SCENARIOS OF CLIMATIC ELEMENTS DAILY VALUES FOR SLOVAKIA UNTIL 2100 AND THEIR UTILIZATION BY USERS

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Abstract: Outputs from the Global and Regional General Circulation Models of the atmosphere (GCMs, RCMs) in the form of daily time series are to disposal recently (means and extremes of air temperature, precipitation totals, incoming solar radiation, specific air humidity and others). Selected results and method of regional modification (downscaling) of the GCM CGCM2 outputs (Canadian coupled GCM of 2nd generation, SRES scenarios A2 and B2) for Hurbanovo and some other stations are presented in this paper. Daily data from the 1961-1990 period have been used as baseline for the GCM output downscaling. The nearest four GCM grid points round Slovakia have been evaluated. Air temperature and solar radiation outputs downscaling were realized without any serious difficulties. Precipitation daily totals modeled for the GCM grid points represent areal averages of about 90 thousands sq km, so they occur significantly more frequent than those measured at selected stations. Statistically based method of daily totals number lowering based on measured data have been applied. Outputs of specific humidity show much higher values than the measured data, the downscaling faced therefore serious problems. Besides the GCMs output downscaling some kind of combined (GCM-Analogue) methods have been applied. Selected examples of results from scenarios design are presented only. At present there are developed by our department some dynamic downscaling methods.

Key words: climate change scenarios, daily data, analogues, dynamic methods, scenarios utilization

M. Lapin, I. Damborská, R. Drinka, M. Gera a M. Melo: SCENÁRE DENNÝCH HODNÔT KLIMATICKÝCH PRVKOV PRE SLOVENSKO DO ROKU 2100 A ICH PRAKTICKÉ VYUŽITIE

Abstrakt: V poslednom období sú už k dispozícii výstupy Globálnych a Regionálnych modelov všeobecnej cirkulácie atmosféry (GCMs, RCMs) vo formáte denných časových radov (priemery a extrémy teploty vzduchu, úhrnov atmosférických zrážok, globálneho slnečného žiarenia, mernej vlhkosti vzduchu a iných prvkov). V tomto príspevku prezentujeme vybrané výsledky a metodiku regionálnej modifikácie (downscaling) výstupov modelu GCM CGCM2 (Kanada, prepojený atmosféricko-oceánsky GCM druhej generácie, emisné SRES scenáre A2 a B2) pre Hurbanovo a niektoré iné stanice. Denné údaje z obdobia 1961-1990 sme považovali za referenčný súbor. Do úvahy sme brali iba najbližšie 4 uzlové body modelu GCM v okolí Slovenska. Modifikácia výstupov teploty vzduchu a globálneho žiarenia prebehla bez akýchkoľvek problémov. V prípade úhrnov atmosférických zrážok reprezentujú hodnoty vo výstupoch modelu CCCM akési priestorové priemery úhrnov z plochy okolo 90 000 km^2. Použili sme preto štatistickú metódu zníženia úhrnov zrážok tak, aby sa získali porovnateľné počty dní bez zrážok a s úhrnom zrážok v obvyklých kategóriách. Výstupy mernej vlhkosti vzduchu predstavujú hodnoty ďaleko vyššie ako podľa meraní na staniciach. Okrem metódy GCMs downscalingu sme využili na prípravu klimatických scenárov aj kombinovanú (GCM-Analógovú) metodiku. V príspevku prezentujeme iba vybrané výsledky a príklady navrhnutých scenárov. V súčasnosti sa pokúšame o vývoj metódy tzv. dynamického downscalingu výstupov GCMs a RCMs.

Kľúčové slová: scenáre klimatickej zmeny, denné údaje, analógy, dynamické metódy, aplikácie.

1. INTRODUCTION

The future climate regime can be influenced by several important factors, only some of them are included into the GCMs (General Circulation Models) or in the RCMs (Regional Circulation Models). In general the future climate regime depends on the development of natural climate forming factors (astronomic, terrestrial, circulation) and on anthropogenic forcing (connected mainly with the green-house gases and aerosols emission and land use change). The newest GCMs and RCMs outputs offer tens of variables (climatic, hydrologic and other elements) in the format of daily means, extremes and sums. These variables describe the future climatic and hydrologic conditions in fact similarly as the measured/observed data series in the past. Of course, there are some limitations making the detail expression of real processes impossible in the model outputs. That is why some specific outlines in the future climate are according to the GCMs and RCMs uncertain. The main problem is inadequate resolution in the GCMs (distance between the grid points is about 200-300 km) and incomplete calculation of all needed dynamic equations both in the GCMs and RCMs (too many processes need to be included). The structure of equations and processes in the GCMs and RCMs is still far from the impeccability, some important processes and mainly some feedbacks are not included. All model outputs represent a sort of areal averages on the smoothed terrain, several of input variables and processes must be modified by parameterization (Flato et al., 2001, Melo, 2003).

Downscaling of the GCMs and RCMs outputs from the resolution applied in the models to selected stations or to more dense network of grid points on real topography is realized by use of data in the "control" or "reference" period (mostly 1961-1990 or 1951-1980, very reliable observed series in the same format as the model output are needed). Such method enables a selection of the most suitable GCM or RCM (the best fit with observed climate) on the one side, and also the design a reliable procedure for model outputs modification (with only insignificant disturbing of physical plausibility among data) on the other. The transformed (modified) model outputs are then in relatively good accordance with the observed data series (based on the comparisons of distribution curves of normalized data). 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). Some variables (air humidity, evaporation, snow cover, runoff, soil moisture…) can not be expressed adequately reliable in the model outputs. This is mainly due to the influence of real topography and real geographical conditions very simply approximated in the models. That is why also other relevant methods of climate change scenarios design need to be developed. Alternative methods are based on the regression relations among measured elements and on elementary physical relations in the atmospheric and terrestrial processes. Such procedures enable to obtain quite reliable alternative climate change scenarios in the format of daily data time series very similar with the observed ones at least for the several next decades. As a principle the different downscaling method is based on the dynamic nesting of GCMs or RCMs outputs – dynamic downscaling. Depending on the variable and the computer facilities there are possibilities for final meteorological fields with about 4x4 km resolution.

2. DATA

In accordance with our previous analyses and activities in the regional GCMs outputs downscaling we applied the Canadian GCM (coupled CGCM2 of 2nd generation from CCC at Victoria in British Columbia) named here as CCCM2000. These outputs are to disposal from 1961 to 2100 and the period 1961-1990 was compared with the measurements at Hurbanovo (SW Slovakia, 115 m a.s.l., lowland) and Liptovský Hrádok (N Slovakia, 640 m a.s.l., hollow). As alternatives there were applied two SRES emission scenarios – A2 and B2 (global fossil carbon emissions in 1990-2100 are shown in Table 1). Four CCCM2000 grid points round Slovakia are as follows: A – south Hungary (49.39° N; 18.75° E; 616 m a.s.l.), B – western Romania (46.39° N; 22.50° E; 554 m a.s.l.), C – west of Katowice in south Poland (50.10° N; 18.75° E; 531 m a.s.l.), D – southeastern Poland (50.10° N; 22.50° E, 566 m a.s.l.). The location and altitude of all mentioned grid points are nearly the same for any CCCM version output. Altitude of these grid points is much higher than the real topography at the same site, they represent some smoothed terrain applied in the model (Lapin et al., 2004). At present the outputs of GCMs from UK (HadCM) and ECHAM are tested, preliminary results will be published in 2007.

Measured data at Hurbanovo in 1951-2005, Liptovský Hrádok in 1961-2005 and some other stations were offered by the Slovak Hydrometeorological Institute in Bratislava. The data from Hurbanovo are of very high quality (tested for homogeneity by Gaál et al., 2002, Auer et al., 2006).

Table 1: Global fossil carbon emission scenarios SRES A2 and B2 annually in billion tones.

Scenario/Horizon	1990	2020	2050	2100
A2	6.0	11.0	16.5	28.9
B2	6.0	9.0	11.2	13.8

3. METHODS

3.1 Statistical methods of GCMs downscaling

Statistical downscaling of the GCMs outputs in the format of monthly time series was successfully realized in 1999-2003 (Lapin et al., 2001, 2004). Deviations in long-term temperature monthly means are caused mainly by different altitude of climatological stations compared to the nearest GCM gridpoint. Low gridpoints density (300x300 km) and simplified physics in the GCMs are another reasons for some serious deviations between measured and modeled long-term means and variability. Specific air humidity means and downward global solar radiation sums are less influenced by different altitude than air temperature means. Final monthly time series of temperature, specific humidity and global radiation differences between climatological stations in 2001-2100 (as climate change scenarios) are based only on the long-term differences for the same stations in 1901-1990. Because of temporal trend in 1901-2100 time series the centered 21-year running averages have been used at standard deviation modification. For precipitation monthly totals time series a special method of downscaling, based on areal deviations of precipitation regime in 1901-1990, was developed. That is why the precipitation scenarios fit much better to the real temporal and areal precipitation totals variability (Lapin and Melo, 1999, Melo, 2003, Lapin and Melo, 2004, Lapin et al., 2005). These scenarios have been applied in many studies in Slovakia (i.e.: Hlavčová et al., 2000, Minďáš et al., 2003, Pekárová et al., 2005).

Nearly the same method can be applied also at the daily GCMs outputs downscaling only for air temperature and global radiation sums. As the first step the means and standard deviations for every day during the year and the total 1961-1990 period have been calculated both for measured and modeled data series (Lapin et al., 2005, 2006). Than the comparison of measured and modeled results took place. It was found that 30-year period is too short for the smooth annual course of deviations. At standard deviations (SD) it was even much worse than at means, more over the irregularities in annual course were not coherent with the measured ones. Therefore we have applied also some smoothing of SD annual course by the method of 11-day running means. A sample of downscaling procedure for March 1-9, 2051 is shown in Figure 1. The simplified formula of final $\boldsymbol{M2_{ij}}$ values as scenarios for $\boldsymbol{i}$ day in $\boldsymbol{j}$ year can be written as follows (^{X} denotes different method of SD quotients smoothing):

$$M2_{ij}^{X} = ([Mo_{ij} + (\overline{MS}_i - \overline{Mo}_i)] - \overline{M1_{ij}^{21}}).(\frac{SDS_i}{SDMo_i})^X + \overline{M1_{ij}^{21}}\,, \qquad (1)$$

where $\boldsymbol{Mo_{ij}}$ is the interpolated value from four gridpoints round Slovakia of selected GCM into the station site (or into the centre of Slovakia) for $\boldsymbol{i}$ day and $\boldsymbol{j}$ year ($\boldsymbol{i}$ = 1….365, $\boldsymbol{j}$ = 1961….2100), $\overline{MS_i}$ and $\overline{Mo_i}$ are 30-year averages of measured station data and ***Mo*** data for $\boldsymbol{i}$ day and the 1961-1990 period, $\overline{M1_{ij}^{21}}$ is 21-year moving average from $[Mo_{ij} + (\overline{MS}_i - \overline{Mo}_i)]$ for $\boldsymbol{i}$ day and centered into the $\boldsymbol{j}$ year, SDS_i and $SDMo_i$ are standard deviations of 30-year series daily data for the selected station (S) and model data Mo for the $\boldsymbol{i}$ day (the SD of Mo and M1 data is the same), the X sign denote the possibility to use the X-day running means centered into the $\boldsymbol{i}$ day (it is recommended X = 11).

This method conserves finally the characteristic annual course, including the known irregularities as June cooling and Christmas warming (Figure 2). In Figure 2 an additional smoothing of final 30-year averages by 5-day running means has been applied. The variability scenarios were designed by the quotient method using 21-year running means as a local center of variability (deviation of each daily value from this local center was modified by the quotient derived from the SDS and SDMo data). It can be seen that the smoothing of these quotients by X-day running means brought some improving, especially at very high individual quotients of SD, but also the temperature scenarios without any smoothing of annual course can be applied. Smoothed variability modification by 11-day running means seems adequate also from the point of view of basic model outputs variability, local extremes and local averages (Figures 1, 2 and 3). It can be seen in Figure 3 that also after two steps of smoothing the differences between SRES A2 and SRES B2 scenarios have irregular annual course. Choosing the method of 11-day running means at temperature imply that also the other variables will be smoothed by the same 11-day running means, because of minimum physical plausibility disturbing.

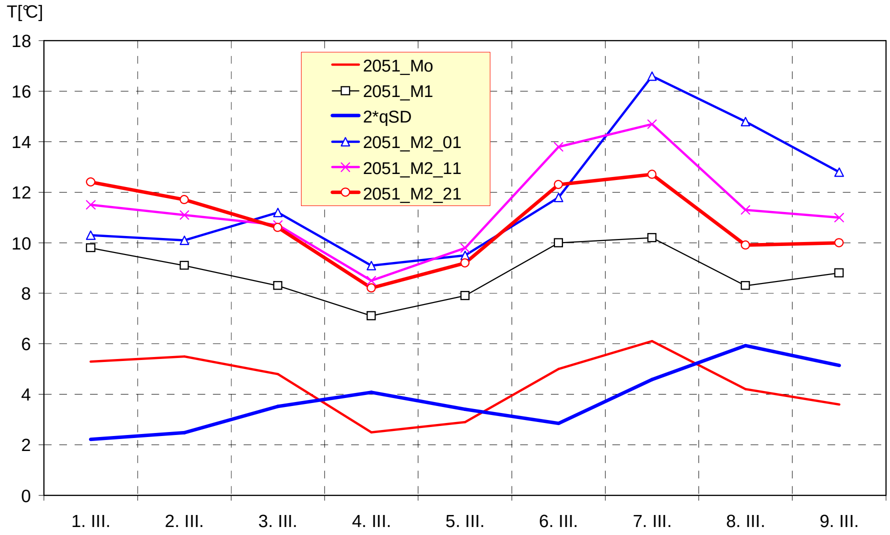


Figure 1: Example of air temperature daily means downscaling from the CCCM2000, SRES-A2 output (2*qSD – quotient of SDS and SDMo data multiplied by 2, 2051_Mo and 2051_M1 – Mo and M1 data for the year 2051, 2051_M2_01, 2051_M2_11, 2051_M2_21 – final downscaled values for the station in 3 versions - unsmoothed qSD, smoothed by 11-day and 21-day running averages (calculation was realized for the station Hurbanovo and March 1st to March 9th 2051).

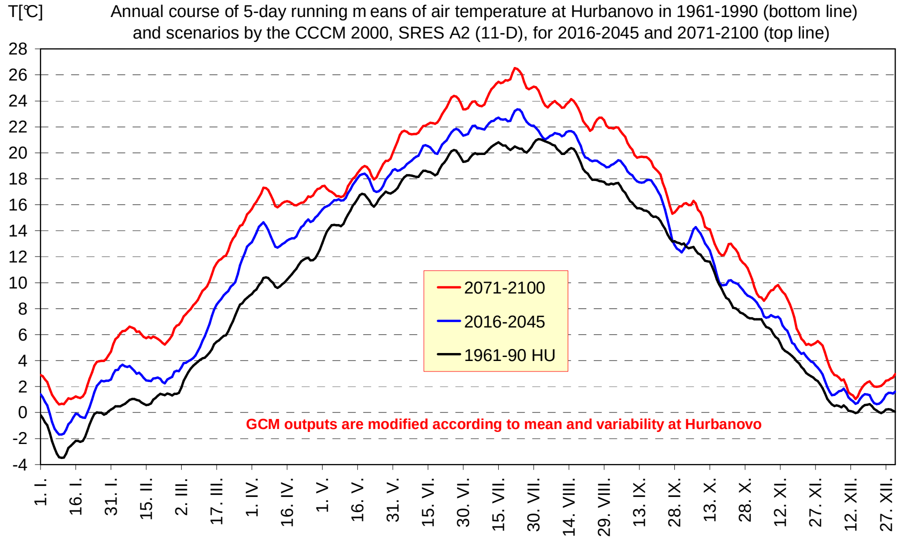


Figure 2: Annual course of air temperature 5-day running means at Hurbanovo in 1961-1990 (bottom line) and scenarios designed by the CCCM 2000, SRES A2 (variability was modified by 11-day running means of SD quotients), for the 2016-2045 and 2071-2100 time frames (top lines).

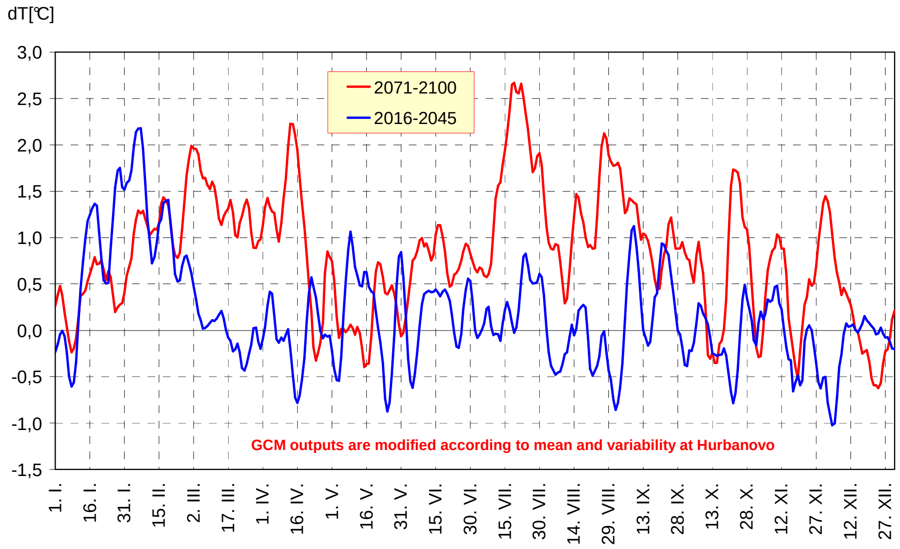


Figure 3: Annual course of air temperature 5-day running means difference (SRES A2 – SRES B2), scenarios designed by the CCCM 2000 outputs, SRES A2 and B2, for the 2016-2045 and 2071-2100 time frames, modified by the Hurbanovo data in 1961-1990 (see Figure 2).

The scenarios of global radiation sums have been designed by similar procedure as at air temperature, just a quotient method instead the difference one was applied there for daily data modification (see the formula (2)). Some negative values arose from variability modification have been replaced by zero. Variability of measured data is much higher than at the modeled by CCCM2000 in the control period. Variability modification without smoothing is impossible at the daily global radiation output because of unrealistic daily extremes (more in Lapin and Melo, 2004, Lapin et al., 2006). Comparison of monthly global radiation values is shown in Figures 4 and 5.

$$M2_{ij}^{X} = ([Mo_{ij}.(\frac{\overline{MS_i}}{\overline{Mo_i}})] - \overline{M1_{ij}^{21}}).(\frac{SDS_i}{SDMo_i})^{X} + \overline{M1_{ij}^{21}}, \qquad (2)$$

where the same values are as in the formula (1). Downscaling uses the same method all year round.

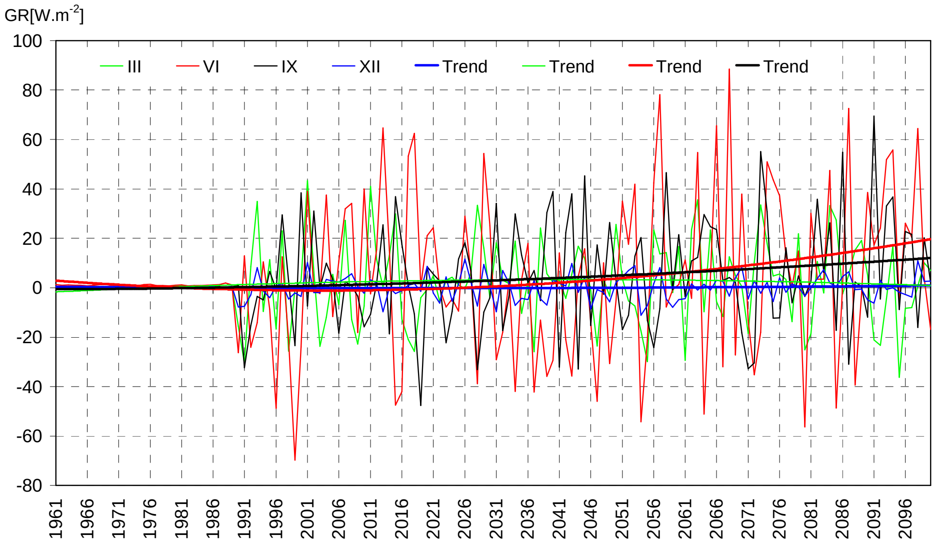


Figure 4: Difference of monthly global radiation means between the downscaled outputs of the GCMs CCCM2000 SRES A2 and SRES B2 for Hurbanovo in 1961-2100 (March, June, September and December); downscaling was done using daily measured values from Hurbanovo in 1961-1990.

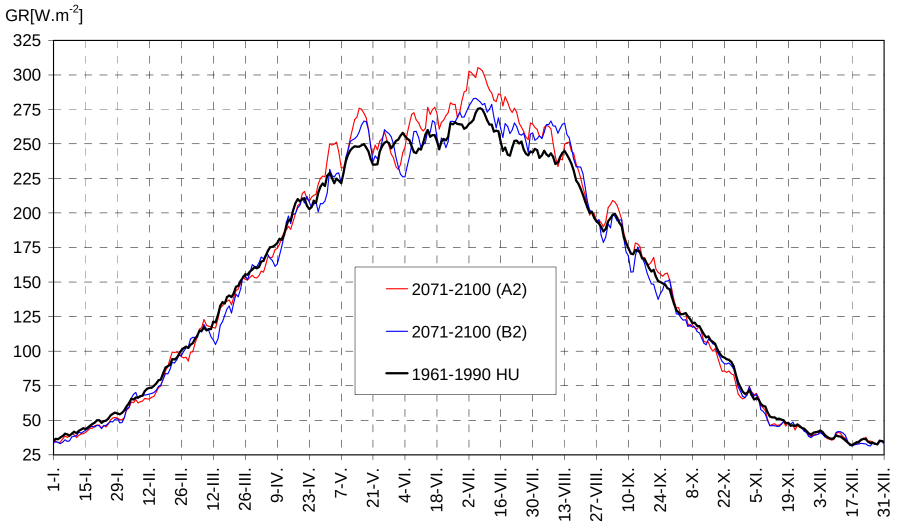


Figure 5: Annual course of mean global radiation (GR) – measured values at Hurbanovo in 1961-1990 and downscaled values from the GCM CCCM2000, SRES A2 and SRES B2 outputs in 2071-2100 (all smoothed by 5-day running means); downscaling was done at use of Hurbanovo data from 1961-1990 and 11-day running means of SD quotients.

Because of insignificant trend in global radiation mean values in 1961-2100 only the differences between SRES A2 and SRES B2 scenarios are interesting, the annual course is shown in Figure 5. It can be seen there some more interesting change in global radiation regime only in the season from the beginning of May to the middle of August. The middle June increase of cloudiness is more pronounced than up to present, mainly at SRES A2 scenario.

The same method was applied also at specific humidity (SH) outputs downscaling. By the end of June 2006 a new version of SH output have been obtained from the Canadian CCC modeling centre. Preliminary analyses show much better correlation with the observed data (Figure 6), that is why some results are presented here. The difference between SRES A2 and SRES B2 monthly means are very similar with those obtained at global radiation downscaling (Figure 7). On the other hand the increase of SH until the time frame 2071-2100 is comparable with the air temperature scenarios (Figures 2, 3 and 8). Not any detail testing for relative humidity was done, we suppose according to mean values that no significant changes in relative humidity are expected (more details in the next paper).

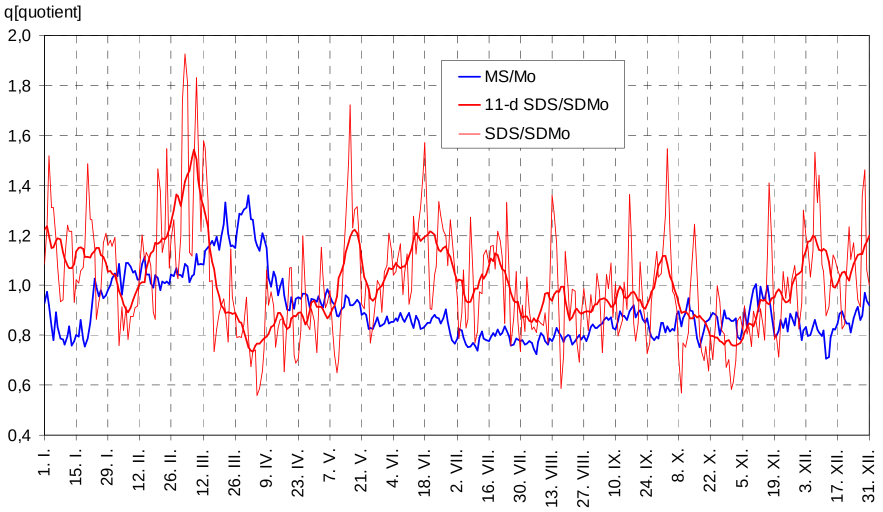


Figure 6: Comparison (quotient) of measured MS and modeled Mo (CCCM2000, SRES A2) daily specific humidity (blue line) and measured (SDS) and modeled (SDMo) standard deviation from daily data (red line) at Hurbanovo in 1961-1990 (11-day running means are included at SD).

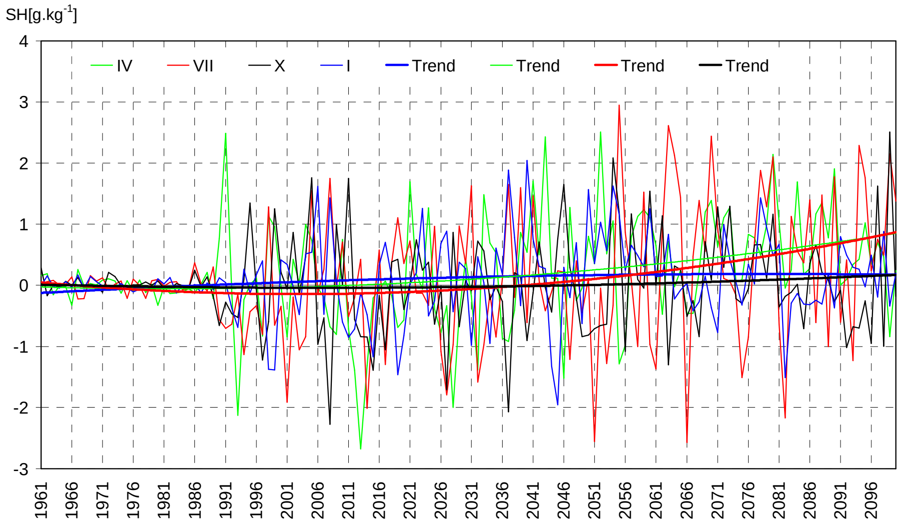


Figure 7: Difference of monthly specific humidity means between the downscaled outputs of the GCMs CCCM2000 SRES A2 and SRES B2 for Hurbanovo in 1961-2100 (January, April, July and October); downscaling was done using daily measured values from Hurbanovo in 1961-1990.

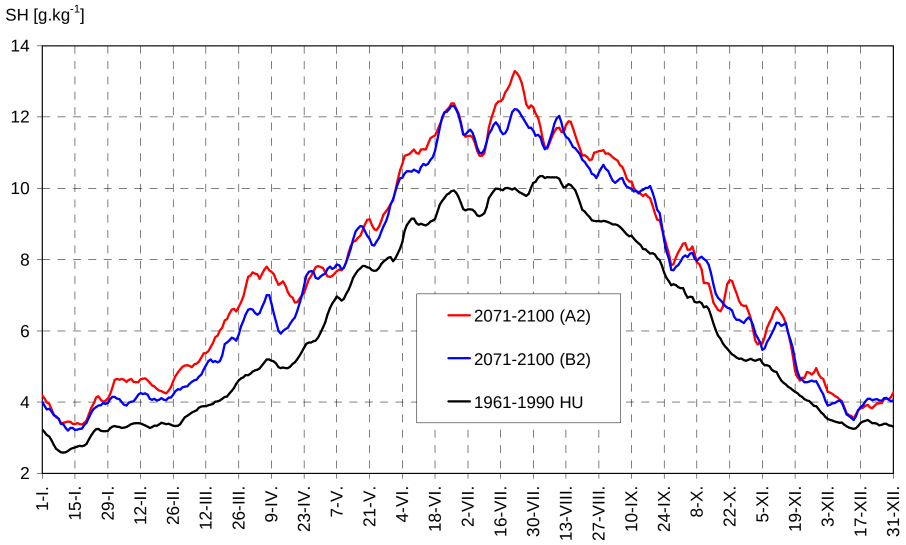


Figure 8: Annual course of mean specific humidity (SH) – measured values at Hurbanovo in 1961-1990 and downscaled values from the GCM CCCM2000, SRES A2 and SRES B2 outputs in 2071-2100 (all smoothed by 5-day running means); downscaling was done at use of Hurbanovo data from 1961-1990 and 11-day running means of SD quotients.

From Figure 5 and 8 we can conclude, that the season April-August is significant by different regimen of temperature, humidity and global radiation. Relatively low GR in the middle of June is accompanied by relatively high SH and low air temperature. This is more significant at the SRES B2 scenario, but it has not so simple impact on precipitation (different in the north and the south of Central Europe).

Precipitation scenarios design was described in Lapin et al., 2006 and Lapin and Melo, 2004. Because of limited space only the comparison SRES A2 and SRES B2 scenarios and two grid points (A and C) are presented in Figure 9. The baseline scenarios for the 1961-1990 period are nearly the same for all four runs (A2_A, A2_C, B2_A, B2_C). The southern A grid point represents the prevailing Mediterrannean and the northern grid point C the prevailing Atlantic and Continental influence on the precipitation regime. It can be seen expected different development of annual precipitation maximum and minimum by the end of 21st century compared to past (based on modified CCCM outputs only).

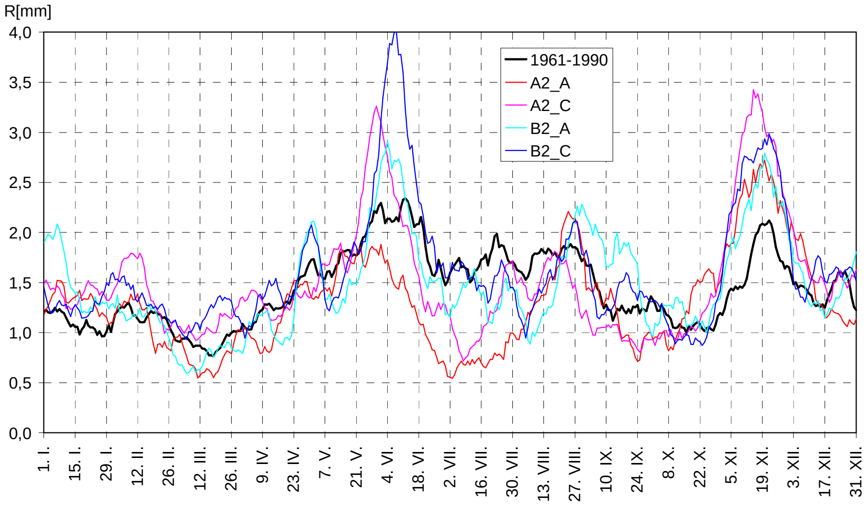


Figure 9: Annual course of mean daily precipitation totals – average of 4 scenarios in 1961-1990 and downscaled values from the GCM CCCM2000, SRES A2 and SRES B2 outputs for A and C grid points in 2071-2100 (all smoothed by 11-day running means); downscaling was done at use of Hurbanovo data from 1961-1990 and method presented in Lapin et al., 2005 and 2006.

3.2 GCMs-analogue method of GCMs output downscaling

Unrealistic topography in the GCMs causes also unreliable regime of variables tightly connected with the terrain. We can include among them mainly wind, snow cover, runoff, soil moisture and consequently also air humidity, evaporation, cloudiness and precipitation. At least three of these variables are very important for impact studies – air humidity, snow cover and evaporation. The use of GCMs-analogue method of climate change scenarios design was successfully realized at monthly data time series (Lapin et al., 2003, 2004). Relations among daily data are much more complex, what can be easily obtained from the regression or correlation analysis (Lapin et al., 2004). That is why we recommend to take from GCMs modified temporal variability of daily data and to modify smoothed daily data (11-day or 21-day running means) according to relations obtained from the series of measured data in the control (reference) period. Some relations have also physically based limits (Figure 10). In such cases these limits must be included into the procedure of scenarios design. It was found that small number of GCMs outputs does not fulfill basic relations among air temperature, air humidity, air pressure and precipitation (relative humidity above 100%, evaporation above precipitation-runoff etc.). This additional modification influences partly the physical plausibility of modeled data on the one side, but makes them more realistic on the other.

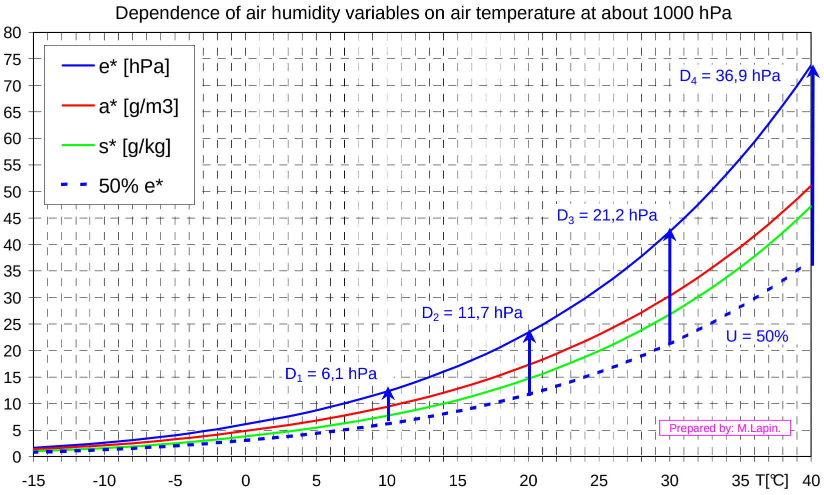


Figure 10: Dependence of water vapor pressure (e), absolute humidity (a), specific humidity (s) and saturation deficit (D) on air temperature T (* denotes the saturation state); in case of constant relative air humidity (U = 50%) the D increases with rising T exponentially; potential evapotranspiration E_o depends on D linearly ($E_o \cong k.D$).

3.3 Dynamic method of GCMs output downscaling

The global climatic models (GCMs) resolution is not sufficient for the regional climatic analysis. From the GCMs one can obtain applicable information, but without regional aspect. These considerations could be in some cases important and have influence to the climatic results interpretation. For these reasons sophistical methods are implemented to obtain climatologic fields with more detailed structure than GCMs are provided.

Dynamical adaptation and regional numerical models are one way, how to do this assumptions. The differences between dynamical adaptation and regional model are not large. Dynamical adaptation is a method that is differed from classical approach applied in regional or limited area climatic models in the using of lateral boundary conditions and in the complexity of algorithm. In other way, similar hydrodynamic equations are used in both mentioned approaches. Dynamical adaptation, which we apply for the regional analysis of atmospheric properties, has the base in the governed equations of fluid motion.

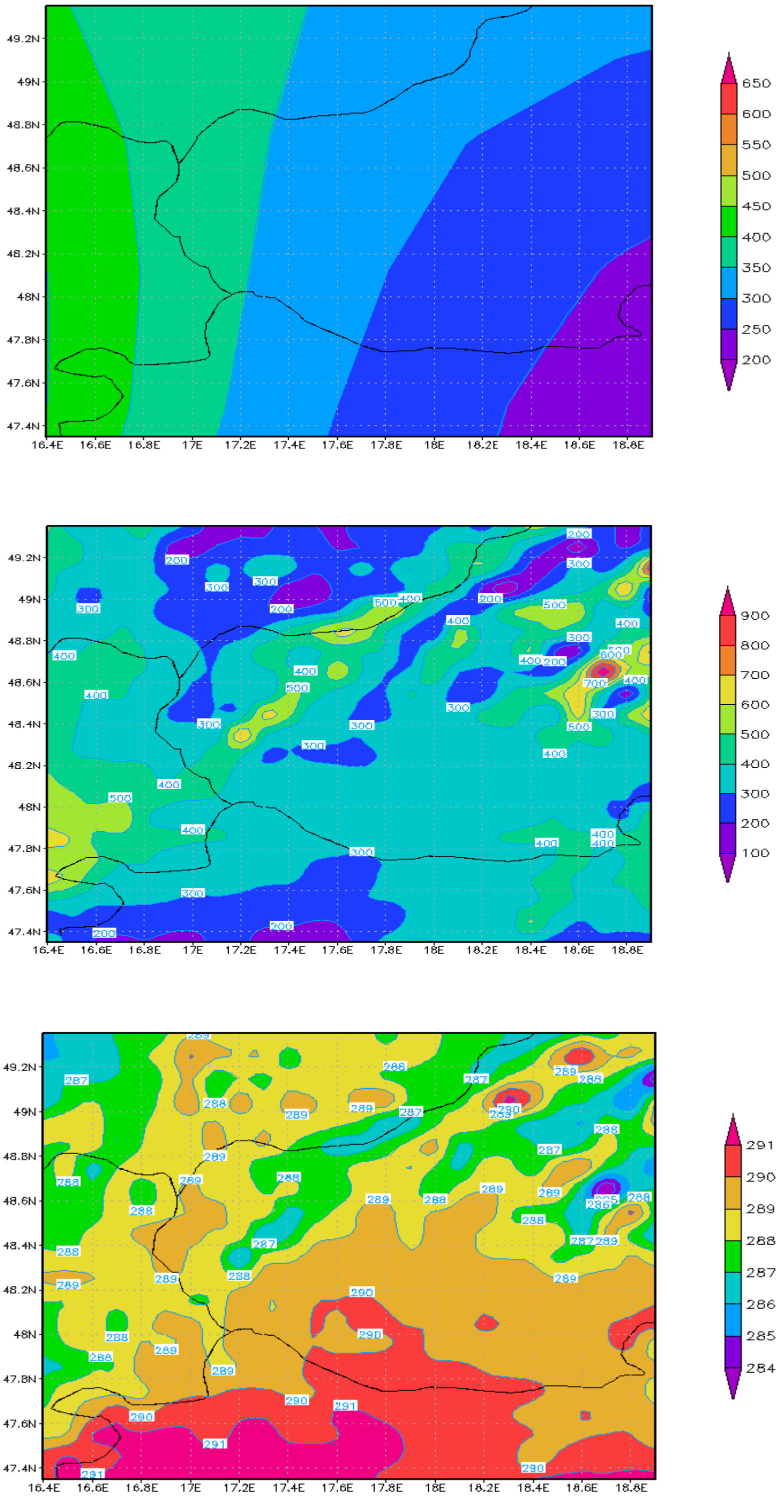
The resolution of investigated GCM model is about 3.5 degree in the meridional and the zonal directions. For Slovakia territory it means that resolution is about 250 km in both directions. The varied topography in Slovakia forces us to use a dynamical adaptation. The topography with resolution of 3.5 degree one can see in the Figure 11.1. It is apparent that this topography is absolutely inconvenient and does not represent features that are observed in the regional scale. Contrary, Figure 11.2 shows topography with higher resolution (0.1 degree). Here we have to remark, that there exist more techniques, how to express topography on more dense grid. We investigated two approaches. The first method, which result is not presented, has the origin in classical spline interpolation. The result is an “envelope” topography. This kind of obtained surface can raise the model instability (the shape of topography can be sharp and it can trigger intense vertical motion). The second method works with the spectral filtering. The density of obtained grid is the same as in first method, but a moderate slopes are observed (Figure 11.2).

To prevent a big stress from the resolution transition, from 3.5 degree to 0.1 degree, it is convenient to apply multi-nesting technique of models. It means that resolution of models is changed gradually. For the first transition, where it is supposed that advective and macro-synoptic processes are important, the more simplified governed equations are used. We chose quasi-geostrophic equivalent barotropic model for this reason. This kind of model is characterized by balance of the wind and the mass field, the gravity waves are absent in this case, but topography is implemented and acts as forcing force on the right side of the equation. These simplifications are valid for the large atmospheric processes. This approach is used for the reason of possibility to compute model on the whole sphere. These results, as one alternative, are used as the initialization of limited area model, which works as the 3D model.

The base of this model is an Arakawa and Lamb enstrophy conservation scheme for nondivergent flow (it is supposed that enstrophy, which is a total or mean square vorticity on the integration area, is conserved in the all model domain; this assumption is valid when no fluxes are observed at the boundaries of the model). These features allow us to use this model in higher resolution, which can be above 10 km. This model works with surface pressure, zonal and meridional wind components and temperature as the prognostic variable. Geopotential of general sigma levels and generalized vertical velocity are diagnostic variable (Arakawa and Lamb, 1981, Arakawa, 1984).

In the vertical direction, the staggered grid is used and top of the models is at the 500 hPa level in this time. The vertical layer is divided on 22 layers and sub-layers. In the horizontal direction the staggered “C” grid is used.

As we have told above, the dynamical adaptation is differed from standard numerical integration mainly in the boundary conditions forcing. In our case we applied daily data. For the integration we took every day separately and we performed integration (dynamical adaptation) on the fields for the chosen day. These fields are adapted to the new topography and can be interpreted as new dynamically consistent fields on the higher dense grid in the same time. An integration duration is not exactly dedicated yet, it requires some other investigation. The dynamical adaptation results for temperature fields on the surface one can see on the Figure 11.3.



Figures 11.1, 11.2 and 11.3 show a different topography files: In the 11.1 (top) one can see the original topography with resolution 3.5°× 3.5° (applied also in the GCMs), in the 11.2 there (center) is the spectral filtered topography with resolution 0.1°×0.1°. In the third Figure 11.3 (bottom) one can see temperature field as a result of dynamical adaptation for the 26.7.1970 at 1200 UTC on the western part of Slovakia.

4. SELECTED RESULTS

Downscaling of the GCMs daily data time series brought huge number of scenarios contained thousands of data for each station. In this chapter we present only very limited amount of results – one figure for each variable and only for Hurbanovo and CCCM2000, SRES A2, version. We would like to show that our method of GCMs output downscaling enables to obtain very realistic data series in all rage of distribution interval (from maximum to minimum). That is why we do not show the mean values, but such characteristics as number of exceptional days.

At air temperature (T) the number of days with mean T≥20 °C was selected (Figure 12), at global solar radiation (GR) we present the number of days with mean GR≥300 W.m^{-2} (Figure 13), at specific humidity (SH) the SH≥12 g.kg^{-1} (roughly represents the muggy day with water vapor pressure e≥18.8 hPa, Figure 14) and at daily precipitation totals number of days with R≥10 mm. Significant increase of such days can be seen mainly in summer months. These changes may impact dramatically the climate conditions for the biosphere (sensitive species) in all Slovakia.

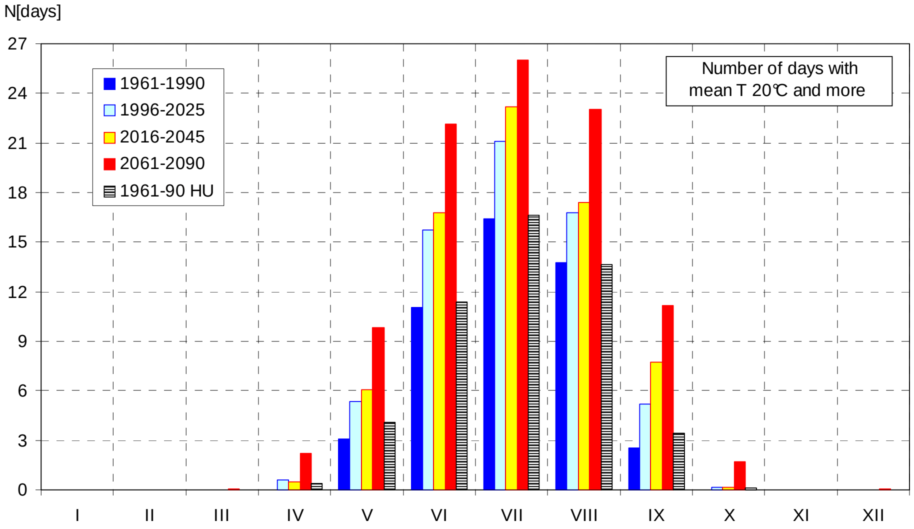


Figure 12: Monthly number of days with mean air temperature T≥20 °C for selected time frames (based on the CCCM2000, SRES A2, outputs downscaling for Hurbanovo) and measured values in 1961-1990 at Hurbanovo (HU).

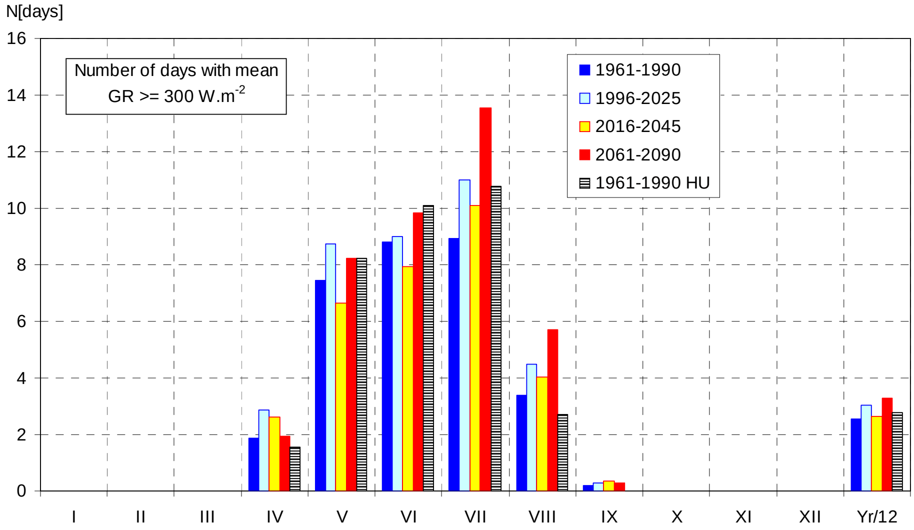


Figure 13: Monthly number of days with mean global radiation GR≥300 W.m^{-2} for selected time frames (based on the CCCM2000, SRES A2, outputs downscaling for Hurbanovo) and measured values in 1961-1990 at Hurbanovo (HU).

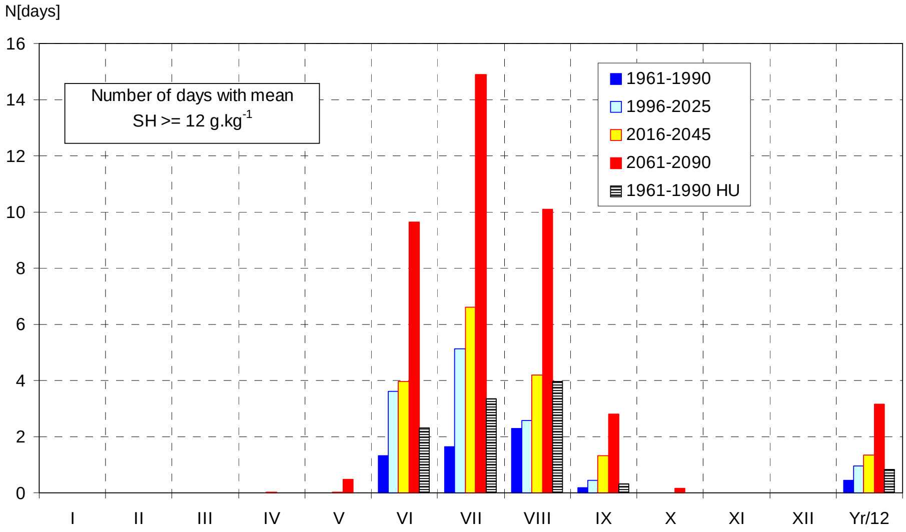


Figure 14: Monthly number of days with mean specific humidity SH≥12 g.kg^{-1} for selected time frames (based on the CCCM2000, SRES A2, outputs downscaling for Hurbanovo) and measured values in 1961-1990 at Hurbanovo (HU).

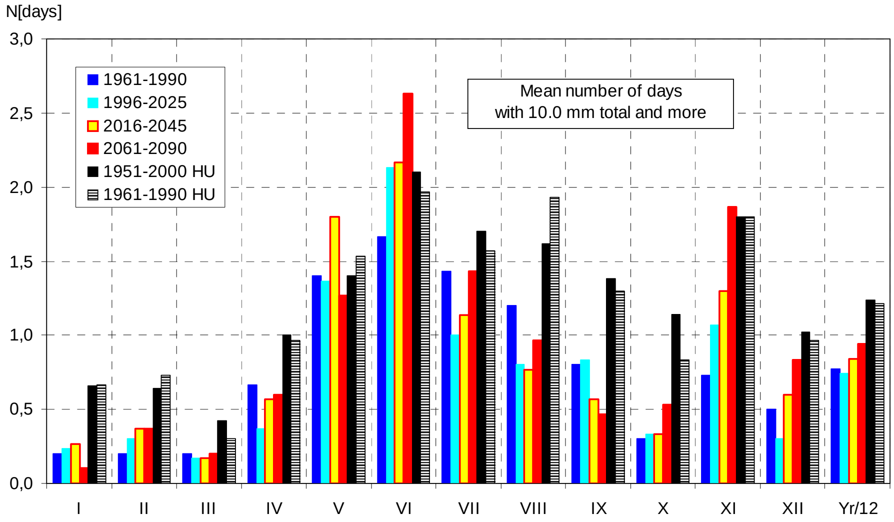


Figure 15: Monthly number of days with precipitation total R≥10 mm for selected time frames (based on the CCCM2000, SRES B2, C grid point, outputs downscaling for Hurbanovo) and measured values in 1951-2000 and 1961-1990 at Hurbanovo (HU), high precipitation totals are somewhat smoothed.

5. CLIMATE SCENARIOS UTILISATION

It is well known that users prefer climate change scenarios in the form of time series with the same structure as the observed ones. It concerns mainly daily and monthly climatic time series with the length no less than 30 years. Some user needs are oriented to particular weather events (drought, floods, heavy rains, heat and cold waves…). Every user needs air temperature scenarios and nearly all also the precipitation ones. After several months of experience with climatic scenarios the users broaden their demands to global solar radiation, air humidity and evaporation, to say at least. Oftentimes they demand also some supplementary climatic elements as precipitation days number, snow cover days number, snow cover daily depths sum, daily maximum and minimum in air temperature, or even complex climatic series for so-called normal, cold, warm, dry and wet year. It is clear that a discussion on the definition of normal, warm, cold, dry and wet year takes place as the first step. Sometimes the agreement of the format and structure of climatic scenarios data is protracted and the scenarios “creators” need to familiarize with the user methods and models (IPCC, 2001).

All types of climatic scenarios can be divided generally into two groups, while the term “climate change” represents only that part from all climatic changes induced by human activities, i.e. by the greenhouse effect increase due to man made greenhouse gases emission:

A) **Climate change scenarios** – values representing differences or quotients between long-term characteristics of future climate and those in the past reference period (between forced and unforced climate by changing GHGs – simplification). We consider as a standard reference period in this case the 1951-1980 time frame. This period represents quite sufficiently also longer 1901-1990 one, no significant trends and not any climate change signal can be recognized in Central Europe until 1980. The newest GCMs outputs prefer the 1961-1990 control period. In Slovakia we accepted as standard model time frames the periods centered in the years 2010, 2030 and 2075, let say 1996-2025, 2016-2045 and 2061-2090, this time frames (time horizons) can be defined as 30- to 50-year periods (IPCC, 2001, Lapin and Melo, 2004).

B) **Scenarios of climatic changes** – values representing future climatic time series, i.e. a composition of the climate change due to anthropogenic greenhouse effect increase and the natural climatic variability. Time series of such scenarios for 2001-2100 usually almost continuously connect the observed time series in 1901-2000. The modeled time series are not possible to consider as weather forecast for individual days, months and years. The modeled series represent only expected temporal trends, long-term means, temporal variability, extremes and distribution curves (frequency distribution) within some 30- to 50-year time frames in the future (IPCC, 2001, Lapin and Melo, 2004, Lapin et al., 2006).

The best way how to apply the climate change scenarios offered by climatologists is consulting with the scenarios designers. Generally it is not possible to apply scenarios of different sources for individual variables. The physical and statistical plausibility among climatic elements are the most important attributes and need to be tested at any use of scenarios (IPCC 2001, The 4th SRNCCC, 2005).

6. CONCLUSIONS

Only selected results and a brief description of GCMs output downscaling methods are presented in this paper. Besides the Hurbanovo station the scenarios of daily time series for Liptovsky Hradok (640 m a.s.l., hollow in northern of Slovakia) and Jaslovske Bohunice (176 m a.s.l., lowland in western of Slovakia) have been designed recently. Some modification is expected only at air humidity outputs downscaling. We consider the same method will be applied also for the GCMs ECHAM and HadCM outputs downscaling. All computations have been provided by the PC computer equipped with only 512 MB RAM. Complete preliminary results are expected by the end of 2006, some information can be obtained also on the web site: www.dmc.fmph.uniba.sk.

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