Title

A new bottom-up emissions estimation approach for aircraft sources in support of air quality modelling for community-scale assessments around airports

Journal
International Journal of Environment and Pollution, 65(1-3)

ISSN
0957-4352

Authors
Arunachalam, Saravanan
Naess, Brian
Seppanen, Catherine
et al.

Publication Date
2019

DOI
10.1504/ijep.2019.101832

Peer reviewed

Published in final edited form as:
Int J Environ Pollut. 2019 ; 65(123): 43–58. doi:10.1504/IJEP.2019.101832.

A new bottom-up emissions estimation approach for aircraft sources in support of air quality modelling for community-scale assessments around airports

Saravanan Arunachalam[1], **Brian Naess**[1], **Catherine Seppanen**[1], **Alejandro Valencia**[1], **Jo Ellen Brandmeyer**[1], **Akula Venkatram**[2], **Jeffrey Weil**[3], **Vlad Isakov**[4], **Timothy Barzyk**[4]

[1.] Institute for the Environment, University of North Carolina at Chapel Hill, NC 27517, USA

[2.] Bourns College of Engineering, University of California, Bourns Hall A343, Riverside, CA 92521, USA

[3.] University Corporation for Atmospheric Research, Boulder, CO80305, USA

[4.] Office of Research and Development, National Exposure Research Laboratory, US Environmental Protection Agency, Research Triangle Park, NC 27711, USA

Abstract

Transportation infrastructure (including roadway traffic, ports, and airports) is critical to the nation's economy. With a growing economy, aircraft activity is expected to grow across the world. In the US, airport-related emissions, while generally small, are not an insignificant source of air pollution and related adverse health effects. However, currently there is a lack of tools that can easily be applied to study near-source pollution and explore the benefits of improvements to air quality and exposures. Screening-level air quality modelling is a useful tool for examining urban-scale air quality impacts of airport operations. Spatially-resolved aircraft emissions are needed for the screening-level modelling. In order to create spatially-resolved aircraft emissions, we developed a bottom-up emissions estimation methodology that includes data from a global chorded inventory dataset from the aviation environmental design tool (AEDT). The initial implementation of this method was performed for Los Angeles International Airport (LAX). This paper describes a new emissions estimation methodology for aircraft emissions in support of community-scale assessments of air quality around airports and presents an illustration of its application at the Los Angeles International Airport during the LAX 2011/2012 Air Quality Source Apportionment Study.

Keywords

air quality; exposure; airports; aircraft emissions; environmental pollution; aviation environmental design tool; AEDT; Los Angeles International; LAX

1 Introduction

Transportation infrastructure (including roadway traffic, ports, and airports) is critical to the nation's economy. With a growing economy, aircraft activity is expected to grow across the world. In the US, airport-related emissions, while generally small (< 1% of all anthropogenic sources in the US), are not an insignificant source of air pollution, and related adverse health effects. Several recent studies have shown the relative contribution of aircraft emissions from landing and take-off (LTO) operations to full flight during cruise modes to surface air quality as well as to adverse health effects. Arunachalam et al. (2011) estimated that LTO operations at the Atlanta Hartsfield airport (the largest in the world based on annual operations) can contribute to eight premature mortalities per year, due to exposure to fine particulate matter ($PM_{2.5}$). Levy et al. (2012) showed that 2005 aircraft LTO operations in the US can contribute to 75 premature mortalities, and this estimate can increase by a factor of 6 by the year 2025. On a global scale, Yim et al. (2015) estimated that full flight aircraft operations contribute to 16,000 premature mortalities, with LTO operations contributing to about 25% of these. Furthermore, Barrett et al. (2012) showed that switching to an ultralow Sulphur jet fuel standard (ULSJ) containing 15 ppm sulphur from a global average of 600 ppm sulphur could help prevent 900–4,000 premature mortalities. While many of these studies are global or national in scale, models are also used at a local scale to study near-source impacts in the immediate vicinity of the airport. However, currently there is a lack of tools that can easily be applied to study near-source pollution at a single airport and explore the benefits of improvements to air quality and exposures due to mitigating programs related to aircraft operations. Screening-level air quality modelling is a useful tool for examining what-if scenarios of changes in emission volume, such as those due to changes in aircraft operations and thus airport emissions. Barzyk et al. (2015) developed a web-based interactive tool called C-LINE to assess changes in air quality due to transportation emissions. Isakov et al. (2017) extended this tool to study near-source impacts of port-related emissions. In both these tools, the emphasis is on using models in a screening mode to look at the impacts of changes in inputs (e.g., emissions, meteorology) on near-field air quality exposures. There is a need to extend these tools further to characterise air quality impacts from airport operations. To address this research gap, we developed a custom approach for building aircraft emission inventories.

Previous approaches for modelling air quality near airports are designed to incorporate flight activity data. Within the United States, the Federal Aviation Administration’s aviation environmental design tool (AEDT) (FAA, 2014) is the designated software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality impacts. AEDT is designed to model various scales ranging in scope from a single flight at an airport to scenarios at the regional, national and global levels.

However, given the goal of the tool to assess changes in near-field exposures due to various ‘what-if’ scenarios, a new approach is needed for building an emission inventory that allows the user to change either aircraft activity or emission factors at the same time. Specific changes that may lead to changes in air quality at an airport include the following: changes in flight paths, aircraft/engine types, fuel content and associated emissions indices (EI) (such as change in fuel from traditional jet fuel to various alternate jet fuels), thrust levels, etc. Given the interdependency between aircraft operations and associated combustion efficiencies, the emissions preparation should allow the user to explore one or more of these in concert to assess changes in related air quality.

2 Modelling approach

In recent years, several studies have been undertaken by airport authorities to study their impacts on ambient air quality as well as assess health risk due to airport-related emissions. However, given the complex mix of emission source types related to an airport (stationary sources, on-road traffic sources, and aircraft sources), there is no established process for modelling airports. Airport practitioners in the US currently use the AEDT for modelling local air quality (FAA, 2014). AEDT, the required regulatory emissions and dispersion model for US airports, employs the Environmental Protection Agency's (EPA's) AERMOD dispersion model (Cimorelli et al., 2005). The Transportation Research Board (TRB), through its Airport Cooperative Research Program (ACRP) mechanism, has identified a research need to provide guidance for airport practitioners in selecting and utilising dispersion models to address local air quality and related health concerns. The new approach uses a dispersion model with emission inputs based on a custom approach for defining aircraft emissions to conduct a screening assessment of local air quality and examine possible what-if scenarios of changes in airport emissions.

This paper focuses on the emissions methodology that will be coupled to the dispersion modelling approach that will be published in a future manuscript, along with detailed evaluation against observations from a comprehensive field study described below. The dispersion model treats each of the paths corresponding to each flight mode [taxi, take-off roll, take-off (TO), climb out (CO), land] as a set of sources laid along the path. Each source along the path is treated as a line source that is perpendicular to the path. The length of the line source corresponds to the wing span of the aircraft to simulate the horizontal mixing induced by aircraft generated turbulence and wingtip vortices. Vertical mixing is simulated using an initial vertical spread of the aircraft plume. Emissions along each path are distributed among the set of these sources; dispersion from each of which is to be treated with the analytical model used in RLINE (Snyder et al., 2013). Plume rise from each line source is treated using a model that accounts for the horizontal momentum of the jet exhaust in addition to its buoyancy.

3 Results: application at the Los Angeles International Airport

The Los Angeles International (LAX) airport was selected for this test case. The LAX airport is consistently ranked in the top ten busiest airports in the world in terms of total passengers. Arunachalam et al. (2016) recently applied four different dispersion models – AERMOD, ADMS-Airport (CERC, 2015), CALPUFF (Earth Tech, 2000), and SCIPUFF (Sykes and Henn, 1995; Sykes et al. 2014) – for the LAX airport and evaluated them against observations from the LAX Air Quality Source Apportionment Study (AQSAS) conducted in 2011–2012. The results from this study were developed into a guidance document for airport operators (Arunachalam et al., 2017a, 2017b). This guidance document identified several areas of improvement in dispersion models for aircraft sources. These include source characterisation, i.e., how best to represent aircraft sources in dispersion models, and incorporating/enhancing plume rise from engine exhaust in dispersion models. These recommendations from this guidance document to improve aircraft emission inputs and dispersion modelling techniques directly support the motivation for this research. We describe below our approach for building the LAX airport aircraft inventory. Specifically, the treatment of aircraft sources as line segments and incorporating of plume rise from aircraft exhaust represented as line sources are the key novel aspects of this methodology. All non-aircraft emissions at LAX airport were the same as used in the LAX AQSAS.

3.1 Data sources for emissions inventories

We used data from a global chorded AEDT dataset for the year 2015 and extracted all records where the arrival or departure airport is LAX. The global dataset was generated using the methods described in Wilkerson et al. (2010). This included the following fields: departure/arrival airport, aircraft type, engine code, engine count, emissions mode, speed, time, thrust, weight, fuel burn, and emissions values for carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulphur oxides (SO_x), particulate matter (PM), and carbon dioxide (CO_2). In addition to this, we compiled emission indices as a function of aircraft thrust from the International Civil Aviation Organization (ICAO)'s Aircraft Engine Emissions Databank, (ICAO, 2017), aircraft manufacturers' data, and LAX flight operations data from the LAX AQSAS.

3.2 Time p

For this illustrative example, we first extracted aircraft operations for the months of January (representing winter) and July (representing summer) in 2015. To simplify our modelling approach, we then identified four representative days with two representative hours selected from a peak (6:00 AM to 11:00 PM) and off-peak (11:00 PM to 6:00 AM) time period. We defined the peak and off-peak time periods based on analysis of aircraft activity during these two months. Thus, to model one day, we need only two representative hours, one for peak and one off-peak. Based upon a detailed analyses of hourly flight activity at LAX for January and July, we selected dates/times to represent typical activity for weekday and weekend patterns. The representative days used are the following:

- winter representative days:

  weekday: Thursday, January 15

  weekend: Saturday, January 17

- summer representative days:

  weekday: Tuesday, July 13

  weekend: Sunday, July 25

3.3 Aircraft types

The AEDT database had 179 different aircraft types taking off or landing at LAX in January and July of 2015. To keep the number of aircraft types manageable, we grouped aircraft based on maximum take-off weight (MTOW). The following six groups were used:

- Less than 110,000 lbs
- 110,000–199,999 lbs
- 200,000–349,999 lbs

- 350,000–499,999 lbs
- 500,000–800,000 lbs
- greater than 800,000 lbs.

With only a couple of exceptions, this grouping allows for lumping aircraft series into a single bin as shown in Table 1.

3.4 Engine types

AEDT has 246 different engine codes for LAX arrivals and departures in January/July, and there are many examples of different aircraft types (even across weight classes) using the same engine code, resulting in 415 different engine/aircraft type combinations. Other than the engine power source category (jet, turboprop, or piston), there is no common convention to grouping engines. Using testing dates for turbojet and turbofan aircraft engines from the ICAO Aircraft Engine Emissions Databank, we grouped engines into the following three groups:

- test date in 1970s/1980s, called as OLD
- test date in 1990s/2000s, called as RECENT
- test date in 2010s, called as CURRENT.

Analysis of average AEDT NO_x EI (NO_x emissions divided by fuel burn) in specific emissions modes of the AEDT dataset used during landing/take-off (LTO) cycles alone (within the lowest 10,000 ft) compared well with corresponding ICAO emissions averages (Figure 1). For more information on how AEDT emissions modes match up with ICAO emissions modes, see Table 3. We analysed matching ICAO engine testing data to calculated averages across weight classes to develop representative engine categories as a function of weight class and engine age. This allowed us to use actual ICAO engine emissions testing data to calculate emissions ‘on-the-fly’ for a 6 × 3 matrix of choices: 6 weight classes (< 110 K, 110–200 K, 200–500 K, 350–500 K, 500–800 K, and > 800 K) and 3 engine age classes (OLD, RECENT and CURRENT) in our modelling approach.

3.5 Flight paths

Because the latitude/longitude coordinates in AEDT’s global chorded dataset do not represent actual flight paths during LTO cycles, flight paths and ground paths were drawn in ArcGIS based on AEDT data on speed and distance travelled during off-the-ground emission modes, along with LAX air traffic flow patterns, provided by the Los Angeles World Airports (LAW A). Average distances by emission mode for different weight classes on the representative days, along with average altitudes when emission modes changed, were calculated and used to inform the development of flight paths in a GIS. Care was taken to capture the flow patterns of aircraft accurately. On-the-ground aircraft emissions are assigned to line features developed in a geographic information system (GIS), drawn based on aerial imagery and taxiway images from LAWA, as shown in Figures 2, 3 and 4. Separate links were drawn for each of the six aircraft weight classes, as the average distance travelled varied by weight class.

3.6 Runway utilisation

At LAX, different runways are preferred based on time of day and operations mode. Since AEDT does not provide information about which runway or taxiways were used for a given flight, runway utilisation fractions were also applied to off-the-ground activity. Table 2 summarises the runway utilisation scheme used in the modelling system for LAX.

3.7 Calculating aircraft emissions

After the activity and spatial data are derived for a given airport, we calculated emissions based on ICAO emissions indexes using the mapping from AEDT emissions mode to ICAO engine mode during testing as described in Table 3. Furthermore, as shown in Table 3, ICAO take-off emissions indices can be used for aircraft in emissions mode 2; ICAO climb out emissions indices can be used for aircraft in emissions mode 3; and, ICAO approach EI can be used for aircraft in emissions mode 7. ICAO approach emissions can also be used for landing ground roll with reverse thrusters (emissions mode 8), since the engine power levels are similar. ICAO idle EI can be used for taxiing (0,10) and initial approach (when aircraft descend from 10,000 feet until they are about 2,500 feet above the ground), and ICAO idle emissions can be used at initial touch-down (emissions mode 8). Based on a comparison of AEDT averages between segments in emissions mode 2 and emissions mode 1, emissions during emissions mode 2 are 1.2% larger than emissions mode 1, so this scaling factor is applied to the ICAO take-off emissions indices. Emissions on the segment are therefore calculated by multiplying the emissions index by the fuel flow during testing by the duration of the aircraft on the segment (based on average speeds in emissions modes from AEDT data). This value is then multiplied by the number of engines, which is assumed to be two, except in the case of aircraft in the GT800K weight class. For aircraft parked at the gate, engine emissions are assumed to be zero, since the aircraft is typically using a terminal-based power source (Auxiliary Power Unit or APU) during loading and unloading.

Each flight path segment with particular starting x, y, z and ending x, y, z (in meters) has a representative day/hour, MTOW, emissions mode, runway, and activity. To get the emission (E_i) in grams of a particular segment, we use the following equation:

$$E_i = (EI)(FF)(t)(N)$$

where

EI emission index in g/kg of fuel

FF fuel flow in kg/sec

t duration of flight path segment in sec

N number of engines.

Using AEDT segment data, we obtain EI as a function of fuel flow (FF) from the ICAO Aircraft Engine Emissions Databank.

The flight path segment duration, t, is assumed to be a function of the distance of the segment (m) divided by the average speed of the representative aircraft (obtained from AEDT), which we convert from knots to metres per second. Once we have an emission for the flight path segment, we calculate the emission rate (ER_i) per segment in grams per hour by:

$$ER_i = (FPH) * (E_i)$$

where FPH is the flights per hour.

The ER is then converted from grams per hour to tons per year, which are used as inputs on the web-based user interface. Figures 5 and 6 show the fuel burn and emissions that we computed compared against the raw numbers provided in the AEDT database. One can see that both fuel burn and emissions using the custom (representative) engine approach has a modest tendency to overestimate compared to the default engines, due to our approach as described earlier. However, this modest overestimate is assumed to be conservative, and gives a worst-case estimate from which the user can design alternative mitigation approaches by varying the inputs.

In Figure 7, we provide a quantitative comparison of diurnal patterns of emissions from AEDT (corresponding to the same six-week period in summer 2015) and our new approach. We breakdown the emissions from the new approach for all days during the six-week period, as well as broken down by weekday vs. weekend. The figure compares distribution of all hourly emissions (of NO_x) by hour of day for a six-week period during the LAX AQSAS from AEDT and emissions estimates based on the new approach. Since our custom approach assumes only two hours for each day (peak vs. off-peak), the diurnal pattern looks flat during two distinct hours of the day as opposed to AEDT.

However, the magnitudes of emissions for estimates based on AEDT and the new methods look similar considering day-to-day and weekday-weekend variability. There are still some differences at noon and during late night hours. These are likely related to our method not capturing the exact maximum take-off weight (MTOW) for flights during that period, and variances in actual aircraft engine type (and associated EI) from typical peak and off-peak activity data using in our representative profiles.

Our modelling approach allows the user to manipulate:

1. runway utilisation
2. flight path lengths
3. altitude changes between emissions modes
4. mix of aircraft and engine ages
5. fuel type.

The user can add or remove flight paths, change engine EI, and add runways and taxiways, all through a web-based interface similar to C-LINE (Barzyk et al., 2015) and C-PORT (Isakov et al., 2017).

4 Summary and conclusions

Previous studies have shown several limitations with dispersion modelling of aircraft sources to assess local air quality. Recent recommendations have focused on research related to source characterisation and incorporating plume rise of aircraft exhaust. To address these, a new bottom-up emissions estimation approach has been developed for characterising air quality impacts of airport operations at local-to-urban scales. This new approach is designed to work with a modelling system that is intended for screening approaches to estimate the impacts of various changes in aircraft activity and emissions factors. The methodology includes data from a global chorded inventory dataset from the AEDT and EI from ICAO database. The initial implementation of this method was performed for the LAX in the US. In the illustrative application of the methodology in LAX airport, we used the flight operations data from the LAX Air Quality Source Apportionment Study.

Our approach has several novelties and potential applications that are included below:

- The emissions modelling approach combines data from various sources: aircraft activity information from AEDT, flight paths information from Los Angeles World Airports (LAWA), and emission indices from the International Civil Aviation Organization database. The methodology provides spatially-resolved emissions in a unique and never-before used format to our knowledge for use in dispersion modelling calculation.
- The approach may be of interest to air quality managers, airport operators, and communities potentially impacted by the emissions from airport operations, who are seeking easy-to-use, non-regulatory, screening tools for air quality assessments.
- The method can be used in other airports for building an emission inventory that allows the user to change either aircraft activity or emission factors at the same time. Specifically, the new approach allows the user to manipulate: Runway utilisation; Flight path lengths; Altitude changes between emissions modes; Mix of aircraft and engine ages; fuel type; EI – and further assess changes in air quality in and around the airport.

It is recommended that the application of this emissions methodology at the LAX airport can be used as an illustrative example of creating spatially-resolved emissions at other airports for conducting community-scale air quality assessments using dispersion models in the future.

Acknowledgements

The US Environmental Protection Agency (EPA), through its Office of Research and Development, partially funded and collaborated in the research described here under Contract EP-D-12-044 to the Institute for the Environment at the University of North Carolina at Chapel Hill (UNC-IE). This paper has been subjected to Agency review and approved for publication. The views expressed in this article are those of the authors and do not necessarily represent the views or policies of the EPA. We gratefully acknowledge the Los Angeles World Airports (LAWA) for providing the datasets from the Los Angeles Air Quality Source Apportionment Study (AQSAS) and the Federal Aviation Administration (FAA) for providing data from AEDT. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

References

Arunachalam S, Valencia A, Soucacos P and Weil JC (2016) 'Assessing air quality impacts of airport emissions at the Los Angeles International Airport using an integrated modeling and measurement approach', Proceedings of the 17th International Conference on Harmonisation within Atmospheric Dispersion Modeling for Regulatory Purposes, May, Budapest, Hungary.

Arunachalam S, Valencia A, Woody M, Snyder M, Huang J, Weil J, Soucacos P and Webb S (2017a) Dispersion Modeling Guidance for Airports Addressing Local Air Quality Concerns, Transportation Research Board Airport Cooperative Research Program (ACRP) Project A02–58 Final Report, Washington, D.C.

Arunachalam S, Valencia A, Woody M, Snyder M, Huang J, Weil J, Soucacos P and Webb S (2017b) Dispersion Modeling Guidance for Airports Addressing Local Air Quality Concerns. Transportation Research Board Airport Cooperative Research Program (ACRP) Research Report 179, Washington, D.C [online] http://nap.edu/24881 (accessed 11 February 2019).

Arunachalam S, Wang B, Davis N, Baek BH and Levy JI (2011) 'Effect of chemistry-transport model scale and resolution on population exposure to PM2.5 from aircraft emissions during landing and takeoff', Atmos. Environ, Vol. 45, No. 19, pp.3294–3300.

Barrett S, Yim S, Gilmore C, Murray LT, Kuhn S, Tai A, Yantosca R, Byun D, Ngan F, Li X, Levy J, Ashok A, Koo J, Wong HM, Dessens O, Balasubramanian S, Fleming G, Pearlson M, Wollersheim C, Malina R, Arunachalam S, Binkowski F, Leibensperger E, Jacob DJ, Hileman J and Waitz I (2012) 'Public health, climate and economic impacts of desulfurizing jet fuel', Environ. Sci. & Tech, Vol. 46, pp.4275–4282.

Barzyk T, Isakov V, Arunachalam S, Venkatram A, Cook R and Naess B (2015) 'A near-road modeling system for community-scale assessments of mobile-source air toxics: the community line source (C-line) modeling system', Environmental Modeling & Software, Vol. 66, No. 2, pp.46–56.

Cambridge Environmental Research Consultants (CERC) (2015) User's Guide for ADMS-Airport, Airport Air Quality Management System Version 4.0, Cambridge, UK.

Cimorelli A, Perry S, Venkatram A, Weil J, Paine R, Wilson R and Brode R (2005) 'AERMOD: a dispersion model for industrial source applications. part I: general model formulation and boundary layer characterization', Journal of Applied Meteorology, Vol. 44, pp.682–693.

Earth Tech (2000) User's Guide for the CALPUFF Model [online] http://www.src.com/calpuff/download/CALPUFF_UsersGuide.pdf (accessed 11 February 2019).

FAA (2014) Aviation Environmental Design Tool (AEDT) [online] https://aedt.faa.gov/ (accessed 11 February 2019).

ICAO (2017) ICAO Aircraft Engine Emissions Databank [online] https://www.easa.europa.eu/document-library/icao-aircraft-engine-emissions-databank (accessed 11 February 2019).

Isakov V, Barzyk T, Smith E, Arunachalam S, Naess B and Venkatram A (2017) 'A web-based modeling system for near-port air quality assessments', Environmental Modeling & Software, Vol. 98, pp.21–34

Levy JI, Woody M, Baek BH, Shankar U and Arunachalam S (2012) 'Current and future particulate-matter-related mortality risks in the united states from aviation emissions during landing and takeoff', Risk Anal, Vol. 32, No. 2, pp.237–249. [PubMed: 21801192]

Snyder M, Venkatram A, Heist D, Perry S, Petersen W and Isakov V (2013) 'RLINE: a line source dispersion model for near-surface releases', Atmos. Environ, Vol. 77, No. 2, pp.748–756.

Sykes RI and Henn DS (1995) 'Representation of velocity gradient effects in a Gaussian puff model', J. Appl. Met, Vol. 34, pp.2715–2723.

Sykes RI, Parker S, Henn D and Chowdhury B (2014) SCIPUFF Version 2.8 Technical Documentation, Sage Management, 15 Roszel Road, Suite 102, Princeton, NJ 08540, p.393.

Wilkerson JT, Jacobson MZ, Malwitz A, Balasubramanian S, Wayson R, Fleming G and Lele SK (2010) 'Analysis of emission data from global commercial aviation: 2004 and 2006', Atmospheric Chemistry and Physics, Vol. 10, pp.6391–6408 [online] 10.5194/acp-10-6391-2010 (accessed 11 February 2019).

Yim SHL, Lee GL, Lee IH, Allroggen F, Ashok A, Caiazzo F and Barrett SRH (2015) 'Global, regional and local health impacts of civil aviation emissions', Environ. Res. Lett, Vol. 10, No. 3, p. 34001 [online] 10.1088/1748-9326/10/3/034001 (accessed 11 February 2019).

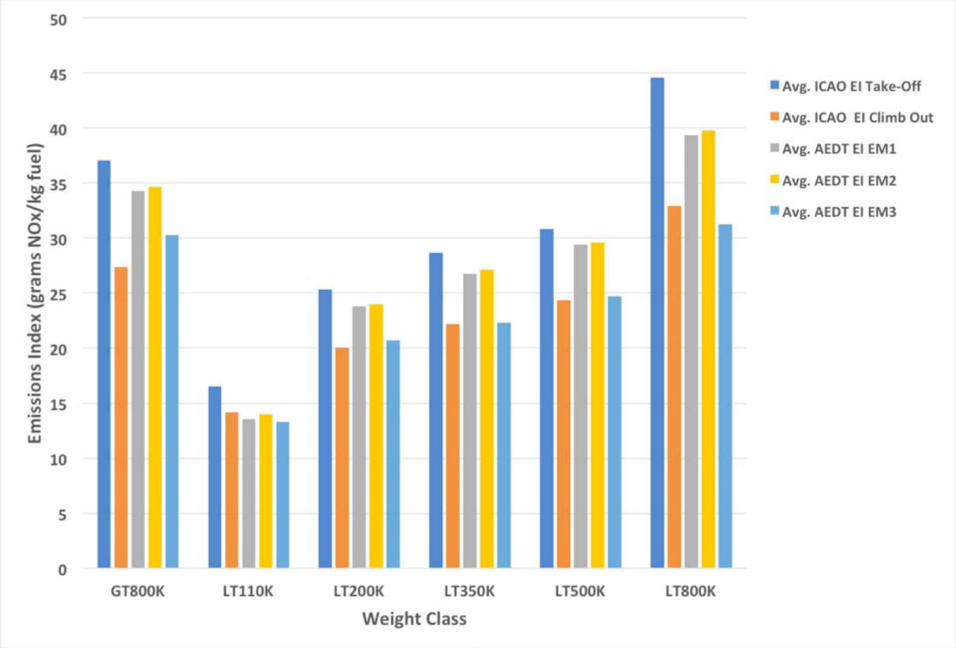

Figure 1.

Comparing average AEDT EI for TO and CO with average ICAO EI for NO_x in three emissions modes across six weight classes (see online version for colours)

Notes: 1 – TO Ground Roll, 2 – TO airborne, 3 – Terminal climb.

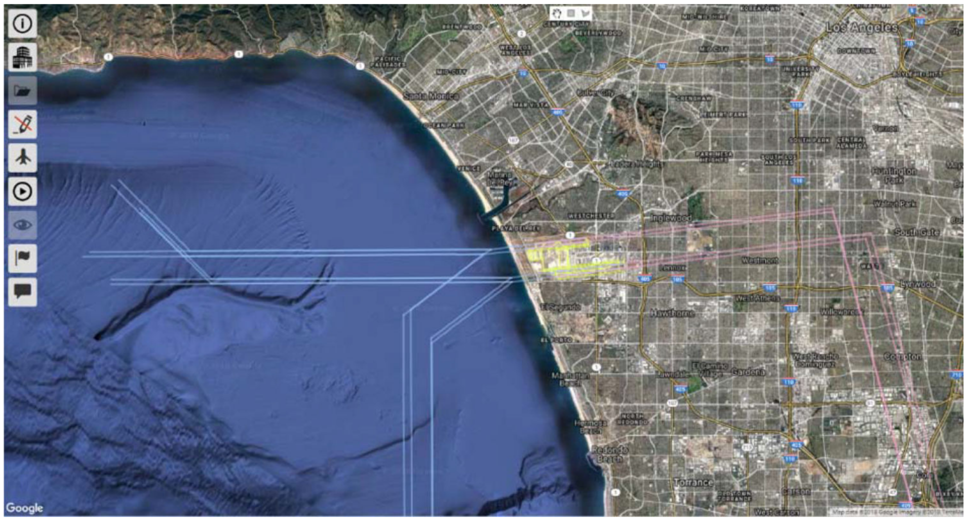

Figure 2.

Geographic domain centred at LAX showing locations of airborne links (see online version for colours)

Note: Note the multiple aircraft flight paths that follow the same general pattern (shown in blue and pink colours) are due to the different average distances that different aircraft types travel.

Figure 3.
Zoomed-in region around LAX showing runway and gate operations in the terminal area (see online version for colours)

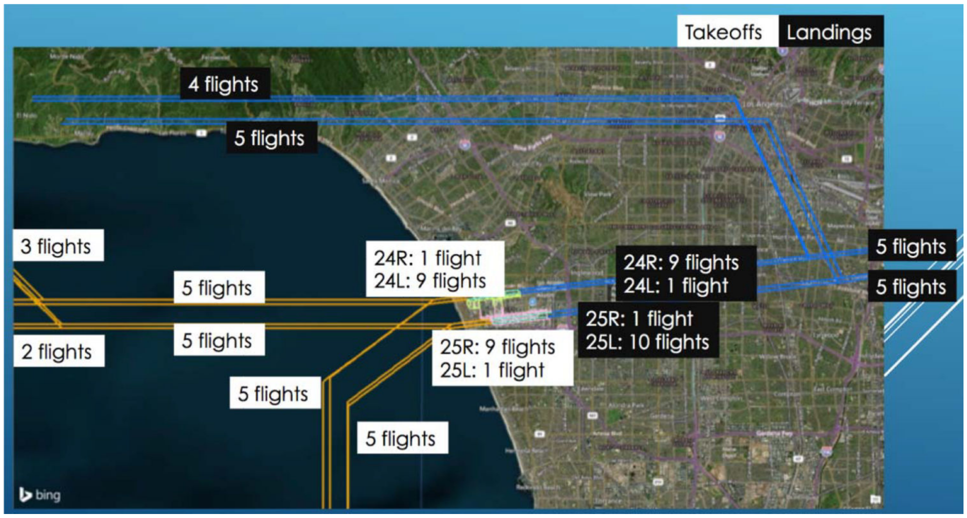

Figure 4.

Illustrative flight paths for aircraft ‘weight class LT200k’ with ‘recent’ engines, and TOs and landings in a peak hour on a summer weekday (see online version for colours)

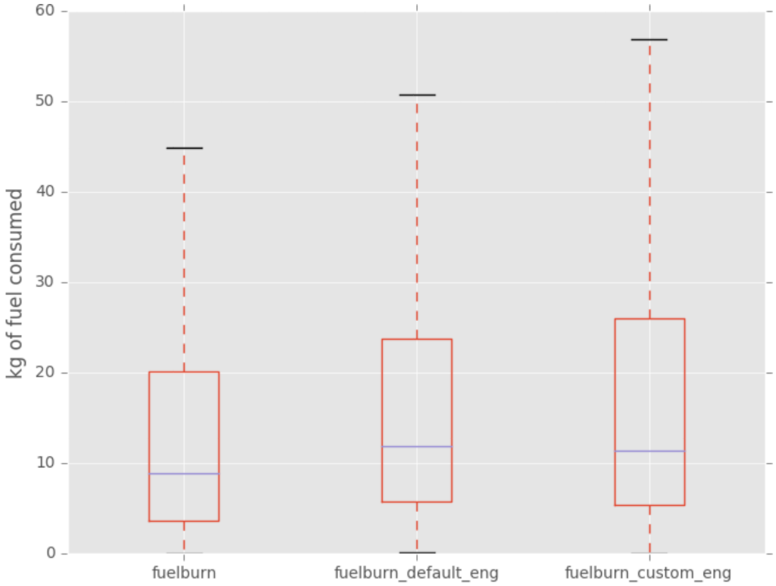

Figure 5.

Comparison of fuel burn from AEDT (left), our approach using default engines (middle), and our approach using custom engines (right) for all LAX airport activity (see online version for colours)

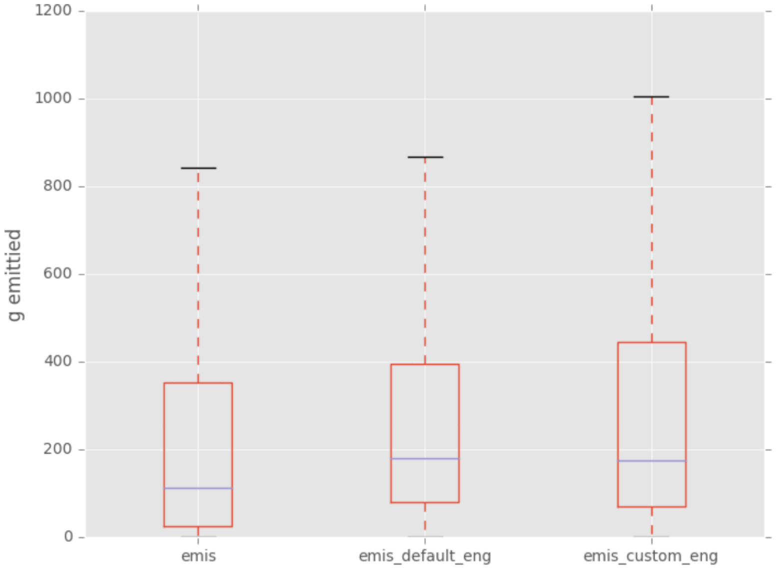

Figure 6.

Comparison of emissions of NO_x from AEDT (left), our approach using default engines (middle), and our approach using custom engines (right) (see online version for colours)

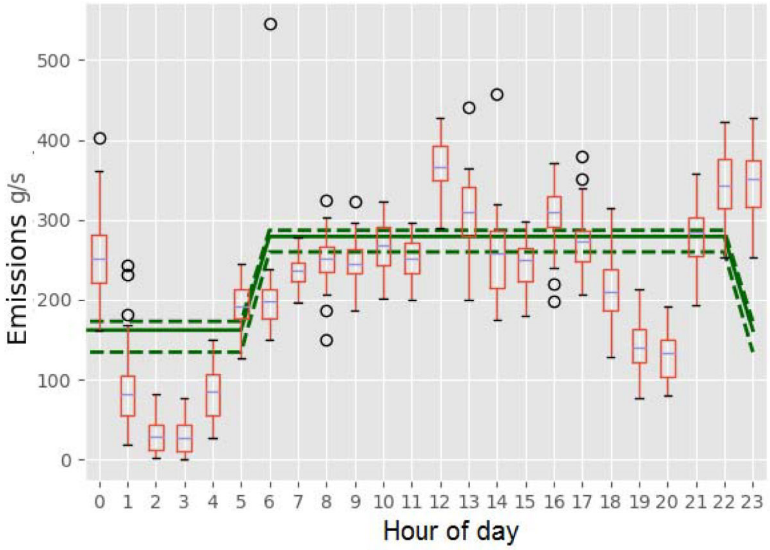

Figure 7.

Comparison of diurnal patterns of NO_X emission distributions from AEDT and new approach for LAX, summer 2015 (see online version for colours)

Notes: Green solid line represents the weighted average, green upper and green lower dashed lines represent the weekday and weekend respectively.

The box and whisker plots represent the distribution of AEDT emissions at LAX for every hour in the six-week period for 2015. Each box and whisker for each hour represents the distribution of 42 days of the summed emissions across all the aircraft activity in LAX. The box extends from the lower to the upper quartile values of the data (25th and 75th percentiles), with a line at the median. The whiskers extend from the box to show the range of the data. IQR is the interquartile range (Q3−Q1), the upper whisker will extend to last datum less than Q3 + 1.5 * IQR). Similarly, the lower whisker will extend to the first datum greater than Q1−1.5 * IQR. The circles are the outliers for each hour in this distribution.

Table 1

Common aircraft types and weight classes

Aircraft type	Weight class	Aircraft type	Weight class
Airbus 300 Series	LT500K	British Aerospace Jetstream 32 Series	LT110K
Airbus 310 Series	LT350K	British Aerospace (Hawker Siddeley) HS 125 Series	LT110K
Airbus 320 Series	LT200K	Canadair Regional Jet Series	LT110K
Airbus 330 Series	LT500K*	Cessna 750 Series	LT110K
Airbus 340 Series	LT800K	de Havilland Canada DHC-8 Series	LT110K
Airbus 380 Series	GT800K	Douglas DC-10 Series	LT500K
Boeing 717 Series	LT200K	Embraer 120 Brasilia	LT110K
Boeing 737 Series	LT200K	Embraer 170 Series	LT110K
Boeing 747 Series	GT800K*	Gulfstream All Series	LT110K
Boeing 757 Series	LT350K	McDonnell-Douglas MD-11 Series	LT800K
Boeing 767 Series	LT500K	McDonnell-Douglas MD-80 Series	LT200K
Boeing 777 Series	LT800K		
Boeing 787 Series	LT800K		

Note:

[*] Only two exceptions: Boeing 747–100 MTOW is LT800K and Airbus A330–200 MTOW is GT 500k.

Table 2

Runway utilisation for both weekdays and weekends in all seasons

	Runway number								Total
	06L	**06R**	**07L**	**07R**	**24L**	**24R**	**25L**	**25R**	
Off-peak arrivals	4%	40%	9%	5%	0%	8%	30%	4%	100%
Peak arrivals	0%	0%	0%	0%	5%	44%	46%	5%	100%
Off-peak departures	0%	0%	0%	0%	15%	0%	9%	76%	100%
Peak departures	0%	0%	0%	0%	47%	4%	3%	46%	100%

Note: These values were derived from a LAX AQSAS Phase II (2008) dataset that included flights in July/August alone.

Table 3

Mapping AEDT emissions modes to ICAO engine testing modes

AEDT emissions mode	ICAO engine mode during testing
0 – taxi out	Idle
1 – take-off ground roll	Take-off multiplied by scaling factor
2 – take-off airborne	Take-off
3 – terminal climb	Climb Out
7 – approach	Approach *
8 – landing ground roll	Idle
9 – landing ground roll with reverse thrusters	Approach
10 – taxi in	Idle

Note:

*Note that ICAO Idle emissions indexes were used for the initial approach (10,000 feet down to 2,500 feet).