POLDER-3 / PARASOL Land Surface Level 3 Albedo & NDVI Products

Data Format and User Manual

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I1.00	01.03.2006	All	First Issue	
I2.00	08.09.2010	All	Focus on Albedos and NDVI provided in raw binary format.	

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1 BACKGROUND

The concept of the POLDER instrument was imagined by several researchers from LERTS (Laboratoire d'Etudes et de Recherche en Télédétection Spatiale), CNES (Centre National d'Etudes Spatiales) and LOA (Laboratoire d'Optique Atmosphérique). The concept was then validated using an airborne version built and operated at LOA.

The spaceborne POLDER instrument has been developed by CNES in partnership with industrial contractors. It was flown on both ADEOS-1 and ADEOS-2 platforms. Unfortunately, the lifetime of both platforms was limited to less than a year following the failure of the solar paddle.

The POLDER-3 sensor on the PARASOL micro-satellite is similar to that of POLDER-1 & 2. It was launched in December 2004 to be part of the A-Train, flying in formation with AQUA, CALIPSO and CLOUDSAT. Significant changes concern:

- The orientation of the CCD matrix was changed. On POLDER-1 & 2, the long axis of the matrix was cross-track. On POLDER-3/PARASOL, it is along track. This results in a lower daily coverage of the Earth, but a larger directional sampling for the pixels that are in the instrument swath (up to 16 from 14 on POLDER-1 & 2)
- The shorter wavelength polarized channel is at 490 nm instead of 443 nm on POLDER-1 & 2.
- On POLDER-1 & 2 there were two channels at 443 nm (for optimised dynamic and signal to noise). There is a single one on POLDER-3, but with an additional channel at 1020 nm. This channel may be used for optimised synergy with the CALIPSO measurements at 1060 nm.

The Land Surfaces scientific algorithms are defined and validated by the following science laboratories:

- Laboratoire d'Optique Atmosphérique (LOA)
- Laboratoire des Sciences du Climat et de l'Environnement (LSCE)
- Centre National de Recherches Météorologiques (CNRM)

The Land Surface algorithms are described in "POLDER-3/PARASOL Land Surface Algorithms Description" report (**DR1**).

2 INTRODUCTION

The POLDER-1 instrument was launched onboard the ADEOS-1 platform in August 1996. The instrument acquired data almost continuously from October 1996 to June 1997 when the platform solar panel failure doomed all instruments onboard. A similar instrument, POLDER-2, launched in December 2002, acquired data from April to October 2003 when the ADEOS-2 platform died. A third sensor, POLDER-3, was launched on the micro-satellite PARASOL in December 2004. All POLDER-3 measurements are sent to CNES where radiometric and geometric processings are applied to generate Level-1 products, which are top-of-the-atmosphere geocoded radiances. The POLDER-3/PARASOL Level-1 products are described in **DR2**. Then, Level-1 products are distributed to the pole of thematic competences, ICARE, which operate the Level-2 and Level-3 processing lines for the Atmosphere and Radiation Budget products. The Level-1 products have been also downloaded by HYGEOS which has operated the Level-2 and Level-3 processing lines for the Land Surface products.

The Land Surface Level-2 products are atmospheric-corrected and cloud screened surface bi-directional reflectances that cover the fraction of the Earth observed during one PARASOL orbit with adequate illumination conditions. The Level-3 Land Surface products are bio-geophysical parameters obtained by global and monthly synthesis of Level-2 products.

The Land Surface processing line analyses the measurements acquired over land surfaces. First, it generates the directional surface reflectances corrected for atmospheric absorption, molecular scattering and aerosol scattering over clear pixels. Then, these Level-2 data are used to retrieve:

- Product A: the 3 directional coefficients resulting from the inversion of a semi-empirical linear kernel BRDF model over a monthly synthesis in 5 spectral bands.
- Product B: the spectral and broadband, directional and hemispheric albedos, and the NDVI.

This document focuses on the Product B, albedos and NDVI, which are available for download on the POSTEL web site (http://postel.mediasfrance.org/en/DOWNLOAD/). The Product A, directional coefficients, can be accessible under request.

3 ALGORITHM

Below a summary of the Land Surface algorithms which are described in detail in "POLDER-3/PARASOL Land Surface Algorithms Description" report (**DR1**).

A new linear semi-empirical BRDF model proposed by Maignan et al. (2004) has been implemented in the Level 3 processing line to normalize bi-directional POLDER measurements. It follows the general formulation (Eq. 1) of the bi-directional reflectance $R(\theta_s, \theta_v, \varphi)$ defined by Roujean et al. (1992):

Eq. 1 $$R(\theta_s,\theta_v,\varphi) = k_0 + k_1 * F_1(\theta_s,\theta_v,\varphi) + k_2 * F_2(\theta_s,\theta_v,\varphi)$$

where θ_s, θ_v and φ are the solar zenith, view zenith and relative azimuth angles respectively, F_i are a-priori kernels based on either physical or empirical considerations, and k_i are free parameters to be inverted on the measurements.

3.1 The spectral directional and hemispheric albedos

The directional coefficients resulting from the BRDF model inversion are used for computing the spectral Directional Hemispherical Reflectances (DHR), also called directional albedo or black-sky albedo, for the noon sun angle θ_{s_noon} of the reference date of the synthesis period (Eq. 8) as specified by CNRM/Météo-France.

Eq. 2 $$DHR(\theta_{s\_noon}) = k_0 + k_1 * G_1(\theta_{s\_noon}) + k_2 * G_2(\theta_{s\_noon})$$

where $G_i(\theta_s) = \frac{1}{\pi}\int_\Omega F_i(\theta_s,\theta_v,\varphi)\cos\theta_v d\omega$ is the integration of kernels F_i over the full viewing hemisphere. The integrals are approximated by pre-computed polynomial relationships of θ_s. The associated error on spectral DHR are estimated by Eq. 3 where [COV] is the variance-covariance matrix of the linear regression.

Eq. 3 $$ErrDHR = \sqrt{[G]^t [COV][G]}$$ with

Eq. 4 $$[COV] = \sigma([F]^t [F]^{-1})$$ with $$\sigma = \frac{\|R\|^2 - [K]^t [F]^t [R]}{N - 3}$$

The Directional coefficients resulting from the BRDF model inversion are also used for computing the spectral Bi-Hemispherical Reflectances (BHR), also called hemispheric albedo or white-sky albedo, for a sun angle integrated over the whole diurnal cycle (Eq. 5).

Eq. 5 $$BHR = k_0 + k_1 * H_1 + k_2 * H_2$$

where $H_i = \frac{1}{\pi} \int_{\theta_s} \int_{\Omega} F_i(\theta_s, \theta_v, \varphi) \cos\theta_s \cos\theta_v \, d\omega \, d\theta_s$ is the integration of kernels F_i over the full viewing and illumination hemispheres.

The associated error on spectral BHR are estimated by Eq. 6:

Eq. 6 $$ErrBHR = \sqrt{[H]^t [COV][H]}$$

The pre-computed polynomial relationships of θ_S, and the values of H_i have been specified by LSCE.

3.2 The broadband albedos

The spectral DHR and BHR are spectrally integrated over 2 broad bands:

- visible [400 – 700 nm] : BDHR_VIS and BBHR_VIS
- whole spectrum [300 – 4000 nm] : BDHR and BBHR

The general narrow to broadband relationship is according to Eq. 7. The respective errors are estimated following the Eq. 8:

Eq. 7 $$Broadband = \alpha_0 + \alpha_4 * 490nm + \alpha_5 * 565nm + \alpha_6 * 670nm + \alpha_7 * 765nm + \alpha_8 * 865nm$$

Eq. 8 $$ErrBroadband = \alpha_4 * Err490nm + \alpha_5 * Err565nm + \alpha_6 * Err670nm + \alpha_7 * Err765nm + \alpha_8 * Err865nm$$

The conversion coefficients are specified by Météo-France/CNRM.

3.3 The normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI), corrected for the directional effects, is derived from DHR_{670nm} and DHR_{865nm} (Eq. 9) , and its error is calculated by Eq. 10.

Eq. 9 $$NDVI = \frac{DHR_{865} - DHR_{670}}{DHR_{865} + DHR_{670}}$$

Eq. 10 $$ErrNDVI = 2 * \mathrm{DHR}_{865} * \mathrm{NDVI} * \frac{\mathrm{ErrDHR}_{865} + \mathrm{ErrDHR}_{670}}{(\mathrm{DHR}_{865} + \mathrm{DHR}_{670})^2}$$

4 PRODUCT DESCRIPTION

4.1 Product identification

A Land Surface Level-3 product generated from POLDER3/PARASOL measurements is identified by

PwLxTyGzaammddv

where w is the instrument number (w = 3)
x indicates the product level (x = 3)
y indicates the product thematic (y = L)
z is a code for product type (z = B)
aammdd is the reference date for the temporal synthesis (year-month-day)
v indicates the reprocessing number

An individual data file is associated to each variable with a filename as pppD.VARNAME (Table 1) where ppp is the 15 characters product identifier above.

Variable	VARNAME
Directional Hemisperical Reflectance (DHR) (490, 565, 670, 765, 865nm)	DHR_λλλ
Error on spectral DHR	ErrDHR_λλλ
Bi-Hemispherical Reflectance (BHR) (490, 565, 670, 765, 865nm)	BHR_λλλ
Error on spectral BHR	ErrBHR_λλλ
Broadband DHR in visible [0.4 – 0.7 µm]	BDHR_VIS
Error on Broadband DHR in visible	ErrBDHR_VIS
Broadband DHR in whole spectrum [0.3 –4 µm]	BDHR
Error on Broadband DHR in whole spectrum	ErrBDHR
Broadband BHR in visible [0.4 – 0.7 µm]	BBHR_VIS
Error on Broadband BHR in visible	ErrBBHR_VIS
Broadband BHR in whole spectrum [0.3 –4 µm]	BBHR
Error on Broadband BHR in whole spectrum	ErrBBHR
NDVI	NDVI
Error on NDVI	ErrNDVI
Sun Zenith Angle	SZA

Table 1: List of data file extension to identify each variable

4.2 Product Structure

The files are organised in *.tar* archives. For the various albedos and NDVI, one archive is done per month as:

- SurfaceAlbedo-DHR_POLDER3_YYYYMM_l2.0.tar contains 33 individual files: the 5 spectral DHR, the 5 associated errors, and the Sun Zenith Angle (SZA, § 3.1) for the 3 synthesis of the month (DD = 05, 15, 25)
- SurfaceAlbedo-BHR_POLDER3_YYYYMM_l2.0.tar contains 30 individual files: 5 spectral BHR, and the 5 associated errors for the 3 synthesis of the month.
- SurfaceAlbedo-BDHR_POLDER3_YYYYMM_l2.0.tar contains 15 individual files: the 2 broadband DHR, the 2 associated errors, and the sun zenith angle for the 3 synthesis of the month.
- SurfaceAlbedo-BBHR_POLDER3_YYYYMM_l2.0.tar contains 12 individual files: the 2 broadband BHR, the 2 associated errors for the 3 synthesis of the month.
- NDVI_POLDER3_YYYYMM_l2.0.tar contains 9 individual files: NDVI, its error, and the sun zenith angle for the 3 synthesis of the month.

4.3 Coding

The individual files are raw binary files which are arrays of 6480 columns and 3240 lines with values coded on one-byte unsigned integer (from 0 to +255). Four values are reserved (Table 2):

- No data: the parameter is not estimated, for instance when no clear observation is available during the synthesis period
- Undefined: the calculation yields a non significant value
- Out of range by higher value: the calculation yields a value larger than the high limit of the physical range (Table 3)
- Out of range by lower value: the calculation yields a value lower than the low limit of the physical range.

	Reserved values
No data	255
Undefined	254
Out of range > val_max	253
Out of range < val_min	252

Table 2: Values reserved for special coding

The files are readable easily. For instance, with the IDL software as on the following example:

```
----------------------
;reading the BBHR file of the 5th November 2006 synthesis
openr, unit, 'P3L3TLGB061105JD_BBHR', /get_lun
BBHR = bytarr(6480,3240)
readu,unit,BBHR
free_lun,unit
----------------------
```

The Physical Values (PV) of variables can be computed from the Digital Number (DN) through :

PV = Slope x BV + Offset

The slope and offset of each variable are given in Table 3.

Variable	Slope	Offset	Physical Range [val_min, val_max]
DHR, BHR, BDHR, BBHR	0.005	0	[0, 1.1]
Error on DHR, BHR, BDHR, BBHR	0.005	0	[0, 1]
NDVI	0.005	-0.2	[-0.2, 1]
Error on NDVI	0.005	0	[0, 1]
SZA	0.5	0	[0, 80°]

Table 3: Slope, Offset and Physical domain of Land Surface Level-3 variables.

4.4 Spatial information

The POLDER-3/PARASOL Land Surface products are provided in the full resolution POLDER reference grid. It is based on the sinusoidal equal area projection (Sanson-Flamsted). The step is constant along a meridian with a resolution of 1/18 degrees. Thus, there are 180x18 = 3240 lines from pole to pole. Along a parallel, the step is chosen in order to have a resolution as constant as possible. The number of pixels from 180°W to 180°E is chosen equal to 2 x NINT[3240 cos(latitude)] where NINT stands for *nearest integer*.

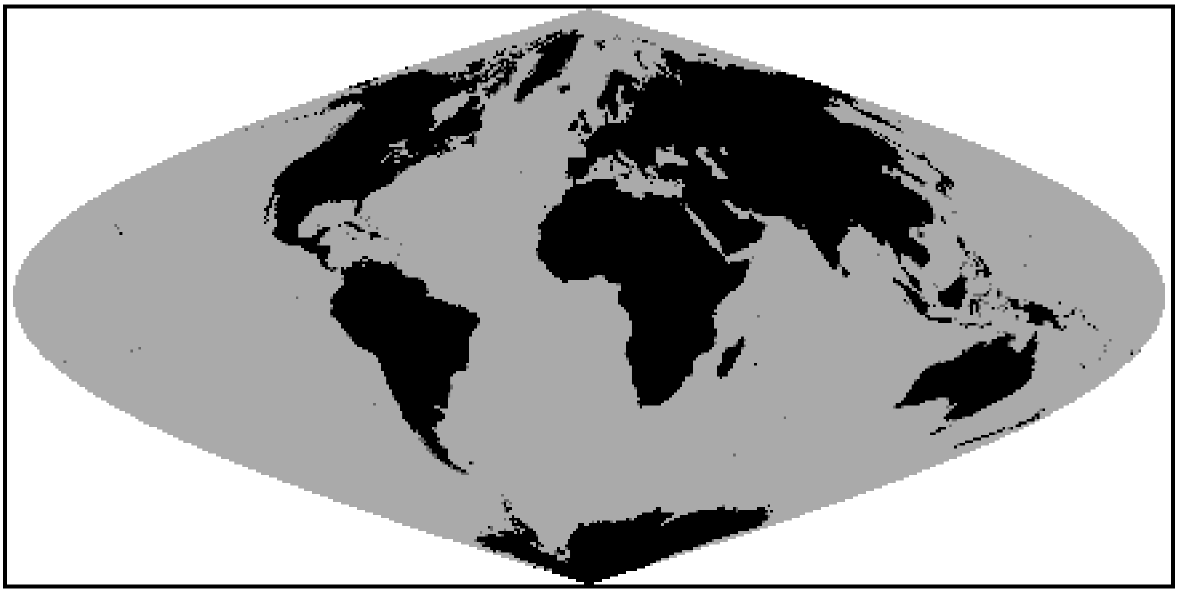

Figure 1 : Global sinusoïdal reference grid

`lin` is 1 to 3240 from top to bottom
`col` is 1 to 6480 from left to right

Note that, in the real world, the coordinates of the neighbours of a given pixel (*lin* , *col*) are ***not*** necessarily given by (*lin* ± 1 , *col* ± 1). It is necessary to account for the deformation of the projection with the longitude.

The following equations yield the latitude and longitude of a pixel given by its (*lin, col*) coordinates in the POLDER reference grid:

$$lat = 90 - \frac{lin - 0.5}{18}$$

$$N_i = \text{NINT}[3240 \cos(lat)]$$

$$lon = \frac{180}{N_i}(col - 3240.5)$$

The following equations yield the (*lin, col*) coordinates in the POLDER reference grid for a pixel of given latitude and longitude:

$$lin = \text{NINT}[18(90 - lat) + 0.5]$$

$$N_i = \text{NINT}[3240\,\text{sin}(\frac{lin - 0.5}{18})]$$

$$col = \text{NINT}[3240.5 + \frac{N_i}{180}\,lon]$$

This POLDER reference grid is centered on the Greenwich meridian. For the extraction and visualisation of POLDER data close to the 180° longitude line, it may be easier to work with a similar grid centered on this meridian. A simple formula allows to switch from one (*lin, col*) coordinate system to the other (*lin', col'*) :

$$lin' = lin$$

$$N_i = \text{NINT}[3240\,\text{sin}(\frac{lin - 0.5}{18})]$$

$$col' = 3241 - N_i + \text{MOD}_{2N_i}(col + 2N_i - 3241)$$

where MOD_{2N_i} returns the remainder of the integer division by $2N_i$.

4.5 Temporal Information

It is given in the `YYMMDD` section of the individual file name. The 3 compositing periods of the month are centered on 5^{th}, 15^{th} and 25^{th}. The synthesis is made with the data acquired in the interval +/- 14 days around the center day of the compositing period.

5 DATA POLICIES

The POLDER-3/PARASOL Land Surface Level 3 products are free of charge and available on the POSTEL web site at the address http://postel.mediasfrance.org.

These products are property of CNES, users are encouraged to widely use them for research and application development. However, users cannot redistribute them and any publication or communication using these products must properly credit CNES.

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6 REFERENCE

DR1: POLDER-3/PARASOL Land Surface Algorithms Description, Ed.3 Rev.11, July 28th 2010. http://postel.mediasfrance.org/en/DOWNLOAD/Documents

DR2: PARASOL Level-1 product, Data Format and User Manual, Ed.1 Rev.1, May 26th 2005, F.M. Bréon, CEA.. http://polder.cnes.fr/downloads/docs/PARASOL_Level-1.pdf.

Maignan, F., F.M. Bréon and R. Lacaze, Bi-directional reflectance of Earth targets : evaluation of analytical models using a large set of spaceborne measurements with emphasis on the Hot Spot, *Remote Sensing of Environment, 90, 210-220,* 2004.

Roujean, J. L., M. Leroy and P. Y. Deschamps, A bi-directional reflectance model of the Earth' s surface for the correction of remote sensing data, *Journal of Geophysical Research, 97, D18, 20,455-20,468,* 1992.

Acronyms

ADEOS	Advanced Earth Observing Satellite
BBHR	Broadband Bi-Hemispheric Reflectance
BDHR	Broadband directional Hemispheric Reflectance
BHR	Bi-Hemispheric Reflectance
BRDF	Bidirectionall Reflectance Distribution Function
CCD	Charge Coupled Device
CEA	Commissariat à l'Energie Atomique
CNES	Centre National d'Etudes Spatiales
CNRM	Centre National de Recherches Météorologiques
DHR	Directional Hemispheric Reflectance
ICARE	Interaction Cloud Atmosphere Radiation Etc...
LERTS	Laboratoire d'Etudes et de Recherche en Télédétection Spatiale
LOA	Laboratoire d'Optique Atmosphérique
LSCE	Laboratoire des Sciences du Climat et de l'Environnement
NDVI	Normalized Difference Vegetation Index
PARASOL	Polarisation et Anisotropie des Réflectances au sommet de l'Atmosphère, couplées avec un Satellite d'Observation emportant un Lidar
POLDER	Polarization and Directionality of the Earth Reflectances
POSTEL	Pôle d'Observation des Surfaces continentales par TELédétection
TOA	Top Of the Atmosphere