The authors have presented an evaluation of the CAMS prediction system, focusing on CO and CO2, during the KORUS-AQ campaign. They evaluated three different CO and CO2 forecast and analysis products: 16-km CO and CO2 forecasts, 9-km CO and CO2 forecasts, and analyses of CO and CO2 at 80 km and 40 km, respectively. The CAMS products were compared to the KORUS-AQ aircraft data as well as to ground-based and satellite measurements of CO and CO2. They found that CAM overestimated CO2, suggesting a positive bias in background CO2, whereas it underestimated CO, with the underestimate confined mainly to the lower troposphere. The authors also found that CAMS underestimates the outflow of pollution from China, possibly due to an underestimate of Chinese emissions. The study is a nice evaluation of CAMS CO and CO2 under unique conditions. I have no major concerns about the analysis.

Response: Thank you!

My main concern is about the appropriateness of the manuscript for ACP. As a model evaluation study, I think it is better suited for GMD than ACP. My comments below are relatively minor, but must be address before the manuscript can be accepted for publication, if the Editor decides it is suitable for ACP.

Response: Thank you. We understand the reviewer's concern. But we think that our manuscript is still within the scope of ACP for the following reasons. We double-checked the main subject areas of ACP, which includes atmospheric modelling, field measurements, remote sensing, and laboratory studies of gases, aerosols, clouds and precipitation, radiation, and so on. In this study, we assess the performance of the Copernicus Atmosphere Monitoring Service (CAMS) global prediction system using field measurements from aircraft, ground sites, and ships, and remote sensing data during the KORUS-AQ field campaign. In addition to model evaluation, this study also addresses a few scientific topics on atmospheric chemistry and physics, including (1) anthropogenic combustion characteristics in Korea and China (as well as how well CAMS captures it), (2) impacts of different model configurations and environmental conditions on CO simulations, and (3) implications for CO emissions in CAMS. Thus, this manuscript is in line with the research focuses of ACP. Furthermore, we believe that the findings of this manuscript will be of interest not only to CAMS developers and users, but also to the general atmospheric chemistry community. Therefore, ACP is a perfect platform for us to share these results with the community. We sincerely hope that the editor will consider publishing this manuscript in ACP.

Comments
1. There is no mention of the **CAMS OH field**, which is critical for the simulation of CO. What is the global mean OH from the analyses and forecasts? On page 5, lines 28, it is mentioned that the 16-km CO forecasts use a linear chemistry scheme. A brief description of the scheme, either in the manuscript or in the supplement, would be helpful.

Response: The two high-resolution forecast products (FC16s and FC9s) employ a linear chemistry scheme, without the direct use of model OH.

The OH fields are only used in the CAMS ANs for CO which has full chemistry. In the ANs, the global and Northern Hemisphere mean are 0.98×10^{-6} molecules/cm^3 and 1.20×10^{-6} molecules/cm^3 during May 2016, respectively. We have extended description of the linear chemistry scheme at the end of Section 2.1. Specifically, we extended

"*A linear chemistry scheme is used in FC16s for CO (C-IFS-LINCO) for computationally expediency (Claeyman et al., 2010; Flemming et al., 2012; Massart et al. 2015; Eskes et al., 2017). Key aspects of the three CAMS configurations evaluated in this study are listed in Table 1.*"
to:
"*ANs for CO use the on-line implemented chemical mechanism (C-IFS-CB05, Flemming et al., 2015) that is an extended version of the Carbon Bond mechanism 5 (CB05, Yarwood et al., 2005). Because hydroxyl radical (OH) is an important sink for CO, modeled OH is critical for the simulation of CO (Gaubert et al., 2016, 2017). In the ANs for CO, the global and NH mean of air mass-weighted OH are 0.98×10^{-6} molecules/cm^3 and 1.20×10^{-6} molecules/cm^3 during May 2016, respectively (calculated following recommendations from Lawrence et al. (2001)). The mean OH from the ANs for CO is consistent with previous studies (e.g., Lawrence et al., 2001; Lelieveld et al., 2016; Gaubert et al., 2016, 2017). A linear chemistry scheme is (C-IFS-LINCO) used in FC16s and FC9s for CO for computationally expediency (Claeyman et al., 2010; Flemming et al., 2012; Massart et al. 2015; Eskes et al., 2017). C-IFS-LINCO computes CO sources and sinks using the approach developed by Cariolle and Déqué (1986) and updated by Cariolle and Teyssèdre (2007), without direct use of modeled OH. C-IFS-LINCO is less computationally demanding than the full chemistry, permitting simulations at higher resolutions (Massart et al. 2015). Key aspects of the three CAMS configurations evaluated in this study are listed in Table 1.*"

2. It is stated that the overestimate in CO2 is associated with the bias correction in the biogenic source of CO2, but there is no discussion of this "bias correction". Furthermore, in Agusti-Panareda et al. (2016) CAMS CO2 was underestimating CO2 observations from the surface in situ network and from TCCON, which the "bias correction" (the biospheric flux adjustment) reduced. Why is CAMS overestimating CO2 here? A discussion is needed about the **treatment of the biospheric fluxes in CAMS and its possible impact on the modeled CO2 over Korea**.
Response: First of all, we appreciate the reviewer for noticing this. According to Agusti-Panareda et al (2016), in the Northern Hemisphere there is a growing overestimation of the atmospheric CO_2 at the end of winter and throughout spring (from March to May); while at the end of the growing season in both the Northern Hemisphere and the Southern Hemisphere (August and March, respectively) there is a growing negative bias, i.e. an overestimation of the sink based on observations from NOAA/ESRL and TCCON (Section 5.1 of Agusti-Panareda et al (2016)). This is consistent with our finding. Agusti-Panareda et al (2016) also implies that the CO_2 overestimation by CAMS is enhanced in the BFAS simulation (Section 5.1 of Agusti-Panareda et al (2016)).
However, we note that the statement "*As found by Agusti-Panareda et al (2016), the overall overestimation of CO_2 is associated with the biogenic bias correction*" is inappropriate. We have changed it to "*Agusti-Panareda et al. [2016] also suggests CO_2 is overestimated by CAMS in the Northern Hemisphere at the end of winter and throughout spring*".
We have also included more discussions on the bias correction section 2.1 (where we introduce biogenic flux adjustment scheme (BFAS)), including treatment of the biospheric fluxes in CAMS, and its possible impact on the modeled CO_2 over Korea.

3. On page 11 it was shown that the model produced steeper vertical gradients in CO and CO2 than observed over Seoul, which the authors suggested may be due to weak boundary layer mixing. Since CAMS seems to perform better over Taehwa, it would be interesting to compare the vertical

Response: We compared the observed vertical gradient of CO_2 over Seoul and Taehwa. We also analyzed the PBL height derived from observations and CAMS.

We have added the following analysis in the revised manuscript (Section 3.3.1):

"*We further find that compared with the Seoul metropolitan, the observed vertical gradient of CO_2 over Taehwa (~0.03 ppmv/hPa) below 925 hPa is smaller, which is relatively better captured by CAMS (0.02–0.12 ppmv/hPa). This again implies the possible inefficient boundary layer mixing in CAMS over the Seoul urban environment.*"

"*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 boundary layer mixing over Taehwa.*"

Response: Analyses of both CO and CO_2 (ANs) do show improvement from the free running simulation (i.e., FC16s). However, the new 9-km forecast product (i.e., FC9s) is expected to have a better performance of FC9s because:

(1) FC9s is initialized with the analysis product every 24 hours (i.e., it incorporates information of analyses every 24 hours);

(2) FC9s has a much higher horizontal resolution (9 km) than the analyses (80 km for CO and 40 km for CO_2).
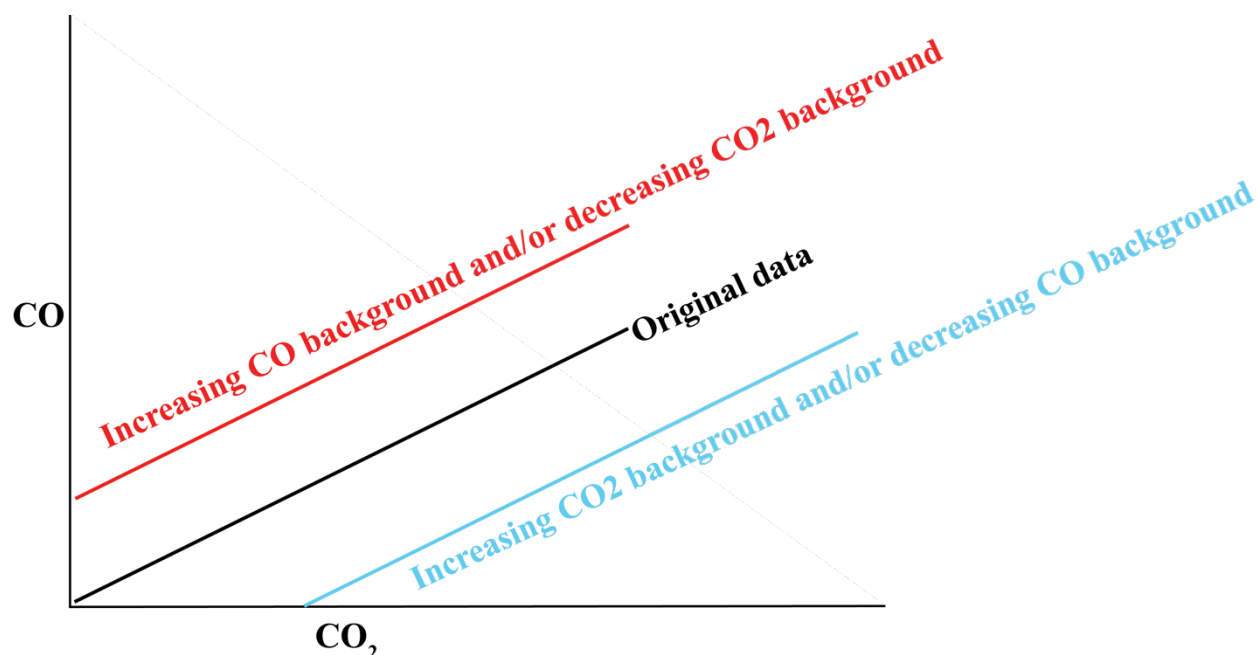
In addition to Figure S1 (i.e., the new Figure S2), Table 1 also summarized configurations of CAMS global atmospheric composition products including the analysis product of CO (AN_CHEM) and CO_2 (AN_GHG). We have also added more information about the configure and quality of the analyses:

"*Observations of both CO and CO_2 are assimilated in 12-hour assimilation windows. Inness et al. (2015) found that CO total column field, vertical distribution, and concentrations in the lower troposphere are improved by assimilating the CO total column from MOPITT. Assimilation of the GOSAT XCO_2 lead to improvements in mean absolute error and bias variability in XCO_2 fields during the year 2013 (Massart et al., 2016).*"

Response: Thank you for pointing this out. We used slopes of the CO to CO_2 regressions as our enhancement ratios.

The estimated regression slope in the RMA corresponds to enhancement ratio of CO and CO_2 (dCO/dCO_2). No background values are used here. In fact, the definition of the background does not change the regression slope. Please see the following figure for a demonstration.

The figure shows a plot of CO (y-axis) versus CO_2 (x-axis) with four lines:
- "Increasing CO background and/or decreasing CO2 background" (red line, upper)
- "Original data" (black line, middle)
- "Increasing CO2 background and/or decreasing CO background" (blue line, lower)

Nevertheless, we agree with the reviewer that the usage of $\Delta CO/\Delta CO_2$ in this manuscript could be misleading, and have changed $\Delta CO/\Delta CO_2$ to dCO/dCO_2.

6. The authors found that CAMS underestimated CO during China outflow events, but overestimated it under normal conditions. What are the **different source regions** for air reach the West Sea during "outflow" and "normal" conditions? To what degree is the model bias due to CAMS not capturing this difference in transport as compared to it not have the correct balance of emissions in China?

Our recent work with Community Atmosphere Model with chemistry (CAM-chem) tagged CO tracers studied the different source regions. Taking condition on June 5th (corresponding to the June 4th flight) as an example of normal conditions, both China and Korea contribute to the CO over the West Sea at surface. At 800 hPa, Japan, Russia, China, the rest of the world, and ocean all contribute to CO over the West Sea. However, CO concentrations over the West Sea is relatively low at these conditions. The following figure (Fig. S6 of Tang et al., 2018) shows spatial distributions of the tagged CO (ppbv) on June 5th, 2016 at model surface, 800 hPa, and 500 hPa (Tag 1: Korea; Tag 2: Japan+Russia; Tag 3: Indonesia+India; Tag 4: EA-S; Tag 5: EA-M; Tag 6: EA-N; Tag 7: the rest of the world+ocean; Tag 8: CH_4 oxidation; Tag 9: biogenic; Tag 10: chemical production besides CH_4):
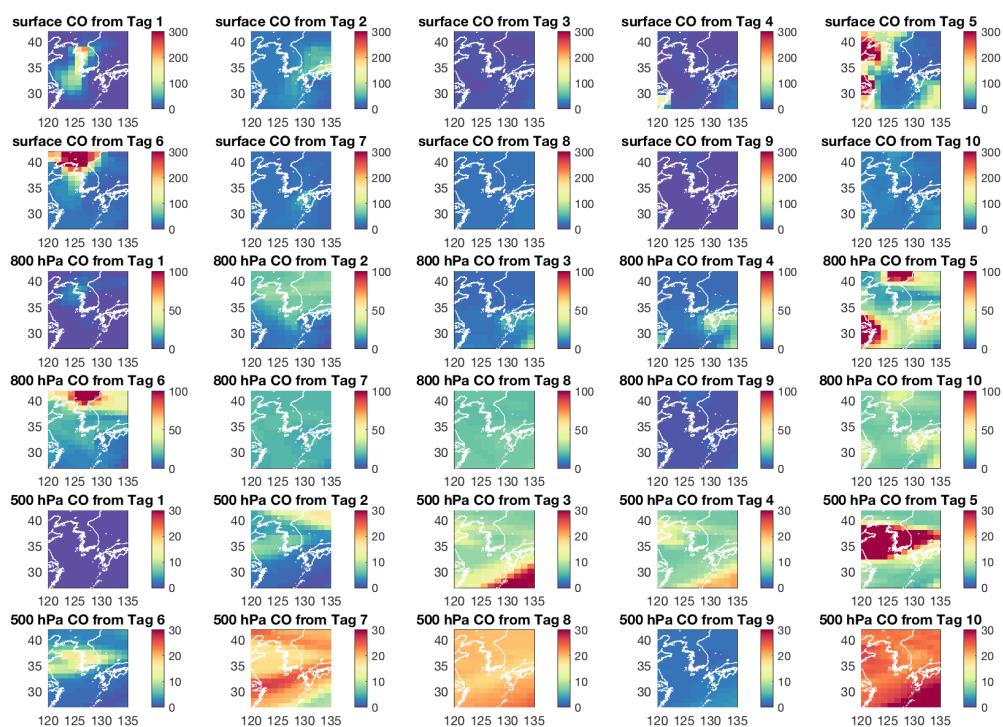
During outflow events (e.g., conditions during the May 30th flight), contribution from China are largely enhanced and becomes dominant at surface, 800 hPa, and 500 hPa. CO concentrations over the West Sea is relatively high during China outflow events. The following figure (Fig. S7 of Tang et al., 2018) shows spatial distributions of the tagged CO (ppbv) on May 31st, 2016 (corresponding to the May 30th flight) at model surface, 800 hPa, and 500 hPa (the Tags are the same as in the Fig. S6).
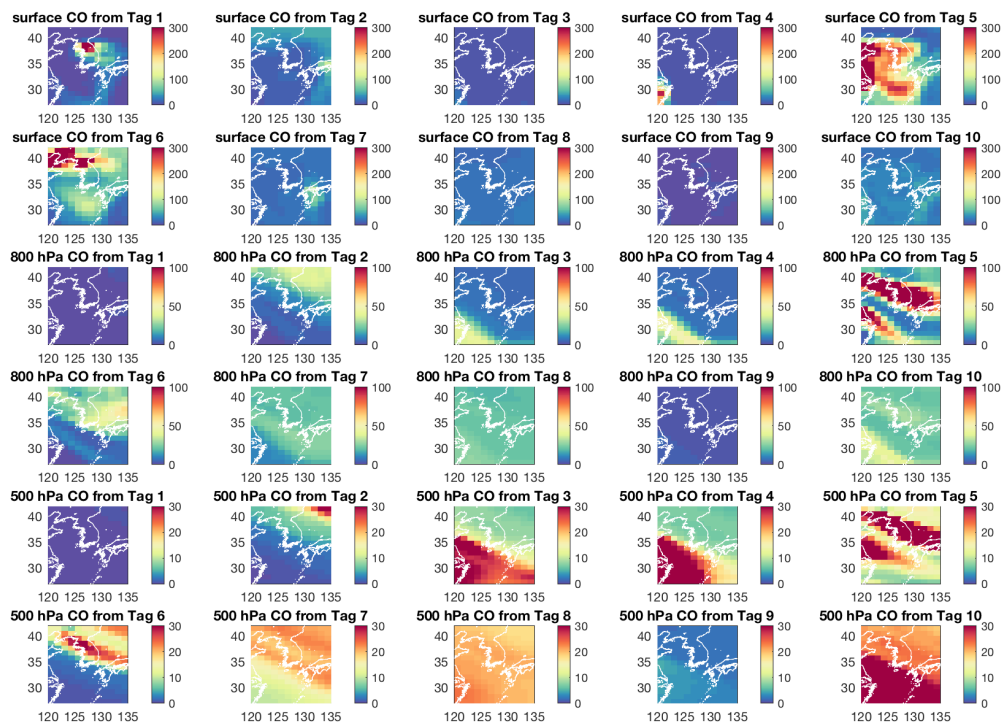
In Tang et al. (2018), we found that estimates of CO emissions in China rather than transport is potentially the main source of model bias over the West Sea. We have included the discussions and reference in the revised manuscript:

"*More elaborate analysis of source contributions during KORUS-AQ is beyond the scope of this study and can be found in Tang et al. (2018), which suggested that during China outflow events, the contribution from Chinese direct emissions to CO over the West Sea is largely enhanced and dominant.*"

Technical Comments

1. Page 4, line 26: add a comma between "forecast" and "CO2".
Response: We have added the comma.

2. Page 4, line 28: add "the" between "on" and "free-running".
Response: Thank you. We have edited accordingly.

3. Page 5, line 1: Is Figure 1 really necessary? I don't think it adds much to the manuscript. Since there are already 11 figures, I would suggest removing Figure 1.
Response: We have moved Figure 1 to supplement (the New Figure S2).

4. Page 6, lines 1 and 2; add "the" before "South Korean peninsula".
Response: Correction made.

5. Page 6, line 7: remove "including" before the list of the three questions.
Response: Thank you. We have deleted the "*including*".

6. Page 6, line 8: The wording for question (3) needs improving. The English is not quite correct.
Response: Thank you for pointing this out. We have changed the sentence to *"(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)."*

7. Page 8, lines 22 and 23: The revisit and overpass times seem to be used interchangeably here. The revisit time of OCO-2, for example, is 16 days since it is in the A-Train orbit. However, the local overpass time is around 1:30 pm. For GOSAT the revisit time is 3 days.
Response: Thank you. We have changed "*revisit*" to "*overpass*".

8. Page 8, line 26: Change 0.09e18 from e-notation to standard SI notation.
Response: We have changed the notation accordingly.

9. Page 9, line 5: Please add "is" between "CO2" and "associated".
Response: We have deleted this sentence.

10. Page 10, line 1: The variance in CO in the May 3rd data does not seem larger than average to me. In fact, it seems to be smaller than average.
Response: We have changed the sentences "*For example, the flights in May 3rd, May 17th, May 24th, May 29th, and May 30th were specifically designed to capture Chinese pollution outflow. In these days, the variances in CAMS biases for CO (but not CO_2) are larger than the average*"
to
"*For example, parts of flight tracks on May 3rd, May 17th, May 24th, May 29th, and May 30th were specifically designed to capture Chinese pollution outflow. In these days, the variances in CAMS biases for CO (but not CO_2) are generally larger than the average except for the flight tracks on May 3rd when Chinese influences were expected to be weak*"

11. Page 10, lines 12 and 14: Please change "tale" to "tail".
Response: Thank you. We have changed it.

12. Page 12, line 4: It is unclear what is meant by the statement that "the wind speeds dominate the transport flux variations in CO2." It the argument here that the meteorological uncertainty is the dominant contribution to the uncertainty in the forecast and analysis fields? If so, how does one come to that conclusion from Figure 7?
Response: Because the variations in CO_2 density are very low relative to CO_2 background, the pattern of the CO_2 fluxes in the Figure (CO_2 fluxes = wind speed $\times$ CO_2 density) mostly display pattern of wind speed instead of pattern of CO_2 density. However, we find the implication of "*the wind speeds dominate the transport flux variations in CO_2*" to be redundant with previous sentences, and this sentence itself is confusing. We have deleted it.

13. Page 15, line 23: Section 4.2 only discusses the comparison to ship data of CO, not CO and CO2.

Response: Thank you. We have deleted "*and CO$_2$*".

14. Page 15, line 23: change "shop tracks" to "ship tracks".
Response: Correction made.

15. Page 17, line 7: Change "size of CO data" to "amount of CO data".
Thank you. We have changed "*size*" to "*amount*".

16. Page 40, Table 3: The title for the table is wrong. This is the same title as for Table 4.
Response: Thank you for pointing this out. We have changed the title to "***Table 3.*** *Enhancement ratios of CO to CO$_2$ (ppbv/ppmv), CO and CO$_2$ correlations, and bias of CO to bias of CO$_2$ correlations from airborne measurements, CAMS FC16s, ANs, and FC9s.*"

17. Figure S1: Should the labels "FX9s" and "FX16s" in the figure be "FC9s" and "FC16s"?
Response: Thank you for noticing this. The labels should be "*FC9s*" and "*FC16s*", and we have corrected them.