ABC Impacts – Users' committee meeting – 2 February 2009

Workshop on non-CO_2 aviation climate impacts

Minutes

Attendances

ABC Impact research team	– Sandrine Meyer (CEESE-ULB) – Julien Matheys (ETEC-VUB) – Tom van Lier (MOSI-T-VUB) – Andrew Ferrone, Philippe Marbaix, Ben Matthews (ASTR-UCL) – Excused : Dr. Walter Hecq (CEESE-ULB), Pr. Cathy Macharis (MOSI-T-VUB), Pr. Joeri Van Mierlo (ETEC-VUB), Pr. Jean-Pascal van Ypersele (ASTR-UCL)
Workshop guests	– Rasa Sceponaviciute (European Commission) – Guy Viselé (Belgocontrol)
Users' committee members	– Bill Hemmings (T&E) – Georges Jamart (The Belgian Scientific Policy) – Bert Jacques (The Brussels Airport Company) – Guy Verluyten (Belgocontrol) – Alain Wilmart (SPF Santé publique et Environnement) Excused : Liesbeth Clerick (AMINAL), Pierre Courbe (IEW), Caroline De Bosscher (Vlaamse Milieumaatschappij), Geoffray Robert (SPF Santé publique et Environnement), Nico Van der Steen (Brussels Airlines)
Guest	– André Clodong (EBAA) – André Heughebaert (ULB)

Agenda of the meeting

1. Welcome .... (10.00)
2. Synthesis ABC Impacts project results and forthcoming work .... (10.10)
   (Sandrine Meyer ; CEESE-ULB)
3. Overview of the ETS and need to address some of the other climate impacts .... (10.30)
   (Rasa Sceponaviciute ; EC – DG Environment – Clean Air and Transport Unit)
4. Belgocontrol and the environment .... (10.50)
   (Guy Viselé ; Belgocontrol)

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5. Aircraft induced cloudiness in the regional climate model CCLM .... (11.30)
   (Andrew Ferrone ; ASTR-UCL)
6. Potential mitigation measures for non-CO_2 climate impacts .... (11.50)
   (Sandrine Meyer ; CEESE-ULB)
7. Some illustrations and videos .... (12.10)
8. Discussion / questions .... (12.15)
9. Conclusions and closure .... (13.00)

Remark: all the words appearing in blue in the text are explained in more detail in the ABC Impacts glossary (http://dev.ulb.ac.be/ceese/ABC_Impacts/open_section_in_brief.php#glossary).

1. Welcome

Seeing that the last users' committee was organised in parallel with a workshop dedicated to the aviation and the offset programmes and that the form was successful, the ABC consortium decided to set up a second workshop for the fifth ABC users' committee. To be in line with the conclusions of the final report of the first phase of the ABC Impacts project, the topic chosen for the workshop is "Non-CO_2 aviation climate impacts".

2. Synthesis ABC Impacts project results and forthcoming work

Sandrine Meyer's presentation: see ABC Impacts website → Open Section → Project publications (http://dev.ulb.ac.be/ceese/ABC_Impacts/documents_abc/workshop_2_February_2009_CEESE_ABC.pdf)

2.1 Synthesis ABC Impacts first phase

In the conclusions of the final report of the first phase of the ABC Impacts project, it appears to be fundamental for Belgium to study more in depth and to tackle non-CO_2 aviation climate impacts. This is the consequence of a range of facts: 1- non-CO_2 emissions from aircraft have regional climate impacts ; 2- Belgium is situated right in the middle of the FLAP area ; 3- the number of overflights above the Belgian territory is expected to double in the following years ; 4- the result of this consists in a potential high concentration of aviation regional climate impacts above Belgium.

1- Regional aviation climate impacts

H_2O, NO_x, PM and other direct or secondary air pollutants emitted by aircraft induce regional climate impacts mainly by generating clouds such as contrails and cirrus (= aircraft induced cloudiness: AIC). It is also interesting to note that there is a trade off between CO_2 and H_2O/NO_x emissions according to the altitude of the flight: at a higher altitude, an aircraft will burn less fuel (and thus emit less CO_2), while H_2O/NO_x emissions will increase in such a proportion that the total aviation climate impact at 12km is equivalent to twice the climate impact at 8km. Consequently, it is very important to tackle AIC as well as CO_2 emissions because there is a high risk to worsen the total aviation climate impact if only CO_2 is taken into account in the climate policies.

Recent scientific works highlight the importance of AIC in the total aviation climate impacts. For example, the European TRADEOFF project has shown that even if contrails have a lower radiative forcing impact than expected in the IPCC report of 1999, cirrus clouds have a higher impact that could potentially reach five times the RF impact of CO_2. Moreover, in very recent researches, it has been shown that different observations of AIC are in line with model predictions.

In brief, there is a certainty: non-CO_2 climate impacts have at least a similar RF impact than CO_2 but they have a shorter lifespan (on average, the global warming potential of non-CO_2 aviation climate impacts is 6 on a 20 years time horizon but only 2.4 on a 100 years time horizon). The uncertainty doesn't lie in the fact that the RF of non-CO_2 emissions could be as high as the RF of CO_2, but rather in the fact that it could be either as high, either much higher than the RF of aviation's CO_2.

It has also to be noted that the secondary climate impacts of aviation, due to the influence on the carbon cycle and CO_2 uptake by oceans (a local warming above oceans induces less CO_2 uptake, which increases the global warming effect) are even not taken into account.

2- Geographical situation of Belgium

The FLAP area is determined by the four major European airports of Frankfurt, London, Amsterdam and Paris. As it can be seen on the map, Belgium is situated right in the middle of this area.

3- Trends in the overflights above the Belgian territory

Eurocontrol foresees that the number of flights in the FLAP area will double between 2000 and 2020. This will have consequences for Belgium because more or less 70% of the flights registered in the Belgian airspace are overflights from the airports of the FLAP area and that most of them fly right through the whole country (see illustration from Belgocontrol).

4- Regional climate impacts for Belgium

The first climate modelling from the ABC Impacts project shows that AIC above Belgium has a huge impact on the RF (blue bars on the top of the graph) compared to the impact of the aviation sector (green bar at the foot of the graph). The estimated error is quite large (black line) but this impact could even be much more important for Belgium than the global climate change induced by all anthropogenic CO_2 emissions.

Secondly, the modelling shows that the main part of the AIC climate impact on Belgium is due to overflights (bar in light blue is due to overflights compared to bar in dark blue due to aircraft movements from and to Belgian airports).

As a result, it is sure that Belgium will increasingly suffer from non-CO_2 aviation climate impacts in the following years while up to now those impacts are up to now not taken into account in climate policies such as the EU-ETS and there are different trade-offs between CO_2 and non-CO_2 mitigation options.

Therefore, it is a necessity to carefully analyse the whole issue to avoid increasing aviation climate impacts, especially above Belgium, and to define complementary measures to mitigate non-CO_2 aviation climate impacts.

2.2 ABC Impacts forthcoming work

In the following months, the ABC consortium will closely watch the revision of the EU-ETS, the negotiations on the post-2012 scheme and objectives in the context of the UNFCCC, the reactions of non-European countries on the European Directive on the inclusion of the aviation sector into the EU-ETS. Another important work concerns the update of aviation development scenarios according to the current global economic and financial crisis.

Concerning the internal work, the focus will be laid on the regional climate modelling, the definition of complementary measures to take non-CO_2 aviation climate impacts into account and the definition of stakeholders' indicators for the MAMCA.

2.3 Questions / remarks

- *Philippe Marbaix indicates that a note on the inclusion of non-CO2 aviation emissions in the EU-ETS is available on the ABC Impacts website: http://dev.ulb.ac.be/ceese/ABC_Impacts/documents_abc/Note_to_stakeholders_aviation_nonco2.pdf. He agrees that it is difficult to find a metric to compare climate impacts from CO_2 and non-CO_2 emissions and that the current situation resorting to RFI is misleading. However it is important to note that AIC have a real important impact and that it is maybe one of the aviation climate impacts that can be mitigated easily with operational measures, which is an opportunity.*

3. Overview of the ETS and need to address some of the other climate impacts

Rasa Sceponaviciute's presentation: see ABC Impacts website → Open Section → Project publications (http://dev.ulb.ac.be/ceese/ABC_Impacts/documents_abc/workshop_2_February_2009_EC.pdf)

3.1 Significance of aviation emissions

The international aviation sector is the sector in the EU with the most important growth in GHG emissions compared to the 1990 levels, while major economic sectors such as Industries, Agriculture and Energy have reduced their emissions.

In 2005, CO_2 emissions related to the aviation fuel sold in the EU reached 144 million tonnes which is in the same order of magnitude as different other sectors included in the EU-ETS such as the Cement and lime, Mineral oil refineries, Iron and steel.

3.2 Aviation and the EU-ETS directive

In November 2008, the Directive 2008/101/EC so as to include aviation activities in the scheme for greenhouse gas (EU-ETS) was adopted. It has entered into force on the 2nd of February 2009.

Concerning the area of application, this directive covers all flights to and from EU airports but several exemptions are allowed:

- small aircraft and certain flights (e.g. emergency, military, humanitarian, test and formation, etc.) are excluded;
- de minimis provision: commercial operators operating on average less than 2 flights per day and commercial operators with total annual emissions of less than 10,000 tonnes p.a. are excluded.

Moreover, there is a specific paragraph in the directive specifying that if a third country adopts an equivalent measure to tackle/mitigate CO_2 emissions from the aviation sector, the directive could be amended to take this measure into account.

Calendar of this inclusion:

2009	Submission of the first tkm monitoring plans
2010	Monitoring of the emissions and tkm data
2011	Application for free allocation allowances
2012	Surrender allowances

This schedule is essential for the operators if they want to obtain some free emissions allocations.

The emission ceiling is equivalent to the average total emissions of the sector in the EU in 2004, 2005 and 2006, but in 2012 the allocation will be limited to 97% of this ceiling and from 2013 it will only represents 95% of the cap.

Currently, the commission is working on the calculation of the cap.

As regards the administrative point of view of the directive, each aircraft operator will be allocated to one EU Member State. The directive allows two compliance mechanisms:

- a penalty (100€ in the beginning) for each missing emission allowance
- the possibility to impose an operating ban on the operator that does not comply with his obligations.

From the total of allowances, 3% will be reserved for new or fast-growing operators, 15% will be auctioned in 2012 and the rest will be allocated for free on the basis of a tkm benchmark. Auctioning proceeds should be spent on tackling climate change in the EU and third countries (emissions reductions, adaptation, administrative costs related to the scheme, Global Energy Efficiency and Renewable Energy Fund, avoiding deforestation in DC, R&D on mitigation and adaptation options in aeronautics and air transport, support to low emission transport).

Regarding the monitoring and reporting, operators may monitor and report tonne-kilometre data if they intend to apply for free allowances and shall monitor and report emissions data. Reports must be verified by an independent verifier and submitted to the competent authority. Guidelines for the monitoring, reporting and verification of emissions from aviation will be soon adopted by the Commission.

It is expected that, compared to business as usual from 2005 emissions, by 2020 the directive should result in a reduction of over 190 M tonnes CO_2 annually.

3.3 Other climate impacts of the aviation sector

The directive concerns exclusively the CO_2 emissions from the aviation sector but it is well known that the climate impacts of aviation are greater than that (cf. impacts induced by NO_x, water vapour, sulphate, soot particles).

Up to now the Commission only committed itself to propose complementary measures to tackle NO_x emissions. A proposal is expected by the end of this year.

The Commission notices that scientific uncertainty about these non-CO_2 aviation climate impacts in its services is a barrier to the development of further policy but asks itself if this uncertainty is due to a need for more research or a need for better communication between scientists and policy makers.

More information available on the European Commission website: http://ec.europa.eu/environment/climat/aviation_en.htm.

3.4 Questions / remarks

- Julien Matheys asks why the different aviation operators will be allocated to a specific Member State and why the administration is not centralised for more efficiency.

  Rasa Sceponaviciute answers that there are more than 3.000 aviation operators concerned by the inclusion in the EU-ETS. It is not feasible for only one Member State to manage all operators on the one hand and on the other hand the subsidiarity principle would be in contradiction with a European central management centre.

- Ben Matthews asks if the revenues would also be used for adaptation measures.

  Rasa Sceponaviciute answers that some adaptation measures are listed in the proposed issues to spend the revenues but the majority of the measures concerns mitigation options. In any case, the final decision depends on the decision of the different Member States. The directive only suggests some ideas to use the revenues.

- Ben Matthews asks if it possible to apply the revenues at the EU level for example to promote mitigation measures in the air-traffic control.

  Rasa Sceponaviciute answers that it is not possible because of the subsidiarity principle: many Member States are opposed to a centralised management.

- Julien Matheys asks how the measures adopted by third countries will be analysed to see if they are similar to the EU-ETS or not. Are there any criteria already defined in the directive?

  Rasa Sceponaviciute answers that this will be analysed on a case by case basis because it is too difficult to adopt criteria while third countries will never suggest similar measures at the same time.

- Guy Viselé highlights that one ICAO's task force is working on market mechanisms related to the post-2012 scheme. A report will be presented at the CAEP in September.

4. Belgocontrol and the environment

Guy Viselé's presentation: see ABC Impacts website → Open Section → Project publications
(http://dev.ulb.ac.be/ceese/ABC_Impacts/documents_abc/workshop_2_February_2009_Belgocontrol.pdf)

4.1 Presentation of Belgocontrol

The missions of Belgocontrol are in priority to guarantee the safety and to deliver the requested capacity. The secondary objectives are to reach the best punctuality and a maximal efficiency, taking the environment into account.

Belgocontrol guarantees the safety of air navigation:

- in the controlled civil airspace above Belgium from ground level to flight level 245 (24,500 feet = 8,000 metres altitude)[1];
- in the controlled civil airspace above the Grand Duchy of Luxembourg from flight level 135 (13,500 feet) to flight level 245
- as well as at the five Belgian public airports: Antwerp, Brussels Airport, Charleroi, Liege and Ostend.

[1] The control of the airspace situated above 24,500 feet has been delegated to MUAC (Maastricht Upper Area Control Centre), managed by Eurocontrol.

In 2007 and 2008, this represented respectively 1.130.332 and 1.147.324 movements, with more or less 49% of the movements corresponding to landings or takes-off from Belgian public airports and 51% from overflights (CANAC line in the table). To obtain the total overflights in the Belgian airspace, the movements controlled by MUAC have to be added to the CANAC line.

4.2 The Environmental approach of Belgocontrol

Environmental decisions are political choices.

For aviation, safety is and remains the top priority. Belgocontrol checks if new procedures respect safety (regulatory separations, non-conflict between departure and arrival routes, Obstacle Clearance Limit), converts decisions in aeronautical terms and publishes them according to ICAO's schedule.

Belgocontrol wants to play a proactive part through the study, proposal and implementation of means, procedures and techniques that have a positive effect on the environment without compromising safety and efficiency in air traffic management (ATM).

The European air traffic is expected to double by 2030. Belgocontrol is facing different challenges related to this traffic growth due to the complex nature of this traffic and because the Belgian airspace is the busiest and the most complex in Europe (at the crossroads of East-West and North-South traffic ; ascending and descending « regional» traffic ; approaches at local airports).

4.3 Emission management

1- ICAO's Circular 303

ICAO edited in 2004 its circular 303 entitled "Operational Opportunities to minimize Fuel Use and reduce Emissions". Its sixth chapter is dedicated to the air traffic management and lists ten principles to minimise aviation emissions:

- Fly most efficient aircraft for the sector,
- **Taxi the most efficient route,**
- **Fly the most efficient route,**
- **Fly at the most efficient speed,**
- **Operate at the most economical altitude,**
- Maximise the load factor,
- Minimise the empty aircraft weight,
- Load the minimum fuel commensurate with safety,
- Minimise non-revenue flights,
- Maintain clean and efficient aircraft.

The four measures in bold are directly in connexion with Air Traffic Management (ATM) and Belgocontrol is involved in different projects related to these issues.

2- Belgocontrol and the ATM

The IPCC report considers a world-wide potential reduction of 6-12 % of emissions by the introduction of better ATM measures, using for example improved flight planning (e.g. CFMU[2]), more direct routes and redesigning the airspace. However, local figures may vary.

Redesigning the airspace

As regards this issue, Belgocontrol is involved in:

- the definition of the future "Functional Airspace Blocks" (FAB) of the Single European Sky (SES);
- the improvement of the Belgian airspace, in particular through civil-military collaboration for the Flexible Use of Airspace (FUA).

More direct routes and improved flight planning/procedures

It is well known that shorter flight routes have a positive impact on fuel burn and related emissions. Route can be shortened not only by minimising the track-miles through a more flexible use of the

[2] CFMU : Central Flow Management Unit

airspace coupled with the definition of more direct routes, but also by improving the predictability for the pilot e.g. to allow absorption of delays by applying lower speed (rather than having to hold or to get track extensions by vectoring).

This optimisation of the flight planning can be done thanks to:

- a better coordination/communication between airports to know if the destination airport slot is available or not;
- the European CFMU[3]: this centre can reduce emissions by proposing more direct routes whenever possible and by keeping the aircraft on the ground, with its engines switched off, until it receives an available slot, rather than make it take off and burn fuel uselessly;
- the CDM (Collaborative Decision Making): it supports extensive exchange of information among operational entities on the airport (Belgocontrol, airports, operators, handlers), the sequencing of departures, the implementation of TOBT (Target Off-Block Time), that allows the restriction of the number of aircraft at the holding point. This tool allows also just-in-time engine start-up, limits taxi-times, reduces ground noise, as well as local emissions and fuel consumption (cf. graph comparing the average fuel consumption of the different power units used by an aircraft due to one minute ground delay).

Another solution to reduce aircraft fuel consumption and related emissions is to implement better flight procedures such as the continuous climb, the Continuous Descent Approach (CDA), the Low Thrust / Low Drag (turbulence) e.g. speed compatible with clean airspeed in arrival phase.

Concerning the CDA, Belgocontrol encounters difficulties to implement it due to the complex and busy nature of the airspace it has in charge. Therefore, a new approach has been adopted: the CDA is implemented when it looks possible (periods with low traffic loads ; only for those flights where circumstances permit CDA in a safe manner with no negative impact on capacity ; as much as possible aligned to current operating procedures ; starting at low flight levels and gradually extend to higher altitudes). This approach is already applied to some extent at Brussels, Charleroi and Ostend airports. Better opportunities are expected with the projects Belgian Airspace Reorganisation (BARe), the Functional Airspace Block Europe Central (FABEC) and the on-going CDA facilitation progress.

The choice of the flight altitude is very important for the fuel efficiency of the flight but it depends on aircraft type, direction of flight and weather conditions. Moreover, the optimum cruise altitude is usually between 30,000 and 40,000 feet where contrails tend to form the easiest (= > trade-off between CO_2 and contrails). Up to now, it is preferred to optimise the fuel consumption given that scientific evidence on contrails is still uncertain, while CO_2 emissions clearly have a major climate change impact.

Interdependency noise and emissions

There are different interdependencies between measures to tackle aviation climate impacts and other environment impacts such as local air quality or noise.

This can take the form of synergies like for example the cases of the CDM that has a positive impact on both local noise and emissions or the CDA where the avoidance of idle thrust reduces both emissions and noise. However, there are also many opposite effects and trade-offs (e.g. longer flight distance to avoid densely populated areas reduces the noise exposition at the expense of the fuel consumption).

4.4 Conclusions

- Emissions of various natures cannot be studied separately.
- An improvement in one kind of emission may result in an increase in another kind of emission (trade-off as for example noise against emissions).
- There is a need for good scientific knowledge taking into account **interdependencies** to help politicians define priorities in environmental measures.

4.5 Questions / remarks

[3] Central Flow Management Unit

- Philippe Marbaix says there is already plenty of information on AIC that is not used appropriately. He agrees that it is not realistic to exclude flight levels to avoid AIC formation but he notes that there are already different measures to adapt the flight patterns in a dynamic way according to meteorological conditions;

  Guy Viselé indicates that it is the case for example for transatlantic flights using the jet stream.

- Philippe Marbaix asks why AIC are not taken into account.

  Guy Viselé answers that the major problem is that air transport is on medium-term basis a growth sector and that it is difficult to focus only on AIC due to trade-offs between the different aviation emissions. Information exists but even in the directive, no multiplier has been introduced due to scientific uncertainties and the difficulty to define a metric to measure the impact (cf. the CE Delft study commissioned by the European Commission and considering potential to tackle by market-based measures the non-CO_2 emissions produced by aviation). The focus now is on CO_2 emissions, other emissions will be treated later when the uncertainties will be reduced.

5. Aircraft induced cloudiness in the regional climate model CCLM

Andrew Ferrone's presentation: see ABC Impacts website → Open Section → References / Project publications (http://dev.ulb.ac.be/ceese/ABC_Impacts/documents_abc/workshop_2_February_2009_ASTR.pdf)

5.1 Impacts of aviation on climate

Due to the combustion of kerosene, aircraft emit different air pollutants, having either a direct (CO_2, H_2O, soot) warming or cooling (SO_x) effect, or either an indirect warming effect (NO_x and hydrocarbons increase ozone concentration which has a strong warming effect and reduce CH_4 concentration which has a cooling effect). Moreover, under specific meteorological conditions (when the temperature is low and the humidity high enough), aircraft induce condensation trails, which can evolve into cirrus clouds. This additional cloud cover is referred to as aircraft induced cloudiness (AIC) and has a general warming effect, resulting from a cooling effect due to the reflexion of incoming solar light and a warming effect due to the absorption of outgoing long wave terrestrial radiations.

An estimation, based on global modelling and air traffic density over Belgium, done within the ABC Impacts project shows that AIC above Belgium has a huge impact on the RF (blue bars on the top of the graph) compared to the impact of the aviation sector (green bar at the foot of the graph). The estimated error is quite large (black line), but the local RF is as important as the RF from all anthropogenic released CO2. .

Secondly, the graph shows that the main part of the AIC climate impact on Belgium is due to overflights (bar in light blue is due to overflights compared to bar in dark blue due to aircraft movements from and to Belgian airports).

The metric used in this graph is the radiative forcing which is an instantaneous measure of the perturbation. Given the fact that CO_2 has a longer lifespan than AIC, the climate impact of AIC is diminishing much more rapidly over the time than the climate impact of CO_2.

5.2 Theory of contrails formation and representation in the model

The Schmidt-Appleman criterion determines the conditions for the formation of short lived (yellow area with green square pattern) or persistent contrails (yellow area). When the exhaust gases leave the turbine, their temperature and water vapour partial pressures (related to the humidity) are very high and they cool down in a few seconds to the ambient temperature and humidity. If during this process the air parcel crosses the liquid water saturation line (left blue line), a contrail is formed.

When the surrounding air is not ice-supersaturated (yellow area with square pattern), the ice crystals that are formed evaporate quite quickly, and we thus have a short-lived contrail. If on contrary the air is ice-supersaturated (yellow area) then water vapour from the ambient air is condensation on the ice-crystals formed in the exhaust of the aircraft and they grow into a persistent contrail.

The fuel efficiency of the aircraft and its resulting exhaust temperature have a direct influence on the slope of the isobaric cooling lines (blue lines), resulting in a higher contrails formation for a better fuel efficiency.

Based on this process a parameterization has been developed and included in the regional climate model CLM. This approach takes into account the detailed cloud microphysics scheme of the model and transforms cloud water into ice-crystals if the conditions to form persistent contrails, which have been explained, are met. The sub-grid scale growth of the contrails (i.e. the amount of ice added) is taken from high-resolution simulations and takes into account the relative humidity. The type of aircraft seems to have only a small impact on the properties of the persistent contrail.

5.3 Some preliminary results

A first test case has been performed with the contrail parameterization explained above. In this case it is assumed that an airplane flies in every grid-box (20 x 20 km) at every time step (80s) and at every altitude. The results presented thus give us the potential coverage of persistent contrails rather than the actual one.

The difference of ice-mass in the run with the contrail parameterization and the reference run, averaged over January shows a quite high potential to form persistent contrails over the North-Sea and the Iberian Peninsula. A quite low potential is present in the west of the Alps. These features are consistent with contrail coverage observed from satellite data.

The contrails as simulated by the model from at altitudes (between 8 and 12 km) where most of the supersaturated areas are observed and when comparing the direct output of the parameterization with the output of the model, we can see that a strong increase seems to indicate that a transition from contrails to cirrus clouds takes place.

The impact of the contrail on the high cloud cover show similar patterns that those observed for the ice-mass.

5.4 Next steps in the ABC Impacts project

The AERO2k database of flight movements (at a resolution of 1°x1°) has been interpolated on the model grid (0.2°x0.2°) and will soon be used to perform simulations based on the real flight distributions, which can then be compared to the homogeneous flight pattern distribution presented above.

The parameterization will then be validated by comparing the results to observations of contrails and the radiative forcing calculated with the CLM model. Finally, the impact of these perturbations on climate indicators, such as the diurnal temperature range and the cloud cover and the sensitivity to cruising altitudes will be analysed.

5.5 Questions / remarks

- Guy Viselé asks if there is a difference in the daily aviation climate impacts compared to the night.

  Andrew Ferrone answers that, up to now, he has not analysed this issue yet but that it will be done in more or less 3 months.

- Guy Viselé mentions that an Austrian scientist (from the W.M.O.) study shows that the climate impacts during the day and the night are completely different. (Note: Guy Visele has sent the power point presentation of that scientist to Andrew Ferrone)

- Ben Matthews asks if it is planned to include the possibility to change the flight patterns automatically in the model if the air is supersaturated.

  Andrew Ferrone answers that this would be an interesting experiment but that time-constrains will probably not permit to perform it.

6. Potential mitigation measures for non-CO_2 climate impacts

Sandrine Meyer's presentation: see ABC Impacts website → Open Section → Project publications (http://dev.ulb.ac.be/ceese/ABC_Impacts/documents_abc/workshop_2_February_2009_CEESE_mitigation_options.pdf)

Potential policy measures can be classified in the headings: regulation, financial and economic instruments, infrastructure, R&D, voluntary actions.

6.1 Regulation

Regulation options mainly consist in the adoption of an emission standard. Concerning the international aviation sector, the ICAO is in charge of setting up international standards. Recently, in 2008, new requirements have made the ICAO standard on NO_x aircraft engine emissions more stringent.

On the one hand, emissions standard at the ICAO level offers different advantages seeing that it is implemented internationally (no market distortion, no evasion, etc.). In this specific context of mitigating aviation climate impacts, setting a limit on NO_x emissions induces additional benefits on local air quality only on one condition - the traffic growth does not surpass this relative emission reduction.

On the other hand, this NO_x standard is based on a LTO cycle, while NO_x emissions need to be reduced for local air quality purposes, NO_x aviation climate impacts occur mainly in the higher troposphere. Moreover, it has been proved that the quantity of NO_x emissions vary according to the flight altitude, which is not taken into account in the ICAO standard. Another drawback of such an international standard is that the implementation process is quite low, so that it is questionable that the technical progress is stimulated by the implementation of such standards. Finally, standards exist for NO_x, CO, etc. emissions but, up to now, it is quite difficult to define a standard applicable to other climate impacts precursors (e.g. water vapour, aircraft design, etc.) and to take into account the trade-offs between aircraft emissions and climate impacts (cf. each kind of emission is regulated separately).

Would it be interesting for the EU to adopt more stringent standards on its territory?

One of the pro arguments of such a measure is to fulfil other EU standards on local air quality (e.g. NEC directive) but no global implementation of such standards could induce market distortions (e.g. European airlines have less opportunity to use their "more polluting" aircraft outside the EU territory than non-EU airlines) and an evasion process that will displace the pollution elsewhere without reducing it globally. If the EU wants to focus on aviation climate impacts, standards should take into account the different parameters determining the emissions (e.g. aircraft/engine couple, weight at take-off, flight altitudes, etc.) and analyse the trade-offs (e.g. between CO_2 and NO_x/AIC).

6.2 Financial and economic instruments

1- Market mechanisms

A first option is to include aviation non-CO_2 emissions in the EU-ETS by means of a multiplier on the aircraft CO_2 emissions. This multiplier can be fixed, as it was already suggested during the discussion about the adoption of the new directive including the aviation sector in the EU-ETS, or with a variable multiplier. The fixed multiplier is more simple to implement but it does not take into account the different trade-offs existing between CO_2 and non-CO_2 aviation climate impacts. On the contrary, a variable multiplier (based for example on simplified indicators such as the altitude, the season, the aircraft type, the route and related meteorological conditions, etc.) is able to highlight the trade-offs but this better accuracy needs the gathering of multiple data. Another way to include non-CO_2 emissions in the EU-ETS could be the existence of separate certificates to be traded in parallel with CO_2 certificates. The underlying question is then the choice of the conversion factor between both kinds of certificates.

A second option could take the form of a separate trading scheme for non-CO_2 aviation emissions. There are already different examples for the NO_x emissions of other sectors but it seems difficult to adapt this system for other climate impact precursors such as water vapour (cf. the climate impact induced also depends on meteorological conditions, the aircraft design, etc.). Moreover, the question of the conversion between CO_2 and non-CO_2 certificates rises again.

2- Tax/fee on emissions

Three European countries have already levied a tax on aircraft NO_x emissions. Sweden and Switzerland have chosen for a revenue-neutral scheme as opposed to the UK. These taxes are based on a LTO charge that has no link with the flight altitude and the real climate impact but is easy to implement. It is also possible to adopt the form of an en-route charge but the related methodology to assess the real emissions and induced climate impacts has to be developed.

6.3 Infrastructure

Slot allocation could be based on different environmental performances but the process is quite different from one airport to the other and it has to be decided how to balance the different environmental impacts (climate, local air quality, noise, etc.).

6.4 R&D

1- Engine improvements

One of the big issues consists of the current trade-off between the fuel efficiency, the noise and AIC formation (cf. a more efficient engine induces more cloudiness in the atmosphere, see presentation of Andrew Ferrone).

At the EU level, the ACARE project aims at reducing emissions at source. The trade-off between fuel efficiency and NO_x emissions can be managed on the longer term and is fully taken into account in the objectives of the project but what about the trade-off between the fuel efficiency and AIC formation?

2- Alternative fuels

First of all, it is necessary to evaluate the total climate impacts of the alternative fuels by analysing the production/transformation/distribution processes.

Secondly, it is important to note that most of the alternative fuels envisaged have potentially a greater AIC impact than the kerosene (cf. most of them have a lower carbon content, a lower energy content per kg, and accordingly a higher hydrogen content).

3- Meteorological forecasts

At present, a German project called UFO evaluates the possibilities to predict ice super saturated areas (where AIC are produced). Lufthansa is partner of the project and has developed the LIDO software to optimise flight patterns taking into account AIC formation (cf. ice super saturated areas are quite thin +/- 300m and it is possible to avoid them by adapting the route or the flight altitude).

The trade-off between AIC avoidance and increased fuel consumption is calculated on the basis of an “energy metric” of contrails (estimated RF x duration x surface occupied) compared to the “energy metric” of CO_2 (RF x 100 years x world-wide surface).

4- Optimisation of operational measures (ATM)

A “simple” measure to avoid AIC formation was suggested: to place a small camera on aircraft to see if contrails form and to adapt the flight pattern to leave the ice super saturated area. However this measure is neither feasible nor realistic because it implies that the aircraft has to load more fuel on board to be able to adapt its flight patterns along the way if necessary, which induces higher fuel consumption and more CO_2 / NO_x emissions.

The Continuous Descent Approach (CDA) is an ATM measure that will potentially reduce fuel consumption and related emissions, as well as noise disturbance, without any trade-off with other climate impacts.

SESAR and other projects aim at improving the airspace capacity and reduce congestion at airports which will potentially reduce fuel consumption and related emissions on a short to medium term but on the longer term, higher available capacity could increase traffic and the related emissions (cf. the highways). Moreover, AIC are not taken into account which could lead to non optimal measures to reduce aviation climate impacts.

6.5 Voluntary actions

Voluntary agreements with engine and/or aircraft manufacturers to reduce aviation climate impacts are another option but it has been demonstrated in the past that such agreements are not really efficient (cf. EU CO_2 agreement with car manufacturers and tackling of climate change by ICAO).

6.6 Questions / remarks

- How does the Lufthansa's model LIDO optimise the costs of contrails versus the costs of CO_2?

  Andrew Ferrone explains that it is based on the comparison of energy metrics (cf. description on slide 12 of the presentation). The price of contrails is calculated by multiplying the CO_2 price by the relative energy metric. The objective of the software is to minimise the global costs.

- Guy Viselé highlights that it is probably better for one aircraft to burn some less fuel than to generate less contrails. For air traffic management safety, capacity and environmental reasons, it would be disastrous to loose the availability of some Flight Levels: the number of movements would remain the same but, if some Flight Levels are unavailable, it creates congestion, delays and more emissions. Moreover those Flight Levels, where cirrus clouds / condensation trails are observed, are the most effective as far as fuel consumption and CO_2 emissions are concerned.

7. Illustrations

A video on 24 hours air traffic in the world (http://radar.zhaw.ch/resources/airtraffic.wmv), illustrations of contrails from an ECAT3 DLR presentation (http://dev.ulb.ac.be/ceese/ABC_Impacts/documents_abc/workshop_2_February_2009_Contrails_illustrations.pdf, courtesy of C. Voigt, DLR) and a video on AIC (http://dev.ulb.ac.be/ceese/ABC_Impacts/documents_abc/workshop_2_February_2009_KondensFlug.mov) have been shown

8. Discussion and questions

- After the slide show from ECAT3 DLR presentation, Ben Matthews asks if it is intrinsically better to favour bigger planes such as A380 to reduce contrails formation per passenger/km?

  Andrew Ferrone answers in the affirmative.

- Guy Viselé comments that in Scandinavia and Switzerland, where NO_x tax have been implemented, it seems that measures to mitigate NO_x emissions generate more noise. Such trade-off explains why it is so difficult to find a global solution to tackle aviation environmental impacts. The complexity of the interactions between the different negative environmental effects of aviation (CO_2, NO_x, contrails, noise, etc.) implies that proposed measures nearly never result in a positive impact on all effects.

- Ben Matthews asks if a policy instrument could be designed to take into account the minimum impacts of AIC, which are certain and non negligible, and adjusted later, for example in 10 years, when the uncertainties are reduced.

  Rasa Sceponaviciute admits that non-CO_2 aviation emissions have a real climate impact. However to be sure that the policy cost will not be higher than the benefit, the impact has to be measurable and verifiable. Moreover, the impact on other sectors of taking non-CO_2 aviation emissions into account has to be studied. The EU is willing to include new measures in the future for NO_x, but also for other impacts.

- Sandrine Meyer asks if there are connections between all the ATM projects led by Eurocontrol, SESAR, etc. and research on AIC such as the UFO-LIDO project.

  Guy Viselé answers that he does not know if there is a connection between SESAR and UFO-LIDO project, but that this is purely a matter of communication and that all these networks (SESAR, Eurocontrol, Lufthansa, etc.) are generally linked. SESAR, which is a huge project, could probably easily take UFO project into account if this is not yet the case.

- Bill Hemmings notes that there is a high level of uncertainty about non-CO_2 climate impacts. What is the roadmap to investigate their different components?

  Andrew Ferrone explains that there are two main components: contrails and cirrus clouds. For the last ones, neither their coverage, nor their impacts on climate change are well known. Some new research try to follow on satellite image the transitions of contrails into cirrus clouds to get an estimation of their coverage. The current approach consists in seeing how many high clouds are formed if contrails are included in the climate model or not.

  The IPCC calculations of contrails climate impacts have recently been lowered due to better knowledge on their optical properties. On the other hand, many contrails are not visible by eye but can be identified by LIDAR. This means that they have nearly no impact on incoming solar light (such as visible contrails) but their impacts on infrared radiation persists so that their warming impacts are even greater than for visible contrails.

  In brief, there are uncertainties about the upper limit of AIC climate impacts but the lower limit is quite well defined with confidence (1,5 based on GWP).

- Julien Matheys notices that, regarding the EU-ETS as a whole, the carbon price depends on the economic situation and is at a very low level now due to the crisis. Would it be useful to apply a minimum (and a maximum) price to stabilise investments in CO_2 mitigation and reduce market volatility?

  Rasa Sceponaviciute explains that the question is examined but the enlargement of the carbon market to other big emitters such as the USA or China could solve the problem because a large market is less volatile than a small one.

  Guy Viselé notices than a minimum price is not necessary because, with the recession, emissions are lower than expected and the objectives are met.

  Sandrine Meyer says that a minimum price would be an incentive for the investments by lowering the uncertainty and the risk on the revenues from these investments.

  Guy Viselé highlights that airlines are already interested in minimising their fuel costs but with the crisis they can not afford to buy more efficient aircrafts.

  Bill Hemmings suggests that the commission publishes the CE Delft study, which is currently not accessible to the public.

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