# Package ‘RAINLINK’

October 18, 2018

**Type** Package

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

**Version** 1.11

**Date** 2017-12-05

**Author** Aart Overeem & Hidde Leijnse

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

**Suggests** sp, gstat, crayon, withr, ggplot2, ggmap, maps, mapproj, labeling, rgdal, ncdf4, digest

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**RoxygenNote** 6.1.0

**Installation** To install this R package run: install.packages("RAINLINK_1.11.tar.gz", repos=NULL, type = "source"). To install it in a specified directory, add ", path", where path is the name of the folder where the package needs to be installed, e.g. "Rlibraries" (use quotation marks).

**Available at** https://github.com/overeem11/RAINLINK

**Additional information** see "ManualRAINLINK.pdf"

## R topics documented:

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

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## 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.

## Usage

```
ClimVarParam(DateStr, TimeScaleHours, TimeZone)
```

## Arguments

| | |
|---|---|
| `DateStr` | The end date of the chosen daily period. |
| `TimeScaleHours` | Rainfall aggregation interval in hours. |
| `TimeZone` | Time zone of data (e.g. "UTC"). |

## Value

Data frame with values of sill, range and nugget.

## Author(s)

Aart Overeem & Hidde Leijnse

## References

”ManualRAINLINK.pdf”

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

Van de Beek, C. Z., Leijnse, H., Torfs, P. J. J. F., and Uijlenhoet, R., 2012: 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.

## Examples

```
ClimVarParam(DateStr="20110911",TimeScaleHours=0.25,TimeZone="UTC")
```

| CorrectMinMaxRSL | *Function for correcting minimum and maximum received signal powers.* |
|---|---|

## Description

Function for correcting minimum (Pmin) and maximum (Pmax) received signal powers. For a rainy time interval the corrected minimum received signal power becomes equal to the minimum received signal power if this is below the reference signal level (Pref). Otherwise the corrected minimum received signal power becomes equal to the reference signal level. The corrected maximum received signal power becomes equal to the maximum received signal power if both the maximum received signal power and the corrected minimum received signal power are below the reference signal level.

Works for a sampling strategy where minimum and maximum received signal powers are provided, and the transmitted power levels are constant.

Also works for a sampling strategy where instantaneous transmitted and received signal levels are obtained. In case of instantaneous signal levels, it does not matter whether transmitted power levels vary or are constant. The only requirement is that the input data for RAINLINK needs some preprocessing. See "ManualRAINLINK.pdf" for instructions.

## Usage

```
CorrectMinMaxRSL(Data = DataOutlierFiltered, Dry = WetDry$Dry,
  Pref = Pref)
```

## Arguments

| | |
|---|---|
| `Data` | Data frame with microwave link data. |
| `Dry` | Data frame: Should interval be considered dry for reference level determination? (0 = wet; 1 = dry). |
| `Pref` | Reference level (dB). |

## Value

Data frame with corrected minimum and maximum received powers (dB).

## Author(s)

Aart Overeem & Hidde Leijnse

## References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

## Examples

```
CorrectMinMaxRSL(Data=DataOutlierFiltered,Dry=WetDry$Dry,Pref=Pref)
```

---

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

---

### Description

Subfunction for inverse distance weighted interpolation on point data.

### Usage

```
IDW(idp, rain.grid, Rainlink)
```

### Arguments

| | |
|---|---|
| `idp` | The inverse distance weighting power. |
| `rain.grid` | Interpolation grid in Azimuthal Equidistant Cartesian coordinate system. |
| `Rainlink` | Coordinates of links in Azimuthal Equidistant Cartesian coordinate system. and rainfall intensity (latitude in km, longitude in km, intensity in mm $h^{-1}$). |

### Value

Interpolated field of rainfall intensities.

### Author(s)

Aart Overeem & Hidde Leijnse

### References

”ManualRAINLINK.pdf”

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

### Examples

```
IDW(idp=idp,rain.grid=rain.grid,Rainlink=Rainlink)
```

---

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

---

## Description

Interpolation of link-based path-averaged rainfall estimates. The type of interpolation has to be specified. 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 intensities for unique link paths. And it assigns path-averaged intensity to the point at the middle of the link path.

The time interval does not have to be an integer but should be equidistant. The minimum time interval length is automatically computed and is employed as the time interval length.

## Usage

```
Interpolation(Data, CoorSystemInputData = NULL, idp = 2,
  IntpMethod = "OK", nmax = 50, NUGGET, RANGE, RainGrid, Rmean, SILL,
  TimeZone = "UTC", Variogram = "ClimVar", OutputDir = NULL)
```

## Arguments

| | |
|---|---|
| `Data` | Data frame with microwave link data. |
| `CoorSystemInputData` | Define coordinate system of input data (in case of WGS84 provide NULL). |
| `idp` | The inverse distance weighting power. |
| `IntpMethod` | Interpolation method: Ordinary kriging ("OK") or inverse distance weighted interpolation ("IDW"). |
| `nmax` | 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. |
| `NUGGET` | Nugget of spherical variogram model (mm). |
| `RANGE` | Range of spherical variogram model (km). |
| `RainGrid` | Data frame containing information on the points in space where rainfall needs to be estimated, is assumed to be in the same coordinate system as the original link data. |
| `Rmean` | Vector of link-derived rainfall intensities (mm $h^{-1}$) with length equal to Data. |
| `SILL` | Sill of spherical variogram model ($mm^2$). |
| `TimeZone` | Time zone of data (e.g. "UTC"). |
| `Variogram` | For OK: which variogram to use? Use "ClimvdBeek" for climatological spherical variogram model. Use "Manual" for spherical variogram model with NUGGET, SILL, and RANGE values supplied as function arguments. |
| `OutputDir` | If supplied (not NULL), files with resulting interpolated rainfall fields will be written to this directory. If not supplied, the interpolated fields will be returned. |

## Value

Interpolated field of rainfall intensities (mm $h^{-1}$).

### Author(s)

Aart Overeem & Hidde Leijnse

### References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

### Examples

```
Interpolation(Data=DataPreprocessed,CoorSystemInputData=NULL,idp=2.0,
IntpMethod="OK",nmax=50,NUGGET=0.37,RANGE=18.7,RainGrid=RainGrid,
Rmean=Rmean,SILL=3.7,TimeZone="UTC",Variogram="ClimVar",OutputDir="RainMapsLinks15min")
```

---

## IntpPathToPoint — *Subfunction for computing path-averaged rainfall intensities for unique link paths. A path-averaged rainfall intensity is assigned to a point at the middle of the link path.*

---

### Description

Subfunction for computing path-averaged rainfall intensities for unique link paths. The link-based, e.g. a 15-minute path-averaged rainfall accumulation is converted to a path-averaged rainfall intensity, and subsequently assigned to a point at the middle of the link path. Path-averaged rainfall intensities are obtained, so data from full-duplex links are averaged.

### Usage

```
IntpPathToPoint(ID, Rmean, XEnd, XStart, YEnd, YStart)
```

### Arguments

| | |
|---|---|
| `ID` | Link identifier. |
| `Rmean` | Data frame with mean path-averaged rainfall intensities (mm $h^{-1}$). |
| `XEnd` | Easting of end of links (km). |
| `XStart` | Easting of start of links (km). |
| `YEnd` | Northing of end of links (km). |
| `YStart` | Northing of start of links (km). |

### Value

Coordinates of links in Azimuthal Equidistant Cartesian coordinate system (latitude, longitude) and rainfall intensity (mm $h^{-1}$)).

### Author(s)

Aart Overeem & Hidde Leijnse

## References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

## Examples

```
IntpPathToPoint(ID=ID,Rmean=Rmean,Xend=Xend,XStart=XStart,YEnd=YEnd,YStart=YStart)
```

---

`Linkdata` *Microwave link dataset from which path-averaged rainfall intensities can be computed. Received signal powers were obtained from Nokia microwave links in one of the national cellular communication networks in The Netherlands, operated by T-Mobile NL. The minimum and maximum received powers over 15-min intervals were provided, based on 10-Hz sampling. The transmitted power was almost constant. Here the data have a resolution of 1 dB, and the majority of these Nokia links used vertically polarised signals.*

---

## Description

Data were obtained from September 9, 0800 UTC - September 11, 0800 UTC (2011). The data set contains data from 2612 microwave links.

## Usage

```
data(Linkdata)
```

## Format

A data frame with link data from a commercial cellular communication network

## Details

Several functions in the RAINLINK package read a data frame with microwave link data. Such a data frame always contains the variables as indicated below, i.e. the variables in the data set supplied to PreprocessingMinMaxRSL.

For each link and time interval the following variables are provided:

- Frequency: microwave frequency f (GHz).
- DateTime: date and end time of observation (YYYYMMDDhhmm, i.e. year (2011), month (09), day (11), hour (08), minutes (00): 201109110800).
- Pmin: minimum received power $P_{min}$ (dBm).
- Pmax: maximum received power $P_{max}$ (dBm).
- PathLength: length of microwave link path L (km).
- XStart: Longitude of start of links (°; WGS84).
- YStart: Latitude of start of links (°; WGS84).
- Xend: Longitude of end of links (°; WGS84).

- YEnd: Latitude of end of links (°; WGS84).
- ID: Link identifier.

---

`MinMaxRSLToMeanR` *Subfunction for path-averaged rainfall estimation from minimum and maximum attenuations from microwave links.*

---

## Description

Subfunction for path-averaged rainfall estimation using microwave links. Compute minimum (Amin) and maximum (Amax) attenuation over the link path. Convert these to minimum and maximum path-averaged rainfall intensities. Convert minimum and maximum path-averaged rainfall intensities to mean path-averaged rainfall intensities.

Works for a sampling strategy where minimum and maximum received signal powers are provided, and the transmitted power levels are constant.

Also works for a sampling strategy where instantaneous transmitted and received signal levels are obtained. In case of instantaneous signal levels, it does not matter whether transmitted power levels vary or are constant. The only requirement is that the input data for RAINLINK needs some preprocessing. See "ManualRAINLINK.pdf" for instructions.

## Usage

```
MinMaxRSLToMeanR(a, Aa, alpha, b, PathLength, PmaxCor, PminCor, Pref)
```

## Arguments

| | |
|---|---|
| `a` | Coefficients in relationship between rainfall intensity and specific attenuation (mm $h^{-1}$ $dB^{-b}$ $km^{b}$). |
| `Aa` | Wet antenna attenuation correction $A_{\mathrm{a}}$ (dB). |
| `alpha` | Coefficient ($\alpha$) determining contribution of minimum and maximum path-averaged rainfall intensity to mean path-averaged rainfall intensity (-). |
| `b` | Exponents in relationship between rainfall intensity and specific attenuation (-). |
| `PathLength` | Lengths of link paths (km). |

## Value

Data frame with mean path-averaged rainfall intensities (mm $h^{-1}$).

## Author(s)

Aart Overeem & Hidde Leijnse

## References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

## Examples

```
MinMaxRSLToMeanR(a=a,Aa=Aa,alpha=alpha,b=b,PathLength=Data$PathLength,
PmaxCor=PmaxCor,PminCor=PminCor,Pref=Pref)
```

---

`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.

## Usage

```
OrdinaryKriging(nmax, Nugget, rain.grid, Rainlink, Range, Sill)
```

## Arguments

| | |
|---|---|
| `nmax` | 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. |
| `Nugget` | Nugget of spherical variogram model (mm). |
| `rain.grid` | Interpolation grid in Azimuthal Equidistant Cartesian coordinate system. |
| `Rainlink` | Coordinates of links in Azimuthal Equidistant Cartesian coordinate system and rainfall intensity (latitude in km, longitude in km, intensity in mm $h^{-1}$). |
| `Range` | Range of spherical variogram model (km). |
| `Sill` | Sill of spherical variogram model ($mm^2$). |

## Value

Interpolated field of rainfall intensities.

## Author(s)

Aart Overeem & Hidde Leijnse

## References

”ManualRAINLINK.pdf”

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

## Examples

```
OrdinaryKriging(nmax=50,Nugget=0.37,rain.grid=rain.grid,Rainlink=Rainlink,
Range=18.7,Sill=3.7)
```

OutlierFilterMinMaxRSL

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

## Description

Function 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), F, becomes lower than a threshold value in dB h km$^{-1}$.

Works for a sampling strategy where minimum and maximum received signal powers are provided, and the transmitted power levels are constant.

The outlier filter has been extensively tested on minimum received signal powers, i.e. for a sampling strategy where minimum and maximum received signal powers are provided, and the transmitted power levels are constant. This function can also be applied in case of other sampling strategies, because it does not explicitly require minimum and maximum received signal powers. It just applies the selection on all rows in a data frame. Whether the outlier filter will give good results when applied to link data obtained from other sampling strategies would need to be tested. Hence, "MinMaxRSL" is kept in this function name to stress that it has been tested for a sampling strategy where minimum and maximum received powers are provided. Update: Now also works for a sampling strategy where instantaneous transmitted and received signal levels are obtained. In case of instantaneous signal levels, it does not matter whether transmitted power levels vary or are constant. The only requirement is that the input data for RAINLINK needs some preprocessing. See "ManualRAINLINK.pdf" for instructions.

Can only be applied when function WetDryNearbyLinkApMinMaxRSL has been executed.

## Usage

```
OutlierFilterMinMaxRSL(Data, F, FilterThreshold = -32.5)
```

## Arguments

| | |
|---|---|
| `Data` | Data frame with microwave link data. |
| `F` | Values for filter to remove outliers (dB km$^{-1}$ h). |
| `FilterThreshold` | Outlier filter threshold (dB h km$^{-1}$). |

## Value

Data frame with microwave link data.

## Author(s)

Aart Overeem & Hidde Leijnse

### References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

### Examples

```
OutlierFilterMinMaxRSL(Data=DataPreprocessed,F=WetDry$F,FilterThreshold=-32.5)
```

---

## `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

Data frame

### Author(s)

Aart Overeem & Hidde Leijnse

### References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

### Examples

```
RAINLINK::Polygons(cond=cond,Selected=Selected)
```

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

### Description

Function for preprocessing of microwave link data. This function performs the following tasks:

1. Link data are selected for microwave frequencies within chosen range.
2. Data selection criteria are applied.

Works for a sampling strategy where minimum and maximum received signal powers are provided, and the transmitted power levels are constant.

Also works for a sampling strategy where instantaneous transmitted and received signal levels are obtained. In case of instantaneous signal levels, it does not matter whether transmitted power levels vary or are constant. The only requirement is that the input data for RAINLINK needs some preprocessing. See "ManualRAINLINK.pdf" for instructions.

The input microwave link data do not have to be sorted chronologically.

It is strongly advised to use the same unique link identifier (ID) for a link during the entire processed period(s). First of all, time series of sufficient length are needed in order to compute e.g. a reference signal level. Moreover, utilizing the same ID allows for plotting (continuous) time series from the same link.

### Usage

```
PreprocessingMinMaxRSL(Data, MaxFrequency = Inf, MinFrequency = 0,
  verbose = TRUE)
```

### Arguments

| | |
|---|---|
| `Data` | Data frame with microwave link data (use data(Linkdata) to load example data). |
| `MaxFrequency` | Maximum allowed microwave frequency of link in output (GHz; default infinite). |
| `MinFrequency` | Minimum allowed microwave frequency of link in output (GHz; default 0). |

### Value

Data frame with microwave link data.

### Author(s)

Aart Overeem & Hidde Leijnse & Lotte de Vos

### References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

## Examples

```
data(Linkdata)
PreprocessingMinMaxRSL(Data=Linkdata,MaxFrequency=40.5,MinFrequency=12.5)
```

---

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

---

## Description

Function for path-averaged rainfall estimation using microwave links. Maximum and minimum path-averaged rainfall intensites are computed in subfunction “MinMaxRSLToMeanR”, where a fixed correction factor is applied to remove wet antenna attenuation.

Works for a sampling strategy where minimum and maximum received signal powers are provided, and the transmitted power levels are constant.

Also works for a sampling strategy where instantaneous transmitted and received signal levels are obtained. In case of instantaneous signal levels, it does not matter whether transmitted power levels vary or are constant. The only requirement is that the input data for RAINLINK needs some preprocessing. See ”ManualRAINLINK.pdf” for instructions.

## Usage

```
RainRetrievalMinMaxRSL(Aa = 2.3, alpha = 0.33, Data, kRPowerLawData,
  PmaxCor, PminCor, Pref)
```

## Arguments

| | |
|---|---|
| `Aa` | Wet antenna attenuation correction $A_{\mathrm{a}}$ (dB). |
| `alpha` | Coefficient ($\alpha$) determining contribution of minimum and maximum path-averaged rainfall intensity to mean path-averaged rainfall intensity (-). |
| `Data` | Data frame with microwave link data. |
| `kRPowerLawData` | Values of coefficients a and b employed to convert specific attenuation to path-averaged rainfall intensity for a range of microwave frequencies. |
| `PmaxCor` | Data frame with corrected maximum received powers (dB). |
| `PminCor` | Data frame with corrected minimum received powers (dB). |
| `Pref` | Reference level (dB). |

## Value

Mean path-averaged rainfall intensity (mm $\mathrm{h}^{-1}$).

## Author(s)

Aart Overeem & Hidde Leijnse

### References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

### Examples

```
RainRetrievalMinMaxRSL(Aa=2.3,alpha=0.33,Data=DataOutlierFiltered,
kRPowerLawData=kRPowerLawData,PmaxCor=Pcor$PmaxCor,PminCor=Pcor$PminCor,Pref=Pref)
```

---

## ReadRainLocation — *Function for finding (interpolated) rainfall value for a given latitude and longitude.*

---

### Description

Function for finding (interpolated) rainfall value for a given latitude and longitude. I.e. find the grid cell which belongs to the location for which latitude and longitude are provided.

### Usage

```
ReadRainLocation(CoorSystemInputData, dataf, FileGrid, Lat, Lon, XMiddle,
  YMiddle)
```

### Arguments

| | |
|---|---|
| `CoorSystemInputData` | Coordinate system of the input data (e.g. "+init=epsg:4326" for WGS84 in degrees). |
| `dataf` | Data frame of (interpolated) rainfall values. |
| `FileGrid` | File with interpolation grid in same coordinate system as CoorSystemInputData. |
| `Lat` | Latitude of location for which (interpolated) rainfall value is to be extracted (in coordinate system CoorSystemInputData). |
| `XMiddle` | The longitude of the centre of the Azimuthal Equidistant Cartesian coordinate system, given in the coordinate system of the input data. |
| `YMiddle` | The latitude of the centre of the Azimuthal Equidistant Cartesian coordinate system, given in the coordinate system of the input data. |
| `Lot` | Longitude of location for which (interpolated) rainfall value is to be extracted (in coordinate system CoorSystemInputData). |

### Value

Rainfall value for selected location (in unit of provided input rainfall data).

### Author(s)

Aart Overeem & Hidde Leijnse

## References


"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.


## Examples

```
ReadRainLocation(CoorSystemInputData=CoorSystemInputData,dataf=dataf,FileGrid=FileGrid,
Lat=Lat,Lon=Lon,XMiddle=XMiddle,YMiddle=YMiddle)
```

---

# `RefLevelMinMaxRSL` *Function for determination of reference signal level (Pref), which is representative of dry weather.*

---

## Description

Function for determination of reference signal level, which is representative of dry weather.

Works for a sampling strategy where minimum and maximum received signal powers are provided, and the transmitted power levels are constant.

Also works for a sampling strategy where instantaneous transmitted and received signal levels are obtained. In case of instantaneous signal levels, it does not matter whether transmitted power levels vary or are constant. The only requirement is that the input data for RAINLINK needs some preprocessing. See "ManualRAINLINK.pdf" for instructions.

The time interval does not have to be an integer but should be equidistant. The minimum time interval length in the time series is automatically computed and is employed as the time interval length.

## Usage

```
RefLevelMinMaxRSL(Data, Dry = NULL, HoursRefLevel = 2.5,
  PeriodHoursRefLevel = 24)
```

## Arguments

| | |
|---|---|
| `Data` | Data frame with microwave link data. |
| `Dry` | Data frame: Should interval be considered dry for reference level determination? (0 = wet; 1 = dry). |
| `HoursRefLevel` | Minimum number of hours that should be dry in preceding PeriodHoursRefLevel hours for computing reference level (h). |
| `PeriodHoursRefLevel` | Period over which reference level is to be determined (h). |

## Value

Reference level (dB).

## Author(s)

Aart Overeem & Hidde Leijnse & Manuel F. Rios Gaona

### References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

### Examples

```
RefLevelMinMaxRSL(Data=DataPreprocessed,Dry=NULL,HoursRefLevel=2.5,
PeriodHoursRefLevel=24)
```

---

## 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` | Field of rainfall depths at the chosen grid. |

### Value

Field of rainfall depths for the polygons at the chosen grid.

### Author(s)

Aart Overeem & Hidde Leijnse

### References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

### Examples

```
ToPolygonsRain(Data=Data)
```

`WetDryNearbyLinkApMinMaxRSL`

*Function for classifying wet and dry periods according to the nearby link approach. Function also prepares link data for determination of reference signal level and for computing 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 minimum 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. The function also prepares link data for determination of reference signal level and for computing corrected received powers.

Works for a sampling strategy where minimum and maximum received signal powers are provided, and the transmitted power levels are constant.

Also works for a sampling strategy where instantaneous transmitted and received signal levels are obtained. In case of instantaneous signal levels, it does not matter whether transmitted power levels vary or are constant. The only requirement is that the input data for RAINLINK needs some preprocessing. See "ManualRAINLINK.pdf" for instructions.

The time interval does not have to be an integer but should be equidistant. The minimum time interval length in the time series is automatically computed and is employed as the time interval length.

## Usage

```
WetDryNearbyLinkApMinMaxRSL(Data, CoorSystemInputData = NULL,
  MinHoursPmin = 6, PeriodHoursPmin = 24, Radius = 15,
  Step8 = TRUE, ThresholdMedian = -1.4, ThresholdMedianL = -0.7,
  ThresholdNumberLinks = 3, ThresholdWetDry = 2)
```

## Arguments

`Data` Data frame with microwave link data.

`CoorSystemInputData` Define coordinate system of input data (in case of WGS84 provide NULL).

`MinHoursPmin` Minimum number of hours in the previous PeriodHoursPmin hours needed for computing max($P_{min}$) (h).

`PeriodHoursPmin` Number of hours that is considered for computation of max($P_{min}$) (h).

`Radius` Radius in wet-dry classification (km).

`Step8` If TRUE step 8 in the wet-dry classification is performed, else it is not executed.

`ThresholdMedian` Threshold value (dB).

ThresholdMedianL
: Threshold value (dB $km^{-1}$).

ThresholdNumberLinks
: Only use data if number of available (surrounding) links is at least larger than this threshold for the time interval under consideration. The selected link is also counted.

## Value

Data frame: Should interval be considered dry for reference level. determination? (0 = wet; 1 = dry)

Values F for filter to remove outliers (dB $km^{-1}$ h)

## Author(s)

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## References

"ManualRAINLINK.pdf"

Overeem, A., Leijnse, H., and Uijlenhoet, R., 2016: Retrieval algorithm for rainfall mapping from microwave links in a cellular communication network, Atmospheric Measurement Techniques, 9, 2425-2444, https://doi.org/10.5194/amt-9-2425-2016.

## Examples

```
WetDryNearbyLinkApMinMaxRSL(Data=DataPreprocessed,CoorSystemInputData=NULL,
MinHoursPmin=6,PeriodHoursPmin=24,Radius=15,Step8=TRUE,ThresholdMedian=-1.4,
ThresholdMedianL=-0.7,ThresholdNumberLinks=3,ThresholdWetDry=2)
```

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