GlobAlbedo Product User Guide

Author: O. Danne

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CONTRIBUTORS

Author Names	Organisation
O. Danne, M.Zuehlke, U. Krämer	Brockmann Consult
S. Kharbouche, Jan-Peter Muller	UCL MSSL

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1 Introduction

This document is the Product User Guide for the GlobAlbedo products.

1.1 Purpose and Scope

The Product User Guide is deliverable D17 of the ESA GlobAlbedo project.

The purpose of the GlobAlbedo processing system is to manage and control the generation of multi-sensor, multi-annual global land surface albedo products. Processing will use MERIS, (A)ATSR(2) and SPOT-VGT data. The processing system will be based on a cluster of processors for different processing steps.

This User Guide basically contains a description of:

- the products content and format
- the spatial and temporal coverage
- the processing system
- the available tools

1.2 Applicable and Reference Documents

The following documents are applicable to this document:

ID	Title	Issue	Date
[AD 1]	EOEP-DUEP-EOPS-SW-09-0001 SoW Statement of Work for DUE-GlobAlbedo Project	1.0	April 2009
[AD 2]	GlobAlbedo AO/1-6060/09/I-OL Proposal, University College London	1.0	02.06.2009
[AD 3]	GlobAlbedo Technical Specification (section 4.5)	2.01	17.06.2010

The following documents are referenced in this document:

ID	Title	Issue	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	Saint, G.: “VEGETATION” onboard SPOT 4 – Products Specifications.	2	18.05.1994

ID	Title	Issue	Date
RD 4	The content of a standard VEGETATION product (http://free.vgt.vito.be/vgtformat.php)		
RD 5	Schaaf, C. B., A. H. Strahler, F. Gao, W. Lucht, X. Li, X. Zhang, Y. Jin, E. Tsvetsinskaya, J.-P. Muller, P. Lewis, M. Barnsley, G. Roberts, C. Doll, S. Liang, and J. L. Privette, (2002) First operational BRDF, albedo nadir reflectance products from MODIS, *Remote Sensing of Environment*, 83, 135-148.		2002
RD 6	MODIS BRDF/Albedo Product (MOD43B) User's Guide (http://www–modis.bu.edu/brdf/ userguide/param.html)		
RD 7	MODIS Grids. (http://modis-land.gsfc.nasa.gov/ MODLAND_grid.htm)		
RD 8	GlobAlbedo ATBD "GlobAlbedo_ATBD_V1.0.pdf"	1.0	09.09.2010
RD 9	GlobAlbedo D-07 'Software Design Document'	1.0	04.01.2011
RD 10	BEAM project website, http://www.brockmann-consult.de/beam/BEAM tutorial, http://www.brockmann-consult.de/beam–wiki/display/BEAM/ BEAM+4+Programming+Tutorial		
RD 11	Danielson, J.J., and Gesch, D.B., 2011, Global multi-resolution terrain elevation data 2010 (GMTED2010): U.S. Geological Survey Open-File Report 2011–1073, 26 p.		2011

1.3 Acronyms and Abbreviations

The following acronyms are used within this document:

Acronym	Definition
AATSR	Advanced ATSR (ESA)
AD	Applicable Document
API	Application Programming Interface
AOT	Aerosol Optical Thickness
ATBD	Algorithm Theoretical Basis Document
ATSR	Along-Track Scanning Radiometer (ESA)
BBDR	Broad Band Downwelling Reflectance
BEAM	Basic ERS & Envisat (A)ATSR and Meris Toolbox
BRDF	Bi-directional reflectance distribution function
CPU	Central Processing Unit

Acronym	Definition
DU	Dobson Unit
EO	Earth observation
ERS	European Remote-Sensing Satellite
fAPAR	fraction of Absorbed Photosynthetically Active Radiation
GA	GlobAlbedo
GB	GigaByte
ISIN	Integerized Sinusoidal (Grid)
LAI	Leaf Area Index
MERIS	Medium Resolution Imaging Spectrometer (ESA)
MODIS	Moderate Resolution Imaging Spectroradiometer (NASA)
NDVI	Normalized Differential Vegetation Index
RD	Reference Document
SDR	Surface Downwelling Reflectance
SoW	Statement of Work
SPOT	Satellite Pour l'Observation de la Terre
TB	TeraByte
TOA	Top Of Atmosphere
TR	Technical Requirement
VGT	Vegetation
VISAT	Visualization and Analysis Tool
XML	eXtenxible Markup Language

1.4 Document Overview

For an overview of the GlobAlbedo processing system, please refer to section 2 of the software design document [RD-9]. After this formal introduction

Chapter 2 describes the contents and formats of all intermediate and final GlobAlbedo products

Chapter 3 gives an overview of the processing chain

Chapter 4 gives an overview of available tools

Chapter 4 briefly describes the binning and merging schemes

Chapter 6 contains various appendices

2 How to get the Globalbedo products

The access to the Globalbedo products will be given through the Globalbedo main website (www.globalbedo.org). At compilation time of this document, this website is under redesign, and final details of the layout as well as links for data access are in preparation. More details can be given at a later stage in an updated version of this document. Also, details on the distribution of the final products, data policy, access restrictions etc. need to be finally decided.

Figure 2-1 shows the Globalbedo website in the preliminary layout which is currently in preparation.

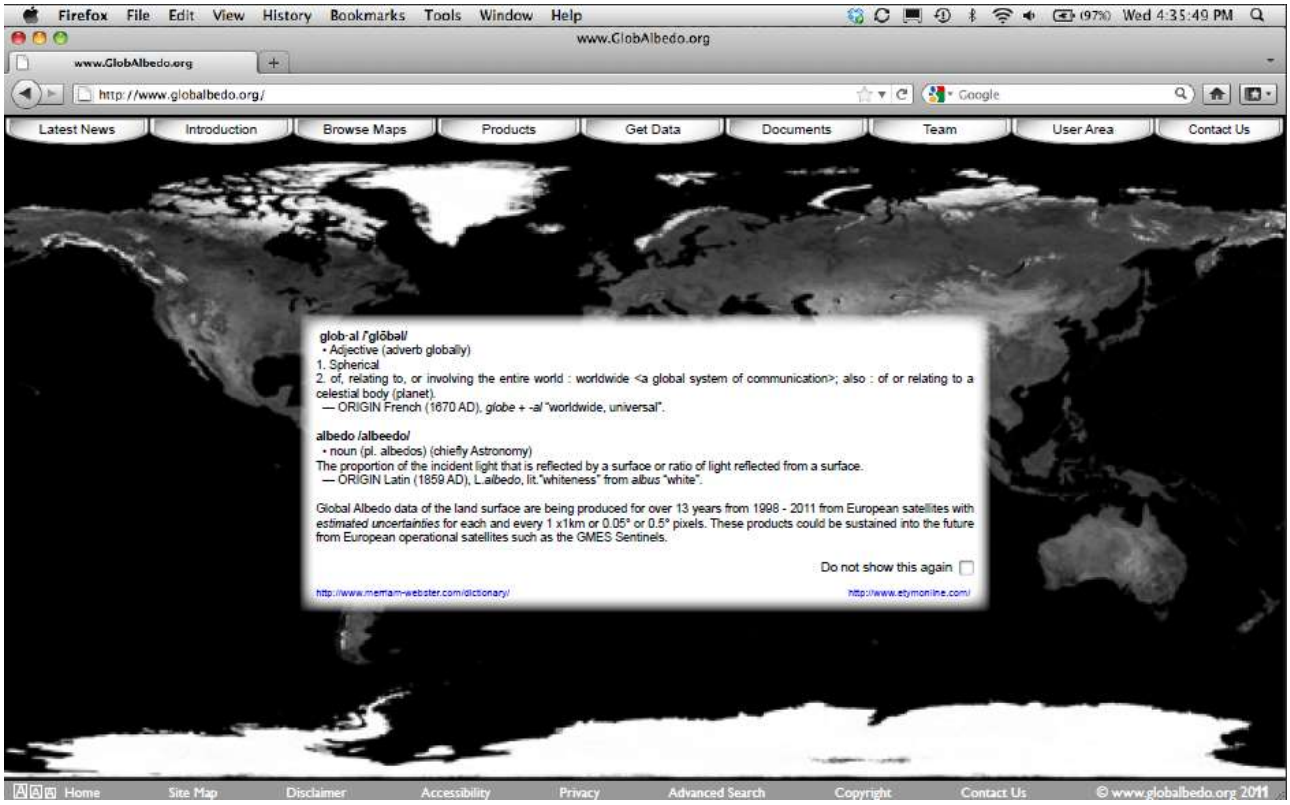

Figure 2-1: The Globalbedo project website (preliminary layout).

3 The Products Content

3.1 Input Products

For albedo retrieval, the GlobAlbedo processor uses as basic input the following products:

- Level 1 products from the sensors MERIS and SPOT VGT[1].
- MODIS BRDF products

3.1.1 Level 1 products

3.1.1.1 MERIS standard L1b product

Table 3-1 to Table 3-4 give an overview of MERIS L1b bands, tie point grids and L1b flag coding, respectively. A more detailed description of the MERIS standard L1b product is given in [RD 1].

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
radiance_<n>; n=1,..,15	mW/(m^2*sr*nm)	float32	TOA radiance in channel <n> (see Table 3-2)
l1_flags	dl (flag band)	uint8	Level 1b classification and quality flags
detector_index	dl	int16	Detector index

Table 3-1: MERIS bands in L1b product

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

[1] The use of (A)ATSR L1b input products has been descoped from this project.

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
latitude	deg	float32	Latitude of the tie points (WGS-84), Greenwich origin, positive N
longitude	deg	float32	Longitude of the tie points (WGS-84), Greenwich origin, positive E
dem_alt	m	float32	Digital elevation model altitude
dem_rough	m	float32	Digital elevation model roughness
lat_corr	deg	float32	Digital elevation model latitude corrections
lon_corr	deg	float32	Digital elevation model longitude corrections
sun_zenith	deg	float32	Sun zenith angle
sun_azimuth	deg	float32	Sun azimuth angle
view_zenith	deg	float32	View zenith angle
view_azimuth	deg	float32	View azimuth angle
zonal_wind	m/s	float32	Zonal wind
merid_wind	m/s	float32	Meridional wind
atm_press	hPa	float32	Mean sea level pressure
ozone	DU	float32	Total ozone
rel_hum	%	float32	Relative humidity

Table 3-3: MERIS tie point grids in L1b product

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 3-4: MERIS L1b flag coding

3.1.1.2 SPOT VGT L1P product

Table 3-5 to Table 3-7 give an overview of SPOT VGT L1P bands, tie point grids and the SM flag coding, respectively. More detailed description of the SPOT VGT products are given in [RD 3] and [RD 4].

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
B0	%/100	float32	TOA reflectance in band B0 (see Table 3-6)
B2	%/100	float32	TOA reflectance in band B2 (see Table 3-6)
B3	%/100	float32	TOA reflectance in band B3 (see Table 3-6)
MIR	%/100	float32	TOA reflectance in band MIR (see Table 3-6)
AG	dl	float32	Troposheric Aerosol
OG	DU	float32	Ozone

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
WVG	g/cm^2	float32	Water Vapor
SAA	deg	float32	Solar azimuth angle
SZA	deg	float32	Solar zenith angle
VAA	deg	float32	View azimuth angle
VZA	deg	float32	View zenith angle
SM	dl (flag band)	uint8	'Status Map': classification and quality flags

Table 3-5: SPOT VGT bands in L1P product

CHANNEL	WAVELENGTH (NM)	BANDWIDTH (NM)
B0	450	4
B2	650	7
B3	850	11
MIR	1650	17

Table 3-6:SPOT VGT instrument channels

BIT	FLAG	DESCRIPTION
0	CLOUD_1	Cloud code 1 if cloud test 1 applies
1	CLOUD_2	Cloud code 1 if cloud test 2 applies
2	ICE_SNOW	Ice/Snow code 1, code 0 if there is no Snow/Ice
3	LAND	Land code 1 or water code 0
4	MIR_GOOD	Radiometric quality for band MIR is good
5	B3_GOOD	Radiometric quality for band B3 is good
6	B2_GOOD	Radiometric quality for band B2 is good
7	B0_GOOD	Radiometric quality for band B0 is good

Table 3-7: SPOT VGT SM flag coding in L1P product.

3.1.2 MODIS BRDF product

Within the intermediate BRDF retrieval, the GlobAlbedo processor uses as additional input the "Prior" information from the MODIS BRDF/Albedo Model Parameters product (MOD43B1). This product is given on an 8-day temporal raster and provides a 16-day climatology of these model parameters on the MODIS global 1km Sinusoidal tile grid ([RD-7]).

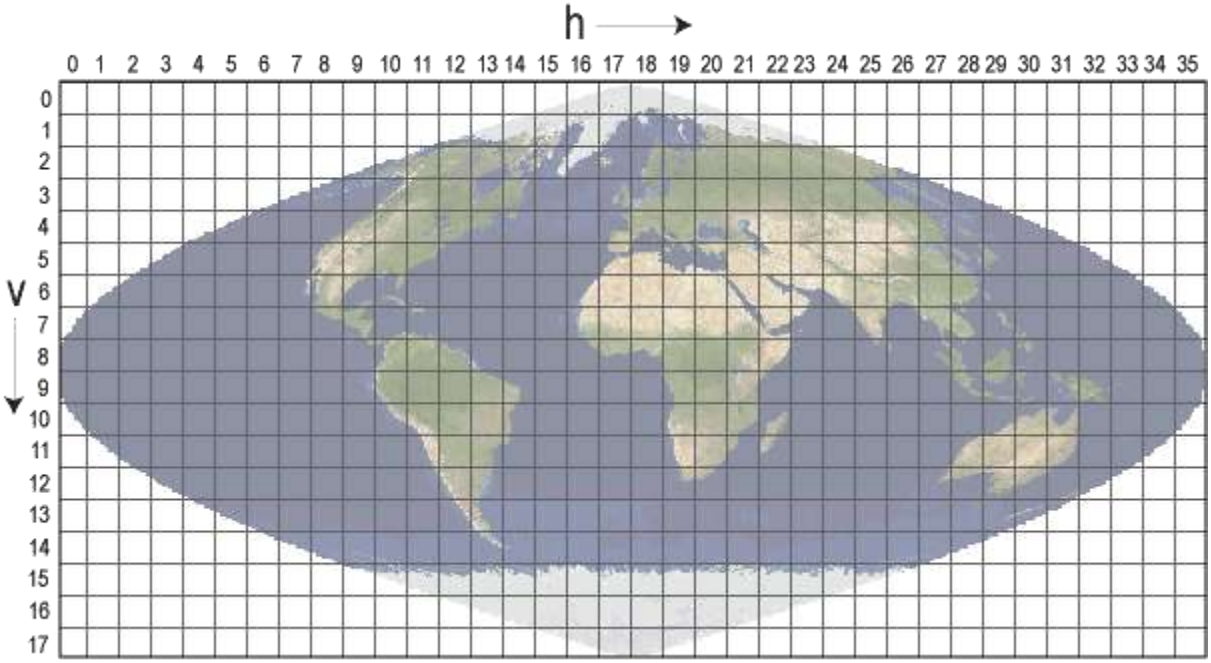

Figure 3-1: MODIS global 1km sinusoidal tile grid (36x18 tiles). See [RD-7].

The contents are described in detail in [RD-5] and [RD-6]. Table 3-8 gives an overview of the MODIS BRDF/Albedo Model Parameter bands.

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
MEAN__BAND_____<n>_PARAMETER_F<m>; n=0,1,2; m=0,1,2	dl	float32	BRDF/Albedo Model Parameters F0, F1, F2 for VIS, NIR, SW.
SD_MEAN__BAND_____<n>_PARAMETER_F<m>; n=0,1,2; m=0,1,2	dl	float32	standard deviation of BRDF/Albedo Model Parameters F0, F1, F2 for VIS, NIR, SW.
N samples	dl	float32	number of samples
Mask	dl	float32	Mask band

Table 3-8: BRDF/Albedo Model Parameters bands in MODIS MOD43B1 product.

3.2 Intermediate products

3.2.1 AOT Product

Within the L1b → BBDR processing chain, an intermediate 'AOT product' is generated. This product contains all original L1b bands together with new bands providing information on aerosol optical thickness required for the BBDR retrieval. After successful BBDR retrieval, this product shall be deleted.

Processing step	L1b → BBDR
Naming convention	${l1bProductBaseName}_AOT.dim
Storage	written to disk, shall be deleted after BBDR retrieval
Format	BEAM-DIMAP
Dimensions	intersected with tile (max.1200x1200 pixels)
Number of bands in file	18 (+ 3 flag bands)
Size per file	variable
Amount of files	per L1b file, per MODIS tile if L1b data intersects MODIS tile
Projection	Lat/Lon

Table 3-9: AOT intermediate product characteristics

Table 3-10 gives an overview of the bands in this AOT product.

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
<all bands and tie point grids from L1b product>		as in L1b product	see Table 3-1 and Table 3-5
elevation	m	float32	Elevation
aot	dl	float32	Aerosol optical thickness
aot_err	dl	float32	Error in aerosol optical thickness
aot_flags	dl (flag band)	uint8	Aerosol retrieval quality flags
cloud_classif_flags	dl (flag band)	uint8	Cloud classification flags

Table 3-10: Bands in intermediate AOT product

Table 3-11 lists the AOT flag coding in the AOT intermediate product.

BIT	FLAG	DESCRIPTION
0	aot_climatology	AOT from climatology only
1	aot_interp	AOT spatially interpolated

Table 3-11: AOT flag coding in AOT intermediate product.

Table 3-12 lists the cloud classification flag coding in the AOT intermediate product.

BIT	FLAG	DESCRIPTION
0	F_INVALID	Invalid pixels
1	F_CLOUD	Cloudy pixels
2	F_CLOUD_BUFFER	Cloud + cloud buffer pixels

BIT	FLAG	DESCRIPTION
3	F_CLOUD_SHADOW	Cloud shadow pixels
4	F_CLEAR_LAND	Clear sky pixels over water
5	F_CLEAR_WATER	Clear sky pixels, snow covered
6	F_LAND	Pixels over land
7	F_WATER	Pixels over water
8	F_BRIGHT	Pixels classified as bright
9	F_WHITE	Pixels classified as white
10	F_BRIGHTWHITE	Pixels classified as 'brightwhite'
11	F_COLD	Cold pixels
12	F_HIGH	High pixels
13	F_VEG_RISK	Pixels may contain vegetation
14	F_GLINT_RISK	Pixels may contain glint

Table 3-12: Cloud classification flag coding in AOT intermediate product.

3.2.2 BBDR Product

As output from the L1b → BBDR processing chain, a BBDR product is generated. This product contains all original L1b bands together with new bands providing information on aerosol optical thickness required for the BBDR retrieval.

In the L1b → BBDR processing chain, the L1b data are reprojected to the MODIS Sinusoidal grid, therefore, the AOT and BBDR products are tile-based. AOT and BBDR products for a distinct tile are generated only if the L1b data intersects this tile.The tiles being used are "land tiles" only, which is a subset of 326 tiles of the whole global set of 648 tiles (Figure 3-2). This set of "land tiles", together with their upper left coordinates, is listed in the appendix.

After successful BRDF retrieval, the used BBDR products shall be deleted.

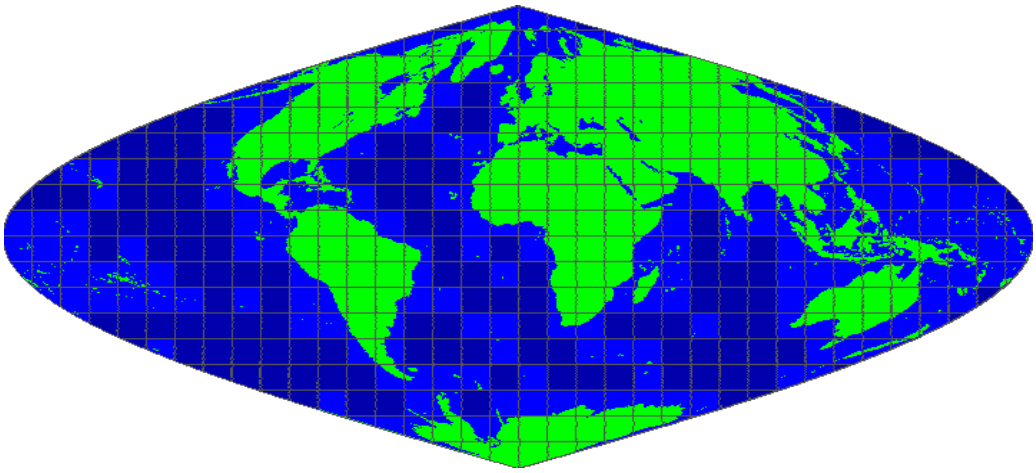

Figure 3-2: MODIS "land" tiles grid (green and light blue) used in Globallbedo processing. Water tiles (dark blue) and tiles "outside" the earth in Sinusoidal projection are not considered (see also Figure 3-1).

Processing step	L1b → BBDR
Naming convention	${l1bProductBaseName}_BBDR_geo.dim
Storage	written to disk
Format	BEAM-DIMAP
Dimensions	subsetted to tile (1200x1200 pixels)
Number of bands in file	23 (+ 1 flag band)
Size per file	~127MB
Amount of files	per L1b file, per MODIS tile if L1b data intersects MODIS tile
Projection	MODIS Sinusoidal

Table 3-13: BBDR intermediate product characteristics

Table 3-14 gives an overview of the bands in the BBDR product.

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
BB_<n>; n=VIS,NIR,SW	dl	float32	BBDR in VIS, NIR and SW range
sig_BB_VIS_VIS	dl	float32	(VIS, VIS) uncertainty covariance matrix element[2]
sig_BB_VIS_NIR	dl	float32	(VIS, NIR) uncertainty covariance matrix element
sig_BB_VIS_SW	dl	float32	(VIS, SW) uncertainty covariance matrix element
sig_BB_NIR_NIR	dl	float32	(NIR, NIR) uncertainty covariance matrix element
sig_BB_NIR_SW	dl	float32	(NIR, SW) uncertainty covariance matrix element
sig_BB_SW_SW	dl	float32	(SW, SW) uncertainty covariance matrix element
Kvol_BRDF_<n>, n=VIS,NIR,SW	dl	float32	kernel parameters for VIS, NIR, SW range (see RD-8 for details)
Kgeo_BRDF_<n>, n=VIS,NIR,SW	dl	float32	kernel parameters for VIS, NIR, SW range (see RD-8 for details)
AOD550	dl	float32	aerosol optical depth at 550nm
NDVI	dl	float32	NDVI
sig_NDVI	dl	float32	NDVI uncertainty
VZA	dl	float32	View zenith angle
SZA	dl	float32	Sun zenith angle
RAA	dl	float32	Relative azimuth angle
DEM	dl	float32	Digital elevation model height
snow_mask	dl	float32	Snow code 1 or no snow code 0
L1b flags (MERIS) or Status Map flags (VGT)	dl	uint8	L1b flag bands, see Table 3-4 and Table 3-7
aot_flags	dl	uint8	Aerosol retrieval quality flags, see Table 3-11
cloud_classif_flags	dl	uint8	Cloud classification flags, see Table 3-12

[2] The uncertainty covariance matrix is symmetric, therefore, only the UR sub-matrix is stored in the product.

Table 3-14: Bands in intermediate BBDR product

3.2.3 Daily accumulator files

As intermediate output from the BBDR → BRDF processing chain, daily accumulator files are generated. These files are written in plain binary format and contain on a daily base all elements of the accumulation matrices and the data mask. See [RD-8] for details on the meaning and the derival of the accumulators. Two separate sets of these files are generated, one for the accumulation of 'no-snow' pixels only, the other one only for snow pixels.

Processing step	BBDR → BRDF
Naming convention	matrices_yyyyddd.bin
Storage	written to disk
Format	binary
Dimensions	MODIS tile size (1200x1200 pixels)
Number of bands in file	92
Size per file	~517MB
Amount of files	per Snow/NoSnow, per day and per MODIS tile
Projection	MODIS Sinusoidal

Table 3-15: Daily accumulator file characteristics

Table 3-16 gives an overview of the quantities in a daily accumulator file.

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
M_ij; i=1,..,9; j=1,..,9	dl	float32	'M' accumulator matrix, M is a 9x9 matrix (for each row/column, number of wavebands (3) * number ofmodel parameters (3)), so we have 81 single elements
V_i; i=1,..,9	dl	float32	'V' accumulator matrix elements, V is a 9x1 matrix (for each row, number of wavebands (3) * number ofmodel parameters (3)), so we have 9 single elements
E	dl	float32	'E' accumulator matrix, E is a 1x1 matrix, i.e. has one single element
mask	dl	float32	Data mask (pixel to be processed or not)

Table 3-16: Quantities in daily accumulator file.

3.2.4 Eight-day accumulator files

In a second step, the daily accumulators are further 'accumulated' to 8-day 'full' accumulators. This step is basically an addition of all daily accumulator matrix elements of an 8-day period, together with a weighting dependent of the 'distance' of the daily accumulator to the 8-day period reference day [RD 8][3]. The characteristics and the contents of 8-day accumulator files are the same as for the daily accumulator files, except that they contain as additional information the number of days (from the reference day) to the closest day with a measurement sample.

Processing step	BBDR → BRDF
Naming convention	matrices_full_yyyyddd.bin
Storage	written to disk
Format	binary
Dimensions	MODIS tile size (1200x1200 pixels)
Number of bands in file	93
Size per file	~523MB
Amount of files	per Snow/NoSnow, per 8-day period and per MODIS tile
Projection	MODIS Sinusoidal

Table 3-17: Eight-day accumulator file characteristics

Table 3-18 gives an overview of the quantities in an 8-day accumulator file.

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
<all accumulation matrix elements as in a daily accumulator>	dl	float32	see previous section
days_to_the_closest_sample	dl	float32	the number of days (from the reference day) to the closest day with a measurement sample

Table 3-18: Quantities in 8-day accumulator file.

3.2.5 BRDF Product

As output from the BBDR → BRDF processing chain, a BRDF product is generated. This product contains all BRDF model parameters as derived from the Globalbedo inversion

[3] Note that in GlobAlbedo, a reference day (denoted as 'ddd' in the tables throughout this section) is defined as the MIDDLE of a 16-day time period, whereas MODIS uses DoY as the START for the 16 days. This means that to compare the datasets requires adjustments to be made.

algorithm (see [RD 8]), together with further bands as listed in Table 3-20. See [RD 8] for details on the meaning and the derival of the single bands.

Processing step	BBDR → BRDF
Naming convention	GlobAlbedo.brdf.yyyyddd.<tile>.<snowflag>.dim (e.g. GlobAlbedo.2005129.h18v04.NoSnow)
Storage	written to disk
Format	BEAM-DIMAP
Dimensions	MODIS tile size (1200x1200 pixels)
Number of bands in file	62
Size per file	~324MB
Amount of files	per Snow/NoSnow, per 8-day period and per MODIS tile
Projection	MODIS Sinusoidal

Table 3-19: BRDF product characteristics

Table 3-20 gives an overview of the bands in the BRDF product.

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
mean_<n>_f<m>; n=VIS,NIR,SW; m=0,1,2	dl	float32	BRDF model parameters f_i in VIS, NIR and SW range. Total of 9 bands.
var_<n>_f<m>_<n>_f_<m>; n=VIS,NIR,SW; m=0,1,2	dl	float32	BRDF model parameter uncertainty matrix elements in VIS, NIR and SW range. Total of 45 bands[4].
Entropy	dl	float32	Entropy
Relative_Entropy	dl	float32	Relative Entropy
Weighted_number_of_samples	dl	float32	number of measurement samples in the 8-day period, weighted with the 'distances' of the single samples to the reference day
Days_to_the_closest_sample	dl	float32	the number of days (from the reference day) to the closest day with a measurement sample
Goodness_of_Fit	dl	float32	Quality parameter

Table 3-20: Bands in BRDF product

3.2.6 Merged BRDF Product

As output from the BBDR → BRDF processing chain, a final 'merged' BRDF product is generated. This product merges the two BRDF products for Snow/NoSnow pixels as

[4] Again, the uncertainty matrix is symmetric, therefore, only the UR sub-matrix is stored in the product.

described above into one product. The merged product serves as input for the final albedo retrieval as well as for the resampling and the mosaicking of the tile-based BRDF uncertainties into a global product. The contents of this merged product are the same as listed in Table 3-20.

Processing step	BBDR → BRDF
Naming convention	GlobAlbedo.brdf.merge.yyyyddd.<tile>.dim (e.g. GlobAlbedo.brdf.merge.2005129.h18v04.dim)
Storage	written to disk
Format	BEAM-DIMAP
Dimensions	MODIS tile size (1200x1200 pixels)
Number of bands in file	62
Size per file	~324MB
Amount of files	per 8-day period and per MODIS tile
Projection	MODIS Sinusoidal

Table 3-21: BRDF product characteristics

3.3 Final products

The final products consist of Albedo and BRDF products. Both tile-based products and global mosaics of albedos are part of the public dataset being delivered in the frame of the Globalbedo project. The BRDF products are an additional outcome of the Globalbedo processing chain, which however are not part of the public dataset.

3.3.1 Published Products

3.3.1.1 Albedo Product (tile-based)

As output from the BRDF → Albedo processing chain, final Albedo global products are generated on various temporal and spatial resolutions. The tile-based albedo derival is done on the merged BRDF inputs for all 8-day reference periods, the resampling and the mosaicking to global products is done in a second step (see next sections). The contents of a final albedo product are listed in Table 3-23.

Processing step	BRDF → Albedo
Naming convention	GlobAlbedo.albedo.yyyyddd.<tile>.dim (e.g. GlobAlbedo.albedo.2005129.h18v04.dim)
Storage	written to disk
Format	BEAM-DIMAP
Dimensions	MODIS tile size (1200x1200 pixels)

Number of bands in file	18
Size per file	~99MB
Amount of files	per 8-day period and per MODIS tile
Projection	MODIS Sinusoidal

Table 3-22: Albedo product characteristics

Table 3-23 gives an overview of the bands in the Albedo product.

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
DHR_<n> ; n=VIS,NIR,SW	dl	float32	Black-sky albedo in VIS, NIR and SW range. Total of 3 bands.
BHR_<n> ; n=VIS,NIR,SW	dl	float32	White-sky albedo in VIS, NIR and SW range. Total of 3 bands.
DHR_sigma<n> ; n=VIS,NIR,SW	dl	float32	Uncertainties of Black-sky albedo in VIS, NIR and SW range. Total of 3 bands.
BHR_sigma<n> ; n=VIS,NIR,SW	dl	float32	Uncertainties of White-sky albedo in VIS, NIR and SW range. Total of 3 bands.
Weighted_number_of_samples	dl	float32	number of measurement samples in the 8-day period, weighted with the 'distances' of the single samples to the reference day
Relative_Entropy	dl	float32	Relative Entropy
Goodness_of_Fit	dl	float32	Quality parameter
Snow_fraction	dl	float32	Snow fraction
Data_mask	dl	float32	Data mask
Solar_zenith_angle	deg	float32	Solar zenith angle

Table 3-23: Bands in Albedo product

3.3.1.2 Albedo Product (global)

After the resampling and mosaicking of the tile-based albedos, global albedo products are generated in BEAM-DIMAP format in the following temporal/spatial resolutions:

Temporal resolution	***Spatial resolution***	***Projections***	***Naming conventions***
8-days	5km	Plate Caree	GlobAlbedo.albedo.yyyyddd.05km.PC.dim
		Sinusoidal	GlobAlbedo.albedo.yyyyddd.05km.SIN.dim
	60km	Plate Caree	GlobAlbedo.albedo.yyyyddd.60km.PC.dim
		Sinusoidal	GlobAlbedo.albedo.yyyyddd.60km.SIN.dim
monthly	5km	Plate Caree	GlobAlbedo.albedo.yyyymm.05km.PC.dim

Temporal resolution	*Spatial resolution*	*Projections*	*Naming conventions*
		Sinusoidal	GlobAlbedo.albedo.yyyymm.05km.SIN.dim
	60km	Plate Caree	GlobAlbedo.albedo.yyyymm.60km.PC.dim
		Sinusoidal	GlobAlbedo.albedo.yyyymm.60km.SIN.dim

3.3.2 Additional products (unpublished)

3.3.2.1 BRDF Product (global)

After the resampling and mosaicking of the tile-based BRDF products, global BRDF products are generated in BEAM-DIMAP format: In this step, the BRDF uncertainties are resampled with an advanced algorithm using cross-dependencies of the covariance matrix elements (see section 6.3.1). The bands in this product are the same as listed in Table 3-20. They are generated in the following temporal/spatial:

Temporal resolution	*Spatial resolution*	*Projections*	*Naming conventions*
8-days	5km	Plate Caree	GlobAlbedo.brdf.yyyyddd.05km.PC.dim
		Sinusoidal	GlobAlbedo.brdf.yyyyddd.05km.SIN.dim
	60km	Plate Caree	GlobAlbedo.brdf.yyyyddd.60km.PC.dim
		Sinusoidal	GlobAlbedo.brdf.yyyyddd.60km.SIN.dim

3.4 fAPAR/LAI

As output from the Albedo → fAPAR/LAI processing chain, final fAPAR/LAI global products are generated on an 8-daily temporal resolution and at 3 spatial resolutions of 1km, 5km and 25km. The input albedo of 5km and 25km are generated from upscaled BRDF using “energy conservation” as the resampling method. The input bands from the albedo product are merged with the output (resulted fAPAR/LAI and their flags) into a single product. The contents of a fAPAR/LAI albedo product are listed in Table 3-25.

Processing step	Albedo → fAPAR/LAI		
Naming convention	GlobAlbedo.ECV_Fo.<resolution>km.yyyyddd.<tile>.nc (e.g. GlobAlbedo.ECV_Fo.25km.2005129.h18v04.nc)		
Storage	written to disk		
Format	NetCDF-3		
Spatial Resolution	1km	5km	25km
Dimensions	1200x1200	240x240	48x48
Size per file	~160MB	~7MB	~0.3MB
Number of bands in file	30 or 16 depending on whether no-snow is all the time		

Amount of files	per 8-day period and per MODIS tile
Projection	MODIS Sinusoidal

Table 3-24: fAPAR/LAI product characteristics

Table **3-24** gives an overview of the bands in the combined Albedo/fAPAR/LAI product.

NAME IN PRODUCT	UNIT	TYPE	DESCRIPTION
BHR_<n>_<m>; n=VIS,NIR,SW ; m=SNOW,NOSNOW	dl	float32	White-sky Snow and NoSnow albedo in VIS, NIR and SW Total of 6 bands.
BHR_sigma<n>_<m> ; n=VIS,NIR SW ; m=SNOW,NOSNOW	dl	float32	Uncertainties of White-sky Snow and NoSnow albedo in VIS, NIR and SW. Total of 6 bands.
BHR_alpha_VIS_NIR_<m> ; m=SNOW,NOSNOW	dl	float32	Correlation coefficient between NoSnow albedo of VIS and NIR Total of 2 bands.
BHR_<n>; n=VIS,NIR,SW	dl	float32	White-sky merged albedo in VIS, NIR and SW Total of 3 bands.
BHR_sigma<n> ; n=VIS,NIR,SW	dl	float32	Uncertainties of White-sky merged albedo in VIS, NIR and SW. Total of 3 bands.
BHR_alpha_VIS_NIR	dl	float32	Correlation coefficient between merged albedo of VIS and NIR Total of 1 band.
fapar_Fo	dl	float32	fAPAR value
sigma_fapar_Fo	dl	float32	Uncertainty of fAPAR
Lai_Fo	dl	float32	LAI value
sigma_Lai_Fo	dl	float32	Uncertainty of LAI
retrieval_flag_Fo	dl	Integer8	Retrieval quality
Snow_Fraction	dl	float32	Snow fraction
Data_mask	dl	Integer	Data mask
Lat	dl	Float32	Latitude
Lon	dl	float32	Longitude

Table 3-25: Bands in fAPAR/LAI product

The first three parameters in Table 3-25 are the input bands which have been subset from the GlobAlbedo product.

The values in “retrieval_flag_Fo” band indicate bit-coded quality flags as follows:

For the 1km product:

bit 1: albedo is fillvalue

bit 7: TIP solution not trusted, in which case FAPAR and LAI are set as fillvalue

bit 8: albedo out of valid range (i.e. one or more albedo values were below 0 or above 1)

For 5km and 25 km products:

bit 1: albedo is fillvalue

bit 2: BHR VIS < 0

bit 3: BHR VIS > 1

bit 4: BHR NIR < 0

bit 5: BHR NIR > 1

bit 6: TIP snow prior used

bit 7: TIP solution not trustworthy, in which case FAPAR and LAI are set as fillvalue

The fapar & LAI data were processed from input GlobAlbedo products and during the course of this processing a number of files were discovered missing from the BRDF dataset. These had to be regenerated which in the case of 2006 meant re-processing a substantial fraction of all the GA tiles from scratch.

The GA tile data needed to be subset into netCDF-3 subsets, loaded into a username/password protected sftp-pull location, pulled using a cron-job at FastOpt, processed and then ftp-pushed back to the UK. Although the process did work it took a huge amount of manual effort to organise all of these files which should be avoided in the future.

The overall schema is shown in Figure 3-3 below.

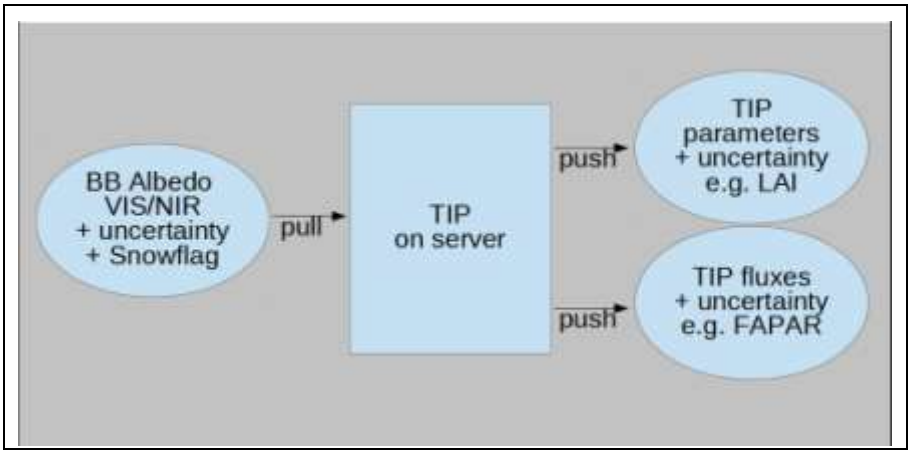

Figure 3-3. Processing schema for FastOpt production of fapar,LAI

4 Overview of the GlobAlbedo processing chain

This section provides a brief overview of the GlobAlbedo processing chain. More details on the design for the processing system architecture, system context/environment and a summary of the operations concept can be found in [RD-9].

The GlobAlbedo project aims at generating multi-sensor multi-annual global land surface albedo products. MERIS and SPOT-VGT level-1 data serves as input data to a processing chain. The function of the processing chain can be summarised as:

- processes each single input to some level in several processing steps
- accumulates at least one year of data for each 10º x 10º tile and then calculates products every 8 days as well as every month, as well as seasonal and annual products
- finally retrieves BRDF and albedo for each composite reporting time-step (every 8 days and every month, as well as seasonal and annual products).

Firstly, all inputs are systematically processed from L1 to surface directional reflectances (SDR). Figure 4-1 depicts this part of the processing chain.

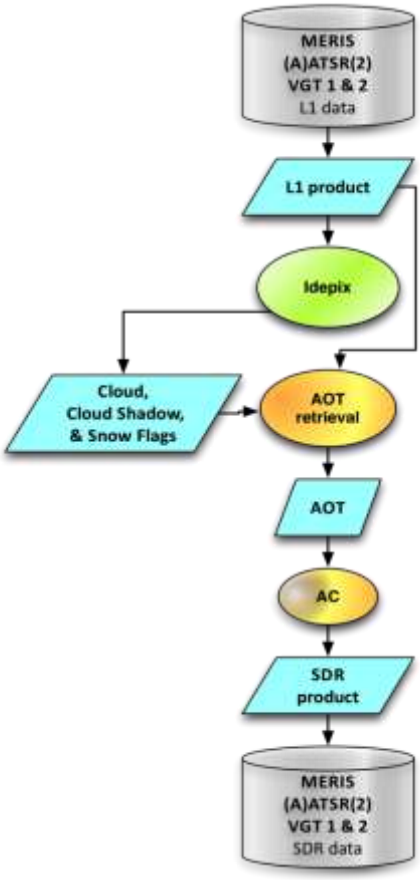

Figure 4-1: SDR retrieval from L1b Inputs for each orbit and sensor

The processing steps to retrieve SDRs are

- pixel classification for cloud, water, etc.. detection
- retrieval of aerosol optical thickness
- atmospheric correction using retrieved aerosol optical thickness

The results are SDR values in the same granularity as the inputs. They are not written to distinct products, but just kept in memory and used as input to the next part of the processing chain depicted in Figure 4-2, which is the broadband computation:

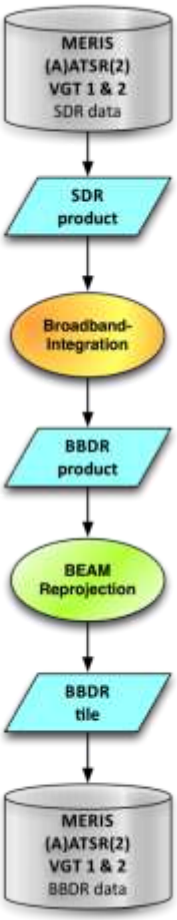

Figure 4-2: Broad band computation of BBDR from narrow band SDR

The processing steps are

- broad-band integration of these SDRs
- re-projection of these broad-band SDRs onto the MODIS Sinusoidal grid

The results of this step are re-projected broadband directional reflectances (BBDR) still in the granularity of the input products. During implementation it has been decided to store this intermediate product of BBDR tiles to disk, but to remove them subsequently after the BRDF computation (accumulation/inversion).

The third part of the chain depicted in Figure 4-3 finally generates the BRDF and albedo composites from the BBDRs.

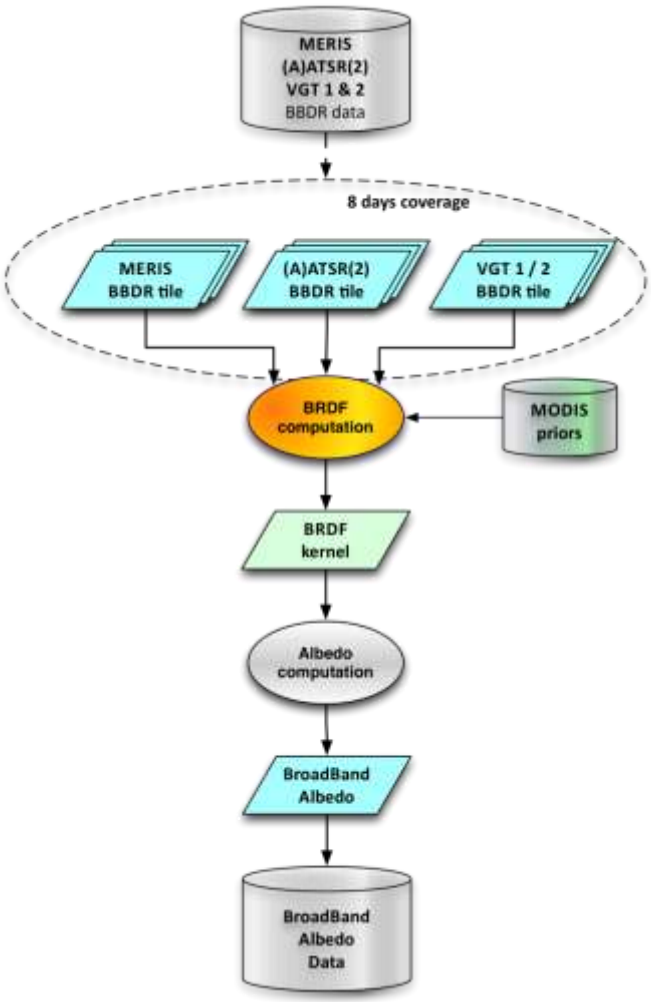

Figure 4-3: Generation of multi-sensor 8 day and monthly composites from BBDR inputs

The steps are:

- computation of BRDFs every 8-days and every month of the broad-band BBDRs from all sensors by accumulation method, using additional land cover mask information from Idepix
- computation of the albedo from these BRDFs

The final results are 8-day, monthly, seasonal and annual composites of broadband albedo.

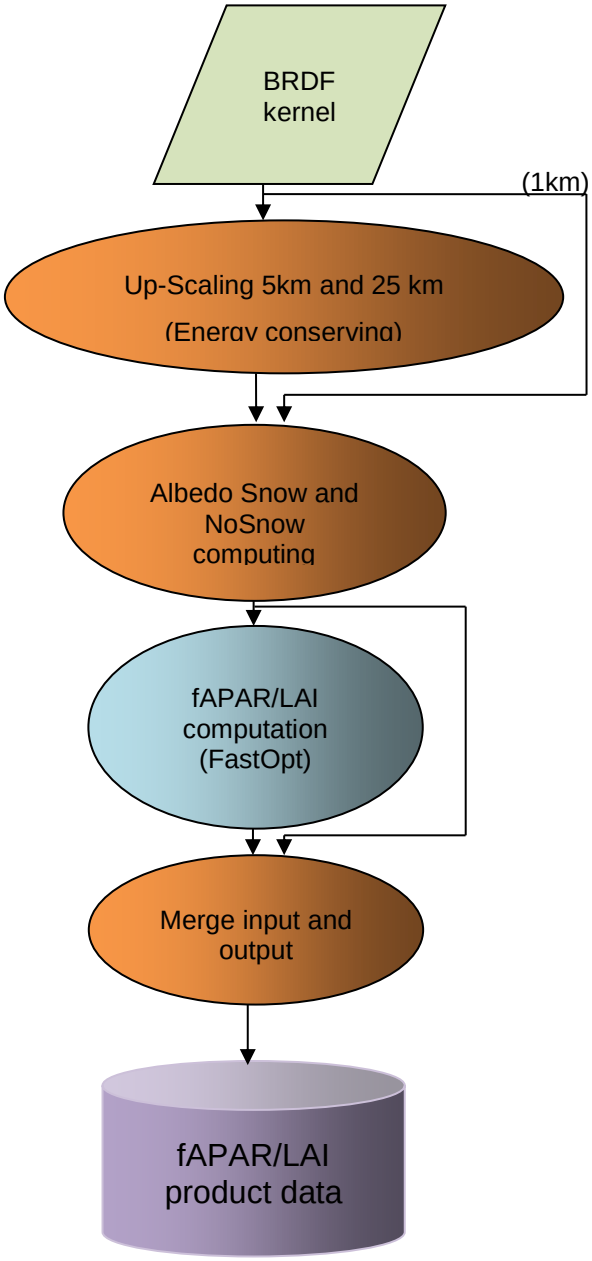

Figure 4-4: Generation of fAPAR/LAI 8 day composites from albedo inputs.

The steps are:

- Upscaling of 1km BRDFs to 5km and 25km
- Computation Snow and NoSnow Albedo for NIR and VIS
- Computation of fAPAR/LAI
- Merge input and output

The final results are 8-day fAPAR/LAI products with 3 spatial resolution: 1km, 5km and 25km.

5 Available Tools

BEAM is the Basic ERS & Envisat (A)ATSR and MERIS Toolbox and is a collection of executable tools and an application programming interface (API) which have been developed to facilitate the use, viewing and processing of data of various sensors. BEAM is used for the validation of the GlobAlbedo data.

As an entry point to get started with BEAM, see The BEAM project (http://www.brockmann-consult.de/cms/web/beam/).

6 The steps of the binning and merging schemes

6.1 BBDR reprojection to MODIS Sinusoidal grid

Most standard MODIS land products use this Sinusoidal grid tiling system. Tiles are 10 degrees by 10 degrees at the equator. The tile coordinate system starts at (0,0) (horizontal tile number, vertical tile number) in the upper left corner and proceeds right (horizontal) and downward (vertical). The tile in the bottom right corner is (35,17).

The Sinusoidal Projection has a unique sphere measuring 6371007.181 meters, longitude_of_center=0, false_easting=0 and false_northing=0.

The upper left corner is in projection coordinates, and identifies the very upper left corner of the upper left pixel of the image data.

The lower right corner identifies the very lower right corner of the lower right pixel of the image data.

An example for the full set of projection parameters is given below for the MODIS tile h18v04.

MODIS tile: h18v04

```
Size is 1200, 1200
Coordinate System is:
PROJCS["unnamed",
    GEOGCS["Unknown datum based upon the custom spheroid",
        DATUM["Not specified (based on custom spheroid)",
            SPHEROID["Custom spheroid",6371007.181,0]],
        PRIMEM["Greenwich",0],
        UNIT["degree",0.0174532925199433]],
    PROJECTION["Sinusoidal"],
    PARAMETER["longitude_of_center",0],
    PARAMETER["false_easting",0],
    PARAMETER["false_northing",0],
    UNIT["Meter",1]]
Origin = (0.000000000000000,5559752.598333000205457)
Pixel Size = (926.625433055833355,-926.625433055000258)

Corner Coordinates:
Upper Left  (       0.000, 5559752.598) (  0d 0'0.01"E, 50d 0'0.00"N)
```

```
Lower Left  (       0.000, 4447802.079) (  0d 0'0.01"E, 40d 0'0.00"N)
Upper Right ( 1111950.520, 5559752.598) ( 15d33'26.06"E, 50d 0'0.00"N)
Lower Right ( 1111950.520, 4447802.079) ( 13d 3'14.66"E, 40d 0'0.00"N)
Centre      (  555975.260, 5003777.339) (  7d 4'15.84"E, 45d 0'0.00"N)
```

6.2 Merge of BRDF Snow/NoSnow products

The BRDF products which are derived separately for Snow/NoSnow pixels are finally merged into one single product, applying a weighting with the number of samples in each product.

No spatial or temporal binning is applied in this step.

6.3 Reprojection and mosaicking of BRDF and albedo to global products

The BRDF and albedo tile-based products are finally reprojected and mosaicked to global products with various temporal and spatial resolutions onto Plate Caree and Sinusoidal projections, as outlined in chapter 2.

- The projections and the mosaicking are provided by the BEAM 'Mosaic' and 'Reprojection' plugins.
- The spatial resampling is provided by a nearest-neighbour algorithm
- The temporal resolutions are provided by simple averaging

6.3.1 Resampling and mosaicking of BRDF uncertainties to a global product

In principle, the BRDF uncertainties are resampled as described above. However, for the spatial resampling, an advanced BEAM reprojection tool has been developed as plugin, which applies an algorithm summarized as follows:

- The layers produced in the GlobAlbedo BRDF product to be resampled are:
  - The BRDF model parameters F, f_0, f_1 and f_2 for each broadband
  - The variance/covariance matrix M
  - Entropy
  - Relative entropy
  - Weighted number of samples
  - Number of days to the closest sample
  - Goodness of fit

- The resampling algorithm is different for the layers mentioned above. I.e., there are cross-dependencies between the various quantities:
  - The BRDF model parameters F resampling includes the associated uncertainty M to compute a scaled mean term F_t:

$$F_t = \left[\sum_{i=1}^{N} F_i M_i^{-1}\right]\left[\sum_{i=1}^{N} M_i^{-1}\right]^{-1}$$

- The scaled uncertainty matrix M_t will be calculated as:

$$M_t = \left[\sum_{i=1}^{N} M_i^{-1} \right]^{-1}$$

- The Entropy, Relative Entropy, Goodness of fit, Weighted number of samples are resampled using a nearest neighbour algorithm.
- The Number of days to the closest sample are resampled using a majority filter.

6.3.2 Step 5: generation of quicklooks (global-PNG)

Quicklooks of all products which are available in BEAM-Dimap format (i.e. the final global albedo products) can be generated by the 'Export view as image…' functionality of BEAM/Visat (see chapter 'Available Tools').

7 Appendices

7.1 Auxiliary data

7.1.1 The GMTED2010 DEM

The GMTED2010 digital elevation model has been provided by USGS Earth Resources Observation & Science (EROS) Center as a preliminary version for exclusive use in the Globalbedo project. GMTED2010 provides seven products generated at various resolutions. In Globalbedo, a resolution of 30 arc-seconds is used. For more details on the GMTED2010 see [RD 11].

This DEM with all its source files has been integrated as plugin into the BEAM software.

7.1.2 The MODIS „land tiles“ considered in the processing

The following listing of the auxiliary data file “Tiles_UpperLeftCorner_Coordinates.txt” shows the 324 “land tiles” considered in the Globalbedo processing.

Tilenumber, upperLeftX, upperLeftY

```
h00v08, -20015109.354, 1111950.520
h00v09, -20015109.354, 0.000
h00v10, -20015109.354, -1111950.520
h01v07, -18903158.834, 2223901.039
h01v08, -18903158.834, 1111950.520
h01v09, -18903158.834, 0.000
h01v10, -18903158.834, -1111950.520
h01v11, -18903158.834, -2223901.039
h02v06, -17791208.315, 3335851.559
h02v08, -17791208.315, 1111950.520
h02v09, -17791208.315, 0.000
h02v10, -17791208.315, -1111950.520
h02v11, -17791208.315, -2223901.039
h03v05, -16679257.795, 4447802.079
h03v06, -16679257.795, 3335851.559
h03v07, -16679257.795, 2223901.039
h03v08, -16679257.795, 1111950.520
h03v09, -16679257.795, 0.000
h03v10, -16679257.795, -1111950.520
h03v11, -16679257.795, -2223901.039
h04v05, -15567307.275, 4447802.079
```

h04v09, -15567307.275, 0.000
h04v10, -15567307.275, -1111950.520
h04v11, -15567307.275, -2223901.039
h05v10, -14455356.756, -1111950.520
h05v11, -14455356.756, -2223901.039
h05v13, -14455356.756, -4447802.079
h06v03, -13343406.236, 6671703.118
h06v11, -13343406.236, -2223901.039
h07v03, -12231455.716, 6671703.118
h07v05, -12231455.716, 4447802.079
h07v06, -12231455.716, 3335851.559
h07v07, -12231455.716, 2223901.039
h08v03, -11119505.197, 6671703.118
h08v04, -11119505.197, 5559752.598
h08v05, -11119505.197, 4447802.079
h08v06, -11119505.197, 3335851.559
h08v07, -11119505.197, 2223901.039
h08v08, -11119505.197, 1111950.520
h08v09, -11119505.197, 0.000
h08v11, -11119505.197, -2223901.039
h09v02, -10007554.677, 7783653.638
h09v03, -10007554.677, 6671703.118
h09v04, -10007554.677, 5559752.598
h09v05, -10007554.677, 4447802.079
h09v06, -10007554.677, 3335851.559
h09v07, -10007554.677, 2223901.039
h09v08, -10007554.677, 1111950.520
h09v09, -10007554.677, 0.000
h10v02, -8895604.157, 7783653.638
h10v03, -8895604.157, 6671703.118
h10v04, -8895604.157, 5559752.598
h10v05, -8895604.157, 4447802.079
h10v06, -8895604.157, 3335851.559
h10v07, -8895604.157, 2223901.039
h10v08, -8895604.157, 1111950.520

h10v09, -8895604.157, 0.000
h10v10, -8895604.157, -1111950.520
h10v11, -8895604.157, -2223901.039
h11v01, -7783653.638, 8895604.157
h11v02, -7783653.638, 7783653.638
h11v03, -7783653.638, 6671703.118
h11v04, -7783653.638, 5559752.598
h11v05, -7783653.638, 4447802.079
h11v06, -7783653.638, 3335851.559
h11v07, -7783653.638, 2223901.039
h11v08, -7783653.638, 1111950.520
h11v09, -7783653.638, 0.000
h11v10, -7783653.638, -1111950.520
h11v11, -7783653.638, -2223901.039
h11v12, -7783653.638, -3335851.559
h12v01, -6671703.118, 8895604.157
h12v02, -6671703.118, 7783653.638
h12v03, -6671703.118, 6671703.118
h12v04, -6671703.118, 5559752.598
h12v05, -6671703.118, 4447802.079
h12v07, -6671703.118, 2223901.039
h12v08, -6671703.118, 1111950.520
h12v09, -6671703.118, 0.000
h12v10, -6671703.118, -1111950.520
h12v11, -6671703.118, -2223901.039
h12v12, -6671703.118, -3335851.559
h12v13, -6671703.118, -4447802.079
h13v01, -5559752.598, 8895604.157
h13v02, -5559752.598, 7783653.638
h13v03, -5559752.598, 6671703.118
h13v04, -5559752.598, 5559752.598
h13v08, -5559752.598, 1111950.520
h13v09, -5559752.598, 0.000
h13v10, -5559752.598, -1111950.520
h13v11, -5559752.598, -2223901.039

h13v12, -5559752.598, -3335851.559
h13v13, -5559752.598, -4447802.079
h13v14, -5559752.598, -5559752.598
h14v01, -4447802.079, 8895604.157
h14v02, -4447802.079, 7783653.638
h14v03, -4447802.079, 6671703.118
h14v04, -4447802.079, 5559752.598
h14v09, -4447802.079, 0.000
h14v10, -4447802.079, -1111950.520
h14v11, -4447802.079, -2223901.039
h14v14, -4447802.079, -5559752.598
h14v15, -4447802.079, -6671703.118
h14v16, -4447802.079, -7783653.638
h14v17, -4447802.079, -8895604.157
h15v01, -3335851.559, 8895604.157
h15v02, -3335851.559, 7783653.638
h15v03, -3335851.559, 6671703.118
h15v05, -3335851.559, 4447802.079
h15v07, -3335851.559, 2223901.039
h15v11, -3335851.559, -2223901.039
h15v14, -3335851.559, -5559752.598
h15v15, -3335851.559, -6671703.118
h15v16, -3335851.559, -7783653.638
h15v17, -3335851.559, -8895604.157
h16v00, -2223901.039, 10007554.677
h16v01, -2223901.039, 8895604.157
h16v02, -2223901.039, 7783653.638
h16v05, -2223901.039, 4447802.079
h16v06, -2223901.039, 3335851.559
h16v07, -2223901.039, 2223901.039
h16v08, -2223901.039, 1111950.520
h16v09, -2223901.039, 0.000
h16v12, -2223901.039, -3335851.559
h16v14, -2223901.039, -5559752.598
h16v16, -2223901.039, -7783653.638

h16v17, -2223901.039, -8895604.157
h17v00, -1111950.520, 10007554.677
h17v01, -1111950.520, 8895604.157
h17v02, -1111950.520, 7783653.638
h17v03, -1111950.520, 6671703.118
h17v04, -1111950.520, 5559752.598
h17v05, -1111950.520, 4447802.079
h17v06, -1111950.520, 3335851.559
h17v07, -1111950.520, 2223901.039
h17v08, -1111950.520, 1111950.520
h17v10, -1111950.520, -1111950.520
h17v12, -1111950.520, -3335851.559
h17v13, -1111950.520, -4447802.079
h17v15, -1111950.520, -6671703.118
h17v16, -1111950.520, -7783653.638
h17v17, -1111950.520, -8895604.157
h18v00, 0.000, 10007554.677
h18v01, 0.000, 8895604.157
h18v02, 0.000, 7783653.638
h18v03, 0.000, 6671703.118
h18v04, 0.000, 5559752.598
h18v05, 0.000, 4447802.079
h18v06, 0.000, 3335851.559
h18v07, 0.000, 2223901.039
h18v08, 0.000, 1111950.520
h18v09, 0.0000000, 0.0000000
h18v14, 0.000, -5559752.598
h18v15, 0.000, -6671703.118
h18v16, 0.000, -7783653.638
h18v17, 0.000, -8895604.157
h19v00, 1111950.520, 10007554.677
h19v01, 1111950.520, 8895604.157
h19v02, 1111950.520, 7783653.638
h19v03, 1111950.520, 6671703.118
h19v04, 1111950.520, 5559752.598

h19v05, 1111950.520, 4447802.079
h19v06, 1111950.520, 3335851.559
h19v07, 1111950.520, 2223901.039
h19v08, 1111950.520, 1111950.520
h19v09, 1111950.520, 0.000
h19v10, 1111950.520, -1111950.520
h19v11, 1111950.520, -2223901.039
h19v12, 1111950.520, -3335851.559
h19v15, 1111950.520, -6671703.118
h19v16, 1111950.520, -7783653.638
h19v17, 1111950.520, -8895604.157
h20v01, 2223901.039, 8895604.157
h20v02, 2223901.039, 7783653.638
h20v03, 2223901.039, 6671703.118
h20v04, 2223901.039, 5559752.598
h20v05, 2223901.039, 4447802.079
h20v06, 2223901.039, 3335851.559
h20v07, 2223901.039, 2223901.039
h20v08, 2223901.039, 1111950.520
h20v09, 2223901.039, 0.000
h20v10, 2223901.039, -1111950.520
h20v11, 2223901.039, -2223901.039
h20v12, 2223901.039, -3335851.559
h20v13, 2223901.039, -4447802.079
h20v15, 2223901.039, -6671703.118
h20v16, 2223901.039, -7783653.638
h20v17, 2223901.039, -8895604.157
h21v01, 3335851.559, 8895604.157
h21v02, 3335851.559, 7783653.638
h21v03, 3335851.559, 6671703.118
h21v04, 3335851.559, 5559752.598
h21v05, 3335851.559, 4447802.079
h21v06, 3335851.559, 3335851.559
h21v07, 3335851.559, 2223901.039
h21v08, 3335851.559, 1111950.520

h21v09, 3335851.559, 0.000
h21v10, 3335851.559, -1111950.520
h21v11, 3335851.559, -2223901.039
h21v13, 3335851.559, -4447802.079
h21v15, 3335851.559, -6671703.118
h21v16, 3335851.559, -7783653.638
h21v17, 3335851.559, -8895604.157
h22v01, 4447802.079, 8895604.157
h22v02, 4447802.079, 7783653.638
h22v03, 4447802.079, 6671703.118
h22v04, 4447802.079, 5559752.598
h22v05, 4447802.079, 4447802.079
h22v06, 4447802.079, 3335851.559
h22v07, 4447802.079, 2223901.039
h22v08, 4447802.079, 1111950.520
h22v09, 4447802.079, 0.000
h22v10, 4447802.079, -1111950.520
h22v11, 4447802.079, -2223901.039
h22v13, 4447802.079, -4447802.079
h22v14, 4447802.079, -5559752.598
h22v15, 4447802.079, -6671703.118
h22v16, 4447802.079, -7783653.638
h23v01, 5559752.598, 8895604.157
h23v02, 5559752.598, 7783653.638
h23v03, 5559752.598, 6671703.118
h23v04, 5559752.598, 5559752.598
h23v05, 5559752.598, 4447802.079
h23v06, 5559752.598, 3335851.559
h23v07, 5559752.598, 2223901.039
h23v08, 5559752.598, 1111950.520
h23v09, 5559752.598, 0.000
h23v10, 5559752.598, -1111950.520
h23v11, 5559752.598, -2223901.039
h23v15, 5559752.598, -6671703.118
h23v16, 5559752.598, -7783653.638

h24v01, 6671703.118, 8895604.157
h24v02, 6671703.118, 7783653.638
h24v03, 6671703.118, 6671703.118
h24v04, 6671703.118, 5559752.598
h24v05, 6671703.118, 4447802.079
h24v06, 6671703.118, 3335851.559
h24v07, 6671703.118, 2223901.039
h24v10, 6671703.118, -1111950.520
h24v12, 6671703.118, -3335851.559
h24v15, 6671703.118, -6671703.118
h25v02, 7783653.638, 7783653.638
h25v03, 7783653.638, 6671703.118
h25v04, 7783653.638, 5559752.598
h25v05, 7783653.638, 4447802.079
h25v06, 7783653.638, 3335851.559
h25v07, 7783653.638, 2223901.039
h25v08, 7783653.638, 1111950.520
h25v09, 7783653.638, 0.000
h26v02, 8895604.157, 7783653.638
h26v03, 8895604.157, 6671703.118
h26v04, 8895604.157, 5559752.598
h26v05, 8895604.157, 4447802.079
h26v06, 8895604.157, 3335851.559
h26v07, 8895604.157, 2223901.039
h26v08, 8895604.157, 1111950.520
h27v03, 10007554.677, 6671703.118
h27v04, 10007554.677, 5559752.598
h27v05, 10007554.677, 4447802.079
h27v06, 10007554.677, 3335851.559
h27v07, 10007554.677, 2223901.039
h27v08, 10007554.677, 1111950.520
h27v09, 10007554.677, 0.000
h27v10, 10007554.677, -1111950.520
h27v11, 10007554.677, -2223901.039
h27v12, 10007554.677, -3335851.559

h27v14, 10007554.677, -5559752.598
h28v03, 11119505.197, 6671703.118
h28v04, 11119505.197, 5559752.598
h28v05, 11119505.197, 4447802.079
h28v06, 11119505.197, 3335851.559
h28v07, 11119505.197, 2223901.039
h28v08, 11119505.197, 1111950.520
h28v09, 11119505.197, 0.000
h28v10, 11119505.197, -1111950.520
h28v11, 11119505.197, -2223901.039
h28v12, 11119505.197, -3335851.559
h28v13, 11119505.197, -4447802.079
h28v14, 11119505.197, -5559752.598
h29v03, 12231455.716, 6671703.118
h29v05, 12231455.716, 4447802.079
h29v06, 12231455.716, 3335851.559
h29v07, 12231455.716, 2223901.039
h29v08, 12231455.716, 1111950.520
h29v09, 12231455.716, 0.000
h29v10, 12231455.716, -1111950.520
h29v11, 12231455.716, -2223901.039
h29v12, 12231455.716, -3335851.559
h29v13, 12231455.716, -4447802.079
h30v04, 13343406.236, 5559752.598
h30v05, 13343406.236, 4447802.079
h30v06, 13343406.236, 3335851.559
h30v07, 13343406.236, 2223901.039
h30v08, 13343406.236, 1111950.520
h30v09, 13343406.236, 0.000
h30v10, 13343406.236, -1111950.520
h30v11, 13343406.236, -2223901.039
h30v12, 13343406.236, -3335851.559
h30v13, 13343406.236, -4447802.079
h31v04, 14455356.756, 5559752.598
h31v06, 14455356.756, 3335851.559

h31v07, 14455356.756, 2223901.039
h31v08, 14455356.756, 1111950.520
h31v09, 14455356.756, 0.000
h31v10, 14455356.756, -1111950.520
h31v11, 14455356.756, -2223901.039
h31v12, 14455356.756, -3335851.559
h31v13, 14455356.756, -4447802.079
h32v07, 15567307.275, 2223901.039
h32v08, 15567307.275, 1111950.520
h32v09, 15567307.275, 0.000
h32v10, 15567307.275, -1111950.520
h32v11, 15567307.275, -2223901.039
h32v12, 15567307.275, -3335851.559
h33v07, 16679257.795, 2223901.039
h33v08, 16679257.795, 1111950.520
h33v09, 16679257.795, 0.000
h33v10, 16679257.795, -1111950.520
h33v11, 16679257.795, -2223901.039
h34v07, 17791208.315, 2223901.039
h34v08, 17791208.315, 1111950.520
h34v09, 17791208.315, 0.000
h34v10, 17791208.315, -1111950.520
h35v08, 18903158.834, 1111950.520
h35v09, 18903158.834, 0.000
h35v10, 18903158.834, -1111950.520

7.1.3 Aerosol retrieval auxiliary files

For the aerosol retrieval within the L1b → BBDR processing, various auxiliary files are used.

7.1.3.1 o3Correction.asc

```
****************************************
* ozone correction factors
* X-Axis = Band Name
* Y1-Axis = Center Wavelength [nm]
* Y2-Axis = CorrFactor [1/DU]
****************************************
M1 412.5 0.000000e+00
M2 442.5 -5.073870e-06
M3 490 -3.792850e-05
M4 510 -7.784970e-05
M5 560 -1.994800e-04
M6 620 -2.116200e-04
M7 665 -9.882330e-05
M8 681.25 -6.746320e-05
M9 708.75 -3.661590e-05
M10 753.75 -1.780230e-05
M11 760.625 -1.349160e-05
M12 778.75 0.000000e+00
M13 865 0.000000e+00
M14 885 0.000000e+00
M15 900 0.000000e+00
A1 555 -1.833610e-04
A2 659 -1.089980e-04
A3 865 0.000000e+00
A4 1610 0.000000e+00
B0 450 -8.005070e-06
B2 645 -1.503790e-04
B3 835 0.000000e+00
MIR 1665 0.000000e+00
```

7.1.3.2 DARKVEG.asc

```
*********************************************************************
* File created by WinSpec 1.27 (23.04.08) on 30.01.2011 at 19:10:40
*********************************************************************
* 1: Data read from file
P:\JAVA\GLOBALBEDO1\SRC\MAIN\RESOURCES\ORG\ESA\BEAM\GLOBALBEDO\SDR\OPERA
TORS\SURFACE_REFLECTANCE_SPEC.ASC
* 2: y-axis: 0.0099999998 subtracted
*********************************************************************
*********************************************************************
*********************************************************************
* File created by WinSpec 1.27 (23.04.08) on 14.05.2010 at 21:13:04
*********************************************************************
* This file contains the spectra of
* surface reflectances for
* bare soil and vegetation
* for the aerosol retrieval
*********************************************************************
*********************************************************************
* X-Axis =  Wavlength [um]
* Y-Axis = Vegetation Reflectance (PROSPECT leaf)
*********************************************************************
  0.4000  4.27000E-02
  0.4010  4.28000E-02
  0.4020  4.29000E-02
  0.4030  4.30000E-02
  0.4040  4.31000E-02
  0.4050  4.32000E-02
  0.4060  4.32400E-02
  0.4070  4.32800E-02
  0.4080  4.33200E-02
  0.4090  4.33600E-02
  0.4100  4.34000E-02
  0.4110  4.35200E-02
  0.4120  4.36400E-02
```

```
  0.4130  4.37600E-02
  0.4140  4.38800E-02
```

……

…….many more lines…

…….

```
  2.4816  2.42080E-02
  2.4828  2.40640E-02
  2.4840  2.39200E-02
  2.4852  2.36800E-02
  2.4864  2.29600E-02
  2.4876  2.22400E-02
  2.4888  2.15200E-02
  2.4900  2.08000E-02
  2.4912  2.07520E-02
  2.4924  2.07040E-02
  2.4936  2.06560E-02
  2.4948  2.06080E-02
  2.4960  2.06600E-02
  2.4972  2.07320E-02
  2.4984  2.08040E-02
  2.4996  2.08760E-02
```

7.1.3.3 LOWBLUEVEG.asc

```
*******************************************************************
* File created by WinSpec 1.27 (23.04.08) on 02.02.2011 at 13:59:03
*******************************************************************
* 1: Data read from file
P:\JAVA\GLOBALBEDO1\SRC\MAIN\RESOURCES\ORG\ESA\BEAM\GLOBALBEDO\SDR\OPERA
TORS\SURFACE_REFLECTANCE_SPEC.ASC
* 2: y-axis: added trace
P:\JAVA\GLOBALBEDO1\SRC\MAIN\RESOURCES\ORG\ESA\BEAM\GLOBALBEDO\SDR\OPERA
TORS\SURFACE_REFLECTANCE_SPEC.ASC
*******************************************************************
*******************************************************************
*******************************************************************
* File created by WinSpec 1.27 (23.04.08) on 14.05.2010 at 21:13:04
*******************************************************************
* This file contains the spectra of
* surface reflectances for
* bare soil and vegetation
* for the aerosol retrieval
*******************************************************************
*******************************************************************
* X-Axis =  Wavlength [um]
* Y-Axis = Vegetation Reflectance (PROSPECT leaf)
*******************************************************************
  0.4000  4.27000E-02
  0.4010  4.28377E-02
  0.4020  4.29755E-02
  0.4030  4.31132E-02
  0.4040  4.32509E-02
  0.4050  4.33887E-02
  0.4060  4.34664E-02
  0.4070  4.35442E-02
  0.4080  4.36219E-02
  0.4090  4.36996E-02
  0.4100  4.37774E-02
```

```
  0.4110  4.39351E-02
  0.4120  4.40928E-02
  0.4130  4.42506E-02
  0.4140  4.44083E-02
  0.4150  4.45660E-02
  0.4160  4.46638E-02
  0.4170  4.47615E-02
  0.4180  4.48592E-02
  0.4190  4.49570E-02
  0.4200  4.50547E-02
  0.4210  4.51925E-02
  0.4220  4.53302E-02
```

……

…….many more lines…

…….

```
  2.4852  3.36800E-02
  2.4864  3.29600E-02
  2.4876  3.22400E-02
  2.4888  3.15200E-02
  2.4900  3.08000E-02
  2.4912  3.07520E-02
  2.4924  3.07040E-02
  2.4936  3.06560E-02
  2.4948  3.06080E-02
  2.4960  3.06600E-02
  2.4972  3.07320E-02
  2.4984  3.08040E-02
  2.4996  3.08760E-02
```

7.1.3.4 surface_reflectance_spec.asc

```
**********************************************************************
* File created by WinSpec 1.27 (23.04.08) on 14.05.2010 at 21:13:04
**********************************************************************
* This file contains the spectra of
* surface reflectances for
* bare soil and vegetation
* for the aerosol retrieval
**********************************************************************
* X-Axis = Wavlength [um]
* Y1-Axis = Bare Soil Reflectance
* Y2-Axis = Vegetation Reflectance (PROSPECT leaf)
* Y3-Axis = dark Veg
* Y4-Axis = high blue Veg
* Y5-Axis = low blue Veg
* Y6-Axis = fake baret
**********************************************************************
  0.4000  3.56770E-02  5.27000E-02  4.27000E-02   6.27000E-02  4.27000E-
02  6.55658E-02
  0.4010  3.79130E-02  5.28000E-02  4.28000E-02   6.27623E-02  4.28377E-
02  6.59290E-02
  0.4020  3.88400E-02  5.29000E-02  4.29000E-02   6.28245E-02  4.29755E-
02  6.63765E-02
  0.4030  4.10500E-02  5.30000E-02  4.30000E-02   6.28868E-02  4.31132E-
02  6.68857E-02
  0.4040  4.10440E-02  5.31000E-02  4.31000E-02   6.29491E-02  4.32509E-
02  6.74355E-02
  0.4050  4.10650E-02  5.32000E-02  4.32000E-02   6.30113E-02  4.33887E-
02  6.80059E-02
  0.4060  4.11020E-02  5.32400E-02  4.32400E-02   6.30136E-02  4.34664E-
02  6.85783E-02
  0.4070  4.72390E-02  5.32800E-02  4.32800E-02   6.30158E-02  4.35442E-
02  6.91458E-02
  0.4080  4.81080E-02  5.33200E-02  4.33200E-02   6.30181E-02  4.36219E-
02  6.97124E-02
  0.4090  4.72320E-02  5.33600E-02  4.33600E-02   6.30204E-02  4.36996E-
02  7.02819E-02
```

```
  0.4100  4.72360E-02  5.34000E-02  4.34000E-02   6.30226E-02  4.37774E-
02  7.08573E-02
  0.4110  4.81080E-02  5.35200E-02  4.35200E-02   6.31049E-02  4.39351E-
02  7.14405E-02
  0.4120  4.89670E-02  5.36400E-02  4.36400E-02   6.31872E-02  4.40928E-
02  7.20325E-02
  0.4130  4.89630E-02  5.37600E-02  4.37600E-02   6.32694E-02  4.42506E-
02  7.26329E-02
  0.4140  5.07170E-02  5.38800E-02  4.38800E-02   6.33517E-02  4.44083E-
02  7.32404E-02
  0.4150  5.15880E-02  5.40000E-02  4.40000E-02   6.34340E-02  4.45660E-
02  7.38532E-02
  0.4160  5.15650E-02  5.40600E-02  4.40600E-02   6.34562E-02  4.46638E-
02  7.44697E-02
  0.4170  5.24410E-02  5.41200E-02  4.41200E-02   6.34785E-02  4.47615E-
02  7.50885E-02
  0.4180  5.43100E-02  5.41800E-02  4.41800E-02   6.35008E-02  4.48592E-
02  7.57087E-02
  0.4190  5.60740E-02  5.42400E-02  4.42400E-02   6.35230E-02  4.49570E-
02  7.63298E-02
  0.4200  5.61780E-02  5.43000E-02  4.43000E-02   6.35453E-02  4.50547E-
02  7.69515E-02
  0.4210  5.61130E-02  5.44000E-02  4.44000E-02   6.36075E-02  4.51925E-
02  7.75738E-02
  0.4220  5.79460E-02  5.45000E-02  4.45000E-02   6.36698E-02  4.53302E-
02  7.81964E-02
  0.4230  5.78240E-02  5.46000E-02  4.46000E-02   6.37321E-02  4.54679E-
02  7.88191E-02
```

.....

.....many more lines...

.....

```
2.4840  3.96840E-01  3.39200E-02  2.39200E-02   3.39200E-02  3.39200E-02
3.96816E-01
  2.4852  3.96364E-01  3.36800E-02  2.36800E-02   3.36800E-02  3.36800E-
02  3.96477E-01
  2.4864  3.95949E-01  3.29600E-02  2.29600E-02   3.29600E-02  3.29600E-
02  3.96168E-01
  2.4876  3.95656E-01  3.22400E-02  2.22400E-02   3.22400E-02  3.22400E-
02  3.95908E-01
  2.4888  3.95499E-01  3.15200E-02  2.15200E-02   3.15200E-02  3.15200E-
02  3.95705E-01
```

2.4900 3.95443E-01 3.08000E-02 2.08000E-02 3.08000E-02 3.08000E-02 3.95556E-01

2.4912 3.95438E-01 3.07520E-02 2.07520E-02 3.07520E-02 3.07520E-02 3.95445E-01

2.4924 3.95412E-01 3.07040E-02 2.07040E-02 3.07040E-02 3.07040E-02 3.95355E-01

2.4936 3.95333E-01 3.06560E-02 2.06560E-02 3.06560E-02 3.06560E-02 3.95269E-01

2.4948 3.95224E-01 3.06080E-02 2.06080E-02 3.06080E-02 3.06080E-02 3.95181E-01

2.4960 3.95092E-01 3.06600E-02 2.06600E-02 3.06600E-02 3.06600E-02 3.95090E-01

2.4972 3.94948E-01 3.07320E-02 2.07320E-02 3.07320E-02 3.07320E-02 3.95002E-01

2.4984 3.94799E-01 3.08040E-02 2.08040E-02 3.08040E-02 3.08040E-02 3.94926E-01

2.4996 3.94645E-01 3.08760E-02 2.08760E-02 3.08760E-02 3.08760E-02 3.94926E-01

7.1.3.5 SYNSURFREFLSPEC.asc

```
**********************************************************************
* File created by WinSpec 1.27 (23.04.08) on 28.01.2011 at 14:45:50
**********************************************************************
* 1: Data read from file
E:\PROJECTS\SYNERGY\AARDVARC\SPECS\SPEC_SOIL.DAT
**********************************************************************
**********************************************************************
* X-Axis = 41  0.002962
* Y-Axis =
* Y2-Axis =
**********************************************************************
  0.4100  2.96200E-03  2.64870E-02
  0.4200  8.29400E-03  2.99890E-02
  0.4300  1.33620E-02  3.09780E-02
  0.4400  2.11990E-02  3.17180E-02
  0.4500  2.69790E-02  3.55860E-02
  0.4600  3.00120E-02  3.63220E-02
  0.4700  3.15920E-02  3.65750E-02
  0.4800  3.74240E-02  3.67400E-02
  0.4900  3.83600E-02  3.69510E-02
  0.5000  4.66150E-02  4.01530E-02
  0.5100  5.30070E-02  4.82820E-02
  0.5200  6.22970E-02  6.69150E-02
  0.5300  6.76550E-02  8.60220E-02
  0.5400  7.40600E-02  9.41360E-02
  0.5500  7.98650E-02  9.72910E-02
  0.5600  8.78580E-02  9.49470E-02
  0.5700  9.55170E-02  8.19700E-02
  0.5800  9.70930E-02  7.14520E-02
  0.5900  1.02501E-01  6.44740E-02
  0.6000  1.05026E-01  6.28670E-02
  0.6100  1.10097E-01  5.93240E-02
  0.6200  1.16173E-01  5.57860E-02
```

0.6300	1.20793E-01	5.31740E-02
0.6400	1.24954E-01	4.90860E-02
0.6500	1.30759E-01	4.38700E-02
0.6600	1.34534E-01	4.15780E-02
0.6700	1.43684E-01	3.90690E-02
0.6800	1.45707E-01	3.89700E-02
0.6900	1.52575E-01	4.90190E-02
0.7000	1.59370E-01	9.13790E-02
0.7100	1.64812E-01	1.63718E-01
0.7200	1.74484E-01	2.54559E-01
0.7300	1.73969E-01	3.72036E-01
0.7400	1.83543E-01	4.96435E-01
0.7500	1.85832E-01	6.00737E-01
0.7600	1.87629E-01	6.60214E-01
0.7700	1.95256E-01	6.78318E-01
0.7800	1.96716E-01	6.87648E-01
0.7900	2.02828E-01	6.93670E-01
0.8000	2.08378E-01	6.97340E-01
0.8100	2.13163E-01	7.00283E-01
0.8200	2.13075E-01	7.04529E-01
0.8300	2.17401E-01	7.02740E-01
0.8400	2.16785E-01	7.06344E-01
0.8500	2.22887E-01	7.07888E-01
0.8600	2.20324E-01	7.04440E-01
0.8700	2.24022E-01	7.04296E-01
0.8800	2.24442E-01	7.01953E-01
0.8900	2.25243E-01	7.05887E-01
0.9000	2.26217E-01	7.05305E-01
0.9100	2.28427E-01	7.04206E-01
0.9200	2.29972E-01	7.01151E-01
0.9300	2.33815E-01	6.97079E-01
0.9400	2.35440E-01	6.90606E-01
0.9500	2.38647E-01	6.79567E-01
0.9600	2.40916E-01	6.60502E-01
0.9700	2.46565E-01	6.57557E-01

0.9800	2.47000E-01	6.59765E-01
0.9900	2.50759E-01	6.58722E-01
1.0000	2.53432E-01	6.66854E-01
1.0100	2.53785E-01	6.72135E-01
1.0200	2.55613E-01	6.80411E-01
1.0300	2.58609E-01	6.88467E-01
1.0400	2.59606E-01	6.94065E-01
1.0500	2.65426E-01	6.95417E-01
1.0600	2.67396E-01	6.98622E-01
1.0700	2.68240E-01	6.98425E-01
1.0800	2.71922E-01	6.99018E-01
1.0900	2.74274E-01	6.98040E-01
1.1000	2.76229E-01	6.92267E-01