

#### General comments:

The paper “Flux and Radiocarbon Evidence of Urban Carbon Emission Reductions under Climate Mitigation Policies” presents three independent types of evidence indicating a reduction in fossil fuel (ff) CO<sub>2</sub> emissions in Beijing and Xi’an from 2021 to 2024. First, it shows a decline in net CO<sub>2</sub> fluxes measured at three urban sites, whereas CO<sub>2</sub> fluxes measured at a fourth, rural site did not decline significantly. Second, the paper presents a decrease in annual CO<sub>2ff</sub> excess concentrations obtained from  $\Delta^{14}\text{C}$  tree-ring measurements at three measurement sites near the EC towers. Due to the decrease in CO<sub>2ff</sub> excess concentrations, the authors attribute the decrease in net eddy covariance CO<sub>2</sub> fluxes to a decrease in CO<sub>2ff</sub> emissions. Third, the paper presents energy consumption data indicating a transition from oil and coal to electricity and natural gas in both Beijing and Xi’an, consistent with the observed decrease in CO<sub>2ff</sub> excess concentrations and CO<sub>2</sub> fluxes.

Given the large contribution of urban areas to global anthropogenic CO<sub>2</sub> emissions and their great potential for reducing CO<sub>2</sub> emissions, observation-based evidence of a reduction in CO<sub>2ff</sub> emissions following mitigation policies, as presented in this paper, is of great relevance. In general, the measurement techniques used in this study (eddy covariance and tree-ring radiocarbon measurements) as well as the bottom-up aggregation of energy consumption data, have been applied in numerous previous urban studies. Therefore, the introduction could benefit from further references to other studies using similar approaches, as well as to studies conducted in the same study area that have, for example, shown an increase in CO<sub>2ff</sub> emissions in previous years. Likewise, the authors could highlight any novel aspects of the combined dataset or data that has never been collected from the study area before. Moreover, the manuscript, particularly the conclusions, could benefit from putting more emphasis on the fact that their observational techniques were able to detect and quantify decreasing trends in CO<sub>2ff</sub> emissions rather than highlighting that the results showed that energy system transformation and transport decarbonization can generally lead to decreased CO<sub>2ff</sub> emissions (which should be obvious). After addressing the specific comments mentioned below and any comments from other reviewers, I recommend the manuscript for publication.

#### Specific comments:

1. Line 31:  
Strictly speaking, I would not describe it as a combination of eddy covariance and tree-ring radiocarbon measurements, as both data sets were analyzed separately. Perhaps “combine” could be replaced with “present” or something similar.
2. Line 33:  
I would suggest indicating how many urban sites were considered for this study.
3. Line 38 / 39:  
Since Lines 33 – 37 considered CO<sub>2</sub> fluxes, it would be helpful to clarify in Lines 38 / 39 that tree-ring  $^{14}\text{C}$  reveals a concurrent decrease in CO<sub>2ff</sub> *concentrations*. As with the number of EC sites, I would suggest indicating the number of  $^{14}\text{C}$  tree-ring sites in the abstract.
4. Line 51/52:  
It should be specified that urban areas contribute more than 70 % of global energy-related CO<sub>2</sub> emissions. Please also update the reference. The provided link (<http://unesdoc.unesco.org/images/0018/001861/186137e.pdf>; last access June 2018 ?!) does not lead to the reference (Canadell et al., 2009). Moreover, the data provided in Canadell et al. (2009) is based on the World Energy Outlook (2008). In any case, it might be

more appropriate to cite more recent publications (e.g., Lwasa et al. (2022) (Chapter 8 of the IPCC AR6; doi: 10.1017/9781009157926.010)).

5. Line 53:  
I would suggest explicitly stating “energy transition from ... to ...”
6. Line 55:  
Perhaps the authors could indicate which measures have been taken to achieve the targets set within the “dual-carbon” strategy. Alternatively, as this has been addressed in Lines 59 – 63, the sentence in Lines 55 – 58 could be moved further down. In any case, I would suggest mentioning climate mitigation measures first before stating that they should be analyzed through atmospheric observations.
7. Line 75:  
Please ensure the correct and consistent use of the terms “biological”, “biogenic”, and “biospheric” CO<sub>2</sub> (see also Lines 65, 80, 244, 389, and 399). Providing a clear definition at the beginning might be helpful. Strictly speaking, <sup>14</sup>C distinguishes between fossil and non-fossil CO<sub>2</sub>, where non-fossil CO<sub>2</sub> includes CO<sub>2</sub> from biospheric respiration and photosynthesis, as well as from human respiration, biomass burning, and biofuel emissions.
8. Line 76:  
I would suggest adding “... independent *proxy or tracer* ...”.
9. Line 82:  
It would be helpful to briefly mention that <sup>14</sup>C is commonly reported in delta-notation according to Stuiver and Pollach (1977).
10. Line 85:  
Please add references to previous studies that used Δ<sup>14</sup>C from tree rings to estimate CO<sub>2ff</sub>.
11. Line 90:  
I would suggest providing the number of EC stations and <sup>14</sup>C sampling sites here. It would also be helpful to indicate the spatial scale here, e.g., provide the approximate size of the flux and concentration footprints.
12. Line 91:  
Again, I would rather say that EC and <sup>14</sup>C measurements were “used” than “combined”.
13. Line 115:  
It would be helpful to start with an overview of the number of EC stations and <sup>14</sup>C sampling sites in both Xi'an and Beijing.
14. Section 2.1 (~Line 122, 133, 145,160):  
I would have expected to find information about the measurement height and the size of the flux footprint, as well as the contributions of the main land cover fractions to the flux footprint. This information is provided later in Section 2.2, but the distinction between Section 2.1 and 2.2 is not very clear to me. The authors could consider combining the two sections or referencing Section 2.2 in Section 2.1.
15. Section 2.1 (Lines 122, 134, 145; Figure 1):  
Please indicate the sites where the <sup>14</sup>C tree-ring samples were collected in Figure 1. It would also be helpful to label the subfigures a), b), c).

16. Line 135:

It was unclear to me to which flux footprint Line 135 refers, as the previous line (Line 134) refers to tree-ring samples, i.e., concentration measurements. Please clarify whether Line 135 refers to the RCEES flux footprint (then it would be better to move the sentence further up) or to the concentration footprint.

17. Lines 145 – 147:

Again, for clarity, I would suggest referring to the vegetation cover within the flux footprint before mentioning the tree-ring concentration measurements.

18. Lines 158 – 160:

This sentence is very similar to the one in Lines 154 – 156. Please check whether the information can be combined.

19. Lines 167 and 192:

As Sections 2.2. and 2.3. only consider the measurements and data processing from the EC measurements, while the  $^{14}\text{C}$  tree-ring measurements are described in Sections 2.4 and 2.5, I suggest specifying this in the headers.

20. Line 178:

What is the average building height within the flux footprints? Can decoupling between the measurement height and the surface be excluded? A measurement height of 140 m seems high. Have other studies been conducted at these measurement sites?

21. Line 186:

The year of the publication (Kljun et al.) is 2015, not 2025.

22. Line 187:

Perhaps the authors could provide the percentage of land cover fractions within the flux footprints for each site in a table.

23. Line 196:

What type of spike removal was used? Did the authors verify that the thresholds were adjusted for the urban environment, i.e., that the thresholds were sufficiently large (usually larger than in natural ecosystems) to account for real increases in concentrations common to urban environments?

24. Line 211:

How much of the data was gap-filled?

25. Line 244:

Please add a reference, e.g., Levin et al. (2003).

26. Lines 248 – 253:

I would suggest to first present the combination of Equations 3 and 4; second, state the assumptions and simplifications made; and third, present the simplified equation (Eq. 5) used in the analysis.

27. Lines 248 and 252:

Please specify and justify the assumptions made by quantifying the uncertainty and/or referencing other studies that have made these assumptions. According to Eq. 4 and 5, for example, I assume that  $\Delta_{\text{bio}}$  has been estimated by  $\Delta_{\text{obs}}$ ? Also note that there are other correction terms for oceanic and stratospheric  $\text{CO}_2$  as well as  $\text{CO}_2$  from nuclear power plants

(Maier et al., 2023; doi: 10.1098/rsta.2022.0203). Please note / explain why these components can be neglected.

28. Line 251:

CO<sub>2other</sub> in Equation 4 has not been defined. See comment 26.

29. Line 259:

How much data was missing?

30. Line 281:

Please specify which relative contributions (which quantity) were considered.

31. Line 352:

For the IAP site, the interannual decline seems to be most pronounced between May and December, and less pronounced between January and April (also apparent in Fig. S2). Do the authors have an explanation for this?

32. Figure S2:

The label on the y-axis should indicate that the figure shows the difference from the average flux from 2021 – 2024 (or 2022 – 2024).

33. Figure 4:

The interannual differences are very difficult to discern. Since the diurnal cycles are already shown in Figure 3, the authors could consider showing the differences with respect to the average CO<sub>2</sub> fluxes, similar to Figure S2.

34. Lines 383 – 390:

Instead of changing back to Figure 3 after the description of Figure 4, the authors could consider moving this paragraph to Line 357.

35. Figure 5:

Please explain what the error bars indicate.

36. Lines 408-409:

It would be great to provide a figure showing these correlations. Were the correlations calculated using only four annually averaged values?

37. Line 412:

It would be helpful to mention the extent of the flux footprint at the IAP site again. Can the flux footprint be considered as "regional scale" (fetch 4.2 km)?

38. Line 438:

If available, analyzing traffic count data could reveal whether the number of vehicles driving within the flux footprint has decreased.

39. Lines 441 – 445:

I would suggest specifying that the results presented indicate that the reduced CO<sub>2</sub> fluxes *observed at three measurement stations in Beijing and Xi'an between 2021 and 2024* were most likely driven by reduced fossil fuel combustion.

40. Line 450:

Again, I would indicate the number of measurement sites.

41. Line 451 ff:

Since the authors state that their study "quantified the temporal evolution and driving mechanisms of urban CO<sub>2</sub> fluxes" (Line 448), I suggest adding numbers in Lines 450 - 460.

Technical corrections:

1. Line 31:

There should be a hyphen in "eddy-covariance measurements".

2. Line 66:

There should not be a hyphen in "in situ", and I do not understand why it is written in italics.

3. Lines 107, 114, 257, 310:

The links should be added to the list of references, including the date of the last access.

4. Line 112:

Since the mean annual temperature of Beijing (Line 106) is only given as an integer, I suggest removing the decimals in Line 112.

5. Line 122:

"Tree-ring samples *were* collected ..."

6. Line 204:

There is a period missing after "(2004)".

7. Line 207:

The sentence appears to be incomplete.

8. Line 236:

"C", "SN", and "abs" should not be written in italics.

9. Line 238:

"... <sup>14</sup>C/<sup>12</sup>C is *the* corresponding ratio ..."

10. Lines 251 and 253:

The minus signs in the denominators are barely visible.

11. Figure 2:

It would be helpful to add grid lines and/or indicate the zero line.

12. Figures 2 – 5:

Instead of "IAP" and "GZ" etc., the authors could write "Beijing urban (IAP)" and "Xi'an rural (GZ)" etc., in the figure and remove the descriptions in the figure captions. This would make the figures easier to read.

13. There should always be a space between a number and its unit, including "°C", "%", and "‰" (e.g., Lines, 106, 112, 227, 228, 229, 233).