A high-resolution 4D spatio-temporal laser scan dataset of the Noordwijk beach-dune system, The Netherlands

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Project: CoastScan – Coastal variability and resilience assessment by permanent laser scanning and modelling

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1. General Information

From July 2019 to June 2022 a stationary laser scanner, installed on top of a hotel was used to survey the beach-dune system at the coast in Noordwijk, The Netherlands (see Figure 1). The observed area is about 1000 m long and, depending on the tides, about 350 m wide and includes dunes and a sandy beach.

A total of 21812 hourly scans were obtained from July 11th 2019, 14:00 until June 21st 2022, 12:00. Each scan produces a 3D point cloud containing about 4 million points depending on atmospheric conditions and the tide-dependent width of the beach. Additional attributes such as the laser return intensity are available for each individual 3D point record.

Figure 1: (A) Aerial photo of the beach-dune system in Noordwijk and the scan area within the red rectangle. (B) The laser scanner positioned on a hotel facing the beach (indicated by a red triangle in A). (C) The location of Noordwijk (52.24°N, 4.42°E) in The Netherlands.

2. System Specifications

The surveys were performed by a Riegl VZ-2000 terrestrial laser scanner [Riegl, 2017]. The scan parameters are summarized in table 1. Hourly scans were performed at 0.03*0.03 degree resolution. For each scan weather information (temperature, air pressure and humidity) from KNMI weather stations, obtained online through [Open weather map, 2019] was uploaded to the instrument to account for varying atmospheric influences on the time-of-flight range measurements.

The laser scanner was displaced about 3 meters northwards on December 2nd 2020 after the scan at 07:00 in the morning and before the subsequent scan at 16:00 in the afternoon.

	Theta (°)			**Phi (°)**		
	Minimum	Maximum	Resolution	Minimum	Maximum	Resolution
Hourly	30.00	130.00	0.030	78.00	281.00	0.030

Table 1: Scan settings, with Theta the horizontal and Phi the vertical scan angle respectively

3. Data Processing

3.1 Time-dependent alignment

For each scan epoch a rigid (rotation/translation) transformation matrix was derived via a cost function minimization method by aligning two stable planar surfaces in the point cloud to the same surfaces in the first epoch in the series of scans (i.e., July 11th 2019: 20:00 and December 2nd 2020, 16:00 [after the shift of the laser scanner]). The time-dependent alignment matrix for each epoch is provided with the dataset as text file (.txt). The file name contains the same date and time as the respective scan. Another way to correct for small tilts in the laser scanner is by using the provided inclination data file (*_incl.asc) and averaging the values to obtain the respective pitch (ϕ) and roll (θ) values for each scan. With the use of the rotation matrix

$$R = \begin{pmatrix} \cos(\phi) & 0 & \sin(\phi) \\ \sin(\phi)\sin(\theta) & \cos(\theta) & -\cos(\phi)\sin(\theta) \\ -\sin(\phi)\cos(\theta) & \sin(\theta) & \cos(\phi)\sin(\theta) \end{pmatrix}$$

tilts measured by the internal inclination sensors of the laser scan can be corrected.

3.2 Georeferencing

The provided data set is in the local coordinate system with the laser scanner as its origin. The location of the laser scanner was determined with six 5-centimeter reflectors on both the hotel and objects around the hotel spread over a 180 degree window in the field of view with the help of RTK-GNSS (real-time kinematic global navigation satellite system measurements). A global transformation matrix from local point coordinates to the Dutch reference system (RD-NAP [Bruine et al., 2005]) was determined using RiSCAN Pro [Riegl, 2021] and is provided with the dataset. Due to the move of the laser scanner on the December 2, 2020, there are two global transformation matrices that account for the shift of the origin of the coordinate system, one for the data before (Global_transformation_matrix_NW_before_2dec2020.dat) and one for after the move

(Global_transformation_matrix_NW_after_2dec2020.dat). If no global transformation is used, a simple transformation of the data **after the change**, from 16:00 on 2 December 2020 by

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} x_{after\ 2\ dec} \\ y_{after\ 2\ dec} \\ z_{after\ 2\ dec} \end{pmatrix} + \begin{pmatrix} 0.05 \\ 3.09 \\ 0 \end{pmatrix}$$

allows to keep the entire data set in the same local coordinate system.

If both the time dependent corrections and global georeferencing are applied, they should be performed in the following order:

1st step: time dependent correction/rotation

2nd step: global transformation with the respective matrix (or shift in x,y to account for move on 2nd December 2020).

3.3 Subsetting of Point Clouds

To reduce the volume of the data set, all point clouds have been cropped to the area starting at 20 m away from the laser scanner in x-direction and 10 m away from the laser scanner in z-direction. This removed all points representing the hotel façade and balcony where the scanner was mounted. The dune and beach area was not affected by this step.

The point density in the target area of the beach and dunes ranges between 50 points/m² down to 1 to 5 points/m² in the outer parts of the beach scene.

4. Final notes

No further processing (e.g., correction, classification or filtering) was applied to the data other than the steps described above. The following data specifications apply:

Coordinate reference system of point clouds and reference datasets:

Coordinates after transformation with the global transformation matrix are given in RD-NAP (RD-NAP, version 2008, EPSG 7415), the Dutch national coordinate system. Elevations are given above mean sea level.

Units:

Meters, decibels

File format:

Point clouds are provided in losslessly compressed laz format. Transformation matrices and inclination data are stored in ASCII format (.dat, .txt, .asc).

Data attributes of the point cloud data:

X **Y** **Z**	3D coordinates of the laser measurement are in the local coordinate system (in meters). Georeferenced data is Dutch national coordinates (RDNAP). Elevations are given above mean sea level.
Offset time [s]	Relative time of each returned signal within the scan.
echo type { 0: single, 1: first, 2: interior, 3: last }	The echo type describes the recorded position of the returned signal within the emitted laser pulse, which can return single or multiple echoes. Multiple echoes occur when the laser beam hits more than one target surface, for example where the laser beam penetrates vegetation on the dunes. The echo type returned for a laser pulse may be single, first, interior or last.
deviation []	The deviation gives a dimensionless estimate of the returned pulse shape after reflection of a surface. The deviation of the returned signal from the emitted pulse shape is dependent on the local surface structure, such as roughness.
amplitude [dB]	The amplitude is the amplitude of the returned signal for each echo at the detection threshold of the instrument, and describes the laser return intensity
reflectance [dB]	The reflectance is a range-corrected amplitude value, provided by the TLS manufacturer (Riegl 2017).

Additional files:

Inclination data (*_incl.asc)	Provided with each scan epoch. Contains inclination information (roll and pitch [°]) recorded by the internal inclination sensor at 1 Hz during scanning.
Time-dependent alignment matrix (*_trafomat.txt)	Provided with each scan epoch. Contains a 4 x 4 rigid transformation matrix derived from the ICP-based alignment to the first scan in the series (cf. Section 3.2).
Global alignment matrix (Global_transformation_matrix_NW_before_2dec2020.dat **and** Global_transformation_matrix_NW_after_2dec2020.dat**)**	Contains a 4 x 4 rigid transformation matrix to georeference point clouds in RD-NAP (EPSG 7415), cf. Section 3.1.

File naming convention:

Point clouds are stored per day in a folder named according to the format YYMMDD, with YY specifying the year, MM the month, and DD the day of the month. Individual scans have the naming format YYMMDD_hhmmss with the start time of the scan in hours (hh), minutes (mm), and seconds (ss). The corresponding transformation matrix is named YYMMDD_hhmmss_trafomat.txt and the file with inclination data YYMMDD_hhmmss_incl.asc.

Additional information:

A similar data set from a different location in the Netherlands and covering a shorter time period of scanning (6 months) was published in 2022 by Vos et al. [Vos, 2022]. A study on the stability of the set up and environmental influences on data quality of this data set was presented in 2021 by Kuschnerus et al. [Kuschnerus, 2021].

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