# Change of Air Temperature Daily Range in the Global Warming Context

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**Abstract**. Climate change due to enhanced greenhouse effect will probably result in several interesting changes in global and regional climate. One of them is the global warming. Because of changed energetic balance daily regime it seems that the daily minimum temperatures will increase more than the daily maximum ones. On the other hand, daily range of air temperature is influenced by several other factors (atmospheric circulation, solar radiation, cloudiness, air humidity, soil moisture, upwind and lee effects etc.). The paper contains a sample from the analysis of past conditions in change of air temperature daily range at several Slovak stations in 1961-2010 and possible change in daily air temperature range up to the time frame of the year 2100 using climate change scenarios by four climatic models (global CGCM3.1 and ECHAM5, regional KNMI and MPI) and three emission scenarios (IPCC SRES A2. B1 and A1B). The analysis results showed that the precipitation and air humidity regime change will modify the air temperature daily range probably comparably as the increase in daily mean temperature. Change in daily temperature range is probably connected also with inter-sequential variability of mean and extreme daily temperatures. Change of those climatic variables regime can cause also some negative socio-economic and environmental impacts.

**Key words**

Climate change, daily temperature range, climate change scenarios and impacts

## Introduction

The global mean surface temperature increased by about 0.9 ± 0.2°C over the last 112 years (1901-2012) as estimated by a linear trend (NOAA (NCDC), GISS, CRU). Increasing trends in mean annual air temperature during the 20th and at the beginning of the 21st centuries were found also for all stations in the Slovak part of the Carpathians (Lapin et al., 2012, Melo et al., 2013).

In this contribution only selected results are presented: the trend of mean temperature, trend of daily temperature range, and trend of relative air humidity at selected meteorological stations in Slovakia in 1961-2010. These issues are studied also in the context of climate change scenarios based on two regional climate models (Dutch KNMI and German MPI) for the same climatic characteristics up to the year 2100. The other aim is an evaluation of intersequential variability of seasonal mean temperatures (spring (III-V), summer (VI-VIII), autumn (IX-XI) and winter (XII-II)).

The daily air temperature range (TR) is defined as a difference between the daily maxima and daily minima. Brázdil et al. (1996) analysed changes in maximum and minimum daily temperatures in central and southeastern Europe (Germany, Mid-Switzerland, Poland, Czech Republic, Slovakia, Austria, Hungary, Slovenia, lowland of Croatia, Bulgaria). A rate of the linear increase in mean annual maximum daily temperatures in central Europe during the period 1951-1990 was slightly lower than that of mean minimum daily temperatures (0.52°C and 0.60°C per decade, respectively). This was reflected in a small decrease in the daily temperature range by -0.08°C per decade. Lapin and Faško (1994) stressed that daily range of air temperature is significantly influenced by relative air humidity a possibly also by other climatic variables. Therefore crosscorrelation of TR with of several climatic variables was analysed.

Slovakia is located in the Central Europe. It has the high-mountain relief features in the North and lowlands in the South. A characteristic sign of the remaining area exhibit mainly the hollows, highland and upland relief.

## Material and methods

Daily data from the Slovak Hydrometeorological Institute (air temperature, air humidity, precipitation, solar radiation, sunshine duration) have been analysed for selected meteorological stations in Slovakia in 1961-2010. Daily outputs of two regional climate change models (General Circulation Models of the atmosphere, Dutch KNMI and German MPI, both with ECHAM5 boundary conditions) have been used for design of climate change scenarios (daily maximum and minimum of air temperature and daily range of air temperature, air humidity, precipitation, global solar radiation) by statistical downscaling method for the same stations in Slovakia and the period 1951-2100 (Lapin et al., 2012). Only a sample of wide elaboration is presented here.

## Results and disscussion

As seen in Tab. 1 mean decade air temperatre increased at Hurbanovo gradually by 1.13°C, the highest increase was in summer, 1.59°C, the lowest (some decrease) in the autumn. Comparable increases were also in mean daily maxima (Tab. 2) and daily minima (Tab. 3) of air temperature, but daily temperature range (TR, Tab. 4) shows that there are some differences among decades and seasons. These differences can be caused by several other factors (solar radiation, air humidity, cloudiness, wind speed, atmospheric circulation etc.). We have selected only several from mentioned variables to assess possible main causes of TR change and trend. Full study will be published later in some scientific journal paper.

***Table 1.*** *Development of annual and seasonal means in daily air temperature averages [°C] at Hurbanovo, 115 m a.s.l., SW Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 9.99 | 10.07 | 10.13 | 10.76 | 11.12 |
| Summer | 19.60 | 19.30 | 19.52 | 20.66 | 21.19 |
| Winter | -1.32 | 0.88 | -0.03 | 0.54 | 0.67 |
| Spring | 10.41 | 10.51 | 10.71 | 11.09 | 11.67 |
| Autumn | 10.87 | 9.41 | 10.07 | 10.42 | 10.86 |

***Table 2.*** *Development of annual and seasonal means in daily air temperature maxima [°C] at Hurbanovo, 115 m a.s.l., SW Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 15.34 | 15.22 | 15.39 | 16.08 | 16.49 |
| Summer | 26.14 | 25.62 | 25.98 | 27.25 | 27.55 |
| Winter | 1.91 | 4.09 | 3.33 | 4.10 | 4.25 |
| Spring | 16.17 | 16.27 | 16.36 | 16.93 | 17.69 |
| Autumn | 16.71 | 14.69 | 15.65 | 15.67 | 16.31 |

***Table 3.*** *Development of annual and seasonal means in daily air temperature minima [°C] at Hurbanovo, 115 m a.s.l., SW Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 4.94 | 5.40 | 5.44 | 6.06 | 6.36 |
| Summer | 13.19 | 13.35 | 13.43 | 14.41 | 15.10 |
| Winter | -4.76 | -2.13 | -3.12 | -2.64 | -2.42 |
| Spring | 4.88 | 5.08 | 5.53 | 5.74 | 6.11 |
| Autumn | 6.04 | 5.19 | 5.72 | 6.44 | 6.61 |

***Table 4.*** *Development of annual and seasonal means in daily air temperature range [°C] at Hurbanovo, 115 m a.s.l., SW Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 10.57 | 10.09 | 10.51 | 10.54 | 10.68 |
| Summer | 12.19 | 11.63 | 12.20 | 12.64 | 12.34 |
| Winter | 8.52 | 8.13 | 8.51 | 8.68 | 8.43 |
| Spring | 10.80 | 10.62 | 10.80 | 10.93 | 11.58 |
| Autumn | 10.78 | 9.87 | 10.51 | 9.86 | 10.25 |

The changes in TR are generally small with temporal increases and decreases. Fig. 1 indicates that there are several climatic variables with significant correlation with TR at each station (presented only Hurbanovo as an example). Global radiation and sunshine duration contribute positively to the increase of TR with very high correlation coefficient (Corr, more in summer). Precipitation totals (PR) and relative humidity (RH) increase cause significant decrease of TR with Corr about -0.55 (at RH more in summer).

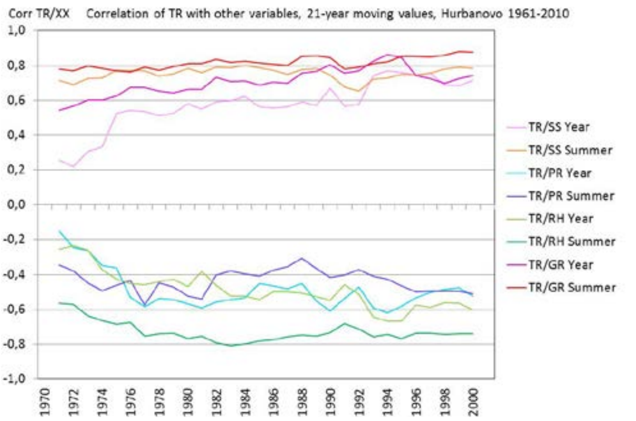


***Figure 1.*** *Correlation coefficient between daily temperature range (TR), sunshine duration (SS), precipitation totals (PR), relative air humidity (RH) and global radiation sums (GR) at Hurbanovo in 1961-2010 (21-year moving means).*

Trends in PR, RH, SS and GR can modify also trend of TR, but it depends on season and on combination of mentioned factors. Fig. 2, 3 and 4 show changes in 10-year means of SS, RH and PR compared to 1961-2010 average. It is clear that differences among decades are very significant, that can modify expected decrease of TR due to enhanced atmospheric greenhouse effect. It is also important that increasing sunshine duration and decreasing relative air humidity contribute to increase of TR in the last two decades, while increasing precipitation totals cause opposite effect.

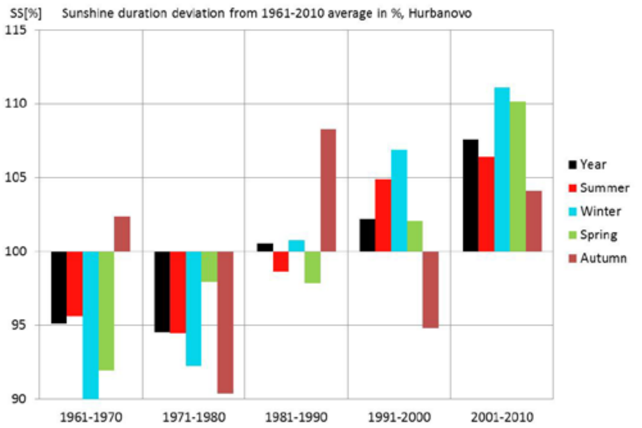


***Figure 2.*** *Annual and seasonal 10-year deviations of sunshine duration (in %) compared to the 1961-2010 average at Hurbanovo.*

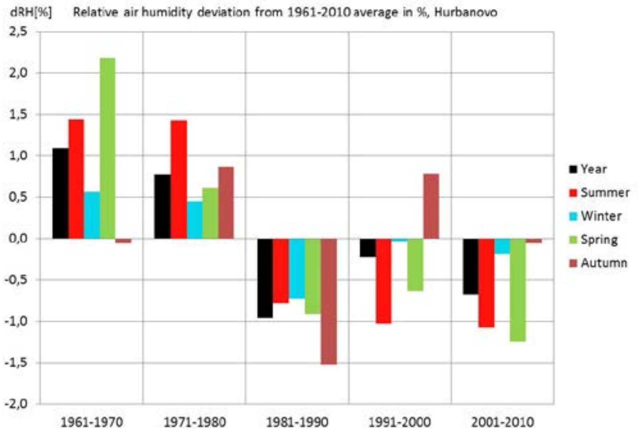


***Figure 3.*** *Annual and seasonal 10-year deviations of relative humidity (in %) compared to the 1961-2010 average at Hurbanovo.*

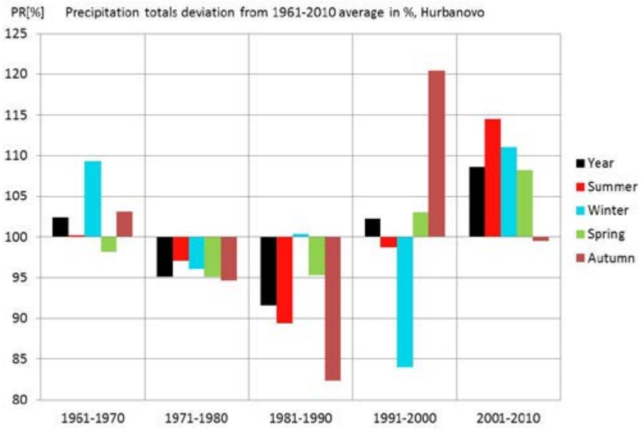


***Figure 4.*** *Annual and seasonal 10-year deviations of precipitation totals (in %) compared to the 1961-2010 average at Hurbanovo.*

From all analysed stations in Slovakia only 5 another are selected for this paper: Oravska Lesna, 780 m a.s.l., lies in NW Slovakia in mountainous area with very high precipitation totals (about 1150 mm annually), Telgart, 901 m a.s.l., lies in SE part of the Low Tatras mountain in the windy region with relatively low annual precipitation totals, Sliac, 314 m a.s.l., lies in frosty hollow in the centre of Slovakia, Kosice, 230 m a.s.l., lies in windy locality at the foot of the Slovenske Rudohorie mountain in SE Slovakia and Bratislava Koliba, 286 m a.s.l., lies on the hill above Bratislava city. All stations have quite different climatic conditions and cover adequately climate in Slovakia. Because of limited area only tables of TR and RH are presented from the selected stations.

***Table 5.*** *Development of annual and seasonal means in daily air temperature range [°C] at Oravska Lesna, 780 m a.s.l., NW Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 11.46 | 10.64 | 10.95 | 10.48 | 10.64 |
| Summer | 13.31 | 12.68 | 12.89 | 12.87 | 12.69 |
| Winter | 9.67 | 8.72 | 8.95 | 8.30 | 8.08 |
| Spring | 11.82 | 11.31 | 11.61 | 11.44 | 11.96 |
| Autumn | 11.07 | 9.77 | 10.29 | 9.26 | 9.70 |

***Table 6.*** *Development of annual and seasonal means in daily air temperature range [°C] at Telgart, 901 m a.s.l., CE Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 8.89 | 9.17 | 9.17 | 9.01 | 9.17 |
| Summer | 10.55 | 10.81 | 10.94 | 10.93 | 11.06 |
| Winter | 6.80 | 7.32 | 7.28 | 7.23 | 7.15 |
| Spring | 9.41 | 9.58 | 9.51 | 9.60 | 10.06 |
| Autumn | 8.69 | 8.90 | 8.96 | 8.20 | 8.35 |

***Table 7.*** *Development of annual and seasonal means in daily air temperature range [°C] at Sliac, 314 m a.s.l., CE Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 11.31 | 10.92 | 11.49 | 11.27 | 11.26 |
| Summer | 13.94 | 13.59 | 14.24 | 14.39 | 13.81 |
| Winter | 7.98 | 7.35 | 8.11 | 8.03 | 7.77 |
| Spring | 12.24 | 12.38 | 12.39 | 12.68 | 13.14 |
| Autumn | 11.06 | 10.18 | 11.18 | 9.93 | 10.20 |

***Table 8.*** *Development of annual and seasonal means in daily air temperature range [°C] at Kosice, 230 m a.s.l., SE Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 9.43 | 9.07 | 9.61 | 9.54 | 9.29 |
| Summer | 11.81 | 11.16 | 12.03 | 11.93 | 11.57 |
| Winter | 6.04 | 5.97 | 6.07 | 6.31 | 5.87 |
| Spring | 10.39 | 10.47 | 10.68 | 10.80 | 10.73 |
| Autumn | 9.52 | 8.57 | 9.57 | 9.05 | 8.89 |

***Table 9.*** *Development of annual and seasonal means in daily air temperature range [°C] at Bratislava Koliba, 286 m a.s.l., SW Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 8.24 | 8.02 | 8.22 | 8.02 | 8.29 |
| Summer | 10.54 | 10.24 | 10.62 | 10.50 | 10.62 |
| Winter | 5.19 | 4.89 | 5.29 | 5.17 | 5.37 |
| Spring | 9.26 | 9.33 | 9.31 | 9.13 | 9.65 |
| Autumn | 7.95 | 7.50 | 7.66 | 7.20 | 7.39 |

***Table 10.*** *Development of annual and seasonal means in relative air humidity [%] at Oravska Lesna, 780 m a.s.l., NW Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 81.7 | 81.9 | 82.4 | 82.1 | 82.5 |
| Summer | 78.2 | 79.1 | 79.2 | 77.1 | 78.2 |
| Winter | 85.8 | 85.9 | 86.5 | 86.8 | 87.1 |
| Spring | 79.4 | 78.8 | 79.5 | 79.5 | 79.6 |
| Autumn | 83.6 | 84.1 | 84.3 | 85.2 | 85.7 |

***Table 10.*** *Development of annual and seasonal means in relative air humidity [%] at Telgart, 901 m a.s.l., CE Slovakia, in decades of the 1961-2010 period.*

| | 1961-70 | 1971-80 | 1981-90 | 1991-00 | 2001-10 |
|---|---|---|---|---|---|
| Year | 78.3 | 79.2 | 78.9 | 78.8 | 78.1 |
| Summer | 75.6 | 77.3 | 76.9 | 75.6 | 75.1 |
| Winter | 82.5 | 81.8 | 82.1 | 81.5 | 82.5 |
| Spring | 74.9 | 76.5 | 75.7 | 74.7 | 72.5 |
| Autumn | 80.3 | 81.3 | 80.9 | 83.1 | 82.9 |

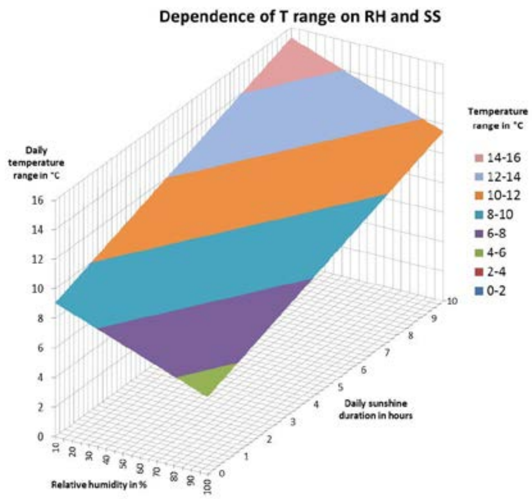


***Figure 5.*** *Multiregression of daily temperature range dependence on relative air humidity and daily sunshine duration at Telgart (Slovakia, 901 m a.s.l.).*

Based on selected table results on TR changes and trends no simple statement can be presented. The TR development is different from site to site in Slovakia and in individual seasons during the year as well. The impact of changing RH, PR, SS and GR is probably stronger than increasing greenhouse effect causing decrease of TR. On the other hand changing greenhouse effect influences probably the atmospheric circulation a therefore also the regime of SS, GR, RH and PR. Fig. 4 shows multiregression analysis of RH and SS influence on TR. Such method enables to assess more precisely individual share of several factors influencing TR.

In the second step of analysis the scenarios of possible change in TR up to the end of 21st century took place. Regional circulation models (RCMs) KNMI and MPI with 25x25 km resolution and quite realistic topography were successful at testing in the control period 1961-2010, so also analysis of TR change might be usefull.

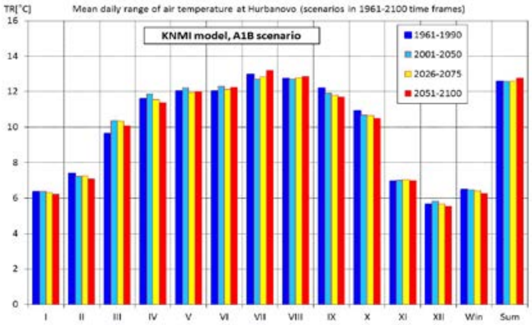


***Figure 5.*** *Monthly and seasonal means of TR in 1961-2100 time frames for Hurbanovo by KNMI, SRES A1B scenario.*

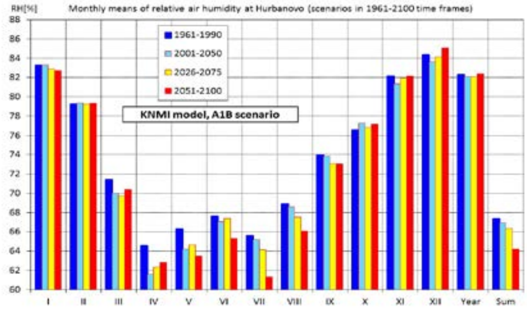


***Figure 6.*** *Monthly and seasonal means of RH in 1961-2100 time frames for Hurbanovo by KNMI, SRES A1B scenario.*

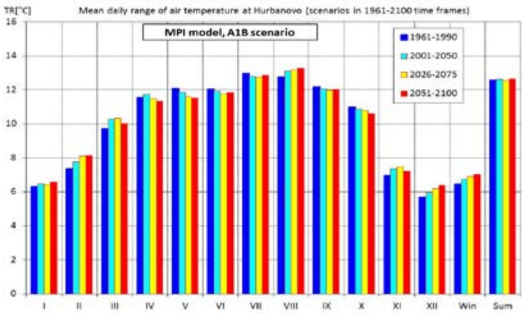


***Figure 7.*** *Monthly and seasonal means of TR in 1961-2100 time frames for Hurbanovo by MPI, SRES A1B scenario.*

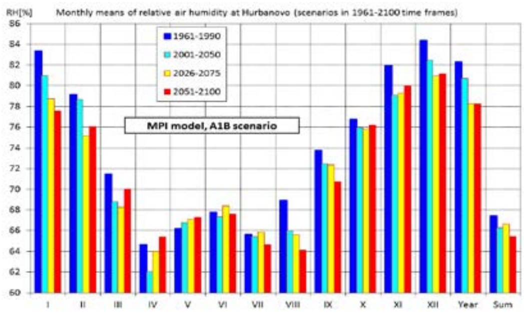


***Figure 8.*** *Monthly and seasonal means of RH in 1961-2100 time frames for Hurbanovo by MPI, SRES A1B scenario.*

Fig. 5 and 7 show that no significant changes in TR are expected in southern Slovakia according to climate change scenarios. On the other hand, scenarios of RH indicate decrease, mainly in the summer, what might compensate the decrease of TR due to increase of greenhouse effect. Because of rise of precipitation and no change of RH in northern Slovakia, the TR should decrease in this region.

Finally the development in interseasonal temperature changes has been analysed at all stations. Fig. 9 shows serious variations in this important characteristic, what tends to continue also according to climate change scenarios. Such process can impact several other climatic elements. We will present comprehensive results on this study later.

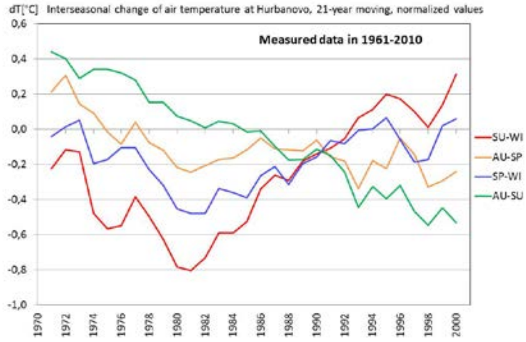


***Figure 9.*** *Interseasonal deviations of temperature (21-year normalized moving means, 1961-2010), Hurbanovo, SW Slovakia (SU-summer, WI-winter, AU-autumn, SP-spring).*

## Conclusions

The elaboration of measured and modeled data on daily temperature means, maximum, minimum and finally daily temperature range (TR) showed that the future development of TR is not so simple as follows from the enhanced atmosphere greenhouse effect theory. It was expected some decrease of TR at increase of greenhouse gases concentration in the atmosphere. The presented study indicates that the changes and trends in cloudiness (sunshine duration), relative air humidity and some other variables can modify future TR trend even to some increase.

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## References

Brázdil R, Budíková M, Auer I, Böhm R, Cegnar T, Faško P, Lapin M, Gajic-Čapka M, Zaninovič K, Koleva E, Niedzwiedz T, Ustrnul Z, Szalai S, Weber RO (1996) Trends of maximum and minimum daily temperatures in CE and SE Europe. Int. J. of Climatology 16, 765-782.

IPCC (2007) Climate Change 2007: The Physical Science Basis. Contribution of WG I to the 4th AR of the IPCC.

Lapin M, Faško P (1994) Daily air temperature range and relative air humidity correlation at Hurbanovo. Contemporary Climatology, Brno, Mas. Un., 359-363

Lapin, M, Bašták-Ďurán, I., Gera, M., Hrvoľ, J., Kremler, M., Melo, M. (2012): New climate change scenarios for Slovakia based on global and regional general circulation models. Acta Met. Univ. Comen., 37, 25-74.

Melo, M., Lapin, M., Kapolková, H., Pecho, J., Kružicová, A. (2013): Climate trends in the Slovak part of the Carpathians. In: Kozak, J. et al. (eds.) (2013): The Carpathians: Integrating Nature and Society Towards Sustainability, Springer-Verlag Berlin Heidelberg, 131-150