Total ozone over Kyiv-Goloseyev station in 2010–2015 from ground-based and satellite observations

A.V. Grytsai, G.P. Milinevsky

a.grytsai@gmail.com

Astronomy and Space Physics Department

Taras Shevchenko National University of Kyiv

Ozone observations at Kyiv-Goloseyev station (KGV)

Measurements by Dobson spectrophotometer No. 040 are used for total ozone calculation from Direct Sun (DS), Zenith Blue (ZB) and Zenith Cloud (ZC) observations.

Total ozone content (TOC) is obtained from Beer–Lambert–Bouguer law for DS observations. ZB and ZC data series are based on statistical correspondence between them and DS results.

Dobson spectrophotometer at Kyiv-Goloseyev station (roof of the Main Astronomical Observatory; 50.36 N, 30.53 E, 206 m above sea level).

Principle of total ozone measurements with Dobson spectrophotometer

Wavelength (nm)	ά (atm-cm)$^{-1}$	β (atm)$^{-1}$
305.5		0.489
325.0		0.375
A	1.806	0.114
308.9		0.466
329.1		0.355
B	1.192	0.111
311.5		0.450
332.4		0.341
C	0.833	0.109
317.5		0.414
339.9		0.310
D	0.374	0.104

Standard pairs of wavelengths in Dobson spectrophotometer

Theory-based total ozone values are retrieved from **Direct Sun** observations.

Single-pair TOC: errors caused predominantly by aerosol influence.

Total ozone calculation from single-pair measurements

A formula from Beer–Lambert–Bouguer law (Komhyr and Evans, 2006):

Aerosol

$$\mathbf{X = \{N-(\beta-\beta')mp/p_0-(\delta-\delta')\sec Z\}/[\mu(\alpha-\alpha')]},$$

Rayleigh **Ozone**

where

X – total ozone content;

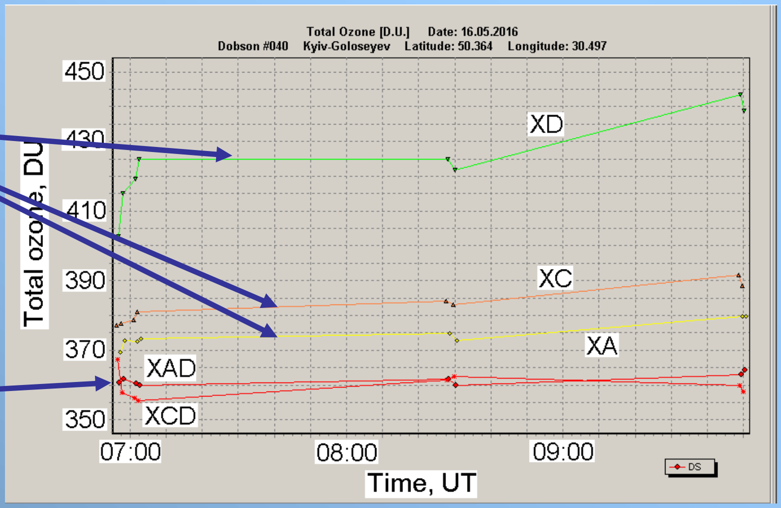
N = L – L$_0$ = lg **(I'/I)** – lg **(I$_0$'/I$_0$)**;

I$_0$, I$_0$' – solar radiation intensity on two wavelengths;

I, **I'** – the intensity at **surface**

Single-pair

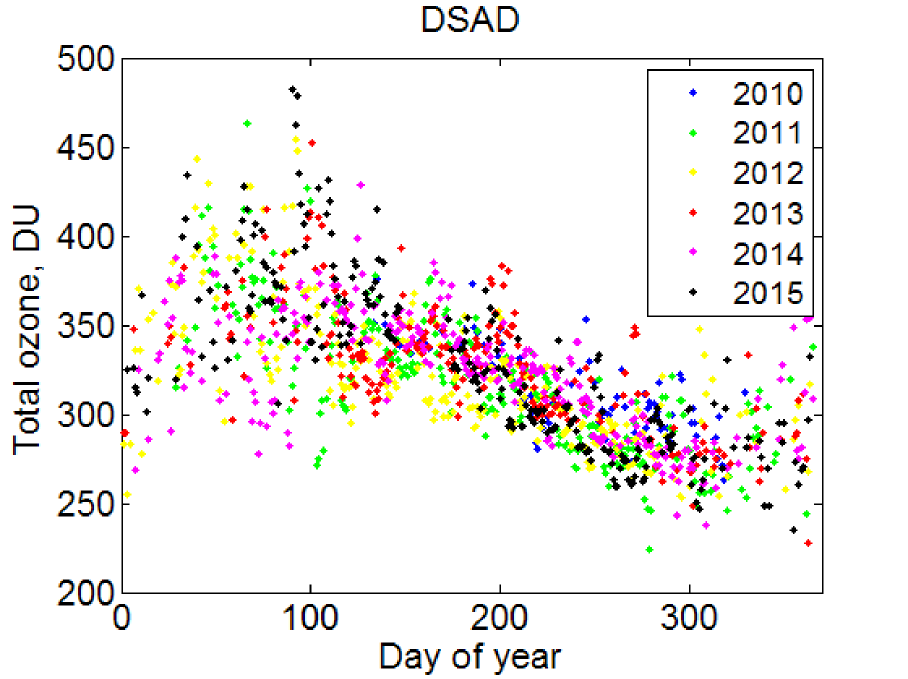
Double-pair



Total ozone in Dobson Units (DU)

Total ozone from DS obs 16 May 2016

Typical ozone levels at Kyiv-Goloseyev

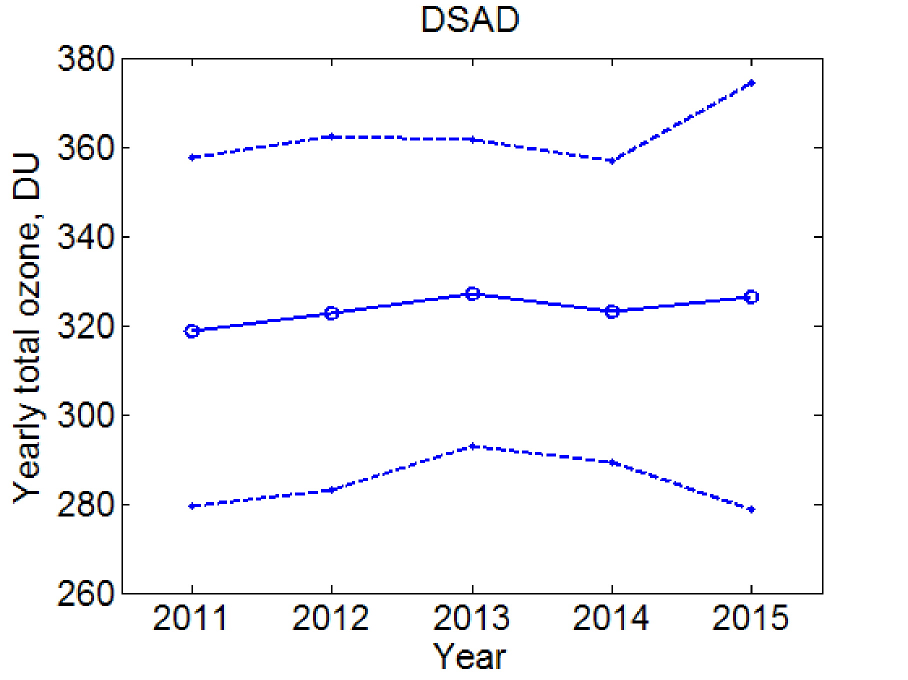


Total ozone at Kyiv-Goloseyev,
daily DSAD data

Kyiv-Goloseyev is a northern mid-latitude station with maximal ozone values during February–March and minimal ones in October–November.

Total ozone variations are minimal during summer (to 50 DU). They increase during seasonal maximum in spring (100–150 DU and greater).

Yearly total ozone at Kyiv-Goloseyev



Total ozone at Kyiv-Goloseyev, yearly mean DSAD data with their standard deviations; Dobson 040 data are presented

Yearly mean values from different types of observations have small distinctions. Minimal mean values:

319–322 DU in 2011

Maximal values:

327–338 DU in 2013.

High ozone levels were registered in 2010, but Kyiv-Goloseyev data for this year are too incomplete to calculate yearly mean.

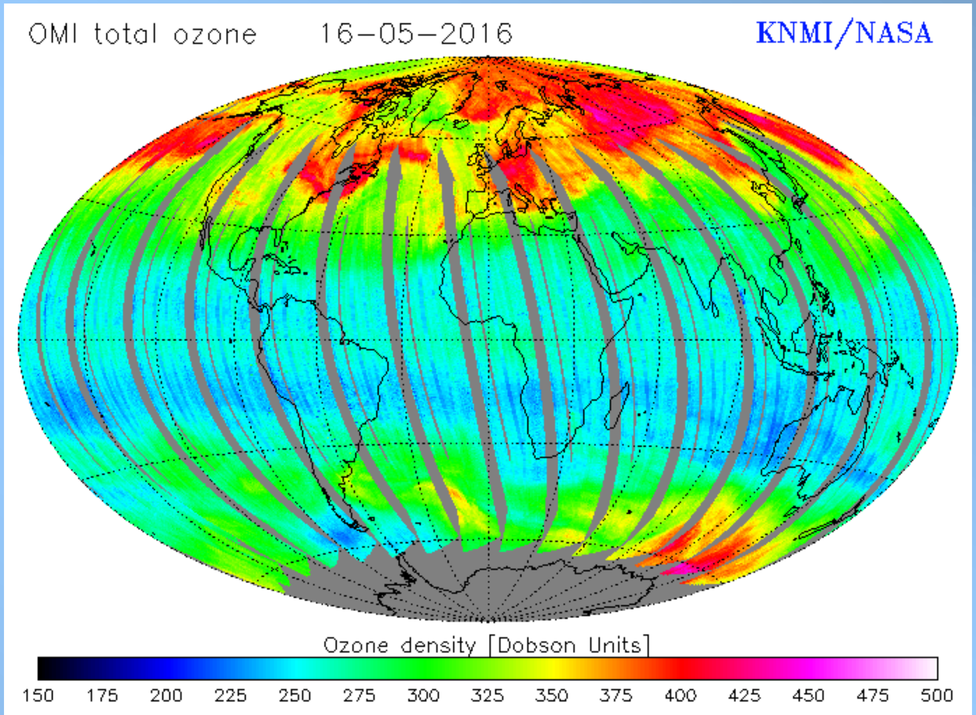
Satellite data

Observations: Ozone Monitoring Instrument **(OMI)** / Aura satellite, Global Ozone Monitoring Experiment – 2 **(GOME-2)** / Metop-A, GOME-2 / Metop-B, and SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY **(SCIAMACHY)** / Envisat.

Daily Dobson values were compared with models based on the satellite measurements.

Satellite values are calculated from intensity of **backscattered ultraviolet radiation** near nadir point.

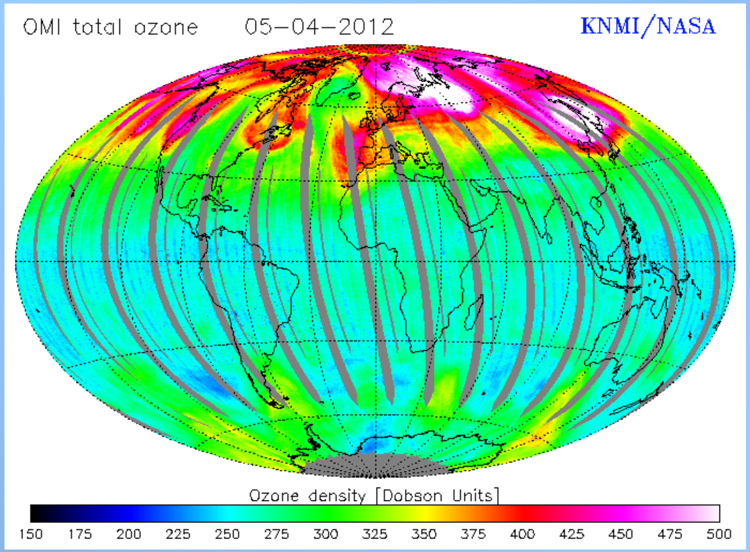
All the satellites have **polar sun-synchronous orbits** with inclination ~98°.

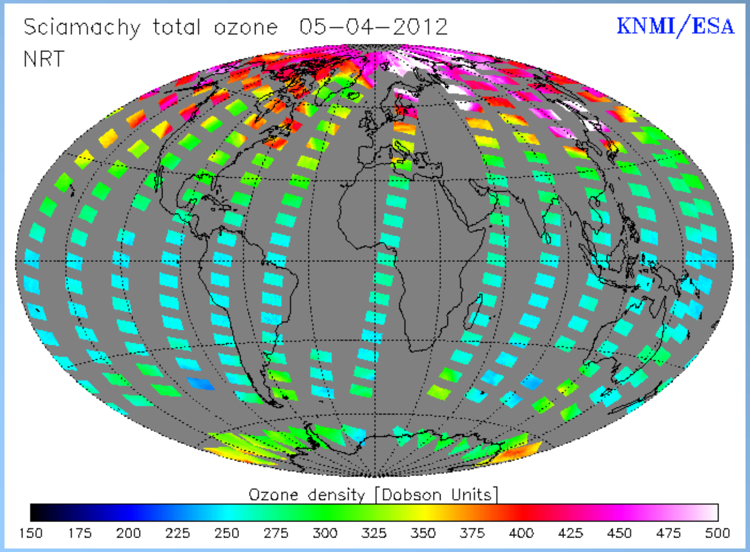


Total ozone on May 16, 2016, OMI data

www.temis.nl

Characteristics of the satellites





Daily total ozone maps obtained by OMI (left) and SCIAMACHY (right), 5 April 2012. ***Communication with Envisat was lost on 8 April 2012***.

Aura, Envisat and Metop-A,B are multi-functional satellites:

Aura has 4 scientific instruments (total mass ~3 tons)

Envisat was equipped with 9 instruments (totally ~8 tons).

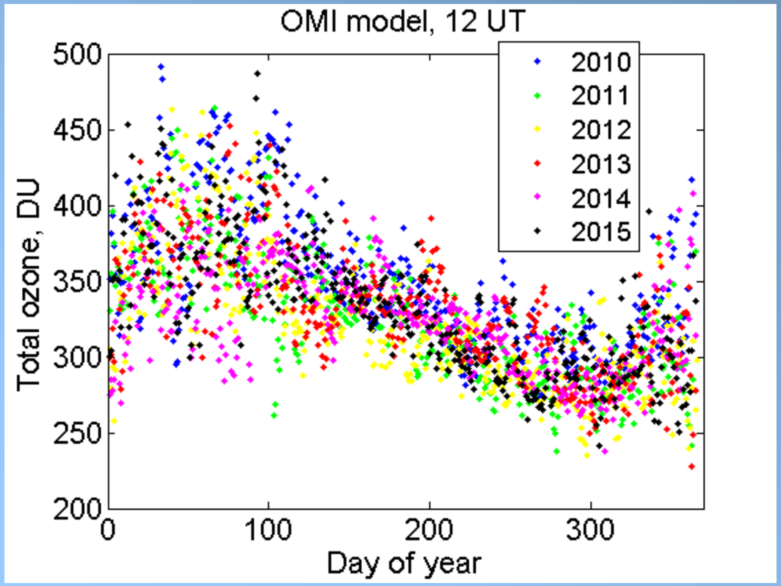
Metop satellites have a payload of 8 instruments (~4 tons).

Model based on OMI measurements

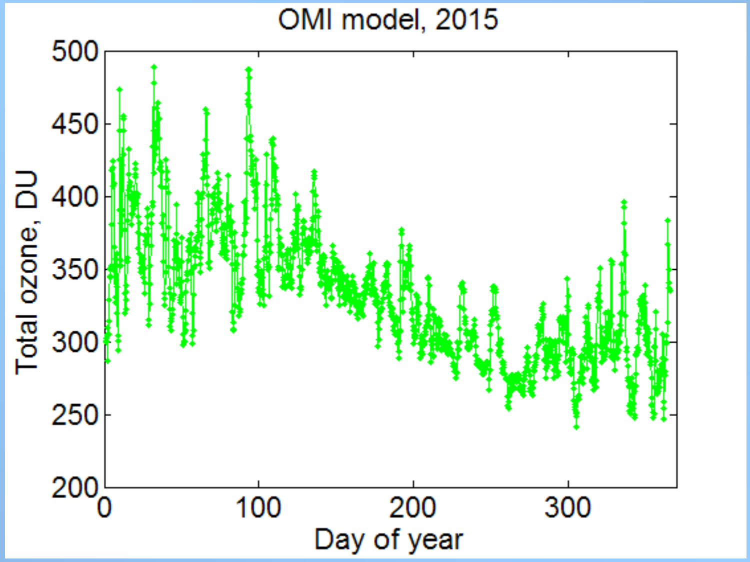
Data from www.temis.nl have been used.

They are calculated with 6-hour step (00, 06, 12, and 18 UT).

Data on 12 UT were compared with ground-based measurements because this is the most appropriate time to the Dobson observations.



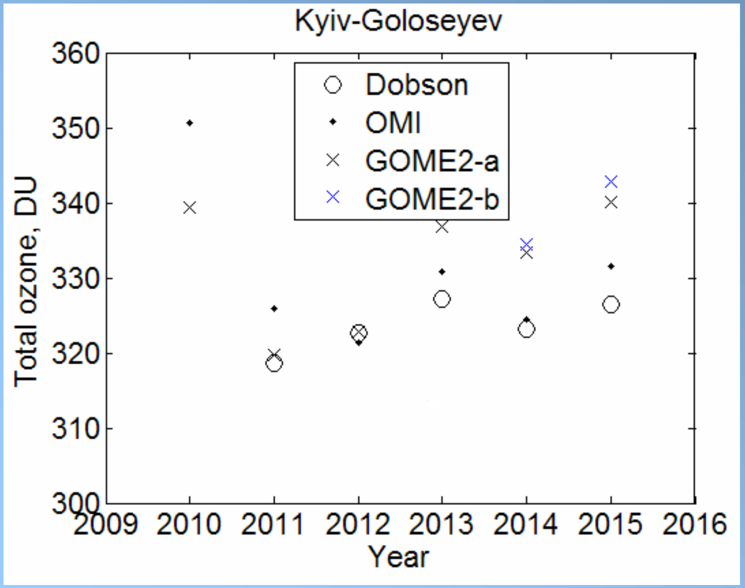
Model values on 12 UT



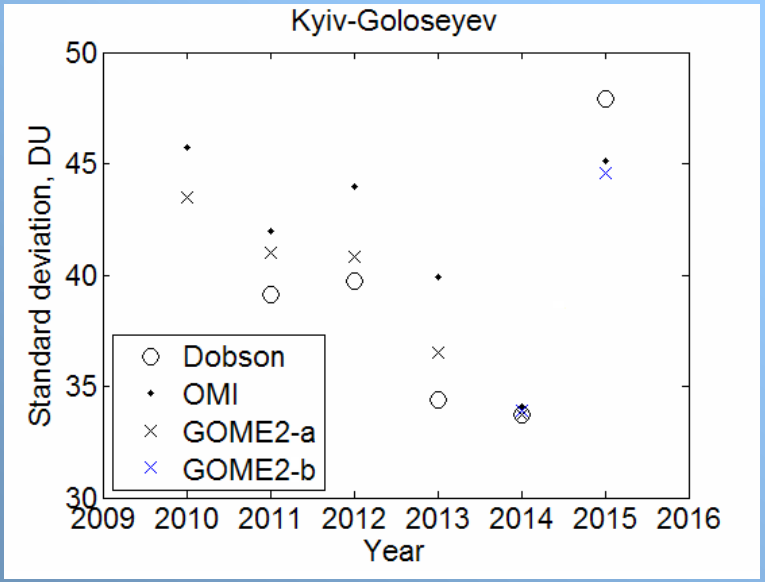
Yearly Dobson and model data

Models based on the data of OMI, GOME2-a and GOME2-b were used to calculate yearly means.

Both Dobson and model yearly means with their standard deviations are presented



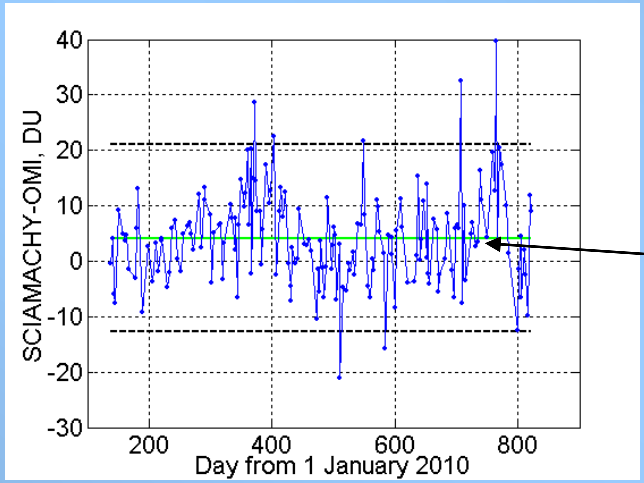
Yearly means for both Dobson spectrophotometer DSAD data and the three models

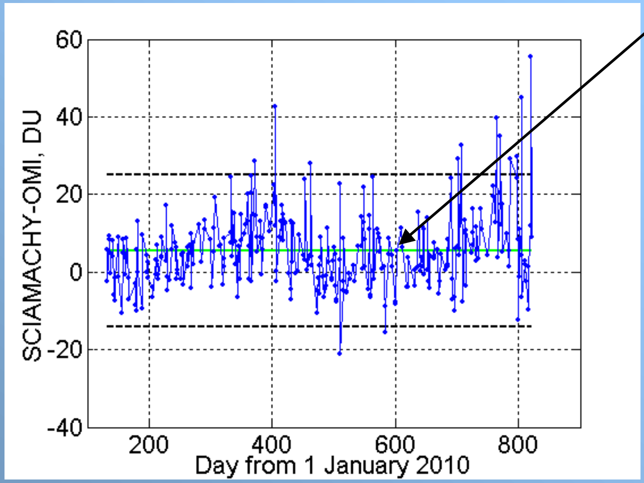


Standard deviations, which determine variability during each separate year

Comparison between OMI and SCIAMACHY individual data

up to 100 km from Kyiv-Goloseyev





Differences between SCIAMACHY and OMI data during 13.05.2010 – 8.04.2012

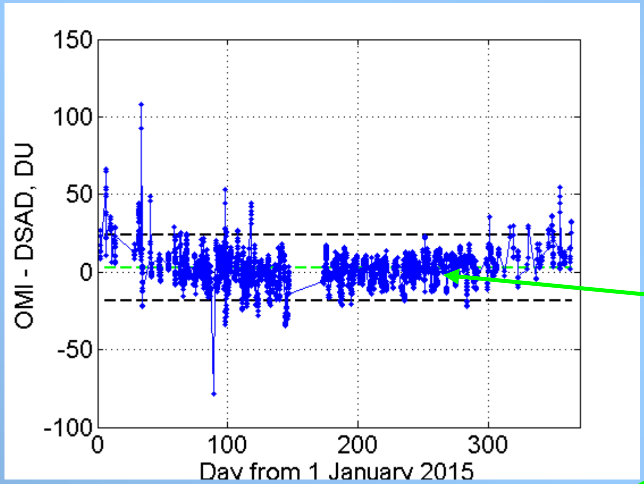
SCIAMACHY – OMI difference:

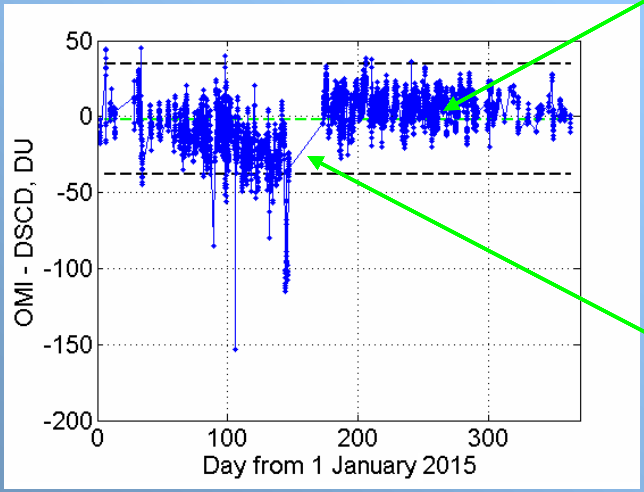
4.1 16.8 DU (here and after two standard deviations are indicated after "±" sign) for measurements within 2 hours;

5.4 **19.6** DU for measurements in the same day.

No significant dependences of the differences on distance (up to 100 km) from Kyiv-Goloseyev and cloud fraction are found out. Influence of time interval (during one day) is small. OMI values are a few lower than SCIAMACHY ones.

Relationship between individual OMI and ground-based measurements





Differences between OMI measurements over Kyiv-Goloseyev and DSAD (DSCD) data

DSCD data typically have poorer quality relative to DSAD ones.

OMI – DSAD: 2.5±21.3 DU

OMI – DSCD: –2.0±36.3 DU

In 2015, DSCD ozone data showed deviations on satellite measurements before Dobson calibration in June.

Calibration in Hohenpeissenberg

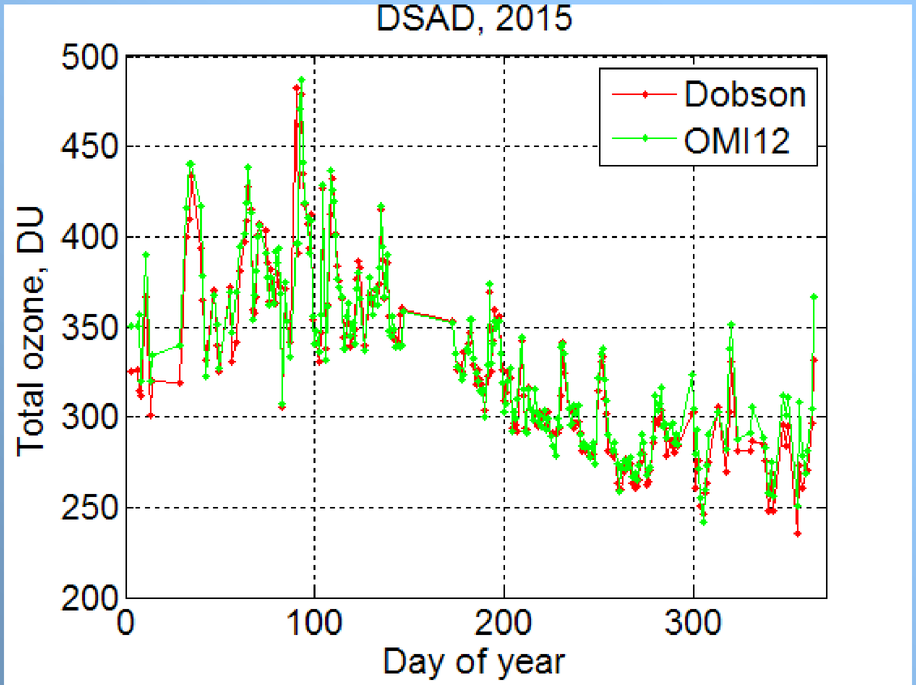
OMI and daily DSAD data

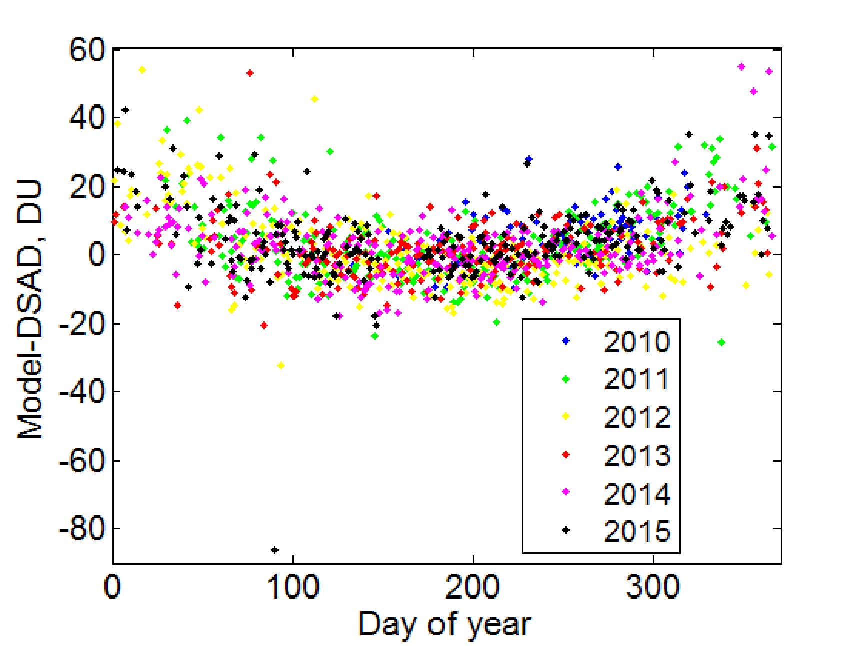
OMI – DSAD, 2015: 4.1±22.3 DU

Total ozone difference is weakly dependent on time if observations are realized during several hours. The **model data** on 12 UT and Dobson daily means have been compared.

KGV seasonal: **spring max**

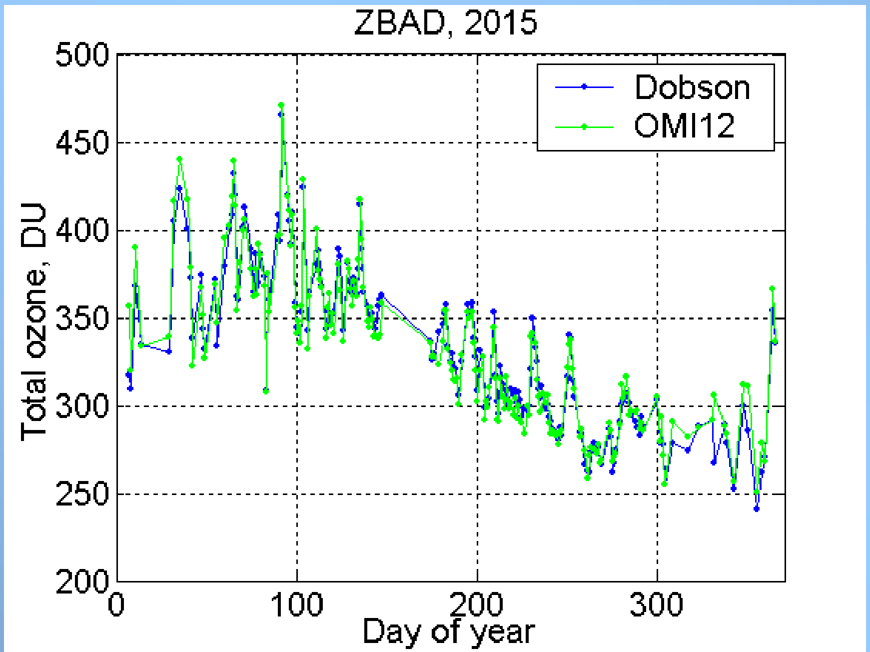
autumn min



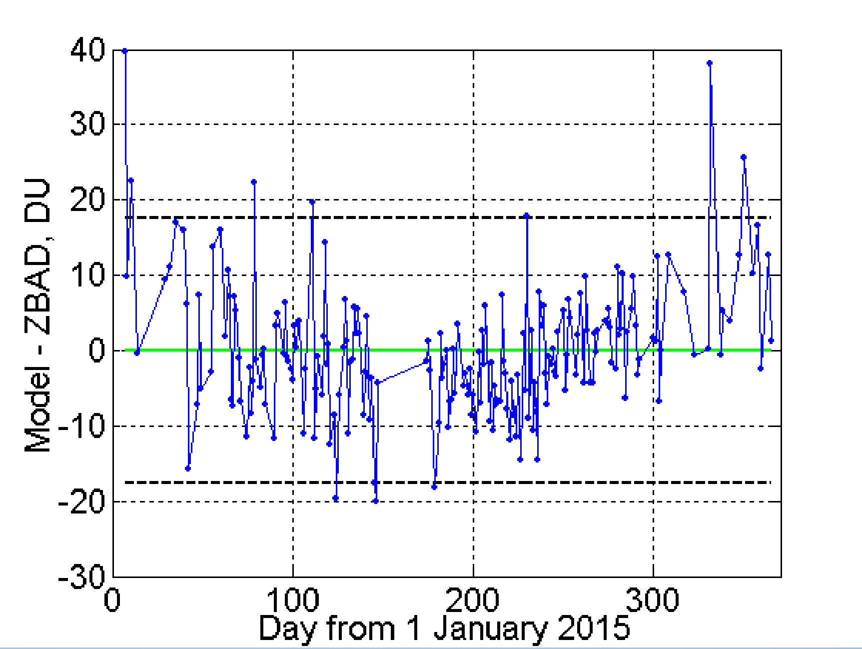


Total ozone over KGV from Dobson DSAD daily means and OMI-model 12 UT values (left, year of 2012); model – DSAD difference (right).

OMI and ZBAD daily data



OMI – ZBAD, 2015: 0.0±17.6 DU



Total ozone from Dobson ZBAD daily means and the 12 UT model (left); model – ZBAD difference (right).

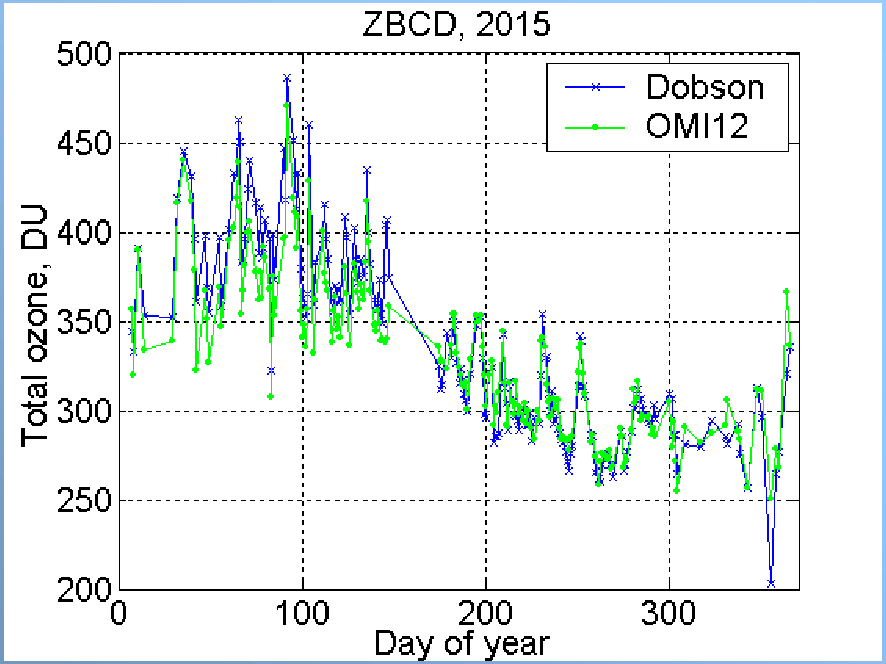
OMI – DSAD, 2015:
4.1±22.3 DU

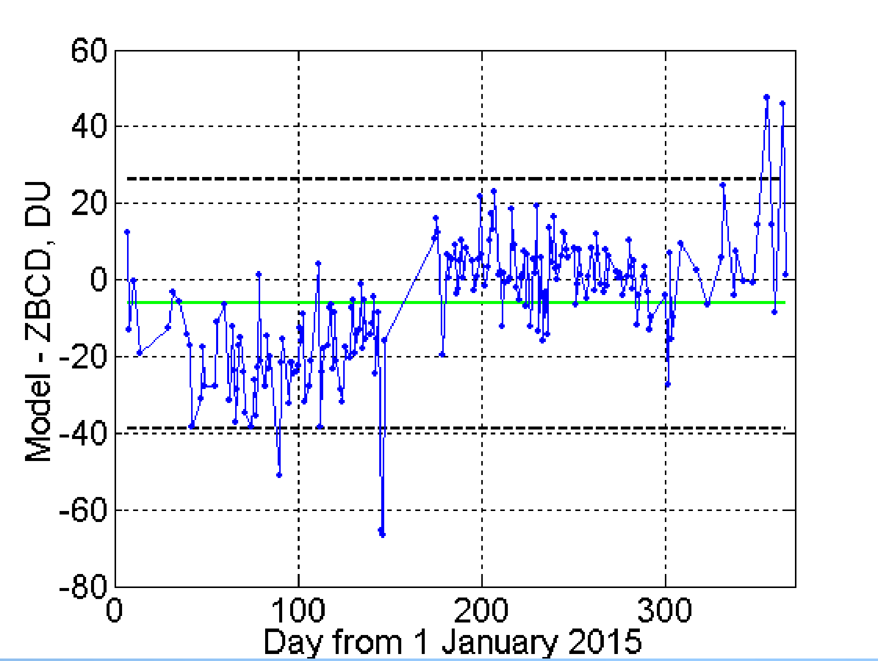
OMI and ZBCD data

ZBCD measurements are the most useful in late autumn and winter supplying DSCD because a quality of the AD measurements could be low. Unfortunately, typical Kyiv meteorological conditions complicate ZB observations during this season.

OMI – ZBCD, 2015: –6.3±32.4 DU.

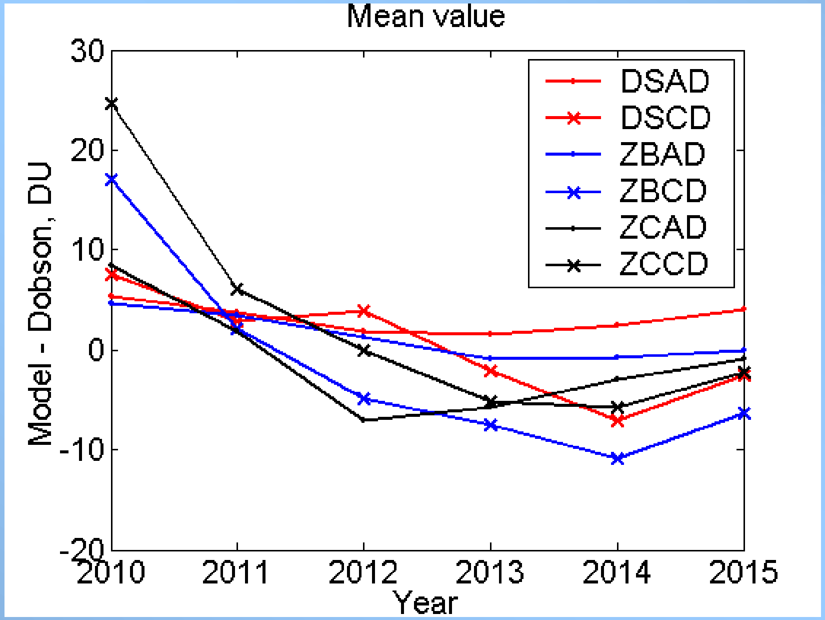
Accuracy of CD measurements is lesser than for AD

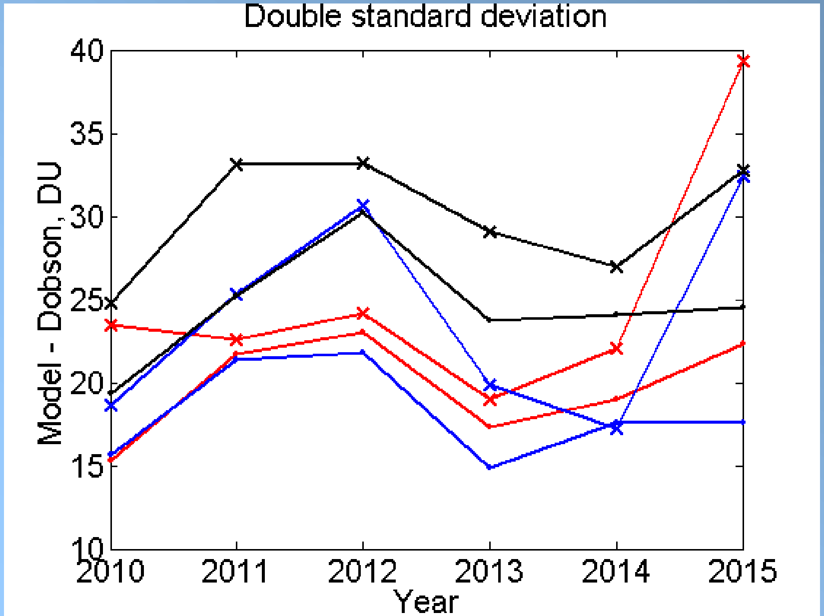




Total ozone from Dobson ZBCD daily means and the 12 UT model (left); model – ZBCD difference (right).

Yearly mean differences





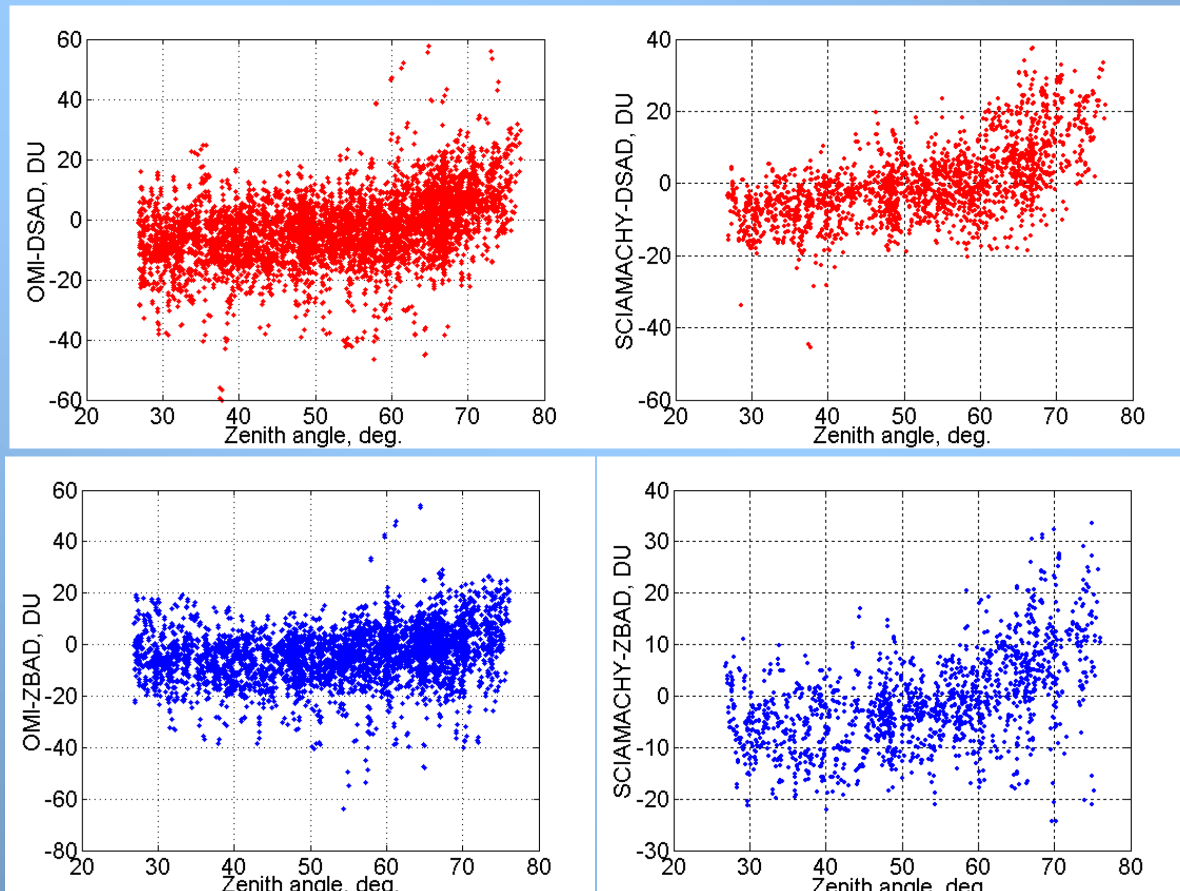
Mean differences and double standard deviations between the 12 UT model and Dobson values.

Daily data for 2010 (from 13 May)–2015 were used.

DSAD, DSCD and ZBAD data obtained by KGV Dobson 040 have a high quality (excluding 2015 for DSCD).

ZBCD and ZC data are significantly unstable relative to mean differences, their double SDs frequently exceed 25 DU.

Zenith angle dependence



Total ozone difference in dependence on zenith angle. DSAD and ZBAD data.

OMI (left) and SCIAMACHY (right) individual measurements are used.

Difference between satellite and Dobson 040 data increases with zenith angle (in particular, for SZA larger than 65-70).

That could be connected with inadequacy of Dobson or satellite algorithms to calculate total ozone under conditions with large SZA.

Conclusions

1. Total ozone observations at Kyiv-Goloseyev have a typical for Northern middle latitudes seasonal cycle, a **maximum in February–March** and a **minimum in October–November**

2. **Satellite – ground-based difference** has also a seasonal cycle with **the largest positive deviations during late autumn – winter**

3. **DSAD** and **ZBAD** measurements at the KGV station display high-quality results, dispersion of their difference with satellite data is close to results of SCIAMACHY – OMI and model–model intercomparison

4. **ZBCD** and **ZC** data are significantly unstable relative to mean differences, their standard deviations are large

5. Total ozone uncertainties are dependent on solar zenith angle being maximal at SZA larger than **65–70**

Дякую за увагу!