Impact of aviation on climate change
- Mitigation options

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Outline

- Climate change happens!
- Physics and observations are basically understood.
  ⇒ I skip this part ….
- Physics and chemistry of air traffic emissions are also basically understood, except for the effect of aerosols on clouds.
  ⇒ I skip this part …
- Short review on emissions from air traffic and their impact on climate.

  ⇒ **More research on the assesment of mitigation options**
- Overview on results from projects aiming at minimizing the climate impact of air traffic by
  - Changes in aircraft design general flight profiles and
  - Utilizing weather situation / avoiding climate sensitive regions.
- Summary

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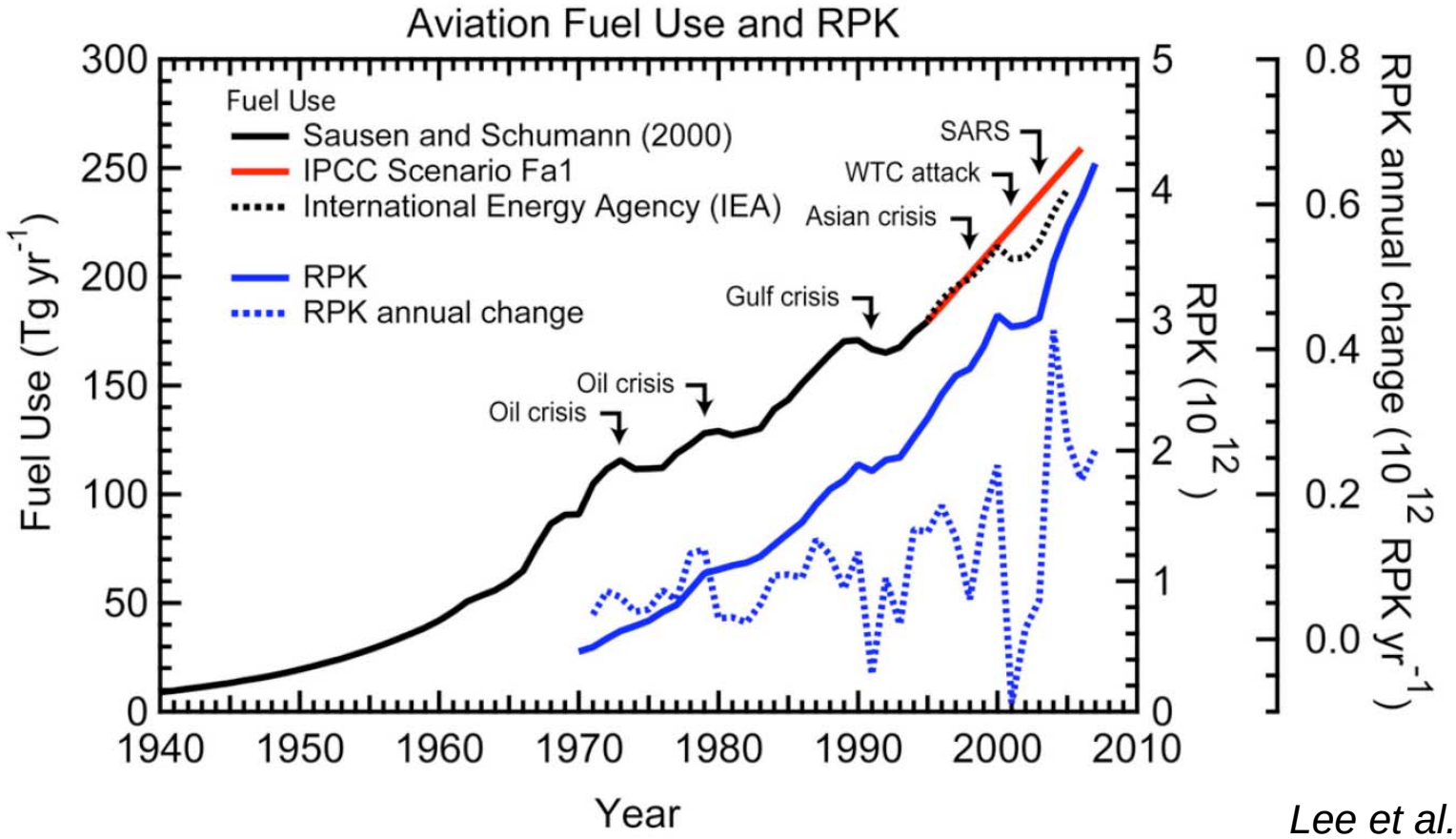
Evolution of air traffic 1940 to 2008



Lee et al., 2009

More than linear increase in transport demand
Crises reduce air traffic for a short time period.

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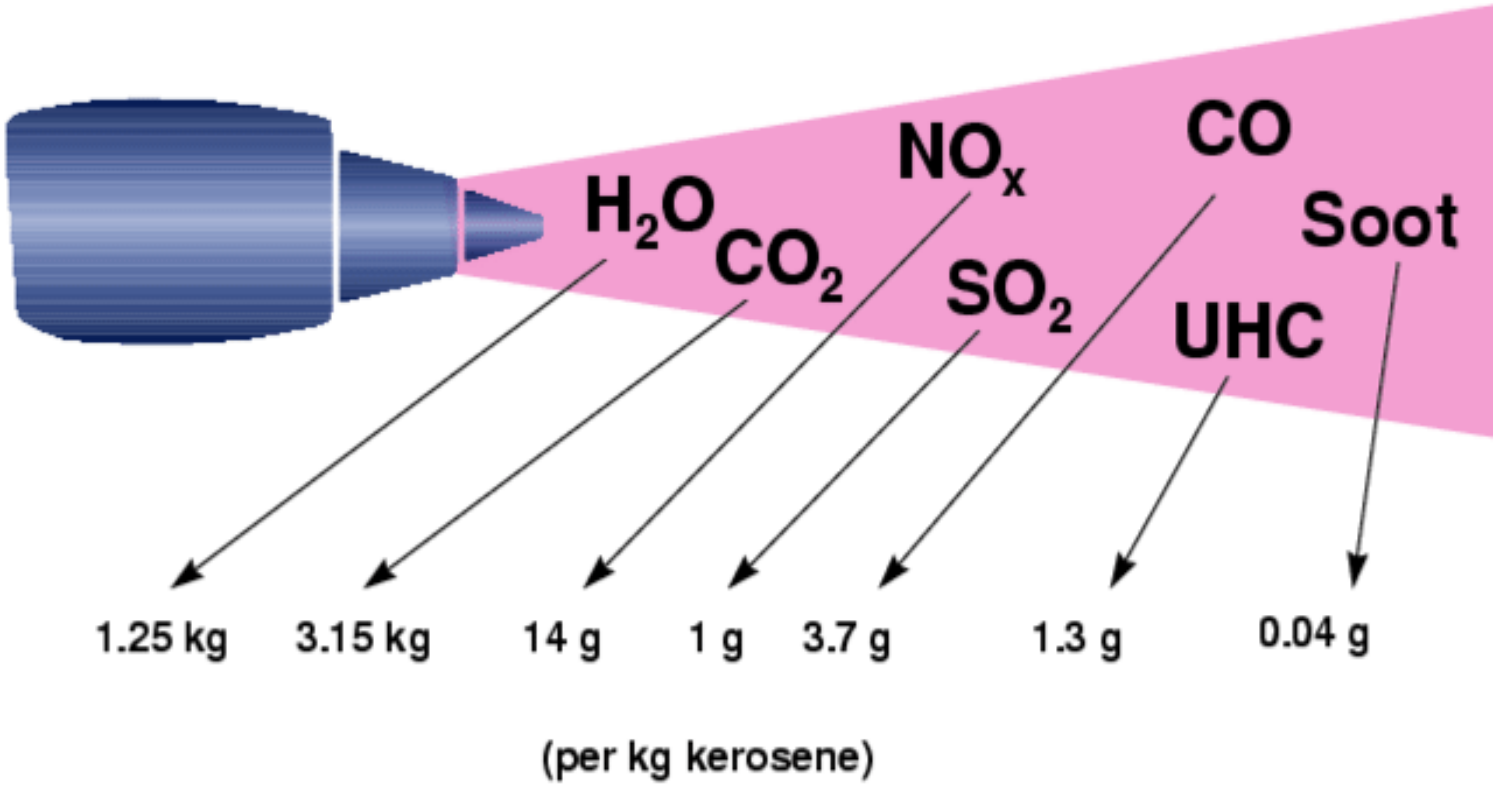
Air traffic emissions

Combustion products
- depending on operating conditions
- at cruise altitude



(per kg kerosene)

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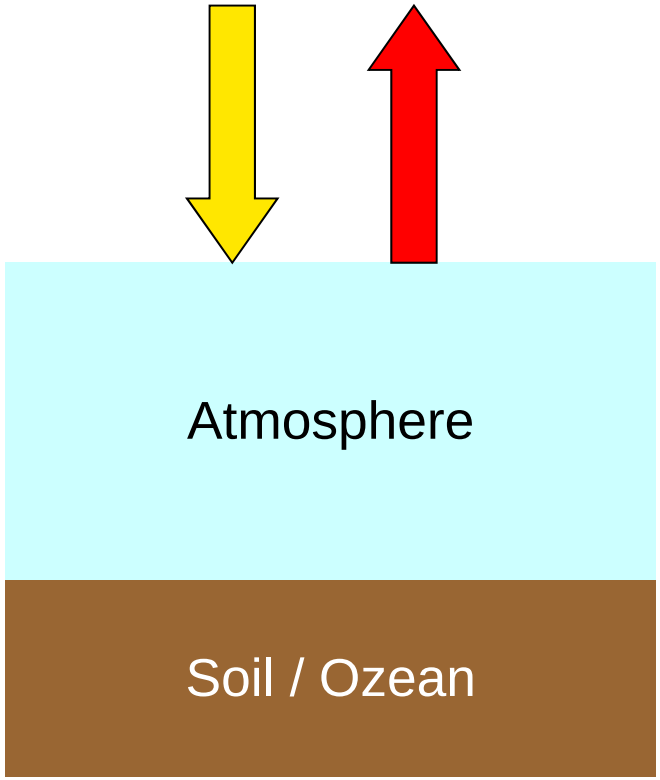
What is Radiative Forcing? (simplified)

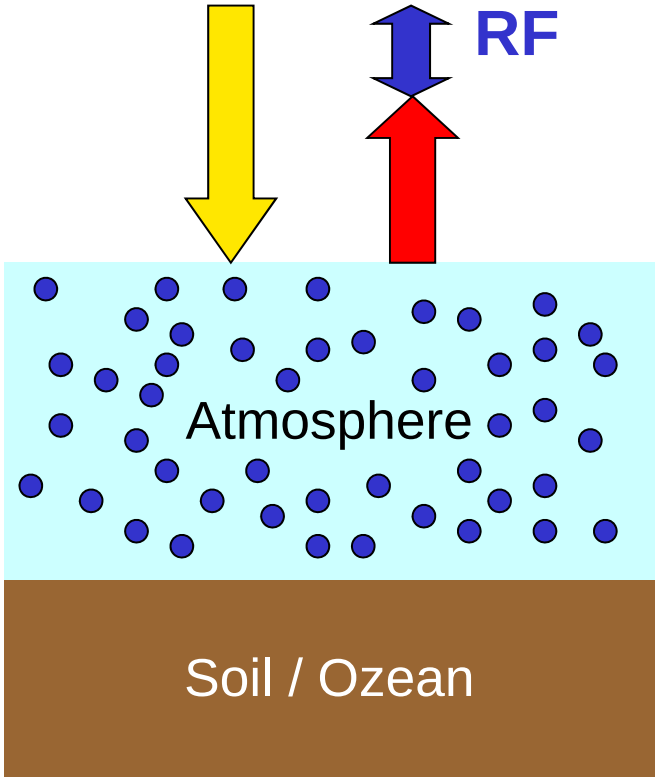
Steady-State

$RF = 0$



Perturbed situation

$RF > 0$ ➔ ΔT ⇗



Why is Radiative Forcing a frequently used concept?

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

Global mean temperature (steady-state)

Radiative Forcing

Climate sensitivity parameter

- Concept works well for well-mixed greenhouse gases, e.g. CO_2
- More difficult for, e.g., ozone, since the location of the perturbation matters

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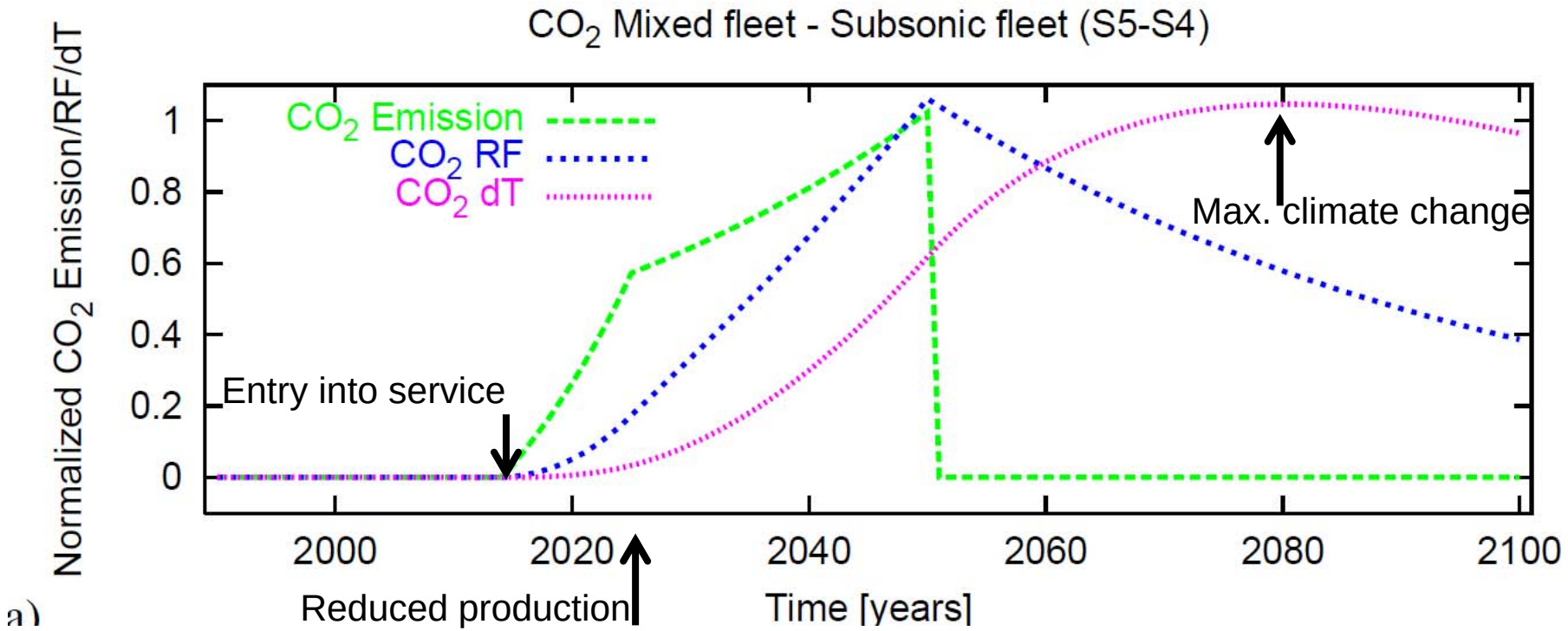
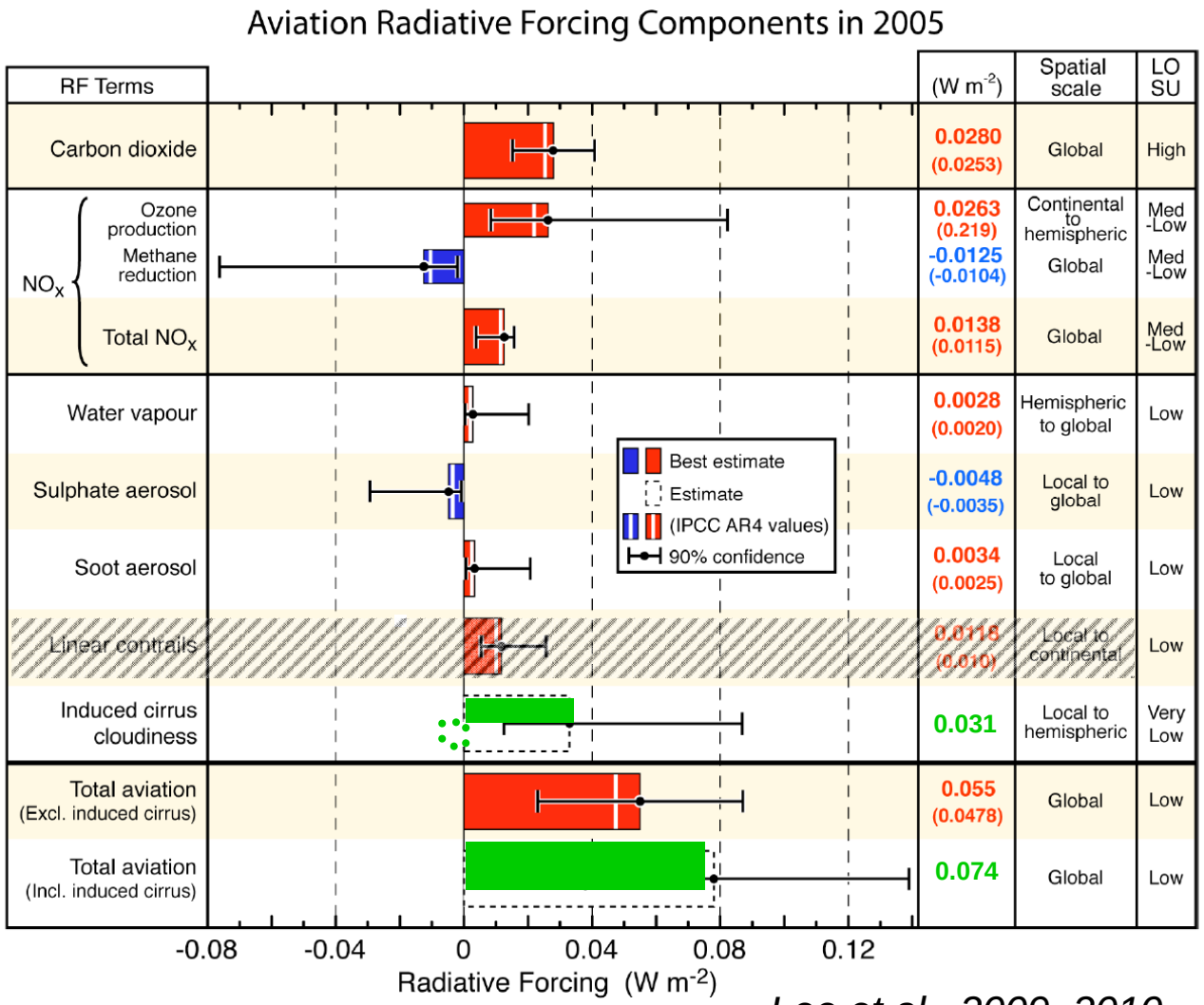
Difference between Emission, RF, and dT (Thought experiment)



Grewe and Stenke, 2008

Climate impact of current air traffic (2005)



Lee et al., 2009, 2010

updated with Burkhardt&Kärcher, 2011

Main contributors:

-Contrails

-CO_2

-NO_x

3.5-5.0% of warming attributed to air traffic

ACARE, 2008

The findings of the IPCC point very clearly to the need to do something but there are areas of detail where more understanding is needed.

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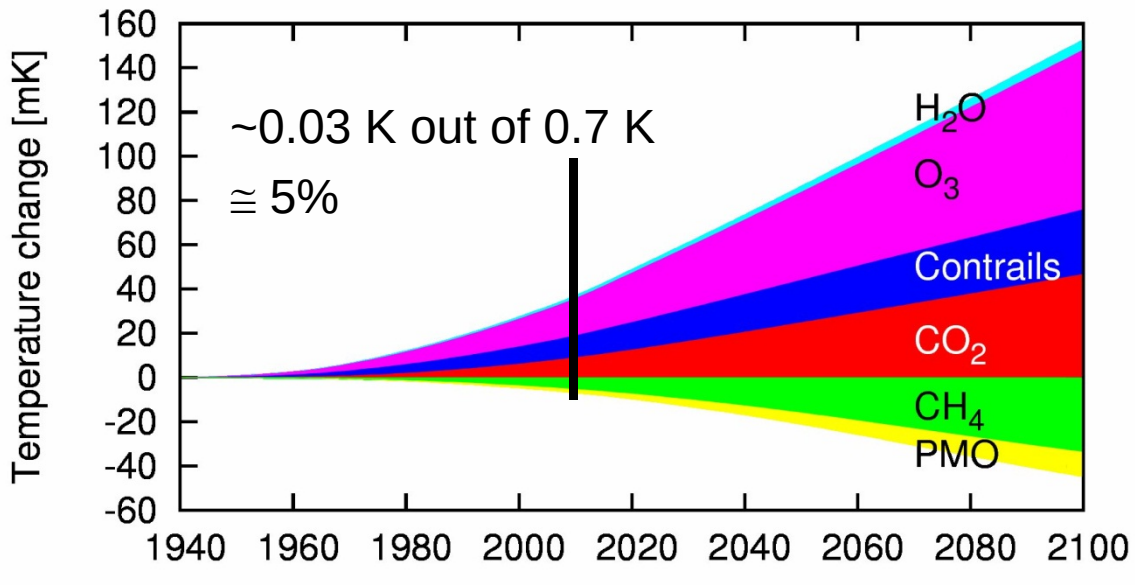
Climate change induced by air traffic = 5% of anthropogenic climate change

Climate change induced by air traffic caused by moderaten increase of air traffic

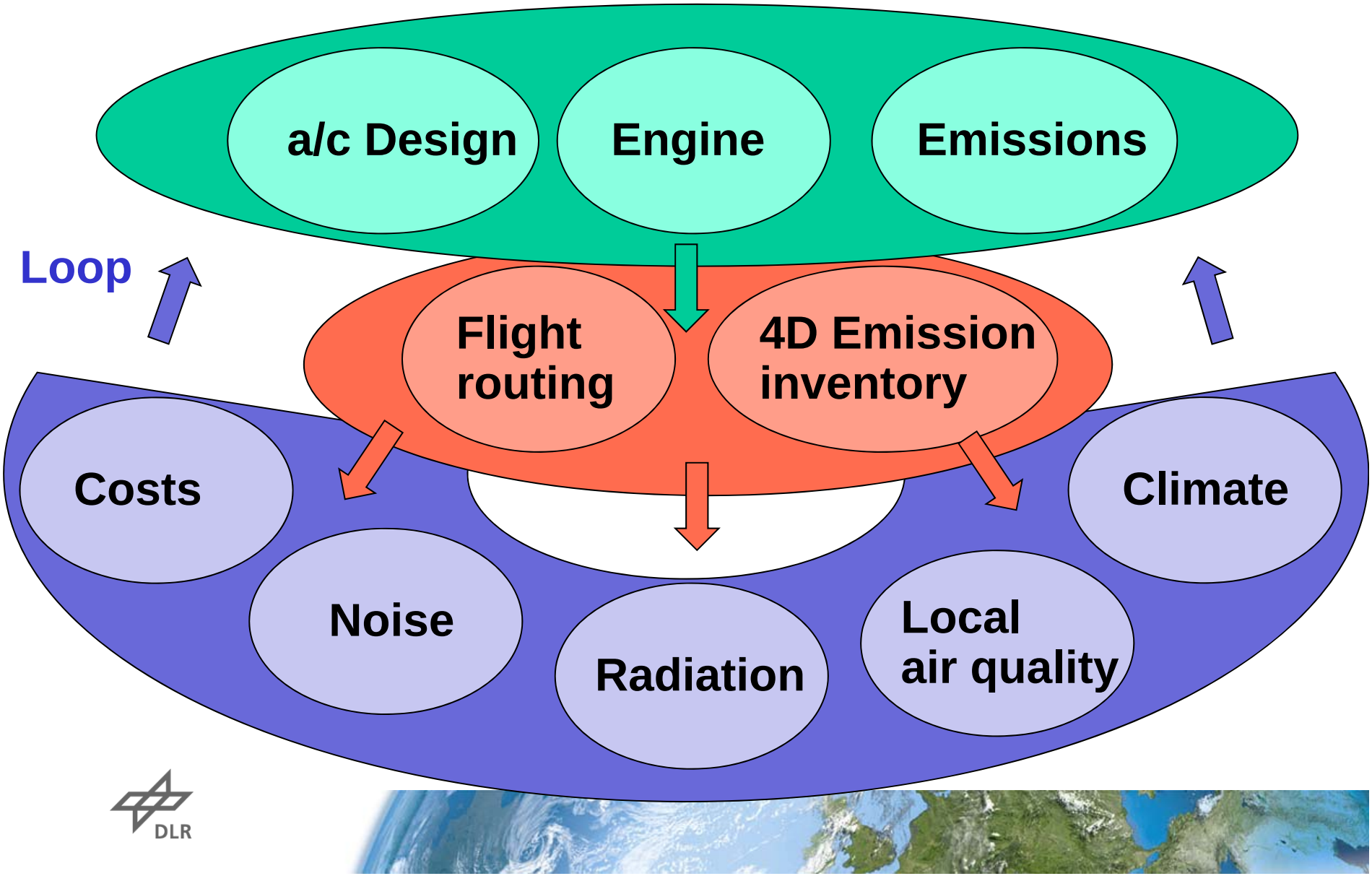


Main contributors:
-Contrails
-CO_2
-NO_x

Order different from RF for various reasons:
- Efficacies
- Temperature reacts with delay

Temperature matters not RF!

What kind of modelling approach is needed to assess the climate impact of new a/c technologies?



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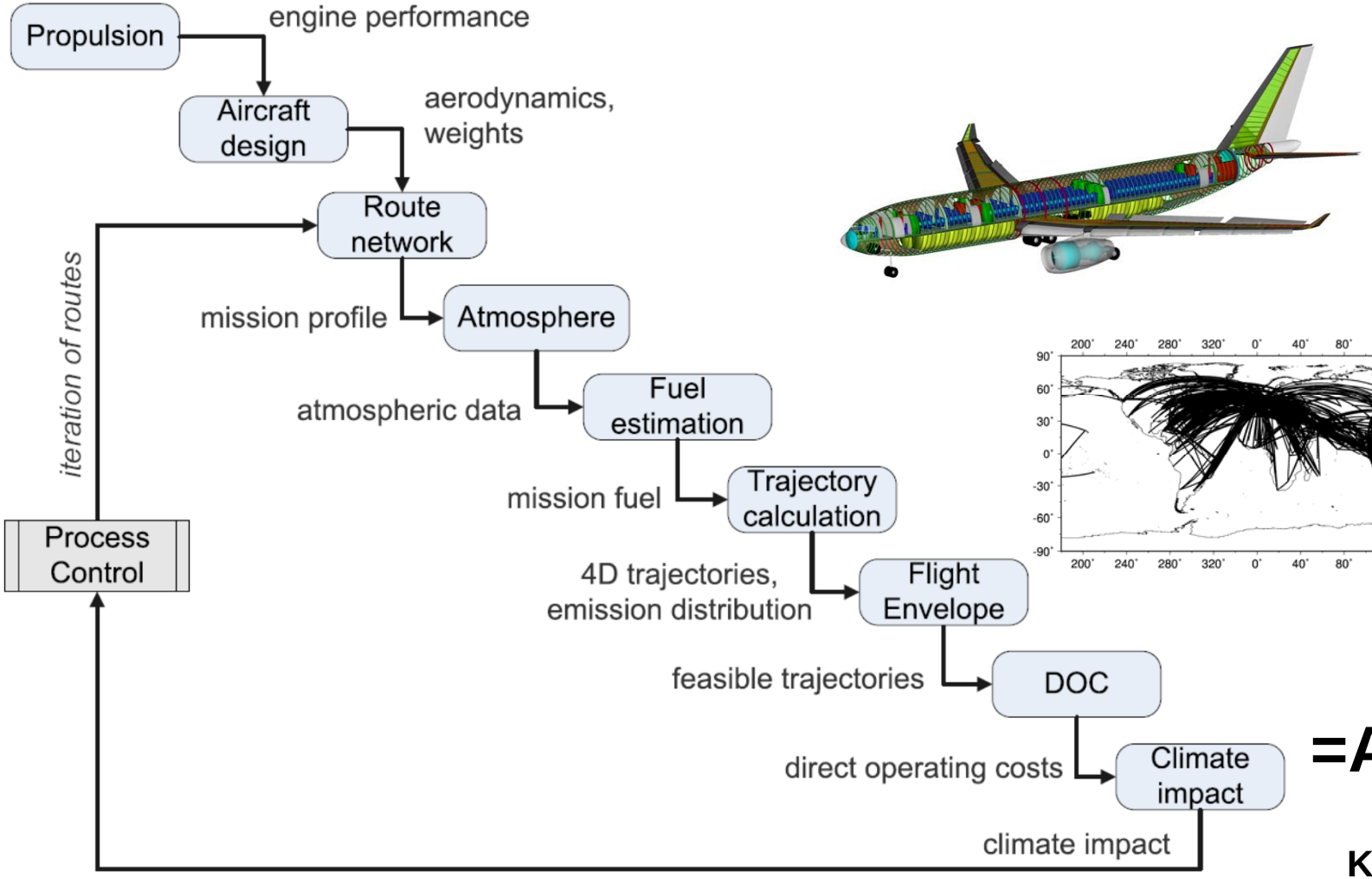
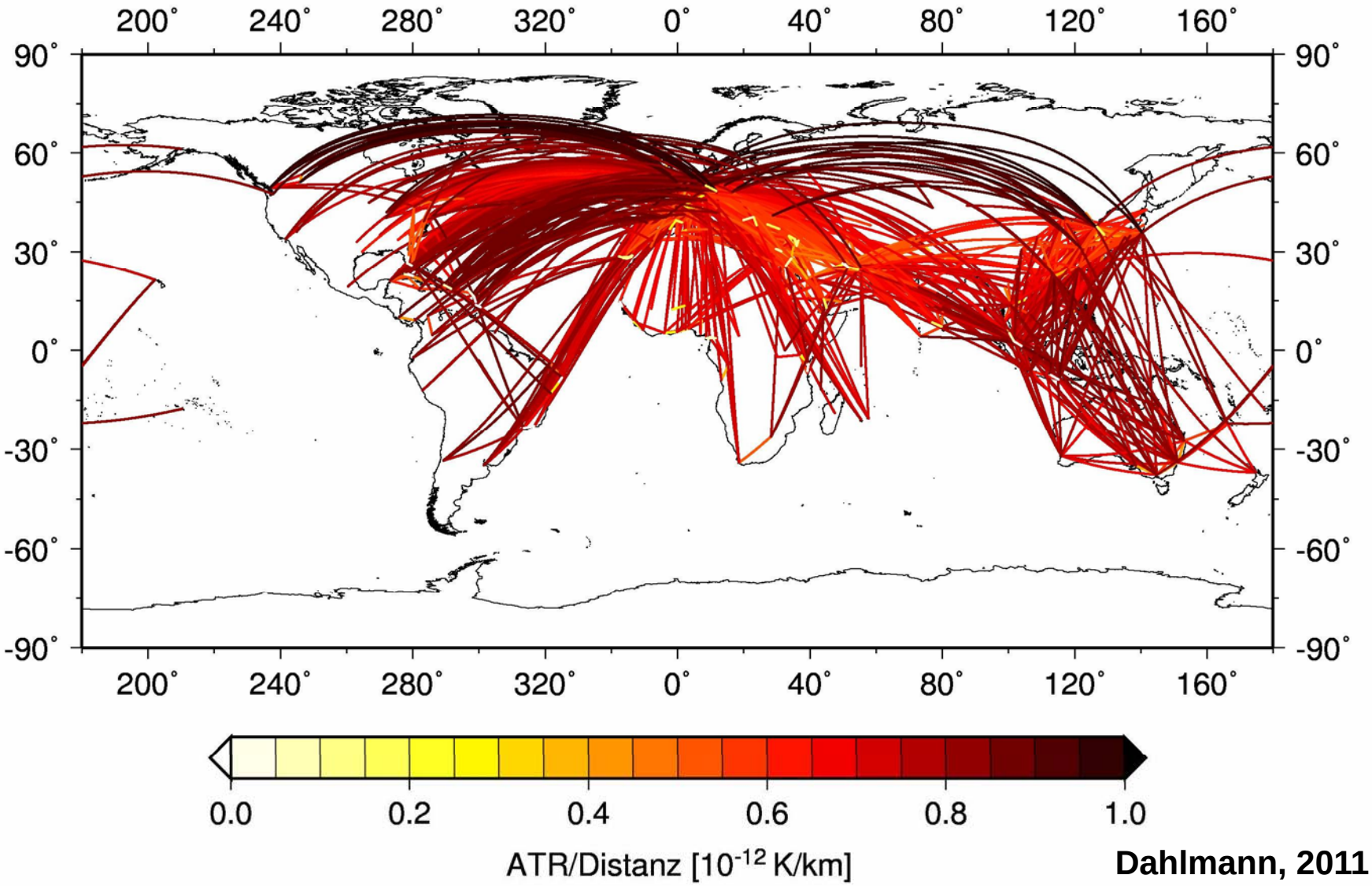
DLR-Project CATS:
Climate Compatible Air Transport System
Focus on a long-range aircraft



=AirClim

Koch et al., 2011

Specific "Global warming" [K/km] induced by individual routes



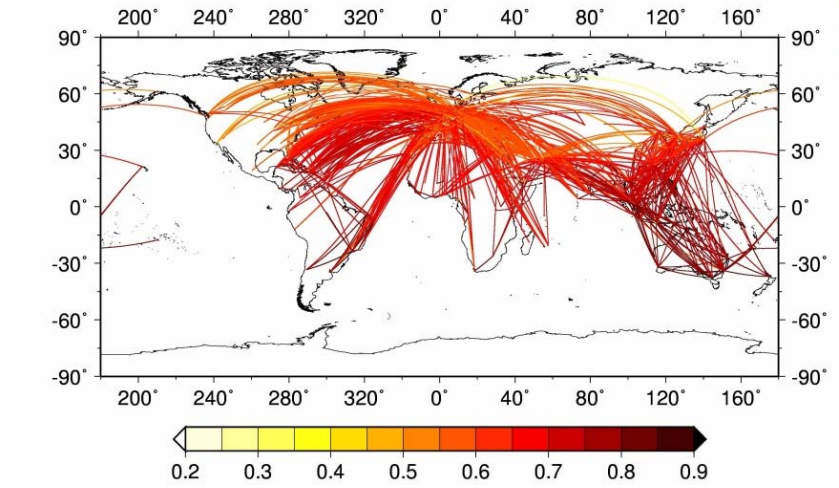
Dahlmann, 2011

A330: Potential of a climate change reduction: CATS-results

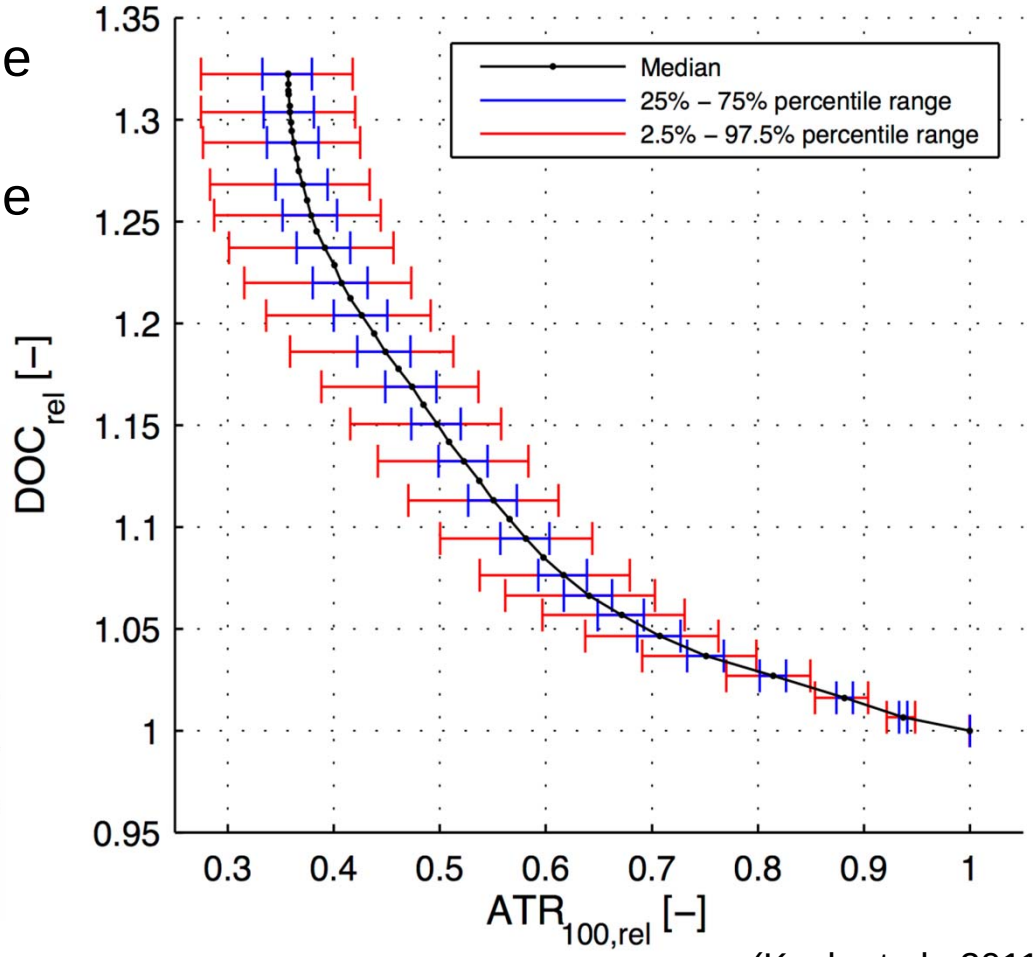
Variation in speed an cruise altitude

30% Reduction in climate change with 5% increase in costs

64% Reduction in climate change with 32% increase in costs (w/o adaption of aircraft)



(Dahlmann, 2012)



(Koch et al., 2011)

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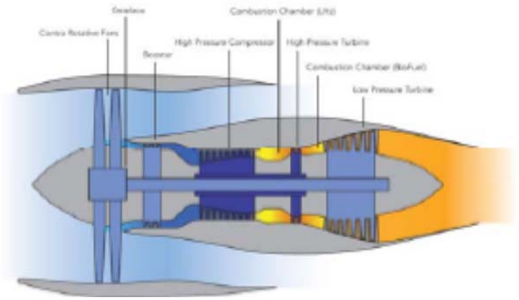
AHEAD Advanced Hybrid Engines for Aircraft Development
(lead by TU Delft)



Fuel-efficient Blended Wing Body (BWB)

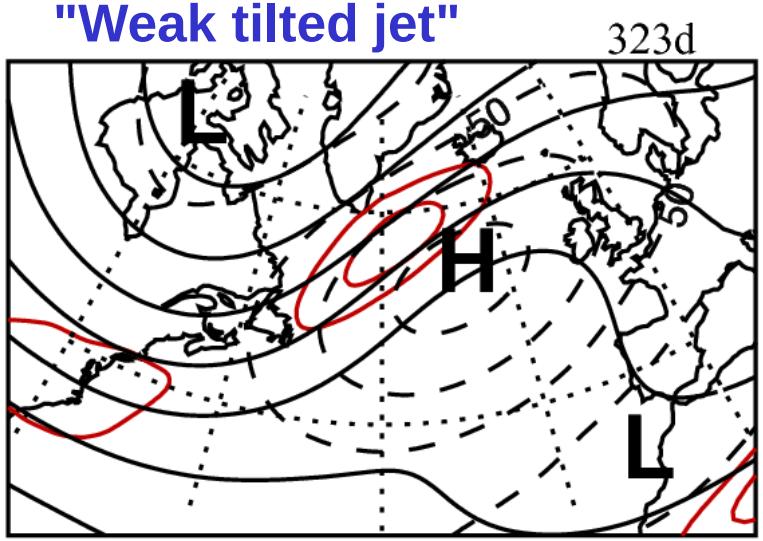
DLR-Contribution: Estimate of
- Contrail characteristics
- Overall climate impact AirClim

EU-Project REACT4C

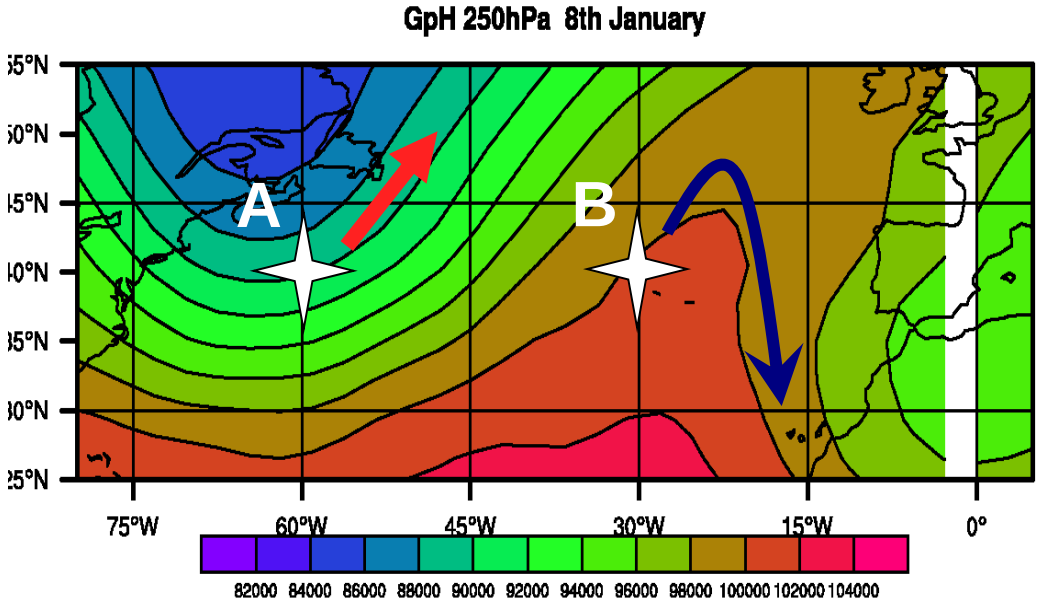
Investigated weather situation: Evolution of aircraft NO_x

Weather type #3

"Weak tilted jet"

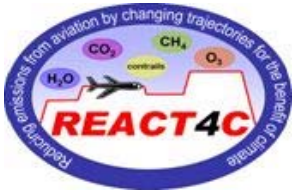


Actual modelled weather: 8th January



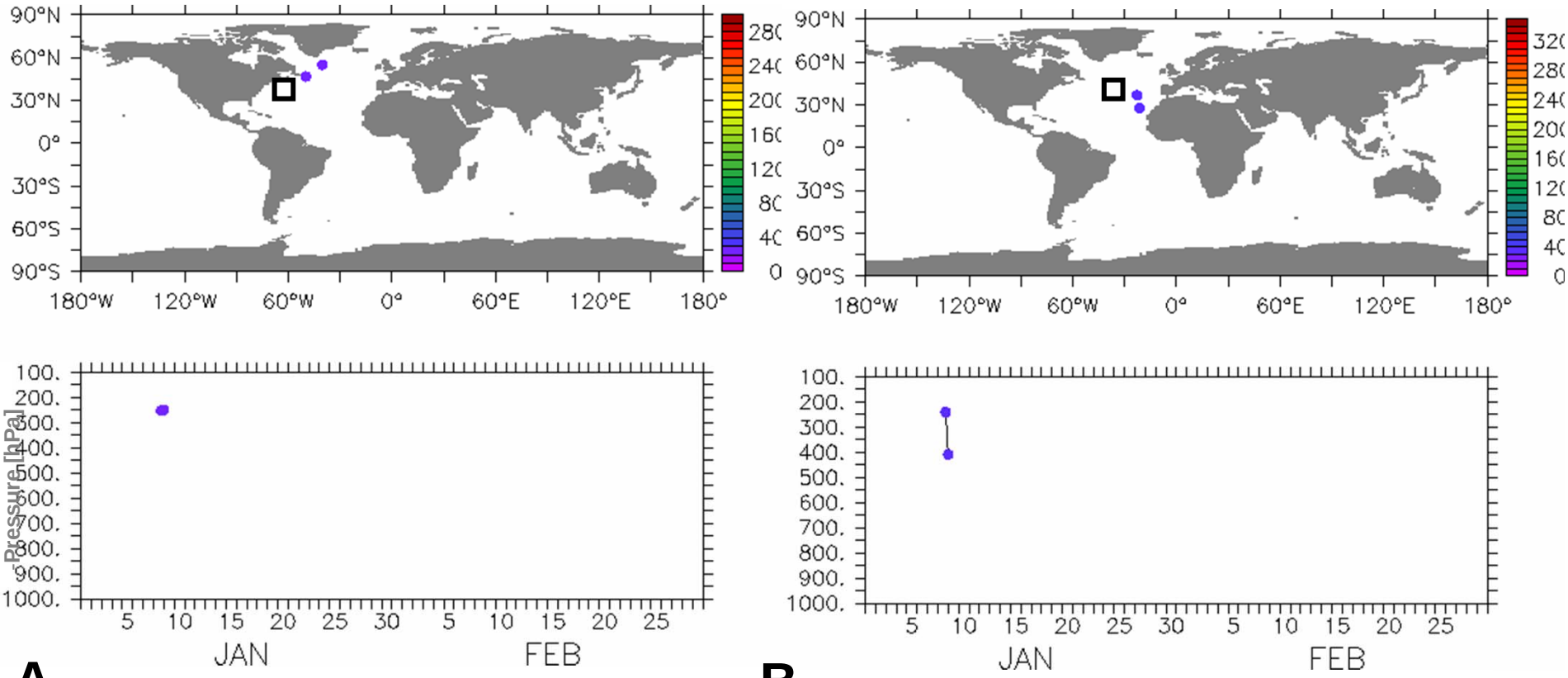
- What happens if an aircraft emitts NO_x at location A compared to location B?
- Where do contrails form?
- What is the impact on radiation?
- What is the expected change in temperature?

Evolution of O_3 [ppt] following a NO_x emission at different locations

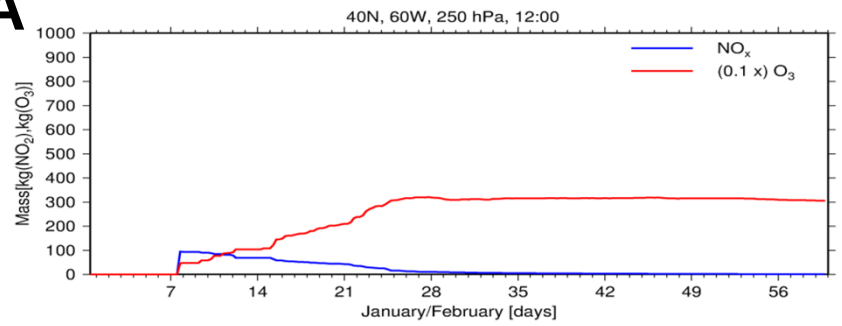


-A: 250hPa, 40 N, 60W, 12 UTC

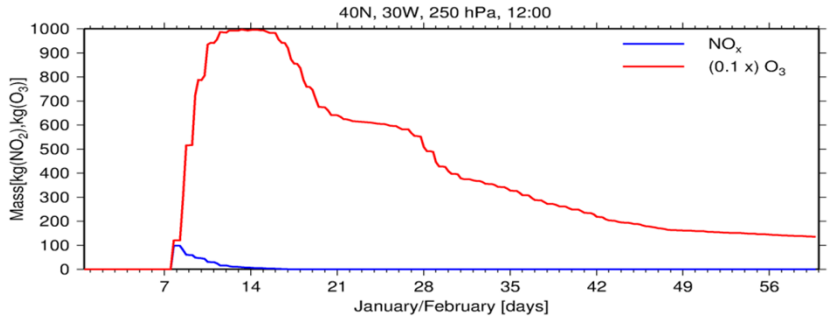
-B: 250hPa, 40 N, 30W, 12 UTC



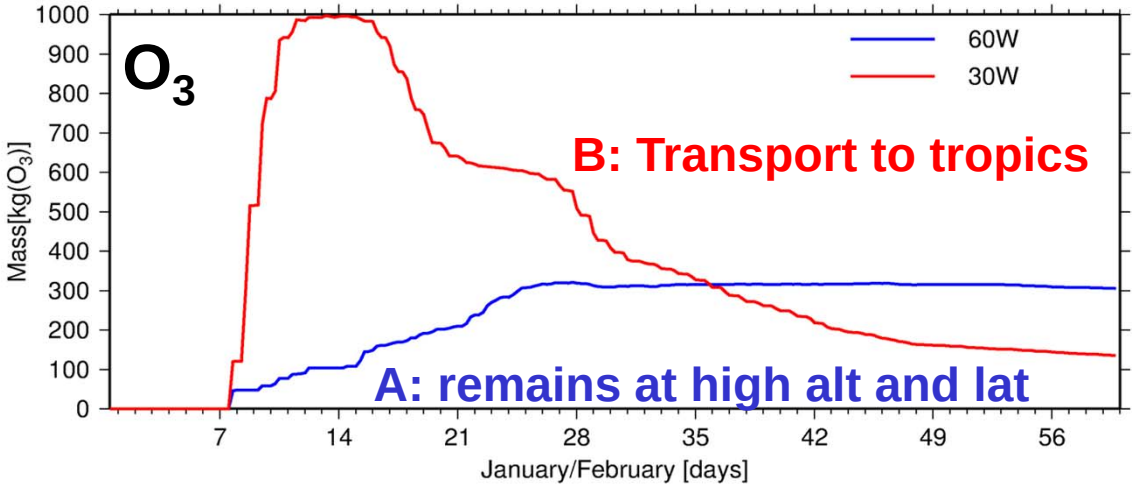
A

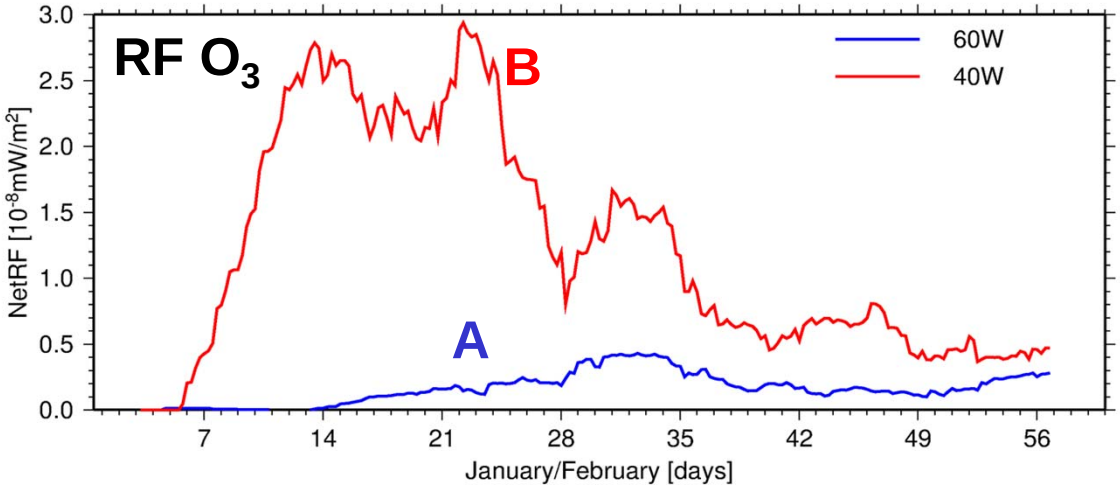


B



O_3 and associated RF for emissions at 250 hPa, 40N, 60W / 30W





⇨ **Big difference between in impact on climate between A and B**

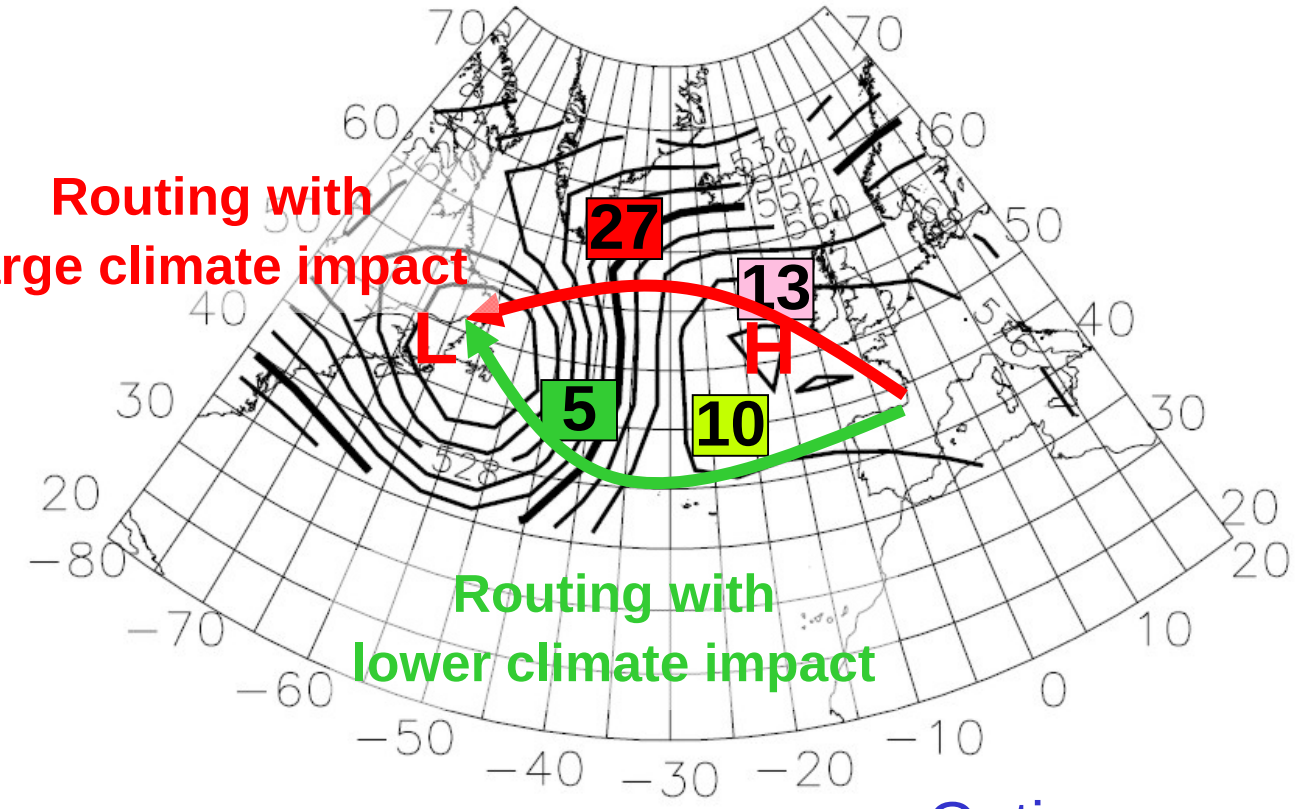
⇨ **Here ~1 order of magnitude**

⇨ **2 orders were the maximum variability**

⇨ **= Mitigation potential**

Mitigation Option: Climate optimised routing

Impact of an emission at t=9:15 UTC at various locations



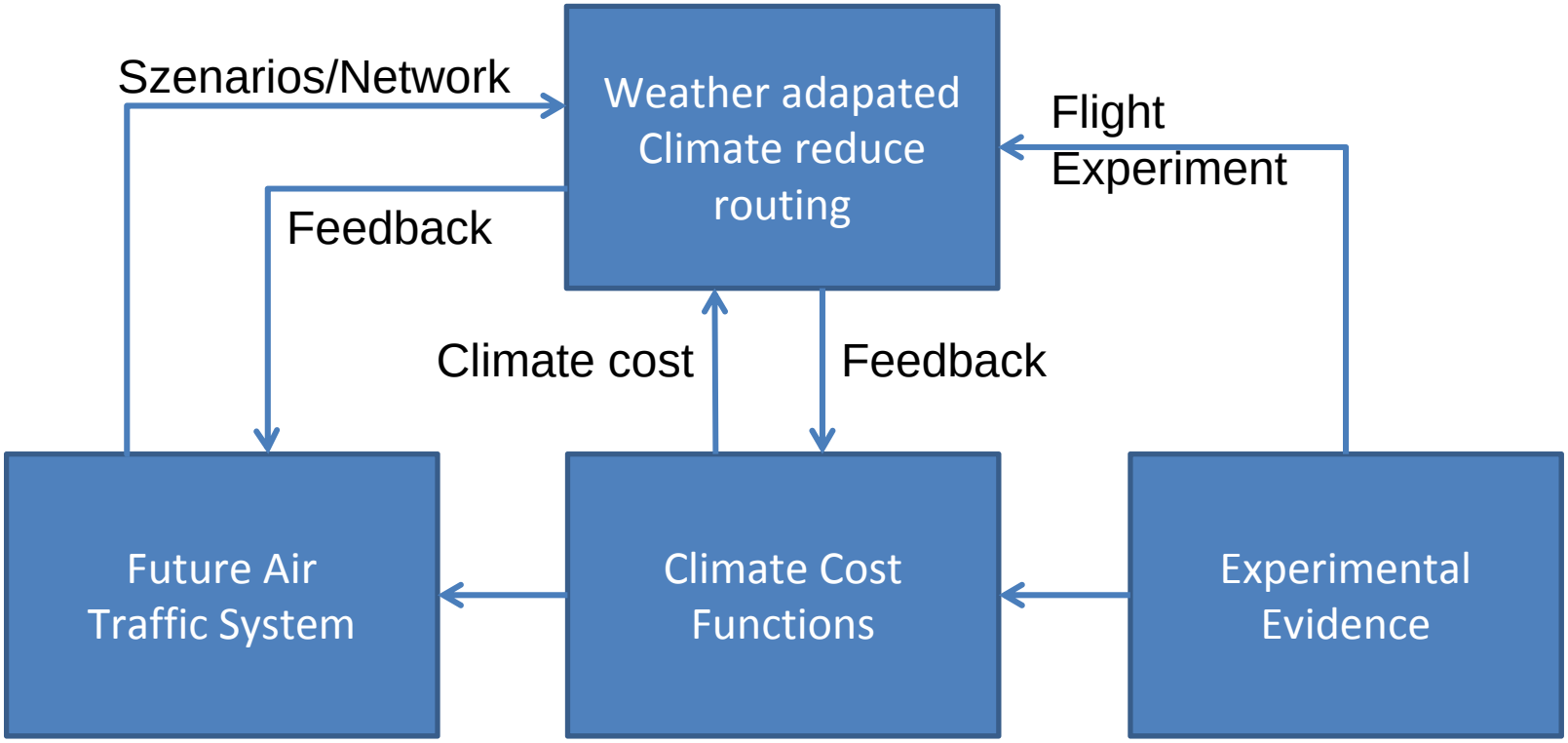
Cost function calculated for
- CO_2
- Ozone
- Methane
- Contrail-Cirrus

in Kelvin per fuel
or
Kelvin per flown distance

Options:
vertical + horizontal

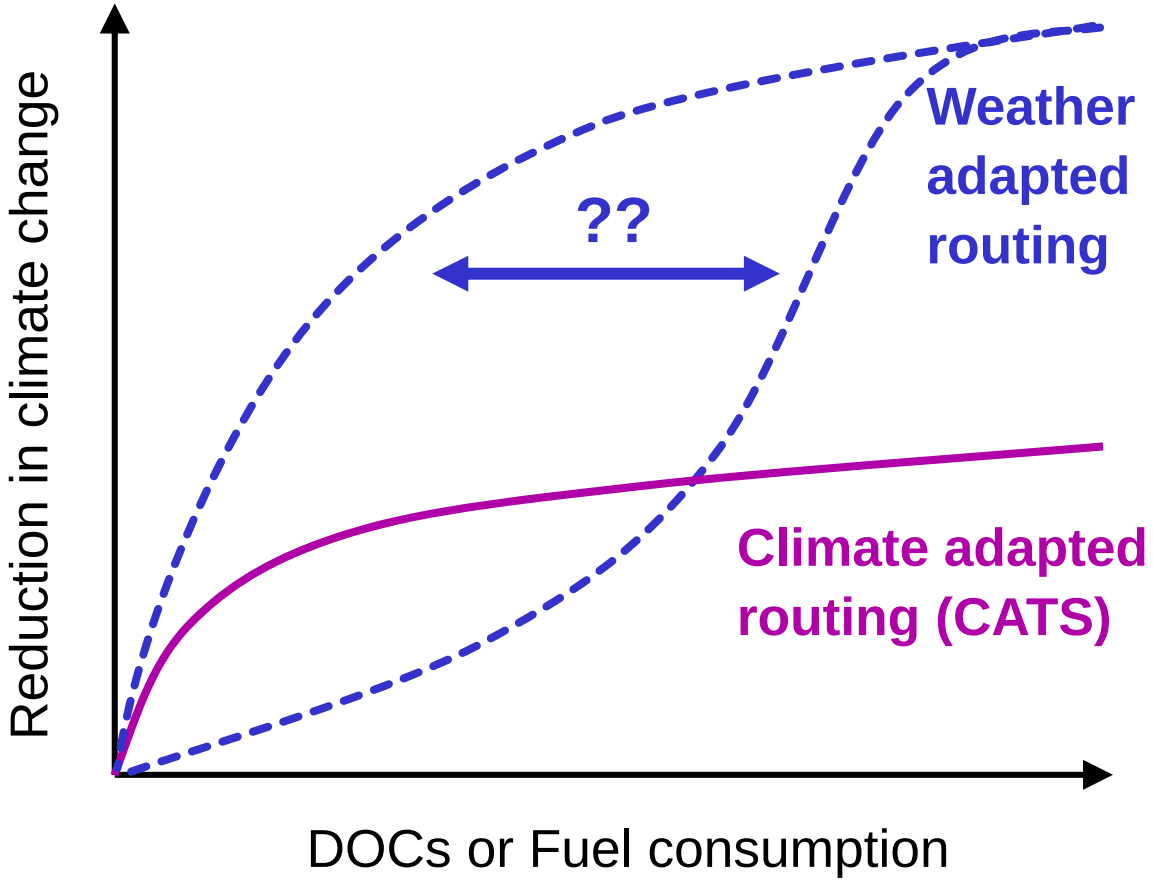
Future Plans: DLR-Project WeCare (2013+)

Utilizing Weather information for climate efficient and eco efficient future aviation



Expected Results of WeCare

Cilmate optimal routing by weather adapted Routing (in Coop with NASA-Ames)



Summary

- There is a good understanding of the main processes with regard to climate change and air traffic effects.
- Quantification is often still associated with large uncertainties.

$\Rightarrow$ We have a good basis to move our focus from Atmospheric processes to Mitigation options

- CATS: Changes in flight profiles already climate friendly:
  30% (64%) reduction for 5% (30%) increase in costs
- AHEAD, FAIR: New combustion concepts and fuels under investigation
- REACT4C, UFO: Adapting flight profiles to weather is promising
- WeCare will provide an overview on these concepts and results

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