VALIDATION OF GOME-2 OZONE PROFILES FOR MID- AND NORDIC LATITUDES, USING BALLOON SOUNDING DATA

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Abstract

A validation of the GOME-2 ozone profiles has been carried out. This has been done by using ozone sounding data, which have a vertical resolution of about 100 m and is measuring ozone from the surface up to about 34 km.
GOME-2 ozone data was made available by KNMI at pre-selected sites. The reference data which was available limited this study to the European mid-latitudes and European Nordic region. The algorithm version used for this retrieval of GOME-2 ozone profiles is 3.2.
For this study, data from other ozone sounding stations besides Uccle have been used (De Bilt, Hohenpeissenberg, Payerne, NY-Alesund, Sodankyla and Lerwick).
GOME-2 ozone profiles show sensibly better results at European mid-latitudes than at Nordic latitudes, especially in the tropopause region.
The target accuracies for the ozone profiles are respectively 30 % in the troposphere and 15 % in the stratosphere. Data analysis over the time period March 2007 - February 2008 has shown that this accuracy is reached at least partially in the stratosphere. In the UTLS region, and especially at high latitudes, GOME-2 ozone profiles are least accurate.
In the troposphere, mean relative differences are reasonable, at least at midlatitudes, but the information content in the lower levels is relatively low.

INTRODUCTION

EUMETSAT's Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (O3M SAF) is producing near real-time and offline products based on Metop satellite data from measurements of the Global Ozone Monitoring Experiment-2 (GOME-2) instrument. GOME-2, launched in October 2006, is a nadir scanning UV/VIS spectrometer designed for ozone and trace gas retrieval.
Ozone profiles are retrieved from GOME-2 spectra by KNMI using optimal estimation. This involves the use of an a-priori ozone profile and error covariances to complement the profile information in the measured spectra. The GOME-2 ozone profile product is currently pre-operational and is available in NRT (3 hours from sensing) via the SAF-Europe channel of EUMETCast. The archived offline products can be ordered via UMARF.
This study shows validation results for GOME-2 ozone profiles, retrieved with **algorithm version 3.2**, for the O3M SAF using ozone-sounding data for the time period 03/2007 – 02/2008. Reference data availability limited this study to the European mid-latitudes and European Nordic region.

Ozone sondes are lightweight balloon-borne instruments capable of making ozone measurements from the surface up to about 34 km, with much better vertical resolution than satellite data. In general also the precision and accuracy will be better, at least in the lower stratosphere and the troposphere. Another advantage is that ozone soundings can be performed at any time and at any meteorological condition.

The precision of ozone sondes varies with altitudes and depends on the type of sonde used. Table 1 below shows indicative precision (in percent) of the Electrochemical Concentration Cell (ECC) and the Brewer-Mast (B-M) ozone sondes, at different pressure levels of the sounding (taken from the O3MSAF Science Plan).

Pressure level (hPa)	ECC	B-M
10	2	10
40	2	4
100	4	6
400	6	16
900	7	14

Table 1: Precision of different types of ozonesondes at different pressure levels in %.

We see that the profiles from ozonesondes are most reliable around the 40 hPa level, which is around the ozone maximum. The error bar of profiles from ozonesondes increases rapidly at levels above the 10 hPa level, which is around 31 km altitude.

DATASET DESCRIPTION

GOME-2 ozone data for the period of March 2007 up to the end of February 2008 are used for validation. GOME-2 ozone data was made available by KNMI at pre-selected sites. These sites correspond to sites where ozone soundings are performed on a regular basis. The algorithm version used for this retrieval of GOME-2 ozone profiles is 3.2.

Ozonesonde data are generally made available by the organization carrying out observations after a delay in order to leave time for necessary verification and correction of the data quality. For validation purposes, ozone profile data from soundings are available in near real time. The stations used and the number of coincidences are summarized in Table 2:

Station	Longitude	Latitude	nr. of coincidences
Uccle (RMI, Belgium)	4.35	50.8	1567
De Bilt (KNMI, The Netherlands)	5.18	52.1	541
Hohenpeissenberg (DWD, Germany)	11.02	45.82	1405
Payerne (MeteoSwiss, Switzerland)	6.95	45.82	1673
Ny-Alesund (AWI, Svalbard)	11.95	78.93	1817
Sodankyla (FMI, Finland)	26.63	67.37	1213
Lerwick (UKMO, UK)	-1.19	60.14	854

Table 2: Overview of number of coincidences at different station locations.

METHODOLOGY

Co-location criteria

The selection criteria, taken into account are two folded:
The geographic distance between the GOME-2 pixel center and the sounding station location is taken into account and the criterion is fixed at a distance of 300 KM.

The time difference between the pixel sensing time and the sounding launch time is the second criterion and is fixed at about ten hours of time difference. Each sounding that is correlated with a GOME-2 overpass is generally correlated with several GOME-2 pixels if the orbit falls within the 300 km circle around the sounding station. This means that a single ozone profile is compared to more than one GOME-2 measurement.

Ozone sounding pre-processing

GOME-2 ozone profiles are given as partial ozone columns on varying pressure levels (40 levels between surface and 0.1 hPa). Ozone partial columns are expressed in Dobson Units.
Ozonesondes measure the ozone concentration along the ascent with a much higher vertical resolution (100 m) than GOME-2, until 30 km.
The integration requires interpolation, as GOME-2 levels never match exactly ozonesonde layers. This interpolation causes negligible errors given the high vertical resolution of ozonesonde profiles.

VALIDATION RESULTS

Figure 1 shows average difference profiles between GOME-2 ozone profiles and ozonesonde profiles for all the stations listed in Table 1. The error bars represent one standard deviation on the mean error. Averaged profiles are shown in Figure 2. In the troposphere, it is observed that GOME-2 ozone profiles are in general within 10 % from the ozone sounding profiles. For the stations of Uccle and De Bilt, GOME-2 is underestimating slightly the ozone concentrations in the lower troposphere, while at Hohenpeissenberg, there is a small overestimation by GOME-2 for ozone in the lower troposphere. The standard deviations are increasing with height in the troposphere and are largest in the UTLS-zone (Upper Troposphere Lower Stratosphere ozone). The relative differences are not significantly different at the 2 sigma level.
The mean difference increases for all the stations in the UTLS-zone, with an overall overestimation of the ozone concentrations by GOME-2. This effect can be observed at all the stations along with a significant increase of the scatter. At higher latitudes (Ny-Alesund), this effect is more pronounced with the relative difference peaking around 8 km in altitude.
In the stratosphere the difference profile stays within 10 % of the reference profile at almost all the stations. There is a small tendency for GOME-2 profiles at all stations except Payerne to underestimate the ozone concentrations, especially around the ozone maximum.
At heights above 25 km, GOME-2 has an overall tendency to overestimate ozone. Only at Uccle we observe a zero difference profile at the highest levels, which can be explained by the particular method for the correction for the loss of pump efficiency with altitude, applied to the ozone profiles obtained at Uccle and an underestimation at the highest levels due to too low pump corrections (De backer *et al.*, 1998, Lemoine and De Backer, 2001)

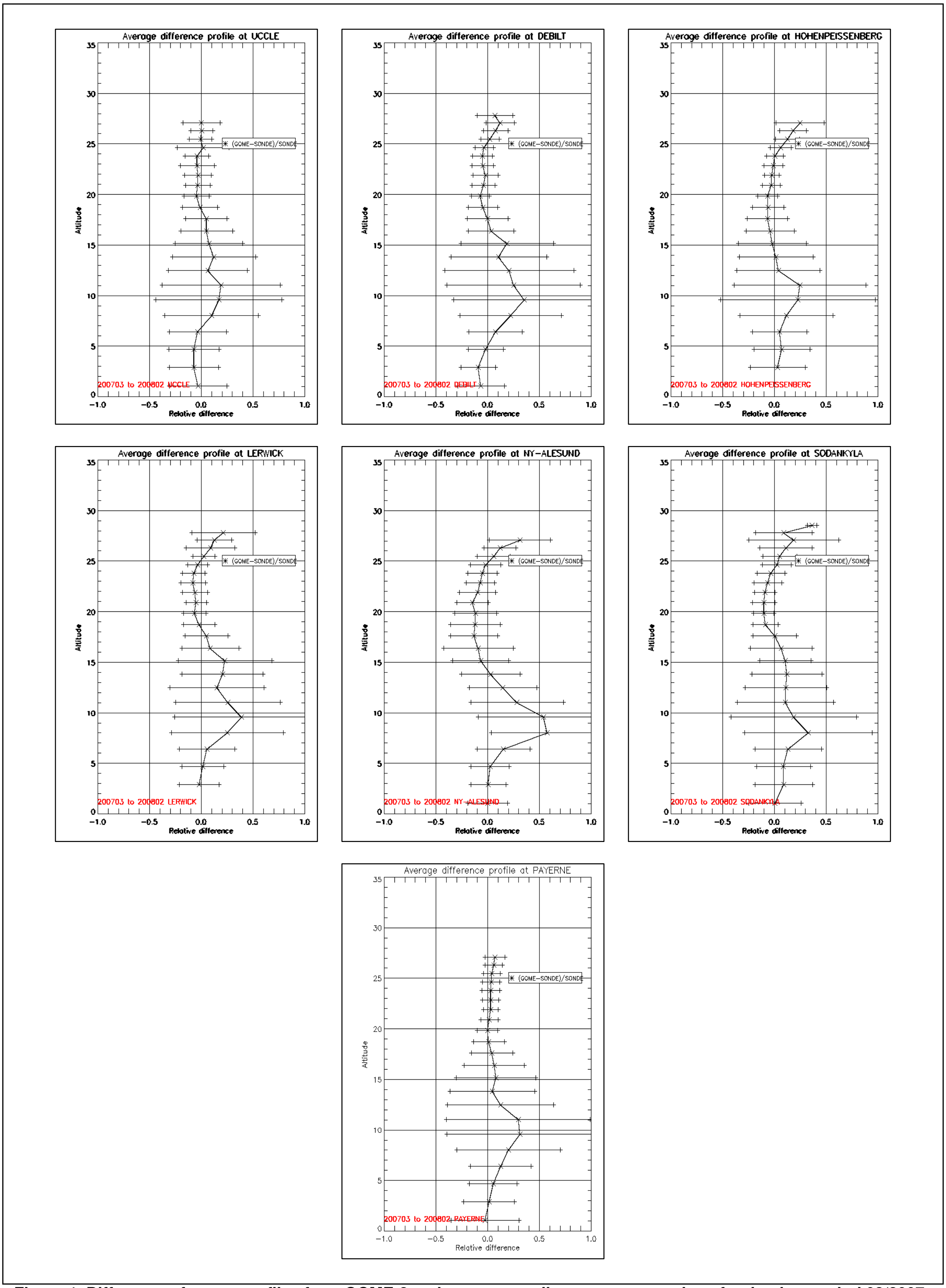

Figure 1. Difference of ozone profiles from GOME-2 and ozone soundings at seven stations for the time period 03/2007-02/2008.

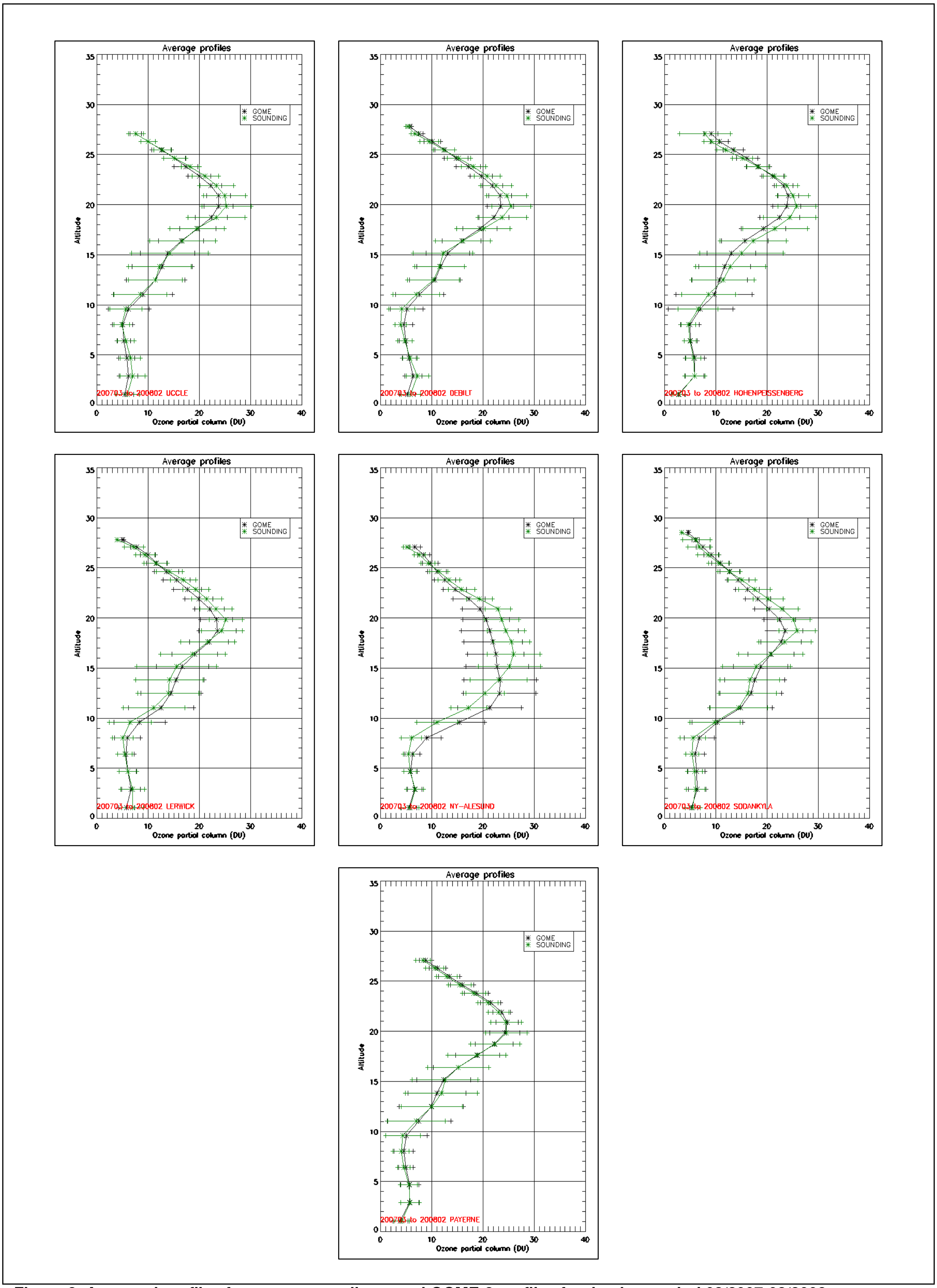

Figure 2. Averaged profiles for ozone soundings- and GOME-2 profiles for the time period 03/2007-02/2008.

INFORMATION CONTENT

The regression line in the scatter plots (Fig. 3) shows that GOME-2 loses sensitivity in the lower troposphere and around the ozone maximum (20 km). Correlation at different altitudes (5, 10, 15, 20, 25 km) are for Uccle summarized in Table 3:

Station	Altitude (km)	Correlation	Slope	Intercept (DU)
PAYERNE	5	0.45	0.45	2.75
PAYERNE	10	0.68	0.56	2.62
PAYERNE	12	0.76	0.70	2.41
PAYERNE	15	0.81	0.63	3.96
PAYERNE	20	0.74	0.54	11.55
PAYERNE	25	0.89	0.91	1.61
UCCLE	5	0.29	0.18	4.02
UCCLE	10	0.74	0.80	1.48
UCCLE	12	0.77	0.79	1.75
UCCLE	15	0.78	0.54	5.75
UCCLE	20	0.58	0.42	13.58
UCCLE	25	0.76	1.01	-0.24
DEBILT	5	0.66	0.56	2.20
DEBILT	10	0.61	0.53	3.20
DEBILT	12	0.52	0.54	3.67
DEBILT	15	0.66	0.46	7.32
DEBILT	20	0.71	0.48	11.88
DEBILT	25	0.87	0.86	2.03
HOHENPEISSENBERG	5	0.40	0.42	2.89
HOHENPEISSENBERG	10	0.65	0.50	4.16
HOHENPEISSENBERG	12	0.77	0.66	3.08
HOHENPEISSENBERG	15	0.84	0.50	5.21
HOHENPEISSENBERG	20	0.67	0.51	11.39
HOHENPEISSENBERG	25	0.78	0.84	3.34
LERWICK	5	0.55	0.67	1.85
LERWICK	10	0.67	0.74	3.62
LERWICK	12	0.79	0.78	3.17
LERWICK	15	0.68	0.45	9.19
LERWICK	20	0.67	0.66	6.90
LERWICK	25	0.86	0.77	2.66
NY-ALESUND	5	0.44	0.71	2.33
NY-ALESUND	10	0.20	0.43	14.49
NY-ALESUND	12	0.47	1.03	2.28
NY-ALESUND	15	0.50	0.59	6.95
NY-ALESUND	20	0.40	0.65	4.15
NY-ALESUND	25	0.59	0.74	2.83
SODANKYLA	5	0.44	0.45	3.46
SODANKYLA	10	0.57	0.60	5.02
SODANKYLA	12	0.61	0.72	3.99
SODANKYLA	15	0.74	0.62	7.14
SODANKYLA	20	0.58	0.50	9.05
SODANKYLA	25	0.61	0.62	4.35

Table 3: Correlation, Slope and intercept (DU) for 6 different levels and seven stations.

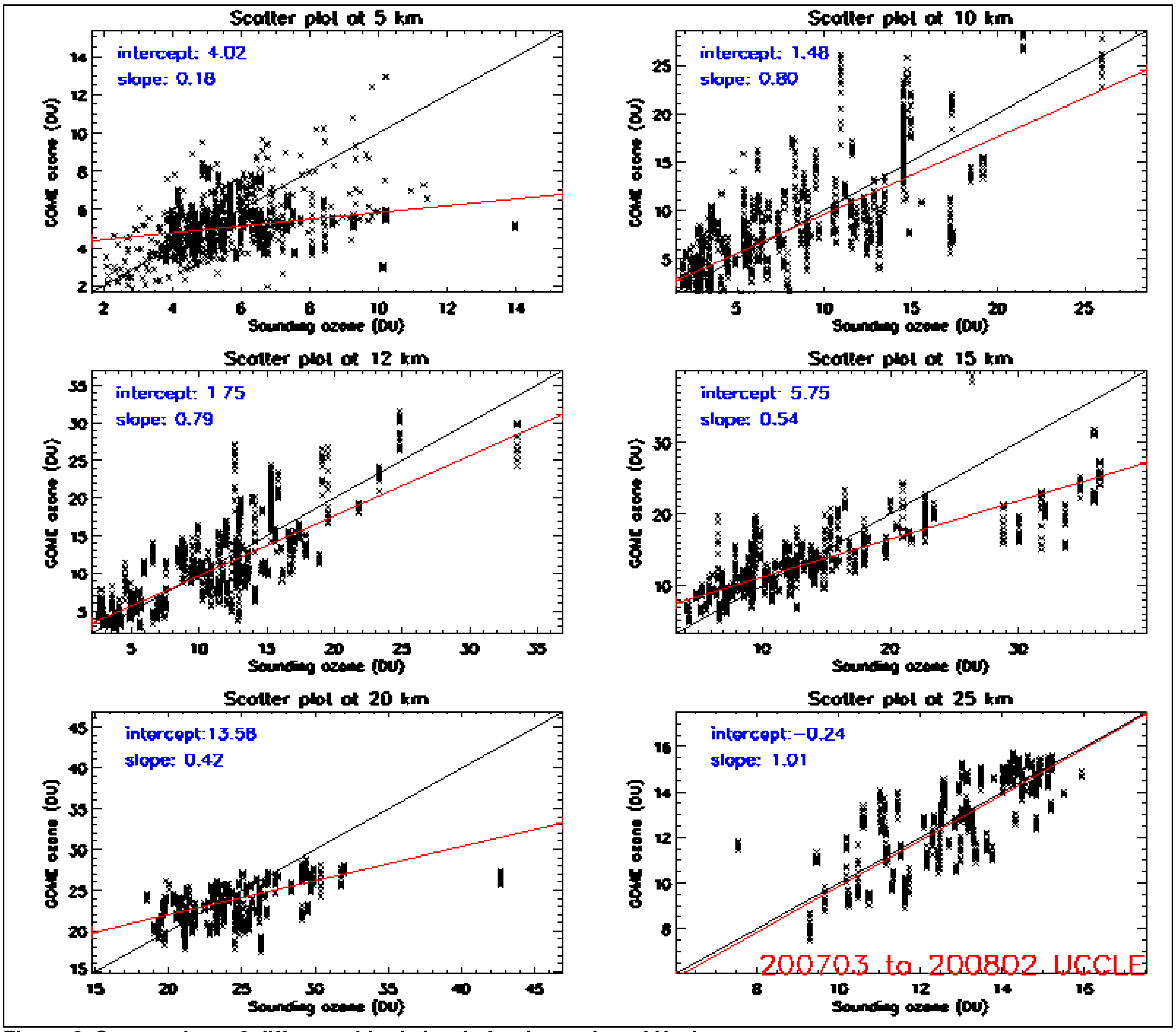

Figure 3. Scatter plot at 6 different altitude levels for the station of Uccle

CONCLUSIONS

This study shows initial validation results of GOME-2 ozone profiles, retrieved with **algorithm version 3.2**, for the O3M SAF using ozone-sounding data. Reference data available limited this study to the European mid-latitudes and European Nordic region for the time period March 2007 – February 2008.

The *threshold* accuracies for the GOME-2 ozone profiles, as set in the Product requirements Document (PRD, v 0.4) are 30% for the stratosphere and 70% for the troposphere. These targets are met after performing a one-year validation for the ozone-sounding stations under consideration.

The *target* accuracies for the ozone profiles are respectively 30% in the troposphere and 15% in the stratosphere. This accuracy is reached at least partially in the stratosphere. Poorer comparisons around the top of the ozone soundings can be attributed to degradation of the sounding accuracy at low pressures (certainly for Hohenpeissenberg). In the UTLS region, and especially at high latitudes, GOME-2 ozone profiles are least accurate. However, ozone concentrations in the UTLS region are generally low, show a large natural variability and a strong dependency on the tropopause altitude so that a part of the differences observed between GOME-2 and ozonesondes could be attributed in part to the fact that small numbers are compared. In the troposphere, mean relative differences are reasonable, at least at mid-latitudes, but the information content in the lower levels is relatively low.

GOME-2 ozone profiles give sensibly better results at European mid-latitudes than at Nordic latitudes, especially in the tropopause region. The mean relative difference between GOME-2 and ozonesondes is within +-10 % in the troposphere (for heights until 7 km) and the stratosphere (for heights between 15 and 25 km). The high latitude stations (Ny-Alesund and Sodankyla) give poorer results: the mean relative difference between GOME-2 and ozonesondes is at those stations within +-15 % in the troposphere (for heights until 7 km) and the stratosphere (for heights between 15 and 25 km). The bias is larger in the UTLS region, especially at high latitudes. The standard deviation on the mean difference is of the order of 30% in the troposphere and 10 to 15% in the stratosphere at mid-latitudes. In the UTLS region, the standard deviation on the mean is considerably larger.

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