Two decades of homogenized satellite ozone measurements for climate services

K.-P. Heue[1], D. Loyola[1], P. Valks[1], M. Coldewey-Egbers[1], A. Delcloo[2], C. Lerot[3], M .v. Roozendael[3]

1 Institut für Methodik der Fernerkundung am Deutschen Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen, Germany

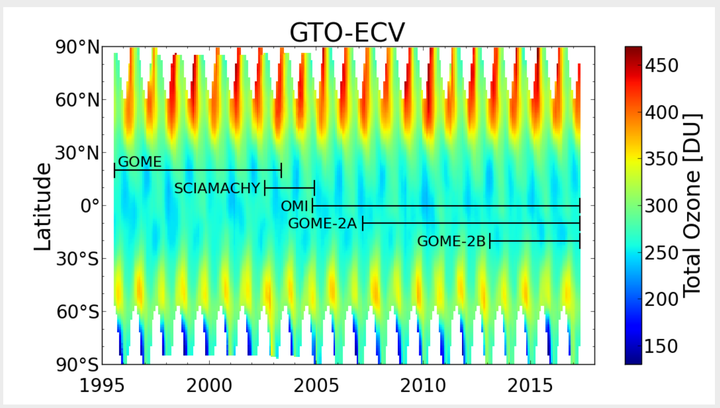
2 Institut Royal Météorologique / Koninklijk Meteorologisch Instituut, Brussels, Belgium

3 Koninklijk Belgisch Instituut voor Ruimte-Aeronomie / Institut royal d'Aéronomie Spatiale de Belgique, Brussels, Belgium

Total ozone column

The total ozone column is retrieved with the GODFIT algorithm (Lerot et al., 2014), where the measured spectrum is compared to a simulated spectrum in the range between 325 and 335 nm. The total ozone column is varied for several simulations until the measured and simulated spectrum agree. The same algorithm is applied to measurements of from GOME/ERS-2, SCIAMACHY/ENIVSAT, OMI/AURA and GOME-2/MetOp-A and MetOp-B, to increase the consistency the spectra are "soft calibrated" with respect to the OMI spectra over a bright surface (dessert). Also the final total column are harmonized by comparing the daily latitudinal mean using OMI as reference (Coldewey-Egbers et al., 2014). The harmonized data of the individual sensors are merged to the mean global total ozone essential climate variable.

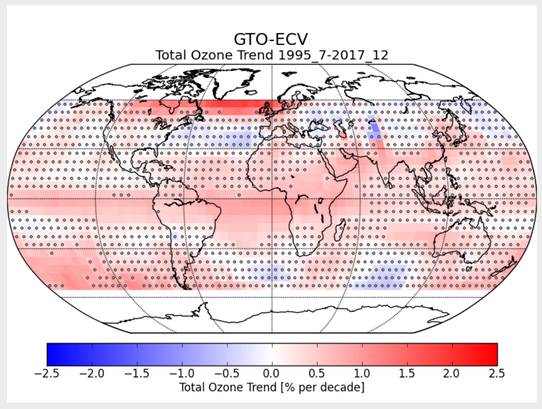
Fig. 1: monthly latitudinal mean of the merged data set for the time period between 1995 and 2017. The periods when the datasets of the individual instruments were used are indicated by the respective lines.



Trends since 1995

The merged data set covers the period from 1995 to 2017 and is regularly extended. Covering a period of more than 22 years the time series can be used to determine trends, or look for correlations with other datasets (ENSO index MEI).

Fig. 2: Global trend map of total ozone. The statistically insignificant trends are marked by a circle. Significant trends can only be observed areas, like central Africa, the tropical Atlantic, the Amazonian forest stretching into the pacific or the northern Atlantic. At mid-latitudes an insignificant decreasing trend is observed, for both northern and southern hemisphere.



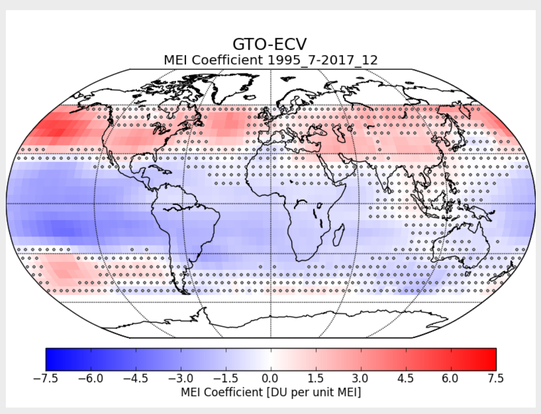


Fig. 3 Correlation plot between the global total ozone and the Multiple ESNO index. The strongest negative correlations are found over central pacific. But for South East Asia to northern Australia no correlation is found, here the tropospheric ozone is strongly correlated to the MEI.

Tropospheric ozone column

The convective cloud differential (CCD) algorithm is applied to retrieve the tropospheric O3 column in the tropics. The same algorithm is applied to the total column data from GOME/ERS-2, SCIAMACHY/ENIVSAT, OMI/AURA and GOME-2/MetOp-A and MetOp-B. The datasets based on the different sensors were harmonised, by comparing the tropical mean for the overlapping period (Heue et al., 2016). The mean of the harmonized datasets gives the merged dataset.

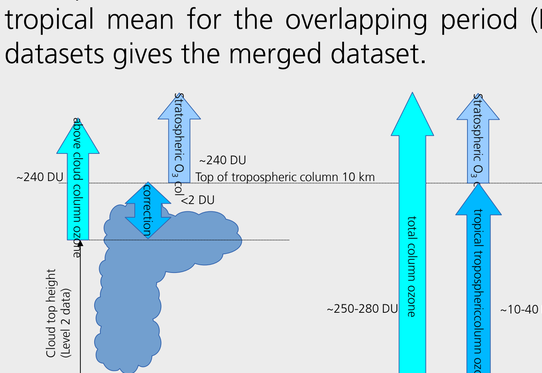


Fig. 4: Principle of the CCD, the stratosphere is estimate by the above cloud column over a clean region and subtracted from the total column for cloud free measurements

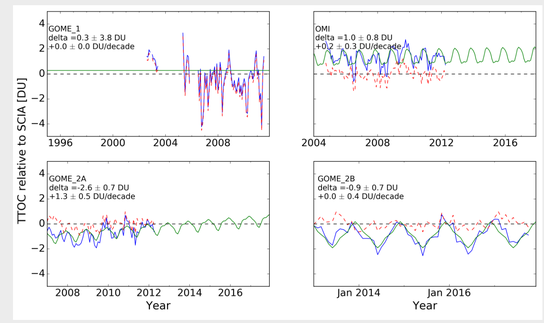


Fig. 5: The datasets are harmonized using SCIAMACHY as reference, by fitting a linear combination of linear function and sine and cosine terms to the mean tropical differences.

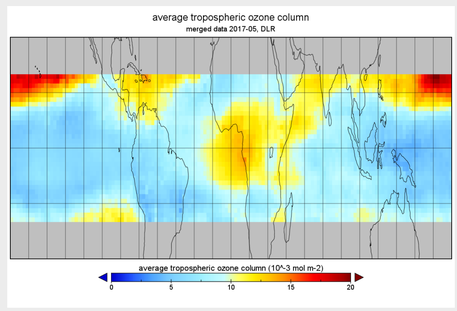


Fig. 6: Example figure of the tropical tropospheric ozone distribution (May 2017). The enhanced ozone column densities between 15 and 20° N are caused by stratospheric influences.

Trends since 1995

The merged data set covers the period from 1995 to 2017 and is regularly extended.
Covering a period of more than 22 years the time series can be used to determine trends, or look for correlations with other datasets (ENSO index, or fire data).
The trend published in Heue et al., 2016 has been updated by using a new ozone total column data and extending the time period until December 2017. The tropical global trend is 0.48 ± 0.11 DU /decade.

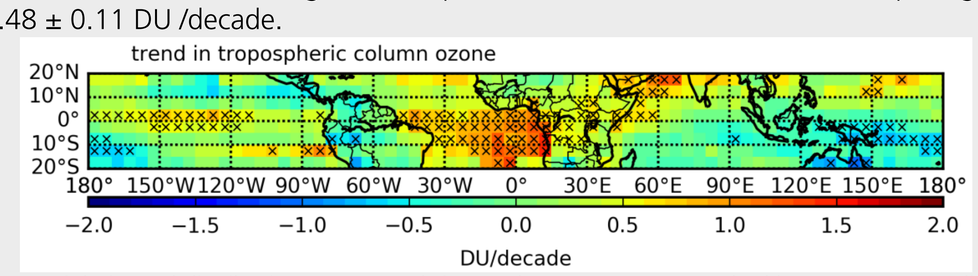
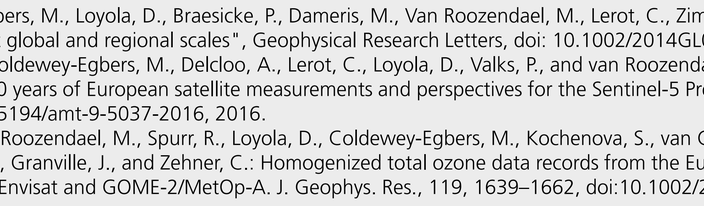


Fig. 7: Global trend distribution map. Trends larger than 2x error are marked by a cross. Large differences in the trends can be observed between the African coats and Pacific Ocean.
Fig. 8: The correlation coefficient between multi ENSO Index and tropical tropospheric ozone. Shows a strong negative correlation over the Pacific Ocean and a positive correlation over South East Asia.



Sentinel 5 Precursor

In October 2017 the S5P satellite was successfully launched into Orbit, the same algorithms as shown above are used for operational products. In the current state the data are not yet validated and therefore not included in the merging. With Sentinel 5P the time series can be extended for the next 5 years. Here we present first preliminary total and tropospheric ozone column densities from TROPOMI/S5P.

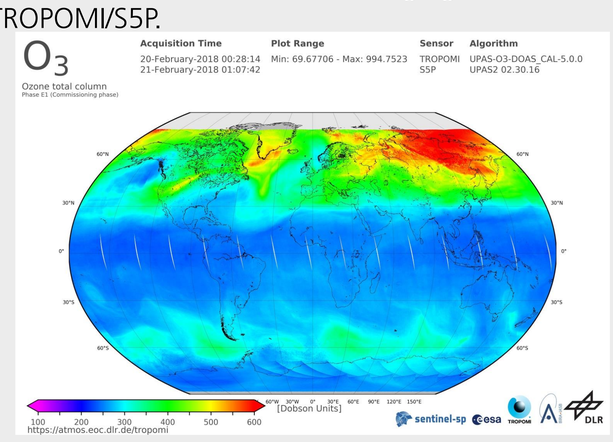


Fig. 9: Global total ozone distribution for Feb. 20. 2018. With S5P a daily global coverage is achieved. The resolution of the instrument is 3.5 by 7 km² .

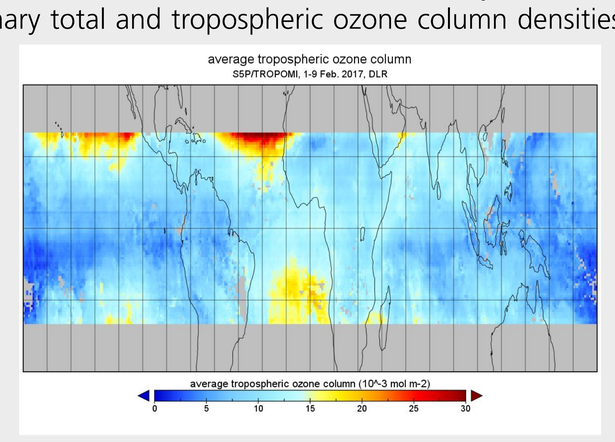


Fig. 10: Tropical tropospheric ozone column for the period 1st to 9th Feb. 2018. Compared to the above mentioned instruments the resolution in time and space is much finer for the TROPOMI instrument.

Disclaimer: The presented work has been performed in the frame of the Sentinel-5 Precursor Validation Team (S5PVT) or Level 1/Level 2 Product Working Group activities. Results are based on preliminary (not fully calibrated/validated) Sentinel-5 Precursor data that will still change.

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Data distribution

The merged total and tropospheric ozone column were created in the Framework of ESA's ozone CCI project (http://www.esa-ozone-cci.org/) . The respective data are free available. The total ozone column ECV is now part of the Copernicus C3S project and regularly updated.

References

Coldewey-Egbers, M., Loyola, D., Braesicke, P., Dameris, M., Van Roozendael, M., Lerot, C., Zimmer, W., "A new health check of the ozone layer at global and regional scales", Geophysical Research Letters, doi: 10.1002/2014GL060212, 2014.
Heue, K.-P., Coldewey-Egbers, M., Delcloo, A., Lerot, C., Loyola, D., Valks, P., and van Roozendael, M.: Trends of tropical tropospheric ozone from 20 years of European satellite measurements and perspectives for the Sentinel-5 Precursor, Atmos. Meas. Tech., 9, 5037-5051, doi:10.5194/amt-9-5037-2016, 2016.
Lerot, C., van Roozendael, M., Spurr, R., Loyola, D., Coldewey-Egbers, M., Kochenova, S., van Gent, J., Koukouli, M., Balis, D., Lambert, J.-C., Granville, J., and Zehner, C.: Homogenized total ozone data records from the European sensors GOME/ERS-2, SCIAMACHY/Envisat and GOME-2/MetOp-A. J. Geophys. Res., 119, 1639–1662, doi:10.1002/2013JD020831, 2014.