

Interactive comment on “Estimates of radiance reflected towards the zenith at the surface of the sea” by E. Aas

Dr. Aas

eyvind.aas@geo.uio.no

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I am due thanks to the two referees for their constructive comments. Referee #2, G. Zibordi, recommends a few revisions, and my replies to his suggestions are presented below.

ZIBORDI: (Section 1) "The author claims that simple and accurate methods do not exist for the correction of reflected radiance in above-water radiometric measurements. This statement requires some major qualification. In fact there is a significant community which applies a combination of theoretical and experimental solutions to determine reflected radiance contributions into the field of view of above-water radiance sensors (e.g., Ruddick et al. 2006, Zibordi et al. 2004, Deschamps et al, 2004)."

REPLY: I see that my statement in Section 1 can be misunderstood. The statement refers to the radiance data collected by radiometers mounted on Norwegian ferries, where the geometry with regard to the sun changes with time. The Ruddick et al. paper describes recordings where the field-of-view is kept at an azimuth angle of 140° away from the sun and the vertical angles are 40° , Zibordi et al. apply a 90° azimuth and a 40° vertical angle, while Deschamps et al. use 135° azimuth and 45° vertical angle (near the Brewster angle), Mobley (Appl. Opt., 1999) recommends 135° as the azimuth angle and 40° vertical angle, while Fougnie et al. (1999), using a polarizer, suggest 45° for the vertical and 135° for the azimuth angle. All of these angles are optimized in order to avoid sun glints. Ferries represent a quite different set-up, because they have to follow fixed courses, and parts of the time during a day the sun will therefore have positions where sun glints are likely to contribute significantly to the recorded radiance. It was the non-existence of simple methods capable of correcting for both sky and sun glints I had in mind. The text in Section 1 has now been rewritten, and the suggested references have been added.

ZIBORDI: (Section 1) "Limiting the analysis to zenith reflected contributions is certainly acceptable. But this is a critical case not generally considered for operational above-water radiometric measurements because of the larger uncertainties affecting the theoretical determination of the sea surface reflectance with respect to other privileged geometries."

REPLY: It is quite correct that the case of zenith-reflected radiance is unusual in operational above-water radiometry. This case was chosen for three reasons: (1) A paper had already been written (Aas et al., 2009, Int. J. Remote Sens, 30: 5767-5729) where the conversion of sub-surface reflectances to above-surface MERIS reflectance had been discussed, and most of the work in the study of upward radiance from nadir in the sea and the zenith-reflected sky and solar radiance at the surface had already been done. (2) I needed to educate myself and get some understanding of how the sky and sun glints were related to sky radiance and diffuse and direct solar downward irradi-

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ances, and in order to do so, the studied system should not be too complicated. (3) The case of radiance in the nadir-zenith directions is mathematically much simpler to study than the optimal angles applied in the references above. It is true that uncertainties will be introduced because there will be more frequent sun glints in this direction, and the accuracy of the sun glints is probably not very high, due to the simplified Cox-Munk model applied here. Still it would be possible to see if the more comprehensive calculations by the Cox-Munk model could be described by simple polynomials. If such a description can be made for the present case, it should then in the next step be possible to transfer parts of the methods and the results to more optimal viewing angles. The two first reasons are only of relevance to the author, while the third reason is why the paper may possibly be of interest to some readers of Ocean Science. It is emphasized several times in the text that the present results only represent a first step.

ZIBORDI: (Section 1) "The work of Mobley (1999) comprehensively addressed the sea surface reflectance as a function of wind speed and geometry. I believe that much more space should be given to that basic work in the introduction of the manuscript."

REPLY: I agree that the work of Mobley (1999) is a basic one, and I have referred to his paper several times in the text. There is, however, only a small part of his results that relates to the nadir viewing angle, which is why his results have not been discussed in more detail. I have now added a section to Section 1 where I mention some of the studies made by different authors of the optimal viewing angles.

ZIBORDI: (Section 2.1) "The work of Cox and Munk (1954) and successive developments certainly provide elegant and appropriate solutions for the statistical quantification of sun-glint as a function of wind speed. Nevertheless, i. uncertainties in wind speed values, ii. effects of bottom topography in coastal regions and iii. the limited number of radiometric observations generally available, reduce the effectiveness of such a statistical modeling. This should be clearly stated."

REPLY: I agree with the points i and ii, and I think I understand what is meant by iii.

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Probably Zibordi means that the radiometric input needed in order to make use of the Cox-Munk model is often missing, and that is true. However, in Oslo we have such local radiometric observations, and I think they have a local validity that theoretical inputs from model atmospheres may be lacking. I could add a point iv: the wave-creating effect of the wind is not only a function of wind force, fetch and duration, but will also be affected by the stability and turbulence conditions in the boundary layers of the sea and the atmosphere. I have now pointed out in Section 2.2 that the present results obtained from the Cox-Munk model is only meant as a first approximation to the real world.

ZIBORDI: (Section 3.2) "The methods proposed in the so called NASA Protocols refer to measurement geometries centered on viewing angles and azimuths much different from that considered in the present manuscript (i.e., nadir view). It is then quite inappropriate to compare differences in surface reflectance determined through comprehensive modeling (as applied in this work) and surface reflectance approximated by the Fresnel reflectance for viewing geometries not significantly affected by sun glint. The text should be revised and the former elements clearly reported. For instance it should not be stated that the NASA methods are only applicable for low wind speeds. This is valid for the measurement geometry considered in this work but not for the measurement geometries proposed in the NASA Protocols."

REPLY: Zibordi is quite right in pointing out the differences between the viewing angles recommended by NASA and the zenith angle studied here. I also agree that it is unjust to mention the disagreement between the present results and the NASA method without explaining the reason for the differences. On the other hand, I have seen some presentations where the Fresnel-type correction has been used uncritically, with reference to the NASA protocols. I have now revised the text in section 3.2 where this topic is discussed.

ZIBORDI: (Section 3.3) "The independence of sun-glint from wavelength was already applied to quantify residual sun-glint contributions in above water radiometry (e.g., Zi-

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bordi et al., 2002)."

REPLY: It is correct that Zibordi et al. pointed this out in their 2002 paper. The reference has been added.

ZIBORDI: (Section 4) "The author makes a commendable effort to quantify uncertainties throughout the manuscript. It should be of general interest to have a table where the various uncertainties are summarized and statistically composed."

REPLY: A new Table 7 has been added.

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