ARGANS

Towards the intercalibration of EO medium resolution multi-spectral imagers:

DIMITRI & MEREMSII

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1.2	08/05/2012	Updated content and code appendix	

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Acronym List

AATSR---------------------Advanced Along Track Scanning Radiometer
AC--------------------------Atmospheric Correction
AD -------------------------Applicable Document
ADEOS --------------------Advanced Earth Observation Satellite
AIMES---------------------Analysis, Integration and Modelling of the Earth System
ATBD ----------------------Algorithm Theoretical Baseline Document
AVHRR --------------------Advanced Very High Resolution Radiometer
BEAM ---------------------Basic ERS and Envisat (A)ATSR and MERIS Toolbox
BOUSSOLE ---------------Bouée pour l'acquisition de Séries Optiques à Long Terme
BPAC ----------------------Bright Pixel Atmospheric Correction
BRDF---------------------- Bidirectional Radiance Distribution Function
CCSM----------------------Community Climate System Model
CDOM---------------------Coloured Dissolved Organic Matter
CEOS ----------------------The Committee on Earth Observation Satellites
CNES ----------------------Centre National d'Etudes Spatiales
COM-----------------------Coloured Organic Matter
CRG------------------------Climate Research Group
CZCS-----------------------Coastal Zone Color Scanner
DDS------------------------Diagnostic Data Set
DIMITRI-------------------Database for Imaging Multi-spectral Instruments and Tools for Radiometric Intercomparison
DUE------------------------Data User Element of the ESA Earth Observation Envelope Programme II
EC--------------------------European Commission
ECSS -----------------------European Cooperation for Space Standardization
EEA ------------------------European Environment Agency
EO--------------------------Earth Observation
EOSDIS--------------------Earth Observing System Data and Information System
ESA ------------------------European Space Agency
ESDR ----------------------Earth Science Data Records
ESL-------------------------Expert Support Laboratories
EU--------------------------European Union
EUMETSAT---------------European Organisation for the Exploitation of Meteorological Satellites
FP6 ------------------------EC Framework Programme 6
FP7 ------------------------EC Framework Programme 7
FR --------------------------Final Report
FVR ------------------------Full Validation Report
GIS-------------------------Geographic Information System
GMES ---------------------Global Monitoring for Environment and Security
GOCI-----------------------Geostationary Ocean Color Imager
GOMOS-------------------Global Ozone Monitoring by Occultation of Stars
GOOS ---------------------Global Ocean Observing System
GSC ------------------------GMES Space Component
GSC CQC------------------GMES Space Component Coordinated Quality Control
Hermes -------------------Data portal for Ocean Colour Data Users http://hermes.acri.fr
HMI------------------------Human Machine Interface
IOPs -----------------------Inherent Optical Properties
IPCC -----------------------Intergovernmental Panel of Climate Change

IVOS ------------------------Infrared and Visible Optical Sensors Subgroup of WGCV
LUT -------------------------Look-Up Table
MEaSUREs ----------------Making Earth Science Data Records for Use in Research Environments
MEREMSII-----------------MEdium REsolution Multi-Spectral Imagers Intercalibration
MERIS----------------------Medium Resolution Imaging Spectrometer
MERSEA -------------------Marine Environment and Security for the European Area – Integrated Project of the EC Framework Programme 6
MODIS ---------------------Moderate Resolution Imaging Spectrometer
MVT ------------------------MERIS Validation Team
NASA ---------------------- National Aeronautics and Space Administration
N/A -------------------------Not Applicable
netCDF---------------------Network Common Data Format
NIR--------------------------Near Infrared
NOAA ----------------------National Oceanic and Atmospheric Administration
NPL -------------------------National Physical Laboratory
NRT-------------------------Near-Real Time
ODESA ---------------------Optical Data Processor of the European Space Agency
OLCI ------------------------Ocean and Land Colour Imager
PDL -------------------------Parameters Data List
PI----------------------------Principal Investigator
POLDER--------------------Polarization and Directionality of the Earth's Reflectances
QA4EO---------------------a Quality Assurance framework for Earth Observation
QWG ----------------------Quality Working Group
RAL -------------------------Rutherford Appleton Laboratory
RD---------------------------Reference Document
REASoN--------------------NASA Research, Education and Applications Solution Network project
Rho ------------------------ Reflectance
RMS ------------------------Root Mean square
RT---------------------------Radiative Transfer
S-3 --------------------------Sentinel-3
SDP -------------------------Software Development Plan
SLSTR----------------------Sea and Land Surface Temperature Radiometer
SME ------------------------Small & Medium size Enterprise
SNO------------------------ Simultaneous Nadir Overpass
TBC -------------------------To Be Confirmed
TBD -------------------------To Be Defined
TOA-------------------------Top Of Atmosphere
TPM ------------------------Third Party Mission
U.K. -------------------------United Kingdom
WG -------------------------Working Group
WGCV----------------------Working Group on Calibration and Validation

Reference Documents

	Document
RD-1	Bouvet M., Intercomparison of imaging spectrometer over the Salar de Uyuni (Bolivia), Proceedings of the 2006 MERIS AATSR Validation Team Workshop
RD-2	Bouvet M. , Ramoino F., Radiometric intercomparison of AATSR, MERIS, and Aqua MODIS over Dome Concordia (Antarctica), Can. J. Remote Sensing, Vol. 36, No. 5, pp. 464–473, 2010
RD-3	Bouvet M., Goryl P., Chander G. Santer R., Saunier S, Preliminary radiometric calibration assessment of ALOS AVNIR-2, proceeding of the IGARSS 2007
RD-4	Smith D., Poulsen C., Latter B.: Calibration Status of the AATSR Reflectance Channels, MERIS AATSR workhop 2008 proceedings
RD-5	Miesch C.; Cabot F.; Briottet X. ; Henry P., Assimilation method to derive spectral ground reflectance of desert sites from satellite datasets, Remote sensing of environment ,2003, vol. 87, no2-3, pp. 359-370
RD-6	P. Henry and A. Meygret, “Calibration of HRVIR and VEGETATION cameras on SPOT4,” Adv. Space Res., vol. 28, pp. 49-58, 2001.
RD-7	Proba-V Mission Requirement Document, ESA document
RD-8	Landnet sites: http://calval.cr.usgs.gov/sites_catalog_ceos_sites.php
RD-9	GEO: http://www.earthobservations.org/about_geo.shtml
RD-10	GSICS: http://www.star.nesdis.noaa.gov/smcd/spb/calibration/icvs/GSICS/
RD-11	http://www.star.nesdis.noaa.gov/smcd/spb/calibration/icvs/GSICS/LLvisibleInfrared.php
RD-12	http://www.eumetsat.int/Home/Main/Access_to_Data/IntercalibrationServices/index.htm?l=en
RD-13	European Cooperation for Space Standardisation, ECSS-E-ST40C
RD-14	Roujean J.L., Leroy M. and Deschamps P.Y. (1992). A bidirectional reflectance model of the Earth’s surface for the correction of remote sensing data. Journal of Geophysical Research, 97(DIS), 20.455-20.468.
RD-15	Irish, R.R. Landsat 7 Automatic Cloud Cover Assessment. See http://landsathandbook.gsfc.nasa.gov/handbook/pdfs/ACCA_SPIE_paper.pdf
RD-16	Plummer, S.E. 2008. The GLOBCARBON Cloud Detection System for the Along-Track Scanning Radiometer (ATSR) Sensor Series, IEEE Transactions on Geoscience and Remote Sensing, 46 (6), 1718 – 1727.
RD-17	Santer, R. 2010. OLCI Pixel Classification ATBD (S3-L2-SD-03-C01-LISE-ATBD). Version 2.0
RD-18	D.L. Smith and C.T. Mutlow and C.R.N. Rao. 2002. Calibration Monitoring of the Visible and Near-Infrared Channels of Along-Track Scanning Radiometer-2 (ATSR-2) using Stable Terrestrial Sites”, Applied Optics, 41 no 3, 515-523
RD-19	Rao, C.R.N., and J. Chen. 1995. Inter-satellite calibration linkages for the visible and near-infrared channels of the Advanced Very High Resolution Radiometer on NOAA-7, -9, and -11 spacecraft, International Journal of Remote Sensing, 16, 1931-1942.
RD-20	Smith, D. 2006. Update on AATSR Visible Channel Long Term Trends. See http://envisat.esa.int/pub/ESA_DOC/ENVISAT/AATSR/Visible_Channel_Update_TN-0552.pdf
RD-21	Bouvet, M. 2011. Simulating VGT from Super Sensor observations version 3 technical note.

1 INTRODUCTION

1.1 DIMITRI

1.1.1 DIMITRI Software Package

The DIMITRI software package contains a suite of IDL routines for the intercomparison of Top Of Atmosphere (TOA) radiance and reflectance values within the 400nm - 4µm wavelength range; this is generally known as Level 1b Earth Observation (EO) satellite data. The package includes product reader and data extraction routines, and allows comparison of satellite data based on User defined cloud screening parameters as well as temporal, spatial and geometric matching. DIMITRI is a database containing the so-called remote sensing TOA reflectance values from 2002 until the present day for ATSR2 (ESA), AATSR (ESA), MERIS (ESA), MODIS-Aqua (NASA), PARASOL POLDER-3 (CNES), and VEGETATION (CNES) over eight predetermined validation sites (see Table 1).

DIMITRI is supplied with all L1b data pre-loaded, giving instant access to time series of data which totals more than 5 terabytes. Additional data for other validation sites, or more recent acquisitions, can be ingested into DIMITRI to allow even greater temporal and spatial analysis.

1.1.2 Purpose and principle of DIMITRI

Within DIMITRI a “reference” sensor relates to a user selected sensor for all other sensors to be intercalibrated against. A “calibration” sensor refers to a chosen sensor which will be compared against the “reference” sensor and recalibrated to its radiometric scale. A number of “calibration” sensors can be compared against one “reference sensor”.

A further function of DIMITRI allows to intercalibrate all ’’calibration’’ sensors to the ‘’reference’’ sensor and to generate radiometrically consistent TOA reflectances from all sensors. This allows computation of a TOA Bidirectional Reflectance Distribution Function (BRDF), (RD-14), over a selected validation site; this is then utilised to simulate VEGETATION TOA reflectance using the VEGETATION products viewing and solar geometries.

All stages of DIMITRI (intercalibration, BRDF modelling and TOA simulation) include an attempt to propagate uncertainties providing detailed information on the processing stages performed. The computed systematic and random uncertainties are provided in the DIMITRI outputs (RD-21).

The standard DIMITRI TOA Reflectance at any given wavelength is defined as:

$$\rho = \pi \frac{L}{F_0 . d^2 . Cos(\theta_s)}$$

Where:

ρ = reflectance, L = TOA Radiance, F_0 = Solar Irradiance Flux, Θ_s = Solar Zenith Angle, and d^2 = a correction factor for the Earth-Sun distance.

Table 1: Geolocation values for the 8 predefined DIMITRI validation sites.

Site Name	North Lat (N)	South Lat (N)	West Lon (E)	East Lon (E)
Uyuni Salt Lake	-20.00	-20.16	-68.05	-67.45
Libya 4	29.05	28.05	22.89	23.89
Dome C	-74.90	-75.30	122.90	123.90
Tuz Golu	38.80	38.70	33.25	33.40
BOUSSOLE	43.45	43.25	7.80	8.00
Amazon Forest	1.33	1.00	-57.00	-56.50
SPG	-31.00	-31.50	-137.5	-137.0
SIO	-30.00	-30.50	80.50	80.00

Table 2: DIMITRI Sensor data location information

Sensor	Data Location	Access
AATSR	http://ats-merci-uk.eo.esa.int:8080/merci/welcome.do	Requires ESA Cat-1 Registration
ATSR2	http://ats-merci-uk.eo.esa.int:8080/merci/welcome.do	Requires ESA Cat-1 Registration
MERIS	http://merci-srv.eo.esa.int/merci/welcome.do	Requires ESA Cat-1 Registration
MODIS-Aqua	http://ladsweb.nascom.nasa.gov/	Freely available
PARASOL	http://polder.cnes.fr/en/index.htm	Requires registration
VEGETATION – 2*	http://www.spot-vegetation.com/index.html	Requires registration

*please note, DIMITRI is currently set up to utilise VGT-2 products distributed by VITO; these products are processed with an erroneous Earth-Sin distance coefficient. A correction, provided by CNES, is implemented within the DIMITRI VGT-2 processing.

1.1.3 Development

DIMITRI V1.0 was prototyped at ESTEC by Marc Bouvet (ESA ESTEC). DIMITRI V2.0 has been developed by ARGANS Ltd in collaboration with ESA through the MEREMSII project.

1.1.4 DIMITRI License and code modification

The DIMITRI software package is made freely available by ESA and ARGANS. The Intellectual Property rights are held by ESA; however modification of code is allowed. The official version of original source code will be held at ARGANS and any modifications are done at the User's risk.

However, Users are welcome to contact the DIMITRI developers at dimitri@argans.co.uk with suggestions for improvement and if verified and approved by ESA, these may be included in later versions of DIMITRI. See section 4 for more information on DIMTIRI routines and compilation.

1.2 System Requirements:

A full IDL license is NOT required for DIMITRI V2.0; the freely available IDL Virtual Machine (available at http://www.ittvis.com/ProductsServices/IDL/IDLModules/IDLVirtualMachine.aspx) will allow use of the pre-compiled DIMITRI package and use of the full functionalities accessible from the HMI.

DIMITRI has been developed to be compatible on both Linux and Windows based systems; however, MAC compatibility cannot be guaranteed. DIMITRI has been developed for use with IDL 7.1 or higher; the minimum requirements required for IDL 7.1 are therefore the minimum requirements for running DIMITRI.

A full IDL license (http://www.ittvis.com) will allow command line usage, modification of routines and recompilation of the software package.

2 SETUP

2.1 Where to acquire DIMITRI

The DIMITRI software package is made available by ESA on the ARGANS website: www.argans.co.uk/dimitri. This webpage provides information on the DIMITRI package and allows registration to download DIMITRI. Email address will only be used to provide notifications of updates to DIMITRI and to obtain User feedback; User information will only be stored at ARGANS Ltd on behalf of ESA, and will not be passed on to any other organisation.

All Users must comply with the following Service Level Agreement (SLA):

1) Acknowledgement to ESA and ARGANS is required for any presentations or publications; however written permission is not required.
2) The DIMITRI package cannot be distributed by anyone other than ESA and ARGANS.
3) Any modifications to the DIMITRI code are appropriately detailed in the code header information, and are performed under the responsibility of the User.
4) ESA and ARGANS are not responsible for any damage to computer systems as a result of using the DIMITRI software package.

Analysis and results using DIMITRI will be uploaded to the CalVal Portal (http://calvalportal.ceos.org). Registration on this site is necessary to see these data.

2.2 Installation

The DIMITRI software package is downloaded as a compressed archive. To install DIMITRI V2.0 unzip the folder into the desired installation location.

It is recommended that either 7zip (http://www.7-zip.org/) or Filzip (http://www.filzip.com/) are used for extraction of the zip archive. Please note, it is recommended to install DIMITRI with administrator or root privileges. This is to allow the creation of all required files and folders.

Linux Users can install the DIMITRI package by typing:

tar –xf DIMITRI_V2.0.tar.gz

2.3 Quickstart

Following extraction, DIMITRI is now ready to be utilised, this can be achieved by:

- ***On Windows***: Double clicking the “**DIMITRI_V2.0.sav**” file, or running IDL runtime and selecting the file
- ***On Linux***: Typing “**idl –vm=DIMITRI_V2.0.sav**”

These commands will load the DIMITRI Human Machine Interface (HMI). See Section 3 for details on the functionality of the HMI.

If using a full IDL license, all DIMITRI routines can be used through the command line. This requires compilation of the routines which can be performed by running the 'compile_DIMITRI' IDL script located in the 'Source' folder:

IDL>cd, './Source'

IDL>@compile_DIMITRI

2.4 Folder Structure

The installed DIMITRI directory has the following folder structure:

The **'Input'** folder will contain all of the Level 1 data for all sensors across all sites (please note, for distribution and size restrictions only the quicklooks and stored TOA reflectance data are available for download).

- All site folders will be indentified through the syntax 'Site_*', (e.g. 'Site_Uyuni') and allows User-defined sites to be added to DIMITRI. It is recommended that all new sites are generated using the DIMITRI HMI "New Site" module.
- All instrument folders will be identified through the defined values such as 'MERIS', 'MODISA' and 'AATSR'.
- All processing versions will be indentified through the syntax 'Proc_*', for example 'Proc_1_Reprocessing' for the 1st reprocessing.

The **'Output'** folder will contain folder names based on the syntax "site_date_ref_sensor" (e.g. "Domc_20100922_ref_MERIS_2nd_Reprocessing"). This syntax allows users to identify different processing options/runs performed. User defined folders will be available through the main DIMITRI HMI.

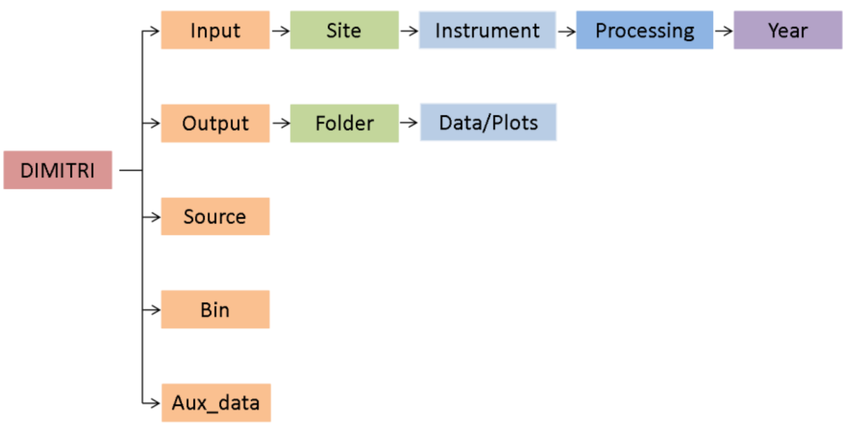

Figure 1: Schematic diagram of the DIMITRI folder structure

Important: A number of routines require the explicit syntax of certain files and folders. It is therefore critical that the folder names are NOT modified as this will result in a loss of functionality.

2.4.1 VEGETATION Folder Structure

Due to the structure of VEGETATION products, the following filename convention must be used for **VEGETATION products ONLY**:

Input→Site→VEGETATION→Proc_Version→Year→Product_Folder→0001→data files

3 HMI FUNCTIONALITY

The DIMITRI HMI has a series of primary and secondary functions, all of which have been designed for command line usage as well as through the DIMITRI HMI. A list of all the routines is included in Appendix 1; described here are the main functions of DIMITRI.

Figure 2 shows the DIMITRI HMI as it appears under Windows and Linux. All HMI figures will be extracted from the Windows version of DIMITRI unless otherwise stated. The following sections explain the functionalities (the buttons) of the HMI GUI.

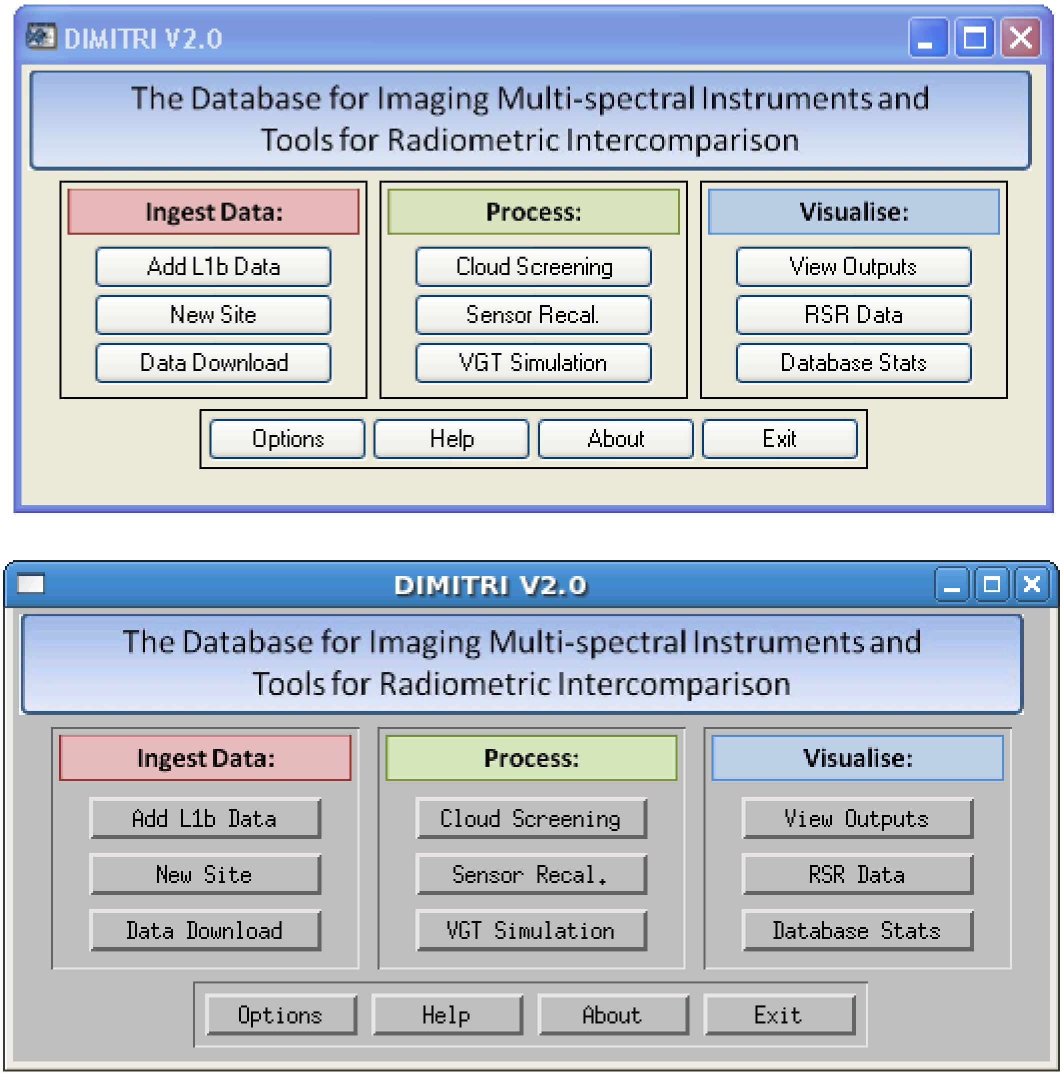

Figure 2: The DIMITRI HMI GUI start page on windows (top) and Linux (bottom)

3.1 Add L1b Data

The “Add L1b data” button starts the ingestion interface for adding L1b data products to the DIMITRI database. A specific site or sensor combination can be requested, or DIMITRI will automatically search for any L1b data not currently ingested into the database. All data is automatically cloud screened according to the sensors associated cloud screening algorithm (see Section 3.6)

Only products located in the correct “Input” folders can be ingested into DIMITRI. If limited hard drive space is available, products can be removed from the input folder following ingestion, however the quicklook should remain for the manual cloud screening module.

Ingestion can take several minutes for each product depending on system performance and which sensor (as well as if child or parent products are used).

3.2 New Site

“New Site” starts the new site creation tool. A new site can be added to the DIMITRI database through selection of Name, Type, and basic geolocation coordinates (North, South, East and West). Once selected, the input folders for the site are automatically generated; there is no need to create any folders manually. Following creation, products can then be placed in the correct input folders for ingestion into DIMITRI.

3.3 Data Download

The “Data Download” module provides quick links to the associated sensor websites for retrieval of products. Please note that not all sensor data is freely available and some data access requires usernames and passwords.

3.4 Sensor Recalibration

“Sensor Recalibration” starts the setup module for intercomparison between a “reference” sensor and a number of “calibration” sensors. This intercomparison is based on the identification of acquisitions made between the two sensors at similar time and under similar geometries. The output folder can be left as “auto” to generate an automatic folder name (e.g. “SIO_20110426_REF_MERIS_2nd_Reprocessing”), or this can be User defined.

3.4.1 Sensor Selection

Selections are then made for the validation site to be used, the reference sensor and its processing version. The available selections are determined from the DIMITRI database file.

The “calibration” sensors and processing versions can then be selected by moving the required sensor configuration into the right hand list (highlighting the configuration and pressing “>>”).

Unwanted configurations can also be removed from the list be selecting the configuration and pressing the << button.

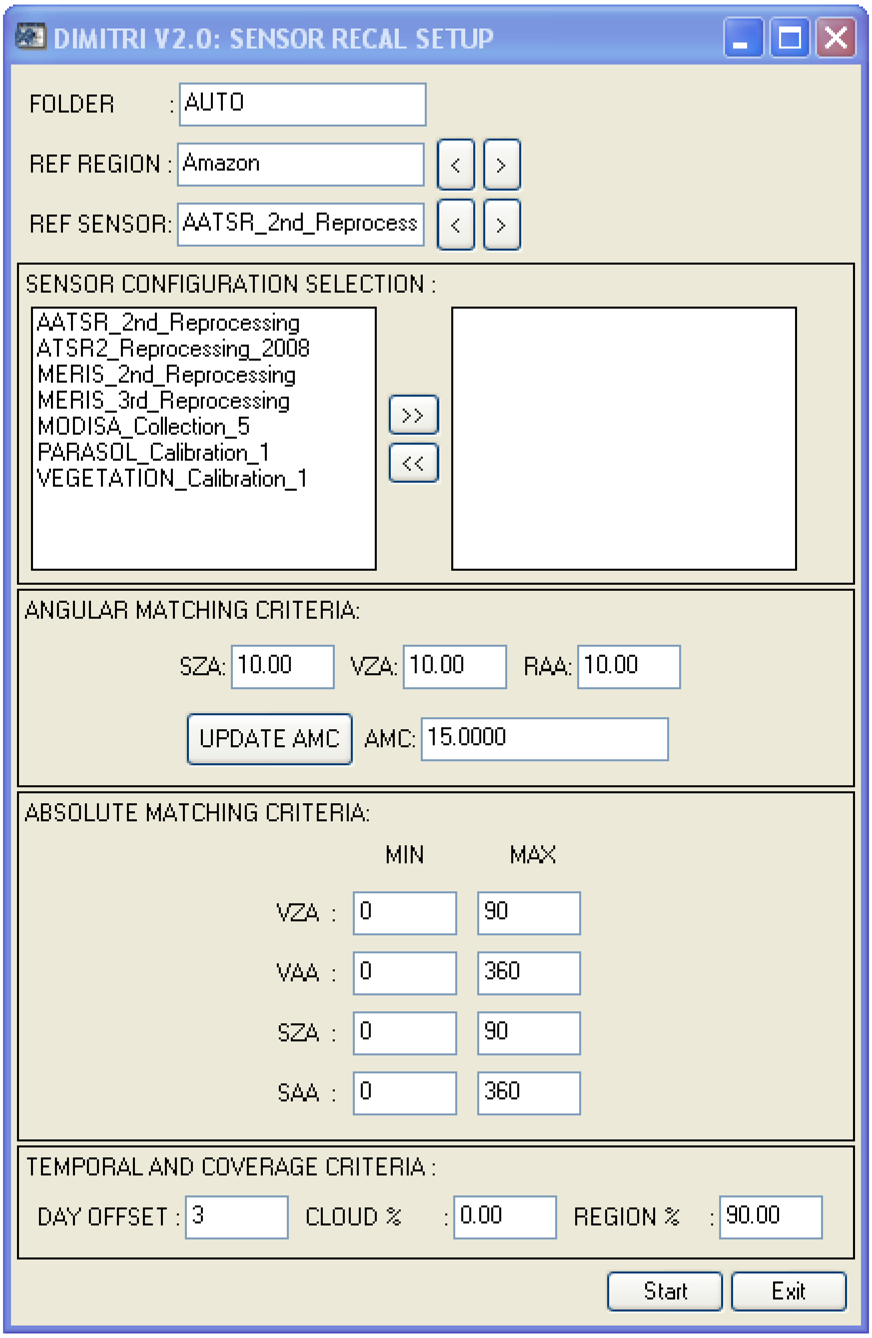

Figure 3: The DIMITRI Sensor Recalibration HMI

3.4.2 Angular Matching Criteria

The parameter AMC is used for geometrically matching satellite data from two different sensors. The SZA, VZA and RAA can be selected and used to update the AMC threshold to be utilised. Any corresponding satellite observations with an AMC value less than the threshold are selected and stored. The AMC parameter is defined as:

$$AMC = \sqrt{([SZA_1 - SZA_2]^2 + [VZA_1 - VZA_2]^2 + \frac{1}{4}[|RAA_1| - |RAA_2|]^2)}$$

The User also has the option of selecting absolute angle criteria for the Viewing Zenith Angle (VZA), Viewing Azimuth Angle (VAA), Solar Zenith Angle (SZA), and Solar Azimuth Angles (SAA).

3.4.3 Temporal, Spatial and Cloud Criteria

The final parameter selections require the User to define the maximum allowed acquisition time difference (in days) between two satellite observations, as well as the automated cloud percentage threshold and percentage of the ROI covered.

Any manual cloud screening results (performed by the User) override the corresponding automated cloud screening threshold checks. For example, if a product has been manually identified as clear (non-cloudy) it will always be considered for matching with other satellite observations. If no manual identification has been performed, the product will only be used if its automated cloud screening percentage is below the cloud threshold set by the User.

If the input ROI percentage coverage is less than 100%, the expected number of pixels for the selected sensor is compared against the actual number for each observation. If however the values is set as 100%, a different test is used; only products in which the four corners of the defined ROI are covered, are kept (this utilises the “ROI_COVER” flag within the DIMITRI database).

Any satellite observations from two separate sensors (or configurations) which are within the defined temporal and spatial matching criteria (including cloud coverage) are known as “doublets”.

3.4.4 Final Steps

Once all parameters have been selected, press the START button to begin processing. “Sensor Recalibration” comprises of doublet matching between the “reference” sensor and all “calibration” sensors, generation of a polynomial to fit the temporal variations of the radiometric difference between these sensors, and recalibration of all “calibration” sensor data to the radiometric scale of the “reference” sensor. These steps are known as doublet extraction, intercalibration and recalibration, and output a so called “super sensor” time series of sensor observations over the same location with different viewing and solar geometries.

During intercalibration a polynomial fit is applied to the temporal differences between the calibration and reference sensor for a given band. The following model is used for the polynomial fit:

$$y = Ax^2 + Bx + C$$

The coefficients A, B and C are computed using a least squares regression fit and are output in the "ICAL" CSV files. No weighting is applied to the polynomial model computation. In addition to the polynomial coefficients, the covariance matrix is also output in the "ICAL" CSV file. The matrix is a 3x3 element array with columns A, B and C, and rows 1, 2 and 3; the output values can therefore be replaced into a matrix given the values header information. For example CVAR_A1 refers to the covariance value matrix [1,1] (starting from 1).

3.4.5 Super Sensor observation uncertainty

The final output of the process previously described is the time series of super sensor observations. All sensors observations have been rescaled to the reference sensor radiometric scale. This does not mean that the super sensor observations have the same systematic uncertainty than the reference sensor because the methodology has introduced additional uncertainties, both random and systematic. To evaluate these uncertainties, it is assumed in DIMITRI V2.0, that all standard satellite TOA reflectance values have both systematic and random uncertainties of respectively 3% and 3% (3σ) – see RD-21. In addition, the doublet matching process has then been estimated to introduce a 3% systematic uncertainty (with respect to the reference sensor) and a 3% (3σ) random uncertainty (see reference RD-1 and RD-2).

The super sensor observation radiometric systematic uncertainty is thus 3% with respect to the reference sensor radiometric scale.

The combined random uncertainty associated to the super sensor observations is the quadratic sum of the random uncertainties of the calibration sensor + reference sensor + methodology uncertainty. This amounts to 5.2% (3σ). The consistency of this figure is checked against the value of the RMSE of the polynomial fit to the radiometric differences between the calibration and reference sensor doublets. If the polynomial's RMSE fit is greater than the combined random uncertainty then this value becomes the random uncertainty for the calibration sensor time series; the super sensor observations can therefore have different uncertainties for each day and wavelength depending on which 'calibration' sensor data has been used.

The propagated uncertainties are output in both internal IDL save files and semi-colon delimited CSV files. Please note, updated uncertainty propagation is foreseen for future releases of DIMITRI.

3.5 VEGETATION Simulation

"VGT Simulation" starts the setup modules for BRDF model generation and simulation of VEGETATION TOA reflectance. This process will only work with outputs from 'Sensor Recalibration' where both MERIS and AATSR have been separately used as "reference" sensors.

3.5.1 Super Sensor Selection

The output folders containing the “Sensor Recalibration” results can be found using the < and > buttons. If the required data is found in the folder, the processing configurations become available for selection in the corresponding selection boxes. If no data is available the value “n/a” is presented.

The routine then determines if any VEGETATION data is available corresponding to the site provided in the selected MERIS folder. All outputs are placed in this MERIS output folder.

3.5.2 BRDF and VEGETATION Criteria

You are then able to select if automatic BRDF plots should be generated (note, for large time series this can take a long time), the BRDF binning period (how many days should cover one bin period), the acquisition limit (how many super sensor observations are required to make the BRDF model valid for each bin), and the cloud and ROI thresholds for the VEGETATION sensor data (recommended to be the same as the doublet extraction values).

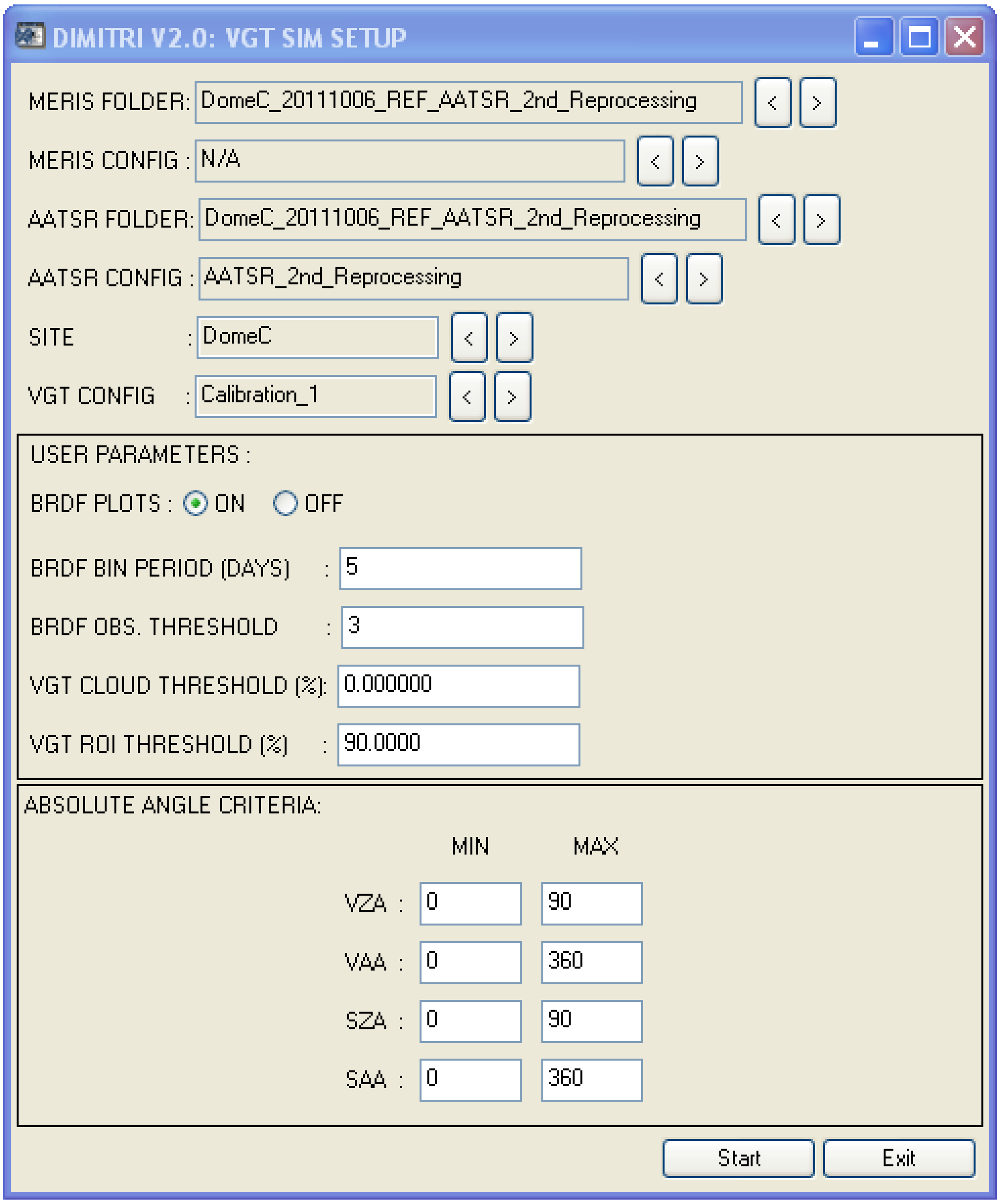

Figure 4: Process 2 setup module HMI

3.5.3 Final Steps

When all parameters are selected, press the “START” button to begin processing. DIMITRI then utilises the “super sensor” time series to generate the ROUJEAN BRDF model (RD-14) for each band and each binning period. Once complete, the BRDF models are concatenated and used to simulate the VEGETATION TOA reflectances. This involves:

- extraction of VEGETATION observations corresponding to each BRDF bin,
- the checking of BRDF models at each MERIS band plus the AATSR 1.6 micron band (any missing MERIS bands are computed from the closest nominal BRDF model),

- the generation of TOA reflectance using VEGETATION geometries and the BRDF models,
- correction for water vapour, ozone and gaseous transmission,
- interpolation to hyperspectral wavelengths,
- re-addition of atmospheric transmission,
- Convolution to the VEGETATION bands.

Please note, the VGT-2 simulation methodology can be performed using only MERIS BRDF models; in this instance the 1.6 micron band is extrapolated from the MERIS 900nm band and should therefore be disregarded.

3.5.4 Simulated VEGETATION TOA reflectance uncertainty

The final uncertainties output are the random and systematic uncertainties associated with the VEGETATION simulated observations.

Starting from the uncertainties associated to the super sensor observations, we need to add the methodology uncertainties. These are described in details in RD-21.

The final uncertainties associated with the simulated VEGETATION observations are respective a systematic uncertainty of at least 8% and a random uncertainty of at least 11% (3σ). The systematic and random uncertainties output can be higher (RD-21).

3.6 Cloud Screening

An important development in DIMITRI V2.0 is the addition of automated cloud screening during ingestion of L1b satellite data. The following algorithms have been implements for each sensor:

- **Landsat ACCA (RD-15):** ATSR2, AATSR, MODIS-Aqua
- **Globcarbon-MERIS (RD-16):** MERIS, PARASOL
- **VGT-operational:** VEGETATION

The computed cloudiness of each product over the validation site is stored in the DIMITRI database file and used with the selected cloudiness thresholds for Sensor Recalibration (Section 3.4) and VEGETATION Simulation (Sections 3.5).

In addition to the automated cloud screening, Users can open the manual cloud screening module. This allows visualisation of a products quicklook for manual determination if it is cloudy or clear, or if the product contains errors (suspect). The manual cloud screening results always override the automated results during Sensor Recalibration and VEGETATION Simulation.

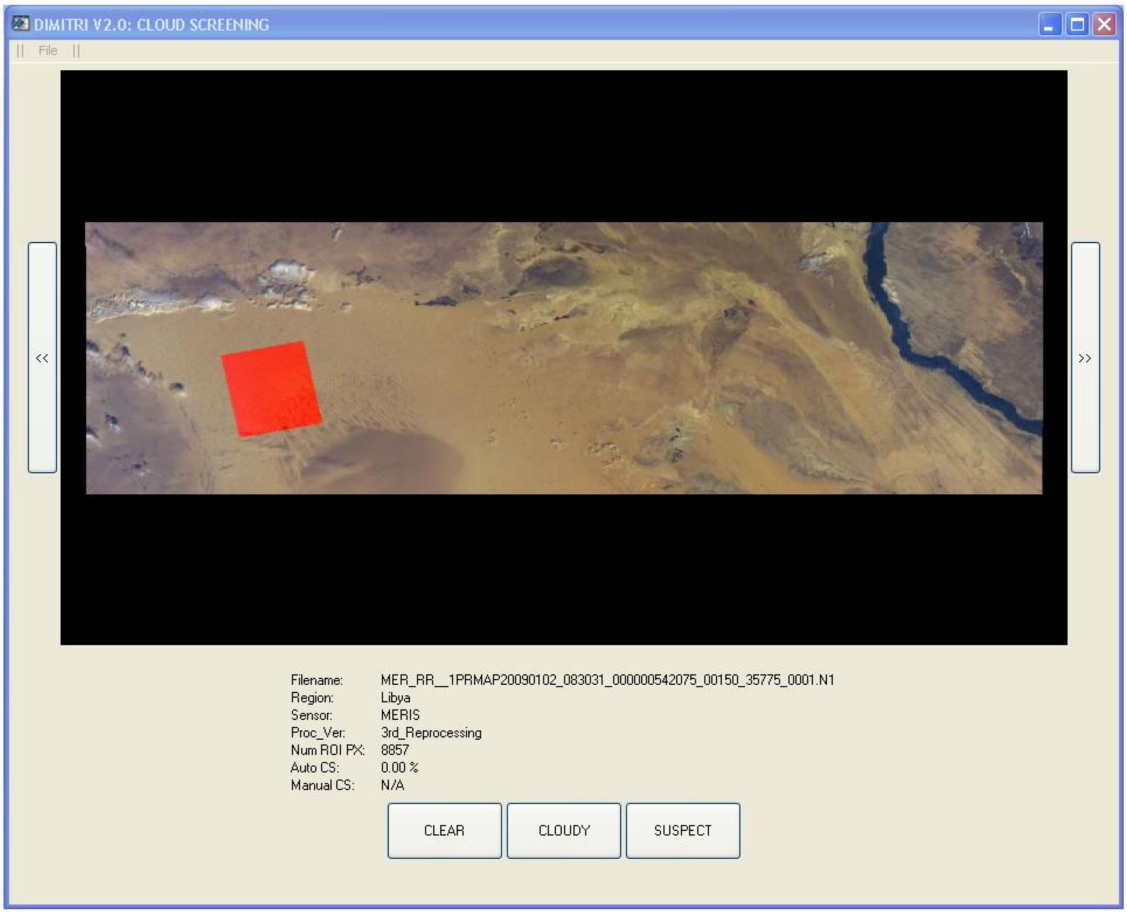

Figure 5: Manual Cloud Screening HMI

3.7 Visualisation

The visualisation module provides a quick and easy opportunity to view any output results from either Sensor Recalibration or VEGETATION Simulation. Each menu is dynamically created depending on which data is available in the output folder selected.

Plots can be generated and saved as JPG's or PNG's, or as a semi-colon delimited (CSV) file. Statistics on plotted data can also be viewed through the visualisation module and saved as a CSV file.

- **TOA RHO:** Plots Sensor doublet observations, Super Sensor and simulated VEGETATION time series.
- **RECAL RHO:** Plots the recalibrated time series data for each "calibration sensor" used.
- **RHO Bias:** Plots the reflectance bias (difference to "reference" sensor) for each "calibration" sensor
- **POLY Bias:** Plots the polynomial bias (difference to "reference" sensor) for each "calibration" sensor
- **VZA/VAA/SZA/SAA:** Plots the doublet angular information
- **AMC:** Plots the computed AMC values between observations

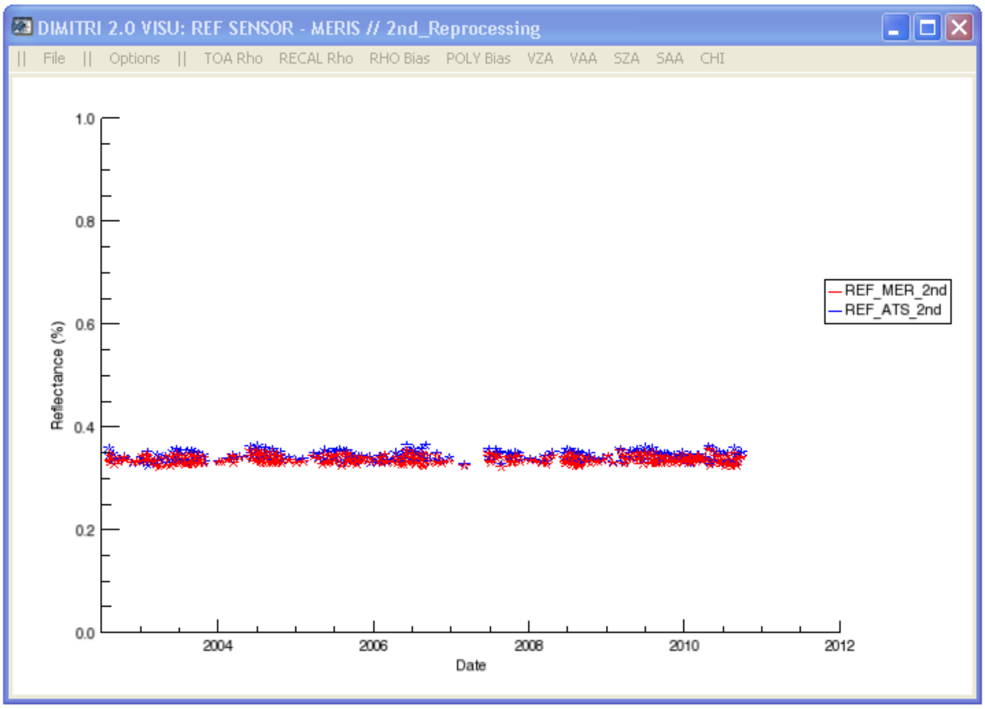

Figure 6: Example of the VISU Module

3.8 Database statistics

The "Database Stats" button starts the database statistics module which provides up to date statistics on the current DIMITRI database file. Further to this, plots can also be viewed highlighting the number of products ingested for each product over each site. Plots can be saved in the JPG, PNG and CSV formats.

3.9 Relative Spectral Response viewer

The Relative Spectral Response (RSR) viewer allows generation and visualisation of plots of sensor RSR functions with User specified wavelength ranges. Users can also view the associated reflectance for each sensor as the spectra is convoluted to the sensor RSR, and add new site spectra to the "AUX_DATA/spectral_response/USER_Sites" folder. These files must be semi-colon separated and contain two columns containing the wavelength in nm, and the RSR function (between 0 and 1). For example, a User generated spectra file would be of the form:

354.000;2.304685712e-01
355.000;2.281964719e-01
356.000;2.259108275e-01
357.000;2.233817428e-01

3.10 Options

The “Options” module allows the definition of the DIMITRI configuration parameters including plot size, colour table, and RGB (red / green / blue) overlays. These values are then loaded into the Sensor Recalibration and VEGETATION Simulation modules as default values.

3.11 Help

Opens this user manual.

3.12 About

Displays information regarding the version of DIMITRI.

3.13 DIMITRI Output

DIMITRI outputs a number of jpg plots and semi-colon delimited CSV files. A number of intermediate results are stored as IDL save files which are restored by DIMITRI when required (see Section 5.3). These files can also be restored by users with full IDL licenses if required by typing:

```
IDL> restore, sav_filename
```

4 DIMITRI ROUTINES

4.1 Routine location

All DIMITRI routines can be found in the source folder. All routines developed by ESA and ARGANS contain a code header providing information on what the routine does, how it is called, what are the outputs, and the modification history. If any routines are updated by Users, please ensure the code header is updated accordingly.

4.2 Recompilation

DIMITRI has been developed in IDL V7.1 and is open to users with full IDL licenses to modify the code and develop it further (note, ESA and ARGANS are not responsible for any damage this may cause to your computer). All routines can be found within the Source folder, including a shell script called "compile_dimitri" which recompiles all routines. A compiled SAV file can then be generated by typing:

IDL> @compile_dimitri

The created save file can then be used by the IDL runtime version which does not require an IDL license.

4.3 External Routines

The DIMITRI software package has been developed by ESA and ARGANS using IDL. However, some functions have been included which were developed by other people. These include:

- **FSC_field.pro:** Created by David Fanning, http://www.idlcoyote.com/ – a must see website containing many pages of useful IDL hints and tips.
- **Mpfit.pro and mpcurvefit.pro:** Created by Craig B. Markwardt (http://www.physics.wisc.edu/~craigm/idl/fitting.html)
- **AATSR/ATSR2 product reader routines:** Created by Dave Smith, RAL (http://www.aatsrops.rl.ac.uk/)
- **FILEINFO.pro:** Created by Liam Gumley (http://www.gumley.com).

5 DATA FILES

The DIMITRI software package utilises a number of different data files. These can be found in the "AUX_data", "Bin" and "Output" folders, and include Database files, internal IDL binary files and Auxiliary data files, each outlined below.

5.1 DIMITRI Database file

The semi-colon delimited Database file contains information regarding all ingested L1b data products. It is used by a number of DIMITRI functions such as doublet extraction and VEGETATION simulation. The database file can be opened in a number of text editors including Microsoft excel to allow further analysis of the ingested product data. A breakdown of the column headers is provided below:

- **DIMITRI_DATE:** The calendar date the product was ingested into DIMITRI, DD-MMM-YY (14-Dec-10)
- **REGION:** ROI folder User placed product ('Uyuni')
- **SENSOR:** Product Sensor ('ATSR2')
- **PROCESSING_VERSION:** User defined processing version of product ('2nd_Reproc')
- **YEAR:** Year of product acquisition (2002)
- **MONTH:** Month of product acquisition (3)
- **DAY:** Day within month of acquisition (30)
- **DOY:** Day-Of-Year relating to YEAR,MONTH and DAY values (89)
- **DECIMAL_YEAR:** Decimal year of data acquisition (2002.244)
- **FILENAME:** Product filename (without path reference)
- **ROI_COVER:** Integer, raised if all corners of the corresponding ROI are covered by the product
- **NUM_ROI_PX:** Number of pixels within the associated ROI (1068)
- **AUTO_CS:** Automated ROI Cloud Screening result in percent (50.0)
- **MANUAL_CS:** Integer flag indicating, -1: not performed, 0: clear, 1: cloudy
- **AUX_DATA(1:10):** A string of auxiliary data used to process the L1b product

5.2 Auxiliary data files

A number of auxiliary data files are used by the DIMITRI software package. The main aux files are:

1. **Sensor info:** This file contains information on the available satellite sensors within the DIMITRI software package.
2. **Site info:** this file contains information on each of the DIMITRI validation sites, as well as any user defined sites.
3. **Configuration file:** this file contains the user's DIMITRI configuration settings (e.g. plot sizes and RGB quicklooks), and is updated by the configuration HMI module.
4. **Band centre index:** This file contains the relative indexes for each sensor band against the defined DIMITRI wavelengths. It is used throughout a number of DIMITRI functions and should not be modified. There are 30 defined "DIMITRI" bands covering the wavelength range 400-12000nm; for each sensor, the band index is linked with the corresponding DIMITRI band to allow comparison against other sensors which also have bands matching that DIMITRI band. This comparison is performed internally, and allows specification of comparing different bands; for example, MODISA has two band setting, land and ocean, which are defined in the Band_centre_index auxiliary file.

5.3 Internal SAV binaries

5.3.1 Extracted TOA Reflectances

For each sensor, over each site, an internal SAV stores the extracted time series data; the syntax for these files are SENSOR_TOA_REF.dat, and have dimensions

[num_of_parameters, num_of_observations*num_directions]

Where the parameters are:

decimal_time, VZA, VAA, SZA, SAA, Ozone*, Pressure*, Humidity*, Zonal_WIND*, Meridional_WIND*, Water_Vapour*, Mean_RHO_Band_0...Band_n, STDEV_RHO_Band_0...Band_n

** Indicates mean value and standard deviation, num_directions are the number of different views from the sensor (e.g. 1 for MERIS, 2 for AATSR). Where more than one viewing direction is available the observations are ordered as [obs_1_dir_1...obs_1_dir_n, obs_2_dir_1...]*

NB, for MODIS Aqua the reflectance bands are stored with indexes 0:14 as the 1Km bands, 15:19 as the 500m bands, and 20:21 as the 250m bands.

5.3.2 Extracted doublets

The extracted doublet internal binaries are of the syntax "ED_SITE_SENSOR1_PROCVER1_SENSOR2_PROCVER2.dat", and contain the extracted doublets for

SENSOR1 when it has been extracted against SENSOR2, given the User selected matching parameters. These files are of the form:

[num_of_parameters, num_of_observations]

Where the parameters are the same as those listed in section 5.3.1, but with the added parameter s of ['Number of pixels', 'automated_cloud_screening', 'manual_cloud_screening', 'matching_type', 'AMC']. The number of observations is dependent on the matching criteria selected.

5.3.3 Intercalibration

A number of internal binaries are created during the intercalibration of sensor doublet information. These include:

- **"ICDIF_SITE_SENSOR_PROCVER_REF_SENSOR_PROCVER_BAND.dat" ,**
  This has the dimensions: [num_observations, num_params], where the parameters are decimal_time, reflectance bias to reference sensor, and the polynomial bias to the reference sensor.

- **"ICERR_ SITE_SENSOR_PROCVER_REF_SENSOR_PROCVER_BAND.dat"**
  This has the dimensions: [num_observations, num_params],where the parameters are the decimal_time and the error between the actual radiometric differences and the polynomial approximation of the differences.

- **"ICOEF_ SITE_SENSOR_PROCVER_REF_SENSOR_PROCVER_BAND.dat"**
  This binary contains the 3 polynomial coefficients for the specified calibration sensor, reference sensor and band.

- **"IUCRT_SENSOR_PROCVER_REF_SENSOR_PROCVER_BAND.dat"**
  This binary contains the uncertainty values associated to the polynomial coefficients and contains the systematic error, the random error, and a flag indicating that the random error has been taken from the polynomial fit rather than the original sensor time series.

5.3.4 Recalibration

A number of internal binaries are output during the recalibration and super sensor time series generation. These include:

- **"RECAL_ SITE_SENSOR_PROCVER_REF_SENSOR_PROCVER.dat"**
  "RECAL_REF_ SITE_SENSOR_PROCVER.dat"
  These SAV files are of the form: [num_parameters, num_observations], where the parameters are as those described in Section 5.3.1, and the observations are the recalibrated and reference sensor reflectances.

- **"SSEN_ SITE_SENSOR_PROCVER _BAND.DAT"**

These files contain the Super Sensor observations generated for the specific band, using the SENSOR value as the reference sensor. These files have the form: [num_parameters, num_observations], where the parameters are:

decimal_time, VZA, VAA, SZA, SAA, Ozone*, Pressure*, Humidity*, Zonal_WIND*, Meridional_WIND*, Water_Vapour*, Mean_RHO_Band, Systematic_uncertainty, Random_uncertainty, Poly_err_flag, and a flag indicating which sensor configuration the observation originates.

5.3.5 ROUJEAN BRDF

The following internal SAV files are generated during the BRDF computation:

- **"ROUJEAN_ER_SITE_REF_SENSOR_PROCVER.dat"**
- **"ROUJEAN_K1_SITE_REF_SENSOR_PROCVER.dat"**
- **"ROUJEAN_K2_SITE_REF_SENSOR_PROCVER.dat"**
- **"ROUJEAN_K3_SITE_REF_SENSOR_PROCVER.dat"**

These files are al of the form: [num_params, number_bins], where the parameters are: decimal_time, the number of sensor observation within the bin, and the corresponding ROUJEAN coefficient for all bands. The number of bins will depend on the bin size selected for processing.

- **"ROUJEAN_UC_SITE_REF_SENSOR_PROCVER.dat"**

This file is of the form: [num_params, number_bins], where the parameters are: time, num_sensor observations, VZA min, VZA max, SZA min, SZA max, RAA min, RAA max, poly_err_flag, the systematic uncertainty for each band, and the random uncertainty for each band.

5.3.6 VGT Simulation

The VEGETATION simulation module outputs the following IDL SAV binaries:

- **"Amazon_VEGETATION_Calibration_1.DAT"**

This file has the same format as the extracted sensor L1b file in Section 5.3.1.

- **"Amazon_VEGETATION_Calibration_1_SIM.DAT"**

This file is of the form: [num_observations, num_parameters], where the parameters are decimal time, and the VEGETATION reflectance bands.

- **"Amazon_VEGETATION_Calibration_1_UCT.DAT"**

This file is also of the form [num_observations, num_parameters], however contains the parameters: decimal time, systematic uncertainty at each VEGETATION band, and the random uncertainty and each VEGETATION band.

6 TROUBLESHOOTING/FAQ

Q: Why doesn't DIMITRI run when I double click on the sav file?

A: Please ensure you have correctly unzipped the DIMITRI zip archive and that you are choosing to open the save file with IDL.

Q: The automated cloud screening values seem incorrect when viewing the product quicklooks, why is this?

A: Automated cloud screening of L1b data is very difficult. The results are likely to vary depending on which validation site you are interested in; clouds over ocean are easy to detect however over snow, ice and salt lakes this is very difficult. The performance of the algorithms is also linked to the available wavebands for each sensor; ideally wavebands in the thermal wavelengths are needed for accurate cloud detection.

Further updates are planned for DIMITRI to also include statistical screening, using the knowledge that validation sites by definition should be generally radiometrically homogeneous.

Q: My computer crashed whilst ingesting new products, is there a backup of the DIMITRI database file?

A: Yes, the latest copy of the DIMITRI database can be found in the folder 'Bin/DB_backup'

Q: Why can't I access the uncertainty data through the visualisation module?

A: The visualisation module is designed to allow quick visual inspection of the general DIMITRI outputs. For uncertainty analysis please use the output CSV files.

Q: Why are some MODIS bands showing a strong cosine dependence?

A: A number of the ocean bands available for MODIS-Aqua can saturate over land; DIMITRI extracts all data no matter which validation site is used, however only intercalibrates/recalibrates the Land bands for Land validation sites

Q: What is the best tool for reading/utilising the output CSV files?

A: The semi-colon delimited output CSV files can be opened in most text editing software; the data can also be read into Microsoft Excel for further analysis (e.g. plots and statistics).

Q: How do I add extra RSR site spectra?

A: User generated site RSR spectra will be automatically read by DIMITRI if placed in the 'AUX_DATA/spectral_response/USER_Sites' folder. These files must be semi-colon separated and contain 2 columns containing the wavelength in nm, and the RSR function. Please see the other site and sensor RSR files for examples.

Q: Why do no new IDL windows open when DIMITRI generates plots/ I stopped DIMITRI during processing, why can't I generate any new IDL plots?

A: DIMITRI utilises IDL's Z-buffer for generating plots; this buffer does not have a viewable window but is stored in the machines memory. Plots can therefore be saved without displaying multiple IDL windows. If you stop DIMITRI during processing it will still be working in the Z-buffer; to return to your normal IDL graphics display type:

WINDOWS: IDL> set_plot, 'win'

LINUX: IDL> set_plot, 'x' under

Q. Why is the super sensor time series so variable?

A. The super sensor time series includes radiometrically corrected data from a number of different sensors. These sensors all have different viewing and solar geometries over the same location (dependant on your chi value chosen). The greater the range of geometries the better the BRDF fit!

Q: How do I find the details of created sites?

A: The DIMITRI file 'DIMITRI_SITE_DATA.txt' is a semi colon delimited file containing the site information including coordinates and type.

Q: How do I add a new sensor to DIMITRI?

A: DIMITRI has be designed in a modules to allow modification by users however adding a new sensor is not a simple task; this requires new product readers, as well as updates to the DIMITRI auxiliary data files located in the 'AUX_DATA' and 'Bin' folders. It is recommended that the DIMITRI auxiliary data files and database are fully backed up before adding any new sensor code.

APPENDIX A: DIMITRI IDL ROUTINES

Routine	Short Description
GET_DIMITRI_BAND_INDEX_TEMPLATE	Returns the DIMITRI band index template
EXTRACT_DIMITRI_RSR	Extracts Relative Spectral Response data over defined wavelengths
CONVERT_TIME_TO_JDAY	Converts ENVISAT Time to Julian Day
GET_DIMITRI_LOCATION	Returns the location of different DIMITRI files and folders
GET_PRODUCT_IDENTIFIERS	Returns the products identifiers used to search for data products
GET_HISTOGRAM	Outputs a histogram JPG
GET_ENDIAN_SIZE	Computes the machine endian size
GREAT_CIRCLE_DISTANCE	Computes the great circle distance between two points
GET_DIMITRI_RSR_TEMPLATE	Returns the DIMITRI Relative Spectral Response template
GET_DIMITRI_SENSOR_DATA_TEMPLATE	Returns the DIMITRI Sensor data template
GET_DIMITRI_SITE_DATA_TEMPLATE	Returns the DIMITRI Site data template
DIMITRI_ANGLE_CORRECTOR	Corrects angular information to the DMIITRI standards
CONVERT_INDEX_TO_WAVELENGTH	Converts instrument Band ID to DIMITRI wavelength
CONVERT_WAVELENGTH_TO_DINDEX	Converts DIMITRI wavelength to Band ID
GET_DIMITRI_CONFIGURATION_TEMPLATE	Returns the DIMITRI configuration template
GET_DIMITRI_CONFIGURATION	Reads the DIMITRI configuration file
GET_SENSOR_BAND_INDEX	Returns the band ID for a given sensor and DIMITRI band
GET_SITE_COORDINATES	Returns the coordinates of a validation site
GET_SITE_TYPE	Returns the site type of a validation site
SAVE_DIMITRI_CONFIGURATION	Saves the DIMITRI configuration file
SENSOR_BAND_INFO	Returns the number of bands for a sensor
SENSOR_PIXEL_SIZE	Returns the pixel resolution for a sensor
GET_DIMITRI_TEMPLATE	Returns the DIMITRI database template
SAVE_DIMITRI_DATABASE	Saves the DIMITRI database
UPDATE_DIMITRI_DATABASE	Updates the DIMITRI database file
DIMITRI_CLOUD_SCREENING_BRIGHT_RHO	Computes if a pixel is "bright" based on the operational MERIS "bright" test
CS_BAND_INFO	Returns the DIMITRI band ID's for a given cloud screening algorithm
CLOUD_MODULE_GLOBCARBON	The GLOBCARBON cloud screening algorithm
CLOUD_MODULE_GLOBCARBON_P	The GLOBCARBON cloud screening algorithm modified for PARASOL bands
CLOUD_MODULE_LCCA	The Landsat Cloud Cover Algorithm (LCCA)
CLOUD_MODULE_VGT	The operational VEGETATION cloud screening algorithm
DIMITRI_CLOUD_SCREENING	The cloud screening interface routine
GET_AATSR_AUX_FILES	Returns AATSR auxiliary data file names
GET_AATSR_L1B_REFLECTANCE	Returns AATSR l1b reflectance
GET_AATSR_LAT_LON	Returns AATSR geolocation

GET_AATSR_QUICKLOOK	Outputs AATSR quicklook
GET_AATSR_VIEWING_GEOMETRIES	Returns AATSR viewing geometries
GET_AATSR_TIMESERIES_PLOTS	Outputs AATSR time series plots
INGEST_AATSR_PRODUCT	Ingests AATSR products into DIMITRI
GET_ATSR2_AUX_FILES	Returns ATSR2 auxiliary data file names
GET_ATSR2_L1B_REFLECTANCE	Returns ATSR2 l1b reflectance
GET_ATSR2_LAT_LON	Returns ATSR2 geolocation
GET_ATSR2_QUICKLOOK	Outputs ATSR2 quicklook
GET_ATSR2_VIEWING_GEOMETRIES	Returns ATSR2 viewing geometries
GET_ATSR2_TIMESERIES_PLOTS	Outputs ATSR2 time series plots
INGEST_ATSR2_PRODUCT	Ingests ATSR2 products into DIMITRI
GET_MERIS_AUX_FILES	Returns MERIS auxiliary data file names
GET_MERIS_ECMWF_HUMIDITY	Returns the MERIS ECMWF parameter
GET_MERIS_ECMWF_OZONE	Returns the MERIS ECMWF parameter
GET_MERIS_ECMWF_PRESSURE	Returns the MERIS ECMWF parameter
GET_MERIS_ECMWF_WIND	Returns the MERIS ECMWF parameter
GET_MERIS_L1B_DETECTOR_INDEX	Returns MERIS detector index
GET_MERIS_L1B_F0	Returns MERIS solar irradiance values
GET_MERIS_L1B_RADIANCE_SF	Returns MERIS radiance scaling factors
GET_MERIS_L1B_RADIANCE	Returns MERIS radiance values
GET_MERIS_LAT_LON	Returns MERIS geolocation
GET_MERIS_QUICKLOOK	Outputs a MERIS quicklook
GET_MERIS_SOLAR_FLUX_RR	Returns MERIS solar flux values
GET_MERIS_VIEWING_GEOMETRIES	Returns MERIS viewing geometry
GET_MERIS_TIMESERIES_PLOTS	Outputs MERIS time series plots
INGEST_MERIS_PRODUCT	Ingests MERIS products into DIMITRI
CONVERT_EMISSIVE_TO_BTEMP	Converts MODISA emissive data to brightness temperature
GET_MODISA_AUX_FILES	Returns MODISA auxiliary data filenames
GET_MODISA_DATE_INFO	Returns MODISA date information
GET_MODISA_VIEWING_GEOMETRIES	Returns MODISA viewing geometries
GET_MODISA_L1B_EMISSIVE	Returns MODISA emissive data values
GET_MODISA_L1B_EMISSIVE_LINUX	Returns MODISA emissive data values for Linux
GET_MODISA_L1B_REFLECTANCE	Returns MODISA reflectance values
GET_MODISA_L1B_RADIANCE	Returns MODISA radiance values
GET_MODISA_L1B_REFLECTANCE_LINUX	Returns MODISA reflectance values on Linux
GET_MODISA_L1B_RADIANCE_LINUX	Returns MODISA radiance values on Linux
GET_MODISA_LAT_LON	Returns MODISA geolocation
GET_MODISA_QUICKLOOK	Outputs MODISA quicklook
GET_MODISA_QUICKLOOK_LINUX	Outputs MODISA quicklook on Linux
GET_MODISA_TIMESERIES_PLOTS	Outputs MODISA time series plots
INGEST_MODISA_PRODUCT	Ingests MODISA products into DIMITRI

INGEST_MODISA_PRODUCT_LINUX	Ingests MODISA products into DIMITRI on Linux
GET_PARASOL_L1B_PIXEL_STRUCTURE	Returns PARASOL pixel structure
GET_PARASOL_L1B_HEADER	Returns PARASOL header information
GET_PARASOL_L1B_DATA	Returns PARASOL pixel data
GET_PARASOL_QUICKLOOK	Outputs PARASOL quicklook
GET_PARASOL_TIMESERIES_PLOTS	Outputs PARASOL time series plots
INGEST_PARASOL_PRODUCT	Ingests PARASOL products into DIMITRI
GET_VEGETATION_HEADER_INFO	Returns VEGETATION header information
GET_VEGETATION_L1B_REFLECTANCE	Returns VEGETATION reflectance data
GET_VEGETATION_LAT_LON	Returns VEGETATION geolocation
GET_VEGETATION_OZONE	Returns VEGETATION ozone values
GET_VEGETATION_WVAP	Returns VEGETATION water vapour values
GET_VEGETATION_VIEWING_GEOMETRIES	Returns VEGETATION viewing geometries
GET_VEGETATION_QUICKLOOK	Outputs VEGETATION quicklook
GET_VEGETATION_TIMESERIES_PLOTS	Outputs VEGETATION time series plots
INGEST_VEGETATION_PRODUCT	Ingests VEGETATION data into DIMITRI
DIMITRI_INTERFACE_INGEST	Interfaces between the DIMITRI HMI and ingestion routines
COMPUTE_AMC	Computes the angular AMC value
COMPUTE_AMC_THRESHOLD	Computes the AMC threshold given angular geometries
EXTRACT_DOUBLETS	Extracts observation doublets between reference and calibration sensor time series
DIMITRI_INTERFACE_DOUBLET	Interfaces between the DIMITRI HMI and doublet extraction routine
DIMITRI_POLYNOMIAL_FIT_FUNCTION	Returns the DIMITRI polynomial fit model
INTERCALIBRATE_DOUBLETS	Intercalibrate doublets between a reference sensor and calibration sensors
DIMITRI_INTERFACE_INTERCALIBRATION	Interfaces between the DIMITRI HMI and the intercalibration routine
RECALIBRATE_DOUBLETS	Recalibrates doublet data using the polynomial fit computed during intercalibration
CONCATENATE_TOA_REFLECTANCE	Concatenates recalibrated doublet data into a super sensor time series
DIMITRI_INTERFACE_RECALIBRATION	Interface between the DIMITRI HMI and the recalibration and concatenation routines
ROUJEAN_BRDF_KERNEL_F2	Computes the F2 ROUJEAN BRDF kernel
ROUJEAN_BRDF_KERNEL_F1	Computes the F1 ROUJEAN BRDF kernel
ROUJEAN_BRDF_COEF	Computes the ROUJEAN K coefficients
ROUJEAN_BRDF_COMPUTE_RHO	Computes the reflectance given BRDF model parameters and solar/viewing angles
ROUJEAN_BRDF_PLOTS	Outputs plots of the computed BRDF model
ROUJEAN_BRDF	Computes the ROUJEAN BRDF model for the super sensor time series
DIMITRI_INTERFACE_ROUJEAN	Interfaces between the DIMITRI HMI and the BRDF routines
GET_GASEOUS_TRANSMISSION	Reads the hyperspectral gaseous transmission data
GET_OZONE_TRANSMISSION	Reads the hyperspectral ozone transmission
GET_WVAP_TRANSMISSION	Reads the hyperspectral water vapour transmission
COMPUTE_TRANSMISSION	Computes the atmospheric transmission due to ozone, water vapour and gaseous components

PLOT_SIM_VEGETATION	Outputs plots of the simulated VEGETATION reflectance
VEGETATION_SIMULATION	Utilises the computed BRDF models to simulate VEGETATION observations over a validation site
CHECK_ROI_COVERAGE	Returns a flag indicating if an ROI is fully covered by a product
COMPARE_DIMITRI_CNES_SADE	Compares DIMITRI and CNES reference dataset files
CONVERT_SADE_TO_DIMITRI	Converts SADE files to DIMITRI arrays
COMPUTE_PARASOL_VIEWING_GEOMETRIES	Computes the PARASOL viewing geometries
CONVERT_TIMESERIES_TO_SADE	Converts DIMITRI time series array to SADE input format
DIMITRI_SADE_INTERFACE_ROUTINES_P1	Allows sensor recalibration using CEOS IVOS dataset files
DIMITRI_SADE_INTERFACE_ROUTINES_P2	Allows VGT-2 simulation using CEOS IVOS dataset files
DIMITRI_INTERFACE_EXTRACT_TOA_NCDF	Interfaces with the NCDF extraction routines
GET_DIMITRI_BAND_NAME_TEMPLATE	Defines the DIMITRI band name template
GET_DIMITRI_EXTRACT_NCDF_DATA_STRUCTURE	Returns the NCDF data structure
GET_DIMITRI_EXTRACT_TOA_NCDF_NAMES	Defines the NCDF variable names
GET_DIMITRI_VISUALISATION_COLOURS_BRDF	Defines the colour codes for the visualisation module
GET_PARASOL_DIRECTION_GEOMETRY	Returns the PARASOL direction geometry
GET_PARASOL_VIEWING_GEOMETRIES	Returns the PARASOL viewing geometries
GET_SENSOR_BAND_NAME	Returns the sensor band name string
GET_VGT_CORRECTION_FACTOR	Returns the VITO VGT-2 reflectance correction factor
READ_DIMITRI_EXTRACT_TOA_NCDF	Reads the DIMITRI NCDF file
READ_SADE_PRODFILE_TEXT	Reads a CEOS IVOS reference dataset product file
READ_SADE_TXT	Reads a SADE input format file
REMOVE_BAD_SADE	Removes manually screened products from the CEOS IVOS dataset
SENSOR_DIRECTION_INFO	Returns the number of directions available for each sensor
UPDATE_DIMITRI_EXTRACT_TOA_NCDF	Updates the DMITRI NCDF files
VGT_CORRECTION_TEMPLATE	Defines the VGT-2 correction file template
WRITE_DIMITRI_EXTRACT_TOA_NCDF	Outputs data to the DIMITRI NCDF files
DHMI_CLOUD_SCREENING	Displays the DIMITRI cloud screening widget
DHMI_CS_SETUP	Displays the DIMITRI cloud screening setup widget
DHMI_CONFIGURATION	Displays the DIMITRI configuration menu widget
DHMI_INGEST	Displays the DIMITRI widget for ingesting l1b data
DHMI_PROCESS_1	Displays the DIMITRI widget for doublet extraction, intercalibration, recalibration and concatenation
DHMI_PROCESS_2	Displays the DIMITRI widget for BRDF computation and VEGETATION simulation
GET_DIMITRI_VISUALISATION_COLOURS	Returns the DIMITRI colour array for the visualisation module
RSR_LEGEND_UPDATE	Updates the legend in the Relative Spectral Response widget
RSR_PLOT_RESET	Resets the DIMITRI Relative Spectral Response object graphics plot
DIMITRI_RSR_COLOURS	Returns the DIMITRI colour array for the Relative Spectral Response module
PLOT_DIMITRI_SENSOR_RSR	Displays the DIMITRI Relative Spectral Response module
DHMI_RSR	Displays the DIMITRI Relative Spectral Response setup module
DIMITRI_VISUALISATION_ANGLES	Returns the angular data for the DIMITRI visualisation module

DIMITRI_VISUALISATION_BRDF_RHO	Returns the BRDF data for the DIMITRI visualisation module
DIMITRI_VISUALISATION_POLYNOMIAL	Returns the polynomial data for the DIMITRI visualisation module
DIMITRI_VISUALISATION_RECALIBRATION	Returns the recalibration data for the DIMITRI visualisation module
DIMITRI_VISUALISATION_REFLECTANCE	Returns the reflectance data for the DIMITRI visualisation module
DIMITRI_VISUALISATION_SUPER_RHO	Returns the super sensor data for the DIMITRI visualisation module
DIMITRI_VISUALISATION_VEGETATION_RHO	Returns the VEGETATION reflectance data for the DIMITRI visualisation module
DIMITRI_VISUALISATION	Displays the DIMITRI visualisation object graphics module
DHMI_VISU	Displays the DIMITRI visualisation setup module
DIMITRI_DATABASE_PLOTS_WD	Displays the DIMITRI acquisition plots module
DIMITRI_DATABASE_STATS_WD	Displays the DIMITRI database statistics module
DIMITRI_DOWNLOAD_WD	Displays the DIMITRI download module
DIMITRI_NEW_SITE_WD	Displays the DIMITRI new site module
DIMITRI_V2	Loads the DIMITRI HMI

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