

Interactive comment on “Regional effects of atmospheric aerosols on temperature: an evaluation of an ensemble of on-line coupled models” by Rocío Baró et al.

Q: [R1] [...] The article has a very clear objective of evaluating the simulations of coupled models including aerosol interactions with radiation and clouds with respect to surface temperatures. This is clearly of general interest since it is an impact on weather forecasting that may motivate changes in operational models around the world. The improvement of temporal variability is an important result. [R2]: [...] The results points towards an improvement of spatial and temporal correlations when adding these interactions. The paper is well written and the topic is in the scope of the Journal. [R3] [...] The paper basically shows that including aerosol effects generally leads to a small improvement in the simulated surface temperature. [R4]: [...] According to the manuscript, the main conclusion obtained from the analyses is that the inclusion of aerosol effect feedbacks did not have a significant impact on the bias observed between modelled and observed temperature. However, the spatial and temporal variability are better represented when aerosol radiative effects are included in the simulations. The subject of the manuscript is within the scope of ACP and it is a relevant scientific issue. [R5]: [...] Overall, the manuscript is well written and can contribute to improve weather forecast models.

A: First of all, we would like to thank the reviewers for their positive opinion on the paper and its importance and their very valuable comments. All the reviewers raise very interesting points, which are addressed point-by-point below. (Reviewer's comments are displayed in black, replies in blue fonts).

Q: [R1] There is a lack of discussion on how well the aerosol concentrations for the two episodes compare with actual observations [...] In the cases used in this paper, how do these values compare to station data? [R2] It would be good to also provide a figure(s) showing observed AOD and clouds for the period of analysis and then how each model was able to represent them. If this is performed in other paper please include it anyways for context. [R3] [...] How can one see that without any plot showing emissions and/or aerosol loading in the manuscript? [R4] The aerosol horizontal and vertical distribution loading is absolutely absent from the manuscript. To address the influence of these effects on the surface temperature it is crucial to have, at least, a clear notion on the aerosol horizontal loading, observed and modelled. [R5] It would be interesting to evaluate the models skills in reproducing AOD and other aerosol optical properties.

A: We fully agree with the reviewers' comments. In fact, AOD representation is so important that the model representation and evaluation of aerosols and AOD are presented in a full accompanying paper, which will be soon re-submitted to this same issue of ACP after considering its own reviewer's

comments (Palacios-Peña et al., submitted. An assessment of aerosol optical properties from remote sensing observations and an ensemble of regional chemistry-climate coupled models over Europe).

However, a short description of the model behaviour for AOD representation is included in the manuscript at the beginning of the results section.

Q: [R1] The reader is left without means to judge whether this is a convincing case or not. In the conclusions, the authors reinforce this feeling by saying that this evaluation should be performed for cases with "episodes with stronger effects on the aerosol cloud interactions" and mentioning that in one of the cases larger concentration were found over the Mediterranean Sea where the evaluation is not performed.

A: The reviewer is right. Despite the substantiated election of the cases in different parts of the bibliography (especially, those related to EuMetChem), the sentence stated by the reviewers is an unfortunate claim. Our intention was to highlight that the ARI+ACI interactions are more pronounced in this episode over ocean areas (unluckily not covered by E-OBS). So we have rephrased the sentence in the conclusions for a better clarification:

"In order to further investigate the impact of including the aerosol interactions in online coupled models, more episodes with effects on the aerosol-radiation-cloud interactions should be considered. In this work, the fires episode represents a situation of clear skies, and therefore the ARI feedbacks are dominant. The dust episode election permits to study aerosol-cloud interaction, most of the ARI+ACI differences found in the models with respect to the base case were found over the Mediterranean sea. Since the observational data E-OBS only has values over land, the effect of ARI+ACI were not evaluation here. Unfortunately part of the interpretation of the results may be missed due to the unavailability of this database over the ocean."

Q: [R1] Page 6, line 8 you mention annual emissions, what is actually used in a daily/hourly basis? Are these cases significant from the point of view of high emissions and concentration of aerosol over land?

A: The methodology for emissions follows that explained by Im et al. (2015). As stated here, consistent temporal profiles (diurnal, day-of-week, seasonal) and vertical distributions were also made available to AQMEII and EuMetChem participating groups for time disaggregation. The temporal profiles for the EU anthropogenic emissions were provided from Schaap et al. (2005). This information has been clarified in the revised manuscript.

Im, U., Bianconi, R., Solazzo, E., Kioutsioukis, I., Badia, A., Balzarini, A., Baró, R., Bellasio, R., Brunner, D., Chemel, C., Curci, G., Flemming, J., Forkel, R., Giordano, L., Jiménez-Guerrero, P., Hirtl, M., Hodzic, A., Honzak, L., Jorba, O., Knote, C., Kuenen, J. J., Makar, P. A., Manders-Groot, A., Neal, L., Pérez, J. L., Pirovano, G., Pouliot, G., Jose, R. S., Savage, N., Schroder, W., Sokhi, R. S., Syrakov,

D., Torian, A., Tuccella, P., Werhahn, J., Wolke, R., Yahya, K., Zabkar, R., Zhang, Y., Zhang, J., Hogrefe, C., and Galmarini, S.: Evaluation of operational on-line-coupled regional air quality models over Europe and North America in the context of AQMEII phase 2. Part I: Ozone, *Atmospheric Environment*, 115, 404–420, 2015.

Schaap, M., Roemer, M., Sauter, F., Boersen, G., Timmermans, R., Bultjes, P.J.H., 2005. LOTOS-EUROS: Documentation. TNO report B&O-A, 2005-297, Apeldoorn.

Q: [R1] Pages 7, Equation 2, objectively define $\hat{\sigma}$; what is the operation defined in eq. 2? What is $V_{k_{ic}}$? [R2] Equation 2. There is either an error on the notation or a variable is not defined ($V_{k_{ic}}$)

A: We strongly appreciate the reviewer's suggestions. There was a typo in the definitions of the equations of variability that has been corrected in the revised version of the manuscript.

Q: [R1] Page 9, lines 3-5, for the whole period, 60 days in one case and 30 days in the other case? Only in figure 10 the exact period is mentioned. Please state that in the text.

A: The exact period is specified in pag 4, lines 23 to 25

Q: [R1] The numbers that summarize results should be organized in tables so they can be easily compared. [R3] The figures with maps are presented in such a way that one cannot gain a clear quantitative understanding of how the models differ beyond very large differences. [...] In most cases, the maps look identical without extremely close examination. A better way needs to be found to present this information. [R1] Page 9, lines 6-28 the average numbers of the bias for each case and run should be summarized in a Table.

A: Following the reviewer's advice, a Table summarizing all the results has been including in the revised version of the manuscript (Tables 2 and 3).

Q: [R1] [...] What is needed is a way to represent the effect on temperature in places where there is a high concentration of aerosol. You could choose a given simulation time with very high aerosol concentrations and show model performance for temperatures. [R2] [...] I suggest the authors to restrict their analysis only to regions where large aerosol impact is expected. For instance, bias could be computed only for regions where AOD is over a fixed threshold, or you could weigh the bias by AOD. [R4] I also wonder about the effectiveness of the discussion largely based on domain-averaged values given the domain considered.

A: The domains presented here are sub-domains of the ensemble of EuMetChem simulations, which covers a European-wide domain. The elections of these sub-domains was based precisely on those European sub-area where the aerosol could affect most the meteorological variables. It is for this reason that these sub-domains for the wildfires episode and the dust episode were selected. Therefore, in our opinion, results regarding bias or

correlation would not change importantly if different domains were selected.

Q: [R1]: [...] There is very little discussion on why given models may perform better than others.

A: We fully agree with the reviewer's comments. However, the point raised by the reviewers was already addressed in Brunner et al. (2015), where the authors present an operational analysis of model performance with respect to key meteorological variables relevant for atmospheric chemistry processes and air quality. So the reader is referred to that work for clarification.

Q: [R3] Gridded temperature data sets typically show a range of uncertainties due to different methodologies used to spatially distribute and average point observations. [...] Most likely, the differences identified between running the models with and without aerosol feedbacks is smaller than the differences between observation data sets.

A: The reviewer raises a very interesting point. One of the works coauthored by the corresponding author of this manuscript (Gómez-Navarro et al., 2012) examines to what extent the evaluation and ranking of an ensemble of regional climate models, according to their ability to reproduce the observed climatologies, is sensitive to the choice of the reference observational data set. The authors found that for maximum and minimum temperatures, it turns out that uncertainties among observations are at least as relevant as uncertainties among the models within an ensemble.

However, the main objective of this work is not to rank the ensemble of simulations included in EuMetChem, but to provide a comprehensive comparison between simulations and to assess the differences when including the aerosol feedbacks. In this sense, the E-OBS dataset was selected because of its wide use in scientific literature when evaluating regional climate models.

Gómez-Navarro, J. J., J. P. Montávez, S. Jerez, P. Jiménez-Guerrero, and E. Zorita (2012), What is the role of the observational dataset in the evaluation and scoring of climate models?, *Geophys. Res. Lett.*, 39, L24701, doi:10.1029/2012GL054206.

Q [R3]: The “third” configuration needs to be defined in relation to the handling of aerosol and/or cloud droplet assumptions when aerosol-cloud interactions are disabled. [...] However, one cannot run a model without aerosol and still form clouds, since the aerosols are required for forming cloud droplets in almost all physically relevant conditions. So, even “without” aerosol-cloud interactions there are still significant assumptions built into the models to account for the ACI processes.

A: The reviewer is right. This point has been clarified in the manuscript (Second paragraph, Section 2) as follows: “*Although NRF case does not*

consider the aerosol effects and feedbacks, there is a standard aerosol assumption of some continental aerosol (250 cm⁻³ used by WRF-Chem in the absence of ACI for estimating cloud droplet number). On the other hand, ARI uses this constant value for accounting the interaction between aerosols and clouds, but allows the modification of the radiation budget by using the on-line estimated aerosols. Last, the ARI+ACI cases are based on simulated aerosol concentrations, which interact both with radiation and aerosols. The common setup for the participating models and a unified output strategy allow analyzing the model output with respect to similarities and differences in the model response to the aerosol direct effect and aerosol-cloud interactions."

Q: [R4] I would recommend the authors to describe the dominant meteorological context during the episodes, with special focus on those variables that govern the surface temperature field.

A: The weather conditions during the Russian forest fires were mainly dry and particularly hot, with light winds. During this situation, the sea-level pressure (SLP) showed a high-pressure system over the northeast part of the Russian area, finding a strong positive SLP anomaly for this period. This resulted in a strong positive surface temperature anomaly accompanied by weak winds from the southeast. On the other hand, a very deep trough characterizes the dust period situation with a vortex reaching 20 degrees of north latitude. This situation is maintained for several days, causing a continuous transport in middle levels. It is also worth mentioning the blocking situation over all central Europe. The dust event was dominated by strong south-easterly wind. This may explain windblown dust emissions increasing with wind speed and being transported to some parts of the European area.

This description has been included in the revised version of the manuscript, Section 2.

Q: [R4] Being the WRF-CHEM individual models dominant and presented basically the same configuration, although from distinct institution, the ensemble results seems to resemble WFR_CHEM features, which is clear when Bias are analysed. Moreover, I wonder about the inclusion of a WRF-CHEM model version with a spatial resolution substantially higher than the others and its influence on the ensemble results. [...] The simultaneous analyses of the inclusion(exclusion) of aerosol effects based on the ensemble field seems to be a challenge since the ensemble may reflect compensation between features from individual models.

A: The meteorological variables simulated by regional models suffer from uncertainties arising from a variety of sources such as internal variability, different model formulations, etc. Results found in the literature indicate that the ensemble mean is usually less biased than the individual members (Fernández et al. 2009, Knutti et al. 2010; Kjellström et al., 2011).

As stated by Annan and Hargreaves (2011), one hypothesis for the improvement of the ensemble mean when compared to the performance of the individual models is the paradigm of models being considered as independent samples from some distribution that is centered on the truth, as in this case the ensemble mean could be expected to converge to the truth as more models are added to the ensemble.

With respect to WRF-CHEM individual models being dominant, Jerez et al. (2013) indicate that the uncertainties associated to the physics of the driving meteorological model are of the same order of magnitude as the uncertainties associated with a multi-model ensemble. Therefore, even though WRF-CHEM models are dominant in the ensemble, the diversity of the parameterizations elected make the election feasible for an ensemble analysis.

Annan JD, Hargreaves JC (2010) Reliability of the CMIP3 ensemble. *Geophys Res Lett* 37:L02703, doi:10.1029/2009 GL041994

Fernández J, Primo C, Cofiño AS, Gutiérrez JM, Rodríguez MA (2009) MVL spatiotemporal analysis for model inter- comparison in EPS: application to the DEMETER multi- model ensemble. *Clim Dyn* 33:233–243

Knutti R, Furrer R, Tebaldi C, Cermak J, Meehl GA (2010) Challenges in combining projections from multiple cli- mate models. *J Clim* 23:2739–2758

Kjellström E, Nikulim F, Hanson U, Strandberg G, Ullerstig A (2011) 21st century changes in the European climate: uncertainties derived from an ensemble of regional cli- mate model simulations. *Tellus* 63A:24–40

Q: [R5] Even though Jiménez-Guerrero is one of the co-authors of the manuscript and reference to Jiménez-Guerrero et al. (2013) is given, at the validation methodology section (page 7, from line 7 and following), many parts of the text are identical to the reference, what must be avoided.

A: An effort has been made to rewrite this part of the manuscript, despite keeping the same nomenclature for the statistical figures.

MINOR COMMENTS:

Q: [R1] Page 4, lines 20-23 – please correct sentence structure

A: These lines have been corrected in the revised version

Q: [R1] Page 35 – Table 1 – define CS1, CS2, DE3, ES1, ES3, in the text you use things like, C11, C12...etc, this should be defined in the text.

A: This information has been clarified in the revised manuscript.

Q: [R1] Page 14, lines 23-26 – for T_{min} the case ENS-C13 is perhaps an exception?

A: The reviewer is right. This comment has been introduced in the revised version of the manuscript.

Q: [R2] Page 2, line 10. Somewhere in the text define “EuMetChem COST Action ES1004”

A: EuMetChem stands for “European framework for online integrated air quality and meteorology modelling”. This definition has been introduced in the second paragraph of the Introduction.

Q: [R2] Page 2, Line 19. I think that the statement “especially for those areas closest to emissions sources of atmospheric aerosols” is not explained or mentioned in the text.

A: This sentence has been removed from the revised version of the abstract.

Q: [R2] Section 3.2. What strikes me the most from these results are the differences between the smoke and the dust case. For the smoke case, most of the changes come from the radiation effects, while for the dust effects most changes come from aerosol-cloud effects. Can you explain why this happens? Does the dust case has more clouds over the domain? Is it related to better cirrus representation?

A: During the fire episode, a predominantly clear-sky situation was found; therefore, the aerosol effects governing the changes in temperature are related to the aerosol-radiation effect. Conversely, during the dust episode, formation of clouds is enhanced because of the meteorological situation explained above.

Q: [R2] Page 4, line 22. Erase “are run”

A: Line has been corrected

Q: [R2] Page 15, line 11. Fix the forkeletal2015 reference. [R3] p. 15, l. 9: Reference to Forkel et al. (2015) is mistyped. [R5] Page 15, line 11: please correct Forkel et al. 2015

A: Reference has been corrected in the revised version of the manuscript.

Q: [R3] p. 4, l. 27: “Three different cases” is better phrased as “Three different configurations.” “Cases” implies different dates and “configurations” is more specific to what is being described.

A: This comment has been introduced in the revised version of the manuscript as suggested.

Q: [R3] p. 5, l. 10: The WRF-Chem citations need to include those relevant to the aerosol direct and indirect effects, particularly because those processes are the focus of this paper. The standard citations for this purpose are Chapman et al. [2009]; Fast et al. [2006]; Gustafson et al. [2007].

A: These references have been added to the WRF-Chem citation.

Chapman, E. G., W. I. Gustafson, R. C. Easter, J. C. Barnard, S. J. Ghan, M. S. Pekour, and J. D. Fast (2009), Coupling aerosol-cloud-radiative processes in the WRF-Chem model: Investigating the radiative impact of elevated point sources, *Atmos. Chem. Phys.*, 9, 945–964, doi:10.5194/acp-9-945-2009.

Fast, J. D., W. I. Gustafson, R. C. Easter, R. A. Zaveri, J. C. Barnard, E. G. Chapman, G. A. Grell, and S. E. Peckham (2006), Evolution of ozone, particulates, and aerosol direct radiative forcing in the vicinity of Houston using a fully coupled meteorology-chemistry-aerosol model, *J. Geophys. Res.*, 111, D21305, doi:10.1029/2005jd006721.

Gustafson, W. I., E. G. Chapman, S. J. Ghan, R. C. Easter, and J. D. Fast (2007), Impact on modeled cloud characteristics due to simplified treatment of uniform cloud condensation nuclei during NEAQS 2004, *Geophys. Res. Lett.*, 34, L19809, doi:10.1029/2007gl0300321

Q: [R3] p. 5, l. 12: “Resolution” needs to be changed to “grid spacing.” The two are not interchangeable.

A: It has been changed as suggested.

Q: [R3] p. 5, l. 15: The authors presumably meant “grid spacing” and not “width.”

A: It has been changed as suggested.

Q: [R3] p. 8, l. 4: The “p” should be subscripted.

A: The reviewer is right. Letter “p” has been subscripted in the revised version of the manuscript.

Q: [R3] p. 11, l. 5: I do not understand what is trying to be conveyed by “...presenting the ensemble always maximum time...” This appears to be a garbled sentence.

A: The sentence has been corrected as “presenting the ensemble always maximum values for...”

Q: [R4] Page 2, Line 03: “...due to direct aerosol-radiation...” to “...due to the direct aerosol-radiation...”

A: This sentence has been changed in the revised version of the manuscript.

Q: [R4] Page 2, Line 04: "...from aerosol-cloud interactions..." to "...from aerosol-cloud-radiation interactions..."

A: This sentence has been changed in the revised version of the manuscript.

Q: [R4] Page 2, Line 09: "...and minimum temperature over Europe..." to "...and minimum temperature at 2 meters over Europe..."

A: This comment has been changed in the revised version of the manuscript.

Q: [R4] Page 2, Line 10: "The evaluated model outputs originate..." to "The evaluated models outputs originate..."

A: Changed as suggested.

Q: [R4]: Page 2, Line 11: "The case studies cover two important..." to "The cases studies cover two important..."

A: Changed as suggested.

Q: [R4] Page 2, Line 12-13: "...a heat wave and forest fires episode..." to "...a heat wave event and a forest fires episode..."

A: Changed as suggested.

Q: [R4] Page 2, Line 19: "...those areas closest to emissions sources..." to "...those areas closest to significant emissions sources..."

A: This sentence has been changed in the revised version of the manuscript.

Q: [R4] Page 2, Line 21 -22: "Atmospheric aerosol particles are known to have an impact on Earth's radiative budget due to their optical, microphysical and chemical properties,..." to "Atmospheric aerosol particles are known to have an impact on Earth's radiative Budget due to their interaction with radiation and clouds properties, which are dependent on their optical, microphysical and chemical properties..."

A: This sentence has been changed as suggested in the revised version of the manuscript.

Q: [R4] Page 2, Line 23-26: "They influence climate by modifying both the global energy balance through absorption and scattering of radiation (direct effect), and by acting as cloud condensation nuclei, thus affecting cloud droplet size distributions and lifetime (Twomey 1977; Lohmann and Feichter, 2005; Chung, 2012) and the reflectance and persistence..." to "They influence climate by modifying the global energy balance through both absorption and scattering of radiation (direct effect) and by acting as

cloud condensation nuclei, thus affecting clouds droplet size distribution, lifetime (Twomey 1977; Lohmann and Feichter, 2005; Chung, 2012) and reflectance (indirect effects)..."

A: This sentence has been changed as suggested in the revised version of the manuscript.

Q: [R4] Page 3, Line 15-17: "...the air quality model evaluation international initiative (AQMEII) in its phase 2 (Alapaty et al., 2012; Galmarini et al., 2015) focused on the assessment of ..." to "..., in its phase 2, the air quality model evaluation international initiative (AQMEII) (Alapaty et al., 2012; Galmarini et al., 2015) focused on the assessment of ..."

A: This sentence has been changed as suggested in the revised version of the manuscript.

Q: [R4] Page 3, Line 20: "...aerosols, radiation, clouds, and precipitation..." to "...aerosols, radiation, clouds and precipitation..."

A: Changed as suggested.

Q: [R4] Page 3, Line 20: "...a coordinated exercise of Working Groups 2 and 4 of the COST Action ES1004 (EuMetChem, <http://eumetchem.info>) emerged, in order to take into account the radiative feedbacks, due to atmospheric aerosol effects over meteorology..." to "..., a coordinated exercise of the working groups 2 and 4 of the COST Action ES1004 (EuMetChem, <http://eumetchem.info>) emerged in order to take into account the radiative feedbacks of atmospheric aerosol effects on meteorology."

A: Changed as suggested.

Q: [R4] Page 3, Line 26: "...of their strong potential of aerosol interactions..." to "... of their strong potential for aerosol-radiation and aerosol-cloud-radiation interactions ..."

A: This comment has been changed in the revised version of the manuscript.

Q: [R4] Page 3, Line 28: "...onto meteorology..." to "...on meteorology..."

A: Changed as suggested.

Q: [R4] Page 4, Line 1: Specify temperature at which level (surface, 2 meters?) the paragraph is referring.

A: Forkel et al. (2015) refer to 2-m temperature. This has been clarified in the revised version of the manuscript.

Q: [R4] Page 4, Line 5: "Forkel et al. (2012) studied an episode in June and July..." specify the nature of the episode that is discussed here.

A: The reason for selecting this two-month episode was clarified in the manuscript.

Q: [R4] Page 4, Line 7: "...this reduction was reflected in its spatial distribution of the planetary boundary layer height..." please, clarify.

A: This sentence has been rewritten in the revised version of the manuscript.

Q: [R4] Based on the first sentence of the last paragraph: Page 4 Line 11: "However, all these studies are based on individual model evaluations and do not take into account an ensemble of regional models, in order to build confidence on model simulations and to characterize the uncertainty associated to the use of different modelling systems". I'm tempted to suggest another perspective on the sentence that describe the manuscript main goal (just a suggestion) from:

Page 4 Line 14: " ...the objective of this work is to assess whether the inclusion of aerosol radiative feedbacks during two important atmospheric aerosol episodes of the year 2010 improves the outputs of an ensemble of regional on-line coupled models for maximum, mean and minimum temperature at 2 meters over Europe."

To " ...the objective of this work is to assess whether the outputs of an ensemble of regional on-line coupled models simulations including aerosol radiative feedbacks, during two important atmospheric aerosol episodes of the year 2010, improves the prognostic for maximum, mean and minimum temperature at 2 meters over Europe"

A: We strongly appreciate the reviewer's suggestion, which clarifies the objective of this contribution. The reviewer's comment has been introduced in the revised version of the manuscript.

Q: [R4] Page 4 Line 23: "...the Russian 2010 heatwave and wildfires episode in summer 2010 (25 July-15 August 2010)..." to "...the Russian heatwave and wildfires episode in the summer of 2010 (25 July-15 August 2010)..."

A: Changed as suggested.

Q: [R4] Page 5 Line 1: "...which does not consider any feedbacks to meteorology with simulated aerosol (NRF)," to "...which does not consider any aerosol effects feedbacks to meteorology (NRF),"

A: Changed as suggested.

Q: [R4] Page 5 Line 2: "...where aerosol-cloud interactions based on simulated aerosol concentrations and direct and indirect aerosol effects are considered (ARI+ACI)." I think this sentence needs to be improved.

A: This sentence has been rewritten for the sake of clarity in the revised version of the manuscript.

Q: [R4] Page 5 Line 11-12: "...with different chemistry and physics options and performed episodes..." The last part of the sentence "and performed episodes" did not make sense to me, please, clarify.

A: This sentence has been rewritten for the sake of clarity in the revised version of the manuscript.

Q: [R4] Page 5 Line 14: "...grid with of 0,125deg /approximately 14 km) there is an additional..." to "...grid with of 0.125 deg (approximately 14 km) and there is an additional..." [R5] Page 5, line 14: please replace "grid with of 0,125deg" by "grid with 0.125deg" (notice the use of comma as decimal separator).

A: Changed as suggested.

Q: [R4] Page 5 Line 21: "...uses the Model for Simulating Aerosol Interactions and Chemistry (MOSAIC)(4 bins) ..." Please, provide the meaning of "(4 bins)".

A: In order to clarify it, "4 bin" has been replaced by "4 aerosol size bins" since the term bins refers to the number of aerosol size bins considered for representing aerosol distribution with respect to their diameter.

Q: [R4] Page 6 Line 3: "2.2 Emissions and boundary conditions" The topic is mentioning "boundary conditions" but it only describe emissions sources. How about dust emission, since one of the case study focus is on an event of dust transport.

A: We appreciate the reviewer's suggestion. The description of boundary conditions has been added to the revised version of the manuscript.

Q: [R4] Page 6 Line 9: "...volatile organic compounds..." to "...volatile organic compounds..."

A: Changed as suggested.

Q: [R4] Page 6 Line 25: "...alter significantly any of our results..." to "... alter significantly our results..."

A: Changed as suggested.

Q: [R5] Page 12, line 20: please replace "intermediate representation the variability" by "intermediate representation of the variability";

A: Changed as suggested.