

Thank you for your thoughtful comments. Including your suggested revisions has improved the quality of the manuscript. Our responses are indicated below in blue text.

Reviewer 2

Interactive comment on

“Understanding the seasonality and climatology of aerosols in Africa through evaluation of CCAM aerosol simulations against AERONET measurements”

Anonymous Referee #2

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General comments: In this study the regional and seasonal representation of aerosols in the global CCAM model is evaluated for the African domain, mainly through comparison of modeled and ground based retrievals of AOD from AERONET across Africa and parts of the Middle East. I find the paper scientifically interesting and mostly well written, and the presentation of model and observationally based results should be useful for others planning to do similar model evaluation studies. Parts of the model description is vague, however, which makes it difficult for the reader to find necessary information about the aerosol treatment without actually reading many of the underlying papers for the model. The treatment of sea salt, in particular, is poorly described, and the potential impact of this component (on coastal and island sites) on the results has mainly been omitted, except (for some sites) in Figure 7.

We thank the reviewer for their input. We have expanded the description of the model and its treatment of sea salt (specific additions are detailed below). In the model, sea salt is not transported, and thus over land there is little influence on the simulated aerosol properties. However, observations at some sites could be impacted by sea salt and the manuscript has been updated to acknowledge this (Section 3). Our responses to the points below are in blue.

Specific comments and technical corrections: (For simplicity, the arrow symbol "->" is used to suggest a change from text version A -> B)

Page 1, line 18: “ground-based observations” should be changed to “ground-based remote retrievals” or something along that line.

This has been changed as suggested to “ground-based remote retrievals” (now page 1, line 17).

Page 3, line 8: “may also feedback on climate” -> “may also feed back on climate” (feedback is a noun)

This has been updated to “may also have a feedback on climate” (now page 2, line 33).

Page 3, line 15: “first AeroCom” -> “first phase of AeroCom”

This has been updated to “first phase of AeroCom” (now page 3, line 7).

Page 3, line 30 and throughout Sect. 2.1: What does non-prognostic / diagnostic sea salt aerosols mean? Do you prescribe the emissions or the concentrations? A reference for this treatment should be added, e.g. after the additional (but not sufficient) info on page 5, line 3.

Additional clarification is provided in Section 2.1, which was updated to include the following (now page 4, lines 10-15): “Sea salt concentrations above the ocean surface are diagnosed (i.e. prescribed) at each time step as a function of the 10-m wind speed. It is assumed that sea salt aerosols are well-mixed in the marine boundary layer (MBL), and that the concentration is zero above the MBL. There are two size bins of sea salt aerosols (mode radii of 0.035 μm and 0.35 μm). As the sea salt concentrations are prescribed at each time step, they are not actively emitted, transported or removed, and thus no sea salt is transported over land (Rotstayn et al., 2007).”

Page 4, line 12; “spun-up” -> “spun up”

This has been corrected.

Page 4, line 19: Is also the semi-direct effect taken into account?

This has been clarified, the following text has been added (page 4, lines 20-22): “The semi-direct effect is also included in CCAM; however, as the vertical temperatures upwards of 900 hPa are nudged towards the ERA-Interim reanalysis data every six hours in accordance with CORDEX, the semi-direct impact on the simulation presented here is diminished.”

Page 4, line 31: The “-“ in “-2” in the exponent (m^{*-2}) is misplaced.

Page 5, line 13: “vary every 5 years” “they vary every 5 years”

Page 5, line 14: “anthropogenic” -> “non-biomass burning anthropogenic”

Page 5, line 17: “found a chemical” -> “found that a chemical”

The above four corrections have been made in the text as suggested.

Page 5, line 17: Unless sea salt concentrations are prescribed, why are these large particles not also affected by gravitational settling?

The sea salt concentrations are prescribed. Clarification was added as described in the response to an earlier comment in Section 2.1.

Page 6, line 2: “AOD” -> “AOD at 550 nm” Page 6, line 5: “34 sites Africa” -> “34 sites in Africa”

Page 6, line 18: “bolded site names” -> “site names in bold font”

The above two corrections and suggestions have been adopted in the text as written. We also similarly revised the caption of Tables 1 and 2.

Page 6, lines 24-25: I would suggest to rewrite “where if more than 30% of the daily values were missing, a monthly average could not be calculated” to “. I.e., if more than 30% of the daily values were missing, a monthly average was not calculated”.

This has been corrected to: "(i.e., if more than 30% of the daily values were missing, a monthly average was not calculated for that time period)" (now page 6, lines 17-18).

Page 6. line 27: "This is to ensure the" -> "This is to ensure that the"

This has been edited as suggested above.

Page 6, lines 30 and 32: The sentence containing "and were aligned as possible" does not make sense, and the meaning of the following sentence is not clear to me either: Should it read "assessed for the averaging period in question" or "assessed for the respective averaging period"?

This sentence has been removed and the entire paragraph clarified following your and the other reviewers' suggestions, as follows (page 6, lines 23-28): " Daily average AOD from AERONET is calculated for a minimum of 3 time points from sun photometer measurements, which can only be made during daytime, while modeled AOD is reported at 6-hourly resolution. Therefore, only CCAM AOD between 06:00 and 18:00 UTC was averaged for monthly and multi-year means (similar to other AERONET-model comparison studies; (e.g., Tegen et al., 2013). Model monthly means were, however, insensitive to the choice of daylight cut-off (see Fig. 2), which gives confidence that the instantaneous 6-hourly values from CCAM can represent the range of daytime hours sampled by AERONET."

Page 7, lines 5-9: Unclear description of the 2 different calculations: "2) all model years" does not preclude 1). Should it be "2) all months of all model years"?

This has been updated to "all months of all model years".

Page 7: Eqs. 4 and 5 are well known and can be skipped, or replaced with an equation for r . Line 17 also repeats the info on line 15.

The two equations have been deleted from the main text and moved to a footnote of what is now Table 4 (formerly, Table 3).

Page 7, line 25: The Angstrom parameter does not equal 2 for all sub-micron particles. It is more correct to write "very fine particles" or "predominantly fine particles", or something along that line.

This sentence has been updated following this suggestion and that of the other reviewer (now page 7, lines 16-18): "The Ångström exponent is an empirical proxy related to the relative contribution to optical thickness from coarse vs. fine aerosols, with values varying between approximately 0 for pure coarse dust particles to 2 for predominantly fine particles (Leon et al., 2009; Hamonou et al., 1999)."

Page 7, line 27 (and throughout the manuscript): Small Angstrom parameter values can also be due to aerosols dominated by coarse sea salt aerosols. Perhaps this is not the case for this particular model and the sites studied here, but this should somehow be shown, at least for the coastal and island sites.

This section is referring to AERONET observations, and thus this has been clarified to, "...indicative of aerosols dominated by coarse particles (e.g., mineral dust or coarse sea salt particles)...". (Page 7, line 24). We update the caption of Figure 4 to be consistent.

We add the following to section 3.1 (now page 8, lines 8-11): “While low values of α_{ext} could represent other coarse particles besides dust like sea salt, previous work has indicated sea salt is a minor contributor to aerosols at island sites to the north of Africa, including Izaña (Rodríguez et al., 2011; Putaud et al., 2000; Querol et al., 2009). The correspondence of the seasonality in α_{ext} and AOD with known dust events suggests mineral dust is the primary contributor to extinction from coarse particles.”

See previous comments for discussion of modeled sea salt.

Page 9, line 4: As above.

We change “coarse dust aerosol” to “coarse aerosol particles, most likely dust” and then add the following discussion (page, lines 4-9): “. Previous work found that minimum values of α_{ext} are related to dust storms at Ouagadougou, Dakar, and Agoufou, and clearly linked to dust at Ilorin and Banizoumbou based on air mass back trajectories and observed seasonality (Ogunjobi et al., 2008). While Dakar is frequently influenced by air transported over the Atlantic Ocean (Ogunjobi et al., 2008), analysis off the coast of Dakar at Cape Verde found the AOD and aerosol mass loading were dominated by desert dust, with sea salt minimally contributing to AOD (6%) in part due to its small extinction (Chiapello et al., 1999) which would also imply a minor influence on α_{ext} .”

Page 10, line 31: “fraction wet deposition” -> “wet deposition fraction”

This has been updated to “wet deposition fraction”

Pages 10-11: Whether this aerosol is prescribed or not, sea salt influences the total AOD and should be discussed and included in Table 2, and also in Fig.5 if prescribed concentrations have not been used.

The description of prescribed sea salt has been updated (Section 2.1, now page 4, lines 10-15) as described in a previous response, which may address this comment. Of the information presented in Table 2 and Figure 5, only the burden of sea salt could be computed, but this would not be very meaningful given concentrations are prescribed only within the mean boundary layer and set to zero everywhere else. Thus sea salt has not been included in Table 2 and Figure 5.

The sea salt AOD values for coastal/island sites in Fig. 7 look small compared to many of the available AerCom models (http://aerocom.met.no/cgi-bin/aerocom/surfobs_annualrs.pl).

We add a sentence to page 15, lines 16 to 18: “A small impact of simulated sea salt can be seen at the Santa Cruz Tenerife site (Fig. 7) (mean AOD of 0.04). The sea salt contribution to simulated monthly AOD at 550nm from AeroCom Phase III-CTRL2015 (AeroCom Phase II Interface, 2017) ranges from negligible to greater than 0.1 at Santa Cruz Tenerife.”

Page 11, line 1: “BC are higher” -> “BC burden and lifetime are higher”.

This has been updated to “BC burden and lifetime are higher”.

Page 11, line 23: “areas are ± 1 standard deviation” -> “areas are within ± 1 standard deviation” (and the same for the following line).

“within” has been added to both lines.

Page 12, line 1: “spurious summertime peaks” -> “missing summertime peaks”

This has been updated to “missing summertime peaks”.

Page 12, lines 11-12: Since there is a severe overestimate in modeled AOD for some sites and some months, the sentence starting with “The model generally represents the magnitude of AOD550nm” should be rephrased.

We revise the sentence (now page 12, lines 12-13): “ In comparison to the other regions, the model better represents the magnitude of AOD at the southern African sites (except for Reunion Island) with a smaller normalized mean bias and mean absolute error (see Fig. 6 and Table 4).”

Page 13, line 8: “The AOD550” -> “The observed AOD550” (?)

This has been updated to “The observed AOD”.

Page 13, line 15: “at the source” -> “at the biomass burning source”

This has been updated to “at the biomass burning source”.

Page 14, line 1: Is the ERA wind bias in winter consistent with the magnitude of the AOD bias? Could you make a simple estimate of this?

We are currently exploring the reasons which may contribute to the AOD bias; however, this is a complex problem that falls beyond the scope of this paper.

Page 14, line 16: There is a “beta” too much in “0.27 m s⁻¹β”

This was a typo and has been removed – thank you for catching it.

Page 14, line 31 and Page 16, lines 17-20: Can you show that the precipitation in the model is underestimated compared to observations (therefore explaining some of the positive dust emission bias)?

The model does not exhibit a significant dry bias in the Sahel and Sahara. This analysis with model set-up from this manuscript is not published; published results of a previous version of model that highlight the wet bias of the model in representing the average daily summer rainfall totals over most of Southern and Tropical Africa (Engelbrecht et al., 2011), Therefore, we suspect that the overestimation of dust is the result of an overestimation of near-surface wind speeds and/or source regions. However, this analysis is ongoing.

Reference: Engelbrecht FA et al., 2011, Multi-scale climate modelling over South Africa using a variable-resolution global model, Water SA, 37(5).

Page 16, line 31: “is slightly underestimated” -> “is underestimated”

This has been updated to “is underestimated”.

Page 17, line 20: "CCAM is able to capture the general seasonal cycle of the emissions of dust, and the transport of all aerosol types". This has not been shown, and such a statement should be limited to the aerosol components covered by the study.

This has been updated to "...transport of dust, carbonaceous and sulfate aerosol types."

Table 1: The second sentence in the table caption is grammatically incomplete.

The previous Table 1 has been split up to Table 1 and Table 2. The heading has been changed and is now complete. "Table 1: AERONET site information (site names in bold font indicate those sites used in model comparison). The average (± 1 standard deviation) and median (25th and 75th percentile) values for AOD₅₅₀ and $\alpha_{440-870}$ per site are shown."

Table 2: The gray shading should be explained in the table caption (as in the text).

The gray shading is to distinguish the different regions studied. A column has been added to identify these regions (as in Table 1). Due to the addition of a new table, this is now Table 4.

Figure 1, caption: "used in model comparison" -> "used in the model comparison".

This has been updated to "used in the model comparison".

Figures 2-4, caption: Explain the whiskers.

To the caption of Figure 2, we add: "Whiskers are ± 1 standard deviation across the 6-hourly model values within each time range." "Whiskers are ± 1 standard deviation" is added to the captions of Figures 3 and 4.