Chemical and aerosol characterisation of the troposphere over West Africa during the monsoon period as part of AMMA

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Supplementary Information

Table 1. Summary of Aircraft Flights – IOP number (coloured by the same code as used in Table 2 of the main manuscript) and flight number

SOP 1a1

Date	ATR-42	BAe-146	DLR-F20	F-F20	M55
01 June	Test as0616	-	-	-	-
04 June	-	-	-	I1.1 #17	-
05 June	I1.1 as0617	-	-	I1.1 #18	-
06 June	I1.1 as0618	-	-	I1.1 #19	-
07 June	I1.1 as0619	-	-	I1.1 #20	-
08 June	I1.2 as0620	-	-	I1.2 #21	-
09 June	-	-	-	I1.2 #22	-
11 June	I1.2 as0621	-	-	I1.1 #23	-
12 June	I1.1 as0622	-	-	I1.1 #24	-
13 June	I1.3 as0623	-	-	I1.3 #25	-
14 June	I1.3 as0624	-	-	I1.3 #26	-
14 June	I1.3 as0625	-	-	I1.3 #27	-
15 June	I1.1-2 as0626	-	-	I1.1 #28	-
Number of science flights	10	-	-	12	-
Number of flight hours	39.3	-	-	37.5	-

SOP 2a1

Date	ATR-42	BAe-146	DLR-F20	F-F20	M55
01 July	I2 as0627	-		-	-
02 July	I2 as0628	-		-	-
03 July	I1.3 as0629	-	I1.1	I1.1 #29	-
04 July	I1.3 as0630	-		-	-
04 July	I1.3 as0631	-		-	-
06 July	I1.1 as0632	-		I1.2 #30	-
07 July	I1.2 as0633	-	I1.1	I1.1 #31	-
10 July	I1.1 as0634	-	I1.1	I1.1 #32	-
12 July	I2 as0635	-		-	-
13 July	I2 as0636	-	I2	-	-
Number of science flights	10	-	4	4	-
Number of flight hours	39.3	-	9.9	13.3	-

SOP 2a2

Date	ATR-42	BAe-146	DLR-F20	F-F20	M55
17 July	-	Transit Arrived B215	-	-	-
18 July	-	-	-	-	-
19 July	-	-	-	-	-
20 July	-	1.4 B216	-	-	-
21 July	-	1.4 B217	-	-	-
22 July	-	1.4 B218	-	-	-
23 July	-	-	-	-	-
24 July	-	-	-	-	-
25 July	Arrived	1.5 B219A/B	-	-	-
26 July	-	-	-	-	-
27 July	-	1.5 B220	-	-	-
28 July	-	1.4 B221	-	-	-
29 July	-	-	-	-	-
30 July	-	1.5 B222	-	-	-
31 July	-	1.4 B223	-	-	Transit 1
1 August	-	1.4 B224A/B	2 Arrived T1 & T2	-	Transit 2 Arrived
2 August	Test as0638/0639	-	-	-	-
3 August	-	2 B225	-	-	-
4 August	Test & 1.7 as0640	-	3 L1	-	3 F1
5 August	2 as0641	1.5 B226	-	-	-
6 August	2 as0642	1.4 B227	2 L2	-	-
7 August	2 as0643	-	2 L3	-	2 F2
8 August	1.7 as0644/0645	1.6 B228/229	-	-	Calipso F3
9 August	1.7 & 1.3 as0646/0647	-	-	-	-
10 August	-	-	-	Arrived	-
11 August	Transit as0648/0649	1.4 B230A/B	2 L4	2 #48	2 F4
12 August	1.8 as0650	-	-	-	-
13 August	1.8 as0651	3 B231	3 L5	3 #49	3 F5
14 August	2	1.4		2	-

15 August	as0652 2 as0653	B232 1.4 B233	2 L6 & L7	#50 2 #51	-
16 August	1.8 & 6 as0654/0655	6 B234	6 L8	1.6 L8	2&6 #52/#53	Transit 3 Departed
17 August	1.8 & 2 as0656/0657	1.5 B235A/B	-	-	Transit 4
18 August	-	-	Departed	-	-
19 August	2 as0658	-	-	3 #54/#55	-
20 August	-	-	-	3 #56	-
21 August	Departed	Departed	-	1.1 Departed	-
22 August	-	-	-	-	-
Number of science flights	17	24	12	9	5
Number of flight hours	60.1	105.1	40	28	20.2 (28.4 with T2 and T3)

Table 2a. BAe-146 Flights

Flight	Time (UTC)	Location	Features
B215	17 July (13:20-16:31)	Agadir-Bamako	Science transit - Sahara and ITF dropsonde survey
B216	20 July (13:03-17:12)	NNW of Niamey	Sequence of flights (B216-18) over banded soil moisture anomalies.
B217	21 July (12:57-17:16)	NW of Niamey -Benin	Sequence of soil moisture flights (B216-18). MCS outflow sampled during B218
B218	22 July (14:37-18:49)	NW of Niamey -Benin	Sequence of soil moisture flights (B216-18).
B219A B219B	25 July (12:51-16:51, 18:25-22:25)	Benin	2 flights, day/night, mapping emissions into boundary layer and cumulus layer
B220	27 July (10:57-15:10)	Benin (Djouguo)	Emissions over forest and into shallow cumulus layer
B221A B221B	28 July (11:51-16:03, 17:31-20:25)	Mali wetlands Via Hombori	2 flights, day/night, across synoptic scale heat low anomaly
B222	30 July (11:26-15:48)	Benin	Mapping emissions of biogenics
B223	31 July (15:00-19:08)	Niger-Mali	MCS initiation over soil moisture
B224A B224B	1 August (12:47-17:16, 18:34-22:11)	NW of Niamey	2 flights, day/night, over soil moisture features.
B225	3 August (13:26-16:40)	S & W of Niamey	Evacuation flight, with MCS science
B226	5 August (11:33-16:01)	Benin (Djougou), Ghana, Togo,	Mapping emissions of biogenics
B227	6 August (12:56-17:08)	NE of Niamey	Soil moisture and NOx emissions
B228	8 August (09:41-13:34)	Cotonou and over ocean	High level with dropsondes over Benin and the ocean.
B229	8 August (15:09-19:10)	Lagos	Lagos survey followed by dropsondes over Benin. MCS wake profile on return to Niamey
B230A B230B	11 August (13:17-17:43, 19:04-22:22)	NE of Niamey	Noxy soil moisture flight following heavy rain on a dry surface.
B231	13 August (07:01-11:32)	Cotonou and over ocean	Characterise meridional section at the level of the AEJ and low level runs over forest
B232	14 August (04:28-08:40)	S Niamey into Benin	Sampled atmospheric state above contrasts in surface vegetation immediately after dawn
B233	15 August (04:30-09:00)	S to 11N, then to NW Ghana	Post-MCS flight as part of coordinated mission with 4 aircraft
B234	16 August (14:18-17:54)	Burkina Faso	3-way comparison flight with the D-F20, F-F20 and ATR-42
B235A B235B	17 August (10:24-14:57, 16:25-20:52)	Benin	2 flights, day/night, mapping emissions into boundary layer and cumulus clouds

Table 2b. D-F20 Flights

Flight	Time (UTC)	Location	Features
T1	01 Aug 06 (03:17-06:54)	Oberpfaffenhofen - Marrakech	Transfer
T2	01 Aug 06 (08:19-11:34)	Marrakech – Ouagadougou	Transfer, measurements in MCS outflow over Mali
L1	04 Aug 06 (08:48-12:19)	North-south survey (Burkina – Ghana)	Sampling of BB plume over southern Ghana from central Africa, measurement of fresh outflow from MCS in Mali
L2	06 Aug 06 (09:23-12:44)	Burkina – Niger	Sampling of fresh MCS outflow over Burkina and aged outflow from MCS in Chad
L3	07 Aug 06 (12:19-15:20)	Burkina – Mali	Sampling of fresh MCS outflow over Mali and aged outflow from MCS in eastern Niger
L4	11 Aug 06 (14:51-17:54)	Burkina- Niger – Mali	Sampling of fresh MCS outflow over Burkina
L5	13 Aug 06 (10:40-14:00)	North-south survey (Burkina – Ghana)	Sampling of BB plume south of Ghana from central Africa, measurements in thunderstorm outflow southwest of Ouagadougou
L6	15 Aug 06 (09:18-12:30)	Burkina – Mali	Sampling of fresh and aged MCS outflow over Mali and Burkina
L7	15 Aug 06 (14:37-17:08)	Burkina – Benin	Sampling of fresh outflow from small MCS over northern Benin located within LINET, measurements in aged outflow from MCS in Nigeria
L8	16 Aug 06 (14:14-16:57)	Burkina – Niger	Formation flight with BAe-146 for measurement comparison, BL probing around Ouagadougou
T3	18 Aug 06 (08:05-11:42)	Ouagadougou - Tozeur	Transfer
T4	18 Aug 06 (12:52-14:59)	Tozeur – Oberpfaffenhofen	Transfer

Table 2c. F-F20 Flights

Flight	Time (UTC)	Location	Features
#17	4 June (0557-0807)	Niger	Sequence of flights over northern Mali of the ITD and heat low structure evolving over 4 days.
#18	5 June (1251-1553)	Niger	
#19	6 June (1216-1514)	Niger	
#20	7 June (1216-1503)	Niger	SAL structure mesoscale variability. Dust plume lifted by a gravity current sampled on 5 June.
#21	8 June (1210-1459)	Niger	Triangle towards Air and Maradi.
#22	9 June (1301-1617)	Niger	SAL structure mesoscale variability.
#23	11 June (1213-1510)	Niger	Triangle towards Air, then into NE Mali.
#24	12 June (1214-1517)	Niger	Sub-tropical jet located over Mali, with possible interaction with the ITD. SAL structure mesoscale variability.
#25	13 June (1109-1410)	Niger-Benin	Return flight coordinated with CALIPSO.
#26	14 June (0803-1056)	Niger-Benin	The aerosol load in return flow above the monsoon was observed to be washed out overninght by a MCS
#27	14 June (1233-1524)	Niger	Structure of ITD over northern Mali and albedo features over Sahara. SAL structure mesoscale variability.
#28	15 June (1107-1418)	Niger	Structure of ITD over northern Niger. Aerosol lifting in the ITD area.
#29	3 July (0532-0824)	Niger	Structure of ITD over northern Niger. Aerosol lifting in the ITD area.
#30	6 July (1252-1613)	Niger	No convection initiation in the sample box
#31	7 July (0550-0851)		
#32	10 July (0615-0917)	Niger	Structure of ITD over northern Niger. Aerosol lifting in the ITD area.
#48	11 August (1200-1530)	Niger	Long-lived MCS propagating westward over Mali and Burkina Faso
#49	13 August (1215-1530)	Niger-Benin	Upper tropospheric meridional transect from Niamey to Cotonou
#50	14 August (0630-0930)	Niger	MCS west of Niamey
#51	15 August (1230-1545)	Benin	Short-lived MCS north of Benin
#52	16 August (0900-1200)	Niger	Intercomparison flight
#53	17 August (0900-1200)	Niger	MCS north-west of Niamey
#54	19 August (0900-1200)	Niger-Benin	Meridional transect from Niamey to Cotonou, plus sortie over the Gulf of Guinea
#55	19 August (1330-1600)	Niger-Benin	Meridional transect from Cotonou to Niamey, plus northward exploration over Mali
#56	20 August (1400-1730)	Niger	AEJ exploration west of Niamey

Table 2d. M55 Flights

Flight	Time (UTC)	Location	Features
T1	31 July 21:00-01:22 UTC)	Italy-Morocco	Constant altitude at tropopause level. Reduced payload operative.
T2	1 August (10:50-15:05 UTC)	Morocco-Algerie-Mali-Burkina Faso	Constant altitude at tropopause level. Reduced payload operative.
F1	4 August (08:10-12:17 UTC)	Burkina Faso-Ghana	Meridional transect toward the gulf of Guinea.
F2	7 August (12:00- 16:11 UTC)	Burkina Faso – Mali	MCS west of Ouagadougou
F3	8 August (11:20-15:35 UTC)	Birkina Faso-Mali-Niger-Benin	CALIPSO validation flight
F4	11 August (14:30- 18:25 UTC)	Burkina Faso - Mali	Aged MCS over Nigeria. Outflow sampling
F5	13 August (12:40-16:25 UTC)	Burkina Faso-Ghana	Meridional transect toward the gulf of Guinea.
T3	16 August (13:16-17:14 UTC)	Morocco-Algerie-Mali-Burkina Faso	Constant altitude at tropopause level. Reduced payload operative.
T4	17 August (04:00-07:55 UTC)	Morocco-Italy	Constant altitude at tropopause level. Reduced payload operative.

Table 2e. ATR-42 Flights

Flight	Time (UTC)	Location	Features
as0616	01 June (13:03-14:23)	Niamey, Niger	Test flight
as0617	05 June (12:25-15:02)	Banizoumbou, Niger	Structure of ITD over northern Niger
as0618	06 June (11:07-14:53)	Banizoumbou, Niger	Structure of ITD over northern Niger
as0619	07 June (12:33-16:12)	Banizoumbou to 12.5N, Niger	Structure of ITD over northern Niger
as0620	08 June (11:18-15:06)	Banizoumbou, Niger	Pre-convection
as0621	11 June (11:48-15:48)	Banizoumbou, Niger	Aerosol lifting post-MCS
as0622	12 June (11:16-15:36)	Banizoumbou, Niger	Structure of ITD over northern Niger
as0623	13 June (10:33-13:28)	Niamey-Cotonou	North-South exploration
as0624 as0525	14 June (7:20-10:58, 13:12-15:57)	Niamey-Cotonou, Gulf of Guinea	North-South exploration – Vertical exploration
as0626	15 June (10:19-14:32)	Banizoumbou, Niger	Aerosol lifting post-MCS
as0727	01 July (13:03-14:23)	Banizoumbou, Niger	pre-MCS
as0728	02 July (11:39-15:24)	Banizoumbou, Niger	post-MCS
as0729	03 July (11:34-15:18)	Niamey-Cotonou	North-South exploration
as0730 as0731	04 July (07:49-11:45, 13:38-17:32)	Niamey-Cotonou, Gulf of Guinea	North-South exploration – Vertical exploration
as0732	06 July (11:17-15:21)	Banizoumbou to 12.5N, Niger	Structure of ITD over northern Niger
as0733	07 July (11:05-15:01)	Banizoumbou, Niger	Aerosol lifting post-MCS
as0734	10 July (11:18-14:14)	Banizoumbou, Niger	Structure of ITD over northern Niger
as0735	12 July (12:50-15:40)	Banizoumbou, Niger	post-MCS
as0736	13 July (12:04-14:39)	Banizoumbou, Niger	post-post-MCS
as0638 as0639	2 August (11:49-13:49, 16:09-17:54)	Banizoumbou-Niamtougou	Test chemistry and aerosols
as0640	4 August (06:30-08:53)	SW of Niamey	Test CVI in clouds
as0641	5 August (11:22-15:10)	SE of Banizoumbou	pre-MCS
as0642	6 August (13:25-17 :46)	E and SE of Banizoumbou	post-MCS
as0643	7 August (11:28-14:22)	E of Banizoumbou	post-post-MCS
as0644 as0645	8 August (06:44-08:50, 12:49-15:25)	Niamey-Niamtougou -Cotonou	North-South exploration – Vertical exploration
as0646 as0647	9 August (08:08-11:01, 12:59-15:48)	Cotonou and over ocean -Niamey	North-South exploration
as0648 as0649	11August (07:59-09:08, 11:22-12:33)	Niamey-Niamtougou	Transit flight
as0650	12 August (15:06-17:05)	Banizoumbou to 12.5N	Convective conditions South of a system - Vertical profile exploration
as0650	13 August (11:19-14:43)	Banizoumbou to 11.2N	Chemistry
as0652	14 August (10:44-13:52)	W of Niamey	Pre-MCS
as0653	15 August (10:42-13:38)	W of Niamey	Post-MCS

as0654	16 August (10:17-13 :03)	S of Banizoumbou to 10.4N.	Chemistry
as0655	16 August (15:59-17:36)	Burkina Faso	Intercomparison flight with the D-F20, F-F20 and BAe-146
as0656	17 August (07:41-11:13)	Benin (11N to 12.5N).	Vertical profile exploration - Starting of diurnal cycle
as0657	17 August (13:55-17:04)	N of Niamey. (14N to 15.5N)	Post-MCS
as0658	19 August (11:10-14:46)	S of Banizoumbou to 12N	Post-MCS

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Table 3a Instrumentation on the BAe-146

Species/Parameter	Reference	Technique	Averaging time	Accuracy	Precision	Detection limit
Non-deiced/deiced temperatures	(Eastin et al., 2002;Lawson and Cooper, 1990)	Rosemount Thermometers	32Hz	0.3ºC	0.005ºC	-
Dew point	-	General eastern	4Hz	0.25-1K	0.03K	-
Water vapour	-	FWVS Lyman-α fluorescence	1s	1%	-	-
Position, winds, u,v,w	-	INS, GPS, wind vanes	0.1s	-	-	~0.01 $\Delta p/P_s$
Position	-	Cruciform GPS	1s	-	-	-
Forward, rearward, upward, downward	-	Video cameras	-	-	-	-
Altitude	-	Radar altimeter	40 ms	2-3%	0.125 ft	-
Rainfall	-	Radar	-	-	-	-
Turbulence	-	5-port turbulence probe	32Hz	0.1%	0.4 m s^{-1}	-
SST	-	Heimann IR thermometer	4Hz	-	-	-
Short wave radiation	-	SWS	-	-	-	-
Vertical profiles of dynamical variables	-	AVAPS dropsondes	-	-	-	-
Broadband radiation	-	Pygreometers and Pyranometers	1s	-	-	-
NO2 photolysis j(NO2)	(Junkermann et al., 1989;VolzThomas et al., 1996)	Photometer	1s	-	-	-
O3 photolysis j(O1D)	(Junkermann et al., 1989;VolzThomas et al., 1996)	Fixed bandwidth radiometry,	1s	-	-	-
Ozone in situ		UV	3s	5%	1 ppbv	2 ppbv
Carbon monoxide CO	(Gerbig et al., 1996)	VUV fluorescence	1s		1ppbv	2 ppbv
Real-time Oxygenates	(Murphy et al., 2010)	PTR-MS	1-2 s	10-50%	10%	20-80 pptv
>100 VOCs inc NMHCs, alcohols, ketones, aldehydes, ethers		Whole air samples (WAS) and ground analysis with dual channel GC	60s	5-10%	1-3%	1-10 pptv
Semivolatile VOCs		WAS and ground analysis with 2DGC	60s	5-10%	1-3%	1-10 pptv
VOCs		Microadsorbent tubes and ground analysis with GCTOF-MS				
>40 halocarbons	(Schauffler et al., 1999)	WAS and ground analysis with GC-MS	60s	5-10%	1-5%	0.1 [[tv
NOY, NO, NO2, HNO3	(Brough et al., 2003)	Gold convertor + chemiluminescence	10s	10%	10%(NO) 30% (NO2) 21% (NOy)	3 ppt NO 15 ppt NO2 10 ppt NOy
NOX	-	TECO	1s	50 ppt	-	50 ppt (for 120s average)
PeroxyacetylNitrate	(Roberts et al., 2004)	Gas chromatography (GC)	~90s	10%	3%	30 ppt
Speciated peroxides	(Penkett et al., 1995)	Fluorometric	10s			5 pptv

(inorg/organic)						
Formaldehyde	(Cardenas et al., 2000)	Fluorometric	10s	30%	12%	50 pptv
Peroxy radicals (RO2 + HO2)	(Green et al., 2006;Monks et al., 1998)	Chemical amplifier – PERCA	30-60s	40%	6%	2 ppt
OH, HO2		FAGE (laser induced fluorescence at low pressure)	30 s (OH) 1s (HO2)	35%		7.2×10^5 cm^{-3} (OH) 3.1×10^6 cm^{-3} (HO2)
Aerosol size and composition	(Jayne et al., 2000)	Aerosol mass spectrometer AMS	30s			15-150 ng m^{-3} (species dependent)
Particle number concentration > 3nm		TSI condensation particle counters		10%		
Aerosols size distribution (0.230 um)		internally and externally sampling (OPCs) PCASP	1s			
Aerosol size distribution (0.230 um)		internally and externally sampling (OPCs) GRIMM				
Drop size spectrum		Fast FSSP	1s			
CCN	(Stolzenburg and McMurry, 1991)	CCN spectrometer	1s			0 cm^{-3}
Particle soot, black carbon		PSAP	1s			
Scattering		Nephelometer (TSI),	1s			
Particle sizes, non-sphericity		SID1				

Table 3b Instrumentation on the D-F20

Species/Parameter	Reference	Technique	Averaging time	Accuracy (%)	Precision (%)	Detection limit
O3	(Schlager et al., 1997)	UV photometer	1 s	5 %	2 %	1 ppb
CO	(Gerbig et al., 1996)	VUV fluorescence	1 s	3 ppb	1 ppb	1ppb
CO2	(Schulte et al., 1997)	ND-IR photometer	1 s	0.3 ppm	0.1 ppm	0.1 ppm
NO	(Schlager et al., 1997)	chemiluminescence	1 s	7 %	4 %	5 ppt
NOy	(Ziereis et al., 2000)	Au converter + chemiluminescence	1 s	12 %	7 %	15 ppt
j(NO2)	(Schlager et al., 1997)	filter radiometer	1 s	1 x 10-4	5 x 10-4	-
HNO3		IT-CIMS	2 s	15	10	50 ppt
SO2		IT-CIMS	2 s	10	5	20 ppt
RO2	(Andres-Hernandez et al., 2009;Kartal, 2009)	PERCA				
HCHO		Hantzsch synthesis, fluorimetry	60 s	15 %	10 %	50 ppt
Aerosol number concentration & size distribution (nucleation & Aitken mode)	(Weinzierl et al., 2009)	3-channel CPC system + DMA	1 s / 60 s	10	<5	-
Aerosol size distribution (accumulation mode)	(Weinzierl et al., 2009)	PCASP-100X	1-10 s	20	Depends on integration time	-
Aerosol size distribution (coarse mode) & cloud information	(Gayet et al., 2006)	FSSP-300, FSSP-100	5-20 s	20	Depends on integration time	-
Non-volatile aerosol size distribution	(Weinzierl et al., 2009)	Thermodenuder (250 °C) + 3-chn. CPC system + OPC Grimm 1.109	1-10 s	10	Depends on integration time	-
Aerosol absorption coefficient	(Petzold et al., 2009)	PSAP 3-wavelength absorption photometer	5-60 s	20	10	0.1×10^{-6} m^{-1}
Single particle analysis	(Kandler et al., 2009)	Impactor sampler	2-5 min	-	-	-
Temperatures		Open wire PT100 in TAT housing	1 s	0.5 K	0.1K	-
Absolute humidity	-	Lyman-α absorption	1 s	Depending on many parameters	5 % (best) -20% (worst, cutoff)	-
Relative humidity	-	Vaisala HMP 233	1 s	Depending on many parameters	5 % (best) -20% (worst, cutoff)	-
Position, winds, u,v,w	(Bogel and Baumann, 1991)	INS, GPS, 5 hole probe	1 s	1 m/s (horiz.) 0.3 m/s (vertical)	-	-
Turbulence		5-hole probe	0.01 s	-	-	-
Position	-	GPS Ashtech GG12-Pro	1 s	10 m (horiz) 20 m	-	-

				(vert)		
Forward view	-	Video camera	1 s	-	-	-
Pressure (altitude)	-	Absolute pressure measurement on noseboom 5 hole probe	1 s	0.5 mbar	-	-

Table 3c Instrumentation on the F-F20

Species/Parameter	Reference	Technique	Averaging time	Accuracy	Precision	Detection limit
O3	(Nedelec et al., 2003)	UV photometer	4s		2 ppb	
CO	(Nedelec et al., 2003)	VUV fluorescence	30s		5 ppb	10 ppb
NO	(Marion et al., 2001)	CL	30s		0.5%	50 ppt
NO2	(Marion et al., 2001)	CL + Photolytic converter	30s		0.5%	50 ppt
j(NO2)	Meteo Consult	Filter radiometer	1s	15%		
VOC and OVOC	(Bechara et al., 2009)	Microadsorbent tubes	10 min.		10%	20 ppt
H2O2 and ROOH	Aerolaser AL2002	Wet chemistry and fluorescence detection	10s	20%		50 ppt
Relative humidity	Aerodata	Capacitive detection	1 s	5%	0.5%	
Humidity	General eastern 1011B	Dew point	1 s	±0.25°C (t>±0°C) ±1.0°C (t <-60°C)	0.03 °C	
IR fluxes	CIMEL	IR radiometer	1s		0.02K	
UV-Visible fluxes	EPLEY	radiometer		3%	0.3 Wm^{-2}	
Temperature		Rosemount temp probes				
Position, wind		INS, GPS				
PTU vertical profile		VAISALA dropsonde				

Table 3d Instrumentation on the M55

Species/Parameter	Reference	Technique	Averaging time	Accuracy	Precision	Detection limit
O3	(Yushkov et al., 1999)	FOZAN Dye chemiluminescence	1 s	0.01 ppmv	8%	-
H2O (total)	(Zoger et al., 1999;Schiller, 2008)	FISH Lyman-α photo-fragment fluorescence	1 s	6 % + 0.15 ppmv	0.15 ppmv	0.15 ppmv
H2O (gas phase)	(Yushkov et al., 1998)	FLASH Lyman-α	1 s	6%	0.2 ppmv	-
NO NOy	(Voigt et al., 2005;Schmitt, 2003)	SIOUX	1 s	10%	3%	-
Particle NOy		Chemiluminescence, + Au-converter + Subisokinetic inlet	1 s	15%	5%	
ClO	(von Hobe et al., 2005)	HALOX Chemical-conversion resonance fluorescence + thermal dissociation	100 s	20%	10%	-
BrO			600 s	35%	25% accuracies and precision may vary according to flight conditions, consult the PI	
N2O, CFC12, CH4	(Volk et al., 2000)	HAGAR GC/ECD	90 s	2 %	1 %	-
CFC11, H-1211,		GC/ECD	90 s	3 %	2 %	
H2		GC/ECD	90 s	4 %	3 %	
SF6		IR absorption	5 s	0.1 %	0.08 %	
CO2						
CH4	(D'Amato et al., 2002)	ALTO TDL	10 s	17%	5%	60 ppbv
CO	(Viciani et al., 2008)	COLD-TDL	4 s	9%	1%	3 ppbv
Aerosol number concentration (total and non-volatile)	(Curtius et al., 2005;Weigel et al., 2008)	COPAS 4-Channel condensation particle counter	1 s	-	-	-
Ice crystal size distribution (3-30 µm)	(Borrmann et al., 2000;Thomas, 2002)	FSSP-100 Forward Scattering Spectrometer Probe	2 s	-	25%	-
Ice crystal shape and size distribution (25-1550 µm)	(de Reus et al., 2008)	CIP 2-Dimensional optical array probe	2 s	-	-	-
Aerosol optical properties	(Buontempo et al., 2006;Cairo et al., 2004)	MAS Multi-wavelength Scattering	5 s	5%	5%	-
Water vapour isotopes	(Kerstel et al., 2006)	IRIS water Isotope Ratio Infrared Spectrometer	1 s	20%	currently limited by thermal management problems with the M55 integration of the spectrometer. Precision improves with averaging time and water mixing ratio.	-
δD(H2O) δ18O(H2O)	(Franz and Rockmann,	WAS Water sampler plus IRMS	~1800 s	-	-	-

δ13C(CH4) δD(CH4) δ15N(N2O) 1δ15N(N2O) 2δ15N(N2O) δ18O(N2O) δD(H2)	2005;Kaiser et al., 2006;Keppler et al., 2006;Rockmann et al., 2003)	Whole air sampler plus IRMS	~240s	0.3‰ 5‰ 0.3‰ 0.5‰ 1‰ 0.3‰ 5‰	0.1‰ 2‰ 0.1‰ 0.2‰ 0.8‰ 0.2‰ 2‰	
Temperature	(Shur, 2007)	TDC Rosemount probe	1 s	0.5 K	0.1 K	-
horizontal wind	(Shur, 2007)	PT100, 5-hole probe	1 s	1 m/s	0.1 m/s	-
H2O, CH4, N2O, O3, F11, HNO3 and others, clouds	(Fischer et al., 2008)	MIPAS Mid-IR emission limb sounder	-	-	-	-
H2O, O3, F11, F12, HNO3 and others, clouds	(Hoffmann et al., 2009;Spang et al., 2008)	CRISTA-NF IR emission limb sounder	Ca. 60 s Per profile	500 m vertical	-	-

Table 3e Instrumentation on the ATR-42

Species/Parameter	Reference	Technique	Averaging time	Accuracy	Precision	Detection limit
Static pressure		Rosemount, Thales Avionic	1s	0,6hPa	0,3hPa	
Temperature T		Rosemount PRT	1s	0,7°C	0,1°C	
Fast temperature T'		Rosemount PRT	25Hz	0,01°C	0,01°C	
Dew point temperature		Dew point sensor (Buck Research)	1s	0,2°C		
Fast water vapour density		Lyman Alpha (AIR)	25Hz	10-3g.m-3	10-3g.m-3	
Horizontal position and ground speed		INS (Sagem), GPS (Trimble)	1s	100m and 1m.s-1	10m and 0,1m/s	
Mean U, V		INS (Sagem), GPS (Trimble) and 5-port turbulence nose	1s	1m.s-1	1m.s-1	
Turbulence u', v', w'		5-port turbulence nose	25Hz	10-3m.s-1	10-3m.s-1	
Height above ground		Radioaltimeter (Thales Avionic)	1s	4%	4%	
Upwelling/Downwelling, SW/LW Broadband radiation		Pyrgeometers, pyranometers (Eppley)	2s, 1s	10W.m-2	5W.m-2	
Liquid water content		Gerber Probe and King Probe	25Hz and 20Hz	10%, 20%	2%, 10%	
CO in situ		IR-CO instrument (Thermo)	5s		0,02ppm	0,02ppm
O3 in situ		UV-O3 instrument (TEI)	3s		1ppb	1ppb
NO, NO2, PAN in situ		Chimiluminescence NOxTOy instrument (METAIR)	1s		20%	200ppt
NO2 photolysis j(NO2)		Filter radiometer (Metcon inc)	1s		2%	2.10-4s-1
Aerosol particle sampling inlet	(Crumeyrolle et al., 2008)	Community Aerosol inlet (CAI)				< 4µm
Cloud droplet sampling	(Schwarzenboeck et al., 2000)	Counter flow Virtual Impactor (CVI)				> 4µm
Coarse particle inlet	(Formenti et al., 2010)	AVIRAD				< 9 µm
Size resolved chemistry of individual particles	(Matsuki et al., 2003)	Dual impactor	10-15min			>100nm & >1µm
Bulk and size-resolved elemental concentration	(Formenti et al., 2010)	Filter and 4-stage impactor sampling	20-60 min	+/-10%	10%	< 9 µm
BC concentration		Aethalometer	~ 30s	+/-10%		0-10µg m-3
Ions trace		filters for sub and supermicron particle collection	~ 60min		5%	10ppb
Particle scattering coefficient	(Anderson and Ogren, 1998)	Spectral nephelometer TSI 3596	1 s	+/-10%	5-30%	< 1000 Mm-1
CN and CCN absorption	(Bond et al., 1999)	PSAP	30s	20%	10%	0,1.10-6m-1
Particle number concentration > 3nm	(McMurry, 2000)	CPC TSI-3025	1s	+/-10% up to 99000/cc	<5%	0-99000 part./cc
Particle number concentration > 11nm	(McMurry, 2000)	CPC TSI-3010	1s	+/-10% up to 10000/cc	<5%	0.0001-10000 part./cc
CCN concentration	(Snider and Brenguier,	CCN counter	~ 30s	+/-20% at 0,2%		50-2000 part./cc

	2000)			supersaturation (SS), +/-15% at other SS		
Size distribution of Aitken and accumulation mode particles (20-2000nm)	(Venzac et al., 2009)	SMPS, OPC	2min	<20%		0-10000 part./cc
Number size distribution, 0.3-17 µm	(Formenti et al., 2010)	GRIMM OPC	6 s	<20%		0-2000 part/cc, 0.3-17 µm
Volatility analysis of particles (20-2000nm)		Thermodenuder + SMPS/OPC	2min	<20%		0-10000 part./cc
Scattering		Nephelometer (TSI)	1s			
Size distribution 0.3-10 µm		Externally sampling PCASP	1s	20%	Depends on integration time	< 20000 part./cc
rain drop distribution	(Gayet et al., 2006)	Externally sampling FSSP (100)	1s	20%	Depends on integration time	
Cloud droplet spectrum	(Brenguier et al., 1998)	Fast FSSP	0,1s	+/- 20% on the Cloud droplet conc.		
COV : C5-C9	New off-line aircraft instrumentation for non-methane hydrocarbon measurements, (Bechara et al., 2009)	Microadsorbent tubes and ground analysis with GC-MS	10min		<24%	1-5ppt
Oxygenated COV: HCHO		DNPH sampling and ground analysis with HPLC-UV	10min		20%	25ppt

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