Package 'RAINLINK'

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Type Package

Title Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network.

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Description The RAINLINK software enables to obtain rainfall maps from microwave links in a cellular telecommunication network.

Suggests sp, gstat, ggplot2, ggmap, maps, mapproj, labeling, rgdal, ncdf4

RoxygenNote 5.0.1

Installation To install this R package run: install.packages(RAINLINK_1.0.tar.gz, repos=NULL, type = "source")

R topics documented:

`ClimVarParam` *Subfunction for obtaining climatological values of sill, range, and nugget of spherical variogram model for RAINLINK.*

Description

Subfunction for obtaining climatological values of sill, range, and nugget of spherical variogram model. This is based on a climatological variogram based on 30-year automatic rain gauge data sets from The Netherlands. Spherical variograms have been modelled as function of the day number and duration in Van de Beek et al. (2012). They use durations of 1 - 24 h. In this function the relationships can be extrapolated to, e.g. 15-min, data. For all input data the middle of the link is used as location of the path-averaged measurement. Input data are link-based, e.g. 15-minute, path-averaged rainfall accumulations. These rainfall accumulations are assumed to be representative for the point at the center of the link. Van de Beek, C. Z., Leijnse, H., Torfs, P. J. J. F., and Uijlenhoet, R.: Seasonal semi-variance of Dutch rainfall at hourly to daily scales, Adv. Water Resour., 45, 76-85, doi:10.1016/j.advwatres.2012.03.023, 2012. The following parameters can be changed in the configuration file "Config.R":

- TIMESTEP: Duration of time interval of sampling strategy (min).

Usage

```
ClimVarParam(DateStr)
```

Arguments

`DateStr`	the end date of the chosen daily period.

Value

Sill, Range and Nugget

Examples

-

`IDW` *Subfunction for inverse distance weighted interpolation on point data.*

Description

Subfunction for inverse distance weighted interpolation on point data. The following parameters can be changed in the configuration file "Config.R":

- idp: The inverse distance weighting power.

Usage

```
IDW(rain.grid)
```

Value

InterpField

Examples

-

`Interpolation` *Interpolation of link-based path-averaged rainfall estimates.*

Description

Interpolation of link-based path-averaged rainfall estimates. The type of interpolation can be specified in the configuration file. The following types are available: 1) Inverse distance weighted interpolation on data (subfunction IDW); 2) Ordinary kriging with spherical variogram model. Its parameter values nugget, sill, and range, can be defined by the user; 3) Ordinary kriging with spherical variogram model with climatological parameter values based on a 30-year rain gauge data set. These are computed for the day of year as obtained from the file name, thus taking into account seasonality in spatial rainfall correlation. The subfunction ClimVarParam computes these parameter values. Ordinary kriging is performed by subfunction OrdinaryKriging. Note that this interpolation algorithm is developed for interpolation of link-based rainfall estimates, which are path averages. The subfunction IntpPathToPoint computes the path-averaged rainfall intensity for unique link paths. And it assigns path-averaged intensity to the point at the middle of the link path.

- FolderRainEstimates: Folder name of input data.
- FolderRainMaps: Folder name of output data.
- CoorSystemInputData: Coordinate system of input data (e.g. "+init=epsg:4326" for WGS84 in degrees).
- FileGrid: File with interpolation grid.
- IntpMethod: Ordinary kriging ("OK") or inverse distance weighted interpolation ("IDW").
- ClimVar: Use "ClimvdBeek" for climatological spherical variogram model. Use "Manual" for spherical variogram model with nugget, sill, and range values manually specified.
- projstring: Proj4string of an Azimuthal Equidistant Cartesian output coordinate system.

Usage

```
Interpolation()
```

Value

InterpField

Examples

-

`IntpPathToPoint` *Subfunction for computing path-averaged rainfall intensity for unique link paths. Assign the path-averaged intensity to point at middle of link path.*

Description

Subfunction for computing path-averaged rainfall intensity for unique link paths. Assign the path-averaged intensity to point at middle of link path. The following parameters can be changed in the configuration file "Config.R":

- ConversionDepthToIntensity: Conversion factor from rainfall depth to intensity.

Usage

```
IntpPathToPoint(Data)
```

Arguments

`Data`	the microwave link data

Value

Rainlink, NrPaths, NrLinks

Examples

-

`MinMaxToMean` *Subfunction for path-averaged rainfall estimation using microwave links from minimum and maximum attenuations over link path.*

Description

Subfunction for path-averaged rainfall estimation using microwave links. Convert minimum and maximum path-averaged rainfall intensity to mean path-averaged rainfall intensity. Works for sampling strategy where minimum and maximum received powers are provided. The following parameters can be changed in the configuration file "Config.R":

- Aa: Wet antenna attenuation correction (dB).
- alpha: Parameter for conversion from minimum and maximum to mean path-averaged rainfall intensity.

Usage

```
MinMaxToMean()
```

Value

Rmean

Examples

-

`NoWetDryMinMax` *Function for determination of reference signal level, and computing corrected received powers.*

Description

Function for determination of reference signal level (subfunction RefLevelMinMax), and computing corrected received powers, and corrected received powers (this function and subfunction RefLevelMinMax). No wet-dry classification of time intervals is applied. Further, the minimum and maximum attenuation over a link path are computed. The following parameters can be changed in the configuration file "Config.R":

- TIMESTEP: Duration of time interval of sampling strategy (min).
- FolderPreprocessed: Folder name of input data.
- FolderCorrected: Folder name of output data.
- FileRainRetr: Filename with values of coefficients in relationship between specific attenuation and rainfall intensity.

Usage

```
NoWetDryMinMax()
```

Examples

-

`OrdinaryKriging` *Subfunction for ordinary kriging interpolation of point values using spherical variogram model with predefined parameters sill, range, and nugget.*

Description

Subfunction for ordinary kriging interpolation of point values using spherical variogram model with predefined parameters sill, range, and nugget. The following parameters can be changed in the configuration file "Config.R":

- nmax: For local kriging: the number of nearest observations that should be used for a kriging prediction or simulation, where nearest is defined in terms of the space of the spatial locations. By default, all observations are used.

Usage

```
OrdinaryKriging(rain.grid)
```

Arguments

rain.grid	rain grid and rainfall intensities

Value

InterpField

Examples

-

OutlierFilterMinMax *Subfunction to apply filter to remove outliers in path-averaged microwave link attenuations.*

Description

Subfunction to apply filter to remove outliers in link-based rainfall estimates. Malfunctioning link antennas can cause outliers in rainfall retrievals (especially for daily accumulations). These outliers can be removed by using a filter that is based on the assumption that rainfall is correlated in space. The filter discards a time interval of a link for which the cumulative difference between its specific attenuation and that of the surrounding links over the previous 24 h (including the present time interval) becomes lower than -32.5 dB h per km. Works for sampling strategy where minimum and maximum received powers are provided. The following parameters can be changed in the configuration file "Config.R":

- OUTLIERFILTER: Threshold outlier filter (-32.5 dB h per km).

Usage

```
OutlierFilterMinMax(Data)
```

Arguments

Data	the microwave link data

Value

ID, a, b, Amax, Amin, PathLength, IntervalNumber, XStart, YStart, XEnd, YEnd, Frequency

Examples

-

`Polygons` *Subfunction which makes dataframe for polygons with rainfall estimates in specific rainfall class.*

Description

Subfunction which makes dataframe for polygons with rainfall estimates in specific rainfall class.

Usage

```
Polygons(cond, Selected)
```

Arguments

`cond`	row numbers of dataframe which fall in specific rainfall class
`Selected`	coordinates of polygons and their assigned rainfall values

Value

dataf, available

Examples

-

`PreprocessingMinMax` *Function for preprocessing of microwave link data.*

Description

Function for preprocessing of microwave link data. Works for sampling strategy where minimum and maximum received powers are provided. This function performs the following tasks:

1. Time interval numbers are computed.
2. Link data are selected for microwave frequencies within chosen range.
3. Data selection criteria are applied.
4. Link coordinates are converted to Cartesian coordinate system.
5. Data from previous and present 24-h period are combined into one file for each day for which rainfall maps need to be obtained.

The following parameters can be changed in the configuration file "Config.R":

- TIMESTEP: Duration of time interval of sampling strategy (min).
- FolderStart: Folder name of input data.
- FolderPreprocessed: Folder name of output data.
- TimeZone: Time zone of data (e.g. "UTC").

- PERIOD: Select daily time interval, i.e., "0800" implies 0800 UTC previous day - 0800 UTC present day (use 2400 for 0000 UTC).
- MinFrequency: Minimum allowed microwave frequency of link in output (GHz).
- MaxFrequency: Maximum allowed microwave frequency of link in output (GHz).
- CoorSystemInputData: Coordinate system of input data (e.g. "+init=epsg:4326" for WGS84 in degrees).
- projstring: Proj4string of an Azimuthal Equidistant Cartesian output coordinate system.

Usage

```
PreprocessingMinMax()
```

Examples

-

`RAINLINK` *The RAINLINK package.*

Description

A sample microwave link data set is provided for The Netherlands (folder "LinkDataOriginal"). This data set needs to be processed in the order described below to obtain link-based rainfall maps. It uses a configuration file "Config.R", which contains all parameter values, coordinate systems, visualisation options, and folder names for rainfall estimation and mapping using microwave links. The file "InterpolationGrid.dat" contains the longitude and latitude of the interpolation and radar grid in degrees (WGS84). The file "PolygonsGrid.dat" contains the corresponding polygons with four angular points (longitude and latitude in degrees in WGS84). Per pixel there are five entries. The first entry is the same as the fifth entry in order to close the polygon. File "ab_values_vertical.txt" contains the values of the coefficients in the relationship which converts path-averaged specific attenuation to path-averaged rainfall intensity.

Step 1: Preprocessing of linkdata:

PreprocessingMinMax()

Step 2: Wet-dry classification with nearby link approach including reference signal level determination:

WetDryNearbyLinkApMinMax()

or no wet-dry classification including reference signal level determination:

NoWetDryMinMax()

Step 3: Compute mean path-averaged rainfall intensities from minimum and maximum powers over sampling time interval (outliers can be removed in case of nearby link approach):

RainRetrievalMinMax()

Step 4: Interpolation of path-averaged rainfall:

Interpolation()

Step 5: Visualisation of link and radar rainfall maps:

Daily link rainfall map for 11 September 2011:

RainMapsLinksDaily(20110911)

Link rainfall maps for chosen time interval:

RainMapsLinksTimeStep()

Daily gauge-adjusted radar rainfall map for 11 September 2011

(file "RAD_NL25_RAC_MFBS_24H_201109110800.nc"):

RainMapsRadarsDaily(20110911)

15-min gauge-adjusted radar rainfall map for 10 September 2011 2030 - 2045 UTC

(file "Radar_201109102045_15min.dat"):

RainMapsRadarsTimeStep

Details

Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network.

References

Aart Overeem, Hidde Leijnse, Remko Uijlenhoet, 2015. Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network. Atmos. Meas. Tech. Discuss., revised version.

`RainMapsLinksDaily` *Function which visualises daily link-based rainfall depths.*

Description

Function which visualises daily link-based rainfall depths. Requires interpolation grid and file with polygons of pixels. Daily rainfall depths are computed irrespective of the number of available files. If, for instance, only one out of 96 files is available, the daily rainfall depth is still computed and visualised. The data availability is plotted as a percentage in the title caption of the graph. The following parameters can be changed in the configuration file "Config.R":

- TIMESTEP: Duration of time interval of sampling strategy (min).

Usage

```
RainMapsLinksDaily(DateMap)
```

Arguments

`DateMap`	end date of daily period for which rainfall map should be plotted

Examples

```
RainMapsLinksDaily(20110911) # To plot daily link rainfall map ending at 11 September 2011.
```

RainMapsLinksTimeStep *Function which visualises link-based rainfall depths for chosen TIMESTEP in configuration file.*

Description

Function which visualises link-based rainfall depths for chosen TIMESTEP in configuration file. Requires interpolation grid and file with polygons of pixels, the polygons having four angular points. Note that the zoom level for Google Maps can be chosen. This zoom level will not always match with the area to be plotted. Downloading a GoogleMaps background map is very fast, but downloading an OpenStreetMap may require tenths of seconds. Note that such a map is downloaded only once, which saves time in case of multiple rainfall maps. The following parameters can be changed in the configuration file "Config.R":

- TIMESTEP: Duration of time interval of sampling strategy (min).

Usage

```
RainMapsLinksTimeStep()
```

Examples

```
RainMapsLinksTimeStep()
```

RainMapsRadarsDaily *Function which visualises daily radar rainfall depths.*

Description

Function which visualises daily radar rainfall depths. Requires interpolation grid and file with polygons of pixels. The radar data have been obtained from http://climate4impact.eu (catalog "Radar precipitation climatology") and are freely available. The following parameters can be changed in the configuration file "Config.R":

- FileNameRadarTimeStep: Filename of radar file of rainfall depths to be visualised (NETCDF4 file).

Usage

```
RainMapsRadarsDaily(DateMap)
```

Arguments

DateMap	end date of daily period for which rainfall map should be plotted

Examples

```
RainMapsRadarsDaily(20110911) # To plot daily radar rainfall map ending at 11 September 2011.
```

`RainMapsRadarsTimeStep` *Function which visualises radar rainfall depths for chosen TIMESTEP in configuration file.*

Description

Function which visualises radar rainfall depths for chosen TIMESTEP in configuration file. Requires interpolation grid and file with polygons of pixels. The following parameters can be changed in the configuration file "Config.R":

- TIMESTEP: Duration of time interval of sampling strategy (min).
- FileNameRadarTimeStep: Filename of radar file of rainfall depths to be visualised (ASCII file).

Usage

```
RainMapsRadarsTimeStep()
```

Examples

```
RainMapsRadarsTimeStep()
```

`RainRetrievalMinMax` *Function for path-averaged rainfall estimation using microwave links.*

Description

Function for path-averaged rainfall estimation using microwave links. Works for sampling strategy where minimum and maximum received powers are provided. Maximum and minimum path-averaged rainfall intensites are computed, where a fixed correction factor is applied to remove wet antenna attenuation (subfunction "MinMaxToMean"). Subfunction "OutlierFilter" can be called to apply an outlier filter. The following parameters can be changed in the configuration file "Config.R":

- TIMESTEP: Duration of time interval of sampling strategy (min).
- FolderCorrected: Folder name of input data.
- FolderRainEstimates: Folder name of output data.
- OutlierFilter: is "no" when no outlier filter is to be applied; is "yes" when an outlier filter is to be applied (will only work when wet-dry classification according to nearby link approach has been performed).

Usage

```
RainRetrievalMinMax()
```

Examples

-

`RefLevelMinMax` *Subfunction for determination of reference signal level, which is representative of dry weather, and to obtain corrected received powers.*

Description

Subfunction for determination of reference signal level, which is representative of dry weather, and to obtain corrected received powers. The following parameters can be changed in the configuration file "Config.R":

- HoursRefLevel: Minimum number of hours that should be dry in preceding 24 hours for computing reference level.

Usage

```
RefLevelMinMax(Pmin, PminCor, Pmin_dry, Pmax, NrStepsDay, NrStepsTwoDays,
  NrStepsDryPeriodsRefLevel, NrStepsDayMinus1, WetDry)
```

Arguments

`Pmin`	minimum received power
`PminCor`	corrected received power (in case of wet-dry classification corrected for dry periods)
`Pmin_dry`	minimum received power
`Pmax`	maximum received power
`NrStepsDay`	number of time intervals in 24 hours
`NrStepsTwoDays`	number of time intervals in 48 hours
`NrStepsDryPeriodsRefLevel`	number of time intervals which falls in minimum number of hours that should be dry in preceding 24 hours for computing reference level
`NrStepsDayMinus1`	number of time intervals in 24 ours minus 1
`WetDry`	is "no" when no wet-dry classification has been applied, is "yes" when a wet-dry classification has been applied.

Value

RefLevel, PmaxCorRL, PminCorRL

Examples

-

`ToPolygonsRain` *Subfunction which assignes values of rainfall grid to polygons.*

Description

Subfunction which assignes values of rainfall grid to polygons.

Usage

```
ToPolygonsRain(Data)
```

Arguments

`Data`	microwave link data

Value

Value

Examples

-

`WetDryNearbyLinkApMinMax` *Function for wet-dry classification according to nearby link approach, determination of reference signal level, and corrected received powers.*

Description

The received signal powers often decrease during non-rainy periods, resulting in non-zero rainfall estimates, e.g., caused by reflection of the beam or dew formation on the antennas. To prevent this rainfall overestimation a reliable classification of wet and dry periods is needed. This is also beneficial for determining an appropriate reference signal level, representative for dry weather. In order to define wet and dry periods, we assume that rain is correlated in space, and hence that several links in a given area should experience a decrease in received signal level in the case of rain. A time interval is labeled as wet if at least half of the links in the vicinity (for chosen radius) of the selected link experience such a decrease. This so called nearby link approach is applied in this function. It also determines the reference signal level (subfunction RefLevelMinMax), and corrected received powers (this function and subfunction RefLevelMinMax). Further, the minimum and maximum attenuation over a link path are computed. Finally, malfunctioning link antennas can cause outliers in rainfall retrievals (especially for daily accumulations). These outliers can be removed by using a filter that is based on the assumption that rainfall is correlated in space. The value of this outlier filter is calculated, but the filter is not applied in this function. The following parameters can be changed in the configuration file "Config.R":

- TIMESTEP: Duration of time interval of sampling strategy (min).
- FolderPreprocessed: Folder name of input data.

- FolderCorrected: Folder name of output data.
- DistanceLimit: Radius in wet-dry classification (km).
- MinHoursPmin: Minimum number of hours in the previous 24 hours needed for computing max(P_min) (h).
- ThresholdNumberLinks: Only use data if number of available links is at least larger than this threshold for present and previous day for those time steps that the selected link is available. Selected link is also counted.
- ThresholdMedianL: Threshold value (dB km^-1).
- ThresholdMedian: Threshold value (dB).
- FileRainRetr: Filename with values of coefficients in relationship between specific attenuation and rainfall intensity.

Usage

```
WetDryNearbyLinkApMinMax()
```

Examples

-

Index