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Research article

Features and evolution of civil aviation CO_2 emissions based on ADS-B data for the period between 2019–2024

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Contents

S1. Emissions distribution

Figure S1.1 illustrates the distribution of emissions across the globe for the year 2019. It can be observed that regions with higher emissions are located in North America, Europe, and Asia and that the various flight corridors can be identified.

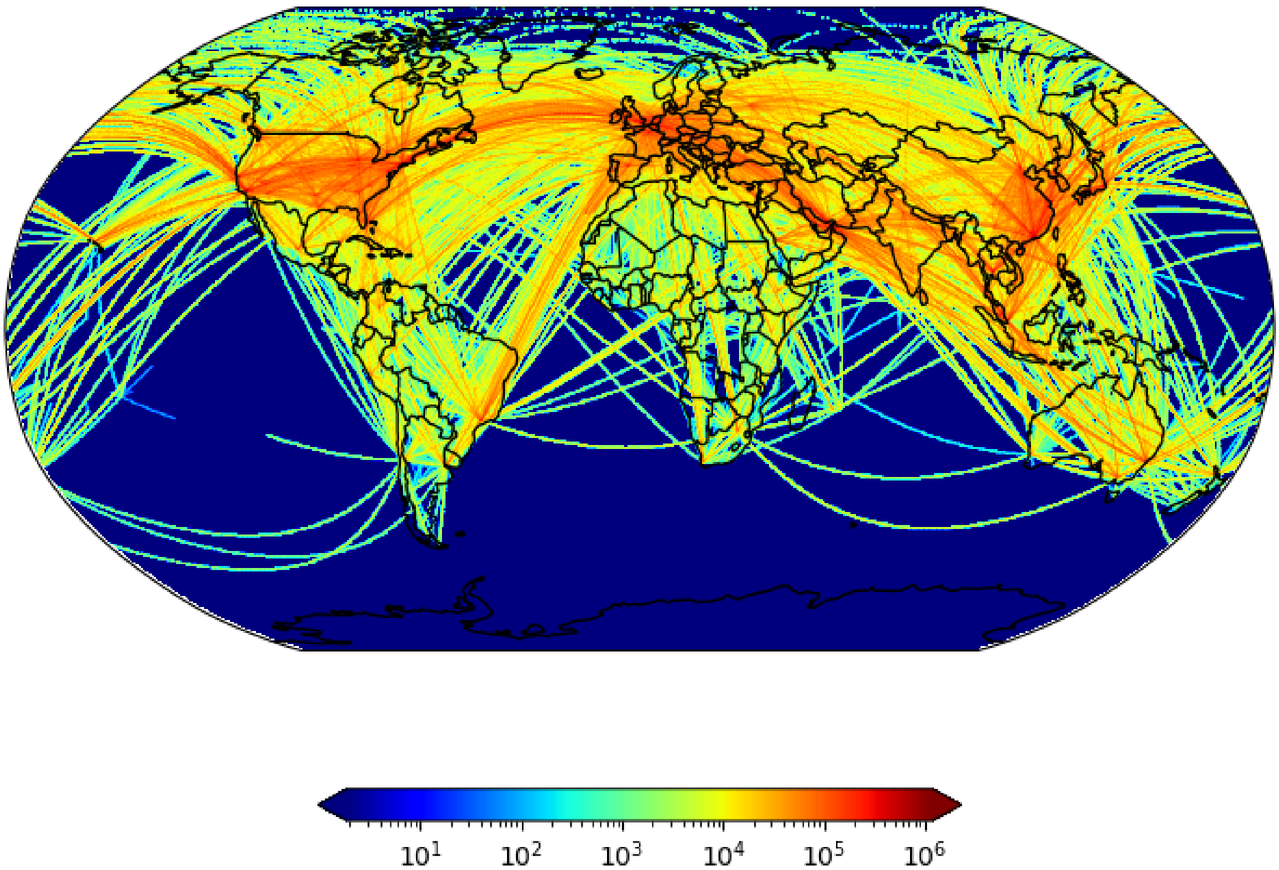

Figure S1.1. Distribution of aviation emissions worldwide in 2019, in $kgCO_2/km^2$, spatialized along great circles between origin and destination airports.

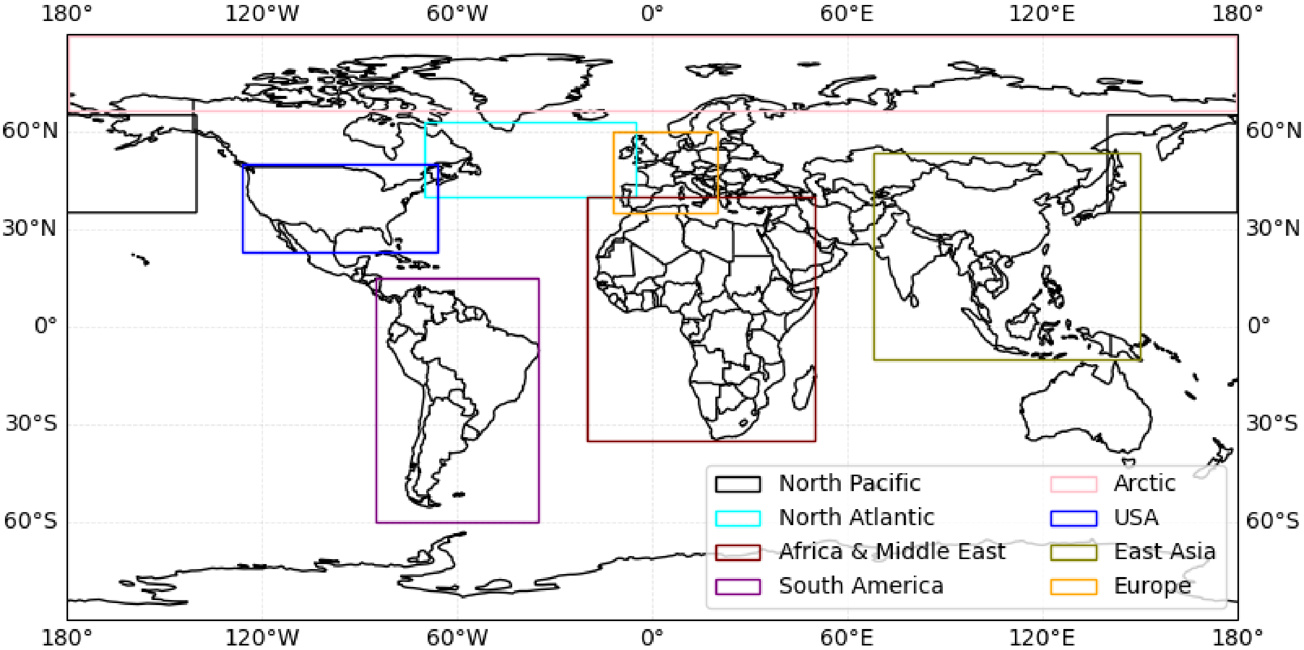

Figure S1.2. Spatial representation of bounding boxes, following Teoh et al. [1], except for East Asia, 68–150 °E × 10 °S–53.5 °N, used to estimate the regional aviation activity and emissions in Tab. S1.1.

Table S1.1. Regional aviation activity as defined in Figure S1.2, for the number of flights, distance, and emissions for 2019 according to the geodesic distance between departure and arrival airports. Emissions were divided evenly along the distance flown. A flight is considered in the area if it flew more than 250 km inside the area.

Regional statistics	Global	North Pacific	North Atlantic	Africa	South America	Arctic	USA	East Asia	Europe
Nb of flights/day	119662	1274	2288	6588	5356	409	42046	30090	26129
- - % by regions	-	1.07	1.91	5.51	4.48	0.34	35.14	25.15	21.84
Distance (10^9 km)	59.24	1.01	2.37	3.44	2.27	0.38	15.92	14.8	9.49
- - % by regions	-	1.7	4.0	5.81	3.83	0.64	26.87	24.98	16.02
CO_2 Emissions (Mt)	895.03	23.86	50.35	60.7	32.69	9.61	180.58	243.42	131.13
- - % by regions	-	2.67	5.63	6.78	3.65	1.07	20.18	27.2	14.65

Note that the percentages from the different regions do not add up to 100% as the bounding boxes do not cover the whole world.

Table S1.2. Same as Tab.S1.1 but for 2020.

Regional statistics	Global	North Pacific	North Atlantic	Africa	South America	Arctic	USA	East Asia	Europe
Nb of flights/day	74912	983	981	2883	2566	244	29219	18604	12105
- - % by regions	-	1.31	1.31	3.85	3.43	0.33	39.01	24.83	16.16
Distance (10^9 km)	32.64	0.76	1.0	1.57	1.06	0.2	10.14	8.54	3.95
- - % by regions	-	2.33	3.06	4.81	3.25	0.61	31.07	26.17	12.1
CO_2 Emissions (Mt)	476.74	18.14	20.59	27.79	15.13	4.65	110.38	138.83	54.38
- - % by regions	-	3.8	4.32	5.83	3.17	0.98	23.15	29.12	11.41

Table S1.3. Same as Tab.S1.1 but for 2021.

Regional statistics	Global	North Pacific	North Atlantic	Africa	South America	Arctic	USA	East Asia	Europe
Nb of flights/day	93464	1111	1214	4291	3844	303	38523	19761	14725
- - % by regions	-	1.19	1.3	4.59	4.11	0.32	41.22	21.14	15.76
Distance (10^9 km)	40.54	0.83	1.28	2.18	1.46	0.25	13.59	8.85	5.12
- - % by regions	-	2.05	3.16	5.38	3.6	0.62	33.52	21.83	12.63
CO_2 Emissions (Mt)	562.66	19.56	25.57	35.82	20.02	5.74	144.26	141.07	67.63
- - % by regions	-	3.48	4.54	6.37	3.56	1.02	25.64	25.07	12.02

Table S1.4. Same as Tab.S1.1 but for 2022.

Regional statistics	Global	North Pacific	North Atlantic	Africa	South America	Arctic	USA	East Asia	Europe
Nb of flights/day	102474	1217	2053	6074	5378	337	38345	19796	22215
- - % by regions	-	1.19	2.0	5.93	5.25	0.33	37.42	19.32	21.68
Distance (10^9 km)	47.75	0.85	2.15	3.12	2.13	0.27	14.17	8.78	8.39
- - % by regions	-	1.78	4.5	6.53	4.46	0.57	29.68	18.39	17.57
CO_2 Emissions (Mt)	683.19	19.7	43.3	50.84	28.85	6.48	161.05	141.23	110.58
- - % by regions	-	2.88	6.34	7.44	4.22	0.95	23.57	20.67	16.19

Table S1.5. Same as Tab.S1.1 but for 2023.

Regional statistics	Global	North Pacific	North Atlantic	Africa	South America	Acrtic	USA	East Asia	Europe
Nb of flights/day	117937	1291	2265	7481	6040	366	40018	29123	24640
- - % by regions	-	1.1	1.92	6.34	5.12	0.31	33.93	24.69	20.89
Distance (10^9 km)	57.08	0.94	2.43	3.81	2.39	0.3	15.08	13.86	9.34
- - % by regions	-	1.65	4.26	6.67	4.19	0.53	26.42	24.28	16.36
CO_2 Emissions (Mt)	825.19	21.93	48.78	61.09	31.99	7.25	172.19	217.08	123.67
- - % by regions	-	2.66	5.91	7.4	3.88	0.88	20.87	26.31	14.99

S2. Emissions per airports

A representation of the main airports is shown in Figure S2.1. For each flight, half of the emissions of the cruise were attributed to the departure airport and half to the destination airport. The airports responsible for most of the emissions are located in the northern hemisphere, especially in the USA, EU27 and Asia. Among the 10 highest emitting airports, 4 are located in Asia, 3 in Europe, 2 in the US and 1 in the Middle East.

S3. Business aviation

Focusing on business jets and their emissions, we found that the traffic very quickly returned to its pre-Covid19 level after the first lockdown and even surpassed it during the year 2021. Figure S3.1 shows that CO_2 emissions due to business jets are 40% larger in 2021 compared to 2019. The distance remained the same compared to the other years, 50% of jet flights worldwide are for distances under 800 km. The majority of business traffic is concentrated in North America, with 66% of business aircraft movements taking place within the US. Figure S3.1 also highlights a peculiarity of the FR24 database. A significant drop in business aviation appeared beginning in the months of January and February 2022. The sudden decline observed in early 2022 is exclusive to the US and other regions are not similarly affected. A comparison was made with the results from Gössling et al. (2024) [2],

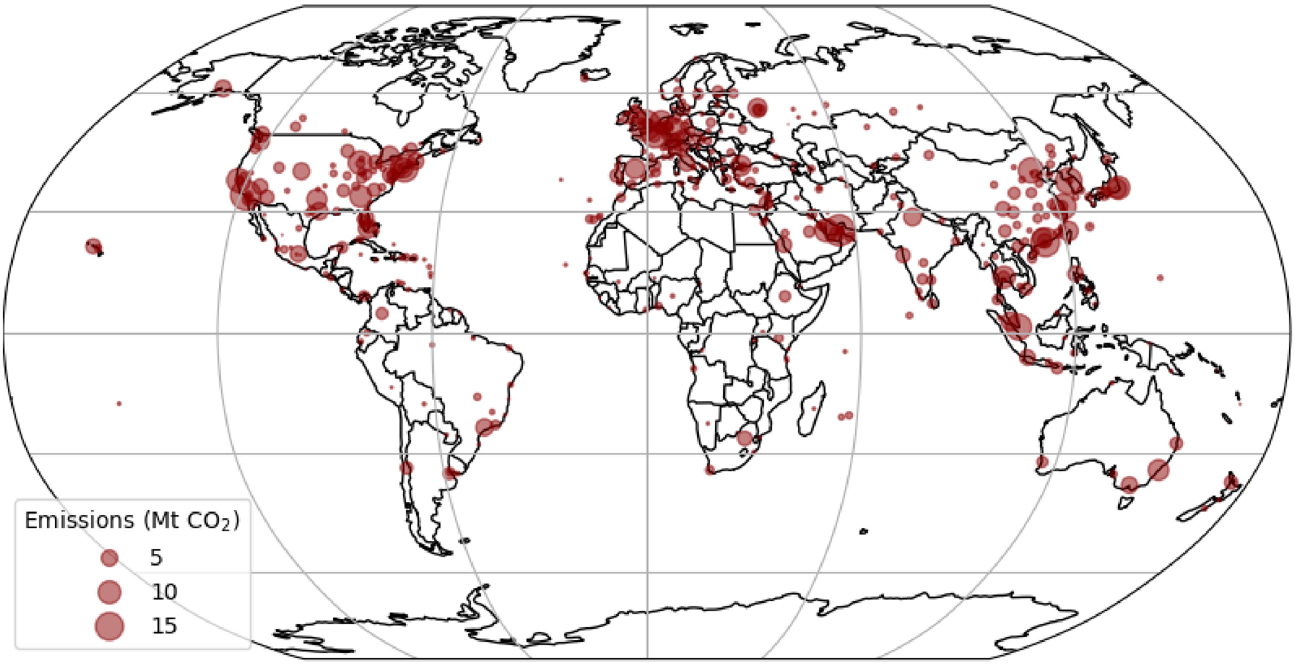

Figure S2.1. Emissions attributed to main airports in the world for 2019. For every flights, half of the emissions were attributed to the departure airport and the other half to the destination airport.

which used a different ADS-B database. The findings indicate that emissions from private aviation follow the same trend in 2019 to 2021. However, their results did not reveal a sudden decrease in 2022, in contrast to the results presented here. The drop seen in the study could be due to more owners or operators registering to the USA FAA's Limiting Aircraft Data Displayed [3], which is designed to filter out registration aircraft numbers (for non-commercial flights) from any public display. The FR24 dataset may become less complete over time, unlike ADS-B Exchange (as used by Gössling et al. [2]) which is unfiltered, and/or ADS-B Exchange becomes more complete over time to track business flights as their network of receivers develops.

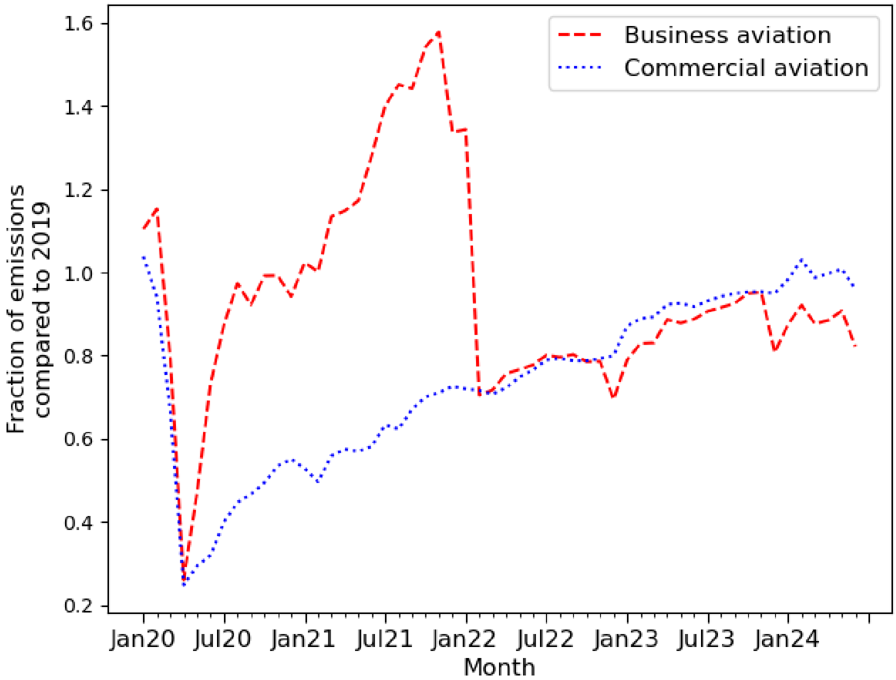

Figure S3.1. Emissions from commercial and business aviation for 2020, 2021, 2022, 2023 and beginning of 2024 normalized to their respective 2019 levels on a month-by-month basis.

S4. Fleet evolution and efficiency

Tab. S4.1 lists the new generation considered in the study. All other aircraft not in the list are considered as belonging to the old generation. The list is similar to [4].

Table S4.1. ICAO aircraft code considered as new generation aircraft.

Narrowbody	Widebody
A19N	A338
A20N	A339
A21N	A359
B37M	A35K
B38M	B788
B39M	B789
B3XM	

Figure S4.1 represents the evolution of the emissions per unit ASK (E/ASK) for the new generation and old generation fleets, either narrowbody or widebody, when the distance increases. On one side, narrowbody aircraft mostly operates flights under 6000 km and they are the most efficient for flights around 2000 to 4000 km. Above, E/ASK skyrockets and below, it increases slightly. Aircraft from the new generation narrowbody are 20% more efficient for all distances. In contrast, widebody can cover all distances but have a better efficiency for distances around 4000 km. The difference between new and old generation widebody fleets becomes more evident when the distance increases. The new generation widebody fleet is 10% more efficient for flight around 8000 km and the reduction can reach 30% for flight above 14000 km compared to the old generation.

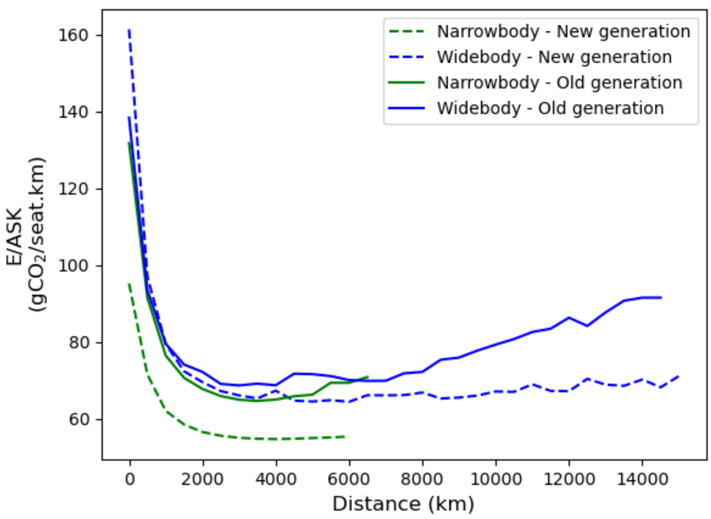

Figure S4.1. Emissions per unit ASK of the old and new generation fleets. The values of the old generation fleet are taken to calculate the projected emission without fleet renewal in the main article.

The incorporation rate of new generation aircraft in the fleet differs according to where the new aircraft are flying as seen in Figure S4.2. The rate is increasing between 2019 and end of 2023. In some routes, new generation aircraft reached 35% of the fleet whereas it was limited to 10% in others. A peak appears during the Covid-19 pandemic, since fewer flights took off, airlines could more easily use newer generation aircraft to save fuel.

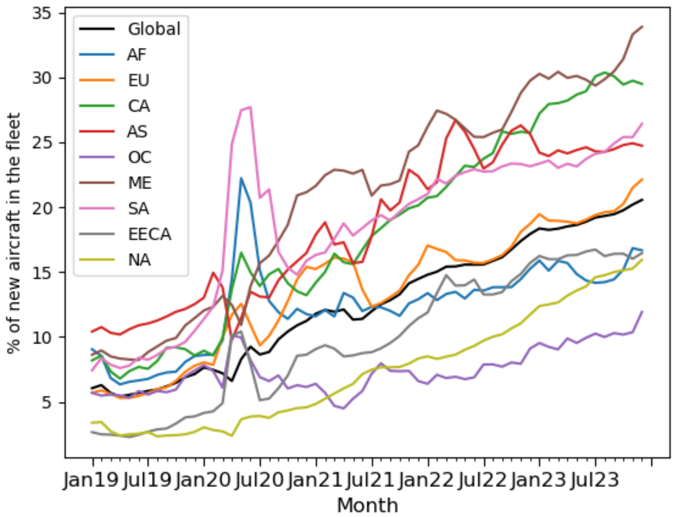

Figure S4.2. Percentage of new generation aircraft in the fleet for different routes for the period 2019–2023. The codes of the legend can be found in Figure 4 of the main article.

The evolution of the efficiency is closely linked to the addition or replacement of new generation aircraft in the fleet. In Figures S4.3, S4.4 and S4.5, it is seen that the tendency of the efficiency is decreasing in Europe, North America and Asia, but some variations can be noticed, especially in Europe. An annual cycle is also observed: European domestic flights are less efficient in winter than in summer due to the annual cycle of domestic flights, which are slightly shorter in winter than in summer. As previously demonstrated in Figure S4.1, very short-haul flights are less efficient than longer flights, resulting in higher fuel consumption. International flights also have an annual cycle but the effect is less pronounced.

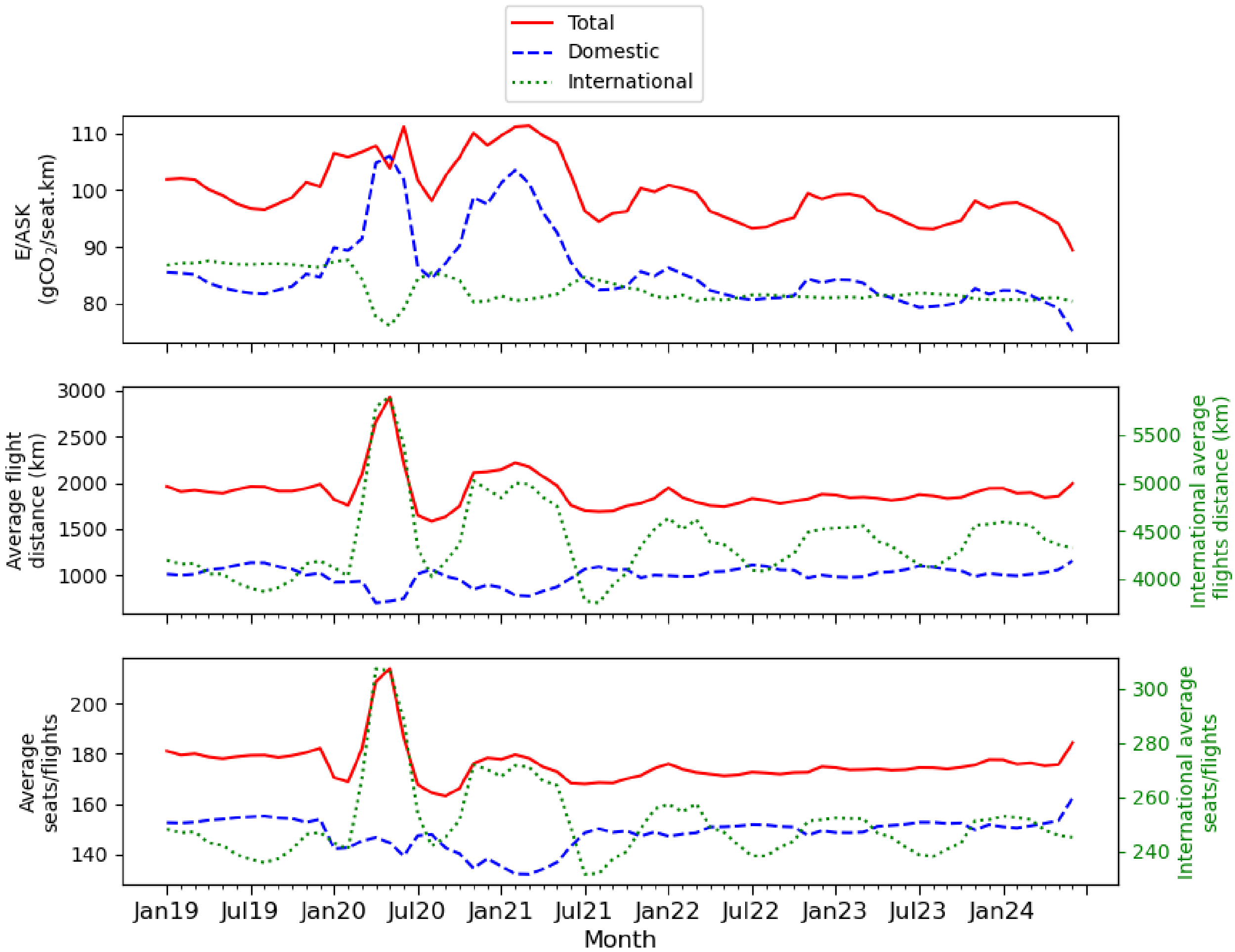

Figure S4.3. Evolution, from top to bottom, of the efficiency, the average flight distance and the average available seats per flight for Europe and for the period January 2019-June 2024. The secondary axis in green is for international flights only.

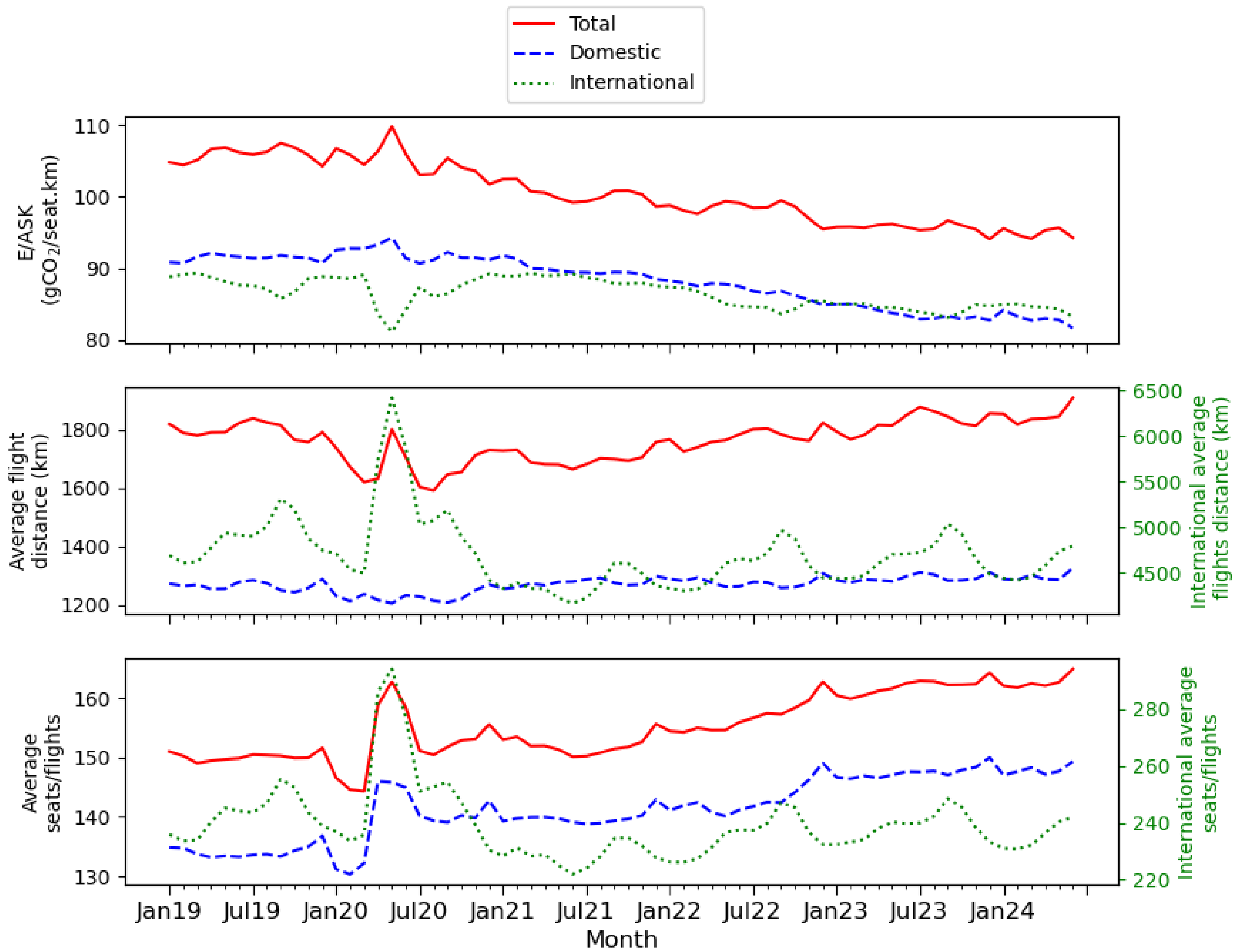

Figure S4.4. Same as Fig. S4.3 but for North America.

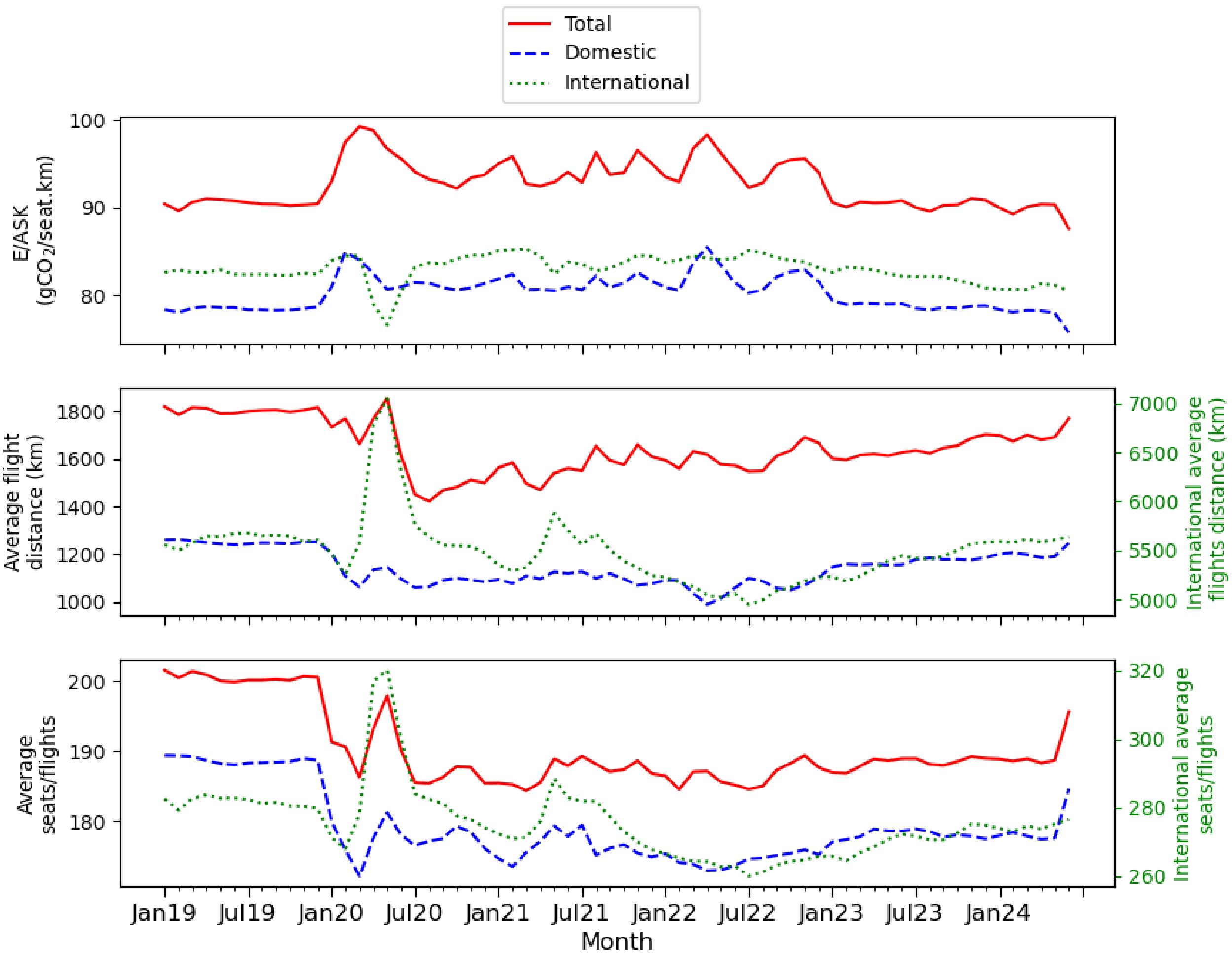

Figure S4.5. Same as Fig. S4.3 but for Asia.

S5. Proper ICAO aircraft code

Table S5.1. List of equipments in the FR24 database that needed to be renamed onto aircraft ICAO codes.

Code given by FR24	ICAO code assigned	Code given by FR24	ICAO code assigned
100	F100	73C	B733
146	B462	73E	B735
310	A310	73F	B737
318	A318	73G	B737
319	A319	73H	B738
31Y	A310	73J	B739
320	A320	73M	B732
321	A321	73N	B734
322	A321	73P	B737
32A	A320	73R	B738
32B	A321	73W	B737
32F	A320	73Y	B733
32N	A20N	743	B744
32Q	A321	744	B744
32S	A320	747	B744
32V	A320	74E	B744
32X	A321	74F	B748
330	A332	74H	B748
332	A332	74N	B748
333	A333	74Y	B744
33X	A332	752	B752
340	A342	753	B753
343	A343	757	B752
346	A346	75F	B752
350	A359	75T	B753
351	A35K	75W	B752
359	A359	762	B762
380	A388	763	B763
388	A388	764	B764
717	B712	767	B763
722	B722	76C	B763
727	B722	76E	B763
732	B732	76F	B763
733	B733	76G	B763
734	B734	76L	B763
735	B735	76P	B763
736	B736	76V	B763
737	B737	76W	B763
738	B738	76Y	B763
739	B739	772	B772

Code given by FR24	ICAO code assigned	Code given by FR24	ICAO code assigned
773	B773	BET	BE1
777	B773	C12	PC12
77F	B77L	CCX	GLEX
77L	B77L	CJ2	C550
77W	B77W	CJ8	C680
77X	B77L	CJL	C560
787	B788	CL3	CL30
788	B788	CN1	C120
789	B789	CN2	C210
78P	B789	CN7	C750
7M8	B38M	CNA	C402
7M9	B39M	CNF	C208
7S8	B738	CR1	CRJ1
A26	AN24	CR2	CRJ2
A35	A359	CR7	CRJ7
A4F	A124	CR9	CRJ9
A81	A148	CRJ	CRJ7
AB3	A306	CRK	CRJX
AB6	A306	CS1	BCS1
ABF	A30B	CS3	BCS3
ABY	A306	CV5	CVLT
AR1	RJ1H	D28	D228
AR8	RJ85	D38	D328
AT45	AT43	D40	DA40
AT46	AT43	D93	DC94
AT4	AT43	DC9	DC94
AT5	AT45	DH1	DH8A
AT7	AT72	DH2	DH8B
AT75	AT72	DH4	DH8D
AT76	AT72	DH8	DH8B
ATF	AT75	DHC	DHC4
ATR	AT43	DHT	DHC6
ATZ	AT43	DR20	DR22
B727	B722	E175	E170
B73M	B37M	E45	E145
B747	B744	E70	E170
B777	B772	E75	E170
B787	B788	E7W	E75S
BE2	BE65	E95	E195
BE9	BE20	EC5	EC35
BEH	B190	EM2	E120
BES	BE1	EM55	E55P

Code given by FR24	ICAO code assigned
EMB	E110
EMJ	E190
EP1	E50P
EP3	E55P
ER3	E135
ERJ	E145
F7X	FA7X
FRJ	J328
G36	GLF5
G6	GLEX
GJ4	GLF4
GR3	G280
H25	H25A
H25X	H25A
IL9	IL96
J300	J328
J31	JS32
J41	JS32
J532	JS32
LJ3	LJ31
LJ4	LJ40
LJ6	LJ60
LJ7	LJ70
M11	MD11
M1F	MD11
M80	MD81
M82	MD82
M83	MD83
M87	MD87
M88	MD88
MC10	MD11
MC21	MD11
PA28	P28A
S20	SB20
SF3	SF34
SH6	SH36
T20	T204
T214	T214
T45	T154

S6. Replaced ICAO code

Table S6.1. List of aircraft ICAO codes that have been replaced by equivalent aircraft available in Seymour et al. [5] in order to compute the fuel consumption according to the BADA [6] model.

Aircraft	Equivalent aircraft
A1	SW4
A178	E190
A19N	A20N
A338	A339
A358	A359
A743	A158
A748	F27
AN22	A339
AN72	F100
ARVA	C208
AT6T	C208
AT7	AT72
B23	E120
B25	AT43
B26	SF34
B37M	B38M
B701	B752
B720	B752
B721	B752
B731	T134
B778	B77W
B779	B77W
BE1	B190
BE10	F406
BE4W	BE40
BLCF	B77W
C119	F27
C141	A310
C15	T154
C17	B764
C212	JS32
C295	F27
C46	F27
C68A	C680
C919	A20N
CN35	AT43
DC3	F27
DC3S	F27
DC3T	F27
DC4	F27
DC91	B712
DC92	DC94
DC95	DC94
DHC4	F27
DHC5	SW4
E275	E75L
E295	B736
E737	B738
ER4	E145
F60	F50
G159	D328
G21T	BE20
G222	F27
G73T	C208
IL62	A30B
JS1	D228
JS20	D228
JS3	D228
L37	JS41
LANC	F27
M28	JS32
MA60	F27
MA6H	F27
MC23	A20N
MRJ7	A148
MRJ9	A148
MU30	BE40
N262	JS41
NIM	B738
P2	F27
P61	D328
R721	MD83
R722	B722
RJ70	RJ85
S2T	JS41
SC7	D228
TBM	JS32
U21	F406
V22	A140
VF14	YK40
Y12F	JS32
YS11	ATP

S7. Aircraft ICAO code for fuel consumption

Table S7.1. List of aircraft ICAO codes in the Seymour et al. [5] database that correspond to leisure aircraft and business jets. The other aircraft are all considered to be commercial aircraft.

Aircraft	Type
AN38	Leisure aircraft
BE40	Business jet
BE55	Leisure aircraft
BN2P	Leisure aircraft
C172	Leisure aircraft
C208	Leisure aircraft
C25A	Business jet
C310	Leisure aircraft
C680	Business jet
DHC2	Leisure aircraft
DHC3	Leisure aircraft
DOVE	Leisure aircraft
E55P	Business jet
F406	Leisure aircraft
GLF4	Business jet
GLF5	Business jet
L410	Leisure aircraft
P28B	Leisure aircraft
PA31	Leisure aircraft
PA46	Leisure aircraft
PC12	Leisure aircraft

Table S7.2. List of aircraft ICAO codes for which average coefficients have been used based on the classification in Table S7.1.

Aircraft	Type	Aircraft	Type	Aircraft	Type
A124	Commercial aircraft	C550	Business jet	FA10	Business jet
A225	Commercial aircraft	C551	Business jet	FA20	Business jet
A337	Commercial aircraft	C55B	Business jet	FA50	Business jet
A3ST	Commercial aircraft	C560	Business jet	FA5X	Business jet
A50	Commercial aircraft	C56X	Business jet	FA7X	Business jet
AC72	Commercial aircraft	C650	Business jet	FA8X	Business jet
AC80	Business jet	C700	Business jet	FGTH	Commercial aircraft
AN12	Commercial aircraft	C750	Business jet	G150	Business jet
AN70	Commercial aircraft	C82	Commercial aircraft	G250	Business jet
ASTR	Business jet	C97	Commercial aircraft	G280	Business jet
AT44	Commercial aircraft	CCJ	Business jet	GA5C	Business jet
AT45	Commercial aircraft	CL30	Business jet	GA6C	Business jet
AT46	Commercial aircraft	CL35	Business jet	GA7C	Business jet
AT73	Commercial aircraft	CL44	Commercial aircraft	GAC7	Business jet
AT75	Commercial aircraft	CL60	Business jet	GALX	Business jet
AT76	Commercial aircraft	CONI	Commercial aircraft	GL5T	Business jet
ATLA	Business jet	CVLP	Commercial aircraft	GL7T	Business jet
B350	Business jet	D28G	Commercial aircraft	GLEX	Business jet
B3XM	Commercial aircraft	DC10	Commercial aircraft	GLF2	Business jet
B703	Commercial aircraft	DC6	Commercial aircraft	GLF3	Business jet
B741	Commercial aircraft	DC7	Commercial aircraft	GLF6	Business jet
B742	Commercial aircraft	DC85	Commercial aircraft	GSPN	Business jet
B743	Commercial aircraft	DC86	Commercial aircraft	H25A	Business jet
B74D	Commercial aircraft	DC87	Commercial aircraft	H25B	Business jet
B74R	Commercial aircraft	DC93	Commercial aircraft	H25C	Business jet
B74S	Commercial aircraft	DH3	Commercial aircraft	HA4T	Business jet
BA11	Commercial aircraft	E2	Business jet	HF20	Business jet
BE12	Business jet	E290	Commercial aircraft	IL18	Commercial aircraft
BELF	Commercial aircraft	E35L	Business jet	IL86	Commercial aircraft
C123	Commercial aircraft	E390	Commercial aircraft	JCOM	Business jet
C125	Commercial aircraft	E45X	Commercial aircraft	L101	Commercial aircraft
C160	Commercial aircraft	E50P	Business jet	L188	Commercial aircraft
C25B	Business jet	E545	Business jet	L29A	Business jet
C25C	Business jet	E550	Business jet	L29B	Business jet
C500	Business jet	E6	Commercial aircraft	LJ23	Business jet
C501	Business jet	E90	Commercial aircraft	LJ24	Business jet
C510	Business jet	EVOT	Business jet	LJ25	Business jet
C525	Business jet	F2TH	Business jet	LJ28	Business jet
C526	Business jet	F900	Business jet	LJ31	Business jet

Aircraft	Type
LJ35	Business jet
LJ36	Business jet
LJ40	Business jet
LJ45	Business jet
LJ55	Business jet
LJ60	Business jet
LJ70	Business jet
LJ75	Business jet
LJ85	Business jet
MD11	Commercial aircraft
P180	Business jet
P1HH	Commercial aircraft
PA47	Business jet
PAY1	Business jet
PAY3	Business jet
PAY4	Business jet
PC24	Business jet
PRM1	Business jet
S210	Commercial aircraft
S601	Business jet
SBR1	Business jet
SBR2	Business jet
SJ30	Business jet
SK70	Business jet
STAR	Business jet
TRIN	Commercial aircraft
TU95	Commercial aircraft
V280	Business jet
VC10	Commercial aircraft
WW23	Business jet
WW24	Business jet

S8. Flow chart for aircraft identification

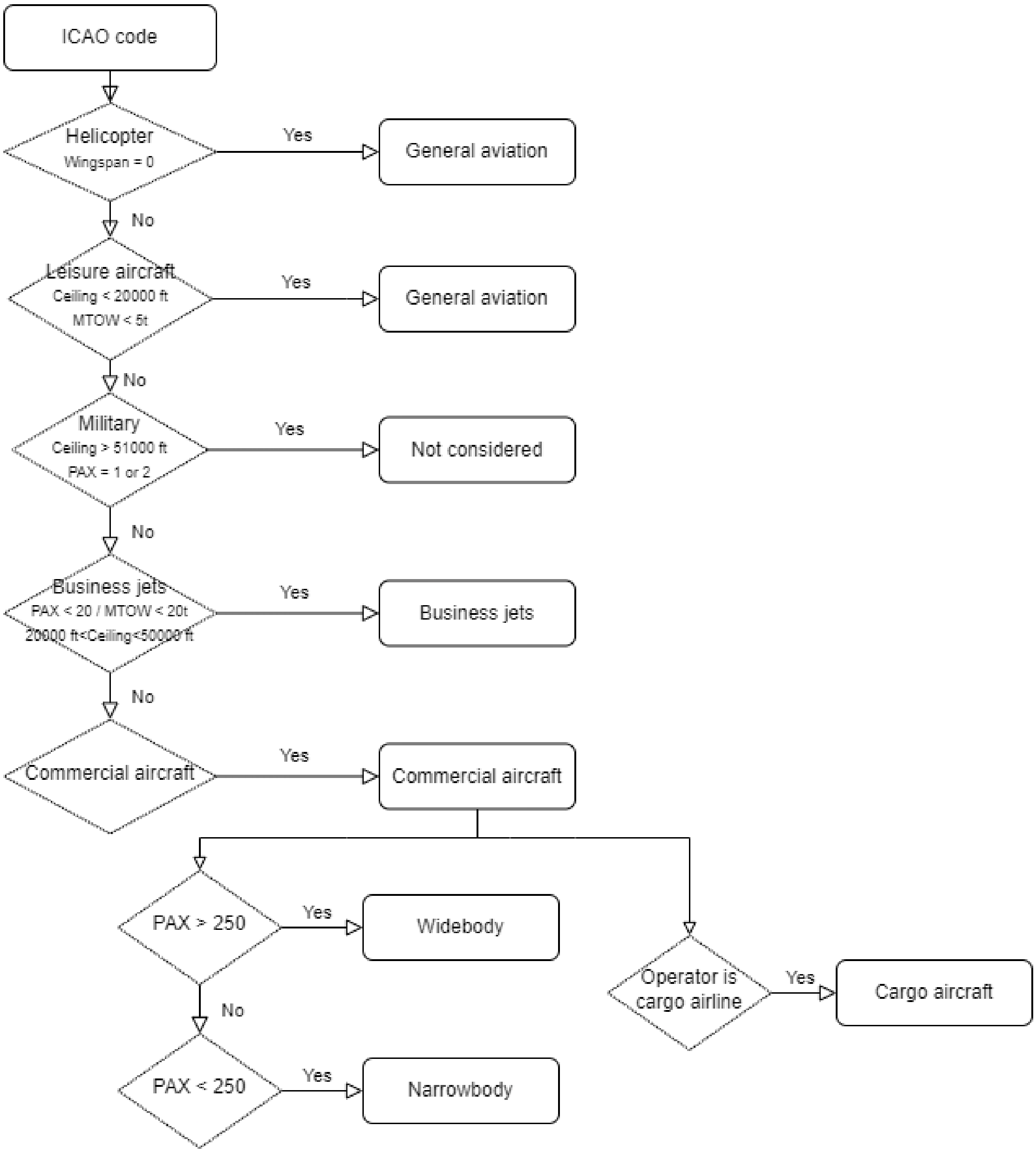

Figure S8.1. Flowchart for identifying the different aircraft categories.

S9. Flowchart for the computation of aircraft fuel consumption

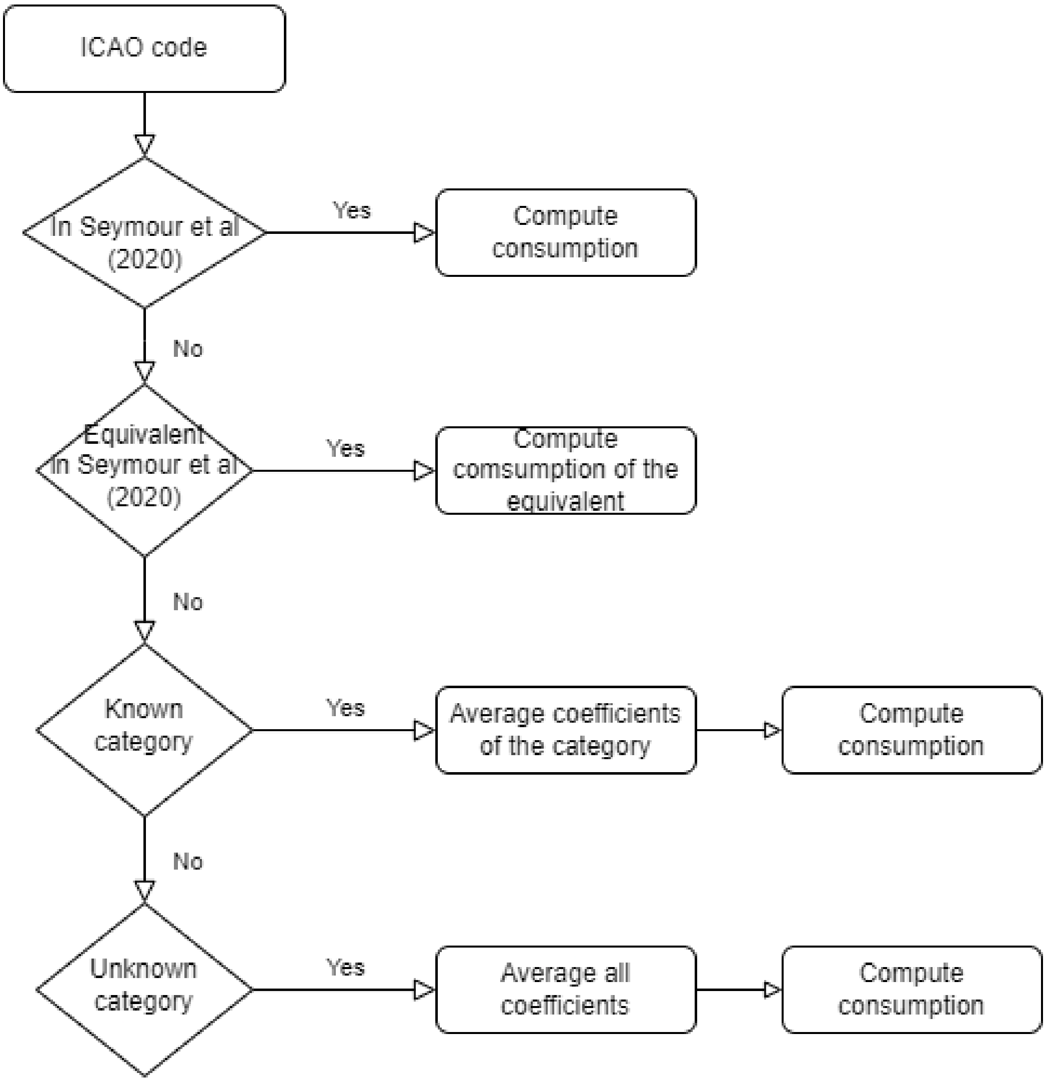

Figure S9.1. Flowchart for computing the fuel consumption of the different aircraft categories.

S10. Cargo airlines

Table S10.1. List of airlines categorized as pure cargo

ICAO airline	Name airline
AAH	Aloha Air Cargo
ABW	AirBridge Cargo
ACQ	Aryan Cargo Express
ACX	Air Cargo Germany
CCI	Capital Cargo International Airlines
CDC	CDI Cargo Airlines
CGP	Cargo Plus Aviation
CJT	Cargojet Airways
CKK	China Cargo Airlines
CLU	Cargo Logic Air
CLX	Cargolux
CRG	Cargoitalia
CWC	Centurion Air Cargo
DHL	Astar Air Cargo
DSR	DAS Air Cargo
FDX	FedEx Express
FSC	Four Star Aviation / Four Star Cargo
FYH	Flyhy Cargo Airlines
GCO	Gemini Air Cargo
GEC	Lufthansa Cargo
GGC	Cargo 360
HKC	Hong Kong Air Cargo
HVY	Heavylift Cargo Airlines
ICL	CAL Cargo Air Lines
ICV	Cargolux Italia
JAE	Jade Cargo International
JCI	Jordan International Air Cargo
JEC	Jett8 Airlines Cargo
KYE	Sky Lease Cargo
KZU	Kuzu Airlines Cargo
LCO	LATAM Cargo Chile
LYC	Lynden Air Cargo
MSA	Poste Air Cargo
MXC	Compania Mexicargo
NAC	Northern Air Cargo
NCA	Nippon Cargo Airlines
NCR	National Air Cargo dba National Airlines
PAC	Polar Air Cargo
PEC	Pacific East Asia Cargo Airlines
RLN	Lankan Cargo
SCL	Switfair Cargo
SNC	Air Cargo Carriers
SQC	Singapore Airlines Cargo
TCG	Thai Air Cargo
TUS	ABSA Cargo
UKS	Ukrainian Cargo Airways
UPS	United Parcel Service
VAS	ATRAN Cargo Airlines
XRC	Express Air Cargo
XRC	Express Air Cargo

S11. Fuel consumption model comparison

Table S11.1. Comparison of the fuel consumption between our study and other published models for the most used routes for the 5 most used aircraft for 7 selected distances. For the total differences (bottom row), each equipment and route has been weighted by the corresponding number of flights in FR24.

Equipment	Distance (km)	Number of flights	Consumption differences [(model - our study)/our study]		
			EEA [7]	FuelPlanner[8]	Quadros et al.[9]
A20N	586	38	-16,3%	20,6%	7,1%
A20N	1137	53	-7,1%	24,9%	2,6%
A20N	2808	7	-3,2%	25,2%	-2%
A20N	3159	8	-2,1%	24,7%	-4,7%
A21N	3856	10	7,7%	19,6%	-1,8%
A21N	4152	6	7,2%	19,1%	-2,1%
A319	641	21	-23,5%	2,3%	1,6%
A319	1177	12	-15,5%	8,6%	1%
A320	983	67	-19,4%	8,8%	2%
A320	1387	29	-16,6%	11,8%	2,3%
A320	2580	12	-14,5%	11,3%	-0,6%
A320	3186	8	-13,8%	9,8%	-1,6%
A321	1160	31	-23,8%	-8,6%	-5,1%
A321	2135	26	-21,2%	-7,9%	-6,6%
A332	4108	6	-3,8%	24,9%	9,9%
A333	5103	6	-16,4%	13,5%	-0,3%
A359	9625	5	-22,9%	-6,7%	-1,2%
B38M	2689	11	6,6%	25,6%	8%
B38M	3346	7	7,9%	25,1%	8,6%
B38M	4302	6	8%	24,1%	7,5%
B738	705	101	-25,9%	4,8%	1,9%
B738	1381	48	-19,7%	8,3%	-2,1%
B738	2231	21	-18,6%	8,8%	-4,8%
B738	3608	18	-17,2%	7,2%	-6,2%
B738	4809	9	-18,2%	5,1%	-7,4%
B77L	6189	5	-7,8%	16,9%	26,2%
B77L	10415	4	-12,4%	7,6%	20,6%
B77W	4941	5	6,7%	31,6%	24,4%
B77W	5540	11	6,7%	30,5%	23,5%
B77W	8760	8	3,7%	22,8%	18,8%
B788	6732	5	0,7%	15,6%	7,6%
B788	8031	6	-0,7%	13%	4,9%
B789	6732	6	8%	15,4%	20,5%
B789	8616	7	6%	11,9%	17,8%
Total			-9,3%	13,5%	7,9%

S12. Regions of the world used the study

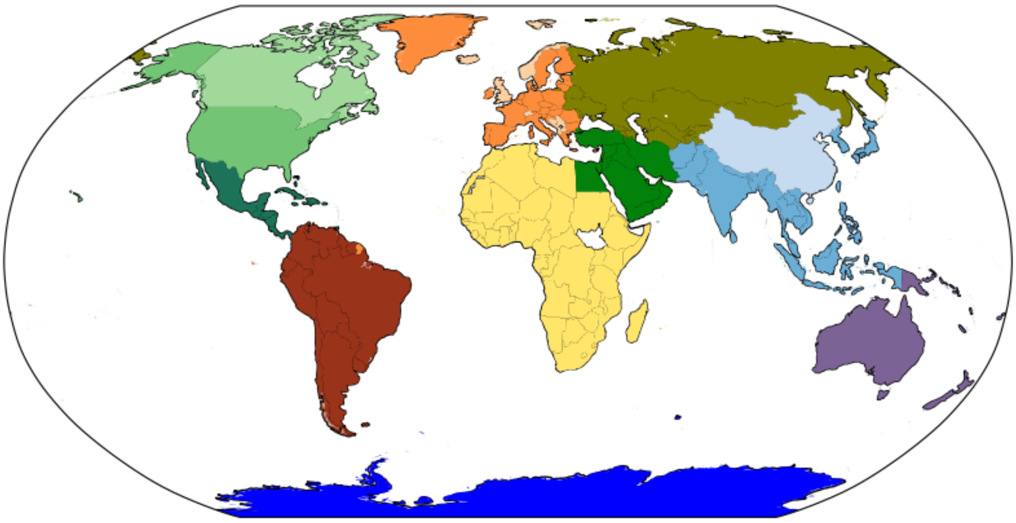

Figure S12.1. Visual representation of the regions used in the main analysis.

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