Total Ozone CEOS AC-VC wrap-up Comparison of GTO-ECV and Adjusted-MERRA

Wissen für Morgen

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Outlook

Motivation

- CEOS VC-02 Ozone dataset validation and harmonization

- Gridded Total Ozone
 - GTO-ECV
 - Adjusted-MERRA
- Comparison results
- Summary



GTO-ECV – GOME-type Total Ozone Essential Climate Variable

- Combination of GOME/ERS-2, SCIAMACHY/ENVISAT,
 OMI/AURA, GOME-2 on MetOp-A and MetOp-B
 - Differences: spatial and temporal sampling
 - Level 2 based on common retrieval algorithm GODFIT version 4 (Lerot et al., JGR, 2014) and fully validated (Garane et al., AMT, 2018)
- Developed as part of the ESA Climate Change Initiative ozone project (phase-1: 2010-2013, phase-2: 2014-2017)
- Merging approach
 - Inter-sensor calibration w.r.t. OMI (excellent long-term stability & long overlap periods)
 - Correction as a function of latitude and time
 - GTO-ECV method described in Coldewey-Egbers et al., AMT, 2015





GTO-ECV – **Product** and **Validation**

- GTO-ECV contains 1°x1° monthly means
 - total ozone columns
 - standard deviation
 - standard error
- Data freely available (July 1995 to December 2018)
 - <u>http://www.esa-ozone-cci.org</u>
- GTO-ECV is regularly updated and expanded in time as part of the ECMWF Copernicus Climate Change Service (C₃S) ozone project
- Geophysical validation using Dobson, Brewer, and SAOZ ground-based data (Garane et al., AMT, 2018)
 - Negligible long-term drift. Dobson: -0.1±0.1
 %/decade and Brewer: 0.2±0.1 %/decade





MERRA-2

MERRA: MODERN-ERA RETROSPECTIVE ANALYSIS FOR RESEARCH AND APPLICATIONS

- Based on the GEOS-5 assimilation system

– Input:

 Ozone profiles & total column (SBUV, MLS, OMI), SST, winds, temperature, pressure (from radiosondes, aircraft, satellites)

- Output:

- 72 vertical layers (about 1km)
- Summed ozone profile
- 576 x 360 gridded data (0.625 x 1 degree)
- Every hour (total ozone)
- 1979 to present
- Global daily maps (pole to pole)





Adjusted-MERRA

- Normalize to SBUV MOD to remove biases
- 5 degree zonal means
 - Total ozone
 - Standard deviation





Adjusted-MERRA vs. GTO-ECV – 5° zonal means from 1995 to 2018



Adjusted-MERRA vs. GTO-ECV – Total Ozone and Standard Deviation





Drift in total ozone difference for three time periods:

- 1995-2018 (black)
 - Negative and significant for all latitudes, except 30°-40°N
 - Drift < 1.0%/dec
- 1995-2004 (blue)
 - Not significant for almost all latitude bands
- 2004-2018 (orange)
 - Negative and significant south of 40°S

Adjusted-MERRA vs. GTO-ECV – Seasonal Cycle



Mean difference per latitude belt and season:

_atitude	Annual	Winter	Spring	Summer	Autumn
60N-90N	0.0 ± 1.5%		0.0 ± 1.5%	0.9 ± 1.1%	-0.8 ± 1.5%
30N-60N	-0.9 ± 1.5%	-1.7 ± 2.0%	-0.7 ± 1.4%	0.1 ±1.0%	-0.9 ± 1.4%
30N-30S	-0.6 ± 1.1%	-0.8 ± 1.2%	-0.5 ± 1.1%	-0.8 ± 1.1%	-0.5 ± 1.1%
30S-60S	-1.5 ± 1.3%	-1.3 ± 1.1%	-1.6 ± 1.3%	-1.4 ± 1.7%	-1.5 ± 1.3%
60S-90S	-1.3 ± 2.0%	-0.6 ± 1.4%	-1.0 ± 1.5%		-1.8 ± 3.6%



Adjusted-MERRA vs. GTO-ECV – Seasonal Comparison





Adjusted-MERRA vs. GTO-ECV – Seasonal Differences

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Standard Deviation Difference [DU]



Adjusted-MERRA vs. GTO-ECV – PDFs



 Total Ozone: Difference (<10/2004): -0.5 ± 1.7% Difference (>10/2004): -1.1 ± 1.2%

 Standard Deviation: Difference (<10/2004): -0.6 ± 3.3DU Difference (>10/2004): -1.8 ± 1.7DU

Adjusted-MERRA vs. GTO-ECV – Anomaly Correlation



- Compute anomalies (w.r.t. 1995-2018 period) for each data record and each grid box
- . Compute correlation coefficient $\boldsymbol{\rho}$ for each grid box
- 97.5% of grid boxes: ρ>0.90, median: ρ=0.96, min: ρ=0.76
- Gaps in GOME data
- ? (Correlation with region of max. negative bias, p.6, left panels)
- See next slide (2 selected longitudes)

Adjusted-MERRA vs. GTO-ECV – Anomalies as function of time



South

Atlantic

- Ozone anomalies [DU] vs. time
- Subtracted seasonal cycle 1995-2018
- Blue: GTO-ECV, green: Adjusted-MERRA
- 7 Latitudes: 72.5°N, 42.5°N, 12.5°N, 2.5°N, 12.5°S, 42.5°S, 72.5°S (from top to bottom)
- 2 Longitudes: 32.5°W (left), 152.5°E (right)

Adjusted-MERRA vs. GTO-ECV – Interannual Variability



GTO-ECV anomaly standard deviation (October)



20

24

Standard deviation [DU]

12

8

16

28 32

36

40

Adjusted_MERRA anomaly standard deviation (April)









Adjusted-MERRA vs. GTO-ECV – Moments of anomalies: skewness



Adjusted-MERRA vs. GTO-ECV – Moments of anomalies: kurtosis





Adjusted-MERRA vs. GTO-ECV – EOF analysis in tropics (25°N-25°S)



EOF analysis in tropics •

- 6 - 4

2

0

F 2 0 0 2 -2 -2

-4

-6

- 3

1 [DN] -103

EOF [DU]

-3

2

0

2

0

1 0 1 EOF [DU]

-2

- 5°x5° total ozone columns: detrend, deseasonalize, and smooth (Savitzky-Golay smoothing filter, window length 13 months)
- First four EOFs account for ~92% of total variance
- Spatial patterns for Adjusted-MERRA and GTO-ECV agree quite well



Adjusted-MERRA vs. GTO-ECV – EOF analysis in tropics (25°N-25°S)

GTO-ECV

Adjusted MERRA

10²



- PC time series and Fourier spectra show very ٠ good agreement
- PCs can be attributed to different modes of • climate variability (green curves):
 - PC 1: correlates with QBO index at 30hPa, frequency = 28 months
 - PC 2: moderate correlation with solar cycle, frequency \approx 138 months
 - PC 3: correlation with "QBO-annual beat"-٠ frequency (21 months) => interaction of QBO and annual variation
 - PC 4: correlation with ENSO, frequency > ٠ 3.5 years

Summary

– Independent and complementary total ozone data records (5° × 5° monthly mean):

- Adjusted-MERRA (start in 1979 and to be continued with OMPS/SNPP)
- GTO-ECV (start in 1995 and to be continued with TROPOMI/S5P and S5)
- Excellent agreement between Adjusted-MERRA and GTO-ECV
 - Mean difference is -0.9±1.5%
 - Before October 2004: -0.5±1.7%
 - After October 2004: 1.1±1.2%
 - Small negative drift in the differences does not exceed 1% decade-1
 - Very high correlation of the temporal and spatial structures
 - Remarkable agreement on interannual variability and strong correlation with QBO, ENSO, solar cycle
- The total ozone part of CEOS VC-02 is now completed

Comparison of GTO-ECV and Adjusted-MERRA total ozone columns from the last two decades and assessment of interannual variability

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Adjusted-MERRA vs. GTO-ECV – Ozone trends



- MLR: Coldewey-Egbers et al., 2014, GRL
- O3(m) =
 A + B*m + C*SF(m) + D*QBO30(m) + E*QBO50(m) + F*MEI(m) + X(m)
- Drift in total ozone difference (p.3) -> difference in trend estimate



Adjusted-MERRA vs. GTO-ECV – QBO30, QBO50, solar cycle, and MEI fit coefficients



