

Package: HazardMaps (via r-universe)

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Type Package

Title Spatial Dependence Modeling and Pseudoscenario Generation for Natural Hazards

Version 0.1.0

Description An R package for reproducible analysis of spatial dependence in environmental and climate-related variables. The package provides a unified workflow to ingest spatial datasets, estimate and visualize spatial correlation structures, fit multiple dependence models including vine copulas (C-vine and D-vine), Gaussian models, and stochastic fields, and compare them using quantitative indicators to support model selection. Based on the selected model, the package enables the generation of spatially dependent pseudoscenarios for uncertainty analysis and simulation studies. The design emphasizes numerical robustness, modularity, and reproducibility across heterogeneous spatial data sources.

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URL <https://github.com/Valentina9619/HazardMaps>,
<https://valentina9619.github.io/HazardMaps/>

BugReports <https://github.com/Valentina9619/HazardMaps/issues>

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hm_cluster_size	<i>Compute spatial cluster sizes of extreme events</i>
-----------------	--

Description

For each time step, counts the land cells where the hazard value meets or exceeds threshold. This is the cluster-size metric $B(t)$ (Eq. 21, Appendix C of Clavijo Mesa et al., 2026) used to validate whether a dependence model reproduces the observed spatial footprint.

Usage

```
hm_cluster_size(X, threshold, time = NULL)
```

Arguments

X Numeric matrix ($T \times N$) from [hm_filter_land_cells()].

threshold A single finite numeric value.

time Optional date vector of length T . Defaults to row indices.

Value

A data.frame with columns date, cluster_size, and cluster_fraction.

References

Clavijo Mesa, M.V., Di Maio, F. & Zio, E. (2026). *Reliability Engineering & System Safety*, 275, 112830.

See Also

[hm_filter_land_cells()], [hm_select_extreme_events()]

Examples

```
## Not run:
X_land <- hm_filter_land_cells(X)
cs      <- hm_cluster_size(X_land, threshold = 25,
                           time = attr(X_land, "time"))
summary(cs$cluster_size)

## End(Not run)
```

hm_decode_time	<i>Decode the NetCDF time axis</i>
----------------	------------------------------------

Description

Converts CF-style time values (e.g. "days since 1970-01-01") to an R Date or POSIXct vector.

Usage

```
hm_decode_time(x, tz = "UTC")
```

Arguments

x An hm_hazard object returned by [hm_read_netcdf()].

tz Time zone string for sub-daily data. Defaults to "UTC".

Value

The same object with `x$time` replaced by a `Date` vector (daily data) or `POSIXct` vector (sub-daily data).

See Also

`[hm_read_netcdf()], [hm_to_matrix()]`

hm_distance_matrix	<i>Compute pairwise haversine distances between grid cells</i>
--------------------	--

Description

Returns a symmetric $N \times N$ distance matrix of great-circle distances in kilometres between all pairs of land cells (Eq. 5 of Clavijo Mesa et al., 2026, SF paper).

Usage

```
hm_distance_matrix(coords)
```

Arguments

coords	A data.frame with <code>lat</code> and <code>lon</code> columns in decimal degrees. Typically <code>attr(X_land, "coords")</code> from <code>[hm_filter_land_cells()]</code> .
--------	--

Value

A symmetric numeric matrix with diagonal zero.

References

Clavijo Mesa, M.V., Broggi, M., Di Maio, F. & Zio, E. (2026). *International Journal of Disaster Risk Reduction*, 141, 106172.

See Also

`[hm_empirical_correlogram()], [hm_filter_land_cells()]`

Examples

```
## Not run:
X_land <- hm_filter_land_cells(X)
D      <- hm_distance_matrix(attr(X_land, "coords"))
range(D)

## End(Not run)
```

hm_empirical_correlogram

Compute the empirical spatial correlogram

Description

Bins pairwise Kendall correlations by inter-site distance to give average correlation as a function of distance. The result is the key input for fitting a covariance model in [hm_fit_correlation_model()], following Eq. 5–6 of Clavijo Mesa et al. (2026, SF paper).

Usage

```
hm_empirical_correlogram(tau, D, n_bins = 30L, max_dist = NULL)
```

Arguments

tau	Symmetric numeric matrix of pairwise Kendall correlations from [hm_empirical_kendall()].
D	Symmetric numeric distance matrix in km from [hm_distance_matrix()]. Must have the same dimensions as tau.
n_bins	Number of equal-width distance bins. Defaults to 30.
max_dist	Maximum distance in km to include. Defaults to the observed maximum.

Value

A data.frame with columns bin_center, mean_tau, n_pairs, bin_lo, and bin_hi.

References

Clavijo Mesa, M.V., Broggi, M., Di Maio, F. & Zio, E. (2026). *International Journal of Disaster Risk Reduction*, 141, 106172.

See Also

[hm_empirical_kendall()], [hm_distance_matrix()], [hm_fit_correlation_model()]

Examples

```
## Not run:
tau <- hm_empirical_kendall(pit$Z, cell_idx = 1:50)
D <- hm_distance_matrix(coords[1:50, ])
corg <- hm_empirical_correlogram(tau, D, n_bins = 20)
head(corg)

## End(Not run)
```

hm_empirical_kendall *Compute the empirical pairwise Kendall correlation matrix*

Description

Estimates Kendall's $\hat{\tau}$ between every pair of grid cells from the Gaussian scores matrix Z from [hm_pit_transform()]. Implements Eq. 20 of Clavijo Mesa et al. (2026, Copernicus paper).

Usage

```
hm_empirical_kendall(Z, cell_idx = NULL)
```

Arguments

Z	Numeric matrix ($T \times N$) of centred Gaussian scores from [hm_pit_transform()].
cell_idx	Optional integer vector of column indices. Defaults to all columns.

Details

For large grids ($N > 1000$) supply a subsample via cell_idx to keep computation feasible.

Value

A symmetric $N \times N$ matrix of Kendall $\hat{\tau}$ values in $[-1, 1]$.

References

Clavijo Mesa, M.V., Di Maio, F. & Zio, E. (2026). *Reliability Engineering & System Safety*, 275, 112830.

See Also

[hm_pit_transform()], [hm_empirical_correlogram()]

Examples

```
## Not run:
fits <- hm_fit_marginals(X)
pit <- hm_pit_transform(X, fits)
tau <- hm_empirical_kendall(pit$Z, cell_idx = 1:30)
range(tau)

## End(Not run)
```

hm_filter_land_cells	<i>Remove sea and no-data cells from a hazard matrix</i>
----------------------	--

Description

Drops columns where the fraction of finite positive values falls below min_valid. Needed for rotated-grid datasets such as EURO-CORDEX where sea cells produce all-NA columns.

Usage

```
hm_filter_land_cells(X, min_valid = 0.8)
```

Arguments

X	A numeric matrix as returned by [hm_to_matrix()].
min_valid	Minimum fraction of valid observations required to keep a column. Defaults to 0.8.

Value

A matrix with only land columns retained. Attributes land_idx, coords, and time are attached.

See Also

[hm_to_matrix()], [hm_fit_marginals()]

hm_fit_copula	<i>Fit a spatial copula model to the uniform PIT data</i>
---------------	---

Description

Fits a C-vine, D-vine, or Gaussian copula to the uniform PIT matrix from [hm_pit_transform()], following Eq. 6 of Clavijo Mesa et al. (2026). The three structures correspond to the comparison in Table IV of that paper.

Usage

```
hm_fit_copula(U, type = "cvine", ...)
```

Arguments

U	Numeric matrix ($T \times N$) of uniform PIT values from [hm_pit_transform()].
type	Copula structure: "cvine" (default), "dvine", or "gaussian".
...	Additional arguments passed to rvinecopulib::vinecop().

Details

Vine copulas are fitted via `rvinecopulib::vinecop()`. The Gaussian copula uses the sin-transform $\rho = \sin(\pi\hat{\tau}/2)$ to convert Kendall τ to a Pearson correlation matrix. Requires `rvinecopulib` (listed in Suggests).

Value

An `hm_copula` list with `type`, `model`, `n_cells`, and `n_obs`.

References

Clavijo Mesa, M.V., Di Maio, F. & Zio, E. (2026). *Reliability Engineering & System Safety*, 275, 112830.

See Also

[`hm_pit_transform()`], [`hm_simulate_copula()`]

Examples

```
## Not run:
X_land <- hm_filter_land_cells(X)
fits  <- hm_fit_marginals(X_land)
pit   <- hm_pit_transform(X_land, fits)

cop_c <- hm_fit_copula(pit$U, type = "cvine")
cop_d <- hm_fit_copula(pit$U, type = "dvine")
cop_g <- hm_fit_copula(pit$U, type = "gaussian")

## End(Not run)
```

```
hm_fit_correlation_model
```

Fit a parametric spatial correlation model to the empirical correlogram

Description

Fits Matérn, Exponential, Gaussian, and/or Spherical covariance families to the correlogram from [`hm_empirical_correlogram()`] by weighted least squares (Eq. 6–7 of Clavijo Mesa et al., 2026, SF paper). Selects the best family by RMSE, matching Table 1 of that paper.

Usage

```
hm_fit_correlation_model(
  corg,
  families = c("matern", "exponential", "gaussian", "spherical"),
  max_dist = NULL
)
```

Arguments

corg	data.frame from [hm_empirical_correlogram()].
families	Covariance families to fit. Any subset of c("matern", "exponential", "gaussian", "spherical"). Defaults to all four.
max_dist	Maximum distance in km to include. Defaults to the full correlogram range.

Value

An hm_corrmodel list with best_family, best_params, best_rmse, all_fits, and corg.

References

Clavijo Mesa, M.V., Broggi, M., Di Maio, F. & Zio, E. (2026). *International Journal of Disaster Risk Reduction*, 141, 106172.

See Also

[hm_empirical_correlogram()], [hm_simulate_sf_kle()]

Examples

```
## Not run:
corg <- hm_empirical_correlogram(tau, D)
model <- hm_fit_correlation_model(corg)
model$best_family
model$all_fits

## End(Not run)
```

hm_fit_marginals	<i>Fit marginal distributions to each grid cell</i>
------------------	---

Description

Fits candidate parametric distributions to each column of X by maximum likelihood and selects the best fit using AIC or BIC, following the methodology in Clavijo Mesa et al. (2026).

Usage

```
hm_fit_marginals(X, dists = .hm_supported_dists, criterion = "bic")
```

Arguments

X	A numeric matrix ($T \times N$) from [hm_to_matrix()]. All values must be strictly positive.
dists	Candidate families. Any subset of c("weibull", "gamma", "lnorm", "gumbel", "tnorm", "tlaplace").
criterion	Selection criterion: "bic" (default) or "aic".

Value

A data.frame with one row per cell and columns cell_id, best_dist, best_dist_label, params, loglik, aic, bic, n_obs, n_failed. The attribute "fits_full" stores raw per-cell fit results for use in [hm_marginal_gof()].

See Also

[hm_marginal_gof()], [hm_pit_transform()]

hm_get_grid_geometry	<i>Extract grid geometry</i>
----------------------	------------------------------

Description

Computes the bounding box, grid spacing, and cell count from the coordinate table and stores them in x\$grid.

Usage

```
hm_get_grid_geometry(x)
```

Arguments

x An hm_hazard object after [hm_standardize_coords()].

Value

The same object with a new \$grid element containing nx, ny, dx, dy, bbox, n_cells, and grid_type.

See Also

[hm_standardize_coords()]

hm_marginal_gof	<i>Goodness-of-fit diagnostics for a single grid cell</i>
-----------------	---

Description

Returns the KS statistic and QQ data for the best-fitting distribution at a chosen cell. The KS test is a complementary diagnostic — distribution selection is done by AIC/BIC in [hm_fit_marginals()].

Usage

```
hm_marginal_gof(X, fits, cell_id)
```

Arguments

<code>X</code>	Numeric matrix passed to <code>[hm_fit_marginals()]</code> .
<code>fits</code>	data.frame from <code>[hm_fit_marginals()]</code> .
<code>cell_id</code>	Column index to diagnose.

Value

A list with `cell_id`, `dist`, `dist_label`, `params`, `ks_statistic`, `ks_pvalue`, `qq`, and `n_obs`.

See Also

`[hm_fit_marginals()]`, `[hm_pit_transform()]`

hm_pit_transform	<i>Apply the Probability Integral Transform</i>
------------------	---

Description

Transforms X to uniform margins using each cell's fitted CDF, then optionally applies the probit transform to obtain centred Gaussian scores. Implements Equations (3)–(4) from Clavijo Mesa et al. (2026, SF paper).

Usage

```
hm_pit_transform(X, fits, gaussian = TRUE)
```

Arguments

<code>X</code>	Numeric matrix ($T \times N$) from <code>[hm_to_matrix()]</code> .
<code>fits</code>	data.frame from <code>[hm_fit_marginals()]</code> .
<code>gaussian</code>	If TRUE (default), also returns centred Gaussian scores $Z = \Phi^{-1}(U)$.

Value

A list with `U` (uniform matrix), `Z` (Gaussian scores or NULL), `n_cells_ok`, and `n_cells_skipped`.

See Also

`[hm_fit_marginals()]`, `[hm_marginal_gof()]`

hm_plot_best_dist	<i>Plot best-fitting marginal distribution by grid cell</i>
-------------------	---

Description

Maps each cell by the marginal family selected by [hm_fit_marginals()]. Reproduces Fig. 6 of Clavijo Mesa et al. (2026).

Usage

```
hm_plot_best_dist(
  x,
  fits,
  bbox = NULL,
  title = NULL,
  show_map = TRUE,
  palette = NULL,
  coord = "fixed"
)
```

Arguments

x	An hm_hazard object after [hm_standardize_coords()].
fits	The data.frame returned by [hm_fit_marginals()].
bbox	Optional named numeric vector with lon_min, lon_max, lat_min, lat_max.
title	Optional plot title.
show_map	Logical. Add world map background (requires maps).
palette	Optional named character vector mapping distribution labels to colours. Names must match the values in 'fits\$best_dist_label' (e.g. "Weibull", "Gamma", "Lognormal", "Gumbel", "Zero-trunc. Gaussian", "Zero-trunc. Laplace", "No fit"). If 'NULL' (default), a built-in muted palette is used.
coord	Coordinate display method. Either "fixed" or "quickmap".

Value

A 'ggplot' object.

See Also

[hm_fit_marginals()], [hm_plot_marginal_fit()], [hm_plot_dist_frequency()]

Examples

```
## Not run:
x      <- hm_read_netcdf(f, var = "i10fg")
x      <- hm_standardize_coords(x)
x      <- hm_decode_time(x)
x_ext  <- hm_select_extreme_events(x, threshold = 25)
X      <- hm_to_matrix(x_ext)
fits   <- hm_fit_marginals(X)

hm_plot_best_dist(x_ext, fits)

## End(Not run)
```

hm_plot_correlogram	<i>Plot the empirical spatial correlogram</i>
---------------------	---

Description

Draws the empirical correlogram produced by [hm_empirical_correlogram()]: average Kendall $\hat{\tau}$ as a function of inter-site distance, with point size proportional to the number of cell pairs in each bin. Reproduces the style of Fig. 8 in Clavijo Mesa et al. (2026, SF paper).

Usage

```
hm_plot_correlogram(
  corg,
  title = NULL,
  colour = "#2166AC",
  show_points = TRUE,
  show_zero = TRUE,
  ylim = NULL
)
```

Arguments

corg	A data.frame returned by [hm_empirical_correlogram()], with columns ‘bin_center’, ‘mean_tau’, and ‘n_pairs’.
title	Optional plot title.
colour	Line and point colour. Defaults to “#2166AC” (steel blue).
show_points	Logical. If ‘TRUE’ (default), draws points at each bin centre sized by the number of pairs.
show_zero	Logical. If ‘TRUE’ (default), adds a horizontal dashed line at $\tau = 0$.
ylim	Optional numeric vector of length 2 for the y-axis range. If ‘NULL’ (default), the range is set automatically.

Details

A horizontal dashed reference line is drawn at $\tau = 0$ to help identify the distance at which spatial dependence becomes negligible. Point size is scaled by 'sqrt(n_pairs)' so bins with more pairs are visually more prominent without dominating the plot.

Value

A 'ggplot' object.

References

Clavijo Mesa, M.V., Broggi, M., Di Maio, F. & Zio, E. (2026). Inoperability assessment of inter-dependent critical infrastructures exposed to natural hazards considering climate change. *International Journal of Disaster Risk Reduction*, 141, 106172.

See Also

[hm_empirical_correlogram()], [hm_empirical_kendall()], [hm_distance_matrix()]

Examples

```
## Not run:
X_land <- hm_filter_land_cells(X)
fits <- hm_fit_marginals(X_land)
pit <- hm_pit_transform(X_land, fits)
tau <- hm_empirical_kendall(pit$Z)
D <- hm_distance_matrix(attr(X_land, "coords"))
corg <- hm_empirical_correlogram(tau, D)

hm_plot_correlogram(corg,
  title = "Empirical correlogram - Copernicus wind gust")

## End(Not run)
```

hm_plot_dist_frequency

Plot frequency of best-fitting marginal distribution families

Description

Draws a bar chart showing how many grid cells were assigned each distribution family by [hm_fit_marginals()]. Reproduces the style of Fig. A1 in Clavijo Mesa et al. (2026, Appendix A).

Usage

```
hm_plot_dist_frequency(
  fits,
  title = NULL,
  bar_fill = NULL,
  bar_colour = "white",
  show_pct = TRUE
)
```

Arguments

<code>fits</code>	The data.frame returned by [hm_fit_marginals()].
<code>title</code>	Optional plot title.
<code>bar_fill</code>	Bar fill colour. If 'NULL' (default), each bar is coloured by distribution family using the same palette as [hm_plot_best_dist()].
<code>bar_colour</code>	Bar border colour.
<code>show_pct</code>	Logical. If 'TRUE', adds percentage labels above each bar.

Value

A 'ggplot' object.

See Also

[hm_fit_marginals()], [hm_plot_best_dist()], [hm_plot_marginal_fit()]

Examples

```
## Not run:
fits <- hm_fit_marginals(X)
hm_plot_dist_frequency(fits)

## End(Not run)
```

hm_plot_exceedance	<i>Plot threshold exceedances</i>
--------------------	-----------------------------------

Description

Maps exceedance count or frequency at each grid cell. Cells are drawn as filled polygons for both regular and rotated grids.

Usage

```
hm_plot_exceedance(
  x,
  threshold,
  metric = "count",
  dataset = "auto",
  bbox = NULL,
  title = NULL,
  show_map = TRUE,
  show_grid = TRUE,
  grid_res = NULL,
  colours = c("white", "gold", "orange", "firebrick"),
  grid_colour = "grey55",
  grid_linewidth = 0.25,
  cell_alpha = 0.9,
  legend_title = NULL,
  coord = "fixed"
)
```

Arguments

<code>x</code>	An <code>hm_hazard</code> object after <code>[hm_standardize_coords()]</code> .
<code>threshold</code>	Numeric threshold defining exceedances.
<code>metric</code>	"count" (default) or "frequency".
<code>dataset</code>	Grid type: "auto", "copernicus", "eurocordex", "regular", or "rotated".
<code>bbox</code>	Optional named numeric vector with <code>lon_min</code> , <code>lon_max</code> , <code>lat_min</code> , <code>lat_max</code> .
<code>title</code>	Optional plot title.
<code>show_map</code>	Logical. Add world map background (requires maps).
<code>show_grid</code>	Logical. Draw cell borders.
<code>grid_res</code>	Grid resolution in degrees (regular grids only).
<code>colours</code>	Colour ramp for filled cells.
<code>grid_colour</code>	Cell border colour.
<code>grid_linewidth</code>	Cell border width.
<code>cell_alpha</code>	Cell transparency.
<code>legend_title</code>	Optional legend title.
<code>coord</code>	"fixed" or "quickmap".

Value

A ggplot object.

`hm_plot_exceedance_time`*Plot extreme-event days over time*

Description

Bar chart of extreme-event days aggregated by year, two-year, five-year or decade periods. A day is counted once when at least one cell exceeds threshold.

Usage

```
hm_plot_exceedance_time(  
  x,  
  threshold,  
  by = "year",  
  title = NULL,  
  xlab = NULL,  
  ylab = NULL,  
  bar_fill = "grey70",  
  bar_colour = "grey30"  
)
```

Arguments

<code>x</code>	An <code>hm_hazard</code> object after <code>[hm_standardize_coords()]</code> .
<code>threshold</code>	Numeric threshold defining exceedances.
<code>by</code>	Aggregation period: "year", "2_years", "5_years", or "decade".
<code>title</code>	Optional plot title.
<code>xlab</code>	Optional x-axis label.
<code>ylab</code>	Optional y-axis label.
<code>bar_fill</code>	Bar fill colour.
<code>bar_colour</code>	Bar border colour.

Value

A `ggplot` object.

hm_plot_marginal_fit *Plot marginal fit diagnostics for a single grid cell*

Description

Produces a three-panel diagnostic figure for the best-fitting marginal distribution at a chosen grid cell: (1) a histogram of the observed values with the fitted PDF overlaid, (2) the empirical vs fitted CDF, and (3) a quantile-quantile plot. Reproduces the style of Fig. 7 and Appendix B (Fig. B1) in Clavijo Mesa et al. (2026).

Usage

```
hm_plot_marginal_fit(
  X,
  fits,
  cell_id,
  title = NULL,
  x = NULL,
  n_bins = 30,
  colour_fit = "firebrick"
)
```

Arguments

X	A numeric matrix (same one passed to [hm_fit_marginals()]).
fits	The data.frame returned by [hm_fit_marginals()].
cell_id	Integer. The cell to diagnose (column index of X).
title	Optional overall plot title. Defaults to the cell coordinates when ‘x’ is supplied, or to the cell index otherwise.
x	Optional ‘hm_hazard’ object after [hm_standardize_coords()]. When supplied, the cell’s geographic coordinates are shown in the title.
n_bins	Number of histogram bins.
colour_fit	Colour used for the fitted PDF and CDF lines.

Value

A ‘ggplot’ object (three panels arranged with [ggplot2::facet_wrap()] on a long-format data frame).

See Also

[hm_fit_marginals()], [hm_marginal_gof()], [hm_plot_best_dist()], [hm_plot_dist_frequency()]

Examples

```
## Not run:
fits <- hm_fit_marginals(X)
hm_plot_marginal_fit(X, fits, cell_id = 1, x = x_ext)

## End(Not run)
```

hm_plot_scenario	<i>Plot one simulated hazard scenario on the spatial grid</i>
------------------	---

Description

Maps a single row of a scenario matrix produced by [hm_simulate_copula()] or [hm_simulate_sf_kle()] onto the spatial grid. Useful for visually inspecting the spatial coherence of generated pseudoscenarios.

Usage

```
hm_plot_scenario(
  scenarios,
  coords,
  scenario_id = 1L,
  title = NULL,
  show_map = TRUE,
  legend_title = "m/s",
  colours = c("white", "#7BAFD4", "#2166AC", "#1A1A2E"),
  coord = "fixed"
)
```

Arguments

scenarios	A numeric matrix ($S \times N$) returned by [hm_simulate_copula()] or [hm_simulate_sf_kle()].
coords	A data.frame with lat, lon, and optionally rlon/rlat columns. Typically attr(X_land, "coords") from [hm_filter_land_cells()]. Must have N rows.
scenario_id	Integer. Row index of the scenario to plot. Defaults to 1L.
title	Optional plot title.
show_map	Logical. Add world map background (requires maps).
legend_title	Optional legend title. Defaults to "m/s".
colours	Colour ramp for cell values.
coord	"fixed" or "quickmap".

Value

A ggplot object.

See Also

[hm_simulate_copula()], [hm_simulate_sf_kle()], [hm_plot_exceedance()]

Examples

```
## Not run:
X_land <- hm_filter_land_cells(X)
fits <- hm_fit_marginals(X_land)
pit <- hm_pit_transform(X_land, fits)
cop <- hm_fit_copula(pit$U, type = "cvine")
scenarios <- hm_simulate_copula(cop, fits, n_scenarios = 100)

hm_plot_scenario(scenarios, attr(X_land, "coords"), scenario_id = 1L)

## End(Not run)
```

hm_plot_spatial_domain

Plot spatial domain grid

Description

Plots the spatial grid of a hazard dataset. Detects regular (Copernicus/ERA5) and rotated (EURO-CORDEX) grids automatically or from dataset.

Usage

```
hm_plot_spatial_domain(
  x,
  dataset = "auto",
  bbox = NULL,
  title = NULL,
  show_map = TRUE,
  show_points = FALSE,
  grid_res = NULL,
  grid_colour = "grey55",
  grid_linewidth = 0.35,
  point_size = 0.5,
  coord = "fixed"
)
```

Arguments

x	An hm_hazard object after [hm_standardize_coords()].
dataset	Grid type: "auto", "copernicus", "eurocordex", "regular", or "rotated".
bbox	Optional named numeric vector with lon_min, lon_max, lat_min, lat_max.

title	Optional plot title.
show_map	Logical. Add world map background (requires maps).
show_points	Logical. Add grid-cell centre points.
grid_res	Grid resolution in degrees (regular grids only).
grid_colour	Grid-line colour.
grid_linewidth	Grid-line width.
point_size	Point size when show_points = TRUE.
coord	"fixed" or "quickmap".

Value

A ggplot object.

hm_read_netcdf	<i>Read a hazard NetCDF dataset</i>
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Description

Reads a NetCDF file containing a hazard variable on a spatial grid (regular or rotated) and returns an 'hm_hazard' object. CRS is not required.

Usage

```
hm_read_netcdf(file, var = NULL)
```

Arguments

file	Path to a NetCDF file.
var	Name of the hazard variable. If NULL and the file contains exactly one variable, it is selected automatically.

Details

Supports CF-convention NetCDF files with regular grids (e.g. Copernicus, ERA5) and rotated or curvilinear grids (e.g. EURO-CORDEX). Coordinate names lat/lon and latitude/longitude are detected automatically.

Value

An object of class hm_hazard.

See Also

[hm_standardize_coords()], [hm_decode_time()]

 hm_select_extreme_events

Select extreme-event days by threshold

Description

Retains only the time steps in which at least one grid cell reaches or exceeds threshold. Call after [hm_decode_time()] and before [hm_to_matrix()].

Usage

```
hm_select_extreme_events(x, threshold)
```

Arguments

x	An hm_hazard object after [hm_standardize_coords()] and [hm_decode_time()].
threshold	A single finite numeric value.

Value

The same object with \$data and \$time restricted to extreme-event days. \$meta\$filter records the threshold and day counts for reproducibility.

See Also

[hm_summarise_events()]

 hm_simulate_copula

Simulate spatially coherent hazard scenarios from a fitted copula

Description

Draws n_scenarios realisations from a fitted copula and back-transforms to physical units via the inverse marginal CDFs. Implements Eq. 7–8 of Clavijo Mesa et al. (2026).

Usage

```
hm_simulate_copula(copula, fits, n_scenarios = 1000L, seed = NULL)
```

Arguments

copula	An hm_copula object from [hm_fit_copula()].
fits	data.frame from [hm_fit_marginals()] for the same land cells used to fit copula.
n_scenarios	Number of scenarios. Defaults to 1000.
seed	Optional integer random seed.

Details

Vine copulas are sampled via `rvinecopulib::rvinecop()`. The Gaussian copula uses `MASS::mvrnorm()` followed by the standard normal CDF. Both packages are listed in Suggests.

Value

A numeric matrix ($S \times N$) of simulated hazard intensities. Attributes `type`, `n_scenarios`, and `n_cells` are attached.

References

Clavijo Mesa, M.V., Di Maio, F. & Zio, E. (2026). *Reliability Engineering & System Safety*, 275, 112830.

See Also

`[hm_fit_copula()]`, `[hm_fit_marginals()]`

Examples

```
## Not run:
cop      <- hm_fit_copula(pit$U, type = "cvine")
scenarios <- hm_simulate_copula(cop, fits, n_scenarios = 1000)
dim(scenarios)
range(scenarios, na.rm = TRUE)

## End(Not run)
```

hm_simulate_sf_kle	Simulate hazard scenarios via Karhunen-Loève Expansion
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Description

Generates `n_scenarios` synthetic hazard fields from the KLE of the fitted covariance model, following Eq. 8–11 of Clavijo Mesa et al. (2026, SF paper): build $\bar{C}$, eigen-decompose and truncate to `var_retain` variance, sample KLE coefficients, back-transform via Φ and the inverse marginal CDFs.

Usage

```
hm_simulate_sf_kle(
  corrmmodel,
  D,
  fits,
  n_scenarios = 1000L,
  var_retain = 0.95,
  seed = NULL
)
```

Arguments

corrmodel	An hm_corrmodel from [hm_fit_correlation_model()].
D	Symmetric distance matrix in km from [hm_distance_matrix()]. Must have nrow(fits) rows.
fits	data.frame from [hm_fit_marginals()] for the same land cells.
n_scenarios	Number of synthetic scenarios. Defaults to 1000.
var_retain	Variance fraction retained in KLE truncation. Defaults to 0.95.
seed	Optional integer random seed.

Value

A numeric matrix ($S \times N$) of simulated hazard intensities. Attributes family, k_modes, var_retain, and var_explained are attached.

References

Clavijo Mesa, M.V., Broggi, M., Di Maio, F. & Zio, E. (2026). *International Journal of Disaster Risk Reduction*, 141, 106172.

See Also

[hm_fit_correlation_model()], [hm_fit_marginals()]

Examples

```
## Not run:
model      <- hm_fit_correlation_model(corg)
scenarios <- hm_simulate_sf_kle(model, D, fits,
                               n_scenarios = 1000, seed = 42)

attr(scenarios, "k_modes")
attr(scenarios, "var_explained")

## End(Not run)
```

hm_standardize_coords *Standardize spatial coordinates*

Description

Converts raw NetCDF coordinates into a canonical data.frame with one row per grid cell.

Usage

```
hm_standardize_coords(x)
```

Arguments

x An hm_hazard object returned by [hm_read_netcdf()].

Details

Regular grids supply lat and lon as 1D vectors; all combinations are expanded with `expand.grid()`. Rotated or curvilinear grids supply lat and lon as 2D matrices, with rotated indices appended when available.

Value

The same object with `x$coords` replaced by a `data.frame` containing `cell_id`, `lat`, and `lon`.

See Also

[hm_read_netcdf()], [hm_get_grid_geometry()]

hm_summarise_events	<i>Summarise retained extreme-event days</i>
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Description

Returns a `data.frame` with one row per time step: `date`, number of cells that met the threshold, and domain-wide maximum value.

Usage

```
hm_summarise_events(x, threshold = NULL)
```

Arguments

x An hm_hazard object, typically from [hm_select_extreme_events()].

threshold Threshold used to count exceeding cells. If NULL, read from `x$meta$filter$threshold`.

Value

A `data.frame` with columns `date`, `n_cells_exceeded`, and `max_value`.

See Also

[hm_select_extreme_events()]

hm_to_matrix	<i>Convert hazard array to a time-by-cell matrix</i>
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Description

Reshapes `x$data` into a $T \times N$ numeric matrix where rows are time steps and columns are grid cells.

Usage

```
hm_to_matrix(x)
```

Arguments

`x` An `hm_hazard` object after `[hm_standardize_coords()]` and `[hm_decode_time()]`.

Value

A numeric matrix with attributes `time` and `coords`.

See Also

`[hm_decode_time()]`, `[hm_standardize_coords()]`

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