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Atmospheric Measurement Techniques
Discussions
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Interactive comment on "The importance of Atmospheric Correction for Airborne Hyperspectral Remote Sensing of Shallow Waters. Application to Depth Estimation" *by* Elena Castillo-López et al.

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Dear Anonymous Referee #4,

I am writing to thank you for the comments and suggestions you provided about the manuscript entitled "The importance of Atmospheric Correction for Airborne Hyperspectral Remote Sensing of Shallow Waters. Application to Depth Estimation". I would like to thank the time you devoted to the revision of the document.

Firstly, English grammar and style have been reworked. In relation with the aspect that

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you pointed, “Also, it does not really present, in my opinion, any significant novel scientific results related to atmospheric measurement techniques, i.e. the mayor subject of the AMT journal”, I have expanded this point because I think the objective of the work was not been well explained in the previous version. It is intended to be able to apply this type of information (hyperspectral imagery) to the study of bathymetries where the reflectance values cannot be greater than 1.5% because otherwise, the background would not be seen. Here lies the importance of a good atmospheric correction. In some cases, the atmospheric correction itself is more important than the bathymetry measurement technique applied.

Water reflectance is related with water quality data (Secchi depth (SD), suspended solids concentration (TSS) and chlorophyll-a concentration ([Cla]), as Dominguez, J.A. et al. showed in the article “Monitoring transparency in inland water bodies using multispectral images) where ASD FieldSpec FR spectroradiometer results were calibrated by the use of a 25% grey card reference panel (Goodin et al. 1993, Mayo et al. 1995, Hand and Rundquist 1998).

Figure 1. Water reflectance spectra with an unknown maximum at 386 nm, [Cla]<1 mg m-3. (Dominguez, J.A. et al, 2009).

Figure 2. Water reflectance spectra with an unknown maximum at 386 nm, [Cla]>1 mg m-3. (Dominguez, J.A. et al, 2009).

Figure 3. Water reflectance spectra showing a minimum at 680 nm corresponding to the maximum absorption of chlorophyll-a and a relative maximum at 705 nm corresponding to the fluorescence of chlorophyll-a. (Dominguez, J.A. et al, 2009).

This manuscript is a research article with significant advances in remote sensing, using in situ and laboratory measurement techniques with detailed error analysis. Information retrieval for gases, aerosols, and clouds are an important part of this article. Considering the case of shallow waters, the accuracy in bathymetric information is highly dependent on the atmospheric correction made to the imagery. The reduction of effects such as glint and cross track illumination in homogeneous shallow-water areas improves the results of the depth estimations.

In relation with the points (1) and (2) of the Major comments I have improved the document in order to follow the style required for AMT publication. Moreover, I have used the math editor and I have introduced and explained the math expressions. In relation with point (3) I have made a revision of the references cited and I have changed the references about removal of scattering in the atmosphere and external reflection from the water surface. Page 3 lines 25 to 26.

To be able to create bathymetric maps, the effects that electromagnetic radiation (EMR) suffers must be taken into account. As the EMR reaches the earth's surface, molecules and particles of the land, water and atmosphere environments interact with solar energy in the 400- 950 spectral region that CASI receives through absorption, reflection, and scattering. This article compares different atmospheric correction methods, as it analyzes the importance of the air column beyond the method applied to estimate the depths. Data from airborne sensors are known to have varying degrees of angle dependent brightness variation, which change with the sensor view angle and altitude, the angle between the sun azimuth and the scan sensor plane, and the surface type of the land. If this effect is not corrected or at least reduced, these variations can hinder the use of data with standard image processing, and the interpretation methods may mask low-amplitude spectral features of interest.

The Near Infrared (NIR) energy is mostly absorbed by water. Their values should be very close to zero. High values are mainly due to atmosphere, scattering and glint effects. As Mischenko M. and Dubovik O. suggested to the author in "Advances in light scattering by particle systems" (an International Workshop that took place in Laredo (Spain), from 5 to 7 of July, 2004), the image brightness has been reduced by subtracting a NIR band to the visible bands. The image brightness effect reduction has been done by subtracting band 34 (908-924 nm) to bands 1 to 24 (408-770 nm) which have been used in the bathymetric algorithm.

The raw data minus band 34 is useful if there is not access to atmospheric models, such as the 6S radiative transfer codes.

The work carried out by other authors does not establish the importance of the atmospheric correction depending on the type of water and the conditions (waves, stelae of ships, contaminants, etc.), in which we are working. In this sense, this work highlights the importance of C1 and SC-B34 correction in shallow waters.

About the point (4), I have tried to improve the quality of the figures and to make a better discussion in the manuscript about it.

I have corrected an error in the document regarding the acronym NNDD, that refers to the digital number (DN). The main document has been modified in this sense while making the corrections that Referee #3 suggested. Finally, in order to make the Dicussion and Conclusions more strong and convincing, I have expanded these sections. I have also expanded the description about the sun position, considering direction and observation point, as it can be found in Page 4, lines 25 to 27 and Page 5 lines 1 to 11). Regarding the aspect "to assess the best atmospheric correction method", error values results between 3 methods (SC, SC-B34 and C1) have been introduced, as correction C2 offers a better dynamic range, but it increases the standard deviation more than the original image.

I am available for any further comments or suggestions about this work.

I look forward to hearing from you soon.

Yours faithfully,

Elena Castillo

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2017-37/amt-2017-37-AC2-supplement.zip

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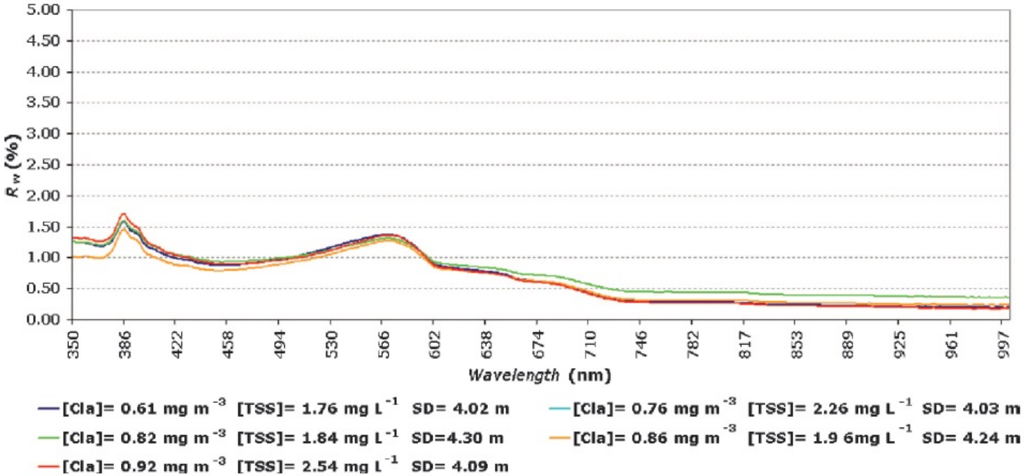
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Wavelength (nm)
[Cla]= 0.61 mg m -3 [TSS]= 1.76 mg L -1 SD= 4.02 m
[Cla]= 0.76 mg m -3 [TSS]= 2.26 mg L -1 SD= 4.03 m
[Cla]= 0.82 mg m -3 [TSS]= 1.84 mg L -1 SD=4.30 m
[Cla]= 0.86 mg m -3 [TSS]= 1.9 6mg L -1 SD= 4.24 m
[Cla]= 0.92 mg m -3 [TSS]= 2.54 mg L -1 SD= 4.09 m

Fig. 1.

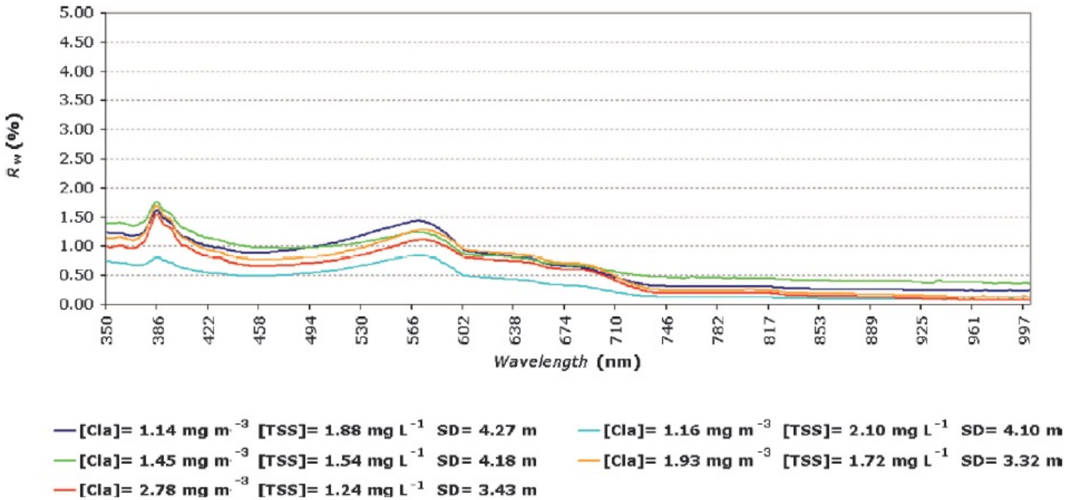

Fig. 2.

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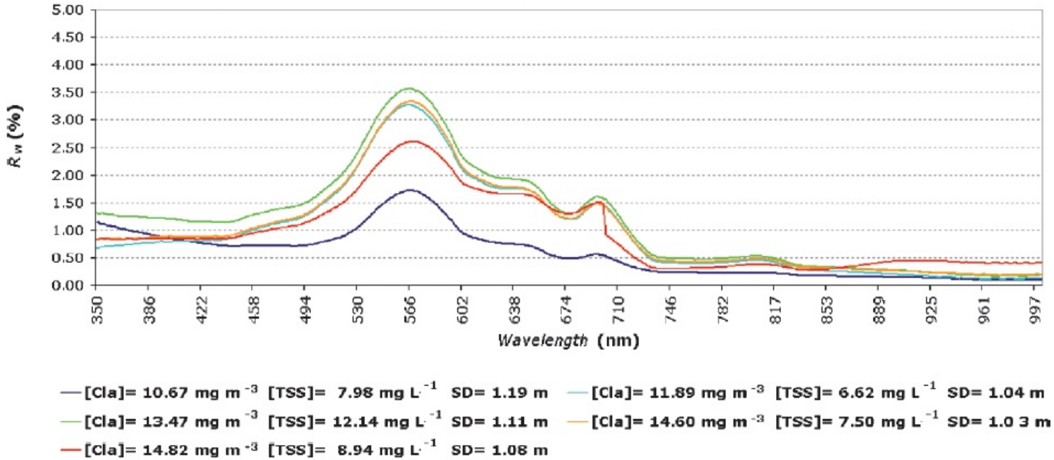
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Wavelength (nm)
[Cla]= 10.67 mg m -3 [TSS]= 7.98 mg L -1 SD= 1.19 m
[Cla]= 11.89 mg m -3 [TSS]= 6.62 mg L -1 SD= 1.04 m
[Cla]= 13.47 mg m -3 [TSS]= 12.14 mg L -1 SD= 1.11 m
[Cla]= 14.60 mg m -3 [TSS]= 7.50 mg L -1 SD= 1.0 3 m
[Cla]= 14.82 mg m -3 [TSS]= 8.94 mg L -1 SD= 1.08 m

Fig. 3.