

“Climate Change and Variability: Impact on Central and Eastern Europe”

Dear Readers,

The CLAVIER team is pleased to present a few results of the joint research activities pursued within the project. It includes the assessment of the climate scenarios and the related uncertainties; the impacts of climate change on weather patterns, air pollution, extreme events, hydrology and water management, buildings and human health; the economic consequences of climate change on agriculture, energy, tourism and public sector.

It is emphasized that all this is only a snapshot of the project achievements. We are going to summarize all results in more detail on the homepage of the project (www.clavier-eu.org).

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1. Ongoing and future climate changes in Bulgaria, Hungary and Romania

1.1. Ongoing climate changes

Observational records show that the global climate has been changing and ongoing changes are visible in the Central and Eastern European countries. During the last decades a clear warming trend has been observed accompanied with a reduction of precipitation. Naturally the strength and pattern of these changes are regionally different. Therefore careful analyses of the changes using observations for the three countries are currently still ongoing.

As an example, we show results from Romania, (Busuioc, A., Boroneanț, C., Baciu, M., Dumitrescu, A. (2008), *Observed temperature and precipitation variability in Romania, South-Eastern Climate Outlook Forum (SEECOF-1), June 11-12, Zagreb, Croatia*). Fig.1 shows a clear warming of the annual mean air temperature of approx. 0.5°C for the last century and total precipitation has been decreased.

Fig. 2. shows the annual mean temperatures and the anomalies of the average annual precipitation in Hungary. It is clearly seen, that the warming is 0,76°C by linear estimation at the homogenized, and 0,42°C at the original time series for the last 104 years. There is no significant trend in the annual precipitation sum, whereas dry years occur more often at the end of the last century (Szalai, S., B.Z. Konkolyiné, M. Lakatos, T. Szentimrey 2005. *Some characteristics of the climate of Hungary since 1901. Hungarian Meteorological Service*)

Fig. 1. The trends of the annual mean temperature (upper panel) and total precipitation (lower panel) over Romania for the last century (Busuioc et al, 2008)

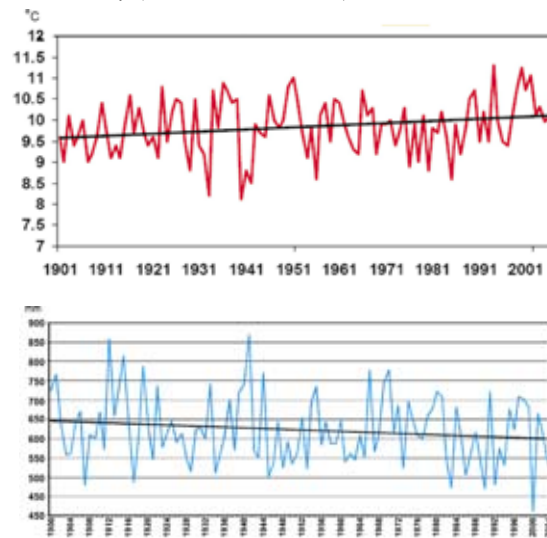
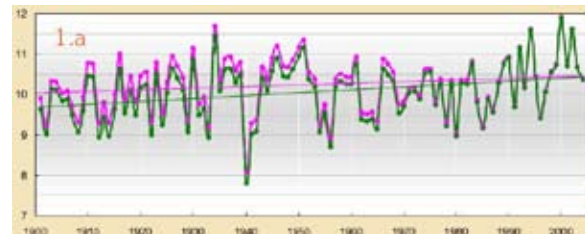


Fig. 2. The characteristics of the climate of Hungary (Szalai et al, 2005)



The annual mean temperatures (°C) in Hungary in the period of 1901-2004. Purple: original time series; green: homogenized time series

1.1.1. Variations in altitude of the relative humidity over Sofia

Here a few results of the study are presented, which were achieved at the National Institute of Meteorology and Hydrology in Sofia, Bulgaria. It relates to evaluation of the relative humidity behaviour at the main isobar standard levels over Sofia for a period of about 50 years.

It is known that summer precipitation is mainly originated from convective clouds of great vertical extent (cumulonimbus). These clouds often produce gusty winds, heavy rain and recently increasing numbers and intensities of thunderstorms. Moisture and air instability play the major role in their formation. Obviously, for the analysis of the effect of climate change on convective clouds and their incident phenomena a profound study of temperature and humidity profiles in altitude is mandatory. The upper tropospheric temperature change is expected to be almost twice higher than the change near the surface, while no change is expected in tropopause temperature. Despite that the increase in temperature leads to increase in specific humidity, most of the authors believe that the temperature changes would not lead to relative humidity changes. However, there is a hypothesis that the increase in water vapour might not be high enough to maintain the relative humidity constant, especially in water-limited continental regions.

The relation between relative humidity (RH) and temperature (T) profiles was considered, as well as any relations with some meteorological phenomena such as precipitation, thunderstorms.

The main conclusions from the study can be summarized as:

- up to 800 hPa, the mean monthly RH increases during the warm half year, which indicates an increase of the available vapour close to the ground (precondition for convective cloud formation);
- a considerable decrease of the RH (especially at 1200 UTC) at 500, 400, and 300 hPa is observed;
- the highest increase of the temperature during the warm half year that is at 300 hPa corresponds to the highest decrease of the relative humidity during the summer (June-August); however, during the colder months (April and September) – the decrease of the RH is the highest at lower level, at 400 hPa;
- the monthly averaged daily temperatures (mean, minimum, maximum, and dew point temperatures) increased during the last 50 years;
- the monthly averaged precipitation amount (mm/day) decreased during the last 50 years, while the number of days per month with precipitation, as with thunderstorm increased.

These results were also used to validate and adjust regional climate models used in CLAVIER.

1.2. Future climate projections

1.2.1. Climate scenarios for the first half of the 21st century - performance of the climate change simulations

In the CLAVIER project, three regional climate models are used to form a small model ensemble: two versions of the REMO model (REMO5.7 at the Max-Planck Institute for Meteorology in Hamburg and REMO5.0 at the Hungarian

Meteorological Service) and the LMDZ model developed at Centre National de la Recherche Scientifique in Paris. The former is a limited-area model and the latter is a variable-grid atmospheric general circulation model with its highest resolution over CEE. With each of these models two types of experiments were carried out: the first one being a simulation of a past period from 1961 to 2000, driven and initialized by the ECMWF ERA40 re-analysis data, the second one being a transient run for the hundred years of 1951 to 2050 driven by scenario experiment of a global coupled atmosphere-ocean model. Data from two global climate models were used to drive and initialize the regional models. All three models used the ECHAM5/MPI-OM (EC5) simulations performed for the 4th IPCC assessment report. In addition, the LMDZ model was forced by boundary data from the IPSL global model (IPSL). For the greenhouse gas emission, the scenario is mainly based on the IPCC A1B scenario; additional simulations with the B1 scenario are available for the LMDZ model. Therefore, an ensemble of climate change simulations allows an advanced analysis of climate change uncertainties. The three regional climate models are used to simulate the climate evolution in CEE for the period 1951 to 2050, the future regional climate projection being the first half of the 21st century. The integration domain and the spatial resolution are comparable for all models and simulations, covering a large part of Central Europe with a horizontal resolution between 25 and 30 km. These simulations serve as a baseline for the impact assessment studies.

It is very important to analyse and validate model results for the climate of present-day conditions, this was realized through the comparison of the ERA40-driving runs and the control climate (1951 to 2000) from the transient runs against observations. This validation, which was carried out for two main parameters (mean temperature and precipitation), provides the baseline information about the model quality and offers the possibility to judge on the performance of the climate change signals.

Future tendencies of the two main parameters (temperature and precipitation) were investigated for the period of 2021–2050 with respect to the reference period of 1961–1990. The main temperature change is quite robust: for 2021–2050 an overall temperature increase is projected for both annual and seasonal means. Concentrating on the changes over the Central and Eastern European CLAVIER countries (Table 1), REMO indicates, that the temperature will increase with approximately 1.4-1.5 Celsius in annual mean, and the largest magnitude of the heating can be concluded in the autumn season for each of the three countries (with 1.9, 1.6 and 1.8 Celsius for Bulgaria, Hungary, Romania, respectively).

When looking at the annual precipitation, simulated by the ensemble members, only small changes are projected for the period of 2021–2050. It is shown in the Table 1, that only non-significant changes can be expected for Bulgaria, Hungary and Romania. However, a large seasonal variability and therefore the projected seasonal absolute precipitation values are estimated. While in spring and in summer the reduction of precipitation is evident, the increase of winter precipitation is observed for three countries. At the same time, some interesting regional features can be underlined. For example, the relative drying is larger in spring than in summer in Hungary. Moreover, an enhancement of the autumn precipitation is observed. It can be explained by the

regional characteristics: more precipitation in the western part of Hungary and less in the Eastern part of the country.

Furthermore, indices for climate extremes have been derived from these simulations, and the possible future evolution of these extremes has been assessed. As an example, Fig. 3 shows the change of the number of warm nights (defined by the minimum temperature exceeding 20°C) for the mean summer season (June, July, August) 2021 to 2050 as compared to the mean summer season from 1961 to 1990 for different models and emission scenarios. Although the spatial pattern of expected changes of the number of warm nights is quite similar from different model simulations, the size of the changes can be quite different among the models, ranging from an increase of only 2 to 4 days for the CLAVIER countries (e.g. REMO-HMS EC5 A1B) to more than 8 days increase for LMDZ IPSL-A1B. Fig. 3 also shows, that for the LMDZ model, the projected changes of the number of tropical nights are more influenced by the driving Global Climate Model (GCM) than by the underlying emission scenario, i. e. the LMDZ-EC5-A1B and the LMDZ-EC5-B1 simulation are in closer agreement than the LMDZ-EC5-A1B and the LMDZ-IPSL-A1B simulation.

The differences between the different model results shown in Fig. 3 reflect some aspects of the uncertainty in the projected climate changes. Where these uncertainties are coming from and which methods can be used to reduce and assess the uncertainties is explained in the section 1.2.3 of this Newsletter.

Table 1: Annual and seasonal change of the mean temperature and precipitation over Bulgaria, Hungary and Romania projected by REMO5.0 for the period of 2021–2050 with respect to the period of 1961–1990.

	TARGET: 2021–2050, REFERENCE: 1961–1990									
	Temperature [°C]					Precipitation [%]				
	Ann.	MAM	JJA	SON	DJF	Ann.	MAM	JJA	SON	DJF
Bulgaria	1.5	1.2	1.6	1.9	1.4	-2.6	-4.4	-10.2	-0.1	7.5
Hungary	1.4	1.1	1.4	1.6	1.3	-0.9	-7.1	-4.8	3.0	7.2
Romania	1.4	1.1	1.3	1.8	1.4	0.9	-2.3	-1.4	-0.2	12.2

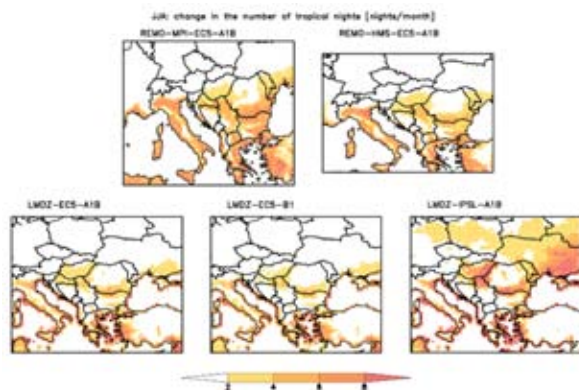


Fig. 3. spatial distribution of the JJA (June, July, August) changes in the number of tropical nights [nights/month] between 2021-2050 and 1961-1990 for REMO-MPI, REMO-HMS, and LMDZ driven by the ECHAM5/MPIOM (EC5) A1B simulation and for LMDZ driven by EC5 B1 and by IPSL A1B.

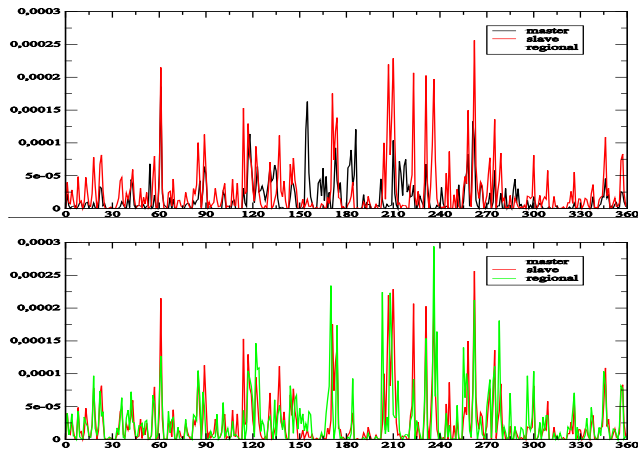
1.2.2. Some general considerations of the regional climate modelling in Central and Eastern Europe

The climate change scenarios performed with both LMDZ and REMO followed a classical approach that is, using the outputs of global models as lateral boundary conditions to force regional models in order to get high-spatial-resolution results for eastern Europe. This approach is sequential: from emission scenarios to global climate scenarios and then to regional climate scenarios. In CLAVIER, this sequential chain was realized by two emission scenarios (B1 and A1B), two global models (MPI and IPSL) and three regional models (LMDZ, REMO5.0 and REMO5.7). The results confirm our general hypothesis that all the three steps introduce spreading and dispersion with roughly an equal importance for each step.

In the given research, we made a special experimental design to investigate the influence of the sequential approach on the simulation of regional climate. It consists of interactively coupling a global climate model (LMDZ-global) and a regional climate model (LMDZ-regional). This is also referred to as two-way nesting, in contrast with the classical one-way nesting from global scale to regional scale. The two-way nesting runs LMDZ-regional and LMDZ-global in parallel with an exchange of information (atmospheric temperature and circulation) every two hours. In this configuration LMDZ-global is named „master” and LMDZ-regional „slave”. In running the two-way nesting system, we recorded the atmospheric temperature and circulation every 6 hours which were then used to force in a sequential manner LMDZ-regional. In this configuration, LMDZ-regional is called „regional”, since the simulation is a classical one-way nesting regional simulation.

We can now compare the three simulations „master”, „slave” and „regional”. To simplify the comparison, we select only one point most suitable for Budapest. Fig. 4 plots the precipitation rate for a period of one year. The upper panel compares „slave” against „master” and can be used to reveal the added values of high-resolution models. The lower panel compares „slave” against „regional”, and will be used to validate the one-way nesting. From the upper panel, we can see that the two models are generally in agreement to produce the rainfall sequence. But two differences can be noted. Firstly, „slave” produces in general stronger precipitation events. This implies that using high-resolution model is essential if we are mostly interested in extreme events. It is well known that the large-scale models under-estimate strong precipitations. Secondly, some discrepancies between „master” and „slave” can be mainly observed during the summer season, from days 120 to 240. This is also in agreement with our general understanding that the local weather in eastern Europe is mainly controlled by large-scale circulations in winter, but can be strongly generated by local conditions in summer. From the lower panel of Fig. 4, we can see that the two curves are generally in a very good agreement. This implies that our sequential approach in doing climate downscaling is valid and the associated biases are small. However some discrepancies can be found also for the summer season.

Fig. 4. Temporal evolution in a year of daily precipitation rate (mm/s) in Budapest. The upper panel shows results of “master” and “slave”. The lower panel shows results of “slave” and “regional”.



1.2.3. Assessment of the uncertainties and the statistical model correction

The outcome of the climate change impact studies presented within CLAVIER relies to a large extent on the performance of the climate models, which were used to provide their input. Each information provided by a climate model has a certain amount of uncertainty, which has to be considered when it is used to project future climate conditions. Three types of uncertainties have to be underlined:

1. The choice of the emission scenarios;
2. Systematic biases which are typical for the individual climate models;
3. Uncertainties due to internal variability of climate models.

An emission scenario providing the input for climate models for future climate projections is a source of uncertainty since we can only estimate the trend of human greenhouse gas emissions in the future. Within CLAVIER, one emission scenario of the IPCC has been chosen, namely the A1B being a medium scenario (applied for REMO and LMDZ). This scenario was adopted within CLAVIER as obligatory. A second IPCC emission scenario has been used for a few studies and is named B1, which can be interpreted as a rather an optimistic scenario (used for LMDZ). Fig. 5 shows the resulting range of the annual cycles for the temperature change signal of Hungary up to the year 2050 for the different regional models, driven by two different global models, and for the two above mentioned emission scenarios.

The most severe systematic error relevant for the CLAVIER domain is known as the “Summer Drying Problem” (SDP), and is characterized by the too dry and too warm simulation of climate over Central and Eastern Europe during (late) summer. It is typical for many regional and also some global climate models. The SDP shows up in REMO, however it is not visible in LMDZ. Its origin is still unknown in general, although sensitivity studies with REMO MPI-M suggest that it might be caused by an unrealistic simulation of atmospheric moisture and heat transport in the Carpathian Basin.

Within CLAVIER, various empirical-statistical methods have been applied and investigated to mitigate such systematic model errors. These approaches analyse the relation of atmospheric parameters from climate simulations (“predictors”) to

meteorological observations (“predictands”) in a historic period in order to correct climatological quantities. The finally selected quantile mapping error-correction fits the modelled cumulative frequency distribution to observed data. This approach is very robust, independent of the distribution of the corrected parameter and therefore applicable not only to daily temperatures but also to daily precipitation sums. Quantile mapping corrects model biases (Fig. 6), errors in variability, as well as in the entire modelled distribution in a very efficient way. Nevertheless, it doesn’t improve the correlation between the simulated and observed data, which, though, is of minor relevance in climatological applications.

The same relationship used to correct historic data can be applied to future climate scenario simulations, strongly assuming similar model error characteristics in the future as in the past. Fig. 7 shows the effect of the error correction (green colours) on the REMO-A1B scenario simulation (black colours) of tropical nights in Bulgaria. The absolute number as well as the trend in tropical nights is highly overestimated by REMO and is strongly reduced in the error-corrected simulation.

In general, model error correction methods are highly useful in climate change impact studies, but cannot replace model improvements which rest on the precise identification of the origin of a bias. In case of the SDP, this turned out to be a scientifically challenging task which requires further investigation.

In contrast to systematic biases, uncertainties due to internal variability are a desired feature of climate models and do not degrade model results. To quantify this type of uncertainty, a new method has been developed within CLAVIER. A physically consistent perturbation of the lateral boundary data as well as the surface boundary data has been created. Therefore, an ensemble of RCM simulations was carried out for one given set of forcing data. The simulations are sensitive to the slightly perturbed input data, and the differences between the individual runs can be attributed to the characteristic internal variability of the RCM. Such an ensemble of nine REMO simulations has already been created over a period of 8 years with reanalysis driving. A large European domain was chosen which is the same as for the REMO simulations provided for CLAVIER. The first results show that the uncertainty related to internal variability of REMO is large in the CLAVIER impact domain, the deviation between the temperatures can exceed 0.5°C. This points at a high sensitivity of the region to the internal model parameters and boundary conditions and thus for the occurrence of systematic biases like the SDP. In the context of uncertainty assessment, this method is complementary to the multi-model and multi-scenario approach.

Fig. 5. Annual cycles of the climate change signal for the temperature for the period 2021-2050 (reference period 1961-1990); regional models: REMO MPI-M, REMO OMSZ, LMDZ; global models: ECHAM5, IPSL; emission scenarios: A1B, B1

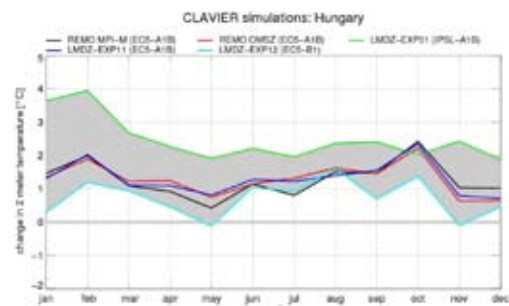


Fig. 6. Mean temperature bias of RCMs in summer, difference to observation data in °C for the period 1981-2000. Left: REMO MPI-M; Center: LMDZ; Right: REMO MPI-M after application of error correction methods

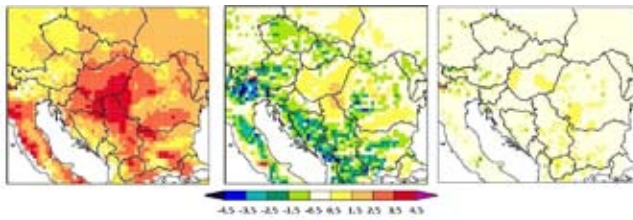
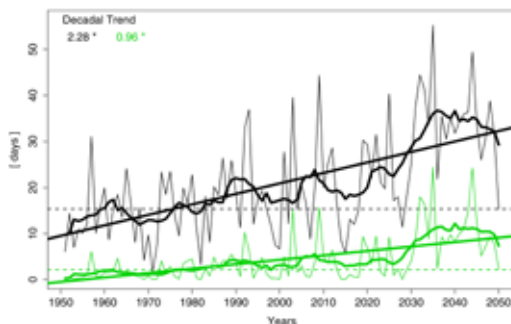


Fig. 7. Trend of the number tropical nights in summer between 1951 and 2050 in Bulgaria. Black: uncorrected REMO57-A1B simulation; green: corrected simulation; dashed: 1961-1990 mean value; bold: 10 year moving averages; bold straight lines: linear trends. Top left corner: Magnitude of the trend, significant trends are marked by an asterisk (“*”).



2. Possible impacts of climate change

2.1. Impacts on the weather patterns in Hungary

The main objectives of the investigations in the framework of the CLAVIER project were to shed some light into the inter-relation between the detected climate change (which is mostly manifested in the temperature increase and the change of the precipitation distribution) and the circulation patterns. This study takes into account that the climate change is induced by the change of circulation characteristics due to the modification of external climate forcings (through the increase of greenhouse gas concentrations and all the related change in the radiative forcing for instance). In other words some answers were sought to the question whether the detected and foreseen climate change can be also demonstrated through the variations of the circulation characteristics of Europe in general and Hungary in particular.

For answering to that question global (ERA40 re-analysis data of the European Centre for Medium-Range Weather Forecasts) and regional (mostly Hungarian observational) databases were scrutinized and circulation-related diagnostics were computed. Additionally some investigations based on the simulated data of the ECHAM global climate model were also taken place (for the past and for the future as well).

The typical macro-circulation types (“Grosswetterlagen”) over Europe are registered and archived on the basis of the Hess-Brezowsky (HB) classification (having 29 different types of macro-synoptic weather patterns). Fig. 8 indicates that the cyclonic types of weather situations were decreased, while the anticyclonic ones were increased in the period of 1961-2000. Nowadays, annually the number of cyclonic and anticyclonic weather types is mainly of equal frequency

(while the cyclonic ones were significantly more frequent in the past).

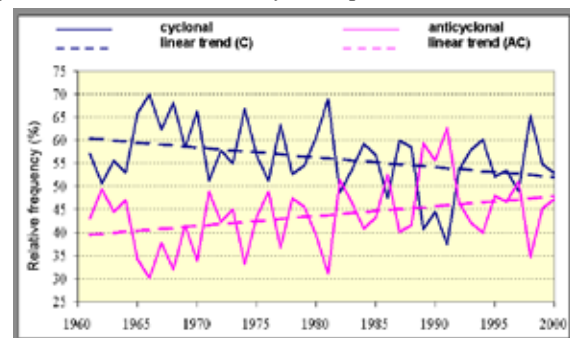
The average annual mean sea level pressure trends are confirming the abovementioned conclusions showing increasing average pressure fields over Hungary in the last 40 years. Beside that the mean 10m wind values are also intensifying slightly.

The zonality is a very important characteristic of the Central European climate, since strong zonal flow (westerly winds) indicates oceanic influence from Western Europe, which results in mild weather conditions in winter and cooler summers. On the other hand the lack of zonal flow might favour the conditions for anticyclone, when the weather is characterised by stable conditions (warm in summer and cold in winter). The zonality index trends show that indeed the zonality over Budapest is increased in the past 40 years. At the same time the ECHAM global climate model is unable to reflect this change of zonality for the past. The main conclusions of the study can be summarized as follows (the statements are valid for the Hungarian territory):

- The average mean sea level pressure values increased in the past 40 years.
- The average wind speed over Hungary also shows increasing trends (it is also valid for the wind gusts) for the last 30 years.
- The level of zonality (westerly flow) has been enhanced (the oceanic influence for the Hungarian climate increased).
- The ECHAM global model is unable to simulate the changes in the weather patterns over Hungary, therefore the study should be repeated with the use of higher resolution regional climate models in order to check whether the regional models can provide added value regarding the circulation characteristics.

It can be summarized, that the studies realized in the framework of the CLAVIER project provided some interesting hints for the change of the circulation patterns for Central Europe. However more detailed investigations are needed to get firmer and more established conclusions.

Fig. 8. The annual relative frequency of cyclonic (dark blue) and anticyclonic (pink) Hess-Brezowsky macro-synoptic types and their linear trends for the period 1961-2000.



2.2. Impacts on extreme events

2.2.1. Assessment of the land degradation in the Curvature Carpathians and Subcarpathians

The importance of this study consists in highlighting through several case-studies, the impact of climate changes on slope and channel processes. It also outlines an extended landslide

reactivation stage and an increased number of flash flood events and floods along the main rivers.

The Curvature Carpathians and Subcarpathians of Romania, part of the seismic region of Vrancea, represent a sector of the Carpathian chain featuring a relief intensely modelled by complex slope and valley processes (Fig. 9). The Cretaceous flysch and Mio-Pliocene formations of the basement are severely affected by a wide range of degradation processes, especially through landslides and erosion, due to such characteristics as structure, lithology and morphometry, in the recent framework of land-use and land-cover changes as a result of an intense human intervention along a transition economical and political period. The main triggering factors are represented by heavy summer rainfalls or early spring showers, simultaneously with snowmelt. In addition, the neotectonic traits (uplift rates of 5 mm/year in the mountain sector and 3-4 m/year in the Subcarpathian hills) and seismic features make the area even more vulnerable to present-day slope processes. That's why this region has been selected as a case study of the CLAVIER project.

The comfortable conditions of life, namely accessible relief, mild climate, the presence of the salt deposits, the mountain-plain are favourable to intense trade relations. It has allowed and encouraged the development of human activities for a long period of time. The direct result of population increase has been land degradation by the slopes overload, the change of the drainage pattern, by overgrazing and the actions encouraged by the changes in the land administration and the ownership, especially after 1989.

In the Curvature Carpathians and especially Subcarpathians, an area of long lasting habitation, the transition period from a centralised economic system to market economy, from a state and collective ownership to a private property had an important impact on the land fund, featuring intense deforestation and sometimes a total lack of interest concerning land management works. A general look at the situation of the Buzău-Teleajen Subcarpathians shows that the population is concentrated mostly in the landslide-prone areas: low hills of less than 400 m in altitude (63% of households), 5-15° slopes (57% of households), and south facing slopes (43% of households).

The trend of precipitation concentration over short time intervals and the increase of their torrential character, led to a higher instability of the slopes, generating large areas affected by landslides and also an increase of flash flood events in small catchments. The quantitative estimations show that at a national level, 47% of the entire Romania's soil surface is affected by erosion and landslides (RAMSOIL FP5 Project). In the Curvature Subcarpathians, the assessment of denuded slopes outlines the importance of landsliding in soil removal, with quantities of 4.4-4.8 t/ha/year.

Due to the major importance of landslides in land degradation, its assessment in the Curvature Carpathians and Subcarpathians was focusing on obtaining a landslide susceptibility estimation based on up-to-date heuristic, statistic and deterministic approaches, correlated with the results of climate simulations within REMO5.7 model (A1B scenario).

First, a regional assessment of landslide susceptibility was obtained, using a semi quantitative, expert-judgement analysis. As landslide-conditioning and triggering variables, several factors were taken into consideration and GIS analyzed (ArcGIS 9.2, Raster Calculator): lithology, slope, maximal precipitation/24 hours, land-use, seismicity and relief energy. The results highlight a landslide susceptibility map (Fig. 10)

showing 5 susceptibility classes: no susceptibility, low, medium, high and very high susceptibility. It generally shows a very important feature, namely the very large areas ranked as highly and very highly susceptible to landslides (59% of the entire area), as a result of a cumulative series of very favourable factors.

For the map validation, an area of 650 km² has been chosen where a landslide inventory (585 field-mapped cases and DGPS and total station survey) was performed with additional aerial photos (2004) support. A good correlation was obtained by comparing the susceptibility classes of the expert judgment analysis and landslide distribution, which confirms the validation of the map: 0.5% of all mapped landslides are listed under a very low susceptibility class, and 64.2% under a very high susceptibility class.

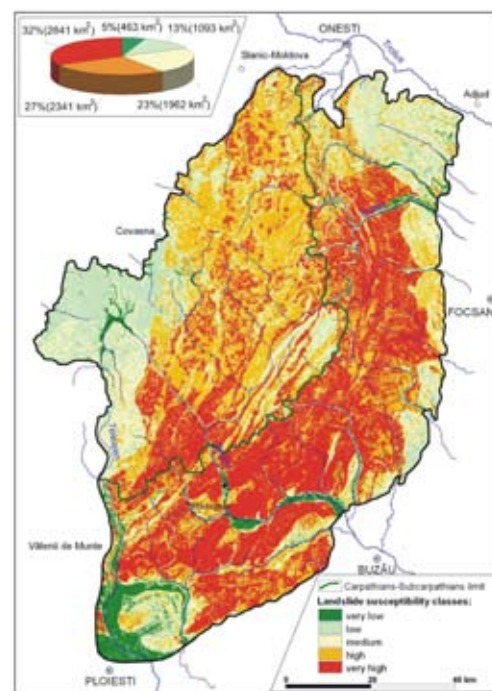
In the same validation area, an assessment of soil degradation due to landslide and erosion processes shows very large areas (79%) affected more than 50 %.

All these results show the practical importance of more detailed studies focused on landslide dynamics, due to the presence of very large areas included in the high-very high landslide susceptibility classes.

Fig. 9. Deep-seated landslide (Groapa Vântului-Siriu) and flash-flood triggered channel processes (Nehoiu Catchment), Curvature Carpathians.



Fig. 10. Landslide susceptibility map: Curvature Carpathians and Subcarpathians



2.3 Hydrological analysis and water management implications

The hydrological impact task of the project is aimed at the production of future hydrological scenarios based on the output of regional climate models.

VITUKI-NHFS and VIDRA (of INHGA) conceptual hydrological models were used to produce long term hydrological series. Mostly the Tisza River Basin (the largest - by drainage basin size - tributary of the Danube) and its sub-catchments have been studied with special emphasis on the Upper Tisza and the Mures/Maros rivers. The entire Danube was also covered resulting as the superposition of separate simulations for the Danube down to the Carpathian Basin, the Drau/Drava, and the Tisza, while the River Sava Basin was captured by a simplistic correlation scheme. Out of the lower Danube tributaries only the Arges Basin was covered.

The raw REMO5.7 ERA40 (1961 – 2000) and REMO5.7 A1B (1951 – 2050) data produced by the Max Planck Institute for Meteorology in Hamburg was further processed to fit the needs of the hydrological models used in CLAVIER. For the statistically corrected data a downscaling procedure was performed by VITUKI based on the elevation distribution functions so that the dataset in the needed fine (10 km) spatial resolution could be obtained.

The transient model simulations were carried out in the period of 1951 - 2050. The validation was related to the period of 1984 - 2000. The sub-basin temperature and precipitation projections were analysed together with the investigation of the impact on the flow conditions. The A1B climate change scenario impact on the hydrological regime characteristics of some selected 30 year periods (1961 – 1990 as reference and 2001 – 2030; 2011 – 2040; 2021 – 2050 as representative periods for the future) was estimated.

The preliminary results in most cases indicate slight decrease of annual mean flow throughout the region, with significant spatial variability and even some increase for the high elevation zones in the Upper Tisza sub-catchments (Fig. 11). The decrease of spring runoff is compensated by the flow resulting from thaw during late winter.

The hydrological simulations indicate a decrease of the mean flow up to 15 % in the southern regions including the Mures and Arges basins. The results of the detailed study coincide with the findings of the less detailed NHFS simulations covering the entire Tisza Basin including the tributary Mures. The results obtained at the station Arad (Fig. 12) indicate a general decreasing tendency of the mean monthly discharges for the future March–November period as compared to the observed reference period. The simulated mean of monthly discharge variations indicate an increase only in the winter season months, especially for February and December.

No clear picture can be drawn about possible changes in the flood conditions. While more frequent winter floods are expected, the decrease of mean flow in some seasons is not followed by the decrease of flood peaks. Torrential type of flood events may occur even more frequently, while the frequency of floods with long duration and large volume may become lower.

The study of the Lower Danube low water conditions indicates the possibility of more expressed and longer low flow periods. Some 25% increase of low water levels/discharges is possible to cause problems for the users who require considerable amount of water. The other problem is limitation of water intake. The navigability of the river section may also deteriorate to a certain extent.

Fig. 11. Comparison of the mean monthly simulated discharges for the selected 30 years future periods (2001-2030, 2011-2040, 2021-2050) and those for the reference period (1961-1990), – Tisza-Tiszabecs

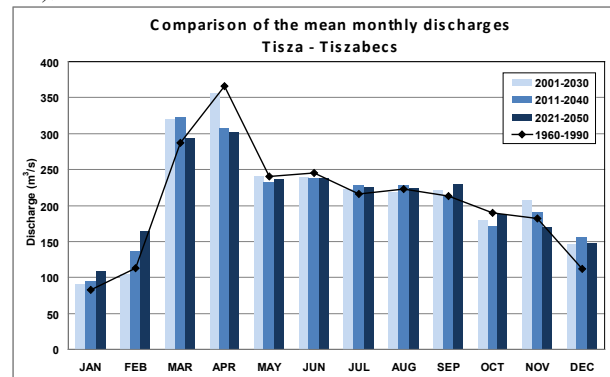
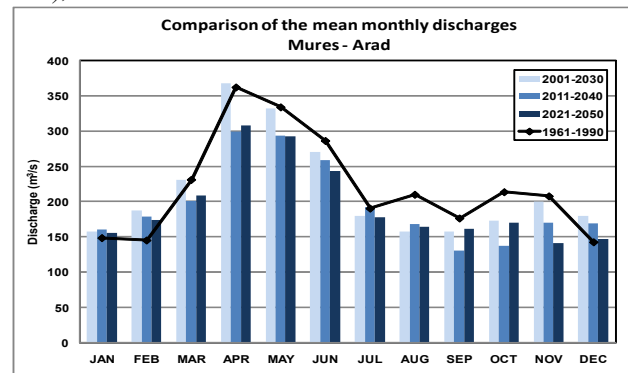


Fig. 12. Comparison of the mean monthly simulated discharges for the selected 30 years future periods (2001-2030, 2011-2040, 2021-2050) and those for the reference period (1961-1990), – Mures - Arad



2.3.1. Evaporation estimation for Lake Balaton

Lake Balaton is one of the most valuable natural resources of Hungary. It plays a significant economic role in the country via its tourism industry: it is the second most popular tourist destination in the country, after Budapest. The main attractions are water sports (including water skiing, sailing, swimming and fishing, just to name a few) thus maintaining a proper lake water level is crucial for these activities.

Since the beginning of this decade, however, significant weather extremes have been observed in Hungary. Initially, lake water level had dropped significantly due to a drought (which made many consider supplementing the missing water from the outside sources) followed by a year of abundant precipitation resulting in a rapid rise in water level reaching the allowable upper maximum that eventually led to opening the Sió Canal to drain the surplus water, something that has happened rather seldom in the recent past.

In the next 50 years the climate may become drier, many inhabitants, municipalities, and tourists can be unfavourably affected by the resulting siltation of the coastal region and a shrinking lake water surface area, which makes water sports and transport more problematic. Therefore, despite today's wetter climate, the idea of a water supplementation system similar to the one built for Lake Velence is the topic of frequent discussion.

The evaporation of Lake Balaton has been changing within a narrow range in the last 80 years, with a difference of 30% between the minimum (723 mm) and maximum (1073 mm) values (Fig. 13). Traditional evaporation estimation methods

employed in Hungary revealed significant errors that justified the development of new techniques.

The calculations with the help of long-term water-balance derived monthly evaporation estimates for the shallow, medium-sized Lake Balaton, and regional climate model (REMO) outputs as inputs to the employed potential evaporation equations, have confirmed that shallow-lake evaporation can typically be considered as intermediary between the two well-defined potential evaporation rates: the Penman evaporation rate and the Priestley-Taylor, the so-called equilibrium or wet-environment evaporation rate. By weighting these two evaporation estimates on a monthly basis, the lake evaporation can be fairly well estimated. In addition to this approach, a standard lake evaporation estimation algorithm, the so called WREVAP model has also been applied.

The input data for the evaporation estimation models were provided by the regional climate model REMO of the Max Planck Institute for Meteorology in Hamburg for the time period of 1951-2050. Future boundary conditions for REMO5.7 were taken from the global coupled atmosphere-ocean model ECHAM5/MPI-OM, based on an A1B scenario (which is a medium scenario), while for the past (1960-2000) another REMO5.0 run with reanalysis (ERA40) data as boundary conditions was chosen additionally.

The evaporation estimation for Lake Balaton was achieved by choosing REMO gridpoints around the lake and using ensemble averages of the gridpoint variables. For the 1960-2000 period the weighted-equation based on annual evaporation estimates were compared to the water-balance derived from the annual rates for the calibration and verification years. In the calibration period the combination method underestimated the water-balance, which derived mean annual evaporation rate of 889 mm by a mere 7 mm (~1% relative error) and the 866 mm by 15 mm in the verification period (~2% relative error). Morton's WREVAP program underestimated it by 23 mm (~2.5% relative error) in the calibration period, and by 22 mm (~2.4% relative error) in the verification period.

After determining the weights with REMO5.7 (driven by ECHAM5/MPI-OM) data for the 1951-2000 period, evaporation for the 2001-2050 period could be obtained (Fig. 14). According to the results no significant changes in mean annual lake evaporation can be expected under the A1B scenario: for the 50-year time period the expected mean annual evaporation rate is 888 mm, which is only a 1-mm increment when compared to the water balance value for 1951-2000 and only a mere 3 mm (~1/3 of a percent relative increase) when compared with the same water balance value for the 1961-2000 period. The Morton model with REMO 5.7 inputs and no tunable parameters yielded 773 mm/year for 1951-2000 and 785 mm/year for 2001-2050, both a significant underestimation, yet the evaporation increase again is under 2% (being close to the limit of error). Considering that Morton's program performed rather well with REMO5.0 forced by ERA40, there may be some slight underestimation of the range of the seasonal cycle of global radiation in the REMO5.7 data required by the evaporation estimation models, which can be in direct relation with the deficiencies in the global fields. The combination method did not solve the problem because its parameters could be adjusted to be on target with the water balance derived values for 1951-2000.

In the light of these results the water supplementation to Lake Balaton from the outside sources, to counteract a possible increase in lake evaporation due to an expected warmer climate, does not seem justified. This may sound as a relief

sign for ecologists and environmentalists who were worried about the possible ecological changes in lake flora and fauna as a result of supplying stream water to the lake.

The results of the analysis of the tourism's sector vulnerability to climate change at lake Balaton can be found in the chapter 3.3.2

Fig. 13. Evaporation from the water balance of Lake Balaton in the period of 1921-2007

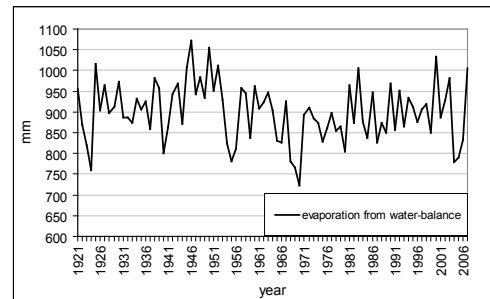
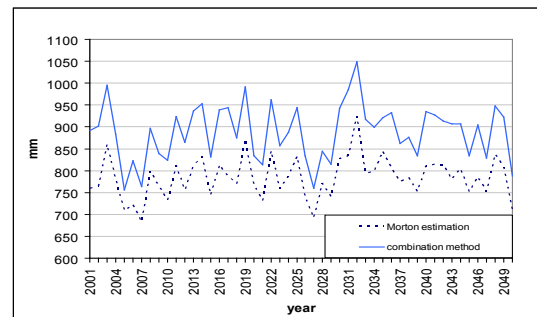


Fig. 14. Evaporation of Lake Balaton in the period 2001-2050 estimated by different methods for REMO5.7 driven by ECHAM with an A1B global scenario.



2.4. Impacts on buildings

The changes in climate have various implications for building design, construction and maintenance. A potential increase in future wind speeds may suggest that the development of more robust roof designs is important. The main objective of the Buildings Case Study is to assess the structural impacts and vulnerability on the roof, particularly in point of the wind loads. (It should be stressed that climate change may also affect building constructions of the roof, e.g. fastening of roof covering elements, rainwater drainage system that would need further researches).

The Building Case Study was implemented in Tatabánya (located in Komárom-Esztergom County in north part of Hungary). The buildings' composition of the town well represents the buildings' stock in Hungary. The methodological framework (Climate Impact and Vulnerability Assessment Scheme, CIVAS) was developed and applied in various CLAVIER impact case studies in order to quantitatively estimate the climate change induced threat of the investigated systems. The theoretical background of CIVAS method is based on IPCC AR4. The vulnerability in CIVAS method integrates the exposure (climate change in case study area), sensitivity (building's weather dependency) and adaptive capacity (socio-economic implication in Tatabánya). During the application of CIVAS method the following steps were made:

1. Building's typization: on the basis of the existing literature and buildings statistics the classification of building stocks were made. In the representative typization there are three main groups (dwellings; industrial/commercial buildings; public buildings). 16 different types were defined in the classification, which represent almost 90% of Hungarian building stock.

2. Determination of critical wind speeds: All the building types can be characterized by a critical wind speed which depends on building's height, terrain categories, peak velocity load as it is determined in EUROCODE and National Building Standards.

3. Estimation of exposure: The exposure indicators are the increase in number of days in the period of 1971-2000 and 2021-2050 when the daily mean wind speed exceeds critical threshold values. These indicators were calculated from the error-corrected regional model REMO (version 5.7, $0.22^\circ \times 0.22^\circ$ grid spacing) A1B-scenario simulations for the decades from 1971-1980 till 2041-2050. In order to reduce the downscaling-error of REMO the daily mean wind speeds have been corrected in advance by means of the observation based and higher resolved ($0.1^\circ \times 0.1^\circ$ grid spacing) gridded dataset HUN-GRID, generated by the Hungarian Meteorological Service.

4. Identification of sensitivity: The building type's sensitivity indexes are attributed to roof covering material, building's age, roof area etc., and determined by expert judgments based on experiences gained in planning, maintenance and insurance activities.

5. Identification of adaptive capacity: The indexes of building type's adaptive capacity depends on the attitude and socio-economic situation of house's owners related to mobility, risk prevention, potential to mitigate the damage costs etc. The adaptive capacity indexes are also determined by expert judgments based on experiences of Tatabánya Major Office.

The main results are summarized in Table 2. It can be shown that almost half of the dwelling categories is attributed higher to than average vulnerability. The obsolete blocks of flats (which are relatively prevalent in Tatabánya), churches and older dilapidated public buildings are the most endangered. Taking into account the buildings' composition in Tatabánya it is possible to map the most vulnerable town's districts. It is obvious that those areas where the blocks of flats from 1945's and the high-rise prefabricated housing blocks dominate are the most vulnerable (Fig. 15.) It is also notable, that almost 25% of the Tatabánya's inhabitants are living in most vulnerable settlements.

Table 2. Exposure, sensitivity, adaptive capacity and vulnerability in various building types in Tatabánya

Code	Types	Exposure (days)	Sensitivity	Adaptive capacity	Vulnerability
BF 2	blocks of flats from 1945's	39	↑↑	★★	●●●●●●
PB 1	traditional public building	39	↑↑↑	★★★	●●●●●●
PB 4	church	31	↑↑↑↑	★★★	●●●●●●
BF 1	pre-war downtown tenement blocks	31	↑	★	●●●●●○
HB2	high-rise prefabricated housing blocks	31	↑↑	★★	●●●●●○
BF 3	modern housing estate	39	↑↑	★★★★	●●●●○
HB1	small prefabricated housing blocks	9	↑↑	★★	●●●●○
FH1	traditional family houses from early 1900's	4	↑↑↑	★★	●●●○
FH2	one-storied family houses of 1945-1990	4	↑↑↑↑	★★	●●●○
PB 2	public building from 1945's	9	↑↑	★★★	●●●○
FH3	multi-storied family houses of 1960-1990	4	↑↑↑	★★★★	●●○
FH4	modern family houses (of 1990's)	4	↑	★★★★★	●○
IB1	small industrial buildings	39	↑	★★★★★	●○
IB2	large industrial buildings	39	↑	★★★★★	●○
IB3	commercial centres	4	↑	★★★★	●○
PB 3	modern office buildings	39	↑	★★★★★	●○

Sensitivity:

Insensitive:	↑
Low sensitivity:	↑↑
Moderate Sensitivity:	↑↑↑
High sensitivity:	↑↑↑↑
Extremely sensitive:	↑↑↑↑↑

Adaptive capacity:

Poor:	★
Weak:	★★
Moderate:	★★★
Fair:	★★★★
Strong:	★★★★★

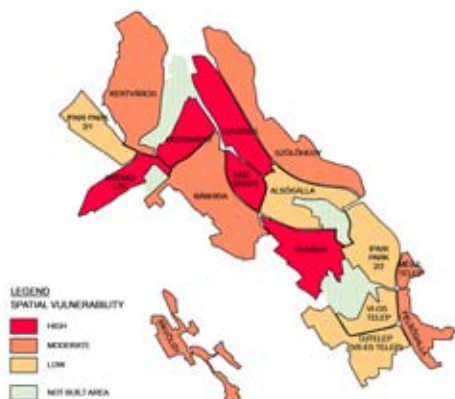
Vulnerability:

Robust:	●○
Low vulnerability:	●●○
Moderate vulner.:	●●●○
Highly vulnerable:	●●●●○
Extremely fragile:	●●●●●

Note: Exposure is based on estimated climate change, sensitivity generally refers to the state of the buildings, while adaptive capacity is related to socio-economic circumstances. Detailed explanation of exposure, sensitivity and adaptive capacity is given above.

Legend: Exposure: increase in number of days in the period of 1971-2000 and 2021-2050 when the daily mean wind speed is greater than the critical values. (The critical characteristic wind speeds depend on the building types.)

Figure 15. Spatial vulnerability of buildings in Tatabánya (Hungary)



2.5. Impacts on human health

The main objective of the Heatwaves Impact Case Study is to assess the changes in daily mortality in Budapest due to the potential climate change induced the summer warming. In order to estimate the effect of the climate change in Budapest in 2021-2050 the excess mortality due to the heat waves was calculated.

The daily total mortality data (from 1st May till 30th Sept) of the permanent residents of Budapest (in 2000 1.732 000), were collected from the Central Statistical Office for the period of 1971-2000. The observed baseline daily average temperature data were provided by the Hungarian Meteorological Service. The data provided by the error-corrected regional model REMO (version 5.7, $0.22^\circ \times 0.22^\circ$ grid spacing) A1B-scenario

simulations were calculated for the reference period (1971-2000) and for the scenario period of 2021-2050 for spatial mean of given gridpoints data close to Budapest.

A time series analysis was carried out by the GAM model, daily mortality on the days with daily mean temperature $>25^{\circ}\text{C}$ was calculated. The interrelation between mortality and temperature is quasi linear in the higher temperature range. By linearizing this section the attributable effect of temperature on excess mortality can be calculated on the days when the temperature is higher than the threshold value.

According to the climate scenario during the years of 2021-2050, the number of heat wave days will increase by 156 days (i.e. around 5 days in every year) compared to the reference period of 1971-2000 (Fig. 16) The ratio of attributable excess mortality during the heat waves in relation to the increase of total mortality depends on the frequency and intensity of heat waves. The heat waves with daily mean temperature of $27-29^{\circ}\text{C}$ have the greatest impact. The effect of the separate heat waves can be summarized for the 30 year period (Fig 17a.)

For the calculation of absolute numbers of excess mortality, the impact of climate change was assessed on the reference population. The effect of the heat waves of different intensity on yearly level was calculated for the reference period (1971-2000) and for the scenario period (2021-2050) (Fig 17b). The calculated excess mortality in the period of 1971-2000 was 44.8 cases per year, while in the scenario period of this number increases by 41.3 cases, so the total number of excess cases will be 86.1 cases. The increase of attributable excess mortality due to the climate change is therefore 93% for the total 30 years' period.

Fig. 16. The total number of days of heat waves during the baseline (1971-2000) and forecast (2021-2050) periods in Budapest.

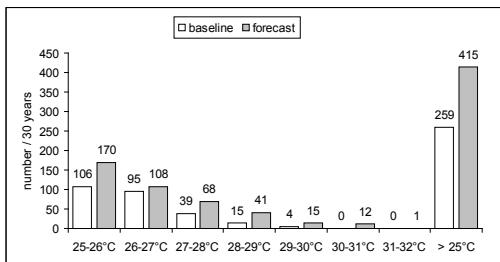


Fig. 17a. Cumulative daily excess mortality estimated for 2021-2050 for Budapest

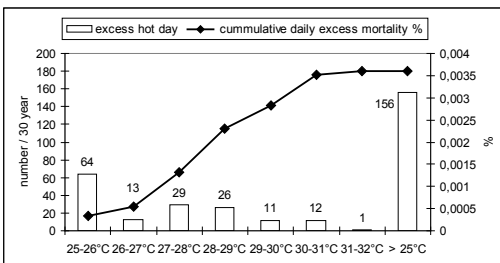
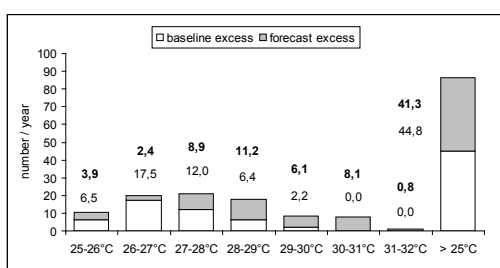


Fig. 17b. Absolute numbers of excess mortality by years for the baseline and forecast models



3. Evaluation of the economic impacts on different economic sectors

3.1. Agriculture: case study in Romania

The impact of climate change on agriculture is evident. However, the quantification of this impact is much more complicated. The CLAVIER project aims to estimate the impact of climate change on yields of different crops and to evaluate how the changes in crop production might influence the main economic indicators: output, income, employment and value added of the region.

There are several case studies in the CLAVIER project. One of them is located in the North-West region of Romania (AGRIROM). The study done at the University of Cluj, Romania aims to assess the impact of climate change on the selected crop yields until the year of 2030.

This study is structured as follows:

The first stage:

- the econometrical modelling of yields' changes based on the evolution of climate parameters. Two regional models REMO 5.7 and LMDZ were used. The trends of the yields of the selected crops in the period of 1975-2000 have been used as a baseline scenario. The different scenarios were estimated as the yields of the selected crops according to the baseline scenario + the trends based on the simulations by the regional models: REMO 5.7 A1B (Scenario 1), LMDZ B1 (Scenario 2) scenario and LMDZ A1B (as scenario 3). The main climate parameters, including monthly mean temperature, monthly precipitation sum and monthly relative humidity were taken into account. As a result, climate impacts on the yields of the selected crops - wheat, maize, barley, potato, lucerne and clover - were estimated. Fig. 18 presents the changes of the crop yields in the North-West region in 2020-2030 compared to 1975-2000 for the different climate scenarios.

It is shown that the impacts of climate change strongly depend on the crops types. Furthermore, the same climate parameter can have a different impact on the yields of selected crops.

The following table presents the difference in the agricultural output in the North-west region of Romania in 2020-2030 compared to 1975 - 2000.

The difference in the agricultural output in the North-West region in 2020-2030 compared to 1975-2000

	Base-line scenario	Scenario 1	Scenario 2	Scenario 3
Change in total output of the 6 crops (lei)	2.85%	-7.43%	25.90%	2.15%
Change in total output of the agricultural sector (lei)	0.56%	-1.47%	5.12%	0.42%

*using prices from 2005

The second stage

- the construction of the regional Input-Output Table based on the national database;
- the quantification of the impact of climate change on the main economic indicators: output, income, employment and value added of the region.

Some results of this study are illustrated below:

*Changes in the region's output, income, value added and employment in 2025 compared to 2005 in the North-West region according to the Baseline Scenario applying BL (backwards linkage) and FL (forwards linkage) - the types of the linkages used in the study**

*change in economy's output (from 2005 to 2025) using BL (FL) = expected change in the final demand (final payments) of the agriculture (from 2005 to 2025) * BL (FL) calculated for output

	BL	% in projected regional values	FL	% in projected regional values
Change in economy's Output (mil.lei)	6211.2	5.3	6308.1	5.4
Change in economy's Income (mil.lei)	210.4	8.6	73.7	3.0
Change in economy's value added (mil.lei)	320.6	5.5	329.6	5.6
Change in economy's employment (pers)	295		332	

Changes in the region's output, income, value added and employment in 2025 compared to 2005 in the North-West region according to the Scenario 1

	BL	% in projected regional values	FL	% in projected regional values
Change in economy's Output (mil.lei)	5456.7	4.7	5541.8	4.8
Change in economy's Income (mil.lei)	184.8	7.6	64.7	2.7
Change in economy's value added (mil.lei)	281.7	4.9	289.6	5.0
Change in economy's employment (pers)	259		291	

Changes in the region's output, income, value added and employment in 2025 compared to 2005 in the North-West region according to the Scenario 2

	BL	% in projected regional values	FL	% in projected regional values
Change in economy's Output (mil.lei)	7902.2	6.7	8025.5	6.8
Change in economy's Income (mil.lei)	267.6	10.9	93.7	3.8
Change in economy's value added (mil.lei)	407.9	6.9	419.4	7.1
Change in economy's employment (pers)	376		422	

Changes in the region's output, income, value added and employment in 2025 compared to 2005 in the North-West region according to the Scenario 3

	BL	% in projected regional values	FL	% in projected regional values
Change in economy's Output (mil.lei)	6159.4	5.3	6255.4	5.4
Change in economy's Income (mil.lei)	208.6	8.5	73.1	3.0
Change in economy's value added (mil.lei)	318.0	5.4	326.9	5.6
Change in economy's employment (pers)	293		329	

It can be clearly seen, that the impact of climate change is the most positive for the scenario 2 and the most negative for the scenario 1.

As a next step, the NIOT 2005 method was applied to estimate the impacts of climate change on the country's economy in year 2025. The results shown in the table below, indicate a relatively low impact of climate changes on the main economic indicators

Changes in the country's output, income, value added in 2025 resulting from the climate change (%)

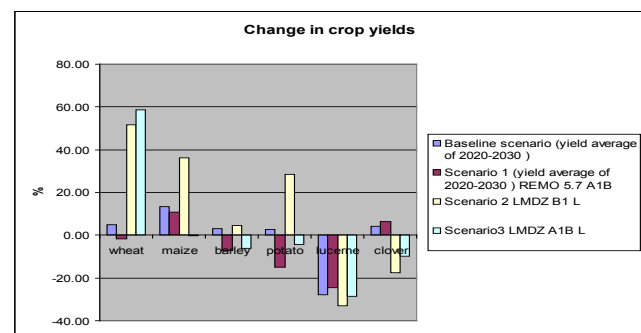
	Scenario 1	Scenario 2	Scenario 3
Change in output	-0.58	1.04	-0.14
Change in income	-0.32	0.64	-0.04
Change in VA	-0.59	1.18	-0.07

*change=(scenario i / baseline scenario *100)-100

Furthermore, the adaptive capacity for the six counties in the North-West region was analysed. As a result, the different levels of vulnerability, ranging from average to presumably high, were identified for the same regions.

The outcome of this study shows, that drought resistant crops need to be developed and used by crop producers in the near future.

Fig. 18. The change in crop yields in the North-West region in 2020-2030 compared to period 1975-2000 for the different climate scenarios



3.2. Energy

3.2.1. Case study in Bulgaria

The purpose of the "EnerBul" study is to evaluate the economic impacts on nuclear energy production in Bulgaria in the light of climate change. The target nuclear power plant is the Kozloduy Nuclear Power Plant (KNPP), located on the Danube River in North West Bulgaria. The EnerBul case study applies various quantitative and qualitative research methods, which are based on the comparative analysis of the results of three statistically corrected model simulations: REMO5.7 A1B, LMDZ A1B and LMDZ B1.

The quantitative analysis in EnerBul has been supplemented by qualitative research methods. A number of interviews with the representatives of KNPP have been conducted in 2008.

The analysis of the vulnerability and adaptive capacity has been made according to the methods of the endogenous regional adaptive capacity (EARC). The degree of tertiarization and industrialization measured by employment shares and value added, the economic development (the level and growth of GDP per capita), and also touristic capacities and spatial conditions such as the accessibility are main determinants of ERAC. The classification was performed by means of utilizing the explorative instruments of factor and cluster analysis.

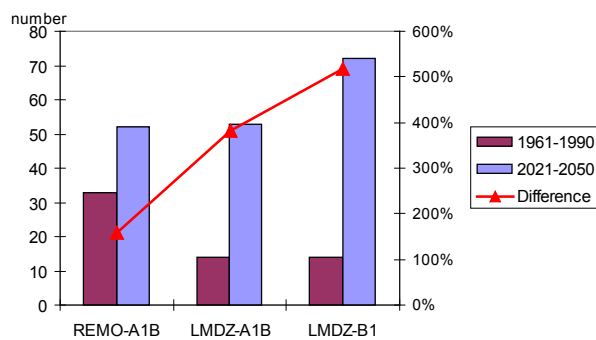
One of the main conclusions drawn is that the projected climate changes in the future will definitely not influence the safety of the KNPP, but will cause the diminishing of the cooling efficiency and the decrease of the energy produced in summer.

According to the three climate models the number of unfavourable days per year (days with the low cooling

efficiency of the energy production at KNPP) will increase at least 1.6 times in the period 2021-2050 as compared to the past period of 1961-1990 (Fig. 19). The worst situation is expected under LMDZ B1 model when the number of these days will increase more than five times and such days will occur not only in summer, but in spring and in autumn as well. However, in monetary terms the expected decrease in electricity production is a small part of the total production in KNPP – about 1%.

Under all scenarios the expected physical impacts on nuclear energy production is low. Hence, the expected economic impacts are insignificant both on regional and national levels. The economic vulnerability to climate change is a function of the adaptive capacity of the region and the expected economic impact. The adaptive capacity of the North West region is rather low. However, taking into account the insignificant economic impact of climate change on the KNPP, expected under the three scenarios, the conclusion is made that the economic vulnerability of the region in the sphere of the nuclear energy is low or insignificant.

Fig. 19. The average number of days per year with $T > 30\text{ }^{\circ}\text{C}$ and the difference between past and future climate



3.2.2. Case study in Hungary

In 2007 a Hungarian-Spanish consortium built the largest Hungarian wind farm consisting of 12 wind turbine masts in Győr-Moson-Sopron. Through the geographic position of the region – the extension of the Burgenland wind channel guarantees average wind speeds of 30-40 km/h at 100 m level– unique conditions for wind farming are provided. Győr-Moson-Sopron is one of the most prosperous regions within Hungary, characterised by high accessibility values, a higher-than-average regional gross domestic product and a distinct and highly productive secondary sector. Furthermore tourism and “knowledge intense services” play an important role in terms of employment and gross value added. Tourism industry as well as electricity production by wind farms are highly dependent on certain climatic conditions. Therefore, the aim of the Hungarian energy case study is the analysis of the vulnerability to climate change of the wind farming sector in Győr-Moson-Sopron, and furthermore, going beyond wind power generation, the evaluation of Győr-Moson-Sopron’s regional vulnerability. For this purpose the region’s present and future climatic conditions, its socio-economic situation and the framework for future development have been analyzed. Based on the results of this analysis, consequences of future climatic conditions for the wind farming sector and the region have been derived and subsequently interpreted in terms of relative regional vulnerability. The results gained

within the case study imply that, although Győr-Moson-Sopron is affected by a changing climate to a certain extent, the regional vulnerability to climate change is estimated to be minor due to the following facts:

- Firstly, Győr-Moson-Sopron’s wind farming industry is directly exposed to climatic changes. Nevertheless, direct impacts of climate change are estimated to be negligible. In order to analyze the impacts of climate change on energy yield, a transfer-function based on the quantile mapping method has been developed and applied to estimate energy yields of the wind farm from coarsely resolved ($0.1^{\circ} \times 0.1^{\circ}$ grid spacing) daily wind speed data from the HUN-GRID observational dataset. The annual energy yield of the wind farm has been estimated by applying the transfer-function on error-corrected daily wind speeds of the regional climate simulation (REMO-A1B) for the scenario period 2021-2030 and the reference period 2003-2012. Comparisons of the annual energy yield (10 year average) between those periods show a statistically insignificant reduction about -1.5%. The climate change impact on the energy yield with respect to changing wind speeds is therefore negligible within this specific configuration (emission scenario A1B, global climate model ECHAM5, regional climate model REMO 5.7, change until 2025 compared to 2007). However, significant (significance <0.05) changes occur later in the future: in the period of 2031 and 2041 the mean annual energy yield (10 year moving average) is reduced by -5.5% to -10%. The trend of the air density for the scenario (2021-2030) and the reference period (2003-2012) is small (-0.03%) and statistically insignificant as well. Minor (between $\sim 0.0\%$ and -1.0%), but statistically significant changes (based on 10 year moving averages) may arise later than 2028. The wake-losses of the wind farm show a complex behaviour: they are supposed to depend on both, directions and velocities of the approaching air flows. Nevertheless, since the regional climate simulations (REMO-A1B) do not indicate climate change effects on wind directions and since the expected changes of wind speeds are insignificantly small between the scenario and reference period, the impact on the energy yield is also supposed to be negligible within the given configuration. Consequently the potential economic impacts on wind farming in Győr-Moson-Sopron are expected to be tendentially negligible.
- Secondly, air temperature is predicted to increase in future during all seasons, which indicates a certain sensitivity to climate change for the whole region. The numbers of cooling days – days, when people use air conditioning to cool their buildings – are projected to increase. The growth in demand for electricity will continue and will be even enhanced by climate change.
- Thirdly, the NUTS 3 region Győr-Moson-Sopron as an Industry Centre has a diverse economy. A high socio-economic standard and a highly productive industry come along with a developed service sector, which is driven not only by classical services such as tourism but also by knowledge intensive branches. Finances, research and development play a major role in the regional economy. Obviously, the regional potential to cope a certain shock is given. The Endogenous Regional Adaptive Capacity (ERAC) is presumably the highest among all CLAVIER regions.

Summarizing, the limitations for a further development of wind farms in Győr-Moson-Sopron are not determined by climate change. The potential of the enhancement of

technologies in the sector of wind energy is assumed to be rather low just because of governmental regulations and lacking infrastructure. Due to severe safety problems in the Hungarian power supply grid the capacity of each installation is limited to 330 MW per installation – energy production is restricted to a level that certainly is not on the scale which is needed in order to contribute to a significant share of the national energy production mix.

3.3. Tourism

3.3.1. Case study in Bulgaria

The purpose of the TourBul study is to outline the current sensitivity and future economic impacts of the climate change on winter tourism in one of the major Bulgarian ski resort Borovets.

The TourBul case study applies different quantitative and qualitative research methods. The snow models for four heights at Borovets resort (1244 m, 1300 m, 1700 m, 2500 m) have been developed by WegCenter. The statistical tests of hypothesis and regression analysis are applied for the study of the relationship between tourist numbers and the meteorological parameters. The type of the data and the characteristics of the changes in the dependent variable (the number of overnights per decade) assume the application of ARIMA model, and specifically its modification for the evaluation of the factor impacts and seasonality $ARIMA(p, d, q)(ps, ds, qs)$. In this case the factors are the number of snowy days and the snow height. It has been determined through statistical tests of hypothesis that there is a relationship between the number of the nights spent, the number of snowy days and the height of the snow cover. Based on the method of competitive models with Schwarz's Bayesian Criterion (BIC) ARIMA model of the type $ARIMA(1, 0, 0)(18, 0, 0)$ has been identified as the most appropriate.

The quantitative analysis in TourBul has been supplemented by the qualitative research methods. A representative local hotel has been selected. The case study describes how the local perceives its dependence on the weather and climatic conditions, as well as what climate changes would be meaningful for the hotel. A half-structured interview with the manager of the hotel has been conducted in February 2009.

The concept of endogenous regional adaptive capacity (ERAC) has been used to evaluate the adaptive capacity of the case study region. The degree of tertiarization and industrialization measured by employment shares and value added, the economic development (the level and growth of GDP per capita), and also touristic capacities and spatial conditions such as the accessibility are main determinants of ERAC. The classification was performed by utilizing the explorative instruments of factor and cluster analysis.

According to the REMO5.7. A1B scenario a conclusion is made that on average Borovets resort will have adequate snow for skiing in the future (Fig. 20), although a stable downward trend in the number of snowy days and snow height is observed (Fig. 21). Here further analyses is ongoing to identify the relation between winter time temperature change and snow for skiing. On the one hand, the regression analysis shows a small change in the number of overnights, because on average the ski zones will still have enough snow. On the other hand, the results of the analysis of the cyclic development in the snow cover are rather alarming, i.e. the indexes of the snow cover in the

period of 1993/94 – 2049/50. The fluctuations above and below the trend represent snow-adequate and snow-deficient years, i.e. good and bad years for tourism. The cyclic variations are significant. In future snow-deficient winters occur more often as compared to the 1990s and 2000s. For example, periods of 2, 4, 5 or 6 consecutive winters with bad snow condition could be expected in 2020-2050.

In the short-run the economic impact on the regional economy will be moderate. It is likely that the impacts in the long-run are much more negative. They depend both on the snow conditions, as well as on the preferences of tourists in Borovets and the flexibility of hotels' marketing policy. The worst possible scenario (the collapse of tourist numbers visiting Borovets because of a long cycle of "bad" winters) will lead to closing down of hotels when only the most competitive ones survive.

The economic vulnerability of the region is considered in two aspects. Under REMO5.7 A1B scenario in the short-run average the ski zones will still have enough snow for skiing, thus, the district is not vulnerable in terms of winter tourism, because although the adaptive capacity is below the average, the economic impacts are expected to be low until 2020s, if other factors are unchanged. In the long-run (2020-2050), the combination of a low adaptive capacity and strong negative economic impacts determine high economic vulnerability of the region as compared to other CLAVIER regions.

Fig. 20. Daily mean parameters in Borovets

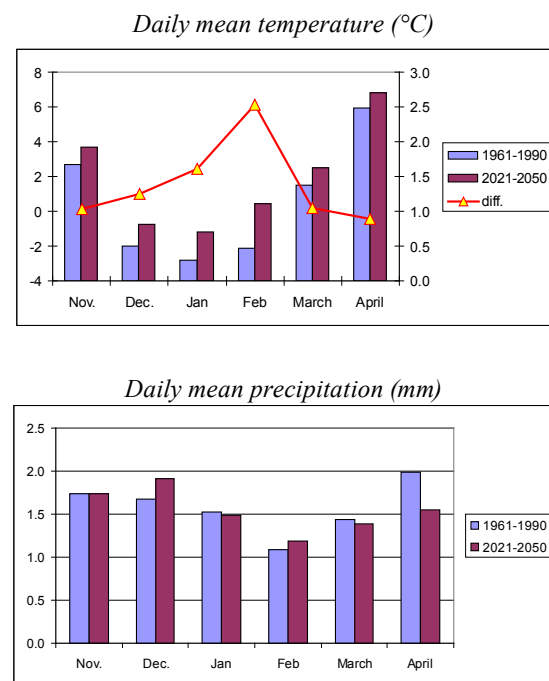
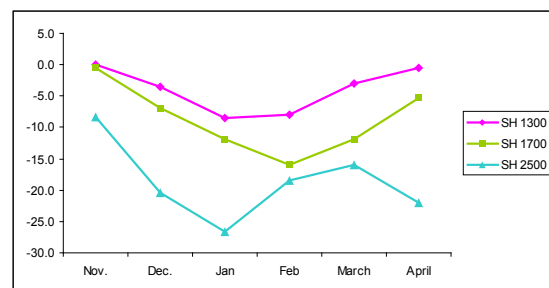


Fig. 21. Difference in snow height in cm between past and future climate at three levels



3.3.2. Case study in Hungary

After Budapest the region of Lake Balaton (see the chapter 3.3.1) counts for the second biggest share of tourists in Hungary. Since lake tourism is sensitive to weather and climatic conditions, the aim of the Hungarian tourism case study is to analyse the tourism sector's vulnerability to climate change at Lake Balaton and in the NUTS 3 region Veszprém and furthermore, going beyond the tourism sector, to evaluate Veszprém's regional vulnerability. For this purpose the region's present and future climatic conditions, its socio-economic situation and the framework for future development have been analysed. Based on the results of this analysis, consequences of future climatic conditions for the tourism sector and the region have been derived and subsequently interpreted in terms of relative regional vulnerability. The results gained within the case study imply that the region under consideration is affected by the changing climate and is vulnerable to this climate change to a certain extent. These conclusions are based on the following aspects:

- Firstly, the number of days at which some portion of the population feels discomfort (measured by the so called Thom's discomfort index that includes the parameters air temperature and relative humidity) is expected to increase during the summer months July and August, which represent the most important months for tourism at Lake Balaton and Veszprém. The adaptation potentials of that problem are limited. However, there are some aspects making the problem of the uncomfortable days rise less severe. Firstly, the northern Adriatic Sea, which represents the destination Lake Balaton is directly competing with, will face similar problems. Secondly, lake tourism in the region under investigation could benefit from the fact that the increase in the number of uncomfortable days, as projected by the regional climate model REMO for the IPCC emission scenario A1B, is higher in Budapest than at Lake Balaton. Thus, the increased demand of the city dwellers fleeing from uncomfortable conditions can be expected. Thirdly, rising air temperatures are expected to lead to extensions of the peak season and increasing numbers of trips outside the season – therefore, commercial establishments would be economically viable for a longer period in the year and employment possibilities would persist for a longer stage.
- Regression analysis indicates that the impacts of changes in the mean air temperature as simulated by the regional climate model REMO for the IPCC emission scenario A1B and the climate model LMDZ for the IPCC emission scenarios A1B and B1 on tourism performance are almost negligible. However, as the region is more vulnerable to changes in extreme than in mean climatic conditions, more significant economic impacts could result in case of an increased occurrence of long dry and hot periods, causing a downturn of the coastline.
- According to the comparative analysis of the endogenous regional adaptive capacity (Fig. 22), the NUTS III region Veszprém counts to the cluster of Industrial Centres that shows a diverse economy and a high socio-economic standard. Although the regional dependency on tourism is far beyond average compared to other CLAVIER regions classified as an Industrial Centre, it is lower than in Tourist Centres. Thus, the regional potential to cope with a certain shock is evident. Besides, the structural framework of tourism has changed dramatically within the last decade and the structural change is still ongoing: the quality of

the touristic capacity is constantly improving, the share of overnight stays in the 4/5 star category is constantly rising, the importance of camping dwelling and private accommodation is declining. In addition, the significance of non lake touristic activities, which are not that climate sensitive, is growing (e.g. spa, wine and village tourism). Consequently, the direct dependence on climate sensitive recourses of tourism is slightly declining in Veszprém.

Summarizing, even positive effects could emerge from the climate change if Veszprém uses its adaptive capacities as industry centre and if the transition of Veszprém (and Lake Balaton) to an all-year tourism destination succeeds.

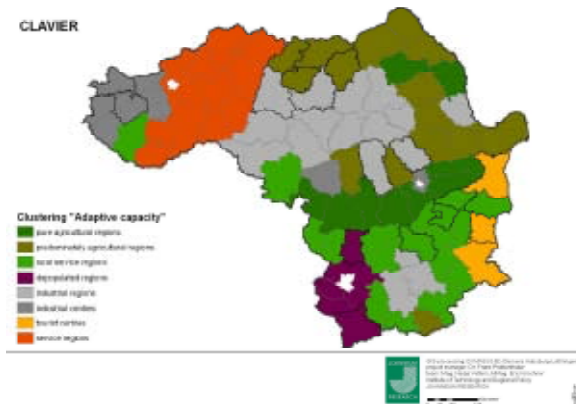


Fig. 22. Identification (clustering) of CLAVIER regions (NUTS III) of similar adaptive capacity by means of cluster analysis. The endogenous absorption capacity of regional economies with respect to macroeconomic shocks from climate change has been compared by using indicators such as employment shares, value added, the level and growth of GDP per capita, touristic capacities and accessibility. The clusters ordered according to their endogenous relative adaptive capacity (ERAC): Depopulation Regions < Pure Agricultural Regions ≈ Rural Service Regions < Predominately Agricultural Regions < Industrial Regions < Tourist Centres < Industrial Centres ≈ Service regions.

3.4. Public Sector

A well implemented plan how to lessen the economic risks from the extreme events within the society and/or transfer them from the victims to the financial markets is a fundamental adaptation measure that crucially is been discussed. It aims at a fair distribution of the cost of the impact of climate change. The list of institutions (such as insurance) that can deal with the rising economic risks of extreme events financially is short, the public sector – besides institutions of the civil society – is the only remaining provider of (ex post) risk transfer that cares for victims. Thus, the public sector case study aims at examining the institutional setting of risk transfer in the three CLAVIER countries and the funds that are used to deal with such emergencies in order to gain insights into the vulnerability of the public sector and also the society as a whole to extreme weather events.

In Bulgaria, insurance against natural hazards is voluntary. Due to long and complicated procedures there exists little confidence in the private insurance market. Thus, catastrophe insurance penetration regarding natural hazards is quite low. Only about 7 % of the Bulgarian homeowners are insured against damages arising from natural disasters. Because of the low insurance penetration, the Bulgarian government has provided financial

assistance to uninsured homeowners after the floods in recent times. However, this is a strategy the Bulgarian state actually cannot afford, since the financial capacity to cope with major disasters is quite low anyway. The budget position “Reserve for unforeseen and urgent expenditures”, which serves the purpose of guaranteeing stability in the process of the budget’s execution as well as envisaging expenditures for the prevention and elimination of natural disasters and major industrial accidents, shows that there is a huge discrepancy between the annual planned emergency budgetary allocations and the potential economic losses. For instance, covering the economic damages that resulted from the floods in 2005 (€ 520 million) would have required about 20 times the reserves budgeted for natural disasters in 2005 (Table 3.)

Table 3. Reserves budgeted for natural disasters

	2005	2006	2007	2008	2009
Reserve for natural disasters (mill. BGN)	55.5	120	70	80	90
Reserve for natural disasters (mill. EUR)	28	61	36	41	46

Source: Bulgarian Ministry of Finance

Due to the low financial capacity of the government to cope with major disasters, several proposals about the reform of the risk transfer scheme have appeared recently, ranging from the installation of a national catastrophe insurance pool similar to the Turkish or the (planned) Romanian scheme to the participation in the regional catastrophe insurance program the World Bank is developing for South Eastern Europe.

As to Hungary, insurance penetration regarding the natural hazard the country is mostly at risk of, namely floods, turns out to be quite high, but the coverage offered by the private insurers is extremely limited. In addition, people living in poor areas that are highly exposed to floods often have no access to private insurance. Since 2003, there exists a state fund – the Wesselényi Miklós Flood and Inland Waters Compensation Fund – in addition to private insurance that deals with homes situated in highly exposed flood plains, which have difficulty in getting private insurance cover. However, as the fund is mainly financed by the state budget (Table 4) the public sector’s vulnerability remains.

Table 4. Revenues of the Flood and Inland Waters Protection Fund by legal title, in million HUF

	Revenues 2004	Revenues 2005	Revenues 2006	Revenues 2007
Regular payments	1.6	1.5	2.2	6.1
Non-regular voluntary payments	0.0	0.0	0.0	0.0
Central budgetary subsidy	100.7	84.5	98.5	79.0
Not identified revenues	12.0	0.0	0.0	0.0
Subtotal	114.3	86.0	100.7	85.1
Pending items	0.0	0.0	1.8	0.0
Total revenues	114.3	86.0	102.5	85.1

Source: Hungarian Ministry of Finance

In Romania, a definite reform process regarding the financial risk transfer mechanism with respect to natural hazards is in progress. It is being worked out on establishing the national catastrophe insurance pool founded through the affiliation with insurance companies. The way things are at the moment (effective July of 2009) household insurance against certain natural risks, namely earthquakes, floods and landslides, is expected to become mandatory since on the 1st of January 2010. The whole system of mandatory household insurance will be guaranteed by the state, a reinsurer of the last resort.

At the moment there are still some unresolved problems with respect to the new system, which could delay or even threaten its implementation. However, if these problems are successfully solved, the new system is likely to increase the adaptation capacity considerably and thus decrease the vulnerability of the public sector and the society as a whole, since at the moment, with household insurance being voluntary yet, only 11-12 % of the 8 million homes in Romania are insured.

4. Dissemination of the CLAVIER results: Cooperation with stakeholders

A substantial part of the project was the establishment of close contacts with wide range of user groups from CEEC, who can directly benefit from the CLAVIER results. This strategy has been thoroughly followed: with the help of the project partners, stakeholders from Bulgaria, Hungary and Romania have been identified and contacted on all national and regional levels.

Three workshops have been dedicated to this aim in Hungary (2009), Romania (2008) and Bulgaria (2007) in cooperation with the CLAVIER annual meetings. The workshops were organised to bring together a wide range of actors within different economic sectors, e.g. tourism, agriculture, energy, public sector. The workshops raised awareness and interest in the quantitative assessment of the climate change in general and the CLAVIER project in particular. These meetings indicated that the CLAVIER research objectives were responsive to actual needs within the case study regions. Climate change was not only considered through the results of the regional climate models (which are the primary tools for the provision climate scenarios for the future), but the impact studies were performed on some specific areas (hydrology, tourism, energy sector etc.) and moreover vulnerability assessments were also analysed in order to quantify the positive and negative financial (economical) impacts of the climate change on these areas of interest.

Furthermore, the developments made by the CLAVIER project came at a timely juncture too, with those National Climate Change Strategies, which are on the table for the target countries (and which were unanimously accepted in Hungary by the Parliament in Spring, 2008). Additionally CLAVIER methodology and results might serve as valuable examples in the public education process: for the general public, but also for the universities.

It is finally recalled that even though the CLAVIER project is going to be completed at the end of August, 2009, the participating institutes would like to continue to keep in contact with all stakeholders.

4. News: Special Issue at the Quarterly Journal of the Hungarian Meteorological Service (Időjárás)

In February, 2008 on behalf of the CLAVIER project the Hungarian Meteorological Service organised a Regional Climate Modelling mini-workshop (more details about the workshop can be found at <http://www.met.hu/seminars/rcm2008.php>). During the workshop it was decided that the Quarterly Journal of the Hungarian Meteorological Service (Időjárás) will devote a Special Issue for the scientific papers to be prepared based on the presentations on the workshop. The papers can be accessed through Internet at <http://www.met.hu/Journal-Idojaras.php> or at http://omsz.met.hu/idojaras/IDOJARAS_vol112_No3-4.pdf (the entire volume).

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