GlobAlbedo Requirements Baseline

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ISSUE	DATE	PAGES CHANGED	COMMENTS
1.1	11/01/10	All new	First Issue
1.2	29/05/10	Revisions	Updates based on PM1 RIDs

CONTENTS

1 Introduction

This document relates to Task 1 of the ITT (RD-1) and I quote

"*…consolidated set of user requirements for:*

- *Albedo product definition, including precise definition of information content and format, spatial and time resolutions, map projections, spectral ranges, accuracies, definition of quality flags and uncertainty statistics, etc.*
- *Product validation, including the possible use of existing ground measurements*
- *Product delivery*"

These user requirements were captured using 2 mechanisms;

- Attendance at the Kick-off meeting and presentation of these requirements with subsequent face-to-face discussions
- Completion of a questionnaire, mostly in closed-format (i.e. select from a series of putative answers, themselves defined by the pre-SoW release inputs and the KO meeting summaries)

Where contradictions or conflicts have arisen these are discussed and justification provided as to why a particular decision was made.

In addition to the 6 GlobAlbedo users who were identified in the KO meeting and are listed below, one further user responded on behalf of the UK Met Office (Samatha Pullen). Another user from KNMI (Dutch Met service) responded to say that they were not interested in any of the products from GlobAlbedo as their model required albedo at two specific wavelengths (0.6 and 1.6 micron). KNMI provided another possible user from the Finnish Meteorological Institute but this information was received too late to be acted on. No response was received from ECMWF.

Name	**Affiliation**	**Main interests**	**Project participation**
Wolfgang **Knorr**	QUEST University of Bristol	Assimilation of albedo in Carbon cycle models	Yes, especially in Phase 3
Alexander **Loew**	Max-Planck Institüt für Meteorologie, Hamburg	Climate research (global and regional) Earth System modelling, Water, energy and carbon fluxes Remote sensing of the Earth system	Yes, especially in Phase 3

Gunnar **Mryhe**	CICERO Oslo	Using satellite data to improve understanding of the impact on the climate of land use changes	Yes, especially in Phase 3
Samantha **Pullen**	UK Met Office, Exeter	assimilation of land surface parameters in the NWP models	No time to participate more actively but liaising with C. Taylor
Jean-Louis **Roujean**	Météo-France, Toulouse	To implement a procedure of optimum analysis (assimilation) of an advanced global albedo product to evaluate the impact on weather forecast	Yes (and host meeting)
Sonia **Seneviratne**	ETH Zurich	"Land-Climate Interactions" research group Modelling, field measurements, and data analysis (ground observations and remote sensing data)	Yes, especially in Phase 3
Christopher **Taylor**	CEH Wallingford	data assimilation of the new albedo within the Met Office HadGAM model, and examination of the impacts of the revised albedo fields on forecasts.	Yes, especially in Phase 3

2 Applicable and Reference documents

2.1.1 Applicable documents

AD1 European Cooperation for Space Standardization: Space Engineering Software, ECSS-E-ST-40C (6 March 2009), available from http://www.ecss.nl

2.1.2 Reference Documents

RD1 EOEP-DUEP-EOPS-SW-09-0001 SoW Statement of Work for DUE-GlobAlbedo Project, Version 1.0, April 2009

Brandt, R., Warren, S., Worby, A., Grenfell, T.C. Surface albedo of the Antarctic sea ice zone. J Climate (2005) vol. 18 pp. 3606-3622

Laine, V. Antarctic ice sheet and sea ice regional albedo and temperature change, 1981-2000, from AVHRR Polar Pathfinder data. Remote sensing of environment (2008) vol. 112 pp. 646-667

3 Acronyms and Abbreviations

3.1 Acronyms

Item	Definition
AD	Applicable document
AERONET	Aerosol Robotic Network
AR	Acceptance Review
ARM	US Atmospheric Radiation Measurement program
ATBD	Algorithm theoretical basis document
ATD	Acceptance Test Document
ATSR	Along-track scanning radiometer (ESA)
AATSR	Advanced ATSR (ESA)
BHR	Bi-hemispherical reflectance
BRDF	Bi-directional reflectance distribution function
BRF	Bi-directional reflectance factor
BSRN	Baseline surface radiation network
CDR	Critical Design Review
COTS	Commercial off-the-shelf (software packages)
CTIV	Centre de Traitement des Images VEGETATION
DGVM	Dynamic global vegetation model
DUE	Data User Element of the ESA Earth Observation Envelope Programme
ECSS	European Cooperation for Space Standardization
EO	Earth observation
FAPAR	Fraction of absorbed photosynthetically active radiation
FTP	File Transfer Protocol
GCM	General circulation model
GSA	Geostationary Meteorological Albedo
HDF	Hierarchical Data Format
HDRF	Hemispherical-directional reflectance factor
IPCC	Intergovernmental Panel on Climate Change
ITT	Invitation to tender
KO	Project kick-off
LAI	Leaf area index
LTO	Linear Tape-Open (magnetic media standard)
MERIS	Medium resolution imaging spectrometer (ESA)
MISR	Multiangle imaging Spectroradiometer (NASA)
MODIS	Moderate resolution imaging spectroradiometer (NASA)
NetCDF	Network Common Data Format
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical weather prediction
OLCI	Ocean and land colour instrument
PDF	Probability density function
PDR	Preliminary Design Review
PM	Progress meeting

PNG	Portable Network Graphics
PUG	Product User Guide
QA	Quality assessment
QR	Qualification Review
RB	Requirements Baseline document
RD	Reference document
RID	Review item discrepancy
SLSTR	Sea and land surface temperature radiometer
SoW	Statement of Work
SUM	Software User Manual
SURFRAD	Surface Radiation Network
SVP	Software Validation Plan
TOA	Top of atmosphere
TR	Technical requirement
TS	Technical Specification document
UCM	User consultation meeting
URL	Uniform resource locator

3.2 Abbreviations

4 System context

4.1 Use Case Exemplar

A number of Use Cases were provided at the KO meeting. However, one of the most straight-forward to understand is presented here.

In the case where land surface albedo is employed to parameterise a NWP (Numerical Weather Prediction Model), the effects of using different albedo sources on the NWP forecast accuracy can be quantitatively assessed.

An example kindly provided by Jean-Louis Roujean highlights the impact of employing the METEOESAT SAF albedo product on improving the prediction of land surface temperature in a nested mesoscale model. Figure 4-1 shows an example of this for 6 months of forecasts of LST taken from a forthcoming publication (Cedilnik, Carrer, Roujean and Mahfouf, “Analysis of satellite derived surface albedo for numerical weather prediction, in preparation). Areas along the Mediterranean coast show biases in the existing forecasts of up to 1ºC which are eliminated using the satellite albedo data.

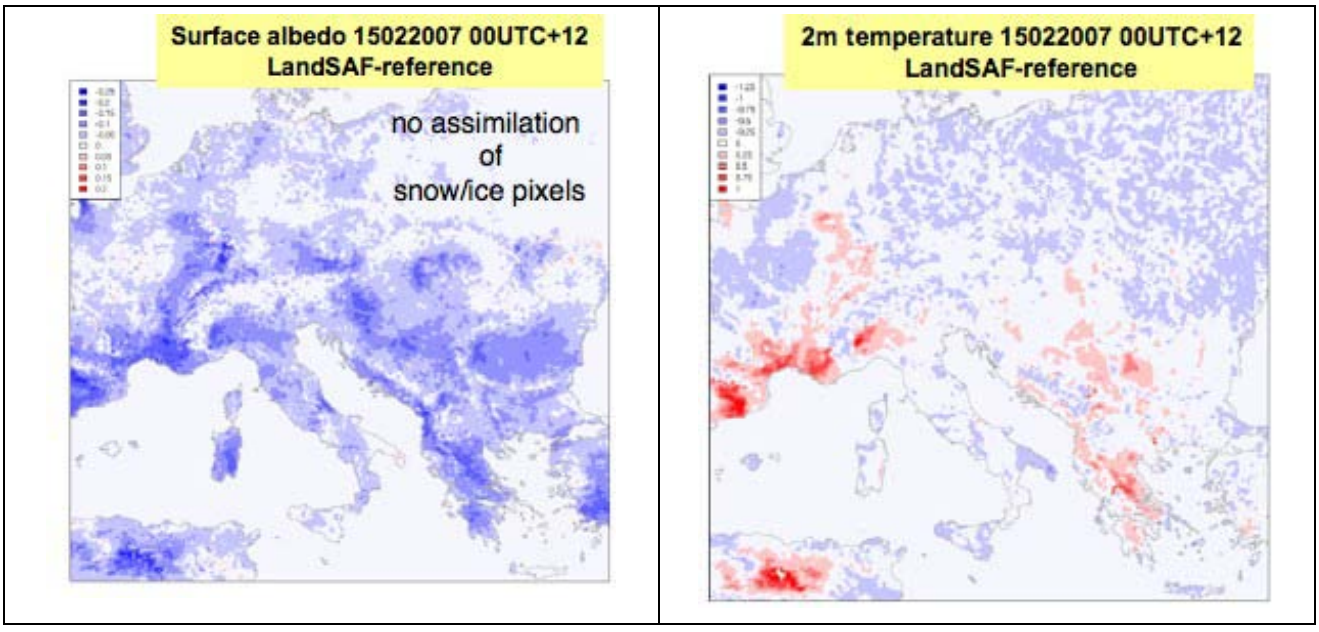

Figure 4.1-1: Comparison of LANDSAF albedo minus reference for 9.5km ALADIN forecast for

4.2 Design Constraints

Where users provided unrealistic requirements, such as sea-ice albedos, these have been identified in the questionnaire responses. However, although the users were requested to quantify the importance of these requirements, none was forthcoming so it is not possible

to assess the significance of these requirements on the impact of the use of the GlobAlbedo products.

5 Requirements

5.1 Review Requirements Baseline Document

No single document was produced except as part of the SoW which listed all of the user requirements. Instead, a series of completed questionnaires were provided by ESA to the contractor prior to KO together with a web-site linked to the presentations made at the 24/9/08 GlobAlbedo UR workshop held at ESRIN[1] which the author himself also attended. The SoW (RD-1) lists 84 technical requirement (TR), some of which come from these user requirements but the vast majority of which come from whoever wrote the SoW. A subset of these were taken from the proposal in which they were again listed but this time with feedback from the GlobAlbedo team and users were asked to indicate their importance and add in any relevant comments (see Annex 1, section 2).

5.2 User Requirements

These have been captured from the requested inputs to the slide presentations made by the users in the relevant section of the KO meeting followed up by a series of mostly closed-form questions to discover, for example, which of the formats proposed were the main priorities so that these requirements could be summarised.

5.2.1 Products

The Globalbedo product is required to be produced in 3 broadband intervals:

PAR: 0.3-0.7µm

NIR: 0.7-3 µm

SW: 0.3-3 µm

Two versions of the product should be produced, one incorporating snow using the majority voting rule employed by MODIS and the other, a so-called snowfree product.

Temporal sampling of either 8 or 16-days is preferred as well as a 30-day product. Both DHR ("black-sky" albedo) and BHR (Bi-directional Hemispherical diffuse Reflectance) are required to be produced.

DHR needs to be integrated over the daylight portion of the day and a separate DHR is required for solar noon for other users.

An estimated uncertainty is required for each output pixel. It did not appear to be relevant how this was expressed (bias and RMS or bias and 3 standard deviations) so long as it is consistent. One of the users (see Annex 1 for full answers) suggested that "The uncertainty should be for the time window used (which would be 16 days here). The value of the uncertainty should be differentiated by conditions of observations (change of resolution, cloudiness, view and sun angle, aerosol load…)". Another user provided an example drawn from the MSG Land-SAF led by Météo-France which is reproduced below.

[1] http://dup.esrin.esa.it/news/news170.asp

SAF on Land Surface Analysis (LSA)

Product-Identifier	Product Name	Product acronym	Product type (product, software, dataset)	Characteristics and Methods	Input Satellite data	Dissemination type (NRT/off-l)	Dissemination Means	Format	Timeliness	spatial coverage	generation frequency	spatial resolution	threshold accuracy	target accuracy	optimal accuracy	Verification method	applications and users	expected start of operation resp. availability
LSA-01	MSG Daily Surface Albedo	MDAL	product	5-day composites of spectral & broad-band AL	MSG	NRT/off line	EUMETCast /web	HDF5	3 h	MSG disk	1 day	MSG pixel resolution	20%	AL>0.15: 20% AL<0.15: 0.03	7.5%	BSRN data / MODIS AL	NWP; Carbon-models; Climate monitoring	Sep 05
LSA-02	MSG 10-day Surface Albedo	MTAL	product	30-day composites of spectral & broad-band AL	MSG	NRT/off line	EUMETCast /web	HDF5	3 h	MSG disk	1 day	MSG pixel resolution	20%	AL>0.15: 10% AL<0.15: 0.015	5%	BSRN data / MODIS AL	NWP; Carbon-models; Climate monitoring	Dec 07
LSA-03	EPS Surface Albedo	EAL	product	30-day composites of spectral & broad-band AL	EPS	NRT/off line	EUMETCast /web	HDF5	3 h	Europe & High Latitudes	1 day	0.01° x 0.01°	20%	AL>0.15: 10% AL<0.15: 0.015	5%	BSRN data / MODIS AL	NWP; Carbon-models; Climate monitoring	Oct 08

Figure 5.2-1: Example taken from the LAND-SAF of accuracy requirements.

Only one user for MSG SEVIRI operational product defined an acceptable accuracy range (Météo-France) which is shown in the figure above (albedo>0.15, 20% and for albedo<0.15, 0.015). No other user provided such a hard boundary.

GlobAlbedo should flag so-called “permanent snow/ice” regions and use an appropriate flag for “snow-free” albedo. One user suggested the use of the IEEE NaN in a snow-free product. There is a clear user requirement for a daily snow flag. However, the GlobAlbedo 16-day time window would only indicate whether the majority of the days within the window were snow-free and snow-covered.

The climate and meteorological users wanted sea-ice but recognised that this activity would need to be funded from elsewhere. The land community thought that sea-ice was surplus to their needs. Subsequent research of the literature (Brandt et al., 2005, Laine, 2008) determined that sea-ice albedo had a significant impact on global climate forecasts and that knowledge was limited to date to AVHRR. Unfortunately, no quantification of these sea-ice requirements is provided in the literature at this time.

Climate and weather forecasters required Plate Carrée (equal latitude-longitude) whereas all other users required an equal area projection. The MODIS SIN equal area projection was acceptable as some users had already invested significant effort in using this.

5.2.2 Output Product Format Specifications

There was general agreement that netCDF data format should be available for all products. Whatever the output format employed, estimated uncertainty as well as pixel flags are required on a per pixel basis along with the estimated albedo values.

5.2.3 Expected Impact

The GlobAlbedo product is expected to have a significant impact on NWP forecast skill, climate model assessment (for hindcasts) as well as the quantification of the impact of albedo changes on the global climate system and hence on sustainability.

6 System Requirements

6.1 Hardware

The software development will be made on the system that will be finally delivered to ESA. This will comprise a state of the art workstation with sufficient storage attached to host the demonstration data set (one year of input products), and all products generated during processing, including intermediate and final products.

6.2 Software

The Globalbedo processing system is the software that is capable of transforming SPOT-VGT, MERIS, ATSR-2 and AATSR input data into the Globalbedo output products. This requires

- the management of all input, auxiliary, intermediate and output products,
- the correct execution of the scientific processing steps and
- the effective usage of the available hardware resources.

The Globalbedo processing system will be a highly modular and unsynchronised system. In particular, the scientific processing modules (cloud screening, atmospheric correction, BRDF correction) will be self-standing executables that will be called by the processing management system. However, the modularisation goes much further in order to achieve the requested high performance of the system. The specific hardware on which the system runs will be described in configuration tables. This makes the system flexible to be deployed on different platforms. This fulfils the requirement that the processing system needs to be run in the different Globalbedo processing centres as well as on the demonstration platform that is delivered to ESA. Also a future transfer of the system to a different hardware platform and service provider is feasible by defining the proper configuration.

6.3 Performance

Fifteen years of input GlobAlbedo level 1b products should be processed within 3 months from level 1b to SDR to BBA. This will be performed using a distributed processing system with nodes at UCL, SU and FUB.

6.4 User Interface Requirements

Products should be available in the desired output format (NetCDF) either via FTP, http, WCS. They should be user-selectable in terms of date-range, geographical extent (from single pixels to small groups of pixels to GIS cut-outs using masks) and estimated uncertainty ranges. A web-GIS should be employed for display of the products but products should use OGC standards so that they can be inter-operable with other products and processes.

7 Integration at ESA

7.1 Infrastructure requirements at ESA

The target example linux system to be delivered to ESA will not require remote access for version updates and error tests. Any such updates will be done manually.

8 Changes from the SoW

The principal change introduced here after user consultation is that products are required to be distributed online rather than on LT optical media as proposed in the SoW.

Annex 1

This consists of the user questionnaire which was sent out, a summary of responses on the first section and a collation of responses on the different importance of different TRs.

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British Computer Society 1990 Technical Award Winner for "3D Image Maker"

British Multimedia Association 1993 Award for "Best European Multimedia Product" for Erd-sicht Global Change Videodisk

Melia 1995 Award for "Best Reference CD-ROM" for 3D Atlas (©EA/UCL/UCL 1994)

NASA Distinguished Group Achievement Award for the NASA MISR Instrument (2001) and EOS Aqua platform (2003)

Putative ESA GlobAlbedo USer 16 December 2009

Dear Colleague

Re: GlobAlbedo Baseline User Requirements: Questionnaire

Two deliverables are required to be prepared for the PDR (Preliminary Design Review) due for completion during the week before. These are due to be presented on 18/1/10 at the PDR:

Baseline Requirements

Technical Specification

The current section headings of these two reports are shown in Annex A. The ITT lists 82 Technical Requirements (TR) and the objective of this questionnaire is to elicit your opinions on the relative importance of these 82 TRs (see part 2).

Please complete this questionnaire and return your results by email to jpm@mssl.ucl.ac.uk by NOON UTC on Wednesday, 6/1/10. Please also email me a phone number where you can be reached on Friday, 8/1/10 from 14-17hrs UTC to follow up on any queries.

The Kick-off meeting highlighted a number of issues which have been discussed within the GlobAlbedo consortium. We would like you to spend a short time completing this questionnaire, preferably using a coloured font (such as red). We very much would value your comments as well.

Please do not hesitate to contact me if you require any further information.

Yours sincerely

(Prof.) Jan-Peter Muller

PI, ESA GlobAlbedo

ESA GlobAlbedo User Requirements Survey

Name:

Affiliation

1. Albedo definition

TR-##	Background	Question(s)	Your answer
85	Globalbedo is proposed to be produced in 3 broadband intervals: PAR: 04.-0.7 NIR: 0.7-3 SW: 0.4-3µm	(i) Are these the spectral ranges of choice? (ii) If not, why not? (iii) If not, what would you rather see and why?	---------- ---------- ---------- -----
86	DHR is usually reported at noon	Would DHR integrated over the daylight portion of the day meet your needs? If so, why? If not, why not?	
87	Albedo will be output with an estimated uncertainty.	What is your absolute albedo accuracy requirement (bias and RMS or bias and 3 sigma)? Why is this the case? Please provide a publication with justification for your requirement. Should this globally averaged value for 1km be for a specific time window? If yes, what time window (8-day, 16-day, other) If not, specify.	
88	User requirements suggest that a snowfree and snowbound albedo be produced.	what should GlobAlbedo do with permanent snow/ice for “snow-free” albedo?	
87	Sea-ice is the most dramatic	If separate and	

	example of surface albedo changes.	additional funds were available, how important would sea-ice albedo be to your application? Quantify, if possible, its contribution.	
88	Albedo will be produced in a user defined projection system	What is your preferred map projection system? Would you like to see a MODIS SIN projection employed? If not, why not?	
89	It has been proposed that a temporal weighting function focused on every 8 days with a monthly derived by interpolation and seasonal and annual ones derived therefrom. GlobAlbedo has an option of reporting that focused albedo or reporting a mean albedo over a particular time period with a lower uncertainty.	What would you prefer regarding focused albedo or reporting a mean albedo over a particular time period with a lower uncertainty?	
90	GlobAlbedo proposes that any output products will be in BEAM-DIMAP format (similar to ENVI) with export tools available in BEAM for different standards	What about your preferred format: netCDF, HDF5, graDS, EASI, bufR? Any other formats?	

Section 2. Clarification of previously assigned Technical Requirements by ESA

Please assess the importance of EACH TRL (5 is v important)

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
1	A multi-sensor multi-annual global land surface albedo data set shall be created			
2	GlobAlbedo products shall be (spatially) gap-free			Cosmetic fill to be used. Use of models such as employed by MODIS offered as an enhancement option as this is not possible within the budget guidelines.
3	Lower resolution time- and space-composited products shall contain appropriate data quality information			
4	Quicklooks of all products shall be provided in PNG format			Available on web-pages
5	DHR products shall additionally be reported via the set of parameter values entering the best-fit BRF model			
6	A complete set of the broadband GlobAlbedo products shall be delivered to ESA and to each User Group member			Hard disks will be provided instead of LT-03 tapes. This will save considerable costs especially the need for users to purchase LT-3 tape drives.
7	A full set of single sensor spectral albedo products shall be retained and made available as a product on request to specialist users			If it is decided to create a single set of broadband albedos directly from BRFs, this product will not be produced. This will no longer be provided.
8	Lower resolution product versions shall include statistical information on the albedo			It is proposed to include: mean, median, var, min, max, number of used pixels, number of gap filled pixels
9	GlobAlbedo products shall be consistent with MODIS & MISR albedo			MODIS & MISR products come in HDF-4 and that is their ONLY common property.

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	products			MISR are produced daily, monthly, 3-monthly or annually whereas MODIS are produced every 8 days.
10	All albedo values shall be supplied with a quantitative uncertainty estimate per pixel			
11	Product quality flags and uncertainties shall be reported per pixel.			
12	Detections of snow-affected surface reflectances shall be reported on a daily basis.			Number of snow-free days will be given.
13	Ancillary product layers shall be provided as appropriate			
14	Information allowing the validation of the quality of the atmospheric correction procedures shall be reported as ancillary information			Only PDF available to avoid creating unrealistically sized products
15	Higher level albedo products shall be provided, based on post-processing of the main GlobAlbedo data set			Requires ESA to provide input land cover map of plant functional types. Monthly albedos will be based on retrieving monthly values rather than pro rata manipulation of 16-day values. This will be one of the USPs of the GlobAlbedo product
16	The albedo products shall include other Glob products as ancillary layers as well as derived NDVI and FPAR from the BRFs			NDVI and FPAR will only be calculated from averaged SBRFs if there is a single inversion from all 3 sensor BRFs to 3 broadband albedos. Glob products require that a common format be available for all these products which is not currently the case. BC are working on Glob inter-operability.
17	If the chosen retrieval produces instrument-specific albedo			Will expand the dataset sizes considerably

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	products prior to the merging step, then both instrument-specific and multi-sensor merged albedo products shall be delivered.			
18	A standard set of continental subsets of the GlobAlbedo products shall be produced and delivered to users.			
19	An analysis shall be made of any statistically significant long term trends in albedo over the full GlobAlbedo time series			This analysis will be performed by the users within the third year of the project.
20	A GlobAlbedo Product User Guide shall be provided both on the web and in hardcopy form			
21	GlobAlbedo products shall be provided in a standard format (e.g., netCDF, HDF)			
22	A GlobAlbedo web portal shall be set up and maintained for at least the duration of the project			
23	A tool shall be provided to allow users to re-project the standard products onto a common set of map projections			Already available within BEAM
24	The necessary algorithm and sample code allowing users to estimate the DHR and uncertainty at any solar zenith angle shall be provided			
25	Prototype and test products shall be generated for a test			

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	year, nominally 2005			
	Algorithm and Processing Requirements			
26	The main input data shall comprise the full time series of ATSR-2, AATSR, MERIS, VEGETATION-1 and VEGETATION-2 data			Both ATSR-2 and AATSR and VGT-1 and VGT-2 have overlap periods. Additional to requirements, some instrument overlap period data will be processed to verify continuity and intercalibration.
27	The input product level shall be Level-1B orbits at ~ 1 km resolution.			
28	Where instrument swaths overlap at high latitude, reflectances shall be derived from all available data			
29	The use of SPOT-VEGETATION or ESA data shall be acknowledged in all product documentation			
	General Characteristics of the Retrieval Algorithm & Processing System			
30	Retrievals shall be performed at the highest globally available resolution of each sensor			
31	The retrieval algorithm adopted to remove the atmospheric contamination shall benefit as much as possible from modern inverse techniques such as those based on optimal control theory (*e.g.* optimal estimation).			Optimal estimation framework will be implemented, based on development of existing MERIS/AATSR surface reflectance algorithm and extension to SPOT-VGT.
32	Full use shall be made of the (A)ATSR dual-view capability in the atmospheric correction			Full use made by inverse modelling, allowing robust retrieval of aerosol and surface reflectance over all

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	method and/or to maximise angular sampling of the HDRF			land covers. Surface reflectance at both (A)ATSR angles available for angular sampling, but degradation caused by difference in spatial resolution and misregistration need to be evaluated for 1km albedo estimates.
33	The retrieval of surface reflectances shall be optimised and performed for each sensor separately			Enhancement offer to include BRFs as deliverables
34	Uncertainties shall be quantitatively propagated from all input measurements (*e.g.* TOA radiances) though to the final albedo products.			Full end-to-end error budget will be provided.
	SNOW			
35	The retrieval of surface reflectances shall identify and report the presence of snow for each (single sensor) 1 km pixel.			Special snow detection is performed for each sensor, exploiting the differences in absorption between snow and clouds in the NIR and SWIR part.
36	An additional test for snow shall be made by analyzing the spectral properties of surface reflectances which are identified as outliers during each accumulation period.			Part of the BRDF retrieval. Could be cloud rather than snow as there are insufficient bands for MERIS and VEGETATION to provide unique identification.
37	When snow is detected during the accumulation period, but snow conditions do not dominate, then the albedo shall be derived from the set of non-snowy reflectances.			An corresponding algorithm will be part of the time and space compositing.
	Atmospheric Correction			
38	The retrieval of surface reflectances shall eliminate to the maximum extent			Atmospheric correction method based on accurate radiative transfer model, and simultaneous retrieval of

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	possible atmospheric contamination of the signal			aerosol.
39	Aerosol, or radiatively equivalent aerosol properties, may be retrieved from the input Level-1B TOA radiances or from standard products from the same sensor.			Aerosol estimates will be made from Level-1B data, avoiding biases introduced by use of a priori assumptions on absolute land surface reflectance.
40	Cloud screening algorithms shall be optimised to make the best use of the capabilities of each individual instrument and applied at Level-1B			
41	An additional test for cloud shall be made by analyzing the spectral properties of the surface reflectances that are identified as outliers			Part of the atmospheric correction via the cost function.
42	For pixels which seem to be cloud-free, the retrieval shall check whether cloud is detected in nearby pixels			Pixel nearby clouds will be rejected to reduce probability of sub-pixel clouds and adjacency effects
43	Pixels affected by cloud shadows shall be flagged.			See TR 42. Additionally cloud shadow will be estimated using CTH and viewing geometry
44	GlobAlbedo shall take into account any relevant results from the ESA project on "MERIS/AATSR Synergy			Members of the consortium participate in and lead SYNERGY; knowledge and code will be transferred to GlobAlbedo on cloud detection and atmospheric correction.
	Calculation of the Spectral Albedo from the Surface Reflectances			
45	the calculation of surface albedo shall necessarily be based			This will be decided on the conduct of experiments as none of the European sensors

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	on sequential time-accumulation of surface reflectance values with a goal of 16 days but no longer than a month			have 16-day repeat (ERS and ENVISAT have 35 days). Also, if a moving window approach is adopted, it my be feasible to provide every 8 days
46	The Contractor shall investigate trade-offs between using a sequential accumulation versus a running accumulation window.			This may be sensor/platform specific as VEGETATION is likely to have the best BRDF sampling of all 3 sensors and MERIS the worst.
47	Estimation of the BRF from the time accumulated set of surface reflectances shall be performed using a parametric BRF model, such as the kernel-based or RPV family			Experience with kernel-based brought to bear. Also, easier to downscale products with linear kernel cf non-linear RPV
48	The method of angular and spectral integration of the BRF model to provide broadband values of the DHR and the BHRiso shall propagate the uncertainties from the surface reflectances to the final albedo values			
49	A back-up retrieval shall be implemented for those cases where the set of multi-angular surface reflectances acquired during the accumulation period is insufficient to constrain the free parameters of the BRF model			
50	Where no observations at all are available during the accumulation period, pixels shall be filled using information from, *e.g.* a climatology, or the nearest available backup or full inversion			
51	Additional tests for the			

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	presence of snow and cloud contamination shall be made by analysing the distribution of outliers when fitting the time-accumulated surface reflectances to the BRF model			
52	The retrieval method shall be robust and reliable, such that the proportion of retrieval failures is negligible			This will have to be on a “best efforts” basis as we cannot see how this can be guaranteed!
53	Albedo products shall be generated as independently as possible from geophysical information derived from non-European satellite sensors			
	Spectral Integration			
54	The spectral integrations required to estimate the broadband visible, near-infrared and shortwave albedo values from sensors with different sets of narrow bands shall be performed consistently across instruments, *i.e.*, they shall be derived from one single modelling protocol.			We will use the radiative transfer code MOMO only and exactly the same cases for each instrument and broadband calculations.
	Merging			
55	At least two strategies for merging albedos shall be tested, including merging albedo products directly, and merging reflectances during the process of fitting the BRDF model per pixel and per accumulation period.			

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	Time and Space Compositing			
56	The time and space compositing procedures shall preserve as much as possible the integrity of the retrieved broadband surface albedo values.			
57	The temporal compositing algorithm shall analyze the albedo distribution and reject outliers as appropriate before building the final statistics.			
58	Uncertainties in the composited products shall be derived from the uncertainties in the daily 1 km albedos.			
	Quality Assessment Requirements			
59	A series of statistical comparisons shall be made against the data sets available from geostationary and polar orbiters satellites			
60	The albedo products shall be validated by comparison against ground-measured vegetation phenological cycles over a range of test sites			Only data available in the public domain will be employed as there are insufficient funds to commission data from other sites
61	A third set of QA procedures shall be based on the exploitation of existing *in-situ* and airborne radiation and albedo measurements to provide quantitative assessment			
62	The fourth set of QA procedures concerns			Only limited examples are feasible within the budget

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	the assessment of the performances of the cloud screening, snow detection and aerosol removal algorithms.			constraints
63	The QA shall include an analysis of the quality of the uncertainty statistics.			
64	The QA investigations shall assess the long term consistency of the GlobAlbedo products			Also part of the science activities
65	GlobAlbedo data set shall be intercompared with albedo data sets commonly used in NWP climate modelling			MPI will include GlobAlbedo datasets in the climate model ECHAM/JSBACH
	Scientific Exploitation			
66	The utility of the GlobAlbedo data set shall be demonstrated by performing a study that scientifically exploits the data set.			
67	A Scientific Exploitation Plan will be produced according to the specifications provided			
68	The Scientific Exploitation shall include, as a direct result of the work performed, the submission of a scientific paper to an appropriate peer reviewed journal			This will form one part of an overall publication plan.
	Data Processing System: General considerations			
69	A fully working version of the software (source code, compilation and configuration systems, documentation, ancillary data sets, COTS, pre-compiled			The software will be installed on a dedicated HW system at Brockmann Consult; this will already be used during the development phase for testing. The server will be delivered to ESA.

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	libraries, *etc.*) installed on a minimum (see [TR-84]) set of hardware shall be delivered to ESA [D-22] at QR and AR			
70	The delivered system shall include a 12 month warranty starting from the date of successful completion of the AR.			
	Data Processing System: Design and Implementation			
71	The data processing system shall be developed following the ECSS standards			We will apply an agile SW development process, that is in use at BC and that complies with the ECSS standard.
72	The data processing software shall be designed to run under the Linux operating system on PC machines with Intel or AMD processors, and compatible with both 32-bit and 64-bit systems.			Only 64-bit will be used as global products cannot be produced using 32-bit architecture
73	As the main focus of GlobAlbedo is not software development, but the production of EO based data products satisfying end user needs, the re-use of existing software components and COTS is encouraged.			No COTS available
74	The delivered system shall operate as a stand-alone system.			
75	The data processing software shall be designed in a modular way			The Globalbedo processing system will be composed at high level into the scientific processors, which run stand-alone, and the processing system, that binds these together and controls the

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
				production.
76	Each module of the data processing software shall be deployed as an independent executable			See [TR-75]
77	The breakdown of the data processing software architecture design into low level functions/routines shall achieve the level of granularity required to facilitate maintenance and bug tracking.			We apply software quality assurance at three levels: (1) the code will be developed test driven. (2) the system will be tested continuously during the development phase using QFS automation tools; (3) end to end tests are performed after system integration.
78	It shall be possible to install updated versions of the data processing software components or dynamic libraries without generating a new complete version of the system.			We will use the BEAM module manager functionality.
79	Hard definition of parameters in function development shall be avoided. Exceptions shall be processed to customer agreement.			All configuration parameters will be externally stored in XML configuration files.
	Data Processing System: Software Operations Requirements			
80	The behaviour of each software module shall be defined by means of ASCII configuration files. These configuration files shall allow the user to define all parameters pertaining to each module.			A much more complex system will be required for production processing. However, this is what will be delivered and ESA should be aware it will not allow global products to be generated without massive manual intervention.
81	A batch processing capability shall be provided. The data processing software shall be operated using initialization files that			This is the basic idea of the Globalbedo processing system.

TR-#	Technical Requirement	Priority (0-5)	Importance cf terrestrial acceptance	GlobAlbedo Comment
	contain all user provided information needed to run a process. Batch processing shall be possible via creation and execution of a series of script files.			
82	The data processing system shall be designed such that processing occurs automatically, with minimal operator intervention.			This is the basic idea of the Globalbedo processing system.
	Data Processing System: Software Operations Requirements			
83	The performance of the data processing system (algorithms, software and hardware) used to generate the FPS [D-19] shall be sufficient to process all products within six months of real time.			Aim is 2 months so re-processing can take place.
84	The delivered system [D-22] shall be capable of automatically processing and merging at least one full month of input data from any one of the sensors listed in Table 2, within 120 hours of real time.			

Table 1. List of Technical Requirements, their compliance and commentary.

Annex A. Structure of the Baseline Requirements and Technical Specifications

Task 1

[D-1] KO + 2 Requirements Baseline Document

1. Introduction
    a. Purpose and Scope
    b. Definition, Acronyms and Abbreviations
2. Documents
    a. Referenced Documents
    b. Applicable Documents
3. System context
    a. Use Case Diagram
    b. Design Constraints
4. Requirements
    a. Review Requirements Baseline Document
    b. User Requirements
        i. Products
        ii. Output Product Format Specification
        iii. Expected Impact
5. System Requirements
    a. Hardware
    b. Software
    c. Performance
    d. User Interface Requirements
6. Integration at ESA
    a. Infrastructure requirements at ESA

[D-2] KO + 2 Technical Specification Document

1. Introduction
    b. Purpose and Scope
    c. Definition, Acronyms and Abbreviations
2. Documents
    a. Referenced Documents
    b. Applicable Documents
3. Description of GlobAlbedo Processing chain
    a. Content of the GlobAlbedo products, including a detailed specification of quality flags and uncertainties.
    b. For each instrument, justification and specification of the algorithms to be prototyped for atmospheric correction, snow and cloud detection, BRF modelling, angular and spectral integration, time and space compositing, and product merging.
    c. Approach to implementing uniform retrieval methods to each of the instruments, intercalibration and merging.
    d. Software requirements specification.
    e. Approach to minimising dependency on non-European data sets.
    f. Proposed product formats and delivery mechanisms
    g. Planned test data set for algorithm prototyping.

h. Detailed plan for validation of the albedo products, including a specification of the in-situ and ancillary data to be used.
i. Limitations of the algorithms and validation techniques

Annex 1. ESA GlobAlbedo User Requirements Survey Results

Section 1:

1. *Question: Globalbedo is proposed to be produced in 3 broadband intervals: PAR: 04.-0.7, NIR: 0.7-3, SW: 0.4-3µm*
   (i) Are these the spectral ranges of choice?
   (ii) If not, why not?
   (iii) If not, what would you rather see and why?
   (ii) Answers

   ETH: OK

   Met-Fr: YES

   Bristol: YES

   CEH: 85-89 see response of Sam Pullen (UKMO)

   CICERO: ----

   MetOff: YES

2. *DHR is usually reported at noon:*
   Would DHR integrated over the daylight portion of the day meet your needs?
   If so, why?
   If not, why not?

   ETH: Yes, reflectance integrated over the day is better, because we expect sub-daily variations in albedo (for instance in case soil wetness changes after a rain event)

   Met-Fr: YES, we do need both: noon, daily

   Bristol: YES, because it better relates to energy balance. Or give d(DHR)/d(solar angle).

   CEH: ----

   CICERO: ----

   MetOff: Yes

3. *Albedo will be output with an estimated uncertainty.*
   What is your absolute albedo accuracy requirement (bias and RMS or bias and 3 sigma)? Why is this the case? Please provide a publication with justification for your requirement. Should this globally averaged value for 1km be for a specific time window? If yes, what time window (8-day, 16-day, other) If not, specify.

   ETH: We definitely need error bars associated with the albedo estimates, however we feel that the data developers are better placed to decide what statistics best represent the uncertainties in the data

Met-Fr: see attached document on Product Requirement Tables as defined for SAF Land (incorporated in the BR document as Figure 5.2-1)

Bristol: What is needed is an estimated uncertainty accompanying each data point. The size of that uncertainty does not matter. The uncertainty should be for the time window used (which would be 8 days here). The value of the unc. should be differentiated by conditions of observations (chance of res. cloudiness, view and sun angle, aerosol load…)

CEH: ----

CICERO: ----

MetOff: -10 % optimal accuracy (threshold ~20%)

4. *User requirements suggest that a snowfree and snowbound albedo be produced: What should GlobAlbedo do with permanent snow/ice for "snow-free" albedo?*

ETH: NaN values?

Met-Fr: It should be flagged. Considering the climatic scale of the product, it is relevant to know where occur the transformations of snow and ice albedo. The word 'permanent' should be considered carefully because of snow/ice disappearance/melt in some regions.

Bristol: Leave it to the modeller to figure out what to assume, just flag.

CEH: ----

CICERO: ----

MetOff: These should be flagged as missing data, but identificaion of "permanent" snow/ice should be updated, rather than using a static mask for permanent snow/ice.

5. *Sea-ice is the most dramatic example of surface albedo changes:*
If separate and additional funds were available, how important would sea-ice albedo be to your application? Quantify, if possible, its contribution.

ETH: As land modelers we are not directly interested in sea-ice albedo

Met-Fr: Albedo of sea ice is certainly relevant. It is difficult to dissociate snow and sea-ice albedo because of the importance of climate evolution.

Bristol: Not so important.

CEH: ----

CICERO: ----

MetOff: Would definitely be of interest for climate applications

6. *Albedo will be produced in a user defined projection system:*
   What is your preferred map projection system?
   Would you like to see a MODIS SIN projection employed? If not, why not?

   ETH: Anything that is on a global regular grid

   Met-Fr: Options are: Goode-Homolosine, Plate-carré, SIN (as MODIS)

   Bristol: MODIS SIN projection is OK. Anything that is equal-area, really (and I assume MODIS SIN is), plate-carree is not, so it is no preferred.

   CEH: ----

   CICERO: ----

   MetOff: Lat-lon, Not MODIS SIN

7. *It has been proposed that a temporal weighting function focused on every 8 days with a monthly derived by interpolation and seasonal and annual ones derived therefrom. GlobAlbedo has an option of reporting that focused albedo or reporting a mean albedo over a particular time period with a lower uncertainty:*
   What would you prefer regarding focused albedo or reporting a mean albedo over a particular time period with a lower uncertainty?

   ETH: I don't fully understand the concept of "focused albedo"… if this means instantaneous albedo as opposed to averaged albedo, then we prefer the latter.(because we want the integrated state of albedo over a given period, which is what is important from an energy point of view)

   Met-Fr: NO, accuracy assessment is the main criterion overall. There is no need to have a product with lower uncertainty even though it pretends to improve the temporal resolution.

   Bristol: An 8-day and a monthly product seem perfect. As before, unc. does not matter as long as it is reliably characterized.

   CEH: ----

   CICERO: ----

   MetOff: t doesn't really matter, as long as the uncertainty is specified.

8. *GlobAlbedo proposes that any output products will be in BEAM-DIMAP format (similar to ENVI) with export tools available in BEAM for different standards:*
   What about your preferred format: netCDF, HDF5, graDS, EASI, bufR?
   Any other formats?

   ETH: Netcdf

Met-Fr: NetCDF, HDF5

Bristol: NetCDF

CEH: Netcdf or grads

CICERO: ----

MetOff: NetCDF or HDF5