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Interactive comment on “Global carbon monoxide products from combined AIRS, TES and MLS measurements on A-train satellites” by J. X. Warner et al.

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We wish to thank reviewer #3 for the valuable comments. We have responded to all of the reviewer's points with each reply starting with "ANSWER:" We have kept the original reviewer's comments before our answers. We appreciate this reviewer's comments, which we believe made this paper and the related study better. Finally, we note that this reviewer recognized a number of positive aspects in our approach, e.g, its novelty. We also thank him/her for this.

— Interactive comment on “Global carbon monoxide products from combined AIRS,

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General comments The manuscript describes a method to combine different sets of carbon monoxide (CO) observations using the Kalman filter equation. Unlike a data assimilation problem, the presented method doesn't use a numerical model to propagate the observational updates in space and time, but the data set with better spatial coverage is used as a background state. The aim of this method is to deliver a new global product combining the advantages of both data sets: better spatial resolution from one side, the AIRS CO retrievals, and better spectral resolution from the other, TES or MLS CO profiles. To my knowledge, this study is the only work applying a data assimilation algorithm to different observations without a model. Whereas, the works on delivering combined observational products are already known.

The authors show that the combined product demonstrates improved sensitivities as compared to the AIRS-only retrievals, and improved coverage compared with the TES and MLS CO data. The combined product is validated against independent data sets. The advantage of using the combined product in a data assimilation work is not discussed.

ANSWER: The advantage of using the combined product in a data assimilation framework, in comparison to assimilating several observational data sets sequentially, needs to be studied. However, it is outside the scope of this study.

The overall presentation of the results is clear and concise. The language is adequate and the use of graphics helps to understand the content.

Specific comments

Page 15412. Line 6: "However, as in the case of other nadir sounders,..." - I would recommend to add a reference here.

ANSWER: We have re-written the sentence in the manuscript as follow. It is clearer,

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and such; we would not need a reference: “However, as a nadir sounder, it measures relatively thick integrated layers with most of the sensitivities in the troposphere; and therefore, lacks details in the relatively thin UTLS (Upper Troposphere and Lower Stratosphere) layer.”

The lines 15-20, a reference is missing as well.

ANSWER: We added the following reference and change the sentences to: “A number of radiatively significant gases have strong vertical gradients in composition across the tropopause, including ozone and water vapor. The variability in their tropopause vertical gradients is due to the transport across the tropopause and their sources and sinks in this region. These interactions have a significant impact on chemistry-climate coupling (Holton et al., 1995).”

Page 15414. Line 25: “...measurements taken within a short time period (15-30 min).” I suggest 1) to describe quantitatively the background and observational state vector; and

ANSWER: We have changed the sentence as: “We do not attempt to evaluate any time variability in the CO field, but to simply combine CO of collocated pixels from AIRS, TES, and/or MLS that are part of the A-train satellite constellation and are measured within a short time period (15 – 30 minutes).” The details about the background and observational state vector are described in the follow up algorithm sections.

2) to discuss if the localization of the error covariances is needed (to filter out small and noisy correlations at large distances).

ANSWER: We use a formulation similar to the Kalman filter equation, however, we do not use the ensemble Kalman filters that cause “spurious correlations” when a small ensemble size is used. Since we use an exponential correlation, the error covariance is not correlated at large distances.

Page 15415. Line 8: “The population of the profiles... is determined... by the observed

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variances..." This sentence is not clear to me.

ANSWER: We have removed this sentence. The algorithm section describes what this sentence was intend to convey.

Line 17: a reference to (Kalman, 1960) is needed.

ANSWER: We added the following reference: "The Kalman filter algorithm (Kalman, 1960) in general form is as follows..." and we added the reference in the References Section: Kalman, R., A new approach to linear filtering and prediction problems Trans. ASME, Ser. D, J. Basic Eng., 82, 35-45, 1960.

Page 15416. Line 1: "Since the variable amount..." It is not clear. Do you mean "the size of the observation vector X_0 "?

ANSWER: Yes, "the size of the background and observation vectors." We have changed the sentence as "Since the number of variables in the control vector is not prohibitively large and R is assumed diagonal, we compute the inverse matrix in the gain matrix (i.e., K) directly."

Line 20. The power law equation is not correct.

ANSWER: This was a mistake during typing for publishing on ACPD. We apologize for not catching the mistake during proof-reading. The correct equation is included in the final text.

Page 15417. Line 10: "the correlation lengths ... were chosen to match the measurement characteristics and sensitivities of AIRS and TES." Could you explain in more details how do you chose these length scales?

ANSWER: We added, "Specifically, we use a horizontal correlation length of 750km so that the entire AIRS swaths are influenced by TES measurements from AIRS nadir points considering AIRS swaths are approximately 1600km wide. The vertical correlation length of 0.17 is chosen to match the number of vertical levels correlated as shown

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in Fig.2 right panel." in the text.

Line 17: "This is based on previous knowledge and validation experience." I suggest to add a reference here.

ANSWER: We replaced "This is based on previous knowledge and validation experience, which shows it is reasonable to place more emphasis on TES data in the lower troposphere and AIRS data in the mid-troposphere." with "Three dimensional retrieval errors are difficult to quantify due to the limited amount of in-situ measurements in both temporal and spatial dimensions. The retrieval errors distributed by the individual teams (AIRS and TES in this case) are defined and computed differently, which means they cannot be used together. We used the statistics of the validation summaries from various studies to derive one global set of error profiles (Luo et al., 2007; McMillan et al., 2011; Warner et al., 2007 and 2011; Yurganov et al., 2008) to reduce prescribed errors for AIRS in the mid troposphere and for TES in the lower troposphere. Additionally, we considered the statistics of the averaging kernels (AKs) from AIRS and TES to weight the relative importance of the data in the vertical dimension. We have found that constructing the global error profiles from our experience of validation and the retrieval AKs provides a better estimate than the errors distributed by the retrieval teams."

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