1. Impacts of aviation on climate

Aviation transportation is one of the fastest growing activities influencing climate, so it is important to take it into account in analysis of mitigation required for climate stabilization (ABCI, 2008). The European Union has adopted several measures to reduce aviation emissions, and these measures include the emission trading scheme (ETS), which is designed to control aviation emissions from aircraft operating in EU airspace. The carbon dioxide emissions from aviation are calculated using the Java Climate Model (JCM, available on www.climate.be/jcm), an "integrated assessment" model that was designed to facilitate the interactive exploration of scenarios, taking different stabilization objectives into account. The originality of JCM is that users can see an instant response to adjusting parameters and thereby explore sensitivities of scenario projections to diverse options and uncertainties. The climate and carbon cycle components consist in relatively simple (but non-linear) models with sets of parameters based on results from more complex models.

2. Background: conditions for contrail formation

The engines of a jet airplane emit mainly water vapour and carbon dioxide at high temperatures. The exhaust gases mix up in a few seconds with the ambient air. If during this mixing process the air becomes saturated with respect to water a contrail will form (case 1). If the environmental air is ice-supersaturated, the contrails will persist (up to several hours) and spread out (case 2). It is important to note that for thermodynamical reasons, more efficient planes are more prone to form contrails.

3. Model and 2°C stabilization

To investigate the implications of aviation on climate stabilization, we use the Java Climate Model (JCM, available on www.climate.be/jcm), an "integrated assessment" model that was designed to facilitate the interactive exploration of scenarios, taking different stabilization objectives into account. The originality of JCM is that users can see an instant response to adjusting parameters and thereby explore sensitivities of scenario projections to diverse options and uncertainties. The climate and carbon cycle components consist in relatively simple (but non-linear) models with sets of parameters based on results from more complex models.

In this poster, the model is used in the "temperature stabilization" mode: it internally adjusts the future emissions mitigation for all sectors together by an iterative process so that temperatures reach stability from a given year, for example 20°C (above preindustrial level) starting in 2100.

4. Example aviation scenarios

Baseline aviation emissions scenarios are taken from IPCC (1999), the CONSAVE project (Berghof et al., 2005), and the FAST scenarios (Quen et al., 2005) of the EU ETS. For aviation emissions, the radiative forcing changes due to aviation are calculated on the basis of IPCC (1999) adjusted to the more recent TRACOFF data (Sausen et al., 2005) for CO₂, NOx, CH₄, sulphur and carbon aerosols, water vapour, lattine contrails and cirrus. An example of results is shown on the right figures for the FAST A1 scenario. The first column relates to the "continuation of existing policy" in the aviation sector: mitigation is required only for domestic flights within Annex I countries. For aviation in these countries, the ratio of actual emissions to baseline aviation emissions is made equal to the ratio of CO₂ emissions for all sectors (constrained by the 2°C stabilization) divided by its baseline (IPCC SRES A1B). As most aviation scenario where not defined after 2050, we use constant emissions thereafter. In this scenario without mitigation of international aviation, emissions are growing a lot. As the stabilisation temperature objective (2°C limit) is maintained, the emission budget available to other sectors is very small, and even the total of the other sectors is very small. According to the fact that there are very significant non-CO₂ emissions, in particular due to the aircraft induced cloudiness.

The 3 following columns present mitigation scenarios applied on the aviation sector. They are based on simple hypotheses aiming at exploring the consequences of mitigation in the aviation sector. The radiative forcing changes due to aviation are calculated on the basis of IPCC (1999) adjusted to the more recent TRACOFF data (Sausen et al., 2005) for CO₂, NOx, CH₄, sulphur and carbon aerosols, water vapour, lattine contrails and cirrus. For aviation in these countries, the ratio of actual emissions to baseline aviation emissions is made equal to the ratio of CO₂ emissions for all sectors (constrained by the 2°C stabilization) divided by its baseline (IPCC SRES A1B). As most aviation scenario where not defined after 2050, we use constant emissions thereafter. In this scenario without mitigation of international aviation, emissions are growing a lot. As the stabilisation temperature objective (2°C limit) is maintained, the emission budget available to other sectors is very small, and even the total of the other sectors is very small. According to the fact that there are very significant non-CO₂ emissions, in particular due to the aircraft induced cloudiness.

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5. Results and conclusion

The table on the right summarize the main results, showing 2050 emissions for all sectors except aviation in % of 1990 emissions. All scenarios (in columns) except the last one are non-mitigation scenarios (no climate stabilization policy) for comparison with the addition scenarios (shown in rows) as explained above. There is one additional intermediate scenario, in which this mitigation is again applied on international flights involving Annex I countries only until 2050, but in both, A1 and non-A1 reduces their emissions by 1%/year after 2050. The main result is that the "continuation of existing policy", avoiding mitigation only for domestic Annex I flights, implies very large emission reduction in other sectors : from -55 to -32 % of 1990 emissions, in order to have roughly 1/2 chances that global warming remains below 2°C from pre-industrial (we use a medium climate sensitivity of 3.2°C and other mean parameters).

When mitigation is applied on aviation, the burden on other sectors becomes more bearable : for example, in the high emission baseline FAST A1, the other sectors can only emit 18% of their 1990 emissions, while the emissions from other countries can still emit 37% of their 1990 emissions. The CONSAVE DfE ("Down to Earth") scenario is another example of mitigation, also showing smaller mitigation efforts in non-aviation sectors than in the "existing policy" cases. The model includes the feedback of increased surface temperature on the carbon cycle (via ocean chemistry and soil respiration) and the subsequent increase of carbon dioxide concentrations in the atmosphere induced by aviation warming. The additional CO₂ released by this feedback has been provisionally estimated to be of the order of 30% of the direct emissions of CO₂ from aviation. It transforms short-lived radiative forcings (not only from aviation) into long term impacts on climate from CO₂.

Avoiding large increases in the aviation emissions is thus an important component of mitigation to achieve climate stabilization at a low level.

Table: reduction of CO₂ emissions from all sectors except aviation in 2050 in % of the corresponding 1990 emissions

<table>
<thead>
<tr>
<th>IPCC</th>
<th>FAST</th>
<th>CONSAVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>emissions back to 2005 emissions until 2050</td>
<td>60</td>
</tr>
<tr>
<td>A1+DC</td>
<td>aviation emissions back to 2005, then -1%/year</td>
<td>42</td>
</tr>
<tr>
<td>Existing policy</td>
<td>-1%/year after 2050</td>
<td>73</td>
</tr>
<tr>
<td>A1 emissions back to 2005</td>
<td>67</td>
<td>68</td>
</tr>
</tbody>
</table>

Note (1) : A similar example is proposed in a recently announced study by the UK Schumann, U., Aviation, Atmosphere and Climate - What has been learned, Proceedings of the AACC-conference, June 7 - July 5, 2003, Friedrichshafen, Germany, 2003 (Note (1)) A similar example is proposed in a recently announced study by the UK Committee on Climate Change.

SOURCES AND LINKS


REFERENCES