General comments

The manuscript by Kim et al. entitled “Inverse modeling of fire emissions constrained by smoke plume transport using HYSPLIT dispersion model and geostationary observations” investigated how to improve fire emission quantifications by assimilating transported smokes with Lagrangian model simulations. The results provide a pathway to improve operational model forecast of fire smoke, which is of critical importance to accurate air-quality assessment. The study described in this paper is attractive and the case experiments were executed well. However, there are still some issues to be addressed and questions to be clarified, which have been listed as follows.

Specific comments

- In section 1 (Introduction), there is no background information of applications of inverse modeling on fire emissions estimations. As this is the focus of this work, it would be helpful to inform readers about previous investigations on this topic, as well as to highlight the features and advantages of the inverse modeling system proposed in this work.
- The HYSPLIT model used to compute dispersion factors using the TCM approach is described in section 2.3, but some details are not provided, e.g., the temporal resolution of the HYSPLIT integration and the TCM results. Also, deposition considered by using a radioactive decay constant. Is it equivalent to the deposition process of fire smoke aerosols? How does it compare with the deposition considered in other Eulerian air quality models with more comprehensive chemistry?
- In the HYSPLIT simulations, dispersed concentrations were vertically integrated up to 5000 m to get partial column mass loading of smoke particles. Is there any reference for the selection of the column height (5000 m)? In addition, smoke loading from satellite observations is converted from AOD using a constant conversion factor. Could the authors further discuss the possible uncertainties that could be introduced by using this constant conversion factor? For example, how is this constant conversion factor compare with values reported by previous literature, and is there any relation between the conversion factor and other plume features (e.g., plume age)? And, this uncertainty can be considered in observation errors in the inverse modeling system.
- In section 3.2 of the cost function used in the inverse system, the estimations of error have not been provided, which are important terms for the inversion method. Firstly, how are the background error variances evaluated, and how does the value used here compare with typical uncertainties of fire emissions? Secondly, as mentioned in section 2, the observation error variances are composed of uncertainties in Lagrangian model, observations, as well as representative errors. It would be important to include more details about the determination of these error components. Thirdly, what kind of error terms should be considered in F_{other} and how are they determined?

- The ASDTA smoke AOD data are assimilated in the HEIMS-fire system to obtain inverse estimation of fire emissions. As indicated in the introduction, the ASDTA data are based on automatic detections of fire smoke plume and represent smoke AOD, which means that the background AOD has been subtracted from total value. Is it correct? Then could the authors explain how is the background AOD derived? Also, the uncertainties in background AODs can impact inversion results, because an overestimation of background AOD will lead to underestimated smoke AOD (then underestimated fire emissions) and vice versa. This uncertainty can also be considered in the observation errors used for inversion.
- In section 3.3, the naming conventions of inversion and forecasting processes are described. It's a bit inaccurate to say that "fire emissions on November 13 can be estimated using ASDTA observations for 24 hours (i.e. oday=0), 48 hours (i.e. oday=-1), 72 hours (i.e. oday=-2), and 96 hours (i.e. oday=-3)." Technically, if we focus on fires on the target day (oday = 0), the regional impact and transported smoke plumes from those fires would be found on the following days (oday=1, 2, 3, etc.). Therefore, in this case the emissions on November 13 can only be constrained by the observations on oday=0 in reanalysis mode. On the other hand, the observations on oday=0 can constrain emissions on oday=0, as well as emissions on previous days simultaneously. So, the major benefit of including more observational days is getting more constraints for fires on multiple days, and providing a better estimation of the background smoke plume for the target day. In this case, it would be more precise to say that "for a target day of November 13, inversions are conducted using ASDTA observations for 24 hours (i.e. oday=0), 48 hours (i.e. oday=-1), 72 hours (i.e. oday=-2), and 96 hours (i.e. oday=-3)."
- Column particle mass loading is used to constrain fire smoke emissions, and emissions released at different numbers of vertical layers are tested in the sensitivity analysis. Including 5000 m level make an obvious improvement for the results. But there is a lack of analysis for the reason. A possible reason is that, 5000 m is usually above the Planetary Boundary Layer Height (PBLH). So, it would be interesting to examine the PBLH and plume injection height for this case, since smoke injection height is important to smoke transport. Smoke lofted into the free troposphere is often transported hundreds or thousands of kilometers downwind because of the higher wind speeds, generally lower turbulence levels, and less scavenging processes at higher altitudes. While, smoke trapped within the PBL is usually well mixed, and remains near the source region. If most of the fire spots in this case showed injected emissions above the PBLH, then it means that, including 5000 m in the simulations allows a better representation of emission injection, and the plume can be transported further and better constrained by observations.
- As a follow-up of the last comment, could it provide better results by tuning the emission release heights incorporating information from a plume rise model?
- For the sensitivity test on the time range of observation data used in inversion, "The 'one-day' (oday=0) simulation is run through the inverse model using dispersion and

observations for the target day, while the ‘two-day’ simulation uses two days (i.e., 48 hours) of dispersion and observations (oday=-1)”. As this sensitivity test focus on the time range of observations, I think it is unfair to compare the results using different days for both of dispersion and observations. For example, if we compare the results using ‘one day’ and ‘two days’ shown in the current test, for the ‘one-day’ simulation, all the mismatches of modeled and observed smoke mass loading would be attributed to adjustments of fires on the target day, which would likely lead to a significant error in the emission estimates for the target day. While the ‘two-day’ simulation allows the fires on oday=-1 to be constrained at the same time. Therefore, it would make more sense to use four days of dispersion for all the simulations for this test, and just change the observation days from 1 (24 hours) to 4 (96 hours).

- At the end of section 4.3, it is mentioned that “The November 17 output shows how the system responds when observations are limited or missing, although it still provides a robust result by honoring the initial guess information”. But no result is referred. It would be clearer to add a reference to the figure/table supporting this sentence. If it is Figure 4, it would also be better to indicate the number of points in each panel to show that the observations are limited on Nov 17, given that many points could be overlapped.
- P8, L249-255, this paragraph can be more concise. Also, a description of the result of the spatial coverage sensitivity test is missing.
- As stated in section 4.5, for the forecasting days, smoke is estimated as the summation of impact from fires existed on previous days and new emissions on the target days, and fire plumes initialized on fday =0, 1, 2 are used here for the summation. How do the authors determine how many previous days should be considered? Since the impact of fires can extend to multiple days, would it give a better result by adding the contribution of smokes initiated on the analysis days, e.g. oday = -1, -2, and -3?

Technical corrections

- In the abstract, it is concluded that the inverse modeling system developed here outperform than the current operational forecast product in terms of RMSE, but it’s not clear RMSE of which variable is denoted here, and what observation dataset are the hindcast results and operational product evaluated against.
- P3, L92: “A modeling framework” -> “As a modeling framework”
- P4, L95: emission rate or emission? Do they represent the same term in this paper (i.e. fire smoke particles emission)? It seems that both are used throughout this paper. It would be better to use one of them and keep consistent.
- P4, L125: I do not quite understand why “the results shown in the study are obtained by multiplying the column height (i.e. 5000 m)” here. It has been shown that, the column TCM is calculated by integrating dispersed concentrations vertically, so the TCM is already in units of column loading per unit emission. Is it correct?

- P7, L189: true color image. There is not a true color channel.
- P7, L214: “estimation of assimilated fire emissions” -> “estimation of fire emissions”
- Section 4.3, the time range of observations assimilated in this case experiment is not indicated.
- What’s the date for the result shown in Figure 5?
- P8, L225: remove “that”
- P8, L242: “smoke dispersions” -> “fire emissions”
- P8, L247, “As expected, including more layers generally produce better result.” This sentence is nearly a duplication of the sentence in L242-243.
- P10, L295: “From the top panel of Figure 9” -> “For the top panels of Figure 9”
- P10, L295: “are solely originated fires” -> “are solely originated from fires”
- P10, L303: “reply on” -> “rely on”
- P10, L312, for the “additional constraint”, “transported smoke plume” could be better. There are other places of this term, please consider revising them accordingly.