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Meteomap: Generation Of Meteorological Variables For Distributed Physically-Based Hydrological Modeling

Cristina Aguilar

Javier Herrero

Agustín Millares

Miguel A. Losada

María José Polo

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METEOMAP: GENERATION OF METEOROLOGICAL VARIABLES FOR DISTRIBUTED PHYSICALLY-BASED HYDROLOGICAL MODELING

C. AGUILAR (1), J. HERRERO (1), A. MILLARES (1), M.A. LOSADA (2), M.J. POLO (3)
(1): Fluvial Dynamics and Hydrology, IIISTA University of Granada, CEAMA, Avda del Mediterráneo s/n, Granada, 18006, Spain
(2): Environmental Flow Dynamics, IIISTA University of Granada, CEAMA, Avda del Mediterráneo s/n, Granada, 18006, Spain
(3): Fluvial Dynamics and Hydrology, IIISTA University of Córdoba, Campus de Rabanales, Área de Ingeniería Hidráulica, Córdoba, 14071, Spain

MeteoMap is a GIS-based software for the spatial and temporal interpolation of meteorological data from weather station records and topographic data. The outputs are tables and maps of the meteorological variables at different temporal scales (e.g. hourly, daily, annually, etc.). It offers both pre and post-processing tools, including video outlook, map printing and the possibility of exporting the maps to ASCII Grid formats. This study presents the friendly user Windows interface of the software and shows two case studies with applications to hydrological modeling.

INTRODUCTION

Distributed energy and water balance models require time-series surfaces of the meteorological variables involved in hydrological processes. Most of the hydrological GIS-based models apply simple interpolation techniques to extrapolate the point scale values registered at weather stations at a watershed scale [1]. In mountainous areas, where the monitoring network ineffectively covers the complex terrain heterogeneity, simple geostatistical methods for spatial interpolation are not always representative enough, and algorithms that explicitly or implicitly account for the features creating strong local gradients in the meteorological variables must be applied [1, 2, 3, 4].

Originally developed as a meteorological pre-processing tool for a complete hydrological model (WiMMed) [5], MeteoMap has become standalone software. The individual interpolation algorithms used to approximate the spatial and temporal distribution of each meteorological variable were carefully selected taking into account both, the specific variable being mapped, and the common lack of input data from Mediterranean mountainous areas. They include corrections with height for both rainfall and temperature [4], and topographic corrections for solar radiation [1].

This study presents the friendly user interface of the software and shows some case studies with applications to hydrological modeling.

METHODOLOGY

MeteoMap is a GIS-based freeware upon registration. The aim of the tool is to generate distributed surfaces of the main meteorological variables that determine hydrological computations. The algorithms and conceptual interpolation schemes included in MeteoMap were developed by the Groups of Fluvial Dynamics and Hydrology of the Universities of Cordoba and Granada and can be found in detail in the literature [1, 4, 7, 9]. The Graphical Interface for Windows was implemented by Bermasoft.com.

Meteorological variables computed by Meteomap are hourly values of: rainfall, snowfall, temperature, solar radiation, atmospheric emissivity, wind-speed, relative humidity and reference evapotranspiration. Estimations at higher temporal scales are computed from the average of hourly values for state variables (e.g. Temperature or relative humidity) and accumulating hourly values for conservative variables (e.g. Rainfall or solar radiation).

Interpolation schemes

The algorithms used to approximate the spatial and temporal distribution of each meteorological variable depend on the specific variable being mapped [4]. A short description follows for the main variables.

Temperature. The spatial distribution of temperature is described by daily linear temperature–elevation regressions to capture the time-varying orographic effect. Residuals from this linear trend are computed at each weather station, and then subjected to inverse distance weighted interpolation (IDW) to compute spatial fields of residuals to describe the horizontal component of the variability. Finally, residual fields are added to the daily linear trend based on the elevation of each grid cell [2, 3, 4]. The hourly evolution of temperature is computed from the maximum and minimum daily values as they show a better trend with elevation than hourly values, the latter affected by the instantaneous solar radiation [5]. Thus, a modification to a synthetic temperature distribution proposed by Parton and Logan [6] was applied for the temporal distribution of hourly temperature values.

Rainfall. The procedure for the estimation of rainfall-elevation relations was the same as for temperature, but at the storm-event scale instead of the daily one [4]. Then, the generation of hourly values is a two steps process. Firstly, the daily rate of rainfall within the storm is computed at each weather station and interpolated with IDW. Secondly, available hourly data are used to define hourly distributions within the day.

Solar radiation. Apart from the well-known latitudinal gradients caused by the Earth’s rotation and translation movements, cloudiness and topography determine the distribution of incoming solar radiation at the local scale. Firstly, daily global radiation values are computed from daily extraterrestrial fields. Secondly, diffuse and direct radiations fields are obtained from a mean daily clearness index CI, including corrections in the atmospheric mass with elevation. Finally, for the hourly distribution of solar radiation, the daily values are distributed following the temporal distribution of extraterrestrial radiation along the day and considering the shadowing effect of the surrounding terrain [1, 8].

Atmospheric emissivity. The parameterization of Brutsaert, as well as the one by Herrero and Polo [9] are included in the model. The latter, takes into account three possible significant atmospheric states related to the cloud cover (clear, completely covered, and partly covered skies) and computes atmospheric emissivity from temperature, relative humidity and solar radiation records measured at weather stations [9].

Wind-speed and *relative humidity*. Simple interpolation methods such as IDW are applied as current research lines of the authors are involved in more detailed interpolation schemes.

Input data

Input data are introduced in the Properties tab within the Project menu (Figure 1) and are specified below:

-Digital Elevation Model (m.a.s.l) in ASCII Grid format.

-Regions map in ASCII Grid format. This is a layer with the spatial units or regions to be analyzed which are identified by a unique code.

-Latitude and longitude of the study site in degrees.

-Weather stations file with the heights (m.a.s.l) and x and y UTM coordinates of the stations.

-Daily records at the weather stations of rainfall (mm), maximum (ºC), minimum (ºC) and mean temperatures (ºC), solar radiation (MJ/m^2), wind-speed (m/s) and relative humidity (%).

-Hourly records of rainfall (mm).

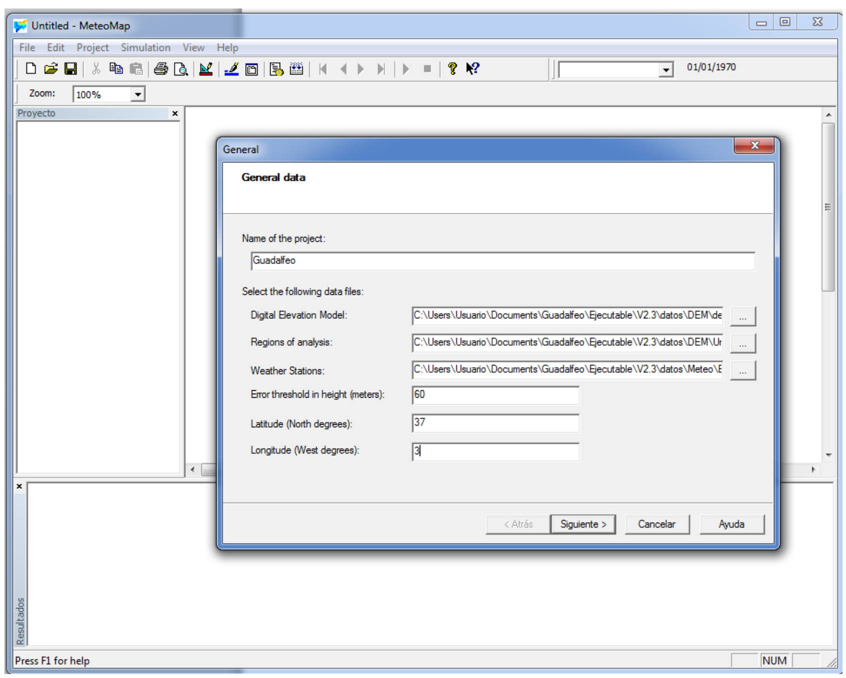

Figure 1. Meteomap interface and Project specifications

Output data

Data generated by Meteomap are tables and maps of the meteorological variables at different temporal scales (e.g. hourly, daily, annually, etc.). They can be visualized within the Meteomap interface for a qualitative interpretation, but they can also be exported into several formats.

Meteomap allows observing for a certain meteorological variable three levels of detail: 1) the spatial distribution in the study site; 2) the punctual value at each cell specified by its x and y UTM coordinates; 3) the temporal evolution at a certain cell of the DEM for a time period.

The temporal variation can be observed spatially in the whole study area through a video, or punctually at a fixed cell through a two dimensional graphic.

Maps can be both printed in the main graphical formats (jpeg, tiff, bmp and png) or exported in ASCII Grid format. Tables with temporal series can be exported in csv format.

Other features

As the graphical interface of Meteomap has a GIS base, it shares the typical features with some well-known GIS programs. Some of these features are listed below:

-Maps are georreferenced.

-Legends of maps can be customized according to the user's needs.

-Visualization of layers of information.

-Preliminary view and printing capabilities.

-Easy installation with an integrated case study as an example.

-Import and export of raster maps in ASCII Grid format.

Computation of a simulation run

To carry out a meteorological computation, the user must specify the following control specifications in the Simulation Configuration within the Simulation Menu:

-Selection of the meteorological variables to be computed.

-Time period to be considered and temporal scale of the results (Figure 2).

-Regions to be analyzed.

Finally, the simulation starts when the user selects Simulation Generation within the Simulation Menu. The results will automatically appear as new layers.

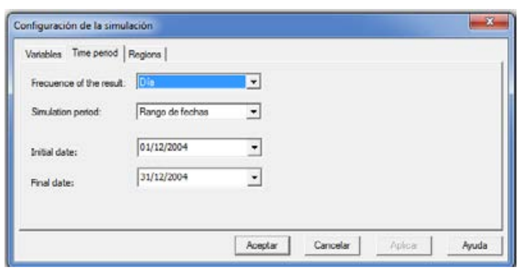

Figure 2. Configuration of a simulation run

CASE STUDY: THE GUADALFEO RIVER BASIN

The Guadalfeo river basin is located 35 km north from the Mediterranean Sea in southeastern Spain. Elevations rise up to 3500 m.a.s.l. and thus, it is characterized by high altitudinal gradients and strong heterogeneity produced by a high mountain climate influenced by the surrounding Mediterranean climate. Climate and weather conditions are so varied that five different climates coexist in the 1300 km^2 of the basin. These climates range from Alpine to semi-arid Mediterranean to tropical [1, 10]. The presence and influence of winter snow becomes important at above 2000 m.a.s.l. The snowmelt season generally extends from April to June, with several melting cycles due to the mild winter periods characteristic of the Mediterranean climate and high solar radiation rates [9, 10].

Precipitation is distributed heterogeneously throughout the area due to the shadow effects produced by the orography. Figure 3 presents the spatial distribution of rainfall on the 30

November 2004 in Meteomap. Moving over the map with the mouse, the user can see the punctual value of rainfall at a certain cell (Figure 3). The spatial heterogeneity of rainfall is also evident in the snowfall dynamics as shows the daily sequence in Figure 4.

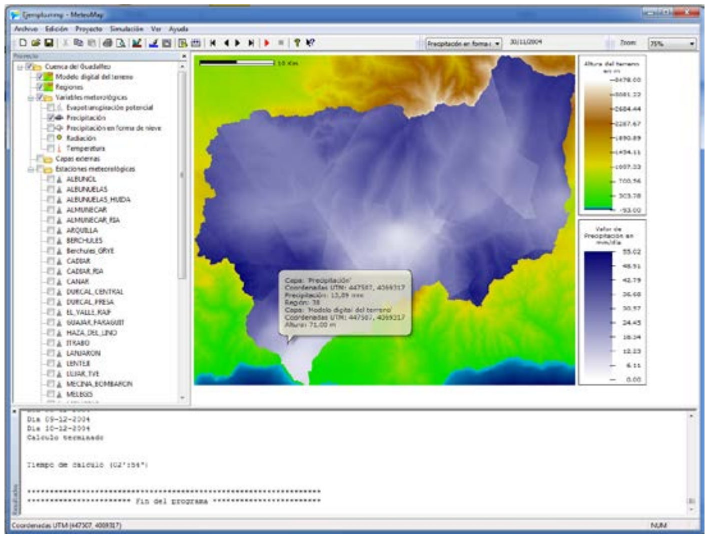

Figure 3. Rainfall on 30 November 2004 (mm/day) and detail of the rainfall (mm) and height (m) at the cell located at the specified x and y UTM coordinates

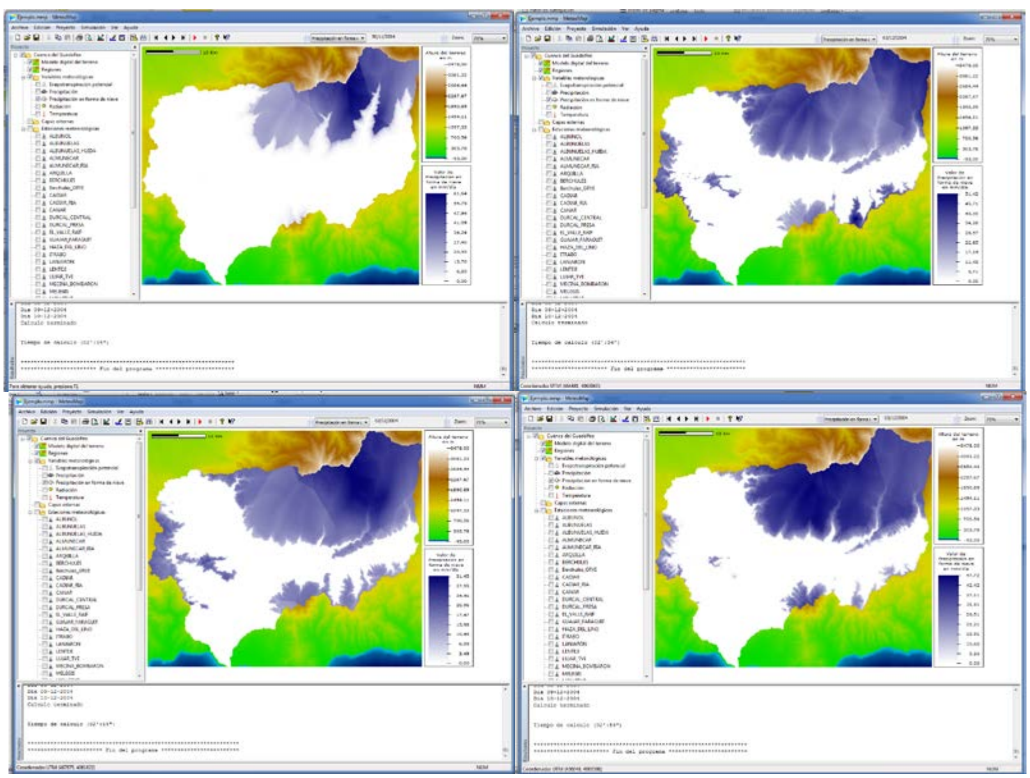

Figure 4. Daily snowfall evolution between the 30th/11/2004 and the 3rd/12/2004 (mm/day)

Finally, Figure 5 shows the temporal evolution of solar radiation in December in the Guadalfeo river basin. A right click over a certain cell allows seeing the temporal evolution in the simulation period. The spatial and temporal variation of solar radiation is thus, visualized in Meteomap and can be numerically analyzed in another software (e.g. GIS or programming environment) if the user exports the generated outputs.

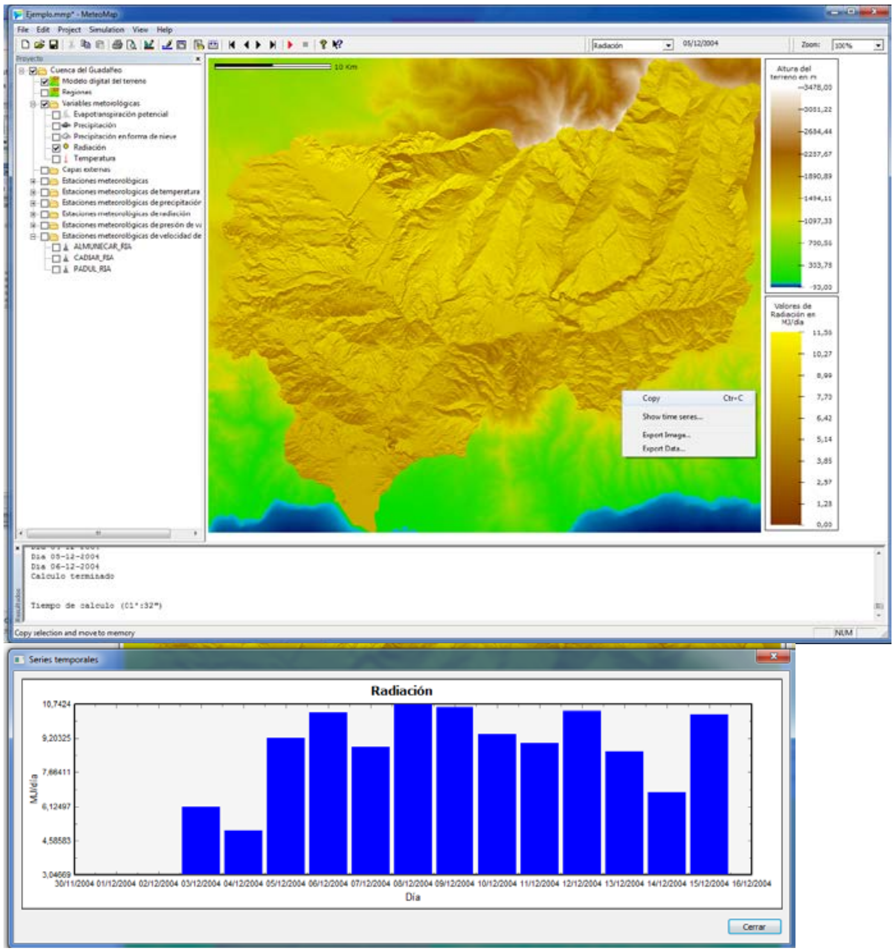

Figure 5. Solar radiation on the watershed on the 5th of December 2004 and daily radiation evolution between the 3rd and the 15th of December 2004 on a certain cell (MJ/m^2/day)

CONCLUSSIONS

Meteomap constitutes a useful tool for the generation of spatial and temporal variation of meteorological variables. Outputs of Meteomap can be directly exported and used as inputs to both, conceptual and distributed hydrological models, using either spatial averages in the region of interest or spatial fields generated in ASCII format.

Meteomap can also be used as a tool for the pre-processing of a certain study site with basic visualization and representation options as well as video capabilities.

As a freeware, it can be implemented in a PC and used by anybody interested in the study of meteorological variables even though Meteomap was originally generated and coupled within a distributed hydrological model.

The friendly user interface as well as the simplicity of application makes it a suitable tool not only for researchers but also for hydrologists and other staff involved in water resources management, environment impact assessment, land-use planning, etc.

The full version is available in Spanish. Translation into English of the whole interface, user manual and technical manual, are currently being carried out by the authors and should be available for the end of 2014.

Acknowledgments

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