TRANSPORTATION
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Luxury Travel and Its Impact. An Analysis of Private Jet Flights to European Holiday Destinations.

Report for Greenpeace in Central and Eastern Europe

Imprint

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Contents

Key Findings

This study analyses private jet arrivals ('business aviation') at 45 European holiday destinations in the year 2023:

- Arrivals of private jets at most airports are concentrated during the summer vacation period, spanning from June 1, 2023 (calendar week 22) to September 30, 2023 (calendar week 39). 42.6% of all flights take place in this period, causing 41.6% of CO_2 emissions.
- Summer destinations (41 of the 45 airports) see 3.5 times more arrivals in July than in January. The seasonality of arrivals is similar to standard tourism.
- A total of 117,965 analysed flights caused 526,071 tonnes of CO_2.
- The energy-related CO_2 emissions of an average private jet flight to one of our analysed destinations (4.46 t CO_2) are almost as high as the annual energy-related CO_2 emissions of an average European Union citizen in 2023 (5.4 t CO_2).
- Private jets emit 2 to 9 times more CO_2 per seat than a typical commercial aircraft.
- 34.7% of all flights are short-haul flights of up to 500 km; 93.2% are intra-European.
- Nice, Geneva and Palma de Mallorca are the three most popular destinations.
- Business and leisure events can significantly influence private jet arrivals at nearby airports.
- These findings exclude jets used for special missions (e.g., medical, offshore, or police). However, some seasonality is observed in these operations due to higher tourist activity.

1) Introduction and Aim of the Study

This study analyses how private jet use varies over the course of a year and whether peaks are visible that can be due to holiday travel. It examines flight data to 45 airports in cities/regions that are well known as holiday destinations and that are promoted and offered as such by luxury tour operators and private jet companies.[1] Data from 2023 was chosen as it provides the most recent information and allows a comprehensive analysis of seasonal trends.

Aviation is a highly energy-intensive sector. In 2022, direct emissions from aviation accounted for 3.8% to 4% of total greenhouse gas (GHG) emissions in the European Union (EU). Aviation accounted for 13.9% of transport GHG emissions, making it the second largest source in the transport sector after road transport.[2]

GHG emissions from air travel in Europe are mostly caused by an affluent minority of people. The top percentile of emitters is responsible for 27% of emissions, exceeding annual per capita emissions of 55 t CO_2-equivalent (CO_2e, Ivanova & Wood 2020).

A recent study examines the distribution of flights over income and other social characteristics. Using data from surveys in the United Kingdom (UK), it finds that across all households in the UK, average air travel emissions per year are around 2.0 tonnes of CO_2e, but these figures are considerably higher for households that fly: "Households that have at least one flight per year have average air travel emissions of 4.6t CO_2e per year […]. Households with two or more flights per year have air travel emissions of 7.1t CO_2e per year" (Büchs & Mattioli 2022). According to the analysis, flight emissions are "very unequally distributed", because "the top 5% of flight GHG emitters are responsible for 40.2% of flight emissions and the top 10% for 60.8% of flight emissions, while the bottom 80% of flight GHG emitters only generate 16.1% of all flight emissions. […] They are also highly unequally distributed over income groups" (ibid.). Other studies confirm this analysis, demonstrating the statistical association between income and frequency of air travel, and patterns of inequality (Banister 2018, Gössling 2019, Schubert et al. 2020, Kim & Mokhtarian 2021).

A recent report has shown that private jet travel is seasonal, with a strong increase in the month of July (Transport & Environment 2021, 21ff). It has also been shown that luxury holiday destinations such as the Côte d'Azur, the Costa Smeralda, or Ibiza show seasonal increases in arrivals during the summer compared to the winter (ibid.).

A private jet is an aircraft designed for transporting small groups of people. It is associated with luxurious cabin design and service. In many cases, a private jet flight is an aviation operation where the aircraft owner or acquaintances use the aircraft for personal or non-commercial purposes. Transport services provided may not involve monetary exchange.[3]

An estimation of fuel consumption undertaken by Gössling & Humpe (2020) suggests that private aviation (as opposed to commercial and military aviation) accounts for about 4% of global emissions from aviation. Private aviation is noted as increasing (Gössling & Dolnicar 2023). Private jets are part of the transport portfolio of the wealthy (Gössling & Humpe 2020, Transport & Environment

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[1] See airports advertised at GlobeAir, LunaJets, Aeroaffairs, PrivateFly, and NetJets.

[2] See website European Commission.

[3] See website Globeair.

2021). This report therefore also calculates resulting CO_2 emissions of the private jet flights to the 45 selected European holiday destinations. In doing so, it highlights the climate impact of these trips, which are supposedly holiday trips undertaken by affluent persons.

Research questions

How many private jets flew to 45 European holiday destinations in the year 2023?

How does the number of arrivals vary throughout the year (considering seasonality)?

What is the total amount of CO_2 emissions generated from these flights?

2) Material and Methods

This chapter defines the research subject, describes the data and demonstrates its analysis. The aim is a) to define private jets and how they are operated and used; and b) to find existing data that matches with these definitions.

Definition and usage of private jets

The International Civil Aviation Organization (ICAO) defines three kinds of operations, namely 'commercial air transport', 'aerial work', and 'general aviation'. Commercial air transport operation is defined as an aircraft operation by airlines involving the transport of passengers, cargo or mail for remuneration or hire. In aerial work, an aircraft is used for specialised services such as agriculture, photography, surveying, search and rescue, etc. General aviation (GA) includes all other civil flights, private or commercial.[4]

The International Business Aviation Council (IBAC) defines 'business aviation' as a sector of aviation “which concerns the operation or use of aircraft by companies for the carriage of passengers or goods as an aid to the conduct of their business, flown for purposes generally considered not for public hire […]”.

Thus, business aviation may be both commercial and non-commercial. In addition, the main difference with commercial air transport is that it is generally not considered to be public hire.[5]

According to IBAC, there are four sub-categories of business aviation:[5] [same footnote]

1. Commercial: The commercial operation or use of aircraft by companies for the carriage of passenger or goods as an aid to the conduct of their business and the availability of the aircraft for whole aircraft charter.
2. Corporate: The non-commercial operation or use of aircraft by a company for the carriage of passengers or goods as an aid to the conduct of company business.
3. Owner Operated: The non-commercial operation or use of aircraft by an individual for the carriage of passengers or goods as an aid to the conduct of his/her business.
4. Fractional Ownership: The operation or use of aircraft operated by an entity for a group of owners who jointly hold minimum shares of aircraft operated by the entity. Fractional Ownership operations are normally non-commercial; however, the operation of the aircraft may be undertaken as a commercial operation to perform specific operations.

At this point, it is important to distinguish between non-commercial aviation and private jets.

Private jets are advertised by certain operators as being private, meaning that they are not made available to the broad public (see below). Private jets can be operated *commercially* by being chartered on a per-flight basis (bullet point 1 above). They can also be operated *non-commercially*. In this latter case, they are owned outright by companies (2) or individuals (3) or shared through fractional ownership programmes (4).

[4] See Wikipedia.

[5] See IBAC.

Regarding the usage of private jets, companies offering chartering services or ownership usually advertise:

- Size and capacity: Private jets range in size from small, light jets that can carry 4-8 passengers to larger, long-range jets that can accommodate 10-18 passengers or more. Benefits of different plane types are explained.[6]
- Luxury and customisation: Private jets often feature luxurious interiors, including plush seating, state-of-the-art entertainment systems, and in some cases, private bedrooms and showers. The cabin layout and amenities can be customised to meet the specific needs and preferences of the owner or charterer.

Private jets are used for a variety of trip purposes, reflecting the flexibility, privacy, and efficiency they offer from the users' perspectives. Operators usually advertise their fleets for holiday use, e.g. by advertising empty legs as suitable for short notice leisure trips.[7] Based on own research, main purposes can be grouped as follows:

- Business travel
- Leisure travel
- Medical and emergency services
- Government and diplomatic travel

Acquisition of data

This report uses flight data about flights to 45 airports in the year 2023. The selection of these airports is based on a general analysis of European holiday destinations, and on literature and desk research about holiday destinations of private jets.

The data provider is a flight analytics company, which gathers flight tracking control data. The company provides the data on condition that it remains anonymous. For data quality assurance and curation, we double-check the data with another source, namely OpenSky. The OpenSky Network is a non-profit organisation based in Switzerland that provides open access to air traffic data. More information about the data quality assurance can be found in the section on data quality (page 11).

The main source for this data is transponder signals. Transponders transmit information and respond to inquiry from air traffic control radar sites. They enable aircraft to receive signals from air traffic control and respond automatically with the aircraft's identification code. Transponders also make an aircraft visible on radar. In addition to travel analytics, the data provider uses airline fleet data, aircraft values, flight information and airline schedules.

The data provider pre-filtered the empirical flight data as follows:

- All tracked unscheduled or IATA service types C (charter passenger only), D (general aviation), G (non-scheduled passenger normal service), and N (business aviation) flights
- Departing from, or arriving at, a specified list of 45 airports (see table 2 on page 10)
- Flights departing between UTC dates 2023-01-01 and 2023-12-31

In sum, we purchased information about 434,358 flights.

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[6] For instance, Aeroaffairs lists the "10 most attractive private jets".

[7] For instance, see VistaJet.

Filter criteria applied to detect private jets

The aim of the filter criteria is to isolate private jets. We aim to exclude not only standard tourism, but also military aviation, and jets which are equipped for special work purposes. The dataset includes three relevant attributes related to private jets and the IBAC definition of business aviation, called 1) 'Aircraft market sector', 2) 'Primary usage', and 3) 'Aircraft operator organization type'.

The dataset includes all unscheduled flights to and from the selected airports. This includes commercial air transport (i.e., chartered flights for standard tourism). In the data, such planes can be found under 'aircraft market sector' -> 'commercial'. Under 'primary usage' and 'operator type', the dataset distinguishes further types.

Table 1 shows the applied filters. In the first step, we excluded departures from the selected airports.

Table 1: Filters applied in the dataset, remaining flights

Attribute	Included	Excluded	Remaining
0) Airport	Arrival airport one of 45	Arrival at other airports *(i.e., departures)*	n=246,950
1) Aircraft market sector	Business General aviation Helicopters	Commercial *(standard tourism)*[8] Military fixed-wing Utility transport	n= 143,925
2) Primary usage	Business - air taxi/air charter Passenger *(commercial)* Business - private company use Private use *(non-commercial)*	Air ambulance, emergency Demonstrator, experimental, R&D Firefighting, water-bomber, chemspray Freight, cargo Government, head of state Police, law enforcement, patrol Military *(all kinds)* Search & rescue coast guard Sightseeing/tourist Skydiving/parachuting Training Works *(all kinds)*	n= 121,335
3) Aircraft op. organization type	*(no additional inclusion criteria as compared to 1 and 2)*	Regulators, assoc. & alliances *(further exclusion criteria)*[9]	n= 117,965

Source: own analysis

As shown in Table 1, the attribute 'Aircraft operator organization type' provides relevant information, but is in most cases an unnecessary filter criterion. For example, the organisation type of 'Police support' oftentimes is 'Government'. 'Police support' is already excluded under 'Primary

[8] In 1,434 cases, the combination is 'Commercial' -> 'Business - air taxi/air charter' or 'Commercial' -> 'Business - private company use'. These two combinations mainly include private jets but may also include some standard tourism flights. We decided to include these flights (average of total seat count: 64.4; median of total seat count: 39).

[9] In 3,233 cases, the arrival airport is the same as the departure airport. We decide to exclude those flights from the analysis. This reduces the data set from 121,198 flights after the application of the filter to 117,965 flights.

usage', so 'Government' is excluded in this case anyhow. In sum, the filters exclude a) standard tourism, b) cargo/freight, and c) special purpose flights such as military, emergency and aerial works.

We also exclude flights that take off and land at the same airport. The rationale is that we focus on flights to holiday destinations and not flights at holiday destinations. For example, parachuting is a leisure activity which is highly carbon-intensive and also highly seasonal. However, it is not at the focus of the research.

The dataset also includes flights with missing information. In many of these cases, the attributes listed in Table 1 are not available. In most of these cases, further information is missing, namely aircraft types and aircraft manager organisations. In some other cases, the departure airport is missing. The filters exclude these flights. The number of excluded flights is 316,393.

The application of all filters reduces the total number of flights we account for down to a final number of 117,965 flights.[10]

Importantly, this includes both commercial and non-commercial business aviation. As mentioned above, business aviation can be non-commercial when private jets are owned by individuals, companies or fractional ownership programmes.

Seasonality of excluded flights

The filter criteria listed in Table 1 aim to ensure the exclusion of flights with special purpose. However, the dataset does not allow a clear distinction to be made between holiday and work trips. The aim of this study is to analyse seasonality of private jet trips that are often referred to as 'business aviation', but may be used by affluent persons for holiday trips.

A comparison of the seasonality of included private jet flights with excluded flights adds relevant context to the analysis. For example, it can be expected that commercial air transport (i.e., standard tourism) is highly seasonal, but military flights could be evenly spread over the year. In Chapter 3, we provide an analysis and comparison of the studied sample of filtered flights. The similarities and differences in the seasonality are discussed.

Selected airports

Table 2 lists the 45 selected airports. Figure 1 on page 11 shows these airport locations on a map.

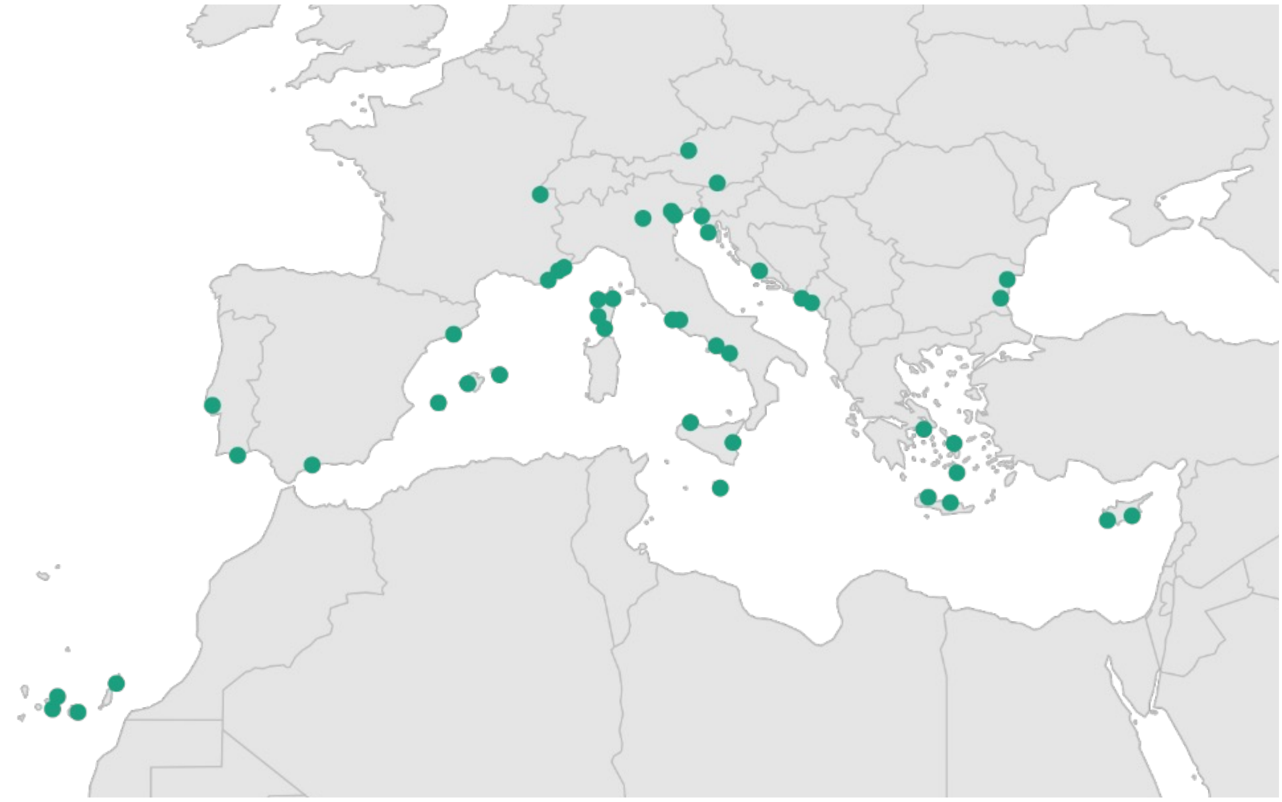
[10] The data is very detailed, but the filtering system cannot guarantee the exact distinction of each flight between business aviation, special mission business aviation and commercial air transport. Therefore, we test several filtering options that all produce similar results in terms of seasonality. The analysis remains robust due to the high sample size.

Table 2: List of airports

Abbreviation	Name	Country
AJA	Ajaccio Napoleon Bonaparte Airport	France
BCN	Barcelona-El Prat Airport	Spain
BIA	Bastia Poretta Airport	France
BOJ	Bourgas Airport	Bulgaria
CTA	Catania-Fontanarossa Airport	Italy
CHQ	Chania International Airport	Greece
CIA	Ciampino-G. B. Pastine International Airport	Italy (Rome)
NCE	Côte d'Azur Airport	France (Nice)
DBV	Dubrovnik Airport	Croatia
ATH	Eleftherios Venizelos International Airport	Greece (Athens)
PMO	Falcone-Borsellino Airport	Italy (Palermo)
FAO	Faro Airport	Portugal
GVA	Geneve Airport	Switzerland
LPA	Gran Canaria Airport	Spain
HER	Heraklion Airport	Greece
LIS	Humberto Delgado Airport	Portugal (Lisbon)
IBZ	Ibiza Airport	Spain
KLU	Klagenfurt Airport	Austria
LTT	La Mole Airport	France (Saint Tropez)
ACE	Lanzarote Airport	Spain
LCA	Larnaca International Airport	Cyprus
FCO	Leonardo da Vinci-Fiumicino Airport	Italy (Rome)
AGP	Malaga Airport	Spain
MLA	Malta International Airport	Malta
CEQ	Mandelieu Airport	France (Cannes)
MAH	Menorca Airport	Spain
JMK	Mykonos Airport	Greece (Cyclades)
NAP	Naples International Airport	Italy
PMI	Palma de Mallorca Airport	Spain
PFO	Paphos International Airport	Cyprus
POW	Portoroz Airport	Slovenia
PUY	Pula Airport	Croatia
CLY	Sainte Catherine Airport	France (Calvi)
QSR	Salerno Costa d'Amalfi Airport	Italy
JTR	Santorini International Airport	Greece (Cyclades)
SPU	Split Airport, Croatia	Croatia
FSC	Sud Corse Airport	France
TFN	Tenerife North Airport	Spain
TFS	Tenerife South Airport	Spain
TIV	Tivat Airport	Montenegro
TSF	Treviso Airport	Italy
VAR	Varna Airport	Bulgaria
VCE	Venice Marco Polo Airport	Italy
VRN	Verona Villafranca Airport	Italy
SZG	W. A. Mozart Salzburg Airport	Austria

Source: own compilation

Figure 1: Location of 45 airports in Europe selected for the analysis. Source: own map



Calculation of carbon dioxide emissions

Carbon dioxide (CO_2) emissions are calculated from the Eurocontrol's Small Emitters Tool (Eurocontrol SET). Other GHG emissions are not taken into account. We use the latest version at the time of writing, from 2023. The Eurocontrol SET estimates the fuel burn and associated CO_2 emissions for an entire flight considering the characteristics of the air traffic covered by the EU emissions trading scheme. According to Eurocontrol, it provides very accurate estimated total fuel and associated CO_2 emissions for a list of flights characterised by aircraft type and flown distance, by using the averaging principle.

Quality of the data

We receive the data on the condition that the data provider is not disclosed. We purchased this data because of its high quality: To our knowledge, the attributes 1), 2) and 3) of Table 1 cannot be obtained open access, but this information is crucial to answer our research question. We double-check the obtained information with the OpenSky Network data to verify the quality.

We systematically search the OpenSky data for the 15 most important routes in our filtered sample (as shown in Table 3, page 17). We also systematically search for the ten most important aircraft types in our filtered sample (as shown in Table 5, page 21). The result in short: All flights as tracked from OpenSky can be found in our dataset. OpenSky's number of detected flights is lower. Details are documented in Annex B (page 28).

We also double-check the flight distances as specified by the data provider by calculating the spherical (great circle) distances between two airports. The resulting numbers match exactly.

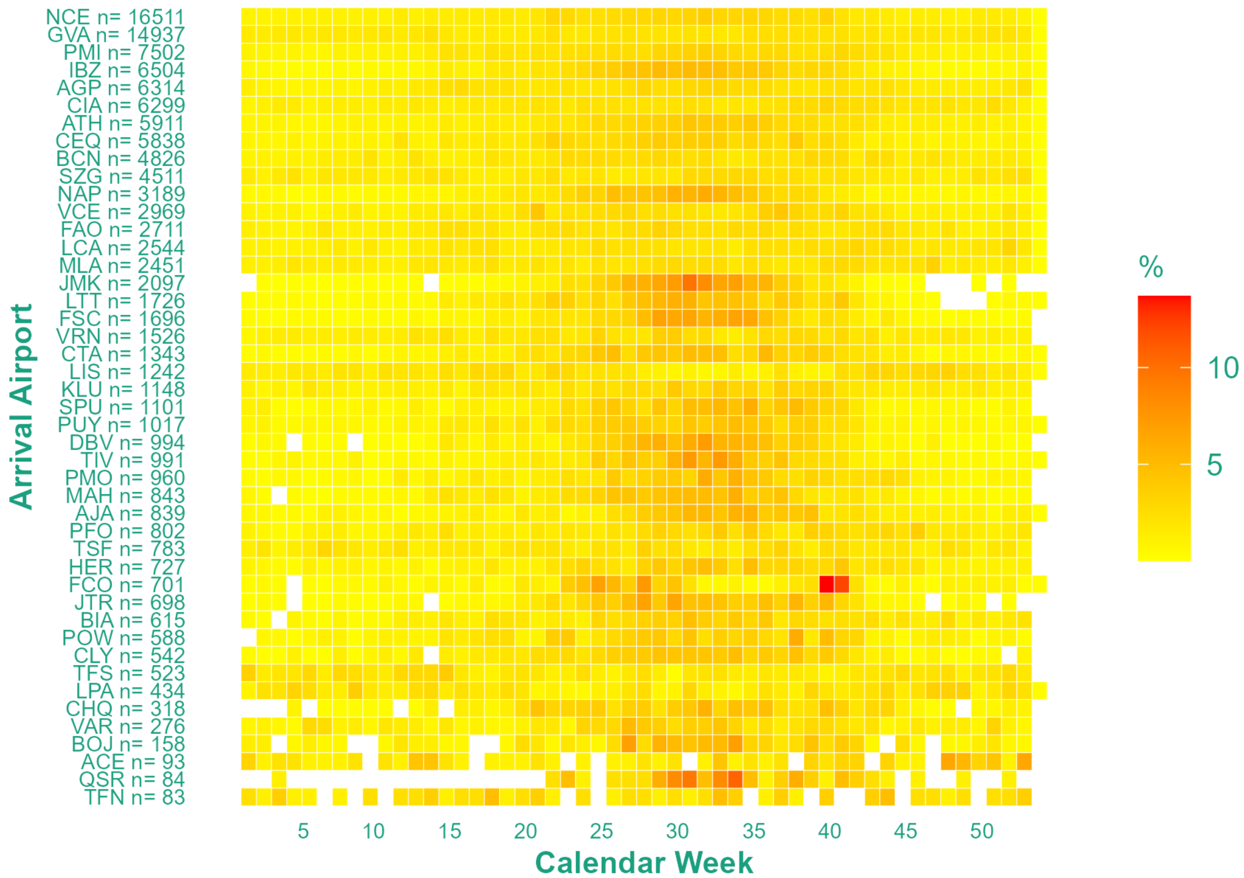
3) RESULTS

Airports with the most flights & seasonality

Figure 2 shows the number of arrivals per airport and the share of arrivals per calendar week in 2023.

The number of arrivals per airport is listed on the figure's left-hand side, there is one row per airport in descending order. Out of the 45 airports, Nice Côte d'Azur (NCE), Geneva (GVA) and Palma de Mallorca (PMI) are the three most frequented. The share of arrivals is presented as a heat map, with a colour coding from white to red representing 0% to 15% share of arrivals during a calendar week in the whole year 2023. The actual values range from 0% to 14.3%.

Figure 2: Number of private jet arrivals at 45 European airports, distribution over the year 2023. Source: own analysis



There is a clear focus of arrivals during the summer vacation time at most airports, starting 1st June 2023 (calendar week 22) and ending 30th September 2023 (calendar week 39). Most airports are located in the Mediterranean Region with its high tourist season in summer. The arrivals at the three airports on Malta and Cyprus (Malta, MLA, 15th, Larnaca, LCA, 14th, Paphos, PFO, 30th) show arrival peaks during autumn. This could indicate more work-related trips, but September and October are also popular tourist periods in Malta and Cyprus, which are the southernmost islands in the Mediterranean.

The three northernmost airports in our sample are located in the Alpine Region. These airports tend to have more arrivals during winter, spring and autumn, namely Geneva (GVA, 2nd row), Salzburg

(SZG, 10th), and Klagenfurt (KLU, 22nd). However, their main season still appears to be the summer (see also Figure 3 below). On average, the number of (selected) private jet arrivals in July 2023 is 3.5 times higher than in January 2023 for all 41 airports located in regions with a high season in summer.

The picture changes for the Canary Islands, namely the four airports of Tenerife South (TFS, 38th), Canary Island (LPA, 39th), Lancarote (ACE, 43th) and Tenerife North (TFN, 45th). All four airports have arrival peaks from autumn to spring. This reflects mild temperatures on these islands during colder periods in Central Europe.

Figure 3 below compares the climate impact of the summer holiday season defined as a period from 1 June to 30 September 2023 ('season') with the rest of the year ('offseason'). It does so by calculating the CO_2 emissions shares from flights that arrived during the summer season and during the rest of the year at each of the 45 airports. For each airport, the overall share is 100%. The shares are adjusted to take account of the shorter summer holiday period (four months) compared with the longer non-summer season (eight months). That is, if the grey bar is longer than the corresponding green bar (and the percentage higher), then private jets landing at the airport in question cause more CO_2 emissions during the four summer months than during the same period in the non-summer season.

Figure 3: Comparison between CO_2 emissions resulting from arrivals in the time span 1 June to 30 September (season) and the rest of the year 2023 (4 months summer season ≙ 4 months non-summer season). Source: own analysis

The CO_2 emissions caused by flights to the four airports in the Canary Islands are higher in the non-summer season, as shown by the following percentages: TFS (56%), LPA (58%), ACE (59%), TFN (50%). For flights to an airport located in a region with a high summer tourist season (the Mediterranean), the summer period's CO_2 emissions shares are significantly higher than the shares of the off season. Lisbon (LIS) is the only exemption with a CO_2 share of the summer season below

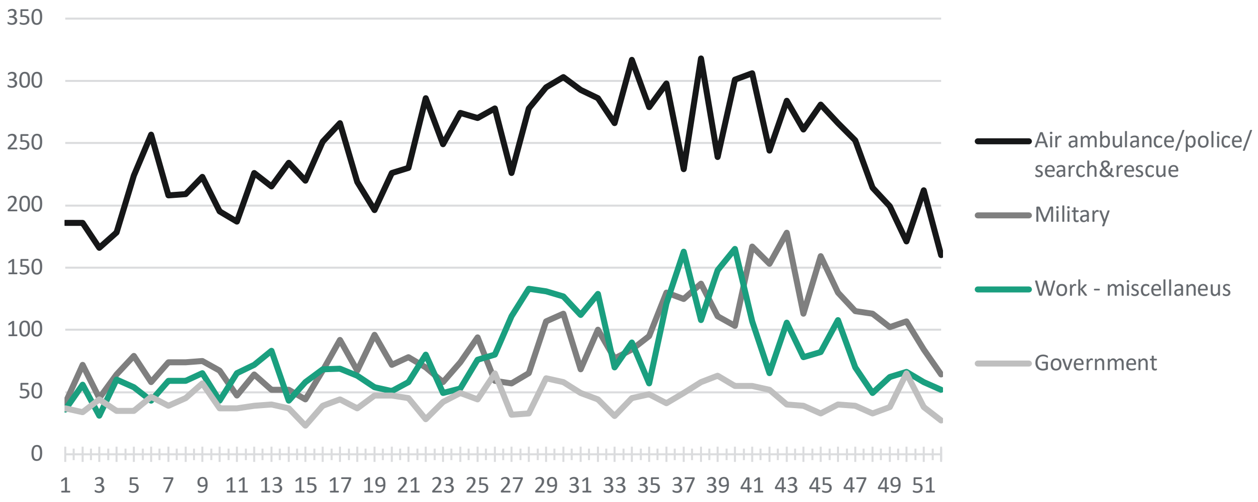
50%, namely 38%. This indicates a more significant influence of work-related private jet trips to Lisbon in our filtered sample. Another airport with a relatively low share of CO_2 emissions during the summer season is Rome Ciampino (CIA, 57%). The third airport in our filtered sample that is serving a national capital, Athens (ATH), shows significant seasonality (72%).

In total, 50,228 out of 117,965 flights arrive between 1 June and 30 September (42.6%). These flights cause 218,635 t CO_2 emissions of the filtered sample (41.6%, compare Table 4 on page 20).

Frequency of flights with special purpose

As explained in Chapter 2, we filter private jets to exclude flights with special purpose (military and special work tasks). However, it is worth looking at the frequency of these flights over the course of the year in order to examine seasonal trends. Figure 4 provides an overview of flights with aircraft used in our dataset for four different special work tasks. The graph lists arrivals grouped by calendar week in 2023. The four airports in the Canary Islands are excluded so as not to distort a potential seasonal pattern.

Figure 4: Arrivals at 41 European airports of business jets with selected primary usage, distribution over the year 2023; n=23,563. Source: own analysis[11]



The graph of 'Air ambulance/police/search&rescue' shows some seasonality, with peaks in the period 24 July to 15 October 2023 (weeks 30 to 41). The summer tourist season should have an impact, as more people in a region may require more such operations. In contrast, the two graphs for 'Military flights' and 'Work - miscellaneus' tend to peak in the (late) autumn, which is unlikely to be related to the high tourist season. Finally, there appears to be no obvious seasonality in government flights.

In sum, a number of special aerial works show a course which is related to the touristic season. Some other special work aircraft have little to do with summer holiday flying.

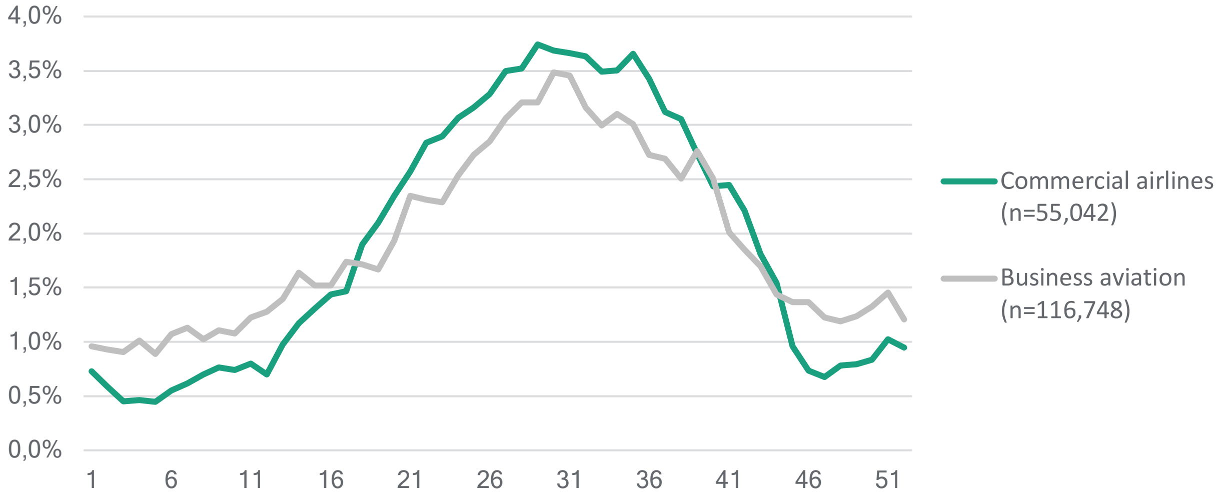
[11] 'Work – miscellaneous' includes: 'Trainer / Training School Aircraft', 'Target Towing', 'Off-Shore / Oil & Gas Support', 'Surveying / Mapping & Power/Pipeline Inspection', 'Navaid / Calibrator / Flight Inspection'.

Comparison of standard tourism with business aviation

The filters separate standard tourism from business aviation. However, seasonality of holiday destinations can be best described by seasonality of chartered aircraft for standard tourism. Therefore, the following two Figures 5 and 6 compare standard tourism (commercial airlines) with business aviation.

Figure 5 counts arrivals at all selected airports except the four airports of the Canary Islands. Seasonality is illustrated by calculating arrivals per calendar week 1-52. Each week makes up a certain share of all arrivals. That is, the weeks' shares add up to 100% of arrivals in 2023. The Canary Islands are left out to account for a different seasonality. Week 53 is a fraction and omitted as well.

Figure 5: Seasonality of arrivals at 41 selected airports (share of months in 2023), comparison of commercial air transport (chartered flights for standard tourism) with business aviation. Source: own analysis



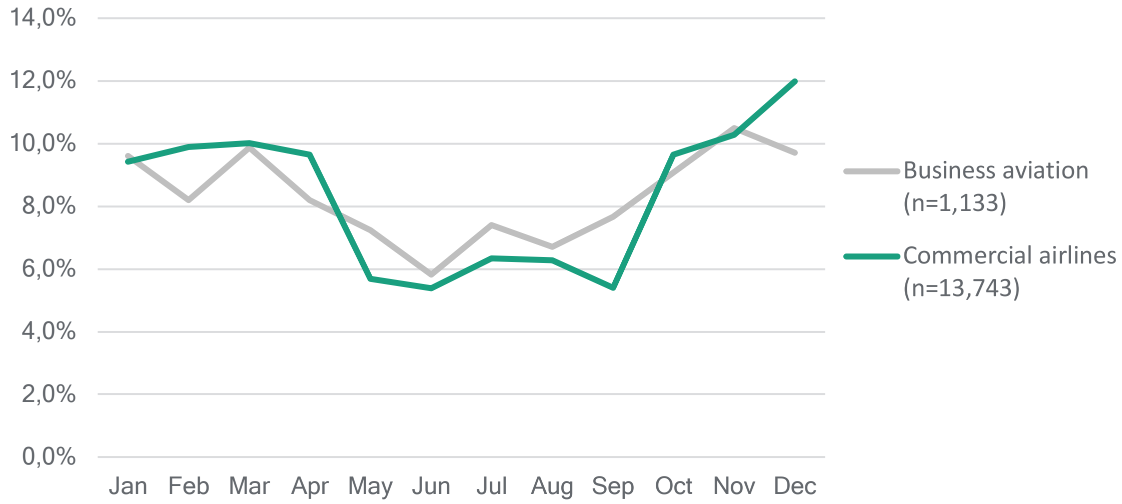
The shares of commercial airlines and business aviation in each calendar week in 2023 are very similar. (R^2=.9544, p-value<.001). Thus, the seasonality of business aviation fits very well with the seasonality of standard tourism, respectively: 95% of the arrivals at the 41 analysed airports can be explained by seasonality of standard tourism.

Importantly, we cannot conclude that 95% of all selected private jet flights are holiday trips. The share of arrivals of business aviation during the low season is slightly higher; and it is slightly lower during the high season. This could indicate that the higher share of arrivals during the low season is a consequence of more work-related trips to the 41 holiday destinations. From Lisbon it is known that private jets arrive anti-seasonal (see Figures 2 and 3). But the city is an exception, as it is the only city with anti-seasonal arrivals of private jets at its airport. Geneva is an important destination for affluent persons, at the same time the city is an attractive winter-season holiday destination. This could indicate that persons travelling by private jet spend more holiday during the low season.

However, the analyses indicate that holiday travel is the most important reason for flying by these private jets. We compare business aviation with chartered, unscheduled commercial aircraft, which is pure tourism, and the two curves in Figure 5 are very similar. They are similar because of their high sample size. If we carry out an analysis for private jets flying to individual destination airports (see Figure 2) and individual destination countries, we find even more pronounced seasonality. The curves of chartered commercial airlines are less pronounced (and arrivals less represented at certain destinations). The curves of the two different markets are aligning with increasing sample size and by adding the arrivals at different airports. Therefore, we assume pure tourism in our filtered sample of private jet flights for many airports.

The seasonality of business aviation is also very similar to that of standard tourism when it comes to the Canary Islands. Figure 6 depicts this similarity. In this Figure 6, the seasonality is illustrated by calculating arrivals as a monthly share of the year 2023 for both aircraft market sectors. The analysis is based on months rather than weeks to account for the small number of private jet flights to these airports (n=1,133).[12]

Figure 6: Seasonality of arrivals at 4 airports in Canary Islands (share of months in 2023), comparison of commercial air transport (chartered flights for standard tourism) with business aviation. Source: own analysis



The role of the aircraft's size

Private jet services provide jets for flying holidays, which tend to be small, light jets with few seats. Private jet services highlight on their websites that bigger aircraft with more than 20 seats are mainly used by business travel groups.[13] In our filtered sample, 1,692 flights are operated by aircraft known to be equipped with more than 20 seats. We analyse seasonality of these flights, and it turns out that arrivals of these aircraft show a typical seasonality.[14] The main difference to aircraft with up to 20 seats is the average flight distance, which is longer.

[12] The coefficient of determination (R^2) in this case is as high as .7250 (p-value: .00044). A disaggregation into calendar weeks leads to R^2=.3458 (p-value: .000005).

[13] See Aeroaffaires.

[14] Some of these flights may be standard tourism, as in some cases it is not possible to distinguish exactly between business aviation and standard tourism on the basis of the information we receive.

Main routes

Table 3 lists the 15 most important routes out of all flights that arrived at one of the 45 airports in the year 2023. The total distance covered by all flights in 2023 per route serves as criterion of importance. The table shows that the main origins are global and/or capital cities. Obviously, the globalised European major cities are well connected with the French Riviera and other typical European holiday regions by private jets. Private jets also fly to Nice from hubs outside Europe.[15]

Table 3: Top 15 flight routes of filtered sample (n=117,965)

	Origin	Destination	Total distance covered	Total CO_2 emissions	Number of flights	Avg. CO_2 per flight
#1	Farnborough (London)	Cote d'Azur (Nice)	786,324 km	3,851.5 t	759	5.07 t
#2	Le Bourget (Paris)	Cote d'Azur (Nice)	758,542 km	3,705.2 t	1,093	3.39 t
#3	Le Bourget (Paris)	Geneve	582,200 km	2,891.1 t	1,420	2.04 t
#4	London Luton	Cote d'Azur (Nice)	537,000 km	2,697.9 t	500	5.40 t
#5	Teterboro (New York)	Cote d'Azur (Nice)	493,878 km	2,571.6 t	77	33.40 t
#6	Biggin Hill (London)	Cote d'Azur (Nice)	405,216 km	1,530.3 t	402	3.81 t
#7	Farnborough (London)	Eleftherios Venizelos (Athens)	389,760 km	1,835.1 t	160	11.47 t
#8	Milano Linate	Ciampino-G. B. Pastine (Rome)	372,068 km	2,232.2 t	764	2.92 t
#9	Farnborough (London)	Geneve	364,936 km	1,887.3 t	484	3.90 t
#10	Farnborough (London)	Malaga	328,350 km	1,381.3 t	199	6.94 t
#11	Dubai Al Maktoum	Cote d'Azur (Nice)	301,959 km	1,776.2 t	63	28.19 t
#12	Amsterdam Schiphol	Ibiza	300,168 km	986.5 t	198	4.98 t
#13	Hamburg	Palma de Mallorca	293,820 km	730.1 t	177	4.13 t
#14	Le Bourget (Paris)	Ibiza	279,000 km	953.9 t	248	3.85 t
#15	King Khalid (Riyadh)	Geneve	270,774 km	1,903.2 t	63	30.21 t

Source: own analysis

Based on our comparison of business aviation with standard tourism it is plausible to assume that trips to a holiday island such as from Hamburg to Palma de Mallorca are exclusively holiday trips. However, for our dataset we select some airports of destinations that are known as business destinations, above all Lisbon, Rome, Athens, Geneva, and Nice. For instance, the route between Milan and Rome (number 8 in Table 3) may be flown primarily for the conduct of business. It connects the two biggest Italian cities and in addition the distance between these cities is very short.

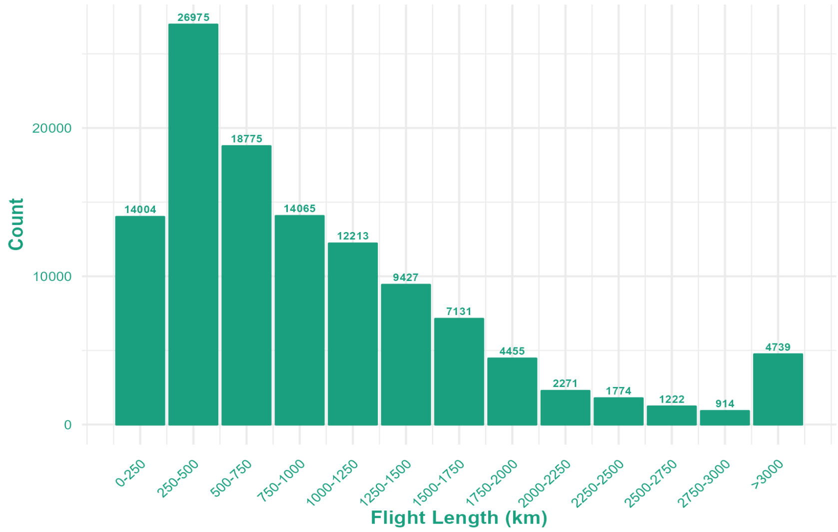
[15] Lisbon airport has a relatively high share of long-haul private jet arrivals, probably due to its geographical location. 26.3% of private jet arrivals in our filtered sample are from outside Europe. 6.8% are from America, 6.5% from Africa.

Analysis of distances

We test if the distances of private jet flights to the respective airports can help to explain the share of business and holiday trips. A similar overall distribution of distances to our filtered sample is found in previous work on private jet flights, yet there is a higher share of short distances (Faber & Raphaël 2023).

The following Figure 7 provides an overview of distances covered by private jet flights to the 45 European holiday destinations in 2023. The largest category of flights is between 251 and 500 km distance. This reflects results of previous work about private jet flights in Europe in the years 2020 to 2022 (Faber & Raphaël 2023). However, the share of the category covering the shortest flights (up to 250 km) is smaller. Faber & Raphaël (2023) calculate that 15% of all trips in their sample of private jet flights in Europe in 2022 cover up to 250 km. In our filtered sample, only 11.9% of all trips fall into this category. Similarly, a slightly smaller proportion (22.9% vs. 24%) of our filtered sample is in the 251-500 km category.

Figure 7: Distances of flights to 45 selected airports in 2023 (n=117,965). Source: own analysis



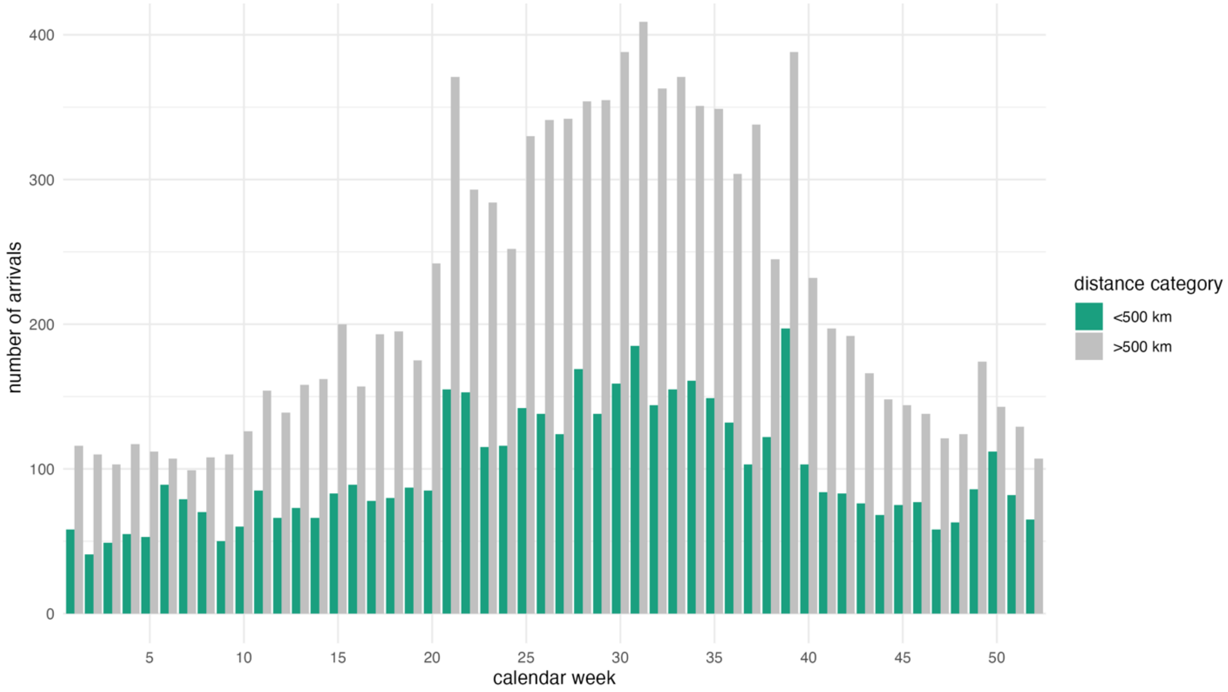
The main difference with the previous work is that it does not focus on holiday destinations but provides a general overview of private jet flights in Europe. This may therefore indicate that such short and very short flights up to a distance of 500 km are less common for holiday trips.

Figure 8 shows the seasonality of arrivals in Nice in our filtered sample, distinguishing between flights of up to 500 km and those of more than 500 km. Both curves are similar, but the curve for distances over 500 km indicates a slightly more intense summer season (see Figure 8).

Côte d'Azur airport in Nice is the only airport where we find such (slight) differences. This may be because long-haul flights arriving in Nice are more likely to be holiday flights than shorter flights. We carry out the same test for Lisbon, Geneva, Rome and Athens and test different distance categories, but the resulting curves do not differ as visibly as those from the Cote d'Azur airport.

In our filtered sample of 45 European airports, distance has little to do with seasonality, that is, short-haul flights should be primarily holiday flights. Further research is needed to determine to what extent distance is or may be an indicator for distinguishing between business and leisure private jet flights to holiday destinations that are also major business centres.

Figure 8: Seasonality of private jet arrivals in Nice 2023, comparison of distances. Source: own analysis

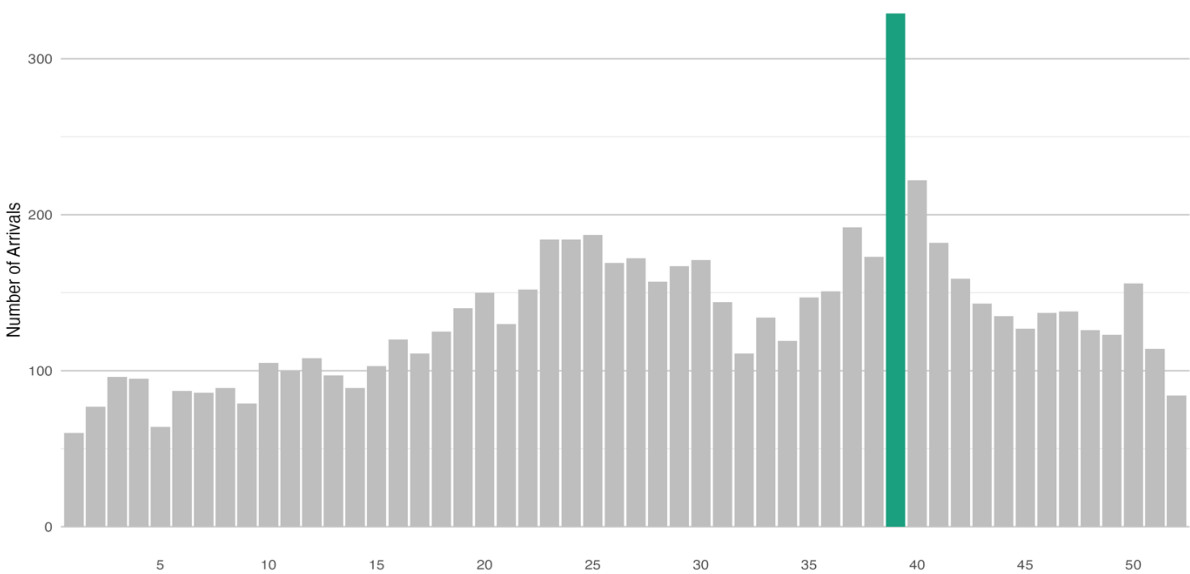


The influence of single events

A previous analysis of private jet flight routes could show that a significant number of private jets were presumably used to travel to the World Economic Forum in Davos, 2022. An exceptional high number of such planes arrived at one of the seven airports in the direct vicinity of the venue during the week of the event (Faber & Raphaël 2022).

Our dataset consists of a similarly obvious outlier, which is also clearly visible in Figure 2 and Figure 9: A significant peak of arrivals occurs at Leonardo da Vinci - Fiumicino Airport in Rome (FCO, 32nd in Figure 2) during the calendar weeks 39 and 40. According to our own desk research, the only plausible reason we can find was Christian events, namely an evening prayer on 30 September, and a session of the Synod of Bishops in October 2023. Figure 9 shows the sum of arrivals of both Roman airports (329 arrivals in week 39, green bar).

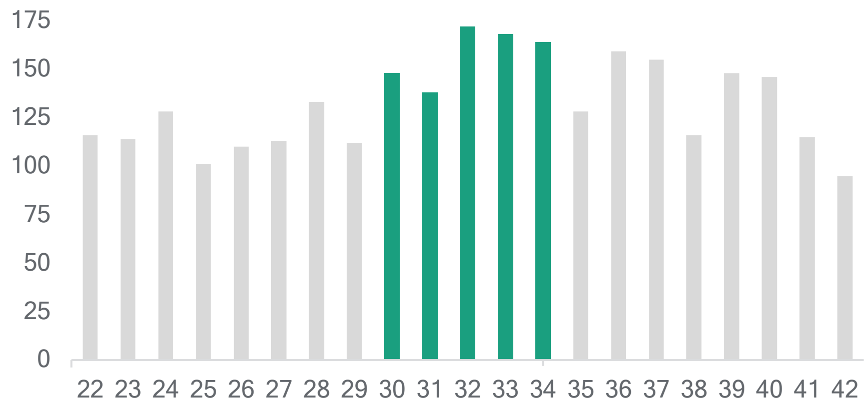
Figure 9: Private jet arrivals in Rome per calendar week in 2023, detection of outlier. Source: own analysis



More such outliers could be interpreted on closer examination of the data. For example, Figure 8 (arrivals in Nice, previous page) reveals two peaks which cannot be explained with the high summer season: Week 21 is the start of Pentecost, a bank holiday in France. The second peak occurs during week 39, and the influence of one or several parallel events is possible. During this week, the Monaco Yacht Show took place.

Another example is the summer of 2023 in Salzburg: There is a period from calendar week 22 to 29 with relatively few arrivals at the airport and a subsequent period from calendar week 30 to 34, starting on Monday 24 July and ending on Sunday 27 August, with more arrivals compared to the previous period (see Figure 10, green bars). This latter period coincides with the Salzburg Festival, which took place between 20 July and 31 August 2023. It could be assumed that some of the festival's visitors flew in on private jets, however, this could also be a standard empirical variance.

Figure 10: Arrivals of private jets at Salzburg airport in calendar weeks 22-42, 2023. Source: own analysis



A correct interpretation of the available data requires more empirical knowledge. The more data available on private jet routes and times, the greater the confidence in the interpretation. In the case of Salzburg Festival, data from other (previous) years could help.

Climate impact

The filtered sample of private jets that flew to 45 selected European airports in 2023 consists of 117,965 flights. This sample excludes private jets equipped for a special work purpose, and military (see Chapter 2). Table 4 illustrates the CO_2 emissions resulting from flights to these destinations.[16]

Table 4: CO_2 emissions of private jet flights to 45 European holiday destinations in 2023

	Total	Commercial business aviation	Non-commercial business aviation
CO_2 emissions total [t]	526,071	357,573 (68%)	168,498 (32%)
CO_2 emissions per flight [t]	4.46 (flights n=117,965)	4.46 (flights n=80,253)	4.47 (flights n=37,712)
CO_2 emissions per seat [t]	0.49 (seats n=1,085,198)	0.46 (seats n=771,823)	0.54 (seats n=313,375)

Source: own analysis

[16] We only consider the direct CO_2 emissions of business aviation, no other climate-relevant effects (CO_2 equivalent).

Almost one third of these private jet flights (32%) is classified as non-commercial business aviation. That is, these planes are privately owned by individuals, companies or fractional ownership programmes (see Chapter 2). The contribution to the climate crisis can be quantified with 4.47 t CO_2 per flight, and 0.54 t CO_2 per seat. Non-commercial business aviation has a slightly higher CO_2 impact per flight and per seat than commercial business aviation, see Table 4.

The CO_2 intensity, which is the total CO_2 emissions divided by the number of flights and the distance covered, tends to increase on shorter distances because of the fuel used for take-off. The Eurocontrol SET uses an increment that compensates for the extra CO_2 emissions of taking off and landing, which is equal to an additional 95 km of flying.

Table 5 lists the ten most frequently used plane types in descending order. Their CO_2 emissions per seat on a 500 km flight range from 0.12 to 0.44 tons, according to the Eurocontrol SET. For comparison: An Airbus A320-200 equipped with 174 cabin seats emits 0.05 tons per seat on the same distance (see Table 5). An A320-200 is a typical aircraft used by commercial airlines.

Table 5: Top 10 aircraft used for the flights. Source: own analysis; CO_2 calculation based on the Eurocontrol SET

	Manufacturer	Model	No. of flights in sample	Mean no. of seats	CO_2 [t], 500 km distance	CO_2 [t], 500 km, per seat
#1	CESSNA	560XL Citation XLS	9,538	7.7	2.44	0.32
#2	EMBRAER	EMB-505 Phenom 300	8,053	8.0	2.14	0.27
#3	PILATUS	PC 12	7,345	7.8	0.91	0.12
#4	BOMBARDIER	BD-100 Challenger 350	5,380	9.5	3.22	0.34
#5	CESSNA	680A Citation Latitude	5,176	7.5	3.13	0.42
#6	CESSNA	525A Citation CJ2	4,966	6.1	1.71	0.28
#7	DASSAULT	Falcon 2000	4,932	10.0	3.31	0.33
#8	EMBRAER	ERJ-135	4,163	13.8	3.82	0.28
#9	BOMBARDIER	BD-700 Global 6000	3,974	13.1	5.75	0.44
#10	CESSNA	510 Citation Mustang	3,635	4.0	1.33	0.33
exemplary comparison						
	AIRBUS	A320-200		174	8.81	0.05

Source: own analysis

As calculated with these numbers, private jets emit 2 to 9 times more CO_2 per seat than a typical passenger aircraft does. In addition, occupancy rates in business aviation tend to be much lower than in commercial passenger aviation (Transport & Environment 2021 based on industry reports). The climate impact per passenger in business aviation can therefore be up to 14 times higher than in commercial air transport (Transport & Environment 2021).

4) CONCLUSION

The main aim of this study is to analyse arrivals of private jet flights, often referred to as 'business aviation', at holiday destinations. We analyse, to what extent the arrivals over the course of a year correspond to the high tourist season. The dataset consists of unscheduled flights to 45 airports in Europe in 2023.

A key result of this analysis is that arrivals strongly correlate with peak tourist seasons. This result applies to all private jets that are not used for special aerial works, such as police actions, medical support, crop dusting, firefighting, offshore works etc. More specifically, we find that

- Private jets fly to resort island airports with similar regularity to commercially chartered aircraft. The arrivals by private jets over the course of the year correspond to the peaks of standard tourism. The arrivals of private jets can be used to identify the high (winter) season for the Canary Islands and the high (summer) season for Mediterranean islands such as the Balearic Islands.
- The arrivals at three airports on Malta and Cyprus show arrival peaks during autumn. This could indicate more work-related trips, but September and October are also popular tourist periods in Malta and Cyprus, which are the southernmost islands in the Mediterranean.
- Several cities which are well-known as tourist destinations such as Malaga (Spain), Naples (Italy), and Athens (Greece) have their arrival peak during the high summer season. These peaks are almost identical to the arrival peaks of standard chartered commercial airline flights (i.e., pure tourism).
- Lisbon and Rome are an exception on our list of 45 holiday destinations. In Lisbon, arrivals peak in spring and autumn, indicating a work-related seasonality. Long-haul arrivals are above average, making the city more of a hub for business jets flying from America to Europe. Rome has an exceptional peak in (long-haul) arrivals in calendar week 39 (25 to 30 September 2023). This coincides with a synod of bishops which started with an evening prayer on 30 September 2023.
- Arrivals at the airports of Geneva and Salzburg are more evenly spread. The influence of both leisure- and work-related trips seems to be relevant. However, both cities are popular tourist destinations for wealthy persons during both winter and summer. Salzburg airport saw more arrivals during the five weeks of the Salzburg Festival than in the previous weeks (however, we cannot unambiguously attribute this peak to the festival based on available data).

We would need information from passengers to determine the exact proportion of work and leisure trips to these destinations. However, the results are unambiguous. We also believe that in some cases the purpose of the trip is mixed: A businessperson might have a meeting and bring the family; or the location of a business meeting might be chosen for its leisure activities.

Importantly, some special purpose flights are also connected to the high tourist season (however, to a lesser extent), namely police air support, medical flights, and search and rescue actions. This can be explained by the fact that there are more people staying at tourist attractions at certain times of the year, which means that more such operations are needed.

This study also calculates CO_2 emissions resulting from private jet flights to these 45 European holiday destinations in 2023. As briefly discussed in chapter 1, most of these flights are most likely trips undertaken by very affluent persons. Pricing measures can therefore be defended from a social justice perspective. Currently, non-commercial aircraft operators with total CO_2 emissions lower than 1,000 t per year are even exempted from the ETS.[17] Scientists call trends in aviation specifically worrying and propose emission reduction efforts to shift from nations to individuals (Gössling & Humpe 2024).

To put our results into perspective, we compare the calculated CO_2 emissions to more easily understandable CO_2 emissions sources. Importantly, the number of private jet flights analysed in this study does not reflect the absolute number of such flights. We select a few airports to analyse seasonality, and we exclude flights to carry out the analysis (see Chapter 2). However, we believe that our results should be put into perspective:

117,965 private jet flights to 45 European holiday destinations in 2023 lead to 526,071 t CO_2 emissions. This number excludes flights for special aerial works. It equals the CO_2 emissions of 250,000 passenger cars in one year, assuming a fuel consumption as high as 7 litres petrol per 100 km, and an annual distance covered of 12,540 km. The latter is the European average.[18] This also equals 7% of the CO_2 emissions of Luxembourg in 2022. That year, the country emitted 7,277,000 t CO_2 emissions (EEA 2024).

Another perspective is to compare the emissions per jet and per capita: CO_2 emissions were as high as 4.46 tons per private jet flight in our filtered sample. In 2023, European Union citizens emitted 5.4 t energy-related CO_2 per capita (IEA 2024).

[17] See guidance document of the European Commission, section 3.2.2.

[18] See website German Federal Environment Agency for fuel consumption in Germany and ACEA (2024) for average annual distance travelled in Europe.

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6) ANNEX

Annex A provides some more details about the flights in the filtered sample of the received dataset. Annex B provides details about the data verification with OpenSky.

Annex A: Details of the dataset

Table 6: Top 5 departure airports per departure country (Austria, Germany, Netherlands, Switzerland, UK) for private jet flights to the 45 holiday destinations in 2023.

Country	Departure city	Departure airport	Number of flights
Austria	Vienna	Vienna International Airport	1,142
Austria	Salzburg	W. A. Mozart Salzburg Airport	660
Austria	Innsbruck	Innsbruck Airport	438
Austria	Linz	Linz Airport	263
Austria	Graz	Graz Airport	199
Germany	Munich	Franz Josef Strauss Airport	885
Germany	Berlin	Berlin Brandenburg Airport	806
Germany	Hamburg	Hamburg Airport	687
Germany	Cologne	Cologne Bonn Airport	517
Germany	Dusseldorf	Dusseldorf International Airport	500
Netherlands	Amsterdam	Amsterdam Airport Schiphol	1,277
Netherlands	Rotterdam	Rotterdam The Hague Airport	435
Netherlands	Maastricht	Maastricht Aachen Airport	124
Netherlands	Eindhoven	Eindhoven Airport	109
Netherlands	Enschede	Twente Airport	57
Switzerland	Geneva	Geneve Airport	2,868
Switzerland	Zurich	Zurich Airport	2,246
Switzerland	Sion	Sion Airport	804
Switzerland	Berne	Bern Airport	470
Switzerland	Altenrhein	Altenrhein Airport	465
UK	Farnborough	Farnborough Airport	3,025
UK	London	London Luton Airport	2,057
UK	London	Biggin Hill Airport	1,846
UK	Northolt	Northolt Airport	608
UK	London	Stansted Airport	523

Source: own filter of received dataset (n=117,965)

Table 7: Top 3 routes per departure country (Austria, France, Germany, Luxembourg, Netherlands, Switzerland, UK) for private jet flights to the 45 holiday destinations in 2023.

Country	Departure airport	Arrival airport	Number of flights
Austria	Vienna International Airport	W. A. Mozart Salzburg Airport	176
Austria	Vienna International Airport	Côte d'Azur Airport (Nice)	147
Austria	W. A. Mozart Salzburg Airport	Palma de Mallorca Airport	117
France	Le Bourget Airport (Paris)	Geneve Airport	1,420
France	Le Bourget Airport (Paris)	Côte d'Azur Airport (Nice)	1,093
France	Côte d'Azur Airport (Nice)	Geneve Airport	767
Germany	Hamburg Airport	Palma de Mallorca Airport	177
Germany	Berlin Brandenburg Airport	Palma de Mallorca Airport	156
Germany	Franz Josef Strauss Airport (Munich)	Côte d'Azur Airport (Nice)	147
Luxembourg	Luxembourg Airport	Geneve Airport	144
Luxembourg	Luxembourg Airport	Cote d'Azur Airport (Nice)	60
Luxembourg	Luxembourg Airport	W. A. Mozart Salzburg Airport	49
Netherlands	Amsterdam Airport Schiphol	Ibiza Airport	198
Netherlands	Amsterdam Airport Schiphol	Côte d'Azur Airport (Nice)	197
Netherlands	Amsterdam Airport Schiphol	Mandelieu Airport (Cannes)	163
Switzerland	Geneve Airport	Côte d'Azur Airport (Nice)	772
Switzerland	Zurich Airport	Côte d'Azur Airport (Nice)	380
Switzerland	Zurich Airport	Geneve Airport	364
UK	Farnborough Airport (London)	Côte d'Azur Airport (Nice)	759
UK	London Luton Airport	Côte d'Azur Airport (Nice)	500
UK	Farnborough Airport (London)	Geneve Airport	484

Source: own filter of received dataset (n=117,965)

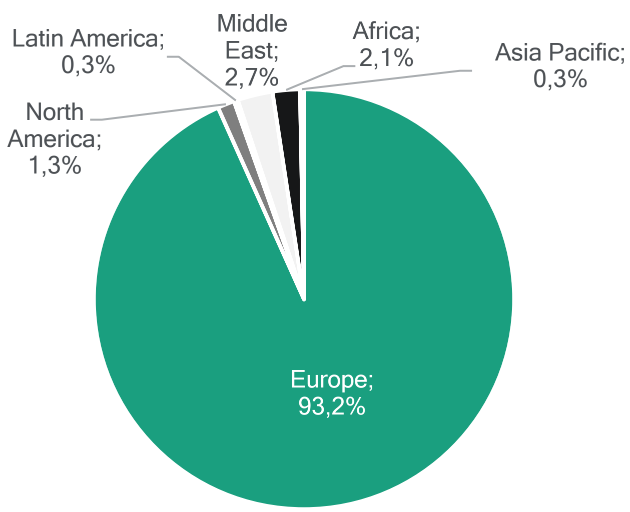
Table 8: Top 5 departure airports per arrival country (Greece, Italy, Spain) for private jet flights to all selected airports in the respective country in 2023.

Country	Departure city	Departure airport	Number of flights
Greece	Athens (Greece)	Eleftherios Venizelos Intl. Airport	511
Greece	Mykonos (Greece)	Mykonos Airport	335
Greece	Thessaloniki (Greece)	Thessaloniki International Airport	305
Greece	Thira (Greece)	Santorini International Airport	287
Greece	Tel Aviv-Yafo (Israel)	Ben Gurion International Airport	267
Italy	Milan (Italy)	Milano Linate Airport	1,370
Italy	Nice (France)	Cote D'Azur Airport	777
Italy	Olbia (Italy)	Olbia Costa Smeralda Airport	597
Italy	Paris (France)	Le Bourget Airport	581
Italy	Rome (Italy)	Ciampino-G. B. Pastine Intl. Airport	561
Spain	Madrid (Spain)	Adolfo Suarez Madrid-Barajas Airport	1,262
Spain	Nice (France)	Cote d'Azur Airport	1,022
Spain	Ibiza (Spain)	Ibiza Airport	863
Spain	Palma de Mallorca (Spain)	Palma de Mallorca Airport	803
Spain	Paris (France)	Le Bourget Airport	773

Source: own filter of received dataset (n=117,965)

Table 9: Departure regions of private jet flights to all selected airports in 2023.

Region	No. of arrivals from region	Share
Europe	109,961	
North America	1,592	
Latin America	410	
Middle East	3,232	
Africa	2,434	
Asia Pacific	336	



Source: own filter of received dataset (n=117,965)

Annex B: Data verification with OpenSky

The OpenSky Network consists of a multitude of sensors, which are connected to the internet by volunteers. All collected (raw) data is archived in a historical database. The database is primarily used by researchers from different areas to analyse and improve air traffic control technologies and processes.[19]

To validate the data quality, we search flights detected by OpenSky in our dataset. We try to match information about the date of the flight, the aircraft registration and the aircraft model. We do not try to match information about the exact time of the day.

We do this using two different random tests: The first test compares flights of the top 15 routes (as listed in Table 3 on page 17). We find those routes in the OpenSky Network database as well, see Table 10.

Table 10: Top 15 flight routes, comparison of dataset with OpenSky data

	Origin	Destination	No. of flights in dataset	*(of which included in filtered sample)*	No. of flights in OpenSky
#1	Farnborough (EGLF)	Cote d'Azur (LFMN)	771	759	379
#2	Le Bourget (LFPB)	Cote d'Azur (LFMN)	1,126	1,093	650
#3	Le Bourget (LFPB)	Geneve (LSGG)	1,438	1,420	1,628
#4	London Luton (EGGW)	Cote d'Azur (LFMN)	503	500	594
#5	Teterboro (KTEB)	Cote d'Azur (LFMN)	79	77	49
#6	Biggin Hill (EGKB)	Cote d'Azur (LFMN)	412	402	214
#7	Farnborough (EGLF)	Eleftherios Venizelos (LGAV)	160	160	55
#8	Milano Linate (LIML)	Ciampino-G. B. Pastine (LIRA)	841	764	852
#9	Farnborough (EGLF)	Geneve (LSGG)	489	484	536
#10	Farnborough (EGLF)	Malaga (LEMG)	201	199	156
#11	Dubai Al Maktoum (OMDW)	Cote d'Azur (LFMN)	64	63	52
#12	Amsterdam Schiphol (EHAM)	Ibiza (LEIB)	269	198	1,119
#13	Hamburg (EDDH)	Palma de Mallorca (LEPA)	243	177	2,423
#14	Le Bourget (LFPB)	Ibiza (LEIB)	249	248	247
#15	King Khalid (OERK)	Geneve (LSGG)	66	63	148

Source: own filter of received dataset (n=117,965); right column: OpenSky data

Our dataset includes more flights than the OpenSky Network database on eight of the 15 routes listed in Table 10. We try to match all flights on these eight routes by searching each flight from OpenSky in our dataset. We do not find a flight in the OpenSky dataset which cannot be matched

[19] See OpenSky Network and Wikipedia.

with any flight in our dataset, according to the matching criteria. In seven out of 15 cases, OpenSky lists more flights. We find three different reasons, which we explain in the following.

Firstly, 428 of 9,102 flights which we find in the OpenSky database by searching for those routes do not provide information about the aircraft registration and aircraft model. Similarly, the dataset which we received from the data provider includes flights with incomplete information. But these are already excluded by the filters, see Chapter 2.

Secondly, we realise that OpenSky consists of some double entries. We find 25 flights with two identical entries each. We also suspect some more double counting, namely some entries with identical information except for the time of day (although it should be possible for a plane/helicopter to fly the same route twice a day, depending on the distance).

Thirdly, Table 10 includes four routes with scheduled flights. Our dataset was pre-filtered by the data provider, it only consists of unscheduled flights. Scheduled flights exist between London Luton and Côte d’Azur, from Amsterdam Schiphol to Ibiza, from Hamburg to Palma, and between King Khalid and Geneva (#4, #12, #13, #15 in Table 10).

Controlling for these three factors, we only find one flight in the OpenSky dataset which cannot be matched with any flight in our dataset.[20] All other flights we find from OpenSky are included in our dataset, according to our matching criteria.

The second test method to validate the data is depicted in Table 11. We systematically search OpenSky for the ten most frequently used aircraft types in our analysis (as listed in Table 5 on page 21). We find 45,929 flights, all of which contain enough information to test a potential match. We are able to find each of those flights in our dataset.[21]

Table 11: Top 10 aircraft used for the flights, comparison of dataset with OpenSky data.

	Manufacturer	Model	No. of flights in dataset	*(of which included in filtered sample)*	No. of flights in OpenSky
#1	CESSNA	560XL Citation XLS	10,308	9,538	8,537
#2	EMBRAER	EMB-505 Phenom 300	8,057	8,053	6,517
#3	PILATUS	PC 12	7,596	7,345	5,675
#4	BOMBARDIER	BD-100 Challenger 350	5,469	5,380	3,906
#5	CESSNA	680A Citation Latitude	5,190	5,176	3,728
#6	CESSNA	525A Citation CJ2	4,980	4,966	3,547
#7	DASSAULT	Falcon 2000	5,020	4,932	4,456
#8	EMBRAER	ERJ-135	4,227	4,163	3,222
#9	BOMBARDIER	BD-700 Global 6000	4,218	3,974	3,512
#10	CESSNA	510 Citation Mustang	3,678	3,635	2,829
		Total	**58,743**	**57,162**	**45,929**

Source: own filter of received dataset (n=117,965); right column: OpenSky data

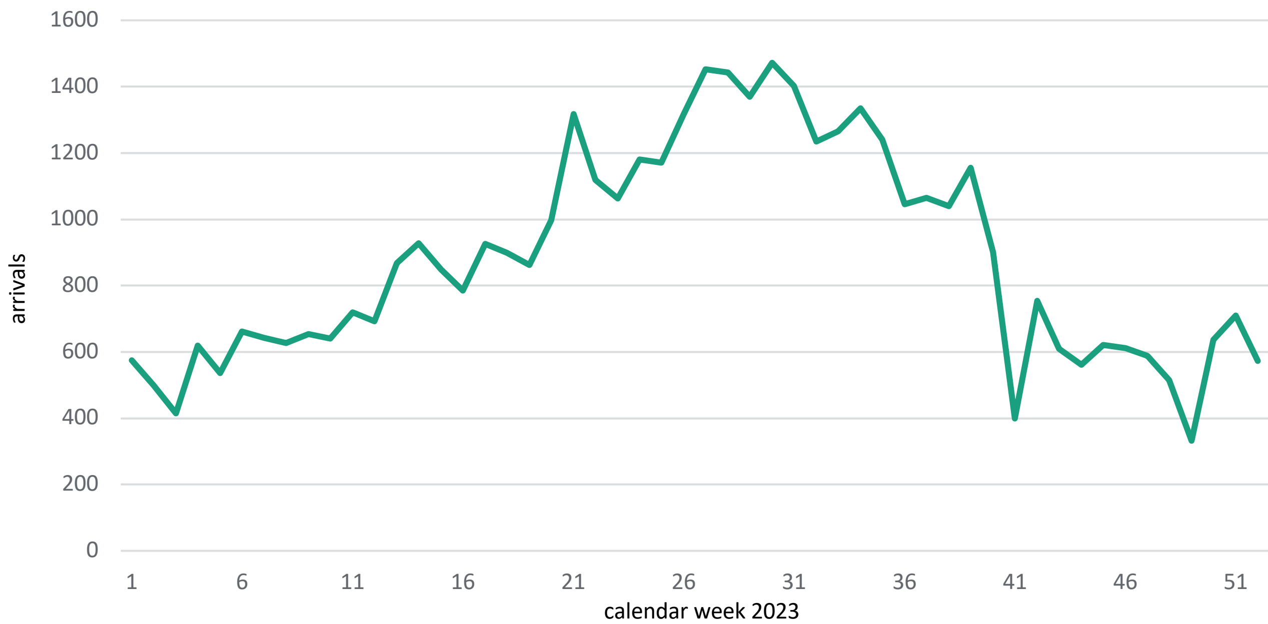
[20] OpenSky does not distinguish between scheduled and unscheduled flights. We assume scheduled flights for certain aircraft such as A319 or A320.

[21] At least 124 flights appear twice in this OpenSky dataset, because each of these flights contains two identical entries.

In conclusion, OpenSky appears to cover fewer flights than the data provider. Coverage is high on the continent but limited for flights to the Canary Islands. The data comparison proves good quality of the received dataset from the data provider.

Finally, Figure 11 illustrates the seasonality of flights recorded from OpenSky. For this graph we use flights as listed in Table 11. As mentioned, some flights seem to be counted twice, but this should not bias the result. The graph indicates a typical summer season as analysed in this report. The sharp decline of arrivals between calendar week 39 and 41 could be the consequence of a temporary reduction of coverage.

Figure 11: Seasonality of arrivals of top 10 aircraft models in the dataset (see Table 5), as found in the OpenSky data*. Source: own analysis based on OpenSky data (n=45.883)



****Left out: 7 jets landing at a Canary Island airport; 39 arrivals during calendar week 53***

Many thanks to the OpenSky Network!

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