Response to community comments by Owen Copper

Comments by Owen R. Cooper (TOAR Scientific Coordinator of the Community Special Issue) on:

Surface and tropospheric ozone over East Asia and Southeast Asia from observations: distributions, trends, and variability

Ke Li, Rong Tan, Wenhao Qiao, Taegyung Lee, Yufen Wang, Danyuting Zhang, Minglong Tang, Wenqing Zhao, Yixuan Gu, Shaojia Fan, Jinqiang Zhang, Xiaopu Lyu, Likun Xue, Jianming Xu, Zhiqiang Ma, Mohd Talib Latif, Teerachai Amnuaylojaroen, Junsu Gil, Mee-Hye Lee, Juseon Bak, Joowan Kim, Hong Liao, Yugo Kanaya, Xiao Lu, Tatsuya Nagashima, and Ja-Ho Koo

EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-3756

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This review is by Owen Cooper, 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.

Thanks for your attention so much. We sincerely prepared our responses about your comments, and suggested those as below.

Comments regarding TOAR-II guidelines:

TOAR-II has produced two guidance documents to help authors develop their manuscripts so that results can be consistently compared across the wide range of studies that will be written for the TOARII Community Special Issue. Both guidance documents can be found on the TOAR-II webpage: (https://igacproject.org/activities/TOAR/TOAR-II).

The TOAR-II Community Special Issue Guidelines: In the spirit of collaboration and to allow TOAR-II findings to be directly comparable across publications, the TOAR-II Steering Committee has issued this set of guidelines regarding style, units, plotting scales, regional and tropospheric column comparisons, and tropopause definitions.

The TOAR-II Recommendations for Statistical Analyses: The aim of this guidance note is to provide recommendations on best statistical practices and to ensure consistent communication of statistical analysis and associated uncertainty across TOAR publications. The scope includes approaches for reporting trends, a discussion of strengths and weaknesses of commonly used techniques, and calibrated language for the communication of uncertainty. Table 3 of the TOAR-II statistical guidelines provides calibrated language for describing trends and uncertainty, similar to the approach of IPCC, which allows trends to be discussed without having to use the problematic expression, "statistically significant".

Thanks for your helpful information so much. We tried our best for following this guideline. In the previous manuscript, generally our analyses are in the range of TOAR-II guidance but some of our analyses were not well matching to the guideline style and the recommended way of statistical analyses.

In this revision process, we now have improved our manuscript based on these two guidance documents. Main improvements are as follows:

1) Recommended color-scale is considered for the Figures. 2) We have the unit of ozone concentrations corrected to the nmol mol^{-1} except for the national ozone air quality standard. 3) Quantile regression methods are adopted for all of the trend analysis. 4) More calibrated language is used now by avoiding the statement as "statistically significance".

General comments:

Line 154: Here the authors state that the ozonesonde stations have at least 10 profiles per year, which does not tell us the typical sampling rate for each station. As shown in a recent paper published in the TOAR-II Community Special Issue (Chang et al., 2024), accurate detection of ozone trends in the free troposphere is not possible if sample sizes are very low. This issue was further addressed by Gaudel et al. (2024) (another TOAR-II paper) who provided confidence levels for the ozone trends calculated from ozonesondes and IAGOS data across the tropics (see their Table 1); they also provided many details regarding the sampling frequency of each time series. It would be helpful to the reader if the approach of Chang et al. (2024) and Gaudel et al. (2024) is taken into consideration by the authors of the submitted paper. Please provide greater details regarding the sampling frequency at each station, and also provide some discussion regarding your confidence in the reported trends.

Thanks for your comments. Now we added the information about the sample sizes for the ozonesonde and IAGOS data. This information is now included in the updated supplements based on the bar-plot format due to the better visualization in Figure S1. Here in the response document, we also added the number information as below (Figure R1 for ozonesonde data and Figures R2-R3 for IAGOS data).

Year/Site	Sapporo	Tsukuba	Pohang	Kagoshima	Naha	Taipei	King's Park	Hanoi	Kuala Lumpur	Watukosek	Beijing
1980	0	16	0	0	0	0	0	0	0	0	0
1981	0	17	0	0	0	0	0	0	0	0	0
1982	0	14	0	0	0	0	0	0	0	0	0
1983	0	18	0	0	0	0	0	0	0	0	0
1984	0	16	0	0	0	0	0	0	0	0	0
1985	0	15	0	0	0	0	0	0	0	0	0
1986	0	15	0	0	0	0	0	0	0	0	0
1987	0	17	0	0	0	0	0	0	0	0	0
1988	0	22	0	0	0	0	0	0	0	0	0
1989	0	24	0	0	0	0	0	0	0	0	0
1990	15	35	0	13	15	0	0	0	0	0	0
1991	23	48	0	26	43	0	0	0	0	0	0
1992	34	56	0	25	31	0	0	0	0	0	0
1993	42	52	0	36	41	0	0	0	0	0	0
1994	45	49	0	35	40	0	0	0	0	0	0
1995	47	57	40	41	37	0	0	0	0	0	0
1996	38	57	15	43	36	0	0	0	0	0	0
1997	43	70	42	35	40	0	0	0	0	0	0
1998	45	61	44	41	41	0	0	0	21	22	0
1999	43	54	43	47	42	0	0	0	21	21	0
2000	45	54	37	50	41	31	45	0	25	44	0
2001	46	73	41	46	41	33	14	0	27	41	45
2002	49	66	34	52	43	0	12	0	27	21	32
2003	48	46	30	46	44	0	41	0	24	44	54
2004	44	51	44	48	39	0	62	11	24	39	59
2005	47	47	48	10	41	0	51	12	21	7	69
2006	45	44	44	0	43	0	43	37	21	8	53
2007	38	44	46	0	38	0	44	28	23	15	45
2008	42	49	51	0	37	0	49	23	24	24	37
2009	34	48	45	0	40	0	50	21	23	15	48
2010	39	48	43	0	37	0	47	10	4	10	48
2011	45	50	46	0	43	0	51	11	0	11	47
2012	49	49	36	0	48	0	49	8	16	12	41
2013	44	45	33	0	49	0	47	20	19	9	59
2014	41	43	42	0	36	16	50	21	24	0	45
2015	51	48	40	0	48	12	48	22	19	0	43
2016	49	47	37	0	46	12	48	21	24	0	47
2017	47	43	35	0	48	14	37	11	24	0	46
2018	5	33	40	0	5	7	45	30	20	0	46
2019	0	43	45	0	0	6	48	23	12	0	5
2020	0	40	48	0	0	6	48	28	13	0	0
2021	0	42	0	0	0	7	48	13	21	14	0
2022	0	39	0	0	0	3	46	0	24	13	0

Figure R1. The number of ozonesonde data used for the analysis in this research.

In previous version, we did not consider the year having ozonesonde data less than 10, and also did not conduct the trend analysis for a site not having at least 5 continual years with data number higher than 10. Using this criteria, we intended to make better reliability of our results. But we recognized that this approach makes somewhat large restriction of data usage. Considering that the ozonesonde data is still rare and difficult to obtain, we now agree with the commnets and think it is much better to use all measured data as possible as we can.

Now, we actually repeated all analyses in a same way, only having different dataset and compared previous and updated results (data used based on our previous standard vs. all data used). As a result, we confirmed that whole analyzed results about the ozonesonde data are not different much – Main lessons are almost identical, just the p-value part changes a little.

In conclusion, we updated all result figures (main manuscript and supplements) using all ozonesonde data (i.e., including a year if data number < 10). With proper citation of recommended results, we have revised our statements in Lines 161-170:

"There are a number of ozonesonde measurement sites, but here, we only consider 10 sites (Table S3), which has at least 10 measurement years continuously for finding reliable trends by considering the lesson from Chang et al. (2024). If a certain site is not satisfying with this standard, we only suggest the mean pattern of ozone vertical profile for that site in order to show all existed data as possible as we can. This approach enables us to compare with recent results produced from other ozonesonde data analyses (Gaudel et al., 2024; Stauffer et al., 2024). Data at 9 sites were obtained from the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) and Southern Hemisphere ADditional OZonesondes (SHADOZ) data archive. Data at Beijing site, which were reported in the previous study (Zhang et al., 2021) were directly provided from the measurement team."

Please check the data availability for the ozonesonde sites of Hanoi, Sepang Jaya and Watukosek, as the information provided in Figure S2 indicates that these data sets are incomplete. These sites are part of the NASA SHADOZ ozonesonde network, and the primary database for these data is here: https://tropo.gsfc.nasa.gov/shadoz/Archive.html

According to the SHADOZ database, these sites have data through 2021 or 2022 (see Stauffer et al. 2024 in the TOAR-II Community Special Issue). For your study please download and use the complete time series. Please also follow the SHADOZ data use guidelines at the bottom of the URL listed above.

Thanks! Previously we only checked the WOUDC data archive, and we now recognized that some SHADOZ data were not successfully transferred to the WOUDC archive (We discussed about this issue with Dr. Ryan Stauffer, who is one of expert scientists in the SHADOZ group).

Now we have used the complete dataset of ozonesonde measurements and updated our results. The key things related to this updating:

1) Site name change: Sepang Jaya => Kuala Lumpur.

2) The period of used data in some sites: Hanoi (2005-2016 => 2005-2021), Watukosek (2000-2012 => 1998-2022), and Kuala Lumpur (1998-2017 => 1998-2022).

3) Trend patterns: All trends are provided with their p-value. For Hanoi, increasing trend is same, but the trend slope becomes smaller. For Kuala Lumpur and Watukosek, trend patterns are almost similar to previous results

In addition, acknowledgements are also added into the text in according to the SHADOZ data use guidelines.

IAGOS data: The authors state that there are very few IAGOS profiles available over Asia after 2014, however there are actually hundreds of available profiles over East Asia and Southeast Asia, as shown in the recent TOAR-II submission by Lu et al., 2024. For example, I went to the IAGOS database and downloaded all of the ozone and carbon monoxide profiles above northeast China for the period 2015- 2022 (this region does not include South Korea or Japan). I found a total of 526 profiles, as shown in the figure below. This is equal to 66 profiles per year, which is a greater sampling frequency than the typical ozonesonde station that launches once per week. Please include the 2015-2022 IAGOS data in your analysis. Please also ensure that the IAGOS data policy has been followed, which is copied below.

Thanks for helpful comments! When we first performed the IAGOS analysis, our concern is the large difference of data number among different years: enough data in some years, but not in other years. Two figures attached below show the number of IAGOS sampling for Northeast and

Southeast Asia, respectively (Figures R2 and R3). This information is newly added to the supplement as Figure S1.

Since the sampling number does not show the inter-annual consistence, in our initial analysis we only considered the year having > 100 IAGOS measurements. That is the reason that our submitted results have short time period (also there was a typo, not 2014 but 2018).

In this revision, however, we follow your comment to use all available data. As a result, we can now extend the trend analysis until the year 2022. This enables us to do the trend analysis in the Southeastern Asia region, too! Main lessons that we found does not change, but it looks much better to show results based on completed data. The text in Lines 398-421 have been updated.

	1	2	3	4	5	6	7	8	9	10	11	12	Sum
1995	2	3	7	16	21	15	28	16	26	17	17	19	187
1996	26	24	13	35	30	28	31	37	22	28	19	23	316
1997	37	33	33	31	37	48	24	51	22	45	49	58	468
1998	55	47	51	43	68	51	54	67	33	48	51	52	620
1999	41	54	22	34	28	24	39	29	33	35	19	20	378
2000	16	18	13	21	15	33	34	28	23	21	21	23	266
2001	10	15	23	20	16	13	11	8	9	15	17	2	159
2002	11	6	2	9	8	3	22	24	22	21	17	9	154
2003	18	22	25	22	26	27	24	22	20	18	20	21	265
2004	19	15	15	15	16	20	25	25	2	7	19	24	202
2005	11	9	40	51	44	53	41	38	33	38	11	9	378
2006	9	1	1	1	7	12	9	11	9	9	0	0	69
2007	0	0	0	0	0	0	0	1	0	1	0	0	2
2008	0	0	0	0	0	0	0	2	0	2	0	2	6
2009	1	2	2	0	2	0	0	0	0	0	4	8	19
2010	3	5	0	0	0	2	2	1	1	2	11	6	33
2011	12	13	22	25	11	20	20	15	14	17	13	8	190
2012	0	3	9	37	15	0	36	50	54	14	16	20	254
2013	29	12	2	20	39	25	30	22	6	6	8	42	241
2014	23	23	30	22	19	28	9	18	6	4	0	5	187
2015	17	14	22	17	0	5	6	19	22	28	14	29	193
2016	29	9	12	14	9	16	63	49	59	77	53	53	443
2017	19	15	0	10	14	10	12	19	11	6	15	70	201
2018	59	39	37	37	39	26	20	21	10	18	0	10	316
2019	12	16	6	1	7	8	10	4	0	0	2	9	75
2020	5	6	0	0	30	1	11	6	0	0	0	1	60
2021	2	1	0	3	8	0	0	6	0	0	0	0	20
2022	2	1	4	0	0	0	0	0	2	2	2	0	13

Figure R2. The number of IAGOS data sampled in the defined region as Northeast Asia.

	1	2	3	4	5	6	7	8	9	10	11	12	Sum
1995	4	16	18	6	4	8	24	14	35	3	11	9	152
1996	31	33	3	25	28	24	23	16	0	32	24	16	255
1997	35	36	44	4	2	10	10	6	6	1	3	8	165
1998	12	4	6	22	6	4	8	8	2	10	2	12	96
1999	5	7	14	0	0	12	7	2	4	6	2	4	63
2000	0	2	8	2	2	0	2	2	0	1	0	3	22
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	2	0	2	0	0	0	0	4	0	0	0	2	10
2003	0	0	2	0	0	0	0	4	4	0	0	0	10
2004	0	2	0	0	0	4	2	1	1	4	7	3	24
2005	13	6	9	15	45	40	6	10	46	38	16	14	258
2006	6	0	0	4	13	16	23	21	12	15	4	4	118
2007	0	4	4	4	4	3	2	4	0	4	3	0	32
2008	0	4	4	0	0	0	0	0	0	0	0	0	8
2009	2	0	0	0	0	0	0	0	0	0	0	0	2
2010	0	0	0	0	0	0	0	0	0	0	8	4	12
2011	6	4	12	14	8	4	6	8	4	8	6	2	82
2012	0	1	3	0	0	0	56	77	60	44	77	56	374
2013	65	5	4	0	0	0	0	5	0	0	4	4	87
2014	4	0	0	2	2	10	0	1	0	0	0	38	57
2015	86	69	82	71	0	50	42	106	88	145	138	128	1005
2016	116	78	28	71	87	41	144	162	115	180	159	153	1334
2017	77	56	2	9	4	10	13	32	7	3	14	159	386
2018	140	150	90	86	74	34	10	11	5	12	0	0	612
2019	0	0	0	0	2	9	0	0	0	0	0	0	11
2020	0	0	0	0	1	2	12	8	0	0	0	2	25
2021	7	1	2	0	0	0	0	0	2	0	2	3	17
2022	2	10	0	0	0	0	0	4	4	6	2	0	28

Figure R3. The number of IAGOS data sampled in the defined region as Southeast Asia.

The IAGOS data use policy is here: https://iagos.aeris-data.fr/data-policy/

We ask you to inform the data providers, traceable through the metadata connected to the provided DOI, when the data is used for publication(s), and to offer them the possibility to comment and/or offer them co-authorship or acknowledgement in the publication when this is justified by the added value of the data for your results. In accordance with the IAGOS data policy, users of IAGOS data products are required to:
1. include the following acknowledgements in publications: "MOZAIC/CARIBIC/IAGOS data were created with support from the European Commission, national agencies in Germany (BMBF), France (MESR), and the UK (NERC), and the IAGOS member institutions (http://www.iagos.org/partners). The participating airlines (Lufthansa, Air France, Austrian, China Airlines, Hawaiian Airlines, Air Canada, Iberia, Eurowings Discover, Cathay Pacific, Air Namibia, Sabena) supported IAGOS by carrying the measurement equipment free of charge since 1994. The data are available at http://www.iagos.fr thanks to additional support from AERIS."
2. offer co-authorship to the IAGOS Principal Investigators if the IAGOS data play a significant role in the publication
3. identify themselves and provide contact information (valid email address)
4. provide a short description of the intended research

Thanks for your notice. We revised our manuscript by acknowledging these data sources.

Beijing ozonesonde trends: The supplement shows decreasing ozone above Beijing, according to the Beijing ozonesonde record (Figures S3-S6). This decreasing trend is the opposite of the positive trends reported by other studies using IAGOS data (Gaudel et al., 2020; Lu et al., 2024). Furthermore, Figure S2 shows a very unusual decrease of ozone after 2011 above Beijing, that I have not seen at any other ozonesonde site. Please download all of the IAGOS ozone profiles above northeastern China (1994- 2022) and compare them to the Beijing ozonesondes to identify the discrepancy.

Thanks for your valuable comments. Actually we were also curious if this negative trend in Beijing is convincing and agree with your statements of "The sharp ozone decrease from the year 2011 is unusual". But we think that we need to discuss about this ozone decrease pattern in Beijing.

1) At first, in the reference papers that you suggested (Gaudel et al., Sci. Adv., 2020; Lu et al., egusphere, 2024), trend analyses using the IAGOS data were performed in the northeast Asia region, not the China or specific city area in China (e.g., Figure 1 in Gaudel et al., 2020 defined the box region as 'Northeast China/Korea, and Figure 1 in Lu et al., 2024 defined the box region as the 'East Asia')

2) We used the IAGOS 'vertical profile' data around the airport. In East Asia, total 11 airports provide this data, as shown in Figure R4. Using this data, we examined the vertical profile of ozone trends for each airport as shown in Figure R5. In Figure R4, you can see that most of airports show the increasing or no trends. Exception cases are Beijing and Qingdao, which are located in the eastern China (Figure R4). In fact, decreasing trends in these two airports have p-value less than 0.05 in the boundary layer (0 to 2 km altitude).

3) We also investigated the time series of ozone at 1, 3, 5, and 7 km altitudes for all 11 airports, and confirmed that ozone in Beijing and Qingdao actually shows the decreasing trend (Figure R6), different from trends at other airports showing increasing trends. Our IAGOS trend analyses in the 'Northeast' and 'Southeast' Asia regions also show clear increasing trends, consistent with previous studies (e.g., Gaudel et al., 2020). But in detail, as we showed, IAGOS data also indicate the 'decreasing trend of ozone' for some regions in eastern China.

Unfortunately, IAGOS does not provide enough data from 2011 to 2013, the period showing sharp ozone decrease based on ozonesonde measurements in Beijing. At this present moment, it is hard to evaluate this sharp ozone drop (from ozonesonde data) during 2011-2013 is meaningful or not. However, comparison with the IAGOS data (as suggested) show that the ozone decrease in Beijing may be a real signal, while the quantity is not clear.

4) Used ozonesonde data at the Beijing site were reported previously in Zhang et al., (2021) (in terms of total column analyses, though). Figure R7 is a figure taken from Zhang et al. (2021), which is the temporal variation of ozone from surface to stratosphere. In their figure, we can see that the tropospheric ozone enhancement during about 2006-2012 looks related to the stratospheric ozone intrusion. This is in line with a number of studies indicating the possible impact of stratospheric ozone intrusion to the tropospheric ozone level in East Asia (e.g., Hua et al., 2024; Koo et al., 2024; Zhao et al., 2024) and a very recent study reported that this stratospheric ozone intrusion becomes weaker in China (declining trend in 2015-2022) (Chen et al., 2024). We do not know that the extent of this stratospheric ozone intrusion can lead the tropospheric ozone decline in China, and this topic is also beyond the scope of this paper. Just

here we would mention that it is hard to neglect the ozone decreasing trend in Beijing that we found based on the ozonesonde and IAGOS data analysis.

In this context, we think that it may be worth to report this ozone decrease in Beijing. But we do not provide features in detail in the manuscript because it seems beyond of the scope of this paper. Now we would leave our discussion here in the response document, and will do some more study in the future. Some statements have been added in Lines 462-467:

"Although trend values are not largely evident, tropospheric ozone decrease at Beijing is quite consistent in all seasons. Zhang et al. (2021) also treated the variation of ozonesonde measurements at Beijing, and it looks that the stratospheric ozone intrusion is strong from 2006 to 2012 but not in other years, which may be related to the ozone trend at Beijing. At this present moment, these decreasing trends were not well explained by our knowledge. Nonetheless, we would report these trends because it can be a motivation of further research."

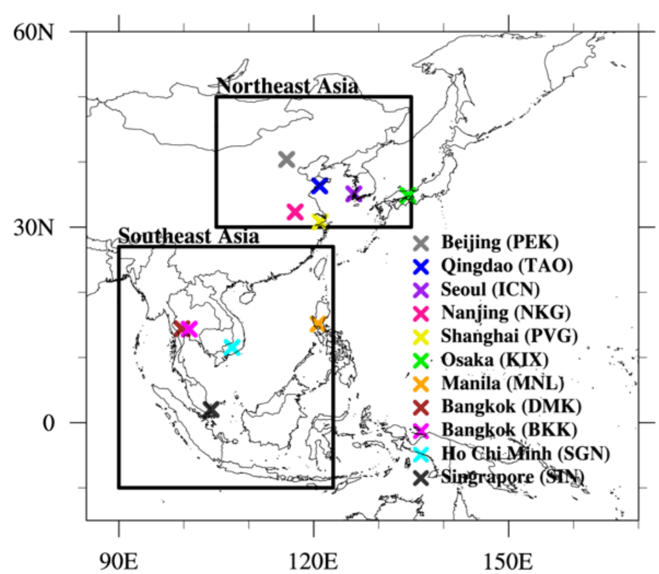
References:

Chen, Z., and co-authors (2024), Stratospheric influence on surface ozone pollution in China. Nature Communications, 15, 4064, https://doi.org/10.1038/s41467-024-48406-x.

Hua, J., and co-authors (2024), Unravelling the impacts of stratospheric intrusions on near-surface ozone during the springtime ozone pollution episodes in Lhasa, China, Atmospheric Research, 311, 107687, https://doi.org/10.1016/j.atmosres.2024.107687.

Koo, J.-H., and co-authors (2024), The Analysis of summertime tropospheric ozone at Anmyeon using ozonesonde measurements in 2021~2022, Journal of Korean Society for Atmospheric Environment, 40(3), 373-383, doi:10.5572/KOSAE.2024.40.3.373

Zhao, K., and co-authors (2024), Impact of stratospheric intrusions on surface ozone enhancement in Hong Kong in the lower troposphere: Implications for ozone control strategy, Atmospheric Environment, 329, 120539, https://doi.org/10.1016/j.atmosenv.2024.120539.



IATA	City	Latitude	Longitude
PEK	Beijing	40.39	115.83
TAO	Qingdao	36.34	120.91
ICN	Seoul	35.10	126.17
NKG	Nanjing	32.33	117.14
PVG	Shanghai	30.79	122.00
KIX	Osaka	34.84	134.51
MNL	Manila	15.13	120.68
DMK	Bangkok	14.40	99.70
BKK	Bangkok	14.35	100.83
SGN	Ho Chi Minh City	11.54	107.43
SIN	Singapore	2.02	104.20

Figure R4. (Left) The location of 11 East Asia airports providing ozone vertical profile data in the IAGOS dataset (https://iagos.aeris-data.fr/download/). (Right) Latitude and Longitude of 11 airports (city name and airport IATA code).

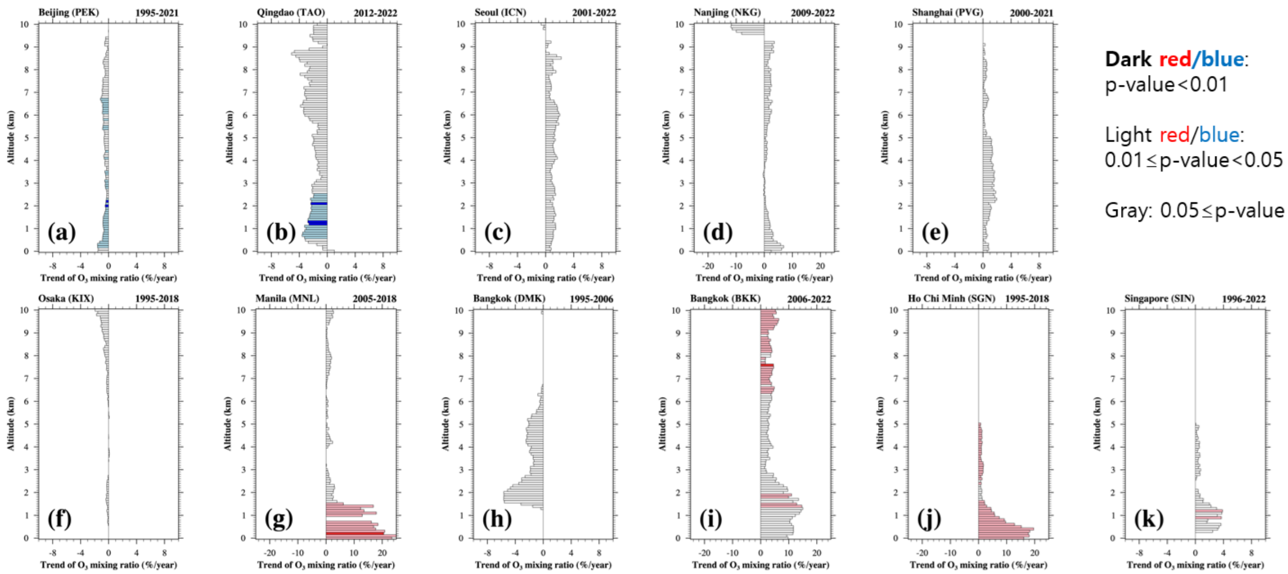


Figure R5. Vertical profiles of ozone trends for 11 IAGOS airports in East Asia.

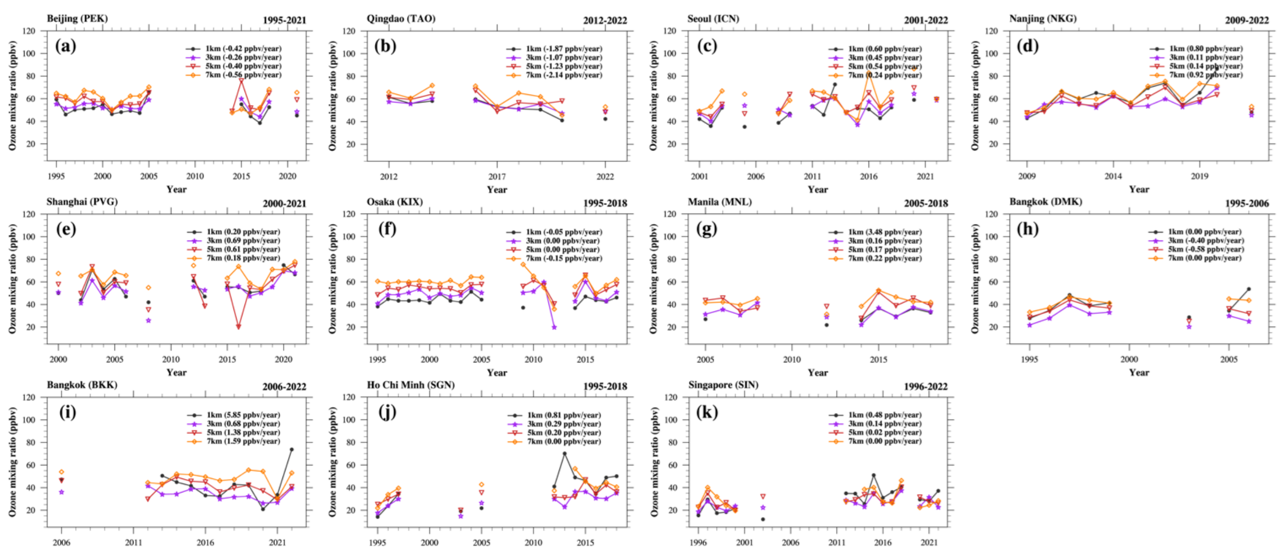


Figure R6. Time series of annual median of ozone at 1, 3, 5, and 7 km altitudes for 11 IAGOS airports in East Asia.

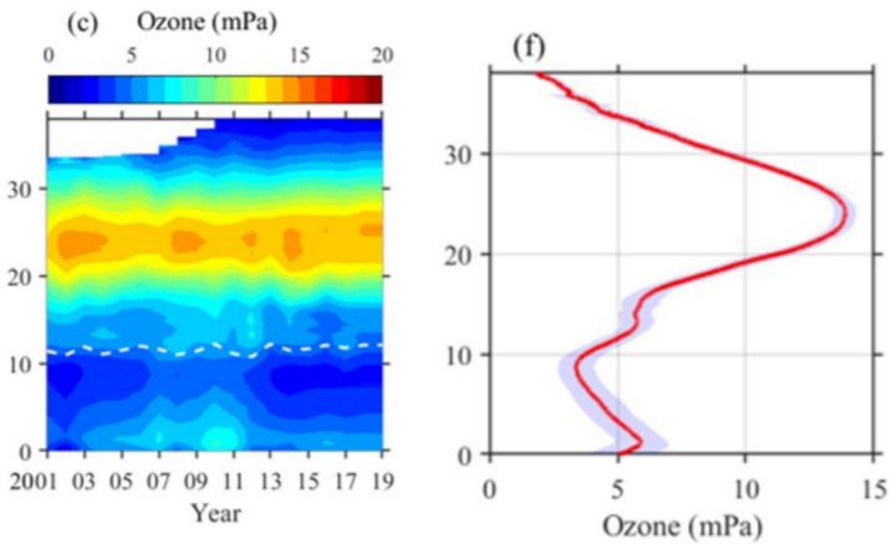


Figure R7. Temporal variation (left) and vertical mean profile of ozone measured by the ozonesonde experiments at Beijing site. These figures were taken from Zhang et al., (2021) (DOI:10.1088/1748-9326/ac109f).

Table S1: Following the TOAR-II statistics guidelines, all trends need to be reported with the 95% confidence interval and the p-value.

Added. Thanks!

Figure S2 This figure is very difficult to read because it is so small. Please enlarge.

We have improved the quality of this Figure now.

References

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