EnMAP Flight Campaigns

Technical Report

Donnersberg, 2014-07-03
An EnMAP Preparatory Flight Campaign

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Abstract

The dataset contains hyperspectral imagery acquired during airplane overflights on 3rd July 2014 consisting of 242 spectral bands, ranging from VIS to SWIR (423 - 2438 nm) wavelength regions. It covers an area of about 78 km² which is dominated by beech and oak forests. The flight campaign was part of several flight campaigns within the EnMAP project and focused on hyperspectral analysis of plant physiology in deciduous forests in the Donnersberg region in Rhineland-Palatinate, Germany.

Approximate coordinates of the imaged areas:

center:	49° 36' N / 7° 54' E
NW:	49° 38' 40" N / 7° 51' 13" E
NE:	49° 38' 45" N / 7° 57' 36" E
SE:	49° 34' 25" N / 7° 57' 42" E
SW:	49° 34' 15" N / 7° 51' 31" E

Keywords: Hyperspectral Imagery, Forest

Related Work:

An overview of the EnMAP mission is provided in Guanter et al. (2015):

Guanter, L., Kaufmann, H., Segl, K., Foerster, S., Rogaß, C., Chabrillat, S., Küster, T., Hollstein, A., Rossner, G., Chlebek, C., Straif, C., Fischer, S., Schrader, S., Storch, T., Heiden, U., Mueller, A., Bachmann, M., Mühle, H., Müller, R., Habermeyer, M., Ohndorf, A., Hill, J., Buddenbaum, H., Hostert, P., van der Linden, S., Leitão, P., Rabe, A., Doerffer, R., Krasemann, H., Xi, H., Mauser, W., Hank, T., Locherer, M., Rast, M., Staenz, K., Sang, B. (2015): The EnMAP Spaceborne Imaging Spectroscopy Mission for Earth Observation. - Remote Sensing, 7, 7, p. 8830-8857, http://doi.org/10.3390/rs70708830.

1 Introduction

The Environmental Mapping and Analysis Program (EnMAP) is a German hyperspectral satellite mission that aims at monitoring and characterizing the Earth's environment on a global scale. EnMAP serves to measure and model key dynamic processes of the Earth's ecosystems by extracting geochemical, biochemical and biophysical parameters, which provide information on the status and evolution of various terrestrial and aquatic ecosystems. In the frame of the EnMAP preparatory phase, pre-flight campaigns including airborne and in-situ measurements in different environments and for several application fields are being conducted. The main purpose of these campaigns is to support the development of scientific applications for EnMAP. In addition, the acquired data are input in the EnMAP end-to-end simulation tool (EeteS) and are employed to test data pre-processing and calibration-validation methods. The campaign data are made freely available to the scientific community under a Creative Commons Attribution-ShareAlike 4.0 International License. An overview of all available data is provided in in the EnMAP Flight Campaigns Metadata Portal
http://www.enmap.org/?q=flightbeta.

Flight Campaign "Donnersberg"

The study area is located in the Donnersberg region in Rhineland-Palatinate, Germany (49.62°N, 7.92°E, Figure 1) and completely covered with forest. Rhineland-Palatinate is located in the west of Germany. 42.3% of the state area is covered by forests and together with Hesse they are the most densely wooded states (Stoffels et al. 2015). Main tree species are European beech (*Fagus sylvatica* L.), Sessile oak (*Quercus petraea* (Mattuschka] Liebl.) and Pedunculate oak (*Quercus robur* L.), followed by Scots pine (*Pinus sylvestris* L.), sycamore maple (*Acer pseudoplatanus* L.), Norway spruce (*Picea abies* (L.) H. Karst.), and other deciduous species. Important characteristics of the study area are relatively poor soils and a warm and dry climate. Average temperature in 2014 was 9.2°C and precipitation sum was 920 mm. The hilly region expands from about 350 to 687 m elevation. Figure 1 shows the location of the study area.

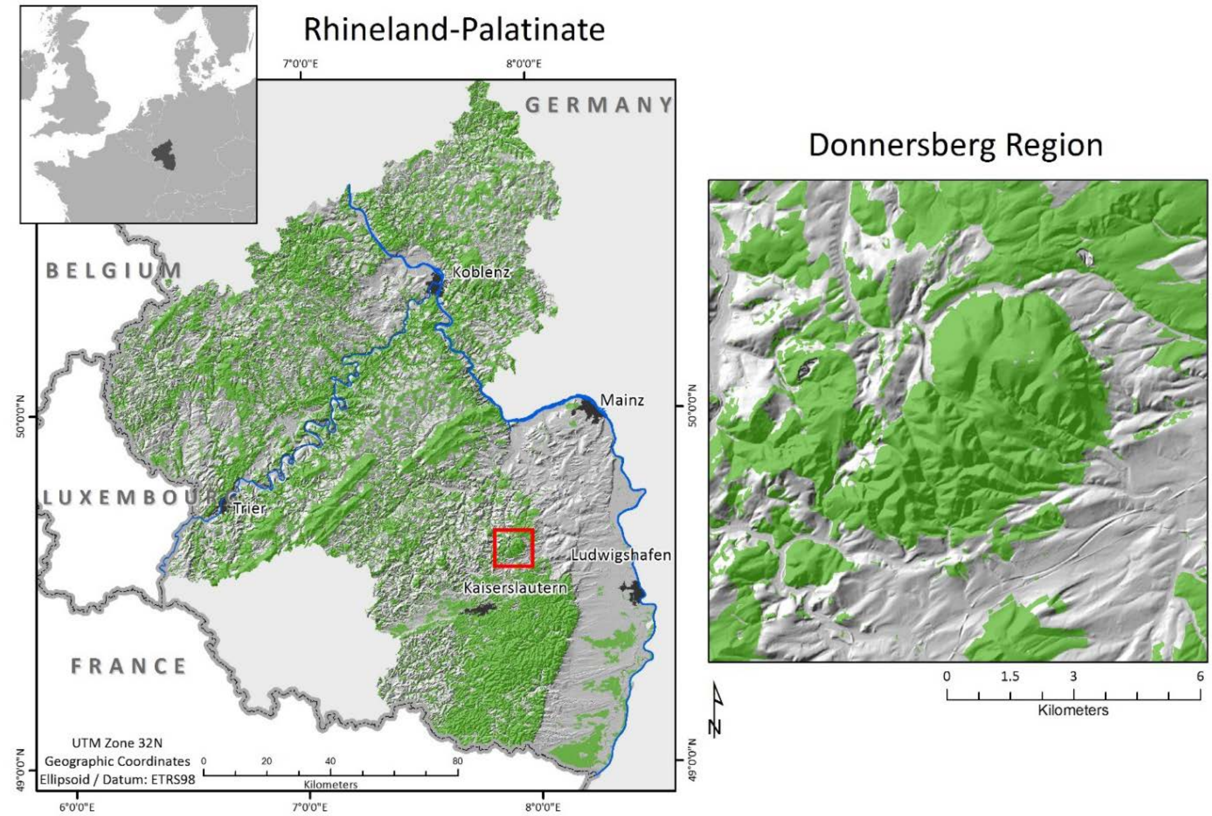


Figure 1: The Donnersberg region in Rhineland-Palatinate, Germany. Forest areas are displayed in green.

2 Data Acquisition

Hyperspectral imagery was acquired during a flight campaign operated by the University of Trier. The camera system consists of one camera for the visible/near infrared (VNIR) spectral range and one camera for the shortwave infrared (SWIR) range: a HySpex VNIR-1600 and a SWIR 320m-e imaging spectrometer (Norsk Elektro Optikk, Skedsmokorset, Norway, Table 1) on board of a Cessna 172 aircraft. Aircraft position and attitude was recorded with an IMAR iTraceRT-F200-E inertial measurement and GPS unit (IMAR GmbH, St. Ingbert, Germany).

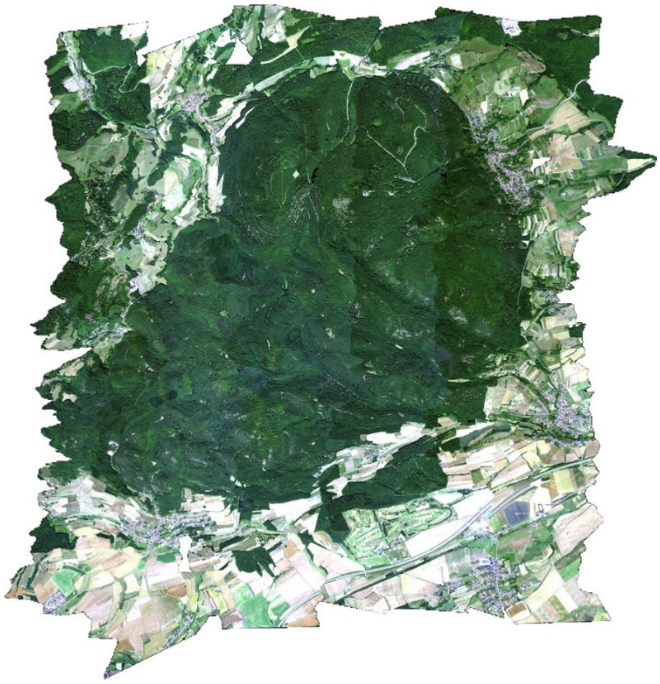
Table 1: Properties of the hyperspectral scanners used.

	VNIR-1600	SWIR-320m-e
Detector	Si CCD, 1600 x 1200 pixels	HgCdTe, 320 x 256 pixels
Spectral range	414 nm – 994 nm	967 nm – 2500 nm
Spatial pixels	1600	320
FOV across track	16.75° (0.29 rad)	13.30° (0.23 rad)
IFOV across track / along track (instantaneous field of view, pixel)	0.01035° / 0.0207° (0.18 mrad / 0.36 mrad)	0.043° (0.75 mrad)
Spectral sampling	3.7 nm	6.0 nm
Number of bands	160	256
Digitization	12 bit	14 bit

Campaign 2014-07-03:

Time: July 3, 2014 start: 13:32 end: 14:16 (Local Time)

Figure 2 shows the GPS track and the recorded image strips of the campaign. The Donnersberg mosaic consists of lines 1 to 14. Table 2 shows logged data of the strips.



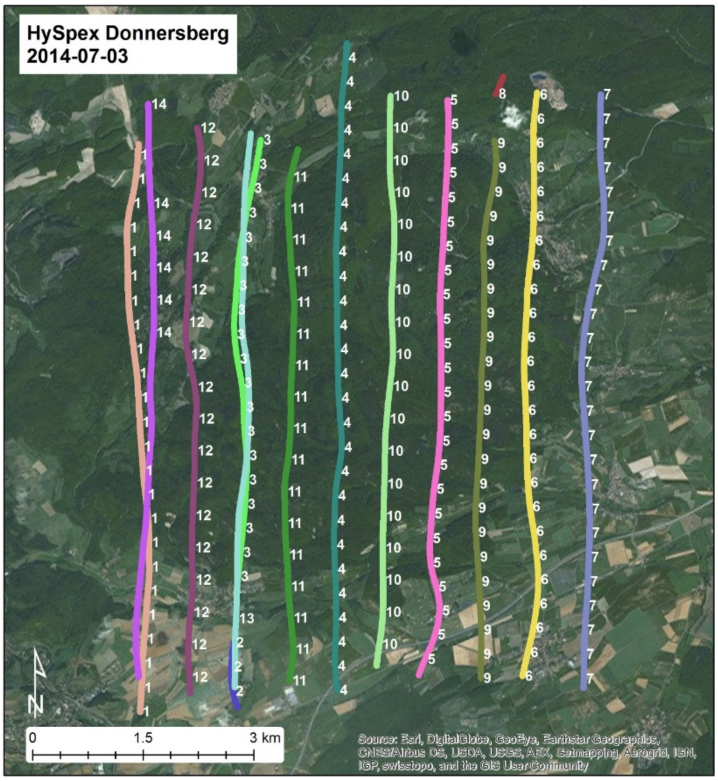


Figure 2: Left: Flight lines of the 2014-07-03 flight campaign. Right: Mosaic.

Table 2: Flight Strips. The SWIR sensor collects half as many lines as the VNIR sensor.

Strip No	# VNIR Lines	Starting Time	Start Lat.	Start Long.	Stop Lat.	Stop Long.	Flying Height [m]	Heading
1	13519	13:32	49.6403	7.8656	49.5700	7.8674	2309	188.8
2	1597	13:33	49.5701	7.8862	49.5787	7.8849	2318	327.8
3	10579	13:35	49.5839	7.8852	49.6404	7.8887	2298	355.1
4	15630	13:40	49.6527	7.9046	49.5730	7.9045	2327	189.2
5	13086	13:45	49.5741	7.9195	49.6451	7.9236	2276	8.8
6	13924	13:50	49.6471	7.9406	49.5749	7.9392	2253	189.2
7	13621	13:56	49.5728	7.9506	49.6465	7.9524	2293	2.7
8	464	13:58	49.6488	7.9344	49.6463	7.9329	2283	206.0
9	12901	14:01	49.6412	7.9324	49.5742	7.9315	2297	175.5
10	12862	14:06	49.5752	7.9117	49.6457	7.9129	2271	0.1
11	12912	14:11	49.6395	7.8958	49.5740	7.8955	2264	202.0
12	12742	14:16	49.5716	7.8768	49.6416	7.8765	2244	358.9
13	12462	14:21	49.6416	7.8868	49.5728	7.8852	2289	189.1
14	12241	14:26	49.5731	7.8672	49.6447	7.8672	2298	357.7

3 Data Processing and Products

Hyperspectral airborne data

Level 1[1]: At sensor radiance in W / (m² sr nm) converted from DN using laboratory radiometric calibration information provided by NEO.

Level 2 atm/geo/mosaic: Ortho-rectified reflectance data. All flight stripes have been resampled to 2.5 m spatial resolution and 242 EnMAP spectral bands and have been mosaicked to one data set. Orthorectification has been done in Parge (Schläpfer and Richter 2002), using GPS and IMU data recorded during the flight, manually selected ground control points, and a high-resolution digital surface model. Atmospheric correction has been done in AtcPro (Hill and Mehl 2003).

The major steps of the processing scheme are shown in Figure 3 followed by a detailed description.

[1] Data levels used here are out-dated and not in line with the future EnMAP data levels.

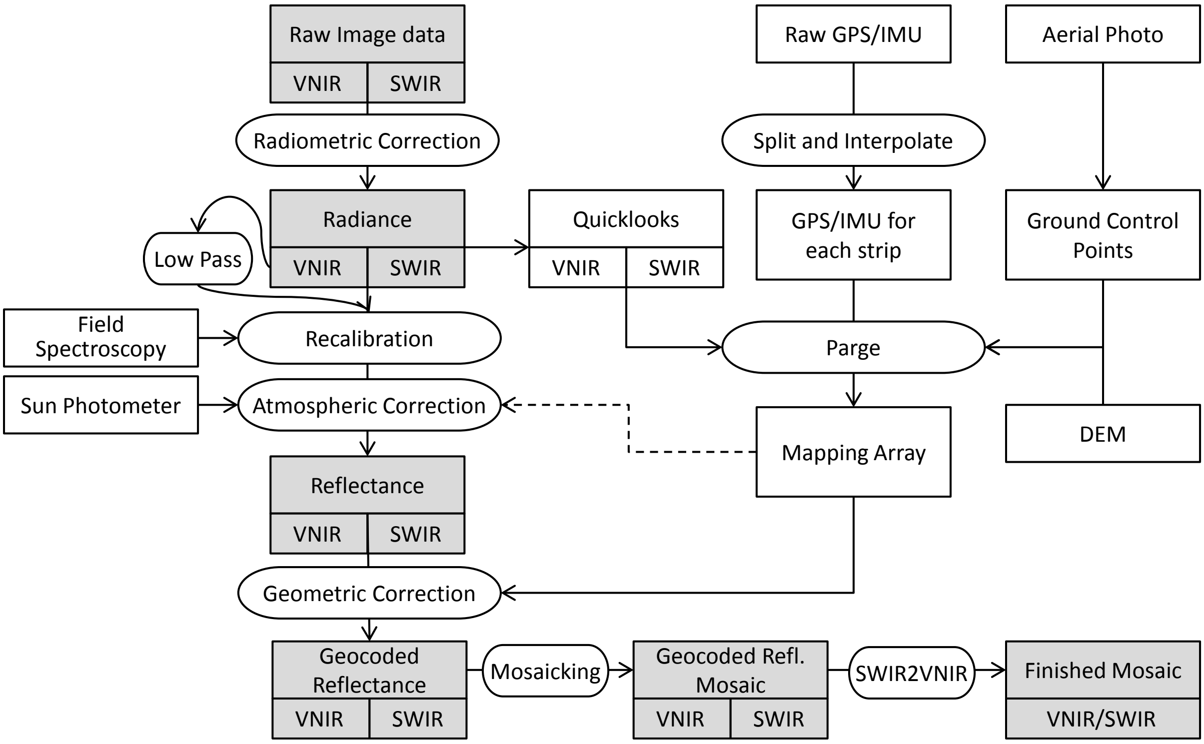


Figure 3: Processing scheme for airborne hyperspectral data.

The image data is recorded as dimensionless digital numbers, separately for the VNIR and the SWIR camera. Using software provided by the cameras' vendor, these data are transformed to radiance in the unit W m^{-2} sr^{-1} nm^{-1} using the vendor's calibration constants for every pixel and every wavelength. For quick visual inspection of the data and for saving processing time in the geocoding steps, 3-band quicklook images are created from every flight strip. The raw binary GPS and IMU data is converted and interpolated to ASCII files for each strip containing the position and attitude of the sensors for every row of the image data. These are used in the geocoding step, and can also be used for creating maps of the flight campaign like the one shown in Figure 2. Since no boresight measurement and no differential GPS is available in the setup used, ground control points (GCPs) are necessary for an exact geocoding. High resolution digital orthophotos are used for identifying GCPs. Parametric geocoding is done using the software Parge. A displacement model is calculated for every image pixel using the sensor model, IMU and GPS data, and a digital surface model (DSM) of the area. The model is optimized in several iterations using the GCPs. Figure 4 shows some of the outputs of Parge for the first flight line of the National Park imaging campaign of 5 May 2014. Figure 4a displays the raw VNIR image (1600 × 23166 pixels × 160 bands) in a true-color band combination. Figure 4b and c show the scan azimuth and zenith angles as recorded by the IMU, respectively. In a first step, Parge outputs an image geometry model (IGM), *i.e.* an image of the X and Y coordinates for each pixel of the original data set (Figure 4 d and e; the Y coordinate map shows that the aircraft was flown in N-S direction). The additional outputs of row and line maps in output geometry (Figure 4 f and g) can be used for retroactive analyses of pixel positions. Figure 5 shows GPS and IMU data for the same flight strip.

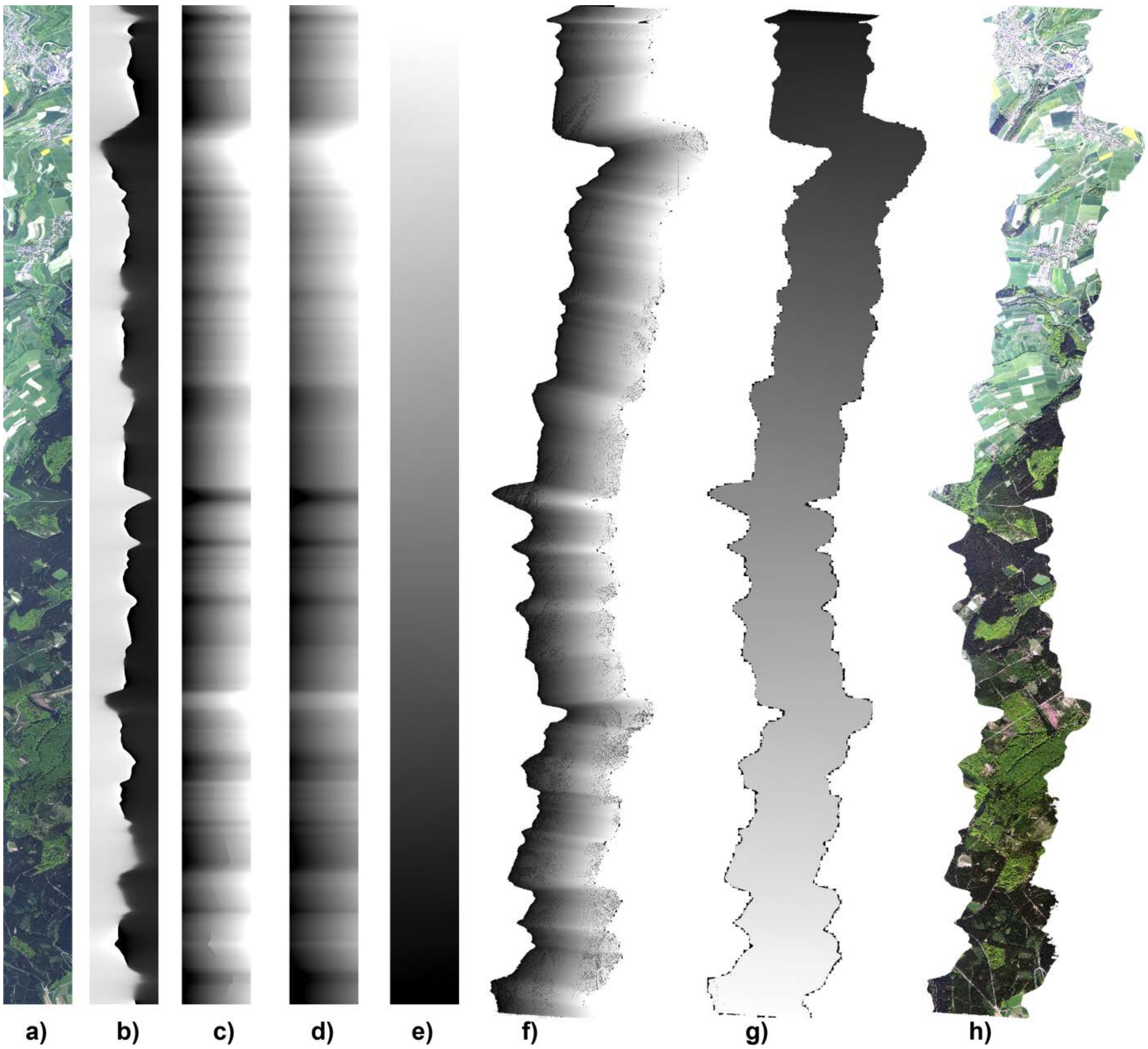


Figure 4: Parge input and outputs. a) Raw Image, b) Scan Azimuth Angle, c) Scan Zenith Angle, d) IGM X coordinate, e) IGM Y coordinate, f) map row coordinate, g) map line coordinate, h) geocoded VNIR image.

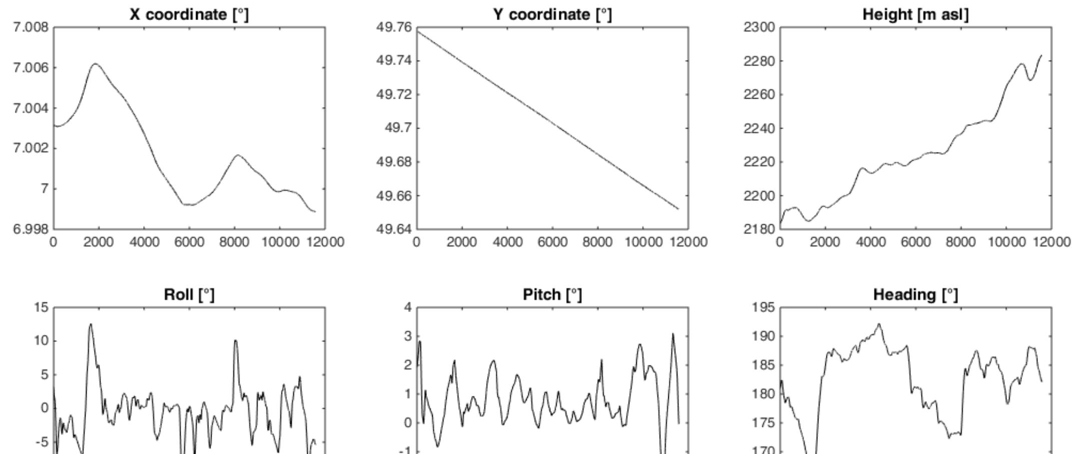


Figure 5: GPS and IMU data of the flight strip shown above plotted against line number

The atmospheric correction was done using AtCPro (Hill and Mehl 2003), an in-house developed software for radiative transfer modelling based on the 5S code by Tanré et al (1990). The mapping array can be used in the atmospheric correction to link the not yet geometrically corrected image to the digital elevation model for corrections of illumination and for water vapor estimation. This has not been done yet for the HySpex data.

The atmospheric radiative transfer model AtCPro has been developed further and is now able to atmospherically correct airborne HySpex images. Problems with the smile effect (a sensor row dependent wavelength shift) have been solved by using an interpolation approach on the most severely affected wavelengths. There is a stable noise pattern in the data that was attributed to the relatively long time since the HySpex sensors have been calibrated. Flat field targets (e.g. Asphalt) were identified in the data sets, and the mean deviations from flat reflectance were used for sensor recalibration. This led to spectra of a higher quality and smoothness without using a smoothing algorithm. Figure 6 shows measured radiance and corrected reflectance spectra for some pixels of the 05 May 2014 HySpex mosaic of the National Park area (Buddenbaum et al., 2015).

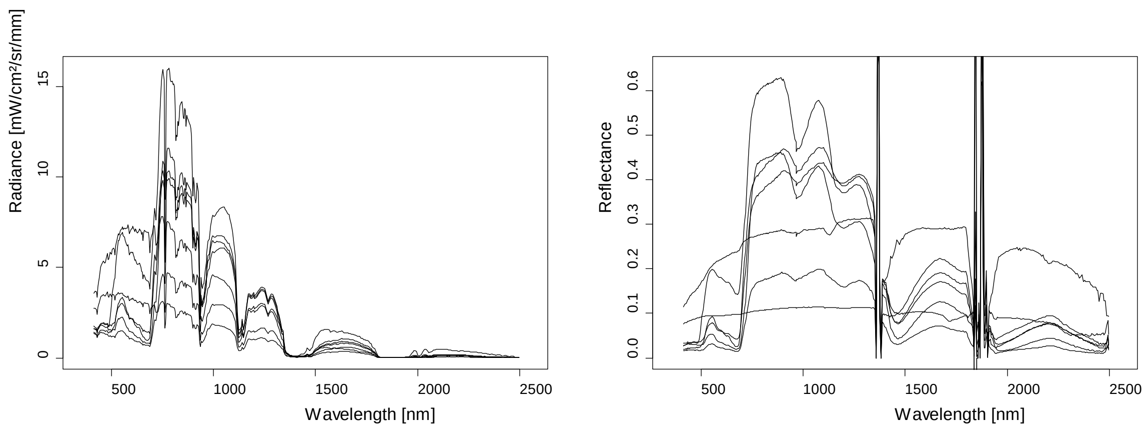


Figure 6: Left: At-Aircraft Radiance, Right: Reflectance of various HySpex pixels after AtCPro correction.

In the next step, the radiometrically and atmospherically corrected image data sets are geometrically corrected using the previously created IGM. All images are resampled to a uniform pixel size. Since the pixel sizes of the VNIR and SWIR images are approximately 0.6 m and 2.4 m, respectively, both data sets are resampled to 2.5 m geometric resolution. A simple resampling of the geometric high resolution VNIR data to the lower target resolution would result in a large part of the pixels being discarded and a low signal to noise ratio. Thus, a low-pass filtering of the VNIR data using a window of 5×5 pixels is performed. This way, the resulting low resolution pixels contain spectral information of the whole area they cover in an improved signal to noise ratio.

All steps have to be done separately for each strip. Only after each strip is fully corrected, they are mosaicked. Because both cameras are never perfectly aligned and the geocorrection also is never perfect, the images from both sensors are not simply stacked, but an image matching (called SWIR2VNIR in the processing scheme) is performed to create mostly seamless spectra. In the image matching step, for each VNIR pixel, a 3x3 window of the nearest SWIR pixels is located. The mean reflectance of both datasets in the spectral overlap region of 960 to 990 nm is calculated and the SWIR pixel with the most similar reflectance in the spectral/spatial window is chosen. Figure 7 shows the resulting VNIR mosaic.

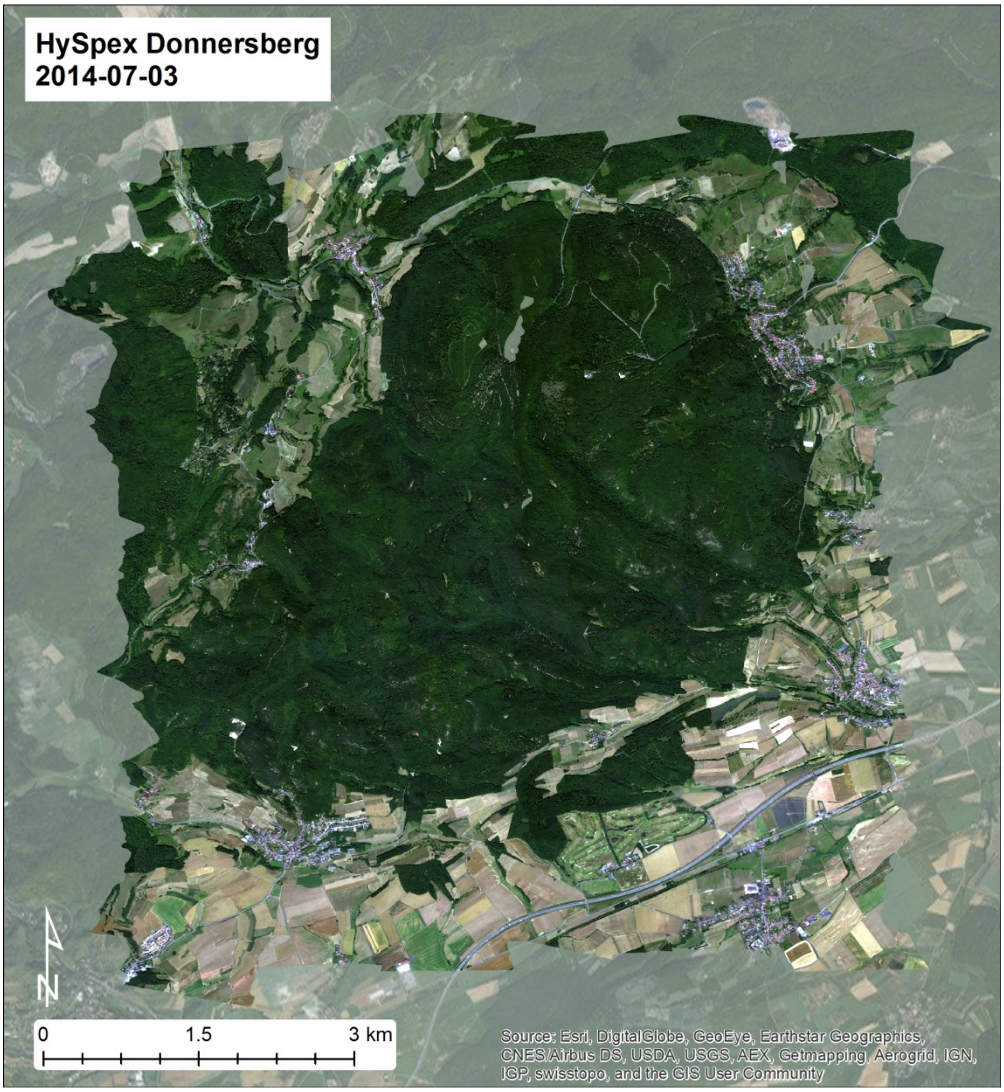


Figure 7: True-color depiction of the VNIR mosaic.

4 File Description

4.1 File Format

The data is available in Envi Band Sequential format [*.bsq] with respective file header [*.hdr].

4.2 Data content and structure

Image files are described in the header file by the following attributes:
ENVI description, samples, lines, bands , header offset, file type, data type, interleave, sensor type, byte order, map info, wavelength units, band names, wavelength, FWHM

5 Data quality/Accuracy

There is no quality assessment of the data besides the information given in chapter 3 of this report.

6 Additional Data

There is no additional data for 2014 available.

7 Dataset Contact

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9 References

Buddenbaum, Henning; Dotzler, Sandra; Hill, Joachim (2015): Nationalpark Hunsrück-Hochwald, 2014-05-05 - An EnMAP Flight Campaign (Datasets). GFZ Data Services. http://doi.org/10.5880/enmap.2015.005.

Guanter, L., Kaufmann, H., Segl, K., Foerster, S., Rogaß, C., Chabrillat, S., Küster, T., Hollstein, A., Rossner, G., Chlebek, C., Straif, C., Fischer, S., Schrader, S., Storch, T., Heiden, U., Mueller, A., Bachmann, M., Mühle, H., Müller, R., Habermeyer, M., Ohndorf, A., Hill, J., Buddenbaum, H., Hostert, P., van der Linden, S., Leitão, P., Rabe, A., Doerffer, R., Krasemann, H., Xi, H., Mauser, W., Hank, T., Locherer, M., Rast, M., Staenz, K., Sang, B. (2015): The EnMAP Spaceborne Imaging Spectroscopy Mission for Earth Observation. - Remote Sensing, 7, 7, p. 8830-8857. http://doi.org/10.3390/rs70708830.

Hill, J., & Mehl, W. (2003). Geo- und radiometrische Aufbereitung multi- und hyperspektraler Daten zur Erzeugung langjähriger kalibrierter Zeitreihen. Photogrammetrie - Fernerkundung - Geoinformation, 2003, 7-14

Schläpfer, D., & Richter, R. (2002). Geo-atmospheric processing of airborne imaging spectrometry data. Part 1: Parametric orthorectification. International Journal of Remote Sensing, 23, 2609 – 2630. http://doi.org/10.1080/01431160110115825.

Stoffels, J., Hill, J., Sachtleber, T., Mader, S., Buddenbaum, H., Stern, O., Langshausen, J., Dietz, J., & Ontrup, G. (2015). Satellite-Based Derivation of High-Resolution Forest Information Layers for Operational Forest Management. Forests, 6, 1982-2013. http://doi.org/10.3390/f6061982.

Tanré, D., Deroo, C., Duhaut, P., Herman, M., Morcrette, J.J., Perbos, J., & Deschamps, P.Y. (1990). Technical note Description of a computer code to simulate the satellite signal in the solar spectrum: the 5S code. International Journal of Remote Sensing, 11, 659-668. http://doi.org/10.1006/jare.1998.0392.

10 Appendix

List of datasets

Combined VNIR/SWIR mosaic at 2.5 m spatial resolution and EnMAP spectral resolution:

File names:	2014-07-03_Donnersberg_VNSWIR_EnMAP_2,5m 2014-07-03_Donnersberg_VNSWIR_EnMAP_2,5m .hdr
Type of data:	ENVI band sequential file
Approx. file size:	6 GB

List of abbreviations

VIS: Visible light (wavelength region 400 to 700 nm)

VNIR: Visible and near infrared (wavelength region 400 to 1000 nm)

SWIR: Shortwave infrared (wavelength region 1000 to 2500 nm)

EnMAP: Environment and Mapping Program (German hyperspectral satellite, to launch in 2018)

FWHM: Full width at half-maximum.