Assimilated total ozone record from 30 year of UV-VIS satellite observations

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Outline

- Data sources of total ozone
- Merging level 2 data => multi-sensor reanalysis level 2
- Data assimilating => multi-sensor reanalysis level 4
- Results and analysis
- Conclusions
Objective of the Total Ozone Record

• Objective:
  – Constructing long-term consistent and complete ozone record of 30 years
  – Applications: ozone monitoring, trend studies and long-term data sets of UV radiation.

• All available satellite retrievals are assimilated in a chemical-transport model to achieve complete global and temporal coverage
  – For data assimilation we need unbiased input data
  – All 14 satellite datasets are corrected for biases with ground observations as reference
### Available level 2 ozone data (UV-VIS)

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Time Period</th>
<th>Version</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOMS Nimbus 7:</td>
<td>1978-1993</td>
<td>TOMS v.8</td>
<td>NASA</td>
</tr>
<tr>
<td>TOMS EarthProbe:</td>
<td>1996-2002</td>
<td>TOMS v.8</td>
<td>NASA</td>
</tr>
<tr>
<td>TOMS Meteor 3:</td>
<td>not yet available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOMS ADEOS:</td>
<td>not available</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBUV 7, 9, 11, 16:</td>
<td>1978-2004</td>
<td>SBUV v.8</td>
<td>NOAA</td>
</tr>
<tr>
<td>GOME:</td>
<td>1995-2008</td>
<td>GDP4, TOGOMI</td>
<td>ESA/DLR, KNMI</td>
</tr>
<tr>
<td>SCIAMACHY:</td>
<td>2002-2008</td>
<td>SGP3, TOSOMI</td>
<td>ESA/DLR, KNMI</td>
</tr>
<tr>
<td>OMI:</td>
<td>2004-2008</td>
<td>TOMS, DOAS</td>
<td>NASA, KNMI</td>
</tr>
<tr>
<td>GOME-2:</td>
<td>2007-2008</td>
<td>GDP v.4.2</td>
<td>EUMETSAT/DLR</td>
</tr>
<tr>
<td>WOUDC:</td>
<td>1978-2008</td>
<td>Brewer(3,4), Dobson, Filter</td>
<td></td>
</tr>
</tbody>
</table>
Used satellite observations

Monthly averaged data.
Shown is “satellite minus MSR” level2 data
Location: The Netherlands
Merging Level 2 data
Constructing a multi-sensor level 2 data set

Multi-Sensor Reanalysis (MSR)

Reference data set:
- Data from 233 ground stations available in WOUDC
- 91 stations selected with a long dataset
- Dobson, Brewer(3,4)–instruments (no filter-instruments used)
- Dobson corrected for temperature dependence (Kerr et al., JGR, 2002)

Correction:
- Generating overpass data for all 14 satellite data sets for the selected 91 stations.
- Fitting all overpass data as function of viewing angle, solar zenith angle, effective temperature, time(trend) and an offset

=> MSR level 2 data
Single-sensor assimilation vs. Ground observations

![Graph showing data points for different sensors over time](image)
Corrected level 2 data vs. Ground observations

![Graph showing corrected level 2 data vs. ground observations.](image)
San Martin
-68.130 South
-67.106 East
Brewer MKIV

4 parameter fit
- Offset
- Trend
- Season

Not corrected

Corrected
Data assimilation (level 4 data)
Ozone assimilation at KNMI

Chemistry-transport assimilation model TM3DAM:
• TM model with 44 layers
• ECMWF analyses of winds, temperatures
• Stratospheric chemistry parametrizations (Cariolle v.2.1)
• Kalman-type data assimilation scheme

• Near-real time and forecasts of SCIAMACHY/OMI/GOME-2
• Operational analyses and forecasts since 2000:

http://www.temis.nl
http://www.gse-promote.org

Forecast error modelling

Sub-optimal Kalman filter approach:

Forecast covariance = time-dependent variance * fixed correlations

Correlation matrix:
  function of the distance only
  functional form determined from OmF statistics

Variance:
• Model error, growth of the forecast variance with time
• Advection of the forecast variance
• Analysis equation of forecast variance
Typical forecast performance of MSR: OmF and OmA

January 2008

\( \text{rms(OmF)} \) typically 2%

bias OmF (black) and OmA (red) are less than 1%
 OmF of the Multi-Sensor Reanalysis (MSR)

Gridded for January 2008
MSR level 4 averaged over zonal bands

Period of 1978-2008
TEMIS.NL

- Ozone hole service:
  - Assimilated ozone
  - NRT ozone
  - Forecasts
Mass deficit in the ozone hole

Average ozone loss in the period 21 to 30 Sept

Ozone loss (megaton) vs Year

Year:
- 1979
- 1980
- 1981
- 1982
- 1983
- 1984
- 1985
- 1986
- 1987
- 1988
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008

Ozone loss (megaton):
- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
Conclusions

Merged level 2 data set
• 14 datasets from TOMS, SBUV, GOME, SCIAMACHY and OMI
• Reference: WOUDC data of 91 stations (Brewer and Dobson)
• Correction as function of viewing angle, solar zenith angle, temperature, time and an offset

Ozone column assimilation:
• Level 2 ozone assimilated with TM3DAM (sub-optimal Kalman filter)
• OmF bias < 1%, rms ~ 2%
• Long-term assimilated ozone reanalysis from 30 year satellite data
• Data available via temis.nl or gse-promote.org

Outlook:
• Reprocessing with new level 2 data.
• Approach can also be used for o3 profiles.