Technical whitepaper

eventTerrain

Terrain Exposure Assessment for Temporary Structures

Methodology, Architecture, Validation, and Standards Alignment

Version: 0.4 DRAFT

Prepared for engineering review, technical assessment, and operational evaluation.

Document Control

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JOHN SEBASTIAN – Not just a different approach to Engineering

Revision History

Version	Description
0.1 Draft	Initial technical whitepaper draft
0.2 Draft	Added expanded methodology and standards integration
0.3 Draft	Added geospatial interpretation framework, directional-factor logic, cross-border behaviour, GPS accuracy handling, coastal proximity modelling, and standards-compliance engine
0.4 Draft	Added appendices, expanded sections

Acronyms and Abbreviations

CEN	European Committee for Standardization
CLC	CORINE Land Cover
DAR	Denmark's Address Register
DDKN	Danish National Grid
DEM	Digital Elevation Model
DS	Danish Standards
DSM	Digital Surface Model
DTM	Digital Terrain Model
DTED	Digital Terrain Elevation Data
EC	European Commission
EEA	European Environment Agency
EN	European Standard
EPSG	European Petroleum Survey Group
ESA	European Space Agency
ETRS89	European Terrestrial Reference System 1989
GeoTIFF	Georeferenced Tagged Image File Format
GIS	Geographic Information System
INSPIRE	INfrastructure for SPatial InfoRmation in Europe
ISO	International Organization for Standardization
LAEA	Lambert Azimuth Equal Area
NS	Standards Norway
SiS	Swedish Institute for Standards
URL	Uniform Resource Locator
UTM	Universal Transverse Mercator
WMS	Web Map Service
WGS	World Geodetic System

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01. Executive Summary

eventTerrain is a browser-based geospatial assessment platform developed to support terrain-category and wind-exposure evaluation for temporary structures. The platform integrates geospatial analysis, terrain category classification, directional exposure evaluation, orography assessment, and Eurocode aligned exposure calculations, within a lightweight operational workflow refined for event planning, temporary structure deployment, engineering coordination, exposure assessment consistency, and field based technical review.

The methodology is based primarily on:

- EN 1991-1-4
- DS/EN 1991-1-4 DK NA
- SS-EN 1991-1-4/NA
- NS-EN 1991-1-4/NA

The system is intended as a geospatial exposure-assessment and engineering decision-support platform. It does not replace project-specific structural verification, structural design, local authority approval, or the professional responsibility of the appointed engineer.

The platform currently supports:

- Denmark
- Sweden (select users)
- Norway (select users)

02. Background and Motivation

Industry Context

Temporary structures—tents, stages, pavilions, and similar installations—are highly sensitive to wind. Their safety depends on correct assumptions about terrain roughness and exposure. Historically, these assumptions have often been subjective, inconsistent, or undocumented.

This leads to avoidable risks, disputes, and delays.

The Need for Consistency

Terrain category is a foundational input for wind-load calculations. A misclassification can result in:

- Under-ballasting
- Insufficient anchoring
- Over-conservative designs
- Compliance challenges
- Increased risk during build and operation

A consistent, site-specific assessment reduces these risks and improves communication between stakeholders.

Why eventTerrain was created

eventTerrain was created to:

- Provide fast, field-ready assessment
- Reduce subjective interpretation
- Present transparent, repeatable results
- Align with Eurocode and National Annex requirements
- Support safer planning and review processes
- Operate without installation or personal-data collection

The tool bridges the gap between engineering standards and real-world event operations.

03. System Overview

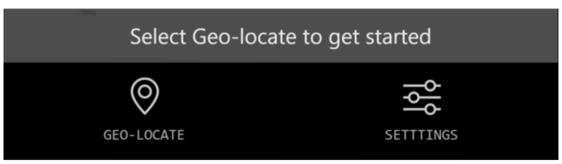
eventTerrain is a mobile-accessible exposure assessment platform operating through a browser-based workflow.

The system performs:

1. Site localization
2. Geospatial terrain sampling
3. Directional sector analysis
4. Terrain-category classification
5. Orography assessment
6. Exposure-factor calculation
7. Output visualization

Use

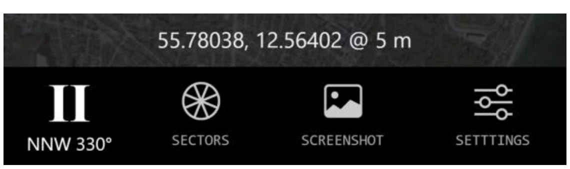
1. scan the QR code on the webpage, or open a browser on a mobile device and go to *https://ndp.dk/event/*
2. Press **Geo-Locate** at the bottom left of the interface (*Fig. 1*)



3. Results of the analysis is displayed on the map view (*Fig. 2*)
4. The terrain category of the prevailing sector is highlighted with a bold border and shown in the lower-left part of the interface.

The user may then

- Press this icon to review position, geolocation accuracy, address, coastline distance, prevailing wind direction, and site elevation where available *(Fig. 3)*



- open Sector Analysis and Exposure Calculation by selecting a sector on the map or pressing the ***Sectors*** icon *(Fig. 4)*
- set the structure height in the ***Settings*** menu.
- export screenshots as PNG images when supported by the device and browse.

Fig. 1 eventTerrain interface

Fig. 2 Analysis results view

Fig. 3 Site Information and Exposure Summary

Example site-information output including:

- GPS position
- Accuracy of the geo-location
- Reverse geo-coded address of the site
- District information
- Distance to Ringkøbing Fjord *(DK only)*
- Distance to nearest coastline
- Prevailing wind direction
- Terrain category of the prevailing wind direction
- Elevation of site *(DK only)*

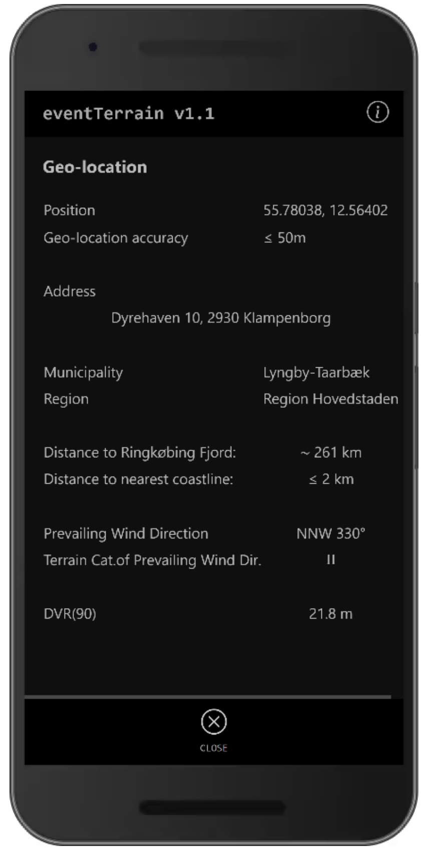
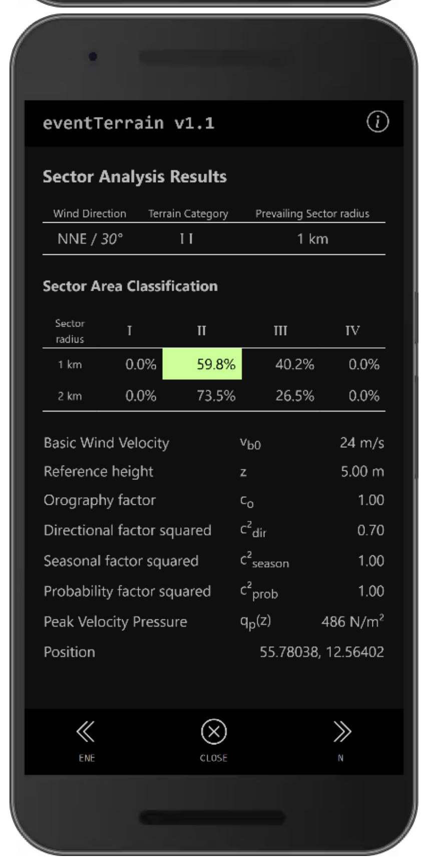


Fig. 4 Sector Analysis and Exposure Calculation View

Example sector-level output including:

- Directional sector classification
- Terrain category percentages of 1 and 2 km sectors
- Prevailing sector is highlighted.
- Reference wind parameters
- Exposure coefficients
- Peak velocity pressure
- GPS position



Output status and review requirement

eventTerrain presents calculated exposure data together with the underlying directional terrain classification.

The output should be reviewed by a competent user before being used in project documentation.

Where the classification is uncertain or close to a category boundary, the more conservative interpretation should be adopted unless a project-specific engineering review supports otherwise.

04. Implemented Standards

The system currently incorporates:

- EN 1991-1-4
- DS/EN 1991-1-4 DK NA – Danish National Annex
- SS-EN 1991-1-4/NA – Swedish National Annex
- NS-EN 1991-1-4/NA – Norwegian National Annex

The system supports:

- Terrain-category interpretation
- Directional-factor handling
- Seasonal-factor handling
- Probability-factor handling
- Roughness parameters
- Minimum reference height handling
- Orography-factor derivation

Scope exclusions

To remain lightweight and field-ready, eventTerrain does **not** perform complete structural wind-load design.

The following items remain outside the platform scope:

- structural verification
- structural safety factors
- load combinations
- force coefficients and pressure coefficients
- member, connection, anchorage, and ballast verification
- assessment of dynamic response or aeroelastic effects

These items remain the responsibility of qualified engineers and must be assessed using the relevant structural design standards, product documentation, and project-specific conditions.

National Annex Integration

Each country may modify Eurocode through a National Annex (NA). eventTerrain incorporates NA-specific rules for supported countries, including:

- Terrain-category definitions
- Roughness values
- Sector-based interpretation
- Local wind-climate considerations

As of 2026, eventTerrain supports:

- Denmark (full support)
- Sweden (beta)
- Norway (beta)

Additional countries will be added as part of the development roadmap.

05. Methodology

Coastal and Fjord Proximity

Distance to the nearest coastline and, for Denmark, distance to Ringkøbing Fjord are computed using high-resolution land polygons. These distances are used as geospatial indicators for exposure interpretation and for location-specific logic where required by the implemented National Annex rules.

Terrain Categories

eventTerrain maps terrain exposure according to the Eurocode terrain categories, including any modifications or interpretation rules stated in the National Annex applicable to the assessed site.

Directional terrain exposure is evaluated independently for each sector. For each sector, the platform calculates the area share of each terrain category within the defined sector geometry and applies the relevant National Annex logic to determine the final sector classification.

Deterministic Interpretation

The classification workflow is implemented as deterministic geospatial logic. For a given input location, dataset version, structure height, and applicable National Annex, the system returns the same result each time. This reduces subjective interpretation and improves repeatability, while still requiring engineering review where terrain transitions, dataset limitations, or project-specific conditions are material.

Assessed Location Quality and Accuracy Handling

The system evaluates GPS accuracy and applies thresholds to ensure valid assessments. If accuracy is insufficient, the user is prompted to re-acquire or manually adjust the location.

Fallback logic is used when GPS is unavailable. Offshore or invalid land-mass positions are rejected. This ensures all downstream calculations are based on a verifiable geographic reference.

Cross-Border Behaviour

The applicable National Annex is selected strictly from the coordinate location of the assessed site. No blending or interpolation between National Annexes is applied. This ensures deterministic and jurisdiction-aligned behaviour at national borders, but it also means that assessments near borders should be reviewed with particular care where nearby terrain, fetch, or wind-climate conditions extend across jurisdictions.

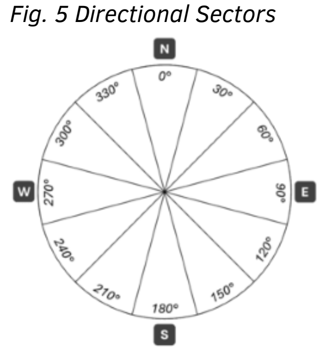
Directional Sector Definition

The terrain surrounding the assessment location is divided into:

- 12 directional sectors,
- 30° angular width
- clockwise orientation
- North referenced at 0°

Sector directions: N, NNE, ENE, E, ESE, SSE, S, SSW, WSW, W, WNW, NNW

Fig. 5 Directional Sectors



Analysis radii

Each directional sector is evaluated using:

- 1 km radius
- 2 km radius

The dual-radius workflow improves sensitivity to:

- local terrain
- open fetch
- coastal exposure
- terrain transitions

Terrain dataset structure

Land-cover datasets are normalized into:

- 50 × 50 m terrain cells

The percentage-overlap between:

- terrain cells
- directional sector geometry

is accumulated and normalized against sector area *(Fig. 6)*.

Fig. 6 Rendering of 50 x 50 m cells intersecting the combined directional sector with radii of 1 and 2 km.

Sector terrain classification logic

Sector terrain classification is performed independently for each directional sector in accordance with the National Annex applicable to the assessment location.

If no mandatory procedure is stated in the relevant National Annex, eventTerrain applies a two-radius override logic based on Procedure 1 in EN 1991-1-4 Annex A.2:

If:
- the 2 km sector classification corresponds to open sea, lake, or equivalent Category 0 exposure

then:
- the final sector classification is assigned as Category 0

else:
- the final sector classification is derived from the 1 km sector analysis

This rule preserves sensitivity to longer open fetch while retaining local terrain sensitivity where no extended open-water exposure governs the sector result.

Automated Annex-Compliance Logic

The compliance engine selects:

- Terrain-category thresholds
- Directional-factor sets
- Roughness parameters
- Minimum reference heights
- Orography-factor applicability

All rules are deterministic and National-Annex-aligned.

06. Geospatial Processing

Dataset Resolutions

Terrain-category grid	50 × 50 m
Orography elevation profile	100 m spacing
Orography profile length	16 km
Orography profile points	161 points
Land polygons	10 m

Processing Architecture

Processing model	Server-side
Execution	Deterministic
Client type	Browser-based mobile interface

Grid size

Terrain classification is performed using a gridded dataset in which each cell is assigned a discrete terrain category. The adopted grid resolution was selected through an iterative sensitivity analysis aimed at balancing spatial resolution, sector-level classification stability, computational efficiency, and robustness against isolated cell-level noise.

Multiple grid resolutions were evaluated, as summarized in *Table 1*, and their aggregated sector-level outputs were compared. Resolutions finer than 50 m resulted in only negligible changes to sector-level classification values, typically limited to the third decimal place. This indicates that further grid refinement did not provide a meaningful improvement in classification fidelity.

Table 1 Comparison of elements per 1 km and 2 km sector and the corresponding dataset size.

Grid	Cell area	elements per sector 1 km *0,262 km²*	elements per sector 2 km *1,047 km²*	Dataset size (min. cells req. to cover the landmass) DK	Dataset size (min. cells req. to cover the landmass) DK+SE+NO
10 m	100 m²	2617,99	10471,98	429.570.000	8.784.590.000
20 m	400 m²	654,50	2617,99	107.392.500	2.196.147.500
25 m	625 m²	418,88	1675,52	68.731.200	1.405.534.400
50 m	2500 m²	104,72	418,88	17.182.800	351.383.600
100 m	0,01 km²	26,18	104,72	4.295.700	87.845.900
250 m	1/16 km²	4,19	16,76	687.312	14.055.344
500 m	1/4 km²	1,05	4,19	171.828	3.513.836
1000 m	1 km²	0,26	1,05	42.957	878.459

To assess the influence of classifier uncertainty, statistical error propagation was evaluated assuming a mean cell-level classification accuracy of 90%. At this accuracy level, approximately 10% of the cells within any sector are expected to be misclassified. For a 1 km radius sector containing approximately 105 cells at 50 m resolution, this corresponds to an expected error magnitude of about 11 cells.

Sector-level classification is governed by the terrain category selected under the applicable National Annex logic. Where classification is based on the dominant area share, the sensitivity of the result depends primarily on the dominance margin between the governing category and the second-highest category. For a 1 km sector at 50 m resolution, approximately 105 cells are evaluated; for a 2 km sector, approximately 419 cells are evaluated. At an assumed mean cell-level classification accuracy of 90%, the expected number of misclassified cells is approximately 11 and 42 cells, respectively.

Random, independent misclassifications are unlikely to change the sector result where one terrain category is clearly dominant. However, classification sensitivity increases where the leading terrain categories have similar area shares, or where dataset errors are spatially correlated. This supports the selection of a 50 m grid as a practical resolution that balances spatial detail, computational demand, and robustness against stochastic classification errors, while still requiring conservative review in transition-sensitive sectors.

Computational performance was also evaluated by comparing processing times for datasets of different sizes. For 12 sectors, analysis using a 10 m resolution dataset, comprising at least 125,664 cells, required substantially more computation than analysis using a 50 m resolution dataset, comprising at least 5,027 cells. This difference is due to the increased number of classification operations and the larger volume of spatial data requiring aggregation. Empirical measurements showed that processing the 10 m dataset required approximately 20–25 times longer execution time than the 50 m dataset, depending on system load, memory behaviour, and spatial-data aggregation overhead.

Although coarser grids reduce computational demand, the 50 m grid provides sufficient spatial detail while maintaining classification stability and reducing the likelihood of sector-level shifts caused by isolated cell-level errors. For these reasons, a 50 m grid resolution was adopted for eventTerrain.

Terrain Category Mapping

eventTerrain converts source land-cover datasets into Eurocode terrain categories through a deterministic raster-processing workflow. The purpose of the mapping process is to translate heterogeneous land-cover information into the terrain-category classes used for wind-exposure assessment.

The source land-cover dataset is stored as a GeoTIFF in the same coordinate reference system as the terrain-grid overlay. This avoids reprojection during the classification process and ensures that the source raster and the analysis grid are evaluated in a consistent spatial reference system.

Each source land-cover value is first associated with a corresponding terrain category using a predefined mapping table. The mapping table assigns each relevant source land-cover class to one of the terrain categories used by eventTerrain. Where a source land-cover class is ambiguous or may represent mixed exposure conditions, the mapping should be defined using a conservative interpretation.

For each 50 × 50 m terrain cell, eventTerrain calculates a raster histogram of the source dataset values falling within the cell boundary. The histogram identifies the proportion of the cell occupied by each mapped terrain category. Histogram values belonging to the same terrain category are summed and divided by the total cell area, giving the terrain-category percentage of the cell.

For a standard 50 × 50 m cell, the cell area is:

$$A_{cell} = 2{,}500\ m^2$$

The terrain-category percentage for each class is calculated as:

$$A_{cat} / A_{cell} \cdot 100\%$$

where:

- A_{cat} is the summed area of source raster pixels mapped to the relevant terrain category
- A_{cell} is the total area of the analysis cell

The final terrain category assigned to the individual cell is then determined using threshold logic based on EN 1991-1-4 Annex A.2, Procedure 1. The classification is applied in order, so that the most exposed terrain class satisfying the threshold governs the cell classification.

For the general Eurocode implementation, the cell terrain category is assigned as follows:

- if Category 0 ≥ 10% of the cell area: assign Category 0
- else if Category I ≥ 10% of the cell area: assign Category I
- else if Category II ≥ 10% of the cell area: assign Category II
- else if Category III ≥ 10% of the cell area: assign Category III
- else if Category IV ≥ 15% of the cell area: assign Category IV

For Denmark, the classification logic is adjusted in accordance with the Danish National Annex. Category 0 is not used in the Danish terrain-category logic, and the cell terrain category is assigned as follows:

- if Category I ≥ 10% of the cell area: assign Category I
- else if Category II ≥ 10% of the cell area: assign Category II
- else if Category III ≥ 10% of the cell area: assign Category III
- else if Category IV ≥ 15% of the cell area: assign Category IV

This threshold-based method ensures that relatively small but exposure-relevant areas within a grid cell can govern the resulting cell classification. The procedure therefore preserves sensitivity to open terrain and low-roughness exposure while maintaining a consistent and repeatable classification workflow across the gridded dataset.

The resulting classified grid forms the basis for the subsequent directional sector analysis. Sector-level terrain percentages are calculated by intersecting the classified terrain cells with the directional sector geometry and normalising the intersected terrain areas against the total sector area.

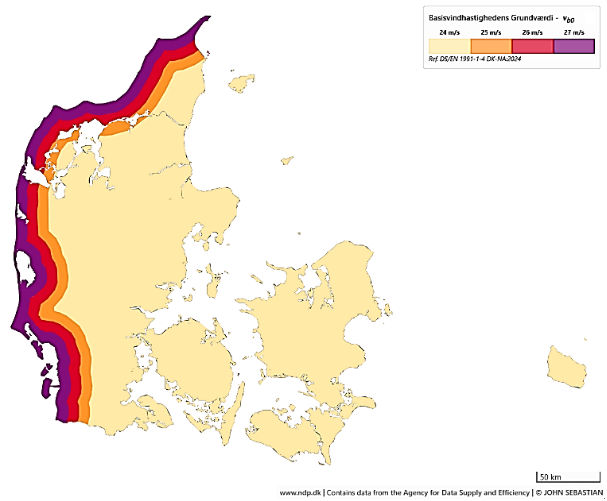
Dataset version control

The terrain classification result depends on the source datasets, preprocessing rules, and grid version used at the time of assessment. For auditability, each production dataset is versioned and associated with a defined processing date, source-data version, and geographic coverage.

07. Danish National Annex – Geospatial Interpretation Framework

Basic Wind Velocity

Fig. 7 Rendering of reference map



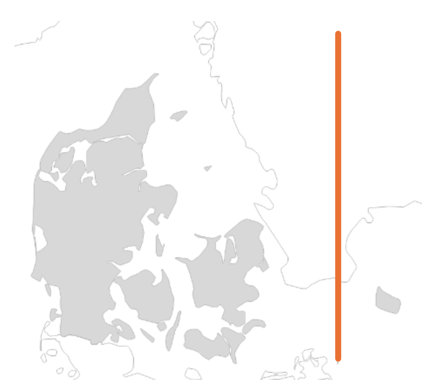
For Danish sites, the fundamental value of the basic wind velocity is determined by projecting the assessed location onto a geospatial interpretation of the Danish National Annex reference map. The model represents the 25 km wide western Jutland coastal zone, where the fundamental basic wind velocity transitions from 27 m/s at the North Sea coastline to 24 m/s at the inland edge of the zone.

This reference map is an operational interpretation of the Danish National Annex to EN 1991-1-4, which specifies that the basic wind velocity is 24 m/s throughout Denmark except within a coastal border zone in western Jutland. In this zone, the National Annex prescribes a linear transition from 27 m/s at the North Sea coastline to 24 m/s at the inland edge, with local orographic conditions—such as the inlets of western Jutland—considered.

The map translates these textual rules into a spatial model that can be applied consistently during automated location-based assessments.

Directional factors

Fig. 8 Longitudinal boundary at 14° E



For sites found in Denmark, the geographic position of the assessment site, is used to decide which set of directional factors applies under the Danish National Annex to EN 1991-1-4.

Although the Danish National Annex distinguishes between Bornholm and the rest of Denmark, eventTerrain operationalises this distinction using a longitudinal boundary at 14° E. This provides a deterministic and automatable rule for Danish locations.

For positions east of 14° E, the stricter directional factors are applied, min. $c^2_{dir} = 0{,}8$.

For positions west of 14° E, the directional-factor set for the rest of Denmark is applied.

Seasonal factor

By default, eventTerrain uses a seasonal correction factor of $c_{season} = 1{,}0$.

Probability factor

By default, eventTerrain uses a probability factor of $c_{prob} = 1{,}0$, corresponding to a 50-year return period.

Terrain classification logic

EN 1991-1-4 Annex A.2 adjusted to the National Danish Annex:

$$\text{Terrain category} = \begin{cases} \mathrm{I} & A_{\mathrm{cat,I}} & \geq 10\ \% \\ \mathrm{II} & A_{\mathrm{cat,II}} & \geq 10\ \% \\ \mathrm{III} & A_{\mathrm{cat,III}} & \geq 10\ \% \\ \mathrm{IV} & A_{\mathrm{cat,IV}} & \geq 15\ \% \end{cases}$$

Two-radius override logic using the adjusted Procedure 1

If:

- 2 km sector classification = Category I

then:

- final sector classification = Category I

else:

- final classification = classification derived from 1 km analysis

Category notation

The Eurocode terrain-category notation may differ between the general Eurocode text and the implemented National Annex terminology. In eventTerrain, the notation used in the calculation engine follows the applicable National Annex for the assessed country. Where Category 0 and Category I logic differ between jurisdictions, the implemented rule set is selected from the coordinate-based National Annex selection and applied consistently throughout the sector classification and exposure calculation workflow.

08. Exposure Calculations

Exposure Calculation Basis

Exposure calculations are performed using:

- user-defined structure height, h
- terrain-category-dependent minimum height, z_{min}
- directional factor, c_{dir}
- seasonal factor, c_{season}
- probability factor, c_{prob}
- terrain roughness parameters, including z_0 and k_r
- orography factor, c_o
- fundamental basic wind velocity, $v_{b,0}$

The effective reference height is:

$$z_e = \max(\, h\, , z_{min}\,)$$

Default:

$$h = 5.0\, m$$

The basic wind velocity is calculated as:

$$v_b = \ c_{dir} \cdot c_{season} \cdot c_{prob} \cdot v_{b,0}$$

where:

- $v_{b,0}$ is the fundamental value of the basic wind velocity
- c_{dir} is the directional factor
- c_{season} is the seasonal factor,
- c_{prob} is the probability factor

Where the user interface or output table presents squared factors, the relationship is:

$$c_{dir} = \sqrt{c_{dir}^2}$$

and similarly for other squared factors where applicable. Squared factors may be displayed, if they are listed as such in the applicable National Annex.

The terrain factor is calculated as:

$$k_{\mathrm{r}} = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07}$$

where:

- $\mathrm{z}_0$the roughness length for the terrain category
- $\mathrm{z}_{0,\mathrm{II}}$ is the reference roughness length for *Terrain Category II*, taken as 1,0 unless otherwise specified by the applicable National Annex

The roughness factor is calculated as:

$$c_r(z_e) = k_r \cdot \ln\left(\frac{z_e}{z_0}\right)$$

for:

$$z_{min} \leq z_e \leq z_{max}$$

For heights below the terrain-category-dependent minimum height, the roughness factor is evaluated at z_{min}.

The mean wind velocity is then calculated as:

$$v_m(z_e) = c_r(z_e) \cdot c_o \cdot v_b$$

where:

- c_o is the orography factor
- $v_m(z_e)$ is the mean wind velocity at the effective reference height

The turbulence intensity is calculated as:

$$I_v(z_e) = \frac{k_I}{c_o(z_e) \cdot \ln\left(\frac{z_e}{z_0}\right)}$$

where:

- k_I is the turbulence factor, taken as 1,0 unless otherwise specified by the applicable National Annex
- c_o is the orography factor

Peak velocity pressure at the effective reference height:

$$q_p(\mathrm{z_e}) = \big(1 + 7I_v(z)\big) \cdot \frac{1}{2} \cdot \rho \cdot v_m(\mathrm{z_e})^2$$

where:

- $I_v(\mathrm{z_e})$ turbulence intensity
- $v_m(\mathrm{z_e})$ is the mean wind velocity
- ρ is the air density, taken as (1,25 kg/m³) unless otherwise specified

Calculation output status

The calculated exposure parameters are intended to support terrain-exposure assessment and preliminary engineering coordination. They do not constitute a complete wind-load calculation for a structure.

Structural wind actions require the additional selection of force coefficients or pressure coefficients, load combinations, structural factors, anchorage conditions, ballast configuration, and project-specific design assumptions.

Worked example

The following example illustrates how eventTerrain output may be interpreted for a temporary structure assessment. *(Appendix C includes a more detailed version to demonstrate calculation traceability*). The example is provided to demonstrate the workflow and does not constitute a complete verification.

Assessment location

An assessment is performed for a site at:

- latitude: 55,78038
- longitude: 12,56402
- geolocation accuracy: ± 5 m
- structure height: h = 5,0 m

The assessed location is in Denmark.

The Danish National Annex is therefore selected automatically by the coordinate-based National Annex logic.

Site and directional exposure

The prevailing wind sector is identified as:

- wind direction: **NNE / 30°**
- governing sector radius: **1 km**
- final terrain category: **Category II**

The sector-level terrain distribution is:

Sector radius	Cat. I	Cat. II	Cat. III	Cat. IV
1 km	0,0%	**59,8%**	40,2%	0,0%
2 km	0,0%	73,5%	26,5%	0,0%

Basic wind velocity and exposure factors

For the assessed Danish location, the fundamental basic wind velocity is: $v_{b,0} = 24\ m/s$

The exposure calculation uses:

- reference height: $z = 5{,}0\ m$
- orography factor: $c_o = 1{,}00$
- directional factor squared: $c^2_{dir} = 0{,}70$
- seasonal factor squared: $c^2_{season} = 1{,}00$
- probability factor squared: $c^2_{prob} = 1{,}00$

Peak velocity pressure

Using the implemented Eurocode and National Annex calculation workflow, eventTerrain calculates the peak velocity pressure for the governing sector as:

$$q_p(z) = 486\ N/m^2$$

This value represents the exposure-related peak velocity pressure at the selected reference height and for the selected directional sector. It is an input for engineering coordination and further structural assessment.

Engineering interpretation

For this example, the governing sector is classified as **Terrain Category II**, with a calculated peak velocity pressure of 486 N/m² at 5.0 m reference height. The result is suitable for terrain-exposure documentation and preliminary coordination of temporary-structure design assumptions.

Before use, the user should confirm that:

- the assessed location corresponds to the actual structure position
- the selected structure height is correct
- the Category II terrain classification is reasonable for the NNE sector
- no recent land-use changes materially affect the sector classification
- local shielding, turbulence, and structure-specific aerodynamic effects are assessed separately
- the final structural verification is performed by a qualified engineer

09. Topographic & Orography Processing

eventTerrain calculates orography factors in accordance with EN 1991-1-4 Annex A.3 using terrain elevation profiles derived from the following digital elevation models:

Country	DEM Source	Resolution
Denmark	DHM	0.4–1.6 m
Sweden	National DEM	2 m
Norway	National DEM	1–10 m
EU-wide	EU-DEM	25 m
	EU-DTM	30 m

Elevation Profile

Profile characteristics:

- total length: 16 km
- point spacing: 100 m
- site located at profile centre
- 161 elevation points per profile

The system:

1. Validates terrain profile.
2. Smooths profile.
3. Identifies dominant crest.
4. Derives topographic parameters

Derived Parameters

The workflow derives:

- crest height, H
- upwind length, L_u
- downwind length, L_d
- effective length, L_e
- site distance, X
- slope, $\phi = {}^{H}/_{L_u}$

Orography Factor

$$c_o = \begin{cases} 1.0 & \phi < 0.05 \\ 1.0 + 2.0 \cdot s \cdot \phi & 0.05 \leq \phi < 0.30 \\ 1.0 + 0.6 \cdot s & \phi \geq 0.30 \end{cases}$$

Orography may be neglected where the derived slope ratio satisfies $\phi < 0.05$, or where the relevant Eurocode 3° criterion is satisfied. Where orography is neglected, the orography factor is taken as: $c_o = 1{,}0$

Where the neglect criteria are not satisfied, the orography factor is calculated from the derived topographic parameters and the applicable Annex A.3 formulation.

The automated orography workflow is intended to identify dominant terrain features that may affect wind exposure at the assessed location. Engineering review is recommended where the site is located near complex terrain where the automated assessment may not adequately represent the wind-relevant topography. In such cases, project-specific topographic assessment may be required

10. Validation and Quality Assurance

Validation Basis

Validation has been performed using:

- manual engineering review
- known terrain environments.
- directional exposure review
- comparative assessment workflows

Observed agreement:

- ≥ 90% agreement against manual assessment workflows for the validation cases assessed

The agreement value represents comparison against manual engineering interpretation and should be read as a validation indicator rather than an absolute accuracy statement. The validation basis will be expanded as additional reviewed sites, terrain types, and national datasets are added.

Validation Objectives

Validation focuses on:

- Repeatability
- Terrain consistency
- Directional exposure plausibility
- Conservative interpretation handling
- Stability near terrain transitions

Known Failure Modes

Known limitations include:

- sites outside land-mass geometry
- offshore assessment points
- terrain-transition ambiguity
- land-use or land-cover changes not yet reflected in the source dataset
- dataset classification errors
- geolocation uncertainty near category boundaries
- simplified representation of local shielding, turbulence, and urban morphology

Recommended operational review

A typical operational review should confirm the assessed location, geolocation accuracy, selected structure height, applicable National Annex, governing wind direction, terrain classification of the governing sector, orography factor, and calculated exposure parameters. Where the result is used for ballast coordination or engineering review, the output should be saved together with the project documentation and checked against the actual site conditions observed during setup.

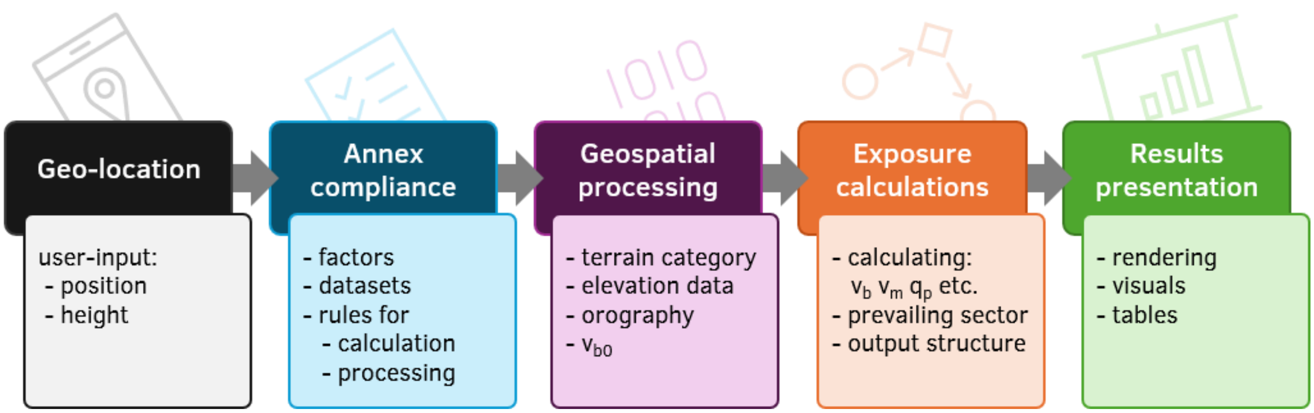
11. Operational Workflows

Typical workflows include:

- ballast coordination
- site visits
- engineering coordination
- planning
- supplier discussions
- audits

Operational workflow

Fig. 9 Operational workflow



12. Limitations

eventTerrain does not perform:

- structural verification
- CFD simulation
- dynamic wind modelling
- aeroelastic analysis
- certification workflows
- structural wind load calculations

The platform should be interpreted as:

- geospatial exposure-assessment support system
- semi-engineering decision-support workflow for terrain and exposure interpretation

It should not be interpreted as:

- structural design engine
- a substitute for project-specific wind-load calculation
- a substitute for engineering judgement or local authority approval

Geo-locating

Position accuracy varies by device, browser, satellite visibility, and local conditions. The effect is mitigated by accuracy checks but cannot be eliminated.

Datasets

Micro-terrain, recent construction, temporary obstructions, vegetation changes, and local terrain modifications may not be captured in the source datasets.

Processing

The platform does not model local shielding, local turbulence, wake effects, local channelling between buildings, or structure-specific aerodynamic behaviour

13. Future Development Roadmap

eventTerrain has been under development since 2018 and is the latest iteration of several internal tools developed and used by John Sebastian. The platform remains under active development, with planned expansion of functionality, datasets, geographic coverage, and engineering workflows.

Planned development includes:

- Desktop engineering interface
- Report-generation workflows.
- Offline mode
- API integration
- Structural engineering extensions
- Improved urban morphology handling
- Enhanced directional exposure analysis
- Support of height adjustment based on adjacent structures (Annex A.4)
- Dataset improvements
  - higher-resolution terrain handling

Expanded area support; current plan of implementation:

– Denmark	*fully supported*
– Sweden	*beta-testing*
– Norway	*beta-testing*
– Finland	*dataset processing and classification workflow in progress*
– Netherlands	
– United Kingdom	
– Germany	
– TBD	

Planned quality improvements

Planned quality improvements include expanded validation datasets, and regression testing of classification rules. These improvements are intended to strengthen reproducibility, auditability, and engineering confidence as the platform expands to additional jurisdictions.

14. References

Standards

- EN 1991-1-4: Eurocode 1 - Actions on structures - Wind actions
- DS/EN 1991-1-4 DK NA
- SS-EN 1991-1-4/NA
- NS-EN 1991-1-4/NA

Geospatial Data Sources

- GeoDanmark
- Lantmäteriet
- Kartverket
- Kortforsyningen
- Datafordeler
- DHM

Basemap05

Levin, G. (2025). *BASEMAP05: Documentation of the data and method for elaboration of a land use and land cover map for Denmark*. (363 udg.) Aarhus University, DCE - Danish Centre for Environment and Energy. *https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Tekniske_rapporter_350-400/TR363.pdf*

CLMS

Generated using European Union's Copernicus Land Monitoring Service information;

CORINE Land Cover 2012:

Data set: *https://doi.org/10.2909/a84ae124-c5c5-4577-8e10-511bfe55cc0d*

Validation report: *https://land.copernicus.eu/en/technical-library/clc-2012-validation-report-1/*

CLC+ Backbone 2018:

Data set: *https://doi.org/10.2909/cd534ebf-f553-42f0-9ac1-62c1dc36d32c*

Validation report: *https://land.copernicus.eu/en/technical-library/validation-report-clcplus-backbone-2018/*

Product User Manual: *https://land.copernicus.eu/en/technical-library/clc-backbone-product-user-manual/*

CLC+ Backbone 2021:

Data set: *https://doi.org/10.2909/71fc9d1b-479f-4da1-aa66-662a2fff2cf7*

Validation report: *https://land.copernicus.eu/en/technical-library/validation-report-clcplus-backbone-2021/*

Product User Manual: *https://library.land.copernicus.eu/products/CLCplus_Backbone_2023_PUM_v1.html*

CLC+ Backbone 2023:

Data set: *https://doi.org/10.2909/b0bd43c6-1fa1-4d88-9c45-98b13a95d0b2*

Validation report: *https://land.copernicus.eu/en/technical-library/validation-report-clcplus-backbone-2023/*

Product User Manual: *https://library.land.copernicus.eu/products/CLCplus_Backbone_2023_PUM_v1.html*

Algorithm theoretical basis doc: *https://library.land.copernicus.eu/products/CLCplus_Backbone_2023_ATBD_v1.html*

Urban Atlas Building Block Height 2021:

Data set: *https://doi.org/10.2909/c5215520-98e9-4035-be56-d28156cd4dcd*

Validation report: *https://land.copernicus.eu/en/technical-library/validation-report-building-block-height-2021/*

Product User Manual: *https://land.copernicus.eu/en/technical-library/clc-backbone-product-user-manual/*

Algorithm theoretical basis document:
https://land.copernicus.eu/en/technical-library/algorithm-theoretical-basis-document-building-block-height-2021/

ESA WorldCover

Zanaga, D., Van De Kerchove, R., Daems, D., De Keersmaecker, W., Brockmann, C., Kirches, G., Wevers, J., Cartus, O., Santoro, M., Fritz, S., Lesiv, M., Herold, M., Tsendbazar, N.E., Xu, P., Ramoino, F., Arino, O., 2022. *ESA WorldCover 10 m 2021 v200*. *https://doi.org/10.5281/zenodo.7254221*

Manual: *https://esa-worldcover.s3.eu-central-1.amazonaws.com/v200/2021/docs/WorldCover_PUM_V2.0.pdf*

Validation report: *https://esa-worldcover.s3.eu-central-1.amazonaws.com/v200/2021/docs/WorldCover_PVR_V2.0.pdf*

EU-DTM

Hengl, Tomislav, Leal Parente, Leandro, Krizan, Josip, & Bonannella, Carmelo. (2020). *Continental Europe Digital Terrain Model at 30 m resolution based on GEDI, ICESat-2, AW3D, GLO-30, EUDEM, MERIT DEM and background layers (v0.3)* [Data set]. Zenodo. *https://doi.org/10.5281/zenodo.4724549*

EU-DEM

Dataset Citation: Hengl, Tomislav, Leal Parente, Leandro, Krizan, Josip, and Bonannella, Carmelo. 2022. Continental Europe Digital Terrain Model. Distributed by OpenTopography. *https://doi.org/10.5069/G99021ZF*
Use License: CC BY 4.0

15. Final Engineering Statement

eventTerrain is intended to support:

- Terrain-exposure interpretation
- operational field workflows
- engineering coordination
- exposure transparency
- standards-aligned terrain assessment

The platform does not replace:

- project-specific engineering verification
- structural analysis
- local authority approval
- product-specific documentation
- professional engineering responsibility

Final design responsibility remains with the qualified professionals appointed to the project.

Appendices

Appendix A. Standards Implementation Matrix

This appendix summarises how eventTerrain implements the relevant provisions of EN 1991-1-4 and the National Annexes for Denmark, Sweden, and Norway.

The matrix distinguishes between provisions implemented directly in the platform, provisions implemented as simplified exposure-assessment logic, and provisions that remain outside the scope of eventTerrain.

Standard	Topic	Impl.	Notes
EN 1991-1-4	Wind-action assessment basis	Partial	The platform does not perform complete structural wind-load design. Pressure coefficients, force coefficients, load combinations, and structural verification remain outside scope.
EN 1991-1-4	Terrain categories	Yes	Land-cover datasets are mapped to Eurocode terrain categories and normalised into a classified grid. Source land-cover uncertainty and recent land-use changes may affect classification.
EN 1991-1-4 Annex A.2	Terrain-category interpretation	Yes	Directional sectors are analysed using classified terrain cells within defined sector geometries.
EN 1991-1-4 Annex A.2, Procedure 1	Open terrain and long-fetch sensitivity	Yes	Where no mandatory National Annex procedure governs, eventTerrain applies a two-radius logic using 1 km and 2 km sector analyses. The procedure is applied as deterministic geospatial logic.
EN 1991-1-4	Basic wind velocity	Yes	Basic wind velocity is calculated from vb = cdir · cseason · cprob · vb,0. The fundamental value vb,0 is selected from the applicable National Annex logic.
EN 1991-1-4	Directional factor	Yes	Directional factors are selected according to the implemented National Annex and the assessed wind direction.
EN 1991-1-4	Seasonal factor	Yes	Default value is applied unless otherwise stated. eventTerrain default is c_{season} = 1.0 unless otherwise stated.
EN 1991-1-4	Probability factor	Yes	Default value is applied for the standard return-period basis. eventTerrain default is c_{prob} = 1.0, corresponding to a 50-year return period, unless otherwise stated.
EN 1991-1-4	Terrain roughness parameters	Yes	Terrain-dependent roughness length z_0, minimum height z_{min}, and terrain factor k_r are selected from the implemented National Annex parameter set.
EN 1991-1-4	Effective reference height	Yes	The effective reference height is calculated as ze = max (h, zmin). The user-defined structure height must represent the relevant height for the temporary structure being assessed.
EN 1991-1-4 Annex A.3	Orography factor	Yes	Elevation profiles are generated from DEM data and used to derive topographic parameters and the orography factor co. Automated assessment may require engineering review in complex terrain.
EN 1991-1-4 Annex A.4	Influence of neighbouring structures	No	Not currently included in the automated exposure workflow. Listed as future development. Local shielding, displacement height, and adjacent-structure effects must be reviewed separately.
EN 1991-1-4	Peak velocity pressure	Yes	Peak velocity pressure is calculated using the implemented Eurocode exposure formulation and the selected terrain, height, and National Annex factors. The resulting qp(z) is an exposure parameter and not a complete structural design action.

Standard	Topic	Impl.	Notes
EN 1991-1-4	Pressure coefficients and force coefficients	No	These remain the responsibility of the appointed engineer and relevant structural design documentation.
EN 1991-1-4	Structural verification	No	Member design, anchorage, ballast, stability, load combinations, and safety factors remain outside platform scope.
DS/EN 1991-1-4 DK NA	National Annex selection	Yes	The Danish National Annex is selected automatically where the assessed coordinates fall within Denmark. No interpolation between National Annexes is applied at national borders.
DS/EN 1991-1-4 DK NA	Fundamental basic wind velocity, vb,0	Yes	The Danish vb,0 model is implemented using a geospatial interpretation of the Danish reference map. The model represents 24 m/s generally and the western Jutland coastal transition from 27 m/s to 24 m/s as described in the Danish Annex interpretation.
DS/EN 1991-1-4 DK NA	Western Jutland coastal transition	Yes	The assessed location is projected onto the implemented spatial model of the 25 km coastal transition zone. Locations near the transition boundary should be reviewed where the resulting vb,0 materially affects the assessment.
DS/EN 1991-1-4 DK NA	Directional-factor region	Yes	The platform distinguishes between Bornholm and the rest of Denmark using a deterministic 14° E longitude boundary. This is an operational geospatial rule intended to reproduce the National Annex distinction.
DS/EN 1991-1-4 DK NA	Terrain-category logic	Yes	Danish terrain-category thresholds are applied without Category 0. The logic assigns Category I, II, III, or IV according to the implemented threshold sequence. The Danish implementation follows the National Annex terrain-category interpretation.
DS/EN 1991-1-4 DK NA	Danish terrain-cell classification thresholds	Yes	If Category I ≥ 10%, assign Category I; else if Category II ≥ 10%, assign Category II; else if Category III ≥ 10%, assign Category III; else if Category IV ≥ 15%, assign Category IV. The threshold sequence is applied at cell level during grid preparation and then used in sector-level analysis
DS/EN 1991-1-4 DK NA	Seasonal factor	Yes	Default Danish seasonal factor is applied as c_{season} = 1.0.
DS/EN 1991-1-4 DK NA	Probability factor	Yes	Default Danish probability factor is applied as cprob = 1.0.
DS/EN 1991-1-4 DK NA	Roughness parameters and minimum heights	Yes	Terrain-dependent values are selected from the Danish National Annex implementation.
DS/EN 1991-1-4 DK NA	Orography	Yes	Orography is calculated using DEM-derived elevation profiles and Annex A.3 logic, with Danish dataset support where available. Complex terrain should always be reviewed by a competent engineer.
SS-EN 1991-1-4/NA	National Annex selection	Yes	The Swedish National Annex is selected automatically where the assessed coordinates fall within Sweden.
SS-EN 1991-1-4/NA	Fundamental basic wind velocity, vb,0	Yes	Swedish National Annex wind-climate parameters are applied through the Swedish rule set.
SS-EN 1991-1-4/NA	Terrain-category interpretation	Yes	Land-cover classes are mapped to Eurocode terrain categories and processed using the Swedish National Annex rule set where applicable.
SS-EN 1991-1-4/NA	Directional, seasonal, and probability factors	Yes	Factor values are selected according to the Swedish National Annex implementation.
SS-EN 1991-1-4/NA	Roughness parameters and minimum heights	Yes	Terrain-dependent z0, zmin, and kr values are selected from the Swedish National Annex implementation.

Standard	Topic	Impl.	Notes
SS-EN 1991-1-4/NA	Orography	Yes	Orography is assessed using Swedish DEM data where available, otherwise fallback elevation data may be used. Complex terrain, coastal slopes, and ridge conditions should be reviewed manually.
SS-EN 1991-1-4/NA	Structural wind-load design	No	Structural verification remains outside eventTerrain scope.
NS-EN 1991-1-4/NA	National Annex selection	Yes	The Norwegian National Annex is selected automatically where the assessed coordinates fall within Norway.
NS-EN 1991-1-4/NA	Fundamental basic wind velocity, vb,0	Yes	Norwegian National Annex wind-climate parameters are applied through the Norwegian rule set.
NS-EN 1991-1-4/NA	Terrain-category interpretation	Yes	Land-cover classes are mapped to Eurocode terrain categories and processed using the Norwegian National Annex rule set where applicable. Classification should be reviewed carefully in mountainous, coastal, fjord, and transition terrain.
NS-EN 1991-1-4/NA	Directional, seasonal, and probability factors	Yes	Factor values are selected according to the Norwegian National Annex implementation.
NS-EN 1991-1-4/NA	Roughness parameters and minimum heights	Yes	Terrain-dependent z0, zmin, and kr values are selected from the Norwegian National Annex implementation.
NS-EN 1991-1-4/NA	Orography	Yes	Orography is assessed using Norwegian DEM data where available, otherwise fallback elevation data may be used. Automated crest detection should be reviewed in steep or complex terrain.
NS-EN 1991-1-4/NA	Structural wind-load design	No	Structural verification remains outside eventTerrain scope.

Appendix B. Reviewer checklist

Before using eventTerrain output for engineering coordination or project documentation, the reviewer should confirm that:

- the assessed location corresponds to the actual structure location,
- the geo-location accuracy is acceptable for the site conditions,
- the correct National Annex has been selected from the site coordinates,
- the structure height used in the calculation matches the intended installation,
- the governing wind direction and prevailing sector have been reviewed,
- the terrain classification is reasonable when compared with current site conditions,
- sectors near coastlines, fjords, terrain transitions, or national borders have been checked manually,
- the orography factor has been reviewed where steep terrain, ridges, slopes, or escarpments are present,
- dataset limitations, recent land-use changes, and local shielding effects have been considered,
- the output is used only as terrain-exposure support and not as a complete structural wind-load verification.

Where uncertainty remains, the more conservative terrain or exposure interpretation should be adopted unless a project-specific engineering assessment justifies otherwise

Appendix C. Worked Example - Sector-Level Exposure Calculation

The following example illustrates the calculation procedure for one directional sector.

The values are representative of the eventTerrain output format and are included to demonstrate calculation traceability.

Input parameters:

Parameter	Symbol	Value
Structure height	h	5,0 m
Governing terrain category		II
Fundamental basic wind velocity	$v_{b,0}$	24,0 m/s
Directional factor squared	c_{dir}^2	0,70
Seasonal factor squared	c_{season}^2	1,00
Probability factor squared	c_{prob}^2	1,00
Orography factor	c_o	1,00
Air density	ρ	1,25 kg/m³

For *Terrain Category II*, the roughness parameters are:

Parameter	Symbol	Value
Roughness length	z_0	0.05 m
Minimum reference height	z_{min}	2.0 m
Reference roughness length	$z_{0,II}$	0.05 m

The effective reference height is:

$$z_e = \max(\, h \,, z_{min}) = \max(\, 5{,}0 \,, 2{,}0 \,) = 5{,}0, m$$

The directional factor is derived from the squared directional factor:

$$c_{dir} = \sqrt{0{,}70} = 0{,}837$$

The seasonal and probability factors are:

$$c_{season} = \sqrt{1{,}00} = 1{,}00 \ \wedge \ \mathrm{c_{prob}} = \sqrt{1{,}00} = 1{,}00$$

The basic wind velocity is:

$$v_b = c_{dir} \cdot c_{season} \cdot c_{prob} \cdot v_{b,0} = 0{,}837 \cdot 1{,}00 \cdot 1{,}00 \cdot 24{,}0 = 20{,}1\ m/s$$

The terrain factor is:

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07} = 0{,}19 \cdot \left(\frac{0{,}05}{0{,}05}\right)^{0{,}07} = 0{,}190$$

The roughness factor is:

$$c_r(z_e) = k_r \cdot \ln\left(\frac{z_e}{z_0}\right) \Rightarrow c_r(5{,}0) = 0{,}190 \cdot \ln\left(\frac{5{,}0}{0{,}05}\right) = 0{,}190 \cdot \ln(100) = 0{,}875$$

The mean wind velocity is:

$$v_m(z_e) = c_r(z_e) \cdot c_o(z_e) \cdot v_b = 0{,}875 \cdot 1{,}00 \cdot 20{,}1 = 17{,}6 m/s$$

The turbulence intensity is:

$$I_v(z_e) = \frac{k_I}{c_o(z_e) \cdot \ln\left(\frac{z_e}{z_0}\right)} \Longrightarrow I_v(5{,}0) = \frac{1{,}0}{1{,}00 \cdot \ln(100)} = 0{,}217$$

The peak velocity pressure is:

$$q_p(z_e) = [1 + 7I_v(z_e)] \cdot \frac{1}{2} \cdot \rho \cdot v_m^2(z_e) \Longrightarrow q_p(5{,}0) = [1 + 7 \cdot 0{,}217] \cdot \frac{1}{2} \cdot 1{,}25 \cdot 17{,}6^2 \approx 486\ N/m^2$$

The resulting peak velocity pressure for this sector is therefore approximately:

$$q_p(z_e) = 0{,}486\ kN/m^2$$

This example shows how the reported exposure result is derived from the terrain category, structure height, roughness parameters, directional factor, seasonal factor, probability factor, and orography factor. The value should be reviewed together with the underlying sector terrain classification, especially where the dominant terrain category is close to a category boundary.