TOWARDS A COMMON ANALYSIS OF VERTICAL FLIGHT EFFICIENCY

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Abstract

Significant efforts are underway to modernize global air traffic management systems. Flight efficiency is a major political design criterion. This paper addresses the identification and measurement of ATM related constraints on vertical flight efficiency with a focus on continuous descent operations. Efficiency of flight operations has become a key driver for identifying bottlenecks and constraints imposed by ATM on airspace user preferred flight trajectories. In particular, measures aiming at fuel-efficient operations attract a lot of attention. This paper reports on the work jointly performed by the FAA and EUROCONTROL to address vertical flight efficiency. Based on an empirical study of trajectory data for US and European airports, a vertical profile analysis algorithm has been developed considering research experiences and stakeholder consultations of both teams. This work was performed as the preparatory action of the joint US/Europe comparison report. The results include a joint and harmonized algorithm to describe the vertical trajectory profile and the initial definition of metrics for the performance measurement. This harmonized algorithm will be further be validated and refined as part of the US/Europe comparison report including a wider set of airports. Demonstrating the general feasibility, the algorithm will be further promoted for use in international performance activities under ICAO.

Introduction

In general, flight efficiency aims at offering airspace users the most efficient trajectory on the day of operation. Both the FAA and EUROCONTROL have been assessing trajectory-based flight efficiency measures in order to identify opportunities of ATM improvements for their respective systems. Efficiency of flight operations has become a key driver for identifying bottlenecks and constraints imposed by ATM on airspace user preferred flight trajectories. To date, the abstraction of a user-preferred trajectory is commonly modelled as a direct flight / shortest route from the departure aerodrome to the destination. This is referred to as horizontal flight efficiency. Although the assessment of direct flight has been the primary indicator for flight efficiency, both the FAA and EUROCONTROL have developed analysis procedures for the vertical profile which strive to translate the full trajectory inefficiencies into a fuel benefit for the airlines. This is a complex task that requires accurate trajectory data as well as links to aircraft performance models which relate aircraft flight profiles to fuel burn. In these cases, the "ideal" flight would be in continuous ascent or continuous descent with flights ascending to their ideal fuel burn altitude absent flight level capping due to ATM constraints.

With respect to the latter, political priorities and airspace user expectations aiming at fuel-efficient continuous descent operations have attracted a lot of attention throughout the recent years. Many current ATC modernization projects are focused on improved flight trajectories through Performance Based Navigation. Assessing these benefit opportunities will require procedures for identifying altitude/level changes in the complete profile of the flight, and – in particular – the descent phase. In order to establish globally comparable results, a harmonized interpretation of these profile changes and the related parameters is a key requirement.

This paper reports on the work jointly performed by the FAA and EUROCONTROL to address vertical flight efficiency and develop a harmonized vertical profile analysis algorithm with the aim to promote its usage within the global ATM performance community. This work was carried out in the context of a Memorandum of Cooperation between the United States of America and the European Union on the promotion and development of civil aviation research and development, specifically its Annex II on air traffic management performance measurement. The vertical profile analysis algorithm has been developed based on an empirical study taking into consideration the research, experiences, and stakeholder consultation of both parties. The existing US and European algorithms focused on the extraction of level flight segments utilizing different parameters. Initial comparisons of these algorithms and associated criteria/parameters helped to identify shortfalls and areas for improvement, and resulted in the joint development of a vertical profile analysis algorithm. This paper reports on the initial work and validation of the algorithm on the basis of a small sample set of US and European airports for the year 2015.

This paper is organized as follows: The introduction establishes the high-level perspective on the harmonized evaluation of descent operations. The next section reviews the related ICAO material and previous work. This is followed by the description of the conceptual approach and the associated conceptual building blocks for developing a harmonized algorithm. These are instantiated and briefly discussed in the results section. The paper wraps up with a conclusion and some recommendations for further work.

Background

Global Guidance

Efficient flight operations are a priority of ICAO and can be found back in all on-going developments and activities, such as the global Aviation System Block Upgrades (ASBU) [1] and the update of the Global Air Navigation Plan (GANP) [2]. Both, the ASBU concept and GANP point at performance enablers at and around airports. Continuous descent operations (CDO) are identified – inter alia – as one of the initial improvements steps.

CDOs have gained significant attention throughout the recent years. It is understood that CDOs address various aspects of the “efficiency spectrum”:

- Fuel-efficiency – costs: airspace users have a strong interest in operating aircraft in a fuel-efficient manner by avoiding fuel-burn due to ATM/ATC related constraints and hence directly influencing the operational costs.
- Environment – emissions: emissions are directly related to fuel-burn. Lower fuel-burn will accordingly result in lower emissions. In that respect CDOs are also linked with the CO_2 footprint of aviation and will support the ambitious goals set out for the contribution of aviation to the world-wide emissions.
- Environment – noise: Vertically efficient operations also positively affect the noise contour at and around airports. With an increasing sensitivity of the non-travelling public to aviation operations, the positive reduction of descent-related noise contributions can ensure higher acceptance in terms of traffic growth.

The implementation of CDOs is seen as a vital contribution to address this spectrum. Equally, being able to measure the constraints imposed by ATC/ATM on such operations is a key capability ranging from airspace and procedure design through tactical interventions by air traffic controllers, including arrangements between adjacent air traffic units.

ICAO Document 9931 describes CDO as “an aircraft operating technique aided by appropriate airspace and procedure design and appropriate ATC clearances enabling the execution of a flight profile optimized to the operating capability of the aircraft, … The optimum vertical profile takes the form of a continuously descending path, with a minimum of level flight segments only as needed to decelerate and configure the aircraft or to establish on a landing guidance system (e.g. ILS)” [3]. Conceptually, CDOs are understood to commence from top of descent (TOD) and end at touchdown. Given prevailing safety and operational procedures, the latter can also be considered as a point close to touchdown from which the paradigm of low thrust / low drag is overridden by procedural aspects (e.g. ILS or PBN approach constraints after the final approach fix).

Previous Work

Both the FAA and EUROCONTROL have been assessing trajectory-based flight efficiency measures in order to identify opportunities of ATM improvements for their respective systems. Europe in fact has been using a trajectory measure as part of the European Performance Scheme [4]. This measure calculates what is called “horizontal flight inefficiency.” This horizontal inefficiency is an indicator of direct flight and tracks the degree to which flight distances between city pairs are increasing or decreasing. For flight distances in which wind is a second order effect, it is a proven useful indicator for tracking progress in flight efficiency. The vertical part of the trajectory was not considered mainly due to limitations in the availability of Europe-wide surveillance data. The US also produces this type of measure for identifying strategic opportunities to improve flight trajectories.

A joint paper was presented by the FAA and EUROCONTROL that focused on estimating benefit pools that ATM could potentially influence in the descent phase of flight [5]. The paper explored the benefits of reducing speed in cruise to minimize inefficiencies in the descent phase due to holding. The proposed methodology evaluated both vertical and horizontal efficiency components within 100NM of the arrival airport to calculate potential fuel savings per flight based on the time inefficiency. The two main indicators of inefficiency in the paper were level flight (vertical component) and the detection of excess distance (horizontal component). For the vertical component, efficiency was calculated by comparing the fuel needed to fly the observed level segment in its descent altitude to the scenario where the level segment inefficiency is removed. The results of the paper showed that at busy airports, such as the New York airports, most of the exhibited inefficiencies are directly related to the need to sequence aircraft.

In addition, FAA and EUROCONTROL produced several papers, including CANSO guidance (e.g. [6]), that integrated the assessment of level-offs in the vertical profile during descent for the purpose of obtaining a more complete fuel benefit pool for approach procedures. While these attempts are targeted at addressing the question at hand or meet the organizational requirements, work on a harmonized approach for assessing the vertical flight profile of trajectories based on measured surveillance data has not been promoted extensively so far.

Conceptual Model

Trajectory Model

The underlying conceptual model of vertical flight operations is an abstraction of the flight profile in distinct portions (i.e. segments). This profile is based on measured trajectory data (4D position) of aircraft operations. A trajectory is therefore represented by the time-ordered set of 4D measurements associated to one flight, typically describing the flight path from the airport of departure to the airport of destination. This concept supports the empirical evaluation, as the model does not depend on aircraft performance models and classical total energy considerations that would require additional aircraft- and flight-specific data. Fig. 1 depicts a principal vertical flight profile.

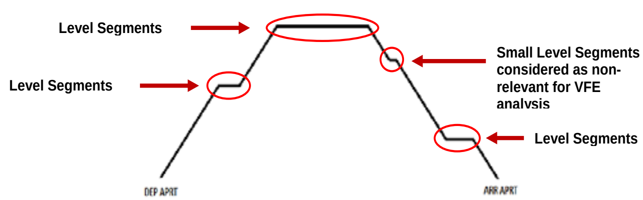

Figure 1. Vertical Flight Profile

With Fig. 1 the analysis problem can be reformulated as reconstructing the segments that describe climb, level, or descent operations. The conceptual approach is therefore to map the 4D positions to tuples describing the respective segments:

$$t(p_1,\ldots, p_n) \rightarrow$$
$$seg([1, p_{1s}, p_{1e}, v_1], \ldots [m, p_{ms}, p_{me}, v_m]$$

t: a flight trajectory, i.e. time-ordered 4D positions p_n,;

seg: the set of segments each described by a tuple and *m*: index of the flight segment tuple; segment start point p_{ms} and its associated endpoint p_{me}, and v_m the vertical movement label for the m-th segment (i.e. level, climb, or descent).

Harmonized Vertical Profile Analysis Algorithm

Following the initial discussion of the data analysis approaches in the US and Europe, it became apparent that data characteristics are the major factor for the development of a harmonized algorithm. In particular, the algorithm would need to address the following aspects:

- varying sampling rates: trajectory data are currently measured with a 5 to 12 second measurement rate in the US, whereas in Europe, the trajectory data is collected from national position reporting with an average of 30 to 40 second update interval. Novel techniques like ADS-B may make trajectory data possible with update rates of one second during ground, take-off, and landing.
- data granularity: strongly linked with the sampling rate is the accuracy of measurement in terms of vertical change (i.e. altitude granularity) and or positional information (i.e. latitude and longitude granularity). Altitude data is currently reported in hundreds of feet while more granular measurements in 25-feet increments are likely to be available in the near future (e.g. ADS-B).
- general data-quality: data imperfections in terms of incorrect measurements (e.g. significant horizontal or vertical displacements) or major data gaps should be addressed appropriately.

To address these aspects, the following pseudo-code workflow was devised (c.f. Fig. 2). The process builds on the 4D data collected through the different processes. In the initial stage, these data are cross-checked to meet the minimum requirements in terms of coverage (i.e. geographical scope of the study) and data artifacts. In particular, data imperfections concerning the 4D positions of each trajectory (e.g. lateral or temporal jumps, altitude glitches) are assessed. For this paper no detailed quality assurance has been implemented. Trajectories would be removed from the study sample, if the coverage shows significant gaps for the study area (e.g. 200NM radius around the destination airport). Singular vertical glitches would be replaced by a linear interpolation.

The pre-processing stage revolves around the imputation of study specific points of interest (c.f. below). This is done to ensure defined start- or end-

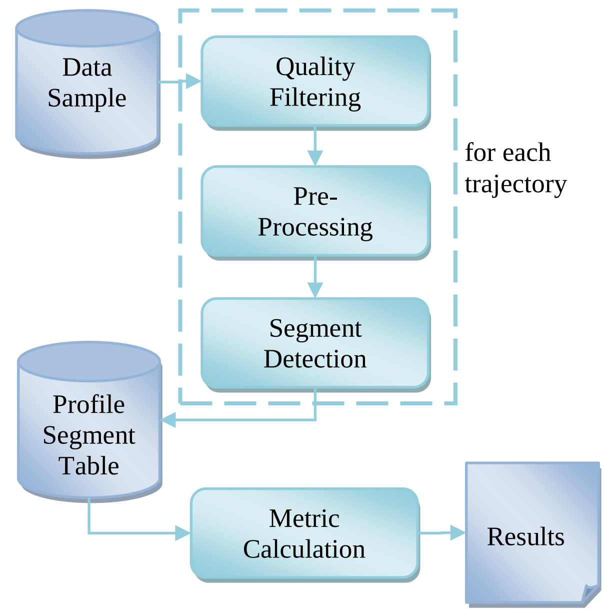

Figure 2. Harmonized Vertical Profile Workflow

points for segments that can be modelled as a 4D position (e.g. procedure points, intersection with ILS glide path). Dependent on the scope of the study, the data sample, i.e. set of trajectories, may be filtered during this stage for memory reasons.

The next stage represents the actual segment detection. For this purpose two parameters are defined:

- vertical speed threshold; and
- vertical altitude threshold.

Segments are considered level if the vertical speed is less than or equal to the vertical speed threshold and the altitude difference is less than or equal the vertical altitude change threshold. If these conditions are not met, the segment is labelled as climb or descent respectively. For each segment, the segment altitude is determined as the average altitude of the current point and the previous points associated with the segment. This procedure is then repeated for the next trajectory point and iteratively produces a profile segment table.

The segment table is the input for the evaluation stage. Based on the respective start and end points of the segments, the associated time and distance flown can be calculated. Aggregation of the latter allows then for the evaluation of the level segments. In order to capture data artifacts (e.g. short level segments due to vertical data granularity limitations, sensor uncertainties) level segments shorter than 0.5 NM or 30 sec are filtered out.

Point of Interests - Top of descent

The vertical profile algorithm presented in this paper uses a 200NM radius from an arrival airport as a starting point for detecting the start of the descent phase. A CDO based top of descent (ToD) is defined to exclude level segments that should be attributed to the cruise phase of flight after the 200NM radius. The ToD-CDO version first determines where ToD within a 200NM radius (ToD-A200) occurs and then searches for the ToD-CDO point by excluding any level segments greater than 5 minutes and in the altitude band at or above 90% of the ToD-A200 altitude.

If the calculated 4D radius location (A200 point) occurs during a level off, then the ToD-A200 point is at the end of the segment as in Fig. 3. Because the next level segment after ToD-A200 was within 10% of the segment end altitude and greater than 5 minutes, the ToD-CDO location is defined as the end of the next segment in the red exclusion box below.

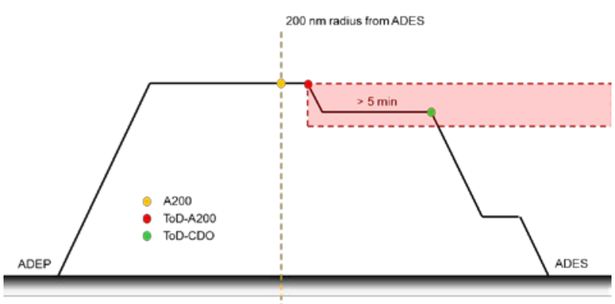

Figure 3. A200 Radius in Level

If the radius location (A200 point) occurs during a descent portion, then the ToD-A200 point is equal to the ToD-A200 point. Again, if the next level segment is within 10% of ToD-A200 altitude and is > 5 minutes then ToD-CDO is pushed back to the end of the last segment as shown in Fig. 4. If no segments match the criteria for ToD-CDO, then ToD-CDO equals ToD-A200.

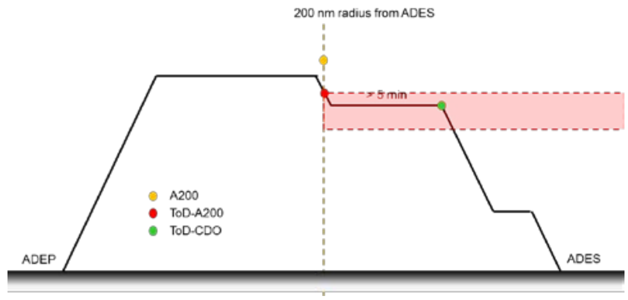

Figure 4. A200 Radius in Descent

Results

Data-Sample

The work in this paper builds on a data sample for the peak day of the top-5 airports in the US and Europe (c.f. Table 1 and Table 2). The data is collected through the existing performance data processes. FAA analysis is performed using RADAR position information reported at 12 second intervals (en-route) or 5 second intervals (terminal). Position information was analyzed for the top 5 US airports by total IFR operations for the uniform peak summer day, July 16, 2015. Within the European context, national ANSPs provide their surveillance data augmented by flight plan information to the Network Manager.

Table 1. Top 5 US Airports, July 16, 2015

Top 5 US Airports	Operations
Hartsfield-Jackson Atlanta Intl. (ATL)	1189
Denver Intl. (DEN)	758
Dallas-Fort Worth Intl. (DFW)	894
Los Angeles Intl. (LAX)	731
Chicago O'Hare Intl. (ORD)	1093

Table 2. Top 5 European Airports, Aug. 28, 2015

Top 5 European Airports	Operations
Amsterdam (EHAM)	705
Paris – Charles de Gaulle (LFPG)	733
Frankfurt (EDDF)	698
London Heathrow (EGLL)	679
Munich (EDDM)	557

Given the local settings these data feeds are provided on 30 seconds to 1 minute intervals. The selected peak day for the European airports was August 28, 2015.

Initial Comparison

The harmonized vertical profile algorithm was used to process the aforementioned flight trajectory data. To help validate results, the same data was also run through existing EUROCONTROL and FAA level segment extraction algorithms. The outcome of each algorithm was a set of level segments, which were furthermore filtered to only include segments exhibiting the following characteristics:

- a start time after the top of descent (ToD-CDO),
- an altitude greater than or equal to 1800 feet, and
- a duration greater than or equal to fifty seconds; however, in the case of the EUROCONTROL methodology, the duration filter was lowered to twenty seconds

These filtering criteria were used during analysis to adequately capture relevant level segments during the descent phase of flight, e.g. short level segments that only last a few seconds may be unintended level-offs that are actually a part of a gradual descent.

Based on the filtered set of level segments, summary statistics were computed to assess level flight behavior across algorithms and airports. One measure of level flight is the average distance flown level per flight, which is plotted in Fig. 5. For the US airports (ATL, DEN, DFW, LAX, and ORD), the results for the FAA and harmonized methodologies appear to be almost the same, while the EUROCONTROL method trends slightly higher. The differences in average level distance are bigger for the European airports; this is probably directly related to the update interval of the data which is much higher for the US flights. For this set of airports, the EUROCONTROL algorithm reports the highest average level distance, while the FAA method shows the lowest averages; the harmonized vertical algorithm lies somewhere in between.

Flight Segment Detection

In order to better understand how the different methodologies result in varying values for the average level distance, two flights—one EU and one US—were selected for a closer examination of level segments. Flight A, which arrives in ATL on July 16th, 2015, has level segments as depicted in Table 3. The table shows level segment assignments as determined by each of the method-

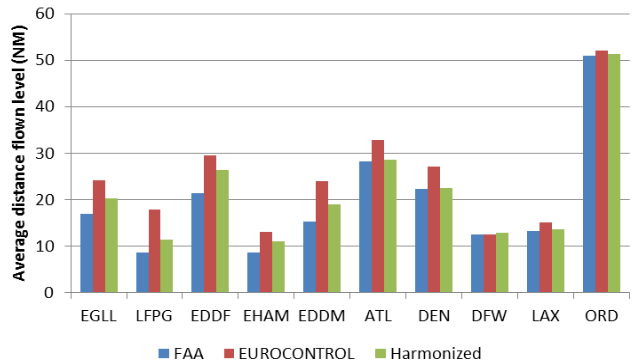

Figure 5. Results with the different algorithms

ologies. The FAA and the harmonized vertical profile approach report a single level segment during the descent phase for this flight; even though the segment does not start and end at precisely the same time, the level distance and level time are nearly the same. The EUROCONTROL methodology detects the aforementioned level segment, albeit shorter in duration, as well as a later level segment lasting less than 40 seconds. Due to its brevity, the other methodologies filter out this second segment. This flight example mirrors the US airport-level summary in which the FAA and harmonized methodologies identify similar level flight, while the EUROCONTROL approach detects greater levels, partly due to its less restrictive filtering criteria.

The other flight (B) in Table 3 represents an aircraft arriving at LFPG on August 28th, 2015. This flight illustrates the overall European airport trend in which the FAA method detects the least level distance flown (in this case 18.5 + 12.8 NM), the EUROCONTROL approach identifies the most level distance (26.5 + 13.0 + 23.2 NM), and the harmonized algorithm lies somewhere in between (26.5 + 13.0 NM). The cause of the reduced level flight in the FAA method can be attributed to a procedure that, under certain conditions, trims the ends of level segments. Level flight numbers according to the EUROCONTROL version trend higher due to the inclusion of more level segments. In this particular case for flight B, the third and

Table 3. Table of level segments for two sample flights as obtained from three extraction algorithms

	FAA				EUROCONTROL				HARMONIZED			
ID	Start Time	End Time	Dist [nm]	Time [sec]	Start Time	End Time	Dist [nm]	Time [sec]	Start Time	End Time	Dist [nm]	Time [sec]
A	00:44:27	00:45:24	4.8	57	00:44:37	00:45:25	4.0	48.1	00:44:27	00:45:25	4.8	57.7
A					00:50:53	00:51:31	2.6	38.6				
B	14:11:06	14:13:48	18.5	162	14:10:39	14:14:19	26.5	220	14:10:39	14:14:19	26.5	220
B	14:17:58	14:19:49	12.8	111	14:17:58	14:19:49	13.0	111	14:17:58	14:19:49	13.0	111
B					14:35:52	14:42:02	23.2	370				

final level segment meets the vertical speed threshold but is not included in the other methodologies because it breaks the altitude change threshold.

This comparison of level segments showcases differences in terms of 1) the number of flight segments and 2) the actual distance and duration values calculated for each segment. The comparison also suggests that while the FAA methodology works well for processing US flight track data, it may not possess the robustness for processing the sparser EU track data. Likewise, the EUROCONTROL approach may more accurately detect level segments in EU data than in US data.

The harmonized approach seeks to bridge the gap and combine strengths from the existing FAA and EUROCONTROL implementations. In the case of flight A, a US flight, the harmonized algorithm produced results similar to the native FAA implementation. Similarly, for flight B, a European flight, the harmonized algorithm exactly matched certain aspects of the native EUROCONTROL methodology. The new methodology builds on previous work and serves as an initial harmonized method for measuring and comparing vertical flight efficiency. Thus, for the airport-related examples that follow, results of the harmonized methodology are shown.

Airport-related analysis - Examples

Based on the harmonized algorithm, the vertical profiles for the top-5 airports in the US and Europe have been analyzed. The following figures show use-cases with considerable level segments during the last 200 NM of the flight. In Fig. 6 level segments are marked in red, while descent operations are presented in blue.

For the US, Dallas/Fort Worth International (DFW) was selected due to it being part of the North Texas Metroplex NextGen project. The Metroplex project aids in reducing significant level flight with the development of PBN procedures and airspace redesign. Although DFW is not one of the top US airports with excess level flight, its significant decrease from 2014 to 2015 made it a good candidate for overall analysis.

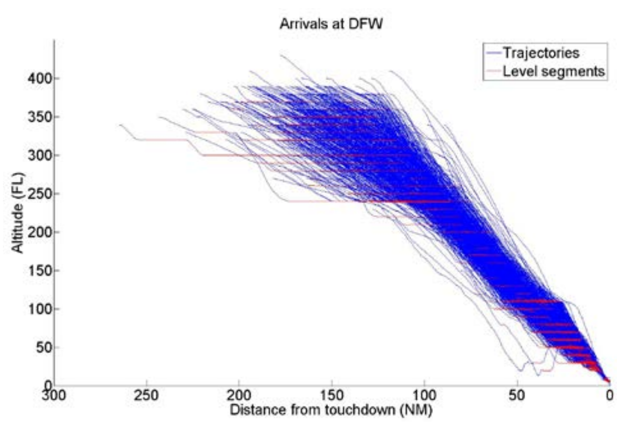

Figure 6. DFW Arrivals Vertical Profile

Fig. 7 shows a horizontal trajectory path for arrivals into DFW. Due to the creation of PBN procedures that establish dedicated arrival routes, arrivals into DFW show limited congestion in the airspace. Following from the vertical profile, Fig. 8 shows the distribution of the level segments. In this example, a significant share of level flight operations occurs around FL50. The lower level segments can be attributed to the procedural alignment with the ILS or final approach procedure.

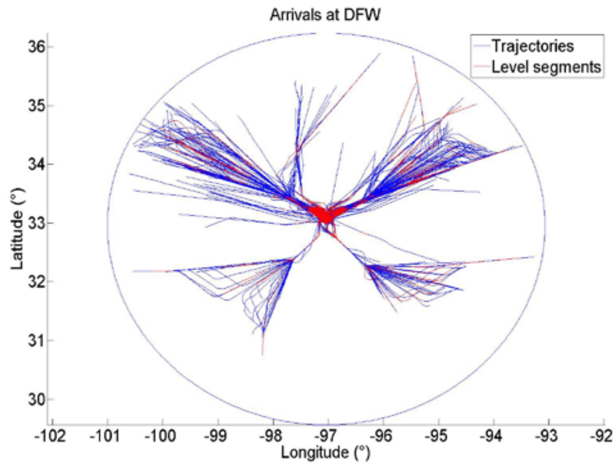

Figure 7. DFW Arrivals Horizontal Profile

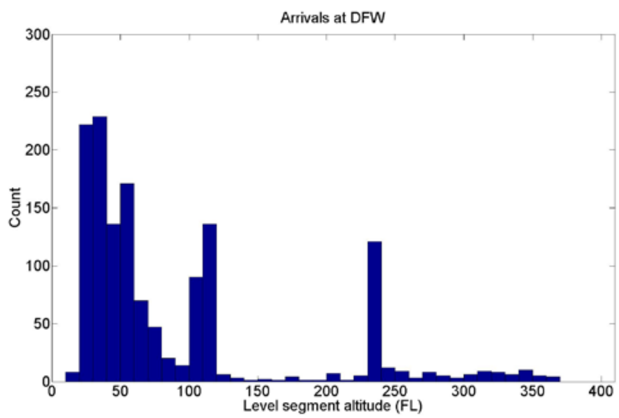

Figure 8. DFW Level Segment Altitude Dist.

For Europe, Frankfurt Airport (EDDF) was selected due to the high amount of level flight when compared to other airports with an equivalent number of movements. Fig. 9 shows the vertical trajectory paths in terms of time flown while Fig. 10 illustrates the lateral trajectory paths for arrivals into EDDF. For each of the approach flows a clear procedural level off segment is identifiable before the flight is handed over to the approach controller. The highest concentration of level flight occurs below FL120. A considerable number of level offs are observed at FL100 (+/- 2000ft) which reflects a procedural handover altitude. The share of level offs at FL50/40/30 represent the pattern altitudes for vectoring and the alignment with the ILS (c.f. Fig 11).

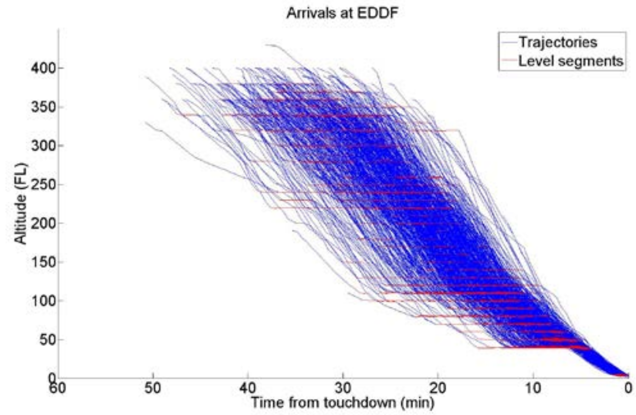

Figure 9. EDDF Arrivals Vertical Profile

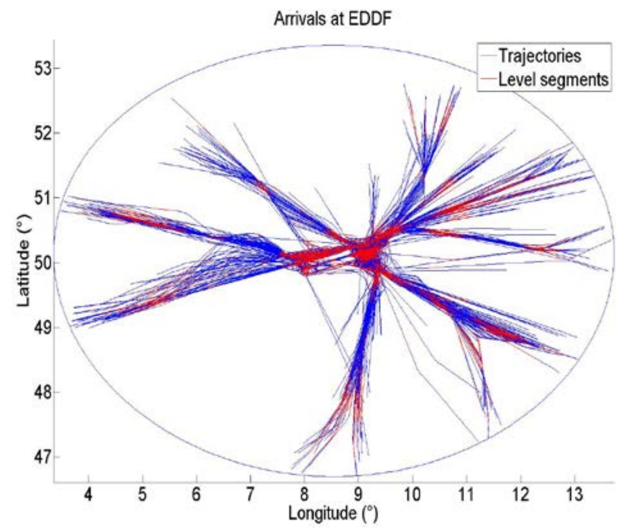

Figure 10. EDDF Arrivals Horizontal Profile

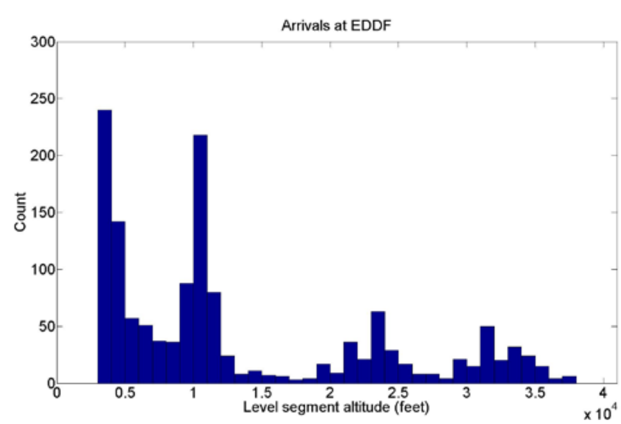

Figure 11. EDDF Level Segment Altitude Dist.

Drill-Down

The following figures take a closer look at a particular arrival fix-runway combination at Chicago O'Hare (ORD) on July 16, 2015. Flights arriving from the southeast corridor and landing on runway 27L contribute the most amount of level flight to ORD.

Recent changes to FAA air traffic policy and a new airport layout plan (O'Hare Modernization Program) have led to a reconfiguration of runway patterns at ORD, shifting the flow of planes to a predominant east-west traffic pattern. A majority of aircraft arrives from the east and departs from the west.

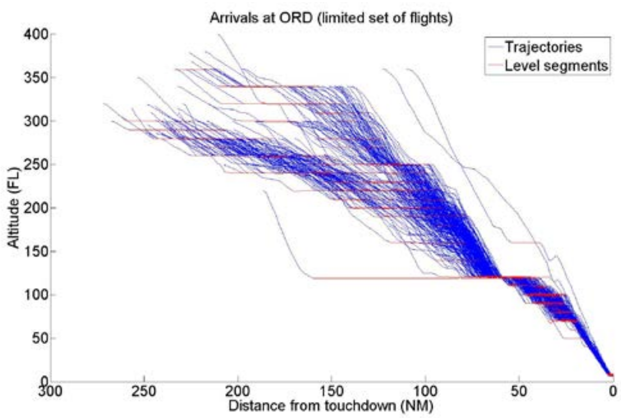

Figure 12. ORD Arrivals Vertical Profile

Due to the increase in arrivals from the east, a concentration of level flight occurs between FL50 and FL100.

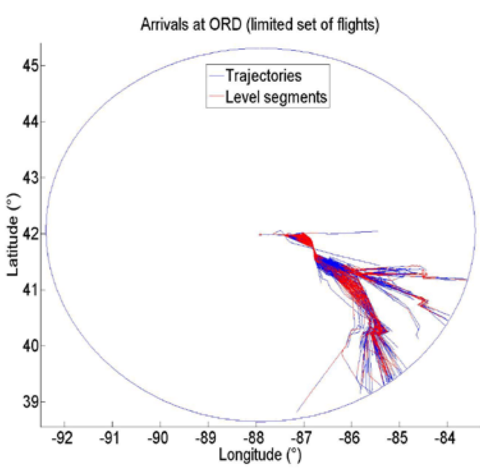

Figure 13. ORD Arrivals Horizontal Profile

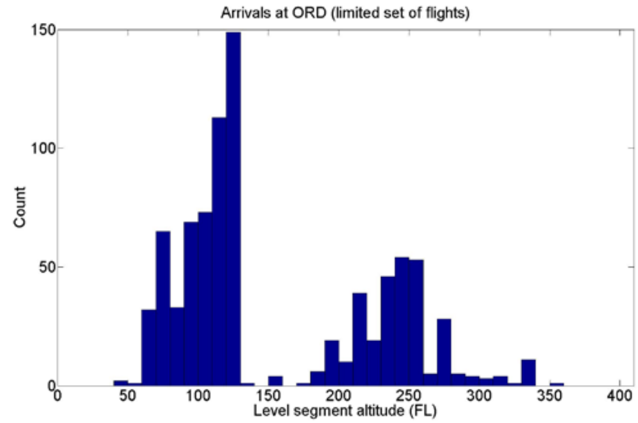

Figure 14. ORD Level Segment Altitude Dist.

The south-easterly arrival stream of flights into London Heathrow was chosen for the European example. Fig. 15 through Fig. 17 highlight the impact of procedural holding patterns on vertical flight efficiency. The time-based vertical profile depiction in Fig. 15 reveals the regular pattern of holding aircraft between FL150 and FL70. Furthermore FL50/Alt 5000ft appears to be a procedural level off for a considerable number of flights and the alignment with the final approach segment.

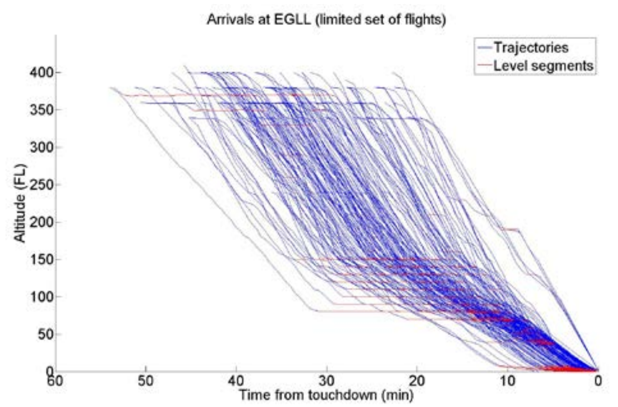

Figure 15. EGLL Arrivals Vertical Profile

The horizontal presentation in Fig.16 shows the actual position of the holding stack. Considering the proximity of the holding stack and the duration of the level segments depicted in Fig. 15 the ATC procedure of "loading the holding stacks" to "ensure pressure on the runway" is clearly identifiable. Fig. 17 confirms the observations by showing the distribution of the level segments.

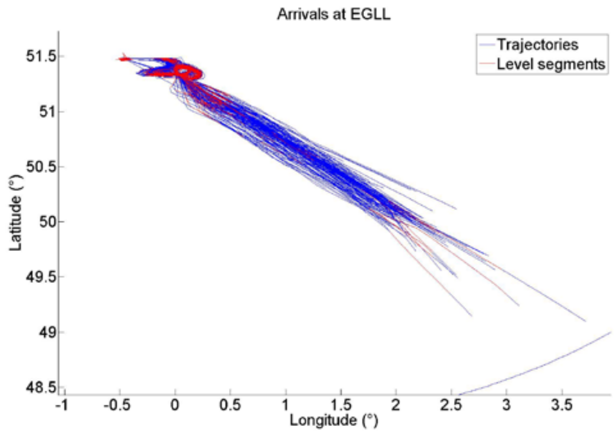

Figure 16. EGLL Arrivals Horizontal Profile

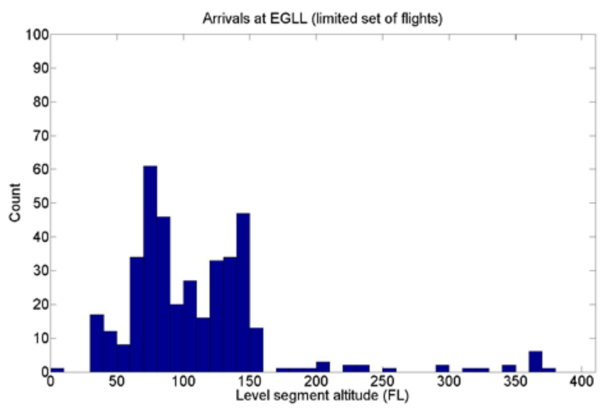

Figure 17. EGLL Level Segment Altitude Dist.

Conclusions

This paper addresses the identification and measurement of ATM related constraints on vertical flight efficiency as part of the operational ATM performance measurement process. Based on the joint work of FAA and EUROCONTROL a harmonized vertical profile analysis algorithm has been developed. The research reported in this paper has been conducted as a preparatory action for the US/Europe comparison report. The empirical work comprised the analysis of differences of the US and European approaches and the respective parameters. Furthermore, the vertical profiles of the top-5 airports in terms of IFR movements in 2015 in the US and Europe were analyzed.

The examples presented in this paper show the predominantly procedural nature of level segments within 200NM from the arrival airports. Accordingly, there is room for improvement by ATC to meet the airspace user expectations and contribute to reduced fuel-burn. Nonetheless, the trade-off between safety, the synchronization and separation of air traffic, and the reduction of procedural level segments or the increased application of CDOs needs to be studied further.

This paper presented the initial work and focused on the development of a harmonized vertical profile analysis algorithm. The validation of this joint algorithm was performed based on the experience of both groups and a subset of the US and European airports. This included the feedback from discussions with airspace users that were underway during this preparatory action. The parameters chosen are strongly informed by this prior knowledge and consultation mechanism and may need to be revisited as part of a wider validation activity.

The common method for the identification of vertical flight profile segments to support the operational benchmarking described in this paper is developed and will be used in the upcoming US/Europe comparison study. It serves as a blueprint to measure vertical flight efficiency in other regions or ATM performance comparison exercises. Combining these results with an aircraft performance model can support stakeholder consultations with airlines and manufacturers to address fuel benefits of efficient vertical flight operations.

The work presented in this paper revolved around the joint development of a harmonized vertical profile analysis algorithm. As one of the related research activities, the findings can be readily transposed to departure operations and the assessment of continuous climb operations. Another research thread can be seen in the integration of the vertical profile assessment in the benefit pool for operational ATM performance and the identification of recommendations for operational improvements. The declared objective of the development activities is the prototyping of a software module – possibly implemented in Java – for international application and re-use under the umbrella of ICAO.

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The views expressed in this paper are the authors's own and do not represent a policy or position of the FAA or EUROCONTROL.

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