Responses to RC1

We greatly appreciate the thorough review and helpful comments and suggestions provided by referee #1. The point-by-point responses to the comments are as follows.

The present study highlights the importance of various physical processes in smoke dispersion from wildfire biomass burning. The manuscript is clearly structured, it is well written and presents important analysis regarding the comparison between twelve state-of-the-art atmospheric models during a specific case study in US. Overall, it will be a very useful addition to current literature, and I suggest publication with a few minor comments as shown below:

1. It is clear from this work that there is still significant lack of knowledge regarding several processes like the quantification of fire emissions and their diurnal cycles, plume injection heights, calculation of AOD and PM2.5, the spatiotemporal representation of smoke plumes in forecasting models etc... However, this is something more-or-less known due to the complexity of the mechanisms involved in these events. Since none of the models managed to provide a realistic description of the case study, the study remains somehow non-conclusive. It might be useful to elaborate more in the conclusions section and provide more physical interpretation on the reported differences between the models as well as some quantification on which of the analyzed parameterizations are more important for similar studies (e.g. plume rise, FRP emissions, etc.). This could help future studies to focus on improving certain model features and discard those that look problematic.

Reply: Thanks for this suggestion! The conclusion section in the old version was structured by summarizing the main findings in each previous section, and several processes and issues affecting the model performance were mentioned. We recognize that a conclusive statement and more physical explanations are lacking. We have extensively revised the conclusions section (section 4) to elaborate the results, try to give more physical interpretations, and highlight the key factors that are significant for future model improvements. Subtitles are added for a better structure. In brief:

1) Model evaluations of smoke emissions and sAOD suggests the advantage of using FRP-based fire emissions and data assimilation in providing less biased forecasts for total column smoke aerosol loading, compared to other differences in model features.

2) The fact that all estimated fire emissions exhibit a large spread in magnitude demonstrate a need of future work to close the gap between these estimates and reduce their uncertainty.

3) As the forecasted air quality impacts still show limitations due to the persistence assumption, methodologies to predict evolution of fire burning needs to be developed.

4) Forecast performance for sAOD and surface sPM2.5 and their discrepancies highlight a key need to improve plume rise parameterizations, in terms of plume rise height and vertical partition of fire emissions as well, which is closely relevant to accuracy of representation of smoke plumes and the performance discrepancies for sPM2.5 and sAOD.

These have been summarized in section 4.5. Please see the revised version for more details.

We agree that it's necessary to quantify which of the analyzed parameterizations are more important, and it would be instructive and important for similar studies. As these forecast models are drastically different from each other with respect to multiple aspects, we think it would be difficult and arbitrary to comment on the relative contributions of the abovementioned factors. We are planning on some follow-up work to further identify their relative significancy based on sensitivity analysis.

2. The computation of modeled smoke AOD in Section 3.2.2 should be further explained with regards to the optical properties of smoke used in each model.

Reply: The treatment of aerosol processes and assumptions of aerosol physical and optical properties have been briefly explained in the descriptions for each model in section 2.1 in the revised paper, and summarized in section 2.2, bullet point 7. The relevant references have also been added. Please refer to the revised paper for more details.

In summary, regarding the diagnosis of AOD, UCLA WRF-Chem, HRRR-Smoke, WISC WRF-Chem, RAQMS, and GEOS-FP used mass-concentration-based aerosol extinction, while CAMS, UIOWA WRF-Chem, NCAR WRF-Chem, NAQFC, AIRPACT, and ARQI used the Mie theory formalism for scattering spheres, and FireWork used a post-processing diagnostic calculation to generate AODs from PM2.5 speciation. We are aware that the uncertainty of AOD calculations owing to the different methods and assumptions can lead to different performance. The assumptions about the chemical species mixing state, density, refractive index, and hygroscopic growth has been estimated to lead to uncertainty in AOD of about 30 – 35 % (Curci et al., 2015), with a tendency of calculated AOD to be less than satellite observations of AOD. Due to the differences in the aerosol models employed and many more differences in meteorology, radiation transfer, chemistry mechanisms, emissions, etc. among the models, this uncertainty introduced by these factors can not be treated explicitly in this work, and it would be necessary to further investigate in our future work by sensitivity analysis.

Curci, G., Ferrero, L., Tuccella, P., Barnaba, F., Angelini, F., Bolzacchini, E., Carbone, C., Denier van der Gon, H. a. C., Facchini, M. C., Gobbi, G. P., Kuenen, J. P. P., Landi, T. C., Perrino, C., Perrone, M. G., Sangiorgi, G. and Stocchi, P.: How much is particulate matter near the ground influenced by upper-level processes within and above the PBL? A summertime case study in Milan (Italy) evidences the distinctive role of nitrate, Atmos. Chem. Phys., 15, 2629–2649, doi:10.5194/acp-15-2629-2015, 2015.

3. At several places (e.g. Lines 89-94, 414-419, 607-610) the authors discuss the importance of including the diurnal variation of smoke emissions inside the forecasting window and the possibility to incorporate data from geostationary satellites. A similar system is available in Europe adopting a modeling strategy of hourly-sequential warm start runs with FLEXPART-WRF, driven by METEOSAT geostationary observations (Solomos et al., 2015, 2019). In this approach, the emissions are updated every hour from the MSG/SEVIRI detections, and each simulation is initialized with the smoke from the previous run (warm start). This provides an efficient way of removing the minor or extinguished fires from the simulation and at the same time to enhance the emissions from the actual burning fires, thus representing the diurnal cycle of biomass burning.

Solomos, S., V. Amiridis, P. Zanis, E. Gerasopoulos, F.I. Sofiou, T. Herekakis, J. Brioude, A. Stohl, R.A. Kahn, C. Kontoes, Smoke dispersion modeling over complex terrain using high resolution meteorological data and satellite observations – The FireHub platform, Atmospheric Environment, Volume 119, October 2015, Pages 348–361, doi:10.1016/j.atmosenv.2015.08.066, 2015

Solomos S., A. Gialitaki, E. Marinou, E. Proestakis, V. Amiridis, Holger Baars, Mika Compula, Albert Ansmann, Modeling and remote sensing of an indirect Pyro-Cb formation and biomass transport from Portugal wildfires towards Europe, Atmospheric Environment, https://doi.org/10.1016/j.atmosenv.2019.03.009 , 2019

Reply: Thanks for this comment. This system is very relevant to our study. We have included some brief descriptions of it and added the above references in section 4.5 in the revised manuscript. We also wanted to mention the special challenges in forecasting fire smoke in the U.S. compared to the Europe fires. Specifically, the following sentences have been added:

"As the forecasted air quality impacts still show limitations due to the persistence assumption, methodologies to describe and predict evolution of fire burning needs to be developed. A relevant system is available in Europe adopting a modeling strategy of hourly-sequential warm start runs (Solomos et al., 2015, 2019), with the emissions updated every hour using geostationary satellite detections. This provides an efficient way of removing the minor or extinguished and at the same time to enhance emissions from actual burning fires, thus tracking the diurnal cycle of biomass burning. However, challenges still exist in making assumptions about the fire intensity and spread over the next hours/days. Also, compared to Europe, the fire intensities and their durations are on much larger scales in North America. The large spatial variability of fuels, complex topography, and different ecosystems in the U.S. adds the complexity."

4. Line 320 typo "biome maps"

Reply: Thanks for noticing this. It has been corrected to "fuel categories".