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Interactive comment on "How does the UKESM1 climate model produce its cloud-aerosol forcing in the North Atlantic?" *by* Daniel P. Grosvenor and Kenneth S. Carslaw

Anonymous Referee #2

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This paper examined the aerosol-cloud interaction performance of UK Earth System Model over the North Atlantic (NA) region. Different components of surface ERF were separated, and contributions from changes of cloud fraction, in-cloud liquid water path and droplet number concentration were evaluated. It was found the dominant forcing component of northern and southern NA region are different, which is associated with climatological cloud amount of the region. A creation of trade cumulus clouds due to the aerosols was found over the southern NA region, where the climatological cloud fraction is smaller. The paper provided a comprehensive analysis on the main topic and the structure is also well organized. Following questions should be replied before it could be published.

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Major comments

In this study, the aerosol radiative forcing is estimated with one-year model simulation. However, the surface ACI forcing is quite noisy over some regions, even a smooth is applied. The estimated ACI forcing could be from model internal variability other than aerosol cloud interaction. With the large internal noise, it is difficult to tell whether further findings of the manuscript are correct. Ensemble simulations could be a useful and simple way to estimate the uncertainty from the internal noise (Liu et al. 2018). Only the point where the estimated ACI forcing is statistically significant could be analyzed.

The authors made detailed evaluation of the model simulated cloud properties against the observation. However, the simulated aerosol properties were barely mentioned in the manuscript. Please compare PD AOD with the observation. The changes in AOD from PI to PD should be also shown. More details could be found in the comments below.

Other comments

Line 100: Does the UKESM1 has the similar performance on global scale? Please make a comparison with the results of Mülmenstädt et al. 2019.

Line 115: Is it done in any previous studies? Please provide references here.

Line 185: Similar methods were applied in previous studies (e.g., Ghan et al. 2012; Jiang et al. 2016), which should be mentioned here.

Line 197: The surface forcing could be decomposed. How about the TOA forcing?

Line 200: There are two many figures for this part. Please consider move some figures (e.g. middle and high cloud fraction) to the supplement.

Line 400: Please show PD AOD values and make a comparison with the observation.

Line 400: Please show changes in AOD from PI to PD. The contribution from different aerosol types (sulfate, BC, dust and POM) should be also shown.

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Line 415: Please show the cloud condensation nuclei (CCN) change together with other cloud properties.

Line 465: The surface ACI forcing due to LWP and fc is very noisy over the southern NA region. It implies the change could be from model internal variability other than aerosol-cloud-interaction.

Line 490: Are the different states classified with the annual mean value or instantaneous value? Are the estimated forcing values statically significantïij§

References

Liu, Y., Zhang, K., Qian, Y., Wang, Y., Zou, Y., Song, Y., Wan, H., Liu, X., and Yang, X.-Q.: Investigation of short-term effective radiative forcing of fire aerosols over North America using nudged hindcast ensembles, Atmos. Chem. Phys., 18, 31–47, https://doi.org/10.5194/acp-18-31-2018, 2018.

Ghan, S. J.: Technical Note: Estimating aerosol effects on cloud radiative forcing, Atmos. Chem. Phys., 13, 9971–9974, https://doi.org/10.5194/acp-13-9971-2013, 2013.

Jiang, Y., Z. Lu, X. Liu, Y. Qian, K. Zhang, Y. Wang, and X. Q. Yang (2016), Impacts of global open-fire aerosols on direct radiative, cloud and surface-albedo effects simulated with CAM5, Atmos. Chem. Phys., 16(23), 14805-14824, doi:10.5194/acp-16-14805-2016.

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