Climate change impacts of CO_2 emissions into the stratosphere / upper troposphere

Thomas Peter (ETH)

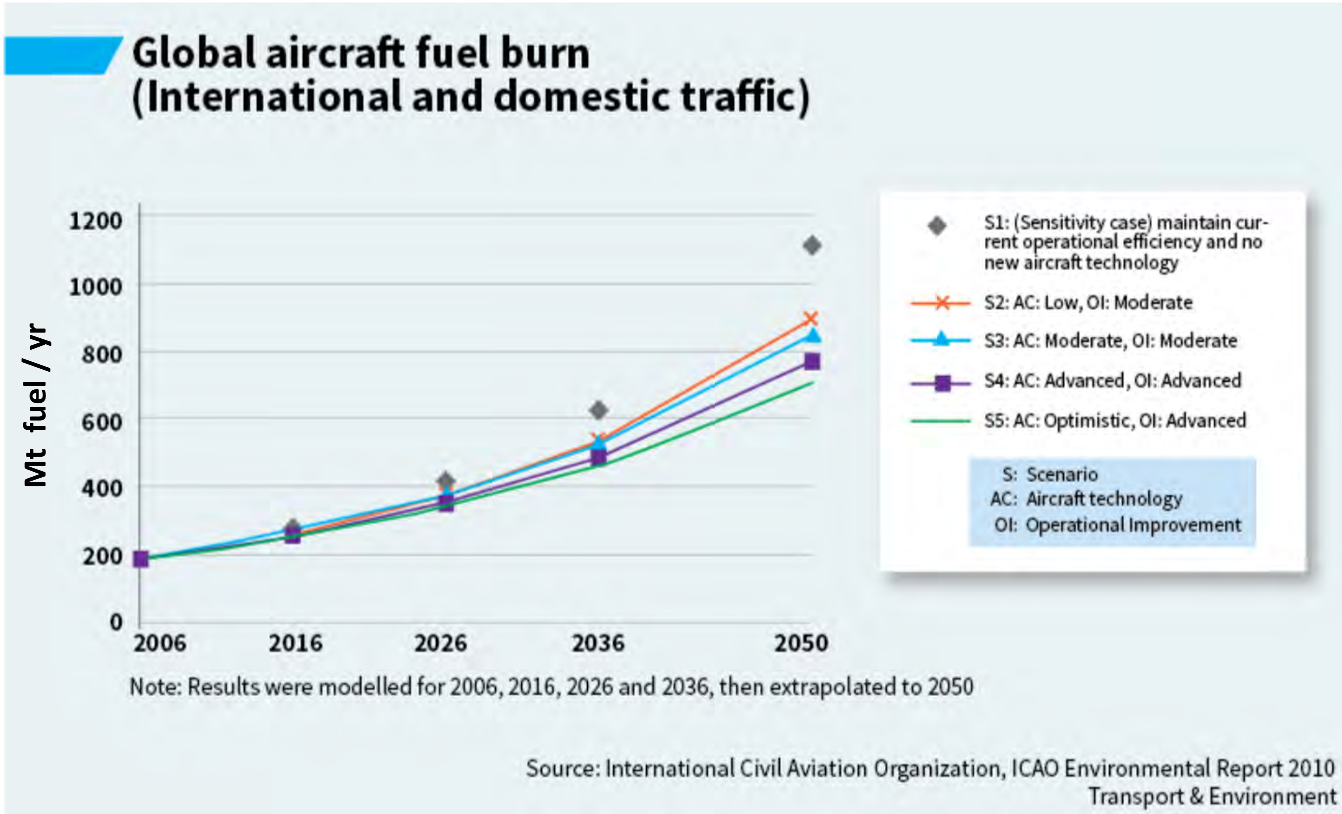
Photo by Fernando Kokubun, https://hudsonvalleyone.com/2016/06/02/government-conspiracyor-just-jet-contrails/

Using aviation fuel

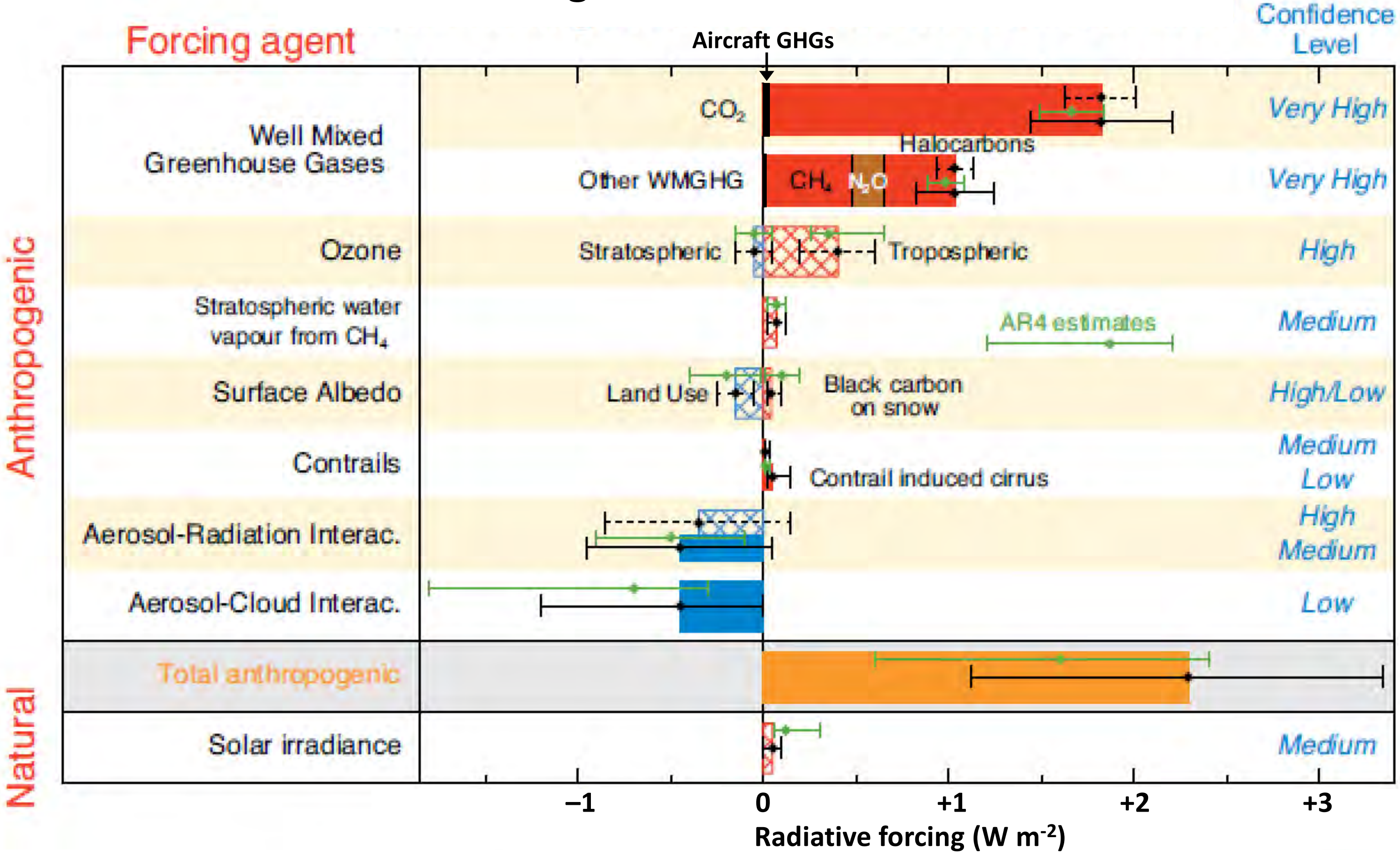
Mainly: $C_7H_{16} + 11\ O_2 \longrightarrow 7\ CO_2 + 8\ H_2O$

- Global air travel = 2.5% of greenhouse gas emissions.
- If air travel were a country, it would be roughly on par with Germany in emissions.
- And if air travel by climate scientists were a city, it would be a one-stoplight outpost.

From Brian Kuhn (Climate Central, 2015)

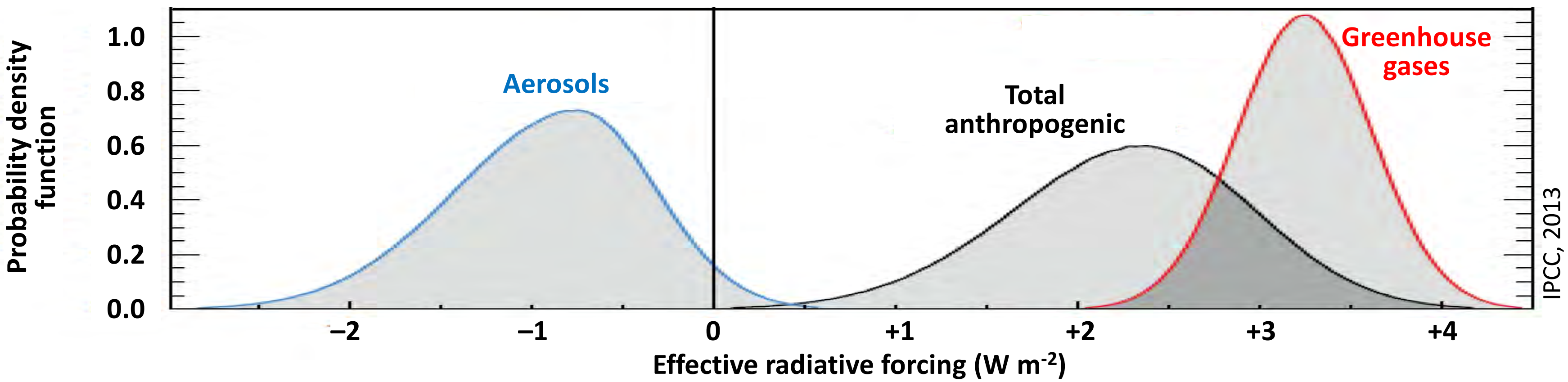


Radiative forcing of climate between 1750 and 2011



IPCC 2013:

- Persistent contrails from aviation RF ≈ 0.01 W m^{-2} for year 2011
- Combined contrails and contrail-cirrus ERF ≈ 0.05 W m^{-2}
- Clouds generally cool the climate, contrails warm it!



Midlatitude high clouds
Radiative forcing (W m^{-2})

As function of
- cloud optical depth
- cloud top altitude

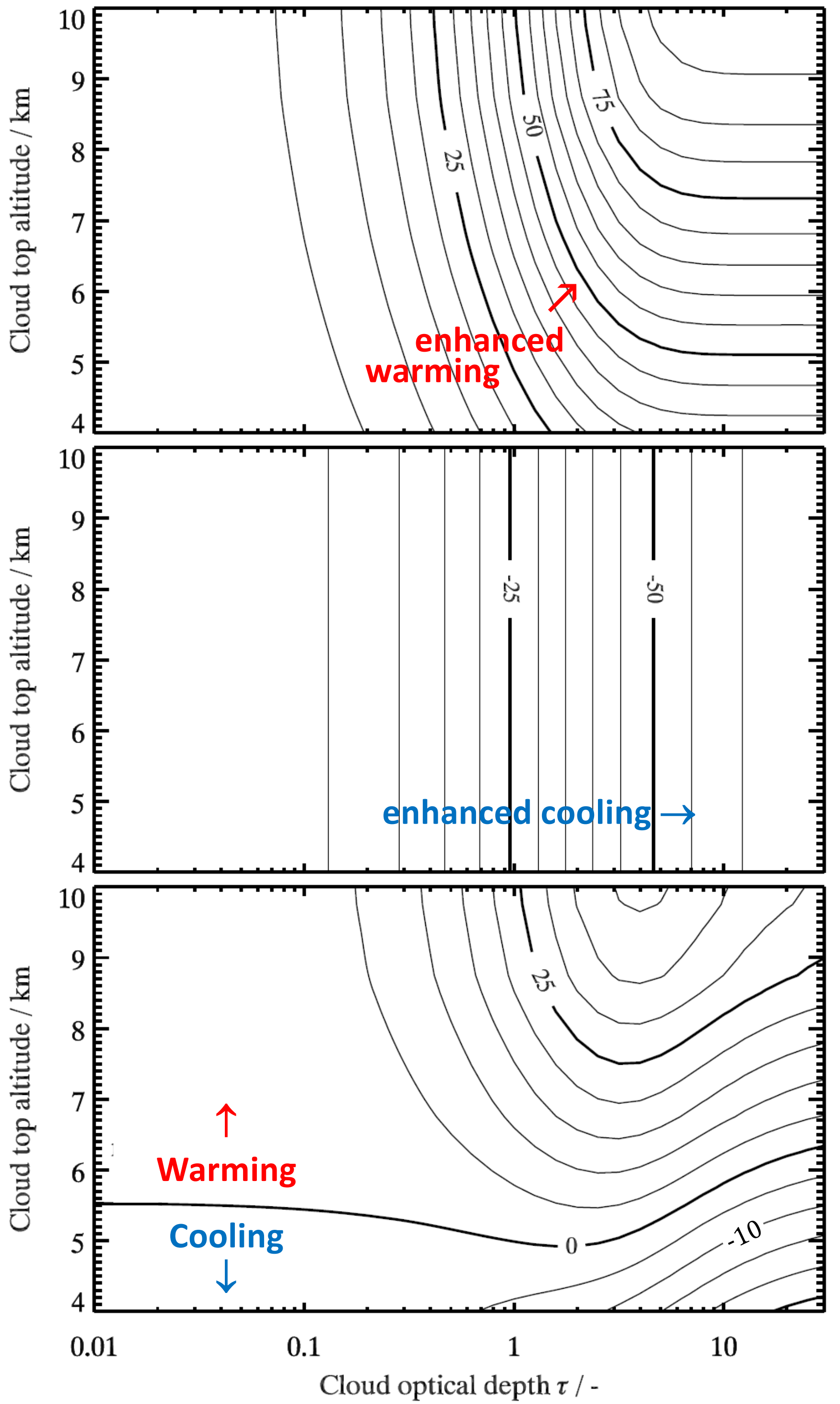
Winter conditions
(January, 50°N)

Tropopause: 9.6 km
Melting level: 5.9 km
(ERA-40)

Longwave forcing
IR absorption
+ emission

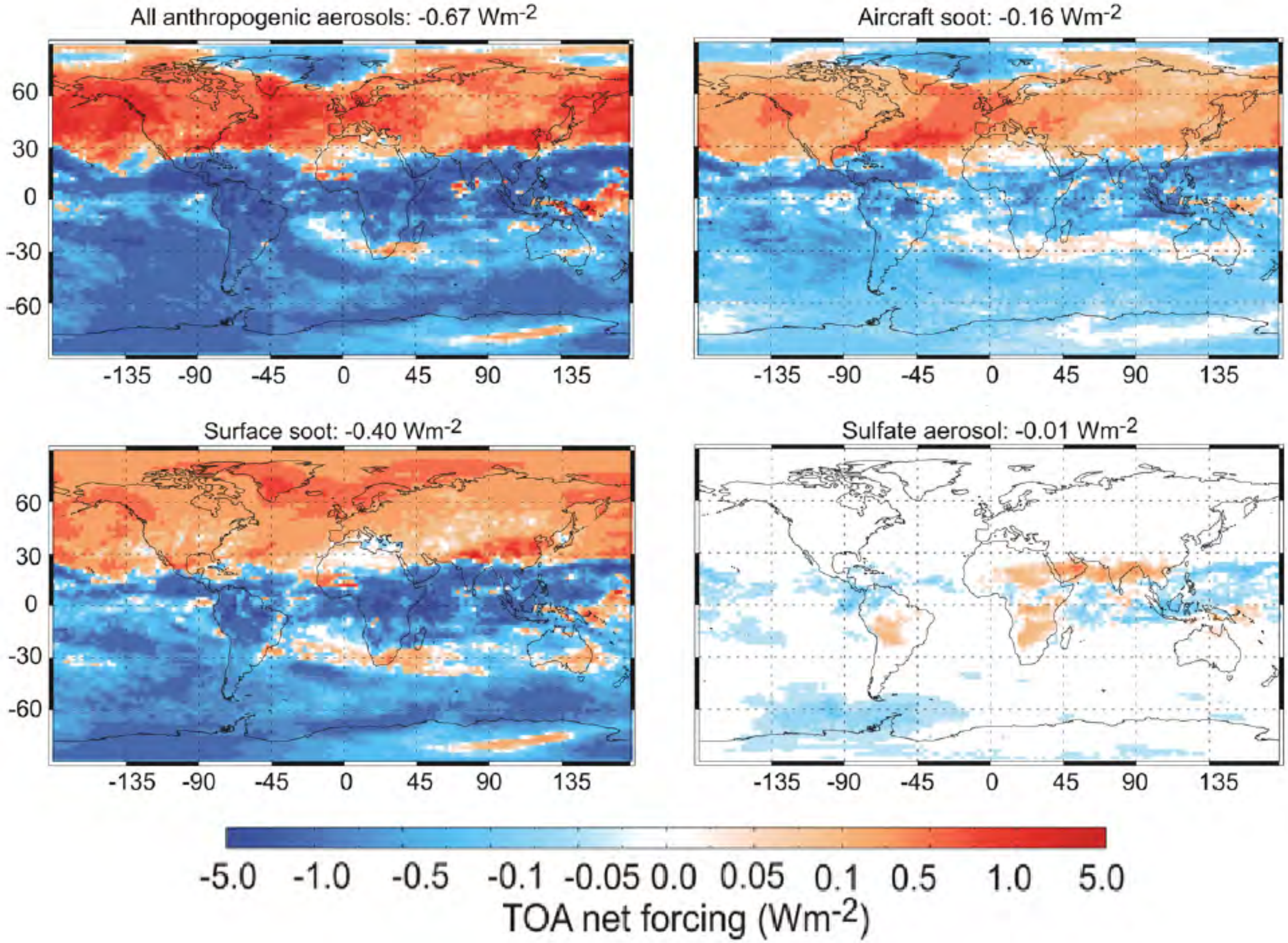
Shortwave forcing
UV + Vis forward
+ backward
scattering

Net effect
absorption
+ emission
+ scattering



Corti + Peter, 2009

Regional differences of aircraft aerosols on radiative forcing



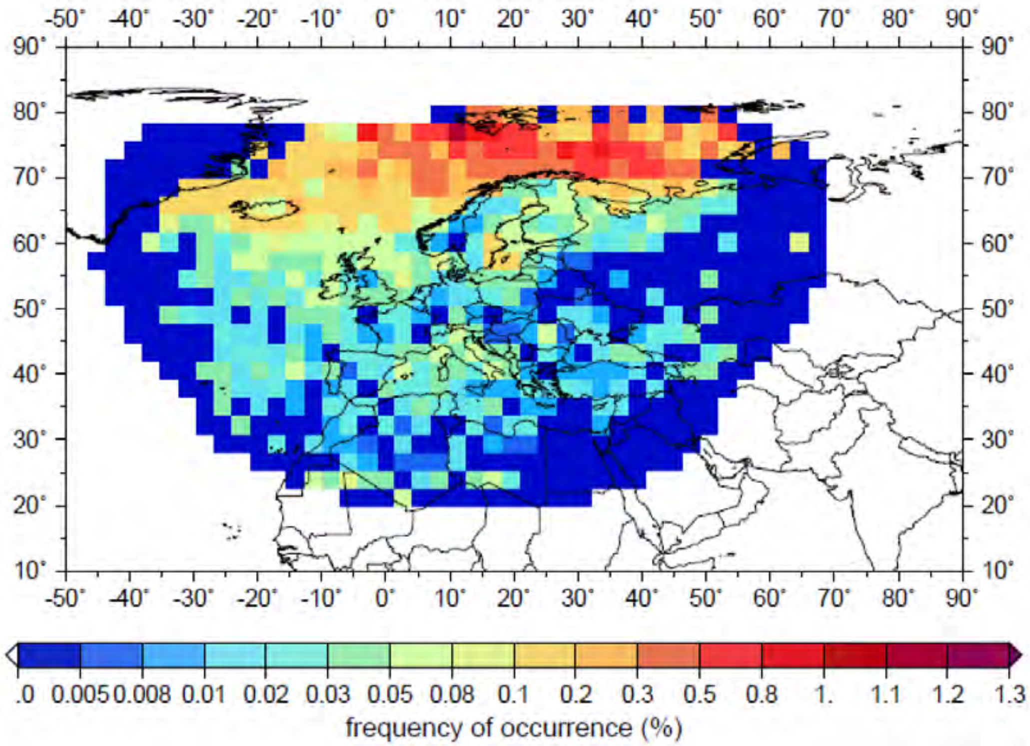
Tropics:
homogeneous ice nucleation
→ heterogeneous nucleation on soot
→ n_{ice} ↓, r_{ice} ↑
→ faster removal of ice
→ less Ci cloudiness
→ NEGATIVE FORCING

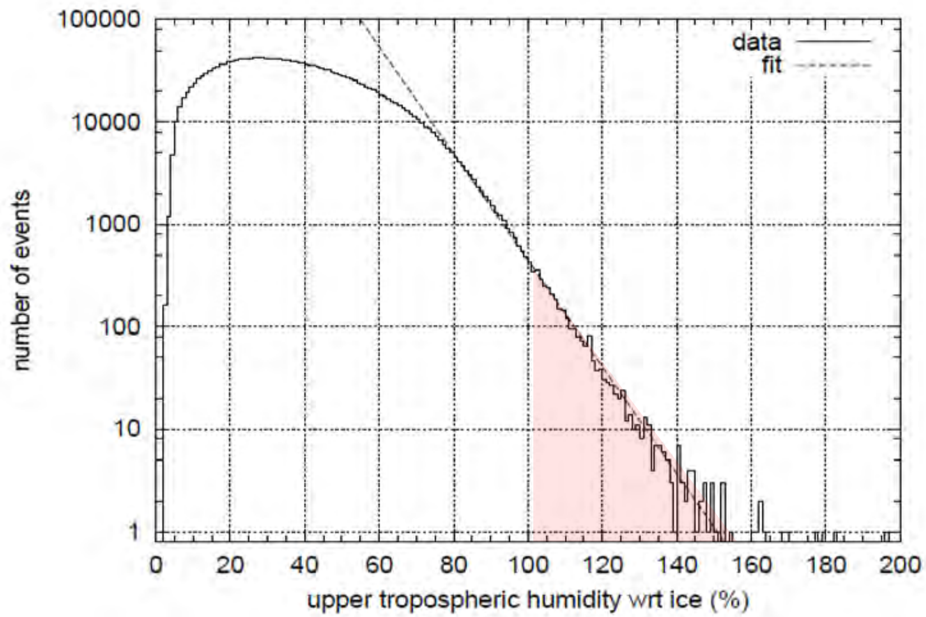
Northern mid-lats:
heterogeneous ice nucleation
→ heterogeneous nucleation on soot adds to this
→ n_{ice} ↑, r_{ice} ↓
→ slower removal of ice
→ more Ci cloudiness
→ POSITIVE FORCING

Adapted from Penner et al. (2009)

ISSRs: Ice-Super-Saturated Regions

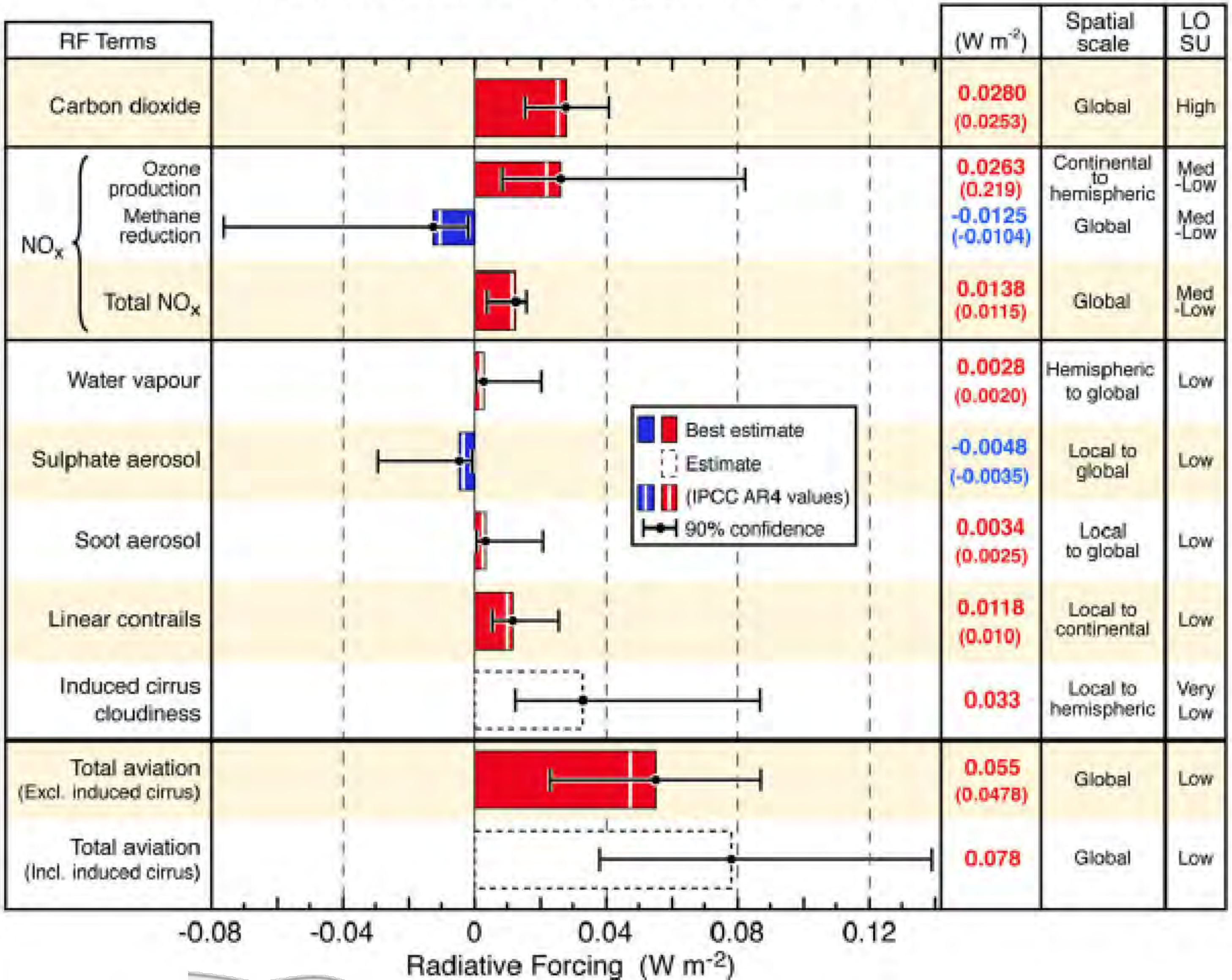
Artificial cloud formation





Gierens et al., 2004

Aviation Radiative Forcing Components in 2005



Lee et al., 2009

$VOC + NO_x \rightarrow O_3$

$O_3 \rightarrow OH$

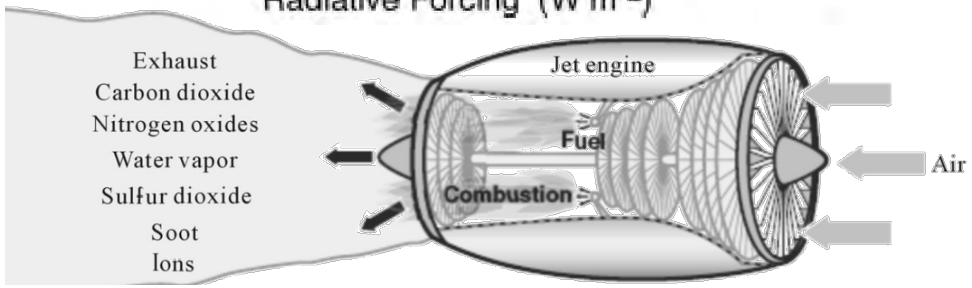
$CH_4 + OH \rightarrow CH_3 + H_2O$

H_2O most important GHG

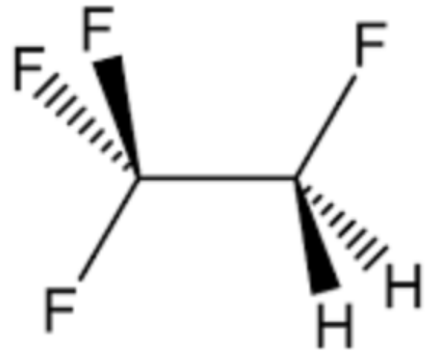
SO_4^{2-} scatters light

Soot absorbs light

Absorb outwelling IR



Short-lived versus long-lived…
Which metrics covers both?

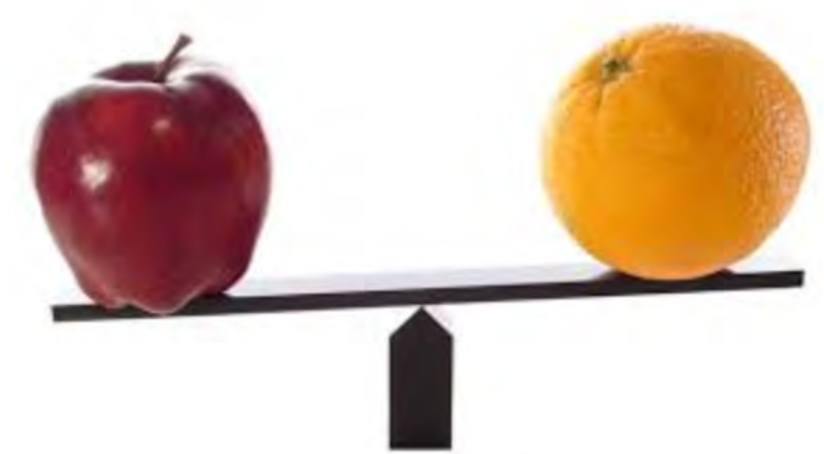


Short-lived versus long-lived pollutants…
Which metrics covers both?

- Challenge:
  - Very different time scales
  - Different impacts

⇨ Comparing apples and oranges:
  - Choice depends on specific question

⇨ There is no optimal metrics



Short-lived versus long-lived pollutants…
Which metrics covers both?

How to incorporate non-CO_2-effects?

- Fixed multiplier applied to CO_2-emissions?
  - No incentive to reduce non-CO_2-effects
  - Fixed multiplier cannot take different aircraft into account

- Radiative forcing (RF)?
  - RF is a measure of emissions in the past: $RF = \int_0^\infty \frac{dI}{d\lambda} \times \sigma_{abs} nL \, d\lambda$

- Global warming potential (GWP)?
  - Is used in the Kyoto Protocol to calculate CO_2-equivalents
  - No proper account of heat capacity of climate system, problematic for short-lived species:

$$AGWP = \int_0^H RF(t)dt \,, \quad H = \text{ time horizon}$$

- Global temperature potential (GTP)?
  - Accounts for short and longlived effects
  - But requires a full-fledged model approach: $AGTP = \frac{1}{H} \int_0^H \Delta T(t)dt$

GWP: comparison of long-lived GHGs

$$GWP_X = \int_0^H RF_X(t)dt \,/\, \int_0^H RF_{CO_2}(t)dt$$

Gas		Lifetime (years)	Global Warming Potential (Time Horizon in years)		
			20 yrs	100 yrs	500 yrs
Carbon dioxide	CO_2	wide span	1	1	1
Methane	CH_4	12	62	23	7
Nitrous oxide	N_2O	114	275	296	156
CFC-12	CCl_2F_2	100	10200	10600	5200
HCFC-21	$CHCl_2F$	2	700	210	65
HFC-23	CHF_3	260	9400	12000	10000
Carbontetrachlorid	CCl_4	35	2700	1800	580
Methylbromide	CH_3Br	0.7	16	5	1
Halon-1211	$CBrClF_2$	11	3600	1300	390
Sulfurhexafluoride	SF_6	3200	15100	22200	32400

Quelle: IPCC 2001

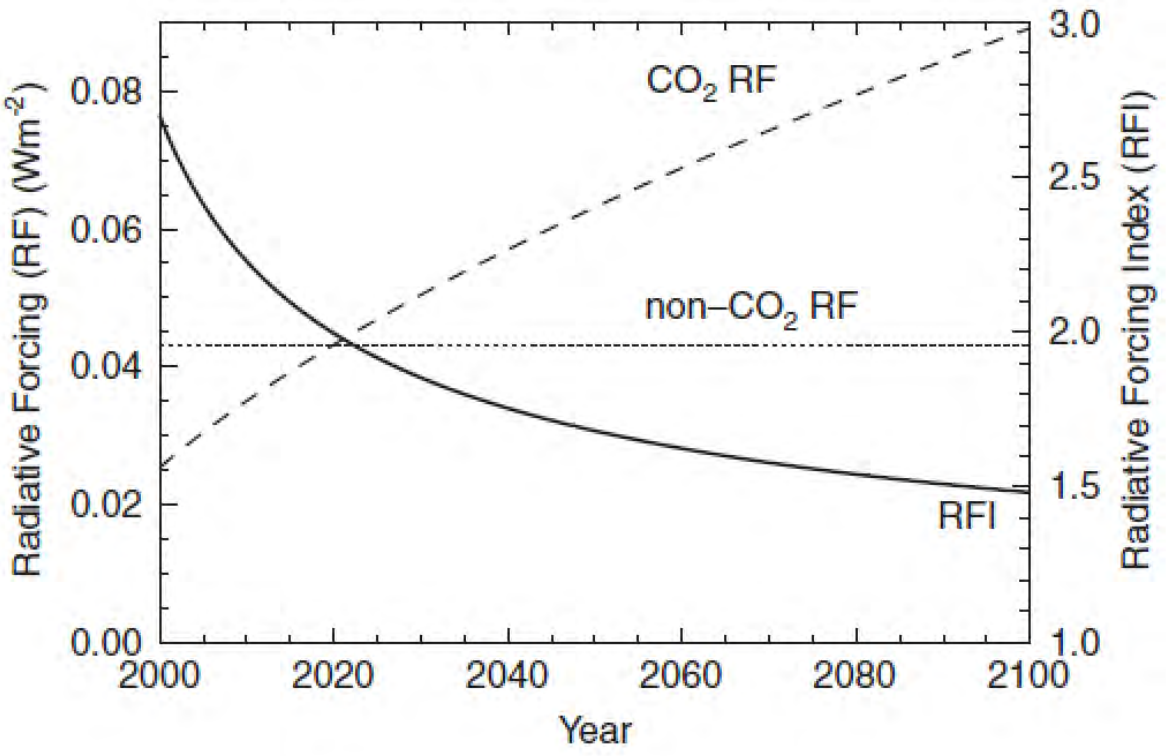
The view of IPCC in 2000 – Penner et al. (2000)

"GWP has provided a convenient measure for policymakers to compare the relative climate impacts of two different emissions. However, the basic definition of ***GWP has flaws that make its use questionable, in particular, for aircraft emissions…***
In summary, GWPs were meant to compare emissions of longlived, well-mixed gases such as CO_2*,* CH_4*,* N_2O*, and hydrofluorocarbons (HFC) for the current atmosphere; they are not adequate to describe the climate impacts of aviation. In view of all these problems, we will not attempt to derive GWP indices for aircraft emissions in this study.* ***The history of radiative forcing, calculated for the changing atmosphere, is a far better index of anthropogenic climate change from different gases and aerosols than is GWP.****"*

Atmospheric Environment 40 (2006) 1117–1121

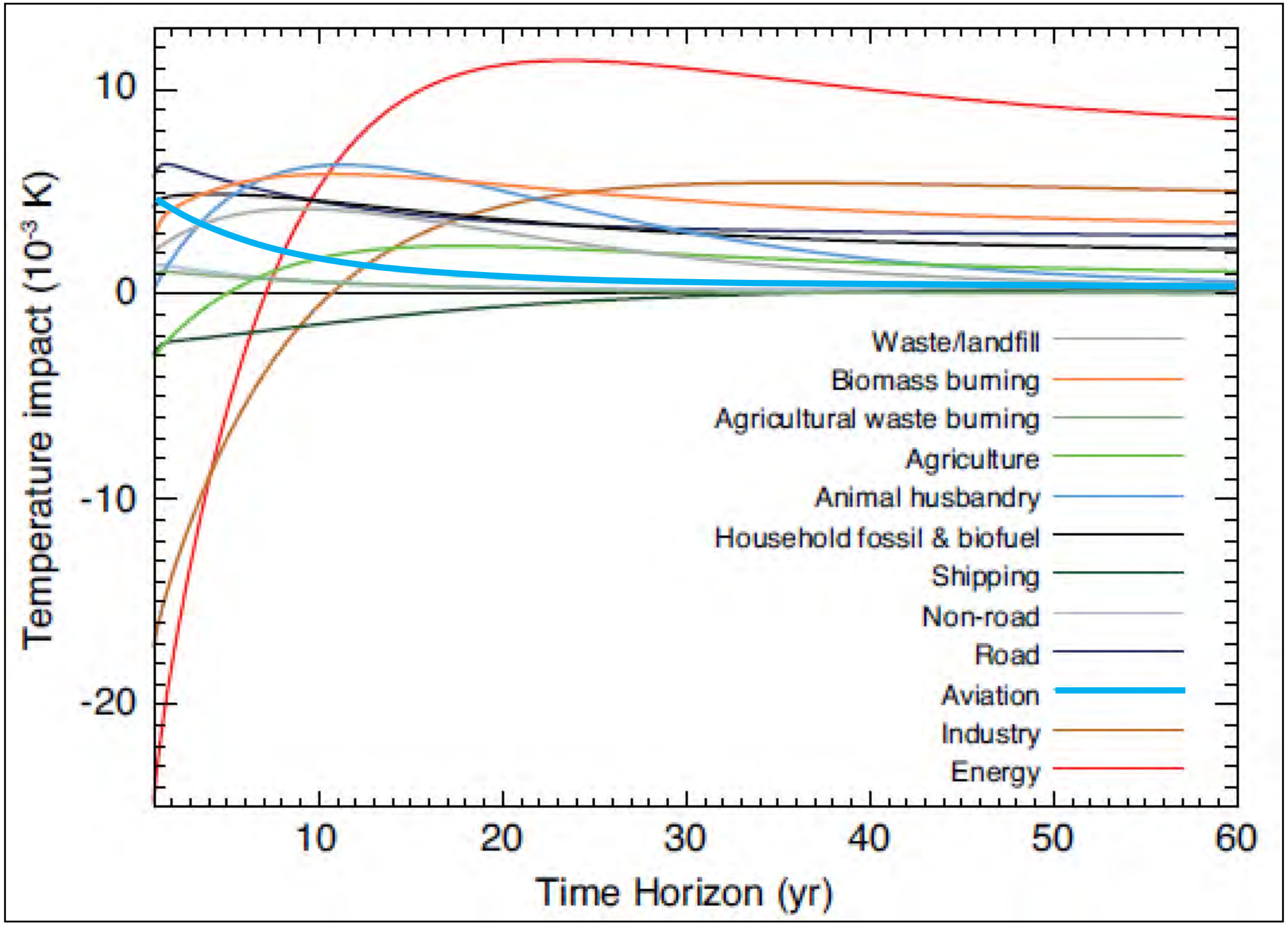
It is premature to include non-CO_2 effects of aviation in emission trading schemes

Piers Forster et al.



The CO_2 radiative forcing (dashed line) and the non-CO_2 radiative forcing (dotted line) as a function of time from constant (year 2000) aviation emissions. The corresponding RFI is also shown (solid line). The scenario is deliberately chosen to have an RFI of 2.7 in 2000—the RFI from the IPCC (1999) report.

Year 2008 (single-year pulse) emissions



The Absolute Global Temperature change Potential as a function of time multiplied by the present-day emissions of all compounds from the indicated sectors is used to estimate global mean temperature response (IPCC, 2013).

New use of global warming potentials to compare cumulative and short-lived climate pollutants

Allen et al., Nature Climate Change 2016

Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have requested guidance on common greenhouse gas metrics in accounting for Nationally determined contributions (NDCs) to emission reductions. Metric choice can affect the relative emphasis placed on reductions of 'cumulative climate pollutants' such as carbon dioxide versus 'short-lived climate pollutants' (SLCPs), including methane and black carbon. Here we show that **the widely used 100-year global warming potential (GWP100) effectively measures the relative impact of both cumulative pollutants and SLCPs on realized warming 20–40 years after the time of emission…**

GWP100 metric fits best with Paris targets. Basically a step change in emission of a shortlived effect (GWP weighted) matches the temperature change from a pulse of a long lived gas. This is finding some traction…

However, EU Emission trading and the new global COSAIR offsetting policy ignore all non CO_2 effects…

Presently, the departments of ETH are being asked to discuss how they can bring their emission down. But there is resistance…

Tages-Anzeiger

Front **Zürich** Schweiz International Wirtschaft Börse Sport Kultur Reisen Wissen Auto Blogs Panorama Mehr

Stadt Zürich Region Bellevue Stadtblog Blaulicht & Justiz Bildstrecken Marktplatz

Jährlich 5000-mal um die Welt fliegen ist der ETH zu viel

Die ETH Zürich steckt in einem Dilemma. Für die Mitarbeiter sind Konferenzen im Ausland wichtig, Fliegen schadet aber dem Klima.

Umwelt: Prosit Klima! | Die Weltwoche, Ausgabe 3/2014 | Mittwoch, 7. Juni 20

DIE WELTWOCHE

Umwelt

Prosit Klima!

Thomas Stocker und Bertrand Piccard sorgen für mehr CO2 in der Luft

Login Abonnieren

Tages-Anzeiger

Immo · Job · Marktplatz · Trauer · Das Magazin Suche

Front Zürich Schweiz International Wirtschaft Börse Sport Kultur Reisen Wissen Auto Blogs Panorama Mehr

Leben // Gesellschaft Style Essen & Trinken Wohnen Bildstrecken

Du sollst nicht fliegen

Es ist fast egal, wie man lebt: Ob man Abfall trennt, Bäume streichelt, bio isst. Was zählt, ist vor allem der Verzicht auf ein Transportmittel: Das Flugzeug.

But there is resistance amongst scientists… How much may I fly as a scientist?

Developing a community roadmap to a low-carbon research space

A new initiative by the ETH board

- Global air travel = 2.5% of greenhouse gas emissions.
- If air travel were a country, it would be roughly on par with Germany in emissions.
- And if air travel by climate scientists were a city, it would be a one-stoplight outpost.
- In other words, climate scientists curtailing their air travel would make a microscopic dent in reducing emissions.
- But a new paper argues they should do it anyway, because their influence goes far beyond numbers.
- "It's a credibility issue. We're trying to support a change in culture"

From Brian Kuhn (Climate Central, 2015) and Corinne Le Quéré (Nachhaltigkeitswoche, 2017)

ETH statistics

Jahresvergleich Emissionen

Grafik 4: Treibhausgas-Emissionen durch Dienstreisen der ETH Zürich im Jahresvergleich (in t CO_2eq), Stand 2016

Jahresvergleich Emissionen pro FTE

Grafik 5: Treibhausgas-Emissionen pro FTE durch Dienstreisen der ETH Zürich im Jahresvergleich (in t CO_2eq), Stand 2016

Presently, the departments are asked to discuss how they can bring their emission down. But there is resistance…

1. International air travel: ~2.5% of global anthropogenic CO_2 emissions
2. Business air travel: ~60% of all CO_2 emissions at ETH
3. Share of business air travel increased from 33% in 2010 to 60% in 2016
4. CO_2 emissions per capita (FTE) for air travel decreased by 24% from 2010 to 2016
5. 7–8% of decrease due to improving aircraft fuel efficiency, i.e. jet fuel per seat km
6. Possibly the other 16% already a consequence of "scientists flying less"!?
7. ETH Annual Report 2016: "Limit air travel and promote the use of alternatives to international networking: NOT ON TRACK. Members of ETH have not opted for the video conferencing service on campus in significant numbers"
8. The Schulleitung has been accused of being too negative and bureaucratic…
9. International scene:
   - Switzerland signed the Paris Agreement (2°C goal)
   - ETH feels the pressure from Bern
   - 2°C requires net ZERO emissions by ~2050
   - This would need a very steep reduction curve NOW
10. 1.68 t CO_2eq/FTE corresponds
    - to 1/3 of total CO_2 per capita worldwide, but just for business air traveling
    - a bit less than a single return flight to NY
    - using my Smart car to drive to work (17km) for 1.5 years
    - using my E-bike for more than 30 years

Presently, the departments are asked to discuss how they can bring their emission down. But there is resistance…

Process:

Departments are asked by the ETH Board to

- (i) come up with plans for measures and monitoring in 2017/18:
    - 3 pathways: mild, medium, agressive;
- (ii) implementation 2019-2025;
- (iii) evaluation in 2022 and 2025.

However, there is resistance:

- Long-haul flights cannot be replaced
- Why this top-down approach?
- Present process psychologically not ideal, very bureaucratic and expensive
- Rather perform workshops, and who likes can participate
- Rather have one pilot dept., e.g. USYS, to figure out what the best measures are
- Rather be more ambitious than saving a few tons of carbon:
    - develop new jet fuels
    - develop new jet engines
- Rather "activate the youngsters" who are much better in handling this
- We hurt ourselves severely if we as single university took measures unilaterally

Tyndall Travel Strategy
hLp://www.tyndall.ac.uk/travel-strategy

Corinne Le Quéré
Tyndall Centre for Climate Change Research
University of East Anglia

Code of conduct:

1. Monitor, justify, reduce
2. Support, encourage, stimulate
3. Reward

Presently, the departments are asked to discuss how they can bring their emission down. But there is resistance…

Discussion:

(1) Should we respond to the ETH Board questionaire?

(2) How do you feel about pros and cons?

(3) What are your suggestions on what we could suggest as USYS?

(4) Who would you feel about unpopular measures, such as
- strict quota for departments
- different quota for different departments
- quota for individual scientists
- different quota for different scientists (status, excellence, age …?)

(5) Anything forgotten you'd like to discuss?