EXTREME WEATHER TENDENCIES IN HUNGARY: ONE EMPIRICAL AND TWO MODEL APPROACHES

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RESUMEN
La frecuencia e intensidad de los eventos extremos constituyen el componente más cuestionable de las proyecciones regionales de cambio climático. En este trabajo se comparan los resultados de tres aproximaciones científicas: la modelizació via GCM, procedente de las compilaciones del IPCC AR4, los modelos de mesoescala, compilados a partir del proyecto PRUDENCE y un método empírico denominado experimento NATURAL. Esta última aproximación facilita los coeficientes de regresión entre ls variables locales y globales durante la fase de calentamiento monotónico entre 1976-2005. La aproximación a través de modelos globales incluye resultados procedentes de 9 AOGCMs, mientras que PRUDENCE analiza en detalle 5 salidas.

Nuestros resultados preliminares indican que las tres aproximaciones muestran resultados similares en lo que se refiere a los extremos térmicos durante la mitad cálida del año en Hungría, mientras que el acuerdo es menor durante la mitad fría. Esta situación puede relacionarse, probablemente, con el aumento en paralelo de la presión, es decir, de la influencia anticiclónica en la región. La precipitación muestra el ampliamente conocido patrón que simultanea aumentos en la frecuencia de sequía y aumentos en la frecuencia de las precipitaciones intensas.

Palabras clave: Eventos meteorlogicos extrem; GCM; modelizacion de mesoescala; downscaling estadistico; Hungria

ABSTRACT
The frequency and intensity of weather extremes are the most questionable components of the projected regional climate changes. Results by three scientific approaches, the raw *GCMs*, from the IPCC AR4 compilations, the mesoscale models, compiled from the *PRUDENCE* project, and an empirical method, called *Natural experiment* are compared. The latter approach provides regression coefficients between the local and global variables in the warming phase during the 1976-2005 period. The global model results comprise results of 9 AOGCMs, whereas in the PRUDENCE set of 5 model outputs are analysed in detail.

According to an initial study of our analyses, there is a fair agreement of the three approaches in the temperature extremes of the warm half-year in Hungary, with a much more varied picture in the cold half of the year. This disagreement may be connected to the parallel increase of pressure i.e. anti-cyclonic influence in the region. Precipitation exhibits the widely known paradox, i.e. the increase of drought frequency and, at the same time, an increase of heavy rainfall frequency, as well.

Key words: extreme events, GCM; mesoscale modelling; statistical downscaling; Hungary

1. INTRODUCTION

Despite the recent significant improvement in regional climate modelling (*Christensen et al.*, 2007), regional impacts of the ongoing and projected global climate change are more difficult to estimate than the global effects. Current global climate models still do not incorporate important scales of physical processes that are significant in formulating regional and local climate. Another problem of the impacts community is the lack of comparison between regional scenarios issued in different periods, with different assumptions and different methodologies.

The aim of the present paper is to compare selected scenarios with respect to four precipitation and temperature extremities. They are dry/wet days, precipitation, frosts and heat-waves. The changes are investigated by three parallel methods:

- average changes in 9 coupled AOGCMs, directly derived from Tebaldi et al., (2006);
- changes in 5 models of the PRDUDENCE Project, provided by both B2 and A2 scenarios (Christensen and Christensen, 2007), specially developed for Hungary;
- empirical linear trends in the warming for the 1976-2007 period.

The applied precipitation extreme indices (following Frich et al. (2002, later F02) are:

1. Maximum number of consecutive dry days (*dry days*, or CDD in F02).
2. Frequency of dry days (R > 0,1 mm or 1,0 mm)
3. Number of days with precipitation greater than 10mm (*precip*>10 or 20; R10, R20 in F02).

The applied indices to describe temperature-related extremes:

4. Total number of frost days, defined as the annual total number of days with absolute minimum temperature below 0◦ C (*frost days*, or Fd in F02).
5. Heat wave duration index, defined as the maximum period of at least 5 consecutive days with maximum temperatures higher by at least 5◦ C than the climate normal for the same calendar day (*heat waves*, or HWDI in F02).
6. Frequency of hot days ($T_{max} > 30\ ^oC$).

Summary of the compared indices are displayed in *Table 1*.

	Wet/dry days	Precipitation	Frost	Heat-wave
GCM	CDD	R>10 mm	$T_{min} < 0\ ^oC$	HWDI
PRUDENCE	R > 0,1 mm	R>20 mm	$T_{min} < 0\ ^oC$	$T_{max} > 30\ ^oC$
Empirical	R > 1,0 mm	R>20 mm	$T_{min} < 0\ ^oC$	$T_{max} > 30\ ^oC$

Table 1. THE RELATIONS (E.G. R > 0,1 MM) INDICATE FREQUENCY OF THE GIVEN EVENT.

2. METHODS PROVIDING EXTREME INDEX SCENARIOS

2.1 GCMs (Tebaldi et al., 2006)

Chapter 10 of the recent IPCC (2007) Report displays maps of extreme indices with reference to Tebaldi et al., (2006). We simply downloaded four graphical maps of the indices from *www.cgd.ucar.edu/ccr/publications/tebaldi-extremes.html*. Three maps are as in Fig. 10.18-19 of the Report (and here the redrawn maps, normalized against standard deviations are used), but for precipitation we used R10 instead of the mean intensity. The models used by Tebaldi et al., (2006) are the DOE/NCAR Parallel Climate Model (PCM; Washington et al., 2000) and Coupled Climate System Model (CCSM3), the CCSR MIROC medium and high resolution models (Hasumi and Emori, 2004), INM-CM3 (Diansky et al., 2002), CNRM-CM3,6 GFDL-CM2.0 and 2.1 (Delworth et al., 2002; Dixon et al., 2003) and MRI-CGCM2 (Yukimoto et al., 2001). The model grid resolutions vary from $5^\circ \times 4^\circ$ to 1.125°. Model simulations are used from the A1B (mid-range) SRES scenarios (Nakicenovic and Swart, 2000). The projected and control periods are 2080–2099 and 1980–1999, respectively.

2.2 Mesoscale models

Results of 5 RCM experiments, carried out in the framework of PRUDENCE (Christensen et al., 2007), which provided both A2 and B2 runs for 2071-2100. These models are: HIRHAM (DMI), RegCM (ITCP), HadRM3P (HC), RCAO (SMHI), PROMES (UCM).

The main objective of the PRUDENCE project was to intercompare high resolution climate change scenarios for Europe at the end of the twenty-first century by dynamical downscaling of global climate simulations. A total of 9 RCMs were used at a spatial resolution of roughly 50 km x 50 km for the time windows 1961-1990 and 2071-2100. More than 30 experiments were conducted with respect to the A2 and B2 SRES emission scenarios. Further details concerning the experimental setup are given in Christensen and Christensen (2007).

2.3 Empirical regression

Estimates of the linear trend of the local extreme indices are performed for the 1976-2007 period which has a strong warming over the Northern Hemisphere. 15 temperature stations and 58 precipitation stations of Hungary are used to estimate the trends (regression coefficients). Since the precipitation results were quite different in their signs and significance, the 58 stations were sorted into 6 groups, according to the administrative numbers to ensure regionality of this amalgamation. The trend values are then multiplied by 110 years, which is the span of the PRUDENCE results. (The GCM-based changes correspond to 100 years, see 2.1.) Before the extreme index calculations, the daily time series were homogenised with the MASHv3.01 (Multiple Analysis of Series for Homogenization: Szentimrey, 1999, 2006) procedure.

3. RESULTS AND CONCLUSIONS

The four different extreme events are briefly analysed in the following pages, where the maps and figures are found. Here, as general experience, we can conclude that the two global and the regional models give fairly similar results for Hungary, despite the fact that the former source is used in average of the 9 models, whereas the PRUDENCE set is analysed model-by-model.

Contrary to the similarity of the behaviour in the two modelling approaches, the empirical analyses differ from the model results in some respects. Frequency of dry days clearly increases according to the modelling approaches, but no unequivocal trends appear empirically. The more frequent occurrence of heavy precipitation seems to be a common feature of climate in all approaches. Frequency of frost days should decrease according to both modelling tools, but the empirical analysis, again, does not support this consequence. For the hot extremes, however, all the three approaches give substantial increase of such days or events.

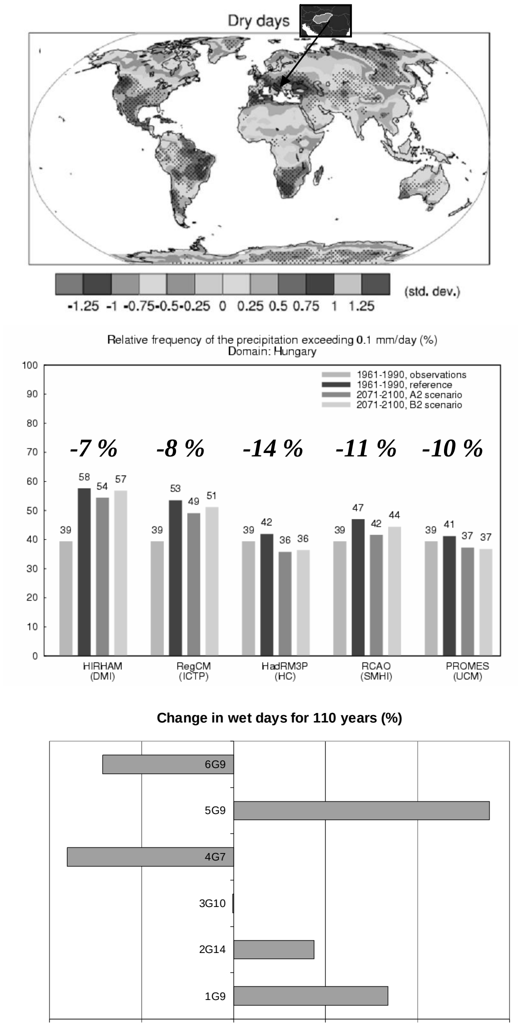

Fig. 1. Changes in the precipitation frequency, based on annual maxima of dry days in 9 GCMs for 2080-2099 vs. 1980-1999 (upper panel), frequency of wet days (R > 0.1 mm/day) in coupled mesoscale PRUDENCE simulations for 2071-2100 vs. 1961-1990 (middle); and of R > 1.0 mm/day for 110 years extrapolated from the trend analysis of 1976-2007 (lower).

To assess the significance of the empirical trends, one should know that only the frequency trends of hot days are significant at the 95 % level for all 15 stations, compared to interannual variability, with respect to the t-test. Contrary to this, frost days did not show significant trend at any station. Precipitation existence and extremity (R>20 mm/day) trends were also rare, 10 and 26 %, respectively. This is why we applied the sub-regional averages.

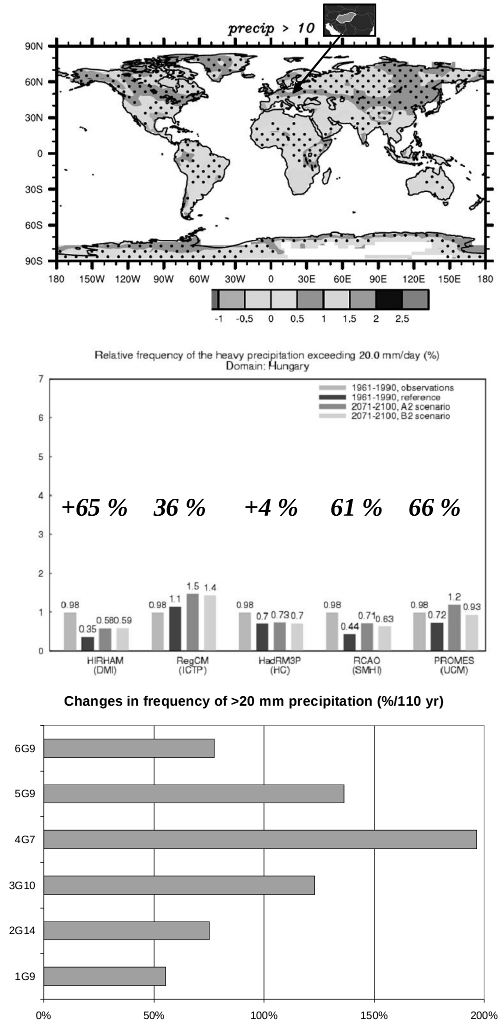

Fig. 2. Same as Fig. 1., but for the frequency of heavy precipitation, based on R>10 mm/day threshold (upper) and on R>20 mm/day threshold (middle and lower).

In case of the diverging results, we need further investigation to explore the origin of the differences. One reason may be the remaining inhomogeneity of the diurnal series. Another reason for the deviations may be that the statistical extrapolation of the trends presumes that the statistical relations remain unchanged in the future. Different forcing factors of various time periods, however, may cause differences in the regional changes. Hence, the results of modelling and empirical approaches should more correctly be intercompared for identical time periods.

3.1 Precipitation occurrence

Frequency of dry days increases in both modelling approaches. In the linear trend extrapolations, the results are less unequivocal and just in 10 % of the stations significant. In 3 regions the wet days became more frequent, in 2 regions less frequent and 1 region showed no trend.

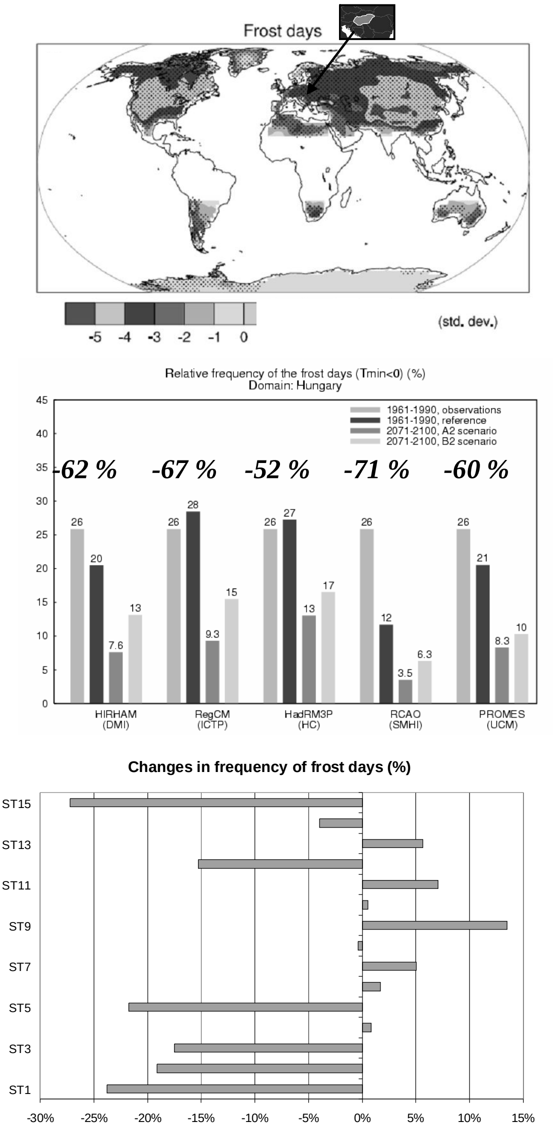

Fig. 3. Same as Fig. 1., but for changes in the number of frost (Tmin <0 ^{o}C) days (all panels

3.2 Precipitation extremes

Frequency of heavy precipitation substantially increases according to all approaches. The empirical trends, significant at 26 % of the stations, yield even stronger increases than mesoscale modelling. In both cases there are strong inter-model and inter-region differences, respectively. The R>10 mm threshold and weaker GCM resolution mean clear but smaller changes.

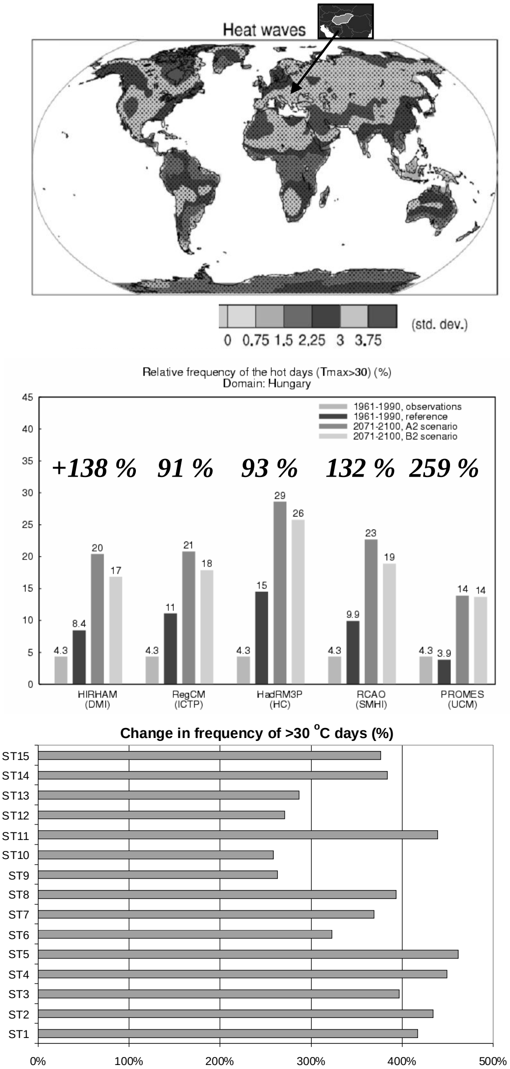

Fig. 4. Same as Fig. 1., but for changes in frequency of heat/waves based on the frequency of the events when at least 5 consecutive days with T_{max} higher than the climate normal of the same day by at least 5◦ C (upper); on frequency of hot days (T_{max}>30 °C) (middle and lower).

3.3 Low temperature extremes

Frequency of frost days substantially decreases according to both model approaches. But, seven of the 15 stations involved into the trend analysis, however, indicate increase of the frost day frequency. But, none of the changes are significant at any individual station!

3.4 High temperature extremes

Frequency of heat waves or hot days increases dramatically according to the three approaches. The empirical approach gives even stronger changes than the PRUDENCE models. The GCM experiments yield very strong changes, indicating that unresolved mesoscale processes do not contribute as strongly to the positive temperature anomalies, as do some other extremes.

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