

Reply to Referee 2 (in blue)

This study presents results from Atmospheric Sounding Interferometer (IASI) on-board MetOp-A satellite. This is an interesting study highlighting the capability of infra-red instrument to provide ozone distribution during polar night. Overall scientific results are well presented and I think the paper should be published in IMT with some minor corrections.

We thank Dr S. Dhomse for his careful reading of the manuscript. We took all the comments provided hereafter into account and tried to improve the text accordingly.

My major concern is that authors use only GOME-2 data to validate their total ozone product. What about ground based stations (Brewer/Dobson spectrometers)? So that reader will get overall review.

For other areas of the globe we did some extended comparison of IASI with Brewer-Dobson spectrometers, as reported in Boynard et al. (2009) and Anton et al. (2011). The problem that we faced in this study was the lack of co-located ozone sondes and satellite measurements for the period of time we were looking at.

Boynard A., C. Clerbaux, P.-F. Coheur, D. Hurtmans, S. Turquety, M. George, J. Hadji-Lazaro, C. Keim, and J. Mayer-Arnek, Measurements of total and tropospheric ozone from the IASI instrument: comparison with satellite and ozonesonde observations, *Atmos. Chem. Phys.*, 9, 6255-6271, 2009.

Antón, M., D. Loyola, C. Clerbaux, M. López, J. M. Vilaplana, M. Bañón, J. Hadji-Lazaro, P. Valks, N. Hao, W. Zimmer, P. F. Coheur, D. Hurtmans, and L. Alados-Arboledas, Validation of the Metop-A total ozone data from GOME-2 and IASI using reference ground-based measurements at the Iberian Peninsula, *Remote Sensing of Environment*, 115, 1380-1386, 2011.

I think authors are also confused with the definition of the ozone hole, polar vortex, and edge of the polar vortex. Terms like polar vortex, edge of the polar vortex and outside the vortex are used to define dynamical boundaries whereas ozone hole, outside the ozone hole are used to define chemical boundaries.

We checked the manuscript and tried to use the proper terms as recommended. We indeed realized that the term polar vortex was sometimes used instead of ozone hole.

Another important issue is the scientific writing. As a non-native English speaker, I can understand the difficulties in writing, however senior co-authors should help to improve the manuscript.

Claire Scannell is a native English speaker and she wrote most of the manuscript. We did changes according to the suggestions when we felt it was relevant.

Minor comments.

1. Title:- I think it can be reworded as “Antarctic ozone hole as observed by Atmospheric Sounding Interferometer (IASI) for 2008-2010.”

The former title was replaced by “Antarctic ozone hole as observed by IASI/MetOp for 2008-2010”

2. Affiliation for 4, typo “Royal”

Corrected

3. Page 4718 - Abstract should be abstract, so remove first couple of sentences.

The abstract has been shortened as recommended.

4. line 14-15- Ozone hole region and period? Confusing. remove “for the ozone hole region and period”

This part of the sentence was removed, as recommended

5. line 15- “Total ozone column from IASI and GOME-2. . .”

Changed as suggested

6.line 17 – “ On average IASI. . .”

Done

7.line 21- I think you meant to say “ The vertical structure of the ozone profile during ozone hole”

The sentence has been corrected

8.Page 4719- line 10, use either noticeable or severe. other IR instruments.

Ok, done

9.line 10-14- very long and inconsistent sentence . Reword it...

Done. These two sentences now read: Since the mid 1980s a noticeable depletion of stratospheric ozone has been observed annually over the Antarctic region during the polar springtime (August, September, October and November). Annual ozone concentrations of less than 100 DU (Dobson Units) have been recorded during this time, while the average stratospheric ozone concentration outside of the ozone hole period is greater than 300 DU. line 21-23 :- There is difference between NO_x, HO_x and halogen related ozone destruction. Inside the polar vortex ozone loss due Chlorine activation only because there is less NO_x or HO_x. So you can reword it as “It is thought that inside the polar vortex approximately 60 %”

The sentence has been rephrased as suggested.

10.line 23- also add “(Feng et al, 2011)”

Done

11.line 25- polar vortex forms over Antarctic or in the Antarctic stratosphere.

Corrected (“over” instead of “in”)

12.line 27- “when the temperatures reach below 195 K and 188 K”. If possible also discuss the effects of the PSCs on IASI retrieval.

The sentence was changed to: “When the temperatures below 195 K and 188 K are reached, type 1 and type 2 polar stratospheric clouds (PSCs) can form”.

PSC do not impact on IASI retrieval of ozone. PSCs can be measured in the thermal infrared spectral range by limb looking remote sensors (eg the Canadian ACE-FTS instrument) owing to their good sensitivity for a range of altitudes. Clouds and aerosols affect the IASI spectra as they absorb as broad band features, but we failed in observing the PSC signatures probably because they are partly transparent and/or localized in a very thin layer.

13.Page 4720 –line 13, In general observations provide very good constraints in understanding our understanding about various chemical and dynamical process on ozone. Satellite data is widely used to validate Chemical transport Models (CTMs) as well as Chemistry Climate Models (CCMs), which are used to predict future ozone changes (See chapter 6 from SPARC 2010 and for Antarctic ozone changes see Austin et al 2010).

The new manuscript includes these sentences and both references were added.

14.line 15 – Please reword it as ozone measurements started well before discovery of the ozone hole.

The sentences have been modified to “Since the discovery of the ozone hole in the 1980's the monitoring of long-term change and variability in ozone levels in the Antarctic have been intensified and recorded from several (Fortuin and Kelder, 1998; Balis et al., 2003).

Measurements provided by ground based monitoring stations are however...”

15.TOMS is no longer operational. So why not SCIAMACHY (Bovensmann et al. 1999)

Changes were done as suggested

16.Page 4721 – line 1, what about other IR instruments POAM,HIRDLES

The sentence was modified to specify “nadir looking TIR instruments”

17.line 6 – remove “ with a small footprint” – high spatial resolution is self explanatory

OK

18.line 10- remove “then”

Done

19.line 17- plaX2?

Part of the sentence was indeed missing (was lost in the ACPD editing step...). It is now corrected to “orbiting MetOp-A satellite platform on the 19th October 2006. The IASI field of view is composed of 2x2 circular pixels »

20. page 4722, line 6, Remove the brackets from the reference. It should be either cite or citealt .

Done, thanks for noting this

21. line 7-8, remove .., “which are observation”

We think that this sentence is important as the algorithm is driven by the fact that it has to process the data in near real time, a huge constrain in the implementation of the retrieval system.

22. line 15- “is needed”. Remove “needs to be applied”.

Corrected

23. I think you need not to define residual.

The new sentence is now: “The grey line shows the difference between the observed and fitted spectrum.”

24. line 30- why do you need fast delivery? For long term ozone monitoring we accurate retrieval.

Fast delivery is not necessary for this work. But IASI being onboard a meteorological platform it is also used to provide meteorological (ozone used as a dynamic tracer) and chemistry (ozone pollution) forecasts. The retrievals are accurate (as accurate as possible). The speed is gained by optimizing the algorithm (using pre-calculated tables) and by running it on parallel processors, not by simplifying the radiative transfer scheme to gain speed.

25. Page 4723- line 2- again remove the brackets for the reference.

Corrected

26. line 5- “were considered”

Done

27. Page 7-11- very long sentence. Divide it.

Changed to: “While IASI provides a good global overview of the distributions and concentrations of ozone, the issues discussed above made it difficult to focus on particular locations such as the Antarctic. This is an area where not only were there large gaps between each overpass but also data gaps at the poles.”

28. Page 11- Boynard et al (2009), found that

Changed as suggested.

29. line 14- They also found that

OK

30. line 16- To allow (remove “ In order”)

Done

31. line 18- remove “continuously”

See our reply to comment 24: This is a big strength of the algorithm that the data can be processed continuously. There are so much IASI data that the continuous processing is really needed.

32. line 23- delete “when usign the FORLI-O3 scheme.

Done.

33. Page 4724-line 8 – confusing. “which is used (Wan, 2008).

Both are used. The sentence was modified to “The Level 2 temperature data distributed by the Eumetcast system are used as input data for the code as well as surface emissivity from the MODIS/TERRA and IASI climatology (Wan, 2008)”.

34. line 27- Infra-red.

Changed to infrared to be consistent with the rest of the text

35. Page 4725- line 4- it should ozone sondes.

Corrected

36. line 21-25- ozone plots or maps plots.. Confusing. why not total ozone values

Changed into “both measurements are located in map plots provided in Fig. 4,”

37. line 25-26- reword. Largest and greatest are confusing words.

The new sentence is “This period marks the time when the ozone hole area and amplitude are the more important. ”

38. Page 4726- line 16-20, confusing.. Austin et. al 2010 should be better reference.

The sentence has been clarified and now reads: “In the last few years this expansion and ozone loss rates have appeared to level off (Newman et al., 2009; Austin et al., 2010).” The Austin reference was also added.

39. Page 4727- line 8-9- ozone hole period is repeated. It is already mentioned in earlier sentence.

Sentence edited.

40. line 16- replace below with “south of”

Done.

41. line 19- replace how with “that”

Done

42. line 21- “ depletion of polar stratospheric clouds?” not correct and 43. line 20-21 – expand the discussion about meteorology or (dynamical) during this period . This is caused by enhanced planetary wave activity during this period. For Antarctic year 2002 see Weber et al, 2003, von Savigny et al. 2005. Enhanced wave activity leads to increase in ozone transport from tropics to mid-high latitudes.

The first sentence was removed and the we added the following one to the new text:” This was caused by enhanced planetary wave activity during this period leading to the increase in ozone transport from the tropics to mid to high latitudes (Weber et al., 2003; von Savigny et al., 2005). ”

44. line 28- “this is mainly due to”

Changed

45. Page 4728, line 8, add comma after studied.

Comma added

46. Page 4729, line 16- I think you meant “edge of the polar vortex”

Yes, corrected

47. Page 4730, page 4- which previous studies?

Reference to Schneider et al., 2008, M. Anton, 2011 moved right after “Previous studies”

48. line 5- and may (spacing)

Done, thanks for noticing this

49. Page 4731- line 11 – long-form first and then short form in bracket (WOUC).

OK, done

50. page 4732- line 13, remove space after kernels,

Done

51. line 27- profiles measured

Space added

52. Page 4733, line 2- IASI slightly overestimates

Changed as suggested

53. page 4734- line 3, “this is in line with”

Changed as suggested

54. Page 4735- line 21, Sweden

Corrected

55. Page 4739 WMO report references, be consistent.

It is consistent now

56. Page 4740- Figure 1, Improve the quality of the figure, Also give the title.

The quality of the plot was improved

57. Caption, remove intense.

Done. The new caption now reads: “Ozone absorption band region (1025cm⁻¹ – 1075cm⁻¹) of a typical IASI spectrum (observed and calculated using a radiative transfer code). The grey line in the bottom panel represents the residual of the fit which is comparable to the IASI instrument noise level (dashed line).”

58. Page 4741, Figure 2, color bar. replace 04-06 September 2009 to total ozone (DU)

Done

59. Page 4742, Figure 3, Also add the date.

Done, the date is now on the plot.

60. Page 4743, Figure 4, Better label the figures as A, B and C. Remove “ as shown in this figure” from the caption.

The labels have been improved and the caption now reads:

“Averaging kernel functions for different altitudes in partial columns characterizing the retrievals (shown in Fig. 3) over the land (A) and over the ocean (B), respectively. It highlights the difficulties in retrieving ozone over the Antarctic region. Figure 4 (C) provides the Antarctic projection of the IASI DOFs distribution”.

61. Page 4744, Figure 5, move Weekly Ozone Distributions on the top. In caption “retrieved using the FORLI-O3. . .”

Done

62. Figure 6- Give title at the top of the Figure. And I don't understand why it is necessary to plot all the versions. Why not only Version 3 and 4.

Title moved. About the different versions: Ozone is processed in near real time, and the retrieval is quite consuming in terms of computing power. So each time a new version of the algorithm is implemented simultaneously to the near-real time processing, a back-processing also starts on the “oldest” (in terms of algorithm) data... until an improved version appears again. At the time of this study a consistent (=processed with the same version of the algo) dataset was not available (and it is still not available). We checked that the changes were minor and did not impact our findings (a sentence was added in the text to clarify this).

63. Figure 7- Again move the titles on the top of the Figure.

Done

64. Figure 8. Add the title on the top

Done

65. Figure 9. Captions should be used to write description of the Figure. Authors have tendency to write discussion part in the caption. Please remove the last sentence from the caption.

Sentence removed as recommended

66. Figure 11, what is in the associated polar vortex?

This sentence was removed

67. Figure 12, how many IASI profiles are used? Please add.

The sentence was changed into “The IASI profile is an averaged profile of between 5 and 10 profiles (depending on the location),”

68. Figure 13. What is ozone hole vortex? Where is other panel?

Corrected. The caption begins now with : “Comparison between IASI and ozone sonde profiles measured at the Davis and USH stations”

References

Austin et al, 2010, J. Geophys. Res., 115, pp.D00M11. doi:10.1029/2009JD013577

Weber et al. 2003, Geophysical Research Letters, 30, pp.1583.

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Bovensmann et al 1999, J. Atmos. Sci., 56, 127–150.

Feng et al, 2011, ATMOS CHEM PHYS, 11, pp.6559-6573. doi:10.5194/acp-11-6559-2011

von Savigny et al 2005: J. Atmos. Sci., 62, 721–734. doi: 10.1175/JAS-3328.1

All added