WORKSHOP NOTES
For the TOAR-II Workshop, 8-10 March, 2023
Meteorological Institute, University of Cologne, Germany

SUMMARY

The TOAR-II Community held its first hybrid workshop at the **Meteorological Institute, University of Cologne, Germany, 8-10 March, 2023**

Almost 50 people from 13 countries met in person in Cologne for the first time during TOAR-II to discuss progress and plan for the TOAR-II initiative. Up to 35 additional people joined the meeting online. Day 1 featured an impressive 21 presentations on draft manuscripts or paper plans from the 16 focus working groups that have been established to cover the manifold aspects related to tropospheric ozone processes, its global distribution and trends. The working groups were then given the opportunity to advance their plans in two rounds of breakout groups. The launch of the first TOAR-II series of publications, the Community Special Issue, was announced. This is an inter-journal special issue featured by Copernicus with Atmospheric Chemistry and Physics as lead journal, but possibilities to submit manuscripts to several other Copernicus journals (ESSD, AMT, GMD, ASCMO and BG) as well and link them to the Special Issue. The Special Issue will accept submissions until 30 April 2024.

On the second day, the focus was placed on cross-cutting science topics and identification of science aspects that may be missing from the planned second tropospheric ozone assessment. In particular, there was larger interest expressed in analyzing the impacts of the recent Covid lockdowns on global ozone air quality, the impact and variability of forest and savanna fire emissions, and the identification of various chemical regimes. Furthermore, it was noted that several ozone precursors on top of those identified for the TOAR-II data collection could be relevant in the future analyses and it was suggested to compile a summary of field campaign data to fill some of the remaining spatial gaps.

The third day provided an initial glimpse of the structure and procedures that the steering committee envisions for the actual assessment report to be written in 2024. This is still in the planning stage, but a few cornerstones have been laid out already. The assessment shall be published in a journal that allows the editors to invite contributed papers. It will consist of updates of the three core papers on health, vegetation, and climate impacts and a few additional papers that need to be identified in a discussion between prospective authors and the steering committee. Among others, it is also envisioned to produce specific regional assessment papers for those regions that have less measurement sites compared to the three core regions of Europe, East Asia, and North America. Only invited papers will be part of the assessment.

PRESENTATIONS

Presentations are available on [B2SHARE](#)

The Agenda is provided in Appendix 1 below.

WORKSHOP OBJECTIVES

DAY 1: Status of papers for Community Special Issue
- • WG breakouts to identify challenges and solutions
- • Resolve overlaps and duplications
- • Identify possible inconsistencies and address them
- • Reflect about gaps within and between draft manuscripts

DAY 2: Cross-cutting topics
- • TOAR database and common analysis tools
- • Impromptu pitches on missing science with plenary discussion

DAY 3: Assessment Preparation
- • Breakouts by health, vegetation, climate + upcoming topics
- • Plenary discussion on content and structure of assessment

Cross-cutting breakout topics and conclusions

1. Impact of COVID lockdowns: several WG papers to address this; need more inverse analysis to quantify emission changes.
2. Fire emissions: identified activities to investigate fire impacts (e.g. model runs w/wo fires), data sets for fire events.
3. Chemical regimes: Many precursors not yet included in planned papers (e.g. isoprene, PAN maybe TOAR-III?); Urban WG is considering effects of PM. Common tools to identify chemical regime in data analysis?
4. Climate variability: agree on climate indices and sources; have recommendations in the Statistics Guidelines – also recommendations for lag times (e.g. ENSO) and how to average over large regions.
5. Spatial Gaps: paper on short term campaign data?

Notes on Cross-Cutting Breakouts

Breakout Group 1: COVID-19 impacts on ozone and precursors

- Paper 1: D. Putero (lead)

Fingerprints of the COVID-19 economic downturn and recovery on ozone anomalies at remote high-altitude sites in North America and Western Europe.

- Paper 2: B. Nelson (lead)

A study of approx. 12 urban areas worldwide, looking at the impact of COVID on ozone and precursors.

- Paper 3: J. Lee (lead)

Regional focus on UK air quality for 20+ years, including COVID period.

Misc. discussion points:

Two ESSD papers have 2020 AQ observations for China and the globe.

Inverse modeling studies are still missing.

G. Dufour has IASI analysis that shows negative ozone anomalies in 2020 above EU, USA and China.

K.-P. Heue has not seen any significant anomaly in the Tropics for precursors or biomass burning based on satellite data.

Possible reference: Model based investigation of the impact of emission reductions on ozone over Europe. Increase of contributions of natural emissions due to increased ozone production efficiency counteract anthropogenic emission reductions. Model results could be made available if someone is interested.

http://iopscience.iop.org/article/10.1088/1748-9326/abf191

- To what extent do fires affect or impact the trends?
- How to study fire influence using different data products (water vapor, precursors).

Identifiable and possible main tasks:

1. Check the available ground-based data (time series) between research groups.

2. Ozone-CO-fire correlation plots (satellite products and ground-based measurements).

3. Aim at model runs (JPL) based on previous analysis of ground-based data and satellite products.

- Develop ancillary data products to aid in trend analysis (fire emissions, satellite CO & water vapor, model runs w/wo fires, global model WG runs, ESA Climate Change Initiative products…)
- Conduct literature review to see if previous works can aid current TOAR analysis.

4. Explore fire events and how they affect the chemical composition using (high-resolution data available, e.g., water vapor, carbon monoxide).

5. Look at specific fire events - for process understanding and possible impact on trends/signals in various data products:

- Fires in Australia, California, for instance 2020
- Fires in the Tropics. (Tropospheric column sensitivity from satellite products).

Links with other working groups:

- COVID lockdown
- Radiative forcing and climate feedback.
- Fires really impact all WG and should be considered at some point.

Breakout Group 4: Chemical regimes

Possible tasks/research areas/open questions:

Precursor trends from satellites, models for NO_x, formaldehyde, CO

NO_x/VOC-limited regimes, perturbed by heterogeneous loss of HO_2 radical. Historical change of the regimes per city where is the spatial border between the two regimes for overall O_3 control in cities.

Mitigation strategies & their impact on ozone.

Automatically identifying regimes based on modeling data or observation.

Missing: heterogeneous processes

VOC: formaldehyde, Isoprene, Monoterpenes, other reactive VOCs?

How does transport affect chemical regimes?

Natural halogen processes over the ocean including Cl, Br, I

Extended wish list for TOAR database: PAN, Formaldehyde, Isoprene, Monoterpenes, Acetaldehyde, H_2O_2, HNO_3, HONO, photolysis frequency.

Links to other WGs or other planned papers:

Statistics working group: approaches for multiple species NO, NO_2, O_3, PM?

Cross cutting to covid: Change in the chemical regime in polluted places.

K. Lu (Urban WG): paper on impact of PM on ozone in polluted places.

Radiative forcing & modelling: Not much work focusing on chemical regimes.

Breakout Group 5: Climate variability

Ideas/possible tasks:

How to account for different lag times with ENSO could be added to statistics Recommendations document

Trends over large areas with different lag times -> Could dilute the trend signal

Determine lag times by grid cell?

Changes in Hadley cell tropical range - affects tropopause over time – OPT WG

Could potentially account for vertical range using XO3 Trop. column avg.

Brewer-Dobson Circulation - does it affect STE or just tropopause range? -> ROSTEES WG

Do regional models capture urban heat changes? -> Urban WG

ENSO, IOD, QBO, MJO, NAM, SAM, Solar Flux (need at least 11 yrs.)

Need to agree on common baseline indices, Sources (e.g., NOAA)

NAM, SAM effects less studied, but could impact NH O_3 trends -> Urban, ROSTEES WGs?

Precursor relationship to climate indices (e.g., fires, lightning)

How are these modes affecting O_3 transport -> Oceans WG?

Want to separate anthropogenic from natural contributions to trend.

EOF analysis to identify contributions from climate indices.

Other approaches to remove natural contributions like ML, ensemble decomposition.

Breakout Group 6: Spatial gaps

Remote sensing, ground-level monitoring and satellite observations all have different kinds of gaps. UV sensors do not measure in polar winter, during cloud periods, or at night. There are

gaps associated with the south Atlantic anomaly, also in the Pacific Ocean and the Indian sea. Regarding surface monitoring stations, there are significant gaps in the southern hemisphere.

What is already being done in the current Working Group papers?

Members of the TOAR community are doing representativeness analysis based on modeling.

Is possible to fill gaps using backward trajectories? It has been used in the stratosphere but can be challenging in the troposphere because of the residence time of the species involved.

How do we address this topic? (deficits, future studies)

- Increase ship measurement to fill gaps (in the short term).
- Interpolate data.
- Encourage aircraft missions in understudy regions.
- Increase the number of background monitoring stations to interpret the climate system.
- Sampling sensitivity testing for correct spectral degradation from satellite observation.
- Include low-cost measurement sensors after testing their performance.

Data and Statistics Keynote talks
Presentations are available on B2SHARE
Need study of how to include climate indices –
Statistics guidelines to include common source for climate indices so we have baselines. Add advice for correlation regressions

Region Definition Breakout Room
- Health impacts: GBD would be best
- Vegetation: TOAR-I climate regions
- Climate: IPCC regions & zonal regions:
    - tropics: 20S-20N
    - sub-tropics: 20-30
    - mid-latitude: 30-60
    - polar: 60-90
- These will be added to publication guidelines

Impromptu Paper Pitches
Presentations are available on B2SHARE
- Comprehensive surface VOC assessment (E. von Schneidemesser)
- Africa and other underrepresented areas – separate assessment paper? (follow WMO/GAW for data policy?) (R. Moolla)
- Trop. O3 model attribution analyses (M. Mertens)
- Amazon tower O3 + precursor record since 2012 (S. Wolff)
- TOAR list of potential student projects (G. Pfister)
- HTAP activities & overlaps with TOAR (T. Keating)
- IASI-GOME ozone (S.Okamoto)

Assessment Breakout Rooms
1. Climate – R. Seguel
2. Health – E. von Schneidemesser
3. Vegetation – B. Singha
4. Other possible assessment papers – R. Moolla

Questions – Scope and structure? Metrics?
(Consider the audiences, e.g., IPCC, GBD)

Note: Coordination teams will be assigned by the TOAR SC, but authors will need to volunteer from the community.

Assessment Breakout Reports

TOAR-Climate

Customers: IPCC AR7 & WMO stratospheric Ozone Assessment

Relatively short assessment paper (12-15 pages) providing synthesis and expert opinion (What do we know, or not?).

Observational section: TOAR surface database (Metrics: Non-urban sites and daily average (In TOAR I). MDA8, and 24 h average and diurnal cycles to compare with models.

HEGIFTOM tropospheric column ozone (monthly or seasonal values) and then trend analysis. (A. Thompson and R. van Malederen volunteered to write a paper for the community special issue)

Reanalysis and satellite products

Radiative forcing focus on troposphere rather than stratosphere + troposphere (IPCC method)

Expert opinion about the preindustrial burden and comparison to present day

Feature scenarios (all, not just SSP3-7) through 2050, based on CMIP6

Climate impacts on surface ozone (heat waves on ozone) and climate penalty. Clarify possible overlap with TOAR health and vegetation?

Address the role of methane and compare ozone and methane observation

TOAR-Health

Further recommendations on ground-based o3 dataset products for health assessments

Possible collaboration with GBD

Open question: what is TOAR providing with this assessment vs what does GBD provide? E.g., response functions (relative risk)

Provide update on the relevant O3 metrics, incl. annual but also especially beyond annual

Address some of the demographics/environmental justice aspects (2 part paper, to complement metrics, etc.) what is that state of this science? Regional contrasts

Emphasize the policy relevance - can't focus on pollutants individually; more holistic view

Looking at where O3 is increasing and how that is changing exposure over time, also linked to NO2; mortality associated with e.g., PM is going down but with O3 is going up

Look at different metrics, so if not considering peak summer season, to understand if aspects are being missed; is the ozone season shifting and what does that mean for health?

Could also provide NO2 dataset for exposure if it was of interest to add that

Orient toward WHO recommendations

Differences for O3 vs other pollutants for exposure/environmental justice disparities

If interest in changes in exposure, can look from 2005-2019

How do we differentiate between O3 effects and the effects of other pollutants? Also temp, etc.

Synthesis of the community papers and update on the previous TOAR assessment; what that provides for future work e.g., from GBD

Attribution of the sources for O3 and how this relates to exposure in different locations; link O3 variation to different processes using various modelling approaches

Possibility to also deliver higher resolution regional products for health assessments; mapped to population

Need a clear distinction between the SI and the assessment

Currently GBD focuses on annual exposure, could TOAR provide more information on metrics that are not just annual but higher temporal resolution?

If GBD is doing all health relevant exposure, are they missing some things because of the metrics chosen and could we look at some of these details?

TOAR-Vegetation

Flux based metrics; (POD) should be used - maybe compared to AOT40 in assess.
But we might only have concentration metrics in some areas.

TOAR-II database will have associated met data for a model flux

We don't need to repeat comparison of multiple metrics

TOAR-I had wheat, rice, natural veg.

Could we have changeable parameters?
    By ecoregion, Irrigation, Crop type, Stomatal model

TOAR-II should include:
- Crop production loss calculations
- Economical loss estimates

Soil moisture from ERA-5? (can't be only from rainfall to account for irrigation)

Which crops to include for TOAR-II? Do we discuss landcover change?

Growing season defined for regions
-Need regional or plant type response functions

Assessment should recommend which metrics are more appropriate for crop types or ecoregions

Need to identify customers for this assessment.

Other potential assessment papers

- Regional focus Coordination teams: Africa, S. America
- Paper 3 of OPT
- Updated STE review paper
- Oceans WG review paper

TOAR-II Workshop

Cologne, Germany and online

Wed, March 8th – Friday, March 10th, 2023

Venue: University of Cologne, Meteorological Institute, Pohligstr. 3, 50969 Cologne;
E**ntrance: Hönninger Weg 100** (at the corner)

Press bell for "Hörsaal Universität" and go to the 4th floor.

Online participation:
https://fz-juelich-de.zoom.us/j/94642572672?pwd=dThqMzF1Q2Q5azh4U1VrL3F5d1dNQT09

Meeting-ID: 946 4257 2672 , passcode: 695893

Agenda

All times given in CET (= local time Germany)

Wednesday, March 8th, 2023

08:30 – 09.30	**Registration and check-in (lobby 4th floor)**
09:30 – 10:00	Welcome and introduction to TOAR-II

-   Welcome address (Martin Schultz)
-   TOAR-II overview and meeting goals (Helen Worden)
-   TOAR-II Community Special Issue (Owen Cooper)

10:00 – 10:42   Draft paper presentations, block 1
4 min presentation + 2 min discussion per paper!

-   A. Keppens: Harmonization of tropospheric ozone data records from satellites
-   D. Hubert: Assessment of interannual variability and long-term changes in harmonised satellite data records of free tropospheric ozone
-   V. Sofieva: Variability and trends of tropospheric ozone column derived from combination of nadir and limb satellite measurements
-   C. Arosio: Tropospheric ozone column dataset from OMPS-LP/OMPS-NM limb-nadir matching
-   J. Neu: Ozone trends from satellites
-   G. Osterman: Update on the TROPESS ozone data products: Evaluation, validation and a preliminary examination of their utility in tropospheric ozone trend analysis
-   K. Miyazaki: Overview of the current reanalysis products for studying global and regional variations in ozone

Wednesday, March 8th, 2023 (continued)

10:42 – 11:10	Coffee break
11:10 – 12:34	Draft paper presentations, block 2

4 min presentation + 2 min discussion per paper!

- B. Nelson: Long Term Ozone Trends in Different Urban Developments
- D. Putero: Fingerprints of the COVID-19 economic downturn and recovery on ozone anomalies at remote high-altitude sites in North America and Western Europe
- D. Poyraz/R. Van Malderan: Homogenization of the European ozonesonde time series
- R. Wegener: Trends of Ozone Precursors in Europe
- R. Bjorklund: Intercomparison of ground-based measurements of tropospheric and stratospheric ozone at Lauder
- J. Keeble: Evolution of Stratosphere-to-Troposphere Transport of Ozone
- W. Collins: Assessment of methods for calculating the radiative forcing of ozone
- J. Dai: Long-term trends of ozone and VOC in Hong Kong
- J. Gil: Estimation for two-decadal variation of surface HONO in South Korea based on the Deep Neural Network model
- L. Zhang: A comparison of ozone stomatal deposition schemes over various vegetation
- W. Gong: Modelling Arctic boundary layer ozone: tropospheric transport, local processes, and budget
- Y. Zhang: Surface ozone concentrations response to current air pollution mitigation strategies in Chinese megacity agglomerations
- B. Sauvage: Present-day distribution of tropospheric ozone and precursors in the tropics
- A. Gaudel: Trends of tropical tropospheric ozone and its precursors
- R. Sommariva: Ozone over the Oceans

12:40 – 13:40	Lunch break
13:40 – 14:45	Working group breakout discussions – round 1

Room allocation will be given on the day of the meeting
Discussion notes: WGBreakoutSession1

- Chemical Reanalysis
- Radiative Forcing
- Human Health
- Ozone over the Oceans
- TOP
- East Asia
- S. Asia
- Statistics

14:45 – 14:55	Switching of breakout rooms

Wednesday, March 8th, 2023 (continued)

14:55 – 16:00   Working group breakout discussions – round 1
Room allocation will be given on the day of the meeting
Discussion notes: WGBreakoutSession2
-   HEGIFTOM
-   Global Models
-   ROSTEES
-   Satellite Ozone
-   Deposition
-   Urban
-   OPT
-   ML

16:00 – 16:30   Coffee break

16:30 – 18:00   Plenary discussions on paper drafts
-   Resolve overlaps and duplications
-   Identify possible inconsistencies and address them
-   Reflect about gaps within and between draft manuscripts

18:00   Adjourn of day 1

Thursday, March 9th, 2023

09:00 – 09:30   Summary of day 1 and plans for day 2 (Helen Worden)

09:30 – 10:30   Cross-cutting topics: breakout discussions
Topics and room allocation will be given on the day of the meeting
Discussion notes: CrossCuttingBreakoutSession

10:30 – 11:00   Coffee break

11:00 – 12:00   Plenary discussions on cross-cutting topics

12:00 – 12:30   Community Special Issue editor presentation (Owen Cooper)
See draft document at
https://drive.google.com/drive/folders/1qke8i7AkmbwWN0eWPVrIzqTmsgi-kCVQ

12:30 – 13:30   Lunch break

13:30 – 14:30   Keynote lectures on data collection and analysis
-   TOAR database quickstart guide (Martin Schultz)
-   TOAR database data collection status and strategy (Sabine Schröder)
-   Statistical analyses on TOAR data (Kai-Lan Chang)
-   TOAR database statistics and analyses services (Niklas Selke)

14:30 – 15:30   Plenary discussion on statistics and common analysis guidelines
See draft document at
https://drive.google.com/drive/folders/1qke8i7AkmbwWN0eWPVrIzqTmsgi-kCVQ

15:30 – 16:00   Coffee break

Thursday, March 9th, 2023 (continued)

16:00 – 16:45   Impromptu pitches on science topics not covered by paper presentations
3 – 8 minutes each, depending on your contributions
These pitches are supposed to widen the scope of our discussions and avoid TOAR-II ignoring important new or upcoming scientific topics.
If you are interested to present an impromptu pitch, please let Helen know before day 1 of the workshop ends and prepare a "variable slide set" which you can present within 3 minutes or extend to up to 8 minutes if sufficient time is available.

16:45 – 18:00   Plenary discussions on science topics

18:00   Adjourn of day 2

19:30 – 22:30   Self-pay conference dinner
Drinks are free up to a limit and sponsored by the ERC grant IntelliAQ.
The conference dinner will take place at the restaurant **Ludwig im Museum**, Heinrich-Böll-Platz, 50667 Köln, near the Cologne cathedral. We will meet at 19:30 h CET in the restaurant.
The dinner will be buffet-style (all vegetarian and vegan options) and costs **40 € per person to be paid in cash upon registration** for the meeting. Drinks (up to a limit) will be covered by the ERC project IntelliAQ.

Friday, March 10th, 2023

09:00 – 09:20   Summary of day 2 and plans for day 3 (Helen Worden)

09:20 – 09:50   Presentation on current planning status of assessment (Martin Schultz)

09:50 – 10:45   Assessment coordination team breakout discussions
Topics and room allocation will be given on the day of the meeting
Discussion notes: AssessCoordBreakoutSession

10:45 – 11:15   Coffee break

11:15 – 12:30   Plenary discussions on the content and structure of the assessment

12:30 – 13:30   Lunch break

13:30 – 15:00   Closing plenary discussion – next steps

15:00 – 15:30   Coffee break

15:30 – 17:00   Optional WG or cross-cutting breakout discussions

17:00   Adjourn of day 3