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DACCIWA

"Dynamics-aerosol-chemistry-cloud interactions in West Africa"

Deliverable

D3.1 Chemistry Campaign

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D3.1 Campaign: summary document for chemistry campaign to inform case study selection and data users.

1 Aim of the report

The objective of the chemistry campaign was manifold: deliver a high-quality dataset of the atmospheric composition in Southern West Africa, explore contrasted environments in the region (biogenic, urban, industrial), investigate the vertical and horizontal distribution of gas and aerosols.

The DACCIWA chemistry campaign started in May 2016 with the installation of the ground based sites of Savé (Benin), Ile-Ife (Nigeria) and Kumasi (Ghana). Measurement period started in 13 June 2016 and ended on 31 July 2016 with the decommissioning of the sites. Between 27 June and 17 July 2016, the aircraft campaign was deployed with three aircrafts covering Benin, Togo, Ghana and south-east of Ivory Coast. The need for characterization of atmospheric composition near and downwind of the sources implied a diversity the flight missions (see Table 1). A comprehensive review of these missions is given in D4.1. The aim of the report is to provide a summary of the chemistry campaign in the light of WP3 objectives.

2 Overview of chemistry campaign

Objectives of WP3 are diverse which includes biogenic environments, anthropogenic environments (with a focus on city emissions from Lomé, Cotonou, Accra, Kumasi, Abidjan), biomass burning and dust advection over the region, and point source characterization (flaring, ship plumes and power plant). In addition to dedicated flights on key processes, specific transects were selected with repeated flights along these routes. The strategy was to obtain a representative statistical sample for model comparisons. The line between Lomé and the supersite at Save in Benin was one of these routes. It overflew a south-north gradient of vegetation from dense rain forest in the coastal belt to the sub-sahelian savanna in the north. Additional lines included Accra-Kumasi (3 flights from F-ATR42 and D-F20) and Lomé-Abidjan (6 flights from F-ATR42 and D-F20). The latest was coordinated with ground-based intensive campaign on emission characterization by WP2.

2.1 Flight missions

Table 2 and Table 3 summarize the number of flights dedicated to the different scientific objectives and the name of the DACCIWA flights made by the German DLR Falcon 20, the French SAFIRE ATR42 and the UK BAS TwinOtter. This counting does not consider yet the quality or the pertinence of the acquired data toward each objective. Data analysis is still an on-going process.

Targeted objectives such as city emissions from Lomé and Accra were heavily characterized (14 dedicated flights) due to the vicinity with the Lomé airport, which allowed all three aircrafts to operate in these areas. Biomass burning plumes in the free troposphere were sampled during 15 flights.

On the opposite, Cotonou was studied twice (one F-ATR42 and one UK-TO flights). The Cotonou pollution plumes were rapidly advected toward Nigeria by the monsoon flux. According to the current data analysis, two flights showed well defined signatures of flaring from a mobile platform.

Table 1: List of all DACCIWA flights including target, locations and scientific objectives. Flights made by the DLR Falcon 20, the SAFIRE ATR42 and the BAS Twin Otter are listed as F20_2016XX, ATR_asYY and TOZZ respectively.

Date	Flight number	Target	Objectives
29.06.2016	F20_20160629a ATR_as17	Togo / Benin Togo / Benin	City emissions: Lomé City emissions: Lomé; Cotonou; Biogenic emissions
30.06.2016	F20_20160630a ATR_as18	Ghana Togo	City emissions: Accra, Kumasi, Takoradi City emissions: Lomé; Cotonou; Biogenic emissions
01.07.2016	F20_20160701a ATR_as19 TO1	Ghana Ghana Togo/Ghana	City emissions: Accra, Kumasi, Takoradi, Tema industrial complex City emissions: Accra, Kumasi; Biogenic emissions City emissions: Lomé
02.07.2016	ATR_as20 ATR_as21	Benin Ocean	Radiationcalibration; Dust Air-sea interactions (OLACTA); Biomass burning
03.07.2016	ATR_as22 TO2	Togo / Benin Togo / Benin	City emissions: Lomé --
04.07.2016	TO3	Ghana	City emissions: Accra
05.07.2016	F20_20160705a ATR_as23 TO4 TO5	Togo / Benin Togo / Benin Togo / Benin Togo / Benin	City emissions: Lomé City emissions: Lomé –- --
06.07.2016	F20_20160706a ATR_as24 ATR_as25 TO6 TO7	Ghana / Ivory Coast Ghana / Ivory Coast Ghana / Ivory Coast Togo / Benin Ghana	City emissions: Abidjan; Biomass burning City emissions: Accra, Abidjan; Biogenic emissions, Biomass burning City emissions: Accra, Abidjan; Biogenic emissions, Biomass burning – City emissions: Accra
07.07.2016	F20_20160707a ATR_as26 TO8	Ocean Ocean Togo	Flaring and shipping emissions (APSOWA) Air-sea interactions (OLACTA) --
08.07.2016	F20_20160708a ATR_as27 ATR_as28 TO9 TO10	Togo / Benin Ghana Benin Togo Togo / Benin	City emissions: Lomé; Tracer experiment City emissions: Accra; Biogenic emissions Dust aerosols – City emissions: Cotonou
10.07.2016	F20_20160710a ATR_as29 TO11 TO12	Ocean / Ghana Benin Togo / Benin Benin	Flaring and shipping emissions (APSOWA); Biomass burning Dust aerosols –

Date	Flight number	Target	Objectives
11.07.2016	F20_20160711a ATR_as30 ATR_as31 TO13 TO14	Ocean / Ivory Coast Ghana / Ivory Coast Ghana / Ivory Coast Togo / Benin Togo	City emissions: Abidjan; Flaring and shipping emissions (APSOWA); Biomass burning; MCS outflow City emissions: Abidjan; Biogenic emissions, Biomass burning City emissions: Abidjan City emissions: Accra, Lomé City emissions: Lomé
12.07.2016	F20_20160712a ATR_as32	Togo Ghana	City emissions: Lomé; Biomass burning; Tracer experiment City emissions: Accra; Biomass burning
13.07.2016	F20_20160713a ATR_as33 TO15	Togo Benin Ghana	City emissions: Lomé; Biomass burning; Tracer experiment; MCS outflowBiomass burning City emissions: Accra
14.07.2016	F20_20160714a ATR_as34 TO16	Ocean / Ghana / Ivory Coast Ocean Togo	City emissions: Accra; Flaring and shipping emissions (APSOWA); Air-sea interactions; Biomass burning City emissions: Lomé
15.07.2016	ATR_as35 TO17 TO18	Togo / Benin Togo / Benin Ghana	City emissions: Lomé City emissions: Lomé City emissions: Accra
16.07.2016	ATR_as36	Ghana	City emissions: Accra

Table 2: Number of dedicated flights per aircraft per WP3 scientific objectives (note: one single flight can cover multiple objectives)

	DLR-F20	F-ATR42	UK-TO	TOTAL
Biogenic		7		7
Anthropogenic				
Lomé	5	5	4	14
Cotonou		1	1	2
Accra	3	6	5	14
Kumasi	2	1		3
Abidjan	2	4		6
Biomass burning / Dust	5	10		15
Power Plant	3	5		8
Ship plumes	4			4
Flaring	2			2

Table 3: Atmospheric chemistry flights (WP3)

Objectives	Flights
Biogenic	ATR_as17, ATR_as18, ATR_as19, ATR_as24, ATR_as25, ATR_as27, ATR_as30
Anthropogenic	
Lomé	F20_20160629a, F20_20160705a, F20_20160708a, F20_20160712a, F20_20160713a ATR_as17, ATR_as18, ATR_as22, ATR_as23, ATR_as35 TO01, TO14, TO16, TO17
Cotonou	ATR_as17 TO10
Accra	F20_20160630a, F20_20160701a, F20_20160714a ATR_as19, ATR_as24, ATR_as25, ATR_as27, ATR_as32, ATR_as36 TO03, TO07, TO13, TO15, TO18
Kumasi	F20_20160630a, F20_20160701a ATR_as19
Abidjan	F20_20160706a, F20_20160711a ATR_as24, ATR_as25, ATR_as30, ATR_as31
Biomass burning	F20_20160706a, F20_20160709a, F20_20160711a, F20_20160712a, F20_20160713a ATR_as21, ATR_as24, ATR_as25, ATR_as30, ATR_as32, ATR_as33, ATR_as34
Dust	ATR_as20, ATR_as28, ATR_as29
Power Plant & industrial complex	F20_20160707a (Tema), F20_20160710a, F20_20160714a ATR_as19, ATR_as24, ATR_as25 (Takoradi)
Ship plumes	F20_20160707a, F20_20160711a, F20_20160714a
Flaring	F20_20160710a, F20_20160714a

2.2 Tropical biogenically dominated environments

The vegetated regions (south of 10°N) emit large amounts of biogenic volatile organic compounds (BVOCs). During a previous campaign in 2006 (the AMMA program), high emission rates of isoprene were observed for West African native plants. Maximum concentrations of HOx and minimum concentrations of ozone were observed over the forested regions. These results remain to be confirmed by the DACCIWA measurements for the coastal forests.

The sampled region during DACCIWA has a rich variety of vegetation and biome: from dense humid forests, light forests, mangrove swamp in the coastal belt to the dense dry forests in the guinean-soudanian transition zone.

Biogenic environments were sampled during DACCIWA by the French ATR42 while performing low level legs between Lomé and Cotonou, west of Accra on the route to Kumasi or on the transect between Lomé and Abidjan over Ghana. During these flights, high levels of organics in PM1 chemical composition from AMS, of isoprene (> 3 ppbv) and MVK+MACR were associated with these vegetated areas.

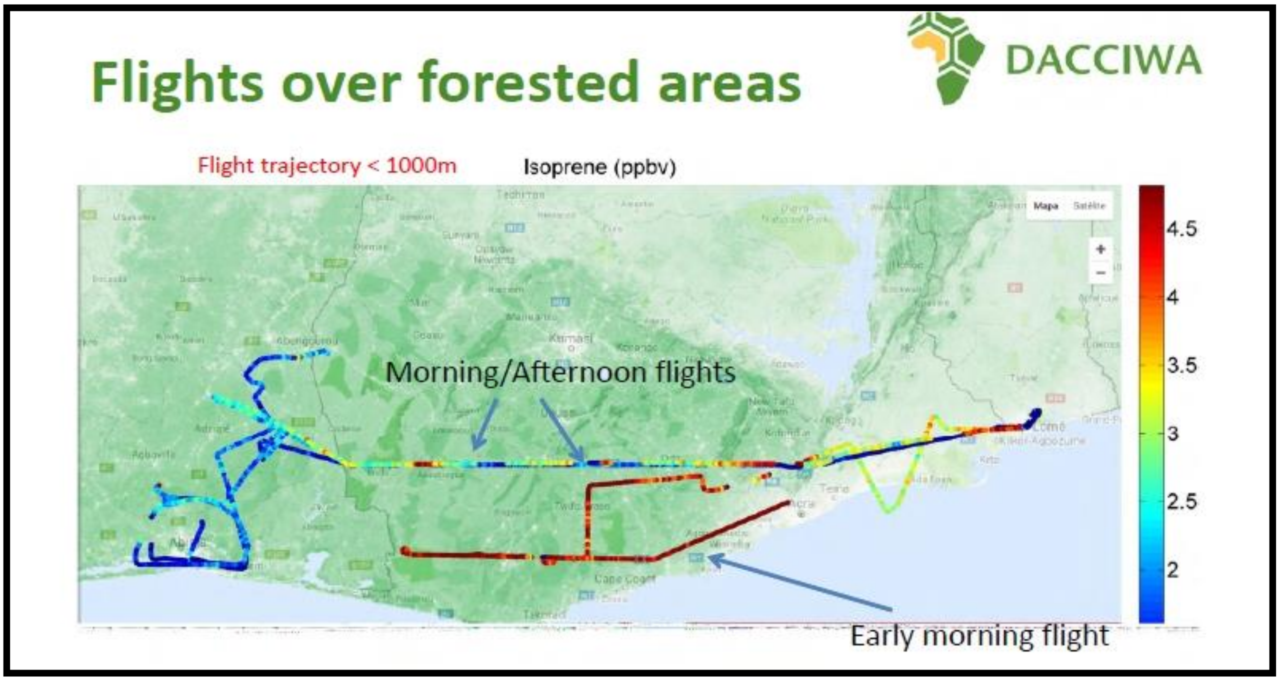

Figure 1: Isoprene mixing ratios along the ATR42 aircraft trajectory on 06 July 2016 showing elevated m.r above the humid forest south of Ghana. High m.r. (> 3ppbv) could be due to thin boundary layer height early in the morning (From A. Coulomb, J. Brito - UBP)

The supersite of Savé (08°02′N 02°29′E) is located in the south part of the guinean-soudanian transition zone, with limited impact of local anthropogenic sources. Of particular interest for WP3 objectives are the measurements of biogenic fluxes (NO, NO2, isoprene turbulent fluxes) and chemical compound concentrations of O3, NO, NO2, CO and isoprene.

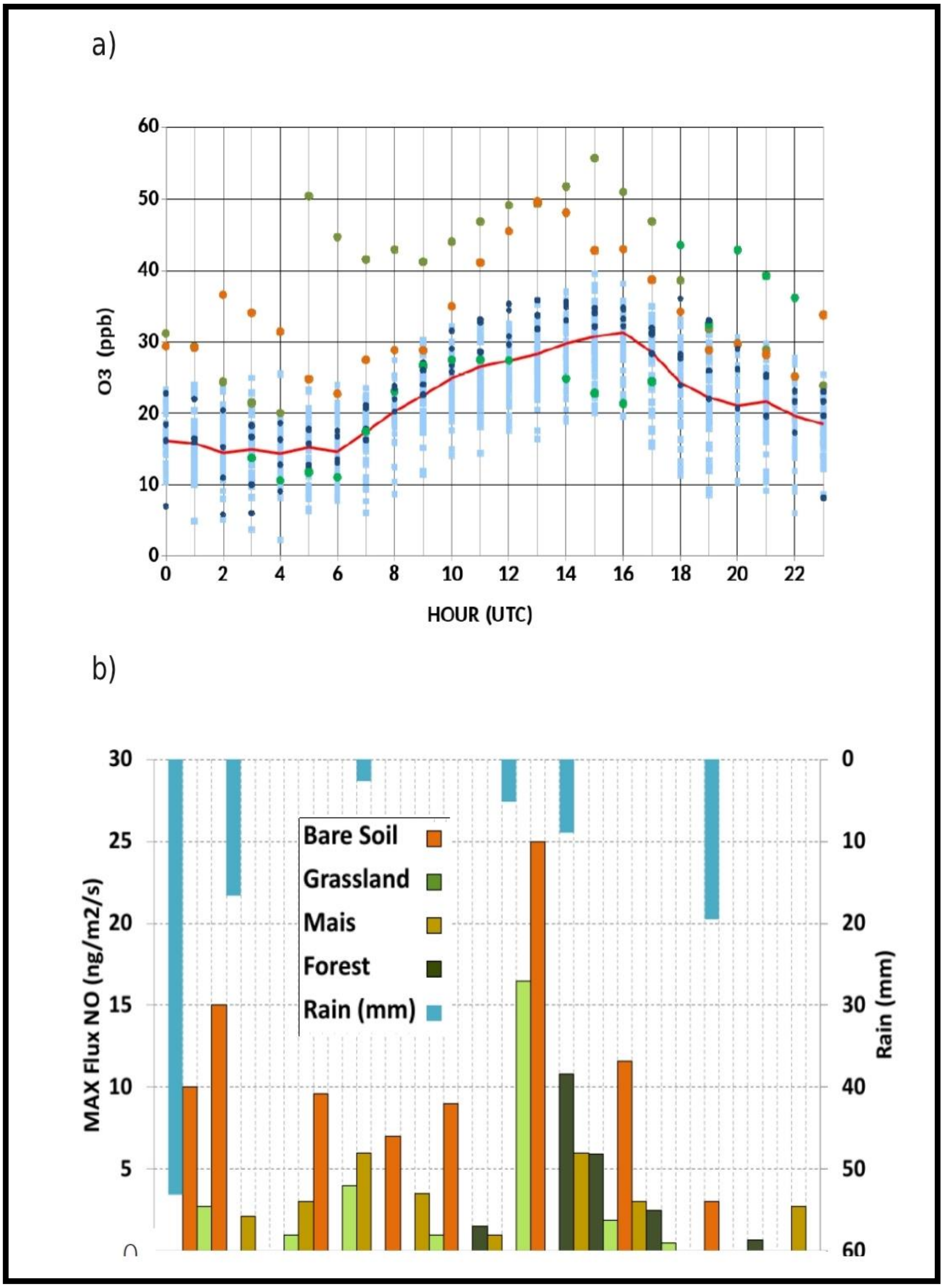

Figure 2: (a) Ozone diurnal cycles measured at the Save supersite (Benin) in ppbv (b) Maxima of NO fluxes in ng/m2/s observed at Savé during the whole campaign and for different landscapes. Blue bars indicate the rainfall events. (From F. Pacifico, C. Delon, C. Jambert / UPS)

2.3 Near-field (urban and sub-urban) atmospheric composition

Characterizing the chemical composition of air masses impacted by anthropogenic activities is one of the key DACCIWA objective. The experimental strategy to reach this goal is not straightforward as the southern West Africa belt has a broad variety of sources from road traffic, waste burning or domestic fuel combustion to power plant or oil refinery.

During the campaign, "budget flights" were conducted near the cities to document upstream and downstream air masses. Both fresh and aged polluted air masses were captured based on raster patterns and circles designed to determine the cross-flow extent of the city plumes (see Table 3).

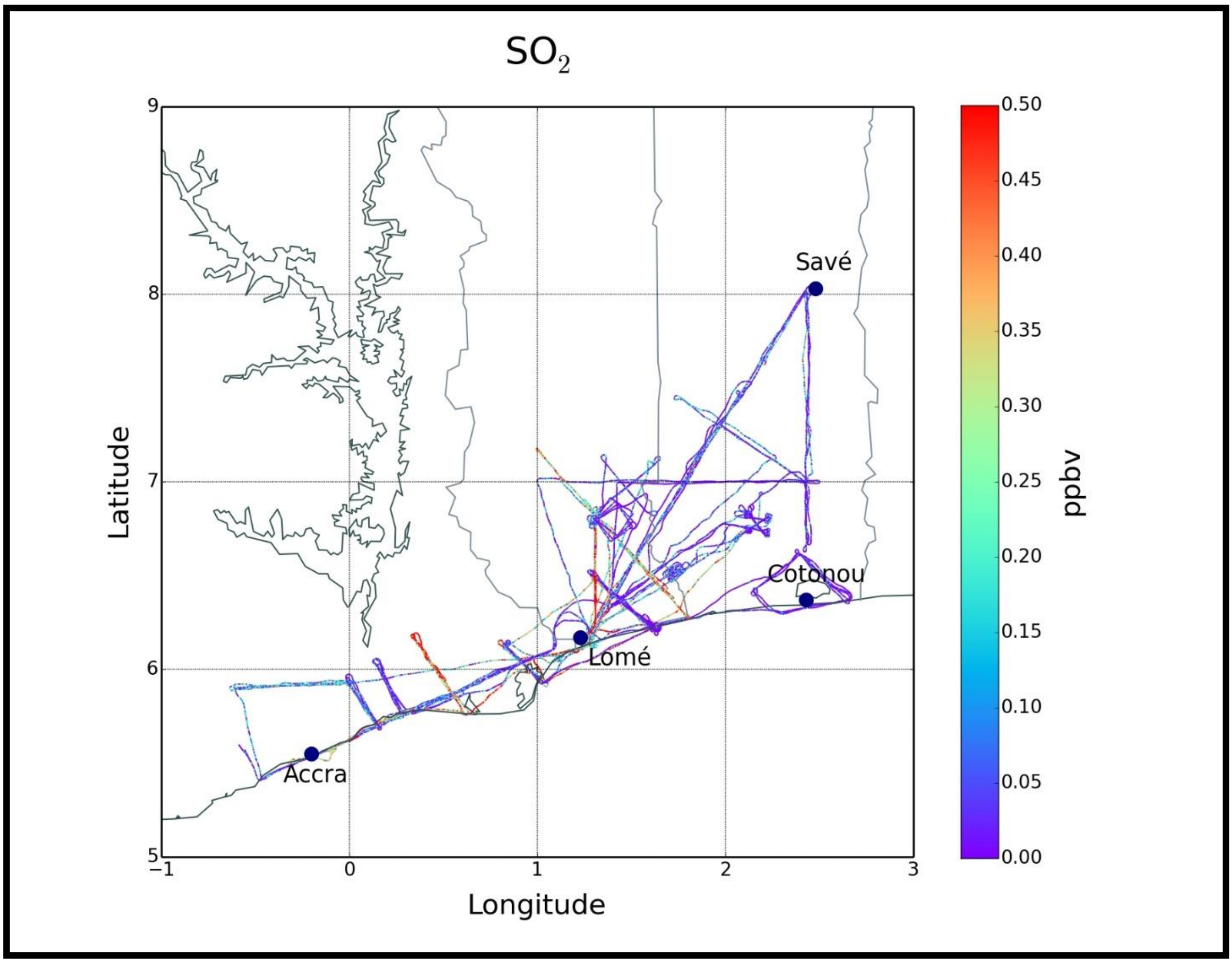

Figure 3: Overview of Twin Otter flights during the DACCIWA intensive field experiment, showing budget, upstream and downstream trajectories, colored with SO2 mixing ratios in ppbv (from J. Lee - UoY)

Three cities were particularly targeted during the campaign: Lomé, Accra and Abidjan. In Ghana, aircraft observations revealed the Sekondi-Takoradi industrial zone (230 km west of Accra) or the Tema Oil refinery as key pollution emitters.

First data analysis reveal high concentrations of sulphate, organics and BC in the city pollution plumes with significant differences between the targeted cities. Whether these differences are due to the diurnal cycle of the species, the atmospheric reactivity, the contrasted emissions sources between the cities, the impact of local circulations or the boundary layer dynamics still need to be addressed.

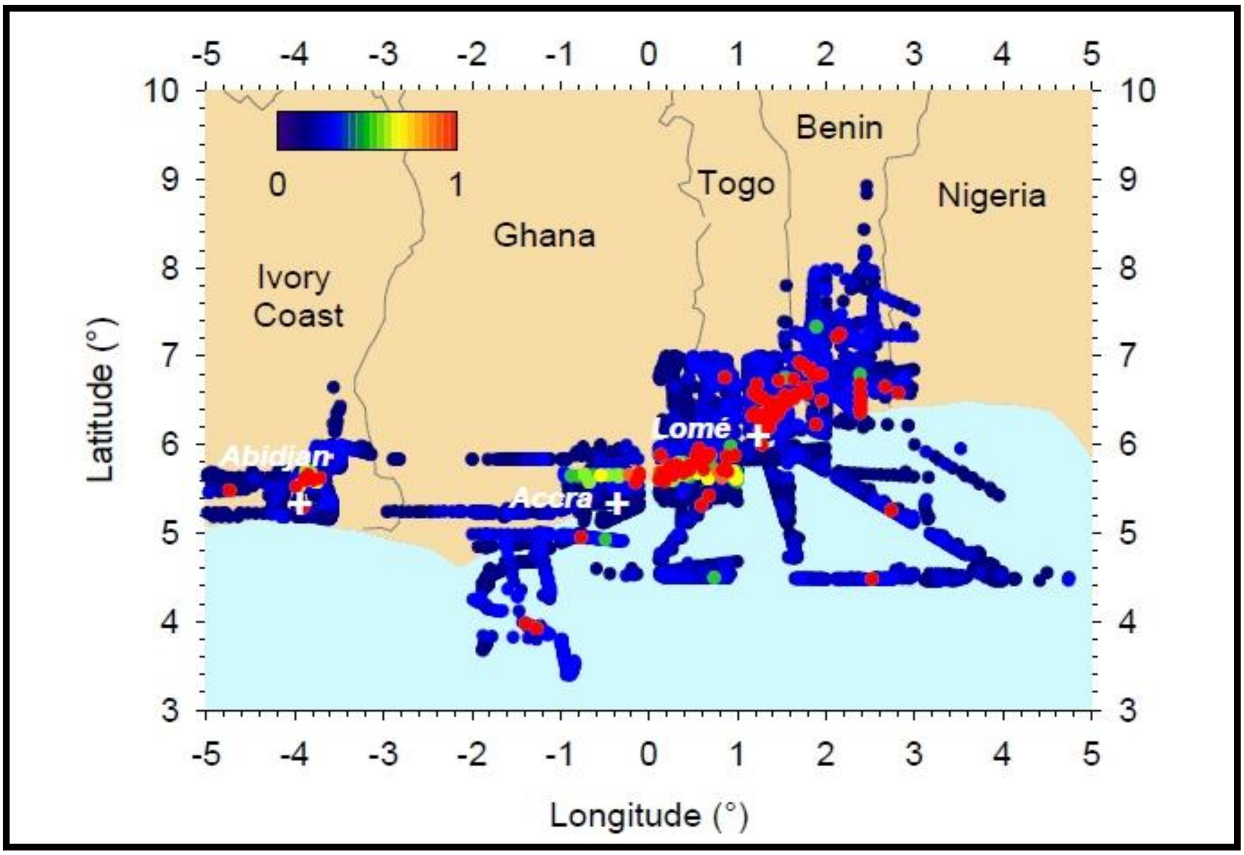

Figure 4: BC concentrations in ug/m3 observed in the planetary boundary layer on board the ATR42. Urban plumes are characterized by concentrations above 0.3 ug/m3 (From C. Denjean – CNRS/CNRM).

City plumes were located prior to the flights based on lagrangian plume forecast (see deliverable D7.2 Campaign forecasting). On July 12th, a tracer experiment was performed by releasing a PFC tracer from the Lomé hotel and chasing the tracer downwind of Lomé with the DLR-F20 (F20_20160712a).

2.4 Dust and biomass burning plumes

Observations during the AMMA program in 2005-2006 revealed a persistent influence of fires from the Southern Hemisphere in the mid and lower troposphere of West Africa during the wet season. Import of biomass burning emissions from Central Africa over the southern part of the region was originally proposed by Sauvage et al. (2005) based on MOZAIC data. DACCIWA confirms the persistence of these biomass burning plumes between 2000 and 5000 m altitude. Both F-ATR42 and D-F20 aircrafts sampled these spatially spread plumes characterized by high BC, aerosol extinction, organic particulate matter.

Dust plumes were captured several times in the northern section of the Lomé-Savé route. In particular, lidar measurements, operational during seven F-ATR42 flights, clearly show dust layers between 3000-4000 m altitude.

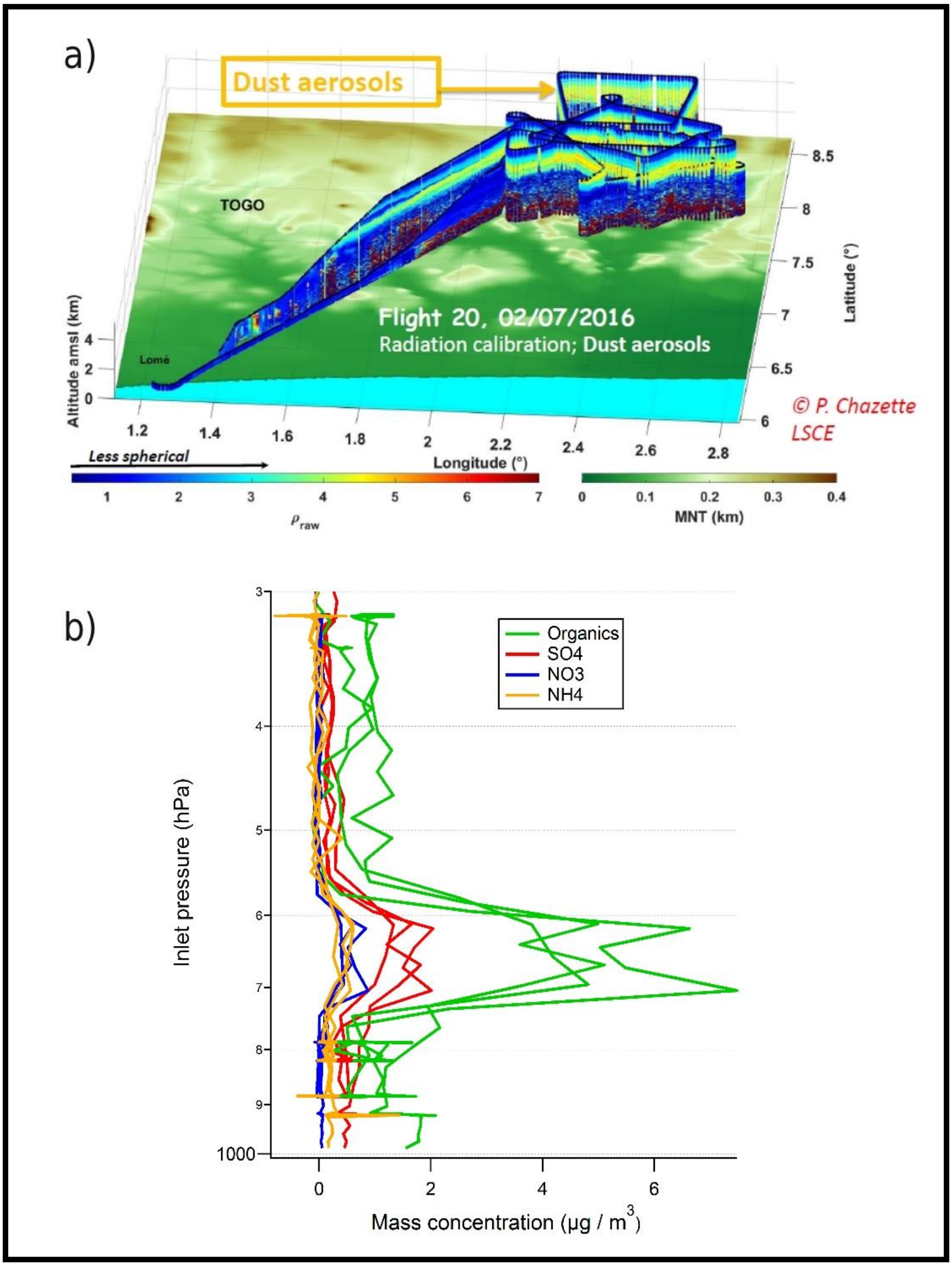

Figure 5: (a) Raw depolarization ratio from lidar measured on 02 July 2016 on board the SAFIRE ATR42 aircraft. Dust layer are well identified in the northern part of the flight (From C. Flamant, P. Chazette - UPMC). (b) C-ToF AMS observations of sulfate, nitrate and ammonium on board the DLR Falcon on 6 July 2016. High concentrations between 750 and 600 hPa could be due to a biomass burning layer (From A. Batenburg, C. Schulz, J. Schneider, and S. Borrmann – MPI Mainz)

2.5 Ship plumes and flaring (the APSOWA project)

APSOWA (Atmospheric Pollution from Shipping and Oil platforms of West Africa) is an EUFAR project to quantify ship and oil platform emissions in the Gulf of Guinea. Four flights were impacted by emissions by the Tema Oil refinery or Takoradi power plant zones, ships, floating vessels used by the offshore oil and gas industry for the production and processing of hydrocarbons (so called FPSO). Work is on-going to distinguish the relative impact of these local sources on the observed chemical signatures. The APSOWA observations will complement the studies on flaring emissions conducted within WP2 and WP3.

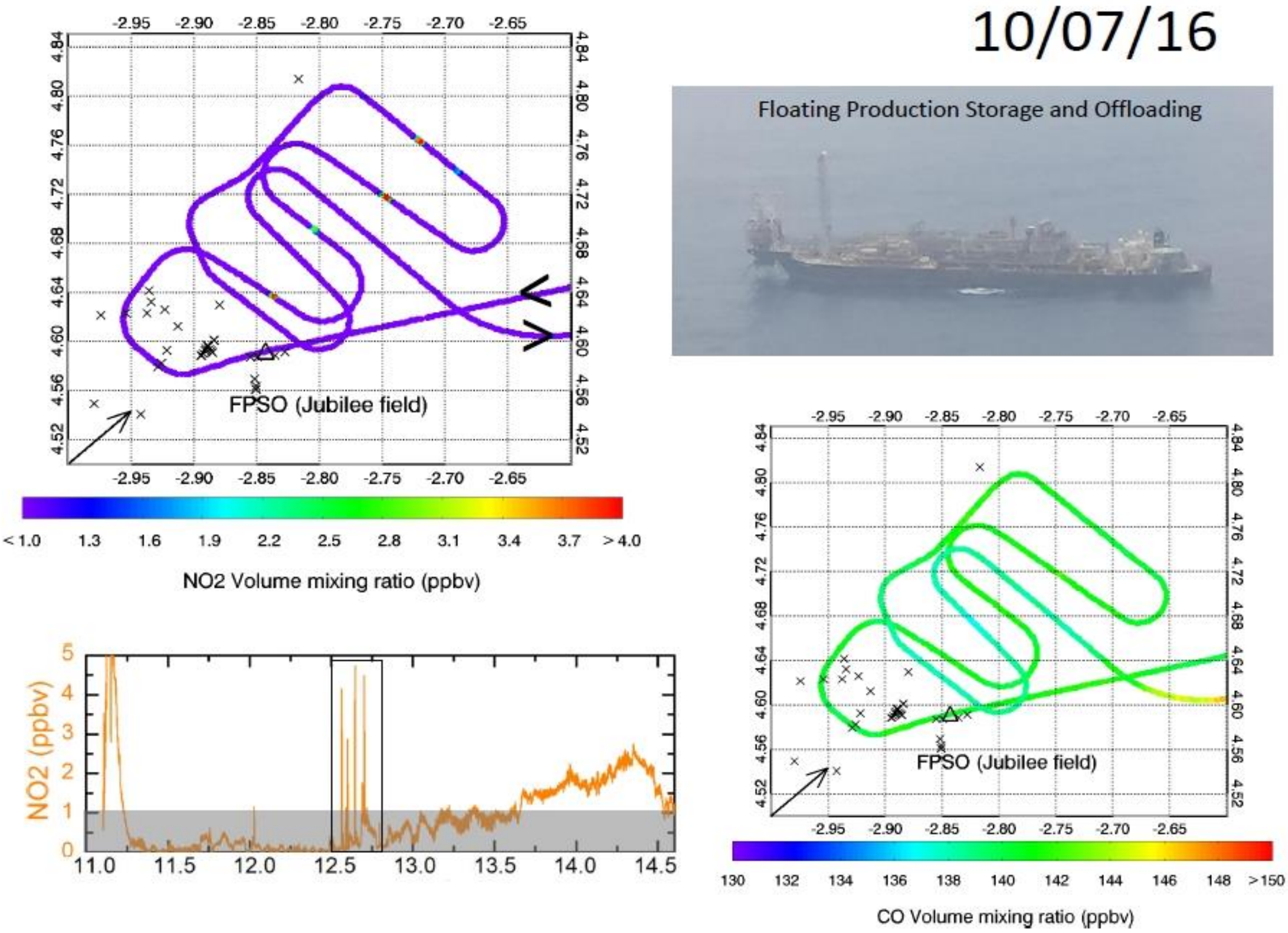

Figure 6: NO2 and CO mixing ratio in ppbv measured on board the DLR Falcon 20 on 10 July 2016. High values of NO2 were observed in a narrow plume of a FPSO vessel in the Gulf of Guinea, off the coast of Ghana (From V. Brocchi, V. Catoire – Univ of Orleans, H. Schlager - DLR)