EnMAP Flight Campaigns

Technical Report

Neusling (Landau a.d. Isar) 2012
A Multitemporal and Multisensoral Agricultural EnMAP Preparatory Flight Campaign

Tobias Hank, Matthias Locherer, Katja Richter,
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Neusling (Landau a.d. Isar) 2012

- A Multitemporal and Multisensoral

Agricultural EnMAP Preparatory Flight Campaign

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Abstract

This data collection contains a multitemporal series of six airborne hyperspectral image mosaics acquired during the growing season of 2012 over the Neusling test area near Landau a.d. Isar in Southern Germany. The airborne hyperspectral data is complemented by accompanying in-situ data acquired parallel to the overflights. The dataset is composed of a) four airborne hyperspectral image mosaics acquired during overflights on April 28th 2012, May 25th 2012, June 16th 2012 and September 8th 2012 with the AVIS-3 imaging spectrometer. The AVIS data consists of 197 spectral bands, ranging from VIS to SWIR (477 - 1704 nm); b) two airborne hyperspectral image mosaics acquired during overflights on May 8th 2012 and August 12th 2012 with a HySpex imaging spectrometer. The HySpex data consists of 332 spectral bands, ranging from VIS to SWIR (417 - 2496 nm); c) spatially comprehensive land use/land cover maps generated from in-situ observations for two time-windows during the growing season of 2012 (May and August); d) Flight-parallel in-situ point-measurements consisting of: i) non-destructively measured leaf area index of winter wheat, winter barley, sugar beet, maize and rapeseed (561 measurements incl. standard deviations), ii) SPAD chlorophyll measurements (522 measurements incl. standard deviations), iii) 557 soil moisture measurements incl. standard deviations iv) 539 phenological observations v) 499 measurements of canopy height incl. standard deviations and vi) 38 measurements of plant density. The dataset was collected in order to cover the seasonal dynamics in the development of agricultural crops in Southern Germany.

Coordinates	
Area:	**Neusling**
Center:	48,69 ° N / 12,86° E
Upper Left:	48,70° N / 12,82° E
Upper Right:	48,70° N / 12,90° E
Lower Left:	48,67° N / 12,82° E
Lower Right:	48,67° N / 12,90° E

Keywords: Multitemporal Hyperspectral Imagery, Agriculture, LAI, Chlorophyll, Phenology

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.

The processing of the airborne data is exhaustively described in:

Locherer, Matthias (2014): Capacity of the hyperspectral satellite mission EnMAP for the multiseasonal monitoring of biophysical and biochemical land surface parameters in agriculture by transferring an analysis method for airborne image spectroscopy to the spaceborne scale. Dissertation, LMU München: Fakultät für Geowissenschaften, accessible online via: https://edoc.ub.uni-muenchen.de/17618/1/Locherer_Matthias.pdf.

The data set has been scientifically applied in:

Locherer, M., Hank, T., Danner, M. & Mauser, W. (2015): Retrieval of Seasonal Leaf Area Index from simulated EnMAP data through optimized LUT-based Inversion of the PROSAIL Model, Remote Sensing 7 (8), pp. 10321-10346. http://doi.org/10.3390/rs70810321.

The environmental characteristics of the test site are described:

Hank, T.; Richter, K.; Mauser, W. (2015): Neusling (Landau a.d. Isar) 2009 - An Agricultural EnMAP Preparatory Flight Campaign Using the HyMap Instrument, GFZ Data Services, http://doi.org/10.2312.enmap.2015.002.

The ground sampling was done according to the following EnMAP Field Guides:

Danner, Martin; Locherer, Matthias; Hank, Tobias (2015a): Campaign Layouts and Sampling Strategies – Theory - Principles - Problems - Practice. An EnMAP Field Guide Technical Report, GFZ Data Services. http://doi.org/10.2312.enmap.2015.012.

Danner, Martin; Locherer, Matthias; Hank, Tobias; Richter, Katja (2015b): Measuring Leaf Area Index (LAI) with the LI-Cor LAI 2200C or LAI-2200 (+2200Clear Kit) – Theory, Measurement, Problems, Interpretation. An EnMAP Field Guide Technical Report, GFZ Data Services. http://doi.org/10.2312.enmap.2015.009.

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Dotzler, Sandra; Danner, Martin; Locherer, Matthias; Hank, Tobias; Richter, Katja (2015): Measuring Soil Moisture with FD-Probes – Theory, Measurement, Problems, Interpretation. An EnMAP Field Guide Technical Report, GFZ Data Services. http://doi.org/10.2312.enmap.2015.011.

Süß, Andreas; Obster, Christina; Danner, Martin; Locherer, Matthias; Hank, Tobias; Richter, Katja (2015): Measuring Leaf Chlorophyll Content with the Konica Minolta SPAD-502Plus – Theory, Measurement, Problems, Interpretation. An EnMAP Field Guide Technical Report, GFZ Data Services. http://doi.org/10.2312.enmap.2015.010.

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.

Preparing for EnMAP's capability of providing repeated hyperspectral observations of the land surface, a coordinated flight campaign was carried out by the Dept. of Geography of the LMU Munich during the growing period of 2012. Thereby, the AVIS-3 imaging spectrometer was applied onboard of a DO-27 aircraft operated by the "Bundeswehr Sportfliegergemeinschaft Fürstenfeldbruck e. V.". In addition, DLR Oberpfaffenhofen contributed observations using a HySpex imaging spectrometer onboard of the DLR aircraft Do-228 (D-CODE). The LMU test site "Neusling", Southern Germany thus could be scanned on six dates between April 28th and September 8th 2012. The borders of the test site were defined as listed in Table 1.01, enclosing an area of 4 x 3 km (12km²).

Table 1.01: Coordinates of the defined Neusling test area

Area:	12km²
Extent W-E:	4 km
Extent N-S:	3 km
Center:	48.691156° N / 12.866129° E
Upper Left:	48.704736° N / 12.838370° E
Upper Right:	48.705768° N / 12.892546° E
Lower Left:	48.677824° N / 12.839278° E
Lower Right:	48.678749° N / 12.893566° E

The dates of the imaging flights are distributed over the growing season of 2012 and thus allow tracing the dynamic processes of growth and senescence of agricultural crops in the area (Table 1.02).

Table 1.02: Airborne data acquisitions over the Neusling test site and corresponding solar zenith angles (SZA) of the seasonal campaign 2012.

Acquisition Date	Sensor	SZA (°)
April, 28th 2012	AVIS-3	42
May, 8th 2012	HySpex	45
May, 25th 2012	AVIS-3	39
June, 16th 2012	AVIS-3	28
August, 12th 2012	HySpex	42
September, 8th 2012	AVIS-3	45

Each sensor overflight consisted of several N-S oriented flight strips, which were mosaicked to provide continuous spatial coverage over the Neusling area (Fig. 1.01).

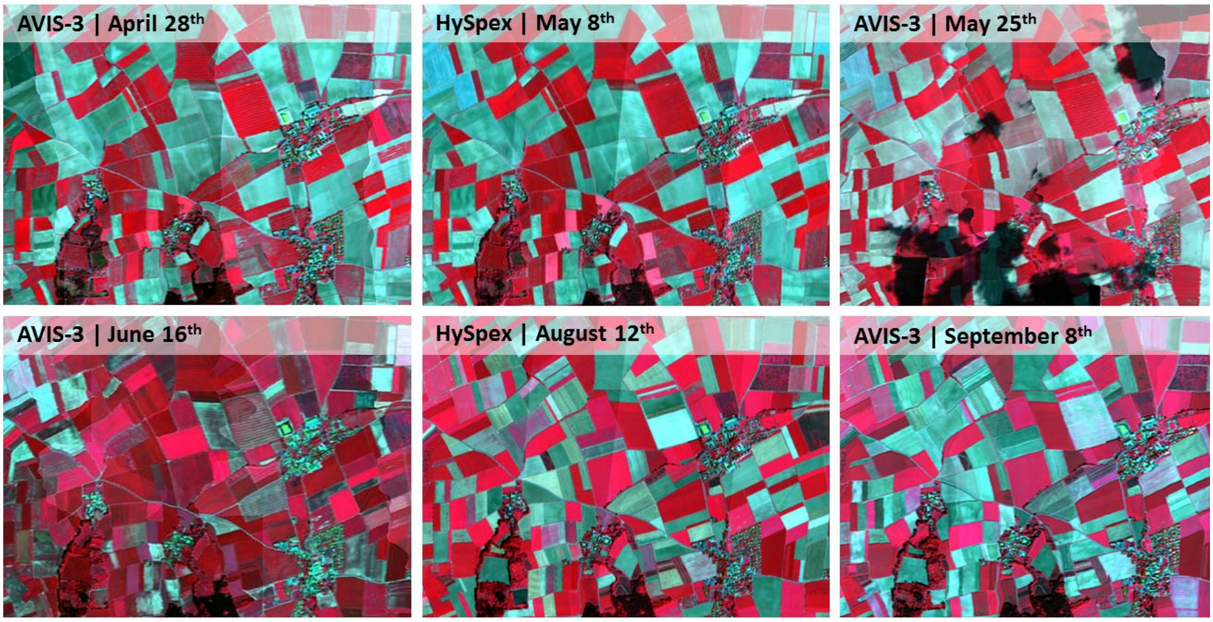

Figure 1.01: Quicklooks (false color infrared) of the multisensoral data acquired during the 2012 growing season over the 'Neusling' test area, Southern Germany.

Parallel to the overflights, ground measurements (Table 1.03) were conducted by the LMU at selected sample points. Depending on the crop-specific growth phase during the six overflights, different crop types were monitored at different dates. The in-situ database thus combines measurements of winter wheat, winter barley, sugar beet, maize and rapeseed. Since the generation of a multitemporal image series with airborne sensors is highly dependent on the weather, the campaign on the 29th of June 2012 had to be aborted, so that no image data is available for that date. However, for reasons of continuity, the in-situ data are nonetheless included in this dataset.

*Table 1.03: Number of in-situ measurements of biophysical variables during the seven campaigns over the 2012 growing season in the Neusling test area (*no image data exists for the 29th of June 2012).*

Campaign Date	Leaf Area Index	SPAD Chlorophyll	TDR Soil Moisture	BBCH Phenology	Canopy height	Plant Density
28.04.2012	86	45	80	83	47	38
08.05.2012	106	106	106	103	106	
25.05.2012	100	101	101	101	97	
16.06.2012	105	105	105	97	103	
***29.06.2012**	43	43	43	43	43	
12.08.2012	38	38	38	38	37	
08.09.2012	83	84	84	74	66	
Total	**561**	**522**	**557**	**539**	**499**	**38**

2 Data Acquisition

2.1 The AVIS-3 Sensor

The AVIS-3 imaging spectrometer is developed from commercially available components at the Department of Geography of the LMU Munich. It combines two individual spectrometers to cover a spectral range from 470 to 1700nm. Table 2.01 lists the major technical properties of the AVIS-3 system.

Table 2.01: Technical characteristics of the AVIS-3 imaging spectrometer (Locherer 2014).

Sensor characteristics	**VDS Vosskühler CCD-1020**	**Xenics-Xeva 1.7-LVDS**
Spectrograph:	SpecIm IMSPECTOR V10 E	SpecIm IMSPECTOR N17 E
Number of Spectral Bands:	398	257
Spectral Range:	400 – 1000 nm	900 -1700 nm
Sampling Interval:	1.7 nm	3.1 nm
Spectral Resolution:	2.8 nm	5.0 nm
Radiometric Resolution:	12 bit (4096:1)	12 bit (4096:1)
Geometrical Resolution (IFOV):	1.2 mrad	1.1 mrad
Maximum Sampling Rate:	15 pic/s	60 pic/s
Swath Width (FOV):	45°, 640 pixels	20°, 320 pixels
Along Track Swivel Range:	-55° > +55°, 0.18 increment	-55° > +55°, 0.18 increment

2.2 The HySpex Sensor

The HySpex imaging spectrometer is a commercially available imaging system, which is operated by DLR Oberpfaffenhofen. It equally is composed of two individual spectrometers, covering a spectral range from 420 to 2500nm. Table 2.02 lists the major technical properties of the HySpex system that was applied in this campaign.

Table 2.02: Technical characteristics of the HySpex imaging spectrometer (Locherer 2014).

Sensor characteristics	**VNIR-1600**	**SWIR-320m-e**
Spectral Bands:	160	256
Spectral Range:	410 – 1000 nm	1000 – 2500 nm
Sampling Interval:	3.7 nm	6.0 nm
Radiometric Resolution:	12 bit	14 bit
FOV / Swath Width:	17°, 1600 pixels	14°, 320 pixels
Min. GSD:	0.3 m	0.6 m

3 Data Processing and Products

3.1 Airborne data

Level2: All airborne data are provided as geometrically and atmospherically corrected reflectances with a ground sampling distance of 4 meters. The processing steps, including radiometric processing, geometric rectification and atmospheric correction, that were applied to the data are described in detail in Locherer (2014). Due to the different characteristics of the two applied hyperspectral imaging systems, some heterogeneities remain in the data series.

3.2 Simulated EnMAP Data

In June 2013, the six image mosaics were used to simulate an EnMAP satellite image series (Fig. 3.01) using the EnMAP-End-to-End-Simulation tool (EeteS; Segl et al. 2012). The image series was reprocessed in June 2015 with the latest version of EeteS. The simulation and the reprocessing was kindly performed by Karl Segl from the GFZ German Research Centre for Geosciences, Potsdam.

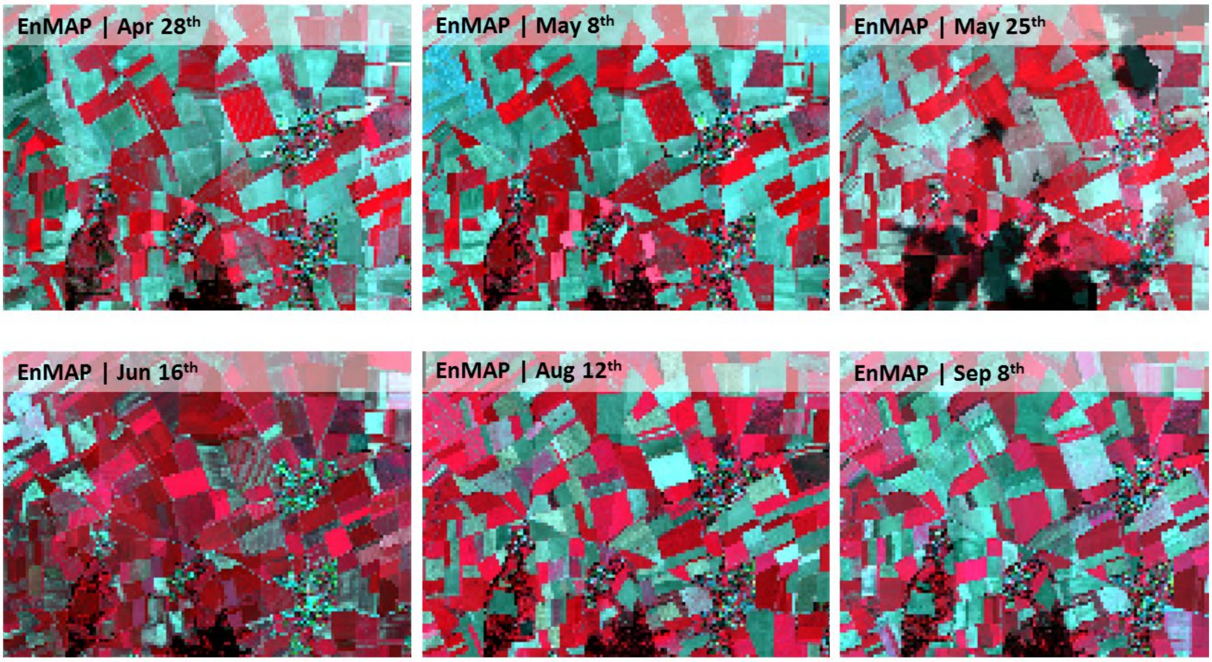

Figure 3.01: Artificial EnMAP image time series derived from the multisensoral airborne hyperspectral image series recorded from April 28th to September 8th 2012 over the Neusling test site in southern Germany.

The spectral range of the AVIS-3 Instrument is from 477 - 1704 nm, while the future EnMAP Hyperspectral Imager will cover a spectral range from 420 – 2450nm. The EnMAP data that was simulated based on AVIS-3 imagery naturally is limited to the spectral range of AVIS-3.

4 File Description

4.1 File Format

Band Sequential ENVI Standard Image File [*.*] 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, wavelength units, band names, wavelength, fwhm

5 Data Quality

5.1 AVIS-3 Blurred N-S Lines

During the season of 2012 some across-track spatial distortions were observed in the first (visible) bands of the AVIS-3 VNIR data, leading to the fact that N-S oriented linear structures may appear as blurred doubled lines (Fig. 5.01, left). However, this effect cannot be observed for the infrared bands (Fig. 5.01, right). For the simulated EnMAP data, these distortions should not play a major role due to the large difference between the spatial scales (4m → 30 m).

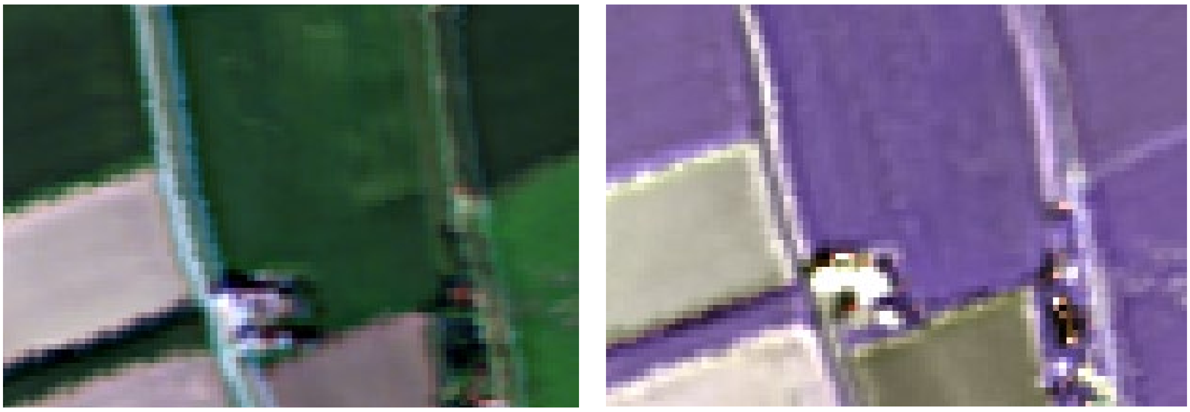

Figure 5.01: Across-track spatial distortions can be discerned in the visible bands of AVIS-3 (left), but are not visible in the infrared bands (right).

5.2 AVIS-3 Spatial Coverage

The AVIS-3 hyperspectral imager is composed of two independent spectrometers for the VNIR and for the SWIR spectral domain (Table 2.01). Due to the smaller FOV of the SWIR system (20°) compared to the VNIR system (45°), some gaps exist along the borders of neighboring image strips in the image mosaics, where the VNIR provides continuous coverage, while the SWIR shows data gaps (e.g. Fig. 5.02).

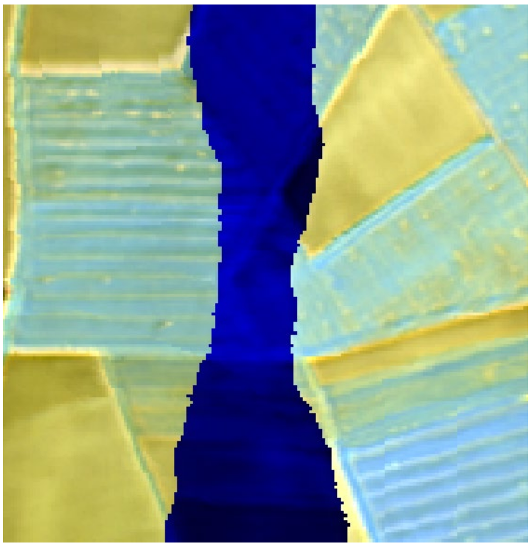

Figure 5.02: Some gaps in the SWIR data occur along the borders of neighboring image strips within the image mosaics due to the different Field of View of the two spectrometers of AVIS-3.

6 Additional data

The flight-parallel sampling of in-situ variables requires a most sensitive evaluation of target resolution, target homogeneity and target accessibility. Field measurements conducted for the collection of in-situ data for this 2012 hyperspectral campaign therefore were designed according to the recommendations given in the EnMAP FieldGuide on Campaign Layout & Sampling Strategies (Danner et al. 2015a).

6.1 Ground Radiometric Measurements

To support the atmospheric correction of the airborne data, homogeneous and constant reference targets were measured parallel to the imaging flights using an ASD FildSpec4 standard spectroradiometer (Fig. 6.01). The ground-based spectral measurements were performed according to the recommendations given in the EnMAP FieldGuide on Field spectroscopy (Danner et al., 2015b).

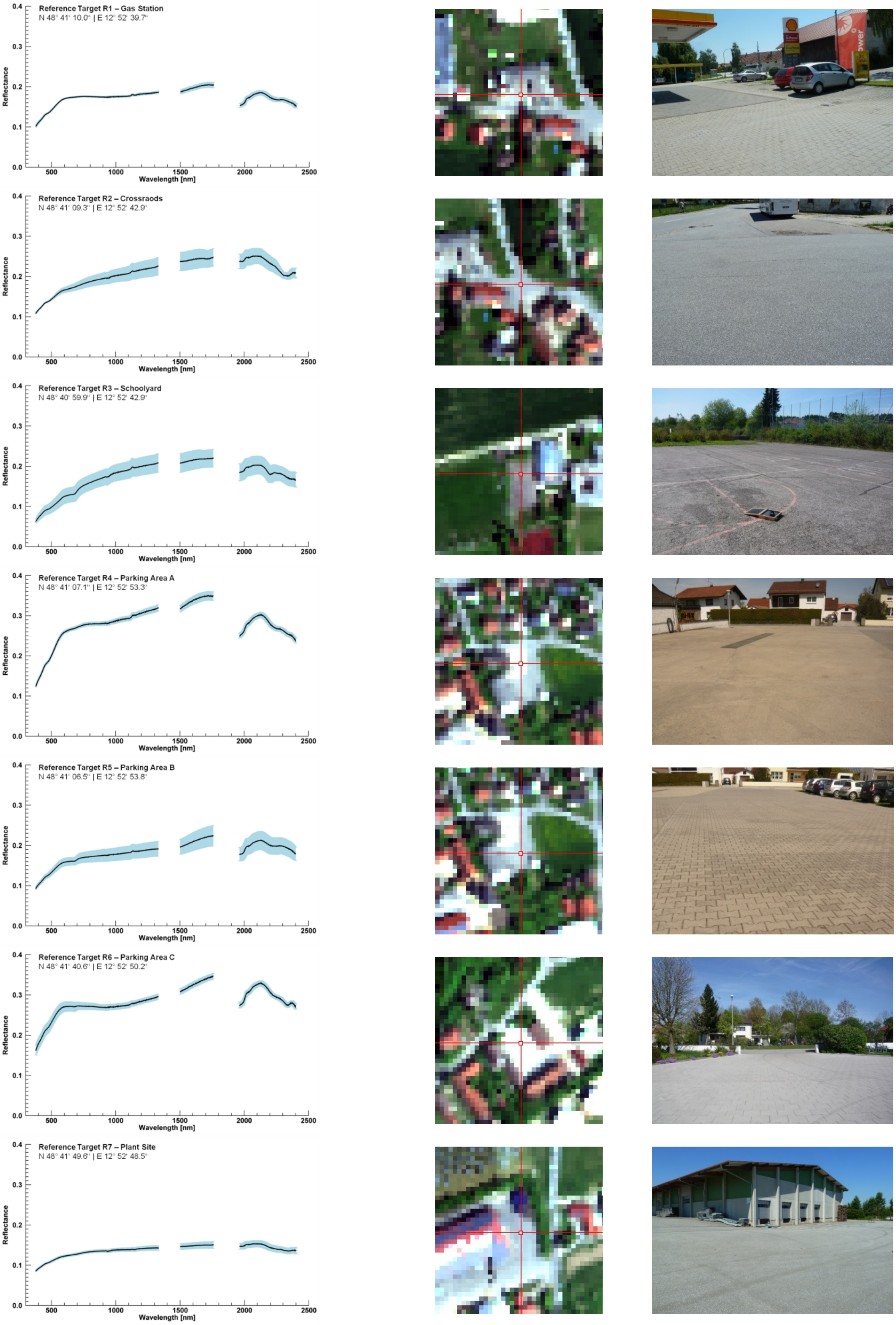

Figure 6.01: ASD reflectance with corresponding standard deviation (left), localization in AVIS-3 true-color image (middle) and on-site photo (right) of the radiometric reference targets that were used for the spectral calibration (Locherer 2014).

6.2 Land Cover Map

Land cover was mapped during the month of May 2012 (Fig. 6.02) for the full extent of the Neusling test site as defined in Table 1.01. Due to the multitemporal character of the campaign, the mapping was repeated in August (Fig. 6.03). All the fields where cereals were cultivated during the season of 2012 show bare soil for the late overflights in August and September.

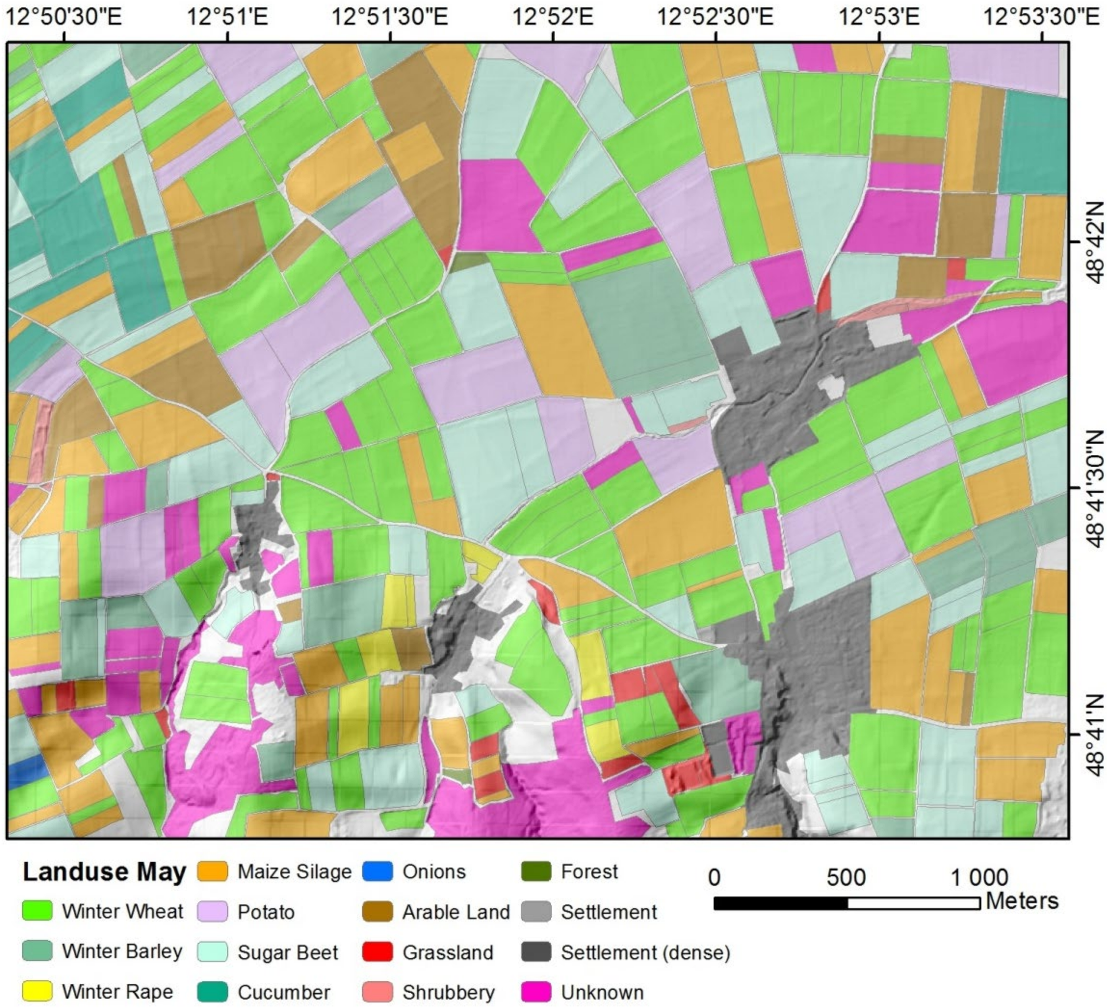

Figure 6.02: Land cover map of the Neusling test area based on in-situ observations during the month of May 2012.

Figure 6.03: Land cover map of the Neusling test area based on in-situ observations during the month of August 2012. All cereals had been harvested by the time of the mapping.

6.3 Leaf Area Index (LAI)

The leaf area index (LAI) was measured using two LI-COR LAI-2200 plant canopy analyzers (Welles and Cohen, 1996) according to sampling procedures described in the EnMAP FieldGuide on non-destructive leaf area index measurements (Danner et al., 2015c). With these instruments, a total of >500 indirect and non-destructive estimates of LAI were collected (Table 1.03). Depending on the growth activity of different crops on the different dates of the imaging flights, the locations of the sample points vary through the season (Fig. 6.04).

Since the campaign covered the entire growth period of 2012, not all crops could be sampled at all flight dates due their individual phenological development. However, the growth dynamics of increasing LAI during early growth stages and decreasing LAI during senescence could be captured by the in-situ measurements (Fig. 6.05).

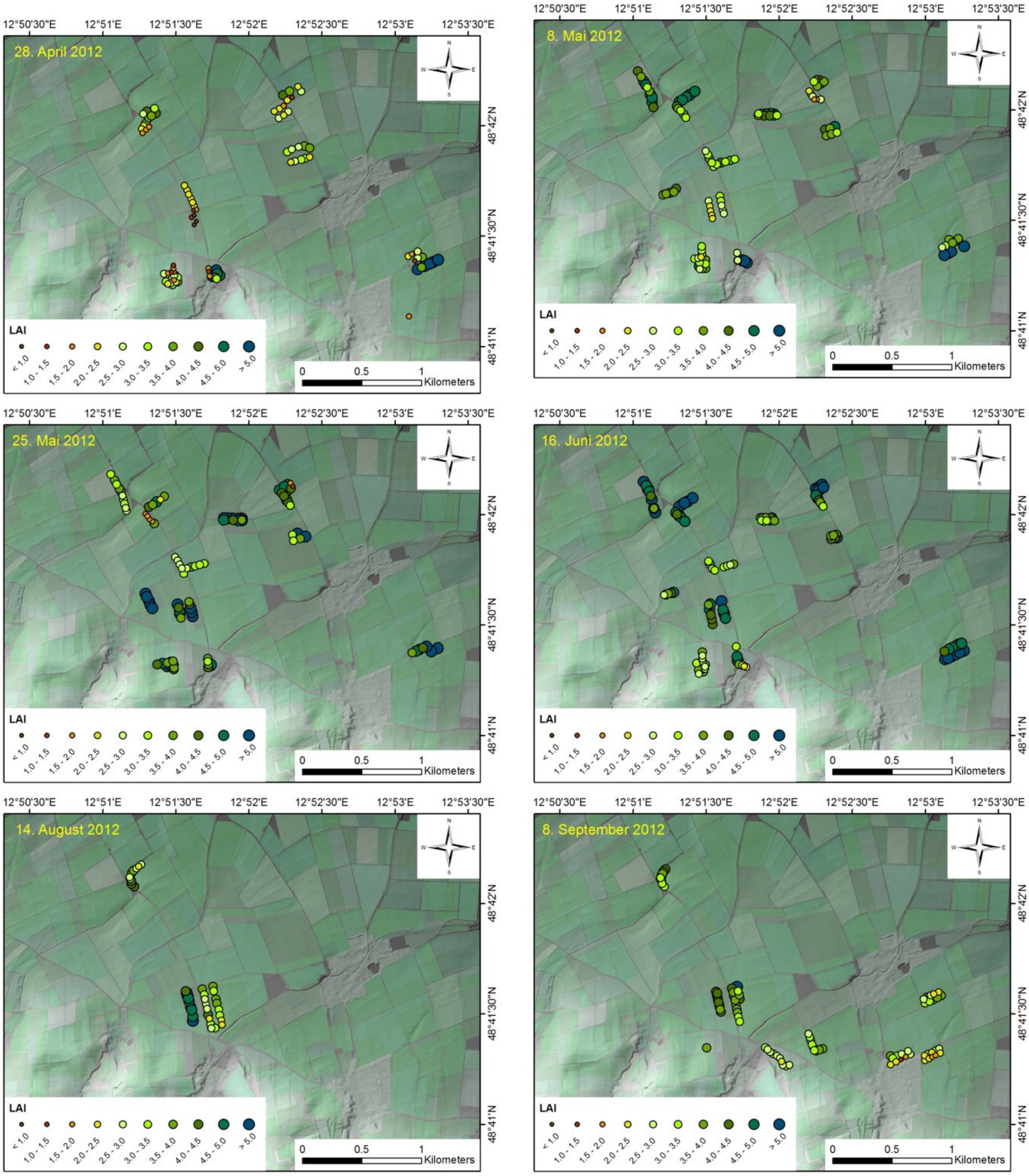

Figure 6.04: Leaf area index measurements collected at different sample points within the test area Neusling during the season of 2012. Upper left: April 28th, upper right: May 8th, middle left: May 20th, middle right: June 16th, lower left: August 14th, lower right: September 8th.

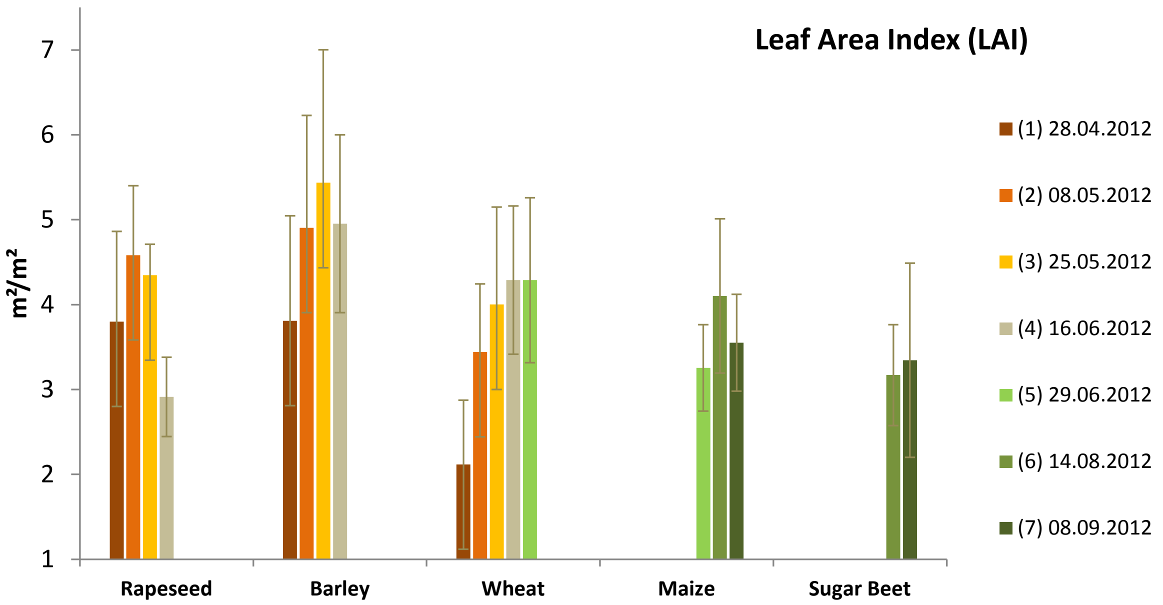

Figure 6.05: In-Situ measurements of leaf area index as collected parallel to the different airborne imaging flights in the Neusling test area for five different crops (Flight 5, planned for the 29th of June 2012, was cancelled due to unstable weather conditions).

6.4 Canopy Height

The height of the canopy was only determined for the uppermost canopy level (depending on the crop either shoot or leaf level) by applying the method described in Hank et al. (2015). The very high development of maize, reaching canopy levels of more than 3m, is notable. Very small standard deviations indicate that the sampled canopies were very homogeneously developed (Fig. 6.06).

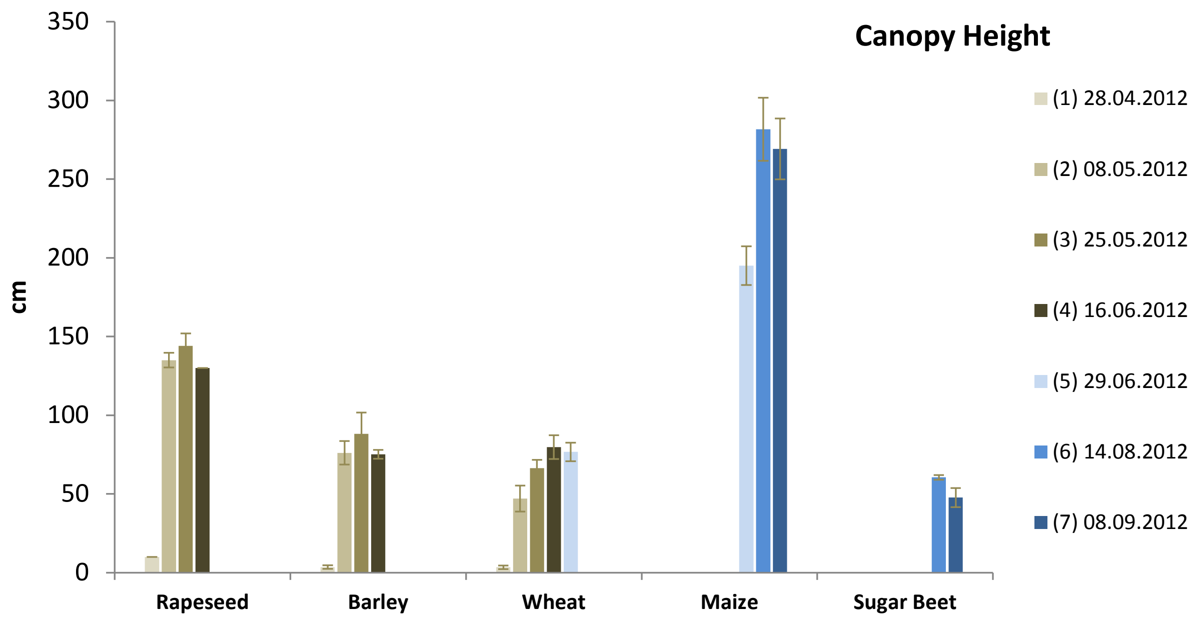

Figure 6.06: In-Situ measurements of canopy height as collected parallel to the different airborne imaging flights in the Neusling test area for five different crops (Flight 5, planned for the 29th of June 2012, was cancelled due to unstable weather conditions).

6.5 Leaf Chlorophyll

Leaf Chlorophyll was sampled using a Konica-Minolta SPAD-502plus instrument according to the procedure described in the EnMAP FieldGuide on leaf chlorophyll measurements (Süß et al., 2015).

The SPAD instrument only provides relative (index-) values. In order to retrieve actual chlorophyll concentrations from these values, the SPAD must be individually calibrated based on destructive laboratory measurements. This has been done for the very instrument that was used for this study. The given SPAD values thus may be converted into leaf chlorophyll concentrations by applying Equation 6.01:

$$Leaf\ Chlorophyll[\mu g/cm^2] = 12.23 \times e^{00278 \times SPAD} \qquad \text{Eq. 6.01}$$

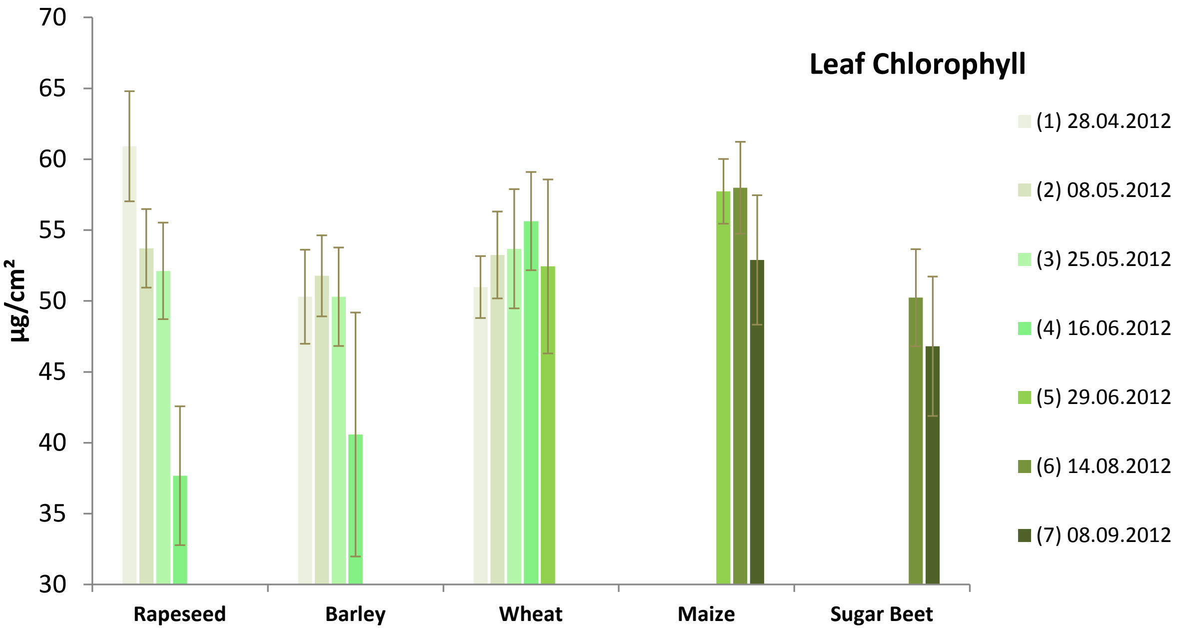

Figure 6.07: In-Situ measurements of leaf chlorophyll as collected parallel to the different airborne imaging flights in the Neusling test area for five different crops (Flight 5, planned for the 29th of June 2012, was cancelled due to unstable weather conditions).

6.6 Soil Moisture

Soil moisture was determined using TDR and FDR probes according to the procedure described in the EnMAP FieldGuide on soil moisture measurements (Dotzler et al., 2015). Although soil moisture is very variable in space and time (Fig. 6.08), it can be helpful for the interpretation of the brightness in the airborne image data.

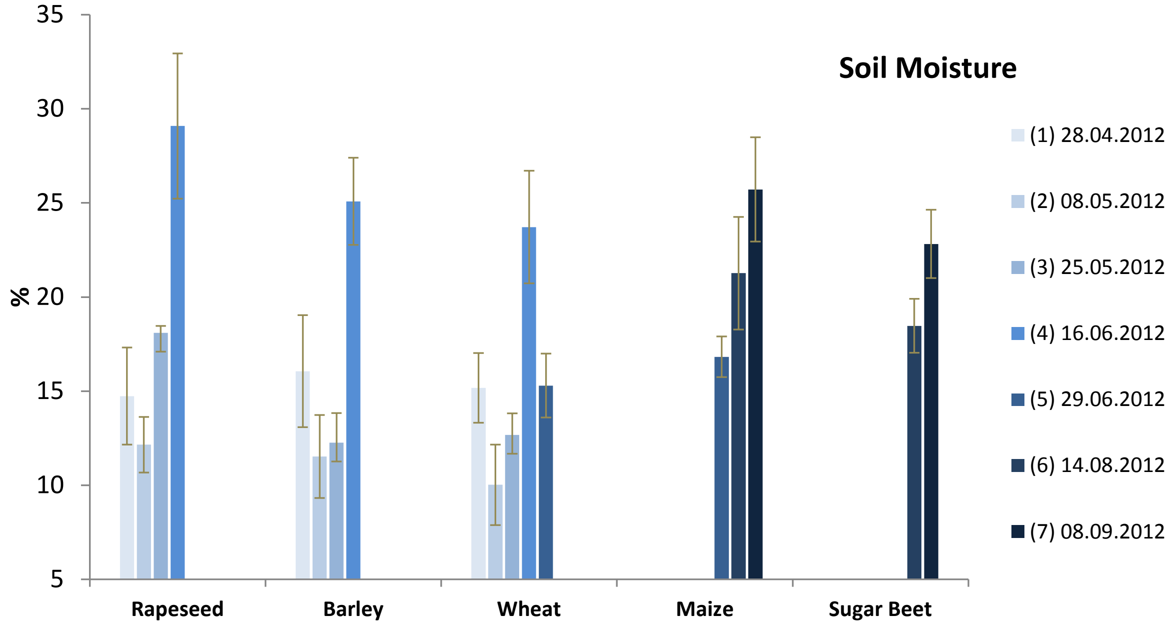

Figure 6.08: In-Situ measurements of soil moisture as collected parallel to the different airborne imaging flights in the Neusling test area for five different crops (Flight 5, planned for the 29th of June 2012, was cancelled due to unstable weather conditions).

6.7 Phenology

Phenology was determined according to the internationally acknowledged BBCH scale, where values above 80 indicate increasing ripeness (Fig. 6.09).

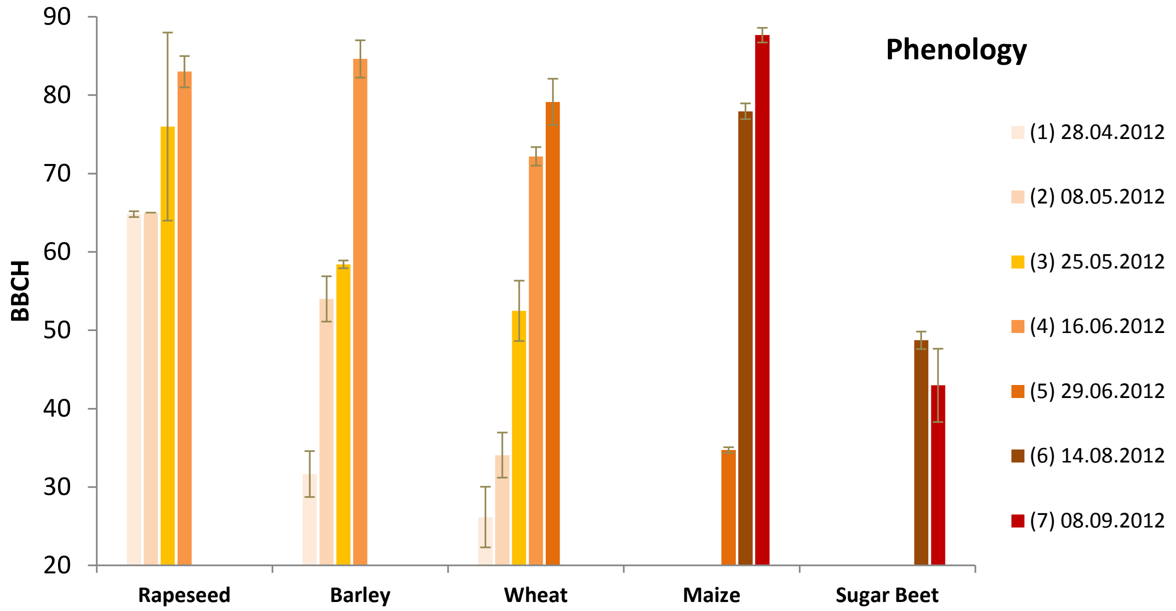

Figure 6.09: In-Situ observations of phenology as collected parallel to the different airborne imaging flights in the Neusling test area for five different crops (Flight 5, planned for the 29th of June 2012, was cancelled due to unstable weather conditions).

7 Dataset Contact

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This campaign is a successful example of collaboration between a university and a research center. The contribution of the DLR Oberpfaffenhofen, personified by Nicole Pinnel and Martin Bachmann, is gratefully acknowledged.

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9 References

Danner, Martin; Locherer, Matthias; Hank, Tobias (2015a): Defining Campaign Layouts & Sampling Strategies – Theory - Principles - Problems - Practice. An EnMAP Field Guide, Technical Report, GFZ Data Services. http://doi.org/10.2312.enmap.2015.012.

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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.

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10 Appendix

10.1 List of available datasets

The provided data (size: 5.5 GB) are structured into five folders:

- 00_Quicklooks
- 01_Airborne_Data
- 02_Simulated_EnMAP_Data
- 03_InSitu_Measurements
- 04_Data_Report

The folder **“00_Quicklooks”** (size: 13 MB) contains the following data:

Filename	Extension	Format	Size	Content
20120428_Neusling_AVIS_Quicklook	*.tif	Tiff-File for direct import e.g. into ESRI ArcGIS	2,2 MB	False-Color-Infrared representation of the Neusling AVIS mosaic from April 28th 2012
20120428_Neusling_AVIS_Quicklook	*.tfw	ESRI ArcGIS World file	1 KB	Contains geometric resolution and lower left corner coordinate
20120508_Neusling_HySpex_Quick-look	*.tif	Tiff-File for direct import e.g. into ESRI ArcGIS	2,2 MB	False-Color-Infrared representation of the Neusling HySpex mosaic from May 8th 2012
20120508_Neusling_HySpex_Quick-look	*.tfw	ESRI ArcGIS World file	1 KB	Contains geometric resolution and lower left corner coordinate
20120525_Neusling_AVIS_Quicklook	*.tif	Tiff-File for direct import e.g. into ESRI ArcGIS	2,2 MB	False-Color-Infrared representation of the Neusling AVIS mosaic from May 25th 2012
20120525_Neusling_AVIS_Quicklook	*.tfw	ESRI ArcGIS World file	1 KB	Contains geometric resolution and lower left corner coordinate
20120616_Neusling_AVIS_Quicklook	*.tif	Tiff-File for direct import e.g. into ESRI ArcGIS	2,2 MB	False-Color-Infrared representation of the Neusling AVIS mosaic from June 16th 2012
20120616_Neusling_AVIS_Quicklook	*.tfw	ESRI ArcGIS World file	1 KB	Contains geometric resolution and lower left corner coordinate
20120812_Neusling_HySpex_Quick-look	*.tif	Tiff-File for direct import e.g. into ESRI ArcGIS	2,2 MB	False-Color-Infrared representation of the Neusling HySpex mosaic from August 12th 2012
20120812_Neusling_HySpex_Quick-look	*.tfw	ESRI ArcGIS World file	1 KB	Contains geometric resolution and lower left corner coordinate

20120908_Neusling_AVIS_Quicklook	*.tif	Tiff-File for direct import e.g. into ESRI ArcGIS	2,2 MB	False-Color-Infrared representation of the Neusling AVIS mosaic from September 8th 2012
20120908_Neusling_AVIS_Quicklook	*.tfw	ESRI ArcGIS World file	1 KB	Contains geometric resolution and lower left corner coordinate

The folder **“01_Airborne_Data”** (size: 5.4 GB) contains the following data:

Filename	Extension	Format	Size	Content
20120428_Neusling_AVIS		ENVI Band sequential Image data	600 MB	Radiometrically, atmospherically and geometrically corrected and mosaicked airborne hyperspectral data of the Neusling area (BOA Reflectance) from April 28th 2012
20120428_Neusling_AVIS	*.enp	ENVI pyramids file	180 MB	Image Pyramids for “20120428_Neusling_AVIS”
20120428_Neusling_AVIS	*.hdr	ENVI Header-File	8 KB	Image metadata for “20120428_Neusling_AVIS”
20120508_Neusling_HySpex		ENVI Band sequential Image data	1 GB	Radiometrically, atmospherically and geometrically corrected and mosaicked airborne hyperspectral data of the Neusling area (BOA Reflectance) from May 8th 2012
20120508_Neusling_HySpex	*.enp	ENVI pyramids file	300 MB	Image Pyramids for “20120508_Neusling_HySpex”
20120508_Neusling_HySpex	*.hdr	ENVI Header-File	9 KB	Image metadata for “20120508_Neusling_HySpex”
20120525_Neusling_AVIS		ENVI Band sequential Image data	600 MB	Radiometrically, atmospherically and geometrically corrected and mosaicked airborne hyperspectral data of the Neusling area (BOA Reflectance) from May 25th 2012
20120525_Neusling_AVIS	*.enp	ENVI pyramids file	180 MB	Image Pyramids for “20120525_Neusling_AVIS”
20120525_Neusling_AVIS	*.hdr	ENVI Header-File	8 KB	Image metadata for “20120525_Neusling_AVIS”
20120616_Neusling_AVIS		ENVI Band sequential Image data	600 MB	Radiometrically, atmospherically and geometrically corrected and mosaicked airborne hyperspectral data of the Neusling area (BOA Reflectance) from June 16th 2012
20120616_Neusling_AVIS	*.enp	ENVI pyramids file	180 MB	Image Pyramids for “20120616_Neusling_AVIS”
20120616_Neusling_AVIS	*.hdr	ENVI Header-File	8 KB	Image metadata for “20120616_Neusling_AVIS”
20120812_Neusling_HySpex		ENVI Band sequential Image data	1 GB	Radiometrically, atmospherically and geometrically corrected and mosaicked airborne hyperspectral data of the Neusling area (BOA Reflectance) from August 12th 2012
20120812_Neusling_HySpex	*.enp	ENVI pyramids file	300 MB	Image Pyramids for “20120812_Neusling_HySpex”
20120812_Neusling_HySpex	*.hdr	ENVI Header-File	9 KB	Image metadata for “20120812_Neusling_HySpex”
20120908_Neusling_AVIS		ENVI Band sequential Image data	600 MB	Radiometrically, atmospherically and geometrically corrected and mosaicked airborne hyperspectral data of the Neusling area (BOA Reflectance) from September 8th 2012
20120908_Neusling_AVIS	*.enp	ENVI pyramids file	180 MB	Image Pyramids for “20120908_Neusling_AVIS”
20120908_Neusling_AVIS	*.hdr	ENVI Header-File	8 KB	Image metadata for “20120908_Neusling_AVIS”

The folder “**02_Simulated_EnMAP_Data**” (size: 70 MB) contains the following data:

Filename	Extension	Format	Size	Content
20120428_Neusling_EnMAP		ENVI Band sequential Image data	5,5 MB	EeteS-simulated EnMAP data of the Neusling area for April 28th 2012
20120428_Neusling_EnMAP	*.enp	ENVI pyramids file	6 MB	Image Pyramids for “20120428_Neusling_EnMAP”
20120428_Neusling_EnMAP	*.hdr	ENVI Header-File	10 KB	Image metadata for “20120428_Neusling_EnMAP”
20120508_Neusling_EnMAP		ENVI Band sequential Image data	5,5 MB	EeteS-simulated EnMAP data of the Neusling area for May 8th 2012
20120508_Neusling_EnMAP	*.enp	ENVI pyramids file	6 MB	Image Pyramids for “20120508_Neusling_EnMAP”
20120508_Neusling_EnMAP	*.hdr	ENVI Header-File	10 KB	Image metadata for “20120508_Neusling_EnMAP”
20120525_Neusling_EnMAP		ENVI Band sequential Image data	5,5 MB	EeteS-simulated EnMAP data of the Neusling area for May 25th 2012
20120525_Neusling_EnMAP	*.enp	ENVI pyramids file	6 MB	Image Pyramids for “20120525_Neusling_EnMAP”
20120525_Neusling_EnMAP	*.hdr	ENVI Header-File	10 KB	Image metadata for “20120525_Neusling_EnMAP”
20120616_Neusling_EnMAP		ENVI Band sequential Image data	5,5 MB	EeteS-simulated EnMAP data of the Neusling area for June 16th 2012
20120616_Neusling_EnMAP	*.enp	ENVI pyramids file	6 MB	Image Pyramids for “20120616_Neusling_EnMAP”
20120616_Neusling_EnMAP	*.hdr	ENVI Header-File	10 KB	Image metadata for “20120616_Neusling_EnMAP”
20120812_Neusling_EnMAP		ENVI Band sequential Image data	5,5 MB	EeteS-simulated EnMAP data of the Neusling area for August 12th 2012
20120812_Neusling_EnMAP	*.enp	ENVI pyramids file	6 MB	Image Pyramids for “20120812_Neusling_EnMAP”
20120812_Neusling_EnMAP	*.hdr	ENVI Header-File	10 KB	Image metadata for “20120812_Neusling_EnMAP”
20120908_Neusling_EnMAP		ENVI Band sequential Image data	5,5 MB	EeteS-simulated EnMAP data of the Neusling area for September 8th 2012
20120908_Neusling_EnMAP	*.enp	ENVI pyramids file	6 MB	Image Pyramids for “20120908_Neusling_EnMAP”
20120908_Neusling_EnMAP	*.hdr	ENVI Header-File	10 KB	Image metadata for “20120908_Neusling_EnMAP”

The folder **“03_InSitu_Measurements”** (size: 1.5 MB) contains two sub-folders:

- 01_Landuse
- 02_Point_Measurements

The folder **“03_InSitu_Measurements/01_Landuse”** (size: 450 KB) contains the following data:

Filename	Extension	Format	Size	Content
Landuse_Neusling_2012*	*.dbf	ESRI ArcGIS dBASE table	300 KB	stores the attribute information of features
Landuse_Neusling_2012	*lyr	ESRI ArcGIS Layer file	12	Can be used to create a color legend
Landuse_Neusling_2012	*.prj	ESRI ArcGIS projection file	1 KB	stores the coordinate system information
Landuse_Neusling_2012	*.sbn	ESRI ArcGIS spatial index file 1	5 KB	stores the spatial index of the features
Landuse_Neusling_2012	*.sbx	ESRI ArcGIS spatial index file 2	1 KB	stores the spatial index of the features
Landuse_Neusling_2012	*.shp	ESRI ArcGIS shapefile	121 KB	Polygon feature geometry of the Landuse, mapped for September 2011 in the Neusling Test Area
Landuse_Neusling_2012.shp	*.xml	ESRI ArcGIS metadata file	7 KB	stores information about the shapefile
Landuse_Neusling_2012	*.shx	ESRI ArcGIS index file	4 KB	stores the index of the feature geometry
Neusling_Testsite_Boundaries	*.dbf	ESRI ArcGIS dBASE table	2 KB	stores the attribute information of features
Neusling_Testsite_Boundaries	*.prj	ESRI ArcGIS projection file	1 KB	stores the coordinate system information
Neusling_Testsite_Boundaries	*.sbn	ESRI ArcGIS spatial index file 1	1 KB	stores the spatial index of the features
Neusling_Testsite_Boundaries	*.sbx	ESRI ArcGIS spatial index file 2	1 KB	stores the spatial index of the features
Neusling_Testsite_Boundaries	*.shp	ESRI ArcGIS shapefile	1 KB	Polygon feature geometry of the boundaries of the defined Neusling Test Area
Neusling_Testsite_Boundaries	*.shx	ESRI ArcGIS index file	1 KB	stores the index of the feature geometry

*The attribute table of “Landuse_Neusling_2012” contains the following information:

FID	= Feature ID: Unique identification number for individual features
Shape	= Polygon
FIELD_ID	= ID number of individual fields
KEY052012	= IGGF- Landcover code observed in May 2012
Info052012	= Comment field for observations in May 2012
LU052012	= Landuse observed in May 2012
KEY082012	= IGGF- Landcover code observed in August 2012
Info082012	= Comment field for observations in August 2012
LU082012	= Landuse observed in August 2012

The folder **“03_InSitu_Measurements/02_Point_Measurements”** (size: 1 MB) contains the following data:

Filename	**Extension**	**Format**	**Size**	**Content**
120428_AVIS_1*	*.dbf	ESRI ArcGIS dBASE table	151 KB	stores the attribute information of features
120428_AVIS_1	*.prj	ESRI ArcGIS projection file	1 KB	stores the coordinate system information
120428_AVIS_1	*.sbn	ESRI ArcGIS spatial index file 1	1 KB	stores the spatial index of the features
120428_AVIS_1	*.sbx	ESRI ArcGIS spatial index file 2	1 KB	stores the spatial index of the features
120428_AVIS_1	*.shp	ESRI ArcGIS shapefile	4 KB	Point feature geometry containing the in-situ measurements collected on the 28th of April 2012 in the Neusling Test Area
120428_AVIS_1.shp	*.xml	ESRI ArcGIS metadata file	1 KB	stores information about the shapefile
120428_AVIS_1	*.shx	ESRI ArcGIS index file	1 KB	stores the index of the feature geometry
120508_HySpex_1*	*.dbf	ESRI ArcGIS dBASE table	212 KB	stores the attribute information of features
120508_HySpex_1	*.prj	ESRI ArcGIS projection file	1 KB	stores the coordinate system information
120508_HySpex_1	*.sbn	ESRI ArcGIS spatial index file 1	12KB	stores the spatial index of the features
120508_HySpex_1	*.sbx	ESRI ArcGIS spatial index file 2	1 KB	stores the spatial index of the features
120508_HySpex_1	*.shp	ESRI ArcGIS shapefile	4 KB	Point feature geometry containing the in-situ measurements collected on the 8th of May 2012 in the Neusling Test Area
120508_HySpex_1.shp	*.xml	ESRI ArcGIS metadata file	1 KB	stores information about the shapefile
120508_HySpex_1	*.shx	ESRI ArcGIS index file	1 KB	stores the index of the feature geometry
120525_AVIS_2*	*.dbf	ESRI ArcGIS dBASE table	198 KB	stores the attribute information of features
120525_AVIS_2	*.prj	ESRI ArcGIS projection file	1 KB	stores the coordinate system information
120525_AVIS_2	*.sbn	ESRI ArcGIS spatial index file 1	2 KB	stores the spatial index of the features
120525_AVIS_2	*.sbx	ESRI ArcGIS spatial index file 2	1 KB	stores the spatial index of the features
120525_AVIS_2	*.shp	ESRI ArcGIS shapefile	3 KB	Point feature geometry containing the in-situ measurements collected on the 25th of May 2012 in the Neusling Test Area
120525_AVIS_2.shp	*.xml	ESRI ArcGIS metadata file	1 KB	stores information about the shapefile
120525_AVIS_2	*.shx	ESRI ArcGIS index file	1 KB	stores the index of the feature geometry
120616_AVIS_3*	*.dbf	ESRI ArcGIS dBASE table	157 KB	stores the attribute information of features
120616_AVIS_3	*.prj	ESRI ArcGIS projection file	1 KB	stores the coordinate system information
120616_AVIS_3	*.sbn	ESRI ArcGIS spatial index file 1	2 KB	stores the spatial index of the features
120616_AVIS_3	*.sbx	ESRI ArcGIS spatial index file 2	1 KB	stores the spatial index of the features
120616_AVIS_3	*.shp	ESRI ArcGIS shapefile	3 KB	Point feature geometry containing the in-situ measurements collected on the 16th of June 2012 in the Neusling Test Area
120616_AVIS_3.shp	*.xml	ESRI ArcGIS metadata file	1 KB	stores information about the shapefile
120616_AVIS_3	*.shx	ESRI ArcGIS index file	1 KB	stores the index of the feature geometry
120629_NoFlight*	*.dbf	ESRI ArcGIS dBASE table	75 KB	stores the attribute information of features
120629_NoFlight	*.prj	ESRI ArcGIS projection file	1 KB	stores the coordinate system information
120629_NoFlight	*.sbn	ESRI ArcGIS spatial index file 1	1 KB	stores the spatial index of the features

Filename	**Extension**	**Format**	**Size**	**Content**
120629_NoFlight	*.sbx	ESRI ArcGIS spatial index file 2	1 KB	stores the spatial index of the features
120629_NoFlight	*.shp	ESRI ArcGIS shapefile	2 KB	Point feature geometry containing the in-situ measurements collected on the 29^{th} of June 2012 in the Neusling Test Area
120629_NoFlight.shp	*.xml	ESRI ArcGIS metadata file	1 KB	stores information about the shapefile
120629_NoFlight	*.shx	ESRI ArcGIS index file	1 KB	stores the index of the feature geometry
120812_HySpex_2*	*.dbf	ESRI ArcGIS dBASE table	84 KB	stores the attribute information of features
120812_HySpex_2	*.prj	ESRI ArcGIS projection file	1 KB	stores the coordinate system information
120812_HySpex_2	*.sbn	ESRI ArcGIS spatial index file 1	1 KB	stores the spatial index of the features
120812_HySpex_2	*.sbx	ESRI ArcGIS spatial index file 2	1 KB	stores the spatial index of the features
120812_HySpex_2	*.shp	ESRI ArcGIS shapefile	2 KB	Point feature geometry containing the in-situ measurements collected on the 12^{th} of August 2012 in the Neusling Test Area
120812_HySpex_2.shp	*.xml	ESRI ArcGIS metadata file	1 KB	stores information about the shapefile
120812_HySpex_2	*.shx	ESRI ArcGIS index file	1 KB	stores the index of the feature geometry
120908_AVIS_4*	*.dbf	ESRI ArcGIS dBASE table	204 KB	stores the attribute information of features
120908_AVIS_4	*.prj	ESRI ArcGIS projection file	1 KB	stores the coordinate system information
120908_AVIS_4	*.sbn	ESRI ArcGIS spatial index file 1	1 KB	stores the spatial index of the features
120908_AVIS_4	*.sbx	ESRI ArcGIS spatial index file 2	1 KB	stores the spatial index of the features
120908_AVIS_4	*.shp	ESRI ArcGIS shapefile	3 KB	Point feature geometry containing the in-situ measurements collected on the 8^{th} of September 2012 in the Neusling Test Area
120908_AVIS_4.shp	*.xml	ESRI ArcGIS metadata file	1 KB	stores information about the shapefile
120908_AVIS_4	*.shx	ESRI ArcGIS index file	1 KB	stores the index of the feature geometry

*The attribute tables contain the following information:

FID	= Feature ID: Unique identification number for individual features
Shape	= Point
ID	= ID number of individual sample points
Field_ID	= ID of the sampling field, where the sample point was located in
Waypoint	= Name of the sample point
Time	= Local time of the measurement [CEST]
X	= UTM Easting (Zone 33 N)
Y	= UTM Northing (Zone 33 N)
CROP	= Type of the sampled crop
LAI	= Average leaf area index
LAI__sel_	= Standard deviation of LAI measurements
SPAD_mean	= Average leaf chlorophyll content [SPAD], (0 = NoData)
SPAD__std_	= Standard deviation of leaf chlorophyll measurements
FD_mean	= Average soil moisture [%], (0 = NoData)
FD__std_	= Standard deviation of soil moisture measurements
Phenology	= Observed average phenology [BBCH] , (0 = NoData)
Pheno_min_	= Minimum observed phenology [BBCH]
Pheno__max	= Maximum observed phenology [BBCH]
Height__cm	= Average canopy height [cm] , (0 = NoData)
Height__st	= Standard deviation of canopy height measurements
Plantdensi	= Plant density [plants per m²] (0 = NoData)
PHOTO_ID	= Code used for identification of digital photographs of the sample point
Info	= Comment field

The folder **“04_Data_Report”** (size: 7 MB) contains the following data

Filename	Extension	Format	Size	Content
EnMAP_TechnicalReport_Neusling_2012	*.pdf	Adobe Portable Document Format	2,6 MB	Technical report describing the 2011 APEX campaign in Neusling
EnMAP_TechnicalReport_Neusling_2012_Data_List	*.pdf	Adobe Portable Document Format	850 KB	List of available datasets (this list)