A 5 year programme on weather, climate and air pollution in West Africa

DACCIWA Newsletter

7th Edition
Summer 2018

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COORDINATOR'S EDITORIAL

Dear Reader,

this newsletter – the seventh of its kind – is part of our effort to communicate our research activities with the scientific community, the general public and policymakers. If you missed previous newsletters, you can find them on our webpage www.dacciwa.eu, together with much more information on the project and the involved partners.

The DACCIWA project is now entering its final half year. A lot of the scientific analyses we are doing is maturing and being written up in papers with new publications coming out almost weekly. You'll find summaries of selected papers in this newsletter. Parallel to that, we are discussing the policy implications of our work. Our measurements have revealed that particle pollution is reaching dangerous levels in many places in southern West Africa and that this is due to both local sources and a substantial import of biomass burning aerosol from Central Africa. These aerosols also reduce the amount of sunlight reaching the ground, which slows the evolution of the boundary layer and decreases convective instability.

In addition, we are making preparations for our last DACCIWA project meeting in Yamoussoukro (Ivory Coast) on October 15–17, which will be flanked by stakeholder events in Abidjan, Accra, Lomé and finally Brussels.

Thank you for your continued interest in DACCIWA!

Peter Knippertz, project coordinator

8TH DACCIWA AIRCRAFT MEETING IN PARIS 14-15 JUNE 2018

The meeting was held on 14 and 15 June 2018 on the Campus of Sorbonne Université in Jussieu - downtown Paris. The meeting was designed to discuss items that are directely related to the legacy of DACCIWA.
Several important topics were covered by the 20 attendees from UPMC, UBP, UNIVMAN, KIT, DLR, UNIREAD, UoY, MPI, CNRM, LPC2E and Univ. of Helsinki:

- Pending issues concerning aircraft data calibration and intercomparison on the way towards homogeneous & consistent cross-aircraft datasets,
- Production of merged chemistry, aerosol and cloud datasets for modellers or other end-users,
- Results to go into a policy brief and presentations for the European Commission and African stakeholders.

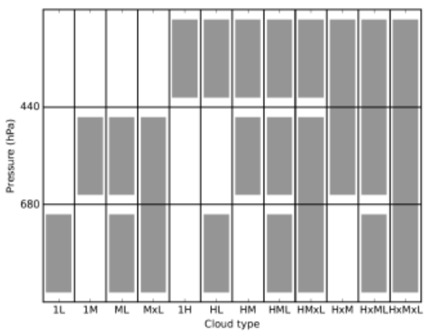
Participants of the 8th DACCIWA Aircraft Meeting at lunch

Publications

Hill et al. 2018 Journal of Climate

Quantifying the Contribution of Different Cloud Types to the Radiation Budget in Southern West Africa.

The contribution of cloud to the radiation budget of southern West Africa (SWA) during June-September is poorly understood and yet it is important for understanding regional monsoon evolution and for evaluating and improving climate models, which have large biases in this region. This study investigated the effect of 12 different cloud types (defined by their vertical structure, as shown in the figure below on the energy budget of the region.

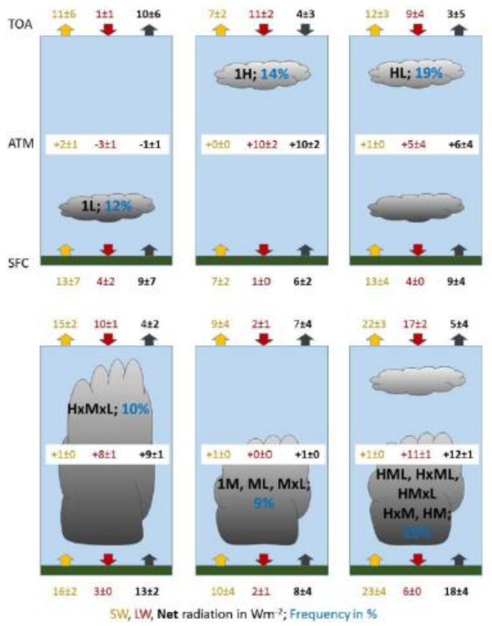


Illustrative schematic of the 12 cloud types used in this study. Low-, mid, and high-level clouds are separated using pressure levels of 680 and 440 hPa. The letter x between two layers indicates they are contiguous in the vertical extent.

Our estimates of cloud radiative effects are based on observations from the CCCM (CloudSat-CALIPSO-CERES-MODIS) dataset, which combines passive active radar and lidar measurements with passive spectral radiances to provide vertical profiles of cloud optical properties. Each profile is assigned to one of the 12 cloud types shown in the figure on the left and fed into a broadband radiative transfer code to calculate radiative fluxes and heating rates for that profile.

The frequency of occurrence and contribution to the regional mean cloud radiative effect for each cloud type are summarised in the figure on the right. SWA experiences many different cloud types; no single cloud type dominates in terms of either frequency of occurrence or radiative effect. The most frequent cloud types are 1L, 1H, HL, and HxMxL, which have frequencies of 12%, 14%, 19%, and 10%, respectively. Contributions from different cloud types to the regional mean cloud radiative effect depend not only on their frequencies, but also on their mean coincident cloud radiative effects, which are linked to cloud thickness in the SW and cloud-top and cloud-base height in the LW.

The large regional mean cloud radiative effect in SWA is due to non-negligible contributions from many different cloud types; eight cloud types have a cloud fraction larger than 5% and contribute at least 5% of the regional mean shortwave cloud radiative effect at the top of the atmosphere. All cloud types lead to a net cooling of the surface, ranging from approximately 2 W m^{-2} for ML to 13 W m^{-2} for HxMxL. 1H results in an increase in the net downwelling irradiance at the TOA (4 W m^{-2}), but all other cloud types have the opposite effect. The 1L type leads to small cloud radiative cooling of the atmosphere, but all other cloud types lead to heating.



Schematic illustrating the contribution of different cloud types to the diurnal mean radiation budget of SWA for June–September 2006–10. The direction of the arrows indicates the direction of the CRE and the area of each arrow is proportional to the magnitude of the Cloud Radiative Effect (CRE). The plus and minus values indicate uncertainty. To reduce the number of panels in the schematic, we show the four most frequent cloud types (1L, 1H, HL, and HxMxL) and the remaining cloud types are split into midlevel top and high top and the combined radiative effects are shown. All values are rounded to the nearest integer.

Reference: Hill, P.G., R.P. Allan, J.C. Chiu, A. Bodas-Salcedo, and P. Knippertz, 2018: Quantifying the Contribution of Different Cloud Types to the Radiation Budget in Southern West Africa. *J. Climate*, **31**, 5273–5291, https://doi.org/10.1175/JCLI-D-17-0586.1

DACCIWA session at EGU 2018

AS4.9/CL2.12 Atmospheric composition, weather and climate in Sub-Saharan Africa (co-organized)

The session with a focus on the DACCIWA project successfully took place for the second year in a row. The session was convened by DACCIWA members Céline Mari, Peter Hill, Véronique Yoboué and John Marsham and included many contributions from DACCIWA participants.

Another session is foreseen for next year's EGU

[Link to oral presentation abstracts]

[Lind to poster presentation abstracts]

DACCIWA Policy Brief

Meet the DACCIWAs

Jeffrey Nii Armah Aryee

I am a PhD student at the Kwame Nkrumah University of Science and Technology (KNUST) in Ghana, involved in Work Package 1 of the DACCIWA project, which focuses primarily on Boundary Layer Dynamics. Prior to my involvement in the DACCIWA project, I pursued BSc. and MPhil. in Meteorology and Climate Science at the same university. After my BSc., I served as a teaching and research assistant at the Physics Department (KNUST) for my compulsory national service. During this period, I developed a keen interest for atmospheric science, partly due to the fact that this field of science is still young in Ghana, and I felt the need to pursue a career in that regard, to enable me to contribute my quota to the development of atmospheric sciences in the country. A single line of quote, "Boundary layer is the region where humans live, and as such, variation in its processes has enormous impact on human life and dependencies", largely influenced my choice to engage in boundary layer studies. I find it quite interesting and purposeful to be involved in a scientific research that seeks to improve the understanding of PBL processes over the West African domain: a region limited in understanding of PBL processes due to sparsity of data. My involvement in DACCIWA has been a great learning experience, providing the opportunity to work with a wider scientific community, yet with a common goal: "Advancing the understanding of Atmospheric Processes in West Africa". As part of my PhD research, under the supervision of Prof. Leonard K. Amekudzi, I study the relationship between PBL evolution and radiation fluxes and surface energy balance in the West African domain. First, I inter-compare various PBL height estimation methods to assess their performance in the study area. Thereafter, with the better performing method(s), I assess the PBL evolution and the radiation and energy controls, as well as, other processes relevant to its development. Additionally, I look at the synergy of low-level stratus clouds, PBL evolution, surface energy balance and stability over the study domain. Findings of this research study, I am certain, will aid in advancing the understanding of PBL processes, particularly in Southern West Africa and enhance the performance of integrated PBL-radiation-energy balance models over the region.

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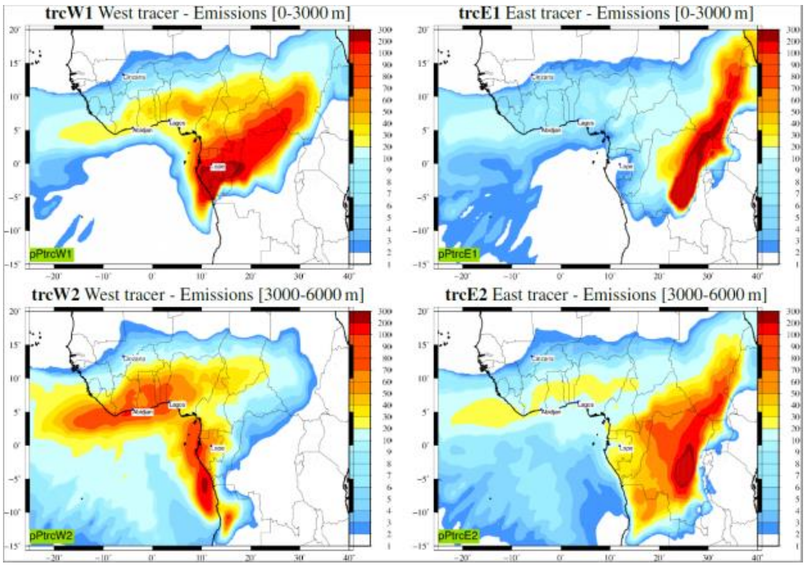
Menut et al. in Atmospheric Chemistry and Physics

Impact of biomass burning on pollutants surface concentrations in megacities of the Gulf of Guinea

This study examines the atmospheric composition during the summer of 2014 (from May to July) in the region of the Gulf of Guinea. The main goal was to quantify the relative contribution of biomass burning emissions, occurring in Central Africa, on the aerosol (i.e. PM_{10}), CO and O_3 surface concentrations in large urbanized areas such as Lagos and Abidjan. The period was modelled with the meteorological model WRF and the chemistry-transport model CHIMERE. Several model configurations were used.

First, in order to know if the biomass burning pollutants may reach the Gulf of Guinea cities (e.g. Lagos and Abidjan), a tracer experiment was performed. It was shown that, independently of the location of emissions in Central Africa, biomass burning always impacts the surface concentrations of pollutants in those cities. Depending on the location of the emissions, the fire plumes may follow the west coast of Central Africa to reach the cities (the most direct transport pathway), or may be advected towards the east over continental Africa and reoriented toward the cities by the north-easterly Harmattan winds. In order to gain insight into the impact of biomass burning emissions injection in the atmosphere, two simulations were performed with different vertical injection profiles, one peaking on the lower troposphere and one peaking in the mid-troposhere. It was shown that resulting tracer surface concentrations are not sensitive to the shape of the profile. The reason is that, during a fire, the pyroconvection induces a strong and fast mixing of the surface flux. Whatever the shape of the injection profile, the pollutants are quickly mixed in the vertical before being transported over long distances (see figure below).

It was shown that biomass burning will induce a regular increase in surface concentrations of pollutants during the whole studied period.

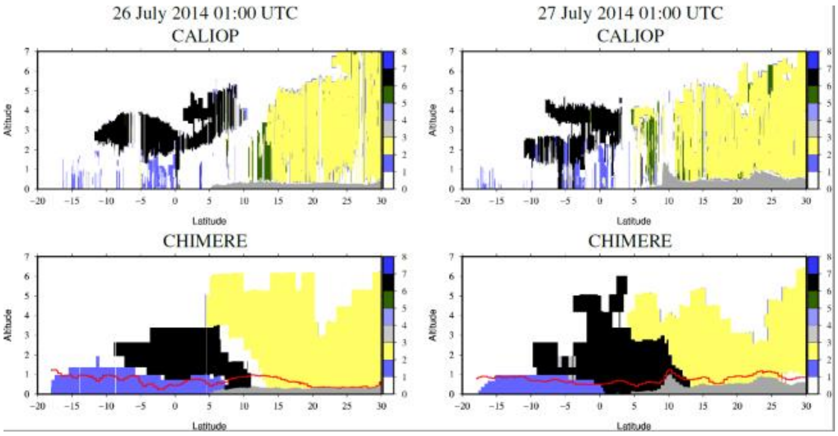


Regional distribution of tracers surface concentrations (arbitrary units) on 27 July 2014 at 1200 UTC for each of the tracer experiments: the tracers emitted in the western part of Africa are noted W and those at the eastern part are noted E.

The simulations with realistic biomass burning emissions were analyzed by comparison to numerous datasets: CO from IASI, AOD from MODIS and AERONET, surface concentrations of PM_{10} from the Sahelian Dust Transect data and aerosol sub-typeclassification from CALIOP. It was shown that the model is able to reproduce the physical and chemical characteristics of the emitted gas and aerosol species due to biomass burning. In addition, and using the vertical information provided by CALIOP, it was shown that the location and altitude of the several aerosol plumes (mineral dust and biomass burning) are correctly modelled (see figure next side).

Finally, and by comparison of simulations without (NoFIRE) and with fire emissions (FIRE), a first quantification of the amount of additional pollutants in Lagos and Abidjan was estimated. It was shown that biomass burning will induce a regular increase in surface concentrations of pollutants during the whole studied period of the order of magnitude of ≈ 150 µg m^{-3} for CO, ≈ 20

Menut et al. at Atmospheric Chemistry and Physics (cont.)



Vertical cross-section of CALIOP aerosol types and comparison to the CHIMERE FIRE simulation. The colorbar is related to the CALIOP classification: (0:1) Not applicable, (1:2) Clean marine, (2:3) Dust, (3:4) Polluted Continental or smoke, (4:5) Clean continental, (5:6) Polluted dust, (6:7) Elevated smoke, (7:8) Dusty marine. For the model, the boundary layer height is superimposed in red.

μg m^{-3} for O_3 and ≈ 5 μg m^{-3} for PM_{10}. Using the modelled speciation, this additional amount was shown to be mainly composed of Primary Organic Matter (POM) and anthropogenic Primary Particulate Matter (PPM).

Reference:

L. Menut, C. Flamant, S. Turquety, A. Deroubaix, P. Chazette, and R. Meynadier 2018: Impact of biomass burning on pollutant surface concentrations in megacities of the Gulf of Guinea, *Atmos. Chem. Phys.*, 18, 2687-2707, 2018 https://www.atmos-chem-phys.net/18/2687/2018/

Meet the DACCIWAs
Jonny Taylor

I'm a postdoc working on DACCIWA at the University of Manchester with Prof Hugh Coe and PhD student Sophie Haslett. My research focus is the impact of pollution aerosols on the cloud field over West Africa. Aerosols may affect the brightness and lifetime of clouds, and therefore have an impact on the region's climate. It's important that we try to quantify how this will change with any population increases in the future.

I flew on the Twin Otter run by British Antarctic Survey during the DACCIWA aircraft campaign. We had a lot of equipment in a small space, plus the plane has special paint to keep warm in the Antarctic where it normally flies, so in the African sun it got pretty toasty inside.

On the ground I was trying to gain experience in flight planning, which is a lot harder than it looks. It's a fiddly 4-D problem of how fast an aircraft can fly horizontally, how fast you can ascend and descend, and how long you can fly before the fuel runs out. All the flight plans had to be submitted 24 hours in advance, so everything was based on forecasts, although part of the reason we

were there was that the cloud is difficult to forecast!

I love that working on aircraft gives me the opportunity to travel the world and see many interesting and different places. When I'm not working I spend most of my days homebrewing, attempting gardening, and hanging out with my baby daughter.

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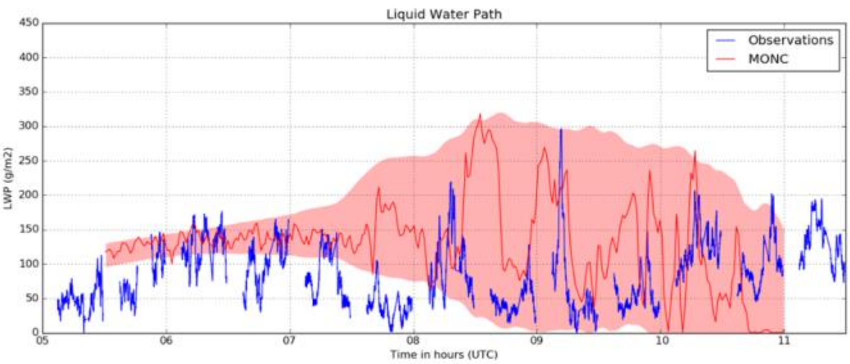
Dearden et al. ACP discussion paper

The role of droplet sedimentation in the evolution of low-level clouds over southern West Africa

Stratocumulus clouds are a common occurrence in southern West Africa during the Monsoon season, forming during the night after the initiation of the nocturnal low-level jet, and then persisting until the early afternoon when the clouds typically start to dissipate. These cloud decks have an important influence on the regional climate due to their radiative effects, yet they remain poorly represented in large-scale models. The principal objective of this study is to understand how the microphysical properties of the low-level cloud layers influence their bulk characteristics, specifically the evolution of liquid water path (LWP). To fulfill this aim, the Met Office-NERC Cloud model (MONC) has been configured to perform simulations of a non-drizzling stratocumulus layer that formed on 5th July 2016 during the DACCIWA Intensive Observation Period.

The MONC model is a re-write of the Met Office Large Eddy Model (LEM), which has been used extensively over the past twenty years to study cloud processes in a variety of meteorological regimes. MONC offers several key advantages over the original LEM, including code optimisations, bug-fixes and a new solver that enables simulations to be performed with relatively large domain sizes without having to compromise on the model resolution. In the present study, MONC has been coupled to the CASIM (Cloud-AeroSol-Interacting-Microphysics) module, a newly developed user configurable multi-moment scheme that represents the interactions between atmospheric aerosols, cloud droplets and the production of rain.

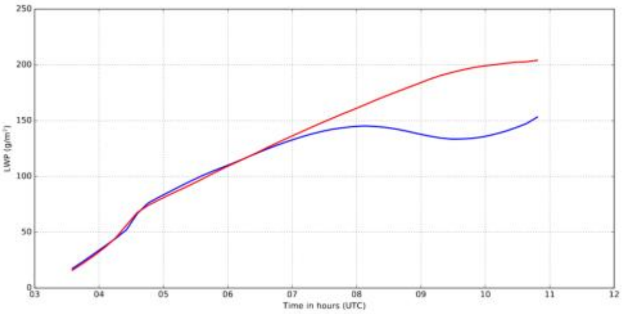
Vertical profiles of potential temperature, cloud water mass mixing ratio and horizontal wind components are used to initialise the model, obtained from radiosonde data from the Savé super site. Time-varying surface fluxes of sensible and latent heat are prescribed using measurements collected at Savé. Aircraft measurements of the aerosol size distribution in the boundary layer are also used to constrain the model, in order to simulate realistic cloud droplet number concentrations. The simulated clouds are validated using observations of cloud base height from ceilometer data, as well as time series observations of LWP derived from the microwave radiometer at Save. The evolution of the boundary layer depth in the model is validated using later radiosonde launches throughout the day on 5th July 2016, specifically at 0530 UTC (immediately before sunrise, which occurred at 0537 UTC) and 1100 UTC.



Timeseries of LWP at Savé from 5 July 2016 as measured by the microwave radiometer at Savé (blue); simulated LWP from the MONC test simulation with droplet sedimentation disabled (red). Solid red line = simulated LWP at the centre of the model domain; shading = the simulated LWP variability within the whole domain, expressed as 2 standard deviations from the domain mean value.

The results of this work reveal the importance of droplet sedimentation (the gravitational settling of liquid cloud droplets) in relation to the evolution of liquid water path. Two simulations are performed - a control simulation where the predicted droplet number concentration agrees well with in-situ observations, and a test simulation where droplet sedimentation is disabled. Compared to the control run, the cloud structure in the test simulation is found to be too homogeneous within the early morning period from 0530 to 0730

Dearden et al. ACP discussion paper (cont.)



Timeseries of the simulated domain mean LWP for 'perpetual night' conditions (no incoming solar radiation, and surface fluxes set to zero) for the control simulation (red) and the test simulation with sedimentation disabled (blue).

UTC, whilst also underestimating the observed variability in liquid water path during this time (figure on last side). After 0800 UTC, the cloud response becomes dominated by the effects of solar heating of the land surface, which results in a lifting of the cloud layer, followed by break-up and dissipation. Thus the effects of sedimentation on LWP are most important throughout the night and into the early part of the morning. To demonstrate this, the test and control simulations are repeated for 'perpetual night' conditions, and the timeseries of LWP is compared. By the end of the simulation period, the LWP in the control simulation is around 33% higher than in the test case where sedimentation is disabled (figure above). Our analysis shows that sedimentation acts to remove liquid water from the entrainment zone close to cloud top, helping to buffer the cloud layer against the effects of entrainment-induced evaporative cooling, thus allowing the cloud deck in the control simulation to maintain a higher LWP for longer. In conclusion, our findings demonstrate that the sensitivity of low level clouds over southern West Africa to changes in aerosol concentration cannot be explained solely through a consideration of the classic 1st indirect effect (aka the 'Twomey effect'), and that sedimentation-entrainment feedbacks must also be accounted for.

Reference:

C. Dearden, A. Hill, H. Coe, and T. Choularton 2018: The role of droplet sedimentation in the evolution of low level cloudsover southern West Africa. *Atmos. Chem. Phys, discussion paper* https://www.atmos-chem-phys-discuss.net/acp-2018-269/

DACCIWA Meetings in Africa

DACCIWA final project meeting:

14-17 October 2018 in Yamoussoukro Côte d'Ivoire

We are expecting around 80 people from the DACCIWA team including a large fraction from the African partners to participate in this last science meeting of the project.

Stakeholder Meetings
12 October 2018: Accra (Ghana)
18 October 2018: Abidjan (Côte d'Ivoire)
19 October 2018: Lomé (Togo)

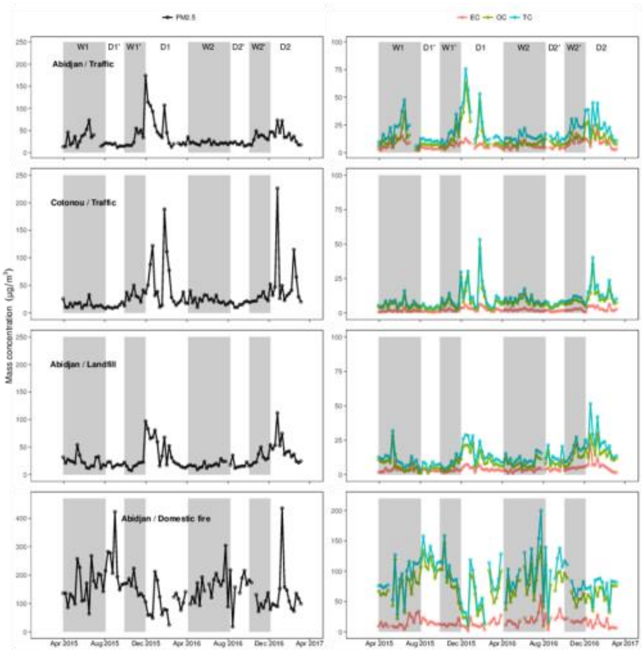
The stakeholder meetings will take place in order to communicate and disseminate the scientific conclusions of DACCIWA to policy makers and other stakeholders groups including governmental agencies, universities, weather services.
The meetings will be organized in collaboration with the local partners and embassies.

Djossou et al. in Atmopspheric Chemistry and Physics

Mass concentration, optical depth and carbon composition of particulate matter in the major southern West African cities of Cotonou (Benin) and Abidjan (Côte d'Ivoire)

Air quality degradation is a major issue in the large conurbations on the shore of the Gulf of Guinea. We present for the first time PM2.5 time series collected in Cotonou, Benin, and Abidjan, Côte d'Ivoire, from February 2015 to March 2017.

Measurements were performed in the vicinity of major combustion aerosol sources: Cotonou/traffic (CT), Abidjan/traffic (AT), Abidjan/landfill (AL) and Abidjan/domestic fires (ADF). We report the weekly PM2.5 mass and carbonaceous content as elemental (EC) and organic (OC) carbon concentrations. We also measure the aerosol optical depth (AOD) and the Ångström exponent in both cities. The average PM2.5 mass concentrations were 32±32, 32±24 and 28±19µgm^{-3} at traffic sites CT and AT and landfill site AL, respectively.

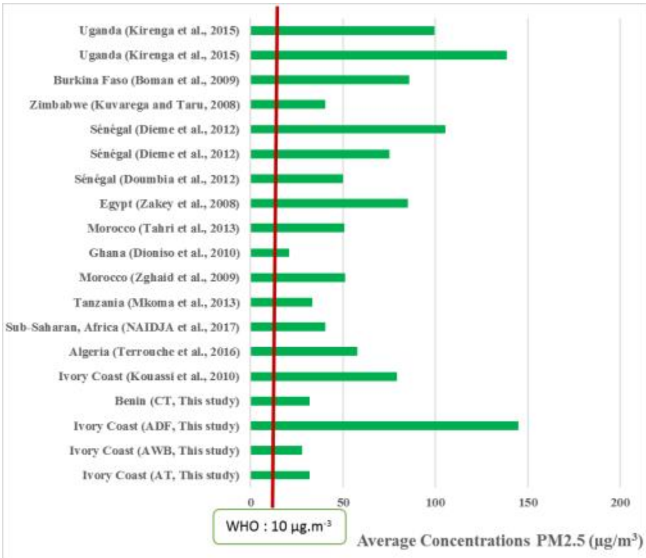


Time series of the (left) PM2.5 in µgm^{-3} and (right) carbonaceous weekly concentrations in µgCm^{-3} at the 4 sites from February 2015 to March 2017. Shaded areas show the different seasons (see text): the long rainy seasons W1 and W2; the short dry seasons D1' and D2'; the short rainy seasons W1' and W2'; and the long dry seasons D1 and D2.

The domestic fire site shows a concentration of 145±69µgm^{-3} due to the contribution of smoking and roasting activities. The highest OC and EC concentrations were also measured at ADF at 71±29 and 15±9µgm^{-3}, respectively, while the other sites present OC concentration between 8 and 12µgm^{-3} and EC concentrations between 2 and 7µgm^{-3}. The OC/EC ratio is 4.3 at CT and 2.0 at AT.

This difference highlights the influence of two-wheel vehicles using gasoline in Cotonou compared to that of four-wheel vehicles using diesel fuel in Abidjan.

AOD was rather similar in both cities, with a mean value of 0.58 in Cotonou and of 0.68 in Abidjan. The seasonal cycle is dominated by the large increase in surface mass concentration and AOD during the long dry season (December–February).



Comparison of PM2.5 mass concentrations at the four sites with other African cities. Red vertical line illustrates current WHO guideline

Reference: Djossou et al. 2018: Mass concentration, optical depth and carbon composition of particulate matter in the major southern West African cities of Cotonou (Benin) and Abidjan (Côte d'Ivoire); *Atmos. Chem. Phys.*, 18, 6275-6291, 2018

Acknowledgments

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Next Newsletter

Autumn 2018

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More DACCIWA Publications

Accepted for Publication:

- Keita et al.: **Particle and VOC emission factor measurements for anthropogenic sources in West Africa**, in ACP, https://doi.org/10.5194/acp-18-7691-2018
- Brosse et al.: **LES study of the impact of moist thermals on the oxidative capacity of the atmosphere in southern West Africa**, in ACP, https://doi.org/10.5194/acp-18-6601-2018
- Deroubaix et al.: **Interactions of atmospheric gases and aerosols with the monsoon dynamics over the Sudano-Guinean region during AMMA** , in ACP, https://doi.org/10.5194/acp-18-445-2018
- Reinarez Martinez and Chaboureau: Precipitation and Mesoscale Convective Systems: Explicit versus Parameterized Convection over Northern Africa, Mon. Wea. Rev. In press, https://doi.org/10.1175/MWR-D-17-0202.1
- Kalthoff et al.: **An overview of the diurnal cycle of the atmospheric boundary layer during the West African monsoon season: results from the 2016 observational campaign** , in ACP, https://doi.org/10.5194/acp-18-2913-2018

Accepted for Discussion:

- Pacifico et al.: **Measurements of nitric oxide and ammonia soil fluxes from a wet savanna ecosystem site in West Africa during the DACCIWA field campaign** , in ACP, https://doi.org/10.5194/acp-2017-1198
- Deetz et al.: **Cloud and aerosol radiative effects as key players for anthropogenic changes in atmospheric dynamics over southern West Africa** , in ACP, https://doi.org/10.5194/acp-2018-186
- Dearden et al.: **The role of droplet sedimentation in the evolution of low level clouds over Southern West Africa** , in ACP, https://doi.org/10.5194/acp-2018-269
- Flamant et al.: **Aerosol distribution in the northern Gulf of Guinea: local anthropogenic sources, long-range transport and the role of coastal shallow circulations** , in ACP, https://doi.org/10.5194/acp-2018-346
- Deetz et al.: **Aerosol liquid water content in the moist southern West African monsoon layer and its radiative impact** , in ACP, https://doi.org/10.5194/acp-2018-420

DACCIWA

Project Partners

- Karlsruher Institut für Technologie (DE)
- University of Leeds (UK)
- University of York (UK)
- The University of Reading (UK)
- The University of Manchester (UK)
- Deutsches Zentrum für Luft- und Raumfahrt e.V. (DE)
- Université Paul Sabatier Toulouse III (FR)
- Université Blaise Pascal Clermont-Ferrand II (FR)

Université Paris Diderot - Paris 7 (FR

- European Centre for Medium-Range Weather Forecasts (UK)
- Eidgenoessische Technische Hochschule Zürich (Switzerland, CH)
- Kwame Nkrumah University of Science and Technology Kumasi (Ghana, GH)
- Obafemi Awolowo University (Nigeria, NGR)
- Université Pierre et Marie Curie - Paris 6 (FR)
- Met Office (UK)
- Centre National de la Recherche Scientifique (FR)

Academic partners associated through subcontracts

- Université Félix Houphouet Boigny, Abijan, Ivory Coast
- Université d'Abomey-Calavi, Cotonou, Benin
- Technische Universität Braunschweig