Field spectroscopy acquisition and processing workflow for hyperspectral reflectance spectra collected at Etosha Pan, Namibia, during 2022 and 2025 field campaigns using an ASD FieldSpec® 3 spectroradiometer

Natasha S. Wallum
School of Geography and the Environment
University of Oxford
Oxford, United Kingdom

1. FIELD SITE SELECTION & SETUP

Field sites were established across Etosha Pan, Namibia, during field campaigns conducted in September 2022 and August–September 2025. Sites were selected to represent contrasting playa surface states associated with dust emission potential, including pre-emission, post-emission, and non-emissive crusted surfaces. Site selection was guided using previous analyses of dust emission activity, field observations, and high-resolution satellite imagery (Wallum et al., 2025, 2026a,b).

At each site, a rectangular sampling grid measuring approximately 120 m east-west by 120 m north-south was established using a handheld GPS and marker flags. The grid consisted of 25 sampling nodes arranged in a 5 x 5 configuration labelled A1–E5 with approximately 30 m spacing between nodes. This sampling geometry was designed to approximate the spatial footprint of pixels acquired by NASA's Earth Surface Mineral Dust Source Investigation (EMIT) imaging spectrometer while capturing sub-pixel spectral variability across heterogeneous playa surfaces. Field photographs and acquisition metadata were collected to document surface conditions and support interpretation of the resulting spectra. Documented surface conditions ranged from continuous evaporite crusts and established dry crusted surfaces to disturbed fine-grained sediment surfaces exhibiting polygonal cracking, crust fragmentation, and windblown sediment accumulations associated with recent surface disruption and dust emission activity.

Images documenting representative field site conditions and field spectroscopy acquisition procedures are included in this data repository, e.g.:

- *EtoshaPan_ASD_FieldSpec_CollectionTechnique.jpg*
- *EtoshaPan_S5_2025_SitePhotoNWcorner.jpg*
- *EtoshaPan_S5_2025_SitePhotoNEcorner.jpg*
- *EtoshaPan_S5_2025_SitePhotoSWcorner.jpg*
- *EtoshaPan_S5_2025_SitePhotoSEcorner.jpg*
- *EtoshaPan_S5_2025_SitePhotoCenter.jpg*
- *EtoshaPan_S5_2025_SkyConditions.jpg*
- *EtoshaPan_SamplingGridLayout.jpg*

These images show representative playa surface conditions, sampling node positions, and ASD collection procedures.

2. FIELD ACQUISITION OF REFLECTANCE SPECTRA

Reflectance spectra were collected using an ASD FieldSpec® 3 field portable spectroradiometer (Malvern Panalytical ASD Inc., Longmont, Colorado, USA) operating across the visible-shortwave infrared (VSWIR) wavelength range from approximately 0.35 to 2.5 microns (350–2500 nm).

Field measurements were collected using the ASD fibre optic cable equipped with an 8° foreoptic. At an approximate operator arm height of ~1.35 m above the target surface, this configuration corresponds to an approximate ground sampling diameter of ~19 cm.

The ASD spectrometer was switched on prior to field acquisition and allowed to warm up before measurements began to improve thermal stability throughout the measurement period. Instrument control and spectral acquisition were performed using RS3 High Contrast software (Malvern Panalytical ASD Inc.). Measurement settings were selected following recommendations described in the U.S. Geological Survey (USGS) Mineral Resources Program ASD spectrometer standard operating procedures (MRP-SPECLAB-SOP-02.02; Swayze, 2022) and field spectroscopy processing workflows described by Meyer et al. (2024).

Measurement settings used during acquisition were:

- Foreoptic = 8°
- Scans per average = 150
- Replicate spectra per node = 5
- White reference scans = 300

Each recorded replicate spectrum therefore represented the average of 150 individual spectral scans.

Before measurements were collected at each node, the ASD spectrometer detectors were optimised for current illumination conditions using the optimisation ("Opt") function in RS3. Following optimisation, a white reference measurement was collected using a National Institute of Standards and Technology (NIST) traceable Labsphere Spectralon® 99% reflective reference panel (Labsphere Inc., North Sutton, New Hampshire, USA). The Spectralon® panel was used for optimisation of the ASD spectrometer and for collection of white reference measurements throughout the acquisition period. Raw detector digital number (DN) measurements recorded by the ASD spectrometer were converted to relative reflectance during acquisition through repeated white reference measurements collected using the Spectralon® reference panel. The resulting calibrated reflectance spectra were recorded in ASD binary (.asd) format. The white reference procedure was repeated before each node and whenever changes in illumination conditions or spectral instability were observed. If detector saturation, unstable reflectance behaviour, or instrument drift was observed, optimisation and white reference procedures were repeated. White reference output was monitored throughout acquisition. The Spectralon® reference panel and ASD foreoptic lens were cleaned regularly during field measurements to minimise contamination effects.

The operator positioned the fibre optic in a nadir-pointing orientation as far as possible from their body with their arm extended away from the torso and oriented towards the sun to minimise interference from operator shadowing and reflected light. During acquisition, the fibre optic was moved systematically across the target surface while replicate spectra were continuously recorded. Real-time visual monitoring of spectral output allowed the operator to identify unstable reflectance behaviour and atmospheric residuals during acquisition. Reflectance spectra were collected under predominantly clear sky conditions with minimal cloud cover (<10%), generally stable illumination conditions, and slight atmospheric haze at some sites. During the measurement period, ASD spectrometer settings were occasionally re-optimised to account for changing illumination conditions and atmospheric variability. Dark current measurements were collected automatically during optimisation and white reference procedures.

Measurements during the 2022 field campaign were collected between approximately 09:00 and 12:45 local Namibia time (UTC+2), whereas measurements during the 2025 campaign were collected between approximately 09:00 and 13:20 local Namibia time (UTC+2). Solar noon occurred at approximately 12:46 local time during the 2022 campaign and approximately 13:00 local time during the 2025 campaign. Solar azimuth angles during acquisition ranged from approximately 27° to 77°, while solar elevation angles ranged from approximately 22° to 61° across all sites and acquisition periods. Representative photographs of sky conditions during acquisition are included in this data repository. Supporting metadata including acquisition time, GPS coordinates, weather conditions, and surface observations were recorded during acquisition.

Surface sediment samples were collected at each site for further analysis by X-ray diffraction (XRD). Individual surface sediment samples were collected from the four corner nodes and the central node of the sampling grid (NW/A1, NE/A5, SW/E1, SE/E5, and centre/C3). Samples were collected separately at each node and stored in heavy-duty plastic zip-lock bags labelled with the site name, sampling node, latitude and longitude coordinates, and date of collection. Mineralogical X-ray diffraction data derived from these samples are archived separately within the Oxford University Research Archive (Wallum, 2026).

3. PRE-PROCESSING OF ASD SPECTROMETER DATA

Raw ASD binary spectra were processed using ViewSpecPro software (Malvern Panalytical ASD Inc.). Relevant ASD Indico (.asd) files corresponding to each site were opened in ViewSpecPro. Splice correction was applied using the ViewSpecPro “Splice Correction” processing function to minimise discontinuities between the visible-near infrared (VNIR), shortwave infrared 1 (SWIR1), and shortwave infrared 2 (SWIR2) detector regions of the ASD spectrometer, producing corrected spectral files with .sco extensions. Corrected spectra were visually inspected throughout processing to identify anomalous reflectance behaviour, atmospheric residuals, and detector-related artefacts. Spectra or wavelength regions affected by strong atmospheric absorption, low signal-to-noise behaviour, or other reductions in spectral quality were excluded from the final averaged datasets where necessary. Mean reflectance and standard deviation statistics were then calculated using the ViewSpecPro “Statistics > Mean and Standard Deviation” processing function. Mean spectra were saved as .mn files and standard deviation spectra were saved as .sd files. Processed outputs were subsequently exported to .csv format for repository deposition and analysis.

4. FILES INCLUDED IN THIS DATA REPOSITORY

This data repository includes:

1. Processed averaged ASD field reflectance spectra and replicate standard deviation spectra in .csv format
2. Latitude and longitude coordinates and metadata for field sites
3. Field site photographs, sampling grid layout and ASD measurement setup images
4. Processing workflow documentation
5. Example raw ASD acquisition files recorded in .asd format (complete raw ASD acquisition datasets are available from the corresponding author upon request).

CONTACT INFORMATION

Natasha S. Wallum
School of Geography and the Environment
University of Oxford
Oxford, United Kingdom
natasha.wallum@ouce.ox.ac.uk

REFERENCES

Meyer, J.M., Kokaly, R.F., Hoefen, T.M., Cox, E.M., and Swayze, G.A. (2024) Reflectance spectra collected August 16, 2022, at Smith Creek Valley, Nevada, with an ASD FieldSpec® 4 Hi-Res NG spectrometer for calibration/validation of imaging spectrometer data: U.S. Geological Survey data release. https://doi.org/10.5066/P9E2TSDF

Swayze, G. (2022). Conducting spectral reflectance measurements with the ASD spectrometers (MRP-SPECLAB-SOP-02.02). U.S. Geological Survey Mineral Resources Program Technical Standard Operating Procedure, Denver Spectroscopy Laboratory, Denver, Colorado, USA.

Wallum, N.S., Wiggs, G.F.S., & Bryant, R.G. (2025). Coupling global climate drivers to dust emission dynamics at Etosha Pan, Namibia. Science of the Total Environment, 995, 180088. https://doi.org/10.1016/j.scitotenv.2025.180088

Wallum, N.S. (2026). X-ray diffraction data for surface sediment samples collected at Etosha Pan, Namibia, during 2022 and 2025 field campaigns [Dataset]. Oxford University Research Archive. DOI TBC.

Wallum, N.S., Bryant, R.G., Wiggs, G.F.S., Reynolds, R.L., Goldstein, H.L. and Leidelmeijer, J.A. (2026a). Surface mineralogy and hydrological controls on "hotspots" of dust emission at Etosha Pan, Namibia. *Journal of Geophysical Research: Earth Surface.*

Wallum, N.S., Wiggs, G.F.S., Huck, R.A. and Leidelmeijer, J.A. (2026b). The influence of surface crust dynamics and sediment availability on aeolian dust emission from ephemeral lake beds: evidence from Etosha Pan, Namibia. *Aeolian Research.*