THE EVOLUTION OF ANNUAL MEAN TEMPERATURE AND PRECIPITATION QUANTITY VARIABILITY BASED ON ESTIMATED CHANGES BY THE REGIONAL CLIMATIC MODELS

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ABSTRACT. **The evolution of the annual mean temperatures and precippitation amount on changes estimated by the regional climatic models.** Climatic changes are representing one of the major challenges of our century, these being forcasted according to climate scenarios and models, which represent plausible and concrete images of future climatic conditions. The results of climate models comparison regarding future water resources and temperature regime trend can become a useful instrument for decision makers in choosing the most effective decisions regarding economic, social and ecologic levels. The aim of this article is the analysis of temperature and pluviometric variability at the closest grid point to Cluj-Napoca, based on data provided by six different regional climate models (RCMs). Analysed on 30 year periods (2001-2030,2031-2060 and 2061-2090), the mean temperature has an ascending general trend, with great varability between periods. The precipitation expressed trough percentage deviation shows a descending general trend, which is more emphazied during 2031-2060 and 2061-2090.

Keywords: regional climatic models, forecasted changes, temperature regime, pluviometric regime, climatic variability.

1. INTRODUCTION

The climatic models are representations of atmospheric, oceanic, terrestrial surface and Sun interactions. They represent trends more than actual events. The models are differential equation systems based on physics, chemistry and fluid dynamics laws, formulated to be solved by super – computers. The solution is Earth representation covered in a 3D grid with the basic equations applied and assessed (Christensen OB, et all, 2006).

Model accuracy is limited by grid resolution and our abilities in mathematically describing the complicated oceanic, atmospheric and chemical processes(http://climateprediction.net/content/regional-climate-models)Because the global climatic models (GCMs) have a typical resolution of 300 km, a more detailed resolution is required for assessing climate predictions, so it corrected by using regional climatic models (RCMs). Regional climatic models work by increasing the resolution of the global climatic models when a smaller area is considered.

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They can cover areas like Western Europe or Southern Africa, for example. Climate parameters (temperature, wind, etc.) computed by GCM are used as input data for RCMs, which can solve local impacts using high scale information regarding orography (altitude)??, land usage, etc and climatic and weather information at a 50 km, or even 25 km resolution.

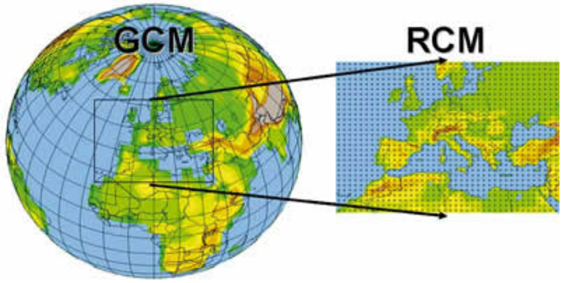

Fig. 1 Schematic depiction of the Regional Climate Model nesting approach[3]

2. DATA AND METHODS USED

2.1 Study area

The Cluj County territory is located in the Central part of Transylvania, with a surface of 179.5 km². It's spreads across 47˚ 28' 44" N, 46̊ 24' 47" S parallels, and 23̊ 39' 22" W and 24̊ 13' 46 S meridians.

Due to its geographical position, Cluj County is located in the moderate continental climate, frequently influenced by the Atlantic Ocean air masses. Often especially in winter, it is characterized by temporary intrusions, of maritime polar air. In the summer, the warm air masses come from Southwest, under the influence of North Mediterranean Cyclones, which shifts towards Northwest.The Cluj-Napoca weather station is located at 46°47'N/23°34'E and 410 m elevation above sea level. [4] (Fig. 2).

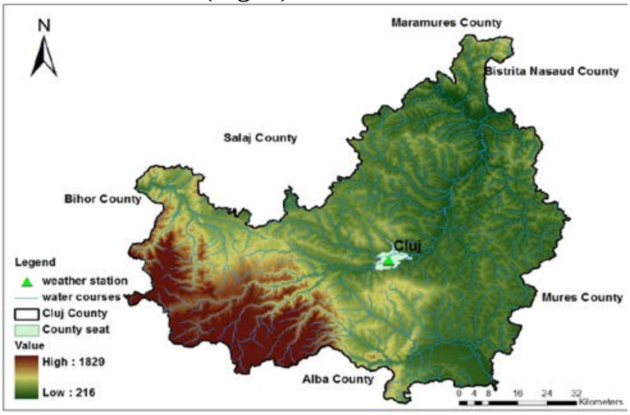

Fig. 2 The Cluj meteological station localisation in the county

[3] http://www.wmo.int/wcc3/bulletin/57_2_en/giorgi_en.html
[4] http://www.meteoromania.ro/anm/?page_id=644&statie=15120

2.2 Data sources and methodology

For the making of this article, a climate study based on climatic modeled data (forecasted) from 1961 until 2090, divided on sets of 30 year periods, emphasizing annual mean temperature and precipitation quantities was made. The acquired data was for the Cluj area, corresponding to the grid point coordinates of 23.5 longitudinal and 46.5 latitudinal for six regional climatic models (DMI-HIRHAM, SMHI_Had3Q3, MPI, ICTP, HadRM3Q0 and HadRM3Q3) available on http://climexp.knmi.nl, at a 25 km resolution.

***Table 1: Regional climate models from which data were analysed*.**

Acronym	Institution	RCM	GCM	Source
DMI-HIRHAM	**DMI** (Danish Meteorological Institute)	HIRHAM	ARPEGE	Christensen et al. (2006)
MPI-M-REMO	**MPI** (Max Planck Institute)	REMO (REgional MOdel)	ECH-REMO	Jacob (2001)
SMHI_Had3Q3	**SMHI** (Sweden's Meteorological and Hydrological Institute)	RCA	HadCM3Q3	Kjellström et al. (2005)
ICTP-REGCM3	**ICTP** (International Centre for Theoretical Physics)	RegCM (Regional Climate Model)	ECHAM5-r3	Giorgi & Mearns (1999)
METO-HC HadRM3Q0	Hadley Centre (**HC**) - Met Office - UK	HadRM3Q0	HadCM3Q0	Collins et al. (2006)
METO-HC HadRM3Q3	Hadley Centre (**HC**) - Met Office - UK	HadRM3Q3	HadCM3Q3	Collins et al. (2009)

The identification of forecasted changes in the analysed climatic parameters variability was done using data from the six models employed. The study period of 1961-2090 was divided on 30 year subperiods: 1961-1990, 2001-2030, 2031-2060 and 2061-2090, thus ensuring representativeness.

Mean temperature changes are calculated as differences between their average on subperiods and the average on the 1961-1990 period, thus the absolute deviation compared to the reference period.

$$\Delta_1 = x_1 - \bar{x}, i = 1, 2, \dots, n$$

$$\text{where } x_1 = \text{annual avarage periods } \bar{x} = \text{avarage period } 1961 - 1990$$

And for precipitation, the percentage deviation for the sub periods compared to the reference period of 1961-2060 was calculated, trough a percentage report between the absolut deviation and 1961-1990 period average.

$$\Delta_1 = \frac{x_1 - \bar{x}}{\bar{x}} * 100 \text{ where } x_1 - \bar{x} = \text{absolute deviation } \bar{x} = \text{avarage period } 1961 - 1990$$

As a research method, the computerized methods will be employed, which allow statistic data analysis, clasification, centralisation and development of chart components and tabelar synthesis. For highlighting forecasted changes, charts were made using the Statistica program.

3. RESULTS AND DISCUSSIONS

3.1 Annual mean temperature analysis

An average is representative only when omogen values are used in its calculation. The more complex the phenomena's are (if they depend on more factors), the higher the variability is and using medium measures becomes insufficient[5]. Statistical analysis can be deepened by calculating the variability indicators, in our case, the most representative are average, absolute and percentage deviations, standard deviation and maximum positive and negative deviations. These calculations are represented next, both chart and table.

a) 2001 – 2030. Compared to the reference period considered, all models show a rise in the mean temperature. The forecasted rise is between 0.5 °C (ICTP) and 1.5 °C (HadRM3Q3). Four from all six models show a rise in temperature by aprox. 1 °C (table 2). This temperature rise can be highlighted by increasing the extreme values too. The maximal temperature values expressed as deviation from the average is, except the MPI model, at least double compared to the minimal values. Total range of variation is also dependent by the variability of the data strings resulted from modeling. Thus, thermal amplitude expressed as a deviation from the average exceeds 3°C if the standard deviation is greater than 0.8 and falls below this threshold if the standard deviation is lower.

b) 2030 – 2061. It can be seen a group of models in terms of the mean value difference of temperature anomalies. The outputs of RCMs which are based on HadCM3 (GCM) show an increase with 2.3 and 2.7 °C compared with the reference period, and, the other models show a more modest increase, between 1.7 and 1.9 °C. If we analyse the change compared with the last period (2001 - 2030), the increase of annual mean temperatures remains significant, ranged between 0.7 and 1.4 °C. For five models out of six the forecasted increase in temperature exceds 1 °C (table 2).

Table 2 Variation indicators for the annual mean temperatures

Period	Model	DMI HIRHAm	SMHI_ Had3Q3	MPI	ICTP	HadRM3Q0	HadRM3Q3
2001-2030	Average	1.122	1.237	0.569	0.547	1.064	1.556
	Min	-1.092	0.094	-1.619	-0.907	-0.141	-0.409
	Max	2.393	2.776	2.110	1.548	2.326	3.552
	Deviation	0.827	0.580	0.893	0.722	0.661	0.890
2031-2060	Average	1.845	2.360	1.930	1.748	2.429	2.700
	Min	0.414	1.132	0.591	0.432	1.839	1.007
	Max	4.506	4.554	3.462	3.366	4.196	5.453
	Deviation	0.925	0.732	0.794	0.691	0.549	0.942
2061-2090	Average	2.365	3.107	3.249	2.974	3.489	3.890
	Min	1.085	0.974	1.772	1.865	2.594	1.733
	Max	3.750	5.141	5.229	4.750	4.621	5.610
	Deviation	0.716	0.861	0.884	0.730	0.594	0.961

[5] http://geografie.ubbcluj.ro/harastasan/statistica/STATISTICA.doc.

The changes in temparature variability are minor, the standard deviation stays in the same parameters. The temperature increase has impact over the extreme as well. During this time lows compared to the average reference period for all models are positive, reaching for the regional model HadRM3Q0 at the value of 1.8 ° C. Peaks also exceed 3.4 ° C (as average deviation) and reach the value of 5.4 ° C in the case of the HadRM3Q3 model.

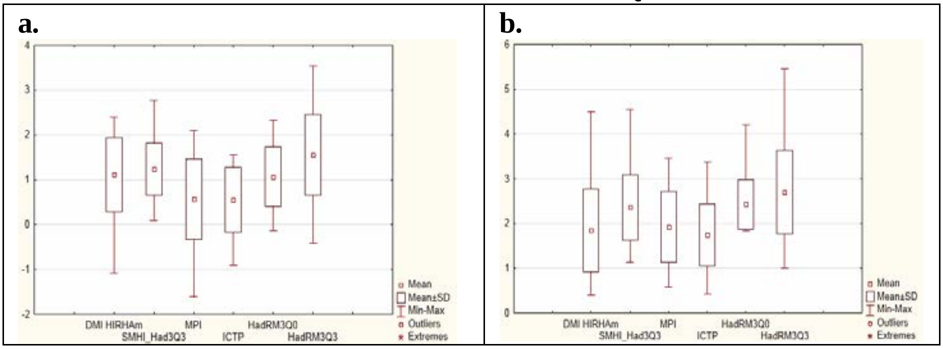

Fig. 3 Mean temperature regimes changes projections in Romania for 2001-2030 (a) and 2031-2060 (b)

c) 2030 – 2061. Models for this period indicate an increase in temperature as compared to the reference (1961-1990) as well as the last period. The total temperature rise for the closest grid point to Cluj-Napoca is between 2.3 and 3.9 °C compared to the reference period and between 0.5 and 1.3 °C compared to 2030 - 2061. These values of temperature rise are important and can have a significant impact over the natural and social enviroment, imposing adaptation measures and policies.

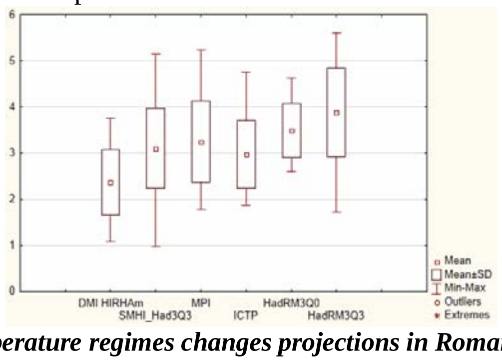

Fig. 5 Mean temperature regimes changes projections in Romania for 2061-2090

The models don’t show a major change in annual mean temperatures variability for this period. Standard deviation is kept within reasonable limits to geographical location of the grid point, not exceeding the value of a degree Celsius. The rise in temperature has repercussions over the extreme values as well. Compared wit the reference period, the peaks deviation to the average of the temperature absolute deviations from 1961 – 1990 is reaching at values between 3.7 and 5.2 °C, also the lows deviations have positive values.

3.2 Precipitation variability analysis

In case of precipitations, the mechanism are more complexe, the variability of pluviometric abnormalities being controlled by the simultaneous action of several factors, both dynamic (air pressure at sea level and altitude) and thermodynamic (ex. specific humidity at 850 mb). Due to high differences between models regarding the average value of precipitation quantity for the reference period, we have used the percentage deviations for comparison. These are commonly used in the precippitations case (see IPCC TAR4).

a) 2001 – 2030. Since the beginning of the analysis we should take note that the German model MPI leaves the general, relative homogeneous in the case of the other five models. For this period, (except MPI with -16.7 %) major changes are unlikely. The majority of models show a modest decrease in precipitation quantities (up to -4.6 % of the average for the reference period). One model (HadRM3Q0) shows a slight increase of precipitation quantities with the same amount (4.3 %). All other 5 models fall within the normal variability, the standard deviation ranging between 15.7 and 22.3 % and the forecasted lows and peaks do not differ significantly compared to those from the reference period.

b) 2031 – 2060. The changes in the reference period are not significant in this period as well. The only model which shows a major change is MPI which anticipates a drop with 33 % of the precipitation quantities average compared to 1961 – 1990 period. For the other models the drop in precipitation quantities stays modest by having values lower that 8 %. Even the HadRM3Q0 model reduces its increase forecast at only 1.9 %.

Talel 3 Variation indicators of the pluviometric regime

Period	Model	DMI HIRHAM	SMHI_ Had3Q3	MPI	ICTP	HadRM3Q0	HadRM3Q3
2001-2030	Average	-3.037	-4.590	-16.656	-0.451	4.258	-2.635
	Min	-37.895	-31.868	-237.543	-39.016	-46.984	-37.077
	Max	30.373	21.980	179.091	38.127	38.467	31.838
	Deviation	19.454	15.721	111.629	19.060	22.309	19.374
2031-2060	Average	-4.553	-7.841	-33.820	-5.348	1.913	-0.494
	Min	-42.522	-33.185	-188.796	-30.310	-30.955	-43.829
	Max	71.738	24.589	171.672	31.622	34.395	35.636
	Deviation	26.800	14.775	90.971	16.126	17.058	21.127
2061-2090	Average	-17.562	-7.779	-14.777	-0.253	-0.819	-5.055
	Min	-59.894	-31.995	-186.624	-21.198	-35.456	-36.959
	Max	22.800	11.451	150.199	32.821	44.220	23.229
	Deviation	23.891	12.325	87.688	15.727	21.536	18.621

Comparative with the previous period (2001 - 2030) the majority of models show a slight decrease (up to 4.9 % for the American ICTP model). The only model that shows a modest increase in precipitation quantities is HadRM3Q3 (2.3 %). MPI leaves the general framework of the other models for this period as well showing a significant drop of the precipitation quantities average compared with the previous period with not less than 17.1%.

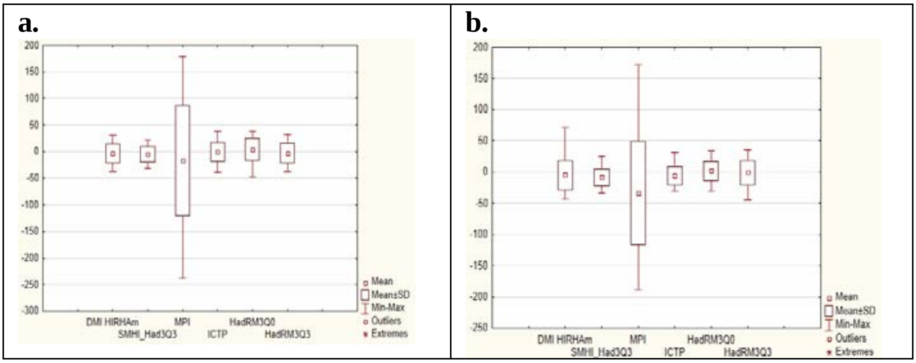

Fig. 5 Pluviometric regimes changes projections for 2001-2030 (a) și 2031-2060 (b)

Regarding interannual precipitation quantity variability for the 2031 – 2060 period, no major changes are observed. The standard deviation is mantained in about the same parameters. Also, in the case of the MPI model, a drop in the standard deviation with 20.7 % and a significant reduction of the total variation interval are being observed. Despite this significant reduction this model appears not to be viable for anticipating the interannual variation in our study area.

c).2061-2090. For this period all the models show a deacrease in precipitation quantities compared to the 1961-1990 period. This drop can have modest values (-0.2 %) and reach the value of -17.3 % in case of the Danish DMI model. Compared with the previous period (2031 - 2060), the same model has a spectacular drop of -13.0 % while for the other models we have more modest rises and drops of 4 – 5 %. The same MPI is characterized by originality with a rise of not less than 19.0 % compared with 2031 – 2060.

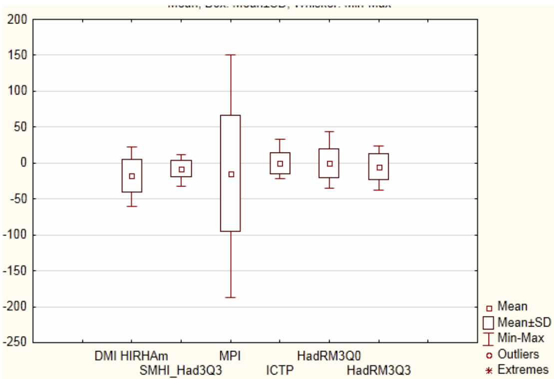

Fig. 6 Pluviometric regimes changes projections for 2061-2090

The interannual variability wasn't significantly changed in this period. The standard deviation is mantained in about the same parameters; therefore the total variation interval doesn't undergo major changes.

4. CONCLUSIONS

Climatic regional models are better able to characterize climate change at mezoscale compared to global. They take into consideration the features of the active surface and its change scenarios in the future

The regional models output analysis results for annual mean temperature show the keeping of the current warming trend. The differences between periods show a mean rise of aprox. 1 °C during period. At the end of the XXI century a rise by 3 °C in temperature if being forecasted. This difference, which falls in trend for the european continent, imposes awareness to the decision makers from different levels regarding the monitoring and reducing the impact. Conversely, when talking about the annual quantities of rainfall the uncertainties are higher. The differences between models are obvious, thus discussing about establishing a trend is difficult. We can, at least, say that compared to the end of the last century we can expect a slight decrease in precipitation or even maintaining the current situation. The total variation interval stays in the same variation parameters, except that the warming trend places its mark on the lows and peaks which rise at the as same rate as the mean values.

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