Impact of Aviation on Atmospheric Composition and Climate

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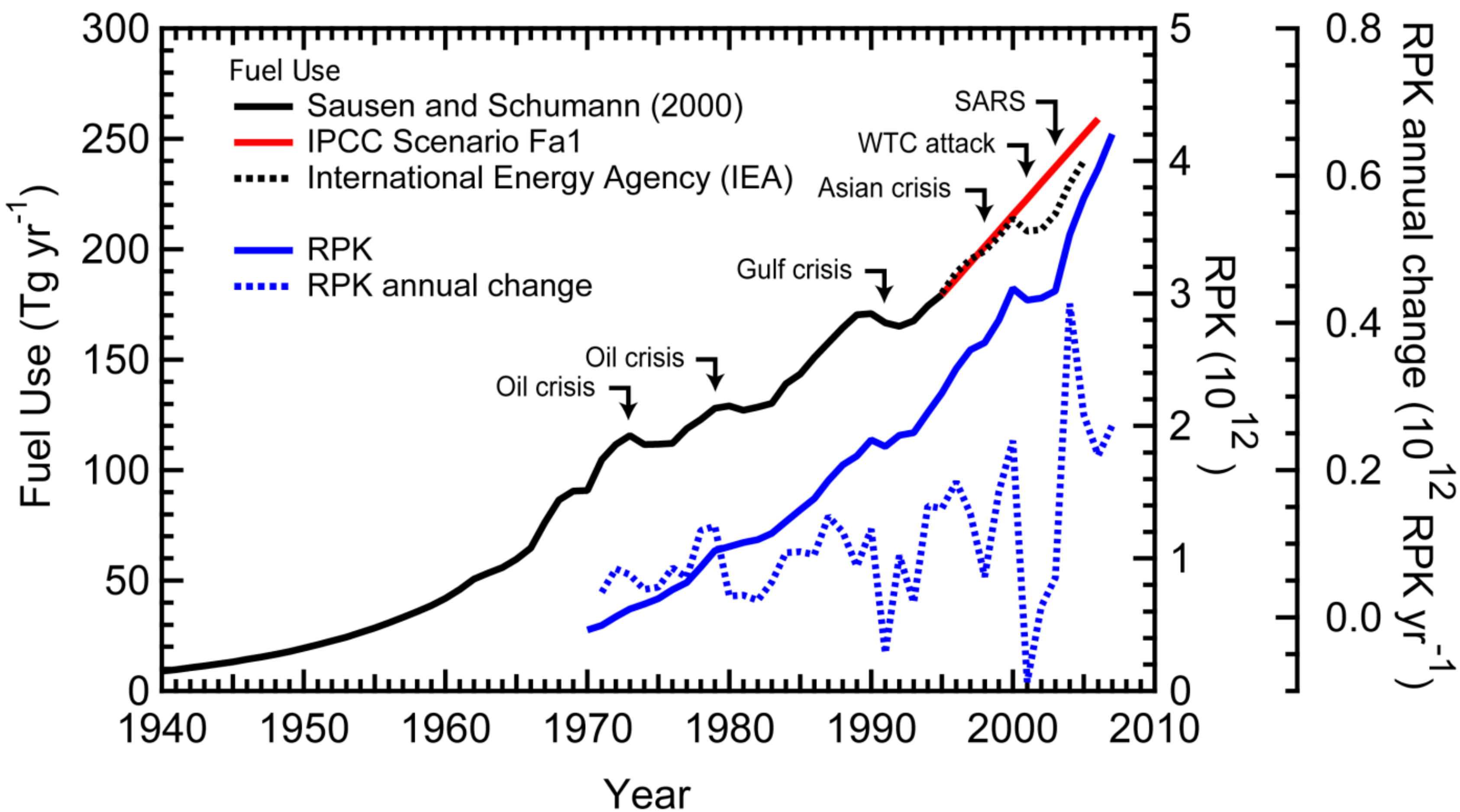
DLR

Why are aviation climate impacts of particular importance?

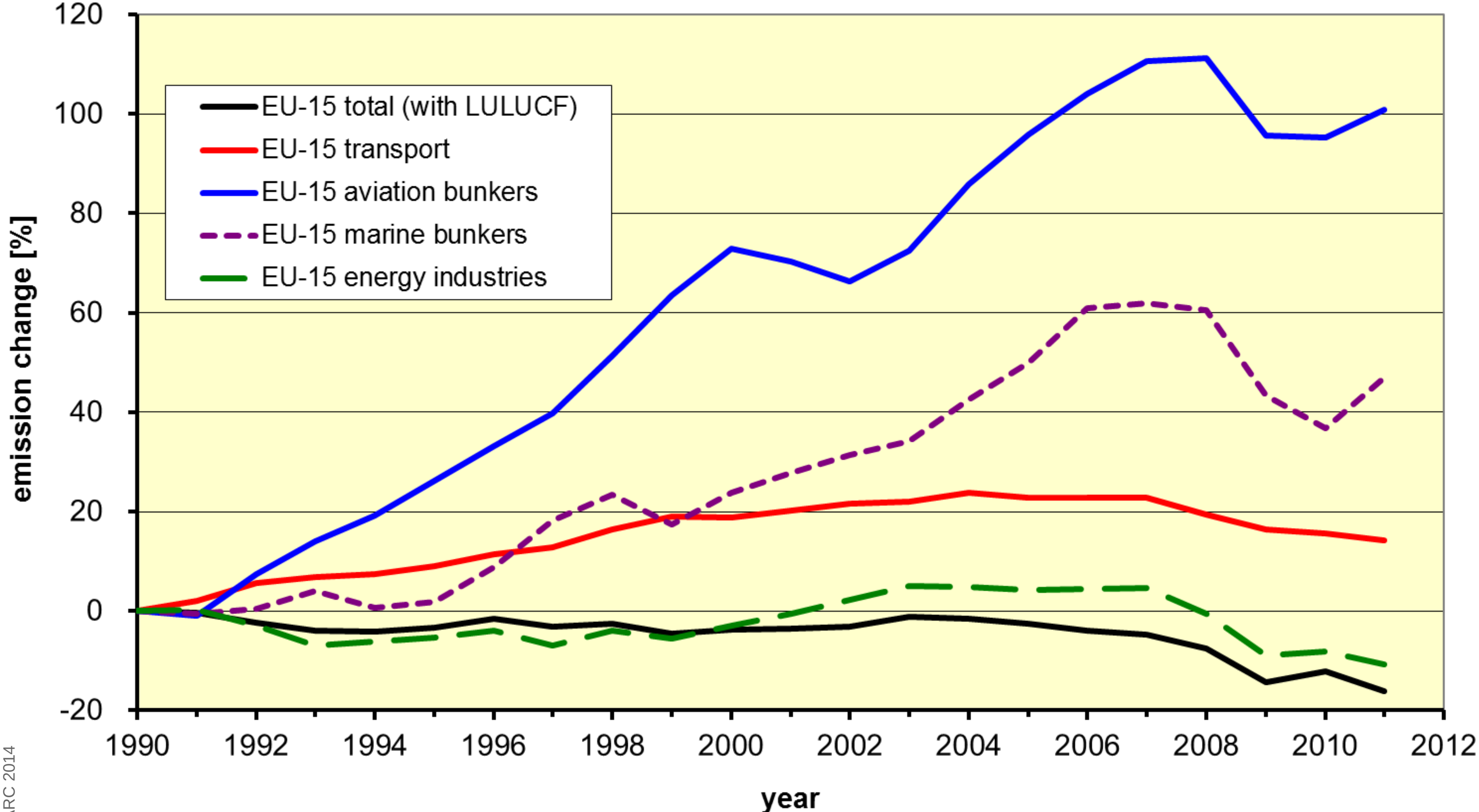
- ✈ Rather strong growth rates.
- ✈ Non-CO_2 effects are stronger than in most other industrial sectors.

Global aviation fuel burn and revenue passenger kilometres



Lee et al., 2009

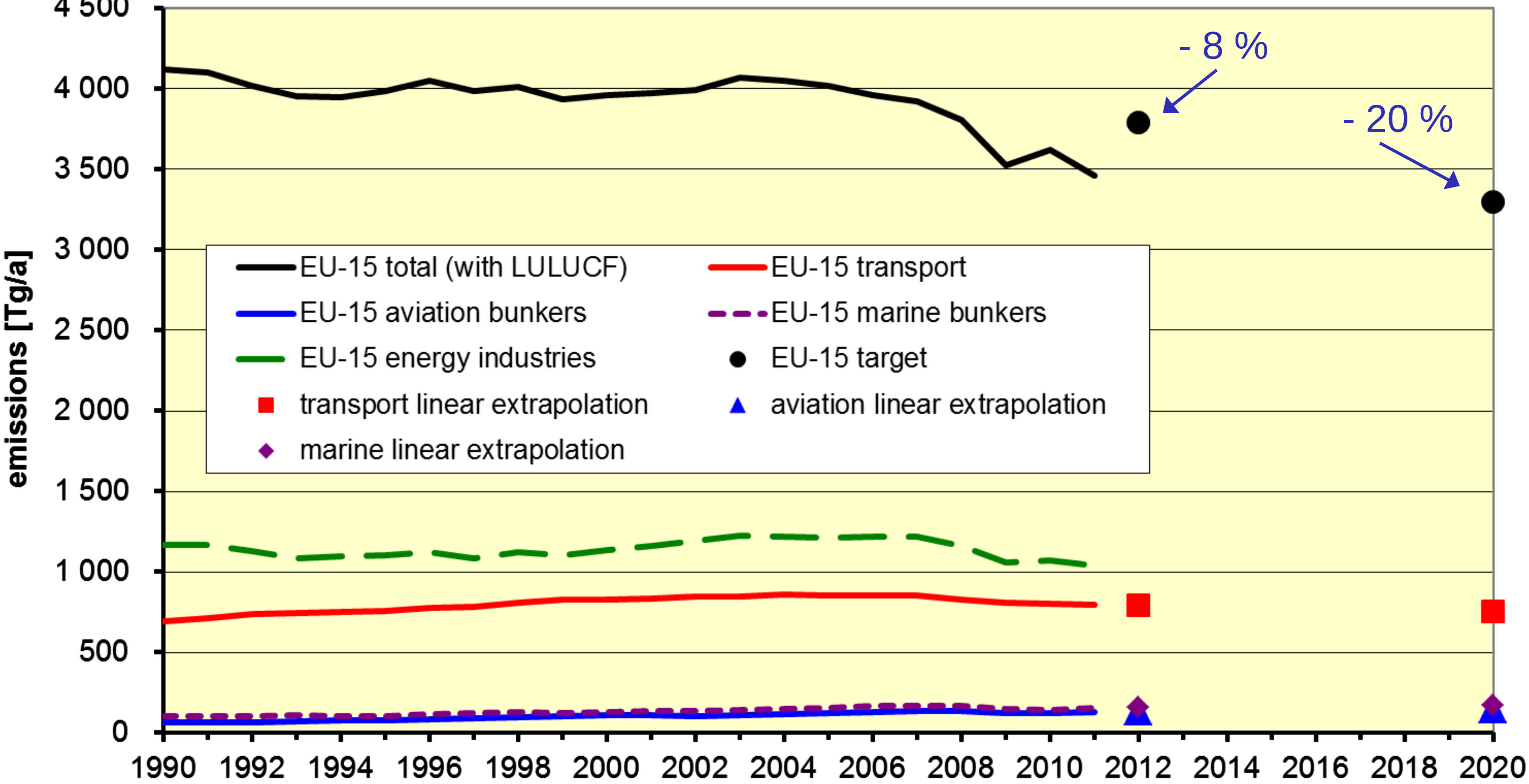
CO_2 equivalent emissions of EU-15
Change since 1990



data: http://unfccc.int/

EU-15 emissions of CO2 equivalent and 2020 target

-20 % relative to 1990

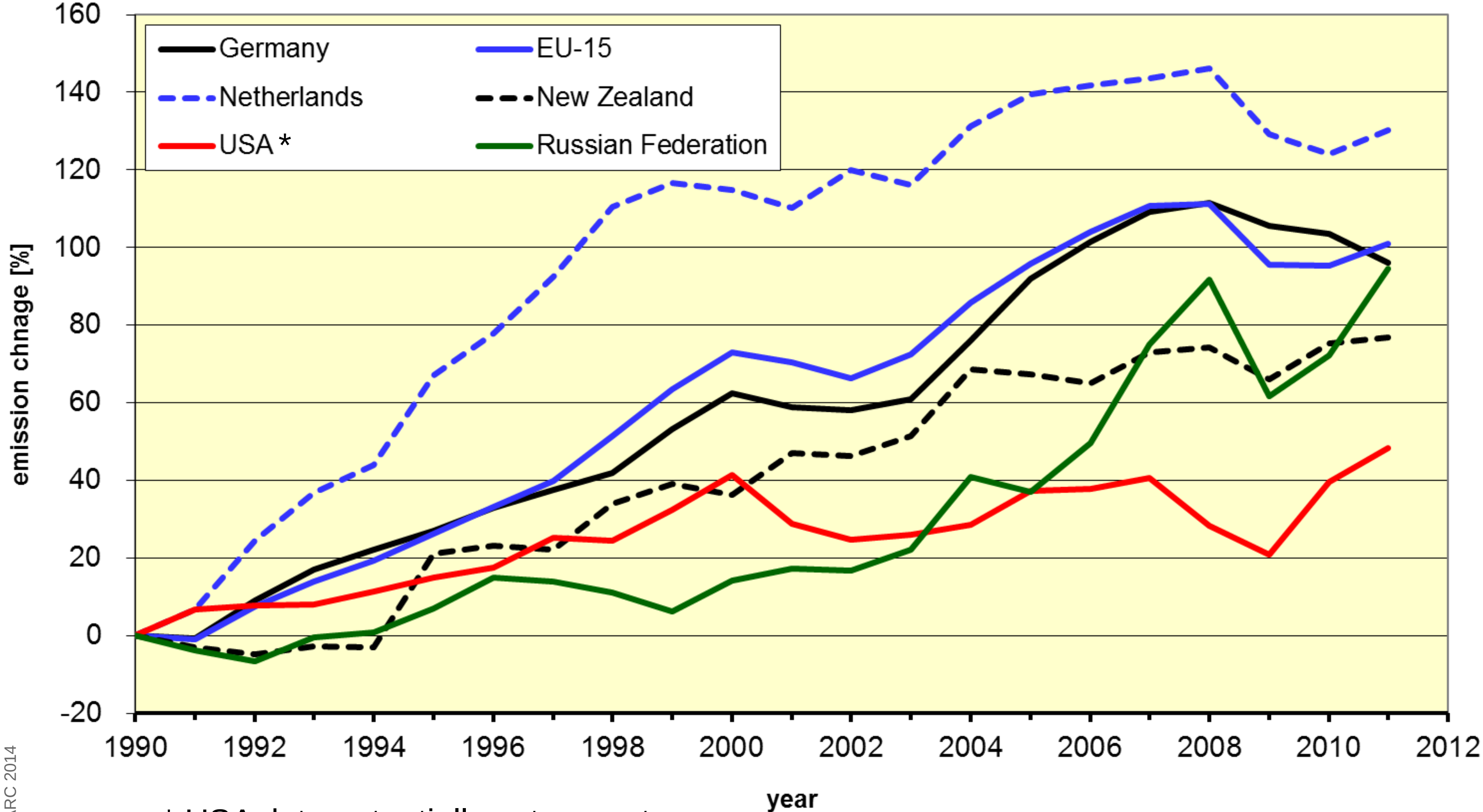


transport fractions (	**1990**	**2005**	***2012***	***2020*** **):**
national transport:	16.9 %	21.3 %	*20.9 %*	*23.0 %*
aviation bunkers:	1.6 %	3.2 %	*3.5 %*	*4.5 %*
marine bunkers:	2.6 %	4.3 %	*4.1 %*	*5.3 %*

linear trend (10 a) of transport emissions after 2011

data: http://unfccc.int/

Aviation bunkers CO_2 equivalent emission change rel. to 1990



* USA data potentially not correct

data: http://unfccc.int/

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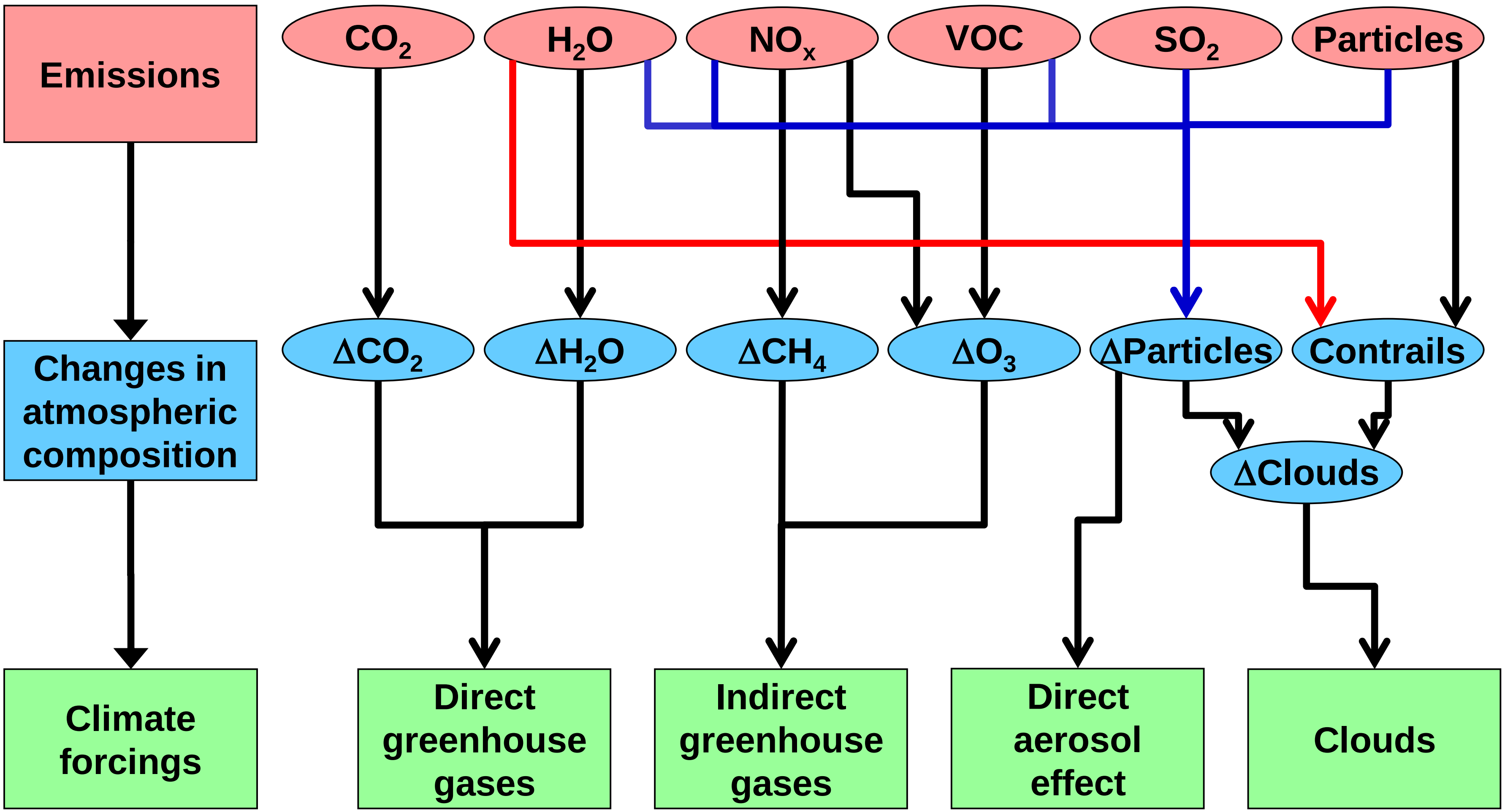
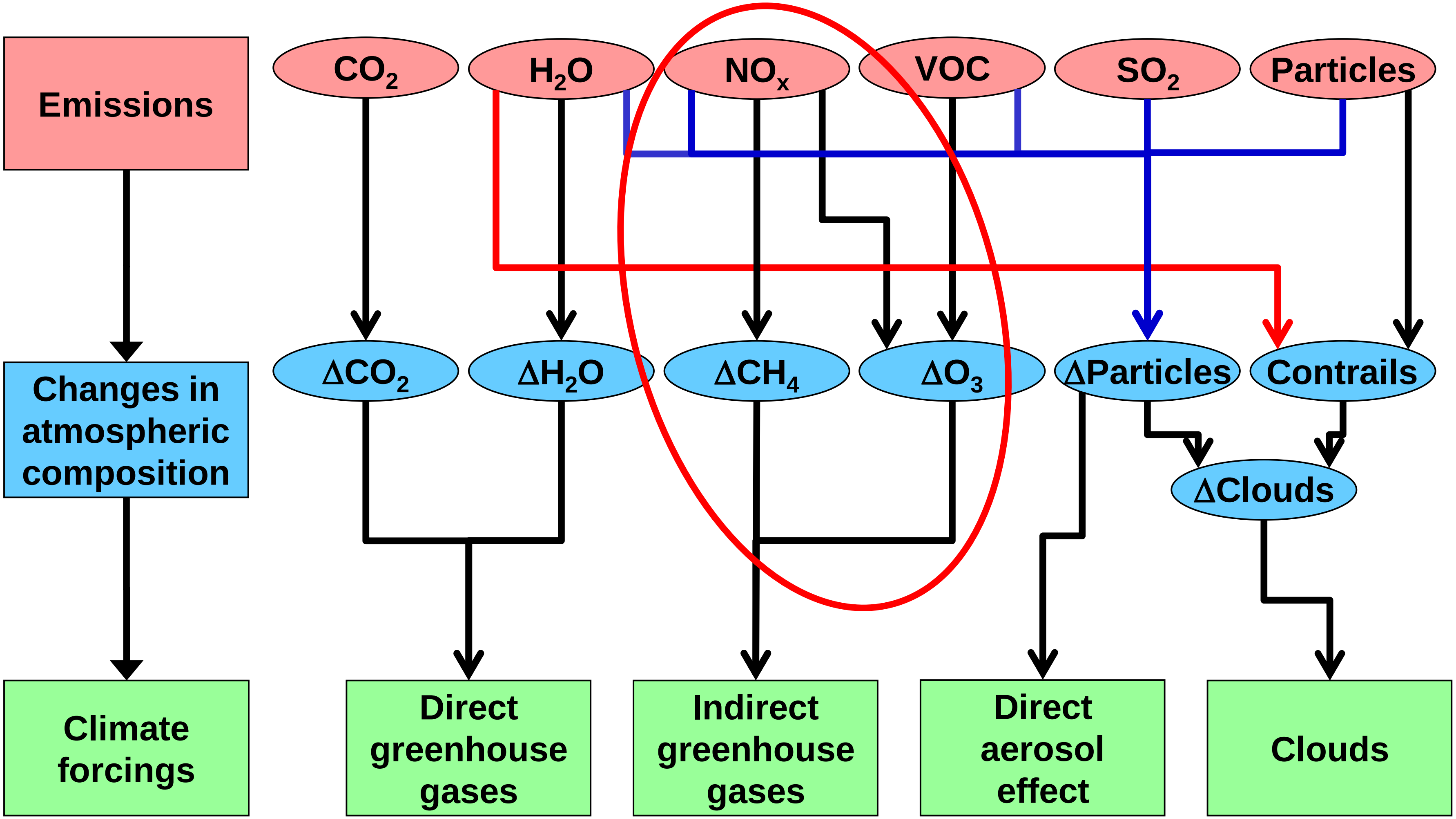
Atmospheric effects of emissions from aviation



Atmospheric effects of emissions from aviation



Impact of NO_x emissions

process		live time	radiative forcing
emissions of NO_x		days	
⇨	increase O_3 concentration	weeks to months	positive RF
⇨	decreased CH_4 concentration	decade	negative RF
⇨	decreased O_3 concentration (primary mode)	decade	negative RF

Efficiency of O_3 production for NO_x emissions from transport

Number of produced O_3 molecules per NO_x molecule emitted

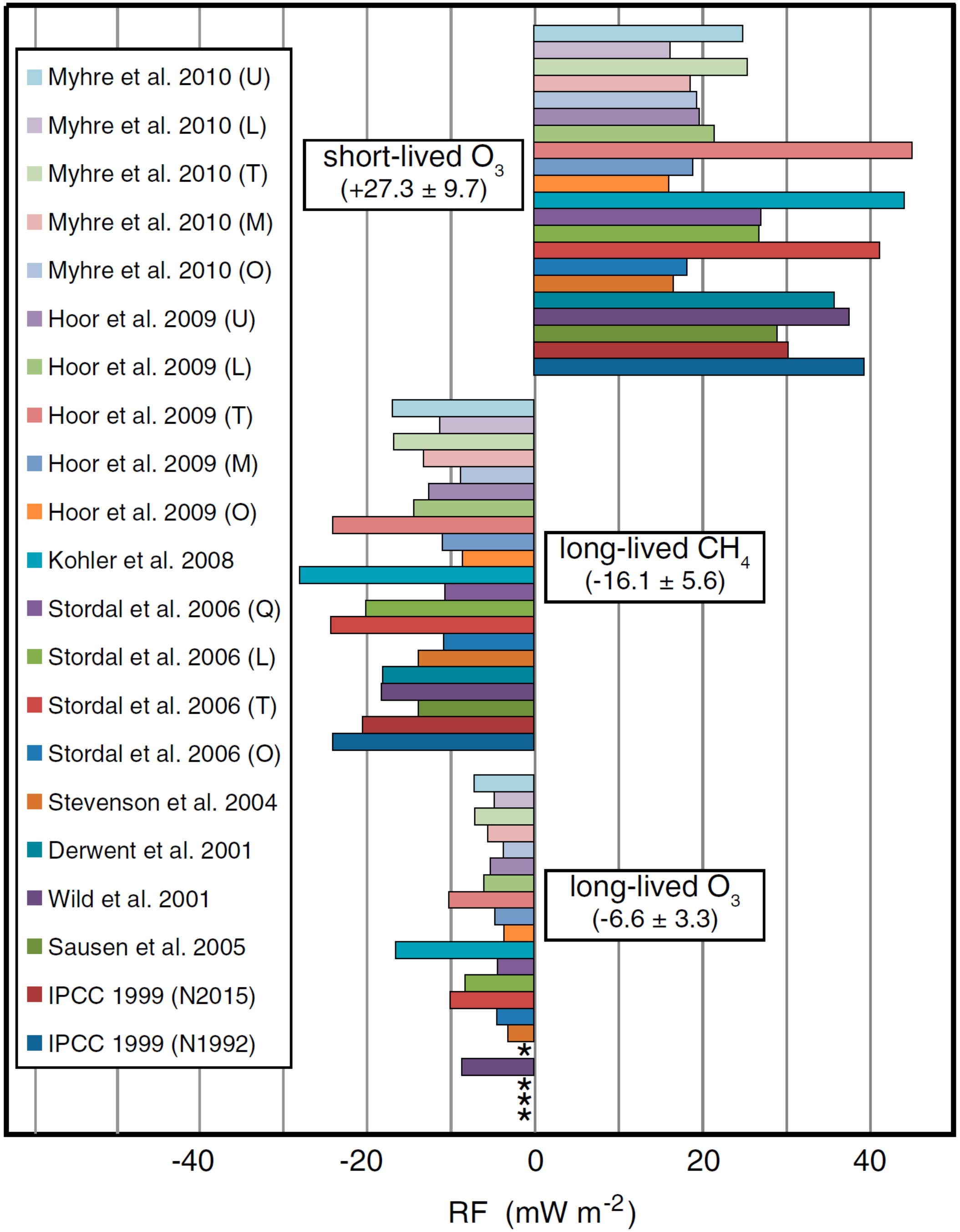
road transport	0.33 ± 0.05
shipping	0.54 ± 0.07
aviation	1.63 ± 0.58

One NO_x molecule from aviation results
ín an O_3 increase five times as large
as by one NO_x molecule from road transport

Hoor et al., 2009

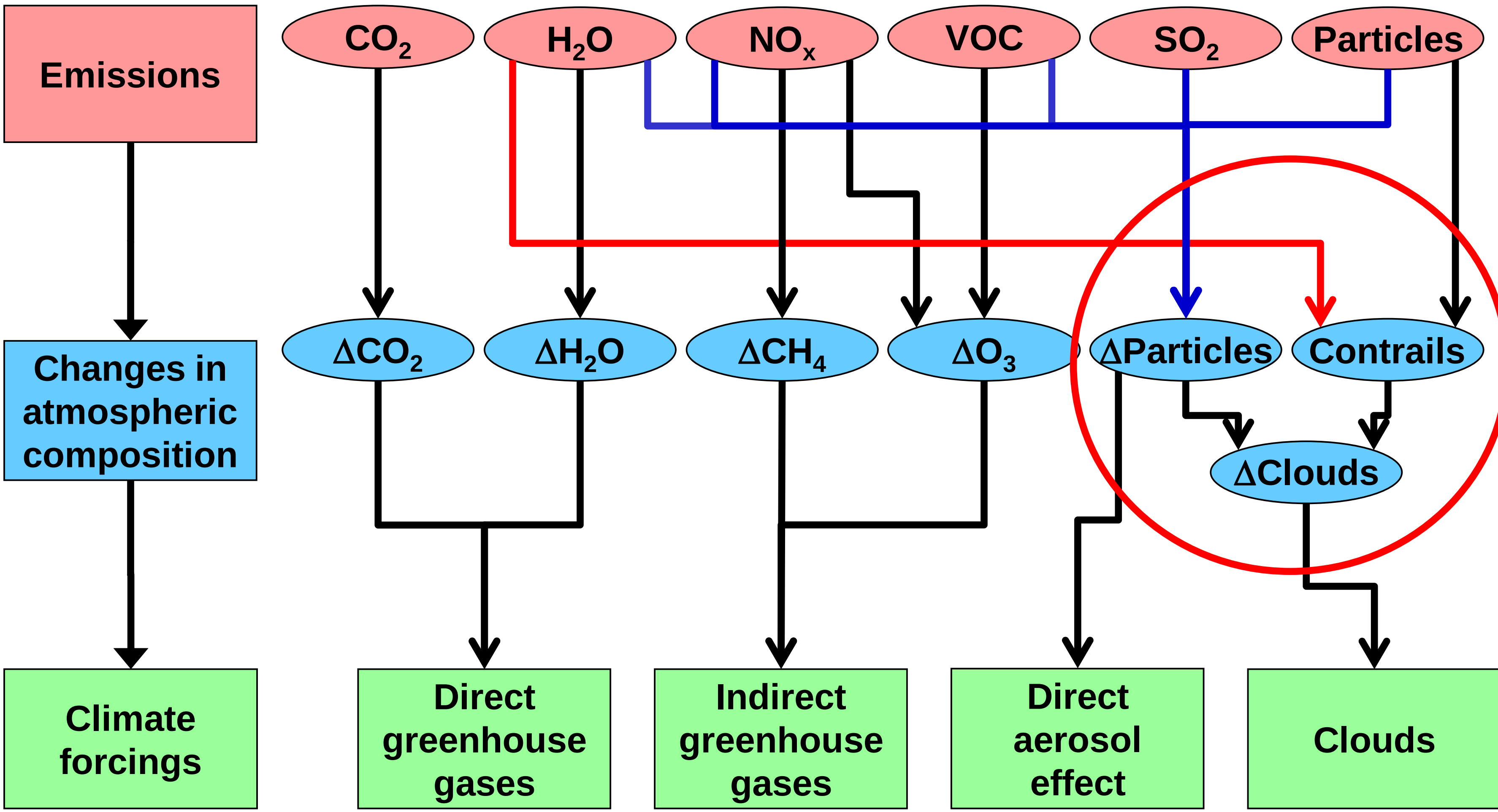
Uncertainties in RF from aviation NO_x

scaled to1 Tg(N)/a



Holmes et al., 2011

Atmospheric effects of emissions from aviation



Aircraft induced cloudiness

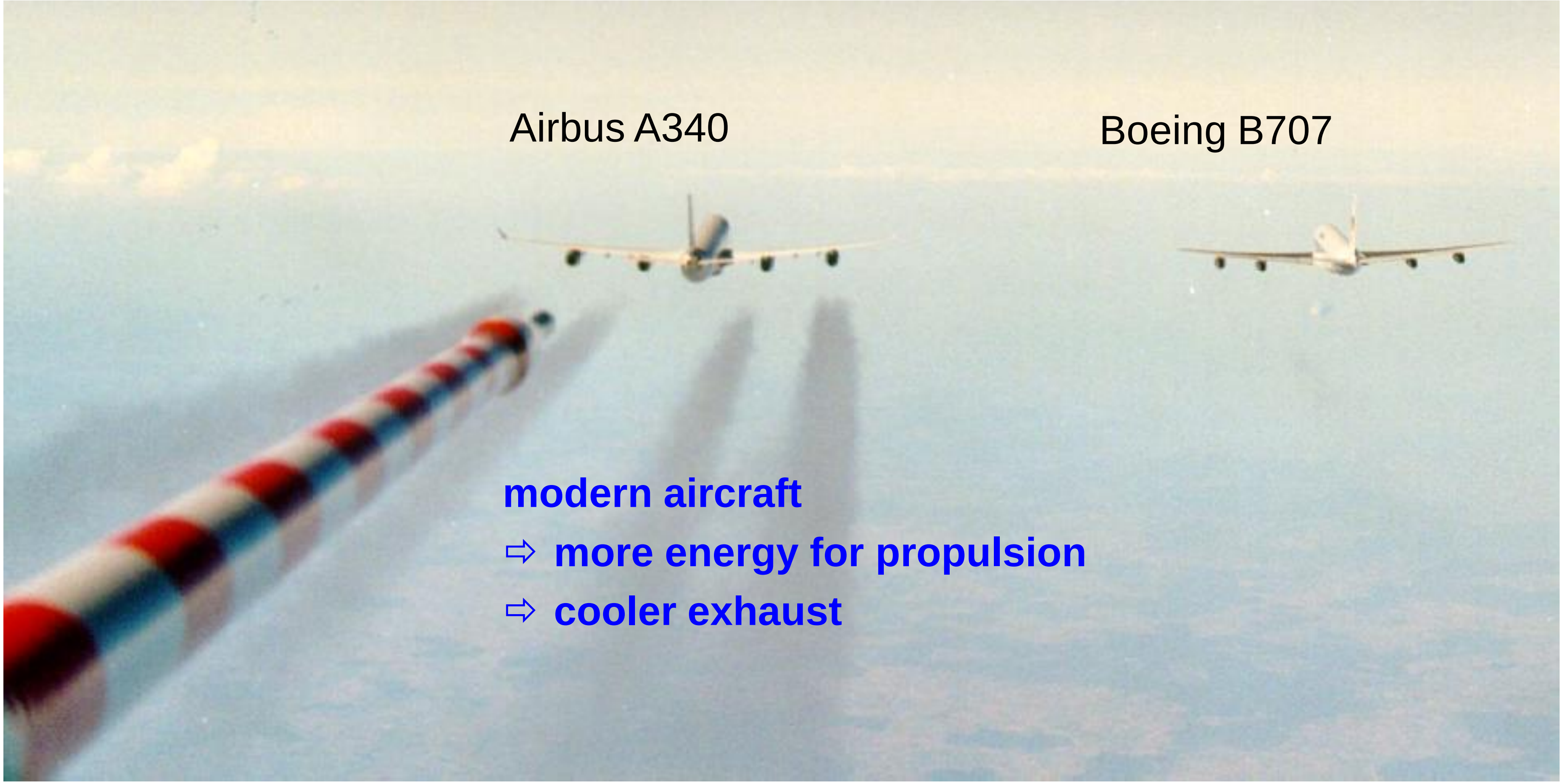
- contrails
- contrail cirrus
- indirect impact on clouds. e.g., soot cirrus

Contrails

- ✈ can by triggered at sufficiently low temperature (Schmitt-Appleman criterion)
- ✈ grow in a sufficiently humid background atmosphere
- ✈ a single contrail can warm or cool (warimng on average)

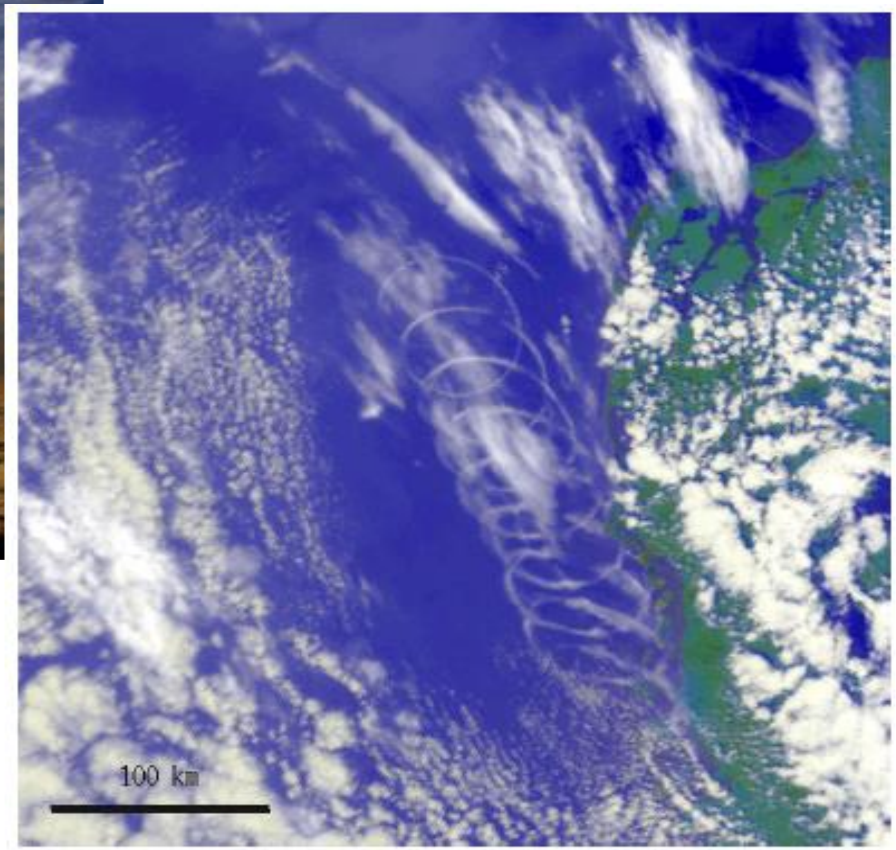
Contrails from old and modern aircraft

altitude 10.5 km (FL 344)

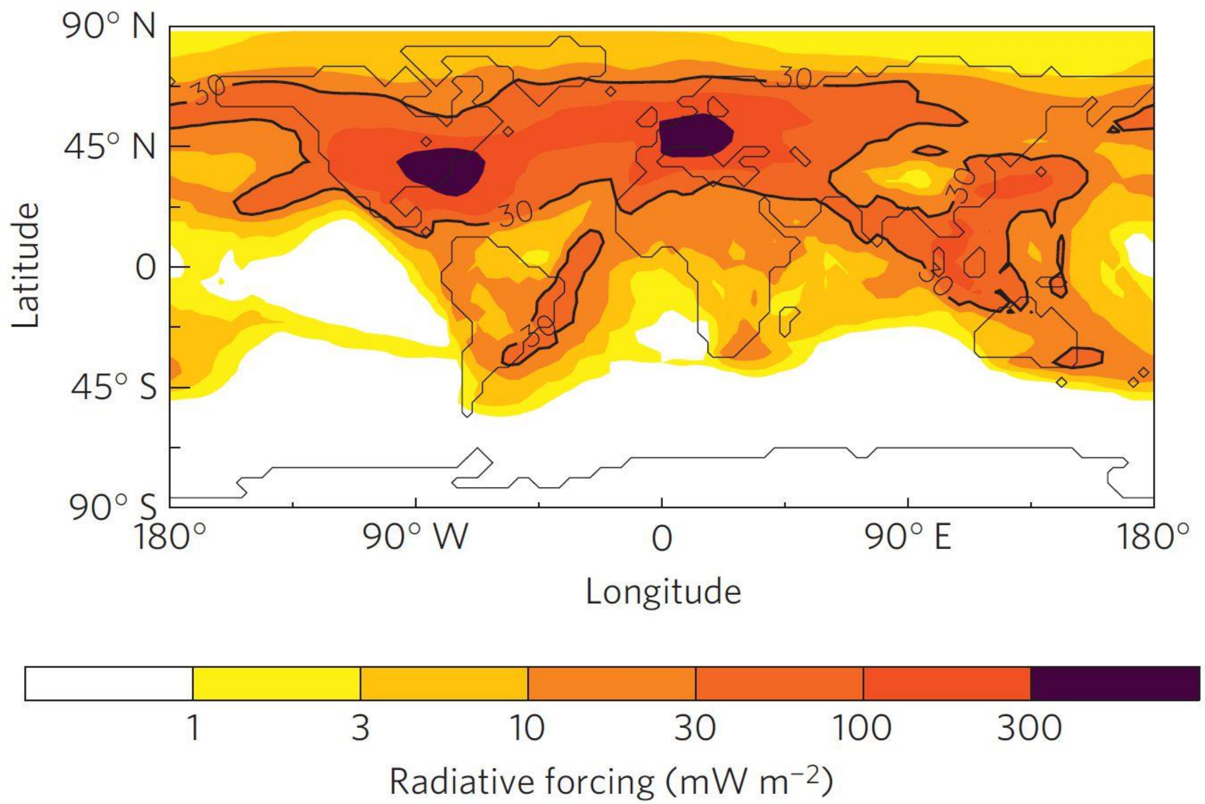


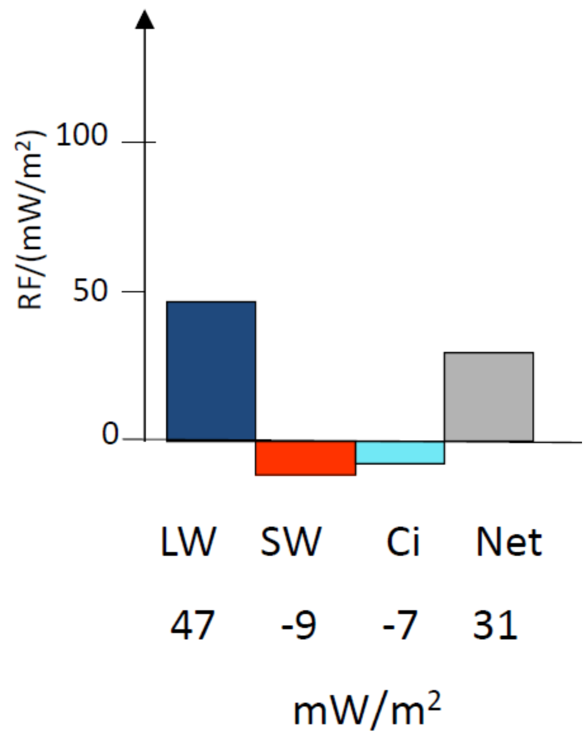
Schumann et al., 2000

Contrails may develop into contrail cirrus (in suitable conditions)



Radiative forcing by contrail cirrus
(linear contrails and longer-lived contrail cirrus)



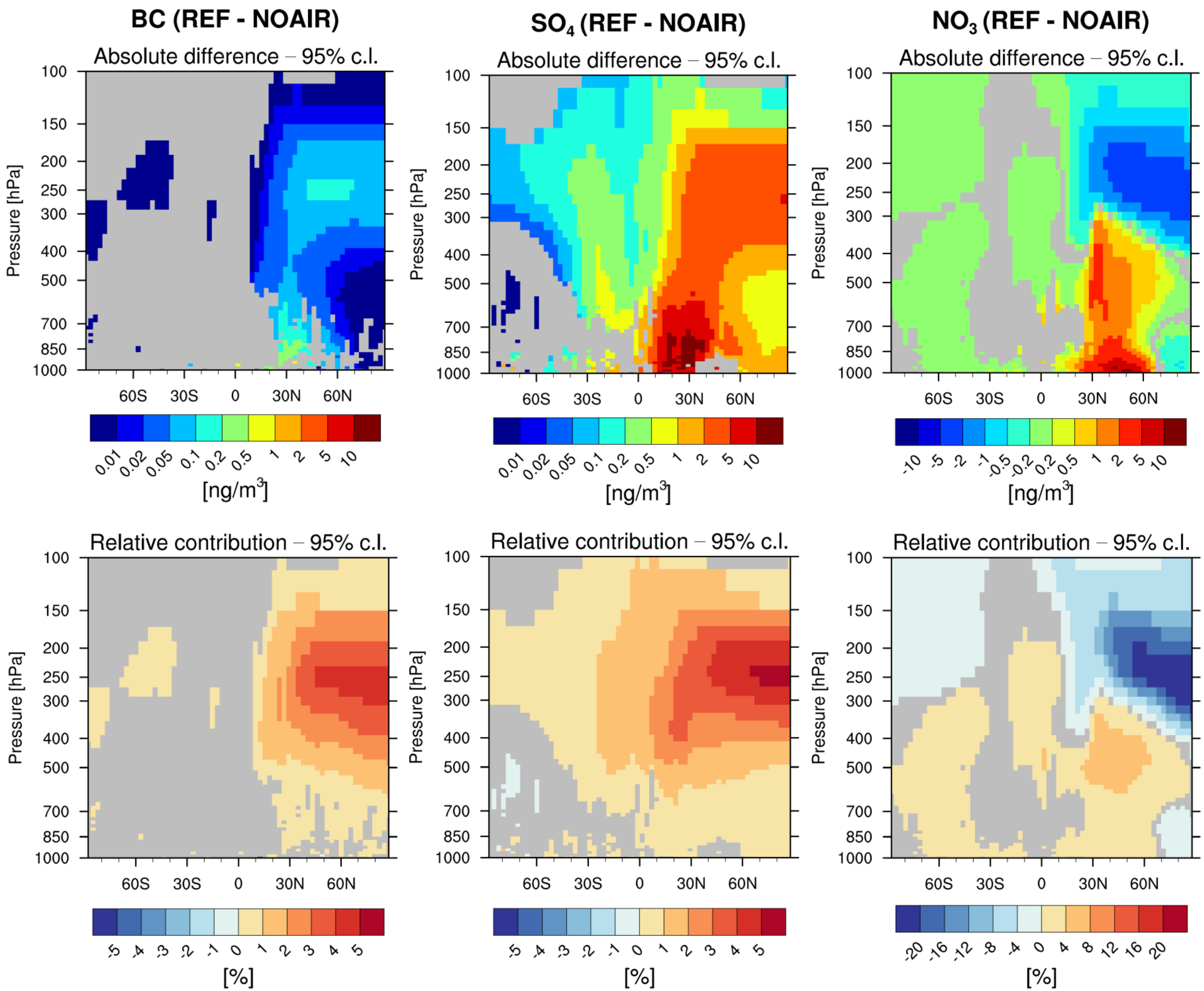


Burkhardt and Kärcher , 2011

Schumann and Graf, 2013: 50 mW/m^2

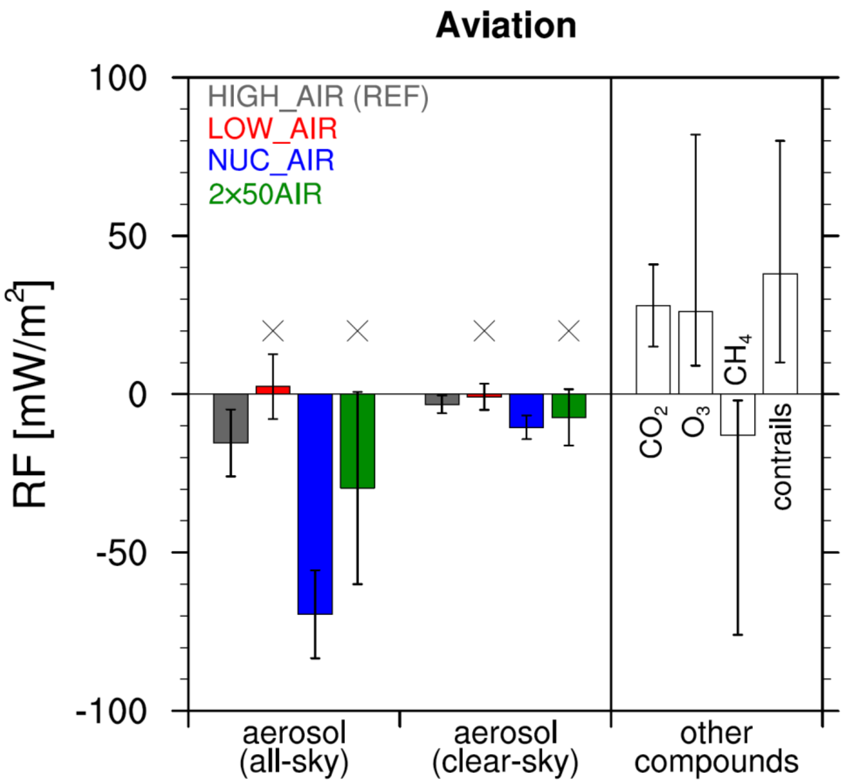
Chen and Gettelman, 2013: 13 mW/m^2

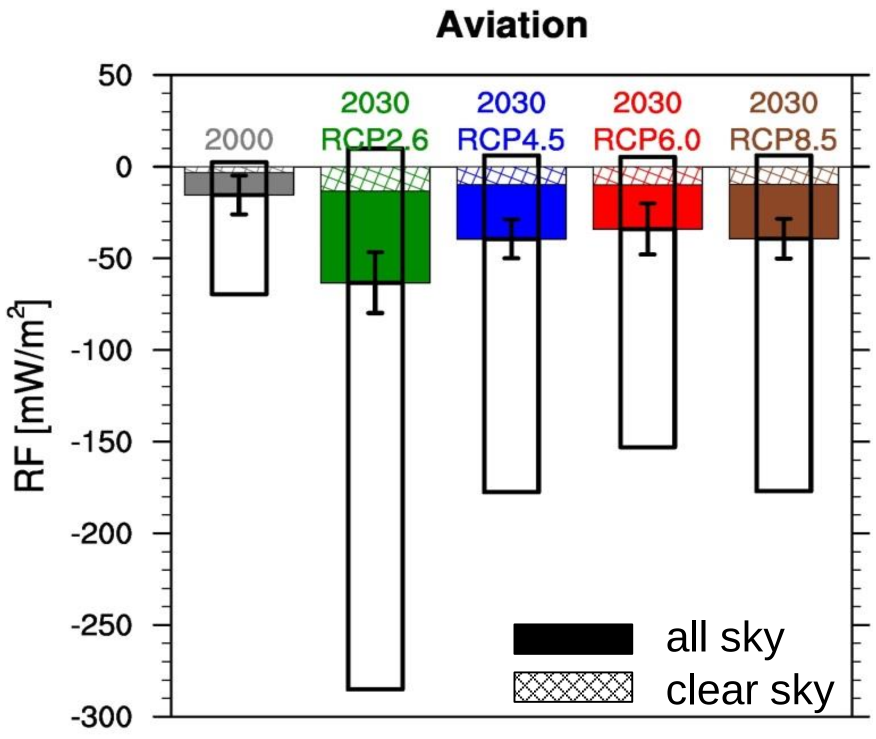
Aerosol load from aviation



Righi et el., 2013

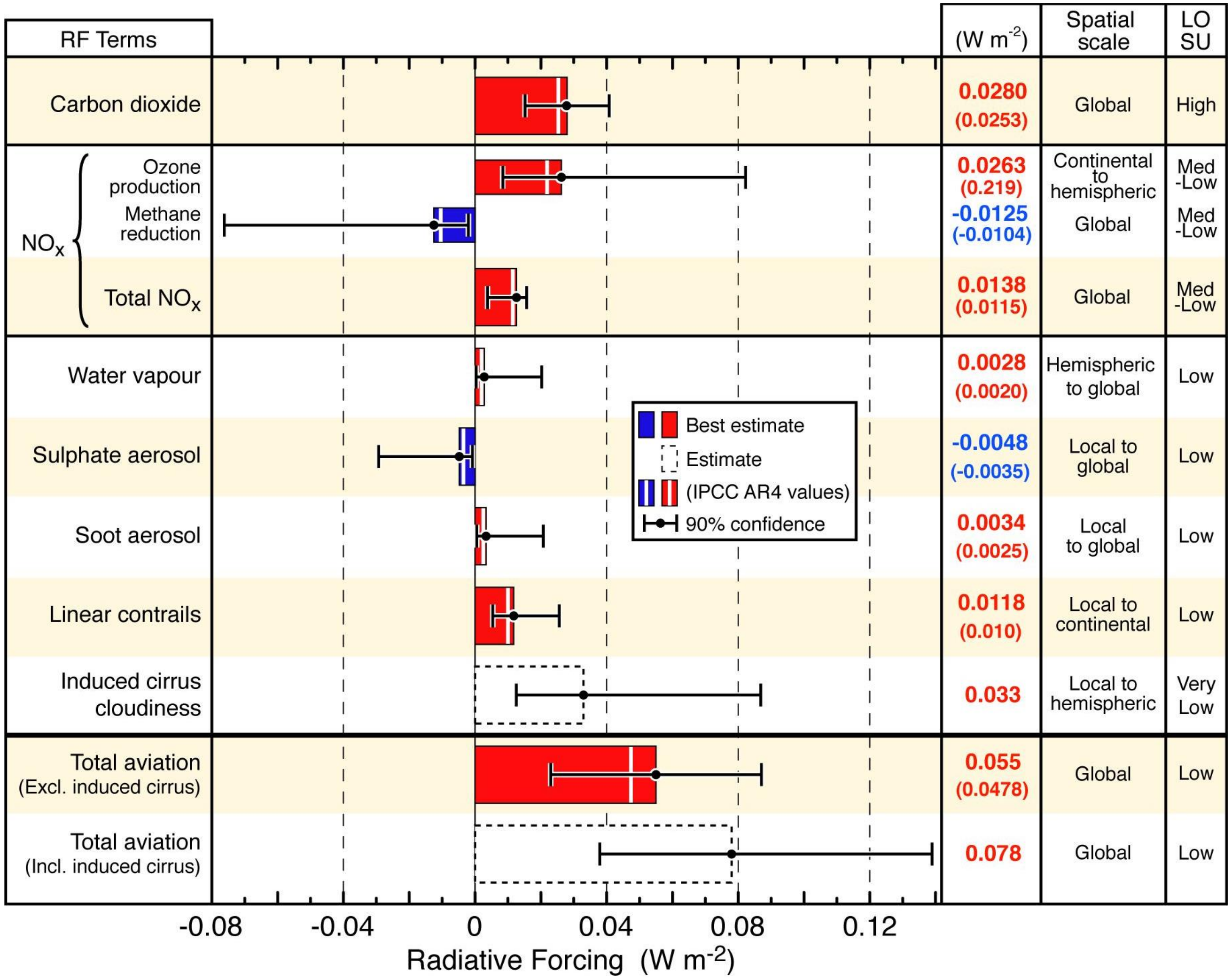
Aerosol-induced RF from aviation





Righi et el., 2013
Righi et al., 2014

Radiative forcing from aviation 2005



$$\Delta T_{surf} = \lambda \cdot RF$$

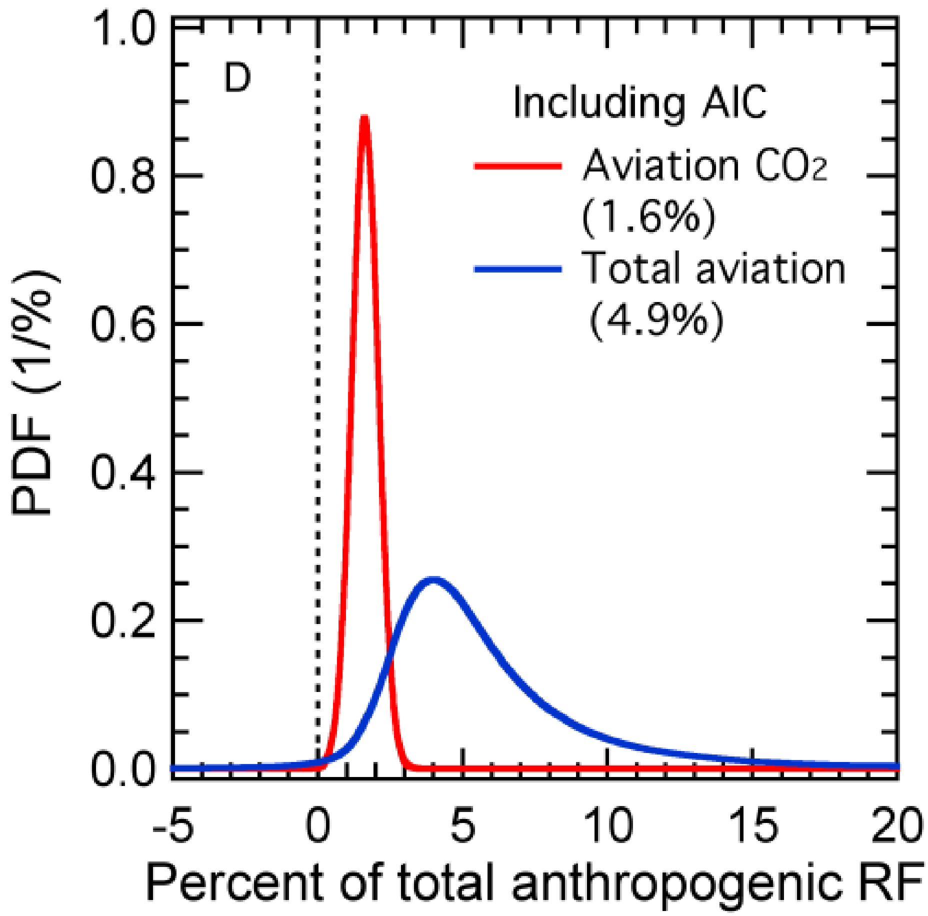
Total anthropogenic forcing 1.6 W/m^2

Aviation fraction:

CO_2	1.6 %
Total	4.9 %

Lee et al., 2009

Aviation contribution to anthropogenic radiative forcing



Lee et al., 2009

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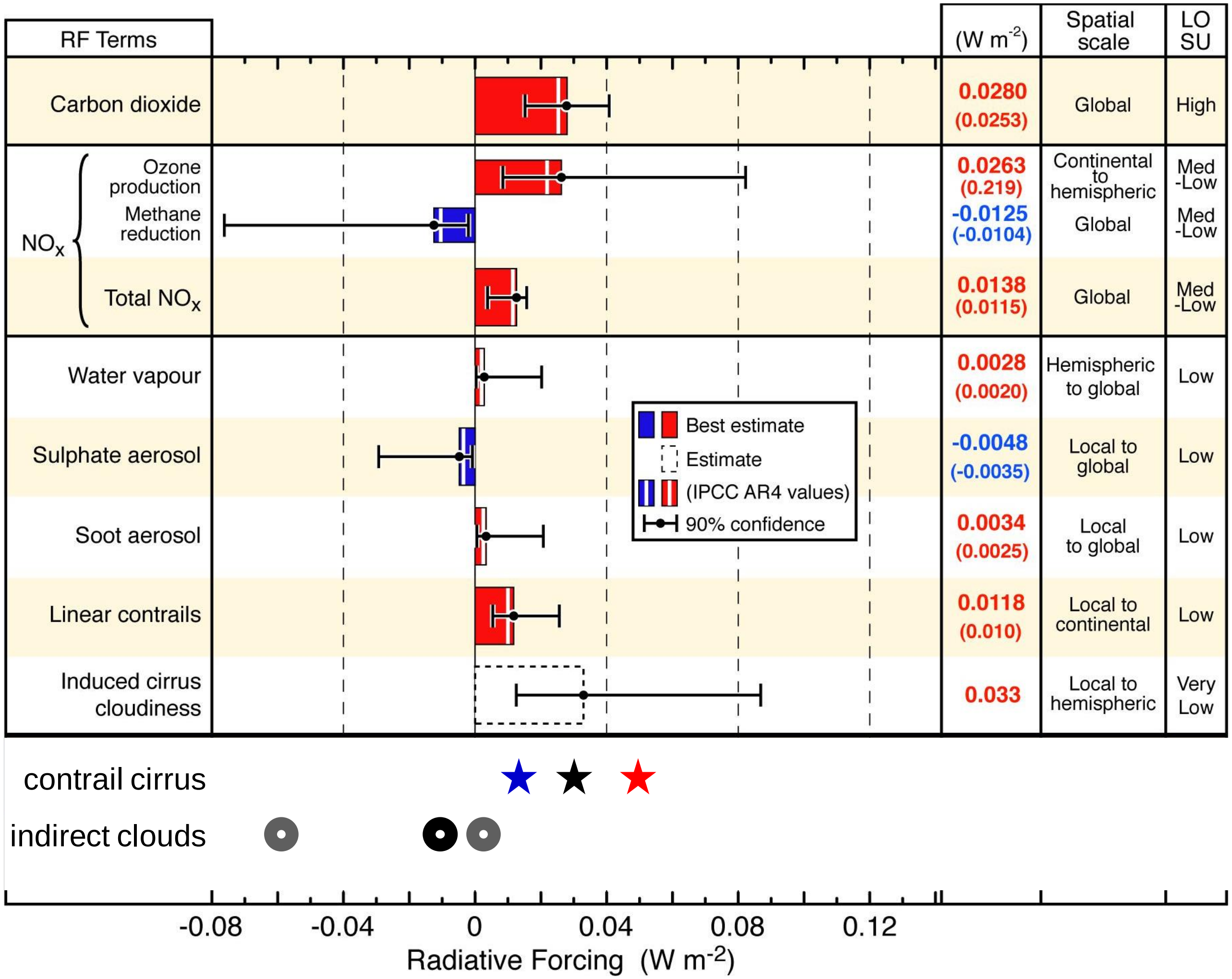

contrail cirrus

★ Chen & Gettelman, 2013

★ Burkhardt & Kärcher, 2011

★ Schumann & Graf, 2013

indirect clouds

reference case

parameter span

Righi et al., 2013

Indirect cirrus effects not considered here.

Conclusions

- Emissions from aviation increase particularly fast, faster than the sum of all anthropogenic impacts.
- RF from aviation-induced CO_2 contributes 1.6% to the total anthropogenic RF.
- RF from non-CO_2 effects are of same order of magnitude than RF from CO_2.
- NO_x effects, contrails and contrail cirrus cause warming.
- Aerosols and indirect cloud effects cause cooling.
- RF from aviation cloud effects is only estimated with very large uncertainty.
- RF from aviation NO_x effects needs to be studied further in order to reduce the uncertainty.
- RF from all aviation effects contributes about 5% to the total anthropogenic RF.

Final remarks

The climate impact of the aviation-induced non-CO_2 effects depends on the actual weather situation, and on the time, geographical location and altitude of the emissions.

⇨ The climate impact from aviation non-CO_2 emissions can be substantially reduced by eco-efficient flight trajectories, at the expense of higher operational costs if using today's aircraft.

   ⇨ However, operational costs can be reduced with aircraft adapted for eco-efficient flight trajectories.