ANNEX: CALCULATIONS OF RADIATIVE FORCING (RF) BAR CHART

Region	Flight Distance (million nm)	Percentage of region movements	Fuel use >FL240 (Gg)	Fuel use <FL240 (Gg)	NOx emitted (Gg)
Belgium	147	100.0	234	346	17
Belgium overflights	103	70.5	225	184	12
Belgium LTO	44	29.5	8	163	5
Europe	2 935	100.0	12 427	9 272	287
Europe overflights	21	0.7	152	0	2
Europe LTO	2 914	99.3	12 278	9 272	285
World	17 720	100.0	91 736	62 232	2 033

Region	RF CO_2 all anthropogenic sources (mWm^{-2})	RF CO_2 aviation (mWm^{-2})	RF O_3 aviation (mWm^{-2})	RF contrails (mWm^{-2})	RF aircraft induced cloudiness (mWm^{-2})
Belgium	1 660 (1 490–1 830)	25 (17.5–32.5)	70 (45–100)	350 (200–520)	1000 (340–2700)
Belgium overflights				340 (195–500)	970 (330–2600)
Belgium LTO				10 (5–20)	30 (10–100)
Europe				150 (80–210)	430 (140–1150)
Europe overflights				3 (1–5)	5 (2–15)
Europe LTO				147 (79-205)	425 (138–1135)
World			22 (14–32)	10 (6–15)	30 (10–80)

The upper part of the table gives an estimation of the traffic in 2002 in the different considered areas (Belgium and Europe) as well as for aircraft taking off and landing (LTO) in these areas and those overflying it. Please note that these figures are only first estimations and are based on a number of assumptions that are detailed hereafter and are to be improved eventually in the second half of this year and during phase II of this project. (Sources: Global and European figures: AERO2k and Eurocontrol, 2006; Belgian figures derived from Matheys et al., 2007)

The second part of the table gives the radiative forcing (RF) of total anthropogenic CO_2, CO_2 emitted by aircraft, the RF of ozone produced by air traffic, contrails and aircraft induced cloudiness (AIC). This was used to create the bar chart at page… Where applicable a distinction was made between the different regions considered. Again it is important to note that these are only preliminary results based on certain hypothesis, detailed in this annex and that need to be confirmed in the second part of the project. (Sources: global RF O_3: Sausen, 2005; all other global RF IPCC AR4)

The rest of this annex will give details about the calculations and hypothesis made to obtain the figures in these two tables.

The fuel used by aircraft that takeoff and/or land (LTO) in Belgium is small compared to the global fuel used by aviation (less than 1%) but on the other side Belgium is situated in one of the regions of the world where the air traffic is most important, due to the fact that the country is surrounded by 4 major HUB-airports of the world (London, Amsterdam, Frankfurt and Paris). Thus it seems clear that the impact of contrails and cirrus clouds as well as that due to ozone from aircraft overflying the Belgian territory (66% of all the flight movements in the Belgian airspace are overflights) is much more important than from the aircraft that actually land in Belgium and contribute to its economic development.

One of the aims of the ABCI project is to give a precise idea of this imbalance. At the present state of the project it is not yet possible to give precise figures, due to the fact that the processing of the database of flight movements over Belgium is not yet complete (no indication of NOx emitted and no precise indication of fuel use for historic emissions) and the regional climate model that will be used to evaluate the impact of aircraft in Europe and in particular of Belgium, is not yet operational.

This section will try however to give a first estimation of the impacts of contrails, aircraft induced cloudiness and ozone due to overflights compared to the same impacts for flights taking off and landing in Belgium and compare this situation to the situation in Europe, where overflights without landing or take-off in Europe represent less than 1% of total flight movements. At a later state of the project this table will be updated with more precise figures.

Calculations of emissions

In a first step the ratio of flight movements LTO in the region[1] considered and those that overfly it is calculated. For Europe figures published in the Eurocontrol were used (Eurocontrol, 2006a), and for Belgium the figures from (Matheys et al., 2007) were used.

These ratios were then used to interpolate the figures published in the AERO2k database made by Manchester University for the LTO aircraft and the overflights for distance flown and NOx emitted (it was not yet possible to distinguish the emissions of NOx at different altitudes, which would be necessary for an exact evaluation as the impact of ozone is changing with altitude, as shown by (Ferrone, 2006; IPCC, 1999)).

As shown by (Sausen et al., 1998), the contrail coverage and thus the impact of these contrails is directly proportional to local fuel use. For this study a distinction was made between fuel used below and above FL240 (24000ft ~ 8000m). In fact below this altitude the atmosphere is too warm for contrails to form (Eurocontrol, 2005). As the AERO2k database gives the fuel use for every flight level, fuel use below and above FL240 for every region could be directly deduced. However this database does not give an indication about the distinction between aircraft performing a part of their LTO cycle in the region and the aircraft overflying it.

In order to do so the following assumptions were made:

- Aircraft overflying Europe are supposed to fly all above FL240.

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[1] For Europe emissions in the region between 40°N-60°N and 10°W-20°E were considered, which is the same region as used for some Eurocontrol studies. For Belgium emission that took place between 49°N-52°N and 2°W-6°W were considered, in the AERO2k database. These emissions were then scaled down to the fuel used as calculated by Matheys et al. (2007), which was itself interpolated to 2002 using growth factors for Belgian traffic between 2002 and 2006.

- Most of the passenger aircraft taking off or landing in Belgium will stay below FL240. However Business jets are capable of climbing much faster than regular passenger jets and thus will be able to reach FL240 before leaving the Belgian territory. Thus it was supposed that aircraft performing a part of their LTO cycle in Belgium only reach FL240 if they are Business jets. Figures from (Eurocontrol, 2006b) indicate that ~10% of flight movements are performed by business jets. To take into account that these jets have to climb up to FL240 only 5% of the fuel used over FL240 was attributed to aircraft performing part of their LTO cycle in Belgium.

As a general rule, it is often difficult to compare data originating from different sources. This is obviously also the case when comparing AERO2k data with data provided by Matheys et al. (2007). Hereunder, we provide some indications on factors which might explain these differences:

- The assessed years are different for both publications, which explains part of the difference between both publications.
- The representative aircraft used in Matheys et al. (2007) correspond to the type aircraft of EMEP/Corinair which differ slightly from the type aircraft used in AERO2k. Also the calculation of the fuel use in AERO2k is more complex than the calculation of the fuel use in Matheys et al. (2007).
- The database used in AERO2k is a general database based on the commercial Back Aviation database, while the database used by Matheys et al. (2007) is a database containing all of the movements as provided directly by the Belgian air traffic management services. The data used by Matheys et al. (2007) are consequently likely to be more extensive for the specific Belgian territory.
- The database of AERO2k is a European database, so the specific data for Belgium might present a lower resolution (one degree by one degree) as compared to the specific Belgian data (exhaustive list of flights in the Belgian airspace) used in Matheys et al. (2007).
- The AERO2k study uses 6 'typical' weeks of the year and extends it to the whole year, while the data provided in Matheys et al. (2007) contain the real movements for every single day of the year 2006.

However some differences may appear between the data obtained from the AERO2k study and Matheys et al. (2007), using homogeneous data is essential before drawing any conclusions concerning the *comparison between LTO flights and overflights* and this is certainly what’s happening in the Belgian context of the ABCI project as the homogeneous and exhaustive data from Belgocontrol will continue to be processed in the coming months.

Climate impacts

To give an estimation of the impact on climate it was decided to relay on radiative forcing, as figures for the global radiative forcing are published whereas the impact on temperature and other climate indicators are not available for all of the impacts considered.

The impact of ozone on surface temperature for the global and the European domain was taken from (Ferrone, 2006). These results were compared with the RF of ozone given by (Sausen et al., 2003) and transformed into RF:

$$RF_{O3,EU} = \frac{RF_{O3,glo}}{T_{O3,glo}} T_{O3,EU}$$

The impact of ozone in Belgium and in Europe in general was supposed to be the same as ozone is more or less evenly distributed on the regional but not on the global level (Berntsen et al., 2003). The distinction between LTO traffic in the region and the overflights was then made proportional to the NOx emitted. This calculation does not take into account the influence of the flight altitude on ozone impacts, as the available data did not permit such a calculation.

The global RF for contrails and aircraft induced cloudiness are taken from IPCC AR4 and are scaled following the fuel use above FL240, as aircraft flying below this level do not form contrails:

$$RF_{cont/AIC,EU/BE} = \frac{FuelUse_{EU/Be,FL>240}}{FuelUse_{glo,FL>240}} \frac{Surface_{glo}}{Surface_{EU/Be}} RF_{cont/AIC,glo}$$

However these results do not take into account the fact that average meteorological conditions over Europe are different from the average conditions on a global scale. Thus the conditions when contrails are formed and the supersaturation needed to take into account the persistence of contrails are different.

Sources

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