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Remote Sensing Group

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

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& NERC's National Centre for Earth Observation

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Science & Technology Facilities Council

ESA CCI O3

Introduction

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- 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

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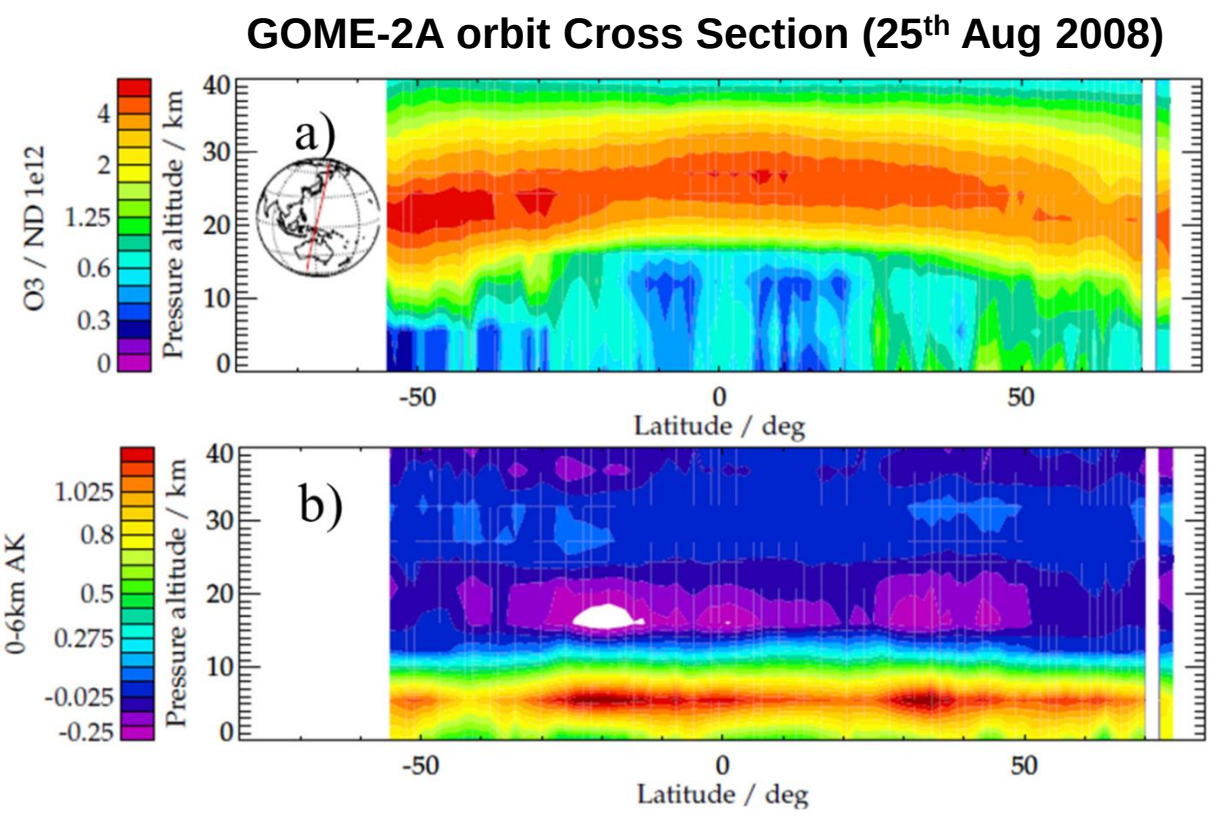
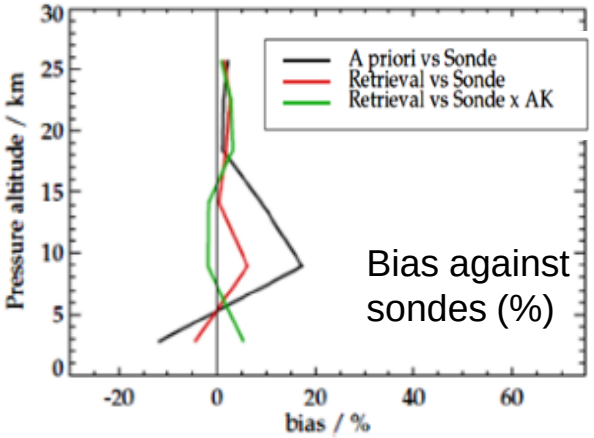
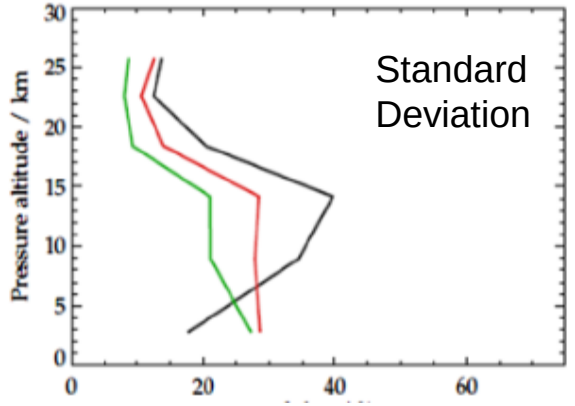
- Exploits wavelength dependence of ozone UV absorption in Hartley and Huggins bands to retrieve height-resolved information R.Munro *et al*, Nature (1998); G.Miles *et al.*, AMT (2015)
- Spectral fitting to <0.1% RMS precision in T-dependent Huggins bands extends information into troposphere







Example: Tropospheric ozone from GOME-2

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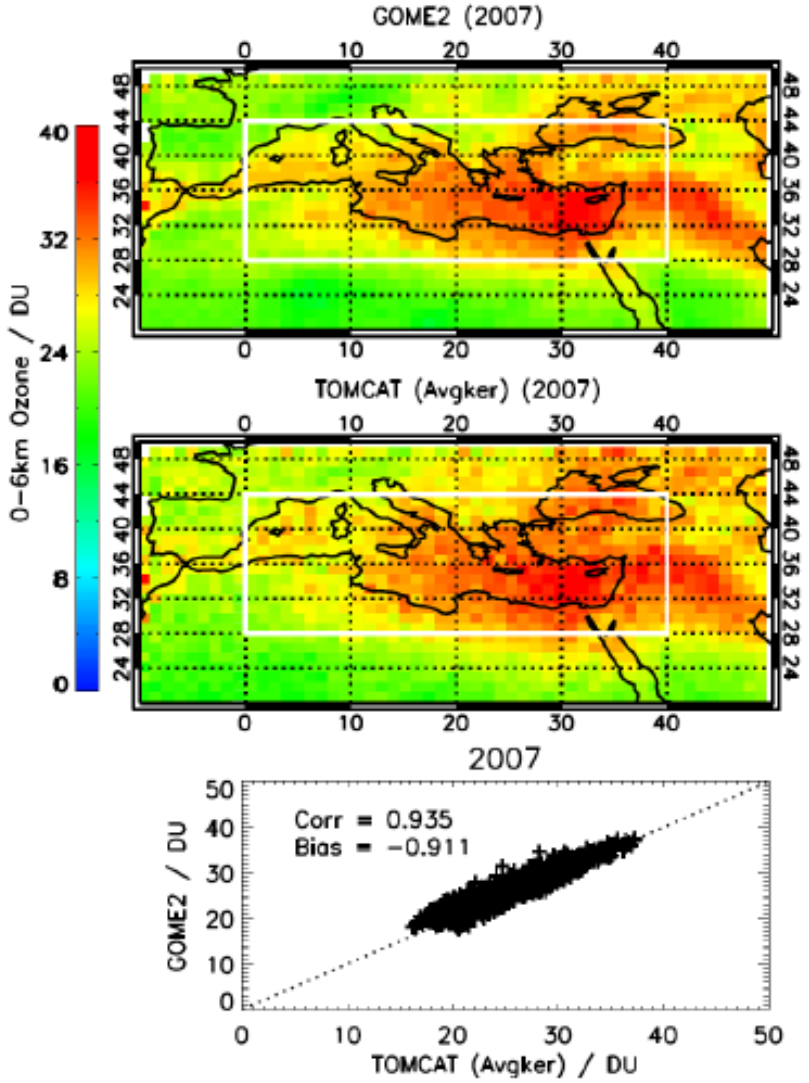

- GOME-2 data used in quantitative study of Mediterranean summer ozone maximum with TOMCAT by *N. Richards et al, ACP, 2013.*
  - *Increasing NO_2 + organics was able to reproduce observed levels.*

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ERA-5 Selection

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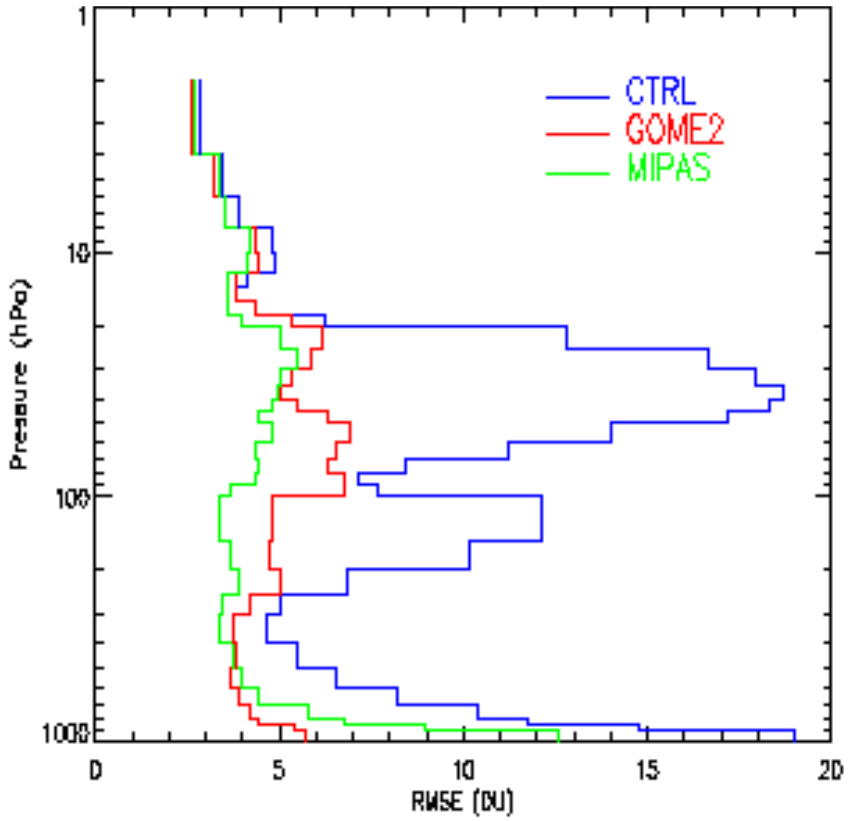
Analysis – Sonde RMS difference
30-60N Aug-Oct'08



CTRL - assimilates O_3 column & SBUV 6 partial columns

- RAL's GOME-1 & -2A data sets selected by ECMWF for ERA-5
  R.Dragani, CCI Climate Modelling User Group Report, July 2015

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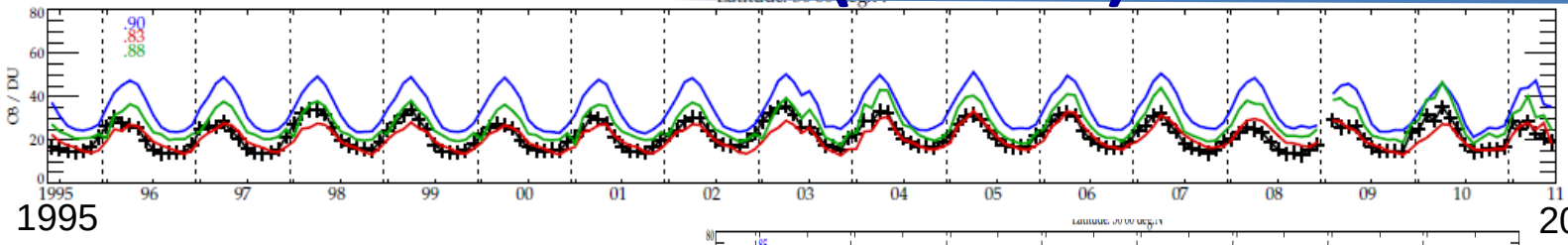
V1 Time-series of ozone (30-60N) from 1995-2013

6-12 km column

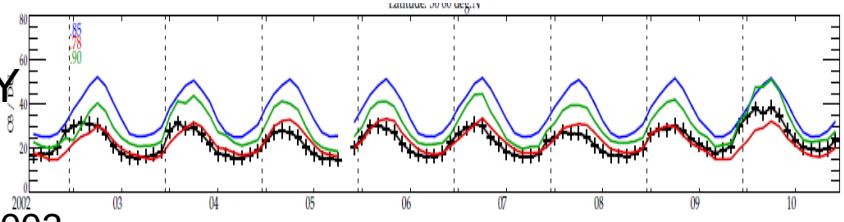


GOME-1

1995

2011

SCIAMACHY



2002

2013

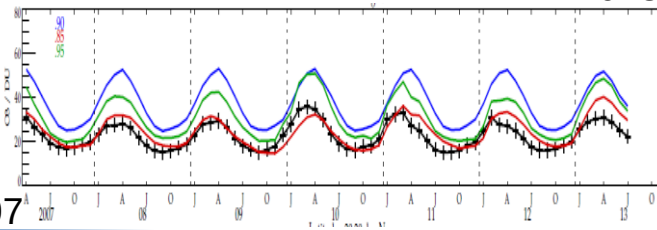
Retrieval

A priori

MACC reanalysis/NRT

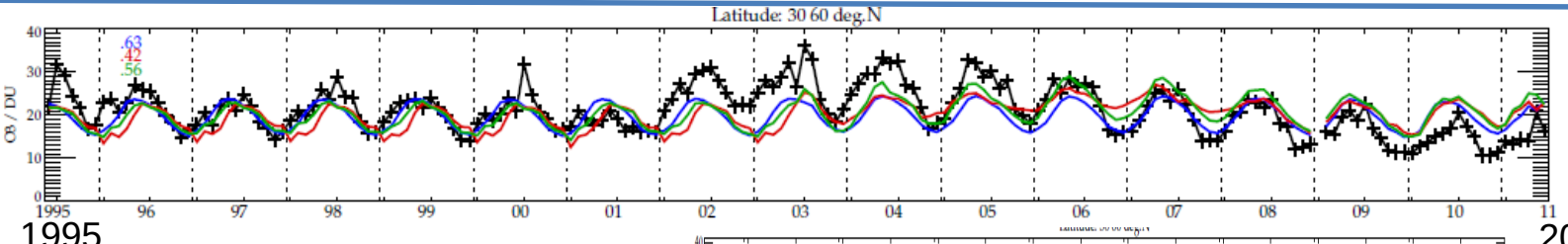
MACC + AK

GOME-2



2007

0-6 km column

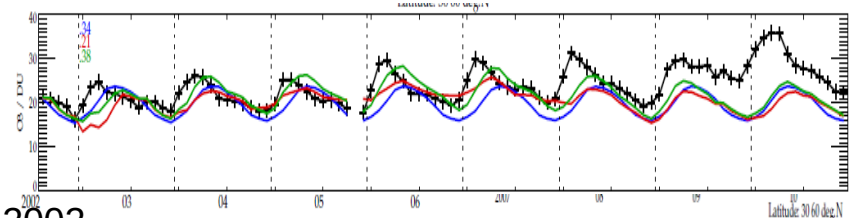


GOME-1

1995

2011

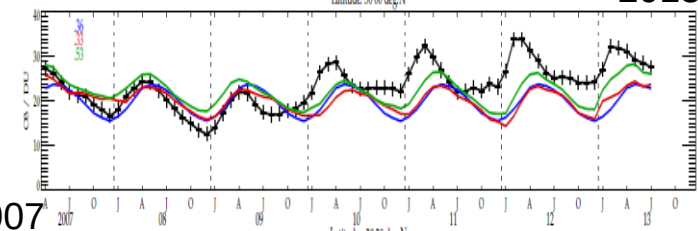
SCIAMACHY



2002

2013

GOME-2



2007

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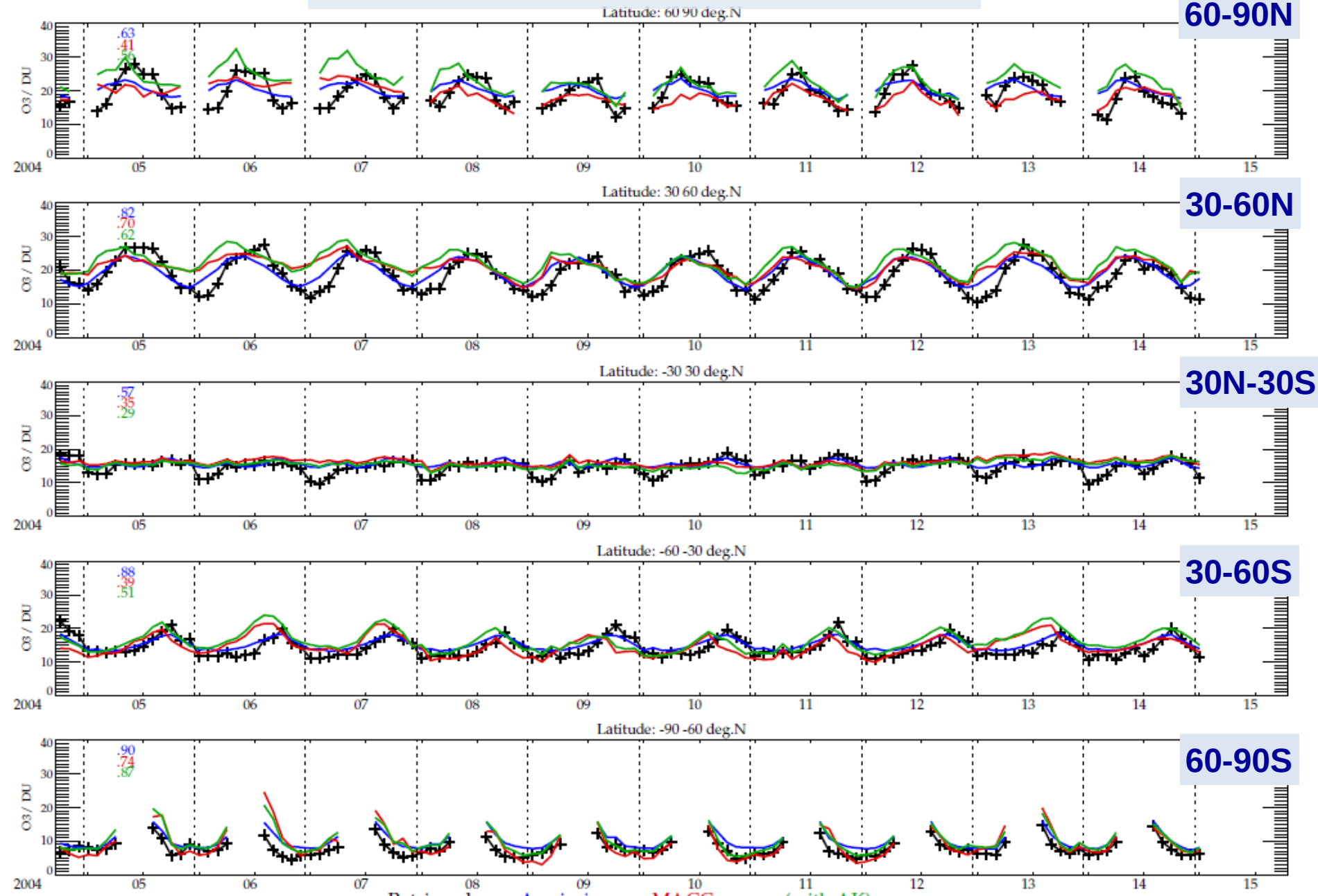
OMI Ozone: Sub-column 0-6km



omi_aura-solopt2-rat0-lip-samp1a2-samp2b2-cmacc-sfg2s-rsfw2-ng37-rat0-misr0-noxfr-retpoly-s5xs-ring3-nomr-newfm2-b2leak_ncld_mcost200_mcb1
OMI_AURA; 0-6km column; ; Cloud cleared

L3 + L4 products in CCI

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- 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

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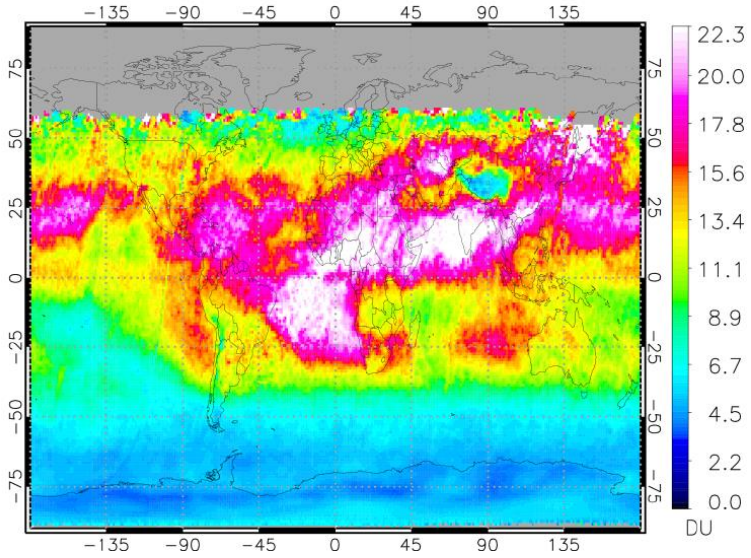
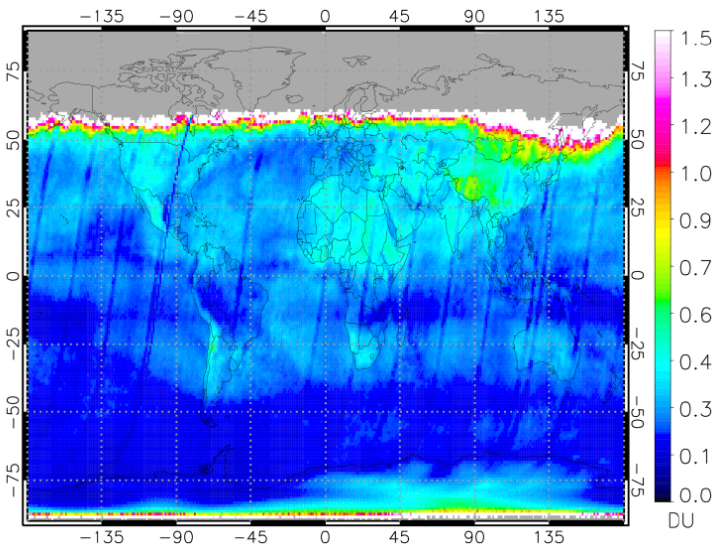
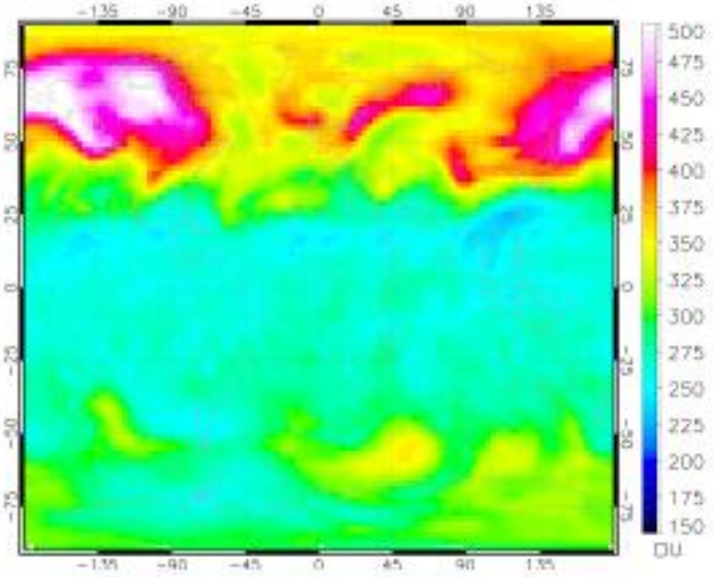
L3 surface-450 hPa sub column (DU) for Jan 2008



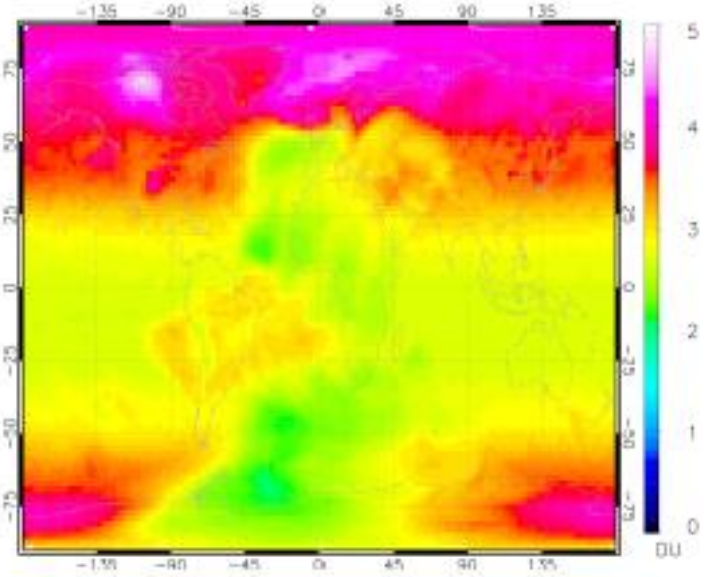
L3 surface-450 hPa standard error (DU)



L4 total ozone (DU) for 31 Jan 2008



L4 total ozone uncertainty (DU)



Figs. From
J. van Peet,
KNMI

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CCI processing status / Next steps

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- 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

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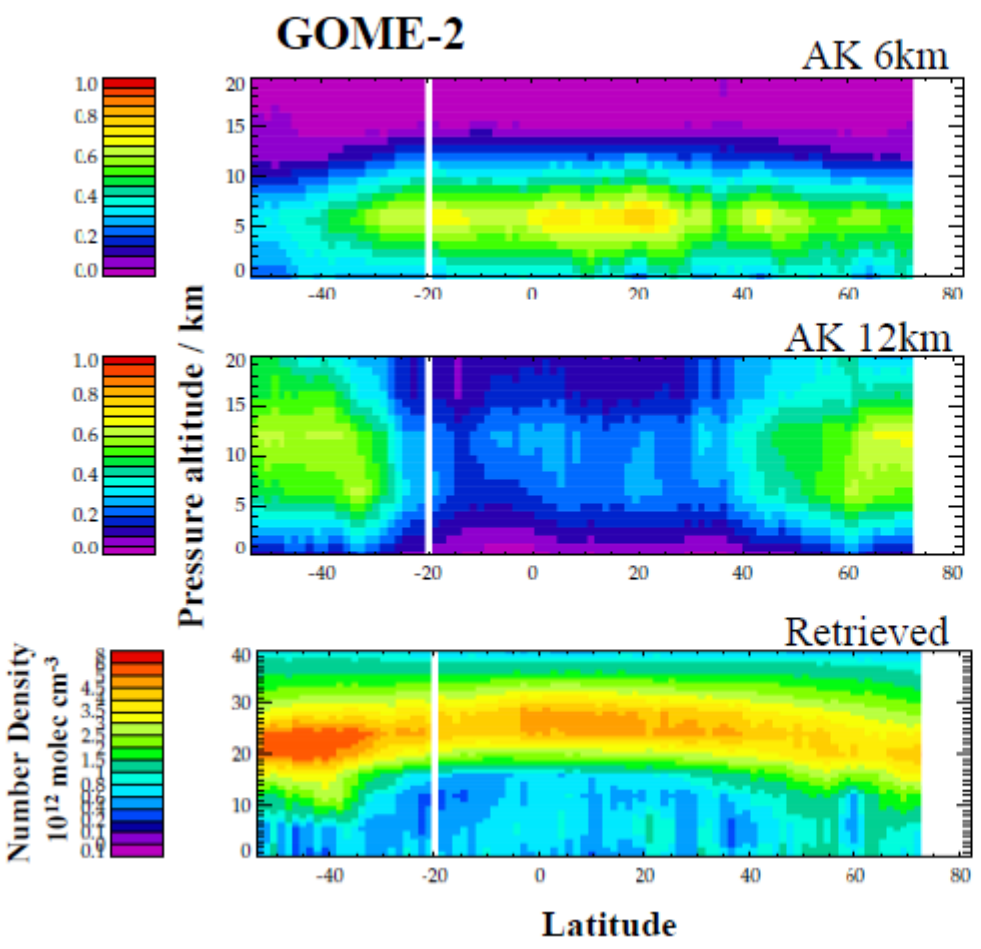
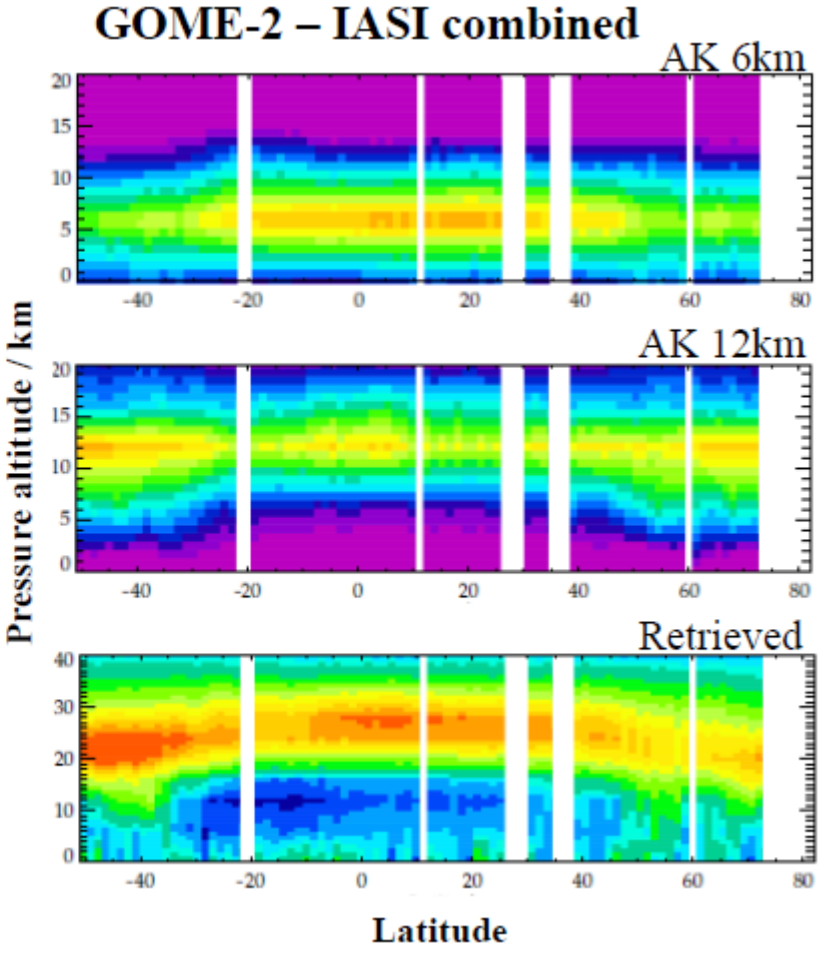
GOME-2 (UV) + IASI (TIR) Joint retrievals





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Future: Use of Chappuis for near-surface ozone

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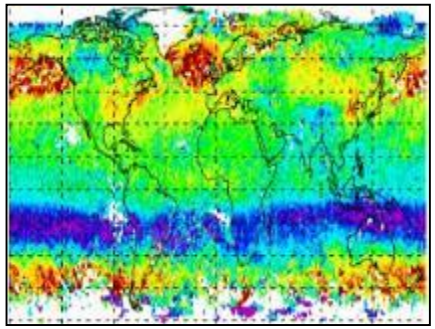
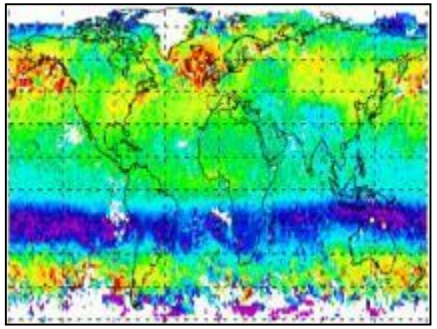
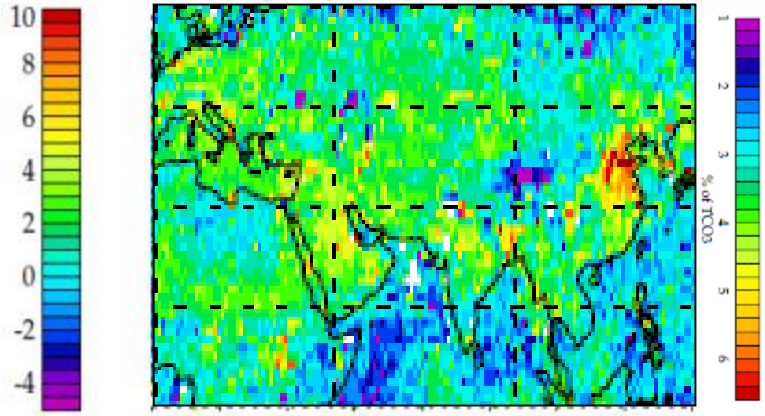
- Scheme developed to infer total ozone from GOME-2 Chappuis band, with better near-surface sensitivity than UV
- Quality of Chappuis Ozone approaching level where this sensitivity can be leveraged to distinguish near-surface ozone

UV vertical column

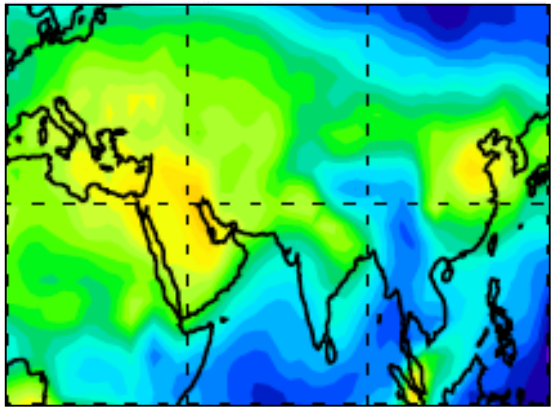


Chappuis vertical column





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

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Future: Tropospheric Ozone from Sentinel 4

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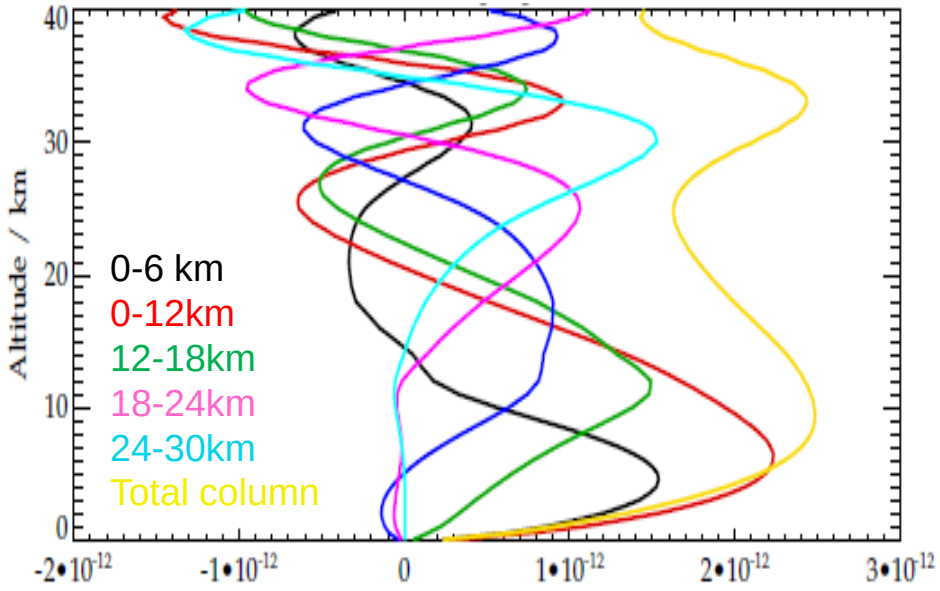
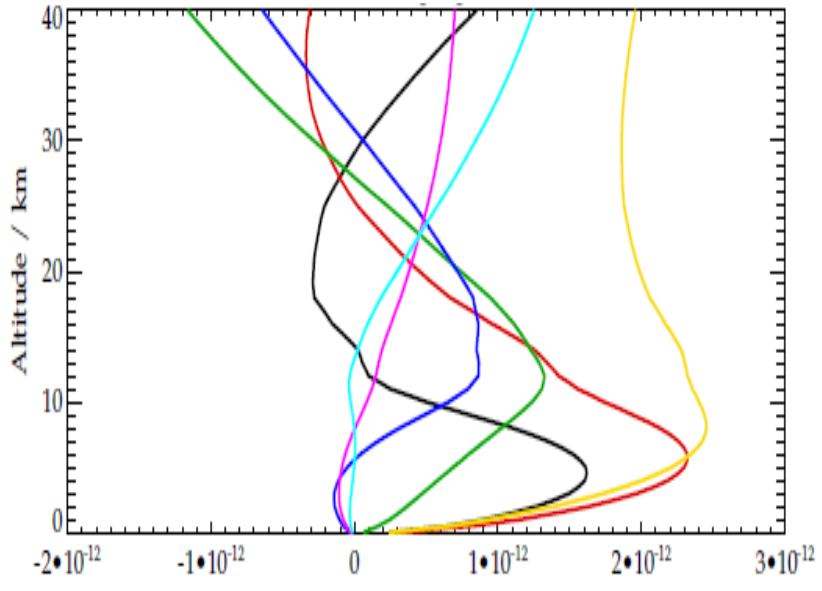
- S4 has no measurements of Hartley band below 305nm, which provides stratospheric profile information in all previous
- Basis for S4 scheme to deliver tropospheric ozone without this spectral range being established via ESA S4 L2 processor development

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



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Summary & Future Prospects

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- 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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