Review report:

Measurement report: Temporal variability of vertical profiles of CO_2 and CH_4 over urban environment

Submitted to ACP

The manuscript presents an overview of a dataset consisting of CO_2, CH_4 concentrations, and meteorological variables collected over an 11-month period in Krakow, Poland. The stated objective of the study is to report these measurements. The authors describe specific vertical profiles of the trace gases and variables collected and conclude that they capture the formation, evolution, and decay of the atmospheric boundary layer, and the influence of local terrain and plumes in the profiles. They also claim that these datasets have the potential for validation of transport models.

Indeed, the dataset is potentially valuable and relevant to improving measurement strategies and advancing the understanding of nocturnal boundary-layer processes. However, in its current form, the manuscript requires substantial revision before it can be considered for publication.

First, the introduction lacks sufficient depth. Key statements are not supported by an adequate literature review, and the contextual framing of the study is relatively superficial. The methodology section is not clearly presented and would benefit from significant restructuring. I strongly recommend including schematic diagrams of the measurement setup and methodological workflow to enhance clarity and reproducibility.

For a measurement report, detailed descriptions of the measurement procedures, calibration protocols, and data quality assurance are essential. These aspects are insufficiently explained in the current manuscript. In addition, a more substantive scientific interpretation of the observations is expected, rather than a primarily descriptive presentation. The case studies presented are only superficially addressed, with only one short paragraph describing the case study of methane. While the manuscript includes the use of modelling to support the interpretation of the data, details on these are not sufficiently developed.

Finally, several figures require improvement. Proper labelling, clearer descriptions, and more thorough interpretation are needed to ensure the results are communicated effectively.

Overall, the manuscript presents a dataset with potential scientific value, but major revisions are required to address the outlined issues.

Overall comments:

Abstract

The abstract refers to the nocturnal boundary layer, but the term *nocturnal* appears only there and is not consistently used or defined in the main text. It is unclear whether the authors use *nocturnal boundary layer* interchangeably with *stable boundary layer (SBL)*.

Introduction

The introduction is lacking sufficient citations, and many statements are not supported by the existing literature. A few specific examples include, but are not limited to:

- Lines 33–39
- Lines 53–57
- Line 58 – this is a particularly important statement and must be supported by appropriate references.
- Line 68 – a citation is needed to substantiate the claim regarding "legal limitations."

Although this manuscript is a measurement report, statements made in the introduction must still be grounded in scientific literature. In several places where citations are provided, they are limited to one or two references that do not adequately represent the current state-of-the-art. For example, **line 80** cites only a case from Marseille, which is not even among the longest-running urban monitoring systems, and a two-year measurement study in remote Alpine locations (Schneefernerhaus and the Zugspitze ridge). These examples do not sufficiently demonstrate the broader context of existing observational networks or related research.

The introduction needs to be substantially revised to reflect the current state-of-the-art and to clearly demonstrate how the observations presented in this study fill a gap or address an unmet need. At present, the introduction is not adequately supported by literature, which is a critical requirement for both measurement reports and full research articles.

Methods

The methodology section requires substantial restructuring. It is difficult to follow and lacks essential procedural detail. This section would greatly benefit from a clear diagram illustrating the instrument setups on each platform, as well as a table listing all sensors used and the conditions under which they were deployed. Information about sensors that were ultimately not used could be moved to the Supplementary Material to improve clarity. Additionally, two “case studies” are mentioned, yet they are not described in the Methods section at all.

The authors should clarify why the selected sites were chosen and how representative they are of the urban boundary layer (UBL). A schematic of the experimental design for both the balloon and the UAV would considerably strengthen the methodological description. There is incomplete information regarding the air inlet in Section 2.2.2 (line 138), which seems only partially addressed later in Section 2.2.3 (line 171). The methodology is also confusing in its description of instrumentation: several sensors are described as being present but not used under certain circumstances (e.g., lines 193–194 for the BME280 and thermocouple; lines 201–204; unused components of the TriSonica anemometer on lines 213–214 and 220–223; and precipitation/radiation sensors on line 230). If the sensors were calibrated using an in-situ meteorological station, a clearer approach would be to justify the selection of each sensor by presenting its performance relative to the stationary reference, rather than listing all instrument capabilities—used or unused.

The manuscript does not specify the local time offset from UTC for Kraków, which prevents the reader from interpreting whether the reported times correspond to day or night. There is also no explicit definition of sunrise and sunset times, and the terms “nighttime” and “morning” are used without clear thresholds. This ambiguity makes the temporal context of the measurements difficult to interpret.

Results

The results section is only superficially developed and lacks clear, traceable interpretation. The authors attempt to describe patterns in the observations, but the text does not sufficiently guide the reader to where these features appear. Figure labeling is poor, and in cases where the authors do reference a specific panel (e.g., Figure 4-d, line 302), the corresponding panel is not labeled within the figure itself. In other instances, figures are cited in an overly general manner, for example, Figure 5 (line 310) is discussed as a whole, yet it contains ten panels that are not individually identified or described. This makes it very difficult for the reader to follow the analysis.

It is also unclear why particular cases were chosen for illustration. For example, at line 310, the manuscript does not state whether the selected profile is representative of typical conditions, an exceptional case, or simply a random example. Without this context, the value of the case studies is significantly diminished.

The two case studies presented, one for CO_2 and one for CH_4, are described only superficially, without sufficient depth or supporting evidence. In the introduction, the authors state: *"The obtained results allowed us to analyse in-depth the formation, development and disappearance of the nocturnal boundary layer. In selected profiles, CO_2 and CH_4 plumes located over the inversion layer (150–250 m AGL) were detected during the nighttime and morning hours."* However, the manuscript does not provide such in-depth analysis. There is not enough detail on even how the boundary-layer height was determined.

Overall, the results require substantial expansion, clearer connection between text and figures, explicit justification for case selection, and a more rigorous scientific interpretation consistent with the claims made in the abstract and introduction.

Conclusion

Specific comments

Line 16: Use *GHG* for *greenhouse gas* (singular) and *GHGs* for *greenhouse gases* (plural).

Line 106: The location of the Vistula River is not clearly visible in the map. Additionally, the location of the balloon site is unclear. Please improve the map to clearly indicate these features.

Line 115: *"The direct distance between measurement sites was 2.9 km."* — Please specify which sites this refers to (presumably the balloon site and AGH). This information should also be added directly to the map.

Lines 152–153: The text mentions a "literature review," but does not specify which literature was consulted. Please clarify and add appropriate citations supporting the choices made.

Lines 157–159: The reference to "recent studies" requires specific citations.

Lines 169–170: Clarify what the intercomparison was performed against (e.g., another instrument, a reference station, a specific calibration standard).

Line 180: Please provide the observed water vapor percentages mentioned.

Lines 233–242: The calibration procedure requires much clearer description. The explanation is vague and incomplete.

- How exactly were the linear calibrations (e.g., $y = ax + b$) derived?
- Table 3 is referenced implicitly, but the methodology leading to those coefficients must be explicitly described.
- The anemometer is said to perform "correctly" under calm conditions (0 m s^{-1}), but no information is given about performance at other wind speeds. This is insufficient, as calm conditions are often excluded from both analysis and modelling. A proper assessment of calibration quality across the measurement range is needed.

Line 260: It is unclear how the concentrations shown in Figure 2a were obtained. Does the figure show monthly averages, monthly maxima, minima, or another metric? Without this clarification, the following text (lines 261–265) is difficult to interpret.

Line 295: Figure 4 does **not** show the evolution of the convective boundary layer, but rather the evolution of vertical profiles of trace gases and meteorological variables.
Please:

- Include a visual indication of the boundary-layer height on the profiles (e.g., horizontal lines).
- Explain how the boundary-layer height was determined (visual inspection? potential temperature gradient? CO_2 gradient? bulk Richardson number?).
- A standard reference such as Stull (1988) should be consulted for correct methodology.

Line 302: The manuscript refers to "Figure 4-d," but the panels in Figure 4 are not labeled. Please ensure all figure panels are clearly identified.

Line 312: This is the first (and apparently only) instance where temperature is expressed in kelvin. Please use consistent units throughout the manuscript.

Lines 336–340: This is the only mention of modelling results, which are used to support the claimed origin of the CO_2 plume—yet these modelling results are not shown (line 338).
I recommend either:

1. Removing this from the paper and saving it for a dedicated publication, **or**
2. Fully incorporating the modelling analysis into this manuscript, including a description in the methodology.

Lines 342–347: It is unclear why the CO_2 plume source could be identified but not the CH_4 plume. If source attribution is to be part of this manuscript, please:

- Provide sufficient information for both GHGs,
- Describe the modelling tools and methodology,
- Integrate this material into the methods and results sections.
  Otherwise, this discussion should be deferred to a future publication where the interpretation can be properly developed.

Lines 4, 66, 74, 101, 114, …, 350–351: The manuscript uses the word *parameters*, but *variables* is the appropriate term here. Please correct this throughout the text.

Figures

Figure 1

- Define all abbreviations at first mention in the caption, including *AGH* and *EC*.
- Clarify whether "m amsl" is a typo and should be "m a.s.l." (metres above sea level).
- Consider adding relevant contextual layers such as major road networks, major industrial facilities (especially high-emitting ones), and landfill locations. Since the text mentions "numerous landfills" (line 100), indicate how many there are and where they are located. This would help readers better understand the spatial distribution of emissions relative to the observation sites.
- *EC Skawina* and *EC Krakow* are not introduced in Section 2.1 (Study area), where Figure 1 is referenced. These facilities only appear later in the manuscript (lines 331–333). Their first mention should be moved earlier.

Figure 2

- Panels must be labelled ("a", "b", "c", "d").
- The caption must explain how the monthly concentrations were derived. Are these monthly means, daily maxima, monthly medians, or another metric? Without this clarification, interpretation is unclear.

Figure 3

- Label each panel ("a", "b", "c", etc.).
- Correct the misspelling (e.g., "repersent").

- The figure is difficult to read due to overlapping lines and excessive information. I strongly recommend focusing on a smaller number of representative cases (as done in Figure 4). Select profiles that best illustrate seasonal and diurnal variability, and move the remaining profiles to supplementary material with appropriate explanation.

Figure 4

- Panels are referenced as “a–d” in the caption, but no labels appear on the figure.
- When using abbreviations (e.g., AT for air temperature, WS for wind speed), define them in the caption for clarity.

Figure 5

- As with previous figures, label all panels clearly and refer to them specifically in the text (e.g., “Figure 5c”).
- Maintain consistency in stylistic conventions, such as using “No.” (line 296 and Table 1) instead of “no” in the caption.

Other editorial comments

- Ensure consistency in the use of *AGL* vs *a.g.l.* The manuscript currently mixes both styles. Since *a.s.l.* is also used, *a.g.l.* would be the more consistent choice.
- Ensure consistency in spelling “nighttime.” Line 314 contains “night-time,” which should be harmonised with the rest of the text.