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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

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The authors wish to thank the reviewer for the helpful comments and suggestions to improve the manuscript.

General comments: 1. The manuscript is well written but I would suggest authors to greatly improve the first paragraph of the introduction.

This paragraph has been improved.

2. The authors state that the NGC algorithm is novel due to dependent on the satellite

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data. We know that standard glint correction algorithm is being widely used and its performance tested in global oceans. How do authors justify the applicability the NGC algorithm in the global oceans? Novelty of the NGC algorithms should be discussed.

For validation of the NGC algorithm, the NOMAD dataset was used and this dataset contains sampling from many coastal regions including Florida Keys, Gulf of Maine, Arabian Sea and Bay of Bengal. NGC was applied to images from different periods to check the seasonal variations. The results contain a set of images for different types of glint pattern varying from spot-like to disk-like and the implication of NGC and SGC in these regions.

3. As it is clear from several studies that curve fitting method uses the linear and non-linear function to fit on data to obtain empirical relationships. In this paper, mathematical formulation of the algorithm is not clear for me. What type of fitting is performed to obtain the empirical algorithm?

Regression analysis is used as a base to fit the curves and derive the equations. For example, Fig 2d shows the regression and polynomial fit used to relate gr with Lrc(2130nm).

4. The authors have used term “optically complex” throughout the manuscript. Please explain the meaning of this term.

Optically complex waters are typical case 2 waters as defined by Morel and Prieur (1977), which contains materials other than phytoplankton such as suspended sediments and coloured dissolved organic matter. These waters have large variations in the radiance in the visible spectrum.

5. I would recommend for showing all the satellite images with proper Lat/Long figure format instead of simply showing the region without any Lat/Long information. Moreover, color bar should cover wider range.

The satellite images represented here give a synoptic view of the region effected by

OSD

11, C1295–C1300, 2015

sunglint. Adding Lat/Long to these images will further reduce the size of the images making it more difficult to interpret. The images are projected with significant land portions (color image over the land) so that the region can be easily identified on a global map.

6. This research will require additional validation and test based on more high quality in situ and satellite data, and refining the algorithm coefficients, in order to provide more accurate water leaving radiances.

We have already used some in-situ data for validating the derived products in the presence of sunglints.

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).

7. Finally, fully recognizing the importance of the objective, the manuscript can be published with some major and minor revisions.

8. Here is a list of major and minor points the authors should address these comments in the revised manuscript.

Major comments: 9. The authors have implemented NGC algorithm only over Arabian Sea. I think apart from Arabian Sea, this algorithm should be tested in some other glint affected region for showing the novelty of NGC.

In the revised manuscript, we have provided another example from other regions to illustrate the novelty of the present method. To further examine the efficiency of the present method, it was tested on the MODIS-Aqua imagery from the North Atlantic region. Figure 10 shows the coastal and offshore regions of Newfoundland with sunglint

OSD
11, C1295–C1300, 2015

contamination. This image contains moderate level of glint (with no pixel saturation in the MODIS-Aqua bands) making it a good example for assessing the relative performance of SGC and NGC algorithms. The extent of the glint is clearly visible in both the total radiance and Rayleigh corrected radiance images (Fig. 10(a) and (b)). Figure 10 (c) and (d) shows the corresponding glint radiance images provided by SGC and NGC respectively. It can be observed that the SGC algorithm fails to recognize all the glint contaminated pixels and thus its applicability is restricted to a small region. By contrast, the NGC algorithm is capable of detecting most of the glint-contaminated pixels in coastal and oceanic waters around Newfoundland (as clearly identified by bright regions in Fig. 10(b) and (d)). In Fig. 10(e), it can be observed that SGC tends to have underestimated the glint radiance and the consequence is the residual radiance visible as bright pixels in the glint corrected image (Lrc–TLg). This underestimation of glint deteriorates the efficiency of aerosol correction causing very low radiances in the blue wavelengths (Fig. 10(g), also see Fig. 11(a) and (c) for clear and moderately turbid waters). As expected, the NGC algorithm is consistent in terms of removing most of the glints and retrieving accurate water-leaving radiances in the glint-contaminated regions. Figures 10(f) and (h) do not show any residual glint in the region contaminated by sunglint, which supports the spatial homogeneity principle adopted for this method. As a result, the spatial structures of the water features are better captured without any spectral distortion as shown in Fig. 11(b) and (d). The results generated by the SGC and NGC algorithms appear to be similar in the glint free regions of open ocean waters and Coccolithophores blooms. However, in the influence of even glints, the aerosol correction algorithm overestimates the aerosol radiance and hence results in the low water-leaving radiance (see Fig. 11(g)). These results are the proof of validation between the SGC and NGC algorithms.

Besides, NGC is validated using global dataset with glint contaminated pixels from Gulf of Maine and Florida Keys. Arabian Sea is shown extensively in the manuscript because it forms one of the most critical cases effected by sunglint and intense aerosols together making it difficult to estimate glint contamination properly.

OSD

11, C1295–C1300, 2015

10. Page 2799-2800, Equations (3) and (4): The determination of glint ratio (g_r), is an "empirical formula" providing glint ratio as a function of the L_{rc} (547)/L_{rc} (667) ratio through some mathematical equations whose parameters are determined by fitting satellite data. This means that the proposed "glint ratio" simply relies on empirical relationships between L_{rc} (2130) and values of g_r. It is not clear from equation (3), how does 2/3 constant is introduced in equation (3).

gr is defined as the ratio of Lrc (547)/Lrc (667) which helps us to determine whether a pixel is glint contaminated or not, along with measure of contamination. Lrc(2130) also does the same job but is not available on many sensors. And equation (3) which is derived using the regression analysis (Fig. 3d) shows a relation between gr and Lrc(2130). The main drawback with using gr is that the efficiency decreases when floating blooms are encountered. Floating blooms cover the water surface restricting the formation of facets and hence, decreasing the glint radiance for the pixel.

11. Page 2819-2820: Figure 2 (c). Scatter plots showing the relationship between L_{rc} (2130 nm) and L_{rc} (667 nm). Slope and intercept values are very low, which is not reasonable. What could be the possible reason for your low values of slope and intercept? In case of best curve fitting slope value usually close to one, provides a very tight relationship on fitted data, but in Figure 3. (a and b) slope is very high, which is impractical. Thus, the authors should check these fittings very carefully.

Figs 2(c) and 3(a and b) shows the relation between bands and hence, slope and intercept don't have any effect but a linear relationship is required. The slope is low because the radiance level at Lrc(2130nm) is negligible compared to 667nm or 547nm as the absorption by water increases with the increasing wavelength (from visible to SWIR (short wave infrared).

Minor comments: 12. Page 2805, lines 19-20: 748 nm is the red band? Please check it.

Yes, 748nm is red band. The image is a false colour composite with R- 748nm, G-

OSD

11, C1295–C1300, 2015

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Discussion Paper

547nm, B-412nm.

13. Page 2807, line 8: How do you define relatively clear waters? Please provide your criteria for relatively clear waters and relatively bloom waters.

It is actually clear water, but with slightly increased chlorophyll as compared to deep blue waters. However, it is now rewritten as clear water to avoid any confusion.

15. Page 2816: In equation (8) TLgi should replace with Tlg.

Equation (8) shows the equation for intermediate glint calculated in ith iteration.

16. Page 2816: The values presented in the table 1 are different from original values reported by Pope and Fry (1997). Please justify it.

Values presented in Table 1 are normalised aw values (divided by mean) which are based on Pope and Fry (1997). Pope and Fry gave aw values for pure waters but the absorption by particulate ocean waters differs, (i.e. scattering occurs in longer wavelengths where absorption starts to decrease) and hence the values till green bands are taken into consideration and then extrapolated till NIR (near infrared) bands.

17. Page 2828: Please mention number of data points in Figure 11(a, b, and g). Yellow color is not clear in Fig 11(g), please use some other color to present your plot.

All statistics for Fig 11 are shown in Table 2

Kindly see the revised version for further information

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