Response to Referee #2

The authors would like to thank the referee for its helpful comments and suggestions. Below are our responses to the questions and suggestions brought up by the referee. Referee comments and our responses are written in blue and in black, respectively. Changes refer to the revised manuscript that we will submit to ACP.

1. The validation with ozonesonde observations can be conducted in a more meticulous way as we compare this paper with other papers that performed similar comparisons between satellite remote sensing of atmospheric species and sounding data or between satellite instruments. Examples include Nassar et al. (2008) and Dupuy et al. (2009) for ozone. Why do the authors use ozonesonde data from only 14 stations, not all the stations?

We fully agree with this comment. At the time of this study (which ended in December 2008) only a limited number of stations provided data to validate IASI observations. In the paper, we report on the comparison with all of the data that were made available to us at that time, ie 14 stations that we used to validate our IASI ozone profile retrievals. A few other stations over Europe (5 stations) linked to the NADIR database made further data available before the completion of this work. It was felt however, that including these would lead to an undesired bias over Europe and the mid-latitudes.

During the review process other data became available. At this stage, it would be a big amount of work to add them due to large computational time required by the radiative transfer calculation, and the additional information may not be worth this large effort.

A fast version of the Atmosphit software is presently being developed, building on the effort already applied to CO retrievals (FORLI software, Turquety et al., George et al., 2009). A more complete validation will be undertaken using these fast retrievals, including all ozonesonde stations and other in situ observations (e.g. MOZAIC aircraft data).

Can the authors provide a more detailed comparison by region, by altitude, and by season?

Table 1 gives a more detailed comparison by region, altitude and season. However we did not include this Table in the new manuscript because it doesn't add so much information. Moreover, some values may be not significant because of the poor number of data (c.f. notation). It is worth noting that the altitude has an impact on the [surface-6 km] partial columns. The agreement is better for stations in altitude; this is due to the sensitivity of IASI which is maximum in the free troposphere but very low near the surface.

Table 1. Summary of the correlation, the bias and the (1σ) standard deviation (RMS) of the IASI tropospheric ozone column relative to the ground-based data, for each season. The bias and the standard deviation are given in Dobson units.

	Jan-Feb-Mar		Apr-May-Jun		Jul-Aug-Sep		Oct-Nov-Dec	
	Corr coef	Bias (1σ)	Corr coef	Bias (1σ)	Corr coef	Bias (1σ)	Corr coef	Bias (1σ)
Ground-6 km columns								
All latitudes	0.94	0.06 (0.96)	0.97	-0.22 (0.90)	0.95	-0.11 (0.94)	0.84	0.39 (1.03)
High latitudes	0.987[1]	-0.09 (0.77)	0.995[1]	0.01 (0.41)	0.97[1]	0.35 (1.18)	0.527	0.54 (0.80)
Mid latitudes	0.887	0.18 (0.96)	0.906	-0.28 (0.93)	0.918	-0.06 (0.80)	0.922	0.53 (0.78)
Tropics	0.963[1]	-0.82 (0.78)	0.925	-0.18 (1.03)	0.828	-0.65 (1.03)	0.710[1]	-0.32 (1.73)
Stations in altitude	0.966	0.01 (0.80)	0.984	-0.30 (0.68)	0.977	-0.11 (0.70)	0.958	0.68 (0.71)
Stations at sea level	0.792	0.10 (1.07)	0.798	-0.16 (1.04)	0.758	-0.12 (1.16)	0.606	0.21 (1.16)
Ground-12 km columns								
All latitudes	0.629	1.44 (5.57)	0.797	1.76 (4.52)	0.805	2.09 (4.10)	0.677	2.34 (4.45)
High latitudes	0.138[1]	-3.04 (9.95)	0.090[1]	0.69 (6.82)	0.748[1]	4.46 (3.66)	0.312[1]	1.96 (4.41)
Mid latitudes	0.753	2.52 (4.30)	0.794	2.43 (3.95)	0.791	2.51 (3.82)	0.753	3.29 (3.89)
Tropics	0.794[1]	-2.75 (3.81)	0.729	0.21 (3.98)	0.663	-1.22 (3.60)	-0.24[1]	-1.48 (4.95)
Stations in altitude	0.42	0.89 (6.34)	0.735	1.17 (5.03)	0.769	2.16 (4.05)	0.875	3.86 (3.23)
Stations at sea level	0.702	1.84 (4.98)	0.818	2.22 (4.05)	0.824	2.01 (4.18)	0.602	1.36 (4.87)

[1] Number of coincidences lower than 20.

Can some intercomparison of ozone data also be made between IASI and other satellite instruments?

We have already extended the validation of total ozone with total ozone ground-based measurements from the Dobson-Brewer network (c.f. comments from Anonymous Referee #1). A full paragraph (Section 3.1.2) with two figures and two Tables were added in the new manuscript in order to describe the comparison of IASI total ozone with ground-based measurements from the Dobson-Brewer network. The additional section is given at the end of this document. As it is not an exhaustive validation, we think the validation is now significant. Moreover we compared IASI and GOME2 as both instruments are on the same platform.

2. The title of the paper is “Measurement of total and tropospheric ozone from IASI”. In the paper, the troposphere is not explicitly defined. Instead, ozone values from the surface to 6 km or from the surface to 12 km is presented. It should be pointed out that the tropopause is not fixed and ozone from the surface to 12 km may include some stratospheric ozone, especially in high latitudes.

We added in the manuscript (section 3.2) :

"It is worth noting that the tropopause level is not fixed and ozone from the surface to 12 km may include some stratospheric ozone, especially at high latitudes."

3. In Figure 5, the secondary ozone maximum at 11 km seems to be more than the primary ozone maximum higher up! It would be helpful to show a profile in the mixing ratio. This is an interesting case, only I am not totally convinced that the interpretation of this ozone peak is correct. The authors talk about a low pressure system. However, the potential vorticity (PV) would be a more convincing variable to examine for the stratospheric influence.

Fig. 1 represents the ozone vertical profile in mixing ratio units. It confirms the second ozone maximum near 11 km but this maximum is not emphasized, so we decided to keep the profile in density units. We also investigated the potential vorticity (PV) at 380 K for that day and it corroborates our interpretation that there is a stratospheric intrusion in the tropopause region above the Canary Island (see the figure of PV here : http://ether.ipsl.jussieu.fr/ether/pubipsl/mim_img/2008/02/pv08021512_n380.png). Unfortunately the initial data required in order to draw again this plot with another scale and projection are not available. That is why we did not include the PV distribution in the paper. But we added this sentence:

"Potential vorticity, which is a tracer of stratospheric air that is transported into the troposphere was also examinated and it corroborates our interpretation of the stratospheric intrusion."

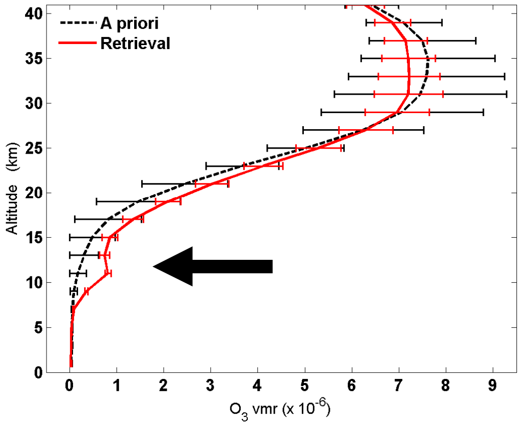

Fig. 1. Retrieved (red) and apriori (black) ozone profile in volume mixing ratio.

Also, it would be good to look at the CO/H2O profile for this case since IASI gives that too.

As suggested, we had a look to the CO/H2O vertical profile for the 15 February 2008 but it gives no additional information as it can be seen in Fig. 2.

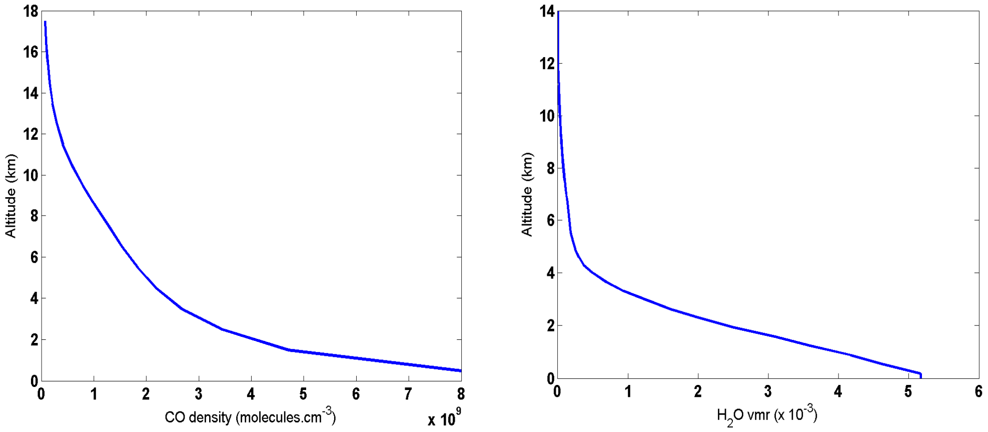

Fig. 2. CO and H2O profile in volume mixing ratio for the 15 February 2008.

A low pressure system implies existence of clouds. How does this condition affect the quality of ozone retrieval?

The ozone retrievals are performed on cloud-free spectra as it is described in detail in Clerbaux et al (2009). Therefore this specific event is cloud free and the quality of the retrieval is not affected.

Specific:
Page 2, Line 27: A reference or references are needed for the accuracy and vertical resolution. Also reference(s) are needed for Page 7, Line 21.

Done for both.

Page 5, Line 18-19: more explanations or some references are needed.

The averaging kernel characteristics are described in Rodgers, (1976, 2000). We added these references.

Page 7, Line 3: Can this internal report be cited as a reference?

Done.

Table 2: Add sample size to each case. More discussion can be given to Table 2. Why does IASI compare poorly with GOME-2 in northern high latitudes during winter?

We think that Table 2 would not be readable if we add sample size to each case. We added sample size to each period on Figure 9 (all merged latitudes). The radiances are a function of the surface temperature but at high latitude, especially in northern high latitude during winter, surface temperature is very low, which implies a very low signal recorded by IASI and therefore a very low signal noise ratio.

Figure 3: Add latitude/longitude to the figure.
Done.

Figure 6a: This figure itself is good. However, an overview on behavior of the averaging kernels globally would be helpful to the reader, such as similar plots by latitude, longitude or by land cover types. The same comment applies to Figure 6b.

We agree with you but we just intended to show an example of IASI averaging kernels and the associated error budget. An overview of the averaging kernels behaviour is out of the scope of this paper. A description of the averaging kernels properties is to be found in Clerbaux et al. (2009).

Figure 11: Add latitude/longitude of the station to the caption.

Done

Technical corrections: Table 1: Pression should be Pressure.
Done.

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Section we added in the new manuscript:

3.1.2 Comparisons with ground-based measurements

The ground-based total ozone data used in this study are from Dobson and Brewer UV spectrophotometer measurements. Total ozone can be derived from direct sun, zenith sky or focused moon observations at different wavelengths. The Dobson instrument, originally developed in the 1920s (Dobson, 1931), uses four wavelengths (two pairs) to determine total ozone quantities. The most commonly used pairs are the AD double pair (305.5/325.5 nm and 317.6/339.8 nm) and the CD pair (311.45/332.4 nm and 317.6/339.8 nm). The Brewer spectrophotometer, available since the early eighties (Brewer, 1973) relies on the same principle as the Dobson instrument, however, the instrument uses several wavelength pairs from five wavelengths between 306.3 and 320.1 nm to derive total ozone. Both Dobson and Brewer instruments present similar performances (Kerr et al., 1988). Dobson and Brewer total ozone measurements have already been used for the validation of satellite derived total ozone measurements (Balis et al., 2007; Weber et al., 2005).

For the comparisons with IASI total ozone columns, we used all the Dobson and Brewer data derived from direct sun and zenith sky observations available for 2008 from the WOUDC archives. The data format currently used consists of daily total ozone values expressed in Dobson units. We set the coincidence criteria to 0.5° radius from the ground-based station, and to the same day of observation. IASI measurements collocated to ground-based measurements were then averaged. 39 Brewer and 50 Dobson stations were considered for the comparison. The stations are summarized in Table 3 and 4.

Fig. 10 shows the collocated total ozone distributions averaged over 5° latitude bands for the year 2008. A positive bias between the two distributions is apparent, with larger differences at low and mid-latitudes, in particular in the southern hemisphere. The variability associated with IASI total ozone columns is somewhat larger than that of the ground-based measurements, except at high latitudes where the latter increases.

A statistical comparison of the columns is represented for the year 2008 in Fig. 11. The correlation, bias, standard deviation and number of collocated observations are also indicated. Globally and on average over the year, the agreement between the two distributions is good with a correlation of 0.85, a bias value of about 9.3 DU (~3%) and an RMS error of 27 DU (9.8%).

These values are consistent with those found for the comparison with GOME-2 measurements. As mentioned in the previous section (3.1.1), the bias observed are partly attributed to the different observation methods used.

Table 3. List of Brewer stations used for the ozone validation.

WMO station number	Station name (country)	Latitude, °N	Longitude, °E	Height, m
262	Sodankyla (Finland)	67.34	26.51	179
284	Vindeln (Switzerland)	64.24	19.77	225
165	Oslo (Norway)	59.91	10.72	90
279	Norrkoeping (Switzerland)	58.58	16.15	43
352	Manchester (Great Britain)	53.48	-2.23	76
174	Lindenberg (Germany)	52.21	14.12	112
316	De bilt (Netherlands)	52.10	5.18	9.5
318	Valentia observatory (Irland)	51.93	-10.25	14
353	Reading (Great Britain)	51.45	-0.93	66
53	Uccle (Belgium)	50.80	4.35	100
96	Hradec kralove (Czech Republic)	50.18	15.83	285
331	Poprad-ganovce (Slovakia)	49.03	20.32	706
99	Hohenpeissenberg (Germany)	47.80	11.02	975
100	Budapest-lorinc (Hungary)	47.43	19.18	139
35	Arosa (Switzerland)	46.78	9.68	1840
326	Longfengshan (China)	44.73	127.60	317
405	La coruða (Spain)	43.33	-8.47	62
411	Zaragoza (Spain)	41.63	-0.91	250
308	Madrid / barajas (Spain)	40.46	-3.65	650
348	Ankara (Turkey)	39.95	32.88	896
447	Goddard (USA)	38.99	-76.83	100
346	Murcia (Spain)	38.00	-1.17	69
213	El arenosillo (Spain)	37.10	-6.73	41
295	Mt. waliguan (China)	36.29	100.90	3810
332	Pohang (Korea)	36.03	129.38	6
336	Isfahan (Iran)	32.48	51.43	1550
376	Mrsa matrouh (Egypt)	31.33	27.22	35
349	Lhasa (China)	29.67	91.13	3640
10	New delhi (India)	28.49	77.16	247.5
95	Taipei (Taiwan)	25.02	121.48	25
30	Minamitorishima (Japan))	24.30	153.97	9
468	Cape d'aguilar (HongKong)	22.21	114.26	60
187	Poona (India)	18.53	73.85	559
322	Petaling jaya	3.10	101.65	61
475	Bandung (India)	-6.90	107.58	731
473	Punta arenas (Chile)	-53.14	-70.88	3
351	King george island (Uruguay)	-62.18	-58.90	10
454	San martin (Argentina)	-68.13	-67.10	30
314	Belgrano ii (Argentina)	-77.87	-34.63	255

Table 4. List of Dobson stations used for the ozone validation.

WMO station number	Station name (country)	Latitude, °N	Longitude, °E	Height, m
105	Fairbanks (college) (USA)	64,817	-147,867	138
43	Lerwick (Great Britain)	60,1315	-1,183	80
53	Uccle (Belgium)	50,8	4,35	100
96	Hradec kralove (Czech Republic)	50,183	15,833	285
99	Hohenpeissenberg (Germany)	47,8	11,02	975
20	Caribou (USA)	46,867	-68,03	192
35	Arosa (Switzerland)	46,78	9,68	1840
19	Bismarck (USA)	46,767	-100,75	511
40	Haute provence (France)	43,933	5,7	674
474	Lannemezan (France)	43,13	0,367	597
12	Sapporo (Japan)	43,06	141,3315	19
410	Amberd (Armenia)	40,38	44,25	2070
67	Boulder (USA)	40,085	-105,25	1689
208	Xianghe (China)	39,975	116,37	80
293	Athens (Greece)	37,98	23,748	195
107	Wallops island (USA)	37,898	-75,483	13
252	Seoul (Korea)	37,567	126,95	84
213	El arenosillo (Spain)	37,1	-6,733	41
341	Hanford (USA)	36,317	-119,633	73
106	Nashville (USA)	36,25	-86,567	182
14	Tateno / tsukuba (Japan)	36,06	140,1	31
464	University of tehran (Iran)	35,73	51,38	1419
152	Cairo (Egypt)	30,08	31,283	37
10	New delhi (India)	28,49	77,16	247,5
409	Hurghada (Egypt)	27,28	33,75	7
190	Naha (Japan)	26,2	127,683	27
74	Varanasi (India)	25,317	83,03	76
209	Kunming (China)	25,03	102,683	1917
245	Aswan (Egypt)	23,967	32,78	193
2	Tamanrasset (Algeria)	22,8	5,517	1377
31	Mauna loa (USA)	19,533	-155,574	3405
218	Manila (Phillipin)	14,633	121,433	61
216	Bangkok (Siam)	13,667	100,612	53
317	Lagos (Nigeria)	6,6	3,333	10
214	Singapore (Singapore)	1,333	103,883	14
84	Darwin (Australia)	-12,417	130,883	31
191	Samoa (USA)	-14,25	-170,56	82
27	Brisbane (Australia)	-27,417	153,117	3
343	Salto (Uruguay)	-31,395	-57,97	31
159	Perth (Australia)	-31,917	115,95	2
91	Buenos aires (Argentina)	-34,583	-58,483	25
253	Melbourne (Australia)	-37,7375	144,9045	128,5
256	Lauder (New Zealand)	-45,03	169,683	370
342	Comodoro rivadavia (Argentina)	-45,783	-67,5	43
29	Macquarie island (Australia)	-54,5	158,967	6
339	Ushuaia (Argentina)	-54,85	-68,308	15
233	Marambio (Argentina)	-64,233	-56,623	196
101	Syowa (Japan)	-69	39,58	21
268	Mcmurdo (Argentina)	-77,83	166,655	215
111	Amundsen-scott (Argentina)	-89,983	0	2820

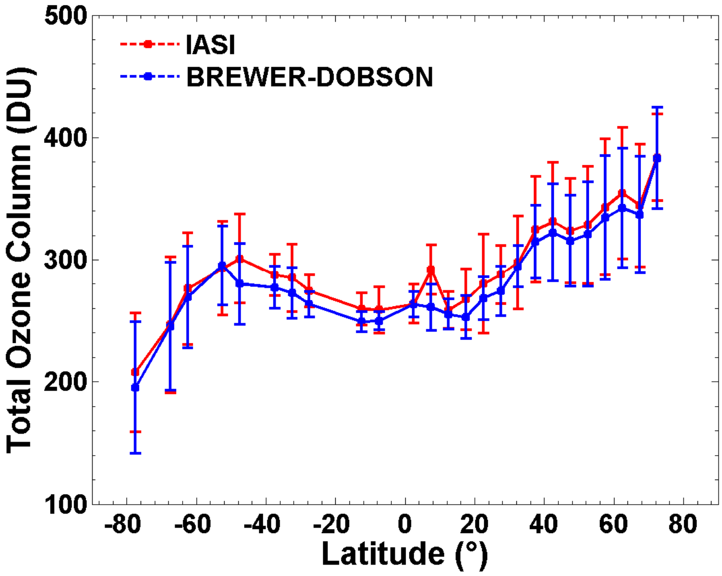

Figure 10

Total ozone columns derived from collocated IASI and ground-based ozone measurements with associated standard deviations, zonally averaged for 2008.

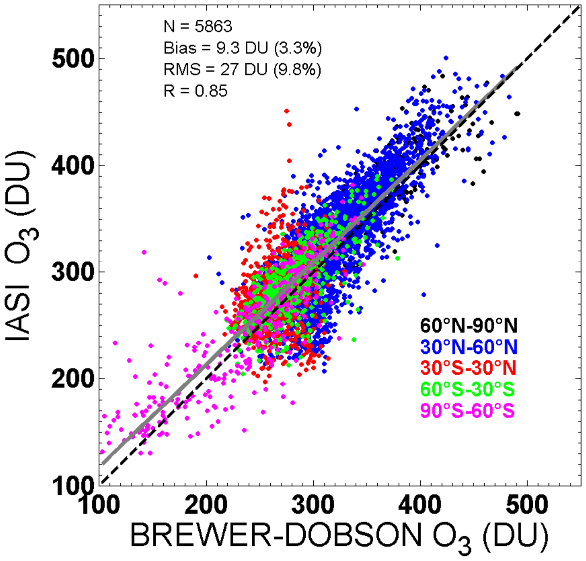

Figure 11

Scatter plots of the IASI and ground-based total ozone columns for 2008. The correlation, bias, standard deviation and number of collocated observations are also indicated on the top of the figure. The shaded line represents the linear regressions between all data points and the black line, of unity slope, is shown for reference. The bias (in relative value) is calculated according to: $100*(IASI-SONDE)/SONDE$.

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