REGIONAL CLIMATIC SCENARIOS FOR SLOVAK MOUNTAIN REGION BASED ON THREE GLOBAL GCMS

M. Melo[1]

[1] Comenius University Bratislava, Slovakia
E-mail : melo@fmph.uniba.sk

Abstract: The aim of this contribution is to prepare climate change scenarios in form of time series of air temperature and precipitation amount for Liptovský Hrádok in 21st century based on three global climate model outputs. Liptovský Hrádok lies at the SW foot of the High Tatras Mts. (640 m a.s.l.). This station is representative station for Liptov basin (mountain region in Slovakia) and it ranks among the best meteorological stations in Slovakia with sufficiently long and good-quality observations (1881-2006). In this contribution model data from the next three different global coupled (atmosphere-ocean) general circulation models (GCMs) are utilized: model data from the Goddard Institute for Space Studies in New York (GISS 1998 model), from the Canadian Centre for Climate Modelling and Analysis in Victoria, B.C. (cgcm2 model) and from the Met Office Hadley Centre in Exeter, UK (HadCM3 model). Statistical method for downscaling of global GCMs outputs to the regional level is used.

Keywords: *climate change, climate models, climate scenarios, air temperature, precipitation total*

1. INTRODUCTION

Climatic scenarios are at present based mainly on global climate models outputs. Climate models are the best tools for assessing the response of the climate system to changes in radiative forcing. The most highly developed global climate models are atmospheric and oceanic general circulation models (GCMs). In many cases the GCMs of the atmosphere and oceans are developed as separate models. The coupled GCMs then arise by mutual combining. The scenarios presented here use the US Goddard Institute for Space Studies GISS 1998 GCM under compounded of 1% CO_2 increase experiment with tropospheric sulfate aerosol changes, Canadian CGCM2 model under two SRES emissions scenarios, A2 and B2, and one emissions scenario IS92a and the UK Hadley centre`s HadCM3 GCM. Climate change experiments have been carried out by e.g. Boer et al., 1992, McFarlane et al., 1992, Murphy and Mitchell, 1995, Russell and Rind, 1999, Flato and Boer, 2001.

Present horizontal resolution of GCMs does not allow make out some regional climate features. Two principally different approaches have been applied for solution of this problem: statistical methods (statistical downscaling) and dynamical methods (dynamical downscaling) that use a detailed regional meteorological model nested into the global model system. Statistical downscaling consists from development of statistical relationships between locally observed climate variables and outputs of global GCM experiments. A set of statistical downscaling techniques has been developed up to present (IPCC, 2001). Also in this contribution statistical downscaling is used.

2. DATA AND METHODS

In this paper the temperature and precipitation time series of Slovak station Liptovský Hrádok (640 m a.s.l., northern part of Slovakia) for 1901-2005 (data from the Slovak Hydrometeorological Institute) and data from the next three global GCMs (GISS 1998, CGCM2, HadCM3) are utilized.

Coupled atmosphere-ocean model GISS 1998 from the NASA / Goddard Institute for Space Studies in New York was developed for climate studies in 1998 (for 1990-2099 period). C085 is control simulation with constant 1989 atmospheric composition, C086 is compounded 1%CO_2 increase experiment and C087 is compounded 1%CO_2 with tropospheric sulfate aerosol changes. We use C085 and C087 simulations here. This model has 4° x 5° horizontal resolution with 9 vertical layers for the atmosphere and 13 layers for the ocean (Russell and Rind, 1999). We take into account model outputs from 4 gridpoints near to Slovakia (gridpoint 1 – 46° N, 17,5° E, 361 m a.s.l., gridpoint 2 – 46 °N, 22,5° E, 386 m a.s.l., gridpoint 3 – 50° N, 17,5° E, 366 m a.s.l. and gridpoint 4 – 50° N, 22,5° E, 345 m a.s.l.).

CGCM2 is the second version of the Canadian Centre for Climate Modelling and Analysis coupled global climate model. Model was developed in 2000. This model is based on the earlier CGCM1, but with some improvements (Flato and Boer, 2001). CGCM2 has been used to produce ensemble climate change projections (for period 1900-2100) using the older IS92a forcing scenario, as well as the newer IPCC SRES A2 and B2 scenarios. For the regional downscaling the CGCM2 outputs of 6 gridpoints near to Slovakia were selected: gridpoint 1 – 46,39° N; 15,00° E; 597 m a.s.l., gridpoint 2 – 49,39° N; 18,75° E; 616 m a.s.l., gridpoint 3 – 46,39° N; 22,50° E; 554 m a.s.l., gridpoint 4 – 50,10° N; 15,00° E; 442 m a.s.l., gridpoint 5 – 50,10° N; 18,75° E; 531 m a.s.l., gridpoint 6 – 50,10° N; 22,50° E, 566 m a.s.l..

HadCM3 is coupled atmosphere - ocean model from the Met Office Hadley Centre in Exeter, UK. This model was developed in 1998. Atmosphere part of GCM has 19 vertical layers and horizontal resolution 2,5° x 3,75°, oceanic GCM has 20 vertical layers and horizontal resolution 1,25° x 1,25°. We take into account model outputs from 6 gridpoints near to Slovakia (gridpoint 1 – 50°N, 15°E, 734 m a.s.l.; gridpoint 2 – 50°N, 18.75°E, 218 m a.s.l.; gridpoint 3 – 50°N, 22.5°E 371 m a.s.l.; gridpoint 4 – 47.5°N,15°E 371 m a.s.l.; gridpoint 5 – 47.5°N, 18.75°E 394 m a.s.l.; gridpoint 6 – 47.5°N, 22.5°E, 418 m a.s.l.) for the period 1950-2099.

Topography is very smooth in all these models. The Alps and Carpathians are presented in these GCMs as one flat hill in Central Europe, without the Danubian hollow in Panonia. The values in individual gridpoints represent some areal mean values. Outputs of these models are used to elaborate climate scenarios for the climate of strengthened greenhouse effect on the territory of northern Slovakia (mountain region in surroundings of Liptovský Hrádok) in the 21st century.

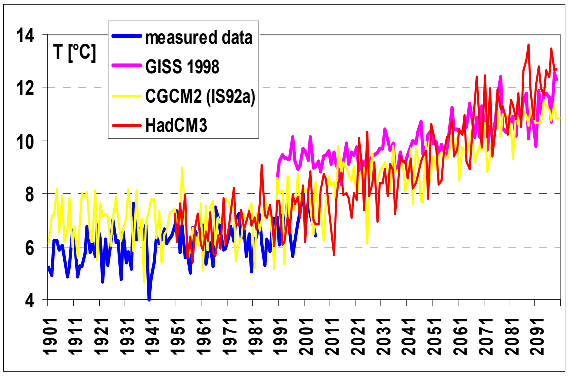
Firstly interpolation from the GCMs gridpoints near to Slovakia to the locality of Liptovský Hrádok (the weights with respect to the distance from this locality) is used. Downscaling of the model outputs for selected locality (Liptovský Hrádok) is realized by use of data from the meteorological station (Liptovský Hrádok) in the "control" or "reference" period (1951-2000). The modified model outputs according to the means and variability (standard deviations in case of air temperature, variation coefficients in case of precipitation amount) are then in relatively good accordance with the observed data series. Supposing only insignificant changes in the transforming relation between measured and modeled data we can similarly modify the model outputs also in the close future (up to the year 2100). This method was applied in Lapin and Melo, 1999, Lapin et al., 2001a, Lapin et al., 2001b, Lapin and Melo, 2004.

3. RESULTS

In 1901-2005 we have achieved moderate air temperature increase (annual mean) in Liptovský Hrádok (according to linear trend about 1.2 °C in this period). In case of summer period (JJA) this summer air temperature increase is higher than annual increase (according to linear trend about 1.5 °C in 1901-2005) and in case of winter air temperature increase (DJF) it is 0.9 °C (by linear trend) in the same period.

Comparison among real (measured) annual air temperature means in Liptovský Hrádok in 1901-2005 and modelled annual air temperature means according to three different GCMs in the same locality in the 20th and 21st centuries (without modification) is outlined in Fig. 1. We can see that means and variability among GCMs outputs and measured data are different. Modification of means and variability of these GCMs outputs is needed according to the standard deviation (variation coefficients in case of precipitation) obtained from the measured series. Result in form of air temperature scenarios for the 21st century is visible in Fig. 2. On the base of all studied GCMs outputs we can state that climate in Liptovský Hrádok will be continue in increase also in the 21st century. Temperature growth according to model GISS 1998 is characterized by the lowest value. On the contrary the most expressive air temperature increase on this territory is projected by model HadCM3. Temperature increase achieved by new B2-SRES emission scenario is smaller than result with older IS92a emission scenario according the same model (CGCM2). Result of A2-SRES is similar to IS92a in case of air temperature increase based on the same model CGCM2.

Precipitation trend in Liptovský Hrádok in 1901-2005 shows 14% decrease (by linear trend) (Fig. 3). Comparison between real (measured) annual precipitation total in Liptovský Hrádok in 1901-2005 and modelled values according to two GCMs in the same locality in the 20th and 21st centuries (without modification) is outlined in Fig. 4 and Fig. 5. Atmospheric precipitation scenarios according to three GCMs after modification (means and variability) we can see in Fig. 6. The results achieved by these climate models (in case of precipitation) are different. In the 21st century we can await decrease of annual precipitation total in Liptovský Hrádok according to next models: GISS 1998, HadCM3, CGCM2 (A2-SRES), even increase of annual precipitation total in Liptovský Hrádok according to CGCM2 (B2-SRES) and CGCM2 (IS92a).



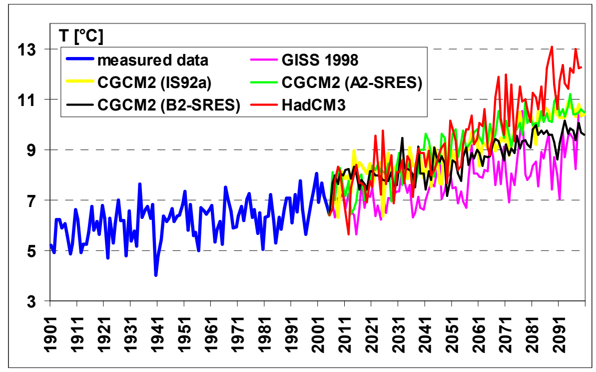
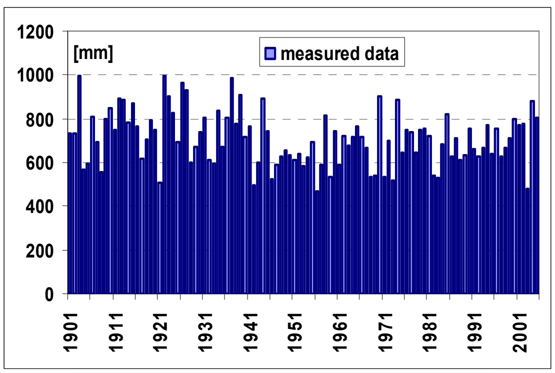


Figure 1: (Left): Annual air temperature means [°C] in Liptovský Hrádok – measured in 1901-2005 and modelled according to three different GCMs in the 20th and 21st centuries (without modification).
Figure 2: (Right): Annual air temperature means [°C] in Liptovský Hrádok – measured in 1901-2005 and scenarios based on different GCMs in 2006-2100 (after modification).



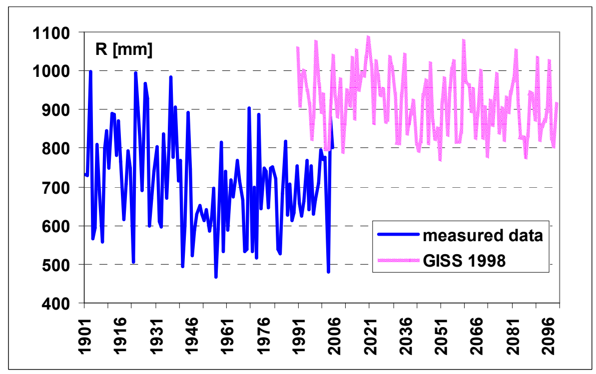
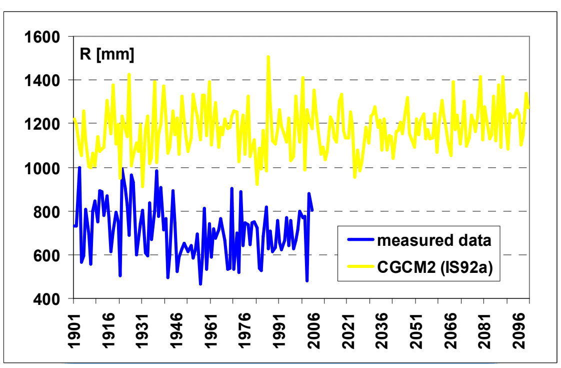


Figure 3: (Left): Annual precipitation total in Liptovský Hrádok in 1901-2005.
Figure 4: (Right): Annual precipitation total in Liptovský Hrádok - measured in 1901-2005 and modelled according to model GISS 1998 in 1990-2099 (without modification).



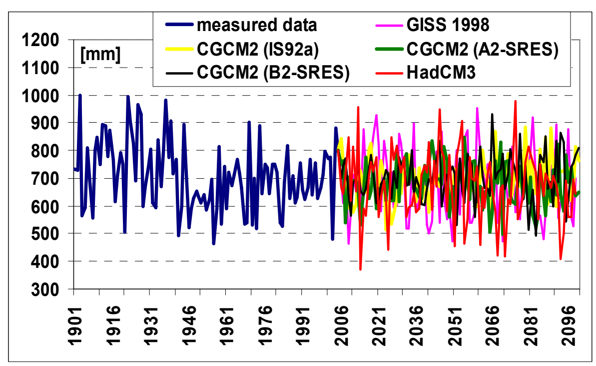


Figure 5: (Left): Annual precipitation total in Liptovský Hrádok - measured in 1901-2005 and modelled according to model CGCM2 (IS92a) in 1901-2100 (without modification).
Figure 6: (Right): Annual precipitation total in Liptovský Hrádok - measured in 1901-2005 and scenarios based on different GCMs in 2006-2100 (after modification).

4. CONCLUSION

Climate in Slovak mountain region (SW foot of the High Tatras Mts.) becomes warmer. Temperature time series of three Slovak mountain stations in this region e.g. were analyzed from the point of view of their warmer periods in Melo, 2005. Results of three GCMs show at the end of the 21st century additional warming on this territory. In the future is appropriate to prepare scenarios of climate change for this region in the 21st century particularly for summer and winter periods and for the next climatic characteristics (global radiation, air humidity). Obtained results can be used as inputs for the impacts and vulnerability assessments e.g. mainly in agriculture, forestry and hydrological applications.

Acknowledgements: *The Science and Technology Agency (Slovakia) under contract No. APVT-51-017804 and the Grant Agency of the Slovak Republic under the Project VEGA No. 1/1042/04 supported this study. In this contribution model data from the Canadian Centre for Climate Modelling and Analysis in Victoria, B.C., from the Goddard Institute for Space Studies in New York, from the Met Office Hadley Centre in Exeter, UK and measured data from the Slovak Hydrometeorological Institute in Bratislava are used.*

REFERENCES

Boer, G.J., McFarlane, N.A., Lazare, M. (1992): Greenhouse Gas-induced Climate Change Simulated with the CCC Second-Generation General Circulation Model. *J.Climate*, 5, 1045-1077.

Flato, G. M., Boer, G. J. (2001): Warming asymmetry in climate change simulations. *Geophysical Research Letters*, 28, 1, 195-198.

IPCC (2001): Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, P. J., Xiaosu, D. (eds.). *Cambridge Univ. Press*, UK, 944 pp.

Lapin, M., Damborská, I., Melo, M. (2001a): Downscaling of GCM outputs for precipitation time series in Slovakia. *Meteorologický časopis*, 4, 3, 29-40.

Lapin, M., Melo, M. (1999): Climatic Changes and Climate Change Scenarios in Slovakia. *Meteorologický časopis*, 2, 4, pp. 5-15.

Lapin, M., Melo, M. (2004): Methods of climate change scenarios projection in Slovakia and selected results. *J. Hydrol. Hydromech.*, 52, 4, 224-238.

Lapin, M., Melo, M., Damborská, I. (2001b): Scenarios of several physically plausible climatic elements. *NKP SR, VI, zv.11/01*. MŽP SR, SHMÚ, Bratislava, 5-30.

McFarlane, N.A., Boer, G.J., Blanchet, J.-P., Lazare, M. (1992): The Canadian Climate Centre Second-Generation General Circulation Model and Its Equilibrium Climate. *J.Climate*, 5, 1013-1044.

Melo, M. (2005): Warmer periods in the Slovak mountains according to analogue method and coupled GCM. *Croatian Meteorological Journal*, 40, 589-592.

Murphy, J.M., Mitchell, J.F.B. (1995): Transient Response of the Hadley Centre Coupled Ocean-Atmosphere Model to Increasing Carbon Dioxide. Part II: Spatial and Temporal Structure of Response. *J.Climate*, 8, 57-80.

Russell, G.L., Rind, D. (1999): Response to CO_2 Transient Increase in the GISS Coupled Model: Regional Coolings in a Warming Climate. *J. Climate*, 12, 531-539.