Package 'openairmaps'

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Type Package

Title Create Maps of Air Pollution Data

Version 0.7.0

Description Combine the air quality data analysis methods of 'openair' with the JavaScript 'Leaflet' (<https://leafletjs.com/>) library. Functionality includes plotting site maps, ``directional analysis'' figures such as polar plots, and air mass trajectories.

License GPL (>= 3)

URL https://davidcarslaw.github.io/openairmaps/

Depends R (>= 3.2.0)

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R topics documented:

`addPolarMarkers` *Add polar markers to leaflet map*

Description

This function is similar (but not identical to) the `leaflet::addMarkers()` and `leaflet::addCircleMarkers()` functions in `leaflet`, which allows users to add `openair` directional analysis plots to any leaflet map and have more control over groups and layerIds than in "all-in-one" functions like `polarMap()`.

Usage

```
addPolarMarkers(
  map,
  data,
  pollutant,
  fun = openair::polarPlot,
  lng = NULL,
  lat = NULL,
  layerId = NULL,
  group = NULL,
  popup = NULL,
  label = NULL,
  key = FALSE,
  d.icon = 200,
  d.fig = 3.5,
```

```
  ...
)

addPolarDiffMarkers(
  map,
  before,
  after,
  pollutant,
  lng = NULL,
  lat = NULL,
  layerId = NULL,
  group = NULL,
  popup = NULL,
  label = NULL,
  key = FALSE,
  d.icon = 200,
  d.fig = 3.5,
  ...
)
```

Arguments

map	a map widget object created from leaflet()
data	A data frame. The data frame must contain the data to plot your choice of openair directional analysis plot, which includes wind speed (ws), wind direction (wd), and the column representing the concentration of a pollutant. In addition, data must include a decimal latitude and longitude.
pollutant	The name of the pollutant to be plot. Note that, if fun = openair::windRose, you must set pollutant = "ws".
fun	An openair directional analysis plotting function. Supported functions include openair::polarPlot() (the default), openair::polarAnnulus(), openair::polarFreq(), openair::percentileRose(), openair::pollutionRose() and openair::windRose(). For openair::polarDiff(), use addPolarDiffMarkers().
lng	The decimal longitude.
lat	The decimal latitude.
layerId	the layer id
group	the name of the group the newly created layers should belong to (for clearGroup and addLayersControl purposes). Human-friendly group names are permitted–they need not be short, identifier-style names. Any number of layers and even different types of layers (e.g. markers and polygons) can share the same group name.
popup	A column of data to be used as a popup.
label	A column of data to be used as a label.
key	Should a key for each marker be drawn? Default is FALSE.

d.icon	The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.
d.fig	The diameter of the plots to be produced using openair in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.
...	Other arguments for the plotting function (e.g. period for openair::polarAnnulus()).
before	A data frame that represents the "before" case. See polarPlot() for details of different input requirements.
after	A data frame that represents the "after" case. See polarPlot() for details of different input requirements.

Value

A leaflet object.

Functions

- addPolarMarkers(): Add any one-table polar marker (e.g., openair::polarPlot())
- addPolarDiffMarkers(): Add the two-table openair::polarDiff() marker.

Examples

```
## Not run:
library(leaflet)
library(openair)

# different types of polar plot on one map
leaflet() %>%
  addTiles() %>%
  addPolarMarkers(
    data = polar_data,
    pollutant = "ws",
    fun = windRose,
    group = "Wind Rose"
  ) %>%
  addPolarMarkers(
    data = polar_data,
    pollutant = "nox",
    fun = polarPlot,
    group = "Polar Plot"
  ) %>%
  addLayersControl(
    baseGroups = c("Wind Rose", "Polar Plot")
  )

# use of polar diff
leaflet() %>%
  addTiles() %>%
  addPolarDiffMarkers(
```

```
  before = polar_data,
  after = dplyr::mutate(polar_data, nox = jitter(nox, 5)),
  pollutant = "nox"
)

## End(Not run)
```

---

addTrajPaths *Add trajectory paths to leaflet map*

Description

This function is similar (but not identical to) the `leaflet::addMarkers()` function in `leaflet`, which allows users to add trajectory paths to any leaflet map and have more control over groups and layerIds than in "all-in-one" functions like `trajMap()`.

Usage

```
addTrajPaths(
  map,
  lng = "lon",
  lat = "lat",
  layerId = NULL,
  group = NULL,
  data,
  npoints = 12,
  ...
)
```

Arguments

`map`	a map widget object created from `leaflet::leaflet()`.
`lng`	The decimal longitude.
`lat`	The decimal latitude.
`layerId`	The layer id.
`group`	the name of the group the newly created layers should belong to (for `leaflet::clearGroup()` and `leaflet::addLayersControl()` purposes). Human-friendly group names are permitted–they need not be short, identifier-style names. Any number of layers and even different types of layers (e.g. markers and polygons) can share the same group name.
`data`	Data frame, the result of importing a trajectory file using `openair::importTraj()`.
`npoints`	A dot is placed every `npoints` along each full trajectory. For hourly back trajectories points are plotted every `npoints` hours. This helps to understand where the air masses were at particular times and get a feel for the speed of the air (points closer together correspond to slower moving air masses). Defaults to 12.

... Other arguments to pass to both `leaflet::addCircleMarkers()` and `leaflet::addPolylines()`. If you use the `color` argument, it is important to ensure the vector you supply is of length one to avoid issues with `leaflet::addPolylines()` (i.e., use `color = ~ pal(nox)[1]`). Note that `opacity` controls the opacity of the lines and `fillOpacity` the opacity of the markers.

Details

`addTrajPaths()` can be a powerful way of quickly plotting trajectories on a leaflet map, but users should take some care due to any additional arguments being passed to both `leaflet::addCircleMarkers()` and `leaflet::addPolylines()`. In particular, users should be weary of the use of the `color` argument. Specifically, if `color` is passed a vector of length greater than one, multiple polylines will be drawn on top of one another. At best this will affect opacity, but at worst this will significantly impact the performance of R and the final leaflet map.

To mitigate this, please ensure that any vector passed to `color` is of length one. This is simple if you want the whole path to be the same colour, but more difficult if you want to colour by a pollutant, for example. The easiest way to achieve this is to write a for loop or use another iterative approach (e.g. the `purrr` package) to add one path per arrival date. An example of this is provided in the Examples.

Value

A leaflet object.

Examples

```
## Not run:
library(leaflet)
library(openairmaps)

pal <- colorNumeric(palette = "viridis", domain = traj_data$nox)

map <- leaflet() %>%
  addTiles()

for (i in seq(length(unique(traj_data$date)))) {
  data <- dplyr::filter(traj_data, date == unique(traj_data$date)[i])

  map <- map %>%
    addTrajPaths(
      data = data,
      color = pal(data$nox)[1]
    )
}

map

## End(Not run)
```

annulusMap *Polar annulus plots on interactive leaflet maps*

Description

annulusMap() creates a leaflet map using polar annulus plots as markers. Any number of pollutants can be specified using the pollutant argument, and multiple layers of markers can be added and toggled between using control.

Usage

```
annulusMap(
  data,
  pollutant = NULL,
  period = "hour",
  limits = NULL,
  latitude = NULL,
  longitude = NULL,
  control = NULL,
  popup = NULL,
  label = NULL,
  provider = "OpenStreetMap",
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  draw.legend = TRUE,
  collapse.control = FALSE,
  d.icon = 200,
  d.fig = 3.5,
  type = NULL,
  ...
)
```

Arguments

data	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (ws), wind direction (wd), and the column representing the concentration of a pollutant. In addition, data must include a decimal latitude and longitude.
pollutant	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they can be toggled between using a "layer control" interface.
period	This determines the temporal period to consider. Options are "hour" (the default, to plot diurnal variations), "season" to plot variation throughout the year, "weekday" to plot day of the week variation and "trend" to plot the trend by wind direction.

limits — By default, each individual polar marker has its own colour scale. The limits argument will force all markers to use the same colour scale. The limits are set in the form c(lower, upper), so limits = c(0, 100) would force the plot limits to span 0-100.

latitude, longitude — The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).

control — Column to be used for splitting the input data into different groups which can be selected between using a "layer control" interface. Appropriate columns could be those added by openair::cutData() or openair::splitByDate(). control cannot be used if multiple pollutant columns have been provided.

popup — Column to be used as the HTML content for marker popups. Popups may be useful to show information about the individual sites (e.g., site names, codes, types, etc.).

label — Column to be used as the HTML content for hover-over labels. Labels are useful for the same reasons as popups, though are typically shorter.

provider — The base map(s) to be used. See http://leaflet-extras.github.io/leaflet-providers/preview/ for a list of all base maps that can be used. If multiple base maps are provided, they can be toggled between using a "layer control" interface.

cols — The colours used for plotting. See openair::openColours() for more information.

alpha — The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

key — Should a key for each marker be drawn? Default is FALSE.

draw.legend — When limits are specified, should a shared legend be created at the side of the map? Default is TRUE.

collapse.control — Should the "layer control" interface be collapsed? Defaults to FALSE.

d.icon — The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

d.fig — The diameter of the plots to be produced using openair in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

type — Deprecated. Please use label and/or popup to label different sites.

... — Arguments passed on to openair::polarAnnulus

resolution Two plot resolutions can be set: “normal” and “fine” (the default).

local.tz Should the results be calculated in local time that includes a treatment of daylight savings time (DST)? The default is not to consider DST issues, provided the data were imported without a DST offset. Emissions activity tends to occur at local time e.g. rush hour is at 8 am every day. When the clocks go forward in spring, the emissions are effectively released into the atmosphere typically 1 hour earlier during the summertime

i.e. when DST applies. When plotting diurnal profiles, this has the effect of "smearing-out" the concentrations. Sometimes, a useful approach is to express time as local time. This correction tends to produce better-defined diurnal profiles of concentration (or other variables) and allows a better comparison to be made with emissions/activity data. If set to FALSE then GMT is used. Examples of usage include local.tz = "Europe/London", local.tz = "America/New_York". See cutData and import for more details.

statistic The statistic that should be applied to each wind speed/direction bin. Can be "mean" (default), "median", "max" (maximum), "frequency". "stdev" (standard deviation), "weighted.mean" or "cpf" (Conditional Probability Function). Because of the smoothing involved, the colour scale for some of these statistics is only to provide an indication of overall pattern and should not be interpreted in concentration units e.g. for statistic = "weighted.mean" where the bin mean is multiplied by the bin frequency and divided by the total frequency. In many cases using polarFreq will be better. Setting statistic = "weighted.mean" can be useful because it provides an indication of the concentration * frequency of occurrence and will highlight the wind speed/direction conditions that dominate the overall mean.

percentile If statistic = "percentile" or statistic = "cpf" then percentile is used, expressed from 0 to 100. Note that the percentile value is calculated in the wind speed, wind direction 'bins'. For this reason it can also be useful to set min.bin to ensure there are a sufficient number of points available to estimate a percentile. See quantile for more details of how percentiles are calculated.

width The width of the annulus; can be "normal" (the default), "thin" or "fat".

min.bin The minimum number of points allowed in a wind speed/wind direction bin. The default is 1. A value of two requires at least 2 valid records in each bin an so on; bins with less than 2 valid records are set to NA. Care should be taken when using a value > 1 because of the risk of removing real data points. It is recommended to consider your data with care. Also, the polarFreq function can be of use in such circumstances.

exclude.missing Setting this option to TRUE (the default) removes points from the plot that are too far from the original data. The smoothing routines will produce predictions at points where no data exist i.e. they predict. By removing the points too far from the original data produces a plot where it is clear where the original data lie. If set to FALSE missing data will be interpolated.

date.pad For type = "trend" (default), date.pad = TRUE will pad-out missing data to the beginning of the first year and the end of the last year. The purpose is to ensure that the trend plot begins and ends at the beginning or end of year.

force.positive The default is TRUE. Sometimes if smoothing data with steep gradients it is possible for predicted values to be negative. force.positive = TRUE ensures that predictions remain positive. This is useful for several reasons. First, with lots of missing data more interpolation is needed and this can result in artefacts because the predictions are too far from the origi-

nal data. Second, if it is known beforehand that the data are all positive, then this option carries that assumption through to the prediction. The only likely time where setting `force.positive = FALSE` would be if background concentrations were first subtracted resulting in data that is legitimately negative. For the vast majority of situations it is expected that the user will not need to alter the default option.

`k` The smoothing value supplied to `gam` for the temporal and wind direction components, respectively. In some cases e.g. a trend plot with less than 1-year of data the smoothing with the default values may become too noisy and affected more by outliers. Choosing a lower value of `k` (say 10) may help produce a better plot.

`normalise` If `TRUE` concentrations are normalised by dividing by their mean value. This is done *after* fitting the smooth surface. This option is particularly useful if one is interested in the patterns of concentrations for several pollutants on different scales e.g. NOx and CO. Often useful if more than one `pollutant` is chosen.

`key.header` Adds additional text/labels to the scale key. For example, passing the options `key.header = "header"`, `key.footer = "footer1"` adds addition text above and below the scale key. These arguments are passed to `drawOpenKey` via `quickText`, applying the `auto.text` argument, to handle formatting.

`key.footer` see `key.footer`.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include `"top"`, `"right"`, `"bottom"` and `"left"`.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

Value

A leaflet object.

See Also

the original `openair::polarAnnulus()`

`annulusMapStatic()` for the static ggmap equivalent of `annulusMap()`

Other interactive directional analysis maps: `diffMap()`, `freqMap()`, `percentileMap()`, `polarMap()`, `pollroseMap()`, `windroseMap()`

Examples

```
## Not run:
annulusMap(polar_data,
  pollutant = "nox",
  period = "hour",
  provider = "Stamen.Toner"
)

## End(Not run)
```

annulusMapStatic *Bivariate polar plots on a static ggmap*

Description

annulusMapStatic() creates a ggplot2 map using polar annulus plots as markers. As this function returns a ggplot2 object, further customisation can be achieved using functions like ggplot2::theme() and ggplot2::guides().

Usage

```
annulusMapStatic(
  data,
  pollutant = NULL,
  period = "hour",
  facet = NULL,
  limits = NULL,
  latitude = NULL,
  longitude = NULL,
  zoom = 13,
  ggmap = NULL,
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  facet.nrow = NULL,
  d.icon = 150,
  d.fig = 3,
  ...
)
```

Arguments

data	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (ws), wind direction (wd), and the column representing the concentration of a pollutant. In addition, data must include a decimal latitude and longitude.
pollutant	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they will each form part of a separate panel.
period	This determines the temporal period to consider. Options are "hour" (the default, to plot diurnal variations), "season" to plot variation throughout the year, "weekday" to plot day of the week variation and "trend" to plot the trend by wind direction.
facet	Column to be used for splitting the input data into different panels. Appropriate columns could be those added by openair::cutData() or openair::splitByDate(). facet cannot be used if multiple pollutant columns have been provided.

limits — By default, each individual polar marker has its own colour scale. The limits argument will force all markers to use the same colour scale. The limits are set in the form c(lower, upper), so limits = c(0, 100) would force the plot limits to span 0-100.

latitude, longitude — The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).

zoom — The zoom level to use for the basemap, passed to ggmap::get_stamenmap(). Alternatively, the ggmap argument can be used for more precise control of the basemap.

ggmap — By default, openairmaps will try to estimate an appropriate bounding box for the input data and then run ggmap::get_stamenmap() to import a basemap. The ggmap argument allows users to provide their own ggmap object to override this, which allows for alternative bounding boxes, map types and colours.

cols — The colours used for plotting. See openair::openColours() for more information.

alpha — The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

key — Should a key for each marker be drawn? Default is FALSE.

facet.nrow — Passed to the nrow argument of ggplot2::facet_wrap().

d.icon — The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

d.fig — The diameter of the plots to be produced using openair in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

... — Arguments passed on to openair::polarAnnulus

resolution Two plot resolutions can be set: “normal” and “fine” (the default).

local.tz Should the results be calculated in local time that includes a treatment of daylight savings time (DST)? The default is not to consider DST issues, provided the data were imported without a DST offset. Emissions activity tends to occur at local time e.g. rush hour is at 8 am every day. When the clocks go forward in spring, the emissions are effectively released into the atmosphere typically 1 hour earlier during the summertime i.e. when DST applies. When plotting diurnal profiles, this has the effect of “smearing-out” the concentrations. Sometimes, a useful approach is to express time as local time. This correction tends to produce better-defined diurnal profiles of concentration (or other variables) and allows a better comparison to be made with emissions/activity data. If set to FALSE then GMT is used. Examples of usage include local.tz = "Europe/London", local.tz = "America/New_York". See cutData and import for more details.

type type determines how the data are split i.e. conditioned, and then plotted. The default is will produce a single plot using the entire data. Type can

be one of the built-in types as detailed in `cutData` e.g. "season", "year", "weekday" and so on. For example, `type = "season"` will produce four plots — one for each season.

It is also possible to choose `type` as another variable in the data frame. If that variable is numeric, then the data will be split into four quantiles (if possible) and labelled accordingly. If type is an existing character or factor variable, then those categories/levels will be used directly. This offers great flexibility for understanding the variation of different variables and how they depend on one another.

Type can be up length two e.g. `type = c("season", "site")` will produce a 2x2 plot split by season and site. The use of two types is mostly meant for situations where there are several sites. Note, when two types are provided the first forms the columns and the second the rows.

Also note that for the `polarAnnulus` function some type/period combinations are forbidden or make little sense. For example, `type = "season"` and `period = "trend"` (which would result in a plot with too many gaps in it for sensible smoothing), or `type = "weekday"` and `period = "weekday"`.

`statistic` The statistic that should be applied to each wind speed/direction bin. Can be "mean" (default), "median", "max" (maximum), "frequency". "stdev" (standard deviation), "weighted.mean" or "cpf" (Conditional Probability Function). Because of the smoothing involved, the colour scale for some of these statistics is only to provide an indication of overall pattern and should not be interpreted in concentration units e.g. for `statistic = "weighted.mean"` where the bin mean is multiplied by the bin frequency and divided by the total frequency. In many cases using `polarFreq` will be better. Setting `statistic = "weighted.mean"` can be useful because it provides an indication of the concentration * frequency of occurrence and will highlight the wind speed/direction conditions that dominate the overall mean.

`percentile` If `statistic = "percentile"` or `statistic = "cpf"` then `percentile` is used, expressed from 0 to 100. Note that the percentile value is calculated in the wind speed, wind direction 'bins'. For this reason it can also be useful to set `min.bin` to ensure there are a sufficient number of points available to estimate a percentile. See `quantile` for more details of how percentiles are calculated.

`width` The width of the annulus; can be "normal" (the default), "thin" or "fat".

`min.bin` The minimum number of points allowed in a wind speed/wind direction bin. The default is 1. A value of two requires at least 2 valid records in each bin an so on; bins with less than 2 valid records are set to NA. Care should be taken when using a value > 1 because of the risk of removing real data points. It is recommended to consider your data with care. Also, the `polarFreq` function can be of use in such circumstances.

`exclude.missing` Setting this option to `TRUE` (the default) removes points from the plot that are too far from the original data. The smoothing routines will produce predictions at points where no data exist i.e. they predict. By removing the points too far from the original data produces a plot where it is clear where the original data lie. If set to `FALSE` missing data will be interpolated.

`date.pad` For `type = "trend"` (default), `date.pad = TRUE` will pad-out missing data to the beginning of the first year and the end of the last year. The purpose is to ensure that the trend plot begins and ends at the beginning or end of year.

`force.positive` The default is `TRUE`. Sometimes if smoothing data with steep gradients it is possible for predicted values to be negative. `force.positive = TRUE` ensures that predictions remain positive. This is useful for several reasons. First, with lots of missing data more interpolation is needed and this can result in artefacts because the predictions are too far from the original data. Second, if it is known beforehand that the data are all positive, then this option carries that assumption through to the prediction. The only likely time where setting `force.positive = FALSE` would be if background concentrations were first subtracted resulting in data that is legitimately negative. For the vast majority of situations it is expected that the user will not need to alter the default option.

`k` The smoothing value supplied to `gam` for the temporal and wind direction components, respectively. In some cases e.g. a trend plot with less than 1-year of data the smoothing with the default values may become too noisy and affected more by outliers. Choosing a lower value of `k` (say 10) may help produce a better plot.

`normalise` If `TRUE` concentrations are normalised by dividing by their mean value. This is done *after* fitting the smooth surface. This option is particularly useful if one is interested in the patterns of concentrations for several pollutants on different scales e.g. NOx and CO. Often useful if more than one `pollutant` is chosen.

`key.header` Adds additional text/labels to the scale key. For example, passing the options `key.header = "header"`, `key.footer = "footer1"` adds addition text above and below the scale key. These arguments are passed to `drawOpenKey` via `quickText`, applying the `auto.text` argument, to handle formatting.

`key.footer` see `key.footer`.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include `"top"`, `"right"`, `"bottom"` and `"left"`.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

Value

a `ggplot2` plot with a `ggmap` basemap

Further customisation using ggplot2

As the outputs of the static directional analysis functions are `ggplot2` figures, further customisation is possible using functions such as `ggplot2::theme()`, `ggplot2::guides()` and `ggplot2::labs()`.

If multiple pollutants are specified, subscripting (e.g., the "x" in "NOx") is achieved using the ggtext package. Therefore if you choose to override the plot theme, it is recommended to use `[ggplot2::theme()]` and `[ggtext::element_markdown()]` to define the `strip.text` parameter.

When arguments like `limits`, `percentile` or `breaks` are defined, a legend is automatically added to the figure. Legends can be removed using `ggplot2::theme(legend.position = "none")`, or further customised using `ggplot2::guides()` and either `color = ggplot2::guide_colourbar()` for continuous legends or `fill = ggplot2::guide_legend()` for discrete legends.

See Also

the original `openair::polarAnnulus()`

`annulusMap()` for the interactive `leaflet` equivalent of `annulusMapStatic()`

Other static directional analysis maps: `diffMapStatic()`, `freqMapStatic()`, `percentileMapStatic()`, `polarMapStatic()`, `pollroseMapStatic()`, `windroseMapStatic()`

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buildPopup *Build a Complex Popup for a Leaflet Map*

Description

Group a dataframe together by latitude/longitude columns and create a HTML popup with user-defined columns. By default, the unique values of character columns are collapsed into comma-separated lists, numeric columns are averaged, and date columns are presented as a range. This function returns the input dataframe appended with a "popup" column, which can then be used in the popup argument of a function like `polarMap()`.

Usage

```
buildPopup(
  data,
  cols,
  latitude = NULL,
  longitude = NULL,
  names = NULL,
  control = NULL,
  fun.character = function(x) paste(unique(x), collapse = ", "),
  fun.numeric = function(x) signif(mean(x, na.rm = TRUE), 3),
 fun.dttm = function(x) paste(lubridate::floor_date(range(x, na.rm = TRUE), "day"),
    collapse = " to ")
)
```

Arguments

`data`	A data frame containing latitude and longitude information that will go on to be used in a function such as `polarMap()`.
`cols`	A character vector of column names, the data from which will appear in the popup.

`latitude, longitude`
: The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"\"longitude". (case-insensitively).

`names`
: Optional. A named vector used to rename certain columns in the popups. See the Example for more information.

`control`
: Optional. Column which will be used for the `control` argument of other mapping functions. This only needs to be used if `control` is going to be used in `polarMap()` or another similar function, and you'd expect different values for the different map layers (for example, if you are calculating a mean pollutant concentration).

`fun.character`
: A function to summarise character and factor columns. Defaults to collapsing unique values into a comma-separated list.

`fun.numeric`
: A function to summarise numeric columns. Defaults to taking the mean to three significant figures.

`fun.dttm`
: A function to summarise date columns. Defaults to presenting the date as a range.

Value

a `tibble::tibble()`

Examples

```
## Not run:
buildPopup(
  data = openairmaps::polar_data,
  cols = c("site", "site_type", "date", "nox"),
  names = c("Site" = "site", "Site Type" = "site_type", "Date Range" = "date")
) %>%
  polarMap("nox", popup = "popup")

## End(Not run)
```

---

diffMap *Bivariate polar plots on interactive leaflet maps*

Description

`diffMap()` creates a `leaflet` map using bivariate polar "difference" plots as markers. Any number of pollutants can be specified using the `pollutant` argument, and multiple layers of markers can be added and toggled between using `control`.

Usage

```
diffMap(
  before,
  after,
  pollutant = NULL,
  x = "ws",
  limits = NULL,
  latitude = NULL,
  longitude = NULL,
  control = NULL,
  popup = NULL,
  label = NULL,
  provider = "OpenStreetMap",
 cols = c("#002F70", "#3167BB", "#879FDB", "#C8D2F1", "#F6F6F6", "#F4C8C8", "#DA8A8B",
    "#AE4647", "#5F1415"),
  alpha = 1,
  key = FALSE,
  draw.legend = TRUE,
  collapse.control = FALSE,
  d.icon = 200,
  d.fig = 3.5,
  type = NULL,
  ...
)
```

Arguments

before	A data frame that represents the "before" case. See polarPlot() for details of different input requirements.
after	A data frame that represents the "after" case. See polarPlot() for details of different input requirements.
pollutant	Mandatory. A pollutant name corresponding to a variable in a data frame should be supplied e.g. pollutant = "nox". There can also be more than one pollutant specified e.g. pollutant = c("nox", "no2"). The main use of using two or more pollutants is for model evaluation where two species would be expected to have similar concentrations. This saves the user stacking the data and it is possible to work with columns of data directly. A typical use would be pollutant = c("obs", "mod") to compare two columns "obs" (the observations) and "mod" (modelled values). When pair-wise statistics such as Pearson correlation and regression techniques are to be plotted, pollutant takes two elements too. For example, pollutant = c("bc", "pm25") where "bc" is a function of "pm25".
x	Name of variable to plot against wind direction in polar coordinates, the default is wind speed, "ws".
limits	By default, each individual polar marker has its own colour scale. The limits argument will force all markers to use the same colour scale. The limits are set in the form c(lower, upper), so limits = c(-5, 5) would force the plot limits

to span -5 to 5. It is recommended to use a symmetrical limit scale (along with a "diverging" colour palette) for effective visualisation.

`latitude, longitude`
: The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).

`control`
: Column to be used for splitting the input data into different groups which can be selected between using a "layer control" interface. Appropriate columns could be those added by `openair::cutData()` or `openair::splitByDate()`. `control` cannot be used if multiple `pollutant` columns have been provided.

`popup`
: Column to be used as the HTML content for marker popups. Popups may be useful to show information about the individual sites (e.g., site names, codes, types, etc.).

`label`
: Column to be used as the HTML content for hover-over labels. Labels are useful for the same reasons as popups, though are typically shorter.

`provider`
: The base map(s) to be used. See http://leaflet-extras.github.io/leaflet-providers/preview/ for a list of all base maps that can be used. If multiple base maps are provided, they can be toggled between using a "layer control" interface.

`cols`
: The colours used for plotting. It is recommended to use a "diverging" colour palette (along with a symmetrical limit scale) for effective visualisation.

`alpha`
: The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

`key`
: Should a key for each marker be drawn? Default is `FALSE`.

`draw.legend`
: When `limits` are specified, should a shared legend be created at the side of the map? Default is `TRUE`.

`collapse.control`
: Should the "layer control" interface be collapsed? Defaults to `FALSE`.

`d.icon`
: The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`d.fig`
: The diameter of the plots to be produced using `openair` in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`type`
: Deprecated. Please use `label` and/or popup to label different sites.

`...`
: Arguments passed on to `openair::polarPlot`

  `wd` Name of wind direction field.

  `statistic` The statistic that should be applied to each wind speed/direction bin. Because of the smoothing involved, the colour scale for some of these statistics is only to provide an indication of overall pattern and should not be interpreted in concentration units e.g. for `statistic = "weighted.mean"` where the bin mean is multiplied by the bin frequency and divided by the total frequency. In many cases using `polarFreq` will be better. Setting `statistic = "weighted.mean"` can be useful because it provides an indication of the concentration * frequency of occurrence and will highlight the wind speed/direction conditions that dominate the overall mean.Can be:

- "mean" (default), "median", "max" (maximum), "frequency". "stdev" (standard deviation), "weighted.mean".
- `statistic = "nwr"` Implements the Non-parametric Wind Regression approach of Henry et al. (2009) that uses kernel smoothers. The `openair` implementation is not identical because Gaussian kernels are used for both wind direction and speed. The smoothing is controlled by `ws_spread` and `wd_spread`.
- `statistic = "cpf"` the conditional probability function (CPF) is plotted and a single (usually high) percentile level is supplied. The CPF is defined as CPF = my/ny, where my is the number of samples in the y bin (by default a wind direction, wind speed interval) with mixing ratios greater than the *overall* percentile concentration, and ny is the total number of samples in the same wind sector (see Ashbaugh et al., 1985). Note that percentile intervals can also be considered; see `percentile` for details.
- When `statistic = "r"` or `statistic = "Pearson"`, the Pearson correlation coefficient is calculated for *two* pollutants. The calculation involves a weighted Pearson correlation coefficient, which is weighted by Gaussian kernels for wind direction an the radial variable (by default wind speed). More weight is assigned to values close to a wind speed-direction interval. Kernel weighting is used to ensure that all data are used rather than relying on the potentially small number of values in a wind speed-direction interval.
- When `statistic = "Spearman"`, the Spearman correlation coefficient is calculated for *two* pollutants. The calculation involves a weighted Spearman correlation coefficient, which is weighted by Gaussian kernels for wind direction an the radial variable (by default wind speed). More weight is assigned to values close to a wind speed-direction interval. Kernel weighting is used to ensure that all data are used rather than relying on the potentially small number of values in a wind speed-direction interval.
- `"robust_slope"` is another option for pair-wise statistics and `"quantile.slope"`, which uses quantile regression to estimate the slope for a particular quantile level (see also `tau` for setting the quantile level).
- `"york_slope"` is another option for pair-wise statistics which uses the *York regression method* to estimate the slope. In this method the uncertainties in `x` and `y` are used in the determination of the slope. The uncertainties are provided by `x_error` and `y_error` — see below.

`exclude.missing` Setting this option to `TRUE` (the default) removes points from the plot that are too far from the original data. The smoothing routines will produce predictions at points where no data exist i.e. they predict. By removing the points too far from the original data produces a plot where it is clear where the original data lie. If set to `FALSE` missing data will be interpolated.

`uncertainty` Should the uncertainty in the calculated surface be shown? If `TRUE` three plots are produced on the same scale showing the predicted surface together with the estimated lower and upper uncertainties at the 95%

confidence interval. Calculating the uncertainties is useful to understand whether features are real or not. For example, at high wind speeds where there are few data there is greater uncertainty over the predicted values. The uncertainties are calculated using the GAM and weighting is done by the frequency of measurements in each wind speed-direction bin. Note that if uncertainties are calculated then the type is set to "default".

`percentile` If `statistic = "percentile"` then `percentile` is used, expressed from 0 to 100. Note that the percentile value is calculated in the wind speed, wind direction 'bins'. For this reason it can also be useful to set `min.bin` to ensure there are a sufficient number of points available to estimate a percentile. See `quantile` for more details of how percentiles are calculated.
`percentile` is also used for the Conditional Probability Function (CPF) plots. `percentile` can be of length two, in which case the percentile *interval* is considered for use with CPF. For example, `percentile = c(90, 100)` will plot the CPF for concentrations between the 90 and 100th percentiles. Percentile intervals can be useful for identifying specific sources. In addition, `percentile` can also be of length 3. The third value is the 'trim' value to be applied. When calculating percentile intervals many can cover very low values where there is no useful information. The trim value ensures that values greater than or equal to the trim * mean value are considered *before* the percentile intervals are calculated. The effect is to extract more detail from many source signatures. See the manual for examples. Finally, if the trim value is less than zero the percentile range is interpreted as absolute concentration values and subsetting is carried out directly.

`weights` At the edges of the plot there may only be a few data points in each wind speed-direction interval, which could in some situations distort the plot if the concentrations are high. `weights` applies a weighting to reduce their influence. For example and by default if only a single data point exists then the weighting factor is 0.25 and for two points 0.5. To not apply any weighting and use the data as is, use `weights = c(1, 1, 1)`.
An alternative to down-weighting these points they can be removed altogether using `min.bin`.

`min.bin` The minimum number of points allowed in a wind speed/wind direction bin. The default is 1. A value of two requires at least 2 valid records in each bin an so on; bins with less than 2 valid records are set to NA. Care should be taken when using a value > 1 because of the risk of removing real data points. It is recommended to consider your data with care. Also, the `polarFreq` function can be of use in such circumstances.

`mis.col` When `min.bin` is > 1 it can be useful to show where data are removed on the plots. This is done by shading the missing data in `mis.col`. To not highlight missing data when `min.bin` > 1 choose `mis.col = "transparent"`.

`upper` This sets the upper limit wind speed to be used. Often there are only a relatively few data points at very high wind speeds and plotting all of them can reduce the useful information in the plot.

`force.positive` The default is `TRUE`. Sometimes if smoothing data with steep gradients it is possible for predicted values to be negative. `force.positive = TRUE` ensures that predictions remain positive. This is useful for several reasons. First, with lots of missing data more interpolation is needed and

this can result in artefacts because the predictions are too far from the original data. Second, if it is known beforehand that the data are all positive, then this option carries that assumption through to the prediction. The only likely time where setting `force.positive = FALSE` would be if background concentrations were first subtracted resulting in data that is legitimately negative. For the vast majority of situations it is expected that the user will not need to alter the default option.

`k` This is the smoothing parameter used by the `gam` function in package `mgcv`. Typically, value of around 100 (the default) seems to be suitable and will resolve important features in the plot. The most appropriate choice of `k` is problem-dependent; but extensive testing of polar plots for many different problems suggests a value of `k` of about 100 is suitable. Setting `k` to higher values will not tend to affect the surface predictions by much but will add to the computation time. Lower values of `k` will increase smoothing. Sometimes with few data to plot `polarPlot` will fail. Under these circumstances it can be worth lowering the value of `k`.

`normalise` If `TRUE` concentrations are normalised by dividing by their mean value. This is done *after* fitting the smooth surface. This option is particularly useful if one is interested in the patterns of concentrations for several pollutants on different scales e.g. NOx and CO. Often useful if more than one `pollutant` is chosen.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

`ws_spread` The value of sigma used for Gaussian kernel weighting of wind speed when `statistic = "nwr"` or when correlation and regression statistics are used such as *r*. Default is `0.5`.

`wd_spread` The value of sigma used for Gaussian kernel weighting of wind direction when `statistic = "nwr"` or when correlation and regression statistics are used such as *r*. Default is `4`.

`x_error` The `x` error / uncertainty used when `statistic = "york_slope"`.

`y_error` The `y` error / uncertainty used when `statistic = "york_slope"`.

`kernel` Type of kernel used for the weighting procedure for when correlation or regression techniques are used. Only `"gaussian"` is supported but this may be enhanced in the future.

`tau` The quantile to be estimated when `statistic` is set to `"quantile.slope"`. Default is `0.5` which is equal to the median and will be ignored if `"quantile.slope"` is not used.

`plot` Should a plot be produced? `FALSE` can be useful when analysing data to extract plot components and plotting them in other ways.

Value

A leaflet object.

See Also

the original `openair::polarDiff()`

diffMapStatic() for the static ggmap equivalent of diffMap()

Other interactive directional analysis maps: annulusMap(), freqMap(), percentileMap(), polarMap(), pollroseMap(), windroseMap()

Examples

```
## Not run:
# NB: "after" is some dummy data to demonstrate functionality
polarDiff(
  before = polar_data,
  after = dplyr::mutate(polar_data, nox = jitter(nox, factor = 5)),
  pollutant = "nox",
  provider = "Stamen.Toner"
)

## End(Not run)
```

---

diffMapStatic *Bivariate polar plots on a static ggmap*

Description

diffMapStatic() creates a ggplot2 map using bivariate "difference" polar plots as markers. As this function returns a ggplot2 object, further customisation can be achieved using functions like ggplot2::theme() and ggplot2::guides().

Usage

```
diffMapStatic(
  before,
  after,
  pollutant = NULL,
  x = "ws",
  facet = NULL,
  limits = NULL,
  latitude = NULL,
  longitude = NULL,
  zoom = 13,
  ggmap = NULL,
 cols = c("#002F70", "#3167BB", "#879FDB", "#C8D2F1", "#F6F6F6", "#F4C8C8", "#DA8A8B",
    "#AE4647", "#5F1415"),
  alpha = 1,
  key = FALSE,
  facet.nrow = NULL,
  d.icon = 150,
  d.fig = 3,
  ...
)
```

Arguments

before	A data frame that represents the "before" case. See polarPlot() for details of different input requirements.
after	A data frame that represents the "after" case. See polarPlot() for details of different input requirements.
pollutant	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they will each form part of a separate panel.
x	The radial axis variable to plot.
facet	Column to be used for splitting the input data into different panels. Appropriate columns could be those added by openair::cutData() or openair::splitByDate(). facet cannot be used if multiple pollutant columns have been provided.
limits	By default, each individual polar marker has its own colour scale. The limits argument will force all markers to use the same colour scale. The limits are set in the form c(lower, upper), so limits = c(0, 100) would force the plot limits to span 0-100.
latitude, longitude	The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).
zoom	The zoom level to use for the basemap, passed to ggmap::get_stamenmap(). Alternatively, the ggmap argument can be used for more precise control of the basemap.
ggmap	By default, openairmaps will try to estimate an appropriate bounding box for the input data and then run ggmap::get_stamenmap() to import a basemap. The ggmap argument allows users to provide their own ggmap object to override this, which allows for alternative bounding boxes, map types and colours.
cols	The colours used for plotting. See openair::openColours() for more information.
alpha	The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).
key	Should a key for each marker be drawn? Default is FALSE.
facet.nrow	Passed to the nrow argument of ggplot2::facet_wrap().
d.icon	The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.
d.fig	The diameter of the plots to be produced using openair in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.
...	Arguments passed on to openair::polarPlot wd Name of wind direction field. statistic The statistic that should be applied to each wind speed/direction bin. Because of the smoothing involved, the colour scale for some of these statistics is only to provide an indication of overall pattern and should not be

interpreted in concentration units e.g. for `statistic = "weighted.mean"` where the bin mean is multiplied by the bin frequency and divided by the total frequency. In many cases using `polarFreq` will be better. Setting `statistic = "weighted.mean"` can be useful because it provides an indication of the concentration * frequency of occurrence and will highlight the wind speed/direction conditions that dominate the overall mean.Can be:

- "mean" (default), "median", "max" (maximum), "frequency". "stdev" (standard deviation), "weighted.mean".
- `statistic = "nwr"` Implements the Non-parametric Wind Regression approach of Henry et al. (2009) that uses kernel smoothers. The `openair` implementation is not identical because Gaussian kernels are used for both wind direction and speed. The smoothing is controlled by `ws_spread` and `wd_spread`.
- `statistic = "cpf"` the conditional probability function (CPF) is plotted and a single (usually high) percentile level is supplied. The CPF is defined as CPF = my/ny, where my is the number of samples in the y bin (by default a wind direction, wind speed interval) with mixing ratios greater than the *overall* percentile concentration, and ny is the total number of samples in the same wind sector (see Ashbaugh et al., 1985). Note that percentile intervals can also be considered; see `percentile` for details.
- When `statistic = "r"` or `statistic = "Pearson"`, the Pearson correlation coefficient is calculated for *two* pollutants. The calculation involves a weighted Pearson correlation coefficient, which is weighted by Gaussian kernels for wind direction an the radial variable (by default wind speed). More weight is assigned to values close to a wind speed-direction interval. Kernel weighting is used to ensure that all data are used rather than relying on the potentially small number of values in a wind speed-direction interval.
- When `statistic = "Spearman"`, the Spearman correlation coefficient is calculated for *two* pollutants. The calculation involves a weighted Spearman correlation coefficient, which is weighted by Gaussian kernels for wind direction an the radial variable (by default wind speed). More weight is assigned to values close to a wind speed-direction interval. Kernel weighting is used to ensure that all data are used rather than relying on the potentially small number of values in a wind speed-direction interval.
- `"robust_slope"` is another option for pair-wise statistics and `"quantile.slope"`, which uses quantile regression to estimate the slope for a particular quantile level (see also `tau` for setting the quantile level).
- `"york_slope"` is another option for pair-wise statistics which uses the *York regression method* to estimate the slope. In this method the uncertainties in `x` and `y` are used in the determination of the slope. The uncertainties are provided by `x_error` and `y_error` — see below.

`exclude.missing` Setting this option to `TRUE` (the default) removes points from the plot that are too far from the original data. The smoothing routines will produce predictions at points where no data exist i.e. they predict. By

removing the points too far from the original data produces a plot where it is clear where the original data lie. If set to FALSE missing data will be interpolated.

uncertainty Should the uncertainty in the calculated surface be shown? If TRUE three plots are produced on the same scale showing the predicted surface together with the estimated lower and upper uncertainties at the 95% confidence interval. Calculating the uncertainties is useful to understand whether features are real or not. For example, at high wind speeds where there are few data there is greater uncertainty over the predicted values. The uncertainties are calculated using the GAM and weighting is done by the frequency of measurements in each wind speed-direction bin. Note that if uncertainties are calculated then the type is set to "default".

percentile If `statistic = "percentile"` then `percentile` is used, expressed from 0 to 100. Note that the percentile value is calculated in the wind speed, wind direction 'bins'. For this reason it can also be useful to set `min.bin` to ensure there are a sufficient number of points available to estimate a percentile. See `quantile` for more details of how percentiles are calculated.
`percentile` is also used for the Conditional Probability Function (CPF) plots. `percentile` can be of length two, in which case the percentile *interval* is considered for use with CPF. For example, `percentile = c(90, 100)` will plot the CPF for concentrations between the 90 and 100th percentiles. Percentile intervals can be useful for identifying specific sources. In addition, `percentile` can also be of length 3. The third value is the 'trim' value to be applied. When calculating percentile intervals many can cover very low values where there is no useful information. The trim value ensures that values greater than or equal to the trim * mean value are considered *before* the percentile intervals are calculated. The effect is to extract more detail from many source signatures. See the manual for examples. Finally, if the trim value is less than zero the percentile range is interpreted as absolute concentration values and subsetting is carried out directly.

weights At the edges of the plot there may only be a few data points in each wind speed-direction interval, which could in some situations distort the plot if the concentrations are high. `weights` applies a weighting to reduce their influence. For example and by default if only a single data point exists then the weighting factor is 0.25 and for two points 0.5. To not apply any weighting and use the data as is, use `weights = c(1, 1, 1)`.
An alternative to down-weighting these points they can be removed altogether using `min.bin`.

min.bin The minimum number of points allowed in a wind speed/wind direction bin. The default is 1. A value of two requires at least 2 valid records in each bin an so on; bins with less than 2 valid records are set to NA. Care should be taken when using a value > 1 because of the risk of removing real data points. It is recommended to consider your data with care. Also, the `polarFreq` function can be of use in such circumstances.

mis.col When `min.bin` is > 1 it can be useful to show where data are removed on the plots. This is done by shading the missing data in `mis.col`. To not highlight missing data when `min.bin` > 1 choose `mis.col = "transparent"`.

upper This sets the upper limit wind speed to be used. Often there are only a

relatively few data points at very high wind speeds and plotting all of them can reduce the useful information in the plot.

`force.positive` The default is `TRUE`. Sometimes if smoothing data with steep gradients it is possible for predicted values to be negative. `force.positive = TRUE` ensures that predictions remain positive. This is useful for several reasons. First, with lots of missing data more interpolation is needed and this can result in artefacts because the predictions are too far from the original data. Second, if it is known beforehand that the data are all positive, then this option carries that assumption through to the prediction. The only likely time where setting `force.positive = FALSE` would be if background concentrations were first subtracted resulting in data that is legitimately negative. For the vast majority of situations it is expected that the user will not need to alter the default option.

`k` This is the smoothing parameter used by the `gam` function in package `mgcv`. Typically, value of around 100 (the default) seems to be suitable and will resolve important features in the plot. The most appropriate choice of `k` is problem-dependent; but extensive testing of polar plots for many different problems suggests a value of `k` of about 100 is suitable. Setting `k` to higher values will not tend to affect the surface predictions by much but will add to the computation time. Lower values of `k` will increase smoothing. Sometimes with few data to plot `polarPlot` will fail. Under these circumstances it can be worth lowering the value of `k`.

`normalise` If `TRUE` concentrations are normalised by dividing by their mean value. This is done *after* fitting the smooth surface. This option is particularly useful if one is interested in the patterns of concentrations for several pollutants on different scales e.g. NOx and CO. Often useful if more than one `pollutant` is chosen.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

`ws_spread` The value of sigma used for Gaussian kernel weighting of wind speed when `statistic = "nwr"` or when correlation and regression statistics are used such as *r*. Default is `0.5`.

`wd_spread` The value of sigma used for Gaussian kernel weighting of wind direction when `statistic = "nwr"` or when correlation and regression statistics are used such as *r*. Default is `4`.

`x_error` The `x` error / uncertainty used when `statistic = "york_slope"`.

`y_error` The `y` error / uncertainty used when `statistic = "york_slope"`.

`kernel` Type of kernel used for the weighting procedure for when correlation or regression techniques are used. Only `"gaussian"` is supported but this may be enhanced in the future.

`tau` The quantile to be estimated when `statistic` is set to `"quantile.slope"`. Default is `0.5` which is equal to the median and will be ignored if `"quantile.slope"` is not used.

`plot` Should a plot be produced? `FALSE` can be useful when analysing data to extract plot components and plotting them in other ways.

Value

a ggplot2 plot with a ggmap basemap

Further customisation using ggplot2

As the outputs of the static directional analysis functions are ggplot2 figures, further customisation is possible using functions such as ggplot2::theme(), ggplot2::guides() and ggplot2::labs().

If multiple pollutants are specified, subscripting (e.g., the "x" in "NOx") is achieved using the ggtext package. Therefore if you choose to override the plot theme, it is recommended to use [ggplot2::theme()] and [ggtext::element_markdown()] to define the strip.text parameter.

When arguments like limits, percentile or breaks are defined, a legend is automatically added to the figure. Legends can be removed using ggplot2::theme(legend.position = "none"), or further customised using ggplot2::guides() and either color = ggplot2::guide_colourbar() for continuous legends or fill = ggplot2::guide_legend() for discrete legends.

See Also

the original openair::polarDiff()

diffMap() for the interactive leaflet equivalent of diffMapStatic()

Other static directional analysis maps: annulusMapStatic(), freqMapStatic(), percentileMapStatic(), polarMapStatic(), pollroseMapStatic(), windroseMapStatic()

---

freqMap *Polar frequency plots on interactive leaflet maps*

Description

freqMap() creates a leaflet map using binned polar plots as markers. Any number of pollutants can be specified using the pollutant argument, and multiple layers of markers can be added and toggled between using control.

Usage

```
freqMap(
  data,
  pollutant = NULL,
  breaks = NULL,
  statistic = "mean",
  latitude = NULL,
  longitude = NULL,
  control = NULL,
  popup = NULL,
  label = NULL,
  provider = "OpenStreetMap",
  cols = "turbo",
```

```
  alpha = 1,
  key = FALSE,
  draw.legend = TRUE,
  collapse.control = FALSE,
  d.icon = 200,
  d.fig = 3.5,
  type = NULL,
  ...
)
```

Arguments

data	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (ws), wind direction (wd), and the column representing the concentration of a pollutant. In addition, data must include a decimal latitude and longitude.
pollutant	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they can be toggled between using a "layer control" interface.
breaks	The user can provide their own scale. breaks expects a sequence of numbers that define the range of the scale. The sequence could represent one with equal spacing, e.g., breaks = seq(0, 100, 10) - a scale from 0-10 in intervals of 10, or a more flexible sequence, e.g., breaks = c(0, 1, 5, 7, 10), which may be useful for some situations.
statistic	The statistic that should be applied to each wind speed/direction bin. Can be "frequency", "mean", "median", "max" (maximum), "stdev" (standard deviation) or "weighted.mean". The option "frequency" is the simplest and plots the frequency of wind speed/direction in different bins. The scale therefore shows the counts in each bin. The option "mean" (the default) will plot the mean concentration of a pollutant (see next point) in wind speed/direction bins, and so on. Finally, "weighted.mean" will plot the concentration of a pollutant weighted by wind speed/direction. Each segment therefore provides the percentage overall contribution to the total concentration. Note that for options other than "frequency", it is necessary to also provide the name of a pollutant. See function openair::cutData() for further details.
latitude, longitude	The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).
control	Column to be used for splitting the input data into different groups which can be selected between using a "layer control" interface. Appropriate columns could be those added by openair::cutData() or openair::splitByDate(). control cannot be used if multiple pollutant columns have been provided.
popup	Column to be used as the HTML content for marker popups. Popups may be useful to show information about the individual sites (e.g., site names, codes, types, etc.).
label	Column to be used as the HTML content for hover-over labels. Labels are useful for the same reasons as popups, though are typically shorter.

provider The base map(s) to be used. See http://leaflet-extras.github.io/leaflet-providers/preview/ for a list of all base maps that can be used. If multiple base maps are provided, they can be toggled between using a "layer control" interface.

cols The colours used for plotting. See openair::openColours() for more information.

alpha The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

key Should a key for each marker be drawn? Default is FALSE.

draw.legend When breaks are specified, should a shared legend be created at the side of the map? Default is TRUE.

collapse.control
Should the "layer control" interface be collapsed? Defaults to FALSE.

d.icon The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

d.fig The diameter of the plots to be produced using openair in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

type Deprecated. Please use label and/or popup to label different sites.

... Arguments passed on to openair::polarFreq

ws.int Wind speed interval assumed. In some cases e.g. a low met mast, an interval of 0.5 may be more appropriate.

wd.nint Number of intervals of wind direction.

grid.line Radial spacing of grid lines.

trans Should a transformation be applied? Sometimes when producing plots of this kind they can be dominated by a few high points. The default therefore is TRUE and a square-root transform is applied. This results in a non-linear scale and (usually) a better representation of the distribution. If set to FALSE a linear scale is used.

min.bin The minimum number of points allowed in a wind speed/wind direction bin. The default is 1. A value of two requires at least 2 valid records in each bin an so on; bins with less than 2 valid records are set to NA. Care should be taken when using a value > 1 because of the risk of removing real data points. It is recommended to consider your data with care. Also, the polarFreq function can be of use in such circumstances.

ws.upper A user-defined upper wind speed to use. This is useful for ensuring a consistent scale between different plots. For example, to always ensure that wind speeds are displayed between 1-10, set ws.int = 10.

offset offset controls the size of the 'hole' in the middle and is expressed as a percentage of the maximum wind speed. Setting a higher offset e.g. 50 is useful for statistic = "weighted.mean" when ws.int is greater than the maximum wind speed. See example below.

border.col The colour of the boundary of each wind speed/direction bin. The default is transparent. Another useful choice sometimes is "white".

`key.header` Adds additional text/labels to the scale key. For example, passing the options `key.header = "header"`, `key.footer = "footer1"` adds addition text above and below the scale key. These arguments are passed to `drawOpenKey` via `quickText`, applying the `auto.text` argument, to handle formatting.

`key.footer` see `key.footer`.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include `"top"`, `"right"`, `"bottom"` and `"left"`.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

Value

A leaflet object.

See Also

the original `openair::polarFreq()`

`freqMapStatic()` for the static ggmap equivalent of `freqMap()`

Other interactive directional analysis maps: `annulusMap()`, `diffMap()`, `percentileMap()`, `polarMap()`, `pollroseMap()`, `windroseMap()`

Examples

```
## Not run:
freqMap(polar_data,
  pollutant = "nox",
  statistic = "mean",
  provider = "Stamen.Toner"
)

## End(Not run)
```

---

freqMapStatic *Polar frequency plots on a static ggmap*

Description

`freqMapStatic()` creates a `ggplot2` map using polar frequency plots as markers. As this function returns a `ggplot2` object, further customisation can be achieved using functions like `ggplot2::theme()` and `ggplot2::guides()`.

Usage

```
freqMapStatic(
  data,
  pollutant = NULL,
  breaks = NULL,
  statistic = "mean",
  facet = NULL,
  limits = NULL,
  latitude = NULL,
  longitude = NULL,
  zoom = 13,
  ggmap = NULL,
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  facet.nrow = NULL,
  d.icon = 150,
  d.fig = 3,
  ...
)
```

Arguments

`data`	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (`ws`), wind direction (`wd`), and the column representing the concentration of a pollutant. In addition, `data` must include a decimal latitude and longitude.
`pollutant`	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they will each form part of a separate panel.
`breaks`	The user can provide their own scale. breaks expects a sequence of numbers that define the range of the scale. The sequence could represent one with equal spacing, e.g., `breaks = seq(0, 100, 10)` - a scale from 0-10 in intervals of 10, or a more flexible sequence, e.g., `breaks = c(0, 1, 5, 7, 10)`, which may be useful for some situations.
`statistic`	The statistic that should be applied to each wind speed/direction bin. Can be "frequency", "mean", "median", "max" (maximum), "stdev" (standard deviation) or "weighted.mean". The option "frequency" is the simplest and plots the frequency of wind speed/direction in different bins. The scale therefore shows the counts in each bin. The option "mean" (the default) will plot the mean concentration of a pollutant (see next point) in wind speed/direction bins, and so on. Finally, "weighted.mean" will plot the concentration of a pollutant weighted by wind speed/direction. Each segment therefore provides the percentage overall contribution to the total concentration. Note that for options other than "frequency", it is necessary to also provide the name of a pollutant. See function `openair::cutData()` for further details.
`facet`	Column to be used for splitting the input data into different panels. Appropriate columns could be those added by `openair::cutData()` or `openair::splitByDate()`.

facet cannot be used if multiple pollutant columns have been provided.

limits By default, each individual polar marker has its own colour scale. The limits argument will force all markers to use the same colour scale. The limits are set in the form c(lower, upper), so limits = c(0, 100) would force the plot limits to span 0-100.

latitude, longitude
The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).

zoom The zoom level to use for the basemap, passed to ggmap::get_stamenmap(). Alternatively, the ggmap argument can be used for more precise control of the basemap.

ggmap By default, openairmaps will try to estimate an appropriate bounding box for the input data and then run ggmap::get_stamenmap() to import a basemap. The ggmap argument allows users to provide their own ggmap object to override this, which allows for alternative bounding boxes, map types and colours.

cols The colours used for plotting. See openair::openColours() for more information.

alpha The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

key Should a key for each marker be drawn? Default is FALSE.

facet.nrow Passed to the nrow argument of ggplot2::facet_wrap().

d.icon The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

d.fig The diameter of the plots to be produced using openair in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

... Arguments passed on to openair::polarFreq

ws.int Wind speed interval assumed. In some cases e.g. a low met mast, an interval of 0.5 may be more appropriate.

wd.nint Number of intervals of wind direction.

grid.line Radial spacing of grid lines.

trans Should a transformation be applied? Sometimes when producing plots of this kind they can be dominated by a few high points. The default therefore is TRUE and a square-root transform is applied. This results in a non-linear scale and (usually) a better representation of the distribution. If set to FALSE a linear scale is used.

type type determines how the data are split i.e. conditioned, and then plotted. The default is will produce a single plot using the entire data. Type can be one of the built-in types as detailed in cutData e.g. “season”, “year”, “weekday” and so on. For example, type = "season" will produce four plots — one for each season.

It is also possible to choose type as another variable in the data frame. If that variable is numeric, then the data will be split into four quantiles (if

possible) and labelled accordingly. If type is an existing character or factor variable, then those categories/levels will be used directly. This offers great flexibility for understanding the variation of different variables and how they depend on one another.
Type can be up length two e.g. `type = c("season", "weekday")` will produce a 2x2 plot split by season and day of the week. Note, when two types are provided the first forms the columns and the second the rows.

`min.bin` The minimum number of points allowed in a wind speed/wind direction bin. The default is 1. A value of two requires at least 2 valid records in each bin an so on; bins with less than 2 valid records are set to NA. Care should be taken when using a value > 1 because of the risk of removing real data points. It is recommended to consider your data with care. Also, the `polarFreq` function can be of use in such circumstances.

`ws.upper` A user-defined upper wind speed to use. This is useful for ensuring a consistent scale between different plots. For example, to always ensure that wind speeds are displayed between 1-10, set `ws.int = 10`.

`offset` `offset` controls the size of the 'hole' in the middle and is expressed as a percentage of the maximum wind speed. Setting a higher `offset` e.g. 50 is useful for `statistic = "weighted.mean"` when `ws.int` is greater than the maximum wind speed. See example below.

`border.col` The colour of the boundary of each wind speed/direction bin. The default is transparent. Another useful choice sometimes is "white".

`key.header` Adds additional text/labels to the scale key. For example, passing the options `key.header = "header"`, `key.footer = "footer1"` adds addition text above and below the scale key. These arguments are passed to `drawOpenKey` via `quickText`, applying the `auto.text` argument, to handle formatting.

`key.footer` see `key.footer`.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include `"top"`, `"right"`, `"bottom"` and `"left"`.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

Value

a `ggplot2` plot with a `ggmap` basemap

Further customisation using ggplot2

As the outputs of the static directional analysis functions are `ggplot2` figures, further customisation is possible using functions such as `ggplot2::theme()`, `ggplot2::guides()` and `ggplot2::labs()`.

If multiple pollutants are specified, subscripting (e.g., the "x" in "NOx") is achieved using the ggtext package. Therefore if you choose to override the plot theme, it is recommended to use `[ggplot2::theme()]` and `[ggtext::element_markdown()]` to define the `strip.text` parameter.

When arguments like `limits`, `percentile` or `breaks` are defined, a legend is automatically added to the figure. Legends can be removed using `ggplot2::theme(legend.position = "none")`, or

further customised using ggplot2::guides() and either color = ggplot2::guide_colourbar() for continuous legends or fill = ggplot2::guide_legend() for discrete legends.

See Also

the original openair::polarFreq()

freqMap() for the interactive leaflet equivalent of freqMapStatic()

Other static directional analysis maps: annulusMapStatic(), diffMapStatic(), percentileMapStatic(), polarMapStatic(), pollroseMapStatic(), windroseMapStatic()

---

networkMap *Create a leaflet map of air quality measurement network sites*

Description

This function uses openair::importMeta() to obtain metadata for measurement sites and uses it to create an attractive leaflet map. By default a map will be created in which readers may toggle between a vector base map and a satellite/aerial image, although users can further customise the control menu using the provider and control parameters.

Usage

```
networkMap(
  source = "aurn",
  control = NULL,
  year = NULL,
  cluster = TRUE,
  provider = c("OpenStreetMap", "Esri.WorldImagery"),
  collapse.control = FALSE
)
```

Arguments

source	One or more sources of meta data. Can be "aurn", "saqn" (or "saqd"), "aqe", "waqn", "ni", "local" (or "lmam"), "kcl" or "europe"; upper or lower case. See the "details" section for further information about selecting multiple networks.
control	Option to add a "layer control" menu to allow readers to select between different site types. Can choose between effectively any column in the openair::importMeta() output, such as "variable", "site_type", or "agglomeration", as well as "network" when more than one source was specified.
year	By default, networkMap() visualises sites which are currently operational. year allows users to show sites open in a specific year, or over a range of years. See openair::importMeta() for more information.

cluster When cluster = TRUE, markers are clustered together. This may be useful for sources like "kcl" where there are many markers very close together. Defaults to TRUE, and is forced to be TRUE when source = "europe" due to the large number of sites.

provider The base map(s) to be used. See http://leaflet-extras.github.io/leaflet-providers/preview/ for a list of all base maps that can be used. If multiple base maps are provided, they can be toggled between using a "layer control" interface.

collapse.control Should the "layer control" interface be collapsed? Defaults to FALSE.

Details

When selecting multiple data sources using source, please be mindful that there can be overlap between the different networks. For example, an air quality site in Scotland may be part of the AURN *and* the SAQN. networkMap() will only show one marker for such sites, and uses the order in which source arguments are provided as the hierarchy by which to assign sites to networks. The aforementioned AURN & SAQN site will therefore have its SAQN code displayed if source = c("saqn", "aurn"), and its AURN code displayed if source = c("aurn", "saqn").

This hierarchy is also reflected when control = "network" is used. As leaflet markers cannot be part of multiple groups, the AURN & SAQN site will be part of the "SAQN" layer control group when source = c("saqn", "aurn") and the "AURN" layer control group when source = c("aurn", "saqn").

Value

A leaflet object.

Examples

```
## Not run:
# view one network, grouped by site type
networkMap(source = "aurn", control = "site_type")

# view multiple networks, grouped by network
networkMap(source = c("aurn", "waqn", "saqn"), control = "network")

## End(Not run)
```

---

percentileMap *Percentile roses on interactive leaflet maps*

Description

percentileMap() creates a leaflet map using percentile roses as markers. Any number of pollutants can be specified using the pollutant argument, and multiple layers of markers can be added and toggled between using control.

Usage

```
percentileMap(
  data,
  pollutant = NULL,
  percentile = c(25, 50, 75, 90, 95),
  latitude = NULL,
  longitude = NULL,
  control = NULL,
  popup = NULL,
  label = NULL,
  provider = "OpenStreetMap",
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  draw.legend = TRUE,
  collapse.control = FALSE,
  d.icon = 200,
  d.fig = 3.5,
  type = NULL,
  ...
)
```

Arguments

`data`	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (`ws`), wind direction (`wd`), and the column representing the concentration of a pollutant. In addition, `data` must include a decimal latitude and longitude.
`pollutant`	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they can be toggled between using a "layer control" interface.
`percentile`	The percentile value(s) to plot. Must be between 0–100. If `percentile = NA` then only a mean line will be shown.
`latitude, longitude`	The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).
`control`	Column to be used for splitting the input data into different groups which can be selected between using a "layer control" interface. Appropriate columns could be those added by `openair::cutData()` or `openair::splitByDate()`. `control` cannot be used if multiple `pollutant` columns have been provided.
`popup`	Column to be used as the HTML content for marker popups. Popups may be useful to show information about the individual sites (e.g., site names, codes, types, etc.).
`label`	Column to be used as the HTML content for hover-over labels. Labels are useful for the same reasons as popups, though are typically shorter.

provider The base map(s) to be used. See http://leaflet-extras.github.io/leaflet-providers/preview/ for a list of all base maps that can be used. If multiple base maps are provided, they can be toggled between using a "layer control" interface.

cols The colours used for plotting. See openair::openColours() for more information.

alpha The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

key Should a key for each marker be drawn? Default is FALSE.

draw.legend Should a shared legend be created at the side of the map? Default is TRUE.

collapse.control
Should the "layer control" interface be collapsed? Defaults to FALSE.

d.icon The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

d.fig The diameter of the plots to be produced using openair in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

type Deprecated. Please use label and/or popup to label different sites.

... Arguments passed on to openair::percentileRose

wd Name of wind direction field.

smooth Should the wind direction data be smoothed using a cyclic spline?

method When method = "default" the supplied percentiles by wind direction are calculated. When method = "cpf" the conditional probability function (CPF) is plotted and a single (usually high) percentile level is supplied. The CPF is defined as CPF = my/ny, where my is the number of samples in the wind sector y with mixing ratios greater than the *overall* percentile concentration, and ny is the total number of samples in the same wind sector (see Ashbaugh et al., 1985).

angle Default angle of "spokes" is when smooth = FALSE.

mean Show the mean by wind direction as a line?

mean.lty Line type for mean line.

mean.lwd Line width for mean line.

mean.col Line colour for mean line.

fill Should the percentile intervals be filled (default) or should lines be drawn (fill = FALSE).

intervals User-supplied intervals for the scale e.g. intervals = c(0, 10, 30, 50)

angle.scale Sometimes the placement of the scale may interfere with an interesting feature. The user can therefore set angle.scale to any value between 0 and 360 degrees to mitigate such problems. For example angle.scale = 45 will draw the scale heading in a NE direction.

auto.text Either TRUE (default) or FALSE. If TRUE titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

key.header Adds additional text/labels to the scale key. For example, passing the options key.header = "header", key.footer = "footer1" adds addition text above and below the scale key. These arguments are passed to drawOpenKey via quickText, applying the auto.text argument, to handle formatting.

key.footer see key.footer.

key.position Location where the scale key is to plotted. Allowed arguments currently include "top", "right", "bottom" and "left".

Value

A leaflet object.

See Also

the original openair::percentileRose()

percentileMapStatic() for the static ggmap equivalent of percentileMap()

Other interactive directional analysis maps: annulusMap(), diffMap(), freqMap(), polarMap(), pollroseMap(), windroseMap()

Examples

```
## Not run:
percentileMap(polar_data,
  pollutant = "nox",
  provider = "Stamen.Toner"
)

## End(Not run)
```

---

percentileMapStatic *Percentile roses on a static ggmap*

Description

percentileMapStatic() creates a ggplot2 map using percentile roses as markers. As this function returns a ggplot2 object, further customisation can be achieved using functions like ggplot2::theme() and ggplot2::guides().

Usage

```
percentileMapStatic(
  data,
  pollutant = NULL,
  percentile = c(25, 50, 75, 90, 95),
  facet = NULL,
  limits = NULL,
```

```
  latitude = NULL,
  longitude = NULL,
  zoom = 13,
  ggmap = NULL,
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  facet.nrow = NULL,
  d.icon = 150,
  d.fig = 3,
  ...
)
```

Arguments

`data`	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (`ws`), wind direction (`wd`), and the column representing the concentration of a pollutant. In addition, `data` must include a decimal latitude and longitude.
`pollutant`	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they will each form part of a separate panel.
`percentile`	The percentile value(s) to plot. Must be between 0–100. If `percentile = NA` then only a mean line will be shown.
`facet`	Column to be used for splitting the input data into different panels. Appropriate columns could be those added by `openair::cutData()` or `openair::splitByDate()`. `facet` cannot be used if multiple `pollutant` columns have been provided.
`limits`	By default, each individual polar marker has its own colour scale. The `limits` argument will force all markers to use the same colour scale. The limits are set in the form `c(lower, upper)`, so `limits = c(0, 100)` would force the plot limits to span 0-100.
`latitude, longitude`	The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).
`zoom`	The zoom level to use for the basemap, passed to `ggmap::get_stamenmap()`. Alternatively, the `ggmap` argument can be used for more precise control of the basemap.
`ggmap`	By default, `openairmaps` will try to estimate an appropriate bounding box for the input data and then run `ggmap::get_stamenmap()` to import a basemap. The `ggmap` argument allows users to provide their own ggmap object to override this, which allows for alternative bounding boxes, map types and colours.
`cols`	The colours used for plotting. See `openair::openColours()` for more information.
`alpha`	The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).
`key`	Should a key for each marker be drawn? Default is `FALSE`.

`facet.nrow` Passed to the `nrow` argument of `ggplot2::facet_wrap()`.

`d.icon` The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`d.fig` The diameter of the plots to be produced using `openair` in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`...` Arguments passed on to `openair::percentileRose`

`wd` Name of wind direction field.

`type` `type` determines how the data are split i.e. conditioned, and then plotted. The default is will produce a single plot using the entire data. Type can be one of the built-in types as detailed in `cutData` e.g. "season", "year", "weekday" and so on. For example, `type = "season"` will produce four plots — one for each season.

It is also possible to choose `type` as another variable in the data frame. If that variable is numeric, then the data will be split into four quantiles (if possible) and labelled accordingly. If type is an existing character or factor variable, then those categories/levels will be used directly. This offers great flexibility for understanding the variation of different variables and how they depend on one another.

Type can be up length two e.g. `type = c("season", "weekday")` will produce a 2x2 plot split by season and day of the week. Note, when two types are provided the first forms the columns and the second the rows.

`smooth` Should the wind direction data be smoothed using a cyclic spline?

`method` When `method = "default"` the supplied percentiles by wind direction are calculated. When `method = "cpf"` the conditional probability function (CPF) is plotted and a single (usually high) percentile level is supplied. The CPF is defined as CPF = my/ny, where my is the number of samples in the wind sector y with mixing ratios greater than the *overall* percentile concentration, and ny is the total number of samples in the same wind sector (see Ashbaugh et al., 1985).

`angle` Default angle of "spokes" is when `smooth = FALSE`.

`mean` Show the mean by wind direction as a line?

`mean.lty` Line type for mean line.

`mean.lwd` Line width for mean line.

`mean.col` Line colour for mean line.

`fill` Should the percentile intervals be filled (default) or should lines be drawn (`fill = FALSE`).

`intervals` User-supplied intervals for the scale e.g. `intervals = c(0, 10, 30, 50)`

`angle.scale` Sometimes the placement of the scale may interfere with an interesting feature. The user can therefore set `angle.scale` to any value between 0 and 360 degrees to mitigate such problems. For example `angle.scale = 45` will draw the scale heading in a NE direction.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

key.header Adds additional text/labels to the scale key. For example, passing the options key.header = "header", key.footer = "footer1" adds addition text above and below the scale key. These arguments are passed to drawOpenKey via quickText, applying the auto.text argument, to handle formatting.

key.footer see key.footer.

key.position Location where the scale key is to plotted. Allowed arguments currently include "top", "right", "bottom" and "left".

Value

a ggplot2 plot with a ggmap basemap

Further customisation using ggplot2

As the outputs of the static directional analysis functions are ggplot2 figures, further customisation is possible using functions such as ggplot2::theme(), ggplot2::guides() and ggplot2::labs().

If multiple pollutants are specified, subscripting (e.g., the "x" in "NOx") is achieved using the ggtext package. Therefore if you choose to override the plot theme, it is recommended to use [ggplot2::theme()] and [ggtext::element_markdown()] to define the strip.text parameter.

When arguments like limits, percentile or breaks are defined, a legend is automatically added to the figure. Legends can be removed using ggplot2::theme(legend.position = "none"), or further customised using ggplot2::guides() and either color = ggplot2::guide_colourbar() for continuous legends or fill = ggplot2::guide_legend() for discrete legends.

See Also

the original openair::percentileRose()

percentileMap() for the interactive leaflet equivalent of percentileMapStatic()

Other static directional analysis maps: annulusMapStatic(), diffMapStatic(), freqMapStatic(), polarMapStatic(), pollroseMapStatic(), windroseMapStatic()

---

polarMap *Bivariate polar plots on interactive leaflet maps*

Description

polarMap() creates a leaflet map using bivariate polar plots as markers. Any number of pollutants can be specified using the pollutant argument, and multiple layers of markers can be added and toggled between using control.

Usage

```
polarMap(
  data,
  pollutant = NULL,
  x = "ws",
  limits = NULL,
  latitude = NULL,
  longitude = NULL,
  control = NULL,
  popup = NULL,
  label = NULL,
  provider = "OpenStreetMap",
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  draw.legend = TRUE,
  collapse.control = FALSE,
  d.icon = 200,
  d.fig = 3.5,
  type = NULL,
  ...
)
```

Arguments

`data`	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (`ws`), wind direction (`wd`), and the column representing the concentration of a pollutant. In addition, `data` must include a decimal latitude and longitude.
`pollutant`	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they can be toggled between using a "layer control" interface.
`x`	The radial axis variable to plot.
`limits`	By default, each individual polar marker has its own colour scale. The `limits` argument will force all markers to use the same colour scale. The limits are set in the form `c(lower, upper)`, so `limits = c(0, 100)` would force the plot limits to span 0-100.
`latitude, longitude`	The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).
`control`	Column to be used for splitting the input data into different groups which can be selected between using a "layer control" interface. Appropriate columns could be those added by `openair::cutData()` or `openair::splitByDate()`. `control` cannot be used if multiple `pollutant` columns have been provided.
`popup`	Column to be used as the HTML content for marker popups. Popups may be useful to show information about the individual sites (e.g., site names, codes, types, etc.).

`label` Column to be used as the HTML content for hover-over labels. Labels are useful for the same reasons as popups, though are typically shorter.

`provider` The base map(s) to be used. See http://leaflet-extras.github.io/leaflet-providers/preview/ for a list of all base maps that can be used. If multiple base maps are provided, they can be toggled between using a "layer control" interface.

`cols` The colours used for plotting. See `openair::openColours()` for more information.

`alpha` The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

`key` Should a key for each marker be drawn? Default is `FALSE`.

`draw.legend` When `limits` are specified, should a shared legend be created at the side of the map? Default is `TRUE`.

`collapse.control`
Should the "layer control" interface be collapsed? Defaults to `FALSE`.

`d.icon` The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`d.fig` The diameter of the plots to be produced using `openair` in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`type` Deprecated. Please use `label` and/or popup to label different sites.

`...` Arguments passed on to `openair::polarPlot`

`wd` Name of wind direction field.

`statistic` The statistic that should be applied to each wind speed/direction bin. Because of the smoothing involved, the colour scale for some of these statistics is only to provide an indication of overall pattern and should not be interpreted in concentration units e.g. for `statistic = "weighted.mean"` where the bin mean is multiplied by the bin frequency and divided by the total frequency. In many cases using `polarFreq` will be better. Setting `statistic = "weighted.mean"` can be useful because it provides an indication of the concentration * frequency of occurrence and will highlight the wind speed/direction conditions that dominate the overall mean.Can be:

- "mean" (default), "median", "max" (maximum), "frequency". "stdev" (standard deviation), "weighted.mean".
- `statistic = "nwr"` Implements the Non-parametric Wind Regression approach of Henry et al. (2009) that uses kernel smoothers. The `openair` implementation is not identical because Gaussian kernels are used for both wind direction and speed. The smoothing is controlled by `ws_spread` and `wd_spread`.
- `statistic = "cpf"` the conditional probability function (CPF) is plotted and a single (usually high) percentile level is supplied. The CPF is defined as CPF = my/ny, where my is the number of samples in the y bin (by default a wind direction, wind speed interval) with mixing ratios greater than the *overall* percentile concentration, and ny is the total number of samples in the same wind sector (see Ashbaugh et al., 1985).

Note that percentile intervals can also be considered; see `percentile` for details.

- When `statistic = "r"` or `statistic = "Pearson"`, the Pearson correlation coefficient is calculated for *two* pollutants. The calculation involves a weighted Pearson correlation coefficient, which is weighted by Gaussian kernels for wind direction an the radial variable (by default wind speed). More weight is assigned to values close to a wind speed-direction interval. Kernel weighting is used to ensure that all data are used rather than relying on the potentially small number of values in a wind speed-direction interval.
- When `statistic = "Spearman"`, the Spearman correlation coefficient is calculated for *two* pollutants. The calculation involves a weighted Spearman correlation coefficient, which is weighted by Gaussian kernels for wind direction an the radial variable (by default wind speed). More weight is assigned to values close to a wind speed-direction interval. Kernel weighting is used to ensure that all data are used rather than relying on the potentially small number of values in a wind speed-direction interval.
- `"robust_slope"` is another option for pair-wise statistics and `"quantile.slope"`, which uses quantile regression to estimate the slope for a particular quantile level (see also `tau` for setting the quantile level).
- `"york_slope"` is another option for pair-wise statistics which uses the *York regression method* to estimate the slope. In this method the uncertainties in `x` and `y` are used in the determination of the slope. The uncertainties are provided by `x_error` and `y_error` — see below.

`exclude.missing` Setting this option to `TRUE` (the default) removes points from the plot that are too far from the original data. The smoothing routines will produce predictions at points where no data exist i.e. they predict. By removing the points too far from the original data produces a plot where it is clear where the original data lie. If set to `FALSE` missing data will be interpolated.

`uncertainty` Should the uncertainty in the calculated surface be shown? If `TRUE` three plots are produced on the same scale showing the predicted surface together with the estimated lower and upper uncertainties at the 95% confidence interval. Calculating the uncertainties is useful to understand whether features are real or not. For example, at high wind speeds where there are few data there is greater uncertainty over the predicted values. The uncertainties are calculated using the GAM and weighting is done by the frequency of measurements in each wind speed-direction bin. Note that if uncertainties are calculated then the type is set to "default".

`percentile` If `statistic = "percentile"` then `percentile` is used, expressed from 0 to 100. Note that the percentile value is calculated in the wind speed, wind direction 'bins'. For this reason it can also be useful to set `min.bin` to ensure there are a sufficient number of points available to estimate a percentile. See `quantile` for more details of how percentiles are calculated. `percentile` is also used for the Conditional Probability Function (CPF) plots. `percentile` can be of length two, in which case the percentile *interval* is considered for use with CPF. For example, `percentile = c(90,`

100) will plot the CPF for concentrations between the 90 and 100th percentiles. Percentile intervals can be useful for identifying specific sources. In addition, percentile can also be of length 3. The third value is the 'trim' value to be applied. When calculating percentile intervals many can cover very low values where there is no useful information. The trim value ensures that values greater than or equal to the trim * mean value are considered *before* the percentile intervals are calculated. The effect is to extract more detail from many source signatures. See the manual for examples. Finally, if the trim value is less than zero the percentile range is interpreted as absolute concentration values and subsetting is carried out directly.

weights At the edges of the plot there may only be a few data points in each wind speed-direction interval, which could in some situations distort the plot if the concentrations are high. weights applies a weighting to reduce their influence. For example and by default if only a single data point exists then the weighting factor is 0.25 and for two points 0.5. To not apply any weighting and use the data as is, use weights = c(1, 1, 1).
An alternative to down-weighting these points they can be removed altogether using min.bin.

min.bin The minimum number of points allowed in a wind speed/wind direction bin. The default is 1. A value of two requires at least 2 valid records in each bin an so on; bins with less than 2 valid records are set to NA. Care should be taken when using a value > 1 because of the risk of removing real data points. It is recommended to consider your data with care. Also, the polarFreq function can be of use in such circumstances.

mis.col When min.bin is > 1 it can be useful to show where data are removed on the plots. This is done by shading the missing data in mis.col. To not highlight missing data when min.bin > 1 choose mis.col = "transparent".

upper This sets the upper limit wind speed to be used. Often there are only a relatively few data points at very high wind speeds and plotting all of them can reduce the useful information in the plot.

angle.scale Sometimes the placement of the scale may interfere with an interesting feature. The user can therefore set angle.scale to any value between 0 and 360 degrees to mitigate such problems. For example angle.scale = 45 will draw the scale heading in a NE direction.

units The units shown on the polar axis scale.

force.positive The default is TRUE. Sometimes if smoothing data with steep gradients it is possible for predicted values to be negative. force.positive = TRUE ensures that predictions remain positive. This is useful for several reasons. First, with lots of missing data more interpolation is needed and this can result in artefacts because the predictions are too far from the original data. Second, if it is known beforehand that the data are all positive, then this option carries that assumption through to the prediction. The only likely time where setting force.positive = FALSE would be if background concentrations were first subtracted resulting in data that is legitimately negative. For the vast majority of situations it is expected that the user will not need to alter the default option.

k This is the smoothing parameter used by the gam function in package mgcv. Typically, value of around 100 (the default) seems to be suitable and will

resolve important features in the plot. The most appropriate choice of k is problem-dependent; but extensive testing of polar plots for many different problems suggests a value of k of about 100 is suitable. Setting k to higher values will not tend to affect the surface predictions by much but will add to the computation time. Lower values of k will increase smoothing. Sometimes with few data to plot `polarPlot` will fail. Under these circumstances it can be worth lowering the value of k.

`normalise` If `TRUE` concentrations are normalised by dividing by their mean value. This is done *after* fitting the smooth surface. This option is particularly useful if one is interested in the patterns of concentrations for several pollutants on different scales e.g. NOx and CO. Often useful if more than one `pollutant` is chosen.

`key.header` Adds additional text/labels to the scale key. For example, passing the options `key.header = "header"`, `key.footer = "footer1"` adds addition text above and below the scale key. These arguments are passed to `drawOpenKey` via `quickText`, applying the `auto.text` argument, to handle formatting.

`key.footer` see `key.footer`.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include `"top"`, `"right"`, `"bottom"` and `"left"`.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

`ws_spread` The value of sigma used for Gaussian kernel weighting of wind speed when `statistic = "nwr"` or when correlation and regression statistics are used such as *r*. Default is `0.5`.

`wd_spread` The value of sigma used for Gaussian kernel weighting of wind direction when `statistic = "nwr"` or when correlation and regression statistics are used such as *r*. Default is `4`.

`x_error` The x error / uncertainty used when `statistic = "york_slope"`.

`y_error` The y error / uncertainty used when `statistic = "york_slope"`.

`kernel` Type of kernel used for the weighting procedure for when correlation or regression techniques are used. Only `"gaussian"` is supported but this may be enhanced in the future.

`tau` The quantile to be estimated when `statistic` is set to `"quantile.slope"`. Default is `0.5` which is equal to the median and will be ignored if `"quantile.slope"` is not used.

Value

A leaflet object.

See Also

the original `openair::polarPlot()`

`polarMapStatic()` for the static ggmap equivalent of `polarMap()`

Other interactive directional analysis maps: `annulusMap()`, `diffMap()`, `freqMap()`, `percentileMap()`, `pollroseMap()`, `windroseMap()`

Examples

```
## Not run:
polarMap(polar_data,
  pollutant = "nox",
  x = "ws",
  provider = "Stamen.Toner"
)

## End(Not run)
```

`polarMapStatic` *Bivariate polar plots on a static ggmap*

Description

`polarMapStatic()` creates a `ggplot2` map using bivariate polar plots as markers. As this function returns a `ggplot2` object, further customisation can be achieved using functions like `ggplot2::theme()` and `ggplot2::guides()`.

Usage

```
polarMapStatic(
  data,
  pollutant = NULL,
  x = "ws",
  facet = NULL,
  limits = NULL,
  latitude = NULL,
  longitude = NULL,
  zoom = 13,
  ggmap = NULL,
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  facet.nrow = NULL,
  d.icon = 150,
  d.fig = 3,
  ...
)
```

Arguments

`data`	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (`ws`), wind direction (`wd`), and the column representing the concentration of a pollutant. In addition, `data` must include a decimal latitude and longitude.

`pollutant` The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they will each form part of a separate panel.

`x` The radial axis variable to plot.

`facet` Column to be used for splitting the input data into different panels. Appropriate columns could be those added by `openair::cutData()` or `openair::splitByDate()`. `facet` cannot be used if multiple `pollutant` columns have been provided.

`limits` By default, each individual polar marker has its own colour scale. The `limits` argument will force all markers to use the same colour scale. The limits are set in the form `c(lower, upper)`, so `limits = c(0, 100)` would force the plot limits to span 0-100.

`latitude, longitude`
The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).

`zoom` The zoom level to use for the basemap, passed to `ggmap::get_stamenmap()`. Alternatively, the `ggmap` argument can be used for more precise control of the basemap.

`ggmap` By default, `openairmaps` will try to estimate an appropriate bounding box for the input data and then run `ggmap::get_stamenmap()` to import a basemap. The `ggmap` argument allows users to provide their own `ggmap` object to override this, which allows for alternative bounding boxes, map types and colours.

`cols` The colours used for plotting. See `openair::openColours()` for more information.

`alpha` The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

`key` Should a key for each marker be drawn? Default is `FALSE`.

`facet.nrow` Passed to the `nrow` argument of `ggplot2::facet_wrap()`.

`d.icon` The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`d.fig` The diameter of the plots to be produced using `openair` in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`...` Arguments passed on to `openair::polarPlot`

`wd` Name of wind direction field.

`statistic` The statistic that should be applied to each wind speed/direction bin. Because of the smoothing involved, the colour scale for some of these statistics is only to provide an indication of overall pattern and should not be interpreted in concentration units e.g. for `statistic = "weighted.mean"` where the bin mean is multiplied by the bin frequency and divided by the total frequency. In many cases using `polarFreq` will be better. Setting `statistic = "weighted.mean"` can be useful because it provides an indication of the concentration * frequency of occurrence and will highlight the wind speed/direction conditions that dominate the overall mean.Can be:

- "mean" (default), "median", "max" (maximum), "frequency". "stdev" (standard deviation), "weighted.mean".
- `statistic = "nwr"` Implements the Non-parametric Wind Regression approach of Henry et al. (2009) that uses kernel smoothers. The `openair` implementation is not identical because Gaussian kernels are used for both wind direction and speed. The smoothing is controlled by `ws_spread` and `wd_spread`.
- `statistic = "cpf"` the conditional probability function (CPF) is plotted and a single (usually high) percentile level is supplied. The CPF is defined as CPF = my/ny, where my is the number of samples in the y bin (by default a wind direction, wind speed interval) with mixing ratios greater than the *overall* percentile concentration, and ny is the total number of samples in the same wind sector (see Ashbaugh et al., 1985). Note that percentile intervals can also be considered; see `percentile` for details.
- When `statistic = "r"` or `statistic = "Pearson"`, the Pearson correlation coefficient is calculated for *two* pollutants. The calculation involves a weighted Pearson correlation coefficient, which is weighted by Gaussian kernels for wind direction an the radial variable (by default wind speed). More weight is assigned to values close to a wind speed-direction interval. Kernel weighting is used to ensure that all data are used rather than relying on the potentially small number of values in a wind speed-direction interval.
- When `statistic = "Spearman"`, the Spearman correlation coefficient is calculated for *two* pollutants. The calculation involves a weighted Spearman correlation coefficient, which is weighted by Gaussian kernels for wind direction an the radial variable (by default wind speed). More weight is assigned to values close to a wind speed-direction interval. Kernel weighting is used to ensure that all data are used rather than relying on the potentially small number of values in a wind speed-direction interval.
- `"robust_slope"` is another option for pair-wise statistics and `"quantile.slope"`, which uses quantile regression to estimate the slope for a particular quantile level (see also `tau` for setting the quantile level).
- `"york_slope"` is another option for pair-wise statistics which uses the *York regression method* to estimate the slope. In this method the uncertainties in `x` and `y` are used in the determination of the slope. The uncertainties are provided by `x_error` and `y_error` — see below.

`exclude.missing` Setting this option to `TRUE` (the default) removes points from the plot that are too far from the original data. The smoothing routines will produce predictions at points where no data exist i.e. they predict. By removing the points too far from the original data produces a plot where it is clear where the original data lie. If set to `FALSE` missing data will be interpolated.

`uncertainty` Should the uncertainty in the calculated surface be shown? If `TRUE` three plots are produced on the same scale showing the predicted surface together with the estimated lower and upper uncertainties at the 95%

confidence interval. Calculating the uncertainties is useful to understand whether features are real or not. For example, at high wind speeds where there are few data there is greater uncertainty over the predicted values. The uncertainties are calculated using the GAM and weighting is done by the frequency of measurements in each wind speed-direction bin. Note that if uncertainties are calculated then the type is set to "default".

`percentile` If `statistic = "percentile"` then `percentile` is used, expressed from 0 to 100. Note that the percentile value is calculated in the wind speed, wind direction 'bins'. For this reason it can also be useful to set `min.bin` to ensure there are a sufficient number of points available to estimate a percentile. See `quantile` for more details of how percentiles are calculated.
`percentile` is also used for the Conditional Probability Function (CPF) plots. `percentile` can be of length two, in which case the percentile *interval* is considered for use with CPF. For example, `percentile = c(90, 100)` will plot the CPF for concentrations between the 90 and 100th percentiles. Percentile intervals can be useful for identifying specific sources. In addition, `percentile` can also be of length 3. The third value is the 'trim' value to be applied. When calculating percentile intervals many can cover very low values where there is no useful information. The trim value ensures that values greater than or equal to the trim * mean value are considered *before* the percentile intervals are calculated. The effect is to extract more detail from many source signatures. See the manual for examples. Finally, if the trim value is less than zero the percentile range is interpreted as absolute concentration values and subsetting is carried out directly.

`weights` At the edges of the plot there may only be a few data points in each wind speed-direction interval, which could in some situations distort the plot if the concentrations are high. `weights` applies a weighting to reduce their influence. For example and by default if only a single data point exists then the weighting factor is 0.25 and for two points 0.5. To not apply any weighting and use the data as is, use `weights = c(1, 1, 1)`.
An alternative to down-weighting these points they can be removed altogether using `min.bin`.

`min.bin` The minimum number of points allowed in a wind speed/wind direction bin. The default is 1. A value of two requires at least 2 valid records in each bin an so on; bins with less than 2 valid records are set to NA. Care should be taken when using a value > 1 because of the risk of removing real data points. It is recommended to consider your data with care. Also, the `polarFreq` function can be of use in such circumstances.

`mis.col` When `min.bin` is > 1 it can be useful to show where data are removed on the plots. This is done by shading the missing data in `mis.col`. To not highlight missing data when `min.bin` > 1 choose `mis.col = "transparent"`.

`upper` This sets the upper limit wind speed to be used. Often there are only a relatively few data points at very high wind speeds and plotting all of them can reduce the useful information in the plot.

`angle.scale` Sometimes the placement of the scale may interfere with an interesting feature. The user can therefore set `angle.scale` to any value between 0 and 360 degrees to mitigate such problems. For example `angle.scale = 45` will draw the scale heading in a NE direction.

`units` The units shown on the polar axis scale.

`force.positive` The default is `TRUE`. Sometimes if smoothing data with steep gradients it is possible for predicted values to be negative. `force.positive = TRUE` ensures that predictions remain positive. This is useful for several reasons. First, with lots of missing data more interpolation is needed and this can result in artefacts because the predictions are too far from the original data. Second, if it is known beforehand that the data are all positive, then this option carries that assumption through to the prediction. The only likely time where setting `force.positive = FALSE` would be if background concentrations were first subtracted resulting in data that is legitimately negative. For the vast majority of situations it is expected that the user will not need to alter the default option.

`k` This is the smoothing parameter used by the `gam` function in package `mgcv`. Typically, value of around 100 (the default) seems to be suitable and will resolve important features in the plot. The most appropriate choice of `k` is problem-dependent; but extensive testing of polar plots for many different problems suggests a value of `k` of about 100 is suitable. Setting `k` to higher values will not tend to affect the surface predictions by much but will add to the computation time. Lower values of `k` will increase smoothing. Sometimes with few data to plot `polarPlot` will fail. Under these circumstances it can be worth lowering the value of `k`.

`normalise` If `TRUE` concentrations are normalised by dividing by their mean value. This is done *after* fitting the smooth surface. This option is particularly useful if one is interested in the patterns of concentrations for several pollutants on different scales e.g. NOx and CO. Often useful if more than one `pollutant` is chosen.

`key.header` Adds additional text/labels to the scale key. For example, passing the options `key.header = "header", key.footer = "footer1"` adds addition text above and below the scale key. These arguments are passed to `drawOpenKey` via `quickText`, applying the `auto.text` argument, to handle formatting.

`key.footer` see `key.footer`.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include `"top"`, `"right"`, `"bottom"` and `"left"`.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

`ws_spread` The value of sigma used for Gaussian kernel weighting of wind speed when `statistic = "nwr"` or when correlation and regression statistics are used such as *r*. Default is `0.5`.

`wd_spread` The value of sigma used for Gaussian kernel weighting of wind direction when `statistic = "nwr"` or when correlation and regression statistics are used such as *r*. Default is `4`.

`x_error` The `x` error / uncertainty used when `statistic = "york_slope"`.

`y_error` The `y` error / uncertainty used when `statistic = "york_slope"`.

`kernel` Type of kernel used for the weighting procedure for when correlation or regression techniques are used. Only `"gaussian"` is supported but this

may be enhanced in the future.

`tau` The quantile to be estimated when `statistic` is set to `"quantile.slope"`. Default is `0.5` which is equal to the median and will be ignored if `"quantile.slope"` is not used.

Value

a `ggplot2` plot with a `ggmap` basemap

Further customisation using ggplot2

As the outputs of the static directional analysis functions are `ggplot2` figures, further customisation is possible using functions such as `ggplot2::theme()`, `ggplot2::guides()` and `ggplot2::labs()`.

If multiple pollutants are specified, subscripting (e.g., the "x" in "NOx") is achieved using the ggtext package. Therefore if you choose to override the plot theme, it is recommended to use `[ggplot2::theme()]` and `[ggtext::element_markdown()]` to define the `strip.text` parameter.

When arguments like `limits`, `percentile` or `breaks` are defined, a legend is automatically added to the figure. Legends can be removed using `ggplot2::theme(legend.position = "none")`, or further customised using `ggplot2::guides()` and either `color = ggplot2::guide_colourbar()` for continuous legends or `fill = ggplot2::guide_legend()` for discrete legends.

See Also

the original `openair::polarPlot()`

`polarMap()` for the interactive `leaflet` equivalent of `polarMapStatic()`

Other static directional analysis maps: `annulusMapStatic()`, `diffMapStatic()`, `freqMapStatic()`, `percentileMapStatic()`, `pollroseMapStatic()`, `windroseMapStatic()`

---

polar_data *Example data for polar mapping functions*

Description

The `polar_data` dataset is provided as an example dataset as part of the `openairmaps` package. The dataset contains hourly measurements of air pollutant concentrations, location and meteorological data.

Format

Data frame with example data from four sites in London in 2009.

date The date and time of the measurement

nox, no2, pm2.5, pm10 Pollutant concentrations

site The site name. Useful for use with the `popup` and `label` arguments in `openairmaps` functions.

latitude, longitude Decimal latitude and longitude of the sites.

site.type Site type of the site (either "Urban Traffic" or "Urban Background").

wd Wind direction, in degrees from North, as a numeric vector.

ws Wind speed, in m/s, as numeric vector.

visibility The visibility in metres.

air_temp Air temperature in degrees Celcius.

Details

`polar_data` is supplied with the `openairmaps` package as an example dataset for use with documented examples.

Source

`polar_data` was compiled from data using the `openair::importAURN()` function from the `openair` package with meteorological data from the `worldmet` package.

Examples

```
# basic structure
head(polar_data)
```

`pollroseMap` *Pollution rose plots on interactive leaflet maps*

Description

`pollroseMap()` creates a `leaflet` map using "pollution roses" as markers. Any number of pollutants can be specified using the `pollutant` argument, and multiple layers of markers can be added and toggled between using `control`.

Usage

```
pollroseMap(
  data,
  pollutant = NULL,
  statistic = "prop.count",
  breaks = NULL,
  latitude = NULL,
  longitude = NULL,
  control = NULL,
  popup = NULL,
  label = NULL,
  provider = "OpenStreetMap",
  cols = "turbo",
  alpha = 1,
```

```
  key = FALSE,
  draw.legend = TRUE,
  collapse.control = FALSE,
  d.icon = 200,
  d.fig = 3.5,
  type = NULL,
  ...
)
```

Arguments

data	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (ws), wind direction (wd), and the column representing the concentration of a pollutant. In addition, data must include a decimal latitude and longitude.
pollutant	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they can be toggled between using a "layer control" interface.
statistic	The statistic to be applied to each data bin in the plot. Options currently include "prop.count", "prop.mean" and "abs.count". The default "prop.count" sizes bins according to the proportion of the frequency of measurements. Similarly, "prop.mean" sizes bins according to their relative contribution to the mean. "abs.count" provides the absolute count of measurements in each bin.
breaks	Most commonly, the number of break points. If not specified, each marker will independently break its supplied data at approximately 6 sensible break points. When breaks are specified, all markers will use the same break points. Breaks can also be used to set specific break points. For example, the argument breaks = c(0, 1, 10, 100) breaks the data into segments <1, 1-10, 10-100, >100.
latitude, longitude	The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).
control	Column to be used for splitting the input data into different groups which can be selected between using a "layer control" interface. Appropriate columns could be those added by openair::cutData() or openair::splitByDate(). control cannot be used if multiple pollutant columns have been provided.
popup	Column to be used as the HTML content for marker popups. Popups may be useful to show information about the individual sites (e.g., site names, codes, types, etc.).
label	Column to be used as the HTML content for hover-over labels. Labels are useful for the same reasons as popups, though are typically shorter.
provider	The base map(s) to be used. See http://leaflet-extras.github.io/leaflet-providers/preview/ for a list of all base maps that can be used. If multiple base maps are provided, they can be toggled between using a "layer control" interface.
cols	The colours used for plotting. See openair::openColours() for more information.

`alpha` The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

`key` Should a key for each marker be drawn? Default is `FALSE`.

`draw.legend` When `breaks` are specified, should a shared legend be created at the side of the map? Default is `TRUE`.

`collapse.control` Should the "layer control" interface be collapsed? Defaults to `FALSE`.

`d.icon` The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`d.fig` The diameter of the plots to be produced using `openair` in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`type` Deprecated. Please use `label` and/or popup to label different sites.

`...` Arguments passed on to `openair::pollutionRose`

`key.footer` Adds additional text/labels below the scale key. See `key.header` for further information.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include “top”, “right”, “bottom” and “left”.

`paddle` Either `TRUE` or `FALSE`. If `TRUE` plots rose using 'paddle' style spokes. If `FALSE` plots rose using 'wedge' style spokes.

`seg` When `paddle = TRUE`, `seg` determines with width of the segments. For example, `seg = 0.5` will produce segments 0.5 * `angle`.

`normalise` If `TRUE` each wind direction segment is normalised to equal one. This is useful for showing how the concentrations (or other parameters) contribute to each wind sector when the proportion of time the wind is from that direction is low. A line showing the probability that the wind directions is from a particular wind sector is also shown.

Value

A leaflet object.

See Also

the original `openair::pollutionRose()`

`pollroseMapStatic()` for the static ggmap equivalent of `pollroseMap()`

Other interactive directional analysis maps: `annulusMap()`, `diffMap()`, `freqMap()`, `percentileMap()`, `polarMap()`, `windroseMap()`

Examples

```
## Not run:
pollroseMap(polar_data,
  pollutant = "nox",
  statistic = "prop.count",
```

```
  provider = "Stamen.Toner"
)

## End(Not run)
```

`pollroseMapStatic` *Percentile roses on a static ggmap*

Description

`pollroseMapStatic()` creates a `ggplot2` map using percentile roses as markers. As this function returns a `ggplot2` object, further customisation can be achieved using functions like `ggplot2::theme()` and `ggplot2::guides()`.

Usage

```
pollroseMapStatic(
  data,
  pollutant = NULL,
  statistic = "prop.count",
  breaks = NULL,
  facet = NULL,
  latitude = NULL,
  longitude = NULL,
  zoom = 13,
  ggmap = NULL,
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  facet.nrow = NULL,
  d.icon = 150,
  d.fig = 3,
  ...
)
```

Arguments

`data`	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (`ws`), wind direction (`wd`), and the column representing the concentration of a pollutant. In addition, `data` must include a decimal latitude and longitude.
`pollutant`	The column name(s) of the pollutant(s) to plot. If multiple pollutants are specified, they will each form part of a separate panel.
`statistic`	The `statistic` to be applied to each data bin in the plot. Options currently include "prop.count", "prop.mean" and "abs.count". The default "prop.count" sizes bins according to the proportion of the frequency of measurements. Similarly, "prop.mean" sizes bins according to their relative contribution to the mean. "abs.count" provides the absolute count of measurements in each bin.

`breaks` Most commonly, the number of break points. If not specified, each marker will independently break its supplied data at approximately 6 sensible break points. When `breaks` are specified, all markers will use the same break points. Breaks can also be used to set specific break points. For example, the argument `breaks = c(0, 1, 10, 100)` breaks the data into segments <1, 1-10, 10-100, >100.

`facet` Column to be used for splitting the input data into different panels. Appropriate columns could be those added by `openair::cutData()` or `openair::splitByDate()`. `facet` cannot be used if multiple `pollutant` columns have been provided.

`latitude, longitude`
The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).

`zoom` The zoom level to use for the basemap, passed to `ggmap::get_stamenmap()`. Alternatively, the `ggmap` argument can be used for more precise control of the basemap.

`ggmap` By default, `openairmaps` will try to estimate an appropriate bounding box for the input data and then run `ggmap::get_stamenmap()` to import a basemap. The `ggmap` argument allows users to provide their own `ggmap` object to override this, which allows for alternative bounding boxes, map types and colours.

`cols` The colours used for plotting. See `openair::openColours()` for more information.

`alpha` The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

`key` Should a key for each marker be drawn? Default is `FALSE`.

`facet.nrow` Passed to the `nrow` argument of `ggplot2::facet_wrap()`.

`d.icon` The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`d.fig` The diameter of the plots to be produced using `openair` in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form `c(width, height)` can be provided if a non-circular marker is desired.

`...` Arguments passed on to `openair::pollutionRose`

`key.footer` Adds additional text/labels below the scale key. See `key.header` for further information.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include “top”, “right”, “bottom” and “left”.

`paddle` Either `TRUE` or `FALSE`. If `TRUE` plots rose using 'paddle' style spokes. If `FALSE` plots rose using 'wedge' style spokes.

`seg` When `paddle = TRUE`, `seg` determines with width of the segments. For example, `seg = 0.5` will produce segments 0.5 * `angle`.

`normalise` If `TRUE` each wind direction segment is normalised to equal one. This is useful for showing how the concentrations (or other parameters) contribute to each wind sector when the proportion of time the wind is from that direction is low. A line showing the probability that the wind directions is from a particular wind sector is also shown.

Value

a ggplot2 plot with a ggmap basemap

Further customisation using ggplot2

As the outputs of the static directional analysis functions are ggplot2 figures, further customisation is possible using functions such as ggplot2::theme(), ggplot2::guides() and ggplot2::labs().

If multiple pollutants are specified, subscripting (e.g., the "x" in "NOx") is achieved using the ggtext package. Therefore if you choose to override the plot theme, it is recommended to use [ggplot2::theme()] and [ggtext::element_markdown()] to define the strip.text parameter.

When arguments like limits, percentile or breaks are defined, a legend is automatically added to the figure. Legends can be removed using ggplot2::theme(legend.position = "none"), or further customised using ggplot2::guides() and either color = ggplot2::guide_colourbar() for continuous legends or fill = ggplot2::guide_legend() for discrete legends.

See Also

the original openair::pollutionRose()

pollroseMap() for the interactive leaflet equivalent of pollroseMapStatic()

Other static directional analysis maps: annulusMapStatic(), diffMapStatic(), freqMapStatic(), percentileMapStatic(), polarMapStatic(), windroseMapStatic()

---

quickTextHTML *Automatic text formatting for openairmaps*

Description

Workhorse function that automatically applies routine text formatting to common pollutant names which may be used in the HTML widgets produced by openairmaps.

Usage

```
quickTextHTML(text)
```

Arguments

text	A character vector.

Details

quickTextHTML() is routine formatting lookup table. It screens the supplied character vector text and automatically applies formatting to any recognised character sub-series to properly render in HTML.

Value

The function returns a character vector for HTML evaluation.

Author(s)

Jack Davison.

See Also

The original `openair::quickText()`, useful for non-HTML/static maps and plots

Examples

```
labs <- c("no2", "o3", "so2")
quickTextHTML(labs)
```

`trajLevelMap` *Trajectory level plots in leaflet*

Description

This function plots back trajectories on a `leaflet` map. This function requires that data are imported using the `openair::importTraj()` function.

Usage

```
trajLevelMap(
  data,
  longitude = "lon",
  latitude = "lat",
  pollutant,
  statistic = "frequency",
  percentile = 90,
  lon.inc = 1,
  lat.inc = 1,
  min.bin = 1,
  cols = "default",
  alpha = 0.5,
  tile.border = NA,
  provider = "OpenStreetMap"
)
```

Arguments

`data`	Data frame, the result of importing a trajectory file using `openair::importTraj()`.
`latitude, longitude`	The decimal latitude/longitude.
`pollutant`	Pollutant to be plotted.

statistic	By default the function will plot the trajectory frequencies. There are also various ways of plotting concentrations. It is also possible to set statistic = "difference". In this case trajectories where the associated concentration is greater than percentile are compared with the the full set of trajectories to understand the differences in frequencies of the origin of air masses. The comparison is made by comparing the percentage change in gridded frequencies. For example, such a plot could show that the top 10\ concentrations of PM10 tend to originate from air-mass origins to the east. If statistic = "pscf" then a Potential Source Contribution Function map is produced. If statistic = "cwt" then the Concentration Weighted Trajectory approach is used. If statistic = "saqn" then Simplified Quantitative Transport Bias Analysis is used. See "details" of openair::trajLevel() for more information.
percentile	For openair::trajLevel(). The percentile concentration of pollutant against which the all trajectories are compared.
lon.inc	The longitude-interval to be used for binning data.
lat.inc	The latitude-interval to be used for binning data.
min.bin	The minimum number of unique points in a grid cell. Counts below min.bin are set as missing.
cols	Colours to be used for plotting. Options include "default", "increment", "heat", "turbo" and RColorBrewer colours — see the openair::openColours() function for more details. For user defined the user can supply a list of colour names recognised by R (type grDevices::colours() to see the full list). An example would be cols = c("yellow", "green", "blue").
alpha	Opacity of the tiles. Must be between 0 and 1.
tile.border	Colour to use for the border of binned tiles. Defaults to NA, which draws no border.
provider	The base map(s) to be used. See http://leaflet-extras.github.io/leaflet-providers/preview/ for a list of all base maps that can be used. If multiple base maps are provided, they can be toggled between using a "layer control" interface.

Value

A leaflet object.

See Also

Other trajectory maps: trajMap()

Examples

```
## Not run:
trajLevelMap(traj_data, pollutant = "pm2.5", statistic = "pscf", min.bin = 10)

## End(Not run)
```

`trajMap` *Trajectory line plots in leaflet*

Description

This function plots back trajectories on a `leaflet` map. This function requires that data are imported using the `openair::importTraj()` function. Options are provided to colour the individual trajectories (e.g., by pollutant concentrations) or create "layer control" menus to show/hide different layers.

Usage

```
trajMap(
  data,
  longitude = "lon",
  latitude = "lat",
  colour,
  control = "default",
  cols = "default",
  alpha = 0.5,
  npoints = 12,
  provider = "OpenStreetMap",
  collapse.control = FALSE
)
```

Arguments

`data`	Data frame, the result of importing a trajectory file using `openair::importTraj()`.
`latitude, longitude`	The decimal latitude/longitude.
`colour`	Column to be used for colouring each trajectory. This column may be numeric, character or factor. This will commonly be a pollutant concentration which has been joined (e.g., by `dplyr::left_join()`) to the trajectory data by "date".
`control`	Column to be used for splitting the trajectories into different groups which can be selected between using a "layer control" menu.
`cols`	Colours to be used for plotting. Options include "default", "increment", "heat", "turbo" and `RColorBrewer` colours — see the `openair::openColours()` function for more details. For user defined the user can supply a list of colour names recognised by R (type `grDevices::colours()` to see the full list). An example would be `cols = c("yellow", "green", "blue")`. If the `"colour"` argument was not used, a single colour can be named which will be used consistently for all lines/points (e.g., `cols = "red"`).
`alpha`	Opacity of lines/points. Must be between `0` and `1`.
`npoints`	A dot is placed every `npoints` along each full trajectory. For hourly back trajectories points are plotted every `npoints` hours. This helps to understand where

the air masses were at particular times and get a feel for the speed of the air (points closer together correspond to slower moving air masses). Defaults to 12.

provider The base map to be used. See http://leaflet-extras.github.io/leaflet-providers/preview/ for a list of all base maps that can be used.

collapse.control
Should the "layer control" interface be collapsed? Defaults to FALSE.

Value

A leaflet object.

See Also

Other trajectory maps: trajLevelMap()

Examples

```
## Not run:
trajMap(traj_data, colour = "nox")

## End(Not run)
```

---

traj_data *Example data for trajectory mapping functions*

Description

The traj_data dataset is provided as an example dataset as part of the openairmaps package. The dataset contains HYSPLIT back trajectory data for air mass parcels arriving in London in 2009. It has been joined with air quality pollutant concentrations from the "London N. Kensington" AURN urban background monitoring site.

Usage

```
traj_data
```

Format

A data frame with 53940 rows and 10 variables:

date The arrival time of the air-mass

receptor The receptor number

year Trajectory year

month Trajectory month

day Trajectory day

hour Trajectory hour

hour.inc Trajectory hour offset from the arrival date

lat Latitude

lon Longitude

height Height of trajectory in m

pressure Pressure of the trajectory in Pa

date2 Date of the trajectory

nox Concentration of oxides of nitrogen (NO + NO2)

no2 Concentration of nitrogen dioxide (NO2)

o3 Concentration of ozone (O3)

pm10 Concentration of particulates (PM10)

pm2.5 Concentration of fine particulates (PM2.5)

Details

`traj_data` is supplied with the `openairmaps` package as an example dataset for use with documented examples.

Source

`traj_data` was compiled from data using the `openair::importTraj()` function from the `openair` package with air quality data from `openair::importAURN()` function.

Examples

```
# basic structure
head(traj_data)
```

`windroseMap` *Wind rose plots on interactive leaflet maps*

Description

`windroseMap()` creates a `leaflet` map using wind roses as markers. Multiple layers of markers can be added and toggled between using `control`.

Usage

```
windroseMap(
  data,
  ws.int = 2,
  breaks = 4,
  latitude = NULL,
  longitude = NULL,
  control = NULL,
```

```
  popup = NULL,
  label = NULL,
  provider = "OpenStreetMap",
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  draw.legend = TRUE,
  collapse.control = FALSE,
  d.icon = 200,
  d.fig = 3.5,
  type = NULL,
  ...
)
```

Arguments

`data`	A data frame. The data frame must contain the data to plot a `openair::windRose()`, which includes wind speed (`ws`), and wind direction (`wd`). In addition, `data` must include a decimal latitude and longitude.
`ws.int`	The wind speed interval. Default is 2 m/s but for low met masts with low mean wind speeds a value of 1 or 0.5 m/s may be better.
`breaks`	Most commonly, the number of break points for wind speed in windRose. For windRose and the ws.int default of 2 m/s, the default, 4, generates the break points 2, 4, 6, 8 m/s. Breaks can also be used to set specific break points. For example, the argument breaks = c(0, 1, 10, 100) breaks the data into segments <1, 1-10, 10-100, >100.
`latitude, longitude`	The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).
`control`	Column to be used for splitting the input data into different groups which can be selected between using a "layer control" interface. Appropriate columns could be those added by `openair::cutData()` or `openair::splitByDate()`. `control` cannot be used if multiple `pollutant` columns have been provided.
`popup`	Column to be used as the HTML content for marker popups. Popups may be useful to show information about the individual sites (e.g., site names, codes, types, etc.).
`label`	Column to be used as the HTML content for hover-over labels. Labels are useful for the same reasons as popups, though are typically shorter.
`provider`	The base map(s) to be used. See `http://leaflet-extras.github.io/leaflet-providers/preview/` for a list of all base maps that can be used. If multiple base maps are provided, they can be toggled between using a "layer control" interface.
`cols`	The colours used for plotting. See `openair::openColours()` for more information.
`alpha`	The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

key Should a key for each marker be drawn? Default is FALSE.

draw.legend Should a shared legend be created at the side of the map? Default is TRUE.

collapse.control
Should the "layer control" interface be collapsed? Defaults to FALSE.

d.icon The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

d.fig The diameter of the plots to be produced using openair in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

type Deprecated. Please use label and/or popup to label different sites.

... Arguments passed on to openair::windRose

ws Name of the column representing wind speed.

wd Name of the column representing wind direction.

ws2,wd2 The user can supply a second set of wind speed and wind direction values with which the first can be compared. See pollutionRose() for more details.

angle Default angle of "spokes" is 30. Other potentially useful angles are 45 and 10. Note that the width of the wind speed interval may need adjusting using width.

bias.corr When angle does not divide exactly into 360 a bias is introduced in the frequencies when the wind direction is already supplied rounded to the nearest 10 degrees, as is often the case. For example, if angle = 22.5, N, E, S, W will include 3 wind sectors and all other angles will be two. A bias correction can made to correct for this problem. A simple method according to Applequist (2012) is used to adjust the frequencies.

grid.line Grid line interval to use. If NULL, as in default, this is assigned based on the available data range. However, it can also be forced to a specific value, e.g. grid.line = 10. grid.line can also be a list to control the interval, line type and colour. For example grid.line = list(value = 10, lty = 5, col = "purple").

width For paddle = TRUE, the adjustment factor for width of wind speed intervals. For example, width = 1.5 will make the paddle width 1.5 times wider.

seg When paddle = TRUE, seg determines with width of the segments. For example, seg = 0.5 will produce segments 0.5 * angle.

auto.text Either TRUE (default) or FALSE. If TRUE titles and axis labels will automatically try and format pollutant names and units properly, e.g., by subscripting the '2' in NO2.

offset The size of the 'hole' in the middle of the plot, expressed as a percentage of the polar axis scale, default 10.

normalise If TRUE each wind direction segment is normalised to equal one. This is useful for showing how the concentrations (or other parameters) contribute to each wind sector when the proportion of time the wind is from that direction is low. A line showing the probability that the wind directions is from a particular wind sector is also shown.

`max.freq` Controls the scaling used by setting the maximum value for the radial limits. This is useful to ensure several plots use the same radial limits.

`paddle` Either `TRUE` or `FALSE`. If `TRUE` plots rose using 'paddle' style spokes. If `FALSE` plots rose using 'wedge' style spokes.

`key.header` Adds additional text/labels above the scale key. For example, passing `windRose(mydata, key.header = "ws")` adds the addition text as a scale header. Note: This argument is passed to `drawOpenKey()` via `quickText()`, applying the auto.text argument, to handle formatting.

`key.footer` Adds additional text/labels below the scale key. See `key.header` for further information.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include "top", "right", "bottom" and "left".

`dig.lab` The number of significant figures at which scientific number formatting is used in break point and key labelling. Default 5.

`include.lowest` Logical. If `FALSE` (the default), the first interval will be left exclusive and right inclusive. If `TRUE`, the first interval will be left and right inclusive. Passed to the `include.lowest` argument of `cut()`.

`statistic` The `statistic` to be applied to each data bin in the plot. Options currently include "prop.count", "prop.mean" and "abs.count". The default "prop.count" sizes bins according to the proportion of the frequency of measurements. Similarly, "prop.mean" sizes bins according to their relative contribution to the mean. "abs.count" provides the absolute count of measurements in each bin.

`pollutant` Alternative data series to be sampled instead of wind speed. The `windRose()` default NULL is equivalent to `pollutant = "ws"`. Use in `pollutionRose()`.

`angle.scale` The scale is by default shown at a 315 degree angle. Sometimes the placement of the scale may interfere with an interesting feature. The user can therefore set `angle.scale` to another value (between 0 and 360 degrees) to mitigate such problems. For example `angle.scale = 45` will draw the scale heading in a NE direction.

`border` Border colour for shaded areas. Default is no border.

Value

A leaflet object.

See Also

the original `openair::windRose()`

`windroseMapStatic()` for the static ggmap equivalent of `windroseMap()`

Other interactive directional analysis maps: `annulusMap()`, `diffMap()`, `freqMap()`, `percentileMap()`, `polarMap()`, `pollroseMap()`

Examples

```
## Not run:
```

```
windroseMap(polar_data,
  provider = "Stamen.Toner"
)

## End(Not run)
```

`windroseMapStatic` *Wind rose plots on a static ggmap*

Description

`windroseMapStatic()` creates a ggplot2 map using wind roses as markers. As this function returns a ggplot2 object, further customisation can be achieved using functions like `ggplot2::theme()` and `ggplot2::guides()`. See `openair::polarPlot()` for more information.

Usage

```
windroseMapStatic(
  data,
  ws.int = 2,
  breaks = 4,
  facet = NULL,
  latitude = NULL,
  longitude = NULL,
  zoom = 13,
  ggmap = NULL,
  cols = "turbo",
  alpha = 1,
  key = FALSE,
  facet.nrow = NULL,
  d.icon = 150,
  d.fig = 3,
  ...
)
```

Arguments

`data`	A data frame. The data frame must contain the data to plot the directional analysis marker, which includes wind speed (`ws`), wind direction (`wd`), and the column representing the concentration of a pollutant. In addition, `data` must include a decimal latitude and longitude.
`ws.int`	The wind speed interval. Default is 2 m/s but for low met masts with low mean wind speeds a value of 1 or 0.5 m/s may be better.
`breaks`	Most commonly, the number of break points for wind speed in windRose. For windRose and the ws.int default of 2 m/s, the default, 4, generates the break points 2, 4, 6, 8 m/s. Breaks can also be used to set specific break points. For example, the argument breaks = c(0, 1, 10, 100) breaks the data into segments <1, 1-10, 10-100, >100.

facet — Column to be used for splitting the input data into different panels. Appropriate columns could be those added by openair::cutData() or openair::splitByDate(). facet cannot be used if multiple pollutant columns have been provided.

latitude, longitude — The decimal latitude/longitude. If not provided, will be automatically inferred from data by looking for a column named "lat"/"latitude" or "lon"/"lng"/"long"/"longitude" (case-insensitively).

zoom — The zoom level to use for the basemap, passed to ggmap::get_stamenmap(). Alternatively, the ggmap argument can be used for more precise control of the basemap.

ggmap — By default, openairmaps will try to estimate an appropriate bounding box for the input data and then run ggmap::get_stamenmap() to import a basemap. The ggmap argument allows users to provide their own ggmap object to override this, which allows for alternative bounding boxes, map types and colours.

cols — The colours used for plotting. See openair::openColours() for more information.

alpha — The alpha transparency to use for the plotting surface (a value between 0 and 1 with zero being fully transparent and 1 fully opaque).

key — Should a key for each marker be drawn? Default is FALSE.

facet.nrow — Passed to the nrow argument of ggplot2::facet_wrap().

d.icon — The diameter of the plot on the map in pixels. This will affect the size of the individual polar markers. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

d.fig — The diameter of the plots to be produced using openair in inches. This will affect the resolution of the markers on the map. Alternatively, a vector in the form c(width, height) can be provided if a non-circular marker is desired.

... — Arguments passed on to openair::polarAnnulus

resolution Two plot resolutions can be set: "normal" and "fine" (the default).

local.tz Should the results be calculated in local time that includes a treatment of daylight savings time (DST)? The default is not to consider DST issues, provided the data were imported without a DST offset. Emissions activity tends to occur at local time e.g. rush hour is at 8 am every day. When the clocks go forward in spring, the emissions are effectively released into the atmosphere typically 1 hour earlier during the summertime i.e. when DST applies. When plotting diurnal profiles, this has the effect of "smearing-out" the concentrations. Sometimes, a useful approach is to express time as local time. This correction tends to produce better-defined diurnal profiles of concentration (or other variables) and allows a better comparison to be made with emissions/activity data. If set to FALSE then GMT is used. Examples of usage include local.tz = "Europe/London", local.tz = "America/New_York". See cutData and import for more details.

type type determines how the data are split i.e. conditioned, and then plotted. The default is will produce a single plot using the entire data. Type can be one of the built-in types as detailed in cutData e.g. "season", "year",

"weekday" and so on. For example, type = "season" will produce four plots — one for each season.

It is also possible to choose type as another variable in the data frame. If that variable is numeric, then the data will be split into four quantiles (if possible) and labelled accordingly. If type is an existing character or factor variable, then those categories/levels will be used directly. This offers great flexibility for understanding the variation of different variables and how they depend on one another.

Type can be up length two e.g. type = c("season", "site") will produce a 2x2 plot split by season and site. The use of two types is mostly meant for situations where there are several sites. Note, when two types are provided the first forms the columns and the second the rows.

Also note that for the polarAnnulus function some type/period combinations are forbidden or make little sense. For example, type = "season" and period = "trend" (which would result in a plot with too many gaps in it for sensible smoothing), or type = "weekday" and period = "weekday".

statistic The statistic that should be applied to each wind speed/direction bin. Can be "mean" (default), "median", "max" (maximum), "frequency". "stdev" (standard deviation), "weighted.mean" or "cpf" (Conditional Probability Function). Because of the smoothing involved, the colour scale for some of these statistics is only to provide an indication of overall pattern and should not be interpreted in concentration units e.g. for statistic = "weighted.mean" where the bin mean is multiplied by the bin frequency and divided by the total frequency. In many cases using polarFreq will be better. Setting statistic = "weighted.mean" can be useful because it provides an indication of the concentration * frequency of occurrence and will highlight the wind speed/direction conditions that dominate the overall mean.

percentile If statistic = "percentile" or statistic = "cpf" then percentile is used, expressed from 0 to 100. Note that the percentile value is calculated in the wind speed, wind direction 'bins'. For this reason it can also be useful to set min.bin to ensure there are a sufficient number of points available to estimate a percentile. See quantile for more details of how percentiles are calculated.

width The width of the annulus; can be "normal" (the default), "thin" or "fat".

min.bin The minimum number of points allowed in a wind speed/wind direction bin. The default is 1. A value of two requires at least 2 valid records in each bin an so on; bins with less than 2 valid records are set to NA. Care should be taken when using a value > 1 because of the risk of removing real data points. It is recommended to consider your data with care. Also, the polarFreq function can be of use in such circumstances.

exclude.missing Setting this option to TRUE (the default) removes points from the plot that are too far from the original data. The smoothing routines will produce predictions at points where no data exist i.e. they predict. By removing the points too far from the original data produces a plot where it is clear where the original data lie. If set to FALSE missing data will be interpolated.

date.pad For type = "trend" (default), date.pad = TRUE will pad-out miss-

ing data to the beginning of the first year and the end of the last year. The purpose is to ensure that the trend plot begins and ends at the beginning or end of year.

`force.positive` The default is `TRUE`. Sometimes if smoothing data with steep gradients it is possible for predicted values to be negative. `force.positive = TRUE` ensures that predictions remain positive. This is useful for several reasons. First, with lots of missing data more interpolation is needed and this can result in artefacts because the predictions are too far from the original data. Second, if it is known beforehand that the data are all positive, then this option carries that assumption through to the prediction. The only likely time where setting `force.positive = FALSE` would be if background concentrations were first subtracted resulting in data that is legitimately negative. For the vast majority of situations it is expected that the user will not need to alter the default option.

`k` The smoothing value supplied to `gam` for the temporal and wind direction components, respectively. In some cases e.g. a trend plot with less than 1-year of data the smoothing with the default values may become too noisy and affected more by outliers. Choosing a lower value of `k` (say 10) may help produce a better plot.

`normalise` If `TRUE` concentrations are normalised by dividing by their mean value. This is done *after* fitting the smooth surface. This option is particularly useful if one is interested in the patterns of concentrations for several pollutants on different scales e.g. NOx and CO. Often useful if more than one `pollutant` is chosen.

`key.header` Adds additional text/labels to the scale key. For example, passing the options `key.header = "header", key.footer = "footer1"` adds addition text above and below the scale key. These arguments are passed to `drawOpenKey` via `quickText`, applying the `auto.text` argument, to handle formatting.

`key.footer` see `key.footer`.

`key.position` Location where the scale key is to plotted. Allowed arguments currently include `"top"`, `"right"`, `"bottom"` and `"left"`.

`auto.text` Either `TRUE` (default) or `FALSE`. If `TRUE` titles and axis labels will automatically try and format pollutant names and units properly e.g. by subscripting the '2' in NO2.

Value

a `ggplot2` plot with a `ggmap` basemap

Further customisation using ggplot2

As the outputs of the static directional analysis functions are `ggplot2` figures, further customisation is possible using functions such as `ggplot2::theme()`, `ggplot2::guides()` and `ggplot2::labs()`.

If multiple pollutants are specified, subscripting (e.g., the "x" in "NOx") is achieved using the ggtext package. Therefore if you choose to override the plot theme, it is recommended to use `[ggplot2::theme()]` and `[ggtext::element_markdown()]` to define the `strip.text` parameter.

When arguments like `limits`, `percentile` or `breaks` are defined, a legend is automatically added to the figure. Legends can be removed using `ggplot2::theme(legend.position = "none")`, or further customised using `ggplot2::guides()` and either `color = ggplot2::guide_colourbar()` for continuous legends or `fill = ggplot2::guide_legend()` for discrete legends.

See Also

the original `openair::windRose()`

`windroseMap()` for the interactive `leaflet` equivalent of `windroseMapStatic()`

Other static directional analysis maps: `annulusMapStatic()`, `diffMapStatic()`, `freqMapStatic()`, `percentileMapStatic()`, `polarMapStatic()`, `pollroseMapStatic()`

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