The novel GOME-type Ozone Profile Essential Climate Variable (GOP-ECV) from the ESA-CCI+ ozone project

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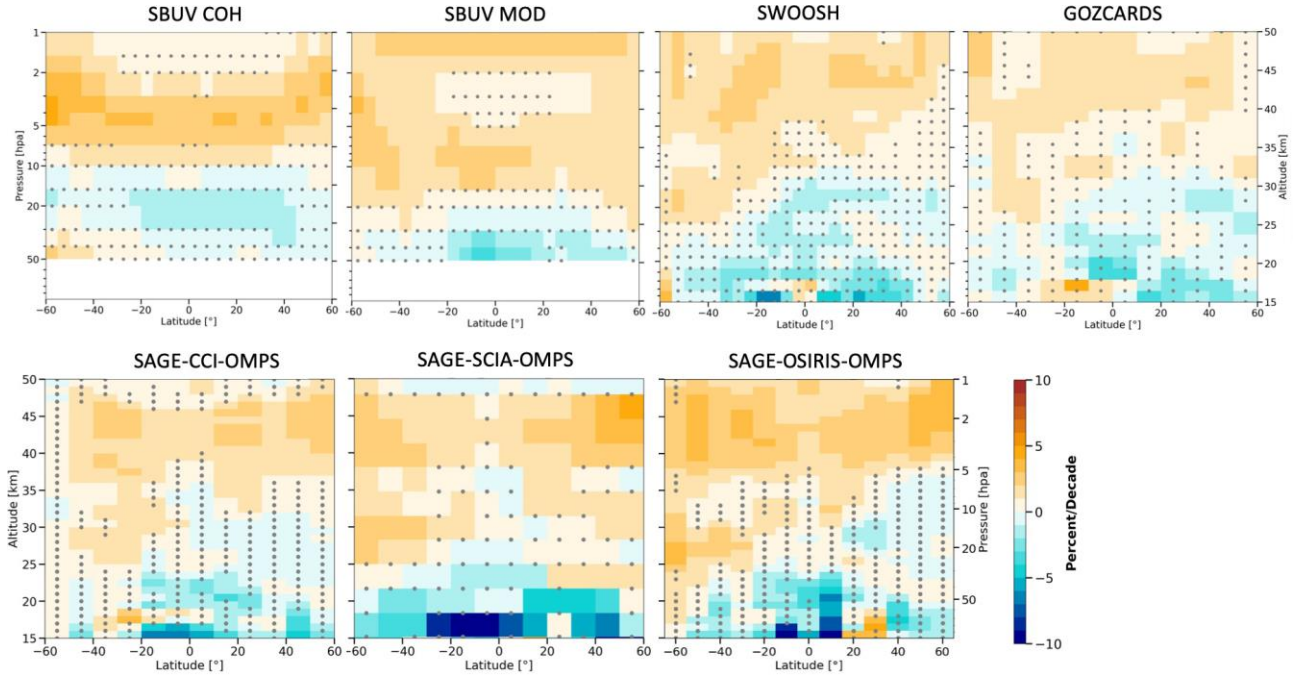
Motivation

Ozone trends in the stratosphere

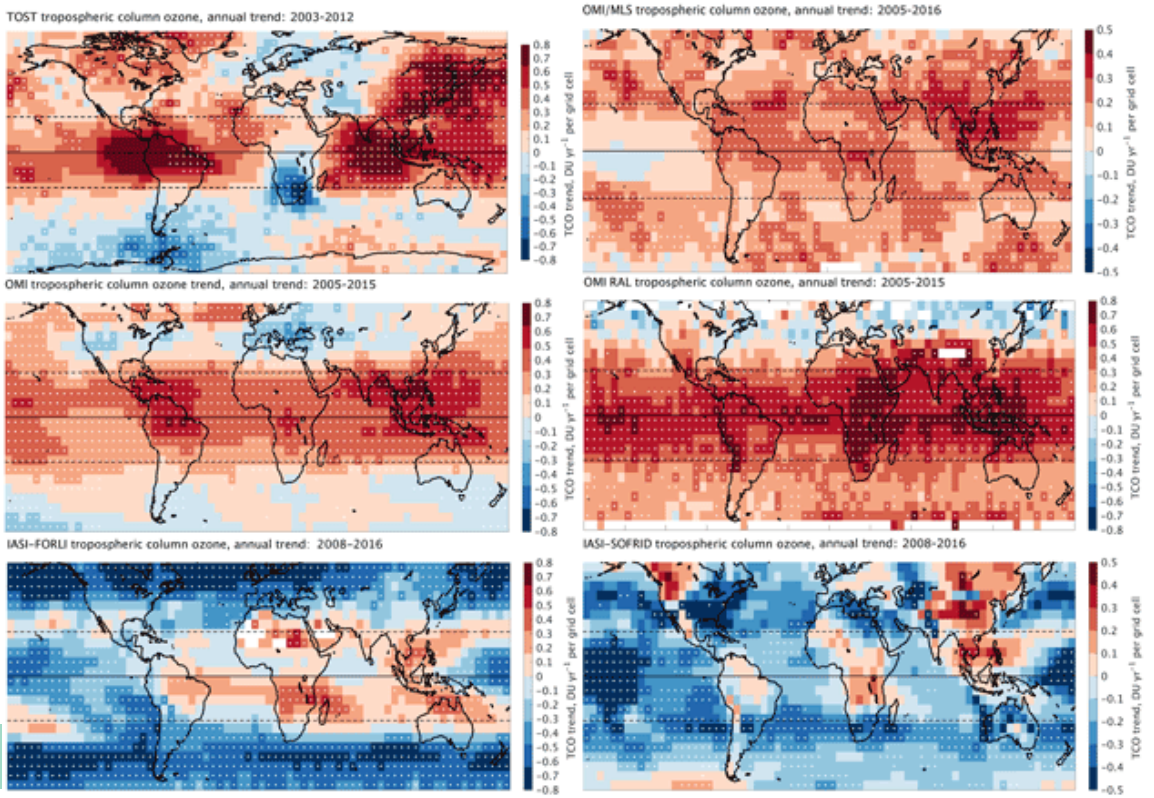
- Significant increase in upper stratosphere
- Non-significant decrease in lower stratosphere (here: discrepancies with model results)



Godin-Beekmann et al., 2022

Ozone trends in the troposphere

- Regional differences
- Different satellite-based products show wide variety of trends



Gaudel et al., 2018

ESA Climate Change Initiative+ Ozone project

- **“Generation of multi-decadal time series of harmonized and consistent ozone data suitable to assess long-term changes in ozone and its vertical distribution”**
- Based on nadir- and limb-viewing sensors
- Single sensor as well as merged products

Consortium

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

UNIVERSITÉ LIBRE DE BRUXELLES

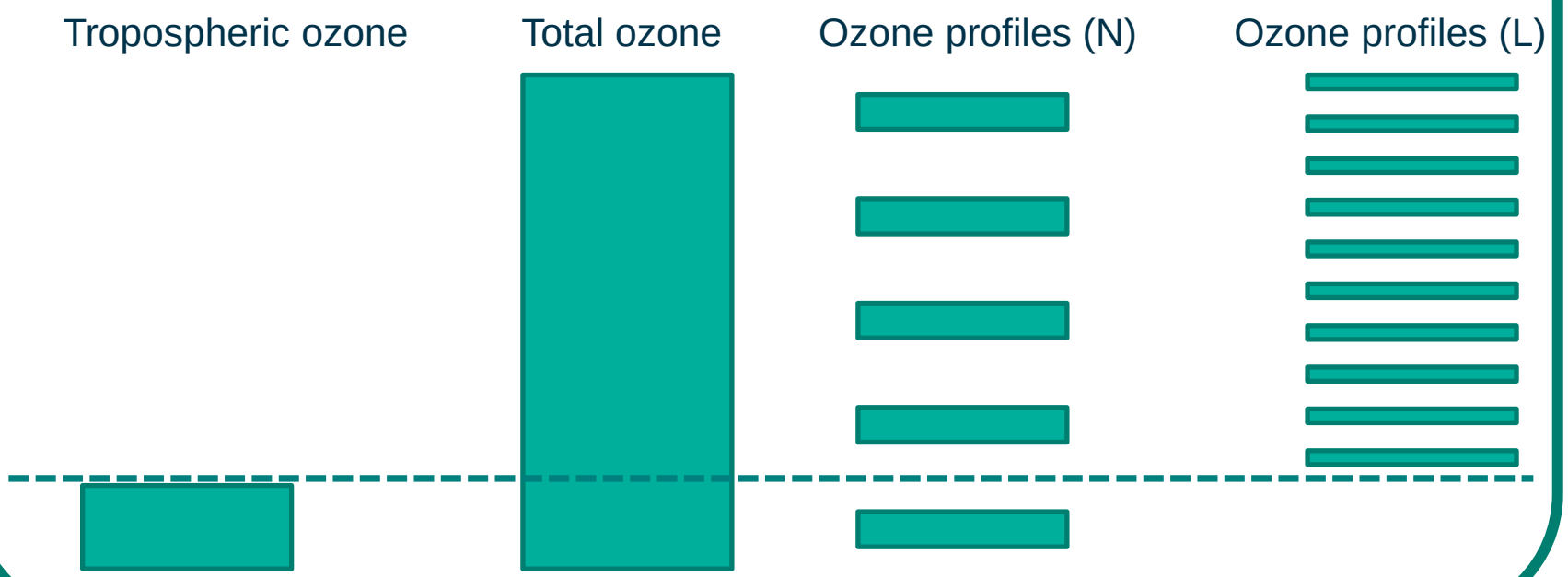
FMI

Universität Bremen

RAL Space

ARISTOTLE UNIVERSITY OF THESSALONIKI

Portfolio of products



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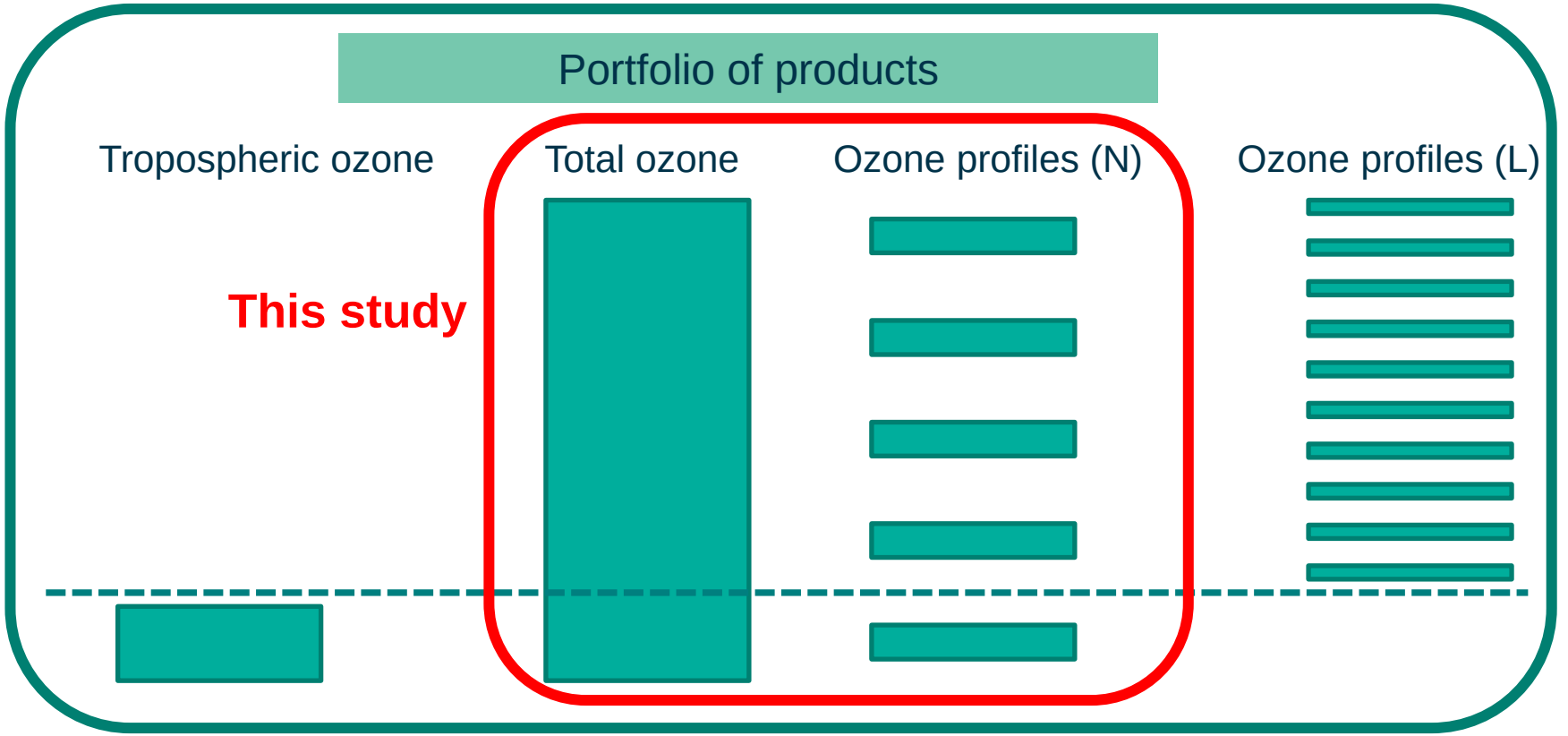
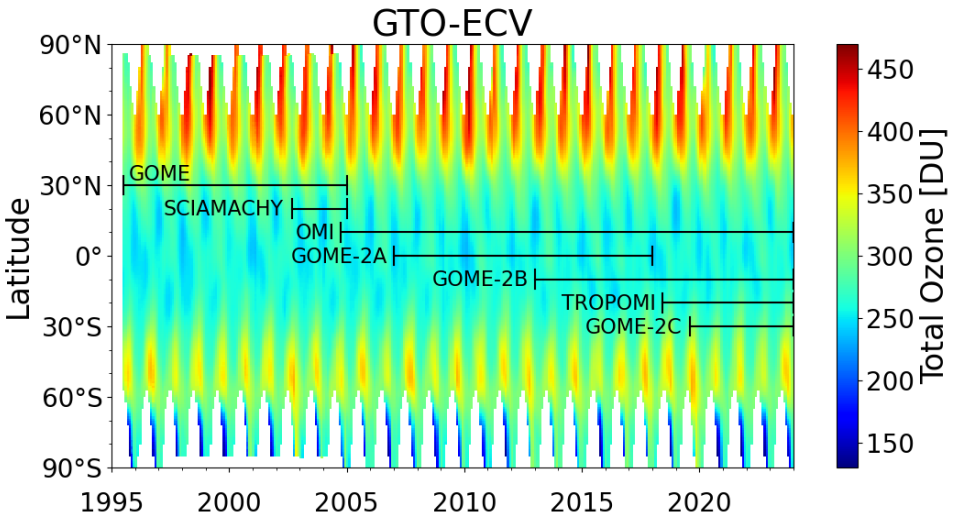


Input data and outline of merging approach

- UVN satellite sensors
  - GOME (1995-2011)
  - SCIAMACHY (2002-2012)
  - OMI (2004-today)
  - GOME-2A/B (2007-2021, 2013-today)

Nearly the same series as for GTO-ECV (total columns)



- Ozone profile retrieval
  - RAL scheme (Miles et al., 2015)
  - Surface – 80km, 19 layers

Same approach for all sensors

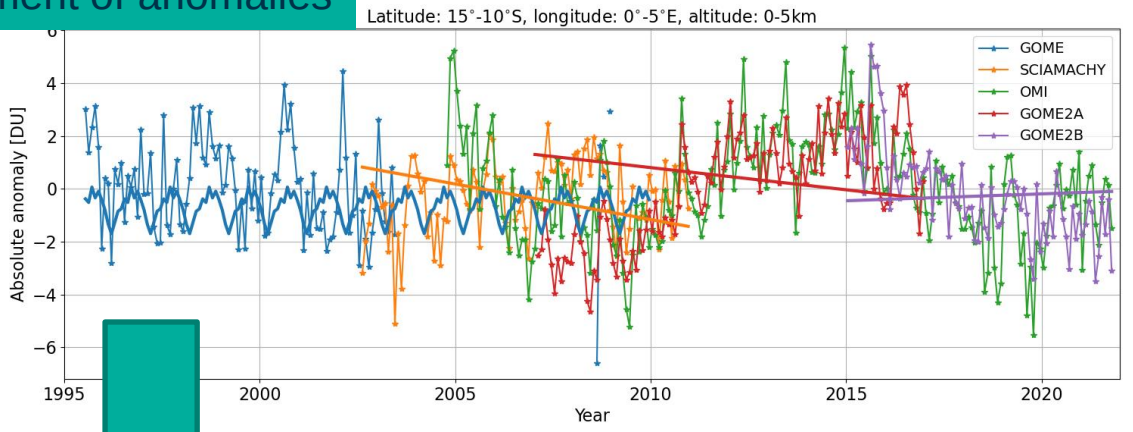
Coldewey-Egbers et al. (2014, 2015, 2020, 2022), Garane et al. (2018), Loyola and Coldewey-Egbers (2012), Loyola et al. (2009)

- Merging approach
  (1) Merge 5° x 5° level-3 ozone profiles (Sofieva et al., 2021)
  (2) Apply clustering approach and derive Jacobians using a Neural Network approach
  (3) Altitude-dependent scaling of merged profiles w.r.t. GTO-ECV total columns

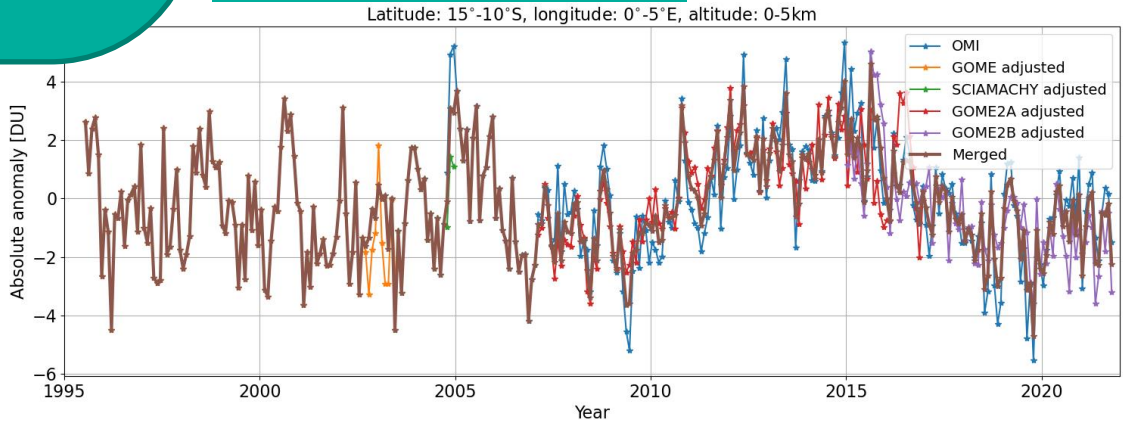
(1) Merging the profiles

- Calculate de-seasonalized anomalies
- Reference sensor OMI (2005-2020)
- Align anomalies w.r.t. OMI
- Merge anomalies and approximate uncertainties
- Use OMI seasonal cycle to calculate back the absolute values

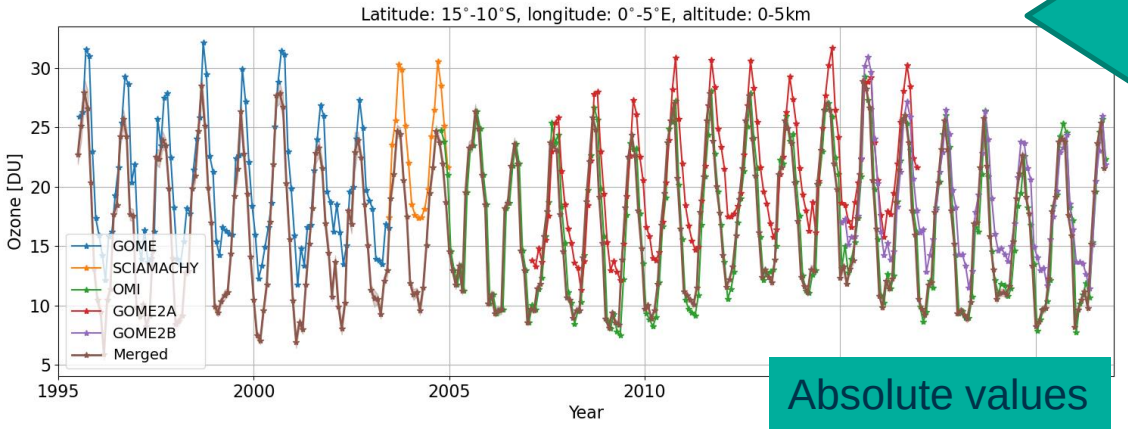
Alignment of anomalies



Merging the anomalies



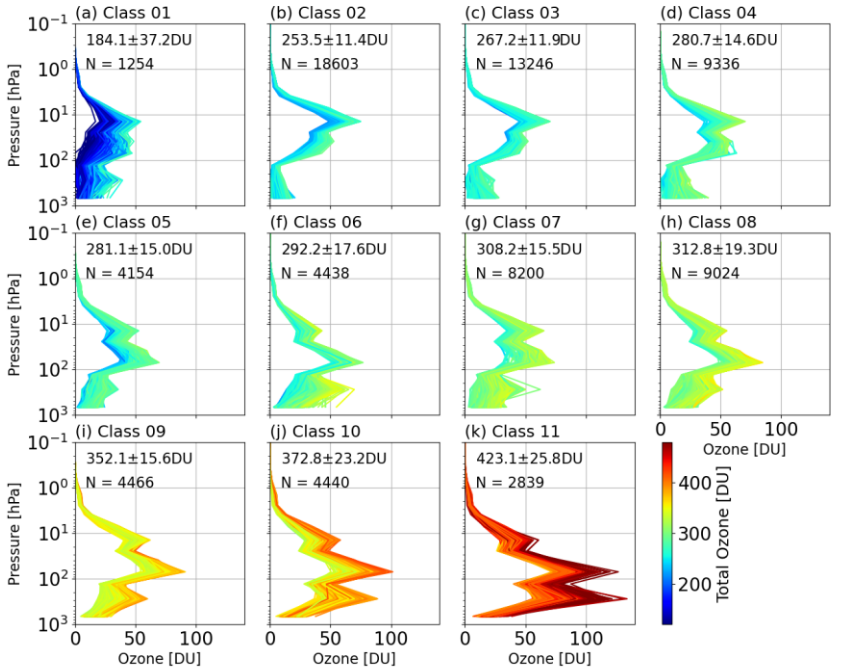
Absolute values



(2) Clustering of profiles and estimation of Jacobians

(a) Clustering:

- Use subset of 80,000 profiles
- *k*-means clustering procedure
- 11 clusters (Xu et al., 2017)



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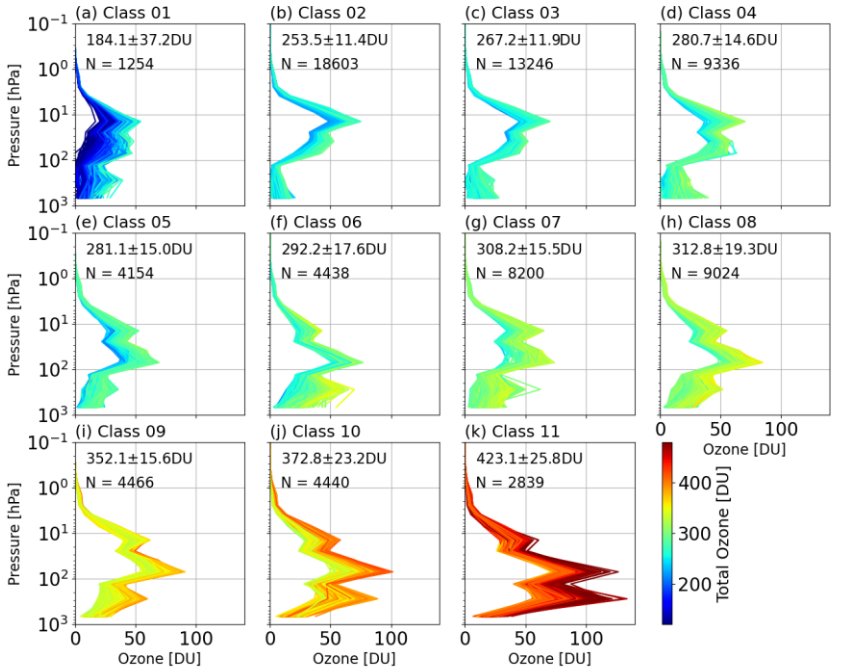
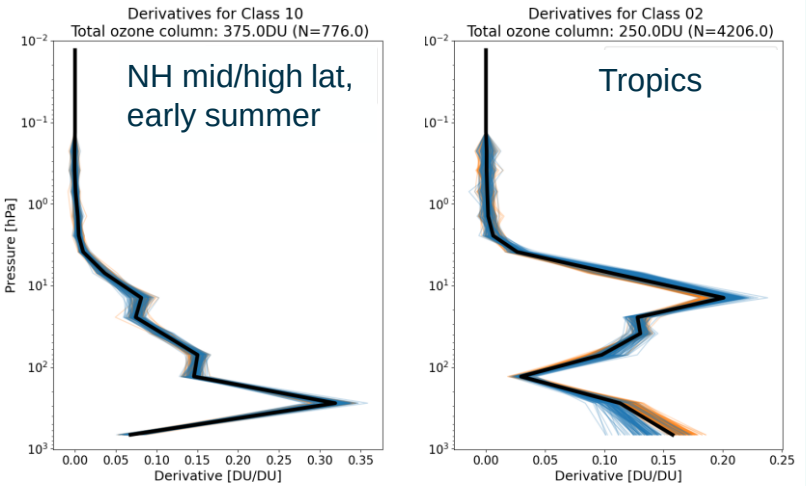


(b) NN training & Jacobians:

- One ensemble (242NNs) for each class
- Output: partial columns
- Calculate median derivative w.r.t. total ozone



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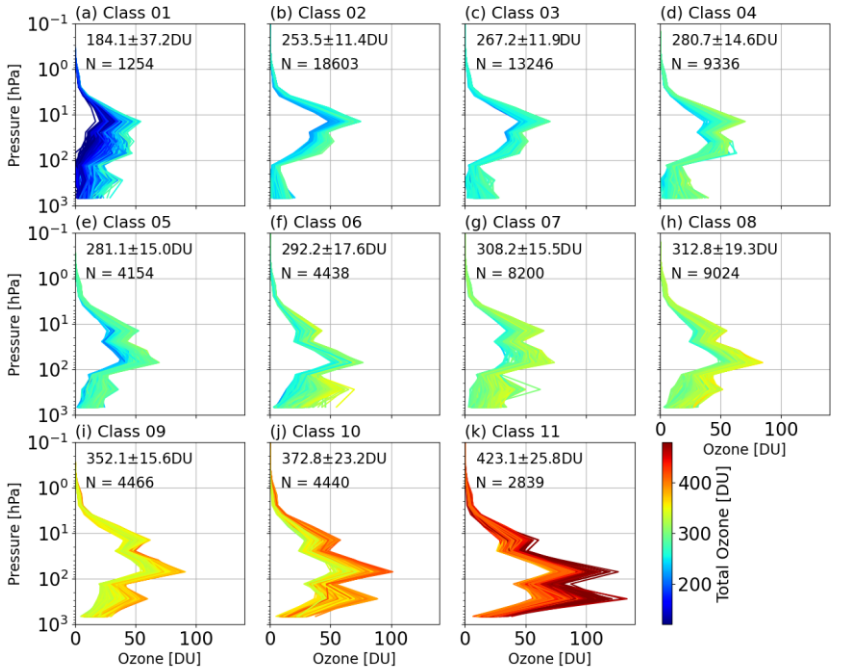

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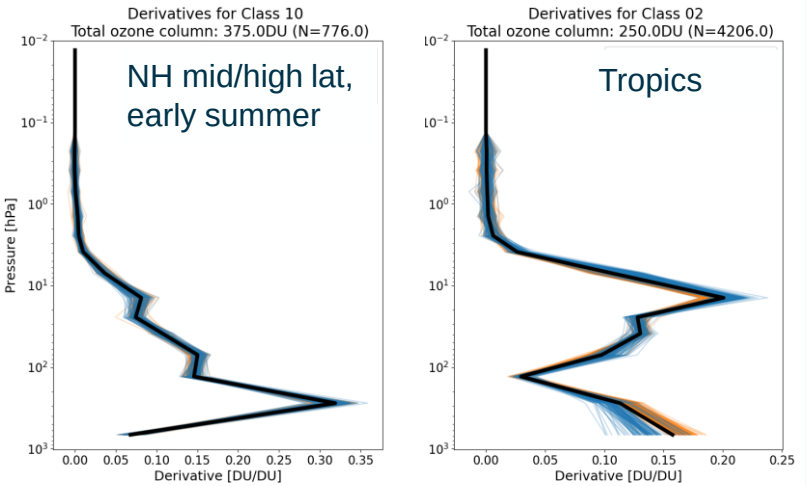
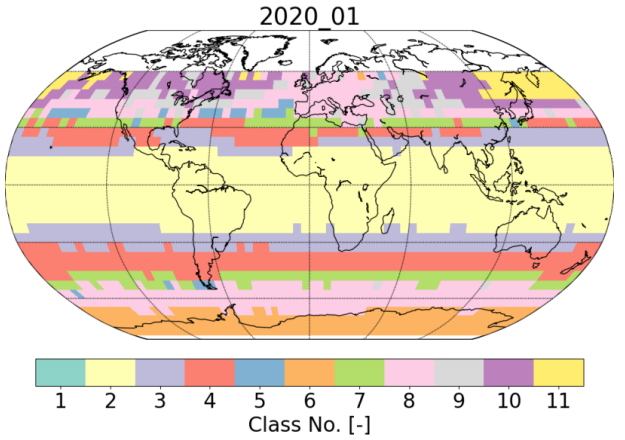




(c) Classification:

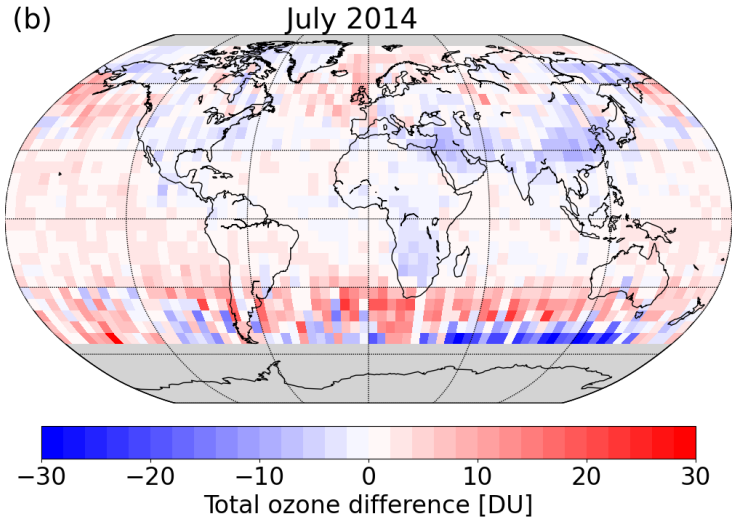
- Assign a class to each individual profile
- *k*-neighbors approach

(3) Scaling the profiles w.r.t. GTO-ECV

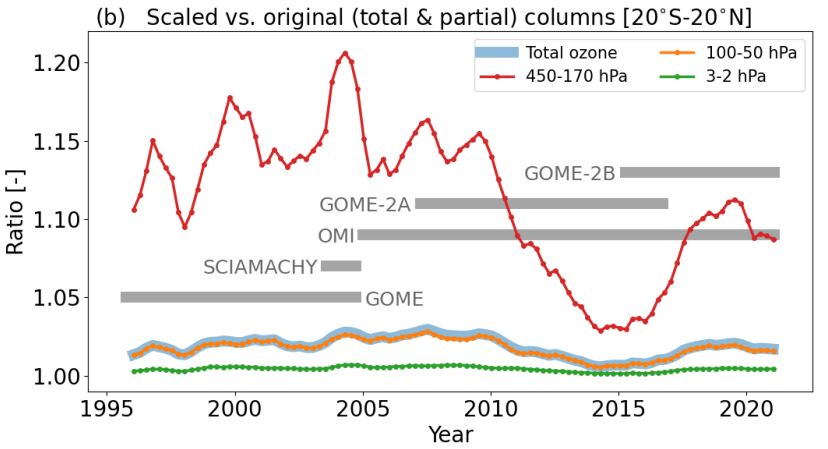
GOME-type Total Ozone Essential Climate Variable

- GOME, SCIAMACHY, OMI, GOME-2A/B/C, TROPOMI
- Common total ozone retrieval GODFIT V4 (Lerot et al., 2014)
- Merging approach: reference sensor OMI
- Merged time series: 07/1995 – 12/2023; 1°x1° monthly means
- Climate applications: trend analysis and CCM evaluation

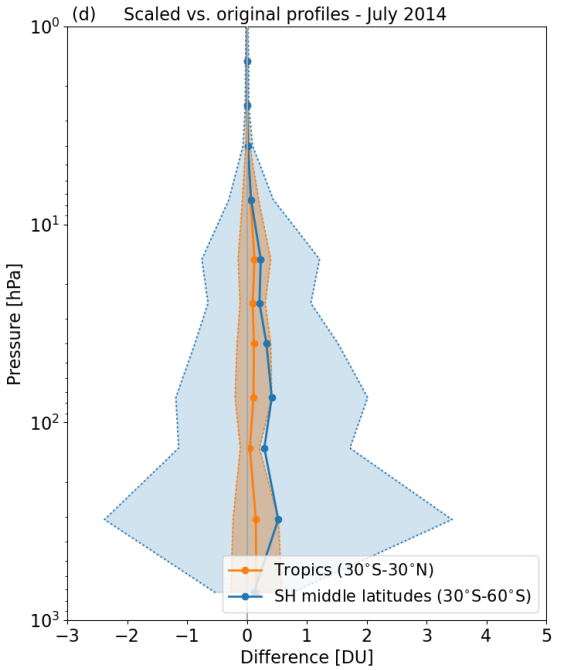
ΔTOZ = GTO-ECV - MERGED



Scaling as a function of time and altitude



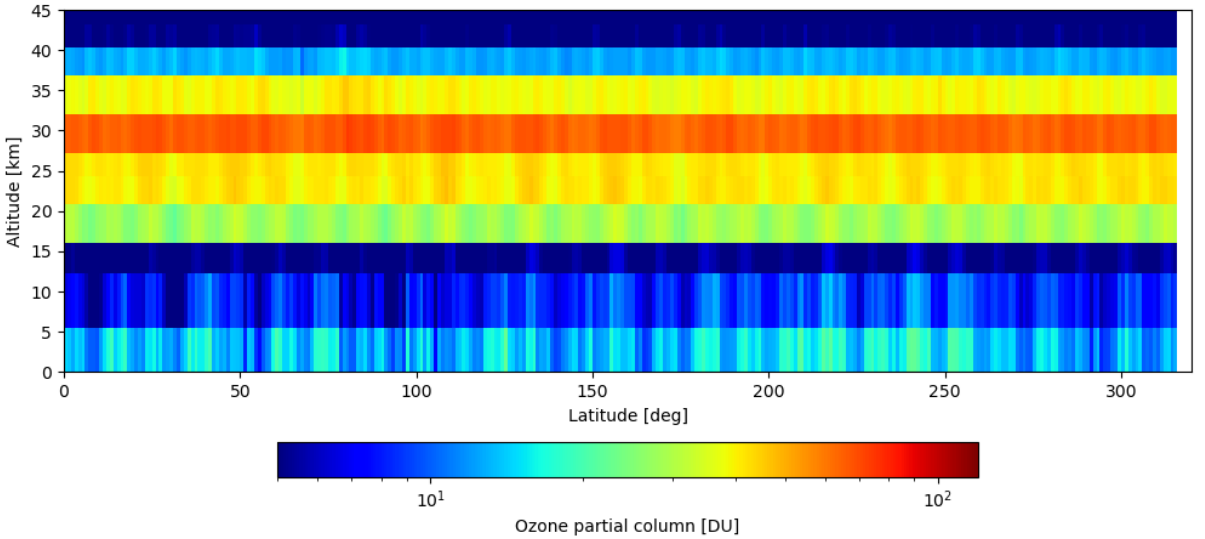
GOP-ECV(z) = MERGED(z) + ΔTOZ*d/dtoz



Summary and outlook

- GOP-ECV developed as part of ESA-CCI+ ozone based on nadir UVN sensors
- 5° x 5° monthly mean partial columns & error estimates 07/1995 – 10/2021
- Integrated ozone column fully consistent with corresponding GTO-ECV product

GOP-ECV partial ozone columns in tropics as a function of time



- Work in progress
  - Validation ongoing
  - Refine merging
  - Comparison with similar data records, e.g. merged SBUV records

Preliminary comparison with RAL Lower Tropospheric Ozone

- RAL Lower Tropospheric Column Ozone (LTCO3, surface – 450hPa) product (Pope et al., 2023)
- Bias observed, but spatial anomalies quite similar
- Temporal anomalies under investigation