Anonymous Referee #1
Received and published: 18 April 2018
The authors use the GEOS-5 chemical forecast system to simulate the CO distribution and the timing of CO enhancements observed during the Atom-1 aircraft mission in July-August 2016, using tagged CO tracers to attribute modelled CO to non-biomass burning and biomass burning (BB) sources from different regions. The authors also use multi-year satellite measurements (MOPITT and MODIS) of CO and AOD to verify if August 2016 is representative of typical boreal summer conditions. One of the goals of Atom is to derive a chemical climatology over the ocean. The paper is well written and the authors have conveyed their results and findings clearly. The methods used to derive the results are sound and thorough. I recommend this paper to be published with some clarification and improvements, detailed below.

We thank the referee for the positive review and respond to specific comments below.

Specific comments

1. My major concern is that the authors combined BB emissions from Europe and from Northern Asia into one tagged CO tracer, which I think leads to difficult attributions of the simulated North Atlantic CO to emissions in these two regions. One would suspect that European BB emissions have a more direct impact on North Atlantic CO peaks than the Asian BB emissions. Moreover, the text seems to imply that BB emissions from Southern Asia and Australia are not included in the simulation, which might lead to the underestimation of simulated South Pacific CO peaks.

We agree that it would be helpful to separate European and northern Asian BB emissions. However, since we used the GEOS-fp system, we are constrained to use the tagged-CO region definitions used by the fp system, and the fp system combines European and northern Asian BB emissions into one tracer. BB emissions from Southern Asia and Australia are included in the simulation, just not in the Eurasian tracer. They are included in the "Other BB" tracer instead. We clarify this by adding the following line to the caption of Table 1: "Other BB does include southern Asia as well Australia." We also added a supplemental figure that shows the definition of each tagged tracer region on a map.

2. Can you add to the map showing the Atom flight route the names of locations mentioned in the text and the labels of flight numbers?

We added a supplemental figure showing the ATom flight route with locations and flight numbers labeled.

3. L116-118: How do you justify adding 20% fossil fuel and 11% BB to CO emissions? What is the basis, and do you have a reference for the scaling factors? Please also show the effective CO total emissions, after scaling, in Table 1.

We include these scalings to account for CO production from VOCs because VOCs are often emitted along with CO from fossil fuel and BB sources, but the GEOS-fp chemical mechanism does not carry VOCs and thus does not explicitly calculate the CO production from these co-emitted VOCs. The reference for these scaling factors is Duncan et al. [2007]. We add the following explanation to the text:
"…since VOC's are not explicitly carried in the GEOS-fp chemical mechanism. This approach was developed by *Duncan et al.* (2007) to account for the CO source from non-

methane hydrocarbon oxidation." We added the effective CO emissions to Table 1 as suggested.

4. L119-120: Which regions? Methane is well-mixed, and is oxidised in all regions. Could you clarify?

The regions depend on where oxidation occurs, not where the methane is emitted. Thus, if methane is oxidized over Asia, the resulting CO is included in the Asian non-BB tracer. If it is oxidized over North America, it is included in the North American non-BB tracer. We add the following example to the text:
"For example, if methane is oxidized over North America, the resulting CO is included in the North American non-BB tracer."

5. L152-154: Could you elaborate why the observed peaks in Figure 1d are not captured by the GEOS-5 analysis? Could it be due to the underestimation of Asian BB or/and non-BB in the inventory?

Tagged tracers in Fig. 1g suggest that they are due to biomass burning, but this could be due to either insufficient emissions or insufficient model resolution.
We add the following text to Section 3.1.1: "Either biases in emissions or insufficient vertical or horizontal model resolution may thus be responsible for the underestimate. The tagged tracer for biomass burning shows a small increase at the time of the underestimated plumes near hour 22 of the Anchorage-Kona flight (Fig. 1d,g), suggesting that those underestimates are due to the insufficient magnitude of the simulated biomass burning plumes."

6. Did you include biomass burning from South Asia and Australia in your CO simulation? If these are not included, would this lead to the underestimation of the peaks in observed CO in Figure 1f? This is related to the comment above.

Yes, they are included. This is now clear from the new supplemental figure showing the tagged tracer region definitions.

7. L194-196: It is somewhat surprising that this region has notable Asian non-BB influence; could it be the case that the majority of this influence originates from Europe or Central Asia rather than from the Far East?

Non-BB CO from Europe is tagged separately so would not show up in the Asian non-BB tracer. We are not able to distinguish Central Asia from East Asia with the tagged tracers. However, the Asian non-BB contribution here, though notable, is not huge, and given the lifetime of CO it is not too surprising that the large Asian CO source would make some contribution to the background even here.

8. L197-198 and Figure 2f: Would it more precise to attribute the observed CO plumes here to European BB? Could N. American BB contribute to the plumes? Separating European and Asian BB emissions could shed more light on this.

The tagged tracers show little N. American BB contribution to these plumes. We agree that separate European and Asian BB tracers would help shed light on this, but as explained above, these are not available. Examination of the fire emissions from this time period shows fires in both Europe and Asia, making it difficult to separate the two.

9. L212-213: “An underestimate of Eurasian biomass burning contributes to the model underestimates in the North Pacific and North Atlantic, : : :” – same comment as above.

As noted above, we do not have the ability to separate the European and Asian biomass burning contributions.

10. Figures 5 and 6: I suggest to use the same scale between the 2 panels in each figure.

Done.

11. L364-369: The negative trends are not necessarily associated with the lower than average value of 2016. Often, IAV is larger than the trend. Whether 2016 is extreme or not should be defined based on statistical metrics.

We agree that IAV can exceed the trend. The purpose of this discussion is just to point out previous work that shows a trend in MOPITT, and that this can be one factor contributing to the low values in 2016. It is also relevant to the 2nd referee’s question about MOPITT drift. We add the following clarification:
This negative trend may be contributing to the low values in 2016, “although there is also substantial IAV in CO.”

Technical corrections

1. L22: add “boreal” before “summer”

Done

2. L293: replace “summer” with “boreal summer/austral winter”

Done

3. L335: replace “autumn” with “September to November”

We now say September-October, since this is when ATom-3 took place.

4. Figure 8: please tidy up the label on the x-axis.

Fixed

5. Figures 11 and 12: please add “August” in the caption.

Done

6. Table S1: flights are labelled from 0 to 10 – should it be 1-11?

Yes, we updated the numbering to be 1-11.