Parasol Level-1 Product

Data Format and User Manual

Ed. 1 - Rev. 4, Dec 13th , 2016

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Last modified on April 10th, 2005

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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-I and ADEOS-II platforms. Unfortunately, the lifetime of both platforms was limited to less than a year following the failure of the solar paddle.
The Parasol instrument is similar to that of POLDER. It was launched in December 2004 to be part of the A-Train, flying is formation with Aqua, Calipso and Cloudsat. Significant changes concern:

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

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)
- Medias-France
- Laboratoire de Météorologie Dynamique (LMD)

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Introduction

The purpose of this document is to describe the Parasol level-1 data format, and to provide some information on how the data were derived from the raw measurements.

The document first gives some information on the Parasol instrument, its observation principle, and the level-1 data processing. It then describes in details the level-1 data format. The appendices provide some tools and equations for an in-depth use of the Parasol level-1 data. The so-called Level-2 and Level-2 scientific products are described in other documents.

The Parasol instrument

The POLDER/Parasol radiometer design consists of three principal components: a CCD matrix detector, a rotating wheel carrying the polarizers and spectral filters, and a wide field of view (FOV) telecentric optics (Deschamps et al., 1994). The optics have a focal length of 3.57 mm, opening to f:4.5 with a maximum FOV of 114°.

The CCD sensor array is composed of 242 x 274 independent sensitive areas. The total array detection unit size is 6.5 x 8.8 mm which, according to the lens focal ratio, corresponds to cross-track and along-track FOVs of ±43° and ±51°, respectively, and to a diagonal FOV of ±57°. The CCD array is equipped with an antiblooming device which prevents image degradation when the incident radiance is above the sensor's dynamic range. The spectral sensitivity of the CCD array extends between 400 and 1050 nm.

The rotating wheel, which has a steady period of 4.9 s, supports the interference filters and polarizers that select the spectral bands and polarization directions. It carries 16 slots, one of which is an opaque filter to estimate the CCD detector *dark current*. The remaining 15 slots carry 6 unpolarized and 9 polarized filters (3 polarization directions for 3 different wavelengths). Thus, Parasol acquires measurements in 9 bands, 3 of which are polarized.

Spectral bands

Table 1 provides the spectral band characteristics for the Parasol instrument. The 9 bands are defined by their central wavelength, spectral width, dynamic range and polarization capabilities. The saturation levels are given, for a specific acquisition integration time, in unit of normalised radiance, i.e. the maximum spectral radiance divided by the solar spectral irradiance at nadir and multiplied by π. The dynamic reflectance range is subsequently obtained by dividing the range given in Table 1 by $\cos(\theta_S)$, where θ_S is the

Parasol band	443	490	565	670	763	765	865	910	1020
Central Wavelength	443.9	491.5	563.9	669.9	762.8	762.5	863.4	906.9	1019.4
Band Width (FWHM)	13.5	16.5	15.5	15.0	11.0	38.0	33.5	21.0	17.0
Polarization	Yes	No	No	Yes	No	No	Yes	No	No
Saturation level 23.8 ms	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1

Table 1 : Characteristics of the 9 POLDER bands. The central Wavelength λ_C is derived from the POLDER spectral transmission $T(\lambda)$ and the solar spectrum $S(\lambda)$: $\lambda_c = \frac{\int_0^\infty \lambda\, S(\lambda) T(\lambda) \partial\lambda}{\int_0^\infty S(\lambda) T(\lambda) \partial\lambda}$

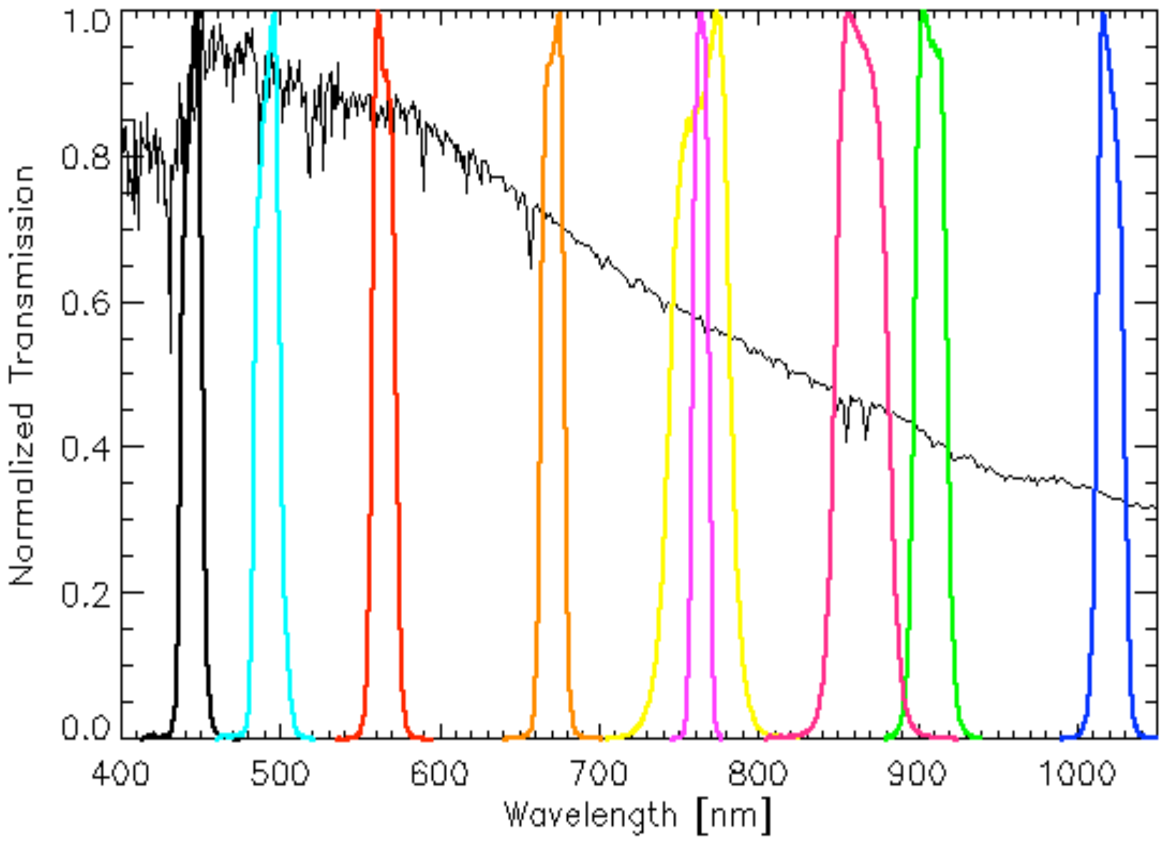


Figure 1: The 9 POLDER channel spectral responses together with the solar irradiance spectum

solar zenith angle. Note that the integration is changed in-flight to optimize the dynamic range of the detector: It increases with the solar zenith angle so that the saturation levels corresponds to a given reflectance level.

Polarization measurements

For three of the eight spectral bands (490, 670 and 865 nm), a polarizer is added to the filters in order to assess the degree of linear polarization and the polarization direction (which are equivalent to the measurements of I, Q, and U in the Stokes vector representation of the polarization). These parameters are derived by combining measurements in three channels with the same spectral filters but with the polarizer axes turned by steps of 60°. The three polarization measurements in a spectral band are successive and have a total time lag of 0.6 s between the first and the third (last) measurement. In order to compensate for spacecraft motion during the lag and to register the three measurements, a small-angle, wedge prism is used in each polarizing assembly. As a consequence, the matrix image is translated in the focal plane to offset the satellite motion, and the three polarization measurements are quasi collocated.

Figure 2: Multidirectional acquisition with POLDER

Spatial resolution

The ground size or resolution of a Parasol-measured pixel is close to (6 km)^2 at nadir. Due to Earth curvature, the viewing angle relative to the local nadir is larger than the viewing angle in the satellite reference frame. Satellite angles (θ_{sat}) of 10°, 20°, 30°, 40° and 50° correspond to local viewing angles (θ_V) of 11.3°, 22.6°, 34.1°, 45.7° and 57.8°, respectively. This leads to a slight viewing angle dependence of the pixel size, leading to an increase of 21% for an incidence angle of 60°.

Fig. 3 : Number of viewing directions available for each surface pixel. Gray shades are from one (Black) to sixteen (white). Fourteen directions are available in the wide area around the satellite subtrack

Data acquisition

The Parasol instrument is in imaging mode on the sunlit part of the orbit only. The acquisition sequence is repeated every 19.6 seconds. A sequence is composed of 16 image acquisitions in the following order : Dark, 490P1, 490P2, 490P3, 443, 1020, 565, 670P1, 670P2, 670P3, 763NP, 765NP, 910NP, 865P1, 865P2, 865P3. The total number of sequences in one orbit depends on the season and can be up to 130.

The 16 filter sequence is repeated every 19.6 s which corresponds to 4 rotations of the filter wheel. During this interval, a given point on the surface, initially at nadir viewing, moves by about 9° relative to the satellite (Fig. 2). The point remains within the Parasol field-of-view. As the satellite passes over a target, about 13 (up to 16) directional radiance measurements (for each spectral band) are performed aiming at the point (Figure 3). Therefore, Parasol successive observations allow the measurement of the bidirectional reflectance properties of any target within the instrument swath.

Level-1 processing

Parasol data are received by CNES receiving station in Toulouse. The Parasol level-0 data are then processed at CNES to produce level-1 data. The so called level-1 processing includes calibration, radiometric and geometric processing.

Calibration

The Parasol instrument does not include any onboard calibration device. The instrument calibration is achieved in flight using geophysical targets of known spectral and angular reflectance properties. The calibration coefficients are monitored and updated during the satellite life (Hagolle et al. , 1999). The calibration coefficients used for the level-1 processing are identified in the leader file ("Data processing parameters" record) by their version number.

The Parasol measurements are given in units of "normalized radiance" : the radiance (W m^{-2} sr^{-1}) has been multiplied by π/E_λ where E_λ is the extraterrestrial solar radiance accounting for the variations of sun-Earth distance. This choice (rather than expressing the measurements in units of W m^{-2} sr^{-1}) was made because the Parasol instrument is calibrated in flight against known *reflectances* rather than known *radiances*. The "normalized radiances" data can be converted to reflectances by a simple division by the cosine of the solar zenith angle.

Radiometric processing

The radiometric processing is based in part on the POLDER/Parasol radiometric model described in Appendix F. Radiometric processing includes :

- Stray light correction
- Subtraction of "dark current"
- Data calibration
- Computation of Stokes parameters (I,Q,U) from the three measurements for the three polarized bands.
- Interpolation of the polarization parameters from the polarized to the unpolarized bands. Correction of the measurements for the lens polarizing effects (which depends on the input radiance polarization properties).

Geometric processing

All Parasol standard products are Earth-registered. The geometric processing navigates the raw data which are registered in the instrument reference frame, to an Earth fixed reference frame. After projection on the Earth frame, accounting for the satellite attitude and the relative orientation of the satellite and radiometer, the data are interpolated on the Parasol reference grid using a bi-cubic algorithm. The satellite-radiometer relative orientation is calibrated in-flight using specific targets such as coastlines. The attitude bias coefficients used for level-1 processing are identified in the leader file ("Data processing parameters" record) by their version number.

In the level 1 product, the data are sorted by pixel of the Earth frame (from South to North, and from West to East). Note that the POLDER-1 and 2 products are given from North to South, opposite to those of Parasol, due to the descending versus ascending daytime node. For each pixel, up to 16 sets of observations (with varying viewing geometries) are available. The acquisition sequence number and the line-column coordinates on the CCD matrix are available in the product, which allow to reconstruct the original CCD acquisition, as shown on the left image of Fig. 4.

The Parasol reference grid is described in Appendix B. The grid has a constant resolution along the meridians (18 pixels per 1° latitude band), and a variable resolution (when expressed in degrees; nearly constant in km) along the parallels, with the objective that all pixels have nearly identical dimensions.

Definitions

Parasol product identification

A POLDER/Parasol standard product is composed of two files. A *leader* file and a *data* file. The *leader* file provides some information on the instrument and the data processing. The *data* file contains the instrument measurements, after radiometric and geometric processing, together with ancillary data.

A Level-1 product generated from Parasol measurement is identified by `P3L1TBG1cccooov` where `ccc` is the orbit cycle number, `ooo` the orbit number in the cycle, and v identifies the reprocessing number (See Appendix A). The *leader* and *data* filenames are `pppL` and `pppD` respectively, where `ppp` is the 15 characters product identificator. Note that the second character "3" is 1 for the POLDER-1 similar products and 2 for those of POLDER-2.

Geometry

Four angles are included in the level-1 product :

• The solar azimuth, ϕ_S, is relative to the local North direction. It may vary between 0 and 360°. The solar

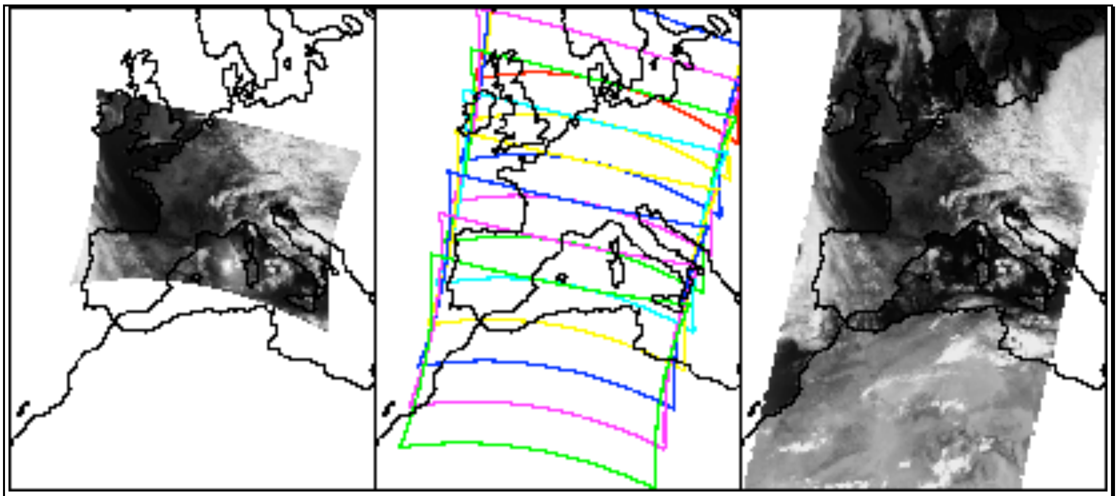


Fig. 4: A single Parasol acquisition by the CCD yield a bidimensional image of a fraction of the Earth (left image). For each channel, a similar acquisition is repeated every 19.6 seconds and the fields of view partially overlap. The center image indicates the borders of every third acquisitions. Level 1 processing integrates, for each Earth pixel of the reference grid, the Parasol observations (up to 16) of this pixel and generates a product where measurements are sorted by pixel (from North to South, and from West to East). The image on the right is the result of an extraction from a level-1 product. For each pixel, the observation with the smaller view zenith angle was selected.

azimuth is 90° when the sun is East of the observed pixel.

- The solar zenith angle, θ_S, is relative to the local zenith. It may vary between 0° (sun at zenith) and approximately 80°.
- The view zenith angle, θ_V, is relative to the local zenith. It may vary between 0° (Parasol at zenith) and approximately 75°.
- The relative azimuth, ϕ, is the difference in azimuth between the sun and the satellite directions: $\phi=\phi_S-\phi_V$ where ϕ_V is defined, as ϕ_S, with respect to the North direction. ϕ may vary between 0° and 360°. ϕ is 0°/360° for backscattering measurements, and 180° for glitter observation.

Stokes parameters

In addition to the total radiance I, the Parasol/POLDER instrument measurements yield the description of the linear polarization for three spectral bands : 490P, 670P and 865P. In the POLDER level-1 product, this information is given as the second (Q) and third (U) components of the Stokes vector. The polarized radiance I_p and polarization direction χ can be derived from Q and U through :

$$I_p = (Q^2 + U^2)^{1/2}$$

$$I_p \sin(2\chi) = U$$

$$I_p \cos(2\chi) = Q$$

In the equations above, the polarization angle χ is defined with respect to the plane defined by the local zenith and the viewing direction. Appendix D provides some equations to get the polarization direction with respect to the scattering plane.

Coding

Most parameters of the leader file are written as formatted ASCII characters, whereas the data file has a binary structure.

In what follows, we make use of the following coding types :

`Ax` : indicates an ASCII field of length x bytes.

`Fx.y` indicates a float written on `x` characters with `y` digits after the floating point (as in FORTRAN). Ex: `F10.4` for `-1234.5678`

`Ex.y` indicates a float written in exponential form on `x` characters with `y` digits after the floating point (as in FORTRAN). Ex: `E14.4` for `-1234.5678E-08`

`Bx` indicates a succession of bits (for quality flags). x is the number of bytes used.

`I4` indicates a four-bytes unsigned Integer (from 0 to 2^{32}-1)

`SI2` indicates a two-bytes signed integer (from -32768 to +32767)

`I2` indicates a two-bytes unsigned Integer (from 0 to +65535)

`SI1` indicates a one-byte signed integer (from -128 to +127)

`I1` indicates a one-byte unsigned integer (from 0 to +255)

In the format description below, the special character "$" is used to indicate the space character. Upper-case letters are used for fixed fields, whereas lower-case letters are used for variable fields.
Spare fields are filled with repetition of the "space" character.

For binary parameters, one or two values are reserved for "Dummy" and "Saturated" data. They depend on the parameter format as indicated in the table below. The "Dummy" value characterizes missing data. The "Saturated" value characterizes out of range data. Saturation is only expected for the parameters that are coded in SI2 (Radiances and polarized radiances in the data records).

	I1	SI1	I2	SI2
Saturated	-	-	-	32767
Dummy	0	-127	0	-32767

Leader File Format

General structure

The leader file is composed of 8 records of variable length. Its total length is 195840 Bytes :

Record Name	Record Length (Bytes)
Leader file descriptor	180
Header	360
Spatio-Temporal Characteristics	1620
Instrument setting parameters	180
Technological parameters	166320
Data processing parameters	720
Scaling factors	13140
Annotations	13320
Total	195840

Leader file descriptor

This record describes the data structure of the leader file.

Position	Type & Length	Content
1-4	I4	Record Number in the file : `1`
5-8	I4	Length of this record : `180`
9-20	A12	Reference Document Identification : PAST33131CN for POLDER1, P2ST33131CN for POLDER2, `SPG9N122-316`
21-26	A6	Reference Document Version Number : `aa/bb$`
27-32	A6	Software Version Number : `aa.bb$`
33-36	A4	File Number : `1$$$`
37-52	A16	File Name[1] : `PwL1TBG1cccooovL`
53-56	I4	Number of "header" record in the file : `1`
57-60	I4	Length of the "Header" record : `360`
61-64	I4	Number of "Spatio-Temporal Characteristics" records in the file : `1`
65-68	I4	Length of the "Spatio-Temporal Characteristics" record : `1620`
69-72	I4	Number of "Instrument setting parameters" records in the file : `1`
73-76	I4	Length of the "Instrument setting parameters" record : `180`
77-80	I4	Number of "Technological parameters" records in the file : `1`
81-84	I4	Length of the "Technological parameters" record : `166320`
85-88	I4	Number of "Data processing parameters" records in the file : `1`

[1] See Annexe A for the POLDER/Parasol standard for filenames

89-92	I4	Length of the "Data processing parameters" record : 720
93-96	I4	Number of "Scaling factors" records in the file : 1
97-100	I4	Length of the "Scaling factors" record : 13140
101-104	I4	Number of "Annotation" records in the file : 1
105-108	I4	Length of the "Annotation" record : 13320
109-180	A72	Spare

Header

The "header" record gives general information on the product and the models used for data registration.

Position	Type & Length	Content
1-4	I4	Record Number in the file : 2
5-8	I4	Length of this record : 360
9-24	A16	Information Point Phone Number
25-40	A16	Product identification : PwL1TBG1cccooov$
41-48	A8	Satellite identificator ADEOS$1 for POLDER1, ADEOS$2 for POLDER, MYRIADE2
49-56	A8	Instrument identificator POLDER$1, POLDER$2, PARASOL1
57-72	A16	Spatial Coverage : VIEWING$SEGMENT$
73-80	A8	Pixel size of the reference grid (km) : 006.180$
81-110	A30	Name of the ellipsoid used for the data registration : GEODETIC$REFERENCE$SYSTEM$1980
111-122	F12.4	Length of the ellipsoid minor axis (meter) : 6356752.3141
123-134	F12.4	Length of the ellipsoid major axis (meter) : 6378137.0000
135-164	A30	Name of the Digital Elevation Model (DEM) used for the data registration : TERRAIN-BASE(NOAA)$$$$$$$$$$$$
165-172	A8	Spatial resolution of the DEM along the latitudes (in degrees) : aaa.aaa$
173-180	A8	Spatial resolution of the DEM along the longitudes (in degrees) : aaa.aaa$
181-360	A180	Spare

Spatio-Temporal Characteristics

This records provides some information on the Earth temporal and spatial coverage for this viewing segment.

Position	Type & Length	Content
1-4	I4	Record Number in the file : 3
5-8	I4	Length of this record : 1620

9-12	A4	Cycle Number : `ccc$`
13-16	A4	Orbit Number in the cycle : `ooo$`
17-20	A4	Sub satellite track number[2] : `ttt$`
21-50	A30	Spare
51-58	A8	Ascending Node Longitude : `ddd.ddd$ (0 - 360°)`
59-74	A16	Ascending node date and UT time : `yyyymmddhhmmsscc`
75-100	A26	Spare
101-116	A16	Date and UT time of the first image acquisition for the viewing segment : `yyyymmddhhmmsscc`
117-132	A16	Date and UT time of the last image acquisition for the viewing segment : `yyyymmddhhmmsscc`
133-200	A68	Spare
201-204	A4	Number of sequences in the viewing segment (`1≤Nseq≤130`)
205-300	A96	Spare
301-304	A4	Line Number of the northern most pixel observed by Parasol in the viewing segment: `nnnn (0001≤nnnn≤3240)`[3]
305-308	A4	Line Number of the southern most pixel observed by Parasol in the viewing segment: `nnnn (0001≤nnnn≤3240)`
309-400	A92	Spare
8 (is[4]-1)+401 - 8 (is-1) + 404	A4	Line Number of the Earth pixel located at the Parasol nadir during acquisition of filter 670P2 of sequence #is : `nnnn` `1≤nnnn≤3240` if 1≤is≤Nseq ; `nnnn=0000` if is>Nseq
8 (is-1) + 405 - 8 (is-1) + 408	A4	Column Number of the Earth pixel located at the Parasol nadir during acquisition of filter 670P2 of sequence #is : `nnnn` `1≤nnnn≤6480` if 1≤is≤Nseq ; `nnnn=0000` if is>Nseq
1441-1620	A180	Spare

2 See Appendix E for Parasol orbital characteristics and useful relationships on cycle, orbit and track numbers.

3 If only a given geographical area is ordered from the Parasol processing center, this field and the next one are automatically updated in agreement with the area selection.

4 `is` is the sequence number. `1 ≤ is ≤ 130`

Instrument setting parameters

This record describes the integration time sequencing (Short Integration Acquisition versus Long Integration Acquisition) used for this viewing segment, as well as the gain.

Position	Type & Length	Content
1-4	I4	Record Number in the file : 4
5-8	I4	Length of this record : 180
9-16	A8	Short Integration Acquisition (SIA) duration (ms) : mmm.mmm$
17-24	A8	Long Integration Acquisition (LIA) duration (ms) : mmm.mmm$
25-40	A16	Integration Time definition for sequence type A : tttttttttttttttt with t=S (SIA duration) or t=L (LIA duration). The 16 characters correspond to the 16 Parasol filters in the following order : Dark , 490P1, 490P2, 490P3, 443NP, 1020NP, 565NP, 670P1, 670P2, 670P3, 763NP, 765NP, 910NP, 865P1, 865P2, 865P3
41-56	A16	Integration Time definition for sequence type B : tttttttttttttttt with t=S (SIA duration) or t=L (LIA duration). Same as above
57-72	B16	Sequence type (A or B) for the 128 first sequences of the orbit (for a total maximum of 130). The 16 bytes include 128 bits. Each bit is for one sequence Bit=0 : Sequence type A Bit=1 : Sequence type B
73-74	A2	Analogic gain number : g$ (1≤g≤7)
75-180	A106	Spare

Technological parameters

In this record the temperature of the lens are given for each -up to 130- acquisition sequence. The two temperatures are for the internal lens (L5 to L10) and the external lens (L1 and L2).

The record also contains the position, speed vector and attitude parameters of the Parasol satellite for each -up to 130- acquisition sequences, and 9 images per sequence. The 9 images correspond to the spectral bands 490P, 443NP, 1020NP, 565NP, 670P, 763NP, 765NP, 910NP, 865P. For each of the 3 polarized bands, only the values corresponding to the central filter are given.

The position and speed vectors are given in a referential fixed to the Earth with the Earth centre as the origin : The Z vector is from the Earth centre to the North Pole, X is from the Earth centre to intersection of the equator and the Greenwich line, and Y=Z^X.

The attitude parameters, yaw, roll and pitch, are given as right handed rotation around respectively the X, Y, and Z axis of the orbital reference frame. The Z vector is from the satellite to the Earth centre. X is perpendicular to Z, in the plan containing X and the satellite speed vector, along the speed vector. Y=Z^X.

The default value (no data) for the date, temperature, position, speed vector and attitude is 0.

Position	Type & length	Content
1-4	I4	Record Number in the file : `5`
5-8	I4	Length of this record : `166320`
1278 (is-1) + 9[5] 1278 (is-1) + 12	A4	Sequence Number : `sss$ (0≤sss≤130).` sss=is if the sequence was acquired and processed; sss=0 otherwise
1278 (is-1) + 13 1278 (is-1) + 20	F8.3 F16.7 for P1/P2	Internal lens temperature during the sequence (°C) : `±ttt.ttt` `For POLDER1 and POLDER2, ±ttttttt.ttttttt`
1278 (is-1) + 21 1278 (is-1) + 28	F8.3 F16.7 for P1/P2	External lens temperature during the sequence (°C) : `±ttt.ttt` `For POLDER1 and POLDER2, ±ttttttt.ttttttt`
1278 (is-1) + 29 1278 (is-1) + 36	F8.3	Short Acquisition Time duration (ms) : `±sss.sss only for PARASOL`
1278 (is-1) + 37 1278 (is-1) + 44	F8.3	Long Acquisition Time duration (ms) : `±sss.sss only for PARASOL`
1278 (is-1)+ 138 (im-1)+45[6]	A2	Image Number : `i$ (0≤i≤9). i=im` if the sequence was acquired and processed; `i=0` otherwise
1278 (is-1)+ 138 (im-1)+47	A16	Date and UT time of the acquisition of image `im` in sequence `is` : `yyyymmddhhmmsscc`
1278 (is-1)+ 138 (im-1)+63	F16.7	X component of the Parasol position during acquisition of image `im` in sequence `is` (km): `±ppppppp.ppppppp`
1278 (is-1)+ 138 (im-1)+79	F16.7	Y component of the Parasol position during acquisition of image `im` in sequence `is` (km): `±ppppppp.ppppppp`
1278 (is-1)+ 138 (im-1)+451)+95	F16.7	Z component of the Parasol position during acquisition of image `im` in sequence `is` (km): `±ppppppp.ppppppp`
1278 (is-1)+ 138 (im-1)+451)+111	F16.7	Vx component of the Parasol speed vector during the acquisition (km s^{-1}): `±vvvvvvv.vvvvvvv`
1278 (is-1)+ 138 (im-1)+451)+127	F16.7	Vy component of the Parasol speed vector during the acquisition (km s^{-1}): `±vvvvvvv.vvvvvvv`
1278 (is-1)+	F16.7	Vz component of the Parasol speed vector during the acquisition

[5] `is` is the sequence number. `1 ≤ is ≤ 130`

[6] `im` is the image number. `1 ≤ im ≤ 9`

138 (im-1)+451)+143		(km s^{-1}): ±vvvvvvv.vvvvvvv
1278 (is-1)+ 138 (im-1)+451)+159	F8.3	Yaw of the Parasol instrument during acquisition of image im in sequence is : ±yyy.yyy
1278 (is-1)+ 138 (im-1)+451)+167	F8.3	Pitch of the Parasol instrument during acquisition of image im in sequence is : ±ppp.ppp
1278 (is-1)+ 138 (im-1)+451)+175	F8.3	Roll of the Parasol instrument during acquisition of image im in sequence is : ±rrr.rrr
166149-166320	A172	Spare

Data processing parameters

This record provides information on the input data and the software version used to generate the Level-1 Parasol data.

Position	Type & Length	Content
1-4	I4	Record Number in the file : 6
5-8	I4	Length of this record : 720
9-16	A8	Level-0 data creation country : JAPAN$$$ for POLDER, FRANCE$$
17-24	A8	Level-0 data creation agency : NASDA$$$ for POLDER, CNES$$$$
25-40	A16	Level-0 data creation facility : HEOC-ADEOS$-HREC for POLDER, CMSN1-PARASOL$$$
41-56	A16	Level-0 data creation date and UT time yyyymmddhhmmss$$
57-64	A8	Level-0 processing software version : e.r$$$$$
65-200	A136	Spare
201-208	A8	Level-1 data creation country : FRANCE$$
209-216	A8	Level-1 data creation agency : CNES$$$$
217-232	A16	Level-1 data creation facility : CST-PGS$$$$$$$$$
233-248	A16	Level-1 data creation date and UT time yyyymmddhhmmss$$
249-256	A8	Level-1 processing software version : ee.rr$$$
257-272	A16	Identificator of the Parasol Level-0 data used as input : aaaaaaaaaaaaaaaa
273-280	A8	Version of the data used for radiometric calibration: ee.rr$$$
281-296	A16	Date and UT time of creation of the radiometric calibration input file : yyyymmddhhmmss$$
297-312	A16	Date and UT time of the beginning of applicability of the radiometric calibration: yyyymmddhhmmss$$
313-320	A8	Version of the data used for geometric processing : ee.rr$$$
321-336	A16	Date and UT time of creation of the geometric data input file : yyyymmddhhmmss$$

337-352	A16	Date and UT time of the beginning of applicability of the geometric data : `yyyymmddhhmmss$$`
353-356	B4	Product Confidence Data. This field contains several indicators on the product quality
357-720	A364	Spare

Scaling factors

This record describes the coding of the parameters in the data file. Most parameters are given using integer binary coding with either 1 or 2 bytes. The physical values (PV) can be computed from the Binary Values (BV) through :

PV = Slope x BV + Offset

The Slope and the Offset are given for each parameter in this record.

Position	Type & Length	Content
1-4	I4	Record Number in the file : `7`
5-8	I4	Length of this record : `13140`
9-16	A8	Interleaving indicator : `BIP$$$$$`
17-32	A16	Byte ordering standard (`BIG ENDIAN` or `LITTLE ENDIAN`): `BIG$ENDIAN$$$$$$` (as on IBM mainframes)
33-36	A4	Number of parameters per pixel : 327$ for POLDER, `373$ for PARASOL`
37-44	A8	Number of bytes per pixel : 00000648 for POLDER, `00000738 for PARASOL`
26 (ip-1) + 45[7] 26 (ip-1) + 46	A2	Number of bytes for parameter `#ip : nn`
26 (ip-1) + 47 26 (ip-1) + 58	E12.5	Slope for the computation of physical value for parameter `#ip : ±s.sssssE±bb`
26 (ip-1) + 59 26 (ip-1) + 70	E12.5	Offset for the computation of physical value for parameter `#ip : ±o.oooooE±cc`
9743-13140 for PARASOL 8547-13140 for POLDER	A3398 for PARASOL A4594 for POLDER	Spare

Annotations

This record gives some statistical information on the results of the level-1 processing. The percentages of “land”, “water” and “mixed” pixels in the viewing segment are given. A rough cloud mask is applied to the

[7] `ip` is the parameter number. `1 ≤ ip ≤ 373 for PARASOL or 327 for POLDER`

data, and the percentage of cloud covered pixels for each 10° latitude band (first : 90N-80N, last : 80S-90S) is given. Finally, this record gives the number of observed pixels for each of the 3240 lines of the Parasol reference grid.

Position	Type	Content
1-4	I4	Record Number in the file : `8`
5-8	I4	Length of this record : `13320`
9-12	A4	Percentage of Dummy data found in level-0 : `ppp$ (0≤ppp≤100)`
13-16	A4	Percentage of saturated observations : `ppp$ (0≤ppp≤100)`
17-20	A4	Percentage of "land" pixels in the viewing segment : `ppp$ (0≤ppp≤100)`
21-24	A4	Percentage of "ocean" pixels in the viewing segment : `ppp$ (0≤ppp≤100)`
25-28	A4	Percentage of "coast" pixels in the viewing segment : `ppp$ (0≤ppp≤100)`
4 (ib-1) + 29[8] 4 (ib-1) + 32	A4	Percentage of pixels recognised as "cloudy" in the 10° latitude band `#ib : ppp$ (0≤ppp≤100)`
101-200	A100	Spare
201-204	A4	Number of lines in the Parasol grid for which at least one pixel is present in the data file[9]: `nnnn`
4 (il-1)+205[10] 4 (il-1)+208	A4	Number of pixels (or records) in the data file for line `#il (1≤il≤3240,` from North to South) : `nnnn (0≤nnnn≤6480)`
13165-13320	A156	Spare

[8] `ib` is the 10° latitude band number (from North to South). `1 ≤ ib ≤ 18`

[9] If only a given geographical area is ordered from the Parasol processing center, this field and the next one are automatically updated in agreement with the area selection.

[10] `il` is the line number in the POLDER/Parasol reference grid. `1 ≤ il ≤ 3240`

Data File Format

The Data file is composed of a first record of length 180 bytes, and a variable number of data records (equal to the number of pixels observed in the viewing segment, i.e. Npixels).

Record Name	Number of records	Record Length (Bytes)
Data file descriptor	1	180
Data record	Npixels	738

Data file descriptor

This record describes the data structure of the data file.

Position	Type & Length	Content
1-4	I4	Record Number in the file : `1`
5-8	I4	Length of this record : `180`
9-20	A12	Reference Document Identification : `SPG9N122-316$`
21-26	A6	Reference Document Version Number : `aa/bb$`
27-32	A6	Software Version Number : `aa.bb$`
33-36	A4	File Number : `2$$$`
37-52	A16	File Name[11] : `PwL1TBG1cccooovD`
53-56	I4	Number of “data” records in the file : ($0 \leq Npixels \leq 1.2\ 10^6$)
57-60	I4	Length of one “data” record : `738`
61-100	A40	Spare
101-104	I4	Length of the prefix in the “data” record (bytes) : 7[12]
105-108	I4	Length of data in the “data” record : 725
109-112	I4	Length of the suffix in the “data” record (bytes) : `0`
113-180	A68	Spare

Data record

A data record is composed of 11 non-directional parameters (including the prefix), followed by 16 sets of 23 parameters. 16 observation directions is a maximum for Parasol, while it was 14 for POLDER onbord ADEOS-1 and 2. Most pixels have either 14 or 15 directional sets of observations; other have less, in particular on both ends of the viewing segment. In the data record, if less than 16 directions are available (Ndir<16), the available directions are stacked first, and the end of the record is filled with Dummy values. Note that the `Ndir` sets of measurements do not necessarily correspond to consecutive observation sequences.

[11] See Annexe A for the POLDER/Parasol standard for filenames

[12]Note that the sum of the prefix, data and suffix lengths do not yield the record length because there are 6 additional bytes before the prefix.

In the table below, the parameter number is the number used in the "scaling factor" record of the leader file. As of April 2005, the Offset for the conversion of binary to physical values is 0 for all parameters. The Slope is indicated in the table below. At this time, there is no plan to change these Slope values, nevertheless a careful user should verify that they agree with the values given in the leader file (scaling factors record).

The radiances and Stokes parameters are given in "normalized radiance" units : the radiance (in W m^{-2} sr^{-1}) has been divided by the top of atmosphere incoming irradiance and multiplied by π. It is necessary to divide the parameter by $\cos(\theta_S)$ to transform the measurement to reflectance units.

Position	Param #	Type & Length	Slope	Content
1-4		I4		Record Number in the file : `2≤RecNum≤Nrec+1`
5-6		I2		Length of this record (bytes): `648 for POLDER, 738 for PARASOL`
7-8		I2		Line Number of the pixel in the POLDER grid
9-10		I2		Column Number of the pixel in the POLDER grid
11-12		SI2		Pixel altitude from the DEM (meters)
13		I1		Land (100), Water (0) or Mixed (50) indicator
14-45	1	B 32	1	Pixel Quality Index. See Appendix G
46	2	I1	1	Rough Cloud Indicator : Clear (0), Cloudy (100) or Undetermined (50)
47	3	I1	1.4	Solar Azimuth Angle (°)
48	4	I1	1	Number of available viewing directions : Ndir In the following `1 ≤ id ≤ Ndir`
49-50	5	B2	1	Sequence Arrangement Indicator[13]
43 (id-1)+51	23 id -17	I1	1	Sequence Number in the orbit[14] : `sn (1≤sn≤130)`
43 (id-1)+52 43 (id-1)+53	23 id -16	SI2	10^{-2}	Line number of the CCD matrix detector which has observed the pixel for filter 670P2
43 (id-1)+54 43 (id-1)+55	23 id -15	SI2	10^{-2}	Column number of the CCD matrix detector which has observed the pixel for filter 670P2
43 (id-1)+56	23 id -14	I2	1.5 10^{-3}	Solar Zenith Angle (°)
43 (id-1)+58	23 id -13	I2	1.5 10^{-3}	View Zenith Angle (°) for filter #8 (670P2)[15]

[13] This two bytes indicator describes, for the 16 directions, whether the acquisition sequence is type A or type B (see the Instrument Setting record in the leader file). bit 0 is for direction #1, bit 15 is for direction #14. The bit is set to 0 (resp. 1) for sequence acquisition type A (resp. B).

[14] This sequence number is needed to identify measurements that have been acquired simultaneously (i.e. during one acquisition), or to retrieve some information about the instrument position, attitude and state during the acquisition (information found in the "Technological parameters" record of the leader file).

[15] Due to the satellite velocity and the fact that the 15 measurements are not strictly coincident in time, there is a small variation of view angle between the spectral filters. See Annexe C for details.

43 (id-1)+60 43 (id-1)+61	23 id - 12	I2	$6.\ 10^{-3}$	Relative Azimuth Angle (°) for filter #8 (670P2)
43 (id-1)+62	23 id -11	SI1	$1.6\ 10^{-3}$	$\Delta[\theta_V \cos(\phi)]$: Relative variation of viewing geometry between the filters (°). See Appendix C
43 (id-1)+63	23 id -10	SI1	$1.6\ 10^{-3}$	$\Delta[\theta_V \sin(\phi)]$: Relative variation of viewing geometry between the filters (°). See Appendix C
43 (id-1)+64 43 (id-1)+65	23 id - 9	SI2	10^{-4}	Normalised Radiance for channel 443NP
43 (id-1)+66 43 (id-1)+67	23 id - 8	SI2	10^{-4}	Normalised Radiance for channel 490P
43 (id-1)+68 43 (id-1)+69	23 id - 7	SI2	10^{-4}	Normalised Radiance for channel 1020NP
43 (id-1)+70 43 (id-1)+71	23 id - 6	SI2	10^{-4}	Normalised Radiance for channel 565NP
43 (id-1)+72 43 (id-1)+73	23 id - 5	SI2	10^{-4}	Normalised Radiance for channel 670P
43 (id-1)+74 43 (id-1)+75	23 id - 4	SI2	10^{-4}	Normalised Radiance for channel 763NP
43 (id-1)+76 43 (id-1)+77	23 id - 3	SI2	10^{-4}	Normalised Radiance for channel 765NP
43 (id-1)+78 43 (id-1)+79	23 id - 2	SI2	10^{-4}	Normalised Radiance for channel 865P
43 (id-1)+80 43 (id-1)+81	23 id - 1	SI2	10^{-4}	Normalised Radiance for channel 910NP
43 (id-1)+82 43 (id-1)+83	23 id	SI2	10^{-4}	Second component of Stokes Vector (Q) for channel 490P
43 (id-1)+84 43 (id-1)+85	23 id +1	SI2	10^{-4}	Second component of Stokes Vector (Q) for channel 670P
43 (id-1)+86 43 (id-1)+87	23 id + 2	SI2	10^{-4}	Second component of Stokes Vector (Q) for channel 865P
43 (id-1)+88 43 (id-1)+89	23 id +3	SI2	10^{-4}	Third component of Stokes Vector (U) for channel 490P
43 (id-1)+90 43 (id-1)+91	23 id +4	SI2	10^{-4}	Third component of Stokes Vector (U) for channel 670P
43 (id-1)+92 43 (id-1)+93	23 id + 5	SI2	10^{-4}	Third component of Stokes Vector (U) for channel 865P
43 Ndir + 51 738 / 648				Spare

References

Hagolle O, Goloub P, Deschamps PY, et al., Results of POLDER in-flight calibration, *IEEE Trans Geosci. Rem. Sens.* **37** (3) 1550-1566 (1999)

Deschamps, P.Y., F.M. Bréon, M. Leroy, A. Podaire, A. Bricaud, J.C. Buriez, and G. Sèze; 1994: The POLDER Mission: Instrument Characteristics and Scientific Objectives. *IEEE Trans. Geosc. Rem. Sens.* **32**, 598-615.

Acronymes

ADEOS	Advanced Earth Observing Satellite
CCD	Charge Coupled Device
CNES	Centre National d'Etudes Spatiales
DEM	Digital Elevation Model
ECMWF	European Center for Medium Range Weather Forecast
ERBE	Earth Radiation Budget Experiment
ISCCP	International Satellite Cloud Climatology Project
LERTS	Laboratoire d'Etudes et de Recherche en Télédétection Spatiale
LIA	Long Integration Acquisition
LOA	Laboratoire d'Optique Atmosphérique
LSCE	Laboratoire des Sciences du Climat et de l'Environnement
LMD	Laboratoire de Météorologie Dynamique
LPCM	Laboratoire de Physique et Chimie Marines
NDVI	Normalized Difference Vegetation Index
NRE	Normalized Radiant Exitence
NWM	Numerical Weather Model
NASDA	National Space Development Agency of Japan
POLDER	Polarization and Directionality of the Earth Reflectances
SIA	Short Integration Acquisition
TOA	Top of the Atmosphere
TOMS	Total Ozone Mapping Spectrometer
UT	Universal Time

Appendix A : Product identification

This Appendix describes the POLDER/Parasol standard for product identification.

A standard Parasol/POLDER product identificator (15 characters) takes the form :

`PwLxTyGzcccooov` (Browse, level 1 or level 2)

`PwLxTyGzaammddv` (level 3)

where `w` is the instrument number (1 for POLDER-1 on ADEOS-1, 2 for POLDER-2 on ADEOS-2, 3 for Parasol)

`x` indicates the product level (1, 2, 3, or 1 for the Browse product)

`y` indicates the product thematic (B (as Basic) for level 1 and Browse products, R (as Radiation and clouds) L (as Land surfaces) or O (as Ocean Color) for Level 2 and 3 products)

`z` is a code for product type (see table below)

`ccc` is the satellite cycle number (`1 ≤ ccc ≤ 999`)

`ooo` is the orbit number in the cycle(`1 ≤ ooo ≤ 585` for POLDER-1; 057 for POLDER-2, 233 for Parasol)

`aammdd` is the reference date for the temporal synthesis (year-month-day)

`v` indicates the reprocessing number (from `A` to `Z`)

Level	Thematic	Product Type	x	y	z	Grid
Browse			1	B	B	
1			1	B	1	Full
2	Clouds & Rad. Budget		2	R	B	Medium
	Ocean & Atm.	Directional parameters (surface)	2	O	A	Full
		Non-Directional param. (surface)	2	O	B	Full
		Aerosols parameters	2	O	C	Medium
	Land & Atm.	Directional parameters (surface)	2	L	A	Full
		Aerosols parameters	2	L	C	Medium
3	Clouds & Rad. Budget	Synthesis	3	R	B	Medium
	Ocean & Atm.	Marine parameters	3	O	B	Full
		Aerosol parameters	3	O	C	Medium
	Land & Atm.	Directional signature param (surf.)	3	L	A	Full
		Albedo & Vegetation parameters	3	L	B	Full
		Atmospheric parameters	3	L	C	Medium

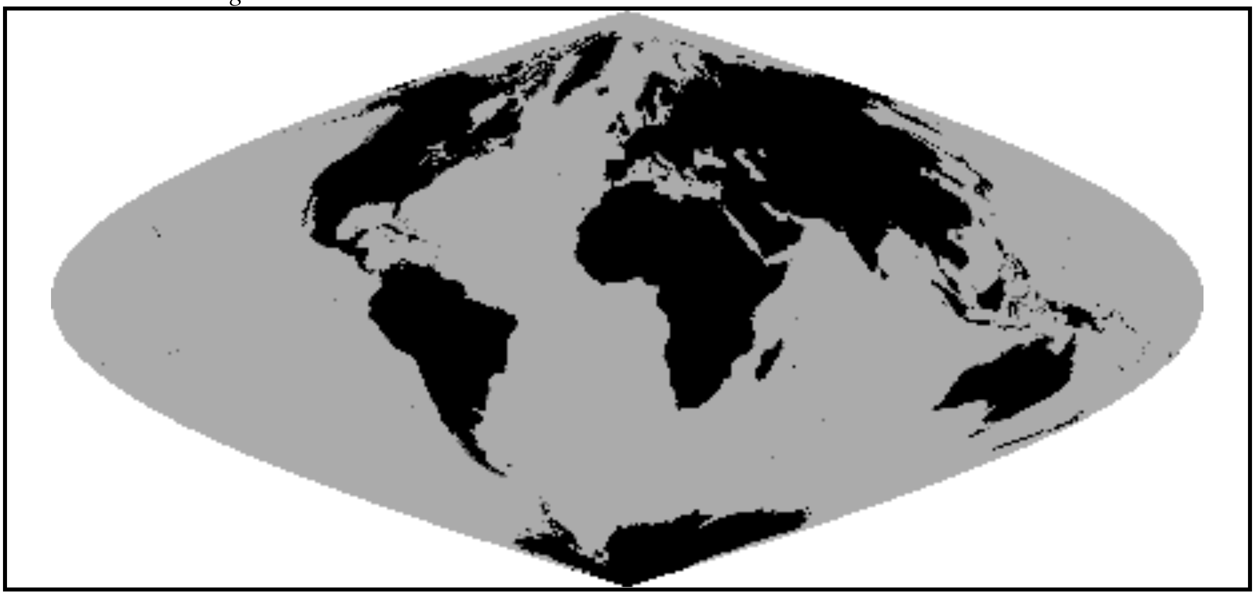
A product consists of two files. A *leader file* and a *data file*. The *leader file* filename takes the form aaaL where aaa is the product identificator (15 characters). Similarly, the *data file* filename is aaaD.

In the table above, the last column indicates the resolution of the grid used for the corresponding product.

Appendix B : POLDER/Parasol Full resolution reference grid

The POLDER/Parasol Full resolution grid is used for level 1 products as well as surface parameters of the level 2 and 3 products.

The POLDER/Parasol reference grid 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*.



`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 :

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

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

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

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

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

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

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

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') :

$$lin' = lin$$
$$N_i = \mathrm{NINT}[3240 \sin(\frac{lin - 0.5}{18})]$$
$$col' = 3241 - N_i + \mathrm{MOD}_{2N_i}(col + 2N_i - 3241)$$

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

Appendix C : Method for deriving the viewing geometry for each channel

With the POLDER/Parasol imaging concept, the 15 spectral/polarized measurements are acquired sequentially. Therefore, a given surface target is observed, for the various spectral bands, with slightly different viewing angles. The differences are very small, but can be significant for some applications that need a very high angular accuracy, such as the atmospheric correction over the ocean.
The view zenith angle (θ_0=VZA) and relative azimuth (φ_0=RelAzim) that are given in the level 1 product are for the central filter, i.e. 670P2. The two parameters DVzC=$\Delta[\theta_V \cos(\phi)]$ and DVzS=$\Delta[\theta_V \sin(\phi)]$, which are given for each viewing direction in the data file, are necessary to derive these angles for other spectral bands θj and φj. The formulae are as follows:

$$\theta_j = \sqrt{(\theta_0 \cos\varphi_0 + X_j\, DVzC)^2 + (\theta_0 \sin\varphi_0 + X_j\, DVzS)^2}$$

$$= \sqrt{\theta_0^2 + 2X_j\,\theta_0\left[\cos\varphi_0\; DVzC + \sin\varphi_0\; DVzS\right] + \left(X_j\right)^2\left[DVzC^2 + DVzS^2\right]}$$

$$\varphi_j = \arctan\left[\frac{\theta_0 \sin\varphi_0 + X_j\, DVzS}{\theta_0 \cos\varphi_0 + X_j\, DVzC}\right]$$

IF $\theta_0 \cos\varphi_0 + X_j\, DVzC < 0$ THEN $\varphi_j = \varphi_j + 180°$

where Xj is given in the table below:

Xj=	-6	-4	-3	-2	0	2	3	4	6
Channel	443P	443NP	1020	565	670	763	765	910	865

Note: This formulation is based on the simple principle that the 15 measurements are acquired equally spaced and on a straight line in an angular system of orthogonal axis ($\theta \sin\varphi$, $\theta \cos\varphi$)

Appendix D : Manipulation of polarization parameters

The POLDER/Parasol level-1 product provides the second, Q, and third, U, parameters of the Stokes vector. The Stokes vector is defined with respect to the reference frame defined by the viewing direction and the local zenith.

The polarized radiance I_p and polarization direction χ can be derived from Q and U through :

$$I_p = (Q^2 + U^2)^{1/2}$$

$$I_p \sin(2 \chi) = U$$

$$I_p \cos(2 \chi) = Q$$

In the equations above, the polarization angle χ is referred to the plane defined by the local zenith and the viewing direction. The following equations yield the polarization angle referred to the scattering plane (defined by the sun and view directions).

$$\chi = \arctan (U / Q) / 2$$

$$\text{IF } (Q<0)\ \chi = \chi + \pi/2$$

$$\tan(\alpha) = \frac{\sin(\phi)}{\frac{\sin(\theta_v)}{\tan(\theta_s)} - \cos(\theta_v)\cos(\phi)}$$

$$\psi = \chi - \alpha$$

where ψ is the polarization direction defined with respect to the scattering plane.

Note that both ψ and χ are defined modulo π.

In general, ψ is close to $\pm\pi/2$.

Appendix E : Orbital characteristics

Sat	Symbol	ADEOS-1	ADEOS-2	Parasol
Repeat Cycle	C	41	4	16
Number of Revolutions	Norb	585	57	233
Origin of Longitudes	$LonEq_0$	191.980	185.394	TBD
Origin of times (Julian)	J_0	2450308.41216167	2452619.41641050	2453344.487611
Local Time at origin of times	$Hloc_0$	10.690525	10.3534	
Correction factor for local time	corH	[-0.0077771851, 1.2939654e-05, -3.9683356e-09, 2.2428582e-13]	[-0.0361971, 4.949845e-05, -1.82803e-09, 0.]	[0,0,0,0]

ADEOS(1 and 2) are sun-synchronous polar satellites. The satellite subtracks are repeated with a period of respectively 41 and 4 days, which defines an orbit repeat cycle. During this period, the ADEOS 1 and 2 satellite makes 585 and 57 revolutions around the Earth respectively.

The following equations allow an easy computation of equator crossing time, local time at equator and date. They make use of the Julian day, which is an integer at noon.

The accumulated orbit number is defined as

```
aaa = (ccc-1)*Norb + ooo
```

where ccc and ooo are the cycle and orbit number respectively

From aaa, the longitude at the equator is given by

```
lonEq = lonEq0 - aaa*360*C/Norb
```

The Julian day for the equator crossing time is given by :

```
Jul = J0 + aaa*C/Norb + sum/24
```

where `sum = corH[0] + corH[1]*aaa + corH[2]*aaa^2 + corH[3]*aaa^3`

Inversely, one can retrieve the accumulated orbit number from a Julian date Jday through:

```
bbb = (jday - J0)*Norb/C
sum = corH[0] + corH[1]*bbb + corH[2]*bbb^2 + corH[3]*bbb^3
aaa = ROUND(bbb -sum/24.*Norb/C )
```

where ROUND returns the closest integer

Appendix F : POLDER radiometric model

The POLDER CCD pixels are numbered (i, j) as seen in Figure 1. For the polarized bands, analysor 2 is parallel to axis j (matrix smaller axis) and analysors 1 and 3 are turned by about ±60° from analysor 2.

Figure 1

The matrix pixel (i, j) images the incident radiance corresponding to zenith viewing angle θ and azimuth viewing angle ϕ such that

$$\theta = Arctg(\sqrt{d_c^2 (i - i_0)^2 + d_a^2 (j - j_0)^2} \,/ f), \; tg(\phi) = \frac{d_a (j - j_0)}{d_c (i - i_0)},$$

where (i_0, j_0) correspond to the central pixel, f is the instrument focal length, and (d_a, d_c) are the CCD pixel sizes (a CCD pixel is not square). Note that these angles are defined in the instrument reference frame, not in the target Earth-fixed frame.

Figure 2

The incident light is assumed to be linearly polarized, and its Stokes parameters (I, Q, U) are defined with respect to axes (l, r) respectively parallel and perpendicular to the meridian plane. For a perfect instrument, the numerical count CN_{ij}^{ka} corresponding to pixel (i, j) in wavelength filter k (k = 1, 2, ..., 9), and polarizer number a, $(a = 1,2,3)$ writes:

$$CN_{ij}^{ka} = A_k\left(I + \cos(2\alpha^{ka})Q + \sin(2\alpha^{ka})U\right) \quad (1)$$

where A_k is the calibration coefficient and α^{ka} stands for the angle between the meridian plane and the analysor a directions.

The instrument is not perfect however, and we write the radiometric model in a generalized form:

$$CN_{ij}^{ka} = t\, A_k g_{ij}^{ka} p^k(\theta) T^{ka}\left(P_I^{ka} I + P_Q^{ka} Q + P_U^{ka} U\right) + CN_{ij}^0 \quad (2)$$

where:

- CN_{ij}^0 is the darkness current;
- t is the integration time (ms)
- $p^k(\theta)$ accounts for the low frequency variation of the optics transmission; it is normalized to $p^k(\theta = 0) = 1$;
- g_{ij}^{ka} is the matrix pixel equalization coefficient, which takes into account high frequency variations in the optics transmission and in the CCD sensitivities. For each filter $g_{i_0,j_0}^{ka} = 1$ for the central pixel (i_0=121, j_0=137);
- T^{ka} accounts for differences in the transmission of the 3 analysors of one given spectral band. It is normalized according to $T^{k2} = 1$ for the central analysor.

In a first order correction of the lens and filters optical effects, the coefficients P_I, P_Q, and P_U can be writen as:

$$P_I^{ka} = 1 + \eta^k \varepsilon^k(\theta)\cos(2\alpha_p^{ka})$$
$$P_Q^{ka} = \eta^k\left(\varepsilon^k(\theta) + \cos(2\alpha_p^{ka}) - \xi^{ka}\sin(2\alpha_p^{ka})\right) \quad (3)$$
$$P_U^{ka} = \eta^k\left(\sin(2\alpha_p^{ka}) + \xi^{ka}\cos(2\alpha_p^{ka})\right)$$

with

$$2\alpha_p^{k1} = 2\alpha^{k2} - 120 = 2\alpha^{k1} - \xi^{k1}$$
$$2\alpha_p^{k1} = 2\alpha^{k2} \qquad \xi^{k2} = 0 \quad (4)$$
$$2\alpha_p^{k3} = 2\alpha^{k2} + 120 = 2\alpha^{k3} - \xi^{k3}$$

The physical interpretation of the correction terms used in eq. (3) and (4) are given below:

- η^k (which is on the order of 1) accounts for the imperfect extinction of the polaroids. It varies with wavelength and with the integration time (because of the polarizer rotations during the acquisition).
- $\varepsilon^k(\theta)$ (<<1) accounts for the linear polarization induced by the optics, an effect which is nearly radial, symmetric around the optical axis, and null for the central pixel. $\varepsilon^k(\theta)$ varies with wavelength.
- α^{k2} is the orientation of polarizer 2 with respect to the meridian plane (see Fig. 2)
- α_p^{k1} and α_p^{k3} are two directions ±60° from the orientation of polarizer 2.

- ξ^{k1} and ξ^{k3} account for the departures of polarisers 1 and 3 with respect to their ideal positioning, ±60° from polarizer 2.

Note that, the formulation used in (3) yields:

$$\sum_{a=1}^{3} \cos(2\alpha_p^{ka}) = 0 \qquad \sum_{a=1}^{3} \sin(2\alpha_p^{ka}) = 0 \tag{5}$$

The signal modeling defined by eqs.(1) to (4) was tested with laboratory measurements, using an integrating sphere, which provided incident unpolarised light, and a transmission device capable of polarizing the incident light by a calibrated, adjustable amount. Level 1 radiometric processing yields the (I,Q,U) Stokes parameters from the CN_{ij}^{ka} numerical counts. The various calibration coefficients that are needed for this inversion have been measured before launch, and are monitored in flight using geophysical targets of known reflectance, spectral signature and polarization properties.

Appendix G : Pixel Quality Index (DQX)

The Level-1 data record includes an indicator of the pixel data quality. This indicator is 32 bytes long, which corresponds to 2 bytes (16 bits) per viewing direction. The first two bytes are for direction number 1, the last two bytes are for directions number 16.

The data quality is nominal when all bits of the DQX are 0. Various causes may yield a degraded measurement quality, which affect Parasol bands differently. Moreover, the various scientific objectives of the Parasol mission have different radiometric quality requirements. This is why different thresholds have been set by the mission team to label a set of bands as "nominal" or "degraded".

In the table below, bit 1 is the least significant, and bit 16 is the most significant. The bit value is 1 if the condition is true.

bit #	Affected bands	Condition
1-3	All	Potential error in the attitude data. Rating is 4 b1 + 2 b2 + b3 Rating of 0 to 7 correspond to error of 0.01; 0.05; 0.1; 0.15; 0.25; 0.50; 1; >1 respectively.
4	1020, 565, 763, 765, 910	Anomaly in the correction for optic polarization
5	490P	Pixel saturated / lacking in the 4x4 window used for bicubic interpolation
6	443, 1020, 565	Pixel saturated / lacking in the 4x4 window used for bicubic interpolation
7	670P	Pixel saturated / lacking in the 4x4 window used for bicubic interpolation
8	763, 765, 865, 910	Pixel saturated / lacking in the 4x4 window used for bicubic interpolation
9	490	CCD pixel may be degraded (matrix border)
10	443, 1020, 565	CCD pixel may be degraded (matrix border)
11	670	CCD pixel may be degraded (matrix border)
12	763, 765, 865, 910	CCD pixel may be degraded (matrix border)
13	443, 1020, 565, 670, 763, 765, 865	Stray light correction (type 1) greater than a threshold. The thresholds are defined by the ocean color mission requirements.
14	490, 670, 763, 765, 865, 910	Stray light correction (type 1) greater than a threshold. The thresholds are defined by the other mission requirements.
15	443, 1020, 565, 670, 763, 765, 865	Stray light correction (type 2) greater than a threshold. The thresholds are defined by the ocean color mission requirements.
16	490, 670, 763, 765, 865, 910	Stray light correction (type 2) greater than a threshold. The thresholds are defined by the other mission requirements.

Appendix H : How to locate a particular pixel in the data file

The pixels of the POLDER/Parasol reference grid are arranged in the data file line by line and column by column. The last record of the leader file includes an array `Npix[3240]` which gives the number of pixels in the data file for each of the 3240 lines of the POLDER grid. This array can be used for a fast location of a particular pixel in the data file :

Let il_0 and ic_0 be the line and column coordinates of the pixel in the POLDER reference grid. The POLDER measurements for this pixel are located in the data file in record number rec_0. The following relation apply :

$$2 + \sum_{il=1}^{il_0 - 1} Npix[\,il\,] \le rec_0 \le 1 + \sum_{il=1}^{il_0} Npix[\,il\,]$$

One method to retrieve the pixel is to read all records that satisfy the relation above, and to read the corresponding column number.

Another, faster, method uses the dicotomy and it is shown below :

$$irecmin = 2 + \sum_{il=1}^{il_0 - 1} Npix[\,il\,]$$

$$irecmax = 1 + \sum_{il=1}^{il_0} Npix[\,il\,]$$

```
rec0 = 0
WHILE [ (rec0 = 0) AND (irecmax ≥ irecmin) ] DO
      irec=(irecmax+irecmin)/2  (if the ratio is not an integer, perform an integer truncation)
      READ record number irec, and get the corresponding column number ic.
      IF (ic = ic0) rec0 = irec
      IF (ic > ic0) irecmax = irec
      IF (ic < ic0) irecmin = irec + 1
END DO
```

If (rec$_0$ *= 0), there is no data corresponding to the selected pixel in the data file.*