

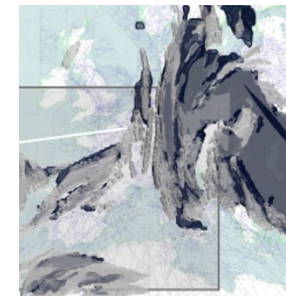
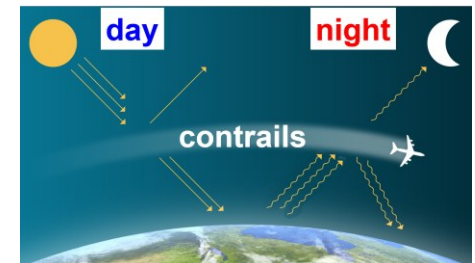
AIRCRAFT DESIGN AND SYSTEMS GROUP (AERO)

What Pilots Can Do – Management of Cabin Air Contamination Events and Contrails

Dieter Scholz

Hamburg University of Applied Sciences

Meeting of the Task Force Environment,
Vereinigung Cockpit, Hamburg, 08./09.06.2026





Conference agenda and information archived at
<https://perma.cc/Q9U4-Q7AZ>.

What Pilots Can Do – Management of Cabin Air Contamination Events and Contrails

Abstract

The presentation looks at two different aspects of passenger aircraft flight: a) Cabin Air Contamination Events (CACE) and b) Contrails. Both topics are connected: a) CACE concern the environment inside the aircraft cabin and cockpit. b) Contrails deal with the outside environment and can contribute to global warming. Pilots can manage both. a) Pilots can mitigate the effect of a CACE by descending to 10000 ft, venting the cabin with outside air. b) Pilots can adjust the flight level to avoid a potentially warming contrail and as such to mitigate the global warming effect of the flight. The presentation looks at both topics and provides information to help pilots to manage the situations.

What Pilots Can Do – Management of Cabin Air Contamination Events and Contrails

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Cabin Air Contamination Events (Fume Events)

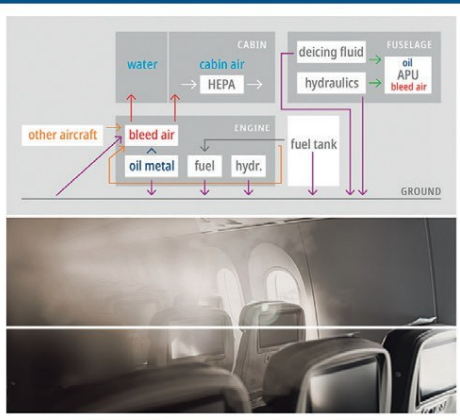
Cabin Air Contamination Events

Introduction

Dieter Scholz

Aircraft Cabin Air Contamination

An Engineering Perspective



HANSER

500 pages

HANSER

Solutions to a Hotly Debated Problem

Abstract

Purpose – This text is written to bring the engineering explanations of aircraft cabin air contamination together in one place and on another level of detail. Explanations go into technical detail, but all interested parties and people from all disciplines should benefit. --- **Methodology** – It is a review of the evidence combined with own contributions to the field. --- **Findings** – At a closer look, the aircraft is anything else but a glamorous polished machine. For technical reasons, dangerous chemicals are in use. These substances leave their intended places and get distributed everywhere. As such they just follow the law of nature: entropy. Unfortunately, while spreading, the substances also arrive in the human body with health and flight safety consequences. All occupants are potentially affected, but predominantly the crew, who spend much more time in an airplane than even a frequent flyer. In this way low dose exposures accumulate and are potentially topped by a high dose exposure in a failure case. --- **Research Limitations** – Focus is on cabin air contamination from engine oil in transport category airplanes. Contamination due to hydraulic fluid, deicing fluid, and even ozone is also considered. --- **Practical Implications** – People who suffer from consequences of aircraft cabin air contamination may find answers to the main question: Why? Others may find hints on how to get protected. --- **Social Implications** – This text can prove evidence of the engineering fundamentals in court. **Originality** – No comparable text seems to be published.



Aircraft Cabin Air

The air you breathe on an aircraft may not be as good as you had hoped for. Coming to this page, you probably know already. However, if it is all new to you, read my [German Memo](#) or watch this [Video in English](#).

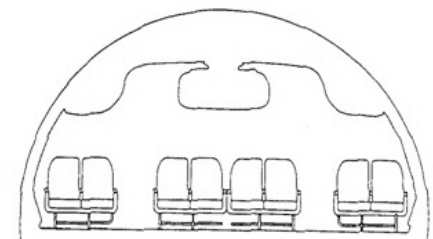
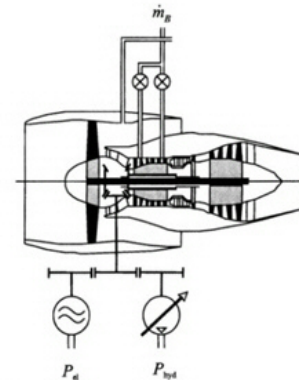


Abstract

A detailed look at the design of jet engines with their bearings, lubrication and sealing reveals that jet engines leak small amounts of oil by design. This oil gets into the engine compressor and the bleed air. Almost all passenger jet aircraft today use this potentially contaminated bleed air for cabin ventilation.

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My webpage: <http://CabinAir.ProfScholz.de>

Technical Analysis of the Accident: Swiss Flight LX1885 with an Airbus A220 – From Uncontained Engine Failure via Smoke on Board, A Dead Flight Attendant to Alleged Cover Up at Austrian's Federal Safety Investigation Authority (SUB)

Air conditioning systems of all large passenger aircraft (except the Boeing 787) take the air unfiltered from the compressor of the engine (bleed air)! Any contamination in normal operation and in failure cases (as in LX1885) goes straight into cockpit and cabin. Such a **system design is inadequate** as stated for decades in SAE AIR 1168-7A [1]: "... the risk of obtaining contaminated air from the engine may preclude its use for transport aircraft, regardless of other reasons [like financial advantages]."

Why is smoke on board after a severe engine failure? The air conditioning system takes air from the engine!

Why a dead flight attendant? Oil fumes are toxic, and aircraft do not offer adequate breathing protection!

Why is the Austrian Air Accident Investigator (SUB) providing an intermediate report below standards?

Why is the Austrian Air Accident Investigator (SUB) prosecuted? Why is the case transferred to the STSB in Switzerland?

Aircraft manufacturers / airlines do not have an interest that the answers given above get into an (intermediate) report!

Poster DLRK 2025: <https://doi.org/10.48441/4427.2885>

Introduction

Cabin Air Contamination Event Due to Engine Oil After Technical Fault



2010-09-17, US Airways US-432, Boeing 757-200 (<https://youtu.be/AZqeA32Em2s>).

US Airways US-432 on 2010-09-17 with Boeing 757-200. The Maui-bound flight enroute overhead the Pacific diverted to San Francisco (900 nm). A passenger wrote:

Our plane was about two hours out over the Pacific Ocean headed for Maui when a thick smoke started to fill the cabin of our plane. There was a burning smell, but flight staff crew couldn't figure out where the smoke was coming from. Since we weren't to the halfway mark we had to turn the plane around and fly back two hours and land in San Francisco. For two hours we had to fly with the smoke and the fire alarms going off in the cabin. I caught this video footage right before we landed in San Francisco ...

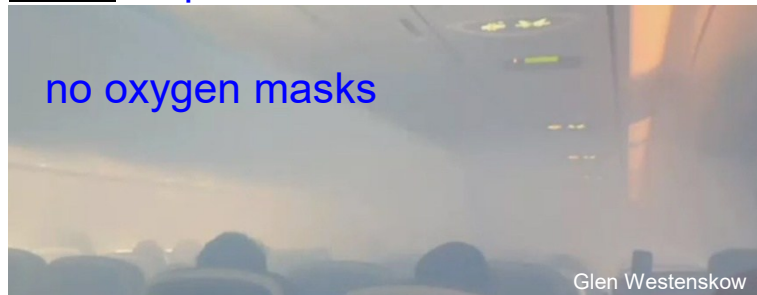
A situation where a descent to 10000 ft was possible but was not initiated.

Introduction

2019-08-22: Hawaiian Airlines, A321neo Emergency Landing and Evacuation; Smoke on Board

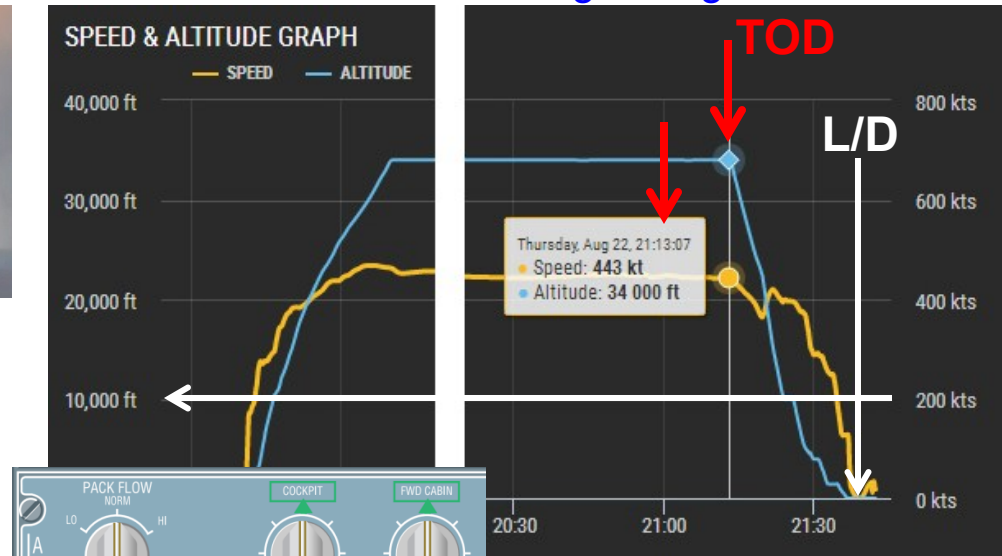
Oakland to Honolulu, Flight HA47, A321neo, N218HA

21:13: **Top of Descent**: Smoke starts to fill cabin i.e. when **thrust setting changed**.

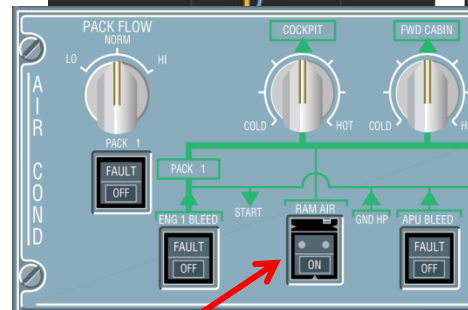


21:16: Pilots received a **fire warning** from the **cargo compartment** and declared an in-flight emergency.

21:36: Landing. After landing there was "no visible evidence of **fire**, no visible flames" said Snook. "We have since determined that a **seal failed in the aircraft's left engine**" said Da Silva.



based on Flight Radar 24

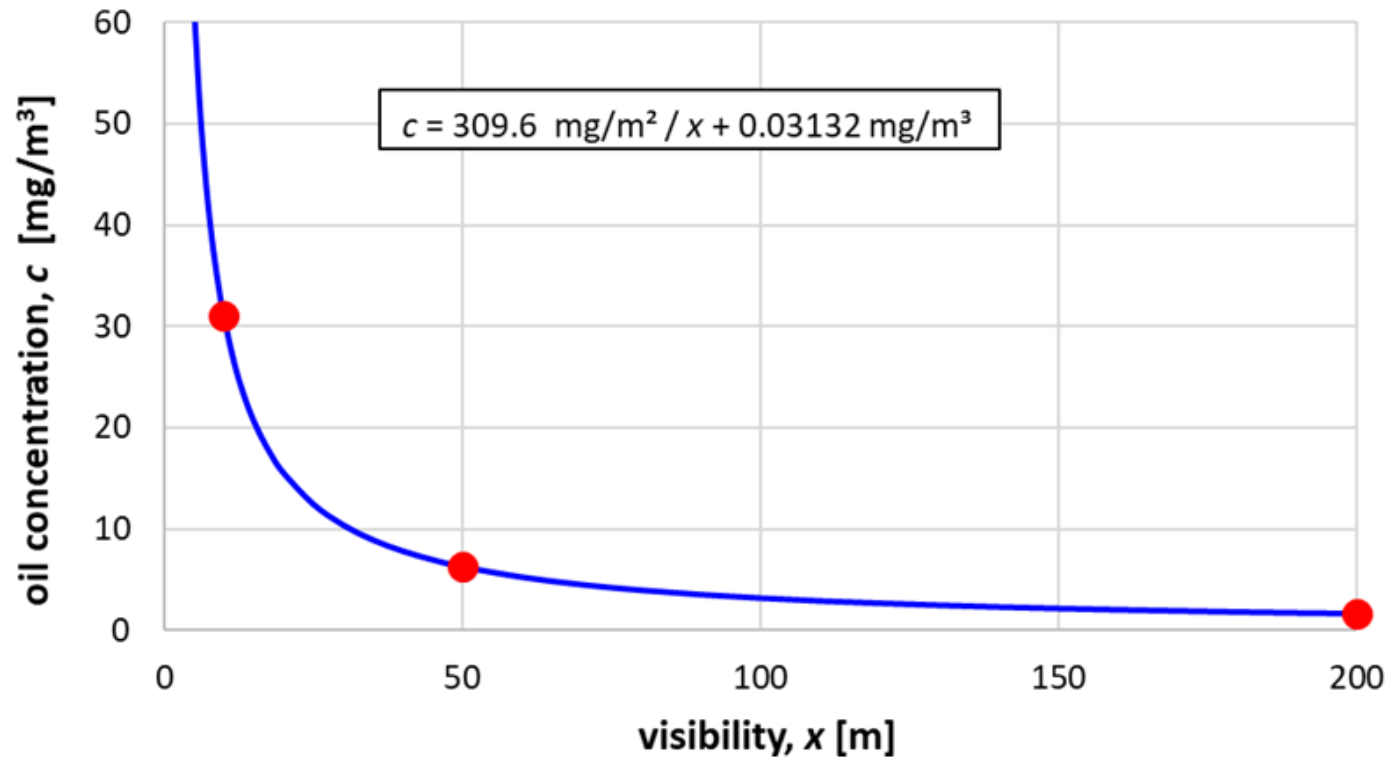


guarded pushbutton

Direct (emergency) venting with ram air (independently of bleed air) is possible **below 10000 ft**, but was **not used**.

Introduction

Oil Concentration, c (mg/m³) in the Cabin versus Visibility, x (m) in the Cabin



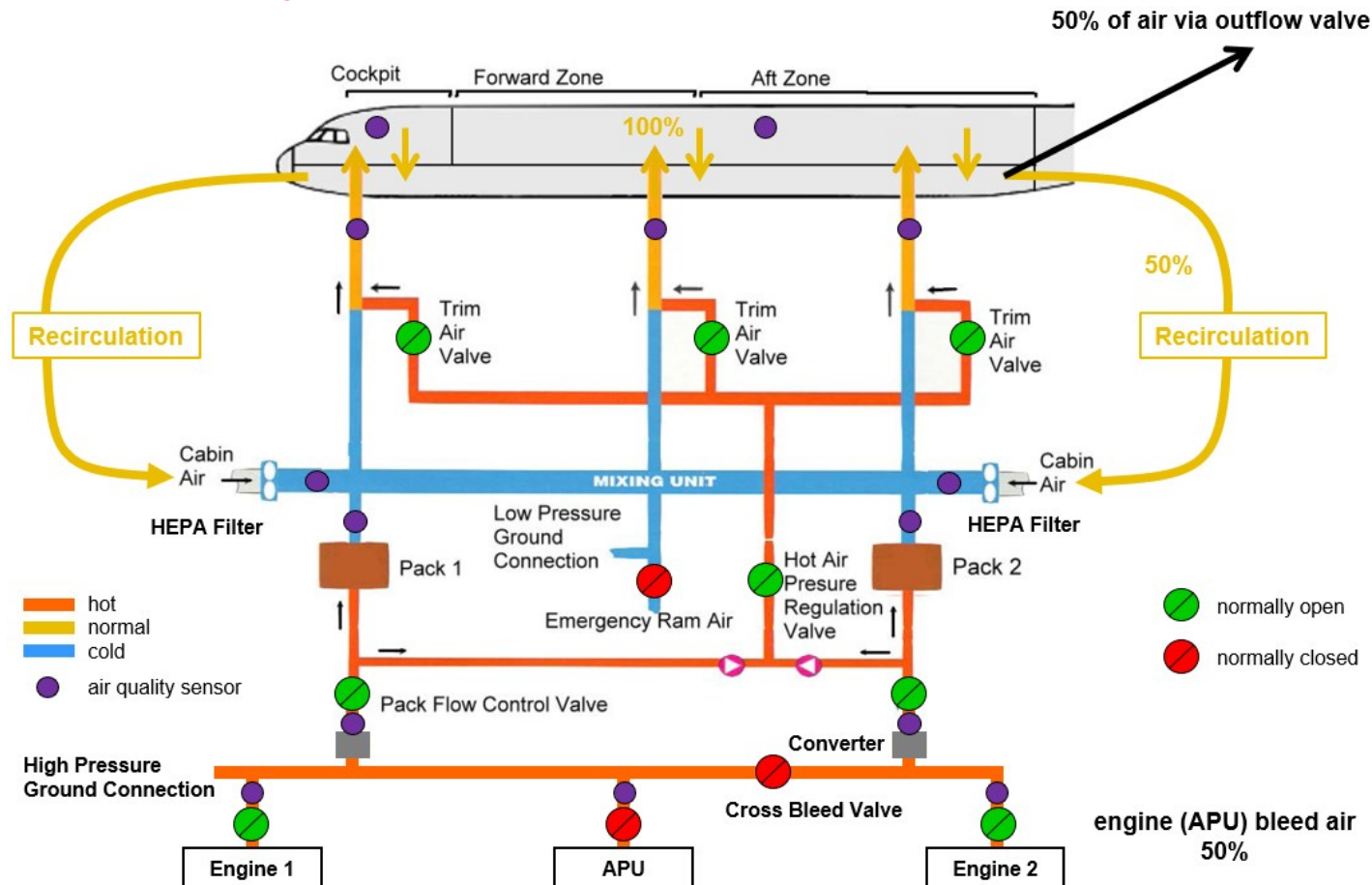
The three points are given in NRC (1997). Source: D. Scholz.

Cabin Air Contamination Events

Sensors

Sensors

Potential Air Quality Sensor Locations



Potential air quality sensor locations (purple dots). Picture source: D. Scholz.

Sensors

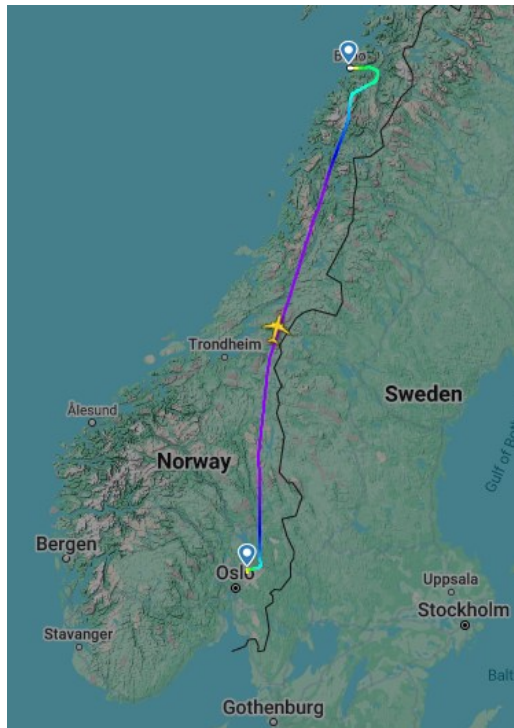
An Affordable Sensor for Cabin and Cockpit: BLATN BR-SMART-128s



The BLATN BR-SMART-128s combines measurements of particles (number concentration and mass concentration), formaldehyde, VOC, and CO₂. This is an interesting combination for aircraft cabin air quality measurements. (Blatn 2025)

Sensors

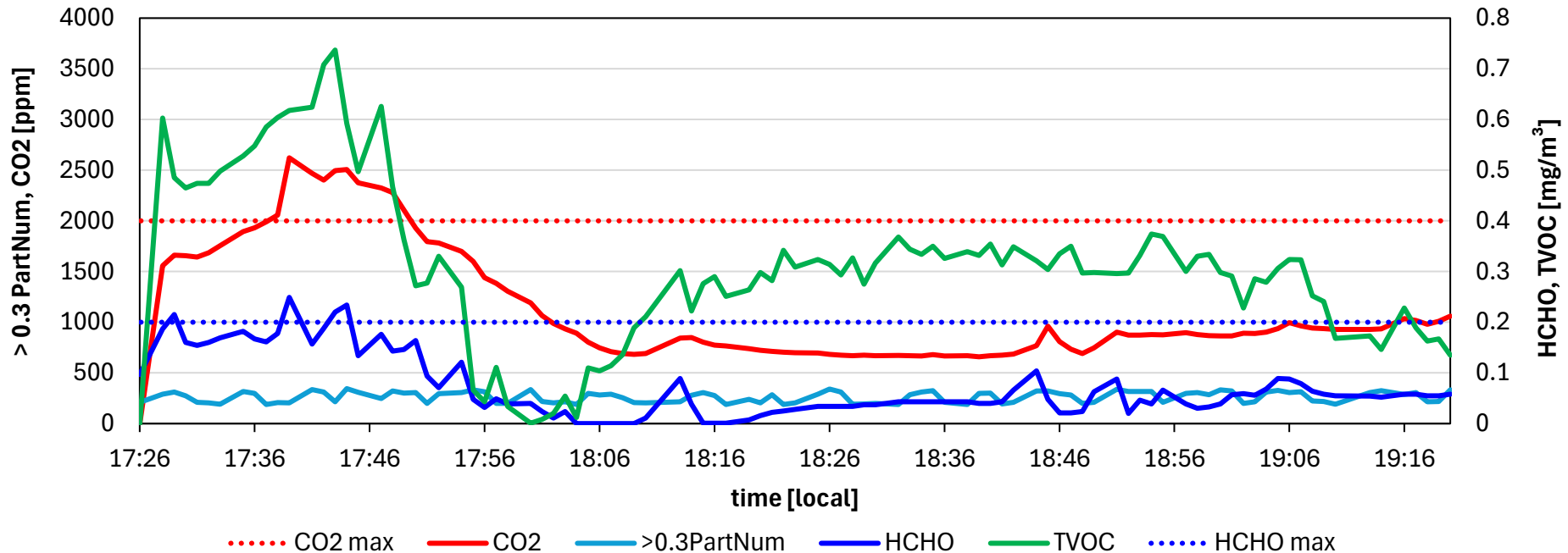
Measurements with BLATN BR-SMART-128s on Flight to Bodø



DATE	FROM	TO	A/C	FT	STD	ATD	STA	STATUS	A/C
07. Apr 25	Oslo (OSL)	Bodo (BOO)	B738 (LN-ENM)	01:23	17:45	17:55	19:15	Landed 19:18	B737-8JP

Sensors

Measurements with BLATN BR-SMART-128s on Flight to Bodø

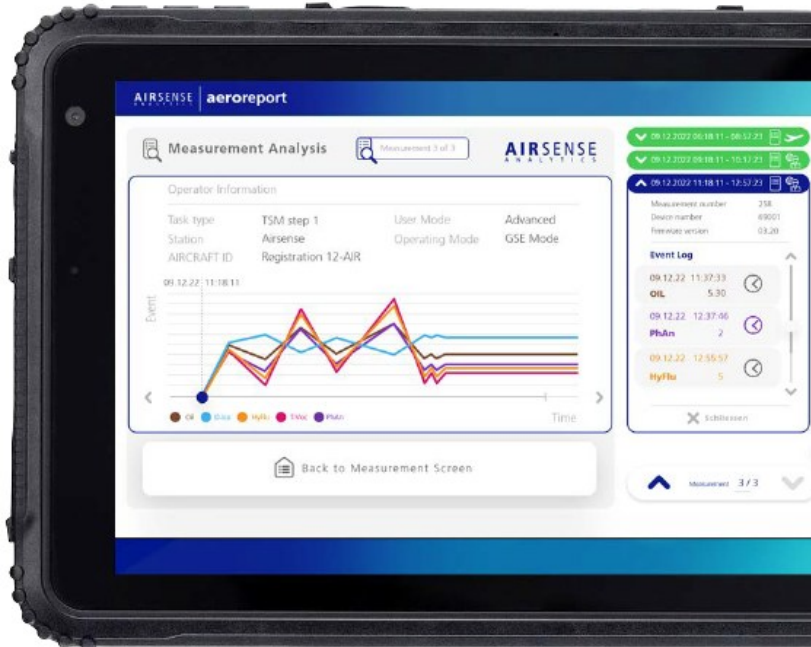


"Hazardous" according to BLATN: CO₂ > 2000 ppm; HCHO > 0.2 mg/m³. This is indicated by the dotted line.
 EASA CS 25.831: CO₂ < 5000 ppm; DIN EN 13779: CO₂ < 1400 ppm or cognitive degradation

DATE	FROM	TO	A/C	FT	STD	ATD	STA	STATUS	A/C
07. Apr 25	Oslo (OSL)	Bodo (B00)	B738 (LN-ENM)	01:23	17:45	17:55	19:15	Landed 19:18	B737-8JP

Sensors

Airsense: Aerolyzer – Sensing in Flight



Distinguish in real time / in flight between Engine Oil / APU Oil, Deicing Fluid, VOC, Hydraulic Fluids & Phtalic Anhydride. The measurement analysis is easy to use on Windows based PCs and Tablets. (Airsense 2026)

Sensors

Airsense: Aerolyzer – Sensing in Flight

SOF event *Flightcase*

➤ AIRSENSE aerolyzer FC available in 2025

Live offline recording of SOF events to accelerate troubleshooting and maintenance even more



SOF events that require technical attention are usually caused by bleedair from engine or APU, deicing system, hydraulics or the ECS as well as electrical burning in general (VOC). (Airsense 2026)

Cabin Air Contamination Events

Flight at 10000 ft to Vent the Cabin with Outside Air

Flight at 10000 ft to Vent the Cabin with Outside Air

Checklists

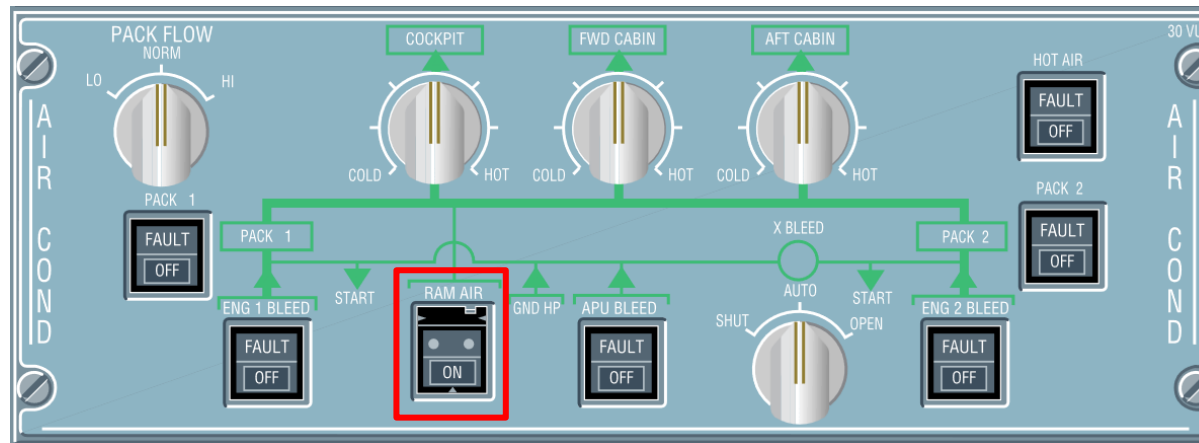
SMOKE/FUMES/AVNCS SMOKE
LAND ASAP IF PERCEPTIBLE SMOKE APPLY IMMEDIATELY : – BLOWER OVRD – EXTRACT OVRD – CAB FANS OFF – GALLEY OFF – SIGNS ON – CKPT/CABIN COM ESTABLISH ● IF REQUIRED : – CREW OXY MASKS .. ON/100%/EMERG ● IF SMOKE SOURCE IMMEDIATELY OBVIOUS, ACCESSIBLE, AND EXTINGUISHABLE : – FAULTY EQPT ISOLATE ● IF SMOKE SOURCE NOT IMMEDIATELY ISOLATED : – DIVERSION INITIATE – DESCENT (FL 100 or MEA, or minimum obstacle clearance altitude) INITIATE ● AT ANY TIME of the procedure, if SMOKE/FUMES becomes the GREATEST THREAT : – SMOKE/FUMES REMOVAL ... CONSIDER – ELEC EMER CONFIG CONSIDER <i>Refer to the end of the procedure to set ELEC EMER CONFIG</i> ● At ANY TIME of the procedure, if situation becomes UNMANAGEABLE : – IMMEDIATE LANDING CONSIDER

SMOKE/FUMES REMOVAL
<i>Use the smoke removal procedure if there is dense smoke, toxic fumes (smell), or if smoke generation cannot be stopped.</i> – EMER EXIT LIGHT ON ... – LDG ELEV 10000 FT/MEA – DESCENT (FL 100, or MEA, or minimum obstacle clearance altitude) INITIATE – ATC NOTIFY – SMOKE/FUMES/AVNCS SMOKE PROC CONTINUE <i>While descending, continue applying the appropriate steps of the SMOKE/FUMES/AVNCS SMOKE procedure depending on the suspected smoke source.</i> ● At FL100 or MEA : – PACK 1+2 OFF – MODE SEL MAN – MAN V/S CTL FULL UP – RAM AIR ON

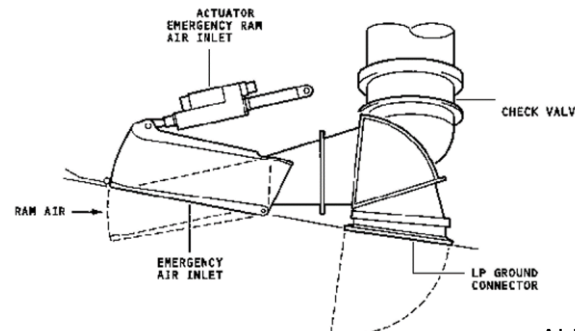
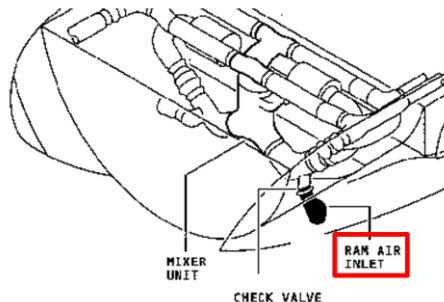
In case of smoke and fumes on an Airbus A320 the "Smoke/Fumes/Avionics Smoke" checklist is applied. If smoke/fumes become the greatest threat, the "Smoke/Fumes Removal" checklist is used. Important steps are shown. If the steps do not show sufficient effect, cockpit windows could be opened as a next step. Based on Smart Cockpit (2020).

Flight at 10000 ft to Vent the Cabin with Outside Air

Activating the Guarded RAM AIR Switch on the Airbus A320



Airbus A320 air conditioning (AIR COND) part of the overhead panel. The air conditioning packs (PACK 1 and PACK 2) can be switched "OFF". The guarded RAM AIR switch is covered to prevent inadvertent use. By pressing RAM AIR "ON", the ram air inlet is opened.



Airbus 1999



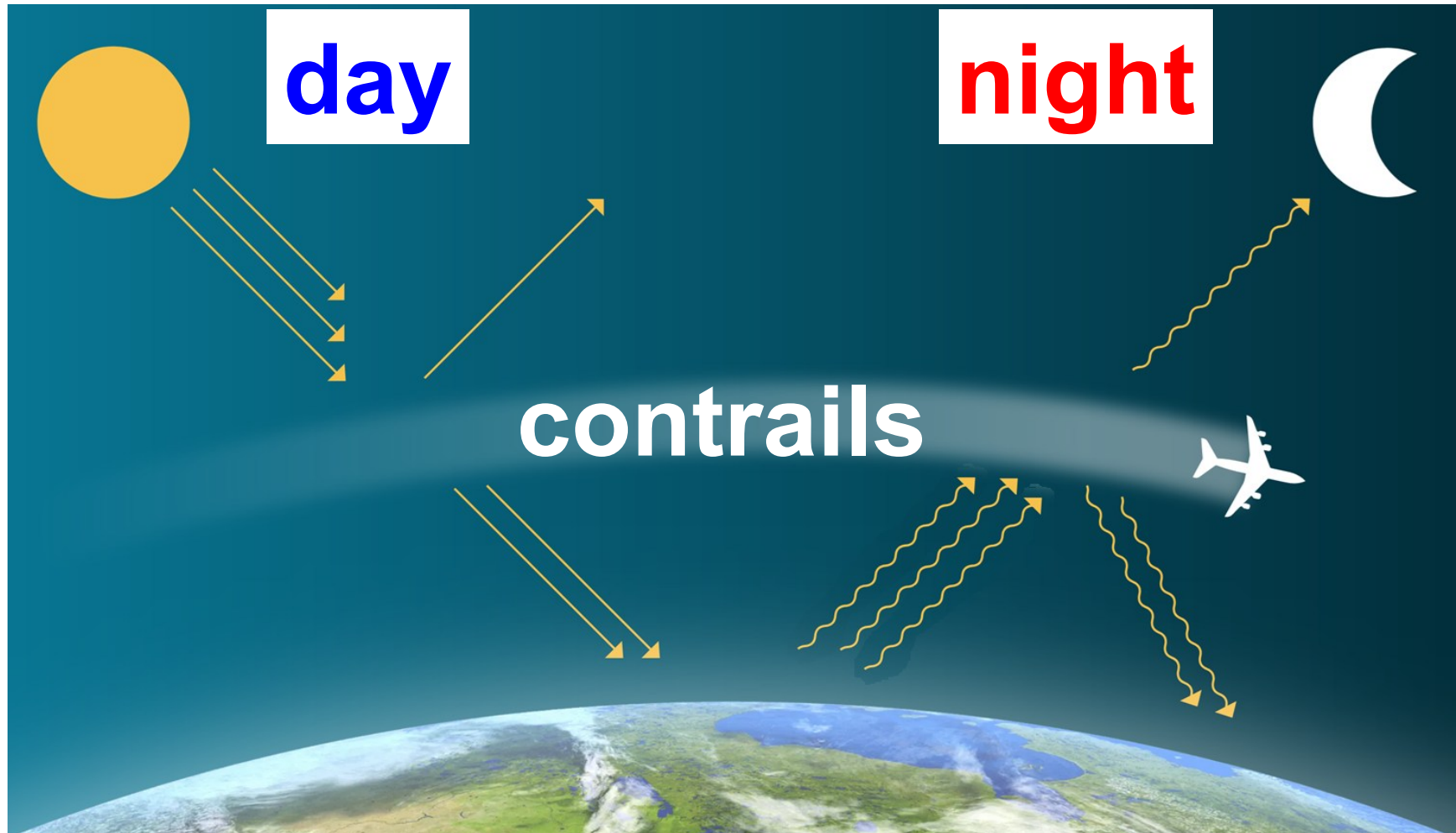
Airbus A320, ECAM System Display (SD) cabin pressurization (CAB PRESS). Flight in FL 100 with the emergency ram air inlet open. Both packs are shown in amber, because they are switched off. The outflow valve is halfway open. Cabin pressure control is set to manual (MAN). The cabin altitude (CAB ALT) is 9850 ft. Vertical speed is now at 0 ft/min and differential pressure, $\Delta p = 0.1$ psi.

Contrail Management

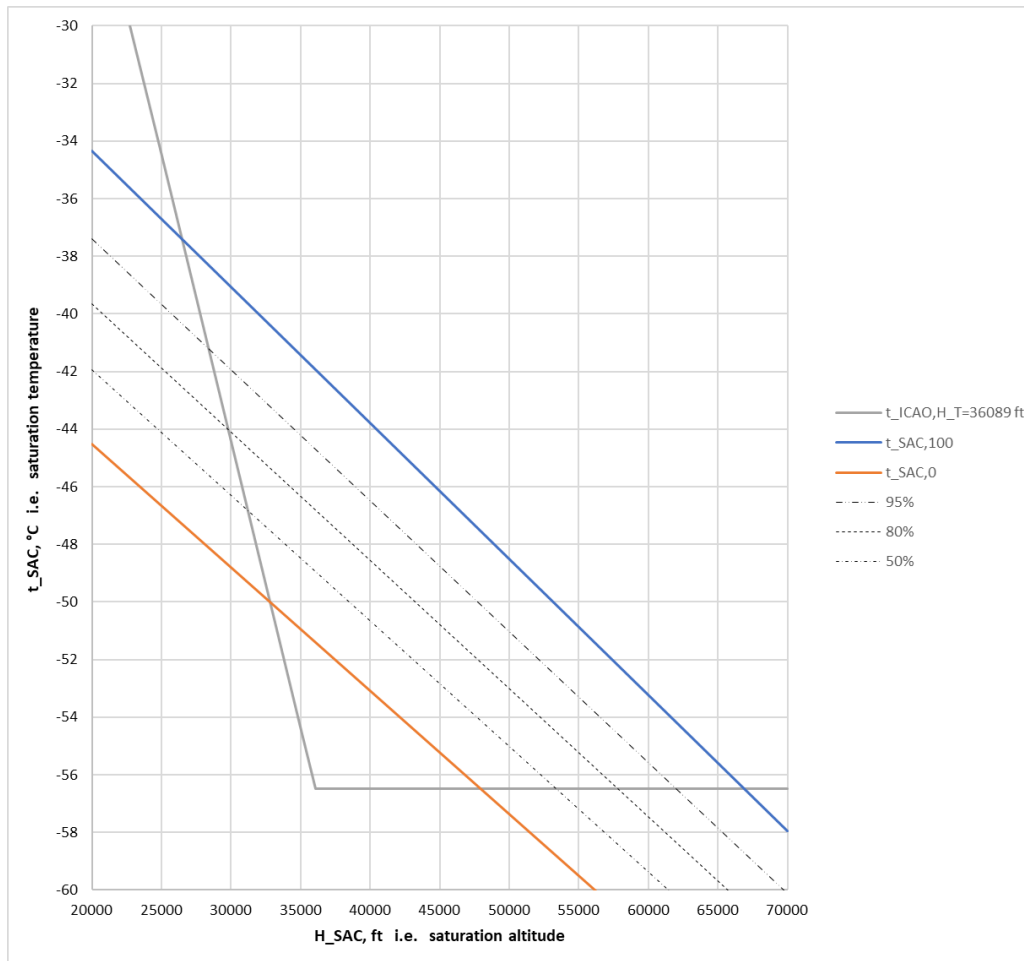
Contrail Management

Contrail Basics

Cooling (Day) versus Warming (Night) Contrails

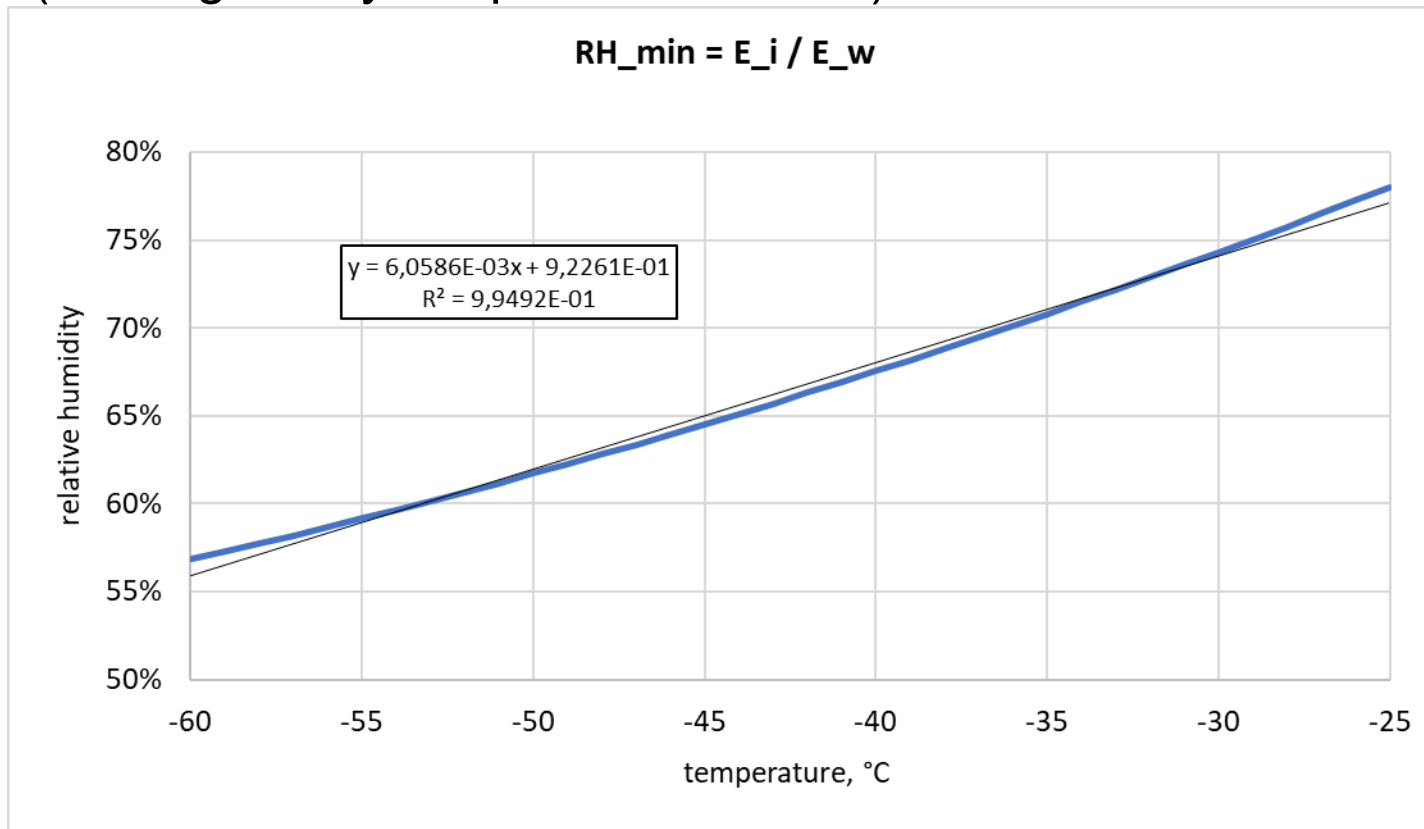


Condition A: Schmidt-Appleman Diagram: Conditions for Contrail Formation (But: contrail may not be persistent)



Calculations by Scholz.
Find the Excel Table [here](#).

Condition B: Conditions for Persistence: **Flight Through Ice Super-Saturated Region (ISSR):** **Relative Humidity Larger Than Minimum Relative Humidity** (But: flight may not produce contrail)



Calculations
by Scholz.
Find the Excel Table
[here](#).

Conditions A and B: Persistent Contrail

For persistent contrails to form, a region of airspace must fulfill:

- **Condition A:** Be **cold** (and humid) enough to cause wet, hot engine exhaust to form ice crystals on engine emissions or pre-existing atmospheric aerosols (i.e., tiny particles). The **Schmidt-Appleman Criterion (SAC)** predicts these conditions. Most contrails that initially form will vaporize in a few minutes (harmless).
- **Condition B:** Be **humid** enough to freeze additional water vapor onto the initial contrail. The technical term for these atmospheric regions is **Ice Super-Saturated Region (ISSR)**. When contrails form in ISSRs, they can persist and grow for many hours (potentially harmful).
- **Together (Condition A and B):** When an aircraft satisfies the Schmidt-Appleman Criterion in a region of atmosphere that is ice super-saturated, we call the region a **Persistent Contrail Region (PCR)** for this aircraft. Aircraft and atmosphere fulfill the **Persistent Contrail Criterion (PCC)**.

See also: [Contrail Regions 101](#) ([archived](#))

Systematic of Cooling and Warming Contrails

Effect of Contrails

No.	CLD / SKC	D / N	R / NR	Effect
1	CLD	D	R	I
2	CLD	D	NR	I
3	CLD	N	R	I
4	CLD	N	NR	I
5	SKC	D	R	I
6	SKC	D	NR	C
7	SKC	N	R	W
8	SKC	N	NR	W

Symbol	Meaning
CLD	cloud (OVC)
SKC	sky clear
D	day
N	night
R	reflective
NR	non-reflective
W	warming
C	cooling
I	indifferent
OVC	overcast

Systematic of Cooling and Warming Contrails

Reasons

Reason 1 to 4: Clouds are present; the contrail does not make a difference.

Reason 5: The surface is reflective. A reflective contrail does not make a difference.

Reason 6: A non-reflective surface, e.g. the ocean, “swallows” the Sun's radiation. The contrail precludes this.

Reason 7 to 8: There is no radiation from the Sun. Reflection back to Earth of long-wavelength radiation due to the contrail is important.

Systematic of Cooling and Warming Contrails

Reasons in More Detail

The climatic effect of a contrail depends on **cloud cover, day or night conditions, and the reflectivity of the Earth's surface.**

If **clouds** are already present (cases 1 to 4), an additional contrail has essentially no effect. Contrails are **indifferent**.

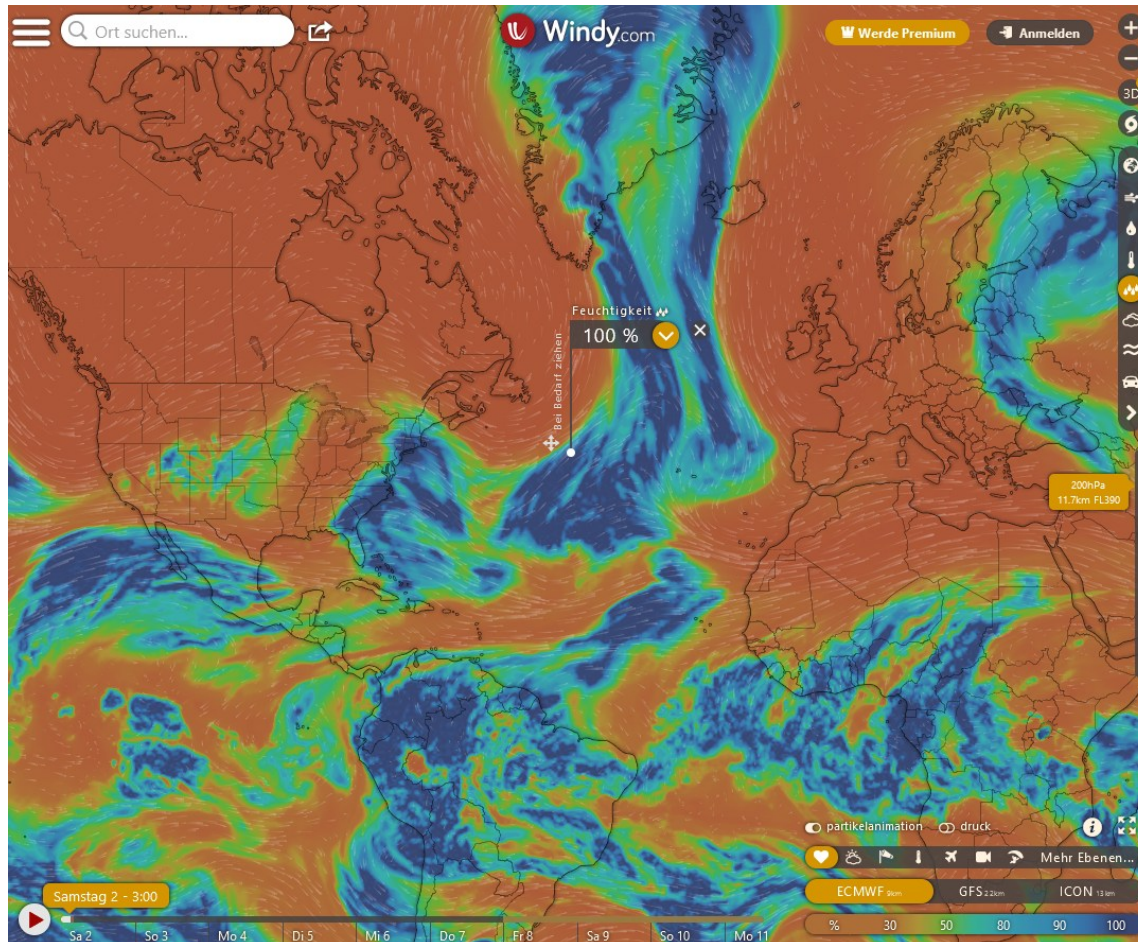
At night there is no incoming solar radiation. Contrails can not be shielding. Therefore, contrails at night cannot have a cooling effect. Contrails are either **indifferent** (with **clouds**; cases 3 and 4) or **warming** (**clear sky**; no matter what the surface is like; cases 7 and 8).

With a **clear sky during daytime**, the effect depends on surface reflectivity:

Over a **reflective surface** (case 5), the contrail makes little difference it is **indifferent**.

Over a **non-reflective surface** such as the ocean (case 6), part of the incoming solar radiation is reflected by the contrail instead of being absorbed by the surface. The contrail therefore has a **cooling** effect.

Windy.com: Relative Humidity from ECMWF as a Function of Location, Altitude and Time (including Forecasts)



Contrail Management

Contrail Prediction with windy.com



Contrail finder v1.1.0

Basic Prediction

39000 ft	Short contrails possible
38000 ft	"
37000 ft	Longer contrails possible
36000 ft	Long, possibly persistent
35000 ft	"
34000 ft	"
33000 ft	"

Contrails will form

No contrails

Persistent Contrails with
RH_i > 100%



Detailed analysis - Contrail persistence

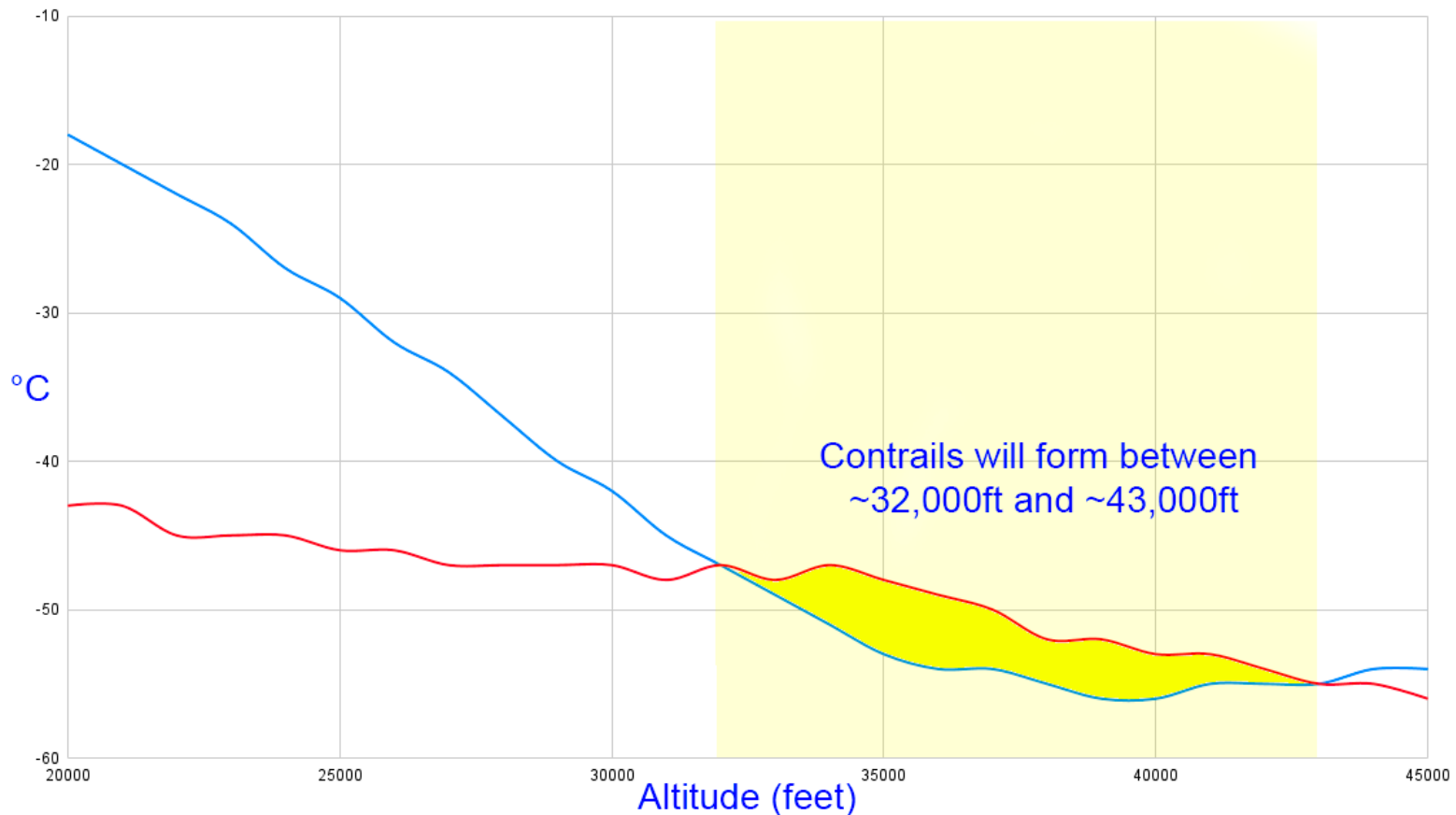
ft	°C	RH _w	RH _i	Max °C	
45000	-53	3	5	-53	
44000	-53	5	8	-53	
43000	-53	7	12	-52	
42000	-53	9	15	-52	
41000	-53	11	19	-51	
40000	-53	14	23	-51	
39000	-53	21	35	-50	
38000	-53	39	65	-50	
37000	-52	58	96	-49	
36000	-52	76	126	-49	✓
35000	-52	94	156	-48	✓
34000	-50	91	150	-48	✓
33000	-48	78	126	-47	✓
32000	-45	64	102	-47	
31000	-43	51	78	-46	
30000	-40	47	70	-46	
29000	-38	46	68	-45	
28000	-36	46	66	-45	
27000	-34	46	64	-44	
26000	-31	46	62	-44	
25000	-29	45	60	-44	
24000	-27	45	57	-43	
23000	-25	40	51	-43	
22000	-22	35	44	-42	
21000	-20	31	37	-42	
20000	-18	26	31	-41	



Contrail finder v1.10

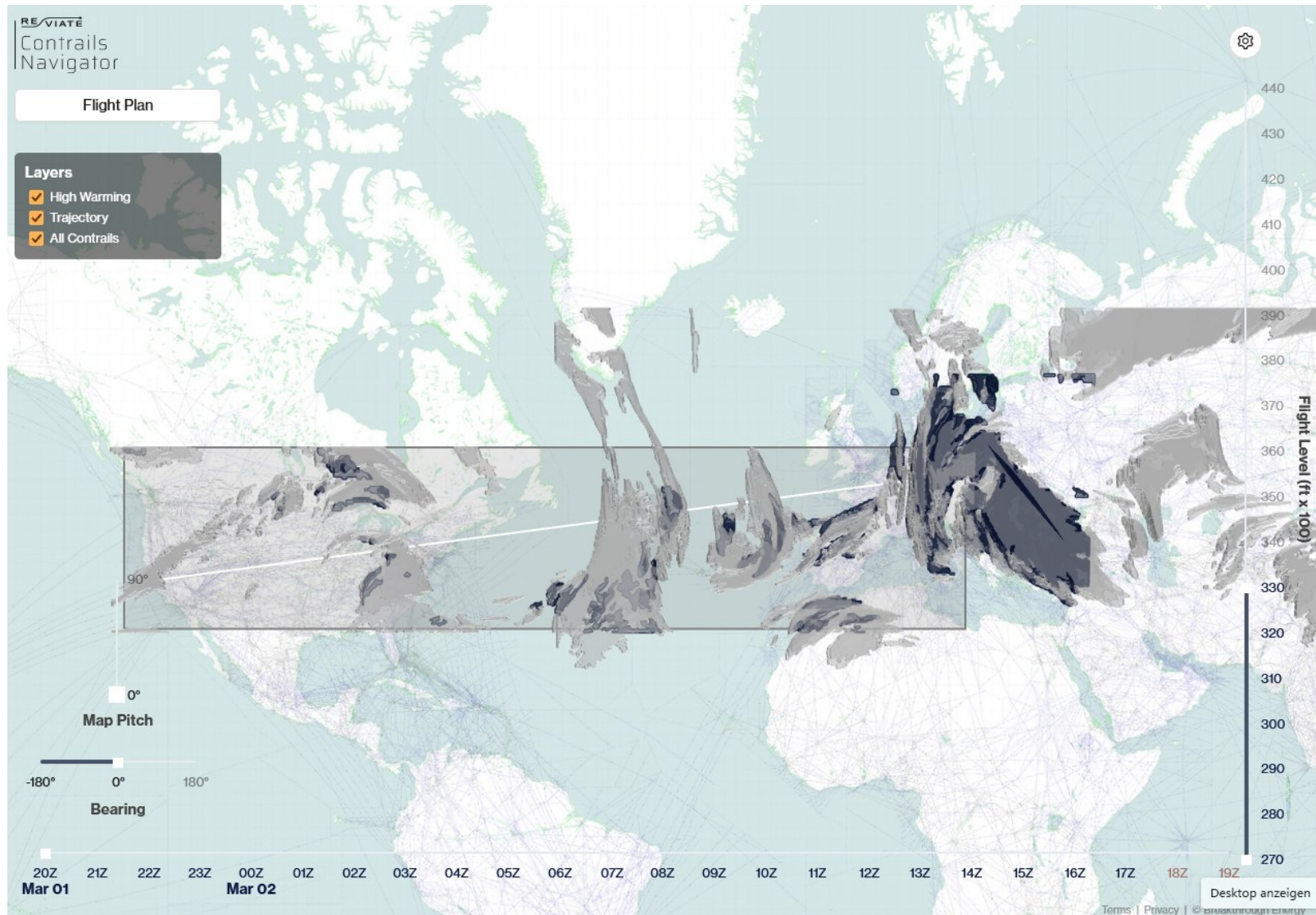
— Temperature — Appleman

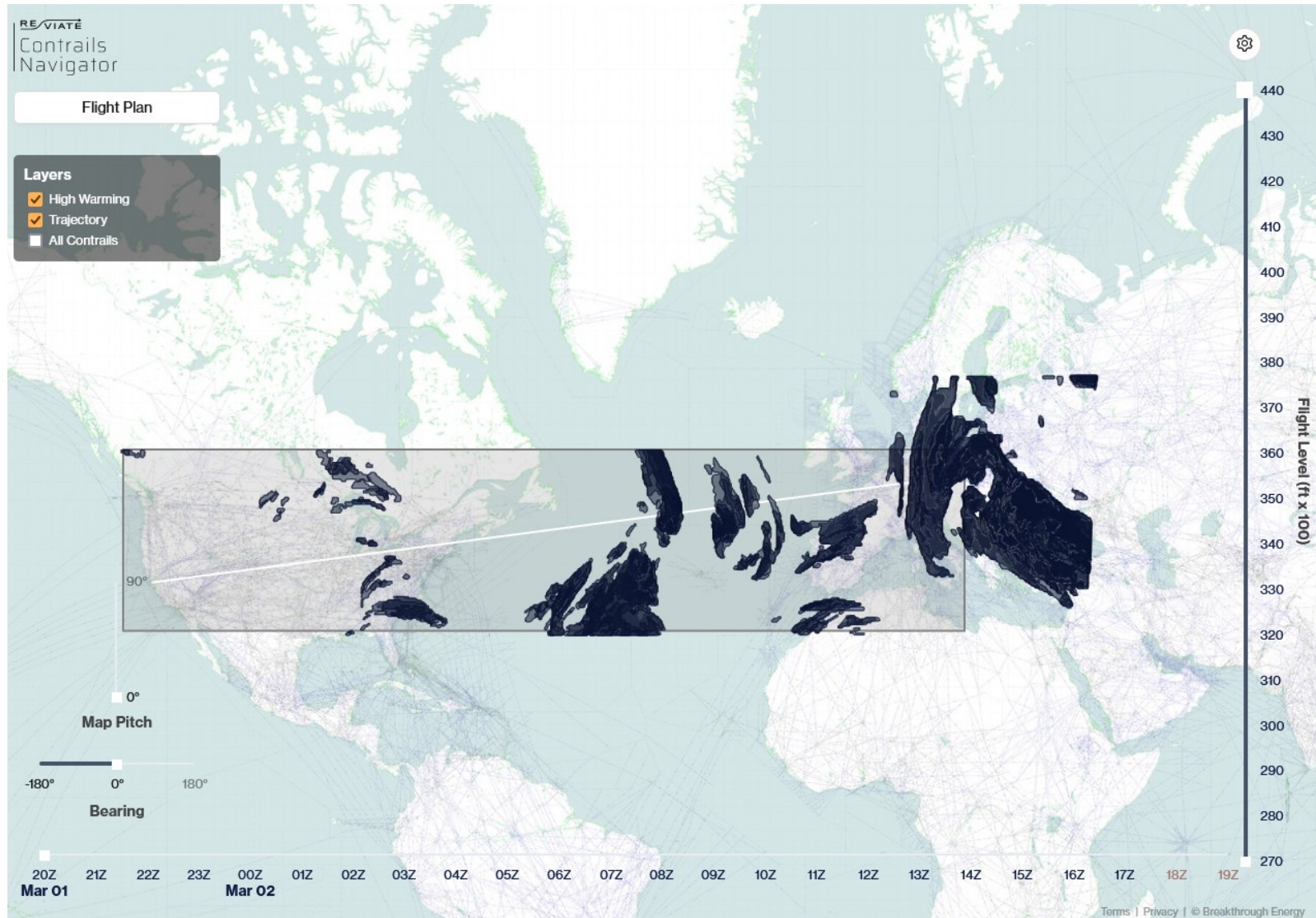
Contrail Prediction Beyond the ISA (Principles Explained with an Example)



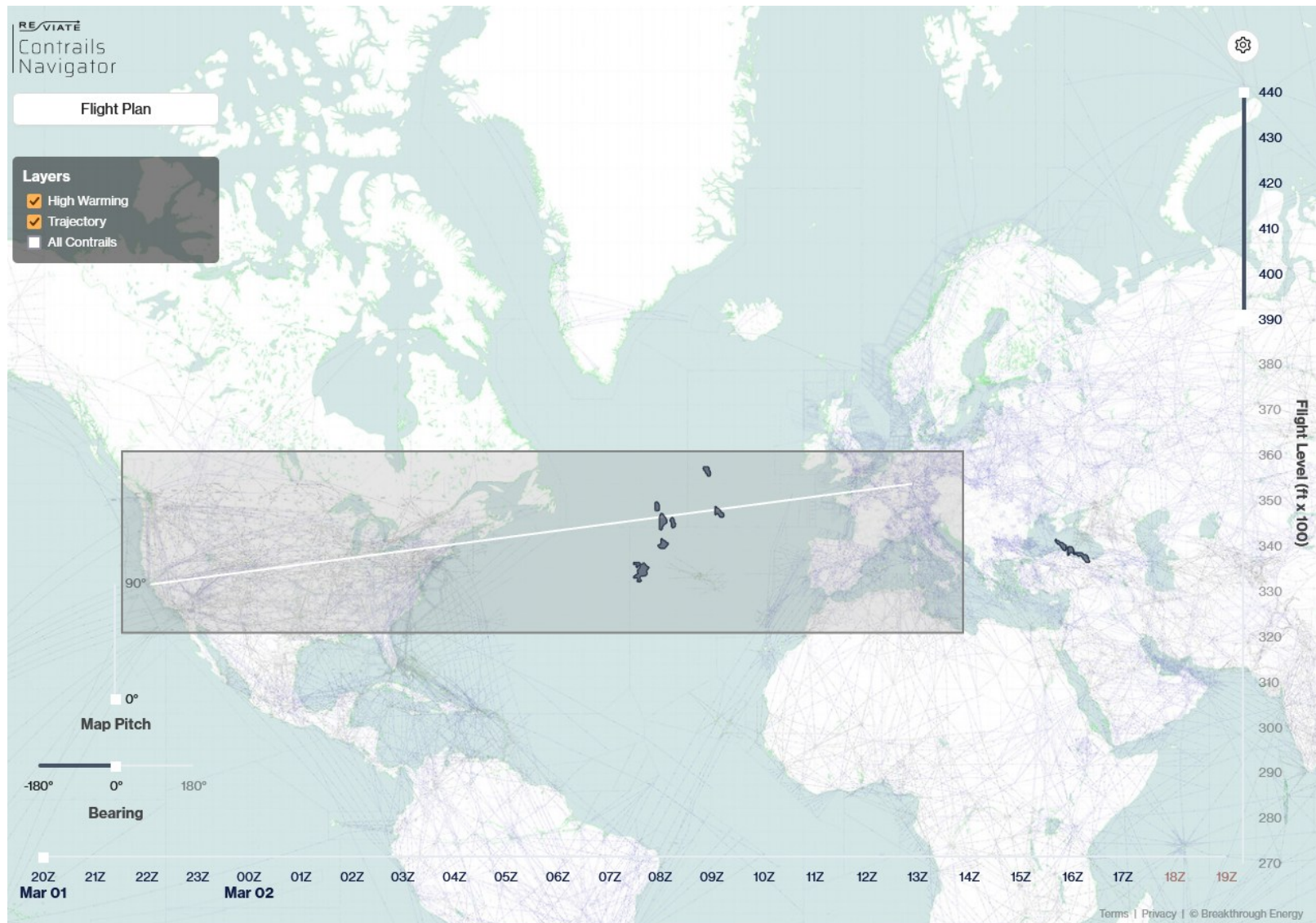
Contrail Management

Contrail Prediction with nav.contrails.org









Flight Planning Software



Lido Flight Planning Solutions

Elevating airlines' operational efficiency & safety

No Support of Contrail Management (as of 2026)

Contrail Management

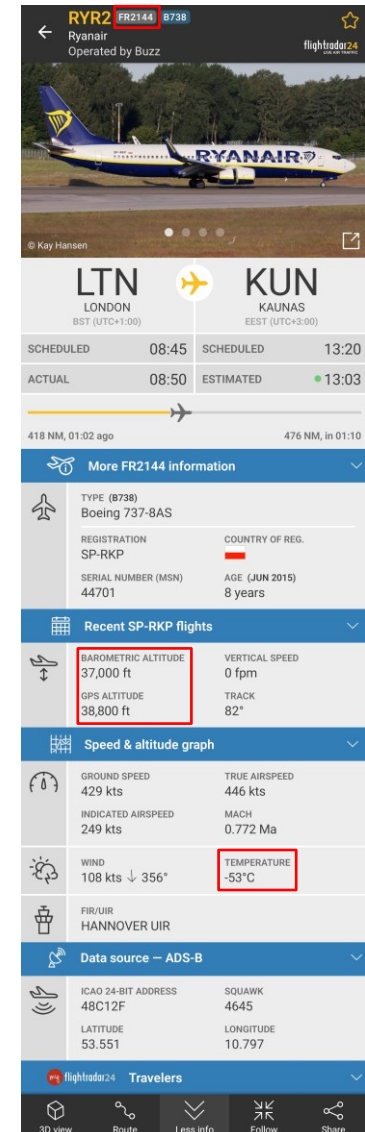
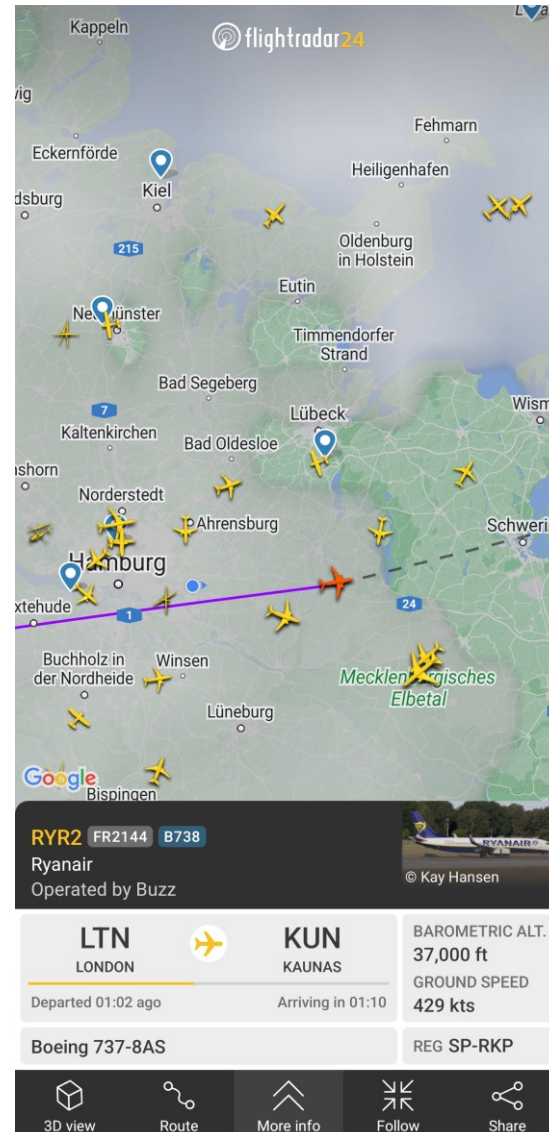
Observation & Prediction from the Ground

Finn Briegert

<https://nbn-resolving.org/urn:nbn:de:gbv:18302-aero2024-03-14.019>

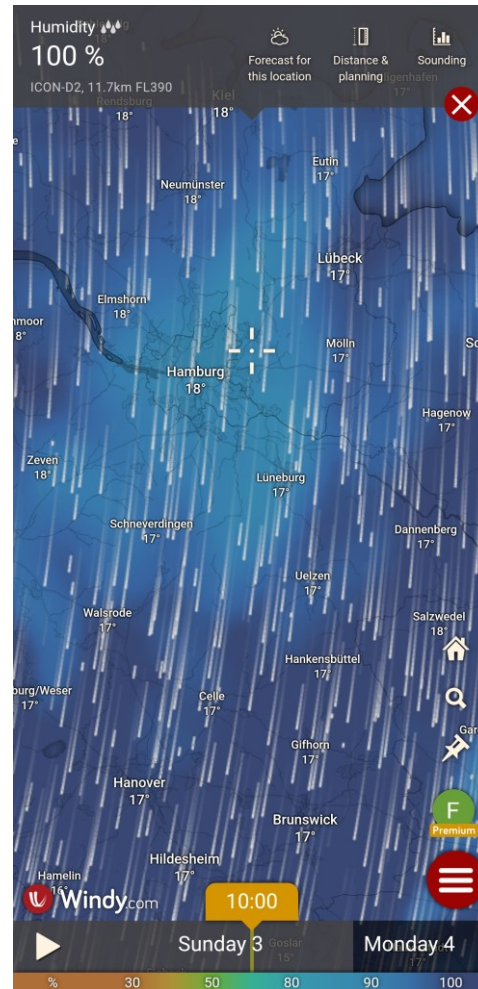
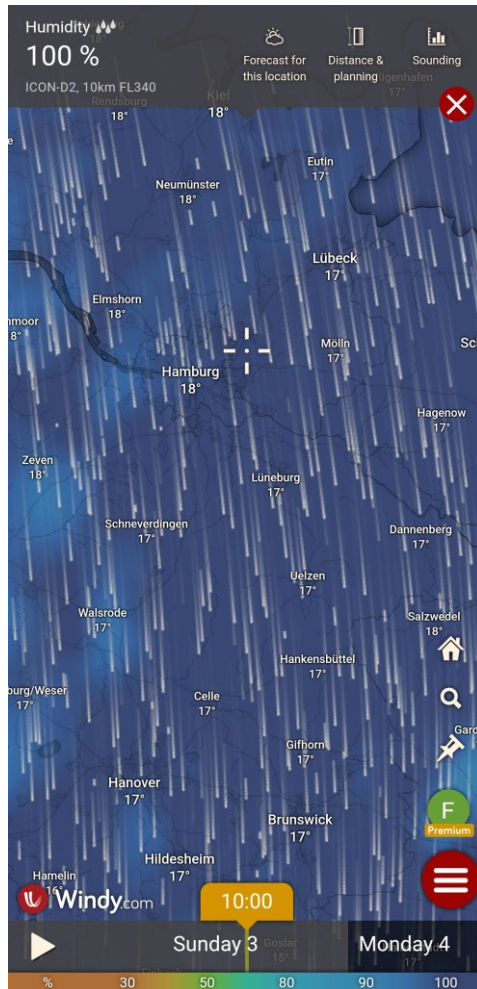
Observation & Prediction

At 10:53 AM, on 3 September 2023, a Boeing 737-8AS, registration SP-RKP, was flying eastbound. This plane left a persistent contrail. The aircraft was at a GPS altitude of 38800 ft (FL 370). The outside temperature was -53 °C.



EGGW
-
EYKA

Relative Humidity

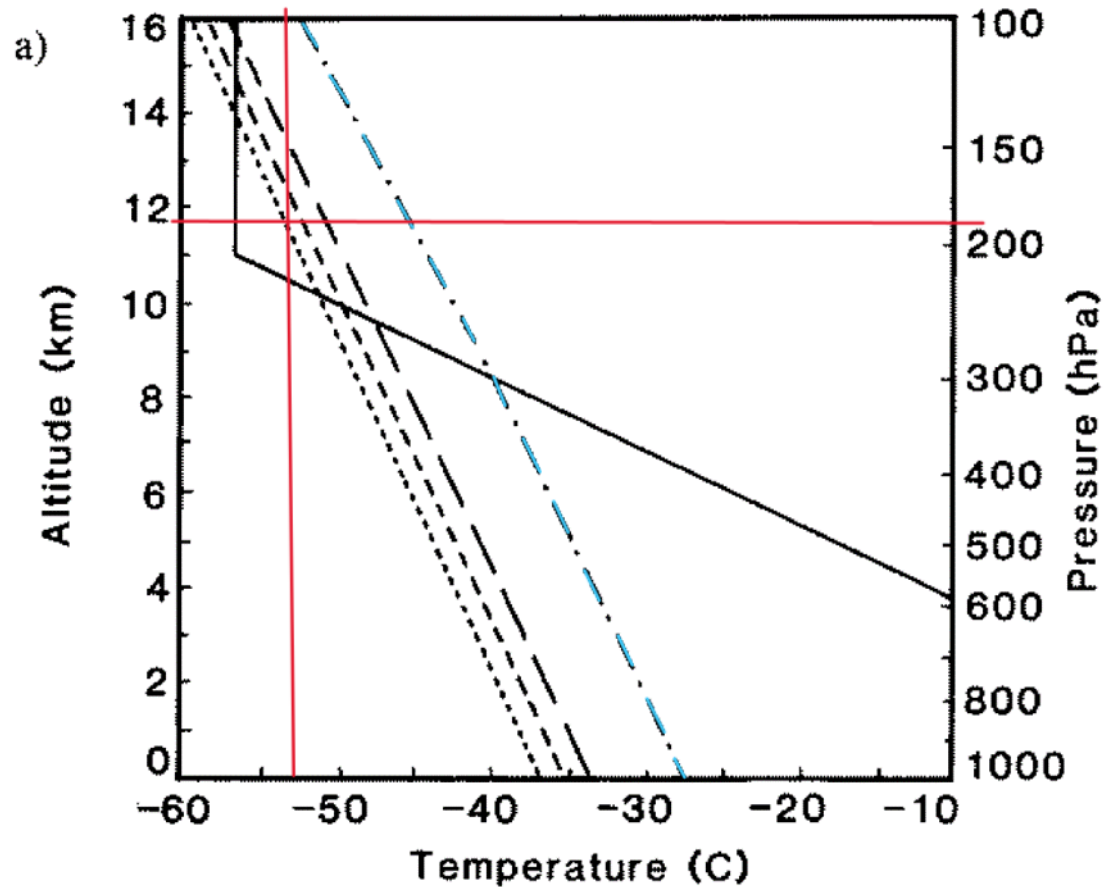


Relative humidity at FL340: 100%

Relative humidity at FL390: 100%

Interpolated relative humidity at FL370:
100%

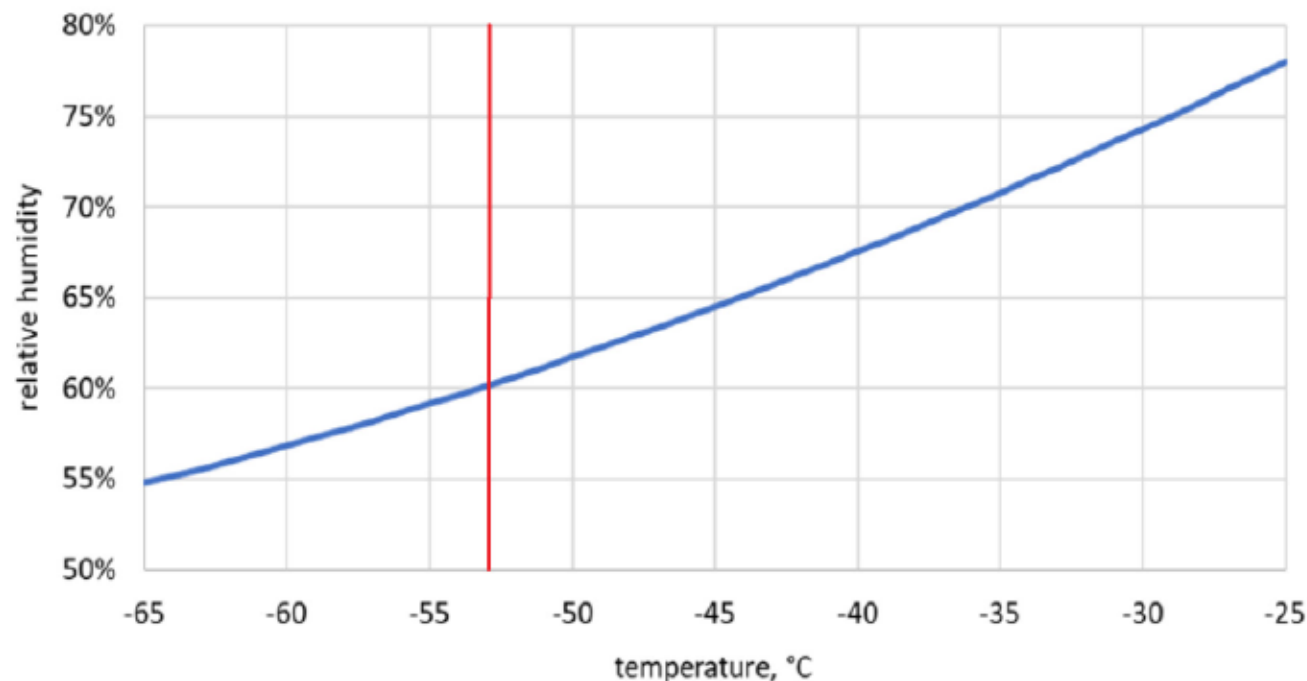
Contrail Formation According to the Schmidt-Appleman Diagram?



The red cross is far left of the blue line (100% relative humidity).

A contrail is expected to form.

Flight in Ice Super-Saturated Region (ISSR)?



Minimum relative humidity for given temperature for persistent contrails to form.

If above the blue line, persistent contrails are expected to form. Here:

$$RH_{water} = 100\% \Rightarrow R = 100\% / 60.2\% = 1.66 \text{ or } RH_{ice} = 166\% (\Rightarrow \text{ISSR})$$

$\Rightarrow$ persistent contrail (survival longer than 5 min.)

Definition of the Persistence Factor, R ($= RH_{ice}$)

This project defines a factor that can be used to see whether a contrail is persistent or not. This factor is called the **persistence factor**.

$$R = \frac{\text{relative humidity of ambient air}}{\text{relative humidity for saturation with respect to ice}} = \frac{RH}{RH_{min}} \quad (3.1)$$

The relative humidity of the ambient air is divided by the relative humidity for saturation with respect to ice (the theoretical relative humidity for a persistent contrail). However, it is unlikely that $R = 1$ is sufficient for a persistent contrail in reality. A somewhat higher factor is probably necessary.

This project starts with this hypothesis:

- $R < 0.5$ no contrail,
- $R = 0.5 \dots 1.3$ transient contrail,
- $R > 1.3$ persistent contrail.

Summary: What Pilots Can Do

Cabin Air Contamination Event (Fume Event):

Measure! – Descent to 10000 ft!

Avoid Warming Contrails:

Do it! – Don't wait for others!

Further reading: Please see below.

What Pilots Can Do – Management of Cabin Air Contamination Events and Contrails

Contact

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<http://www.ProfScholz.de>

Quote this document:

SCHOLZ, Dieter, 2026. *What Pilots Can Do – Management of Cabin Air Contamination Events and Contrails*. Meeting of the Task Force Environment, Vereinigung Cockpit (Hamburg, 08./09.06.2026). Available from: <https://doi.org/10.48441/4427.3795>.

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Further Reading

Ein Bericht als populärwissenschaftlicher Einstieg (2021)



Im Repositorium:

<https://doi.org/10.48441/4427.225>

Zum PDF:

<https://purl.org/aero/RR2021-07-03>

Zum HTML:

https://www.fzt.haw-hamburg.de/pers/Scholz/Aero/AERO_PR_UmweltschutzLuftfahrt/Umweltschutz-in-der-Luftfahrt.html

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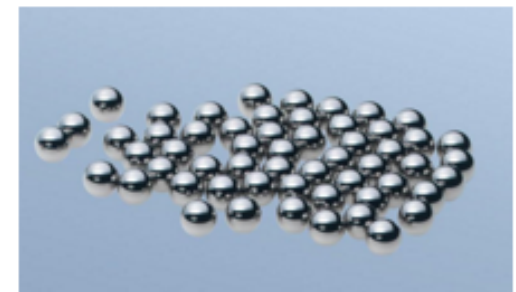
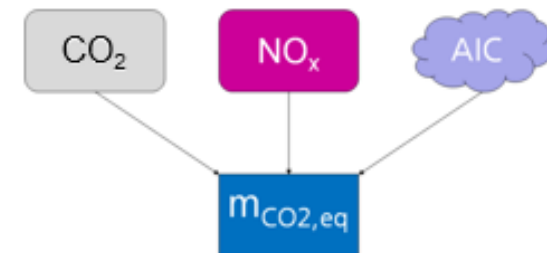
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Dieter Scholz

Hamburg University of Applied Sciences

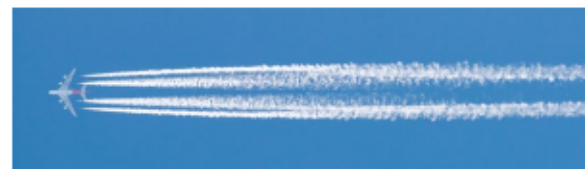
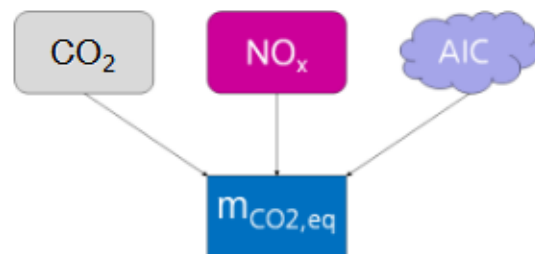
Physikalisches Kolloquium

Bergische Universität Wuppertal

Fakultät für Mathematik und Naturwissenschaften

Fachgruppe Physik, 2024-06-10

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