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Ocean Science Discussions

Interactive comment on "Spectral studies of ocean water using DOAS" *by* M. Vountas et al.

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We would like to thank the referee1 for his inputs.

1)Referee comment
The paper applies an "optical absorption" analysis technique to satellite radiance measurements made by SCIAMACHY. This gives interesting results. However, the paper needs to explain why the standard techniques of water colour analysis, as used for SeaWiFS, MODIS and MERIS, are not applied. In view of the extensive literature on the standard techniques, most readers will be expecting these. Clearly, they could be applied, but SCIAMACHY may be lacking in calibration accuracy. I note that much of the background literature on the standard techniques is referenced on page 467 to compute effects of VRS.

- The focus of this paper is different. In order to further clarify we add the following paragraph “In this study DOAS, which...“ (in sec. 1):
“The DOAS method is used to retrieve ocean optical parameters, such as VRS and phytoplankton absorption, which can only be detected in spectrally high resolved ranges of the UV-Vis. Both parameters are also interesting to improve the ocean color retrievals of phytoplankton biomass from high spatially resolved sensors like MERIS, MODIS and SeaWIFS. From VRS the information on light penetration depth, i. e. the underwater light path which is seen by the satellite sensor, can be retrieved and the information on phytoplankton absorption can help to adjust for the spectral absorption differences of different phytoplankton groups. Since both parameters cannot be considered so far in highly spatially resolved chlorophyll-a retrievals, such as the commonly used NASA algorithm OC4 (ocean color chlorophyll algorithm version 4 used for SeaWiFS data) which uses a single biooptical model based on fitting a mean relationship from a large dataset of coincident nLw and chl a in-situ measurements (O’Reilly et al. 2000), errors are still around 50

  - Carder K.L., Chen F.R., Cannizzaro J.P., Campbell J.W, Mitchell B.G. (2004) Performance of the MODIS semi-analytical ocean color algorithm for chlorophyll-a. Advances in Space Research 33: 1152-1159
  - Murphy R.J., Pinkerton M.H., Richardson K.M., Bradford-Grieve J.M., Boyd P.W: (2001) Phytoplankton distributions around New Zealand derived from SeaWiFS remotely-sensed ocean colour dataNew Zealand Journal of Marine and Freshwater Research 35: 343-362
  - O’Reilly J.E., Maritorena S., Siegel D., O’Brien M.C., Toole D., et al. (2000) Ocean color chlorophyll a algorithms for SeaWiFS, OC2, and OC4: Version 4. In: SeaWiFS Postlaunch Technical Report Series, edited by Hooker, S.B and Firestone, E.R. Volume 11, SeaWiFS Postlaunch Calibration and Validation Analyses, Part 3.NASA, Goddard Space Flight Center, Greenbelt,

OSD
4, S199–S208, 2007

Maryland, p9-23.

2)Referee comment
Equation 1 shows that the analysis assumes that absorption features are spectrally narrow compared to the smooth continuum, which is fitted by a polynomial. Is this condition really met for chlorophyll? This needs a comment. I believe that the explanation would be clearer for many readers if the contrasts with the standard technique were explained.

- The approach utilizing relatively broad spectral absorption features has been applied before in atmospheric trace gas retrievals, see for example Haley et al. (2004): here, ozone has been fitted using DOAS in the so called Chappuis bands (i.e. in a wavelength range of 440-740 nm). The absorption cross-section of ozone oscillates slowly over 20-30 nm (signal wavelength) and can be used for the retrieval. In the case of phytoplankton absorption the spectrum is varying on the same scale. The polynomial takes over the spectral signature of atmospheric scattering (Rayleigh and Mie) and broad band aquatic optical properties for instance yellow substance absorption (see Fig. 1).
  - Haley C.S., Von Savigny C., Brohede S., Sioris C.E., McDade I.C., Llewellyn E.J., Murtagh D.P., "A comparison of methods for retrieving stratospheric ozone profiles from OSIRIS limb-scatter measurements", Advances in Space Research, 34 (4), pp. 769-774, 2004

3)Referee comment
A better title would use the word SCIAMACHY instead of DOAS. The present title does not even tell the reader that this is a satellite observation. "Differential" refers to switching between a sample and a reference. This is not the technique used here. I recommend "Estimates of ocean surface chlorophyll using SCIAMACHY." "Spectral

OSD
4, S199–S208, 2007

studies" seems unnecessarily vague.

- The term "spectral studies" has been used to emphasize that aquatic information is derived from high-resolution spectral information. The paper is especially addressed to readers interested in the potential of these spectral approaches. However, we agree that the reader should be informed that the satellite observation is performed. We propose the following title:
"Spectral studies of ocean water with space-borne sensor SCIAMACHY using Differential Optical Absorption Spectroscopy (DOAS)".

- The term "Differential" within the DOAS acronym is owed to the fact that a polynomial is removed from the measured optical depth: the polynomial is subtracting broadband, i.e. "slowly" changing spectral features (mostly from scattering) and acts like a high-pass filter.

4)Referee comment
The paper needs to end with a scatter plot comparing MODIS and SCIAMACHY chlorophylls.

- This paper focusses on methods to retrieve aquatic parameters from hyperspectral, space-borne instrumentation using DOAS. Here, we wanted to show the feasibility of the methods. For this reason we introduced Fig. 9 to emphasize that these methods have a promising potential. We agree, that further analysis, i.e. also further validation is necessary. A thorough validation involves the comparison of large data sets from distinct provinces and temporal intervals. The statistical methods applied will have to be explained as well as the underlying data sets and of course the results. As explained, this is not focus of this publication and for the sake of clarity and brevity we restricted the comparison to

OSD
4, S199–S208, 2007

monthly means. We think that the recommendation of the referee should be part of a forthcoming publication.

5)Referee comment
Some estimate needs to be given for the errors in SCIAMACHY chlorophyll concentration in Fig 9. I have the impression from Fig 8 that this is large enough that you probably should not be citing MODIS errors as a significant problem at this stage, p476.

- Probably this is a misconception. Most likely the reviewer refers to the sentence: "However, this approach is strongly dependent on the quality of MODIS data. Problems with MODIS' chlorophyll concentrations significantly interfere with such a retrieval." This statement belongs to a small study not further elaborated where fit factors for VRS (Sv) were scaled using MODIS' chlorophyll concentrations according to the function derived from Fig. 8 (right). Or in other words, the Sv values were transformed directly to chlorophyll concentrations using the functional dependence between Sv and MODIS' chlorophyll concentrations derived beforehand. The statement is not related to the results in Fig. 9.
- To clarify we changed from "However, this approach is strongly dependent on the quality of MODIS data." on p476 to "For this approach the quality of the resulting chlorophyll concentration is not only hampered by errors due to problems within the VRS retrieval but also due to errors introduced to the MODIS chlorophyll concentrations used for the fitting."

6)Referee comment
The text suggests that Fig 9 is derived from VRS only. This should be made clear.

OSD
4, S199–S208, 2007

- We cannot follow this comment: In section 4.3 we explicitly explain: “For the whole retrievals of Sa [fit factor for phytoplankton] for July 2005 ... all corresponding values of Sv [fit factor for VRS] have been used within Eq. (3) to model a global map of chlorophyll concentrations...“.

7)Referee comment
In Figure 8, I have a strong feeling that the shape of the right panel has to do with Figure 3. This needs a comment

- We agree, an additional comment could be helpful. We added the reference to Fig. 3.: “The absolute value of the VRS fit factor decreases with increasing MODIS chlorophyll concentrations, which is expected behavior and has already been illustrated in Fig. 3. and discussed section 3.1.“

8)Referee comment
The Figures need improving, see below.

- We agree, see Text below.

9)Referee comment
Why is a resolution of 1 km necessary? (page 462). It is provided by other sensors, but this value is neither necessary nor optimal.

- The reviewer is right and we changed the sentence to a more precise statement: Significant ocean color variability occurs down to the sub-mesoscale (0.5 to 10 km) and mesoscale (10 to 200 km) (e.g. Denman and Gargett 1995).The large-scale ocean color field is governed by the seasonal distributions of light, nutrients, upwelling and upper ocean mixing (Yoder et al. 1993).

OSD
4, S199–S208, 2007

- Denman, K.L., Garbett, A. E. (1995) Biological-physical interactions in the upper ocean: the role of vertical and small scale transport processes, Annu. Rev. Fluid Mech. 27:225-255.
- Yoder J. A. (1993) Annual cycles of phytoplankton chlorophyll concentrations in the global ocean: a satellite view. Global Biogeochemical Cycles 7: 181-193

10)Referee comment
I strongly feel the need to include a Figure illustrating the effect of VRS on a typical ocean radiance spectrum. (p 465)

- Fig. 1 illustrates the pure impact of VRS on the radiance (ln I+VRS/I-VRS). To support this information we extend the sentence on p467 from “For a wavelength range of 300-450 nm relevant scattering and absorption coefficients are shown in Fig. 1“ to “For a wavelength range of 300-450 nm the VRS spectrum as well as relevant scattering and absorption coefficients are shown in Fig. 1“.
- We hope that the updated, color-coded Fig. 1 also helps (see below).

11)Referee comment
Surely the fit factor can be defined to be positive, p469? Negative values are an unneeded complication. The name also seems to shift from “fit factor” to “slant factor” (Fig 8 caption and axes). Language must be kept as simple and consistent as possible.

- We agree. The name “slant factor” has been replaced by “fit factor” in the whole paper.

13)Referee comment
Were there 999 orbits in July 2005 (p 471)? I would expect about half that, 31x14. Perhaps you mean half-orbits, but then half these will be at night.

OSD
4, S199–S208, 2007

- This is a typo. In fact we analyzed 578 SCIAMACHY files containing 442 individual orbits. ENVISAT's precise numbers of orbits per day is 14 11/35. This leads to a theoretical number of orbits for July 2005 of 31 x 14 11/35 = 444. The discrepancy of two orbits results from the fact that we exclusively have used the near real time (NRT) data set of SCIAMACHY, which is not always complete.

14)Referee comment
Figure 1 could be made clearer if lines were made more distinct and labeled individually. The VRS spectrum needs additional explanation, as noted above. "Call" presumably refers to ionized Calcium, but as written it looks like an English word.

- We agree. We have changed Fig. 1 accordingly.
- Yes, CaII refers to singly-ionized Calcium. For clarity we will change to "... two strong Fraunhofer lines due to singly-ionized Calcium (Ca-II) ... "

15)Referee comment
In Figure 2, the left panel needs more explanation of SCIAMACHY's properties. Why is the swath intermittent? What is the swath width? Where is the instrument's instantaneous field of view? The right hand panels need to have the same vertical scale. I guess DOD to mean differential optical depth. This needs to be spelled out. In what sense is it differential? "Readout 2 of state 5" and "readout 253 of state 5" need to be explained.

- We change the caption of Fig. 2. Left: VRS fit factor for SCIAMACHY orbit 12429. Please note that the intermittent orbit shown here or in Fig. 5 goes back to the consecutive change of measurement cycle (for explanation see section 2). Right: Differential Optical Depths (DOD) of the VRS fit for readout 2 of state 5 over open water (above) and readout 253 of state 5 over land (below).

OSD
4, S199–S208, 2007

- To further clarify we changed the last paragraph on p 462 to: “In particular, the spectrometer continuously alternates between limb and nadir modes, which allows the observation of the same volume of air under different viewing angles, facilitating the separation of stratospheric and tropospheric components of molecular absorbers. The drawback of this potential is that no consecutive nadir measurements are provided. Instead each nadir measurement cycle is followed by a limb cycle which cannot be used within this study. The nadir scan along-track is therefore intermittent (like in Fig. 2 or Fig. 5). The swath width for both measurement cycles is 960 km. The instrument takes backscatter measurements...“

- For clarity we change the wording from “Readout 2 of state 5” and “readout 253 of state 5” to “Ground pixel 2 of the fifth nadir mode“ and “Ground pixel 253 of the fifth nadir mode“

16)Referee comment
Figure 5, as for Figure 2.

- Fig. 5. Left: Phytoplankton fit factor for SCIAMACHY orbit 17712. Please note that the intermittent orbit shown here or in Fig. 2 goes back to the consecutive change of measurement cycle (for explanation see section 2). Right: Differential Optical Depths (DOD) of the phytoplankton fit for ground pixel 214 of nadir mode 7 over upwelling (above) and ground pixel 6 of nadir mode 7 over oligotrophic water (below).

17)Referee comment
Something is very odd about Figure 9. In my version, the range 0.85 to 1.25 appears to be coloured the same as the “no data” area south of 40S. I assume from Figs 4 and 6 that you have almost complete global coverage from 50S to 80N. This figure needs to use the same colour palette as all the others.

OSD
4, S199–S208, 2007

- We could not follow this problem. The range between 0.85 to 1.25 in Fig. 9 is green/yellow and cannot be mixed up with any other part of the color scale. The used color scale should “immitate“ the standard MODIS color table. The intention was/is to enable the reader easy visual comparison between MODIS (Fig. 7) and our results (Fig. 9).

Interactive comment on Ocean Sci. Discuss., 4, 459, 2007.