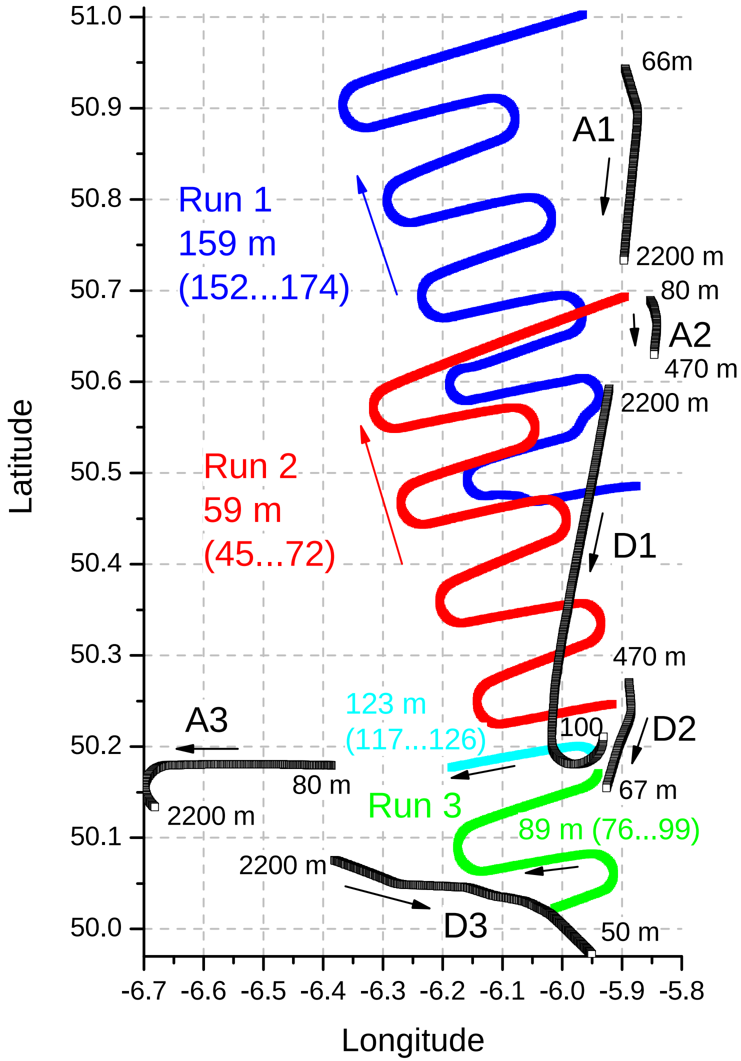
# Atlantic Conveyor Plume Study: Overview



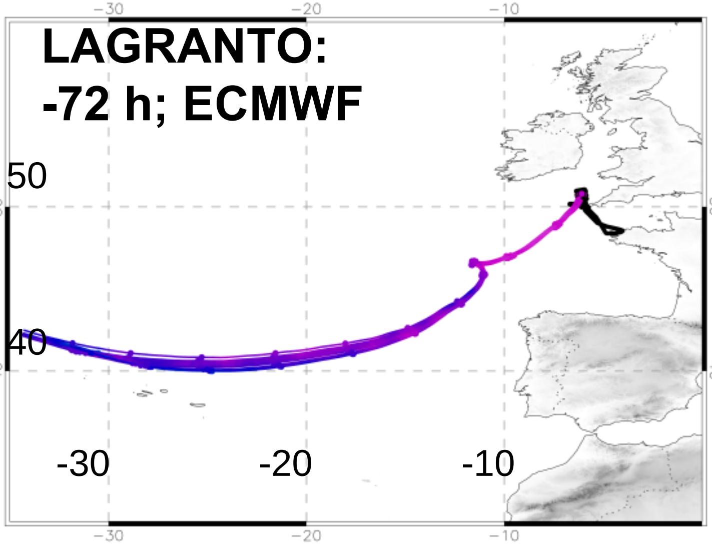

Sequence: Run1-A1-D1-Run2-A2-D2-Run3-A3-D3

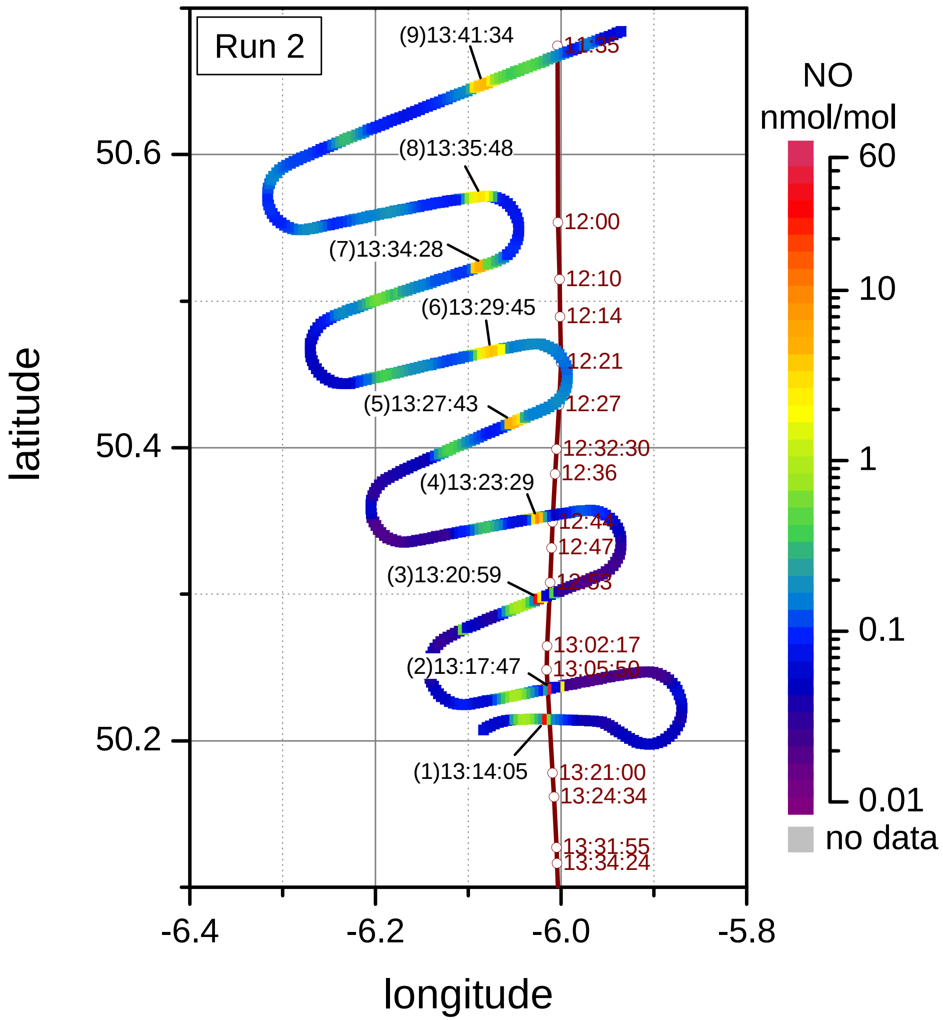





Sausen, 2010: Why particular emphasis on climate impacts of transport

# Atlantic Conveyor Plume Study: Overview


AIM: Measure the plume of the container vessel “Atlantic Conveyor” from fresh exhaust to one hour plume age in otherwise clean air.

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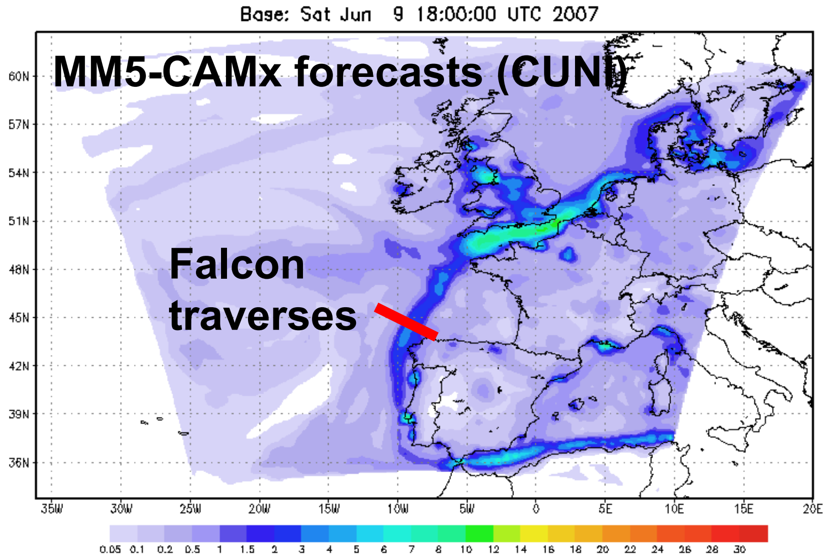
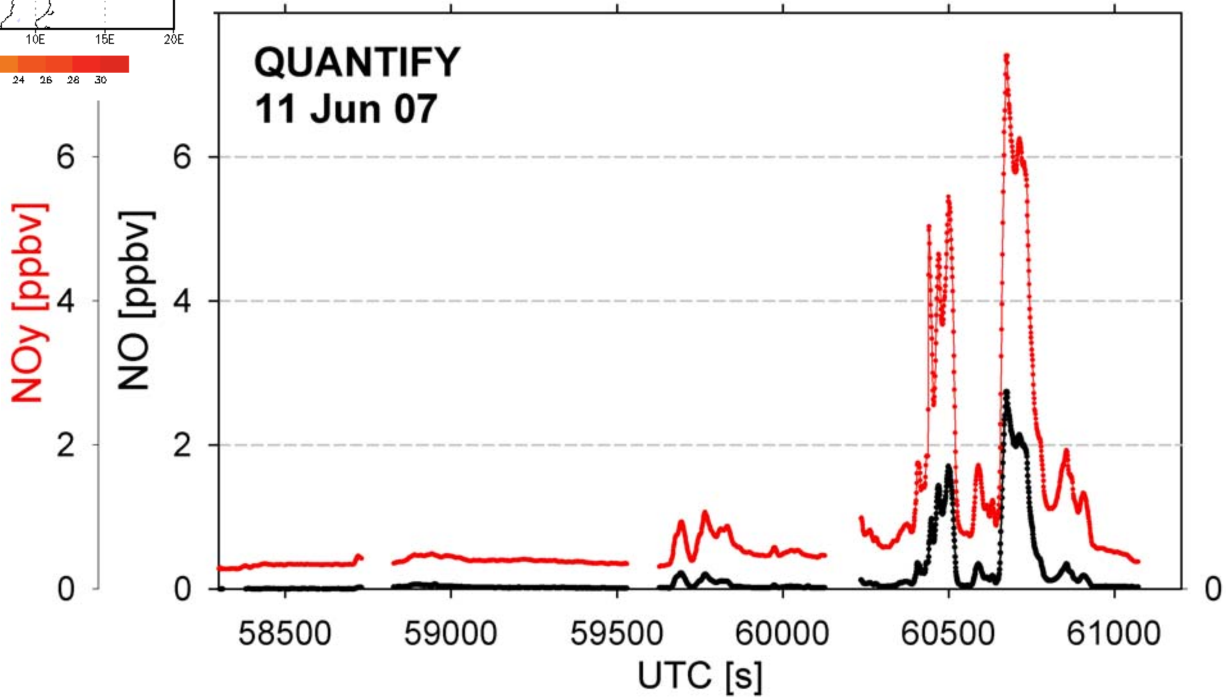
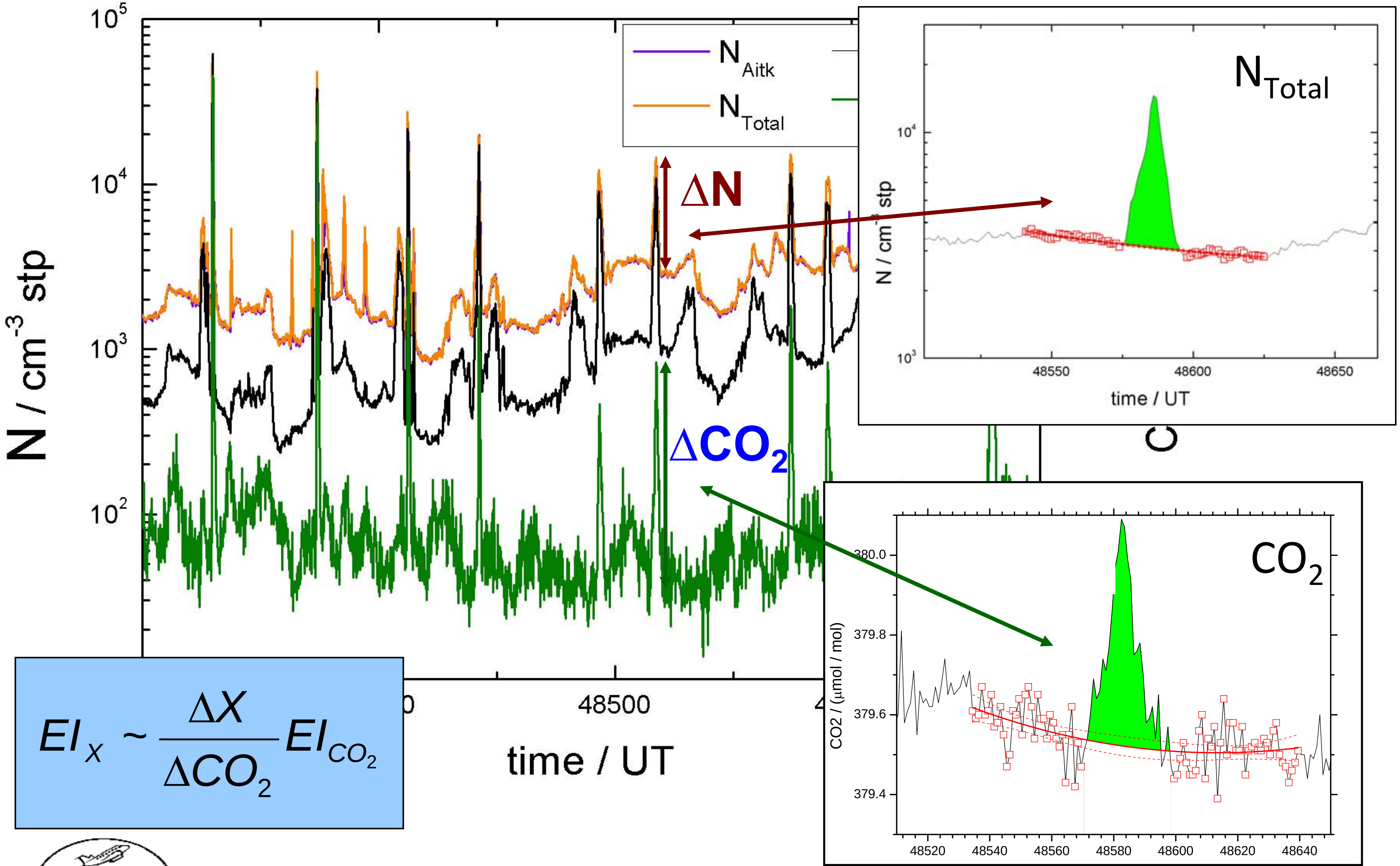
# Ship Corridor Sampling: Overview



# Effective Index Approach




$$EI_X \sim \frac{\Delta X}{\Delta CO_2} EI_{CO_2}$$

# Scientific Questions and Answers

**How are emissions from ships transported and transformed within the atmospheric boundary layer, in particular upwards into the free troposphere?**

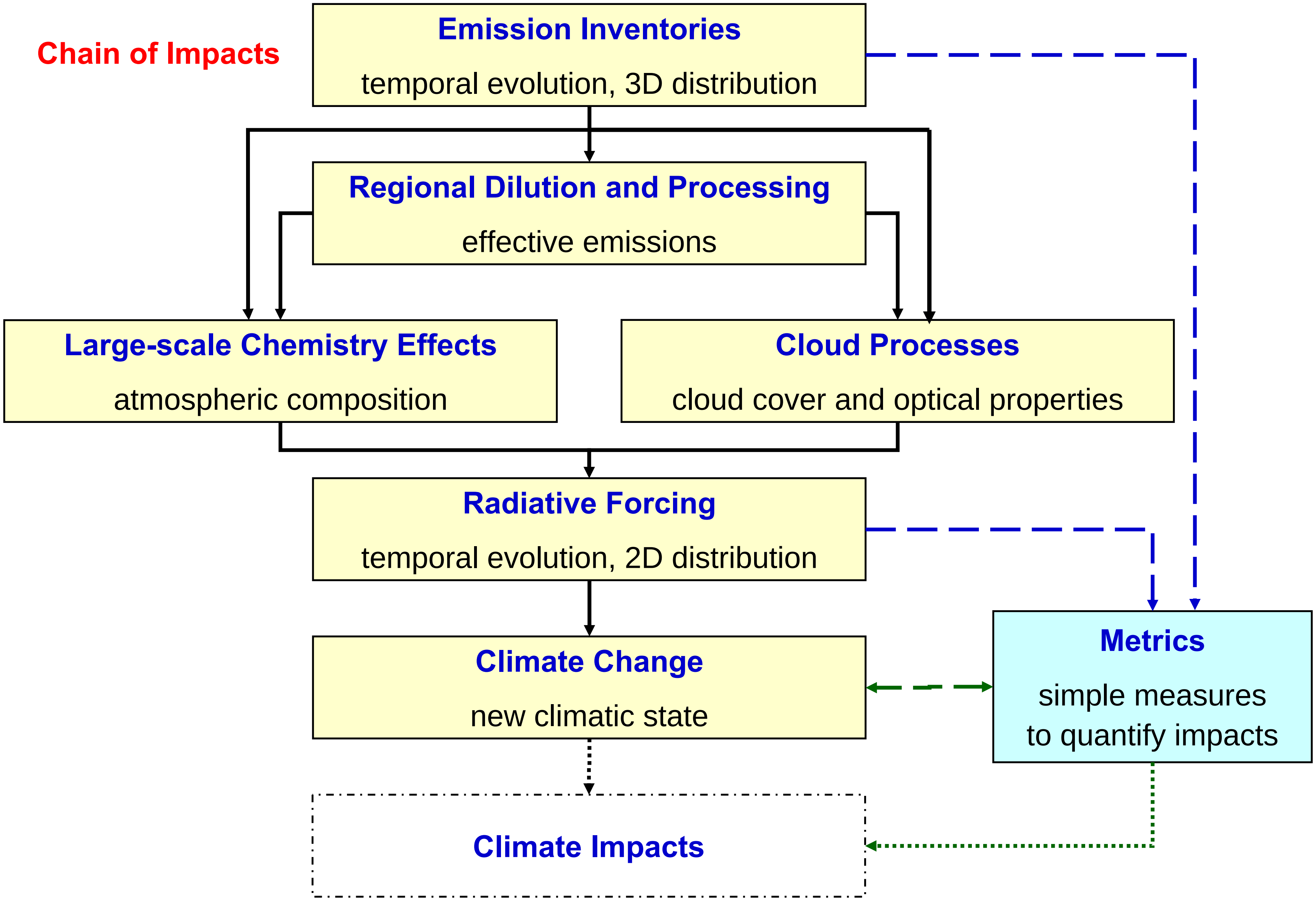
**No efficient mixing of fresh exhaust into the free troposphere.**

**Do ship emissions significantly contribute to the atmospheric pollution in the marine boundary layer?**

**YES, > factor 3 for non-volatile particles; 50% for NOx in polluted marine boundary layer.**

**Are the local meteorological conditions (temperature, humidity, wind shear) important for the emission transformations?**

**YES, humidity and photochemical activity affect photooxidation and particle coagulation and growth.**


Chain of Impacts
Emission Inventories
temporal evolution, 3D distribution
Regional Dilution and Processing
effective emissions
Large-scale Chemistry Effects
atmospheric composition
Cloud Processes
cloud cover and optical properties
Radiative Forcing
temporal evolution, 2D distribution
Climate Change
new climatic state
Metrics
simple measures
to quantify impacts
Climate Impacts