How does transport change climate ?

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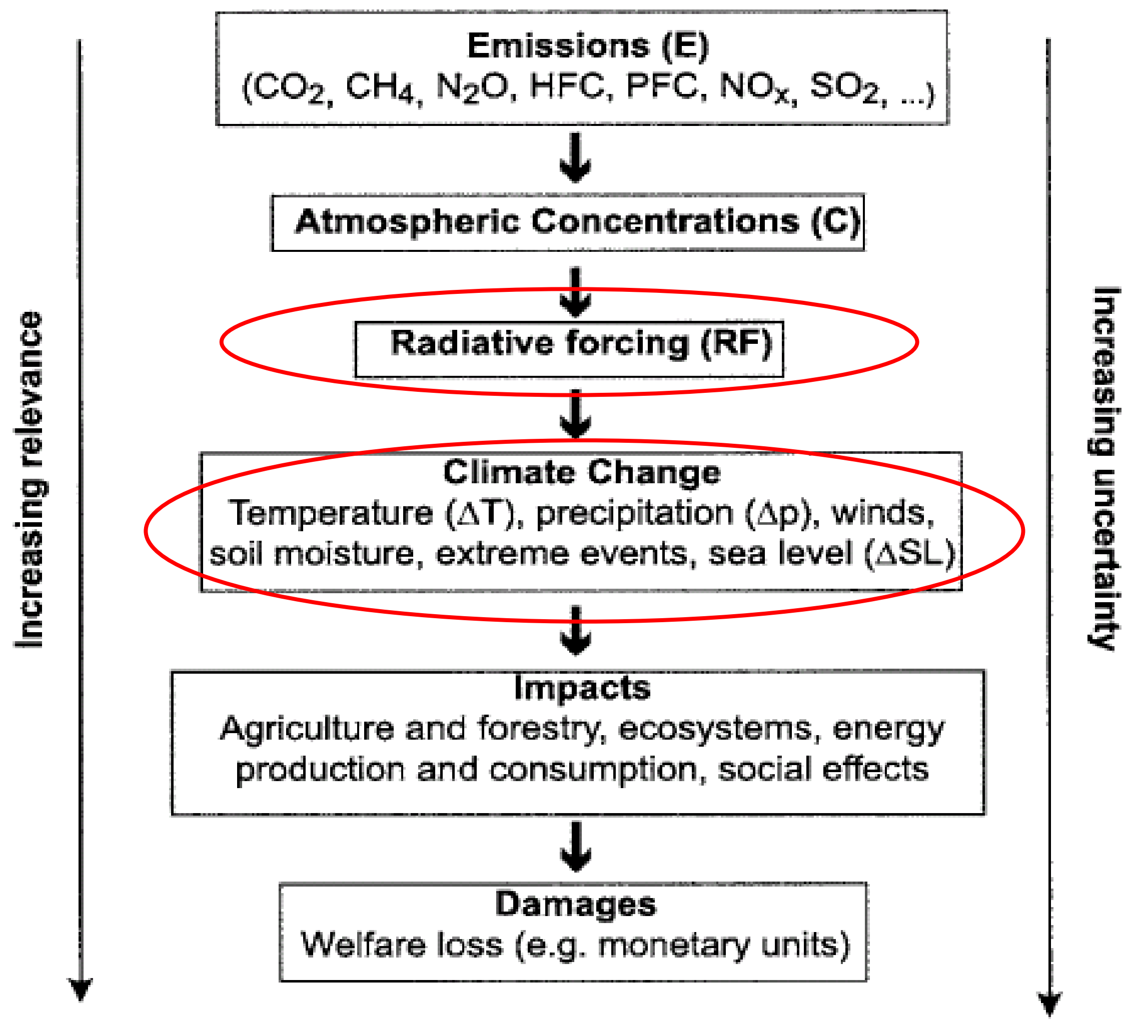
with thanks to _*very*_ *many colleagues in Quantify and Attica*

Transport Emissions: The Climate Challenge
Results from IP QUANTIFY and SSA ATTICA
Brussels, 24 June 2010

University of Reading

Cause and effect chain for impact of emissions



Fuglestvedt et al. 2003 *Climatic Change* 58:267-331

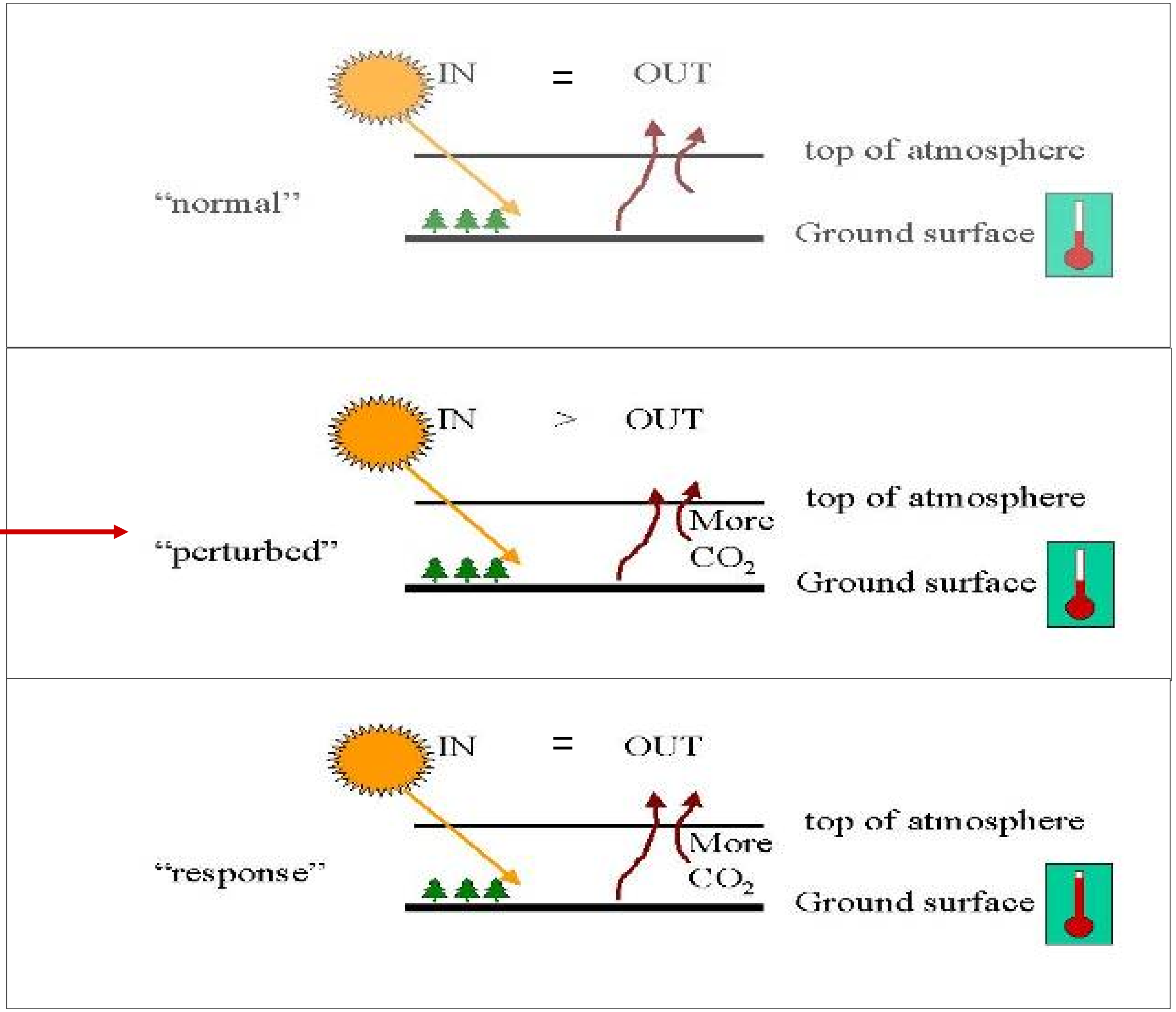
Contents

Evaluation of radiative forcing due to the transport emissions

Understanding how temperatures respond to these radiative forcings

What *is* radiative forcing (of climate change)?

Forcing is the perturbation of the planetary radiation budget in absence of (almost!) any other change

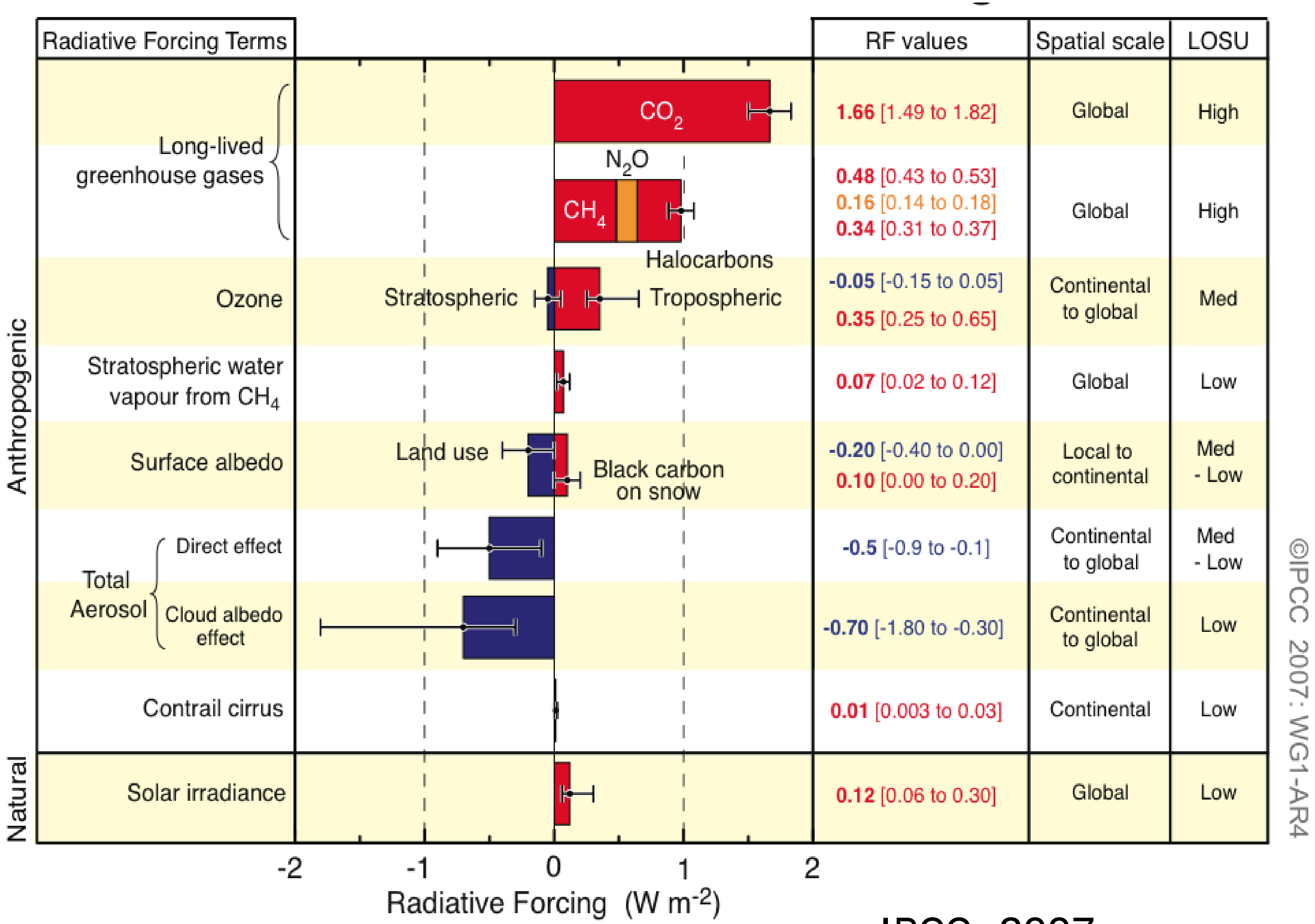


Why do we calculate radiative forcing?

1. Useful initial indicator of climate importance of transport-induced changes in atmospheric composition
2. Convenient way to explore the impact and size of uncertainties, and to compare results from different laboratories
3. Important “pre-cursor” to performing calculations with computationally-expensive climate models
4. Widely used as a measure of climate change, for example, by the Intergovernmental Panel on Climate Change

A negative forcing causes a cooling and a positive forcing causes a warming – the size of the warming is related to the size of the forcing, and how long the forcing lasts

Radiative forcing since pre-industrial times – “all” sources



IPCC, 2007

Issues in calculating transport radiative forcing

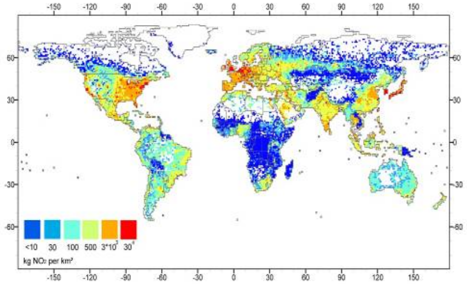
Need to know what each mode of transport emits and where it emits it

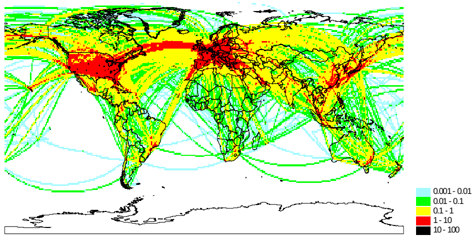
CO_2 emitted by transport sectors is no different (in terms of climate impact) to CO_2 emitted by other human activity

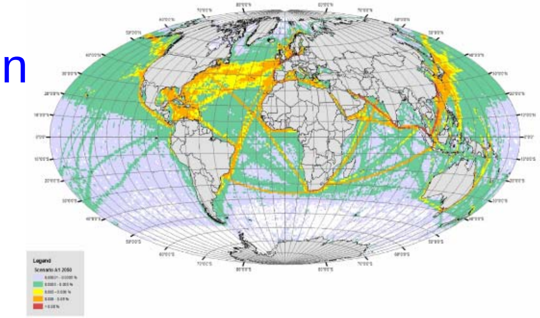
But there are many “non-CO_2” contributors from transport sectors

Almost all of these are *short-lived* in the atmosphere and hence “patchy” and the forcing depends on *where* the emission occurs

They include many of the most poorly understood radiative forcing mechanisms

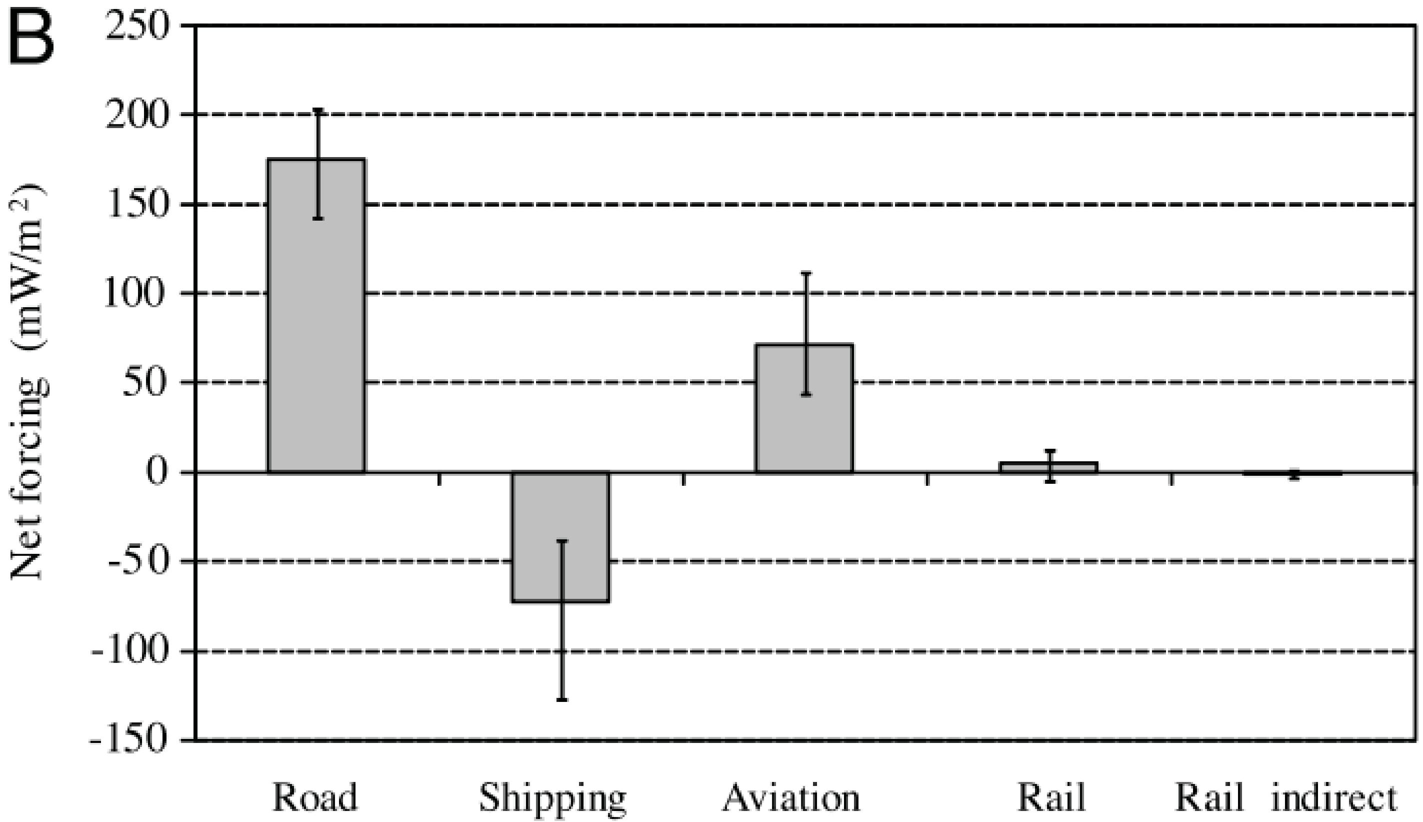






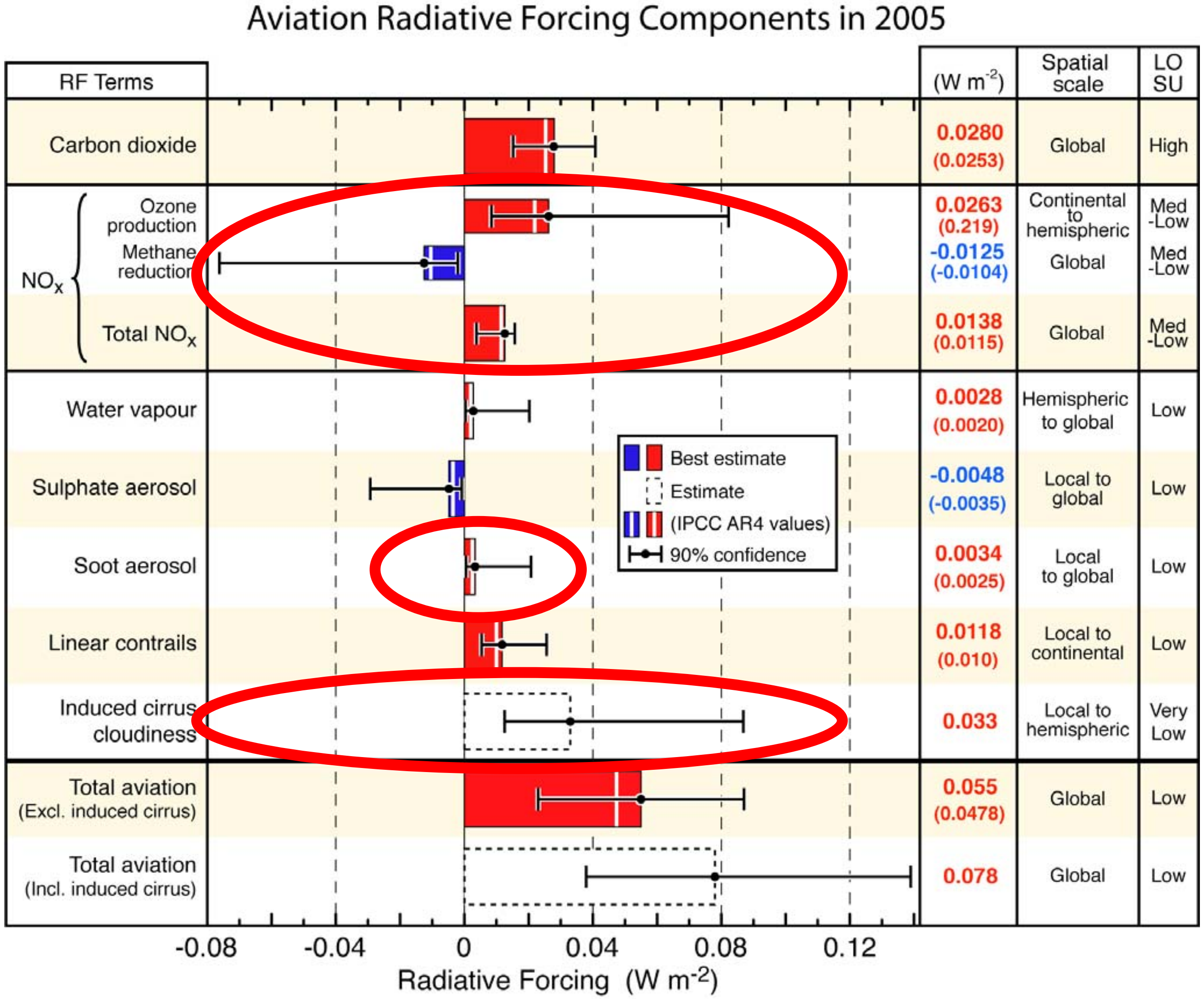
Borken et al. 2009

First attempt at a multi-sector summary for the present-day radiative forcing of transport



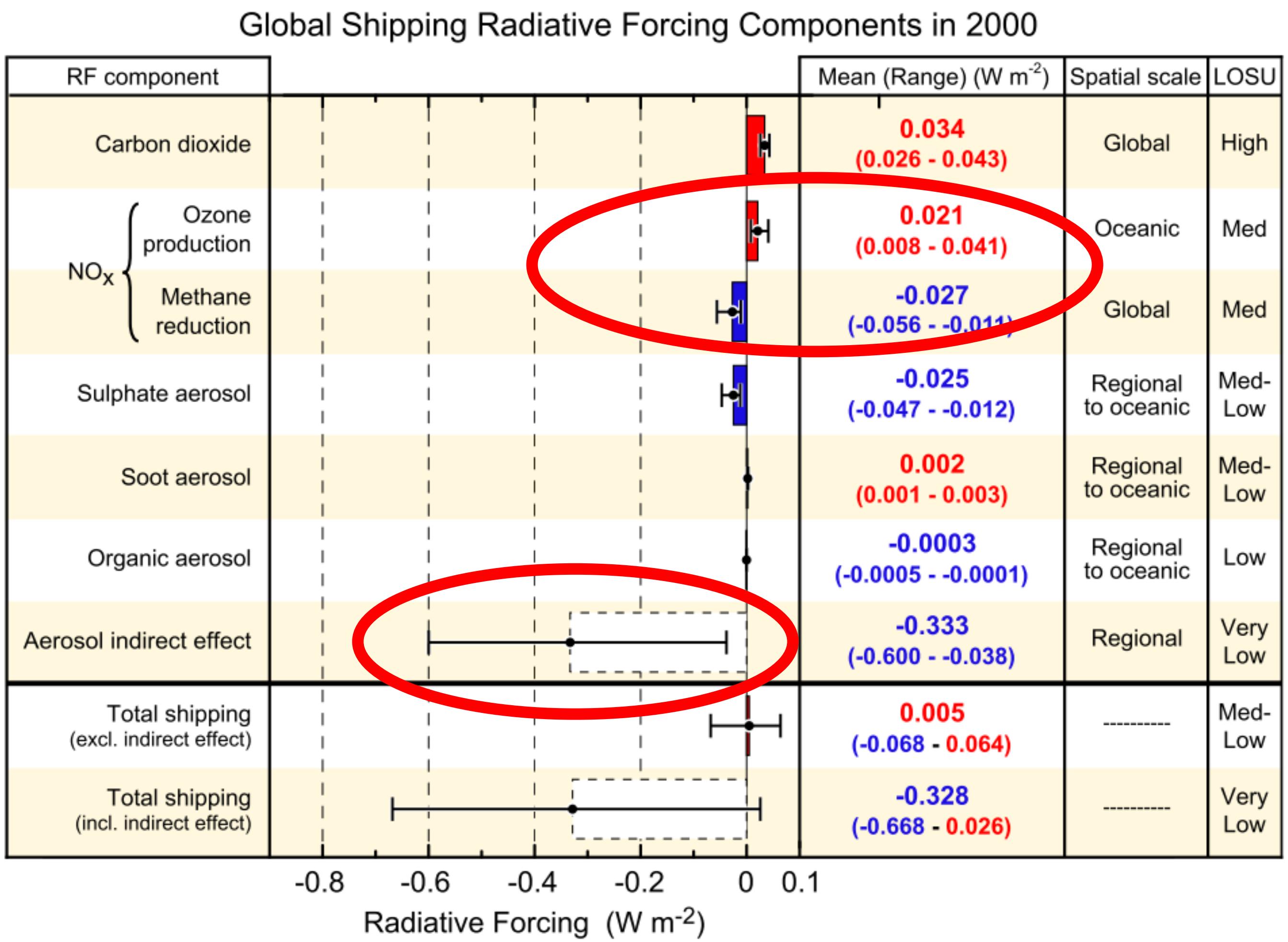
Fuglestvedt et al. PNAS 2008

Aviation



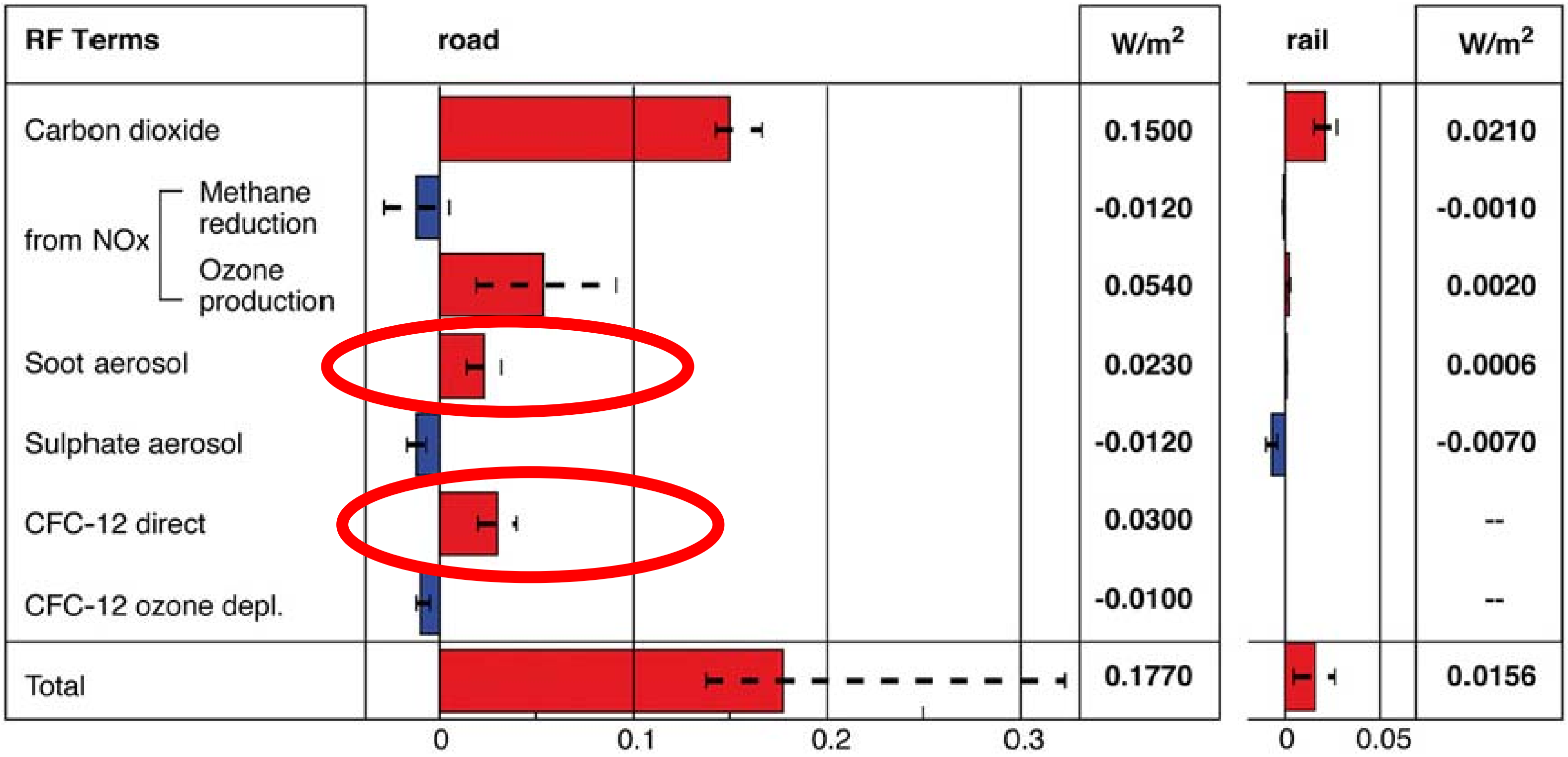
Lee et al, Atmos Environ, 2009

Shipping



Eyring et al, Atmos Environ, to appear

Road transport



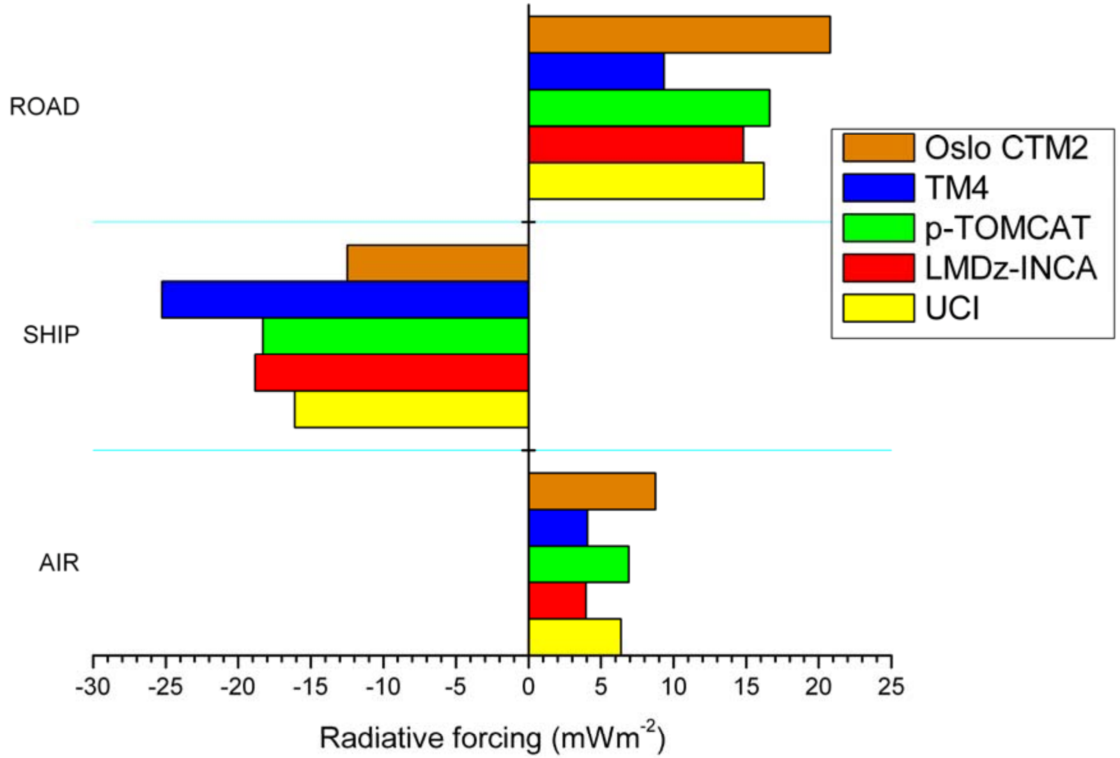
Uherek et al, Atmos Environ, to appear

QUANTIFYing the uncertainty in radiative forcing: 1

Impact of NO_x (and other short-lived gaseous) emissions by transport on radiative forcing – shows the effect of uncertainty in atmospheric chemistry models

The plot shows the net effect … including increases in ozone, decreases in methane, etc

Roughly a factor of two difference between the largest and the smallest.



Myhre et al, Atmos Environ, (submitted)

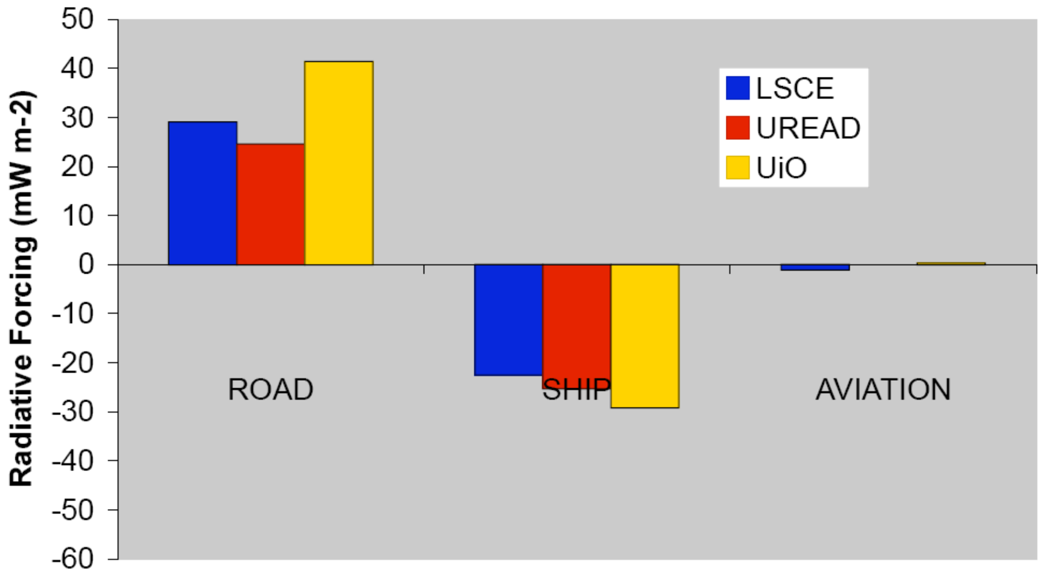
QUANTIFY

QUANTIFYing the uncertainty in radiative forcing: 2

Impact of particulates ("aerosols") from transport sectors

The results for the road sector showed the largest differences between models

We show that these result from assumptions on how black carbon ("soot") mixes with other particles

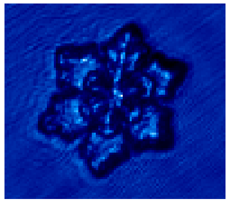


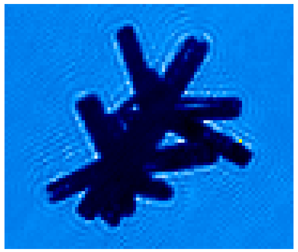
Balkanski et al. 2010 Atmospheric Chemistry and Physics 10:4477-4489

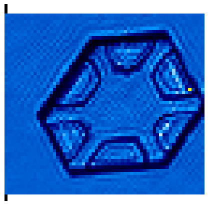
QUANTIFYing the uncertainty in radiative forcing: 3

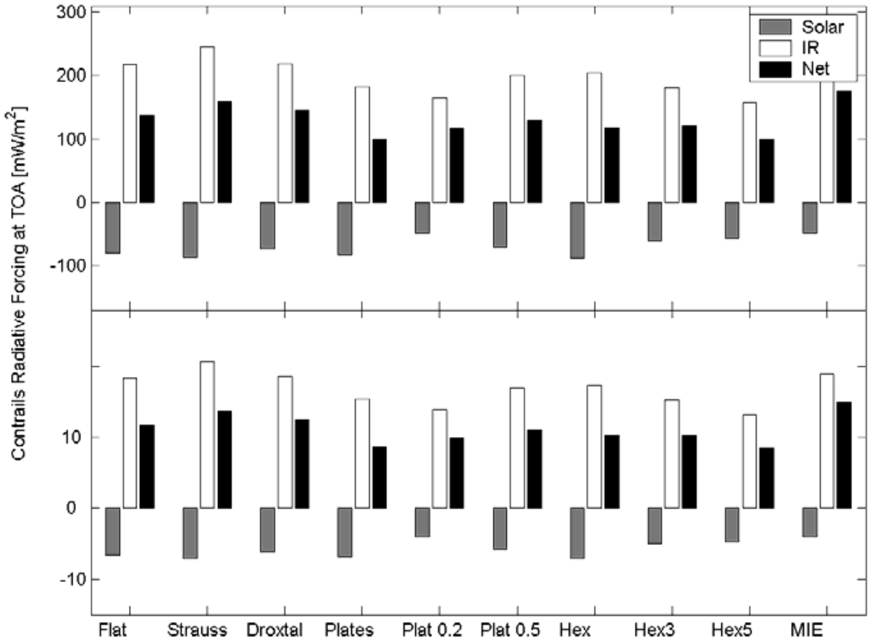
Contrail radiative forcing depends significantly on assumptions about the shape of ice crystals in the contrails

These crystals shapes are likely to vary with atmospheric conditions and the age of the contrail







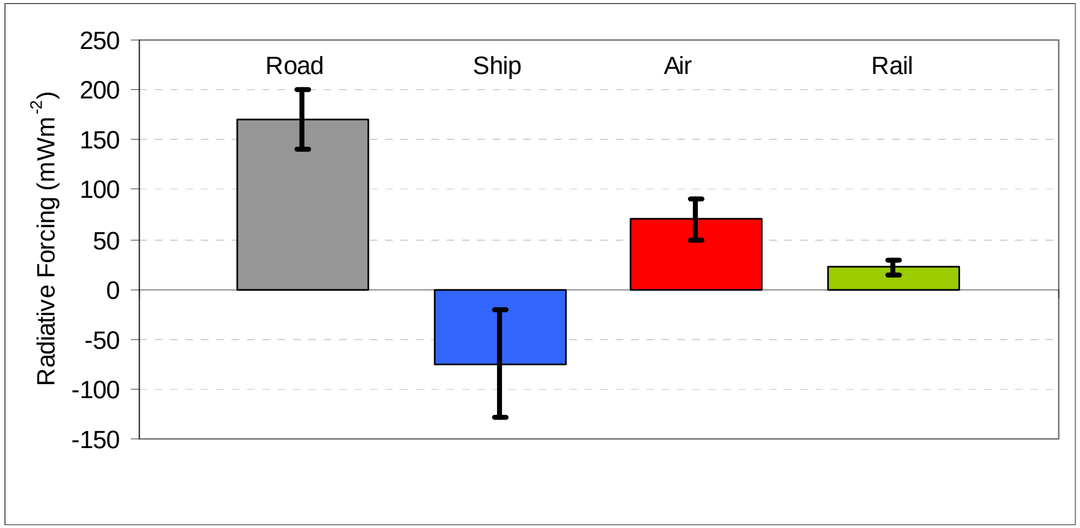


K.Marcowicz, University of Warsaw – to be submitted

QUANTIFY (near) final radiative forcing estimate

We have quite high confidence in the sign and size of the ROAD (and RAIL) forcing. Impact of black carbon on clouds not yet quantified with confidence

We have less confidence in the SHIP forcing, due to the uncertainties in calculating the effect of sulphur emissions on cloud



We have even less confidence in the AIR forcing – difficult to estimate the impact of "aviation-induced cirrus" and the impact of aircraft aerosols on natural cirrus clouds

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Several groups within QUANTIFY (CNRM Toulouse, University of Reading and DLR) used sophisticated climate models to study the effect of the radiative forcings on temperatures

(We also made considerable progress in understanding how good radiative forcing is at predicting global temperature response …)

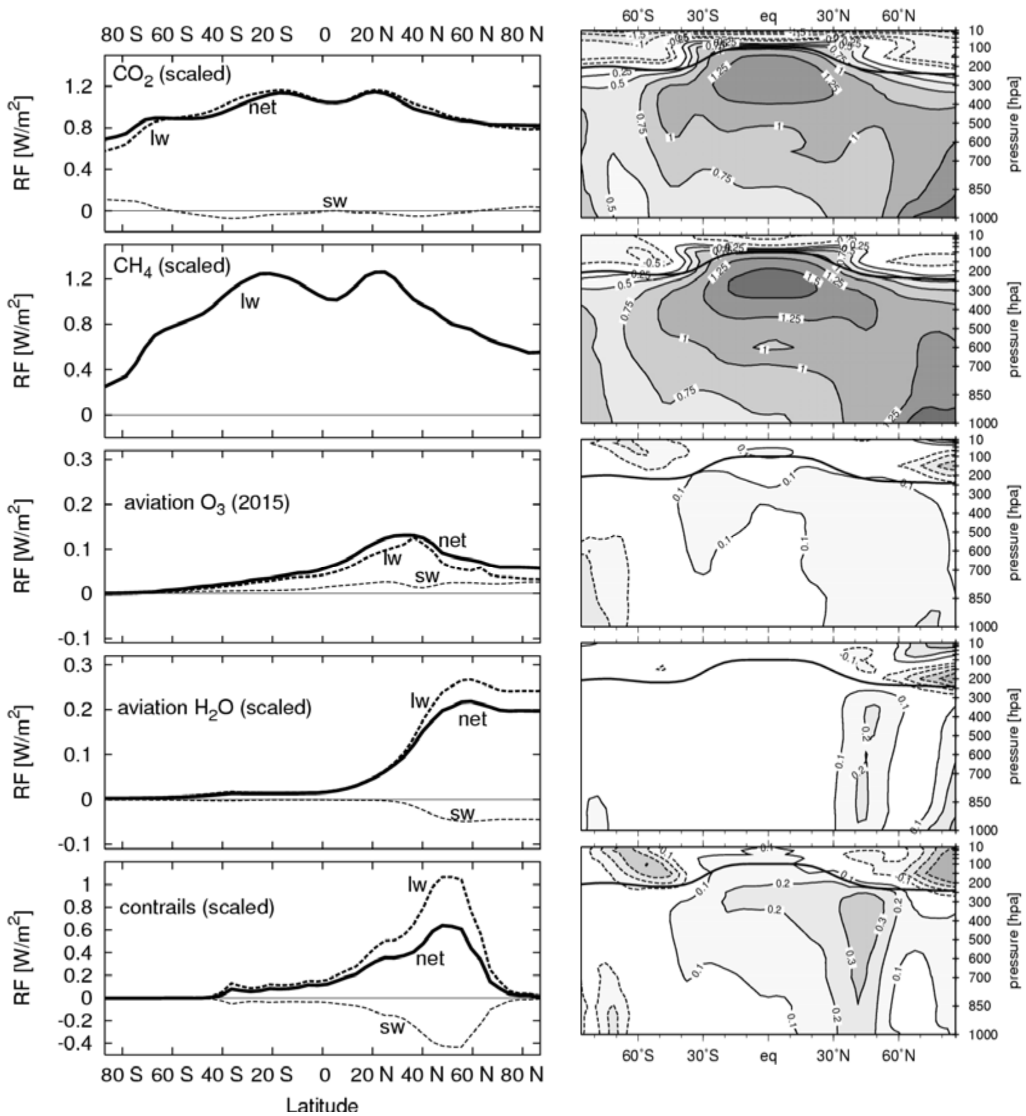
See also Jan Fuglestvedt’s talk, up next!

How does the pattern of radiative forcing map onto the pattern of climate change?

Some transport related radiative forcing mechanisms (notably CO_2 and methane) are global in extent

Others (e.g. ozone changes and contrails) are restricted to the hemisphere in which the emissions occur – i.e. normally the northern hemisphere

Plots show the pattern of climate response due to various AIR forcings – if the forcing is in only one hemisphere, so too is most the response

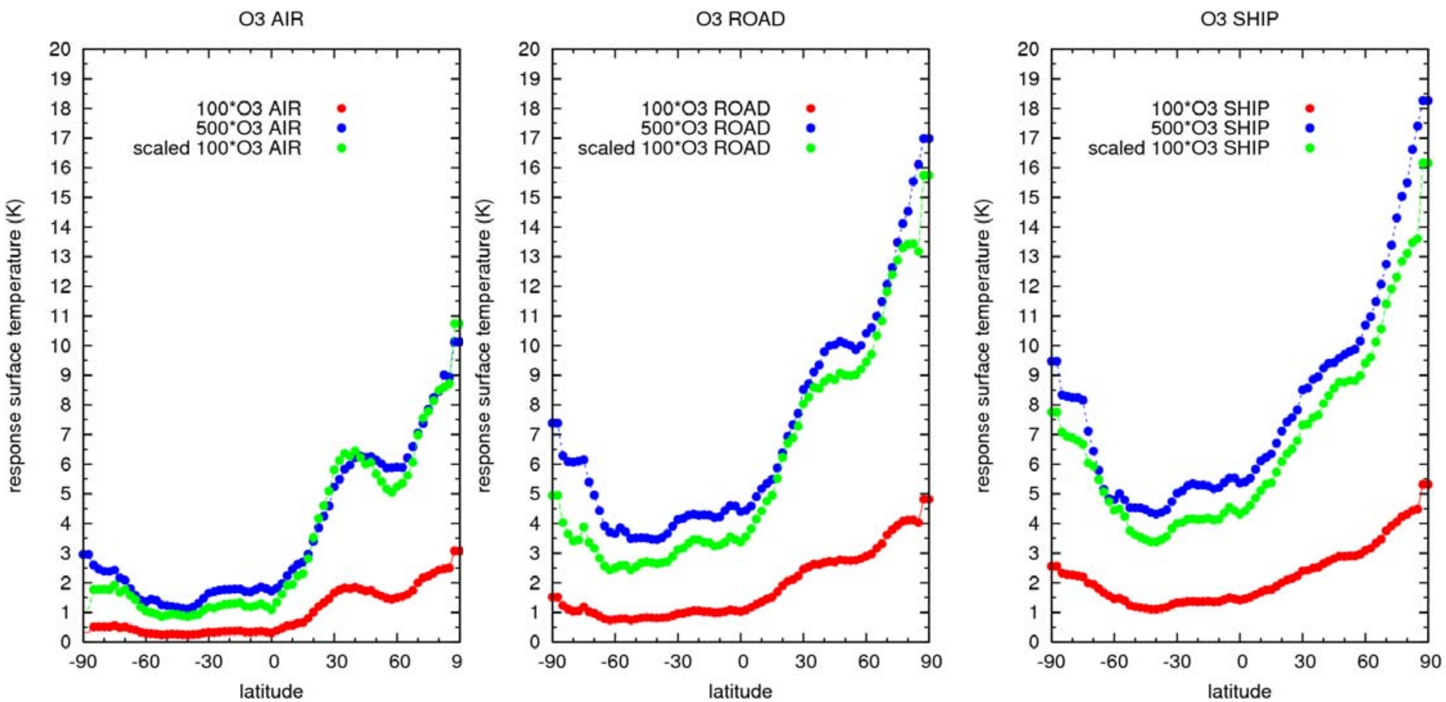


Ponater et al. TAC proceedings 2007

Response to transport-related ozone forcings

The response to ozone forcings are mostly found in the northern hemisphere (whereas the “opposing” methane forcing is in both hemispheres)

The response to AIR ozone changes is more constrained to the northern hemisphere, than for SHIP, due to differences in where emissions occur



Stuber et al. in preparation

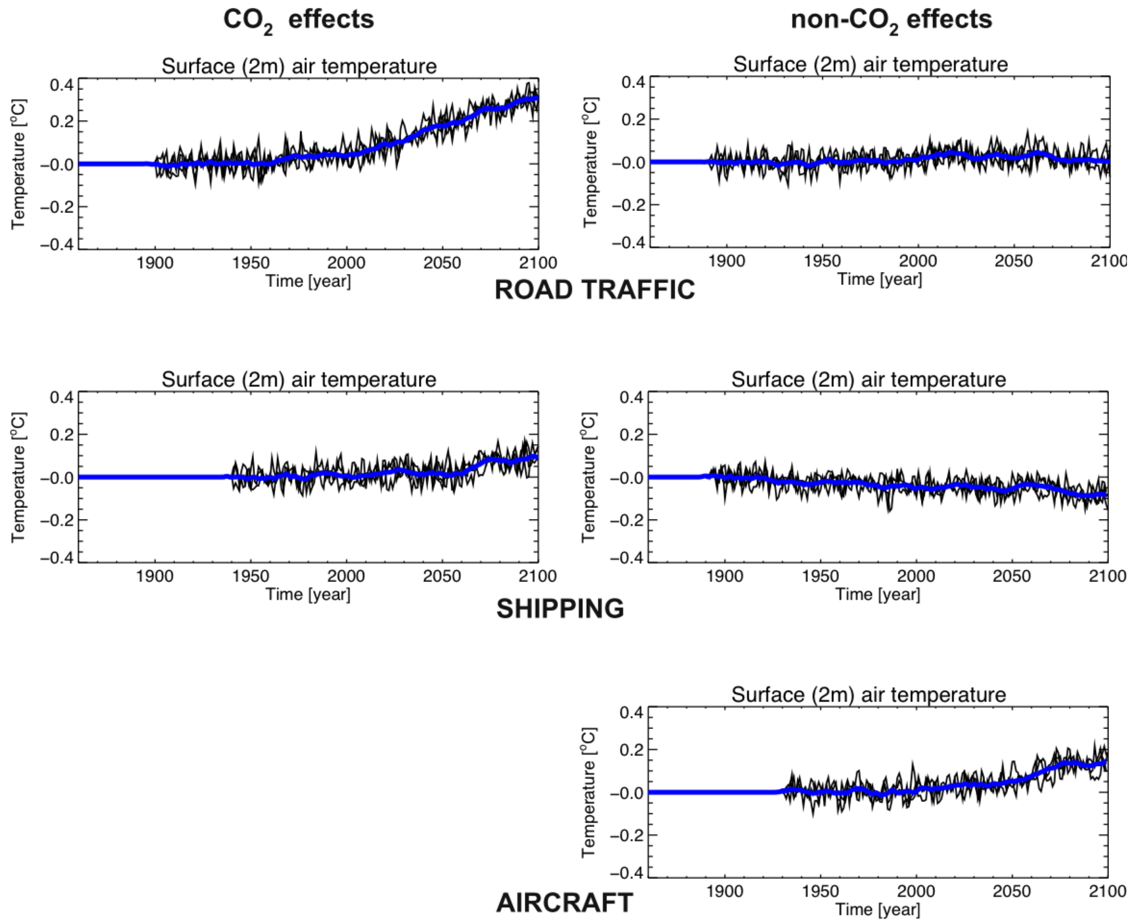
Coupled ocean-atmosphere model calculations of the climate effect of aviation emissions

The CNRM climate model was used, together with information on past and possible future changes in emissions

By 2100 the warming from all sectors due to CO_2 is 0.5 K with a major contribution from ROAD (0.3 K); the warmings from SHIP and AIR are about equal (0.1 K)

The non-CO_2 impact peaks at 0.05 K in 2050 for the road traffic, whereas the non-CO_2 impact from SHIP is negative reaching, 0.1K in 2100

The non-CO_2 impact from AIR is larger than the CO_2 impact, reaching 0.15 K in 2100



Olivié at al., 2010

Summary

ROAD:

1. Net forcing is *strongly* positive
2. CO_2, ozone, HFCs/CFCs and black carbon aerosols are the main contributors
3. Main uncertainty is climate response to black carbon forcing

SHIP:

1. Net forcing is negative
2. Positive forcing from CO_2 and ozone is more than offset by the negative forcings from methane change, the direct sulphate forcing and the aerosol impact on clouds, resulting in a net *negative forcing*
3. Main uncertainty is the size of the impact of aerosols on clouds

AIR:

1. The net forcing is "very likely" positive
2. CO_2, ozone and aviation-induced cloudiness are the dominant positive forcings
3. Significant uncertainties on the size of the aviation-induced cloudiness and, especially, the effect of aerosols on high-altitude ice cloud properties

Conclusions

ATTICA and QUANTIFY have provided comprehensive assessments of the radiative forcing due to the transport sectors

The detail of the individual contributions from each sector will help inform future decisions on various options (operational, technological, economic) for mitigating emissions in the future

We have identified areas of particular uncertainty where more research is necessary

We have improved understanding of how reliable radiative forcing is as a measure of climate impact, and helped understand how patterns of climate change due to the transport sectors depend on the distribution of the different forcings

QUANTIFY