Exploitation of the CEOS Pseudo Invariant Calibration Sites (PICS) for Vicarious Calibration of Optical Imagers

Soil samples spectro-directional measurement database description document

For the attention of: Mr Marc BOUVET – ESA CONTRACT OFFICER

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Exploitation of the CEOS Pseudo Invariant Calibration Sites (PICS) for Vicarious Calibration of Optical Imagers Soil samples spectro-directional measurement database description document			
Issue	**Revision**	**Date**	**Reason for the revision**
1	0	26/06/2018	Initial version
1	1	04/07/2018	Change measurement condition for K. White's data in Namibia
2	0	21/09/2018	Addition of the quantitative mineralogy characterization for some selected samples

Modification status				
Issue	Rev	Status *	Modified pages	Reason for the modification
2	0	I	§4.1.3	New results

* *I = Inserted* *D = deleted* *M = Modified*

Acronyms

AZI	Relative Azimuth Angle
BRDF	Bi-directional Reflectance Distribution Function
BRGM	Bureau de Recherches Géologiques et Minières
GEOPS	Geosciences Paris Sud
PI	Principal Investigator
RF	Reflectance Factor
SZA	Sun / Illumination Zenith Angle
VZA	View Zenith Angle

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Table of contents

1. Introduction

1.1. Context and objectives

The main objectives of the ESA-PICS study consist in

i) **revisiting the list of Pseudo-Invariant Calibration Sites (PICS) over desert areas** defined 20 years ago by [RD1] based on more recent multi-spectral remotely sensed data with enhanced temporal and spatial coverages and resolutions ([RD2]),

ii) **collecting sand samples** from an ensemble of identified sites and **analysing in laboratory their physical** (mineralogy and grain size analysis) **and optical** (spectro-directional reflectance) **properties** ([RD3] and [RD4]),

iii) **building a database** combining the sand optical properties estimated from the sampled collected with other databases available in the literature to be made available to the scientific community.

In this document, we describe the database of sand optical properties, using *i)* the BRF measurements performed in [RD4] for the various sand samples and *ii)* additional datasets shared by the scientific community.

1.2. Plan of the document

The first section will provide definitions on the observation geometries considered in PICSAND and on reflectance nomenclature.

The second section will present the various datasets used in the PICSAND database.

The third section will describe the structure of the database and the nomenclature for the directories and files.

The fourth section will provide an overview of the online PICSAND portal.

The final section defines the data use policy of the PICSAND database.

2. Definitions

2.1. Observation geometry

The observation geometry considered hereinafter is described in the figure below:

- θ_s is the illumination zenith angle;
- θ_v is the view zenith angle;
- ϕ is the relative azimuth angle (corresponding to the difference between the illumination azimuth and view azimuth, angles).

The range of variation for the relative azimuth angle ϕ is [0°; 360°]; θ_s and θ_v vary between 0° and 90°. The definition used PICSAND is such that the **backward scattering direction corresponds to 0°** while the **forward scattering direction corresponds to 180°**.

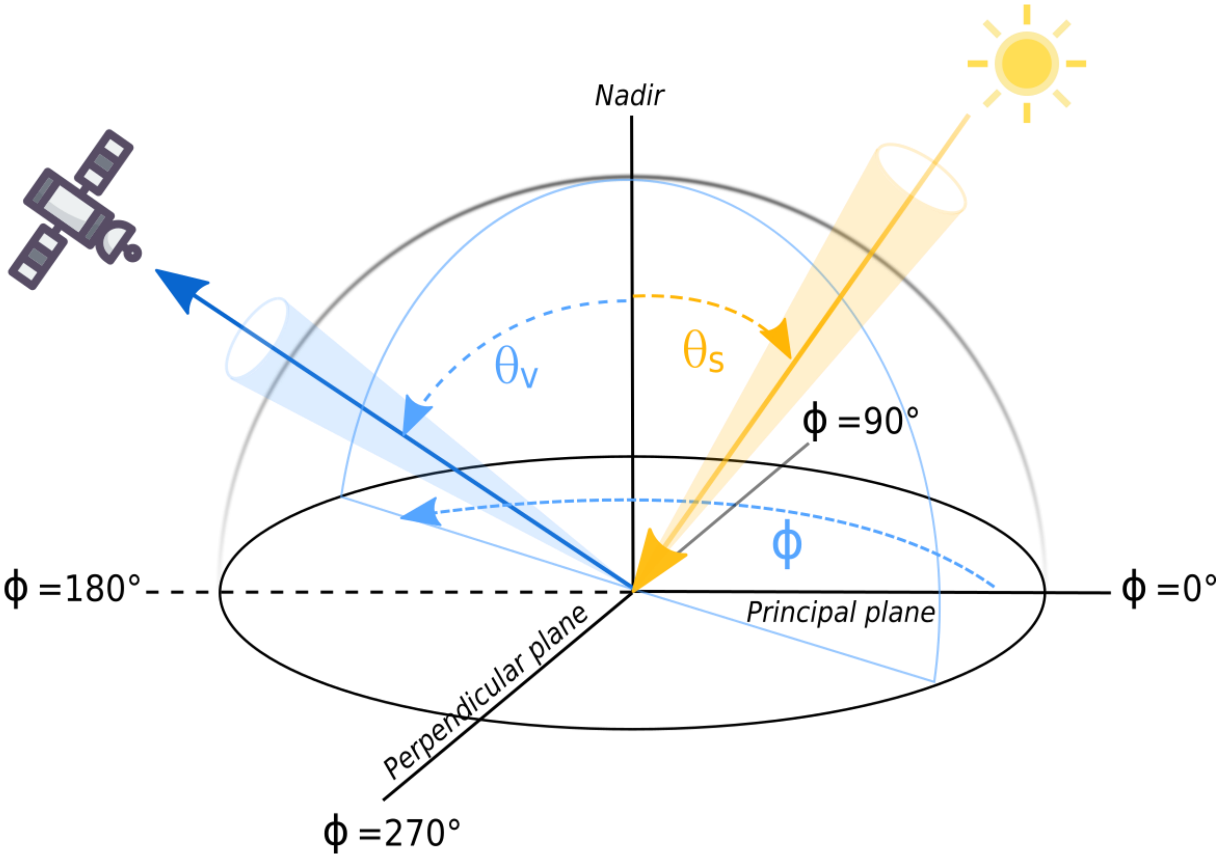

Figure 1: Definition of angles used in the representation of directional reflectance measurements

2.2. Reflectance nomenclature

Several reflectance quantities have been defined over the years depending on the conditions of measurements and the geometries of illumination/viewing. Comprehensive terminologies are available in [RD5] or [RD6].

- **Reflectance:**

  Ratio of the reflected to incident flux. Following energy conversion laws, reflectance varies between 0 and 1.

- **Reflectance factor:**

  Ratio of the radiant flux reflected by a surface to that reflected into the same reflected-beam geometry by an ideal (lossless) and diffuse (Lambertian) standard surface, irradiated under the same conditions. Reflectance factors may reach values beyond 1. Spectralon© is commonly used as the standard diffuse surface.

Reflectance and Reflectance Factor are rather generic terms to describe the reflectance properties of the surface. Both vary spectrally and with the observation geometry (illumination and view zenith angles, relative azimuth angle), as well as with the solid angles of the incident and measured fluxes.

The figure below, extracted from [RD6], describes these different types of illumination-viewing geometries. To each is associated a specific reflectance quantity. Among the 9 different types of reflectances, only 4 can be directly measured.

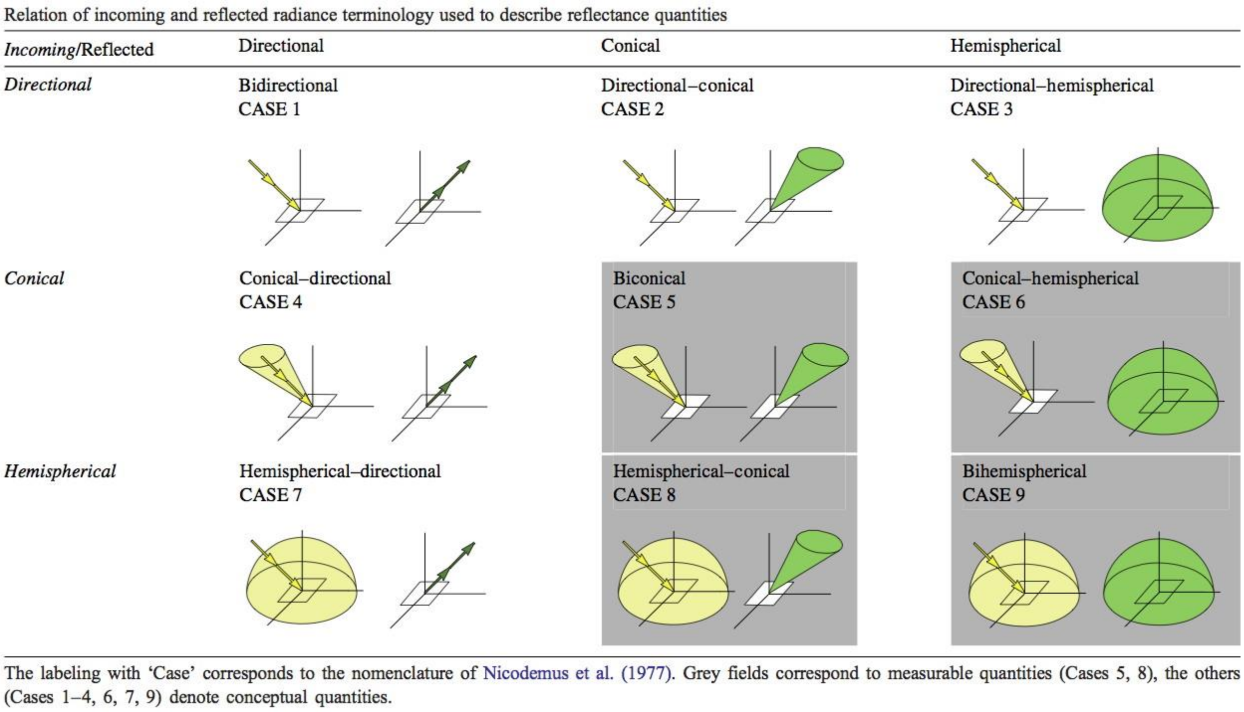

Figure 2: Schematic diagrams of different methods of measuring reflectance (from Schaepman & Schaepman [2006]).

- The most commonly used directional quantity used in remote sensing to characterize the directional dependency of the surface leaving radiance (surface anisotropy) is the **Bi-directional Reflectance Distribution Function (BRDF).**

  It describes the intrinsic scattering properties of a surface. BRDF is the ratio between the spectral radiance leaving the surface in a given direction (spectral energy per unit area contained within a unit solid angle expressed in $W.m^{-2}.sr^{-1}.nm^{-1}$) to the spectral irradiance (in $W.m^{-2}.nm^{-1}$). BRDF unit is sr^{-1}.

  BRDF cannot be measured directly given it involves infinitesimal elements of solid angle. However, it is used to define other reflectance quantities.

  The BRDF of a perfect (Lambertian) diffuse surface is $1/\pi$ sr^{-1}.

- **BRF: Bi-directional Reflectance Factor**

  Ratio of the flux reflected by a surface area to the flux reflected from an ideal and diffuse (Lambertian) surface of the same area under identical view and illumination geometry. Hence, the BRF of any surface can be expressed as π times its BRDF.
  BRF is a dimensionless ratio (case 1).

- **BCRF: Bi-conical Reflectance Factor**

  Special case of BRF where illumination and viewing directions are associated to "conical" solid angle. It corresponds typically to the quantity measured in laboratory (case 5).

- **HDRF: Hemispherical-Directional Reflectance Factor**

  The definition is similar to that of BRF but considers illumination from the entire hemisphere (case 7)

- **DHR: Directional-Hemispherical Reflectance**

  Similar to the definition of BRF considering the special case of a pure direct illumination and a measured radiance integrated over the hemisphere (case 3).

- **BHR: Bi-hemispherical Reflectance**

  Similar to the definition of BRF considering the special case where the illumination comes from the entire hemisphere and the measured radiance is integrated over the hemisphere (case 9). It usually refers to "albedo".

3. Overview of the datasets used in the PICSAND database

The measurements performed in the frame of the study, detailed in [RD4], will not be described further. Only the additional datasets provided by research scientists to build PICSAND will be detailed. The list of the PIs for the contributing datasets are recalled in §6.3.

3.1. Directional measurements

Table 1 presents an overview of the datasets with spectro-directional measurements that are used in PICSAND.

Table 1: Characteristics of the datasets with spectro-directional measurements

PI	Country	Characteristics	Meas. Condition	Ref.	Spectral Domain	Directional Domain
ONERA	France	Algier / Narbonne	laboratory	[RD7]	520-910 nm	SZA [0,60] VZA [0-90] (10 deg step) AZI [0-180] (10° step)
ONERA	Algeria	Algeria3 / Algeria5	laboratory	[RD4]	350-2500 nm	SZA [10,60] VZA [0-50] (10° step) AZI [0-180] (20° step)
ONERA	Morocco	Erg Chebbi	laboratory	[RD4]		
ONERA	Namibia	RadCalNet site / Gobabeb	laboratory	[RD4]		
ONERA	Arabia	ArabiaPICS2	laboratory	[RD2], [RD4]		
ONERA	Niger	Niamey	laboratory	[RD4]		
ONERA	Libya	Erg Ubaru	laboratory	[RD4]		
Cierniewski - Karnieli	Israel	Negev	In situ	[RD8]	450, 550, 650, 850,1650 nm	principal plane
Coburn	USA	Algodones Dunes	in situ	[RD9]	400-900 nm	SZA [Diurnal set] VZA [0, 60] (10° step) and [0,30] (5° step) AZI [0,360] (10° step)
Peltoniemi	Finland	beach, football, car park	in situ	[RD10]	350-2500 nm	SZA (sun) VZA [0° - 62°] AZI [0° - 180°]
Roosjen	Netherlands	sand, sandy loam	laboratory	[RD11]	350 - 2499 nm	SZA [30] Principal plane: VZA [0 - 65] (5° step) ; AZI [0 - 180] (180° step) Other azimuth angles: VZA [0 - 60] (15° step) ; AZI [0 - 180] (30° step). Additional measurements around the hotspot position.
Sun	China	Xianjiamu Sumu / 3 grain size	laboratory	[RD13]	400 - 2500nm	SZA [40, 60] VZA [0 - 60] (10° step) AZI [180 - 360] (15° step)
Zhang/Voss	USA	sand beach + White sands	laboratory	[RD14]	475, 658 nm	SZA [0,5,15,25,35,45,55,65]; VZA [min 5- max 65] (5-15° step) ; AZI [min +-5 - max +-180] (5-15° step)
Zhang	China	Dunhuang site	in situ	[RD15]	399-2386 nm	SZA [0,60]deg ; VZA [0 - 70] (14° step) ; relative azimuth angles from 0° to 150° at steps of 30°

Note that for the datasets of Cierniewski-Karnieli and Zhang (at Dunhuang site), the data correspond to reflectances ratioed by the reflectance measured at nadir.

3.2. Spectral measurements

Table 2 presents an overview of the datasets with only spectral measurements that contributes to the PICSAND database.

Table 2: Characteristics of the datasets with only spectral measurements.

PI	Country	Characteristics	Meas. Condition	Ref.	Spectral Domain
ONERA	Libya	Fezzan Fez	laboratory	[RD4]	350-2500 nm
ONERA	Australia	Lucky Bay / Pinnacle / Wylie Bay			
ONERA	USA	RailRoad Valley playa / White Sands			
ONERA	Namibia				
ASTER			in situ	[RD16], [RD17]	400 – 14011 nm
USGS	USA		in situ	[RD18]	350 - 2500 nm
Hueni	Swiss	sand (bright, coarse, fine, dark..)	in situ	[RD19]	350 – 2500 nm
NPL	Namibia	different soil colours	in situ	[RD20]	380 – 2500 nm
White, Bullard	Australia	Simpson Desert	in situ		400 - 2500 nm
White, Bullard	Namibia		laboratory		400 - 2500 nm
White, Bullard	USA	Muleshoe Dunes	in situ	[RD21]	400 - 2500 nm

3.3. PICSAND processing

The different datasets provided by the PIs in heterogeneous numerical files have been processed in order to generate homogenized data files. The processing was performed such that the output data are as close as possible to the original ones. However, we have chosen to keep only 3 significant digits for the reflectance data and to remove abnormal reflectance values. *in situ* measurements can be strongly contaminated by atmospheric absorption in specific absorption bands (water vapor and carbon dioxide mainly). We have chosen to keep the corresponding measurements, even if very noisy and hence likely non-usable, when provided in the original datasets. In addition, we have added a flag in the output files allowing to screen the corresponding measurements, depending on the user's choice (see §4.2).

4. Structure and format of the PICSAND database

4.1. Structure and nomenclature

4.1.1. Directories

- The data gathered by measurement types: **Spectro-directional** and **Spectral**, and the datasets are archived under the corresponding directories.
- The name of the sub-directories (**Spectro-directional/** and **Spectral/**) are designed in order to identify the different datasets.

  The nomenclature for the directory names is: `dataprovider-`*`owner`*`_Country-`*`GenericName`*
  Where:

  - `dataprovider`: identifier of the data provider (institute or PI's name);
  - `owner` (optional): in case the data provider is not the owner of the sand sample, identifier of the owner;
  - `country`: country where the sand sample where measured/collected;
  - `GenericName` (optional): additional informations on the dataset (location, site name)

- For calibration sites (either those of [RD1] or those identified in this study), `GenericName` follows the nomenclature: `siteNameNum_ID`

  with ID being

  - *`PICSCEOS`* : for official CEOS sites (Algeria3, Algeria5, Libya1, Libya4, Mauritania1, Mauritania2);
  - *`PICSAND`*: for sites identified in this study (2 sites in Arabia, 1 site in Namibia).

4.1.1.1. Spectro-directional directory

The content of the directory is:

```
.
├── Cierniewski-Karnieli_Israel-Negev
├── Coburn_USA-AlgodonesDunes
├── ONERA_Algeria3_PICSCEOS
├── ONERA_Algeria4_PICSCEOS
├── ONERA_Algier
├── ONERA-Bristow_Algeria5_PICSCEOS
├── ONERA-Bristow_Morocco_Erg_Chebbi
├── ONERA-CNES_Namibia_RadCalNet
├── ONERA-ESA_ArabiaPICS2_PICSAND
├── ONERA_Namibia_Gobabeb_Dunes
├── ONERA_Narbonne
├── ONERA_Niger_Niamey
├── ONERA-Schaepman_Libya_Erg_Ubari
├── Peltoniemi_Finland
├── Roosjen_Netherlands-Noord-Brabant
├── Sun_China-XinjiamuSumu
├── Zhang_China-Dunhuang
├── Zhang_USA-Crandon-beach
```

```
├── Zhang_USA-RSMAS-beach
└── Zhang_USA-White-sands
```

4.1.1.2. Spectral directory

The content of the directory is:

```
.
├── ASTER
├── Hueni_Swiss
├── NPL_Namibia
├── ONERA-Bristow_Libya_Fezzan_Fez
├── ONERA-Lau_Australia_Lucky_Bay
├── ONERA-Lau_Australia_Pinnacle
├── ONERA-Lau_Australia_Wylie_Bay
├── ONERA-Thome_USA_Rail_Road_Valley
├── ONERA-Thome_USA_White_sands
├── ONERA-White_Namibia
├── USGS
├── White_Australia-Simpson
├── White_Namibia
└── White_USA-MuleshoeDunes
```

4.1.2. Main files

- For all directories (samples), two kind of files are provided:
  - Data files containing the reflectance measurements. The extension of these files is **.brf** for files contained in the **Spectro-directional/** directory or **.spe** for files contained in the **Spectral/** directory. Their content is described in §4.2.1.
  - Header files containing meta information on the sample and measurement characteristics. The extension of these files is **.txt**. Their content is described in §4.2.2.
  - All files are in ASCII format. Although this format do not optimize the size of the PICSAND archive, it is easy to read/manipulate and do not require any particular third party software.

- The data files (for Spectro-directional and Spectal) are associated to a unique location. To avoid too large Spectro-directional files, they are usually provided for a given illumination angle (SZA) used in the measurements. This is not always the case, as for instance the files for the datasets of [RD13] and [RD14] contain measurements performed under different SZAs.

  The name of the data files follows the nomenclature:
  `dataprovider-`*`owner`*`_Country-`*`GenericName`*`_otherInfo`
  With *`otherInfo`* being tags corresponding to any other additional information unique to the measurements, as for instance:

  - `szaXXX`: value of the sun zenith angle;
  - `grainXXXmm`: value of the grain size for the data of [RD13];
  - SPLXXX: number of the sand sample (for ONERA measurements);
  - posXXX: identifier of the orientation of the sample (for ONERA measurements);
  - etc.
  - or a combination of several tags.

- Each dataset directory contains a main header file (dataprovider-*owner*_Country-*GenericName*_header_main.txt) gathering all information on the dataset characteristics (PI, reference, measurement characteristics, location, etc.). In particular, this file is used by PICSAND portal to explore the database and display the information (see §5.2.3).

  When a dataset directory contains several data files with different characteristics (location, sample characteristics, etc.), each data file is provided with its own header (dataprovider-*owner*_Country-*GenericName*_header.txt)

- In addition, some dataset directory contains pictures of the samples or measurement location, depending on what was provided by the PIs.

4.1.3. Ancillary files

- For each ONERA analysis is provided an additional file in which the records of air temperature and humidity along the measurement period is provided: *Easylog_xxxx.xlsx*. The name of the corresponding file is provided in the *header_main.txt* file.

- For some sand samples, mineralogy and grain size distribution were characterized (see [RD4]): for all sand samples measured by ONERA, GEOPS laboratory performed a determination of the grain size distribution and a qualitative characterization of the mineralogy; for those from Algeria, Arabia, and Namibia (17 samples), a quantitative mineralogy characterization was performed by BRGM laboratory.
  For each of those samples, the name of the corresponding files are provided in the *header_main.txt* file (*Mineralogy* and *Granulometry* fields):
  - *SampleName_granulometry_GEOPS.txt* for the granulometry data
  - *SampleName_mineralogy_lab.csv* (with *lab = GEOPS, BRGM*) for mineralogy data

4.2. Format of the main files

4.2.1. Spectro-directional data files

The structure of the **.brf** files follows the structure:

```
# file name
# col0: SZA
# col1: VZA
# col2: AZI (0/180 in backward/forward scattering directions)
# col3 -> end: spectral bands (nelements): 400.0 410.0 420.0 430.0 440.0 …
# quality flag (nelements) : 1  ; 1 ; 1 ; 1 ; 0 ; 0 ; 1 ; …
 28.9 ;   5.0 ; 170.0 ; 0.089 ; 0.100 ; 0.113 ; 0.125 ;…
 28.9 ;  10.0 ; 170.0 ; 0.092 ; 0.102 ; 0.114 ; 0.126 ;…
```

The line associated to the *quality flag* is optional (depending on the dataset). A quality flag of 0 correspond to noisy measurement (for instance in atmospheric absorption band) that should be removedSpectrum data files in any quantitative analysis. Note that the definition of the quality flag is very arbitrary; the spectral range of "noisy" data has been determined based on a visual examination of the spectral profiles.

4.2.2. Spectral data files

Except for the USGS and ASTER dataset for which the `.spe` files contain in the header information of the original data files, the `.spe` files follow the structure:

```
# file name
# spectral bands (nelements) : from   waveband min to waveband max / individual bands
# quality flag (nelements) : 1  ; 1 ; 1 ; 1 ; ….
# sza   :  35.715 ;  35.715 ;  35.716 ;  …
# vza   :   0.000 ;   0.000 ;   0.000 ;   …
# azi   : 182.103 ; 182.124 ; 182.152 ; …
  353.0 ; 0.150 ; 0.149 ; 0.160 ; 0.157 ; …
  354.0 ; 0.150 ; 0.149 ; 0.160 ; 0.157 ; …
```

```
355.0 ; 0.150 ; 0.149 ; 0.160 ; 0.157 ; …
```

The first column corresponds to the wavebands (hence each line corresponds to a measurement in a different spectral band) and the following ones to the measurements performed in different observation geometries.

The columns associated to the observation geometries (sza, vza and azi) are optional (depending on the datasets). Actually only the datasets Hueni_Swiss and NPL_Namibia contain spectra acquired for different observations geometries; because only the sun illumination angle varies along the measurements, they were not associated to the Spectro-directional datasets. All other files have only one observation geometry (hence made of 2 columns).

Other information can be provided in the header (as for instance the time of measurements for measurements performed at different times and hence associated to different observations geometries).

4.2.3. Header files

The header file contains the following fields:

```
# Sample name                           : file name
# Contact person                        : PI Name (email@adress)
# Institute                             : Name, City (Country)
# Reference                             : Publication
# Web link                              :
# Measurement conditions                : laboratory / in situ
# Measurement type                      : spectro-directional / spectral
# PICS site                             : yes / no
# Measured physical quantity            :
# Number of files                       :
# Measurement date                      :
# Instrument name                       :
# Instrument characteristics & settings :
# Campaign                              :
# Sampling geometry                     :
# Sampling scheme                       :
# Spectral domain                       : min-max nm (x nm step)
# Surface type                          :
# Soil Colour                           :
# Mineralogy                            :
# Granulometry                          :
# Sampling date                         : DD/MM/YYYY
# Sampling location                     : (lat / lon in decimal°)
# Country                               :
# Reference pannel characteristics      :
# Processing                            :
# Environmental condition               :
# Illumination source characteristics   :
# Target characteristics                :
# Pictures                              :
# Other                                 :
```

The fields `granulometry` and `mineralogy` are provided only for some datasets generated in the frame of this study (see §4.1.3).

The field `Measured physical quantity` aims at identifying the physical quantity that is provided, based on the nomenclature in §2.2. Typically:

- **Biconical reflectance factor**, for goniometric measurements performed in laboratory;
- **Hemispherical/conical conical reflectance factor** for goniometric measurements performed *in situ*;
- **Biconical reflectance factor** for measurements performed with a contact probe device.

5. PICSAND Portal Overview

5.1. Introduction

The PICSAND database is available at https://picsand.noveltis.fr/ and is designed to be referenced by the CEOS/WGCV/ICOS portal.

Figure 3 provides a screenshot of the PICSAND welcome page.

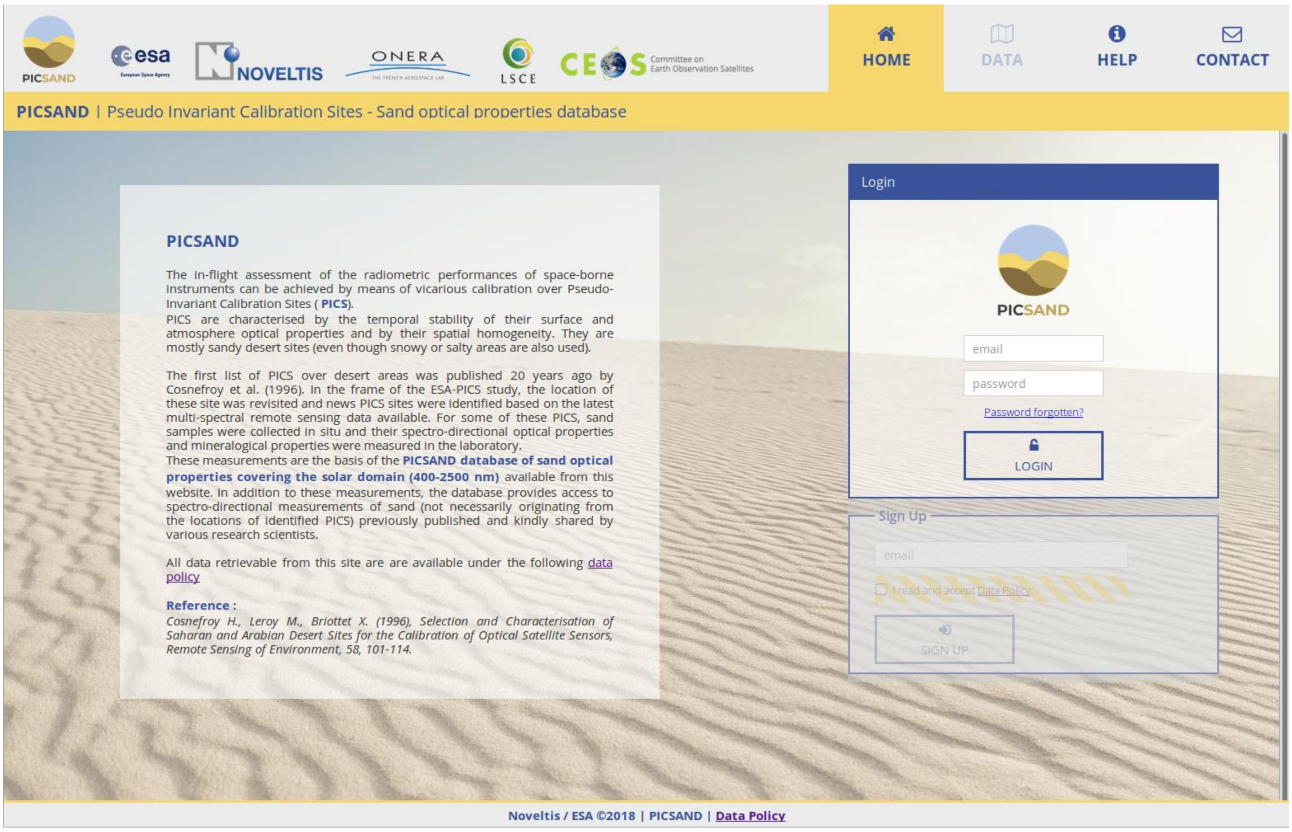

Figure 3: Screenshot of the PICSAND main page.

5.2. Functionalities

5.2.1. Registration / Login

Non-registered users are invited to sign up after agreeing with the PICSAND data policy (see §6). They will then receive an email with their password. The latter will be required for logging in.

5.2.2. Exploring the database

Exploring the database of downloading the full database (as well as a visualization tool) is performed from the PICSAND data page (Figure 4).

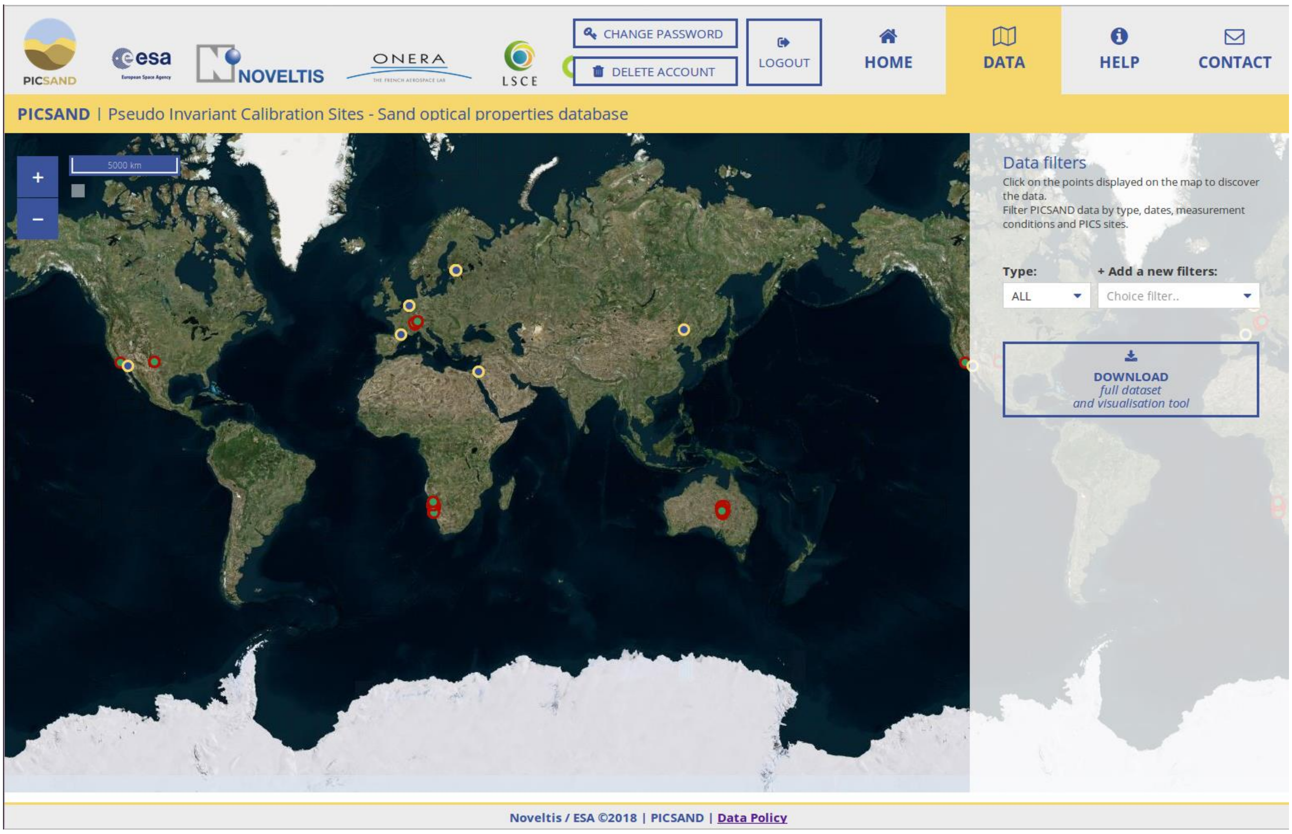

Figure 4: Screenshot of PICSAND data page designed to explore the database by selecting specific datasets to visualize their characteristics.

- Access to information of a given dataset is performed by clicking on a pin on the global map. Then a window pops up.

  Each pin corresponds to the location associated to a dataset (generally that of the location where the sampling was performed, except for ASTER and USGS, the coordinates of which correspond to NASA JPL and USGS main buildings).
  The colour of pins is blue for “Spectro-directional” and green for “Spectral” datasets.
  The user may zoom in/ zoom out on the map.

- The user may refine the search of a given dataset by adding search filters. The latter screen the dataset depending on the following keywords:
  - Type: *Spectro-directional* and/or *Spectral*;
  - PICS site: *yes / no*;
  - Measurement conditions: *in situ / laboratory*;
  - Date: period of measurement defined by a start and end date.

5.2.3. Data display

For each data set are provided the information of all fields contained in the header file (see §4.2.3) as well as spectrum and polar plot (for directional measurements) graphs illustrating the main features of the data. Depending on the dataset, pictures of the samples or site can also be displayed (Figure 5).

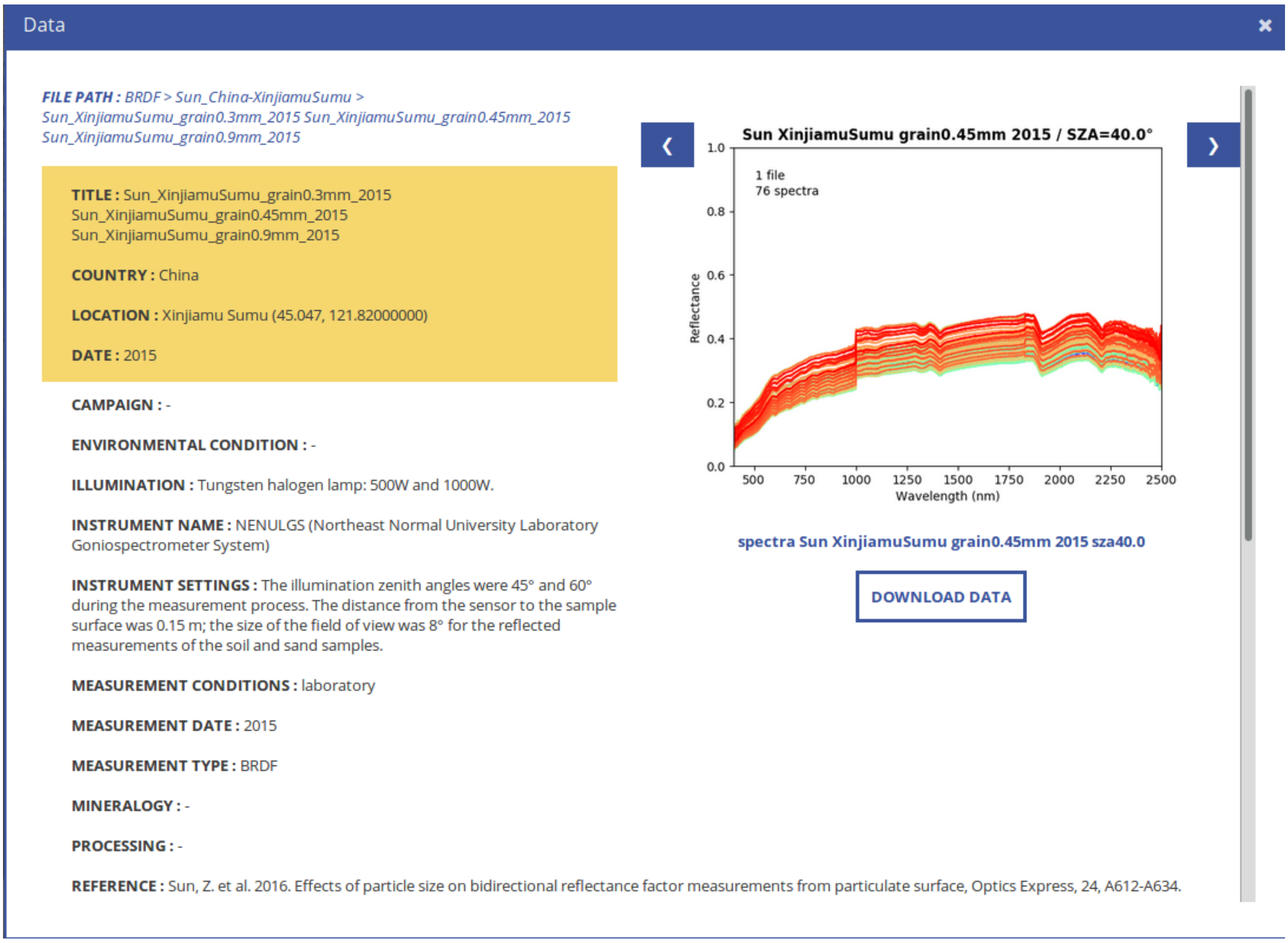

Figure 5: Screenshot of the information displayed for data of [RD13].

5.2.4. Downloading the database

- Clicking on the DOWNLOAD button from the main data page (Figure 4) allows retrieving the whole of the PICSAND database as well as self-documented Python script allowing to read and display the several datasets (generating spectral graphs and polar plots figures for Spectro-directional measurements).
- It is also possible to download a specific dataset by clicking of the DOWNLOAD DATA button on the pop up window of that given dataset (Figure 5).

6. PICSAND Data Use Policy

6.1. Disclaimer

The information contained on this website is for general information purposes and scientific use only. The information is provided by the PICSAND project team and ESA/ESTEC (in the following referred to as "we").

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6.2. Data Access & Policy

The PICSAND database and product information, as made available via the CEOS calval portal and hosted by NOVELTIS, may be freely used and copied for **research, educational** and other **non-commercial purposes**, provided that any use of the data are accompanied by an acknowledgement of the PICSAND project (see below) and the input data providers/owners (see Table below). The use of the data is free within the scope above mentioned.

For commercial uses, an approval of the concerned Principal Investigator of the dataset is mandatory.

When accessing the PICSAND database portal for the first time, a valid email address is required. This information will only help keep track of the database users while advertise them in case of updates and will be kept confidential.

6.3. Acknowledgments

If you intend to use PICSAND data in a publication or a report, please:

- Acknowledge the PICSAND project in the following way: "The PICSAND database of sand optical properties have been collected and produced by the PICSAND team under the European Space Agency (ESA) study contract Nr. 4000116561/16/NL/AF."
- Consult the PI(s) of the concerned dataset via e-mail to get approval of data use, inform him/her/them of his/her/their data use and offer co-authorship.
- Refer to the associated publication(s) as listed in the Table below.

Dataset	Principal Investigator	Affiliation	email	Reference
ASTER	Simon J. Hook	National Aeronautics and Space Administration NASA (USA)	Simon.J.Hook@jpl.nasa.gov	https://speclib.jpl.nasa.gov/ Meerdink, S. K., Hook, S. J., Abbott, E.A., & Roberts, D.A. (in prep). The ECOSTRESS Spectral Library 1.0. Baldridge, A. M., S.J. Hook, C.I. Grove and G. Rivera, 2009.. The ASTER Spectral Library Version 2.0. Remote Sensing of Environment, vol 113, pp. 711-715 Reproduced from the ECOSTRESS Spectral Library through the courtesy of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California. Copyright © 2017, California Institute of Technology. ALL RIGHTS RESERVED.
Cierniewski-Karnieli	Jerzy Cierniewski Arnon Karnieli	Department of Soil Science and Remote Sensing of Soils, Institute of Physical Geography and Environmental Planning, Adam Mickiewicz University in Poznań (Poland) Blaustein International Center for Desert Studies (Israel)	ciernje@amu.edu.pl	Cierniewski J. and Karnieli A. (2003), Virtual surfaces simulating the bidirectional reflectance of semiarid soils, Int. J. Remote Sensing , 24(7): 1469-1486
Coburn	Craig Coburn	University of Lethbridge, Lethbridge (Canada)	craig.coburn@uleth.ca	Temporal dynamics of sand dune bidirectional reflectance characteristics for absolute radiometric calibration of optical remote sensing data Craig Coburn, Gordon S. Logie J. Appl. Remote Sens 12(1), 012006 (28 September 2017) doi:10.1117/1.JRS.12.012006
Hueni	Andreas Hueni	University of Zurich (Switzerland)	ahueni@geo.uzh.ch	Hueni, A., Damm, A., Kneubuehler, M., Schläpfer, D. and Schaepman, M. (2017). "Field and Airborne Spectroscopy Cross-Validation - Some Considerations." IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 10(3): 1117 - 1135.

Dataset	Principal Investigator	Affiliation	email	Reference
Peltoniemi	Jouni Peltoniemi	Finnish Geodetic Institute (Finland)	jouni.peltoniemi@nls.fi	J. Suomalainen, T. Hakala, J. Peltoniemi, E. Puttonen (2009), Polarised multiangular reflectance measurements using the Finnish Geodetic Institute Field Goniospectrometer, Sensors, 9:381-3907, oi:10.3390/s90503891 J.I. Peltoniemi, J. Piironen, J. Näränen, J. Suomalainen, R. Kuittinen, L. Markelin, E. Honkavaara (2007), Bidirectional reflectance spectrometry of gravel at the Sjökulla test field, ISPRS Journal of Photogrammetry & Remote Sensing 62: 434 – 446, doi:10.1016/j.isprsjprs.2007.07.009
NPL	Claire Greenwell	National Physical Laboratory (UK)	claire.greenwell@npl.co.uk	Bialek A., Greenwell C., Lamare M. (2016),New radiometric calibration site located at gobabeb, Namib desert, Geoscience and Remote Sensing Symposium (IGARSS), doi: 10.1109/IGARSS.2016.7730592
ONERA (Algier /Narbonne)	Yannick Boucher	ONERA, Toulouse (France)	Yannick.Boucher@onera.fr	Von Schönermark M., Geiger B, Röser H. P. (2004), Reflection properties of vegetation and soil, ISBN 3-89685-565-4
ONERA	Françoise Viallefont-Robinet	ONERA, Toulouse (France)	francoise.viallefont@onera.fr	To be published
Roosjen	Peter Roosjen	Laboratory of Geo-Information Science and Remote Sensing, Wageningen University & Research (The Netherlands)	peter.roosjen@wur.nl	Roosjen, P.P.J.; Bartholomeus, H.M.; Clevers, J.G.P.W. (2015). Effects of soil moisture content on reflectance anisotropy - Laboratory goniometer measurements and RPV model inversions. Remote Sensing of Environment, 170, 229-238. Roosjen, P.P.J.; Clevers, J.G.P.W.; Bartholomeus, H.M.; Schaepman, M.E.; Schaepman-Strub, G.; Jalink, H.; van der Schoor, R.; de Jong, A. (2012). A laboratory goniometer system for measuring reflectance and emittance anisotropy. Sensors, 12(12), 17358-17371.
Sun	Zhongqiu Sun	School of Geographical Science, Northeast Normal University, Changchun, Jilin (China)	sunzq465@nenu.edu.cn	Sun, Z. et al. 2016. Effects of particle size on bidirectional reflectance factor measurements from particulate surface, Optics Express, 24, A612-A634.
USGS	Roger N. Clark Raymond F. Kokaly	United States Geological Survey USGS (USA)	rclark@usgs.gov raymond@usgs.gov	https://speclab.cr.usgs.gov/spectral-lib.html Kokaly, R.F., Clark, R.N., Swayze, G.A., Livo, K.E., Hoefen, T.M., Pearson, N.C., Wise, R.A., Benzel, W.M., Lowers, H.A., Driscoll, R.L., and Klein, A.J., 2017, USGS Spectral Library Version 7: U.S. Geological Survey Data Series 1035, 61 p., https://doi.org/10.3133/ds1035

Dataset	Principal Investigator	Affiliation	email	Reference
White	Kevin White Joanna Bullard	Department of Geography, University of Reading, Whiteknights, Reading (UK) Department of Geography, Loughborough University, Loughborough, Leicestershire (UK)	k.h.white@reading.ac.uk J.E.Bullard@lboro.ac.uk	White, K. and Bullard, J.E. (2009). Abrasion control on dune colour: Muleshoe Dunes, SW USA. Geomorphology, 105 (1-2). pp. 59-66. White, K., Walden, J., & Gurney, S. D. (2007). Spectral properties, iron oxide content and provenance of Namib dune sands. Geomorphology, 86(3-4), 219-229.
Zhang_USA	Hao Zhang Kenneth Voss	China university of Geosciences, Wuhan (China), University of Miami, Miami, FL (USA)	zhanghao@cug.edu.cn voss@physics.miami.edu	Zhang, H., & Voss, K. J. (2006). Bidirectional reflectance study on dry, wet, and submerged particulate layers: effects of pore liquid refractive index and translucent particle concentrations. Applied optics, 45(34), 8753-8763.
Zhang_China	Hao Zhang Zhengchao Chen	Institute of Remote Sensing and Digital Earth,Chinese Academy of Sciences, Beijing 100094, China	zhanghao612@radi.ac.cn chenzc@radi.ac.cn	Chen Z.C, Zhang B., Zhang H. et al.,Vicarious Calibration of Beijing-1 Multispectral Imagers,Remote Sens. 2014, 6(2), 1432-1450,doi:10.3390/rs6021432