Snow grid data in Carpathian region

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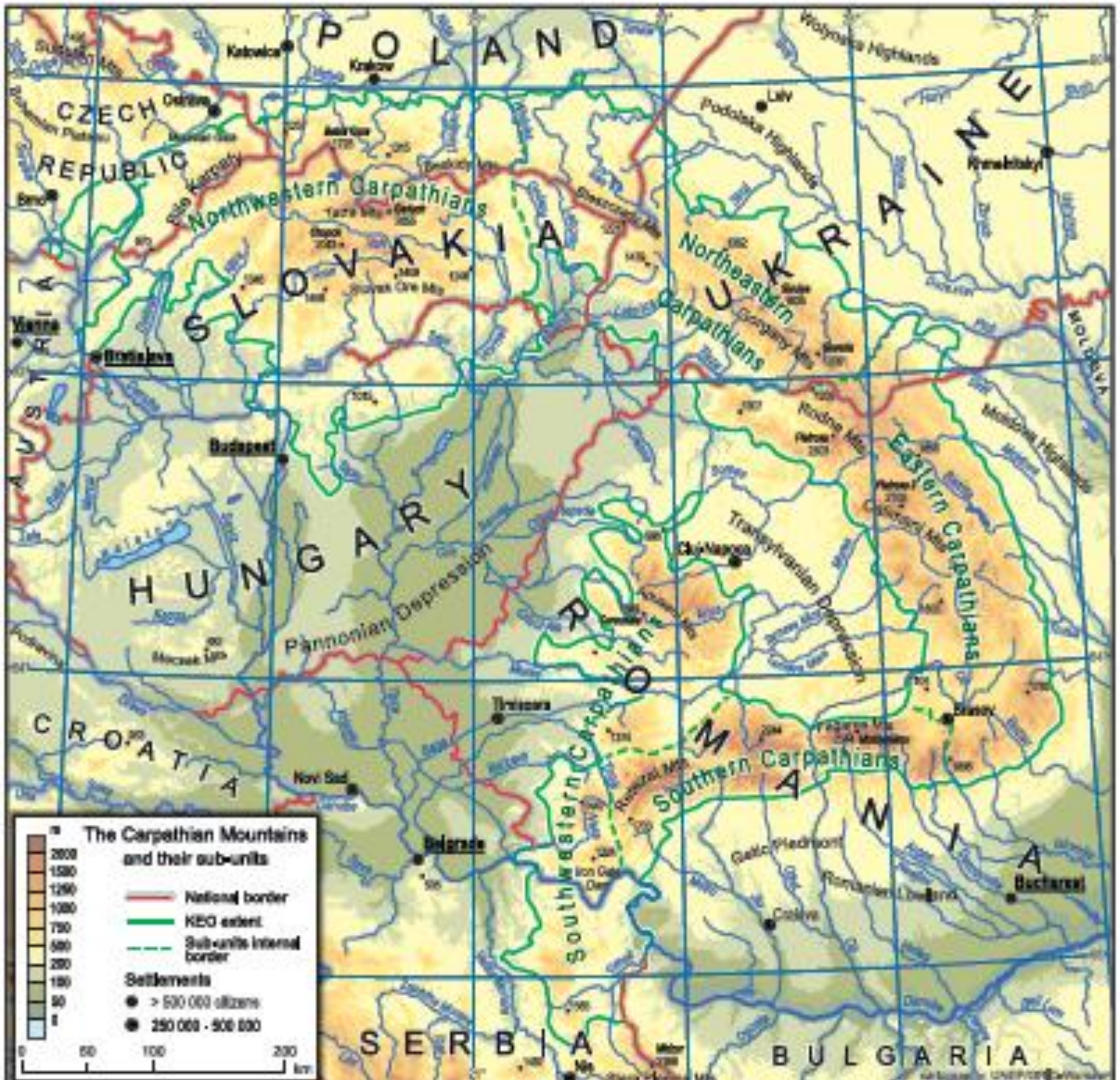
Content

- CarpatClim database
- Snow in the CarpatClim
- Comparison with modelled data

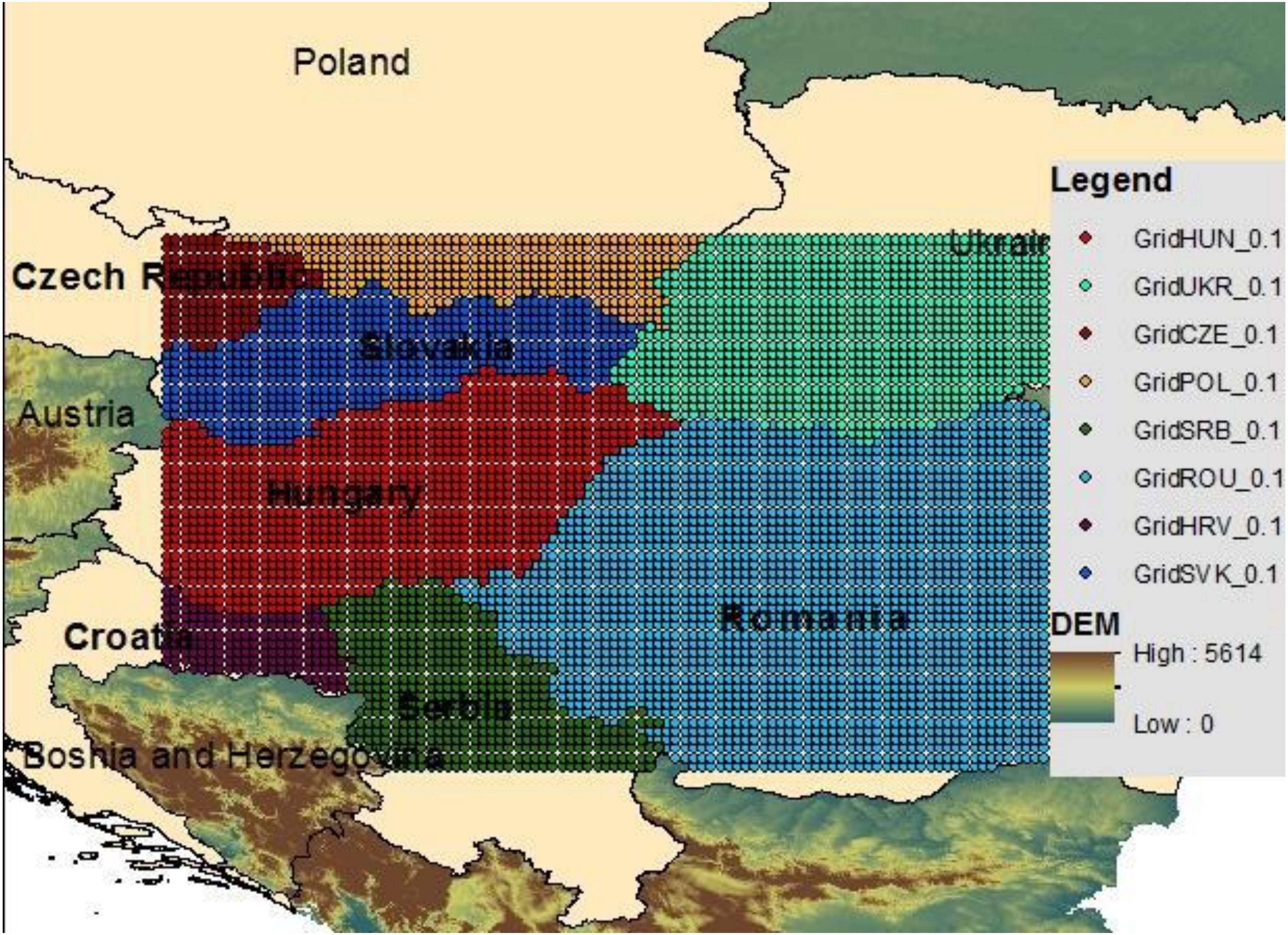
Status

- Increasing needs for good quality regional/subregional databases
- Several attempts:
  - Gridded datasets:
    - dynamical modelling
    - statistical modelling
  - Raw data
    - regional climate centres
    - specific databases

Map



POLAND
CZECH REPUBLIC
SLOVAKIA
UKRAINE
HUNGARY
ROMANIA
CROATIA
SERBIA
BULGARIA
Northwestern Carpathians
Northeastern Carpathians
Eastern Carpathians
Southern Carpathians
Southwestern Carpathians
Pannonian Depression
Transylvanian Depression
Podolska Highlands
Moldova Highlands
Bucharest
Belgrade
Budapest
Bratislava
Vienna
Timisoara
Novi Sad
The Carpathian Mountains and their sub-units
National border
KEO extent
Sub-units internal border
Settlements
> 500 000 citizens
250 000 - 500 000


Poland
Czech Republic
Slovakia
Austria
Hungary
Croatia
Serbia
Bosnia and Herzegovina
Romania
Legend
GridHUN_0.1
GridUKR_0.1
GridCZE_0.1
GridPOL_0.1
GridSRB_0.1
GridROU_0.1
GridHRV_0.1
GridSVK_0.1
DEM
High : 5614
Low : 0

Countries of the Carpathian Region

Country	Area in sq. km
Croatia	14 662,66
Czech Rep.	17 570,58
Hungary	86 996,47
Poland	19 794,32
Serbia	45 015,09
Slovakia	48 520,49
Bulgaria	1 208,63
Moldova	437,90
Romania	184 434,63
Ukraine	71 530,71

Philosophy of CARPATCLIM

- No common database of raw data
- Each country provide the same work (hope for a network as dense as requested/possible for the project)
- Common software
- National and international consistency
- Near border data exchange (minimum number of data exchanged on equal basis)

Structure

- Module 1: Data rescue, quality control, and data homogenisation by the use of MASH. (Leader: SHMU)
- Module 2: Data harmonisation and gridded datasets by the use of MISH. (Leader: OMSZ)
- Module 3: Climate Atlas, publicly accessible dedicated web site, gridded climatological datasets and searchable metadata catalogue (Leader: RHMSS)

Gridded meteorological variables

Daily variables listed in the contract
Mean daily air temperature
Minimum air temperature
Maximum air temperature
Accumulated total precipitation
Wind direction
Wind speed (10 m)
Sunshine duration
Cloud cover
Global radiation
Relative humidity
Surface vapour pressure
Surface air pressure
Snow depth

Additional variables
Maximum daily wind speed
Wind speed (2m)
Snow water equivalent

Computed varibles

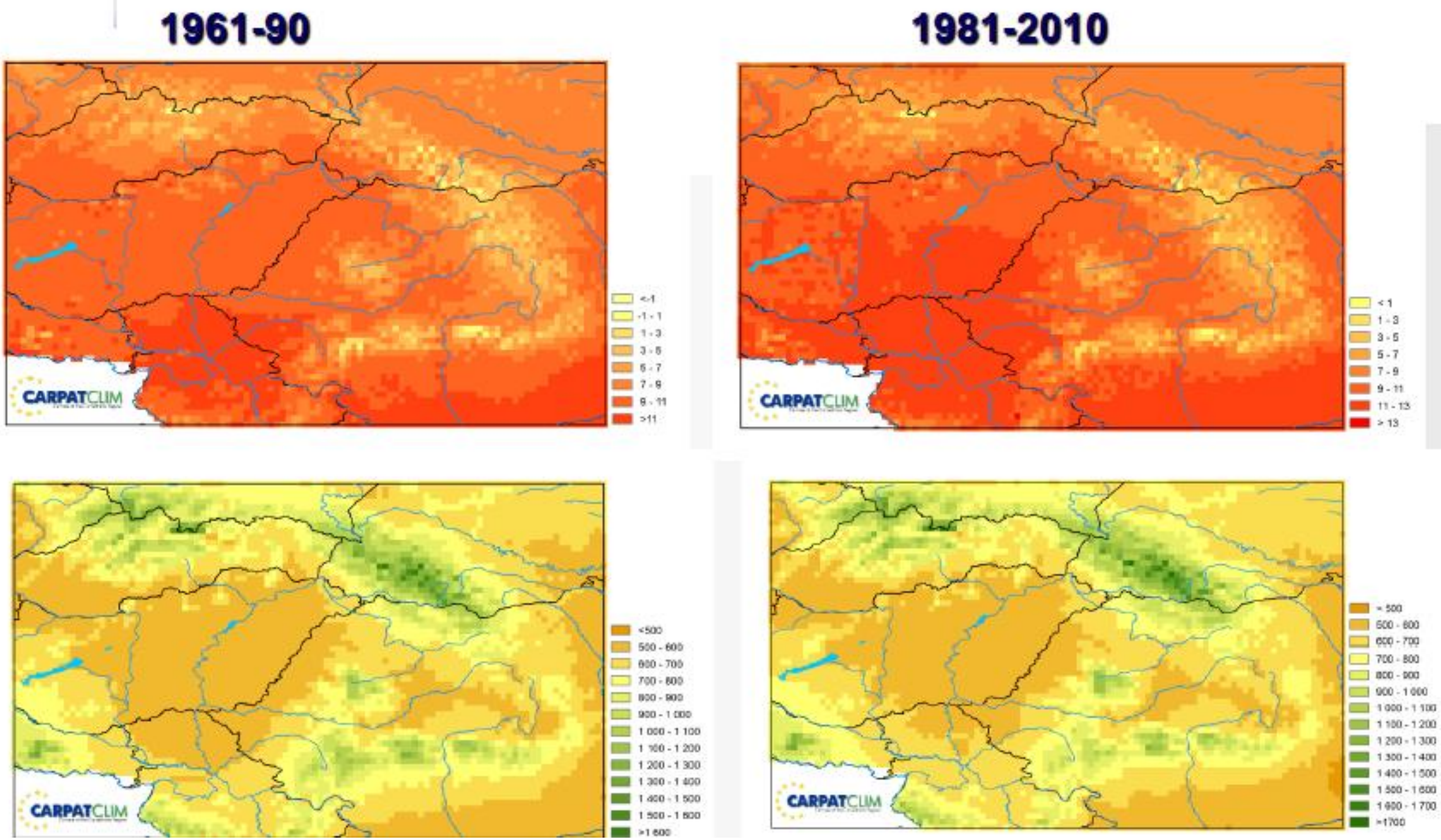
- Mean daily air temperature
- Daily mean wind speed and direction
- Daily maximum wind speed
- Daily mean wind speed at 2m
- Sunshine duration/ Global radiation
- Surface water vapour pressure
- Daily snow depth and snow water equivalent

Set of variables and indicators to be provided for the Digital Climate Atlas of the Carpathian Region

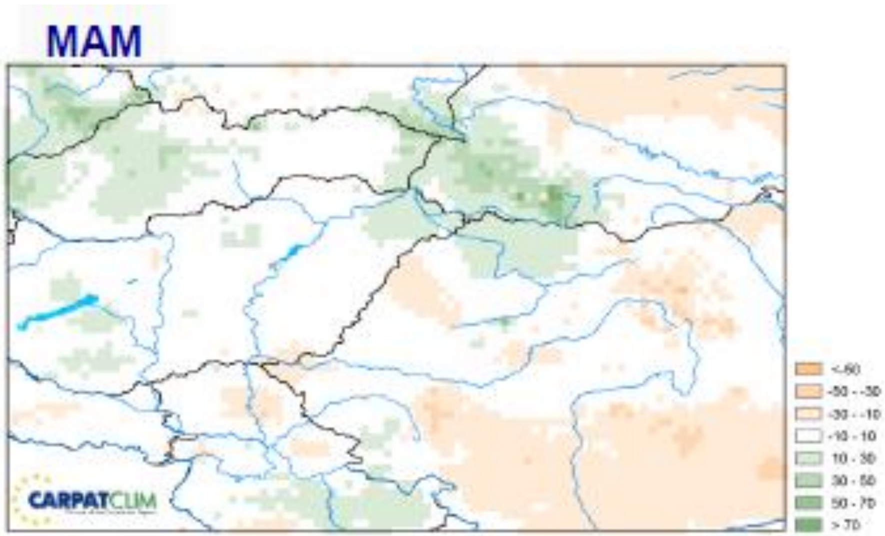
Average air temperature (2 m), average mean air temperature (2 m), minimum air temperature, maximum air temperature, precipitation, maximum 10 m horizontal wind speed, average 10 m horizontal wind speed, sunshine duration, cloud cover, global radiation, relative humidity, vapour pressure, surface air pressure, snow depth, snow water equivalent, number of frost days, number of days with Tmax above 25 °C, number of days with Tmax above 30 °C, Palfai Drought Index, Standardized Precipitation Index averaged over a three-months period, Reconnaissance Drought Index, Palmer Drought Severity Index, percentage of days without defrost (ice days), percentage of extremely hot days, percentage of severe cold days, growing season length, percentage of wet days, percentage of wet days above 20 mm/d, greatest 1-day total rainfall, greatest 5-day total rainfall, aridity index, moisture index, Ellenberg index

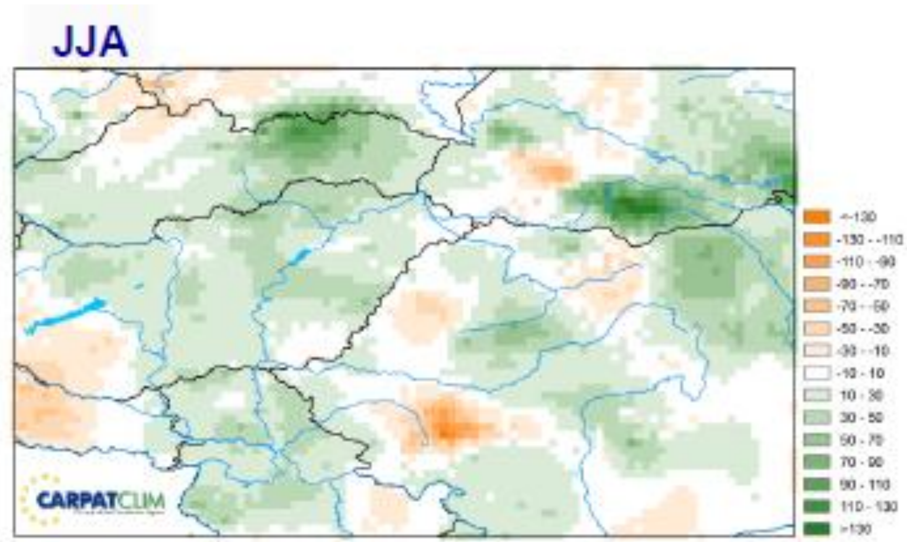
Web Atlas - Home page www.carpatclim-eu.org

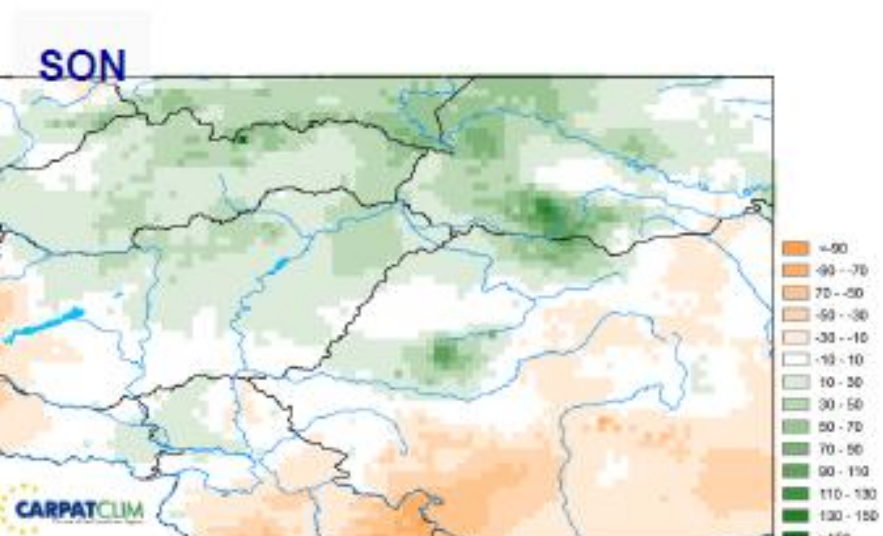
Temperature and precipitation averages

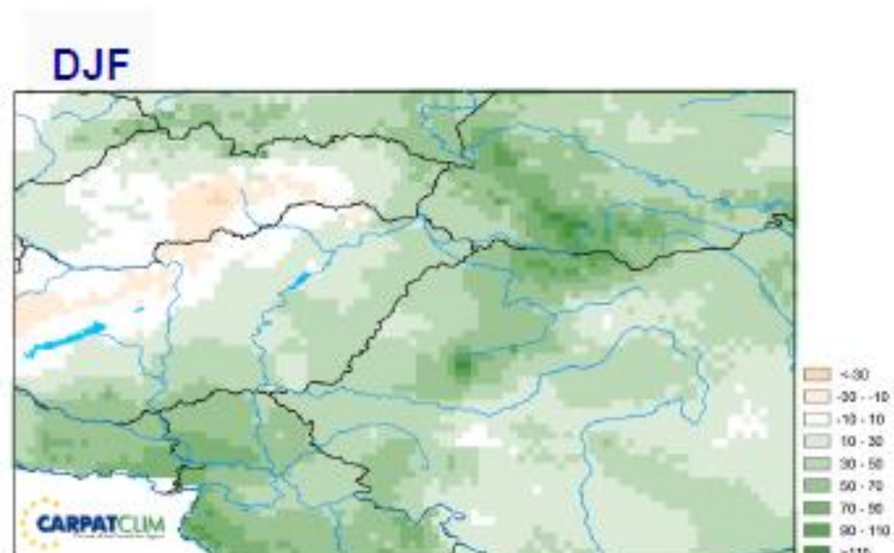


Change of the seasonal precipitation sums 1961-2010

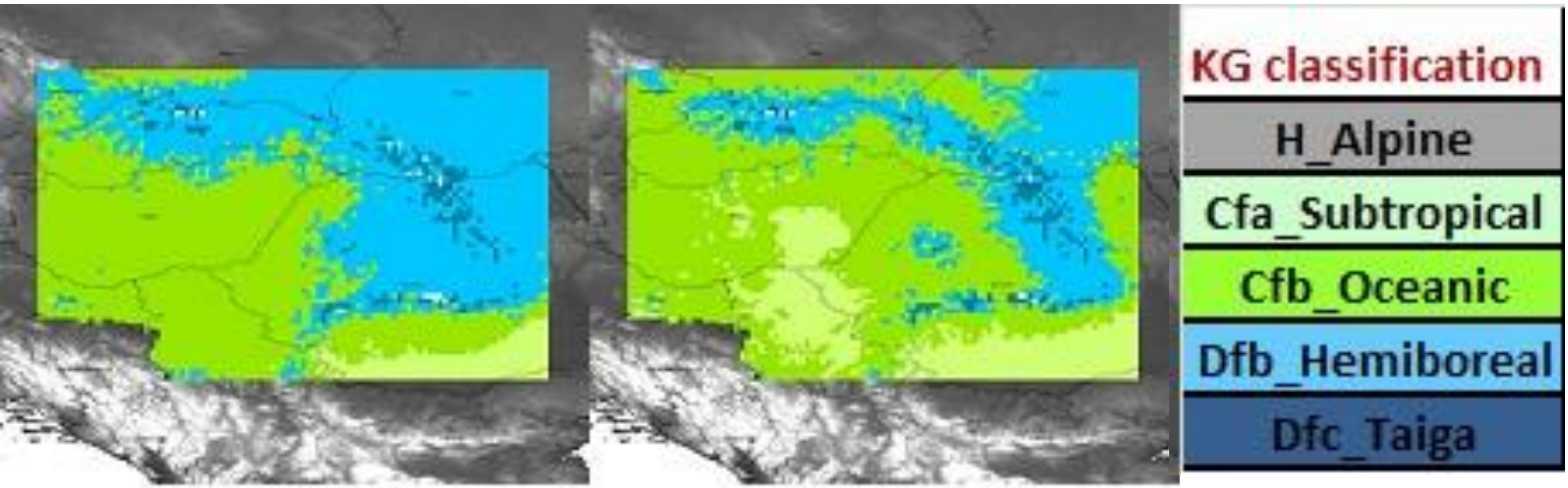








1961-90 versus 1981-2010 Köppen-Geiger's climate maps



KG 61-90 KG 81-10

Snow parameters

- **Snow depth**
-
- The monthly value of snow depth was computed as the ratio of the sum of daily snow depths and the number of days with snow cover, for the specific month.
-
- **Snow water equivalent**
-
- The monthly value of snow water equivalent was computed by cumulating the daily values of snow water equivalent of newly fallen snow for the specific month.

Method

- The applied model is a continuous development of different authors at different institutes. It rests mainly upon the work by Scheppler (2000) in a version by Schöner and Hiebl (2009) with adjustments according to Jordan (1991) and Olefs (2010). But also for the application in the Carpathian region was not a plug-and-play procedure but the result of model calibration and adjustments.
- Method was applied and described by Hiebl in the CarpatClim.

Model structure

- The used snow cover model is based on the degree day procedure and easily applicable in many regions. It calculates the build-up and degradation of the snow cover (but ignores the outflow from the snow cover) in daily resolution.
- The input variables of each day are grids of mean air temperature, precipitation sum and relative air humidity. They are then processed by the snow cover model regarding three main parts accumulation of snow cover, ablation of snow cover and transformation of SWE to snow depth. This results in daily output grids of SWE, snow depth and snow temperature, which all in turn are used as additional input variables for the next day.

Model benefits

- 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.

Accumulation of snow cover

- Using the input variables air temperature, precipitation and relative humidity, the SWE of fresh-fallen snow is calculated via wet-bulb temperature which is a better indicator for the type of precipitation than temperature itself .
- Air temperature determines the snow temperature of fresh-fallen snow as well.
- The sum of the SWE of old snow and fresh-fallen snow makes the preliminary SWE after accumulation.
- The mean of the temperatures of old snow and fresh-fallen snow weighted by their respective SWE produce the preliminary snow temperature after accumulation

Ablation of snow cover

- Preliminary SWE and preliminary snow temperature after accumulation are used to calculate the preliminary cold content(.
- With the aid of air temperature the amount of potential melt or effective cooling respectively is specified.
- The preliminary cold content and potential melt/effective cooling together determine the amount of effective melt and decrease of cold content (if air temperatures are above melting temperature) or the increase of cold content (if air temperature is below melting temperature).
- Effective melt subtracted from preliminary SWE gives the final output variable SWE.
- The cold content applied on the final SWE allows the calculation of the final snow temperature.

Transformation of SWE to snow depth

- For the calculation of the depth of fresh-fallen snow, the SWE of fresh-fallen snow is used considering the settling by degrading transformation (i.e. breakup of snow crystals) which depends on air temperature and the density of fresh-fallen snow .
- For the calculation of the depth of old snow, the old SWE is used considering the settling by degrading transformation, which depends on air temperature and the density of old snow, and the settling by the weight of the fresh-fallen snow, which depends on air temperature, the density of old snow and the SWE of fresh-fallen snow.
- The snow depths of fresh-fallen snow and old snow are added up to the final total snow depth.

Parameters

- The critical melting temperature accounts for the threshold beneath which all precipitation falls in solid form.
- The critical temperature specifies the temperature above which all precipitation falls in liquid form and cannot be used for snow cover build-up. It most importantly steers snow accumulation.
- The cooling factor accounts for thermal loss of the snow cover in the case of air temperature lying lower than snow temperature.
- The snow cover layer boundary separates the snow cover into two for the calculation of the snow cover’s thermal properties. If the total SWE is smaller than the layer boundary, only one layer is existent.
- The degree day factor determines the amount of melting water that incurs per degree day and therefore controls snow ablation. Contrary to the other parameters it varies over the year in a sinus wave reaching its minimum on December 21st and its maximum on June 21st

Calibration

- In order to produce better results in terms of the concrete study region, the most important model parameters were calibrated with respect to observational station data from the Carpathian region. As SWE measurements are not available, daily snow depth observations are the only reference for calibration and evaluation.
- Daily snow depth measurements were provided by the national data holders. Altogether, 220 series were available, from which again those 121 series were selected for evaluation whose station altitude differs less than ±50 m (cf. fig. 6). For calibration, the first five seasons of the study period were used.

Calibration 2

- The critical temperature (Tc), responsible for accumulation, was progressively altered from the initial value 1.5 °C to 0° C leading to smaller and smaller error values (fig. 5a). Finally, a value of 0 °C was assigned to Tc making it practically ineffective. Apparently, this is due to the fact that the mean daily temperature is too rough as an input variable to describe temperature at the precipitation event.

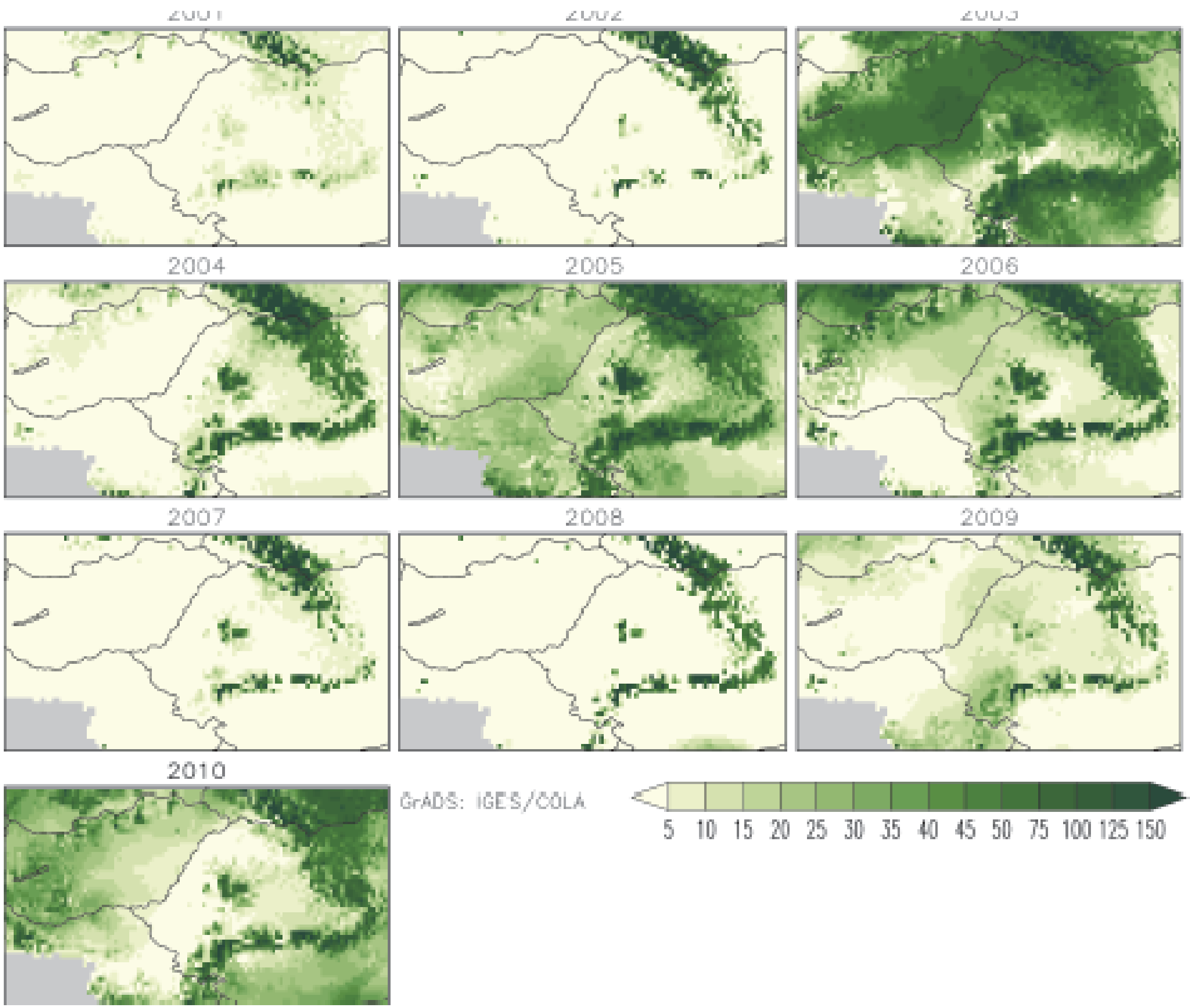
Calibration 3.

- Next, the degree day factor (Amelt) highly controlling ablation was changed watching the effect on error measures. This was done by maintaining the minimum seasonal value at 1 mm/(°C*d) but changing the maximum value from 3 to 10 mm/(°C*d). Taking into account all stations the error values could constantly be lowered with higher Amelt values .
- Still, there is a strong bias among the reference stations towards low altitudes. Regarding the nine highest stations only, the turning point of error values can be detected at 8 mm/(°C*d). This number was accepted for the final model run.

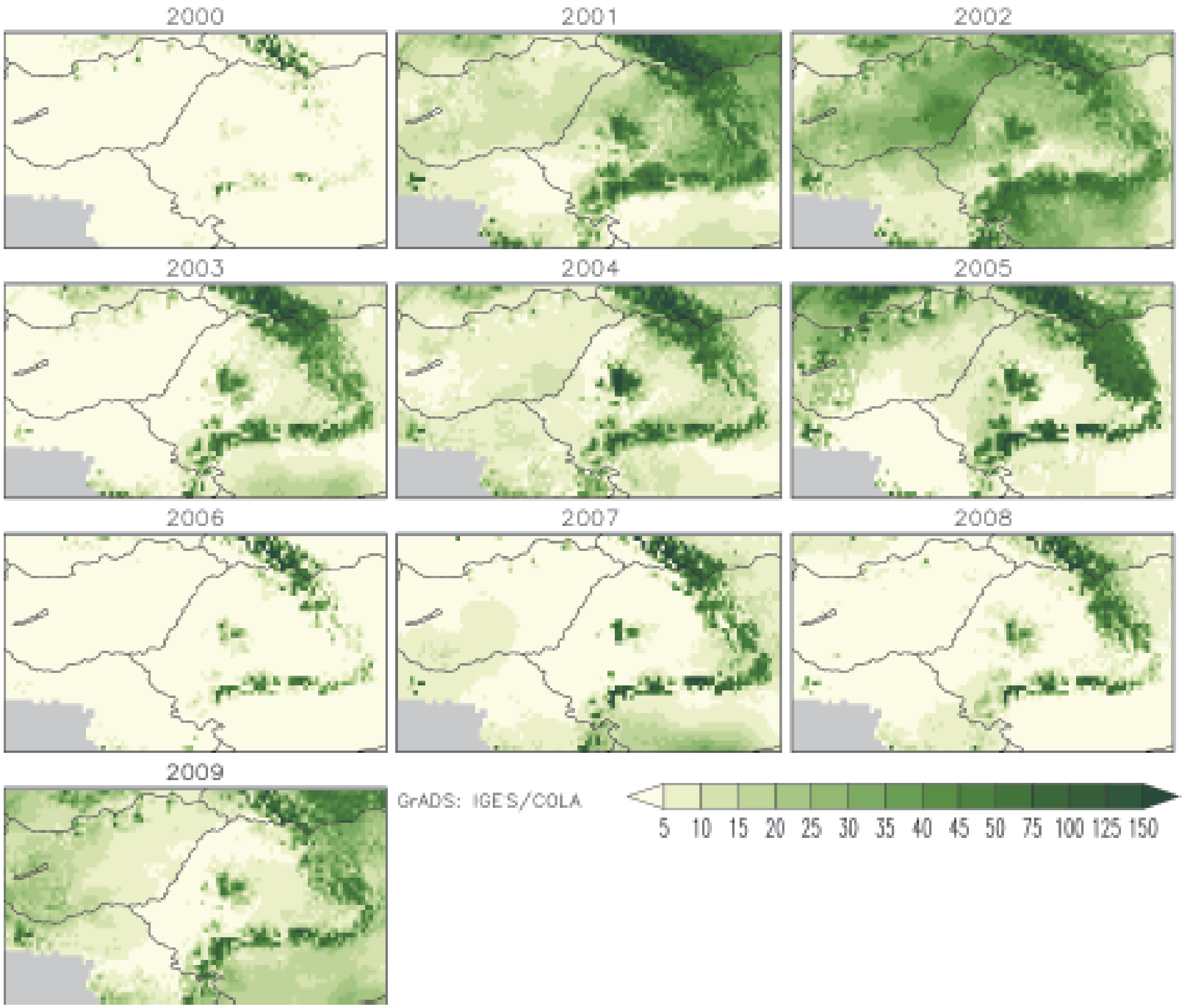
Evaluation

- Evaluation was based on the same 121 observational snow depth series as calibration. This time, the entire study period was investigated. The overall mean error (ME) is 0.3 cm indicating a small tendency of the model to overestimate snow depth in terms of the station observations. Obviously, the model tends to slightly overestimate at lower altitude and underestimate at higher estimates where the potential measurement errors of winter precipitation may play a role .
- The mean absolute error (MAE) accounts for 1.2 cm. Good agreement can be seen in the Pannonian Basin whereas MAE values of 2 to 3 cm are typical for the more complex terrain of the Carpathian mountain chain and towards the northeast where generally higher snow depth values appear. The root mean squared error (RMSE) is 3.8 cm showing a similar spatial distribution as the MAE

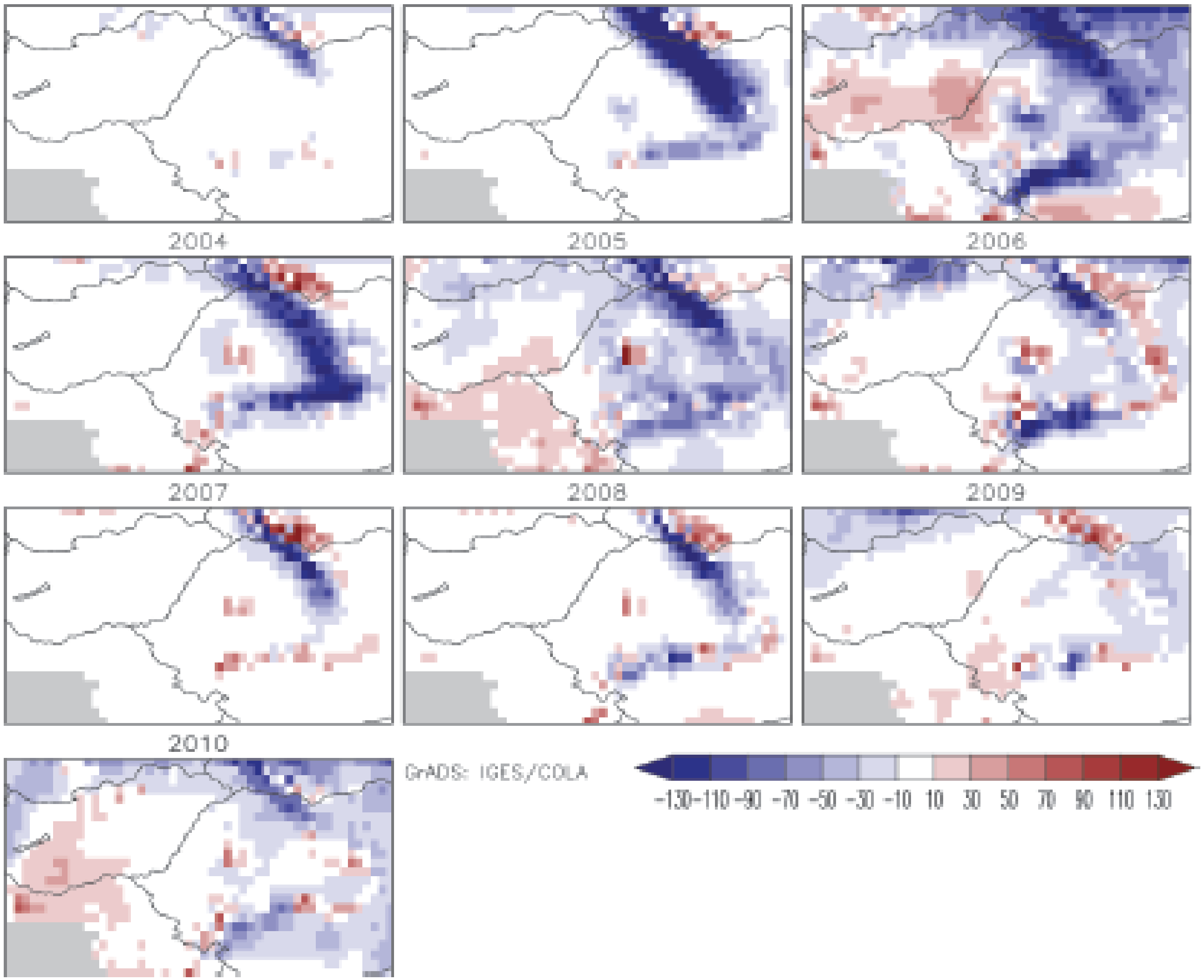
Monthly average CARPATCLIM SWE (unit: mm) distribution for February



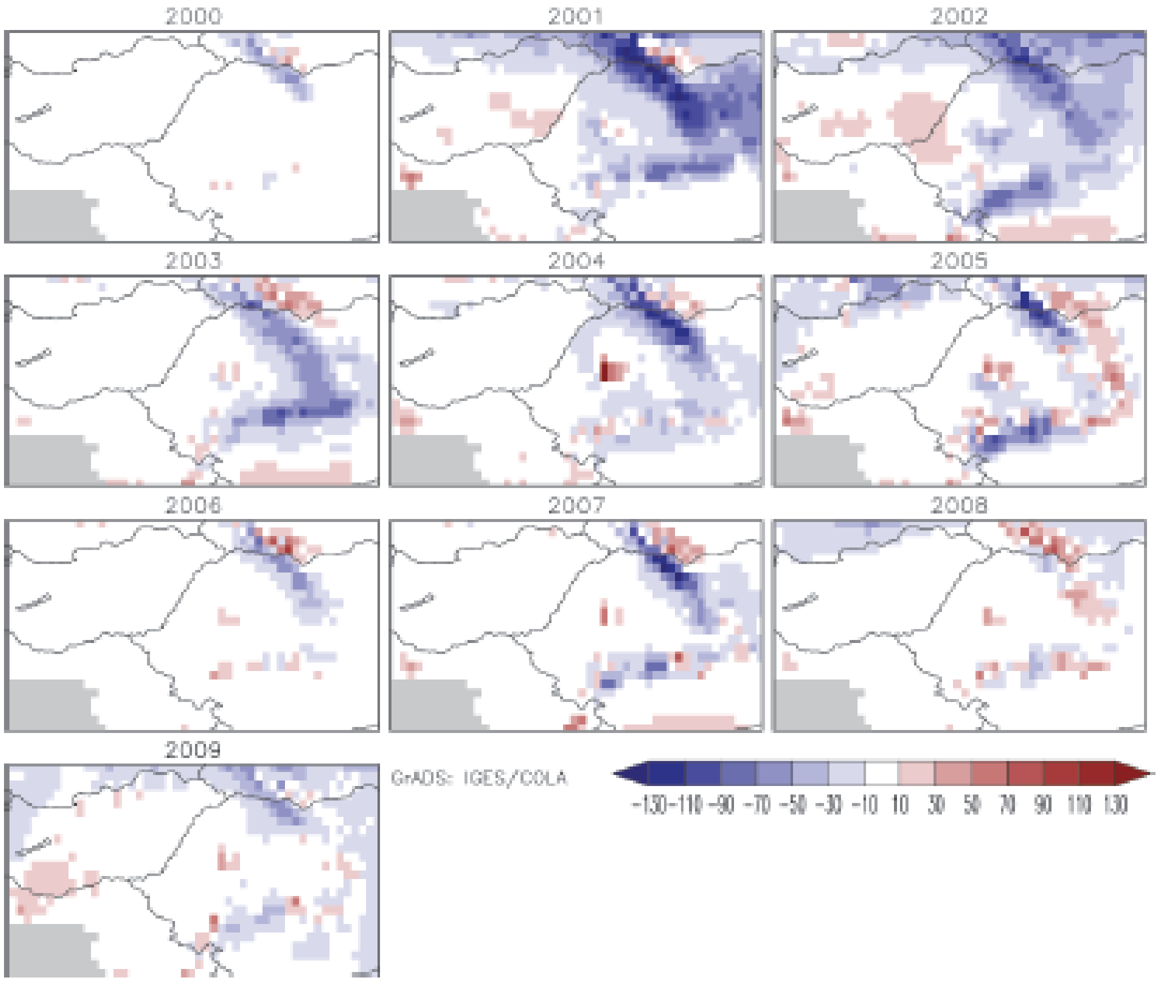
Winter average of SWE



Bias February



Bias winter


2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
GrADS: IGES/COLA
-130 -110 -90 -70 -50 -30 -10 10 30 50 70 90 110 130

Literature

- Hiebl in D2.8 and 2.9 of CarpatClim
- Hristo Chervenkov and Kiril Slavov: Comparison of simulated and objectively analyzed distribution patterns of snow water equivalent over the Carpathian Region IDŐJÁRÁS, Quarterly Journal of the Hungarian Meteorological Service Vol. 120, No. 3, July – September, 2016, pp. 315–329