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Chapter 8

New Directions: Assessing the real impact of CO_2 emissions trading by the aviation industry

David S. Lee
Defence Evaluation and Research Agency, Propulsion and Performance Department, Pyestock, GU14 0LS, UK
E-mail: dslee@dera.gov.uk

Robert Sausen
Deutsches Zentrum für Luft und Raumfahrt e.V., Institut für Physik der Atmosphäre, Oberpfaffenhofen, D-82234, Wessling, Germany
E-mail: robert.sausen@dlr.de

The recent report of the Intergovernmental Panel on Climate Change (IPCC, Aviation and the Global Atmosphere 1999) assessed the impacts of subsonic aviation on the radiative forcing of climate for 1992 and 2050. Radiative forcing (RF) effects arise from CO_2 from the fuel burned, plus other emissions that result in aerosol, contrails, ozone (O_3) formation, methane (CH_4) destruction (the latter two from NO_x emissions), and possibly enhanced cloudiness. These effects are shown in Fig. 1.

The CH_4 loss results in a negative RF. The effect of positive RF from O_3 formation and negative RF from CH_4 removal do not, however, cancel each other out, nor do they imply a null climatic effect. The negative RF from CH_4 is rather uniform across latitudes (like the positive RF from CO_2), whereas the RF from O_3 is concentrated in the Northern Hemisphere. The overall climate effect from inhomogeneous forcing (remembering that RF is a proxy for climate change) is unknown. There are indications, however, that it might be larger than that expected from homogeneous forcing (Ponater et al., Climate Dynamics, Vol. 15 (1999) pp. 631–642). Contrails and aviation-induced cloudiness also result in a large RF, but there are large uncertainties associated with the estimated effects.

The RF from aviation CO_2 amounts to 37% of the total aviation RF (excluding the possibility of enhanced cirrus formation); the rest being attributed to other effects associated with aviation emissions. The RF effect of tropospheric O_3 formation and contrails is dependent upon factors such as altitude, latitude and longitude, which define chemical and physical conditions. Thus, the RF

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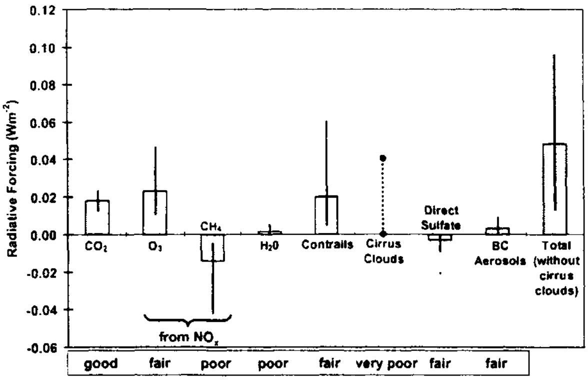

Figure 1. Globally averaged radiative forcing (RF) from 1992 subsonic aviation (IPCC, 1999). The evaluations ('good', 'fair' etc.) are a relative appraisal associated with each component, and indicate the level of scientific understanding.

effects from O_3 and contrails are aviation specific, whereas CO_2 RF (from burning aviation fuel) is not.

Currently, emissions of CO_2 from international aviation are not covered by the Kyoto Protocol. Following the publication of the IPCC report, the International Civil Aviation Organisation (ICAO) Assembly adopted a resolution that its Committee on Aviation Environmental Protection (CAEP) would study options to limit or reduce 'greenhouse'gases (GHGs) from aviation. CAEP is looking at possibilities from technology and standards, operational measures, and market-based options (ICAO Journal, Vol. 54 (1999) pp. 5–8). Market-based options might include emission charges, fuel taxes and emissions trading. Gander and Helme suggest (ICAO Journal, Vol. 54 (1999) pp. 12–14) that emissions trading of CO_2 may offer a workable solution to emissions reductions from aviation. One of CAEP's Working Groups is considering market-based options and focussing its efforts on CO_2.

Here we consider emissions trading from an atmospheric impacts perspective. Emissions trading can be instituted in a number of ways but for simplicity we will define 'open trading' as being inter-sector, and 'closed trading' as being intra-sector (i.e. within the aviation industry). We consider the potential consequences assuming that aviation is, overall, a purchaser rather than a seller of CO_2 emissions permits, which we believe to be a reasonable assumption.

Considering *'open trading'* first, two major issues need to be discussed: firstly, NO_x emissions associated with fossil fuel combustion (and therefore CO_2 emission) at the Earth's surface are involved in O_3 production, but the overall production efficiency is higher at cruise altitudes in the upper troposphere. Moreover, the temperature response (and thus RF) of O_3 is very altitudinally dependent. Secondly, fossil fuel combustion at the Earth's surface results in water vapour, but for aviation the resultant water vapour is involved in contrail formation resulting in an RF that would not occur in the case of surface emissions.

Next, we consider '*closed trading*': within the aviation sector the magnitude of the RF from other emitted species is also variable for the same global fuel burn and thus, CO_2 emissions. For example, the O_3 production efficiency of the upper troposphere depends upon the background NO_x concentration. An approximately linear relationship (Grewe et al., Geophysics Research Letters, Vol. 26 (1999) pp. 47–50) has been found between increases in global aviation NO_x and increases in global tropospheric O_3 in modelling studies. However, when these changes are examined by latitude, different sensitivities are found. For example, incremental increases in O_3 are much greater at southerly latitudes than for the whole atmosphere for the same increase in NO_x emissions. This implies that for capped global CO_2 emissions from aviation, if emissions were traded such that more flights occurred in the tropics or the Southern Hemisphere, then increases in O_3 (and its associated RF) would be much stronger than if emissions occurred over areas with relatively high background NO_x (e.g. northerly latitudes).

A similar phenomenon will occur for contrails. The tropics are more susceptible to contrail formation because of the higher humidity (Sausen et al., Theoretical and Applied Climatology, Vol. 61 (1998) pp. 127–141) such that a shift of growth to lower latitudes enabled by CO_2 emissions trading would increase RF. This would be exacerbated if the fleet growth occurred in these regions from newer aircraft, as they have a higher propulsive efficiency than older aircraft and trigger contrail formation more easily (Schumann, Aerospace Science and Technology (2000), in press).

The differential sensitivity of the atmosphere to aircraft emissions of NO_x, particles and water vapour dictates the amount of O_3 and persistent contrails formed, and therefore the overall RF effect. In addition, these spatially variable effects may amplify responses under the open trading scenario.

We conclude the following:

- If aviation participates in an open regime of inter-sector CO_2 emissions trading and aviation is an overall purchaser, then for capped global CO_2 emissions, any purchase of additional CO_2 emission permits by aviation from other sectors will result in a larger RF from associated aviation emissions than if the CO_2 had been emitted at the Earth's surface.
- If a closed intra-sector emissions trading scheme for aviation CO_2 is envisaged, the total RF effects from associated emissions could be greater or lesser, depending upon the latitude, longitude and altitude at which they are emitted for the same global capped CO_2 emissions.

It is evidently important to consider RF effects from other aviation emissions in addition to CO_2, as aviation is a unique source sector in terms of RF effects. It is possible that emissions trading – which has the ambition of reducing RF – could actually increase the RF from aviation for the same global capped CO_2 emission. Aviation's unique emission characteristics and potential RF effects should, therefore, be considered in formulating policies to mitigate climate change.

The obvious way forward in an open sector emissions trading regime is to weight any CO_2 permits purchased by aviation such that the additional RF effects are accounted for. However, such weighting functions would be spatially and temporally variable, and the supporting science to define these require further development.