Local Climate Change Scenarios
for Forest Management Units
in Brasov Mountains (South-Eastern Transylvania)

Victor Dan PACURAR, Ph.D.
Associate Professor
***Transilvania** University of Braşov*
ROMANIA

Local Climate Change Scenarios

for Forest Management Units

in Brasov Mountains (South-Eastern Transylvania)

In mountain and hill regions the **site climate conditions** show a **high spatial variability**, easily observable by analyzing the **vegetation cover structure and dynamics** (especially the phenological timing differences).

Vegetation always provides valuable information regarding site conditions.

As all foresters know so well, some small plants indicate the type of humus.

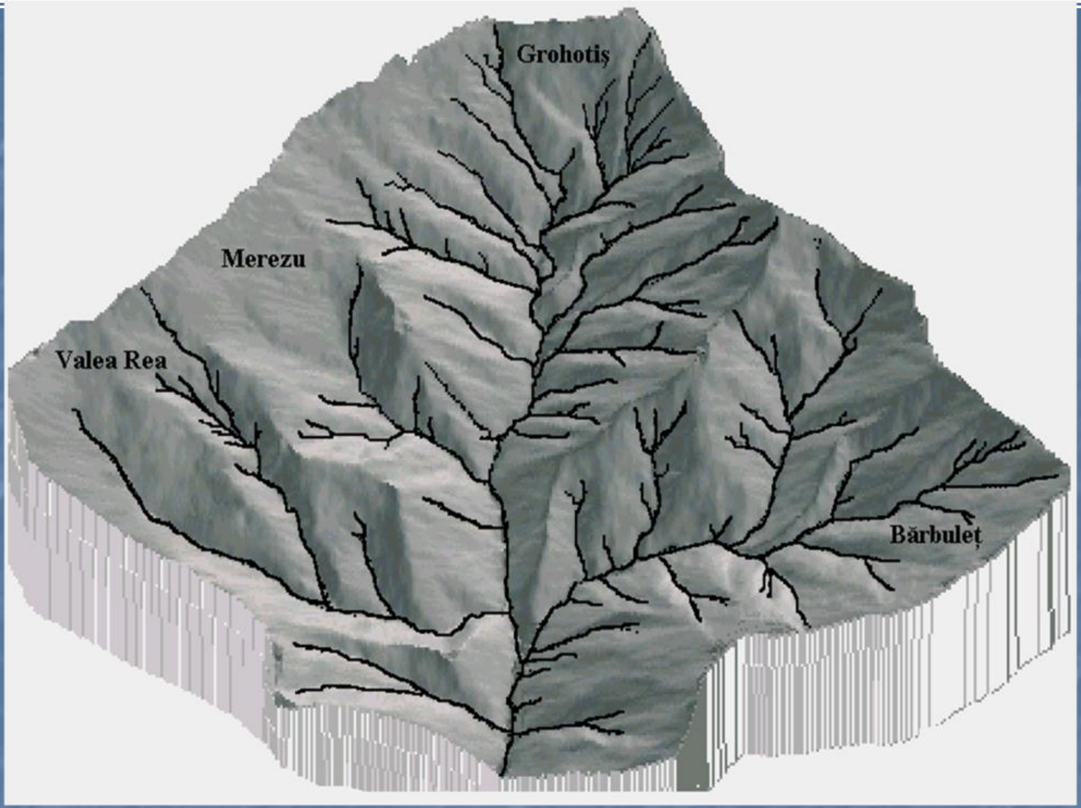
The long living trees also offer us accurate information regarding the climate conditions, particularly illustrating the differences between specific sites, related to slope inclination and orientation, wind exposure and so on.

These characteristics could be accurately inferred by examining tree and stand growth (especially tree ring analisys), phenology etc.

The climate change prospective brings in a new focus the tree/ forest stand – climate relationships.

Trees as organisms with a fixed position are very sensitive to even slight differences in the climate factors regime, given the cumulative effects. Thus, the analysis of the climate parameters spatial distribution is a prerequisite for the sustainable management of mountain forests.

Its importance is enhanced in the context of the possible climate changes. For example, assuming a warming trend, its effects would be buffered on northern aspects, in deep valleys, but these would be emphasised to extreme on steep southern slopes, with shallow dry soils and exposed to strong winds.



Presently, the development of the geographic information systems allows researchers and engineers to quantify the spatial variation of the natural conditions, including the climate parameters.

Given the pronounced variability of local climate conditions in steep terrain regions, the analysis of climate change possible impacts on vegetation is not possible without reliable information regarding the local and regional climate.

As regards the well known and often quoted climate change predictions for this century, these are derived from simulation experiments using Global Climate Models (GCM), which provide only large scale data and thus for information at regional scale, downscaling techniques are required.

For establishing details at regional or local scales it is necessary to use various downscaling techniques. The most important ways for doing this are regional climate modelling (RCM), usually referred as numerical or dynamical downscaling, and the statistical downscaling, which consists basically of establishing regression relationships between the large-scale climatic state and local variations derived from historical data records.

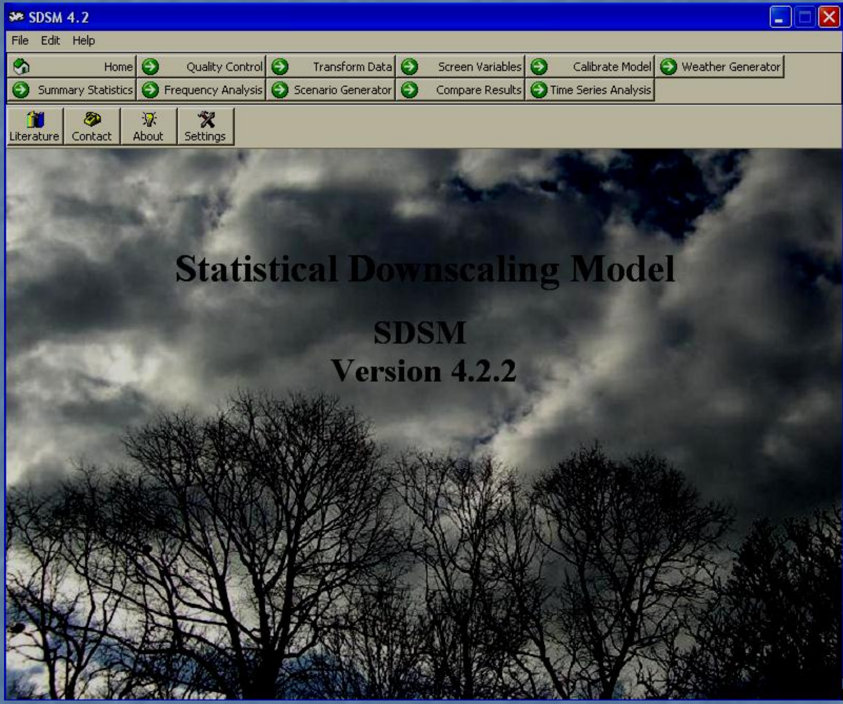
A Regional Climate Model (RCM) is coupled to a global model which regularly provides boundary conditions to the subordinated model during the integration.

Thus, it uses the GCM to define time-varying atmospheric boundary conditions around its smaller domain, within which the physical dynamics of the atmosphere are modelled using a horizontal grid of about 50 kilometres. The scenarios produced by RCMs are sensitive to the choice of boundary conditions used but their main advantage is that they can better represent smaller–scale atmospheric features such as orographic precipitation.

Statistical downscaling methods have several practical advantages. These are easier to use and are not requiring huge computation power (hundreds of processors) as in the case of the dynamical approach.

For downscaling the global climate change scenarios, it was used the Statistical Downscaling Model (SDSM), which has been applied in numerous meteorological, hydrological and environmental impact studies all over the world.

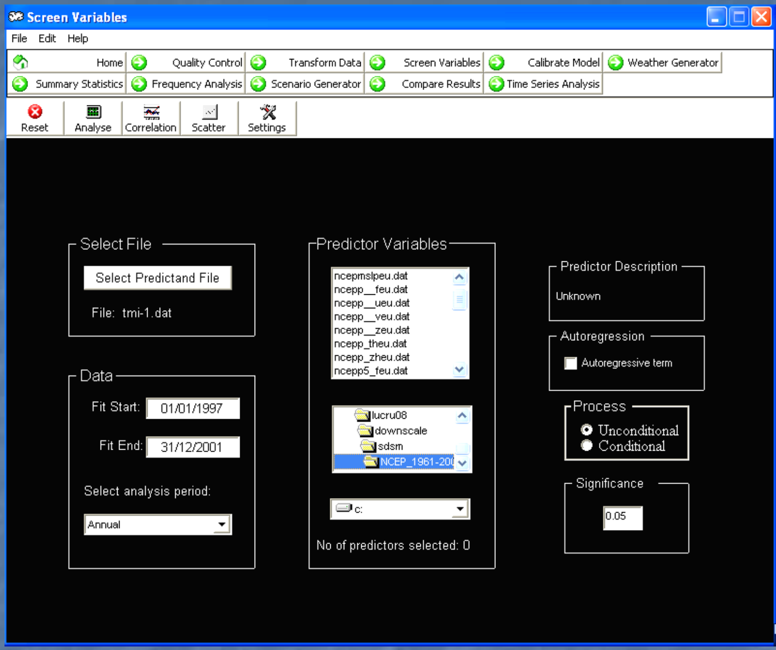
SDSM uses a mixture of stochastic weather generator and transfer function procedures. It uses large–scale circulation patterns and atmospheric moisture variables for determining local–scale weather generator parameters (for example precipitation occurrence and intensity).

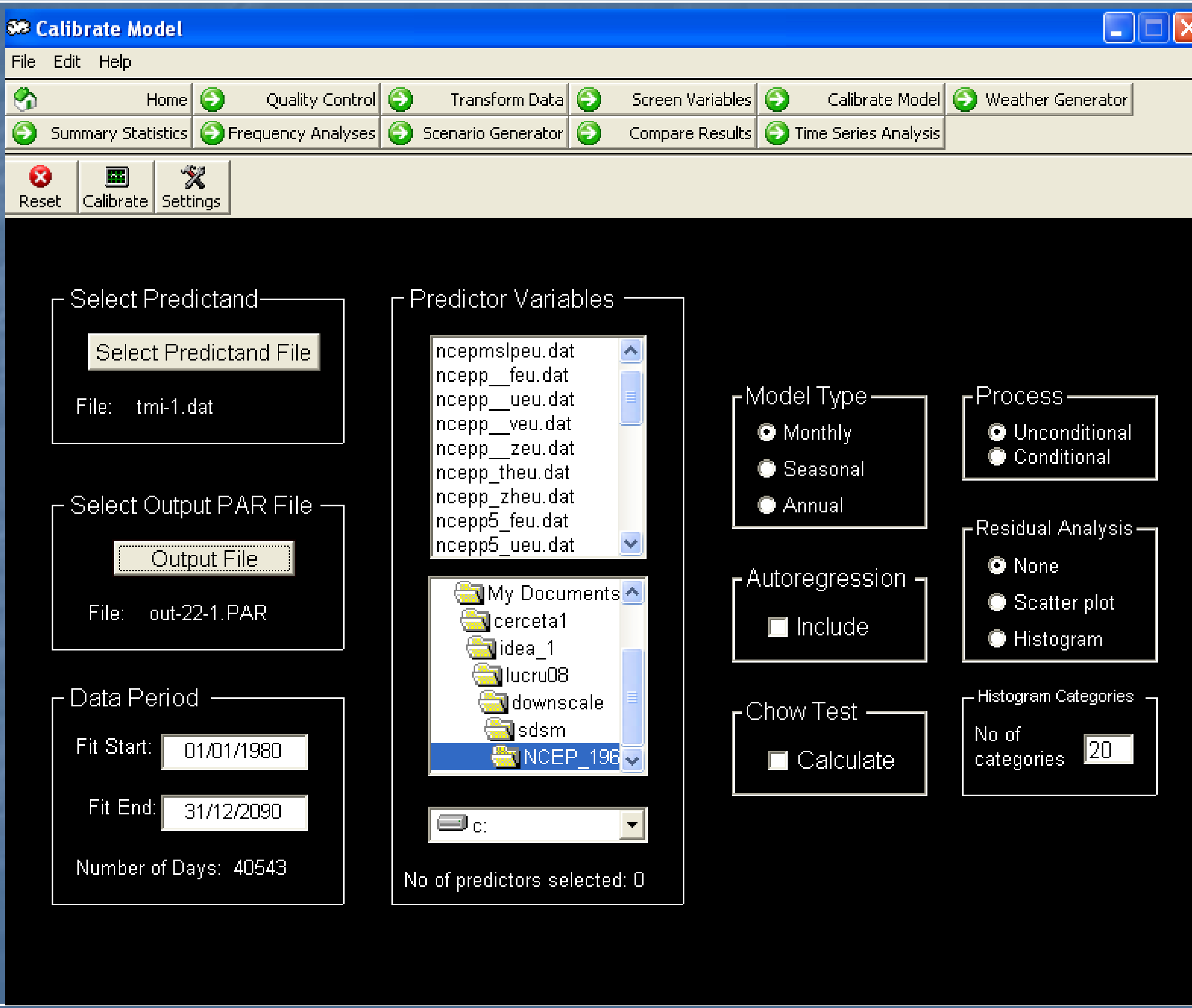


The SDSM modules perform the following tasks: quality control and data transformation, screening of predictor variables, model calibration, weather generation, statistical analyses, graphing model output, scenario generation.

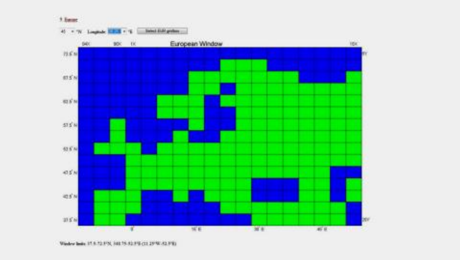
Basically, the down-scaling procedure consists in establishing a transfer function that relates the local variable time series (named predictand) and a set of variables corresponding to the GCM cell (called predictors).

After calibrating the model using observed data, the predictand values are computed for a certain future period using the predictor values simulated by a GCM for an emission scenario (SRES).




Calibrate Model
File
Edit
Help
Home
Quality Control
Transform Data
Screen Variables
Calibrate Model
Weather Generator
Summary Statistics
Frequency Analyses
Scenario Generator
Compare Results
Time Series Analysis
Reset
Calibrate
Settings
Select Predictand
Select Predictand File
File: tmi-1.dat
Select Output PAR File
Output File
File: out-22-1.PAR
Data Period
Fit Start: 01/01/1980
Fit End: 31/12/2090
Number of Days: 40543
Predictor Variables
ncepmslpeu.dat
ncepp__feu.dat
ncepp__ueu.dat
ncepp__veu.dat
ncepp__zeu.dat
ncepp_theu.dat
ncepp_zheu.dat
ncepp5_feu.dat
ncepp5_ueu.dat
My Documents
cerceta1
idea_1
lucru08
downscale
sdsm
NCEP_196
c:
No of predictors selected: 0
Model Type
Monthly
Seasonal
Annual
Process
Unconditional
Conditional
Autoregression
Include
Residual Analysis
None
Scatter plot
Histogram
Chow Test
Calculate
Histogram Categories
No of categories
20

The necessary data for the SDSM predictors were obtained from the Canadian Climate Impacts Scenarios Group, respectively data series produced by HadCM3 for the A2 and B2 scenarios (1961-2099) and the National Centre for Environmental Prediction (NCEP) data set (1961-2000) provided by NOAA-CIRES Climate Diagnostics (Center, Boulder, Colorado, USA).



The local data used for calibrating the transfer functions were measured at the Prund weather station. This station, located in upper Braşov, at the Postavaru mountain foot, is operated by the Forest Meteorology Laboratory of the *Transilvania* University of Braşov.

The greenhouse gases emission scenarios considered in the IPCC simulations are known as SRES - IPCC Special Report on Emission Scenarios.

The A2 SRES scenario describes a very heterogeneous world, characterised by self-reliance and preservation of local identities. Economic development is primarily regionally oriented and economic growth and technological change more fragmented and slower than in other storylines.

The B2 scenario also corresponds to a world in which the emphasis is on local solutions to economic, social and environmental sustainability. The population growth rate is considered lower than for A2 and the scenario is also oriented towards environmental protection and social equity.

Three important climate variables were considered for downscaling:

- daily maximum temperatures,
- minimum temperatures
- and rainfall amounts.

The procedure is not very simple requiring a series of steps. It starts with the quality control of the data followed by analysing the predictand-potential predictors relationships (Screen Variables). This is an iterative trial and error process which is not detailed here. Finally, in the calibration phase, the parameters of the transfer functions are determined and stored in a special parameter file.

For the maximum temperatures the predictors (values for the NCEP and HadCM3 grid cell) selected in the transfer function were:

average sea level pressure,

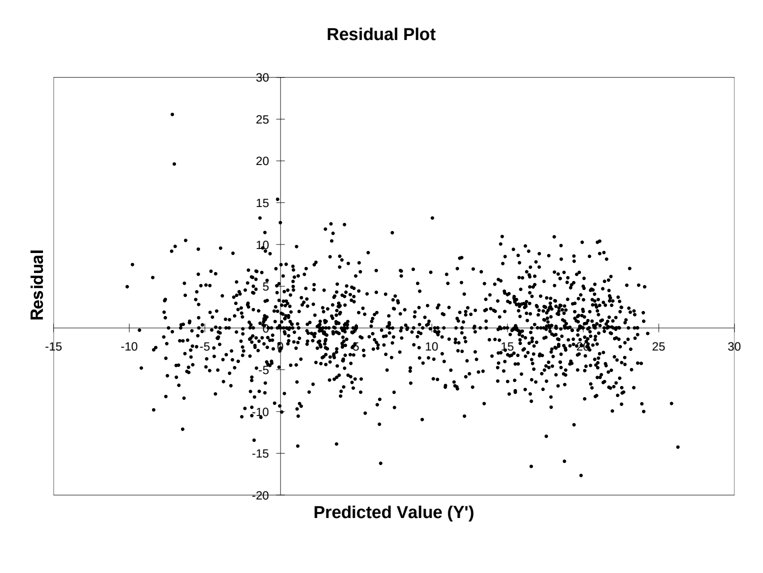
surface and 500 hPa,

zonal and meridional velocity components (u and v),

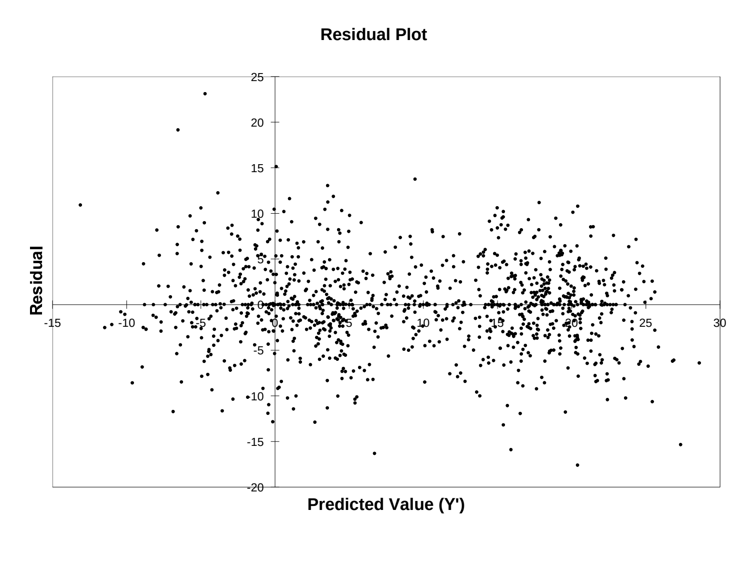
wind direction,

near surface and 500 hPa height relative humidity

and average temperature at the 2 m standard level.



For the minimum temperature the predictors were the same but also the 500 hPa potential height was added.

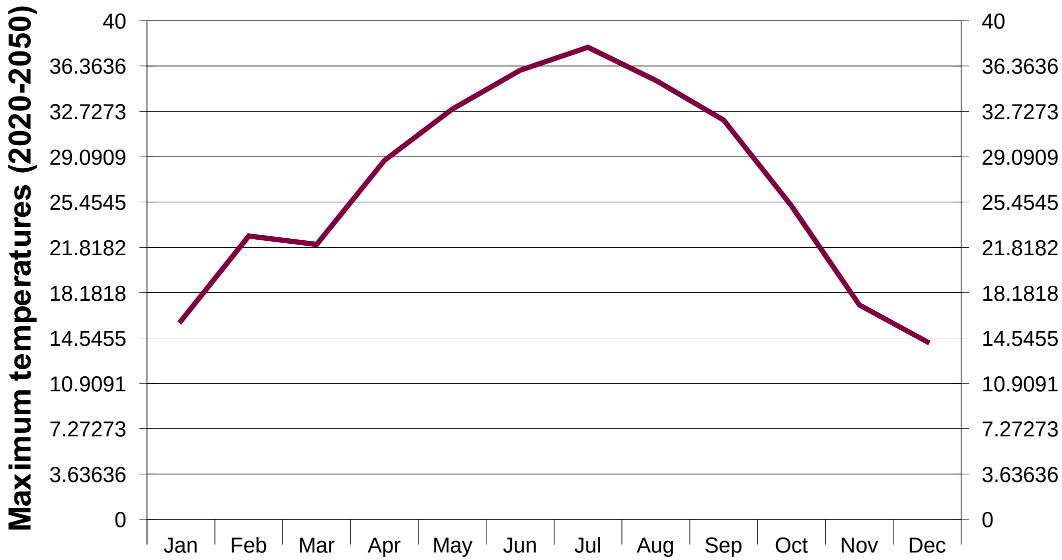


As regards the daily precipitation amounts the predictors used were average sea level pressure, surface zonal and meridional velocity components, airflow strength and velocity zonal component (westerly winds) at 500 hPa level, wind direction at 500 hPa and 850 hPa levels, near surface and 500 hPa height relative humidity and ground mean temperature.

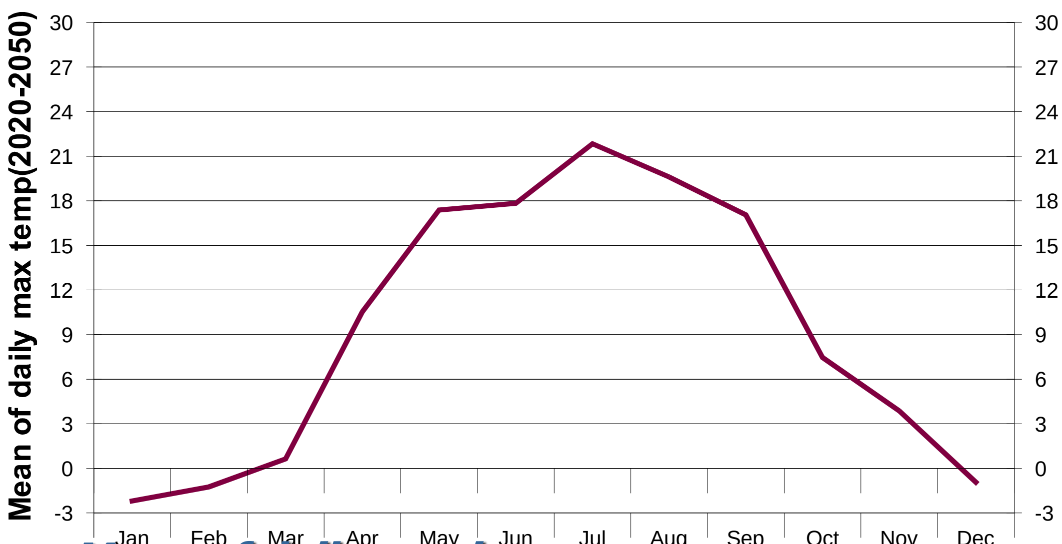
After generating the raw data (series of daily values), these could be used for feeding the various models necessary in impact studies.

By applying the functions provided by the SDSM *Summary Statistics* and *Compare Results* modules monthly multiannual values for the interval 2020-2050 were calculated and graphically represented.

Monthly values (2020-2050) for the SRES A2 scenario:



Absolute maximum temperatures

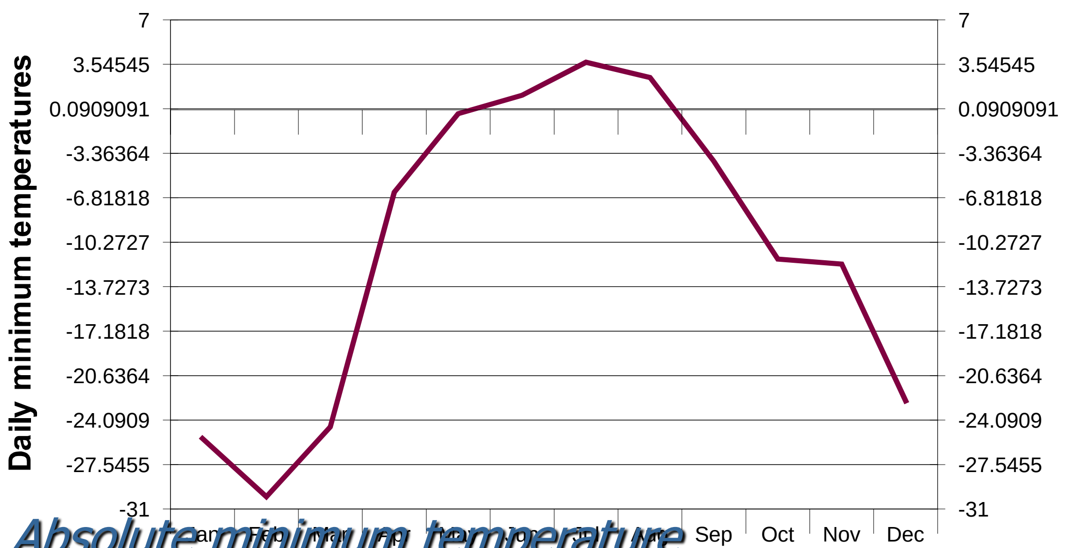


Mean of daily maximums,

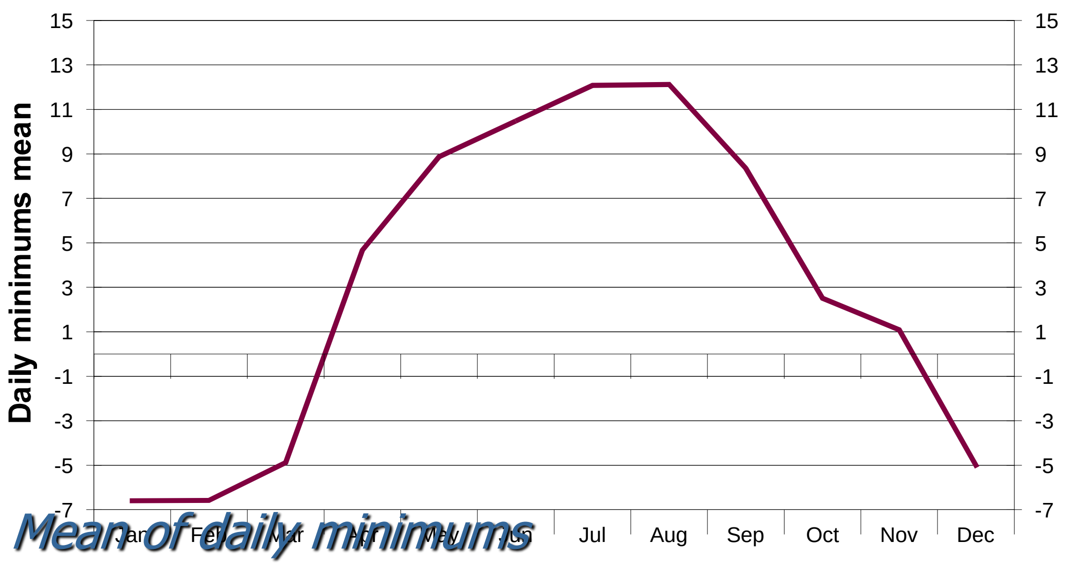
By analysing the temperature charts, it results that the analysed period 2020-2050 will be warmer but the differences are not dramatic.

The maximum temperatures are expected to exceed 35^{o}C in June, July and August and the average of the daily maximums will be greater that 17 ^{o}C in the same months plus September.

Monthly values (2020-2050) for the SRES A2 scenario:



Absolute minimum temperature



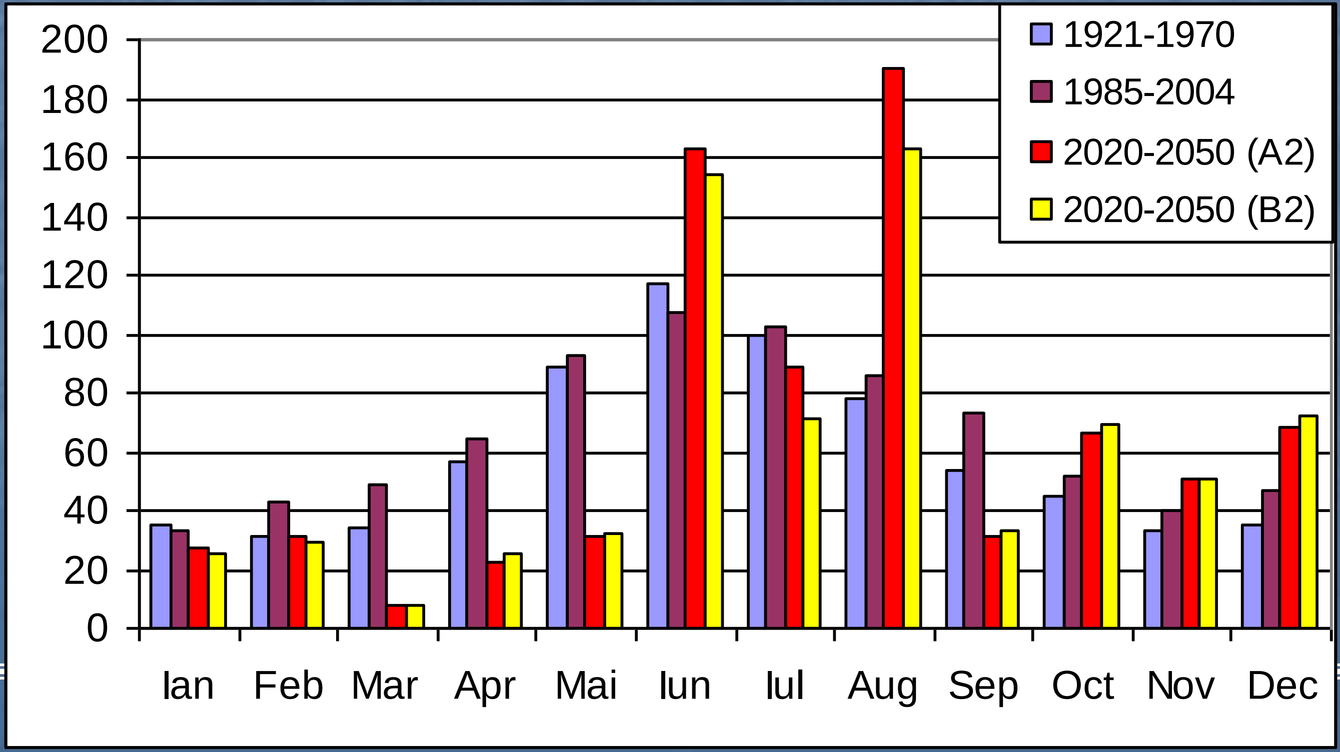
Mean of daily minimums

Winters will not be very warm considering that from December to March the minimums averages occur lower than -4 ºC

and the absolute minimums will fall under -20 ºC.

Generally rainfalls are less well simulated by the GCMs, but the downscaled data show a possible major change, especially as regards the distribution over the year.

Springs occur to be much drier as compared with the summers and late autumns. Such changes, if also confirmed by future studies, are highly hazardous and require special response strategies (planning afforestations in the autumn etc.).



For determining the temperature spatial distribution in this mountain region, a simple original method, based on the GIS complex digital models was developed, considering two main variation factors:

- **local heating (produced by the incoming solar energy)**
- **and air circulation (advection) that brings air with a certain temperature from the same level in the free atmosphere.**

The local factor was modelled, by computing for each month the ratio between the incoming solar radiation in each cell of the raster layer and the value corresponding to the position of the local weather stations.

Solar radiation is the main energy source for all the processes taking place in the earth atmosphere, and consequently it plays the central role in climate genesis. This energy is not entering the atmosphere system directly but through the interaction with ground surface, that influences the climate by its shape (landform) and reflective properties.

The amount of incident solar energy depends on astronomic factors (time of the year, moment of the day) that could be easily computed and also on stochastic factors, such as air masses transparency.

The inclination and aspect influence the incident beam, diffuse and reflected radiation. The effect of slope and aspect is higher under clear-sky as compared to the cloudy conditions, when diffuse radiation dominates and the main influence factor is the visible sky.

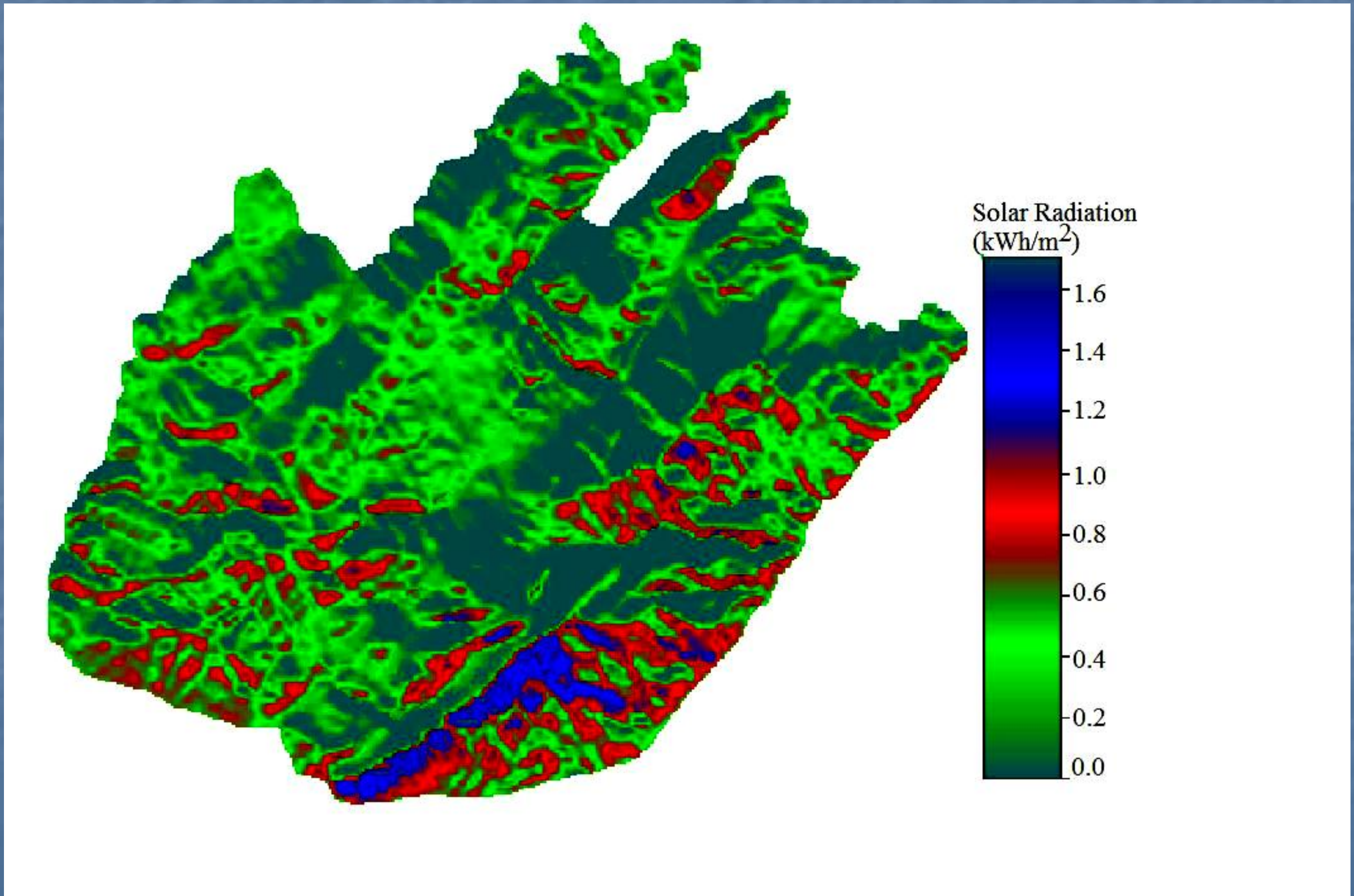
According to Lambert's law, the solar direct radiation received by the surface unit is a function of the angle formed by the solar beam with the surface (it could be computed as the product between the intensity on the beam cross section and the cosine of the beam inclination angle).

The sunshine duration and the amount of diffuse radiation depend on the visible sky that is determined in GIS by taking into account the height of the mountain ridges which delineate the horizon, considering the main cardinal directions.

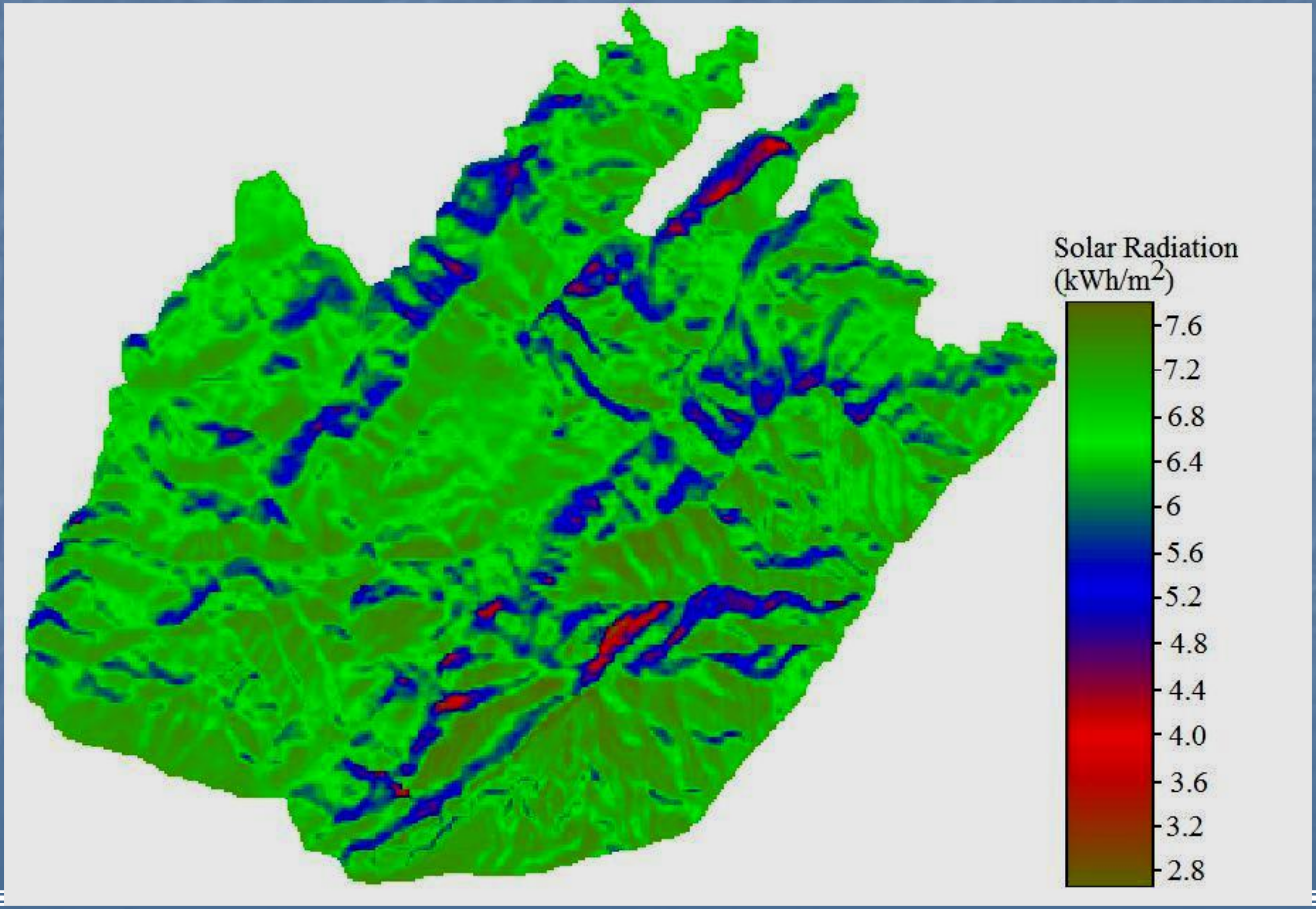
For calculating the incoming solar radiation and sunshine duration, it was used the SAGA software (System for Automated Geo-Scientific Analysis), primarily developed in two German Universities.

In order to establish the radiation factors to be used for modelling the distribution of air temperature in the study areas, the above mentioned solar parameters were calculated for each month (considering the sun position at the monthly middle).

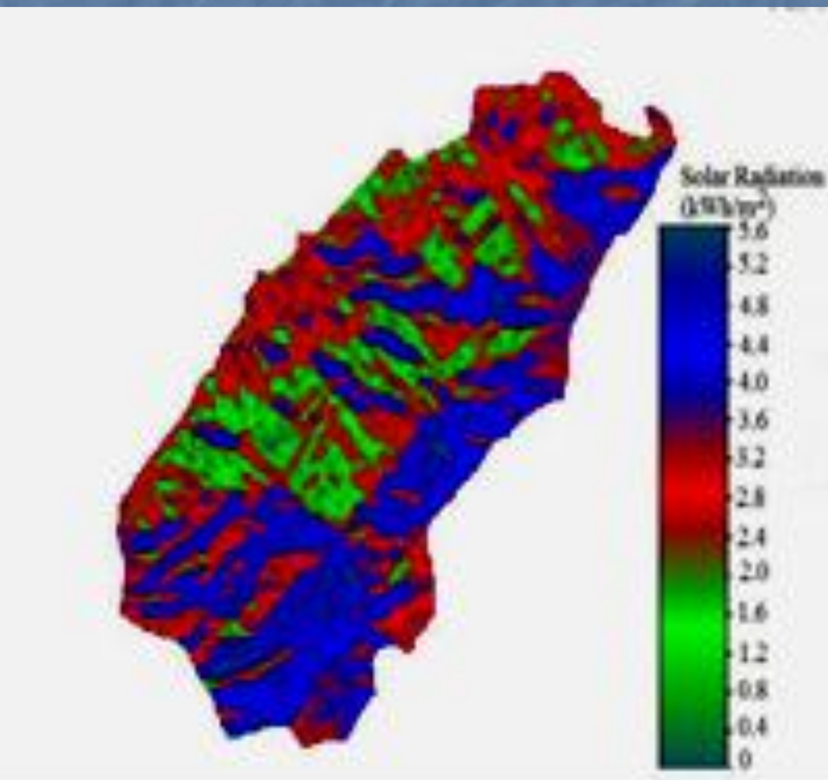
In January, when the sun position is low, the incoming energy on the slopes of Postavaru is reduced, higher values occurring on the southern cliffs (marked in blue).

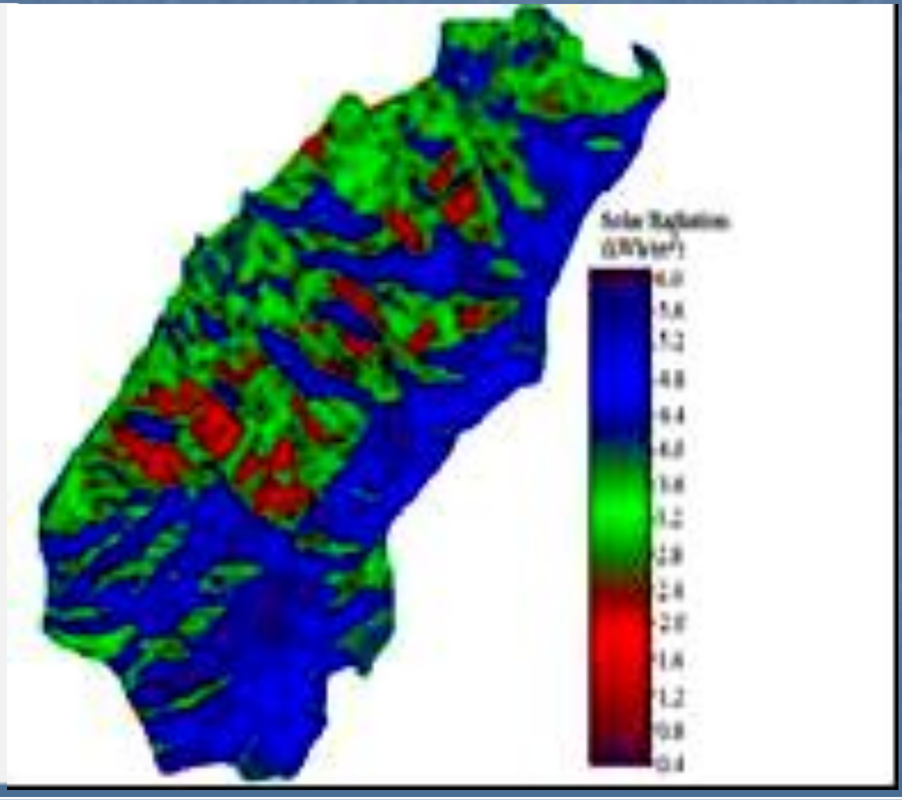


In June, with the sun at maximum apparent height, despite the differences at particular moments between various slopes, the daily amounts are less variable.



The examples for Piatra Mare, in March and September, show that the range of values is similar but the spatial distribution of received energy is completely different





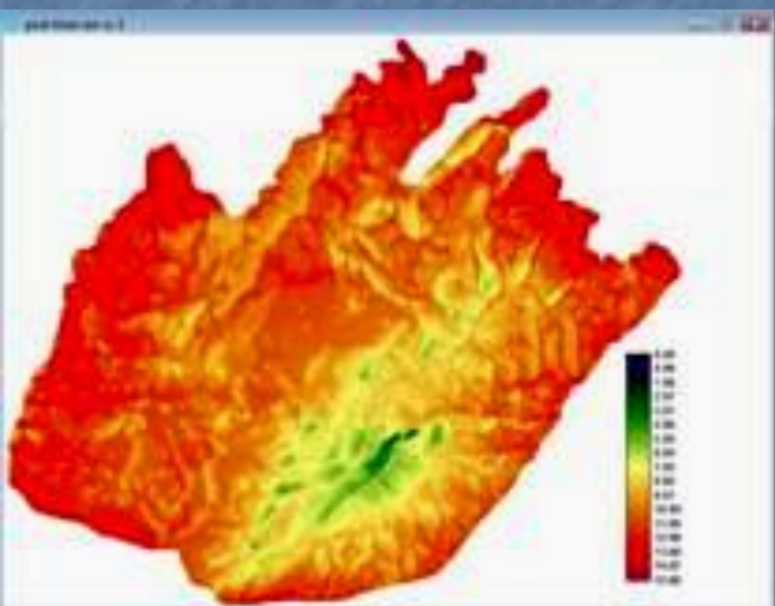
In these researches two climate change scenarios were taken into account.

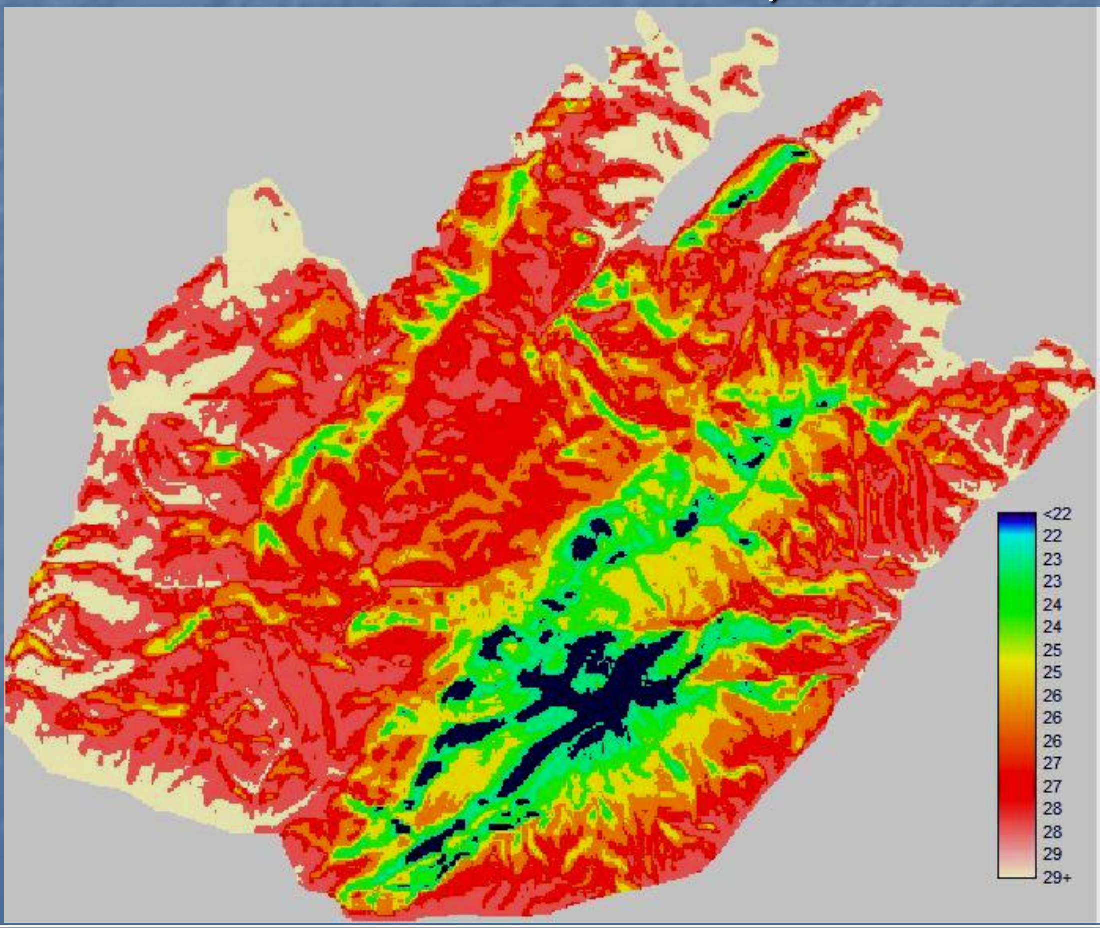
The first scenario was simulated using EdGCM, for the increase of CO_2 to 450 ppm and of CH_4 to 2 ppm, and the data were extracted for the decade 2011-2020.

The second scenario was produced for the hypothesis of a CO_2 content reaching 800 ppm and the data were computed for the interval 2021-2030.

Temperature spatial distribution maps: examples for Postavaru (maximum temperatures)

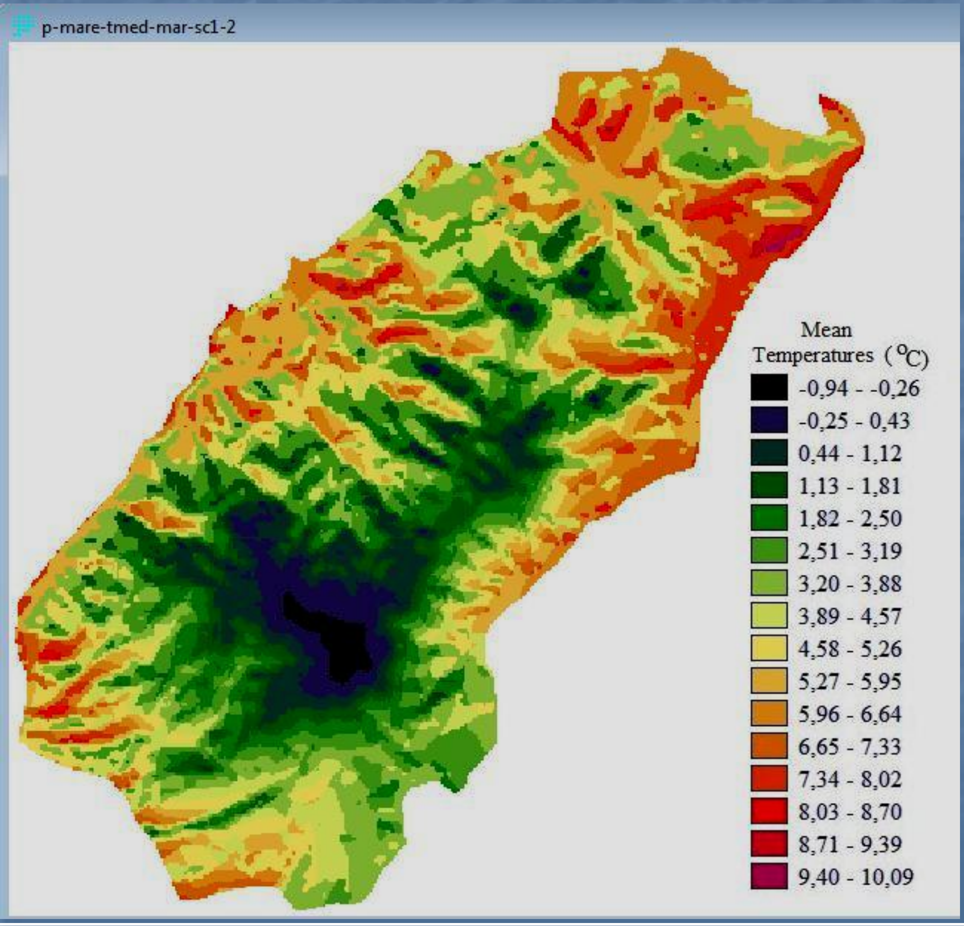
in January, scenario 1 | *June, scenario 2*



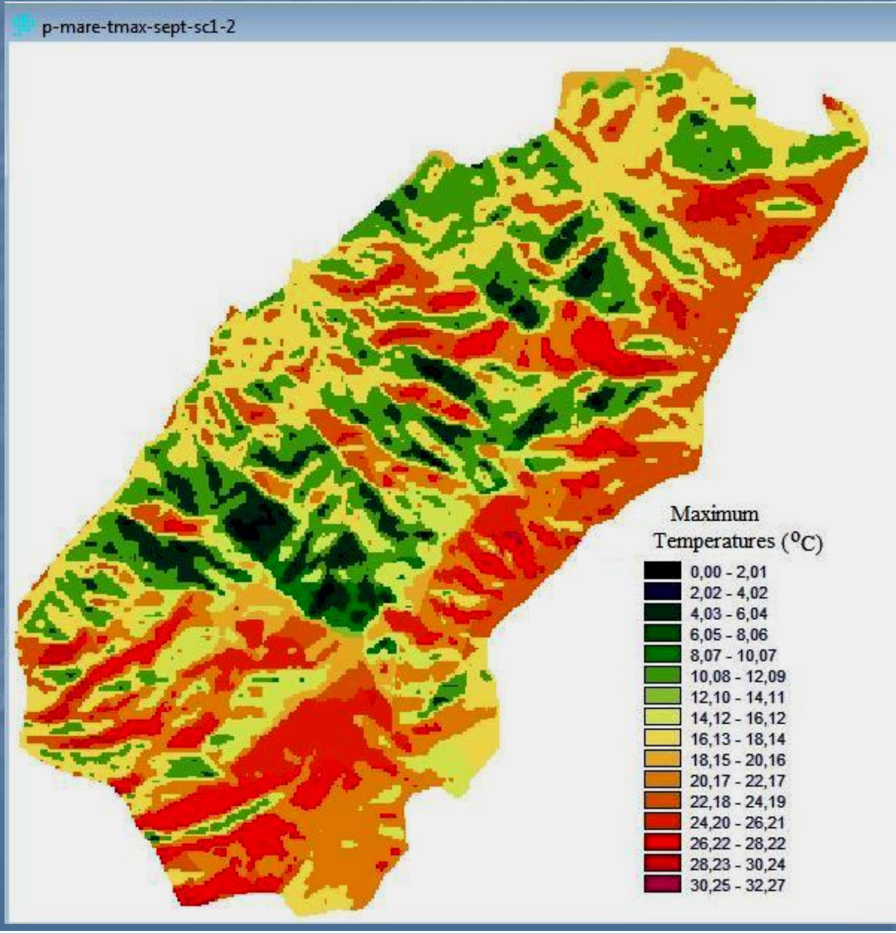


Temperature spatial distribution maps: examples for Piatra Mare for scenario 1

Mean temperatures in March



Maximum temperatures in September



The **forest management decision making** process requires **climate data at stand level** (forest management units).

Consequently, for mountain regions it is not enough to use regional climate change scenarios, because the local climate conditions are modified on the mountain slopes, in accordance with aspect, inclination and shading.

The **GIS layers** with the temperature spatial distribution, determined for each month and climate change scenario, as shown in the examples presented are very useful. From these **spatial databases**, **climate parameters values could be extracted for each forest management unit**.

Such sets of local climate parameters (different from the regional level ones) are necessary for feeding the forest growth models, in order to estimate the impact of a certain climate change scenario, which is extremely important for the **sustainable management of mountain forests**.

Thank you very much for your attention.