IASI-Boynard Paper Comment – 13 May 2025

Anne Thompson, Debra Kollonige, Ryan Stauffer

SUMMARY COMMENTS AND SUGGESTIONS FOR REVISION

This Comment follows that of HEGIFTOM Co-Chair R. Van Malderen and amplifies his major points. We refer to the same "Van Malderen et al, in press, 2025" that he does and designate it as "HEGIFTOM-1" because there is a second HEGIFTOM paper in review in the TOAR II collection. We go beyond Van Malderen's comments to 3 summary recommendations:

1) The selection and number of ground-based stations for which ozone data are compared to the IASI-CDR product is *inadequate in number* and 'non-homogenized' datasets should not be used. In contrast to the 7 stations used in this paper, more than 25 stations, homogenized over the 2008-2019 period, need to be used in evaluation of the IASI products *and* the trends. The 7 sites included no equatorial stations and far too few northern mid-latitude stations, in some cases where more than sonde data are available. The recommended ozonesonde 27 stations appear in Table 1 at the end of this Comment.
2) The authors conclude with general, not well-defined speculation on why there is little progress in how computed trends from the new IASI products diverge from the UV-based product trends from the Gaudel et al. (2018) TOAR I paper. More analysis and insights on this issue are needed before the paper is worthy of publication in a quality Copernicus journal. Specific questions are raised for consideration.
3) HEGIFTOM-1 is now "THE Reference dataset" for trends comparisons. The mismatch of years (2008-2019 in Boynard et al. vs 2000-2022 in HEGIFTOM-1) is speculated as one reason for why the trends in this paper differ from the ground-based trends in HEGIFTOM-1. We reran the trends in HEGIFTOM-1 for 27 stations for 2008-2019, see Table below, to support a valid comparison. *Some of the HEGIFTOM-1 site trend signs changed and uncertainties increased, leading to a clear TOAR-worthy conclusion that trends computed from 12 or 16 years of IASI or ground-based data is inadequate. A revision must include this important result!*

SYNOPSIS – This study presents an IASI product over 16 years, consisting of contributions from METOP-A, METOP-B and METOP-C, merged to create the IASI-CDR (Climate Data Record, 2008-2023). Several tropospheric ozone columns (to 450, to tropopause) are presented and compared on a monthly mean basis with (1) the CrIS IR ozone product and with (2) comparable ozonesonde columns from 43 stations over the period. Trends for global mid-latitudes and the tropics are computed using Quantile Regression (QR) for the period 2008-2019 (pre-COVID) and 2008-2023; the latter trends reflect an apparent COVID impact. As in the TOAR I paper in which Gaudel et al. (2018) summarized satellite product trends (2005/2008 – 2016) showing IASI (FORLI version) to be an outlier compared to UV-type satellite records, it appears that the IASI-CDR trends (now 2008-2019, omitting COVID period) is an outlier with the corresponding UV-based time-series. In both cases the greatest discrepancies are in the tropics except for SE Asia where all products display increases of ~1-2 DU/decade. The UV-type satellite products tend to be more variable with regions in the tropical Americas, Africa and Atlantic showing some increases (~2005-2019; Gaudel et al., 2024; Thompson et al., 2024). The IASI-CDR TOAR II-period (Fig. 12 in paper) shows little increase over Europe, a decrease over North America and only modest increases in east Asia, again in disagreement with more variable UV-type satellite trends. IASI 2008-2019 trend comparisons are made with 7 ozonesonde time-series: one subtropical site, 4 northern mid-latitude (majority European), 1 southern mid-latitude (Fig. 16). The authors speculate briefly on causes of the persistent discrepancy between the IASI vs UV trends and what is emerging as the prevailing view of tropospheric changes over the prior ~15 years. Comparisons among comparable IR products eg. IASI-CDR, IASI-KOPRA, and CrIS global ozone products are described with varying degrees of detail or with Figures that are suggestive but not conclusive.

OVERALL COMMENT – The paper poses good questions, presents a reasonable approach for its calculations and selection of results and is well-arranged. However, it leaves too many unanswered questions and does not advance the scientific understanding of its ozone trends beyond the first TOAR study. The three most important aspects of the paper that require additional analysis are summarized as follows:

1>> **Quality assurance and evaluation of the IASI-CDR.** There is reference to a larger set of sonde stations used for comparisons (43 stations; Fig 8 and 10) but Table 2 is inaccurate. The following stations are *not* available on HEGIFTOM archive because they are not homogenized datasets: Lindenberg, Prague, Tateno, Hong Kong, Broadmeadows, and Macquarie. We recommend using only homogenized datasets for reference datasets and trends. Comparison of trends is restricted to 7 stations, none truly tropical, 15 degrees or less, despite the fact that a number of cited and other TOAR II studies, both satellite and ground-based, focus on the tropics e.g., Froidevaux et al., 2025; Gaudel et al., 2024; Thompson et al., 2025. Time-series comparisons in Fig. 16 show only 7 stations with limited geographical coverage.

Concerning the evaluation of IASI-CDR:

- Extensive discussion of CDR vs earlier FORLI product appears – but no illustrations of why you expect the CDR product to perform better than the earlier one.
- IASI-KOPRA product mentioned but why is there no extensive comparison with this product or at least a paragraph comparing results of Dufour et al. (https://egusphere.copernicus.org/preprints/2025/egusphere-2024-4096/) to those shown here, particularly for sonde comparisons?
- Vertical discrepancies mentioned in comparisons with sondes (tropical, mid-latitudes, and polar) appear in Fig. 10. Although overall IASI column amounts are compared favorably to the sondes (Line 22, only 2% offset in tropics) can this be due to a cancelling of offsets illustrated in the Figure? Discuss the potential impact on the trends.

- The CrIS-TROPESS *a priori* looks so much better than the IASI (varies with season and latitude). Although the IASI climatology (Fig. 7) looks reasonable, can the IASI *a priori* (Fig. B1) – with apparently little seasonal information and only latitude dependence- be a cause of the discrepancies with other products? Does inadequate representation of seasonality (monthly variations in trends are typical and significant in the tropics, for example: Stauffer et al., 2024; Thompson et al., 2021) propagate to trends that disagree with both sondes and UV-products? What additional insights can you derive from scatterplots with ozonesondes (Figs. A1-4)? Comparing to sondes seasonally can help identify discrepancies. There is extensive discussion of similarities and differences with CrIS but it doesn't get to the crux of understanding the large negative ozone trends here that are at odds with other products.

2>> **Inadequate number of ground-based (GB) reference sites.** There are two aspects of this issue.

- First, the authors show 43 potential stations (Table 2, Fig. 8) but make trend comparisons with only 7 ozonesonde data sets. Perhaps they don't understand the fine points of which data are appropriate to use (see Van Malderen comment). There is no need to speculate, as the authors have done, on why their results do not resemble those from mostly UV sensors. All satellites now have the HEGIFTOM-1 trends at individual stations (some with multiple instruments, not only sondes) as the <u>gold standard independent reference</u> at 55 sites total for 2000-2022. The HEGIFTOM reprocessing includes references of the data for each instrument type (sonde, FTIR, UV Umkehr) to a global absolute standard. Your trends analysis should add at least 20 stations (exclude polar sites where IASI-CDR struggles with DOFS) to have a more representative picture of IASI performance. Note that of the 7 reference sites (Boulder, Hilo, Lauder), there is more than one GB record for comparison. The stations in the Table below have sufficiently temporally dense records for comparison.
- Second, Line 330 states that months with only 1-2 sondes/month give 'inadequate' results for 50%-ile trends. In the accepted version of HEGIFTOM-1, it is shown that these trends (computed with QR or MLR) are unaffected by cutting from 4-5 sondes/ month to 2; only the uncertainty changes (increases). That is a second justification for using more sonde locations for the GB comparisons - candidates in the Table.

3>> **Brevity of the IASI record is a concern for 2008-2019 trends.** For comparison, we re-ran the QR trends for the authors' selected 7 stations as well as 20 other HEGIFTOM reference ozonesonde stations (excluding polar sites). The results are listed in the Table below, which also includes results from the HEGIFTOM-1 2000-2022 trends for surface-300 hPa (in ppbv/decade) as well as XO3 (ppbv/decade) and DU (DU/decade) for surface to tropopause tropospheric columns as a reference.

- Note for the recalculated 2008-2019 ozonesonde trends, that 4 out of the 7 author selected stations change sign of trend from the longer time series to the shorter time series. For example, Boulder, a station with a high certainty ($p<0.05$) associated with a negative trend for the longer time series (2000-2022), has a slightly positive trend with large uncertainties for the 2008-2019 period. Of the 27 ozonesonde stations listed in the table, 9 sites have trend sign changes. Discussion on the point of *reduced* reliability and value of the shorter time series (12 or 16 years vs 23 years in HEGIFTOM and sonde studies*) is needed and is now a view that can be made with confidence. In a sort of "reversal" of your paper's message, a significant *advance and outcome of your paper, with the contracted (2008-2019) HEGIFTOM calculation, is that TOAR II needs to recognize the limitations of datasets that cover fewer than ~20 years!*

- The uncertainties in the trends also increase with the shorter time series (ie. double those for the 2000-2022 time period – see Table below).
- On your paper (also noted by R. Van Malderen) the reported uncertainties in Fig. 16 seem small for only 12 years of data. Can you check those and discuss your bootstrap method in more detail?

*In addition to the sondes studies you have referenced, Stauffer et al., 2024; Thompson et al., 2021; Thompson et al., 2024, there is an excellent new sonde trends paper submitted on Réunion SHADOZ and SAOZ time-series (1998-2021) submitted to *Earth and Space Science:* *https://essopenarchive.org/doi/full/10.22541/essoar.174594999.98715985/v1*

'HEGIFTOM-1" below is posted. Final version is in press.

Van Malderen, R., Thompson, A. M., Kollonige, D. E., Stauffer, R. M., Smit, H. G. J., Maillard Barras, E., Vigouroux, C., Petropavlovskikh, I., Leblanc, T., Thouret, V., Wolff, P., Effertz, P., Tarasick, D. W., Poyraz, D., Ancellet, G., De Backer, M.-R., Evan, S., Flood, V., Frey, M. M., Hannigan, J. W., Hernandez, J. L., Iarlori, M., Johnson, B. J., Jones, N., Kivi, R., Mahieu, E., McConville, G., Müller, K., Nagahama, T., Notholt, J., Piters, A., Prats, N., Querel, R., Smale, D., Steinbrecht, W., Strong, K., and Sussmann, R.: Global Ground-based Tropospheric Ozone Measurements: Reference Data and Individual Site Trends (2000–2022) from the TOAR-II/HEGIFTOM Project, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-3736, 2025.

Also referred to is Thompson et al., submitted, 2024, Posted in 2025:

Thompson, A. M., Stauffer, R. M., Kollonige, D. E., Ziemke, J. R., Cazorla, M., Wolff, P., and Sauvage, B.: Tropical Ozone Trends (1998 to 2023): A Synthesis from SHADOZ, IAGOS and OMI/MLS Observations, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-3761, 2025.

TABLE. This is essentially an update of Table 1 in HEGIFTOM-1, Van Malderen et al., in press, 2025, run again with the QR method, same as employed in Boynard et al. Ozonesonde stations with homogenized data and sufficient sample size are listed and exclude near-polar regions. Yellow-coded lines represent the 7 author-selected IASI-sonde comparison stations. Orange-coded lines indicate where the sign of the trend changes based on the different periods of trends calculations (23 years vs. 12 years).

Northern Hemisphere (180W-20W) TrCO Trends								
Station	Latitude	Longitude	L1 Observation #	L3 Observation #	2000-2022 XO3 surf-300hPa QR L1 Annual Trend ± 2*sigma (ppbv/decade)	2000-2022 XO3 surf-TP QR L1 Annual Trend ± 2*sigma (ppbv/decade)	2000-2022 DU surf-TP QR L1 Annual Trend ± 2*sigma (DU/decade)	2008-2019 DU surf-TP QR L1 Annual Trend ± 2*sigma (DU/decade)
Boulder	40.00	-105.25	1243	275	**-1.14 ± 0.86**	-0.76 ± 0.88	**-0.53 ± 0.42**	0.23 ± 1.56
Churchill	58.74	-94.07	690	183	**-3.37 ± 1.60**	**-3.15 ± 1.38**	**-2.39 ± 0.50**	-0.67 ± 2.60
Edmonton	53.54	-114.10	969	244	-0.56 ± 0.94	-0.41 ± 1.04	-0.12 ± 0.52	0.45 ± 1.30
Goose Bay	53.31	-60.36	953	230	-0.72 ± 0.96	-0.40 ± 0.92	-0.09 ± 0.72	-1.25 ± 1.80
Hilo	19.43	-155.04	1142	276	-0.28 ± 0.98	-0.92 ± 1.34	-0.82 ± 0.94	**-1.22 ± 1.18**
Paramaribo	5.80	-55.21	855	247	0.40 ± 0.78	0.08 ± 0.86	0.16 ± 0.62	0.59 ± 1.84
Trinidad Head	40.80	-124.16	1217	266	**-0.76 ± 0.68**	-0.65 ± 0.80	-0.60 ± 0.68	0.63 ± 1.32
Wallops Island	37.93	-75.48	1143	245	**-2.61 ± 0.92**	**-2.79 ± 1.14**	**-1.40 ± 0.70**	**-1.98 ± 1.92**
Northern Hemisph								
Station	Latitude	Longitude	L1 Observation #	L3 Observation #	2000-2022 XO3 surf-300hPa QR L1 Annual Trend ± 2*sigma (ppbv/decade)	2000-2022 XO3 surf-TP QR L1 Annual Trend ± 2*sigma (ppbv/decade)	2000-2022 DU surf-TP QR L1 Annual Trend ± 2*sigma (DU/decade)	2008-2019 DU surf-TP QR L1 Annual Trend ± 2*sigma (DU/decade)
Ascension Island	-7.58	-14.24	676	174	-1.01 ± 1.58	-0.88 ± 1.64	-0.33 ± 1.04	-0.33 ± 2.46
De Bilt	52.10	5.18	1085	252	**1.34 ± 0.86**	**1.78 ± 0.98**	**1.61 ± 0.66**	**3.23 ± 2.00**
Hohenpeissenberg	47.80	11.01	2924	276	**0.50 ± 0.46**	**0.78 ± 0.60**	0.36 ± 0.40	**0.84 ± 0.80**
Izana	28.50	-16.30	1086	270	**2.59 ± 0.68**	**3.48 ± 1.24**	**2.49 ± 1.02**	**2.68± 2.60**
Legionowo	52.40	20.97	1340	276	-0.39 ± 0.80	-0.14 ± 0.84	-0.11 ± 0.52	0.32 ± 1.30
Lerwick	60.13	-1.18	1203	243	-0.66 ± 0.80	**-0.99 ± 0.64**	**-0.85 ± 0.68**	**1.77 ± 1.70**
Madrid	40.47	-3.58	935	234	-0.36 ± 0.90	-0.68 ± 1.38	-0.52 ± 0.62	0.93 ± 1.66
OHP	43.94	5.71	1051	272	**1.95 ± 1.08**	**1.90 ± 1.18**	**1.65 ± 0.68**	**1.62 ± 1.52**
Payerne	46.49	6.57	3112	244	**-1.30 ± 0.62**	**-1.28 ± 0.66**	**-0.67 ± 0.50**	0.39 ± 0.78
Uccle	50.80	4.35	3258	276	**0.90 ± 0.48**	**1.01 ± 0.58**	**0.92 ± 0.44**	**-0.11 ± 0.96**
Valentia	51.94	-10.25	600	127	**1.33 ± 1.32**	**1.84 ± 1.58**	**1.33 ± 1.24**	**2.23 ± 2.14**
Northern Hemisphere (80E-180E) TrCO Trends								
Station	Latitude	Longitude	L1 Observation #	L3 Observation #	2000-2022 XO3 surf-300hPa QR L1 Annual Trend ± 2*sigma (ppbv/decade)	2000-2022 XO3 surf-TP QR L1 Annual Trend ± 2*sigma (ppbv/decade)	2000-2022 DU surf-TP QR L1 Annual Trend ± 2*sigma (DU/decade)	2008-2019 DU surf-TP QR L1 Annual Trend ± 2*sigma (DU/decade)
Kuala Lumpur	2.73	101.27	456	203	**1.91 ± 1.38**	**1.53 ± 1.50**	**1.04 ± 1.00**	3.42 ± 4.00
Southern Hemisphere TrCO Trends								
Station	Latitude	Longitude	L1 Observation #	L3 Observation #	2000-2022 XO3 surf-300hPa QR L1 Annual Trend ± 2*sigma (ppbv/decade)	2000-2022 XO3 surf-TP QR L1 Annual Trend ± 2*sigma (ppbv/decade)	2000-2022 DU surf-TP QR L1 Annual Trend ± 2*sigma (DU/decade)	2008-2019 DU surf-TP QR L1 Annual Trend ± 2*sigma (DU/decade)
Fiji	-18.13	178.40	391	123	-0.57 ± 1.88	-0.53 ± 1.82	-0.49 ± 1.30	-1.86 ± 3.08
Irene	-25.90	28.22	387	139	0.54 ± 1.62	-0.14 ± 1.92	0.19 ± 1.04	-3.49 ± 4.00
Lauder	-45.00	169.68	923	237	0.13 ± 0.50	0.23 ± 0.58	0.23 ± 0.40	0.75 ± 1.20
Nairobi	-1.27	36.80	872	223	0.68 ± 1.14	0.56 ± 1.26	0.32 ± 0.64	0.45 ± 1.82
Natal	-5.42	-35.38	676	175	0.26 ± 1.02	0.96 ± 1.16	0.77 ± 0.82	-0.84 ± 1.68
Reunion	-21.06	55.48	735	215	**1.88 ± 1.08**	**2.92 ± 1.32**	**2.12 ± 0.84**	1.23 ± 2.54
Samoa	-14.23	-170.56	797	234	-0.06 ± 1.04	-0.76 ± 1.00	-0.52 ± 0.99	**-2.95 ± 2.74**