How to address aviation's climate problem with open data

~

A story of my research journey since 2015

Dr. Junzi Sun

Faculty of Aerospace Engineering
Delft University of Technology

TU Delft

2015

Started of my PhD:

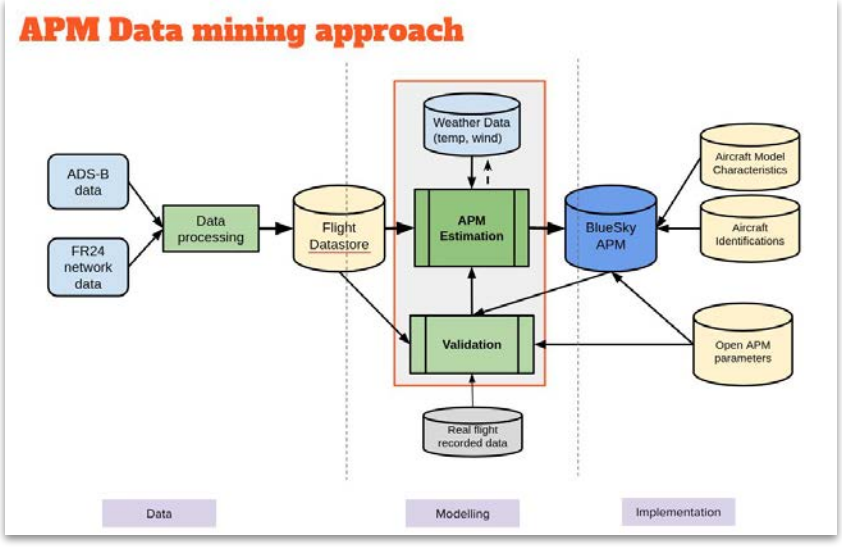
Modeling **aircraft performance** with **open** data

Research question:

Is it possible to use only open data to study the performance of aircraft?

- for simulations?
- for inferring fuel?
- for estimating emissions?

10 months later (go-no-go moment)

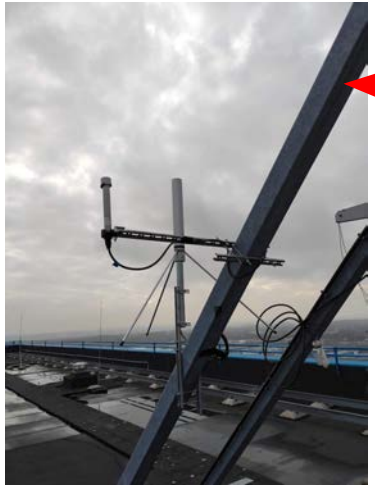


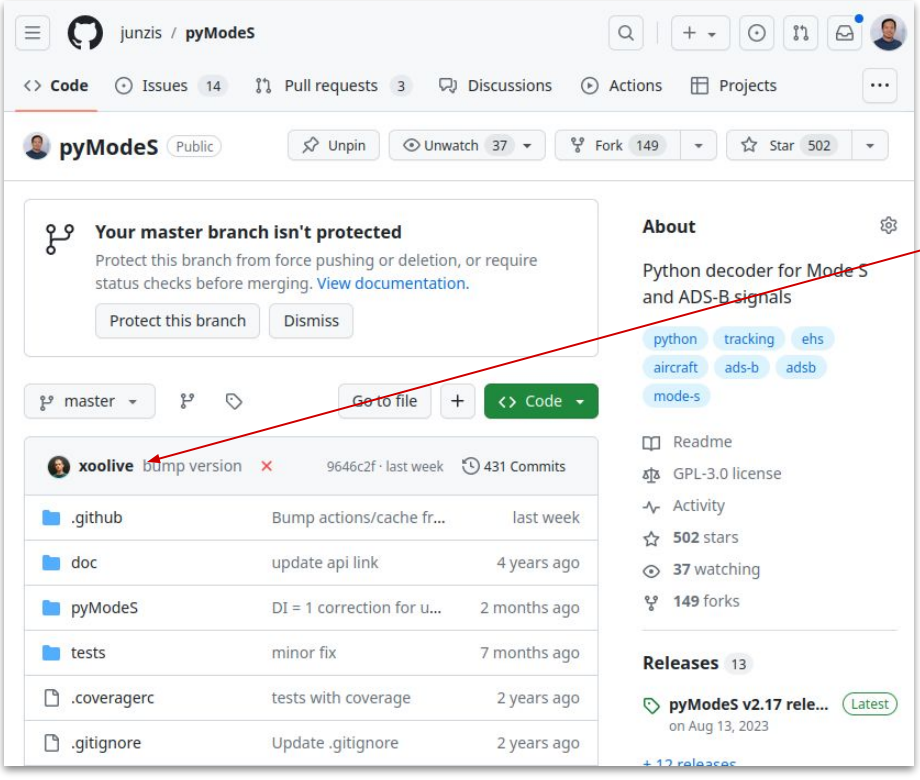
Arvind Gangoli Rao · 1st
Professor, Sustainable Aircraft Propulsion, Aerospace Engineering, TU Delft

Jacco Hoekstra · 1st
Full professor CNS/ATM (Communication, Surveilance, Navigation / Air Traffic Management) bij TU Delft

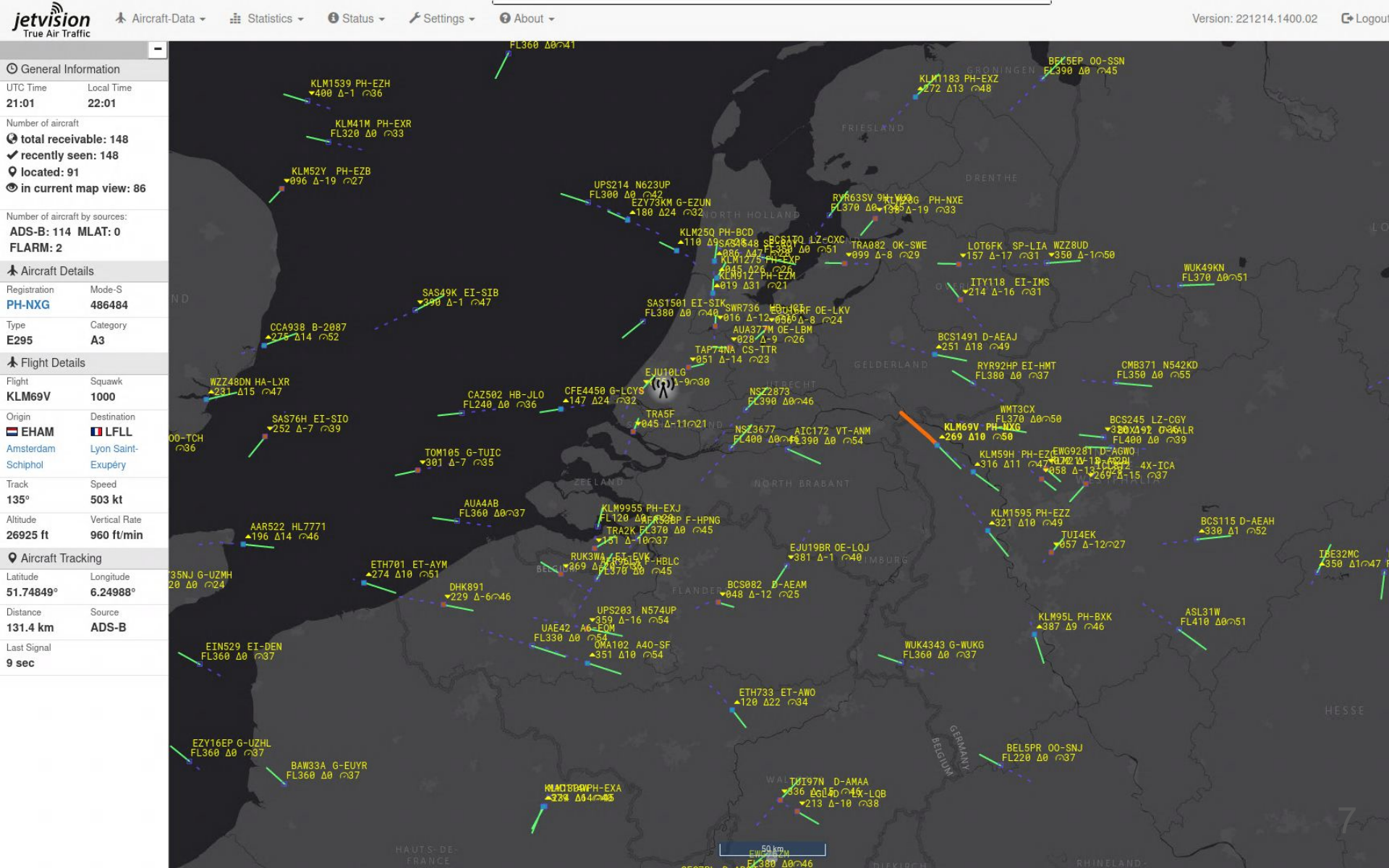
Joost Ellerbroek · 1st
Assistant Professor at Delft University of Technology

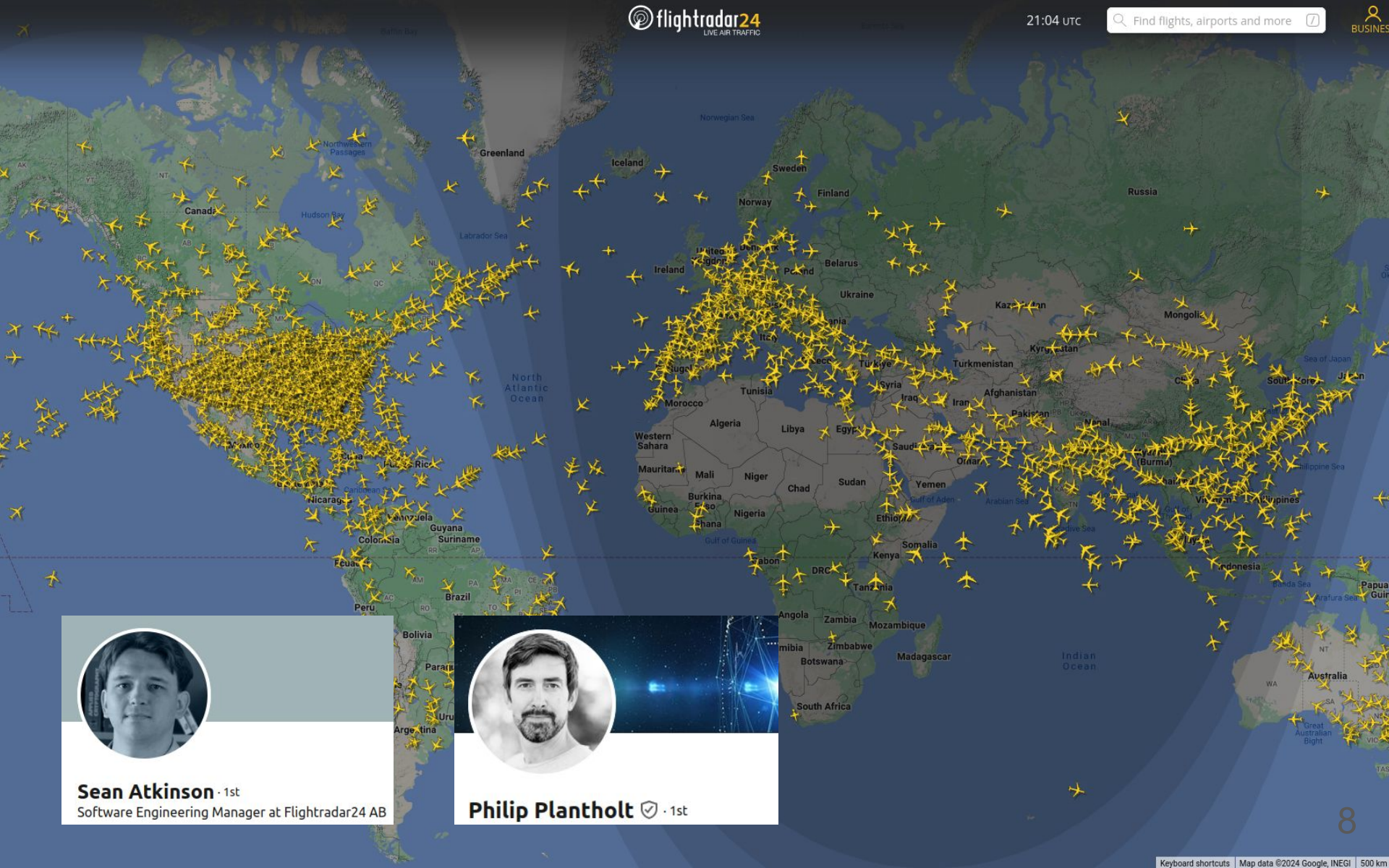
My journey starts here

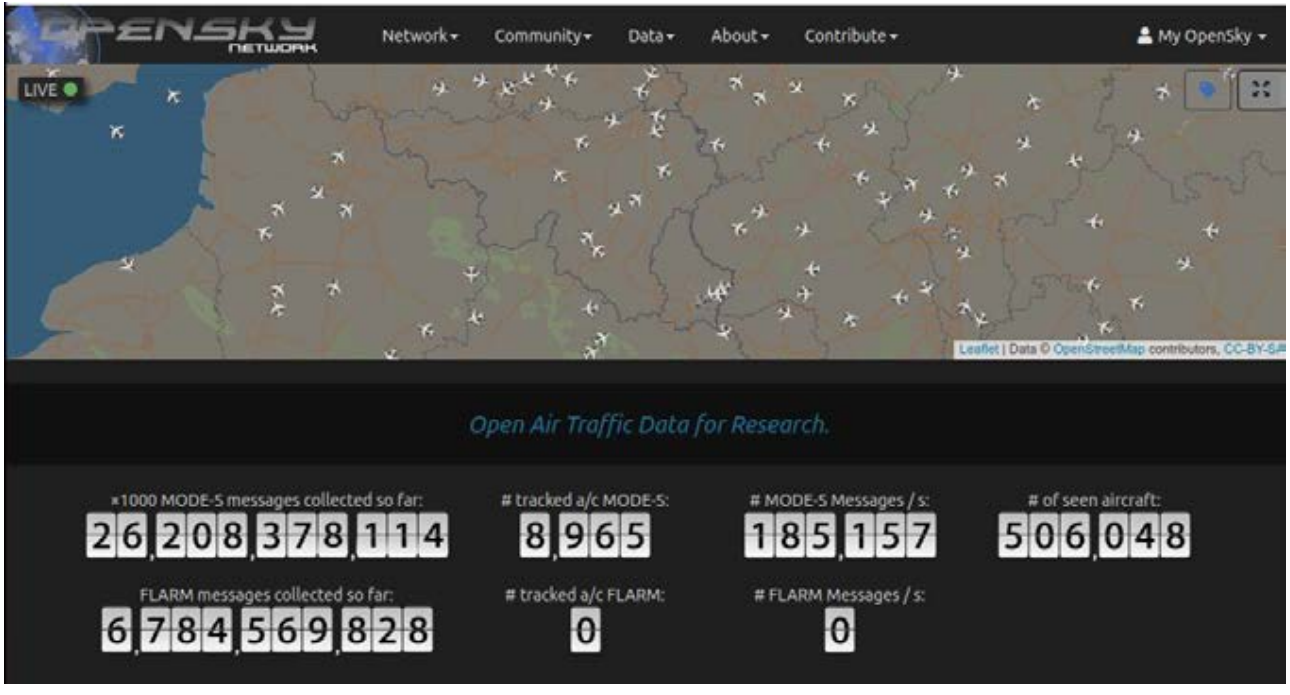



junzis / pyModeS
Code
Issues 14
Pull requests 3
Discussions
Actions
Projects
pyModeS Public
Unpin
Unwatch 37
Fork 149
Star 502
Your master branch isn't protected
Protect this branch from force pushing or deletion, or require status checks before merging. View documentation.
Protect this branch
Dismiss
master
Go to file
Code
xoolive bump version
9646c2f · last week
431 Commits
.github Bump actions/cache fr... last week
doc update api link 4 years ago
pyModeS DI = 1 correction for u... 2 months ago
tests minor fix 7 months ago
.coveragerc tests with coverage 2 years ago
.gitignore Update .gitignore 2 years ago
About
Python decoder for Mode S and ADS-B signals
python tracking ehs aircraft ads-b adsb mode-s
Readme
GPL-3.0 license
Activity
502 stars
37 watching
149 forks
Releases 13
pyModeS v2.17 rele... Latest
on Aug 13, 2023


Xavier Olive · 1st
Senior Research Scientist, HDR

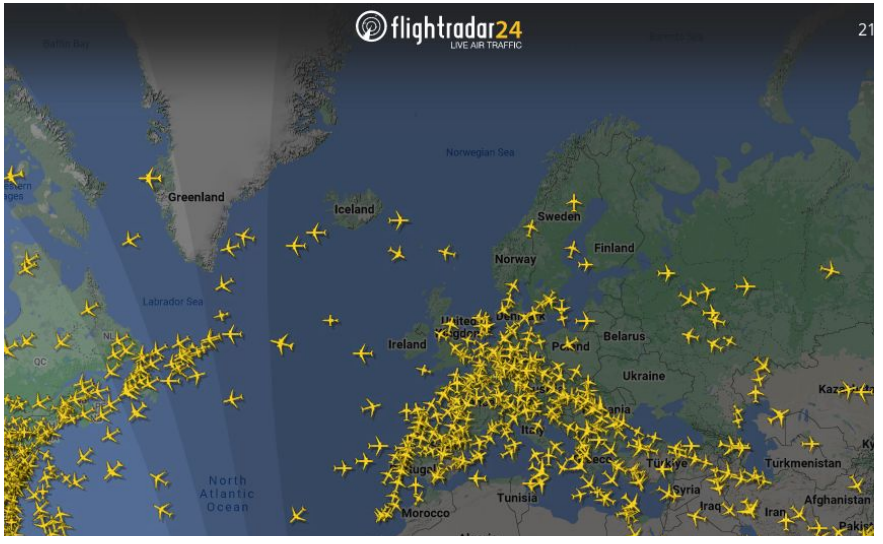

jetvision
True Air Traffic
Aircraft-Data
Statistics
Status
Settings
About
Version: 221214.1400.02
Logout
General Information
UTC Time
21:01
Local Time
22:01
Number of aircraft
total receivable: 148
recently seen: 148
located: 91
in current map view: 86
Number of aircraft by sources:
ADS-B: 114 MLAT: 0
FLARM: 2
Aircraft Details
Registration
PH-NXG
Mode-S
486484
Type
E295
Category
A3
Flight Details
Flight
KLM69V
Squawk
1000
Origin
EHAM
Amsterdam Schiphol
Destination
LFLL
Lyon Saint-Exupéry
Track
135°
Speed
503 kt
Altitude
26925 ft
Vertical Rate
960 ft/min
Aircraft Tracking
Latitude
51.74849°
Longitude
6.24988°
Distance
131.4 km
Source
ADS-B
Last Signal
9 sec
KLM69V PH-NXG
FRIESLAND
DRENTHE
GELDERLAND
UTRECHT
NORTH HOLLAND
ZEELAND
NORTH BRABANT
FLANDERS
HESSE
GERMANY
BELGIUM
50 km

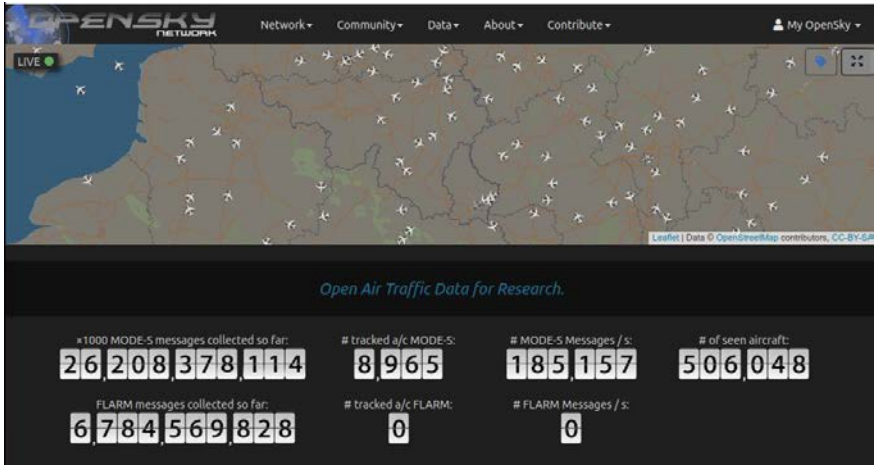

flightradar24
LIVE AIR TRAFFIC
21:04 UTC
Find flights, airports and more
BUSINES
Greenland
Iceland
Sweden
Norway
Finland
Russia
Canada
Ireland
Belarus
Ukraine
Mongolia
Turkmenistan
Afghanistan
Pakistan
Syria
Iraq
Iran
Tunisia
Morocco
Algeria
Libya
Egypt
Western Sahara
Mauritania
Mali
Niger
Chad
Sudan
Yemen
Nigeria
Ethiopia
Somalia
Kenya
Guinea
Burkina Faso
Ghana
Gabon
DRC
Tanzania
Angola
Zambia
Mozambique
Zimbabwe
Botswana
Madagascar
South Africa
Indonesia
Australia
Brazil
Peru
Bolivia
Colombia
Guyana
Suriname
Venezuela
Nicaragua
Cuba
Philippines
North Atlantic Ocean
Indian Ocean
Sea of Japan
Arabian Sea
Gulf of Aden
Gulf of Guinea
Great Australian Bight
Sean Atkinson · 1st
Software Engineering Manager at Flightradar24 AB
Philip Plantholt · 1st
Keyboard shortcuts
Map data ©2024 Google, INEGI
500 km



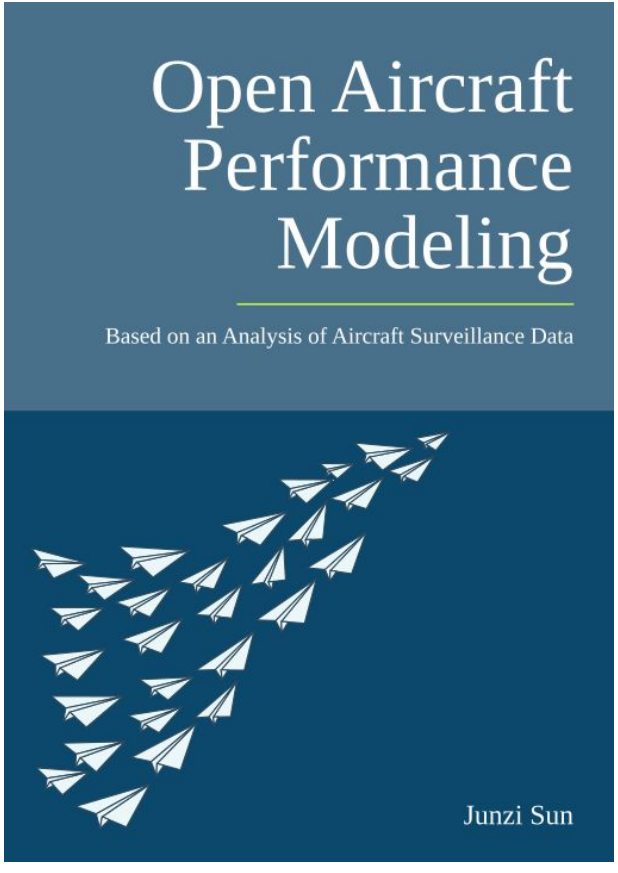
Xavier Olive · 1st
Senior Research Scientist, HDR

Martin Strohmeier · 1st
Senior Scientist at Swiss Cyber-Defence Campus (ar W&T)


flightradar24
LIVE AIR TRAFFIC
Greenland
Iceland
Norwegian Sea
Sweden
Finland
Norway
Labrador Sea
Ireland
Belarus
Ukraine
North Atlantic Ocean
Tunisia
Morocco
Turkmenistan
Syria
Afghanistan

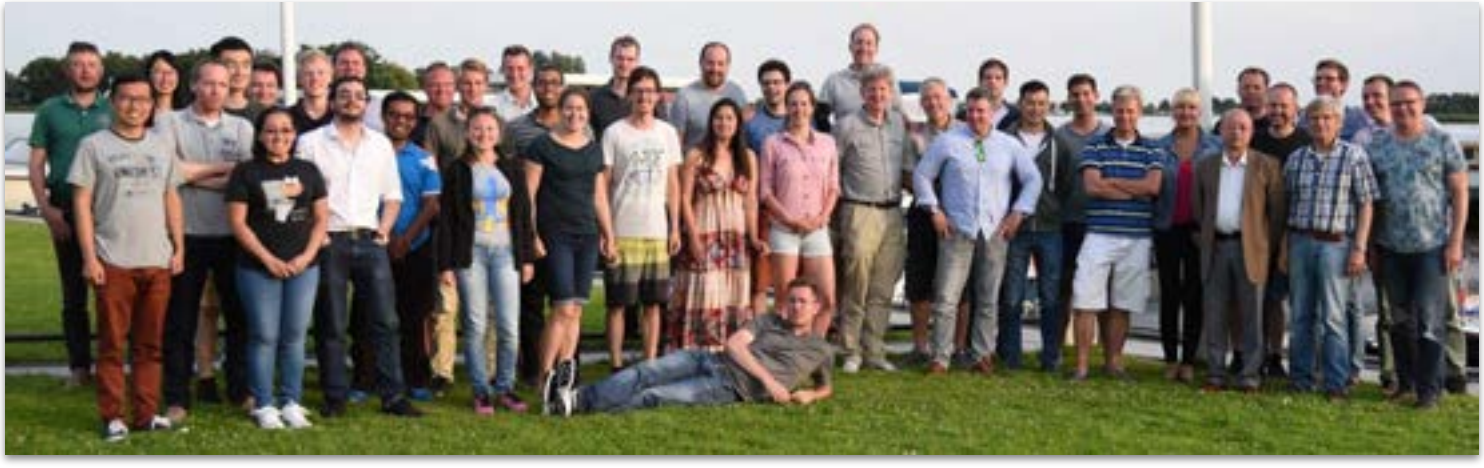

OPENSKY NETWORK
Network
Community
Data
About
Contribute
My OpenSky
LIVE
Open Air Traffic Data for Research.
×1000 MODE-S messages collected so far:
26,208,378,114
tracked a/c MODE-S:
8,965
MODE-S Messages / s:
185,157
# of seen aircraft:
506,048
FLARM messages collected so far:
6,784,569,828
tracked a/c FLARM:
0
FLARM Messages / s:
0

2019



OpenAP

An Open Tool for Aircraft
Performance and **Emissions**



Department of Control and Operations

My research focus:

Efficiency and sustainability in air traffic management and operations

New chapter:

sustainability with opensky & its community

Evaluation of Aviation Emissions and Environmental Costs in Europe Using OpenSky and OpenAP †

by Junzi Sun * and Irene Dedoussi

Sustainable Aviation Lab, Control and Operations Department, Faculty of Aerospace Engineering, Delft University of Technology, 2629 HS Delft, The Netherlands

* Author to whom correspondence should be addressed.

† Presented at the 9th OpenSky Symposium, Brussels, Belgium, 18–19 November 2021.

Eng. Proc. **2021**, *13*(1), 5; **https://doi.org/10.3390/engproc2021013005**

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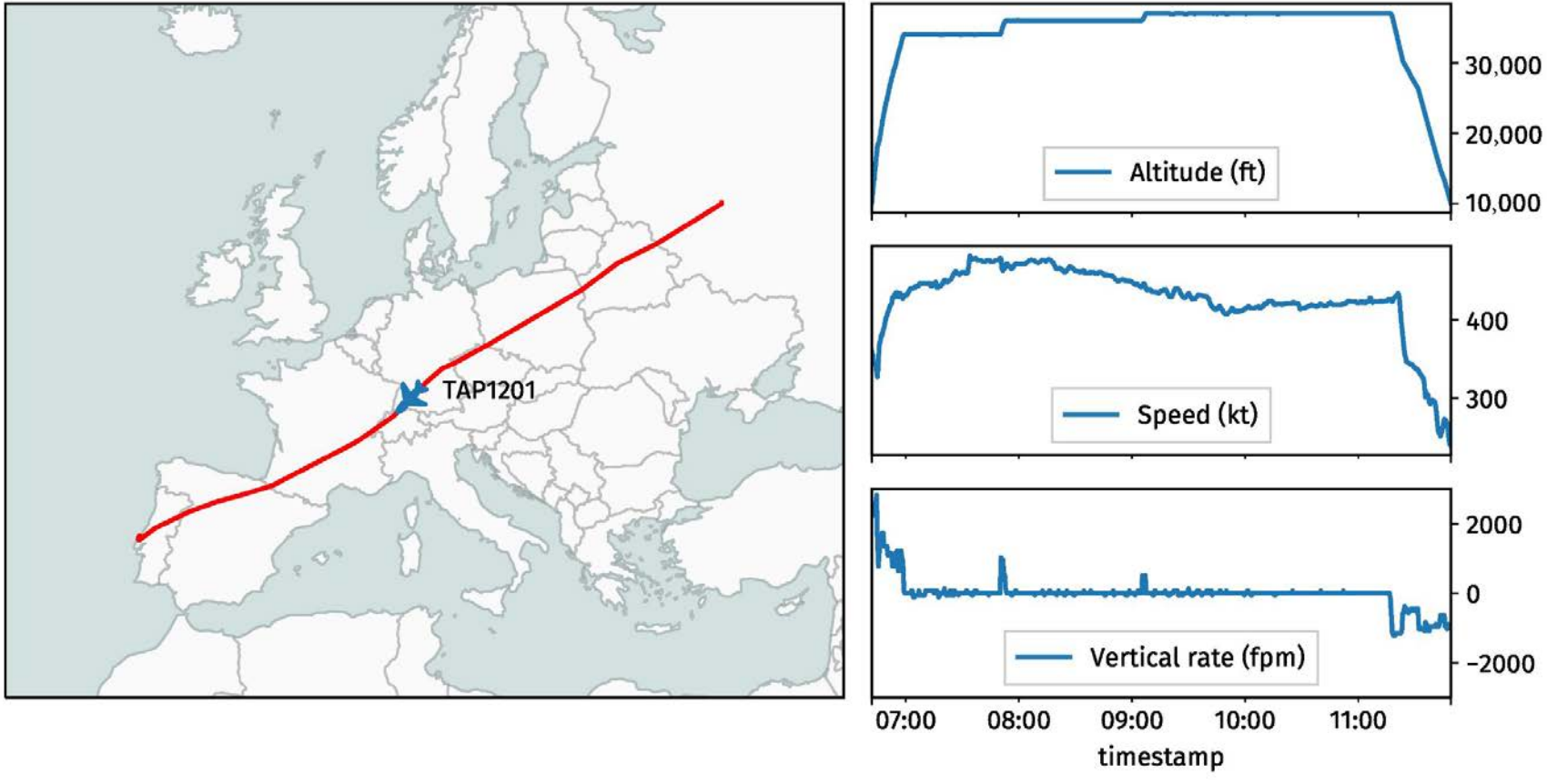
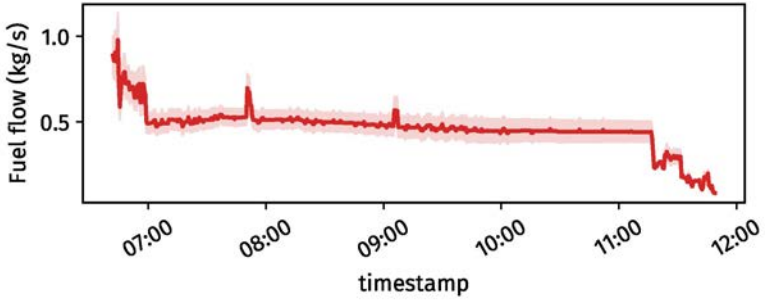
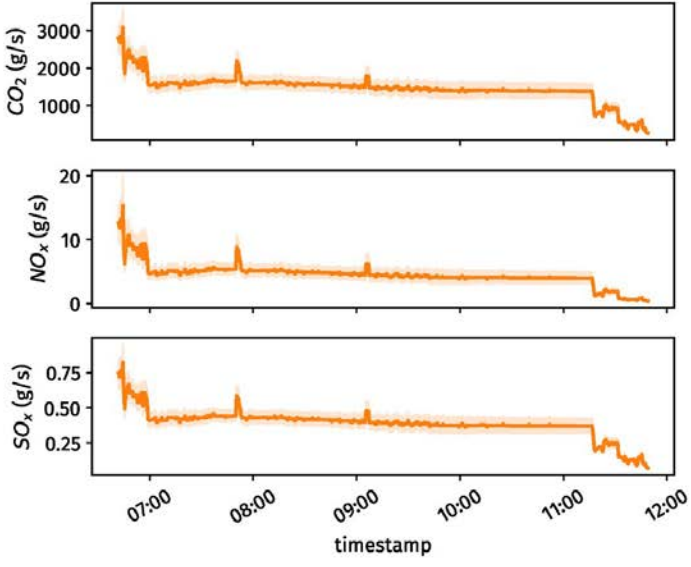
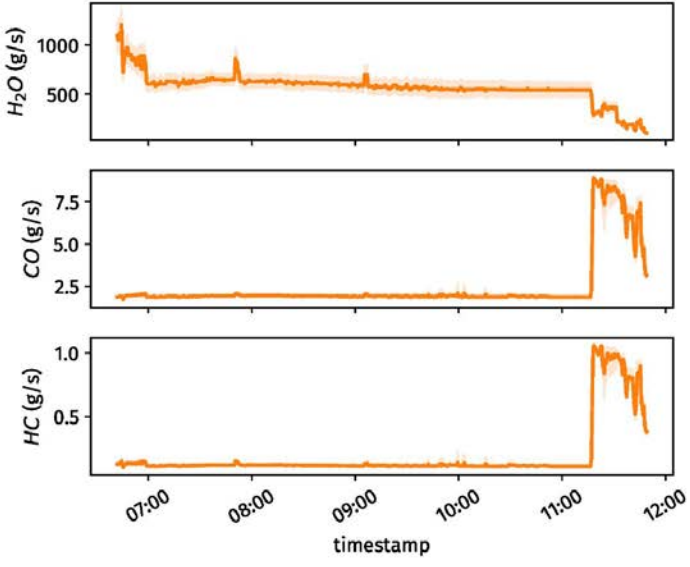
(This article belongs to the Proceedings of **The 9th OpenSky Symposium**)

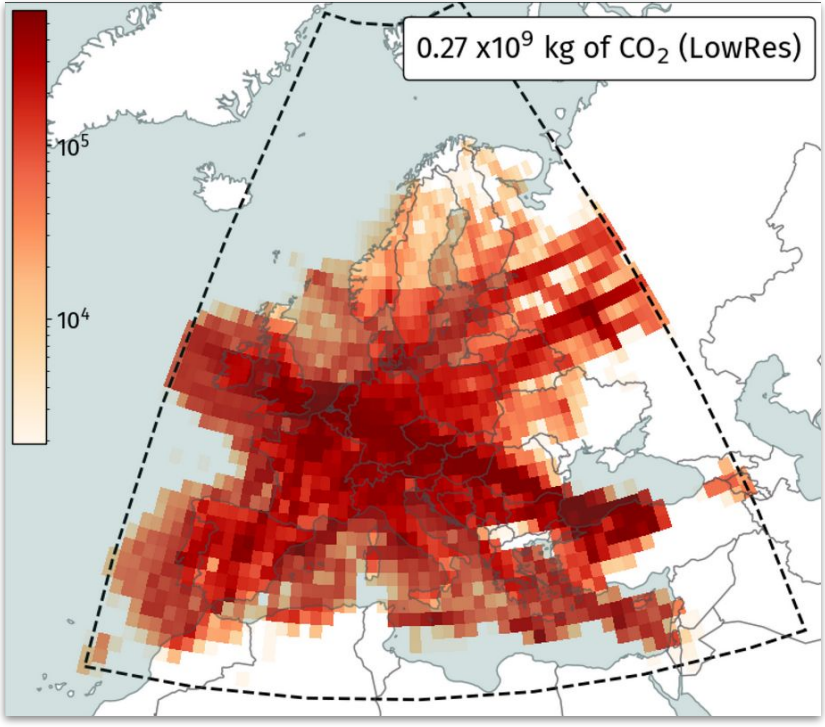

TAP1201
Altitude (ft)
30,000
20,000
10,000
Speed (kt)
400
300
Vertical rate (fpm)
2000
0
−2000
07:00
08:00
09:00
10:00
11:00
timestamp

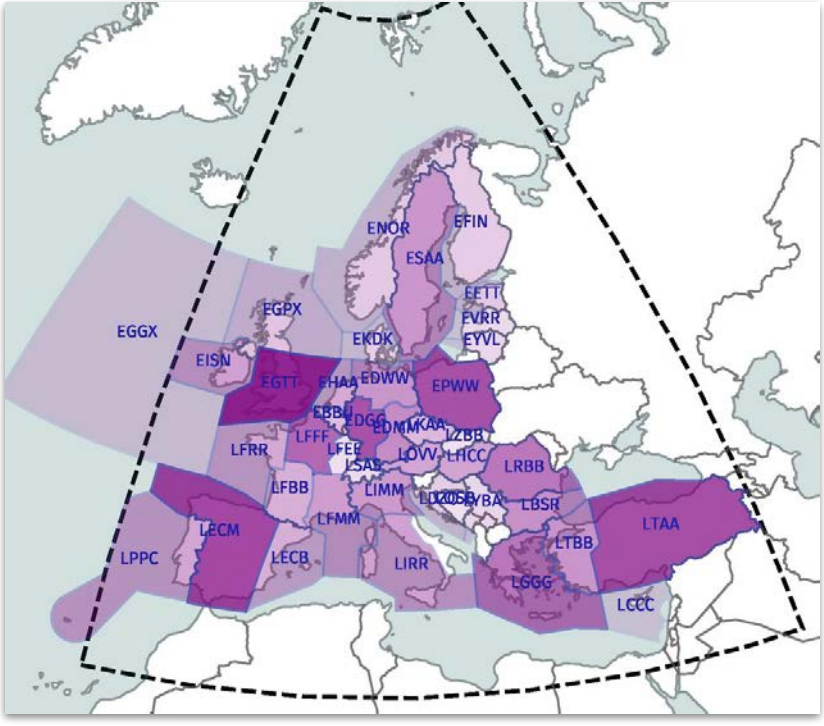

TAP1201

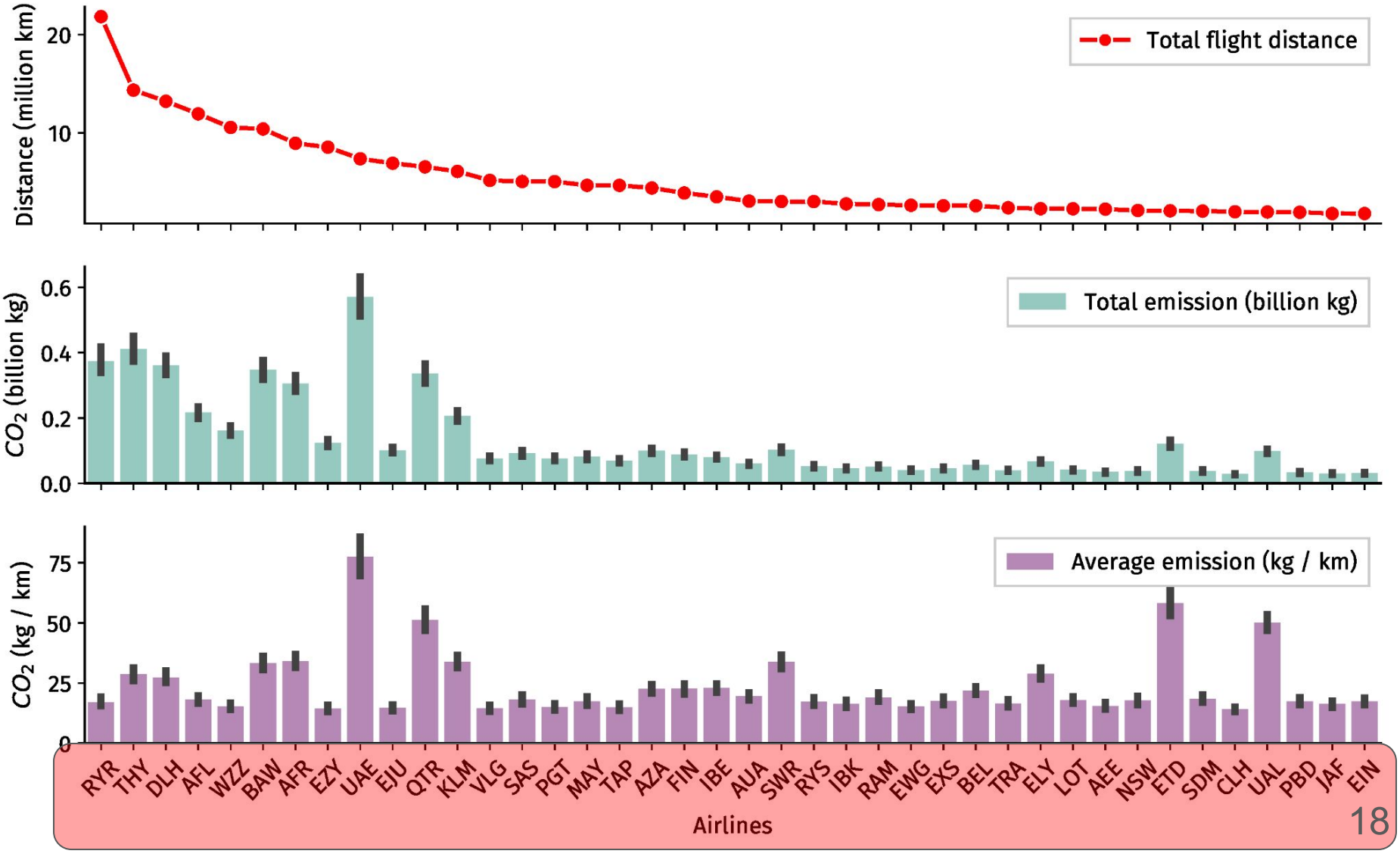

Fuel flow (kg/s)
1.0
0.5
07:00
08:00
09:00
10:00
11:00
12:00
timestamp


CO_2 (g/s)
3000
2000
1000
NO_x (g/s)
20
10
0
SO_x (g/s)
0.75
0.50
0.25
07:00
08:00
09:00
10:00
11:00
12:00
timestamp


H_2O (g/s)
1000
500
CO (g/s)
7.5
5.0
2.5
HC (g/s)
1.0
0.5
07:00
08:00
09:00
10:00
11:00
12:00
timestamp


0.27 x10^9 kg of CO2 (LowRes)
10^5
10^4


ENOR
EFIN
ESAA
EETT
EVRR
EYVL
EGPX
EGGX
EKDK
EISN
EGTT
EHAA
EDWW
EPWW
EBBU
EDGG
EDMM
KAA
LZBB
LFFF
LFEE
LFRR
LOVV
LHCC
LRBB
LSAS
LFBB
LIMM
LDZOSBYBA
LBSR
LFMM
LECM
LTAA
LTBB
LPPC
LECB
LIRR
LGGG
LCCC


Distance (million km)
20
10
Total flight distance
CO_2 (billion kg)
0.6
0.4
0.2
0.0
Total emission (billion kg)
CO_2 (kg / km)
75
50
25
0
Average emission (kg / km)
RYR
THY
DLH
AFL
WZZ
BAW
AFR
EZY
UAE
EJU
QTR
KLM
VLG
SAS
PGT
MAY
TAP
AZA
FIN
IBE
AUA
SWR
RYS
IBK
RAM
EWG
EXS
BEL
TRA
ELY
LOT
AEE
NSW
ETD
SDM
CLH
UAL
PBD
JAF
EIN
Airlines

2022

Environmental Footprint of Private and Business Jets †

by Junzi Sun [1,2,*], Xavier Olive [2] and Martin Strohmeier [2]

[1] Faculty of Aerospace Engineering, Delft University of Technology, 2628 CE Delft, The Netherlands

[2] OpenSky Network, 3400 Burgdorf, Switzerland

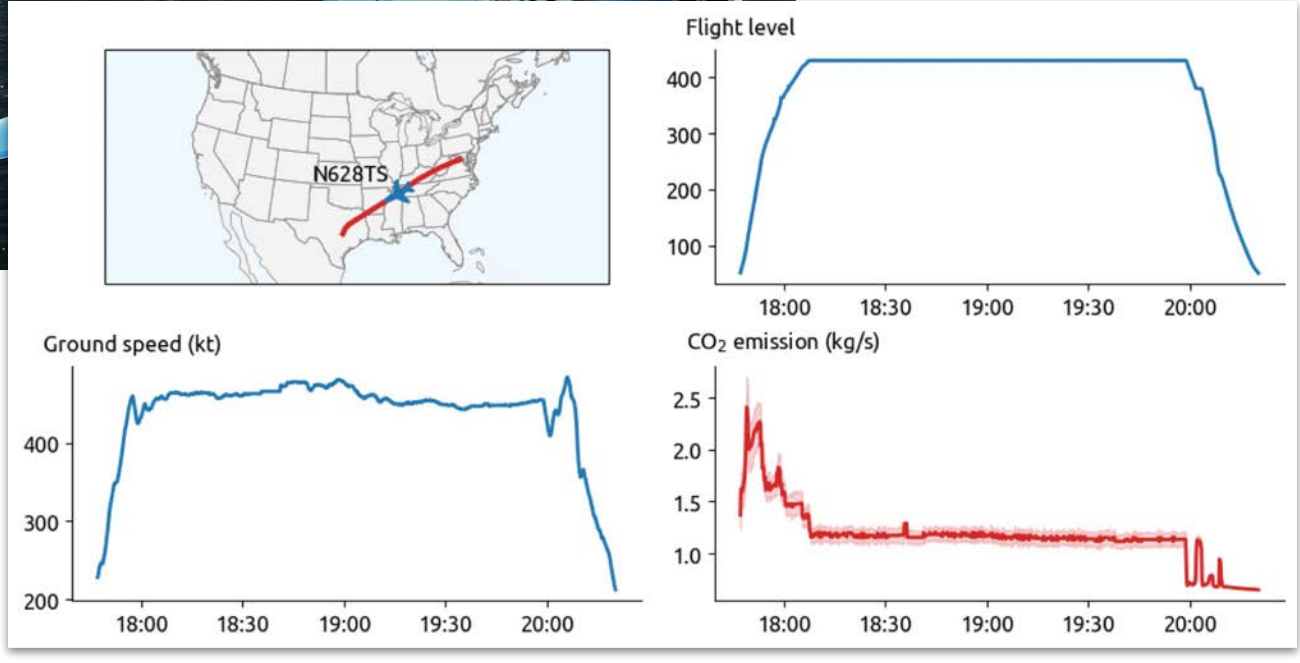
[*] Author to whom correspondence should be addressed.

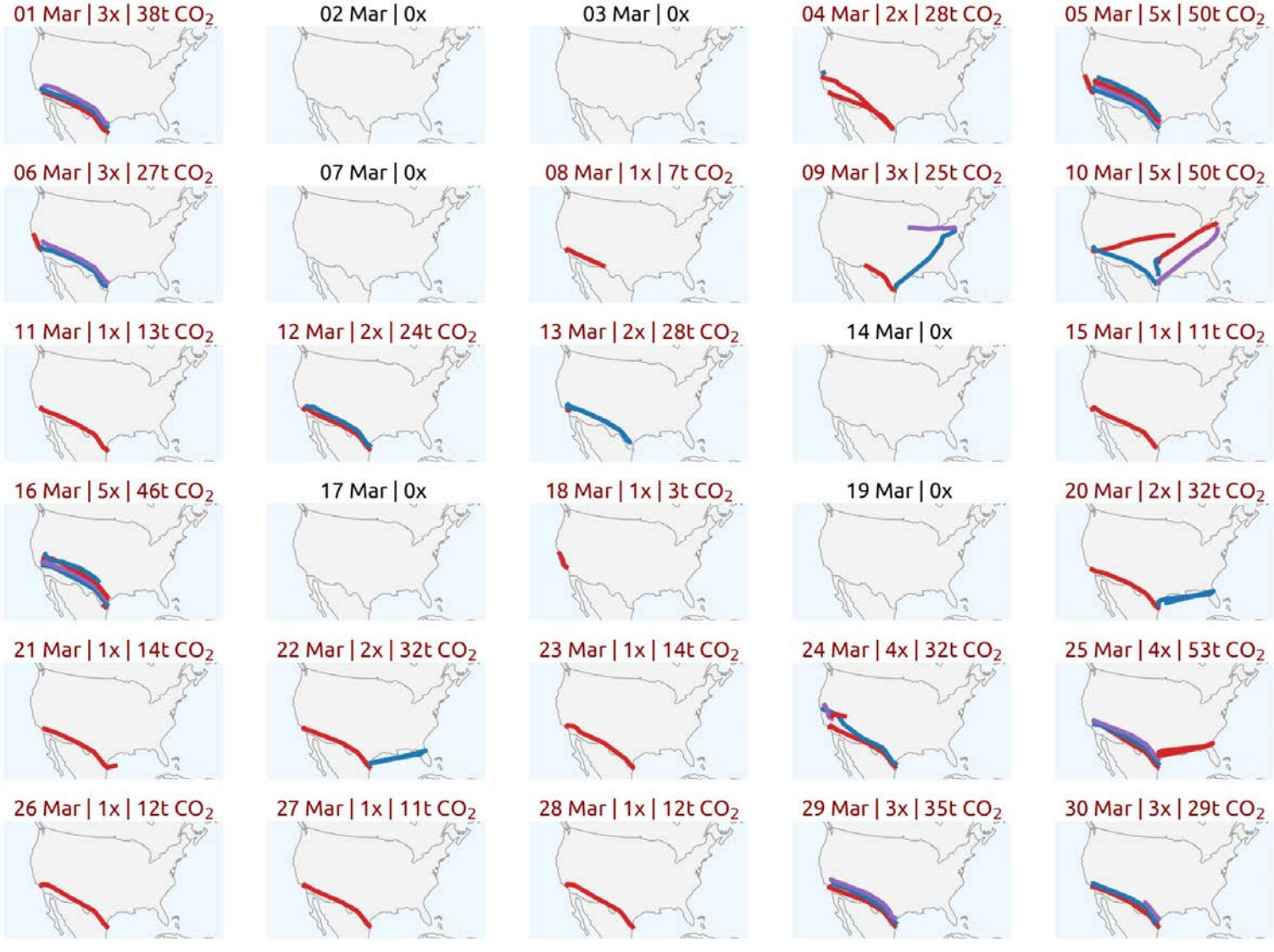
† Presented at the 10th OpenSky Symposium, Delft, The Netherlands, 10–11 November 2022.

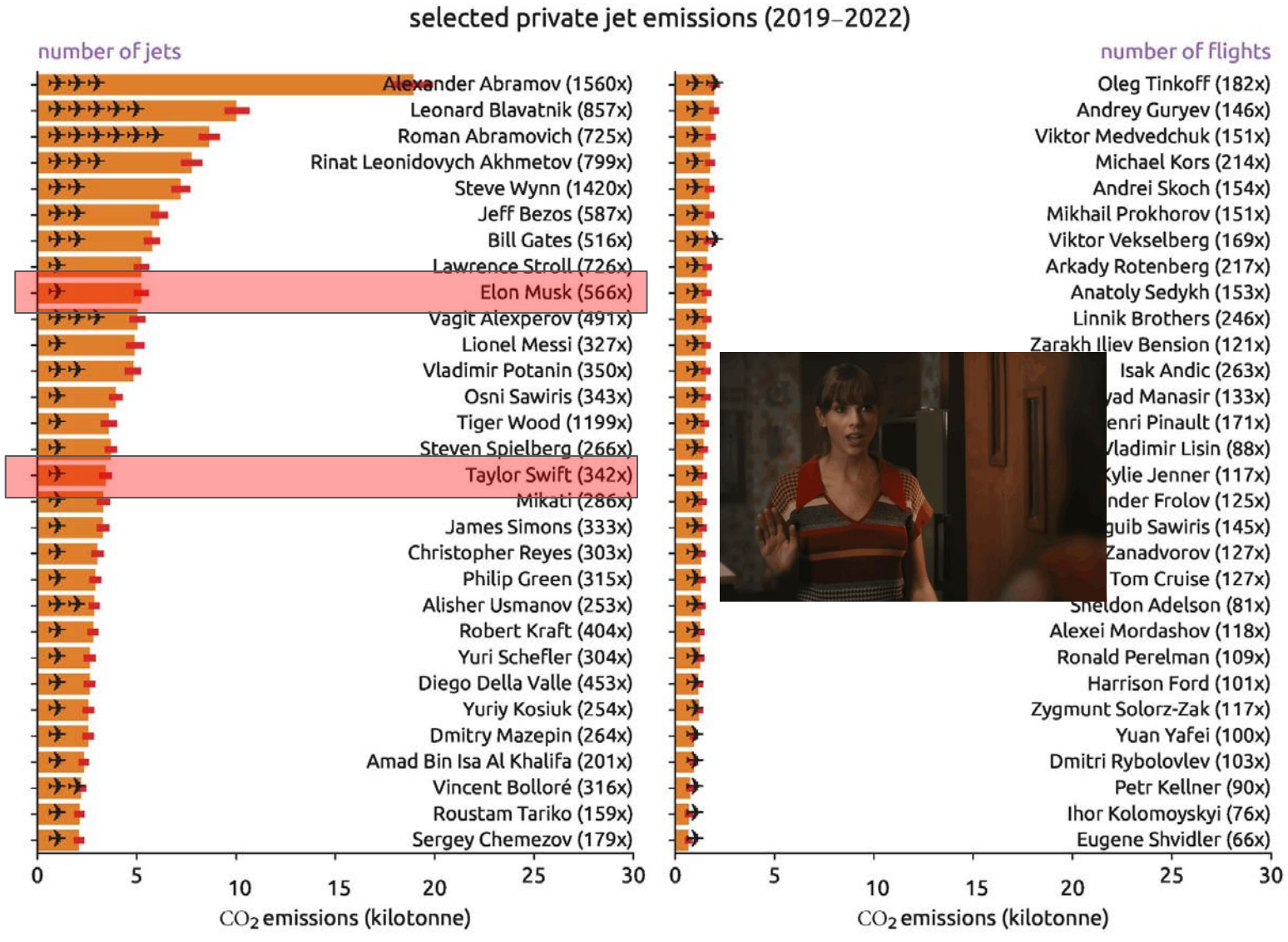
Xavier Olive · 1st
Senior Research Scientist, HDR

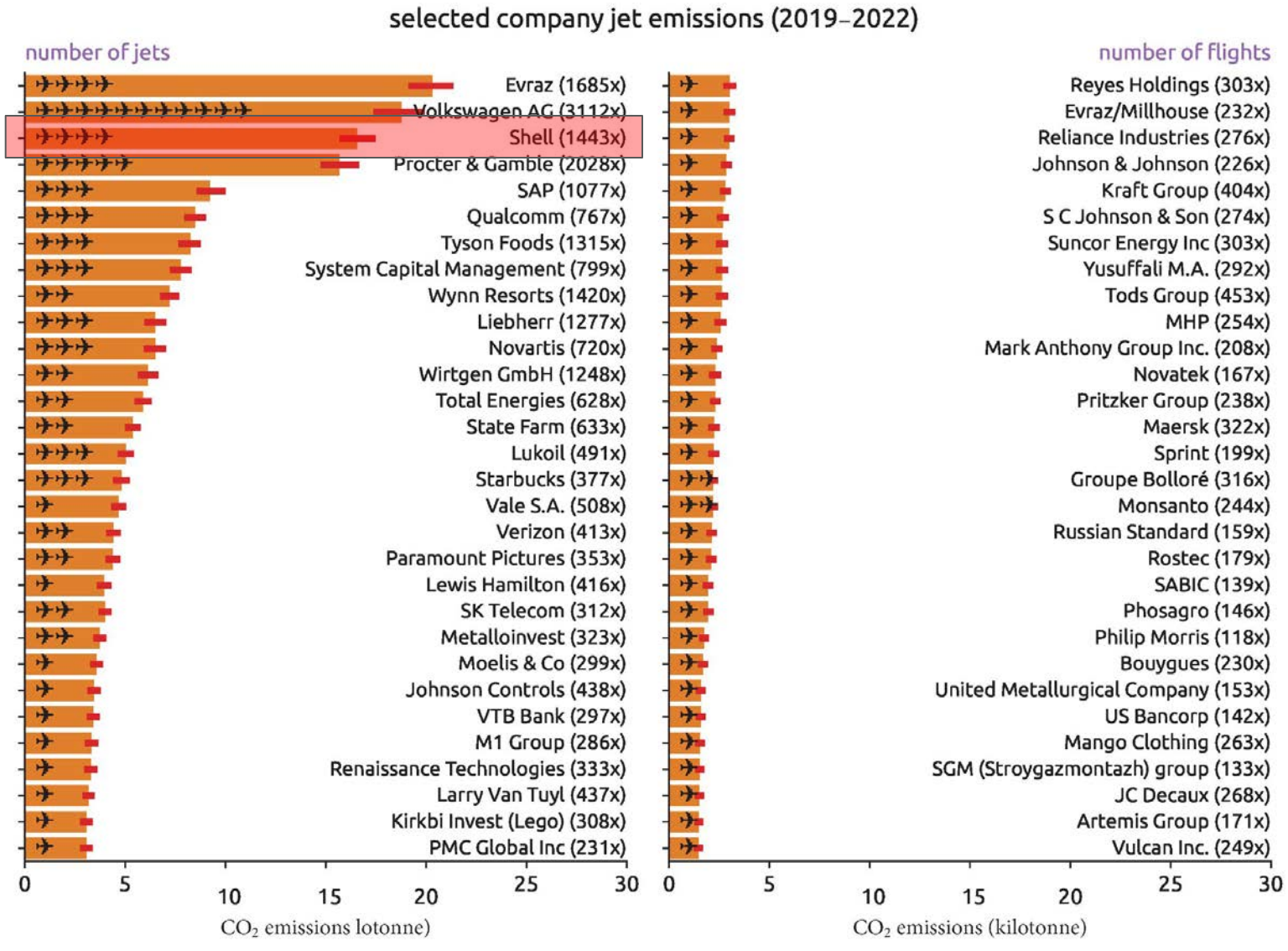
Martin Strohmeier · 1st
Senior Scientist at Swiss Cyber-Defence Campus (ar W&T)


Elon Musk
@elonmusk
My commitment to free speech extends even to not banning the account following my plane, even though that is a direct personal safety risk
Readers added context they thought people might want to know
The implied account in this tweet is elonjet, which is currently banned:
twitter.com/elonjet


N628TS
Flight level
400
300
200
100
18:00
18:30
19:00
19:30
20:00
Ground speed (kt)
400
300
200
18:00
18:30
19:00
19:30
20:00
CO_2 emission (kg/s)
2.5
2.0
1.5
1.0
18:00
18:30
19:00
19:30
20:00


01 Mar | 3x | 38t CO_2
02 Mar | 0x
03 Mar | 0x
04 Mar | 2x | 28t CO_2
05 Mar | 5x | 50t CO_2
06 Mar | 3x | 27t CO_2
07 Mar | 0x
08 Mar | 1x | 7t CO_2
09 Mar | 3x | 25t CO_2
10 Mar | 5x | 50t CO_2
11 Mar | 1x | 13t CO_2
12 Mar | 2x | 24t CO_2
13 Mar | 2x | 28t CO_2
14 Mar | 0x
15 Mar | 1x | 11t CO_2
16 Mar | 5x | 46t CO_2
17 Mar | 0x
18 Mar | 1x | 3t CO_2
19 Mar | 0x
20 Mar | 2x | 32t CO_2
21 Mar | 1x | 14t CO_2
22 Mar | 2x | 32t CO_2
23 Mar | 1x | 14t CO_2
24 Mar | 4x | 32t CO_2
25 Mar | 4x | 53t CO_2
26 Mar | 1x | 12t CO_2
27 Mar | 1x | 11t CO_2
28 Mar | 1x | 12t CO_2
29 Mar | 3x | 35t CO_2
30 Mar | 3x | 29t CO_2


selected private jet emissions (2019–2022)
number of jets
Alexander Abramov (1560x)
Leonard Blavatnik (857x)
Roman Abramovich (725x)
Rinat Leonidovych Akhmetov (799x)
Steve Wynn (1420x)
Jeff Bezos (587x)
Bill Gates (516x)
Lawrence Stroll (726x)
Elon Musk (566x)
Vagit Alexperov (491x)
Lionel Messi (327x)
Vladimir Potanin (350x)
Osni Sawiris (343x)
Tiger Wood (1199x)
Steven Spielberg (266x)
Taylor Swift (342x)
Mikati (286x)
James Simons (333x)
Christopher Reyes (303x)
Philip Green (315x)
Alisher Usmanov (253x)
Robert Kraft (404x)
Yuri Schefler (304x)
Diego Della Valle (453x)
Yuriy Kosiuk (254x)
Dmitry Mazepin (264x)
Amad Bin Isa Al Khalifa (201x)
Vincent Bolloré (316x)
Roustam Tariko (159x)
Sergey Chemezov (179x)
0
5
10
15
20
25
30
CO_2 emissions (kilotonne)
number of flights
Oleg Tinkoff (182x)
Andrey Guryev (146x)
Viktor Medvedchuk (151x)
Michael Kors (214x)
Andrei Skoch (154x)
Mikhail Prokhorov (151x)
Viktor Vekselberg (169x)
Arkady Rotenberg (217x)
Anatoly Sedykh (153x)
Linnik Brothers (246x)
Zarakh Iliev Bension (121x)
Isak Andic (263x)
vad Manasir (133x)
enri Pinault (171x)
Vladimir Lisin (88x)
Kylie Jenner (117x)
nder Frolov (125x)
guib Sawiris (145x)
Zanadvorov (127x)
Tom Cruise (127x)
Sheldon Adelson (81x)
Alexei Mordashov (118x)
Ronald Perelman (109x)
Harrison Ford (101x)
Zygmunt Solorz-Zak (117x)
Yuan Yafei (100x)
Dmitri Rybolovlev (103x)
Petr Kellner (90x)
Ihor Kolomoyskyi (76x)
Eugene Shvidler (66x)
0
5
10
15
20
25
30
CO_2 emissions (kilotonne)

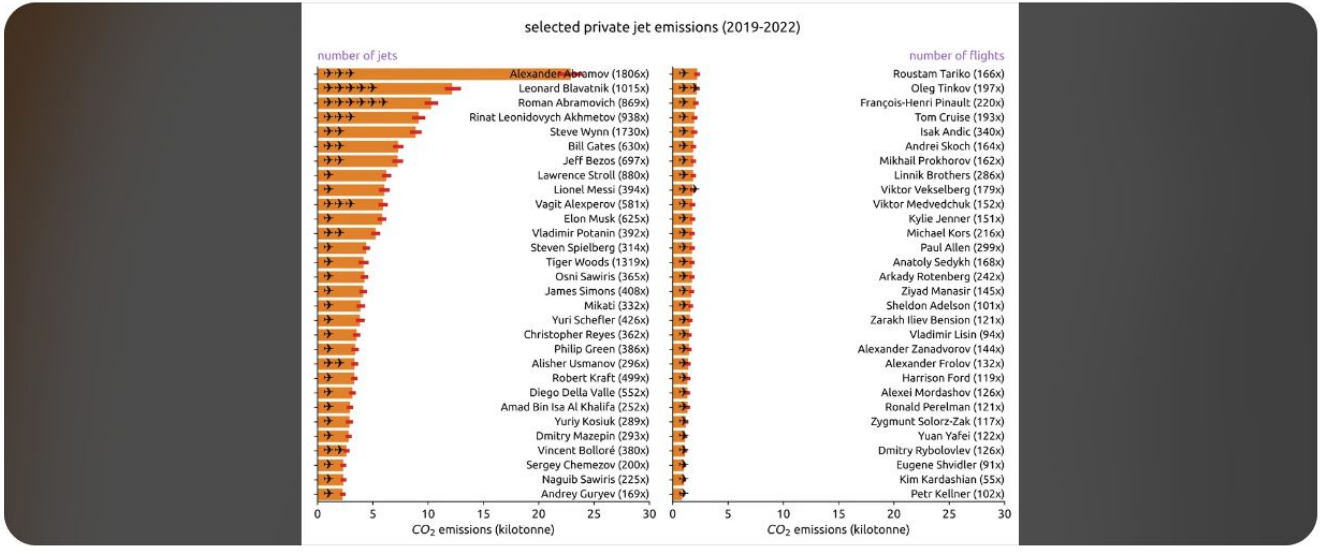

selected company jet emissions (2019–2022)
number of jets
Evraz (1685x)
Volkswagen AG (3112x)
Shell (1443x)
Procter & Gamble (2028x)
SAP (1077x)
Qualcomm (767x)
Tyson Foods (1315x)
System Capital Management (799x)
Wynn Resorts (1420x)
Liebherr (1277x)
Novartis (720x)
Wirtgen GmbH (1248x)
Total Energies (628x)
State Farm (633x)
Lukoil (491x)
Starbucks (377x)
Vale S.A. (508x)
Verizon (413x)
Paramount Pictures (353x)
Lewis Hamilton (416x)
SK Telecom (312x)
Metalloinvest (323x)
Moelis & Co (299x)
Johnson Controls (438x)
VTB Bank (297x)
M1 Group (286x)
Renaissance Technologies (333x)
Larry Van Tuyl (437x)
Kirkbi Invest (Lego) (308x)
PMC Global Inc (231x)
0
5
10
15
20
25
30
CO2 emissions lotonne)
number of flights
Reyes Holdings (303x)
Evraz/Millhouse (232x)
Reliance Industries (276x)
Johnson & Johnson (226x)
Kraft Group (404x)
S C Johnson & Son (274x)
Suncor Energy Inc (303x)
Yusuffali M.A. (292x)
Tods Group (453x)
MHP (254x)
Mark Anthony Group Inc. (208x)
Novatek (167x)
Pritzker Group (238x)
Maersk (322x)
Sprint (199x)
Groupe Bolloré (316x)
Monsanto (244x)
Russian Standard (159x)
Rostec (179x)
SABIC (139x)
Phosagro (146x)
Philip Morris (118x)
Bouygues (230x)
United Metallurgical Company (153x)
US Bancorp (142x)
Mango Clothing (263x)
SGM (Stroygazmontazh) group (133x)
JC Decaux (268x)
Artemis Group (171x)
Vulcan Inc. (249x)
0
5
10
15
20
25
30
CO2 emissions (kilotonne)


STUDENTS, SCIENTISTS, THE WORLD
TU DELFT ~~OIL & GAS COLLABORATION~~
FOSSIL DELIBERATIONS & DIALOGUES

reddit r/dataisbeautiful Search in r/dataisbeautiful

r/dataisbeautiful • 1 yr. ago
AndooBundoo

Private jet emissions in the last 3 years of well-known individuals, computed using open ADS-B data



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Embassy Science Fellowship

Ministerie van Buitenlandse Zaken

NWO

Embassy Science Fellowship - **France**

Sustainable aviation: collaboration for research into cleaner air traffic

What:

1) Flight emission inefficiency

2) Electric flights?

Conclusion:

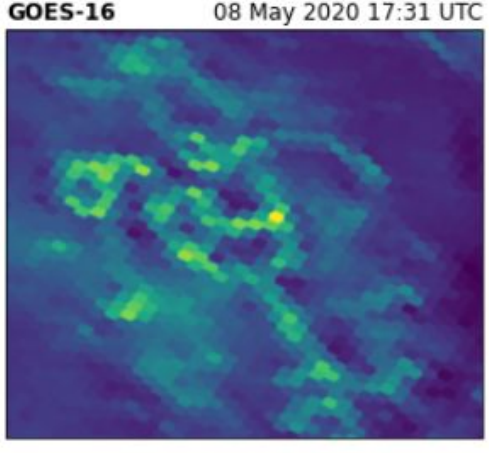
1) 19% excess emission

2) not feasible

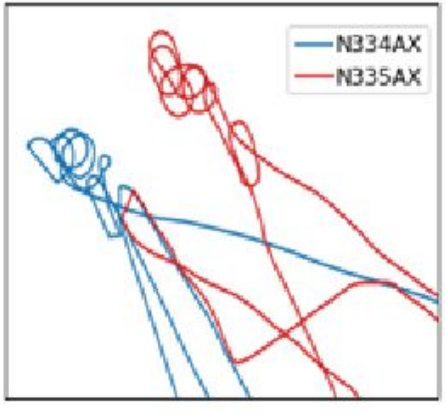
New chapter: **Contrails**


Esther Roosenbrand · 1st
PHD Candidate at Technische Universiteit Delft
2021

Esther Roosenbrand · 1st
PHD Candidate at Technische Universiteit Delft

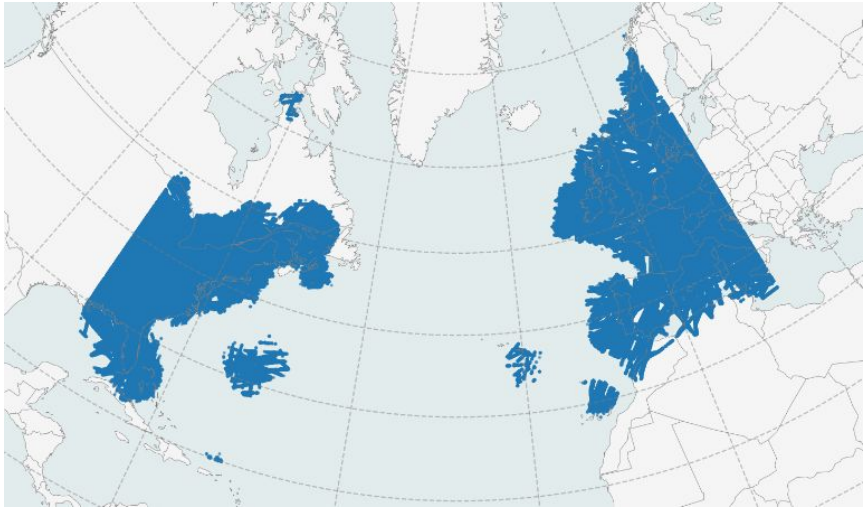


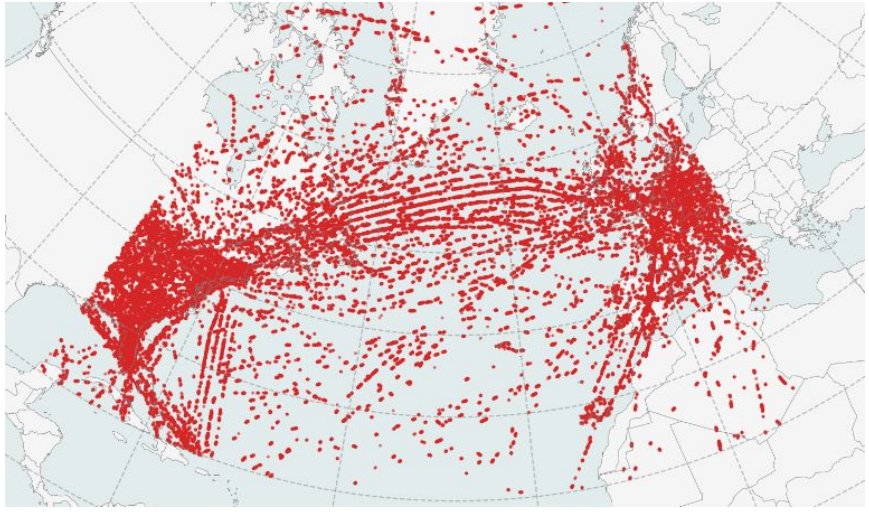
(a) GOES-16 BTD-image



(b) OpenSky trajectories of N334AX and N335AX

(c) Terra MODIS: Corrected Reflectance (true color)





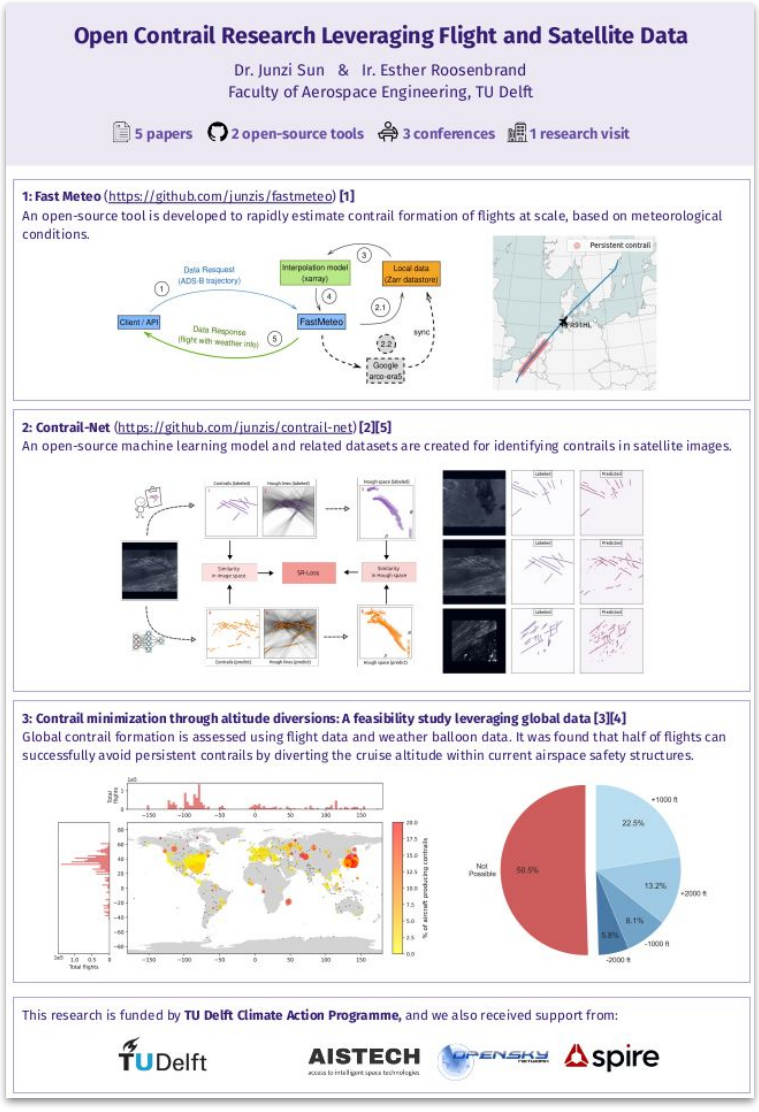
OPENSKY NETWORK

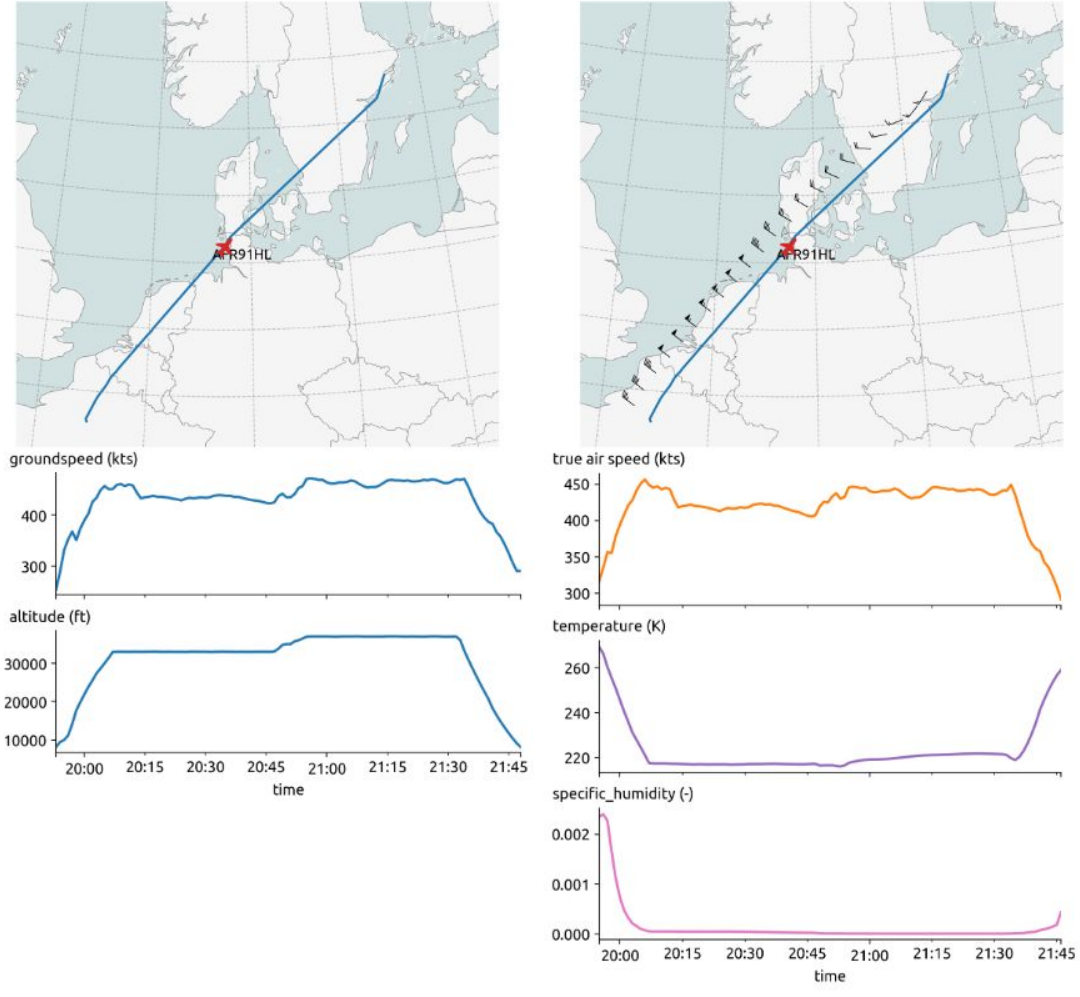
spire

2022

Climate Action Seed Fund:

MOCHA - Multidisciplinary Open Collaborations on High Altitude Contrail Detection with Aviation and Satellite Data Fusion

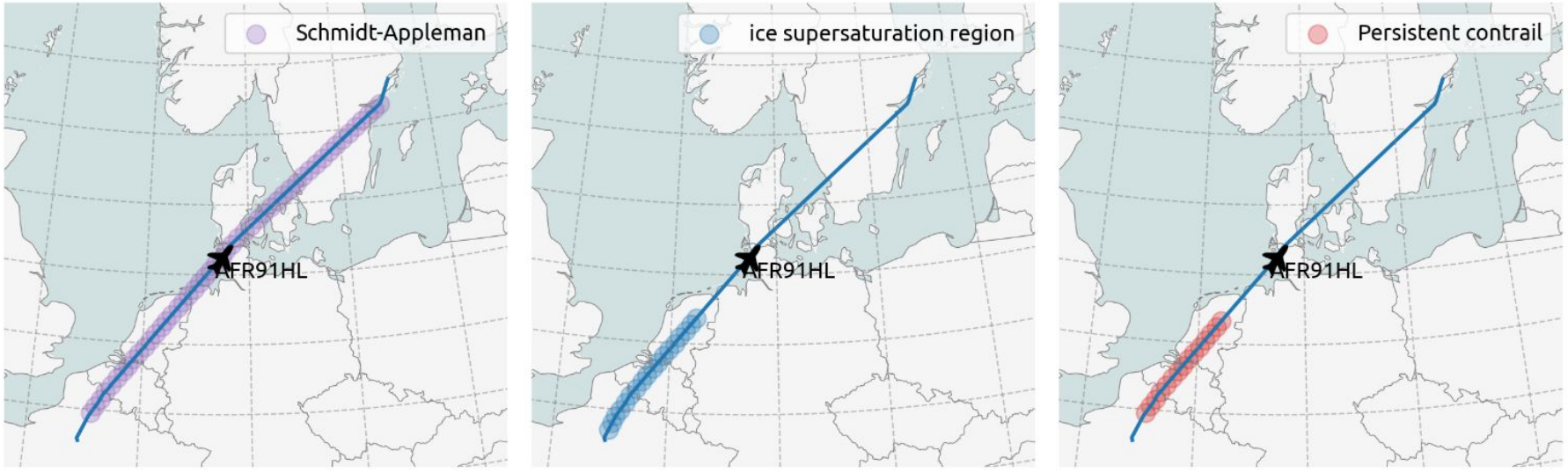




Open tool: ***FastMeteo***

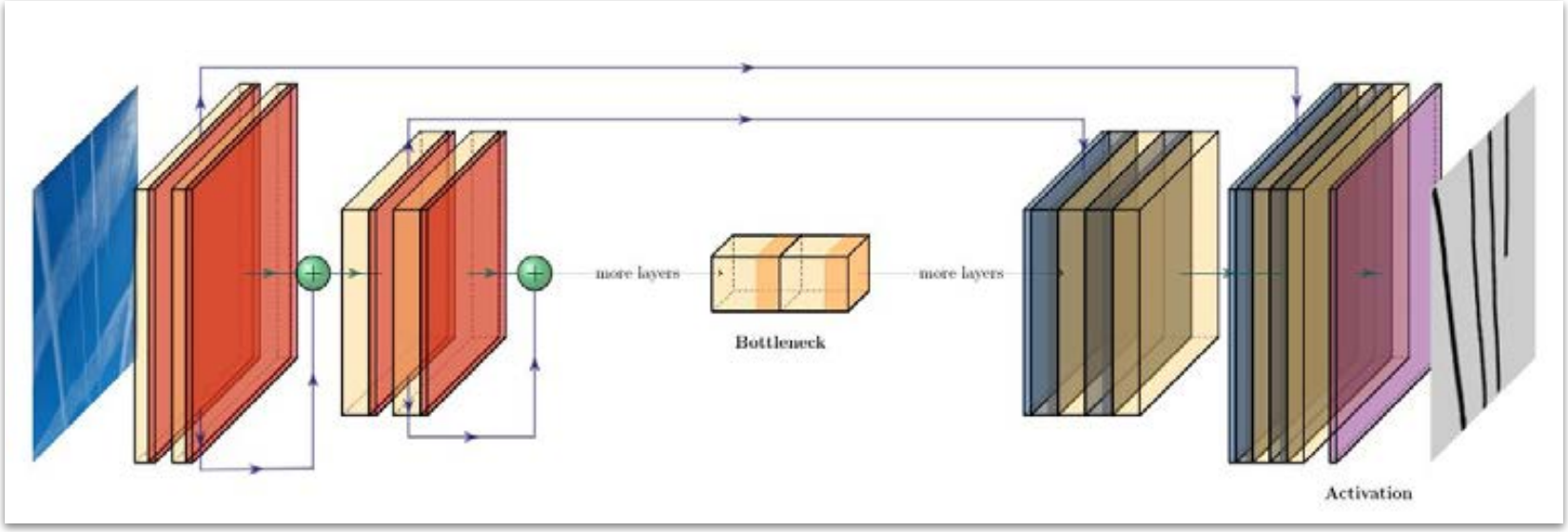
Improve the speed of aggregating meteorological data to flight.

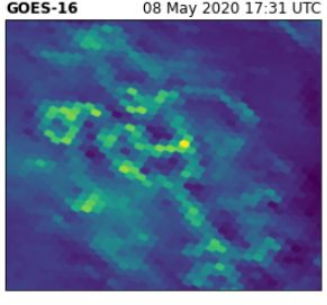
(from tens of minutes / hours to seconds)



Examining the contrail forming regions based on different **theories**

Alignment: ***theory models*** vs ***remote sensing***





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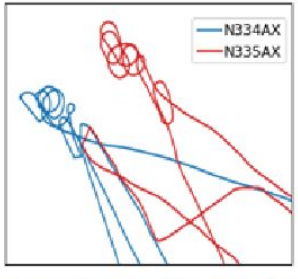

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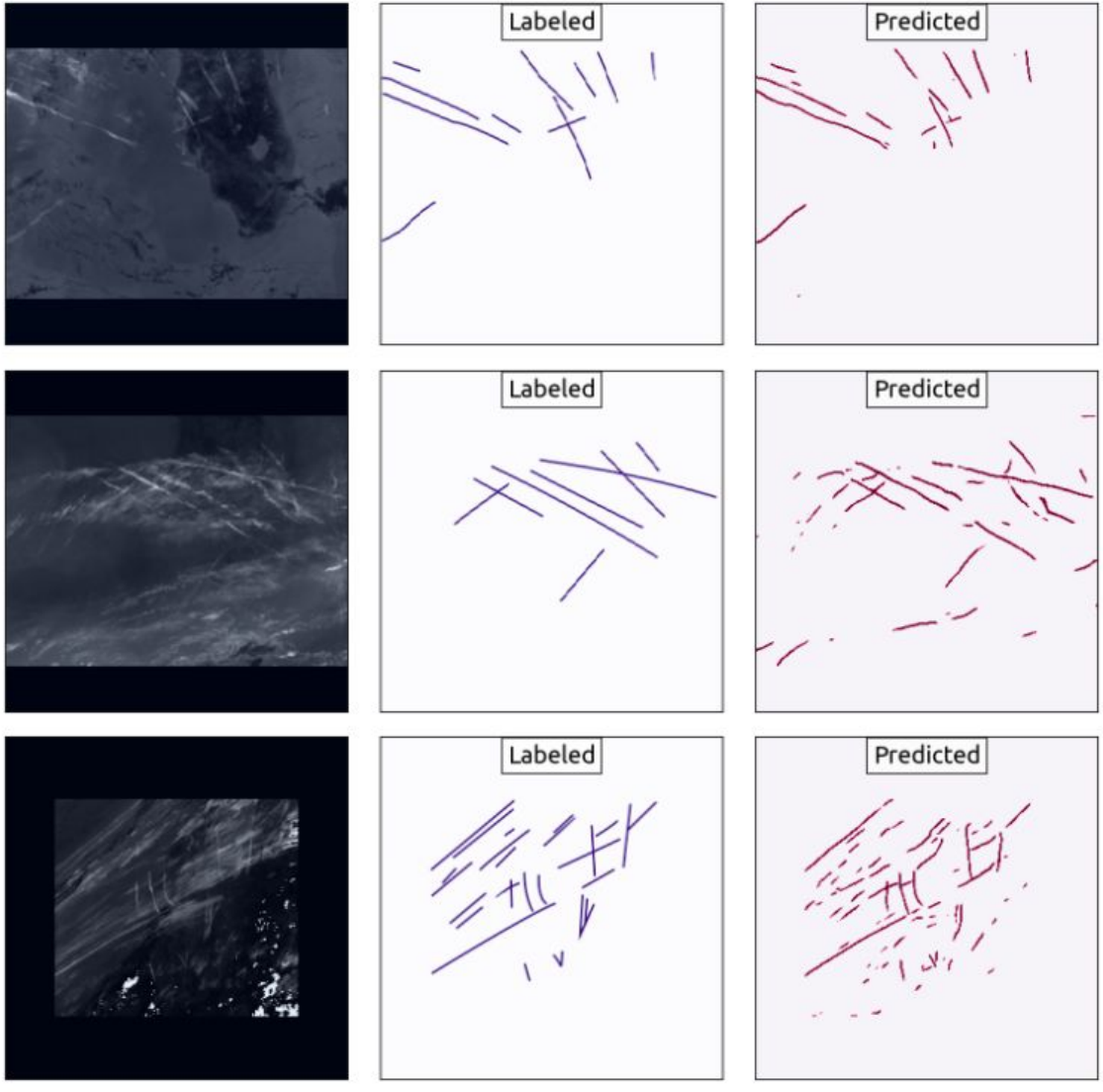
Labeled
Predicted
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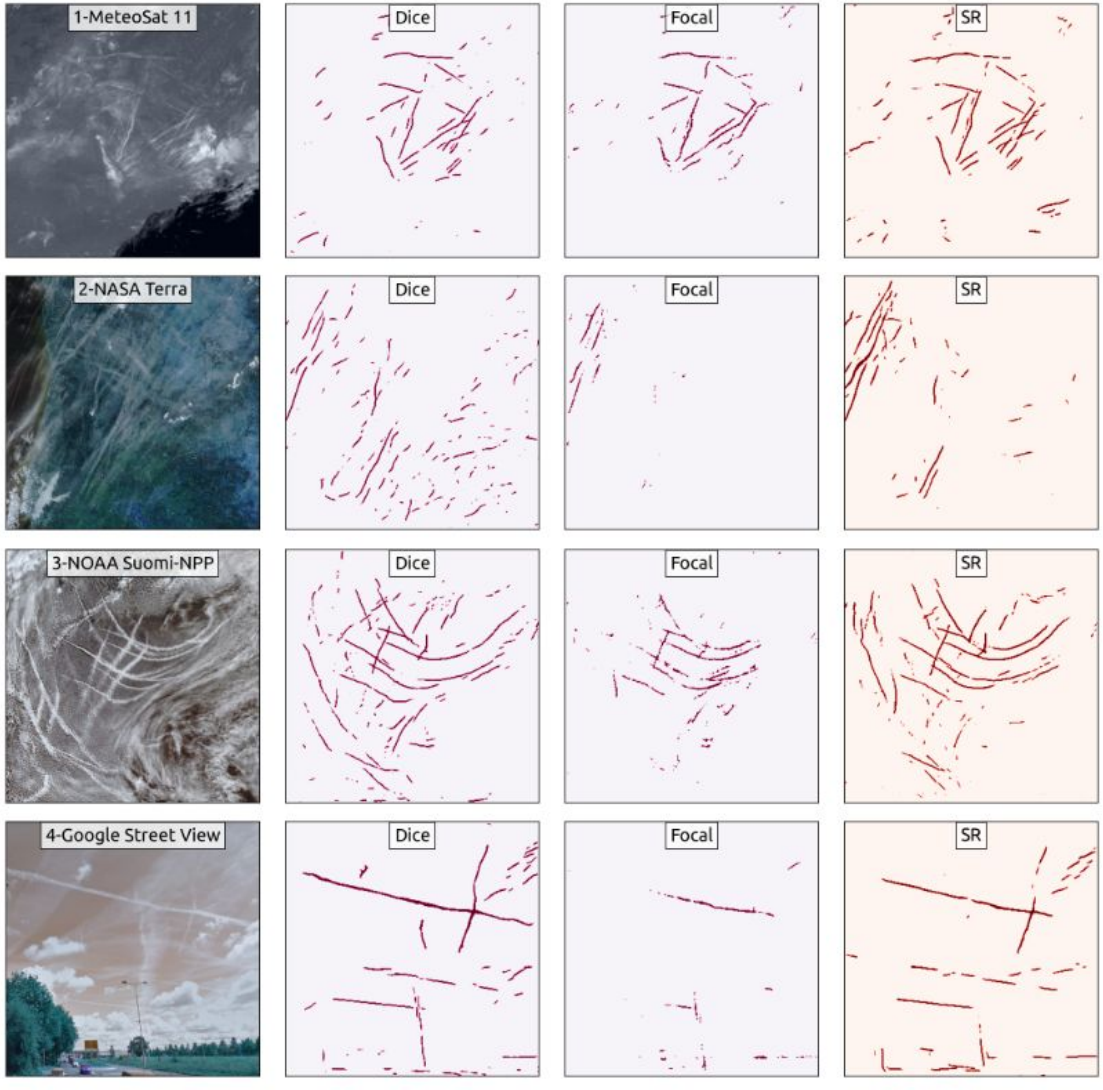
1-MeteoSat 11
Dice
Focal
SR
2-NASA Terra
Dice
Focal
SR
3-NOAA Suomi-NPP
Dice
Focal
SR
4-Google Street View
Dice
Focal
SR

Open Contrail Research Leveraging Flight and Satellite Data

Dr. Junzi Sun & Ir. Esther Roosenbrand
Faculty of Aerospace Engineering, TU Delft

5 papers · 2 open-source tools · 3 conferences · 1 research visit

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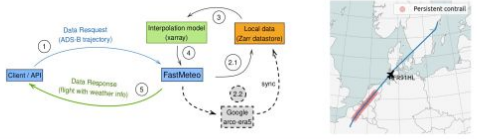
An open-source tool is developed to rapidly estimate contrail formation of flights at scale, based on meteorological conditions.



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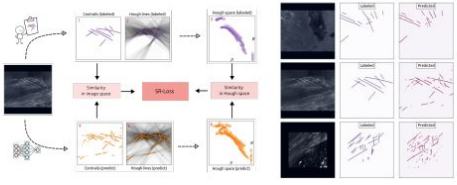
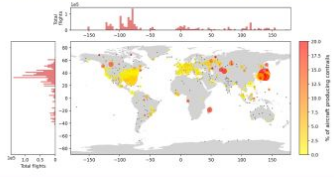
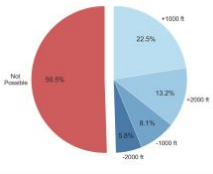
An open-source machine learning model and related datasets are created for identifying contrails in satellite images.



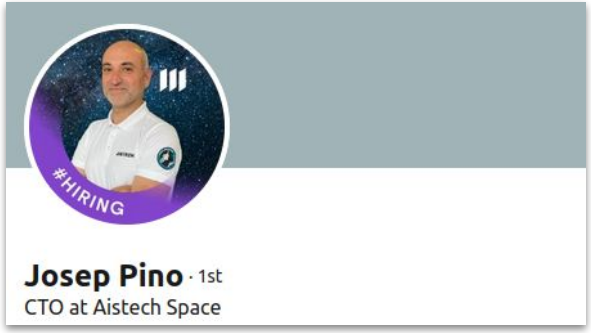
3: Contrail minimization through altitude diversions: A feasibility study leveraging global data [3][4]
Global contrail formation is assessed using flight data and weather balloon data. It was found that half of flights can successfully avoid persistent contrails by diverting the cruise altitude within current airspace safety structures.

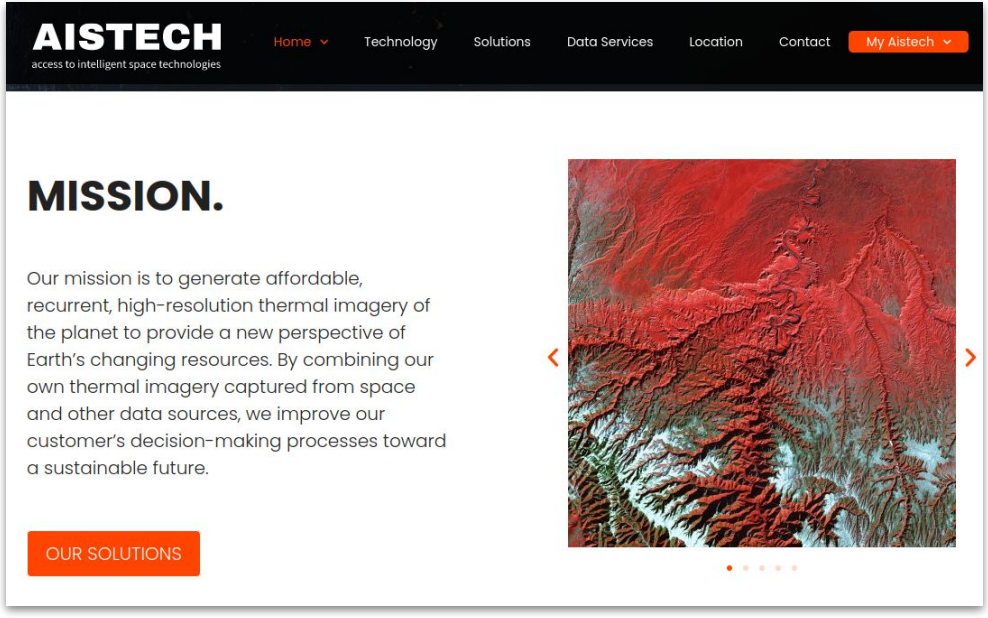




This research is funded by **TU Delft Climate Action Programme,** and we also received support from:

TU Delft · AISTECH · OpenSky · spire





Open Contrail Research Leveraging Flight and Satellite Data

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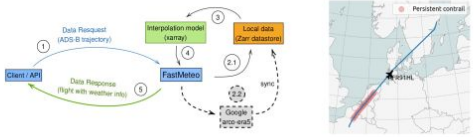

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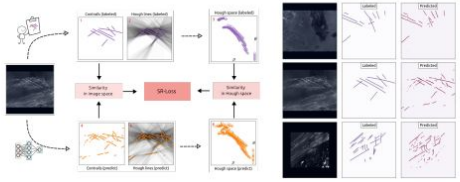

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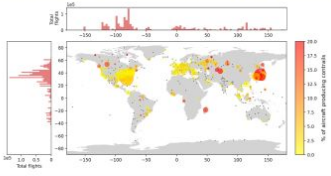

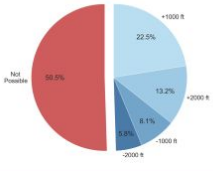

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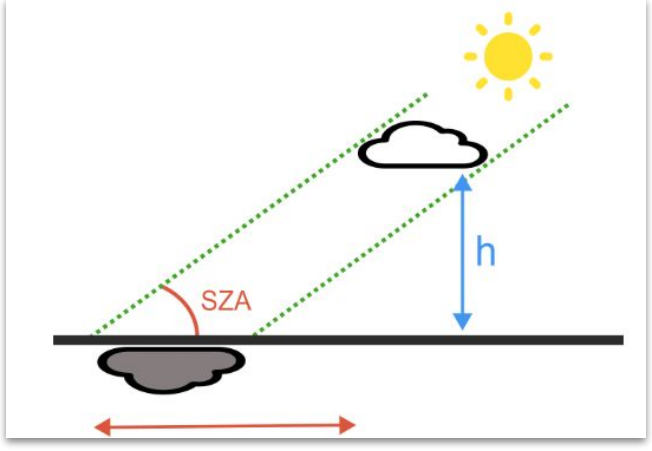
TUDelft AISTECH OPENSKY spire



New challenges: **Mitigation?**

Transportation Research Interdisciplinary Perspectives
Volume 22, November 2023, 100953

Contrail minimization through altitude diversions: A feasibility study leveraging global data

Esther Roosenbrand, Junzi Sun, Jacco Hoekstra

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Esther Roosenbrand · 1st
PHD Candidate at Technische Universiteit Delft

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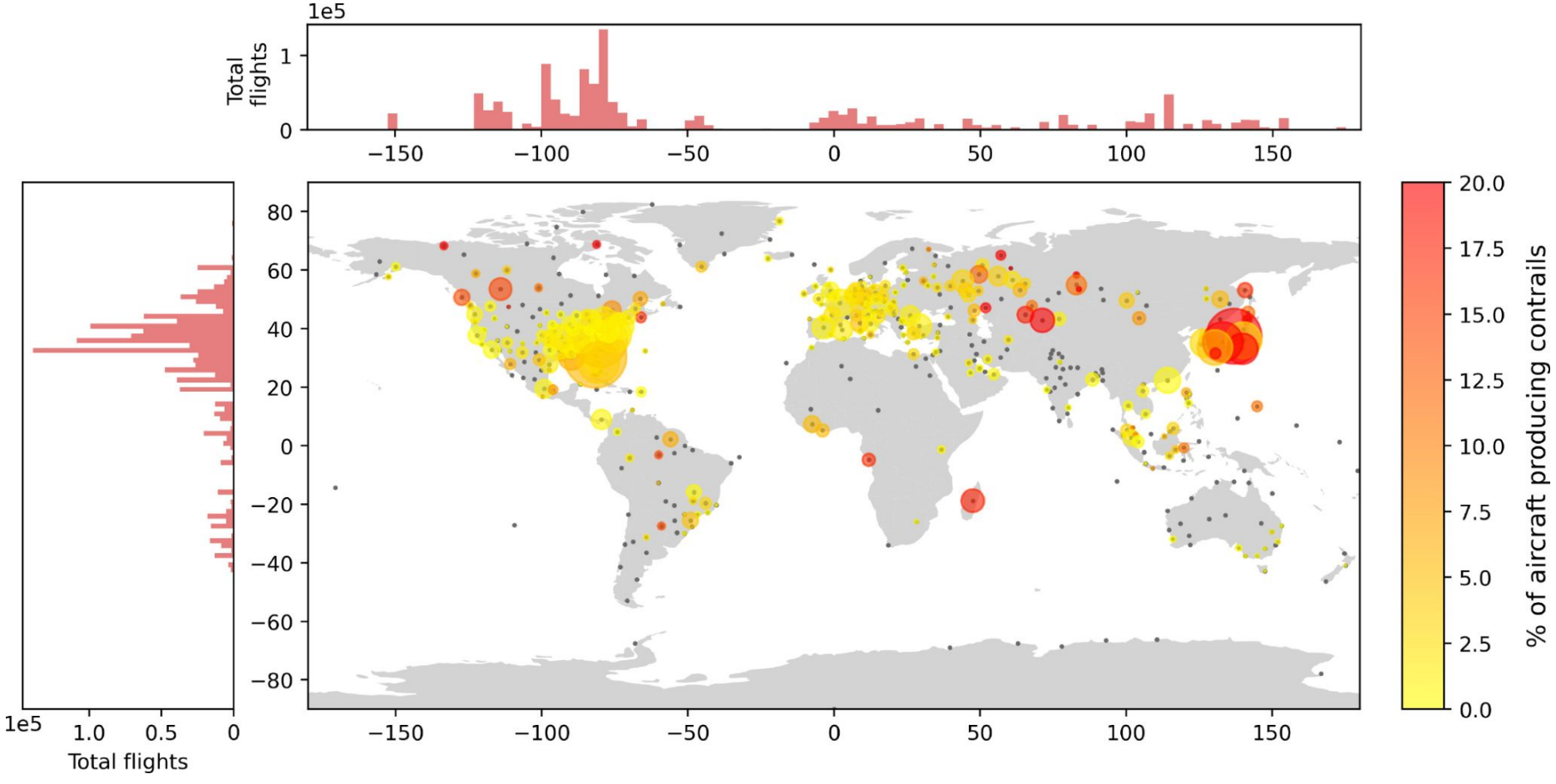
Slight flight altitude changes could slash aviation's climate impact

Contrail clouds that form behind planes are responsible for much of the climate warming effects of flying. Small altitude adjustments would help minimise them

By James Dinneen

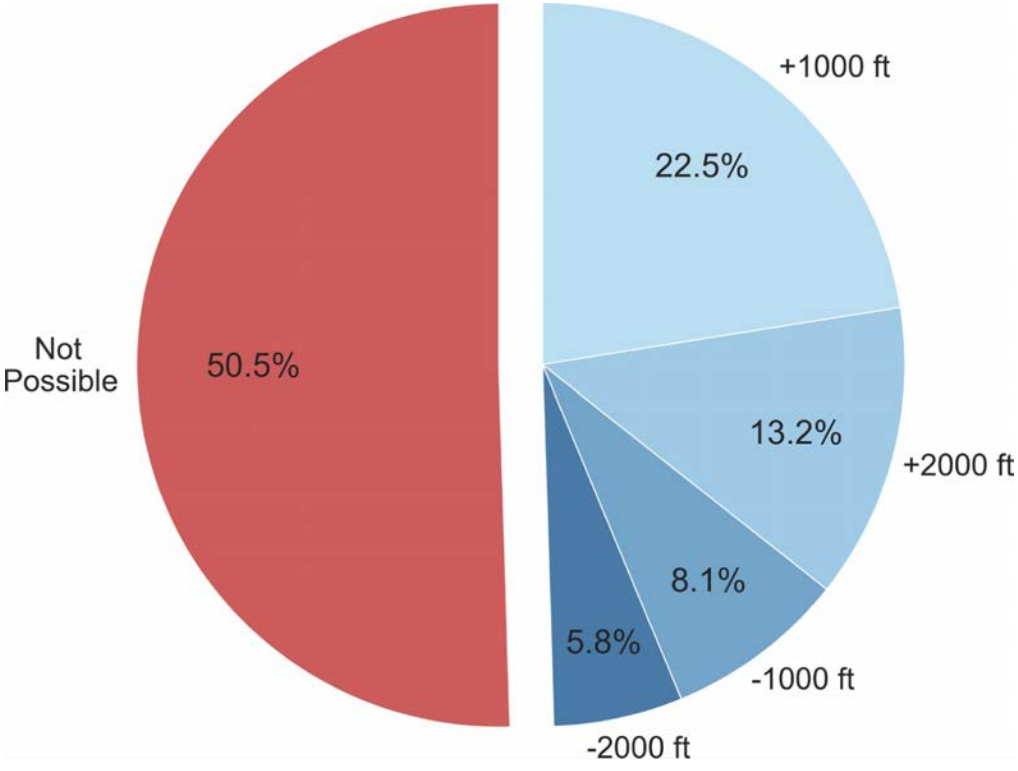
30 January 2024

Contrails contribute to climate change, but slight changes in aeroplane altitude can reduce their impact
siloto/Shutterstock


1e5
Total flights
1
0
−150
−100
−50
0
50
100
150
80
60
40
20
0
−20
−40
−60
−80
1e5
1.0
0.5
0
Total flights
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
% of aircraft producing contrails

50% contrails could have been avoided with altitude changes

- Marginal extra fuel
- No safety issues



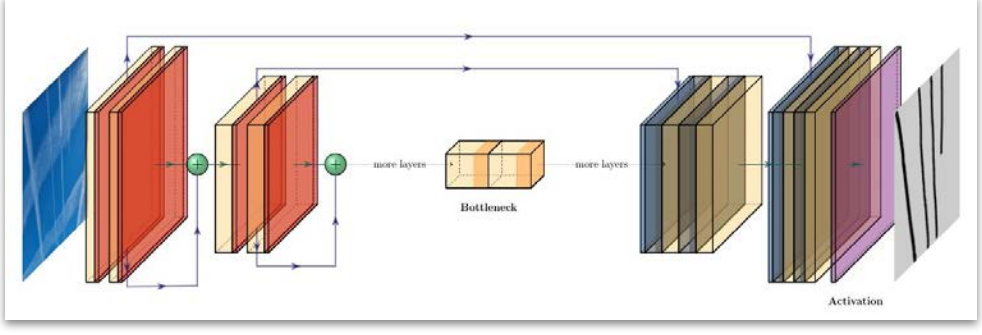
What’s next?

Short term: next week

Study of global contrail forming based on OpenSky data.

Longer term:

*Better **AI model** for contrail detection in remote sensing images, and mapping to flights with higher accuracy.* *(with researchers from EUROCONTROL)*



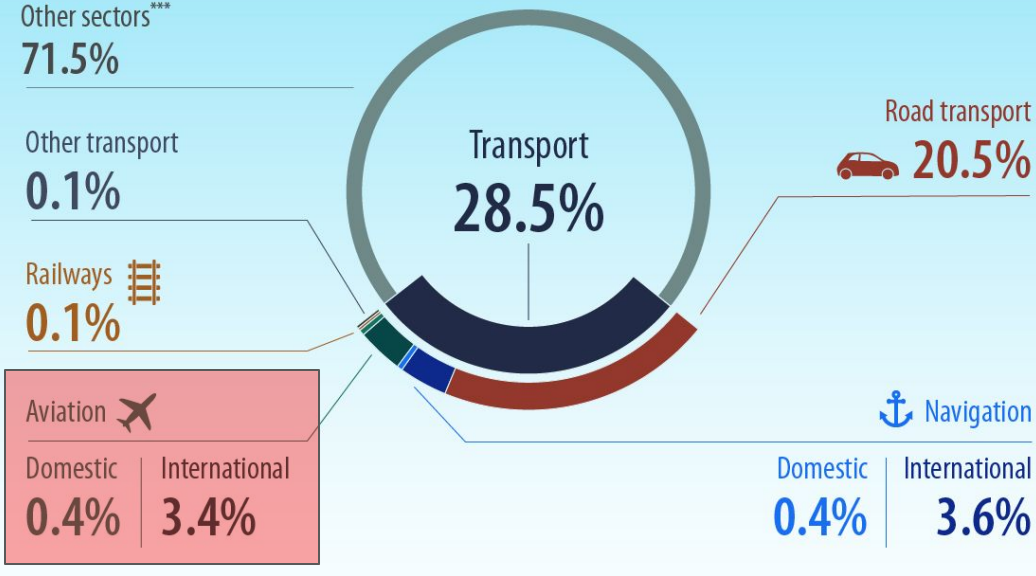
Follow my colleagues at ***Control & Operations***:

Better understanding of aviation, Non-CO_2 effects, and climate dynamics

So what now?

Transport emissions

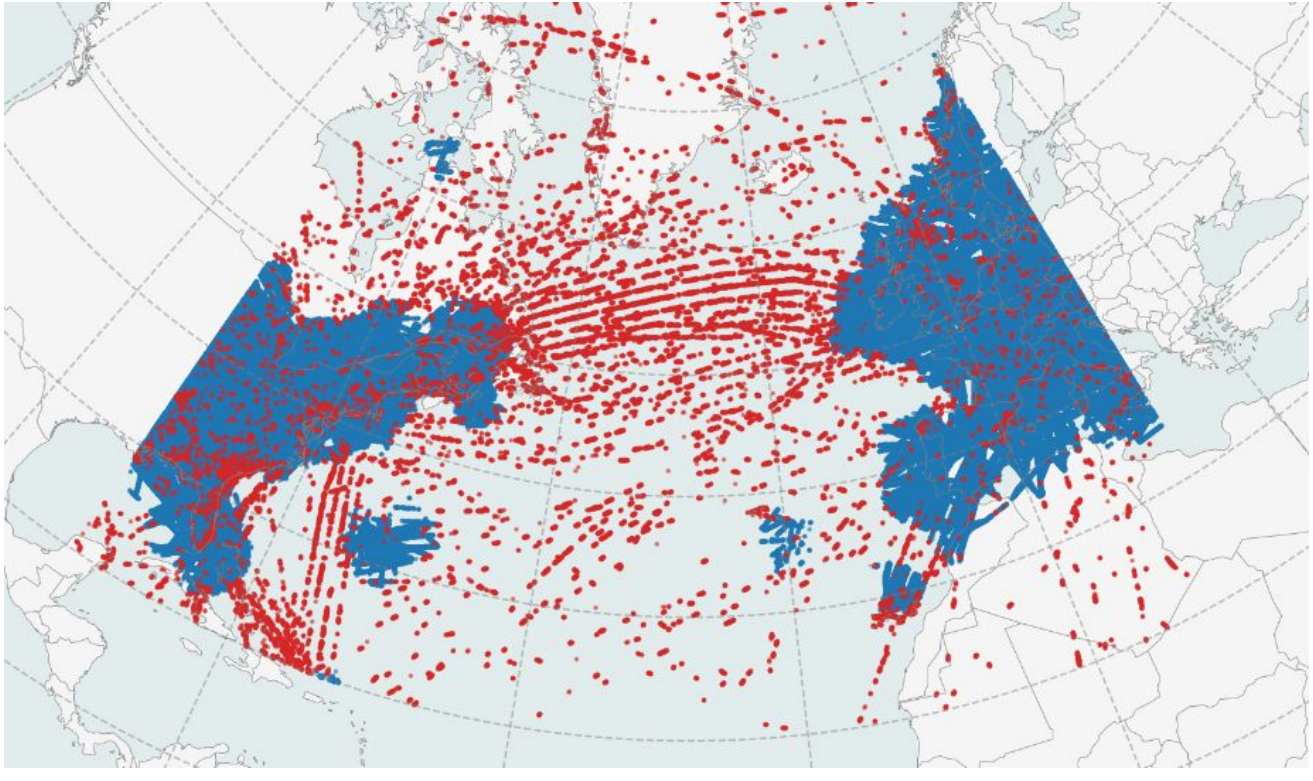
as share of the EU*'s total greenhouse gas emissions (2019)**



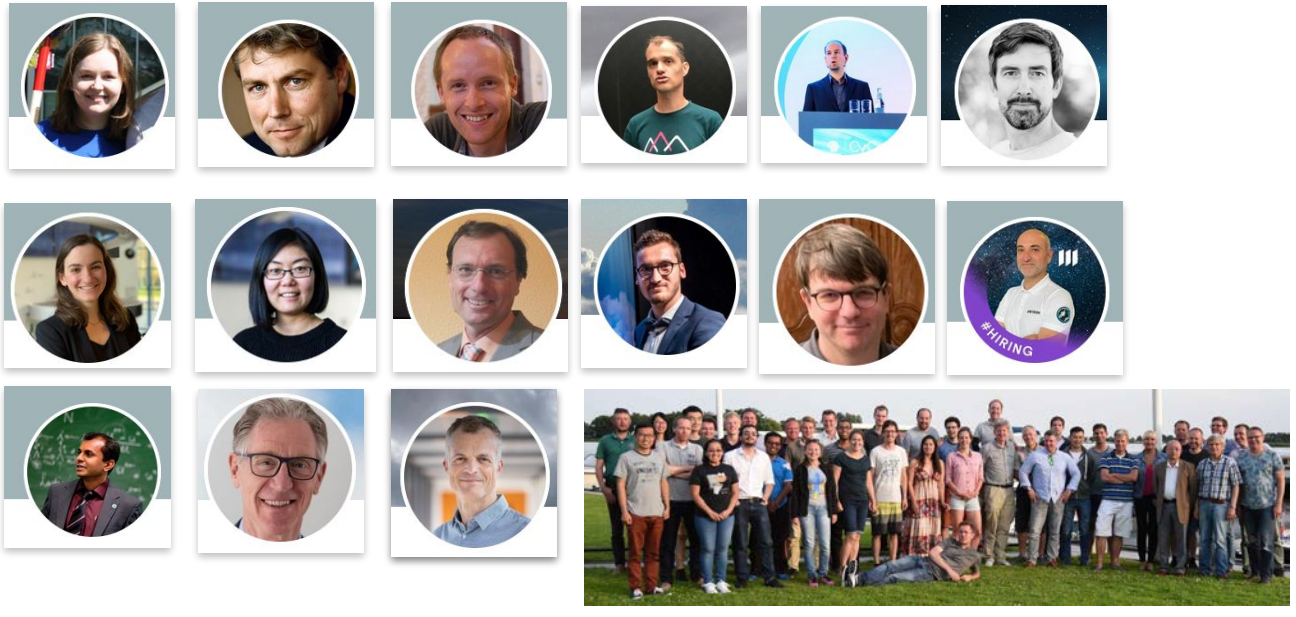
*Excluding the United Kingdom
**Excluding land use, land-use change and forestry
***Energy, industry, residential, commercial, institutional, agriculture, forestry, fisheries and other

Source: European Environment Agency (2022)

How to address aviation's climate problem with open data



How to address aviation's climate problem with open ~~data~~ ***community***



Thank you!

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Twitter: @junzi
GitHub: junzis