Introduction to meteoland

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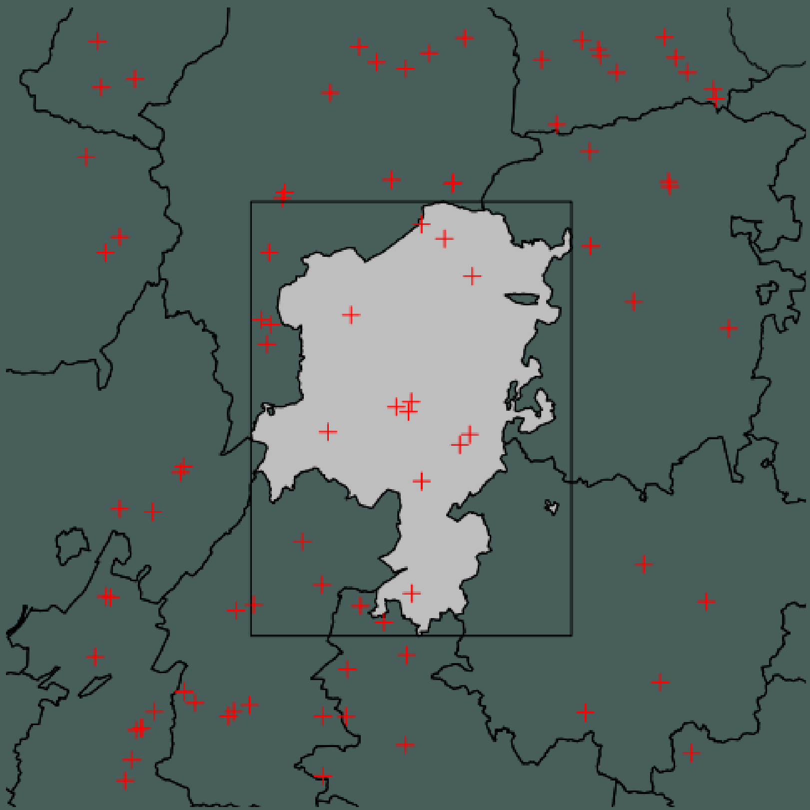

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a. Purpose, installation and documentation

b. Data structures and main functions

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2. Spatial interpolation

a. General interpolation procedure

b. Interpolation of weather variables

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3. Estimation of additional variables

1. Introduction: Purpose, installation and documentation

Purpose

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- **Statistical correction** of meteorological data series (e.g. from climate models).
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NOTE: Important modifications in the package made in **ver. 2.0** have led to a completely new set of functions for spatial interpolation. At the same time, previous functions for statistical correction and weather generation have been deprecated.

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Documentation

Additional articles can be found at the package website.

Detailed documentation on **meteoland** calculation routines can be found at:

https://emf-creaf.github.io/meteolandbook/index.html

1. Introduction: Data structures and main functions

Weather data frames

R name	Definition	Units
`DOY`	Day of the year	[1-366]
`MeanTemperature`	Mean daily temperature	$^{\circ}C$
`MinTemperature`	Minimum daily temperature	$^{\circ}C$
`MaxTemperature`	Maximum daily temperature	$^{\circ}C$
`Precipitation`	Daily precipitation	mm
`MeanRelativeHumidity`	Mean daily relative humidity	$\%$
`MinRelativeHumidity`	Minimum daily relative humidity	$\%$
`MaxRelativeHumidity`	Maximum daily relative humidity	$\%$
`Radiation`	Incoming shortwave solar radiation	$MJ \cdot m^2$
`MaxRelativeHumidity`	Maximum daily relative humidity	$\%$
`WindSpeed`	Wind speed	$m \cdot s^{-1}$
`WindDirection`	Wind direction	$^{\circ}$
`PET`	Potential evapo-transpiration	mm

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Target topography

Spatial structures

- **Points/polygons**: `sf` objects with target geometries as rows and topographic variables as columns
- **Raster**: `stars` objects with topographic variables as attributes and space dimensions

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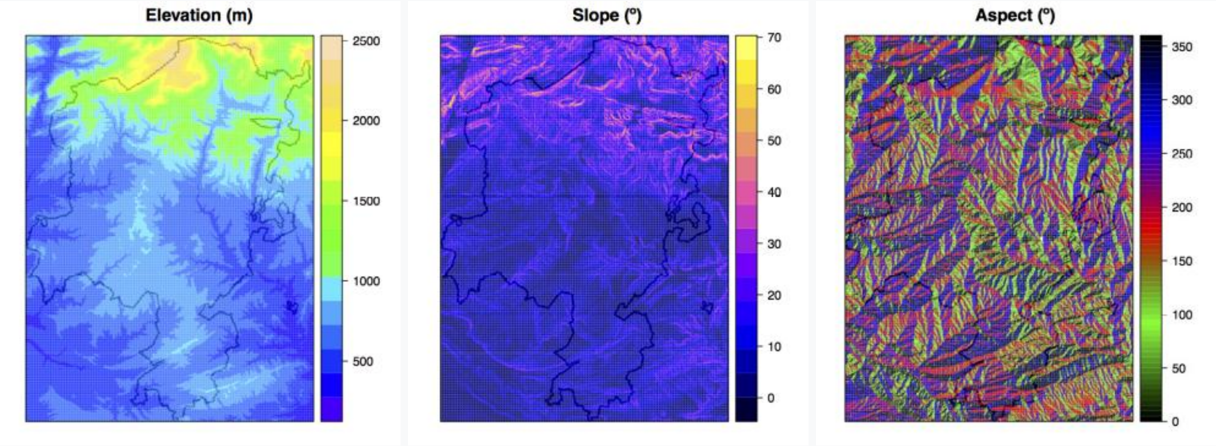
Topographic variables

- `elevation` (in meters)
- `slope` (in degrees from the horizontal plane)
- `aspect` (in degrees from North)



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Weather data

Reference point weather data

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Interpolated weather data

- **Points/polygons**: `sf` objects with weather data frames in a special column called `interpolated_data`
- **Raster**: `stars` objects with weather variables as attributes and space/time dimensions

1. Introduction: Data structures and main functions

Main functions

Interpolation

R function	Description
`with_meteo()`	Checks reference weather data integrity
`create_meteo_interpolator()`	Creates object containing weather reference data
`interpolator_calibration()`	Calibration of interpolation parameters
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Low-level utility functions

R function	Description
radiation_*()	Set of functions used in the calculation of incoming solar radiation and net radiation.
utils_*()	Set of functions used in the calculation of physical variables.
humidity_*()	Set of utility functions for air humidity.
penman()	Calculation of potential evapotranspiration using Penman's formula.

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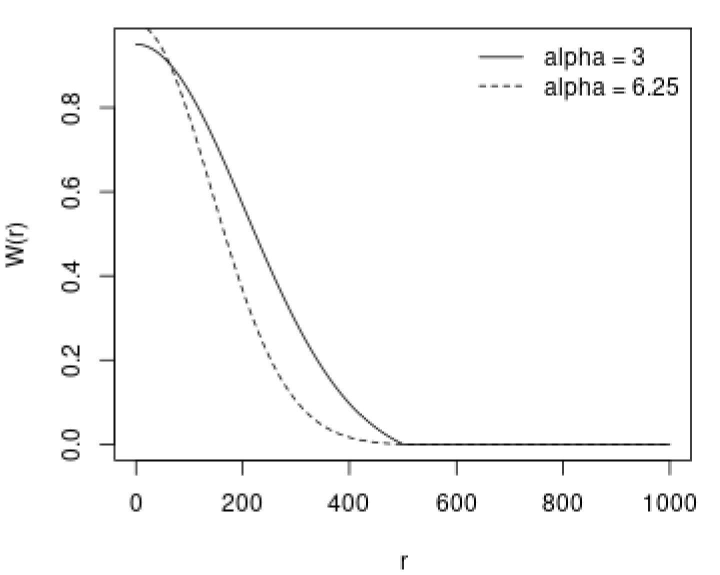
- It is based on a **truncated Gaussian filter** with respect to a central point p:

$$W(r) = e^{-\alpha \cdot (r/R_p)^2} - e^{-\alpha}$$

- Here r is the radial distance from p, R_p is the truncation distance and α is the **shape parameter**.



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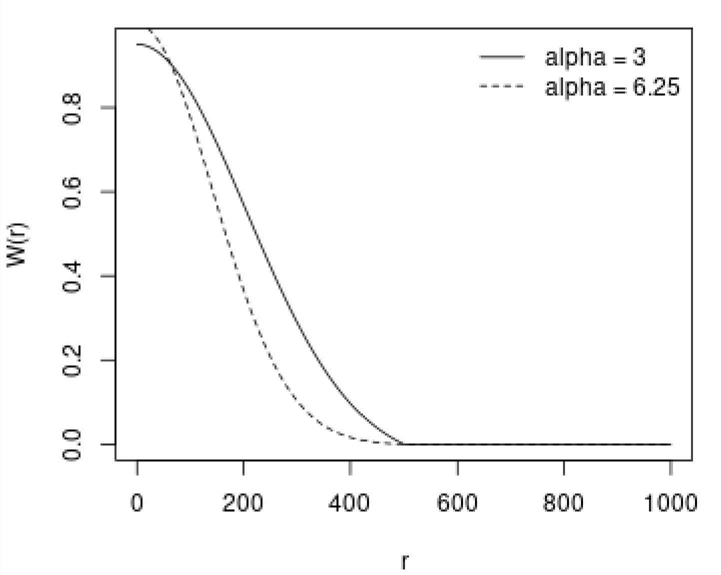

- The spatial convolution of this filter with a set of reference stations results, for each target point, in a vector of **weights** (W).

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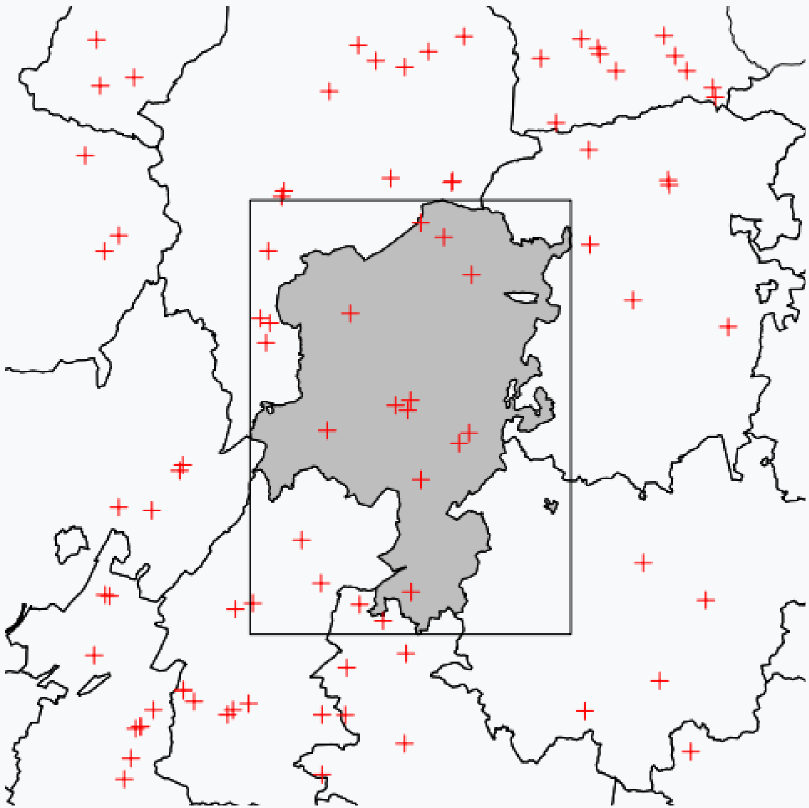

2. Spatial interpolation: Interpolation of weather variables

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- Instead of regressing z_i on T_i, the independent variable is the **difference in elevations** associated with a pair of stations, and the dependent variable is the corresponding **difference in temperatures**:

$$(T_1 - T_2) = \beta_0 + \beta_1 \cdot (z_1 - z_2)$$

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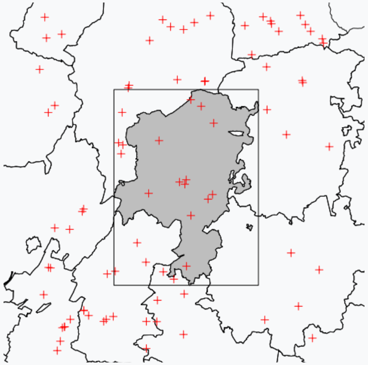
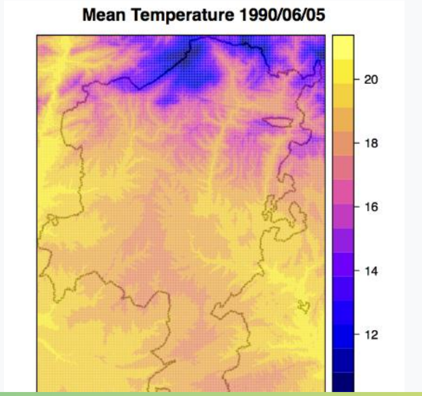
- The temperature for the target point, T_p is finally predicted using a weighted regression:

$$T_p = \frac{\sum_{i=1}^{n} W_i \cdot (T_i + \beta_0 + \beta_1 \cdot (z_p - z_i))}{\sum_{i=1}^{n} W_i}$$





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Precipitation

Predictions of precipitation are complicated by the need to predict both **precipitation occurrence** and, conditioned on this, **precipitation amount**.

Precipitation event

- The precipitation occurrence probability POP_p is:

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Precipitation amount

- Prediction of precipitation amount includes a correction for the effects of **elevation differences**.

- The dependent variable in the regression function is defined as the normalized difference of the precipitation observations P_i for any given pair of stations:

$$\left(\frac{P_1 - P_2}{P_1 + P_2}\right) = \beta_0 + \beta_1 \cdot (z_1 - z_2)$$

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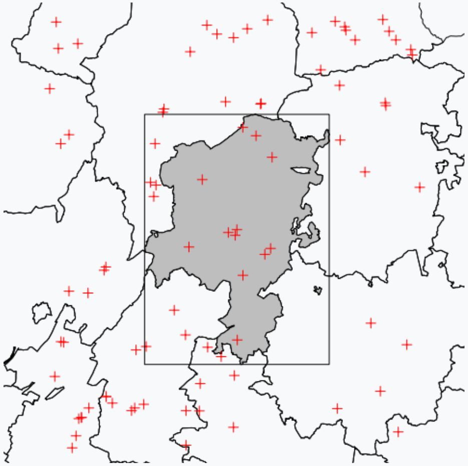
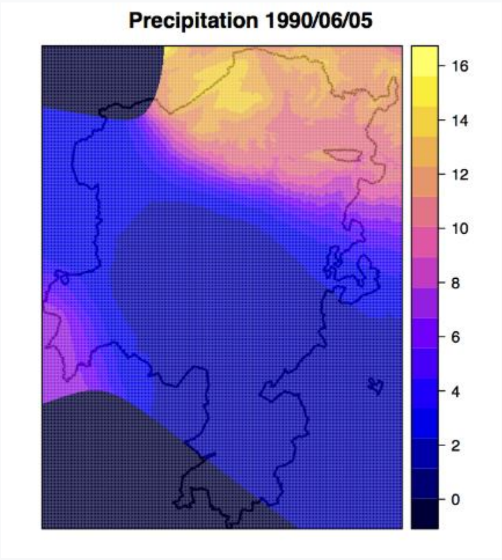
Precipitation

- To obtain the predicted daily total P_p we use the following equation:

$$P_p = \frac{\sum_{i=1}^{n} W_{o,i} \cdot P_i \cdot PO_i \cdot \left(\frac{1+f}{1-f}\right)}{\sum_{i=1}^{n} W_{o,i} \cdot PO_i}$$

- Here, $f = \beta_0 + \beta_1 \cdot (z_p - z_i)$.





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Wind

Interpolation of wind characteristics depends on the amount of information available:

- Interpolation of wind speed only
- Interpolation of wind vectors (speed and direction)

2. Spatial interpolation: Interpolation parameters

- The following table summarizes the most important interpolation parameters:

Parameter	R name	Description
$R_{p,initial}$	`initial_Rp`	Initial value of the truncation radius
α_{Tmin}	`alpha_MinTemperature`	Gaussian shape parameter for minimum temperature
α_{Tmax}	`alpha_MaxTemperature`	Gaussian shape parameter for maximum temperature
α_{Tdew}	`alpha_DewTemperature`	Gaussian shape parameter for dew-point temperature
α_{Pevent}	`alpha_PrecipitationEvent`	Gaussian shape parameter for precipitation event
$\alpha_{Pamount}$	`alpha_PrecipitationAmount`	Gaussian shape parameter for precipitation amount
α_{wind}	`alpha_Wind`	Gaussian shape parameter for wind
N_{Tmin}	`N_MinTemperature`	Average number of stations for minimum temperature
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N_{wind}	`N_Wind`	Average number of stations for wind

3. Estimation of additional variables

Solar radiation

- Potential solar radiation, R_{pot}, is the radiation that a surface on earth would receive if atmosphere was not present (i.e. without the effects of cloud reflection, scattering, …).
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- Following Thornton, Running and White (1997), in **meteoland** is estimated R_g using:

$$R_g = R_{pot} \cdot T_{t,max} \cdot T_{f,max}$$

- Here, $T_{t,max}$ is the maximum (cloud-free) transmittance, which depends on temperature and relative humidity, and $T_{f,max}$ is the proportion of $T_{t,max}$ realized (cloud correction).

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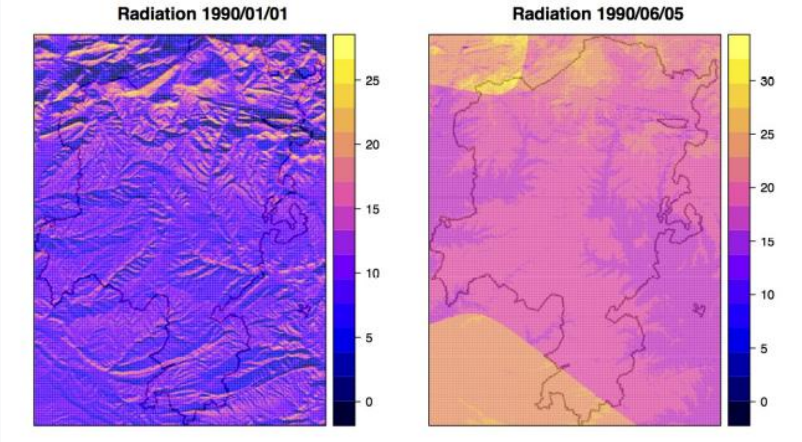

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- If wind speed is available, the Penman (1948) equation is used, that combines an energy equation based on net incoming radiation with an aerodynamic approach, depends on wind.
- If wind speed is not available, an alternative formulation for E_{pot} is used as an approximation by Valiantzas (2006) based on solar radiation, mean temperature and relative humidity.

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