Note: Author responses are in blue, italicized text.

Comments by Owen R. Cooper (TOAR Scientific Coordinator of the Community Special Issue) on: Dynamical drivers of free-tropospheric ozone increases over equatorial Southeast Asia
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This manuscript was submitted to ACP as part of the TOAR-II Community Special Issue https://doi.org/10.5194/egusphere-2023-2618 Preprint. Discussion started: November 4, 2023; discussion closes January 20, 2024 This review is by Owen Cooper (NOAA CSL), TOAR Scientific Coordinator of the TOAR-II Community Special Issue. I, or a member of the TOAR-II Steering Committee, will post comments on all papers submitted to the TOAR-II Community Special Issue, which is an inter-journal special issue accommodating submissions to six Copernicus journals: ACP (lead journal), AMT, GMD, ESSD, ASCMO and BG. The primary purpose of these reviews is to identify any discrepancies across the TOAR-II submissions, and to allow the author teams time to address the discrepancies. Additional comments may be included with the reviews. While O. Cooper and members of the TOAR Steering Committee may post open comments on papers submitted to the TOAR-II Community Special Issue, they are not involved with the decision to accept or reject a paper for publication, which is entirely handled by the journal's editorial team.

This paper is very well written, with a thorough meteorological analysis to demonstrate the impact of seasonal convection patterns on mid- and upper tropospheric ozone above equatorial Southeast Asia. I recommend some additional text to explain how the current study fits within the context of previous work on the same topic, and to provide some discussion on the relative contributions of changing meteorology and the continuing increase of anthropogenic emissions on the observed increase of ozone above this region.

We thank O. Cooper for helpful contextual comments, additional references, and pointers on topics to address in the manuscript text.

1) The following statements in the introduction suggest that previous studies have not investigated the impact of climate variability and seasonal cycles on ozone trends and variability: "the possible effects of dynamics and climate change have been given little consideration." and "Seasonally or monthly resolved analyses are less common (e.g., Chang et al., 2023; Section 3.4)". There is a very large body or work that addresses the impact of climate change on ozone, summarized by several review papers and IPCC AR6 (Jacob and Winner, 2009; Fiore et al., 2012; Fiore et al., 2015; von Schneidemesser et al., 2015; Szopa et al., 2021). Many studies have examined how trends vary by season or with climate variability (such as ENSO), and it is now standard procedure for modeling studies to quantify the impact of meteorological variability on ozone trends (Columbi et al., 2023; Cooper, M.J. et al., 2013; Li S. et al., 2023; Lin et al. 2014,2015,2017; Rowlinson et al., 2019; Wang et al. 2022a; Wang et al 2022b; Xue et al. 2020). To provide a broader context for the submitted paper it would be helpful to point out the new aspects of this study and how they build on earlier work.

We have removed this statement in Section 1: "However, the possible effects of dynamics and climate change have been given little consideration. This is somewhat surprising…".

We have also made this edit to Section 1: "There is a tendency to report tropospheric ozone trends using a single (annually averaged) value over some period of interest. Seasonally or monthly resolved analyses are less common (e.g., Chang et al., 2023; Section 3.4)." We strongly believe that these statements are still true. For example, as prominently displayed in the BAMS State of the Climate Report published each year.

The novelty of this work is the unambiguous result linking free-tropospheric (5-15 km) ozone trends to trends in convective parameters from multiple observational datasets. This was achieved using the highest-quality, homogenized, 100 meter resolution vertical ozonesonde profiles. The ozone trend computation by itself is not so original, but to our knowledge no other study has shown such a conclusive link between ozone and convective trends in this region. Our hope is that this motivates modelers to re-examine their simulations of free-tropospheric ozone and model convective parameters. Indeed, this is something we are exploring in preparation for the July 2024 Quadrennial Ozone Symposium. These mechanisms should also be explored elsewhere in the tropics and globally.

2) Detailed budget studies on the drivers of ozone trends across the tropics began in the mid-1990s with the development of global scale three-dimensional atmospheric chemistry models. The earliest studies indicate that increasing anthropogenic emissions are the primary cause of increasing tropical ozone (Levy et al., 1997; Roelofs et al., 1997). Since that time models and emissions inventories have continued to improve and successive generations of models (Szopa et al., 2021; Skeie et al, 2020; Griffiths et al., 2021; Liu et al., 2022) have attributed the observed ozone increases in the tropics to anthropogenic and biomass burning emissions, with anthropogenic emissions continuing to increase in the region of SE Asia (Li, M. et al., 2023). Two recent model studies explored the relative contributions of changing emissions and meteorological variability across SE Asia and concluded that rising emissions are driving the ozone increase (Wang et al., 2022b; Li. S. et al., 2023). The submitted paper does not address the impact of rising emissions on the observed ozone variability in the ozonesonde record, and some discussion is needed to quantify the relative contributions of dynamical changes and rising ozone precursors.

There is little doubt that the near-surface ozone trends of 4+ nmol mol^{-1} per decade are the result of local and regional emissions increases. We have now noted that in Section 3.2. Again, that segment of the profile is not the primary focus of our paper, especially because the free and upper troposphere are where ozone climate radiative forcing impacts are the greatest. However, Reviewer 1 brought up a good point about the lack of "communication" between the near-surface and free-tropospheric trends. A more detailed examination of the relationship between ENSO, VP200, and the near-surface and FT segments of the profile suggests that the trends in the two different layers are likely somewhat independent of each other. That is, the FT trends are driven by changes to ENSO, MJO (VP200), and convection, while the near-surface is likely more sensitive to emissions changes, and less sensitive to ENSO and MJO.

From our response to Reviewer 1: "We show here (Figure R4) the relationships between MEIv2 and ozone, and VP200 anomalies (computed for the black dash boxed region on previous Figures) and ozone, further indicating that any trend or change in VP200 anomalies in particular will result in tropospheric ozone changes. The relationship between these quantities and ozone is stronger for the 5-15 km layer (top of Figure R4) than the surface-5 km layer (bottom of Figure R4). The fact that there is still a weak relationship between surface-5 km ozone and VP200 anomalies may result in the correspondence between near-surface and FT ozone trends in Feb-Apr (Figure 6, and as you note below)." The data unequivocally show how strong the relationship is between FT ozone and VP200, and that the SHADOZ monthly means are more than sufficient to describe the convection/FT ozone interactions.

3) Several papers in the literature have discussed the impact of ozone sampling frequency and the challenges of detecting trends (Prinn 1988; Chang et al., 2020), or calculating accurate monthly or seasonal mean ozone values (Logan, 1999, Saunois et al., 2012). These earlier studies focused on northern mid-latitudes and a new study submitted to the TOAR-II Community Special Issue addresses this challenge at a tropical location (Chang et el., 2024). Some discussion is needed regarding the ozonesonde sample size and the confidence in the reported trends.

The Chang et al., (2024) paper is a nice resource for understanding sampling and ozone trends calculated for sub-tropical and higher latitude locations. Our analyses (as with Thompson et al., 2021) are restricted to stations in the deep tropics within ~10 degrees of the Equator. Variability induced by STE, for example, below 15 km will be minimal. Achieving higher confidence in our calculated trends in addition to providing attribution is precisely why we analyzed so many ancillary datasets, all of them with daily (OLR, AIRS CO) or sub-daily (GridSat-B1, MERRA-2) resolution. In response to Reviewer 1, we also examined precipitation data – further confirmation of the other independent parameters. They each arrive at the same conclusion, that ESEA convection has waned in ~Feb-Apr over the last 25 years, which matches the patterns in free-tropospheric ozone trends at the two SHADOZ stations. Our ozone trend results for the ESEA stations are essentially confirmed by examining the larger picture of MJO, ENSO, etc. variability. Again, we do not dismiss the impact of emissions increases on the strongly positive near-surface ozone trends.

Figure R4 (provided in the Response to Reviewer 1) shows the relationship between monthly averages of tropospheric ozone and MEIv2 (ENSO), and VP200 anomalies (MJO), and that the SHADOZ sampling is sufficient to capture the expected covariance in these metrics.

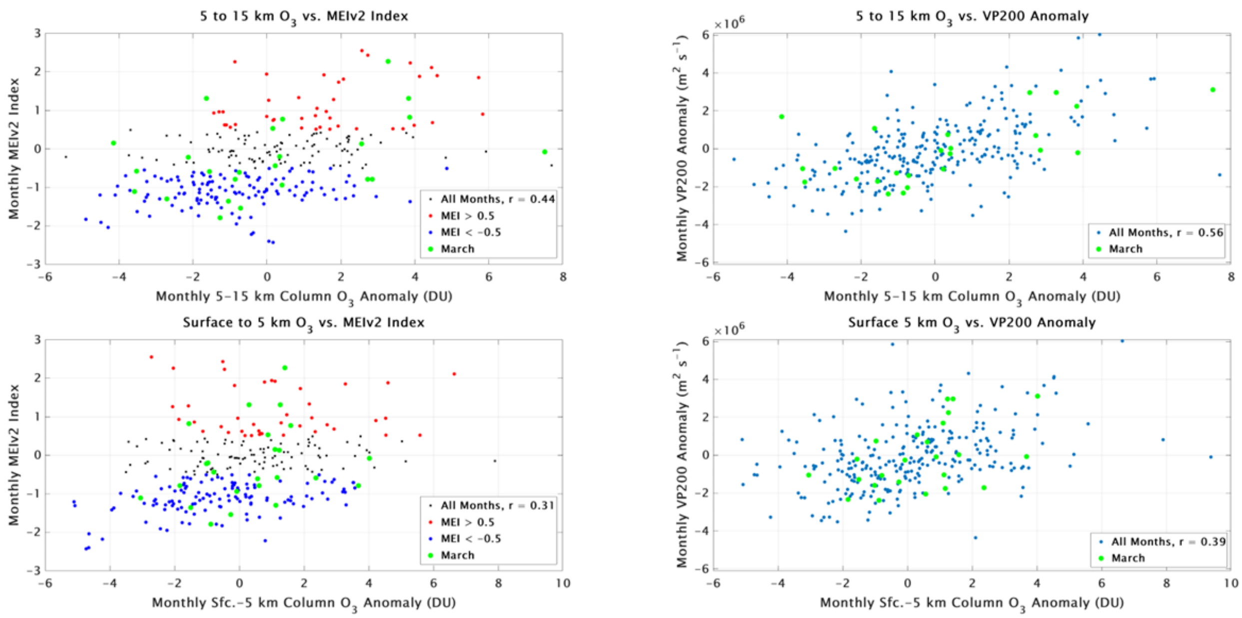

Figure R4. Scatterplots of 5 to 15 km (top row) and surface to 5 km (bottom row) partial column ozone anomalies corresponding to MEIv2 (left column) and VP200 anomaly values (right column). VP200 anomalies are computed for the black dash boxed region shown on Figures in the manuscript and above.

Thank you for providing the references listed below.

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