MERIS / AATSR SYNERGY ALGORITHMS FOR CLOUD SCREENING, AEROSOL RETRIEVAL AND ATMOSPHERIC CORRECTION

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1 INTRODUCTION

1.1 Scope

The Input Output Data Definition Document (IODD) is intended to provide the specification for the ‚MERIS/AATSR Synergy' Products and auxiliary data products that will be produced and used by the processors of the different branches.
This issue of the document is a draft version, which does not reflect the final consolidated status of the products specification.

1.2 Purpose

The primary purpose is to provide a precise product description of the entire set of products derived from the synergistic use of the MERIS and AATSR instruments on board the Envisat platform, identified in RD-1, 2, 3. The IODD is an applicable document for downstream deliverables.

1.3 Reader Level

This specification is written for the following audiences:

- MERIS/(A)ATSR Synergy Toolbox users

This IODD assumes that the reader is familiar with basic concepts in using the BEAM software and its integrated processors.

1.4 References

1.4.1 *Applicable Documents*

This document is in compliance with the following applicable documents:

REF	TITLE	DOCUMENT CODE	VERSION	DATE
AD-1	"MERIS/AATSR Synergy – Algorithms for cloud screening, aerosol retrieval and atmospheric correction" STATEMENT OF WORK.	ENVI-DTEX-EOPS-SW-07-0007,	1.0	June 2007

Table 1-1: Applicable documents

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1.4.2 *Reference Documents*

The following reference documents were taken into account in preparing this document:

REF	TITLE	DOCUMENT CODE	VERSION	DATE
RD-1	European Space Agency – MERIS Product Handbook		2.1	October 2006
RD-2	European Space Agency – AATSR Product Handbook		2.2	February 2007
RD-3	Preusker, R., and J. Fischer: Remote Sensing of Aerosol over Ocean Using a Synergy of MERIS and AATSR. SYNAO ATBD, Free University of Berlin	SYN-FUB-ATBD	1.0	June 2009
RD-4	North, P., Grey, W., Heckel, A., Fischer, J., Preusker, R., and C. Brockmann: MERIS/AATSR Synergy – Algorithms for cloud screening, aerosol retrieval and atmospheric correction: Land Aerosol and Surface Reflectance ATBD. Swansea University, Free University of Berlin, Brockmann Consult Geesthacht.	SYN-SU-ATBD	3.1	June 2009
RD-5	Gomez-Chova, L., Camps-Valls, G., Calpe, J., Munoz, J., and J. Moreno: MERIS/AATSR Synergy Algorithms for cloud screening, aerosol retrieval and atmospheric correction: Cloud Screening ATBD. University of Valencia	SYN-UV-ATBD	1.0	January 2009

Table 1-2: Reference documents

1.5 Notation and Conventions

1.5.1 *Acronyms*

ACRONYM	MEANING
AASTR	Advanced Along Track Scanning Radiometer
API	Application Programming Interface
BC	Brockmann Consult
BEAM	Basic ERS & Envisat AATSR and MERIS Toolbox
DPM	Detailed Processing Model
EO	Earth Observation
ESA	European Space Agency
FUB	Free University of Berlin
HKTM	Housekeeping Telemetry
IODD	Input/Output Data Definition
MERIS	Resolution Imaging Spectrometer Instrument
SU	Swansea University

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ACRONYM	MEANING
UV	University of Valencia
VISAT	Visualization and Analysis Tool
XML	Extensible Mark-up Language

Table 1-3: List of acronyms

1.5.2 *Definitions and Terminology*

The following terms have been defined:.

Table 1-4: List of terms

TERM	MEANING
Ancillary Data	All on-board data other than Observation and HKTM necessary for the Products processing..
Auxiliary Data	Data necessary to some steps of the products processing, that are either provided by internal databases and/or facilities of the PDGS (e.g. the parameters, the calibration and the static data bases), or by external entities (e.g. meteorological data).

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2 SYNERGY PRODUCTS OVERVIEW

2.1 SYNERGY Processing Tree

The MERIS/(A)ATSR Synergy processing tree is illustrated in Figure 3-1. Processing steps are coloured light blue, data products are coloured green, and auxiliary data are coloured white.

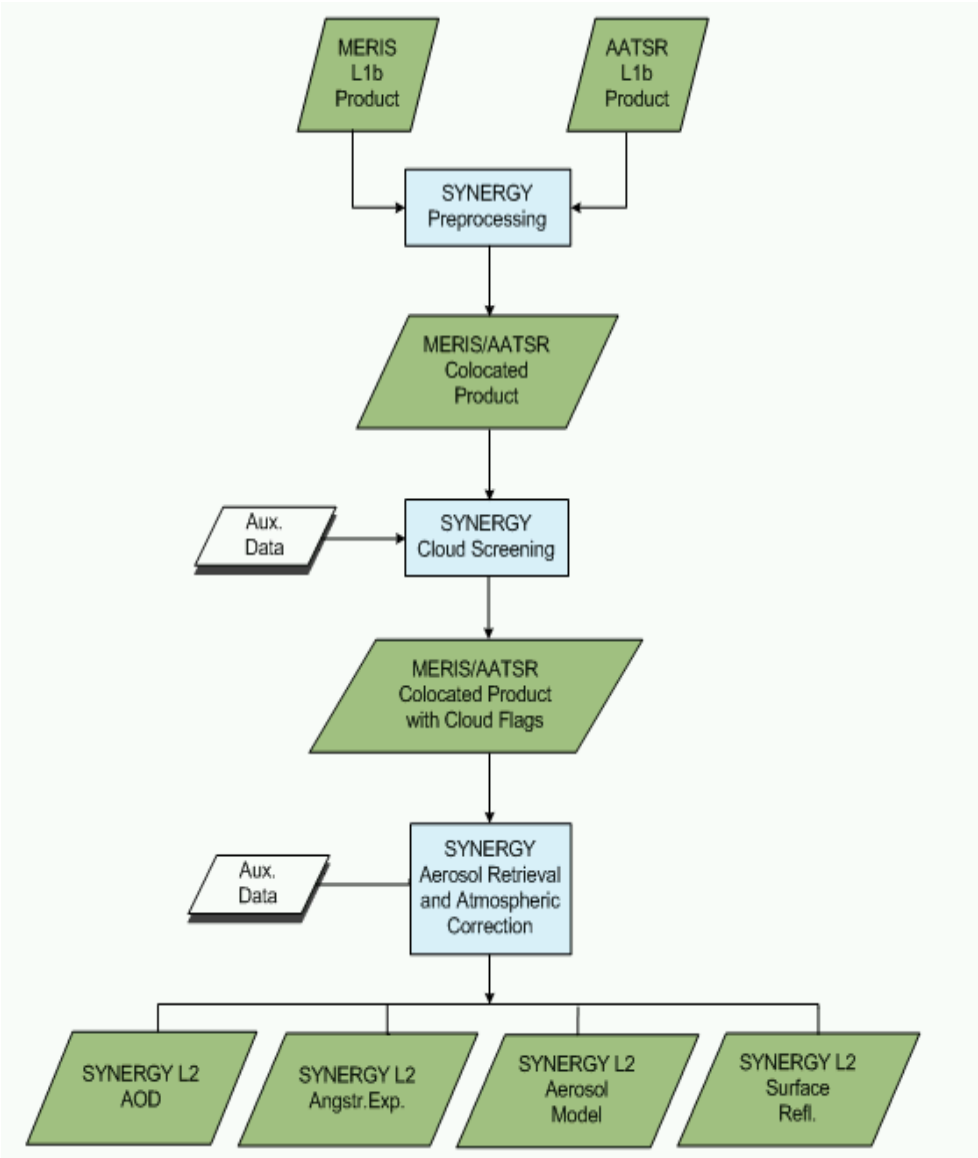

Figure 2-1: SYN product processing tree

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As indicated by Fig. 3.1, the Synergy processing starts from the following two input products:

- MERIS standard L1b product, as described in detail in [RD-1]
- AATSR standard L1b product, as described in detail in [RD-2].

2.2 Common annotation data

2.2.1 *Flag bands*

All Synergy products include the following flags copied from the MERIS and AATSR L1b products:

- MERIS L1 flags
- MERIS cloud flags
- AATSR cloud flags (nadir and forward view)
- AATSR confidence flags (nadir and forward view)

The Synergy intermediate cloud screening product and the final aerosol retrieval and atmospheric correction product contain further flags comprising the result status and quality They are described in Section 4.2.

BIT	FLAG	DESCRIPTION
0	Cosmetic	Pixel is cosmetic
1	Duplicated	Pixel has been duplicated (filled in)c
2	Glint_Risk	Pixel has glint risk
3	Suspect	Pixel is suspect
4	Land_Ocean	Pixel is over land, not ocean
5	Bright	Pixel is bright
6	Coastline	Pixel is part of a coastline
7	Invalid	Pixel is invalid

Table 2-1: MERIS L1b flag coding in Synergy products

BIT	FLAG	DESCRIPTION
0	Cloudy	Pixel is with more than 80% cloudy
1	Cloudfree	Pixel is with less than 20% cloudy
2	Cloud_Uncertain	Pixel is between 20% and 80% cloudy

Table 2-2: MERIS cloud flag coding in Synergy products

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BIT	FLAG	DESCRIPTION
0	Land	Pixel is over land
1	Cloudy	Pixel is cloudy (result of all cloud tests)
2	Sun_Glint	Sunglint detected in pixel
3	Cloudy_Refl_Hist	1.6 micron reflectance histogram test shows pixel cloudy (day-time only)
4	Cloudy_Spat_Coher_16	1.6 micron spatial coherence test shows pixel cloudy (day-time only)
5	Cloudy_Spat_Coher_11	11 micron spatial coherence test shows pixel cloudy
6	Cloudy_Gross_12	12 micron Gross test shows pixel cloudy
7	Cloudy_Cirrus_11_12	11/12 micron thin cirrus test shows pixel cloudy
8	Cloudy_Med_Hi_Level_37_12	3.7/12 micron medium/high level test shows pixel cloudy (night-time only)
9	Cloudy_Fog_Low_Startus_11_37	11/3.7 micron fog/low stratus test shows pixel cloudy (night-time only)
10	Cloudy_Vw_Diff_11_12	11/12 micron view difference test shows pixel cloudy
11	Cloudy_Vw_Diff_37_11	3.7/11 micron view difference test shows pixel cloudy (night-time only)
12	Cloudy_Therm_Hist_11_12	11/12 micron thermal histogram test shows pixel cloudy

Table 2-3: MERIS cloud flag coding in Synergy products

BIT	FLAG	DESCRIPTION
0	Blanking	Blanking pulse
1	Cosmetic	Cosmetic FillPixel
2	Scan_Absent	Entire scan absent from telemetry
3	Absent	Pixel absent from telemetry
4	Not_Decompr	Pixel not decompressed owing to error in packet validation
5	NO_Signal	No signal in some channel (zero count)
6	Saturation	Saturation in some channel (maximum count)
7	Out_of_Range	Derived radiance of some channel outside range of calibration
8	No_Calib_Param	Calibration parameters unavailable for pixel
9	Unfilled	Pixel unfilled (cosmetic fill algorithm unable to find nearest neighbour pixel)

Table 2-4: AATSR confidence flag coding (nadir and forward view) in Synergy products

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2.2.2 *Grid*

All Synergy products basically use the L1b master grid (MERIS).
All AATSR bands and AATSR tie-point grids are resampled to this common grid. This oversampling will be performed using nearest neighbour resampling. The aerosol retrieval can be performed on a coarser grid (by user option).
The tie point grids contain meteorological, geographical and geometrical information as described below.

2.2.3 *Meteorological data*

All Synergy products include the meteorological data copied from the MERIS L1b product:

- Mean sea level atmospheric pressure [hPa]
- Meridional and zonal wind speed at 10 m [$m.s^{-1}$]
- Relative Humidity at 850 hPa [%]
- Total column ozone [$kg.m^{-2}$]
- Atmospheric temperature profile [K]

2.2.4 *Geographical data*

The following geographical information will be provided with respect to the Earth reference model WGS84:

- Latitude, Longitude
- DEM altitude
- DEM roughness
- DEM latitudeand longitude correction

2.2.5 *Geometrical data*

The following geometrical information will be provided:

- Solar illumination zenith angle
- Solar illumination azimuth angle
- Viewing zenith angle
- Viewing azimuth angle

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3 SYNERGY PREPROCESSOR

3.1 Input Product

The Synergy preprocessor works with the following two input products:

- MERIS standard L1b product, as described in detail in [RD-1]
- AATSR standard L1b product, as described in detail in [RD-2].

3.2 Output Product

The output product obtained from the Synergy preprocessor is a colocated MERIS/AATSR product. In this preprocessing step, the MERIS input product is regarded as 'master' product (pixel values are conserved), and the AATSR input product is regarded as 'slave' product (pixel values are resampled onto the master grid).

- MERIS standard L1b product, as described in detail in [RD-1]
- AATSR standard L1b product, as described in detail in [RD-2].

The following tables specify the datasets of the colocated MERIS/AATSR product. The product comprises measurement datasets (MDS) and common annotation datasets (ADS) such as flag bands and tie point grids, as outlined in the previous section. For the specification of the MDS and ADS we use the abbreviations

- **NC**, the number of columns in a scan line and
- **NL**, the number of scan lines in a dataset (= MERIS frames).

The following table provides an overview of the datasets the Synergy product is composed of:

Dataset	Band name	Description	Unit	Dimension x #bytes
MERIS Surface Reflectances (15 bands)	`reflectance_<n>_MERIS`	Bands as specified in Table 3.2	dl	15*NL*NC*4
MERIS L1b radiances (15 bands)	`radiance_<n>_MERIS`	Radiances copied from L1b input product, bands as in Table 3.2	mW/(m^2*sr*nm)	15*NL*NC*4
MERIS detector index (1 band)	`detector_index_ _MERIS`		dl	NL*NC*4
AATSR nadir brightness	`btemp_nadir_<n>_AATSR`	Brightness temperatures in	K	3*NL*NC*4

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temperature (3 bands)		bands 5-7, as specified in Table 3.2		
AATSR forward brightness temperature (3 bands)	btemp_ fward_<n>_AATSR	Brightness temperatures in bands 5-7, as specified	K	3*NL*NC*4
AATSR nadir TOA reflectance (4 bands)	reflec_ nadir_<n>_AATSR	Reflectances in bands 1-4, as specified in Table 3.3	dl	4*NL*NC*4
AATSR forward TOA reflectance (4 bands)	reflec_ fward_<n>_AATSR	Reflectances in bands 1-4, as specified in Table 3.3	dl	4*NL*NC*4
AATSR latitude, longitude (2 bands)	latitude_AATSR longitude_AATSR		deg	2*NL*NC*4
AATSR altitude (1 band)	altitude_AATSR		m	NL*NC*4
AATSR nadir latitude, longitude corrections (2 bands)	lat_corr_nadir_ AATSR lon_corr_nadir_ AATSR		deg	2*NL*NC*4
AATSR forward latitude, longitude corrections (2 bands)	lat_corr_fward_ AATSR lon_corr_fward_ AATSR		deg	2*NL*NC*4
AATSR nadir geometrical information (4 bands)	view_elev_nadir_ AATSR sun_elev_nadir_ AATSR view_azimuth_nadir_ AATSR sun_azimuth_nadir_ AATSR	as described in section 2.2.4	deg	4*NL*NC*4
AATSR forward geometrical information (4 bands)	view_elev_fward_ AATSR sun_elev_fward_ AATSR view_azimuth_fward_ AATSR sun_azimuth_fward_ AATSR	as described in section 2.2.4	deg	4*NL*NC*4
MERIS flag bands	l1_flags_MERIS cloud_flag_MERIS	as described in section 2.2	dl	2*NL*NC*4
AATSR flag bands	confid_flags_nadir_ AATSR cloud_flags_nadir_	as described in section 2.2	dl	4*NL*NC*4

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	AATSR confid_flags_fward_ AATSR cloud_flags_fward_ AATSR			
Tie point grids	latitude longitude dem_alt dem_rough lat_corr lon_corr sun_zenith sun_azimuth view_zenith view_azimuth zonal_wind merid_wind atm_press ozone rel_hum	as described in section 2.2		15*NL*NC*4

Table 3-1: Synergy colocation product dataset overview

CHANNEL	WAVELENGTH (NM)	BANDWIDTH
1	412.5	10
2	442.5	10
3	490	10
4	510	10
5	560	10
6	620	10
7	665	10
8	681.2	7.5
9	708.7	10
10	753.7	7.5
11	760.6	3.75
12	778.7	15
13	865	20
14	885	10
15	900	10

Table 3-2: MERIS instrument channels

CHANNEL	WAVELENGTH (NM)	BANDWIDTH
1	550	20
2	665	20
3	865	20
4	1610	60
5	3740	380
6	10850	90
7	12000	1000

Table 3-3: AATSR instrument channels

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4 CLOUD SCREENING

4.1 Input Product

The Cloud Screening processor works with the following input product:

- MERIS/AATSR colocated product, which is the output product of the Synergy preprocessing as described in detail in section 3.2.

4.2 Output Product

The output product obtained from the Cloud Screening processor is again a colocated MERIS/AATSR product. It contains all the bands of the input product, and additional bands containing the results from the cloud screening. These additional bands are listed in table 4.1

Dataset	Band name	Description	Unit	Dimension x #bytes
All bands and tie point grids from input product		Bands as specified in Table 3.1		
Synergy cloud index	`cloud_flags_synergy`	Cloud index as derived from cloud screening algo-rithm (see [RD-5])	dl	NL*NC*4
Synergy cloud flag	`cloud_index_synergy`	Cloud flag as derived from cloud screening algo-rithm (see [RD-5] and table 4.2)	dl	NL*NC*4

Table 4-1: Cloud screening product dataset overview

BIT	FLAG	DESCRIPTION
0	Shadow	Cloud shadow risk
1	Snow _filled	Snow (filled)
2	Snow	Snow risk
3	Cloud_filled	Cloud (filled)
4	Cloud	Cloudy

Table 4-2: Synergy cloud flag coding in cloud screening product

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5 AEROSOL RETRIEVAL AND ATMOSPHERIC CORRECTION

5.1 Input Product

The Aerosol Retrieval and Atmospheric Correction processor works with the following input product:

- MERIS/AATSR colocated product, which is the output product of the Cloud Screening processing as described in detail in section 4.2.

5.2 Look-up tables

For computational efficiency, a set of precalculated look-up tables of atmospherric properties is used in both land and ocean aerosol retrievals as well as in the atmospheric correction.

5.2.1 *Ocean aerosol retrieval*

Glint LUT

This LUT was generated and filled using radiative transfer (MOMO) calculations for 15 different wind-speeds, 11 different real parts of refractive indices of water, 13 solar zenith angles, 12 viewing zenith angles and 19 azimuth angle differences.

The resulting lookup table has therefore 5 dimensions (table 5.1): 3 angles, the windspeed and the refractive index. To reduce this number to 4 dimensions (which saves an order of magnitude of time), the glint is approximated by a Gaussian for each combination of sun zenith, windspeed ws and refractive index n (see [R-3]).

FILENAME	FORMAT	SIZE	INPUT VARIABLE	RANGE	DIMENSION	OUTPUT VARIABLE
gauss_lut.nc	netCDF	43 KB	windspeed	1,...,15 m/s	15	glint
			refractive index	1.3,...,1.4	11	
			solar zenith angle	0°,...,70°	13	
			viewing zenith angle	0°,...,60°	12	
			azimuth angle difference	0°,...,180°	19	

Table 5-1: Glint look-up table used ocean aerosol retrieval

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TOA reflectance LUTs

The primary LUTs were generated for 40 different aerosol models. Each primary LUT was filled using radiative transfer (MOMO) calculations for 3 surface pressures p, 15 different windspeeds ws, 13 solar zenith angles, 11 viewing zenith angles, 19 azimuth difference angles and 9 values of optical thickness at 550 nm. The calculated top of atmosphere radiances were corrected for the glint influence by a simple subtraction.

For each aerosol class and each wavelength the look up table has therefore 6 dimensions (table 5.2): the surface pressure, the windspeed, 3 angles and the optical thickness at 550nm.

FILENAME	FORMAT	SIZE	INPUT VARIABLE	RANGE	DIMENSION	OUTPUT VARIABLE
aer_<n>_ wvl0<m>.nc with aerosol model n=1,..,40 and wavelength m = {778, 865, 1610}	netCDF	2470 KB each	surface pressure	{980, 1000, 1030 hPa}	3	TOA reflectance
			windspeed	1,...,15 m/s	15	
			solar zenith angle	0°,...,70°	13	
			viewing zenith angle	0°,...,60°	11	
			azimuth angle difference	0°,...,180°	19	
			optical thickness at 550nm	{0, 0.05, 0.1, 0.2, 0.4, 0.6, 1. 1.5, 2}	9	

Table 5-2: TOA reflectance look-up table used ocean aerosol retrieval

5.2.2 *Land aerosol retrieval / atmospheric correction*

The atmospheric parameters in the lookup tables for land aerosol retrieval / atmospheric correction are sampled at irregular intervals in the optical bands of AATSR and MERIS instruments across a range of sun-sensor geometries, AOD and other key atmospheric and surface properties.
The lookup table consists of the geometric, atmospheric and surface parameters. It provides modelled TOA reflectances depending on 6 dimensions: solar zenith angle (SZA), relative azimuth angle, view zenith angle (VZA), Lambertian surface albedo, AOD and surface pressure. This table is calculated for each aerosol model and each wavelength of both instruments. Aerosol optical properties (AOD, Angstrom, single scattering albedo and phase functions) are defined by up to 40 predefined aerosol models. Channels with strong absorption bands (i.e. MERIS channel 11 and 15) are excluded to avoid interference from oxygen and water vapour absorption. Thus we have lookup tables for 13 MERIS and 4 AATSR spectral channels and 40 aerosol models, resulting in a total of (13+4) * 40 = 680 tables.

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FILENAME	FORMAT	SIZE	INPUT VARIABLE	RANGE	DIMENSION	OUTPUT VARIABLE
<instr>_<wvl>.00_ <model> with <instr> = {MERIS, AATSR}, aerosol model = 1,..,40 and wvl = {all MERIS/AATSR channels except MERIS 11, 15}	binary	10039 KB each	surface pressure	{800, 900, 1000, 1030 hPa}	4	surface reflectance
			solar zenith angle	0°,...,87.14°	17	
			viewing zenith angle	0°,...,87.14°	17	
			azimuth angle difference	0°,...,180°	19	
			optical thickness at 550nm	0.0,...,2.0	9	
			albedo	{0.0, 0.020, 0.050, 0.100, 0.200, 0.300, 0.400, 0.500, 0.600, 0.700, 0.800, 0.900, 1.0}	13	

Table 5-3: TOA reflectance look-up table used ocean aerosol retrieval

5.3 Output Product

The output product obtained from the Aerosol Retrieval and Atmospheric Correction processor contains all the flag bands and tie point grids of the input product, and additional bands containing the results from the aerosol retrieval and (optionally) the atmospheric correction. These additional bands are listed in table 5.1

Dataset	Band name	Description	Unit	Dimension x #bytes
All flag bands and tie point grids from input product		as specified in previous sections		22*NL*NC*4
Synergy aerosol land flags	`aerosol_land_flags`	Aerosol land flags as derived from land aerosol retrieval algorithm (see [RD-4] and table 5.2)	dl	NL*NC*4

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Synergy AOD	aot	Aerosol optical depth as derived from land aerosol retrieval algorithm (see [RD-4])	dl	NL*NC*4
Synergy AOD filled	aot_filled	AOD with gaps filled by bilinear interpolation	dl	NL*NC*4
Synergy AOD uncertainty	aot_uncertainty	Uncertainty in aerosol optical depth as derived from land aerosol retrieval algorithm (see [RD-4])	dl	NL*NC*4
Synergy AOD uncertainty filled	aot_uncertainty_filled	AOD uncertainty with gaps filled by bilinear interpolation	dl	NL*NC*4
Synergy land aerosol model	land_aerosol_model	Index of aerosol model giving the best retrieval result	dl	NL*NC*4
Synergy land aerosol model filled	land_aerosol_model_ filled	Index of aerosol model with gaps filled by bilinear interpolation	dl	NL*NC*4
MERIS surface reflectances (optional, 15 bands)	SynergySDR_ <n>_MERIS	Surface reflectances in bands as specified in Table 3.2	dl	15*NL*NC*4
AATSR nadir surface reflectance (optional, 4 bands)	SynergySDR_ nadir_<n>_AATSR	Surface reflectances in bands 1-4, as specified in Table 3.3	dl	4*NL*NC*4
AATSR forward surface reflectances	SynergySDR_ fward_<n>_AATSR	Surface reflectances in bands 1-4, as specified	dl	4*NL*NC*4

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(optional, 4 bands)		in Table 3.3		

Table 5-4: Cloud screening product dataset overview

BIT	FLAG	DESCRIPTION
0	Aerosol_cloudy	No land aerosol retrieval due to clouds
1	Aerosol_ocean	No land aerosol retrieval due to ocean
2	Aerosol_successful	Land aerosol retrieval performed
3	Aerosol_border	Land aerosol retrieval average for border pixel
4	Aerosol_filled	No aerosol retrieval, pixel values interpolated
5	Negative_metric	Negative_metric
6	Aot_low	Aot_low
7	Aot_error_high	Aot_error_high
8	Aerosol_coastline	Coast line pixel

Table 5-5: Synergy land aerosol flag coding in aerosol retrieval product

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