The reviewer's comments are presented in black, while our answers are in blue. The references used to support our responses to the reviewer's comments are presented at the end of the text.

Response to Reviewer 1

General comments:

Review on paper titled "The impact of assimilating Aeolus wind data on regional Aeolian dust model simulations using WRF-Chem" by Pantelis Kiriakidis et al.

Paper compares output from two WRF-Chem model runs: with and without assimilated wind fields. In particular, authors use extensive set of ground and satellite observations to estimate model skill to simulate dust events. The article is well written and easy to follow. Authors conclude that they got significant improvements in dust simulation over the EMME region using assimilated wind data, while comparisons with the whole simulated domain diffused the improvements.

My main concern is the ability of WRF-Chem to correctly simulate the dust cycle in this study. Fig. 2 demonstrates it, i.e there is a better agreement in PM10 between runs rather than between runs and observations. See also Fig. A2, where good agreement between models is shown. Model also overpredicts PM10 and not capable to capture high pollution events in most of the cases. Thus, I think, authors pay attention to the 2nd order effect, while 1st order effect (dust simulation itself) is not satisfactory resolved. Therefore, I recommend revision before accepting for publication.

Reply -> We thank the referee for the constructive comments. Past dust simulation studies face various uncertainty sources in accurately depicting dust mobilisation and transport (Evan et al.,2014; Klose et al., 2014; Shao et al., 2011). This is also highlighted in the reference provided by the reviewer [2], where a source function was able to capture various point-scale dust sources, however, being applicable solely to high-resolution studies. Similarly, Nabavi (2017) tested a source function which was able to improve the predictive ability to the model, but signified deficiencies in the transport and deposition mechanisms used. Also stated in reference [2] and within our paper, past studies varied the parameterisation of the threshold velocity to improve the simulation of dust (Kok et al., 2014; Wu et al., 2016). Likewise, the paper aims to show the impact of using IFS assimilated Aeolus winds in the WRF-Chem model on dust transport, where the WRF-Chem model configuration follows the most recent parameterisations, source functions and mechanisms sourced from literature on dust simulation in the East Mediterranean and Middle East region. Thereby, using the most updated version of the model relative to dust simulations, we aim to show whether an improvement can be attained from incorporating the Aeolus wind fields.

Regarding the comparison with the EMEP dataset (Fig. 2), the authors demonstrate the deviations between the two model runs in autumn compared to the near-identical simulated PM10 values in spring, shown in Fig. A2. Furthermore, the highlighted instances in

Fig. 2 point out that strong deviations between model runs materialise in periods of anticyclogenesis, where statistical improvements achieved in the assimilated run can be seen in Table 1. Use of AERONET, Polly^{XT}, MIDAS and LIVAS, ground and satellite observation datasets, the paper aimed to observe the impact of Aeolus on horizontal, vertical and temporal evolution of dust in the region for the case study of 14-25 of October. Through statistical comparisons of the simulated values to observed ones, the assimilated run proved to be more able to accurately depict dust transport in the region.

Specific comments

- the title is a misleading. It is not clear, whether WRF model itself assimilates wind data or not.

  Correction -> The impact of using assimilated Aeolus wind data on Regional WRF-Chem dust simulations.

- Introduction is lengthy, 2nd paragraph on page 1 and 1st on page 3 could be shortened. References [2] and [3] devoted to rigorous dust simulation on the Middle East are missing in the manuscript.

  Correction -> Removed some of the context from paragraphs 2 and 3 of the introduction and included references 2. and 3.

- Not clear why authors used complex (MADE/SORGAM) aerosol scheme to simulate dust? Is there any justification for it? However, here [1] you may find some useful details on how to simulate dust in WRF-Chem using modal aerosol scheme.

  Reply -> We would like to thank the referee for the references which we have incorporated in the manuscript. We are using a modal aerosol scheme that was excessively tested and was shown to perform well across the EMME region [Georgiou (2018), Kushta (2018)]. This will allow us in the future to investigate the impact of using assimilated data on other components of the Earth system.

Technical corrections:

- Line 62: first occurrence of WRF-Chem. Please add reference.

  Corrected

- Line 90: HSRL, HLOS unknown abbreviations.

  Corrected

- Line 107: .. seasons of the region. Please specify which region.

  Corrected

- Line 130: Natural emissions. Please explain, what do you mean?

Correction-> Changed to: Mineral dust and sea-salt emissions were calculated on-line by the WRF-Chem model, driven by IFS Aeolus-assimilated data

- Line 170-172: what type of FDDA you used? Not clear, who lateral boundary conditions can be improved by FDDA? If FDDA is enabled in WRF, then model fields (not observations) are nudged to reanalysis fields.

  Correction-> Following the reviewers comment we have modified the text to clarify as follows: FDDA has been applied towards IFS re-analysis fields with and without assimilated Aeolus observations. It was shown that by nudging above and within the Planetary Boundary Layer, the accuracy of the meteorological variables simulated within the WRF-Chem model is improved (Deng et al., 2007) and has since been used in other dust-related studies (e.g. Kumar et al., (2014)). Following this, the horizontal wind components, temperature and moisture were nudged in all the model vertical layers, except the surface level, with a nudging coefficient of $3 \times 10^{-4}\ s^{-1}$. Nudging was carried out at each time step throughout the whole simulation, with a time interval between analysis times of 6 hours. Ramping started at the last analysis time and ended as a step function.

- Line 188: remove ; ?

  Corrected

- Line 200: height of (t,V,lat,lon) model level, and ΔH - width of the (t,V,lat,lon) model level.

  Corrected

- Lines 200-201: Please remove in in units.

  Corrected

- Formula 1: add (t,V,lat,lon) to PH and PHB

  Corrected

- Formula 2: Replace by AOD(t,lat,lon)=∑EC55(t,V,lat,lon) ∗ ΔH(t,V,lat,lon), where ∑ - sum over V.

  Corrected

- Figure 1: Land contours are hardly seen (Fig. A3 same).

  Corrected

- Line 301: missing formula for IOA.

  Corrected

- Line 317: 14-19th. Please add October.

  Corrected

- Figure 5: what os hel1, 4 on plot legend? Please cut top altitude to 5km.

  Corrected

- Figure 6: Please replace AERONET-alpha by “Ångström Coefficient”, replace y-axis label by “Ångström Coefficient”

  Corrected

- Figure 8: Please replace ‘black boxes’ by ‘black rectangles’.

  Corrected

- Figure A1: Please move it to the main text and illustrate all (if possible) geographical locations mentioned in the study. Also plot locations of AERONET stations (remove Fig. 4a, which is empty anyway).

  Corrected -> Fig. A4 has now been corrected and includes the geographical locations mentioned in the study. Similarly, fig. A1 now includes geographical locations mentioned in the text, however, it was decided that fig. A1 will remain in the appendix.

References given by the reviewer:

1. Osipov et al, Severe atmospheric pollution in the Middle East is attributable to anthropogenic sources

2. Parajuli et al, Dust Emission Modeling Using a New High-Resolution Dust Source Function in WRF-Chem With Implications for Air Quality

3. Ukhov, A. et al. Assessment of natural and anthropogenic aerosol air pollution in the Middle East using MERRA-2, CAMS data assimilation products, and high-resolution WRF-Chem model simulations

References used in the reply

Evan, A. T., Flamant, C., Fiedler, S., & Doherty, O. (2014). An analysis of aeolian dust in climate models.Geophysical Research Letters,41,5996–6001. https://doi.org/10.1002/2014GL060545

Nabavi, S.O., Haimberger, L. and Samimi, C., 2017. Sensitivity of WRF-chem predictions to dust source function specification in West Asia. Aeolian research, 24, pp.115-131., Vancouver,

Klose, M., Shao, Y., Li, X., Zhang, H., Ishizuka, M., Mikami, M., & Leys, J. F. (2014). Further development of a parameterization for con-vective turbulent dust emission and evaluation based onfield observations.Journal of Geophysical Research: Atmospheres,119,10,441–10,457. https://doi.org/10.1002/2014JD021688

Kok, J. F., Albani, S., Mahowald, N. M., & Ward, D. S. (2014). An improved dust emission model—Part 2: Evaluation in the CommunityEarth System Model, with implications for the use of dust source functions.Atmospheric Chemistry and Physics,14(23), 13,043–13,061.https://doi.org/10.5194/acp-14-13043-2014

Shao, Y., Wyrwoll, K. H., Chappell, A., Huang, J., Lin, Z., McTainsh, G. H., et al. (2011). Dust cycle: An emerging core theme in Earthsystem science.Aeolian Research,2(4), 181–204. https://doi.org/10.1016/j.aeolia.2011.02.001

Wu, C., Lin, Z., He, J., Zhang, M., Liu, X., Zhang, R., & Brown, H. (2016). A process-oriented evaluation of dust emission parameterizationsin CESM: Simulation of a typical severe dust storm in East Asia.Journal of Advances in Modeling Earth Systems,8, 1432–1452.https://doi.org/10.1002/2016MS000723