EnMAP Flight Campaigns
Technical Report

Berlin-Urban-Gradient dataset 2009
An EnMAP Preparatory Flight Campaign

Akpona Okujeni, Sebastian van der Linden, Patrick Hostert

Version 1.2

Recommended citation of the report:

Okujeni, A.; van der Linden, S.; Hostert, P. (2016): Berlin-Urban-Gradient dataset 2009 - An EnMAP Preparatory Flight Campaign. EnMAP Flight Campaigns Technical Report, version 1.2, GFZ Data Services.
DOI: http://doi.org/10.2312/enmap.2016.008

Supplementary datasets:

Okujeni, Akpona; van der Linden, Sebastian; Hostert, Patrick (2016): Berlin-Urban-Gradient dataset 2009 - An EnMAP Preparatory Flight Campaign (Datasets). V. 1.2. GFZ Data Services.
DOI: http://doi.org/10.5880/enmap.2016.008

Imprint

EnMAP Consortium

GFZ Data Services

Telegrafenberg
D-14473 Potsdam

Published in Potsdam, Germany
March 2016

http://doi.org/10.2312/enmap.2016.008

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Humboldt-Universität zu Berlin, Geography Department

Version 1.2

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

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Version History

This report is a new version of:

Okujeni, Akpona; van der Linden, Sebastian; Hostert, Patrick; (2016): Berlin-Urban-Gradient dataset 2009 - an EnMAP Preparatory Flight Campaign; GFZ Data Services. https://doi.org/10.2312/enmap.2016.002

Changes to the previous version:

This version of the Berlin-Urban-Gradient-Dataset was updated to account for errors in the spatial referencing. The following files were updated:

- **Folder "BerlinUrbGrad2009_01_image_products\01_image_products"**:
    - Replacement of header files of the four image products (EnMAP01_Berlin_Urban_Gradient_2009.hdr, EnMAP02_Berlin_Urban_Gradient_2009.hdr, HyMap01_Berlin_Urban_Gradient_2009.hdr, HyMap02_Berlin_Urban_Gradient_2009.hdr).

- **Folder "BerlinUrbGrad2009_02_additional_data\02_additional_data\land_cover"**:
    - Replacement of header files of the two reference land cover images (Land-Cov_Layer_Level1_Berlin_Urban_Gradient_2009.hdr, Land-Cov_Layer_Level2_Berlin_Urban_Gradient_2009.hdr).
    - Replacement of the shapefile (incl. extensions) representing the references polygons (LandCov_Vec_polygons_Berlin_Urban_Gradient_2009.shp, *.dbf, *.prj, *.sbn, *.sbx, *.shp.xml, *.shx).

Abstract

Berlin-Urban-Gradient is a ready-to-use imaging spectrometry dataset for multi-scale unmixing and hard classification analyses in urban environments. The dataset comprises two airborne HyMap scenes at 3.6 and 9 m resolution, a simulated spaceborne EnMAP scene at 30 m resolution, an image endmember spectral library and detailed land cover reference information. All images are provided as geocoded reflectance products and cover the same subset along Berlin's urban-rural gradient. The variety of land cover and land use patterns captured make the dataset an ideal playground for testing the transfer of methods and research approaches at multiple spatial scales.

Keywords: Imaging spectrometry, hyperspectral, EnMAP, HyMap, urban land cover, unmixing, classification, regression, support vector machines, multi-scale

Related Work:

Berlin-Urban-Gradient is used in the following key publications:

Okujeni, A., van der Linden, S., & Hostert, P. (2015). Extending the vegetation–impervious–soil model using simulated EnMAP data and machine learning. Remote Sensing of Environment, 158, 69-80. http://doi.org/10.1016/j.rse.2014.11.009.

Okujeni, A., van der Linden, S., Jakimow, B., Rabe, A., Verrelst, J., & Hostert, P. (2014). A comparison of advanced regression algorithms for quantifying urban land cover. Remote Sensing, 6, 6324-6346, http://doi.org/10.3390/rs6076324.

Okujeni, A., van der Linden, S., Tits, L., Somers, B., & Hostert, P. (2013). Support vector regression and synthetically mixed training data for quantifying urban land cover. Remote Sensing of Environment, 137, 184-197, http://doi.org/10.1016/j.rse.2013.06.007.

An overview of the EnMAP mission is provided in:

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.

An overview of the EnMAP end-to-end simulator is provided in:

Segl, K.; Guanter, L.; Rogass, C.; Kuester, T.; Roessner, S.; Kaufmann, H.; Sang, B.; Mogulsky, V.; Hofer, S. (2012): EeteS - The EnMAP End-to-End Simulation Tool. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 5, 522–530, http://doi.org/10.1109/JSTARS.2012.2188994.

1 Introduction

The Environmental Mapping and Analysis Program (EnMAP; Guanter et al. 2015) 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; Segl et al. 2012) 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=flights).

***Berlin-Urban-Gradient* dataset 2009**

The Geomatics Lab at Humboldt-Universität zu Berlin is member of the EnMAP Science Advisory Group and actively participates in the EnMAP preparatory activities with a focus on ecosystem transitions, including the urban-rural gradient. The step from high spatial resolution airborne to coarser spatial resolution spaceborne data will be one of the major challenges when exploiting EnMAP images from heterogeneous environments. *Berlin-Urban-Gradient* is a multi-scale imaging spectrometer dataset dedicated to explore the impact of these changes in spatial scales. The dataset comprises two HyMap scenes at 3.6 and 9 m, complemented by a simulated EnMAP scene at 30 m. The images are delivered together with an image spectral library and detailed land cover reference information suitable for unmixing and hard classification analyses. The variety of urban land cover and land uses patterns captured make the dataset an ideal playground for testing the transfer of methods and research approaches at multiple spatial scales.

2 Data Acquisition

The two HyMap images were acquired during the HyEurope 2009 Campaign operated by the German Aerospace Centre (DLR) on 20 August 2009. Detailed information about the HyMap sensor can be found in Cocks et al. (1998). Both images cover the same subset of Berlin's urban-rural gradient, at two different spatial resolutions of 3.6 m and 9 m due to the maximum possible difference in flight altitude. Acquisition took place around solar noon under clear sky conditions. Details on the HyMap data acquisition are provided in Table 1 and 2. Figure 1 illustrates the *Berlin-Urban-Gradient* study site, which corresponds to the outline of the HyMap images.

Table 1: Acquisition details of HyMap data.

Name	Date	UTC Time	Flight altitude	Flight heading	Solar Azimuth	Solar Zenith
HyMap01	2009/08/20	09:44-09:50	2005 m AGL	359°	149.6°	43.4°
HyMap02	2009/08/20	10:07-10:12	4753 m AGL	179°	157.2°	41.9°

Table 2: Spatial dimensions of HyMap data.

Name	Centre	Upper left	Upper right	Lower left	Lower right	Swath width	Scene length
HyMap01	52.4164° 13.2971°	52.5183° 13.2800°	52.5204° 13.3141°	52.3131° 13.2800°	52.3140° 13.3142°	2.3 km	22.8 km
HyMap02	52.4218° 13.2974°	52.5243° 13.2561°	52.5249° 13.3387°	52.3182° 13.2565°	52.3193° 13.3384°	5.5 km	22.8 km

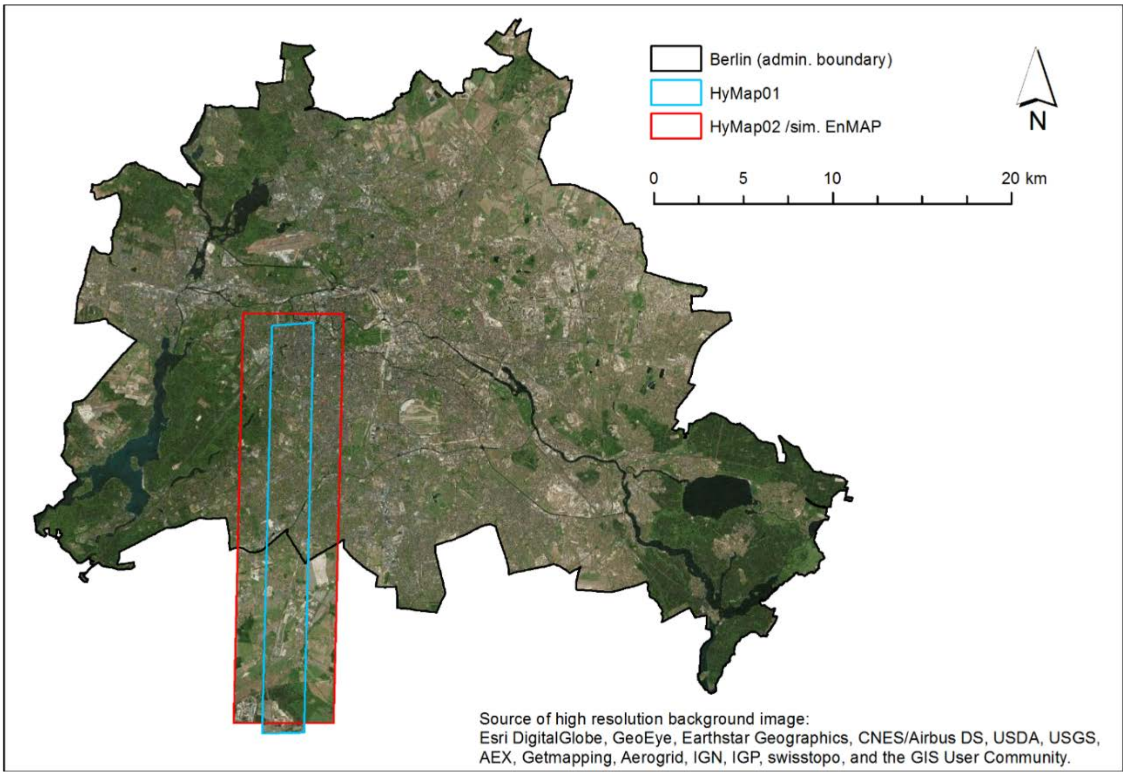

Figure 1: Coverage of the Berlin-Urban-Gradient dataset. High resolution versions of this figure are provided in the supplementary material.

3 Data Processing and Products

Images of the *Berlin-Urban-Gradient* dataset are delivered as geocoded reflectance products (Level 2). An overview of the image products is provided in Table 3.

Table 3: Berlin-Urban-Gradient – Image products.

Name	Spectral bands	Spatial resolution	Lines	Samples	Coordinate system and datum	Wavelength units	Scale factor
HyMap01	111	3.6 m	6805	1830	UTM 33N, WGS-84	µm	ref %/100
HyMap02	111	9 m	2722	732	UTM 33N, WGS-84	µm	Ref %/100
EnMAP01	111	30 m	817	220	UTM 33N, WGS-84	µm	Ref %/100
EnMAP02	244	30 m	817	220	UTM 33N, WGS-84	µm	Ref %/100

3.1 HyMap Pre-processing

Pre-processing of HyMap01 and HyMap02 images (compare Table 3) encompassed system correction (Cocks et al. 1998), atmospheric correction (Richter and Schläpfer 2002), parametric geocoding (Schläpfer and Richter 2002) and band removal:

- Digital number (DN) to at-sensor-radiance in µW / (cm² sr nm) using laboratory radiometric calibration information and in-flight measurements of the on-board calibration lamp provided by HyVista Corporation.
- At-sensor-radiance to surface reflectance with the ATCOR4 model based on atmospheric lookup tables generated with the radiative transfer model MODTRAN4.
- Parametric geocoding of surface reflectance data with the PARGE software using flight movement parameters, terrain information (LiDAR based DSM in the city, isoline based DTM in the urban fringe), and ground control reference points.
- Band removal: 111 out of 128 bands retained after removing noisy bands.

3.2 EnMAP Simulation

Simulated EnMAP data (see Table 3) were derived from HyMap at 9 m using EeteS. Two different types of simulations were performed: EnMAP01 is a spatially simulated EnMAP scene, the spectral bands correspond to the band setting of HyMap02 (Table 3). EnMAP02 is a spatially and spectrally simulated EnMAP scene.

4 File Description

4.1 File Format

Band Sequential Image File [*.bsq] and 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, coordinate system string, wavelength units, z plot titles, band names, wavelength, FWHM.

5 Data Quality/Accuracy

Table 4: Geometric accuracy of HyMap data.

Name	Ground control points	RMSE easting	RMSE northing
HyMap01 vs. reference (orthophotos)	15	2.91 m	3.08 m
HyMap02 vs. reference (orthophoto)	15	2.69 m	2.23 m
HyMap01 vs. HyMap02	30	1.82 m	2.52 m

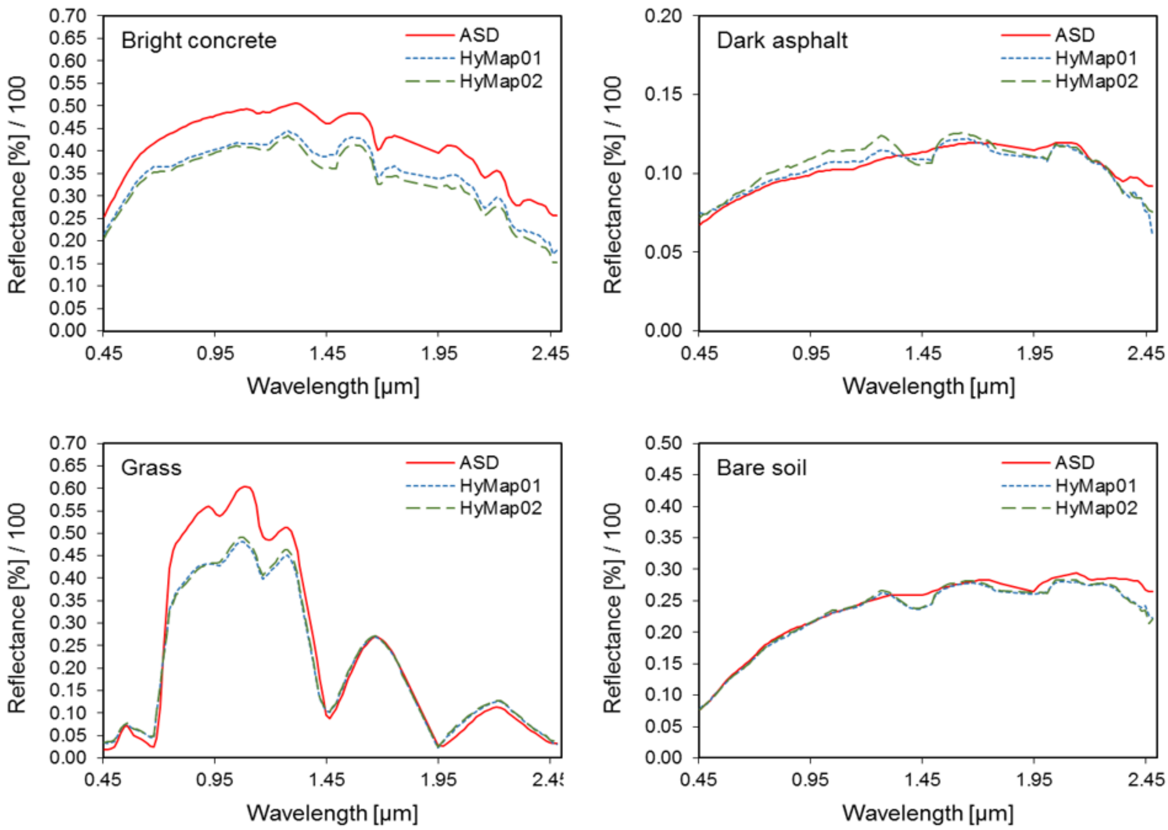

Figure 2: Comparison of ASD field spectra and HyMap01 and HyMap02 image spectra for different surface cover types (bright concrete, dark asphalt, grass, bare soil).

6 Additional Data

The *Berlin-Urban-Gradient* dataset is delivered with an image spectral library and detailed land cover reference information useful for both unmixing and hard classification purposes. An overview of the additional data is provided in Table 5.

Table 5: Berlin-Urban-Gradient – Additional data.

Name	Description
SpecLib	Spectral library in ENVI- [*.sli] and ASCII- [*.txt] format.
LandCov_Vec	Land cover reference information as vector file [*.shp].
LandCov_Layer	Land cover reference fraction layer at 30 m EnMAP resolution as band sequential image file [*.bsq] and file header [*.hdr].

6.1 Spectral Library

The spectral library consists of 75 artificial and natural surface materials relevant for the study region. The spectral library is hierarchically structured into two land cover type levels (Table 6). All spectra were extracted from HyMap01 as mean reflectance spectra of spectrally homogeneous regions of interest. Regions for spectral sampling were identified based on field mapping data, digital orthophotos and Google Street View. More detailed information on the library development can be found in Okujeni et al. (2015; 2013).

Table 6: Hierarchically structured spectral library.

Level 1	Level 2	Material name	No. spectra
Impervious	Roof	Red clay tile	4
		Red cement tile	3
		Bitumen	5
		Brown tile	1
		Black tile	1
		Brown shingle	1
		White roof material (polyethylene)	1
		White roof material (unknown)	4
		Greenish roof material (unknown)	1
		Light grey roof material (unknown)	1
		Zinc	1
	Pavement	Asphalt	4
		Concrete	3
Vegetation	Low vegetation	Grass (intensively manicured)	2
		Grass (extensively manicured)	1
		Grass (agricultural grassland)	3
		Grass (meadow clover)	2
		Grass (meadow alfalfa, lucerne)	1
		Grass (dry)	2
		Grass (dry agricultural grassland)	1
		Sunflower	1
		Corn	1
		Sorghum	1
		Sugarbeet	2
		Potatoes	1
	Tree	Deciduous tree	11
		Coniferous tree	2
Soil		Bare soil	2
		Sand (playground)	2
Other		Red sand (cinder field)	1
		Red sand (cinder court)	2
		Railtrack	2
		Artificial turf	2
		Tartan (sports ground)	1
		Water	2

Multiple spectra per material (see column 4) considered to account for spectral variability due to variations in illumination and shading effects or variations in material condition.

6.2 Reference Land Cover Information

Detailed land cover reference information was manually derived within 114 polygons. All polygons are located within the city boundary of Berlin and within a ±10° off-nadir region to minimize effects of the urban 3D-geometry on comparisons between images and reference data. Land cover reference information is labelled according to Level 1 and Level 2 land cover types (compare Table 6). The spatial extend of buildings was extracted from Berlin's building cadastre (compare 6.3 Related Datasets), vegetation types and paved impervious grounds were manually delineated at 1:500 map scale based on an available LiDAR DSM and orthophotos.

The land cover reference information is provided in vector format and as land cover fraction layer (see Tables 5 and Appendix). The vector file allows an overlay with HyMap01, HyMap02 and EnMAP and can be flexibly prepared by the user for his/her own needs. The land cover fraction layer is a multi-band image at the 30 m scale derived through calculating percentage of land cover within each

EnMAP pixel (see Tables 5 and Appendix). Only pixels with a fully land cover coverage were considered, i.e., boundary pixel were excluded.

6.3 Related Datasets

- The Berlin Senate provides a rich database of environmental data for free download via their Web Feature- (WFS) and Web Map Services (WMS): http://www.stadtentwicklung.berlin.de/geoinformation/geodateninfrastruktur/de/geodienste/.
- The Urban Atlas – implemented as part of the Copernicus Land Monitoring Service – provides harmonized land use/land cover data for functional urban areas across Europe: http://www.eea.europa.eu/data-and-maps/data/urban-atlas.

7 Dataset Contact

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8 Acknowledgements

The authors thank the German Aerospace Centre (DLR) for the HyMap data acquisition and pre-processing during the HyEurope 2009 Campaign. This data acquisition and related field work was financially supported by the Federal Ministry of Research and Education (BMBF) in the project "EnMap-Nutzungsvorbereitung – Unterstützung der Hochschulforschung mit HyMap-Hyperspektraldaten" (FKZ 01LK0901A). The processing of the image data and the generation of ground truth data was supported by the German Research Foundation (DFG) under grant "Städtisches Umweltmonitoring mit spektral und geometrisch hoch auflösenden Fernerkundungsdaten" (HO 2568/2-3) and the Federal Ministry of Economics and Technology (BMWi) as part of the EnMAP Core Science Team activities (FKZ 50EE0949). The authors thank Karl Segl and Christian Rogaß from the German Research Centre (GFZ) for the EnMAP simulation and Maria Cierpinski for generating the reference land cover information based on data provided by the Department for Urban Development of the Berlin Senate.

9 References

Cocks, T., Jenssen, R., Stewart, A., Wilson, I., & Shields, T. (1998). The HyMap^{TM} airborne hyperspectral sensor: The system, calibration and performance. 1st Earsel Workshop on Imaging Spectroscopy, 37-42.

Guanter, L., Kaufmann, H., Segl, K., Foerster, S., Rogass, C., Chabrillat, S., Kuester, 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, 8830, http://doi.org/10.3390/rs70708830.

Okujeni, A., van der Linden, S., & Hostert, P. (2015). Extending the vegetation–impervious–soil model using simulated EnMAP data and machine learning. Remote Sensing of Environment, 158, 69-80, http://doi.org/10.1016/j.rse.2014.11.009.

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Richter, R., & Schläpfer, D. (2002). Geo-atmospheric processing of airborne imaging spectrometry data. Part 2: Atmospheric/topographic correction. International Journal of Remote Sensing, 23, 2631-2649, http://doi.org/10.1080/01431160110115834.

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.

Segl, K., Guanter, L., Rogass, C., Kuester, T., Roessner, S., Kaufmann, H., Sang, B., Mogulsky, V., & Hofer, S. (2012). EeteS-The EnMAP End-to-End Simulation Tool. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 5, 522-530, http://doi.org/10.1109/JSTARS.2012.2188994.

10 Appendix

Table Appendix: Folder structure and files of Berlin-Urban-Gradient dataset.

Folder	File
01_image_products	• HyMap01_Berlin_Urban_Gradient_2009.bsq/.hdr • HyMap02_Berlin_Urban_Gradient_2009.bsq/.hdr • EnMAP01_Berlin_Urban_Gradient_2009.bsq/.hdr • EnMAP02_Berlin_Urban_Gradient_2009.bsq/.hdr
02_additional_data/spectral_library	• SpecLib_Berlin_Urban_Gradient_2009.sli/.hdr • SpecLib_Berlin_Urban_Gradient_2009.txt
02_additional_data/land_cover	• Land-Cov_Vec_Berlin_Urban_Gradient_2009.shp/.shx/.sbx/.sbn/.prj/.dbf • Land-Cov_Vec_polygons_Berlin_Urban_Gradient_2009.shp/.shx/.sbx/.sbn/.prj/.dbf • Land-Cov_Layer_Level1_Berlin_Urban_Gradient_2009.bsq/.hdr • Land-Cov_Layer_Level2_Berlin_Urban_Gradient_2009.bsq/.hdr
03_supplementary_material	• Berlin_Urban_Gradient_2009_Coverage1.png • Berlin_Urban_Gradient_2009_Coverage2.png • Berlin_Urban_Gradient_2009_Coverage3.png • Berlin_Urban_Gradient_2009_Coverage4.png • Berlin_Urban_Gradient_2009_Coverage5.png • Berlin_Urban_Gradient_2009_Coverage6.png