

1 **Title: Observed Impacts of Aerosol Regimes on Energy and Carbon Fluxes in the**
2 **Amazon Forest**

3
4 Response (blue color) to anonymous Referee #1 (black). The original manuscript was
5 changed accordingly. The lines indicated in our answers correspond to the track
6 version of the manuscript.

7
8
9 **General comment**

10
11 The manuscript investigates how contrasting aerosol optical depth (AOD) regimes
12 affect surface energy and carbon fluxes over an undisturbed Amazon rainforest using
13 long-term in situ data (2016–2022) from the Amazon Tall Tower Observatory (ATTO).
14 The authors focus on differences between “clean” (AOD < 0.13) and “polluted” (AOD
15 > 0.40) regimes and assess impacts on radiation, sensible and latent heat fluxes, and
16 CO₂ exchange. The topic is highly relevant to ACP because it addresses aerosol–
17 biosphere–atmosphere interactions in one of the planet’s key ecosystems. The study
18 provides new observational insights from a unique long-term dataset and uses
19 appropriate statistical tools (Spearman correlation, Pillai’s trace, Random Forest) to
20 assess nonlinear relationships. I think the paper is well written and it is neatly exposed.
21 The literature cited is adequate.

22
23 We would like to thank Referee #1 for their detailed review of our manuscript and for
24 the positive feedback. We are also grateful for the valuable contributions that helped
25 to clarify the text and refine the analyses.

26
27 The manuscript presents an interesting empirical analysis of aerosol effects on energy
28 and carbon fluxes in the Amazon. However, the methodology lacks quantitative
29 robustness in (i) defining aerosol pollution regimes and in assessing statistical
30 significance of differences between them and improved discussion. The structure and
31 figures are generally clear, but the (ii) discussion often repeats background concepts
32 and lacks a mechanistic synthesis connecting radiation, energy partitioning, and
33 ecosystem carbon exchange.

34
35 We thank the Reviewer #1 for these important comments. They will certainly help to
36 improve the methodology and discussion of the results.

37
38 We would like to begin our responses by stating that in the new version of the
39 manuscript, we regrouped our data in a way that allowed us to include a greater
40 number of runs (half-hour periods). In the previous version of the manuscript, in
41 addition to excluding all periods when clouds were present, which is very common in
42 the Amazon, we also excluded all data from a given day and time when a variable was
43 missing. For example, if we did not have the reflected shortwave radiation
44 measurement for a given time, we removed all other variables for that same time. This
45 resulted in only 523 valid half-hour periods (370 dry season, 153 wet). In the new
46 version of the Manuscript, we decided to regroup the variables so that they did not
47 depend on each other. We first identified the periods in which we had the Clean and
48 Polluted regimes (AOD < 0.13 and AOD > 0.40) and then identified how many runs of

49 each variable were available for each regime. After this procedure, the number of runs
 50 increased substantially, as shown in Table R1, comparison between the dataset used
 51 in the first version of the manuscript (single database) and the dataset used for this
 52 new version (database by variable).

53
 54 Table R1: Number of runs (half-hour periods) after all quality controls mentioned in section 2.2.

Variables	Single database					Database by variable				
	10:00 -14:00 LT		07:00 -17:00 LT		Total	10:00 -14:00 LT		07:00 -17:00 LT		Total
	No. Clean	No. Polluted	No. Clean	No. Polluted	No. Sample	No. Clean	No. Polluted	No. Clean	No. Polluted	No. Sample
SWin(Wm ⁻²)	98	81	219	151	370	301	204	736	459	1195
SWout(Wm ⁻²)	98	81	219	151	370	301	204	736	459	1195
LWatm(Wm ⁻²)	98	81	219	151	370	301	200	733	453	1186
LWterr(Wm ⁻²)	98	81	219	151	370	301	204	735	459	1194
Rn(Wm ⁻²)	98	81	219	151	370	301	200	733	453	1186
H(Wm ⁻²)	98	81	219	151	370	197	192	455	389	844
LE(Wm ⁻²)	98	81	219	151	370	183	180	447	386	833
FCO ₂ (μmolm ⁻² s ⁻¹)	98	81	219	151	370	247	195	596	405	1001
G(Wm ⁻²)	98	81	219	151	370	301	218	741	487	1228

55
 56
 57 In the new version of the manuscript, we rewrote L107:

58
 59 “After filtering, the resulting dataset is summarized in Table S1 and S2.”

60
 61 (i) In the previous version of the manuscript the classification into “Clean” and
 62 “Polluted” regimes was based on the 10th and 90th percentiles of the AOD distribution
 63 at ATTO. However, following the reviewer's recommendation, we performed a
 64 sensitivity analysis by applying the statistical test using three percentile thresholds
 65 (10th/90th, 15th/85th, and 20th/80th) to quantitatively assess the robustness of the
 66 regime separation (Table R2). The results show that the 10th/90th and 15th/85th
 67 percentile thresholds provide stronger physical contrasts between aerosol regimes,
 68 expressed as larger differences in median values of key variables, and are associated
 69 with statistically significant differences. Conversely, the 20th/80th threshold leads to a
 70 loss of statistical significance for several variables, indicating a dilution of the physical
 71 contrast between regimes. Based on these tests, the threshold was maintained to the
 72 10th/90th percentiles, as this choice preserves physically meaningful differences
 73 between aerosol regimes.

74
 75 Table R2. Results of the statistical test comparing all analyzed variables between clean and polluted
 76 aerosol regimes for three AOD thresholds. Panels correspond to: 10th–90th percentiles (top), 15th–85th
 77 percentiles (middle), and 20th–80th percentiles (bottom).

78

Main Stage - Percentil 10 (AOD \leq 0.13), Percentil 90 (AOD \geq 0.40)

Variable	N Clean	Mean Clean	SD Clean	N Polluted	Mean Polluted	SD Polluted	U Statistic	p-value	Significance
SWin(Wm ⁻²)	301	836.5	165.2	204	813.5	124.4	35391	0.004	**
SWout(Wm ⁻²)	301	92.8	19.7	204	95.9	15.1	27859	0.077	ns
LWatm(Wm ⁻²)	301	431.5	10.4	200	432.1	9.4	29439	0.677	ns
LWterr(Wm ⁻²)	301	484.7	14.0	204	483.6	10.8	34148	0.032	*
Rn(Wm ⁻²)	301	659.3	137.8	200	632.8	100.8	35671	0.000	***
H(Wm ⁻²)	197	160.6	67.8	192	138.9	61.4	22611	0.001	***
LE(Wm ⁻²)	183	426.7	136.8	180	417.8	146.7	17246	0.438	ns
FCO ₂ (μ molm ⁻² s ⁻¹)	247	-12.5	8.0	195	-17.4	8.6	32125	0.000	***
G(Wm ⁻²)	301	1.8	1.6	218	0.8	1.4	43719	0.000	***

Wide Stage - Percentil 15 (AOD \leq 0.14), Percentil 85 (AOD \geq 0.36)

Variable	N Clean	Mean Clean	SD Clean	N Polluted	Mean Polluted	SD Polluted	U Statistic	p-value	Significance
SWin(Wm ⁻²)	423	829.1	166.2	272	816.6	131.5	62510	0.054	ns
SWout(Wm ⁻²)	423	91.8	20.1	272	95.7	15.6	50534	0.007	**
LWatm(Wm ⁻²)	423	432.7	10.0	268	433.2	9.4	55655	0.688	ns
LWterr(Wm ⁻²)	423	484.1	14.5	272	484.5	11.0	59785	0.382	ns
Rn(Wm ⁻²)	423	654.7	138.0	268	634.7	107.7	64197	0.003	**
H(Wm ⁻²)	281	157.5	70.0	258	139.0	62.7	42045	0.001	**
LE(Wm ⁻²)	265	422.3	133.9	241	419.8	145.7	32675	0.651	ns
FCO ₂ (μ molm ⁻² s ⁻¹)	354	-12.6	8.2	263	-16.7	8.5	60056	0.000	***
G(Wm ⁻²)	427	1.8	1.6	298	0.9	1.4	83989	0.000	***

Alternative Stage - Percentil 20 (AOD \leq 0.16), Percentil 80 (AOD \geq 0.32)

Variable	N Clean	Mean Clean	SD Clean	N Polluted	Mean Polluted	SD Polluted	U Statistic	p-value	Significance
SWin(Wm ⁻²)	547	822.9	172.0	372	828.2	132.4	103274	0.698	ns
SWout(Wm ⁻²)	547	91.1	20.4	372	96.3	15.4	85935	0.000	***
LWatm(Wm ⁻²)	544	433.4	9.8	366	433.6	9.5	98174	0.723	ns
LWterr(Wm ⁻²)	547	483.7	14.6	372	485.2	11.0	100283	0.712	ns
Rn(Wm ⁻²)	544	650.5	144.8	366	644.3	112.1	105788	0.109	ns
H(Wm ⁻²)	377	155.9	71.0	350	140.8	64.5	74993	0.001	**
LE(Wm ⁻²)	355	416.4	135.7	331	420.4	148.0	58402	0.893	ns
FCO ₂ (μ molm ⁻² s ⁻¹)	472	-12.7	8.3	364	-16.0	8.5	105109	0.000	***
G(Wm ⁻²)	587	1.9	1.6	411	1.0	1.5	150612	0.000	***

79

80

81 We clarified this point in the revised manuscript as follows:

82

83 Section 2.3:

84 L134-137: "Daily averages of AOD values were obtained to investigate seasonal
85 variability. Our analysis distinguishes two contrasting atmospheric conditions at the
86 ATTO site, defined as "Clean" and "Polluted" using AOD thresholds derived from the
87 dry-season AOD distribution. The Clean and Polluted regimes correspond to the 10th
88 (AOD \leq 0.13) and 90th (AOD \geq 0.40) percentiles, respectively. Further details on the
89 seasonal aerosol analysis are provided in Section 3.1 and Table S3."

90

91 Section 3.1:

92 L201-207: "As the main goal of this work is to investigate the impact of aerosols on
93 surface turbulent fluxes, the analysis focuses on data from the dry season. In addition,
94 during the dry season there is more aerosol data since the could interference is much

95 *less pronounced than during the wet season. Two aerosol regimes were defined based*
96 *on percentile thresholds of the dry-season AOD distribution. Several percentile*
97 *combinations were tested to assess the robustness of the regime separation. Based*
98 *on this analysis, the 10th and 90th percentiles were selected to define the Clean (AOD*
99 *≤ 0.13) and Polluted (AOD ≥ 0.40) regimes, respectively, as they preserve physically*
100 *meaningful differences between aerosol regimes (See table S1)."*

101
102 **(ii)** In the new version of the manuscript, we improved the methodology by adding a
103 statistical analysis for the definition of Clean and Polluted regimes. We also improved
104 the discussion of the results to avoid repeating background concepts.

105
106 In its present form, I recommend **major revisions** according to my specific comments
107 before the manuscript can be considered for publication in *ACP*.

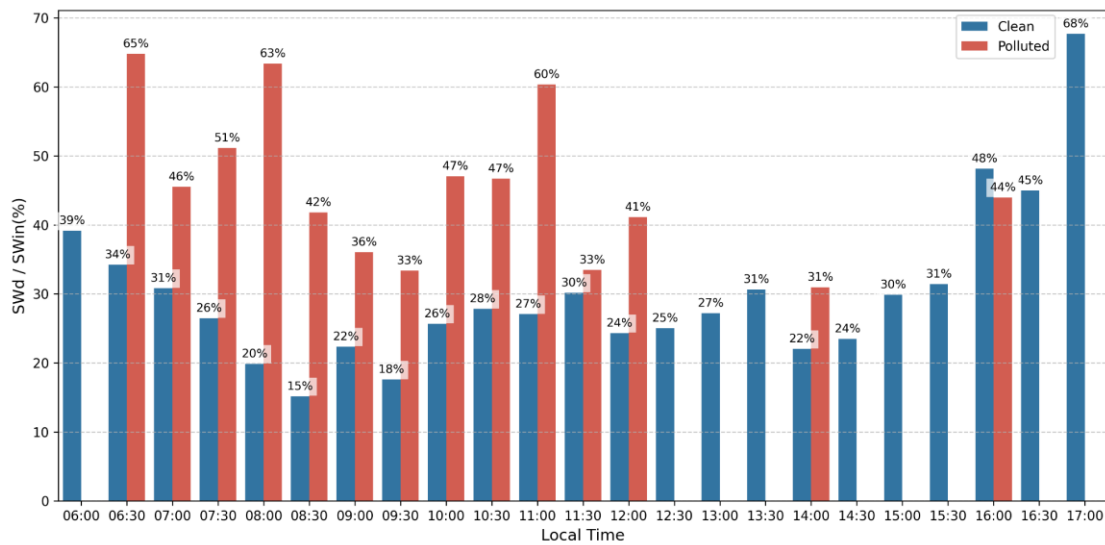
108 **Specific comments**

109
110
111 The study contributes observational evidence from a rare, pristine tropical forest site.
112 The long-term dataset and the combination of aerosol and flux measurements are
113 strengths. Nevertheless, the novelty is moderate, as the main conclusions - reduction
114 of net radiation and turbulent fluxes under high AOD, accompanied by enhanced CO₂
115 assimilation - are qualitatively consistent with previous literature (e.g., Cirino et al.
116 2014; Braghieri et al. 2020; Palácios et al. 2022). **(i)** The novelty would be
117 strengthened by including a quantitative analysis of diffuse versus direct radiation, or
118 by exploring seasonally resolved patterns rather than aggregating all data into two
119 AOD categories. **(ii)** Defining "Clean" (AOD < 0.13) and "Polluted" (AOD > 0.40) purely
120 from percentiles is arbitrary. Include a sensitivity test or physical rationale for these
121 cutoffs. **(iii)** To increase the scientific value of the study, the authors should
122 demonstrate, through appropriate statistical testing, whether the observed reductions
123 ($\approx 10\%$) are robust across years and not driven by interannual variability.

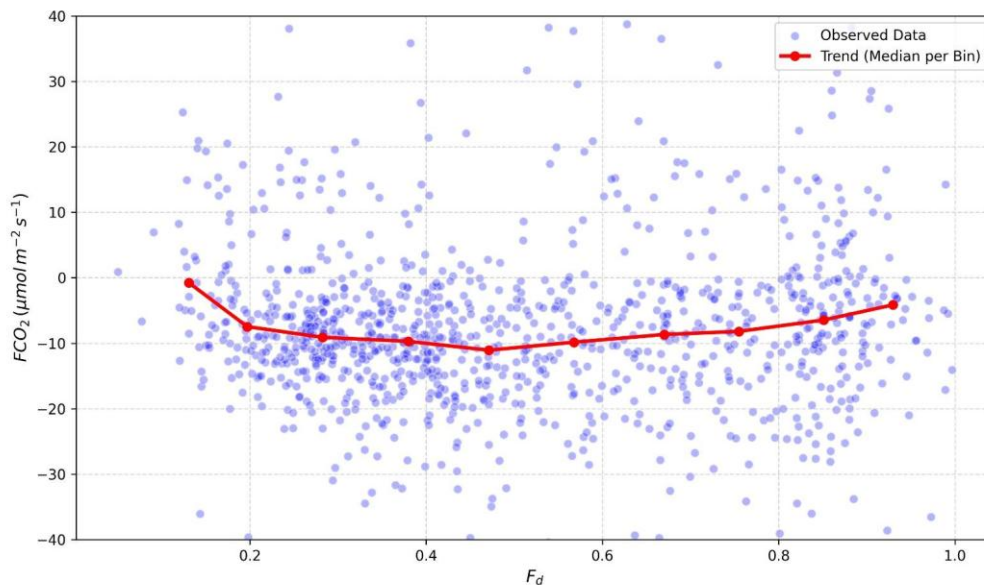
124
125 **(i)** We thank the reviewer for their valuable comment. Diffuse radiation (SWd)
126 measurements are available only for the year 2021 for our experimental site. Prior to
127 this period, SWd was not measured at the ATTO site, and in 2022 the sensor
128 experienced technical issues that affected data quality. Nevertheless, to address the
129 reviewer's suggestion, we quantified the diffuse radiation fraction ($F_d = SW_d/SW_{in}$) for
130 the available period (2021) and compared F_d between Clean and Polluted aerosol
131 regimes. Our results indicate higher F_d values under Polluted regime compared to
132 Clean regime (Figure R1). Specifically between 10:00 and 14:00 LT, the mean F_d
133 values were 0.43 and 0.27 for Polluted and Clean regime, respectively, indicating an
134 absolute difference of 0.16 between the two regimes ($p < 0.05$). This is consistent with
135 enhanced scattering of solar radiation associated with increased aerosol loading
136 (Giorgi et al., 2002; Seinfeld and Pandis, 2016; Ezhova et al., 2018). Moreover,
137 daytime CO₂ fluxes showed a non-linear dependence on F_d , with net CO₂ uptake
138 increasing up to an F_d threshold (≈ 0.6) and decreasing at higher F_d values (Figure
139 R2). This behaviour was consistent with the response of NEE (net ecosystem
140 exchange) for diffuse radiation reported by Deng et al. (2022) for four forest sites in
141 China and aligns with the global-scale mechanisms proposed by Mercado et al. (2009).

142 These results provide observational support for the proposed mechanism linking
 143 aerosol loading, radiation partitioning, and ecosystem carbon exchange.

144



145
 146 Figure R1. Diffuse radiation fraction ($F_d = SW_d/SW_{in}$) under Clean and Polluted aerosol regimes during
 147 2021.
 148



149
 150 Figure R2. The relationship between CO_2 flux and diffuse radiation fraction (F_d) during 2021 at ATTO
 151 site.

152
 153 The Methodology and Results sections have been updated in the new version of the
 154 manuscript as follows:

155
 156 L87-90: “Additionally, diffuse shortwave radiation (SWd) was measured using a SPN1
 157 Pyranometer (Delta-T Devices) installed at 75 m above ground level. However, SWd
 158 data were available only for 2021, prior to this year, SWd was not measured at the
 159 ATTO site, and data from 2022 were excluded due to technical issues with the sensor.”

160

161 L328-337: “We quantified the diffuse radiation fraction ($F_d = SW_d/SW_{in}$) for the
162 available period (2021) and compared F_d between Clean and Polluted aerosol
163 regimes. Our results indicate higher F_d values under the Polluted regime compared to
164 Clean regime (Figure S1). Specifically for the 10:00 and 14:00 LT interval, the mean
165 F_d values were 0.43 and 0.27 for Polluted and Clean regime, respectively, indicating
166 an absolute difference of 0.16 between the two regimes ($p < 0.05$). This is consistent
167 with enhanced scattering of solar radiation associated with increased aerosol loading
168 (Giorgi et al., 2002; Seinfeld and Pandis, 2016; Ezhova et al., 2018). Moreover,
169 daytime CO_2 fluxes showed a non-linear dependence on F_d , with net CO_2 uptake
170 increasing up to an F_d threshold (~ 0.6) and decreasing at higher F_d values (Figure
171 S2). This behaviour was consistent with the response of net ecosystem exchange for
172 diffuse radiation reported by Deng et al. (2022) for four forest sites in China, and aligns
173 with the global-scale mechanisms proposed by Mercado et al. (2009). These results
174 provide observational support for the proposed mechanism linking aerosol loading,
175 radiation partitioning, and ecosystem carbon exchange.”

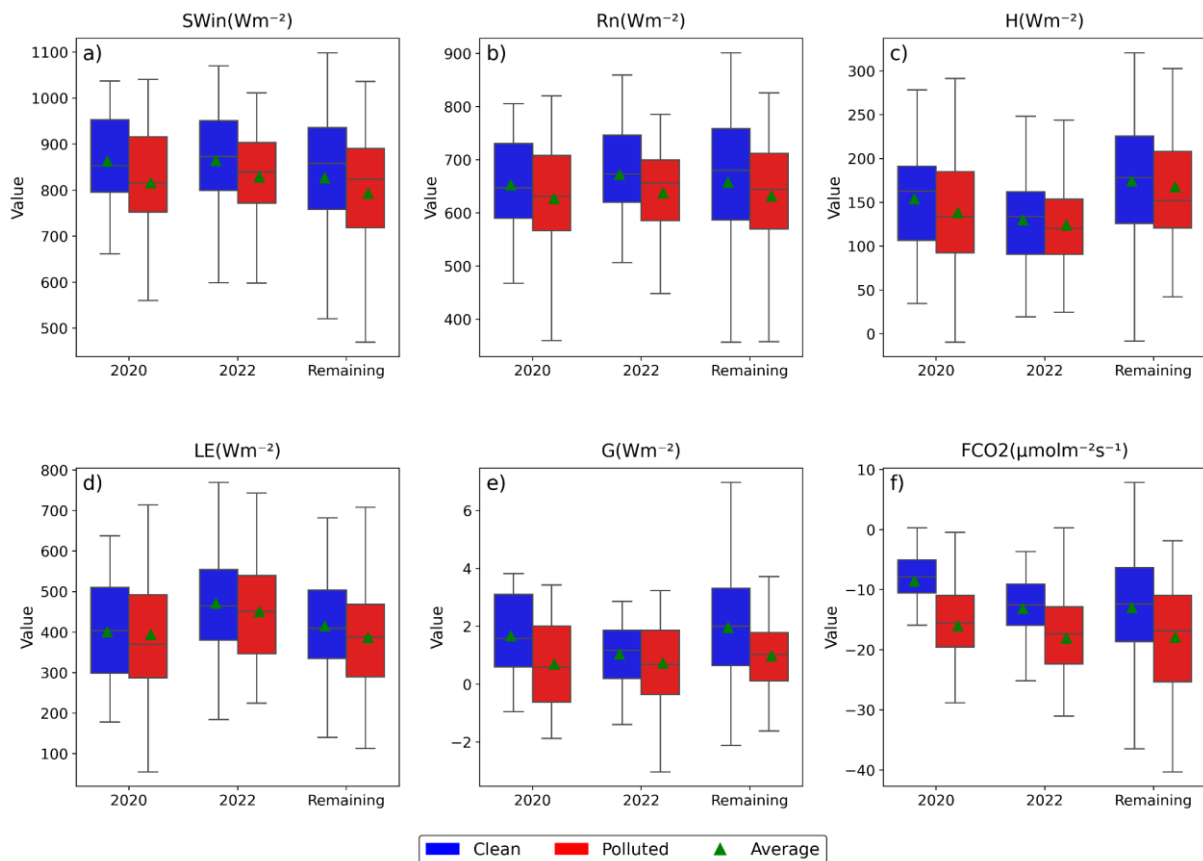
176
177 **(ii)** We assessed the robustness of our results in relation to different regime thresholds
178 as detailed in the General comment (L59-71 and Table R2 of this document).

179
180 **(iii)** We analyzed 2020 and 2022 separately due to higher data availability, while the
181 remaining years (2016, 2017, 2018, 2019, and 2021), which had lower data availability,
182 were grouped into a single category (Remaining). The pattern observed in the
183 preliminary version of the manuscript (Figs. 5 and 6) was consistent across individual
184 years (Figure R3). That is, under polluted conditions, reductions in SW_{in} lead to a
185 decrease in R_n , followed by decreases in H , LE , G , and FCO_2 .

186
187 The following sentence has been added to the revised manuscript.

188
189 L293: “The reductions in H , LE , G , and FCO_2 shown in Fig. 6 and Fig. 7 were also
190 observed across individual years (see Fig. S3).”

191



192
 193 Figure R3. Box plots of a) incoming shortwave radiation (SWin), b) net radiation (Rn), c) sensible heat
 194 flux (H), d) latent heat flux (LE), e) ground heat flux (G), f) CO₂ flux (FCO₂). All variables under clean
 195 (blue) and polluted (red) aerosol regimes for 2020, 2022, and the remaining years (2016, 2017, 2018,
 196 2019 and 2021), grouped due to limited data availability. Triangles indicate the mean value.

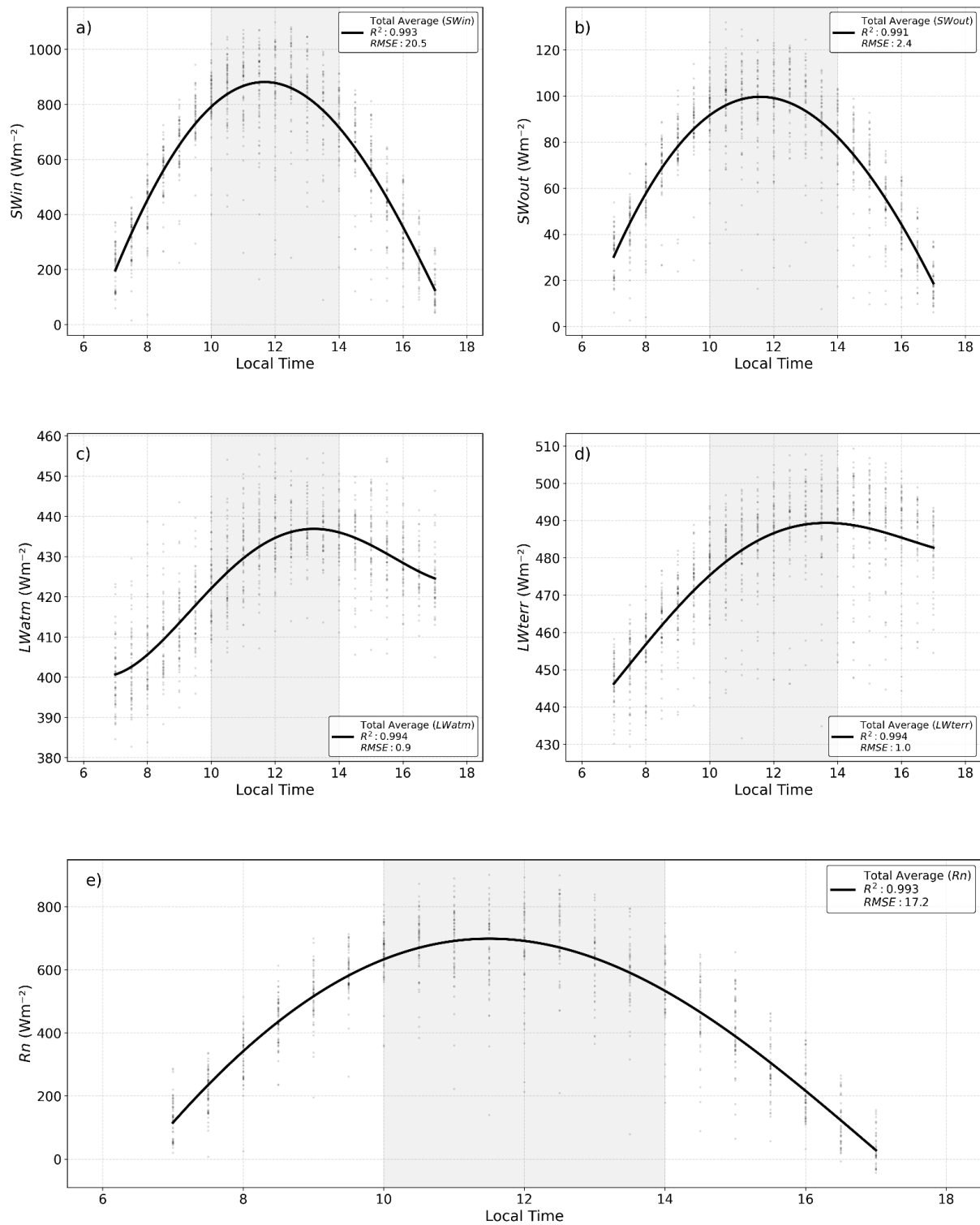
197
 198 Line 94-97. Only 523 valid half-hour periods (370 dry season, 153 wet) are quite small
 199 relative to the six-year period. The statistical representativeness and interannual
 200 variability need further discussion.

201
 202 We modified our methodology to obtain as much data as possible, as detailed in lines
 203 L36-50 and Table R1 of this document.

204
 205 Line 173-174. The section on radiative fluxes should include a graph of the full diurnal
 206 cycle of SW, LW, and Rn to visually demonstrate the 10:00 - 14:00 LT maximum. This
 207 would strengthen the rationale for focusing on that time window.

208
 209 We thank Reviewer #1 for this valuable comment. As recommended, we have included
 210 Figure R4 in Section 3.2 of the manuscript (Figure 4 in the new version of the
 211 manuscript), which shows the full diurnal cycles of shortwave (SW), longwave (LW),
 212 and net radiation (Rn), and highlights the maximum between 10:00 and 14:00 LT.

213



214
 215 **Figura R4.** Diurnal cycles of radiative fluxes during the dry season from 2016 to 2022: (a) incoming
 216 (SWin) and (b) outgoing (SWout) shortwave radiation, (c) incoming atmospheric (LWatm) and (d)
 217 outgoing terrestrial (LWterr) longwave radiation, and (e) net radiation (Rn). Markers indicate observed
 218 data, and solid lines represent fourth-order polynomial fits, with the corresponding R^2 and RMSE.

219
 220 **In the revised version of the manuscript, we have added Figure R4 and the following**
 221 **paragraph to clarify the choice of the analysis period:**
 222

223 L209-212 : “As described in Section 2.3, the comparisons between Clean and Polluted
224 regimes were restricted to the 10:00–14:00 LT period, corresponding to the maximum
225 net radiation. The full diurnal cycles of shortwave, longwave, and net radiation during
226 the dry season (2016–2022) show that the maximum values occur between 10:00 and
227 14:00 LT (Figure 4), supporting the choice of this time window for the subsequent
228 analyses.”

229
230 Line 203-204. The physical interpretation of the longwave radiation components
231 (LW_{atm} and LW_{terr}) is interesting, but it would benefit from quantitative support - for
232 instance, by including a vertical temperature profile or an estimate of surface and
233 atmospheric emissivity.

234
235 We used the Stefan–Boltzmann equation: $LW = \epsilon\sigma T^4$, where LW is the longwave
236 radiation (Wm^{-2}), ϵ is the emissivity, σ is the Stefan–Boltzmann constant (5.67×10^{-8}
237 $Wm^{-2}K^{-4}$) e T is the absolute temperature (K).

238
239 Using this relationship, separately for the Clean and Polluted regimes, we estimated
240 the surface emissivity (ϵ_s) from the measured outgoing longwave radiation (LW_{terr})
241 and the infrared surface temperature (T_s), and the atmospheric emissivity (ϵ_a) from
242 the measured incoming longwave radiation (LW_{atm}) and air temperature (T_a). The
243 resulting emissivity values are shown in Table 3. The emissivities exhibit very similar
244 values under both regimes, suggesting that the differences in aerosol conditions were
245 not sufficient to affect the surface emissivity or the atmospheric emissivity.

246
247 Table R3: Mean values of incoming and outgoing longwave radiation (LW_{atm} and LW_{terr}), air
248 temperature (T_a), surface infrared temperature (T_s), and the corresponding atmospheric (ϵ_a) and
249 surface (ϵ_s) emissivities, under Clean and Polluted regimes for the 10:00 and 14:00 LT interval.

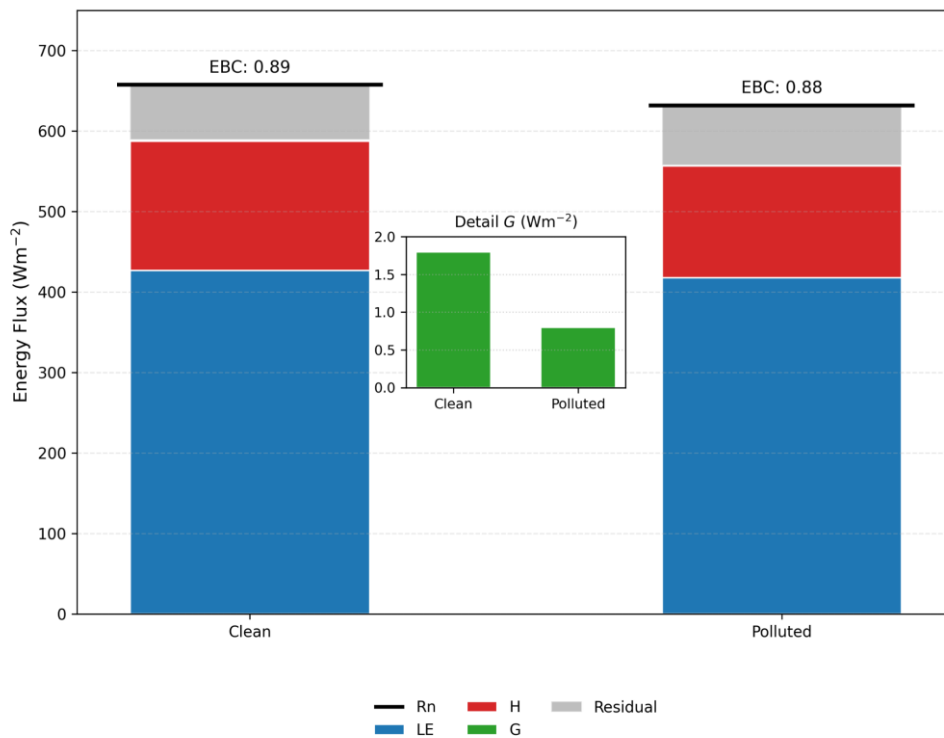
	LW _{atm} (Wm ⁻²)	LW _{terr} (Wm ⁻²)	T _a (°C)	T _s (°C)	ϵ_a	ϵ_s
Clean	431.5	484.74	30.3	32.6	0.898	0.978
Polluted	432.1	483.60	30.0	31.7	0.902	0.988

250
251 Line 227-232. The manuscript would benefit from a discussion of the energy balance
252 closure, specifically addressing the discrepancy between R_n and the sum of H, LE,
253 and G. Reporting the residuals for both clean and polluted regimes would provide a
254 clearer evaluation of data quality and potential systematic biases.

255
256 We thank the reviewer for this important comment. Following this suggestion, we
257 updated the manuscript by adding the following text:

258
259 L278-281: “The surface energy balance closure was 0.89 for the Clean regime and
260 0.88 for the Polluted regime, comparable to values reported in the literature (Mauder
261 et al., 2024). The corresponding residuals were of similar magnitude (70 Wm⁻² for
262 Clean and 75 Wm⁻² for Polluted), indicating that the observed differences in energy
263 fluxes are not related to differences in energy balance closure.”

264



265
 266 [Figura R5. Energy balance closure for Clean and Polluted regimes during the dry season from 2016 to](#)
 267 [2022, considering the 10:00–14:00 local time.](#)

268
 269 Figure 6. The fourth-order polynomial fits to the diurnal cycles provide a useful visual
 270 comparison, but the authors should complement them with statistical analyses to
 271 confirm that the apparent differences between regimes are statistically significant.

272
 273 [We thank the reviewer for this comment. The statistical analyses comparing Clean and](#)
 274 [Polluted aerosol regimes were performed for all analyzed variables, including those](#)
 275 [shown in Figure 6. The results are presented in Table R1, as requested in the General](#)
 276 [Comments.](#)

277
 278 Line 250-255. The connection between aerosol effects and water-use efficiency (WUE)
 279 is largely speculative because WUE is not quantitatively evaluated in the manuscript.
 280 The authors should consider calculating WUE (for example, as GPP/ET using FCO_2
 281 and LE data) or presenting an appropriate proxy to substantiate this aspect of the
 282 discussion.

283
 284 [We thank the reviewer for this important comment. Following this suggestion, we now](#)
 285 [quantify water-use efficiency \(WUE\) using \$|\text{FCO}_2| / \text{LE}\$ as a proxy, and performed](#)
 286 [statistical analyses comparing Clean and Polluted aerosol regimes \(Table R4\).](#)

287
 288 [Table R4: Mean water-use efficiency \(WUE\) calculated as \$|\text{FCO}_2| / \text{LE}\$ \(\$\mu\text{molJ}^{-1}\$ \), under polluted and](#)
 289 [clean regimes for individual years \(2020 and 2022\), the remaining years \(2016, 2017, 2018, 2019 and](#)
 290 [2021\) and all years combined.](#)

Year	AOD Regime	FCO ₂ / LE (μmolJ ⁻¹)
2020	Clean	0.022
2020	Polluted	0.042
2022	Clean	0.031
2022	Polluted	0.044
Remaining	Clean	0.026
Remaining	Polluted	0.049
All Years	Clean	0.029
All Years	Polluted	0.042

291

292 In the new version of the Manuscript we added the follow sentence:

293

294 L304-307: *“In this study, WUE was estimated using FCO₂/LE as a proxy. WUE was*
 295 *significantly higher under Polluted compared to Clean regime(mean values of 0.042*
 296 *and 0.029, respectively, $p < 0.05$). This indicates that under Polluted regime,*
 297 *vegetation assimilates more carbon per unit of water lost, consistent with the observed*
 298 *reduction in latent heat flux (Figure 6) despite enhanced CO₂ uptake (Figure 7).”*

299

300 Line 242-245. It seems to me that there is some inconsistency throughout the
 301 manuscript regarding the sign convention of CO₂ flux. The authors should clearly state
 302 that CO₂ uptake by the ecosystem corresponds to a negative flux, while positive flux
 303 values indicate a CO₂ emission to the atmosphere. Accordingly, a “drop” or decrease
 304 in FCO₂ should represent reduced carbon uptake, not enhanced assimilation. In the
 305 Abstract, for example, Authors should clarify the meaning of “decrease in CO₂ fluxes
 306 by 58%” (does this mean more negative flux, i.e., greater uptake?). Clarifying this point
 307 is essential for avoiding misinterpretation of the results and ensuring consistency
 308 across figures, tables, and the discussion.

309

310 We thank the reviewer for pointing out this important issue. To avoid any ambiguity,
 311 we have clarified throughout the manuscript that negative CO₂ fluxes indicate net
 312 ecosystem uptake. The text has been revised as follows:

313

314 L290-292: *“In addition to their effect on energy fluxes, aerosols were found to have a*
 315 *significant influence on the CO₂ flux, becoming more negative by an average of 4.9*
 316 *μmol m⁻²s⁻¹ (39.5 %) in the polluted regime compared to clean conditions between*
 317 *10:00 and 14:00 LT.”*

318

319 Abstract: *“We find that enhanced aerosol presence reduces both sensible heat flux*
 320 *and energy available for evapotranspiration by approximately 13.5 % and 2.1%*
 321 *respectively, while increasing CO₂ uptake (i.e., CO₂ flux becoming more negative) by*
 322 *about 39.5 %.”*

323

324 The figures are generally clear and well designed, but they would benefit from the
 325 inclusion of confidence intervals or error bars to convey the statistical variability of the
 326 data. Adding uncertainty information would allow readers to better assess the
 327 robustness of the observed differences between regimes and the reliability of the fitted
 328 curves.

329

330 We thank the reviewer for this suggestion. Figures 4, 5, and 6 (Fig. 5, 6, 7 in the new
331 version of the manuscript) have been revised to include the observed data points
332 underlying the averaged curves, allowing a direct visualization of the data variability.

333 334 **Minor comments**

335
336 All physical variables (Rn, H, LE, FCO₂, AOD, etc.) should be written in italics or
337 formatted with the equation editor for consistency and readability.

338
339 The entire manuscript was revised to ensure consistent formatting of all physical
340 variables. Thanks.

341
342 Throughout the manuscript, several acronyms are not explicitly defined (ARF24h,
343 LWterr), which may affect readability. I recommend defining each acronym upon first
344 use.

345
346 The entire manuscript was revised to ensure that all acronyms are explicitly defined at
347 their first occurrence. Thanks.

348
349 Line 191. "ARF24h", did Authors refer to daily mean? It should be clarified

350
351 Yes, in the revised manuscript, we have removed the term *ARF24h* to avoid ambiguity
352 as follows:

353
354 L227-230: "*Consistent with these findings, Palácios et al. (2022) estimated an average*
355 *ARF of $-20.77 \pm 5.04 \text{ Wm}^{-2}$ for the dry season in the central Amazon. Procopio et al.*
356 *(2004) found daily ARF values ranging from -21 to -74 Wm^{-2} in the deforestation arc,*
357 *an area with higher levels of pollution than the central Amazon. Rizzo et al. (2011)*
358 *investigated this central region and reported a daily ARF value of -32 Wm^{-2} ."*

359
360 Line 187-188. The phrase "In contrast" seems used incorrectly; the studies cited do
361 not contradict one another, showing similar ARF values (within the estimated errors).
362 The Authors should revise wording.

363
364 We thank the reviewer for this comment. The term "*In contrast*" was replaced by
365 "*Consistent with these findings*" as detailed in previous comment (L352-356 in this
366 document).

367
368 Table3. Caption. FCO should be replaced by FCO₂

369
370 The caption of Table 3 has been revised.

371
372 Line 299. As before, CO -> CO₂

373
374 The text has been updated accordingly.

375 376 **References**

377

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1 **Title: Observed Impacts of Aerosol Regimes on Energy and Carbon Fluxes in the**
2 **Amazon Forest**

3
4 Response (blue color) to anonymous Referee #2 (black). The original manuscript was
5 changed accordingly. The lines indicated in our answers correspond to the track
6 version of the manuscript.

7
8 **General comments**

9
10 The work uses observations of AOD to evaluate impacts of aerosols on amazon forest
11 energy balance fluxes at unique data set from a relatively new flux site in Manaus.

12
13 We would like to thank Referee #2 for their attention to detail and helpful comments,
14 which have contributed to the improvement of the manuscript.

15
16 First of all we would like to begin our responses by stating that in the new version of
17 the manuscript, we regrouped our data in a way that allowed us to include a greater
18 number of runs (half-hour periods). In the previous version of the manuscript, in
19 addition to excluding all periods when clouds were present, which is very common in
20 the Amazon, we also excluded all data from a given day and time when a variable was
21 missing. For example, if we did not have the reflected shortwave radiation
22 measurement for a given time, we removed all other variables for that same time. This
23 resulted in only 523 valid half-hour periods (370 dry season, 153 wet). In the new
24 version of the Manuscript, we decided to regroup the variables so that they did not
25 depend on each other. We first identified the periods in which we had the Clean and
26 Polluted regimes and then identified how many runs of each variable were available
27 for each regime. After this procedure, the number of runs increased substantially, as
28 shown in Table R1, comparison between the dataset used in the first version of the
29 manuscript (single database) and the dataset used for this new version (database by
30 variable).

31
32 Table R1: Number of runs (half-hour periods) after all quality controls mentioned in section 2.2.

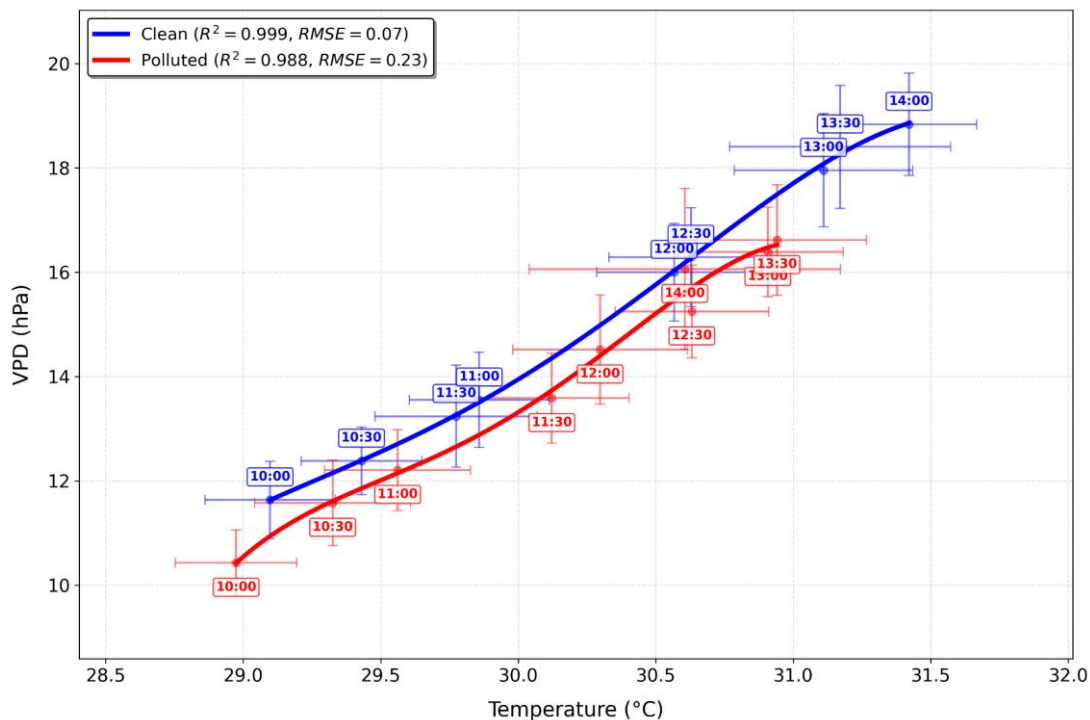
Variables	Single database					Database by variable				
	10:00 -14:00 LT		07:00 -17:00 LT		Total	10:00 -14:00 LT		07:00 -17:00 LT		Total
	No. Clean	No. Polluted	No. Clean	No. Polluted		No. Clean	No. Polluted	No. Clean	No. Polluted	
SWin(Wm ⁻²)	98	81	219	151	370	301	204	736	459	1195
SWout(Wm ⁻²)	98	81	219	151	370	301	204	736	459	1195
LWatm(Wm ⁻²)	98	81	219	151	370	301	200	733	453	1186
LWterr(Wm ⁻²)	98	81	219	151	370	301	204	735	459	1194
Rn(Wm ⁻²)	98	81	219	151	370	301	200	733	453	1186
H(Wm ⁻²)	98	81	219	151	370	197	192	455	389	844
LE(Wm ⁻²)	98	81	219	151	370	183	180	447	386	833
FCO ₂ (μmolm ⁻² s ⁻¹)	98	81	219	151	370	247	195	596	405	1001
G(Wm ⁻²)	98	81	219	151	370	301	218	741	487	1228

33
34
35 **Specific comments**
36

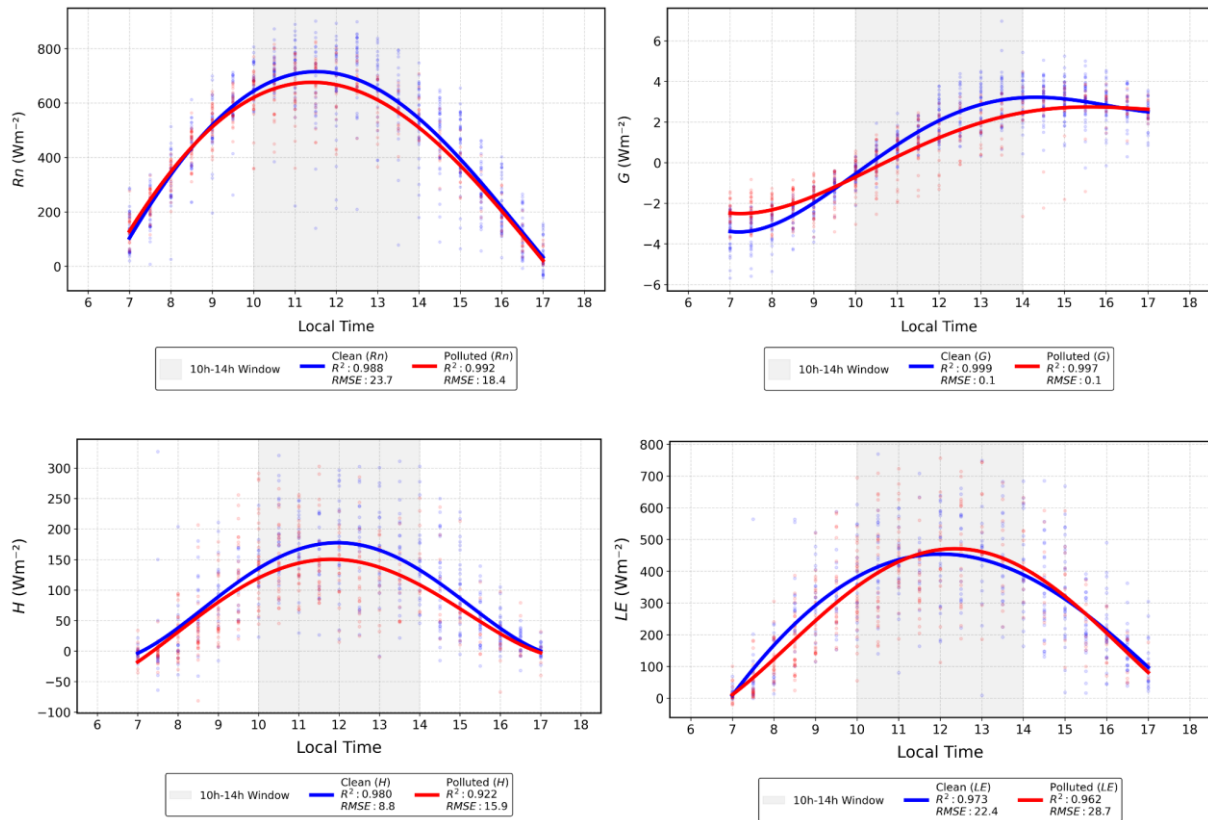
37 The work is highly relevant, and the data used is state of the art. However, most of the
38 analysis is done with output from a model rather than with the 30 min H and LE
39 observed fluxes (Figs 4-6). Justification for this approach was not 100% clear and there
40 is no mention of how good the models are at representing the observations and what
41 is the uncertainty related to the results inferred from such simulations. Why is not better
42 to use the data?
43

44 We thank the reviewer #2 for their comment. We clarify that all analyses in this study
45 were based on the measured data. The polynomial fit shown in Figs. 4-6 (Fig. 5-7 in
46 the new version of the manuscript) was applied solely as a smoothing technique for
47 visualization purposes. In the revised manuscript, we have included the 30-min
48 observed data points in the figures to better illustrate data variability. This clarification
49 has been incorporated into the manuscript as follows:
50

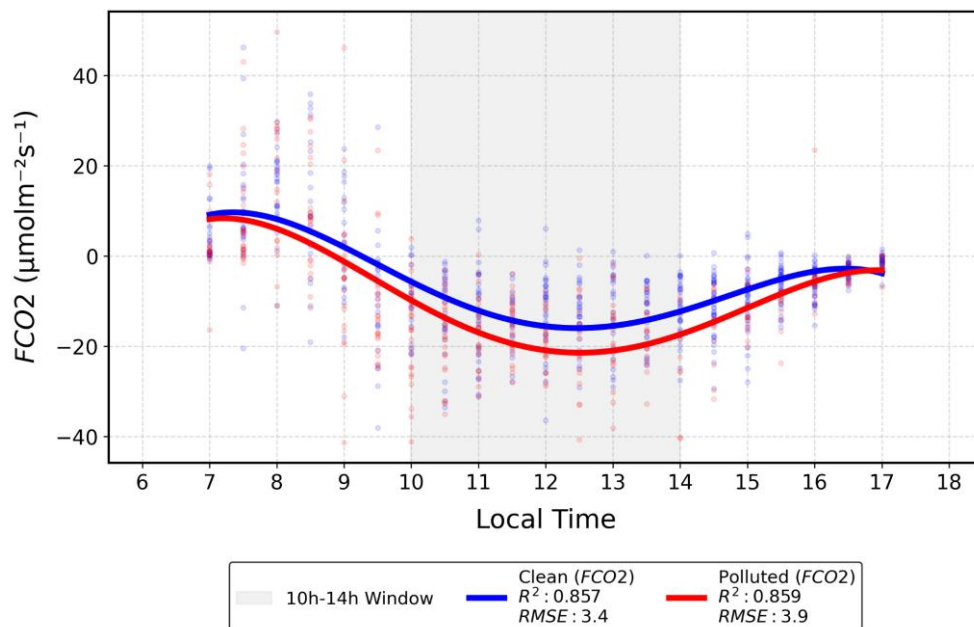
51 L139-141: *“To improve the visualization of the mean diurnal patterns, a 4th-order
52 polynomial curve was applied exclusively as a smoothing technique to the
53 observational data. This curve fitting was used solely for graphical purposes and does
54 not represent a physical or predictive model. All analyses were based on the measured
55 data.”*
56



57
58 Figure R1. Relationship between temperature and vapor pressure deficit (VPD) above the forest canopy
59 at the ATTO site for Clean and Polluted regimes during the dry season (2016–2022) (Figure 5 in the
60 new version of the manuscript).
61



62
 63 Figure R2. Diurnal cycle of surface fluxes during the dry season (2016–2022) under Clean (blue) and
 64 Polluted (red) regimes, highlighting the 10:00–14:00 LT period. Rn (net radiation), G (ground heat flux),
 65 H (sensible heat flux), and LE (latent heat flux). (Figure 6 in the new version of the manuscript).
 66



67
 68 Figure R3. Diurnal cycle of CO_2 flux (FCO_2) during the dry season (2016–2022) under Clean (blue) and
 69 Polluted (red) regimes, highlighting the 10:00-14:00 LT period (Figure 7 in the new version of the
 70 manuscript).
 71

72 The study estimates a cooling effect of 0.53C from aerosol on the forest-atmosphere
73 interface. The authors should estimate what this means for forest surface temperature
74 using the LW out fluxes, this is more relevant as the energy fluxes are driven by surface
75 temperature rather than air temperature.

76

77 We thank the reviewer for this comment. In this study, forest surface temperature can
78 be evaluated independently of LWout, because infrared surface temperature (Ts) was
79 directly measured throughout the study period. Based on these measurements, mean
80 Ts values were 32.6 ± 3.8 °C for the Clean regime and 31.7 ± 3.9 °C for the Polluted
81 regime, indicating a surface cooling of 0.9 °C associated with aerosol conditions. For
82 comparison, the corresponding air temperature difference between the two regimes
83 was 0.3 °C.

84

85 The following sentence has been added to the revised manuscript.

86

87 L249-250: *“The cooling between the 10:00 and 14:00 LT regimes implies an average*
88 *reduction in canopy surface temperature of 0.9 °C (not shown here), based on infrared*
89 *surface temperature measurements, and a corresponding reduction in air temperature*
90 *of 0.3 °C, resulting in a -2 hPa (13%) decrease in VPD.”*

91

92 In addition, Table 1 (in the revised manuscript) has been updated to include detailed
93 information on the infrared surface temperature measurements.

94

95 Some parts of the work appear rather descriptive. Here two examples

96

97 i) 247..the authors need to elaborate more specifically why/how this would lead to an
98 increase in evapotranspiration

99

100 We thank the reviewer for this comment. We have revised the text to clarify the
101 physiological mechanism linking enhanced CO₂ uptake and evapotranspiration. In
102 addition, we estimated water-use efficiency (WUE) using FCO₂/LE as a proxy to
103 address the link between photosynthetic gas exchange and evapotranspiration, and
104 revised the discussion accordingly.

105

106 L269-300: *“In the Polluted regime, CO₂ fluxes were more negative (Figure 7), indicating*
107 *increased CO₂ uptake by vegetation related to photosynthetic activity. Such enhanced*
108 *photosynthesis may be linked to changes in stomatal regulation that allow greater CO₂*
109 *uptake without a proportional increase in transpiration, reflecting higher stomatal*
110 *conductance efficiency (Liu et al., 2022; Crous et al., 2025). However, analysis of the*
111 *LE, which represents the fraction of available energy converted into*
112 *evapotranspiration, shows a consistent decrease in the polluted regime compared to*
113 *the Clean regime (Figure 6).“*

114

115 L302-307: *“The apparent paradox of an increase in CO₂ absorption alongside a*
116 *reduction in LE can be explained by differences in water use efficiency (WUE).*
117 *According to Dekker et al. (2016) and Yang et al. (2016), WUE is defined as the ratio*
118 *of carbon assimilated to water transpired by vegetation. In this study, WUE was*
119 *estimated using FCO₂/LE as a proxy. WUE was significantly higher under Polluted*
120 *compared to Clean regime(mean values of 0.042 and 0.029, respectively, p < 0.05).*
121 *This indicates that under Polluted regime, vegetation assimilates more carbon per unit*
122 *of water lost, consistent with the observed reduction in latent heat flux (Figure 6)*
123 *despite enhanced CO₂ uptake (Figure 7).*

124
125 ii) Regarding impacts of aerosols on evapotranspiration and the relation to the CO₂
126 enhancement, there is a key discussion missing around what happens to stomatal
127 conductance.

128
129 We agree with the reviewer and have revised the manuscript to address the role of
130 stomatal conductance in the discussion, as detailed in the response to the previous
131 comment (L106-123, in this document).

132
133 Line 35 The references in this line should come in parenthesis. Same in line 44

134
135 Thank you for pointing this out. The reference formatting in lines 35 and 45 has been
136 corrected in the revised manuscript.

137
138 236 -237 this sentence is unclear: ‘The sum of H and LE was also found to be
139 67.85Wm⁻² lower for the clean regime than for Rn,’

140
141 Thank you for pointing this out. We agree that the sentence was unclear. To address
142 this issue, we revised the text to avoid redundancy. A discussion of the surface energy
143 balance closure has been included (L278), and the sentence referring to the sum of H
144 and LE relative to Rn has been removed (L286) as follows:

145
146 L278-281: *“The surface energy balance closure was 0.89 for the clean regime and*
147 *0.88 for the polluted regime, comparable to values reported in the literature (Mauder*
148 *et al., 2024). The corresponding residuals were of similar magnitude (70 Wm⁻² for clean*
149 *and 75 Wm⁻² for polluted), indicating that the observed differences in energy fluxes are*
150 *not related to differences in energy balance closure.”*

151
152 L283-285: *“Sensible heat decreased by an average of -21.7 Wm⁻² (13.5 %), reflecting*
153 *reduced energy transfer to the atmospheric boundary layer. Similarly, LE decreased*
154 *by -8.9 Wm⁻² (2 %), indicating limited evapotranspiration due to the reduced radiative*
155 *energy available. The Bowen ratio, which relates H and LE, recorded 0.38 in the clean*
156 *regime and 0.33 in the polluted regime, suggesting that a higher proportion of energy*
157 *was allocated to latent processes, as expected in forest environments.”*

158 238-239: this could also be clearer : *It appears that the polluted regime is further from*
159 *the energy balance close, suggesting a change in how this energy is distributed.'*

160
161 Thank you for this comment. The sentence has been removed, as the revised
162 manuscript now includes a discussion of energy balance closure as detailed in
163 response to the previous comment.

164
165 Line 250 add units to VPD

166
167 The text has been revised accordingly. Thanks.

168
169 Line 255 water 'emitted' by evapotranspiration?

170
171 We thank the reviewer for pointing this out. We agree that the original wording was
172 imprecise. The text has been removed.

173
174 **References**

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1 **Title: Observed Impacts of Aerosol Regimes on Energy and Carbon Fluxes in the**
2 **Amazon Forest**

3
4 Response (blue color) to anonymous Referee #3 (black). The original manuscript was
5 changed accordingly. The lines indicated in our answers correspond to the track
6 version of the manuscript.

7
8
9 **General comment**

10
11 This comment was prepared as part of MSc course work at Wageningen University
12 under supervision of Prof Wouter Peters. They were uploaded as a comment as they
13 were regarded to be of good quality, and likely helpful to the authors and editor in the
14 review process.

15
16 We would like to express our sincere gratitude to Professor Wouter Peters and his
17 students for their interest in our manuscript. Their comments help us to improve our
18 results and discussion.

19
20 This study examines how aerosol regimes affect energy and carbon fluxes in a pristine
21 central Amazon forest. Using 2016–2022 meteorological and flux data from the
22 Amazon Tall Tower Observatory (ATTO) and AOD (500 nm) from AERONET, it tests
23 whether aerosol loading alters latent heat (LE), net radiation (Rn), and CO₂ fluxes
24 (FCO₂). The study focuses on the dry season (August–November), when biomass
25 burning elevates aerosol concentrations across the southern Amazon Basin. The
26 authors define two aerosol regimes: clean (AOD < 0.13) and polluted (AOD > 0.40),
27 consistent with previous studies such as Steiner et al. (2013) and Ross Herbert & Stier
28 (2023). This threshold-based approach, derived from data percentiles, provides a
29 simple yet robust framework for distinguishing contrasting aerosol loading conditions.
30 Their analysis focuses on the 10:00–14:00 LT period to examine energy partitioning
31 under contrasting aerosol regimes. Authors interestingly present, VPD vs Temperature
32 (Figure 4), a combination of variables that I have not encountered in other studies
33 reviewed during this process. It is particularly valuable, as it effectively illustrates—
34 through the observed variables of VPD and temperature—the realistic delay caused
35 by reduced shortwave incoming radiation (SWin) during polluted periods. They report
36 a delay in the rise of temperature and VPD under polluted conditions, highlighting the
37 moderating effect of aerosols. They conclude by confirming the well-documented
38 finding that, paradoxically, CO₂ uptake increases under polluted conditions—by about
39 57.7% in this case—due to the diffuse radiation effect, where scattered sunlight
40 enhances photosynthesis within shaded canopy layers. This result is in strong
41 agreement with previous studies on Amazonian aerosol dynamics, particularly
42 Rodrigues et al. (2024) and Cirino et al. (2014), which similarly observed elevated

43 carbon uptake under high-AOD conditions. The study concludes by emphasizing the
44 nonlinear and complex interactions between AOD and surface fluxes, demonstrated
45 through MANCOVA and Random Forest Model analyses, underlining however the
46 need for further investigation.

47

48 **Remarks on several aspects:**

49

50 (1) Midday Averaging

51

52 The authors assess the effects of aerosols on surface energy and carbon fluxes by
53 averaging 30-minute flux measurements over the 10:00–14:00 LT period and then
54 calculating percentage reductions between clean and polluted aerosol regimes. This
55 time window is identified as representing the period of strongest radiative and
56 convective activity (line 173). However, the diurnal cycle plots (Figs. 5 and 6) reveal
57 uneven flux patterns, with noticeable uninvestigated areas (Figure 5 & 6 “white
58 spaces”, outside 10:00–14:00 LT window) within both the clean and polluted regimes.
59 As a starting point, Figure 4 clearly shows a delay in the increase of temperature and
60 vapor pressure deficit (VPD). Because natural processes evolve non-uniformly
61 throughout the day, using a short and non-equidistant time subset which may bias the
62 calculated percentage reductions and misrepresent the actual aerosol influence. The
63 paper’s methodology follows Steiner et al. (2013), who also analyzed fluxes over the
64 10:00–14:00 LT period and compared similar aerosol optical depth (AOD) regimes
65 (AOD < 0.3 vs. > 0.5). However, within the text, fluxes reductions’ comparisons are
66 made with studies that employed different approaches to assess aerosol-load effects.
67 For example, Rodrigues et al. (2024) and Cirino et al. (2014) estimated flux reductions
68 under specific irradiance conditions, distinguishing Solar Zenith Angle (SZA) zones
69 and thereby incorporating the time-of-day variability, rather than relying on a fixed
70 midday average. A closer examination of Figures 5 and 6, which depict sensible, latent,
71 and ground heat fluxes, reveals an interesting but unexamined pattern during i.e. the
72 morning transition (06:00–10:00 LT). Both H and G occasionally exceed their
73 respective values under polluted conditions, while the consistent dominance of the
74 clean regime in LE appears to be underestimated. Early-morning CO₂ uptake (Figure
75 6) also exhibits a more dynamic behavior, with pronounced transitions between clean
76 and polluted regimes. To better capture the full evolution of the phenomena and
77 associated fluxes, the authors could integrate the area under the fluxes’ curves over
78 the 06:00–17:00 LT period and compare the resulting averages between the clean and
79 polluted aerosol regimes. Alternatively, if there is sufficient data outside the window
80 10:00-14:00 LT the authors could consider reporting morning (06:00-10:00 LT) and
81 afternoon sub-period (14:00-17:00 LT) averages separately to capture diurnal
82 variability better. Analyzing relative irradiance would require substantially more
83 methodological development and investigation by the authors; therefore, it is not
84 recommended.

85

86 We thank the Referee #3 for this comment. We agree that surface fluxes exhibit
87 variable features outside the 10:00–14:00 LT window. However, during these periods,
88 flux variability may be influenced by boundary-layer dynamics and low solar elevation
89 angles, which can affect H, LE, and FCO₂ and complicate the isolation of the radiative
90 effects of aerosols. Moreover, radiometer uncertainties (typically within ~5%) are less
91 significant when radiation levels are high. At low solar elevation angles (early morning
92 and late afternoon), radiation magnitudes are smaller, which increases the relative
93 importance of measurement errors and energy balance closure uncertainties. For
94 these reasons, the 10:00–14:00 LT period provides more favorable conditions for
95 isolating aerosol-induced radiative effects.

96

97 In the revised manuscript, we have added Figure 4 showing the full diurnal cycles of
98 shortwave, longwave, and net radiation during the dry season (2016–2022). This figure
99 demonstrates that peak net radiation consistently occurs between 10:00 and 14:00 LT,
100 supporting our choice of this time window.

101

102 (2) Gaps Manipulation

103

104 The authors state that their initial dataset comprised 10,890 half-hourly observations
105 (line 87), which, after several filtering steps, was reduced to 523 rows—of which only
106 370 belong to the dry season (lines 94–96). However, the paper does not clarify how
107 these 10,890 records were originally obtained. Figure 2 further raises questions about
108 data representativeness and statistical treatment: the monthly boxplots show means
109 much higher than medians, indicating positive skewness, while the number of valid
110 data points per month is not reported. The data filtering process is clearly described,
111 resulting in 523 rows of 30-minute averaged meteorological, flux, and AOD values.
112 However, the dataset distribution across years is highly uneven, as also noted by the
113 authors (line 97: “The distribution...effects of aerosol”). Specifically, years contributing
114 less than 5 % of the total dataset are treated equivalently to years such as 2020 and
115 2022 (42,4% and 29,2% data coverage respectively), despite potentially different
116 atmospheric and surface conditions. This raises concerns regarding the robustness of
117 the study’s conclusions. Evidentially, no quantitative assessment of data
118 representativeness or uncertainty is provided. Similar studies (e.g., Schmitt et al.,
119 2023) have explicitly visualized monthly data availability and included “fraction of
120 missing data”. Moreover, the extremely low number of data rows for certain years
121 warrants further examination, as such sparse temporal coverage could substantially
122 affect the robustness of the Random Forest Model (RFM) used later in the statistical
123 analysis. Limited data availability may lead to overfitting, biased feature importance
124 when training and validation subsets are unevenly represented. It is recommended that
125 the authors include the fraction of valid rows per month, which could be directly
126 incorporated into Figure 2. Furthermore, the manuscript should clearly describe the

127 origin of the initial 10,890 observations—specifying the time period covered, sampling
 128 frequency, and measured variables—to better contextualize the subsequent data
 129 filtering process.

130

131 We thank the Referee #3 for these important comments. They will certainly help to
 132 improve the methodology and discussion of the results.

133

134 We would like to begin our responses by stating that in the new version of the
 135 manuscript, we regrouped our data in a way that allowed us to include a greater
 136 number of runs (half-hour periods). In the previous version of the manuscript, in
 137 addition to excluding all periods when clouds were present, which is very common in
 138 the Amazon, we also excluded all data from a given day and time when a variable was
 139 missing. For example, if we did not have the reflected shortwave radiation
 140 measurement for a given time, we removed all other variables for that same time. This
 141 resulted in only 523 valid half-hour periods (370 dry season, 153 wet). In the new
 142 version of the Manuscript, we decided to regroup the variables so that they did not
 143 depend on each other. We first identified the periods in which we had the Clean and
 144 Polluted regimes and then identified how many runs of each variable were available
 145 for each regime. After this procedure, the number of runs increased substantially, as
 146 shown in Table R1, comparison between the dataset used in the first version of the
 147 manuscript (single database) and the dataset used for this new version (database by
 148 variable).

149

150 Table R1: Number of runs (half-hour periods) after all quality controls mentioned in
 151 section 2.2.

Variables	Single database					Database by variable				
	10:00 -14:00 LT		07:00 -17:00 LT		Total No. Sample	10:00 -14:00 LT		07:00 -17:00 LT		Total No. Sample
	No. Clean	No. Polluted	No. Clean	No. Polluted		No. Clean	No. Polluted	No. Clean	No. Polluted	
SWin(Wm ⁻²)	98	81	219	151	370	301	204	736	459	1195
SWout(Wm ⁻²)	98	81	219	151	370	301	204	736	459	1195
LWatm(Wm ⁻²)	98	81	219	151	370	301	200	733	453	1186
LWterr(Wm ⁻²)	98	81	219	151	370	301	204	735	459	1194
Rn(Wm ⁻²)	98	81	219	151	370	301	200	733	453	1186
H(Wm ⁻²)	98	81	219	151	370	197	192	455	389	844
LE(Wm ⁻²)	98	81	219	151	370	183	180	447	386	833
FCO ₂ (μmolm ⁻² s ⁻¹)	98	81	219	151	370	247	195	596	405	1001
G(Wm ⁻²)	98	81	219	151	370	301	218	741	487	1228

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153

154 The initial number of 10,890 observations does not represent the full raw eddy-
 155 covariance dataset, which contains 122,734 half-hourly records over 2016–2022.
 156 Instead, this number corresponds to the subset of 30-minute periods for which aerosol
 157 optical depth (AOD) data from AERONET (version 3, level 2) were available and could
 158 be matched with surface flux and radiation measurements. The text has been updated
 159 accordingly to improve clarity (Section 2.2 in the revised version of the manuscript).

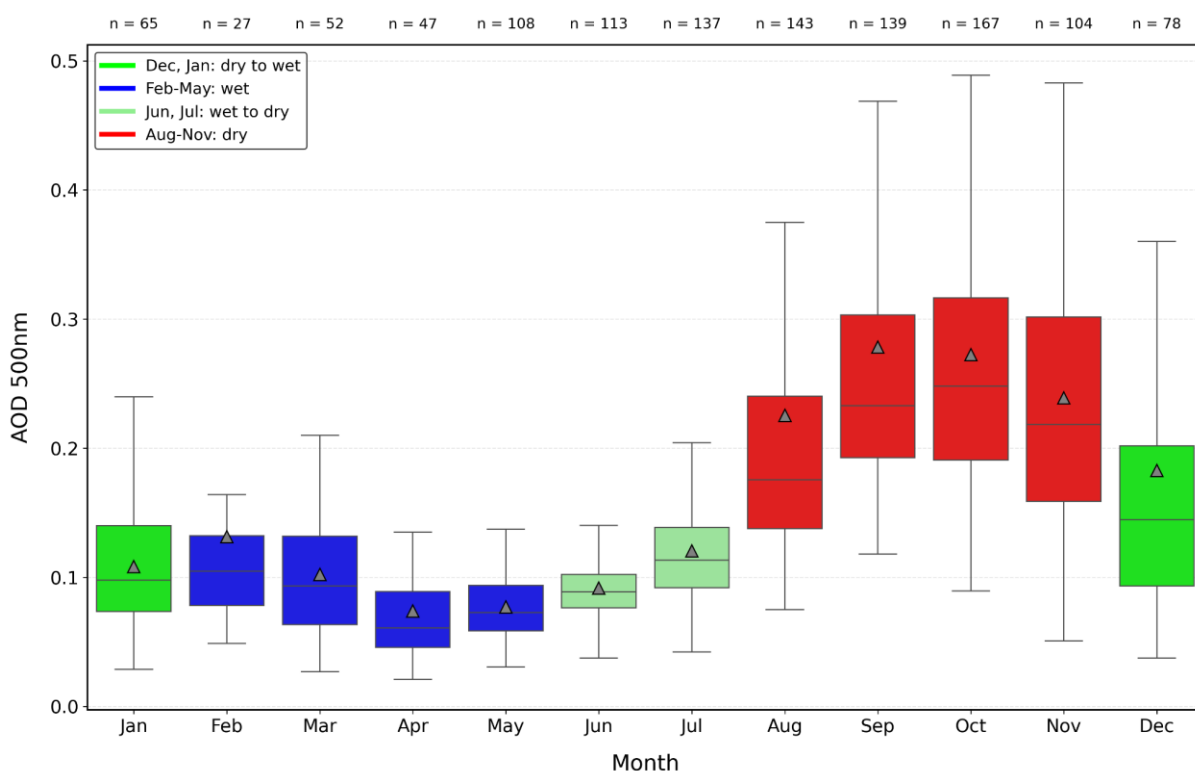
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161 L95-107: “To eliminate cloud interference and investigate the role of aerosols in surface
 162 energy fluxes, the central objective of this study, we used data from the Aerosol
 163 Robotic Network (AERONET) at the ATTO site, specifically AOD (version 3, level 2).
 164 These data are free of cloud contamination due to pre and post-field calibration (Giles
 165 et al., 2019). Based on this, 30-minute averages were calculated between 2016 and

166 2022 for which AOD data from AERONET were available, the initial combined dataset
 167 comprised 10,890 observations, including all variables listed in Table 1. This matched
 168 dataset served as the starting point for the subsequent quality control and filtering
 169 procedures. First, the turbulent fluxes underwent quality control based on Foken et al.
 170 (2004). Only data with flags "0" (best quality) and "1" (acceptable for general analysis)
 171 were used; data with flag "2" (poor quality) were discarded. Second, this study only
 172 considered the daytime period (from 7:00 to 17:00 LT) because the highest Rn values
 173 occur during this time. After filtering, the resulting dataset is summarized in Table S1
 174 and S2."

175
 176 As described in the previous comment, we regrouped our data in a way that allowed
 177 us to include a greater number of runs (half-hour periods). Based on this updated
 178 dataset, Figure R1 was revised and now includes the number of samples per month
 179 (n). The mean values are higher than the medians, particularly during the dry season,
 180 reflecting the influence of episodic high-AOD events (e.g., biomass burning, smoke
 181 intrusions) that shift the distributions toward positive skewness. We additionally verified
 182 that the main seasonal contrasts remain qualitatively unchanged when using median
 183 AOD instead of mean AOD.

184



185
 186 Figure R1. Box plot showing monthly AOD 500 nm values measured at the ATTO site between 2016
 187 and 2022. The box represents the central 50% of the data, the whiskers represent the smallest and
 188 largest non-outlier values, while the means are indicated by the green triangles and the medians are the
 189 lines inside the box. Numbers above each month indicate the sample size (n) (Figure 2 in the revised
 190 version of the manuscript).

191

192 (3) Statistical Analysis

193

194 The study explores the relationship between aerosol optical depth (AOD) and surface
195 fluxes (R_n , H , LE , FCO_2) implementing Spearman correlations, multivariate
196 MANCOVA testing assessed by Pillai test and a Random Forest Model (RFM) to
197 quantify nonlinear dependencies and variable importance. However, several
198 methodological lack in processes or data-handling limitations seem to weaken the
199 robustness of the conclusions. The manuscript provides a general introduction to the
200 application of Pillai's test and outlines the advantages of using the Random Forest
201 Model (RFM) to investigate nonlinear and complex interactions between variables and
202 systems. However, it remains unclear to what extent these principles—particularly in
203 the case of RFM—have been appropriately implemented and demonstrated in the
204 study. In comparable RFM environmental works, such as Miao et al. (2018) and Zhang
205 et al. (2023), linear correlation analyses were explicitly conducted to assess collinearity
206 among key variables by providing comprehensive correlation matrices, providing direct
207 linear insights. In contrast, Rocha et al. (2025) only briefly mention in line 272 that “the
208 statistical relationships show low intensity or no statistical significance,” without offering
209 supporting analyses or graphical evidence. Furthermore, while Miao et al. (2018)
210 thoroughly examined their multivariate equations and reported the statistical
211 significance of their models and variables, Rocha et al. (2025) limit the discussion to
212 the significance of Pillai's test (line 275), suggesting the absence of linear interactions
213 without presenting sufficient analytical support or methodological transparency.
214 Another major concern is data volume, as mentioned in major argument 2. Miao et al.
215 (2018) utilized approximately 7,000 samples, and Zhang et al. (2023) worked with
216 about 60,000 samples. In contrast, Rocha et al. (2025) rely on only 370 rows of data
217 for the dry period, which raises serious concerns about potential overfitting of the RFM.
218 Moreover, although the manuscript mentions a cross-validation approach in Table 3, it
219 does not specify the technique used or report its results. Finally, the model assessment
220 presented in Table 3 appears inadequate and leaves substantial uncertainty regarding
221 the RFM's reliability. In the referenced studies, Miao et al. (2018) implemented multiple
222 factor matrices, and Zhang et al. (2023) validated their models through scatter density
223 plots and strong statistical metrics across training and testing datasets, including mean
224 absolute error (MAE) and percentage variation analyses. Rocha et al. 2025 attempt to
225 employ a RFM to capture the nonlinear influence of aerosols on surface fluxes.
226 However, this approach lacks sufficient methodological justification and statistical
227 robustness. The authors do not provide any evidence of cross-validation or other
228 procedures to assess model generalisability. Furthermore, the dataset used for
229 training—only 370 observations—is several orders of magnitude smaller than what is
230 typically required for stable Random Forest performance, raising serious concerns
231 about overfitting and the reliability of the reported metrics. Consequently, the predictive
232 results presented in Table 3 should be interpreted with caution, as their statistical
233 validity is uncertain. Given the limited dataset, the application of the Random Forest
234 Model (RFM) in this study does not appear to add substantial value to the results or
235 discussion. With such a small sample size, the model's capacity to generalise is

236 minimal, and its predictive performance cannot be reliably validated. Moreover, the
237 manuscript provides no detailed explanation of the model evaluation or validation
238 procedures, which further undermines confidence in the reported outcomes. To
239 strengthen the analysis, I suggest replacing or complementing the RFM with a
240 correlation matrix to explicitly reveal potential collinearity among variables, particularly
241 regarding the influence of AOD (as in Table 3). Additionally, presenting multivariate
242 regression equations and reporting their levels of statistical significance would offer a
243 clearer and more interpretable understanding of how other environmental factors
244 interacts with AOD. Such an approach could also serve as a solid foundation for future
245 studies investigating aerosol impacts on surface fluxes under polluted regimes.

246
247 We sincerely thank the MSc students at Wageningen University, under the supervision
248 of Prof Wouter Peters, for their detailed and constructive feedback regarding our
249 statistical methodology.

250
251 We agree with the referee and have removed the RFM analysis from the revised
252 manuscript. We emphasize that the RFM was originally intended as a complementary
253 exploratory tool, and its removal does not affect the main results or interpretations of
254 the study. In the revised version, to assess whether clean and polluted regimes exhibit
255 statistically significant differences in radiation and surface energy and CO₂ fluxes, we
256 apply the Mann–Whitney U test, which is well suited for non-normally distributed data
257 and unequal sample sizes. These revisions provide a clearer and more robust
258 statistical framework to support our conclusions regarding aerosol impacts on surface–
259 atmosphere interactions.

260
261 **Minor arguments and typos:**

262
263 **Minor issue 1:** Several sentences are poorly structured or ambiguous, leading to
264 confusion or misinterpretation. Examples include lines 74–75, 97, 99–101, 112–113,
265 134, and 247–248, as well as the descriptions for Figures, especially 2 and 4, where I
266 suggest rephrasing or clarifying.

267
268 L76: *“The climate is tropical humid and characterized by two seasons (wet and dry),
269 driven by seasonal shifts of the Intertropical Convergence Zone over the Amazon Basin
270 (Andreae et al., 2015).”*

271
272 L299: *“However, analysis of LE, which represents the fraction of available energy
273 converted into evapotranspiration, shows a consistent decrease in the polluted regime
274 compared to the clean regime (Figure 6), which contradicts this expectation.”*

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276 Additionally, Section 2.3 (Analysis Methods) has been revised to address all the
277 reviewer’s comments.

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Minor issue 2: Several statements lack adequate justification or references, I suggest further elaboration on the statements:

Line 114: The use of a fourth-order polynomial is mentioned but not explained or visualized.

The polynomial fit shown in Figs. 4–6 was applied solely as a smoothing technique for visualization purposes. In the revised manuscript, we have included the 30-min observed data points in the figures to better illustrate data variability. This clarification has been incorporated into the manuscript as follows:

L139-141: *“To facilitate the visualization of the mean diurnal patterns, a 4th-order polynomial curve was applied exclusively as a smoothing technique to the observational data. This curve fitting was used solely for graphical purposes and does not represent a physical or predictive model. All analyses were based on the measured data.”*

Lines 135–136: Require citation or elaboration.

We appreciate your suggestion, but we have removed the RFM.

Lines 220–222: Could be expanded with a brief example of the described method.

The expansion was carried out as follows:

L261-267: *“They identified a correlation between relative irradiance, air temperature, and VPD. Meanwhile, Herbert and Stier (2023) and Palácios et al. (2024) reinforce the idea that AOD significantly influences temperature variations, particularly on a regional scale. For instance, Palácios et al. (2024) observed positive linear correlations between AOD and air temperature across distinct climatic phases, attributed to the absorption of solar radiation by biomass burning emissions resulting in atmospheric heating. Similarly, Herbert and Stier (2023) utilized reanalysis data to demonstrate that 2-meter air temperature increases as a function of AOD, consistent with localized heating of the smoke layer due to strong absorption of solar radiation.”*

Minor Issue 3: Some methodological descriptions (e.g., line 12 in the Abstract; lines 87–90 on data filtering; lines 137–144 on the RFM methodology) could be condensed, as they do not add substantial value to the manuscript.

We thank the referee for this comment. The RFM analysis has been removed from the revised manuscript, as detailed in lines 251-259 of this document.

320

321 **Minor Issue 4:** GPP is mentioned in the Abstract and Conclusion but is neither
322 discussed nor analyzed in the main text.

323

324 The Abstract and Conclusion has been updated, and references to GPP have been
325 removed in the revised manuscript.

326

327 **Minor Issue 5:** The manuscript refers to two towers at the ATTO site but does not
328 specify which tower's data are used in the analyses and figures.

329

330 Thanks for this comment. The text has been revised to specify that the analyses are
331 based on data from the Instant Tower (81 m).

332

333 L66: *"The data used in this study were collected as part of the ATTO project, a bilateral*
334 *initiative between Brazil and Germany. Since 2012, ATTO has carried out continuous*
335 *measurements, as described by Andreae et al. (2015), located in an area of pristine*
336 *tropical forests in the central Amazon (Figure 1), which contains the Instant Tower of*
337 *81 meters (-2.1441°S, -58.9999°W)."*

338

339 P1, line 12: The last sentence of the Abstract adds no clear value to the manuscript
340 and could be removed.

341

342 The text has been removed from the abstract in the new version of the manuscript.

343

344 P3, line 81: Change LiCor to LI-COR for correct company citation.

345

346 The text has been updated accordingly. Thanks.

347

348 P5, line 112: The text states that hourly averages are used, while figures show 30-
349 minute values—this inconsistency should be corrected.

350

351 Section 2.3 (Analysis Methods) has been revised accordingly.

352

353 P14, Table 3 description: Typo — change FCO to FCO₂.

354

355 The table description has been updated accordingly. Thanks.

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357 P15, line 312: Typo — change aerossol to aerosol.

358

359 The text has been updated accordingly. Thanks.

360

361 References:

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