

## **Introduction**

This manuscript evaluates air pollutant trends in time (annual, seasonal, daily) and space (regions, agglomerations) from 1364 monitoring sites across China which have been individually categorized into one of five distinct urban functional zones. The authors have sliced, diced and presented the data in many different ways and go on to discuss the results in relation to social (management) and environmental factors.

## **Overall Quality of Pre-print**

The authors have undeniably acquired, analysed and visualised large volumes of monitoring data (hourly data for 1364 sites x 6 years) but the manuscript is highly descriptive, not particularly analytical in nature and provides little novelty in approach or outcome in its current form. Some elements of the paper also assume that the reader has a good knowledge of China which is not necessarily the case.

The introduction suggests that other researchers have already commented on reductions in air pollutants across China, with regional differences, with the possible exception of ozone, so the novel element here is analysis of trends in time and space through the lens of urban functional zones. I think the emphasis on urban functional zones is interesting because these provide a different means of grouping the data and establishing trends by sector which may ultimately be related to the success or otherwise of management actions. The danger, of course, is that by grouping data everything collapses to the mean, and variation is lost. For example, subtleties linked to differences in the scale and form of urban areas, or local and regional climatic influences cannot be considered.

This manuscript, then, demonstrates how ambient pollutant concentrations have reduced over space and time. Interestingly, it does not include any information on emissions. It would be good to include some information on emissions in a revised version of this manuscript – the authors could then evaluate on which emission reduction strategies (and in which sectors) had been most successful in reducing ambient concentrations.

I would particularly like to see better quantification of differences in pollutant concentrations in space and time for air pollutants in the different urban functional zones. It should be possible, for example, to test whether differences between mean concentrations across zones are statistically significant. Likewise, it should be possible to compute trend lines over individual time series and report rates of change and significance of change. The authors could then discuss their main results with more confidence, and include some headline statistics in the abstract.

The manuscript at present does not have a discussion section. I think that once the results have been re-analysed, with more statistical rigour, the main results and discussion points should become more apparent. Using urban functional zones, the

authors should be well-placed to comment on the significant progress that has been made towards reducing harmful ambient pollutant concentrations, with more rapid progress being made in some parts of the country than others presumably attributed to a combination of more effective emission reduction strategies target at specific source sectors and favourable environmental conditions.

It would also be useful for the authors to reflect on the limitations of their approach, for example, loss of variation caused by grouping data into zones, unequal numbers of sites per zone, broader issues of scale and local topographic influences. I would personally place less emphasis on ozone in the revised manuscript – because regional influences are likely to far outweigh local influences and differences between urban functional zones are likely to be negligible. It is also less responsive to control measures (as your analysis demonstrates).

### **Specific Comments**

Section 2. Subsection 2.1. Please improve the description of the study area. Could you include the 6 major regions as polygon outlines and the 6 major urban agglomerations as colour filled polygons on Figure 1? Could you show the 336-prefecture cities as points on Figure 1. These changes would provide the reader with a much clearer understanding of the different geographical units used in this study.

Section 2. Subsection 2.2. Please check your weblinks and ensure they are all accessible to the wider scientific community. I could not reach:

- [beijingair.sinaapp.com](http://beijingair.sinaapp.com) (pollutant data)
- <https://data.ess.tsinghua.edu.cn/> (global land cover data)

The latter redirected me to another site, but this hung.

Section 2. Subsection 2.3.2. Please could you provide a clearer explanation of the way in which you used GIS techniques to categorize each monitoring station by urban functional zone. I presume you conducted a point-in-polygon test? Did you consider constructing a buffer and assigning the monitoring station to the dominant functional zone within that buffer (to reduce edge effects)?

Section 3. Subsection 3.1. Please could you provide a new table summarizing the number of monitoring stations per urban functional zone. You could also summarize the number of monitoring stations per urban functional zone per region, and per urban agglomeration. This would be far more effective than the map (Figure 2) which could be deleted.

Section 3. Subsection 3.2.1. Could you come up with a more effective way of showing reductions in pollutant concentrations over time? Your left hand plots show percentage reduction over time and presents all pollutants on similar sized plots but with very

different scales on the y-axes (ranging from -8% for O<sub>3</sub> to -60% for SO<sub>2</sub>). Could you either plot these all on the same vertical percentage scale, or, better still, plot on an absolute scale (micrograms per cubic metre) with trend lines. These could usefully a) quantify absolute reductions in pollutant concentrations over time and b) determine whether reductions in some urban functional zones were greater than in others (through an analysis of gradients) which could link to policy measures. Some of this new quantitative information could be included in a revised abstract. Your right hand plots are more difficult to interpret. Are they necessary?

Section 3. Subsection 3.2.2. (Seasonal). Figure 4 highlights seasonal variations in PM<sub>2.5</sub> and O<sub>3</sub> across the 5 urban functional zones over a 6 year period. I have two comments to make here. Firstly, you only show 2 pollutants, when others, such as SO<sub>2</sub> presumably exhibit significant seasonal variation. Why not include these too? Secondly, despite having a separate plot for each urban functional zone, it is difficult to establish whether there are meaningful differences between these zones. Are they all behaving the same, or are some behaving differently. Could you test this, statistically?

Section 3. Subsection 3.2.2 (Daily). Figure 5 shows daily variations in pollutant concentrations per urban functional zone and you conclude that some pollutant concentrations vary more in some urban functional zones than others. Could you be more quantitative in your assessment here, please? Could you statistically test for differences? For example, PM<sub>2.5</sub> looks to exhibit much less diurnal variation in the public management functional zone than other functional zones, but is this statistically significant?

Section 3. Subsection 3.3.1. Again, I wonder if there are more effective ways of communicating differences over geographical regions and whether these are statistically significant. Could, for example, the bar charts be organised by urban functional zone rather than by geographical region, so we have 6 adjacent bars showing pollutant concentrations for the residential, commercial, industrial, transport and management zones side-by-side? You could label these N, NE, E, SE, SW and NW, respectively. Could these also be tested to determine a) whether concentrations in one zone were significantly different to those in another zone and b) whether concentrations for a single zone, e.g., industry, were significantly different in different geographic regions? You do something similar in Figure 7 which works quite well.

Section 3. Subsection 3.3.1. Figure 7 is more effective than Figure 6 and focusses on agglomeration zones not regions. Again, it would help the discussion (management of pollution sources) if differences in pollutant concentrations in different functional zones in different urban agglomerations could be quantified in some way. For example, are SO<sub>2</sub> concentrations from industrial sources in BTH and TC significantly different to those in YRD, GBA, CC and NSTM?

Section 3. Subsection 3.4.1. It is good that you link improvements in air quality to management actions and here you talk more specifically about 3 key regions which seem different (larger) to those included on Figure 1. I wonder, do we need additional figures at this stage, or could content from line 365 onwards form part of the discussion.

Section 3. Subsection 3.4.2. I wondered to what extent you were testing altitudinal effects and to what extent you were testing urbanisation effects – with highly populated urban areas and associated infrastructure generally located at lower altitudes. Please check your interpretation of this section.

Section 3. Subsection 3.4.3. I wondered whether this material would be better placed earlier in the manuscript, maybe after the material on seasonal variations, since this is essentially a story of pollution by time? I also wanted to challenge your meanings of positive and negative weekend effects. For me, less pollution is a positive thing, not a negative thing. Here, I think you interpret ‘positive weekend effect’ as concentrations being higher than in the week, and vice-versa for ‘negative weekend effect’. Again, it would be useful to test whether weekday and weekend differences in pollutant concentrations between different urban functional zones were statistically significant.

Section 4. You do not appear to include a discussion section in your paper. I would restructure your manuscript such that you have a substantive discussion section that reflects on the main findings of your analysis, comparing and contrasting your results to those reported by others. I would particularly focus upon the novel element of your study, the use of urban functional zones, and the differential impacts of air quality management on different pollutants in different zones in different regions. I would also comment on the limitations of your study – for example, you do not really consider scale effects or the issue of variable sample size, with some of your results based on many monitoring sites per urban functional zone and others very few. There is also the issue as to whether you should classify a point based on its immediate interaction with the land use, or some broader geographical zone (e.g., 1km buffer, 5km buffer).

Section 5. I would encourage you to revisit your conclusions once you have revised your analysis taking a more critical, quantitative approach to analysing spatial and temporal trends across your different urban functional zones. I do like the method you propose here, and think there is much to be learned from evaluating data grouped across areas with common geographical characteristics to establish which management actions have been most effective at reducing which pollutants across which sectors.