Summary of "Quantifying and Attributing CO Emissions over Central Asia using TROPOMI and Explicit Observational Uncertainty" by Feng et al.

In this paper, Feng et al. apply a top-down inversion method to derive CO emissions estimates over Central Asia using TROPOMI CO observations. They incorporate a novel uncertainty analysis into their approach, which excludes emission estimates from grid cells that have high sensitivity to observational perturbations within the uncertainty range of TROPOMI. They analyse the timeseries of their top-down CO emissions in several site categories, showing considerable decreases in emissions between 2019 and later years. They then infer the emission factors of coal powerplants within the study area. Finally, they compare to bottom-up database EDGAR, which shows considerable under/over estimations depending on the location investigated.

This study builds upon previously published work, applying the inversion framework to an understudied region whilst expanding it to include a new uncertainty analysis. It advances both the methodological approach of the inversion scheme used, and the scientific knowledge of CO emissions within the study region. Emission trends within the timespan of the study are well analysed. Spatial correlations to industrial and natural sources are investigated, from which inventory and policy recommendations are justified. The figures generally support the scientific arguments presented, though the presentation of the data could be improved in most cases. Interesting and scientifically relevant conclusions are found regarding the decline in CO emissions within the region over the study period, the effect of observational uncertainty on the inversion results, and correlations between coal power station size and emission factors.

The comparison between the EDGAR anthropogenic inventory and inversion results substantially limits the conclusions that can be reached from this work because, as the authors note, "discrepancy arises because the bottom-up EDGAR inventory, by design, excludes non-industrial sources". Furthermore, this study would be greatly improved with a validation of the inversion scheme's performance using independent data. In the absence of this, an expanded account of the limitations and known errors of the inversion would be sufficient, but again this limits the conclusions that can be drawn from the study. Comparison to coal consumption data shows the inversion results are physically plausible, but demonstrates nothing further than this. Overall, justifications of confirming "the consistency between satellite-inferred emissions and bottom-up activity estimates" are not valid when the inversion scheme accuracy has not been rigorously tested, the bottom-up inventories include only anthropogenic emissions, and the coal power stations have poorly-constrained emission factors.

Conclusions on the "effectiveness of MFIEF" inversion scheme should not be claimed to be shown in this study without a comparison to independent data. The decrease in annual CO emissions found (~38%) should have a significance attached to it, and efforts should be made to quantify statements such as "weakening of emission hotspots" within the abstract and conclusion.

A clearer message should be presented on the specific inventory and policy recommendations the reader should draw from the report, particularly in the conclusion section. Paragraph two of the conclusion summarises the findings well, but makes no effort to suggest where future efforts to reduce air pollution should look based on these findings. For instance, the correlation between power plant size and emission factor found from Table 2, or missing emissions from the EDGAR database could be mentioned explicitly as points of further investigation.

Figure presentation is a recurring issue, with poor labelling, captions and resolution for most figures, though the data presented is mostly of a good scientific standard that is explained well in the text. There are also a considerable number of minor errors that hinder the clarity and reproducibility.

Overall, my recommendation is that this study is a good fit to the journal ACP and should be published, subject to the corrections outlined in this document.

High-level comments/corrections

The text includes a high volume of typos and poor phrasing, and will need to be reviewed again.

The captions provided are generally insufficient. The authors should consider these more carefully and perhaps refer to guides on good practices for caption writing. The resolution of all figures is poor and includes areas of very blurry text. The resolution must be improved, and where possible, vector files should be generated. Axis labels and titles are often inadequate and sometimes missing altogether. Rainbow colourbars are used throughout, which gives a false impression of the data.

Cities (e.g. Urumqi) referred to in the text are never labelled on a map, and it is often not clear they are cities without contextual hints from the surrounding text.

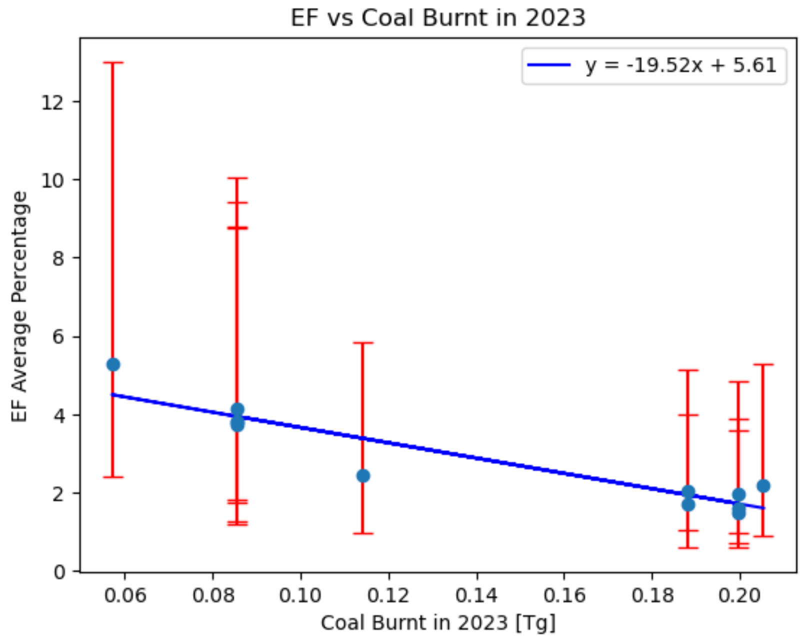
Major comments/corrections

Further discussion on the limitations of the direct comparison to EDGAR data are needed, with exploration of possible reasons that may account for differences observed beyond bottom-up inventory inaccuracies. Figure 9b shows a difference plot in emissions despite EDGAR explicitly not including non-anthropogenic emissions, making this direct comparison surprising at best and misleading at worst. The comparison in Figure 10a between EDGAR emissions and derived inversion fluxes seems misplaced, unless the authors are arguing for the (natural?) underground coal fires to be included in anthropogenic emission inventories in future.

Natural coal fires are mentioned several times in the paper, but it is often unclear if these are natural or human-controlled/influenced events. An explanation of these events, including the context they occur within the study region, is missing from the introduction, and should be highlighted more clearly throughout the text. Does the coal fire site represent a source independent of human regulation controls in Figures 4a and 8a? If so, specify this in the text and comment on it. If not, why not? They show considerable decline, so if they are natural this weakens the proposed link between the observed declines at anthropogenic facilities and new emissions regulations.

"number of valid observational days" presumably means average number of valid observational days per gridcell within one month. This needs to be explicitly mentioned, otherwise there is no information about how one defines a valid day over the entire domain. It isn't clear why average emissions and average number of valid days are presented together in Figure 7—is there a connection between the two? There doesn't appear to be, but "The joint evolution of these two metrics highlights both the long-term decline in regional CO emissions and the persistence of seasonal emission peaks” implies that there is some link that includes the valid day data that I have missed.

The correlation between power plant size and emission factor presented in Table 2 is an interesting result which isn’t highlighted. The table structure buries this because it is ordered by latitude rather than Tons of CO (2023). This could be more clearly visualised in a graph (see mock graph I quickly generated from the data in Table 2 below).



Figures

Figure 1 requires an inset to place the region geographically in the world. Major cities referred to in the text should be named on the map. Borders should be clarified as international or internal, with internal border linewidths thickened if they aren’t removed entirely, and countries could be named to make the figure more interpretable. It is unclear if the power and steel plants labelled are only for those within China/Xinjiang or if none exist outside this region. Legend text should be larger and less blurry.

Figure 2 should be restructured to show the flow of the methodology from top to bottom. The box labelled “the same method” should be removed and a parallel line of processes should be added to show the same steps. It isn’t clear if prior CO emissions and wind data also provide input to the random perturbation path (as I would guess), or if this is independent of these inputs (as the current figure suggests).

Figure 3a uses a rainbow colourbar, which gives a false visual impression of the CO concentrations and should be changed. The colourbar label should have a title as well as units. The 19-24 text should be modified to something clearer or removed. Figure 3b requires axis labels. The legend and labels that are currently present should be larger. The figure should be created as a vector to improve its resolution. The captions for Figure 3 are both insufficient.

Figure 4 requires axis labels. The date tick marks could be simplified to one per year at the start of the year. It is not clear over what area the TROPOMI CO total column data was averaged to generate the timeseries (average of nearest gridcell, closest point of each overpass, etc.). Legends should be improved, it is not clear Urumqi is a city or that “coal fire” represents (natural?) underground coal fires, or that “power plant” refers to a coal power plant. It isn’t clear if steel and coal plants represent a mean of all plants in the region, or if not which one they refer to. Resolution needs to be improved substantially, and the figure should be generated as a vector.

Figure 5a should change colourbar and change label to AAOD443/AAOD880 Ratio. Remove (a) in bottom left corner of figure. Figure 5b is very hard to read, I can’t easily interpret the meaning or point of this figure. It requires axis labels with units. The legend should make clear that the +-10% and +-20% lines refer to uncertainty thresholds of TROPOMI data. Resolution needs to be improved. Figure 5c should change the colourbar, which should be different to figure 5a to show that it is different data plotted. Colourbar label should be added. Captions should be improved.

All panels in Figure 6 should have axis labels added. Rainbow colourbars should be changed. “emission” and “std” titles should be improved.

Figure 7 left axis should have units added. “per grid” presumably means “per gridcell”.

Figure 8 legends need to be improved, see Figure 4 comments. Axis labels are needed.

Figure 9 has the same problems as Figure 6.

Figure 10 needs axis labels. 10a should have y axis limits standardised across the 4 panels for ease of comparison. The drastically different y axis scale in the bottom left panel of figure 10b should be mentioned in the caption.

Minor comments/corrections

Line	Type	Original	Correction	Comment
12	Addition	marked interannual decline		Across the study period
22	Addition	significant environmental problems		Expand on this
25	Modify	… major sink of the hydroxyl radical (OH) affecting the concentrations of…	… major sink of the hydroxyl radical (OH), which in turn affects the concentrations of…	
29	Restructure	Once emitted into the atmosphere, CO undergoes chemistry in-situ including 30 oxidation into carbon dioxide (CO2) and production from the oxidation of volatile organic compounds		CO can’t be produced if it’s already been emitted, needs rephrasing.
31	Modify	In unpolluted atmosphere…	Under unpolluted atmospheric conditions…	
32	Remove	…in winter…		
33	Modify	…higher values during times controlled mostly by…	…elevated concentrations…	
37	Modify	…due to when and where…	…when…	
41	Add	China's MEIC system		Define acronym
44	Add	WMO GAW		Define acronym
48	Add	(Jiang et al., 2015; Kopacz et al., 2010)		Add more, recent citations
49	Remove	integrate atmospheric transport and chemistry to infer emissions from concentration fields		duplicated
60	Modify	…the emissions of CO is both…	…the emission of CO is…	
61	Modify	Though	thought	
65	Modify	As related…	Those related…	

65	Restructure	non-power generating industries, as well as for industry and power production		So... all forms of industry then?
84	Restructure	extensive coal mining as well as many industries which use the coal and are powered by the coal.		Repeat coal too much
86	Remove	Also		
94	Add	TROPOMI	TROPOspheric Monitoring Instrument (TROPOMI)	
95	Modify	Column loading	Total column	
95	Modify	Retrieved daily	retrieved	
96	Restructure	...2.3 μm spectral range of the shortwave infrared (SWIR)...	This is the absorption feature of CO (which is in the SWIR), not the spectral range	
97	Remove	CH4, and aerosols		Not relevant to this study
100	Remove	And then resampled		repeated
101	Restructure	The data were then resampled with a resolution of 0.05°×0.05°.		Is the resampling repeated? Confusingly worded here.
103	Modify	HCHO is one of VOCs...		
105	Restructure	lifetime of HCHO columns is far shorter than those of CO columns,		Lifetime is for chemicals, not concentrations
108	Modify	its uncertainty is larger than for CO	It is less sensitive to HCHO than CO	
109	Modify	In this work, concurrent data of	In this work, concurrent total column observations	
110	Modify	GEE is utilized, resampled by HARP	GEE is utilized and resampled by HARP	
112	Restructure	wind:		I'm not a fan of these headers to the paragraphs. Wind should at least be capitalised.
115	Modify	The 05:00 115 and 06:00 UTC times correspond to the observation periods of the TROPOMI satellite		Presumably this is only applies over the region of interest in this study?
119	Modify	with a resolution of 0.1°×0.1°, with subsequent resampling at 120 0.05°×0.05°.	with a resolution of 0.1°×0.1° subsequently resampled to 0.05°×0.05°.	
123	Add	nine distinct angles	Nine distinct viewing angles	
126	Restructure	The L3 AAOD data product used in this paper has a resolution of 0.25° and is resampled to 0.05° to distinguish dust-affected regions.		How will this resampling help to distinguish dust-affected regions? No more information is added by resampling like this.
130	Modify	Equation (2)		Do you mean equation 1? If not, why reference eq 2 first?
132	Modify	approximation of	approximate	
132	Restructure	weighting terms of the underlying partial differential equations that govern the transformation between CO and its driving factors,		Unclear what this means. Partial differential equations aren't mentioned before, and aren't explicitly represented in eq 1. By weighting terms do you mean the alpha terms?
142	Modify	these terms	Emission, production, and transport terms	
142	Modify	Eq. (1)	Equation (1)	
143	Modify	after converted the unit into	in units of	
149	Restructure	The terms of this equation are initialized using this equation,		Repetition of this equation, reference the specific equation (eq 1 I think)
151	Modify	grid-by-grid		Unclear what this means. Gridcell-by-gridcell?
151	Restructure	The fitting is based on multiple least squares regression grid-by-grid on a month-by-month basis, reflecting the differences in albedo, elevation, land-surface use, emissions type, and differences in confounding variables on each pixel specifically grouping all daily data from		Too long sentence

		TROPOMI and the ECMWF reanalysis where they all occur.		
154	Add	weighting terms	weighting terms alpha_i	
156	Restructure	To ensure physically realistic and mathematically consistent values for the coefficients α2, α3, and α4, physical cutoffs are applied. Any value that is not positive (α > 0) is set to NaN.	To ensure physically realistic and mathematically consistent values for the coefficients α2, α3, and α4, any value that is not positive (α > 0) is set to NaN.	If using more cutoffs than this, list them.
159	Modify	The resulting equation	Equation (1)	
159	Modify	Grids	gridcells	Across the paper too
213	Modify	biomass incomplete combustion		Specify wildfires, agricultural, both?
214	Add	The statistical distribution of the CO total column		Averaged over what time period?
224	Add	The CO total column on a daily basis is provided in Fig. 4 for the following sites...		Over what spatial location? Closest TROPOMI observation? Averaged over gridbox?
224	Add	Wugonggou Coal Fire in Fukang		Brief background on what this is. Natural? Long-term? Remote? Underground?
225	Add	representative power plant, a representative steel plant		How are they determined to be representative? Which ones were chosen?
225		center of Urumqi		Presumably a city? Where is it located?
248	Add	thereby minimizing potential biases in CO emission estimates associated with dust contamination		Provide a source and/or explain further
260	Add	135 days	135 valid days	
271	Remove	Been		
272	Remove	with a reduction of approximately 38%	a reduction of 38%	
273	Modify	which are defined as regions where the concentration is exceeded twice the study area’s mean	which we define as regions where the concentration exceeded twice the study area’s mean	
276	Modify	average annual decrease of 0.68 μg/m2/s	average annual decrease of 0.68 μg/m2/s per year	
348	Add	Overall, these emission factors align well with typical ranges for CO from coal combustion reported in established bottom-up inventories such as EDGAR		What are these emission factors from EDGAR and MEIC? Include numbers and errors.
354	Modify	A comparison between this emission and EDGAR		What emission?
366	Restructure	In the figure, the blue areas of the figure are mainly distributed.		rephrase
375	Add	These statistics suggest that our inversion generally yields higher CO emissions than EDGAR		Why are emissions higher, why so distributed?
395	Modify	we applied the MFIEF		Define MFIEF or at least mention it is an inversion algorithm
399	Remove	Both		
401	Modify	all of which leads to	Both of which contribute to	
402	Modify	The results reveal	We find	
403	Modify	that it is never the less	That CO is nevertheless	
404	Add	with stronger emissions 405 during winter and early spring		Add some statistics
408	Modify	urban agglomerations	Urban centers	
421	Modify	different directions	sources	
421	Modify	on-the-ground	Ground-based	
424	Remove	the issue of		