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Comparing the CO_2 emissions and contrail formation from short and long haul air traffic routes from London Heathrow

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ABSTRACT

This paper considers the relative climate impacts of long haul and short haul air travel. This is particularly important in the context of changing markets for air travel. New competing aircraft technologies will enhance competition between the hub and spoke model of aircraft operations and that of smaller aircraft operating direct routes for long haul trips. The substitution of shorter trips by high-speed rail could also free otherwise constrained airport capacity for additional long haul flights. Previous comparisons have focused on fuel consumption per passenger km so long haul trips, where a much higher proportion of the journey is in the relatively efficient cruise phase, are more efficient than shorter trips. This study considers the additional role of contrails, believed to be important for the net climate impact of aviation. Short aircraft trips tend not to reach the very high altitudes attained by long haul cruising aircraft and so encounter different atmospheric conditions and have different probabilities of contrail formation. By including consideration of the variability in contrail formation conditions throughout the year, estimates of the linear contrail produced along various aircraft trajectories are obtained. The potential to mitigate contrail impacts by altering the flight schedule is also discussed.

1. Background

Rapid growth in air travel has ensured that aviation remains a significant and growing contributor to climate change, despite technological advances that continue to improve efficiency and reduce emissions as new aircraft are introduced. As a hydrocarbon fuel, aircraft kerosene produces carbon dioxide and water vapor when burned. Both contribute to warming. Oxides of nitrogen (NO_x) are also produced in the combustion process. The amount of NO_x emissions and their impact depends on local atmospheric conditions, but at cruise altitudes in the upper troposphere, these emissions increase ozone and reduce methane. As clouds play an important role in climate, the formation of contrails is also a contributor to climate impact, particularly where those contrails are long lived and spread to form large cirrus clouds. Soot and sulfate particles in the aircraft exhaust have a direct radiative impact, as well as providing condensation nuclei for cloud formation.

Comparison or prioritization of the different impacts is difficult; the total impact is influenced by the lifetime of the emission or effect, the spatial distribution of the impacts and the spectral signature of absorption and emission of radiation. The comparison measure most commonly used for climate studies is radiative forcing, which determines the global and annual average increase in radiative energy in the troposphere due to a particular forcing measure, relative to the pre-industrial atmosphere. Changes in radiative forcing have been shown to be proportional to changes in global mean surface temperature.

Using this comparison, the Intergovernmental Panel on Climate Change (IPCC) special report on aviation identified

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that the effects contributing most to aviation's impact were carbon dioxide, nitrogen oxides (for which the warming due to increased ozone is partially offset by a cooling due to the reduced methane), and contrails (Penner et al., 1999). The IPCC study identified gaps in understanding, particularly regarding the climate impact of aviation-induced cirrus cloud. Further research has followed, but uncertainties remain. It has been suggested that the impact of contrail–cirrus may be a warming up to 10 times that due to carbon dioxide from aviation (Mannstein and Schumann, 2003), but other studies show more conservative estimates and the nature of the forcing from contrail is far from certain (Schumann, 2005).

A range of policy measures have been considered to address the climate impacts of aviation, both globally, through ICAO and through the European Union. Many of these options rely on indicators of environmental performance for a flight to provide incentives for good practice through a charge or levy or through tradable permits. CO_2 is one of the key contributors to aviation's impact and is conceptually the easiest to consider, as emissions to the atmosphere are proportional to fuel consumption and their impacts are independent of the location or time of emission. As such, CO_2 has been the primary focus of policy proposals. Policies such as CO_2 emissions trading or a tax on aviation fuel could provide an enhanced economic incentive for improved fuel efficiency (beyond that associated with rising fuel costs), but definitions of efficiency are important. For long haul flights, the fraction of the flight time spent in the high-thrust take off and climb out phase is reduced (i.e., as the distance at cruise increases), so the fuel efficiency per km of the trip improves. This interpretation has led to the conclusion that, per passenger km, long haul flights have a lower climate impact than short haul, but this fails to consider contrail formation. As short haul flights are generally at lower altitudes where contrails are typically less likely to form, contrail formation could be expected to be lower per passenger km than for long haul trips.

The relative impacts of long and short haul travel are relevant to the debate on the introduction of environmental taxes, charges or levies on air travel, whether applied to the purchase price of tickets, fuel, aircraft or the use of airspace. Any such charge would inherently include assumptions about the relative impact of air travel from different climate mechanisms. For example, a global tax on aviation fuel would increase fares on all routes, but could reduce the price differential between short and long haul routes, reflecting the improved efficiency per passenger km of longer flights. As carbon dioxide emissions are proportional to fuel consumed, a CO_2 emissions trading system could have a similar effect. For both mechanisms, the impact on fares would be offset by the contribution of fuel to operating cost; for long haul flights fuel represents about 30% of the airline's cost, while for short haul it is only 10% (Department for Transport, 2004).

In comparing the long and short haul impacts of aviation, this study considers both CO_2 emissions and linear contrail formation. The processes of contrail spreading to form cirrus cloud are beyond the scope of this paper. As contrail formation depends on local atmospheric conditions and impacts depend on time of day, opportunities to mitigate contrail impacts by altering flight schedules are also discussed.

2. London Heathrow airport and changes in airline technology

This study focuses on routes serving London's Heathrow airport. Heathrow is the busiest passenger airport in Europe; globally, only Atlanta Hartsfield and Chicago O'Hare handled more passengers in 2004 (Airports Council International, 2005). In that year, there were over 467,000 aircraft movements at London Heathrow—almost one in four of the UK total. Of the five main airports serving London (the others being Gatwick, London City, Luton and Stansted), Heathrow handles more than one-half of the total passengers using scheduled services and 79% of the total freight. It is also an important hub airport, with 93% of transit passengers through London using Heathrow (Civil Aviation Authority, 2005).

Operations at Heathrow are currently capacity constrained. Work is underway to construct a fifth passenger terminal to increase capacity, and a proposal to construct a sixth, along with a third runway, has been drafted. In addition to the physical infrastructure constraints, environmental capacity must also be considered (Upham et al., 2003). The government has expressed support for the economic case for a third runway, but development will be delayed by the need to meet restrictions on noise and particularly NO_x emissions (Department for Transport, 2003b).

In the context of continuing growth in demand for air transport and constraints on runway capacity, there are a range of possible scenarios for future airport use. Limited slot availability could potentially be associated with increased load factors or a transition from smaller to larger planes on popular routes as airlines are less able to increase the frequency of a service to meet increasing demand (Focke and Wilken, 2001). However, despite increases in passenger numbers, recent decades have seen a downward trend in the average size of aircraft in operation, reflecting partly the increased use of regional jets.

Capacity constraints could also influence the mix between short and long haul traffic. While impacts on local air quality and noise are related to the type of aircraft and number of operations at an airport, the balance between long haul and short haul flights plays a key role in determining the climate impact of those operations. Constraints on the terminal space available to handle passengers and their luggage may encourage a focus on higher fare long haul flights. There is even scope for the airlines to encourage the substitution of short haul air trips with rail, as a reduction in the frequency of short haul services would free slots for higher revenue long haul operations. The substitution of short haul air for rail travel has also been advocated as an environmental measure (Aviation Environment Federation, 2001), but any benefit assumes that freed airport and airspace capacity is not used to expand services on other routes.

Other factors could affect the mix of long and short haul traffic from primary airports. Airlines operating both short and long haul services could choose to eliminate or reduce the frequency of services on those short haul routes where competitive fares are threatened by the higher cost of operating from Heathrow amidst rising competition from the no frills carriers operating from other airports in the region. In addition, domestic rail speeds are increasing with the introduction of new track and rolling stock. Demand for short haul flights is