Lowering the Impact of Aviation on Global Earth´s Radiation Balance

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ABSTRACT: This paper discusses the possible involvement of contrail radiation in the scheme of the EU ETS to decrease aviation impact on the global Earth´s radiation balance. The main goal of this involvement should be the lowering of aviation radiation balance without any further costs for aviation operators. This fact should encourage further research of this possibility due to this being a "win - win" scenario. Lowering the aviation impact on the radiation balance with lower costs than only the charges dependent on the EU ETS scheme, which nowadays covers only emissions of CO_2.

KEY WORDS: aviation, radiative balance, contrails, EU ETS.

1 AVIATION AND CLIMATE CHANGES

The goals of the Kyoto protocol were taken on by the EU in 1998. Although the Kyoto protocol tackles only the emissions of greenhouse gases, it is important to stress that lowering the emissions of greenhouse gases is not the main purpose of the Kyoto Protocol. Lowering emissions of greenhouse gases is only a tool with which to achieve the real goal. The real goal should be the minimization of the impact of human activities on the radiative balance of the Earth´s atmosphere.

Today´s level of scientific understanding of aviation's impact on global atmosphere is very low. We are able to estimate the impact of greenhouse gas emission from engines quite well. However, the area which is still necessary to explore is the problem of induced cloudiness and contrails.

Aviation has a negative impact on global Earth´s radiation balance. One part of this negative impact is the production of greenhouse gases, mainly CO_2. This part of negative impact is directly dependant on fuel consumption, and, as such, is only very slightly susceptible. However, there is second component of the whole aviation on global Earth´s radiation balance impact. Radiative forcing is a commonly used indicator of how much an activity influences the total energy balance of the Earth. RF is an indicator which shows to what extent each component of aviation emission influences the global warming. The relation between radiative forcing and the equilibrium Earth surface temperature change (ΔTs) can be simply represented by the equation:

$$\Delta\, Ts = \lambda\, RF$$

where λ represents the climate sensitivity parameter (K/(W/m^2)).

The addition, on which we will focus in this paper, are contrails and induced cloudiness. The danger of contrails and induced cloudiness work on the assumption that the flight of jets or turbofan aircraft may sometimes produce contrails. Contrails can be the building blocks of more massive cloudiness which may occur on some occasions (Schumann, 2005; Mannstein & Schumann, 2005). Cloud coverage works very similarly as greenhouse gases do. Clouds let through radiation from the upper atmosphere and from the Sun, but reflect radiation which is coming from Earth. As such it is conserving energy in the Earth´s atmosphere, and, through this, its increasing the volume of energy on one side of the global Earth´s radiation balance equation (Haywood et al., 2009). This is the reason why aviation's contribution to the global Earth´s radiation misbalance is more important than any other emission which would be of an equal amount. Aviation contributes to atmosphere energy twice; once, as every fossil burning engine, and, second, from creating contrails and clouds which have a surplus negative effect. Estimates of the negative impacts of aviation are burdened with a high level of scientific uncertainty and they vary between 15% and 350% of negative addition of aviation greenhouse gases production. For more details see Blockley (2010), Chapter 304.

2 AVOIDING CONTRAILS AND INDUCED CLOUDINESS

The avoidance of negative effects from contrails and induced cloudiness is quite simple; we have to avoid producing contrails. Avoiding contrail production is possible via different methods, but one of the most practical ones is by changing the flight levels. The change of flight level can be either through descending or climbing. However, due to the fact that modern jet aircrafts are flying as high as possible, for the reason of better engine effectiveness at higher flight levels, the only applicable change is descending. It is here that the first issue is to be solved, as flight at lower flight levels means engine operation would be less effective and would consume surplus fuel and produce surplus emissions. These surplus emissions of greenhouse gases would have an additional negative impact on the global Earth´s radiation balance. Therefore should there be any decision-making mechanism, a formula or table to decide on a change of flight level would be advantageous. This is the key decision, and the goal of our future research.

The problem connected with this key decision is the level of scientific understanding of all incorporated aspects. The LOSU of aspects is variable between full understanding of specific incorporated problems and a low level of LOSU of others. We are able very precisely to estimate the amount of emissions which would be produced during flight. We are also able to summarize with a rule for which situations contrails will occur. The precise probability of developing cloudiness from contrails is a less studied area. The lowest LOSU is connected with the direct estimation of cloudiness and contrails' impact on global Earth´s radiation balance. Another unknown aspect is the price of EU ETS allowances, which may change rapidly in future. The EU ETS connection with this issue will be discussed later.

3 AVOIDING CONTRAILS LEADS TO SURPLUS FUEL CONSUMPTION

The first issue is the estimation of the negative impact of induced cloudiness and contrails in comparison with the negative impact of changed flight level/fuel consumption. The estimate of the negative impact of induced cloudiness and contrails is burdened with a high level of uncertainty. Lowering this level of uncertainty will be long term issue, which will not disappear in next few years. We think that a responsible approach should not have to waitfor the results of long term research on the impact of cloudiness on the Earth´s atmosphere, but instead to find a solution from a different angle. We would like to define how important the negative impact of cloudiness and contrails would have to be in order to justify the needs of level changing during flight planning. This means we would like to start detail research of this issue now and when there will be more precise results on the impact of cloudiness on atmosphere balance we will be able within a short time to decide which flights should be implemented in some kind of contrails avoiding procedures, and which flights need not.

Despite the fact that we theoretically know in which atmosphere the contrails will occur we cannot forecast them as today's weather forecasting is not aimed at forecasting humidity and filled up of air in flight levels where most of airliners fly, which is necessary for contrail prediction. Additionally, prediction models of how contrails will form in cloudiness is today again fraught with many uncertainties. However, prediction models of contrails are dependent on atmospheric pressure, temperature, and humidity and have very good tools in mode S of secondary radar. Especially information from BDS registers 44 Routine meteorological data, and 45 hazardous meteorological data are very important. Data from these registers shall be sufficient for models similar to "Contrail Cirrus Prediction Tool" (CoCiP), or MM5T (Schumann, 2012; Steufer et al., 2005) which shall be sufficient for a new kind of forecast for aviation. Unfortunately, information involved in these clusters are nowadays transmitted by only a negligible percentage of aircraft and so it is insufficient for forecasting. A change will only come about by equipping more aircraft with humidity measuring equipment.

4 LEGISLATIVE FRAME

An important step in decreasing the impact of aviation on the atmosphere radiative balance is to prepare legislation on how a voluntary change of flight level would be made in practice, because in controlled air space airplanes cannot change their level however they like. There are two main problems connected with this level change to avoid contrail production.

The first are regulations and procedures of air traffic management which shall enable the changing of flight levels depending on contrail forecast. This procedure preparation should work on a basis which is adopted for avoiding thunderstorms and weather hazards during flight.

The second area is developing such a program which would motivate aviation operators to change their flight level. The motivation program which may be used for this purpose has been in operation in aviation since 2012. The program is called the EU ETS.

The EU ETS, European trading scheme for trading allowances to emit CO_2. From the year 2012 aviation has been implemented in this scheme. The EU ETS is a trading scheme based on a cap and trade basis. It is one of the policies introduced across the European Union (EU) to help it meet its greenhouse gas emissions reduction target under the Kyoto Protocol. Very simply put, the EU ETS allows the producer to emit only as much greenhouse gas as the producer has allowances for. Allowances are partially distributed free of charge according to emission background and are partially accessible on the free market where they can be sold and purchased by anyone.

This market instrument allows the contributors who spare some of their allowances to sell them for profit. Theoretically, this system should be used for every greenhouse gas.

In practice, only the emissions of CO_2 are taken into account. More about the EU ETS can be found in EU Directive 87/2003.

As mentioned before the EU ETS is obligatory and aviation operators are now getting used to working within this legislative framework. Although today's contrails production is not part of the EU ETS, this system could very easily be changed to fulfill this new role. The EU ETS has been working since 2005 and covers more than 10 000 industry installations. Starting from 1st January 2012 all aircraft operators attaining the limits of transport performance and performing flights arriving at or departing from any airport situated in the territory of the European Union or an EEA-EFTA1 country (Iceland, Liechtenstein and Norway) will be included in the EU Emissions Trading System. Aviation is included in the system by EU Directive 101/2008. This is going to be implemented in several gradual steps to help businesses to become established within the EU ETS. For the first year there will be allowances for 97% of historical aviation emissions. Historical emissions represent the average of the estimated annual emissions for the years 2004, 2005, and 2006. For each of the next years there will be allowances only for 95% of historical emissions. But only 15% of all allowances are auctioned. The rest, more than 80 %, is allocated freely to airlines according their historical emissions. The number of needed allowances is counted according to the equation (2), where fuel consumption is in tonnes, and the emission factor should be taken from 2006 IPCC Inventory Guidelines or subsequent updates of these Guidelines, for each type of fuel; for the most commonly used aviation fuel the emission factor 3.15 is used.

$$\text{Fuel consumption} \times \text{emission factor} \quad (2)$$

Emission factor 3.15 covers only the production of carbon dioxide, for the inclusion of emissions of other greenhouse gases which are produced during the combustion of aviation fuel we would have to raise the emission factor. The inclusion of aviation in the EU ETS gives rise to a few issues which have been obvious even before aviation really starts to work within the EU ETS. A crucial problem is that the EU ETS takes into account only the production of CO_2 and its RF addition. The EU ETS doesn´t take into account any other sources of RF from aviation, even though the RF from CO_2 emissions may only be 1/3 of all RF. Aviation companies are forced to obtain allowances to emit CO_2. There is a big opportunity for the implementation of a new development scheme for decreasing the impact of aviation on global Earth´s radiation balance.

Nevertheless, the EU ETS is appropriate and suitable for incorporating contrail avoidance. A possible way may be a change in equation (2). Depending on the situation there should be another constituent which would decrease emission factors dependent on how much the aircraft would have to fly at a lower flight level, compared to the flight level stated in the flight plan, to avoid airspace where there is a risk of contrails. The value this constituent shall be the subject of expert debate.

The EU ETS is the only program suitable for use with contrails airspace avoidance. Without any stimulus there is no chance that aviation companies would voluntarily change their flight levels only to avoid contrails. It is absolutely essential to prepare changes in the EU ETS to be ready to involve this scheme as soon as the impact of induced cloudiness and controls will be proved.

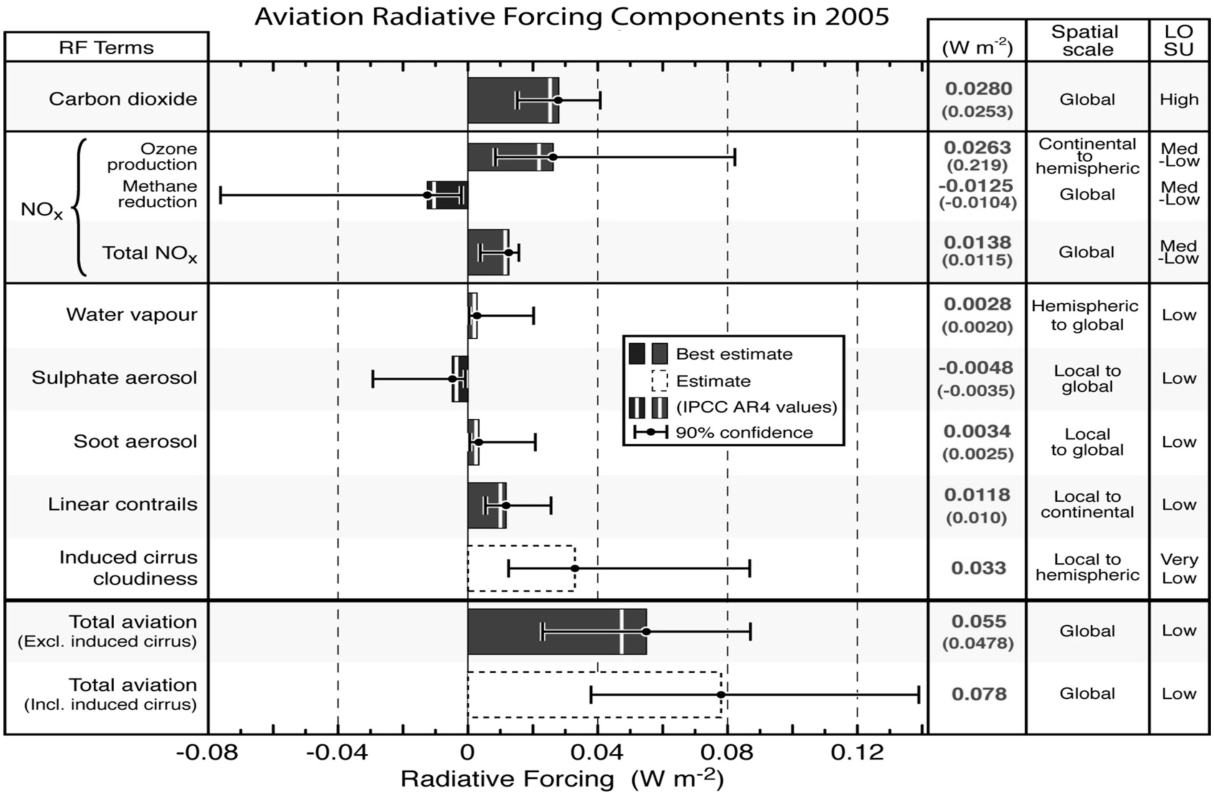

Figure 1: Aviation Radiative Forcing estimates (Lee et al., 2010).

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