Land characterisation of the Perdigão site

Data guide

1st edition

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Summary: This document contains information on the structure and organisation of the files for land characterisation of the Perdigão site, available at https://perdigao.fe.up.pt/datasets/thredds/catalog/landCharacterization/catalog, namely aerial lidar survey and ortophotos, computational topography meshes, digital surface cover and digital terrain models.

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1 Introduction. Objective

This document contains information on the structure and organisation of the files, available at https://perdigao.fe.up.pt, for land characterisation of the Perdigão site. Information on terrain can be found in menu items named `Maps`, `Datasets` and `Documents`.

The objective of the present document is to guide the user in the navigation of the Perdigão web site, namely on the location and contents of information concerning terrain data and terrain coverage data. The actual data is available at:

> `Datasets` ⇒ `Land Characterization`
> https://perdigao.fe.up.pt/datasets/thredds/catalog/landCharacterization/catalog

There are four types of data, each stored in a different directory:

- `Aerial Survey Lidar and Photography Data`;
- `Digital Terrain Models`;
- `Digital Surface Cover Models`; and
- `Computational Topography Meshes`.

The following four sections describe in detail the contents of each of these four directories. The appendix, in page 14, is a quick reference list of direct links to all major data files the reader might use.

2 Aerial Survey Lidar and Photography Data

> `Datasets` ⇒ `Land Characterization` ⇒ `Aerial Survey Lidar and Photography Data`
> https://perdigao.fe.up.pt/datasets/thredds/catalog/landCharacterization/Aerial%20Survey%20Lidar%20and%20Photography%20Data/catalog

The raw aerial lidar and orthophotography survey data from 2015 is stored in this directory, along with some auxiliary pre-processed data and tools. It contains two files and two directories. The two files are the following:

- `Portugal Laserscanning Report.pdf` is the report by NIRAS in 2015 [1].
- `NIRAS_LAS_Scan.nb` is a `Mathematica` notebook file used for point cloud data processing.

The two directories are `Images` and `Pointcloud`, with the raw survey data broken into 382 separate 300 m square tiles (Figure 1).

`Images` contains two subdirectories with ortophoto data (named `20cm` and `5cm`) and five files:

- `ImageComposePerdigao.nb` – `Mathematica` notebook file for the creation of the composite aerial views `PerdigaoComp###ppp.pdf`
- `PerdigaoComp250ppp.pdf` – aerial view of the scanned region at a resolution of 250 pixels per picture (1.2 m/pixel)
- `PerdigaoComp120ppp.pdf` – aerial view of the scanned region at a resolution of 120 pixels per picture (2.5 m/pixel)
- `PerdigaoComp60ppp.pdf` – aerial view of the scanned region at a resolution of 60 pixels per picture (5.0 m/pixel), shown in Figure 1
- `PerdigaoComp30ppp.pdf` – aerial view of the scanned region at a resolution of 30 pixels per picture (10.0 m/pixel)

20 cm (subdirectory) contains 1122 files on the ortophoto survey in `.ecw` format, at 20 cm resolution. Each 300 m square tile corresponds to a raw ortophoto data file named `3928_20cm0###.ecw`, where `###` is the tile number (between 1 and 381, with a few missing tiles, see note below), accompanied by auxiliary image raster (`.png`) and metadata files (`.png.aux.xml`). Tiles number 232, 250, 251 and 274 have additional `.tfw` extension files.

5 cm (subdirectory) contains 1122 files on the ortophoto survey in `.ecw` format, at 5 cm resolution. Each 300 m square tile corresponds to a raw ortophoto data file named `3928_05cm0###.ecw`, where `###` corresponds to the tile number plus 382 (a few missing tiles, see note below), accompanied by auxiliary image raster (`.png`) and metadata files (`.png.aux.xml`). Figure 2 is an example of one of these 300 m square tiles (file `3928_5cm0503.png`). Tiles number 232, 250, 251 and 274 have additional `.tfw` extension files.

NOTE on tile numbering and file names: tiles are numbered sequentially from 1 until 381; however, tiles number 62, 63, 74, 92, 97, 363, 369 and 375 do not exist. There is a total of 374 tiles and therefore 1122 files. File naming in the case of 5 cm resolution starts on 382.

`Pointcloud` contains 767 files on the lidar survey pointcloud data in LAS 1.2 format. Each 300 m square tile corresponds to a raw pointcloud data file named `pt000###.las`, where `###` is the tile number, available also in packed (`.laz` extension) format. The remaining files are packing/unpacking scripts and executables (`laszip.exe`, `pack_las_to_laz.cmd` and `extract_las_to_laz.cmd`).

The average lidar scanning density was equal to 28.5 points/m^2 (first returns only). Figure 3 shows the spatial distribution with lower densities associated with the centre of non-overlapping flight paths and no points in watersheds.

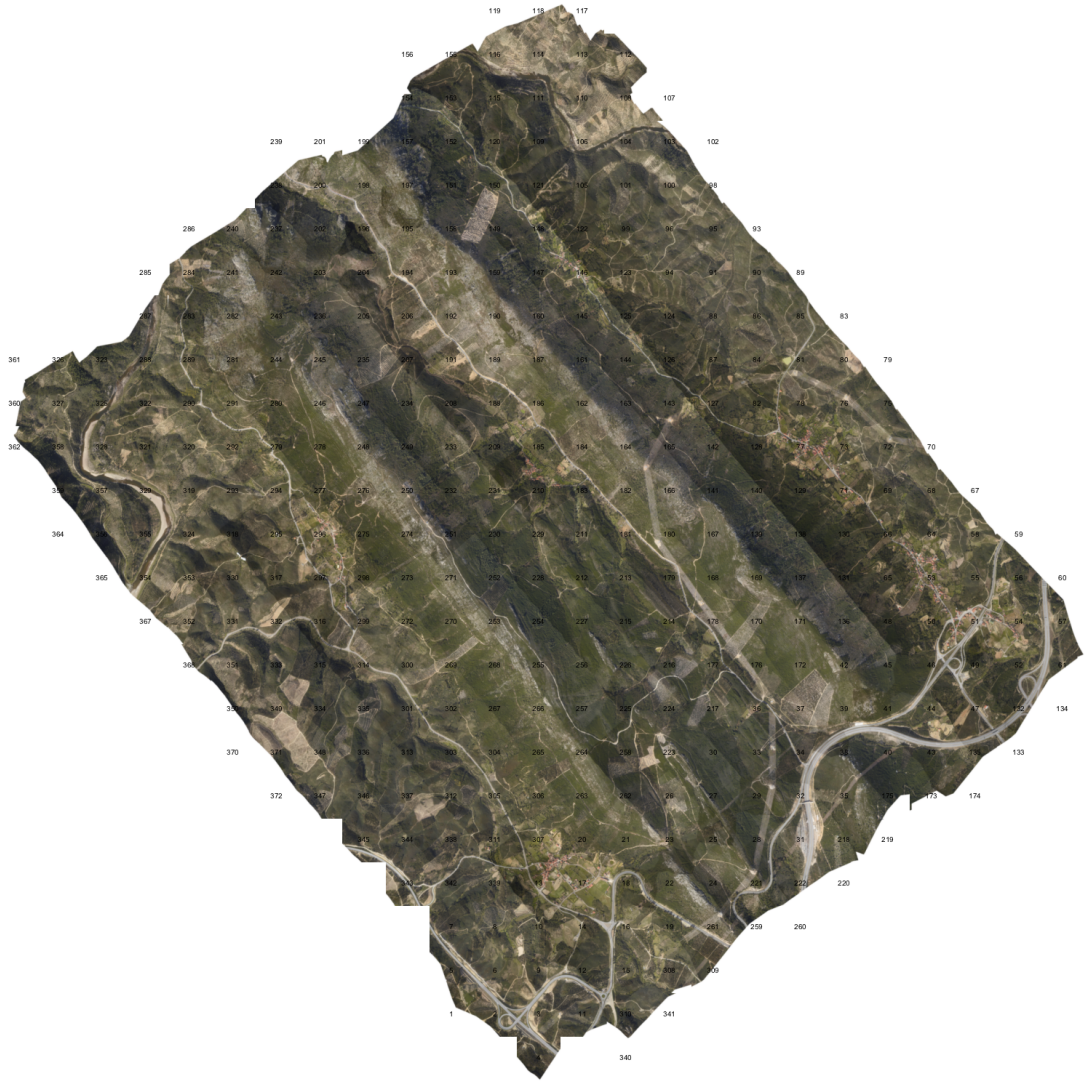


Figure 1: Perdigão site at a resolution of 5.0 m/pixel (file `PerdigaoComp60ppp.pdf`), with the tile number clearly visible. Tiles are numbered sequentially from 1 until 381; however, tiles number 62, 63, 74, 92, 97, 363, 369 and 375 do not exist. There is a total of 374 tiles.

Figure 2: Example of ortophoto, 5 cm resolution (file `3928_5cm0567.png`; tile N. 185 centred at 34050N, 5250E). Available at: https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Aerial%20Survey%20Lidar%20and%20Photography%20Data/Images/5cm/3928_5cm0567.png

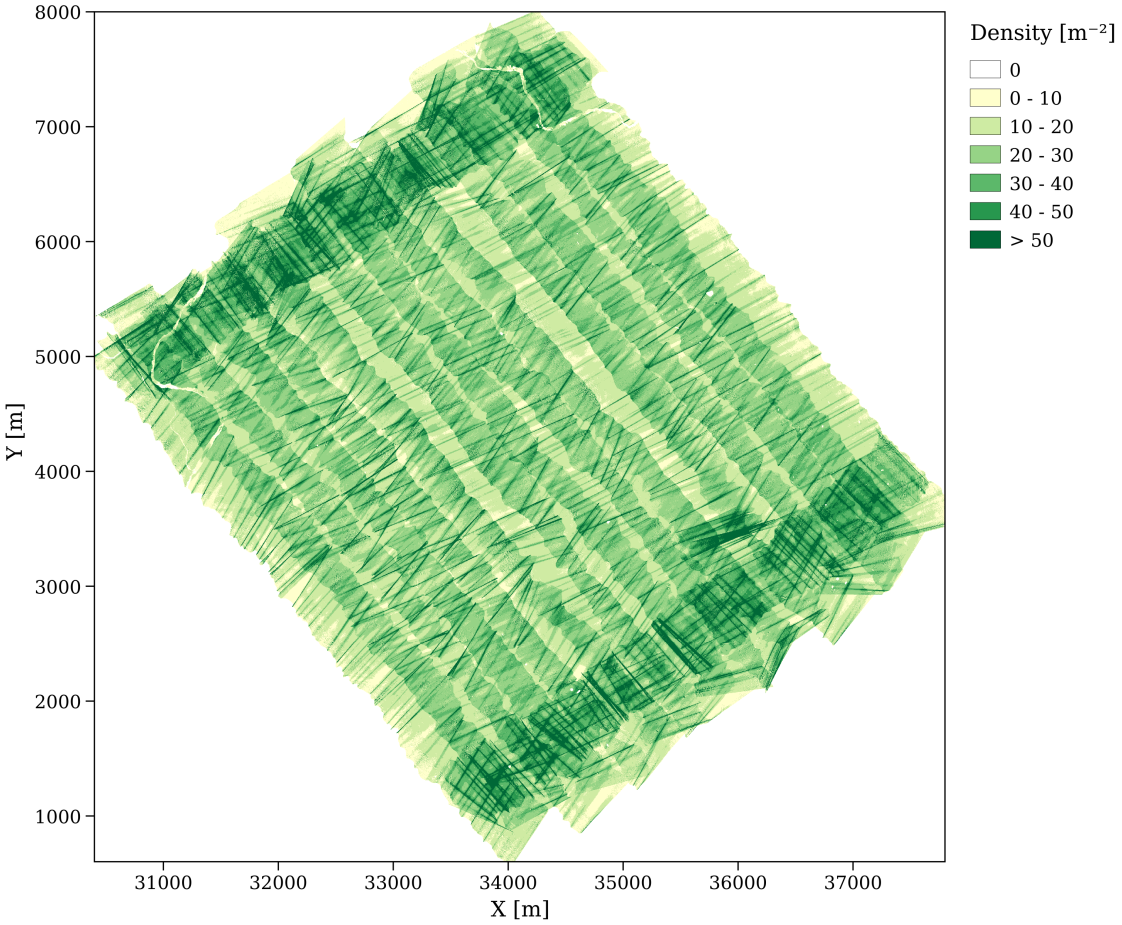


Figure 3: Point cloud (first return) distribution (X, Y – ETRS89/PT-TM06).

3 Digital Terrain Models

`Datasets` ⇒ `Land Characterization` ⇒ `Digital Terrain Models`
https://perdigao.fe.up.pt/datasets/thredds/catalog/landCharacterization/Digital%20Terrain%20Models/catalog

This directory contains digital terrain models, derived from three independent sources, providing different levels of resolution, accuracy and area coverage.

The contents and data format are discussed under the heading **Data structure**, while the second heading **Map description** details the data sources and processing steps involved. The highest resolution DTM covers only the Perdigão site and is produced from the 2015 aerial lidar survey (ALS) campaign [1] discussed in Section 2.

Data structure

The source data and respective derived Digital Terrain Model files available in this directory are the following:

- `dtm_srtm_1arcsec.dat` – SRTM raster map of Perdigão region, ∼ 100 km square area at resolution of 1 arc-second (≈ 24 m × 31 m, Easting × Northing) (non-uniform)
- `dtm_mil_10m.dat` – military charts raster map of Perdigão region, 16 km × 20 km area at 10 m resolution
- `dtm_als_no_buildings_2m.dat` – ALS derived raster maps of Perdigão site, ∼ 5 km× 6 km area (net) at 2 m resolution, without buildings
- `dtm_als_buildings_2m.dat` – ALS derived raster maps of Perdigão site, ∼ 5 km × 6 km area (net) at 2 m resolution, with buildings

The topographic data here included is as close to the source as possible, with processing limited to a harmonization in format and geographic datum. As such, all topographic maps are provided as structured grid files in ASCII format, with comma separated `X Y Z` coordinates in the following pattern:

- A header line indicating the raster's grid dimensions (in the W-E and S-N directions)
- Three columns containing the Easting, Northing and terrain elevation (a.s.l.) coordinates
- Points ordered in the W-E (inner loop) and S-N (outer loop) direction
- Empty areas are represented by a value of NODATA = −9999

All coordinates are referred to the ETRS89/Portugal TM06 (EPSG:3763) datum, the native coordinate system to both lidar point cloud and Army cartography. Given to their size, these four files are available in compressed format (`.zip`).

Map description

The SRTM (*Shuttle Radar Topography Mission*) [2] map (in Figure 4) was sourced from https://earthexplorer.usgs.gov/: a 1° square section in 1 arc-second resolution (entity ID `SRTM1N39W008V3`), with plane coordinates in WGS84 lon/lat (EPSG:4326). A coordinate transformation was performed on this raster to match the two other DTMs, using the `proj4` package (via *pyproj* module in Python 3.7). The convertion from a lat/long grid into metric grid in the local datum ETRS89/PT-TM06 datum implied the loss of constant mesh spacing, resulting in a distorted grid.

The Portuguese Army cartography map (in Figure 5) was obtained from the Portuguese Army Geospatial Information Centre (*CIGeoE Centro de Informação Geoespacial do Exército*), with 10 m resolution. It is a composition of multiple contiguous map sections, natively on the ETRS89/Portugal TM06 datum.

The ALS based DTMs (in Figure 6) were obtained directly from the 2015 Perdigão survey [3] pointclound data (natively on the ETRS89/Portugal TM06 datum), and processed using the LAStools© software suite [4], QGIS® [5] and Python. On top of the procedure described in [6], additional processing steps have been added to complete the DTM recovered from the ALS data, namely: reclassification of areas devoid of ground points and the parsing of buildings. The former, which would result in sparsely distributed areas of higher elevation error (when compared to the Army cartography maps), required the reclassification of data amounting to a total area of about 3.6 % of the domain. The inclusion of buildings (`dtm_lidar_buildings_2m.dat`) first required the use of a shapefile [6] to identify existing structures in the area (Figure 6a). Points found within the polygons would be reclassified for inclusion into the ground-class cloud and consequently the DTM.

The buildings are visible via comparison between both ALS-based DTMs, as displayed in Figure 6b.

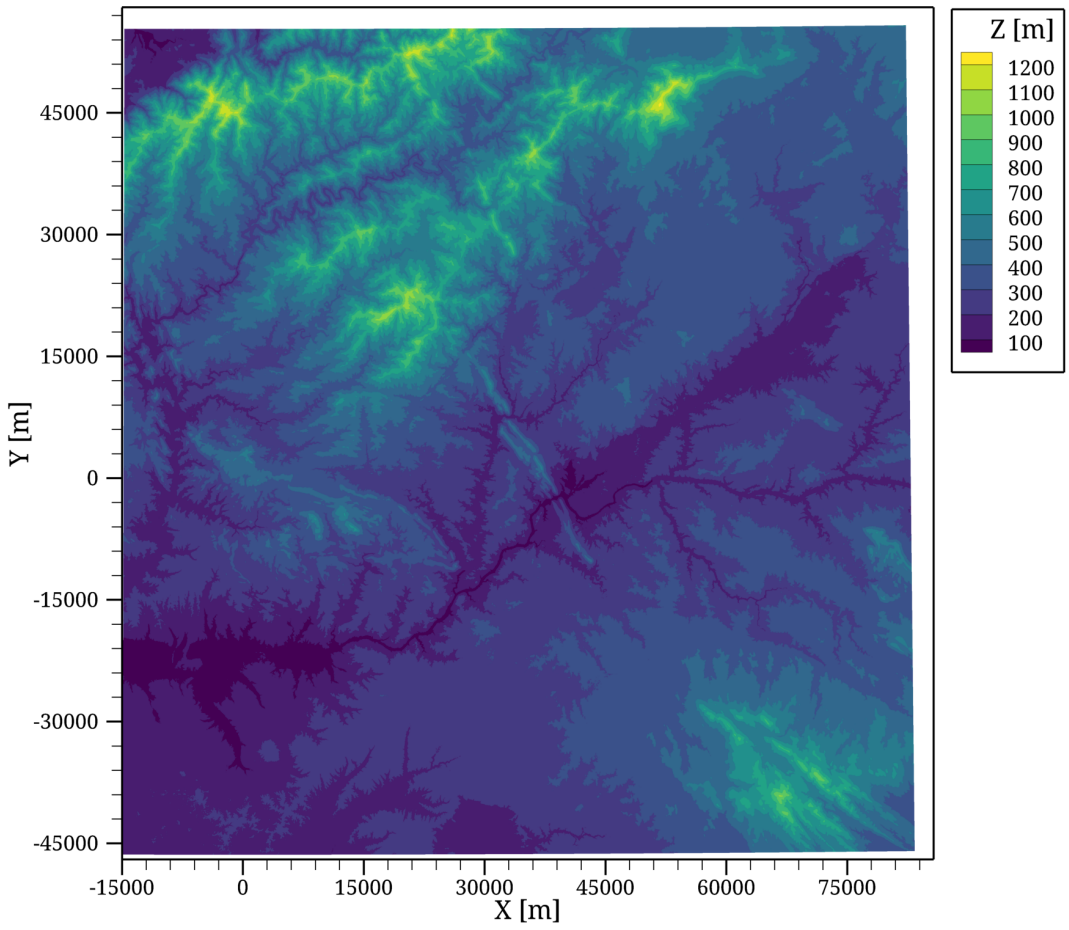


Figure 4: SRTM map for the Perdigão site (X, Y – ETRS89/PT-TM06) (file `dtm_srtm_1arcsec.dat`).

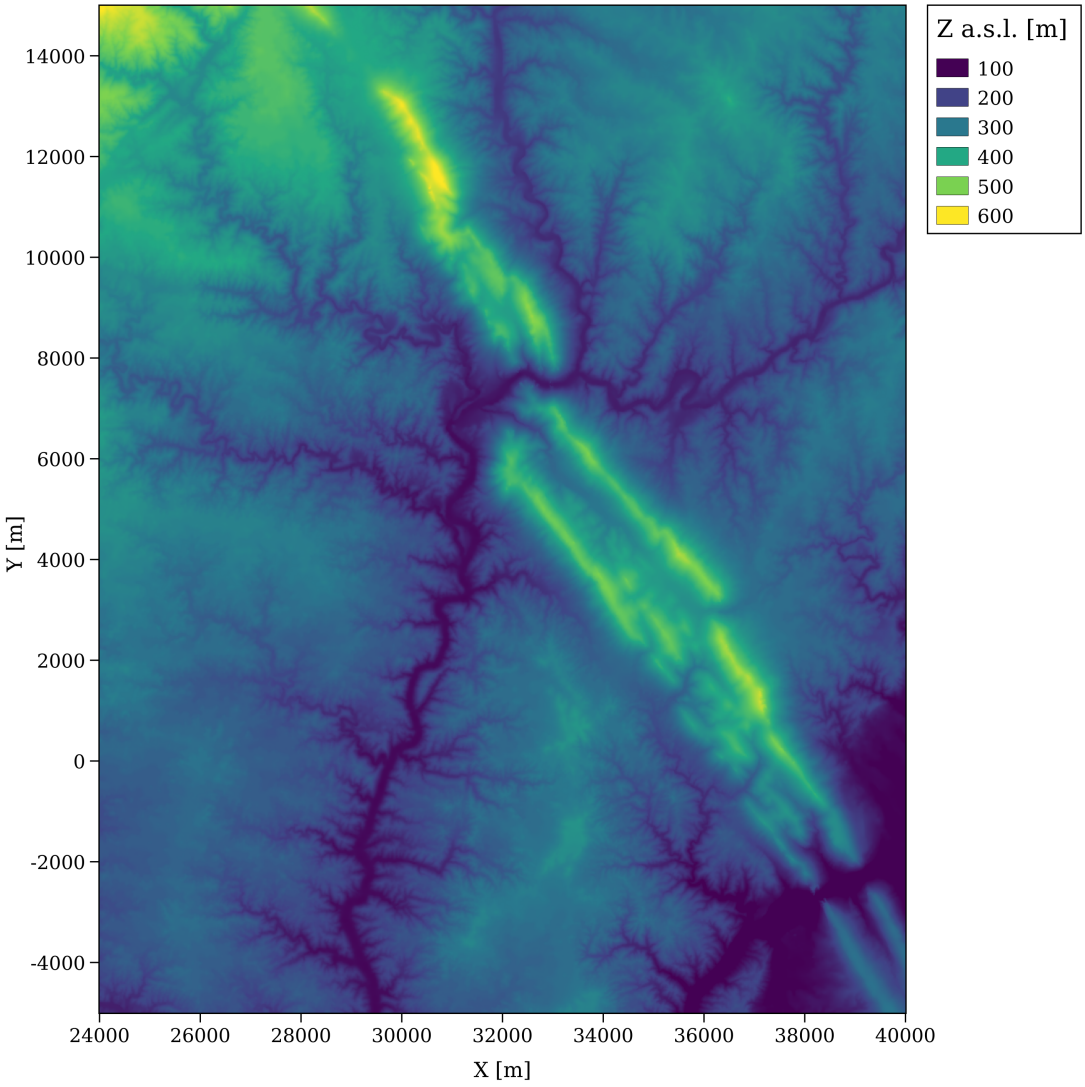
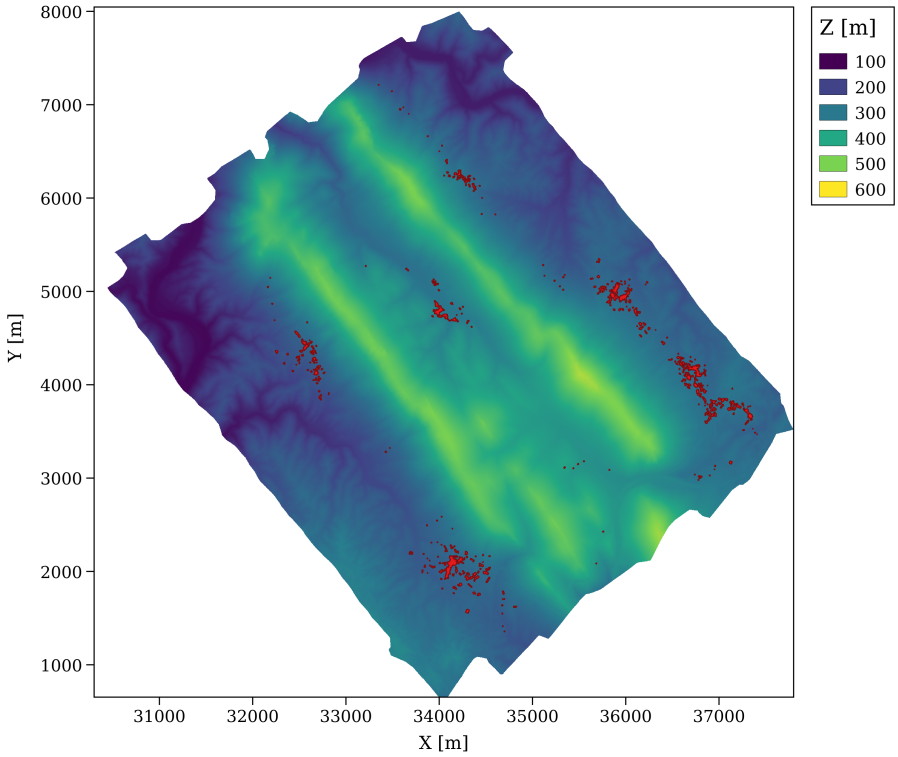
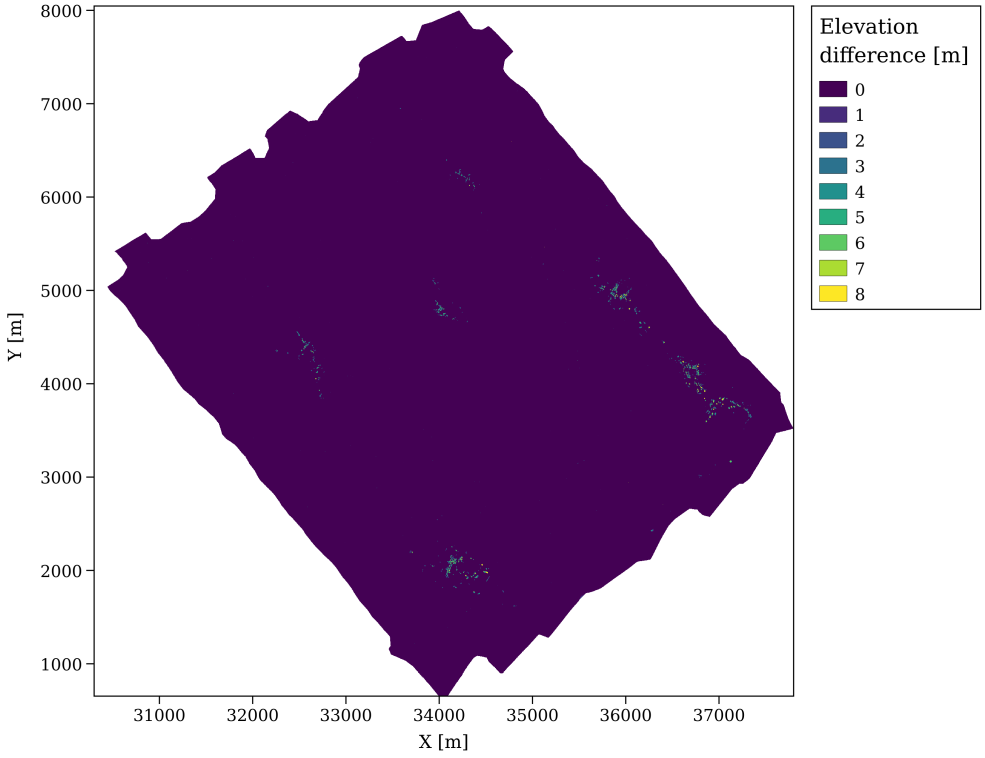


Figure 5: Portuguese Army cartography maps for the Perdigão site (X, Y – ETRS89/PT-TM06) (file `dtm_mil_10m.dat`).



(a) Full domain.



(b) Comparison between ALS-based DTMs with and without buildings.

Figure 6: Shapefile and results from the inclusion of buildings (X, Y – ETRS89/PT-TM06).

4 Digital Surface Cover Models

`Datasets` ⇒ `Land Characterization` ⇒ `Digital Surface Cover Models`
LINK

This directory will include digital surface cover (DSC) models describing surface roughness and forest canopy (height, leaf area density and leaf area index), derived from the 2015 Perdigão aerial survey data, Section 2. These models are the subject of ongoing work, and will be discussed herein and made publicly available in a future edition of the present document.

5 Computational Topography Meshes

`Datasets` ⇒ `Land Characterization` ⇒ `Computational Topography Meshes`
https://perdigao.fe.up.pt/datasets/thredds/catalog/landCharacterization/Computational%20Topography%20Meshes/catalog

This directory contains surface meshes used in a micro-scale computational flow model of the Perdigão region, for which a topography and computational grid size sensitivity analysis was conducted [6]. These meshes are the result of the combination of the DTMs described in Section 3, resampled into grids of different horizontal resolution.

The surface meshes were produced by creating the horizontal grid for which terrain elevations were bi-linearly interpolated from the existing DTMs. To combine data from three DTMs into a single map, the higher quality topographic data available at any point of the mesh was prioritized (SRTM → Military → lidar survey, in order of increasing quality), with inverse hyperbolic tangent blending between sources to smooth discontinuities. Blending margin was 1000 m between SRTM and Military charts, and 500 m between Military charts and lidar survey data.

Three horizontal resolutions and two dominant wind directions were studied, resulting in six mesh files, with their naming denoting the dominant inflow wind direction and peak horizontal resolution:

- `mesh_ne_20x20.dat` – NE wind flows, 20 m × 20 m horizontal resolution
- `mesh_ne_40x40.dat` – NE wind flows, 40 m × 40 m horizontal resolution
- `mesh_ne_80x80.dat` – NE wind flows, 80 m × 80 m horizontal resolution
- `mesh_sw_20x20.dat` – SW wind flows, 20 m × 20 m horizontal resolution
- `mesh_sw_40x40.dat` – SW wind flows, 40 m × 40 m horizontal resolution
- `mesh_sw_80x80.dat` – SW wind flows, 80 m × 80 m horizontal resolution

All maps are formed by structured, orthogonal grids, covering a rectangular area parallel to the ridges measuring 19 km × 18.8 km. Grid points are not georeferenced: they were translated and rotated around a pivot point (33830.6E, 4785.0N – ETRS89/Portugal TM06), to have a positive `X` axis orientation of SW-NE (`sw` variants) or NE-SW (`ne` variants) to reflect the dominant inflow wind directions. All six maps are presented in ASCII format files with comma separated `X Y Z` coordinates in the pattern:

- A header line indicating the grid dimensions in the longitudinal (`X`) and transversal (`Y`) directions
- Three columns containing the `X` and `Y` coordinates, and terrain elevation `Z` (height a.s.l.), in scientific format.
- Points ordered in the positive `X` (inner loop) and positive `Y` (outer loop) directions.

Grid spacing is irregular in both directions, with maximum horizontal resolution concentrated in an inner area measuring 4 km × 6 km, centered around the pivot point and expanding towards the map edges. Axis orientation, number of points (`ni`, `nj`) and maximum geometric expansion factors in each direction (`X`, `Y`) are presented in Table 1 for each mesh. The 80 m × 80 m mesh (SW) is shown in Figure 7, as an example.

	Axis orientation		No. of points		Expansion factors	
Mesh	`X`	`Y`	`ni`	`nj`	`X`	`Y`
`mesh_ne_20x20.dat`	SW	SE	319	469	1.0518	1.0271
`mesh_ne_40x40.dat`	SW	SE	199	269	1.0471	1.0299
`mesh_ne_80x80.dat`	SW	SE	119	154	1.0524	1.0331
`mesh_sw_20x20.dat`	NE	NW	319	469	1.0518	1.0271
`mesh_sw_40x40.dat`	NE	NW	199	269	1.0471	1.0299
`mesh_sw_80x80.dat`	NE	NW	119	154	1.0524	1.0331

Table 1: Axis orientation, number of points and maximum expansion factors in each direction and for each mesh [6].

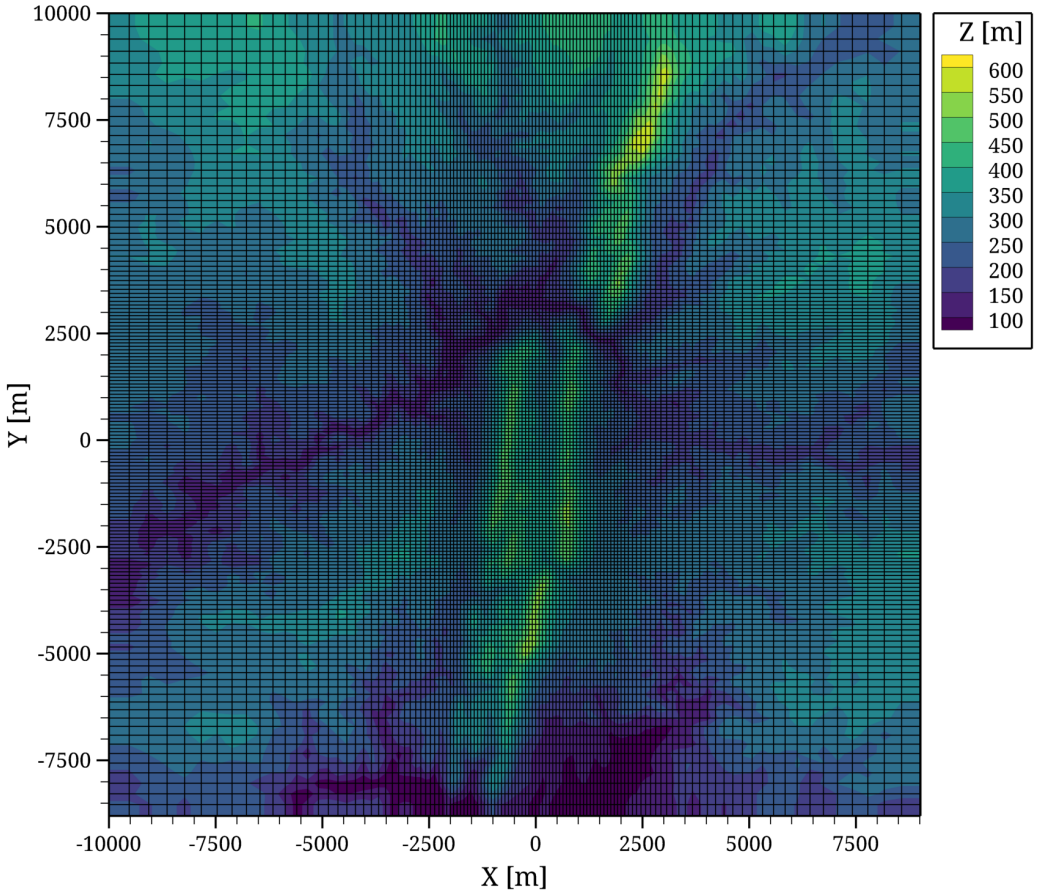


Figure 7: Mesh of 80 m×80 m horizontal resolution for SW winds (file `mesh_sw_80x80.dat`).

A Data files

Land characterization data is available under the following four categories, each detailed in a separate section of this document.

Aerial Survey Lidar and Photography Data files, split into 300 m square tiles (Section 2)

1. Ortophotos in 5 cm and 20 cm resolution
   https://perdigao.fe.up.pt/datasets/thredds/catalog/landCharacterization/Aerial%20Survey%20Lidar%20and%20Photography%20Data/Images/catalog
2. Lidar point cloud data
   https://perdigao.fe.up.pt/datasets/thredds/catalog/landCharacterization/Aerial%20Survey%20Lidar%20and%20Photography%20Data/Pointcloud/catalog

Digital Terrain Models in local metric datum (Section 3)

1. SRTM raster map of Perdigão region, ~ 100 km square area at resolution of 1 arc-second (≈ 24 m $\times$ 31 m, Easting $\times$ Northing) (non-uniform)
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Digital%20Terrain%20Models/dtm_srtm_1arcsec.zip
2. Military charts raster map of Perdigão region, 16 km $\times$ 20 km area at 10 m resolution
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Digital%20Terrain%20Models/dtm_mil_10m.zip
3. ALS derived raster maps of Perdigão site, ~ 5 km $\times$ 6 km area (net) at 2 m resolution, without buildings
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Digital%20Terrain%20Models/dtm_als_no_buildings_2m.zip:
4. ALS derived raster maps of Perdigão site, ~ 5 km $\times$ 6 km area (net) at 2 m resolution with buildings
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Digital%20Terrain%20Models/dtm_als_buildings_2m.zip

Digital Surface Cover Models (Section 4)

This directory is empty. Data files (subject of ongoing work) will be made available in a future revision of the present document.

Computational Topography Meshes files used in CFD simulations (Section 5)

1. NE inflow, 20 m × 20 m
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Computational%20Topography%20Meshes/mesh_ne_20x20.dat
2. NE inflow, 40 m × 40 m
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Computational%20Topography%20Meshes/mesh_ne_40x40.dat
3. NE inflow, 80 m × 80 m
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Computational%20Topography%20Meshes/mesh_ne_80x80.dat
4. SW inflow, 20 m × 20 m
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Computational%20Topography%20Meshes/mesh_sw_20x20.dat
5. SW inflow, 40 m × 40 m
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Computational%20Topography%20Meshes/mesh_sw_40x40.dat
6. SW inflow, 80 m × 80 m
   https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Computational%20Topography%20Meshes/mesh_sw_80x80.dat

References

[1] NIRAS. Perdigão aerial survey. Technical report, NIRAS, 4 2015. URL https://windsptds.fe.up.pt//thredds/fileServer/landCharacterization/Aerial%20Survey%20Lidar%20and%20Photography%20Data/Portugal%20Laserscanning%20Report.pdf. This is a report of a helicopter airborne survey delivered by NIRAS with assistance from Blom TopEye in order to produce data for digital elevation model and ortho photo. This delivery includes a lidar point cloud, and 5 cm and 20 cm orthophotos.

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