GOME-Type tropical tropospheric ozone
and
S5P-BASCOE tropospheric ozone

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Overview

- Motivation
- CCD (convective cloud Differential) tropics only
  - Principle
  - Harmonisation
  - Trends
    - Comparison to EMAC simulations
- S5p-BASCOE global
  - Principle
  - Comparison to OMPS-MERRA2
  - Application to GOME-Type Ozone -ECV
Sources of tropospheric Ozone

Downwards transport ~10%

Chemical Production ~90%

NO + O3

NO2 + NO2 +
+HO2 O2

NO + O*

O* +O2

O3

NO + R’O

NO + O3

NO + RO2

VOCs + O2

Sofieva et al. 2014 DOI: 10.5194/acp-14-283-2014
Ozone pollution threatens the production of major staple crops in East Asia

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East Asia is a hotspot of surface ozone (O\textsubscript{3}) pollution, which hinders crop growth and reduces yields. Here, we assess the relative yield loss in rice, wheat and maize due to O\textsubscript{3} by combining O\textsubscript{3} elevation experiments across Asia and air monitoring at about 3,000 locations in China, Japan and Korea. China shows the highest relative yield loss at 33%, 23% and 9% for wheat, rice and maize, respectively. The relative yield loss is much greater in hybrid than inbred rice, being close to that for wheat. Total O\textsubscript{3}-induced annual loss of crop production is estimated at US$63 billion. The large impact of O\textsubscript{3} on crop production urges us to take mitigation action for O\textsubscript{3} emission control and adaptive agronomic measures against the rising surface O\textsubscript{3} levels across East Asia.

Tropospheric ozone (O\textsubscript{3}) is a secondary air pollutant produced from the oxidation of precursor gases such as nitrogen oxides and volatile organic compounds. O\textsubscript{3} is harmful to human health and ecosystems, and assess the yield losses induced by ambient O\textsubscript{3}. Estimates of yield loss due to O\textsubscript{3} are needed to be able to quantify the impact on agriculture, which is crucial for meeting food needs of the rapidly increasing population.
Haitong Zhe Sun et al., 2022: Cohort-based long-term ozone exposure-associated mortality risks with adjusted metrics: A systematic review and meta-analysis
https://doi.org/10.1016/j.xinn.2022.100246
Change in effective radiative forcing from 1750 to 2019

Carbon dioxide: 2.16 [1.90 to 2.41] W m\(^{-2}\)
Other well-mixed greenhouse gases: 0.54 [0.43 to 0.65] W m\(^{-2}\)
Ozone: 0.21 [0.18 to 0.24] W m\(^{-2}\)
Stratospheric water vapour: 0.41 [0.33 to 0.49] W m\(^{-2}\)
Albedo: 0.47 [0.24 to 0.71] W m\(^{-2}\)
Contrails & aviation-induced cirrus: 0.05 [0.00 to 0.10] W m\(^{-2}\)
Land use: -0.20 [-0.30 to -0.10] W m\(^{-2}\)
Light absorbing particles on snow and ice: 0.08 [0.00 to 0.18] W m\(^{-2}\)
Aerosols: 0.06 [0.02 to 0.10] W m\(^{-2}\)
Aerosol-cloud: -0.22 [-0.47 to 0.04] W m\(^{-2}\)
Aerosol-radiation: -0.84 [-1.45 to -0.25] W m\(^{-2}\)
Total anthropogenic: 2.72 [1.96 to 3.48] W m\(^{-2}\)
Solar: -0.02 [-0.08 to 0.06] W m\(^{-2}\)

details CCD Specifications

• definition tropospheric column, close to the top of deep convective clouds

• Two data sets:
  – 270 hPa operational S5P RPRO data
  – 200 hPa S5P internally processed

• Stratospheric column is averaged over 70°E to 190°E (=170°W)

• CCD files also contain averaged VMR

• spatial & temporal sampling, 1°x1° x 1month

• S5P data are averaged to the spatial and temporal resolution (op. 0.5° x 1° x 3 days)
Harmonisation 200 hPa

- GOME_1: delta = -1.4 ± 0.0 DU
- SCIA: delta = -2.5 ± 0.8 DU
- GOME_2A: delta = -3.2 ± 1.0 DU
- GOME_2B: delta = -3.1 ± 1.3 DU
- GOME_2C: delta = -2.7 ± 0.5 DU
- S5P: delta = -0.2 ± 0.6 DU
Harmonisation
Trend Results

- Fit Trends from 1995 to 2008
- And from 2008 to 2022

- For the trends the percentile trends are recommended
Trend between 1995 and 2007

Fit to tropospheric ozone above: global tropics

Trend: 1.271 ± 0.340 DU/decade

Increase
~ 1.23 DU/decade

~ 4.6 Tg/decade

<table>
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<th>startyear</th>
<th>Trend DU/decade</th>
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<tr>
<td>1996</td>
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<tr>
<td>1997</td>
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<td>2.64</td>
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<td>1999</td>
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Trend between 2008 and 2022

Trend: -0.668 ± 0.256 DU/decade

Decrease
~ 0.71 DU/decade
~ 2.7 Tg/decade
Trends 1995-2023

The same fit was applied for each grid point, the median slope is shown here, the dots indicate significant trends.
EMAC simulation

Trend in tropospheric column ozone

O3 column trend per decade (DU/Decade)

DU/decade

-4 -3 -2 -1 0 1 2 3 4

RD1SD Tropospheric (200hPa); 1995 - 2007

RD1SD Tropospheric (200hPa); 2008 - 2019
Mean map and temporal change

average tropospheric ozone mixing ratio
mean 1995-2023

Data Min = 21.2, Max = 55.9
Summary and outlook CCD

- Harmonized CCD tropical tropospheric data set from 1995-2022
- Mean tropical trend
  - up to 2007 +1.2 DU/decade or 4.5 Tg/decade
  - between 2008 and 2022 -0.67 DU/decade or -2.5 Tg/decade
- Update publication from 2016
TROPOMI total column ozone cloud free (cf<0.2)

Subtract stratospheric from total column

Stratospheric ozone mixing ratio 2018-09-18 between 79.6 and 74.1 hPa

BASCOE ozone profile integrated above tropopause and interpolated to TROPOMI pixel

S5P - BASCOE

Heue et al. 2022
10.5194/amt-15-5563-2022
Longitudinal
mean

- Drift between the instruments old S5P Level-1
- Good agreement in the tropics
- Reduced tropospheric ozone in summer 2020 due to Corona lockdown
- North south development in time is tilted
Applied to GTO-ECV (first quicklooks)

- Apply harmonisation factor to daily orbital CCI-GODFIT dataset
- Subtract BASCOE (BRAM2) stratospheric columns

Delta tropospheric ozone column
March 2009 mean

Graph showing the distribution of tropospheric ozone column mean (DU) with color bars indicating values from 0 to 60 DU.
2004-2019 mean climatology

tropospheric ozone column

Time: 1

tropospheric ozone column (DU)

Data Min = 12.8, Max = Infinity, Mean = 33.7
GTO-ECV internal comparisons

G2A

G2A - G2B

OMI

OMI - G2A

G2B

G2A

Date

Latitude

20130101 20140101 20150101 20160101 20170101 20180101

20080101 20100101 20120101 20140101 20160101 20180101

DU

0 10 15 20 25 30 35 40 45 50
Summary  S5p-BASCOE

- Global tropospheric ozone columns are retrieved from S5P-BASCOE data
- Same algorithm is currently applied to GTO-ECV
Harmonisation

- The mean difference (given in the figures) and the mean annual cycle relative OMI is subtracted/added to the measurements.

- For GOME_1 the harmonized data set (SCIAMACHY) is used as reference. Due to short period of tropical overlap (one year) we use the mean difference between GOME-1 and SCIAMACHY here.
average tropospheric ozone mixing ratio

change in tropospheric ozone (ppb)

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average tropospheric ozone mixing ratio
(2021-Jul 23) minus (1995-2023)

change in tropospheric ozone (ppb)
Beside the linear function a set of harmonic functions and the indices for ENSO (MEI), QBO and Solar flux were fitted.
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Harmonisation 270 hPa

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delta = -2.8 ± 0.5 DU

SSP
delta = 1.1 ± 0.8 DU
Harmonisation 200 hPa

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- **S5P**
  - delta = -0.2 ± 0.6 DU
The sonde data are integrated up to 270/200 hPa and averaged over one month before comparing to the grid cell (1°x1°) that contains the sounding station.
Validation Natal

very good agreement for May
Larger deviation for higher columns (Aug.-Sep.)
Except for the east Asian stations (Kuala Lumpur and Java) we observe a positive bias (~20%) relative to the sondes. This finding is independent of the CCD top level (200/270 hPa)