Aviation and climate change: a global sectored approach is the need of the hour

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Abstract
The Intergovernmental Panel on Climate Change has estimated that ill-effects of carbon emissions will grow to 5% by 2050. Although ICAO had initially endorsed the idea of the emissions trading system to meet CO2 emission reduction objectives, prospects for a comprehensive global agreement appear to be distant, and a multi-faceted approach is required with a strong commitment from all stakeholders. Other options could be the usage of carbon neutral fuels, coming from biomass, algae and most recently the usage of CO2 in the air and water in the atmosphere, and then the Fischer Tropsche process to combine the H2 and CO2 together to produce oil (Louise and Paul. Aviation and climate change. House of Commons Library, 2008).

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1 AIM
The paper sets out to explain the effects of carbon emissions in aviation, how aviation stakeholders contribute towards climate change and the sectored approach which is the need of the hour.

2 INTRODUCTION
The interest in aviation’s effects on climate change dates back decades. The details of aviation’s impact on climate could be traced as late as 1960s and early 1970s [1]. However, the initial concern over aviation’s overall impacts in the early 1970s was related to potential stratospheric ozone (O3) depletion from Concorde fleet and TU-144 fleet. In the late 1980s and early 1990s, research was conducted about the effects of nitrogen oxide emissions (NOx = NO + NO2) on the formation of tropospheric O3 (a greenhouse gas) and, to some extent, about contrails [1]. There were also other number of researches conducted about emissions and its effects on aviation other than those from CO2, which might influence climate. In assessing the potential of anthropogenic activities to affect climate, aviation stands out as a unique sector since the largest division of its emission are injected at cruise altitudes of 8–12 km! At these levels, the emissions increase the effectiveness to cause chemical and aerosol effects relevant to climate forcing (Figure 1).

A recent study by Intergovernmental Panel for Climate Change (IPCC) states that ‘measurements of water vapour in the upper troposphere and the lower stratosphere, where the naturally occurring humidity’s are the lowest found on earth, have always been a source of controversy’ [2]. Not only are the emissions of water vapour from the aeroplanes very critical for understanding radiative impacts of exhaust gases but also the accurate knowledge of background of water vapour distribution, the associated temperature variations and the microphysics of water-containing particles are essential to accurately model heterogeneous chemistry in the upper troposphere/ lower stratosphere by sedimentation.

The IPCC 1999 report suggests that ‘the main source of NOx in the stratosphere is Oxidation of N2O, and based on correlations that have been observed between NOY (the sum of reactive nitrogen species) and N2O, it is relatively straightforward to simulate the impact of an additional sources of NOx from direct injection of aeroplane exhaust or parameterized transport from the troposphere’. However, there are various potentially significant sources of NOx in the atmosphere, not limiting only to aeroplane emissions and those dominant sources are lightning and convective transport from the boundary layer [2]. Aeroplane emissions are more confined in altitude and to heavily travelled corridors. What makes assessing these impacts so difficult is the quantification of the larger global sources and specifying their geographic distributions with sufficient precision so that the contributions due to the highly localized aeroplane emissions could be quantified (Figure 2).
Aviation is an industry which displays an enormous growth potential—be it infrastructure or in operations platform. The governmental bodies or the non-governmental bodies around the globe as well as the aviation industry recognizes the importance and link between aviation emissions and climate change although there exists an uncertainty about the quantum of exact impact/changes. A study conducted by International Air Transport Association (IATA) confirms that ‘aviation is responsible for 2% of global Carbon dioxide (CO$_2$) emissions, 12% of CO$_2$ emissions from all transport sources; compared to 74% from road transport, 3% of the total man-made contribution to climate change’ [3]. By the year 2020, airlines aim for at least an additional 25% improvement in fuel efficiency and CO$_2$ emissions through technology and operational enhancement. Keeping in mind the level of uncertainty existing in the amount, probability and nature of climate change impact, scientists around the globe believe that additional warming linked to human activity may cause climate to change irreversibly. The crux of the matter remains the same—the natural greenhouse effect is vital for human existence!

There also exists a disagreement over aviation’s contribution to climate change. Along with carbon emissions, nitrogen oxides (NO$_x$) contribute indirectly by creating ozone in the lower levels of the atmosphere. But a little is known about the effects of contrails, cirrus cloud formation and the methane-reducing capabilities of NO$_x$. The air transport industry has to strive reasonably harder to achieve carbon neutral growth on the way to a carbon-free industry. The areas which could be looked into are technical progress, operational

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**Figure 1.** Scheme showing the principal emissions from aviation operations and the atmospheric processes that lead to climate change. Climate change creates impact on human activities and ecosystems and can lead to social damages. This is adapted from Prather et al. (1990) and Wuebbles et al. (2007).

**Figure 2.** Vertical profile of the zonally averaged response of ozone to aircraft emissions of NO$_x$ assuming background aerosols and aircraft aerosol perturbations for a 2050 Mixed fleet, as described in Sovde et al., 2007.
measures, infrastructure improvements, economic instruments, eco-friendly/environmental up-gradations and fuel upgradation/bio fuels.

3 HOW DO AEROPLANES AFFECT THE CLIMATE CHANGE?

Aeroplanes typically operate at cruising altitudes of 8–13 km, where they release a mixture of particles and gases that alter the composition of the atmosphere and add to the climate change. Carbon dioxide (CO₂) is the most common greenhouse gas because of the large quantities released and its long residence time in the atmosphere. It has a direct effect which warms the Earth’s surface. NOₓ has two indirect effects on the climate change. They produce ozone under the influence of sunlight, but they also reduce the atmospheric concentration of methane. Both ozone and methane are powerful greenhouse gases (GHGs). They have opposite effects, but the net result is that the ozone dominates the methane effect, thus warming the Earth. Water vapour released by aircraft has a direct GHG effect, but its effect is negligible as it is easily removed by precipitation. However, water vapour emitted at higher altitudes trigger the formation of contrails which may eventually form as cirrus clouds. These are also suspected of having a significant warming effect, but still, this is uncertain. Sulphate and soot particles also play a direct effect compared with other aeroplane emissions. These too influence the formation and properties of clouds to varied extent [6].

4 WHAT IS AIR TRANSPORT INDUSTRY?

The air transport industry includes those activities that are directly dependent on transporting people and goods by air. The civil aviation sector comprising of airline, airport, air navigation service providers and those activities directly serving passengers and/or providing air freight services; and the civil aerospace sector comprising of aeroplane/spare parts manufacturer and maintenance firms and aviation specific ground equipment forms the basis for air transport industry. This industry is an innovative industry which drives economic and social progress. It connects people, culture and countries in the least available time. It also opens up the international market and generates trade and tourism among developed and developing nations, in particular.

Like any other human activities, air transport has an impact on the environment through noise and emissions that affect local air quality and the climate. The air transport industry recognizes its responsibility in this regard and is determined to speed up the action aimed at justifying its environmental impact while preserving and enhancing its economic and social benefits.

5 THE IMPORTANCE OF AIR TRANSPORT INDUSTRY

According to IATA, aviation provides the only rapid worldwide transportation network, which makes it essential for global business and tourism. Aviation transports about 2.2 billion passengers annually. Some 2000 airlines around the world operate a total fleet of 23 000 aircraft, serving some 3750 airports through a route network of several million kilometres managed by around 160 air navigation service providers. Air transport facilitates world trade, helping countries participate in the global economy by increasing access to international markets and allowing globalization of production, thus the value of goods transported by air represents 35% of all international trade [3]. Air transport contributes 40% towards tourism which is a major engine for economic growth. The industry in discussion also improves productivity, by encouraging investment and innovation, improving business operations and efficiency, and allowing companies to attract high quality employees thus generating 32 million jobs globally through direct, indirect, induced and catalytic impacts.

Air transport is a highly efficient user of resources and infrastructure. Its occupancy rates exceed by far those of road and rail transportation. Unlike other modes of transportation, air transport industry pays for its own infrastructure costs (example: runways, airport terminals, air traffic control) rather than being financed through taxation and public investment or subsidy as in the case of road and railways. Aviation companies also aid substantial tax payments to national treasuries.

According to IATA, air transport is responsibly reducing its environmental impact. IATA claims that ‘air transport’s contribution to climate change represents 2% of man-made CO₂ emissions and this could reach 3% by 2050’ [2]. The evolution is based on a growth in aviation CO₂ emissions of 2–3% per year, with an annual traffic growth of 5%. Air transport industry under the guidance of ICAO and IATA initiatives, now, working towards carbon-neutral growth to ensure no increase in carbon emissions in spite of traffic growth; as a first step towards a carbon-free future. Aeroplanes entering today’s fleet are 70% more fuel-efficient than 40 years ago, consuming 3.5 l per passenger per 100 km! The new Airbus 380 and Boeing 787 consume <3 l/100 km. A further 25% fuel efficiency gain is targeted for 2020. Aeroplane entering today’s fleet are 20 decibels (dB) quieter than comparable aircraft 40 years ago. This represents a reduction of 75% in noise. There are a lot of research programs underway to achieve further 50% reduction in noise and CO₂ emissions and an 80% reduction on oxides of nitrogen by 2020.

6 HOW ARE AVIATION EMISSIONS PROJECTED TO GROW IN THE FUTURE

Global passenger air travel, as measured in revenue passenger-km, is projected to grow by about 5% per year between
1990 and 2015, whereas the total aviation fuel use—including passenger, freight and military—is projected to increase by 3% per year, over the same period, the difference being largely due to improved aircraft efficiency. All of these scenarios assume that technological improvements leading to reduced emissions per revenue passenger-km will continue in the future and that the optimal use of airspace availability taking into consideration, the widespread acknowledgement of Free Flight concept, CNS/ATM, RNP, ADS-B procedures is achieved by 2050. If these improvements do not materialize, then the fuel use and emissions will be higher and it is further assumed that the number of aircraft as well as the number of airports and associated infrastructure will continue to grow and not limit the demand for air travel. If the infrastructure is not available, the growth of traffic reflected in these scenarios would not materialize.

6.1 Water/soil pollution near airports
Various chemicals are used by airport operators and by aircraft operators. Through the action of rainwater, these chemicals may cause water pollution if they find their way to local water way or becomes a part of airport waste water and are not adequately treated. Examples include chemicals used in aircraft de-icing and runway ice prevention or removal. In addition, water and soil pollution may be caused by leakage from storage tanks. The problem will be particularly serious in case of runways which also function as water catchment areas for rain water collection. New water pollution control programmes could include an upgrading of existing surface water drainage facilities, operation changes designed to minimize the amounts of pollution discharged into the environment and the selection of more environmentally acceptable de-icing and washing materials (Airport Technology International, London, UK, 1993, p. 62).

6.2 Airport waste management
In aircraft servicing and maintenance, environmentally harmful materials are used (for example oils, cleaning fluids, paints). Once used they need to be exposed of in a satisfactory manner such as recycling. Airports and incoming air crafts also generate large quantities of waste material which is capable of causing environmental damage if not disposed off properly. Waste management issues are becoming increasingly important component of all airports pollution abatement programmes. The emergence of waste management as a major part of environmental protection strategies has been prompted by:

(i) Rapidly rising costs associated with waste disposal
(ii) The increasingly onerous statutory and civil law liabilities associated with waste management
(iii) Understanding that waste streams are often symptomatic of inefficient processes

6.3 Noise pollution
Pollution is a noun derived from the verb pollute, meaning: to foul. It is now increasingly understood that pollution from noise is an important component of air pollution, which was previously understood as being limited to material pollution. Noise is an inescapable by-product of the industrial environment, which is increasing with advances in industrialization and urbanization. Even in non-industrial areas, noise from activities such as printing, auto-repair, grinding, affects those living in the immediate surroundings. Noise not only causes irritation or annoyance but also constricts the arteries, and increases the flow of adrenaline and forces the heart to work faster. Continuous noise causes an increase in the cholesterol level resulting in permanent constriction of blood vessels, making one prone to heart attacks and strokes. Health experts are of the opinion that excessive noise can also lead to neurosis and nervous breakdown.

Noise travels through air and hence it is measured in ambient air quality level. Noise is measured in decibels. Experts believe that continuous noise levels in excess of 90 decibels can cause loss of hearing and irreversible changes in nervous systems. The World Health Organization (WHO) has fixed 45 decibels as the safe noise level for a city [4]. Metropolitan areas in India usually register an average more than 90 decibels; Mumbai is rated the third noisiest city in the world, with New Delhi following closely.

6.4 Airport noise and pollution increases risk of illness
On a 1997 questionnaire distributed to two groups—one living near a major airport and the other in a quiet neighbourhood—two-thirds of those living near the airport indicated they were bothered by aircraft noise, and most said that it interfered with their daily activities. The same two-thirds complained more than the other group of sleep difficulties, and also perceived themselves as being in poorer health.

Perhaps even more alarming, the European Commission, which governs the European Union (EU), considers living near an airport to be a risk factor for coronary heart disease and stroke, as increased blood pressure from noise pollution can trigger these more serious maladies. The EU estimates that 20% of Europe’s population—or about 80 million people—are exposed to airport noise levels: it considers this unhealthy and unacceptable.

6.5 Airport noise affects children
Airport noise can also have negative effects on children’s health and development. A 1980 study examining the impact of airport noise on children’s health found higher blood pressure in kids living near Los Angeles’ LAX airport than those living farther away. A 1995 German study found a link between chronic noise exposure at Munich’s International Airport and elevated nervous system activity and cardiovascular levels in children living nearby. And a 2005 study published in the prestigious British Medical Journal, The Lancet, found that kids living
near airports in Britain, Holland and Spain lagged behind their classmates in reading by 2 months for every 5 decibel increase above average noise levels in their surroundings. The study also associated aircraft noise with lowered reading comprehension, even after socio-economic differences were considered.

7 VISION FOR THE FUTURE

In June, 2007 IATA laid out its environmental vision to mitigate GHG emissions from aviation. The points under consideration was to build a zero-emissions commercial aircraft within 50 years, adoption of four pillar strategy based on improved technology, effective operations, efficient infrastructure and positive economic measures by all states. These aspects were adopted by the global aviation industry as well as ICAO states, in 2007. In June 2009, airlines under IATA membership took a landmark decision to adopt a set of ambitious targets such as a cap on aviation CO₂ emissions from 2020 (carbon neutral growth), an average improvement in fuel efficiency of 1.5% per year from 2009 to 2020, a reduction in CO₂ emissions of 50% by 2050, relative to 2005 levels [5]. All these collective goals were endorsed by the aviation industry in the joint industry submission to ICAO in September 2009.

In the 37th session of ICAO assembly, a resolution was signed by the aviation community and ICAO in October 2010 with the following deliberations:

(i) 2% annual fuel efficiency improvement up to 2020
(ii) Medium term goal of stabilizing global CO₂ emissions from 2020
(iii) Exploring feasibility of long term aspirational goal
(iv) Global CO₂ standards for aircraft
(v) Sustainable alternative fuels for aviation
(vi) Framework for market-based measures
(vii) Minimizing burden on states with low emissions
(viii) Assistance to states
(ix) States’ voluntary action plans

The issues like medium term goal of stabilizing global CO₂ emissions from 2020, framework for market-based measures and minimizing burden on states with low emissions are the agenda to be discussed in the 38th session of ICAO Assembly.

8 WHY SHOULD AVIATION BE TREATED AS A SECTOR?

Aviation is a global industry. For a typical route in any part of the globe covering different countries, CO₂ will be emitted over several different countries and over international waters and in various continents. Though it is a simple task for the governments to account for emissions from fixed sources within the boundaries, it is very difficult to do so in the case of aviation. Hence, aviation should be treated as a different sector. Its emissions should be calculated at a global scale and not by the state. Different governments treat aviation emissions differently and this leads to a conflicting and overlapping national and regional policies. Any scheme should cover CO₂ and non CO₂ emissions from airplanes consistent with the Kyoto Protocol. Whatever is the system adopted mutually by the states must be simple and straightforward to operate and account for by all participating states. Administration and management of a sectored approach should be undertaken in consultation and guidance by ICAO. And there is a need for an appropriate legal structure through which the issues arising from compliance/non-compliance is addressed.

9 ISSUES FOR THE FUTURE

There are a number of key areas of scientific uncertainty that limit our ability to project aviation impacts on climate and ozone:

(i) The influence of contrails and aerosols on cirrus clouds
(ii) The role of NOₓ in changing ozone and methane concentrations
(iii) The ability of aerosols to alter chemical processes
(iv) The transport of atmospheric gases and particles in the upper troposphere/lower stratosphere
(v) The climate response to regional forcing and stratospheric perturbations

There are a number of key socio-economic and technological issues that need greater definition, including inter alia the following:

(i) Characterization of demand for commercial aviation services, including airport and airway infrastructure constraints and associated technological change
(ii) Methods to assess external costs and the environmental benefits of regulatory and market-based options
(iii) Assessment of the macroeconomic effects of emission reductions in the aviation industry that might result from mitigation measures
(iv) Technological capabilities and operational practices to reduce emissions leading to the formation of contrails and increased cloudiness
(v) The understanding of the economic and environmental effects of meeting potential stabilization scenarios (for atmospheric concentrations of greenhouse gases), including measures to reduce emissions from aviation and also including such issues as the relative environmental impacts of different transportation modes [4]

10 CONCLUSIONS

There is a range of options to reduce the impact of aviation emissions, including changes in aircraft and engine
Substantial aircraft and engine technology advances and the air traffic management improvements should be incorporated in the aircraft emissions scenarios used for climate change calculations. Further technology advances have the potential to provide additional fuel and emissions reductions. In practice, some of the improvements are expected to take place for commercial reasons. The timing and scope of regulatory, economic and other options may affect the introduction of improvements and may affect demand for air transport.

REFERENCES