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Using visible spectra to improve sensitivity to near-surface ozone of UV-retrieved profiles from MetOp GOME-2

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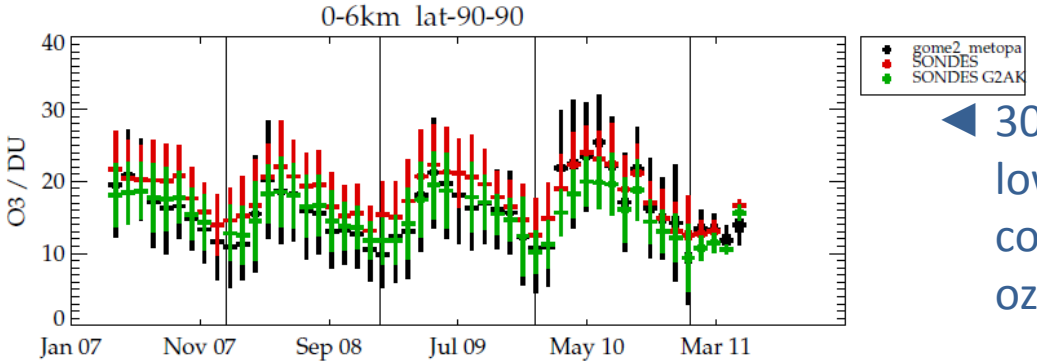
RAL UV Ozone Scheme

- ESA Climate Change Initiative - Essential Climate Variable O3
  - 20 years of global ozone profiles
  - RAL scheme is O3 ECV UV nadir profile product for:
    - GOME (1996-2011) – available June
    - SCIAMACHY (2002-2012) – available July
    - OMI (2005-2015) – available 2016
    - GOME2A/B (2007-present day) – available now
- RAL currently producing NRT profiles for GOME-2 for trial assimilation by ECMWF (MACC-III).
- Contributing to IGAC Tropospheric Ozone Assessment Report (TOAR)
- Algorithm/validation paper: Miles *et al.,* (2015), AMT



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

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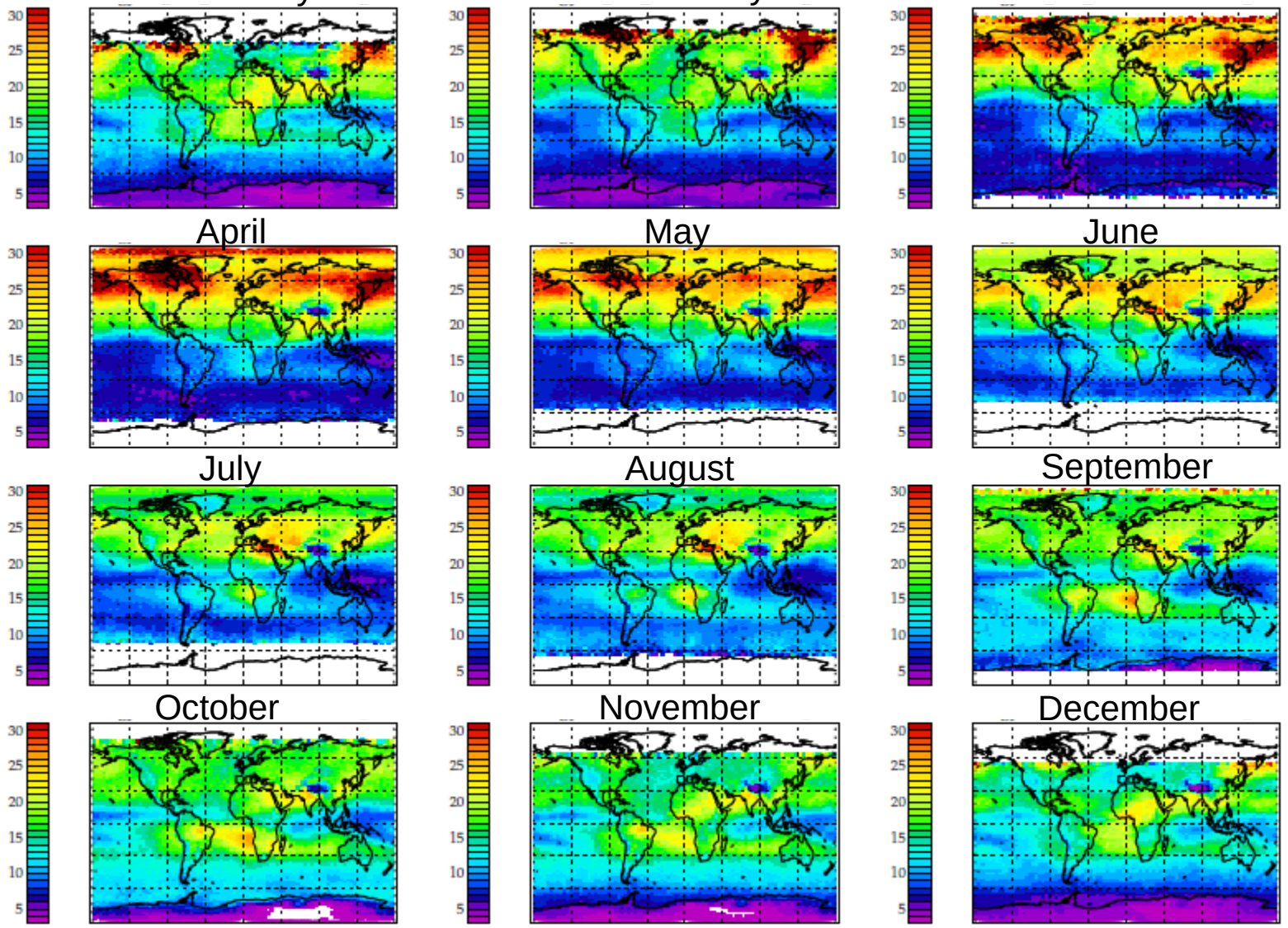
7-year GOME-2A Lower tropospheric ozone climatology (2007-2013)



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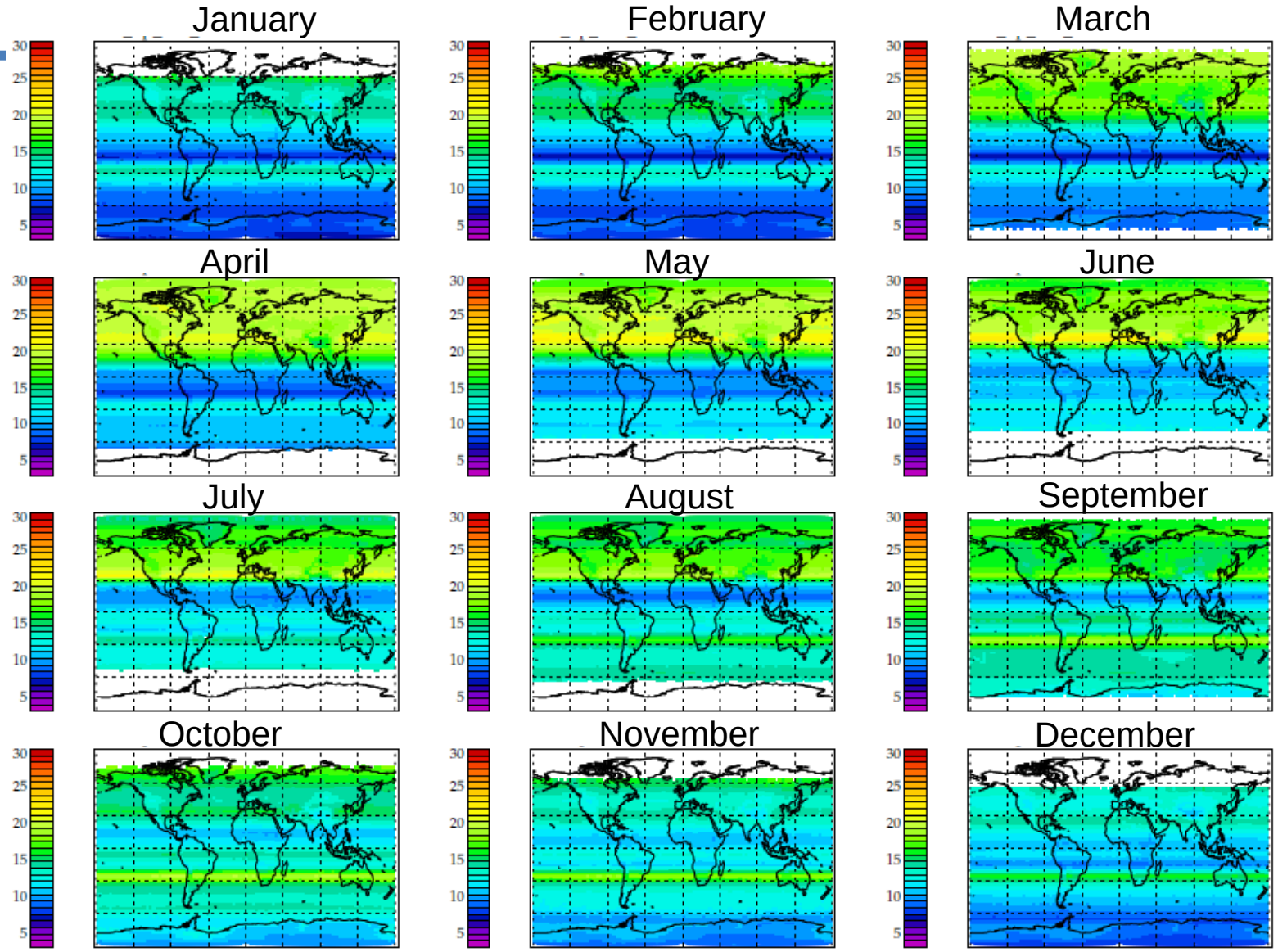
Monthly mean *a priori* Lower tropospheric ozone climatology



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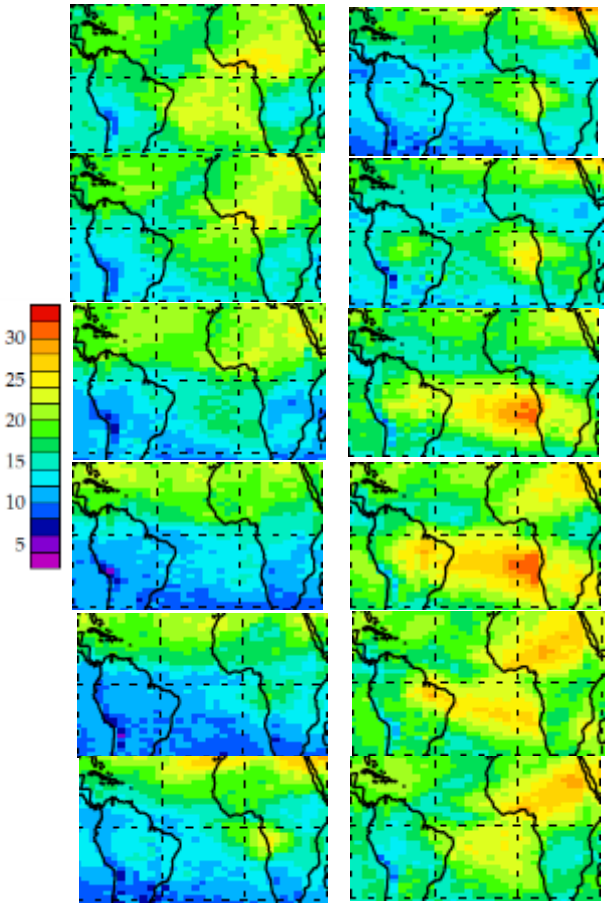
Regional seasonal cycles in lower tropospheric ozone

Jan-June 2008 July-Dec

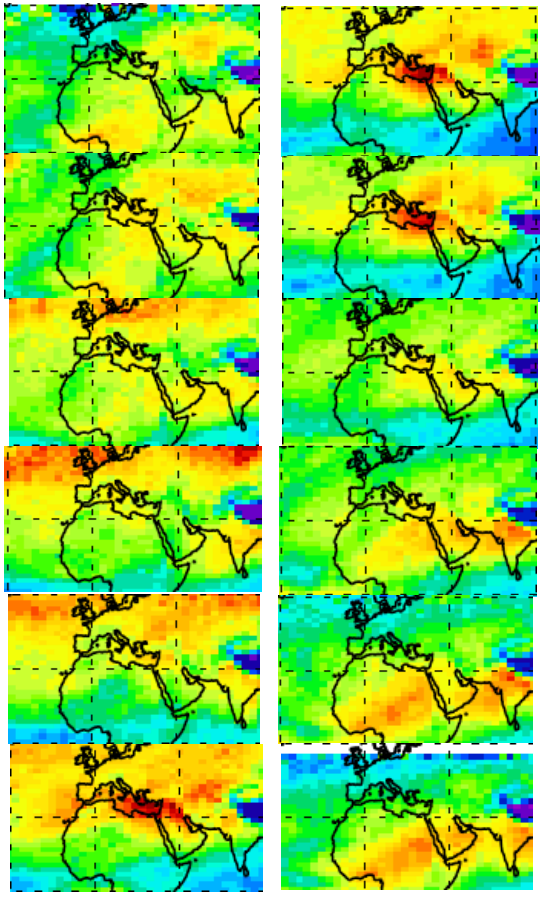


Lower tropospheric ozone
(Dobson Units monthly mean)

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
(Dobson Units monthly mean)

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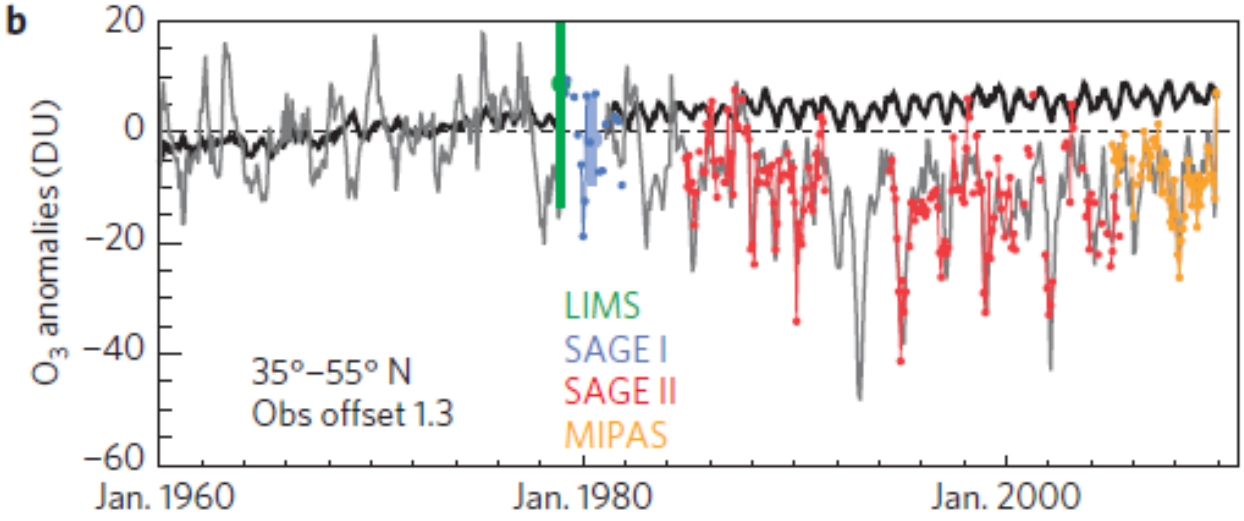
CCM comparisons

~ 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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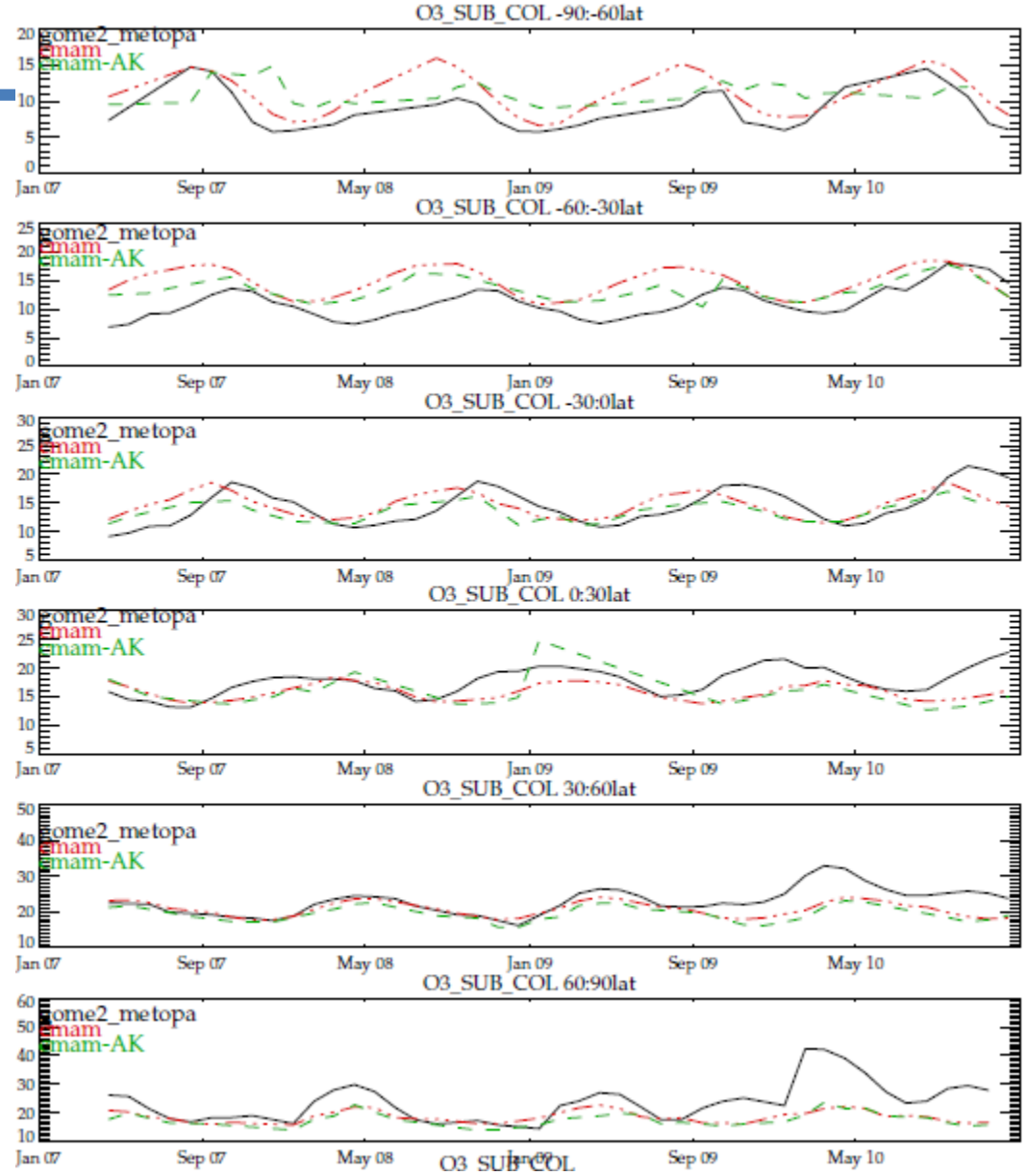
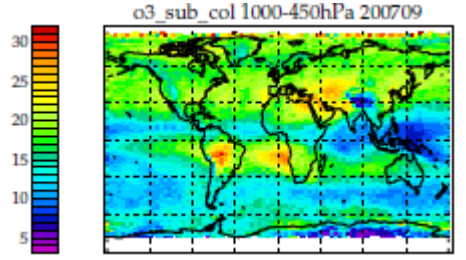
Zonal Mean Timeseries: CCM comparison



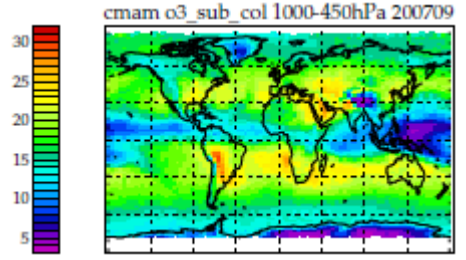
- CMAM (nudged), part of CCMI
- Surface – 450hPa sub-column
- Very early results!

August 2007 mean

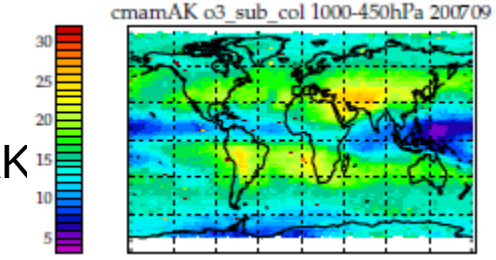
GOME2



CMAM



CMAM+AK



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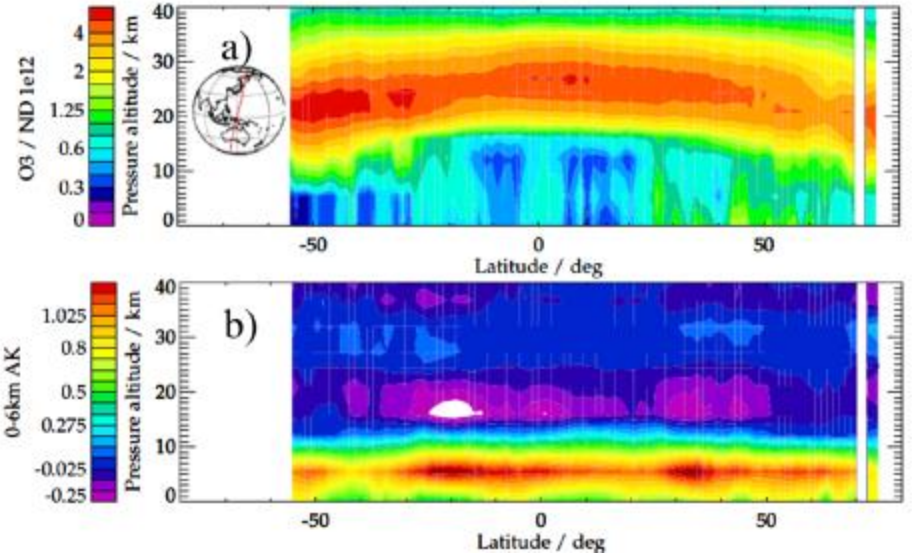
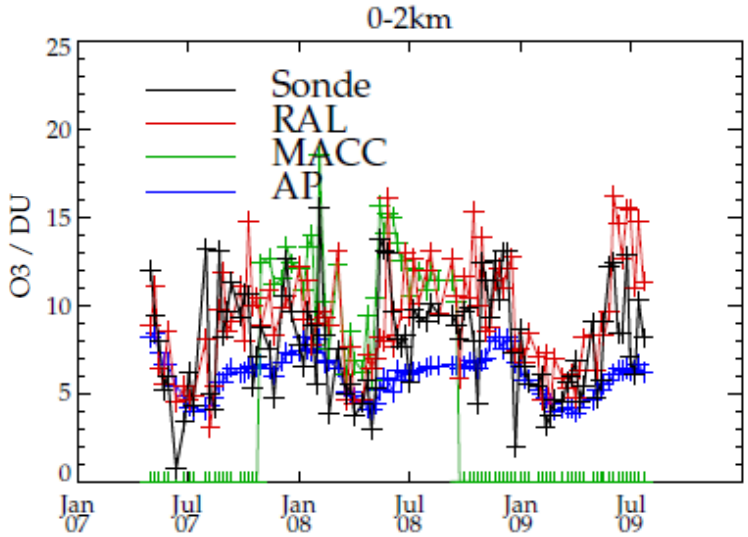
Lower troposphere from GOME-2A

- Examples of
  a) Orbit ozone cross section
  b) 0-5.5km averaging kernel





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

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

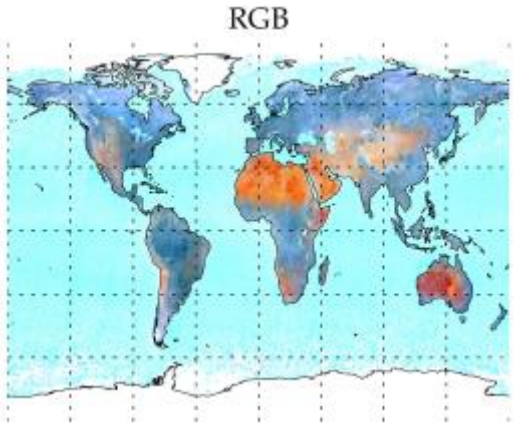
Advantages over UV retrieval:

- Lower Rayleigh scattering
- Potentially brighter over land

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
  - **Poorly known spectral shape of surface**

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.



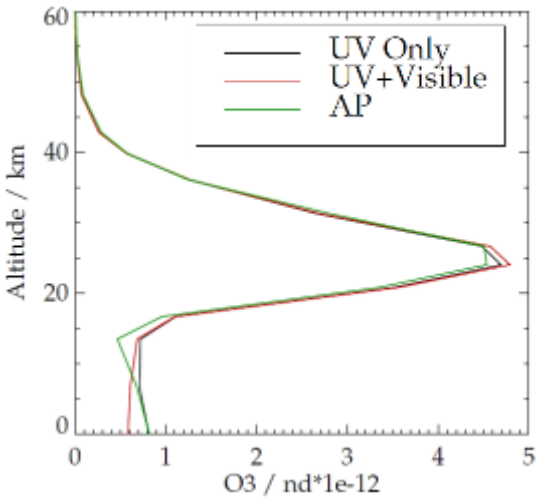
GOME-2A 2008 mean cloud free 3-channel RGB

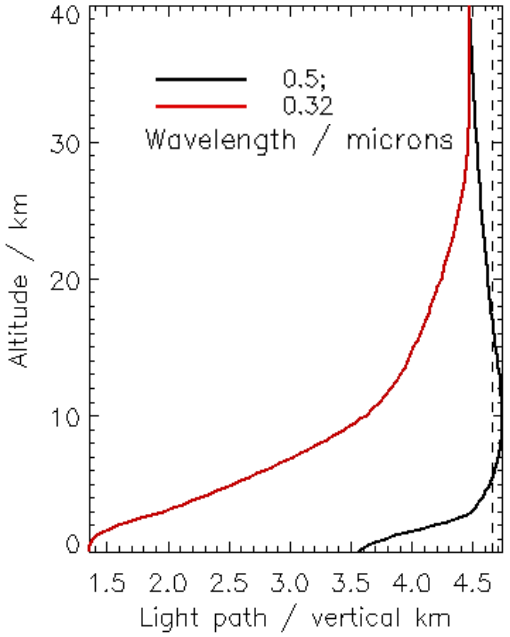
Combining UV and visible information

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

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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2 approaches to Chappuis slant column fitting

- SVD
  - Mathematical approach
  - Just uses Chappuis measurement vector and UV-derived slant columns to evaluate principle components to fit for ozone variability from measurements
  - Clean but difficult to interpret
- DOAS
  - Physically based approach
  - Patterns fit to represent atmospheric features in GOME-2/TEMPO fit windows
  - Intuitive and independent but noisy

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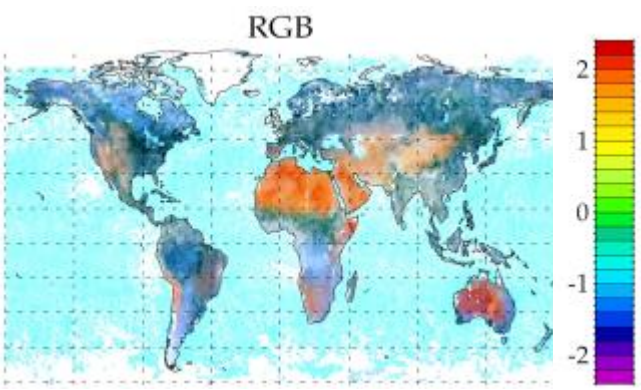
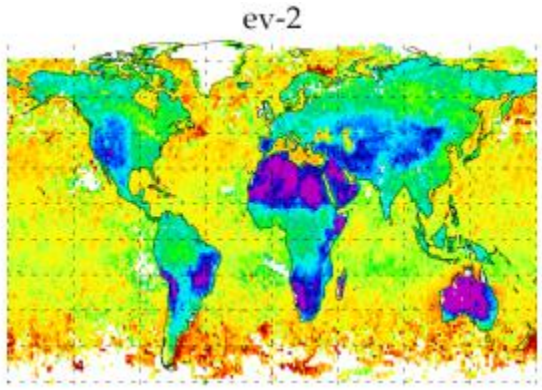
SVD – Results/status

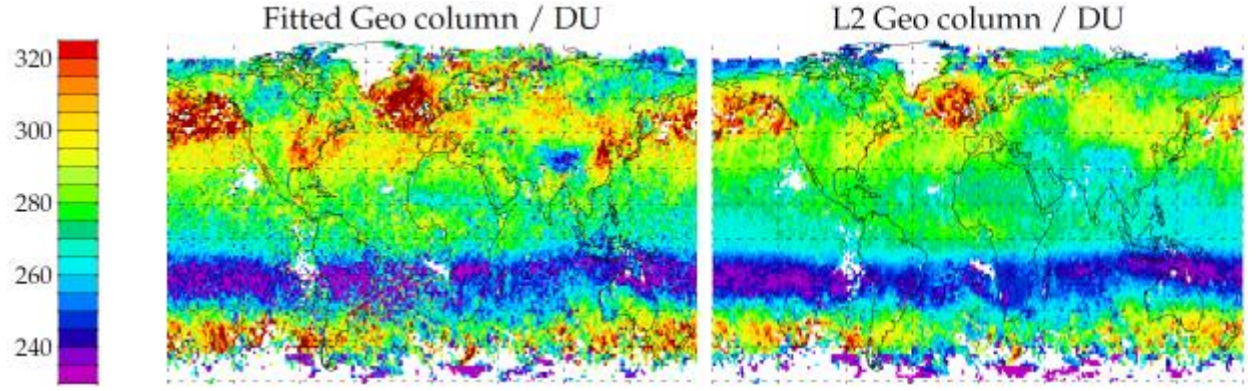
- Very good correlation with UV slant columns, but early results indicate that over 30 patterns need to be fit which may impair information content for ozone
- Fewer needed over ocean
- GOME-2 measurements are sensitive to many things



GOME-2A 2008 August mean cloud free 3-channel RGB

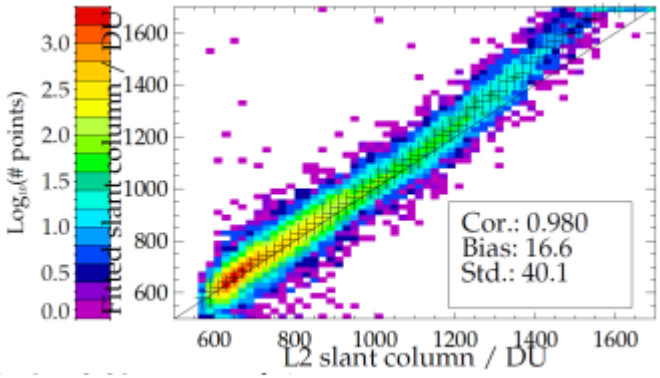


Low order patterns capture most of surface spectral shape, but many of the higher order ones do too



Chappuis slant column converted to a geometric total column

UV slant column converted to a geometric total column



2008 August cloud cleared mean

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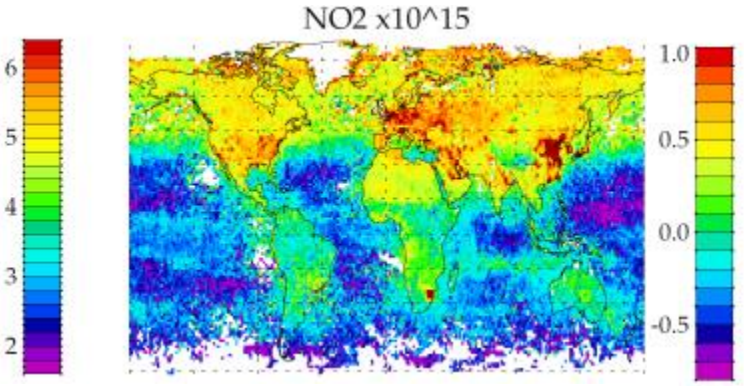
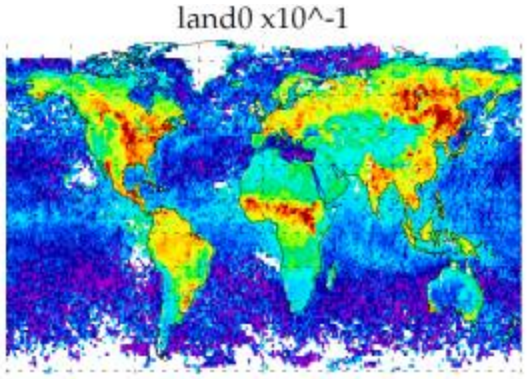
DOAS – Results/status

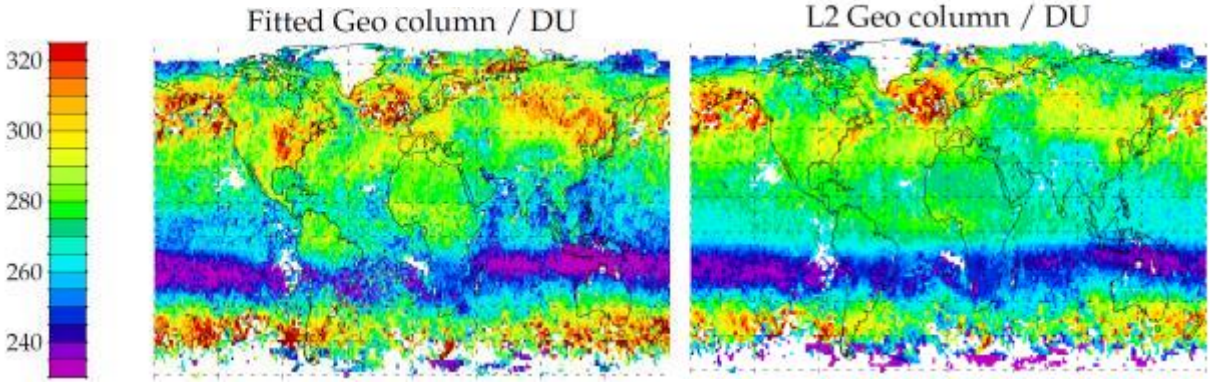
- Good correlation but still limited quality over some surface types
- 37+ patterns needed to represent spectral variability, including 7 for land
- Limited by spectral resolution of surface spectral databases



NO_2 slant column

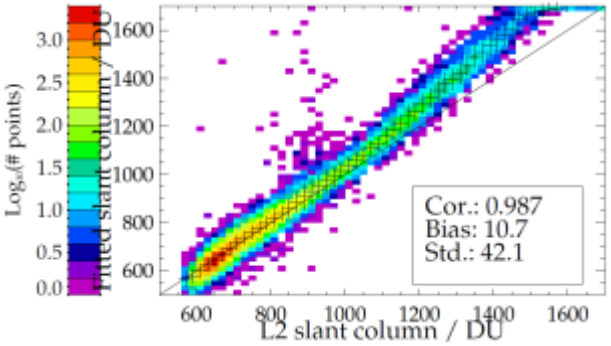


First of 7 “land” patterns used in DOAS fit



Chappuis slant column converted to a geometric total column

UV slant column converted to a geometric total column



2008 August cloud cleared mean

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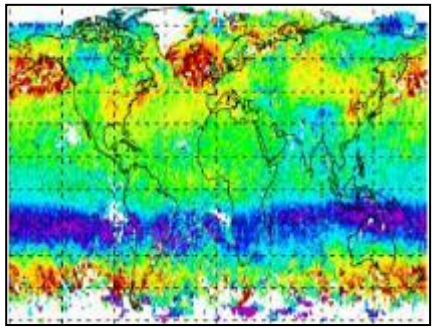
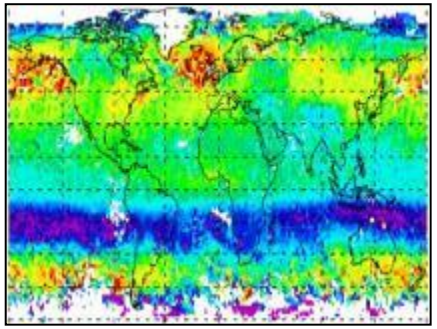
Is there boundary layer ozone information?

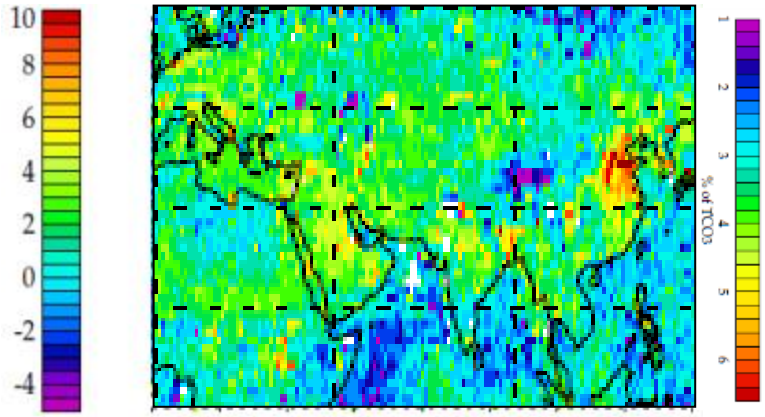
- Use CTM to constrain tropospheric ozone in simulation using real measurements
- Difference between simulated UV slant column and visible slant column is associated with different **sensitivity to boundary layer ozone**, as compared to modelled "boundary layer" ozone**:**

UV vertical column

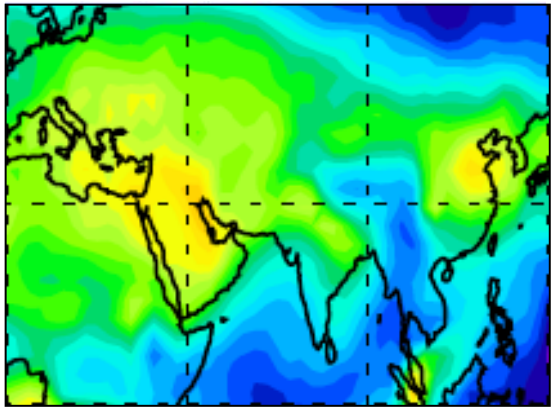


Chappuis vertical column





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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Chappuis - Next steps

- Current retrievals would benefit from **better constraint on land spectral patterns** - currently need to fit many patterns makes ozone fit noisy (as well as possibly introducing systematic errors in ozone depending on land/surface type)
- Improve radiative transfer modelling of Chappuis light path before combining UV and vis information
  - Can exploit other measures of light path from vis/nir (O4,O2, Ring)
- TEMPO will have big advantage of multi-time of day obs from which spectral surface patterns might be drawn out more clearly.
- Working towards a publication in 2015.