Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

Tropospheric Ozone from TROPOMI

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Introduction

- Tropospheric ozone requirements
- TROPOMI tropospheric ozone column:
  - As part of the ozone profile product
  - Tropospheric ozone using convective cloud differential algorithm (CCD) method
- TROPOMI spectral bands
- TROPOMI ozone profile algorithm
- Examples of tropospheric ozone from OMI

ESA CCI Requirements

User Requirement Document
Issue: 3.0 – Date of issue: 12/04/2016
Reference: Ozone_cci_URD_3.0

Parameter	Application	Horizontal Resolution (km)	Vertical Resolution (km)	Observing Cycle (h)	Precision (%)	Accuracy (%)	Stability (%)	Types of error
Ozone								
Troposphere column	Model Development and Evaluation	50		72	15	15	5.0 %/decade	SSEOB
	Reanalysis and Data Assimilation	10		3	5	5	3.0 %/decade	SSEOB

Comments:

- The precision will depend strongly on the a-prior error.
- Is the smoothing error included in the accuracy?

TROPOMI Requirements

Table 4.3-1. Accuracy requirements for sub columns of the ozone profile.

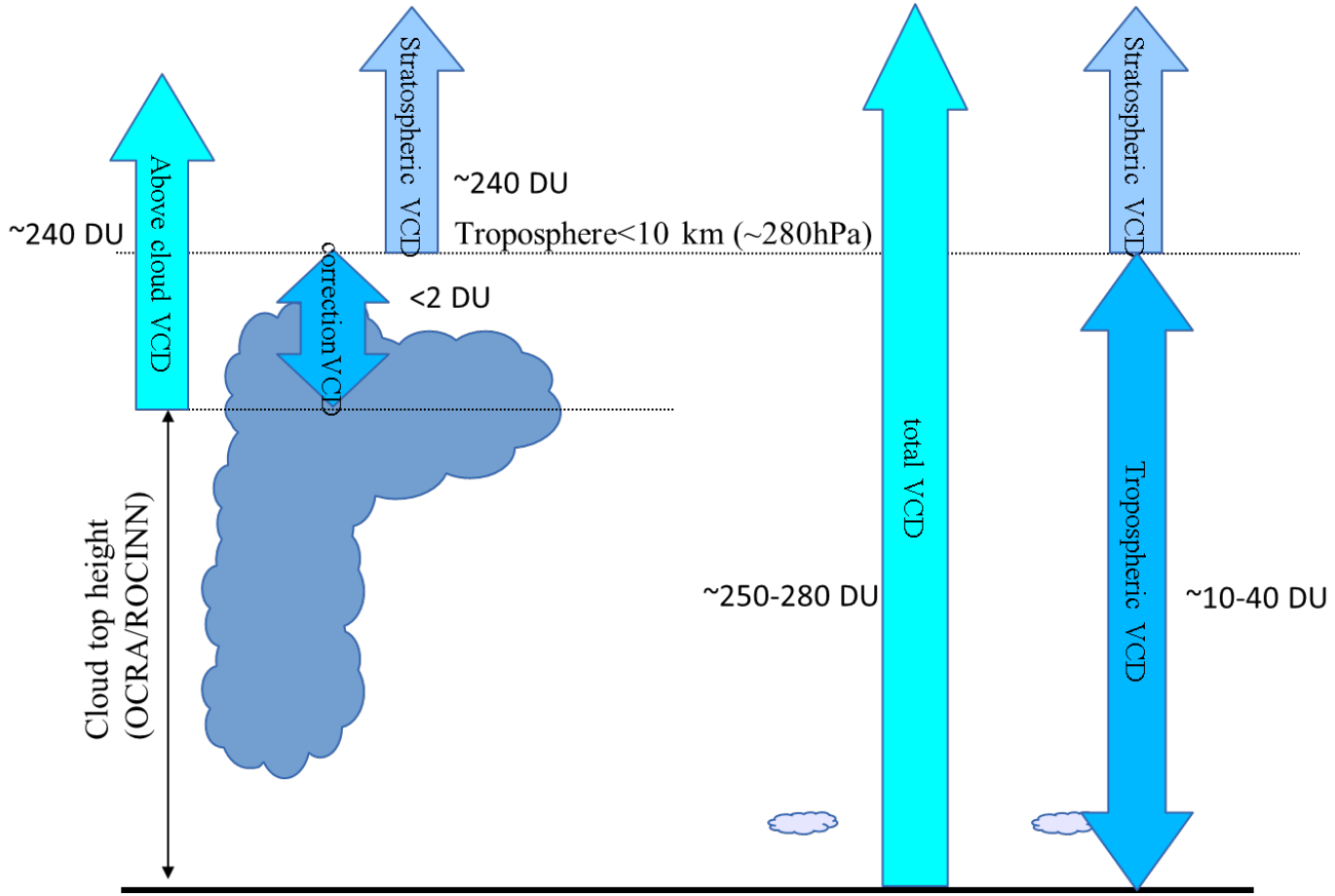
Sub column	PBL[1)]	0 - 6 km	6-12 km	12-18 km	18-50 km
Required accuracy	≤ 60 %	≤ 20 %	≤ 12 %	≤ 5 %	≤ 3 %

[1)] In practice the pressure at the top of the planetary boundary layer is not known and results for this sub column can not be provided. Simulation studies can be used to estimate the accuracy for the PBL.

Comments:

- Accuracy is defined as the total error, including precision.

S5P Tropospheric Ozone Algorithm – CCD

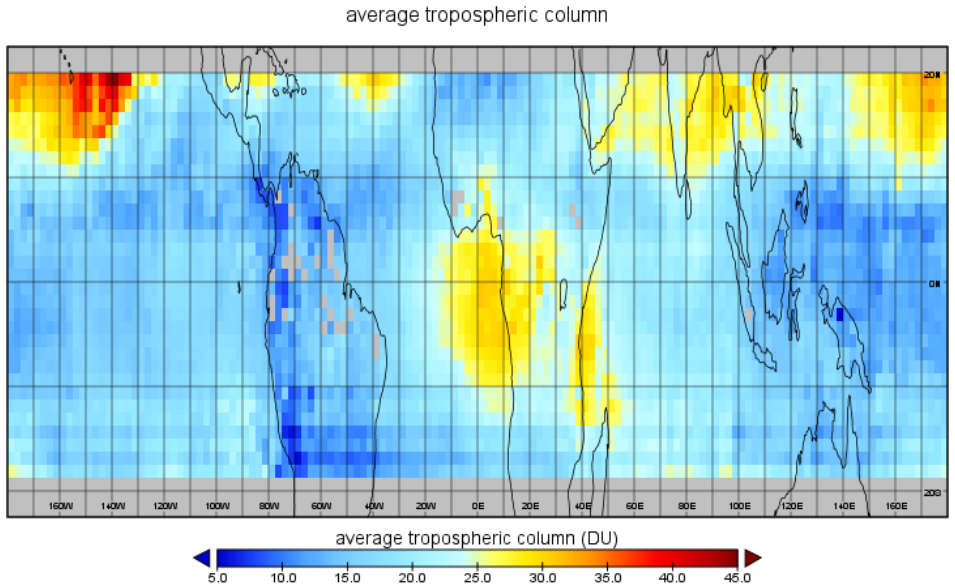


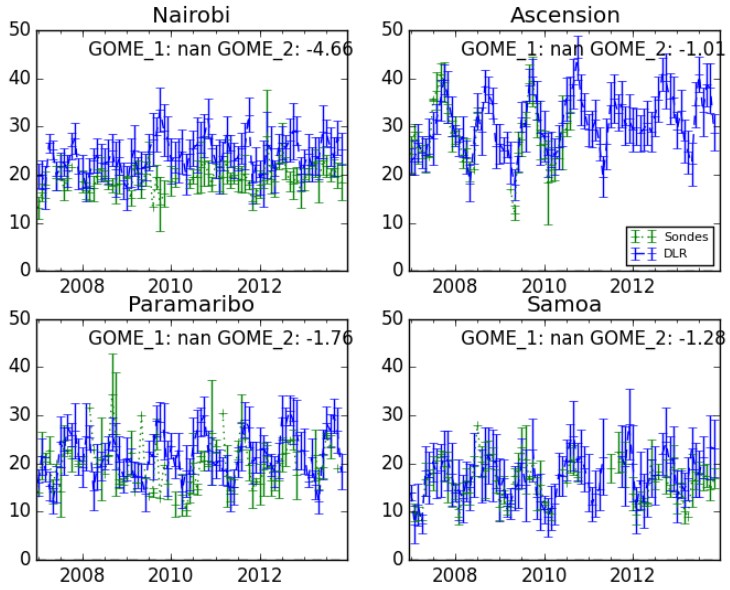
Valks et al., AMT 2014

Tropospheric Ozone CCD from GOME-2

- CCD algorithm applied to operational O3M-SAF GOME-2 GDP 4.8 data
  - DOAS total ozone (*Loyola et al., JGR 2011; Hao et al., AMT 2014*)
  - OCRA & ROCINN clouds (*Loyola et al., TGRS 2007; Lutz et al., AMT 2016*)
  - http://atmos.caf.dlr.de/products/gome2

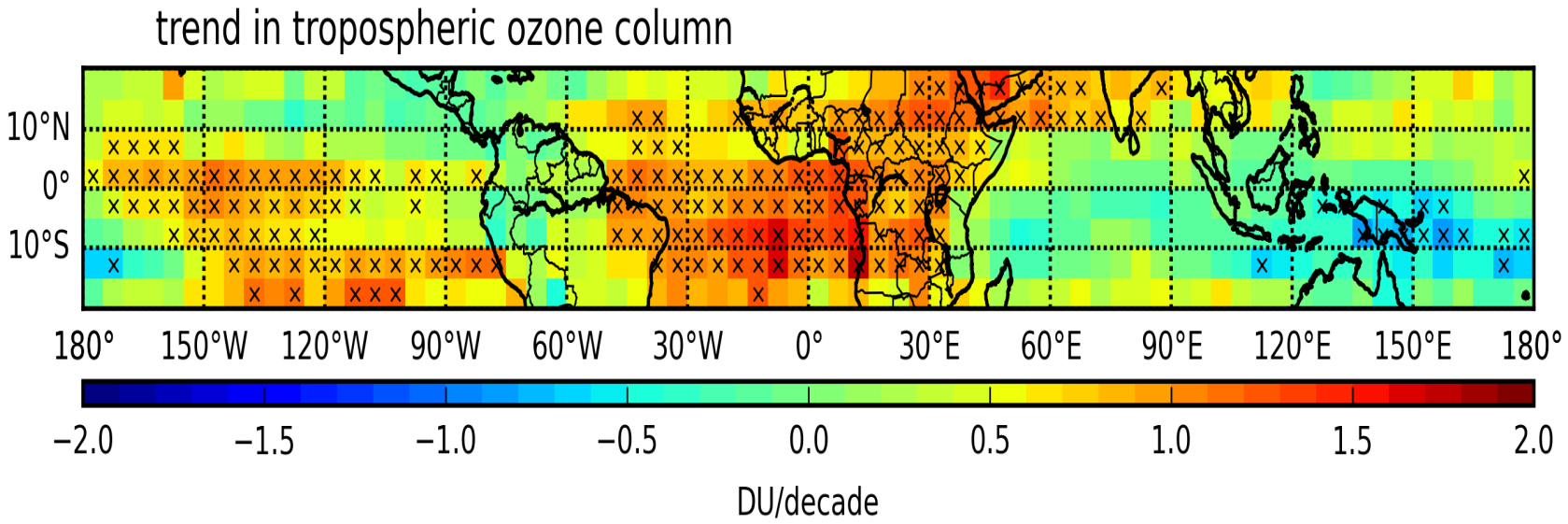
- Tropospheric column up to 10 km (~280 hPa) monthly means with a resolution of 2.5 x 1.25˚(long x lat)





Tropospheric Ozone CCD Trends

- Tropospheric Ozone CCD Time series 1995 to 2015 (~20 years) using ESA CCI data from GOME, SCIA, OMI, GOME-2A and GOME-2B
- Harmonized using SCIAMACHY as reference
- Fit linear function, sine, cosine, and indices for ENSO, QBO, solar flux
- Global tropical trend 0.7 ± 0.12 DU/decade
- Regional trends



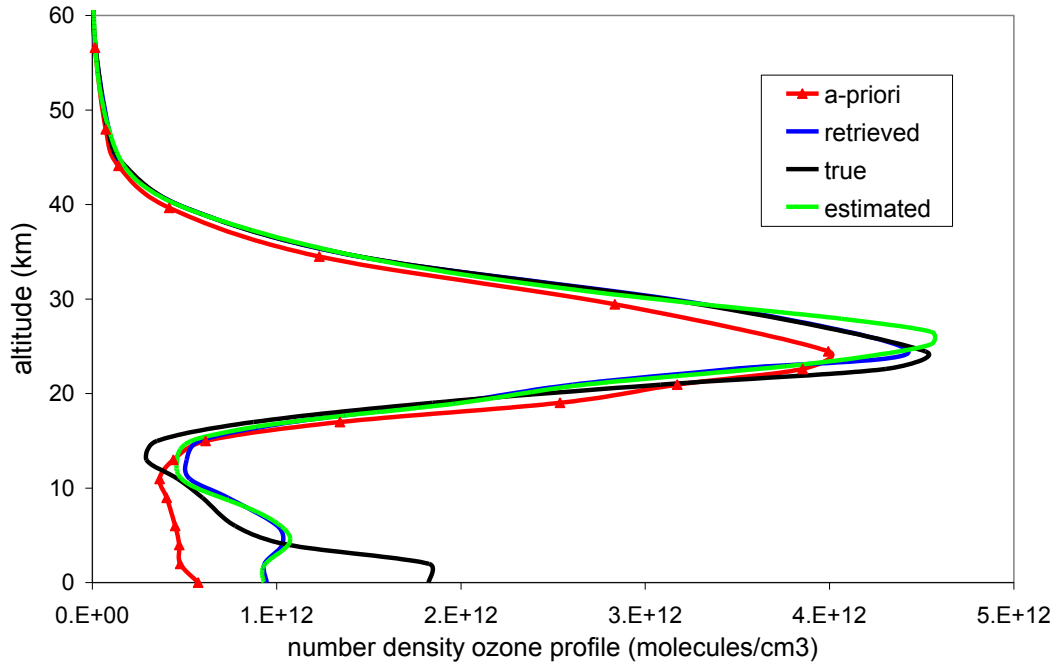
Heue et al., AMT in-press

TROPOMI spectral bands

TROPOMI	UV		UVIS		NIR		SWIR	
Band	1	2	3	4	5	6	7	8
Spectral coverage [nm]	270 – 320		320 – 495		675 - 775		2305 – 2385	
Full spectral coverage [nm]	267 - 332		303 - 499		660 - 784		2299 - 2390	
Spectral resolution [nm]	0.49		0.54		0.38		0.25	
Spectral sampling ratio	6.7		2.5		2.8		2.5	
Spatial sampling [km^2]	7 x 28		**7 x 3.5**				7 x 7	

TROPOMI O3 Profile Algorithm

- Optimal estimation with on-line radiative transfer
- State vector elements: see next slide
- Initially, the a priori profile will be taken from the TOMS V8 climatology with simple a priori errors.
- Spectral window: 270-325 nm
- Output product:
  - Ozone profile: 21 levels
  - 4 sub-columns, 2 in the troposphere
  - Tropospheric column
  - + averaging kernels etc.



State vector elements

Table 5.1. State vector elements.

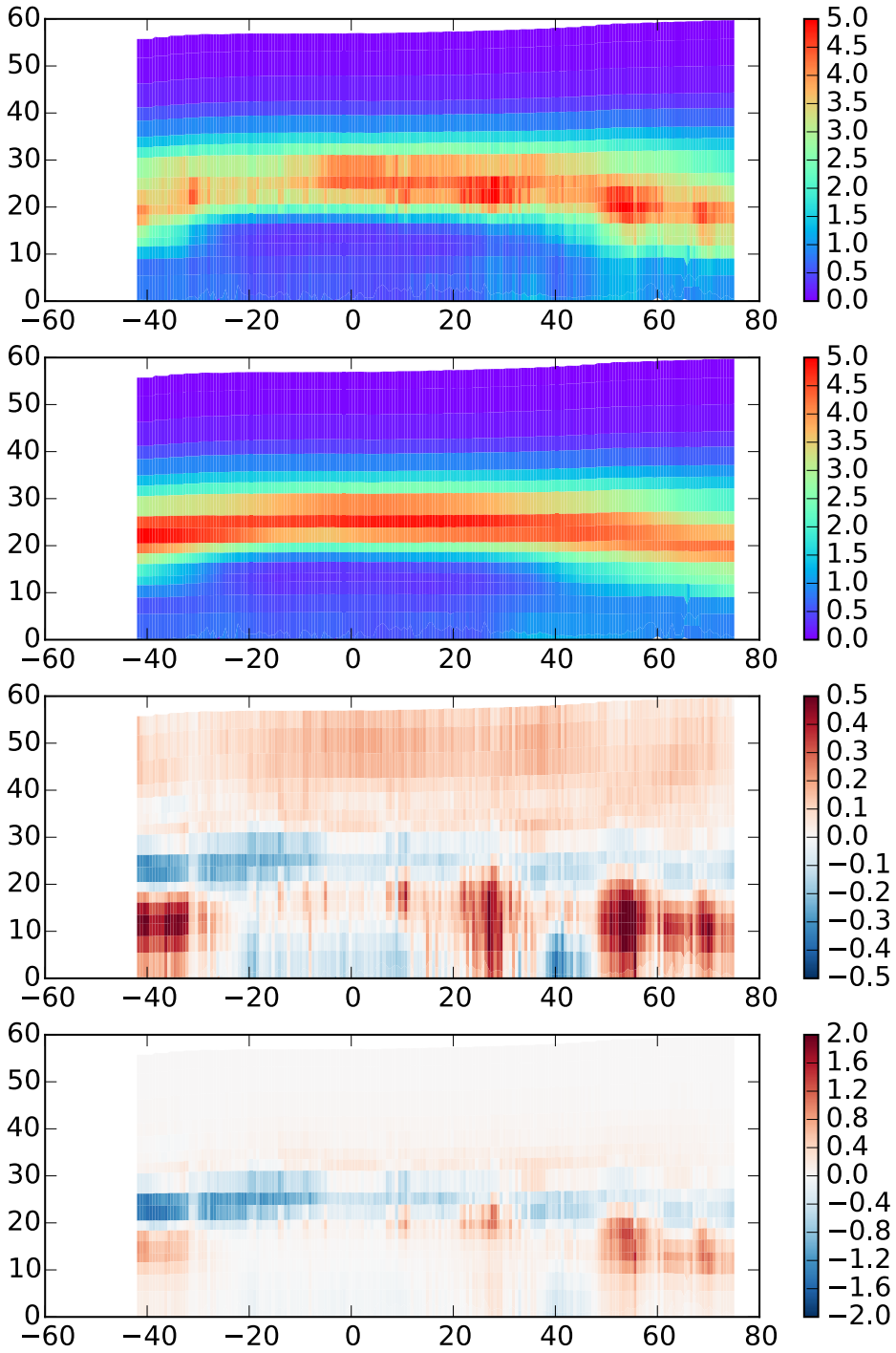
State vector elements	**A priori value**	**A priori error (1 sigma)**
The logarithm of the ozone volume mixing ratio at different pressure levels	From climatology.	20% for the volume mixing ratio outside ozone hole conditions. 60% for ozone hole conditions.
SO_2 column	0.1 DU	5 DU
Temperature shift at all ECMWF pressure levels or one shift that applied to all levels.	ECMWF data	5 K (TBD)
Surface albedo at one or more nodes (optionally one for band 1 and one for band 2)	0.05	1.0 (is large to account for snow/ice)
Cloud fraction (optionally one for band 1 and one for band 2). Cloud fraction can be made wavelength dependent to reduce errors due to differences in co-registration.	From FRESCO	From FRESCO + additional error to account for mis-registration
Cloud albedo (optionally one for band 1 and one for band 2)	From FRESCO	0.3 (TBD)
Cloud pressure	From FRESCO	From FRESCO
Wavelength at one or more wavelength nodes	Nominal wavelength from Level 1b product	0.02 nm (TBD)
Stray light coefficients at one or more wavelength nodes	0.0	TBD

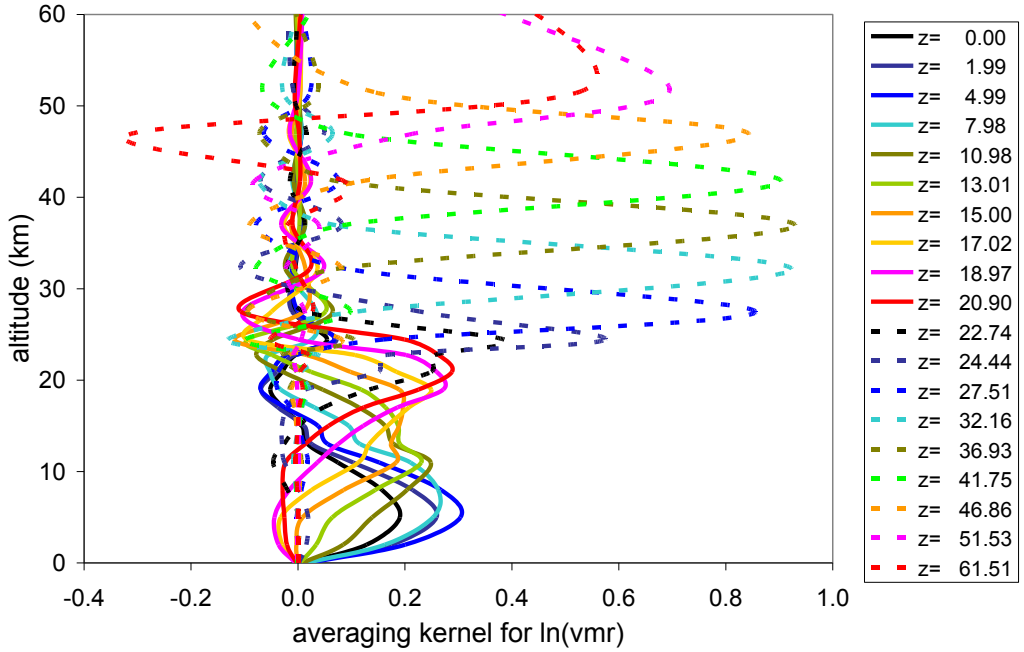
Retrieved

A priori

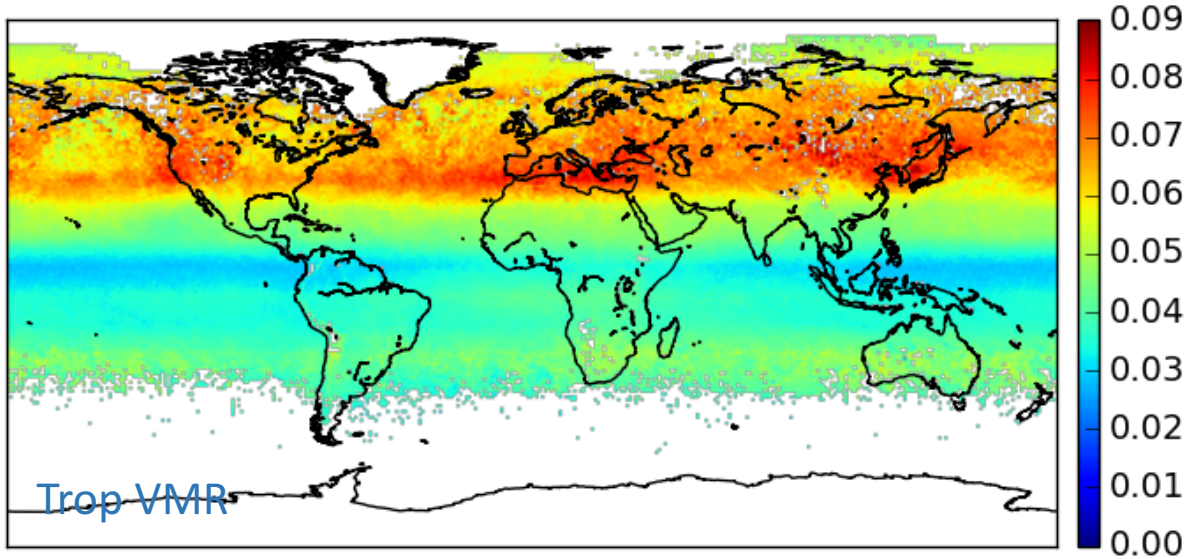
Relative difference

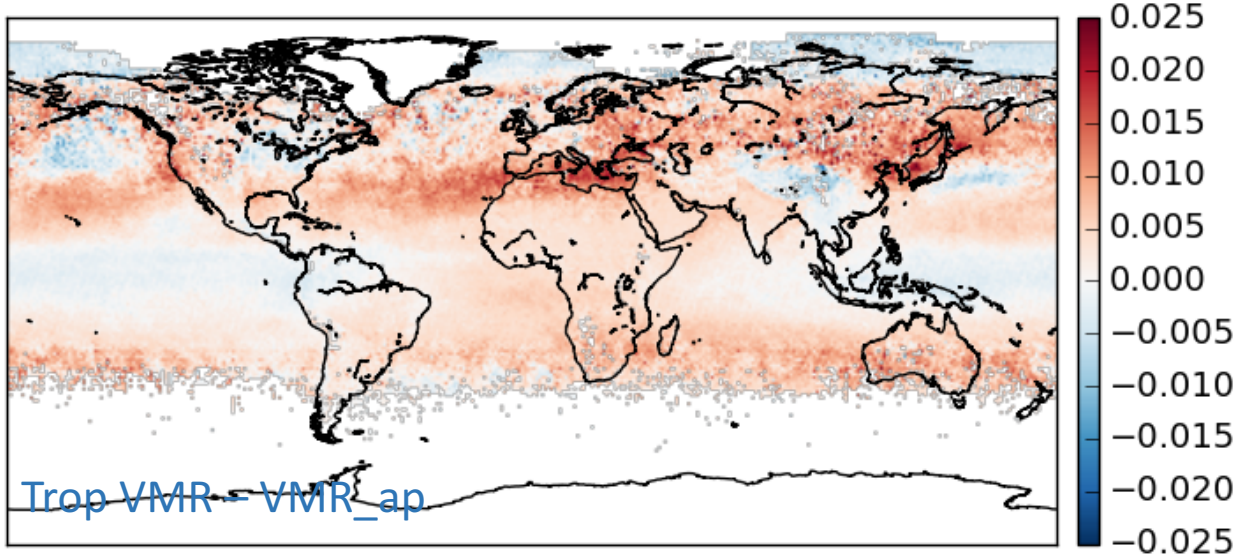
Absolute difference

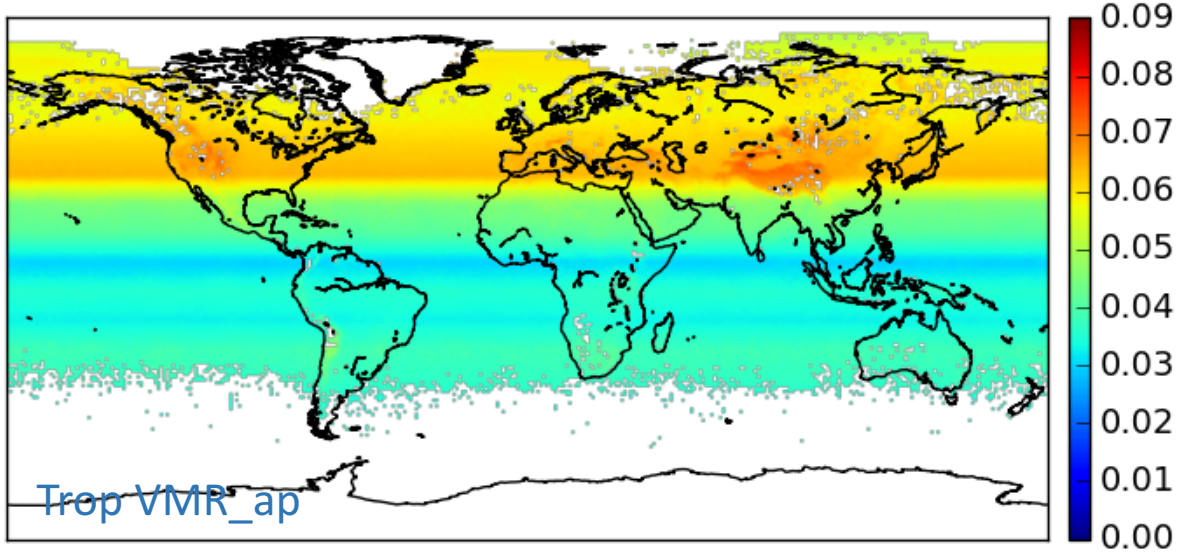




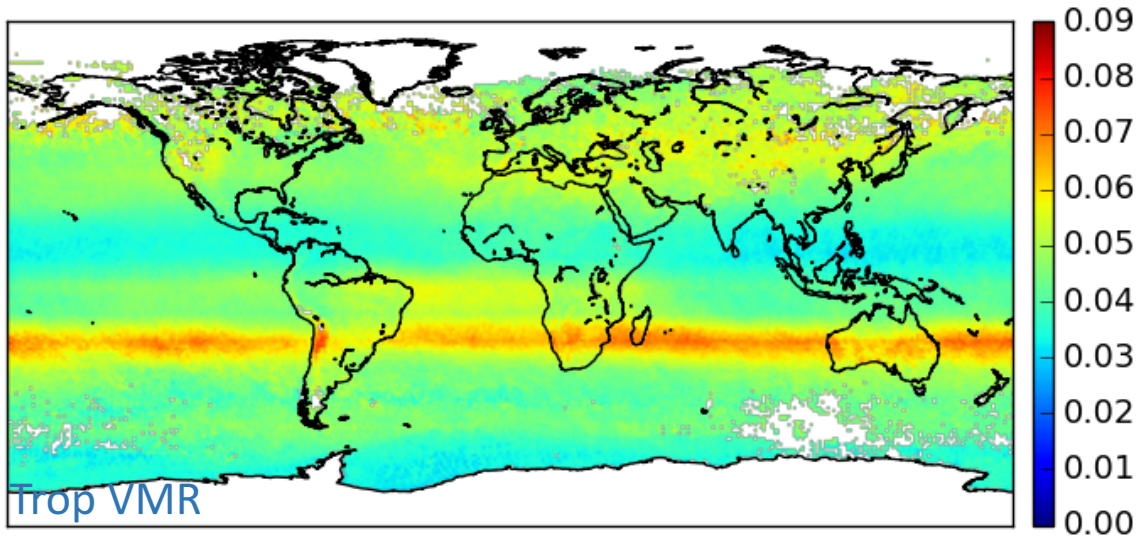
OMO3PR 2005-06

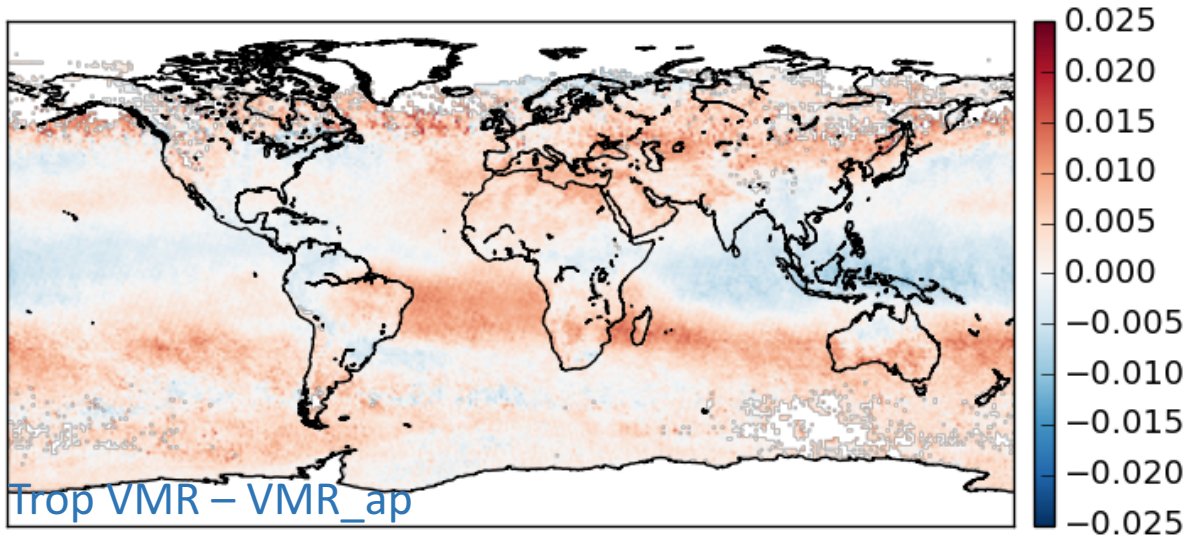


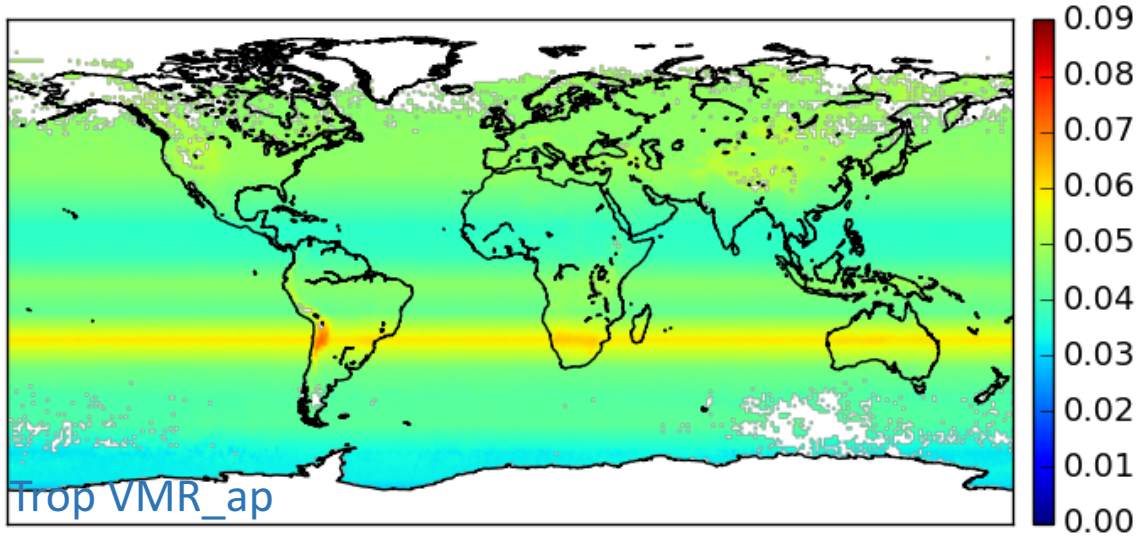




OMO3PR 2005-10







Summary

- TROPOMI tropospheric ozone products:
  - Cloud convective cloud differential algorithm (CCD) method
  - Ozone profile
- The UV spectrometer is optimized for ozone profile retrieval.
- Research opportunities for combined UV-TIR retrieval (with NPP/CrIS) and higher spatial resolution products.
- Algorithms should be optimized for tropospheric ozone w.r.t. a-priori ozone profile and a-priori errors.
- UV ozone profile products are complex to use, because of the tropospheric ozone averaging kernels and dependence on a priori.