

Figure 1: Ozone trends in %/decade since 2000 derived from the HARMOZ data set. Adapted from Figure 2.10 of the WMO Scientific Assessment of Ozone Depletion: 2014. See p.3 for more details.

In this issue:

- Project overview
- Main achievements
- New ozone data products
- The Scientific Assessment of Ozone Depletion: 2014
- A new health check of the ozone layer
- Integration of Ozone_cci products in the ECMWF ERA5 system
- Peer-reviewed scientific publications

Project overview

Ozone is one of the atmospheric Essential Climate Variables. It impacts the radiation budget of the Earth, interacts with atmospheric dynamics and climate, and influences chemically other radiatively active species. The Ozone_cci project aims at generating state-of-the-art and fully traceable long-term data records of ozone measurements from all relevant ESA, EUMETSAT and Third Party Missions. These data are needed to better assess the ozone variability at all scales, and improve our understanding of the fate of our protective ozone layer in a changing climate.

Building on the work realized in the first phase of the CCI programme, which culminated with the delivery in late 2013 of the first version of the ozone "Climate Research Data Package", Ozone_cci Phase-2 focuses on extending and improving the data products to better match requirements formulated by the science user community.

This includes the extension in time of the data products to produce multi-decadal series of harmonized and consistent ozone data

suitable to assess long-term changes in the vertical distribution of ozone. In particular efforts concentrate on improving the accuracy of the products in the upper troposphere/lower stratosphere (UT/LS), and in the mesosphere which are both critical altitude regions in terms of ozone-climate feedbacks.

In the following, we summarize the main achievements of the project and present some of the most significant realizations. This covers the generation of new reference

time-series of ozone products derived from the successive GOME, SCIAMACHY, GOME-2 and OMI sensors complemented by the thermal infrared IASI instrument. Also addressed is the extension of the HARMOZ ozone profile which currently represents the most comprehensive data set for characterizing the stratospheric ozone variability in the years 2000.

All these data products are freely available from the project website.





Main achievements of Ozone_cci

In the second phase of the programme, the focus and ambition of Ozone_cci is to produce a fully harmonised data base of ozone measurements derived from all ESA and ESA Third Party Missions, and to demonstrate the added-value of these data as an input for chemistry-climate research and development.

The following achievements have been attained so far:

1. Total ozone data sets from all currently available backscatter nadir spectral UV-Vis sensors, i.e. GOME, SCIAMACHY, GOME-2 and OMI, have been reprocessed (Lerot et al., 2014) and the resulting harmonized product used for long-term trend analysis in the WMO Scientific Assessment of Ozone Depletion: 2014.

2. Ozone profile data covering 20 years of observations by the GOME, SCIAMACHY and GOME-2 instruments have been fully

reprocessed. This data set of unprecedented accuracy and consistency (Miles et al., 2015; Keppens et al., 2015) has been selected for inclusion in the 2015 ECMWF reanalysis ERA5.

3. The **HARMOZ** data base of ozone profiles (Sofieva et al., 2013) assembled from all ENVISAT and ESA TPM limb sensors available since 2000 has been further extended with data from the US MLS sensor, and work is ongoing to improve the data accuracy and long-term consistency of these data in the UT/LS and in the mesosphere. The HARMOZ product has also been included in

the WMO Scientific Assessment of Ozone Depletion: 2014.

Ozone_cci data products have been extensively documented following GCOS/CCI rules (see project documents available on www.esa-ozone-cci.org) and validated against GCOS and user requirements as formulated in the URD and documented in the PVIR.

All products distributed to the international scientific community follow a GCOS-compliant NetCDF-CF format.

New ozone data products: the Ozone_cci Climate Research Data Package (CDRP Aug. 2015)

The CRDP Aug. 2015 is the second version of the Ozone_cci data package. It contains extended data sets of total ozone, nadir ozone profiles and limb ozone profiles from all ESA and ESA TPM sensors. In Phase 2 a strong emphasis is put on deriving improved tropospheric and UT/LS ozone products from both nadir and limb sensors.

Ozone_cci Climate Research Data Package (August 2015)																				
Product ID	Product level	Years Processed																		
		95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13
<i>Total column data products</i>																				
TC_GOME	L2/L3M	[Processed and available on the project web site]																		
TC_SCIAMACHY	L2/L3M	[Processed and available on the project web site]																		
TC_GOME2	L2/L3M	[Processed and available on the project web site]																		
TC_OMI	L2/L3M	[Processed and available on the project web site]																		
<i>Tropospheric column data products</i>																				
TTOC_GOME2	L2	[Processed and available on the project web site]																		
LNTOC_SCIAMACHY	L2	[Processed and available on the project web site]																		
<i>Nadir profile data products</i>																				
NP_GOME	L2	[Processed and available on the project web site]																		
NP_SCIAMACHY	L2	[Processed and available on the project web site]																		
NP_GOME2	L2	[Processed and available on the project web site]																		
NP_IASI	L2	[Processed and available on the project web site]																		
<i>Limb profile data products</i>																				
LP_SCIAMACHY	L2/L3	[Processed and available on the project web site]																		
LP_MIPAS	L2/L3	[Processed and available on the project web site]																		
LP_GOMOS	L2/L3	[Processed and available on the project web site]																		
LP_OSIRIS	L2/L3	[Processed and available on the project web site]																		
LP_SMR	L2/L3	[Processed and available on the project web site]																		
LP_ACE	L2/L3	[Processed and available on the project web site]																		
LP_MLS	L2	[Processed and available on the project web site]																		
Comments:																				
L2/L3: Level-2/ Level-3 data sets																				
L3M: Merged Level-3 data sets																				
<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> Processed and available on the project web site </div> <div style="text-align: center;"> Processed but still under evaluation </div> </div>																				



The Scientific Assessment of Ozone Depletion: 2014

Following the discovery of the Antarctic ozone hole in 1985, an international agreement known as Montreal Protocol was reached in 1987 to progressively phase out the use of ozone-depleting chemicals. Conducted under the auspices of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), the Scientific Assessment of Ozone Depletion periodically update governments on the latest scientific findings related to the ozone layer.

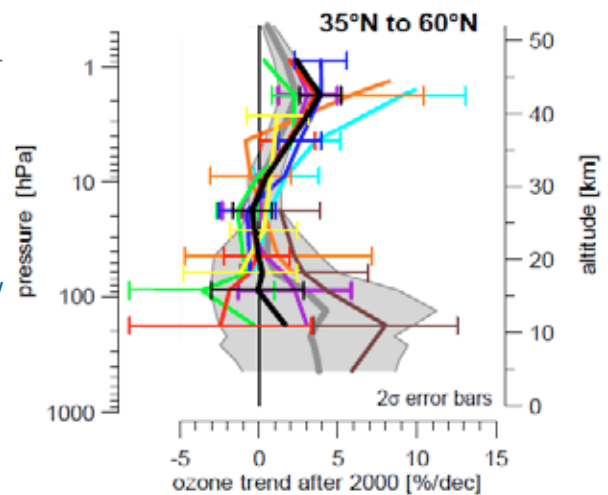
The recently published Scientific Assessment of Ozone Depletion: 2014, contains the most up-to-date understanding of ozone depletion. It reflects the thinking of hundreds of international scientific experts who contributed to its preparation and review. Among them, 11 scientists of the Ozone_cci project provided their contribution as lead author, coauthor or contributor.

Several Ozone_cci data sets were included in the report, in particular the reprocessed total ozone data series and the HARMOZ limb profiles. The latter were used to infer ozone trends after 2000 showing clear evidences for an ozone recovery in the upper-stratosphere at 40 km of altitude [see Figure 2, adapted from Figure 2.11 of the 2014 WMO Ozone Assessment report].

For more details see www.wmo.int/pages/prog/arep/gaw/ozone_2014/full_report_TOC.html.

Figure 2: Ozone trends after 2000 showing clear evidences for an ozone recovery in the upper-stratosphere at 40 km of altitude

SBUV-NASA, GOZCARDS, SAGE II V7.0, HARMOZ NDACC lidar, mwave, FTIR, Umkehr, Sondes, average, CCMVal-2



A new health check of the ozone layer

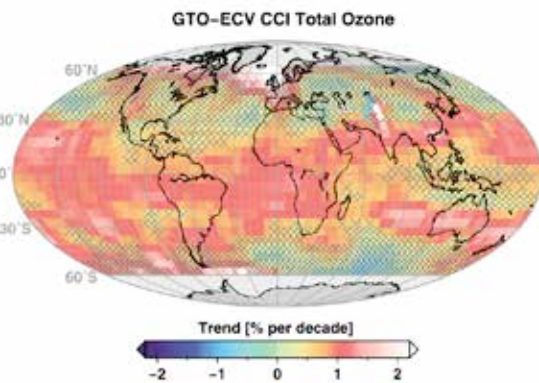


Figure 3: Linear total ozone trend estimates 1995–2013 from satellite data GTO-ECV CCI

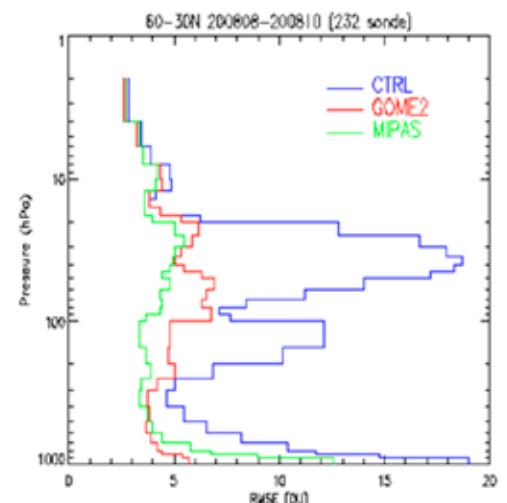
In a study recently published in Geophysical Research Letters (see [Col-dewey-Egbers et al., 2015](#)) a new perspective on the current state of the ozone layer has been derived using the merged total ozone data record (GTO-ECV) recently released in the framework of the ESA Climate Change Initiative. Based on a multivariate regression analysis covering the 1995-2013 period, various aspects of ozone change and variability

are disentangled on global and regional scales [see Figure 3]. This enables the monitoring of the effectiveness of the Montreal Protocol. Given dominant natural variability the expected mid-latitude onset of ozone recovery is still not significant and on estimates that 5 additional years of observations would be needed for an unequivocal detection. A regional increase identified in the tropics is a likely manifestation of a long-term change in El Niño-Southern Oscillation intensity over the last two decades induced by strong El Niño in 1997/1998 and strong La Niña in 2010/2011.

Integration of Ozone_cci products in the ECMWF ERA5 system

As part of the ongoing ERA-CLIM project aiming at generating a new version of the ECMWF reanalysis (ERA5) covering the period from 1979 until present, a round-robin exercise has been recently performed to assess the respective merits of several ozone data sets as an input to the long-term data assimilation system. 6 ozone data sets available from the Ozone_cci project have been included in the exercise: total ozone columns from GOME, SCIAMACHY and GOME-2, ozone profiles from GOME and GOME-2 and stratospheric ozone

profiles from MIPAS. Their effect on the assimilation system has been extensively tested over a 4 months period in 2008 demonstrating a positive impact on the resulting ozone fields, which are brought into better agreement with reference data sets (see figure). As a result of the experiment, Ozone_cci data sets from GOME, SCIAMACHY, GOME-2 and MIPAS sensors are recommended for inclusion in ERA5 (Dragani, unpublished result).





Peer-reviewed scientific publications

Selected publications resulting from Ozone_cci data sets and activities.

- Adams, C., A. E. Bourassa, V. Sofieva, et al., **Assessment of Odin-OSIRIS ozone measurements from 2001 to the present using MLS, GOMOS, and ozone sondes**, *Atmos. Meas. Tech.*, 7, 49-64, doi:10.5194/amt-7-49-2014, 2014.
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- Coldewey-Egbers, M., D. G. Loyola, M. Koukouli, et al., **The GOME-type Total Ozone Essential Climate Variable (GTO-ECV) data record from the ESA Climate Change Initiative**, *Atmos. Meas. Tech. Discuss.*, 8, 1-46, 2015.
- Coldewey-Egbers, M., Loyola R., D. G., Braesicke, P., et al., **A new health check of the ozone layer at global and regional scales**, *Geophysical Research Letters*, doi:10.1002/2014GL060212, 2014.
- Dameris, M. and P. Jöckel, **Numerical modeling of climate-chemistry connections: Recent developments and future challenges**, *Atmosphere*, 4, 132-156, doi:10.3390/atmos4020132, 2013.
- Dameris, M. and D. Loyola, **Recent and future evolution of the stratospheric ozone layer**, Chapter 45 in *Atmospheric Physics, Background-Methods-Trends*, Ed. U. Schumann, Springer Heidelberg New York Dordrecht London, ISBN 978-3-642-30182-7, doi:10.1007/978-3-642-30183-4, pp.747-761, 2012.
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