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Interactive comment on "A robust method for removal of glint effects from satellite ocean colour imagery" *by* R. K. Singh and P. Shanmugam

R. K. Singh and P. Shanmugam

pshanmugam@iitm.ac.in

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We greatly thank the anonymous reviewer for valuable comments which helped to improve the quality of this manuscript. The responses are given below.

1. The paper describes a new empirical method to assess the crucial question of glint correction of ocean color imagery. A high percentage of the ocean color imagery is unavailable due to saturation of marine radiances by sun specular reflection which prevents correct chlorophyll estimation and phytoplankton discrimination. It is thus essential to get correct estimations of radiances in glint affected regions to better understand

biogeochemistry of the ocean. The new glint correction algorithm (NGC) method uses no ancillary data. The algorithm uses only satellite data in the NIR and SWIR channels for the same pixels. The idea is to use either the NIR radiances (for high chlorophyll blooms) or SWIR radiances (in the case of floating blooms) and the known spectral dependency of glint reflectance (positive slope from the visible to the NIR- SWIR bands) to correct the glint effect in visible wavelengths. Substantial improvement is reached in high chlorophyll waters, compared to the default algorithm used in the Seadas processing. Maybe this limitation of the NGC to high chlorophyll areas should be found in the title ?

The NGC is applicable to all types of waters. The retrieval of sunglint radiance becomes more difficult in bloom and suspended sediment dominated waters due to their absorption and scattering properties in the visible and near-infrared region. Therefore, the manuscript gives special emphasis on the productive ocean waters along with clear oceanic waters.

2. The paper is well written and clear. References are complete. Despite some needed revision, and the fact that this method applies particularly well on areas already well-studied by the authors (also for aerosol correction), this paper shows that empirical method can be robust compared to more sophisticated method and can be helpful. Indeed, the radiance validation data set is still limited and collection of in situ radiances should be extended particularly in regions where bloom occur or/and in optically complex areas.

It is difficult to find in-situ observations when the sunglint contamination occurs in the satellite sensor data. We are having only four in-situ points to show the validity of algorithm for moderate and intense glint areas. However, we have provided a number of cases where it can be observed that the sunglint is removed synoptically and even more complex waters are recovered accurately in the presence of variable atmospheric and surface conditions (including sunglint).

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3. The organogram of the algorithm Figure 1 is clear and explains the iteration procedure based on the value of two glint ratios (either the NIR bands, either the SWIR band) with coefficients adapted to rich chlorophyll regions until the glitter ratio reach the threshold value. It is not clear why the correction by normalized absorption by water is needed (is it normalized absorption or absorption ?).

Satellite sensors represent the composite signal containing the radiance from the whole pixel area. In this study we have observed that the sunglint radiance is not only dependent on the facets creating glitter but the background which contains water, also plays an important role in modifying the spectral shape and magnitude of the observed data. Thus, this fact has been taken into account when dealing with glint pixels in this study. 4. Is it necessary to take it into account only in the case of high blooms ? No, normalized absorption by water is necessary in all types of waters as shown in the organogram.

5. Values of Table 1 are not those of Pope and Fry. Explain why.

Pope and Fry provided aw values for pure water. But our study needs particulate oceanic waters whose absorption is lesser than the pure water due to particulate scattering. We used polynomial to extrapolate the normalised Pope and Fry values in blue bands to NIR region for our use.

6. Did you check the real impact of this correction and at which wavelength is it required?

It was examined and glint contribution exists in most visible bands.

7. Some comments requiring corrections or precisions: I am not sure to understand why this correction is not applicable to oligotrophic waters (equation 2). If it is a problem of radiance saturation by glint, which prevents the use of NIR and SWIR radiances in the case of oligotrophic areas, and shown at Figures 4abcd. In this case, this should be clarified by a sentence.

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This correction is applicable to all types of oceanic waters, including oligotrophic waters. Thus, the new method has no restriction on its applicability.

8. The performance of the glint correction is well described in high chlorophyll bloom areas, mainly in the Arabian Sea. Many examples are shown (illustrations) and statistical data (tables) are given to show the spectacular effect of the new correction algorithm in these areas.

9. Figure5: obviously, the figure shows the impact of NGC compared to SGC but there is no in-situ radiance validation at this time. How do we know that b) is better than c) and d) and e) (is it better if the difference Lrc-LTg is flat along the transect? is this difference Lra +Lw ?)

Yes, this difference is (Lra + Lw). As shown in the figure, sunglint is maximum in the center and gradually decreasing in both the sides. The SGC and NGC correction identifies the glint contamination and both methods try to fix it. But the glint radiance estimated by the SGC does not coincide with the actual glint peak decreasing its efficiency. The radiance level in the vicinity of a pixel remains almost the same (spatial homogeneity) and hence, the transect should be flat.

10. Figure 6: it is important to note that final results of the NGC also depend of the successful application of a new algorithm for aerosol correction (CAAS, Shanmugan, 2012). This is shown at Figure 6. As a result of the NGC application compared to the SGC, the aerosol is no more overestimated, and consequently, visible radiances are correctly retrieved (chlorophyll overestimation is limited) and this depends also on the new aerosol correction scheme. Thus, objectively, in the absence of in situ data: how do we know that the NGC result in f) is right compared to the e)? How do we know that the bloom is better retrieved?

The aerosol correction algorithm used to derive Lw is Singh and Shanmugam (2014). Fig 6c shows the remaining glint after glint correction by SGC, whereas negligible glint is observed in Fig 6d produced after NGC is applied. To further support the claim, corresponding Lw false colour composite images are shown. For instance, Figure 6e clearly shows a dark patch in the glint contaminated region which is due to the residual glint radiance in the prior step which leads to the over-estimation of La in the final step.

11. Figure 7 shows the effect on radiances and are convincing. Figures 8 and 9 (false color composites) are difficult to interpret, and as they are just illustrations and nobody can tell if SGC or NGC are correct without comparing spectra, I suggest reducing the number of these images 8 and 9 to only one example.

Figures 8 and 9 show a variety of sunglint images including spot-like (more concentrated spatially) to disk-like (spread over a large area). These figures are illustrating the consistency of the NGC. The SGC products show residual glint in almost all the (Lrc-Lg) images whereas NGC is consistently producing output with negligible glint. The effect of residual glint on Lw and chlorophyll is clearly shown in Fig 6 and 7.

12. Figure 10: without in situ radiance data or sea truths chlorophyll data, it is not clear if chlorophyll is overestimated by SGC or not.

Chlorophyll products with and without sunglint correction are generated to demonstrate how sunglint deteriorates the spatial distribution patterns and concentration of chlorophyll from one pixel to other pixels as contaminated by sunglints. Inaccurate retrievals of the water-leaving radiances are apparently getting reflected in the biogeophysical products such as chlorophyll.

13. Page 2809. Do the authors suggest that aerosols SGC correction prevents the use of images during sand transport? in this case, say it clearly.

Sometimes, when the sediment (SS) concentration occurs high, the radiance level in the green and red bands increases significantly. The increase in radiance level makes the SGC to wrongly identify SS dominated pixels as glint contaminated and hence over correction occurs.

14. Figure 11: why do not we get the regression coefficients of these figures ? The

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mention of Table 2 is not found in the article (should be there).

The regression coefficient for Fig 11 is in Table 2.

15. We see that for non glint-contamined pixels, NGC better retrieves radiances at 667m while the retrieval success is not so high for higher radiances (other wavelengths in the blue-green). Please, explain.

The radiance level at 667nm remains quite low. The retrieval for the 667nm band is relatively low, but the absolute error is less. When we calculate the percentage error, at 667nm it will be relatively high. For example, the radiance level at 667nm be 0.05 μWcm-2nm-1sr-1 and the retrieved radiance be 0.1 μWcm-2nm-1sr-1, the absolute error is only 0.05 μWcm-2nm-1sr-1 but the percentage error will be 5%.

16. Figure 11c: why such an underestimation of radiance by NGC or SGC and so what prevents the possibility to get the right magnitude of the in situ spectrum? please, explain.

In satellite derived data, a number of corrections are applied. All these algorithms are not so accurate, for example aerosol estimation, and lead to over-correction of the data received at the top of atmosphere. This leads to underestimation of Lw by both the methods.

17. For Figure 11g, markers are not different enough, please use either empty and full squares or circles. Again, the NGC effect is higher on lower radiances, please explain.

Squares or circles are not used so as to avoid confusion to the readers that only single pixel is taken into consideration, not an area enclosed by a circle or square.

18. Again, Fig 11h, explain why the Lw is not correctly retrieved either by NGC either by SGC: do you have an explanation of such a discrepancy in both algorithms?

As explained earlier, all the data processing algorithms are still improving and hence the accuracy is not so high, leading to overestimation by the corrections and lower Lw.

19. Page 2593 : the most of the cases should be most of the cases

Corrected

20. Page 2805 : Fig 3j should Fig 4j.

Corrected

21. Tables 1 or 2 : I did not find mention of these tables in the text.

Included

22. Table 2 legend should indicate Error statistics on Lw values produced by SGC and NGC algorithms

Indicated

Kindly see the revised version for further information

Interactive comment on Ocean Sci. Discuss., 11, 2791, 2014.