

# Multi-sensor Match up System (MMS) Manual

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## 2 Introduction

This document is the user manual for the Multisensor Matchup System software (MMS). It covers all tools, configuration files, supported data formats and plugin configurations used by the software. In addition, a description of the installation and operation procedures on the CEDA JASMIN cluster is given.

The software system has been used to successfully support the following projects:



Fidelity and uncertainty in climate data records from Earth Observations. FIDUCEO has received funding from the European Union's Horizon 2020 Programme for Research and Innovation, under Grant Agreement no. 638822 (<https://research.reading.ac.uk/fiduceo/>)



Sea Surface Temperature (SST) project of the European Space Agency (ESA) Climate Change Initiative (CCI) Programme (<https://climate.esa.int/en/projects/sea-surface-temperature/>)

### **CIRCAS**

Consistent Retrieval of Cloud Aerosol Surface, ESA Contract 4000121362/17/I-NB (<http://www.circas.eu/>)

### **CIMR-SCEPS**

Copernicus Imaging Microwave Radiometer – scientific end-to-end simulation.  
(<https://www.eoportal.org/satellite-missions/cimr>)

## 2.1 Scope

This document is thought as a living document, updates will be integrated whenever applicable or necessary. The contents of this version of the manual refers to the MMS software version 1.6.0.



## 2.2 Version Control

| Version | Reason                                   | Reviewer | Date of Issue |
|---------|--|----------|---------------|
| 1.0     | Initial version                          |          |               |
| 1.1     | New minor version                        |          |               |
| 1.2     | New minor version, added post-processing |          | 2017-01-17    |
| 1.3     | New minor version, cumulative updates    |          | 2017-10-13    |
| 1.4     | Updates to V 1.4                         |          | 2019-04-04    |
| 1.4     | New minor version, cumulative updates    |          | 2019-06-20    |
| 1.5     | Updates to v 1.5                         |          | 2019-08-26    |
| 1.5.2   | Updates for SST-CCI COO-1 MODIS          |          | 2020-10-15    |
| 1.5.3   | Updates for SST-CCI COO-2 and 3          |          | 2021-02-19    |
|         | Update ERA5 post-processing              |          | 2021-05-27    |
| 1.5.4   | SIRDS support                            |          | 2021-07-30    |
| 1.5.5   | Cumulative updates                       |          | 2021-09-16    |
| 1.5.6   | Updates for SST CCI COO2                 |          | 2022-09-19    |
| 1.5.7   | CIMR updates, bugfixes                   |          | 2022-12-14    |
| 1.5.8   | CIMR updates, bugfixes                   |          | 2023-09-27    |
| 1.6.0   | Era5 Post Processing generalized         |          | 2025-07-14    |

## 2.3 Software Changelog

This chapter lists the changes, updates and bugfixes applied to the MMS software.

### 2.3.1 Updates from version 1.5.8 to 1.6.0

- Updated NOAA NDBC reader to add WTMP (SST) variable
- Added support for Uk Met Office SIRDS gtmba2 dataset in raw format.
- In era5-post-processing-general-info.xml a fill value per variable can be defined.
- Era5 post processing plugin can now load generalized information from an optional era5-post-processing-general-info.xml in the config directory. A general info file can contain variable definition for satellite-fields.
- Upgrade Mockito to version 4.11.0 and include artifact mockito-inline for static mocking
- era5 post processing .. setter and getter of variable names in class SatelliteFieldsConfiguration was generalized. E.g. `config.set_an_ml_q_name("abcde")` was replaced by `config.setVarName("an_ml_q", "abcde")`
- era5 post processing .. "length" attribute of tag `<satellite-fields><z_dim length='???' />` is no longer optional.
- era5 post processing .. The translation of variable name to variable name for file access has been made switchable.

- post processing .. added PostProcessingContext to method PostProcessingPlugin.createPostProcessing(...). Now plugins can perform extended initializations. E.g. by loading extra files from config directory.
- post processing .. the config directory has been added to the PostProcessingContext so that plugins can load additional generalized information required for the plugin from this directory.

## 2.3.2 Updates from version 1.5.7 to 1.5.8

- Added support for SMAP Salinity L2C data
- Added support for NOAA TAO insitu data
- MMD Writer configuration for global attributes "title", "institution", "contact" and "licence" was added
- added support for NOAA NDBC insitu data
- Added support for Windsat Coriolis data
- Added conda environment for Python code
- Extended workflow to run without scheduler on plain console
- Added option to use different name for matchup dimension in post processing

## 2.3.3 Updates from version 1.5.6 to 1.5.7

- Added support for SMOS L1B daily gridded data
- Added support for SIC-CCI RRDP insitu data
- Corrected reading bug in slstr-s3x-uor reader

## 2.3.4 Updates from version 1.5.5 to 1.5.6

- Added support for SLSTR subset data processed by UoR
- updated to use SNAP 9.0.2 / S3TBX 9.0.3
- corrected TAI 1993 to UTC conversion for MODIS data
- added support for MODIS MxD035 cloud data
- updated H2 database driver
- added option for IngestionTool to update already existing entries
- changed database to use relative archive paths and added migration tool
- updated SLSTR reader to allow switching geo-coding source between tie-point/pixel data
- added database timeout to configuration
- Updated ERA5 processing – simplified configuration
- Fixed bug in ERA5 post-processing - time series iteration was incorrect

## 2.3.5 Updates from version 1.5.4 to 1.5.5

- added shutdown hook for resource cleanup on hard shutdowns
- corrected fill value handling for time-variable in ERA-5 post processing
- corrected ERA-5 raster position calculations

## 2.3.6 Updates from version 1.5.3 to 1.5.4

- updated to use SNAP version 8.0.5 / S3TBX version 8.0.3
- updated Postgres/PostGIS drivers

- corrected bug in Postgres connection where segmented geometries were read incorrectly sometimes
- added support for SIRDS SST insitu data

## 2.3.7 Updates from version 1.5.2 to 1.5.3

- Updated to SNAP 8.0.3
- added random string to SLSTR uncompressed temp directory to allow parallel processing of the same product by multiple nodes
- updated workflow handling to new PMonitor version
- updated random seed strategy: keeps on iterating after IOException
- update MxD021km reader - split vector based attributes to channel layer
- added post-processing to handle ERA-5 NWP data
- added support for AVHRR FRAC MetOp-C
- fixed issues with SNAP readers and non-quadratic extraction window

## 2.3.8 Updates from version 1.5.1 to 1.5.2

- Updated to SNAP 8-SNAPSHOT
- Updated to use NetCDF library version 5.3.1
- Added facility to store scaled variables to MMD
- Added support for MxD021KM MODIS level 1 data
- Added support for AVHRR FRAC MetopB data
- Integrated SLURM scheduler
- corrected too-far-apart matches issue when using SOBOL based sampling

## 2.3.9 Updates from version 1.5.0 to 1.5.1

- Added PixelPositionCondition
- Corrected geocoding bug in SLSTR reader
- Added distinction between SLSTR NR and NT products

## 2.3.10 Updates from version 1.4.9 to 1.5.0

- corrected bug in SLSTR reader - read over product borders
- added data caching for SLSTR reader

## 2.3.11 Updates from version 1.4.8 to 1.4.9

- added support for compressed SLSTR L1B data
- corrected SeedPointMatchupStrategy coordinate rounding
- corrected SLSTR L1B time coding calculations
- updated AVHRR FCDR naming regular expression
- corrected post-processing for AVHRR FCDR correlation coefficients

## 2.3.12 Updates from version 1.4.7 to 1.4.8

- implemented support for segmented geo-location data for AVHRR GAC
- added support for AVHRR GAC v2.10.2 data

## 2.3.13 Updates from version 1.4.6 to 1.4.7

- Added inverse cosine scaling for Sobol random sequences
- Added post-processing for AVHRR FCDR correlation coefficients
- Added support for SLSTR L1B data
- Added support for AVHRR\_GAC v2.10.1 data
- Changed MongoDB socket timeout to 2 minutes

## 2.3.14 Updates from version 1.4.5 to 1.4.6

- Added option to switch Sobol sequences between equal-area and equal-angle sampling.

## 2.3.15 Updates from version 1.4.4 to 1.4.5

- Updated AVHRR FCDR reader to follow new filename regular expression

## 2.3.16 Updates from version 1.4.3 to 1.4.4

- Updated AVHRR FCDR reader to support format changes

## 2.3.17 Updates from version 1.4.2 to 1.4.3

- Added support for compressed AVHRR FRAC data products
- Corrected NetCDF lib fill value initialisation during write operations

## 2.3.18 Updates from version 1.4.1 to 1.4.2

- Added reader for AVHRR FIDUCEO FCDR products
- Added reader for AVHRR HIRS FCDR products
- Added support for GRUAN data reference format
- Corrected bug in distance-to-land: NPE when two or more instances are allocated
- Added support for AVHRR FRAC data products
- updated scripts to new JASMIN file system
- added optional paging and offset to database drivers
- updated to SNAP 6.0.8
- updated 3dr party libraries
- added DB maintenance tool

## 2.3.19 Updates from version 1.4.0 to 1.4.1

- migrated to asynchronous PMonitor
- AIRS reader implemented
- AIRS post processing to add channel data implemented
- Bugfix BowTiePixellocator

## 2.3.20 Updates from version 1.3.9 to 1.4.0

- NWP Post Processing improvements
- Post processing to add AIRS channel data to matchup implemented
- AIRS Level-1B IR Radiances reader implemented
- Bug - null pointer exception if MODIS products with bow tied geocoding has gaps - fixed

## 2.3.21 Updates from version 1.3.8 to 1.3.9

- Improved performance of IASI geo-coding
- Speed up in polar-orbiting matchup strategy
- Corrected handling of multiple intersecting areas in one orbit file

## 2.3.22 Updates from version 1.3.7 to 1.3.8

- Added post-processing that copies the AMSR2 Scan\_Data\_Quality variable to the MMD
- Renamed PostProcessing Plugin AddAmsreSolarAngles, expanded to be applicable also for AMSR-2

## 2.3.23 Updates from version 1.3.6 to 1.3.7

- Update to use SNAP version 6.0.0
- Corrected bug in PostGRES database driver
- Maintenance of core modules

## 2.3.24 Updates from version 1.3.5 to 1.3.6

- Implemented support for AMSR 2 data
- Added functionality to extract all overflights over a single location
- Added global temp-file handling with automated cleanup
- Improved geocoding for MxD06 sensor data, improved accuracy

## 2.3.25 Updates from version 1.3.4 to 1.3.5

- Improve check if product is already ingested to speed up database ingestion
- Improve geocoding for MxD06 data, bow tie case, to handle with data gaps

## 2.3.26 Updates from version 1.3.3 to 1.3.4

- Bugfix. Wrong day of year (DOY) handling at PathContext.

## 2.3.27 Updates from version 1.3.2 to 1.3.3

- Bugfix. Fix read for AcquisitionInfo of CALIOP\_xxx\_Reader.  
Caliop reader must be able to create product bounding geometry for very small products.

## 2.3.28 Updates from version 1.3.1 to 1.3.2

- Urgent workaround to resolve NetCDF v4.6.10 bug

## 2.3.29 Updates from version 1.3.0 to 1.3.1

- Caliop L2 CLay Post Processing to add CLay data to an MMD file which already contain Caliop VFM Data.

## 2.3.30 Updates from version 1.2.9 to 1.3.0

- Added condition plugin to ensure unique samples per MMD file
- Implemented support for AVHRR GAC data in version 1.5

## 2.3.31 Updates from version 1.2.8 to 1.2.9

- Added satellite sensor reader for CALIOP L2 Clay products
- Implemented support for MxD06 Modis cloud products
- Fixed bug in NWP post processing plugin configuration parsing

## 2.3.32 Updates from version 1.2.7 to 1.2.8

- Implemented support for AVHRR GAC data in version 1.3 and 1.4
- Updated SST-In-situ reader to support v04.0 data

## 2.3.33 Updates from version 1.2.6 to 1.2.7

- Implemented support for OceanRain insitu SST data

## 2.3.34 Updates from version 1.2.5 to 1.2.6

- MMD – Writer ensures CF conform usage of variable attribute “units”
- Initialize ReaderCache from system or writer configuration
- Corrected SeedPointStrategy to use numPointsPerDay
- Post Processing for CALIOP Feature\_Classification\_Flags

## 2.3.35 Updates from version 1.2.4 to 1.2.5

- Optimized resource usage for distance-to-land calculations
- Updated NWP post processing to accept scaled integer geolocation data
- Added post processing that calculates the distance to land
- Added support for matchup with multiple secondary sensors
- Added satellite sensor reader for CALIOP L2 VFM products
- Border distance condition is ready to support multiple secondary sensors
- Time Delta condition is ready to support multiple secondary sensors
- Overlap remove condition is ready to support multiple secondary sensors
- Window value screening is ready to support multiple secondary sensors

## 2.3.36 Updates from version 1.2.3 to 1.2.4

- Fixed bug in IASI reader that caused crashes when reading files significantly larger than 2 GB
- Updated third party libraries: NetCDF, MongoDB, H2, MySQL and SNAP

## 2.3.37 Updates from version 1.2.2 to 1.2.3

- Added “Sun\_Glint\_Angle” variable to AMSR-E reader
- Extended IASI reader to support v4 and v5 MDR data
- Implemented post processing to add IASI spectrum to MMD
- Added IASI reader for EUMETSAT format
- Fixed bug in AngularScreening that removed too many pixels in some cases.

## 2.3.38 Updates from version 1.2.1 to 1.2.2

- Extended Archive class to understand DAY\_OF\_YEAR elements
- Added post processing plugin to convert elevation to zenith angles

- Improved PostProcessingTool – now creates target directory if not existing

## 2.3.39 Updates from version 1.2.0 to 1.2.1

- Updated BorderDistance condition to allow distinguishing between reference and secondary sensor
- Added RFI glint variables to AMSR-E reader
- Added post processing plugin to add ERA-interim NWP data to matchup datasets

## 2.3.40 Updates from version 1.1.3 to 1.2.0

- Implemented post processing engine
- Added spherical distance post-processing plugin
- Added AMSRE solar angles post-processing plugin
- Added SST in-situ time series extraction post-processing plugin
- Added WindowValue screening plugin

## 2.3.41 Updates from version 1.1.2 to 1.1.3

- Added reader cache size parameter to MMD writer configuration
- Updated MMDWriter to store CF conforming default fill value attributes

## 2.3.42 Updates from version 1.1.1 to 1.1.2

- Fixed bug in AVHRR reader that causes crashes when extracting 1x1 pixel windows

## 2.3.43 Updates from version 1.1.0 to 1.1.1

- Implemented full support for PostGIS databases

## 2.3.44 Updates from version 1.0.5 to 1.1.0

- Added condition plugin for overlap removal
- Added support for SST-CCI insitu data

## 2.3.45 Updates from version 1.0.4 to 1.0.5

- Migrated system configuration from properties to XML format
- Implemented configurable archiving rules

## 2.3.46 Updates from version 1.0.3 to 1.0.4

- Added MMD Writer configuration file
- Added MMD variable renaming engine

## 2.3.47 Updates from version 1.0.2 to 1.0.3

- Added reader for SSM/T-2 data
- Added full support for Apache H2 database
- Renamed parameter for AngularScreening plugin
- Added mmd writer configuration
- Fixed bug in HIRS reader plugin that prevented HIRS NOAA 18 data to be handled

## 2.3.48 Updates from version 1.0.1 to 1.0.2

- Added HIRS “Iza” angular screening
- Added HIRS L1C reader
- Updated regular expression for AMSU-B/MHS reader
- Added reader for ATSR1, ATSR2 and AATSR L1B data in ENVISAT format
- Added optional calculation of matchup center distance variable
- Added PixelValue screening plugin
- Corrected fill value handling to follow CF conventions
- Added reader form AMSR-E L2A data in HDF format
- Added support for multiple processing version of sensor data

## 2.3.49 Updates from version 1.0.0 to 1.0.1

- Implemented cloud screening algorithm for AMSU-B, MHS and SSMIS according to University of Hamburg
- Bugfixes:
  - Fixed issue where input files were not closed correctly
  - Fixed performance bottleneck when adding secondary observation pixels



## 2.4 Applicable and Reference Documents

The following documents are applicable (AD) or references (RD) in this manual

|      |                             |  |
|------|-----------------------------|--|
| RD 1 | FIDUCEO_MMS_IP_v_1_1        | Fiduceo Multisensor Matchup System Implementation Plan, version 1.1  |
| RD 2 | Buehler2007                 | S. A. Buehler, M. Kuvatov, T. R. Sreerekha, V. O. John, B. Rydberg, P. Eriksson, and J. Notholt: A cloud filtering method for microwave upper tropospheric humidity measurements, Atmos. Chem Phys. Discuss., 7, 7509–7534, 2007 |
| RD 3 | Hans2016                    | TN: Computing the Tb thresholds for cloud detection for the different viewing angles, Imke Hans, University of Hamburg   |
| RD 4 | SST_CCI-TN-UOL-003          | ESA CCI Phase 2 (SST) - MMD Content Specification  |
| RD 5 | Worby et al                 | Worby, A. P., C. Geiger, M. J. Paget, M. van Woert, S. F Ackley, T. DeLiberty, (2008). Thickness distribution of Antarctic sea ice. J. Geophys. Res., 113, C05S92, doi:10.1029/2007JC004254.                                     |
| AD 1 | EUM/OPS-<br>EPS/MAN/04/0032 | IASI Level 1: Product Guide, issue v4C, 3 December 2014  |

## 2.5 Glossary

|        |   |
|--------|---|
| CDO    | Climate Data Operators                          |
| CEDA   | Centre for Environmental Data Analysis          |
| CEMS   | Climate and Environmental Monitoring from Space |
| DMI    | Danmarks Meteorologiske Institut                |
| DTU    | Danmarks Tekniske Universitet                   |
| JDBC   | Java DataBase Connectivity                      |
| JDK    | Java Development Kit                            |
| LZA    | Local Zenith Angle                              |
| MMD    | Multisensor Matchup Dataset                     |
| MMS    | Multisensor Matchup System                      |
| NetCDF | Network Common Data Format                      |
| NDBC   | National Data Buoy Center                       |
| NOAA   | National Oceanic and Atmospheric Administration |
| NWP    | Numerical Weather Prediction                    |
| TAO    | Tropical Atmosphere/Ocean array                 |
| TN     | Technical Note                                  |
| SLSTR  | Sea and Land Surface Temperature Radiometer     |
| VZA    | Viewing Zenith Angle                            |
| XML    | eXtensible Markup Language                      |

## 3 Software Overview

The MMS is a software system that is composed of several interacting components. This chapter gives a high-level overview of the purpose and interactions of the components.

To operate the MMS tools, some external components need to be installed and accessible to the tools. This is mainly a unified archive of input data (see 4.1.1) and a database server engine (currently supported MongoDB, Apache H2 and PostGIS) with a user account accessible to the tools.

The calculation of matchup datasets is a three-step process:

1. Ingest satellite metadata into the database. This has to be run once for every input dataset that should be used for matchup analysis. This task is executed by the IngestionTool (chapter 3.1)
2. Find matchups and generate MMD files. This is done by the MatchupTool (chapter 3.2).
3. (optionally) Run a post-processing job on the generated MMDs. This is done by the PostProcessingTool (chapter 3.3).

### 3.1 Ingestion Tool

This tool extracts satellite metadata from the input files, pre-processes the metadata and stores the records to the database. The tool is invoked from the command line using the script *ingestion-tool.sh/bat* which is located in the *bin* directory of the MMS installation. The command line parameters can be plotted using the *-h/--help* option:

```
ingestion-tool version 1.5.6

usage: ingestion-tool <options>
Valid options are:
  -c,--config <arg>           Defines the configuration directory. Defaults to './config'.
  -end,--end-time <Date>      Define the ending time of products to inject.
  -h,--help                    Prints the tool usage.
  -s,--sensor <arg>           Defines the sensor to be ingested.
  -start,--start-time <Date>  Define the starting time of products to inject.
  -u,--update                  Update database entries if already existing.
  -v,--version <arg>         Define the sensor data processing version.
```

**--config:** define the path to the configuration files directory

**--sensor:** define the sensor key to be ingested. Sensor keys are defined by the product reader modules available, see chapter 3.5.

**--version:** defines the sensor data processing version to be ingested. Must match one of the versions stored in the archive, see 4.1.1.

**--start-date:** defines the start date for the ingestion (format: "yyyy-DDD")

**--end-date:** defines the end date for the ingestion (format: "yyyy-DDD")

**--update:** this option allows updating already existing entries in the database instead of skipping them during the ingestion process.

All satellite data files matching the type and version with an acquisition time start that falls into the interval defined by *start-date* and *end-date* will be processed.

The ingestion tool uses the following configuration files:

- system-config.xml (chapter 4.1.1)
- database.properties (chapter 4.1.2)

## 3.2 Matchup Tool

The matchup tool calculates matchups and generates MMD files. The tool is invoked from the command line using the script *matchup-tool.sh/bat* which is located in the *bin* directory of the MMS installation. The command line parameters can be plotted using the *-h/--help* option:

```
matchup-tool version 1.5.6

usage: matchup-tool <options>
Valid options are:
  -c,--config <arg>           Defines the configuration directory. Defaults to './config'.
  -end,--end-time <arg>       Defines the processing end-date, format 'yyyy-DDD'
  -h,--help                    Prints the tool usage.
  -start,--start-time <arg>    Defines the processing start-date, format 'yyyy-DDD'
  -u,--usecase <arg>          Defines the path to the use-case configuration file. Path is
                               relative to the configuration directory.
```

**--config:** define the path to the configuration files directory

**--start-time:** defines the start date for the matchup processing (format: "yyyy-DDD")

**--end-time:** defines the end date for the matchup processing (format: "yyyy-DDD")

**--usecase:** defines the usecase configuration file to use, see chapter 4.1.4

The matchup tool uses the following configuration files:

- system-config.xml (chapter 4.1.1)
- database.properties (chapter 4.1.2)
- mmd-writer-config.xml (chapter 4.1.3)

## 3.3 Post Processing Tool

The post processing tool allows to add/remove/modify variables in a set of MMD files already generated. It is a command line tool using the following parameters (the same printout can be achieved by running the

tool using the `-h` parameter). The tool is started using shells scripts located in the bin directory of the installation named *post-processing-tool.sh/bat*.

```
post-processing-tool version 1.5.6

usage: post-processing-tool <options>
Valid options are:
  -c,--config <arg>           Defines the configuration directory. Defaults to './config'.
  -end,--end-date <arg>       Defines the processing end-date, format 'yyyy-DDD'.
                               DDD = day of year.
  -h,--help                   Prints the tool usage.
  -i,--input-dir <arg>        Defines the path to the input mmd files directory.
  -j,--job-config <arg>       Defines the path to post processing job configuration file.
                               Path is relative to the configuration directory.
  -start,--start-date <arg>   Defines the processing start-date, format 'yyyy-DDD'.
                               DDD = day of year.
```

**--config:** define the path to the configuration files directory

**--job-config:** define the job-configuration file to use; the format of this file is described in chapter 4.1.5.

**--input-dir:** defines the input data directory. All files inside this directory which match the file naming pattern "*mmd\{d{1,2}.\*\_.\*\_\{d{4}-\{d{3}\_\{d{4}-\{d{3}.nc*" are collected as input files for post processing. The directory search runs recursively through all subdirectories.

**--start-date:** defines the start date for the post-processing (format: "yyyy-DDD")

**--end-date:** defines the end date for the post processing (format: "yyyy-DDD")

All MMD files with a start date within the period defined by start-date and end-date will be taken into account for processing. If any severe error occurs while computing a post processing, the processing will report the error and continue processing with the next input file, if possible.

The post processing tool uses the following configuration files:

- system-config.xml (chapter 4.1.1)
- post processing configuration (chapter 4.1.5)

## 3.4 Database Maintenance Tool

The database maintenance tool allows to modify the data paths of the metadata database. This may be necessary when the physical disk archive is moved or rearranged. It is a command line tool using the following parameters (the same printout can be achieved by running the tool using the `-h` parameter). The tool is started using shells scripts located in the bin directory of the installation named *db\_maintenance.sh/bat*.

```
db-maintenance-tool version 1.5.6

usage: db_maintenance <options>
Valid options are:
  -c,--config <arg>           Defines the configuration directory. Defaults to './config'.
  -d,--dryrun                 Defines 'dryrun' status, i.e. just test the replacement and report
                               problems.
```

|   |  |
|---|--|
| <code>-h, --help</code>                                 | Prints the tool usage.   |
| <code>-p, --path &lt;arg&gt;</code>                     | Observation path segment to be replaced or truncated.                  |
| <code>-r, --replace &lt;arg&gt;</code>                  | Observation path segment replacement.                                  |
| <code>-s, --segments &lt;arg&gt;</code><br>(default: 4) | Number of segments to consider for paths missing the search expression |
| <code>-t, --truncate</code>                             | Command to truncate path segment.                                      |

**--config:** define the path to the configuration files directory

**--dryrun:** set to dryrun state, which is testing the requested operations without performing them and reporting the result to the console.

**--segments:** set the length of the path segments to be distinguished in the --dryrun report, defaults to 4. This allows to detail the amount of paths that are reported to a meaningful subset, i.e. the sensor and the version. For a database containing paths in the form of

`<SENSOR>/<VERSION>/<YEAR>/<MONTH>/<DAY>/data_product`

An example printout with `--segments 2` gives the following result:

```
Datasets checked: 863712
Datasets ok to convert: 0
Datasets with deviating path:
- slstr-s3b-nt/v1: 376100
- slstr-s3a-nt/v1: 362673
- avhrr-frac-ma/v1: 52228
- avhrr-frac-mb/v1: 47583
- aatsr-en/v3: 25127
```

**--path:** defines the path segment to search for. Updating of the path of the database entry will be executed for all entries containing the path segment.

**--replace:** defines the path segment to replace the search path defined with the `--path` argument

**--truncate:** set this to truncate the search path segment defined in `--path` from the database entry path

The database maintenance tool uses the following configuration files:

- system-config.xml (chapter 4.1.1)
- database.properties (chapter 4.1.2)

## 3.5 Supported Satellite Sensors

This chapter lists the input satellite data source types available for matchup processing. In subsequent chapters, the sensors, the data format, and the available variables are described in more detail.

### 3.5.1 AIRS-Level-1B

AIRS Level-1B Version v5.0.0.0

IR Calibrated Radiance Products (AIRIBRAD)

# Multi-sensor Match up System (MMS) Manual V 1.6

| Sensor Key | Source                                |
|------------|---------------------------------------|
| airs-aq    | AIRS Level-1B data from Aqua platform |

| Variable Name | Description  |
|---------------|--|
| Latitude      | Footprint boresight geodetic Latitude in degrees North (-90.0 ... 90.0)  |
| Longitude     | Footprint boresight geodetic Longitude in degrees East (-180.0 ... 180.0)  |
| Time          | Footprint "shutter" TAI Time: floating-point elapsed seconds since Jan 1, 1993   |
| scanang       | Scanning angle of AIRS instrument with respect to the AIRS Instrument for this footprint (-180.0 ... 180.0, negative at start of scan, 0 at nadir)   |
| satheight     | Satellite altitude at nadirTAI in km above reference ellipsoid (e.g. 725.2)  |
| satroll       | Satellite attitude roll angle at nadirTAI (-180.0 ... 180.0 angle about the +x (roll) ORB axis, +x axis is positively oriented in the direction of orbital flight completing an orthogonal triad with y and z.)  |
| satpitch      | Satellite attitude pitch angle at nadirTAI (-180.0 ... 180.0 angle about +y (pitch) ORB axis. +y axis is oriented normal to the orbit plane with the positive sense opposite to that of the orbit's angular momentum vector H.)  |
| satyaw        | Satellite attitude yaw angle at nadirTAI (-180.0 ... 180.0 angle about +z (yaw) axis. +z axis is positively oriented Earthward parallel to the satellite radius vector R from the spacecraft center of mass to the center of the Earth.)   |
| satgeoqa      | <p>Satellite Geolocation QA flags:</p> <p>Bit 0: (LSB, value 1) bad input value;</p> <p>Bit 1: (value 2) PGS_TD_TAItUTC() gave PGSTD_E_NO_LEAP_SECS;</p> <p>Bit 2: (value 4) PGS_TD_TAItUTC() gave PGS_E_TOOLKIT;</p> <p>Bit 3: (value 8) PGS_EPH_EphemAttit() gave PGSEPH_W_BAD_EPHEM_VALUE;</p> <p>Bit 4: (value 16) PGS_EPH_EphemAttit() gave PGSEPH_E_BAD_EPHEM_FILE_HDR;</p> <p>Bit 5: (value 32) PGS_EPH_EphemAttit() gave PGSEPH_E_NO_SC_EPHEM_FILE;</p> <p>Bit 6: (value 64) PGS_EPH_EphemAttit() gave PGSEPH_E_NO_DATA_REQUESTED;</p> <p>Bit 7: (value 128) PGS_EPH_EphemAttit() gave PGSTD_E_SC_TAG_UNKNOWN;</p> <p>Bit 8: (value 256) PGS_EPH_EphemAttit() gave PGSEPH_E_BAD_ARRAY_SIZE;</p> <p>Bit 9: (value 512) PGS_EPH_EphemAttit() gave PGSTD_E_TIME_FMT_ERROR;</p> <p>Bit 10: (value 1024) PGS_EPH_EphemAttit() gave PGSTD_E_TIME_VALUE_ERROR;</p> <p>Bit 11: (value 2048) PGS_EPH_EphemAttit() gave PGSTD_E_NO_LEAP_SECS;</p> <p>Bit 12: (value 4096) PGS_EPH_EphemAttit() gave PGS_E_TOOLKIT;</p> <p>Bit 13: (value 8192) PGS_CSC_ECItECR() gave PGSCSC_W_BAD_TRANSFORM_VALUE;</p> <p>Bit 14: (value 16384) PGS_CSC_ECItECR() gave PGSCSC_E_BAD_ARRAY_SIZE;</p> <p>Bit 15: (value 32768) PGS_CSC_ECItECR() gave PGSTD_E_NO_LEAP_SECS;</p> |

|            |  |
|------------|--|
|            | <p>Bit 16: (value 65536) PGS_CSC_ECIttoECR() gave PGSTD_E_TIME_FMT_ERROR;</p> <p>Bit 17: (value 131072) PGS_CSC_ECIttoECR() gave PGSTD_E_TIME_VALUE_ERROR;</p> <p>Bit 18: unused (set to zero);</p> <p>Bit 19: (value 524288) PGS_CSC_ECIttoECR() gave PGSTD_E_NO_UT1_VALUE;</p> <p>Bit 20: (value 1048576) PGS_CSC_ECIttoECR() gave PGS_E_TOOLKIT;</p> <p>Bit 21: (value 2097152) PGS_CSC_ECRtoGEO() gave PGSCSC_W_TOO_MANY_ITERS;</p> <p>Bit 22: (value 4194304) PGS_CSC_ECRtoGEO() gave PGSCSC_W_INVALID_ALTITUDE;</p> <p>Bit 23: (value 8388608) PGS_CSC_ECRtoGEO() gave PGSCSC_W_SPHERE_BODY;</p> <p>Bit 24: (value 16777216) PGS_CSC_ECRtoGEO() gave PGSCSC_W_LARGE_FLATTENING;</p> <p>Bit 25: (value 33554432) PGS_CSC_ECRtoGEO() gave PGSCSC_W_DEFAULT_EARTH_MODEL;</p> <p>Bit 26: (value 67108864) PGS_CSC_ECRtoGEO() gave PGSCSC_E_BAD_EARTH_MODEL;</p> <p>Bit 27: (value 134217728) PGS_CSC_ECRtoGEO() gave PGS_E_TOOLKIT;</p> <p>Bit 28-31: not used</p>   |
| glintgeoqa | <p>Glint Geolocation QA flags:</p> <p>Bit 0: (LSB, value 1) bad input value;</p> <p>Bit 1: (value 2) glint location in Earth's shadow (Normal for night FOVs);</p> <p>Bit 2: (value 4) glint calculation not converging;</p> <p>Bit 3: (value 8) glint location sun vs. satellite zenith mismatch;</p> <p>Bit 4: (value 16) glint location sun vs. satellite azimuth mismatch;</p> <p>Bit 5: (value 32) bad glint location;</p> <p>Bit 6: (value 64) PGS_CSC_ZenithAzimuth() gave any 'W' class return code;</p> <p>Bit 7: (value 128) PGS_CSC_ZenithAzimuth() gave any 'E' class return code;</p> <p>Bit 8: (value 256) PGS_CBP_Earth_CB_Vector() gave any 'W' class return code;</p> <p>Bit 9: (value 512) PGS_CBP_Earth_CB_Vector() gave any 'E' class return code;</p> <p>Bit 10: (value 1024) PGS_CSC_ECIttoECR() gave any 'W' class return code except PGSCSC_W_PREDICTED_UT1 (for Glint);</p> <p>Bit 11: (value 2048) PGS_CSC_ECIttoECR() gave any 'E' class return code (for Glint);</p> <p>Bit 12: (value 4096) PGS_CSC_ECRtoGEO() gave any 'W' class return code (for Glint);</p> <p>Bit 13: (value 8192) PGS_CSC_ECRtoGEO() gave any 'E' class return code (for Glint);</p> <p>Bit 14: (value 16384) PGS_CSC_ECIttoECR() gave any 'W' class return code except PGSCSC_W_PREDICTED_UT1 ;</p> <p>Bit 15: (value 32768) PGS_CSC_ECIttoECR() gave any 'E' class return code</p> |
| moongeoqa  | <p>Moon Geolocation QA flags:</p> <p>Bit 0: (LSB, value 1) bad input value;</p> <p>Bit 1: (value 2) PGS_TD_TAIttoUTC() gave PGSTD_E_NO_LEAP_SECS;</p> <p>Bit 2: (value 4) PGS_TD_TAIttoUTC() gave PGS_E_TOOLKIT;</p> <p>Bit 3: (value 8) PGS_CBP_Sat_CB_Vector() gave</p>  |

|           |  |
|-----------|--|
|           | <p>PGSCSC_W_BELOW_SURFACE;<br/> Bit 4: (value 16) PGS_CBP_Sat_CB_Vector() gave<br/> PGSCBP_W_BAD_CB_VECTOR;<br/> Bit 5: (value 32) PGS_CBP_Sat_CB_Vector() gave<br/> PGSCBP_E_BAD_ARRAY_SIZE;<br/> Bit 6: (value 64) PGS_CBP_Sat_CB_Vector() gave<br/> PGSCBP_E_INVALID_CB_ID;<br/> Bit 7: (value 128) PGS_CBP_Sat_CB_Vector() gave<br/> PGSMEM_E_NO_MEMORY;<br/> Bit 8: (value 256) PGS_CBP_Sat_CB_Vector() gave<br/> PGSCBP_E_UNABLE_TO_OPEN_FILE;<br/> Bit 9: (value 512) PGS_CBP_Sat_CB_Vector() gave<br/> PGSTD_E_BAD_INITIAL_TIME;<br/> Bit 10: (value 1024) PGS_CBP_Sat_CB_Vector() gave<br/> PGSCBP_E_TIME_OUT_OF_RANGE;<br/> Bit 11: (value 2048) PGS_CBP_Sat_CB_Vector() gave<br/> PGSTD_E_SC_TAG_UNKNOWN;<br/> Bit 12: (value 4096) PGS_CBP_Sat_CB_Vector() gave<br/> PGSEPH_E_BAD_EPHEM_FILE_HDR;<br/> Bit 13: (value 8192) PGS_CBP_Sat_CB_Vector() gave<br/> PGSEPH_E_NO_SC_EPHEM_FILE;<br/> Bit 14: (value 16384) PGS_CBP_Sat_CB_Vector() gave PGS_E_TOOLKIT;<br/> Bit 15: not used</p>  |
| ftptgeoqa | <p>Footprint Geolocation QA flags:<br/> Bit 0: (LSB, value 1) bad input value;<br/> Bit 1: (value 2) PGS_TD_TAtoUTC() gave PGSTD_E_NO_LEAP_SECS;<br/> Bit 2: (value 4) PGS_TD_TAtoUTC() gave PGS_E_TOOLKIT;<br/> Bit 3: (value 8) PGS_CSC_GetFOV_Pixel() gave<br/> PGSCSC_W_MISS_EARTH;<br/> Bit 4: (value 16) PGS_CSC_GetFOV_Pixel() gave<br/> PGSTD_E_SC_TAG_UNKNOWN;<br/> Bit 5: (value 32) PGS_CSC_GetFOV_Pixel() gave<br/> PGSCSC_W_ZERO_PIXEL_VECTOR;<br/> Bit 6: (value 64) PGS_CSC_GetFOV_Pixel() gave<br/> PGSCSC_W_BAD_EPH_FOR_PIXEL;<br/> Bit 7: (value 128) PGS_CSC_GetFOV_Pixel() gave<br/> PGSCSC_W_INSTRUMENT_OFF_BOARD;<br/> Bit 8: (value 256) PGS_CSC_GetFOV_Pixel() gave<br/> PGSCSC_W_BAD_ACCURACY_FLAG;<br/> Bit 9: (value 512) PGS_CSC_GetFOV_Pixel() gave<br/> PGSCSC_E_BAD_ARRAY_SIZE;<br/> Bit 10: (value 1024) PGS_CSC_GetFOV_Pixel() gave<br/> PGSCSC_W_DEFAULT_EARTH_MODEL;<br/> Bit 11: (value 2048) PGS_CSC_GetFOV_Pixel() gave<br/> PGSCSC_W_DATA_FILE_MISSING;<br/> Bit 12: (value 4096) PGS_CSC_GetFOV_Pixel() gave<br/> PGSCSC_E_NEG_OR_ZERO_RAD;<br/> Bit 13: (value 8192) PGS_CSC_GetFOV_Pixel() gave<br/> PGSMEM_E_NO_MEMORY;<br/> Bit 14: (value 16384) PGS_CSC_GetFOV_Pixel() gave<br/> PGSTD_E_NO_LEAP_SECS;</p> |



|          |   |
|----------|---|
|          | <p>Bit 15: (value 32768) PGS_CSC_GetFOV_Pixel() gave PGSTD_E_TIME_FMT_ERROR;</p> <p>Bit 16: (value 65536) PGS_CSC_GetFOV_Pixel() gave PGSTD_E_TIME_VALUE_ERROR;</p> <p>Bit 17: (value 131072) PGS_CSC_GetFOV_Pixel() gave PGSCSC_W_PREDICTED_UT1;</p> <p>Bit 18: (value 262144) PGS_CSC_GetFOV_Pixel() gave PGSTD_E_NO_UT1_VALUE;</p> <p>Bit 19: (value 524288) PGS_CSC_GetFOV_Pixel() gave PGS_E_TOOLKIT;</p> <p>Bit 20: (value 1048576) PGS_CSC_GetFOV_Pixel() gave PGSEPH_E_BAD_EPHEM_FILE_HDR;</p> <p>Bit 21: (value 2097152) PGS_CSC_GetFOV_Pixel() gave PGSEPH_E_NO_SC_EPHEM_FILE;</p> <p>Bit 22-31: not used</p>   |
| zengeoqa | <p>Satellite zenith Geolocation QA flags:</p> <p>Bit 0: (LSB, value 1) (Spacecraft) bad input value;</p> <p>Bit 1: (value 2) PGS_CSC_ZenithAzimuth(S/C) gave PGSCSC_W_BELOW_HORIZON;</p> <p>Bit 2: (value 4) PGS_CSC_ZenithAzimuth(S/C) gave PGSCSC_W_UNDEFINED_AZIMUTH;</p> <p>Bit 3: (value 8) PGS_CSC_ZenithAzimuth(S/C) gave PGSCSC_W_NO_REFRACTION;</p> <p>Bit 4: (value 16) PGS_CSC_ZenithAzimuth(S/C) gave PGSCSC_E_INVALID_VECTAG;</p> <p>Bit 5: (value 32) PGS_CSC_ZenithAzimuth(S/C) gave PGSCSC_E_LOOK_PT_ALTIT_RANGE;</p> <p>Bit 6: (value 64) PGS_CSC_ZenithAzimuth(S/C) gave PGSCSC_E_ZERO_INPUT_VECTOR;</p> <p>Bit 7: (value 128) PGS_CSC_ZenithAzimuth(S/C) gave PGS_E_TOOLKIT;</p> <p>Bit 8: (value 256) (Sun) bad input value;</p> <p>Bit 9: (value 512) (suppressed) PGS_CSC_ZenithAzimuth(Sun) gave PGSCSC_W_BELOW_HORIZON (This is not an error condition - the sun is below the horizon at night);</p> <p>Bit 10: (value 1024) PGS_CSC_ZenithAzimuth(Sun) gave PGSCSC_W_UNDEFINED_AZIMUTH;</p> <p>Bit 11: (value 2048) PGS_CSC_ZenithAzimuth(Sun) gave PGSCSC_W_NO_REFRACTION;</p> <p>Bit 12: (value 4096) PGS_CSC_ZenithAzimuth(Sun) gave PGSCSC_E_INVALID_VECTAG;</p> <p>Bit 13: (value 8192) PGS_CSC_ZenithAzimuth(Sun) gave PGSCSC_E_LOOK_PT_ALTIT_RANGE;</p> <p>Bit 14: (value 16384) PGS_CSC_ZenithAzimuth(Sun) gave PGSCSC_E_ZERO_INPUT_VECTOR;</p> <p>Bit 15: (value 32768) PGS_CSC_ZenithAzimuth(Sun) gave PGS_E_TOOLKIT</p> |
| demgeoqa | <p>Digital Elevation Model (DEM) Geolocation QA flags:</p> <p>Bit 0: (LSB, value 1) bad input value;</p> <p>Bit 1: (value 2) Could not allocate memory;</p> <p>Bit 2: (value 4) Too close to North or South pole. Excluded. (This is not an</p>   |

|                    |  |
|--------------------|--|
|                    | <p>error condition - a different model is used);</p> <p>Bit 3: (value 8) Layer resolution incompatibility. Excluded;</p> <p>Bit 4: (value 16) Any DEM Routine (elev) gave PGSDM_E_IMPROPER_TAG;</p> <p>Bit 5: (value 32) Any DEM Routine (elev) gave PGSDM_E_CANNOT_ACCESS_DATA;</p> <p>Bit 6: (value 64) Any DEM Routine (land/water) gave PGSDM_E_IMPROPER_TAG;</p> <p>Bit 7: (value 128) Any DEM Routine (land/water) gave PGSDM_E_CANNOT_ACCESS_DATA;</p> <p>Bit 8: (value 256) Reserved for future layers;</p> <p>Bit 9: (value 512) Reserved for future layers;</p> <p>Bit 10: (value 1024) PGS_DEM_GetRegion(elev) gave PGSDM_M_FILLVALUE_INCLUDED;</p> <p>Bit 11: (value 2048) PGS_DEM_GetRegion(land/water) gave PGSDM_M_FILLVALUE_INCLUDED;</p> <p>Bit 12: (value 4096) Reserved for future layers;</p> <p>Bit 13: (value 8192) PGS_DEM_GetRegion(all) gave PGSDM_M_MULTIPLE_RESOLUTIONS;</p> <p>Bit 14: (value 16384) PGS_CSC_GetFOV_Pixel() gave any 'W' class return code except PGSCSC_W_PREDICTED_UT1;</p> <p>Bit 15: (value 32768) PGS_CSC_GetFOV_Pixel() gave any 'E' class return code</p> |
| nadirTAI           | TAI time at which instrument is nominally looking directly down. (between footprints 15 & 16 for AMSU or between footprints 45 & 46 for AIRS/Vis & HSB) (floating-point elapsed seconds since start of 1993)   |
| sat_lat            | Satellite geodetic latitude in degrees North (-90.0 ... 90.0)  |
| sat_lon            | Satellite geodetic longitude in degrees East (-180.0 ... 180.0)  |
| scan_node_type     | 'A' for ascending, 'D' for descending, 'E' when an error is encountered in trying to determine a value.  |
| satzen             | Spacecraft zenith angle (0.0 ... 180.0) degrees from zenith (measured relative to the geodetic vertical on the reference (WGS84) spheroid and including corrections outlined in EOS SDP toolkit for normal accuracy.)  |
| satazi             | Spacecraft azimuth angle (-180.0 ... 180.0) degrees E of N GEO)  |
| glintlat           | Solar glint geodetic latitude in degrees North at nadirTAI (-90.0 ... 90.0)  |
| glintlon           | Solar glint geodetic longitude in degrees East at nadirTAI (-180.0 ... 180.0)  |
| sun_glint_distance | Distance (km) from footprint center to location of the sun glint (-9999 for unknown, 30000 for no glint visible because spacecraft is in Earth's shadow)   |
| topog              | Mean topography in meters above reference ellipsoid  |
| topog_err          | Error estimate for topog   |
| landFrac           | Fraction of spot that is land (0.0 ... 1.0)  |
| landFrac_err       | Error estimate for landFrac  |
| state              | Data state: 0:Process, 1:Special, 2:Erroneous, 3:Missing   |
| CalScanSummary     | <p>Bit field. Bitwise OR of CalFlag over the all channels with ExcludedChans &lt; 3. Zero means all "good" channels were well calibrated for this scanline</p> <p>Bit 7 (MSB): scene over/underflow;</p> <p>Bit 6: (value 64) anomaly in offset calculation;</p> <p>Bit 5: (value 32) anomaly in gain calculation;</p>   |

|                          |  |
|--------------------------|--|
|                          | Bit 4: (value 16) pop detected;<br>Bit 3: (value 8) DCR Occurred;<br>Bit 2: (value 4) Moon in View;<br>Bit 1: (value 2) telemetry out of limit condition;<br>Bit 0: (LSB, value 1) cold scene noise  |
| spaceview_selection      | Indicates which footprints were included for this scan. Each bit is high when the corresponding space view is used in the spaceview offset calculation. (See L1B Processing Requirements, section 6.2); LSB is first space view.   |
| Rdiff_swindow            | Radiance difference in the 2560 cm <sup>-1</sup> window region used to warn of possible errors caused by scene non-uniformity and misalignment of the beams: radiance(Rdiff_swindow_M1a_chan) - radiance(Rdiff_swindow_M2a_chan). (radiance units)   |
| Rdiff_lwindow            | Radiance difference in the longwave window(850 cm <sup>-1</sup> ) used to warn of possible errors caused by scene non-uniformity and misalignment of the point beams: radiance(Rdiff_lwindow_M8_chan) - radiance(Rdiff_lwindow_M9_chan). (radiance units)  |
| SceneInhomogeneous       | Threshold test for scene inhomogeneity, using band-overlap detectors (bit fields).;<br>Bit 7 (MSB, value 128): scene is inhomogeneous, as determined by the Rdiff_swindow threshold. For v5.0 the test is $\text{abs}(\text{Rdiff\_swindow}) > 5 * \sqrt{\text{NeN}(\text{Rdiff\_swindow\_M1a\_chan})^2 + \text{NeN}(\text{Rdiff\_swindow\_M2a\_chan})}$ ;<br>Bit 6 (value 64): scene is inhomogeneous, as determined by the Rdiff_lwindow threshold. For v5.0 the test is $\text{abs}(\text{Rdiff\_lwindow}) > 5 * \sqrt{\text{NeN}(\text{Rdiff\_lwindow\_M8\_chan})^2 + \text{NeN}(\text{Rdiff\_lwindow\_M9\_chan})}$ ;<br>Bits 5-0: unused (reserved) |
| dust_flag                | Flag telling whether dust was detected in this scene;<br>1: Dust detected;<br>0: Dust not detected;<br>-1: Dust test not valid because of land;<br>-2: Dust test not valid because of high latitude;<br>-3: Dust test not valid because of suspected cloud;<br>-4: Dust test not valid because of bad input data   |
| dust_score               | Dust score. Each bit results from a different test comparing radiances. Higher scores indicate more certainty of dust present. Dust probable when score is over 380. Not valid when dust_flag is negative.   |
| spectral_clear_indicator | Flag telling whether scene was flagged as clear by a spectral filter. Only ocean filter is validated;<br>2: Ocean test applied and scene identified as clear;<br>1: Ocean test applied and scene not identified as clear;<br>0: Calculation could not be completed. Possibly some inputs were missing or FOV is on coast or on the edge of a scan or granule;<br>-1: Unvalidated land test applied and scene not identified as clear;<br>-2: Unvalidated land test applied and scene identified as clear   |
| BT_diff_SO2              | Brightness temperature difference Tb(1361.44 cm <sup>-1</sup> ) - Tb(1433.06 cm <sup>-1</sup> ) used as an indicator of SO2 release from volcanoes. Values under -6 K have likely volcanic SO2. (Kelvins)  |
| OpMode                   | Instrument Operations Mode. See AIRS Command Handbook, section 6.4 for   |

|          |  |
|----------|--|
|          | a definition of each bit.<br>Bits 0 (LSB)-2 cal phase;<br>bits 3-6 Cal Func;<br>Bit 7 quicklook (expedited) flag;<br>bits 8-11 submode<br>Bits 12-14 Mode (0=standby, 1=ready, 2=operate, 3=checkout, 4=decontaminate, 5=off, 6=survival);<br>bit 16 transition flag |
| EDCBOARD | EDC A/B Powered on Indicator;;<br>0: Both sides off;<br>1: Side A;<br>2: Side B;<br>3: Invalid;<br>65534: No value downlinked  |

### 3.5.2 AMSR-2

AMSR-2 L1R brightness temperatures in HDF5 format as supplied by JAXA. This reader only handles data in the low resolution, the 89 GHz A and B data are ignored.

| Sensor Key | Source                            |
|------------|-----------------------------------|
| amsr2-gcw1 | AMSR-2 data from GCOM-W1 platform |

| Variable Name                            | Description   |
|--|---|
| Area_Mean_Height                         | Altitude data   |
| Brightness_Temperature_(resXX,6.9GHz,Y)  | Observed brightness temperature at 6.9 GHz, resampled to resolution XX, polarisation Y  |
| Brightness_Temperature_(resXX,7.3GHz,Y)  | Observed brightness temperature at 7.3 GHz, resampled to resolution XX, polarisation Y  |
| Brightness_Temperature_(resXX,10.7GHz,Y) | Observed brightness temperature at 10.7 GHz, resampled to resolution XX, polarisation Y |
| Brightness_Temperature_(resXX,18.7GHz,Y) | Observed brightness temperature at 18.7 GHz, resampled to resolution XX, polarisation Y |
| Brightness_Temperature_(resXX,23.8GHz,Y) | Observed brightness temperature at 23.8 GHz, resampled to resolution XX, polarisation Y |
| Brightness_Temperature_(resXX,36.5GHz,Y) | Observed brightness temperature at 36.5 GHz, resampled to resolution XX, polarisation Y |
| Brightness_Temperature_(resXX,89.0GHz,Y) | Observed brightness temperature at 89.0 GHz, resampled to resolution XX, polarisation Y |
| Earth_Incidence                          | Incidence angle of observation in degrees   |
| Earth_Azimuth                            | Azimuth angle of observation in degrees   |
| Sun_Elevation                            | Sun elevation angle in degrees  |
| Sun_Azimuth                              | Sun azimuth angle in degrees  |
| Land_Ocean_Flag_6                        | Land coverage flag for 6.9 GHz channel  |
| Land_Ocean_Flag_10                       | Land coverage flag for 10.7 GHz channel   |
| Land_Ocean_Flag_23                       | Land coverage flag for 23.8 GHz channel   |
| Land_Ocean_Flag_36                       | Land coverage flag for 36.5 GHz channel   |

|  |   |
|--|---|
| Latitude_of_Observation_Point_for_89A  | Latitude in degrees, subsampled to match the low resolution raster size                     |
| Longitude_of_Observation_Point_for_89A | Longitude in degrees, subsampled to match the low resolution raster size                    |
| Pixel_Data_Quality_6_to_36             | Pixel data quality flags, rearranged to SHORT data type by merging the two BYTE data arrays |
| Position_in_Orbit                      | The satellite position on the orbit   |
| Scan_Time                              | Acquisition time per scanline in TAI seconds since 1993                                     |

### 3.5.3 AMSR-E

AMSR-E L2A brightness temperatures in HDF4 format. This reader only handles the “Low\_Res\_Swath” data.

| Sensor Key | Source                         |
|------------|--------------------------------|
| amsre-aq   | AMSR-E data from Aqua platform |

| Variable Name                      | Description  |
|------------------------------------|--|
| Time                               | Acquisition time per scanline in TAI seconds since 1993  |
| Latitude                           | Latitude of pixel in decimal degrees   |
| Longitude                          | Longitude of pixel in decimal degrees  |
| Earth_Incidence                    | Incidence angle of observation in degrees  |
| Earth_Azimuth                      | Azimuth angle of observation in degrees  |
| Sun_Elevation                      | Sun elevation angle in degrees   |
| Sun_Azimuth                        | Sun azimuth angle in degrees   |
| Land_Ocean_Flag_6                  | Land coverage flag for 6 GHz channel   |
| X_XV_Res_1_TB                      | Brightness temperatures vertical polarisation in low resolution for channels X_X (6_9, 10_7, 18_7, 23_8, 36_5, 89_0)   |
| X_XH_Res_1_TB                      | Brightness temperatures horizontal polarisation in low resolution for channels X_X (6_9, 10_7, 18_7, 23_8, 36_5, 89_0)   |
| Scan_Quality_Flag                  | Quality flags per scan   |
| Channel_Quality_Flag_XXV           | Quality flags per vertical polarisation channel XX (6, 10, 18, 23, 36, 89)   |
| Channel_Quality_Flag_XXH           | Quality flags per horizontal polarisation channel XX (6, 10, 18, 23, 36, 89)   |
| Res1_Surf                          | Land coverage percentage for resolution one  |
| Geostationary_Reflection_Latitude  | RFI sources glint angles latitude  |
| Geostationary_Reflection_Longitude | RFI sources glint angles longitude   |
| Sun_Glint_Angle                    | Angular separation between the Reflected Satellite View Vector and the Sun Vector. When Sun_Glint_Angle is zero, the instrument views the center of the specular (mirror-like) sun reflection. |

### 3.5.4 AMSU-B

AMSU-B L1c data from NOAA CLASS storage, converted to HDF using “atovin” and “convert\_to\_hdf5”.

| Sensor Key | Source        |
|------------|---------------|
| amsub-n15  | AMSU-B NOAA15 |
| amsub-n16  | AMSU-B NOAA16 |
| amsub-n17  | AMSU-B NOAA17 |

| Variable Name           | Description   |
|-------------------------|---|
| btemps_ch1              | Brightness temperature in channel 1 (2.9684 m <sup>-1</sup> ) |
| btemps_ch2              | Brightness temperature in channel 2 (5.0032 m <sup>-1</sup> ) |
| btemps_ch3              | Brightness temperature in channel 3 (6.1146 m <sup>-1</sup> ) |
| btemps_ch4              | Brightness temperature in channel 4 (6.1146 m <sup>-1</sup> ) |
| btemps_ch5              | Brightness temperature in channel 5 (6.1146 m <sup>-1</sup> ) |
| chanqual_ch1            | Channel quality for channel 1                                 |
| chanqual_ch2            | Channel quality for channel 2                                 |
| chanqual_ch3            | Channel quality for channel 3                                 |
| chanqual_ch4            | Channel quality for channel 4                                 |
| chanqual_ch5            | Channel quality for channel 5                                 |
| instrtemp               | Instrument temperature  |
| qualind                 | Quality indicator   |
| scanqual                | Scan line quality   |
| scnlin                  | Scan line number  |
| scnlindy                | Day of scan line acquisition                                  |
| scnlintime              | Time of scan line acquisition                                 |
| scnlinyr                | Year of scan line acquisition                                 |
| Latitude                | Latitude of pixel   |
| Longitude               | Longitude of pixel  |
| Time                    | Acquisition time in TAI93 seconds                             |
| Satellite_azimuth_angle | The satellite azimuth angle                                   |
| Satellite_zenith_angle  | The satellite zenith angle                                    |
| Solar_azimuth_angle     | The solar azimuth angle                                       |
| Solar_zenith_angle      | The solar zenith angle  |

All per-scan line variables are extended to cover the full pixel grid.

### 3.5.5 (A)ATSR

ATSR1, ATSR2 and AATSR data in ENVISAT native format (\*.N1). The MMS supports data in processing version v2.1 and v3 format.

| Sensor Key | Source           |
|------------|------------------|
| atsr-e1    | ATSR1 on ERS1    |
| atsr-e2    | ATSR2 on ERS2    |
| aatsr-en   | AATSR on ENVISAT |

| Variable Name    | Description   |
|------------------|---|
| btemp_nadir_1200 | Brightness temperature, nadir view (11500-12500 nm) |

|                    |   |
|--------------------|---|
| btemp_nadir_1100   | Brightness temperature, nadir view (10400-11300 nm)   |
| btemp_nadir_0370   | Brightness temperature, nadir view (3505-3895 nm)     |
| reflec_nadir_1600  | Reflectance, nadir view (1580-1640 nm)                |
| reflec_nadir_0870  | Reflectance, nadir view (855-875 nm)                  |
| reflec_nadir_0670  | Reflectance, nadir view (649-669 nm)                  |
| reflec_nadir_0550  | Reflectance, nadir view (545-565 nm)                  |
| confid_flags_nadir | Confidence flags, nadir view                          |
| cloud_flags_nadir  | Cloud flags, nadir view                               |
| btemp_fward_1200   | Brightness temperature, forward view (11500-12500 nm) |
| btemp_fward_1100   | Brightness temperature, forward view (10400-11300 nm) |
| btemp_fward_0370   | Brightness temperature, forward view (3505-3895 nm)   |
| reflec_fward_1600  | Reflectance, forward view (1580-1640 nm)              |
| reflec_fward_0870  | Reflectance, forward view (855-875 nm)                |
| reflec_fward_0670  | Reflectance, forward view (649-669 nm)                |
| reflec_fward_0550  | Reflectance, forward view (545-565 nm)                |
| confid_flags_fward | Confidence flags, forward view                        |
| cloud_flags_fward  | Cloud flags, forward view                             |
| lat_corr_nadir     | Latitude corrections, nadir view                      |
| lon_corr_nadir     | Longitude corrections, nadir view                     |
| sun_elev_nadir     | Solar elevation, nadir view                           |
| view_elev_nadir    | Satellite elevation, nadir view                       |
| sun_azimuth_nadir  | Solar azimuth, nadir view                             |
| view_azimuth_nadir | Satellite azimuth, nadir view                         |
| lat_corr_fward     | Latitude corrections, forward view                    |
| lon_corr_fward     | Longitude corrections, forward view                   |
| sun_elev_fward     | Solar elevation, forward view                         |
| view_elev_fward    | Satellite elevation, forward view                     |
| sun_azimuth_fward  | Solar azimuth, forward view                           |
| view_azimuth_fward | Satellite azimuth, forward view                       |
| latitude           | Latitudes   |
| longitude          | Longitudes  |
| altitude           | Topographic altitude                                  |

All tie-point raster variables are interpolated to the full raster resolution.

### 3.5.6 AVHRR GAC

AVHRR L1C GAC data in NetCDF format, converted using routines developed at University of Reading. The MMS supports data of processing versions 1.2, 1.3, 1.4-cspp, 1.5 and 2.10.1.

| Sensor Key | Source         |
|------------|----------------|
| avhrr-n06  | AVHRR NOAA06   |
| avhrr-n07  | AVHRR/2 NOAA07 |
| avhrr-n08  | AVHRR NOAA08   |
| avhrr-n09  | AVHRR/2 NOAA09 |
| avhrr-n10  | AVHRR NOAA10   |
| avhrr-n11  | AVHRR/2 NOAA11 |

|           |                 |
|-----------|-----------------|
| avhrr-n12 | AVHRR/2 NOAA12  |
| avhrr-n14 | AVHRR/2 NOAA14  |
| avhrr-n15 | AVHRR/3 NOAA15  |
| avhrr-n16 | AVHRR/3 NOAA16  |
| avhrr-n17 | AVHRR/3 NOAA17  |
| avhrr-n18 | AVHRR/3 NOAA18  |
| avhrr-n19 | AVHRR/3 NOAA19  |
| avhrr-m02 | AVHRR/3 METOP A |
| avhrr-ma  | AVHRR/3 METOP A |
| avhrr-m01 | AVHRR/3 METOP B |
| avhrr-mb  | AVHRR/3 METOP B |

| Variable Name     | Description   |
|-------------------|---|
| ch1               | Channel 1 reflectance   |
| ch1_earth_counts  | Channel 1 photon counts earth view (only v2.10.1)                         |
| ch1_noise         | Channel 1 noise estimate (only v01.4-cspp, 1.5, v2.10.1)                  |
| ch2               | Channel 2 reflectance   |
| ch2_earth_counts  | Channel 2 photon counts earth view (only v2.10.1)                         |
| ch2_noise         | Channel 2 noise estimate (only v01.4-cspp, 1.5, v2.10.1)                  |
| ch3               | Channel 3 reflectance (only AVHRR/2)                                      |
| ch3_earth_counts  | Channel 3 photon counts earth view (only v2.10.1) (only AVHRR/2)          |
| ch3_noise         | Channel 3 noise estimate (only v01.4-cspp, 1.5) (only AVHRR/2)            |
| ch3a              | Channel 3a reflectance (only AVHRR/2 AVHRR/3)                             |
| ch3a_earth_counts | Channel 3a photon counts earth view (only v2.10.1) (only AVHRR/2 AVHRR/3) |
| ch3a_noise        | Channel 3a noise estimate (only v01.4-cspp, 1.5) (only AVHRR/2 AVHRR/3)   |
| ch3b              | Channel 3b brightness temperature   |
| ch3b_bbody_counts | Channel 3b smoothed black body counts (only v2.10.1)                      |
| ch3b_earth_counts | Channel 3b photon counts earth view (only v2.10.1)                        |
| ch3b_nedt         | Channel 3b noise estimate (only v01.4-cspp, 1.5)                          |
| ch3b_space_counts | Channel 3b photon counts space view (only v2.10.1)                        |
| ch4               | Channel 4 brightness temperature  |
| ch4_bbody_counts  | Channel 4 smoothed black body counts (only v2.10.1)                       |
| ch4_earth_counts  | Channel 4 photon counts earth view (only v2.10.1)                         |
| ch4_nedt          | Channel 4 noise estimate (only v01.4-cspp, 1.5)                           |
| ch4_space_counts  | Channel 4 photon counts space view (only v2.10.1)                         |
| ch5               | Channel 5 brightness temperature (only AVHRR/3)                           |
| ch5_bbody_counts  | Channel 5 smoothed black body counts (only v2.10.1)                       |
| ch5_earth_counts  | Channel 5 photon counts earth view (only v2.10.1)                         |
| ch5_nedt          | Channel 5 noise estimate (only v01.4-cspp, 1.5)                           |
| ch5_space_counts  | Channel 5 photon counts space view (only v2.10.1)                         |
| cloud_mask        | CLAVER-X cloud mask   |
| cloud_probability | CLAVER-X cloud probability  |
| dtime             | Scanline time difference from start time                                  |
| ict_temp          | Temperature of internal calibration target                                |
| l1b_line_number   | Level 1b line number  |
| lat               | Latitude coordinates  |
| lon               | Longitude coordinates   |



|                            |  |
|----------------------------|--|
| orbital_temperature        | Average orbital temperature (t_inst) (only v2.10.1)                                      |
| orbital_temperature_nlines | Number of lines over which the average orbital temperature was calculated (only v2.10.1) |
| prt_1                      | PRT1 smoothed temperatures (only v2.10.1)  |
| prt_2                      | PRT2 smoothed temperatures (only v2.10.1)  |
| prt_3                      | PRT3 smoothed temperatures (only v2.10.1)  |
| prt_4                      | PRT4 smoothed temperatures (only v2.10.1)  |
| qual_flags                 | Quality Flags  |
| relative_azimuth_angle     | Relative Azimuth Angle (not v2.10.1)   |
| satellite_azimuth_angle    | satellite azimuth angle (only v2.10.1)   |
| solar_azimuth_angle        | solar azimuth angle (only v2.10.1)   |
| satellite_zenith_angle     | Satellite zenith angle   |
| solar_zenith_angle         | Solar zenith angle   |

### 3.5.7 AVHRR FCDR

AVHRR FCDR data from FIDUCEO project in NetCDF format. Some variables need to be transferred to the MMD using a post-processing as their dimensionality does not match the core engine requirements. Please refer to chapter 4.1.5.1.15.

| Sensor Key     | Source               |
|----------------|----------------------|
| avhrr-n06-fcdr | AVHRR NOAA06 FCDR    |
| avhrr-n07-fcdr | AVHRR/2 NOAA07 FCDR  |
| avhrr-n08-fcdr | AVHRR NOAA08 FCDR    |
| avhrr-n09-fcdr | AVHRR/2 NOAA09 FCDR  |
| avhrr-n10-fcdr | AVHRR NOAA10 FCDR    |
| avhrr-n11-fcdr | AVHRR/2 NOAA11 FCDR  |
| avhrr-n12-fcdr | AVHRR/2 NOAA12 FCDR  |
| avhrr-n14-fcdr | AVHRR/2 NOAA14 FCDR  |
| avhrr-n15-fcdr | AVHRR/3 NOAA15 FCDR  |
| avhrr-n16-fcdr | AVHRR/3 NOAA16 FCDR  |
| avhrr-n17-fcdr | AVHRR/3 NOAA17 FCDR  |
| avhrr-n18-fcdr | AVHRR/3 NOAA18 FCDR  |
| avhrr-n19-fcdr | AVHRR/3 NOAA19 FCDR  |
| avhrr-ma-fcdr  | AVHRR/3 METOP A FCDR |

| Variable Name        | Description   |
|----------------------|---|
| Ch1                  | Channel 1 reflectance                                 |
| Ch2                  | Channel 2 reflectance                                 |
| Ch3a                 | Channel 3a reflectance                                |
| Ch3b                 | Channel 3b brightness temperature                     |
| Ch4                  | Channel 4 brightness temperature                      |
| Ch5                  | Channel 5 brightness temperature                      |
| Time                 | Acquisition time in seconds since 1970-01-01 00:00:00 |
| data_quality_bitmask | bitmask for quality per pixel                         |
| latitude             | Geolocation latitude                                  |

|                             |  |
|-----------------------------|--|
| longitude                   | Geolocation longitude  |
| quality_pixel_bitmask       | Flag mask  |
| quality_scanline_bitmask    | bitmask for quality per scanline   |
| relative_azimuth_angle      | Viewing geometry azimuth angle   |
| satellite_zenith_angle      | Viewing geometry zenith angle  |
| scanline_map_to_origl1bfile | Indicator for mapping each line to its corresponding original level 1b file. See global attribute 'source' for the filenames. 0 corresponds to 1st listed file, 1 to 2nd file. |
| scanline_origl1b            | Original scan line numbers from corresponding l1b records  |
| solar_zenith_angle          | Solar zenith angle   |
| u_common_Ch1                | common uncertainty per pixel for channel 1   |
| u_common_Ch2                | common uncertainty per pixel for channel 2   |
| u_common_Ch3a               | common uncertainty per pixel for channel 3a  |
| u_common_Ch3b               | common uncertainty per pixel for channel 3b  |
| u_common_Ch4                | common uncertainty per pixel for channel 4   |
| u_common_Ch5                | common uncertainty per pixel for channel 5   |
| u_independent_Ch1           | independent uncertainty per pixel for channel 1  |
| u_independent_Ch2           | independent uncertainty per pixel for channel 2  |
| u_independent_Ch3a          | independent uncertainty per pixel for channel 3a   |
| u_independent_Ch3b          | independent uncertainty per pixel for channel 3b   |
| u_independent_Ch4           | independent uncertainty per pixel for channel 4  |
| u_independent_Ch5           | independent uncertainty per pixel for channel 5  |
| u_structured_Ch1            | structured uncertainty per pixel for channel 1   |
| u_structured_Ch2            | structured uncertainty per pixel for channel 2   |
| u_structured_Ch3a           | structured uncertainty per pixel for channel 3a  |
| u_structured_Ch3b           | structured uncertainty per pixel for channel 3b  |
| u_structured_Ch4            | structured uncertainty per pixel for channel 4   |
| u_structured_Ch5            | structured uncertainty per pixel for channel 5   |

### 3.5.8 AVHRR FRAC

AVHRR full resolution L1B data in NOAA format. Reader supports gzip compressed products.

| Sensor Key    | Source                          |
|---------------|---------------------------------|
| avhrr-frac-ma | AVHRR full resolution on MetopA |
| avhrr-frac-mb | AVHRR full resolution on MetopB |
| avhrr-frac-mc | AVHRR full resolution on MetopC |

| Variable Name                 | Description              |
|-------------------------------|--------------------------|
| radiance_[1, 2, 3a, 3b, 4, 5] | TOA radiances            |
| reflec_[1, 2, 3a, 3b, 4, 5]   | TOA reflectances         |
| flags                         | Quality flags            |
| cloudFlag                     | Cloud flags              |
| sun_zenith                    | Solar zenith angle       |
| view_zenith                   | Viewing zenith angle     |
| delta_azimuth                 | Azimuth angle difference |

|           |  |
|-----------|--|
| latitude  |  |
| longitude |  |

### 3.5.9 CALIOP CLay

CALIOP Lidar L2 Cloud Layer Product in NetCDF file format.

| Sensor Key      | Source                                |
|-----------------|---------------------------------------|
| caliop_clay-cal | CALIOP Clay Standard V4.10 on CALIPSO |

| Variable Name                         | Description   |
|---------------------------------------|---|
| Profile_ID                            | The ID of the vertical profile  |
| Latitude                              | Latitude in degrees of the laser footprint  |
| Longitude                             | Longitude in degrees of the laser footprint   |
| Profile_Time                          | Time expressed in International Atomic Time (TAI)   |
| Profile_UTC_Time                      | Time expressed in Coordinated Universal Time (UTC)  |
| Spacecraft_Position_x                 | ECR coordinate system X   |
| Spacecraft_Position_y                 | ECR coordinate system Y   |
| Spacecraft_Position_z                 | ECR coordinate system Z   |
| Number_Layers_Found                   | The number of cloud layers found in this column   |
| Column_Feature_Fraction               | The fraction of the 5-km horizontally averaged profile, which has been identified as containing a feature (i.e., either a cloud, an aerosol, or a stratospheric layer)                                      |
| FeatureFinderQC                       | A set of feature finder QC flags  |
| Feature_Classification_Flags          | See <a href="https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/data_summaries/vfm/index.php">https://www-calipso.larc.nasa.gov/resources/calipso_users_guide/data_summaries/vfm/index.php</a> |
| ExtinctionQC_532                      | cloud extinction is only reported at 532 nm   |
| CAD_Score                             | The cloud-aerosol discrimination score  |
| Layer_IAB_QA_Factor                   | $= 1 - F(y'_{\text{above}})$ , where $F(y'_{\text{above}})$ is the <u>cumulative probability</u> of measuring a complete column IABequal to $y'_{\text{above}}$ .   |
| Opacity_Flag                          | An opacity flag value of 1 indicates an opaque layer; values of 0 indicate transparent layers   |
| Ice_Water_Path                        | The integral, from layer top to layer base, of the ice-water content profile within any ice cloud layer   |
| Ice_Water_Path_Uncertainty            |   |
| Feature_Optical_Depth_532             | Layer optical depth computed according to the procedures outlined in the CALIOP extinction retrieval ATBD, cloud optical depth is reported only for the 532 nm measurements                                 |
| Feature_Optical_Depth_Uncertainty_532 |   |
| Layer_Top_Altitude                    |   |
| Layer_Base_Altitude                   |   |

### 3.5.10 CALIOP VFM

CALIOP Lidar L2 Vertical Feature Product in NetCDF file format.

| Sensor Key     | Source                               |
|----------------|--------------------------------------|
| caliop_vfm-cal | CALIOP VFM Standard V4.10 on CALIPSO |

| Variable Name         | Description  |
|-----------------------|--|
| Profile_ID            | The ID of the vertical profile   |
| Latitude              | Latitude in degrees of the laser footprint   |
| Longitude             | Longitude in degrees of the laser footprint  |
| Profile_Time          | Time expressed in International Atomic Time (TAI)  |
| Profile_UTC_Time      | Time expressed in Coordinated Universal Time (UTC)   |
| Day_Night_Flag        | Indicates the lighting conditions at an altitude of ~24 km above mean sea level.<br>0 = day, 1 = night |
| Land_Water_Mask       | a 30 arc second resolution land/water mask provided by the SDP toolkit                                 |
| Spacecraft_Position_x | ECR coordinate system X  |
| Spacecraft_Position_y | ECR coordinate system Y  |
| Spacecraft_Position_z | ECR coordinate system Z  |

### 3.5.11 HIRS

HIRS L1C data converted to NetCDF using tools developed at University of Reading.

| Sensor Key     | Source                       |
|----------------|------------------------------|
| hirs-tn        | HIRS/2 on Tiros-N            |
| hirs-n06 – n12 | HIRS/2 on NOAA 6 to NOAA 12  |
| hirs-n14       | HIRS/2 on NOAA 14            |
| hirs-n15 – n17 | HIRS/3 on NOAA 15 to NOAA 17 |
| hirs-n18 – n19 | HIRS/4 on NOAA 18 to NOAA 19 |
| hirs-ma        | HIRS/4 on Metop-A            |
| hirs-mb        | HIRS/4 on Metop-B            |

| Variable Name        | Description   |
|----------------------|---|
| time                 | Acquisition time per scanline in seconds since 1970 |
| lat                  | Latitude of pixel                                   |
| lon                  | Longitude of pixel                                  |
| bt_ch01 – ch19       | Brightness temperatures for channel 1 to 19         |
| radiance_ch01 – ch19 | TOA radiances for channel 1 to 19                   |
| counts_ch01 – ch19   | Raw measurement counts for channels 1 to 19         |
| lza                  | Local zenith angle                                  |
| scanline             | Original scanline number                            |
| scanpos              | Original scan position number                       |
| scanline_type        | Scanline type flag                                  |

## 3.5.12 HIRS FCDR

HIRS FCDR data from FIDUCEO project in NetCDF format. Some variables need to be transferred to the MMD using a post-processing as their dimensionality does not match the core engine requirements.

| Sensor Key          | Source                       |
|---------------------|------------------------------|
| hirs-n06 – n12-fcdr | HIRS/2 on NOAA 6 to NOAA 12  |
| hirs-n14-fcdr       | HIRS/2 on NOAA 14            |
| hirs-n15 – n17-fcdr | HIRS/3 on NOAA 15 to NOAA 17 |
| hirs-n18 – n19-fcdr | HIRS/4 on NOAA 18 to NOAA 19 |
| hirs-ma-fcdr        | HIRS/4 on Metop-A            |
| hirs-mb-fcdr        | HIRS/4 on Metop-B            |

| Variable Name                       | Description   |
|-------------------------------------|---|
| latitude                            | Latitude of pixel   |
| longitude                           | Longitude of pixel  |
| bt_ch01 – ch19                      | Brightness temperature, NOAA/EUMETSAT calibrated for channel 1 to 19  |
| satellite_zenith_angle              | platform_zenith_angle   |
| satellite_azimuth_angle             | sensor_azimuth_angle  |
| solar_zenith_angle                  | solar_zenith_angle  |
| solar_azimuth_angle                 | solar_azimuth_angle   |
| time                                | Acquisition time in seconds since 1970-01-01 00:00:00   |
| quality_scanline_bitmask            | Scanline quality indicator  |
| scanline_map_to_origl1bfile         | Indicator for mapping each line to its corresponding original level 1b file. See global attribute 'source' for the filenames. 0 corresponds to 1st listed file, 1 to 2nd file |
| scanline_origl1b                    | Original scan line numbers from corresponding l1b records   |
| quality_channel_bitmask_ch01 – ch19 | Channel quality indicator for channel 1 to 19   |
| u_independent_ch01 – ch19           | Uncertainty from independent errors for channel 1 to 19   |
| u_structured_ch01 – ch19            | Uncertainty from structured errors for channel 1 to 19  |
| u_common_ch01 – ch19                | Uncertainty from common errors for channel 1 to 19  |

## 3.5.13 IASI

IASIS L1C data in Eumetsat format following the specification in AD 1. Supported is data using an MDR of class 8, subclass 2, version 4 and version 5.

The reader implements a virtual x/y raster on a per-EFOV basis, all per scan or per snapshot variables are extended to this raster.

IMPORTANT: this reader per-se does not supply the IASI spectrum, this has to be added using a post-processing step (see chapter 4.1.5.1.8).

| Sensor Key | Source         |
|------------|----------------|
| iasi-ma    | IASI on MetopA |
| iasi-mb    | IASI on MetopB |

| Variable Name               | Description  |
|-----------------------------|--|
| DEGRADED_INST_MDR           | Quality of MDR has been degraded from nominal due to an instrument degradation       |
| DEGRADED_PROC_MDR           | Quality of MDR has been degraded from nominal due to a processing degradation        |
| GEPSIasiMode                | Instrument mode  |
| GEPSOPSProcessingMode       | Processing mode  |
| OBT                         | On Board Time (Coarse time + Fine time)  |
| OnboardUTC                  | Date of IASI measure (on board UTC)  |
| GEPSDatIasi                 | Date of IASI measure (corrected UTC)   |
| GEPS_CCD                    | Corner Cube Direction for all observational targets                                  |
| GEPS_SP                     | Scan position for all observational targets  |
| GQisFlagQualDetailed        | Detailed quality flag for the system ( <i>not in v4</i> )                            |
| GQisQualIndex               | System-IASI general quality index  |
| GQisQualIndexIIS            | IIS imager quality index inside 1c product   |
| GQisQualIndexLoc            | Geometric quality index for sounder product  |
| GQisQualIndexRad            | Radiometric quality index for sounder product  |
| GQisQualIndexSpect          | Spectral quality index for sounder product   |
| GQisSysTecIISQual           | System-TEC quality index for IIS   |
| GQisSysTecSondQual          | System-TEC quality index for sounder   |
| GGeoSondLoc_Lon             | Location of pixel centre in geodetic coordinates for each sounder pixel (lon)        |
| GGeoSondLoc_Lat             | Location of pixel centre in geodetic coordinates for each sounder pixel (lat)        |
| GGeoSondAnglesMETOP_Zenith  | Measurement angles for each sounder pixel (zenith)                                   |
| GGeoSondAnglesMETOP_Azimuth | Measurement angles for each sounder pixel (azimuth)                                  |
| GGeoSondAnglesSUN_Zenith    | Solar angles at the surface for each sounder pixel (zenith)                          |
| GGeoSondAnglesSUN_Azimuth   | Solar angles at the surface for each sounder pixel (azimuth)                         |
| EARTH_SATELLITE_DISTANCE    | Distance of satellite from Earth centre  |
| IDefSpectDWn1b              | Sample width of IASI 1C spectra (same as 1B)   |
| IDefNsfirst1b               | Number of the first sample of IASI 1C spectra (same as 1B)                           |
| IDefNsLast1b                | Number of the last sample of IASI 1C spectra (same as 1B)                            |
| GCcsRadAnalNbClass          | Radiance Analysis: Number of identified classes in the sounder FOV                   |
| IDefCcsMode                 | Radiance Analysis: Image used is from AVHRR or IIS imager (degraded cases)           |
| GCcsImageClassifiedNbLin    | Radiance Analysis: Number of useful lines  |
| GCcsImageClassifiedNbCol    | Radiance Analysis: Number of useful columns  |
| GCcsImageClassifiedFirstLin | First line of the classified image (number in the Avhrr raster, as per section 2.5 ) |

|                             |  |
|-----------------------------|--|
| GCcsImageClassifiedFirstCol | First column of the classified image (number in the Avhrr raster, as per section 2.5 )             |
| GlacVarImagIIS              | Variance of IIS image ( <i>not in v4</i> )   |
| GlacAvgImagIIS              | Average of IIS image ( <i>not in v4</i> )  |
| GEUMAvhrr1BCldFrac          | Cloud fraction in IASI FOV from AVHRR 1B in IASI FOV ( <i>not in v4</i> )                          |
| GEUMAvhrr1BLandFrac         | Land and Coast fraction in IASI FOV from AVHRR 1B ( <i>not in v4</i> )                             |
| GEUMAvhrr1BQual             | Quality indicator. If the quality is good, it gives the coverage of snow/ice. ( <i>not in v4</i> ) |

**Note:** The MMD will always generate variables according to the MDR\_1C specification version 5, when encountering a file containing MDR\_1C version 4 data, the additional variables will be “fake” variables that contain only the appropriate fill value. The variables are marked as “not in v4” in the table above.

## 3.5.14 MHS

MHS L1c data from NOAA CLASS storage, converted to HDF using “atovin” and “convert\_to\_hdf5”.

| Sensor Key | Source        |
|------------|---------------|
| mhs-n18    | MHS on NOAA18 |
| mhs-n19    | MHS on NOAA19 |
| mhs-ma     | MHS on MetopA |
| mhs-mb     | MHS on MetopB |

| Variable Name           | Description                                |
|-------------------------|--|
| btemps_ch1 ... ch5      | Brightness temperatures for channel 1 to 5 |
| chanqual_ch1 ... ch5    | Channel quality flags                      |
| instrtemp               | Instrument temperature in Kelvin           |
| qualind                 | Quality indicator                          |
| scanqual                | Scan line quality                          |
| scnlin                  | Scan line number                           |
| scnlindy                | Scan line acquisition day of year          |
| scnlintim               | Scan line acquisition seconds of day       |
| scnlinyr                | Scan line acquisition year                 |
| Latitude                | Pixel latitude in degrees                  |
| Longitude               | Pixel longitude in degrees                 |
| Satellite_azimuth_angle | Satellite azimuth angle                    |
| Satellite_zenith_angle  | Satellite zenith angle                     |
| Solar_azimuth_angle     | Sun azimuth angle                          |
| Solar_zenith_angle      | Sun zenith angle                           |

All per-scan line variables are extended to cover the full pixel grid.

### 3.5.15 MODIS MxD021KM

Modis MxD012KM L1 products from Terra and Aqua platform in 1 km resolution, standard NASA HDF file format. This reader uses geo-location and sensor/solar geometry data from the associated MxD03 geolocation file. Please ensure that both MxD012KM and MxD03 data files are mounted in the archive with the same processing version.

| Sensor Key  | Source                            |
|-------------|-----------------------------------|
| mod021km-te | Modis L1 data from Terra platform |
| myd021km-aq | Modis L1 data from Aqua platform  |

Variables in the MMD originating from the MxD03 geolocation files are tagged with (mxd03) in the table below.

| Variable Name                                     | Description   |
|---|---|
| Noise_in_Thermal_Detectors_ch20 ... ch36          | Detector noise per sensor and scan  |
| EV_1KM_RefSB_ch08 ... ch26                        | Earth View 1KM Reflective Solar Bands   |
| EV_1KM_RefSB_Uncert_Indexes_ch08 ... ch26         | Earth View 1KM Reflective Solar Bands Uncertainty Indexes                                   |
| EV_1KM_Emissive_ch20 ... ch36                     | Earth View 1KM Emissive Band  |
| EV_1KM_Emissive_Uncert_Indexes_ch20 ... ch36      | Earth View 1KM Emissive Bands Uncertainty Indexes   |
| EV_250_Aggr1km_RefSB_ch01/ch02                    | Earth View 250M Aggregated 1km Reflective Solar Bands                                       |
| EV_250_Aggr1km_RefSB_Uncert_Indexes_ch01/ch02     | Earth View 250M Aggregated 1km Reflective Solar Bands Uncertainty Indexes                   |
| EV_250_Aggr1km_RefSB_Samples_Used_ch01/ch02       | Earth View 250M Aggregated 1km Reflective Solar Bands Number of Samples Used in Aggregation |
| EV_500_Aggr1km_RefSB_ch03 ... ch07                | Earth View 500M Aggregated 1km Reflective Solar Bands                                       |
| EV_500_Aggr1km_RefSB_Uncert_Indexes_ch03 ... ch07 | Earth View 500M Aggregated 1km Reflective Solar Bands Uncertainty Indexes                   |
| EV_500_Aggr1km_RefSB_Samples_Used_ch03 ... ch07   | Earth View 500M Aggregated 1km Reflective Solar Bands Number of Samples Used in Aggregation |
| EV_Band26   | Earth View Band 26  |
| EV_Band26_Uncert_Indexes                          | Earth View Band 26 Uncertainty Indexes  |
| Scan_number                                       | Scan number   |
| Latitude  | Latitude (mxd03)  |
| Longitude   | Longitude (mxd03)   |
| Height  | Height (mxd03)  |
| SensorZenith                                      | SensorZenith (mxd03)  |
| SensorAzimuth                                     | SensorAzimuth (mxd03)   |
| Range   | Range (mxd03)   |
| SolarZenith                                       | SolarZenith (mxd03)   |
| SolarAzimuth                                      | SolarAzimuth (mxd03)  |
| Land_SeaMask                                      | Land_SeaMask (mxd03)  |
| WaterPresent                                      | WaterPresent (mxd03)  |



|        |                |
|--------|----------------|
| Gflags | gflags (mxd03) |
|--------|----------------|

### 3.5.16 MODIS MxD06

Modis MxD06 L2 cloud products from Terra and Aqua platform, standard NASA HDF file format.

This reader only uses the low-resolution data. High resolution data is re-mapped to the low resolution data by picking the centre pixel of a 5x5 1km pixel acquisition.

| Sensor Key | Source                               |
|------------|--------------------------------------|
| mod06-te   | Modis cloud data from Terra platform |
| myd06-aq   | Modis cloud data from Aqua platform  |

| Variable Name                | Description   |
|------------------------------|---|
| Latitude                     | Pixel latitude in degrees   |
| Longitude                    | Pixel longitude in degrees  |
| Scan_Start_Time              | TAI time at start of scan replicated across the swath   |
| Solar_Zenith                 | Solar Zenith Angle, Cell to Sun   |
| Solar_Zenith_Day             | Solar Zenith Angle, Cell to Sun, Day Data Only  |
| Solar_Zenith_Night           | Solar Zenith Angle, Cell to Sun, Night Data Only  |
| Solar_Azimuth                | Solar Azimuth Angle, Cell to Sun  |
| Solar_Azimuth_Day            | Solar Azimuth Angle, Cell to Sun, Day Data Only   |
| Solar_Azimuth_Night          | Solar Azimuth Angle, Cell to Sun, Night Data Only   |
| Sensor_Zenith                | Sensor Zenith Angle, Cell to Sensor   |
| Sensor_Zenith_Day            | Sensor Zenith Angle, Cell to Sensor, Day Data Only  |
| Sensor_Zenith_Night          | Sensor Zenith Angle, Cell to Sensor, Night Data Only  |
| Sensor_Azimuth               | Sensor Azimuth Angle, Cell to Sensor  |
| Sensor_Azimuth_Day           | Sensor Azimuth Angle, Cell to Sensor, Day Data Only   |
| Sensor_Azimuth_Night         | Sensor Azimuth Angle, Cell to Sensor, Night Data Only   |
| Surface_Temperature          | Surface Temperature from Ancillary Data   |
| Surface_Pressure             | Surface Pressure from Ancillary Data  |
| Cloud_Height_Method          | Index Indicating MODIS Bands Used for Cloud Top Pressure Retrieval  |
| Cloud_Top_Height             | Geopotential Height at Retrieved Cloud Top Pressure Level (rounded to nearest 50 m)   |
| Cloud_Top_Height_Nadir       | Geopotential Height at Retrieved Cloud Top Pressure Level for Sensor Zenith (View) Angles <=32 Degrees (rounded to nearest 50 m)                  |
| Cloud_Top_Height_Nadir_Day   | Geopotential Height at Retrieved Cloud Top Pressure Level for Sensor Zenith (View) Angles <=32 Degrees, Day Data Only (rounded to nearest 50 m)   |
| Cloud_Top_Height_Nadir_Night | Geopotential Height at Retrieved Cloud Top Pressure Level for Sensor Zenith (View) Angles <=32 Degrees, Night Data Only (rounded to nearest 50 m) |
| Cloud_Top_Pressure           | Cloud Top Pressure Level (rounded to nearest 5 mb)  |
| Cloud_Top_Pressure_Nadir     | Cloud Top Pressure Level for Sensor Zenith (View) Angles <= 32 Degrees (rounded to nearest 5 mb)  |

|  |  |
|--|--|
| Cloud_Top_Pressure_Night               | Cloud Top Pressure Level, Night Data Only (rounded to nearest 5 mb)  |
| Cloud_Top_Pressure_Nadir_Night         | Cloud Top Pressure Level for Sensor Zenith (View) Angles $\leq 32$ Degrees (rounded to nearest 5 mb), Night Data Only                        |
| Cloud_Top_Pressure_Day                 | Cloud Top Pressure Level, Day Only (rounded to nearest 5 mb)   |
| Cloud_Top_Pressure_Nadir_Day           | Cloud Top Pressure Level for Sensor Zenith (View) Angles $\leq 32$ Degrees (rounded to nearest 5 mb), Day Data Only                          |
| Cloud_Top_Temperature                  | Temperature from Ancillary Data at Retrieved Cloud Top Pressure Level  |
| Cloud_Top_Temperature_Nadir            | Temperature from Ancillary Data at Retrieved Cloud Top Pressure Level for Sensor Zenith (View) Angles $\leq 32$ Degrees                      |
| Cloud_Top_Temperature_Night            | Temperature from Ancillary Data at Retrieved Cloud Top Pressure Level, Night Only  |
| Cloud_Top_Temperature_Nadir_Night      | Temperature from Ancillary Data at Retrieved Cloud Top Pressure Level for Sensor Zenith (View) Angles $\leq 32$ Degrees, Night Data Only     |
| Cloud_Top_Temperature_Day              | Temperature from Ancillary Data at Retrieved Cloud Top Pressure Level, Day Only  |
| Cloud_Top_Temperature_Nadir_Day        | Temperature from Ancillary Data at Retrieved Cloud Top Pressure Level for Sensor Zenith (View) Angles $\leq 32$ Degrees, Day Data Only       |
| Tropopause_Height                      | Tropopause Height from Ancillary Data  |
| Cloud_Fraction                         | Cloud Fraction in Retrieval Region (5x5 1-km Pixels) from 1-km Cloud Mask  |
| Cloud_Fraction_Nadir                   | Cloud Fraction in Retrieval Region (5x5 1-km Pixels) from 1-km Cloud Mask for Sensor Zenith (View) Angles $\leq 32$ Degrees                  |
| Cloud_Fraction_Night                   | Cloud Fraction in Retrieval Region (5x5 1-km Pixels) from 1-km Cloud Mask, Night Only  |
| Cloud_Fraction_Nadir_Night             | Cloud Fraction in Retrieval Region (5x5 1-km Pixels) from 1-km Cloud Mask for Sensor Zenith (View) Angles $\leq 32$ Degrees, Night Data Only |
| Cloud_Fraction_Day                     | Cloud Fraction in Retrieval Region (5x5 1-km Pixels) from 1-km Cloud Mask, Day Only  |
| Cloud_Fraction_Nadir_Day               | Cloud Fraction in Retrieval Region (5x5 1-km Pixels) from 1-km Cloud Mask for Sensor Zenith (View) Angles $\leq 32$ Degrees, Day Data Only   |
| Cloud_Effective_Emissivity             | Cloud Effective Emissivity from Cloud Top Pressure Retrieval   |
| Cloud_Effective_Emissivity_Nadir       | Cloud Effective Emissivity from Cloud Top Pressure Retrieval for Sensor Zenith (View) Angles $\leq 32$ Degrees                               |
| Cloud_Effective_Emissivity_Night       | Cloud Effective Emissivity from Cloud Top Pressure Retrieval, Night Only   |
| Cloud_Effective_Emissivity_Nadir_Night | Cloud Effective Emissivity from Cloud Top Pressure Retrieval for Sensor Zenith (View) Angles $\leq 32$ Degrees, Night Data Only              |
| Cloud_Effective_Emissivity_Day         | Cloud Effective Emissivity from Cloud Top Pressure Retrieval, Day Only   |

|                                      |   |
|--------------------------------------|---|
| Cloud_Effective_Emissivity_Nadir_Day | Cloud Effective Emissivity from Cloud Top Pressure Retrieval for Sensor Zenith (View) Angles <= 32 Degrees, Day Data Only   |
| Cloud_Top_Pressure_Infrared          | Cloud Top Pressure from IR Window Retrieval   |
| Radiance_Variance                    | Band 31 Radiance Standard Deviation   |
| Cloud_Phase_Infrared                 | Cloud Phase from 8.5 and 11 um Bands  |
| Cloud_Phase_Infrared_Night           | Cloud Phase from 8.5 and 11 um Bands, Night Only  |
| Cloud_Phase_Infrared_Day             | Cloud Phase from 8.5 and 11 um Bands, Day Only  |
| Cloud_Phase_Infrared_1km             | Cloud Phase at 1-km resolution from 8.5- 11 um BTDS and cloud emissivity ratios (12/11, 8.5/11, and 7.2/11 um)  |
| IRP_CTH_Consistency_Flag_1km         | Indicates Cloud_Phase_Infrared_1km results changed to ice from water when cloud_top_method_1km reports valid band 36/35 CO2-slicing result (1=change)   |
| os_top_flag_1km                      | Upper Tropospheric/Lower Stratospheric (UTLS) Cloud Flag at 1-km resolution - valid from -50 to +50 Degrees Latitude  |
| cloud_top_pressure_1km               | Cloud Top Pressure at 1-km resolution from LEOCAT, Cloud Top Pressure Level rounded to nearest 5 mb   |
| cloud_top_temperature_1km            | Cloud Top Temperature at 1-km resolution from LEOCAT, Temperature from Ancillary Data at Retrieved Cloud Top Pressure Level   |
| cloud_emissivity_1km                 | Cloud Emissivity at 1-km resolution from LEOCAT Cloud Top Pressure Retrieval  |
| cloud_top_method_1km                 | Index Indicating the MODIS Band(s) Used to Produce the Cloud Top Pressure Result  |
| surface_temperature_1km              | Surface Temperature for Each 1-km MODIS Pixel Interplated from Ancillary Data   |
| cloud_emiss11_1km                    | 11 micron Cloud Emissivity at 1-km resolution from LEOCAT for All Clouds  |
| cloud_emiss12_1km                    | 12 micron Cloud Emissivity at 1-km resolution from LEOCAT for All Clouds  |
| cloud_emiss13_1km                    | 13.3 micron Cloud Emissivity at 1-km resolution from LEOCAT for All Clouds  |
| cloud_emiss85_1km                    | 8.5 micron Cloud Emissivity at 1-km resolution from LEOCAT for All Clouds   |
| Cloud_Effective_Radius               | Cloud Particle Effective Radius two-channel retrieval using band 7(2.1um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from best points: not failed in any way, not marked for clear sky restoral                  |
| Cloud_Effective_Radius_PCL           | Cloud Particle Effective Radius two-channel retrieval using band 7(2.1um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges |
| Cloud_Effective_Radius_16            | Cloud Particle Effective Radius two-channel retrieval using band 6(1.6um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from best points: not failed in any way, not marked for clear sky restoral                  |

|                                 |  |
|---------------------------------|--|
| Cloud_Effective_Radius_16_PCL   | Cloud Particle Effective Radius two-channel retrieval using band 6(1.6um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges  |
| Cloud_Effective_Radius_37       | Cloud Particle Effective Radius two-channel retrieval using band 20(3.7um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from best points: not failed in any way, not marked for clear sky restoral                  |
| Cloud_Effective_Radius_37_PCL   | Cloud Particle Effective Radius two-channel retrieval using band 20(3.7um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges |
| Cloud_Optical_Thickness         | Cloud Optical Thickness two-channel retrieval using band 7(2.1um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from best points: not failed in any way, not marked for clear sky restoral                           |
| Cloud_Optical_Thickness_PCL     | Cloud Optical Thickness two-channel retrieval using band 7(2.1um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges          |
| Cloud_Optical_Thickness_16      | Cloud Optical Thickness two-channel retrieval using band 6(1.6um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from best points: not failed in any way, not marked for clear sky restoral                           |
| Cloud_Optical_Thickness_16_PCL  | Cloud Optical Thickness two-channel retrieval using band 6(1.6um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges          |
| Cloud_Optical_Thickness_37      | Cloud Optical Thickness two-channel retrieval using band 20(3.7um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from best points: not failed in any way, not marked for clear sky restoral                          |
| Cloud_Optical_Thickness_37_PCL  | Cloud Optical Thickness two-channel retrieval using band 20(3.7um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges         |
| Cloud_Effective_Radius_1621     | Cloud Particle Effective Radius two-channel retrieval using band 7(2.1um) and band 6(1.6um)from best points: not failed in any way, not marked for clear sky restoral  |
| Cloud_Effective_Radius_1621_PCL | Cloud Particle Effective Radius two-channel retrieval using band 7(2.1um) and band 6(1.6um)from points identified  |

|                                    |  |
|------------------------------------|--|
|                                    | as either partly cloudy from 250m cloud mask test or 1km cloud edges   |
| Cloud_Optical_Thickness_1621       | Cloud Optical Thickness two-channel retrieval using band 7(2.1um) and band 6(1.6um)from best points: not failed in any way, not marked for clear sky restoral  |
| Cloud_Optical_Thickness_1621_PCL   | Cloud Optical Thickness two-channel retrieval using band 7(2.1um) and band 6(1.6um)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges   |
| Cloud_Water_Path                   | Column Water Path two-channel retrieval using band 7(2.1um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from best points: not failed in any way, not marked for clear sky restoral                   |
| Cloud_Water_Path_PCL               | Column Water Path two-channel retrieval using band 7(2.1um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges  |
| Cloud_Water_Path_1621              | Column Water Path two-channel retrieval using band 7(2.1um) and band 6(1.6um)from best points: not failed in any way, not marked for clear sky restoral  |
| Cloud_Water_Path_1621_PCL          | Column Water Path two-channel retrieval using band 7(2.1um) and band 6(1.6um)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges   |
| Cloud_Water_Path_16                | Column Water Path two-channel retrieval using band 6(1.6um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from best points: not failed in any way, not marked for clear sky restoral                   |
| Cloud_Water_Path_16_PCL            | Column Water Path two-channel retrieval using band 6(1.6um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges  |
| Cloud_Water_Path_37                | Column Water Path two-channel retrieval using band 20(3.7um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from best points: not failed in any way, not marked for clear sky restoral                  |
| Cloud_Water_Path_37_PCL            | Column Water Path two-channel retrieval using band 20(3.7um) and either band 1(0.65um), 2(0.86um), or 5(1.2um) (specified in Quality_Assurance_1km)from points identified as either partly cloudy from 250m cloud mask test or 1km cloud edges |
| Cloud_Effective_Radius_Uncertainty | Cloud Effective Particle Radius (from band 7(2.1um)) Relative Uncertainty (Percent)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m  |

|  |  |
|--|--|
| Cloud_Effective_Radius_Uncertainty_16    | Cloud Effective Particle Radius (from band 6(1.6um) Relative Uncertainty (Percent)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m   |
| Cloud_Effective_Radius_Uncertainty_37    | Cloud Effective Particle Radius (from band 20(3.7um)) Relative Uncertainty (Percent)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m   |
| Cloud_Optical_Thickness_Uncertainty      | Cloud Optical Thickness Relative Uncertainty (Percent)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m based on the Cloud_Optical_Thickness and Cloud_Effective_Radius results       |
| Cloud_Optical_Thickness_Uncertainty_16   | Cloud Optical Thickness Relative Uncertainty (Percent)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m based on the Cloud_Optical_Thickness_16 and Cloud_Effective_Radius_16 results |
| Cloud_Optical_Thickness_Uncertainty_37   | Cloud Optical Thickness Relative Uncertainty (Percent)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m based on the Cloud_Optical_Thickness_37 and Cloud_Effective_Radius_37 result  |
| Cloud_Water_Path_Uncertainty             | Cloud Water Path Relative Uncertainty (Percent)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m based on the Cloud_Water_Path result   |
| Cloud_Effective_Radius_Uncertainty_1621  | Cloud Effective Particle Radius Relative Uncertainty (Percent) using band 7(2.1um) and band 6(1.6um)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m                                 |
| Cloud_Optical_Thickness_Uncertainty_1621 | Cloud Optical Thickness Relative Uncertainty (Percent) using band 7(2.1um) and band 6(1.6um)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m   |
| Cloud_Water_Path_Uncertainty_1621        | Cloud Water Path Relative Uncertainty (Percent) using band 7(2.1um) and band 6(1.6um)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m  |
| Cloud_Water_Path_Uncertainty_16          | Cloud Water Path Relative Uncertainty (Percent)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m using the VNSWIR-1.6um retrieval   |
| Cloud_Water_Path_Uncertainty_37          | Cloud Water Path Relative Uncertainty (Percent)from both best points and points identified as cloud edge at 1km resolution or partly cloudy at 250m using the VNSWIR-3.7um retrieval   |
| Above_Cloud_Water_Vapor_094              | Above-cloud water vapor amount from 0.94um channel, ocean only, tau > 5.   |
| IRW_Low_Cloud_Temperature_From_COP       | Low Cloud Temperature from IR Window retrieval using cloud emissivity based on cloud optical thickness   |

|                                |   |
|--------------------------------|---|
| Cloud_Phase_Optical_Properties | Cloud Phase Determination Used in Optical Thickness/Effective Radius Retrieval  |
| Cloud_Multi_Layer_Flag         | Cloud Multi Layer Identification From MODIS Shortwave Observations  |
| Cirrus_Reflectance             | Cirrus Reflectance  |
| Cirrus_Reflectance_Flag        | Cirrus_Reflectance_Flag   |
| Cloud_Mask_5km                 | First Byte of MODIS Cloud Mask Plus Additional Stats for L3 (2nd Byte)<br><b>NOTE: both bytes are merged to one short value, first byte as higher byte of the short</b> |
| Quality_Assurance_5km_03       | Quality Assurance at 5x5 Resolution - Number of cloudy pixels   |
| Quality_Assurance_5km_04       | Quality Assurance at 5x5 Resolution - Number of clear pixels  |
| Quality_Assurance_5km_05       | Quality Assurance at 5x5 Resolution - Number of missing pixels  |
| Quality_Assurance_5km_09       | Quality Assurance at 5x5 Resolution - Cloud height Category   |

### 3.5.17 MODIS MxD35

A Modis MxD35 product is an L2 cloud mask product from Terra and Aqua platforms in 1km and 5km resolution. Standard NASA HDF (HDFEOS) file format.

The reader super-samples all data to 1km resolution.

This reader uses geo-location from the associated MxD03 geolocation file. If the expected MxD03 file is not available, this reader uses the internal latitude and longitude tie-point variables as fallback, interpolated to a resolution of 1km and taking into account the bow-tie effect.

Please ensure that both MxD35 and MxD03 data files are mounted in the archive with the same processing version.

| Sensor Key | Source                                       |
|------------|--|
| mod35-te   | Modis L2 cloud mask data from Terra platform |
| myd35-aq   | Modis L2 cloud mask data from Aqua platform  |

| Variable Name    | Description   |
|------------------|---|
| Latitude         | Latitude  |
| Longitude        | Longitude   |
| Scan_Start_Time  | Scan start time   |
| Solar_Zenith     | Solar zenith  |
| Solar_Azimuth    | Solar azimuth   |
| Sensor_Zenith    | Sensor zenith   |
| Sensor_Azimuth   | Sensor azimuth  |
| Cloud_Mask_SPI_0 | Dispersion in band 1 from 250m reflectance statistics of cloud mask |
| Cloud_Mask_SPI_1 | Dispersion in band 2 from 250m reflectance statistics of cloud mask |



| Cloud_Mask_0 | <div>MODIS Cloud Mask and Spectral Test Results / Byte 0</div> <table><tr><th colspan="3">Flags</th></tr><tr><th>Mask</th><th>Value</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>0000 0001</td><td>cloud_mask_valid</td></tr><tr><td>0000 0110</td><td>0000 0000</td><td>cloudy</td></tr><tr><td>0000 0110</td><td>0000 0010</td><td>Uncertain</td></tr><tr><td>0000 0110</td><td>0000 0100</td><td>probably_clear</td></tr><tr><td>0000 0110</td><td>0000 0110</td><td>confident_clear</td></tr><tr><td>0000 1000</td><td>0000 1000</td><td>Day</td></tr><tr><td>0001 0000</td><td>0001 0000</td><td>no_sunglint</td></tr><tr><td>0010 0000</td><td>0010 0000</td><td>no_snow_or_ice</td></tr><tr><td>1100 0000</td><td>0000 0000</td><td>Water</td></tr><tr><td>1100 0000</td><td>0100 0000</td><td>Costal</td></tr><tr><td>1100 0000</td><td>1000 0000</td><td>Desert</td></tr><tr><td>1100 0000</td><td>1100 0000</td><td>Land</td></tr></table> | Flags            |  |      | Mask    | Value     | Meaning               | 0000 0001 | 0000 0001                     | cloud_mask_valid | 0000 0110                 | 0000 0000 | cloudy               | 0000 0110 | 0000 0010           | Uncertain | 0000 0110          | 0000 0100 | probably_clear         | 0000 0110 | 0000 0110            | confident_clear | 0000 1000 | 0000 1000 | Day | 0001 0000 | 0001 0000 | no_sunglint | 0010 0000 | 0010 0000 | no_snow_or_ice | 1100 0000 | 0000 0000 | Water | 1100 0000 | 0100 0000 | Costal | 1100 0000 | 1000 0000 | Desert | 1100 0000 | 1100 0000 | Land |
|--------------|--|------------------|--|------|---------|-----------|-----------------------|-----------|-------------------------------|------------------|---------------------------|-----------|----------------------|-----------|---------------------|-----------|--------------------|-----------|------------------------|-----------|----------------------|-----------------|-----------|-----------|-----|-----------|-----------|-------------|-----------|-----------|----------------|-----------|-----------|-------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|------|
| Flags        |  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Mask         | Value  | Meaning          |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0001    | 0000 0001  | cloud_mask_valid |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0110    | 0000 0000  | cloudy           |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0110    | 0000 0010  | Uncertain        |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0110    | 0000 0100  | probably_clear   |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0110    | 0000 0110  | confident_clear  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 1000    | 0000 1000  | Day              |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0001 0000    | 0001 0000  | no_sunglint      |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0010 0000    | 0010 0000  | no_snow_or_ice   |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 1100 0000    | 0000 0000  | Water            |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 1100 0000    | 0100 0000  | Costal           |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 1100 0000    | 1000 0000  | Desert           |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 1100 0000    | 1100 0000  | Land             |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Cloud_Mask_1 | <div>MODIS Cloud Mask and Spectral Test Results / Byte 1</div> <table><tr><th colspan="2">Flags</th></tr><tr><th>Mask</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>non_cloud_obstruction</td></tr><tr><td>0000 0010</td><td>thin_cirrus_solar</td></tr><tr><td>0000 0100</td><td>snow_cover_ancillary</td></tr><tr><td>0000 1000</td><td>thin_cirrus_infrared</td></tr><tr><td>0001 0000</td><td>cloud_adjacency</td></tr><tr><td>0010 0000</td><td>ir_threshold</td></tr><tr><td>0100 0000</td><td>high_cloud_co2</td></tr><tr><td>1000 0000</td><td>high_cloud_6.7micron</td></tr></table>   | Flags            |  | Mask | Meaning | 0000 0001 | non_cloud_obstruction | 0000 0010 | thin_cirrus_solar             | 0000 0100        | snow_cover_ancillary      | 0000 1000 | thin_cirrus_infrared | 0001 0000 | cloud_adjacency     | 0010 0000 | ir_threshold       | 0100 0000 | high_cloud_co2         | 1000 0000 | high_cloud_6.7micron |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Flags        |  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Mask         | Meaning  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0001    | non_cloud_obstruction  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0010    | thin_cirrus_solar  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0100    | snow_cover_ancillary   |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 1000    | thin_cirrus_infrared   |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0001 0000    | cloud_adjacency  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0010 0000    | ir_threshold   |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0100 0000    | high_cloud_co2   |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 1000 0000    | high_cloud_6.7micron   |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Cloud_Mask_2 | <div>MODIS Cloud Mask and Spectral Test Results / Byte 2</div> <table><tr><th colspan="2">Flags</th></tr><tr><th>Mask</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>high_cloud_1.38micron</td></tr><tr><td>0000 0010</td><td>high_cloud_3.9_12</td></tr><tr><td>0000 0100</td><td>ir_temperature_difference</td></tr><tr><td>0000 1000</td><td>3.9_11_difference</td></tr><tr><td>0001 0000</td><td>visible_reflectance</td></tr><tr><td>0010 0000</td><td>visible_nir_ratio</td></tr><tr><td>0100 0000</td><td>clear_sky_ndvi</td></tr><tr><td>1000 0000</td><td>7.3_11_difference</td></tr></table>   | Flags            |  | Mask | Meaning | 0000 0001 | high_cloud_1.38micron | 0000 0010 | high_cloud_3.9_12             | 0000 0100        | ir_temperature_difference | 0000 1000 | 3.9_11_difference    | 0001 0000 | visible_reflectance | 0010 0000 | visible_nir_ratio  | 0100 0000 | clear_sky_ndvi         | 1000 0000 | 7.3_11_difference    |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Flags        |  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Mask         | Meaning  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0001    | high_cloud_1.38micron  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0010    | high_cloud_3.9_12  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0100    | ir_temperature_difference  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 1000    | 3.9_11_difference  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0001 0000    | visible_reflectance  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0010 0000    | visible_nir_ratio  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0100 0000    | clear_sky_ndvi   |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 1000 0000    | 7.3_11_difference  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Cloud_Mask_3 | <div>MODIS Cloud Mask and Spectral Test Results / Byte 3</div> <table><tr><th colspan="2">Flags</th></tr><tr><th>Mask</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>8.6_11_difference</td></tr><tr><td>0000 0010</td><td>clear_sky_spatial_variability</td></tr><tr><td>0000 0100</td><td>clear_sky_other</td></tr><tr><td>0000 1000</td><td>spatial_variability</td></tr><tr><td>0001 0000</td><td>suspended_dust</td></tr><tr><td>0010 0000</td><td>8.6_7.3_difference</td></tr><tr><td>0100 0000</td><td>spatial_variability_11</td></tr><tr><td>1000 0000</td><td>3.9_11_difference</td></tr></table>   | Flags            |  | Mask | Meaning | 0000 0001 | 8.6_11_difference     | 0000 0010 | clear_sky_spatial_variability | 0000 0100        | clear_sky_other           | 0000 1000 | spatial_variability  | 0001 0000 | suspended_dust      | 0010 0000 | 8.6_7.3_difference | 0100 0000 | spatial_variability_11 | 1000 0000 | 3.9_11_difference    |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Flags        |  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Mask         | Meaning  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0001    | 8.6_11_difference  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0010    | clear_sky_spatial_variability  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0100    | clear_sky_other  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 1000    | spatial_variability  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0001 0000    | suspended_dust   |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0010 0000    | 8.6_7.3_difference   |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0100 0000    | spatial_variability_11   |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 1000 0000    | 3.9_11_difference  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Cloud_Mask_4 | <div>MODIS Cloud Mask and Spectral Test Results / Byte 4</div> <table><tr><th colspan="2">Flags</th></tr><tr><th>Mask</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>250m_element_11</td></tr><tr><td>0000 0010</td><td>250m_element_12</td></tr><tr><td>0000 0100</td><td>250m_element_13</td></tr><tr><td>0000 1000</td><td>250m_element_14</td></tr><tr><td>0001 0000</td><td>250m_element_21</td></tr><tr><td>0010 0000</td><td>250m_element_22</td></tr><tr><td>0100 0000</td><td>250m_element_23</td></tr><tr><td>1000 0000</td><td>250m_element_24</td></tr></table>  | Flags            |  | Mask | Meaning | 0000 0001 | 250m_element_11       | 0000 0010 | 250m_element_12               | 0000 0100        | 250m_element_13           | 0000 1000 | 250m_element_14      | 0001 0000 | 250m_element_21     | 0010 0000 | 250m_element_22    | 0100 0000 | 250m_element_23        | 1000 0000 | 250m_element_24      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Flags        |  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| Mask         | Meaning  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0001    | 250m_element_11  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0010    | 250m_element_12  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 0100    | 250m_element_13  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0000 1000    | 250m_element_14  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0001 0000    | 250m_element_21  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0010 0000    | 250m_element_22  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 0100 0000    | 250m_element_23  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |
| 1000 0000    | 250m_element_24  |                  |  |      |         |           |                       |           |                               |                  |                           |           |                      |           |                     |           |                    |           |                        |           |                      |                 |           |           |     |           |           |             |           |           |                |           |           |       |           |           |        |           |           |        |           |           |      |



| Cloud_Mask_5        | <div>MODIS Cloud Mask and Spectral Test Results / Byte 5</div> <table><tr><th colspan="2">Flags</th></tr><tr><th>Mask</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>250m_element_31</td></tr><tr><td>0000 0010</td><td>250m_element_32</td></tr><tr><td>0000 0100</td><td>250m_element_33</td></tr><tr><td>0000 1000</td><td>250m_element_34</td></tr><tr><td>0001 0000</td><td>250m_element_41</td></tr><tr><td>0010 0000</td><td>250m_element_42</td></tr><tr><td>0100 0000</td><td>250m_element_43</td></tr><tr><td>1000 0000</td><td>250m_element_44</td></tr></table>  | Flags                    |  | Mask | Meaning | 0000 0001 | 250m_element_31       | 0000 0010 | 250m_element_32               | 0000 0100     | 250m_element_33           | 0000 1000 | 250m_element_34          | 0001 0000 | 250m_element_41     | 0010 0000                | 250m_element_42    | 0100 0000 | 250m_element_43          | 1000 0000 | 250m_element_44      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
|---------------------|--|--------------------------|--|------|---------|-----------|-----------------------|-----------|-------------------------------|---------------|---------------------------|-----------|--------------------------|-----------|---------------------|--------------------------|--------------------|-----------|--------------------------|-----------|----------------------|--------------------------|-----------|-----------|--------------------------|-----------|-----------|--------------------------|-----------|-----------|--------------------------|-----------|-----------|--------------------------|
| Flags               |  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Mask                | Meaning  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0001           | 250m_element_31  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0010           | 250m_element_32  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0100           | 250m_element_33  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1000           | 250m_element_34  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0001 0000           | 250m_element_41  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0010 0000           | 250m_element_42  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0100 0000           | 250m_element_43  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 1000 0000           | 250m_element_44  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Quality_Assurance_0 | <div>Quality Assurance for Cloud Mask / Byte 0</div> <table><tr><th colspan="3">Flags</th></tr><tr><th>Mask</th><th>Value</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>0000 0001</td><td>cloud_mask_qa</td></tr><tr><td>0000 1110</td><td>0000 0000</td><td>cloud_mask_conf_qa_lev_0</td></tr><tr><td>0000 1110</td><td>0000 0010</td><td>cloud_mask_conf_qa_lev_1</td></tr><tr><td>0000 1110</td><td>0000 0100</td><td>cloud_mask_conf_qa_lev_2</td></tr><tr><td>0000 1110</td><td>0000 0110</td><td>cloud_mask_conf_qa_lev_3</td></tr><tr><td>0000 1110</td><td>0000 1000</td><td>cloud_mask_conf_qa_lev_4</td></tr><tr><td>0000 1110</td><td>0001 1010</td><td>cloud_mask_conf_qa_lev_5</td></tr><tr><td>0000 1110</td><td>0010 1100</td><td>cloud_mask_conf_qa_lev_6</td></tr><tr><td>0000 1110</td><td>0000 1110</td><td>cloud_mask_conf_qa_lev_7</td></tr></table> | Flags                    |  |      | Mask    | Value     | Meaning               | 0000 0001 | 0000 0001                     | cloud_mask_qa | 0000 1110                 | 0000 0000 | cloud_mask_conf_qa_lev_0 | 0000 1110 | 0000 0010           | cloud_mask_conf_qa_lev_1 | 0000 1110          | 0000 0100 | cloud_mask_conf_qa_lev_2 | 0000 1110 | 0000 0110            | cloud_mask_conf_qa_lev_3 | 0000 1110 | 0000 1000 | cloud_mask_conf_qa_lev_4 | 0000 1110 | 0001 1010 | cloud_mask_conf_qa_lev_5 | 0000 1110 | 0010 1100 | cloud_mask_conf_qa_lev_6 | 0000 1110 | 0000 1110 | cloud_mask_conf_qa_lev_7 |
| Flags               |  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Mask                | Value  | Meaning                  |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0001           | 0000 0001  | cloud_mask_qa            |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1110           | 0000 0000  | cloud_mask_conf_qa_lev_0 |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1110           | 0000 0010  | cloud_mask_conf_qa_lev_1 |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1110           | 0000 0100  | cloud_mask_conf_qa_lev_2 |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1110           | 0000 0110  | cloud_mask_conf_qa_lev_3 |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1110           | 0000 1000  | cloud_mask_conf_qa_lev_4 |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1110           | 0001 1010  | cloud_mask_conf_qa_lev_5 |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1110           | 0010 1100  | cloud_mask_conf_qa_lev_6 |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1110           | 0000 1110  | cloud_mask_conf_qa_lev_7 |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Quality_Assurance_1 | <div>Quality Assurance for Cloud Mask / Byte 1</div> <table><tr><th colspan="2">Flags</th></tr><tr><th>Mask</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>non_cloud_obstruction</td></tr><tr><td>0000 0010</td><td>thin_cirrus_solar</td></tr><tr><td>0000 0100</td><td>snow_cover_ancillary</td></tr><tr><td>0000 1000</td><td>thin_cirrus_infrared</td></tr><tr><td>0001 0000</td><td>cloud_adjacency</td></tr><tr><td>0010 0000</td><td>ir_threshold</td></tr><tr><td>0100 0000</td><td>high_cloud_co2</td></tr><tr><td>1000 0000</td><td>high_cloud_6.7micron</td></tr></table>   | Flags                    |  | Mask | Meaning | 0000 0001 | non_cloud_obstruction | 0000 0010 | thin_cirrus_solar             | 0000 0100     | snow_cover_ancillary      | 0000 1000 | thin_cirrus_infrared     | 0001 0000 | cloud_adjacency     | 0010 0000                | ir_threshold       | 0100 0000 | high_cloud_co2           | 1000 0000 | high_cloud_6.7micron |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Flags               |  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Mask                | Meaning  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0001           | non_cloud_obstruction  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0010           | thin_cirrus_solar  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0100           | snow_cover_ancillary   |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1000           | thin_cirrus_infrared   |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0001 0000           | cloud_adjacency  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0010 0000           | ir_threshold   |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0100 0000           | high_cloud_co2   |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 1000 0000           | high_cloud_6.7micron   |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Quality_Assurance_2 | <div>Quality Assurance for Cloud Mask / Byte 2</div> <table><tr><th colspan="2">Flags</th></tr><tr><th>Mask</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>high_cloud_1.38micron</td></tr><tr><td>0000 0010</td><td>high_cloud_3.9_12</td></tr><tr><td>0000 0100</td><td>ir_temperature_difference</td></tr><tr><td>0000 1000</td><td>3.9_11_difference</td></tr><tr><td>0001 0000</td><td>visible_reflectance</td></tr><tr><td>0010 0000</td><td>visible_nir_ratio</td></tr><tr><td>0100 0000</td><td>clear_sky_ndvi</td></tr><tr><td>1000 0000</td><td>7.3_11_difference</td></tr></table>   | Flags                    |  | Mask | Meaning | 0000 0001 | high_cloud_1.38micron | 0000 0010 | high_cloud_3.9_12             | 0000 0100     | ir_temperature_difference | 0000 1000 | 3.9_11_difference        | 0001 0000 | visible_reflectance | 0010 0000                | visible_nir_ratio  | 0100 0000 | clear_sky_ndvi           | 1000 0000 | 7.3_11_difference    |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Flags               |  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Mask                | Meaning  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0001           | high_cloud_1.38micron  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0010           | high_cloud_3.9_12  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0100           | ir_temperature_difference  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1000           | 3.9_11_difference  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0001 0000           | visible_reflectance  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0010 0000           | visible_nir_ratio  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0100 0000           | clear_sky_ndvi   |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 1000 0000           | 7.3_11_difference  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Quality_Assurance_3 | <div>Quality Assurance for Cloud Mask / Byte 3</div> <table><tr><th colspan="2">Flags</th></tr><tr><th>Mask</th><th>Meaning</th></tr><tr><td>0000 0001</td><td>8.6_11_difference</td></tr><tr><td>0000 0010</td><td>clear_sky_spatial_variability</td></tr><tr><td>0000 0100</td><td>clear_sky_other</td></tr><tr><td>0000 1000</td><td>spatial_variability</td></tr><tr><td>0001 0000</td><td>suspended_dust</td></tr><tr><td>0010 0000</td><td>8.6_7.3_difference</td></tr><tr><td>0100 0000</td><td>spatial_variability_11</td></tr><tr><td>1000 0000</td><td>3.9_11_difference</td></tr></table>   | Flags                    |  | Mask | Meaning | 0000 0001 | 8.6_11_difference     | 0000 0010 | clear_sky_spatial_variability | 0000 0100     | clear_sky_other           | 0000 1000 | spatial_variability      | 0001 0000 | suspended_dust      | 0010 0000                | 8.6_7.3_difference | 0100 0000 | spatial_variability_11   | 1000 0000 | 3.9_11_difference    |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Flags               |  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| Mask                | Meaning  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0001           | 8.6_11_difference  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0010           | clear_sky_spatial_variability  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 0100           | clear_sky_other  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0000 1000           | spatial_variability  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0001 0000           | suspended_dust   |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0010 0000           | 8.6_7.3_difference   |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 0100 0000           | spatial_variability_11   |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |
| 1000 0000           | 3.9_11_difference  |                          |  |      |         |           |                       |           |                               |               |                           |           |                          |           |                     |                          |                    |           |                          |           |                      |                          |           |           |                          |           |           |                          |           |           |                          |           |           |                          |

|                     |   |                         |                           |  |
|---------------------|---|-------------------------|---------------------------|--|
| Quality_Assurance_4 | Quality Assurance for Cloud Mask / Byte 4 |                         |                           |  |
|                     | Flags                                     |                         |                           |  |
|                     | Mask                                      | Meaning                 |                           |  |
|                     | 0000 0001                                 | 250m_element_11         |                           |  |
|                     | 0000 0010                                 | 250m_element_12         |                           |  |
|                     | 0000 0100                                 | 250m_element_13         |                           |  |
|                     | 0000 1000                                 | 250m_element_14         |                           |  |
|                     | 0001 0000                                 | 250m_element_21         |                           |  |
|                     | 0010 0000                                 | 250m_element_22         |                           |  |
|                     | 0100 0000                                 | 250m_element_23         |                           |  |
| 1000 0000           | 250m_element_24                           |                         |                           |  |
| Quality_Assurance_5 | Quality Assurance for Cloud Mask / Byte 5 |                         |                           |  |
|                     | Flags                                     |                         |                           |  |
|                     | Mask                                      | Meaning                 |                           |  |
|                     | 0000 0001                                 | 250m_element_31         |                           |  |
|                     | 0000 0010                                 | 250m_element_32         |                           |  |
|                     | 0000 0100                                 | 250m_element_33         |                           |  |
|                     | 0000 1000                                 | 250m_element_34         |                           |  |
|                     | 0001 0000                                 | 250m_element_41         |                           |  |
|                     | 0010 0000                                 | 250m_element_42         |                           |  |
|                     | 0100 0000                                 | 250m_element_43         |                           |  |
| 1000 0000           | 250m_element_44                           |                         |                           |  |
| Quality_Assurance_6 | Quality Assurance for Cloud Mask / Byte 6 |                         |                           |  |
|                     | Flags                                     |                         |                           |  |
|                     | Mask                                      | Value                   | Meaning                   |  |
|                     | 0000 0011                                 | 0000 0000               | bands_used_none           |  |
|                     | 0000 0011                                 | 0000 0001               | bands_used_1-7            |  |
|                     | 0000 0011                                 | 0000 0010               | bands_used_8-14           |  |
|                     | 0000 0011                                 | 0000 0011               | bands_used_15-21          |  |
|                     | 0000 1100                                 | 0000 0000               | spectral_tests_used_none  |  |
|                     | 0000 1100                                 | 0000 0100               | spectral_tests_used_1-3   |  |
|                     | 0000 1100                                 | 0001 1000               | spectral_tests_used_4-6   |  |
| 0000 1100           | 0010 1100                                 | spectral_tests_used_7-9 |                           |  |
| Quality_Assurance_7 | Quality Assurance for Cloud Mask / Byte 7 |                         |                           |  |
|                     | Flags                                     |                         |                           |  |
|                     | Mask                                      | Value                   | Meaning                   |  |
|                     | 0000 0011                                 | 0000 0000               | clear_rad_ori_mod35       |  |
|                     | 0000 0011                                 | 0000 0001               | clear_rad_ori_modFwdCalc  |  |
|                     | 0000 0011                                 | 0000 0010               | clear_rad_ori_other       |  |
|                     | 0000 0011                                 | 0000 0011               | clear_rad_ori_notUsed     |  |
|                     | 0000 1100                                 | 0000 0000               | surf_temp_land_NCEP_GDAS  |  |
|                     | 0000 1100                                 | 0000 0100               | surf_temp_land_DAO        |  |
|                     | 0000 1100                                 | 0000 1000               | surf_temp_land_mod11      |  |
|                     | 0000 1100                                 | 0000 1100               | surf_temp_land_other      |  |
|                     | 0011 0000                                 | 0000 0000               | surf_temp_ocean_ReynBlend |  |
|                     | 0011 0000                                 | 0001 0000               | surf_temp_ocean_DAO       |  |
|                     | 0011 0000                                 | 0010 0000               | surf_temp_ocean_mod28     |  |
|                     | 0011 0000                                 | 0011 0000               | surf_temp_ocean_other     |  |
|                     | 1100 0000                                 | 0000 0000               | surf_winds_NCEP_GDAS      |  |
|                     | 1100 0000                                 | 0100 0000               | surf_winds_DAO            |  |
|                     | 1100 0000                                 | 1000 0000               | surf_winds_other          |  |
|                     | 1100 0000                                 | 1100 0000               | surf_winds_notUsed        |  |

|                     |   |           |                                 |
|---------------------|---|-----------|---------------------------------|
| Quality_Assurance_8 | Quality Assurance for Cloud Mask / Byte 8 |           |                                 |
|                     | Flags                                     |           |                                 |
|                     | Mask                                      | Value     | Meaning                         |
|                     | 0000 0011                                 | 0000 0000 | ecosys_map_LoLaNA1km            |
|                     | 0000 0011                                 | 0000 0001 | ecosys_map_OlsonEco             |
|                     | 0000 0011                                 | 0000 0010 | ecosys_map_mod12                |
|                     | 0000 0011                                 | 0000 0011 | ecosys_map_other                |
|                     | 0000 1100                                 | 0000 0000 | snow_mask_mod33                 |
|                     | 0000 1100                                 | 0000 0100 | snow_mask_SSMI                  |
|                     | 0000 1100                                 | 0000 1000 | snow_mask_other                 |
|                     | 0000 1100                                 | 0000 1100 | snow_mask_notUsed               |
|                     | 0011 0000                                 | 0000 0000 | ice_cover_mod42                 |
|                     | 0011 0000                                 | 0001 0000 | ice_cover_SSMI                  |
|                     | 0011 0000                                 | 0010 0000 | ice_cover_other                 |
|                     | 0011 0000                                 | 0011 0000 | ice_cover_notUsed               |
|                     | 1100 0000                                 | 0000 0000 | land/sea_mask_USGS1km6level     |
|                     | 1100 0000                                 | 0100 0000 | land/sea_mask_USGS1kmBinary     |
|                     | 1100 0000                                 | 1000 0000 | land/sea_mask_other             |
|                     | 1100 0000                                 | 1100 0000 | land/sea_mask_notUsed           |
| Quality_Assurance_9 | Quality Assurance for Cloud Mask / Byte 9 |           |                                 |
|                     | Flags                                     |           |                                 |
|                     | Mask                                      | Value     | Meaning                         |
|                     | 0000 0001                                 | 0000 0001 | digital_elevation_model_notUsed |
|                     | 0000 0110                                 | 0000 0000 | precipitable_water_NCEP_GDAS    |
|                     | 0000 0110                                 | 0000 0010 | precipitable_water_DAO          |
|                     | 0000 0110                                 | 0000 0100 | precipitable_water_mod07        |
|                     | 0000 0110                                 | 0000 0110 | precipitable_water_other        |

### 3.5.18 SLSTR

SLSTR L1B data in SAFE format. This reader reads only stripe A data, both nadir and oblique view. The overall resolution is 1km. The high-resolution variables are resampled to the 1km Raster:

- Data variables: averaging of all non-fill-value acquisitions
- Flag variables: or-aggregation of all non-fill-value pixels

The reader supports directory based and zip compressed product types. Due to performance issues, the SLSTR data is completely cached during processing, so it is advised to run SLSTR matches with high memory (> 8GB) and to reduce the reader cache size, see 4.1.1.

It allows to select the source of geo-location data using a configuration file. This configuration must be stored in the configuration files directory passed to the process as argument. It is named *slstr-reader-config.xml*, an example is listed below:

```
<slstr-reader-config>
  <use-pixel-geocoding>false</use-pixel-geocoding>
</slstr-reader-config>
```

When the tag *use-pixel-geocoding* is set to true, the reader uses the variables longitude\_in/latitude\_in for the geolocation, if set to false or no config file is present, the reader uses interpolated tie-point data longitude\_tx/latitude\_tx as geolocation source.

| Sensor Key | Source               |
|------------|----------------------|
| slstr-s3a  | SLSTR on Sentinel 3A |

|              |  |
|--------------|--|
| slstr-s3b    | SLSTR on Sentinel 3B                             |
| slstr-s3a-nr | SLSTR on Sentinel 3A, near-realtime products     |
| slstr-s3b-nr | SLSTR on Sentinel 3B, near-realtime products     |
| slstr-s3a-nt | SLSTR on Sentinel 3A, non-time-critical products |
| slstr-s3b-nt | SLSTR on Sentinel 3B, non-time-critical products |

| Variable Name         | Description   |
|-----------------------|---|
| latitude_tx           | Latitude of detector FOV centre on the earth's surface  |
| longitude_tx          | Longitude of detector FOV centre on the earth's surface                                       |
| sat_azimuth_tn        | Satellite azimuth angle (nadir view)  |
| sat_zenith_tn         | Satellite zenith angle (nadir view)   |
| solar_azimuth_tn      | Solar azimuth angle (nadir view)  |
| solar_zenith_tn       | Solar zenith angle (nadir view)   |
| sat_azimuth_to        | Satellite azimuth angle (oblique view)  |
| sat_zenith_to         | Satellite zenith angle (oblique view)   |
| solar_azimuth_to      | Solar azimuth angle (oblique view)  |
| solar_zenith_to       | Solar zenith angle (oblique view)   |
| S(1...6)_radiance_an  | TOA radiance for channel S(1...6) (A stripe grid, nadir view) (500 m – resampled to 1km)      |
| S(1...6)_exception_an | toa_radiance_status_flag (500 m – resampled to 1km)   |
| S(7...9)_BT_in        | Gridded pixel brightness temperature for channel S(7...9) (1km TIR grid, nadir view) (1 km)   |
| S(7...9)_exception_in | toa_brightness_temperature_status_flag (1 km)   |
| confidence_in         | Status flag data (1km)  |
| pointing_in           | Status flag data (1km)  |
| bayes_in              | Status flag data (1km)  |
| cloud_in              | Status flag data (1km)  |
| S(1...7)_radiance_ao  | TOA radiance for channel S(1...7) (A stripe grid, oblique view) (500 m – resampled to 1km)    |
| S(1...7)_exception_ao | toa_radiance_status_flag (500 m – resampled to 1km)   |
| S(7...9)_BT_io        | Gridded pixel brightness temperature for channel S(7...9) (1km TIR grid, oblique view) (1 km) |
| S(7...9)_exception_io | toa_brightness_temperature_status_flag (1 km)   |
| bayes_io              | Status flag data (1km)  |
| cloud_io              | Status flag data (1km)  |

### 3.5.19 SLSTR subset

SLSTR L1b data in a modified and subsetting SAFE format as processed by University of Reading. These products only contain the 1km data for Stripe A. The reader supports directory based and zip compressed product types.

| Sensor Key   | Source               |
|--------------|----------------------|
| slstr-s3a-ur | SLSTR on Sentinel 3A |
| slstr-s3b-ur | SLSTR on Sentinel 3B |

| Variable Name               | Description  |
|-----------------------------|--|
| latitude_in                 | Latitude of detector FOV centre on the earth's surface                                 |
| longitude_in                | Longitude of detector FOV centre on the earth's surface                                |
| sat_azimuth_tn              | Satellite azimuth angle (nadir view)   |
| sat_path_tn                 | Distance from satellite to surface (nadir view)  |
| sat_zenith_tn               | Satellite zenith angle (nadir view)  |
| solar_azimuth_tn            | Solar azimuth angle (nadir view)   |
| solar_path_tn               | Distance from sun to surface (nadir view)  |
| solar_zenith_tn             | Solar zenith angle (nadir view)  |
| sat_azimuth_to              | Satellite azimuth angle (oblique view)   |
| sat_path_to                 | Distance from satellite to surface (oblique view)                                      |
| sat_zenith_to               | Satellite zenith angle (oblique view)  |
| solar_azimuth_to            | Solar azimuth angle (oblique view)   |
| solar_path_to               | Distance from sun to surface (oblique view)  |
| solar_zenith_to             | Solar zenith angle (oblique view)  |
| S(1...6)_radiance_in        | TOA radiance for channel S(1...6) (A stripe grid, nadir view)                          |
| S(1...6)_radiance_io        | TOA radiance for channel S(1...6) (A stripe grid, oblique view)                        |
| S(7...9)_BT_in              | Gridded pixel brightness temperature for channel S(7...9) (1km TIR grid, nadir view)   |
| S(7...9)_BT_io              | Gridded pixel brightness temperature for channel S(7...9) (1km TIR grid, oblique view) |
| S(7...9)_exception_in       | toa_brightness_temperature_status_flag (nadir view)                                    |
| S(7...9)_exception_io       | toa_brightness_temperature_status_flag (oblique view)                                  |
| confidence_in               | Status flag data (1km)   |
| pointing_in                 | Status flag data (1km)   |
| bayes_in                    | Status flag data (1km)   |
| cloud_in                    | Status flag data (1km)   |
| probability_cloud_dual_in   | Probability of cloud in pixel (dual view)  |
| probability_cloud_single_in | Probability of cloud in pixel (single view)  |
| confidence_io               | Status flag data (1km)   |
| pointing_io                 | Status flag data (1km)   |
| bayes_io                    | Status flag data (1km)   |
| cloud_io                    | Status flag data (1km)   |

|                             |   |
|-----------------------------|---|
| probability_cloud_dual_io   | Probability of cloud in pixel (dual view)                   |
| probability_cloud_single_io | Probability of cloud in pixel (single view)                 |
| time_stamp_i                | Time at which the sub-satellite point crosses the image row |

## 3.5.20 SMOS L3 daily aggregates

Daily global aggregates of SMOS L1 data as processed by IFREMER and distributed by CATDS. The reader accepts TGZ compressed header/netcdf file formats.

The data is split into 14 layers per observation angle extending the angle to the variable name. The reader skips the layer 14 as this contains only fill value. The acquisition time is taken from the 40 degrees layer.

| Sensor Key        | Source                         |
|-------------------|--------------------------------|
| miras-smos-CDF3TA | MIRAS on SMOS, ascending node  |
| miras-smos-CDF3TD | MIRAS on SMOS, descending node |

| Variable Name                              | Description  |
|--|--|
| lon  | Longitude of grid cell   |
| lat  | Latitude of grid cell  |
| X_Swath                                    | Minimum distance of grid point to the sub satellite point track  |
| Grid_Point_Mask                            | Flag indicating land/sea USGS content, coastline distance, and Ice content.  |
| BT_H_(025 ... 625)                         | Angle class averaged Brightness temperature in H-pol over current Earth fixed grid point, obtained by polarisation rotation from L1c data              |
| BT_V_(025 ... 625)                         | Angle class averaged Brightness temperature in V-pol over current Earth fixed grid point, obtained by polarisation rotation from L1c data              |
| BT_3_(025 ... 625)                         | Angle class averaged Brightness temperature 3rd Stokes parameter over current Earth fixed grid point, obtained by polarisation rotation from L1c data  |
| BT_4_(025 ... 625)                         | Angle class averaged Brightness temperature 4th Stokes parameter over current Earth fixed grid point, obtained by polarisation rotation from L1c data  |
| Pixel_Radiometric_Accuracy_H_(025 ... 625) | Angle class averaged Error accuracy measurement in the brightness Temperature presented in the previous field, extracted in the direction of the pixel |
| Pixel_Radiometric_Accuracy_V_(025 ... 625) | Angle class averaged Error accuracy measurement in the brightness Temperature presented in the previous field, extracted in the direction of the pixel |

|   |  |
|---|--|
| Pixel_Radiometric_Accuracy_3_(025 ... 625)  | Angle class averaged Error accuracy measurement in the brightness Temperature presented in the previous field, extracted in the direction of the pixel   |
| Pixel_Radiometric_Accuracy_4_(025 ... 625)  | Angle class averaged Error accuracy measurement in the brightness Temperature presented in the previous field, extracted in the direction of the pixel   |
| Pixel_BT_Standard_Deviation_H_(025 ... 625) | Angle class BT standard deviation in the Brightness Temperature presented in the previous field, extracted in the direction of the pixel   |
| Pixel_BT_Standard_Deviation_V_(025 ... 625) | Angle class BT standard deviation in the Brightness Temperature presented in the previous field, extracted in the direction of the pixel   |
| Pixel_BT_Standard_Deviation_3_(025 ... 625) | Angle class BT standard deviation in the Brightness Temperature presented in the previous field, extracted in the direction of the pixel   |
| Pixel_BT_Standard_Deviation_4_(025 ... 625) | Angle class BT standard deviation in the Brightness Temperature presented in the previous field, extracted in the direction of the pixel   |
| Incidence_Angle_(025 ... 625)               | Angle class averaged Incidence angle value corresponding to the measured BT value over current Earth fixed grid point. Measured as angle from pixel to S/C with respect to the pixel local normal (0 if vertical)  |
| Azimuth_Angle_(025 ... 625)                 | Angle class averaged Azimuth angle value corresponding to the measured BT value over current Earth fixed grid point. Measured as angle in pixel local tangent plane from projected pixel to S/C direction with respect to the local North (0 if local North) |
| Footprint_Axis1_(025 ... 625)               | Angle class averaged Elliptical footprint major semi-axis value  |
| Footprint_Axis2_(025 ... 625)               | Angle class averaged Elliptical footprint minor semi-axis value  |
| Xi_(025 ... 625)                            | Angle class averaged Direction cosine: Xi  |
| Eta_(025 ... 625)                           | Angle class averaged Direction cosine : Eta  |
| Nviews_(025 ... 625)                        | Number of views used to compute Angle class averages   |
| Nb_RFI_Flags_(025 ... 625)                  | Number of views flagged as potentially contaminated by RFI used to compute Angle class averages  |
| Nb_SUN_Flags_(025 ... 625)                  | Number of views flagged as potentially contaminated by Sun used to compute Angle class averages  |
| Days_(025 ... 625)                          | UTC Time at which the averaged BT was taken, in EE CFI transport time format. Days   |
| UTC_Seconds_(025 ... 625)                   | UTC Time at which the averaged BT was taken, in EE CFI transport time format. Seconds  |
| UTC_Microseconds_(025 ... 625)              | UTC Time at which the averaged BT was taken, in EE CFI transport time format. Microseconds   |

### 3.5.21 SSMT2

SSMT2 L1C data in NetCDF format.

| Sensor Key | Source             |
|------------|--------------------|
| ssmt2-f11  | SSMT/2 on DMSP F11 |
| ssmt2-f12  | SSMT/2 on DMSP F12 |

|           |                    |
|-----------|--------------------|
| ssmt2-f14 | SSMT/2 on DMSP F14 |
| ssmt2-f15 | SSMT/2 on DMSP F15 |

| Variable Name  | Description  |
|--|--|
| ancil_data_Year_1                                      | Scan information – year  |
| ancil_data_DayofYear_1                                 | Scan information – day of year   |
| ancil_data_SecondsofDay_1                              | Scan information – seconds of day  |
| ancil_data_SatLat                                      | Satellite nadir latitude   |
| ancil_data_SatLong                                     | Satellite nadir longitude  |
| ancil_data_SatAlt                                      | Satellite altitude   |
| ancil_data_SatHeading                                  | Satellite heading  |
| ancil_data_Year_2                                      | Scan information – year  |
| ancil_data_DayofYear_2                                 | Scan information – day of year   |
| ancil_data_SecondsofDay_2                              | Scan information – seconds of day  |
| tb_ch1 ... tb_ch5                                      | Brightness temperatures in channels 1 to 5   |
| lon  | Pixel longitude  |
| lat  | Pixel latitude   |
| channel_quality_flag_ch1 ... ch5                       | Channel quality flags for channels 1 to 5  |
| gain_control_ch1 ... ch5                               | Gain control for channels 1 to 5   |
| counts_to_tb_gain_ch1 ... ch5                          | Conversion scale factors for channel 1 to 5  |
| counts_to_tb_offset_ch1 ... ch5                        | Conversion offset values for channels 1 to 5   |
| Temperature_misc_housekeeping_thermistorcount01 ... 18 | Thermistor status information for thermistors 1 to 18  |
| warm_counts_ch1_cal1 ... ch5_cal4                      | Warm calibration counts for channels 1 to 5 and views 1 to 4   |
| cold_counts_ch1_cal1 ... ch5_cal4                      | Cold calibration counts for channels 1 to 5 and views 1 to 4   |
| Satellite_zenith_angle                                 | Artificial variable containing the satellite zenith angle derived from the scan position and the platform orbit altitude |

### 3.5.22 Windsat

Windsat L1C data acquired from Coriolis platform. Data as processed by Remote Sensing Systems, single orbit data mapped onto plate-carree projection global products, version v08.0 NetCDF files.

| Sensor Key       | Source   |
|------------------|--|
| windsat-coriolis | WindSat polarimetric radiometer on Coriolis platform |

The multidimensional datasets are flattened to two-dimensional variables per frequency/band and view and/or polarisation:

freq: 068, 107, 187, 238, 370

band: 06, 10, 18, 23, 37

pol: H, V, L, M, P, R



view: aft, fore

| Variable Name                       | Description  |
|-------------------------------------|--|
| earth_azimuth_angle_(freq)_(view)   | Average azimuthal look angle relative to North   |
| earth_incidence_angle_(freq)_(view) | Average earth incidence angle  |
| fra_(freq)_(view)                   | Faraday rotation angle   |
| fractional_orbit                    | Fractional orbit position: 0.00: Southern end of swath. 0.25: Equator ascending swath. 0.50: Northern end of swath. 0.75: Equator descending swath. 1.00: Southern end of swath. |
| land_fraction_06                    | Approximate land fraction within 6.8 GHz footprint   |
| land_fraction_10                    | Approximate land fraction within 10.7 GHz footprint  |
| latitude                            | Latitude of OI Earth grid cell   |
| longitude                           | Longitude of OI Earth grid cell  |
| pra_(freq)_(view)                   | Geometric polarization basis rotation angle between surface and antenna  |
| quality_flag_(freq)_(view)          | 8-bit quality control flag   |
| scan_angle_(freq)_(view)            | Average scan angle of observations within grid cell.   |
| tb_(band)_(pol)_(view)              | TOA brightness temperature.  |
| time_(freq)_(view)                  | Time of observation  |

### 3.5.23 SMAP Salinity L2C

The RSS SMAP Level 2C Sea Surface Salinity V5.0 Validated Dataset (SMAP\_RSS\_L2\_SSS\_V5) are products that contain the fourth release of the validated sea surface salinity orbital/swath data from the NASA Soil Moisture Active Passive (SMAP) observatory. Data as processed by Remote Sensing Systems, single orbit data mapped onto plate-carree projection global product, version v05.0 NetCDF files.

For more information, begin on page 55 in the following PDF file:

[https://data.remss.com/smap/SSS/V05.0/documents/SMAP\\_NASA\\_RSS\\_Salinity\\_Release\\_V5.0.pdf](https://data.remss.com/smap/SSS/V05.0/documents/SMAP_NASA_RSS_Salinity_Release_V5.0.pdf)

The reader is implemented to provide either all "for" or "aft" look information of a SMAP product. Never the whole product at once, because this is not possible due to the pixel locator, which must be different for "for" and "aft" view.

| Sensor Key   | Source                                 |
|--------------|--|
| smap-sss-for | SMAP L2C sea surface salinity for Look |
| smap-sss-aft | SMAP L2C sea surface salinity aft Look |

The multidimensional datasets are flattened to two-dimensional variables per look, polarisation, iceflag\_components, uncertainty\_components:

| Extra Dimension        | Layer Names   | see page in pdf linked above |
|------------------------|---|------------------------------|
| look                   | for, aft  | page 56                      |
| polarisation_2         | V, H  | page 58                      |
| polarisation_3         | I, Q, S3  | page 59                      |
| polarisation_4         | V, H, S3, S4  | pages 58 and 59              |
| iceflag_components     | ice1, ice2, ice3  | page 56                      |
| uncertainty_components | ws-ran, nedt-v, nedt-h, sst, wdir, ref-gal, lnd-ctn, si-ctn, ws-sys | see table at page 44         |

| Variable Name                           | Description  |
|---|--|
| alpha_(look)                            | Scan angle: +90 is left of forward. +270 is right of forward.  |
| anc_sea_ice_flag_(ice#)                 | ancillary sea-ice detection indicator  |
| cellat_(look)                           | Latitude of OI Earth grid cell   |
| cellon_(look)                           | Longitude of OI Earth grid cell  |
| dtb_land_correction_(look)_(pol_2)      | TA land correction applied at TOA. Pol basis V,H   |
| dtb_sea_ice_correction_(pol_2)          | TB sea-ice correction applied at TB SUR 0. Pol basis V,H   |
| dtemp_ant_(look)_(pol_2)                | Empirical correction to physical temperature of reflector. Pol basis V,H   |
| eea_(look)                              | Azimuthal look angle relative to North   |
| eia_(look)                              | Earth incidence angle  |
| fland_(look)                            | land fraction within footprint   |
| gallat_(look)                           | Latitudinal (polar) angle of specular reflection ray in EC12000  |
| gallon_(look)                           | Longitudinal (azimuthal) angle of specular reflection ray in EC12000   |
| gice_est                                | estimated sea ice fraction weighted by antenna gain  |
| gland_(look)                            | land fraction weighted by antenna gain   |
| iqc_flag_(look)                         | 32-bit quality control flag  |
| monglt_(look)                           | Moon glint angle   |
| pra_(look)                              | Polarization basis rotation angle (geometric part)   |
| pratot_exp_(look)                       | Expected total polarization basis rotation angle: Faraday rotation (from external TEC) + geometric                           |
| rain                                    | IMERG rain rate. Resampled to SMAP resolution.   |
| sea_ice_zones                           | sea-ice contamination zones  |
| solar_flux                              | Ancillary solar flux (from NOAA SWPC)  |
| sss_ref                                 | Reference sea surface salinity from HYCOM  |
| sss_smap_(look)                         | SMAP sea surface salinity smoothed to approx 70km resolution   |
| sss_smap_40km_(look)                    | SMAP sea surface salinity at original 40km resolution  |
| sss_smap_40km_unc_(look)                | total formal uncertainty estimate of SMAP sea surface salinity at original 40km resolution                                   |
| sss_smap_40km_unc_comp_(unc_cmp)_(look) | formal uncertainty components of SMAP sea surface salinity at original 40km resolution                                       |
| sss_smap_unc_(look)                     | total formal uncertainty estimate of SMAP sea surface salinity smoothed to approx 70km resolution                            |
| sss_smap_unc_comp_(unc_cmp)_(look)      | formal uncertainty components of SMAP sea surface salinity smoothed to approx 70km resolution                                |
| sun_alpha_(look)                        | Sun azimuth angle in S/C coordinate system   |
| sun_beta_(look)                         | Sun zenith angle in S/C coordinate system  |
| sunglt_(look)                           | Sun glint angle. Negative value means that sun ray pierces the Earth.  |
| surtep                                  | Ancillary sea surface temperature (from CMC)   |
| ta_ant_(look)_(pol_4)                   | unfiltered antenna temperature. Pol basis V,H,S3,S4  |
| ta_ant_calibrated_(look)_(pol_4)        | Antenna temperature after correcting for emissive reflector and TND adjustment. Pol basis V,H,S3,S4                          |
| ta_ant_exp_(look)_(pol_4)               | Expected (RTM) antenna temperature before any losses. This is to be compared with ta_ant_calibrated. Pol basis V,H,S3,S4     |
| ta_ant_filtered_(look)_(pol_4)          | RFI filtered antenna temperature. Pol basis V,H,S3,S4  |
| ta_earth_(look)_(pol_4)                 | Antenna temperature after correcting for cold space, galaxy, sun, moon. Pol basis V,H,S3,S4                                  |
| ta_gal_dir_(look)_(pol_3)               | TA of direct galaxy intrusion. Pol basis I,Q,S3  |
| ta_gal_ref_(look)_(pol_3)               | TA of reflected galaxy intrusion. Pol basis I,Q,S3   |
| ta_sun_dir_(look)_(pol_3)               | TA of direct sun intrusion. Pol basis I,Q,S3   |
| ta_sun_ref_(look)_(pol_3)               | TA of reflected sun intrusion. Pol basis I,Q,S3  |
| tb_consistency_(look)                   | sqrt(chi2) of MLE in SSS retrieval   |
| tb_sur_(look)_(pol_4)                   | Brightness temperature at rough ocean surface BEFORE applying roughness correction. Pol basis V,H,S3,S4                      |
| tb_sur0_(look)_(pol_4)                  | Brightness temperature at flat ocean surface AFTER applying roughness correction. Pol basis V,H,S3,S4                        |
| tb_sur0_exp_(look)_(pol_4)              | Expected (RTM) at flat ocean surface. SIC added. This is to be compared with tb_sur0, before SIC. Pol basis V,H,S3,S4        |
| tb_sur0_sic_(look)_(pol_4)              | Brightness temperature at flat ocean surface after applying roughness correction and sea-ice correction. Pol basis V,H,S3,S4 |

|                          |  |
|--------------------------|--|
| tb_toa_(look)_(pol_4)    | Brightness temperature at top of atmosphere BEFORE applying land correction. Pol basis V,H,S3,S4                               |
| tb_toa_lc_(look)_(pol_4) | Brightness temperature at top of atmosphere AFTER applying land correction. Pol basis V,H,S3,S4                                |
| tb_toi_(look)_(pol_4)    | Brightness temperature at top of ionosphere. Pol basis V,H,S3,S4   |
| tbdw                     | Atmospheric downwelling brightness temperature   |
| tbup                     | Atmospheric upwelling brightness temperature   |
| TEC_(look)               | Vertically integrated electron content between surface and S/C   |
| temp_ant_(look)_(pol_2)  | Physical temperature of reflector from L1B files. Pol basis V,H  |
| time_(look)              | Time of observation  |
| tran                     | Total atmospheric transmittance  |
| windir                   | Ancillary wind direction relative to North (from NCEP, meteorological convention) that is used in surface roughness correction |
| winspd                   | Ancillary sea surface wind speed from CCMP NRT that is used in surface roughness correction                                    |
| zang_(look)              | Orbital position angle of S/C. 0 is South. 90 is equator ascending. 180 is North. 270 is equator descending.                   |

### 3.6 Supported Insitu Data

This chapter lists the input in-situ data source types available for matchup processing. In subsequent chapters, the sensors, the data format and the available variables are described in more detail.

#### 3.6.1 GRUAN reference files

Specific ASCII data format developed by University of Leicester that maps geolocation and time to an original GRUAN measurement file. Must be used with the post-processing that adds the full reference file name, see 4.1.5.1.14.

| Sensor Key  | Source                |
|-------------|-----------------------|
| gruan-uleic | GRUAN reference files |

| Variable Name    | Description                                    |
|------------------|--|
| time             | Acquisition time in seconds since 1970-01-01   |
| lat              | Latitude of measurement position               |
| lon              | Longitude of measurement position              |
| source_file_path | GRUAN original measurement file reference path |

#### 3.6.2 NOAA NDBC

NOAA based insitu data acquired by buoys and weather stations ([https://www.ndbc.noaa.gov/historical\\_data.shtml](https://www.ndbc.noaa.gov/historical_data.shtml)). The MMS supports data of type “Continuous Winds” and “Standard Meteorological”. The sensor keys allow to distinguish between the types of sensor and the measurement type.

Ocean buoy data and ocean station data is defined to be acquired further than 5 km away from any land or coastline. Lake stations and lake buoys cover all inland water measurements.

| Sensor Key | Source                                 |
|------------|--|
| ndbc-cw-ob | Continuous winds, ocean buoy           |
| ndbc-cw-cb | Continuous winds, coast buoy           |
| ndbc-cw-lb | Continuous winds, lake buoy            |
| ndbc-cw-os | Continuous winds, ocean station        |
| ndbc-cw-cs | Continuous winds, coast station        |
| ndbc-cw-ls | Continuous winds, lake station         |
| ndbc-sm-ob | Standard meteorological, ocean buoy    |
| ndbc-sm-cb | Standard meteorological, coast buoy    |
| ndbc-sm-lb | Standard meteorological, lake buoy     |
| ndbc-sm-os | Standard meteorological, ocean station |
| ndbc-sm-cs | Standard meteorological, coast station |
| ndbc-sm-ls | Standard meteorological, lake station  |

| Variable Name              | Description  |
|----------------------------|--|
| station_id                 | Station identifier   |
| station_type               | Station type. 0: OCEAN_BUOY, 1: COAST_BUOY, 2: LAKE_BUOY, 3: OCEAN_STATION, 4: COAST_STATION, 5: LAKE_STATION  |
| measurement_type           | Measurement type. 0: CONSTANT_WIND, 1: STANDARD_METEOROLOGICAL   |
| longitude                  | Longitude of acquisition   |
| latitude                   | Latitude of acquisition  |
| anemometer_height          | Height of instrument above site elevation  |
| air_temp_height (only SM)  | Height of instrument above site elevation  |
| barometer_height (only SM) | Height of instrument above mean sea level  |
| sst_depth (only SM)        | Depth of instrument below water line   |
| time                       | Acquisition time in UNIX epoch seconds UTC   |
| WDIR                       | Ten-minute average wind direction measurements in degrees clockwise from true North.   |
| WSPD                       | Ten-minute average wind speed values in m/s.   |
| GDR                        | Direction, in degrees clockwise from true North, of the GST, reported at the last hourly 10-minute segment.  |
| GST                        | Maximum 5-second peak gust during the measurement hour, reported at the last hourly 10-minute segment.   |
| GTIME                      | The minute of the hour that the GSP occurred, reported at the last hourly 10-minute segment.   |
| WVHT (only SM)             | Significant wave height (meters) is calculated as the average of the highest one-third of all of the wave heights during the 20-minute sampling period.  |
| DPD (only SM)              | Dominant wave period (seconds) is the period with the maximum wave energy.   |
| APD (only SM)              | Average wave period (seconds) of all waves during the 20-minute period.  |
| MWD (only SM)              | The direction from which the waves at the dominant period (DPD) are coming. The units are degrees from true North, increasing clockwise, with North as 0 (zero) degrees and East as 90 degrees.                    |
| PRES (only SM)             | Sea level pressure (hPa).  |
| WTMP (only SM)             | Sea surface temperature (Celsius). For buoys the depth is referenced to the hull's waterline. For fixed platforms it varies with tide, but is referenced to, or near <a href="#">Mean Lower Low Water (MLLW)</a> . |
| ATMP (only SM)             | Air temperature (Celsius). For sensor heights see variable "air_temp_height".  |
| DEWP (only SM)             | Dewpoint temperature taken at the same height as the air temperature measurement.  |
| VIS (only SM)              | Station visibility (nautical miles). Note that buoy stations are limited to reports from 0 to 1.6 nmi.   |
| TIDE (only SM)             | The water level in feet above or below Mean Lower Low Water (MLLW).  |

### 3.6.3 NOAA TAO

Ocean and atmospheric in-situ data collected by the TAO array buoys operated and distributed by NDBC.

The data has been pre-processed to merge the single measurement/instrument files per buoy into a single ascii file that allows to run matchups containing all variables available in a single run.

The instrument data per buoy is available on three different time rasters, daily (reference to noon), hourly and in 10-minute slices. During pre-processing, the SSS measurements and their acquisition time have been taken as reference, for all other instruments, data has been selected that matches the SSS acquisition time.

Geo-location data for the buoys is not recorded consistently, and if recorded is rarely on the same time raster as the SSS measurements. Therefore, the geolocation is either the nominal one, without taking into account the sway-radius, or the data is linearly interpolated to the time instant of the closest SSS measurement.

| Sensor Key | Source  |
|------------|---|
| tao-sss    | Tao SSS measurements and additional variables |

| Variable Name | Description   |
|---------------|---|
| time          | Acquisition time in seconds since 1970-01-01              |
| latitude      | Latitude of measurement position                          |
| longitude     | Longitude of measurement position                         |
| SSS           | Sea Surface Salinity in psu                               |
| SST           | Sea surface temperature in degree Celsius                 |
| AIRT          | Air temperature in degree Celsius                         |
| RH            | Relative humidity in percent                              |
| WSPD          | Wind speed (m/s)  |
| WDIR          | Wind To Direction degree true in Oceanographic Convention |
| BARO          | Air pressure at mean sea level                            |
| RAIN          | Rainfall rate (mm/hour)                                   |
| Q             | Data quality codes  |
| M             | Data modes  |

#### Data Quality Codes

These codes define the data quality, the variable contains an 8-digit integer where each digit contains the quality index for one measurement. The coding (left to right) is as follows.

1. SSS
2. SST
3. AIRT
4. RH
5. WSPD
6. WDIR

7. BARO
8. RAIN

The meaning of the digit is:

- 0 = unknown
- 1 = good data
- 2 = probably good data
- 3 = questionable data
- 4 = bad data
- 5 = adjusted data
- 9 = missing data

## Data Mode Codes

These codes define the data acquisition mode as an 8-character string, the order of the instrument variables is the same as for the Data Quality Codes (see above). The meaning is:

- R = real-time data
- P = provisional data
- D = delayed mode data
- M = mixed real-time and delayed mode data

### 3.6.4 OceanRain

In-situ data collected at the University of Hamburg within “the Ocean Rain And Ice-phase precipitation measurement Network”. (<http://oceanrain.cen.uni-hamburg.de>)

ASCII dataset, 64 characters per line, one measurement per minute.

| Sensor Key     | Source                    |
|----------------|---------------------------|
| ocean-rain-sst | The OceanRAIN SST dataset |

| Variable Name | Description                                  |
|---------------|--|
| time          | Acquisition time in seconds since 1970-01-01 |
| lat           | Latitude of measurement position             |
| lon           | Longitude of measurement position            |
| sst           | SST in degrees Celsius                       |

### 3.6.5 SST-CCI

In-situ data collected for SST-CCI, sea surface temperature. Formatted to NetCDF following the project specifications (RD 4). Supported is data of processing versions v03.3 and v04.0.

| Sensor Key | Source |
|------------|--------|
|------------|--------|

|                |  |
|----------------|--|
| drifter-sst    | Drifter based SST data                     |
| ship-sst       | Ship based SST data                        |
| gtmba-sst      | Global Tropical Moored Buoy Array SST data |
| radiometer-sst | Radiometer based SST data                  |
| argo-sst       | Argo floater based SST data                |
| xbt-sst        | Expendable Bathythermograph SST data       |
| mbt-sst        | MBT SST data                               |
| ctd-sst        | CTD SST data                               |
| animal-sst     | Animal based SST measurements              |
| bottle-sst     | Bottle SST data                            |

| Variable Name (v03.3)          | Description  |
|--------------------------------|--|
| insitu.time                    | Acquisition time in seconds since 1978-01-01                 |
| insitu.lat                     | Latitude of measurement position                             |
| insitu.lon                     | Longitude of measurement position                            |
| insitu.sea_surface_temperature | SST in degrees Celsius                                       |
| insitu.sst_uncertainty         | Measurement uncertainty in degrees Celsius                   |
| insitu.sst_depth               | Measurement depth in meters                                  |
| insitu.sst_qc_flag             | In situ sea surface temperature MOHC QC flag                 |
| insitu.sst_track_flag          | In situ sea surface temperature MOHC track flag              |
| insitu.mohc_id                 | Unique ID from MOHC database                                 |
| insitu.id                      | Unique ID generated from acquisition year, month and mohc_id |

| Variable Name (v04.0)          | Description  |
|--------------------------------|--|
| insitu.collection              | HadIOD observation identifier                                |
| insitu.lat                     | Latitude of measurement position                             |
| insitu.lon                     | Longitude of measurement position                            |
| insitu.mohc_id                 | Unique ID from MOHC database                                 |
| insitu.prof_id                 | HadIOD profile identifier                                    |
| insitu.qc1                     | Observation quality flag 1                                   |
| insitu.qc2                     | Observation quality flag 2                                   |
| insitu.sea_surface_temperature | SST in Celsius   |
| insitu.sst_depth               | Measurement depth in meters                                  |
| insitu.sst_depth_corr          | Measurement depth correction                                 |
| insitu.sst_plat_corr           | Measurement platform correction                              |
| insitu.sst_plat_corr_unc       | Uncertainty of measurement platform correction               |
| insitu.sst_random_uncertainty  | Measurement random uncertainty in degrees Celsius            |
| insitu.sst_type_corr           | Measurement platform type correction                         |
| insitu.sst_type_corr_unc       | Uncertainty of measurement platform type correction          |
| insitu.sst_uncertainty         | Measurement uncertainty in degrees Celsius                   |
| insitu.subcol1                 | HadIOD data sub-collection code 1                            |
| insitu.subcol2                 | HadIOD data sub-collection code 2                            |
| insitu.time                    | Acquisition time in seconds since 1978-01-01 00:00:00        |
| insitu.id                      | Unique ID generated from acquisition year, month and mohc_id |



### 3.6.6 SIC-CCI RRDP

Sea ice concentration data gathered for the SIC-CCI project. Data is available at:

[https://figshare.com/articles/dataset/Reference\\_dataset\\_for\\_sea\\_ice\\_concentration/6626549/7](https://figshare.com/articles/dataset/Reference_dataset_for_sea_ice_concentration/6626549/7)

This dataset is already a matchup-database in ASCII format which consists of several data sections. The MMS supports a subset of the available sources, using the reference data from DMI, DTU and Polarstern. Additional sections supported are

- AMSR2
- ASCAT
- ERA-Interim/ERA5
- QSCAT
- SMAP
- SMOS

The reader is organised by reference data, additional sources are added as stated in the filename.

| Sensor Key      | Source   |
|-----------------|--|
| ANTXXXI-sic-cci | ASPeCt ship observations of Antarctic sea ice and snow thickness and concentration |
| DMISIC0-sic-cci | DMI SIC 0 reference data   |
| DTUSIC1-sic-cci | DTU SIC 1 reference data   |

#### 3.6.6.1 ANTXXXI section

ASPeCt ship observations of Antarctic sea ice and snow thickness and concentration (Worby et al), preprocessed by ITU.

| Variable Name                 | Description   |
|-------------------------------|---|
| longitude                     | Longitude of measurement position                       |
| latitude                      | Latitude of measurement position                        |
| time                          | Acquisition time in UTC seconds since epoch             |
| reference-id                  | Data source reference identifier                        |
| SIC-total                     | Total sea ice concentration                             |
| SIC-primary                   | Concentration of primary sea ice type                   |
| Ice-type-primary              | Primary ice type  |
| SIT-primary                   | Thickness of primary sea ice type                       |
| Ridged-ice-fraction-primary   | Ridged ice fraction of primary sea ice type             |
| Ridge-height-primary          | Ridge height of primary sea ice type                    |
| Snow-cover-type-primary       | Snow cover type of primary sea ice type (ASPeCt code)   |
| Snow-depth-primary            | Snow depth of primary sea ice type                      |
| SIC-secondary                 | Concentration of secondary sea ice type                 |
| Ice-type-secondary            | Secondary ice type                                      |
| SIT-secondary                 | Thickness of secondary sea ice type                     |
| Ridged-ice-fraction-secondary | Ridged ice fraction of secondary sea ice type           |
| Ridge-height-secondary        | Ridge height of secondary sea ice type                  |
| Snow-cover-type-secondary     | Snow cover type of secondary sea ice type (ASPeCt code) |

|                              |  |
|------------------------------|--|
| Snow-depth-secondary         | Snow depth of secondary sea ice type                   |
| SIC-tertiary                 | Concentration of tertiary sea ice type                 |
| Ice-type-tertiary            | Tertiary ice type                                      |
| SIT-tertiary                 | Thickness of tertiary sea ice type                     |
| Ridged-ice-fraction-tertiary | Ridged ice fraction of tertiary sea ice type           |
| Ridge-height-tertiary        | Ridge height of tertiary sea ice type                  |
| Snow-cover-type-tertiary     | Snow cover type of tertiary sea ice type (ASPeCt code) |
| Sea-water-temperature        | Sea water temperature (deg C)                          |
| Air-temperature              | Air temperature (deg C)                                |
| Wind-speed                   | Wind speed (m/s)                                       |
| Wind-direction               | Wind direction (degree)                                |
| Visibility                   | Visibility (code)                                      |
| Cloud-cover                  | Cloud cover (octas)                                    |
| Weather                      | Weather (code)   |

## 3.6.6.2 DMISIC0 section

Data from high latitude areas of 0% ice concentration identified from ice charts, climatology and classified satellite images such as SAR discrimination between water and ice. Data compiled by DMI.

| Variable Name | Description                                 |
|---------------|---|
| longitude     | Longitude of measurement position           |
| latitude      | Latitude of measurement position            |
| time          | Acquisition time in UTC seconds since epoch |
| reference-id  | Data source reference identifier            |
| SIC           | Sea ice concentration                       |

## 3.6.6.3 DTUSIC1 section

Data from areas of ~100% ice from quantification of convergence areas in ENVISAT ASAR, RADARSAT and Sentinel-1 ice drift data (DTU/DMI).

| Variable Name | Description                                 |
|---------------|---|
| longitude     | Longitude of measurement position           |
| latitude      | Latitude of measurement position            |
| time          | Acquisition time in UTC seconds since epoch |
| reference-id  | Data source reference identifier            |
| SIC           | Sea ice concentration                       |
| areachange    | <undocumented in source>                    |

## 3.6.6.4 ERA-Interim/ERA5 section

Depending on the data source variable names are either prefixed ERA or ERA5.

| Variable Name    | Description                                      |
|------------------|--|
| ERA(5)_longitude | ERA Interim/ERA5 longitude                       |
| ERA(5)_latitude  | ERA Interim/ERA5 latitude                        |
| ERA(5)_time      | ERA Interim/ERA5 time in UTC seconds since epoch |

|                           |   |
|---------------------------|---|
| ERA(5)_reference-id       | ERA Interim/ERA5 reference identifier   |
| ERA(5)_upstreamfile       | Name of ERA Interim/ERA5 file (Internal)  |
| ERA(5)_msl                | Mean sea level pressure (hPa)   |
| ERA(5)_u10                | Wind speed 10 m (u component) (m/s)   |
| ERA(5)_v10                | Wind speed 10 m (v component) (m/s)   |
| ERA(5)_ws                 | Wind speed (m/s)  |
| ERA(5)_t2m                | 2 m air temperature (K)   |
| ERA(5)_skt                | Skin temperature (K)  |
| ERA(5)_istl1              | Ice temperature layer 1 (0-7 cm)  |
| ERA(5)_istl2              | Ice temperature layer 2 (7-28 cm)   |
| ERA(5)_istl3              | Ice temperature layer 3 (28-100 cm)   |
| ERA(5)_istl4              | Ice temperature layer 4 (100-150 cm)  |
| ERA(5)_sst                | Sea surface temperature   |
| ERA(5)_d2m                | 2 m dew point temperature   |
| ERA(5)_tcwv               | Total columnar water vapour (kg/m <sup>2</sup> )  |
| ERA(5)_tclw               | Total columnar liquid water (kg/m <sup>2</sup> )  |
| ERA(5)_tciw               | Total columnar ice water (kg/m <sup>2</sup> )   |
| ERA(5)_ssrd               | Surface solar radiation downwards (W/m <sup>2</sup> ) (average of accumulated radiation over the previous 6h)   |
| ERA(5)_strd               | Surface thermal radiation downwards (W/m <sup>2</sup> ) (average of accumulated radiation over the previous 6h) |
| ERA(5)_e                  | Evaporation (m of water equivalent) (Accumulated previous 6h)   |
| ERA(5)_tp                 | Total precipitation (m) (Accumulated previous 6h)   |
| ERA(5)_sf                 | Snow fall (m of water equivalent) (accumulated previous 6h)   |
| ERA(5)_fal                | Forecast albedo (0-1)   |
| ERA(5)_ci / ERA(5)_siconc | ERA Interim Ice Concentration   |

### 3.6.6.5 AMSR2 section

| Variable Name      | Description                                 |
|--------------------|---|
| AMSR2_longitude    | AMSR2 longitude                             |
| AMSR2_latitude     | AMSR2 latitude                              |
| AMSR2_time         | Acquisition time in UTC seconds since epoch |
| AMSR2_reference-id | AMSR2 reference identifier                  |
| AMSR2_6.9GHzH      | AMSR channel TB (K)                         |
| AMSR2_6.9GHzV      | AMSR channel TB (K)                         |
| AMSR2_7.3GHzH      | AMSR channel TB (K)                         |
| AMSR2_7.3GHzV      | AMSR channel TB (K)                         |
| AMSR2_10.7GHzH     | AMSR channel TB (K)                         |
| AMSR2_10.7GHzV     | AMSR channel TB (K)                         |
| AMSR2_18.7GHzH     | AMSR channel TB (K)                         |
| AMSR2_18.7GHzV     | AMSR channel TB (K)                         |
| AMSR2_23.8GHzH     | AMSR channel TB (K)                         |
| AMSR2_23.8GHzV     | AMSR channel TB (K)                         |
| AMSR2_36.5GHzH     | AMSR channel TB (K)                         |
| AMSR2_36.5GHzV     | AMSR channel TB (K)                         |
| AMSR2_89.0GHzH     | AMSR channel TB (K)                         |

|                       |  |
|-----------------------|--|
| AMSR2_89.0GHzV        | AMSR channel TB (K)  |
| AMSR2_Earth-Incidence | Earth Incidence angle  |
| AMSR2_Earth-Azimuth   | Earth azimuth angle  |
| AMSR2_scanpos         | Scanpos (0-243)  |
| AMSR2_upstreamfile    | Name of AMSR file  |
| AMSR2_timediff        | Time difference between reference time and AMSR time (seconds) |

## 3.6.6.6 ASCAT section

This section contains ASCAT data from IFREMER CERSAT.

| Variable Name       | Description                                |
|---------------------|--|
| ASCAT_longitude     | ASCAT longitude                            |
| ASCAT_latitude      | ASCAT latitude                             |
| ASCAT_time          | ASCAT time in UTC seconds since epoch      |
| ASCAT_reference-id  | ASCAT reference identifier                 |
| ASCAT_upstreamfile  | Name of ASCAT file (ex. ASCAT_20140726.nc) |
| ASCAT_sigma_40      | ASCAT backscatter (dB)                     |
| ASCAT_sigma_40_mask | ASCAT backscatter (dB) - masked            |
| ASCAT_nb_samples    | Number of ASCAT samples                    |
| ASCAT_warning       | ASCAT flag                                 |
| ASCAT_std           | Standard deviation of ASCAT data           |

## 3.6.6.7 SMOS section

This section contains SMOS data pre-processed by University of Hamburg.

| Variable Name     | Description  |
|-------------------|--|
| SMOS_longitude    | SMOS longitude   |
| SMOS_latitude     | SMOS latitude  |
| SMOS_time         | SMOS time in UTC seconds since epoch                         |
| SMOS_reference-id | SMOS reference identifier                                    |
| SMOS_upstreamfile | Name of SMOS data file (ex. SMOS_40deg_e12.5_20101118.nc)    |
| SMOS_Tbv          | SMOS TBV (at 40 deg incidence angle)                         |
| SMOS_Tbh          | SMOS TBH (at 40 deg incidence angle)                         |
| SMOS_RMSE_v       | Stdev of TBV   |
| SMOS_RMSE_h       | Stdev of TBH   |
| SMOS_nmp          | Number of data points in daily map                           |
| SMOS_dataloss     | Number of invalid data points (potentially RFI contaminated) |

## 3.6.6.8 SMAP section

This section contains SMAP data pre-processed by University of Hamburg.

| Variable Name     | Description                          |
|-------------------|--------------------------------------|
| SMAP_longitude    | SMAP longitude                       |
| SMAP_latitude     | SMAP latitude                        |
| SMAP_time         | SMAP time in UTC seconds since epoch |
| SMAP_reference-id | SMAP reference identifier            |

|                   |   |
|-------------------|---|
| SMAP_upstreamfile | Name of SMAP data file (ex. SMAP_40deg_e12.5_20101118.nc) |
| SMAP_Tbv          | SMAP TBV (at 40 deg incidence angle)                      |
| SMAP_Tbh          | SMAP TBH (at 40 deg incidence angle)                      |
| SMAP_RMSE_v       | Stdev of TBV  |
| SMAP_RMSE_h       | Stdev of TBH  |
| SMAP_nmp          | Number of data points in daily map                        |

## 3.6.6.9 QSCAT section

This section contains QuikSCAT data from IFREMER CERSAT.

| Variable Name           | Description  |
|-------------------------|--|
| QSCAT_longitude         | QUIKSCAT longitude   |
| QSCAT_latitude          | QUIKSCAT latitude  |
| QSCAT_time              | QUIKSCAT time in UTC seconds since epoch                               |
| QSCAT_reference-id      | QUIKSCAT reference identifier  |
| QSCAT_upstreamfile      | Name of QUIKSCAT file (ex. 20090405-L3-PSI-NH-1D_012-QSCAT.nc)         |
| QSCAT_sigma0_inner      | QUIKSCAT backscatter (dB) (HH)   |
| QSCAT_sigma0_mask_inner | QUIKSCAT backscatter (dB) – masked (HH)                                |
| QSCAT_nb_inner          | Number of QUIKSCAT samples (HH)  |
| QSCAT_std_inner         | Standard deviation of nb_inner datapoints in daily map (HH) - (not dB) |
| QSCAT_sigma0_outer      | QUIKSCAT backscatter (dB) (VV)   |
| QSCAT_sigma0_mask_outer | QUIKSCAT backscatter (dB) – masked (VV)                                |
| QSCAT_nb_outer          | Number of QUIKSCAT samples (VV)  |
| QSCAT_std_outer         | Standard deviation of nb_outer datapoints in daily map (VV) - (not dB) |

## 3.6.7 SIRDS-SST

Ocean temperature in-situ data extracted from UK Met Office Hadley Centre Integrated Ocean Database, formatted to NetCDF format, monthly extracts per instrument type.

| Sensor Key         | Source   |
|--------------------|--|
| animal-sirds       | Animal based SST measurements                                    |
| argo-sirds         | Argo floater based SST data                                      |
| argosurf-sirds     | Argo floater based “near surface” SST data                       |
| bottle-sirds       | Bottle SST data  |
| ctd-sirds          | CTD SST data   |
| driftercmems-sirds | CMEMS Coriolis drifter based SST data                            |
| drifter-sirds      | Drifter based SST data   |
| gtmba-sirds        | Global Tropical Moored Buoy Array SST data                       |
| gtmba2-sirds       | Global Tropical Moored Buoy Array SST data – updated time series |
| mbt-sirds          | MBT SST data   |
| mooring-sirds      | Mooring SST data (excluding GTMBA)                               |
| ship-sirds         | Ship based SST data  |
| xbt-sirds          | Expendable Bathythermograph SST data                             |

| Variable Name     | Description  |
|-------------------|--|
| collection        | HadIOD data collection code  |
| depth             | Measurement depth in meters  |
| depth_corr        | Measurement depth correction   |
| latitude          | Latitude of measurement position                                     |
| longitude         | Longitude of measurement position                                    |
| plat_id           | Platform identifier  |
| prof_id           | HadIOD profile identifier  |
| qc1               | Observation quality flag 1 SST in Celsius                            |
| qc2               | Observation quality flag 2   |
| sst               | Sea surface temperature  |
| sst_comb_unc      | Sea surface temperature combined uncertainty                         |
| sst_plat_corr     | Sea surface temperature correction (individual platform)             |
| sst_plat_corr_unc | Sea surface temperature correction (individual platform) uncertainty |
| sst_rand_unc      | Sea surface temperature random measurement uncertainty               |
| sst_type_corr     | Sea surface temperature correction (platform type)                   |
| sst_type_corr_unc | Sea surface temperature correction (platform type) uncertainty       |
| subcol1           | HadIOD data sub-collection code 1                                    |
| subcol2           | HadIOD data sub-collection code 2                                    |
| unique_id         | Unique ID generated from acquisition year, month and mohc_id         |

## 4 Configuration

The Fiduceo MMS is a highly configurable software system that allows customisation wherever applicable.

### 4.1 Configuration Files

This chapter lists the available parameters in various configuration files that are used by the software. All configuration files should be located in a single configuration directory.

#### 4.1.1 System Configuration

The system configuration file “system-config.xml” contains global settings that affect all components of the MMS. An example XML configuration is displayed below; each tag is explained later in the document.

```
<system-config>
  <geometry-library name="S2"/>
  <reader-cache-size>64</reader-cache-size>
  <temp-directory>/tmp</temp-directory>

  <archive>
    <root-path>
      /usr/local/data/fiduceo
    </root-path>

    <rule sensors="drifter-sst, ship-sst, gtmba-sst, ..."
      insitu/SENSOR/VERSION"
    </rule>
  </archive>
</system-config>
```

**geometry-library:** defines the geometry library to be used for geometric operations. Available values are

- “S2” – use the Google S2 spherical library – the default and recommended value
- “JTS” – use the Java Topology Suite library – experimental

**reader-cache-size:** defines the number of product-readers which are cached with open files. It depends on the size of the input sensor products how many readers can be cached. Default value is 8.

**temp-directory:** defines the system directory for temporary file storage. When omitted to set the software uses the standard directory as defined by the system property “java.io.tmpdir”. All temporary files created by the system will be deleted on process exit, if files cannot be cleaned an associated entry in the log-file states this.

**archive:** defines all settings related to the satellite data archive.

**root-path:** defines the root directory containing the input datasets used for matchup processing by default, the archive is organised as

```
<root>/<sensor-platform>/<version>/<year>/<month>/<day>
```

**rule:** this tag allows to define specific archiving rules that may differ from the default organisation. Any number of rules may be added to the configuration. A rule can apply to one or many sensors, defined by the “*sensors*” attribute of the rule tag. Multiple sensors are written as comma-separated list of sensor - keys. All sensor-keys defined in chapter 3.5 are valid entries for this tag.

A rule defines a general path into the archive. The elements of the path must be separated by a forward slash “/”. Path elements can be either selected from a list of pre-defined entities or defined as custom elements. The pre-defined entities will be expanded dynamically during runtime; the custom elements are treated as constant path elements. Pre-defined path elements are:

- **SENSOR** – will be expanded to the sensor key being processed
- **VERSION** – will be expanded to the data version being processed
- **YEAR** – will be expanded to the currently processed year
- **MONTH** - will be expanded to the currently processed month
- **DAY** - will be expanded to the currently processed day
- **DAY\_OF\_YEAR** - will be expanded to the currently processed day of year

## 4.1.2 Database Configuration

The database configuration file “database.properties” defines the connection properties for the MMS database. It is a java properties file containing unstructured key/value pairs.

The following settings are available:

**driverClassName:** defines the database connection driver class name. The following values are available:

- “mongodb”: use the MongoDB database driver class – the default and recommended value
- “org.postgresql.Driver”: use the PostGIS JDBC database driver
- “org.h2.driver”: use the H2 in memory database driver
- “com.mysql.jdbc.driver”: use the MySQL JDBC database driver – experimental, do not use

**url:** defines the database connection URL. The format depends on the driverClassName selected, please consult the documentation of the specific database vendor for details.

**username:** defines the database user name that is submitted during the database connection process.

**password:** defines the password that is submitted during the database connection process.

**timeout:** defines the timeout for database connections in seconds, defaults to 120 (i.e. 2 minutes).

## 4.1.3 MMD Writer Configuration

The MMD output format and content can be configured using this file. In addition, it allows fine-tuning of the writer performance and behaviour. The configuration file is an XML file named “mmd-writer-config.xml” and located in the standard configuration directory.



An example configuration is displayed below; each tag is explained later in the document.

```
<?xml version="1.0" encoding="UTF-8"?>
<mmd-writer-config>
  <overwrite>false</overwrite>
  <cache-size>2048</cache-size>
  <reader-cache-size>8</reader-cache-size>
  <netcdf-format>N4</netcdf-format>
  <global-attributes>
    ...
  </global-attributes>
  <variables-configuration>
    ...
  </variables-configuration>
</mmd-writer-config>
```

**overwrite:** this tag defines the MMD writer behaviour when encountering an already existing file with the same name in the target directory.

- false: software raises an exception and stops
- true: software deletes the existing file and writes the new one.

**cache-size:** defines the cache size in number of matchups that is used by the mmd-writer. Default value is 2048. Reduce this number when experiencing OutOfMemory errors on large subset window sizes.

**reader-cache-size:** defines the reader cache size in number of open file readers. The reader cache keeps frequently used input files open to increase the MMD writing performance. This setting defines the number of input files that are kept simultaneously open.

**netcdf-format:** defines the NetCDF file format version used for the MMD files. Available values are:

- "N3" - write MMDs in NetCDF version 3 format
- "N4" - write MMDs in NetCDF version 4 format – the default value

**variables-configuration:** allows to rename or exclude variables or attributes. A detailed description is given in the following chapter.

#### 4.1.3.1 Global Attributes Configuration

When writing an MMD file, global attributes are added to the file. (see 5.1) Some of the global attributes are configurable via the writer configuration.

Example:

```
<mmd-writer-config>
  <global-attributes>
    <attribute name="title" value="Multi-sensor match-up dataset for use case XXXXX" />
    <attribute name="institution" value="Company or institution name" />
    <attribute name="contact" value="example name (example@mail.address.xx)" />
    <attribute name="licence" value="Your licence text" />
  </global-attributes>
</mmd-writer-config>
```

##### 4.1.3.1.1 List of configurable attributes:

- **title** → the title for the MMD file

- `institution` → the institution or company name of the file creator
- `contact` → the contact name and/or email of the contact person
- `licence` → The licence information under which the data in the generated file may be used.

## 4.1.3.2 Variables Configuration

The variables configuration section of the MMD writer configuration allows fine-tuning the content of the final matchup data files. It is possible to

- rename a sensor
- define a separator per sensor namespace for name concatenation
- exclude variables
- rename variables
- rename attributes of variables

For a detailed description of the content and structure of an MMD file and the naming convention used, please refer to chapter 0.

### 4.1.3.2.1 Renaming a sensor

In the standard configuration the sensors reference are named as they appear in the descriptions in chapters 3.5 and 3.6. This behaviour can be changed using the `sensor-rename` tag. Multiple `sensor-rename` tags are allowed inside a variables configuration.

Example:

```
<mmd-writer-config>
  <variables-configuration>
    <sensor-rename source-name="amsub-n16" target-name="AMSU-B_NOAA16" />
  </variables-configuration>
</mmd-writer-config>
```

### 4.1.3.2.2 Define a separator per sensor namespace

The MMS stores input variables to the MMD using the pattern `<sensor-name><separator><variable-name>`, for example "ssmt2-f14\_tb-ch4". This configuration aspect allows to change the separator character, which is set to the underscore character `'_'` by default. Separators can be associated to one or many sensors, which have to be added as a comma-separated list.

Example:

```
<mmd-writer-config>
  <variables-configuration>
    <separator sensor-names="sen1, sen2, ..." separator = "." />
  </variables-configuration>
</mmd-writer-config>
```

## 4.1.3.2.3 Exclude variables

It is possible to exclude variables of the input data from being written to the MMD file. The exclude tag allows to exclude any number of variables from a given sensors variables list. The names appearing in the exclude tag must exactly match the variable names of the input products as listed in chapters 3.5 and 3.6.

Example:

```
<mmd-writer-config>
  <variables-configuration>
    <sensors names="hirs-n17, hirs-n16">
      <exclude source-name="not_needed" />
      <exclude source-name="useless" />
    </sensors>
  </variables-configuration>
</mmd-writer-config>
```

## 4.1.3.2.4 Rename variables

Using this tag, it is possible to rename variables, i.e. to define a different name for the variable in the MMD as it originally appeared in the input data. This tag only changes the variable name, the sensor and separator parts of the final composite name are not affected, these can be changed separately. The names of the source variables appearing in the rename tag must exactly match the variable names of the input product as listed in chapters 3.5 and 3.6.

Example:

```
<mmd-writer-config>
  <variables-configuration>
    <sensors names="hirs-n17, hirs-n16">
      <rename source-name="stupid" target-name="cool" />
      <rename source-name="boring" target-name="exciting" />
    </sensors>
  </variables-configuration>
</mmd-writer-config>
```

## 4.1.3.2.5 Rename attributes of variables

It is possible to adapt the names of attributes of any variable in the MMD. The names of the source variables and attribute names appearing in the rename-attribute tag must exactly match the variable and attribute names of the input product as listed in chapters 3.5 and 3.6.

```
<mmd-writer-config>
  <variables-configuration>
    <sensors names="hirs-n17, hirs-n16">
      <rename-attribute source-name="attN1" target-name="attN1_r" />
      <rename-attribute variable-names="var1" source-name="attN2" target-name="attN2_r" />
      <rename-attribute variable-names="var1, var2" source-name="attN3" target-name="attN3_r" />
    </sensors>
  </variables-configuration>
</mmd-writer-config>
```

## 4.1.3.2.6 Write scaled data

The overall configuration of the MMS is to store the data in the MMD as it is in the original satellite product. There may be circumstances where it is desirable to store the scaled geophysical data instead of raw integer counts with scale factor and offset attributes. The “writeScaled” tag allows to switch this behaviour on for single variables and specific sensors. Variables where scaled writing is enabled will always be of data type double.

**NOTE:** it is highly recommended when using the scaled writing feature to exclude the scale-factor and offset attributes of the original variable. Some tools detect these attributes and scale automatically – which may lead to unusable data as the scaling will be applied twice.

```
<mmd-writer-config>
  <variables-configuration>
    <sensors names="hirs-n17, hirs-n16">
      <writeScaled source-name="signed_int_variable" />
    </sensors>
  </variables-configuration>
</mmd-writer-config>
```

## 4.1.4 UseCase Configuration

This configuration file defines the parameter-set to be used for a matchup processing. It is an XML file that has to be located in the configuration directory used for processing.

An example configuration is displayed below; each tag is explained later in the document.

```
<?xml version="1.0" encoding="UTF-8"?>
<use-case-config name="mmd02">
  <sensors>
    <sensor>
      <name>avhrr-n17</name>
      <primary>false</primary>
    </sensor>
    <sensor>
      <name>avhrr-n18</name>
      <primary>true</primary>
    </sensor>
  </sensors>

  <dimensions>
    <dimension name="avhrr-n17">
      <nx>5</nx>
      <ny>5</ny>
    </dimension>
    <dimension name="avhrr-n18">
      <nx>5</nx>
      <ny>5</ny>
    </dimension>
  </dimensions>

  <location>
    <lon>-12.7</lon>
    <lat>33.24</lat>
  </location>

  <write-distance>true</write-distance>
  <random-sampling>
```

```

    <points-per-day>20000</points-per-day>
    <distribution>true</distribution >
  </random-sampling>
  <output-path>/tmp/fiduceo_test/usecase-02</output-path>

  <conditions>
    <time-delta>
      <time-delta-seconds>10800</time-delta-seconds>
    </time-delta>
    <spherical-distance>
      <max-pixel-distance-km>3.0</max-pixel-distance-km>
    </spherical-distance>
  </conditions>

  <screenings>
    <angular>
      <primaryVZAVariable name="satellite_zenith_angle" />
      <secondaryVZAVariable name="satellite_zenith_angle" />
      <maxAngleDelta>10.0</maxAngleDelta>
    </angular>
  </screenings>
</use-case-config>

```

Each usecase configuration file starts with an XML version and character encoding statement. The enclosing `<use-case-config name="mmd02">` tag defines the content of the configuration. Each usecase configuration has to be given a name that is set in the “name” attribute as shown above. This name is used during MMD file generation to create the result file names.

**sensors:** this tag encloses a list of sensors to be processed. Each sensor element in this list must contain a valid `<name>` tag that defines the sensor name. The sensor names must match one name of the list of supported sensors, see chapters 3.5 and 3.6. One (and only one) of the sensors must be tagged as being the primary (i.e. reference) sensor in this list of sensors. This is accomplished by adding a primary tag with the value “true”:

```
<primary>true</primary>
```

The primary tag with a value of “false” can be omitted, the software automatically assumes this when the tag is missing.

Optionally, sensor data can be restricted to a single data/processing version. This can be expressed by adding a version tag:

```
<data-version>v2.08</data-version>
```

When the version tag is omitted, the MMS uses all available data versions for this sensor for processing.

**dimensions:** enclosed by this tag is a list of dimension tags. These define the output window size for each matchup, i.e. the size of the data extract stored to the MMD with the matchup x/y location in the centre. It is required that for each sensor defined in the sensor list, an associated dimension is being defined. The association is realised by matching the names, stored as dimension attribute “name”.

The tags “nx” and “ny” define the extent of each dimension, they define the complete width and height of the extract. Following the requirement of a central matchup pixel, both values have to be odd numbers.

**location:** optional tag to define a matchup processing that extracts input sensor pixels that contain the location defined by the tags **lon** and **lat**. If set, this setting supersedes the standard matchup processing and allows overflight detection for a fixed ground location. All geodesic matches within the time-interval and sensor(s) configured are considered as valid matchups.

**write-distance:** specifies whether the MMD file shall contain an additional variable that stores the matchup centre distance in kilometres. Valid values are “true” and “false”, defaults to “false”.

**output-path:** defines the target directory for the processing. All MMD files generated will be stored in the directory denoted by this tag.

**conditions:** this tag encloses a list of condition plugin configurations. The values in each configuration are depending on the plugin and are explained in more detail in chapter 4.1.4.1.

**screenings:** this tag encloses a list of screening plugin configurations. The values in each configuration are depending on the plugin and are explained in more detail in chapter 4.1.4.2.

**random-sampling:** specifies to use a random sampling point matchup strategy. The random “Seed Point Matchup Strategy” is helpful to avoid that all the pixels of the entire observations are matchups, e.g. if the primary and secondary observation geometries are congruent, because they are on the same platform.

**points-per-day:** Defines the number of global generated pseudo random seed points (sobol generated points) per day. The points are nearly equidistant distributed on the globe and nearly equidistant distributed in the time range defined by the matchup tool command line arguments. (See 3.2 Matchup Tool)

**distribution:** defines the random distribution properties. The time and longitude axes are always equally distributed. The latitude axis can be scaled using the distribution tag; valid values are:

- FLAT: equally distributed – which increases the probability of polar matches because it generates an equal-angle sampling.
- COSINE\_LAT: the latitude distribution is weighted by  $\cos(\text{latitude})$ . This generates an equal area distribution by good approximation
- INV\_TRUNC\_COSINE\_LAT; the latitude distribution is weighted by  $\frac{1}{3} * \min(\frac{1}{\cos(\text{latitude})}, 3)$ . This weighting increases the probability of polar matches even more than FLAT.

The old syntax:

```
<random-points-per-day>20000</random-points-per-day>
```

is still supported by the software and generates a cosine-weighted distribution.

#### 4.1.4.1 Conditions

This chapter lists the configuration settings for all condition plugins available for the MatchupTool. A condition plugin serves for checking that a matchup conforms to the condition defined. A condition plugin operates solely on the raw matchup information, i.e.

- Primary and secondary pixel

- Geo-location longitude and latitude
- Pixel raster location x and y
- Pixel acquisition time in seconds since epoch
- Primary and secondary product raster width and height
- Primary and secondary extraction window sizes
- The processing time-range

When one or more of the subsequent plugin configurations are present in the configuration, the corresponding plugin is loaded and configured using the values supplied. During processing, the chain of plugins is applied to the matchups. The order of the condition configurations defines the processing order.

#### 4.1.4.1.1 Border Distance Condition

This condition ensures that the matchup location within the data file raster is within a defined distance from the raster borders. The condition can check primary and multiple secondary acquisition positions using different parameters, according to the configuration. If the pixel is outside the defined boundaries, the matchup is rejected.

Example with one secondary sensor:

```
<border-distance>
  <primary>
    <nx>22</nx>
    <ny>6</ny>
  </primary>

  <secondary>
    <nx>5</nx>
    <ny>8</ny>
  </secondary>
</border-distance>
```

“primary”: if tag is present, the primary (i.e. reference) sensor position is checked

“secondary”: if tag is present, the secondary sensor position is checked

“nx” defines the minimal distance of the matchup centre location x coordinate to the left or right data raster boundary.

“ny” defines the minimal distance of the matchup centre location y coordinate to the upper or lower data raster boundary.

Example with three secondary sensors:

```
<border-distance>
  <primary>
    <nx>22</nx>
    <ny>6</ny>
  </primary>

  <secondary names="sensor-A">
    <nx>5</nx>
    <ny>8</ny>
```

```

</secondary>

<secondary names="sensor-B, sensor-C">
  <nx>3</nx>
  <ny>3</ny>
</secondary>
</border-distance>

```

A “secondary” tag can be used twice or more times. Each of the “secondary” tags must have assigned a “names” attribute containing one or more secondary sensor names. Border distance calculations will be applied to all of these sensors.

It is not allowed to use a secondary sensor name twice.

It is not allowed to use more than one “secondary” tag without names.

It is not allowed to mix “secondary” tag without name and “secondary” tag with name.

#### 4.1.4.1.2 Spherical Distance Condition

This condition ensures that the primary and secondary matchup location are within a given spherical distance. If the matchup pixel centre locations (in lon/lat) are further apart than the threshold value, the matchup is rejected. Example:

```

<spherical-distance>
  <max-pixel-distance-km>6</max-pixel-distance-km>
</spherical-distance>

```

#### 4.1.4.1.3 Time Delta Condition

This condition verifies that the pixel acquisition time difference of the contributing primary and secondary (named or not named) products do not exceed the configured threshold. All pixels with an acquisition time difference above the threshold are rejected.

Example Case: primary and one secondary sensor

```

<time-delta>
  <time-delta-seconds>10800</time-delta-seconds>
</time-delta>

```

Example Case: primary and two or more secondary sensors

```

<time-delta>
  <time-delta-seconds names="name1, name2, ..."
    secondaryCheck="true"> <!-- default is false -->
    300
  </time-delta-seconds>
</time-delta>

```

“names” attribute contain comma separated secondary sensor names to which this condition applies  
 “secondaryCheck” attribute

- If “true” the check also applies between the named secondaries
- If “false” (default) the check applies NOT between secondaries



Example Case: extra time delta for each sensor combination

```
<time-delta>

  <!-- time delta between primary and name1 sensor -->
  <time-delta-seconds names="name1">
    300
  </time-delta-seconds>

  <!-- time delta between primary and name2 sensor -->
  <time-delta-seconds names="name2">
    250
  </time-delta-seconds>

  <!-- time delta between named secondary sensors -->
  <time-delta-seconds names="name3,name4,..."
    primaryCheck="false"      <!-- default is true -->
    secondaryCheck="true">   <!-- default is false -->
    400
  </time-delta-seconds>
  ...
</time-delta>
```

“primaryCheck” attribute

- If “true” (default) the check applies between primary and secondary
- If “false” NOT primary check will be applied

#### 4.1.4.1.4 Overlap Remove Condition

This condition plugin removes overlapping extraction windows. The plugin can operate either on the primary or on the secondary sensor extracts. It checks all matchup pixels for overlapping extraction windows and rejects all appropriate, so that the remaining list of matchups does not have overlapping areas. Example:

```
<overlap-remove>
  <reference>PRIMARY</reference>
</overlap-remove>
```

“reference”: denotes the sensor that shall be used for overlap removal. Valid choices are “PRIMARY” and “SECONDARY”.

If more than one secondary sensors defined in use case configuration, a “names” attribute must be applied to the “SECONDARY” reference tag to define to which secondary sensor the overlap remove should be applied.

```
<overlap-remove>
  <reference names="name-a, name-b, ...">
    SECONDARY
  </reference>
</overlap-remove>
```

#### 4.1.4.1.5 UniqueSamples Condition

This condition plugin ensures that duplicate matches are removed from the MMD. Duplicate matches can e.g. occur when a single satellite measurement is associated to two or more in-situ measurements because

the acquisition interval of the in-situ instrument is shorter than the matchup time criterion. The sample with the smallest geodetic distance to the reference is kept, all other matches are rejected.

Example:

```
<unique-samples>
  <reference-sensor>sensor_a</reference-sensor>
  <associated-sensor>sensor_b</associated-sensor>
</unique-samples>
```

The reference sensor is the sensor whose matchups shall be kept, the associated sensor is the one to be checked for multiple references. Both tags must contain a valid sensor key, as listed in section 3.5 and 3.6.

#### 4.1.4.1.6 PixelPosition Condition

A condition plug-in that allows to specify a raster position region constrained by xMin, xMax, yMin, yMax that contains valid matchups. All pixels outside this region are rejected. The condition can be applied to the primary sensor or to one, many or all secondary sensors .

Example:

```
<pixel-position>
  <minX>256</minX>
  <maxX>1056</maxX>
  <minY>8000</minY>
  <maxY>14</maxY>
  <reference>PRIMARY</reference>
</pixel-position>
```

“minX” denotes the minimal x position. Any pixel x position smaller than this is rejected. If parameter is omitted, a check for minimal x is skipped.

“maxX” denotes the maximal x position. Any pixel x position larger than this is rejected. If parameter is omitted, a check for maximal x is skipped.

“minY” denotes the minimal y position. Any pixel y position smaller than this is rejected. If parameter is omitted, a check for minimal y is skipped.

“maxY” denotes the maximal y position. Any pixel y position larger than this is rejected. If parameter is omitted, a check for maximal y is skipped.

“reference” denotes the reference sensor for the position check. Valid values are “PRIMARY” or “SECONDARY”.

If more than one secondary sensors defined in use case configuration, a “names” attribute must be added to the “SECONDARY” reference tag to define to which secondary sensor(s) pixel position shall be checked.

```
<pixel-position>
  <reference names="aatsr-en, atsr-e2">SECONDARY</reference>
</pixel-position>
```

## 4.1.4.2 Screenings

This chapter lists the configuration settings for all screening plugins available for the MatchupTool. A screening plugin serves for checking that a matchup conforms to the condition defined. A screening plugin operates on the raw matchup information (see chapter 4.1.4.1) and additionally has access to the product data readers.

When one or more of the subsequent plugin configurations are present in the configuration, the corresponding plugin is loaded and configured using the values supplied. During processing, the chain of plugins is applied to the matchups. The order of the screening configurations defines the processing order.

### 4.1.4.2.1 Angular Screening

This plugin performs a number of screenings on the satellite or viewing zenith or azimuth angles. The names of the variables can be configured, as well as the screenings that shall be applied and the associated thresholds. A screening is executed only when the associated tag is present in the configuration. Example:

```
<angular>
  <primary-vza-variable name="zenith_angle"/>
  <secondary-vza-variable name="satellite_zenith_angle"/>
  <max-primary-vza>10.0</max-primary-vza>
  <max-secondary-vza>15.0</max-secondary-vza>
  <max-angle-delta>17.0</max-angle-delta>
</angular>
```

“primary-vza-variable” denotes the variable name containing the angle to be screened for the primary sensor.

“secondary-vza-variable” denotes the variable name containing the angle to be screened for the secondary sensor.

“max-primary-vza” denotes the threshold for the primary angular variable in decimal degrees. All matchups with a value higher than the threshold value are rejected. Requires “primary-vza-variable” to be set. If tag is not present, the screening is not applied.

“max-secondary-vza” denotes the threshold for the secondary angular variable in decimal degrees. All matchups with a value higher than the threshold value are rejected. Requires “secondary-vza-variable” to be set. If tag is not present, the screening is not applied.

“max-angle-delta” denotes the maximal angular difference absolute value in decimal degrees. Matchups with an angular difference higher than the threshold are rejected. Requires “primary-vza-variable” and “secondary-vza-variable” to be set. If tag is not present, the screening is not applied.

### 4.1.4.2.2 Angular Cosine Proportion Screening

This plugin performs a screening on satellite viewing zenith angles as defined by the University of Hamburg (see RD 1), following the equation:

$$\left| \frac{\cos(primaryVZA)}{\cos(secondaryVZA)} - 1 \right| < \varepsilon_1$$

All matchups with a proportion value exceeding the threshold are rejected. Example configuration:

```
<angular-cosine-proportion>
  <primary-variable name="zenith_angle"/>
  <secondary-variable name="satellite_zenith_angle"/>
  <threshold>0.02</threshold>
</angular-cosine-proportion>
```

“primary-variable” denotes the variable name containing the angle to be screened for the primary sensor.

“secondary-variable” denotes the variable name containing the angle to be screened for the primary sensor.

“threshold” denotes the threshold value (i.e. the  $\varepsilon_1$  in the equation above).

#### 4.1.4.2.3 HIRS LZA Angular Screening

The LZA variable in the HIRS L1C data describes the local zenith angle for each scanline x-position. It does not distinguish left and right nadir positions. To implement a correct angular difference screening, the scanposition dataset has to be taken into account.

This plugin implements a correct angular difference screening for HIRS data following the algorithm:

```
sigmaprimary = scanposprimary < 28 ? -1.0 : 1.0

sigmasecondary = scanpossecondary < 28 ? -1.0 : 1.0

angDelta = abs(sigmaprimary * lzaprimary - sigmasecondary * lzasecondary)
```

All matchups with an angDelta above the “max-lza-delta” threshold are rejected. Values are in decimal degrees. Example configuration:

```
<hirs-lza-delta>
  <max-lza-delta>10.0</max-lza-delta>
</hirs-lza-delta>
```

#### 4.1.4.2.4 Buehler Cloud Screening

This plugin performs a cloud screening for microwave sensors based on the algorithm described in RD 2 and RD 3. It is applicable to AMSU-B, MHS and SSM/T-2. It can be applied either to primary, secondary or both sensor data. The screening is only executed when all three configuration values for the sensors are set. To switch the screening for a sensor off, remove the associated tags from the configuration. All matchups detected as cloudy are rejected.

Example configuration:

```
<buehler-cloud>
  <primary-narrow-channel name="btemp_ch18"/>
  <primary-wide-channel name="btemp_ch20"/>
  <primary-vza name="Satellite_zenith_angle"/>

  <secondary-narrow-channel name="btemp_ch3"/>
  <secondary-wide-channel name="btemp_ch4"/>
  <secondary-vza name="Satellite_zenith_angle"/>
</buehler-cloud>
```

“primary-narrow-channel” denotes the variable name containing the narrow bandwidth channel for the primary sensor.

“primary-wide-channel” denotes the variable name containing the wide bandwidth channel for the primary sensor.

“primary-vza” denotes the variable name containing the satellite zenith angle values for the primary sensor.

“secondary-narrow-channel” denotes the variable name containing the narrow bandwidth channel for the secondary sensor.

“secondary-wide-channel” denotes the variable name containing the wide bandwidth channel for the secondary sensor.

“secondary-vza” denotes the variable name containing the satellite zenith angle values for the secondary sensor.

#### 4.1.4.2.5 Pixel Value Screening

This screening plugin allows selecting matchups using a mathematical expression consisting of any combination of input variables. The plugin allows entering different expressions for primary and secondary sensor. Mathematical expressions can be arbitrarily complex but must evaluate to a Boolean value. The mathematical expressions are evaluated using the matchup location only. All matchups where either the primary or the secondary expression evaluate to false are rejected.

Mathematical expressions can be composed of variables and functions.

Variables available are all variables contained in the input satellite or in-situ data using the name as it appears in the file and as documented in section chapters 3.5 and 3.6, e.g. “btemps\_ch5” for AMSU-B brightness temperature in channel 5. In addition to this, the constants “PI” and “E” are available denoting pi and e. And of course any number typed into the expression is treated as numerical constant.

Mathematical operations and functions available are:

| Function | Description         |
|----------|---------------------|
| +        | Addition            |
| -        | Subtraction         |
| *        | Multiplication      |
| /        | Division            |
| ==       | Equality comparison |

|                 |  |
|-----------------|--|
| !=              | Inequality comparison  |
| >               | Greater than   |
| >=              | Greater than or equal  |
| <               | Less than  |
| <=              | Less than or equal   |
| abs             | Calculates absolute value of argument  |
| acos            | Arc cosine of argument   |
| ampl            | Calculates amplitude of arguments ( $a^2 + b^2$ )  |
| asin            | Arc sine of argument   |
| atan            | Arc tangent of argument  |
| atan2           | The theta component of the point (r, theta) in polar coordinates that corresponds to the point (x, y) in Cartesian coordinates.<br>( <a href="https://docs.oracle.com/javase/7/docs/api/java/lang/Math.html#atan2(double,%20double)">https://docs.oracle.com/javase/7/docs/api/java/lang/Math.html#atan2(double,%20double)</a> ) |
| avg             | Mean value of arguments  |
| bit_set         | Checks whether a bit is set or not, first argument is the value to check, second argument is the bit index (e.g. bit_set(cloud_flags_fward , 1))   |
| ceil            | Round upwards to next integer value  |
| cos             | Cosine of argument   |
| cosech          | Hyperbolic cosecant of argument  |
| cosh            | Hyperbolic cosine of argument  |
| deg             | Converts argument from radians to decimal degrees  |
| distance        | Calculates the distance (sqrt of sum of squares)   |
| exp             | Exponential of argument  |
| exp10           | Ten to the power of argument   |
| feq             | Fuzzy equality (1e-6 accuracy) or when used with three arguments, third argument supplies maximal delta.   |
| floor           | Round downwards to next integer value  |
| fneq            | Fuzzy inequality (1e-6 accuracy) or when used with three arguments, third argument supplies maximal delta.   |
| inf             | Check argument for infinity. Returns 1 if argument is positive or negative infinite, returns 0 otherwise   |
| log             | Natural logarithm of argument  |
| log10           | Logarithm to the base of 10 of argument  |
| max             | Maximum value of arguments   |
| min             | Minimum value of arguments   |
| nan             | Checks argument for “not a number”. Returns 1 if argument is not a number, 0 otherwise   |
| phase           | Calculates phase of arguments (atan2(b,a))   |
| pow             | General power function $a^b$   |
| rad             | Converts argument in decimal degrees to radians  |
| random_gaussian | Generates a random number from a gaussian distributed process  |
| random_uniform  | Generates a random number from a uniformly distributed process   |
| round           | Round to closes integer value  |
| sech            | Hyperbolic secant of argument  |
| sign            | Compute signum, returns +1 for positive, -1 for negative and 0 for zero argument   |
| sin             | Sine of argument   |
| sinh            | Hyperbolic sine of argument  |
| sq              | Square of argument   |

|      |                                |
|------|--------------------------------|
| sqrt | Square root of argument        |
| tan  | Tangent of argument            |
| tanh | Hyperbolic tangent of argument |

All matchups where the mathematical expression for either primary or secondary sensor evaluates to false are rejected. Example configuration:

```
<pixel-value>
  <primary-expression>btemp_ch4 >= 180.5</primary-expression>
  <secondary-expression>cloud_probability < 0.25</secondary-expression>
</pixel-value>
```

#### 4.1.4.2.6 Window Value Screening

This screening plugin allows selecting matchups using a mathematical expression consisting of any combination of input variables. The plugin allows entering different expressions for primary and secondary sensor. Mathematical expressions can be arbitrarily complex but must evaluate to a Boolean value. The mathematical expressions are evaluated for each pixel of a window defined by the matchup location and an interval defined by the use case configuration.

Additional to the mathematical expression two more properties must be defined. The percentage and the evaluate property. The evaluate property decide whether pixels with fill value should be ignored or all pixels of the window are used to calculate the percentage pixel count.

All matchups where either the primary or the secondary percentage evaluate to less pixels are valid are rejected.

Mathematical expressions can be composed of variables and functions.

Variables available are all variables contained in the input satellite or in-situ data using the name as it appears in the file and as documented in section chapters 3.5 and 3.6, e.g. “btemps\_ch5” for AMSU-B brightness temperature in channel 5. Satellite variables are always scaled to geophysical entities before evaluated, if the original data is stored as scaled integer data.

In addition to this, the constants “PI” and “E” are available denoting pi and e. And of course any number typed into the expression is treated as numerical constant.

Mathematical operations and functions available are the same as in 4.1.4.2.5.

Example case 1: Primary and only one secondary sensor defined in use case configuration

```
<window-value>
  <primary>
    <expression>btemp_ch4 >= 180.5</expression>
    <percentage>22.3</percentage>
    <evaluate>EntireWindow</evaluate> // second option is “IgnoreNoData”
  </primary>
  <secondary>
    <expression> cloud_probability < 0.25</expression>
    <percentage>50.0</percentage>
    <evaluate>IgnoreNoData</evaluate>
```

```
</secondary >
</window-value>
```

Example case 2: Screening for one primary and multiple secondaries

```
<window-value>
  <primary>
    <expression>btemp_ch4 >= 180.5</expression>
    <percentage>22.3</percentage>
    <evaluate>EntireWindow</evaluate> // second option is "IgnoreNoData"
  </primary>
  <secondary names="name-A">
    <expression> cloud_probability < 0.25</expression>
    <percentage>50.0</percentage>
    <evaluate>IgnoreNoData</evaluate>
  </secondary >
  <secondary names="name-B, name-C">
    <expression>CH_wavelength233 < 0.33</expression>
    <percentage>75.0</percentage>
  </secondary >
</window-value>
```

#### 4.1.5 Post Processing Configuration

The post processing configuration file stores the parameters and configuration used by the post-processing tool. It is an XML file that must be located in the general configuration files directory, see chapter 4.1. It contains the main tag *<post-processing-config>* and a list of *<post-processings>* which contain the configurations of the plugins. A list of implemented post processing plugins is described in 4.1.5.1.

Also, the configuration file contains information whether the input mmd files should be overwritten in place

```
<overwrite>
```

or new extended files should be written to the output directory

```
<create-new-files>
  <output-directory><!--the existing output directory path --></output-directory>
</create-new-files>
```

In rare cases, it can be necessary to adapt the name of the matchup dimension. This can be achieved with the tag:

```
<matchup-dimension-name>a_different_name</matchup-dimension-name>
```

If not set, the standard value *"matchup\_count"* is used.

Example Post Processing Configuration File:

```
<post-processing-config>
  <create-new-files>
    <output-directory><!--the existing output directory path --></output-directory>
  </create-new-files>
```



```
<post-processings>
... <!-- List of plugin configurations -->
</post-processings>
</post-processing-config>
```

Plugins can be chained and are processed in the order they appear in the configuration file.

## 4.1.5.1 Post Processing Plugins

Each post processing plugin has its own XML signature.

### 4.1.5.1.1 Spherical Distance Plugin

The spherical distance plugin is a post processing plugin, which can be used to add a spherical distance variable to a matchup dataset i.e. the distance of the matchup acquisitions for primary and additional sensor, calculated as geodesic distance in kilometers.

Requirements:

- The matchup dataset must contain latitude and longitude information for primary and secondary sensor.
- This geo information can be organized in 1 by 1, 3 by 3, 5 by 5 or each other odd manner.
- The matchup dataset must not contain a variable with the name, defined in `<var-name>` tag.

```
<spherical-distance>
  <target>
    <data-type>Float</data-type>
    <var-name>post_dist</var-name>
    <dim-name>matchup_count</dim-name>
  </target>

  <primary-lat-variable scaleAttrName="Scale">amsub-n16_Latitude</primary-lat-variable>
  <primary-lon-variable scaleAttrName="Scale">amsub-n16_Longitude</primary-lon-variable>
  <secondary-lat-variable>ssmt2-f14_lat</secondary-lat-variable>
  <secondary-lon-variable>ssmt2-f14_lon</secondary-lon-variable>
</spherical-distance>
```

If the geo information variable contains values which must be scaled to get the real lat/lon information, in the plugin XML the names of scaling (*scaleAttrName*) and offset (*offsetAttrName*) attributes have to be supplied. The plugin scales the variables accordingly before calculating the geodesic distance. If scaling or offset attributes are defined but not available, a runtime exception will be thrown.

The primary and secondary lat/lon value will always be extracted from the center pixel.

### 4.1.5.1.2 SST Insitu Timeseries Plugin

This plugin extracts a time series from in the situ data files and appends the data to the mmd file.

Requirements:

- An input mmd file must contain variables containing “\_insitu.” in its name. The part before “\_insitu.” is interpreted as the insitu sensor type.  
e.g. “gtmba-sst\_insitu.id” resolves to insitu sensor type “gtmba-sst”
- An input mmd file must contain a variable named “<insitu-sensor-type>\_file\_name” which contains the original insitu data file name per matchup
- An input mmd file must contain a dimension named “file\_name” which defines the field size of a file\_name field in the “<insitu-sensor-type>\_file\_name variable.
- An input mmd file must contain a dimension named “matchup\_count” which defines the number of matchups in this file.

Example sst time series post processing plugin xml part:

```
<sst-insitu-time-series>
  <version>v03.3</version>
  <time-range-in-seconds>129600</time-range-in-seconds>
  <time-series-size>220</time-series-size>
  <secondary-sensor-matchup-time-variable>
    amsre.acquisition_time
  </secondary-sensor-matchup-time-variable>
  <insitu-sensor>ship-sst</insitu-sensor>
  <file-name-variable>ship-sst.file_name</file-name-variable>
  <y-variable>ship-sst.y</y-variable>
</sst-insitu-time-series>
```

- version: defines the processing version of the insitu data files. Also encodes the data archive path.
- time-range-in-seconds: defines the complete time range extract range from the insitu acquisitions
- time-series-size: defines the size of the extract – should match the maximum number of acquisitions possible within the extraction time range
- secondary-sensor-matchup-time-variable: variable name for the reference times
- insitu-sensor: name of the insitu sensor (optional). This configuration parameter can be skipped if the MMD to process uses standard variable notation. If variable names or naming rules have been updated you can set the correct sensor name here.
- file-name-variable: name of the insitu file name variable in the input MMD (optional). This configuration parameter can be skipped if the MMD to process uses standard variable notation. If variable names or naming rules have been updated you can set the correct file name variable name here.
- y-variable: name of the insitu y-position variable in the input MMD (optional). This configuration parameter can be skipped if the MMD to process uses standard variable notation. If variable names or naming rules have been updated you can set the correct file y variable name here.

The plugin expects that the insitu file archive is organized without year/month/day paths. This means that all the insitu files of same sensor type and version should be in one directory.

Example archive snippet from system-config.xml

```
<system-config>
  . . .
  <archive>
    <root-path><!-- archive root path --></root-path>
    <rule sensors="animal-sst, gtmba-sst">insitu/SENSOR/VERSION</rule>
```

```
</archive>
. . .
</system-config>
```

Time series variables created by the plugin:

- insitu.dtime [int] (time delta between secondary matchup time and insitu time)
- insitu.id [long] (this a unique id generated by combining YEAR, MONTH and mohc\_id)
- insitu.lat [float]
- insitu.lon [float]
- insitu.mohc\_id [int]
- insitu.sea\_surface\_temperature [float]
- insitu.sst\_depth [float]
- insitu.sst\_qc\_flag [short]
- insitu.sst\_track\_flag [short]
- insitu.sst\_uncertainty [float]
- insitu.time [int]
- insitu.y [int]

#### 4.1.5.1.3 NWP plugin

This plugin adds numerical weather prediction (NWP) data to matchup datasets. The NWP data is extracted from ERA-Interim data (<http://www.ecmwf.int/en/research/climate-reanalysis/era-interim>). The plugin allows two different processes to be executed, a time series extraction for single pixel matchups (like insitu data) or an n x m pixel extract with profile data for atmospheric parameters for satellite-sensor extracts. The plugin relies on the publicly available CDO software (<https://code.zmaw.de/projects/cdo>) to perform the time-series aggregation and projection tasks.

The parametrization for the time-series and sensor-extracts is configured in specific sub-tags, see example below.

Configuration example:

```
<nwp>
  <cdo-home>/usr/local/bin/cdo</cdo-home>
  <nwp-aux-dir>/the/auxiliary/files</nwp-aux-dir>
  <delete-on-exit>true</delete-on-exit>

  <time-series-extraction>
    <analysis-steps>19</analysis-steps>
    <forecast-steps>33</forecast-steps>

    <time-variable-name>acquisition-time</time-variable-name>
    <longitude-variable-name>animal-sst_inistu.lon</longitude-variable-name>
    <latitude-variable-name>animal-sst_inistu.lat</latitude-variable-name>

    <analysis-center-time-name>matchup.nwp.an.t0</analysis-center-time-name>
    <forecast-center-time-name>matchup.nwp.fc.t0</forecast-center-time-name>

    <an-ci-name>an_sea-ice-fraction</an-ci-name>
    <an-sstk-name>an_sea-surface-temperature</an-sstk-name>
    <fc-sstk-name>fc_sea-surface-temperature</fc-sstk-name>
    <an-u10-name>an_east_wind</an-u10-name>
    <an-v10-name>an_north_wind</an-v10-name>
    <fc-u10-name>10m_east_wind_component</fc-u10-name>
```

```

<fc-v10-name>10m_north_wind_component</fc-v10-name>
<fc-msl-name>mean_surface_pressure</fc-msl-name>
<fc-t2-name>2m-temperature</fc-t2-name>
<fc-d2-name>2m_dew_point</fc-d2-name>
<fc-tp-name>total_precipitation</fc-tp-name>
<an-clwc-name>cloud_liquid_water_content</an-clwc-name>
<fc-clwc-content-name>cloud_liquid_water_content</fc-clwc-name>
<an-tcwg-name>an_total_column_water_vapour</an-tcwg-name>
<fc-tcwg-name>fc_total_column_water_vapour</fc-tcwg-name>
<fc-sshf-name>fc_surface_sensible_heat_flux</fc-sshf-name>
<fc-slhf-name>surface_latent_heat_flux</fc-slhf-name>
<fc-blh-name>boundary_layer_height</fc-blh-name>
<fc-ssrd-name>fc_downward_surface_solar_radiation</fc-ssrd-name>
<fc-strd-name>fc_downward_surface_thermal_radiation</fc-strd-name>
<fc-ssr-name>fc_surface_solar_radiation</fc-ssr-name>
<fc-str-name>fc_surface_thermal_radiation</fc-str-name>
<fc-ewss-name>fc_turbulent_stress_east_component</fc-ewss-name>
<fc-nsss-name>fc_turbulent_stress_north_component</fc-nsss-name>
<fc-e-name>fc_evaporation</fc-e-name>
</time-series-extraction>

<sensor-extraction>
  <time-variable-name>acquisition_time</time-variable-name>
  <longitude-variable-name>amsre.longitude</longitude-variable-name>
  <latitude-variable-name>amsre.latitude</latitude-variable-name>

  <x-dimension>5</x-dimension>
  <x-dimension-name>nwp_x</x-dimension-name>
  <y-dimension>5</y-dimension>
  <y-dimension-name>nwp_y</y-dimension-name>
  <z-dimension>60</z-dimension>
  <z-dimension-name>nwp_z</z-dimension-name>

  <an-ci-name>seaice_fraction</an-ci-name>
  <an-asn-name>snow_albedo</an-asn-name>
  <an-sstk-name>sea_surface_temperature</an-sstk-name>
  <an-tcwg-name>total_column_water_vapour</an-tcwg-name>
  <an-msl-name>mean_sea_level_pressure</an-msl-name>
  <an-tcc-name>total_cloud_cover</an-tcc-name>
  <an-u10-name>10m_east_wind_component</an-u10-name>
  <an-v10-name>north_wind</an-v10-name>
  <an-t2-name>2m_temperature</an-t2-name>
  <an-d2-name>2m_dew_point</an-d2-name>
  <an-al-name>albedo</an-al-name>
  <an-lnsp-name>log_surface_pressure</an-lnsp-name>
  <an-skt-name>skin_temperature</an-skt-name>
  <an-t-name>temperature_profile</an-t-name>
  <an-q-name>water_vapour_profile</an-q-name>
  <an-o3-name>ozone_profile</an-o3-name>
  <an-clwc-name>cloud_liquid_water</an-clwc-name>
  <an-ciwc-name>cloud_ice_water</an-ciwc-name>
  <an-tp-name>total_precipitation</an-tp-name>
</sensor-extraction>
</nwp>

```

Configuration parameters are explained in detail below:

- “cdo-home”: denotes the absolute path to the root directory of the binary CDO operators installation.
- “nwp-aux-dir”: defines the directory where the ERA-Interim auxiliary files are located.
- “delete-on-exit”: Set whether to delete all temporary files after processing or not. Default value is: true

Configuration parameter for the time-series extraction process:

- “analysis-steps”: Defines the number of time steps around the matchup time for NWP analysis data (6 hr time resolution). Default is: 17.
- “forecast-steps”: Defines the number of time steps around the matchup time for NWP forecast data (3 hr time resolution). Default is: 33.
- “time-variable-name”: Defines the name of the time variable to use as reference time. Time variables are expected to store data in seconds since 1970 format.
- “longitude-variable-name”: Defines the name of the longitude variable to use as reference. Data is expected in decimal degrees east.
- “latitude-variable-name”: Defines the name of the longitude variable to use as reference. Data is expected in decimal degrees north.
- “analysis-center-time-name”: Defines the name of the variable for analysis center times. Values are in seconds since 1970-01-01. Default: matchup.nwp.an.t0.
- “forecast-center-time-name”: Defines the name of the variable for forecast center times. Values are in seconds since 1970-01-01. Default: matchup.nwp.fc.t0.
- “an-ci-name”: Defines the name of the target variable for analysis sea-ice-fraction (CI). Default: matchup.nwp.an.sea\_ice\_fraction.
- “an-sstk-name”: Defines the name of the target variable for analysis sea surface temperature (SSTK). Default: matchup.nwp.an.sea\_surface\_temperature.
- “fc-sstk-name”: Defines the name of the target variable for forecast sea surface temperature (SSTK). Default: matchup.nwp.fc.sea\_surface\_temperature.
- “an-u10-name”: Defines the name of the target variable for analysis 10m east wind component (U10). Default: matchup.nwp.an.10m\_east\_wind\_component.
- “an-v10-name”: Defines the name of the target variable for analysis 10m north wind component (V10). Default: matchup.nwp.an.10m\_north\_wind\_component.
- “fc-u10-name”: Defines the name of the target variable for forecast 10m east wind component (U10). Default: matchup.nwp.fc.10m\_east\_wind\_component.
- “fc-v10-name”: Defines the name of the target variable for forecast 10m north wind component (V10). Default: matchup.nwp.fc.10m\_north\_wind\_component.
- “fc-msl-name”: Defines the name of the target variable for forecast mean sea level pressure (MSL). Default: matchup.nwp.fc.mean\_sea\_level\_pressure.
- “fc-t2-name”: Defines the name of the target variable for forecast 2m temperature (T2). Default: matchup.nwp.fc.2m\_temperature.
- “fc-d2-name”: Defines the name of the target variable for forecast 2m dew point (D2). Default: matchup.nwp.fc.2m\_dew\_point.
- “fc-tp-name”: Defines the name of the target variable for forecast total precipitation (TP). Default: matchup.nwp.fc.total\_precipitation.
- “an-clwc-name”: Defines the name of the target variable for analysis cloud liquid water content (CLWC). Default: matchup.nwp.an.cloud\_liquid\_water\_content
- “fc-clwc-name”: Defines the name of the target variable for forecast cloud liquid water content (CLWC). Default: matchup.nwp.fc.cloud\_liquid\_water\_content
- “an-tcww-name”: Defines the name of the target variable for analysis total column water vapour (TCWV). Default: matchup.nwp.an.total\_column\_water\_vapour
- “fc-tcww-name”: Defines the name of the target variable for forecast total column water vapour (TCWV). Default: matchup.nwp.fc.total\_column\_water\_vapour
- “fc-sshf-name”: Defines the name of the target variable for forecast surface sensible heat flux (SSHf). Default: matchup.nwp.fc.surface\_sensible\_heat\_flux
- “fc-slhf-name”: Defines the name of the target variable for forecast latent sensible heat flux (SLHF). Default: matchup.nwp.fc.surface\_latent\_heat\_flux.

- “fc-blh-name”: Defines the name of the target variable for forecast boundary layer height (BLH). Default: `matchup.nwp.fc.boundary_layer_height`.
- “fc-ssrd-name”: Defines the name of the target variable for forecast downward surface solar radiation (SSRD). Default: `matchup.nwp.fc.downward_surface_solar_radiation`.
- “fc-strd-name”: Defines the name of the target variable for forecast downward surface thermal radiation (STRD). Default: `matchup.nwp.fc.downward_surface_thermal_radiation`.
- “fc-ssr-name”: Defines the name of the target variable for forecast surface solar radiation (SSR). Default: `matchup.nwp.fc.surface_solar_radiation`.
- “fc-str-name”: Defines the name of the target variable for forecast surface thermal radiation (STR). Default: `matchup.nwp.fc.surface_thermal_radiation`.
- “fc-ewss-name”: Defines the name of the target variable for forecast turbulent stress east component (EWSS). Default: `matchup.nwp.fc.turbulent_stress_east_component`.
- “fc-nsss-name”: Defines the name of the target variable for forecast turbulent stress north component (NSSS). Default: `matchup.nwp.fc.turbulent_stress_north_component`.

Configuration parameter for the sensor extraction process:

- “time-variable-name”: Defines the name of the time variable to use as reference time. Time variables are expected to store data in seconds since 1970 format.
- “longitude-variable-name”: Defines the name of the longitude variable to use as reference. Data is expected in decimal degrees east.
- “latitude-variable-name”: Defines the name of the longitude variable to use as reference. Data is expected in decimal degrees north.
- “x-dimension”: defines the extract window extent in x direction.
- “x-dimension-name”: defines the name of the NetCDF dimension for the x direction extent of the NWP extract.
- “y-dimension”: defines the extract window extent in y direction.
- “y-dimension-name”: defines the name of the NetCDF dimension for the y direction extent of the NWP extract.
- “z-dimension”: defines the extract window extent in z direction (i.e. atmospheric layers).
- “z-dimension-name”: defines the name of the NetCDF dimension for the z direction extent of the NWP extract.
- “an-ci-name”: Defines the name of the target variable for analysis sea-ice-fraction (CI). Default: `amsre.nwp.seaice_fraction`.
- “an-asn-name”: Defines the name of the target variable for analysis snow albedo (ASN). Default: `amsre.nwp.snow_albedo`.
- “an-sstk-name”: Defines the name of the target variable for analysis sea surface temperature (SSTK). Default: `amsre.nwp.sea_surface_temperature`.
- “an-tcwg-name”: Defines the name of the target variable for analysis total column water vapour content (TCWV). Default: `amsre.nwp.total_column_water_vapour`.
- “an-msl-name”: Defines the name of the target variable for analysis mean sea level pressure (MSL). Default: `amsre.nwp.mean_sea_level_pressure`.
- “an-tcc-name”: Defines the name of the target variable for analysis total cloud coverage (TCC). Default: `amsre.nwp.total_cloud_cover`.
- “an-u10-name”: Defines the name of the target variable for analysis 10m east wind component (U10). Default: `amsre.nwp.10m_east_wind_component`.
- “an-v10-name”: Defines the name of the target variable for analysis 10m north wind component (V10). Default: `amsre.nwp.10m_north_wind_component`.

- “an-t2-name”: Defines the name of the target variable for analysis 2m temperature (T2). Default: `amsre.nwp.2m_temperature`.
- “an-d2-name”: Defines the name of the target variable for analysis 2m dew point (D2). Default: `amsre.nwp.2m_dew_point`.
- “an-al-name”: Defines the name of the target variable for analysis albedo (AL). Default: `amsre.nwp.albedo`.
- “an-lnspr-name”: Defines the name of the target variable for analysis logarithmic surface pressure (LNSP). Default: `amsre.nwp.log_surface_pressure`.
- “an-skt-name”: Defines the name of the target variable for analysis skin temperature (SKT). Default: `amsre.nwp.skin_temperature`.
- “an-t-name”: Defines the name of the target variable for analysis temperature profile (T). Default: `amsre.nwp.temperature_profile`.
- “an-q-name”: Defines the name of the target variable for analysis water vapour profile (Q). Default: `amsre.nwp.water_vapour_profile`.
- “an-o3-name”: Defines the name of the target variable for analysis ozone profile (O3). Default: `amsre.nwp.ozone_profile`.
- “an-clwc-name”: Defines the name of the target variable for analysis cloud liquid water (CLWC). Default: `amsre.nwp.cloud_liquid_water`.
- “an-ciwc-name”: Defines the name of the target variable for analysis cloud ice water (CIWC). Default: `amsre.nwp.cloud_ice_water`.
- “an-tp-name”: Defines the name of the target variable for analysis total precipitation (TP). Default: `amsre.nwp.total_precip`.

#### 4.1.5.1.4 ERA-5 NWP

A plugin which adds numerical weather prediction (NWP) data to matchup datasets. The NWP data is extracted e.g. from ERA-5 data (<https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5>) or downloaded from (<https://cds.climate.copernicus.eu/>).

This plugin requires the data to be stored on the local filesystem or mount point. The plugin is not implemented to download the needed era5 data from an online catalog system.

The plugin allows two different processes to be executed, a time series extraction for single pixel matchups (like insitu data) or an  $n \times m$  pixel extract with profile data for atmospheric parameters for satellite-sensor extracts. All ERA-5 data is interpolated to the referring satellite or insitu data raster, using the same geolocation as the satellite/insitu dataset. All times are rounded to the nearest ERA-5 time-stamp, i.e. to the next full hour UTC. A separate NWP-time variable tracks the NWP time instant for all matchups.

The parametrization for the time-series and sensor-extracts is configured in specific sub-tags.

`<matchup-fields>` and `<satellite-fields>` ... see configuration example below.

The existence of an extract-type sub-tag defines if the data shall be processed. A missing tag skips the type completely from processing. For example, if the `<matchup-fields>` tag is not present, no in-situ matchup extraction is performed and the associated variables are not created.

The configuration for the satellite extraction process (`<satellite-fields>`) consists of a general part and a variable definition part. The variable definition part can be realized in two different ways.

- a. A fixed historical way, which was not removed for backwards compatibility.  
In this case, a hard-coded list of variables is defined.  
See “Fixed variable definition part of configuration parameter for satellite extraction process:”
- b. Free variable definition using the additional `era5-post-processing-general-info.xml` file in the configuration directory.  
In this case the user is free to define the era5 variables to be extracted.  
See “Free variable definition part of configuration parameter for satellite extraction process:”  
See “`era5-post-processing-general-info.xml` example” for how to freely define variables.

**Configuration example: (--job-config: see: 3.3)**

```
<post-processing-config>
...
<era5>
  <nwp-aux-dir>/location/of/era5/data</nwp-aux-dir>
  <era5-collection>ERA-5T</era5-collection>
  <variable-translation>off</variable-translation>

  <satellite-fields>
    <x_dim name='nwp_x' length='5' />
    <y_dim name='nwp_y' length='5' />
    <z_dim name='nwp_z' length='86' />

    <era5_time_variable>era5-time</era5_time_variable>
    <longitude_variable>slstr-s3b_lon</longitude_variable>
    <latitude_variable>slstr-s3b_lat</latitude_variable>
    <time_variable>slstr-s3b_acquisition_time</time_variable>

    <an_ml_q>humidity</an_ml_q>
    <an_ml_t>temperature</an_ml_t>
    <an_ml_o3>ozone</an_ml_o3>
    <an_ml_lnspr>pressure</an_ml_lnspr>
    <an_sfc_t2m>2m_temperature</an_sfc_t2m>
    <an_sfc_u10>u_wind</an_sfc_u10>
    <an_sfc_v10>v_wind</an_sfc_v10>
    <an_sfc_siconc>sea_ice</an_sfc_siconc>
    <an_sfc_msl>mean_pressure</an_sfc_msl>
    <an_sfc_skt>skin_temp</an_sfc_skt>
    <an_sfc_sst>ocean_temp</an_sfc_sst>
    <an_sfc_tcc>cloud_cover</an_sfc_tcc>
    <an_sfc_tcwv>water_vapour</an_sfc_tcwv>
  </satellite-fields>

  <matchup-fields>
    <time_dim_name>matchup_time</time_dim_name>
    <time_steps_past>14</time_steps_past>
    <time_steps_future>12</time_steps_future>

    <era5_time_variable> era5-mu-time </era5_time_variable>
    <longitude_variable>insitu_lon</longitude_variable>
    <latitude_variable>insitu_lat</latitude_variable>
    <time_variable>insitu_time</time_variable>

    <an_sfc_u10>mu_u10_wind</an_sfc_u10>
    <an_sfc_v10>mu_v10_wind</an_sfc_v10>
    <an_sfc_siconc>mu_sea_ice </an_sfc_siconc>
    <an_sfc_sst>mu_ocean_temp</an_sfc_sst>
    <fc_sfc_metss>mu_stress_east</fc_sfc_metss>
    <fc_sfc_mntss>mu_stress_north</fc_sfc_mntss>
    <fc_sfc_mslhf>mu_heat_flux</fc_sfc_mslhf>
```



```
<fc_sfc_msnlwrwf>mu_long_wave</fc_sfc_msnlwrwf>
<fc_sfc_msnswrf>mu_short_wave</fc_sfc_msnswrf>
<fc_sfc_msshf>mu_sens_flux</fc_sfc_msshf>
</matchup-fields>
</era5>
</post-processing-config>
```

Configuration parameters are explained in detail below:

- `<nwp-aux-dir>` defines the root directory file system location of the ERA-5 dataset
- `<era5-collection>` defines the era-5 collection used, valid entries are “ERA5”, “ERA5T” and “ERA5I”. This value is stored in the MMD global meta-data as field “era5-collection”. If the configuration field is empty, the MMS tries to deduce the value from the “nwp-aux-dir” path. If this is not successful, an exception is raised.
- `<variable-translation>` (optional)  
In some cases the era5 variable name is not equal to the variable name denoted in NetCDF filename. Such a case for example is an historical case, when this era5 post-processing was implemented and used the first time in combination with era5 data organized that way.

For reasons of backwards compatibility, this translation has not been removed, but can be switched off.

The variable translation is a mapping between the era5 variable name as it is used in the era5-NetCDF file and the variable name as it is written in the filename of the era5-NetCDF file.

The era5 files must be found in the era5 archive directory. With old data records, this often does not work with the original variable name but with the translated name.

Translation:

| original var name | file var name |
|-------------------|---------------|
| t2m               | 2t            |
| u10               | 10u           |
| v10               | 10v           |
| siconc            | Ci            |

The value of this optional parameter can be one of [ "off", "false", "no", "dont", "not", "do not" ] to switch off the translation. With any other value or even if this parameter is not present, the translation is active.

**General part of configuration parameter for the satellite extraction process:**

- `x_dim`: Defines the x-axis raster extent of the NWP data extract. Attributes:
  - name: the name of the dimension
  - length: the extent of the dimension. If dimension length is larger than the satellite data extract the value is clipped to the satellite data size.
- `y_dim`: Defines the y-axis raster extent of the NWP data extract. Attributes:
  - name: the name of the dimension
  - length: the extent of the dimension. If dimension length is larger than the satellite data extract the value is clipped to the satellite data size.
- `z_dim`: Defines the z-axis raster extent of the NWP data extract.  
This parameter is optional and only needed if multi layer era5 data shall be extracted.  
Attributes:

- name: the name of the dimension
- length: the extent of the dimension. If the length of the dimension is greater than the entire z-range of the ERA-5 data, an error occurs. Else the number of layers from the bottom upwards will be used.
- era5\_time\_variable: defines the name of the variable which stores the ERA-5 satellite extraction time stamps in seconds since 1970.
- longitude\_variable: defines the satellite longitude variable name
- latitude\_variable: defines the satellite latitude variable name
- time\_variable: defines the satellite matchup time variable name

## Fixed variable definition part of configuration parameter for satellite extraction process:

- an\_ml\_q: defines the name of the target variable containing the specific humidity “q”. If not set the default value "nwp\_q" is used.
- an\_ml\_t: defines the name of the target variable containing the temperature “t”. If not set the default value "nwp\_t" is used.
- an\_ml\_o3: defines the name of the target variable containing the ozone mass mixing ratio “o3”. If not set the default value "nwp\_o3" is used.
- an\_ml\_lnsf: defines the name of the target variable containing the logarithm of surface pressure “lnsf”. If not set the default value "nwp\_lnsf" is used.
- an\_sfc\_t2m: defines the name of the target variable containing the 2 metre temperature “t2m”. If not set the default value "nwp\_t2m" is used.
- an\_sfc\_u10: defines the name of the target variable containing the 10 metre U wind component “u10”. If not set the default value "nwp\_u10" is used.
- an\_sfc\_v10: defines the name of the target variable containing the 10 metre V wind component “v10”. If not set the default value "nwp\_v10" is used.
- an\_sfc\_siconc: defines the name of the target variable containing the sea ice area fraction “siconc”. If not set the default value "nwp\_siconc" is used.
- an\_sfc\_msl: defines the name of the target variable containing the mean sea level pressure “msl”. If not set the default value "nwp\_msl" is used.
- an\_sfc\_skt: defines the name of the target variable containing the skin temperature “skt”. If not set the default value "nwp\_skt" is used.
- an\_sfc\_sst: defines the name of the target variable containing the sea surface temperature “sst”. If not set the default value "nwp\_sst" is used.
- an\_sfc\_tcc: defines the name of the target variable containing the total cloud cover “tcc”. If not set the default value "nwp\_tcc" is used.
- an\_sfc\_tcwv: defines the name of the target variable containing the total column water vapour “tcwv”. If not set the default value "nwp\_tcwv" is used.

## Free variable definition part of configuration parameter for satellite extraction process:

```
<post-processing-config>
...

<era5>
  <nwp-aux-dir>/location/of/era5/data</nwp-aux-dir>
  <era5-collection>ERA-5T</era5-collection>
```

```

<variable-translation>off</variable-translation>

<satellite-fields>
...
  The tags <x_dim>, <y_dim>, <z_dim>, <era5_time_variable>, <longitude_variable>,
  <latitude_variable> and <time_variable> are the same as described in
  "General part of configuration parameter for the satellite extraction process:"
...

  <c-name_e-name>variable name in target mmd file</c-name_e-name>
  <c-name_e-name>variable name in target mmd file</c-name_e-name>
  <c-name_e-name>variable name in target mmd file</c-name_e-name>
  ...
</satellite-fields>

<matchup-fields>
... these variables are not freely definable ...
... therefore the same as in the example above ...
</matchup-fields>
</era5>
</post-processing-config>

```

- **<c-name\_e-name>**  
Tagnames for freely defined variables are a combination of collection name ("c-name") and the era5 variable name ("e-name").  
See "**General info xml example:**"

## Configuration parameter for the matchup time-series extraction process:

- time-dim-name: defines the name of the time-series dimension
- time\_steps\_past: defines the number of time steps (i.e. one hour steps) that the time-series is expanding into the past from starting the matchup time
- time\_steps\_future: defines the number of time steps (i.e. one hour steps) that the time-series is expanding into the future starting from the matchup time
- era5\_time\_variable: defines the name of the variable which stores the ERA-5 insitu extraction time stamps in seconds since 1970.
- longitude\_variable: defines the insitu longitude variable name
- latitude\_variable: defines the insitu latitude variable name
- time\_variable: defines the insitu matchup time variable name
- an\_sfc\_u10: defines the name of the target variable containing the 10 metre U wind component "u10". If not set the default value "nwp\_mu\_u10" is used.
- an\_sfc\_v10: defines the name of the target variable containing the 10 metre V wind component "v10". If not set the default value "nwp\_mu\_v10" is used.
- an\_sfc\_siconc: defines the name of the target variable containing the sea ice area fraction "siconc". If not set the default value "nwp\_mu\_siconc" is used.
- an\_sfc\_sst: defines the name of the target variable containing the sea surface temperature "sst". If not set the default value "nwp\_mu\_sst" is used.
- fc\_sfc\_metss: defines the name of the target variable containing the mean eastward turbulent surface stress "metss". If not set the default value "nwp\_mu\_metss" is used.

- `fc_sfc_mntss`: defines the name of the target variable containing the mean northward turbulent surface stress "mntss". If not set the default value "nwp\_mu\_mntss" is used.
- `fc_sfc_mslhf`: defines the name of the target variable containing the mean surface latent heat flux "mslhf". If not set the default value "nwp\_mu\_mslhf" is used.
- `fc_sfc_msnlwr`: defines the name of the target variable containing the mean surface net long-wave radiation flux "msnlwr". If not set the default value "nwp\_mu\_msnlwr" is used.
- `fc_sfc_msnsrwr`: defines the name of the target variable containing the mean surface net short-wave radiation flux "msnsrwr". If not set the default value "nwp\_mu\_msnsrwr" is used.
- `fc_sfc_msshf`: defines the name of the target variable containing the mean surface sensible heat flux "msshf". If not set the default value "nwp\_mu\_msshf" is used.

To simplify adaptation of a given processing naming configuration to multiple sensors, for both satellite extraction and matchup timeseries configuration, an expression replacement mechanism is available. This allows to define target variable names with a varying sensor/insitu source element. When a tag

```
<sensor-ref>avhrr-n11</sensor-ref>
```

or

```
<insitu-ref>sirds-drifter</insitu-ref>
```

Is set, all variables names containing the expression

```
{sensor-ref}
```

Or

```
{insitu-ref}
```

Will be expanded to contain the reference value. Example (for the matchup fields configuration, a similar approach is valid for the satellite fields configuration):

The configuration

```
<matchup-fields>
  <insitu-ref>sirds-drifter</insitu-ref>

  <an_sfc_u10>{insitu-ref}_u10_wind</an_sfc_u10>
  <an_sfc_v10>{insitu-ref}_v10_wind</an_sfc_v10>
</matchup-fields>
```

Will be expanded during loading to

```
<matchup-fields>
  <insitu-ref>sirds-drifter</insitu-ref>

  <an_sfc_u10>sirds-drifter_u10_wind</an_sfc_u10>
  <an_sfc_v10>sirds-drifter_v10_wind</an_sfc_v10>
</matchup-fields>
```

## General info xml example:

(era5-post-processing-general-info.xml in the config directory)

```
<era5>
  <satellite-fields>
    <collection name="an_pl">
      <is3d>true</is3d>
      <var name="t">
        <att name="units">K</att>
        <att name="long_name">Temperature</att>
        <att name="standard_name">air_temperature</att>
      </var>
      ...
    </collection>
    <collection name="an_sfc">
      <var name="tclw">
        <att name="units">kg m**-2</att>
        <att name="long_name">Total column cloud liquid water</att>
        <att name="_FillValue">2.999e-45</att>
      </var>
      ...
    </collection>
  </satellite-fields>
</era5>
```

- Parsing of era5 general information xml is currently implemented just to freely define variables for `<satellite-fields>`.
- The value of `<collection>` is the collection name in the era5 archive.  
For example:
  - `an_pl` for "ERA5 hourly data on pressure levels from 1940 to present"
  - `an_sfc` for "ERA5 hourly data on single levels from 1940 to present"
- `<is3d> true` means the variables has a third dimension (`z_dim`).  
See "General part of configuration parameter for the satellite extraction process".
- `<var>` is the start tag for a single variable definition.
  - The `name` attribute of the `<var>` tag is mandatory, and its value must exactly be the era5 variable short name from within era5 source .nc files.
  - To define the mmd target variable name, the job configuration file must be used.  
There, the corresponding tag name is a combination of the collection name and the era5 variable name, separated by the character "\_".  
For example, if the collection name is "an\_pl" and the era5 variable name is "t", the tag name that must be used to define the mmd target variable name is: `<an_pl_t>`  
See:  
"Configuration example"  
or  
"Free variable definition part of configuration parameter for satellite extraction process"
- `<att>` defines the NetCDF attributes of a variable.
  - The name attribute of the `<att>` tag is mandatory, and must be one of the allowed attribute names:
  - Allowed names are:
    - "units"
    - "long\_name"
    - "standard\_name"
    - "\_FillValue"

## 4.1.5.1.5 Cloud Flagging for HIRS

This plugin computes and adds cloud flag data to a matchup dataset containing HIRS data.

Currently the software is not able to differentiate the cases “water” and “ice covered water”.  
So “ice covered water” now is calculated like “water”.

Example plugin xml part:

```
<hirs-l1-cloudy-flags>
  <hirs-sensor-name>hirs-n18</hirs-sensor-name>
  <hirs-var-name-source-file-name>hirs-n18_file_name</hirs-var-name-source-file-name>
  <hirs-var-name-source-x>hirs-n18_x</hirs-var-name-source-x>
  <hirs-var-name-source-y>hirs-n18_y</hirs-var-name-source-y>
  <hirs-var-name-processing-version>hirs-n18_processing_version</hirs-var-name-processing-
version>
  <hirs-var-name-source-11_1-um>bt_ch08</hirs-var-name-source-11_1-um>
  <hirs-var-name-cloud-flags>hirs-n18_cloudy_flags</hirs-var-name-cloud-flags>
  <hirs-var-name-latitude>hirs-n18_lat</hirs-var-name-latitude>
  <hirs-var-name-longitude>hirs-n18_lon</hirs-var-name-longitude>
  <hirs-var-name-11_1-um>hirs-n18_bt_ch08</hirs-var-name-11_1-um>
  <hirs-var-name-6_5-um>hirs-n18_bt_ch12</hirs-var-name-6_5-um>
  <distance-product-file-path>/path/to/the/distance-NetCDF-file.nc</distance-product-file-
path>
</hirs-l1-cloudy-flags>
```

The plugin differentiates three matchup scenes:

- “water”
- “ice covered water”
- “land”

In the case of a “water” scene, it is needed to reopen the source orbit and extract a 45 x 45 pixels area around the center position of the current matchup.

Therefor this list of parameters is needed:

- <hirs-sensor-name>  
The sensor name, which was used to ingest the input product to the database.
- <hirs-var-name-source-file-name>  
The name of the MMD variable, which contains the source filename of the input file
- <hirs-var-name-source-x>  
The name of the MMD variable, which contains the source center pixel **x** of the matchup
- <hirs-var-name-source-y>  
The name of the MMD variable, which contains the source center pixel **y** of the matchup
- <hirs-var-name-processing-version>  
The processing version, which was used to ingest the input product to the database.
- <hirs-var-name-source-11\_1-um>  
The name of the 11,1µm brightness temperature variable of the source file

In the cases “ice covered water” or “land” the plugin can compute the flags without extraction of data from the source product.

The following list of parameters are effective for all cases.

- `<hirs-var-name-cloud-flags>`  
The name of the cloud flags variable, which will be attached to the MMD file.
- `<hirs-var-name-11_1-um>`  
The name of the variable containing the brightness temperature values of 11,1 $\mu$ m.
- `<hirs-var-name-6_5-um>`  
The name of the variable containing the brightness temperature values of 6,5 $\mu$ m.

Since HIRS input data currently does not contain quality flags, the only way to detect “land” or “water” scene is to fetch a distance to land value from a verified map file.

To detect “land” case currently the distance file: Globolakes-static\_distance\_to\_land\_Map-300m-P5Y-2005-ESACCI\_WB-fv1.0\_RES120.nc is used.

- Input: lat and lon position of the matchup center pixel
- Output: distance to land value (unit km)
- Evaluation: “land” = distance to land value is less than 0.3 km

Therefor the following list of parameters is needed.

- `<hirs-var-name-latitude>`  
The name of the variable containing the latitude values.
- `<hirs-var-name-longitude>`  
The name of the variable containing the longitude values.
- `<distance-product-file-path>`  
The path to the distance to land map file.

#### 4.1.5.1.6 ElevationToSolzen

This plugin converts viewing geometry angles stored as elevation angles (i.e. angles defined wrt. the normal plane) to zenith angles (i.e. angles defined wrt. the nadir line). It optionally allows to remove the original elevation angle variables.

Example configuration:

```
<elevation-to-solzen-angle>
  <convert source-name = "elevation_angle_1"
    target-name = "zenith_angle_1"
    remove-source = "false"/>
  <convert source-name = "elevation_angle_2"
    target-name = "zenith_angle_2"
    remove-source = "true"/>
</elevation-to-solzen-angle>
```

The configuration consists of a list of “convert” elements that describe a single angle conversion process. Any number of “convert” elements can be added to the configuration. Each of the element has three attributes:

- “source-name”: defines the source elevation variable name. Must appear exactly as stored in the MMD.
- “target-name”: defines the target zenith angle variable name.
- “remove-source”: Flag to keep/remove the source variable. If set to “true”, the source variable is removed from the MMD, if set to “false”, the variable is kept. Default value when not set is “true”.

## 4.1.5.1.7 AddAmsrAngles

Post processing plugin that adds solar zenith and solar azimuth angle variables to AMSR-E and AMSR -2 data that follow the (A)ATSR angles convention. These are calculated following the equations:

$$\text{solarZenithAngle} = \text{SunElevation} + \text{EarthIncidence}$$

$$\text{solarAzimuthAngle} = (\text{EarthAzimuth} - \text{SunAzimuth} + 180.0) \% 360.0$$

Example configuration:

```
<add-amsr-solar-angles>
  <sun-elevation-variable name = "Sun_Elevation" />
  <sun-azimuth-variable name = "Sun_Azimuth" />
  <earth-incidence-variable name = "Earth_Incidence" />
  <earth-azimuth-variable name = "Earth_Azimuth" />
  <sza-target-variable name = "amsre.solar_zenith_angle" />
  <saa-target-variable name = "amsre.solar_azimuth_angle" />
</add-amsr-solar-angles>
```

The configuration parameters are:

- sun-elevation-variable: name of the sun elevation input variable
- sun-azimuth-variable: name of the sun azimuth input variable.
- earth-incidence-variable: name of the earth incidence input variable
- earth-azimuth-variable: name of the earth azimuth input variable
- sza-target-variable: name of the target variable containing the solar zenith angle
- saa-target-variable: name of the target variable containing the solar azimuth angle

## 4.1.5.1.8 AddAmsr2ScanQualityData

This post processing plugin adds the AMSR2 Scan\_Data\_Quality variable to the MMD. It copies the matching original 512 bytes data array to the MMD data.

Example configuration:

```
<add-amsr2-scan-data-quality>
  <filename-variable name = "amsr2-gcw1_file_name" />
  <processing-version-variable name = "amsr2-gcw1_processing_version" />
  <y-variable name = "amsr2-gcw1_y" />
  <target-variable name = "amsr2-gcw1_Scan_Data_Quality" />
</add-amsr2-scan-data-quality>
```



The configuration parameter are:

- filename-variable: name of the file name input variable
- processing-version-variable: name of the processing version input variable.
- y-variable: name of the original scanline input variable
- target-variable: name of target variable

#### 4.1.5.1.9 AddIasiSpectrum

This plugin extends MMDs that have been generated using the IASI reader (see chapter 3.5.12) to contain the full IASI hyper-spectral data. This step is implemented as a post-processing because the target variable is a 4-dimensional dataset that cannot per-se be handled by the MMS core engine. The variable generated by this plugins has the dimensions matchup/y/x/spectrum.

Example configuration:

```
<add-iasi-spectrum>
  <target-variable name = "GS1cSpect" />
  <reference-variable name = "OnboardUTC" />
  <x-variable name = "iasi-ma_x" />
  <y-variable name = "iasi-ma_y" />
  <file-name-variable name = "iasi-ma_file_name" />
  <processing-version-variable name = "iasi-ma_processing_version" />
</add-iasi-spectrum>
```

The configuration parameter are:

- target-variable: name of the target variable
- reference-variable: name of reference input variable. This is used to detect the target dimensions.
- x-variable: name of the x-position input variable containing the matchup raster x position
- y-variable: name of the x-position input variable containing the matchup raster y position
- file-name-variable: name of the input variable that contains the filename where the matchup was taken from
- processing-version-variable: name of the input variable containing the file processing version

#### 4.1.5.1.10 AddDistanceToLand

A post-processing plugin that adds a variable containing the distance to the closest landmass/coastline. The distance is calculated based on an auxiliary file generated in the GLOBOLAKES project with a spatial resolution of 0.0083 degrees. Land pixels contain a distance of 0.0 km.

Example configuration:

```
<add-distance-to-land>
  <aux-file-path>/data/fiduceo/aux/globolakes.nc</aux-file-path>
  <target-variable name = "distance-to-land" />
  <lon-variable name = "xyz_longitude" />
  <lat-variable name = " xyz_latitude " />
</add-distance-to-land>
```

The configuration parameter are:

- aux-file-path: absolute path to the GLOBOLAKES distance auxiliary file
- target-variable: name of the variable written. The datatype is float and the dimension of this variable is the same as the dimension of the longitude variable used as input.
- lon-variable: input variable name of the variable containing the geolocation longitudes
- lat-variable: input variable name of the variable containing the geolocation latitudes

#### 4.1.5.1.11 CALIOP Feature Classification Flags Midpoints Extract

This plugin extracts horizontal midpoints from each vertical layer of the source CALIOP file from the variable “Feature\_Classification\_Flags” and adds the data to the mmd file to an user defined target variable.

Example configuration:

```
<post-processings>
  <caliop-level2-vfm-flags>
    <mmd-source-file-variable-name>
      caliop_vfm.file_name
    </mmd-source-file-variable-name>
    <mmd-processing-version-variable-name>
      caliop_vfm.processing_version
    </mmd-processing-version-variable-name>
    <mmd-y-variable-name>
      caliop_vfm.y
    </mmd-y-variable-name>
    <target-fcf-variable-name>
      caliop_vfm.Center_Feature_Classification_Flags
    </target-fcf-variable-name>
  </caliop-level2-vfm-flags>
</post-processings>
```

The configuration parameter are:

- <mmd-source-file-variable-name>  
The name of the MMD variable, which contains the source filename of the input file
- <mmd-processing-version-variable-name>  
The processing version, which was used to ingest the input product to the database.
- <mmd-y-variable-name>  
The name of the MMD variable, which contains the source center pixel **y** of the matchup.  
A center x variable is not needed because CALIOP products have a width of 1
- <target-fcf-variable-name>  
The name of the new variable which will be added.

#### 4.1.5.1.12 CALIOP add L2 CLay variables

This plugin adds “caliop\_clay-cal” (clay = cloud layer) product variables and data to an mmd file which already contains “caliop\_vfm-cal” data. (vfm = vertical feature mask)

Example configuration:

```
<post-processings>
  <caliop-sst-wp100-clay>
    <mmd-source-file-variable-name>
      caliop_vfm.file_name
    </mmd-source-file-variable-name>
```

```

        <processing-version>
            4.10
        </processing-version>
        <mmd-y-variable-name>
            caliop_vfm.y
        </mmd-y-variable-name>
        <target-variable-prefix>
            caliop_clay.
        </target-variable-prefix>
    </caliop-sst-wp100-clay>
</post-processings>

```

The configuration parameter are:

- **<caliop-sst-wp100-clay>**  
The main tag of this post processing plugin for caliop cloud layer product data
- **<mmd-source-file-variable-name>**  
The name of the MMD variable, which contains the VFM source filename. The VFM source file name is needed to create the corresponding caliop\_clay-cal filename.
- **<processing-version>**  
The processing version of caliop\_clay-cal products, which was used to ingest the clay products to the database.
- **<mmd-y-variable-name>**  
The name of the MMD variable, which contains the VFM source center pixel **y** of the matchup. A center x variable is not needed because CALIOP products have a width of 1
- **<target-variable-prefix>**  
To insert the caliop cloud layer product variables to an mmd file a variable prefix is needed. e.g. "caliop-cal."

#### 4.1.5.1.13 AIRS add channel variables

This plugin adds channel data from AIRS L1B source products

Example configuration:

```

<post-processings>
    <add-airs-channel-data>
        <mmd-source-file-variable-name>
            airs-aq_file_name
        </mmd-source-file-variable-name>
        <mmd-processing-version-variable-name>
            airs-aq_processing_version
        </mmd-processing-version-variable-name>
        <mmd-x-variable-name>
            airs-aq_x
        </mmd-x-variable-name>
        <mmd-y-variable-name>
            airs-aq_y
        </mmd-y-variable-name>
        <mmd-variable-name-cut-out-reference>
            airs-aq_cutOutRef
        </mmd-variable-name-cut-out-reference>
        <target-variable-name-radiances>
            airs-aq_radiances
        </target-variable-name-radiances>
        <target_variable_name_CalFlag>
            airs-aq_CalFlag
        </target_variable_name_CalFlag>
        <target_variable_name_SpaceViewDelta>

```

```

        airs-aq_spaceViewDelta
      </target_variable_name_SpaceViewDelta>
    </add-airs-channel-data>
  </post-processings>

```

Configuration parameters are:

- `< add-airs-channel-data >`  
The main tag of this post processing plugin for AIRS channel data
- `<mmd-source-file-variable-name>`  
The name of the MMD variable, which contains the AIRS product source filename. The source file name is needed to fetch channel data from the sam file as other data per matchup.
- `<mmd-processing-version-variable-name>`  
The processing version of AIRS products, which was used to ingest the clay products to the database.
- `<mmd-x-variable-name>`  
The name of the MMD variable, which contains the AIRS source center pixel **x** of the matchup.
- `<mmd-y-variable-name>`  
The name of the MMD variable, which contains the AIRS source center pixel **y** of the matchup.
- `<mmd-variable-name-cut-out-reference>`  
Name of reference input variable. This is used to detect the target dimensions.
- `<target-variable-name-radiances>`  
Target variable name for radiances channel data.  
e.g. "airs-aq\_radiances"
- `<target_variable_name_CalFlag>`  
Target variable name for CalFlag channel data.  
e.g. "airs-aq\_CalFlag"
- `<target_variable_name_SpaceViewDelta>`  
Target variable name for SpaceViewDelta channel data.  
e.g. "airs-aq\_SpaceViewDelta"

#### 4.1.5.1.14 AddGruanSource

Post processing that adds the GRUAN reference file path to the MMD.

Example configuration:

```

<add-gruan-source>
  <target-variable name = "gruan-source-file" />
  <y-variable name = "gruan-uleic_y" />
  <file-name-variable name = "gruan-uleic_file_name" />
  <processing-version-variable name = "gruan-uleic_processing_version" />
</add-gruan-source>

```

Configuration parameters are:

- `<target-variable>`: the name of the variable in the target containing the file references
- `<y-variable>`: The name of the variable containing the GRUAN **y** matchup location
- `<file-name-variable>`: the name of the variable containing the Gruan reference file in-situ file name
- `<processing-version-variable>`: the name of the variable containing the input file version.

## 4.1.5.1.15 AddAvhrrCorrCoeffs

Post processing that adds the AVHRR FIDUCEO FCDR correlation variables to the MMD. This processing adds a variable that contains one set of correlation coefficients for each input file. The data dimension is therefore different from the number of matchups. Instead, an additional dimension "input\_files" is created that contains for each dimension the associated input file name.

Example configuration:

```
<add-avhrr-corr-coeffs>
  <file-name-variable name = "input-file-name-variable" />
  <processing-version-variable name = "input-processing-version" />
  <target-x-elem-variable name = "cross_element_correlation_coefficients" />
  <target-x-line-variable name = "cross_line_correlation_coefficients" />
</add-avhrr-corr-coeffs>
```

Configuration parameters are:

- <file-name-variable>: the name of the variable containing the AVHRR FCDR input file name.
- <processing-version-variable>: the name of the variable containing the input file version.
- <target-x-elem-variable>: the name of the target variable for the cross element correlation coefficients variable
- <target-x-line-variable>: the name of the target variable for the cross line correlation coefficients variable

## 5 MMD file format

The result data of a matchup-processing or post processing is stored in an MMD file. There will be one MMD file generated for each processing time slot (e.g. daily or one per week).

The MMD file is a self-descriptive NetCDF file that contains all variables of the input data as listed in subsections of 3.5 and 3.6 (except for those that have explicitly been excluded by mechanisms described in 4.1.3).

For each variable, the MMD file contains a three dimensional dataset where the x and y dimensions are the extract-window dimensions around the matchup and the z-dimension is the index of the matchup detected in the time slot processed. Thus each unique (x/y/z) in the MMD belongs to the same measurement and can therefore easily be processed by other analysis software.

### 5.1 Global Attributes

This section lists all global attributes of the MMD that are added by the MMS.

#### 5.1.1 title

This attribute contains the title of the mmd file.

See “Global Attributes Configuration” (4.1.3.1) how to configure the title attribute.

#### 5.1.2 institution

This attribute contains information about the institute/creator of the mmd file.

See “Global Attributes Configuration” (4.1.3.1) how to configure the institution attribute.

#### 5.1.3 contact

This attribute contains the contact information of the mmd file.

See “Global Attributes Configuration” (4.1.3.1) how to configure contact information attribute.

#### 5.1.4 licence

This attribute contains the licence of the mmd file.

See “Global Attributes Configuration” (4.1.3.1) how to configure the licence information attribute.

#### 5.1.5 creation\_date

This attribute contains the creation date of the MMD file in the following format:

`yyyy-MM-dd HH:mm:ss`

#### 5.1.6 software\_version

This attribute contains the software version used at the time the MMD file was created.

#### 5.1.7 comment

An immutable global attribute which is the introduction to the following global attribute use-case-configuration (see 5.1.8).

It contains the predefined standard text: „This MMD file is created based on the use case configuration documented in the attribute 'use-case-configuration'.“

## 5.1.8 **use-case-configuration**

This attribute contains the full text of the use case configuration file. (see 4.1.4)

## 5.1.9 **sensor-names**

This attribute contains a comma separated list of sensor names that have been used to generate the MMD. The first name in the list is the name of the primary (reference) sensor.

## 5.2 **Extra MMD Variables**

In addition to the original sensor variable extracts, the MMS adds a number of useful variables that facilitate traceability of the data. These are listed in the following chapters.

### 5.2.1 **<sensor-name>\_x, <sensor-name>\_y**

These variables contain the x and y position of the matchup location for the sensor *<sensor>* in the input data raster. The variables are vectors with one value per matchup layer containing the matchup centre location.

### 5.2.2 **<sensor-name>\_file\_name**

A variable that contains for each matchup-layer the name of the sensor input file for each sensor *<sensor>*.

### 5.2.3 **<sensor-name>\_processing\_version**

Contains the processing version of the original sensor input file for each sensor *<sensor>* as stated during the database ingestion of the sensor data.

### 5.2.4 **<sensor-name>\_acquisition\_time**

This variable contains for each pixel in the matchup-extraction window the normalized acquisition time in seconds since 1970-01-01 (Unix epoch). All sensor specific acquisition times are converted to this value with the highest precision possible.

## 5.3 CF Conformity

### 5.3.1 CF conform usage of “units” attribute

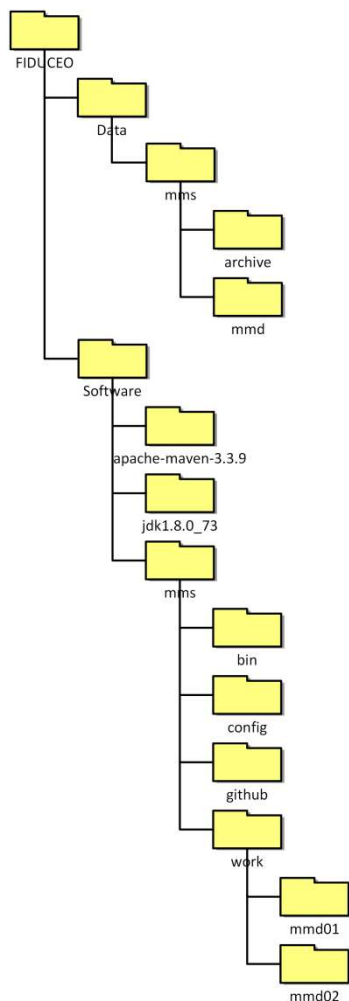
If the MMD-File-Writer detects, that an input variable contain a non CF conform “unit” attribute, the writer duplicates the attribute with the CF conform name “units” instead of “unit”. Finally such a variable contain two unit attributes with the same value. One with a non CF conform attribute name and one with a CF conform attribute name.

## 6 Installation and Operation on CEMS

This chapter covers the installation and operation of the Fiduceo MMS on the parallel processing facility JASMIN/CEMS supplied by CEDA. The Fiduceo project has a specific virtual machine assigned on the CEMS system for operations.

### 6.1 Workspace Structure

This chapter describes the Fiduceo workspace directory structure and the way the MMS is embedded into it. The sketches omit all non-MMS-related directories for a more clear view of the workspace structure.



The directory branch below “Data” contains a subdirectory for the “mms” that contains MMS related data. The “archive” directory contains all sensor and in-situ input data ordered in the directory structure described in the MMS Implementation Plan (see RD 1) whereas the directory “mmd” serves as target directory for the processing results. Subdirectories for each use-case will be generated during the processing of matchups.

The directories below “Software” contain all software comprising the MMS and also all third-party software used to build and run the MMS. Subdirectories “apache-maven-3.3.9” and “jdk1.8.0\_73” contain the apache maven build manager and the Java JDK/runtime required to compile and run the MMS.

The subdirectory “mms” contains all MMS related software, configuration, a build directory and a set of working directories. The current operating version of the MMS is contained in the directory “bin”. The configuration files used by the MMS are stored in the directory “config”.

The subdirectory “github” is the build directory. It contains the complete source code of the MMS and is configured to be able to fetch code changes from github and to build and deploy the software.

In the “work” directory contained are the working directories for processing. Any processing job needs to be operated from a dedicated sub-directory of “work”. Each subdirectory for a specific use-case processing contains status files, log-directories and all other files required by PMonitor to operate.



## 6.2 Building the MMS on CEMS

The build and deployment process is mostly automated. To build and deploy “master” branch (i.e. the latest development version) of the github repository, change to the directory “FIDUCEO/Software/mms/github/fiduceo” and invoke the script “build\_and\_install\_on\_cems.sh”. This script performs the following steps:

- Checkout the latest version of the code from github
- Invoke maven to build the code and run all tests
- Clean up the “bin” directory
- Invoke maven to build an assembly of the binaries and deploy it to the “bin” directory.

When these steps have been run successfully, the MMS software is ready to operate.

## 6.3 Operating the MMS on CEMS

This chapter covers all information with respect to operations of the MMS on the CEMS environment and specific configuration and set-up tasks.

### 6.3.1 Setting up the Scheduler

The MMS process control layer can operate two different scheduler implementations

- LSF
- SLURM

The scheduler implementation to be used needs to be configured before any operations are possible.

To do so, please open the environment script “bin/mms-env.sh” in an editor. Two settings need to be adapted, in the section “project and user settings” and in “export scheduling engine”.

#### project and user settings

- export PROJECT=<project\_name>: when using LSF the jobs are grouped by *project\_name*. Please set to an appropriate value when using LSF. Is ignored for SLURM.
- export MMS\_USER=<user\_name>: when using SLURM jobs are submitted as the user *user\_name*. This name needs to have a SLURM account, in most cases it’s the Linux user name. Is ignored by LSF. **If the MMS shall be operated by multiple users, it is strongly advised to assign a separate environment script for each user. When assigning separate scripts per user, a file naming convention like mms-env\_xxx.sh should be used. It is necessary to update the MMS\_USER field and to set MMS\_ENV\_NAME to the file name assigned to the user.**

#### export scheduling engine

- `export SCHEDULER='<engine>':` Defines the scheduling engine to use. Valid values are *LSF* and *SLURM*.

## 6.3.2 Setting up the Environment

Before the MMS is able to operate on the LOTUS cluster, a number of environment variables and paths need to be set. This is done by simply sourcing a pre-configured script.

Assuming that you are in a use-case subdirectory e.g. in “FIDUCEO/Software/mms/work/mmd08” sourcing the environment file is accomplished by executing:

```
[tblock01@lotus mmd08]$ ../../bin/mms-env.sh
```

The script file is automatically installed to the directory “FIDUCEO/Software/mms/bin” by the maven deployment script.

## 6.3.3 CEMS Specific Configuration

The CEMS environment requires a number of specific configuration settings that ensure the proper operation on the cluster. All configuration files accessed by the operational MMS are located in the directory “FIDUCEO/Software/mms/config”.

**IMPORTANT:** The configuration files in this directory will not be updated by the MMS build and deploy procedure. Any changes in the file content, e.g. additional fields or field renaming, have to be inserted manually into the operational configuration.

### 6.3.3.1 System Configuration

The MMS system configuration is set up to pick up the correct input data archive path for the CEMS installation. The following setting is mandatory on CEMS:

**archive-root:** /group\_workspaces/cems2/fiduceo/Data/mms/archive

For a description of the system configuration file, please refer to chapter 4.1.1.

### 6.3.3.2 Database Configuration

The database installed on the Fiduceo workspace is a MongoDB server installation, version 3.2. This database requires a fixed set of access configuration parameters for the database configuration:

**driverClassName:** mongodb

**url:** mongodb://172.26.69.130:27017/FIDUCEO

**username:** xxxx

**password:** xxxx

Username and password are available on request. For a description of the database configuration file, please refer to chapter 4.1.2.

## 6.3.4 Operating the MMS

On the parallel processing environment on the LOTUS cluster, the MMS software is controlled by an additional Python layer, PMonitor. This software layer controls the deployment and parallel execution of MMS-Tool processes (Ingestion, Matchup, Post Processing) to the cluster nodes. It ensures that processing can be paused and re-invoked and that on e.g. hardware or network failures, large processing jobs can safely continue where they have been interrupted.

PMonitor is invoked from the console on the lotus VM using three shell scripts that are located in the directory “FIDUCEO/Software/mms/bin” – and that are automatically available on the path when the environment is set up correctly following the instructions in chapter 6.3.1.

**pmstart.sh:** this command is used to submit a parallel processing task to the cluster. It assumes a single cmd-line argument, the name of the workflow-file that contains the process description, e.g.

```
“pmstart.sh ingest_avhrr_n07.py”
```

**pmstop.sh:** this command stops the execution of parallel tasks and kills the currently running processes on LOTUS. PMonitor ensures that the processing can later pick up processing at the point where the job has been stopped. It assumes a single cmd-line argument, the name of the workflow-file that contains the process description, e.g.

```
“pmstop.sh ingest_avhrr_n11.py”
```

**pmclean.sh:** this command cleans up all temporary files that have been generated during the processing execution. It assumes a single cmd-line argument, the name of the workflow that has been processed, e.g.

```
“pmclean ingest_avhrr_m02”
```

The shell scripts are designed in a way that it is safe to close the console after a processing job has been started. Processing will keep on running in the background.

## 6.3.5 Workflow Files

The definition of the jobs to be executed by PMonitor is stored in workflow files. These are Python files that create and configure a workflow object, which is using PMonitor to execute the parallel processing on the cluster. Workflow files are available from and have to be stored into the directory “FIDUCEO/Software/mms/bin/python”.

An example workflow-file is displayed below:

```
from workflow import Workflow
```

```
w = Workflow('usecase02_avhrr_m02_n18', 7,
            '/group_workspaces/cems2/fiduceo/Software/mms/config')

w.add_primary_sensor('avhrr-m02', '2006-10-30', '2015-12-31', 'v01.2')
w.add_secondary_sensor('avhrr-n18', '2006-10-30', '2015-12-31', 'v01.2')

w.set_usecase_config('usecase-02.xml')

w.run_matchup(hosts=[('localhost', 10)], num_parallel_tasks=24)
```

A workflow is constructed using three parameters:

- usecase: the name of the usecase the workflow is operating on – used to name log-files and other process control files
- time\_slot\_days: the time slicing applied to the processing period in days. Every time slice is processed as a separate job on the cluster.
- config\_dir: the absolute path to the configuration directory

Subsequently, a number of sensors can be added to the workflow using the commands

- add\_primary\_sensor(...): adds the primary (i.e. reference) sensor to the workflow
- add\_secondary\_sensor(...): adds a secondary (i.e. associated) sensor to the workflow.

Each workflow must have a reference sensor, the number of associated sensors is not restricted. The parametrisation for both methods is the same, using:

- name: the sensor name as listed in chapter 3.5.
- start\_date: processing interval start date , formatted yyyy-MM-dd
- end\_date: processing interval end date , formatted yyyy-MM-dd
- version: the sensor data version

The start and end dates of the sensors must not (although they can) match the processing interval. These tags are meant to narrow down the validity range of the data. PMonitor automatically calculates the largest possible processing interval.

The workflow must know the processing configuration file to be used. This is accomplished by the call to `set_usecase_config()`. The argument is the name of a configuration file stored in the configuration directory passed in to the constructor. Configuration files are described in chapters 4.1.4 and 4.1.5.

The final line sets the hostnames and the parallelization to be used to execute the job. On CEMS, the only possible host for submitting jobs is “localhost”, assuming the MMS is operated on one of the CEMS science nodes. The number behind the host name denotes the maximum number of jobs submitted to the scheduler at once. The second parameter “num\_parallel\_tasks” denotes the number of parallel executed jobs on the cluster. PMonitor submits jobs in chunks of the maximum number of jobs to be submitted until the maximum number of parallel tasks is reached. Then it constantly checks the job status and submits new Jobs when a slot has become free until the batch is processed.

**IMPORTANT:** the LSF scheduler on CEMS is overloaded when using more than approx. 150 parallel nodes.