612: Dynamical Drivers of Free-Tropospheric Ozone Increases Over Equatorial Southeast Asia

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CONSISTENT PATTERN IN TROPICAL O_3 TRENDS. WHY?

- Tropical free tropospheric O_3 trends from SHADOZ balloon-borne ozonesonde data at 8 sites (1998-2019) were reported in Thompson et al (2021; "T21") using GSFC Multiple Linear Regression (MLR) model
- Consistent pattern emerged in T21 with largest positive free tropospheric O_3 trends appearing in early part of the year at most stations (Fig. 1)
- The positive trends tend to coincide with the low-O_3, convectively active season at all tropical SHADOZ stations
- *Are ozone increases linked to changes in convective activity?*
- *Case Study: Equatorial SE Asia SHADOZ stations Kuala Lumpur and Watukosek* (Fig. 2)

Fig. 1

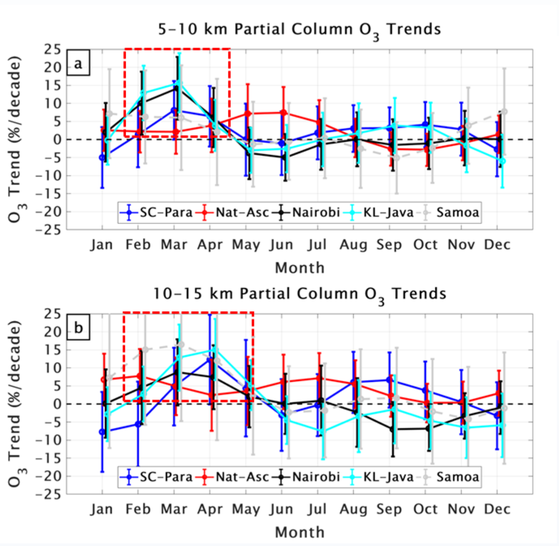


Fig. 2

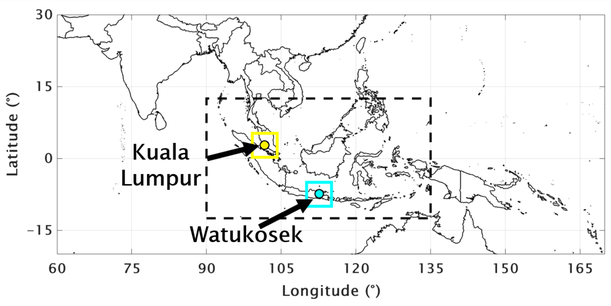


Fig. 2 (above)**: Map of study area with Kuala Lumpur (KL) and Watukosek (Java) highlighted. Boxed regions indicate areas with more detailed trend computations in our paper.* ***See QR code in References for preprint!

***Fig. 1 (above left)**: Figure 7 from T21. 1998-2019 partial column monthly MLR ozone trend calculations (%/decade) for 8 SHADOZ stations (5 combination stations) for (a) 5-10 km and (b) 10-15 km altitudes.*

CONVECTION: "TUNING KNOB" for TROPOSPHERIC O_3

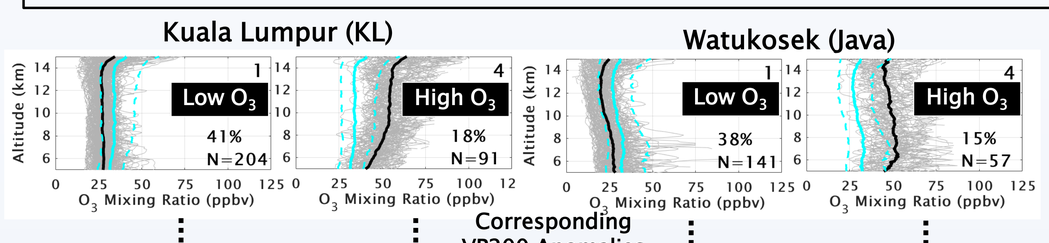


Fig. 3

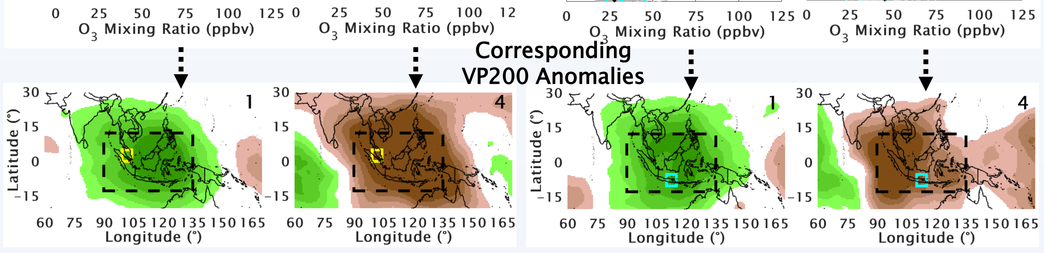


Fig. 4

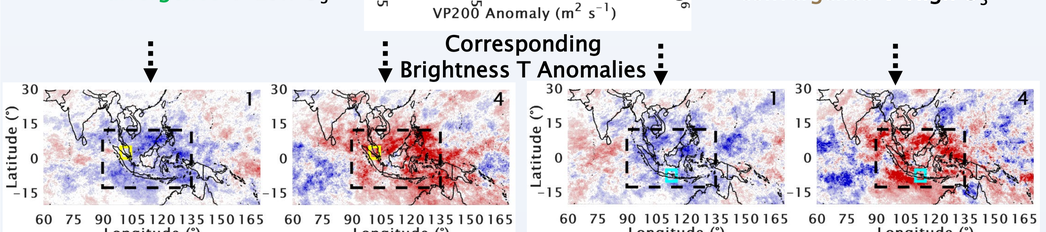


Fig. 5

Clusters of low and high 5-15 km O_3 profiles at KL and Java (Fig. 3) correspond to periods of anomalous upper-tropospheric winds (VP200; Fig. 4) and satellite cloud top brightness temperatures (T_b; Fig. 5). See Stauffer et al., (2018; JGR) for more on ozonesonde clustering.

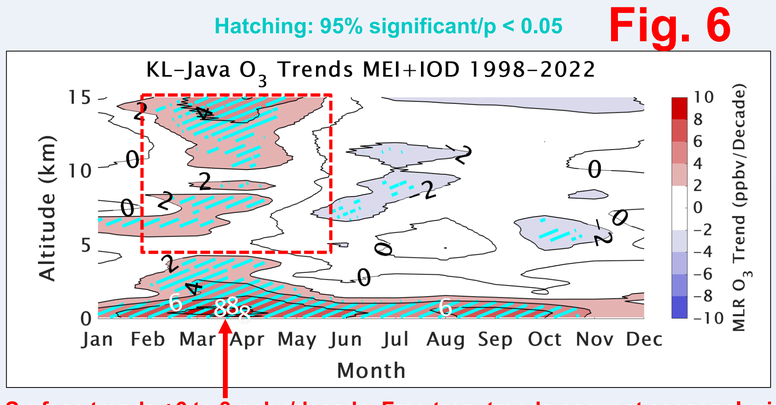
1998-2022 O_3 TRENDS ABOVE EQUATORIAL SE ASIA

$$O_3(t) = A(t) + B(t) + C(t)MEI(t) + D(t)IOD(t) + \varepsilon(t)$$

trend

Hatching: 95% significant/p < 0.05

Fig. 6



Surface trends +6 to 8 ppbv/decade. Free trop. trends occur at seasonal min

MLR ozone trends updated from T21 for combined KL-Java station (1998-2022) reaffirm early year large positive free tropospheric trends (+2-6 ppbv/decade)

How might have "convective tuning knob" parameters changed in 25 years? Is there a link to the positive free tropospheric O_3 trends?

CONVECTIVE PARAMETER and O_3 TRENDS COINCIDE!

Fig. 7

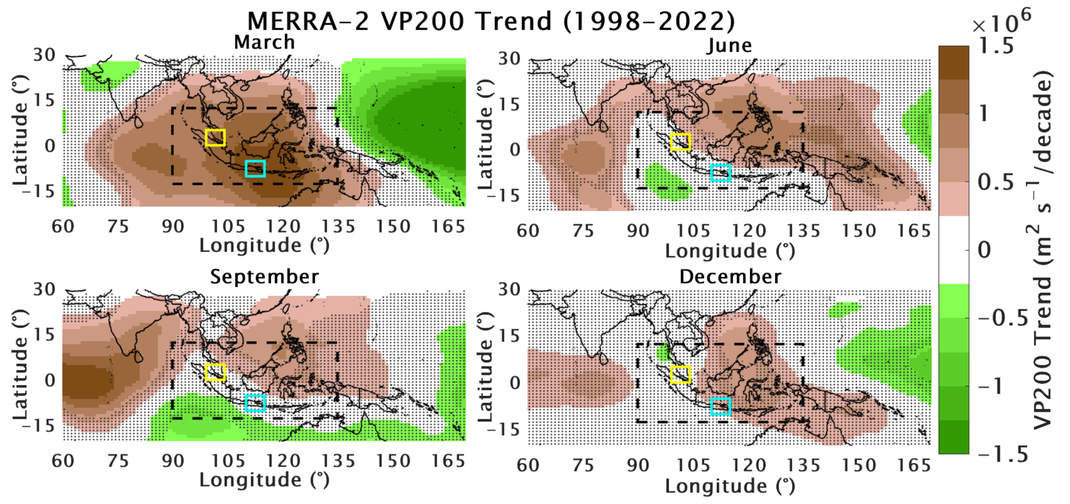
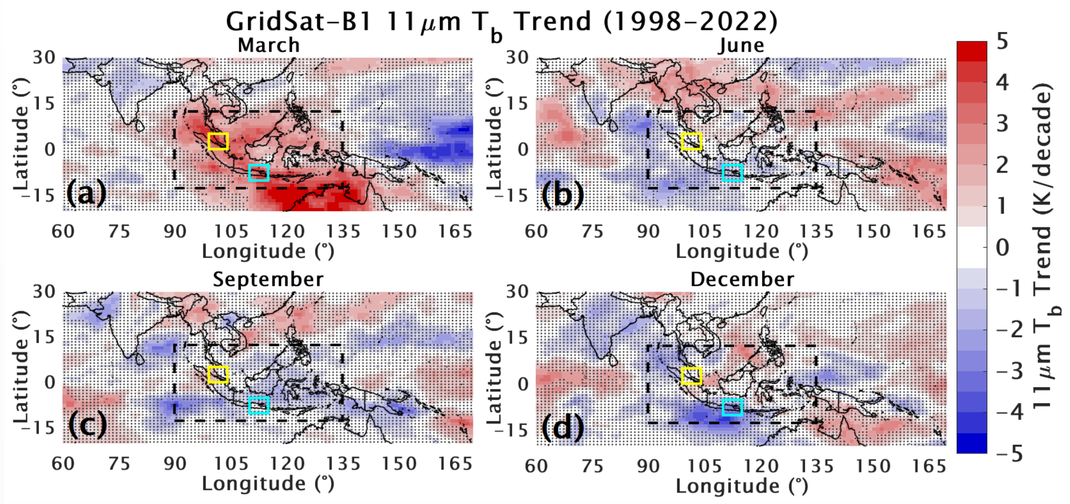


Fig. 8



- 1998-2022 MLR trends computed for VP200 (Fig. 7) and satellite cloud top T_b (Fig. 8) show significant decreases in convective activity *only in months when large positive free tropospheric ozone trends are observed*. Trends are weak thereafter
- Similar trends found for Outgoing Longwave Radiation, Precipitable Water, and even satellite Carbon Monoxide
- Suppressed convection allows O_3 accumulation, and we have found a link between 25-year decreases in convection and increases in free tropospheric ozone above Equatorial Southeast Asia SHADOZ stations in ~February-May

SUMMARY and RELEVANCE

- Early year positive free tropospheric (radiatively relevant!) ozone trends found at most tropical SHADOZ stations
- Case study with two Equatorial Southeast Asia stations show that convection has decreased in the early part of the year over 1998-2022. This is closely linked with the seasonally large positive free tropospheric O_3 trends in this region
- We have discovered tropospheric O_3 trends that are driven primarily by dynamical, not necessarily chemical, changes
- Relevant for Tropospheric Ozone Assessment Report Phase 2 (TOAR-II) and studies on climate change impacts on O_3!
- The power of monthly-resolved, as opposed to annual trends, lies in the greater potential for *attribution*. These trends are a dynamic (climate), rather than a chemical signal. *Challenge models and satellite data to reproduce these seasonal signals*
- More on ozonesondes and tropospheric O_3 trends – note D. Kollonige poster #355 (Tue) and A. Thompson talk on global free tropospheric O_3 sonde trends 3A.3 (14:15 Mon)

REFERENCES AND ACKNOWLEDGMENTS

This Work: Stauffer, R. M., Thompson, A. M., Kollonige, D. E., Komala, N., Al-Ghazali, H. K., Risdianto, D. Y., Dindang, A., Fairudz bin Jamaluddin, A., Sammathuria, M. K., Zakaria, N. B., Johnson, B. J., and Cullis, P. D.: Dynamical drivers of free-tropospheric ozone increases over equatorial Southeast Asia, *EGUsphere [preprint]*, https://doi.org/10.5194/egusphere-2023-2618, 2023. SEE QR CODE FOR PAPER PREPRINT →

– "T21": Thompson, A. M., Stauffer, R. M., Wargan, K., Witte, J. C., Kollonige, D. E., & Ziemke, J. R. (2021). Regional and seasonal trends in tropical ozone from SHADOZ profiles: Reference for models and satellite products, *J. Geophys. Res.: Atmospheres*, 126, https://doi.org/10.1029/2021JD034691.

– Stauffer, R. M., Thompson, A. M., & Witte, J. C. (2018). Characterizing global ozonesonde profile variability from surface to the UT/LS with a clustering technique and MERRA-2 reanalysis. J. of Geophys. Res.: Atmospheres, 123, 6213–6229. https://doi.org/10.1029/2018JD028465.

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