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Federal Office for Civil Aviation (FOCA)

Aviation Policy and Strategy
Environment (LEUW)

SWISS FOCA National Greenhouse Gas Inventory (IPCC)

Year 2004

To	**BUWAL/ P. Filliger, A. Liechti, B. C. Müller**
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0. Results

[in Metric Tonnes]	FUEL	CO2	H2O	SO2	Pb	NOx	VOC	CO
CH Total International	1090689	3435670	1341548	1091	1	13099	598	3384
CH Total Domestic	45659	143827	56161	46	4	594	104	3001
CH Total	1136348	3579497	1397709	1137	5	13693	702	6385

1. Method

Swiss FOCA uses Tier 3a Method in order to estimate both LTO and Cruise emissions for domestic and international flights on the basis of very detailed movement statistics: The FOCA movement statistic contains all movements that have taken place on Swiss airports and airfields. The movement statistic contains the necessary information of all individual aircraft registrations. The primary key for all calculations is the aircraft registration.

First of all, the 718 673 aircraft movement records for 2004 were split into domestic and international flights. Data were then sorted and accumulated by aircraft registration, airport/airfield, company, type of flight, domestic/international (65 000 records in 2004). The data sets were connected to FOCA aircraft_engine_combinations database. This database links aircraft registration to engine codes, number of engines, aircraft cruise codes, and LTO-Time codes. Missing aircraft (aircraft that were not yet flying in Switzerland the year before) were listed out. In 2004, a total of nearly 3000 new aircraft had to be added to this database, each with assignment of aircraft, engine and cruise codes. The codes are linked to corresponding codes in FOCA engine_data, LTO_cycle and aircraft_cruise_factors database for emission calculation.

2. Movement Statistics (Input Data)

Table 1: Aircraft Movement Data 2004. One observation for each single movement (small extract):

CH_Airport	Arr. Dep.	Immatr.	Type of Aircraft	Number of Movements	Origine / Destination	Distance in km
LSGG	D	HBPLL	P28A	1	LSZG	144.967059
LSGG	A	HBPLL	P28A	1	LSZG	144.967059

LSGG	D	HBIJJ	A320	1	BIKF	2646.64554
LSGG	A	HBIJL	A320	1	BIKF	2646.64554
LSGG	A	TSIOM	B736	1	DTKA	1056.11738
LSGG	D	TSIOM	B736	1	DTKA	1056.11738
LSGG	A	ECFHK	MD87	1	LEMD	1011.54965
LSGG	D	ECFHK	MD87	1	LEMD	1011.54965
Up to 800'000 Records						

Table 2: Emission and fuel consumption data per aircraft type for LTO and cruise

Airport	Distance km	Type Traffic	Number of Move-ments	Type	Aircraft ICAO	Engine Name	LTO FUEL	LTO CO2	LTO H2O	LTO SO2	LTO NOX	LTO VOC	LTO CO
LSGG	181501.69	Taxi	165	2B	C550	JT15D-4	5673.492	17871.5	6978.395	5.673	26.04	139	359.2
LSGG	164165.197	Taxi	77	2J	B752	RB211-535E4	47470.5	149532.1	58388.72	47.47	554.91	0	361.47
LSGG	133166.837	Taxi	118	2B	F2TH	CFE738-1-1B	6164.2728	19417.46	7582.056	6.164	87.539	40.59	185.53
LSGG	117228.943	Taxi	99	3B	F900	TFE731-60-1C	5668.542	17855.91	6972.307	5.669	46.937	28.13	163.44
LSGG	114258.902	Taxi	134	2B	LJ45	TFE731-20R	4725.108	14884.09	5811.883	4.725	31.31	53.62	169.01
LSGG	112510.267	Taxi	100	2B	F2TH	CFE738-1-1B	5223.96	16455.47	6425.471	5.224	74.186	34.4	157.23
LSGG	107945.477	Taxi	96	2B	C560	JT15D-5D	3795.3216	11955.26	4668.246	3.795	16.959	271.6	287.98
Airport	Distance km	Type Traffic	Number of Move-ments	Type	Aircraft ICAO	Engine Name	Cruise Fuel	Cruise CO2	Cruise H2O	Cruise SO2	Cruise NOx	Cruise VOC	Cruise CO
LSGG	181501.69	Taxi	165	2B	C550	JT15D-4	307732.68	969357.9	378511.2	307.7	4513	29.43	274.71
LSGG	164165.197	Taxi	77	2J	B752	RB211-535E4	673698.47	2122150	828649.1	673.7	7986.4	647.8	1038.2
LSGG	133166.837	Taxi	118	2B	F2TH	CFE738-1-1B	225781.85	711212.8	277711.7	225.8	3311.2	21.59	201.55
LSGG	117228.943	Taxi	99	3B	F900	TFE731-60-1C	298139.18	939138.4	366711.2	298.1	4372.3	28.52	266.14
LSGG	114258.902	Taxi	134	2B	LJ45	TFE731-20R	193723.81	610230	238280.3	193.7	2841	18.53	172.93
LSGG	106761.289	Taxi	100	2B	F2TH	CFE738-1-1B	181011.75	570187	222644.4	181	2654.6	17.31	161.58
LSGG	103217.159	Taxi	96	2B	C560	JT15D-5D	175002.74	551258.6	215253.4	175	2566.5	16.74	156.22

3. Calculation Basics

3.1 Scheduled and Charter traffic

a) Definition used for Domestic Flights:

All flights between A and B in Switzerland

b) Definition used for International Flights:

For LTO: All flights which take place between Switzerland and another country. Arriving traffic from abroad is also counted in the LTO.
For Cruise: All flights which start in Switzerland and end in another country.

c) Assignment of Emission Factors:

Emission Factors are assigned to every individual aircraft (see Appendix). Swiss FOCA developed a data base, linking more than 14 000 aircraft registrations to engine codes (FOCA engine emission database), times in mode, and cruise factors (FOCA cruise emission database). [see Appendix]

d) LTO-Emission Factors:

The Swiss FOCA engine emissions database consists of more than 450 individual engine data sets. Jet engine factors for engines above 26.7 kN thrust (emission certificated) are identical to the ICAO engine emissions databank. Emission factors for lower thrust engines, piston engines and helicopters were taken from manufacturers or from own measurements. Emission factors for turboprops could be obtained in collaboration with the Swedish Defence Research Agency (FOI)

e) Cruise Emission Factors

Part of the cruise emission factors are taken from CORINAIR Version 2.3. To compute the aircraft cruise factors, representative flight distances per aircraft type and a load factor of 65% are assumed, because the factors are dependent on those. Part of the cruise factors are also taken from former CROSSAIR (1991). The whole Airbus fleet (which produces a great portion of the Swiss Inventory) has been modeled on the basis of real operational aircraft data from SWISS aircraft data acquisition system. Actual fuel burn of hundreds of flights has been analyzed. FOCA is now able to compute realistic mean fuel burn (and emissions) of the Airbus fleet very accurately. From FOCA statistics, the great circle distance for every flight is known (In the inventory, the great circle distance is multiplied by a mean factor of 1.05 to estimate the effective flight distance for 2004 [Polyméris, SWISS operations, October 2005]). The cruise factor database gives emission factors per nautical mile for every aircraft. Multiplication with flight distance per aircraft directly produces cruise emissions per aircraft.
Some of the old or missing aircraft cruise factors had to be modeled on the basis of the ICAO engine emissions databank. Vast knowledge of aircraft types and engine technology was necessary to perform this task. For piston engine aircraft, Swiss FOCA has produced its own data, which were taken under real flight conditions (2005 data, publication envisaged in 2006).

f) LTO-Times in Mode

Swiss FOCA does not use all ICAO standard cycle times for all aircraft categories. For jets, the mean time for taxi-in and taxi-out at Swiss airports has been determined 20 minutes instead of the standard 26 minutes. For jets, business jets, turboprops, piston engines and helicopters, the times in mode shown in the Appendix are used, based on ICAO, US EPA and Swiss FOCA data.

g) Emission factors for CO2, H2O, SO2 and Pb

3.15 kg CO_2 / kg fuel
1.23 kg H_2O / kg fuel
0.001 kg SO_2 / kg fuel (JET-A1 only)
0.794 g Pb / kg fuel (AVGAS only)

3.2 Non-scheduled, non-charter, General Aviation (including Helicopters)

a) General remarks

Airports and most of the airfields report individual aircraft data (aircraft registration). FOCA is able to compute the inventory for small aircraft with Tier 3a method. However, helicopter and small jet emission data are still sparse, so aggregation of aircraft is necessary.

b) Airfields without individual aircraft information

For some airfields there was no information available about actual aircraft that have been flying and no information was recorded about their destination, however, from the fleet register, the most frequent (generic small) aircraft have been derived. The Swiss FOCA statistical database 2004 contains records of the number of all movements per airport, including all movements from airfields. Movements from airfields are dominated by small piston engine aircraft. In those cases where destination information was missing or for local flights, the track distances have been estimated by mean flight times. In Switzerland, the mean cruising time for small aircraft has been estimated 20 minutes, corresponding to a mean total flight time of 30 to 40 minutes (LTO included). With this information and the FOCA emissions data base (2004), cruise emissions of small aircraft have been calculated.

c) Helicopter rotations

Helicopters can contribute quite significantly to domestic emissions, basically through a huge number of rotations. For the inventory, the number of helicopter rotations was taken from *“Unternehmensstatistik der Schweizer Helikopterunternehmen.”* The number of rotations has been converted to movements by multiplying with a factor of two. Further corrections have been made in order to avoid double counting with LTO at airports. From fleet composition, a split between 87% single engine helicopters and 13% twin engine helicopter has been made, applying two corresponding FOCA emission factor data sets and special times in mode (no take-off and taxi) for the actual emission calculation.

For the IPCC inventory, Helicopter rotations emissions are considered 100% domestic.

4. Completeness

The methods should account for all fuel used for aviation in the country. General aviation emissions, like helicopters emissions, have been added because they are considered significant as far as VOC and CO is concerned.
Any other aviation related activities that generate emissions are not included within the scope of the IPCC methodology. The bottom-up approach in this inventory is considered complete.

Besides inaccuracies in the model, differences of more than 10% between calculated total fuel consumption and the fuel sold can be attributed to the fuelling strategy of airlines. FOCA investigation showed that airlines are calculating whether it is economically beneficial to refuel at a place with lower fuel prize, although the penalty is higher fuel burn (higher aircraft weight). For the year 2004 FOCA investigation showed that for short and medium haul flights, airlines have the tendency to buy fuel abroad. The difference of + 6 % for the calculation can therefore easily be explained.

APPENDIX

Table 4: LTO-Cycle times

LTO_CYCLE				
Typ	Zeit_Take_Off	Zeit_Climbout	Zeit_Approach	Zeit_Taxi
1J	0.7	2.2	4	20
1T	0.5	2.5	4.5	13
1P	0.3	2.5	3	12
1H	0	6.5	6.5	7
2B	0.4	0.5	1.6	13
3B	0.4	0.5	1.6	13
2T	0.5	2.5	4.5	13
4T	0.5	2.5	4.5	13
2J	0.7	2.2	4	20
3J	0.7	2.2	4	20
4J	0.7	2.2	4	20
2P	0.3	2.5	3	12
3P	0.3	2.5	3	12
4P	0.3	2.5	3	12
2H	0	6.5	6.5	7
4SJ	1.2	2	2.3	20
3H	0	6.5	6.5	7
4H	0	6.5	6.5	7
4B	0.4	0.5	1.6	13

Table 5: Aircraft-Engine Combinations and associated codes for SWISS FOCA emissions database. (Extract from list of 14043 individual aircraft)

AIRCRAFT_ENGINE_COMBINATIONS							
Engne_ Name	Airraft_Name	Aircraft_ Registration	Number_ of_Engines	Code	Typ	Aircraft_ ICAO	Source
V2527-A5	AIRBUS A320-232	ECHXA	2	J220	2J	A320	1IA003
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHXM	2	J090	2J	CRJ2	1GE034
CFM56-3C1	BOEING 737-4K5	ECHXT	2	J022	2J	B734	1CM007
TPE331-11U-611G	FAIRCHILD (SWEARIN-GEN) SA227AC METR	ECHXY	2	T310	2T	SW4	FOI
CFM56-5B4/P	AIRBUS A320-214	ECHYC	2	J067	2J	A320	3CM026
CFM56-5B4/P	AIRBUS A320-214	ECHYD	2	J067	2J	A320	3CM026

AIRCRAFT_ENGINE_COMBINATIONS							
Engne_ Name	**Airraft_Name**	**Aircraft_ Registration**	**Number_ of_Engines**	**Code**	**Typ**	**Aircraft_ ICAO**	**Source**
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHYG	2	J090	2J	CRJ2	1GE034
CFEC-FE738-1-1B	DASSAULT FALCON 2000	ECHYI	2	B130	2B	F2TH	FOI-Honey-well
GA TPE331-11U-612G		ECHZH	2	T310	2T	FA3	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECHZR	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-86Q (WINGLETS)	ECHZS	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECHZU	2	J067	2J	A320	3CM026
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIAA	2	J090	2J	CRJ2	1GE034
FJ44-1A	CESSNA 525 CITATIONJET	ECIAB	2	B001	2B	C525	FOCA
CFM56-5B4/P	AIRBUS A320-214	ECIAG	2	J067	2J	A320	3CM026
V2527-A5	AIRBUS A320-232	ECIAZ	2	J220	2J	A320	1IA003
BRBR700-710A2-20	BOMBARDIER BD-700-1A10 GLOBAL EX-PRE	ECIBD	2	J854	2J	GLEX	4BR009
PT6A-60A	BEECH-CRAFT KING AIR 350 (RAYTHEON B	ECIBK	2	T738	2T	B350	FOI
CF34-3B1	BOMBARDIER CRJ200ER (CL-600-2B19)	ECIBM	2	J090	2J	CRJ2	1GE034
CFM56-7B27B1	BOEING 737-81Q (WINGLETS)	ECICD	2	J075	2J	B738	3CM034
CFM56-5B4/P	AIRBUS A320-214	ECICK	2	J067	2J	A320	3CM026

Table 6: Aircraft cruise factors, used for cruise emission calculation (extract of list of 671 aircraft)

AIRCRAFT_CRUISE_FACTORS						
Aircraft_ICAO	**GKL_ICAO**	**Cruise_D_Source**	**kg_fuel_NM**	**kg_NOx_NM**	**g_VOC_NM**	**g_CO_NM**
AA1	0	P002FOCA	0.21	0.0098	1.79	61.7
AA5	0	P002FOCA	0.21	0.0098	1.79	61.7
AC11	0	P002FOCA	0.21	0.0098	1.79	61.7
AC14	0	P002FOCA	0.21	0.0098	1.79	61.7
AC50	0	P001FOCA	0.766666667	0.021014333	4.14	364.1666667
AC68	0	P001FOCA	0.766666667	0.007452	4.14	364.1666667
AC6T	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AC90	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AC95	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AEST	0	P001FOCA	0.766666667	0.021014333	4.14	364.1666667
AJET	0	FOCAEDBJ014	2.92	0.0146	8.53	63
ALO2	0	FOCAHeli	1.91	0.024	0.42	2.1
ALO3	0	FOCAHeli	1.91	0.024	0.42	2.1
AN12	0	AN26*2	5.36	0.0062	143	348
AN2	0	FOCA/91/DC3	0.82	0.0002	13.7	1000
AN22	6	FOCAINV95-03.2T*2	3.16	0.042	1.74	5.8
AN24	2	AN26	2.68	0.0031	71.7	174
AN26	1	500	2.68	0.0031	71.7	174
AN72	2	FOCAINV95-03.2J	6.4	0.1	0.83	10
AR7	0	P002FOCA	0.21	0.0098	1.79	61.7
AR7A	0	P002FOCA	0.21	0.0098	1.79	61.7
AS02	0	P002FOCA	0.21	0.0098	1.79	61.7
AS16	0	P002FOCA	0.21	0.0098	1.79	61.7
AS20	0	P002FOCA	0.21	0.0098	1.79	61.7
AS24	0	P002FOCA	0.21	0.0098	1.79	61.7
AS25	0	P002FOCA	0.21	0.0098	1.79	61.7
AS26	0	P002FOCA	0.21	0.0098	1.79	61.7
AS2T	0	FOCAEDBT758	0.95	0.005	1.8	12
AS30	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS32	1	FOCAHeli*2	3.82	0.048	0.82	4.2
AS33	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS35	0	FOCAHeli	1.91	0.024	0.42	2.1
AS50	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS55	0	FOCAHeli*2	3.82	0.048	0.82	4.2
AS65	0	FOCAHeli*2	3.82	0.048	0.82	4.2
ASK1	0	P002FOCA	0.21	0.0098	1.79	61.7
ASTA	0	FOCAINV95-03.B	3.016	0.046	0.3	2.8
ASTR	0	FOCAINV95-03.B	3.016	0.046	0.3	2.8
ASTRA	0	FOCAINV95-03.B	3.016	0.046	0.3	2.8
AT42	1	FOCAINV95-03.2T	1.58	0.021	0.87	2.9
AT43	1	500	1.6	0.013	0	15