

Initial applications of the novel GOME-type Ozone Profile Essential Climate Variable (GOP-ECV) data record covering the past 2.5 decades

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Introduction

The European Space Agency's Climate Change Initiative+ ozone project was initiated in 2010 and aims at generating multi-decadal time series of harmonized and consistent ozone data suitable to assess long-term changes in ozone and its vertical distribution. We have developed a combined merging and harmonization approach for ozone profiles. Profiles derived from nadir-viewing ultraviolet-visible-near-infrared (UVN) satellite sensors of the GOME-type are combined into a homogeneous data record covering more than two decades (1995-2021). In addition, we apply an altitude-dependent scaling and harmonize the merged time series with respect to the well-established GOME-type Total Ozone Essential Climate Variable (GTO-ECV) data record. In this study, we present first applications of GOP-ECV: comparisons with ozonesonde measurements from the SHADOZ network and a comparison of lower tropospheric ozone from a similar satellite-based record.

Ozone profile and total ozone data

Ozone profiles

- Level-3 monthly mean ozone partial columns (19 layers from surface to 80km)
- UVN nadir sensors: GOME (1995-2011), SCIAMACHY (2002-2012), OMI (2004-today), GOME-2A (2007-2021), and GOME-2B (2013-today)
- Profile retrieval algorithm: Rutherford Appleton Laboratory (RAL) scheme (Miles et al., 2015)

GOME-type Total Ozone Essential Climate Variable (GTO-ECV)

- Merged level-3 monthly mean total ozone columns 1995-2023 (see Fig.1; Coldewey-Egbers et al., 2022)
- UVN nadir sensors: same as for ozone profiles and TROPOMI (2018-today) and GOME-2C (2019-today)
- Total ozone retrieval algorithm: GODFIT V4 (Lerot et al., 2014)

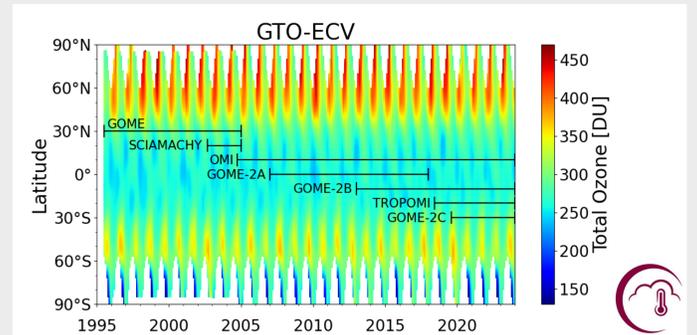


Fig. 1: GTO-ECV monthly total ozone zonal means 1995-2023.

Merging approach

- Based on 5°x5° monthly mean de-seasonalized anomalies (Fig. 2) (Sofieva et al., 2021); reference sensor is OMI
- Adjustment:** time-dependent correction for SCIAMACHY, GOME-2A, and GOME-2B for each spatial bin; for GOME correction based on comparisons for broad latitude bands
- Merging:** average OMI and adjusted GOME, SCIAMACHY, GOME-2A, and GOME-2B
- Absolute values: use OMI seasonal cycle (2005-2020) to calculate absolute values from anomalies (Fig. 3)

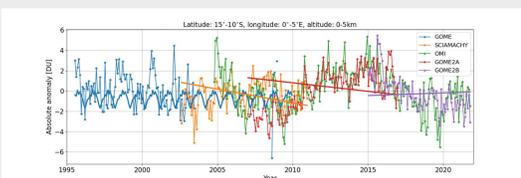


Fig. 2: De-seasonalized ozone anomalies 1995-2021.

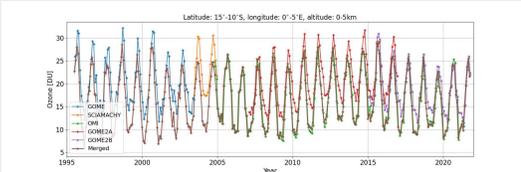


Fig. 3: Merged ozone partial columns 0-6km 1995-2021.

Clustering and Neural Network training

Clustering procedure

- Apply k-means clustering (Xu et al., 2017)
- Output: 11 ozone profile classes (Fig. 4)

Neural Network (NN) approach

- Ensemble of 242 NNs per cluster (input: total ozone, month, latitude, and longitude; two hidden layers; output: partial ozone columns)
- Extract Jacobians: altitude-dependent change of profile due to change in total column (see Fig. 5)

Classification algorithm

- k-neighbors classification → assign one class to each monthly mean profile

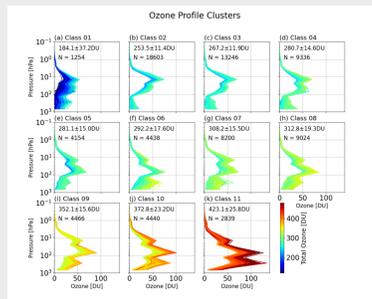
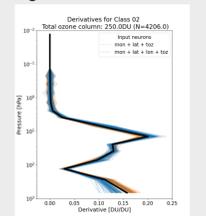


Fig. 4: 11 profile classes.

Figure 5: Jacobians for class 2



Harmonization w.r.t. GTO-ECV

- Difference: GTO-ECV total and integrated profile columns
- Use difference ΔTOZ (see Fig. 6) and Jacobians $d/dtoz$ from NN training for altitude-dependent scaling (Fig. 7)
- $GOP-ECV(z) = MERGED(z) + \Delta TOZ * d/dtoz(z)$

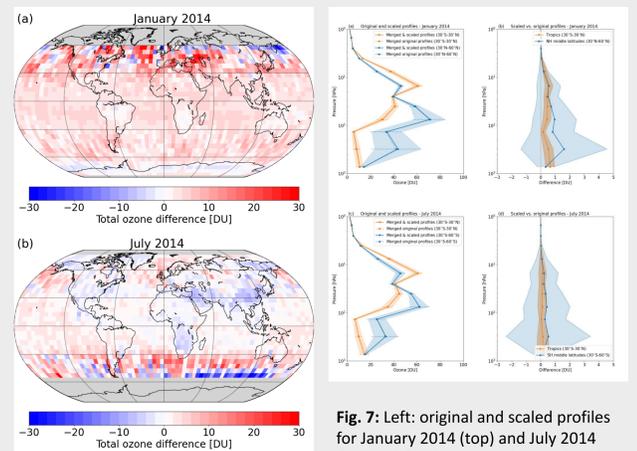


Fig. 6: Total ozone difference ΔTOZ between GTO-ECV and integrated merged ozone profiles for January 2014 (top) and July 2014 (bottom).

Fig. 7: Left: original and scaled profiles for January 2014 (top) and July 2014 (bottom) for the tropics (orange) and SH middle latitudes (blue). Right: corresponding mean difference and standard deviation between original and scaled profiles.

Climatological Ozone Distribution

- Fig. 8 shows climatological ozone distributions 1995-2021 for the integrated total column (top), and the partial column amounts in the layers: surface-450 hPa (0-6 km, middle), and 100-50 hPa (16-20 km, bottom). For the total column and each layer, the values for April (left) and October (right) are shown.

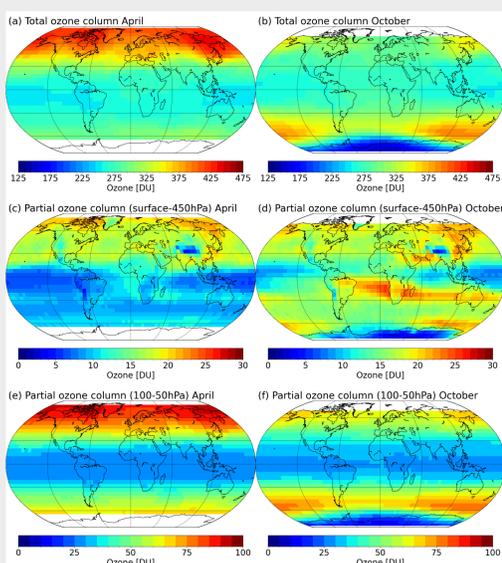


Fig. 8: Climatological ozone distribution (see text for details)

Comparison of Lower Tropospheric Ozone

- Compare GOP-ECV surface-450hPa partial column and Lower Tropospheric Ozone Column by Pope et al. (2023)
- Spatial distributions of long-term mean (1996-2017) agree well, but indicate a small offset of ~3DU (see Fig. 9).

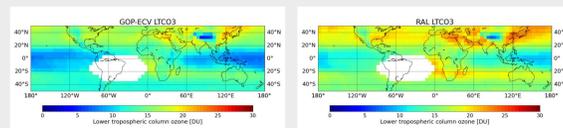


Fig. 9: Lower tropospheric (surface-450hPa) ozone 1996-2017 average from GOP-ECV (left) and RAL LTCO3 (right).

- Calculate 1996-2000 and 2013-2017 5-year averages and deviations w.r.t. long-term (1996-2017) mean (see Fig. 10).
- Both GOP-ECV and RAL LTCO3 show negative anomalies for 1996-2000 and positive anomalies for the later period.

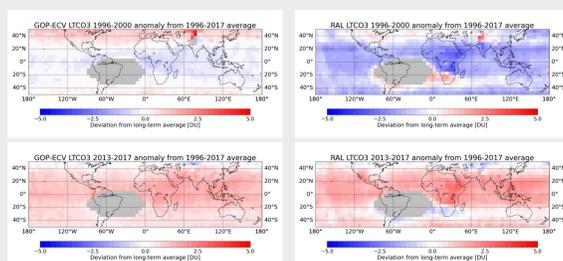


Fig. 10: Top: 1996-2000 average deviation from long-term (1996-2017) mean for GOP-ECV (left) and RAL LTCO3 (right). Bottom: same as top panels, but for 2013-2017 mean compared to long-term average.

Preliminary Comparison with SHADOZ

- Calculate partial column ozone for (i) surface-450hPa and (ii) 450-170hPa from 9 SHADOZ (Southern Hemisphere Additional Ozonesondes) stations (Witte et al., 2017).
- GOP-ECV indicates a negative bias of 2-3 DU compared to sondes; correlation coefficient is ~0.73.

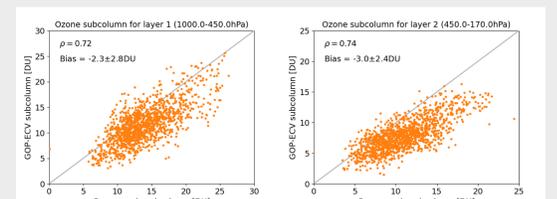


Fig. 11: GOP-ECV vs. SHADOZ ozone subcolumns for surface-450hPa (left) and 450-170hPa (right)

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