Atmos. Meas. Tech. Discuss., 7, C4782–C4792, 2015
www.atmos-meas-tech-discuss.net/7/C4782/2015/

Atmospheric Measurement Techniques Discussions

AMTD

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Interactive Comment

Interactive comment on "Atomic oxygen retrievals in the MLT region from SCIAMACHY nightglow limb measurements" *by* O. Lednyts'kyy et al.

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Received and published: 30 January 2015

Anonymous Referee #2 (received and published: 27 November 2014):
In this paper the authors present a new global dataset of vertical profiles of atomic oxygen in the mesosphere and lower thermosphere based on retrievals from SCIAMACHY/Envisat limb observations of the OI 557.7 nm green line nightglow emission. Since atomic oxygen is the major carrier of chemical energy in this part of the atmosphere and a key component for the aeronomy in this region, this new dataset will be valuable to the scientific community.
The manuscript is well written and to a large part easy to read. The retrieval method, error analysis and verification of the retrieved profiles are described in detail and first results are presented.

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Interactive Discussion

Discussion Paper

I have only a few minor comments and suggestions to be addressed before the manuscript can be published.
Dear Referee, first of all thank you for very interesting and helpful comments. Our final responses and changes to the manuscript (in normal font) follow each comment (in bold font).

Page 10831:
Line 14 - $O(^1S_0)$ should be $O(^1S-^1D)$.
Changes in manuscript: "$O(^1S_0)$" has been changed to "$O(^1S-^1D)$"

Line 27 - Scanning.
Last sentence - sounds strange, maybe: "The SCanning Imaging... (SCIAMACHY) on board Envisat observe the atmosphere in a dedicated mesosphere/thermosphere limb mode that enables vertically resolved measurements of the nightglow green line emission to be made."
Changes in manuscript: "The Scanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) examining the atmosphere in a dedicated limb mesosphere/thermosphere mode enables vertically resolved measurements of the nightglow green line emission." has been changed to "The SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) on board Envisat observed the atmosphere in a dedicated mesosphere/thermosphere limb mode that enabled vertically resolved measurements of the nightglow green line emission to be made."

Page 10832:
Line 5 - $O(^1S_0)$ should be $O(^1S-^1D)$.
Changes in manuscript: "$O(^1S_0)$" has been changed to "$O(^1S-^1D)$"

Line 16 - (Liu et al., 2010) ...as in the list of references.
Changes in manuscript: "(Liu et al., 2007)" has been changed to "(Liu et al., 2010)"

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Page 10833:

Line 6 - ...Imager System (OSIRIS)... (not Imaging).
Changes in manuscript: "Imaging" has been changed to "Imager"

Line 7 - It would have been interesting to also see a comparison with the OSIRIS and ISUAL [O] data, which I'm sure could be easily accessed from the respective research groups.
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1. We are indebted to the OSIRIS team and particularly to Patrick Sheese, University of Toronto, Canada, for making OSIRIS data available to us. We are going to analyze the retrieved SCIAMACHY [O] in comparison with the 22:00 LT data of OSIRIS [O], ISUAL [O], and the WINDII [O] in a future publication.

Line 10 - $O(^1S_0)$ should be $O(^1S-^1D)$.
Changes in manuscript: "$O(^1S_0)$" has been changed to "$O(^1S-^1D)$"

Line 18 - SCIAMACHY is already defined on page 10831, no need to do it again.
Changes in manuscript: "the Scanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY)" has been changed to "SCIAMACHY"

Line 19 - I assume it is the atmospheric radiation field in the Earth's limb that is observed.
Changes in manuscript: "radiation field" has been changed to "atmospheric radiation field"

Page 10834:

Line 20 - Maybe add a reference to the SABER instrument here, why not the

paper by Russell et al., 1999 that already is in the list of references.
Changes in manuscript: “radiometer on board” has been changed to “radiometer (Mlynczak, 1997, Russell et al., 1999) on board”
Mlynczak, 1997:
Mlynczak, M. G., Energetics of the mesosphere and lower thermosphere and the SABER experiment, Adv. in Space Res., 20, 1177–1183, doi:10.1016/S0273-1177(97)00769-2, 1997.

Line 22 - sounds better to write e.g. “...and NASA provides the data online...”
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Changes in manuscript: “provides data via the Internet” has been changed to “provides the data online via their website”

Page 10835:
Line 5 - Is it a really a valid assumption to say that the mixing ratios of O_2 and N_2 are constant also above 95-100 km? Or would it be better to use the mixing ratios from e.g. NRLMSISE-00?
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1. The SD-WACCM4 data that we had in our disposition did not let us determine if the mixing ratios at 105 km are constant or not. NRLMSISE-00 data show a steadily falling $[O_2]/[N_2]$ ratio by 9% in the altitude range 100–105 km that (presumably) is exaggerated. Picone et al. (2002) suggest that entirely empirical MSIS-class models await the addition of credible mesospheric $[O_2]$ data to the NRLMSISE-00 database.
In the presented O retrieval we supposed that a constant mixing ratio is valid at 105 km, which is also assumed in the SABER O retrieval (Smith et al., 2010). Smith et al. (2010) suggest a small decrease in O_2 mixing ratio that causes slight underestimation of O. We also expect slight underestimation of O.

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To estimate errors introduced by the constant mixing ratio assumption we used the a priori information of varying mixing ratio obtained from NRLMSISE-00 in our O retrieval with SABER density/temperature profiles. The relative differences of [O] without the mixing ratio correction vs. [O] with such a correction is less than 4% in the altitude range 100–105 km.
Smith et al. (2010):
Smith, A. K., Marsh, D. R., Mlynczak, M. G., Mast, J. C.: Temporal variations of atomic oxygen in the upper mesosphere from SABER, J. Geophys. Res., 115, D18309, doi: 10.1029/2009JD013434, 2010.
Changes in manuscript: “The concentrations of [O_2] and [N_2] were calculated from atmospheric density profiles assuming constant mixing ratios. The atomic oxygen mixing ratio” has been changed to “The concentrations of molecular oxygen ([O_2]) and molecular nitrogen ([N_2]) were calculated from atmospheric density profiles assuming constant mixing ratios. The decrease of the [O_2]/[N_2] ratio with altitude according to NRLMSISE-00 data is not reliable as pointed out by Picone et al. (2002), because credible mesospheric [O_2] data are absent in the NRLMSISE-00 database. If the mixing ratio correction based on NRLMSISE-00 [O_2] and [N_2] profiles were applied in the O retrieval, [O] values would fall by 4% in the altitude range 100–105 km. In the presented O retrieval we supposed that a constant mixing ratio is valid at altitudes up to 105 km, which is also assumed in the SABER O retrieval (Smith et al., 2010). The atomic oxygen mixing ratio”

Line 15 - ...provided by the National...
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Changes in manuscript: “by National” has been changed to “by the National”

Line 17 - ...provided online...
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.

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Changes in manuscript: “provided via the Internet” has been changed to “provided online”

Page 10836:
Line 4 - Same as page 10835 line 5... is it really a valid assumption that the O_2 and N_2 mixing ratios are constant?
Response: Our response is the same as to the page 10835, line 5.

Line 18 - It is not only the SAA data that is green in Figure 2, the text should be updated here (the figure caption is good).
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Changes in manuscript: “The measurements within the South Atlantic Anomaly (SAA) are shown in green in Fig. 2.” has been changed to “For the retrieval we used the limb measurements marked in blue in Fig. 2, but not the measurements that are affected by Aurora Borealis, highly energetic particles or by contaminating emissions, shown in green.”

Page 10837:
Line 7 - The SAA is already defined, no need to do it here again.
Response: Done, see our response to the text on page 10836, line 18.

Line 16 - ...auroral events...
Changes in manuscript: “aurora events” has been changed to “auroral events”

Line 17 and afterwards- ...auroral oval...
Changes in manuscript: “aurora oval” has been changed to “auroral oval”

Page 10838:
Line 9-10 and afterwards - the acronym LER is already defined, no need to do it

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again.
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Done. LER is now only defined once.

Line 16 and afterwards - the acronym VER is already defined...
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Done. VER is now only defined once.

Page 10845:
Line 19 - ^{1}S-^{1}D should be $\mathrm{O}(^1\mathrm{S}-^1\mathrm{D})$.
Changes in manuscript: "^{1}S–^{1}D" has been changed to "$\mathrm{O}(^1\mathrm{S}-^1\mathrm{D})$"

Page 10847:
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Line 20 - I would write "unperturbed" instead of "error-free".
Changes in manuscript: "error-free" has been changed to "unperturbed"

Page 10851:
Line 24 - Figure 9 show data above 85 km altitude, so you must mean the altitude range from 85 to 87 km.
Response: We provide a cumulative response to the text on pages 10851–10853 below.

Page 10852:
Section 7.2-7.3 - Please specify what is meant by "much higher", "a bit higher", "quite similar", "significantly higher", "even bigger"... it would be good to be more quantitative.

Page 10853:
Line 13 - How good is "very good"?
Response: Our cumulative response to the text on pages 10851–10853 considers the interactive comments of the Anonymous Referee #1 and the Anonymous Referee #2.
Changes in manuscript for Sections 7.2 and 7.3:
"7.2 Verification step 1
Figure 9 shows atomic oxygen concentration ($[\mathrm{O}^{\mathrm{quench}}_{\mathrm{SABER}}]$) profiles and reference [O] profiles provided by SABER, NRLMSISE-00 and SD-WACCM4 in the altitude range 85–105 km in the latitude bin 20–25° N for a sample day (9th September 2010) and month (September 2010). The altitude dependence of $[\mathrm{O}^{\mathrm{quench}}_{\mathrm{SABER}}]$ in comparison with $[\mathrm{O}^{\mathrm{SABER}}]$, $[\mathrm{O}^{\mathrm{MSIS00}}]$ and $[\mathrm{O}^{\mathrm{WACCM4}}]$ exhibits some deviations in the altitude range 85–87 km. These deviations correspond to low values of the measurement response (see Fig. 5) in the altitude range 82–87 km. The comparisons shown in Fig. 9 allow to make the preliminary conclusion that SABER as the source of temperature and density profiles (which we need to retrieve [O] profiles from SCIAMACHY VER profiles) seems to be preferable.
Figure 9 allows the conclusion to be drawn that the reference $[\mathrm{O}^{\mathrm{MSIS00}}]$ profiles are characterized by lower concentrations in comparison with the retrieved $[\mathrm{O}^{\mathrm{quench}}_{\mathrm{SABER}}]$ profiles. We use the absolute of the mean relative difference ($<|\epsilon|>$) determined according to the equation $<|\epsilon|>=<|([\mathrm{O}^{\mathrm{current}}]-[\mathrm{O}^{\mathrm{reference}}])/[\mathrm{O}^{\mathrm{reference}}]|>$ averaged over the altitude range 90–100 km to quantify differences between different [O] profiles. For $[\mathrm{O}^{\mathrm{MSIS00}}]$ ($[\mathrm{O}^{\mathrm{current}}]$) in comparison with $[\mathrm{O}^{\mathrm{quench}}_{\mathrm{SABER}}]$ ($[\mathrm{O}^{\mathrm{reference}}]$) we obtain $<|\epsilon|>\approx 0.6$ on the daily timescale and ≈ 0.54 on the monthly timescale. For $[\mathrm{O}^{\mathrm{WACCM4}}]$ in comparison with $[\mathrm{O}^{\mathrm{quench}}_{\mathrm{SABER}}]$ we obtain $<|\epsilon|>\approx 0.27$ on the daily timescale and ≈ 0.24 on the monthly timescale. For $[\mathrm{O}^{\mathrm{SABER}}]$ in comparison with $[\mathrm{O}^{\mathrm{quench}}_{\mathrm{SABER}}]$ we obtain $<|\epsilon|>\approx 0.13$ on the daily timescale and ≈ 0.14 on the monthly timescale.
Figures 10 and 11 (with data corresponding to the same altitude, latitude and time ranges as in Fig. 9) present [O] profiles retrieved from SCIAMACHY VER profiles according to the cubic ($[\mathrm{O}^{\mathrm{cubic}}]$) and extended cubic ($[\mathrm{O}^{\mathrm{quench}}]$) approaches (see Eq. 15), and show that $[\mathrm{O}^{\mathrm{quench}}]$ concentrations are higher than the $[\mathrm{O}^{\mathrm{cubic}}]$ concentrations.

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$< |\epsilon| >$ for [O^{cubic}_{WACCM4}] in comparison with [O^{cubic}_{SABER}] is about 0.02 on the daily and monthly timescale. $< |\epsilon| >$ for [O^{cubic}_{MSIS00}] in comparison with [O^{cubic}_{SABER}] is about 0.05 on the daily timescale and 0.06 on the monthly timescale. $< |\epsilon| >$ for [O^{quench}_{WACCM4}] in comparison with [O^{quench}_{SABER}] is about 0.05 on the daily timescale and 0.02 on the monthly timescale. $< |\epsilon| >$ for [O^{quench}_{MSIS00}] in comparison with [O^{quench}_{SABER}] is about 0.13 on the daily timescale and 0.11 on the monthly timescale. This leads to the preliminary conclusion that NRLMSISE-00 does not seem to be a reliable source of temperature and density profiles. A comparison between Figs. 9, 10 and 11 indicates that [O^{quench}_{SABER}] profiles are (by sight) in better agreement with [O^{SABER}] profiles than [O^{cubic}] profiles are. This implies that the extended cubic equation seems to be preferable for the retrieval of [O] profiles.

7.3 Verification step 2

Relative differences (ϵ) between different [O] profiles were calculated according to the equation $\epsilon = ([O^{current}] - [O^{reference}])/[O^{reference}]$. Figure 12 presents sample distributions of relative [O] differences as a function of latitude and altitude in the time period from April 2010 to March 2011 which corresponds to SD-WACCM4 data that we had in our disposition.

Provided that $< |\epsilon| >$ in the following text is averaged over altitude range 86–100 km, over the latitude range 50° S–70° N and over the time period from April 2010 to March 2011, we find that $< |\epsilon| >$ for [O^{cubic}_{MSIS00}] ([$O^{current}$]) in comparison with [O^{MSIS00}] ([$O^{reference}$]) is about 0.81 on the monthly timescale. The mean absolute relative difference between [O^{quench}_{MSIS00}] and [O^{MSIS00}] (not shown in Fig. 12) of $< |\epsilon| > \approx 1.74$ is at least twice as big as the value for [O^{cubic}_{MSIS00}] vs. [O^{MSIS00}]. The mean absolute relative difference between [O^{quench}_{WACCM4}] and [O^{WACCM4}] (not shown in Fig. 12) is ≈ 0.65. $< |\epsilon| >$ for [O^{cubic}_{WACCM4}] in comparison with [O^{WACCM4}] is about 0.24 and exhibits the same anomaly cluster with high negative $< |\epsilon| >$ of unknown origin in the subtropical region as for [O^{quench}_{WACCM4}] vs. [O^{WACCM4}]. For [O^{quench}_{SABER}] in comparison with [O^{SABER}] we obtain $< |\epsilon| > \approx 0.19$, which is smaller than $< |\epsilon| >$ for [O^{cubic}_{SABER}] vs. [O^{SABER}] of about 0.28."

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Page 10855:
Line 26 - What earlier studies?
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Changes in manuscript: "earlier studies, and" has been changed to "earlier studies (e.g., Liu and Shepherd, 2008; von Savigny and Lednyts'kyy, 2013), and"
Liu and Shepherd (2008):
Liu, G. and Shepherd G. G.: An investigation of the solar cycle impact on the lower thermosphere $O(^1S_0)$ nightglow emission as observed by WINDII/UARS, Adv. Space Res., 42, 933–938, doi:10.1016/j.asr.2007.10.008, 2008.

Page 10856:
Line 18 - A "4" is missing (SD-WCCAM4).
Changes in manuscript on page 10856 line 18, page 10854 line 3, page 10855 line 10: "SD-WACCM" has been changed to "SD-WACCM4"

Table 1 caption: **last line - remove "in".**
Changes in manuscript: "further in details" has been changed to "further details"

Figure 2 caption: **add "to" between related and contaminating**
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Changes in manuscript: "related contaminating" has been changed to "related to contaminating"

Figure 7 caption: **add a description what the vertical blue lines mean.**
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Changes in manuscript: "the identification of the optimal regularization parameter

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γ_r. The cross-validation (CV) function" has been changed to "the identification of the optimal regularization parameter γ_r. Shading (with vertical blue lines) of the regions in the range of possible regularization parameters means their rejection from the retrieval, absence of shading means their acceptance. The cross-validation (CV) function"

Figures 9–11: Why is the x-axis range so large? Why not limit the range to, say, 1.2×10^{12} or 1.3×10^{12} atoms/cm3.
Response: Our response considers the interactive comments of the Anonymous Referee #2 and the Anonymous Referee #1.
Changes in manuscript: Figures 9–11 are changed providing plots with the proposed range and changed labels for SCIAMACHY retrievals.

Figure 14 caption: remove "(bottom right)" since it is already written that it is the bottom right panel.
Changes in manuscript: "rates (bottom right)." has been changed to "rates."

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