Flight Carbon Calculators: Which One Should We Use in International Education?

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SUMMARY

Several publicly available flight carbon calculators have been evaluated based on multiple criteria. It is concluded that the recommended flight carbon calculator for the international education community to adopt is Atmosfair. Alternatively, if comparison between multiple modes of transportation is the aim, perhaps for student educational purposes, then the Travel & Climate calculator is an excellent choice.

EVALUATION

International education by its very nature involves travel by air for students, faculty, and staff. It is thought that, for most international students and programs, that the flights to and from their home and education location will be a significant component of their personal carbon footprint, in many cases overwhelming other aspects. Therefore, a robust method of calculating the flight carbon footprint for international education is required in order to benchmark this footprint and work towards reductions. Other aspects of the climate impact of international education, including travel by other means and accommodation, are important, but are not considered in this note.

Air travel is well known to be the most carbon intensive mode of mass passenger travel.The combustion of aviation fuel at high altitude is also well known to have other climate forcing impacts (the production of contrails, ozone, nitrous oxide etc.) that amplify the warming (Lee et al., 2021). Shields (2019) estimated that global student mobility contributed to between 14 and 38 megatonnes of CO_2eq, while Robinson *et al.* (in press) presented a low-end estimate that the U.S. study abroad sector alone contributed 1.1 megatonnes.

Calculating the emissions and impact of flying can be a difficult task seeing as there are multiple online flight carbon calculators available to use. These calculators may differ in calculations, conversion factors and assumptions, and may use different flight databases. Unfortunately, there is no standard for calculating flight carbon emissions, and all results should be interpreted as estimates. It appears that all calculators use great circle distances[1], and then add modifiers to that distance to account for avoiding weather, circling the airport, and maintaining close proximity to land. Some calculators (e.g. Atmosfair, ICAO, MyClimate) incorporate databases that allow the calculations to include known average passenger loading, average diversion distances, average cargo loading, and aircraft and engine types commonly used on certain

[1] The great circle distance is the shortest distance between two points on the surface of the Earth, following the sphericity of the globe. Owing to distortions caused by projections on a flat surface, a straight line on a map is not necessarily the shortest distance.

routes. Other calculators (C-Level, Carbonfootprint.com, AirMilesCalculator, Travel and Climate) rely more heavily on industry averages and great circle distances combined with published conversion factors, without respect to route-specific data.

This note reviews several free online carbon calculators and makes a recommendation for the international education community in terms of a consistent calculator to use. More detailed descriptions of each calculator under consideration can be found in the Appendix.

In assessing the best calculator to use for the international education community, the following criteria are taken into consideration.

1) ***Robust calculation methodology and documentation;***
   Required: Documentation and information on calculation methods is required. **Preferred:** Route-specific calculations that incorporate aircraft type, engine type, average diversions, passenger and cargo loadings, and data from different airlines that fly that routing. Great circle calculations are used, but should include compensation for detours and aircraft circling. **Less Preferred:** Calculations based on great circle distances without detour factors included, combined with industry averages for emissions per passenger distance. In all cases, detailed documentation on calculation methods is required.
2) ***Inclusion of a high altitude radiative forcing index (RFI);***
   Required: The incorporation of a high altitude radiative forcing index (RFI). An RFI is a multiplier applied to account for the additional climate impacts generated when aviation fuel is combusted at high altitudes. Commonly used values within the literature indicate the RFI multiplier should be between 1.9 (DEFRA) and 3.0 (Atmosfair). That is, the total climate impact, expressed at CO_2eq, is between 1.9 and 3.0 times the combustion CO_2 impact alone. While the scientific community agrees that an RFI multiplier needs to be applied, there is disagreement about what value the multiplier should be (see Murlis, 2021 for a discussion). Seeing as the science is not settled, calculators will be evaluated on the basis that they include an RFI, but take no consideration as to what that value may be. The **Preferred** calculator should apply such a multiplier only for portions of the flight above a certain altitude. This means that some short flights may only reach such an altitude briefly or not at all, and would only have the RFI applied for that portion of the flight. The **Less Preferred** calculator would include an RFI but would apply it over the entire flight distance. In this case the total climate impact of short flights would be overestimated.
3) ***Ease of use and intuitiveness;***
   The end user of the selected calculator is intended to be an international educator with no background in climate science or the use of carbon calculators. For this reason, the **Preferred** calculator should have 1) simple and intuitive input 2) ability to add connecting airports, 3) ability to choose class of service, 4) easy to understand output, 5) a breakdown of climate impact based on combustion emissions and additional climate impacts. A **Less Preferred** calculator may be missing one or more of these inputs and outputs.
4) ***Global and complete coverage;***

The **Preferred** calculator should include the vast majority of global airports in the global IATA and ICAO systems, easily searchable by airport or city name. A **Less Preferred** calculator may require inputs by IATA airport code, or may have airports that are difficult to find (for example by only using the airport name, instead of the name of the city it serves) or have incomplete airport listings.

5) ***Returns results from multiple airlines and plane types on that route;***

Different airlines with different plane and engine models often fly the same popular routes, often resulting in emissions that significantly differ. The **Preferred** calculator should show the emissions from a selection of airlines that fly popular routes. A Less Preferred calculator returns results that do not differentiate between airlines on popular routes.

Based on these criteria, a total of 7 flight calculators with a global reach have been assessed. These calculators are listed in Table 1 below. More detailed descriptions of each calculator, including comments on the above criteria are available in the Appendix.

Table 1. Flight carbon emissions calculators under consideration for international education purposes. Evaluations for each of the above criteria are also included. Where the calculator is deemed to meet the **Preferred** criteria, this is denoted in as ✅. A calculator that is deemed to be **Less Preferred** for certain criteria is denoted as 🔶. A calculator that does not provide **Required** documentation or the calculation methodology, or include the **Required** RFI is denoted as 🔴, indicating its exclusion from further consideration.

Calculator and Host Organisation	Robust calculation methodology and documentation	Inclusion of a high altitude radiative forcing index (RFI)	Ease of use and intuitiveness	Global and complete coverage	Returns results from multiple airlines and plane types on that route
Atmosfair (Atmosfair)	Excellent calculation methodology and documentation ✅ Available here.	RFI of 3.0 for the portion of the flight at > 9,000m altitude ✅	Easy to use, intuitive, excellent layout. ✅. Returns breakdown of CO_2 emissions and total climate impact.✅.	Full global coverage by city name, airport name, or IATA codes ✅	Returns results for several airlines on popular routes, highlighting possible differences in emissions based on airline and plane type ✅
MyClimate (myClimate Foundation)	Excellent calculation methodology and documentation ✅ Available here	RFI of 2.0 applied ✅to the entire flight distance 🔶	Easy to use, intuitive, excellent layout. ✅. Does not provide breakdown between CO_2 emissions and total climate impact.🔶	Full global coverage by city name, airport name, or IATA codes ✅	Returns results for an 'average' airline only. Returns results rounded to the nearest 0.1 tonnes.🔶
ICAO (International Civil	Excellent calculation methodology and	Does not include an RFI🔴	Easy to use, intuitive,	Full global coverage by city name, airport name,	Returns results for an 'average' airline only. 🔶

Aviation Organisation of the United Nations)	documentation ✅ Available here		good layout. ✅ Does not provide breakdown between CO_2 emissions and total climate impact.🔶	or IATA codes ✅	
Carbonfootprint.com (Carbon Footprint Ltd. (UK))	Limited documentation and calculation methodology. Available here. 🔶	RFI of 1.9 applied✅ to the entire flight distance.🔶	Easy to use, intuitive, excellent layout. ✅. Does not provide breakdown between CO_2 emissions and total climate impact.🔶	Some airports appear to be missing when typing in city name, requiring knowledge of IATA codes.🔶	Returns results for an 'average' airline only. 🔶
C Level (C Level Carbon consultants (UK))	Limited documentation and calculation methodology. Available here. 🔶	RFI of 1.9 applied ✅ to the entire flight distance. 🔶	Easy to use, intuitive, good layout. ✅ Does not provide breakdown between CO_2 emissions and total climate impact.🔶	Full global coverage by city name, airport name, or IATA codes ✅	Returns results for an 'average' airline only. 🔶
AirMilesCalculator (Unknown)	No documentation or methodology 🔴	Does not include an RFI🔴	Easy to use, intuitive, excellent layout. ✅. Does not provide breakdown between CO_2 emissions and total climate impact.🔶	Full global coverage by city name, airport name, or IATA codes ✅	Returns results for an 'average' airline only. 🔶
Travel and Climate (Swedish Academic and Tourism Consortium)	Excellent calculation methodology and documentation ✅ Available here. Also includes comparisons to train, bus, car, and ferry journeys on the same routing.	RFI of 1.7 applied ✅ to the entire flight distance. 🔶	Easy to use, intuitive, excellent layout. ✅. Does not provide breakdown between CO_2 emissions and total climate impact.🔶	Full global coverage by city name ✅	Returns results for an 'average' airline only. 🔶

CONCLUSION

The atmosfair calculator provides all of the **Preferable** criteria included in this assessment, and is suggested as a flight carbon calculator for the international education community to utilise. Other calculators under consideration had one or more items that were deemed **Less Preferable** in the criteria listings.

The Travel & Climate calculator may be of interest to the international education community as an educational tool for showing emissions amongst different modes of transportation, but note that it does give different, and likely lower, values for travel by plane compared to Atmosfair.

REFERENCES

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Appendix 1

Calculator specifics

Atmosfair

Atmosfair is a German non-profit organisation that actively contributes to CO_2 mitigation by promoting, developing and financing renewable energies in over 15 countries worldwide. They specifically focus on climate issues related to air travel. They also publish the atmosfair Airline Index, which compares and ranks the carbon efficiency of the world's top 200 airlines. Atmosfair also provides an offsetting service, with 90% of its projects being certified to CDM Gold Standard. The calculator and documentation are available in German and English.

Atmosfair provides an easy to use and intuitive web interface for calculating the carbon footprint of flights between input departure and destination airports, as well as connecting flights. Calculations can be conducted for one-way or round-trip flights. Optional inputs include class of service (first, business, premium economy, economy), type of flight (charter or scheduled), and aircraft type. The calculator uses data from the atmosfair Airline Index, which contains information representing about 92% of global air traffic, including 200 of the world's largest airlines, 22,300 city pairs, 119 aircraft types, and 408 engines. Emissions are based on actual fuel consumption. Also taken into account as an average for each routing are flight path deviations from the great circle distance, cargo load, passenger load, airline fleet type and age, engine type, and seating class distribution. Flight profiles (time at various altitudes) are also known for each route, and the RFI is calculated as x3.0 for all time spent cruising at greater than 9,000m altitude. The methodology of the calculator has been approved by the Umweltbundesamt (German Environment Agency). Where more than one airline flies that particular route, atmosfair returns estimates for the major airlines as well as an average for that route.

myClimate

myClimate.org is a Swiss-based non-profit foundation who provide carbon calculators for travel, events, companies, households, and personal habits. They provide a number of certified voluntary carbon offset projects around the world, and also provide educational and consulting services globally.

The myClimate flight carbon emissions calculator provides a simple, intuitive web interface with inputs of departure, destination, and connecting airports (only one), the option of one-way or round trip, and class of service (Economy, Business, or First). Outputs are rounded to the nearest 0.1 tonne, or 100 kg. The calculator incorporates flight distance, fuel consumption for major aircraft types, cargo weighting, cabin class weighting, an aircraft infrastructure allocation (e.g. airports and aircraft manufacture), and a value to account for the carbon emissions related to the production of jet fuel. The myClimate calculator uses an RFI factor of 2.0. It is important to note that myClimate's calculator does not use data related to aircraft and passenger loads on specific routes (in contrast to atmosfair), but does incorporate industry averages.

Overall, myClimate is deemed to be an excellent calculator, but is let down by returning values rounded to the nearest 100 kg, and is not using route specific calculations and emissions from different airlines on a specific route, as atmosfair does. While there continues to be much

debate in the scientific literature concerning the appropriate RFI value to use (myClimate uses a 2.0 multiplier), the most recent literature indicates that a slightly higher RFI value may be most appropriate.

Carbonfootprint.com

This is really a lifestyle calculator (including other travel, food consumption, housing etc.) that also includes flights. The flight calculator documentation is not very detailed. City inputs are sometimes missing or not intuitive, so the 3 letter IATA airport codes are sometimes required. For example, typing in Shanghai returns no results and users need to know the main airport is called Pudong or the IATA code is PVG.

ICAO

The ICAO calculator, which is the official United Nations calculator, relies on detailed databases of fuel burn for aircraft types, passenger and cargo loads, and cabin class. It appears to only allow routings that are currently in operation and have commercial flights between the cities. So, for example with London, Ontario as a starting destination, the only options for destination airports are only those directly served from London. The exact routing would need to be known in order to use this calculator. This calculator does not include an RFI multiplier. The ICAO states that they will not be applying an RFI multiplier to their emissions calculator outputs until the scientific community has reached a general agreement on the issue. The ICAO has developed a subscription-based API interface to allow integration with web pages and other software.

C-Level Calculator

The C-Level calculator is from a carbon consultancy firm based in the UK. It uses DEFRA (UK Department of Food, Environment and Rural Affairs) published conversion factors per passenger per km travelled for different classes of air travel to arrive at the full carbon footprint of an individual's journey by air. The calculator differentiates between class of service, and states that it incorporates differences between short and long haul flights, but provides few details other than suggesting it follows DEFRA methodology.

Air Miles Calculator

The Air Miles Calculator appears to primarily be a tool to calculate flight distances between city pairs, including connecting flights. CO_2 emissions are also calculated, but the calculator lacks any kind of documentation. It is unclear if a high altitude radiative forcing factor is included, but seeing as the estimated carbon emissions are quite low, it is thought not. This calculator only returns values for one-way flights.

Travel & Climate Calculator

The Travel & Climate calculator is a very useful calculator that also includes calculations from city centre to city centre, not just airport to airport. Also includes comparisons between flights and other modes of travel, including train and bus, car (internal combustion and electric), and ferry. Also includes calculations for hotel or hostel stays. Includes an RFI of 1.7, reasoning that '*Shorter flights result in high CO2 emissions per passenger kilometre because the ascent consumes a lot of fuel. In addition, shorter flights do not normally contribute to non-CO2 effects as they do not fly at very high altitudes. The opposite is true for long flights: the ascent is only a small part of the whole flight, but on the other hand, the flight is largely at a high altitude, which adds an extra climate footprint. Due to this it is reasonable to assume roughly the same emissions per passenger kilometre for short and longer flights*'. This appears to be the most useful calculator for comparing amongst different modes of transport, and is simple and robust enough to be used for educational purposes. But, note that for flights, the methodology is not considered to be as robust as that used by atmosfair.

Other calculators not under consideration

Note that some airlines (e.g. Ryanair, Air France/KLM, and United) offer carbon calculators during flight booking, often to promote the purchase of carbon offsets. However, these calculators only appear to work using routes on that particular airline and thus are not considered here. The Air France/KLM group calculator is based on actual fuel consumption, and suggests that upstream emissions (fuel extraction, refining, and distribution) should be multiplied by a factor of 0.2 and added to the base CO_2 emissions. However this calculator only includes destinations served by Air France/KLM and their partners, and does not include a high altitude emissions multiplier.