Reviewer 2

Comment 2.1

The authors present a comparison of ground based HCHO retrievals from 5 Pandora sites with retrievals from OMI. The authors compare both direct sun and sky scan retrievals from Pandora to OMI and use those comparisons to suggest the use of sky scans would be preferable for satellite validation in the tropics. This work presents interesting data from an understudied part of the world. Unfortunately, the manuscripts conclusions rely on an incomplete analysis and questionable experimental design. Substantial revisions are needed before this work can be published.

Response 2.1

We thank the reviewer for the constructive assessment and for recognizing the value of the dataset in an understudied tropical region. We agree that the original manuscript required substantial improvements in both experimental design and analytical rigor. In response, the manuscript has been fundamentally revised. The previous OMI-only analysis and multi-scenario experimental design have been replaced with a physically consistent collocation framework based on nearest-time matching and overpass-centered averaging. In addition, an uncertainty-based quality control protocol following Rawat et al. (2025) has been implemented to ensure that all analyses are based on robust and physically meaningful Pandora observations. Furthermore, the study has been expanded to include TROPOMI and GEMS, alongside OMI, providing a more comprehensive multi-sensor evaluation across different spatial and temporal scales. The comparison between direct-sun and sky-scan retrievals is now performed using temporally matched pairs with quality-stratified analysis, enabling a more rigorous assessment of their consistency and behavior.

Revised Text

Section 1 (Introduction)

"In this study, we present a comprehensive evaluation of Pandora HCHO observations across Southeast Asia, explicitly distinguishing between Direct-sun and Sky-scan retrievals and assessing their consistency with multiple satellite products (OMI, TROPOMI, and GEMS). By applying an uncertainty-based quality-control framework and a unified temporal collocation strategy, this work aims to quantify how retrieval geometry, temporal sampling, and spatial representativeness jointly influence satellite–ground agreement in tropical environments."

Section 2.1.1 (Quality Control)

"To improve the robustness of ground-based HCHO observations used for intercomparison and satellite validation, an uncertainty-based quality control (QC) protocol following the methodological framework of Rawat et al. (2025) was applied to contemporaneous Pandora direct-sun (DS) and sky-scan (SS) observations. DS and SS retrievals were first paired within a 5 min tolerance window. A high-quality reference subset was then defined using Pandora quality flags QF = 0 or 10 for both DS and SS retrievals, and dynamic absolute uncertainty thresholds were calculated separately for DS and SS as the mean plus three standard deviations of the uncertainty in this subset. Matched observations were retained when either both DS and SS absolute uncertainties were below these dynamic thresholds or both relative uncertainties were below 10 %. Additional filters required WRMS < 0.01 for both DS and SS retrievals and, for sky-scan observations, maximum horizontal distance (MHxD) < 20 km when available. Pandora quality flags were subsequently used to classify observations into high-quality (QF = 0, 10), medium-quality (QF = 1, 11), low-quality (QF = 2, 12), and unusable (QF ≥ 20) categories for diagnostic analysis. This procedure reduces the influence of retrieval noise, poor spectral fits, and unfavorable viewing geometry prior to satellite collocation."

Section 2.3 (Collocation Strategy)

"To evaluate the consistency between ground-based and satellite-derived HCHO columns, filtered Pandora observations were collocated with station-level OMI, TROPOMI and GEMS retrievals using a time-based matching framework designed to account for differences in temporal sampling. The overall methodology of the study is illustrated in Figure 2. Two complementary approaches were applied. First, a nearest-time matching method paired each satellite observation with the closest Pandora measurement within a ±2 h tolerance window. Second, an overpass-window averaging method was used, in which all Pandora observations within symmetric windows centered on the satellite overpass time were averaged to form representative ground-based column estimates. Three temporal windows were tested (±30 min, ±1 h, and ±2 h) to assess sensitivity to temporal smoothing."

Section 2.2 (Satellite Data – addition of TROPOMI and GEMS)

"TROPOMI, launched in 2017, provides substantially finer spatial sampling than OMI and improved signal-to-noise performance. For the product version used here, the nominal pixel size is approximately 5.5 × 3.5 km^2 (De Smedt et al., 2021). The TROPOMI HCHO product (S5P OFFL HCHO) is derived using a similar DOAS framework but includes updated air-mass factor calculations and surface reflectance treatment (Su et al., 2020). Station-level TROPOMI HCHO values were extracted from pixels within a 10 km radius of each Pandora site. Quality screening followed recommended criteria, including qa_value ≥ 0.5, cloud fraction cloud_fraction_crb < 0.3, and SZA < 60° (De Smedt et al., 2021; Dimitropoulou et al., 2021). TROPOMI can be regarded as the next-generation continuation of the UV–visible trace-gas observing capability established by OMI, providing improved spatial resolution and signal-to-noise performance while maintaining similar measurement principles and orbital sampling. The temporal overlap between OMI and TROPOMI enables consistent long-term validation of satellite HCHO retrievals and facilitates assessment of algorithm evolution across successive instrument generations. The inclusion of both OMI and TROPOMI allows evaluation of retrieval consistency across successive satellite generations. While OMI provides a long-term observational baseline beginning in 2004, TROPOMI extends this record with enhanced spatial resolution and improved sensitivity to sub-pixel variability. The overlap period between the two sensors enables assessment of temporal continuity in satellite HCHO products and supports robust validation of long-term atmospheric composition trends.

Satellite observations from the Geostationary Environment Monitoring Spectrometer (GEMS) onboard the GEO-KOMPSAT-2B platform were additionally used to complement polar-orbiting measurements. GEMS provides hourly hyperspectral observations over East and Southeast Asia, enabling improved characterization of diurnal variability in tropospheric formaldehyde (HCHO) (Lee et al., 2023). In this study, Level-2 HCHO data (GEMS L2 HCHO) from January 2021 to December 2024 were obtained via the National Institute of Environmental Research (NIER) API, with only forward-calculated (FC) retrievals retained to ensure algorithmic consistency and data reliability. Station-level GEMS HCHO values were derived by averaging pixels within a 10 km radius of each Pandora site. Quality control followed conservative filtering criteria, including FinalAlgorithmFlags = 0, cloud radiance fraction < 0.4, and solar zenith angle SZA < 60° (Lee et al., 2024). The inclusion of GEMS provides enhanced temporal sampling relative to polar-orbiting sensors, allowing improved assessment of sub-daily variability and reducing temporal representativeness errors in satellite–ground validation over Southeast Asia."

Comment 2.2

Major issues:

This paper doesn't work without a more robust intercomparison of the two ground-based datasets to support the conclusions. Comparing both to OMI and discussing the differences between each and OMI is not sufficient. The authors point out that SZA dependent uncertainties exist in OMI products, so why are the authors conducting their analysis assuming OMI is the more trustworthy observation? We use ground-based measurements to evaluate satellite-based retrievals, not the other way around. How do the retrieved columns compare to each other? What are the conditions where they diverge from each other. What are the conditions when the direct sun and sky scan agree and disagree? Are there potential explanations that might impact the utility of each for satellite validation?

Response 2.2

We thank the reviewer for this important and insightful comment. We fully agree that a robust intercomparison between Direct-sun (DS) and Sky-scan (SS) Pandora retrievals must form the foundation of the analysis, and that satellite observations should not be treated as the reference standard. In the revised manuscript, the analysis has been fundamentally restructured to prioritize DS–SS intercomparison. A dedicated section (Section 3.2) now presents a comprehensive evaluation of DS–SS consistency using temporally matched pairs (±5 min) and quality-stratified correlation analysis, allowing direct assessment of agreement between the two retrieval geometries independent of satellite data. This analysis explicitly quantifies the conditions under which DS and SS agree and diverge. The results show that DS and SS retrievals exhibit strong agreement under high-quality conditions ($r > 0.7$), indicating that both measurement modes provide consistent representations of the HCHO column when retrieval uncertainties are well constrained. Divergence between DS and SS is primarily observed under lower-quality conditions, where increased retrieval noise, atmospheric heterogeneity, and viewing geometry effects introduce variability. In addition, systematic differences in variability are identified: DS retrievals exhibit a larger dynamic range and stronger short-timescale variability, while SS retrievals provide smoother and more spatially integrated column estimates. Satellite comparisons are therefore used not as a reference standard, but as an independent observational framework to interpret how these differences in sampling characteristics influence satellite–ground consistency. The revised manuscript explicitly avoids treating satellite retrievals as truth and instead uses them to diagnose the role of spatial representativeness and temporal sampling.

Revised Text

Section 3.2 (DS-SS Intercomparison)

"The nine-panel correlation analyses (Figs. 3) reveal that DS–SS agreement depends strongly on retrieval quality category, with the highest correlations observed when both measurements fall within the high-quality regime (QF = 0, 10). Across all stations, high-quality DS–SS pairs exhibit correlation coefficients typically exceeding 0.70, indicating strong agreement between retrieval geometries under well-constrained uncertainty conditions. Bangkok demonstrates the most robust behaviour, with correlations reaching approximately $r \approx 0.78$ in the high-quality category."

Section 3.2 (Differences between DS-SS)

"Differences between DS and SS retrievals arise primarily from sampling characteristics rather than systematic bias, with DS observations exhibiting greater sensitivity to short-timescale variability and SS retrievals providing more spatially integrated column estimates. High-quality observations yield robust agreement across all stations, while lower-quality measurements introduce increased variability and reduced correlation. The application of uncertainty-based QC therefore represents a critical step in ensuring the reliability of Pandora HCHO datasets for atmospheric analysis and satellite validation."

Section 4.0 Discussion

"Satellite observations are not treated as a reference standard in this study; instead, they provide an independent observational framework to evaluate how differences in retrieval geometry and sampling characteristics influence satellite–ground agreement."

Comment 2.3

Sky scan retrievals are not sensitive to the whole column, one would expect that the direct sun retrieval would typically be higher since it is sensitive to the whole column. Sky scans that use a temporally local zenith reference are typically only sensitive to the lowest 2 km of the atmosphere. This doesn't necessarily imply mean direct sun retrievals are "highly sensitive to episodic enhancements" as a general rule, but they are more likely to pick up lofted plumes than a sky scan observation where the plume would impact the reference spectrum and not impact the measured slant columns in the same way as a direct sun observation.

Response 2.3

We thank the reviewer for this important clarification regarding the sensitivity characteristics of sky-scan (SS) and direct-sun (DS) retrievals. We agree that DS retrievals represent the total column along the solar beam, while SS retrievals—depending on retrieval configuration—can have reduced sensitivity to the full column and may be more influenced by the lower troposphere. In the revised manuscript, we have avoided interpreting DS–SS differences in terms of vertical sensitivity, as this would require detailed radiative transfer analysis beyond the scope of this study. Instead, the analysis focuses on observational sampling characteristics and representativeness. Our results show that DS and SS retrievals exhibit strong agreement under high-quality conditions but differ in their variability: DS retrievals display a larger dynamic range and stronger short-timescale fluctuations, while SS retrievals provide smoother and more spatially integrated column estimates. We interpret this behaviour primarily in terms of sampling geometry and sensitivity to localized variability, rather than attributing it directly to vertical sensitivity differences. We have revised the manuscript to clarify this interpretation and to avoid overstating the role of vertical sensitivity in explaining DS–SS differences.

Revised Text

Section 1 (Introduction – refined clarification)

"Differences between direct-sun and sky-scan retrievals are primarily associated with sampling characteristics and spatial representativeness. While the two retrieval modes may differ in their effective sensitivity to atmospheric structure, this study focuses on their observational behaviour and consistency rather than explicit vertical sensitivity differences."

Section 3.2 (Interpretation refinement)

"The larger variability observed in DS retrievals and the smoother behaviour of SS observations are interpreted as a consequence of differences in sampling geometry and sensitivity to localized atmospheric variability, rather than systematic differences in vertical sensitivity."

Section 4 (Discussion – strengthening statement)

“The observed differences between DS and SS retrievals reflect the interplay between measurement geometry and atmospheric heterogeneity, with DS capturing localized variability and SS providing a more spatially integrated representation of the atmospheric column.”

Comment 2.4

The chosen experiments for comparison don't all have utility for satellite evaluation, so it is unclear why these 9 scenarios were chosen.

1. Given that formaldehyde columns generally have a strong temperature and sunlight dependence and thus vary throughout the day, I'm unclear what the utility of daily averaging is in a satellite evaluation context, where the overpass time is known. Most studies just consider the average around the overpass time .
2. The daytime averaging period is given as 07-09 local, is this a typo or should the label be changed from daytime to early morning? Assuming a typo, for measurements that require sunlight, what is the utility of separate daytime and daily averages? Aren't they pretty much the same aside from some less reliable measurements in low light conditions that would typically be discarded anyway?
3. Similarly, given Rayleigh scattering limits the effective horizontal pathlength of the Pandora measurements to ~20 km under clear sky conditions in this fit window, it makes little sense to average over 2 adjacent OMI pixels (5x5) for comparison as the Pandora may not even be sampling adjacent pixels let alone two over.

Response 2.4

We thank the reviewer for this detailed and insightful comment. We fully agree that the previous nine-scenario (E1–E9) framework, including the use of daily and fixed-time averaging, was not well suited for satellite validation given the strong diurnal variability of HCHO and the known satellite overpass timing. In the revised manuscript, this entire experimental design has been removed and replaced with a physically consistent collocation framework. Pandora observations are now matched to satellite measurements using nearest-time pairing (±2 h) and overpass-centered averaging windows (±30 min, ±1 h, ±2 h), ensuring temporal consistency with satellite sampling and avoiding biases associated with full-day or mismatched temporal averages. In addition, satellite–Pandora comparisons are now performed using multi-pixel averaging within a 10 km radius, rather than fixed adjacent pixel selection, to better account for spatial representativeness and the effective sampling scale of Pandora observations.

Revised Text

Section 2.3 (Collocation Strategy)

“Two complementary approaches were applied. First, a nearest-time matching method paired each satellite observation with the closest Pandora measurement within a ±2 h tolerance window. Second, an overpass-window averaging method was used, in which all Pandora observations within symmetric windows centered on the satellite overpass time were averaged to form representative ground-based column estimates. Three temporal windows were tested (±30 min, ±1 h, and ±2 h) to assess sensitivity to temporal smoothing.”

Section 2.3 (Spatial representativeness clarification)

“Satellite HCHO columns were calculated by averaging all valid pixels within a 10 km radius of each Pandora site, providing a spatially representative estimate consistent with the effective sampling scale of ground-based observations.”

Comment 2.5

There doesn't appear to be sufficient data quality checks done on the Pandora data. While there is a case to be made for not relying solely on Pandora L2 QC flags (e.g. Rawat et al 2025), one should still check fit quality (RMS) and do cloud screening before comparing to satellite based measurements. For example, the statistics presented for your retrievals at Agam show unrealistically large columns with no explanation. Are these actual events or retrieval artifacts?

Response 2.5

We thank the reviewer for this important comment and fully agree that robust quality control is essential for reliable Pandora–satellite comparisons. In the revised manuscript, we have implemented an uncertainty-based quality control protocol following Rawat et al. (2025), which goes beyond the use of Pandora L2 quality flags alone. This includes explicit filtering based on spectral fitting residual (WRMS < 0.01), relative uncertainty (<10%), and dynamic absolute uncertainty thresholds, as well as MHxD constraints for sky-scan retrievals. These criteria effectively remove retrieval artefacts associated with poor spectral fits, cloud contamination, and unfavorable viewing geometry. Regarding the reviewer’s concern about unrealistically large HCHO columns at Agam, we confirm that such extreme values in the original manuscript were primarily associated with low-quality retrievals and high-uncertainty conditions. After applying the revised QC protocol, these outliers are substantially reduced, and the retained dataset exhibits physically consistent variability. The impact of QC filtering, including the removal of such artefacts, is now explicitly demonstrated in the revised time-series analysis.

Revised Text

Section 2.1.1 (Quality Control)

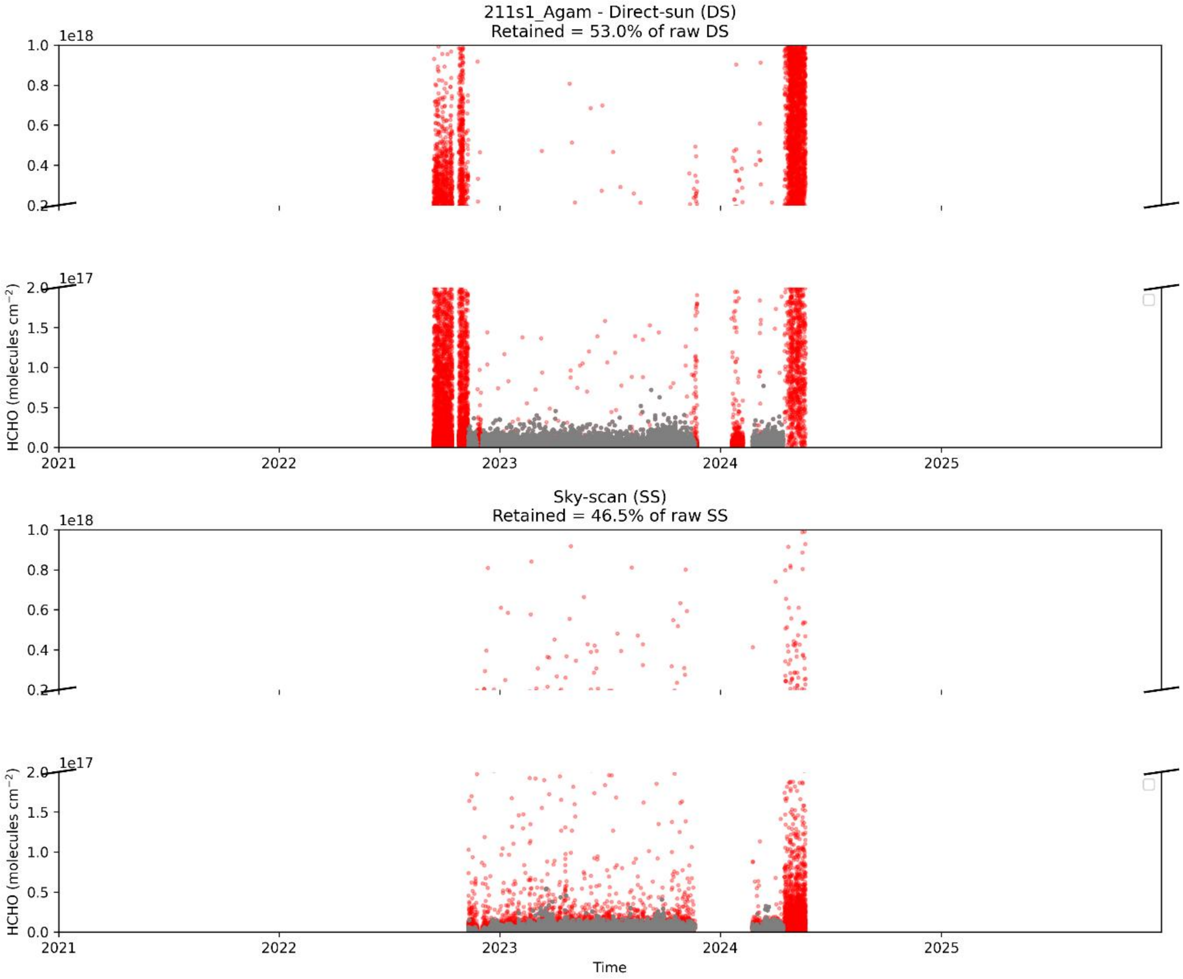
"Additional filters required WRMS < 0.01 for both DS and SS retrievals, and, for sky-scan observations, maximum horizontal distance (MHxD < 20 km) when available. Matched observations were retained only when uncertainty-based criteria were satisfied, ensuring removal of retrieval artefacts associated with poor spectral fitting and unfavorable measurement conditions."

Section 3.1 (QC impact)

"The application of uncertainty-based QC substantially reduces extreme outliers, particularly at sites such as Agam, where high-uncertainty retrievals can otherwise produce unrealistically large column values."

Figure 4 (supporting evidence)

"Removed data points failing quality control (QC) are highlighted in red, illustrating the impact of uncertainty-based filtering in eliminating unrealistic retrievals."



Same as Figure 4 but at the Pandora Agam station.

Comment 2.6

It looks like the Pandora data are filtered when making the Figures 4 and 5, but not when calculating the statistics in Table 3. You need consistent treatment throughout the analysis.

Response 2.6

In the revised manuscript, all comparative analyses (e.g., DS–SS correlation and satellite validation) are based on the QC-filtered dataset, while Table 3 presents both raw and after QC statistics to illustrate the impact of filtering.

Revised Text

Section 2.3 (Methodology Flowchart)

“The analysis includes observations from OMI, TROPOMI, and GEMS over the period 2021–2024, allowing a more robust and statistically consistent evaluation of satellite–ground agreement across multiple observational platforms. The overall methodology of the study is illustrated in Figure 2.”

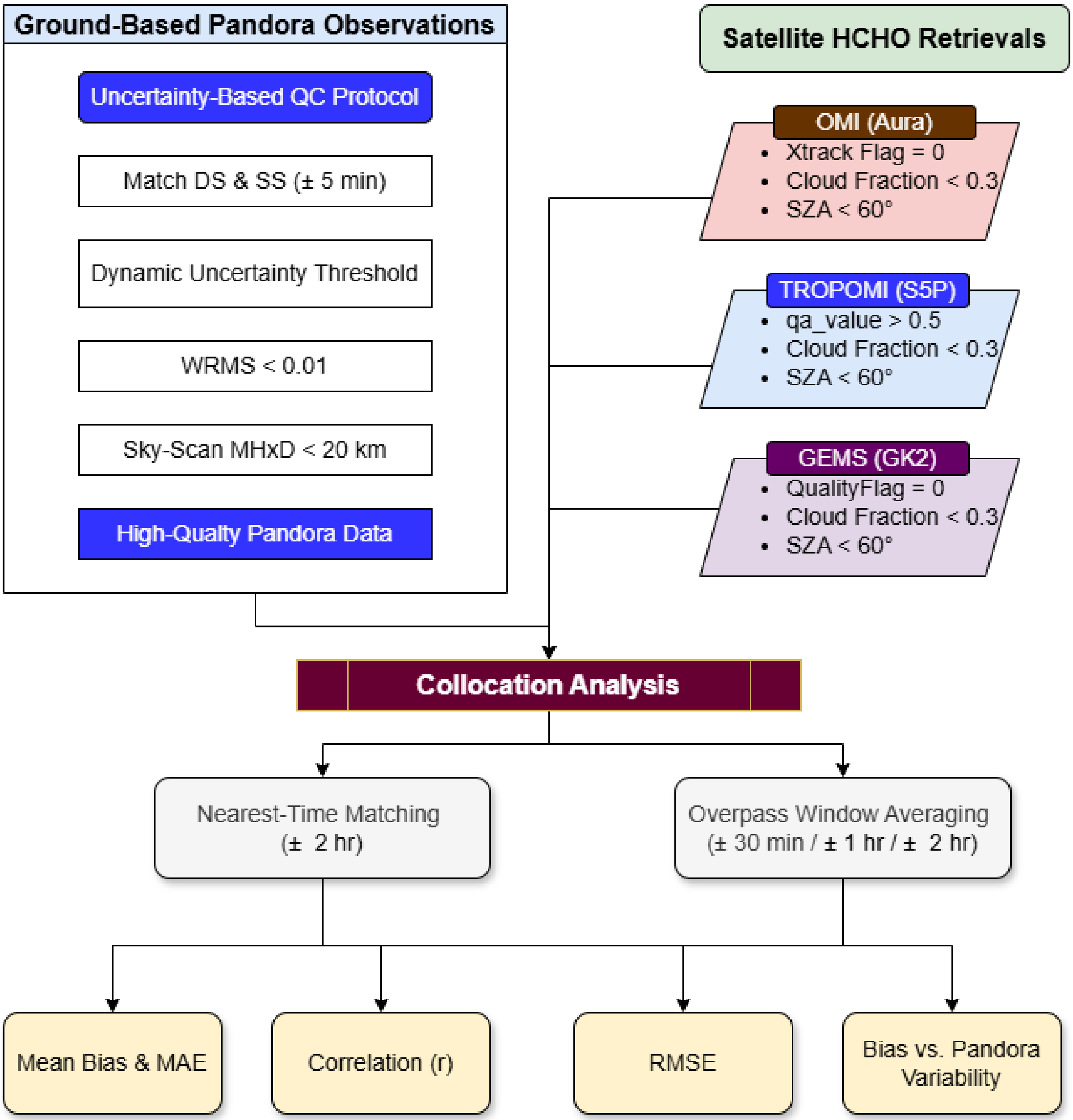


Figure 2. Flowchart illustrating the satellite–Pandora HCHO validation framework applied in this study. The methodology includes uncertainty-based quality control of Pandora observations following **Rawat et al. (2025)**, standard quality screening of OMI, TROPOMI and GEMS retrievals, temporal collocation using multiple overpass windows, and statistical evaluation of bias, error metrics, and representativeness effects in tropical environments.

Section 3.1 (Descriptive Statistics Before QC and After QC)

“The statistical distributions of HCHO columns before and after QC filtering (Table 3) confirm that the protocol primarily removes extreme outliers while preserving the central tendency of the observations. At most stations, mean and median HCHO values remain nearly unchanged following QC application, indicating that the filtering does not introduce systematic bias.”

Table 3. Descriptive statistics of Pandora Level-2 formaldehyde (HCHO) retrieved from Direct-sun (DS) and Sky-scan (SS; rfuh5p1-8) observations at selected Southeast Asian stations. Statistics are shown for contemporaneous matched DS–SS pairs before and after applying the Rawat quality control (QC) protocol. Values are reported as mean ± standard deviation (SD), median with interquartile range (IQR; Q1–Q3), and minimum–maximum. All HCHO columns are expressed in units of $\times 10^{15}$ molecules cm^{-2}.

Station	Dataset	Mean ± SD	Median (IQR)	Min–Max	N
(a) Direct-sun (DS) HCHO					
Bangkok	Raw	21.2 ± 7.88	20.6 (16.0–25.7)	0.018–200	80,336
	After QC	21.3 ± 7.83	20.7 (16.1–25.8)	0.018–83.6	79,072
Bandung	Raw	19.6 ± 44.4	15.0 (10.2–21.0)	0.012–988	34,248
	After QC	16.4 ± 8.29	15.3 (10.5–21.1)	0.012–76.9	30,268
Agam	Raw	63.0 ± 166.6	9.93 (6.76–14.0)	0.013–999	35,504
	After QC	9.01 ± 4.07	8.93 (6.40–11.2)	0.013–77.0	18,804
Pontianak	Raw	11.9 ± 7.90	11.7 (8.93–14.4)	0.013–569	25,694
	After QC	11.8 ± 5.17	11.7 (9.00–14.4)	0.013–107	25,095
Singapore-NUS	Raw	10.8 ± 6.89	9.33 (6.53–13.2)	0.012–131	39,791
	After QC	10.9 ± 7.23	9.30 (6.36–13.3)	0.012–131	32,455
(b) Sky-scan (SS) HCHO					
Bangkok	Raw	12.8 ± 10.8	11.9 (8.31–16.1)	0.013–956	135,664
	After QC	13.2 ± 5.57	12.6 (9.43–16.3)	0.025–61.3	79,072
Bandung	Raw	13.0 ± 17.6	11.0 (6.67–16.6)	0.014–923	47,161
	After QC	13.1 ± 7.18	11.8 (7.91–17.1)	0.026–116	30,268
Agam	Raw	7.40 ± 26.9	4.39 (2.52–6.78)	0.010–992	40,440
	After QC	4.93 ± 3.07	4.51 (2.92–6.40)	0.010–54.5	18,804
Pontianak	Raw	8.10 ± 15.0	6.75 (4.46–9.77)	0.010–919	36,279
	After QC	8.22 ± 3.82	7.62 (5.53–10.2)	0.027–45.2	25,095
Singapore-NUS	Raw	10.9 ± 11.1	9.02 (6.05–13.4)	0.013–883	61,473
	After QC	11.7 ± 7.34	9.90 (7.11–14.0)	0.024–90.6	32,455

Comment 2.7

Minor Points

Figures 2 and 3: I think your analysis would be better served by correlation plots of these data rather than frequency distributions. If the authors want to present frequency distributions, all three retrievals should be present on the same axis for each site, so the reader can more easily compare the distributions.

Response 2.7

We thank the reviewer for this helpful suggestion and agree that correlation-based analysis provides a more direct assessment of consistency between retrievals. In the revised manuscript, the DS–SS comparison has been updated to use scatter plot (correlation) analysis of temporally matched pairs, replacing the previous reliance on frequency distributions. This allows a more quantitative evaluation of agreement between retrieval modes across different quality categories. Frequency distributions have been retained only where appropriate to illustrate overall variability, but the primary analysis now emphasizes correlation-based diagnostics.

Revised Text

Section 3.2 (DS–SS Comparison)

"The nine-panel correlation analyses (Figs. 3) reveal that DS–SS agreement depends strongly on retrieval quality category, with the highest correlations observed when both measurements fall within the high-quality regime (QF = 0, 10)."

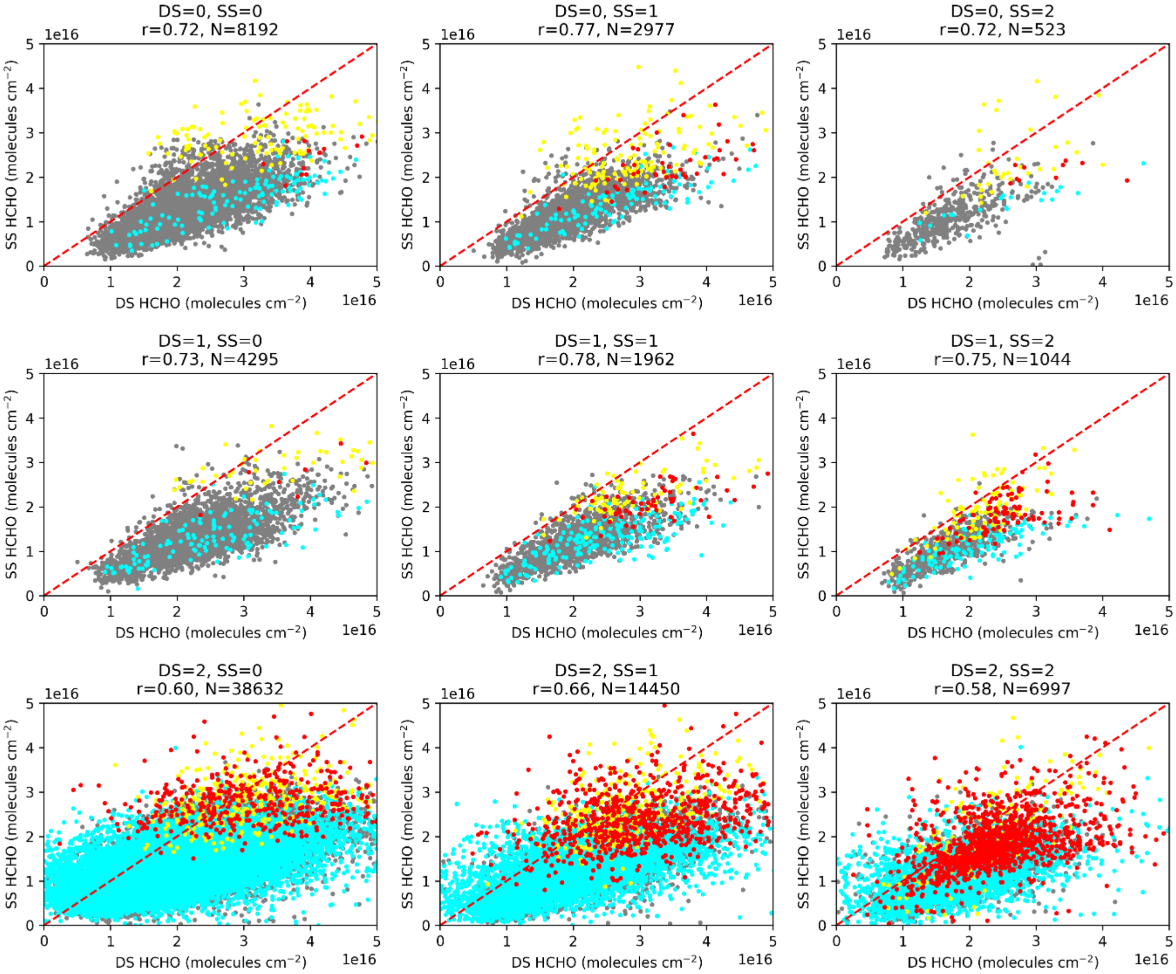


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Figure 3. Nine-panel plot of correlation between contemporaneous Pandora HCHO column amounts: direct-sun (DS) vs sky-scan (SS) for each quality category, following the Rawat et al. (2025, AMT) QC method at Bangkok station. Panels are organized by DS and SS quality categories (0 = high, 1 = medium, 2 = low). Each panel shows the scatter of DS vs SS HCHO (molecules cm^{-2}), with points color-coded by uncertainty thresholds: gray = both below cutoff, cyan = DS above cutoff, yellow = SS above cutoff, red = both above cutoff. The red dashed line represents the 1:1 relationship, and the correlation coefficient (r) and number of matched observations (N) are indicated in each panel.

Comment 2.8

Line 241: Elevated has an ambiguous meaning when discussing atmospheric measurements, do you mean aloft or enhanced relative to background.

Response 2.8

In the revised manuscript, this line has been removed from the text due to the substantial revisions.

Comment 2.9

OMI while providing a long timeseries is not really the most widely used HCHO product used these days, the community would likely find more benefit from comparisons with TROPOMI and GEMS. Spatial averaging can be utilized to deal with the Pandora path crossing multiple pixels.

Response 2.9

We thank the reviewer for this valuable comment and fully agree that comparisons with more recent satellite products are important for current applications. In the revised manuscript, the analysis has been expanded to include both TROPOMI and GEMS, in addition to OMI. TROPOMI provides higher spatial resolution, while GEMS offers high-temporal-resolution observations over Southeast Asia, making them highly relevant for satellite validation in this region. As a result, the study is no longer centered on OMI alone but instead adopts a multi-sensor framework to evaluate satellite–Pandora consistency across different spatial and temporal scales. OMI is retained to provide continuity with previous validation studies and to serve as a stable reference for examining first-order representativeness effects. In addition, satellite–Pandora comparisons are now performed using multi-pixel averaging within a 10 km radius, ensuring that the satellite data are spatially representative of the effective Pandora sampling scale.

Revised Text

Section 2.3 (Satellite Data)

"To evaluate the consistency between ground-based and satellite-derived HCHO columns, filtered Pandora observations were collocated with station-level OMI, TROPOMI and GEMS retrievals using a time-based matching framework designed to account for differences in temporal sampling. The analysis includes observations from OMI, TROPOMI, and GEMS over the period 2021–2024, allowing a more robust and statistically consistent evaluation of satellite–ground agreement across multiple observational platforms."

Section 2.3 (Spatial Representativeness)

"Satellite HCHO columns were derived by averaging all valid pixels within a 10 km radius of each Pandora site, ensuring consistency with the effective spatial sampling of ground-based observations."

References:

Dimitropoulou, E., Hendrick, F., Friedrich, M. M., Tack, F., Pinardi, G., Merlaud, A., et al. (2022). Horizontal distribution of tropospheric NO2 and aerosols derived by dual-scan multi-wavelength multi-axis differential optical absorption spectroscopy (MAX-DOAS) measurements in Uccle, Belgium. Atmospheric Measurement Techniques, 15(15), 4503–4529. https://doi.org/10.5194/amt-15-4503-2022

Rawat, P., Crawford, J. H., Travis, K. R., Judd, L. M., Demetillo, M. A. G., Valin, L. C., et al. (2025). Maximizing the scientific application of Pandora column observations of HCHO and NO_2. Atmospheric Measurement Techniques, 18(13), 2899–2917. https://doi.org/10.5194/amt-18-2899-2025