Long-term time-series of height-resolved ozone for nadir-uv spectrometers: CCI and beyond

Richard Siddans, Georgina Miles, Barry Latter, Brian Kerridge

RAL Remote Sensing Group
Earth Observation & Atmospheric Science Division, RAL Space, Harwell
& NERC’s National Centre for Earth Observation

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Introduction

• Retrieval scheme developed at RAL to infer ozone profiles, with tropospheric sensitivity, from nadir-uv spectrometers.

• Scheme selected to provide the nadir-uv-profile data for ESA’s Climate Change Initiative (CCI) to generate multi-year data sets from GOME-1, GOME-2, SCIAMACHY and OMI
  – Re-processed versions of this data also to feed into Copernicus Climate Change service (C3S)

• Scheme forms the basis for development of the operational processors for Sentinel 4 & 5

• This presentation to outline:
  1. Brief overview of the retrieval scheme
  2. Status of the ESA-CCI multi-satellite datasets
  3. Future plans
Tropospheric ozone from uv sounders


- Spectral fitting to <0.1% RMS precision in T-dependent Huggins bands extends information into troposphere

![GOME-2A orbit Cross Section (25th Aug 2008)](image)

- Bias against sondes (%)
- Standard Deviation
GOME-2 data used in quantitative study of Mediterranean summer ozone maximum with TOMCAT by N. Richards et al, ACP, 2013.

- Increasing $NO_2 +$ organics was able to reproduce observed levels.
ER-5 Selection

Analysis – Sonde RMS difference
30-60N Aug-Oct’08

CTRL - assimilates O₃ column & SBUV 6 partial columns

• RAL’s GOME-1 & -2A data sets selected by ECMWF for ERA-5
V1 Time-series of ozone (30-60N) from 1995-2013

6-12 km column

Retrieval
A priori
MACC reanalysis/NRT
MACC + AK

0-6 km column

GOME-1
SCIAMACHY
GOME-2

1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

MACC reanalysis/NRT
MACC + AK

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L3 + L4 products in CCI

• In CCI L3 and L4 products being generated by KNMI from the RAL L2 files

• L3 files are monthly 1x1 degree binned files containing
  – Retrieval-error weighted mean ozone mixing ratios + sub-column amounts (DU) integrated between the retrieval levels (surface, 450, 170, 100, 50, 30, 20, 10, 5, 3, 2 hPa)
  – Estimated standard error in the mean values

• L4 files generated by assimilating profiles into TM5 model, to produce.
  – Kalman filter used, taking into account retrieval averaging kernels
  – Fills observation gaps
  – Can generate complete daily fields, including evolving estimated uncertainty

• L3 + L4 to combine information from the multiple sensors where data-sets overlap
L3 + L4 products in CCI

L3 surface-450 hPa sub column (DU) for Jan 2008

L3 surface-450 hPa standard error (DU)

L4 total ozone (DU) for 31 Jan 2008

L4 total ozone uncertainty (DU)

Figs. From J. van Peet, KNMI
CCI processing status / Next steps

- First full versions of GOME-1, GOME-2, SCIA, OMI L2 data generated
- Known shortcomings of existing product (mainly relating to troposphere):
  - GOME-1 relatively stable long term, but has occasional day-day “jumps” due to diffuser spectral features – to be fixed in next version via “soft calibration” (empirical correction from time-series cf MACC in remote pacific)
  - GOME-2 affected by changes in slit-function over mission and within orbits, leading to biases which evolve over time and tendency for negative bias in southern hemisphere
    - To be improved by refining treatment of in-orbit slit-function variations
    - Time dependence over mission may require soft calibration cf OMI
  - SCIAMACHY has problems after ~2008, related to degradation
    - Re-processing with latest “m-factors” underway
- Other algorithm updates implemented including use of updated uv cross-sections and refinement of Ring-effect modelling
- Improved data-sets now expected by end of year (some earlier)
Future: Improving vertical resolution in the UTLS

GOME-2 (UV) + IASI (TIR) Joint retrievals
Future: Use of Chappuis for near-surface ozone

- Scheme developed to infer total ozone from GOME-2 Chappuis band, with better near-surface sensitivity than UV.
- Quality of Chappuis Ozone approaching level where this sensitivity can be leveraged to distinguish near-surface ozone.

Relative difference, August 2008, using cloud-cleared radiances, corrected for stratospheric differences.

August 2008, TOMCAT CTM mean boundary layer (0-2km) ozone as a fraction of total column.
Future: Tropospheric Ozone from Sentinel 4

- S4 has no measurements of Hartley band below 305nm, which provides stratospheric profile information in all previous
- Basis for S4 scheme to deliver tropospheric ozone without this spectral range being established via ESA S4 L2 processor development

**S5 simulation (270nm+)**
- Profile degrees of freedom: 6.5
- 0-6km column uncertainty: 30%
- 0-12km uncertainty: 11%
- Averaging kernels

**S4 simulation (305nm+)**
- Ozone DFS: 2.74
- 0-6km column uncertainty: 30%
- 0-12km uncertainty: 15%
- Averaging kernels
Summary & Future Prospects

- Global ozone (1995-2015) data sets including tropospheric ozone being produced for ESA CCI using RAL scheme, with L3 + L4 data being generated by KNMI
- Scheme also operated in near-real time at RAL, providing data for assimilation trials at ECMWF
- In current version, tropospheric ozone affected by instrumental artefacts, limiting assessment of trends
  - Refinements in progress to improve consistency for exploitation by C3S, TOAR, CCMi
- R&D in progress
  - combine IR with UV to improve vertical resolution in UTLS
  - Exploit ozone visible band to increase near-surface sensitivity
- Scheme being adapted to be used as basis for the Sentinels 4 + 5 operational processors
Thank you for your attention

http://www.ralspace.stfc.ac.uk/remotesensing
Contact: richard.siddans@stfc.ac.uk

ESA – CCI Ozone Nadir product:
http://www.esa-ozone-cci.org/?q=node/164

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