

Tropospheric ozone retrieval from OMPS

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What do we want to do?

Retrieve tropospheric ozone using a tropospheric ozone residual technique from OMPS limb-nadir matching observations

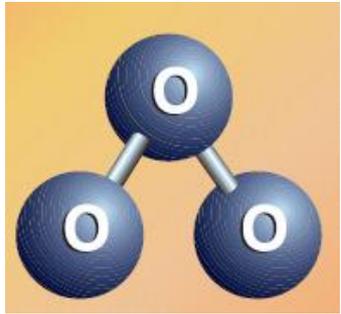
Subtract the stratospheric ozone column from the total ozone column.

$$TropO_3 = TOC - SOC$$

1° Total ozone column (TOC) – from OMPS Nadir Mapper

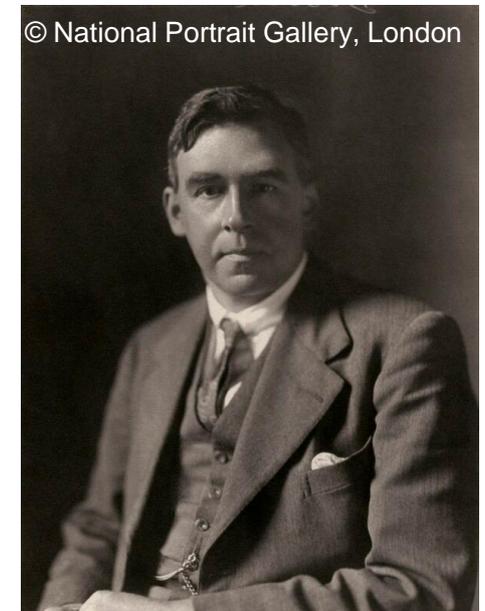
2° Stratospheric ozone column (SOC) – from OMPS Limb Profiler

What is Ozone?



Blue gas

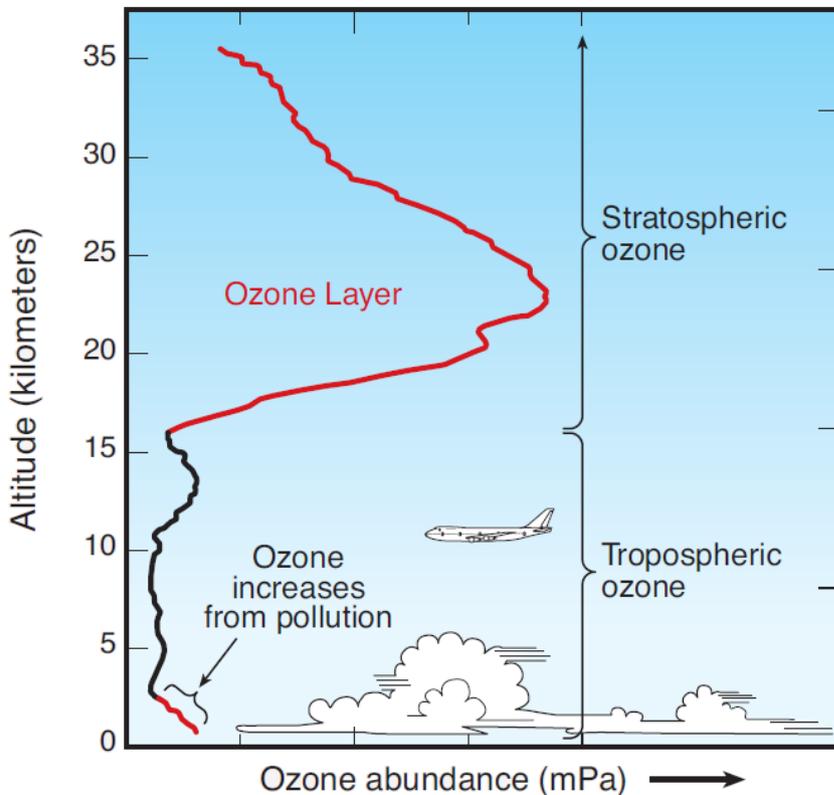
From *ὄζειν* - "to smell"



© National Portrait Gallery, London

Gordon Miller Bourne Dobson

Ozone in the Atmosphere



~ 90%
Good ozone



~ 10%
Bad ozone

Dobson units

Vertical thickness of atmosphere in thousandths of a centimetre that is occupied by O_3 at 273 [K] and 1 [atm]

Hegglin et al., 2014

Tropospheric ozone: the “bad ozone”

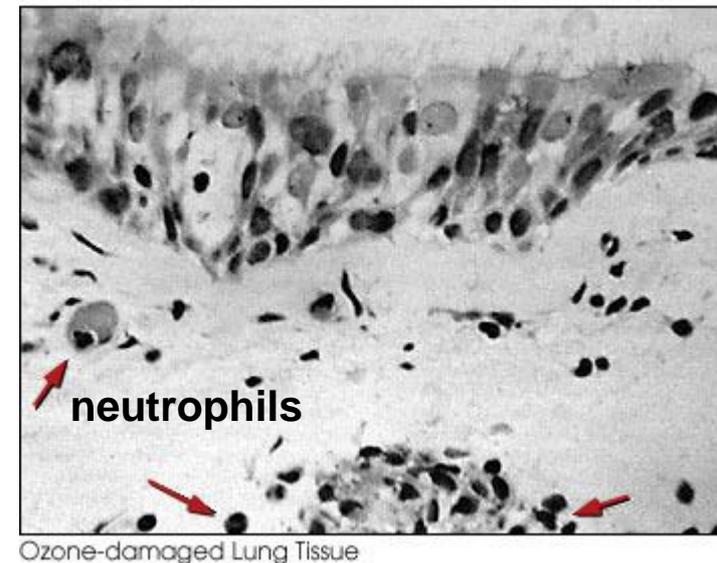
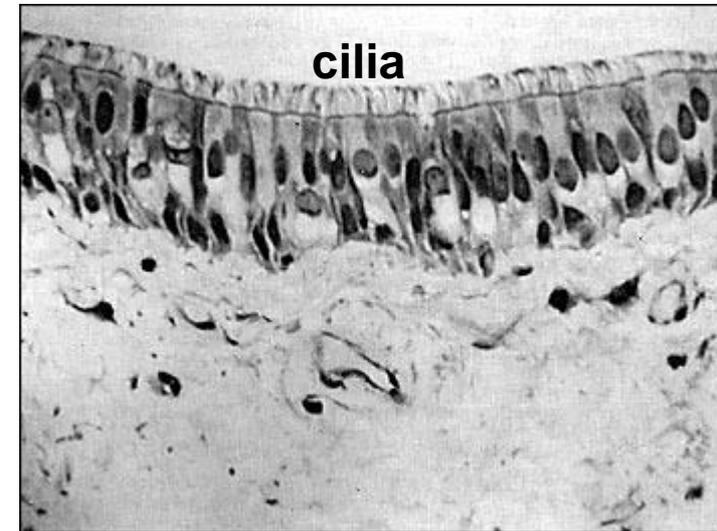
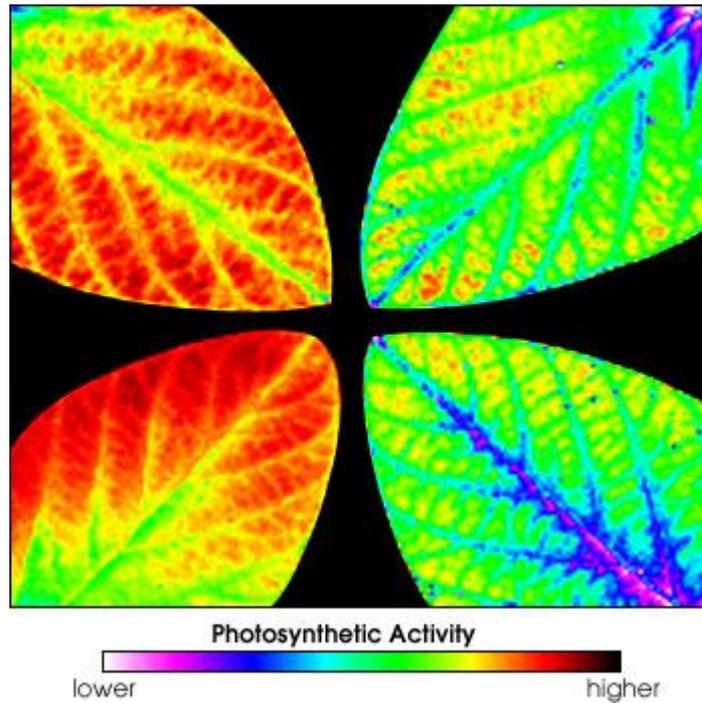
Effects on Human Health

Ozone can cause the muscles in the airways to constrict, trapping air in the alveoli.

Shortness of breath, pain, tightness of the chest, wheezing, and sometimes even nausea.

Effects on Plants

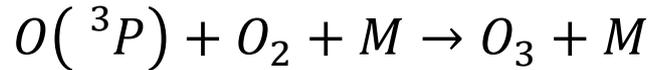
Ozone enters the plant's leaves through its gas exchange pores (stomata), it dissolves in the water within the plant and reacts with other chemicals, causing a variety of problems.



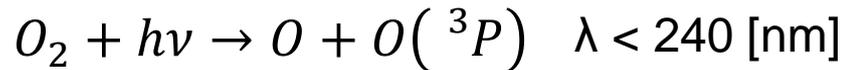
<https://earthobservatory.nasa.gov/Features/OzoneWeBreathe/>

Tropospheric ozone and photochemical air pollution

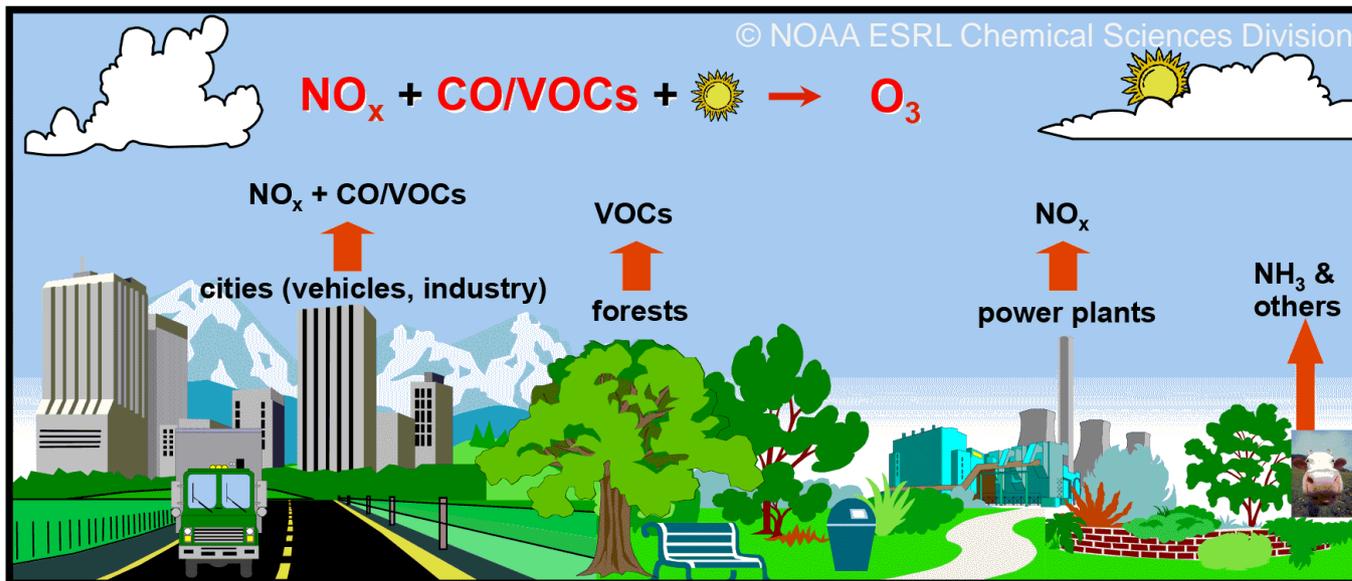
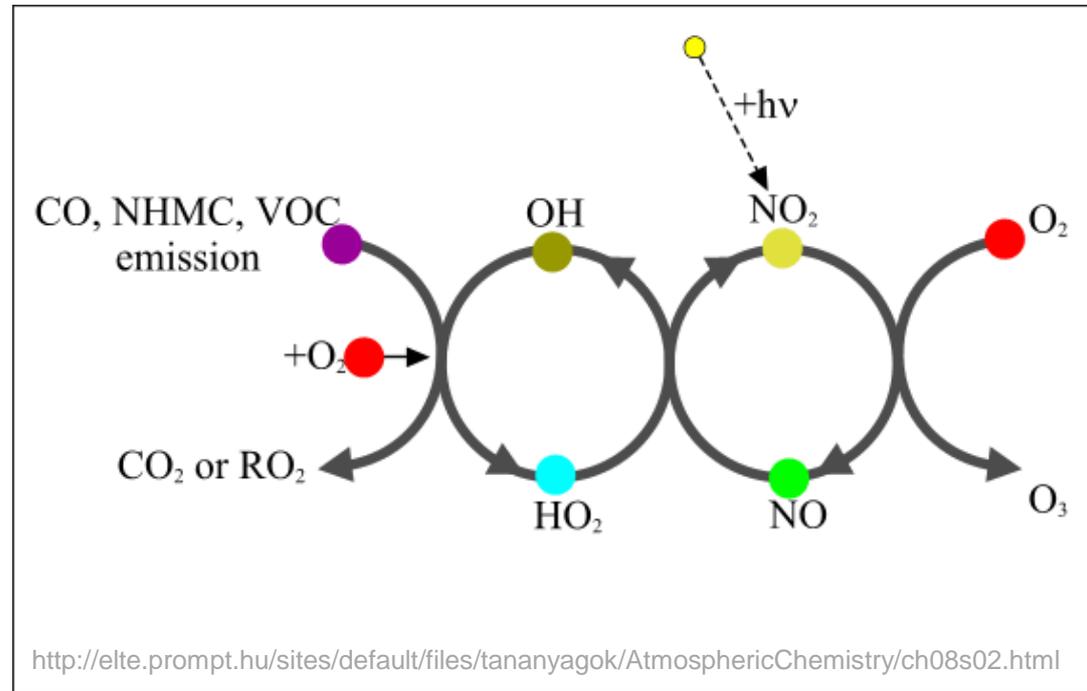
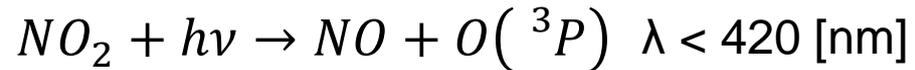
Ozone production



In the stratosphere



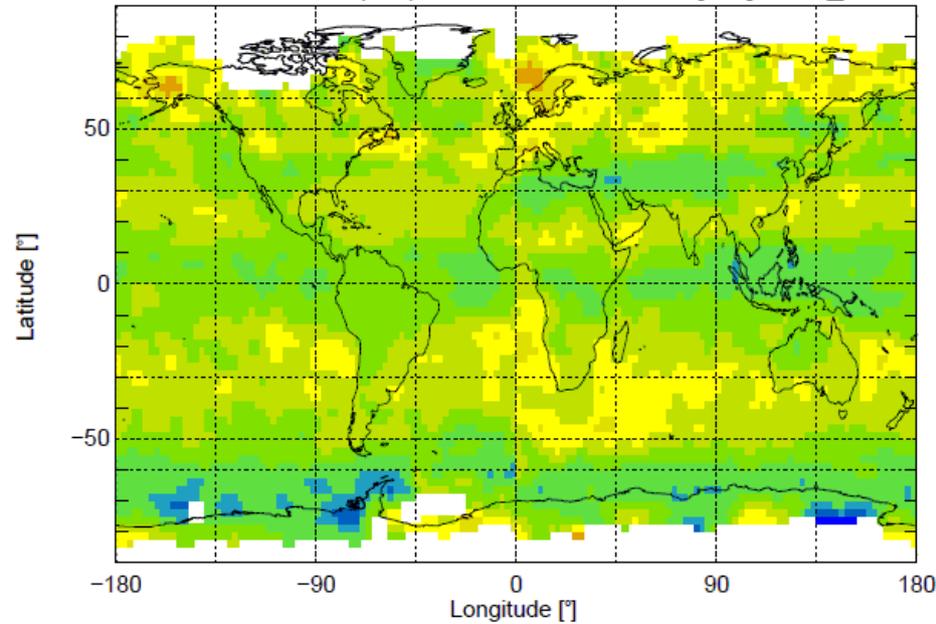
In the troposphere



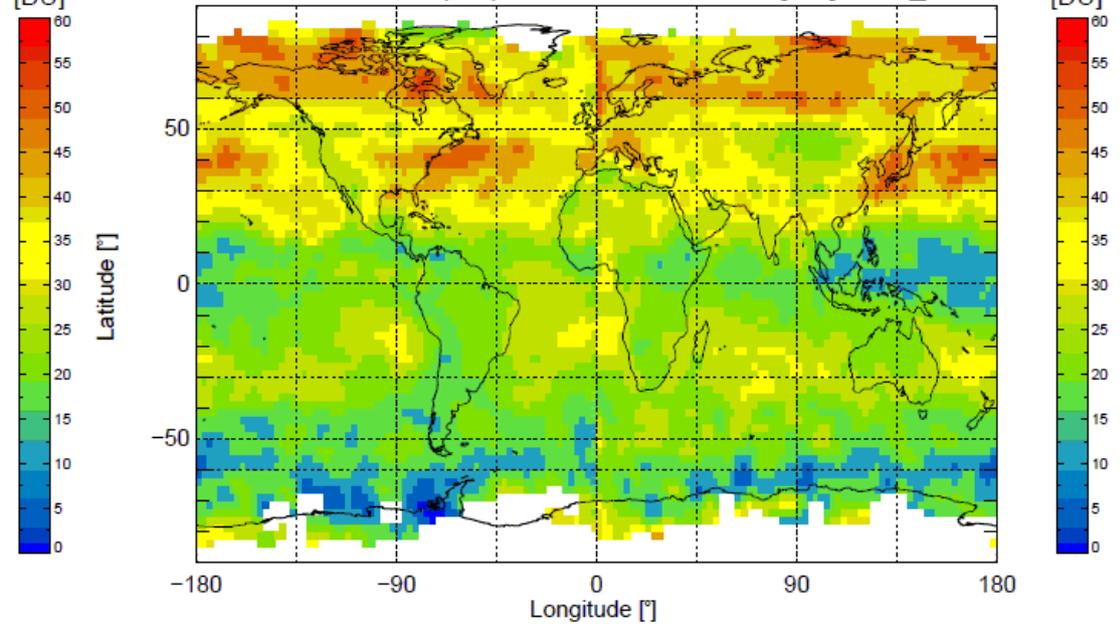
Estimated mean
lifetime in the free
troposphere of ~ 22
days

Global distribution and concentrations

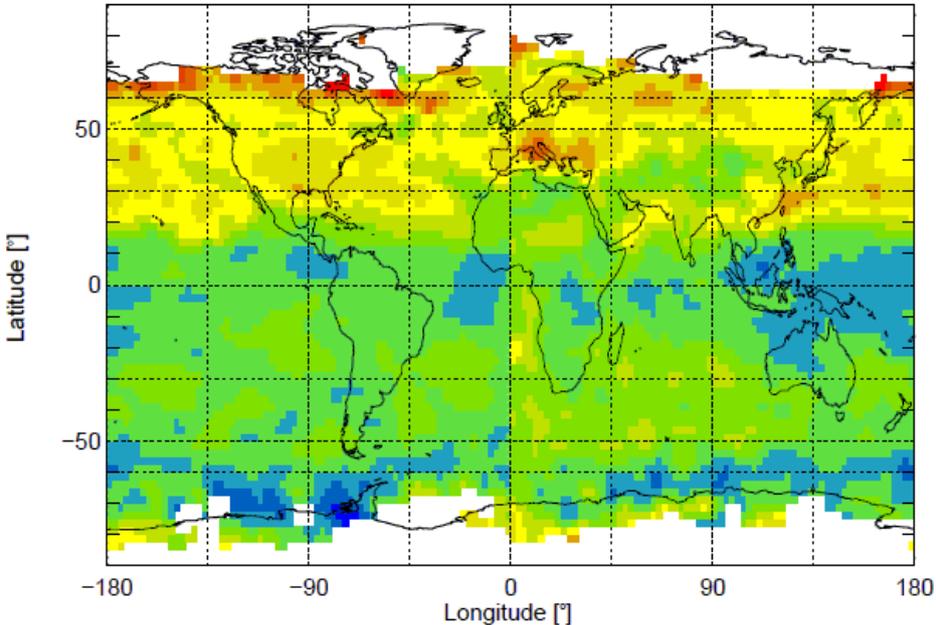
SCIAMACHY Tropospheric Column Ozone [DU] 2003_DJF



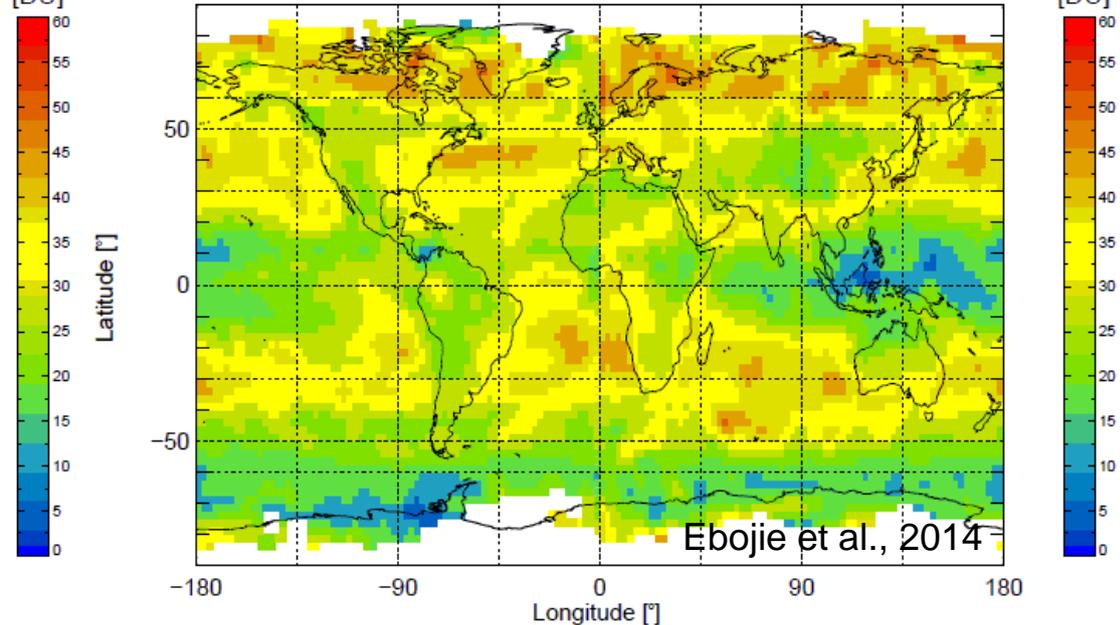
SCIAMACHY Tropospheric Column Ozone [DU] 2003_JJA



SCIAMACHY Tropospheric Column Ozone [DU] 2003_MAM



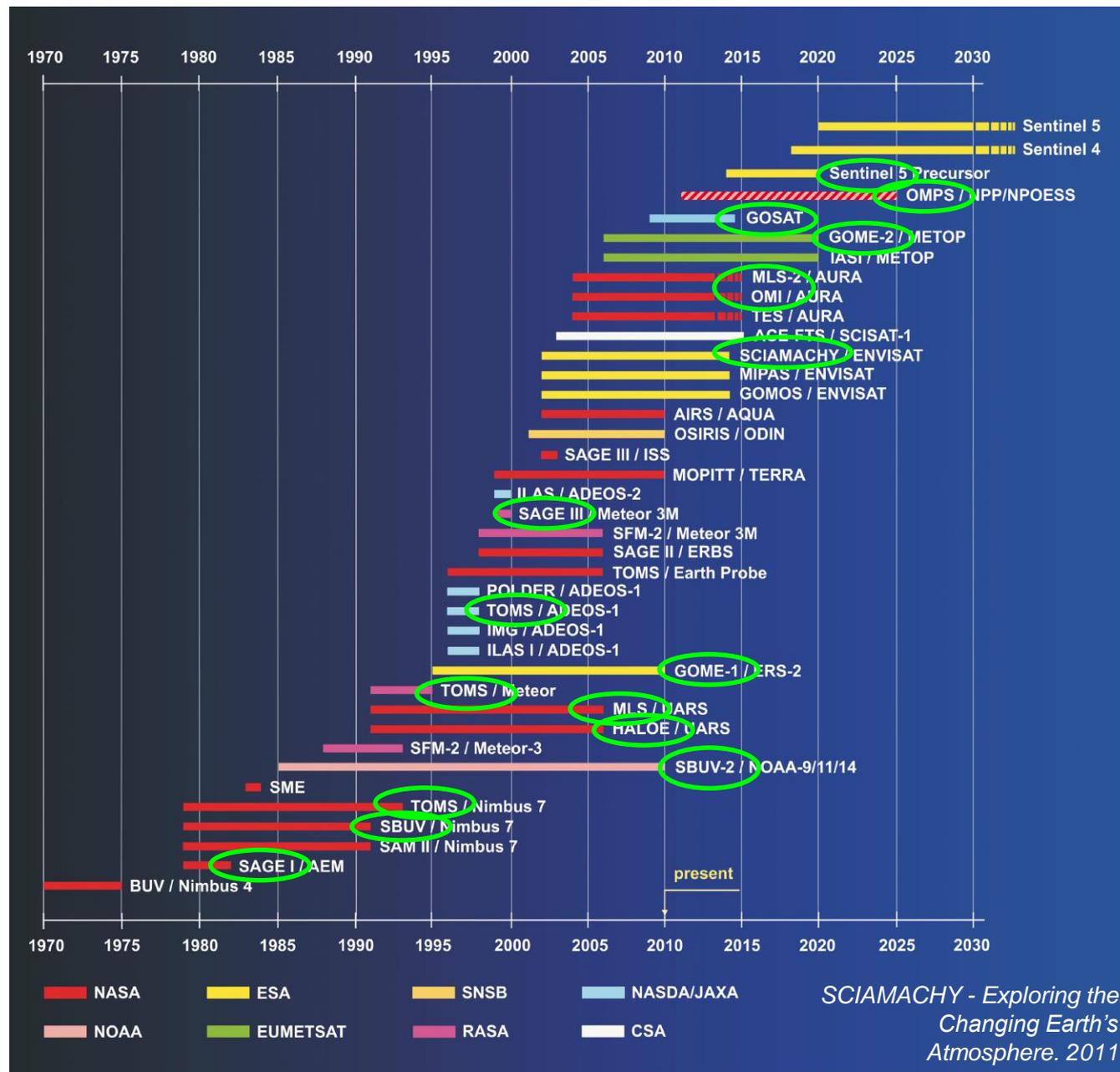
SCIAMACHY Tropospheric Column Ozone [DU] 2003_SON



What has been done?

Passive satellite instruments designed to determine trace gas distributions in the atmosphere

 Tropospheric ozone retrieval



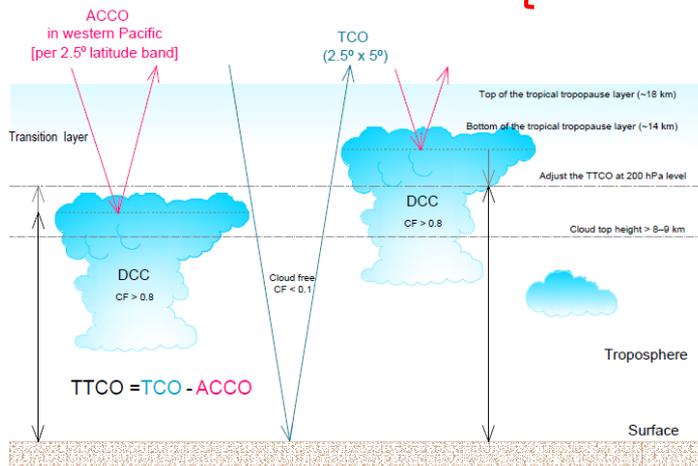
Previous instruments and techniques

Using residual techniques

- Subtract stratospheric O_3 from total ozone column
- Subtract stratospheric O_3 from ozone profiles
- Tropospheric excess method: zonally no variation of stratospheric O_3

Convective cloud differential technique (CCD)

GOME-1
SCIAMACHY
GOME-2



SBUV + TOMS

HALOE + MLS

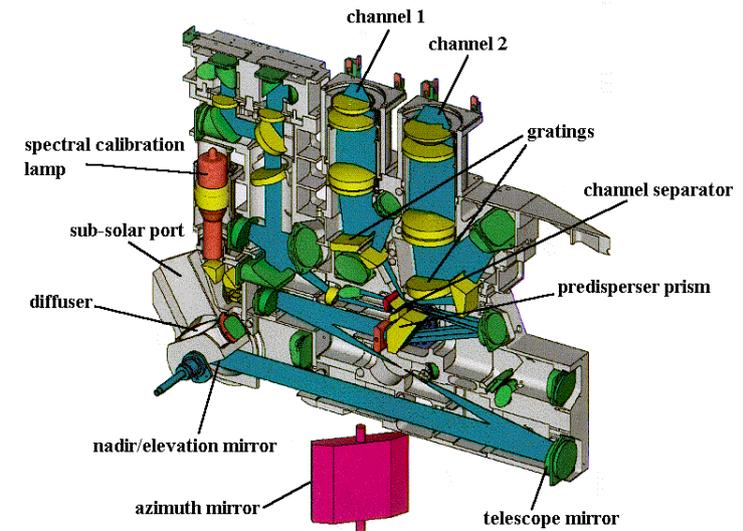
MLS + OMI

SAGE II

GOME

GOME-2

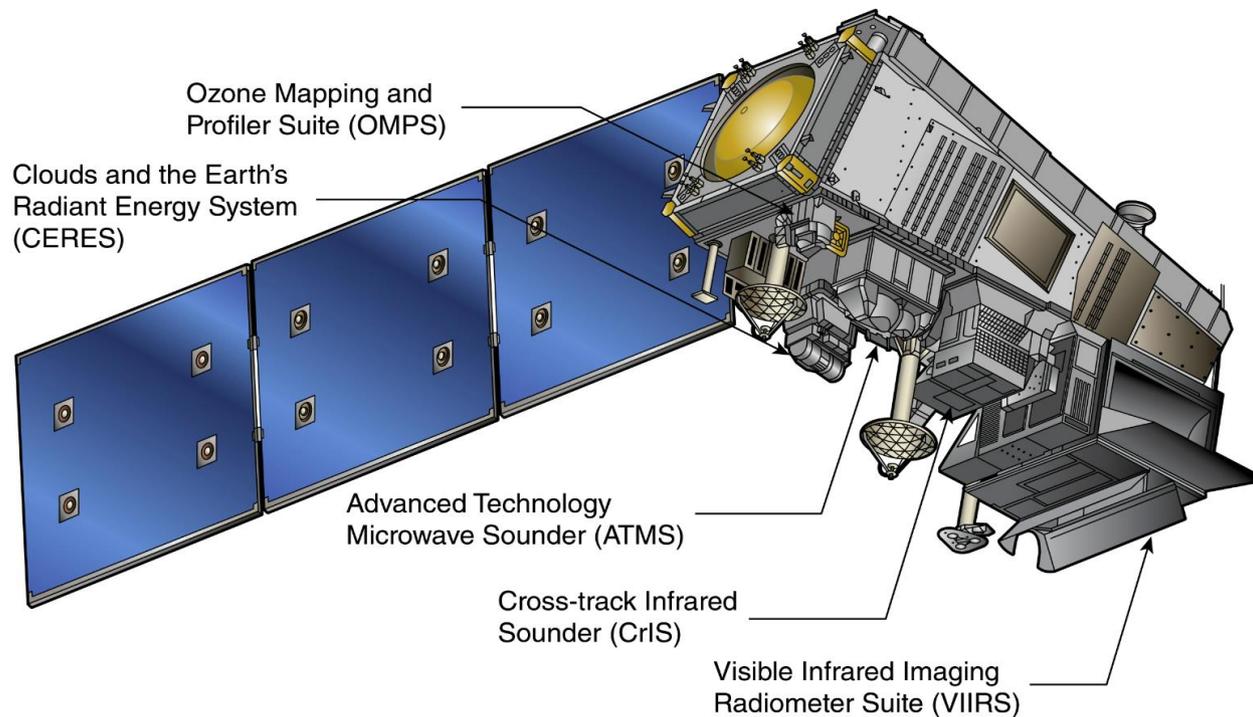
SCIAMACHY



Leventidou et al., 2016

Suomi NPP – JPSS

The Suomi National Polar-orbiting Partnership
Joint Polar Satellite System



OMPS Ozone Mapping & Profiler Suite



<http://cimss.ssec.wisc.edu/goes/blog/suomi-nppjpss-proving-ground>

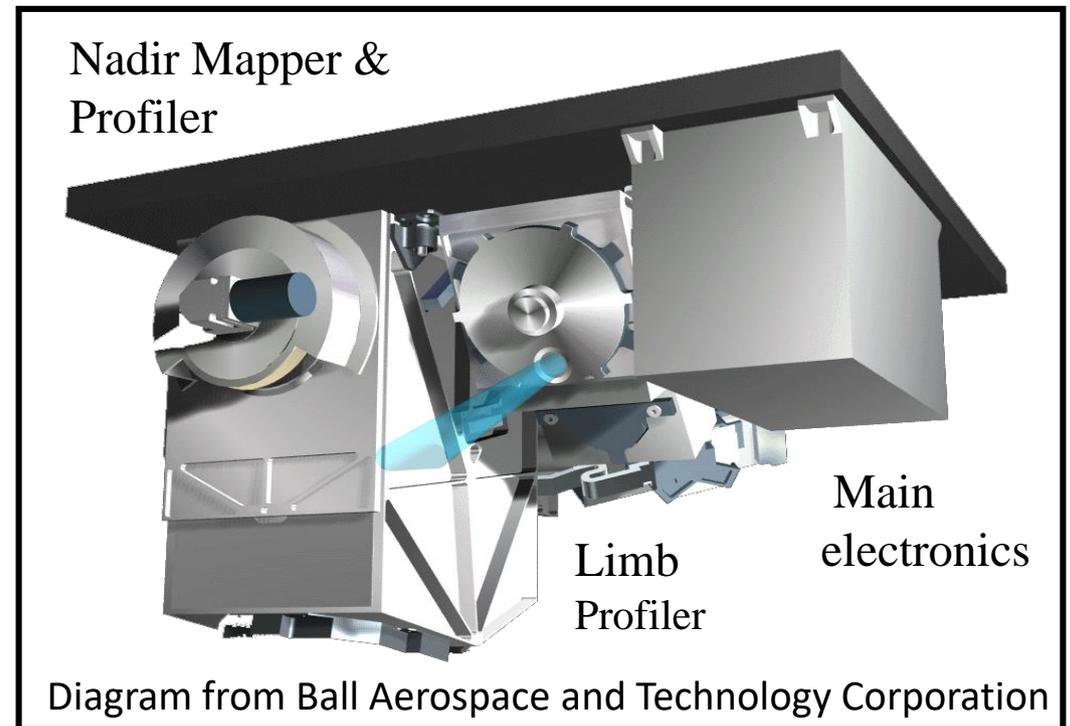
Instrument description

Suomi NPP

- Launch: October 28, 2011
- orbit sun-synchronous with 1330 ascending node
- Altitude: 824 [km]
- 14 orbits per day

OMPS

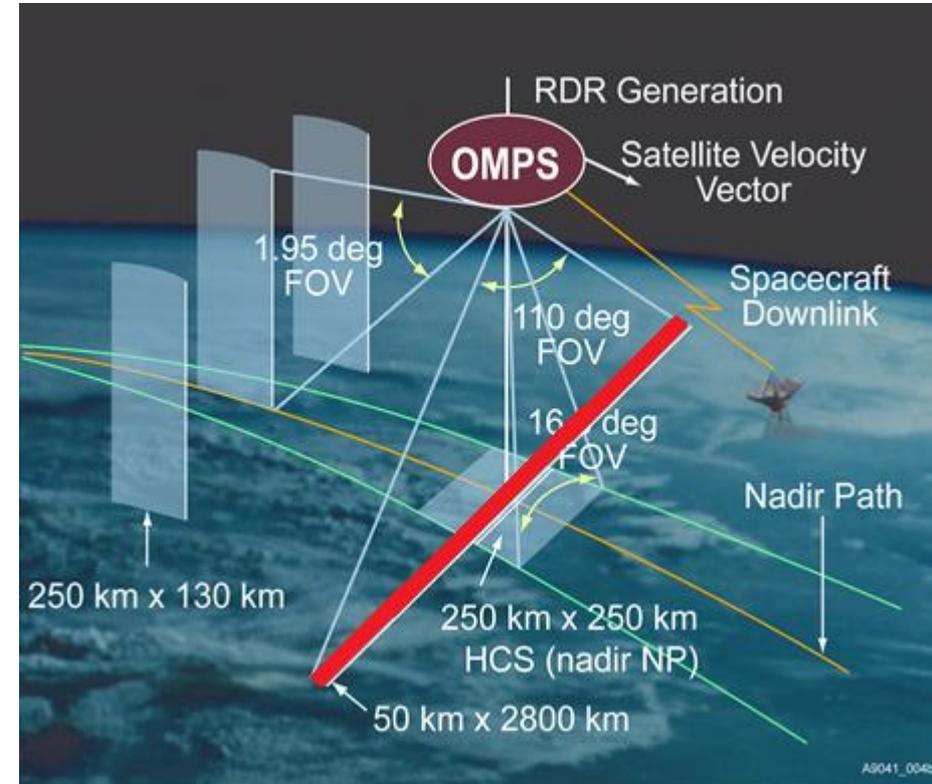
- Collect data since January 2012
- Three-part instrument:
 - Nadir Mapper (NM)
 - Nadir Profiler (NP)
 - Limb Profiler(LP)



The instruments measure radiance scattered from the Earth's atmosphere and surface. The detectors are 2-D CCD arrays with one spectral and one spatial dimension.

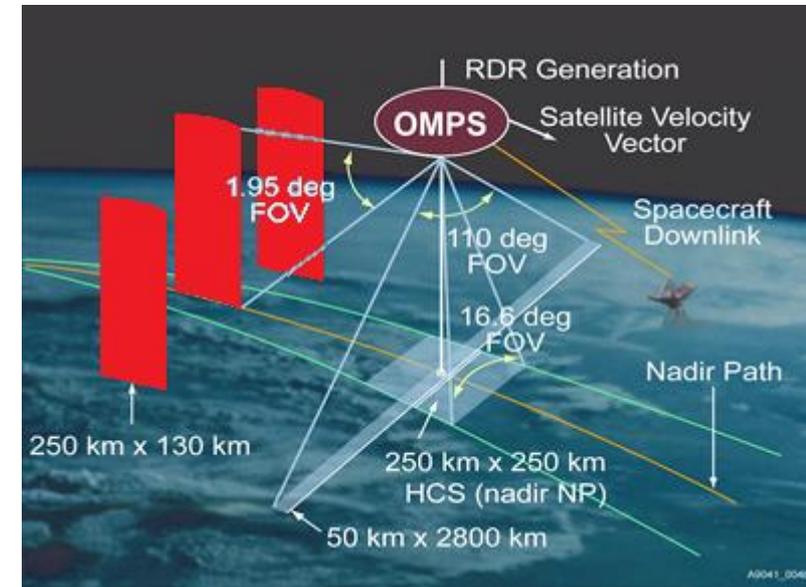
OMPS Nadir Mapper (NM)

| | |
|---------------------|------------------|
| Spectral range | 300 – 380 [nm] |
| Spectral resolution | FWHM = 1 [nm] |
| Sampling | 0.4 [nm] |
| Cross track (FOV) | 110° - 2800 [km] |
| | 35 bins |
| Along track | 0.27° |
| | 50 [km] |
| Reporting period | 7.6 [s] |

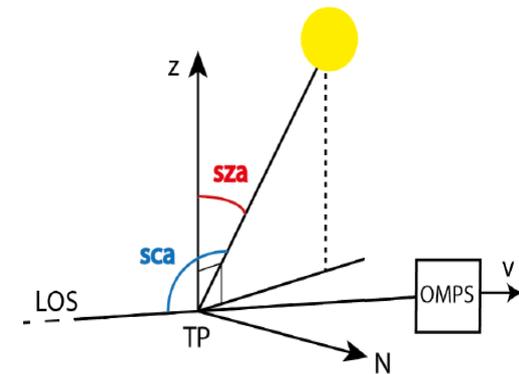


OMPS Limb Profiler (LP)

- 3 vertical slits with Tangent Points 250 [km] far apart.
- Measurements every 19 [s], 1° latitude sampling.
- 180 states per orbit, 14 orbits per day.



| | |
|---------------------|----------------------|
| Spectral range | 280 – 1050 nm |
| Spectral resolution | FWHM = 1 up to 30 nm |
| Vertical sampling | 1-1.5 km |
| FOV | 1.85° |



Tropospheric ozone residual technique

$$TropO_3 = TOC - SOC$$

1° Total ozone column (TOC) – NM

Weighting Function DOAS

2° Stratospheric ozone column (SOC) – LP

- i. Ozone profiles: SCIAMACHY retrieval scheme (by Carlo Arosio et al.)
- ii. Tropopause Height
- iii. SOC: Integrated O₃ from the Tropopause Height upwards

3° Limb – Nadir Matching

Weighting Function Differential Optical Absorption Spectroscopy

From WFM-DOAS (Buchwitz et al., 2000)

$$\begin{aligned}
 \ln I_i^{mea}(V^t, \mathbf{b}^t) \approx & \\
 \ln I_i^{mod}(\bar{V}, \bar{\mathbf{b}}) & \\
 + \frac{\partial \ln I_i^{mod}}{\partial V} \Big|_{\bar{V}} \times (\hat{V} - \bar{V}) & \\
 + \frac{\partial \ln I_i^{mod}}{\partial T} \Big|_{\bar{T}} \times (\hat{T} - \bar{T}) & \\
 + SCD_{NO_2} \cdot \sigma_{i,NO_2} & \\
 + SCD_{BrO} \cdot \sigma_{BrO} & \\
 + SCD_{Ring} \cdot \sigma_{Ring} & \\
 + P_i &
 \end{aligned}$$

- Spectral fitting window: 326.8–335.0 nm
- Fitting terms:
 - ozone vertical column (weighting function)
 - temperature (weighting function)
 - Ring (including ozone filling-in)
 - NO₂
 - BrO
- A-priori ozone profile shape from total ozone dependent TOMS V7 ozone and temperature climatology (Wellemeyer et al., 1997)
- Absorption cross section – Serdyuchenko et al., 2014
- Cubic polynomial subtracted in the fit

Coldewey-Egbers et al., 2005

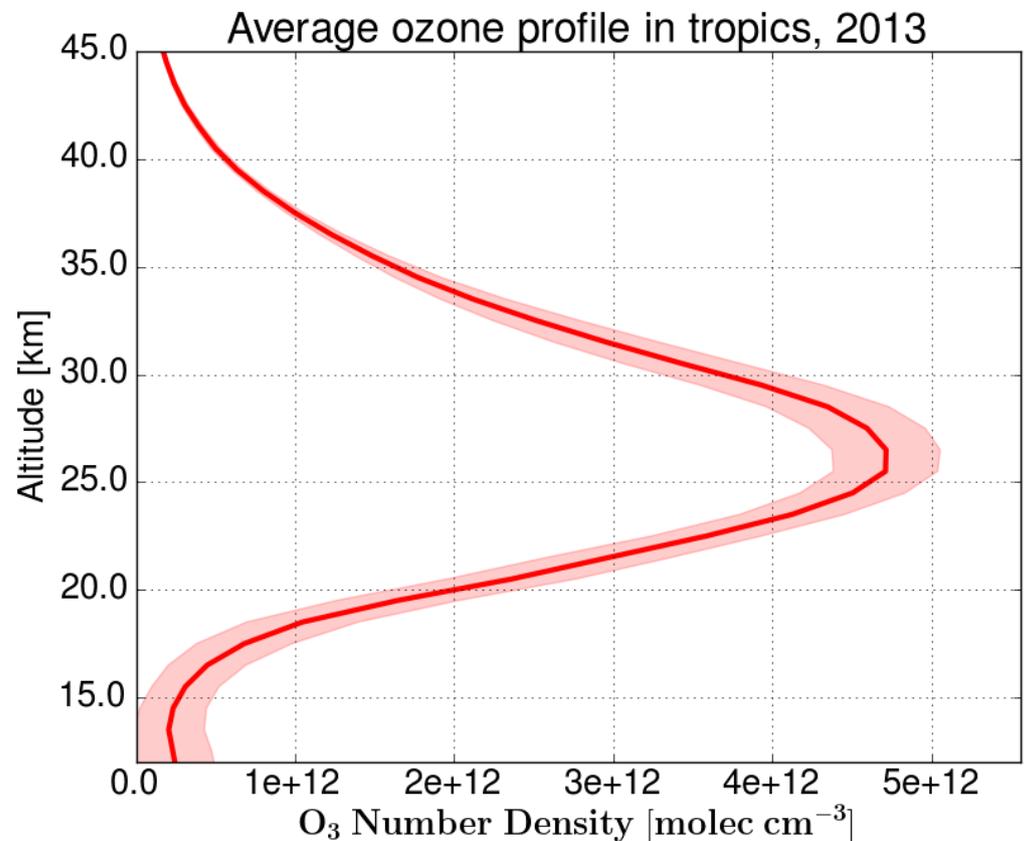
Weber et al., 2005

SOC → Ozone profiles

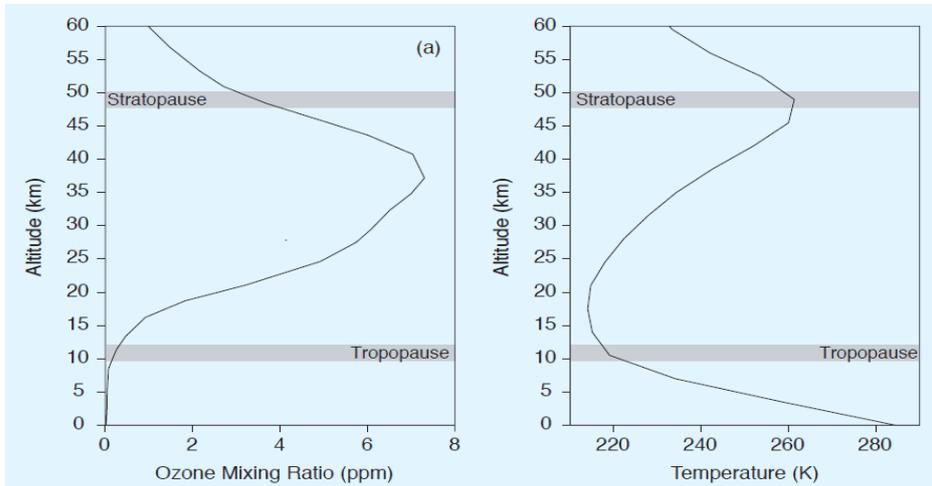
Retrieval of ozone profiles from OMPS limb scattering observations

Carlo Arosio¹, Alexei Rozanov¹, Elizaveta Malinina¹, Kai-Uwe Eichmann¹, Thomas von Clarmann², and John P. Burrows¹

The SCIAMACHY retrieval scheme was adjusted to OMPS limb measurements, exploiting spectral ranges in Hartley, Huggins and Chappuis ozone bands, to retrieve ozone profiles between 12 and 60 km.



SOC → Tropopause Height

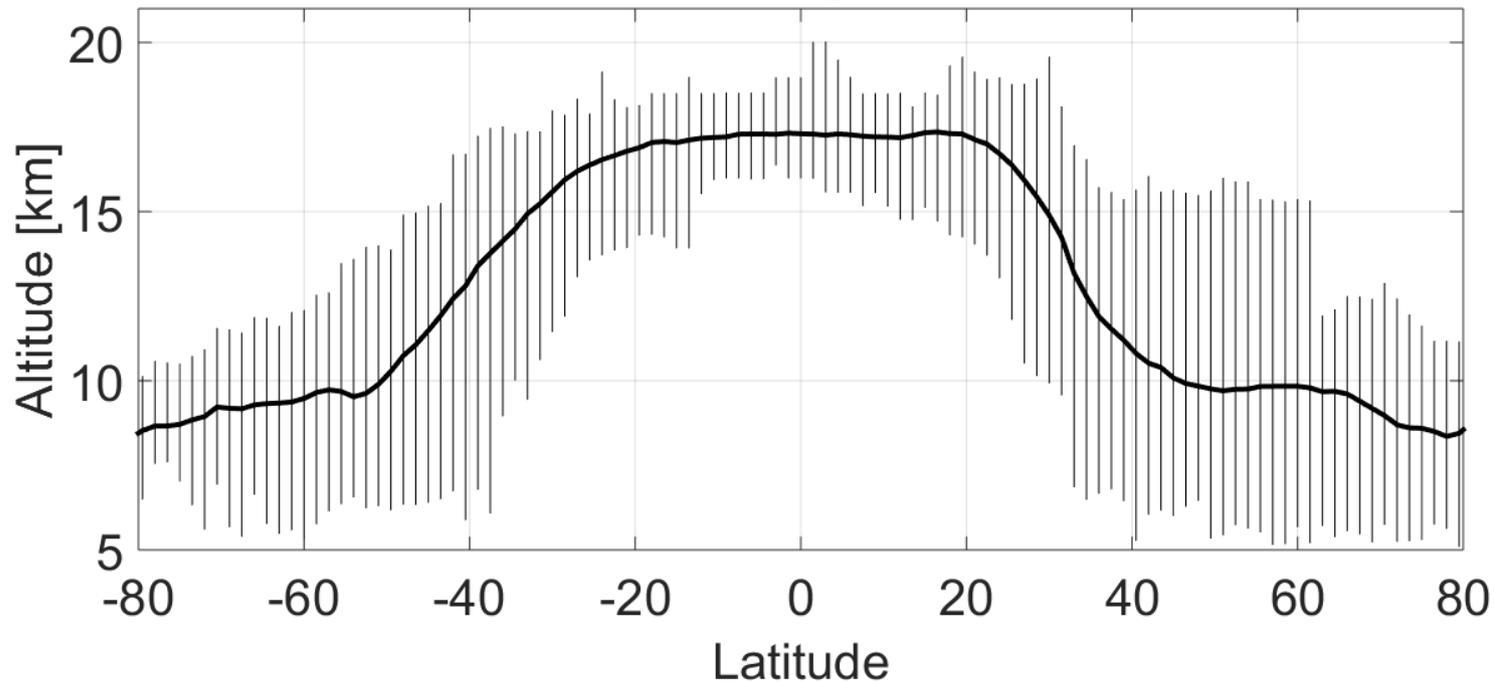


©IPCC/TEAP Special Report. 2005

WMO thermal definition: The lowest level at which the lapse rate decreases to 2 °C/km or less.

- IUP Program (by Jia Jia)
- IUP ECMWF (European Centre for Medium-Range Weather Forecast) analysis

Tropopause Height 01.01.2013

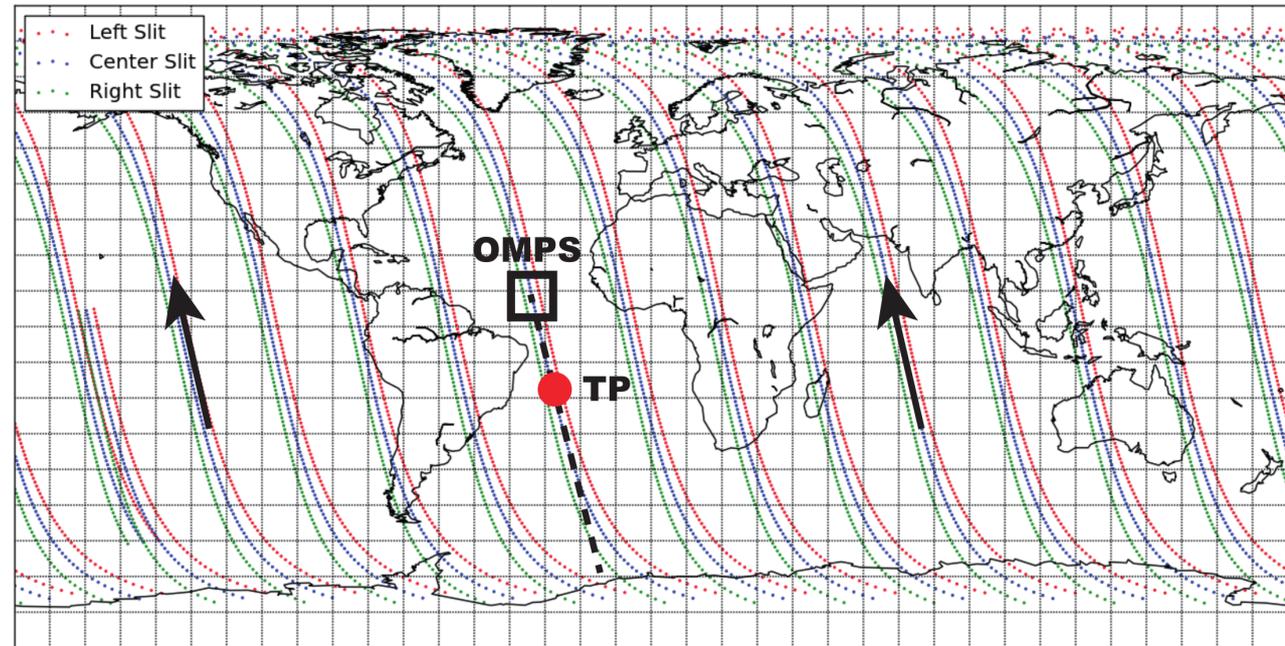
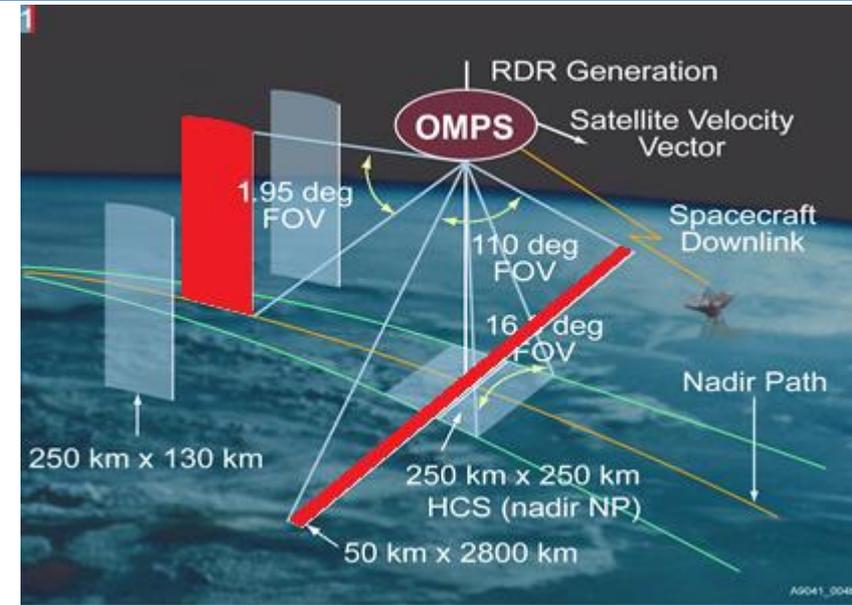


Limb-Nadir matching

Created by Jia Jia
Implemented by Felix Ebojie @ IUP Bremen
July 2013
Changed by Nabiz Rahpoe October 2013
Rewritten from IDL to python by Andrea
Orfanoz-Cheuquelaf Dec. 2017

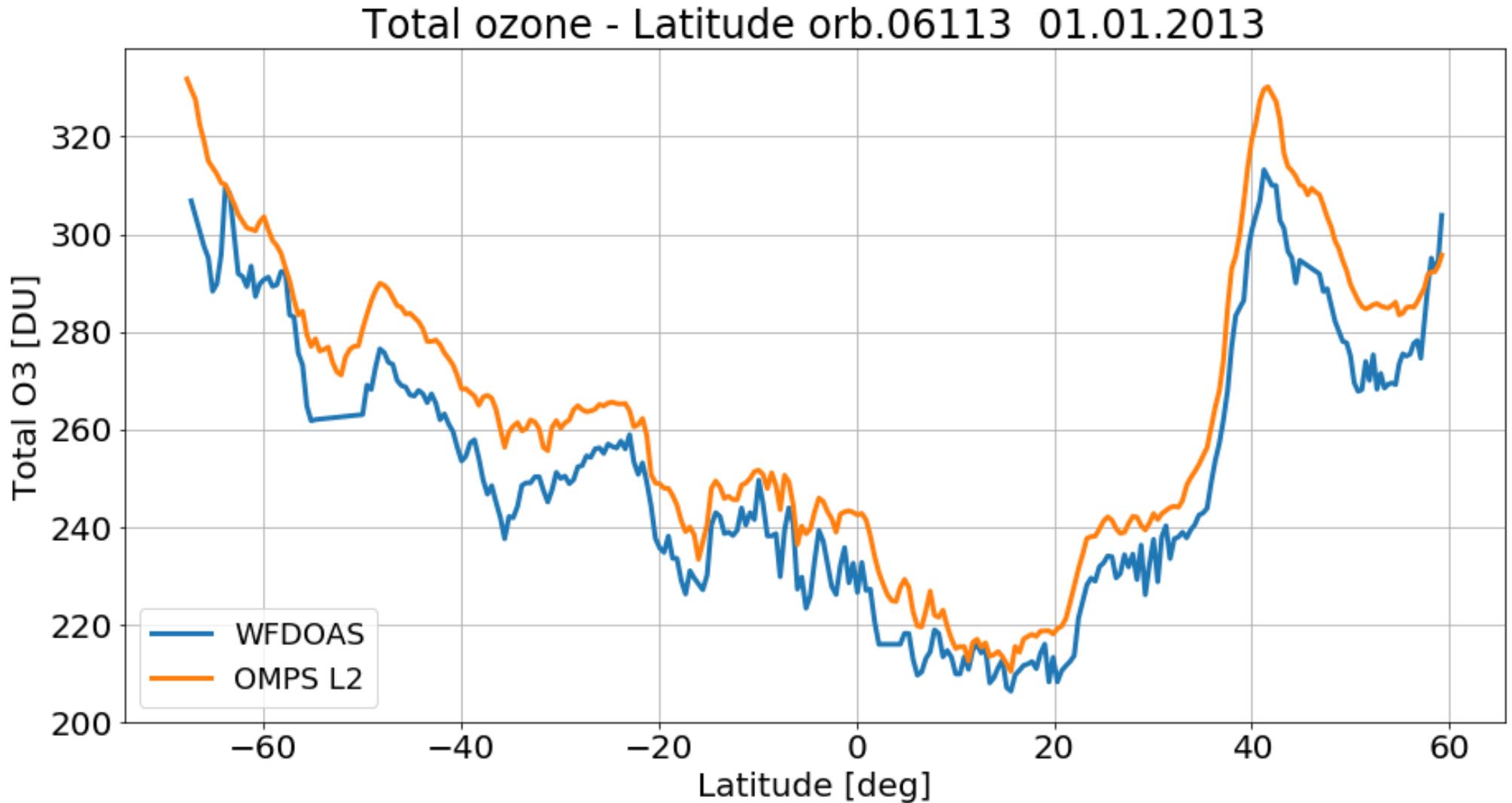
The optical axis of the telescope tilts downward relative to the baseplate by 27.3°

The limb view tangent points pass each geographic location approximately 7 min after they are viewed by the Nadir instrument.



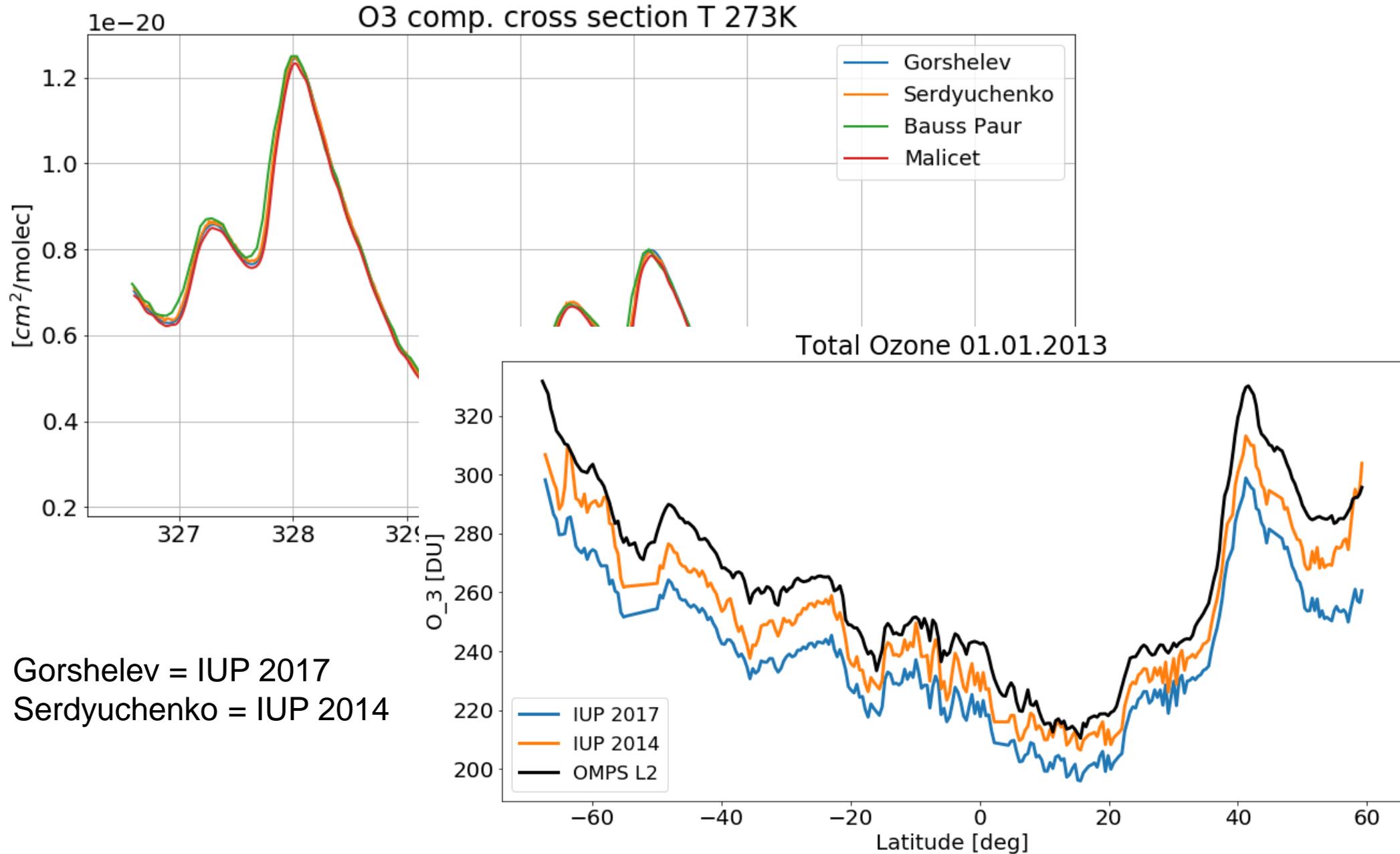
Arosio et al., 2017

Preliminary results: Total ozone column



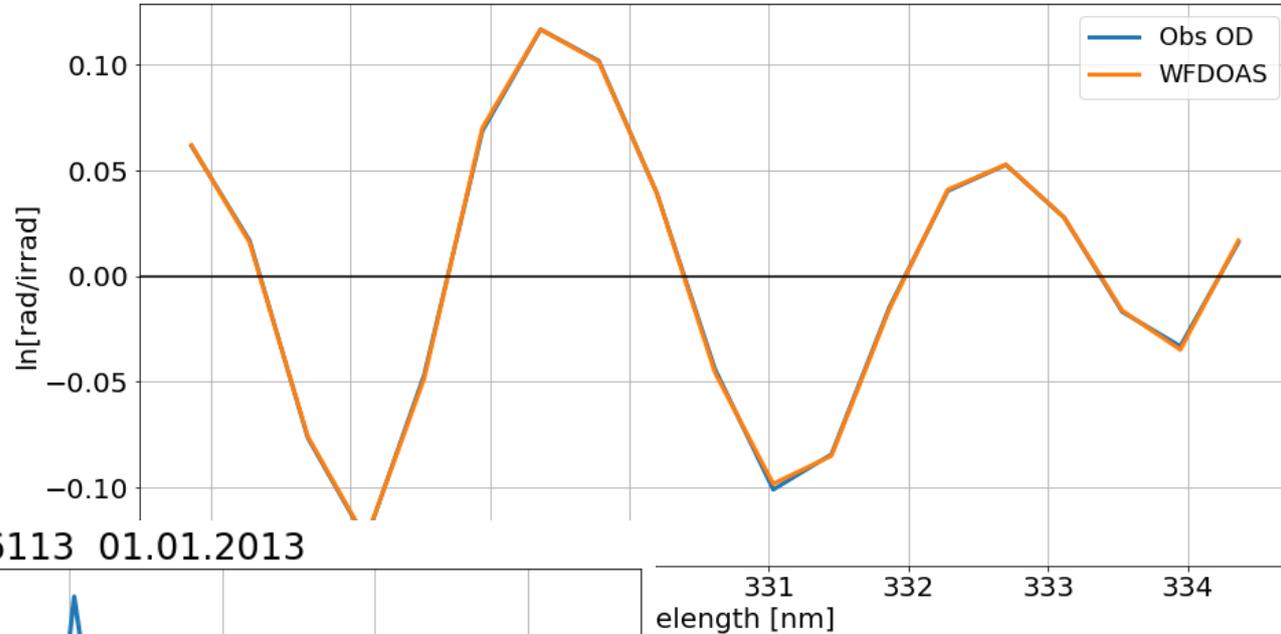
Assuming
Cloud fraction = 0

Absorption cross section diagnostic

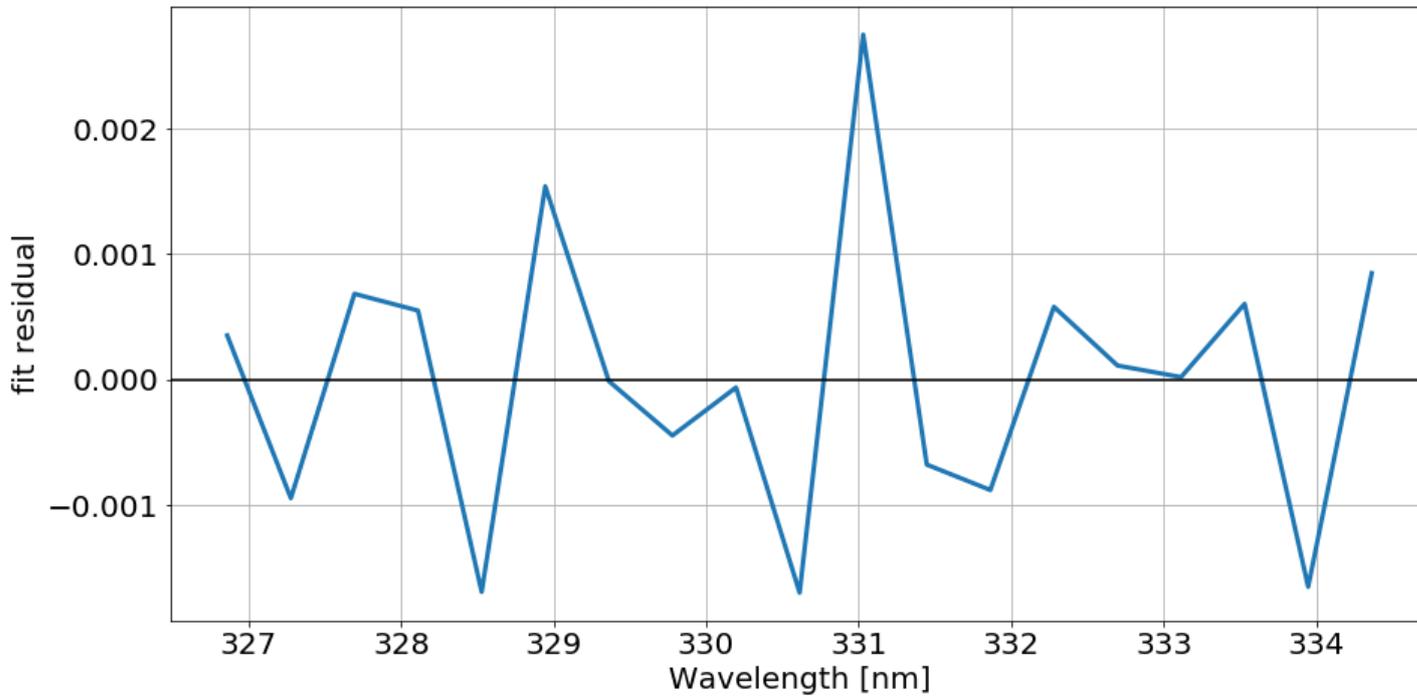


Preliminary results: WFDOAS fit

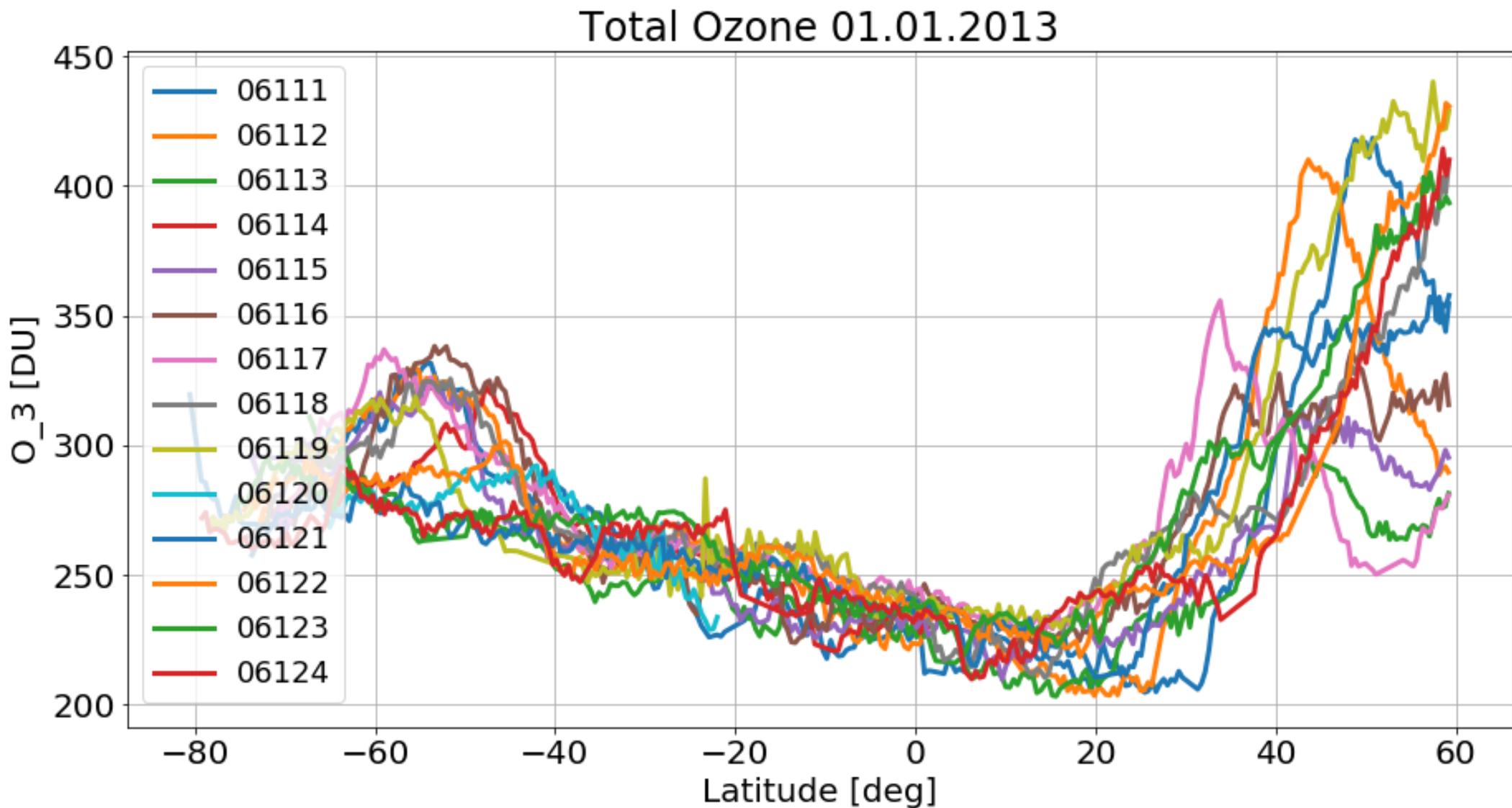
Obs OD-WFDOAS o.06113 01.01.2013



Fit residual o.06113 01.01.2013

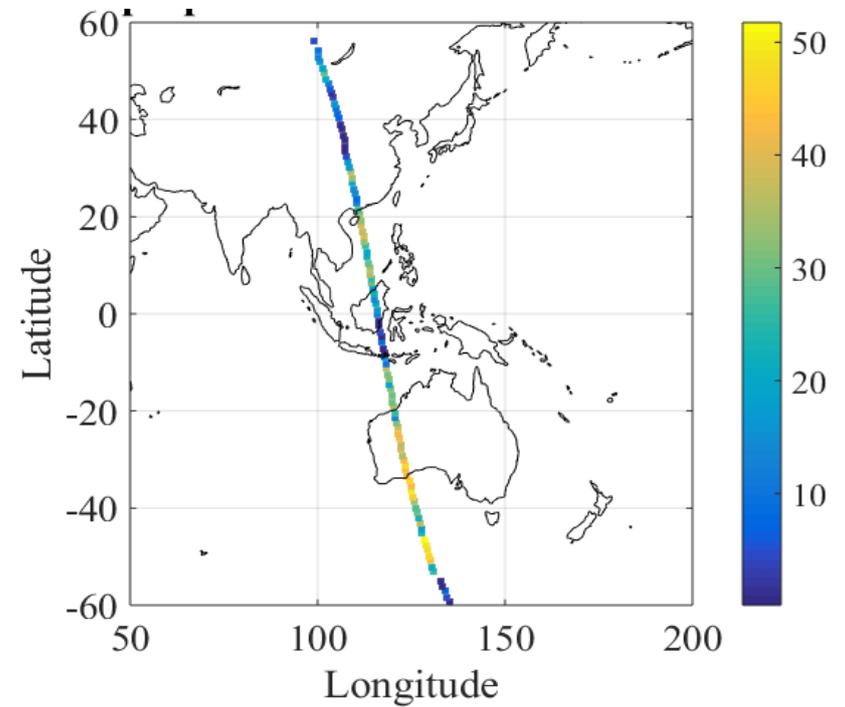
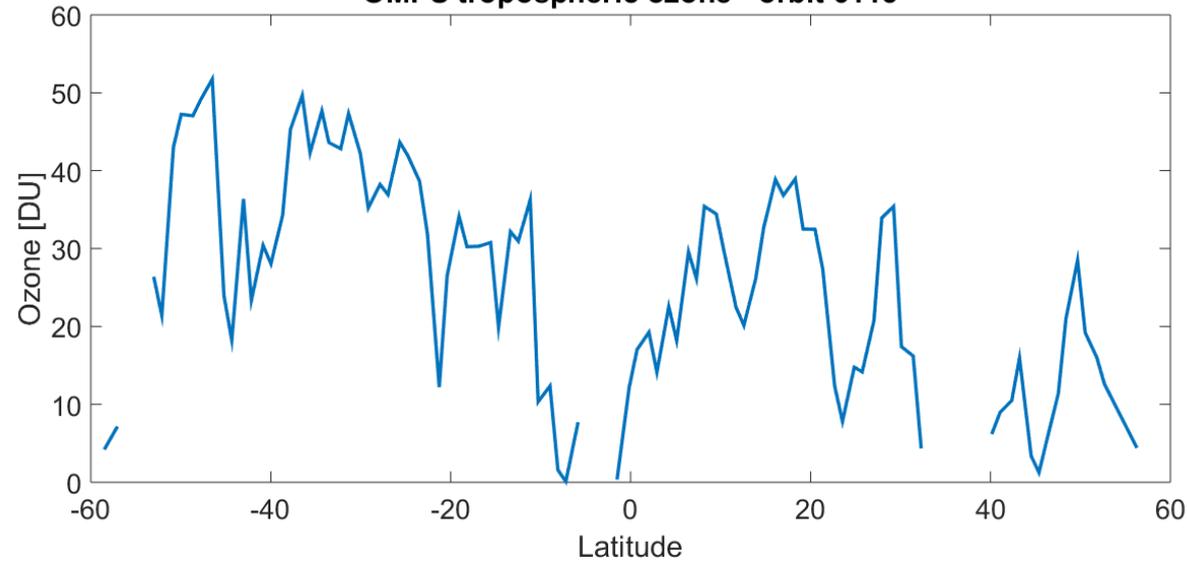


Total ozone column

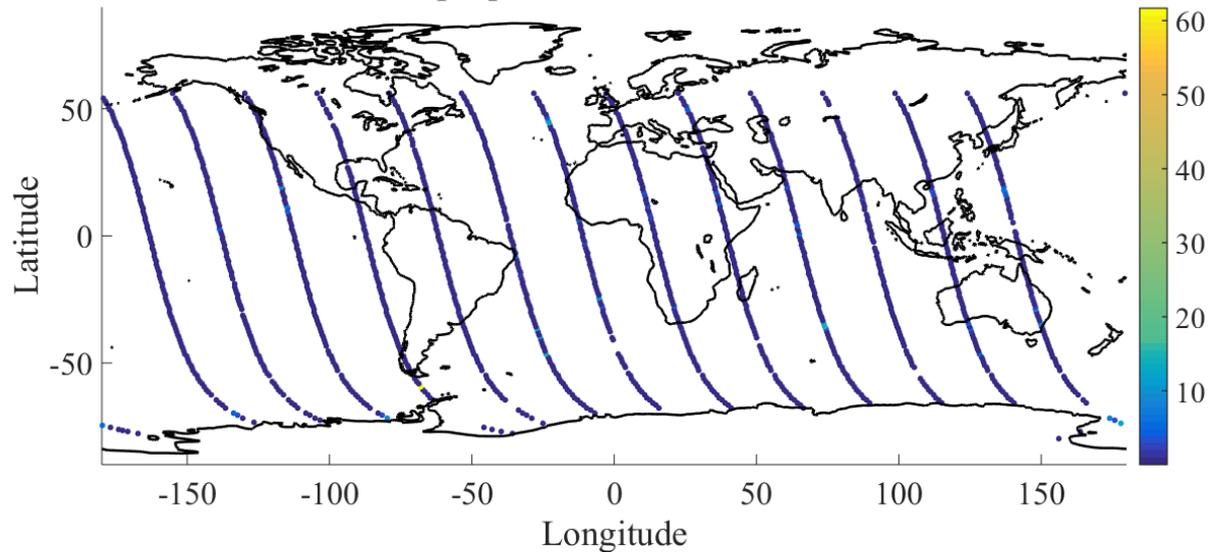


Tropospheric ozone

OMPS tropospheric ozone - orbit 6113



Tropospheric ozone 01.01.2013



What is next?

- Improve TOC algorithm
 - Cloud correction
- Apply the method for the entire OMPS data set
- Validation of the data set
 - OMPS products
 - Other satellites
 - Ozone sondes
 - Models
- First thesis committee meeting

Danke!
Thank you!
¡Gracias!

