FINAL REPORT PROGRAM LEFE

Program LEFE/CHAT	Project Title AErosol RAdiation and CLOuds in southern Africa (AEROCLO-SA)	Years 2016 – 2018

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Partners: LATMOS, LOA, IRCELYON, LCE, LSCE

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Context

The west coast of southern Africa (WCSA) is a key region of Earth's system. It is characterized by a semi-permanent and extensive stratocumulus (Sc) cloud deck, whose properties strongly affect the temperature gradients of the Atlantic Ocean's surface waters and large-scale energy balance. Future climate projections point to Southern Africa as a region where severe warming will occur.

Objectives / scientific questions

Global climate models (GCMs) have difficulties in representing the energy balance at the TOA, particularly due to aerosols. As a matter of fact, the WCSA is a crossroad of large quantities of natural and anthropogenic aerosols of distant and local origins (biogenic, anthropogenic, biomass burning, sea salt and mineral dust) from continental and marine sources, with significant differences in terms of physico-chemical and optical properties, water affinity, and height of transport.

The AErosols, RadiatiOn and CLOuds in southern Africa (AEROCLO-sA) addresses the following questions: what is the chemical composition of mineral dust, biomass burning and marine aerosols emitted or transported in the WCSA? What is their state of mixing? What are their spectral absorption properties? What is their hygroscopicity? What is the vertical distribution of aerosols and clouds over land and over ocean? Is there entrainment of biomass burning in the marine Sc clouds? Is there an anthropogenic signature in the MBL aerosols (e.g., from ships)? What are the mechanisms of dust uplift and how far is it transported offshore? What is the role of aerosols in the development of coastal fog?

Thanks to the persistence of the Sc clouds in the region, AEROCLO-sA is also a unique opportunity to evaluate the development of advanced space-borne remote sensing of aerosols and clouds. As part of its major objectives, AEROCLO-sA also supports the development of the novel multi-spectral retrieval algorithms planned by CNES in preparation for the future 3MI and IASI-NG instruments on MetOp-SG, with a planned launch in 2021.

Main results

AEROCLO-sA project is centered on a field campaign that was conducted in Namibia in August and September 2017. The ground-based detachment took place at the SANUMARC Research Centre of the University of Namibia in Henties Bay (22°6'S, 14°30'E, 20 m asl; HBAO, www.hbao.cnrs.fr). The ground-based mobile laboratory PEGASUS of LISA, equipped with a full suite of aerosols and gas-phase instrumentation, fog sizers and collectors, radiosondes and tethered balloons (LISA, IRCELYON, LCE, CNRM, Univ. Padoa, NorthWest University, NASA).

The airborne campaign was conducted with the SAFIRE/Falcon 20 research aircraft operated from the Walvis Bay International Airport from 5 to 12 September 2017. The aircraft was equipped with active and passive remote sensors as well as in situ probes (LATMOS, PI C. Flamant; LOA, PI. F. Waquet) to measure aerosol optical and radiative properties over land and over maritime Sc clouds. It performed 10 research flights (~30 flight hours) over northern Namibia.

The modelling strategy is constructed around emission/transport and regional climate models at various resolutions. To illustrate meso-scale features (emission and transport of aerosols from point sources, dispersion …), we used Meso-NH (LA, PI. J.-P. Chaboureau). The COSMO-MUSCAT model (K. Schepanski, TROPOS) provided the representation of southern African dust source in meso-scale models.

Regional climate modelling exercises are being conducted with two models: ALADIN-Climate (CNRM, PI. M. Mallet) and RegCM (LA, PI. F. Somon).

Emission and transport of mineral dust

The meteorological situation and the dynamical processes that led to the intense emission episode over Etosha during the campaign are investigated further on specific case studies. On September 5, a westerly disturbance and cold front approached and passed over the southern portion of the subcontinent. The near-surface circulation pattern associated with the Atlantic anticyclone was characterized by weak southwesterly winds along the coast (corroborated by 10-m wind speed measurements made at Henties Bay, not shown), and moderate activation of the coastal dust sources. The most notable feature in the near-surface circulation pattern is the proximity of the semi-permanent Indian Ocean anticyclone with the eastern coast of southern Africa. This favors the penetration of a strong easterly flow over the interior of southern Africa, which in turn leads to the activation of dust sources over the continental plateau in northern Namibia (e.g., Etosha Pan) and in South Africa.

Improving the representation of the properties and radiative effects of biomass burning aerosols

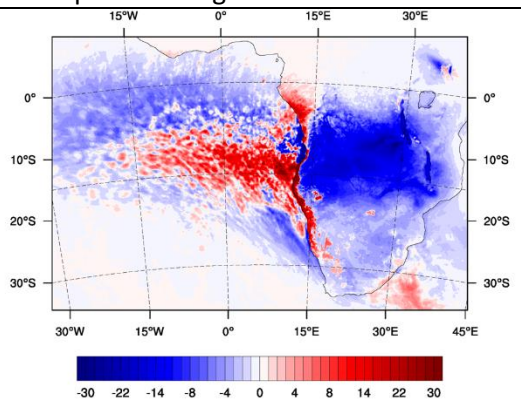
Biomass burning is the overwhelming feature of the campaign. Complex BBA layers were seen consistently over land and coast, and sampled remotely and in situ on all the research flights. Overall, 29 in situ vertical profiles of the BBA were obtained at different distances from sources.

The evaluation of the ALADIN-Climate model using AEROCLO-sA aircraft remote sensing data is ongoing. A first estimate of the monthly-mean (September 2017) DRE in the visible spectral range and for all-sky conditions exerted by BBA at the TOA is provided in **Figure 1**. There is a significant regional gradient in the sign of DRE, with a negative forcing over the continent (net cooling) and positive (net heating) over the Southeast Atlantic. Over the ocean, the calculated DRE is found to be in agreement with the literature over this region. In addition, positive values are also identified along the Namibian coast, certainly due to the presence of BBA and low Sc clouds. This is consistent with the positive values of the DRE measured by OSIRIS onboard the F20.

The marine boundary layer as a source of marine aerosols and cloud condensation nuclei

AEROCLO-sA also studies the chemical composition of the marine aerosols and its impact on radiation and cloud microphysics. To the best of our knowledge, there is no study in the area since the early paper by Andreae et al. (1995), linking the oxidation of the marine DMS to new sulfate aerosols in the accumulation mode and to new cloud condensation nuclei (CCN) for the Sc (the CLAW hypothesis).

Numerous new particle formation events were observed during the field campaign linked with marine biogenic emissions. An example is shown in **Figure 2**, when a strong increase in the particle number concentration was observed in the diameter ranges of 20 to 40 nm and 60 to 90 nm (less pronounced). This event is associated with an increase in the CH3SO2+ fragment (linked to MSA) and the total organic concentrations measured by the c-ToF-AMS in particles larger than 100 nm in diameter.



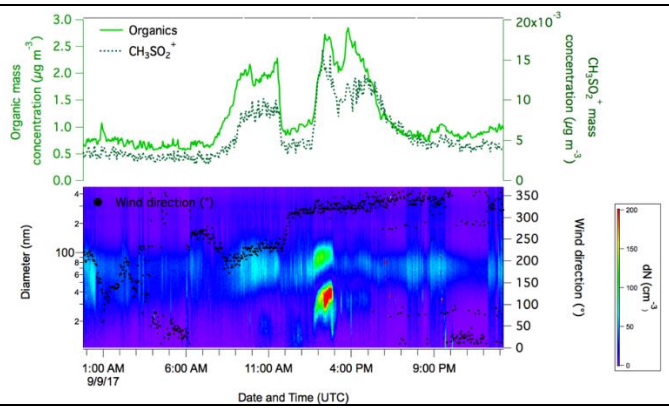


Figure 1. ALADIN-Climate derived monthly-mean (September 2017) shortwave direct radiative effect (W m-2) exerted by smoke particles at the top of the atmosphere (all-sky conditions).

Figure 2. Selected time series during the new particle formation event observed on 9 September 2017 at Henties Bay. The upper panel shows the time series of the organic mass concentrations (green solid line) and the CH3SO2+ fragment (dashed black line, representative of methanesulfonic acid) measured by the C-ToF-AMS. The lower panel shows the concurrent number size distribution measured by the SMPS. The z axis represents the total particle number concentration within the measured diameter (left axis) bin. Wind direction (black dots) is displayed on the right axis.

Future of the project

The data analysis is still ongoing, and the project participants are now focused on the analysis and exploitation of the results.

Publications related to the project

Publications: 5 (ACP/AMT inter-journal SI special issue: https://www.atmos-chem-phys.net/special_issue978.html)
Communications: > 30
PhD thesis: 1 defended, 1 soutenue, 1 in progress (defense planned in 2020)

Data are provided on the national repository BAOBAB maintained by AERIS/Sedoo: https://baobab.sedoo.fr/AEROCLO/.

Project web site: https://aeroclo.aeris-data.fr/