Reply to Referee # 3

The authors adopt one ensemble learning model by integrating three Machine Learning models, including Gradient Boosting Regression Trees (GBT), eXtreme Gradient Boosting (XGB) and Random Forest (RF), coupled with ridge regression to generate robust predictions, to fill the gap of the element carbon (EC) data from 2013 to 2023 in Yangtze River Delta, China. The reconstructed EC dataset is valid by the intercomparison of EC with other datasets. Lastly, ensemble learning was used to design a fixed emission approximation method to disentangle and quantify the contribution of anthropogenic drivers to EC reduction. This work is well organized. The authors present sufficient evidence to prove their robust and good performance in terms of the ensemble learning method. However, I'm sceptical about certain results of this study, particularly on the fixed emission approximation method. The acceptance of this manuscript is contingent upon the authors thoroughly validating those results. In addition, several places in this manuscript require an improvement. I recommend the acceptance after the authors address the comments and concerns detailed below.

Reply: The authors thank the referee for their thoughtful and constructive comments. We have made the necessary revisions to address the concerns and suggestions raised. Below is a summary of the changes made in response to the referee's comments:

General comment:

After reading this manuscript, my initial impression is that the authors have a wide knowledge of Machine Learning. However, I have some concerns as follows: As you mentioned in the 2.4.3 section (Line: 225): the errors increase when 2018 and 2019 are used as baseline years. 1) I am confused by the reason you provided, which is due to the missing meteorological parameters. As far as I know, ERA5 is a continuously updated dataset. It should not have missing values in 2018 and 2019. Please clarify this point.

Reply: Sorry for the confusion in our initial explanation. The higher uncertainties observed in those years stem from using different baseline years in the Fixed Emission Approximation (FEA) method. These uncertainties reflect the variability in results when different years are used as baselines. To address this, we have revised the manuscript to remove the original explanation and have instead provided a clearer presentation of the uncertainty range in the results (see Figure 5).

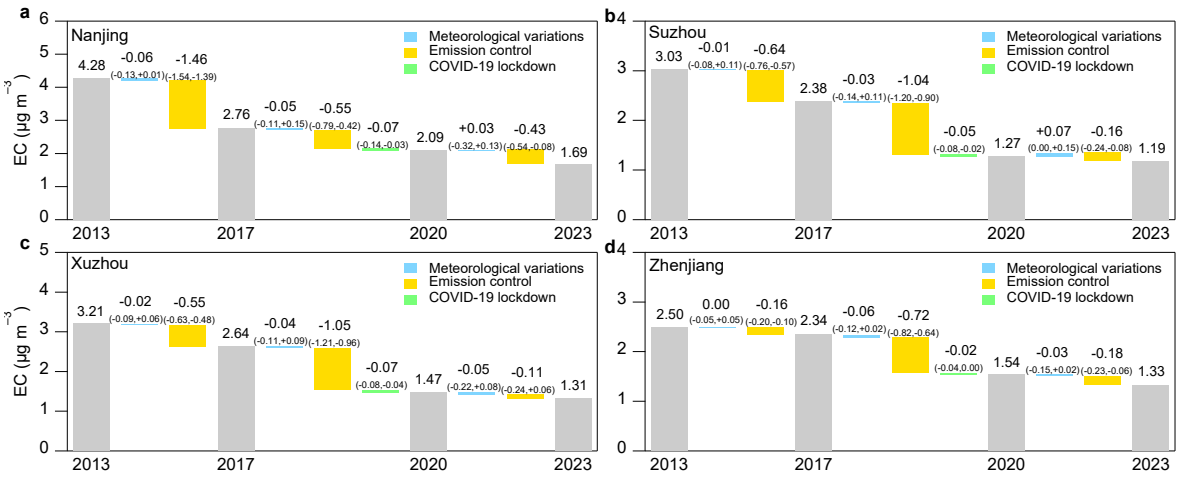

Figure 5. Drivers of the EC trend from 2013 to 2023. a-d the contributions of anthropogenic emission control, meteorological variations and COVID-19 lockdown on the trends in EC concentration in the four cities.

2) If possible, try to use the ground-based measurements of meteorological factors rather than ERA5;

Reply: Thank you for referee's suggestion. While we agree that ground-based measurements are valuable, we explain the challenges associated with their use in this study. Ground-based measurements often do not provide the full set of 18 meteorological parameters offered by ERA5, and they can also be affected by missing values. We will continue to explore ways to integrate such measurements when feasible.

3) Please clarify how you retrieved the meteorological factors from the ERA5 in four cities in the 2.1 section.

Reply: Thank you for referee's suggestion. We clarified how we retrieved the meteorological factors from ERA5 for the four cities in Section 2.1. The revised text now reads: "*To represent the meteorological conditions at the observation sites, we extracted data from the ERA5 grid cells that correspond to the coordinates of the monitoring stations.*" More detailed modifications can be found on lines 90 - 91 in the revised manuscript.

4) In principle, the choice of the baseline year is critical. Basically, the baseline year is representative of typical conditions. If the selected year is an anomaly (e.g. huge emission reduction in COVID year), it could lead to an overestimation/underestimation. Could you explain how you chose the baseline year?

Reply: Thank you for referee's suggestion and comments. This is a very good point. We addressed the concern about baseline year selection by explaining that we considered multiple potential baseline years and averaged the results for each year. This helped mitigate any anomalies, such as those caused by the emission reductions during the COVID-19 lockdown. Error bounds were also provided in Figure 5 to reflect the range of potential baseline year impacts.

Specific comment:

1) Line 27: Rephase the sentence: from 2013 to 2020 (-0.24 to -0.15 μg m^{-3} a^{-1}) from 3.26 μg m^{-3} to 1.59 μg m^{-3}

Reply: Thanks for the suggestion. The sentence indeed had some ambiguity. The revised text now reads: "*Over the 11-year period, EC exhibited an overall decline (-0.20 to -0.14 μg m^{-3} a^{-1}), with a more significant decrease from 2013 to 2020 (-0.24 to -0.15 μg m^{-3} a^{-1}). During this time, the average EC concentration in the four cities dropped from 3.26 μg m^{-3} to 1.59 μg m^{-3}, followed by a noticeable slowdown in the rate of decline from 2020 to 2023 (-0.12 to -0.04 μg m^{-3} a^{-1}).*" More detailed modifications can be found on lines 25 - 28 in the revised manuscript.

2) When narrating, maintain consistency in sentence tenses. For example, we evaluated… in Line 199 and we propose… in Line 206

Reply: Thanks for the suggestion. We agree that consistency in sentence tenses is important. We have used the past tense throughout, and the necessary changes have already been made.

3) Line 214: If the FEA method were…. Please double-check the whole text and use the singular and plural correctly.

Reply: Thanks for the suggestion. Modified. The entire text has been reviewed to ensure correct usage of singular and plural forms.