Review comments to manuscript egusphere-2025-177

The Impact of Multi-Scale Turbulence Structures within the Urban Canopy of a Basin City on Haze Pollution Processes

by Liu et al.

The manuscript seeks to investigate the impact of multiscale turbulence structures within the urban canopy layer (UCL) of a basin city on haze pollution processes, using field observations from Lanzhou, China. It identifies a typical daily cycle of $PM_{2.5}$ concentration variations, influenced by small-scale turbulence, sub-mesoscale motions, and anthropogenic heat sources. The study employs turbulence decomposition techniques, quadrant analysis, and spectral analysis to understand the complex interactions between turbulence and haze pollution, with implications for improving urban air pollution forecasting. The authors highlight how turbulent eddies with timescales under 15 minutes contribute to pollutant dispersion, while coherent structures such as thermal plumes influence pollutant transport. Specifically, they conclude that small-scale turbulent eddies enhance pollutant dispersion and sub-mesoscale motions contribute to turbulence intermittency. While the manuscript seeks to address a complex and relevant issue, major concerns have been identified as discussed in the general and specific points below:

General comments:

1. **Writing:** The writing is at times confusing and/or contradictory. A thorough editing, looking for typos and unclear sentences, should be done.
2. **Evidence in support of conclusions**: The scientific claims and conclusions are not well supported by the evidence provided in the results, as detailed in the specific comments below. A major concern is that the study relies on observational data from a single monitoring station, which may not adequately capture spatial variations in turbulence and pollution dynamics across the city. Given only hourly pollution data are used in the analysis, could other sensors from the city included to analyze spatio-temporal coherence of the pollution? This limitation makes it impossible to determine whether the observed features are representative of the entire urban area, both in terms of pollution and meteorological/turbulence dynamics. This is a critical issue, given the study's objective of assessing the influence of multiscale drivers on urban pollution and haze events. For instance, the analysis lacks sufficient evidence to draw definitive conclusions about the impact of sub-mesoscale motions on pollutant dispersion.
3. **Generalizability of findings**: Related to point 2, there are concerns about the generalizability of the findings to other urban areas or time periods. The study focuses solely on Lanzhou, making it difficult to extend its conclusions to cities with different topographies and climates. If data from other locations are not available, a longer time series of events should be analyzed to ensure statistically robust conclusions.

4. **Methods**: While the study provides a detailed observational analysis, its conclusions often rely on visual inspections of metrics and indicators derived from observational data, lacking robust statistical analyses or objective methods to distinguish specific dynamics and regimes. Additionally, the absence of a predictive modeling component limits the study's ability to test the influence of various turbulence structures under different conditions. Although the study highlights human activities as a primary driver of pollution events, it does not provide a detailed quantification of emissions in space or time, nor does it analyze their interaction with turbulence structures. It remains unclear whether the pollution is solely locally produced. A spatial emission map or pollution modeling would help clarify the sources, drivers, and relevant scales of these events.

Specific comments:

- Page 2, line 6: The term "basin cities" should be clearly defined, along with an explanation of why the analyzed city, Lanzhou, fits this definition. Providing this context is essential for identifying other regions that may experience similar pollution regimes and atmospheric dynamics.
- Page 2, line 17: turbulence is not the only drivers of pollution dispersion. Please check through the manuscript as several oversimplified claims are made.
- Page 3, line 4: UCL is defined in the abstract as urban canopy layer, which justifies the acronym. However here and through the text UCL stands for urban boundary layer, so maybe the acronym should be revised and/or used consistently through the text.
- Page 3, line 6 and 8: no need to cite twice Oke, 1987.
- Page 3, line 11-14: this statement is not necessarily always true. More context for such claims is needed.
- Page 5, line 4: it is not clear what the frequency of the observations is. For $PM_{2.5}$ an hourly resolution is mentioned, while for the meteorological/turbulence data no information is provided. Also, the turbulence analyses seem to be done at 30 min resolution, which opens questions about their actual representation of turbulence processes.
- Page 9, line 20: how is haze defined? Is it just based on pollution concentration?
- Page 10, line 2: please rephrase "temperature supposed the development…"
- Page 10, line 10-14: please rephrase, this section is not clear. Also this sentence seems to contradict what was just said above that higher turbulence was present during clear sky periods.
- Figure 3: The authors claim that low $PM_{2.5}$ concentrations coincide with TKE peaks. However, it is hard to establish a causal relationship, as similar low $PM_{2.5}$ concentrations are observed through the analyzed events and no TKE peak was observed. Extending the analysis to longer time periods and multiple events may help generalize the conclusions and build more robust

statistics. The relationship between TKE and $PM_{2.5}$ cannot be based solely on the visual inspection of a time series, such as the one presented in Figure 3.

- Page 13, line 5: Why use KE instead of TKE?
- Page 13: the entire page is difficult to follow and more work is needed to generalize mechanisms and findings. Currently results are presented as a series of observations without a clear explanation of what's happening.
- Figure 4: what are the yellow and green arrows?
- Figure 5 and quadrant analysis: this section needs to be revised as it's not clear what the key outcome of this analysis is and how conclusions are supported/drawn.
- Page 18: from the title of section 3.4 and through the manuscript it is not very clear where the multi-scale component of turbulence comes from, how it is diagnosed and what is causing that.
- Figure 6: why are only 6 time points considered? Why not examine more complete statistics?
- Page 20, line 9: the paper does not address any urban related process as there is no spatial component/variability in the observations analyzed. It is therefore challenging to attribute the findings presented to urban scale processes. The conclusions should be revised accordingly in multiple instances.