First year of ozone determination from UV radiation measurements at Stara Zagora

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Introduction

The history of the discovery of ozone is going back to the middle of the 18th century. It is connected with famous scientist as **Schönbein**, who had given the name of ozone; **Huggins, Chappius, Hartley**, **Ladenburg** and **Lehmann**, **Fowler** and **Rayleigh**, the discoverer of the ozone absorption bands; **Chapman**, who suggested that the formation of ozone resulted from photolysis of molecular oxygen; **Crutzen** and **Johnston**, who found the catalytic destruction of ozone by nitrogen oxides; **Rowland** and **Molina**, established the chlorine chemistry, **Götze**, who had discovered the Umkehreffekt, and of course **Dobson**, the creator of routine ozone measurements with his spectrometers. **Brewer**, **Wardle**, **McElroy** and **Kerr** developed the Brewer Ozone Spectrophotometer to measure not only total Ozone but also sulphur dioxide (SO_2) and ultraviolet (UV) radiation.

Introduction

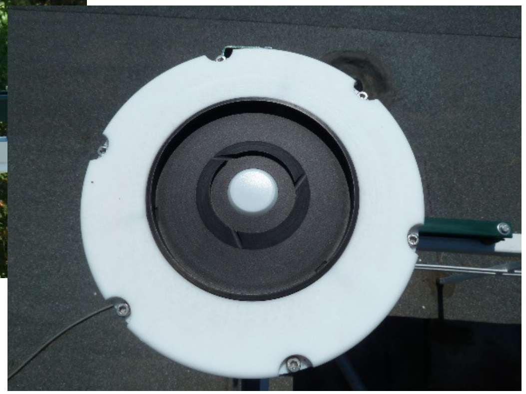
By Dobson-spectrometer routine observations of ozone were possible with an error less of 1%. Dobson and also Brewer spectrometers have a spectral resolution of approximately 1 nm. In the 90-ties broadband filter instruments were developed to increase the global coverage of the measurements. Dahlback (1996) has shown that broadband instruments with a few filters also allow to determine the biological UV dose, the total ozone abundances, and the cloud optical depths.

Main goal: presentation of the results from the measurements during the first year and short description of the methodology to derive the total ozone content (TOC).

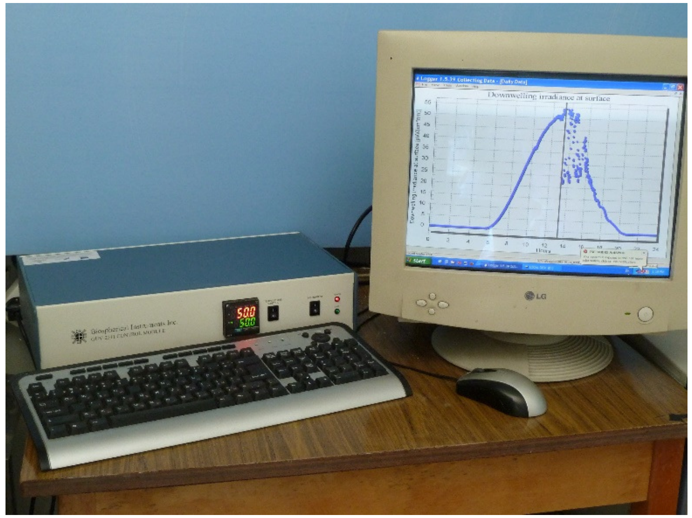
Instrument

The Ground-based Ultraviolet Radiometer (GUV) 2511 instrument was installed in February 2015 on the roof of the Stara Zagora observatory.

GUV 2511

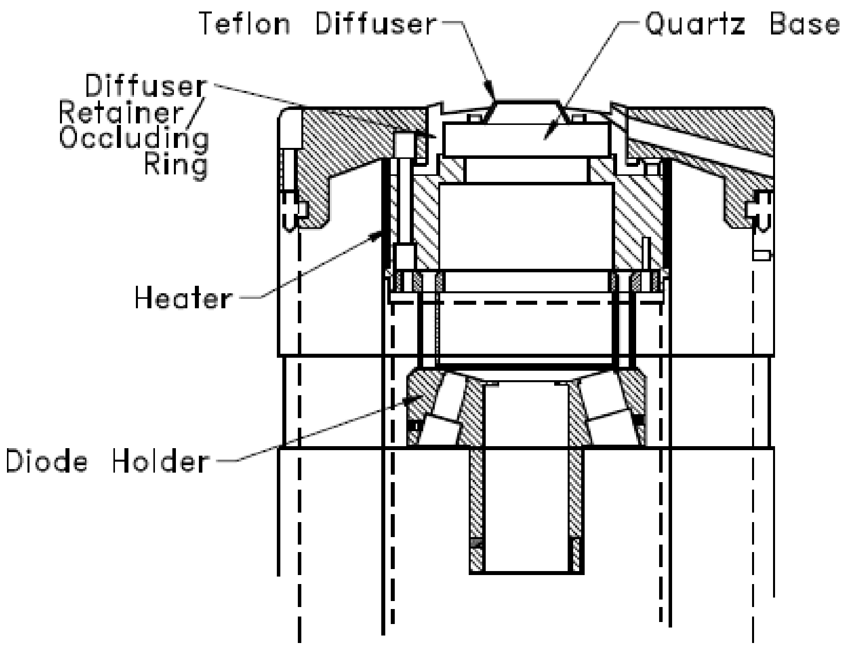


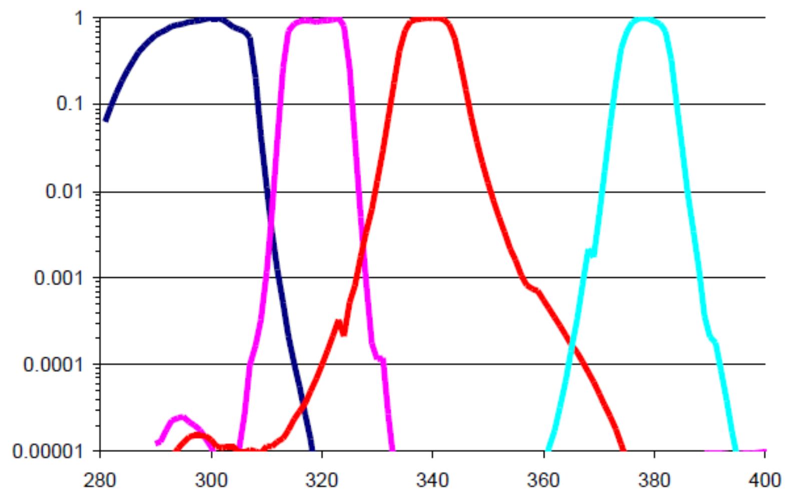
Instrument head



Instrument controller and monitor for control of the measurement progress.

Instrument





Every channel consists of a filter and photodiode with amplifier, not moving components → very stable instrument

Typical normalized filter response functions for 305, 320, 340 and 380 nm

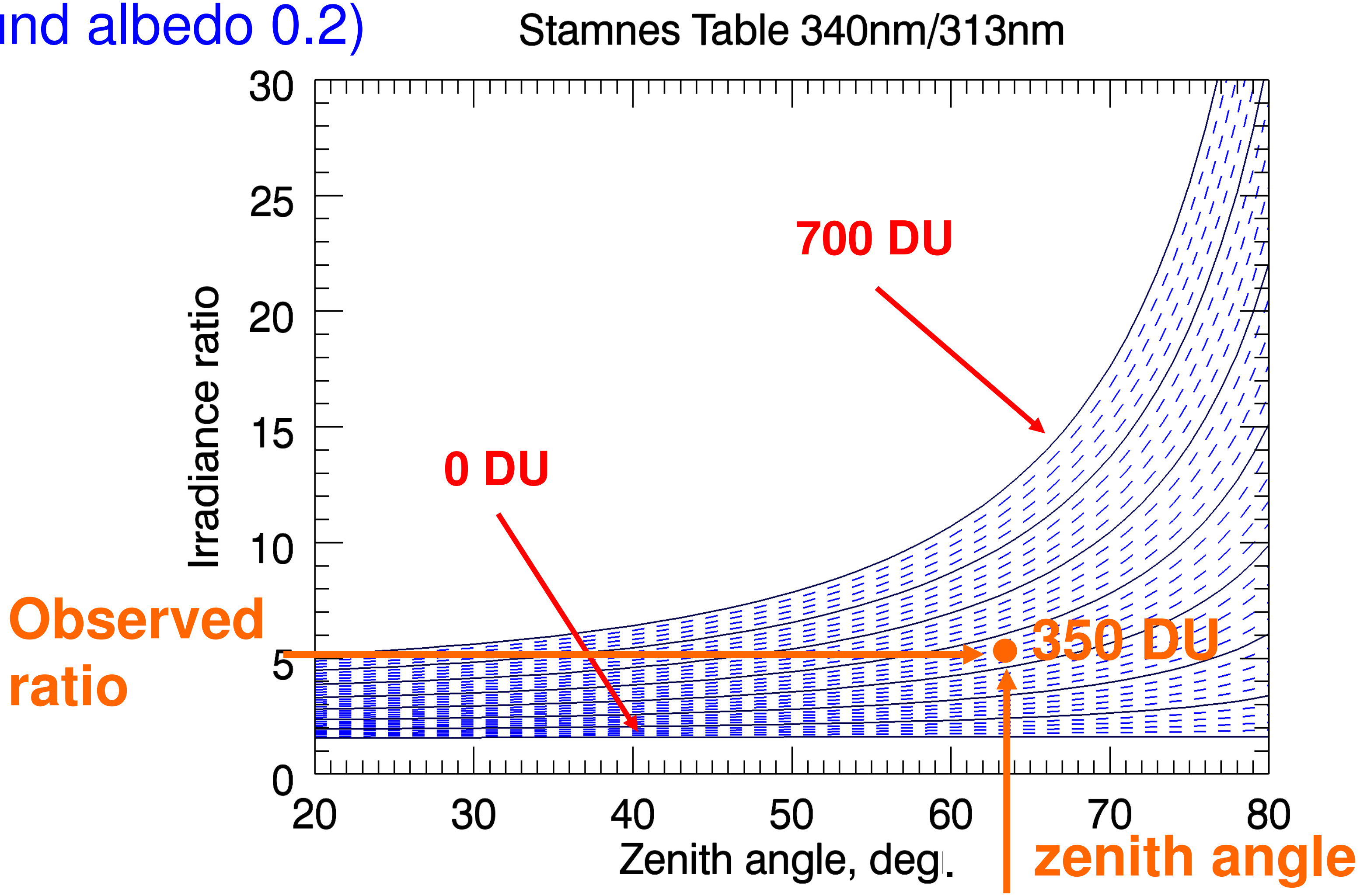
Figures are taken from "GUV data processing and quality control procedures", Biospherical Instruments Inc.

Methodology of TOC determination

By GUV instruments the global (the diffuse and the direct) component of the downwelling irradiation are measured. TOC can not be determined directly by the measured irradiance ratio. To determine TOC from UVA/UVB ratios we used the Tropospheric Ultraviolet and Visible (TUV) model version 4.1. developed by Madronich (1993). Spectra were calculated for the Stara Zagora location (Lat=42.4°N, Long=25.6°E, alt=0.43 km) for different TOC from 0 up to 700 DU in steps of 20 DU and zenith angels from 20° up to 90° with a step of 1°. The obtained spectra were multiplied with the relative filter response functions, approximated by a Gaussian with 10 nm Full Width at Half Maximum (FWHM). The irradiance ratios for wavelengths 340 nm and 313 nm were used.

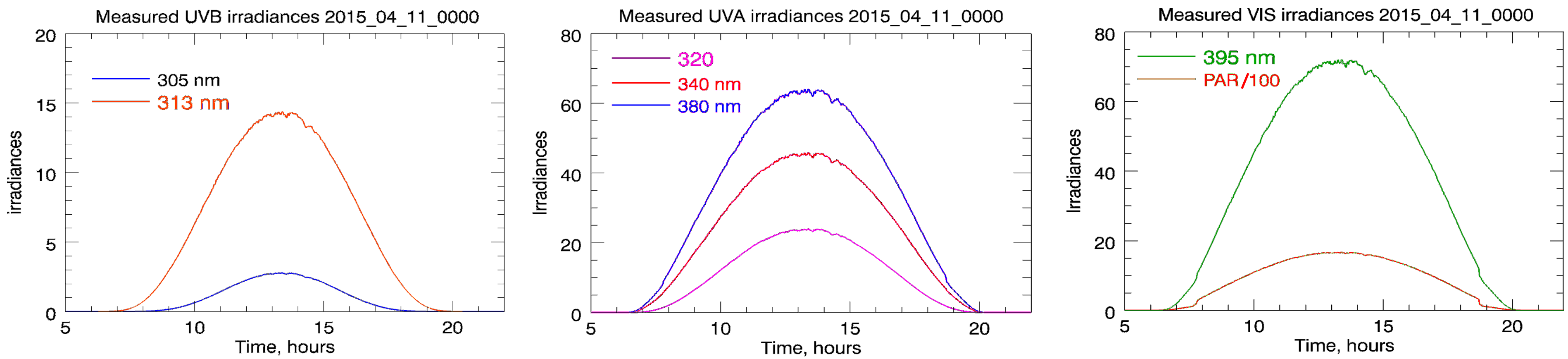
Methodology of TCO determination

Stamnes Look-up table calculated for the Stara Zagora location (ground albedo 0.2)



Measurement results

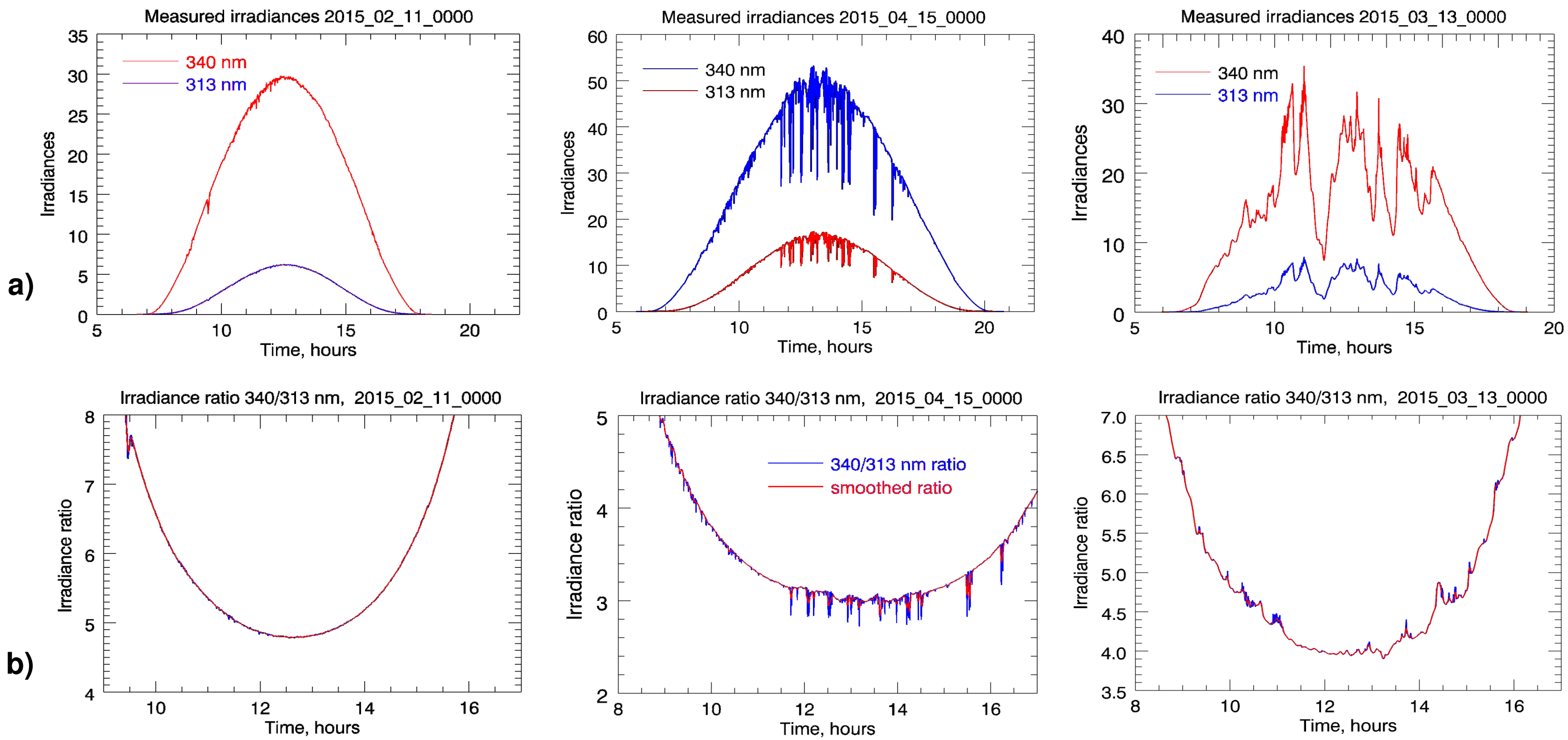
Example for the measurement irradiances on 11 April 2015 in all GUV 2511 channels



Daily measurements, with an integration time of 10 seconds were carried out from February to May 2016 with some interrupts for technical reasons. An example for all channels for almost cloudless conditions is shown in the plots. The irradiances are given in μW/(cm^{2}nm).

Measurement results

Measured irradiances, given in $\mu W/(cm^2 nm)$, during days with different cloudiness.



an almost clear day

a day with fast changing of the clouds covering the solar disc

a day with large cloud fraction

Data processing 1

The irradiances show high variations depending of the atmospheric optical depth caused by different cloudiness. Although the irradiance ratios are less affected by clouds than the irradiances, high cloudiness leads to tampering of TOC values. To reduce the cloudiness influence the following data pre-processing was applied:

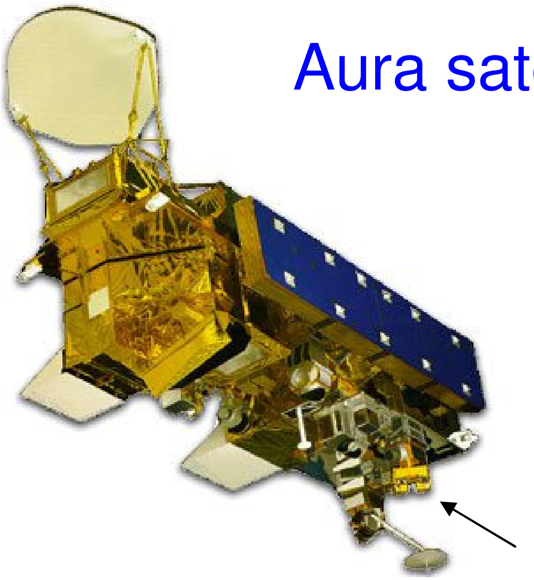
1. If the average **irradiance at 340 nm** between 10:30 and 14:30 LT is **lower than approximately 1/3** of the average monthly mean for cloudless days, then we assumed, that the **ozone** determination will be **wrong** because of strong cloudiness. Therefore we do not use these measurements.

Data processing 2

2. The ratios were additionally **smoothed** by a running boxcar over 17 values, e.g. over 170 sec. The greatest effect of the smoothing appeared in cases of fast changes in the cloud cover reducing the maximal variation of the irradiance ratios to 0.1, which would lead to an error of 10 DU in the ozone determination (compare with the Stamnes table - Fig.1).

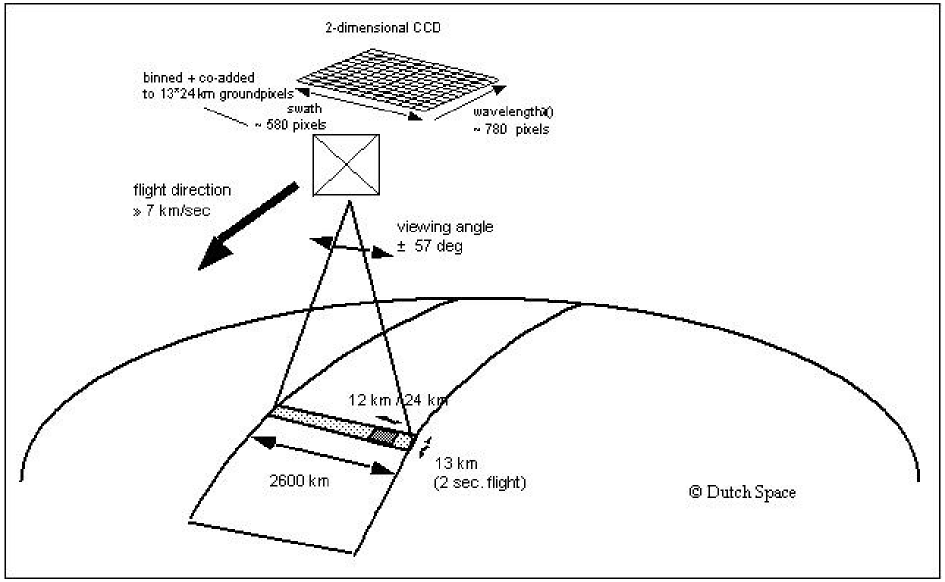
3. Under strong cloudiness the irradiance ratios variations decrease only up to 0.5. Therefore an **upper envelope** for each daily ratio development was determined and the envelope value at the measured time was used instead of the original ratio.

Comparison with OMI satellite data



Aura satellite

OMI instrument



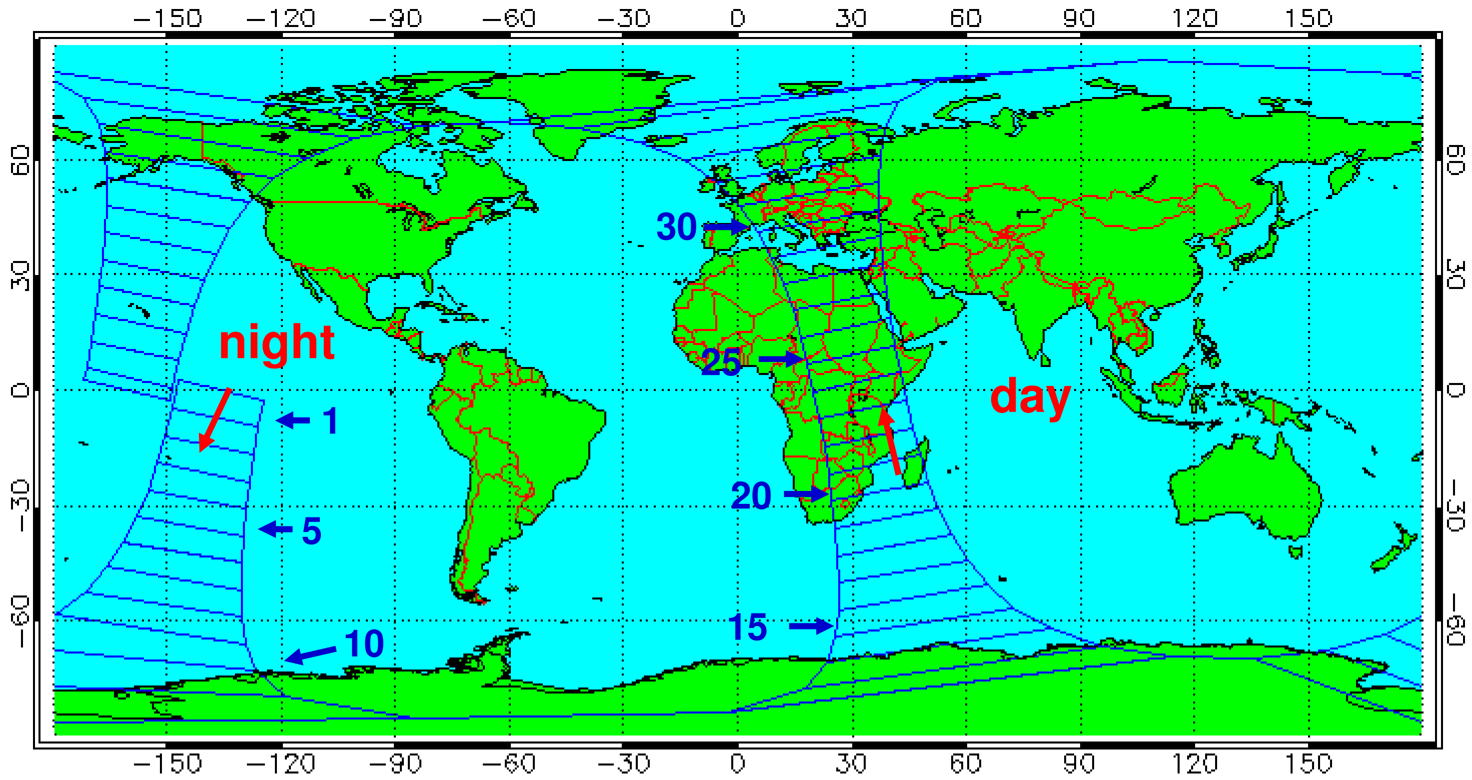
Sun synchronous orbit
(near polar orbit – perigee: 708 km apogee: 710 km, inclination: 98.83°)

https://directory.eoportal.org/web/eoportal/satellite-missions/a/aura

OMI instrument: data about ozone content, UV aerosol index, SO_2 index, cloud fraction, cloud pressure

Comparison with OMI satellite data

Ground Track for the Path 094, 2015-03-14



The satellite passes over Bulgaria in 11:41 UT (13:41 LT)

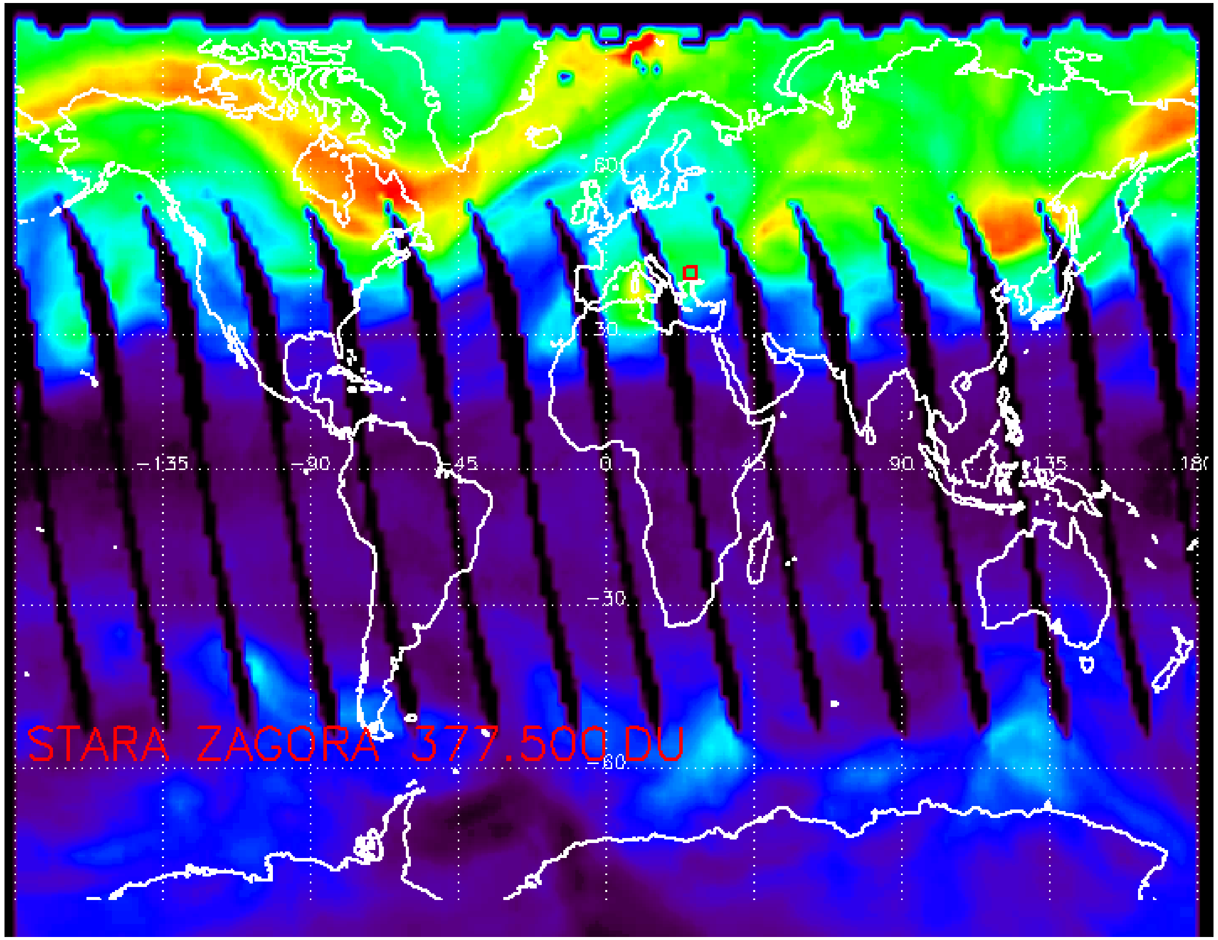
Orbit 56709 starts at 10:41:02 UT

and ends at 12:19:56 UT (Period: 99 min)

(knmi/research/calibration/instrument_status_v3/daily_reports/2015/http://projects)

Comparison with OMI satellite data

OMI – Aura – Global Ozone gridded data 1.0 x 1.0 deg., based on an enhanced TOMS 8 algorithm, used radiances at 317.5 nm and 331.2 nm.



08.03.2015

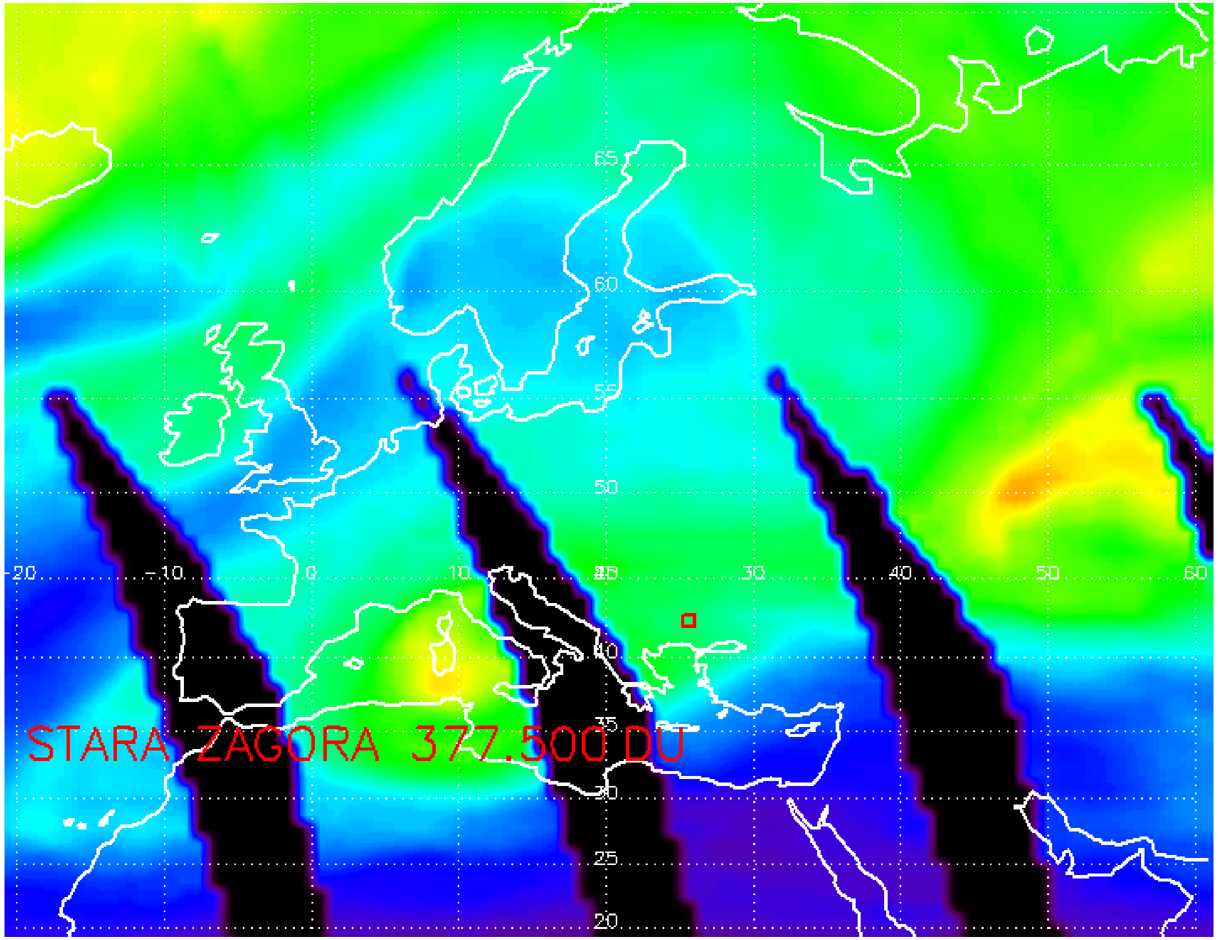
558 DU

224 DU

https://ozoneaq.gsfc.nasa.gov/data/ozone/

Comparison with OMI satellite data

OMI ozone Europe map



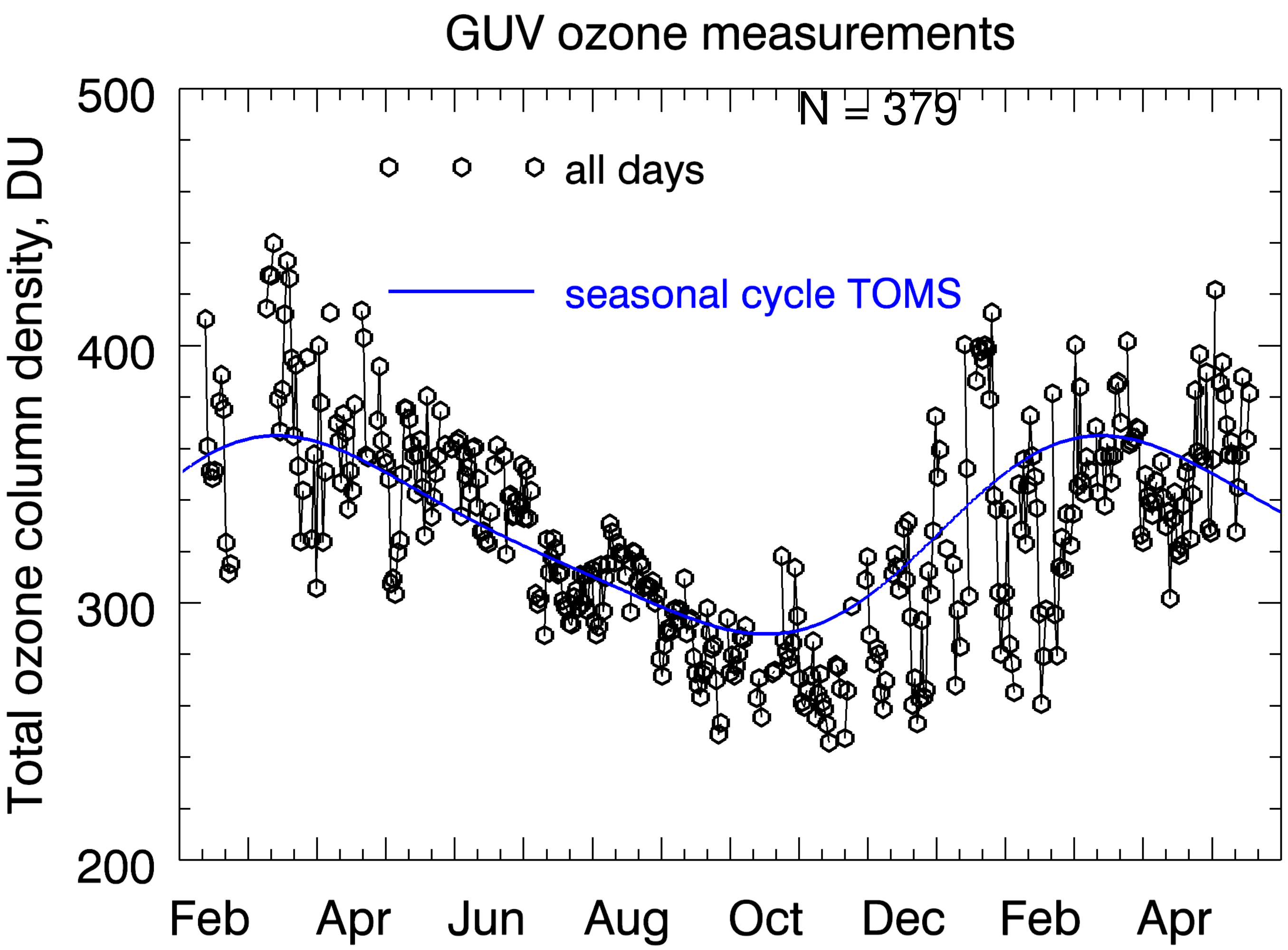
08.03.2015

558 DU

224 DU

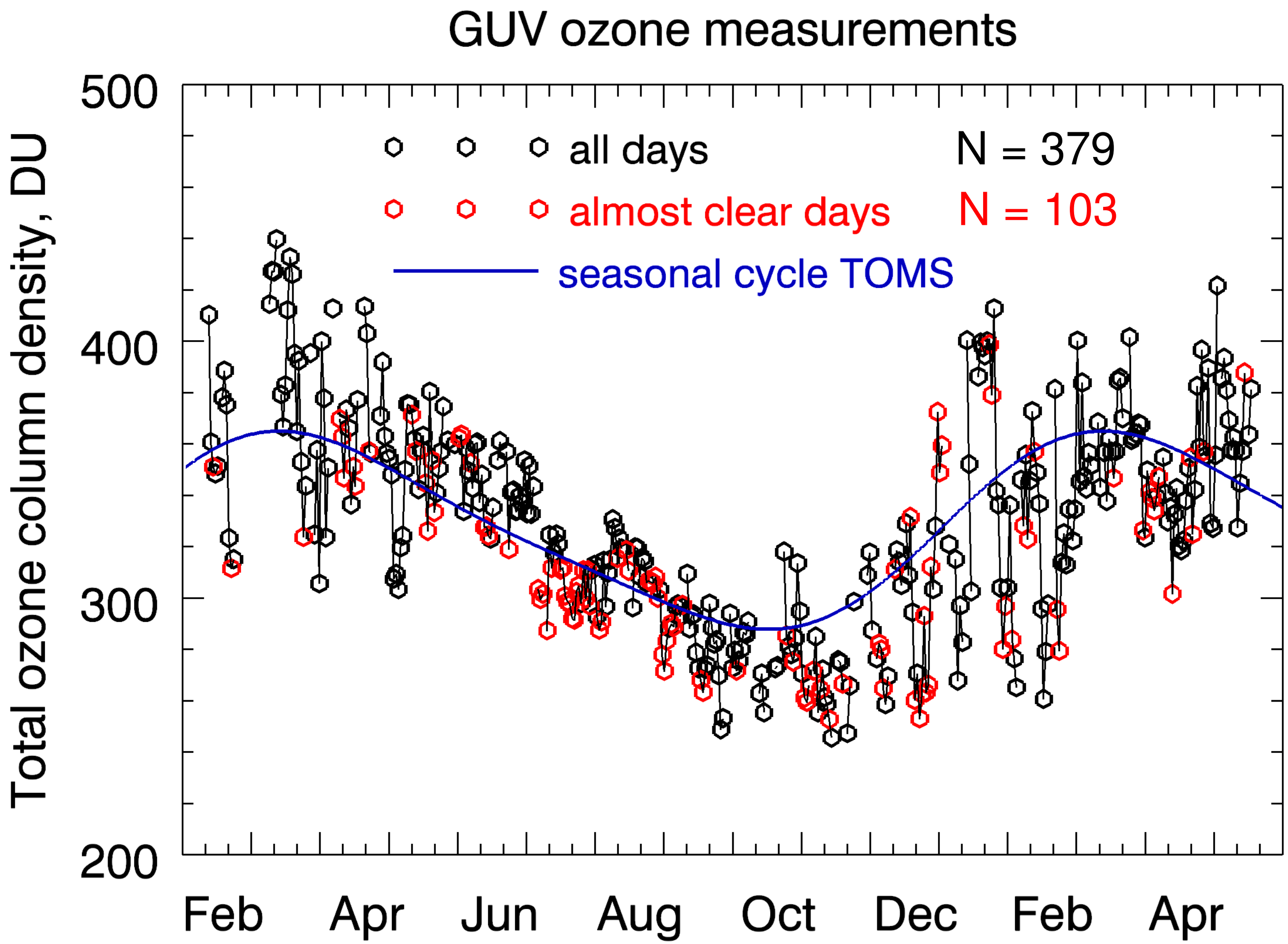
Results

Results for the ozone determination by the 340 nm/313 nm ratios

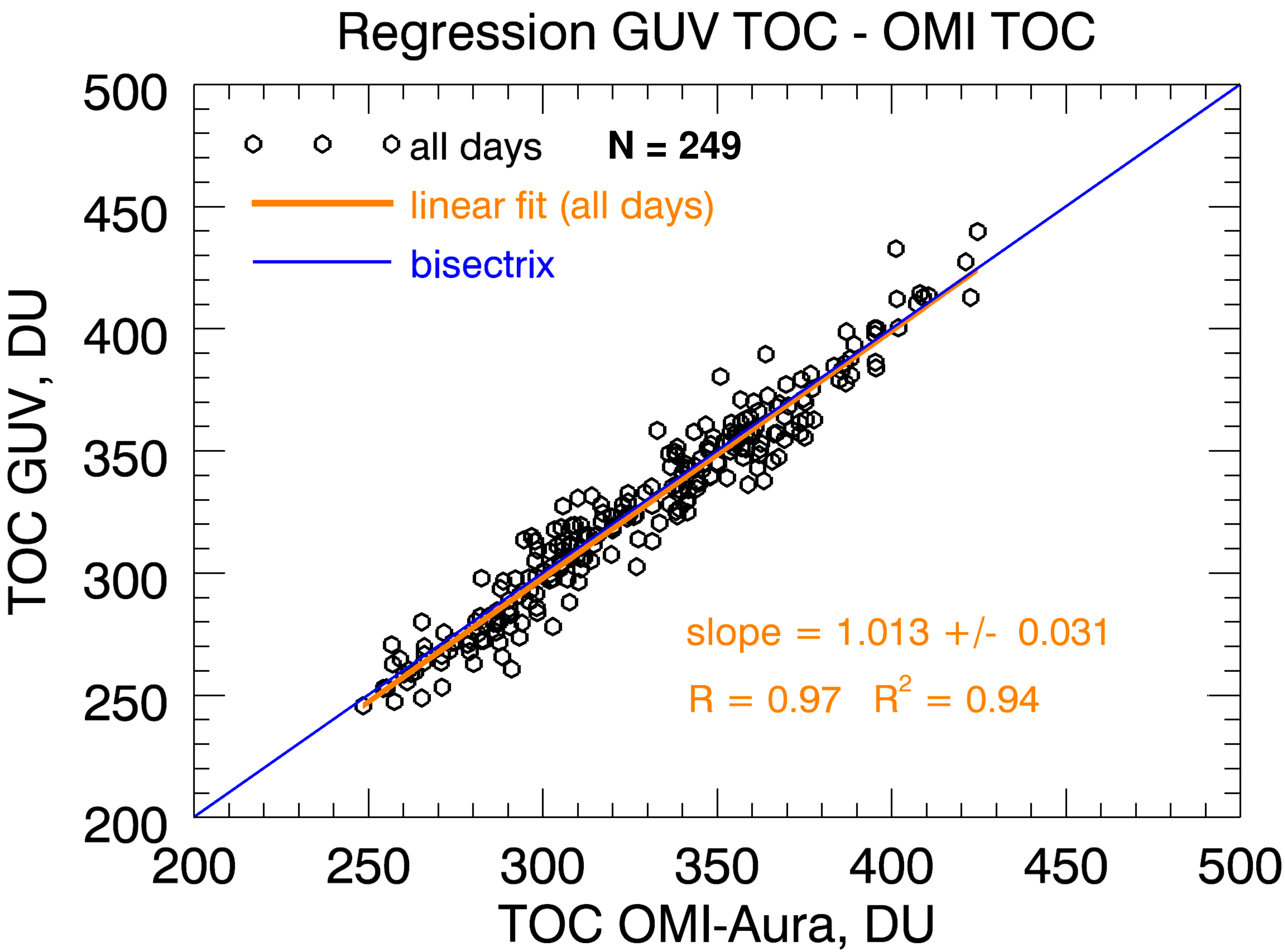


Results

Results for the ozone determination by the 340 nm/313 nm ratios

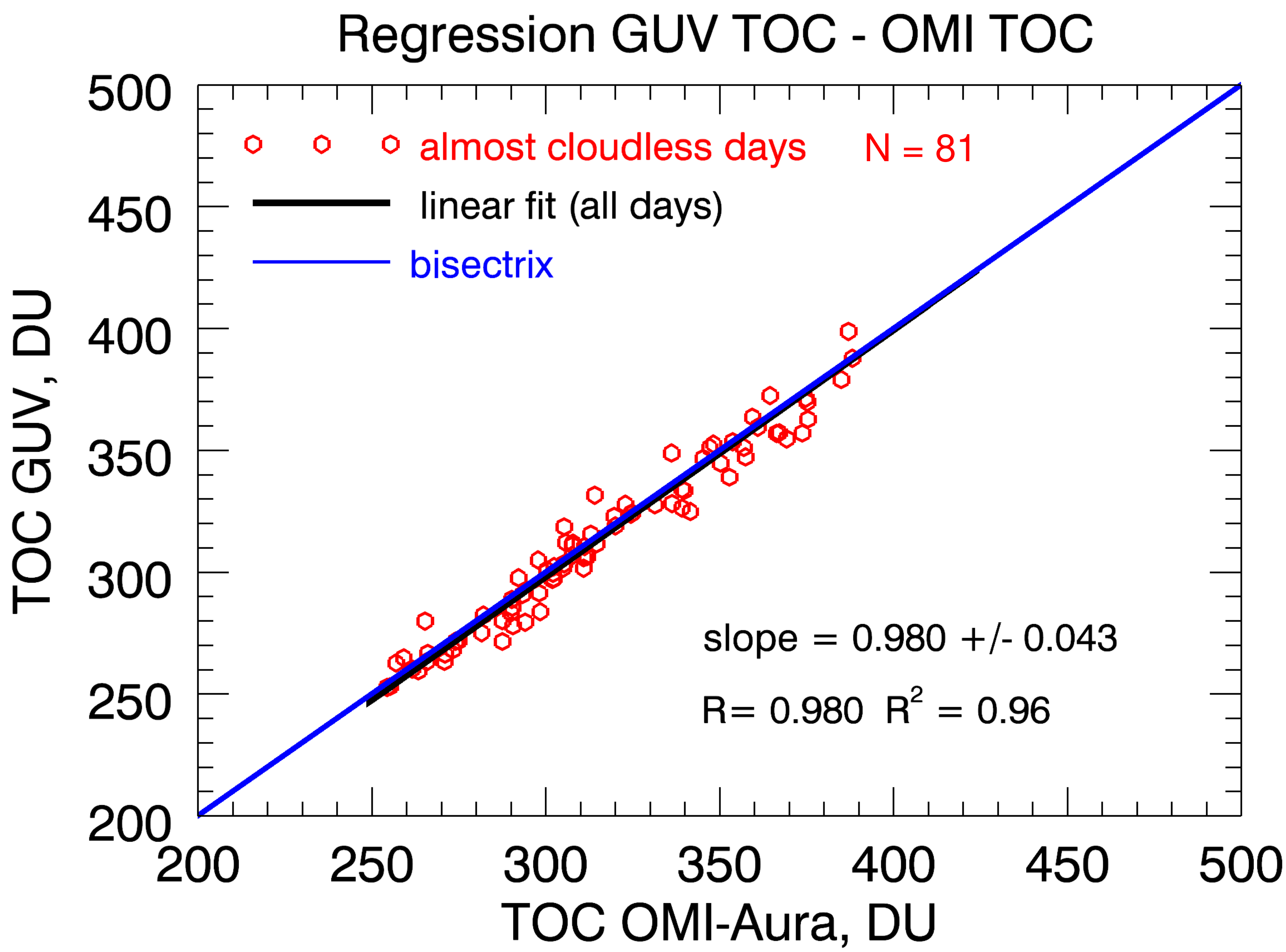


Results



Regression GUV TOC - OMI TOC
all days
N = 249
linear fit (all days)
bisectrix
slope = 1.013 +/- 0.031
R = 0.97 R² = 0.94
TOC GUV, DU
TOC OMI-Aura, DU
500
450
400
350
300
250
200
200
250
300
350
400
450
500

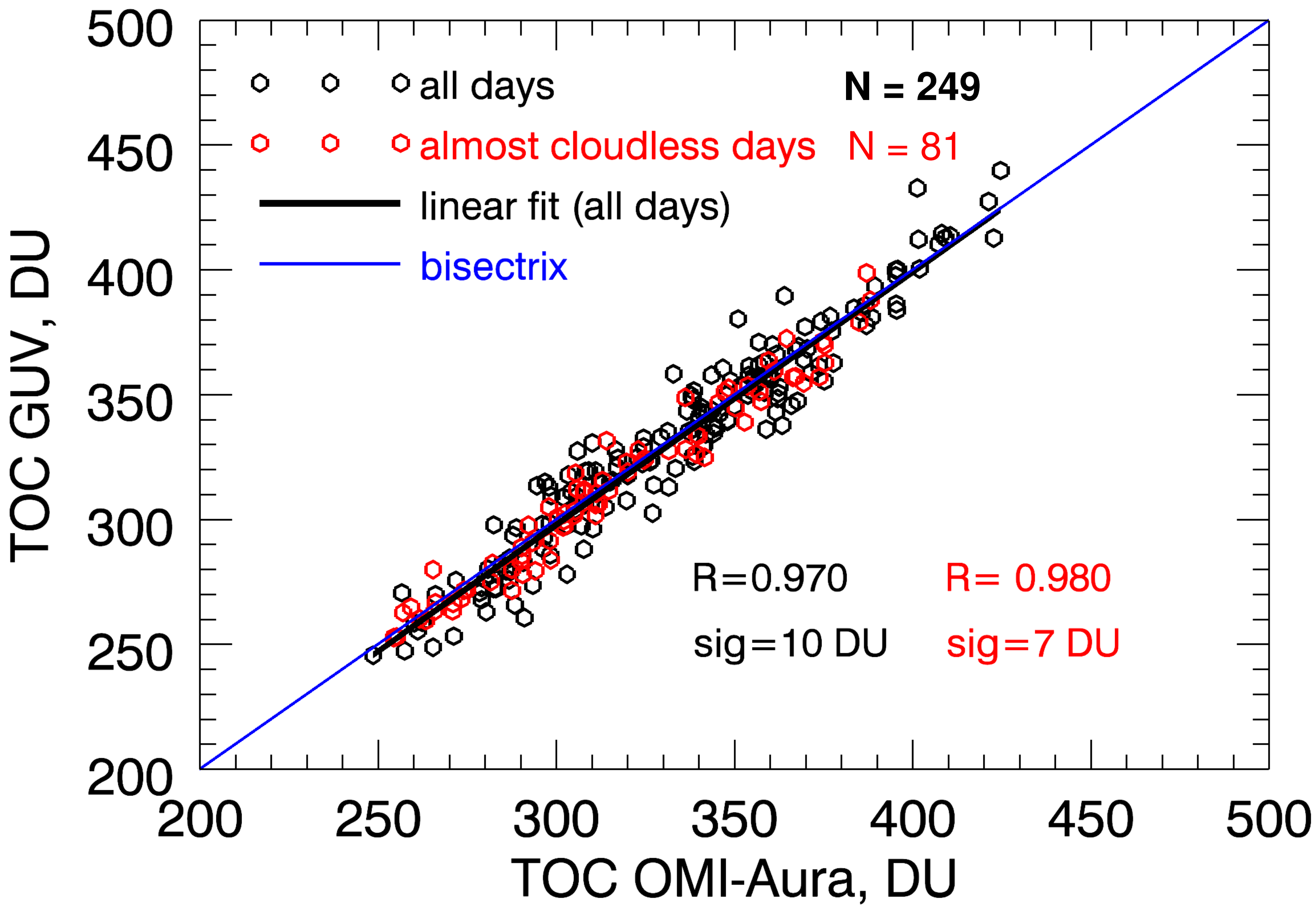
Results



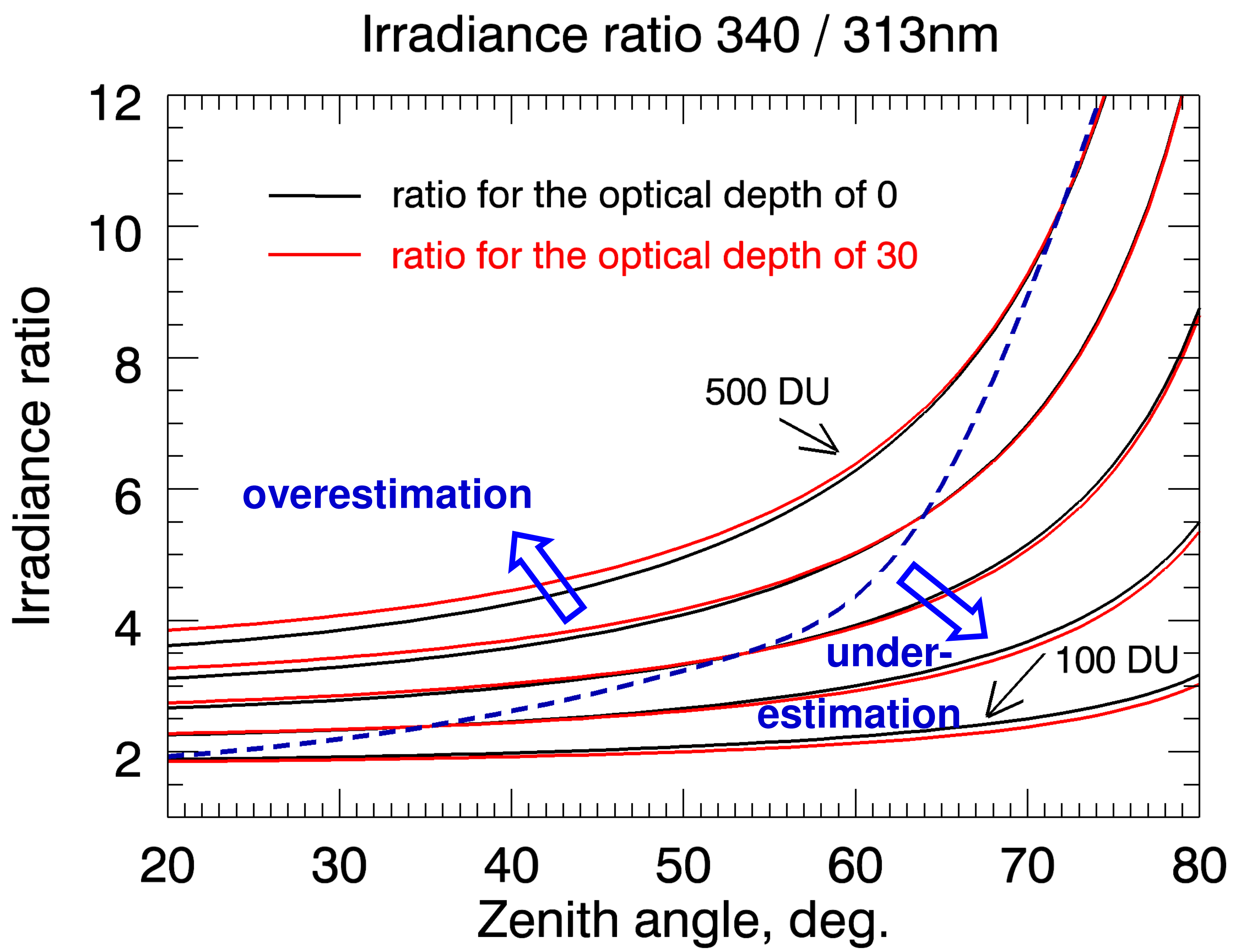
Regression GUV TOC - OMI TOC
almost cloudless days N = 81
linear fit (all days)
bisectrix
slope = 0.980 +/- 0.043
R= 0.980 R2 = 0.96
TOC GUV, DU
TOC OMI-Aura, DU
200
250
300
350
400
450
500

Results

Regression GUV ozone against OMI ozone

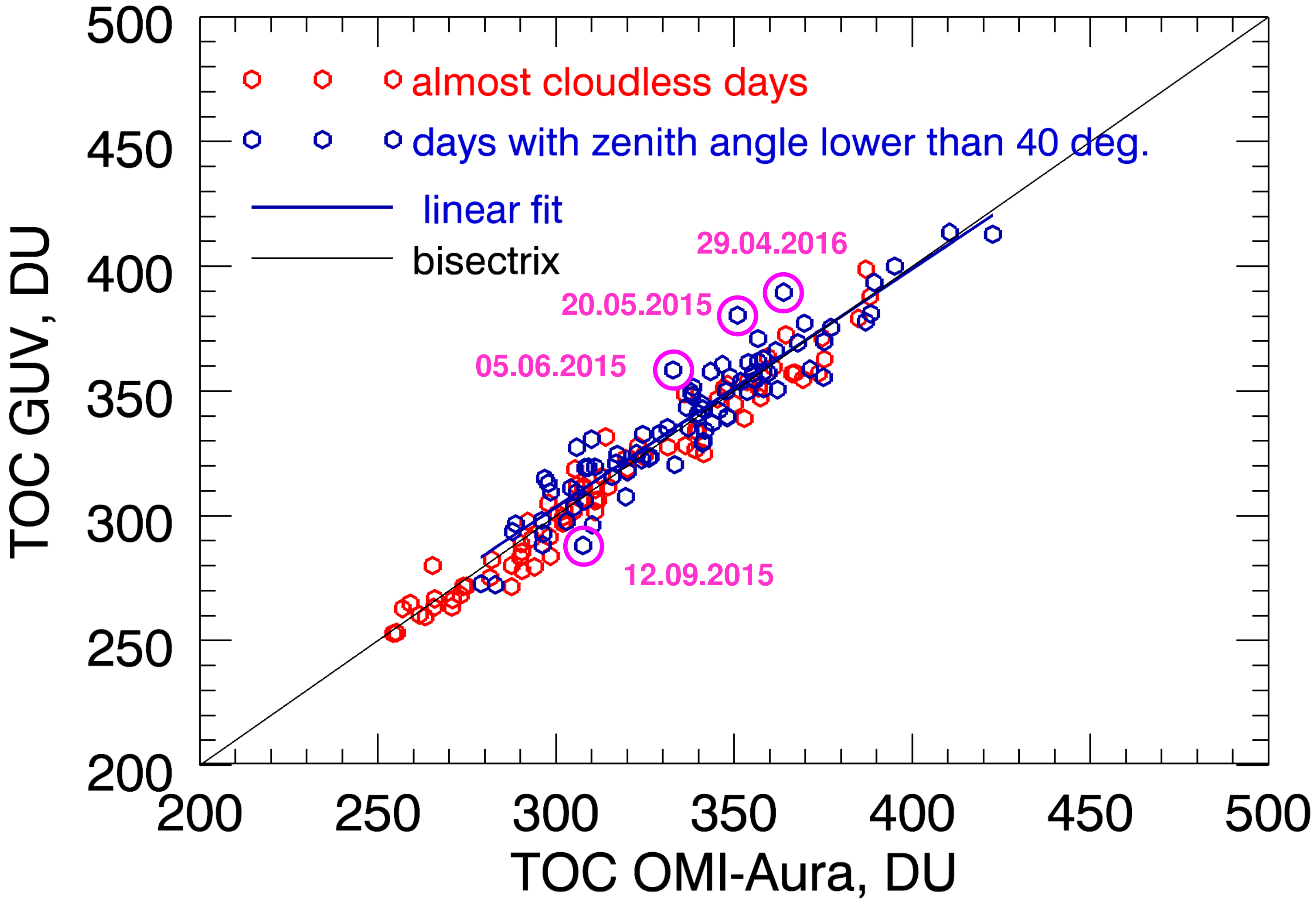


Preliminary results

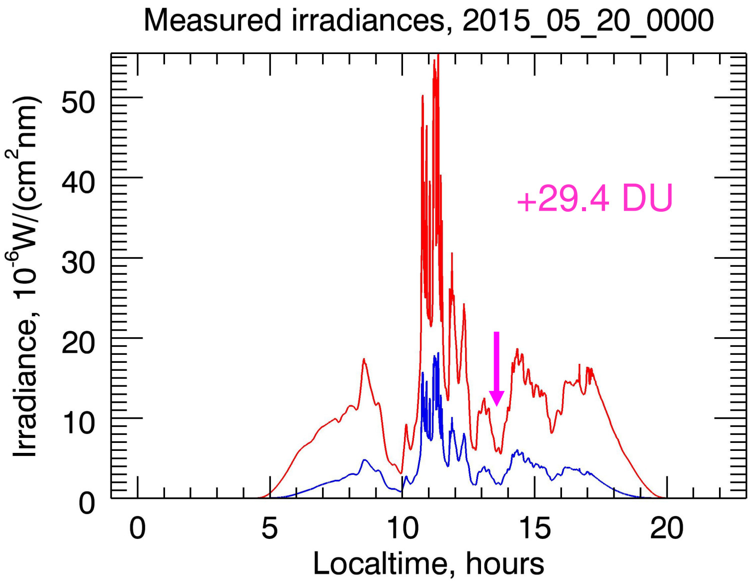


Results

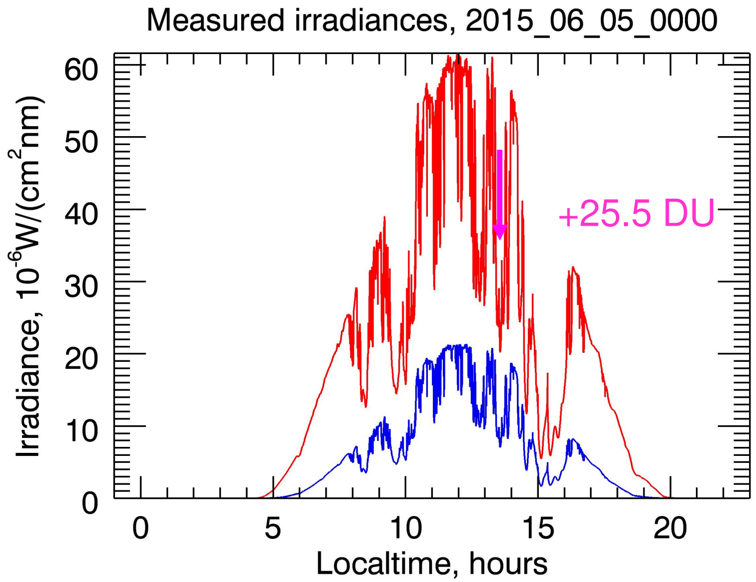
Regression GUV ozone against OMI ozone



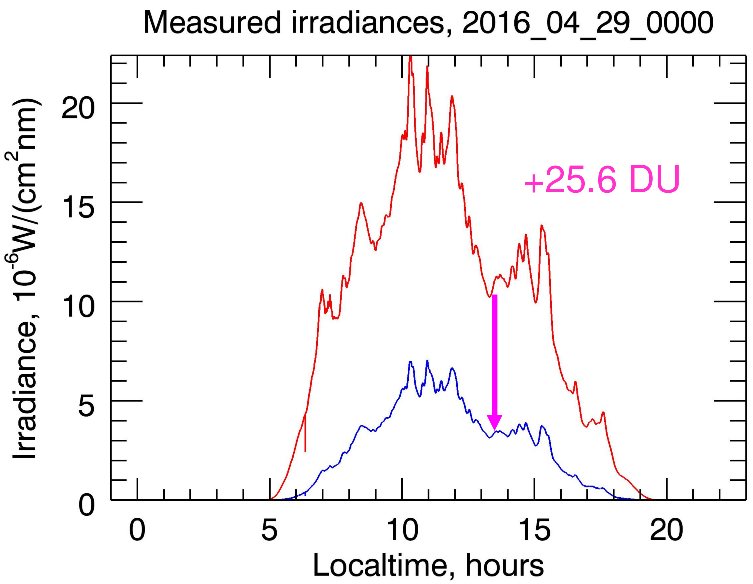
Results



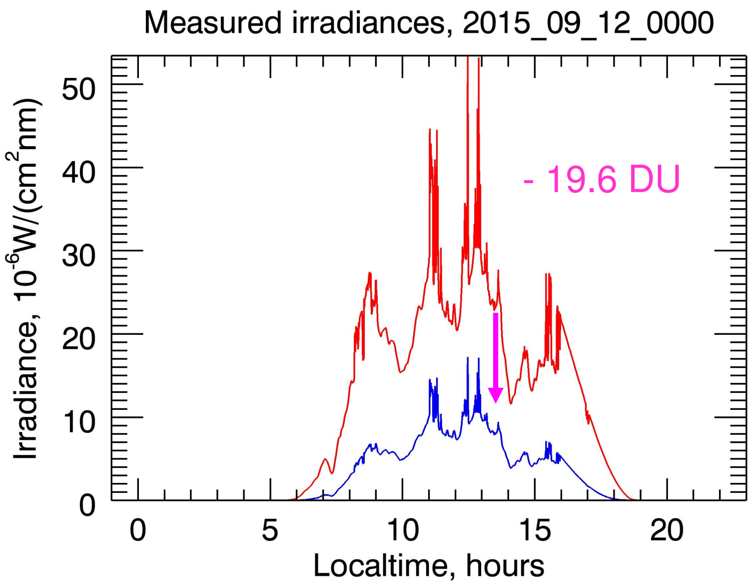
Measured irradiances, 2015_05_20_0000
+29.4 DU
Irradiance, 10^{-6}W/(cm^{2}nm)
Localtime, hours



Measured irradiances, 2015_06_05_0000
+25.5 DU
Irradiance, 10^{-6}W/(cm^{2}nm)
Localtime, hours



Measured irradiances, 2016_04_29_0000
+25.6 DU
Irradiance, 10^{-6}W/(cm^{2}nm)
Localtime, hours



Measured irradiances, 2015_09_12_0000
- 19.6 DU
Irradiance, 10^{-6}W/(cm^{2}nm)
Localtime, hours

Conclusions

- ✓ The results show a good ozone retrieval for the Stara Zagora location by GUV 2511 data.
- ✓ The retrieval error is about 10 DU (or 3%)
- ✓ It was found a cloud dependence of the ozone values for the used here irradiance ratio 313 nm/340 nm.
- ✓ To improve the ozone retrieval it is necessary to determine the atmospheric optical depth and to calculate new Look-up tables with the atmospheric optical depth as additional parameter.

Acknowledgement

The GUV instrument was provided by the project *BG161PO003-1.2.04-0053* “Information Complex for Aerospace Monitoring of the Environment“ (ICASME) implemented with the financial support of Operational Programme „Development of the Competitiveness of the Bulgarian Economy 2007-2013”, co-financed by the European Regional Development Fund and the national budget of the Republic of Bulgaria.

Thank you

for

your attention