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Remote Sensing of Commercial Aircraft Emissions

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Introduction

On September 23 and 24, 1997, a study was undertaken by the University of Denver, with the cooperation of British Airways and the British Airports Authority, to remotely measure the emissions of commercial aircraft. During the two day sampling period at London's Heathrow Airport, a total of 131 measurements were made of 96 different aircraft. The aircraft, ranging in size from Gulfstream executive jets to Boeing 747-400s, were measured in a mix of idle, taxi-out, and takeoff modes.

While it has been shown that air pollution totals from automobiles and many major industrial sources have been steady or decreasing with time, emissions from commercial aircraft continue to increase. This trend is primarily driven by a constantly increasing number of commercial flights worldwide.[1] In the United States, levels of carbon monoxide (CO), volatile organic compounds (VOCs), and nitrogen oxides (NO_x, which is the sum of nitrogen oxide, NO, and nitrogen dioxide, NO_2) emitted from aircraft during commercial flights have all more than doubled from 1970 to 1993.[2]

Carbon monoxide is known to cause respiratory distress, particularly among individuals with cardiovascular disease, and at elevated levels also causes impairment of visual perception, work capacity and learning ability. Combined, VOCs and NO_x are the principal precursors in the photochemical production of tropospheric ozone, a major component of urban smog. Individually, NO_x has been shown to be responsible for the production of atmospheric particulate matter and acidic precipitation, and may contribute to aquatic algal blooms.[2]

Technical Description

The remote sensor used in this study was developed at the University of Denver for measuring the pollutants in motor vehicle exhaust, and has previously been described in the literature.[3,4] The instrument consists of a non-dispersive infrared (IR) component for detecting carbon monoxide, carbon dioxide (CO_2), and hydrocarbons (HC), and a dispersive ultraviolet (UV) spectrometer for measuring nitrogen oxide. The system is shown schematically in Figure 1. The source and detector units are positioned to create an open-air sample path between them, approximately 20 feet in

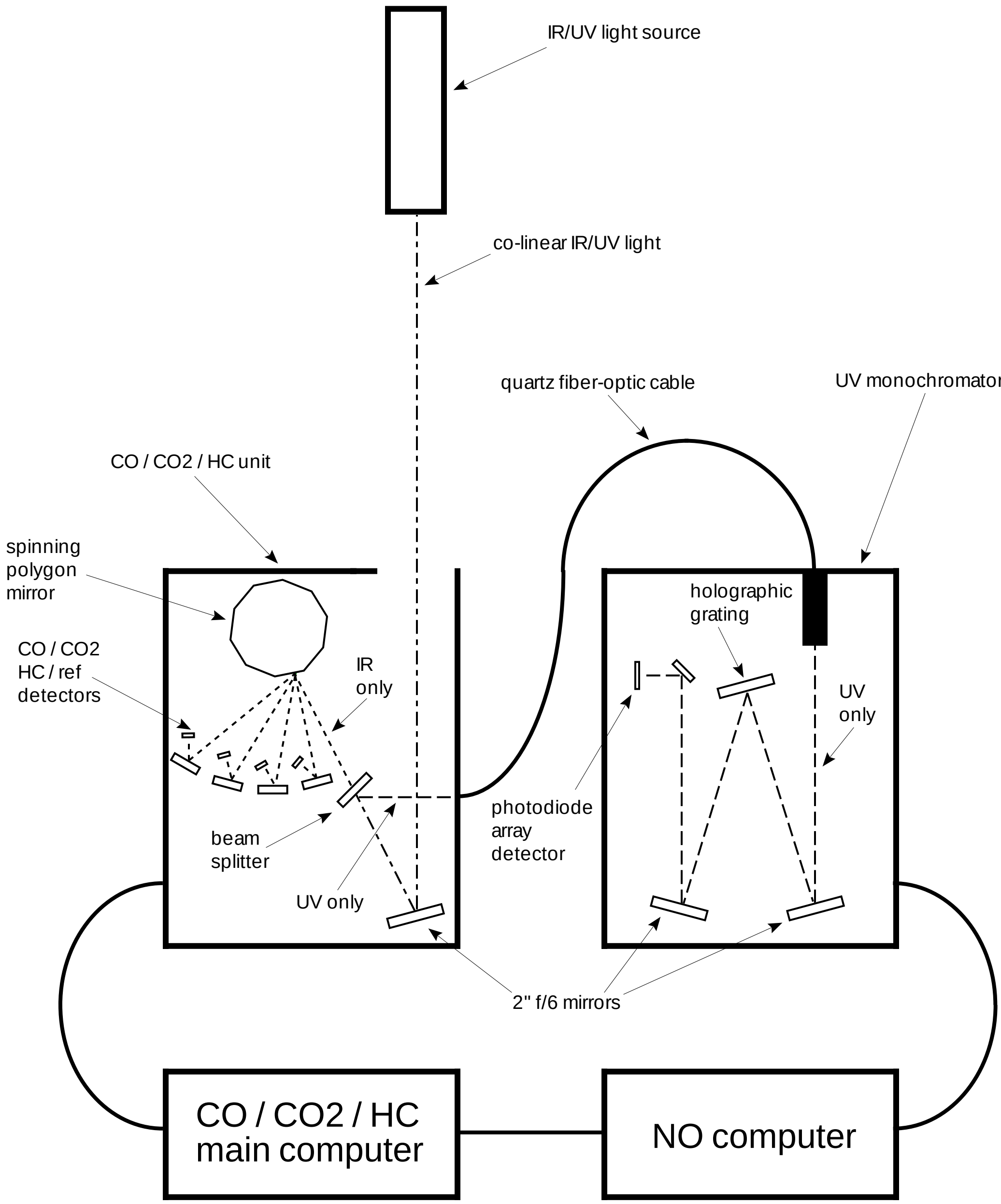

Figure 1. Schematic diagram of the University of Denver remote sensing system.

length. Colinear beams of IR and UV light are passed across the sample path into the IR detection unit, and are then focused onto a dichroic beam splitter, which serves to separate the beams into their IR and UV components. The IR light is then passed onto a spinning polygon mirror, which spreads the light across the four infrared detectors (CO, CO_2, HC and reference).

The UV light is reflected off the surface of the beam splitter, and is focused into the end of a quartz fiber-optic cable, which transmits the light to the ultraviolet spectrometer. The UV unit is then capable of quantifying nitrogen oxide by measuring an absorbance band at 226.5 nm in the ultraviolet spectrum and comparing to a calibration spectrum in the same region. Since most of the NO_x emitted from a combustion engine is in the form of NO,[5] this instrument is effectively measuring NO_x.

When measuring aircraft exhaust, the system is manually triggered when the operator determines that exhaust is present at the sensor. Once data collection is initiated, the instrument samples continuously at 100 Hz, for a period of 10 seconds. At the end of the 10 s sampling period, a data file is compiled that contains 1000 voltages from each of the 4 IR detectors, as well as the corresponding 1000 calculated NO concentrations from the UV spectrometer. Post-processing first involves converting the 4 IR voltages to concentration values for CO, CO_2, and HC for all of the 1000 measurements. The ratios of CO/CO_2, HC/CO_2, and NO/CO_2 in the exhaust are then determined by a classical least squares analysis involving the 1000 values for CO_2 along with the corresponding 1000 values for CO, HC and NO. On their own, the ratios of CO/CO_2, HC/CO_2, and NO/CO_2 are useful parameters to describe a hydrocarbon combustion system[3], but a knowledge of combustion chemistry allows one to use these ratios to further calculate the mass emissions of CO, HC and NO in the exhaust, in units of g/kg of fuel consumed.

There were primarily two locations used for data collection at Heathrow Airport. The first was the Lima cul-de-sac, where measurements were made from approximately 11:30 to 13:30 on September 23. Aircraft measured at this location were either idling or lightly accelerating immediately after push-out. The second location was directly north-west of the west end of runway 09 Right. Depending on wind conditions, aircraft at this location were measured during either taxi-out or takeoff. Data were collected at the second location from 15:30 to 16:30 on September 23 and from 11:00 to 15:00 on September 24.

Results

A complete listing of all data collected is shown in Appendix A. This table includes the measured values for CO, HC and NO, in units of g/kg of fuel, as well as the associated error (±1 s.d.) for these values. Carbon monoxide is measured and reported as such, and hydrocarbons are measured and reported as propane equivalents. We measure and report NO_x emissions as NO, and do not use the convention by which the mass is assumed to be NO_2. Also included is the date and time of the measurement, as well as the airline, aircraft model, and registration. The emissions data are summarized graphically in Figures 2, 3, and 4, for NO, CO, and HC, respectively. These scatter plots show the measured values for each of the pollutants, in the order the measurements were made. Also shown on these plots are the idle and takeoff emissions for three representative aircraft as calculated from the FAA Aircraft Engine Emission Database.[6] The three aircraft shown are a Boeing 747-400 with RB211-524G engines, a Boeing 737-400 with CFM56-3C-1 engines, and a Boeing 757-200 with RB211-535C engines. The final point on each of these plots is an airport service light-duty diesel truck that we measured on the last day of testing.

One can see from the scatter plot of NO emissions that aircraft were measured in a mix of idle, taxi, and takeoff modes. The data collected agrees well with the values from the FAA database, and this plot also shows that a typical light-duty diesel truck emits NO, in units of g/kg of fuel, at a rate comparable to a commercial airplane at takeoff. This point seems less surprising, however, when one considers that a B757-200 consumes over 7600 times more fuel at takeoff than the diesel truck does when cruising at 50 km/h.

The scatter plots for both CO and HC (Figures 3 and 4) show that we were less effective at measuring these pollutants. Aircraft are typically thought to emit very low levels of CO and HC regardless of operating mode, and this is illustrated in Figures 3 and 4 by the values derived from the FAA database. If the range of the measured points lying below the zero line in these plots is an indication of the instrumental noise, one can see that the noise in the system is far too great to draw confident conclusions regarding the CO and HC measurements made in this study. These high noise levels are in contrast to previous studies using this instrument to measure motor vehicle exhaust in a roadside situation. Figures 5 and 6 show scatter plots of the noise obtained on the CO and HC channels of the instrument that was used in this study. These plots were obtained from an audit truck, equipped to simulate automobile exhaust that contains CO_2, but no CO or HC. One can clearly see that the noise about zero in these plots is much lower than the noise in Figures 3 and 4. It is suspected that the winds created by the aircraft exhaust are the cause of the increased noise. This may be a result of the winds either shaking the instrument or cooling the infrared light source, thereby causing fluctuations in the voltage output of the infrared detectors. It should be possible in future studies to greatly reduce the noise levels in the instrument by securing the source and detector with sandbags, and installing shielding to prevent wind from cooling the source.

The NO channel of the instrument is much less susceptible to instrument movement or voltage fluctuations due to the spectroscopic technique by which NO is measured. Nitrogen oxide is quantified by measuring the height of an absorption peak above a baseline, and although fluctuations in source intensity caused by movement or cooling may change the level of the baseline, the height of the peak above the baseline remains constant.

A frequency distribution plot for the aircraft NO emissions is shown in Figure 7. This plot is constructed by assigning each measurement to an emission category, and it can be seen that the data forms a bi-modal distribution. The majority of planes emit NO at levels between 0-4 g/kg of fuel, with another maximum occurring in the chart at 20-24 g/kg of fuel. This distribution is a result of aircraft being measured in two distinctly different operating modes; idle or taxi, where little or no NO is being produced, and takeoff mode, where most NO production takes place. In contrast to the results shown here, NO emissions from automobiles follow a gamma distribution.[7] This observation is primarily driven by a combination of vehicle age and lack of maintenance, with the latter problem not normally associated with commercial aircraft.

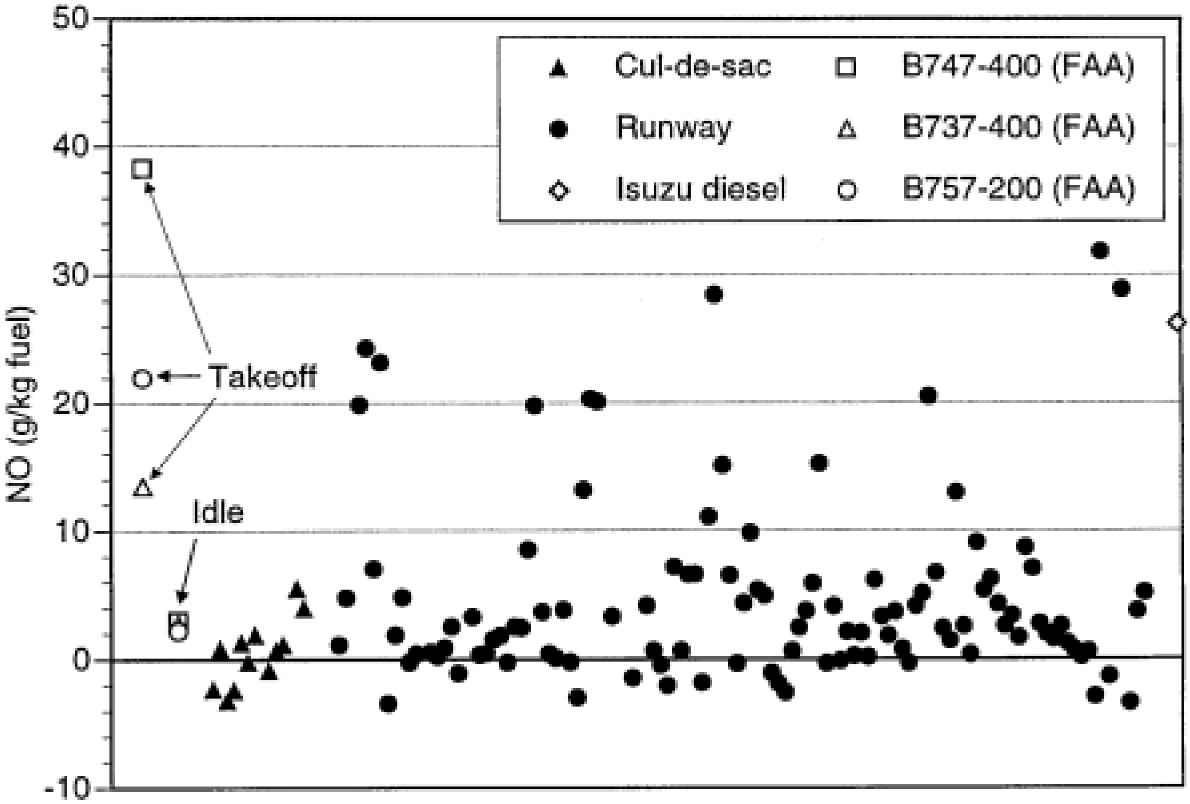

Figure 2. Scatter plot of aircraft NO emissions. Data is shown in the order measurements were made.

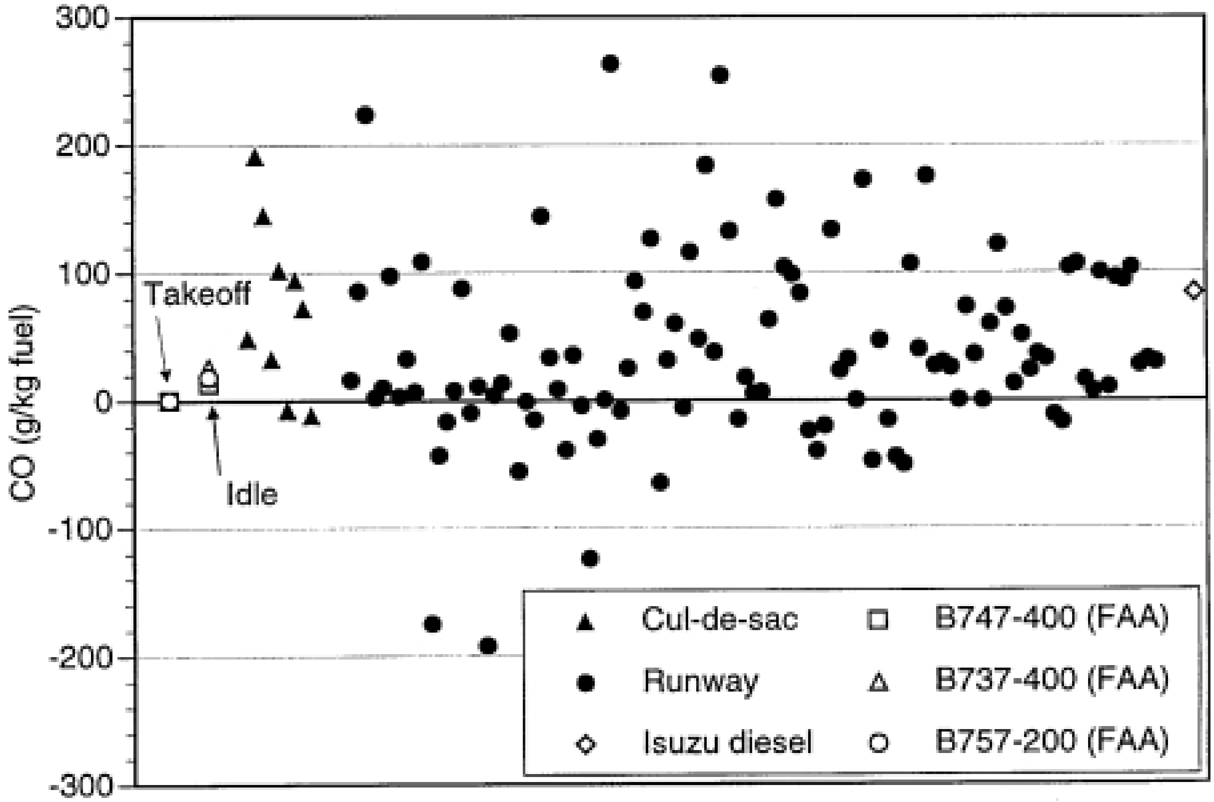

Figure 3. Scatter plot of aircraft CO emissions. Data is shown in the order measurements were made.

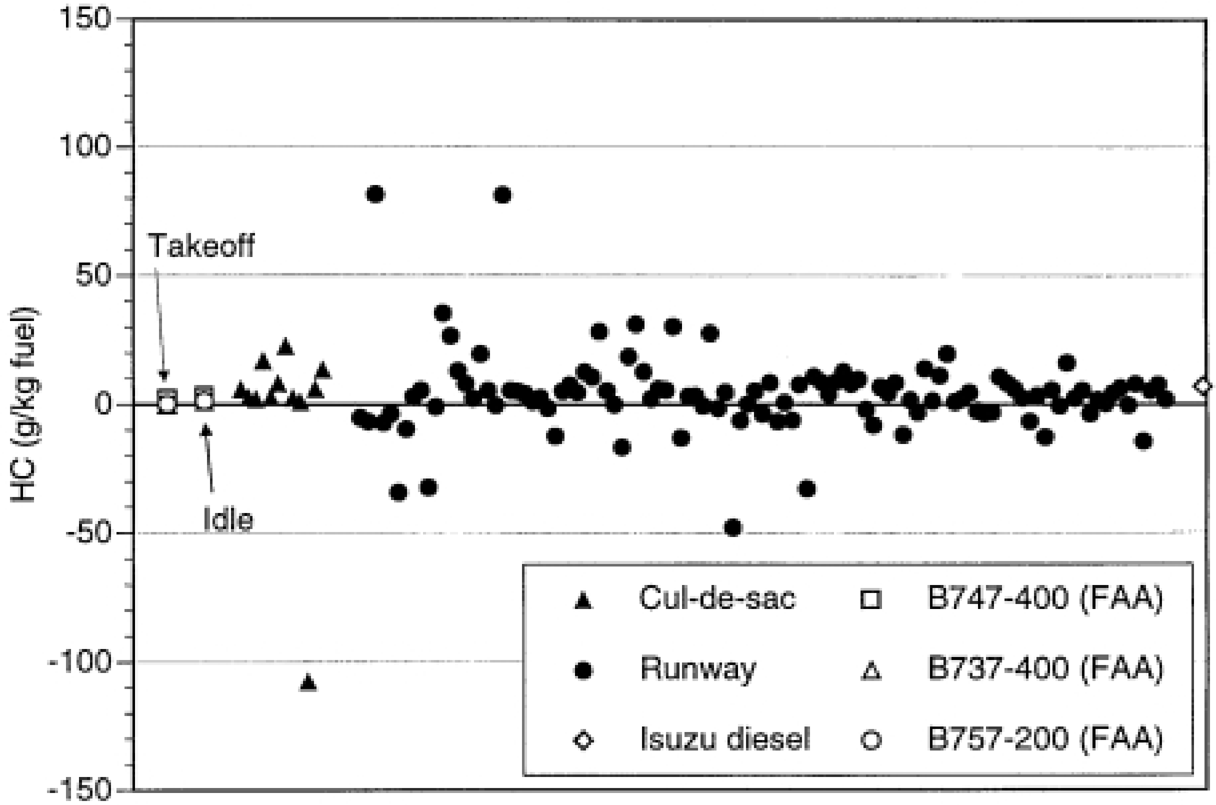

Figure 4. Scatter plot of aircraft HC emissions. Data is shown in the order measurements were made.

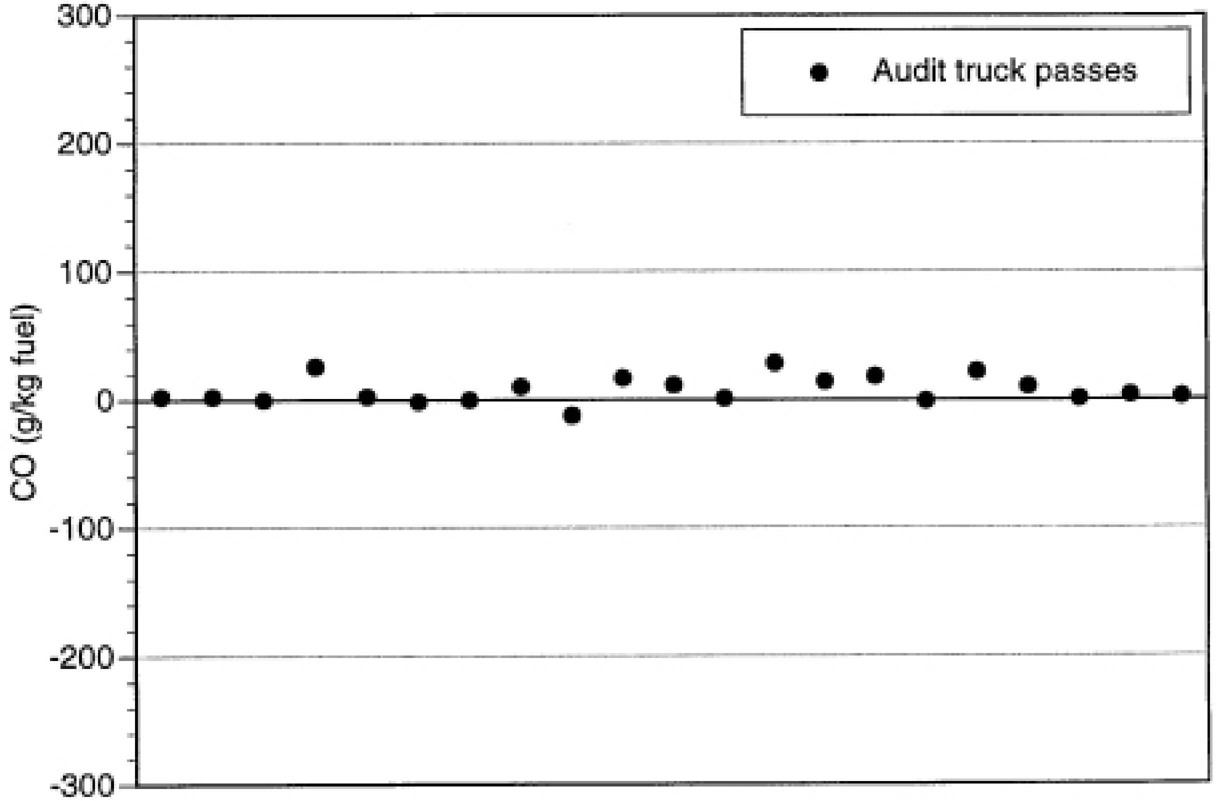

Figure 5. Scatter plot of the noise from the CO channel when the remote sensor is operated in an on-road situation.

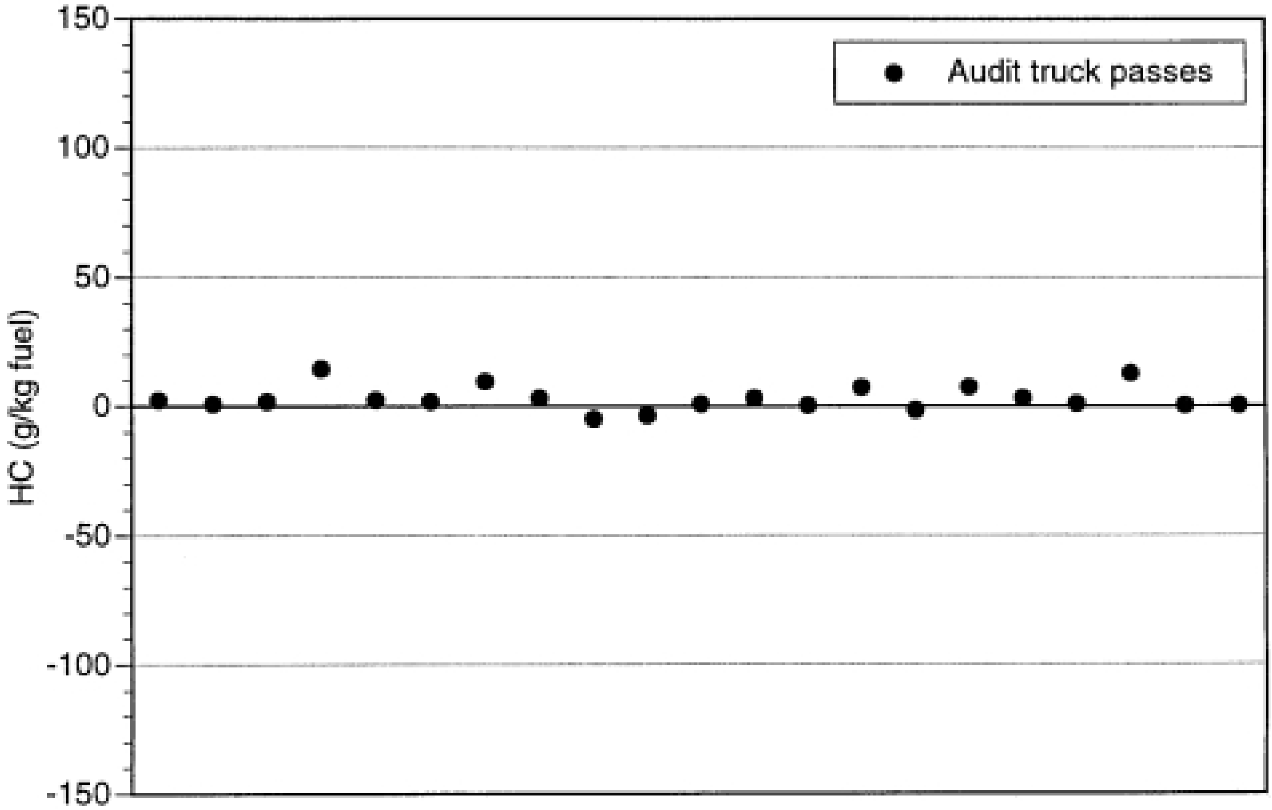

Figure 6. Scatter plot of the noise from the HC channel when the remote sensor is operated in an on-road situation.

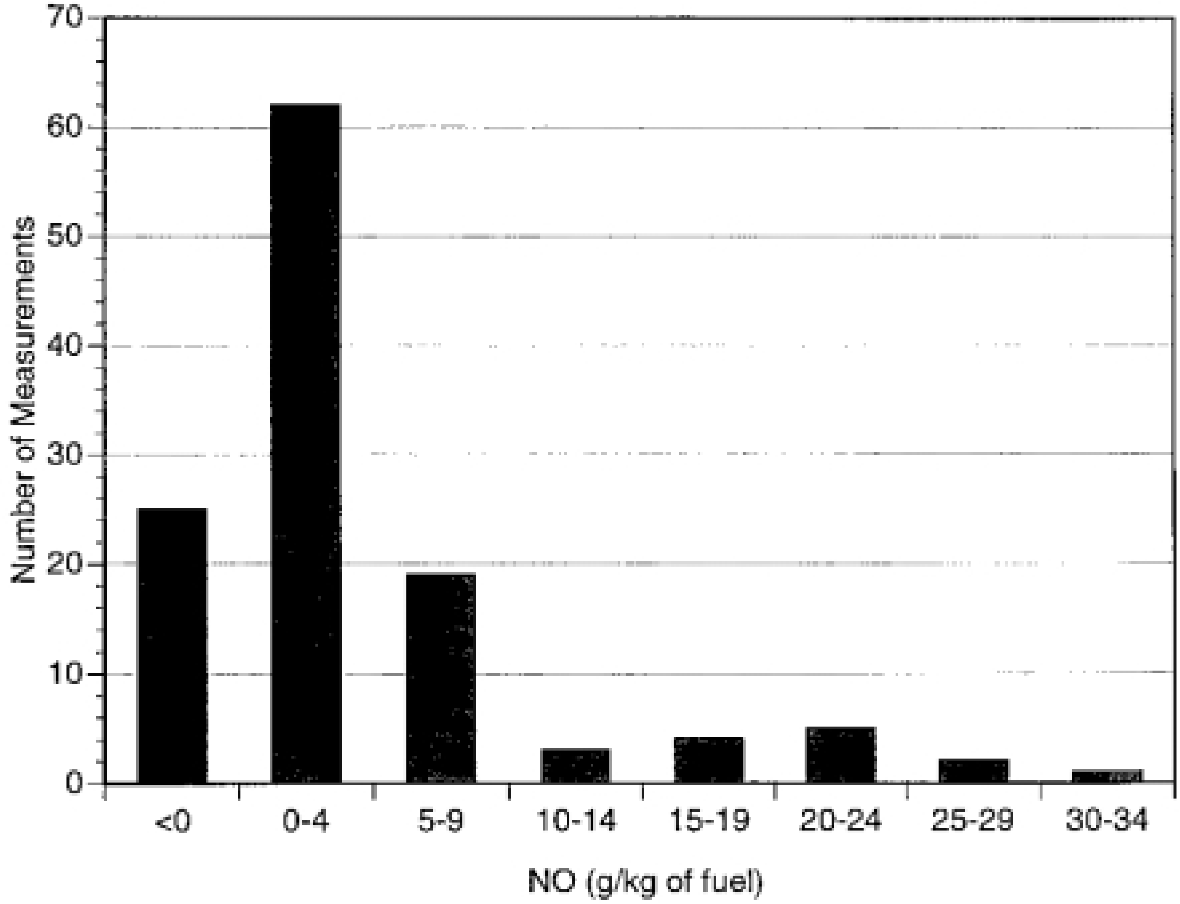

Figure 7. Frequency distribution plot for the aircraft NO emissions.

Conclusions

A study was successfully undertaken to remotely measure the emissions of commercial aircraft. A fleet of 96 aircraft were characterized for NO emissions, and it was shown that these emissions follow a bi-modal distribution, driven primarily by the operating mode of the airplane during measurement. The CO and HC emissions of the aircraft were also measured, but the noise levels displayed by the instrument during these measurements was higher than expected. It is believed that installing the remote sensor more securely on the airfield, and shielding the light source from any wind created by the aircraft would alleviate these problems. Future studies should then allow an aircraft fleet to be characterized for CO and HC emissions as well.

References

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3. Bishop, G.A.; Stedman, D.H. "Measuring the Emissions of Passing Cars." *Acc. Chem. Res.* **1996**, 29, 489.

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6. Federal Aviation Administration Aircraft Engine Emissions Database. Reference No. AEE-110.

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Appendix A

Aircraft Emissions Data

Date	Time	Airline	Aircraft	Registration	Data File	CO (g/kg)	CO err. (g/kg)	HC (g/kg)	HC err. (g/kg)	NO (g/kg)	NO err. (g/kg)
9/23/97	11:46	Virgin	B747		054603			5.98	0.65	-2.30	0.16
9/23/97	11:47	Virgin	B747		054729	48.95	0.96	2.80	0.11	0.83	0.02
9/23/97	12:56	Air Canada	B747	CFTOC	065841	191.50	5.33	2.26	0.63	-3.17	0.23
9/23/97	12:58	Air Canada	B747	CFTOC	065820	144.87	3.86	17.13	0.55	-2.37	0.15
9/23/97	13:01	Air Canada	B747	CFTOC	070142	32.84	2.18	2.88	0.20	1.32	0.05
9/23/97	13:02	Air Canada	B747	CFTOC	070200	101.86	1.37	8.19	0.17	-0.16	0.04
9/23/97	13:22	American	A300	N14068	072254					1.90	0.16
9/23/97	13:23	American	A300	N14068	072311						
9/23/97	13:29	Quantas	B747-400	VHOJI	072925	-7.06	5.93	22.75	0.68	-0.81	0.26
9/23/97	13:29	Quantas	B747-400	VHOJI	072951	94.30	3.25	2.72	0.32	0.69	0.11
9/23/97	13:30	Quantas	B747-400	VHOJI	073057	72.43	3.58	1.23	0.48	1.17	0.10
9/23/97	13:31	Quantas	B747-400	VHOJI	073149			-107.36	3.72		
9/23/97	13:31	Quantas	B747-400	VHOJI	073113			6.03	0.42	5.52	0.15
9/23/97	13:31	Quantas	B747-400	VHOJI	073129	-11.43	1.76	13.54	0.33	3.99	0.05
9/23/97	15:29	BA	B757		092907	16.74	0.78	-5.01	0.12	1.14	0.03
9/23/97	15:32	Lufthansa	A320	DAIPD	093254	85.97	1.23	-6.51	0.13	4.79	0.15
9/23/97	15:33	Lufthansa	A320	DAIPD	093350						
9/23/97	15:33	Lufthansa	A320	DAIPD	093332			81.64	2.27	19.87	0.56
9/23/97	15:33	Lufthansa	A320	DAIPD	093312	224.19	8.09	-7.08	0.52	24.34	0.37
9/23/97	15:35	BA	B767	GBNWV	093553	2.53	1.55	-3.50	0.29	7.04	0.10
9/23/97	15:36	BA	B767	GBNWV	093610	10.59	2.72	-34.25	0.73	23.24	0.14
9/23/97	15:38	BA	A320	GBUSK	093851	97.86	2.62	-9.39	0.30	-3.41	0.11
9/23/97	15:40	BA	B757	GBMRB	094009	3.74	0.64	3.01	0.04	1.88	0.03
9/23/97	15:41	British Mid.	B737	GBVKC	094153	33.06	1.18	5.52	0.13	4.84	0.07
9/23/97	15:42	British Mid.	B737	GBVKC	094210	7.00	5.53	-32.29	0.45	-0.21	0.24
9/23/97	15:43	Air Canada	A340	CFYKX	094353	109.01	6.88	-0.88	0.44	0.42	0.11
9/23/97	15:44	Air Canada	A340	CFYKX	094417			35.52	1.43		
9/23/97	15:44	Egyptair	A340	SUGBO	094452	-174.68	5.97	26.63	0.72	0.55	0.15
9/23/97	15:52	British Mid.	B737	GOBMG	095211	-42.76	3.29	13.03	0.25	0.24	0.06
9/23/97	15:53	BA	B767	GBNWY	095301	-16.07	1.05	8.22	0.12	0.89	0.06
9/23/97	15:56	JAT	B737	YUANK	095624	8.02	1.54	2.40	0.07	2.53	0.05
9/23/97	15:57	BA	A300	GBUSH	095703	87.96	1.08	19.74	0.41	-1.08	0.05
9/23/97	15:58	MEA	A310	PHAGF	095824						
9/23/97	15:58	MEA	A310	PHAGF	095806	-9.01	1.62	5.38	0.14	3.27	0.04
9/23/97	15:59	BA	B757	GBMRF	095935	11.26	0.69	-0.22	0.09	0.36	0.03
9/23/97	16:01	United	B777	M789UA	100133	-191.94	8.39	81.59	1.57	0.47	0.25

Date	Time	Airline	Aircraft	Registration	Data File	CO (g/kg)	CO err. (g/kg)	HC (g/kg)	HC err. (g/kg)	NO (g/kg)	NO err. (g/kg)
9/23/97	16:01	United	B777	M789UA	100115	4.59	0.46	5.43	0.06	1.55	0.04
9/23/97	16:02	BA	B757	GCPEL	100208	13.76	2.48	5.04	0.11	1.82	0.05
9/23/97	16:12	American	A300	N2S021	101250	53.05	0.52	4.01	0.08	-0.23	0.03
9/23/97	16:13	Air Canada	B747-400	CGACN	101357	-55.16	1.65	1.21	0.36	2.50	0.06
9/23/97	16:14	Air Canada	B747-400	CGACN	101414	-0.71	1.40	2.62	0.15	2.45	0.07
9/23/97	16:16	BA	B757	GBIKD	101654	-14.73	1.08	-1.39	0.15	8.56	0.09
9/23/97	16:17	BA	B757	GBIKD	101714	144.44	3.38	-12.38	0.20	19.82	0.10
9/23/97	16:18	BA	A320	GBUSJ	101846	34.02	1.97	5.09	0.08	3.67	0.07
9/23/97	16:20	Air France	A320	FGFKM	102003			7.55	0.58	0.44	0.17
9/23/97	16:21	Virgin	B747-400	GVFAB	102150	9.17	1.15	4.63	0.09	0.08	0.04
9/23/97	16:22	Virgin	B747-400	GVFAB	102206	-38.63	2.25	12.52	0.15	3.84	0.03
9/23/97	16:26	Iberia	B727	ECDCD	102641	35.86	1.49	10.51	0.18	-0.19	0.06
9/24/97	11:09	private	Gulfstream	N900MP	050957	-3.54	5.11	28.34	0.43	-2.98	0.19
9/24/97	11:13	United	B777		051323	-123.92	3.03	5.25	0.21	13.21	0.13
9/24/97	11:25	Thai	B747-400	HSTGT	052533	-29.98	6.79	0.02	0.31	20.35	0.28
9/24/97	11:25	Thai	B747-400	HSTGT	052551			-16.75	0.60	20.12	0.16
9/24/97	11:29	BA	B757	GBIKY	052942			18.61	0.91		
9/24/97	11:30	BA	B757	GBIKY	053001	0.75	1.82	31.19	0.63	3.33	0.09
9/24/97	11:39	BA	B777	GUIID	053951						
9/24/97	11:39	BA	B777	GUIID	053934	263.52	12.93				
9/24/97	11:45	BA	B747	GAWNP	054542	-7.72	1.31	12.67	0.08	-1.42	0.05
9/24/97	11:55	BA	B747-400	GBNLX	055501						
9/24/97	12:13	BA	B767		061306	25.58	0.81	2.18	0.15	4.17	0.07
9/24/97	12:42	BA	B737	GDOCT	064219	93.42	2.11	6.08	0.20	0.66	0.07
9/24/97	12:44	Lufthansa	A320-200	DAIQF	064403	69.44	3.96	5.59	0.21	-0.43	0.05
9/24/97	12:49	BA	B757		064916	126.80	1.80	30.29	0.15	-2.03	0.03
9/24/97	12:53	Olympia	A300	SXBEI	065343	-64.39	2.17	-13.07	0.36	7.19	0.08
9/24/97	12:53	Olympia	A300	SXBEI	065326	31.79	2.96	3.17	0.20	0.65	0.06
9/24/97	12:54	British Mid.	B737	BSMDB	065412	60.36	1.77	3.36	0.10	6.60	0.05
9/24/97	12:55	SAS	MD80	SEDMF	065558	-5.36	2.27	-0.45	0.22	6.63	0.05
9/24/97	12:57	Turkish Air	A310	TCJOM	065755	116.26	1.27	27.66	0.14	-1.79	0.05
9/24/97	12:58	BA	B757	GCPEN	065851	48.29	3.24	-1.43	0.19	11.10	0.12
9/24/97	13:03	BA	B757	GBMF	070335	184.49	7.09			28.49	0.43
9/24/97	13:03	BA	B747-400	GCIVG	070313	38.13	1.76	4.72	0.24	15.14	0.15
9/24/97	13:05	Air Jamaica	A310	N837AB	070555	254.74	7.43	-48.10	0.93	6.53	0.18
9/24/97	13:06	TARDOM	B737	YRGBC	070625	132.59	1.98	-6.20	0.43	-0.33	0.21

Date	Time	Airline	Aircraft	Registration	Data File	CO (g/kg)	CO err. (g/kg)	HC (g/kg)	HC err. (g/kg)	NO (g/kg)	NO err. (g/kg)
9/24/97	13:08	BA	B767	GBNWV	070811	-14.25	1.65	0.21	0.18	4.36	0.04
9/24/97	13:13	Air Canada	B747-400	CGAGM	071325	18.38	1.77	5.23	0.14	9.86	0.12
9/24/97	13:13	Air Canada	B747-400	CGAGM	071342	5.76	0.05	-3.70	0.32	5.38	0.05
9/24/97	13:14	Croatia	B737	9ACTE	071417	6.89	3.15	8.38	0.39	4.95	0.10
9/24/97	13:17	Air UK	146	GBUHC	071715	63.36	4.61	-6.51	0.41	-1.05	0.17
9/24/97	13:17	Air Canada	B747-400	CGAGA	071757	157.56	1.30	0.73	0.09	-1.87	0.04
9/24/97	13:18	Air Canada	B747-400	CGAGA	071816	104.34	4.88	-6.10	0.48	-2.57	0.19
9/24/97	13:18	United	B777	N768UA	071854	98.74	1.70	7.72	0.14	0.63	0.05
9/24/97	13:20	Lufthansa	A300	DAIAN	072019	84.05	6.18	-32.93	0.84	2.46	0.23
9/24/97	13:20	Lufthansa	A300	DAIAN	072000	-23.34	4.62	10.79	0.28	3.75	0.11
9/24/97	13:21	American	B767	N383AN	072145	-39.39	3.25	8.66	0.29	5.90	0.03
9/24/97	13:23	BA	B757	GBMRJ	072357	-19.57	2.20	4.00	0.16	15.29	0.08
9/24/97	13:23	American	A300	N33069	072315	133.95	3.50	8.93	0.11	-0.30	0.04
9/24/97	13:30	Air France	A320	FGFKR	073055	23.85	1.83	12.63	0.50	4.13	0.06
9/24/97	13:33	British Mid.	B737	GSFBH	073318	32.75	4.60	7.95	0.37	-0.09	0.09
9/24/97	13:34	BA	B737	GDOCX	073455	0.29	1.67	9.79	0.10	2.13	0.03
9/24/97	13:35	BA	A320	GBUSG	073522	173.24	2.67	-1.91	0.18	0.28	0.06
9/24/97	13:36	BA	B767	GBNWS	073624	-47.12	1.59	-8.11	0.21	2.02	0.03
9/24/97	13:38	Air India	B747-400	VTESP	073849	47.09	2.10	6.85	0.16	0.19	0.04
9/24/97	13:43	BA	B767	GBNWJ	074317	-14.90	0.98	4.42	0.07	6.15	0.05
9/24/97	13:43	Quantas	B747-400	VHOJB	074359	-44.28	1.01	8.48	0.08	3.30	0.03
9/24/97	13:44	Quantas	B747-400	VHOJB	074418	-50.12	3.34	-11.82	0.46	1.84	0.14
9/24/97	13:45	British Mid.	B737-400	GOMBF	074500	107.01	1.59	1.64	0.09	3.68	0.04
9/24/97	13:46	BA	B757	GBIKN	074651	40.48	2.48	-2.97	0.19	0.79	0.09
9/24/97	13:47	Air Canada	B747-100	CFTOG	074749	175.91	4.41	13.95	0.22	-0.30	0.16
9/24/97	13:49	Icelandair	B757	TFFIH	074907	27.67	2.38	1.27	0.17	4.14	0.08
9/24/97	13:52	American	B767	N319AA	075223	29.82	2.42	11.14	0.77	5.10	0.08
9/24/97	13:53	Aeroflot	A310	FOGYV	075333					20.56	0.28
9/24/97	13:53	Aeroflot	A310	FOGYV	075316	26.19	3.27	19.71	0.23	6.71	0.07
9/24/97	13:55	United	B777	N788UA	075516	0.63	3.83	0.93	0.49	2.37	0.10
9/24/97	14:00	SAS	MD80	SEDDS	080035	73.66	3.33	2.02	0.25	1.45	0.05
9/24/97	14:04	BA	B757	GBIKZ	080426	36.16	1.42	4.57	0.16	13.00	0.07
9/24/97	14:06	BA	B767	GBNWE	080644	0.39	4.26	-2.42	0.34	2.56	0.11
9/24/97	14:07	BA	B767	GBNWE	080702			-3.42	0.41	0.37	0.18
9/24/97	14:08	Air Portugal	A310	CSTEH	080824	60.19	0.99	-2.93	0.08	9.10	0.08
9/24/97	14:10	MEA	A310	FOHLA	081017	122.29	2.73	10.64	0.20	5.38	0.10

Date	Time	Airline	Aircraft	Registration	Data File	CO (g/kg)	CO err. (g/kg)	HC (g/kg)	HC err. (g/kg)	NO (g/kg)	NO err. (g/kg)
9/24/97	14:11	Lingus	B737-400	EIBXB	081136	72.25	2.76	8.30	0.16	6.23	0.08
9/24/97	14:13	BA	B757	GDOCG	081329	13.47	1.12	6.11	0.14	4.29	0.03
9/24/97	14:14	Luxair	B737	LXLGO	081418	51.64	1.88	2.51	0.08	2.58	0.08
9/24/97	14:15	United	B777	N776UA	081528	24.21	4.88	-6.57	0.45	3.40	0.08
9/24/97	14:17	Emirates	B777	A6EMH	081744	36.66	2.39	3.42	0.11	1.68	0.17
9/24/97	14:18	Emirates	B777	A6EMH	081801	33.17	2.13	-12.71	0.51	8.71	0.09
9/24/97	14:18	Air France	A320	FGFKD	081849	-11.05	3.16	5.50	0.14	7.05	0.08
9/24/97	14:24	BA	B767	GBNWF	082404	-16.60	1.32	-0.40	0.14	2.75	0.05
9/24/97	14:25	Varig	MD11	PPVPK	082558	104.47	3.39	16.12	0.27	1.97	0.20
9/24/97	14:26	Air France	BA146	GJGAO	082659	107.27	2.89	2.41	0.15	1.58	0.20
9/24/97	14:28	BA	B737	GDOCH	082853	16.48	3.50	5.37	0.26	2.58	0.06
9/24/97	14:30	Lingus	B737	EIBXK	083035			-3.50	0.55	1.23	0.29
9/24/97	14:31		Fokker 100	GBVJC	083119	7.80	0.72	1.81	0.06	0.68	0.03
9/24/97	14:32	BA	B757	GBMRA	083233	100.29	2.60	0.44	0.23	0.21	0.06
9/24/97	14:33	Lingus	B737	EIBXA	083305	10.55	1.41	4.30	0.08	0.59	0.04
9/24/97	14:36	British Mid.	B737	GDBMH	083601	96.21	1.42	6.46	0.11	-2.86	0.10
9/24/97	14:43	Virgin	B747-100	GVGIN	084355			-0.19	0.80	31.83	0.19
9/24/97	14:43	Virgin	B747-100	GVGIN	084321	94.01	1.28	7.92	0.17	-1.32	0.03
9/24/97	14:43	Virgin	B747-100	GVGIN	084337						
9/24/97	14:48	BA	B777	GZZZC	084834	103.93	3.80	-14.44	0.27	28.91	0.09
9/24/97	14:49	BA	B757	GBMRI	084903	28.06	1.72	5.44	0.12	-3.37	0.25
9/24/97	14:51	Lufthansa	A320	DAIPA	085137	32.40	1.49	7.72	0.07	3.74	0.05
9/24/97	14:55	Air Canada	B767	CGDSU615	085533	29.88	1.37	1.91	0.10	5.16	0.04
9/24/97	15:02	BAA truck	yellow Isuzu	diesel	090246	83.89	0.19	7.00	0.18	26.22	0.23