

Response to Reviewer 1

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Thank you for your review and comments on our manuscript. We have revised the manuscript to improve clarity and have provided additional results to better illustrate the effects of revisions to the aerosol scheme, in particular the importance of boundary layer nucleation. Please see below our responses to each comment.

General comments

1. The new model configuration presented here is, by nature, complex. I think that it would be useful if the main components (and important updates like the use of CASIM) were presented in a Table or perhaps a schematic to help the reader understand the whole system.

We have added a table (Table 1) to Section 2.1 that provides a summary of the main model components including domains, resolution, initial and boundary conditions, schemes, emission sources and any revisions:

Table 1. Summary of the ACCESS-EMS-GBR configuration, key components and revisions.

Model	Atmosphere (UM)	Ocean (EMS)
Domain	NE Aus (RAL3.2, Bush et al., 2025)	GBR4 (Baird et al., 2020)
Extent	6 - 31°S, 141 - 163°E	7 – 28.5°S, 142 - 157°E
Horizontal resolution	0.04° (~4 km)	~4 km
Grid size (x, y)	550, 625	180, 600
Vertical levels	90 (surface – 80 km)	48 (surface – 4 km)
Initial conditions	Global UM (N216)	eReefs GBR4 hindcast
Boundary conditions	Atmosphere: Global UM	Atmosphere: NE Aus
	Ocean: Merged BRAN2020-GBR4 SST	Ocean: BRAN2020 (Chamberlain et al., 2021)
	Land: JULES (Best et al., 2011; Clark et al., 2011)	Land: Observed riverine flows (Ellis, 2018; McCloskey et al., 2021; QLD Government)
Key components	Aerosol: GLOMAP-mode (Mann et al., 2010, 2012), with organic-mediated BLN enabled, and revised to include Aitken mode sea salt, a reduced SOA yield and modified activation scheme (Ghosh et al., 2025)	Hydrodynamics: SHOC
	Cloud microphysics: CASIM (Field et al., 2023; Shipway & Hill, 2012), coupled to GLOMAP-mode	Biogeochemistry: SHOC transport model, used to drive the ecology, optical, sediment, carbon chemistry and coral bleaching processes.
	Large-scale cloud: PC2 (Wilson et al., 2008)	
	Radiation: SOCRATES (Edwards & Slingo, 1996)	
Emissions	Anthropogenic: EDGAR 2022 time-slice (Crippa et al., 2024)	N/A

Monoterpenes: MEGAN-MACC (Sindelarova et al., 2014)

Biomass burning: CMIP6 (van Marle et al., 2017)

Sea salt: sea-air flux calculated using the parameterisation of Gong (2003).

PMOC: sea-air flux calculated from the GlobColor chl-a climatology (Ford et al., 2012), with revised emission mode mean dry diameter (40 nm).

DMS: sea-air flux calculated from a seawater climatology (Hulswar et al., 2022).

2. Could the authors please clarify a few points regarding the revised aerosol parameterisations and their impacts on model behaviour:

- i. Figure 4 and L473-484: Figure 4 shows that the revised aerosol parameterizations improve the model's simulation of Aitken mode aerosol (which is positive) but worsen the simulation of accumulation mode aerosol. If I understand correctly, the authors suggest that too many particles grow into the accumulation mode rather than 'growing within' the Aitken mode. Can the authors suggest how this could be addressed in GLOMAP-mode?

Yes, we suggest that biases in the size distribution reflect (i) too much growth of the Aitken to the accumulation mode, (ii) the need to tune the emission size assumptions for the GBR region and/or (iii) missing marine pathways for new particle formation.

We explain this hypothesis in more detail in the Discussion:

Edited Discussion para. 5: *"While enabling BLN... improved the model agreement with observed N10, biases persist in the size distribution, with too few Aitken and too many accumulation mode aerosol leading to an overestimate of CCN. The Aitken and accumulation mode number concentrations increased without a shift in the mode median diameters, suggesting that new particle formation and subsequent growth dominated over growth of the accumulation mode, in which a shift in the modal diameters would have been expected. The biases in modal number concentration indicate that additional tuning for the GBR region is needed, where high concentrations of condensable organics may lead to too much growth of new Aitken mode particles to the accumulation mode, rather than growth within the Aitken mode."*

See also Discussion para. 6-9, where we note other ways that this could be investigated and possibly improved e.g.:

"He et al. (2026)... suggest that the Aitken mode bias is due to missing new particle formation pathways (such as marine boundary layer nucleation), involving species such as marine organic vapours... the organic concentrations that drive the organic-mediated BLN rate in GLOMAP-mode are entirely derived from terrestrial monoterpenes. However, the coral reef is also a source of organic vapours (Deschaseaux et al., 2025; Okuljar et al., 2026; Swan et al., 2017) that are not currently represented in the model."

and:

“Another possible source of bias in the Aitken and accumulation mode number concentrations is the terrestrial emission size assumptions.... The emission size assumptions in the model could reasonably be adjusted so that a larger portion contributes to the Aitken mode.”

- ii. *Have the authors tested the impact of the BLN scheme and the Aitken mode sea salt emissions independently to understand their individual impacts on the Aitken and accumulation mode aerosol (and CCN)? From the results shown, the benefit of the BLN scheme is not immediately clear to me because it appears to (1) have little impact on sulphate and organic aerosol concentrations (Figure 6) and (2) introduce a model bias by adding aerosol at particle diameters < ~20 nm that are not observed (Figure 4). While the BLN scheme improves the model’s process realism, which is an important goal, is there a scientific benefit to using the BLN in this region?*

The model initially simulated the observed aerosol masses and CCN number concentration quite well, indicating that the N10 bias was due to missing sources of Aitken mode aerosol. We therefore targeted our revisions to increase aerosol number rather than mass.

We tested a number of revisions but it wasn’t until BLN was enabled with monoterpene emissions from terrestrial vegetation that the modelled N10 and aerosol size distribution improved substantially. The size distribution improved slightly again when we revised the SOA yield and PMOC emission mean diameter.

We have added Appendix B ‘Effect of revisions to the aerosol scheme on modelled aerosol biases’, with additional plots and discussion that show the effect of:

- adding Aitken mode sea salt emissions + revised anthropogenic emissions.
- adding Aitken mode sea salt emissions + revised anthropogenic emissions + BLN + terrestrial monoterpene emissions (highlighting the importance of BLN).
- the above + additional revisions to the PMOC mean diameter and scaled SOA yield (presented as the revised configuration in the main text).

However, we note in that while BLN appears to have correctly increased aerosol number concentration, the BLN scheme should perhaps involve marine organics and/or the SOA yield could be further refined to better represent nucleation and Aitken mode aerosol over the reef.

3. *The new model system, as described, is specific to the North-Eastern Australia and the Great Barrier Reef region, for example bespoke emissions data sets are used. While I think this necessary to benefit from a regional scale Earth system model, could the authors add a comment on how their approach could be deployed for other locations with appropriate modifications?*

Both the UM RNS and the EMS hydrodynamic and biogeochemical models are relocatable and can be configured to run over other domains. This is a good point to highlight, which we’ve added to the Discussion:

“The regional ACCESS and EMS source codes are relocatable and can be configured to run over any domain of interest, provided that appropriate boundary conditions, forcings, emissions and other inputs (such as riverine flows) are available. In ACCESS-EMS-GBR, boundary conditions for the atmosphere (global UM), ocean (BRAN2020) and land (JULES), as well as emissions

(including the EDGAR emissions inventory) are all derived from global data sources that could be adapted to other regions.”

Technical comments

4. Section 2.1.2, L182: “Here, the SOA yield is further scaled to a factor of 0.1 (0.013) in both...”

Could the authors please clarify what the SOA is further scaled to in their configuration? If it’s 0.013, I suggest modifying the sentence to: “Here, the SOA yield is scaled further by an additional factor of 0.1 (to 0.013) in both...”

We clarify that the SOA yield is reduced to 0.013 in Sect. 2.1.2:

“the SOA yield is further scaled by an additional factor of 0.1 (to 0.013)...”

5. Section 2.1.3, L201: For clarity I suggest modifying “GLOMAP-mode and the cloud schemes are...” to “Within ACCESS-EMS-GBR GLOMAP-mode and the cloud schemes are...”

The revised manuscript now reads: “In ACCESS-EMS-GBR, GLOMAP-mode and the cloud schemes are...”.

6. Section 4, Figure 3: For me, there is little contrast between the line colours used for the model results making the figure less easy to interpret. Please consider using a brighter colour for the control simulation. See also Figures 4, 6 and 7.

We have revised Section 4 to present only the results of the final revised aerosol configuration, with comparisons to the control aerosol setup moved to Appendix B (as suggested by Reviewer #2). The figures in Appendix B use colour schemes that allow clearer distinction between the model results.

7. Section 4, Figure 5: Could the authors please clarify if the data presented in Figure 5 is from the control model simulation?

Section 4 has been revised to present only the model results for the revised aerosol configuration, including in Figure 5.

8. Section 4, Figure 8: Could the author’s please increase the font sizes, particularly for the y-axis labels as these are hard to read. Please also consider the font sizes for Figure 9.

We have revised Figure 8 and 9 to use a larger font size, consistent with the other figures.

9. Discussion, L636: (see UKCA Ticket #106). I Don’t think that this reference alone is suitable.

We have provided further details here: “See UM Ticket #6174 and related UKCA Ticket #106 which revise the aerosol hygroscopicity values based on the kappa-kohler framework of Petters and Kreidenweis, 2007”.