Copenhagen Contrails Conference, day 1

Joachim Majholm, Blue Lines, opened the conference. It is the flights in the afternoon and evening, and thus flights during the polar night, that especially create contrails. But not alone. Contrails can occur throughout the day, and at all altitudes, if the right conditions in the atmosphere are present.

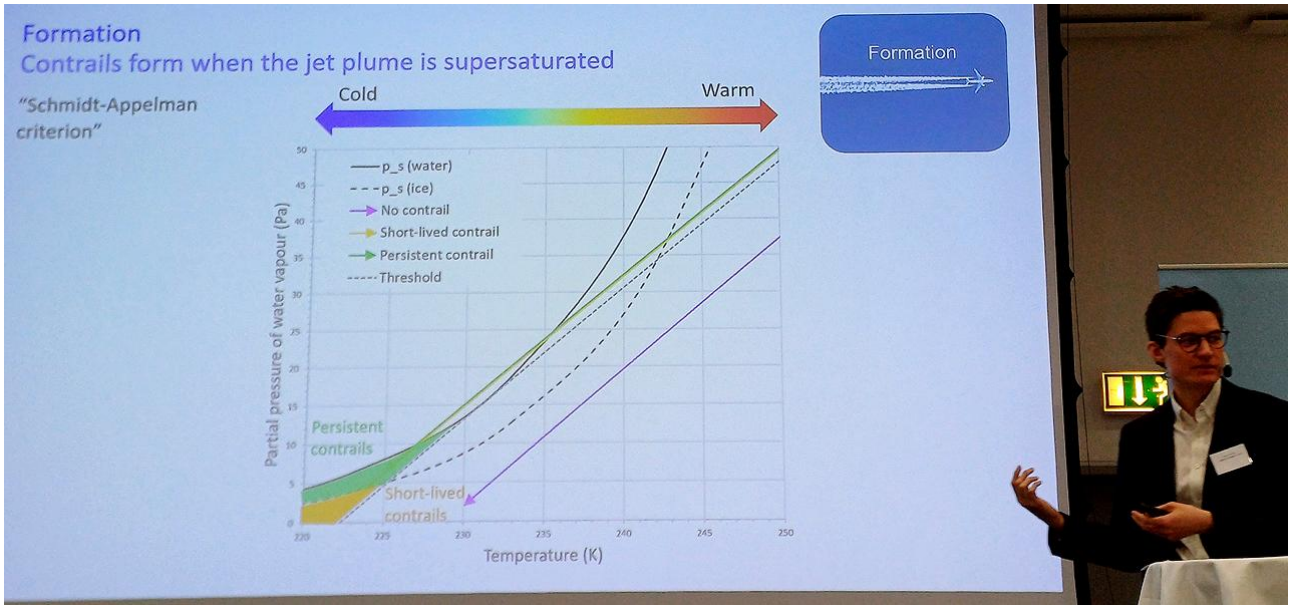
Masterclass: What are contrails, how do they impact the climate, and what can be done to stop them from warming the climate?

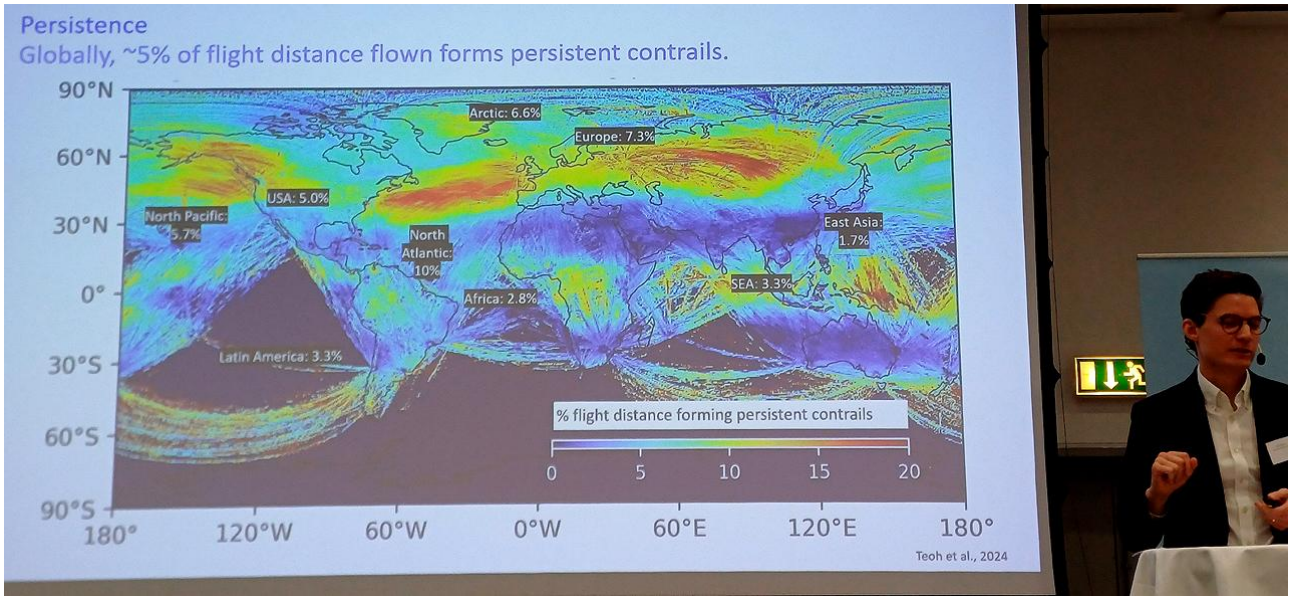
Marc Stettler, Imperial College London, provided a scientific background (and did it well)

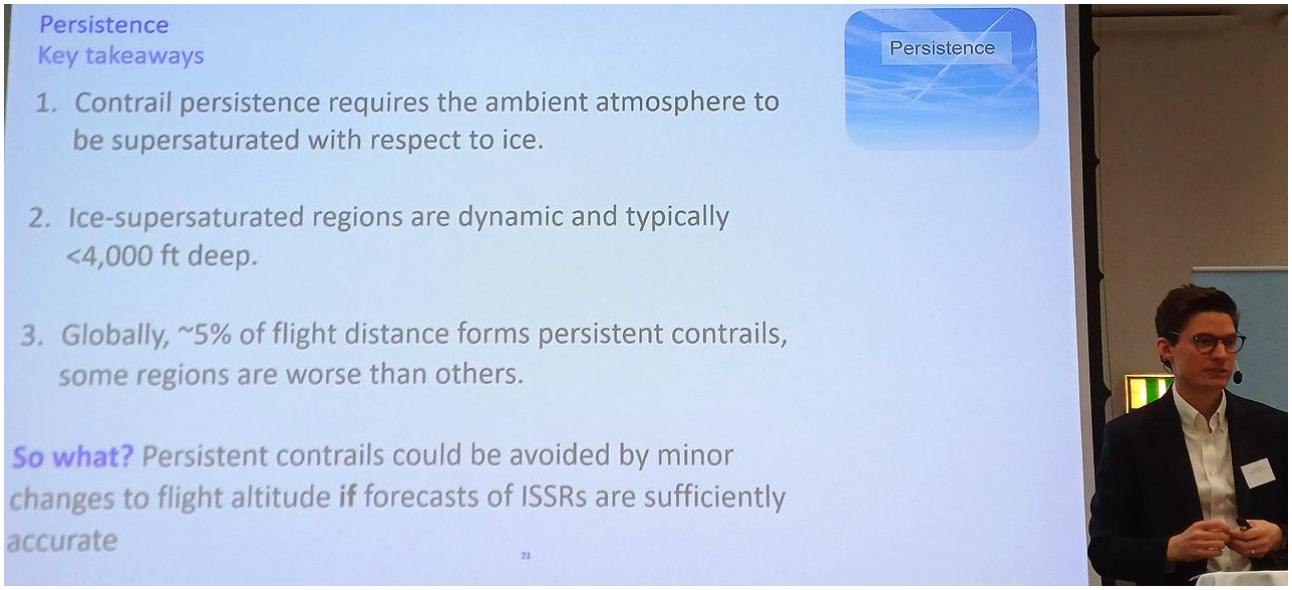
Contrails are in fact the most visible trace of human climate warming.

All contributions from the exhaust must be taken into account. SAF will not solve the problem alone.

It is important to know that the atmospheric effects in the short term are very large but short-lived, while the CO2 effects are cumulative. In the time horizons we have for reductions in global warming, it makes the most sense to count on a 20-year perspective, but this is based on the fact that there will actually be a 20-year phase-out of these effects. If this continues year by year, then the contribution from non-CO2 related warming is still very high!



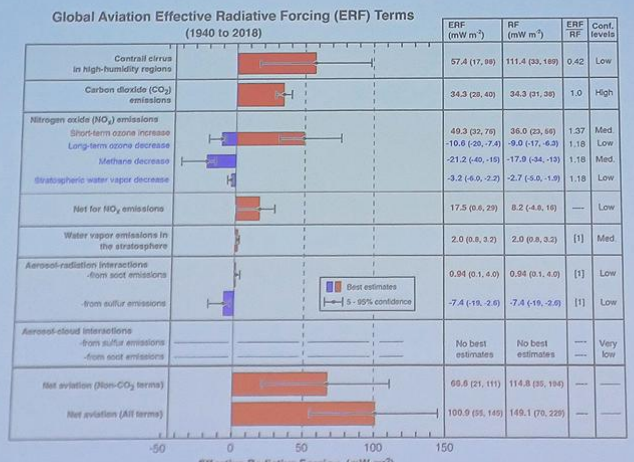

Persistence
Globally, ~5% of flight distance flown forms persistent contrails.
90°N
60°N
30°N
0°
30°S
60°S
90°S
180°
120°W
60°W
0°W
60°E
120°E
180°
Arctic: 6.6%
Europe: 7.3%
USA: 5.0%
North Pacific: 5.7%
North Atlantic: 10%
East Asia: 1.7%
SEA: 3.3%
Africa: 2.8%
Latin America: 3.3%
% flight distance forming persistent contrails
0
5
10
15
20
Teoh et al., 2024


Persistence
Key takeaways
Persistence
1. Contrail persistence requires the ambient atmosphere to be supersaturated with respect to ice.
2. Ice-supersaturated regions are dynamic and typically <4,000 ft deep.
3. Globally, ~5% of flight distance forms persistent contrails, some regions are worse than others.
So what? Persistent contrails could be avoided by minor changes to flight altitude if forecasts of ISSRs are sufficiently accurate

Radiative forcing

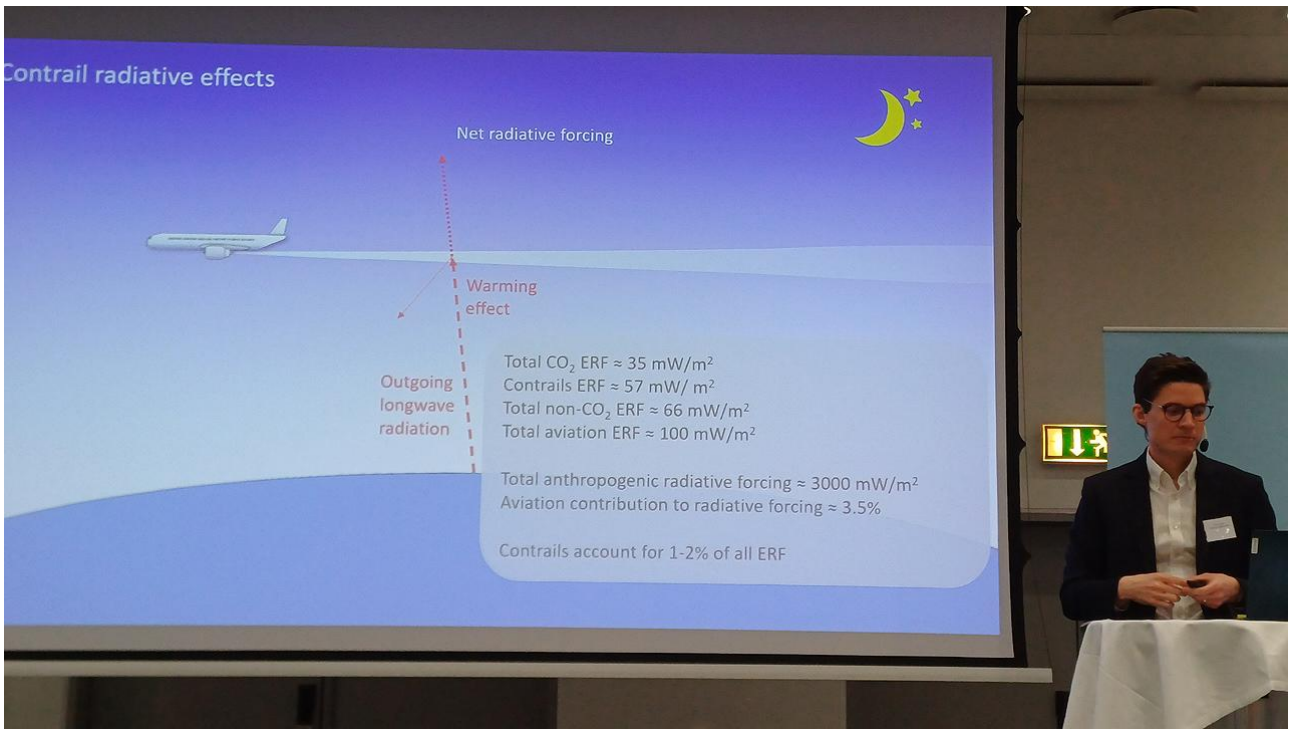
"Non-CO2 terms sum to yield a net positive (warming) ERF that accounts for more than half (66%) of the aviation net ERF in 2018."

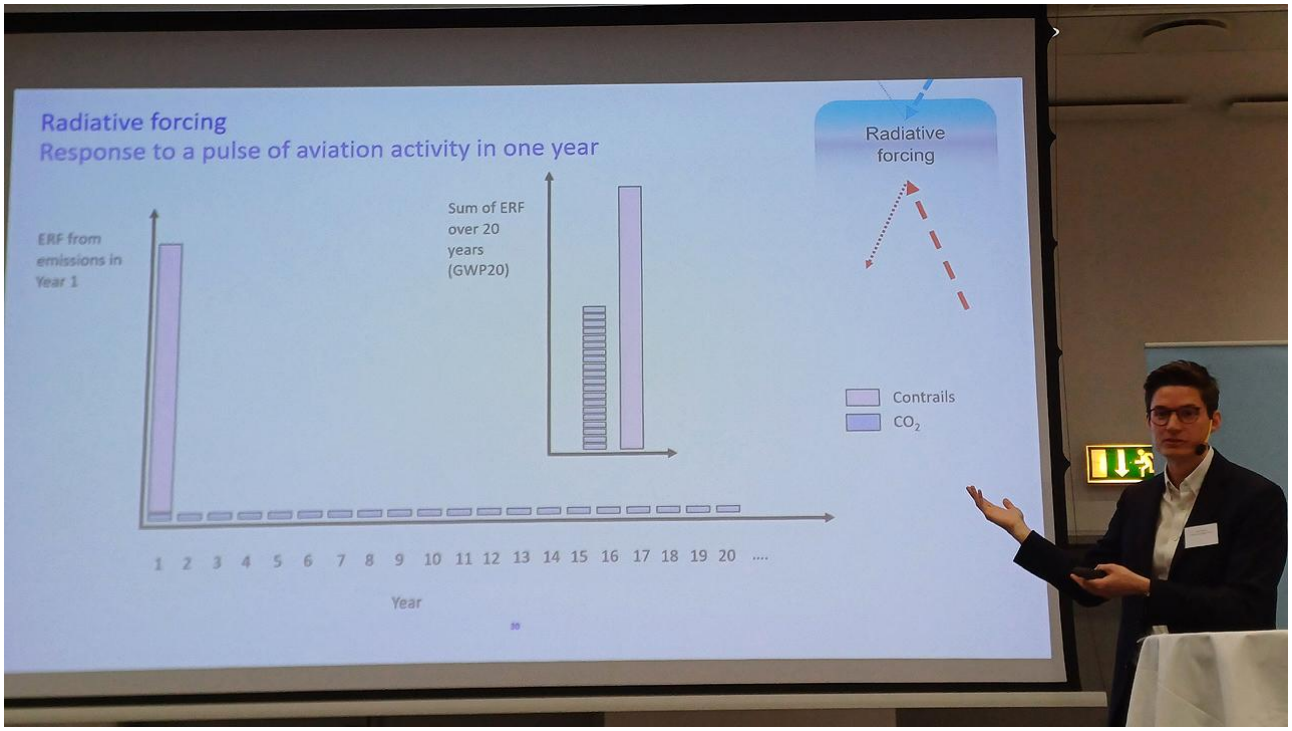
Radiative forcing



	ERF (mW m^{-2})	RF (mW m^{-2})	ERF RF	Conf. levels
Contrail cirrus in high-humidity regions	57.4 (17, 98)	111.4 (33, 189)	0.42	Low
Carbon dioxide (CO_2) emissions	34.3 (28, 40)	34.3 (31, 38)	1.0	High
Nitrogen oxide (NO_x) emissions				
Short-term ozone increase	49.3 (32, 76)	36.0 (23, 56)	1.37	Med.
Long-term ozone decrease	-10.6 (-20, -7.4)	-9.0 (-17, -6.3)	1.18	Low
Methane decrease	-21.2 (-40, -15)	-17.9 (-34, -13)	1.18	Med.
Stratospheric water vapor decrease	-3.2 (-6.0, -2.2)	-2.7 (-5.0, -1.9)	1.18	Low
Net for NO_x emissions	17.5 (0.6, 29)	8.2 (-4.8, 16)	—	Low
Water vapor emissions in the stratosphere	2.0 (0.8, 3.2)	2.0 (0.8, 3.2)	[1]	Med.
Aerosol-radiation interactions				
-from soot emissions	0.94 (0.1, 4.0)	0.94 (0.1, 4.0)	[1]	Low
-from sulfur emissions	-7.4 (-19, -2.6)	-7.4 (-19, -2.6)	[1]	Low
Aerosol-cloud interactions				
-from sulfur emissions	No best estimates	No best estimates	---	Very low
-from soot emissions			---	
Net aviation (Non-CO_2 terms)	66.6 (21, 111)	114.8 (35, 194)	---	—
Net aviation (All terms)	100.9 (55, 145)	149.1 (70, 229)	---	—

Lee et al., 2021





During Corona, as expected, it was possible to register from the satellites that the sky was clearer, but there is still so much "noise" in the global temperature measurements that it could not be measured with certainty.

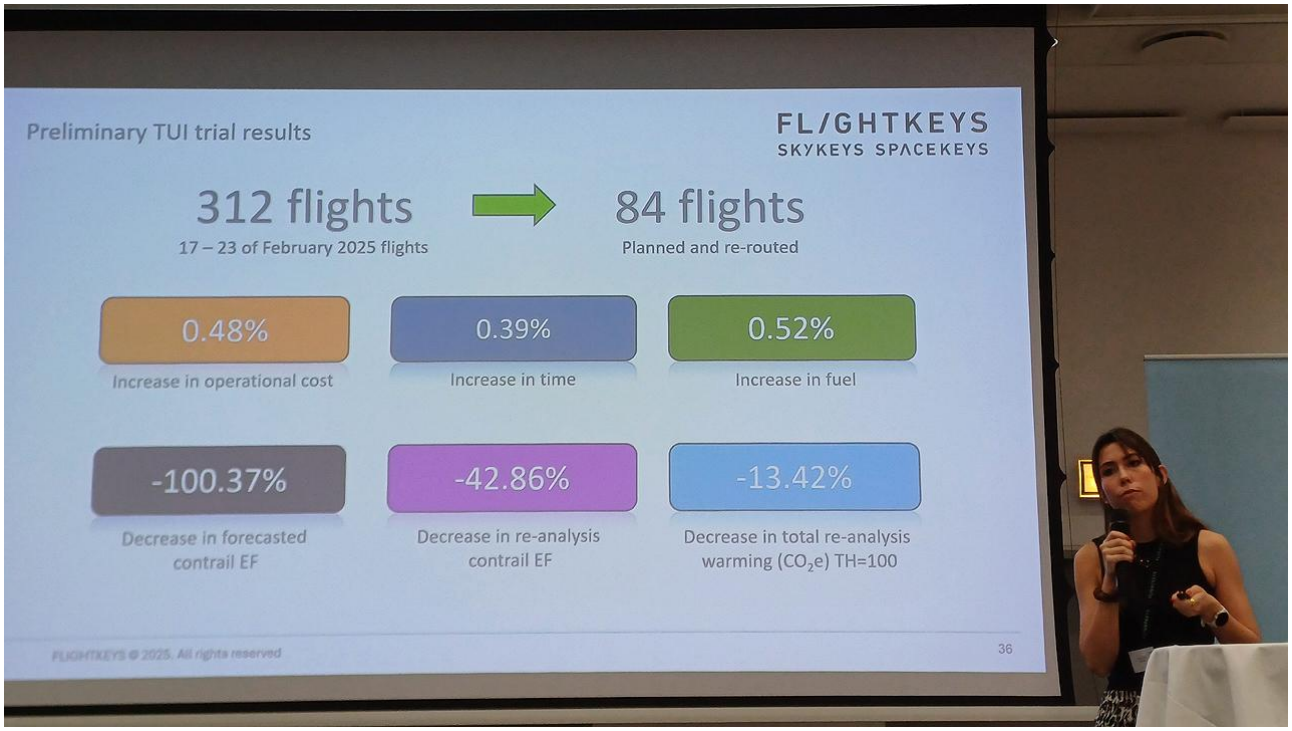
Presentation: Airlines' and partners' experience with contrail mitigation.

Christoph Todt, TUI

A very difficult process over 15 months, the pilots and air traffic controllers are not very prepared for these changes. Quite a few flights in the beginning. Route from Germany mainly to the Canary Islands. The experiment was carried out for a week this winter (17.-23.2), and it was possible. 76% of flights are the most sensitive day for contrails. We got 20 flights to change route. But there were problems with timeliness. What is most important for the pilots? Feedback is important: did the pilot succeed? There are massive reductions for individual flights, which surprises the pilots. It can be convincing, and they also looked up at other planes, and saw streaks of planes that they did not leave in the sky. When we can show that it can work on a large scale, then there are of course good reasons to convince the legislators of change.

Alejandra Martin Frias, Flightkeys

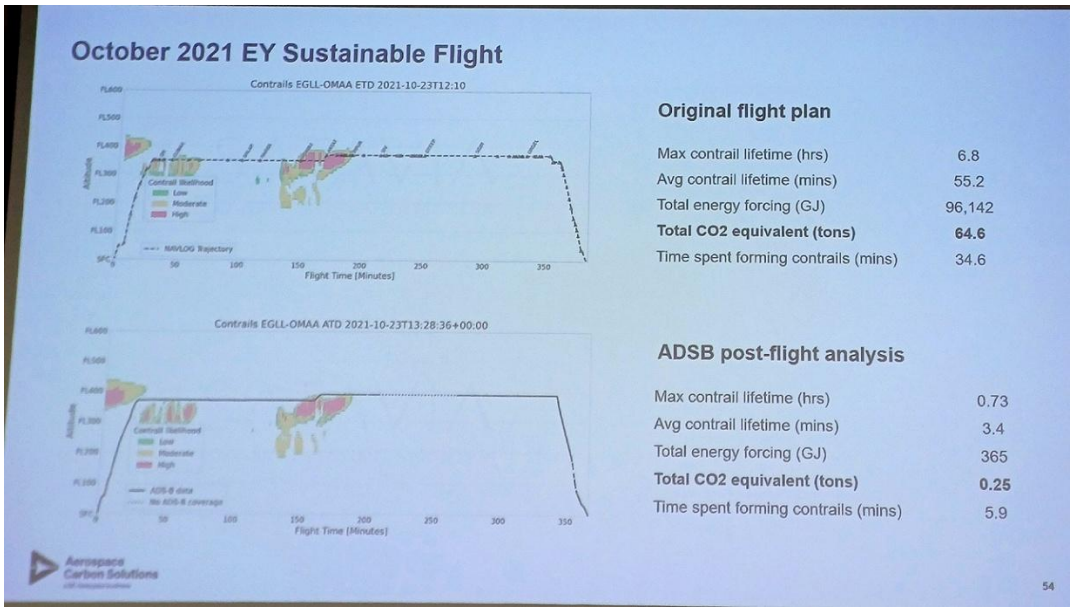
Their equipment was behind the TUI experiments. Personally, she checked a flight on the evening of 20.3. this year between Madrid and Vienna, which gave 9 tons of CO2e extra due to the establishment of Contrails. Their software is able to advise the flights. Software also includes extra fuel and any delays due to rescheduling of flights.



Adam Durant, Satavia

GE Aerospace has to do with the engines, but also with software. This is where Satavia comes into play. With our software, we must also take into account when we want to reschedule flights that there are also other effects from the flights than contrails. It is about laying the foundation for the right regulations. Weather forecasts don't actually give us more than 24 hours of predictions, but that's also good enough. We are most successful by rescheduling long-haul flights. The biggest obstacle is that the air traffic controllers did not allow the planes to follow the designated routes.

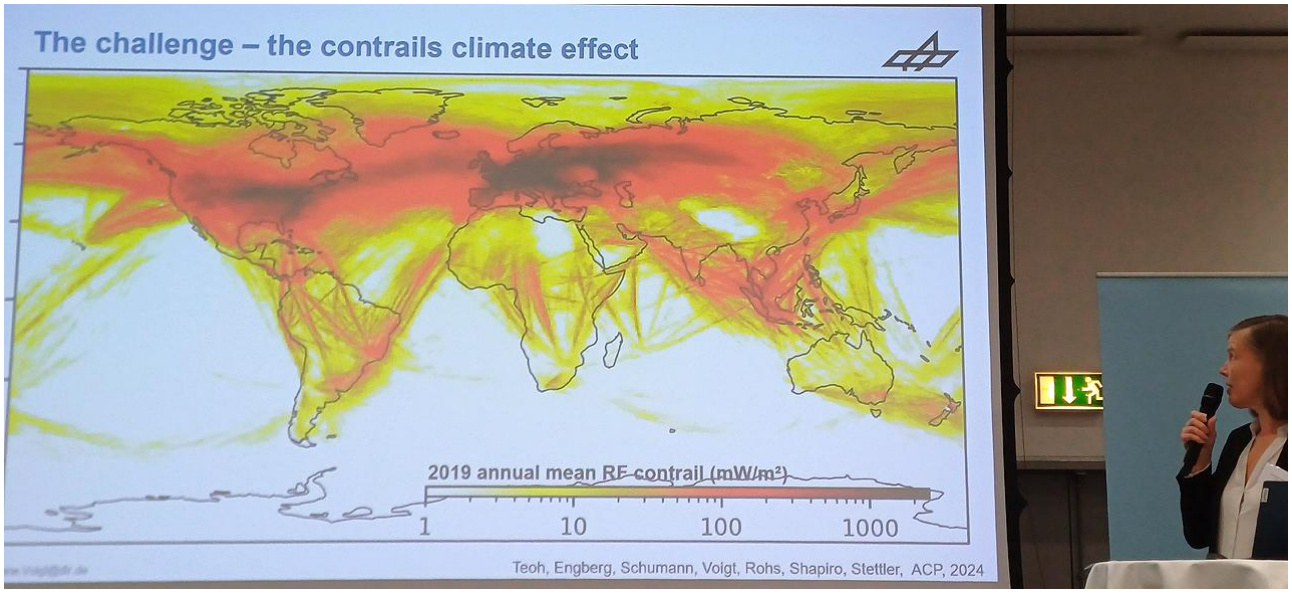
Everything indicates that more humidity in the atmosphere will actualize this with the contrails. In fact, using SAF will do that too.



Presentation: How can low-aromatic fuels mitigate contrails?

Christiane Voigt, DLR (Germany)

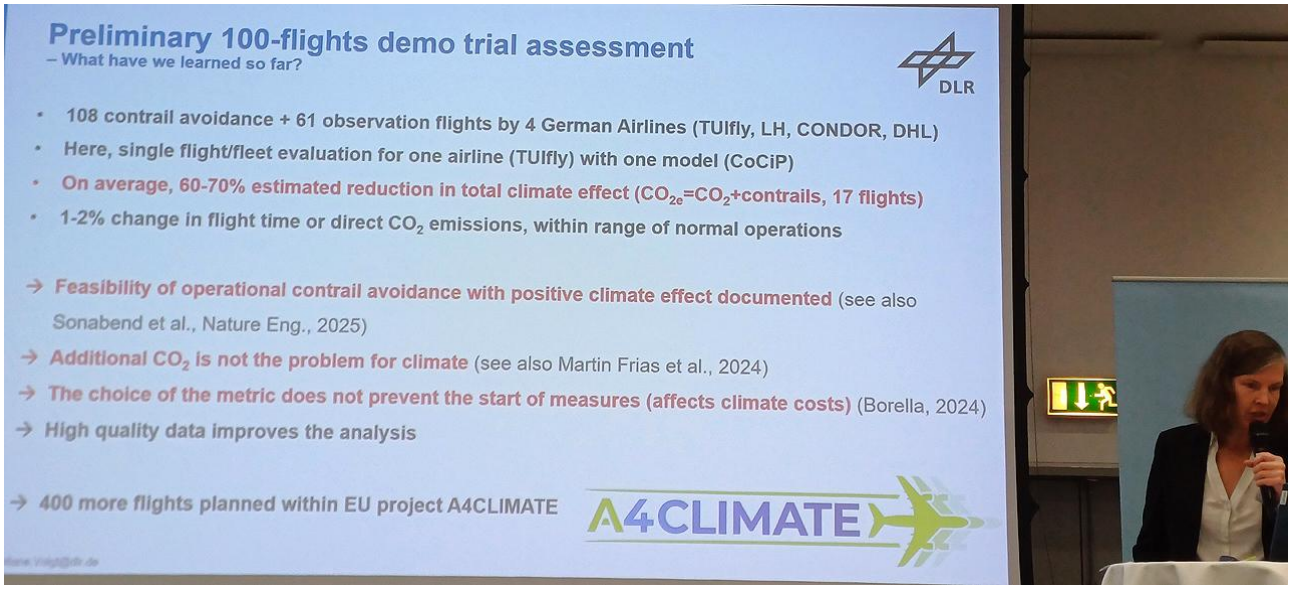
The focus should be on night flights, they will have to be reduced. We had the opportunity to study 108 German flights from four companies, of which we managed to observe 61. There is no doubt that rescheduling has positive effects!



Effects from fewer soot particles, e.g. from SAF, work. But so do newer and better engines.

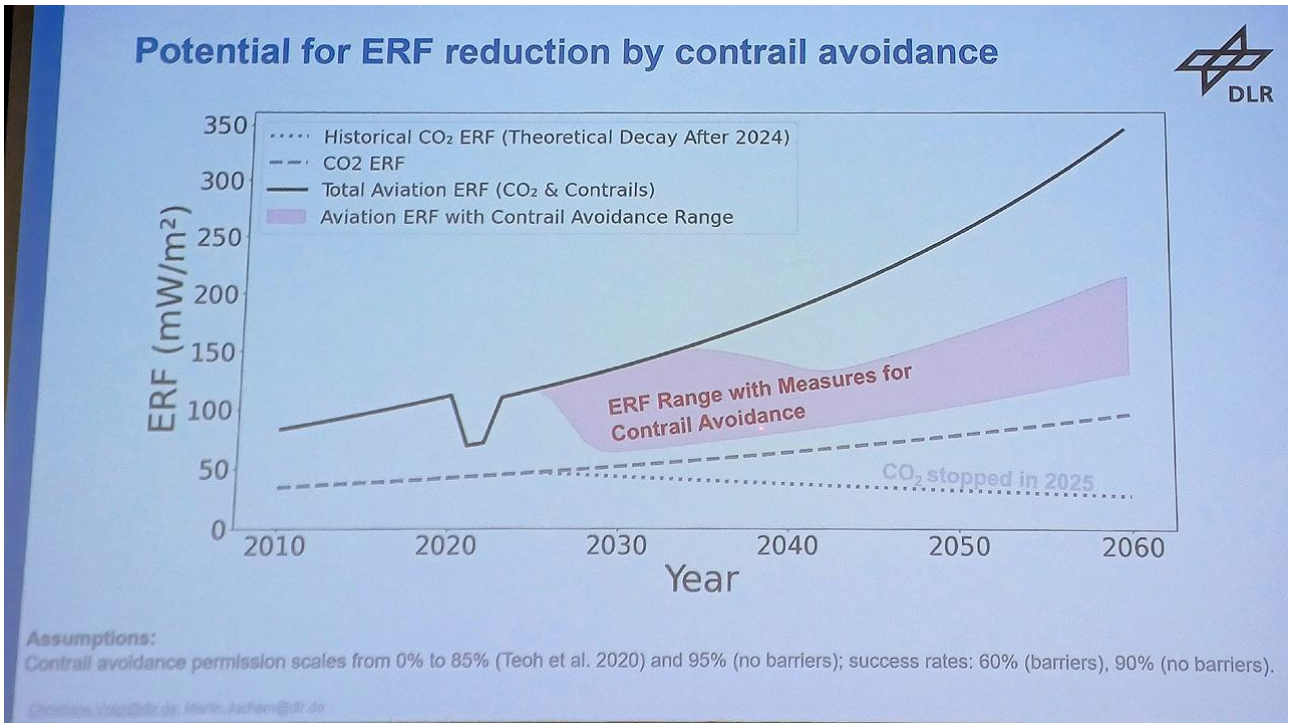
Effects from turboprop and emissions from 100% e-fuels are also good and better than the other. Lean burn engines, and low-sulfur fuels have some effects, but they can be counterproductive.

But whatever we think we can do (see photo), which already contains quite optimistic assumptions, other things must be used. Hydrogen planes are necessary – or other measures.



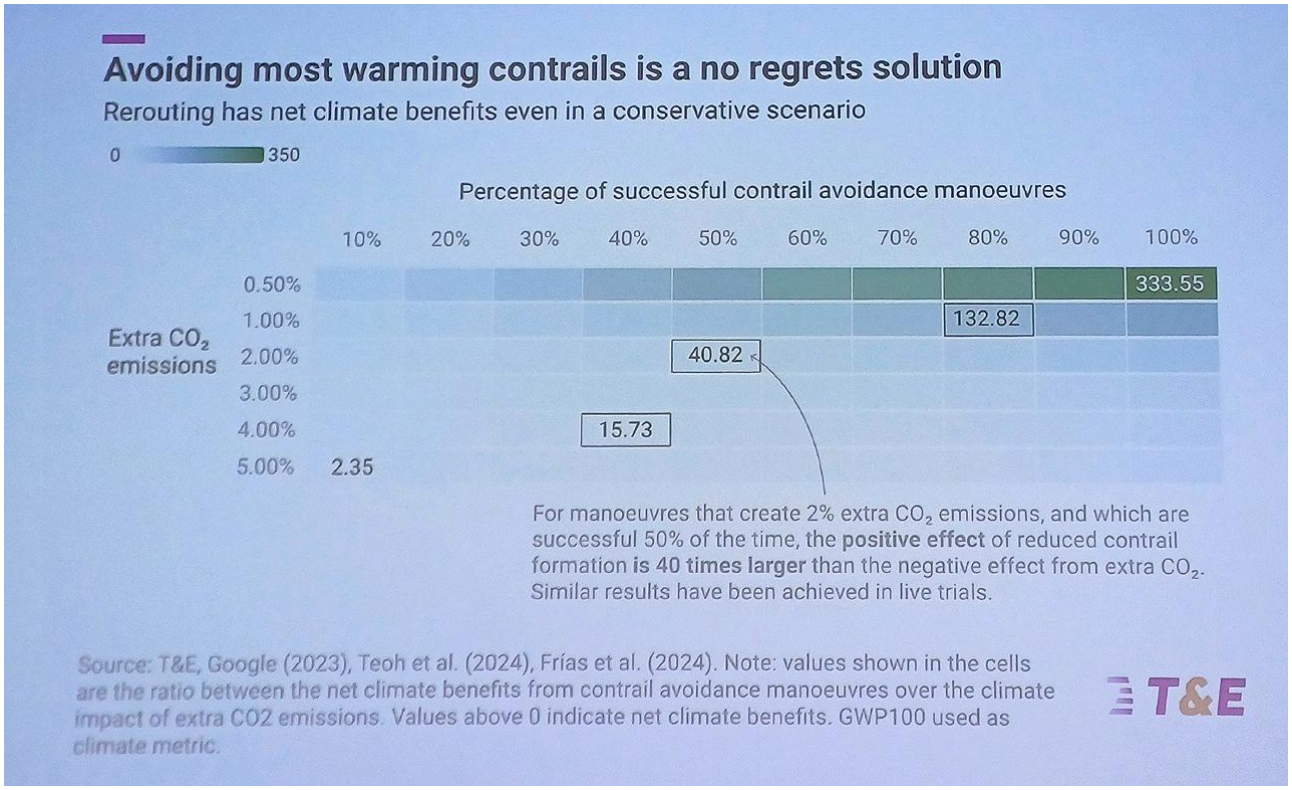
Panel Discussion: Should we wait for more data and certainty in contrail prediction and climate impact, or can we learn to deal with uncertainty? Panel Discussion

Paul: Predictions of flight routes to avoid Contrails come with uncertainties (photo). It is this improved safety that the industry is working towards. The question is also whether 'hypersensitivity' is a major problem. In fact, we don't need the world's best predictions to achieve success. Marc: I think the predictions will quickly become satisfactorily good. There are also great uncertainties about aviation's pure CO2 emissions. I asked about CO2 estimates if it referred to the Norwegian studies: https://norwegianscitechnews.com/2024/04/big-data-reveals-true-climate-impact-of-worldwide-air-travel/) Paul replied that yes, there are actually large uncertainties for data reported on aviation's CO2 emissions. The simplest is to use the amount of jet fuel sold. Me: The Norwegian study just mentioned that such information is uncertain and clearly under-estimated from large parts of the world.



Presentation: What does contrail management cost?

Carlos López de la Osa, T&E: Despite uncertainties about non-CO2 effects, we are trying to spread the knowledge we have. For example, air traffic controllers are not necessarily unwilling, they are used to dealing with uncertainties. Carlos believes that it can be done.



Nikhil Sachdeva, Roland Berger: If practical problems and predictive tools are not obstacles, then surely there must be economic reasons why this is happening so slowly?

Technically, the flight can be determined before take-off, but the pilot can also influence via data along the way.

The price is not unreasonable to live up to 80% of Contrails, if you compare with the typical CO2 prices you see in the debate.

Carlos: See our analysis here: https://www.transportenvironment.org/topics/planes/contrails

50% reductions from contrails. T&E was based on the lowest value from Lee et al. Looking at a future with 66% fossil fuel, 24% bio-SAF and 10% e-SAG (i.e. European flights). T&E believes that the price is very low for making these contrails reductions. In this context, T&E does **not** assume that the ETS should be changed and include contrails in a new CO2e price.

Panel Discussion: Carrot or stick – incentives for contrail management.

Matteo Mirolo, Contrails.org: Carrot or stick – incentives for contrail management

Will the EU's new initiative on compulsory monitoring, reporting and verification (MRV) of the warming effects of airstrip be sufficient? Matteo is obviously asking with the assumption that the ETS has to include contrails.

Nuala: Volunteering will not do it alone! MRV doesn't do it alone! We don't have time on our side! The MRV is based solely on European airspace (outside the EU there is no requirement), and this is also a major weakness. Nuala was the panel's obvious green element.

Jan: The pressure from our customers to react to Contrails does not exist. MRV and possibly regulation of Contrails is very important to DHL, because we fly at night. We need fair regulation! Otherwise, we risk giving up our business. Can't see it any other way than that there will be a price screw related to MRV. How will air traffic control allocate routes when the degrees of freedom become fewer than they are today? The Single European Sky policy is currently not good. Who will be assigned the ideal route around sensitive areas? That worries us. (There were no representatives from air traffic control present in the room)

Dimitar Nikov, Policy Officer, DG Clima. Initially, we are still in a learning corner, and then we may want to do something. The ETS actually funds some of the research on contrails. He thinks he heard the contributions in the direction that everything will go well without coercive measures. MRV can of course one day be used as a starting point for active regulation. I'm curious about how the industry will use MRV.

Andrew, RMI. It may well happen that the reporting of contrails will have a certain voluntary, positive effect. Also to the outside world, which takes a critical view of aviation's climate responsibility. Good to get the facts on the table, but optimistic calculation and greenwashing is an obvious risk.

Presentation: Operation Blue Skies: A tangible plan for what to do now, in 5 years, and 10 years.

Part of the Aviation Impact Accelerator, which is a plan to get aviation to reach net zero by 2025.

CO2 emissions from aviation from 1940 to 2050 with the expected development will mean 0.07 degrees of global warming in 2025. Contrails will mean 0.1 degrees in addition. Considering the uncertainty of the latter, non-CO2 is either a big problem or a huge problem.

The problem can only be solved to net-zero with CCS.

A bit strange that this presentation tells us that the scale-up of the operations can only be ready around 2050. At the same time, we heard earlier in the day that **it can work today**! Were these Englishmen representatives of an environment of "pay us to do many more studies"?

A global effort requires that money be collected globally to make the system work reliably. It would be embarrassing if the industry, which can make a jet engine work as well as it does, cannot solve something as relatively simple as the non-CO2 related effects.

Presentation: The climate opportunity that no one knows about – the challenge of communicating contrails.

Trying to describe the problem so that it is understandable:

https://www.transportenvironment.org/topics/planes/contrails

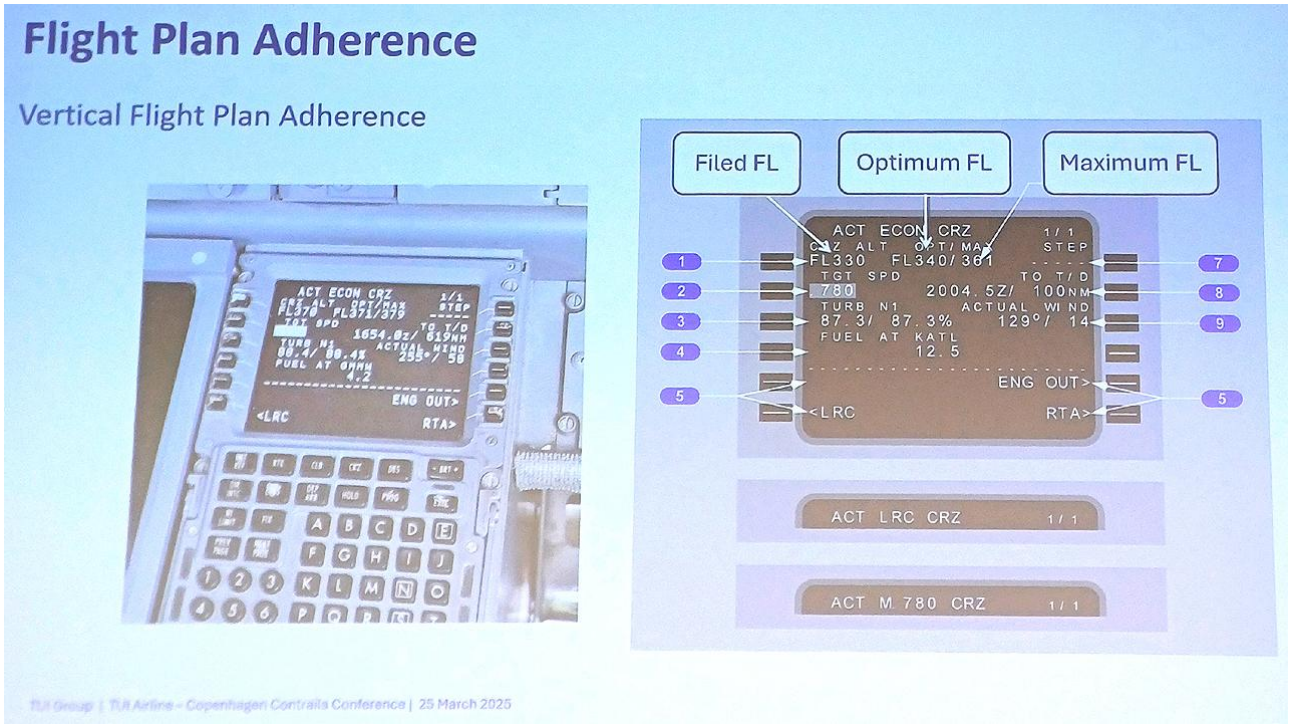
Interactive map https://map.contrails.org/ (with a 24-hour delay) where individual flight routes can be studied in real-time.

Copenhagen Contrails Conference, day 2

Conversation: Contrail avoidance from a pilot's perspective.

Jeppe Juel, Green Transition Denmark and **Tony Schweigert,** TUI Airline

Aviation operations are very rule-based (OPS notam), so new methods must be fully incorporated into these daily operations – something the pilots do not have to think about but follow orders. Unfortunately, visualization in the cockpit is not yet included with TUI, so the pilot cannot see what sensitive areas lie ahead but must base his route according to what the pilot has been instructed in by the airline and air traffic control (ATC). Remember that the pilot does not have a rearview mirror! Such a small camera would be nice to have. Flying detours (in 3 dimensions) are nothing new for the pilot, it can be military exercises, bad weather, heavy traffic (slots). Today, the pilot has access to fairly simple information (photo next page) by default. In practice, there are many considerations to take into account, and other, more pressing problems may arise, so that's why the theoretical values won't hold up out there. Remember that pilots are craftsmen – they are not scientists.



Presentation: Big hits! Contrail avoidance in the airspace over Denmark.

Julien Lopez, Thales and **Anders Næsby**, Air Support

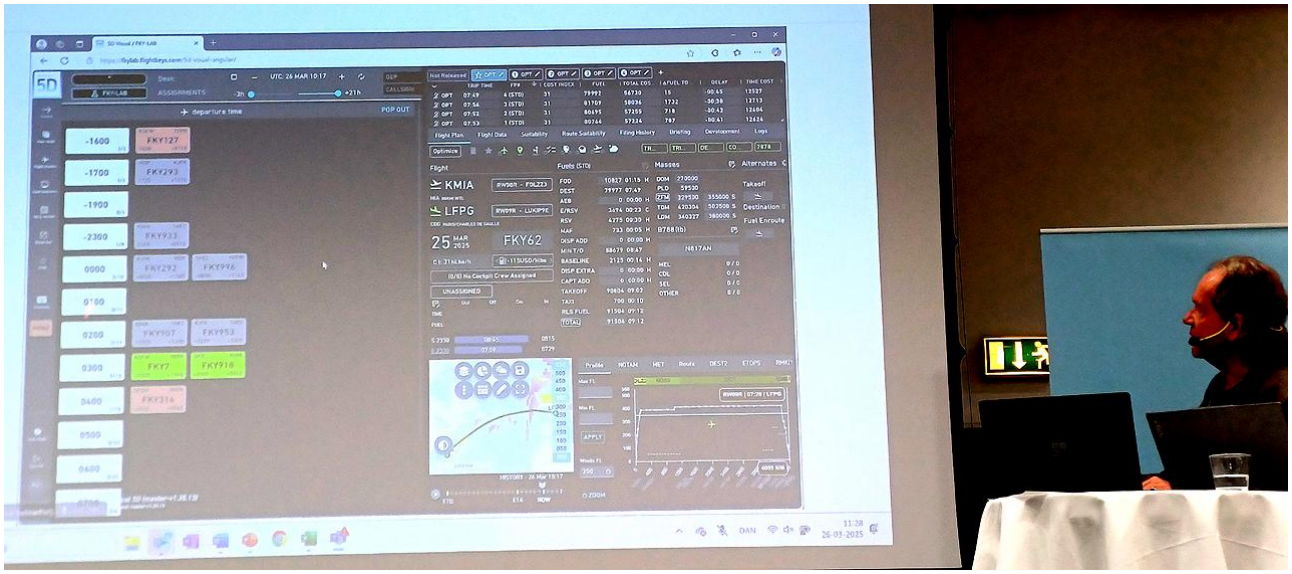
Sesar Concerto (EU-funded project) covers Northern Europe. The aim of the project is to focus overall, and to a lesser extent on the individual operators. Private jets tend to fly higher up, which is probably a problem, and their operations will be included in the study.

The results from a 14-day test period (data-based only) showed that 10% of the aircraft's total climate impact could be eliminated (23% of non-CO2) – but the results are not as encouraging as other studies that have been presented here at the conference.

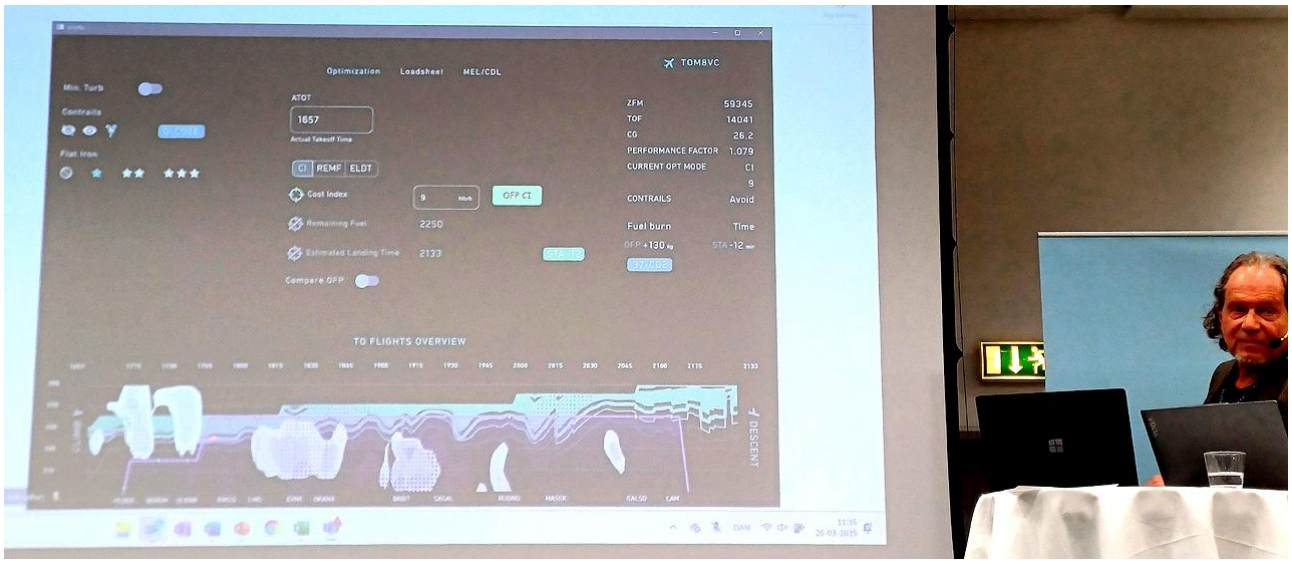
Showcase Part 1: First two of four companies working hands-on with contrail management present their practical solutions.

Raimund Zopp, Flightkeys

For 10 years, the company has been making flight plans, and has already integrated avoiding flight streaks into software (first edition). What TUI has accomplished has been done with their software. Similarly, controlled real tests also take place in the United States. The pilot has an additional screen available. We saw a screen from the dispatcher's screen (i.e. the company's practical planner):



and the pilot's screen:

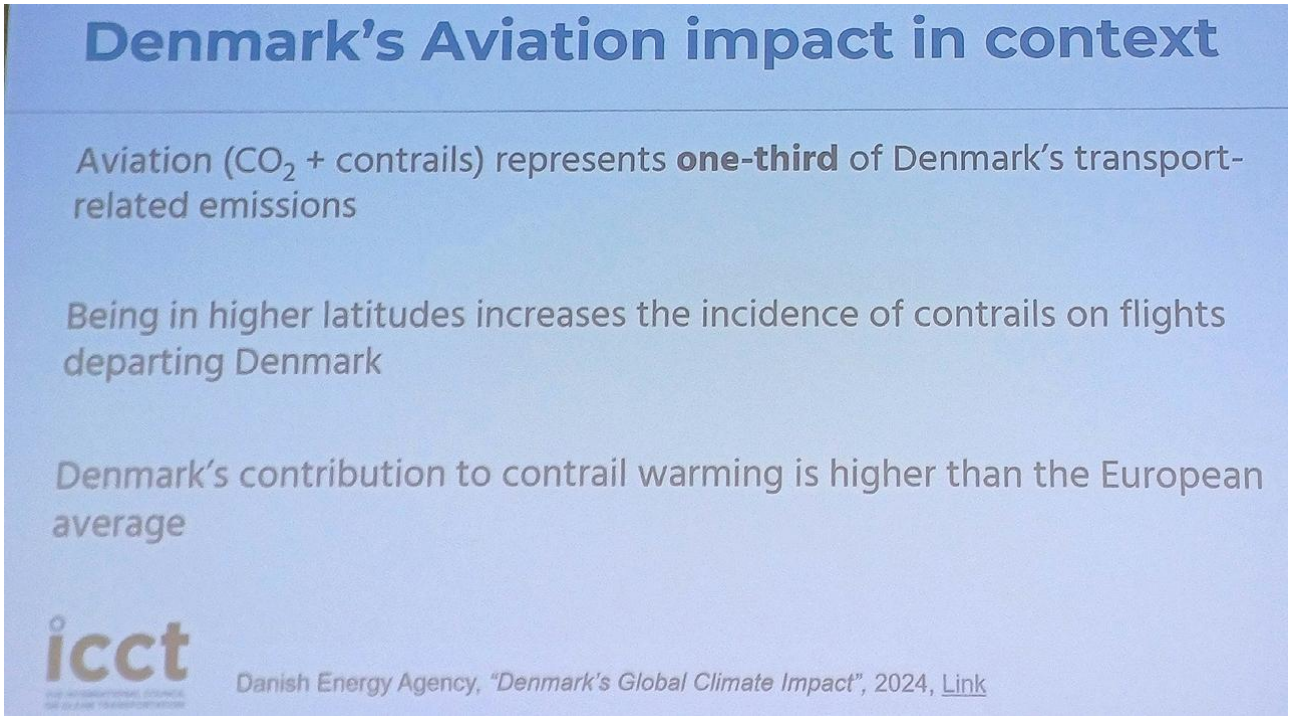


It is not easy to manually overview 3D airspace, time periods and a number of other parameters. Therefore, the system makes the various calculations. The example shows how the route can be laid out so that contrails are avoided.

Presentation: Tracking aviation's worldwide emissions – with a special focus on Denmark.

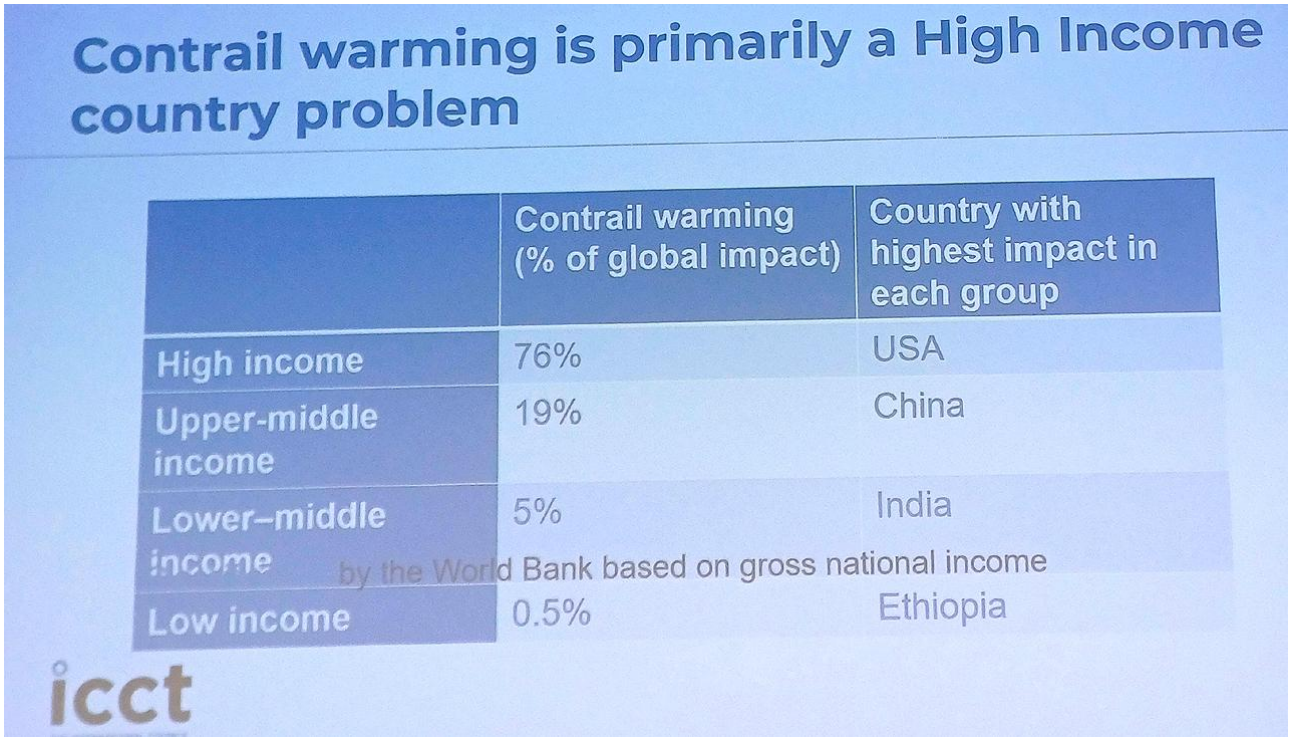
Jayant Mukhopadhaya, ICCT theicct.com

Conclusions for Danish aviation in photo on next page:

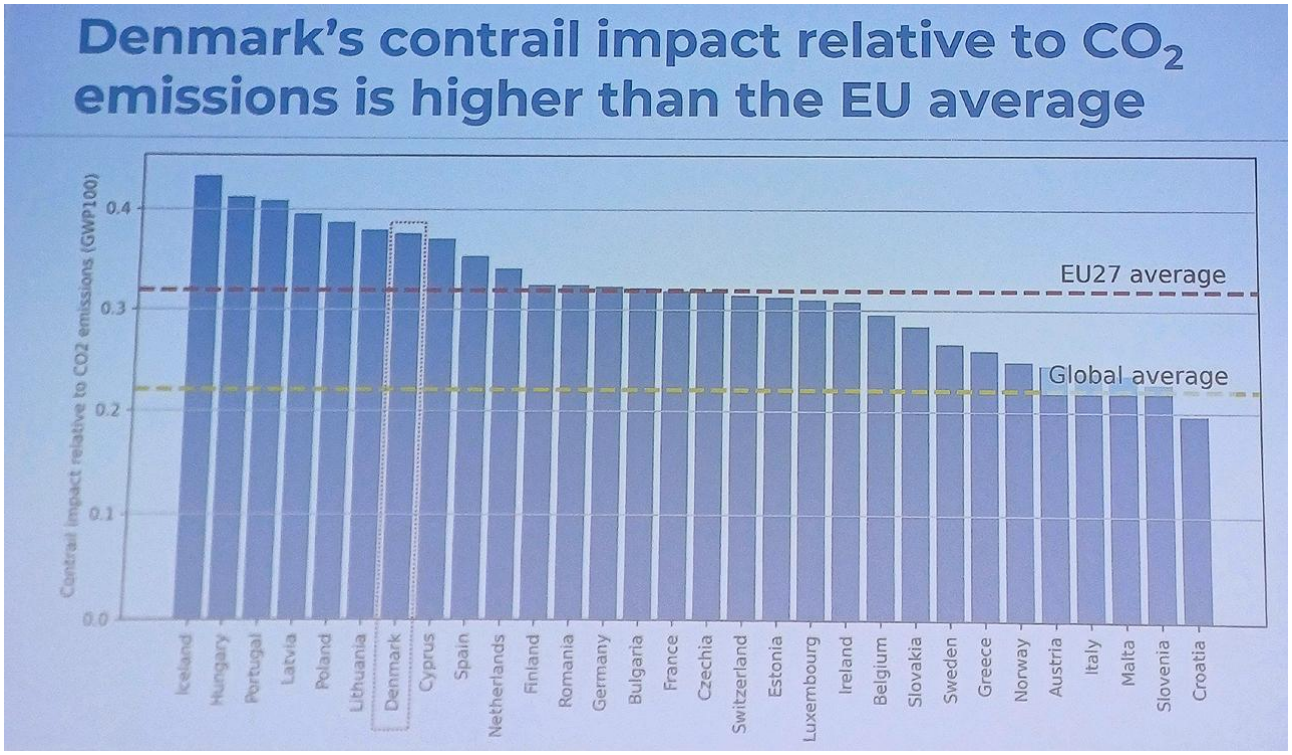


Later studies than Lee et al 2021 indicate that non-CO2 is not in the highest end (but within Lee et al's uncertainty), but is above 2.0.

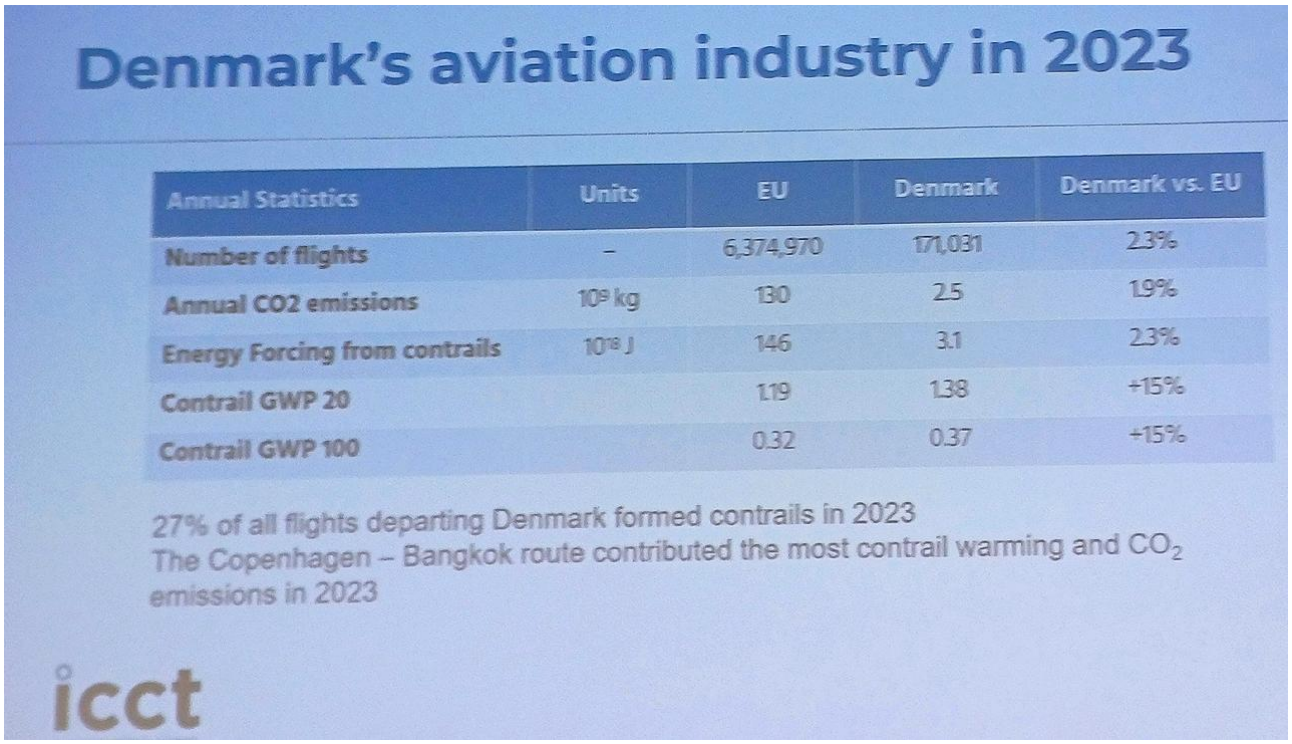
High-income countries take up the most of the non-CO2 problem, namely 75%. 50% from the US, UK and EU alone.



Denmark has a responsibility for non-CO2 that is above the EU average. Overall, aviation accounts for a third of the transport sector.



There is the particular problem that other sectors of transport have opportunities for electrification and are already in the process of being electrified, so aviation will take up more and more space – just like elsewhere in the world.



Annual Statistics	Units	EU	Denmark	Denmark vs. EU
Number of flights	–	6,374,970	171,031	2.3%
Annual CO2 emissions	10^9 kg	130	2.5	1.9%
Energy Forcing from contrails	10^{18} J	146	3.1	2.3%
Contrail GWP 20		1.19	1.38	+15%
Contrail GWP 100		0.32	0.37	+15%

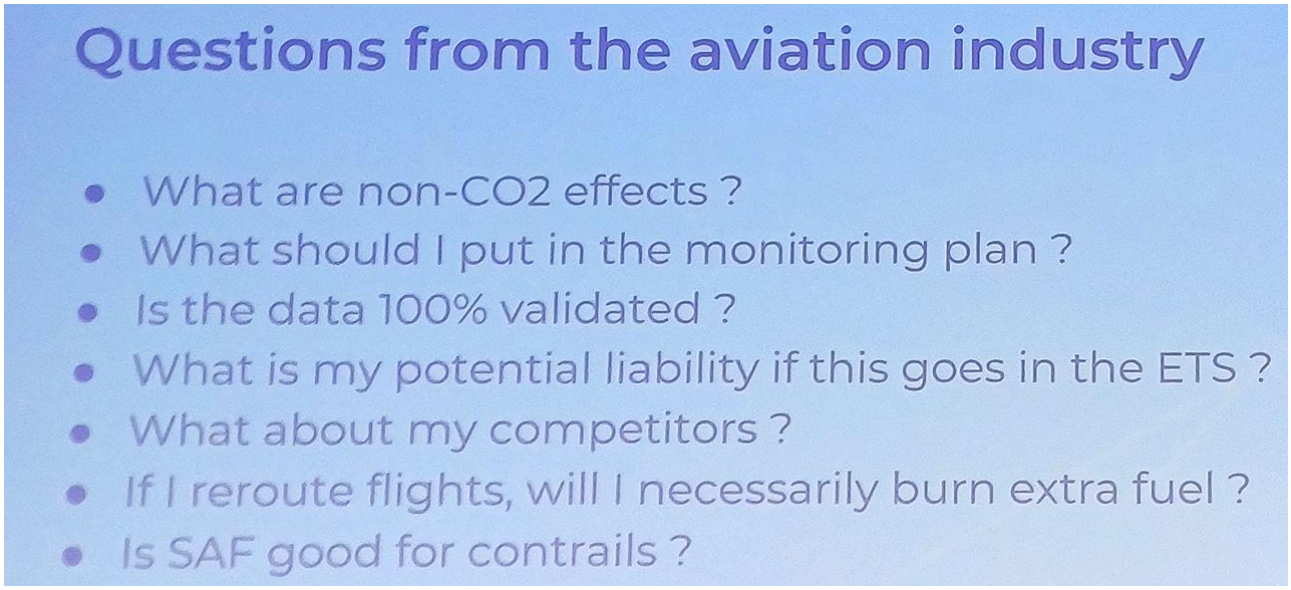
Conversation: How can companies get better estimates for their non-CO2 scope 3 emissions?

Sebnem Erzan, Google. Google Flight https://www.google.com/travel/flights will include the non-CO2 related effects. Their use of CO2e is according to the Kyoto Protocol, but not fully. But they are working to get the numbers right, even though it is inherently not easy for a particular flight into the future. Nor is SAF included. The goal is that individual passengers, but also companies, they can get information for their climate accounts and can follow whether they are reducing their climate footprint or not. The interest is present and growing to get good numbers. Google has no equivalent for shipping and railways.

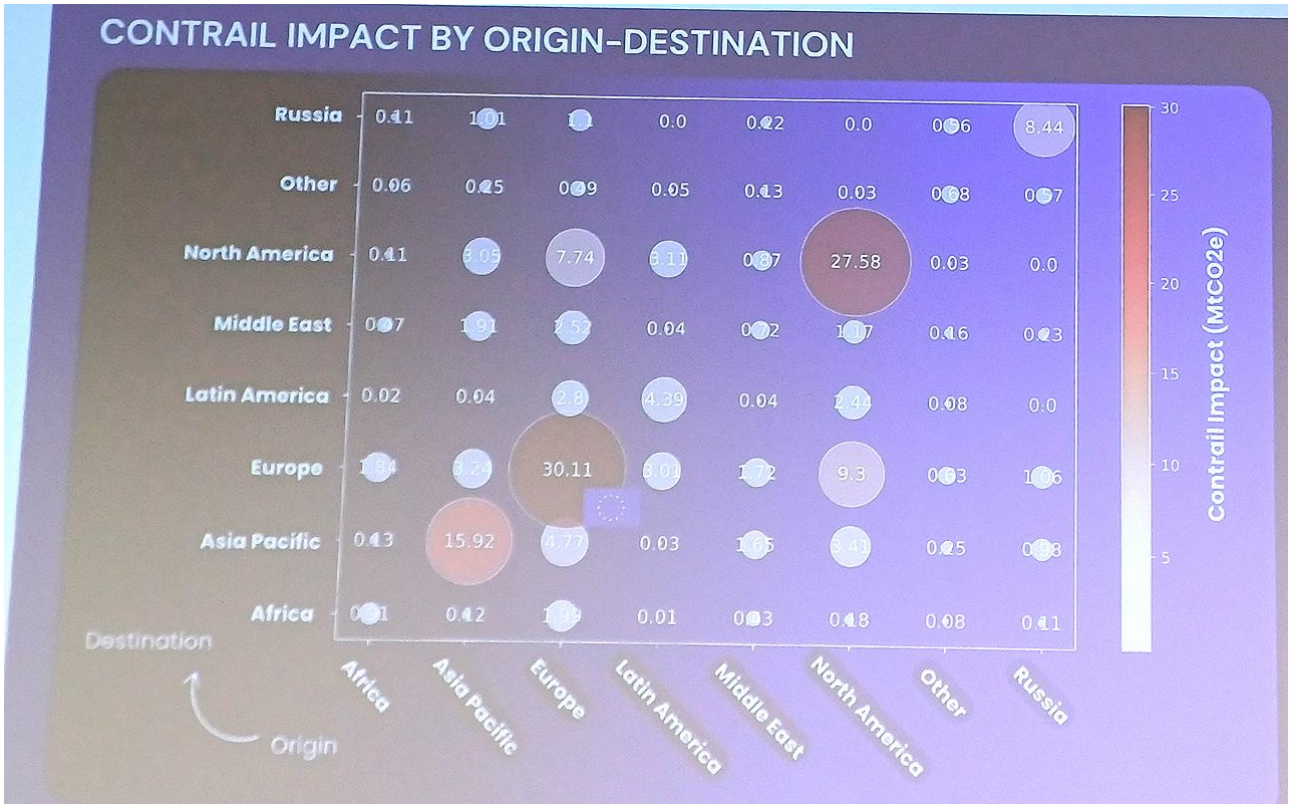
Showcase Part 2: Last two of four companies working hands-on with contrail management present their practical solutions.

Julien Lopez, Thales. About their work with the French airline Amelia. They fly on shorter routes Paris – Pau with smaller planes and fly charter. Roughly the same message as previous projects.

Maxime Meijers, Estuaire. Questions we encounter from the aviation industry. https://estuaire.dev/



This figure gives the low non-CO2 contribution because they count on GWP100. But it is an excellent figure. The next diagram with the dots is very funny, because you can see that despite tailwinds, flights from North America to Europe are worse in CO2e as opposed to the other way.



In MRV (monitoring) to the EU, the composition of the fuel is quite important, but is rarely reported well enough.