HySpex Product Guide

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Prepared		
	C. H. Köhler, MF-EXV	22.05.15
	M. Schneider, MF-PBA	22.05.15

Reviewed		
	P. Haschberger, MF-EXV	22.05.15

Approved		
	P. Haschberger, MF-EXV	11.08.15

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ABBREVIATIONS

Term	Definition
DEM	Digital Elevation Model
DN	Digital Number
FOV	Field of View
GCP	Ground Control Point
GPS	Global Postioning System
IFOV	Instantaneous Field of View
IMU	Inertial Measurement Unit
INS	inertial navigation system
NEO	Norsk Elektro Optikk
SWIR	short wave infrared spectral range
VNIR	visible and near infrared spectral domain

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CONTENTS

1. Scope

This document is intended to provide an overview over the data delivered to customers by the DLR entity Optical Airborne Remote Sensing & Calibration Homebase (OpAiRS). It encompasses a short description of the sensor system used to produce the data as well as an extensive description of the data formats and file name conventions.

2.   The HySpex Sensor System

2.1   System Overview

The HySpex system, manufactured by the Norwegian company Norsk Elektro Optikk (NEO), consists of two imaging spectrometers (or cameras) which record the solar radiance reflected at the Earth surface in the wavelength-range 400 – 2500 nm. The first camera (VNIR-1600) records data in the visible and near infrared (VNIR) spectral domain at 160 channels distributed over the interval 420 – 990 nm. The second spectrometer (SWIR-320m-e) acquires data in 256 channels in the short wave infrared (SWIR, 970 – 2500 nm). The sensors are typically operated facing nadir on small single- or twin-engine aircraft in the altitude range 1000-2000 m above ground-level.

Both sensors are pushbroom scanners (or line imagers), which implies that the radiance spectra for all across-track pixels are recorded simultaneously each time the camera is triggered. The thus acquired data is often referred to as one frame and the area covered by it is designated as the swath (measured in meters) or the field of view (FOV, measured in degrees). Additionally the instantaneous field of view (IFOV) is defined as the field of view of an individual pixel. The final image is formed by successive acquisition of frames in combination with the steady along-track movement of the camera (through the aircraft movement). The set of simultaneously acquired images is referred to as a flight line. Typically both HySpex cameras are operated with a so-called field of view expander, which doubles the field of view of each camera to achieve a larger swath (and pixel size) at a given flight altitude. Typical spatial resolutions achievable with the HySpex sensors are in the range 0.5 – 2 m.

An inertial navigation system (INS) aided by the Global Positioning System (GPS) (iTrace RT-200 manufactured by iMAR) provides position and attitude for georeferencing of the acquired images. The position of the sensor in three-dimensional space is monitored by a DGPS receiver in combination with an Inertial Measurement Unit (IMU), which records lateral acceleration in all spatial dimensions and rotational acceleration around the associated axes. The data of both systems is merged by a deeply coupled Kalman filter. Synchronisation of the position and attitude measurements with the images is guaranteed through synchronisation pulses sent from the sensor to the INS.

The geometric and spectral characteristics of the individual HySpex cameras are summarised in the following tables. Note that the IFOV of the VNIR sensor is rectangular while the SWIR IFOV is quadratic.

Table 1: Geometric specification of the HySpex sensors

	VNIR-1600	SWIR-320m-e
IFOV*	0.36 mrad across track 0.72 mrad along track	1.50 mrad across track 1.50 mrad along track
FOV*	34 degrees (1600 pixels)	28 degree (320 pixels)
Swath*	1.6 km at 1 m IFOV (along track) 3.2 km at 2 m IFOV (along track)	1.32 km at 2 m IFOV (along track) 2.64 km at 4 m IFOV (along track)

* with field of view expander attached.

Table 2: Spectral specifications of the HySpex sensors

Sensor	Spectral range	Number of channels	Sensor
VNIR-1600	416 – 992 nm	160	5 nm
SWIR-320m-e	968 – 2498 nm	256	6 nm

2.2   Sensor Characterisation & Calibration

The HySpex sensor has been extensively characterised in terms of spectral and geometric properties as well as in terms of its radiometric accuracy in the DLR Calibration Homebase laboratory. A detailed description of the associated measurements and results can be found in [RD01] and [RD02].

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3.   Data Products

HySpex data is available in several processing levels to optimally meet the customer's needs and requirements. For each product different file formats may be used depending on the customer specifications in the Survey Request. Typically the user receives a report file (ref. chapter 3.3.1) listing all processed datasets and a set of .tar.gz archive files containing the processed data. One such archive file is generated for each dataset listed in the report file.

This chapter provides an overview of the available products and the available formats in which they are delivered.

3.1   Naming Conventions

In order to keep the notation as concise as possible, the following naming conventions are used for the description of file names within the scope of this chapter:

Table 3: Possible fields in file names

Symbol	Explanation	Example
<NAME>	Field called NAME	*<SENSOR>*
YYYY	Year as four digit number	*2014*
MM	Month as two digit number (1-12)	*06*
DD	Day as two digit number (1-31)	*12*
Hh	Hour as two digit number (0-23)	*12*
Mm	Minute as two digit number (0-59)	*33*
Ss	Seconds as two digit number (0-59)	*00*
<YYYYMMDD>	Acquisition date of an image	*20140612*
<hhmmss>	Acquisition time of an image (UTC)	*123300*
<SENSOR>	"VNIR" or "SWIR"	*VNIR*
<LEVEL>	Processing level	*L1L1*
<ID>	Unique numeric identifier created during processing	*292514.1*
<EXT>	File name extension specifying file type/ format	*.tar.gz*

3.2   File Formats

Depending on the user requirements provided to OpAiRS in the Survey Request, image data and metadata may be delivered in one of the file formats listed in the following table.. Image data are created using gdal [RD03], a library for reading and writing raster geospatial data formats.

Table 4: Possible file formats

File Extension	Description	References
.hdr, .bsq	ENVI Header labelled raster format	[RD04]
.kml, .kmz	Keyhole Markup Language (KML)	[RD05]
.xml	Extensible Markup Language (XML)	[RD06]
.html	HyperText Markup Language (HTML)	[RD07]
.tif	GeoTIFF	[RD08], [RD09]
.img	HFA, Erdas Imagine	[RD10]
.hdr, .bil	ESRI Header labelled raster format	[RD11]
.jp2	JPEG 2000	[RD12], [RD13]
_img, _aux	XDIBIAS format	[RD14]
.hdf	HDF4	[RD15]

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3.3 Files Independent of Processing Level

A number of files are generated independently of the processing level chosen for delivery. These files are discussed in the following sections.

3.3.1 Report File

A report file in HTML format called

report.html

is delivered once with each dataset. This file provides an overview over all processed flight lines and includes some general information about the processed lines in tabular form.

3.3.2 Metadata file

Each archive file contains an XML file including all processing parameters and results. This file is named

HySpex_<YYYYMMDD>_<HHMMSS>_<ID>_export.xml

and contains information about the processing parameters and processing results as well as metadata of all products.

- All tags starting with *PPAR* contain processing parameters
- All tags starting with *Result* contain results of the executed modules.
  For the user, the following results may be of interest:
  - Tags starting with *Results_cmimport* contain mostly metadata of the raw images, e.g. channel wavelengths, bandwidths, gains, etc.
  - The tag *Result_cmortho_Boresight.A.1* contains the boresight angles for the VNIR image (roll pitch yaw in degrees).
  - The tag *Result_cmortho2_Boresight.B.1* contains the boresight angles for the SWIR image relatively to the VNIR image.
  - The tags starting with *Result_cmatcorpy* contain results of ATCOR
- All tags in the products section contain metadata for the products. E.g., wavelength, bandwidth, gain and offset values for the product are listed. Note, that not all products described in this section are delivered to the customer. Product names can be:

Table 5: Product names in metadata file

Product Name	Description
A.1*	VNIR data at sensor radiance (L1)
B.1*	SWIR data at sensor radiance (L1)
O.1*	Orthorectified VNIR data (L2geo)
O.2*	Orthorectified SWIR data (L2geo)
Q.1*	Atmospheric corrected orthorectified VNIR data (L2atm)
Q.2*	Atmospheric corrected orthorectified SWIR data (L2atm)
Osca.1*	Scan angle files for orthorectified VNIR data
Osca.2*	Scan angle files for orthorectified SWIR data

3.3.3 Flight Track

In addition to the navigation data described in chapter3.4.2 a single file named

HySpex_<YYYYMMDD>_<ID>.kmz

is created per survey flight, which contains the flight path of the airplane along with the approximate location of each flight line.

3.4   Level 1B Product Files

The level 1B product contains the at-sensor radiance and the navigation information required for geocoding.

3.4.1   Image Data

VNIR and SWIR image data are provided in physical units of at-sensor radiance in mW / (cm² sr µm). The in-flight recorded DN (digital numbers) have been corrected for dark current/electronic offsets and converted to radiance using laboratory radiometric calibration information. The signals stemming from bad pixels are corrected by interpolating neighbouring signals. Smile and keystone correction are based on camera models derived in the laboratory. The HySpex VNIR data are additionally corrected for a radiometric nonlinearity and stray light. Details can be found in [RD01] and [RD02].

The wavelength and bandwidth (in nanometers) information is usually embedded in the image data (depending on file type and processing level) as well as in the products section of the metadata file (ref chapter 3.3.2).

If the data is converted from raw DN readings to a 16 bit unsigned integer format, a scaling factor is used. This scaling factor is included in the gains and can be found in the products section of the metadata file described in chapter 3.3.2.

Depending on the requirements of the user, the image data can be provided in one of the following formats (ref. chapter 3.2 for details):

- ENVI header labelled raster format
- GeoTIFF
- HFA, Erdas Imagine
- ESRI Header labelled raster format
- JPEG2000
- HDF4
- XDIBIAS format

All images are stored according to the naming convention:

HySpex_<YYYYMMDD>_<hhmmss>_<SENSOR>_<Level>_<ID>.<ext>

3.4.2   Navigation Data

The sensor location and orientation is specified in an ASCII text file named

HySpex_<YYYYMMDD>_<hhmmss>_<SENSOR>_<ID>.nav,

which is required for orthorectification and georeferencing of the image data.

The file contains a header (escaped by the comment character '#') containing some meta data followed by a data block containing the following data sets in tabular form:

1. Frame number (1-based)
2. WGS84 Longitude in degrees (negative west of prime meridian)
3. WGS84 Latitude in degrees (negative south of equator)
4. WGS84 Ellipsoid altitude [m]
5. Roll [deg] (see chapter 3.4.3 for details)
6. Pitch [deg] (see chapter 3.4.3 for details)
7. Yaw [degrees] (see chapter 3.4.3 for details)
8. GPS seconds of the week
9. Estimated uncertainty in easterly direction [m]
10. Estimated uncertainty in northerly direction [m]

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11. Estimated uncertainty in vertical direction [m]

12. Estimated uncertainty in roll angle [deg]

13. Estimated uncertainty in pitch angle [deg]

14. Estimated uncertainty in yaw angle [deg]

3.4.3   Coordinate Frame Conventions

Roll pitch and yaw are the rotation angles around the x, y and z axes, respectively, which transform the local level North(x)-East(y)-Down(z) frame into the sensor frame. The latter is defined with

- X in flight direction
- Y perpendicular to the flight direction pointing right (i.e. roughly along right wing)
- Z downward

All rotations are defined as right hand rotations of the coordinate frame around the respective axis and shall be executed in the order (primes indicate the once and twice rotated axes, respectively)

1. Yaw (around z)

2. Pitch (around y')

3. Roll. (around x'')

The sensor coordinate frame has its origin in the focal plane. The sensor orientation with respect to the (X,Y,Z)-coordinate frame is provided in terms of the boresight angles found in the results section of the metadata file (ref chapter 3.3.2).

3.5   Level 1C Product Files

The level 1C product contains the orthorectified at-sensor radiance image and the scan angle file that is needed for the atmospheric correction.

3.5.1   Image data

The L1B data have been orthorectified using a SRTM-DEM (or a user provided DEM optionally). The units of the image data are mW / (cm² sr μm). For the orthorectification, the DLR software ORTHO [RD16] is used.

To correct for the boresight misalignment angles, a geometric calibration is carried out at the beginning of each campaign. The result of this calibration is taken into account for the VNIR data. The VNIR boresight misalignment angles can be found in the metadata file in the tag *Result_cmortho_Boresight.A.1*. For the SWIR data, they are calculated relatively to the VNIR data to achieve high co-registration accuracy. Therefore, a BRISK matching is performed between VNIR and SWIR and the resulting tie points are used as GCPs. Details can be found in [RD17]. The SWIR boresight misalignment angles can be found in the tag *Result_cmortho2_Boresight.B.1* in the metadata file. The resampling method (nearest neighbour, bilinear, cubic convolution) can be chosen by the user. It can be found in the metadata file in the tags *Result_cmortho_Resampling.OA.1* (VNIR) or *Result_cmortho2_Resampling.OB.1* (SWIR), respectively.

Depending on the requirements of the user, the image data can be provided in one of the following formats (ref. chapter 3.2 for details):

- ENVI header labelled raster format
- GeoTIFF
- HFA, Erdas Imagine
- ESRI Header labelled raster format
- JPEG2000
- HDF4
- XDIBIAS format

All images are stored according to the naming convention:

HySpex_<YYYYMMDD>_<hhmmss>_<SENSOR>_<Level>_<ID>.<ext>

3.5.2 Scan angle file

The scan angle file is delivered in the same format as the L1C image and contains the following two bands:

- Scan angles. Negative values refer to the right hand part of the scan line with respect to flight heading, positive for left hand part. Scale factor 100. The value 9100 indicates a background pixel.
- Absolute azimuth angles (range 0 - 360 degree). Scale factor 10.

All scan angle files are stored according to the naming convention:

HySpex_<YYYYMMDD>_<hhmmss>_<SENSOR>_sca_<ID>.<ext>

3.6 Level 2A Product Files

The level 2A data contain surface reflectance data and ATCOR log files.

3.6.1 Image data

The image contains surface reflectance data with atmospheric correction. Therefore, the ATCOR4 model based on atmospheric lookup tables generated with the radiative transfer model MODTRAN4 is used. For more information about ATCOR4 see [RD18].

For the atmospheric correction, the DEM was taken into account. VNIR and SWIR data are corrected separately using the same visibility for both images.

Depending on the requirements of the user, the image data can be provided in one of the following formats (ref. chapter 3.2 for details):

- ENVI header labelled raster format
- GeoTIFF
- HFA, Erdas Imagine
- ESRI Header labelled raster format
- JPEG2000
- HDF4
- XDIBIAS format

All images are stored according to the naming convention:

HySpex_<YYYYMMDD>_<hhmmss>_<SENSOR>_<Level>_<ID>.<ext>

3.6.2 ATCOR4 log files

These files are ASCII files containing atmospheric and processing parameters derived by ATCOR during atmospheric correction for VNIR and SWIR data. They are stored according to the naming convention:

HySpex_<YYYYMMDD>_<hhmmss>_<SENSOR>_atmlog_<ID>.txt

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