Anonymous Referee #2
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This manuscript presents a comparison between three modelling products of the Copernicus Atmosphere Monitoring Service (CAMS) and in situ measurements from the KORUS-AQ (and KORUS-OC) campaign in the vicinity of the Korean peninsula during May/June 2016. Airborne, surface, ship-based, and satellite measurements of CO and CO2 are compared to the CAMS analysis and two forecast products at different spatial resolutions. The statistical analysis is relatively straightforward and clearly laid out, and some patterns of over- and underestimation are found for the two tracers under different conditions. The importance of vertical transport in the understanding of these differences could be further explored, as outlined below.

While I understand the other reviewer's comment that this manuscript might be a better fit for GMD, as it is assessing the capabilities of a specific modelling system, the general conclusions about the potential underestimation of CO emissions from China make it relevant for a broader audience as well. This is ultimately an editorial decision. However the quality of the manuscript, datasets and analysis is good, and appropriate for publication.
Response: Thank you!

Below are some suggestions, some major, some minor, on how the analysis might be slightly extended in order to better understand the processes driving the model-data mismatch.

Section 3.3: In the discussion about the **relative agreement in the profile for CO2** vs. **the disagreement between the lower atmosphere values between the observations and the model**, a discussion of the relevance of the mixing height and/or **planetary boundary layer** was somewhat lacking. A difference in profile shape can be attributed **to incorrect fluxes, incorrect mixing**, or a combination of the two. By having two tracers with differing results, it should be possible to deepen this analysis a bit.
There is further discussion about the vertical gradients of the tracers, but no attempt is made to diagnose the **PBL height**. Given the model data and the meteorological information from the aircraft profiles, this should be possible. Could you at least comment on this, and why such an approach was not undertaken? It is even suggested that there might be a "**possible weaker boundary layer mixing in CAMS**". Here **diagnosing the PBL height (as a function of time) from both the model fields and the profiles might be enlightening**.
Response: We have added the following discussion of analyzing differences in profile shapes by having two tracers in Section 3.3: "*CO over Taehwa is more likely to be due to regional transport, as Taehwa is not a strong CO source region. Thus, the vertical gradient of CO over Taehwa does not necessarily reflect the impact of BL mixing over Taehwa.*"
We have also added analyses and discussions of the relevance of the mixing height and/or planetary boundary layer, by adding the new Figure S7 (time series of the mixing layer heights from both the model fields and the measurements), and the following discussion:
"*We further compared the mixing layer (ML) height derived from the KORUS-AQ airborne DIAL-HSRL measurements of aerosol backscatter following the technique from Brooks et al. (2003), and the BL heights from CAMS. We note that ML height is only approximately equal to BL height. We find that CAMS generally underestimates BL heights during KORUS-AQ (Fig. S6). The model underestimation of BL over the Seoul metropolitan (-761.3±39.7 m) is stronger than that over Taehwa (721.7±38.6 m) which is covered by forests instead of urban. This is consistent with the*

CAMS's relatively better capability of capturing vertical gradient of CO_2 over Taehwa compared to that over Seoul, supporting our previous implication of the possible inefficient BL mixing in CAMS over the Seoul urban environment."

Another interesting point might be the representation of urban effects for Seoul in particular. Here it would be interesting to compare the **PBL height** as modelled vs. measured in the vicinity of Seoul compared to other less rural sites. However, this may be beyond the scope of this study.
Response: Thank you. We compared modeled profiles of CO and CO_2 over Seoul and Taehwa to imply possible inefficient modeled boundary layer mixing over the Seoul metropolitan. Please see the response to the previous comment and the response to Reviewer #1, Comment 3 for details. We also added Figure S8, Model bias of boundary layer heights over Seoul and Taehwa (a less rural site).

For the special case of Seoul, the low altitude measurements were taken during missed approaches at the airport. Given all the air traffic in the region, might it be that the CO in this area is locally very much enhanced, and as such not representative of even the relatively small spatial footprint of the CAMS model? Here perhaps a referral to a relevant paper by Boschetti et al. (Tellus B, 2015) looking at **enhancements of CO in the boundary layer** from commercial airline measurements might be relevant.
Response: Thank you. We have added the reference (Boschetti et al., 2015) as well as the following discussion in the Section 3.3.1:
"*In addition, given the air traffic over the Seoul Air Base (where the DC-8 aircraft frequently conducted missed approaches), emissions from airplanes may also contribute to the model biases.*"

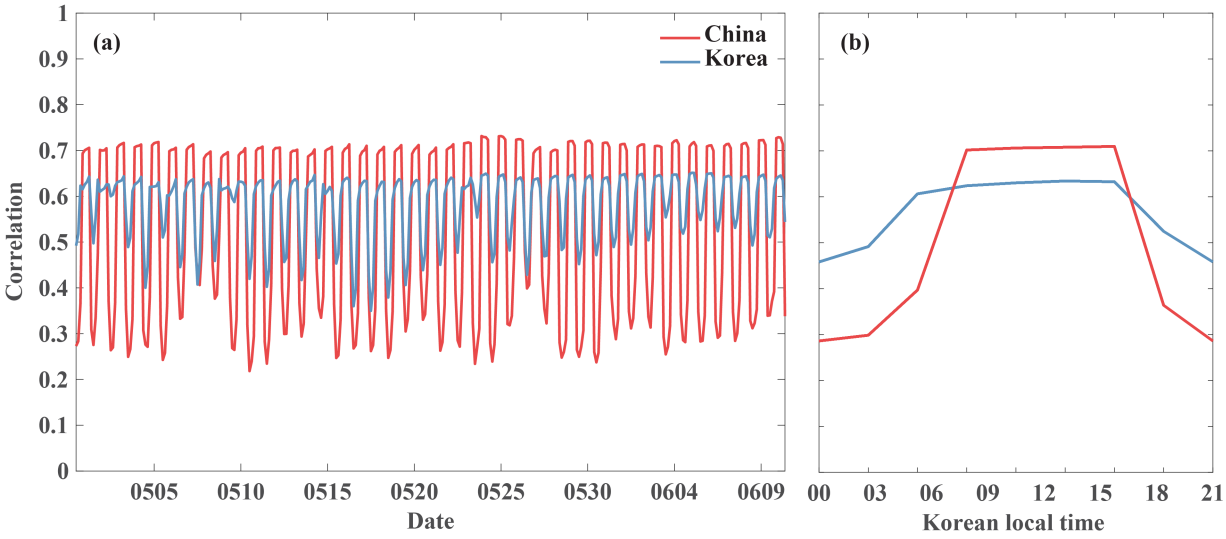
Regarding the assessment of the outflow over the West Sea, I was confused by the phrase: "Hence, the wind speeds dominate the transport flux variations in CO2." I'm not sure what is meant here. Is this because the outflow pattern wasn't as strong as for CO? But aren't both flux variations (more or less) linearly dependent on wind speed anyhow? Please clarify.
Response: Thank you. We have deleted this sentence. Please see the response to Reviewer #1, Comment 12 for details.

The discussion about the correlation of CO and CO2 over the West Sea is quite interesting, and invites further inquiry. The suggestion that the difference in time factors for anthropogenic CO and CO2 (with the former having constant monthly values and the latter having diurnal variability) should effect the correlation over Korea as well. Could it be explained by the differences in transport times, e.g. diurnal CO2 emissions peak in daytime while measurements are being made over Korea, whereas daytime measurements over the West Sea represent nighttime emissions from China, where the difference in time factors is at a maximum? In terms of just the correlation in the fluxes, it should be easy to test if EDGAR has a higher spatial correlation between CO2 and CO in Korea vs. China.
Response: Thank you. The high observed CO and CO_2 correlations over the West Sea and Seoul suggest that CO and CO_2 are likely from common sources. We found that the difference in the time factors of CO emissions and CO_2 fluxes may contribute to the model's inability of capturing such high correlation over the West Sea. However, such difference in the time factors is unlikely to impact the modeled correlation over Seoul as much as it impacts the West Sea. In fact, the diurnal variability of CO_2 fluxes comes from the CO_2 net ecosystem exchange rather than the

anthropogenic part. Since the flights over Seoul are close to the strong common anthropogenic sources of CO and CO_2 (i.e., the Seoul metropolitan area), the correlation over Seoul is dominated by anthropogenic emissions and unlikely impacted by diurnal variability of CO_2 fluxes that comes from the CO_2 net ecosystem exchange. This is supported by the consistency between observed and modeled correlations.

As for the other 3 groups over Korea (i.e., Taehwa, Seoul-Jeju jetway, Seoul-Busan jetway), their observed correlations are not high (i.e., 0.68, 0.62, 0.60, respectively) at the first place compared to the observed high correlations over the West Sea (0.89) and Seoul (0.78). This implies that CO_2 and CO observed over these three flight groups may not come from common sources and/or have been mixed with the environment.

We agree with the reviewer that correlation in the fluxes may provide valuable insights to explain the correlations in the modeled abundance correlations. The following figure shows that time series of spatial correlations between CO emissions and CO_2 fluxes in CAMS over East China (which dominates Chinese contribution to the West Sea (Tang et al., 2018)) and Korea. There is a strong diurnal cycle in the correlations caused by the difference in time factors.



The diurnal cycle of spatial correlations between CO emissions and CO_2 fluxes over Korea in CAMS peaks (~0.7) in daytime while measurements over Korea were made. On the other hand, during the nighttime, the correlations between CO emissions and CO_2 fluxes in CAMS are relatively low over East China (<0.4). This implies that the relatively low correlations between the CO and CO_2 abundances over the West Sea in CAMS may reflect the effect of nighttime emissions from East China in CAMS.

We thank the reviewer for pointing this out and have included this in the manuscript (text in Section 3.4 and the new Fig. S8).

The analysis of the satellite data is not particularly illuminating, with the exception of the separation of MOPITT data into those influence by outflow. Regarding the use of the OCO-2 data, most of the data references are pre-launch, and should be updated. Wunch et al. 2017 would be a better up to date reference than those from 2011, and an updated estimate of the OCO-2 precision, even if it is coming from grey literature (such as the ACOS OCO-2 User's Guide) would be preferable to a largely theoretical assessment from Boesch et al., 2011.

Response: Thank you. We have included the following two references:

Osterman, G. B., Eldering, A., Avis, C., Chafin, B., O'Dell, C., Frankenberg, C., ... & Crisp, D. (2015). Orbiting Carbon Observatory-2 (OCO-2) Data Product User's Guide, Operational L1 and L2 Data Versions 7 and 7R. NASA Jet Propulsion Laboratory, California Institute of Technology.
Wunch, D., Wennberg, P. O., Osterman, G., Fisher, B., Naylor, B., Roehl, C. M., ... & Griffith, D. W. (2017). Comparisons of the Orbiting Carbon Observatory-2 (OCO-2) X CO 2 measurements with TCCON. Atmospheric Measurement Techniques, 10(6), 2209.

It is unclear what is meant by the "recommended quality control" in section 2.2.4. Does this mean the standard quality flag? Was the bias correction applied? Was a certain warn-level threshold used? Please elaborate.

Response: "recommended quality control" means the standard quality flag, and we have changed the term in the manuscript. The standard quality flag we used is from Table 1 and Table 2 of Mandrake et al. (2015) (https://co2.jpl.nasa.gov/static/docs/OCO2_XCO2_Lite_Files_and_Bias_Correction_0716.docx):

Table 1: Quality Filters Applied to Land Soundings

All Land Soundings		
Field	**Lower Limit** (> or =)	**Upper Limit** (< or =)
Warn level	N/A	15
Outcome flag (not in lite file)	N/A	2
Preprocessors/h2o_ratio	0.700	1.030
Preprocessors/co2_ratio	0.995	1.025
Preprocessors/dp_apb	-15.00	5.00
Retrieval/dp	-5.00	10.0
Retrieval/aod_ice	N/A	0.050
Retrieval/Aod_sulfate	N/A	0.400
Retrieval/Aod_dust*	0.001	0.30
Retrieval/Co2_grad_del	-70.0	70.0
Retrieval/albedo_2	0.10	N/A
Blended albedo (2.4*albedo_3 – 1.13*albedo_1) (both in retrieval group)	N/A	0.8
dof_co2 (not in lite product)	1.8	N/A
Sounding/airmass	N/A	3.6
* or AOD dust = 0.0		

Table 2: Quality Filters Applied to Ocean Glint Soundings

Ocean Glint Soundings		
Field	**Lower Limit** (> or =)	**Upper Limit** (< or =)
Warn level	N/A	15
Outcome flag (not in lite file)	N/A	2
Preprocessors/co2_ratio	0.994	1.020
Preprocessors/dp_apb	N/A	0.00

Retrieval/dp	-3.00	9.0
Retrieval/Co2_grad_del	-30.0	5.0
Retrieval/albedo_slope_3•10^5	1.0	10.0
Retrieval/windspeed	2.0	N/a
Sounding/snr_weak_co2	380	N/A
Sounding/airmass	N/A	3.5

We used the suggested warn-level threshold in the Table (i.e., <=15). We have added the warn_level information in the manuscript. The bias correction is not applied to the data used in this study, as we used Standard Data files (L2Std) instead of Lite files.

If the Taylor skill score is being used for the assessment of the forecasting skill as in section 3.1, the equation should be in the main paper, and not just in the suppplement. Please include it here as well.
Response: We have moved the equation from supplement to the section 3.1 of the paper.

P4, L18-20: The text here states that the CO analysis runs at "approximately 40 km horizontal resolution", but in Figure 1 it is shown to be 80 km horizontal resolution. Later on page 5 80 km is given again, and the text on P4 refers to that fact that the CO2 analysis is at a higher spatial resolution (in both the horizontal and vertical). Please ensure that the information is consistent and correct.
Response: Thank you for pointing it out. The CO analysis is at approximately 80 km horizontal resolution while the CO_2 analysis is at the approximately 40 km horizontal resolution. We have corrected the P4, L18-20.

Minor/typographical comments:
P2, L11: show -> shows
Response: We have corrected it.

P2, L12: "over Seoul metropolitan" -> either "over the Seoul metropolitan area" or "over Seoul"
Response: Thank you. We have changed that to "*over the Seoul metropolitan area*".

P3, L6: near-real time -> near-real-time
Response: Correction made.

P3, L16: field -> field campaign
Response: Thank you. We have added "*campaign*" there.

P4, L20: Perhaps this should be one sentence?
Response: Thank you for noticing this. This should be one sentence and we have corrected it.

P4, L25: 4-days shouldn't be hyphenated (four days)
Response: Correction made.

P4, L26: 16km -> 16 km
Response: Thank you for pointing this out. We noticed that in the text we used "*16km forecast*" or "*16 km forecast*" a few times. To be consistent, we changed them into "*16-km forecast*". Same for the "*9-km forecast*".

P5, L26: The -> the
Response: Correction made.

P6, L1, L2, and often afterwards: South Korean peninsula -> the South Korean peninsula
Response: Thank you. We have edited the manuscript accordingly.

P6, L8-10: The third scientific question needs to be restated. It doesn't make sense as it is written here.
Response: Thank you. We have rephrased the question (3):
"(3) how well do models perform and what improvements are needed to better represent atmospheric composition over Korea and its connection to the larger global atmosphere (Kim and Park, 2014, KORUS-AQ White Paper)."

P6, L27: data is -> data are
Response: Correction made.

P6, L30-31: Wouldn't UTC be one day behind local time?
Response: Thank you for pointing this out. Korea time = UTC time +9. We have changed "*UTC time is one day ahead of Korea local time*" to "*UTC time is one day behind Korea local time*".

P7, L7: combustion signatureS (plural needed to match grammar)
Response: Correction made.
P7, L10-12: Not sure which preposition should be used to describe the jetway flights, I would suggest "in", but consistency is more important. Also check the grammar: "Flights in the Seoul-Busan jetway were designed to capture... Flight in the Seoul-Jeju jetway, on the other hand, sampled air over..."
Response: We have changed "*Flights over Seoul-Busan jetway*" to "*Flights in Seoul-Busan jetway*"; and "*The flights in Seoul-Jeju jetway, on the other hand, samples air over local power*" to "*The flights in Seoul-Jeju jetway, on the other hand, sample air over local power*".

P7, L17: Baengnyeong site is located in less populated Baengnyeong Island, Incheon which is northwest of Seoul. -> The Baengnyeong site is located on the sparsely populated Baengnyeong Island, Incheon, northwest of Seoul.
Response: Thank you. We have changed accordingly.

P7, L19: "on remote" -> "on the remote"
Response: Correction made.

P8, L21: resolutions -> the resolutions
Response: Correction made.

P9, L2: Here is the first of many instances of referring to the in situ measurements collected from the DC-8 aircraft as simply "DC-8". As a reader I found this jarring. Perhaps instead refer to the dataset as the "DC-8 in situ data" or the "aircraft data" or "the airborne measurements"?
Response: Thank you for pointing it out. We have changed "*DC-8*" to "*the DC-8 aircraft data*" or "*the airborne measurements*" in the manuscript to refer the airborne measurements from the DC-8 aircraft.

P9, L8: inconsistent description of correlation range (to vs. -)
Response: We have changed the "*to*" to "–".

P9, L12: CAMS have -> CAMS has
Response: Correction made.

P9, L15: those for -> that of
Response: Correction made.

P10, L14: tale -> tail (Please change later instances as well.)
Response: Correction made.

P10, L25: West Sea -> the West Sea
Response: Thank you. We have changed all the "*West Sea*" to "*the West Sea*" in the revised manuscript.

P11, L28: than in Korea -> as in Korea
Response: Correction made.
P12, L1: West Sea -> the West Sea
Response: Correction made.

P13, L27: West Sea -> the West Sea
Response: Correction made.

P14, L11: Baengnyeong -> the Baengnyeong
Response: Correction made.

P15, L10 (and other locations): Olympic Park should always be capitalized (both words)
Response: Thank you. Correction made.

P15, L13: exhibit -> exhibits
Response: Correction made.

P15, L23: shop tracks -> ship tracks
Response: Correction made.

P17, L7-9: There are a few disjointed short sentences here. (e.g. "Because the size of CO data () is much larger than that of CO2 ()."") Perhaps they could be joined together to make more sense?
Response: We have joined this sentence and the two followed sentences into one. I.e., we have

changed:
"*Because the amount of CO data (13612 retrievals for MOPITT and 25509 for IASI over our study domain during KORUS-AQ) is much larger than that of CO_2 (42 for GOSAT over our domain during KORUS-AQ). This is illustrated in Fig. 10 and listed in Table 4. There are more observational constraints for CO in CAMS resulting to better performance of ANs CO.*"
to:
"*Because the amount of CO data (13612 retrievals for MOPITT and 25509 for IASI over our study domain during KORUS-AQ) is much larger than that of CO_2 (42 for GOSAT over our domain during KORUS-AQ), there are more observational constraints for CO in CAMS resulting to better performance of ANs CO (Fig. 10 and Table 4).*"

P17, L24-25: near Korean coast -> near the Korean coast
Response: Correction made.

P18, L15: "(by -2 to -4 ppmv for CO2 and -86 to -88 ppbv)" -> "(by -2 to -4 ppmv for CO2 and -86 to -88 ppbv for CO)"
Response: Correction made.

P27, caption label: I would suggest using "bright" instead of "luminous" to describe the colours. Also add some articles when describing the sites, i.e. "The Olympic Park and Yonsei sites are located in an urban region (Seoul) while the Baengnyeong and Fukue sites are located in remote regions. The Taehwa site is located in a forest near Seoul."
Response: Thank you. We have substituted "*luminous*" with "*bright*". We have also added references to the caption when describing the sites.

P34, Figure 9: The figure label includes DC-8 still, but I believe this is in fact surfacebased in situ data. If so, please remove these confusing labels.
Response: Thank you for pointing this out. We have changed "*DC-8*" to "*Observations*" in the label.

P40, Table 3: The label refers to satellite measurements, but it should be in situ measurements.
Response: Thank you. Correction made.