MERMAID: The MEris MAtchup In-situ Database

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1. ABSTRACT

In the frame of the activities of the MERIS Validation Team (MVT) and Quality Working Group (QWG), a database centralising in-situ optical measurements has been set up. The long-term objectives of this database are to a) enable the assessment of the MERIS Level 2 (L2) products delivered by the ENVISAT ground segment, b) support the monitoring of these MERIS products over the lifetime of the mission by providing a complete temporal coverage of the mission and c) support vicarious adjustment of the instrument and atmospheric correction. The database contains in-situ fully normalised water-leaving reflectances with concurrent and comparable extractions of the MERIS L2 products (including flags and auxiliary data). The database contains data from sources such as AAOT (PI: G. Zibordi), BOUSSOLE (PI: D. Antoine) and MOBY (PI: M. Ondrusek). Further data are being acquired from a broader range of PIs through an invitation to contribute to this central tool in the MERIS validation strategy. These data are currently available to the members of the MERIS QWG under the strict data access policy of their original provider, but a future aim is to create a subset for wider distribution.

2. INTRODUCTION

Assessment of MERIS L2 products is at the core of the MERIS Validation Team (MVT) and Quality Working Group (QWG). Within this framework fall the calibration and validation activities essential to product assessment and quality assurance (e.g. [1; 2]) An integral requirement for such activities is a reliable source of in-situ radiometric data, inclusive of the metadata and parameters required for the calibration and validation research and decision making. While satellite-borne ocean colour instruments such as MERIS are capable of providing a regular, synoptic view of the Earth's oceans, concurrent in-situ measurements for calibration and validation (cal/val) are not nearly as plentiful as would be desired. Even field campaigns that plan to take measurements to coincide with a sensor overpass are constrained by weather (e.g. clouds), sea conditions and time, and therefore can't always collect a dataset that provides the quantity and quality of data required. A number of projects exist that aim to abate this issue to some extent, notably the SeaWiFS (Sea-viewing Wide Field-of-view Sensor) Bio-optical Algorithm Mini-workshop (SeaBAM) [3], which ultimately gave rise to the SeaBAM dataset (SBDS) [4; 5]. The SBDS, while still realising continued value to refinement and verification of bio-optical reflectance models, suffers from the limitation of not including associated metadata (i.e. temporal and spatial information) which renders it unusable to projects aiming to match with sensor-derived data. The SeaBASS effort (SeaWiFS Bio-Optical Archive and Storage System) [6], has taken the concept further by collating modern data sets, largely from NASA-funded researchers and voluntary contributions [6-9] and retaining detailed metadata coincident with a wide-ranging suit of parameters. The NASA bio-Optical Marine Algorithm Data set (NOMAD) is a publically-available subset of this database.

Other strategies exist for the dedicated purpose of cal/val. The BOUSSOLE cruise and mooring programme [10-12] was specifically designed to provide a time-series of optical properties in the Mediterranean Sea, in support of MERIS. It encompasses a monthly cruise programme, and permanent optical mooring and a coastal Aerosol Robotic Network (AERONET) station [13]. AERONET-Ocean Color (AERONET-OC) is an additional framework supporting ocean colour validation activities through standardized radiometric measurements in coastal water [14]. Current AERONET-OC measurement sites include the Acqua Alta Oceanographic Tower (AAOT) in the northern Adriatic Sea [15]. The strategy employed for the cal/val of SeaWiFS and the Moderate Imaging Spectrometer on board AQUA (MODIS-A) similarly relies on a permanent marine optical buoy, MOBY [16-18] for continuous radiometric measurements.

There is a requirement within the ESA MERIS QWG for a MERIS dedicated database: in-situ matchups to not only support QWG cal/val activities, but also to enable the assessment of the MERIS L2 products delivered by the ENVISAT ground segment, and to support the monitoring of MERIS products over the lifetime of the mission by providing a complete temporal coverage of the mission. ESA-funded researchers now have the potential to contribute to the development of this valuable resource. It differs in intent from SeaBASS in that the aim is specifically to provide sensor matchups, not just the in-situ data.. MERis MAtchup In-situ Database (MERMAID) was created to satisfy this aim, and currently holds matchups for in-situ normalised water-leaving reflectances (ρ_{wn}) together with MERIS L2 product extractions.

3. METHODS

3.1. Data acquisition

Currently, the BOUSSOLE programme, AAOT and MOBY provide data to MERMAID under existing agreements with the relevant PI. Efforts have initially focused on contacting European PI's routinely involved in making in-situ radiometric measurements and sending an explanatory letter of introduction and project outline. The letter outlines the aim of MERMAID and invites the PI to contribute their data, especially if their research has been ESA funded. The effort is now being extended outside Europe; ARGANS is the initial point of contact, and together they negotiate an agreement of use and the data is provided in a suitable format.

Currently, PI's are asked to submit their radiometric measurements (water-leaving reflectance, ρ_w, or water-leaving radiances, L_w) along with coincident metadata i.e. temporal/positional information such as time, date, latitude and longitude), and any other data such as chlorophyll-a (Chl), suspended particulate matter concentrations and primary inherent optical properties i.e. total absorption, $a_t(\lambda)$; backscattering $b_b(\lambda)$; component IOPs (i.e. those contributing to $a_t(\lambda)$ and $b_b(\lambda)$. Chl is useful to the normalisation procedure, but additionally it is envisaged that in the future the database will be extended to other parameters. Additional information such as the instruments used and the protocols followed is also requested, and indeed it's a requirement of potential usage in matchups that adherence to a known protocol is confirmed. For instance, BOUSSOLE, MOBY and AAOT all have their own protocols strictly adhering to well-established methods of radiometric measurement (see the relevant publications for further details).

3.2. Processing

MERMAID presently does not strictly specify a format for data submission. The reason for this is that as long as the aforementioned metadata and radiometric measurements are received, it's a relatively simply process to convert to $\rho_{w,}$ from which ρ_{wn} is calculated. Further development of the database will likely include a change to this policy such that specific requirements are made, but presently the processing includes formatting to a fixed MERMAID template. Ideal requirement for submission to the database are that the radiometric data are not normalised, as it is preferable to be sure of consistency in the normalisation procedure, and that the data are no affected by sun glint.

a. Data formats and conversion

Currently held in the database are BOUSSOLE, MOBY and AAOT (Table 1). BOUSSOLE contains Chl, $\rho_w(\lambda)$, the solar zenith angle, θs, and the relevant metadata. AAOT contains water leaving radiances $L_w(\lambda)$, normalised water leaving radiances $L_{wn}(\lambda)$, aerosol optical thickness $\tau_a(\lambda)$, atmospheric diffuse transmittance $t_d(\lambda)$ and the metadata. MOBY contains $L_w(\lambda)$, and $L_{wn}(\lambda)$, and downward solar irradiance, $E_s(\lambda)$. Not all data are at MERIS bands, and a spectral interpolation is necessary to correct for this.

The initial stage of processing requires standardisation of the data to a common template convenient for the whole processing procedure. The in-situ template consists of the geographical and temporal information, θ_s (calculated from date, time, latitude and longitude if not measured), Chl (if available), depth and $\rho_w(\lambda)$. Additionally, the traceability of the data is considered essential and the template retains the site and the PI name.

Table 1: In-situ data sources currently available. Water type as defined by [19].

Site	Lat / Lon	Water type	Relevant Data
AAOT	45.314°N, 12.508°E	Case 1 & 2	$L_w(\lambda)$, $L_{wn}(\lambda)$, $\tau_a(\lambda)$, $t_d(\lambda)$
MOBY	20.822°N, 157.187°W	Case 1	$L_w(\lambda)$, $L_{wn}(\lambda)$, $E_s(\lambda)$.
BOUSSOLE	43.367°N, 7.9°E	Case 1	$\rho_w(\lambda)$, Chl, E_s

Radiometric data is received in a variety of forms, and to add $\rho_w(\lambda)$.to the template a conversion may be required. In the case of BOUSSOLE, $\rho_w(\lambda)$.is already received. AAOT is provided as $L_{wn}(\lambda)$ - the procedure of this normalisation being consistent with the MERMAID protocol - and does not require normalisation after the conversion to ρ_{wn} by:

$$\rho_{wn} = \frac{\pi L_{wn}(\lambda)}{F_0(\lambda)} \qquad (1)$$

where: F_0 is top of atmosphere solar irradiance

For MOBY, although $L_{wn}(\lambda)$, is provided, $L_w(\lambda)$ is taken to ensure consistency in the normalisation procedure.

$$\rho_w = \pi \frac{L_w(\lambda)}{E_s(\lambda)} \qquad (2)$$

where: E_s is downwelling irradiance.

b. Matchup with L2 MERIS data

Level 0 (L0) MERIS data are received by ACRI-ST through DDS (Data Dissemination System) and locally archived. From the geographic and temporal information, ACRI-ST processes the relevant L0 products with the MERIS Ground Segment data processing prototype, (MEGS 7.4) up to L2. MEGS is developed in ACRI-ST and is in line with the MERIS IPF (Instrument Processing Facility). A custom processing of the L0 data is required as some of the MERMAID data are not available in standard Level 1 (L1) or L2 products and have to be extracted from intermediary products From these MERIS data are extracted a range of products, coincident with the in-situ information. Extraction is achieved on a 5x5 reduced resolution pixels around the site corresponding to in situ acquisition. The web interface (Figure 1) allows the user to extract the data for a 1, 3x3 or 5x5 pixel grid as well as for a number of criteria. The default extraction criteria follows that of [20]:

- Difference in time between MERIS and the in-situ measurement does not exceed 3 hours.
- At least 50% of the pixels in the box are not flagged as land, cloud, medium-glint, or ice haze, or PCD-1-13 or PCD-19. The latter two flags correspond to a failure in atmospheric correction and thus depend highly on the algorithm itself. However [20] recommend their inclusion.
- For a given wavelength, the mean, $\overline{\rho_w}$, and standard deviation, σ, of ρ_w, is evaluated over non-flagged pixels and then filtered statistics are computed on points such that: $(\rho_w - \overline{\rho_w}) < 1.5.\sigma$. Finally the, coefficient of variation (CV), defined as the ratio of filtered σ over filtered $\overline{\rho_w}$, must be below 0.15. If not, the ρ_w is considered invalid. This is done band per band, allowing some reflectances to be selected and other not.

The web interface is however very versatile in allowing the user to specify its own extraction criteria. Of the products extracted, and additional to $\rho_w(\lambda)$, aerosol optical depth at 560 nm ($\tau_{aer}(560)$), θ_s, senor view angle (θ_v), the azimuthal difference between sun and sensor (dφ) and wind speed are necessary to perform normalisation. All are added to the MERMAID template already containing the in-situ data.

c. Normalisation of in-situ and sensor ρw

The final stage of processing, prior to upload on the extraction site, is the normalisation on both the in-situ and MERIS $\rho_w(\lambda)$. To ensure consistency, this is carried out in the same way to each set of data. Normalisation is done as in the MEGS processor, using a lookup table for *f/Q* and following Morel [21-23] thus:

$$\rho_{wn}(\lambda) = \frac{\rho_w(\lambda).\Re_0.\left[\frac{f_0}{Q_0}\right].(\lambda, Chl, w, \tau)}{\Re(\theta', w).\left[\frac{f_0}{Q_0}\right].(\lambda, hl, \Delta\phi, \theta', \theta_s, w, \tau)} \qquad (3)$$

where:

$\theta' = \arcsin(\sin(\theta_v)/n_w)$ and n_w is the water refractive index.

$$\Re_0 = \Re(\theta' = 0, w = 0)$$

$$\left[\frac{f_0}{Q_0}\right](\lambda, Chl, w, \tau) = \left[\frac{f_0}{Q_0}\right](\lambda, Chl, \Delta\phi = 0, \theta' = 0, \theta_s = 0, w, \tau)$$

Chl is known from in-situ or computation.

$\tau = 0.2$

4. DATA AVAILABILITY AND DATA POLICY

Following formatting and normalisation, the matchups, and a RGB image, are made available on the 'CalVal portal', a website providing support for cal/val activities. The Portal is a tool for the Committee on Earth Observation Satellites (CEOS) to provide the GMES (Global Monitoring for Environment and Security) programme with the best products and information available. By providing data such as MERMAID, documents and information, the Portal aims to increase measurement activity of all sensors (infrared and visible). The site is maintained by Brockmann Consult, and provides a link to MERMAID at (http://calvalportal.ceos.org/CalValPortal/mermaid).

Extraction is subject to agreement to a number of terms and conditions. Primarily MERMAID is a QWG facility, and the extraction site is password-protected. The potential value of this matchup facility is such that in encouragement of in-situ data submission, PI's whose data can be matched and included in the database are provided access. The goal of this recently-introduced policy is for the mutual benefit of the QWG and, it is anticipated, the PI.

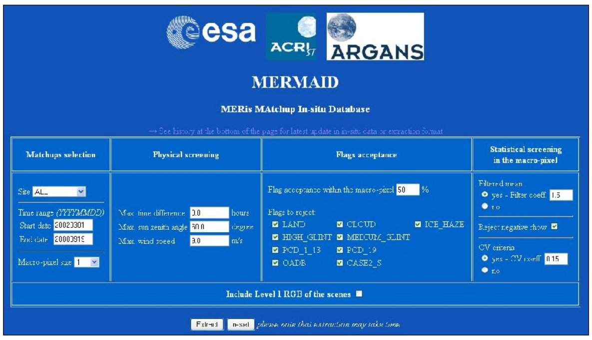

Figure 1: The MERMAID extraction page, on the CalVal portal.

The extraction page (Figure 1) is an interactive site wherein the user can specify a number of selection criteria. From the datasets available, the user can select a specific site (e.g. MOBY or BOUSSOLE) or the whole set, and temporal range of interest. Further, specific criteria to select from include the number of pixel from 1, 3x3 and 5x5; physical screening (time difference from the overpass, sun zenith angle, wind speed); flag acceptance/rejection (e.g. glint, land, cloud, ice haze, case 2) and level of acceptance; and a number of statistical options.

Maintaining traceability of the data is an important element of MERMAID and a record is kept of all PI's who have contributed data and received the password. In the extraction itself the PI name is specified, along with cruise or mooring name. Following requirement selection, the user passes to a page detailing the data use policy; it makes clear the PI's ownership of the in-situ data in the database, and elucidates the right of the PI to be named as an author in any publication arising from use of the data and matchups. In proceeding to make an extraction the user agrees to these terms, and receives a download link for their matchups in CSV format.

5. CURRENT AND FUTURE DEVELOPMENTS

For the time being, the MERMAID effort is focused on in-situ ρ_{wn}, and recently, the latest set of radiometric measurements from BOUSSOLE was added to MERMAID. Currently in preparation are NOMAD and SIMBADA (PI: Pierre-Yves Deschamps; [24]). There is, however, considerable interest within the QWG, in expanding the number of parameters available to include Chl (used where available in the normalisation procedure), the aerosol optical thickness and Angstrom exponent (useful in atmospheric correction, validation and the vicarious adjustment process). To this end MERMAID will likely be upgraded in the future.

Furthermore, the database will include matchups for not only case 1 but case 2 waters also. AAOT already contains some case 2 data, but the goal will be to populate the database with more fully normalised case 2 and coastal matchups. For this the Neural Network algorithm by GKSS (Pers. comm. Roland Doerffer) is currently being tested, for normalisation of case 2 in-situ ρ_{w}..

MERMAID aims to ensure users are provided with high quality matchups. Currently in preparation is a protocol document detailing the procedures followed for all the radiometric measurements included in the database. The document should also serve in extension to Sentinel-3, as MERMAID is envisaged to transition to this new ocean colour mission when it is launched. Furthermore, it is anticipated that as the database develops a quality-screened subset will be derived and made available for wider distribution, much like NOMAD, but with concurrent MERIS L2 (and, in time, Sentinel-3) matchups.

6. ACKNOWLEDGEMENTS AND CONTACT

The MERMAID team would like to acknowledge all contributions of data to the database and support to its development so far. Particular thanks to Brockmann Consult who host the MERMAID extraction page on the CalVal Portal.

Any enquiries, expressions of interest and contributions can be made by contacting the lead author directly or by emailing: mermaid@esa.int

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