
# Deliverable D2.8

## Final version of gridded datasets of all harmonized and spatially interpolated meteorological parameters, per country

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## INTRODUCTION

According to the accepted deliverables D1.12, D2.5 the homogenization, the data quality control and the data completion furthermore controlling of the cross-border harmonization were completed. These procedures were performed by common software MASH on national level. After these the next step was the interpolation or gridding also per countries by common software MISH. The preliminary results of the gridded datasets were presented in the accepted deliverables D2.6, D2.7. The methodology, the working plan and some statistical results of gridding procedure are detailed in the deliverable D2.9.
For the snow variables a special methodology was used by Johann Hiebl that is detailed in the deliverable D2.9 too moreover a summary is also presented here at section 1.9.
The gridded data series are loaded into the directories created for countries on the FTP site of HMS reserved for CARPATCLIM project. The gridded series from countries are compiled in one file per variable for the area of interest. These final result files are uploaded to the FTP site in a separated directory:
ftp://ftp.met.hu/omsz/CompiledGriddedDatasets/
On the above FTP site there are the gridded data series for 16 meteorological variables altogether. The basic 13 variables are presented in the Table 1.

**Table 1. The meteorological variables in daily temporal resolution to be provided**

| ***Variable*** | ***Description*** | ***units*** |
|---|---|---|
| *Ta* | *2 m mean daily air temperature* | *°C* |
| *Tmin* | *Minimum air temperature* | *°C* |
| *Tmax* | *Maximum air temperature* | *°C* |
| *p* | *Accumulated total precipitation* | *mm* |
| *DD* | *10 m wind direction, Degrees* | *0-360* |
| *VV* | *10 m horizontal wind speed* | *m/s* |
| *Sunshine* | *Sunshine duration* | *hours* |
| *cc* | *Cloud cover* | *tenths* |
| *Rglobal* | *Global radiation* | *J/cm$^2$* |
| *RH* | *Relative humidity* | *%* |
| *pvapour* | *Surface vapour pressure* | *hPa* |
| *pair* | *Surface air pressure* | *hPa* |
| *Snow depth* | *Snow depth* | *cm* |

There were also some extra daily variables provided for the Digital Climate Atlas as follows: maximum wind speed, mean wind speed at 2m and snow water equivalent.
The files of the gridded series per variables are described at section 1.6.

## 1. COMPILED GRIDDED DATASETS

### 1.1 Time resolution

Daily gridded data series for the period 1961-2010. (18262 days)

### 1.2 Area of interest and spatial resolution

Area: between latitudes 44°N and 50°N, and longitudes 17°E and 27°E, except Bosnia.

Spatial resolution: $0.1^\circ \times 0.1^\circ \; (\approx 10 \times 10 \text{ km})$ grid

For the coordinates (latitude, longitude) the WGS84 geodetic system was used.

Number of grids: 5895 = 6161 (whole area) – 266 (Bosnia)

### 1.3 The countries

The homogenization, data quality control, data completion and gridding were implemented per countries by common software MASH and MISH.

The predictor countries are (in anti-clockwise direction starting with Hungary and Croatia ending with Czech Republic): Hungary and Croatia (1), Serbia (2), Romania (3), Ukraine (4), Slovakia (5), Poland (6), Czech Republic (7). The countries with the grids and the region are presented on Figure 1.

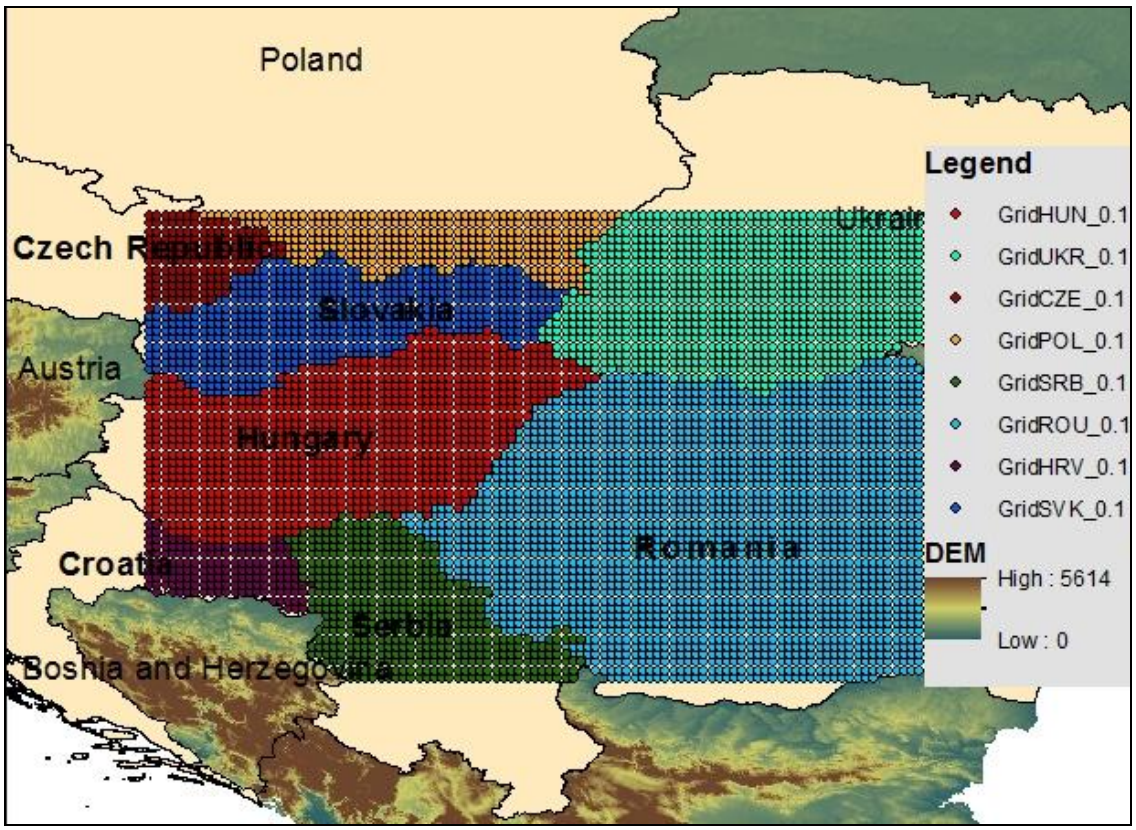


**Figure 1. The area of interest and the CARPATCLIM countries**

We have the same structure that was used at the deliverables D1.12, D2.5, where the tables were given for the above seven predictor areas of the countries, including the predictor station systems.

### 1.3.1 Remark

As regards the expression 'per country', it is necessary to make a nice distinction between the concept of predictor and predictand countries. The procedures of homogenization and gridding were performed at seven areas of countries, where Croatia and Hungary were together. These are the predictor areas. However we have eleven predictand countries altogether since there are some gridded series also for Austria, Bulgaria and Moldova according to the contract. On Figure 2 we present all the predictand area coloured by predictor countries.

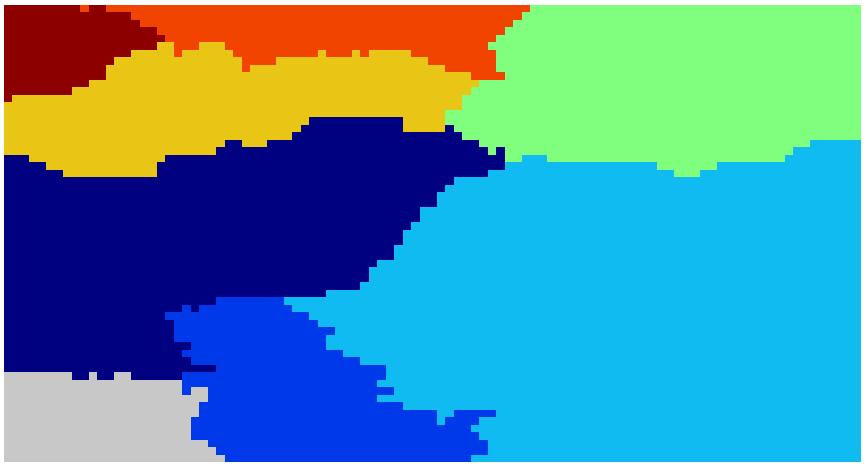

**Figure 2. The area of interest and the grids per predictor countries (except Bosnia)**

**Table 2. Number of grids per countries**

| | |
|---|---|
| Hungary and Croatia (1) | 1214 |
| Serbia (2) | 507 |
| Romania (3) | 2192 |
| Ukraine (4) | 912 |
| Slovakia (5) | 599 |
| Poland (6) | 303 |
| Czech Republic (7) | 168 |

### 1.4 The gridded daily data series compiled in one file

After the implementation of gridding per countries, the gridded series from countries are compiled in one file per variable in row continuous mode.

The names of these files are **{Variable}DailyGrid.ser**. Such a file includes 5895 gridded daily data series for 1961-2010. One column is one series, and the format is:

row 1: indices of the series ( j=1,…,5895)
column 1: year (i4)
column 2: month (i3)
column 3: day (i3)
column 3+j: series j (f8.2), j=1,…,5895

The WGS84 coordinates (longitude λ, latitude ϕ) and the altitudes of the grids with the mark of countries (1-7) are listed in the file **PredtandfilaGrid.dat** for the 5895 grids of area (without Bosnia).
Stored data (grids) format: ASCII

### 1.4.1 Remark

In respect of storage mode of gridded series there would have been two possibilities:

- to store the gridded series in separated files per country,
- to compile the gridded series in one file with an auxiliary file of marking the countries.

In both cases the gridded series are given per country, only the storage mode is different:
in separated files per country versus in one file with an auxiliary file.
We have chosen the second mode because of the following reasons:

- this one is the user friendly solution, since the gridded series are in one file where they are ordered by their locations,
- this one is more general and more elegant mode, since the compiled file and the mark of countries uniquely define the files for countries (see 1.5). It is not true conversely!

## 1.5 Software for selection of the gridded daily data series per country

Referring to 1.4.1, in case of wish it is possible to select the datasets per country from the compiled datasets, since the compiled files of **{Variable}DailyGrid.ser** and the file **PredtandfilaGrid.dat** uniquely define the files for countries.
For this purpose a very simple software is given on FTP in subdirectory:
ftp://ftp.met.hu/omsz/CompiledGriddedDatasets/PerCountry/
Executive file: **GridPerCountry.exe**
Input (compiled) data file: **DailyGrid.ser**
Input (auxiliary) file: **PredtandfilaGrid.dat**
Input (to type): mark of country (**1-7**)
Output (country) data file: **DailyGridCountry.ser**
Output (country) file of coordinates: **PredfilaGrid.dat**

## 1.6 The files of the gridded series per variables

The variables and their compiled gridded daily data series files are as follows:
Minimum air temperature: **TminDailyGrid.ser**
Maximum air temperature: **TmaxDailyGrid.ser**
Mean air temperature: **TaDailyGrid.ser**

- The gridded mean series were calculated as arithmetic mean of minimum and maximum.

Precipitation sum: **PrecDailyGrid.ser**
Relative humidity: **RhDailyGrid.ser**

Surface air pressure: **PairDailyGrid.ser**
Surface vapour pressure: **PvapDailyGrid.ser**

- The gridded series were calculated from the gridded minimum, maximum temperature and relative humidity series.

Cloud cover: **CcDailyGrid.ser**
Sunshine duration: **SunshineDailyGrid.ser**
Global radiation: **RglobalDailyGrid.ser**
Wind speed (mean, 10m): **WindVVDailyGrid.ser**
Wind direction: **WindDDDailyGrid.ser**
Extra wind variables provided for the Digital Climate Atlas:
Wind speed (mean, 2m): **WindVV2mDailyGrid.ser**

- The gridded series at 2m were calculated from the gridded series at 10m.

Maximum wind speed (10m): **WindMaxDailyGrid.ser**
Snow variables (mark of missing values for 1961 01.01-30.09: 9999 ):

- The draft methodology is presented at 1.9.

Snow depth (cm): **SnowdDailyGrid.ser**
Snow water equivalent (mm): **SnowweDailyGrid.ser**

### 1.7 Directory Maps

For the first impression some maps can be found in the directory **Maps**.
On the maps the many years (1961-2010) means are presented that were calculated on the basis of the above gridded daily data series.
The file **MeanWindDirection.doc** is enclosed in order to present the calculation method for means of wind direction.

### 1.8 Number of stations used to compute the grids for different variables, per country

**Table 3.1 Number of stations for Hungary and Croatia**

| | number of all stations | number of stations from neighbouring countries |
|---|---|---|
| Daily mean temperature | 68 | 19 |
| Minimum air temperature | 68 | 19 |
| Maximum air temperature | 68 | 19 |
| Daily precipitation | 233 | 33 |
| 10 m wind direction | 66 | 17 |
| 10 m horizontal wind speed | 66 | 17 |
| Sunshine duration | 33 | 17 |
| Cloud cover | 66 | 19 |
| Global radiation | 33 | 17 |
| Relative humidity | 68 | 19 |
| Surface vapour pressure | 68 | 19 |
| Surface air pressure | 41 | 15 |

**Table 3.2 Number of stations for Serbia**

| | number of all stations | number of stations from neighbouring countries |
|---|---|---|
| Daily mean temperature | 39 | 12 |
| Minimum air temperature | 39 | 12 |
| Maximum air temperature | 39 | 12 |
| Daily precipitation | 114 | 16 |
| 10 m wind direction | 40 | 11 |
| 10 m horizontal wind speed | 40 | 11 |
| Sunshine duration | 28 | 10 |
| Cloud cover | 39 | 12 |
| Global radiation | 28 | 10 |
| Relative humidity | 35 | 12 |
| Surface vapour pressure | 35 | 12 |
| Surface air pressure | 26 | 12 |

**Table 3.3 Number of stations for Romania**

| | number of all stations | number of stations from neighbouring countries |
|---|---|---|
| Daily mean temperature | 140 | 16 |
| Minimum air temperature | 140 | 16 |
| Maximum air temperature | 140 | 16 |
| Daily precipitation | 182 | 16 |
| 10 m wind direction | 119 | 15 |
| 10 m horizontal wind speed | 119 | 15 |
| Sunshine duration | 112 | 12 |
| Cloud cover | 110 | 16 |
| Global radiation | 112 | 12 |
| Relative humidity | 140 | 16 |
| Surface vapour pressure | 182 | 16 |
| Surface air pressure | 139 | 15 |

**Table 3.4 Number of stations for Ukraine**

| | number of all stations | number of stations from neighbouring countries |
|---|---|---|
| Daily mean temperature | 53 | 14 |
| Minimum air temperature | 53 | 14 |
| Maximum air temperature | 53 | 14 |
| Daily precipitation | 57 | 18 |
| 10 m wind direction | 53 | 14 |
| 10 m horizontal wind speed | 53 | 14 |
| Sunshine duration | 24 | 12 |
| Cloud cover | 53 | 14 |
| Global radiation | 24 | 12 |
| Relative humidity | 53 | 14 |
| Surface vapour pressure | 53 | 14 |
| Surface air pressure | 49 | 10 |

**Table 3.5 Number of stations for Slovakia**

| | number of all stations | number of stations from neighbouring countries |
|---|---|---|
| Daily mean temperature | 59 | 37 |
| Minimum air temperature | 59 | 37 |
| Maximum air temperature | 59 | 37 |
| Daily precipitation | 165 | 102 |
| 10 m wind direction | 53 | 31 |
| 10 m horizontal wind speed | 53 | 31 |
| Sunshine duration | 27 | 16 |
| Cloud cover | 52 | 30 |
| Global radiation | 29 | 17 |
| Relative humidity | 44 | 22 |
| Surface vapour pressure | 52 | 30 |
| Surface air pressure | 26 | 18 |

**Table 3.6 Number of stations for Poland**

| | number of all stations | number of stations from neighbouring countries |
|---|---|---|
| Daily mean temperature | 38 | 17 |
| Minimum air temperature | 38 | 17 |
| Maximum air temperature | 38 | 17 |
| Daily precipitation | 102 | 48 |
| 10 m wind direction | 42 | 21 |
| 10 m horizontal wind speed | 42 | 21 |
| Sunshine duration | 17 | 8 |
| Cloud cover | 40 | 19 |
| Global radiation | 17 | 8 |
| Relative humidity | 31 | 19 |
| Surface vapour pressure | 40 | 19 |
| Surface air pressure | 26 | 15 |

**Table 3.7 Number of stations for Czech Republic**

| | number of all stations | number of stations from neighbouring countries |
|---|---|---|
| Daily mean temperature | 18 | 12 |
| Minimum air temperature | 18 | 12 |
| Maximum air temperature | 18 | 12 |
| Daily precipitation | 51 | 28 |
| 10 m wind direction | 17 | 11 |
| 10 m horizontal wind speed | 17 | 11 |
| Sunshine duration | 9 | 5 |
| Cloud cover | 17 | 11 |
| Global radiation | 9 | 5 |
| Relative humidity | 17 | 11 |
| Surface vapour pressure | 17 | 11 |
| Surface air pressure | 8 | 5 |

### 1.9 Gridding of snow depth and snow water equivalent (Johann Hiebl)

In contrast to the other variables, a process-related snow cover model based on pre-finished CARPATCLIM grids was applied for the gridding of the snow depth and snow water equivalent (SWE). The applied model (Scheppler 2000; Schöner and Hiebl 2009) is based on the degree day procedure and calculates the build-up and degradation of the snow cover in daily resolution. The input variables of each day are grids of air temperature, precipitation and relative air humidity. They are processed regarding accumulation and ablation of the snow cover as well as transformation of SWE to snow depth. Five parameters control the day-to-day build-up and degradation of snow cover.

In order to produce better results in terms of the concrete study region, the most important model parameters were calibrated with respect to 121 observational snow depth stations from the Carpathian region. The final evaluation produced an overall mean error of 0.2 cm and a mean absolute error of 1.1 cm.

A clear strength of the model approach is that a number of physical processes of snow accumulation and ablation can be simulated, even though daily resolution is obviously too rough in some cases. Furthermore, there is no need to deal with the representativity of local snow depth observations at grid cell resolution thinking of differences in altitude, wind exposure, slope orientation and radiation balance.

### References

D1.7 Proposal for quality control tests to be performed for all observational time series, Submitted to JRC.

D1.8 Proposal for homogenization methods to be applied to all observational time series, Submitted to JRC.

D1.11 Report on preliminary results of the quality control and data homogenization measures applied per country, including QC protocols and measures to determine the achieved increase in data quality

D1.12 Final report on quality control and data homogenization measures applied per country, including QC protocols and measures to determine the achieved increase in data quality

D2.3 Proposal for the methodology to harmonize observational time series across country borders

D2.4 Report with preliminary results of the data harmonization procedures applied, including all protocols, per country

D2.5 Report with final results of the data harmonization procedures applied, including all protocols, per country

D2.6 Preliminary version of gridded datasets of harmonized and spatially interpolated meteorological parameters, per country

D2.7 Progress report on the creation of national gridded datasets

D2.9 Final report on the creation of national gridded datasets, per country

Hungarian Meteorological Service. 2001: Proceedings of the third seminar for Homogenisation and Quality Control in Climatological Databases, Budapest, September 2000. Budapest.

Jordan R. (1991): A one-dimensional temperature model for snow cover. Technical documentation for SNTHERM.89. Hanover: U.S. Army Corps of Engineers, Special Report 91–16, 49 p.

Olefs et al. (2010): Boundary conditions for artificial snow production in the Austrian Alps. J Appl Meteorol Clim 49, 1096-1113, doi:10.1175/2010JAMC2251.1

Scheppler P. (2000): Schneedeckenmodellierung und Kalibrationsmöglichkeiten für ausgewählte Beobachtungsstationen. Bern: University of Bern, master thesis, 111p.

Schöner W. and Hiebl J. (2009): webklim.at. Präsentation hochauflösender Klimainformation im Internet am Beispiel von Lufttemperatur, Niederschlag und Schneedecke. Vienna: ZAMG, project report, 36 p.

Steinacker R. (1983): Diagnose und Prognose der Schneefallgrenze.Wetter und Leben 35, 81–90

Szentimrey, T., 1999: Multiple Analysis of Series for Homogenization (MASH), Proceedings of the Second Seminar for Homogenization of Surface Climatological Data, Budapest, Hungary; WMO, WCDMP-No. 41, pp. 27-46.

Szentimrey, T., 2008: Development of MASH homogenization procedure for daily data, Proceedings of the Fifth Seminar for Homogenization and Quality Control in Climatological Databases, Budapest, Hungary, 2006; WCDMP-No. 68, WMO-TD NO. 1434, 2008, pp. 116-125.

Szentimrey, T., 2011: Manual of homogenization software MASHv3.03, Hungarian Meteorological Service, pp. 64.

Szentimrey, T., Bihari, Z., 2006: MISH (Meteorological Interpolation based on Surface Homogenized Data Basis), COST Action 719 Final Report, The use of GIS in climatology and meteorology, Edited by Ole Einar Tveito, Martin Wegehenkel, Frans van der Wel and Hartwig Dobesch, 2006, pp. 54-56

Szentimrey, T., Bihari, Z., 2007a: Mathematical background of the spatial interpolation methods and the software MISH (Meteorological Interpolation based on Surface Homogenized Data Basis), Proceedings from the Conference on Spatial Interpolation in Climatology and Meteorology, Budapest, Hungary, 2004, COST Action 719, COST Office, 2007, pp. 17-27

Szentimrey, T., Bihari, Z., 2007b: Manual of interpolation software MISHv1.02, Hungarian Meteorological Service, p. 32

Szentimrey, T., Bihari, Z., Szalai,S., 2007c: Comparison of geostatistical and meteorological interpolation methods (what is what?), Spatial Interpolation for climate data - the use of GIS in Climatology and meteorology, Edited by Hartwig Dobesch, Pierre Dumolard and Izabela Dyras, 2007, ISTE ltd., London, UK, 284pp, ISBN 978-1-905209-70-5, pp.45-56

Szentimrey, T, Bihari, Z., Lakatos, M., Szalai,S., 2011: Mathematical, methodological questions concerning the spatial interpolation of climate elements. Proceedings from the Second Conference on Spatial Interpolation in Climatology and Meteorology, Budapest, Hungary, 2009, Időjárás 115, 1-2, 1-11

Venema, V. K. C. et al., 2012: Benchmarking homogenization algorithms for monthly data, Climate of the Past, 8, 89-115

WMO, 1999: Proceedings of the Second Seminar for Homogenization of Surface Climatological Data (Budapest, Hungary, November 1998). WMO, WCDMP-No. 41.

WMO, 2004: Fourth Seminar for Homogenisation and Quality Control in Climatological Databases (Budapest, Hungary, 6-10 October 2003). WCDMP-No 56, WMO-TD 1236. Geneva.

WMO, 2008: Proceedings of the Fifth Seminar for Homogenization and Quality Control in Climatological Databases (Budapest, Hungary, May 2006). WCDMP-No. 71, WMO/TD-NO. 1493

WMO, 2011: Proceedings of COST-ES0601 (HOME) Action Management Committee and Working Groups and Sixth Seminar for Homogenization and Quality Control in Climatological Databases, (Budapest, Hungary, May 2006). WCDMP-No. 76, WMO/TD-No. 1576