

# DATA QUALITY CONTROL FOR OPERATIONAL SATELLITE BORNE INSTRUMENTS

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## ABSTRACT

Space-borne optical sensors can provide global coverage for a variety of surface parameters that are utilised by a large scientific community, and feed into a growing time series extending over several decades.

In order to provide optimal product performance and confidence, a stable and integrated approach to Quality Control (QC) is required. This paper sets out a general overview and description of activities carried out by the Sensor Performance Product and Algorithm (SPPA) Teams under the VEGA-lead Instrument Data quality Evaluation and Analysis Service (IDEAS) consortium. The IDEAS SPPA service is provided for the MERIS, MODIS, SeaWiFS & Landsat instruments to the European Space Agency (ESA).

The information in this paper is provided to encourage QC knowledge transfer for optical satellite sensors, and promote User confidence in ESA processed products.

## 1. INTRODUCTION

Many space-borne optical sensors provide global coverage of a variety of parameters such as Ocean Colour (above surface reflectance of visible light), Sea Surface Temperature (SST) and Land parameters. The QC and support for ESA-processed products from the MERIS, MODIS (Aqua and Terra), SeaWiFS and Landsat (5 and 7) optical sensors is provided through SPPA Teams based at ARGANS - with expert support from ACRI-ST and Gael Consultant - under the VEGA-lead IDEAS consortium.

In addition to providing specific QC activities and reporting for the individual sensors, the SPPA Teams located at ARGANS form part of the wider IDEAS Optical Group - which also includes the AATSR, ALOS-AVNIR-2, ALOS-PRISM, and JERS-1 instruments, and provides monthly reporting on all activities to ESA.

Several systematic and manual activities have been developed and are performed by all SPPA Teams in order to provide consistent QC and provide expert support to the global remote sensing community.

## 2. MERIS

The Medium Resolution Imaging Spectrometer (MERIS) instrument is a programmable hyperspectral radiometer onboard ESA's ENVISAT satellite [1]. It has been providing optical measurements in the solar reflective range (visible to near-infra-red, NIR) since 2002. The daily coverage of the MERIS instrument is approximately 15 orbits, and on several product levels (FR, FRS, RR, RRC, RRV and Browse). These products are generated in both Near-Real-Time (NRT) using predicted auxiliary data and downstream (Consolidated) processing that uses definitive auxiliary data. Pixel resolution is 300m for MERIS Full Resolution (FR) products and 1200m for Reduced Resolution (RR).

The primary mission of MERIS is Ocean Colour. However, due to its wide spectral range, and global coverage within 3 days, MERIS data is utilised in a number of important geophysical areas for both Land and Ocean research, and feeds into the growing debate on aspects of climate change. Fig. 1 is an RGB colour image of an oil spill in the Gulf of Mexico acquired by MERIS on 21<sup>st</sup> May 2010.



Figure 1: An RGB colour composite of an oil spill in the Gulf of Mexico acquired by MERIS on 21<sup>st</sup> May 2010.

In order to maintain User confidence in its production, MERIS is supported by a number of detailed QC activities to deliver the optimal product to Users. At present, the MERIS SPPA Team (located at ARGANS with expert support from ACRI-ST) provide day to day

monitoring of product generation and sensor performance, as well as validation activities required as a consequence of evolutions to the data handling architecture at ESA ground stations.

### **2.1. MERIS Product Quality Control**

Daily MERIS production is monitored through automatically generated reports. These reports contain information on the duration of all products (across all product levels) for each orbit – and thereby support NRT monitoring of the operational state of the instrument. The Daily Report (DR) [2] can also be used to highlight any delays in dissemination to the ESA Ground Stations and their Rolling Archives (RA). The MERIS DR is supplemented by the use of a Quicklook report which is automatically updated throughout the day, thereby allowing a visual assessment of product quality in NRT. Any anomalous product generation found in the Daily Reports and quicklooks are investigated by the SPPA Team, and advice is issued to ESA via the Earth Observation (EO) Help Desk ([EOHELP@ESA.int](mailto:EOHELP@ESA.int)).

The MERIS SPPA Team has also developed a tool, similar to the DR, to monitor production of MERIS Level 3 demonstration products produced by the ESA Grid Processing On Demand (GPOD) Team. A report is generated indicating the file size of the processed products, thus enabling the SPPA Team to raise any anomalous processing issues concerning missing data to the GPOD Team.

Product investigations carried out by the MERIS SPPA Team utilise a number of bespoke scripts which assess product format and header information, and BEAM VISAT [3] (Brockmann Consult), an open-source tool, for radiometric data quality and geolocation assessment.

Operational QC on Level 1 and 2 NRT products sent on media to Users is provided by the ASAR MERIS AATSR Labelling Facility Inspection (AMALFI) tool (Gael Consultant). AMALFI is provided at ESA Ground Stations, and is the offline QC tool. Any products that fail the AMALFI tests - which include product header information and visual assessment - are supplied to the SPPA Team and subjected to an in-depth investigation.

The investigation assesses the viability of the product, and whether the anomaly can be resolved via reprocessing, with the outcome of the investigation being fed back to the AMALFI operator via an online Routine Tracker (RT). The approved media is distributed in a DVD booklet format, along with the results of the SPPA Team's investigation.

AMALFI-2 is currently under development and will represent a significant development in existing MERIS

product QC. AMALFI-2 will assess all processed MERIS products and will be based on tests utilised in AMALFI and new tests developed by the MERIS SPPA Team.

### **2.2. Service Requests and Processor Evolution**

In addition to the investigation of anomalies and monitoring of product generation, the MERIS SPPA Team also provides support to ESA through the validation of new software and hardware updates. A recent evolution of this is the identification and supply of a generic MERIS Test Dataset (TDS). The TDS has been defined to allow validation of MERIS processing upon a variety of geophysical parameters (clear ocean, clear land, coastal zones and cloud cover). The TDS has also been selected to deliberately include known product anomalies - such as missing frames and errors in product consolidation. These can be used to determine the correct handling of future evolutions in Instrument Processing Facilities (IPFs) and QC tools.

In order to assess the impact of changes against existing processing, the validation of a newly-processed TDS utilises bespoke code (developed at both ARGANS and ACRI-ST) and BEAM VISAT, and thereby highlights any issues with the software/hardware update.

Recent validation activities performed by the MERIS SPPA Team include the transfer of MERIS L1 and L2 IPF from the AIX platform to Linux, and the implementation of this change at all ESA processing stations. In addition to this, the corresponding porting of the Level 0 NRT generating software has also been completed and is now operational at the Kiruna ground station; this coupled with the Linux-based IPF has provided a significant increase in the NRT processing capabilities for MERIS, and has resulted in the NRT processing of FR products over Africa. Efforts are now ongoing to improve this coverage to all acquired FR products.

The MERIS SPPA Team have also recently completed the validation for the Envisat Reduced Resolution Level 0 consolidation software (ECONS) on the Linux platform. This is expected to become operational shortly, and will be transparent to Users.

### **2.3. MERIS Scientific Community Support**

The MERIS SPPA Team offers in-depth support to the MERIS User community by its direct linkage to the MERIS Quality Working Group (MQWG). The MQWG is composed of ESA and industry engineers and experts drawn from the scientific community. The MQWG meets throughout the year to report on and determine the operational status of the instrument. It

also evaluates ongoing investigations with regard to the calibration and scientific quality of the instrument, and future needs – such as reprocessing of the mission archive. The MERIS SPPA Team are also present at MERIS Validation Team (MVT) meetings, and provide support to the calibration teams through notifications regarding planned MERIS periods of unavailability.

The MERIS SPPA Team also responds to external User requests via the ESA EO Helpdesk. This is supplemented by allowing the entire data QC procedures - including daily reporting and Long Loop Sensor Analysis (LLSA) - through a variety of media including: documentation, a newly-formed User forum entitled ODESA [4], and FAQs, with comments, feedback and questions actively encouraged to ensure the ongoing evolution of the data quality of the mission.

#### 2.4. ENVISAT 2010+

The planned lifetime of the ENVISAT platform was due to be bought to a close in 2007. However, precise management of orbital control manoeuvres throughout the intended lifetime of the mission enabled enough fuel to be set aside to allow nominal operations to be extended for an additional 3.5 years (i.e. until the end of 2010).

However, by careful consideration of the individual instrument requirements, the mission will be extended to 2014. This extension, ENVISAT 2010+ [5], will be made possible by the reduction in altitude of the platform by approximately 17 km, and allowing the inclination to drift until the end of the mission – reducing the need for Orbital manoeuvres. The change in Orbit scenario will take place during the period 22<sup>nd</sup> – 26<sup>th</sup> October 2010 with nominal data production - quality disclaimers will be included - expected to resume from 2<sup>nd</sup> November 2010.

The MERIS SPPA Team will play a significant role during this period by coordinating with the MERIS QWG to assess the newly-acquired products, and determine if they are of acceptable quality to be distributed. It should be stressed that no major impact to MERIS data is expected, but routine parameters such as geolocation and radiometric quality will be subjected to detailed scrutiny. Notifications concerning the status of MERIS and the acquired products will be through quality disclaimers distributed via EO Help, web forums and email correspondence.

### 3. MODIS AND SEAWIFS SPPA

MODIS and SeaWiFS are both monitored as Third Party Missions (TPM) [6] for ESA. MODIS (MODERate Resolution Imaging Spectroradiometer) is a key instrument aboard the NASA Terra (EOS AM) and

Aqua (EOS PM) satellites [7]. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. The two MODIS instruments are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands [8].

The SeaWiFS (Sea viewing Wide Field-of-view Sensor) instrument was launched onboard GeoEYE's OrbView-2 satellite in 1997 into a sun-synchronous, descending, daytime orbit. SeaWiFS acquires radiometric measurements of the Earth's surface in eight spectral bands (visible to NIR wavelengths) [9].

#### 3.1. MODIS and SeaWiFS Product Quality Control

MODIS Level 1B products are available through the MERCI MODIS Catalogue System, an online archive from which Quicklooks, entire products, or sections of swaths can be downloaded by registered Users [10]. Products are acquired via ESA Stations at Matera in Italy, Maspalomas on Gran Canaria, and Kiruna in Sweden. Product delivery is monitored on a daily basis, and feeds into the MODIS DR. Any product anomalies are investigated through interrogation using bespoke code developed at ARGANS; outputting invalid pixel statistics, the locations of any missing rows of data and a spectrum check in a PDF report.

MODIS Aqua Level 1A and SeaWiFS Level 0 HRPT NRT products from the Matera and Maspalomas Receiving Stations are made available to Users as part of the GMES (Global Monitoring for the Environment and Security) MyOcean Dataset. MyOcean is the implementation project of the GMES Marine Core Service, aiming at deploying the first concerted and integrated pan-European capacity for Ocean Monitoring and Forecasting [11]. Fig. 2 shows a chlorophyll-*a* image generated using SeaDAS from a Matera acquired MODIS-Aqua product.

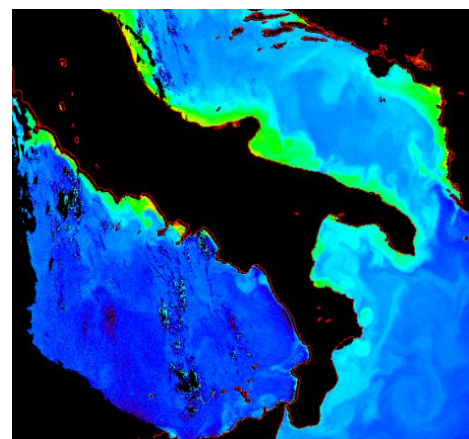


Figure 2: Chlorophyll-*a* image generated from an ESA acquired MODIS-Aqua product.

Products are made available to the User community via FTP Rolling Archives (RAs). Daily product monitoring involves download, inspection, processing and generation of quicklooks for all products using the open-source software SeaDAS [12]. Products are then archived locally for future applications - such as LLSA or specific anomaly investigations. Techniques include semi-automated download and processing capabilities and tools to map product swaths and the locations of missing frames in conjunction with the global mapping tool, Google Earth.

### 3.2. Service Requests and Validation Activities

Specific anomaly investigations have included identifying the source of missing rows of data in MODIS products and interference in SeaWiFS products leading to recommendations to alter the receiving angles of the acquisition antennae at stations. In addition, Level 0 processing parameters were recommended for adjustment at stations in line with recommendations from the MODIS Direct Broadcast Community. These actions resulted in improvements to product quality through an enhanced understanding of the behaviour of the data stream during satellite-to-ground transmission.

Recent validations have included the investigation of a number of SeaWiFS products received via Tromso, Norway, during which optimum product length was determined and the need for more accurate satellite overpass prediction at the station was identified. Further activities have seen the ongoing installation of the MEOS Polar System at the Matera station and the release the first data set of MODIS and SeaWiFS products for investigation,

In order to provide a standard suite of reference products for future validation efforts, Generic TDS have recently been compiled for both the MODIS and SeaWiFS Instruments. This provides a baseline to allow accurate comparisons when assessing the implications of both hardware and software updates.

Support to the User community has taken the form of responses to queries regarding the presence of missing frames in MODIS products, for which a process of sub-setting was recommended to allow geolocation validation during processing.

Product disclaimer documents have also been generated in response to both flight and ground segment anomalies such as a GPS outage onboard the OrbView-2 spacecraft and erroneous products resulting from a lunar calibration manoeuvre onboard MODIS AQUA.

### 3.3. MODIS and SeaWiFS Future Evolutions

Future evolutions of the service are envisaged in the form of an automated daily report for SeaWiFS based

on the MyOcean dataset and the upload of product PNG images onto the RAs to provide Users with a preview of product coverage and quality for both MODIS and SeaWiFS. Further validation of the MEOS Polar System at Matera is also imminent.

## 4. LANDSAT SPPA

The USGS Landsat mission started in 1972, and is still acquiring data to this day - providing a 38-year dataset of optical measurements. Current acquisitions are performed by the TM (Thematic Mapper) onboard LANDSAT 5 (launched in 1984) and by ETM+ (Enhanced Thematic Mapper +) onboard LANDSAT 7 (launched in 1999). Both instruments provide high resolution (30m) land coverage in the visible to thermal wavelengths of light. Landsat 5 and 7 are both in sun synchronous orbits and provide repeat coverage of an area every 16 days.

As a consequence of a failure of the Scan Line Corrector (SLC) in May 2003, no new Landsat 7 products have been acquired by ESA ground stations. Therefore ESA Landsat 7 ETM+ products cover the period 1999 to 2003 (4 years). More recent products are available from the USGS, but these contain reduced geometric precision.

In order to extend the lifetime of the Landsat 5 instrument an acquisition plan was introduced in May 2010 that is designed to result in better prediction cloud coverage, and therefore allow targeting of optimal land scenes for inclusion in the product catalogue.

### 4.1. Landsat QC activities

Landsat QC is systematically performed at the ground stations on media-based products using the QUISS tool (Gael Consultant). Each failure in this procedure leads to an investigation by the Landsat SPPA Team.

European Landsat products can be ordered in a variety of formats - including RAW, FAST, GEOTIFF and CEOS, all of which can be ordered through the ESA EO Link (EOLI) catalogue [13] for either FTP or DVD delivery. The Landsat SPPA Team check previews on the catalogue daily and order suspect products for a further investigation. Fig. 3 highlights the Landsat 5 European coverage available in the EOLI-SA catalogue.

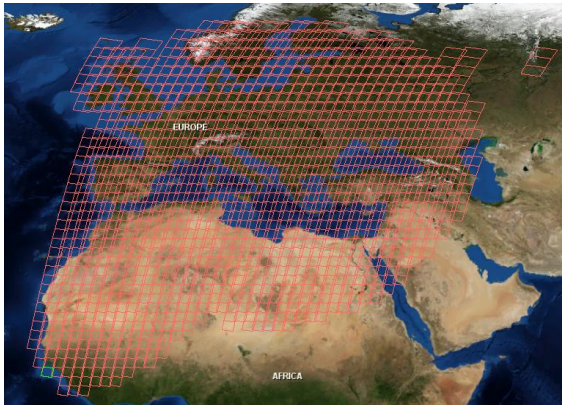


Figure 3: ESA Landsat 5 European coverage available in the EOLI-SA catalogue.

The Landsat SPPA Team provide support to the large Landsat community by updating FAQs and documentation, which are made available on the ESA Landsat webpage [14], offering Users a source of information for better comprehension of, and utilization of, the Landsat data. In addition to this, the SPPA Team provide Users with expert advice to requests and questions via the EO Help Desk.

In order to monitor data quality, and observe and report on changes occurring in the sensor over its lifetime, LLSA activities are carried out by the Landsat SPPA Team. Analysis of the ageing of the sensor is carried out over two Vicarious Calibration test sites: Libya-4 (Path 181, Row 40) and Lacrau, France (Path 196, Row 30) [15].

Since June 2009 a new radiometric correction based on in-flight calibration has been applied to Landsat data, this is known as the LifeTime Model (LTM). This new model offers better precision for radiometry when compared to the previous calibration which was based on pre-flight calibrations

## 5. GMES AND QA4EO

Within the GMES programme [16], ESA is responsible for developing a harmonised system that facilitates access to EO data; this is achieved through the GMES Space Component Data Access (GSCDA) system. This includes the development and operational service of the Coordinated Quality Control (CQC) which ensures full traceability and accessibility of the Quality Information Items (e.g. documents, reports, auxiliary information).

The CQC is also tasked to coordinate anomaly investigations, detailed quality control and quality assurance analysis for GMES Contributing Missions (GCMs); this is currently being achieved through coordination with the relevant instrument SPPA Teams.

QA4EO [17] has been established by the Committee on Earth Observation Satellites (CEOS) to facilitate the Group on Earth Observations (GEO) vision for a Global Earth Observation System of Systems (GEOSS). The aim is to provide a global infrastructure that generates comprehensive near-real-time environmental data, information and analysis for a wide range of users. QA4EO is based on the adoption of guiding principles, which are implemented via guidelines derived from best practices. Evolution activities are currently ongoing to ensure all GCMs are QA4EO compliant.

## 6. CONCLUSION

Space-borne optical sensors provide invaluable data regarding the changes and alteration in the atmospheric, oceanic and terrestrial environments to the global scientific community; resulting in a consistent requirement to ensure the generated products are of sufficient quality throughout the lifetime of the mission.

The activities of the MERIS, MODIS, SeaWiFS and Landsat SPPA Teams at ARGANS benefit from the expert support of ACRI-ST and Gael Consultant, and as a result, provide support to ESA in a variety of QC activities including automated analysis and checking of products, LLSA, software and hardware update validations, general monitoring of product catalogues, and support to User forums and FAQs.

These activities form part of an ever-evolving service which aims to harmonize an approach to operational quality control across all EO instruments. The GMES and QA4EO initiatives have been discussed, and it's understood that these are important steps towards cross-platform harmonization, and will represent a new milestone in the consistent delivery of a high quality product to the wider scientific community.

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