Advancing our understanding of global tropospheric ozone changes – The Tropospheric Ozone Assessment Report

with focus on TOAR-II

MARTIN SCHULTZ

Research Group Earth System Data Exploration

Jülich Supercomputing Centre, Forschungszentrum Jülich, Germany

CCMI Workshop, Hong Kong CUHK, 07-09 August 2019

nature geoscience
LETTERS
PUBLISHED ONLINE: 7 NOVEMBER 2016 | DOI: 10.1038/NGEO2827

Tropospheric ozone change from 1980 to 2010 dominated by equatorward redistribution of emissions

Yuqiang Zhang[1†], Owen R. Cooper[2,3], Audrey Gaudel[2,3], Anne M.
Shin-Ya Ogino[6] and J. Jason West[1*]

The global tropospheric ozone burden increased by 9% from 1980 to 2010.

Half of the increase was due to the increase of emissions.

The other half was caused by the equatorward shift of emissions.

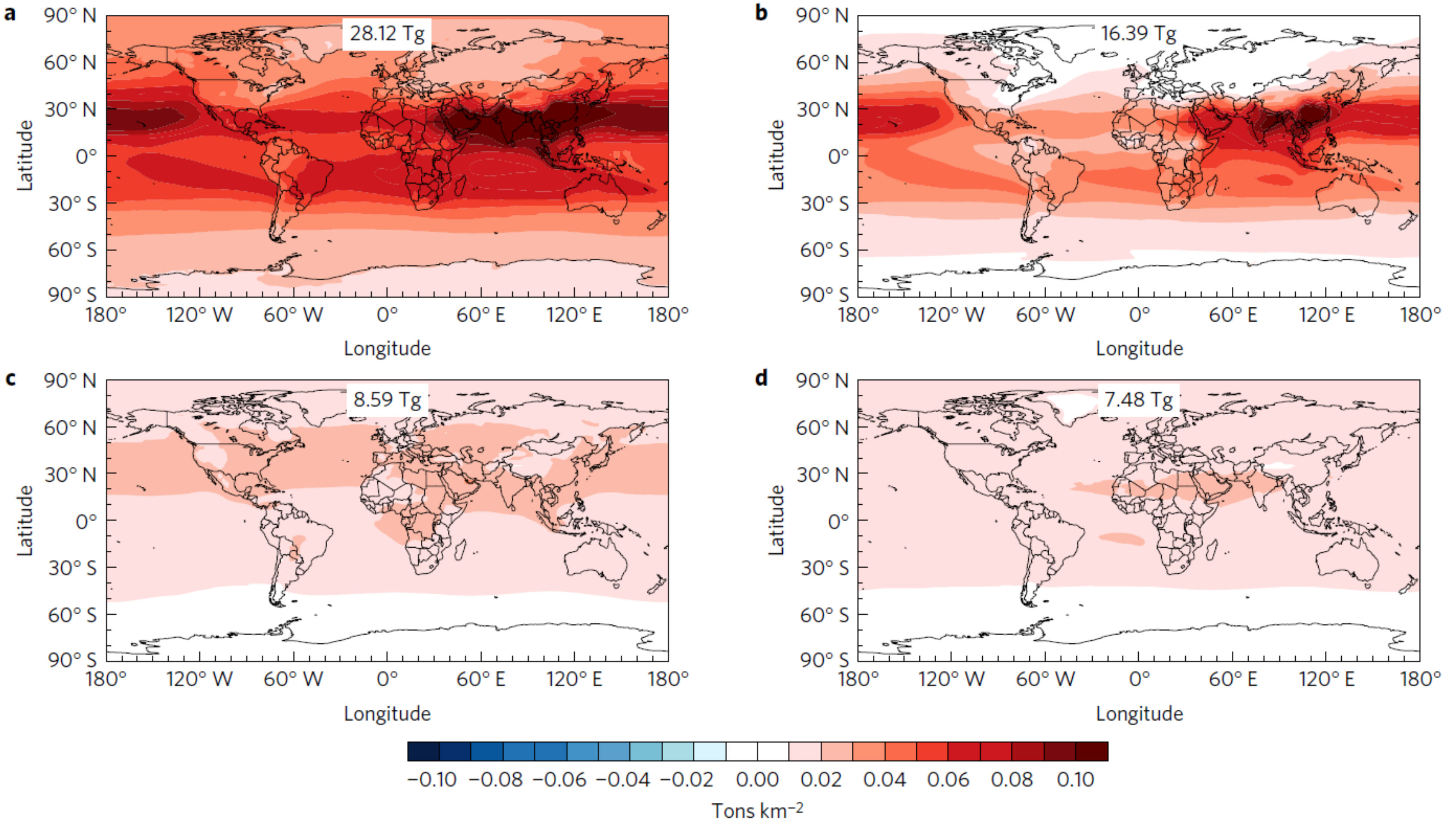


Figure 2 | Spatial distributions for ΔB_{O_3} (tons km^{-2}) from 1980 to 2010. a, Total changes from 1980 to 2010. **b**–**d**, Influences of changes in the global emissions spatial distribution (**b**), the global emissions magnitude (**c**), and global CH_4 mixing ratio (**d**).

Slide by Owen Cooper, NOAA

What is TOAR?

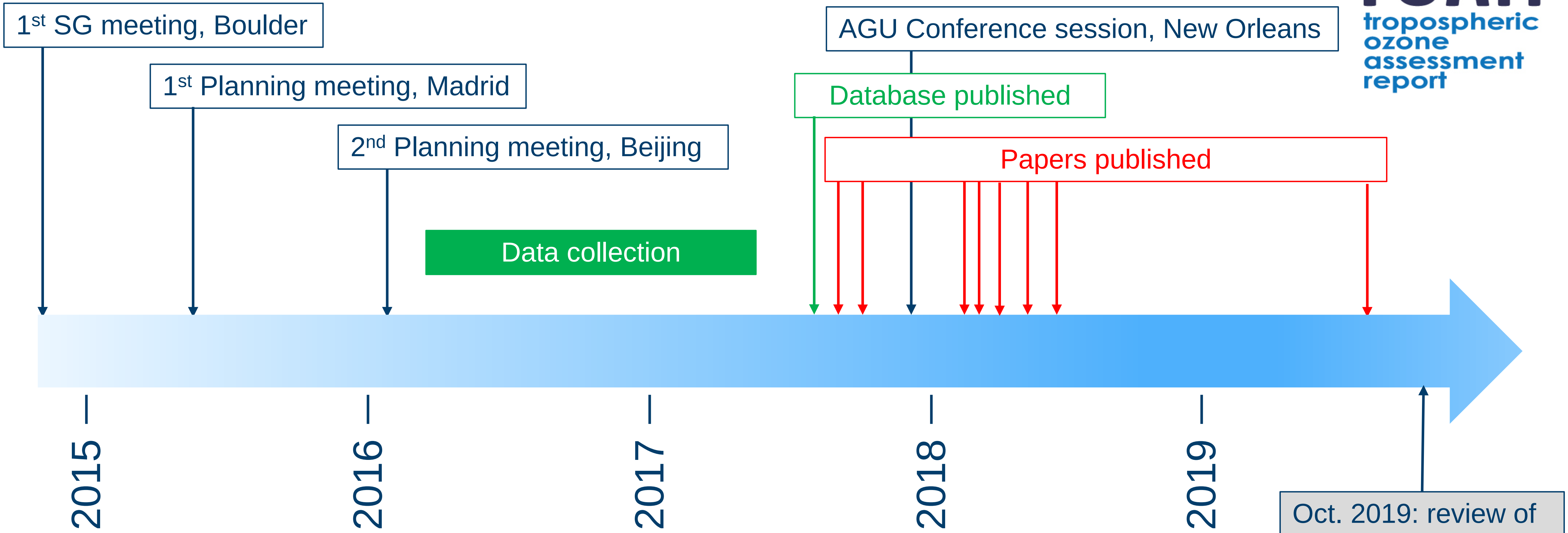
TOAR
tropospheric ozone assessment report

The „Tropospheric Ozone Assessment Report“ has been created by more than 230 scientists from 36 countries to:

1. Produce the first tropospheric ozone assessment report based on the peer-reviewed literature and new analyses.
2. Generate easily accessible, documented data on ozone exposure and dose metrics at thousands of measurement sites around the world (urban and non-urban), freely accessible for research on the global-scale impact of ozone on climate, human health and crop/ecosystem productivity.

Web link: http://www.igacproject.org/activities/TOAR

TOAR Timeline



Oct. 2019: review of TOAR-1 by IGAC SC and possible launch of TOAR-2

Oct. 2009: First community workshop on tropospheric ozone changes, Boulder, USA
Apr. 2011: Second community workshop on tropospheric ozone changes, Toulouse, France

TOAR Publications

ELEMENTA Science of the Anthropocene

Schultz, MG, et al 2017 Tropospheric Ozone Assessment Report: Data and metrics data of global surface ozone observations. Elem Sci Anth 5: 58, DOI: https://doi.org/10.1525/elementa.244

RESEARCH ARTICLE

Tropospheric Ozone Assessment Report: Database and metrics data of global surface ozone observations

Martin G. Schultz[1,82], Sabine Schröder[1], Olga Lyapina[1], Owen R. Cooper[2,3], Ian Galbal
Irina Petropavlovskikh[2,3], Erika von Schneidemesser[5], Hiroshi Tanimoto[6],
Yasin Elshorbany[7,8], Manish Naja[9], Rodrigo J. Seguel[10], Ute Dauert[11], Paul Eckhardt[12],
Stefan Feigenspan[11], Markus Fiebig[12], Anne-Gunn Hjellbrekke[12], You-Deog Hong[13],
Peter Christian Kjeld[14], Hiroshi Koide[15], Gary Lear[16], David Tarasick[17], Mikio Ueno[15],
Markus Wallasch[18], Darrel Baumgardner[19], Ming-Tung Chuang[20], Robert Gillett[4],

ELEMENTA Science of the Anthropocene

Chang, K-L, et al 2017 Regional trend analysis of surface ozo monitoring networks in eastern North America, Europe and Ea 5: 50, DOI: https://doi.org/10.1525/elementa.243

RESEARCH ARTICLE

Regional trend analysis of surface ozone observ from monitoring networks in eastern North Ame Europe and East Asia

Kai-Lan Chang*, Irina Petropavlovskikh*,†, Owen R. Cooper*,†, Martin G. Sch
Wang§

Surface ozone is a greenhouse gas and pollutant detrimental to human health and cr productivity. The Tropospheric Ozone Assessment Report (TOAR) is designed to pro community with an up-to-date observation-based overview of tropospheric ozone's g and trends. The TOAR Surface Ozone Database contains ozone metrics at thousands of around the world, densely clustered across mid-latitude North America, western Euro

ELEMENTA Science of the Anthropocene

Lefohn, AS, et al. 2018 Tropospheric ozone assessment report: Global ozone metrics for climate change, human health, and crop/ecosystem research. Elem Sci Anth, 6: 28. DOI: https://doi.org/10.1525/elementa.279

RESEARCH ARTICLE

Tropospheric ozone assessment report: Global ozone metrics for climate change, human health, and crop/ecosystem research

Allen S. Lefohn*, Christopher S. Malley†,‡,§, Luther Smith‖, Benjamin Wells¶, Milan Hazucha**, Heather Simon¶, Vaishali Naik††, Gina Mills‡‡, Martin G. Schultz§§,
Elena Paoletti‖‖, Alessandra De Marco¶¶, Xiaobin Xu***, Li Zhang†††, Tao Wang†††,

ELEMENTA Science of the Anthropocene

Young, PJ, et al. 2018 Tropospheric Ozone Assessment Report: Assessment of global-scale model performance for global and regional ozone distributions, variability, and trends. Elem Sci Anth, 6: 10. DOI: https://doi.org/10.1525/elementa.265

REVIEW

Tropospheric Ozone Assessment Report: Assessment of global-scale model performance for global and regional ozone distributions, variability, and trends

P. J. Young*,†,‡, V. Naik§, A. M. Fiore‖,¶, A. Gaudel**,††, J. Guo‖, M. Y. Lin§,‡‡, J. L. Neu§§,
D. D. Parrish**,††, H. E. Rieder¶,‖‖, J. L. Schnell¶¶, S. Tilmes***, O. Wild*, L. Zhang†††,
J. Ziemke‡‡‡,§§§, J. Brandt‖‖‖, A. Delcloo¶¶¶, R. M. Doherty****, C. Geels‖‖‖, M. I. Hegglin††††,
L. Hu‡‡‡‡, U. Im‖‖‖, R. Kumar§§§§, A. Luhar‖‖‖‖, L. Murray¶¶¶¶, D. Plummer*****, J. Rodriguez‡‡‡,
A. Saiz-Lopez†††††, M. G. Schultz‡‡‡‡‡, M. T. Woodhouse‖‖‖‖‖ and G. Zeng§§§§§

The goal of the Tropospheric Ozone Assessment Report (TOAR) is to provide the research community with an up-to-date scientific assessment of tropospheric ozone, from the surface to the tropopause. While a suite of observations provides significant information on the spatial and temporal distribution of tropospheric ozone, observational gaps make it necessary to use global atmospheric chemistry models to synthesize our understanding of the processes and variables that control tropospheric ozone abundance and its variability. Models facilitate the interpretation of the observations and allow us to make projections of future tropospheric ozone and trace gas distributions for different anthropogenic or natural perturbations. This paper assesses the skill of current-generation global atmospheric chemistry models in simulating the observed present-day tropospheric ozone distribution, variability, and trends. Drawing upon the results of recent international multi-model intercomparisons and using a range of model evaluation techniques, we demonstrate that global chemistry models are broadly skillful in capturing the spatio-temporal variations of tropospheric ozone over the seasonal cycle, for extreme pollution episodes, and changes over interannual to decadal periods. However, models are consistently biased high in the northern hemisphere and biased low in the southern hemisphere, throughout the depth of the troposphere, and are unable to replicate particular metrics that define the longer term trends in tropospheric ozone as derived from some background sites. When the models compare unfavorably against observations, we discuss the potential causes of model biases and propose directions for future developments, including improved evaluations that may be able to better diagnose the root cause of the model-observation critically, including determining whether the model ssed, whether biases can be tolerated or corrected, whether there is a way to satisfactorily quantify

ELEMENTA Science of the Anthropocene

Gaudel, A, et al. 2018. Tropospheric Ozone Assessment Report: Present and trends of tropospheric ozone relevant to climate and global atmos model evaluation. Elem Sci Anth, 6: 39. DOI: https://doi.org/10.1525/el

RESEARCH ARTICLE

Tropospheric Ozone Assessment Report: Present-d distribution and trends of tropospheric ozone rele to climate and global atmospheric chemistry mode evaluation

A. Gaudel[1,2], O. R. Cooper[1,2], G. Ancellet[3], B. Barret[4], A. Boynard[3,5], J. P. Burro
C. Clerbaux[3], P.-F. Coheur[7], J. Cuesta[8], E. Cuevas[9], S. Doniki[7], G. Dufour[8], F. E
G. Foret[8], O. Garcia[11], M. J. Granados-Muñoz[12,13], J. W. Hannigan[14], F. Hase[15],
B. Hassler[1,2,16], G. Huang[17], D. Hurtmans[7], D. Jaffe[18,19], N. Jones[20], P. Kalabokas
B. Kerridge[22], S. Kulawik[23,24], B. Latter[22], T. Leblanc[12], E. Le Flochmoën[4], W. Li
J. Liu[26,27], X. Liu[17], E. Mahieu[27], A. McClure-Begley[1,2], J. L. Neu[23], M. Osman[29],
H. Petetin[4], I. Petropavlovskikh[1,2], R. Querel[28], N. Rahpoe[23], A. Rozanov[23],
M. G. Schultz[31,32], J. Schwab[33], R. Siddans[22], D. Smale[20], M. Steinbacher[34],
H. Tanimoto[35], D. W. Tarasick[36], V. Thouret[4], A. M. Thompson[37], T. Trickl[38],
E. Weatherhead[1,2], C. Wespes[39], H. M. Worden[40], C. Vigouroux[40], X. Xu[41],
G. Zeng[30], J. Ziemke[42]

The Tropospheric Ozone Assessment Report (TOAR) is an activity of the International Globa Chemistry Project. This paper is a component of the report, focusing on the present-da and trends of tropospheric ozone relevant to climate and global atmospheric chemistry mod Utilizing the TOAR surface ozone database, several figures present the global distribution daytime average ozone at 2702 non-urban monitoring sites, highlighting the regions and s world with the greatest ozone levels. Similarly, ozonesonde and commercial aircraft obser ozone's distribution throughout the depth of the free troposphere. Long-term surface obs limited in their global spatial coverage, but data from remote locations indicate that ozo century is greater than during the 1970s and 1980s. While some remote sites and many heavily polluted regions of East Asia show ozone increases since 2000, many others show there is no clear global pattern for surface ozone changes since 2000. Two new satellite pro detailed views of ozone in the lower troposphere across East Asia and Europe, revealing t

ELEMENTA Science of the Anthropocene

Fleming, ZL, et al. 2018 Tropospheric Ozone Assessment Report: Present-day ozone distribution and trends relevant to human health. Elem Sci Anth, 6: 12. DOI: https://doi.org/10.1525/elementa.273

RESEARCH ARTICLE

Tropospheric Ozone Assessment Report: Present-day ozone distribution and trends relevant to human health

Zoë L. Fleming*, Ruth M. Doherty†, Erika von Schneidemesser‡,
Christopher S. Malley§,****,††††, Owen R. Cooper‖,‖‖‖, Joseph P. Pinto¶,
Augustin Colette**, Xiaobin Xu††, David Simpson‡‡,¶¶¶, Martin G. Schultz§§,‖‖,
Allen S. Lefohn¶¶, Samera Hamad***, Raeesa Moolla†††, Sverre Solberg‡‡‡ and
Zhaozhong Feng§§§

ELEMENTA Science of the Anthropocene

Mills, G, et al. 2018. Tropospheric Ozone Assessment Report: Present-day tropospheric ozone distribution and trends relevant to vegetation. Elem Sci Anth, 6: 47. DOI: https://doi.org/10.1525/elementa.302

RESEARCH ARTICLE

Tropospheric Ozone Assessment Report: Present-day tropospheric ozone distribution and trends relevant to vegetation

Gina Mills*,†, Håkan Pleijel†, Christopher S. Malley‡,§,‖, Baerbel Sinha¶, Owen R. Cooper**,
Martin G. Schultz††, Howard S. Neufeld‡‡, David Simpson§§,‖‖, Katrina Sharps*, Zhaozhong
Feng¶¶, Giacomo Gerosa***, Harry Harmens*, Kazuhiko Kobayashi†††, Pallavi Saxena‡‡‡,
Elena Paoletti§§§, Vinayak Sinha¶ and Xiaobin Xu‖‖‖

This Tropospheric Ozone Assessment Report (TOAR) on the current state of knowledge of ozone metrics of relevance to vegetation (*TOAR-Vegetation*) reports on present-day global distribution of ozone at over 3300 vegetated sites and the long-term trends at nearly 1200 sites. *TOAR-Vegetation* focusses on three metrics over vegetation-relevant time-periods across major world climatic zones: M12, the mean ozone during 08:00–19:59; AOT40, the accumulation of hourly mean ozone values over 40 ppb during daylight hours, and W126 with stronger weighting to higher hourly mean values, accumulated during 08:00–19:59.
Although the density of measurement stations is highly variable across regions, in general, the highest ozone values (mean, 2010–14) are in mid-latitudes of the northern hemisphere, including southern USA, the Mediterranean basin, northern India, north, north-west and east China, the Republic of Korea and

TOAR article views and citations

05 August 2019

1. **Tropospheric Ozone Assessment Report: Present-day tropospheric ozone distribution and trends relevant to vegetation**
   By: Mills, Gina; Pleijel, Hakan; Malley, Christopher S.; et al.
   ELEMENTA-SCIENCE OF THE ANTHROPOCENE Volume: 6 Article Number: 47 Published: JUN 28 2018
   Full text @ FZJ | Free Full Text from Publisher | View Abstract
   Times Cited: 11 *(from Web of Science Core Collection)*
   Usage Count

2. **Tropospheric Ozone Assessment Report: Present-day distribution and trends of tropospheric ozone relevant to climate and global atmospheric chemistry model evaluation**
   By: Gaudel, A.; Cooper, O. R.; Ancellet, G.; et al.
   ELEMENTA-SCIENCE OF THE ANTHROPOCENE Volume: 6 Article Number: 39 Published: MAY 10 2018
   Full text @ FZJ | Free Full Text from Publisher | View Abstract
   Times Cited: 35 *(from Web of Science Core Collection)*
   Highly Cited Paper
   Usage Count

3. **Tropospheric ozone assessment report: Global ozone metrics for climate change, human health, and crop/ecosystem research**
   By: Lefohn, Allen S.; Malley, Christopher S.; Smith, Luther; et al.
   ELEMENTA-SCIENCE OF THE ANTHROPOCENE Volume: 6 Article Number: 28 Published: APR 6 2018
   Full text @ FZJ | Free Full Text from Publisher | View Abstract
   Times Cited: 26 *(from Web of Science Core Collection)*
   Highly Cited Paper
   Usage Count

4. **Tropospheric Ozone Assessment Report: Present-day ozone distribution and trends relevant to human health**
   By: Fleming, Zoe L.; Doherty, Ruth M.; von Schneidemesser, Erika; et al.
   ELEMENTA-SCIENCE OF THE ANTHROPOCENE Volume: 6 Article Number: 12 Published: FEB 5 2018
   Full text @ FZJ | Free Full Text from Publisher | View Abstract
   Times Cited: 16 *(from Web of Science Core Collection)*
   Usage Count

5. **Tropospheric Ozone Assessment Report: Assessment of global-scale model performance for global and regional ozone distributions, variability, and trends**
   By: Young, P. J.; Naik, V.; Fiore, A. M.; et al.
   ELEMENTA-SCIENCE OF THE ANTHROPOCENE Volume: 6 Article Number: 10 Published: JAN 31 2018
   Full text @ FZJ | Free Full Text from Publisher | View Abstract
   Times Cited: 27 *(from Web of Science Core Collection)*
   Highly Cited Paper
   Usage Count

6. **Tropospheric Ozone Assessment Report: Database and metrics data of global surface ozone observations**
   By: Schultz, Martin G.; Schroder, Sabine; Lyapina, Olga; et al.
   ELEMENTA-SCIENCE OF THE ANTHROPOCENE Volume: 5 Article Number: 58 Published: OCT 18 2017
   Full text @ FZJ | Free Full Text from Publisher | View Abstract
   Times Cited: 34 *(from Web of Science Core Collection)*
   Usage Count

Source: Web of Knowledge, Clarivate Analytics

First intercomparison of satellite-detected tropospheric column ozone

All annual products show similar features, but with varying intensity.

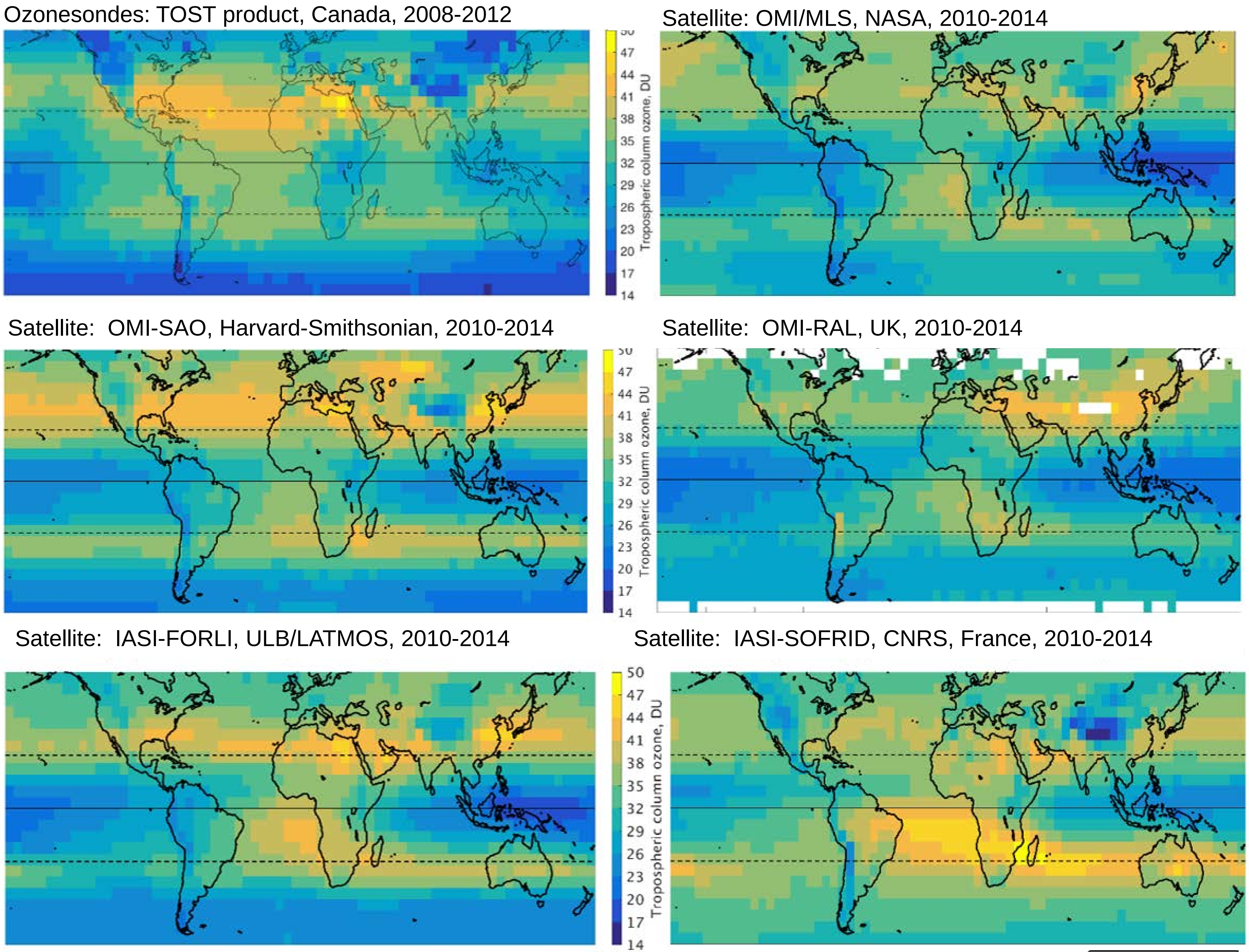
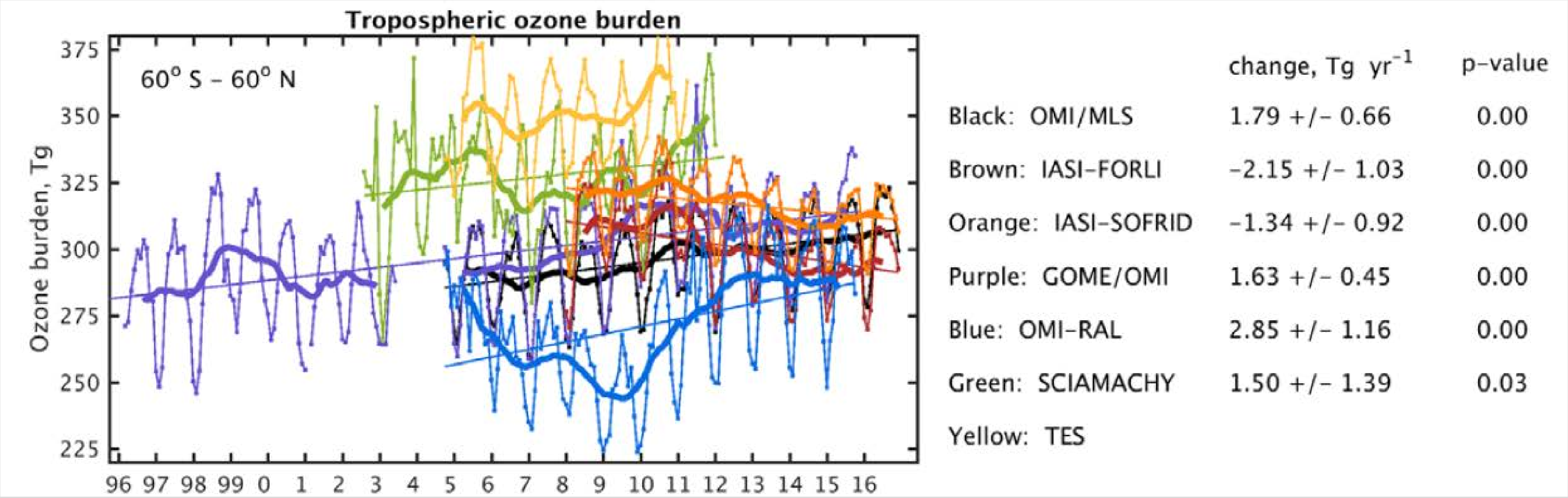


Figure from Gaudel et al. (2018), https://doi.org/10.1525/elementa.291

Tropospheric column ozone trends

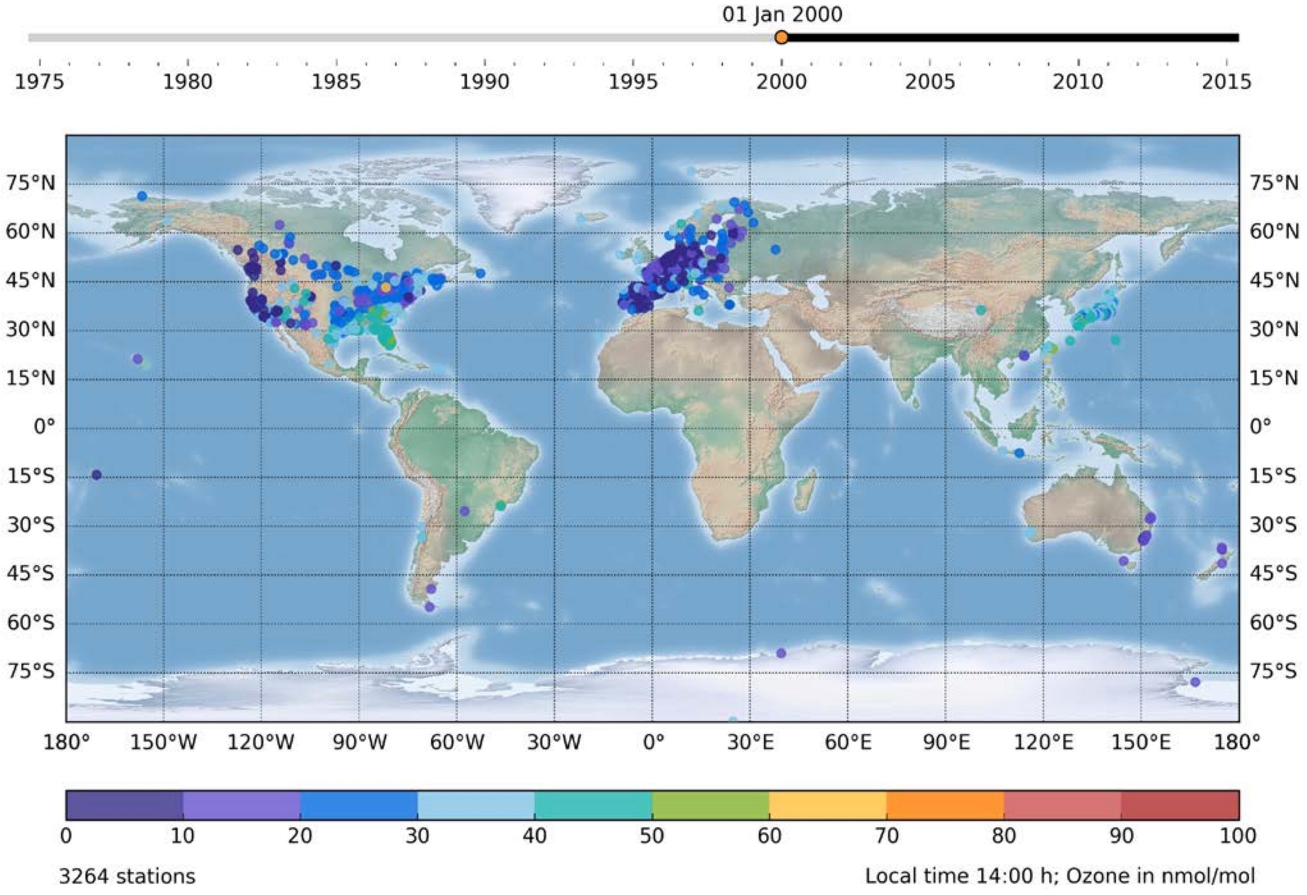


Satellite estimated ozone burden, 60° S – 60° N: **300 ± 12 Tg**

ACCMIP model ensemble estimate, 60° S – 60° N: **299 ± 21 Tg**

Figure and data from Gaudel et al. (2018), https://doi.org/10.1525/elementa.291

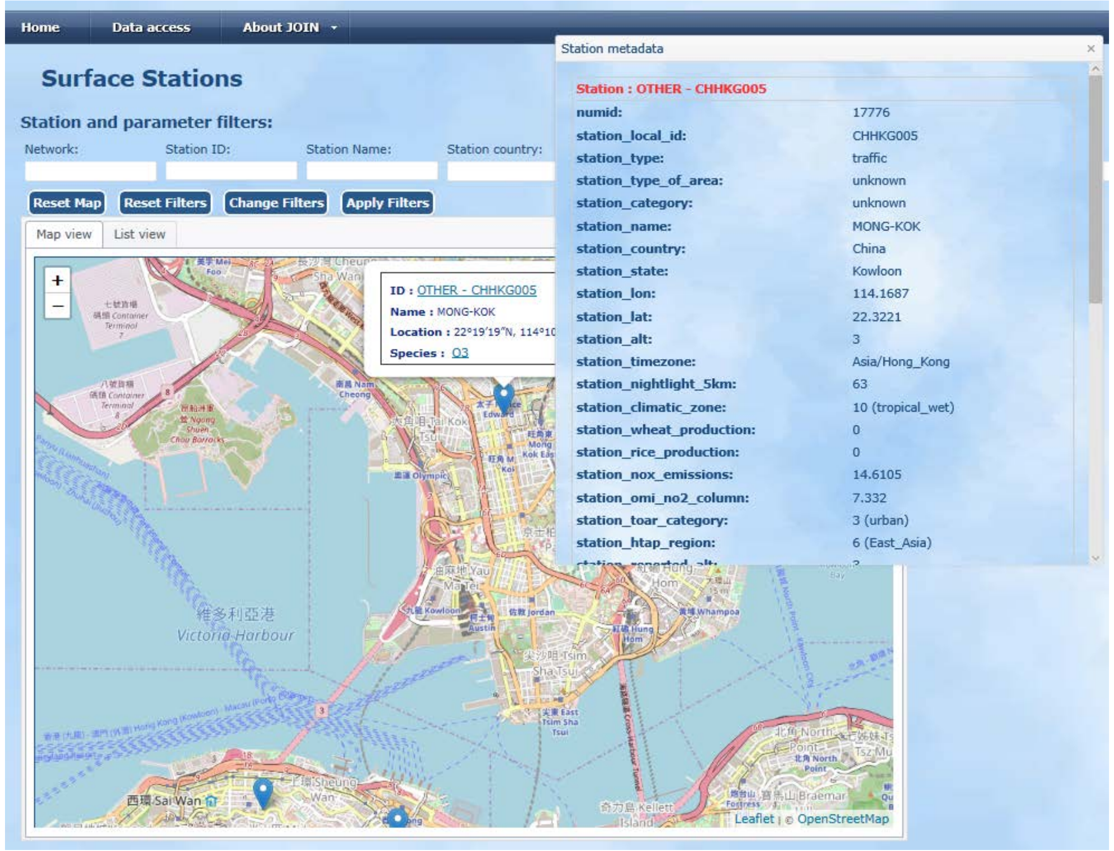
The TOAR database

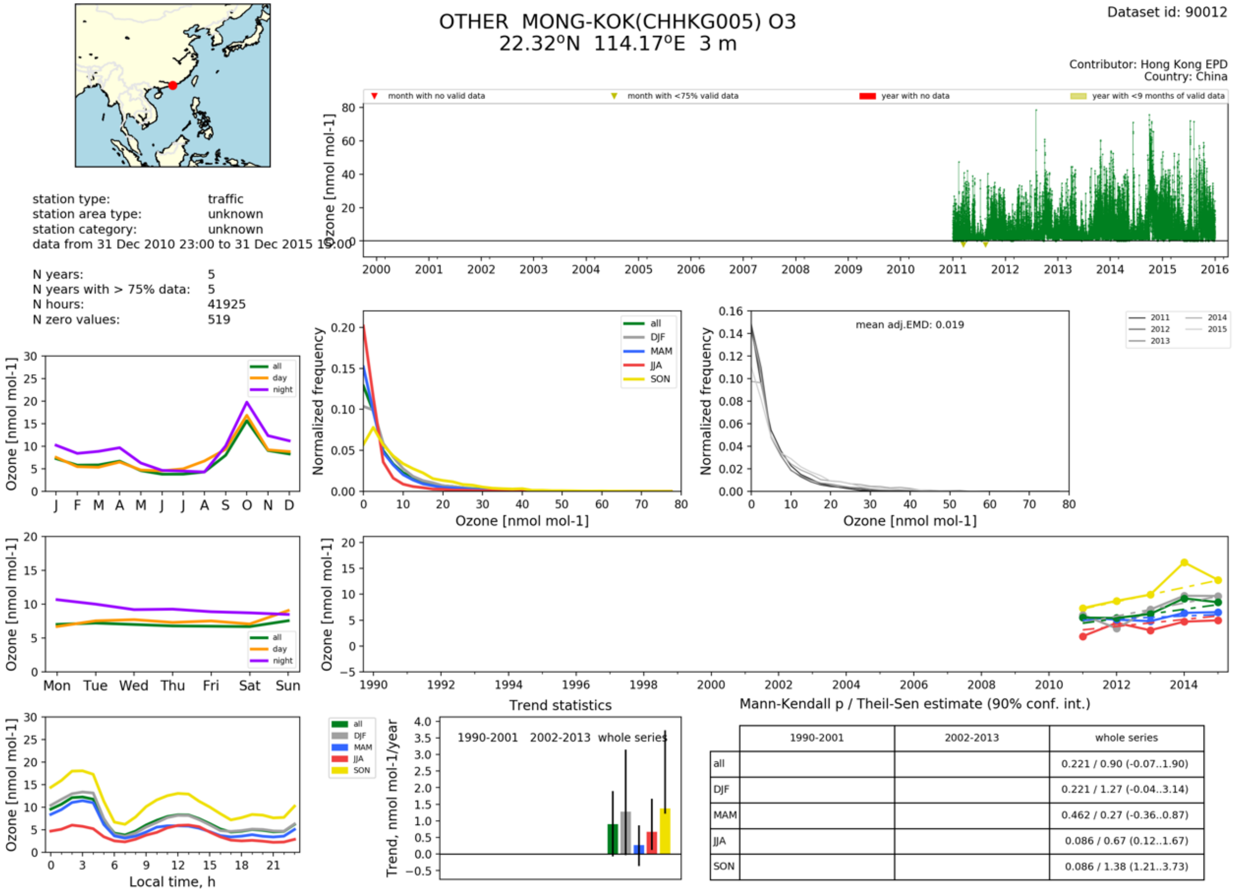


as of 06 August 2019:
12,795 Ozone data series at 10,002 stations

Precursors and meteorology:
9278 data series NO_2
6253 data series NO
396 data series PM10
2744 data series CO
7560 data series temperature
…

Figure: M.G. Schultz





	1990-2001	2002-2013	whole series
all			0.221 / 0.90 (-0.07..1.90)
DJF			0.221 / 1.27 (-0.04..3.14)
MAM			0.462 / 0.27 (-0.36..0.87)
JJA			0.086 / 0.67 (0.12..1.67)
SON			0.086 / 1.38 (1.21..3.73)

https://join.fz-juelich.de

Figure: M.G. Schultz

Access to the TOAR Database

TOAR
tropospheric ozone assessment report

Graphical web interface: https:/join.fz-juelich.de

REST Service: https:/join.fz-juelich.de/services/rest/surfacedata/

Pre-processed data products at

https://doi.pangaea.de/10.1594/PANGAEA.876108

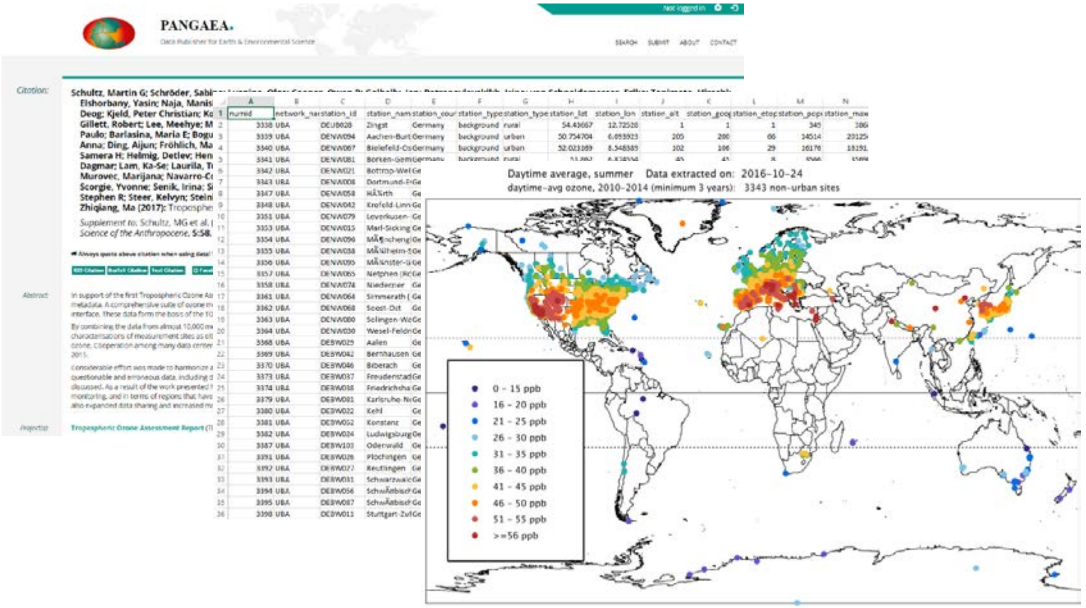
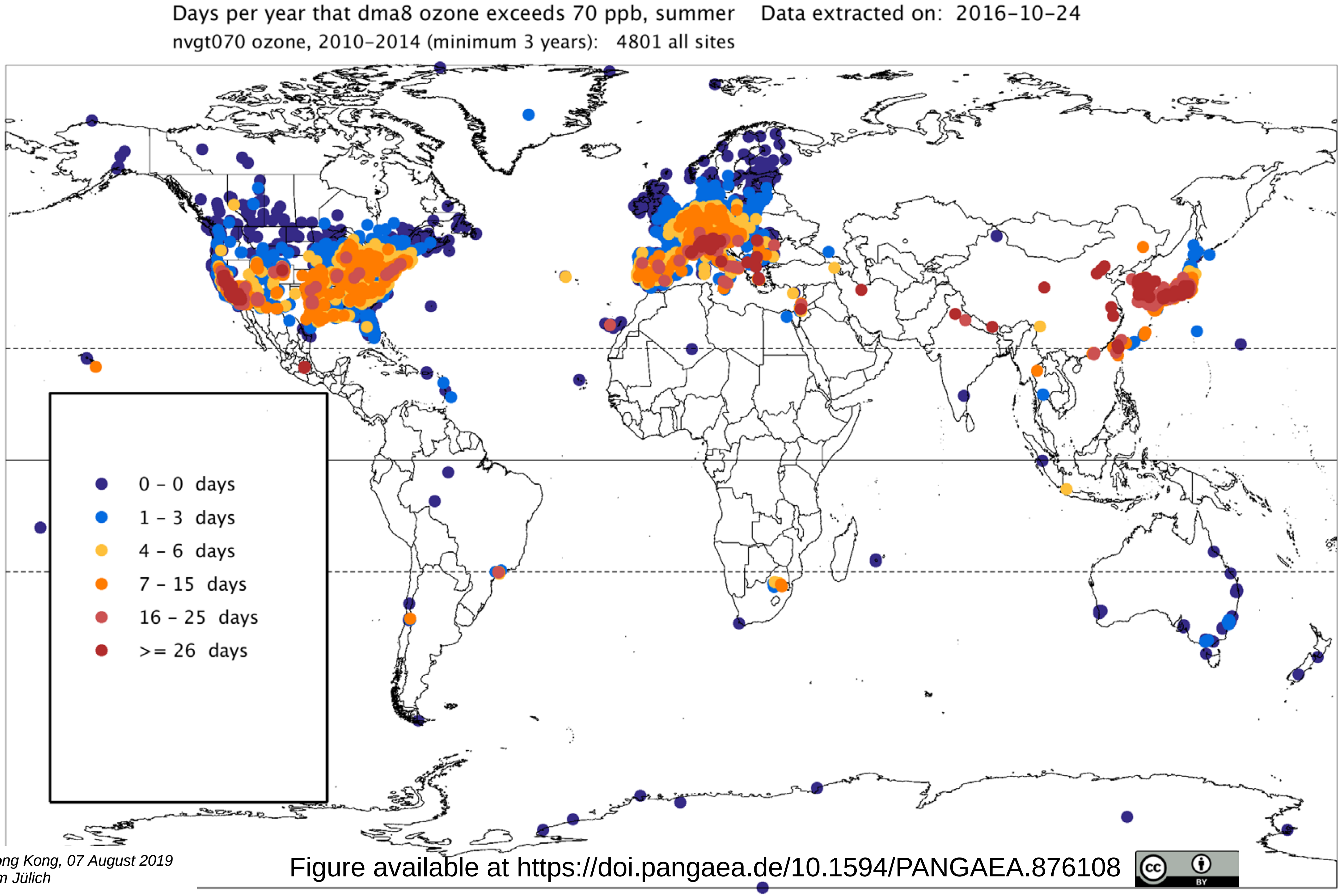


Figure: M.G. Schultz

One example of a TOAR surface ozone metric



Schultz, TOAR, Hong Kong, 07 August 2019
Forschungszentrum Jülich

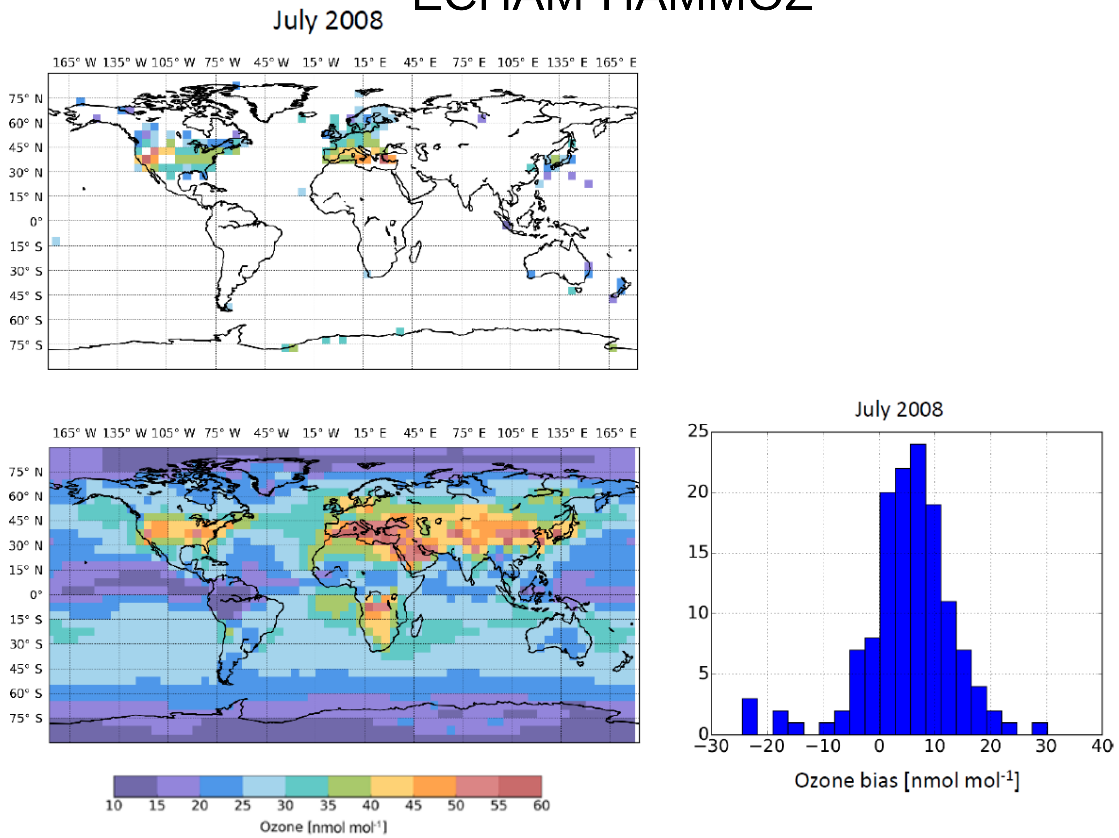
Figure available at https://doi.pangaea.de/10.1594/PANGAEA.876108

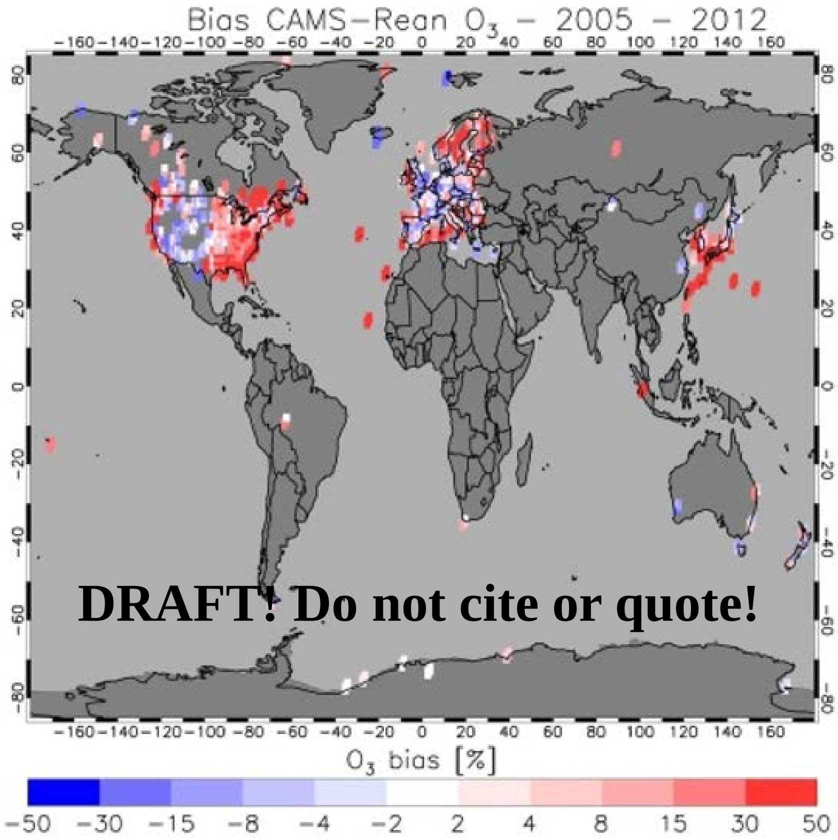
Applications and ongoing developments

Use of TOAR data in model evaluation

Atmosphere Monitoring Service

ECHAM-HAMMOZ





Schultz et al., 2018
https://doi.org/10.5194/gmd-11-1695-2018

Huijnen et al., in preparation

Regional analyses – especially China

Environmental Science & Technology LETTERS

Letter

Cite This: Environ. Sci. Technol. Lett. 2018, 5, 487−494

pubs.acs.org/journal/estlcu

Severe Surface Ozone Pollution in China: A Global Perspective

Xiao Lu,[†] Jiayun Hong,[†] Lin Zhang,[*,†] Owen R. Cooper,[‡,§] Martin G. Schultz,[∥] Xiaobin Xu,[⊥] Tao Wang,[#] Meng Gao,[@] Yuanhong Zhao,[†] and Yuanhang Zhang[*,∇]

[†]Laboratory for Climate and Ocean-Atmosphere Studies, Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University, Beijing 100871, China

[‡]Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder, Colorado 80309, United States

[§]NOAA Earth System Research Laboratory, Boulder, Colorado 80305, United States

[∥]Jülich Supercomputing Centre, Forschungszentrum Jülich, 52425 Jülich, Germany

[⊥]State Key Laboratory of Severe Weather and Key Laboratory for Atmospheric Chemistry of China Meteorological Administration, Chinese Academy of Meteorological Sciences, Beijing 100081, China

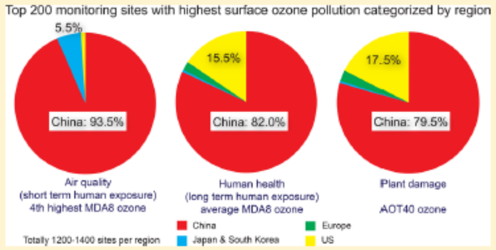
[#]Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong 99907, China

[@]School of Engineering and Applied Sciences, Harvard University, Cambridge, Massachusetts 02138, United States

[∇]State Key Joint Laboratory of Environmental Simulation and Pollution Control, College of Environmental Sciences and Engineering, Peking University, Beijing 100871, China

Supporting Information

ABSTRACT: The nationwide extent of surface ozone pollution in China and its comparison to the global ozone distribution have not been recognized because of the scarcity of Chinese monitoring sites before 2012. Here we address this issue by using the latest 5 year (2013−2017) surface ozone measurements from the Chinese monitoring network, combined with the recent Tropospheric Ozone Assessment Report (TOAR) database for other industrialized regions such as Japan, South Korea, Europe, and the United States (JKEU). We use various human health and vegetation exposure metrics. We find that although the median ozone values are comparable between Chinese and JKEU cities, the magnitude and frequency of high-ozone events are much larger in China. The national warm-season (April−September) fourth highest daily maximum 8 h average (4MDA8) ozone level (86.0 ppb) and the number of days with MDA8 values of >70 ppb (NDGT70, 29.7 days) in China are 6.3−30% (range of regional mean differences) and 93−575% higher, respectively, than the JKEU regional averages. Health exposure metrics such as warm-season mean MDA8 and annual SOMO35 (sum of ozone means over 35 ppb) are 6.3−16 and 25−95% higher in China, respectively. We also find an increase in the surface ozone level over China in 2016 and 2017 relative to 2013 and 2014. Our results show that on the regional scale the exposure of humans and vegetation to ozone is greater in China than in other developed regions of the world with comprehensive ozone monitoring.



Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

ELSEVIER

Ozone pollution in China: A review of concentrations, meteorological influences, chemical precursors, and effects

CrossMark

Tao Wang [a,*], Likun Xue [b], Peter Brimblecombe [c], Yun Fat Lam [c], Li Li [d], Li Zhang [a]

[a] Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong

[b] Environment Research Institute, Shandong University, Ji'nan, Shandong, China

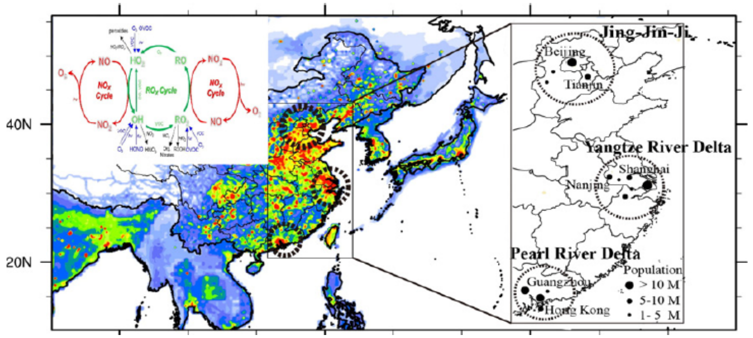
[c] School of Energy and Environment, City University of Hong Kong, Hong Kong

[d] Shanghai Academy of Environmental Sciences, Shanghai, China

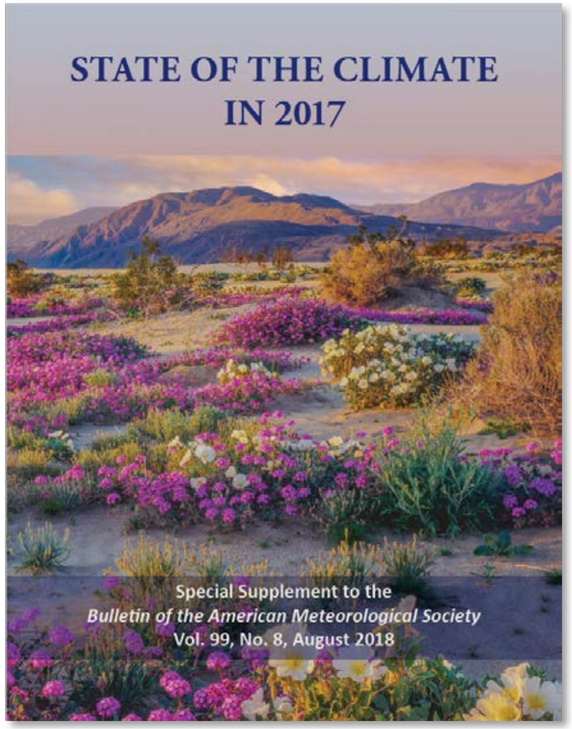
HIGHLIGHTS

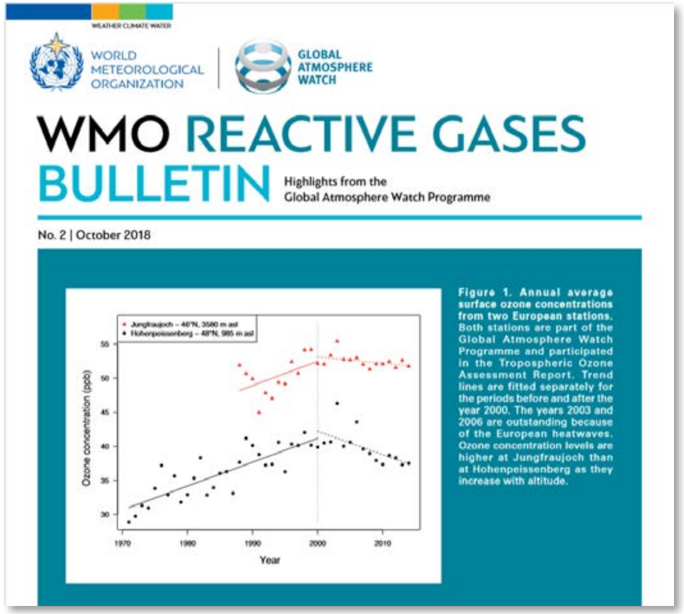
- Studies of atmospheric ozone in urban and rural areas of China are reviewed.
- Topics include abundance, chemical and meteorological processes, and effects.
- Available data reveals serious and worsening ozone pollution in major areas of China.
- Data from national network are needed to get a full picture of ozone pollution and to evaluate its impact.
- Strategies for control ozone precursors need to be developed.

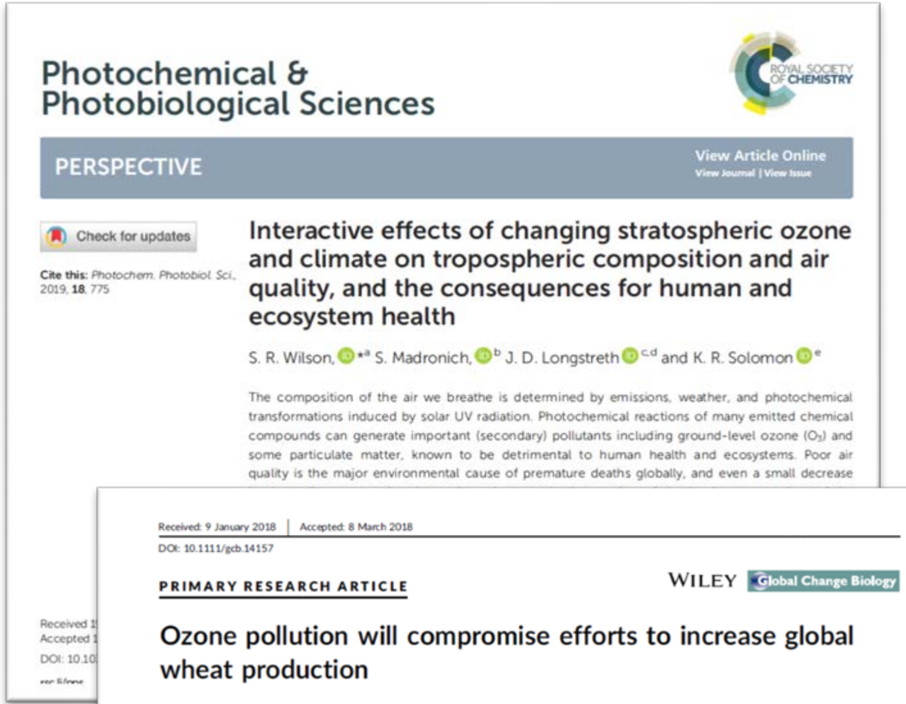
GRAPHICAL ABSTRACT



… and more …







Photochemical & Photobiological Sciences

ROYAL SOCIETY OF CHEMISTRY

PERSPECTIVE

View Article Online
View Journal | View Issue

Check for updates

Cite this: Photochem. Photobiol. Sci., 2019, 18, 775

Interactive effects of changing stratospheric ozone and climate on tropospheric composition and air quality, and the consequences for human and ecosystem health

S. R. Wilson, S. Madronich, J. D. Longstreth and K. R. Solomon

The composition of the air we breathe is determined by emissions, weather, and photochemical transformations induced by solar UV radiation. Photochemical reactions of many emitted chemical compounds can generate important (secondary) pollutants including ground-level ozone (O_3) and some particulate matter, known to be detrimental to human health and ecosystems. Poor air quality is the major environmental cause of premature deaths globally, and even a small decrease

Received: 9 January 2018 | Accepted: 8 March 2018
DOI: 10.1111/gcb.14157

PRIMARY RESEARCH ARTICLE

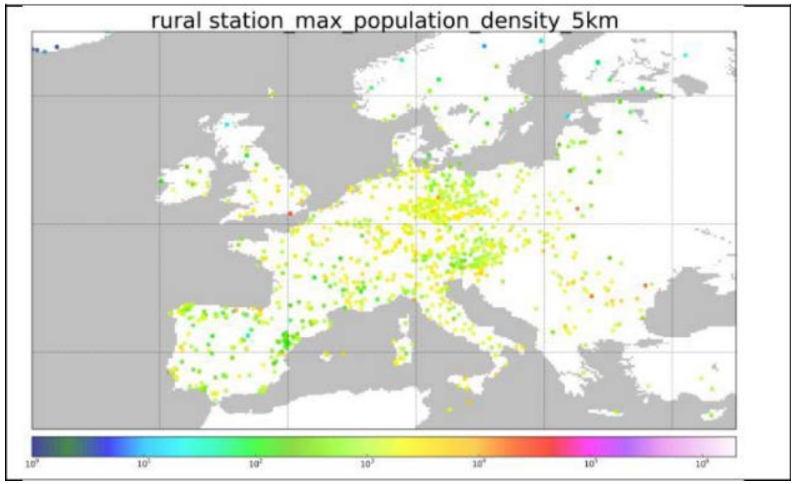
WILEY Global Change Biology

Ozone pollution will compromise efforts to increase global wheat production

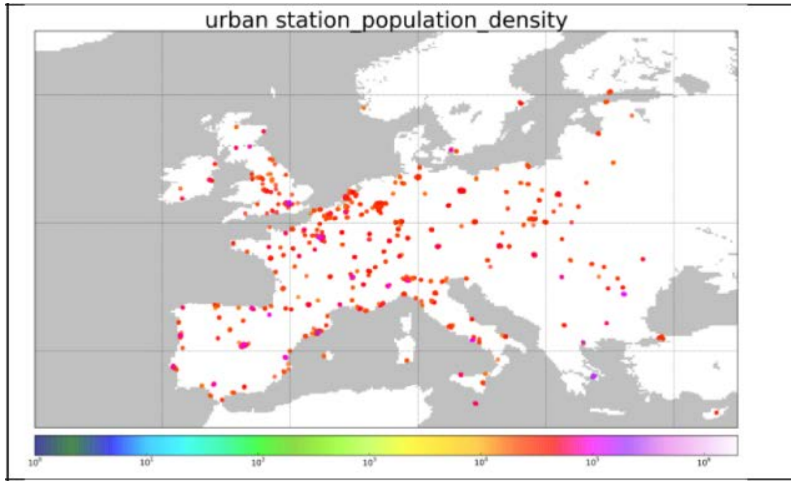
Gina Mills[1,2] | Katrina Sharps[1] | David Simpson[3,4] | Håkan Pleijel[2] | Malin Broberg[2] | Johan Uddling[2] | Fernando Jaramillo[5,6] | William J Davies[7] | Frank Dentener[8] | Maurits Van den Berg[7] | Madhoolika Agrawal[9] | Shahibhushan B. Agrawal[9] | Elizabeth A. Ainsworth[10] | Patrick Büker[11] | Lisa Emberson[11] | Zhaozhong Feng[12] | Harry Harmens[1] | Felicity Hayes[1] | Kazuhiko Kobayashi[13] | Elena Paoletti[14] | Rita Van Dingenen[8]

[1]Centre for Ecology and Hydrology, Bangor, UK
[2]Department of Biological and Environmental Sciences, University of Gothenburg, Gothenburg, Sweden
[3]EMEP MSC-W, Norwegian Meteorological Institute, Oslo, Norway
[4]Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden
[5]Department of Physical Geography and Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden
[6]Stockholm Resilience Center, Stockholm University, Stockholm, Sweden
[7]Lancaster Environment Centre, Lancaster University, Lancaster, UK
[8]European Commission, Joint Research Centre, Ispra, Italy
[9]Institute of science, Banaras Hindu University, Varanasi, India
[10]Department of Plant Biology, University of Illinois, Urbana, Illinois
[11]Stockholm Environment Institute, University of York, York, UK
[12]Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China
[13]Department of Global Agricultural Sciences, The University of Tokyo, Tokyo, Japan
[14]National Research Council, Firenze, Italy

@Jülich: Improve globally consistent site classification based on EO data



Sites in Europe classified as „rural“



Sites in Europe classified as „urban“

omi_no2_column <= 8
AND nightlight_5km <= 25
AND population_density <= 3000
AND max_population_density_5km <= 30000
AND google_alt <= 1500
AND etopo_relative_alt <= 500

population_density > 1500
AND nightlight_1km >= 60
AND max_nightlight_25km = 63

Use clustering to obtain objective grouping of stations …
(PhD thesis Lukas Leufen)

1-10 km scale 100 m scale

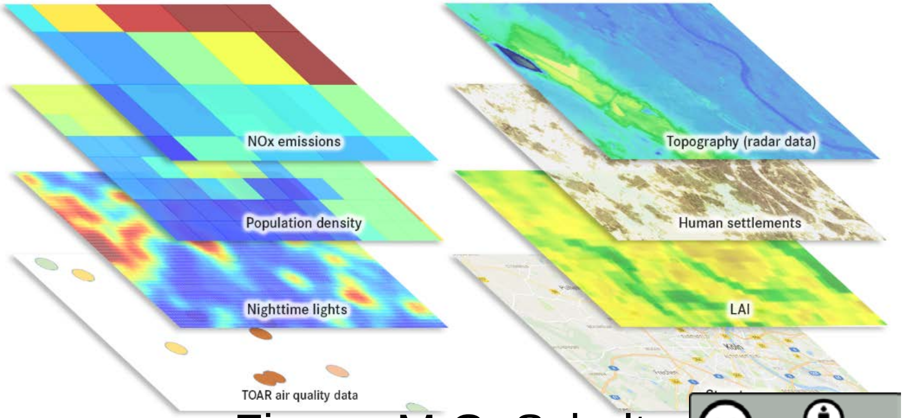
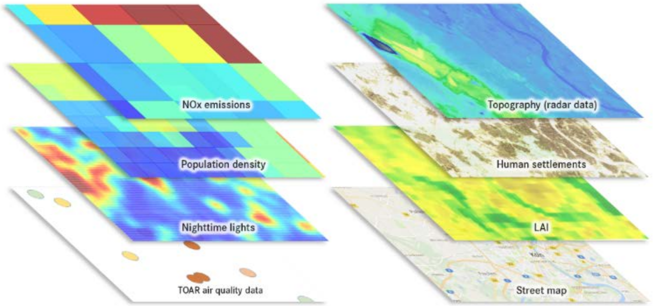


Figure: M.G. Schultz

European Research Council
Established by the European Commission
ERC-2017-ADG
#787576

@Jülich: Extend geographic information use



Provide location-specific geodata as a REST service

Example: /location/population_density/

Population density →

?lon=6.5&lat=50.3
→ value at location

?lon=6.5&lat=50.3&stats=max&radius=25
→ maximum value within 25 km radius

?lon=6.5&lat=50.3&stats=mean&radius=25&direction=WNW
→ mean value in WNW sector within 25 km radius

?lon=6.5&lat=50.3&stats=mean&radius=40&by_sector=True
→ mean value in all 16 wind sectors within 40 km radius

Status: in preparation – code available for climatic zones, HTAP regions, major roads, NOx emissions, NO2 columns, population density, rice roduction, wheat production, stable nighttime lights, tandem-x topography

@Jülich: Develop and apply deep learning to fused ESS data

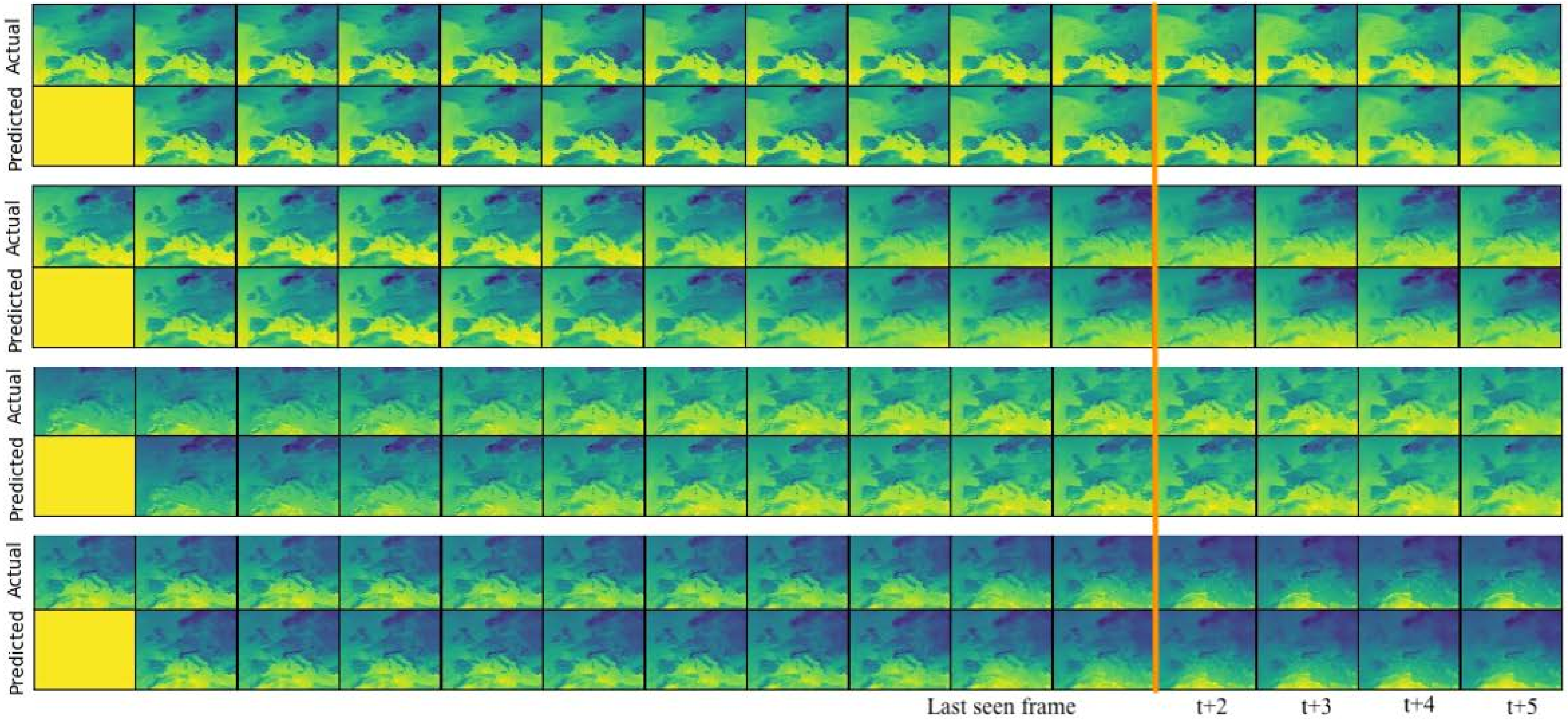


Figure 4: Sample results from a video frame prediction of the weather maps using machine learning

European Research Council
Established by the European Commission

ERC-2017-ADG
#787576

2m temperature predictions using a PredNet (Lotter et al., 2016)

Figure: Severin Hußmann, JSC and HU Berlin

Vision for the data and service architecture in TOAR-II

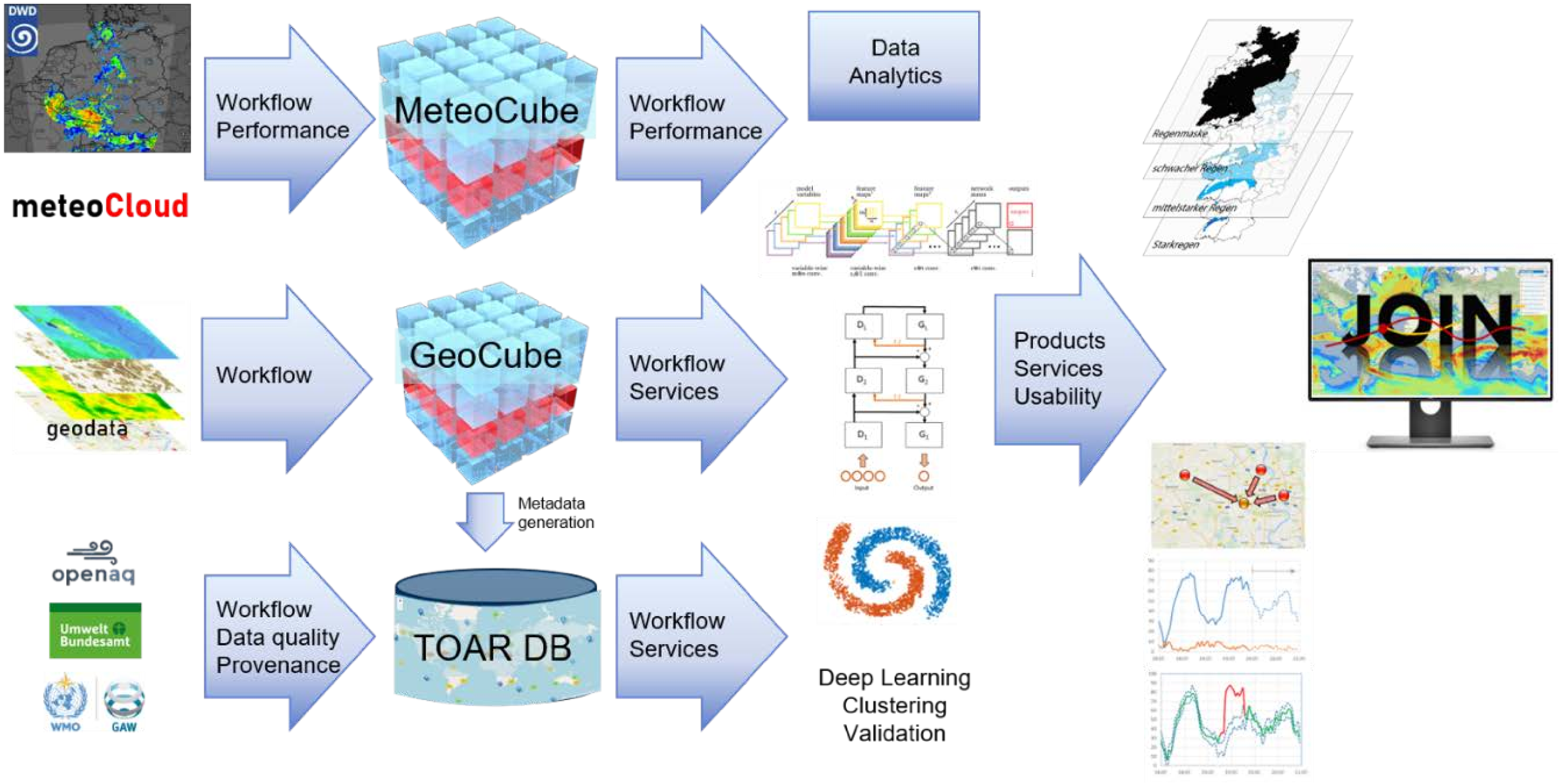


Figure: M.G. Schultz

New science questions and necessary updates

- What is the role of meteorology and precursor changes for tropospheric ozone changes? (attribution)
- Improve vegetation impact estimates by using stomatal fluxes
- etc.

For example:

- Update trend estimates
- Complement burden analysis with careful model evaluation
- Can we obtain a robust interpolation of surface ozone/tropospheric ozone maps to obtain full global coverage?

TOAR-II to be launched after decision of IGAC Steering Group in October 2019

TOAR-II Steering Group to be assembled and to decide on science issues and roadmap.

We need community buy-in and an active and engaged community to make TOAR-II happen!

Conclusions

- TOAR has produced the first comprehensive global assessment of tropospheric ozone. It is being picked up by the international community.
- The TOAR surface air quality database has pioneered open access to global ozone data and is being expanded to include precursors and meteorological data.
- The future of TOAR will be decided in October 2019 (but we believe it will happen and are ready to support it)
- Through ERC grant IntelliAQ Jülich continues the development of the TOAR database and analysis methods, especially machine learning.
- Science questions and roadmap for TOAR-II shall be defined by the community (there is strong interest to link much better to modelling)

Thank you!

The Earth System Data Exploration research group at JSC