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Atmospheric Chemistry and Physics
Discussions
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Interactive comment on "Cloud and aerosol radiative effects as key players for anthropogenic changes in atmospheric dynamics over southernWest Africa" *by* Konrad Deetz et al.

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Answer to Referee #2 Konrad Deetz 19 June 2018

Dear Referee (Atmospheric Chemistry and Physics),

thank you for your report from 16 April 2018. We have accounted for the comments and suggestions in the revised manuscript version. Please find our replies (marked with #) to the individual comments in the following. Before the detailed replies to your comments we want to stress one important overarching point: This study mainly focuses on the sensitivity of atmospheric dynamics and cloud properties to aerosols and not on a

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detailed validation of the model system. Nevertheless, we have done a comprehensive evaluation of the model with the available observations of the DACCIWA measurement campaign. We show corresponding figures in our replies which appear at the end of this document. (The complete figure captions are given within the text because the figure caption space for the uploaded figures is not sufficient.)

Sincerely, Konrad Deetz on behalf of all coauthors

Referee comments:

(0) The authors focus on South West Africa, a region which is in a developing phase with an expected massive population growth and urbanisation. Therefore, an increase in anthropogenic aerosol concentration is expected. The authors assess the implication of aerosols and their possible changes on clouds and atmospheric dynamics. They present a process study with the regional model COSMO-ART. In particular, they discuss the impacts of aerosols on the propagation of the Atlantic Inflow frontal location and the Stratus to Cumulus Transition. In general, the paper is well written and the topic is of general interest. Deetz et al. conducted a detailed analysis of the performed simulations to understand the processes how aerosols influence prominent South West African dynamical features. Their main conclusions are based on three different simulations, the reference, the polluted and the clean case.

(1) I miss the discussion about the realistic representation of the current aerosol distribution in the model. Since an extensive measurement campaign took place during July 2016 it should be possible to evaluate the simulated distribution of aerosols against more measurements (here only a comparison with measures liquid cloud properties are shown).

The DACCIWA observations focus more on the eastern part of SWA and not on central Ivory Coast where we set the focus due to the pronounced evolution of the AI front. The supersites are located in Ghana, Benin and Nigeria. Remote sensing aerosol measurements are impeded by clouds and the supersites does not provide aerosol in-

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formation apart from sun photometer observations. The only source of aerosol observations are the research aircrafts. And these information does not suffice to get a clear picture of the current aerosol distribution at least over Ivory Coast. The assessment of the current aerosol distribution is further impeded by the overall uncertainty of the emission datasets. Therefore, we can provide and assess effects of relative changes in the aerosol amount but cannot clearly define the actual state. As mentioned in the text, the period 3-4 July was selected because of extensive NLLS at Save, standing this day out as a golden day for further research. Unfortunately, for 3-4 July no aircraft observations were available for Ivory Coast. This data shortcoming we bypassed by evaluating the model in the eastern part of the domain via aircraft observations in the Lome-Save area (Fig. 3 and 4). To meet your concerns, we added further evaluations of aerosol properties in the Lome-Save area by using observations from the ATR42 SAFIRE aircraft. However, this evaluation focuses on the Lome-Save area and not on Ivory Coast. In Section 2.2 (Observational data) we added the following text: "The aerosol aerosol number density is evaluated using observations of the ATR42 SAFIRE (Service des Avions Français 25 Instrumentés pour la Recherche en Environnement) for the 3 July 2016. Additionally, the comparison of the modeled net downward shortwave and longwave radiation as well as the sensible and latent heat flux with Savè supersite is presented in Figure 19 of Appendix B. COSMO-ART reasonably reproduces the fluxes with lower fluxes with increasing aerosol as expected." In Section 4 (Evaluation of modeled cloud and aerosol properties with aircraft observations) we added the following text: "The research aircraft ATR42 SAFIRE also obtained aerosol properties in the Lomé-Savè area on 3 July 2016 (8:32–13:16 UTC). The flight track and altitude is presented in Figure 5, showing similar flight patterns compared to the Twin Otter (Fig. 3). By assuming dry aerosol, Figure 6 shows the comparison between COSMO-ART and the Spectrometer Scanning Mobility Particle Sizer (SMPS) to evaluate the Aerosol Number Density in the size range 0.02–0.5 mu m. Figure 6 reveals that the modeled aerosol number density shows a similar temporal evolution compared to the observations but has a constant bias, overestimating the observed aerosol number density by a factor of about 2 (indicated by the blue dashed line). Therefore, in the subsequent study it has to be considered that the reference case shows already higher aerosol concentrations compared to the current state in SWA as quantified by the aircraft measurements. Overall, the evaluation reveals that COSMO-ART is capable to reproduce the aerosol situation on 3 July 2016 over SWA which is the basis for further sensitivity studies.

The figures related to this passage are attached in this review answer:

Fig.5 -> Review-Figure-1: Flight track of the ATR42 SAFIRE on 3 July 2016 between 08:32 UTC and 13:13 UTC in (a) horizontal and (b) vertical dimension (m AGL). For (a) the topography (m ASL) is added. The flight track in (a) and (b) is separated in hourly time steps for the subsequent collocation with hourly model data from COSMO-ART, highlighted by the pink (08:32âĂŤ09:30 UTC), blue (09:30–10:30 UTC), gray (10:30–11:30 UTC), red (11:30–12:30 UTC) and black color (12:30–13:13 UTC). Furthermore, the arrows in (a) indicate the flight direction with the takeoff at Lomé, the flight to Savè and the return to Lomé airport. Shortly. Note the meridional compression of the map in (a).

Fig.6 -> Review-Figure-2: Aerosol number density (AND, cm-3) in the size interval 0.02 to 0.5 mu m as measured by the Spectrometer Scanning Mobility Particle Sizer (SMPS) on board the ATR42 (black) and modeled with COSMO-ART (solid blue, reference case). The horizontal dashed blue line shows the COSMO-ART AND divided by 2. The vertical blue dashed lines indicate the COSMO-ART model output hours, which are compared to the observations.

Fig. 19 (Appendix B) -> Review-Figure-3: Comparison between Savè supersite observations (grey) and COSMO-ART reference (black), clean (blue) and polluted (red) of (a) net downward shortwave radiation (W m-2), (b) net downward longwave radiation (W m-2), sensible heat flux (W m-2) and latent heat flux (W m-2). The horizontal lines in (a) denote clouds over Savè in the observations and COSMO-ART.

(2) Since the direct aerosol effect depends mainly on the radiative properties of the aerosols it is of interest to show the aerosol composition in the region during the 2nd -3rd of July. And again, it would be helpful if the simulated aerosol radiative properties or the simulated radiative fluxes could be evaluated against observations. To understand the full meaning of polluted and clean case it is necessary to know about the aerosol content and composition in the reference case. Without that knowledge, a fractional increase or decrease is not meaningful. Do the authors change the aerosol concentration of the different types equally? This should be clarified in the revised manuscript.

Refers to (1). We see your point and to consider your remark we have added a comparison of net downward shortwave radiation, net downward longwave radiation, sensible heat flux and latent heat flux with respect to the supersite Save (Appendix B (Fig. 19) -> Review-Figure-3). Yes, all aerosol types are changed equally by the factor. We clarified the following sentence to make this more precise: " All aerosol modes and thus all aerosol types are changed uniformly by the factors."

(3) Another clarification is needed in terms of the general model setup. How are aerosols treated at the outer boundaries? Are they prescribed by output of global model simulations? The meteorological state is initialized every day at 0 UTC. Are the wind and temperature fields pulled back to the ICON forecast every day at 0 UTC? If yes, how is it possible to analyse the impact of the direct and indirect aerosol effect on the dynamics? I also wonder about the choice of the inner model domain (figure 1, indicated by red box). The western as well as the eastern and part of the northern boundary are located in a mountainous region. Could that cause problems due to resolution effects?

As denoted in Section 2.1 and Table 2, the COSMO-ART aerosol-interaction simulations (2.5 km grid mesh size) are realized via a nesting in a COSMO-ART realization with 5 km grid mesh size. For this simulation the aerosol boundary is taken from the global model simulation MOZART (see Tab. 2). Therefore, the aerosol coming from the

boundary into the domain of the 2.5 km domain is a combination of MOZART aerosol and aerosol that is emitted within the 5 km domain. Just for clarification: The aerosol scaling is just done within the aerosol activation and the radiative transfer calculation and not in the entire aerosol dynamics. Therefore it does not matter whether the aerosol is emitted locally in the 2.5 km domain or advected from outside. No, COSMO-ART does not include a two-way nesting. Therefore there is no feedback from the 2.5 km domain to the 5 km domain. This feature will be available in the new model system ICON-ART. Also without two-way nesting, the 2.5 km domain developes its on dynamics. The predominant wind direction is southwest via the monsoon flow. So the wind is coming from the southeast Atlantic. The SST is fixed in the 2,5 km realization as well as in the coarser domain (5 km). The aerosol effect on AI and SCT is therefore only and directly evolving in the 2.5 km realization because the southern AI "boundary condition" (incoming monsoon flow) and the northern AI "boundary condition" (saharan heat low) are unaffected. We are just focusing on the changes in between and this is the 2.5 km domain. The mountains heights in the domain are below 1 km, in most cases below 500 m. With the predominant wind direction southwest we have not faced any problems.

(4) Page 1 line 22: The population is expected to growth.

Please specify. Do you propose to replace the two sentences: "More than half of the global population growth between now and 2050 will occur in Africa. For Nigeria, which has a population of 182 million in 2015 (rank 7), a population increase to 399 million (rank 3) is expected for 2050 (UNO, 2015)." by your sentence? To highlight that especially SWA will be affected by a significant population increase which will be directly linked to a substantial enhancement of air pollution, we would like to include the population projections from UNO (2015).

(5) Page 2 line 19: Please replace “react” with “are”.

We agree on that and have changed the manuscript and the figures accordingly.

(6) Page 10 line 25: Please rewrite that sentence

Please specify. We are interested in the results of LES aerosol-atmosphere interaction simulations in the framework of DACCIWA since the aerosol effects on spatial scales of 100 m might be different to the COSMO-ART results on spatial scales of 2500 m. With this sentence we will express our interest and simultaneously provide an outlook and link to other research that is done in DACCIWA and which is related to our field of research.

(7) Table 1: I recommend to rename the simulations (the names are unnecessary long), ADE and AIE are scaled by the same factor, the simulations could be named as AE0.1, AE0.25... (AE = aerosol effect)

We agree on that and have changed the table as well as figure captions and legends accordingly.

(8) General remark: Maybe it is not necessary to present results of all 6 simulations. It underlines somehow the results but for the discussion it seems not to be important to present them. I recommend that the authors rethink the demand to present the AE0.1, AE0.5, AE2 simulations in the paper.

As you have remarked, the purpose of these additional realizations is to underline the results and to make the conclusions based on the realizations more robust. Just from three realizations it can hardly be concluded about the relationship of aerosol change and atmospheric response, e.g. whether it is linear or nonlinear. Your remark is in contrast to the remarks provided by referee #3, asking for longer simulation periods. These realizations are very expensive but we did these three additional runs and we gained added value from them. Furthermore, we are aware of the problem that showing results of all realizations might confuse the reader. Therefore only two selected figures present all realizations (Fig. 9 and 12). All other figures refer to the key realizations of clean, reference and polluted.

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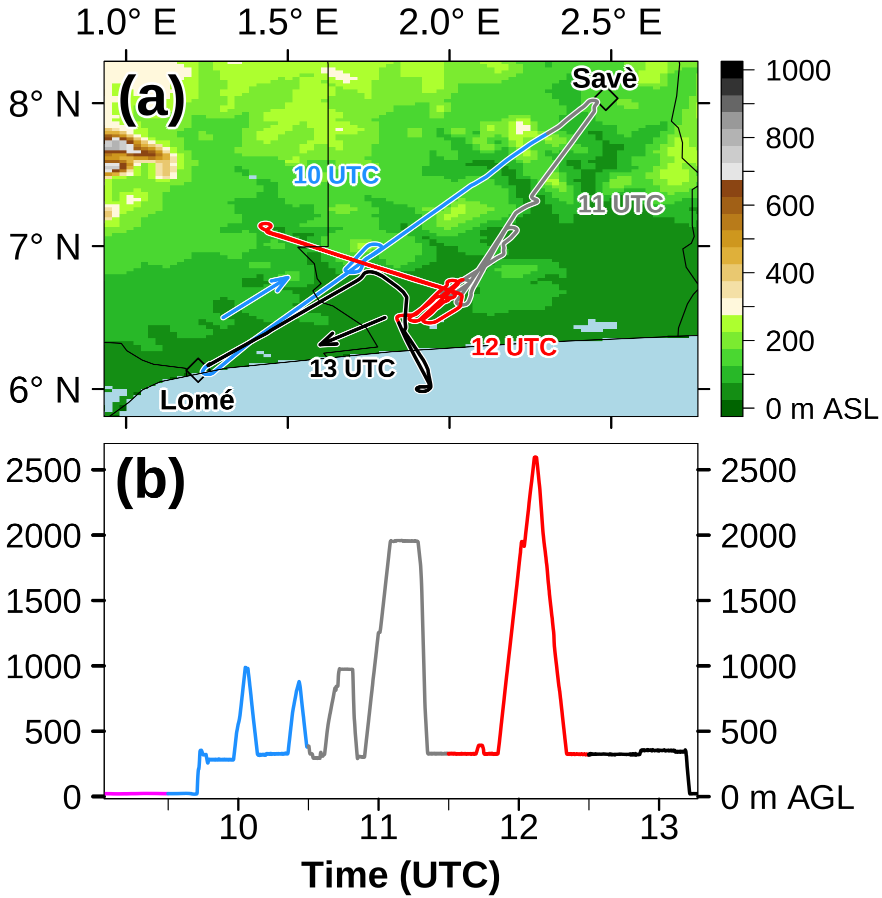

Fig. 1. Review-Figure-1: Flight track of the ATR42 SAFIRE on 3 July 2016 between 08:32 UTC and 13:13 UTC in (a) horizontal and (b) vertical dimension (m AGL). For (a) the topography (m ASL) is added. The flig

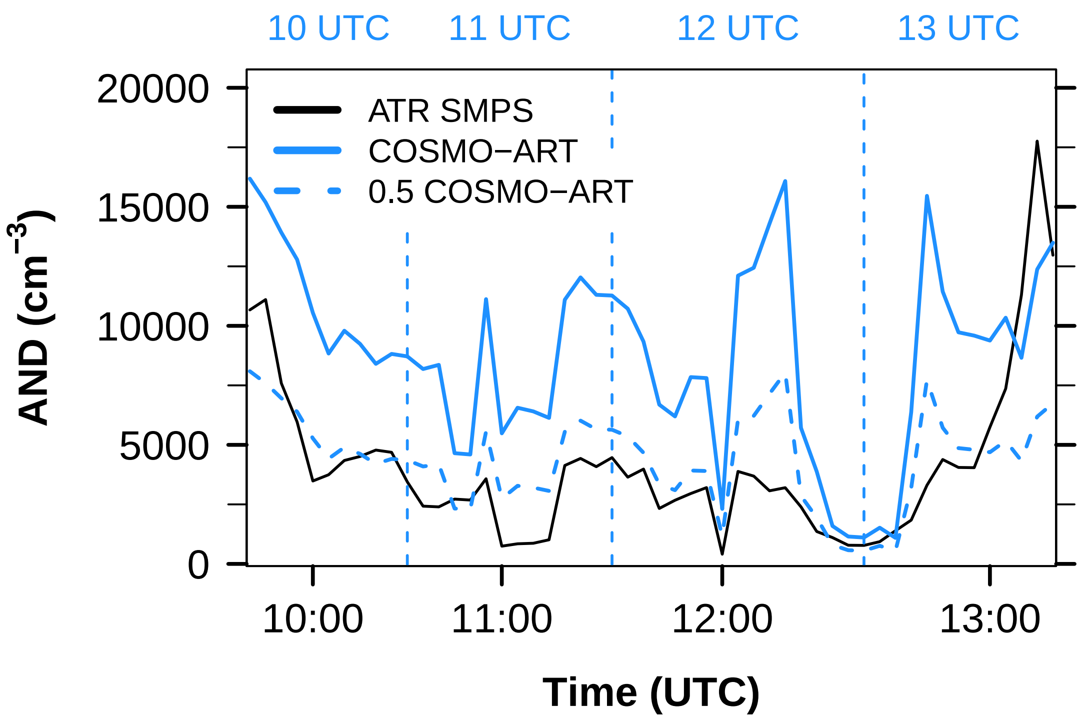

Fig. 2. Review-Figure-2: Aerosol number density (AND, cm-3) in the size interval 0.02 to 0.5 mu m as measured by the Spectrometer Scanning Mobility Particle Sizer (SMPS) on board the ATR42 (black) and modeled

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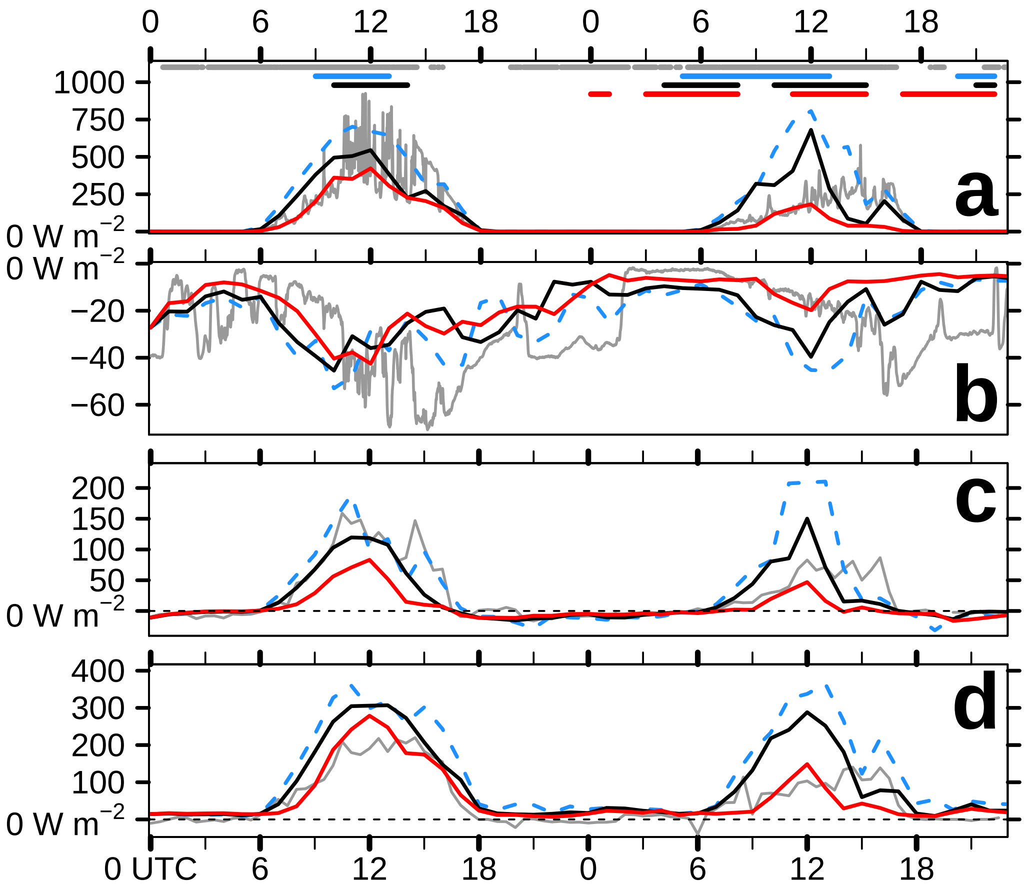

Fig. 3. Review-Figure-3: Comparison between Savè supersite observations (grey) and COSMO-ART reference (black), clean (blue) and polluted (red) of (a) net downward shortwave radiation (W m-2), (b) net downwar

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