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# ANALYSIS OF DATA QUALITY ELEMENT'S APPLICABILITY FOR RADIOMETRIC MEASUREMENTS IN REMOTE SENSING OF WATER: A CASE STUDY IN NOVA AVANHANDAVA RESERVOIR, SÃO PAULO, BRAZIL

*Análise da Aplicabilidade dos Elementos de Qualidade de Dados Aplicados ao Sensoriamento Remoto da Água: Estudo de Caso no Reservatório de Nova Avanhandava, São Paulo, Brasil*

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## ABSTRACT

Information from the spectral properties of natural or artificial targets of the Earth's surface is relevant to the development of bio-optical models that will be applied to satellite images during estimation of the water quality parameters. For this reason, the radiometric datasets acquired in the field must comply with quality requirements to ensure the accuracy of the target information. The aim of this study was to analyze the elements of spatial data quality that can be applied to the radiometric data, as well as proposing a flowchart for providing the protocols related to the stages of field planning, acquisition, analysis. Moreover, in this study we analyzed the requirements for metadata applied to radiometric measurements of water targets. For this, a case study in Nova Avanhandava reservoir, São Paulo State, was used to demonstrate the mentioned steps, emphasizing as the final product the construction of spectral curves of remote sensing reflectance (). As a result we observed that to obtain reliable data, it is recommended to follow the protocols available for acquisition and analysis of radiometric data, as well as ensure that key information relevant to the field campaign, the target and the environment are stored.

**Keywords**: Spatial Data Quality, Remote Sensing of Water, Hyperspectral Data.

## RESUMO

Informações sobre as propriedades espectrais de alvos naturais ou artificiais da superfície terrestre são relevantes para o desenvolvimento de modelos bio-ópticos, que posteriormente devem ser aplicados em imagens de satélite visando a estimativa de parâmetros de qualidade da água. Por esta razão, o conjunto de dados radiométricos adquiridos em campo devem atender requisitos de qualidade que garantam a acurácia das informações sobre os alvos. Dessa forma, o objetivo deste trabalho foi analisar os elementos de qualidade de dados espaciais que possam ser aplicados aos dados radiométricos, propondo ainda, um fluxograma que visa fornecer os protocolos relacionados as etapas de planejamento de campo, aquisição, análise e requisitos para um metadado aplicado às medidas radiométricas de alvos aquáticos. Para isso, um estudo de caso no reservatório de Nova Avanhandava, Estado de São Paulo, foi utilizado para demonstrar as etapas mencionadas, enfatizando como produto final, a construção de curvas espectrais de reflectância de sensoriamento remoto () coletadas em campo por meio do espectroradiômetro TriOS. Como resultado, foi possível observar que para amostrar dados confiáveis é recomendado seguir os protocolos disponíveis para aquisição e análise de dados radiométricos, assim como, garantir que as principais informações relevantes à campanha de campo, do alvo e do ambiente sejam armazenadas.


**Palavras chaves**: Qualidade de Dados Espaciais, Sensoriamento Remoto da Água, Dados Hiperespectrais.

## 1. INTRODUCTION

Any spatial dataset is a model of a reality produced with a certain purpose, in which some elements judged to be non-essential are synthesized or eliminated in order to make the dataset more understandable (DEVILLERS and JEANSOULIN, 2006). A spatial dataset that complies with all user requirements is considered to be fit for use (IVÁNOVÁ *et al.*, 2013)

Considering the radiometric dataset which comprises the radiance and irradiance measurements, the protocols of acquisition are crucial to achieve reliable data. Those measurements depend on solar illumination for the investigation of terrestrial targets by passive remote sensing, and for water bodies, additional factors, such as geometric relationship between the Sun, sensor and target during acquisition, are involved. Analysis of the data acquisition process is essential prior to the specification of user requirements for data quality. These elements can be described through metadata that provide information about the dataset's identification, spatial and temporal extent, quality, content, and spatial reference, among others (ISO, 2003).

The aim of this paper was to analyze the elements that influence data quality in radiometric measurements and propose a flowchart providing the protocols used during the field campaign planning, data acquisition, analysis, and parameters of a metadata applied to radiometric measurement of water target. We demonstrate our proposal by a case study in Nova Avanhandava reservoir.

## 2. RESEARCH APPROACH

Radiometric measurements are used to provide information about the water content and support bio-optical modeling of inland waters. However, to get reliable measurements it is essential to follow the procedures suggested by research institutions focused in the analysis of optical data of water targets, such as the NASA`s protocols (NASA/TM-2000-209966) from Mueller (2000).

### 2.1 Planning Field Campaign

According to Pompilio *et al.* (2013), in order to ensure economy and efficiency of a field campaign the survey planning must consider the target to be sampled as well as the number of samples and distribution thereof, and, if necessary, handle the logistics of the campaign, including tools and the required documents to enable entry into private property. The cost of the survey must also be estimated, including the rent of the boat, fuel, material to preserve the water samples, calibration and maintenance of the limnological and optical equipment. Authors also suggested executing an area reconnaissance before the field campaign, to obtain information of the characteristics of the study area, such as access, water quality appearance, pictures of the study sites and so forth. It is noteworthy that for surveys on water bodies it is of utmost importance to know the professionals who will drive the boat, aiming at the good progress of the campaign, as well as the personal safety of the people involved on the boat.

## 2.2 Data Acquisition

The collection of radiometric data follows the NASA/TM-2000-209966 protocol that guides researchers to get reliable results from field measurements. The radiometric data are acquired with optical instruments for measuring the energy that interacts with the water surface, water bottom and the components present within the water body. Radiometric measurements below the water surface are: downwelling irradiance – $E_d$ (0-), the upwelling irradiance – $E_u$ (0-) and the upwelling underwater radiance – $L_u$. The measurements above the water surface include sky radiance – $L_{sky}$, total upwelling radiance – $L_t$ and incident spectral irradiance – $E_s$. To exemplify how to collect these radiometric measurements, we used the RAMSES Hyperspectral radiance and irradiance sensors and their configuration is illustrated on Fig. 1. The radiance sensor measures the incoming light within an angle of 7 degrees. The irradiance sensor is equipped with a cosine collector (yielding a hemispherical 180° field of view) (TriOS, 2015).

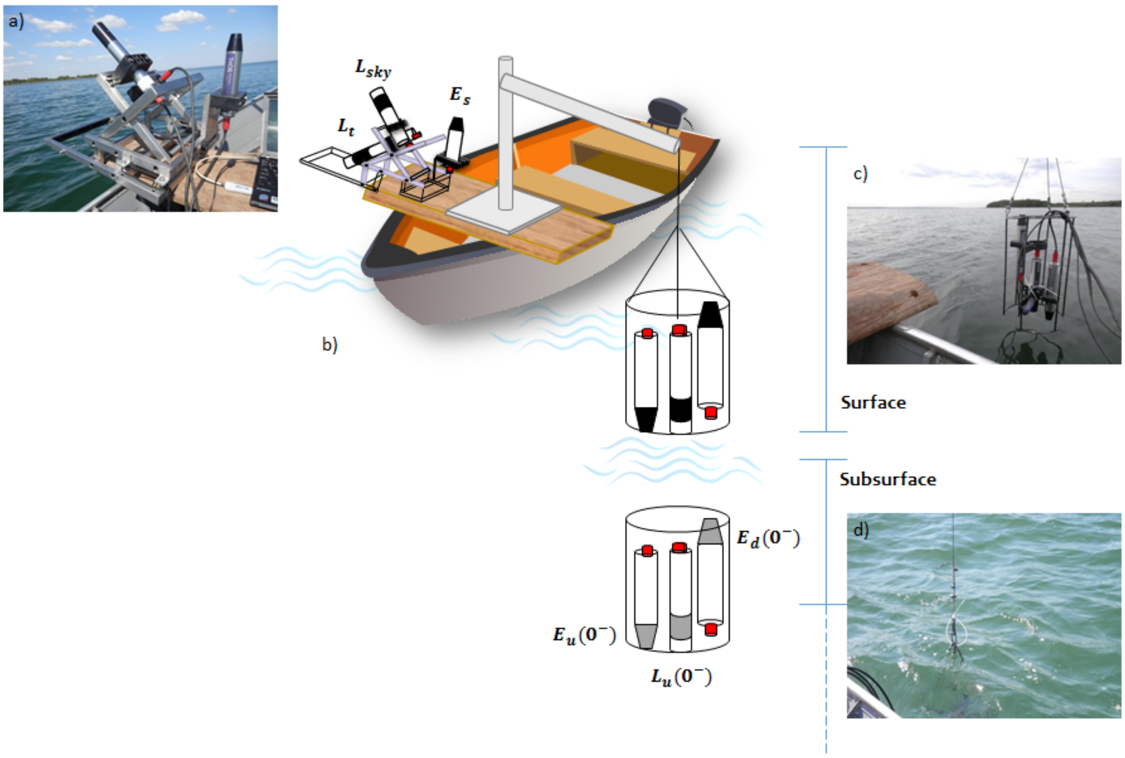


Fig. 1 - Configuration of radiometers above and below water surface during a field campaign (Adapted from Dev and Shanmugam, 2014): (a) configuration of sensors above water surface. (b) Two radiometers for measuring radiance ($L_t$ and $L_{sky}$) above the water surface and one radiometer for measuring the irradiance ($E_s$), and radiometers for measuring irradiance ($E_d$(0-) and $E_u$(0-)) and radiance ($L_d$(0-)) measures below the water surface. c) Frame and the sensors for measurements below water surface. d) Sensors in the water column.

The surface radiance and sky radiance measurements should be taken at a distance that minimizes the effects of both shadow and reflection of the structure supporting the equipment (MUELLER, 2000). According to Mobley (1999), the radiometer is generally oriented at right angles to the direction of the Sun (see Figure 2). This configuration allows that radiometric with minimal noise resulting from environmental conditions. Ignoring the above recommendations may compromise the quality of the measured data.

According to NASA's protocol (MUELLER *et al.*, 2003), it is useful to store additional information of *in situ* acquisition radiometric data, such as geographic coordinate, date and time of sampling. Furthermore, wind speed and direction data are required for calculation of reflected skylight and the sun glint in radiative transfer models e.g. HydroLight 5.2 (MOBLEY and SUNDMAN, 2013). Cloud cover information is also important to characterize the radiometric data quality, since the irradiance that reaches the sensor is dependent on the incoming light over the atmosphere, and if the sky is overcast, the amount of energy reaching the sensor is affected by inducing different qualities into the observations.

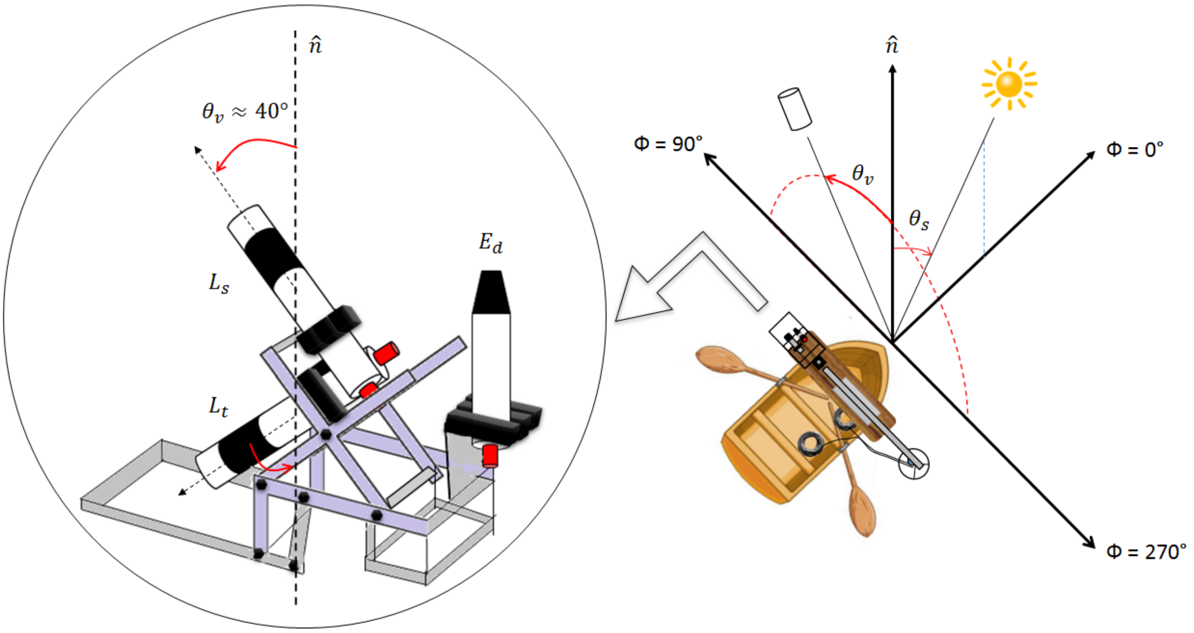


Fig. 2 - (a) Angle ($\theta_v$) of the sensors to avoid specular scattering (Mobley, 1999) (b) Geometry of the sensor relative to the Sun used for radiometric measurements, represented by zenith angles ($\theta_s$), and azimuthal ($\phi$) and nadir ($\hat{n}$).

It is suggested by the NASA's protocol (NASA/TM-2000-209966) to take pictures of the sky during the measurements in the field to support the interpretation of the results. Moreover, the protocol also recommends acquiring data about the water transparency by using a Secchi disk (SD) to provide information to the radiometric profile analysis and a portable depth finder can be used for analysis of the water bottom reflection contribution, which could affect the water-leaving radiance. Additional data, such as conductivity, temperature and pressure (CTD), provide suitable information about the physics of the water mass. CTD offers depth information from the pressure data and can be related to optical measures collected by absorption, attenuation and backscattering equipment.

## 2.3 Analysis and Remote Sensing Reflectance Estimation

The radiometric data collected in aquatic systems can be used to determine the diffuse attenuation coefficient ($k_d$) of light in water, as well as the ratio of irradiances ($R$). In our paper, focus is given only for measurements of remote sensing reflectance ($R_{rs}$), responsible for the feedback regarding the interaction of OAC and electromagnetic energy. The quality of $R_{rs}$ defines the accuracy of the models to retrieve the OAC concentration (HOMMERSOM *et al.*, 2012).

According to Mueller (2000), the method that defines the $R_{rs}$ takes into account the determination of the water-leaving radiance – $L_w$ as:

$$L_w = tL_u(0^-, \lambda)n^2 \tag{1}$$

where, $t$ is the Fresnel transmittance at the air-water interface (0.98); $L_u$ is the upwelling underwater radiance; λ is the wavelength; $n$ refers to the refractive index of water relative to air (1.33). Moreover, the incident spectral irradiance – $E_s$ needs to be measured. Both and $E_s$ quantities are necessary to determine the $R_{rs}$, and according to Mobley (1999), the equation is defined as:

$$R_{rs} = \frac{L_w(\theta, \phi, \lambda)}{E_s\ (\lambda)} \quad (2)$$

where $L_w$ is the water-leaving radiance; $E_s$ is the incident spectral irradiance; θ and Φ correspond to the polar and azimuthal angles, respectively, and λ is the wavelength.

Inserting the Eq. (1) in Eq. (2), we have that $R_{rs}$ is defined as:

$$R_{rs} = \frac{tL_u(0^-, \lambda)n^2}{E_s\ (\lambda)} \quad (3)$$

Dall'olmo and Gitelson (2005) used the same concept as Mobley (1999) to determine $R_{rs}$, including an immersion factor $Fi$ described by Ohde and Siegel (2003). This immersion factor was introduced in the $R_{rs}$ computation to provide a correct way to calibrate radiance measurements in water, considering the changes in the wavelength–dependent refractive index in the interface of air-glass to water-glass:

$$R_{rs} = \frac{tL_u(\lambda)n^2}{E_s(\lambda)} \times Fi(\lambda) \quad (4)$$

where $Fi$ is the spectral immersion factor (OHDE and SIEGEL, 2003).

## 2.4 Definition of Data Quality Parameters

A geographic object is described by its spatial, temporal and thematic components (VEREGIN, 1999). According to the International Organization for Standardization (ISO), spatial data quality is the degree to which a set of (spatial, thematic and temporal) characteristics fulfills (stated or implied) requirements (ISO, 2014). From the list of elements, defined for the spatial data quality in ISO 19157 (ISO, 2013), the subset of elements relevant for radiometric measurements is the following:

a) **Completeness** refers to the presence or the absence of objects, attributes or relationship in a dataset and can be expressed by two sub-elements: commission and omission.

b) **Positional accuracy** is defined as the accuracy of the absolute (closeness to the value accepted or being true) or relative (closeness of the distance between two objects in the dataset to their respective distance in reality) position (horizontal or vertical) of features within a spatial reference system.

c) **Temporal quality** is defined as the quality of temporal attributes and temporal relationships of geographic objects. Temporal quality can be expressed with the accuracy of the temporal measurement, temporal validity and consistency.

d) **Thematic accuracy** is related to the information that characterizes the geographic data. Depending on the semantics of the attribute, thematic accuracy can refer to the accuracy of the quantitative attributes, correctness of the non-quantitative attributes and to the classification correctness of the geographic objects and their relationships.

e) **Lineage** describes the history of the data by describing the source of spatial data and steps of the dataset's creation process.

The elements listed above can refer to various data quality scopes the whole database (i.e. several datasets), a dataset, part of the dataset (i.e. group of geographic objects), attributes or group of attributes. Quality information of a spatial dataset is documented in metadata (ISO, 2003). According to Hueni *et al.* (2009), there are four types of variables that must be addressed in spectral metadata:

*a) quantitative* variables representing quantitative features of the sampled object - e.g. water temperature;

*b) categorical* variables representing the a priori knowledge of the object - e.g. type of land cover;

*c) alphanumeric* variables used to represent a textual description, and

*d) pictorial* variables, which purpose is to provide additional information about the sampling site and the target itself, in the form of a photographic record.

## 2.5 Description of the study area

Nova Avanhandava (Nav) is a run-of-river reservoir, which was formed in 1982 by flooding an area of 210 km², with a usable volume of 3.8 x $10^8$ $m^3$, dam perimeter of 462 km, mean residence time of water of about 46 days and an average flow of 688 $m^3$ $s^{-1}$ (TORLONI *et al.*, 1993). Nav reservoir is characterized as oligo-mesotrophic with the upper portion of the water column well oxygenated (mean value for May of 2009 equal to 4.87 mg/L), pH ranging from slightly acid to alkaline (6.92), and conductivity relatively high (mean value of 177,51 µS.cm$^{-1}$, for May of 2009) (DOS SANTOS, 2010).

## 3. METHOD OF ANALYSIS

The dataset used for the analysis as well as the methods applied to achieve the main goal of this research is explained in the next sections.

3.1 Datasets

Two campaigns were carried out in Nav reservoir in two different periods: the first in Austral spring of 2011 (C01) and the second in Austral fall of 2014 (C02). For the C01 we used an ASD FieldSpec® portable spectroradiometer, model HandHeld UV/VNIR with a spectral range from 274 nm to 1085 nm. For the C02 we used the TriOS spectroradiometers with spectral resolution ranging from 320 nm to 950 nm configured to acquire data using six sensors: three to measure radiance and three to measure irradiance. Garmin GPSMAP78 and ArcGIS 10.1 were used for acquisition of the geographic coordinates and for data post processing, respectively. In addition, a camera registered the sky conditions and land use and land cover of the lake's watershed.

### 3.2 Data Analysis

The flowchart presented on Fig. 3 guides the acquisition process of radiometric data through systematic steps ranging from the planning field campaign, data acquisition and generation of spectral curves of $R_{rs}$ and other radiometric quantities documented in the output database.

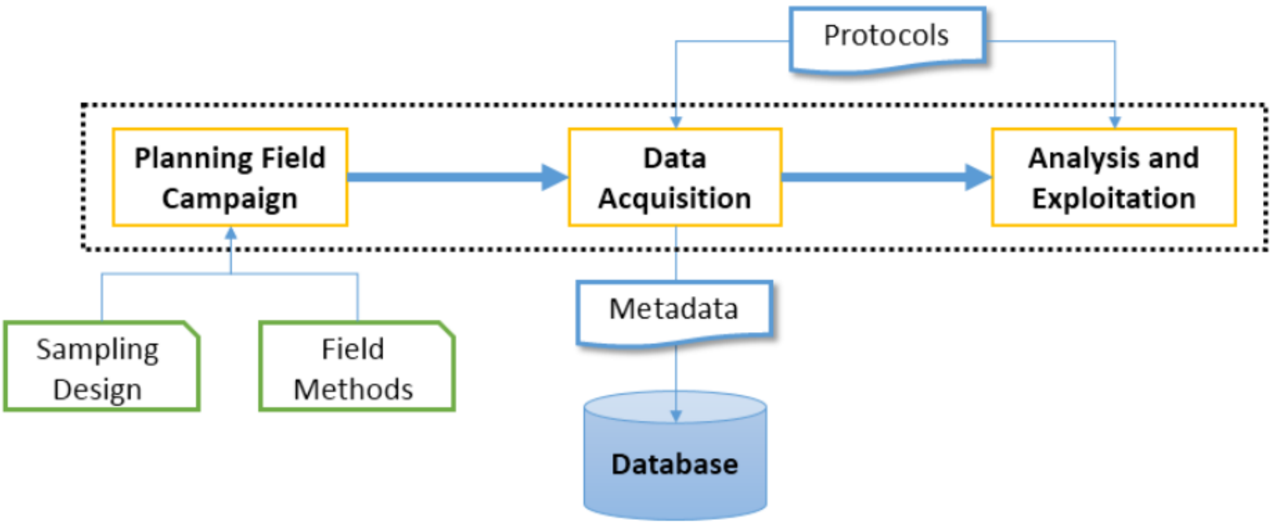


Fig. 3 - Flowchart showing steps that must be taken in consideration to get reliable radiometric data in aquatic systems.

The first step was the elaboration of a statistical method to select sampling points focused on the acquisition of spectral data of aquatic targets. The second step involved the collection of radiometric data and the last step was the production of  curves through spatial analysis.

Field campaign C02 was carried out in 2014 according to NASA/TM-2000-209966 protocol using statistical scheme for planning a field campaign. We compared C02 with C01 field campaign performed in 2011. The steps of the field campaigns execution are depicted on Fig. 4.

The main aspect that grants reliability in spectral curves is the absence of the sun glint effect. This effect can compromise the results destined to provide bio-optical algorithms to retrieve OAC concentration and characterize the water quality.

The procedure for field survey planning included the determination of sample points using Landsat-8 (OLI - Operational Land Imager) images in the dry season for representing high spectral variability. The sample points were chosen automatically by the method of stratified random sampling in the Hawth's Tools enabled for ArcGIS software (Rodrigues *et al.*, In Press).

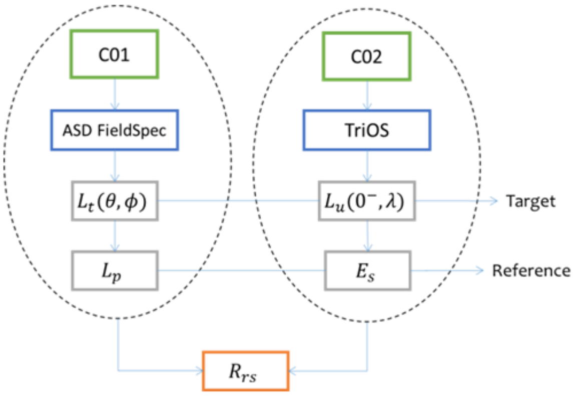


Fig. 4 - Flowchart of the methods used for both campaigns. The C01 campaign collected one measure of the target $L_t$ which is the sum of a portion of the $L_s$ and the $L_w$; and other measure known as radiance of the plaque ($L_p$). The C02 campaign collected one measure referred as the upwelling radiance below water surface $L_u(0^-,\lambda)$

As the aim of our research was to avoid spectral response of the bottom of the reservoir, we adopted a buffer of 200 m from the edge of the reservoir, and in the field, the depths of the sample spot were taken before implementing the radiometric measures, and we only measured at depths deeper than seven meters.

The identification of sample points is critical for spatial and behavioral inferences and their environmental context. For the acquisition of radiometric data, we followed a routine operation which consisted of:

I. Positioning the boat, as suggested by Mobley (1999), relative to the Sun, (see Figure 2),

II. Simultaneous measurements (15 in total) with the sensors below (0-) and above (0+) the water, indicating calibration files for use in water or in the air. This redundancy is to avoid the abrupt change of luminosity and surface wave's effect;

III. Photographic record of the water, sky and surroundings, in order to characterize the environmental and weather conditions at the acquisition time (Fig. 5), and

IV. Information of environmental conditions (cloud cover, ambient temperature, air pressure, wind speed and direction), photo of the land cover around the water body, time and date (UTC).

The radiometric data are stored in a database containing information about the sensor, date and comments including sampling name, name of the study area and water depth. These data were later used to estimate the . For database creation, we followed the steps described by BOJINSKI *et al.* (2003); the details of this process are beyond the scope of this paper.

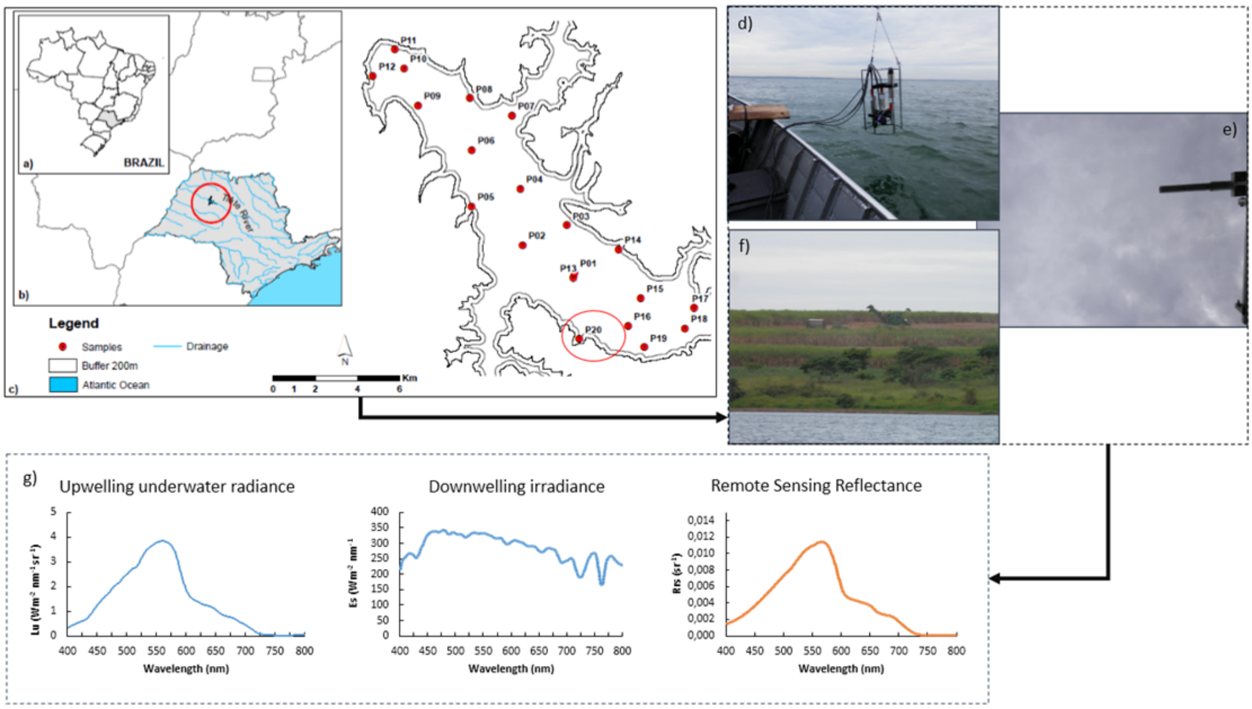


Fig. 5 - Photos of point 20. (a) Map of Brazil with São Paulo state in grey, (b) location of the Nova Avanhandava reservoir in São Paulo state, (c) distribution of samples; (d) water level and wave height; (e) sky condition including cloud cover; (f) land cover next to the sample spot and (g) spectral curves related to $L_u$, $E_s$ and $R_{rs}$.

## 4 RESULTS AND DISCUSSION

In this section, we discuss the main aspects related to data quality of radiometric measurements relevant for the case study in Nav reservoir by comparing two field campaigns.

### 4.1 Case study: C01

The C01 campaign was executed in September, 2011 using the ASD FieldSpec Spectroradiometer. During the measurements, two radiometric quantities were acquired: one of the target (water surface) $L_t$, and one of the reference plaque (Spectralon) $L_p$.

According to Eq (2), the $R_{rs}$ is a ratio of $L_w$ and $E_s$ and, as defined in (Mobley, 1999), the $L_w$ is a subtraction of $L_t$ and the surface-reflected portion of the $L_s$ is called $L_r$. Therefore, the $R_{rs}$ can be rewritten as:

$$R_{rs} = \frac{L_t - \rho L_s}{E_s} \tag{5}$$

where $p$ is the proportionality factor that relates two radiances: one when the detector is pointed to the sky and the other when it is pointed to the water target. Mobley (1999) suggests the use of $p \approx 0.028$ for wind speed less than 5 m s$^{-1}$ or for measurements under an overcast sky.

Without the contribution of the sky radiance it is almost impossible to obtain direct determination of water-leaving radiance using sensors above water surface (DEV and SHANMUGAM, 2014). As C01 results show on Fig. 6, the spectral curves represent $R_{rs}$, which relates the $L_t$, $L_p$ and a calibration factor (RUNDQUIST *et al.*, 1996).

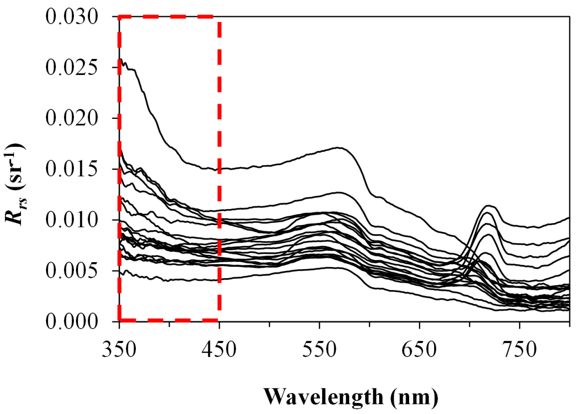


Fig. 6 - Spectral curves of $R_{rs}$ related to C01 campaign. The dashed rectangle is depicting the UV-blue region that is been affected by the sun glint effect.

As we can see on Fig. 6, the UV-blue region (350 – 450 nm, highlighted in red color) presents a power function with a decreasing pattern which is attributed to the sun glint effect (KUTSER *et al.*, 2013). This effect is spectrally dependent and its magnitude is affected by the water surface waves, cloud cover, acquisition geometry of the sensor, sun elevation and azimuth, wind speed and direction (GOULD *et al.*, 2001, KUTSER *et al.*, 2013, GARABA and ZIELINSKI, 2013). The sun glint effect can be removed by using one of the available methods, such as the one described in (STREHER *et al.* 2014). Without this correction, the $R_{rs}$ cannot be used accurately to estimate OAC concentration.

The curves presented on Fig. 6 present two peaks characteristics of vegetation influence. The peak near 550 nm and 720 nm suggest the presence of floating macrophytes in the water. (WATANABE *et al.*, 2013). However, it is also noticed in some spectral curves the absence of the peak at 720 nm, which means that the floating vegetation or phytoplankton influence is very low and the inorganic matter fraction is more evident.

In general, measuring the by directing the spectroradiometer straight up to the sky, it would be possible to estimate the according to Eq (5). The lack of useful data such as those explained in sections 2.1 and 2.2 compromise the progress of a campaign, therefore, the utilization of protocols of acquisition and analysis could be decisive to achieve better results.

### 4.2 Case study: C02

$R_{rs}$ spectral curves without sun glint effect (Fig. 7) were estimated following the NASA/TM-2000-209966 protocol of acquisition and analysis (Eq. 4). For planning field campaign, we used the method described in Section 3.2.

The radiometric measurements above and below water surface were registered and depicted in graphic plots. Following additional information was collected for further characterization of the study area: pictures of the site spot, sky condition and the edge of the lake (Fig. 5), date and time of collection, wind speed and others limnological data.

The spectral curves presented on Fig. 7 show the presence of phytoplankton influence in Nav reservoir. The observed reflectance peak near 720 nm from the previous field data (see Fig. 6) was not observed in the C02 field campaign.

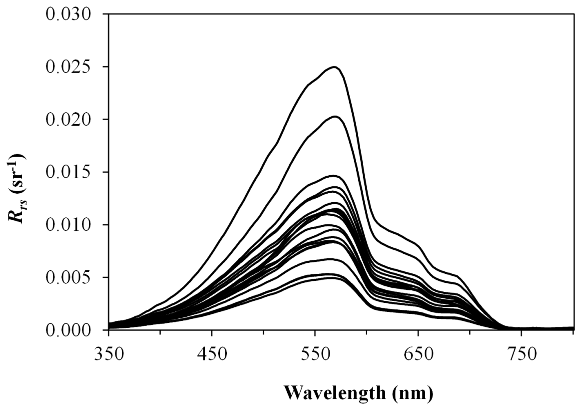


Fig. 7 - $R_{rs}$ spectral curves related to C02 campaign.

### 4.3 Curves of C02 With and Without Quality Control

A comparison between the spectral curves with and without sun glint effect correction (see Fig. 8) shows a difference in magnitude, especially in blue spectral region.

As visible on Fig. 8 as well as confirmed by a *t*-test ($\alpha$ = 5%) the two spectral curves are different from each other ($p$ = 0.000). We can conclude from the above that data acquisition is not the only limiting factor for the quality of the final data, but the analysis following recommended protocols are also relevant.

As presented on Fig. 9, the UV-blue region presents the highest standard deviation indicating that along this region the discrepancy between both curves is steeper than in other spectral regions. These particular wavelengths are extensively affected by the atmospheric scattering and without the proper correction this noise can be embedded to the $R_{rs}$ curve (REES, 2001).

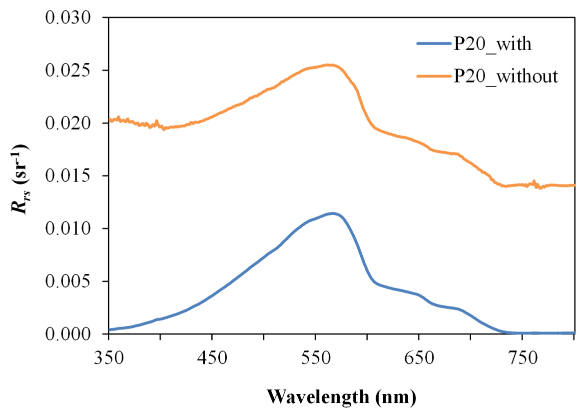


Fig. 8 - Spectral curves related to point 20. The upper curve represents the spectral curve without sun glint effect (P20_without), and the lower represents a curve with sun glint correction (P20_with).

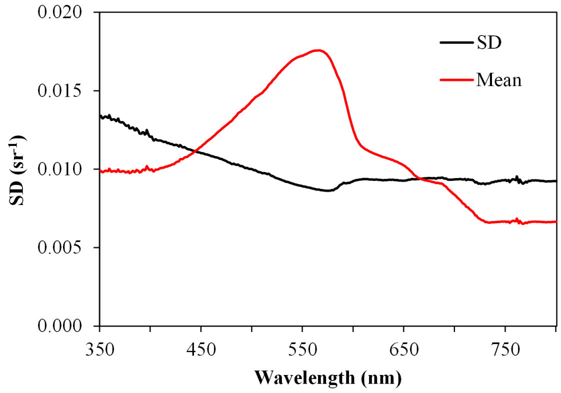


Fig. 9 - Standard deviation between two spectral curves: one with sun glint effect and referred as without quality control and other without the sun glint effect and referred as with quality control.

### 4.4 Data Quality Parameters Applied to the Case Study

Radiometric, environmental and meteorological measurements are stored as attributes of every sample in a database. Below we discuss the relevant data quality elements for radiometric measurements defined in Section 2.4.

The **completeness** represents the presence or absence of the features in the dataset. In our research, a feature is a radiometric measurement with its respective attributes and geographic location. These features contain valuable information that cannot be suppressed or omitted. However there are regions in the reservoir, which can be considered spectrally homogeneous, and therefore, a low variability in radiometric data is expected, which may possibly cause features omission. The samples collected in the field must be free of omission, however, some attributes such as, the name of the collector or even the pictures registered from the sky, can be omitted without compromising the survey. To estimate the acceptable percentage of omission a detailed experiment must be conducted. .

When the geographic location of the sample is not registered, it becomes more difficult to show correspondence between the radiometric properties and local environmental characteristics, as well as, the particularities of the water body, such as the water color. Thus, it is of utmost importance put on record the geographical location of the point collected.

The delineation of the geographical location of each measure is necessary. However, in the case of an aquatic system, the **positional accuracy** (horizontal and vertical) becomes unimportant due to variability of the target, accepting the accuracy of GPS used for localization of the sample.

The **temporal accuracy** is linked to the time, in which the measurements were acquired. The radiometric variables are subject to changes over time; they depend on the environmental and anthropogenic evolution of the studied aquatic system. Moreover, certain features such as the presence of phytoplankton become more or less evident in a particular month of the year. Thus, it becomes mandatory to register the hour and month that the measurement was made. This allows the analyst to make inferences regarding the collection period and the results obtained. The absence of this information may decrease the quality of the output, because it would contain environmental noise.

The **lineage** records the history of data acquisition, reporting source and references to the operator who collected the sample in the field. This information helps judging the reliability of sample acquisition. The absence of documentation relative to some steps of acquisition, processing and post-processing can be an obstacle in replicating the technique in order study sites and provide comparable conditions. Information such as the equations applied to retrieval of remote sensing reflectance could be very relevant.

**Thematic accuracy** refers to the attribute values related to the sample. Rule adopted in the radiometric measurements is the more detailed attributes the better characterization of the sample spot, leading to a better understanding of radiometric properties and the respective relation with others variables, such as the environment. The attributes must follow requirements defined before data acquisition. The lack of attributes results in a product with low quality and may even compromise the usage of the measure.

We suggest additional metadata (adapted from (BOJINSKI *et al.*, 2002; HUENI *et al.*, 2009) for the SPECCHIO database) for the hyperspectral datasets containing radiometric data of aquatic system (Fig. 10).

| *Group* | *Variable* | *Description* |
|---|---|---|
| *General/Campaign* | Campaign name | Name defined to the campaign |
| | Campaign description | Description of the campaign |
| | Investigator | Person responsible to the campaign |
| | File path | Directory of the campaign data |
| *Spatial and temporal information* | Register date and time | Date and time of the sampling |
| | Latitude | Spatial sampling position |
| | Longitude | |
| | Depth | Depth of the measurement |
| *Target information* | Landcover type | Define a reference to landcover type i.e. FAO |
| | Spectrum name | Name of the target |
| | Hand sample | ID name of the sample directly collected in the field |
| | Pictures | Images depicting the target |
| *Sampling geometry* | Sensor zenith angle | Measured from nadir, i.e., nadir=0 |
| | Sensor azimuth angle | Relative to the illumination angle |
| | Illumination zenith angle | Illumination source zenith angle measured from nadir |
| | Illumination azimuth angle | Measured from geographic North |
| *Measurement details* | Number of measures | Number of redundancy of spectra |
| | Sensor/Instrument | Sensor model/serial number |
| | Instrument calibration number | Number of the instrument calibration |
| | Measurement type | Single, directional, temporal |
| | Measurement unit | Irradiance or radiance |
| *Environmental conditions* | Cloud cover | Covering the sun or not |
| | Ambient temperature | Air temperature degrees |
| | Air pressure | Air pressure in hPa |
| | Wind speed/direction | Speed m/s/direction |
| | Wave | Absent, Small, medium or high |
| | Water color | Transparent, little green or green |
| *File information* | User comment | Comment added by the user |
| | Spectral file name | Name of the spectral file |
| | File format | File format of the spectral file |

Fig. 10 - Metadata parameters applied to spectroradiometric measurements, adapted from SPECCHIO database requirements.

## 5. CONCLUSION

The requirements necessary to maintain the radiometric data quality focused on bio-optical characterization of water bodies are defined by the acquisition and analysis protocols developed by NASA and other researcher in hydrologic optics. However, there is information inherent to the radiometric data that must be recorded in order to support data interpretation, as well as ensuring the long-term usability and provide a basis for assessing the quality. To follow the required steps to ensure data quality, a case study of Nova Avanhandava reservoir was used, and the purpose was to present the reality of the radiometric data collected in reservoirs in Brazil. As a result, we presented a flowchart with data acquisition steps, analysis of the spatial data quality elements relevant for the study of radiometric data, a comparison between two datasets displaying curves with and without quality control. Moreover, we proposed additional metadata related to spectroradiometric data based on SPECCHIO database to enrich the data quality information of radiometric measurements of a water body. In this work we highlighted the main phases of the acquisition and processing steps of radiometric measurements of water body analyzed the quality elements relevant for such measurement. However, the quantitative assessment of the relevant data quality elements remains the objective of future research, in which we intend to propose requirements for acceptance of the radiometric measurements collected in the field as established by NASA/TM-2000-209966 protocol, and provide the structure of a database and metadata related to radiometric data of water.

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