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The magnitude of detours faced by commercial flights: A global assessment

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Abstract

Scholars and experts in transportation, economics, geography and environmental studies have largely assumed the distance flown by commercial planes represents the shortest route (also known as the great-circle or orthodromic route). However, in the real world, planes follow longer itineraries for various reasons. The magnitude of these detours is assessed through a large, one-week sample of actual flight traces obtained from Flightradar, which we compare with great-circle distances (n=393,360). The results suggest that the average lengthening is 7.6 %, although under conservative hypotheses and with high standard deviation. The shortest flights are proportionally more affected. They also contribute more to the global amount of extra kilometres. The geography of detours by departure airport is the consequence of a wide range of factors. As a result, considering the use of great-circle distances to feed spatial interaction models, emission (or fuel burnt) assessments or airline rankings can lead to significantly skewed outcomes. In addition, detours imposed on certain airlines for geopolitical reasons increase costs, emissions and time aboard, and could be anticompetitive.

Keywords

Air transport geography; airline routes; distance; great-circle distance; horizontal flight efficiency

1. Introduction

The dramatic increase in air services in recent decades has induced conflicting consequences. On the one hand, it has favoured long-distance tourism (Forsyth, 2010), boosted specific economic sectors (Albalate and Fageda, 2016) and helped migrants to maintain social links with their home region (Burrell, 2011; Boonekamp et al., 2018). On the other hand, aircraft operations also have several adverse environmental impacts (Daley, 2010). Scholars have comprehensively investigated noise exposure near airports and the impact of aviation on climate change, and these issues remain the subject of ongoing political debate (Bröer, 2007; Azar and Johansson, 2012; Masiol and Harrison, 2014). In contrast, the impact of aviation on air pollution – and thus on air quality and health – has received less attention. What is more, most authors have focused only on landing and take-off (LTO) cycles, with the implicit or explicit idea that emissions above a height of about 1 km do not affect air quality near ground level (Masiol and Harrison, 2014). However, it is now suspected that pollutants emitted at higher altitudes also affect ground-level air quality and could be responsible for premature mortalities (Barrett et al., 2010; Yim et al., 2015), although other authors have made contrasting findings (e.g., Lee et al., 2013), and the conclusions appear to be sensitive to the modelling techniques considered (Cameron et al., 2017). The emission of both greenhouse gases and air pollutants relates to the quantity of fuel burnt. In addition, consumption of fuel raises economic and geopolitical issues for airlines and for nations that are not self-sufficient. In this regard, it is estimated aviation is responsible for 4.8% of fossil fuel energy (or 7.8% of oil products) usage in 2016.[1]

All this means that the distance flown by planes is a key environmental and economic factor, since it directly influences the volume of fuel burnt and related emissions. Beyond environmental issues, distance is also used to compute traffic volumes (often expressed in seat-km or passenger-km), to feed models (including interaction or modal choice models) and to sort air flows by distance class (e.g., Adey et al., 2007).

Consequently, it is important to know precisely the distances flown. But, strangely, to the best of our knowledge, the actual distance flown by commercial planes has been largely neglected. Most online trackers (e.g., Flightradar and Flightstats) and databases (e.g., OAG) supply the shortest hypothetical distances flown (aka the great-circle distance) instead of actual distances, and so do scholars, experts and international organisations. However, in reality, planes do not really follow great circles and can even significantly move away from them. This is due to various (and possibly combined) technical, natural, geopolitical and social factors, most of which involve an increase in fuel burnt, and thus in emissions (Table 1) (see Dobruszkes, 2019, for a review).

Nature	Factor	Temporality	Impact on fuel burnt
Technical	Route design	Permanent	Increase
	Traffic density	Temporary or permanent	Increase
	Time to alternate airports	Permanent	Increase
Natural factors	Relief	Permanent	Increase
	Storms	Temporary	Increase
	Jet streams	Permanent but changing location	Decrease (tail) or increase (front)
	Cyclones	Temporary	Increase
	Volcanism	Temporary	Increase
Geopolitical	First air freedom	Permanent	Increase
	No-fly zones	Temporary or permanent	Increase
	War, terrorism	Temporary	Increase
Social	Strike	Temporary	Increase

Table 1. Factors related to detours and the main attributes.
Source: Dobruszkes (2019)

In this context, the aim of this paper is to estimate the magnitude of these detours. Section 2 introduces a brief literature review. Section 3 explains our methodology. Section 4 proposes an estimation of the magnitude of detours based on flight traces over one week. Section 5 then discusses the environmental, economic and methodological implications of detours. Section 6 concludes.

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[1] Computed by the authors from IEA (2018).

2. The magnitude of detours: What do we know?

The issue of distance actually flown by commercial planes has received the most attention in the grey and academic literature interested in the optimisation of air procedures and air traffic control. Indeed, the magnitude of detours has been analysed thanks to performance indicators established by various civil aviation authorities. But in all cases, only restricted samples of city pairs or limited spaces have been considered, but results nevertheless give some interesting indications. The FAA and Eurocontrol (2016) compared actual distances flown to flight plans; that is, airways published by civil aviation authorities, and to the shortest routes. This was done for the US and for Europe (to/from the top 34 airports), considering en-route sections, thus excluding 40 NM from the airport of departure and 100 NM to the airport of arrival. In 2015 it was found that, on average and compared to the shortest routes, flight plans imposed detours of 3.4% in the US and 4.6% in Europe, and that distances flown were extended by 2.83% and 2.92%, respectively. The fact that distances flown are shorter than flight plans suggests that pilots obtain shortcuts from air traffic control (ATC) authorities. Excluding 40 NM around the departure and arrival airports, the Eurocontrol watchdog[2] found that from 2014 onwards, flights within its airspace have been lengthened by about 2.7%. Of course, any average hides lower and higher values. For instance, Eurocontrol (2013) found that the Munich to Paris CDG route had been lengthened by 13% and the Paris CDG to Munich by 4.7%. No-fly military areas were cited as the main reason for the detours.

Furthermore, Valenti Clari et al. (2000) compared flight plans imposed by published procedures to the working hypothesis of a so-called Free Flight Air Traffic Management. According to this potential scheme, planes would not follow published airways imposed by the ATC but would be free to fly as the pilot wanted, while appropriate hardware and software would manage the routes to avoid fatal collisions. Based on an experiment that considered a large sample of flights within North-Western Europe, Valenti Clari et al. (2000) found that free flight would decrease distances flown by about 40 percent compared to published routes. This seems surprisingly higher than the aforementioned results, even though it includes whole flights, and thus also detours imposed at take-off and landing locations. In contrast, Edwards et al. (2016), considering a 10,284-km flight operated by a B767-300ER, find that fitting to the great circle route would save 7% in fuel and in CO_2 emissions.

Beyond these examples of spatially restricted investigations, and to the best of our knowledge, no global assessment has been made of detours experienced by airlines. Filling this gap is at the core of this paper.

3. Assessing detours: Data and methods

To assess the magnitude of detours, we took advantage of real aircraft trajectories made available to analysts by private firms recently, but which have remained underexplored (Ren and Li, 2018), possibly because of issues related to cost and spatial database know-how. We bought one week of historical flight traces from Flightradar. The time frame is from November 3 to 9, 2017 (this specific week was imposed by a parallel R&D project). Flightradar data is based mostly on the so-called Automatic Dependent Surveillance-Broadcast technology (ADS-B), according to which aircraft locate themselves thanks to on-board GPS and satellites, and then regularly transmit their position through their ADS-B transponder, if any; a network of about 17,000 Flightradar ground receivers pick up the signal and feed the real-time website and historical data. For technical reasons, each receiver has a range of between 250 and 450 km in all directions, so covering the oceans is impossible, except close to land (including islands)

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[2] See http://ansperformance.eu for the methodology and results.

equipped with receivers. In certain areas, Flightradar also estimates the position of planes not equipped with ADS-B, thanks to the Multilateration (MLAT) method, between 3,000 and 10,000 feet. Flightradar is also fed by radar data in North America (including the US and Canadian airspaces and part of the Pacific and Atlantic oceans), where data are thus also received from aircraft without ADS-B transponders. Finally, Flightradar also gets data from the so-called Flarm technology, a simplified ADS-B system smaller aircraft (mostly gliders) use. More technical information can be retrieved from the Flightradar website,[3] especially for those who would like to help improve their spatial coverage.[4]

Flightradar's historical data are made up of two types of files. First, a text file includes a list of all flights considered for one day and several attributes (flight metadata), such as flight id, call sign, aircraft type, scheduled origin/destination and the actual destination (should the flight be rerouted). Second, each flight's route is described in a specific text file, which includes the 3D coordinates of all successive known positions of the plane. These positions were all uploaded into a single database table, while the flight data file was loaded into another table for efficiency of processing by filtering, then computing the distances flown. Apart from the sample size, the data processing is simple, since after the elimination of the problem cases it is not difficult to calculate flight lengths and compare them to the shortest distances between origin and destination.

The initial one-week dataset thus obtained included about one million flights made up of about 193 millions points. Investigations of the data, visualisations and preliminary computations helped to isolate non-relevant flights. Conditions for exclusions were:

- Incomplete flights, which are mostly flights that started before November 3, 2017, or flights that had not arrived yet by the end of November 9, 2017 (i.e., flights with first or last known position farther than 5 km (2D) from either departure or destination airports). This also affected flights to/from areas of poor coverage and countries in which Flightradar has no coverage at all (e.g., inner Algeria).
- Departure airport equalled the arrival airport.
- The plane did not land at the scheduled airports, considering that rerouted flights would include atypical itineraries in the context of unforeseen circumstances.
- Equipment and modes of transport other than planes (e.g., helicopters and balloons).
- No flight code, so private and technical flights were not considered.
- Flights shorter than 75 km, where take-off and approach procedures accounted for a significant share of the distance flown.
- Aberrant distances due to various causes, for instance, in case of one odd intermediate point erroneously located far from the actual route.
- Planes that have never taken off.

This left us with a sample of 393,360 flights. The actual distance flown was then computed on a Postgresql/PostGIS (2.3) system. The positions were initially joined into 3D line strings, and then their lengths were calculated using the ST_LengthSpheroid() function provided by PostGIS, which in this case computes the length along the WGS 84 ellipsoid[5]. Taking the ellipsoid into account is crucial to avoid measuring the distance in a 2D projection (e.g., via the inside of the Earth).

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[3] See https://www.flightradar24.com/how-it-works. One understands that despite its name, Flightradar is thus not based primarily on radars.

[4] See https://www.flightradar24.com/add-coverage

[5] ST_LengthSpheroid(geometry, 'SPHEROID["WGS 84",6378137,298.257223563]')

It is worth noting that the distance between two subsequent points, and thus the precision of itineraries flown and related distance computed, is not constant. Considering flights from London Heathrow, for instance, the median time between two points is 31 seconds, and in 99% of cases, the time remains under 180 seconds. However, the remaining 1% corresponds to long distances, as evidenced by Figure 1. In this sub-sample, the 1% segments in question account for 18% of the distance computed. This is due to the aforementioned poor oceanic coverage, and to the lack of data received in Africa, inner China, Mongolia, Siberia, Greenland and Arctic Canada. In such cases, related portions of routes flown are long, straight segments, instead of more precise, broken lines. Such long segments are likely shorter than the actual distance flown. In other words, the poorer knowledge of itineraries in certain areas means our computation of actual distance flown is shorter for part of the sample, and the lengthening of flights is then underestimated. This means the forthcoming estimation of the magnitude of the detour is a conservative one.

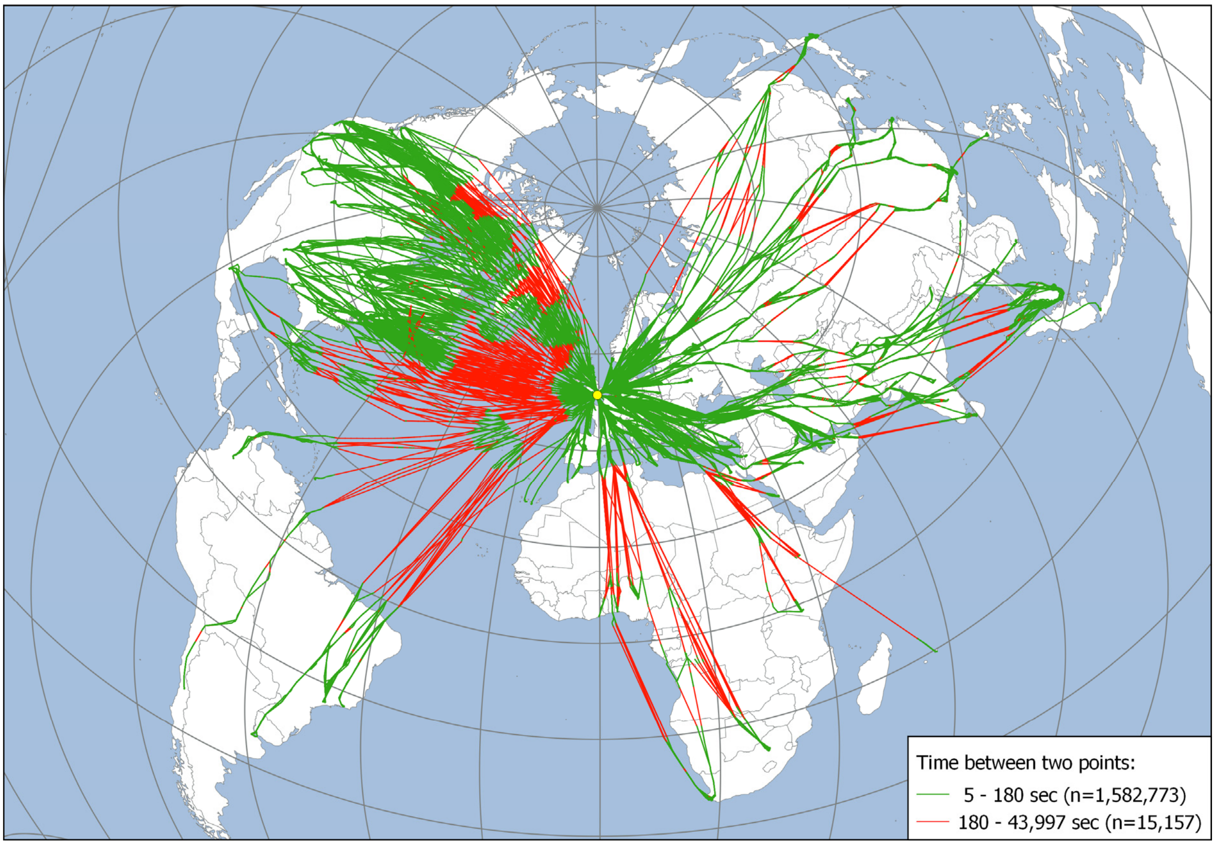

Figure 1. The uneven coverage of Flightradar through the distance between two subsequent points (flights departed from London Heathrow, November 3 to 9, 2017).

Great-circle distances were then considered as a reference. For most flights, the value was found in the OAG Schedule database. For remaining flights, we used airport coordinates supplied by OpenFlights[6] to compute great-circle distances, thanks to an appropriate formula. The analysis then compared the actual distance flown with this great-circle distance to identify the difference. It is these differences that are the focus of the analysis that follows.

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[6] See https://openflights.org/data.html

4. The magnitude of detours

Considering global absolute figures first, Table 2 shows that within our sample, at least 49.87 million more kilometres were flown compared to 656.95 million km if all flights had followed great-circle routes. This leads to a weighted average lengthening of +7.6%. This magnitude is higher for short-haul flights and lower for medium- and long-haul flights. However, given the global split of flights by distance range, detours imposed on medium-haul carriers account for half of the extra kilometres flown, and short-haul flights "only" 30%, then 21% due to long-haul flights.

	All flights	Short haul	Medium haul	Long haul
Cumulative shortest distances (10^6 km)	656.95	104.81	336.09	216.05
Cumulative actual distances flown (10^6 km)	706.82	119.79	360.67	226.36
Cumulative lengthening (10^6 km)	+49.87 +7.6%	+14.98 +14.3%	+24.58 +7.3%	+10.31 +4.8%
Contribution to cumulative detours	100%	30%	49%	21%

Table 2. The magnitude of detours in absolute terms (n=393,360, November 3 to 9, 2017).
Short haul means up to 1000 km, medium haul 1001-4000 km and long haul more than 4000 km, based on the shortest route.

Turning to individual flights and relative figures, Figure 2 shows the cumulative frequency of detours indentified within our sample. Flight lengthening compared to shortest routes ranges from about 0% to +460% (i.e., distance flown multiplied by a factor 5.6). The median lengthening is 8.2%. Figure 3 introduces the magnitude of detours compared to great-circle distances, and confirms that shorter flights proportionally face longer detours, and conversely.

In light of the examples of detours shown above, average and median values may seem rather low at first glance, although they are actually not. First, recall that this is a conservative estimation, especially for long-haul flights (see Figure 1 above). Second, it must be considered that the standard deviation is high (11.9%) and the magnitude is of at least +23.5% for the top 10-% longest detours (computed in relative terms). Third, the average or median lengthening found here is usually significantly higher than computations restricted to the en-route portions of flights (see Section 2) and to corrective factors applied to the great-circle distance by various authors. For instance, Vespermann and Wald (2011) considered 10% extra km for short-haul flights and 5% for long-haul flights; Scheelhaase et al. (2010) considered 6% and 3%, respectively, while Park and O'Kelly (2014) applied a 4-% penalty to all flights.

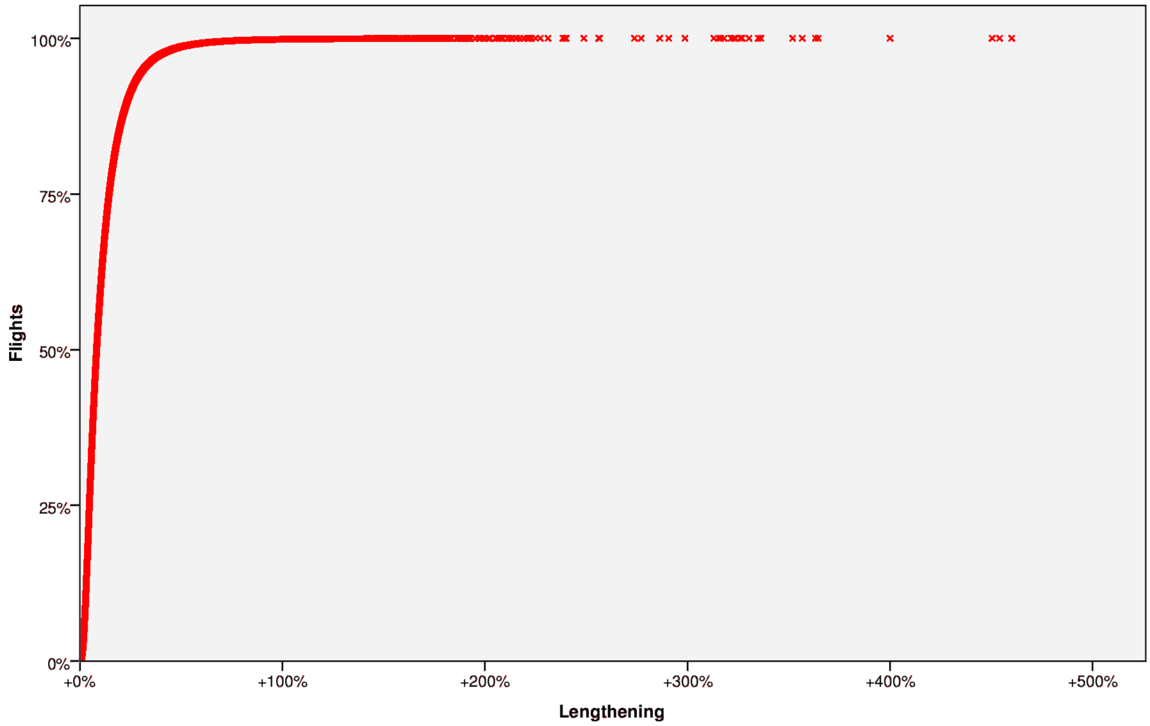

Figure 2. The distribution of detours (one marker per flight, n=393,360, November 3 to 9, 2017)

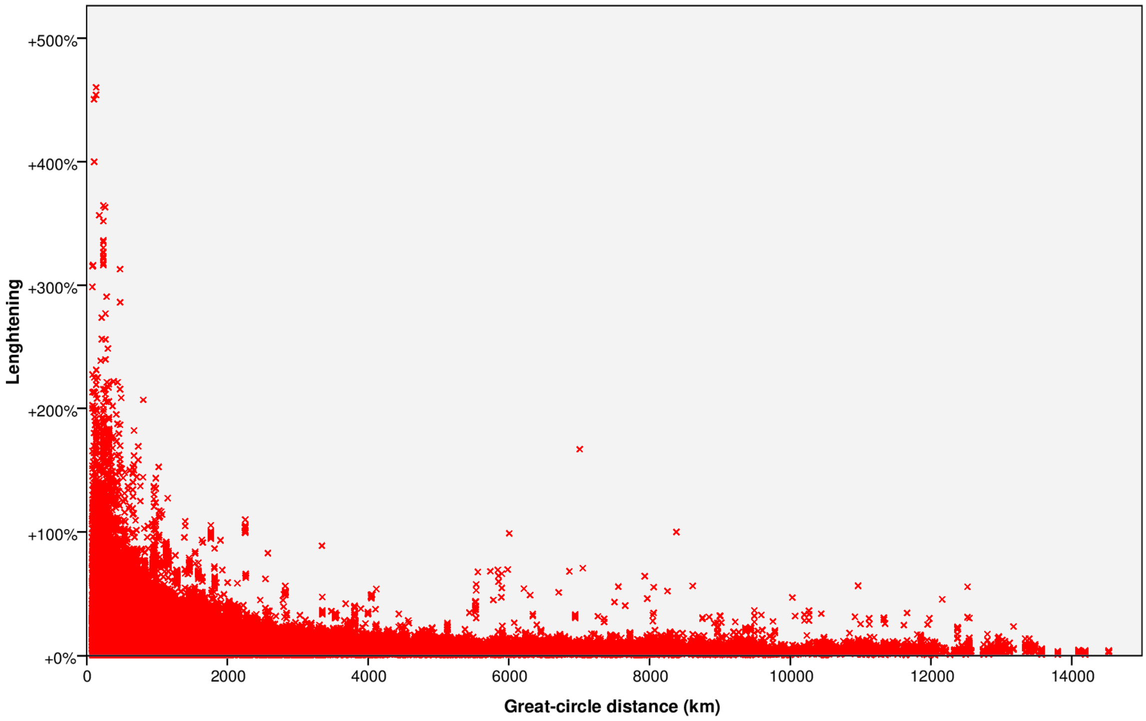

Figure 3. Detour vs. great-circle distance (one marker per flight, n=393,360, November 3 to 9, 2017)

Finally, Figure 4 unveils the geography of detours at the airport level.[7] The results should be understood as the consequence of all the factors introduced in Table 1. It is beyond the scope of this paper to rank factors by the importance of each airport or region. However, results are affected by traffic structure. In several regions (including the US, Europe, India, Japan and Australia), smaller airports usually contend with larger detours, likely because they are served mostly by short-haul flights, which means longer detours in relative terms. Conversely, larger airports and several remote places dominated by long-haul flights (including Australia and New Zealand) experience shorter detours. The contrast is very clear, for instance, within Japan, between Tokyo (with its high share of long-haul flights) and other cities (dominated by short-haul flights and sometimes complex routes because of mountains).

However, China's situation is quite different, mainly because of the lower density of China's air navigation network for commercial operations (Ren and Li, 2018; Hsu, 2014), which imposes less direct routes. Africa's main cities are another specific case, with little traffic but less detours. This is usually due to the lack of intra-regional air services, and thus the dominance of long-haul flights (Scotti et al., 2018).

Average detours are also greater at cities that are near to closed airspaces following wars or other political disputes. This includes, for instance, Lebanon (vs. Israel), Turkey (vs. Syria) and Qatar (vs. Saudi Arabia and Syria). Of course, this needs to be balanced by traffic structure. For example, Israeli airlines cannot fly over several neighbouring countries, but most of its traffic goes to Europe and the US via the Mediterranean, so in the end, the average detour we detect is small.

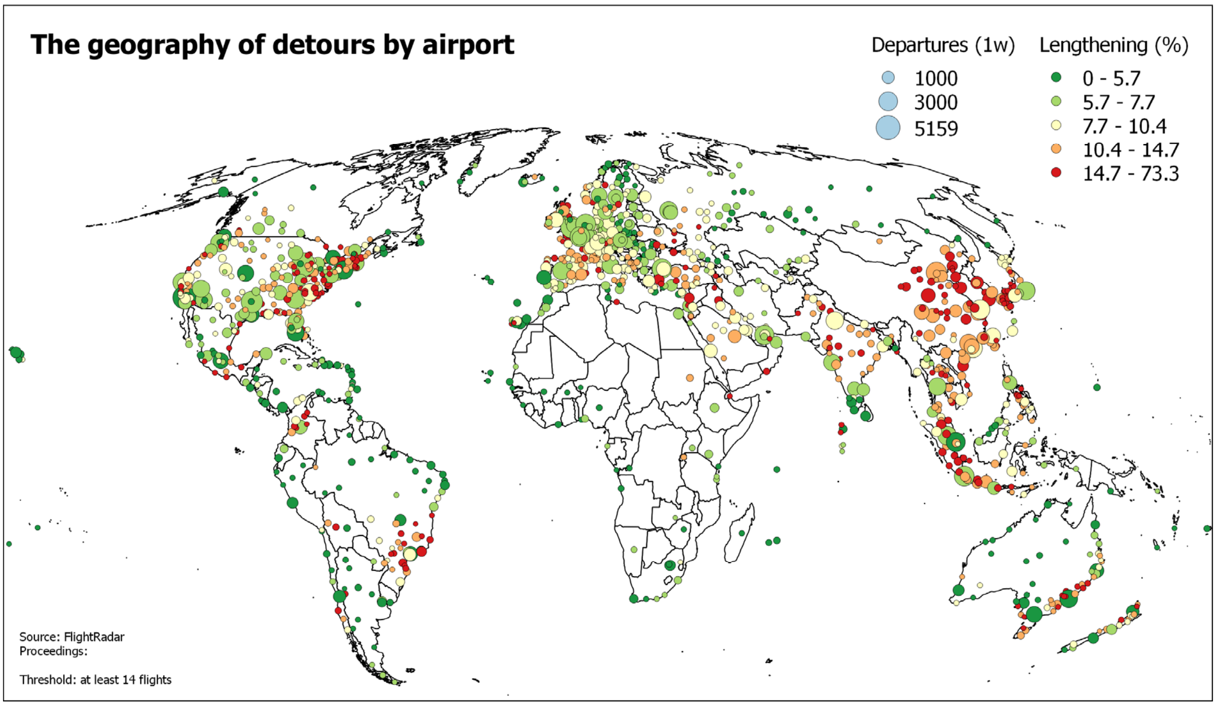

Figure 4. Average detour by departure airport (November 3 to 9, 2017). Circle sizes for number of departures and colours for average detours. Airports with less than 14 flights have been excluded.

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[7] It should be clear this figure is not a global map of the air services geography, since not all flights are covered by Flightradar and not all available flights could be considered for computations.

5. Implications

Detours imposed on commercial flights have several implications. Firstly, they have significant economic impacts. The longer the flight, the higher the cost, since more fuel is needed (Park and O'Kelly, 2014), labour is used for a longer time, and high fleet-related fixed costs are less balanced by the number of rotations. In addition, there is potentially unfair competition if different airlines have to fly different distances on a same airport-pair because of traffic rights. However, one needs to consider all the parameters. For instance, Qatar Airways suffers at the hands of its ban by Saudi Arabia, which requires it to make significant detours. On the other hand, the airline is believed by US airlines[8] to enjoy large state grants, which also distorts competition (Partnership for Open & Fair Skies, 2015).

Another important consideration is the fuel used. The more fuel burnt due to longer trips involves more greenhouse gas (GHG) emissions and air pollution, despite uncertainties about the impact of emissions at higher altitudes. The precise magnitude of the contribution of aviation to climate change is not known because of insufficient knowledge about the actual impact of aviation-induced cirrus effects and of high-altitude NO_x emissions (Lee et al., 2009). Furthermore, more research is needed into the heterogeneous impact of emissions subject to their latitude and altitude (Dahlmann et al., 2016). Lee et al. (2009) estimate that considering all GHGs and the cirrus effect, the impact of aviation on anthropogenic radiative forcing ranges between 2.0% and 14.0%, the median being 4.9%. In addition, projections suggest high rates of increased emissions. Also, it is now suspected that even pollutants emitted en route would eventually affect air quality at ground level (Cameron et al., 2017). All this suggests avoiding detours that increase GHG emissions. However, one also needs to think about the rebound effect. If flights are made shorter and cheaper, the demand would increase to some extent, and so would the emissions.

In addition, from a passenger perspective, detours mean longer journeys and potentially higher airfares. Furthermore, distance-based loyalty programs are somewhat misleading. Time- or fare-based miles earned actually make more sense.

The existence of detours outlined above also questions the ability of public bodies to monitor the so-called horizontal flight efficiency, which is based on flight plans or actual distances compared to the shortest routes (see Eurocontrol, 2014; FAA and Eurocontrol, 2014). While flying shorter routes is highly desirable[9], such indicators should at least take into account that some longer journeys are simply inevitable (especially those related to natural constraints), while others could be spared should authorities be more flexible and proactive.

In addition, all common rankings of airlines based on available seat-km, passenger-km, ton-km or total distance flown are also presumably biased by the use of great-circle distances in computations. The magnitude of errors relates to each airline's network geography (including the split between shorter and longer flights as well as areas served, and thus both natural and geopolitical factors).

Finally, the analysis challenges research methodologies. Most of the time, scholars who need to consider distance flown will use great-circle distances. Typical cases include estimating fuel burnt and/or GHGs emissions (e.g., Jamin et al., 2004; Miyoshi and Mason, 2009; Scheelhaase et al., 2010; Park and O'Kelly, 2014; Budd and Suau-Sanchez, 2016), tankering strategies in aviation (e.g., Cames, 2007), the investigation of airline cost structure (Swan and Adler, 2006; Zuidberg, 2014) and interaction models (Matsumoto, 2007; Hwang and Shiao, 2011; Mao et al., 2015; Matsumoto et al., 2016). Only a few scholars (e.g., Miyoshi and Mason, 2009; Budd

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[8] See http://www.openandfairskies.com/ (Accessed 16 July 2018).

[9] Except in cases where flying at optimal altitudes to save fuel may impose longer flights. In other words, both vertical and horizontal efficiencies should be considered jointly.

and Suau-Sanchez, 2016; Turgut et al., 2019) have highlighted that great-circle distances are shorter than actual distance flown, and even fewer studies have applied corrective factors to great-circle distance to avoid underestimations (see previous section). However, given the lengthening range and its geographic pattern, such correctives factors should be considered with caution and customised subject to the markets considered. In other cases, results could only be biased, and considering flying time (when available) could be more relevant.

6. Conclusions

Parker Van Zandt's (1944: 7) "myth of great circle flying" is still a myth despite dramatic technological progress and less global geopolitical concerns. This paper has supplied the first comprehensive assessment of detours based on a large sample of worldwide commercial flights. It has been estimated that the average detour is about 7.6%, compared to the shortest routes. However, this is a conservative estimation and the range of lengthening is very large. The geography of average detour by airport of origin also shows a high spatial heterogeneity.

This first assessment arguably calls for further work. First, it would be relevant to think in terms of fuel and of emissions instead of distance flown. This includes a trade-off between lower and higher altitude impacts. On the one hand, a proportionally larger share of fuel is burnt during take-off, since planes have to be pulled out of the Earth's attraction (Turgut et al., 2019). This suggests en-route detours would have proportionally less impact than suggested by horizontal distances. On the other hand, however, NOx emissions at cruise altitudes plus en-route contrails and resultant cloud formation account for a significant part of the climate impact induced by aviation. Here, longer flights mean more climate impacts. In addition, one challenge will be to investigate the geography of detour magnitudes at route level to potentially detect spatial patterns and possibly estimate the contribution of (families of) factors to detours. Furthermore, one could also make a distinction between en-route detours and detours imposed on airlines during take-off and landing. Also, historical trends in the magnitude of detours could also be assessed to investigate the impacts of changes in aircraft technology, geopolitics and air control methods, subject to data availability. Another potential focus could be seasonality. However, this would require the cost of acquiring the data. Finally, it would also be relevant to move from our airlines' perspective to a passengers' one, considering actual origins-destinations flown and weighting detours by the number of passengers or seats (as a proxy for demand), notwithstanding data availability issues. As an example, Table 3 illustrates the impact of weighting the average detour by the number of seats supplied, over one week on the Doha-Amman route. In this market, Royal Jordanian can fly close to the shortest route via Saudi Arabia. In contrast, Qatar Airways has been banned from Saudi Arabia (see Dobruszkes, 2019), and thus needs to route its flights via Kuwait and Iraq (Figure 5). Given respective aircraft capacity, the weighted detour is eventually 185 km instead of 165 km if not weighted.

Date	Flight	Aircraft	Seats	Distance flown (km)	Detour (km)
1/06/2019	QR400	B77W	412	1,885	203
2/06/2019	QR400	B77W	412	1,889	207
3/06/2019	QR400	B77W	412	1,888	206
4/06/2019	QR400	B77W	412	1,861	179
5/06/2019	QR400	B77W	358	1,952	270
6/06/2019	QR400	B77W	412	1,899	217
7/06/2019	QR400	B77W	412	1,883	201
1/06/2019	QR402	B77W	412	1,897	215
2/06/2019	QR402	B359	283	1,906	224
3/06/2019	QR402	B77W	412	1,901	219

4/06/2019	QR402	B77W	354	1,872	190
5/06/2019	QR402	B77W	412	1,941	259
6/06/2019	QR402	B77W	412	1,956	274
7/06/2019	QR402	B77W	412	1,958	276
1/06/2019	RJ651	A321	167	1,889	207
2/06/2019	RJ651	A321	167	1,776	94
3/06/2019	RJ651	B788	271	1,754	72
4/06/2019	RJ651	B788	271	1,734	52
5/06/2019	RJ651	A321	167	1,797	115
6/06/2019	RJ651	A320	136	1,764	82
7/06/2019	RJ651	A321	167	1,785	103
1/06/2019	RJ653	B788	271	1,807	125
3/06/2019	RJ653	A321	167	1,785	103
4/06/2019	RJ653	B788	271	1,807	125
5/06/2019	RJ653	B788	271	1,728	46
6/06/2019	RJ653	A321	167	1,822	140
7/06/2019	RJ653	A319	110	1,779	97
				Average detour:	**167**
				Average detour (weighted by seats):	**185**

Table 3. Average vs. seat-weighted average detour on the Doha-Amman route, June 1 to 7, 2019 (great circle distance is 1,682 km)

Source: Computed by the authors from FlightRadar and OAG.

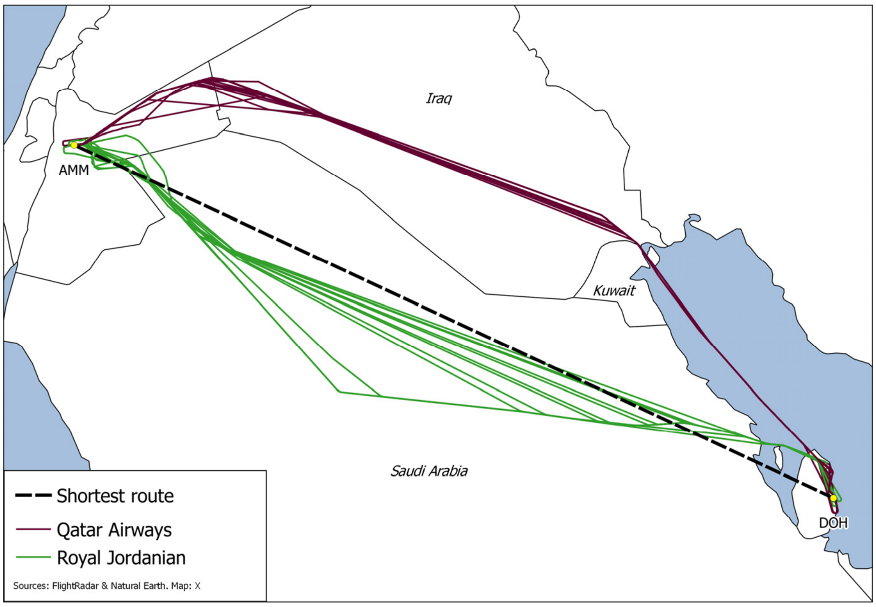

Figure 5. Flight itineraries from Doha (DOH) to Amman (AMM), June 1 to 7, 2019

Gnomonic projection so any distance is maintained.

This paper is in line with authors (including Ren and Li, 2018; Burmester et al., 2018; and Li and Ryerson, 2019) who have highlighted the potential of new big data sources for aviation research in general, but de facto also includes air transport geography. Today, and once ADS-B technology has been fully implemented in aircraft, several new directions for research could be considered (provided ground-level spatial coverage is increased). Such new directions would include works based on the actual trajectories followed by planes and investigations into air procedures in relation to aircraft noise around airports. Indeed, published navigation charts are figurative and need to be controlled by the real tracks flown (Dobruszkes and Peeters, 2017). This is especially interesting for researchers who cannot access flight traces held by Air Navigation Service Providers. In addition, ADS-B makes it possible to capture data on flights that are not part of commercial databases describing air services (such as OAG). This especially includes charter flights, which still account for a significant share of the air traffic in certain regions (Wu et al., 2018). However, as with most sources of big data, quantity does not mean exhaustive coverage, since not all aircraft types or all areas and airports are evenly covered. What is more, most aviation-related new big data sources are proprietary sources (Li and Ryerson, 2019). This usually involves high purchase prices, and thus inequality among scholars.

Finally, the investigation of an apparently obvious topic, namely the distance flown by commercial air services, reveals how much distance – even in its basic, physical form – is still worth investigating. This poses questions for today's air transport geography. Air transport geographers have often engaged in advanced research and the use of complex techniques. But surprisingly, research on the basics of aviation – including its very relationship with physical spaces – has remained underexplored. May this paper encourage scholars to do the groundwork in this direction.

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