# EnMAP Flight Campaigns
## Technical Report

### Toolik Lake, Alaska 2016

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# EnMAP Flight Campaigns
## Technical Report

### Toolik Lake, Alaska 2016

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# 1. Abstract

The dataset is composed of AisaEAGLE airborne hyperspectral imagery data acquired during the AIRMETH2016 campaign on August 27th, 2016 within the Toolik Lake Natural Research Area on the Alaskan North Slope. The Toolik Lake Research Natural Area is representative of the North Slope physiographic province of the Southern Arctic Foothills (Walker et al., 1989). Dominant vegetation types are dictated by soil moisture and geology and include moist tussock tundra, wet sedge meadows, and dry upland heaths. The dataset includes three flight lines with 130 spectral bands ranging from VIS to NIR (451.7 – 897 nm) wavelength regions. The dataset also includes Level 2A EnMAP simulated imagery using the end-to-end Simulation tool (EeteS) with 78 bands from VIS to NIR (423 – 903 mn). The overall goal of the campaign was to acquire airborne imagery over the Toolik Vegetation grid encompassing 94 permanent 1 x 1 m vegetation plots where corresponding, comprehensive multi-seasonal spectral reflectance, photosynthetic pigment, and detailed species composition data exists. The remote sensing data are highly novel and can be used for vegetation mapping of species composition, plant biomass, and photosynthetic activity.

| | | |
|---|---|---|
| **Coordinates:** | **centroid:** | 68.62 N / -149.62 E |
| | **NW:** | 68.65 N / -149.64 E |
| | **NE:** | 68.65 N / -149.59 E |
| | **SE:** | 68.60 N / -149.59 E |
| | **SW:** | 68.60 N / -149.64 E |

**Keywords:** Hyperspectral Imagery, Arctic tundra, Plant Species, phenology, photosynthetic pigments

**Related sources:** Published papers as well as spectral reflectance datasets, digital plot photographs, and photosynthetic pigment content datasets from the Toolik Vegetation Grid.

**Dataset**: *Beamish, AL (2018a): Ground-based spectroscopic measurements of low-Arctic vegetation, Toolik Vegetation Grid and Imnavait Vegetation Grid Toolik Lake, Alaska (2016). https://doi.org/10.1594/PANGAEA.885808*

**Related to:** *Beamish, AL; Coops, N; Chabrillat, S et al. (2017): A phenological approach to spectral differentiation of low-arctic tundra vegetation communities, North Slope, Alaska. Remote Sensing. https://doi.org/10.3390/rs9111200*

**Dataset:** *Beamish, AL (2018b): Ground-based digital camera (RGB), spectroscopy, and pigment data from Toolik Vegetation Grid, Toolik Lake, Alaska. https://doi.org/10.1594/PANGAEA.886340*

**Related to**: *Beamish, AL; Coops, N; Hermosilla, T et al. (2018): Monitoring pigment-driven vegetation changes in a low-Arctic tundra ecosystem using digital cameras. Ecosphere.* https:/*/doi.org/10.1002/ecs2.2123*

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

# 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 and other science support programs, 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 and upcoming hyperspectral systems. 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 retrieval methods for thematic products (Segl et al., 2012). The campaign data and related flight campaigns funded by other sources are made freely available to the scientific community under a Creative Commons Attribution 4.0 International License (CC BY-4.0). An overview of all available data is provided in a specifically developed metadata portal on the project website (http://www.enmap.org/?q=flights).

The Toolik Lake Research Natural Area (TLNRA) (68°62.57 N, 149°61.43 W) is located in north central Alaska on the North Slope of the Brooks Range. The TLNRA is representative of the North Slope physiographic province of the Southern Arctic Foothills (M. D. Walker et al., 1989). Dominant vegetation types are dictated by soil moisture and geology and include moist tussock tundra, wet sedge meadows, and dry upland heaths. The Toolik Vegetation Grid within the Toolik Lake Research Natural Area is 1 × 1 km long-term monitoring site established by the National Science Foundation as part of the R4D Project (Response, Resistance, Resilience, and Recovery to Disturbance in Arctic Ecosystems, (Reynolds and Tenhunen, 1996, Figure 1). In the frame of the AIRMETH2016 campaign funded by the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, hyperspectral imagery (AisaEAGLE) was acquired over the TLRNA with concurrent, comprehensive field surveys to explore applications of hyperspectral imagery to questions of Arctic vegetation change.

# 2 Data Acquisition

Hyperspectral imagery was acquired during a flight campaign operated by the Alfred Wegener Institute using a Specim imaging spectrometer AisaEAGLE on board the Polar 5 Basler BT-67 aircraft. The overflight encompassed an area of approximately 700 ha.

Time: August 27, 2016 start: 12:20:51 end: 12:50:10 (Universal Time)
Samples: 1585
Bands: 130; Bandwidth: 4 nm
Wavelengths: 404.9 – 1002.5 nm

| **Strip Number** | **Flight Altitude** | **Scan Frequency** | **Flight Heading** | **Solar Azimuth** | **Solar Zenith** | **Pixel Size** | **Lines** |
|---|---|---|---|---|---|---|---|
| Toolik_mosaic | 1300 m | 15.5 Hz | 360° | 170.6° | 30.8° | 1.3 m | 3593 |

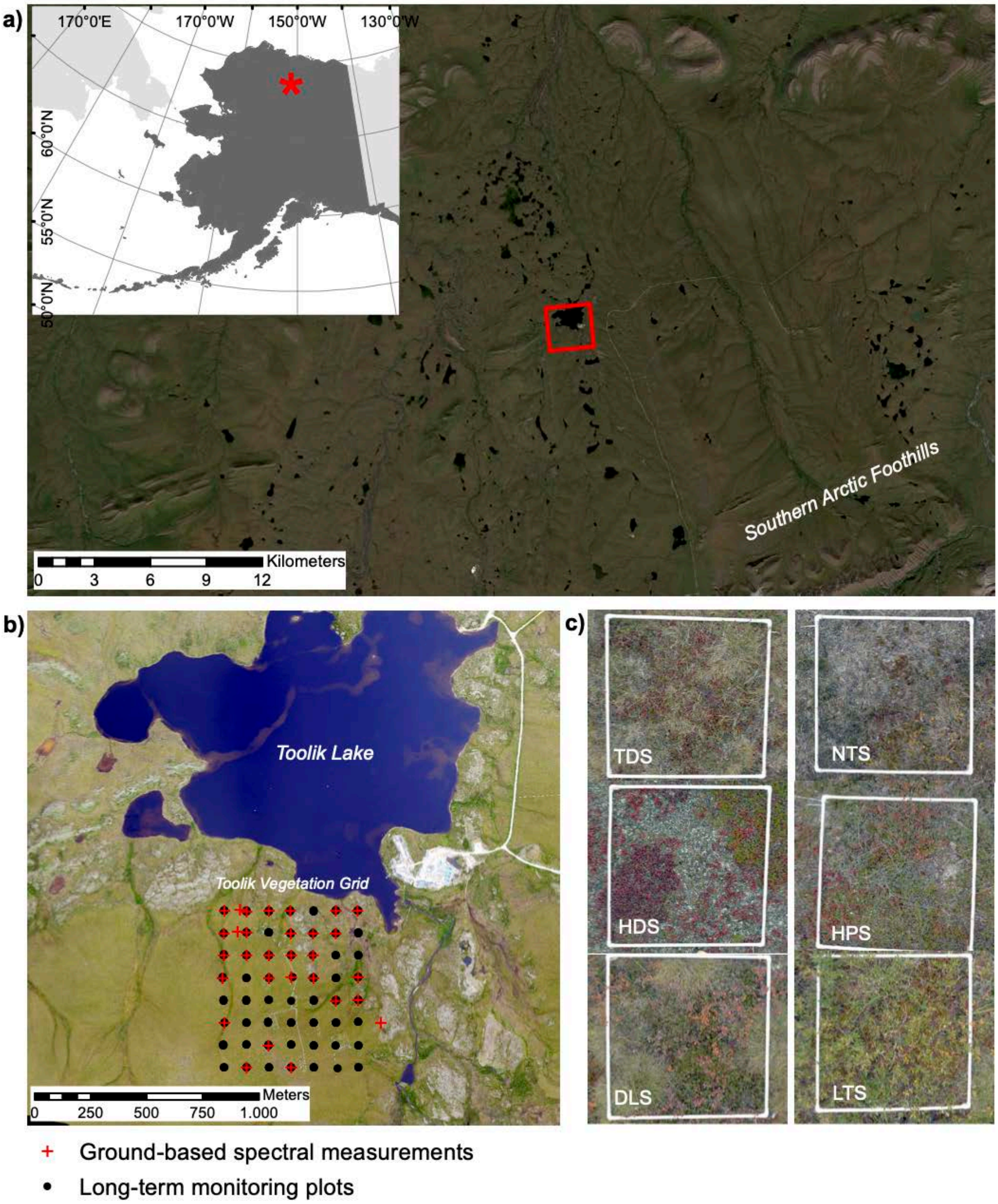


*Figure 1 a) Toolik Lake Research Natural Area located in north central Alaska in the Southern Arctic Foothills on the North Slope of the Brooks Range. b) Toolik Vegetation Grid where ground-based spectral measurements were collected. c) Typical late season digital photographs of each of the six vegetation communities where ground-based spectra were collected. TDS: Tussock sedge, dwarf-shrub, moss tundra, NTS: Non-tussock sedge, dwarf-shrub, moss tundra, HDS: Hemi-prostrate and prostrate dwarf-shrub, forb, moss, fruticose-lichen tundra, HPS: Hemi-prostrate dwarf shrub fruticose-lichen tundra, DLS: Dwarf-shrub or low-shrub, sedge, moss, tundra, LTS: Low and tall shrublands. Aerial photo courtesy of Toolik Field Station Environmental Data Center, Plot photos courtesy A Beamish and* Beamish, (2018).

# 3 Data Processing and Products

The data are available radiometrically corrected using sensor specific software of the instrument manufacturer (Richter and Schläpfer, 2012) and atmospherically corrected using ATCOR4. The direct geometric correction was performed using the manufacturer software with the simultaneously measured IMU/GPS data stream. Simulated EnMAP data were generated using the EnMAP end-to-end simulation software (Segl et al., 2012).

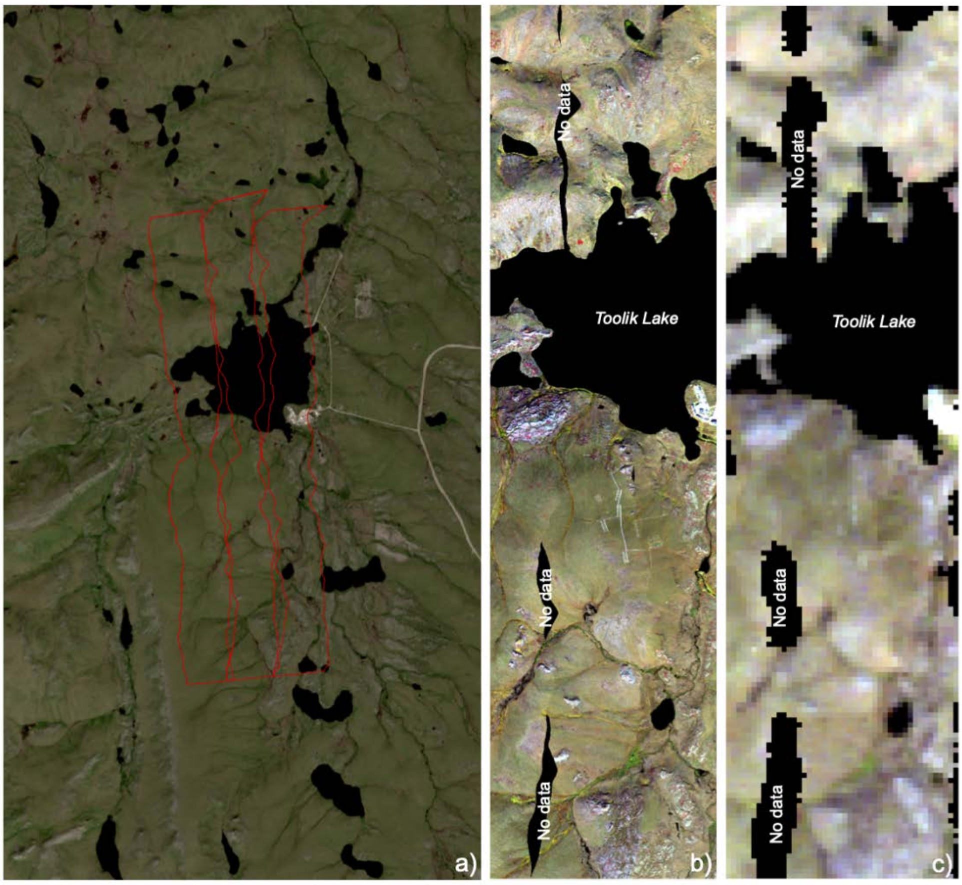


*Figure 2 a) Sentinel-2 image (06.07.2016) overlaid with the three flightlines used to create the orthomosaic, b) Orthomosaic of the AISA flight lines clipped to the general area where ground-based data were collected. c) Simulated EnMAP orthomosaic generated from the AISA data. Black areas marked with No data are the result of non-overlapping flight lines. Black areas not marked with No data are water bodies. Imagery courtesy A Beamish and* (Beamish, 2018)

# 4 File Description

## 4.1 File Format

Dat Image File [*.dat] 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 Hyperspectral data

There were timing shifts (between 0 to 1 second) caused by an error in the synchronisation of the navigation and motion system and the Eagle sensors due to a fault in the Nav-Sync-Box of the Specim system that were corrected manually prior to delivery. Therefore, subsets of the investigation area that depict the shoreline of Lake Toolik were processed with different time offsets for each flight strip and compared with a high-resolution shapefile of the shoreline. The entire flight strip was then calculated with the time offset determined with an accuracy of 0.01 seconds. In addition, the data were collected in the late season resulting in low sun angle and senesced vegetation. There were also high cirrus clouds and illumination shift present throughout the acquisition.

## 5.2 EnMAP simulation

The quality of simulated EnMAP data is related to the quality of the AISA data that the simulation was based on. The illumination changes affect the EnMAP data as well.

# 6 Additional Data

The airborne data were collected in addition to two intensive field campaigns in 2015 and 2016. The resulting ground-based datasets includes detailed plant species data, multi-seasonal spectral reflectance data, vegetation pigment content and digital plot photos.

## 6.1 Vegetation species data

At each long-term plot within the Toolik Vegetation Grid detailed point framing was carried out in the growing season of 2018. A 1 × 1 m quadrat frame with an equally spaced 10 cm grid points was placed over each plot (Figure 3c). Using a rod with centimeter increments lowered slowly in each 10 cm grid square and all vascular plants, bryophytes and lichens were identified to the species level. Species height was also recorded and their condition of living, dead or standing litter was noted. Species data were defined as top (canopy) and bottom (understory) in each 10 cm square. From these data, two measures of percent vegetation cover (PVC) were calculated. The first is the PVC2D which includes all point frame records defined as top divided by the total number of grid points (i.e. 100) with values ranging from 0–100%. The PVC2D is considered two-dimensional species composition that can be seen from nadir. PVC3D was also calculated as the total number of hits from the top and bottom divided by the total number of grid point and can have values > 100% due to multiple canopy layers. The PVC3D is considered three-dimensional species composition and is related to total leaf area index (LAI) of a species or PFT (Van Wijk and Williams, 2005).

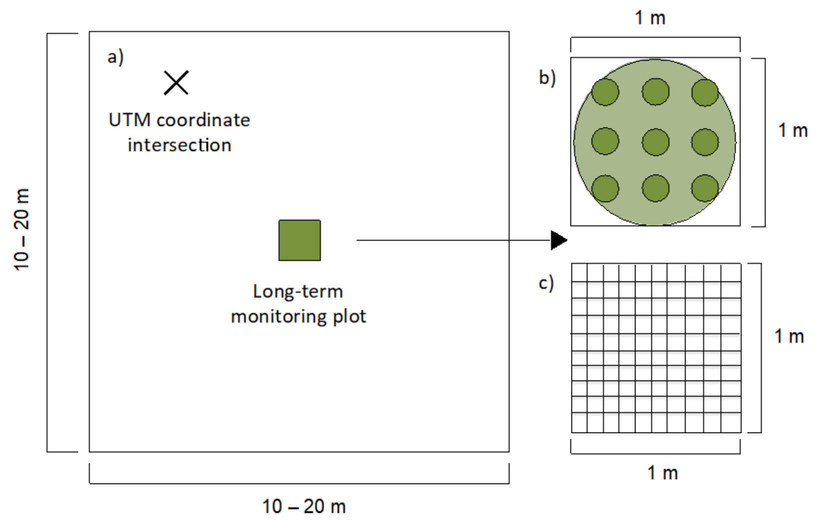


*Figure 3 Schematic of the field-based sampling; a) a homogeneous area in the vicinity of the UTM intersection encompassing a long-term monitoring plot; b) The dark green circles represent the 3 × 3 grid in the long-term monitoring plot in which field spectra were collected. The light green circle represents a rough approximation of the averaged spectral data; c) the point frame method with 10 × 10 cm grid squares over the entire long-term plot where species cover and abundance data are recorded.*

## 6.2 Spectral reflectance data

Field-based spectral radiance measurements were acquired with a GER 1500 field spectrometer (350–1050 nm; 512 bands, spectral resolution 3 nm, spectral sampling 1.5 nm, and 8° field of view, Spectra Vista Co., Poughkeepsie, USA) at a subset of the long-term monitoring plots (Figure 3a). Data were collected on August 23rd 2016 (Day of Year (DOY) 236) under clear sky conditions between 10:00 and 14:00 local time to ensure the highest solar zenith angle. Spectra were acquired at nadir approximately 1 m off the ground resulting in a circular Ground Instantaneous Field of View (GIFOV) of approximately 15 cm in diameter. Nine point-measurements of upwelling radiance ($L_{up}$) collected in a 3 × 3 grid in each 1 × 1 m plot approximately 33 cm apart and were averaged to characterize the heterogeneity of community in each plot (Figure3b). Downwelling radiance ($L_{down}$) was measured as the reflectance from a white Spectralon© panel. Surface reflectance ® was processed as $L_{up}/L_{down}$ × 100 (0–100%). Reflectance spectra were subset to 400–900 nm to remove sensor noise at the edges of the radiometer detector and for comparison with airborne and simulated satellite data (Beamish et al., 2017, 2018a).

## 6.3 Vegetation pigment content

Photosynthetic pigment content of the dominant vascular species in a subset of the permanent, long-term monitoring plots was measured. Chlorophyll a chlorophyll b, total chlorophyll, and carotenoids were measured using a spectrophotometer (Beamish et al., 2018b, 2018c).

## 6.4 Digital plot photos

For reference and as an additional data source, nadir digital plot photographs were taken approximately 1 m off the ground concurrently with spectral reflectance measurements in the permanent, long-term monitoring plots (Beamish 2018c).

# 7 Dataset Contact

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Dataset: Beamish, AL (2018b): Ground-based digital camera (RGB), spectroscopy, and pigment data from Toolik Vegetation Grid, Toolik Lake, Alaska. https://doi.org/10.1594/PANGAEA.886340

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