

In “Tropospheric Low Ozone and Its Diurnal Cycle over the Western Pacific Warm Pool from Solar Absorption FTIR observation”, Sun et al. present FTIR-based tropospheric ozone column measurements over the Palau Atmospheric Observatory in the Pacific Warm Pool between September and October 2022. Low ozone is observed and attributed to the low precursor availability, including low lightning activity, and the transport of clean marine air. The authors find a pronounced diurnal cycle of ozone, which cannot be reproduced by GEOS-Chem model simulations.

The paper is well-written and presents interesting observations in a part of the globe that is currently still understudied, but highly important to atmospheric chemistry processes with global implications. I have a few questions and comments. Once these are addressed, the paper will be a valuable addition to the current literature.

Specific comments:

L. 31 f.: An important removal process for O<sub>3</sub>, that’s missing here, is photolysis and subsequent reaction with H<sub>2</sub>O, particularly in the marine boundary layer.

**Response:** Yes, we agree with you and thank you for this helpful comment. The photolysis-driven ozone loss pathway was previously implicit in our discussion of HOx chemistry. To make this more explicit, we have revised the text to clearly state that ozone photolysis followed by reaction with water vapor constitutes a major primary removal pathway in the sunlit marine boundary layer. This process acts as a principal source of OH radicals, thereby initiating and sustaining subsequent HOx-mediated ozone loss cycles. In the revised manuscript, this process has been moved to the beginning of the ozone removal discussion to better reflect its importance under clean marine background conditions, relative to processes such as dry deposition.

We added in L31:

“In the sunlit marine boundary layer, a major chemical sink of ozone is photolysis, followed by reaction of excited oxygen atoms with water vapor, producing OH radicals (Levy, 1971). Additionally ...”

L. 33 f.: The reaction of NO with O<sub>3</sub> is not really a sink of O<sub>3</sub> because NO<sub>2</sub> can be photolyzed back to O<sub>3</sub> and the interconversion occurs on a short timescale.

**Response:** We agree that, in sunlit, low-NO<sub>x</sub> marine environments, ozone loss is dominated by photolysis followed by reaction with water vapor and subsequent HOx chemistry, whereas other processes play a more limited role in controlling ozone concentrations. To avoid overemphasizing non-dominant pathways, we have removed dry deposition from this paragraph and revised the text to focus on the chemically relevant ozone loss processes under marine boundary layer conditions.

L. 250 / Figure 2: Which area does the model represent? Is it the grid extracted at the observatory? How do the error bars look like?

**Response:** The model results shown in Fig. 2 represent the GEOS-Chem grid cell containing the Palau Atmospheric Observatory (PAO), corresponding to the 2° × 2.5° grid box spanning 132.5°–135° E and 6°–8° N. No additional spatial averaging was applied.

The error bars indicate the temporal standard deviation ( $1\sigma$ ) of the model output over the averaging period. Because model-simulated ozone over the tropical marine region exhibits relatively weak temporal variability, the resulting error bars are small.

L. 267 / Figure 3: Are these hourly averages including all observation days? I recommend adding error bars to the plot or showing them in the Supplement.

**Response:** Yes, the hourly averages include all available observation days during the campaign. We have added error bars to quantify the variability within each hourly bin.

L. 270: Is there really any significant variation in the model throughout the day? Please add error bars.

**Response:** We agree that the modeled diurnal variation is weak. To address this, error bars have been added to the hourly mean model results in the revised manuscript (Fig. 3). These error bars represent the temporal standard deviation ( $1\sigma$ ) of the model output within each hourly bin.

The small magnitude of the error bars reflects the smooth temporal behavior of simulated ozone over the tropical marine region, indicating that the model exhibits little intrinsic diurnal variability. The modeled ozone diurnal cycle is now provided in the Appendix.

L. 276: What about the diurnal cycle of other trace gases? And it would be interesting to look at the diurnal cycle of ozone production and loss, since you have the GEOS Chem outputs.

**Response:** We thank the reviewer for this suggestion. Following this comment, we have analyzed the modeled diurnal cycles of NO, NO<sub>2</sub>, and OH, and added the results to Appendix B (Fig. B1).

The model results show that while these radicals exhibit significant relative diurnal variability (e.g., OH increases by midday), their absolute concentrations remain extremely low (peak OH < 0.5 ppt; NO < 20 ppt; NO<sub>2</sub> < 40 ppt). Under these pristine conditions, the absolute magnitude of net ozone photochemical production and loss is too small to drive a discernible diurnal amplitude in the O<sub>3</sub> column. This analysis explains why the model's O<sub>3</sub> cycle appears muted despite active diurnal chemistry in the model. We have updated the manuscript (Lines 278-282) to include this discussion.

L. 291 f.: Is the pattern significant given the large variability in the data points? Please add error bars.

**Response:** We agree that the variability of individual data points needs to be quantified. In the revised manuscript, we clarify that the diurnal pattern is assessed based on hourly mean values rather than individual measurements. We add error bars representing the uncertainty of the hourly mean (standard deviation).

In addition, we include supplementary figures showing the hourly mean concentrations from ozonesonde with their variability in Appendix A, Fig. A1.

L. 319: HCHO is not only a precursor, but also an important by-product of O<sub>3</sub> formation from VOCs.

**Response:** We agree that HCHO is not solely an ozone precursor, but also an important intermediate and by-product of VOC oxidation associated with ozone formation. We have revised the text to distinguish between ozone precursors and photochemical tracers, and no longer refer to HCHO as a precursor. The revised sentence is this:

“Satellite retrievals support this interpretation. A broad ozone minimum is evident over the western Pacific warm pool (Fig. 4c), coinciding with low column densities of major ozone precursors and photochemical tracers, including CO (Fig. 4d), HCHO (Fig. 4e), and NO<sub>2</sub> (Fig. 4f).”

L. 325: NO<sub>x</sub> itself is not removed by precipitation; it can only be removed indirectly after formation of HNO<sub>3</sub>.

**Response:** We agree that NO<sub>x</sub> itself is not directly removed by precipitation. We have revised the text to clarify that precipitation removes nitrogen reservoir species formed from NO<sub>x</sub> oxidation (e.g., HNO<sub>3</sub>), thereby indirectly reducing NO<sub>x</sub> availability for ozone production. The revised sentence is like:

“Enhanced humidity in the tropical troposphere promotes ozone loss via OH chemistry. At the same time, precipitation efficiently removes soluble species such as HCHO and nitrogen reservoir species produced from NO<sub>x</sub> oxidation (e.g., HNO<sub>3</sub>), indirectly reducing NO<sub>x</sub> availability and suppressing ozone production.”

L. 325: Is Rex et al., 2014, really the correct citation here regarding the washout of soluble species?

**Response:** Thanks, we agree. To avoid an imprecise citation, we have revised the text and removed this reference. The statement is now presented as a general description of well-established processes in the tropical troposphere.

L. 328 f.: HCHO might not be transported over long distances, but it can be formed locally from longer-lived VOCs, including CH<sub>4</sub>.

**Response:** We agree that HCHO can be produced locally from the oxidation of longer-lived VOCs, including methane, and is therefore not solely controlled by transport. We have revised the text to clarify that the low HCHO columns over Palau reflect weak VOC oxidation and overall photochemical activity under pristine marine conditions, rather than inefficient transport alone. The interpretation for NO<sub>2</sub> remains based on its short lifetime and limited transport. The sentence has been revised like:

“HCHO, while also short-lived, is primarily produced locally through VOC oxidation; its low abundance therefore indicates weak photochemical activity under pristine marine conditions (Fig. 4e), further limiting in situ ozone formation.”

L. 368 / Figure 6: Could the authors also show a panel for NO<sub>x</sub> to highlight the changes introduced by the sensitivity run?

**Response:** We agree that changes in NO<sub>x</sub> are relevant for interpreting the sensitivity experiments. We have added the plots for NO<sub>x</sub> (Fig. C1) in the appendix and the difference between the base and the sensitivity simulations for NO<sub>x</sub> (Fig. 6).

L. 371: Is the difference really only 7 pptv? If so, that would show that lightning has basically no impact on O<sub>3</sub> (< 0.1%). Or is 7 ppbv meant here? However, that would be a surprisingly large impact.

**Response:** We thank the reviewer for pointing this out. The unit in Fig.6 was incorrectly labeled as pptv and has been corrected to ppbv. The simulated ozone differences associated with the lightning NO<sub>x</sub> sensitivity experiments are on the order of several ppb, reaching approximately 5–10 ppb over the tropical western Pacific.

While this magnitude may appear large, it reflects the strong chemical sensitivity of free-tropospheric ozone to NO<sub>x</sub> under low-background conditions, where lightning constitutes a major NO<sub>x</sub> source. These sensitivity experiments are intended to illustrate the chemical response under idealized conditions rather than to represent realistic variability.

L. 373: I recommend adding a sensitivity study with enhanced lightning, e.g. doubled or tripled lightning NO<sub>x</sub> emissions. The Warm Pool experiences very low lightning activity and therefore it would be interesting to show the impact of lightning enhancements on O<sub>3</sub> and OH as well.

**Response:** Yes, thank you for this suggestion. We add the simulation with 2xLnox and put the results in the Fig. 6.

Technical comments:

L. 226 f.: Please double-check the sentence: double use of “available”.

**Response:** Checked and deleted the words “available”.

L. 406: Do you mean day-to-day variation here? “Daily” implies “Diurnal” to me.

**Response:** Yes, thanks. We changed the word to “day-to-day”.

L. 440: Same here; day-to-day would be better than daily.

**Response:** Yes, thanks. We also changed the word to “day-to-day”.