RAL UV (IR, Vis) Ozone Profiles

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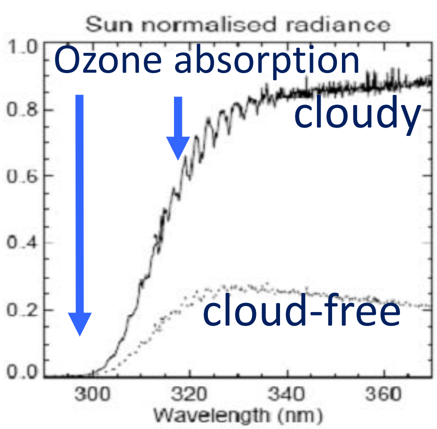
28-30th April 2015

Outline

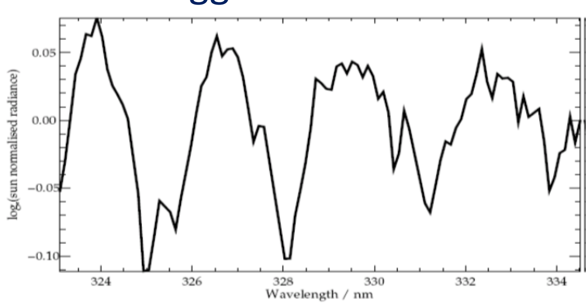
- UV profile algorithm
- Model comparisons
- Adding visible measurements to improves sensitivity to near-surface ozone
- Next steps/future

RAL UV Ozone Scheme Overview

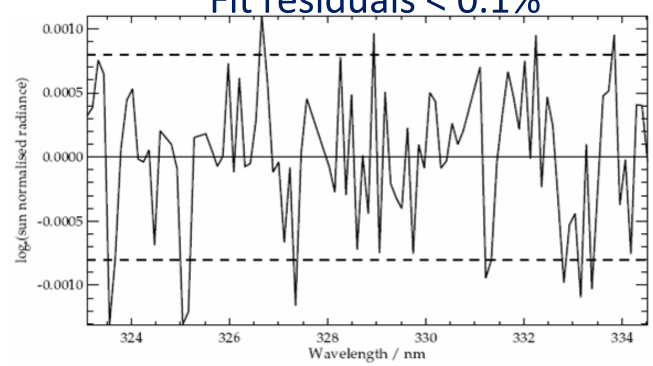
- Use sun-normalised radiance in Hartley and Huggins bands to measure ozone in Earth's atmosphere
- 3-step retrieval: 270-307nm (B1), surface albedo, 323-335nm (B2b).
- Forward model can inc. Rayleigh+cloud scattering, surface
- Huggins band reveals information on tropospheric ozone, requires precision of fit <0.1%.
- For B1, absolute calibration is important, especially for stratospheric ozone.
- For B2b, a good estimate of noise is important for precision of the fitting for tropospheric ozone



Measured spectra in Huggins bands

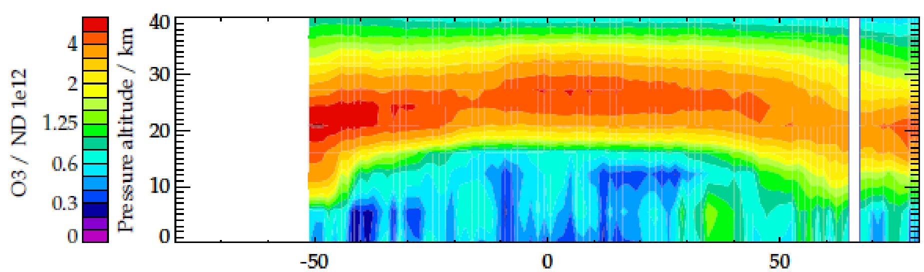


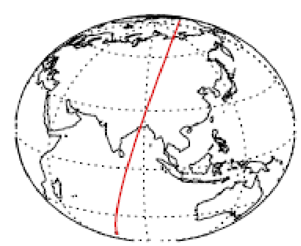
Fit residuals < 0.1%



RAL UV Ozone Scheme

- ESA Climate Change Initiative - Essential Climate Variable
  - Producing climate quality long-term datasets from satellite measurements
  - RAL scheme is O3 ECV UV nadir profile product for:
    - GOME (1996-2011)
    - SCIAMACHY (2002-2012)
    - OMI (2005-2015)
    - GOME2A&B (2007-present day)
- RAL currently produces NRT profiles for GOME-2
- Part of trial assimilation into ECMWF analysis





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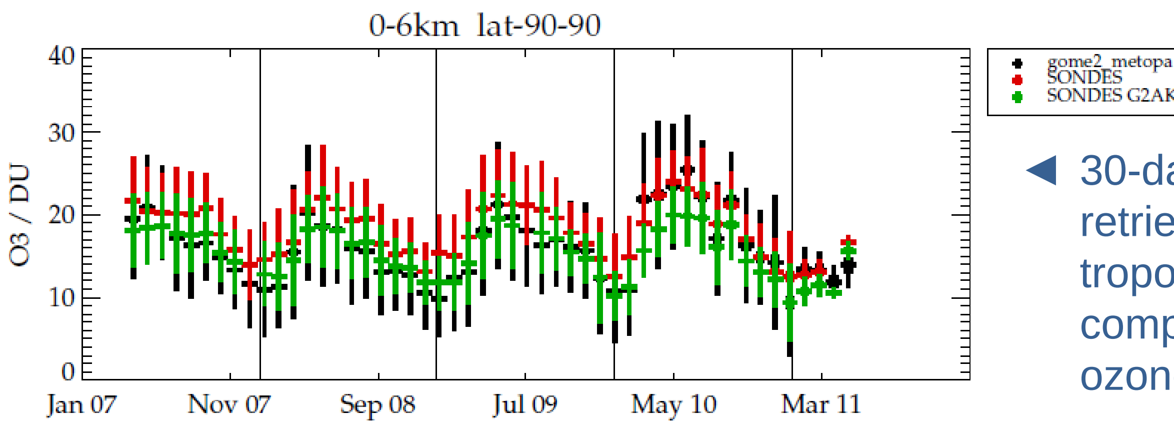
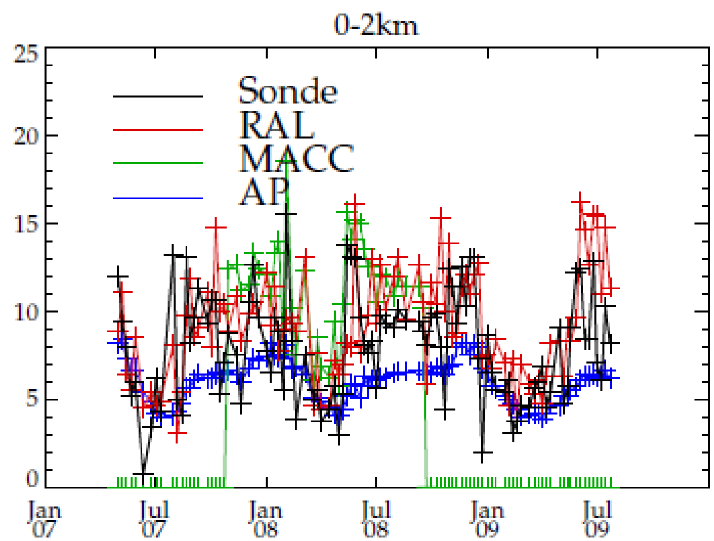
Profiles from MetOp GOME-2



- 30-day global mean retrieved lower tropospheric ozone compared to ozonesondes

WOUDC/SHADOZ ozonesondes



- Comparison to Hong Kong Observatory ozonesonde time series of boundary layer ozone.

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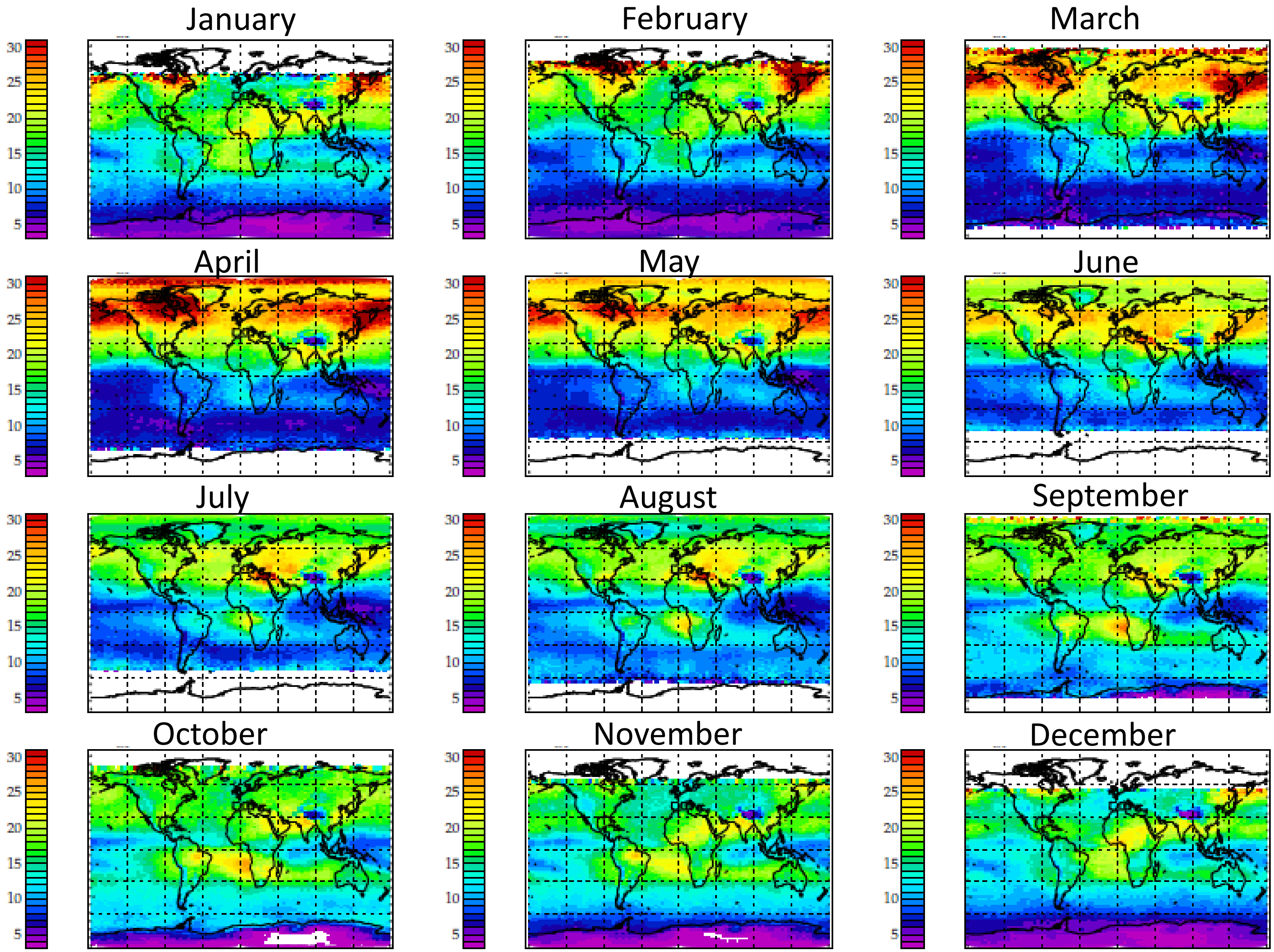
7-year GOME-2A Lower tropospheric ozone climatology (2007-2013)



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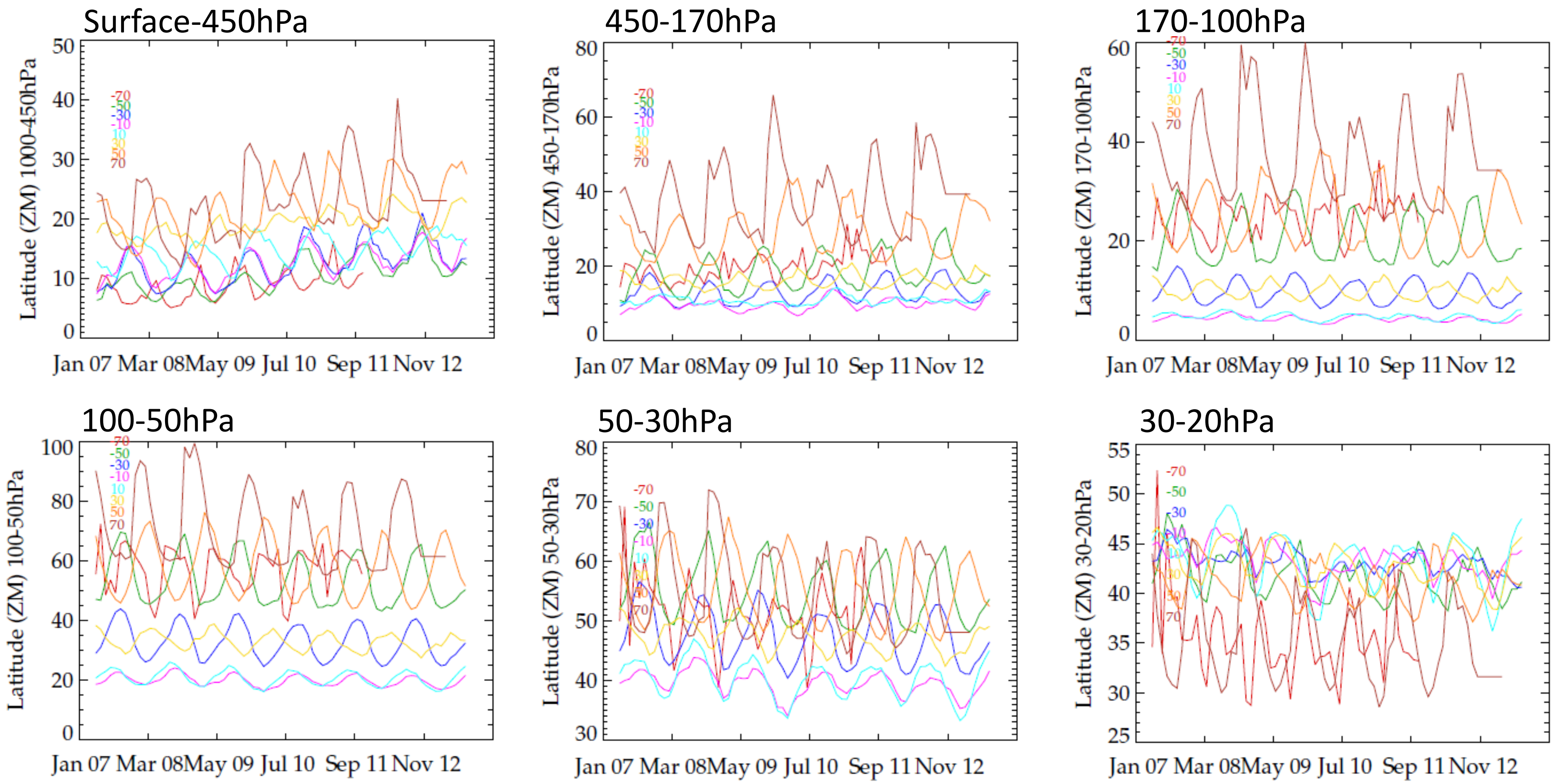
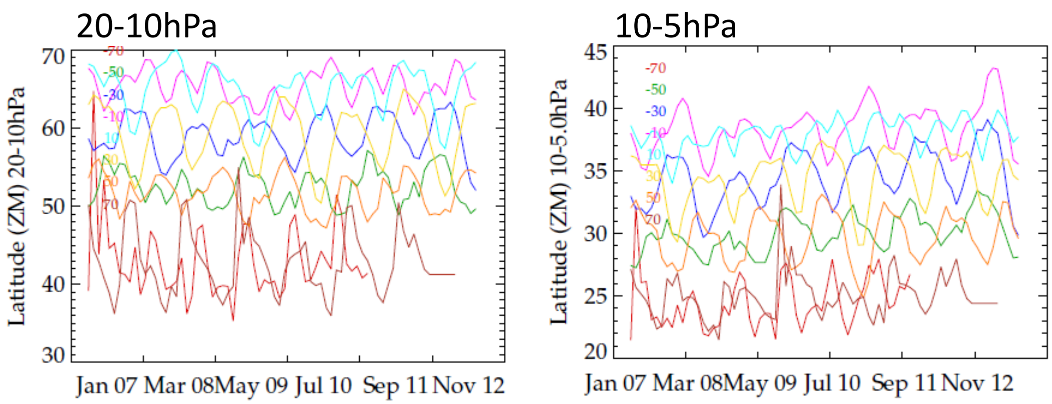




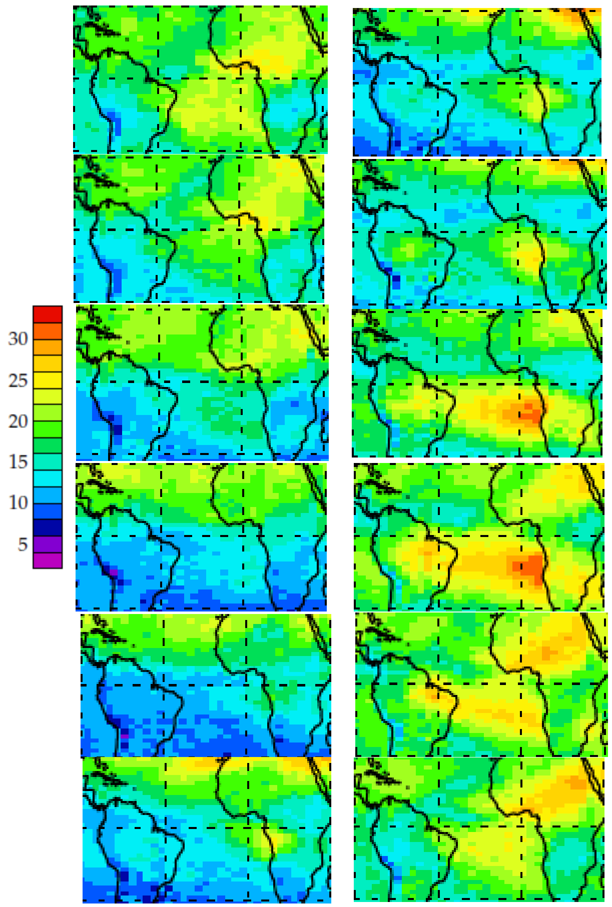
Zonal mean 7-year timeseries' for GOME-2

Red and orange represent polar regions (larger extremes)

Science & Technology Facilities Cc Jan 07 Mar 08May 09 Jul 10 Sep 11 Nov 12

Regional seasonal cycles in lower tropospheric ozone

Jan-June 2008 July-Dec

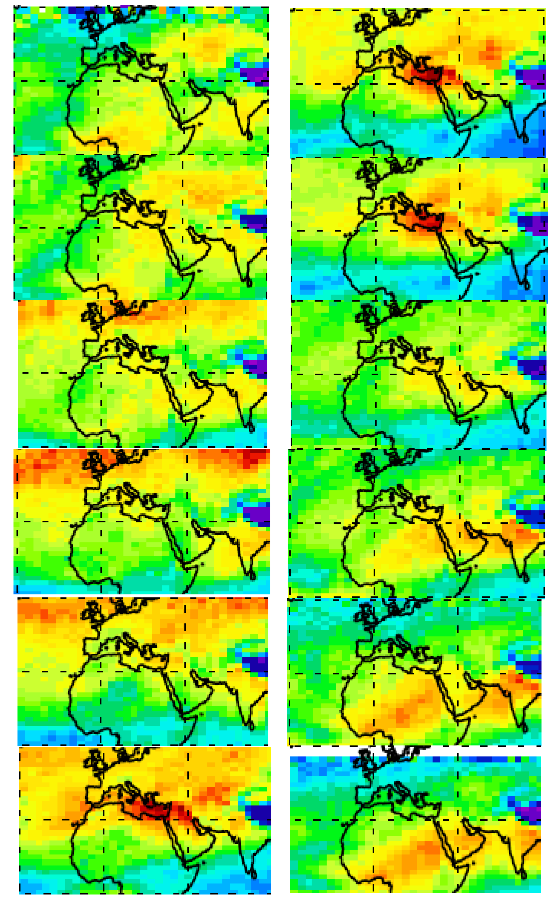


Lower tropospheric ozone (monthly mean)

Ozone transport in the lower troposphere over the **Southern Atlantic** (biomass burning)

Seasonal cycle of ozone over Europe and Asia

Jan-June 2008 July-Dec



Lower tropospheric ozone (monthly mean)

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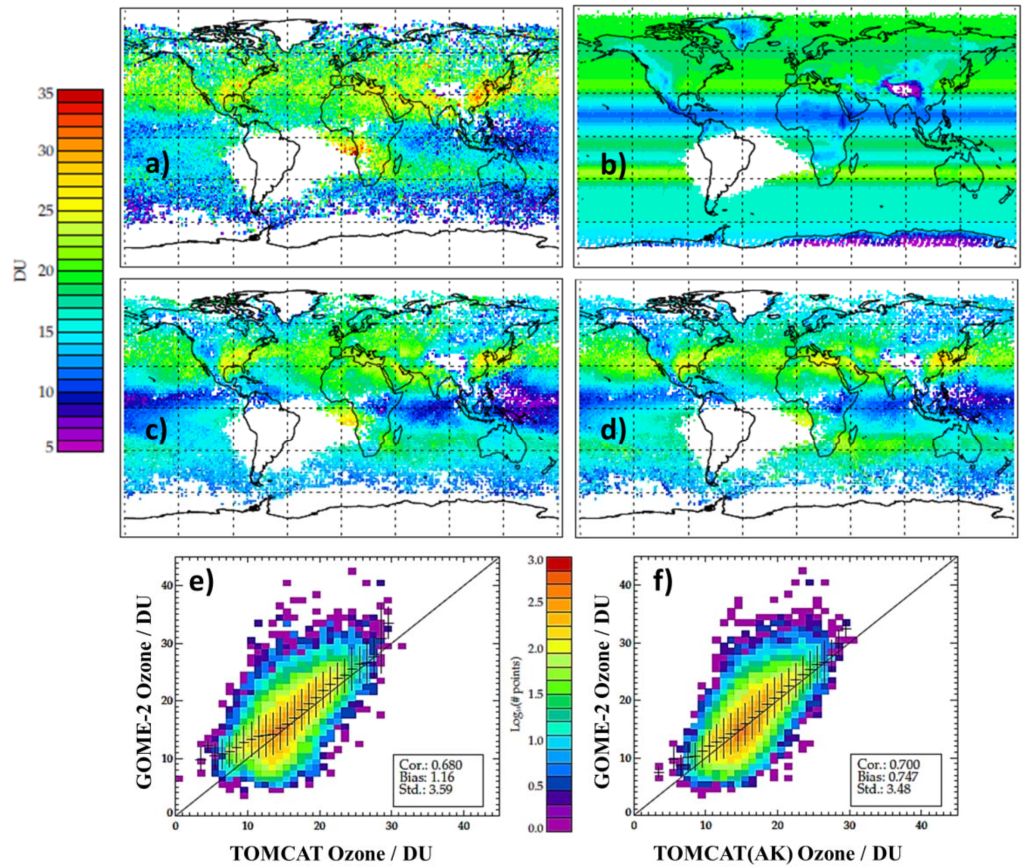
Model comparisons

Surface-450hPa ozone, cloud cleared
September 2008

Ozonesondes are used to validate the product, but they are geographically sparse.
We can use CTMs to assess whether the global spatial distribution is realistic.

a) GOME-2 Surface to 450hPa layer ozone gridded (1.125) monthly-mean for September 2008. Pixels have been strictly cloud cleared such that only pixels with a cloud fraction of < 0.2 *and* cloud top pressure of > 700hPa remain.
b) A priori for GOME-2 retrieval (all pixels).
c) TOMCAT model with satellite sampling.
d) TOMCAT model with GOME-2 averaging kernels applied, e) correlation of a and c with associated bias and standard deviation, f) correlation of a and d.

(Miles *et al.*, 2015 AMT)



Comparisons of retrieved lower tropospheric ozone to the CTM TOMCAT

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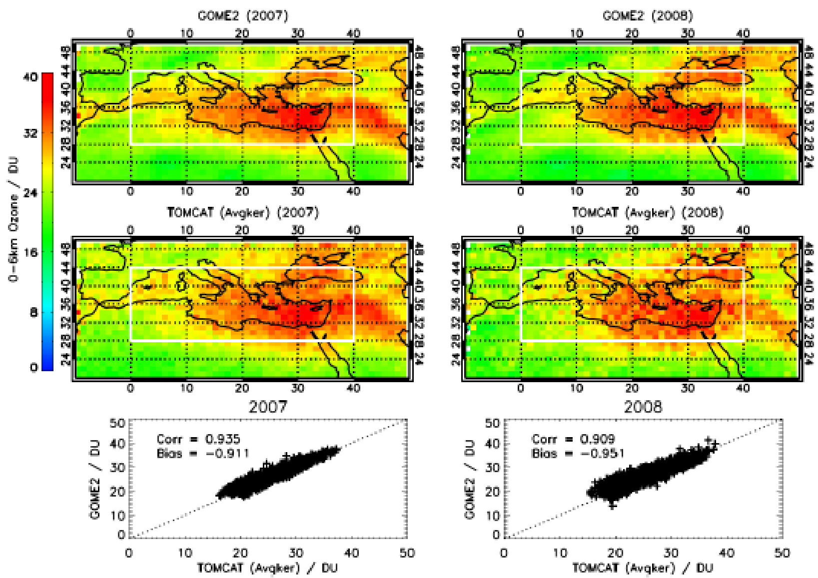
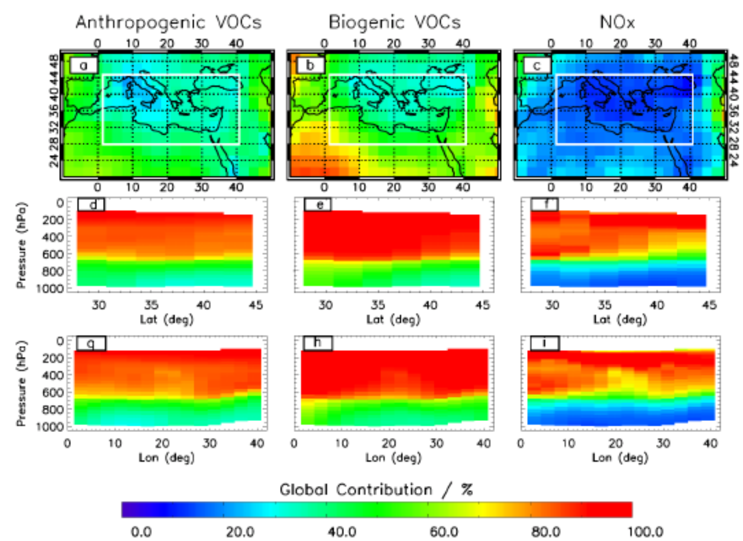
Model comparisons

Richards *et al*., (2013): Used RAL GOME-2 observations to qualify TOMCAT-modelled lower tropospheric ozone over the Mediterranean before doing source attribution and radiative forcing experiments:





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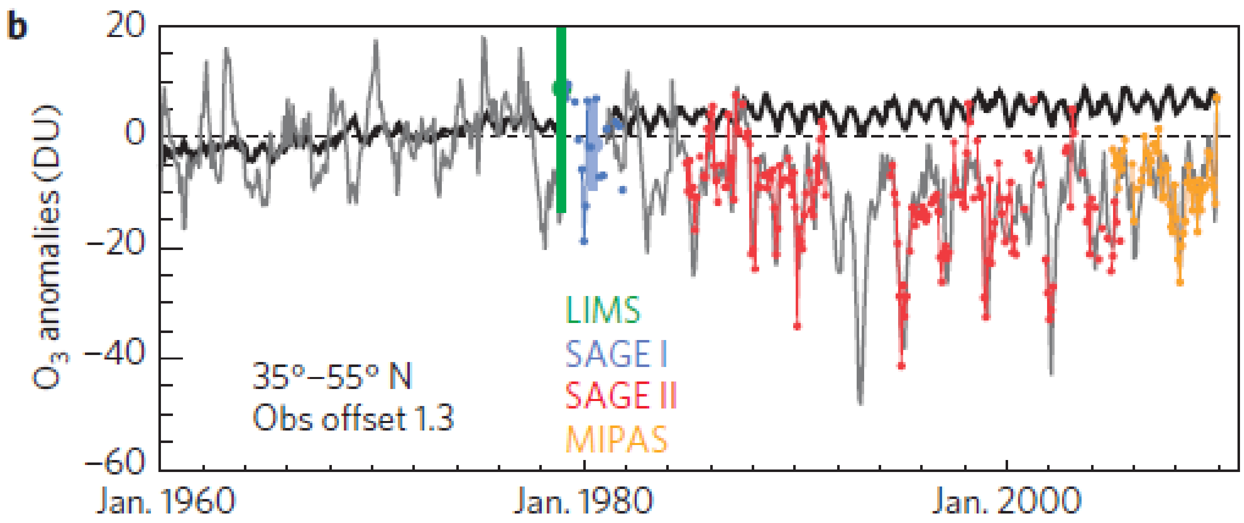
Model comparisons

- NH tropospheric ozone anomalies from CMAM (Shepard *et al*, 2014 Nature Geosciences). Modelled stratospheric anomalies are also shown (grey) with satellite products overlain:
Our tropospheric satellite product is now available to compare.



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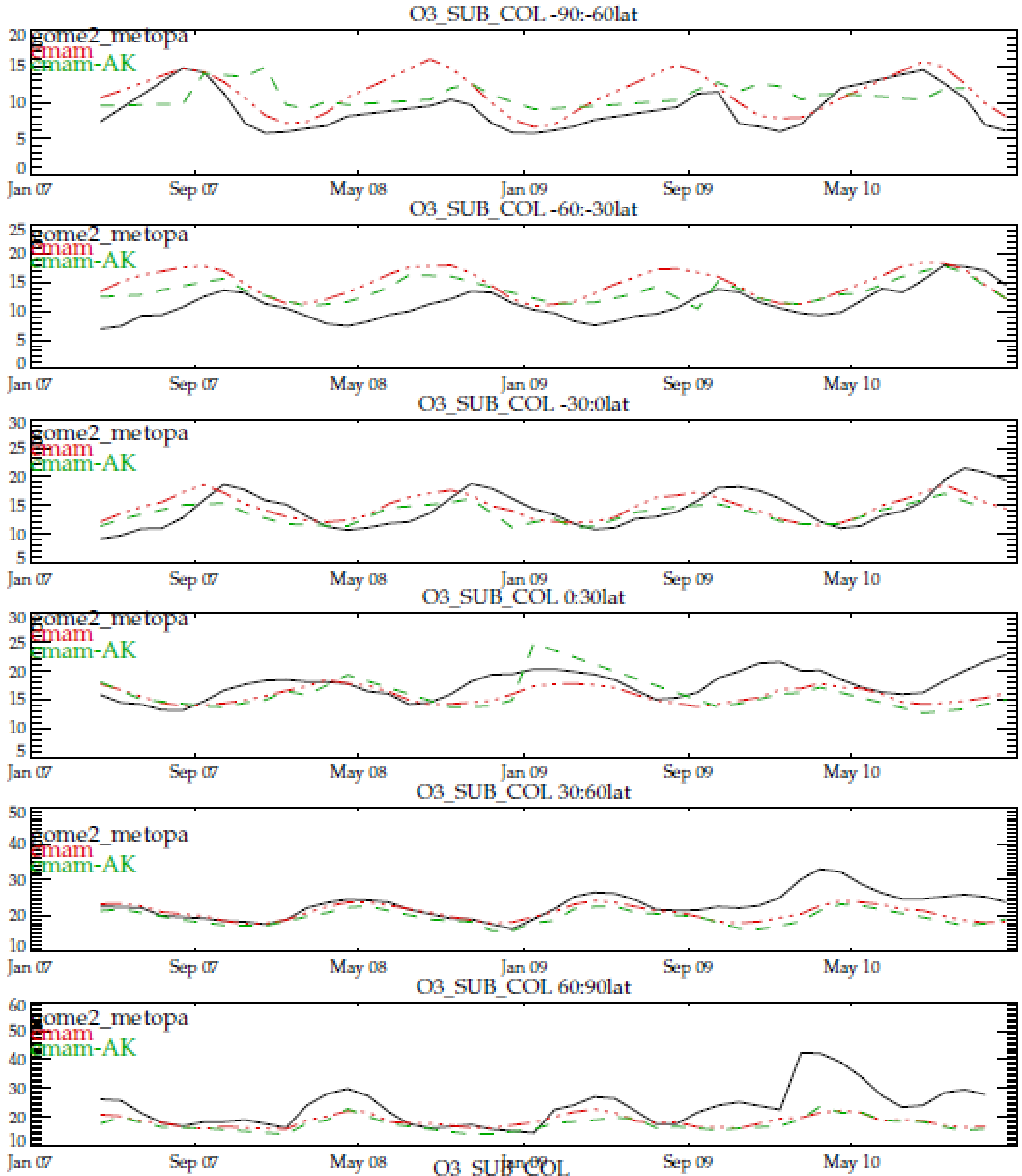
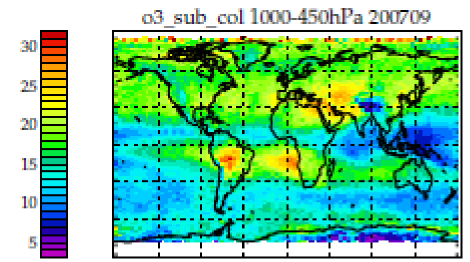
Zonal Mean Timeseries: CCM comparison



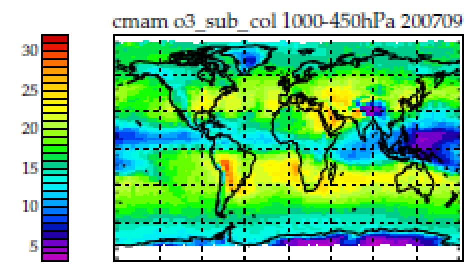
- CMAM (nudged), part of CCMI
- Surface – 450hPa sub-column
- Very early results!

August 2007 mean

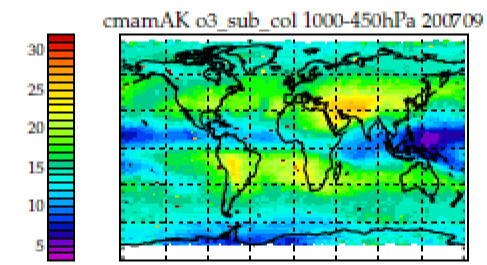
GOME2



CMAM



CMAM+AK



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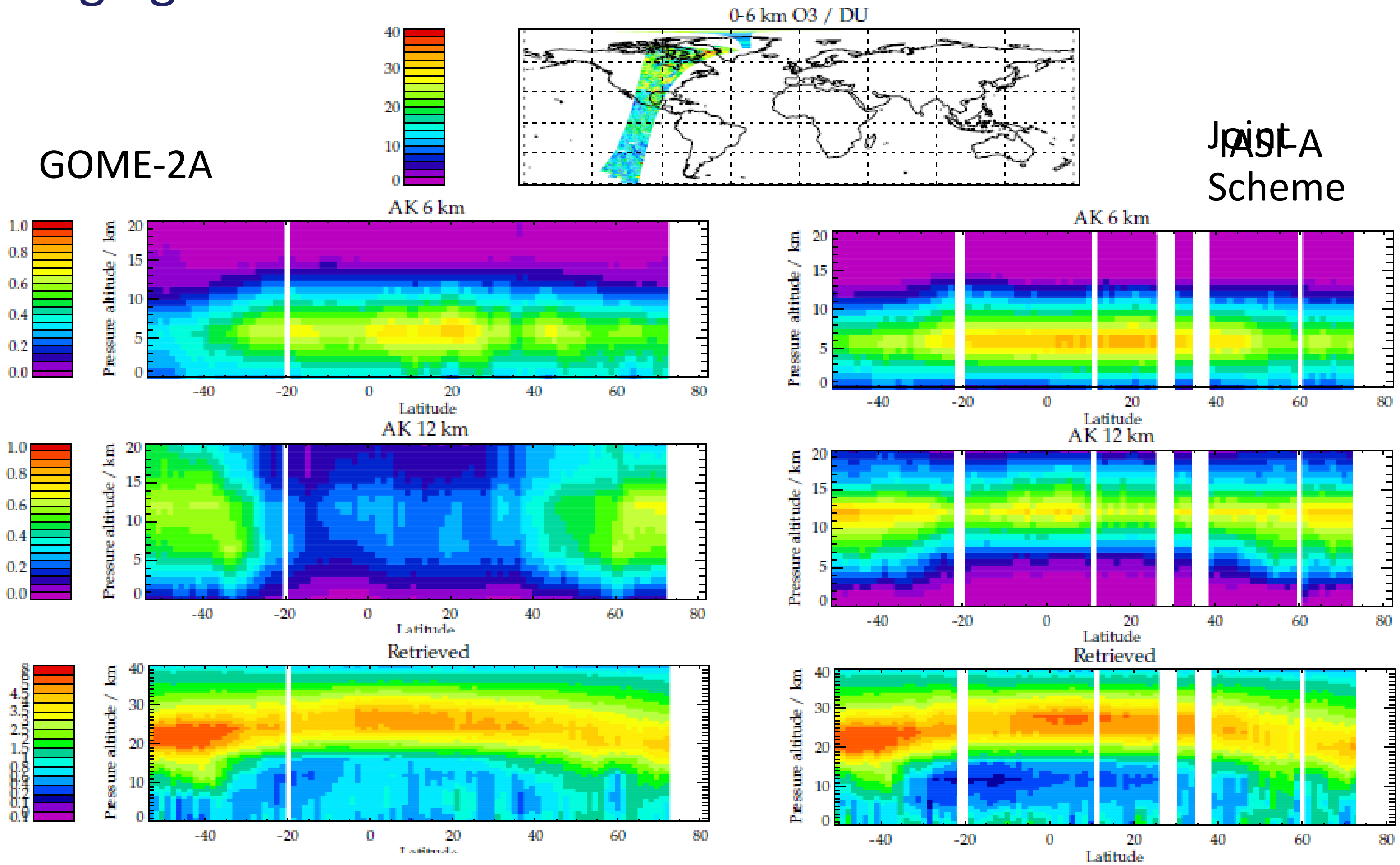
RAL UV+**IR** Ozone Profiles

Averaging Kernels: Orbit Cross-section



Note: IASI is very sensitive to cloud

RAL Space

Towards the surface: using the visible Chappuis bands (400-700nm)

In theory, the Chappuis bands have information about near-surface which can not be realised using any other passive technique

Advantages over conventional UV/IR retrieval:

- Lower Rayleigh scattering
- Potentially brighter

Disadvantages:

- Only 1 piece of information
- Very challenging fitting region! Mainly due to:
  - Broad-band structure of Chappuis bands
  - Interfering species
  - Potential sensitivity to instrumental artefacts
  - **<u>Poorly known spectral shape of surface</u>**

However…

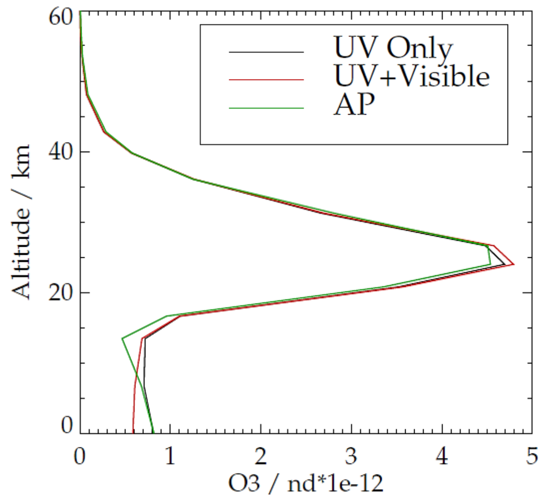
If ozone slant columns can be fit with sufficient accuracy using just visible spectra, the differential vertical sensitivity between the UV and visible can be used to combine the slant columns with conventional UV profiles using a linear retrieval step.

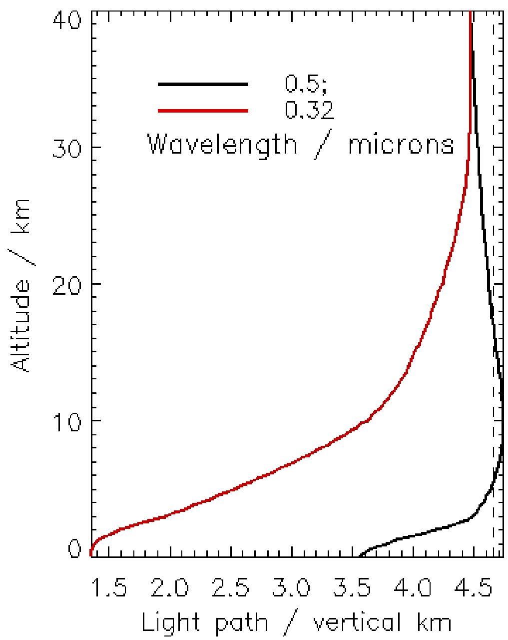
Combining UV and visible information

$$x_{UV+Vis} = x + (S_x^{-1} + K^t S_y^{-1} K)^{-1} K^t S_y^{-1} (y-Kx)$$

x, S_x: UV retrieved profile and covariance
y, S_y: Chappuis column and fit error
K: weighting functions that map x onto y

Impact of visible information on UV derived ozone profile using linear step:





The differential light path sensitivity at 325 (red) and 500nm (black) can be modelled using a radiative transfer model.

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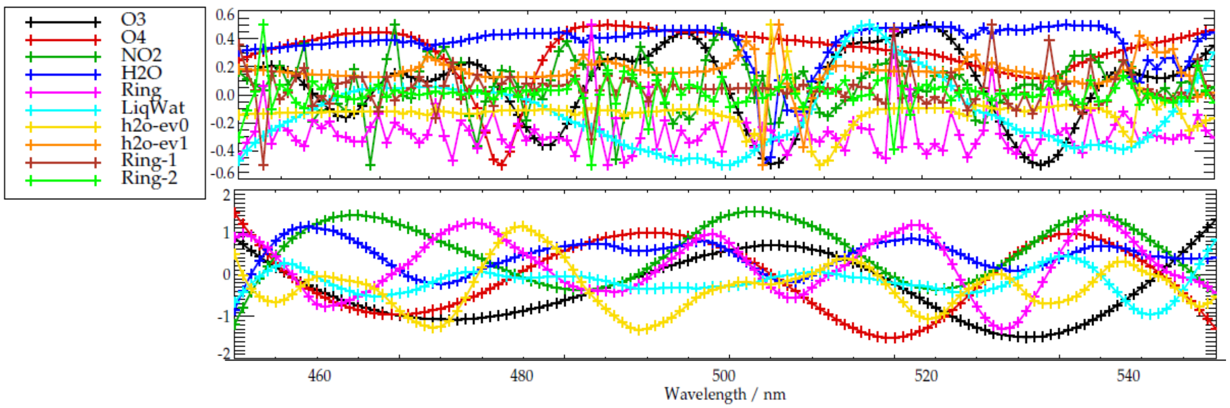
DOAS ozone slant column using the Chappuis bands

Many spectral patterns interfere with the fit of ozone in the visible, and need to be accounted for in a DOAS retrieval (trace gases, the spectral shapes of the surface, instrumental features…)

- Fitting too many patterns reduces the information about ozone.
- Too few and the measurement can not be accurately fit.



Surface patterns are the biggest challenge. They can be represented by the leading principal components from a spectral database, but the spectral resolution of these databases is very limiting, and will fundamentally limit the accuracy of the ozone retrieval.

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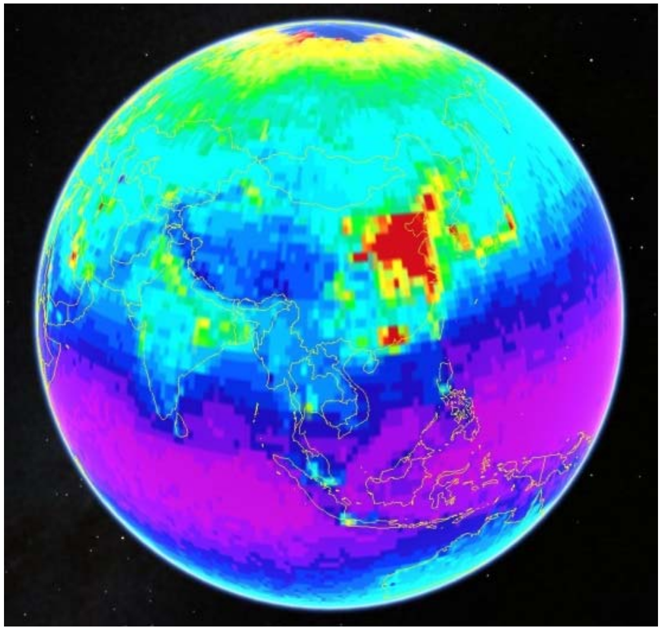
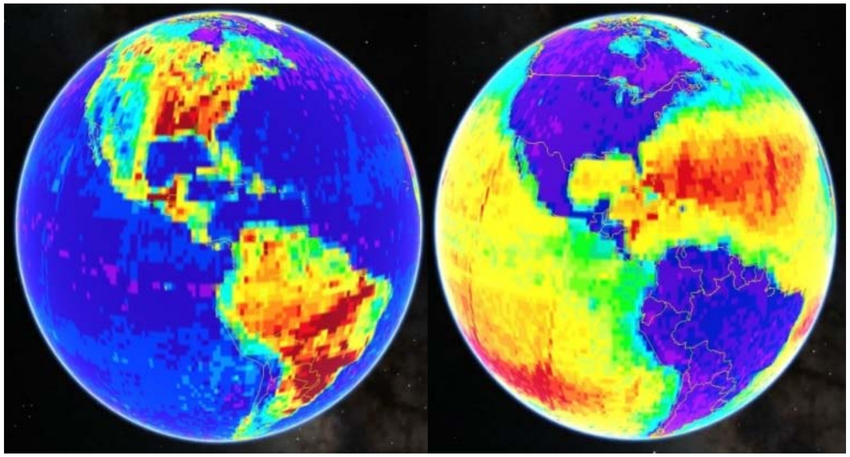
Co-fit species

Some co-fit species are useful products in themselves, and are derived from an unconventional fitting window (450-550nm), e.g. NO_2.

1 year mean (2008) cloud cleared NO_2 slant column over China. The results show much reduced noise and have very good sensitivity.



Scaling factors for Land and liquid water spectral features responding to ocean and land colour. These need to be fit because they interfere with the ozone signal.



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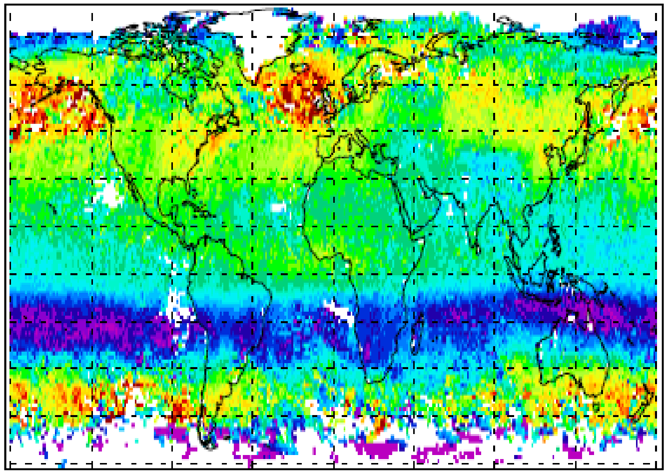
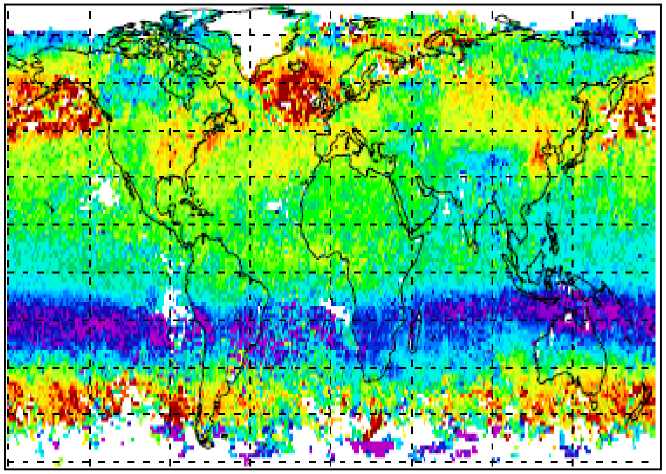
Ozone fit precision

In many cases it is possible to estimate Chappuis slant columns using DOAS to a precision required for the information to be useful to conventional UV-derived ozone profiles as shown below:

RAL UV geo-total column



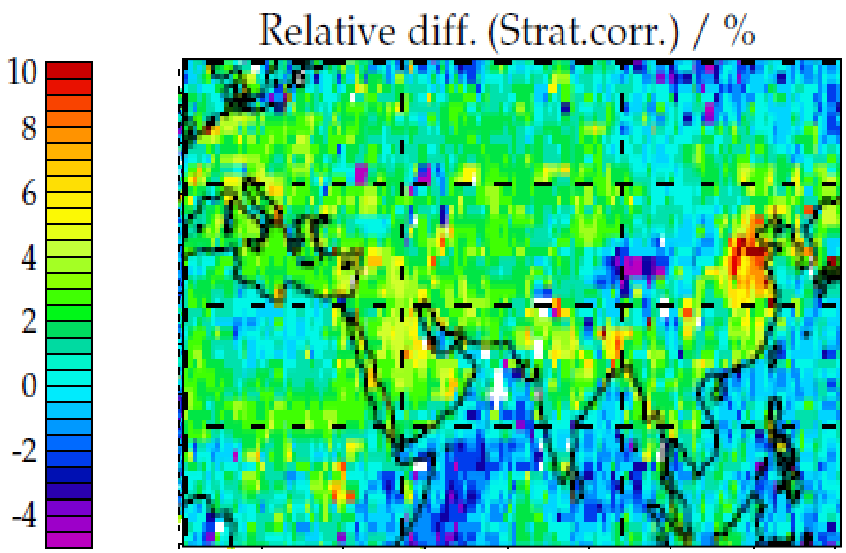
Chappuis geo-total column



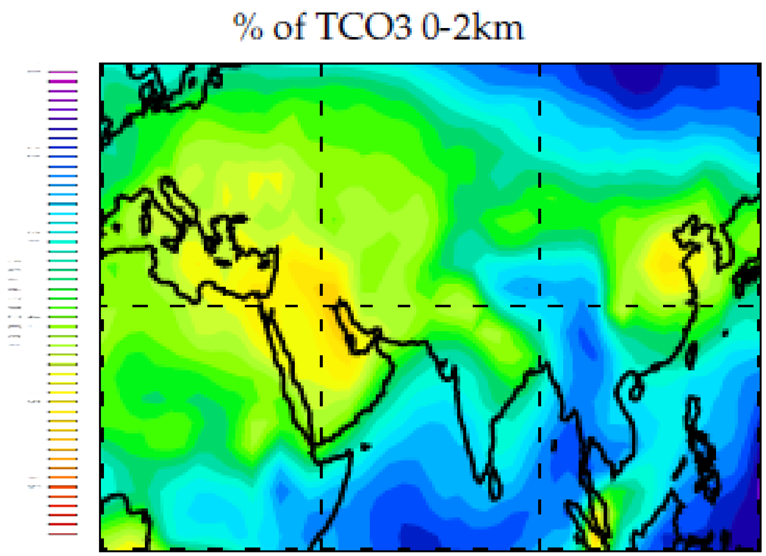
August 2008 mean, cloud cleared. Total columns from geometric AMF applied to slant columns. UV and Visible slant columns agree very well, but not everywhere.

Sensitivity to boundary layer ozone

It is possible to simulate what sensitivity can be added by using a CTM ozone profiles to *simulate* slant columns in the UV and visible. Difference between simulated UV slant column and visible slant column is associated with different **sensitivity to boundary layer ozone:**



August 2008, using cloud-cleared radiances



August 2008, TOMCAT mean boundary layer ozone

Next steps

- Some improvement still expected/needed for some land types/scattering processes/spectroscopy. The TEMPO should have a better handle of surface spectral shape but will have different spectral coverage than GOME-2.
- Apply linear step to combine Chappuis and UV(+IR) information to GOME-2A mission and evaluate improved sensitivity to boundary layer with ozonesondes
- Working towards a publication in 2015.

SUPPLEMENTARY

RAL Space

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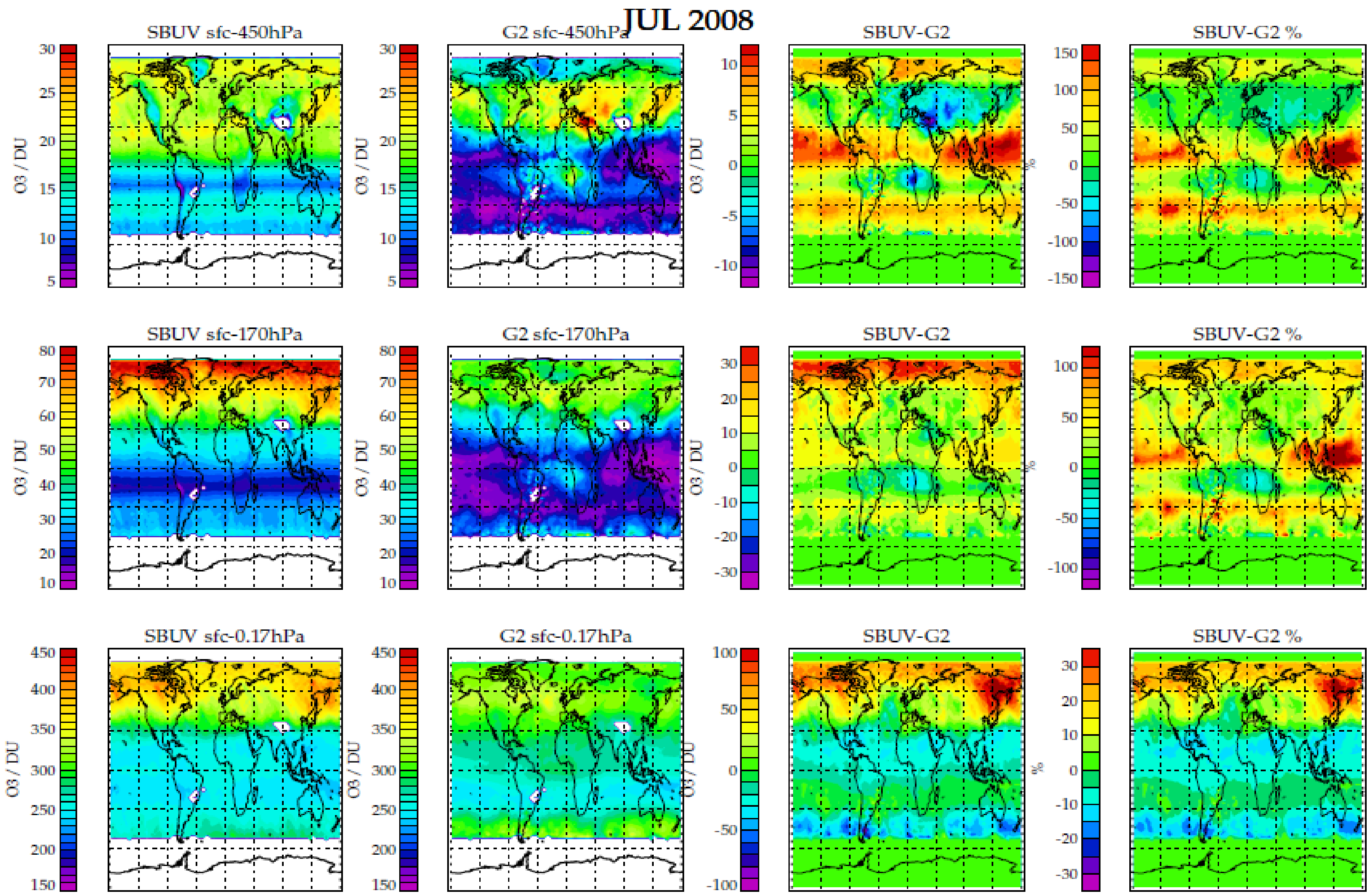
Comparisons to SBUV data: 2008



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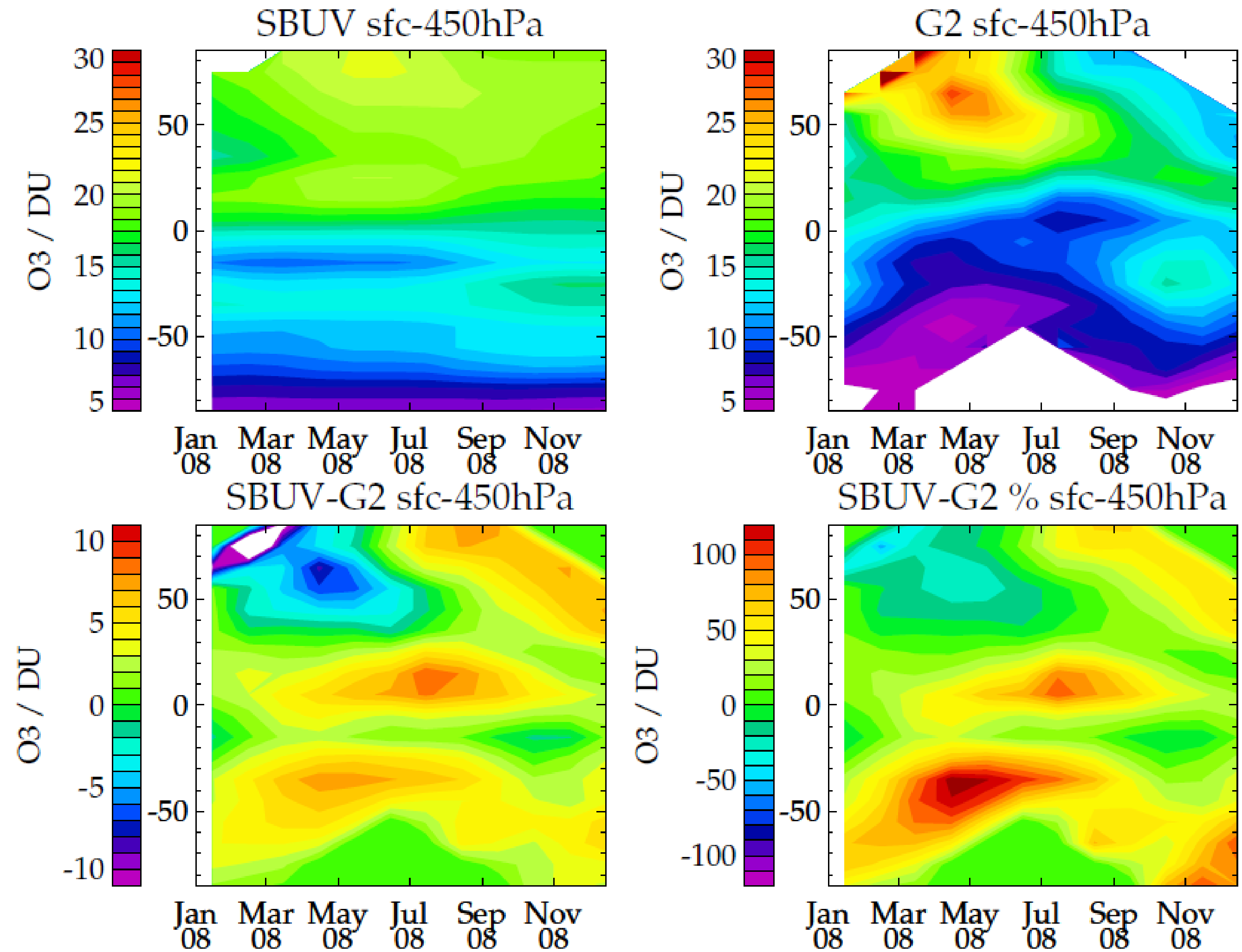
GOME-2A vs SBUV: surface-450hPa



- Surface to ~6km sub-column
- zonal mean with time

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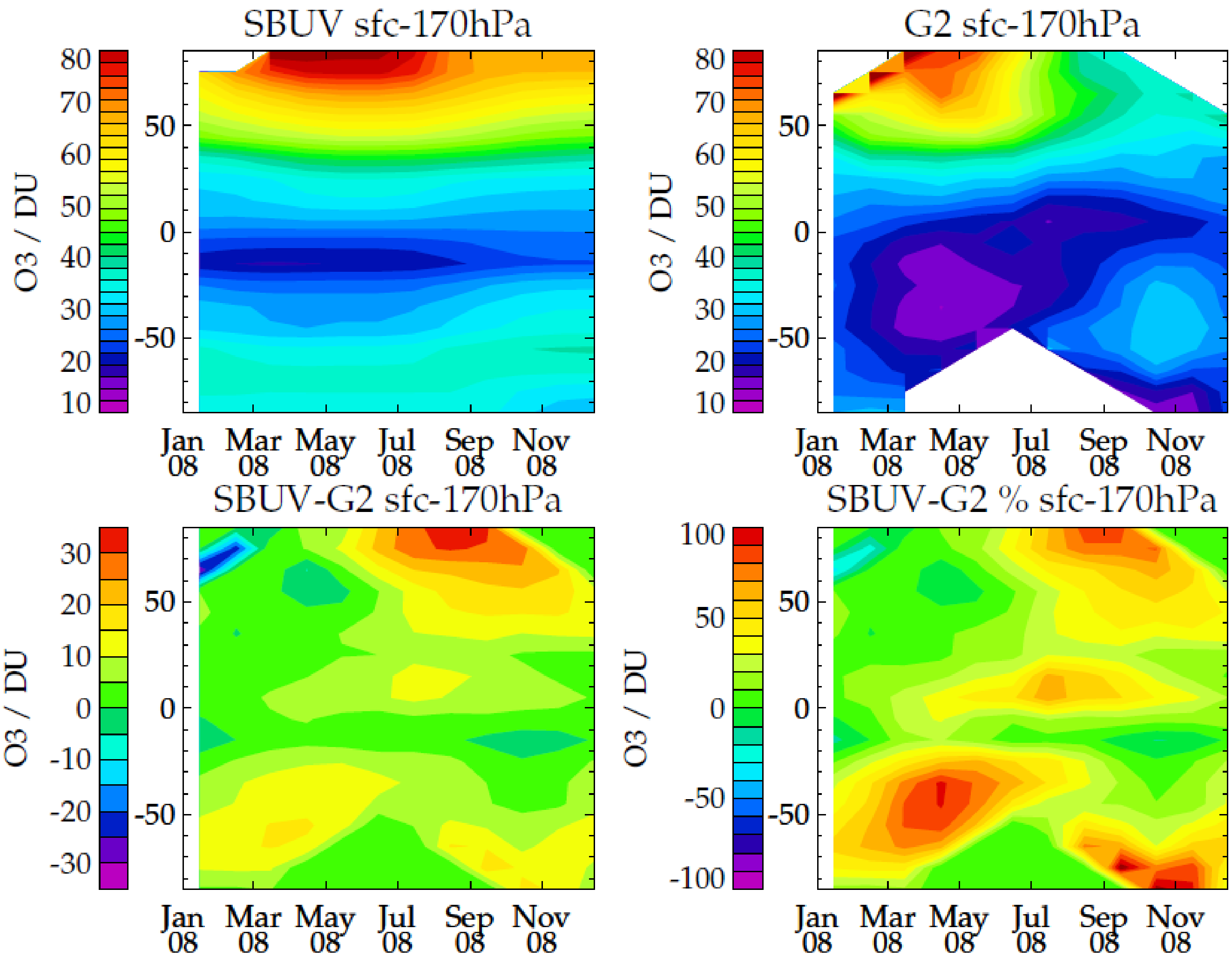
GOME-2A vs SBUV: Surface-170hPa



- Surface to ~12km sub-column
- zonal mean with time

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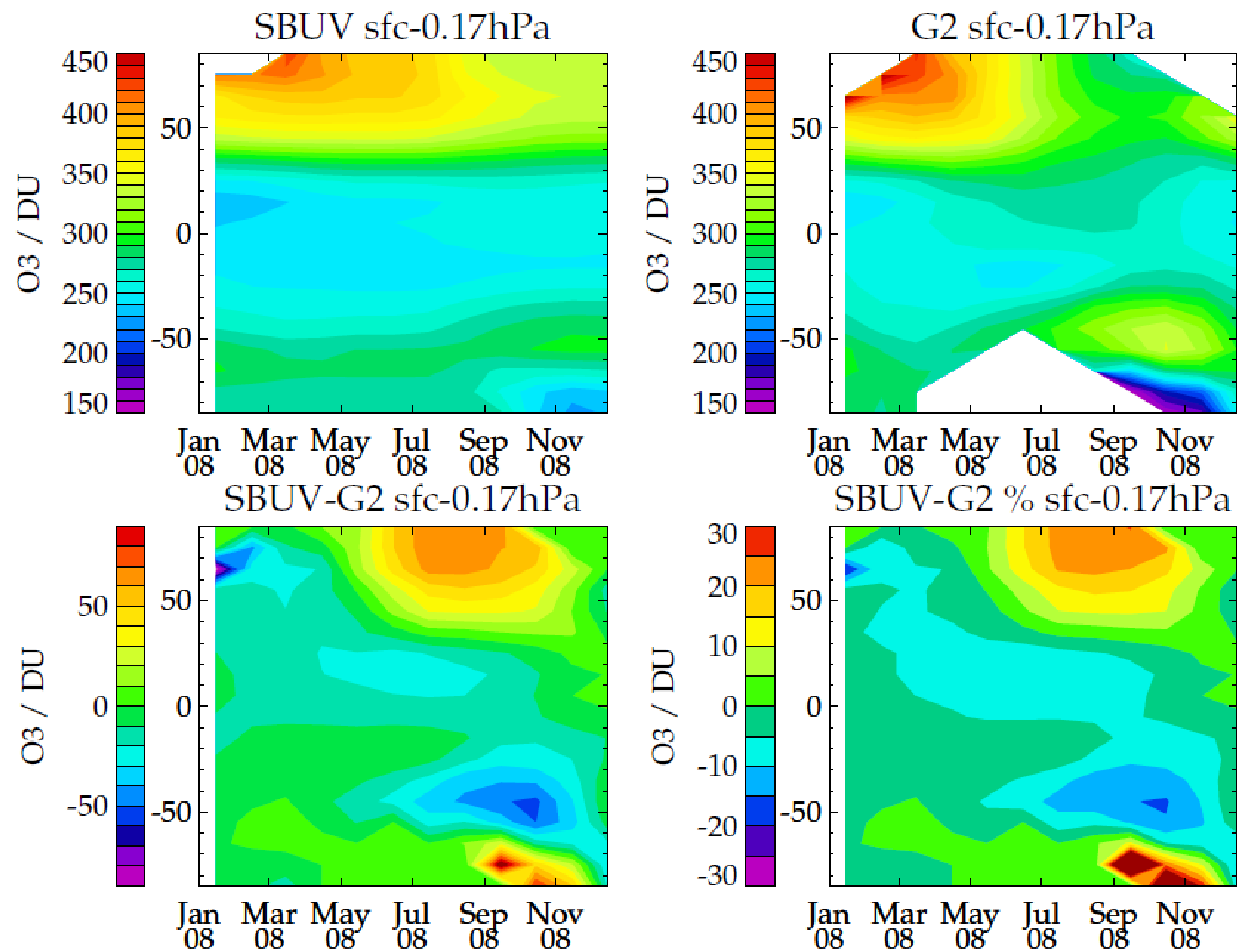
GOME-2A vs SBUV: surface-0.17hPa



- Surface to ~60km sub-column
- zonal mean with time

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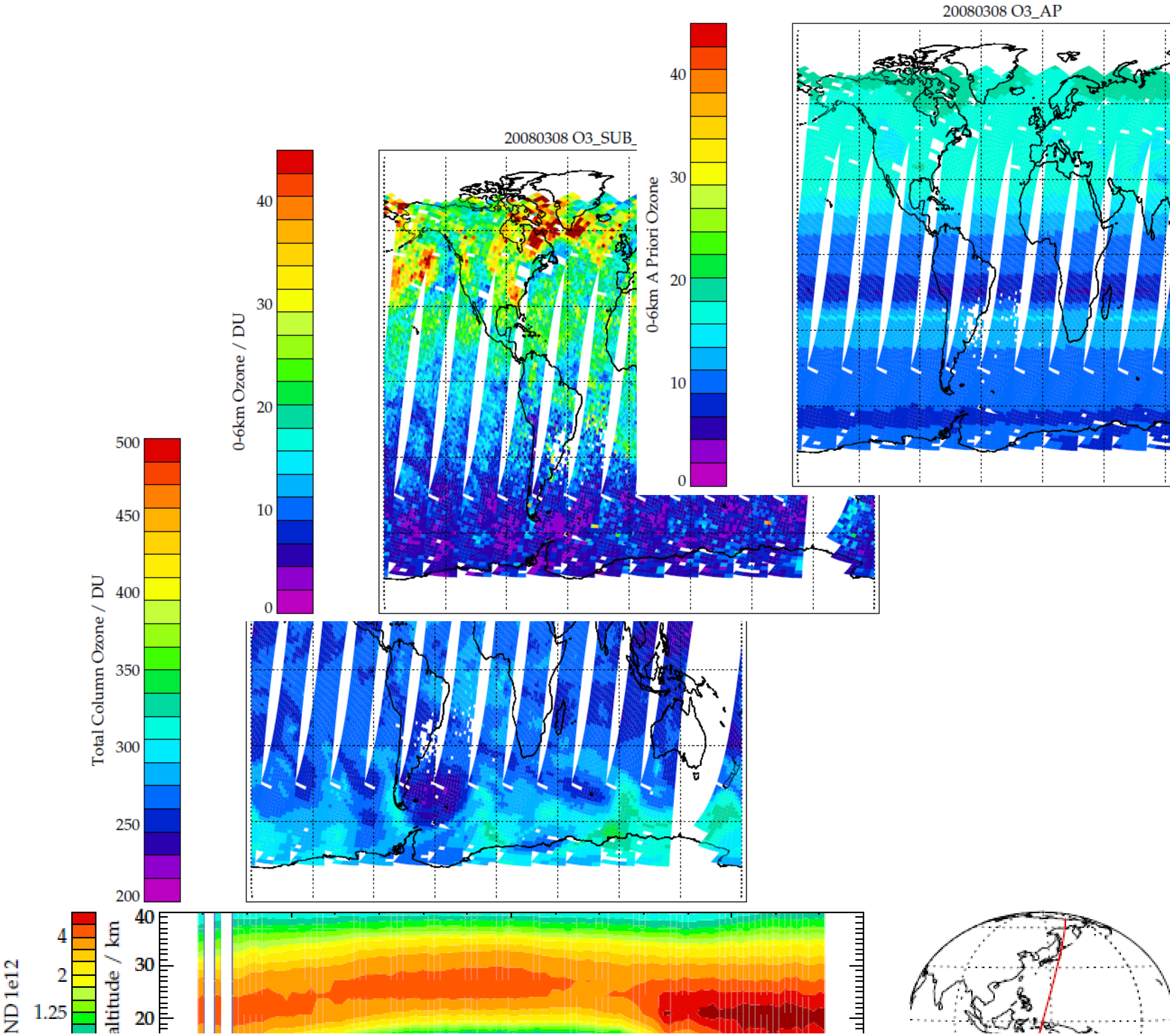
20080308 O3_AP
20080308 O3_SUB_
0-6km A Priori Ozone
0-6km Ozone / DU
Total Column Ozone / DU
0
10
20
30
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200
250
300
350
400
450
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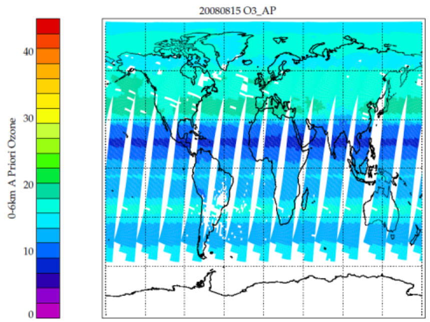
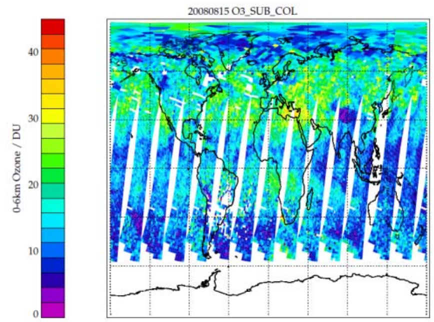
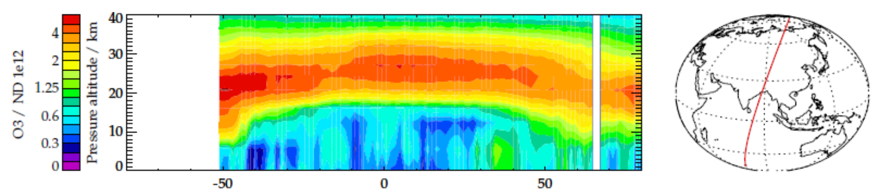
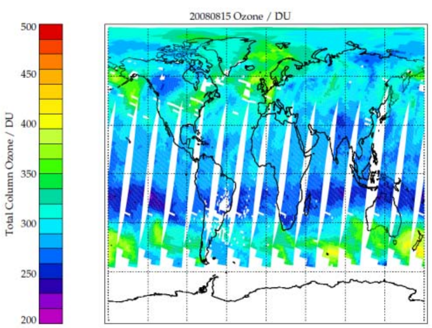
ND 1e12
1.25
2
4
altitude / km
20
30
40









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