Referee 2:

General Comments

The manuscript presents a comprehensive analysis of two years of continuous ground-based in-situ carbon dioxide and methane measurements at a suburban site in India. The authors compare these observations with satellite products, simulated CO_2 data, and other measured variables such as planetary boundary layer height and carbon monoxide. The study covers a wide range of approaches and datasets, which is commendable.

However, the manuscript suffers from several issues that require major revision:

- The language is often imprecise, wordy, and repetitive.
- The conclusions largely reiterate textbook knowledge and remain qualitative, even when quantitative data is presented.
- Methodological details are sometimes unclear or inconsistent.
- Figures and data presentation could be improved for clarity and comparability.

The manuscript would benefit significantly from major language editing and restructuring to improve clarity and conciseness.

We sincerely thank the reviewer for the thorough evaluation of our manuscript and for acknowledging the comprehensiveness of the dataset and the integration of multiple data products. We appreciate the constructive comments and have carefully addressed each concern in the revised version. Specifically:

1. The language has been carefully edited to improve clarity and conciseness. The repetitive sentences have been avoided.

2. The conclusions have been modified by focusing on the quantitative results from this study and avoiding common text book knowledge. The text has been modified as :

   "*In this study, we conducted high frequency measurements of atmospheric CO_2 mole fractions at a suburban station in the Indo-Gangetic Plain, Sonipat and investigated the carbon cycle dynamics over IGP. The atmospheric CO_2 mole fractions from February 2023 to January 2025 have been measured using a GHG analyser with laser-based cavity ring-down spectroscopy. CO_2 mole fractions over Sonipat recorded an annual average of 440.8±19.7 parts per million (ppm) in 2024, with a very high seasonal variability of ~60 ppm, much higher than that of other monitoring stations in the same latitudnal band. Post-monsoon recorded the highest diurnal variability (~ 60 ppm) and monsoon recorded the least (~20 ppm) with a consistent diurnal pattern irrespective of season. By examining a series of observational and modelling data, such as ground-based and satellite-based measurements, three model outputs, ecosystem proxy variables, and the tracer-tracer analysis technique, we identified the drivers of the high temporal variability of CO_2 over Sonipat and the IGP region. First, this high seasonality is attributed to elevated CO_2 mole fractions in November (post-monsoon), driven by local emissions and crop residue burning. We found that biospheric activity was the primary driver of seasonal changes over Sonipat, with anthropogenic emissions and soil respiration as the major sources and photosynthetic* *carbon uptake as the major sink. In addition, boundary-layer dynamics and air-mass transport from upwind regions significantly contribute to the buildup of CO_2 mole fraction. Second, we found that although both the CarbonTracker and MIROC-ACTM models captured the broad seasonal pattern of CO_2 mole fractions, they substantially underestimated it. Moreover, the OCO-2 and OCO-3 satellite XCO_2 retrievals also showed similar seasonal variability; however, the satellites could not capture CO_2 enhancements from local sources. Third, we found that the atmospheric CO_2 mole fraction at Sonipat exhibits a consistent diurnal pattern irrespective of season, with a maximum during the morning hours, attributed to the fumigation effect, followed by a gradual decrease during the day and a minimum during the afternoon hours, when photosynthetic activity is enhanced. Finally, tracer-tracer relationships across different time periods in the post-monsoon and winter seasons revealed common sources of CO_2 and CH_4. The CO/CO_2 ratios reveal the combined influence of vehicular emissions, crop residue burning, and open burning on CO_2 mole fractions in Sonipat during the post-monsoon period. This study identifies key sources and drivers of high CO_2 temporal variability in a data-sparse IGP region. These findings advance our understanding of carbon cycle dynamics, with direct implications for mitigation and policy."*

3. Methodological descriptions have been clarified and made consistent to improve clarity.

4. Figures have been revised for improved clarity and better comparability. Further the results section has been shortened, emphasising on the major findings from this study. Also a discussion section has been added after the results section focusing on the interpretations and avoiding repetitions.

We believe these revisions significantly strengthen the manuscript and improve its overall scientific rigour and presentation.

Specific Comments

1. CO_2, expressed as parts per million (ppm), refers to mole fractions, not concentrations.

Noted. In the revised manuscript, CO_2 is now consistently referred to as mole fractions, throughout the manuscript.

2. Line 20: Add height above sea level (asl).

We modified the text as *"Given the paramount significance of the IGP, a GHG observatory was established at a suburban monitoring station in Sonipat, Haryana (28.95 °N, 77.10 °E; 228m asl), within the Delhi National Capital Region."*

3. Line 23: Clarify how an annual average is determined over a two-year period.

We have modified the text as follows: *"We observed an annual average CO_2 mole fraction of 440.8 ± 19.7 parts per million (ppm) between January and December 2024, with unusually* *strong seasonal variability, ranging from 422.6 ± 23.3 to 456.4 ± 30.8 ppm during the monsoon and post-monsoon periods, respectively."*

4. Section 2.1: Include station location relative to Delhi (direction, distance).

We have modified the text to "*Sonipat is an upwind suburban region of the Delhi National Capital Region (NCR), situated in the northern Indian state of Haryana, approximately 45 kilometres north of Delhi*" for clarity in the manuscript in section 2.1

5. Line 118: A cavity temperature of 45°C is standard and not user-adjustable.

The text has been rephrased as *"The standard cavity temperature of 45°C (throughout the measurement period) ensures the necessary etalon mechanical stability of the measurement cavity."*

6. Lines 120–121: Clarify what is located 10 m above the instrument housing. Specify building height, canopy height, and inlet height above ground.

We have included this additional information into the manuscript: *"A pole is positioned on top of the roof, on which the inlet is mounted (about 15 m above ground level). The building is 3 stories tall, with the roof serving as the fourth floor. The inlet on the pole is positioned well above the surrounding canopy at the monitoring site."*

7. Line 121: Teflon tubing is permeable to CO_2 and thus inappropriate. Include tubing size, sample residence time, and any checks for CO_2 losses or contamination.

Teflon (PTFE) tubing was used for sampling because of its widespread use in atmospheric trace gas measurements due to its chemical inertness and low adsorption properties (Li et al., 2023). Ambient air samples were drawn using a 5 m-long PTFE tube with an inner diameter of 4mm, connected to an external vacuum pump operating at approximately 400 SCCM (residence time ~5.9 s). Given the short residence time and continuous sampling configuration, CO_2 losses or contamination due to permeation through the tubing are expected to be negligible relative to the observed atmospheric variability. In addition, the stability of the CO_2 measurements was routinely monitored using calibrations and instrument diagnostics, and no systematic offsets or drifts attributable to the sampling line were detected.

These details are included in the supplementary information. Also, the text has been modified as "The *sample air was taken from the top of the building and above the tree canopy (5 meters above the instrument housing) through a Teflon (PTFE) tube with an inner diameter of 2 mm using an external vacuum pump with ~400 SCCM flow rate (residence time ~5.9 s)*."

8. Line 149: Provide specifications for low-cost sensors (e.g. precision, accuracy, drift).

We have added these lines to the text: "*The sensitivity of the $PM_{2.5}$ and CO sensors was evaluated in Nagasaki, Japan, through intercomparisons with reference-grade instruments employing a beta attenuation monitor (BAM) for $PM_{2.5}$ and non-dispersive infrared (NDIR) spectroscopy for CO measurements. The estimated unit-to-unit variability was 29% for $PM_{2.5}$ sensors and 21% for CO sensors. Further details on the sensor specifications and the calibration methodology are described in Mangaraj et al. (2025).*"

9. Clarify the distance between the 1-Techpark building and the CRDS location.

The inlet is located on the roof of the I-Tech building, positioned on a pole approximately 3 metres above the roof. The roof is on the fourth floor of the I-Tech building. The instrument is placed inside the laboratory on the third floor. We have this information into the manuscript.

10. Lines 165–166: Describe calibration procedures for low-cost sensors.

We have addressed this in comment 8.

11. Line 175: Justify exclusion of Boulder Laboratory data.

We have modified the text as follows: "*We used the five-year averaged data for all sites in the same latitudinal band as India (5 °N - 40 °N). The data was averaged for five years from 2018 to 2022 for all stations except Boulder Atmospheric Observatory, Colorado (2011-2016), to compare the seasonality over different locations across the globe*". The Boulder Atmospheric Observatory data is not excluded, rather a different time period is used. Our intention in this section was to compare Sonipat CO_2 seasonality against some data from similar latitudinal bands (not all stations) across different regions, based on the availability of data.

Line 180: Confirm whether all 625 datasets were used.

Thanks for noting this misleading text in the manuscript. Note that we have selected available datasets from monitoring stations corresponding to similar latitudinal bands as Sonipat. Therefore, the misleading sentences (which described the ObsPack data in general) were removed from the manuscript: *"This product includes 625 atmospheric carbon dioxide datasets from observations made by 79 laboratories from 28 countries. The ObsPack dataset provides data for the period 1957-2023."*

Line 252: Add missing citation.

Added. Moreover, all references have been carefully cross-checked to ensure completeness throughout the manuscript.

12. Figure 1c: Add boundaries of the Indo-Gangetic Plain.

We have added the boundaries of the Indo-Gangetic Plain in the new Figure 1b.

13. Split Figure 1 into two: one for spatial context (Fig. 1b, c, d), one for time series, add CH4 and CO (new Fig. 2).

The new figures 1 and 2 have been added in section 3.1

Line 299: Clarify that the "annual mean" is a two-year average.

Throughout the manuscript, it has been corrected that the annual mean refers to the mean value of CO_2 from January 2024 to December 2024, for better clarity.

14. Lines 300–302: Rephrase for clarity.

The sentence has been rephrased as *"Interestingly, despite differences in site characteristics, the annual mean CO_2 levels at rural stations like Gadanki and urban stations such as Ahmedabad are comparable, whereas Sonipat exhibits distinctly higher values."*

15. Figure 2: Highlight seasonal regimes (monsoon, pre-monsoon, post-monsoon, winter) with background colors. Define pre-monsoon explicitly. Not done yet. Do you exclude any data when regimes transition?

We appreciate this suggestion. In the revised manuscript, the seasons have been highlighted using background colours for better clarity. Pre-monsoon has been defined in section 2.1 now. The modified text is given here: *"The climatic conditions over this site are similar to Delhi which has sweltering summers (March - May), damp or moist monsoons (June - September), and extreme winters. Similar to Delhi, this region also has frequent haze and smog with low visibility during winter (December - February) and post-monsoon (October - November) seasons."*

16. Monthly separation is coarse given the availability of hourly data. Consider using meteorological indicators (humidity, precipitation, temperature) for regime classification.

We appreciate the reviewer's suggestion to use meteorological indicators such as humidity, precipitation, and temperature for regime classification. We acknowledge that monthly separation is still coarse. However, the analysis using monthly and seasonal regimes could lead to sufficient insights into the seasonal variability of the CO_2 dynamics over the region. Moreover, the seasonal regimes adopted in this study follow the standard classification prescribed by the India Meteorological Department (IMD), which is widely used in climatological and atmospheric studies over the Indian region. Furthermore, we have updated the figure in the supplementary information (Figure S2) to examine the regime transition in relation to meteorological parameters.

17. Lines 321 ff.: Detrend data before comparing seasonal regimes to avoid bias from annual trends (~2.5–3 ppm/year).

The point we highlighted in this figure was about the monthly variation of atmospheric CO_2 mole fraction over the monitoring station. Detrending was intentionally applied in Figure 8 to isolate the influence of the long-term growth rate when examining the drivers of CO_2 variability.

18. Lines 360 ff.: The association between increased CO_2 and ecosystem productivity is unclear.

We thank the reviewer for the comment. During the post-monsoon season (October to mid-November), before crop harvest, the ecosystem exhibits higher nocturnal respiration and enhanced soil microbial activity, which contribute to elevated CO_2 mole fractions. We have clarified this in the manuscript for better clarity: *"Further, an increase in CO_2 mole fraction (~ 34 ppm) is observed during post-monsoon, reflecting higher ecosystem productivity (Sharma et al., 2014) and an enhancement in soil microbial activity (Fan & Forkel, 2025; Munksgaard et al., 2022), particularly from nocturnal respiration prior to crop harvest."*

19. Seasonality discussion is verbose and based on coarse temporal resolution. Regime transitions likely do not align with calendar months, leading to blurred results.

We agree with the reviewer that regime transitions do not strictly follow calendar months, however, the seasonal classification is used only as a regime-labelling framework. The seasons follow the IMD-defined regimes, which represent physically distinct and well-established meteorological conditions over India. This approach ensures consistency with prior studies and enables robust interpretation of CO_2 variability under dominant regional regimes.

20. Figures 3 & 4: Use consistent scales for observed and simulated data. Current presentation is misleading due to scale differences (e.g., 60 ppm vs. 8 ppm (Fig. 3) and 70 ppm vs. 20 ppm (Fig. 4)).

The point of this comparison was to demonstrate that the model can capture the seasonal pattern, but not the actual values. Using the same scale would hinder the depiction of the comparable seasonal pattern due to the totally different amplitudes.

21. Section 3.2.3: Clarify why only 12 ObsPack stations are used and why Boulder data is treated inconsistently. Above, it is mentioned that Boulder data were excluded.

This point has been clarified in Section 2.3.1. The Boulder Atmospheric Observatory data is not excluded, rather a different time period is used. Our intention in this section was to compare Sonipat CO_2 seasonality against some data from similar latitudinal bands (not all stations) across different regions, based on the availability of data.

22. Figure 6: Apply detrending before calculating seasonal cycles.

We appreciate this suggestion from the reviewer. Detrending was intentionally applied in Figure 8 to isolate the influence of the long-term growth rate when examining the drivers of CO_2 variability. Seasonal analyses presented in other sections are based on the original time series.

23. Section 3.3: Explain why the growth rate is considered for diurnal cycles but not for seasonal cycles.

The intention of the seasonal and diurnal variations plots here was to present the total CO_2 mole fractions over Sonipat on a seasonal and diurnal scale. The long-term CO_2 growth rate was not explicitly removed in the diurnal analysis. Instead, the diurnal cycles are analysed separately for each year to avoid any influence of interannual CO_2 increases on the derived diurnal amplitudes. Analysing multiple years together could bias the diurnal signal due to differences in background CO_2 levels between years. We have rephrased the sentence for clarity: *"To isolate diurnal variability, the diurnal cycle is analysed separately for each year, thereby minimising the influence of the long-term CO_2 growth rate on the estimated diurnal amplitude."* Note that the growth rate has been removed while studying the drivers of CO_2. In the revised manuscript, an analysis is added by removing the growth rates from both diurnal and seasonal means.

24. Lines 540–541: Clarify what is meant by "other local sources." Define "local emissions" consistently. Is crop burning considered local? Examples show inconsistent treatment:
    a. Line 657–658: "… high concentrations of CO2 during November (post-monsoon) from local emissions and crop residue burning …"

b. Line 32 ff.: "… CO2 variability in the IGP is driven by the interplay of local anthropogenic and biomass burning emissions …"
c. Line 461 ff.: "Being surrounded by agricultural land, Sonipat is prone to emissions from crop residue burning."
d. Line 417 ff.: "This enhancement during the post-monsoon season can be attributed to crop residue burning over the monitoring station and the added transport from Punjab […] This highlights the inability of high-resolution satellite data to capture enhancements from local sources."

Thank you for pointing that out. 'Other local sources' refer to vehicular emissions from the nearby highway and industrial emissions from facilities located to the northwest of the monitoring site. In addition, the station located upwind of Delhi is affected by small-scale crop residue burning during the post-monsoon season, as well as occasional biomass (wood) burning in surrounding areas. These sources collectively constitute the other local sources around the site. We have carefully reviewed the manuscript and corrected it to ensure a consistent and uniform treatment throughout.

25. Figures 8 & 9: Justify use of Mauna Loa as a baseline. Explain deviation from ADHS methodology. Specify which Mauna Loa data were used and whether a background filter was applied.

In Figure 8, the analysis focuses on examining the dominant drivers of CO_2 at Sonipat. As India currently lacks a long-term, regionally representative background CO_2 monitoring site, Mauna Loa was used as a global reference to estimate and remove the large-scale growth rate. CO_2 observations from Mauna Loa corresponding exactly to the study period were used for detrending. No additional background filtering was applied to the Mauna Loa dataset, as the objective was solely to capture the global growth rate.

Figure 9 employs the ADVS method, which is used consistently throughout this study, to estimate background CO_2 concentrations and thereby estimate enhancements relative to the background.

26. Clarify how CH_4 and CO backgrounds were determined.

The background concentrations of CH_4 and CO were determined using the same approach applied to CO_2, namely the Adaptive Diurnal Variation Selection (ADVS) technique.

While the manuscript addresses an important topic and presents valuable observational data from a region with limited coverage, it requires substantial revisions to improve clarity, consistency, and methodological rigor. The most compelling insight is the difficulty global products have in resolving local processes—an important but not unexpected finding.

With careful revision, the study has the potential to contribute meaningfully to the understanding of regional CO_2 variability in the Indo-Gangetic Plain.

We thank the reviewer for acknowledging the dataset's comprehensiveness and potential, as well as the insights gained from analysing the local observations. This study improves our current understanding of CO_2 dynamics over the IGP region with this unique measurement dataset and analysis. Following the reviewers' suggestions, we have thoroughly revised the manuscript to clarify the analysis and strengthen its scientific rigor.

Referee 3:

General Comments

The authors present a comprehensive data analysis of CO2 observations from an India monitoring station, which is a relevant contribution to this special issue about GHG in the Asia-Pacific region. The analysis, which includes related parameters like PBLH, NEE, CH4, and CO, is also competently discussed. However, the work is primarily descriptive, presenting a common data analysis without showing substantial scientific depth for the scope of ACP. The manuscript's emphasis on reporting and discussing measurements appears more aligned with the scope of AMT or a measurement report.

We sincerely thank the reviewer for the careful evaluation of our manuscript and for recognising the relevance of our dataset to the special issue on greenhouse gases in the Asia-Pacific region. We also appreciate the positive remarks regarding the comprehensive nature of the data analysis and the inclusion of related parameters such as PBLH, NEE, CH_4, and CO.

We understand the reviewer's concern that the previous version of the manuscript appeared descriptive.

1. In this revised version, we have substantially improved the writing and restructured the manuscript to show the scientific depth and analytical focus clearer. We have reduced purely descriptive content and strengthened analytical depth. Also, we have improved the results and discussion sections by better linking observed CO_2 variability with boundary-layer dynamics, regional fluxes, and co-emitted tracers (CH_4 and CO), thereby providing a more process-oriented and scientifically robust interpretation.

2. Moreover, we now explicitly highlight the novel scientific insights gained from the CO_2 measurements from the Sonipat observatory, the first continuous CO_2 monitoring station in the Indo-Gangetic Plain (IGP), a globally significant yet under-observed region for long-term atmospheric CO_2 measurements.

Through these revisions, we aim to clearly demonstrate that the manuscript not only presents high-quality measurements but also provides new scientific insight into CO_2 variability and its drivers in the Indo-Gangetic Plain, which we believe aligns well with ACP's scope and expectations.

Major comments:

1. Line 588: emissions from vehicular and natural gas combustion may exhibit different patterns. Could the authors elaborate on this? Additionally, as mentioned before, biomass burning is also a potential source -- how is this reflected in the correlation data? This is particularly interesting given Sonipat's proximity to Delhi. Could the authors clarify how urban emissions from the city contribute to the observed enhancements?

Furthermore, the correlation analysis could be enhanced by incorporating wind direction.

We agree with the reviewer that vehicular emissions and natural gas combustion can exhibit distinct temporal and chemical signatures. The intention of this discussion is not to imply identical emission characteristics, but rather to highlight that both source types act as common contributors to enhanced CO_2 and CH_4 at the Sonipat site, thereby leading to their correlated variability.

Biomass burning is indeed an important regional source, particularly during the post-monsoon season, as discussed in Section 3.5.2. During this period, crop residue burning contributes to enhancements in CO and CO_2. The derived $\Delta CO/\Delta CO_2$ ratios (4–12.5 ppb ppm^{-1}), while lower than values typically associated with intense open biomass burning reported in previous studies, are consistent with mixed influences from biofuel combustion and fossil-fuel sources, indicating overlapping source contributions rather than a single dominant process (Lin et al., 2015; Russo et al., 2003; Andrae and Merlet., 2001).

Sonipat's proximity to Delhi and its location along major transport corridors further modulate the observed enhancements. The prevailing north-westerly winds during most seasons (except the monsoon; Fig. S3) transport air masses from the urban city centre, nearby industrial clusters, and the NH-44 highway, all of which lie upwind of the monitoring station. This persistent upwind influence results in sustained contributions from urban vehicular traffic and industrial activities to the measured CO_2 levels.

We agree that incorporating wind direction can strengthen the interpretation of the correlation analysis. Seasonal wind patterns have therefore been presented using wind-rose analyses (Fig. S3), which provide meteorological context for the tracer–tracer relationships discussed in the manuscript.

2. How does the satellite-derived tracer-tracer correlations?

Satellite-derived tracer-tracer correlation study has not been carried out. The comparison with the satellite-derived columnar values was to assess the satellite's ability to capture the temporal pattern of carbon dioxide over the monitoring site.

3. Line 594-598: The description of deltaCH4/deltaCO2 appears contradictory. During periods of low photosynthetic activity (post-monsoon and winter), CO2 enhancement should increase, resulting in lower slope values. Conversely, higher photosynthetic activity during the monsoon season should lead to elevated slope values. However, the data show that deltaCO2 levels are significantly higher during monsoon afternoons compared to other periods. Could the authors explain this inconsistency?

We thank the reviewer for raising this point and apologise for the lack of clarity in the earlier description. We emphasise that the reported slopes are derived from excess concentrations (ΔCH_4 and ΔCO_2), calculated after removing the background using the ADVS method, rather than from absolute mole fractions.
The background concentrations estimated by ADVS are season-dependent and are notably higher during the post-monsoon and winter seasons. Consequently, even though absolute CO_2 enhancements are reduced during periods of low photosynthetic activity, the corresponding ΔCH_4 does not necessarily increase proportionally because a larger fraction of the measured

signal is attributed to the elevated background. This results in comparatively lower $\Delta CH_4/\Delta CO_2$ slopes during these seasons.

Similar seasonal behaviour in $\Delta CH_4/\Delta CO_2$ ratios has been reported in previous studies (e.g., Lin et al., 2015; Sreenivas et al., 2018), supporting the interpretation presented here. The text has been revised to clarify this distinction between absolute enhancements and background-subtracted excess concentrations.

During the monsoon season, the background CO_2 concentration estimated using the ADVS method is relatively low due to enhanced photosynthetic uptake under favourable moisture conditions. As a result, even moderate increases in observed CO_2 led to larger Δ CO_2 values. In addition, monsoon meteorology plays an important role. Persistent cloud cover and high humidity often suppress the development of a deep planetary boundary layer (PBL) during daytime hours. Consequently, vertical mixing remains weak during the typical afternoon window (11:00–14:00 LT), allowing locally influenced CO_2 to accumulate near the surface. The combined effect of a lower background concentration and limited PBL growth likely explains the elevated Δ CO_2 observed during monsoon afternoons

4. Line 596: What does the "long-range transport" indicate?

The "long-range transport" in this study refers to the movement of air masses from surrounding regions, primarily Punjab and Haryana, to the monitoring site at Sonipat, carrying emissions and influencing local CO_2 variability. We acknowledge that "long-range transport' may not be an appropriate way to indicate these aspects in a general sense. Therefore, we clarified it in the methods section.

5. Line 603: What are the correlations between deltaCO and deltaCO2 during the pre-monsoon and monsoon seasons?

We appreciate the reviewer for pointing this out. The CUPI-G sensor used for CO measurements was installed in September 2022; therefore, data for the pre-monsoon and monsoon periods of 2022 are not available. The sensor also experienced downtime during the pre-monsoon of 2023. Thus, we are unable to present statistical analysis for the pre-monsoon and monsoon seasons.

6. Line 646-648: The authors highlight that Sonipat's location—between Punjab and Delhi, with predominant northwesterly winds—makes it an ideal site for studying the influence of different regional air masses in the IGP region. However, this potential is not fully explored in the manuscript, aside from brief mentions in the tracer-tracer correlations section. Could the authors expand on this aspect?

We thank the reviewer for the comment. We find that Sonipat's unique location between Punjab and Delhi, under the influence of north-westerly winds, contributes to its unusually high temporal variability in CO_2. This hypothesis is supported by our tracer-tracer analysis, which indicates the mixing of local and transported emissions. While we acknowledge that this aspect has not been explored in full depth in the current study, we plan to investigate it further in future research to better quantify the role of regional air masses on CO_2 variability at Sonipat.

Technical comments:

1. Line 25: better specified the month period for “monsoon” and “post-monsoon”

Noted and added.

2. Line 70: column >>> columnar

Rectified.

3. Line 107: two “such as”

Thank you for pointing this out. Rectified.

4. Line 136: >>> background of CO2…

We still believe that the current sentence structure better suits here.

5. Line 252: a citation is missing

Thanks for noting this aspect. We have cross-checked all references to ensure consistency throughout.

6. Line 283: Figure 1(a) better add year on the x-axis

Added.

7. Line 311: what’s the sources on the northwest of study site?

Vehicular emissions from the nearby highway and industrial emissions from facilities located to the northwest of the monitoring site. Added this information into the manuscript.

8. Line 335: Figure2(a) shows minimum values in PBLH in January and highest values in April/May. The monsoon period covers June to September. Doesn’t mean that the maximum values also occur during pre-monsoon months? Please explain this.

This typo has been corrected and the text has been modified in section 3.2.1: *“Figure 3(a) shows that the minimum values in PBLH occur during winter months and the maximum values during pre-monsoon months.”*

9. Line 344: Figure 2(b) NDVI shows an increase during November – April, even surpassing its summer values. However, this pattern is not reflected in the SIF data. Could you please explain this?

The NDVI and SIF data measure some distinct aspects of vegetation. NDVI reflects canopy greenness or the amount of green biomass. During November-April, following post-monsoon crop residue burning, new winter crops are sown. These crops remain lush from November until April-May, leading to higher NDVI values. SIF measures photosynthetic activity directly. Even if green biomass increases, SIF can remain relatively low if photosynthetic rates are limited by light, temperature, or crop type. Thus, the observed enhancement in NDVI during November-April reflects the structural greenness of newly sown winter crops, whereas the SIF signal does not show a corresponding increase because actual photosynthetic activity may be lower.

10. Line 434: Figure 6: Sonipat monitoring station is presented as “SNPT”, which is “SNT” in the text. Please modify.

This has been rectified and updated (now Figure 9).

References:

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Updated figures:

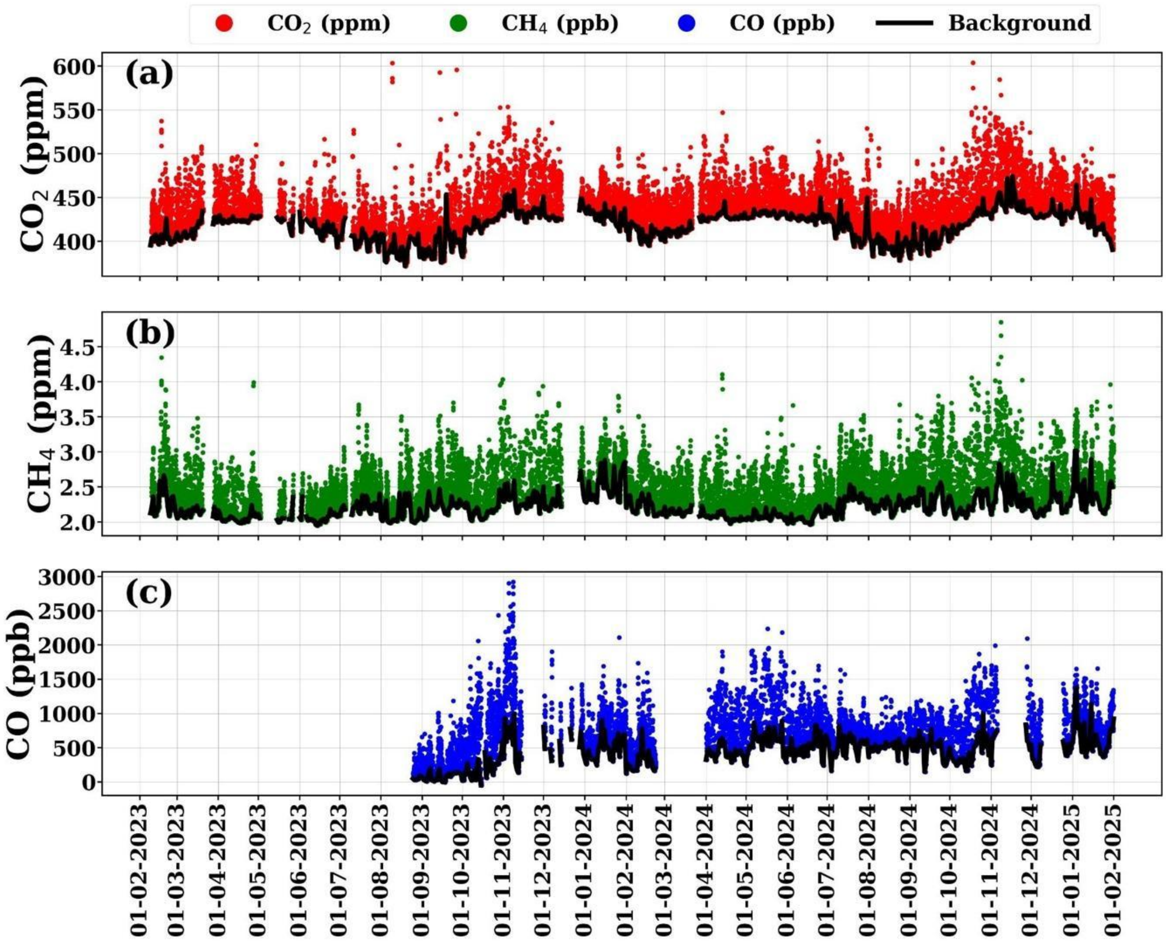

Figure 1: (a) Hourly averaged time series of atmospheric (a) CO_2 (red) (b) CH_4 and (c) CO mole fraction for the study period (February 2023 to January 2025) over Sonipat. The thick black line represents the background mole fraction estimated using the Adaptive Diurnal least Variation Selection (ADVS).

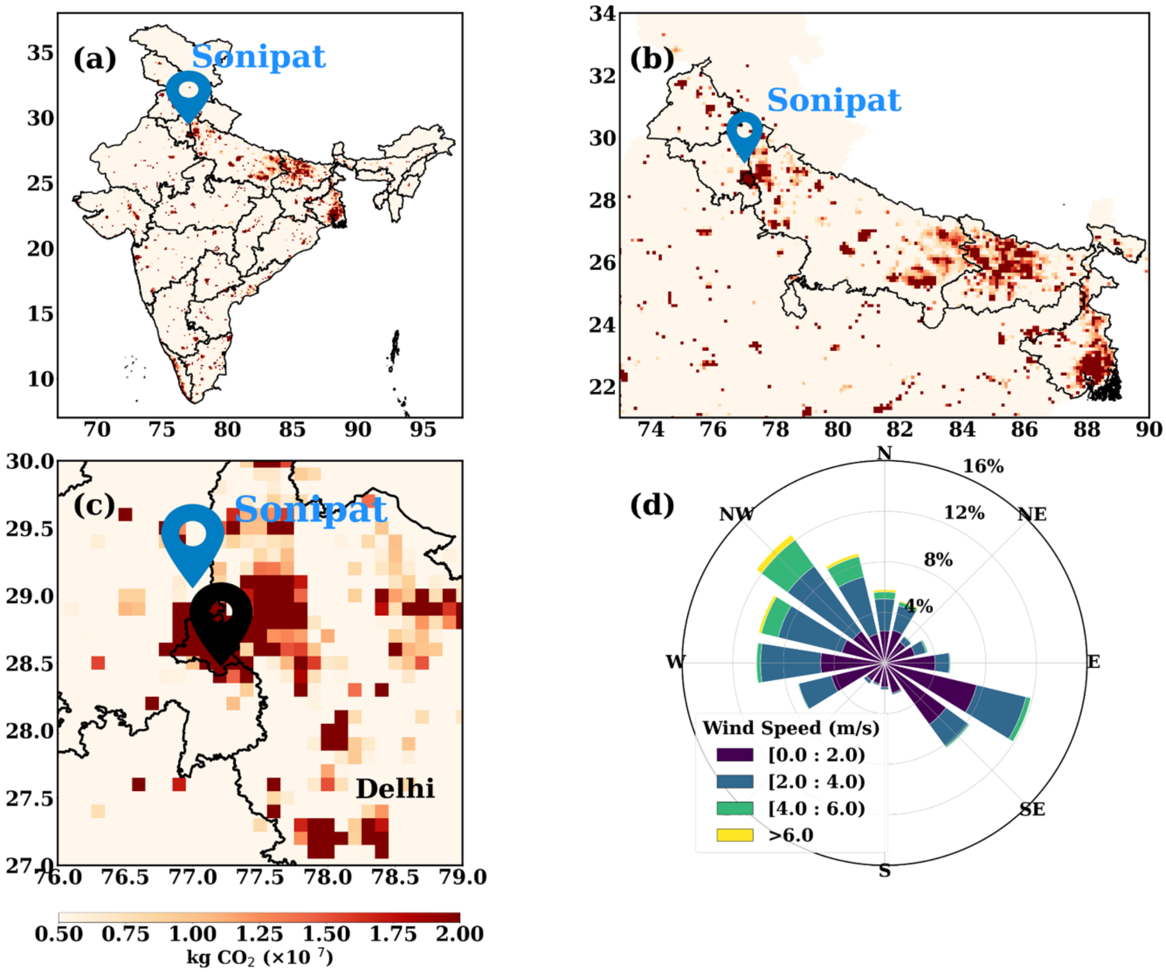

Figure 2: Anthropogenic CO_2 emissions over (a) India (b) Indo-Gangetic Plain and (c) Sonipat/Delhi are derived from the EDGAR emission inventory for 2021. (d) Annually averaged wind patterns over Sonipat for February 2023 – January 2024.

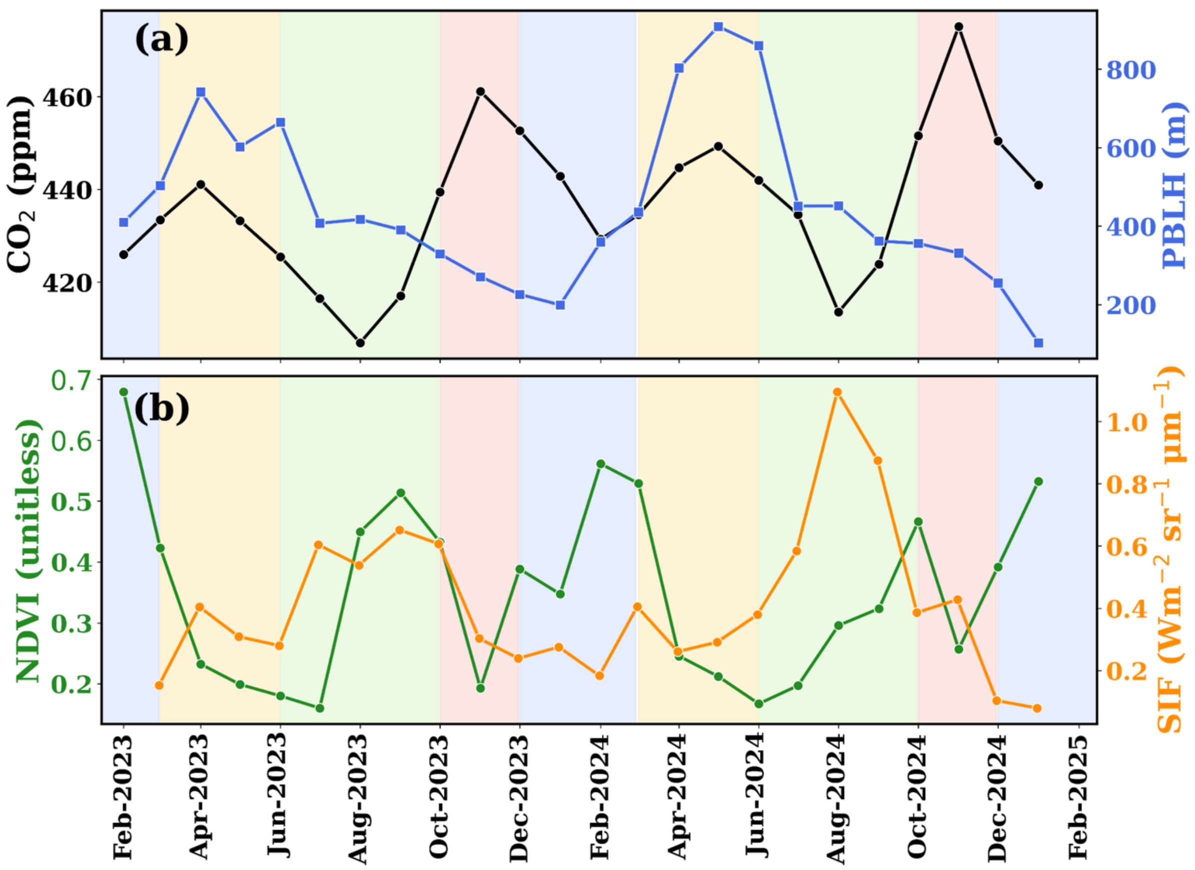

Figure 3: (a) Monthly variations of atmospheric CO_2 mole fraction (black) and PBLH (blue) and (b) NDVI (green) and SIF (olive green) over the Sonipat monitoring station during the study period.

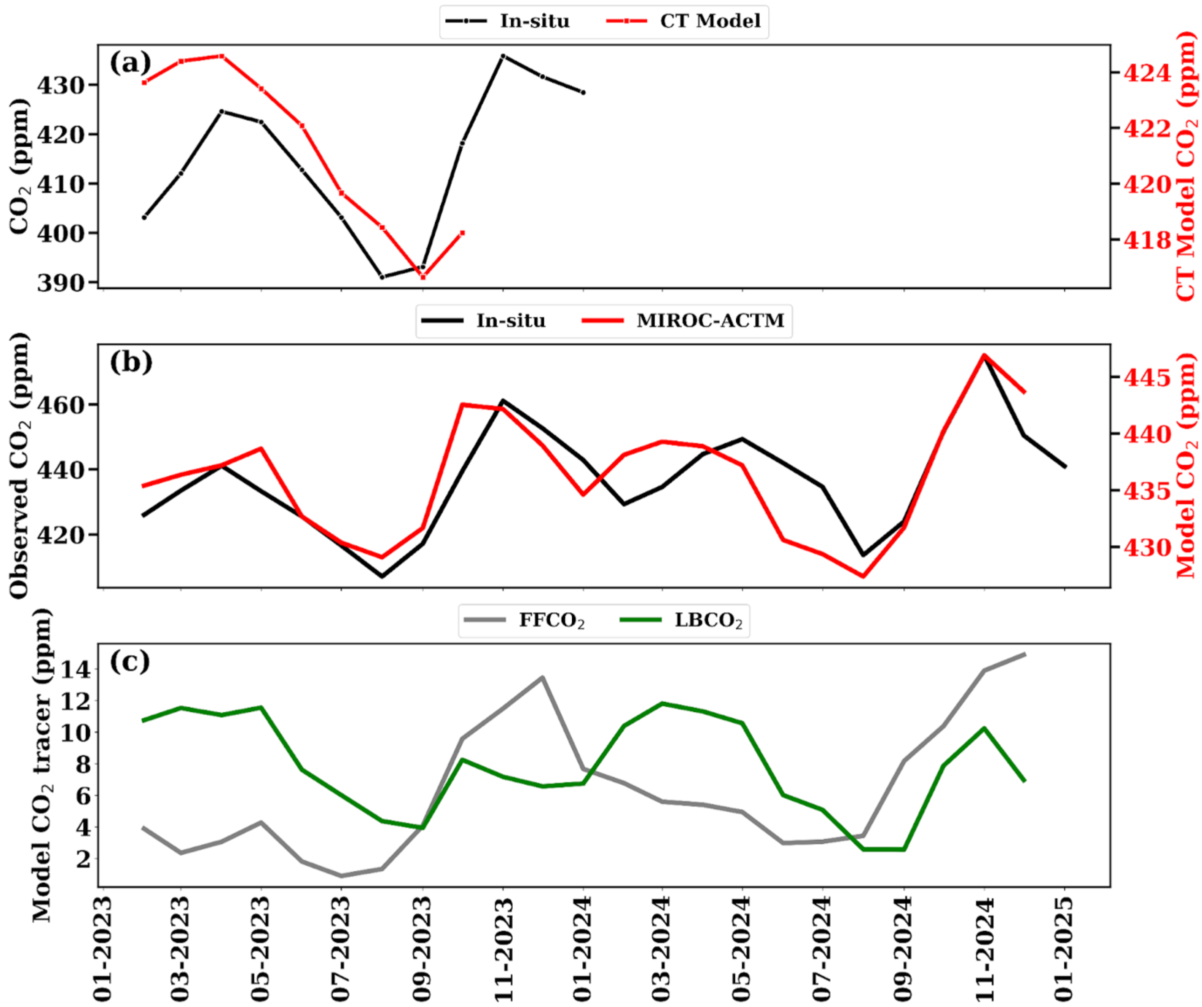

Figure 4: (a) Monthly mean background CO_2 mole fraction over Sonipat (estimated using the ADVS method) compared to CarbonTracker (CT2022) model-simulated values at daytime (13:00 – 16:00). Note that the left y-axis represents surface mole fraction from in situ measurements, and the right y-axis represents CT2022-simulated mole fraction. (b) comparison of simulated mole fraction of atmospheric CO_2 from MIROC-ACTM with in situ measurements at Sonipat and (c) monthly averaged time series of different tracers from the MIROC-ACTM.

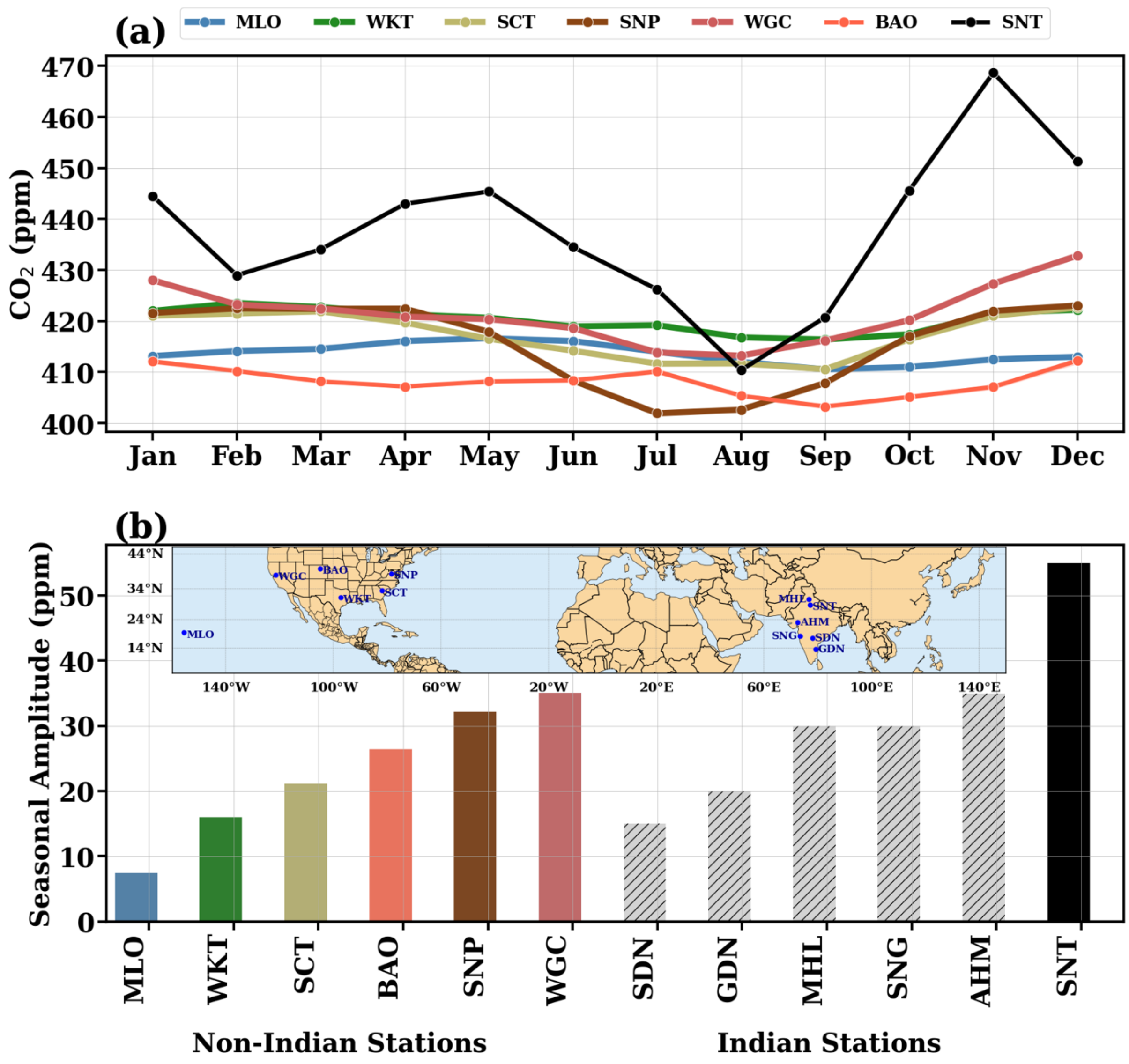

Figure 9: (a) Comparison of the seasonal variability of atmospheric CO_2 over Sonipat monitoring station with various locations in the same latitudinal band. (b) Comparison of the seasonal amplitude between Indian (coloured bars) and international monitoring stations (grey bars). Indian stations include Shadnagar (SDN), Sinhagad (SNG), Ahmedabad (AHM), Mohali (MHL), Gadanki (GDN), and Sonipat (SNT). International stations include Mauna Loa (MLO), South Carolina (SCT), Shenandoah National Park (SNP), Walnut Grove, (WGC), Moody (WKT) and Boulder (BAO). For all international stations except BAO, the five-year average (2018 - 2022) has been chosen for the seasonality. For BAO, 2011 – 2016 has been used. The monthly average of the entire study period (February 2023 – January 2025) has been used for this comparison.

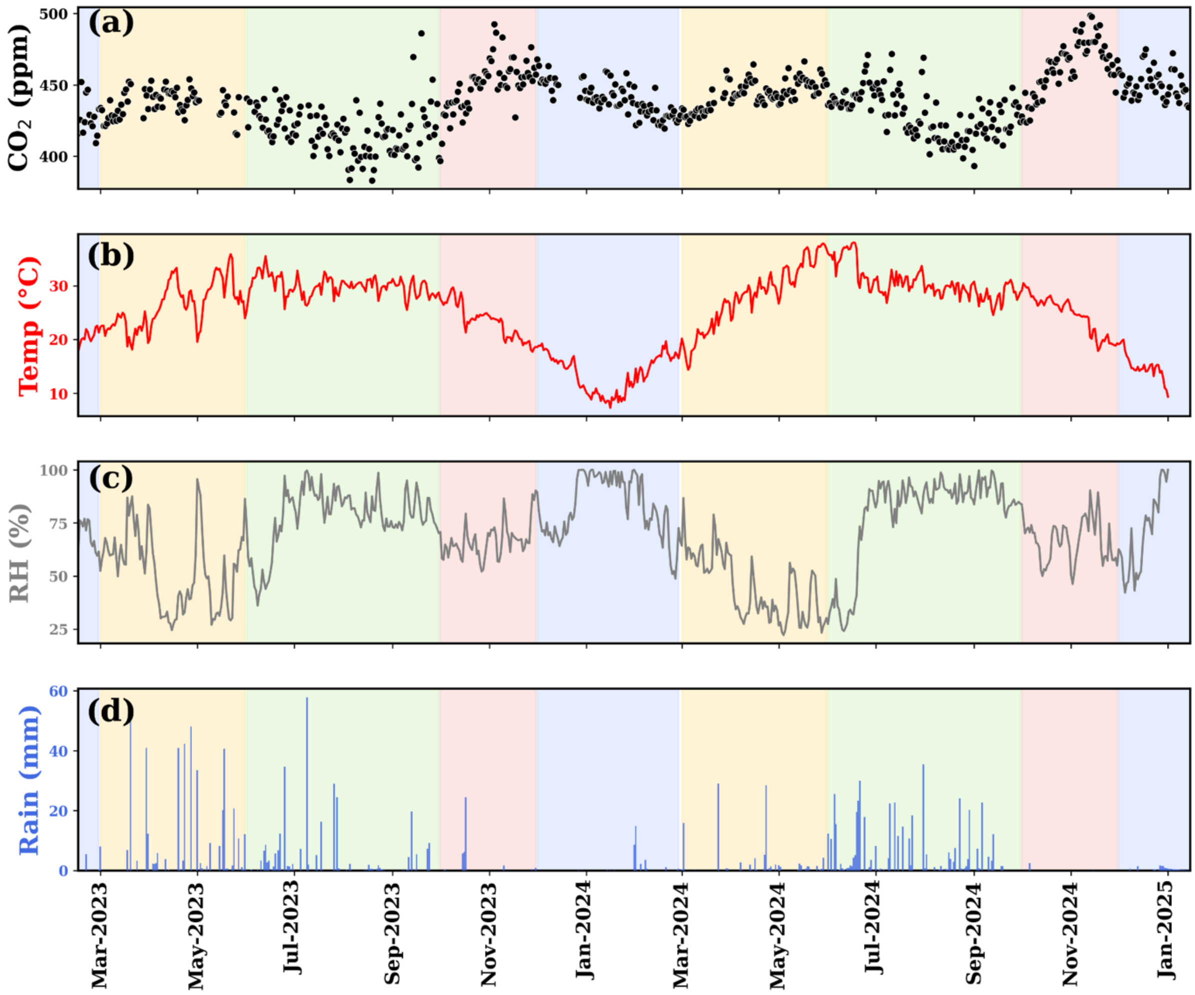

Figure S2: Daily variation in atmospheric carbon dioxide concentrations (a) and meteorological parameters (air temperature, relative humidity and rain) over Sonipat (b-d) during the study period. All measurements have been made using the Automatic Weather Station (AWS) in Sonipat.