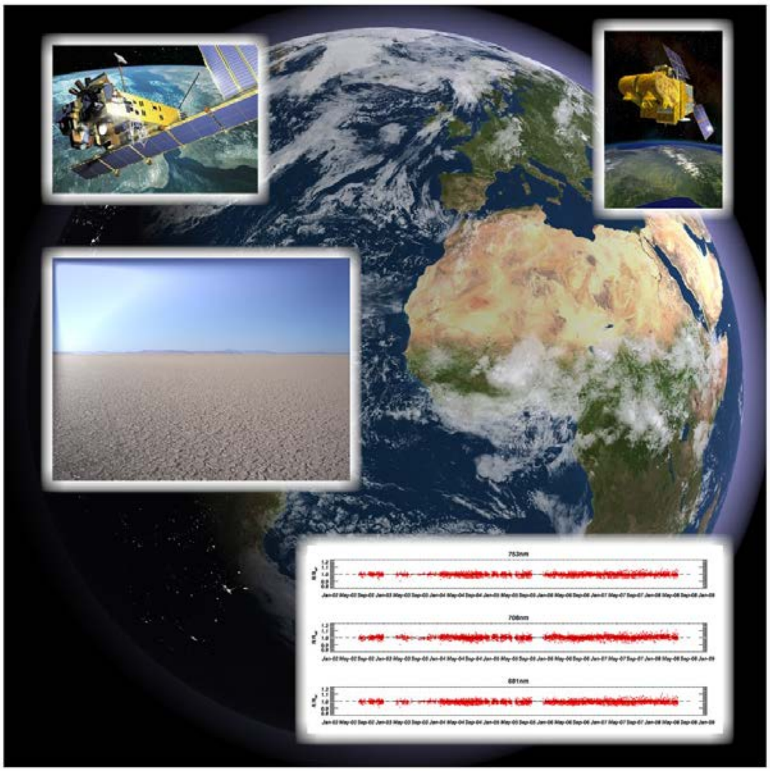
"Towards the Intercalibration of EO medium resolution multi-spectral imagers"

MEREMSII

FINAL REPORT EXECUTIVE SUMMARY



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1 Executive Summary

1.1 Scope of the document

This document overviews and reviews the work and achievements of ESA contract (4000101605/10/NL/CBi) "Towards the Intercalibration of EO medium resolution multi-spectral imagers"; hereafter named MEREMSII ("Medium Resolution Multi-Spectral Imagers Intercomparison"). The project is reviewed in terms of the work initial proposed, eventual deviations and explanations for those deviations, and the eventual outcomes. This review is structured according to the project Tasks and deliverables, and includes some key results from the work conducted; further information on this work can be requested from the ESA Technical Officer, M. Bouvet, or obtained from open access sources.

1.2 Project Consortium

The MEREMSII consortium consisted of:

- **ARGANS Ltd (UK; lead):** Dr. K. Barker and C. Kent
- **ACRI-ST (France):** Dr. L. Bourg and Dr. G. Fontanilles
- **NPL (UK):** Dr. N. Fox
- **Onera (France):** Dr. F. Viallefont
- **RAL (UK):** Dr. D. Smith

1.3 Work plan and approach

1.3.1 Major objectives

MEREMSII had two central objectives:

- Enhance the ESA/ESTEC vicarious calibration system named the Database for Imaging Multi-spectral Instruments and Tools for Radiometric Intercomparison (DIMITRI).
- Define the key elements to put in place in order to move towards an operational radiometric calibration of the medium resolution multi-spectral imager component of GEOSS.

1.3.2 Summary of activities

MEREMSII was split into 3 main tasks that had interactions with each other and facilitated interaction with the CEOS/IVOS. This format was maintained throughout the project. The three main Tasks - overarched by a Project Management work package - were:

i. **Development of DIMITRI**

This activity addressed the development of DIMITRI. Two releases of DIMITRI were made: an intermediate release as output of the "implementation" stage, and final release as output of the "improvements" stage.

ii. **Application and population of DIMITRI**

Using DIMITRI to perform radiometric intercomparison between sensors;

iii. Definition of an operational service for the calibration of GEOSS

The third activity aimed to define an operational service for the calibration of GEOSS, in conjunction with the Infrared and Visible Optical Sensors Subgroup of CEOS (CEOS/IVOS) and a named group of experts as a working group. This original idea for one working group studying many vicarious calibration methodologies evolved during the project into MEREMSII supporting and conducting CEOS/IVOS WG4 (comprising of the same people and a few more) and studying methodologies making use of pseudo-invariant sites for vicarious calibration only. This evolution was driven by CEOS/IVOS interactions and evolutions to requirements during the project lifetime. The result was a more focused study group, with a clear Terms of Reference, and a more suitable alternative for investment of the MEREMSII resources.

1.4 Summary of outcomes and results

1.4.1 DIMITRI development

The DIMITRI tool was developed to allow radiometric intercomparison of TOA reflectances from a number of satellite sensors over fixed validation sites and long time periods. DIMITRI was originally developed on an ad hoc basis at ESA/ESTEC (M. Bouvet), and it lacked the user friendliness and degree of automation needed to be routinely operated. The requirement was to develop DIMITRI to be a user-friendly tool and populate it with up to date remote sensing data. An additional requirement was to implement a module to simulate observations of the VGT-2 sensor (onboard SPOT-5) using the narrow spectral band data from DIMITRI (following the approach detailed in RD-3 and RD-26).

The DIMITRI database now contains time series of data from 2002 to 2012 for the sensors and sites shown in Table 1-1.

Table 1-1: Sensors and sites included in the DIMITRI V2.0 database

SENSOR	Supplier
AATSR (Envisat)	ESA
MERIS, 2^{nd} and 3^{rd} reprocessing (Envisat)	ESA
ATSR-2 (ERS-2)	ESA
MODIS-A (Aqua)	NASA
POLDER-3 (Parasol)	CNES
VEGETATION-2 (SPOT5)	CNES

Site	Site type
Salar de Uyuni, Bolivia	Salt lake
Libya-4, Libyan Desert	Desert
Dome-Concordia (Dome-C), Antarctica	Snow
Tuz Golu, Turkey	Salt Lake
Amazon Forest	Vegetation
BOUSSOLE, Mediterranean Sea	Marine
South Pacific Gyre (SPG)	Marine
Southern Indian Ocean (SIO)	Marine

Figure 1-1 shows the Graphical User Interface of the final DIMITRI tool (V2.0), from which can easily be accessed the DIMITRI functionalities. A full licence is not required to run DIMITRI as it is provided as an IDL Virtual Machine. A User Manual is available to support users.

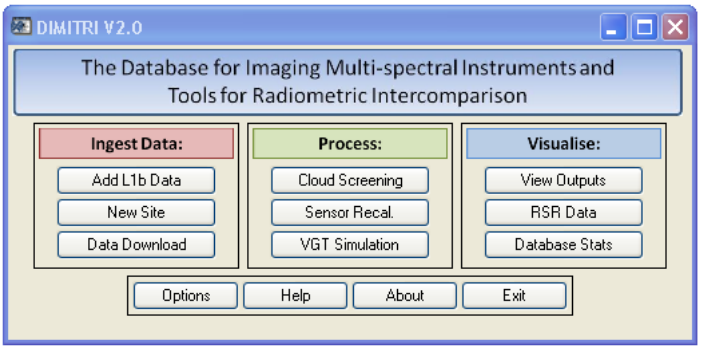

Figure 1-1: DIMITRI V2.0 Graphical User Interface

1.4.2 Sensor intercomparisons using DIMITRI

A requirement of the project, once DIMITRI had been updated, was to perform intercomparisons between the sensors, using the tool and database.

Level 1 data from all the optical sensors (except VGT-2) were compared at top-of-atmosphere (TOA) over three bright target sites: Libyan-4, Dome-C and the Salar de Uyuni (hereafter referred to as Uyuni), and three stable dark marine sites: BOUSSOLE, the SPG and the SIO. Near-simultaneous observations were extracted using the DIMITRI tool to identify almost identical geometries and close matchup times, at 555nm, 660nm, 870nm and 1600nm. For the 555nm, 660nm and 870nm the MERIS 3rd reprocessing was used as the reference sensor; for the 1600nm AATSR 2nd reprocessing was used as the reference.

In general, comparison of TOA reflectances over bright targets found good agreement between sensors, except for MODIS-Aqua over the Libyan Desert site. All sensors were found to be within approximately 5% of the reference sensor MERIS (excluding ATSR-2) at comparable wave bands. Intercomparison of marine targets was found to be difficult for sensors on different platforms due to the diurnal variability in meteorological conditions and sun glint. Analysis of sensors on the same platform over marine sites found AATSR and MERIS to be in agreement with the bright target analysis

A Technical Note describing this work is available upon request.

1.4.3 VGT-2 Simulations and comparisons with actual observations

During the ALOS commissioning phase, a methodology to simulate AVNIR-2 TOA reflectances over the Libyan Desert was developed (see RD-3); this methodology was implemented in DIMITRI and adapted for simulation of the VEGETATION-2 sensor and consists of several steps. First, intercalibration coefficients are derived between MERIS and other narrow band sensors by identifying near-simultaneous acquisitions made under similar observational geometry. From this intercalibrated time series of satellite observations (from MERIS, MODIS-Aqua, AATSR and PARASOL) over a given pseudo-invariant site, a TOA Bidirectional Reflectance Distribution Field (BRDF) model is fitted to a time series of radiometrically intercalibrated. This multi-spectral BRDF model is corrected for gaseous absorption and resampled to a higher spectral resolution using a simplistic TOA signal decomposition and high spectral resolution gaseous absorption transmissions. The DIMITRI tool was developed to provide VGT-2 simulations over several validation sites and for long time series analysis.

For Dome C, Libya4 and Tuz Golu, this simulation method gives good results in comparison to observed values; VGT-2 reflectance can be simulated with an accuracy of below 5 % for B0, B3 and SWIR thanks to Dome C and Libya4. The accuracy for B2 is around 10%.

However, a more accurate uncertainty assessment is required.

1.4.4 CEOS/IVOS WG4 Methodology Intercomparisons

The objective of this work was to compare the results of several methodologies making use of pseudo-invariant sites for vicarious calibration or for radiometric intercomparisons. The sensors considered in this work were spaceborne medium spatial resolution sensors with multi-spectral capabilities operating in the visible to thermal infrared. The objective of the work was to build on the DIMITRI intercomparisons: to identify and understand the differences between the results of the methodologies, with an attempt to quantify uncertainties and identify sources of observed biases, and to facilitate the traceability efforts (i.e. QA4EO).

This work was carried out in the frame of the CEOS/IVOS Working Group 4 focusing on pseudo-invariant sites. Three sites were selected: Libya-4, Niger-2 and Dome-C, for which time series of cloud screened Top of Atmosphere (TOA) reflectance averaged over pre-defined regions of interest were generated for: AATSR, MERIS, MODIS-Aqua, POLDER-3 and VEGETATION-2. The time series of extractions covers the years 2006 to 2009, and these data were distributed to the WG in a predefined format i.e. a standardised reference dataset to which each participating team applied its vicarious calibration methodologies and/or sensor-to-sensor radiometric intercomparison methodologies. MERIS data (2nd reprocessing) were chosen as the radiometric reference to which other sensor radiometry was compared. MERIS was chosen because its spectral sampling facilitates the matching of spectral bands from other sensors. The comparison was carried out for each methodology and for each site using standardised statistical indicators associated to the time series of radiometric differences between MERIS and other sensors. The comparison was deliberately restricted to 3 spectral regions around 560 nm, 660 nm and 860 nm in which all sensors have spectral bands to limit the analysis work. Moreover, comparisons were restricted to cases involving MERIS and AATSR, MODIS-Aqua and POLDER-3 (comparisons involving VEGETATION-2 were left out of this work due to time limitation).

The results of the work are detailed in a Final Report to CEOS/IVOS, available on the CalVal Portal at: http://calvalportal.ceos.org/cvp/web/guest/ivos/wg4.

1.5 Conclusions

1.5.1 DIMITRI development and population

DIMITRI performed comparably to the 4 other methods in the WG4 category, after correction for the estimates of systematic uncertainties arising from comparing sensors with non-identical spectral responses. This is a successful result considering it was a prototype system before the MERMESII contract. It's inclusion in the WG4 intercomparisons study enabled much to be learnt about it and improvements were made as the study progressed. However, more can be done to improve the methodology and tool further, to bring it to a standard where it might be considered of an operational standard.

1.5.2 CEOS/IVOS WG4 Methodology Intercomparisons

The following central conclusions were drawn:

- Having used the reference datasets for the comparison of methodologies gives confidence that the differences between results are actually due to the methodologies themselves rather than the site selection methods, cloud screening scheme or radiometric correction applied to the native L1 data.

- The different methodologies compared give results consistent within the 2-3 % random uncertainty estimates of the methodologies, as long as the impact of differences between sensor spectral responses is accounted for.

- The use of different scene types with different spectral characteristics (ice, snow) is beneficial to test assumptions embedded in vicarious calibration and radiometric intercomparison methodologies.

1.6 Roadmap and recommendations

1.6.1 Operational calibration system

The GEOSS goal is for a real-time fully automated system for GEOSS; however this is not realistic in the foreseeable future and we make a number of general recommendations for moving towards an operational calibration system scenario. These recommendations (expanded further in the Full Report include: more sites to be defined and better characterisation of existing sites to improve uncertainty budgets; establish agreed methodologies and test, similar to the activities of the CEOS/IVOS WG4 approach and make results available to the community in a standard format; develop and improve the means by which uncertainties are estimated.

In the meantime, CEOS/IVOS should consider what alternatives may be feasibility implemented to provide regular on-going comparisons over a range of selected CEOS sites to a readily accessible database. DIMITRI has potential for adaptation as a reference tool or front-end for a set of tools, to regularly collect acquisitions for further analysis by the community.

1.6.2 DIMITRI Evolution

DIMITRI has a large potential for further evolution to include new sensors, more sites and additional methodologies. Higher resolution sensors should be considered, as well as building the medium-resolution database. Some of the methodologies described are to be implemented in a follow-on ESA project (Rayleigh Scattering, Sunglint, Drift monitoring/BRDF). Improved uncertainty quantification and cloud screening is also a recommendation, and will also be addressed in the follow-on project.

To improve the operational potential for DIMITRI, a number of issues need to be addressed, including:

- Improved/automated data ingestion – including data from automated sites;
- Accurate assessment of uncertainties - Presently, DIMITRI shouldn't be considered as a calibration tool i.e. as a source of calibration "coefficients", for sensors that rely on on-board calibration systems;
- Data exchange format – standardize to one format only (e.g. Net CDF);

- Include atmospheric/spectral correction – in order to perform meaningful inter-comparisons and long term trend analysis;
- Potential for connection with other tools and services which are moving towards achieving and providing operational data search/access and analysis services.

1.7 Access to DIMITRI and CEOS/IVOS WG4 Intercomparison Report and Reference Dataset

- DIMITRI can be obtained following registration at: www.argans.co.uk/dimitri
- The CEOS/IVOS WG4 report can be obtained from: http://calvalportal.ceos.org/cvp/web/guest/ivos/wg4

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