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ANALYSIS OF THE IMPACT OF CLIMATE CHANGE ON TOURISM IN SOME EUROPEAN COUNTRIES

Maria Carmen IORDACHE*, Iuliana CEBUC**

Abstract

The world's climate is changing at unprecedented rates affecting nearly every industry globally. Tourism, because of its strong connection to the natural environment is particularly susceptible to climate change.

The paper outlines the conceptual framework of the different types of climate change impacts and justifies the necessity of economic impact studies, especially on a local level. Results of a number of impacts studies on a global level (about international tourist flows and expenditures), as well as on a European and country level (both about summer and winter tourism) have been examined.

However, the purpose is not to give single values of damage or impact of climate change, but to explore the plausible ranges of impacts. In conclusion, the paper presents the expected results of a new research project – CLAVIER (Climate Change and Viability: Impacts on Central and Easter) funded by the 6th Framework Programme and aiming at filling in the research gap concerning studies on a local level, related especially to economic impact and vulnerability issues.

Keywords: climate change, impact, tourism, effects of climate change on tourism, Central and Eastern European, CLAVIER project.
JEL classification: L83, Q54

1. Introduction

There are four complicated interactions between tourism development and climate change, ranging from natural, external phenomena to those resulting from human behaviors:

1. ***Direct impact*** (Scott, D. et al., 2004, Amelung, B. and Viner, D., 2006, Amelung, B. et al., 2007) from weather phenomena caused by warming: destruction wrought by floods, storms, fires and drought, glacial lake overflows, the disappearance of beaches and so on.
2. ***Indirect, long-term impacts*** resulting from a substantial and lasting alteration of the environment of a tourist destination that reduces its attractiveness (polluted waters, receding forests, decreased biodiversity, retreating glaciers and snow caps, etc.).
3. ***Lifestyle changes***, causing, for example, the reorientation of tourism flows both in winter and summer.
4. ***Induced impacts***, which include the efforts of individuals and public policies aimed at attenuating the effects of warming that produce a series of consequences for tourism

* **Maria Carmen IORDACHE** (iordache72@yahoo.com) , PhD, Lecturer , "Constantin Brâncoveanu" University of Pitesti, Faculty of Management and Marketing, Ramnicu Valcea.

** **Iuliana CEBUC** (iuliacebuc@yahoo.com), PhD, Lecturer , "Constantin Brâncoveanu" University of Pitesti, Faculty of Management Marketing , Ramnicu Valcea.

activity: for example, the adoption of new, more energy-efficient technologies, increased transport costs, product-diversification efforts aimed at prolonging a season and reducing vulnerability, etc.

Given the complexity of these interactions, we can see that climate change will produce winners and losers in the tourism industry. In contrast to such events like natural disasters and terrorist attacks (and even health issues such as SARS), climate change is not simply a short-term issue; it will permanently alter the attraction of some holiday regions and force them to take adaptive steps over the next few decades (Gössling, S. and Hall, C. M. 2006, Scott, D. 2006, Becken, S. and Hay, J. 2007)

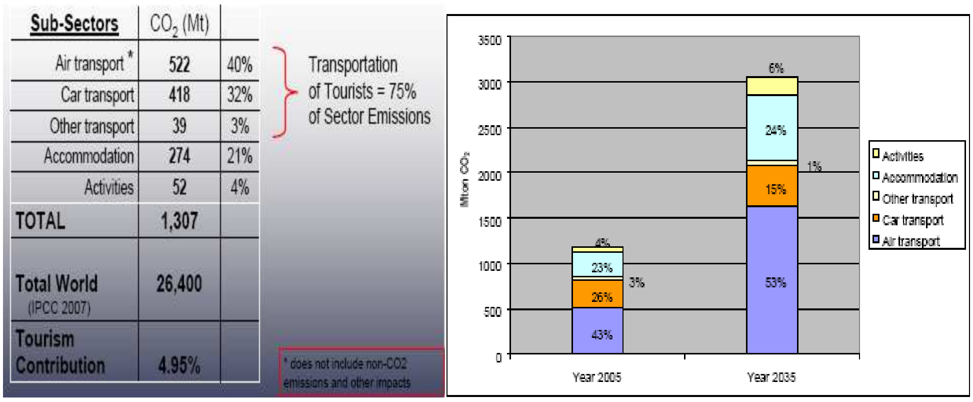
Heymann (2008) believes the tourism industry will still be a growth engine in the world, experiencing average annual increases of around 3.5% to 4% in international tourist arrivals through 2020, but he also forecasts substantial changes in tourist flows by region and within regions of the world based on a comparative scoring model developed by DBR.

The DBR model compares the most important countries in the mainstream tourism sector to 2030. The model is based on four quantitative and qualitative parameters:

1. Consequences of climatic changes, including substitution effects;
2. Consequences of regulatory measures to slow climate change and/or mitigate its negative effects (in particular, the increase in the price of mobility);
3. Possibility of adaptation to the changing conditions open to individual regions;
4. Economic dependence of tourist destinations on (climate-sensitive) tourism.

The warming trend through Europe is well established (+0.90°C for 1901 to 2005) and the recent period shows a trend considerably higher than the mean trend. Precipitation trends are being variable and the number of extreme weather events has been increasing. According to the IPCC Fourth Assessment Report wide ranging impacts of changing in current climate in Europe have been documented for the first time: retreating glaciers, longer growing seasons, shifts of species ranges, and health impacts due to a heat wave of unprecedented magnitude.

Nearly all European regions are anticipated to be negatively affected by some future impacts of climate change and these will pose challenges to many Economic sectors (Alcamo at al, 2007). According to a research carried out by UNWTO (2007) CO2 emissions from international tourism including all forms of transport accounted for just under 5% of the world total or 1,307 million tonnes in 2050.



Sub-Sectors	CO_2 (Mt)	
Air transport *	522	40%
Car transport	418	32%
Other transport	39	3%
Accommodation	274	21%
Activities	52	4%
TOTAL	1,307	
Total World (IPCC 2007)	26,400	
Tourism Contribution	4.95%	

Figure 1 - Emissions from global tourism, 2005/2005 & 2035

Transport accounts for 75% of all emissions by the tourism sector, with aviation making up about 40% of all tourism emissions, road transport 32% and other forms of transport 3% (figure 1). Accommodation represents about 21% of total tourism sector emissions. Emissions from tourism are also predicted to grow rapidly, with an increase of 152% predicted between the years 2005 and 2035 without concrete action to reduce them.

Emissions from tourism are far below many other sectors, such as agriculture with 15% of global emissions. However, apart from transport emissions, tourism is a relatively clean activity – one that governments around the world encourage as an alternative to heavy industry. Clean environment and favourable weather conditions are crucial to visitor satisfaction and fundamental factor for the development of the tourism sector. Therefore, tourism is more a victim, than a vector of climate change. The purpose of this paper is to outline the current sensitivity and future impacts of climate change on tourism activities in Europe based on results of existing studies and to present the expected results of a new research project – CLAVIER.

2. Impacts and global trends

Climate impact is the consequences of climate change on natural and human systems (IPCC, 2001). Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts. Impacts can generally be described quantitatively by changes in biophysical indicators (e.g., the primary productivity of an ecosystem, snow cover depth) or in socio-economic indicators (e.g., the revenues from ski tourism, effects on the gross domestic product) (Füssel et al. 2006). Potential economic impacts could be defined as a function of the exposure of human (socio-economic) systems and their sensitivity to climatic stimuli. Most of these impacts in tern will lead to economic costs. These economic costs of climate change are often known as the “costs of inaction” and they are very important to inform the policy debate on adaptation and to identify key areas of concern (EEA, 2007) However, most of publications are dedicated to biophysical impacts only. There are few studies on economic impacts, including the impacts on tourism, mainly on a global or regional scale. For example, a study by Bigano et al. (2006) simulates the effects of development and climate change on tourism. The model predicts shifts in international tourist flows towards higher altitudes and latitudes. Climate change could negatively affect countries and regions that depend heavily on incomes from tourism and could also bring benefits to places that are currently not popular with tourists. The authors use a statistical model (Hamburg Tourism Model, version 1.2.) which goal is to describe, at a high level of geographic disaggregation, the reactions to climate change of tourist behaviour, both in terms of changes in their (domestic and international) numbers and in terms of changes in their expenditure decisions. First, the authors construct a matrix of tourism flows from one country to the next. Second, they perturb this matrix with scenarios of population, income, and climate change. Third, the resulting changes in the average length of stay and expenditures have been computed.

Some characteristics of the A1B scenario without climate change for 16 major world regions are shown on Figure 2.

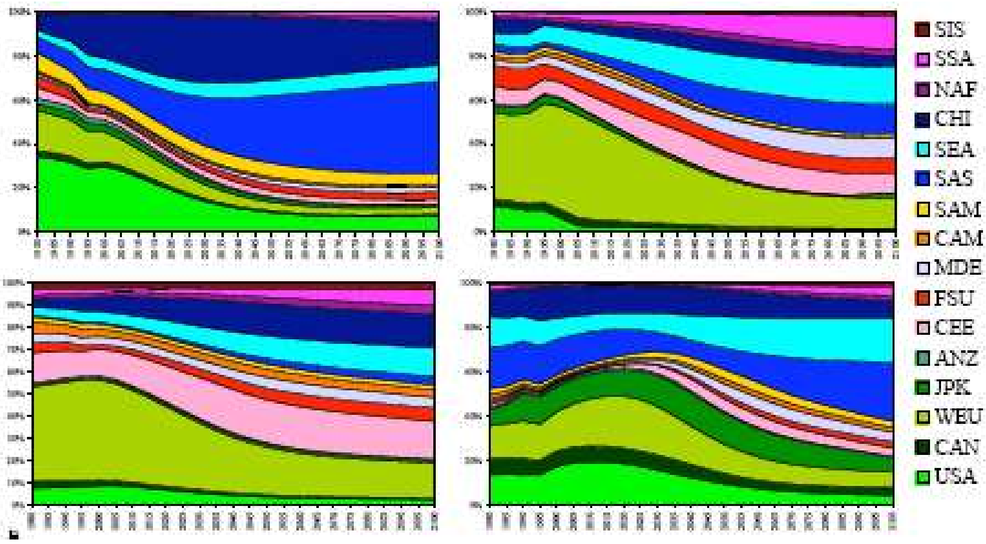


Figure 2 - The regional distribution of domestic tourists (top, left), international departures (top, right), international arrivals (bottom, left) and tourism receipts (bottom, right) for the A1B scenarios without climate change*

* The regions are, from top to bottom: Small Island States; Sub-Saharan Africa; North Africa; China, North Korea and Mongolia; South East Asia; South Asia; South America; Central America; Middle East; Former Soviet Union; Central and Eastern Europe; Australia and New Zealand; Japan and South Korea; Western Europe; Canada, and the USA.

Currently, the regions at the bottom of the graph (including OECD and Central and Eastern Europe) dominate tourism, with over half of world tourists but only a fraction of the world population. However, their share has been declining over the last 20 years, and will continue to do so. According to the Hamburg Model for most of the 21st century, tourism will be predominantly Asian. The pattern of receipts from domestic and international tourists is different. Here, the OECD first expands its market. The model predicts that after 2030 the other regions, but particularly Asia, capture a larger share of the market. While the world aggregate number of domestic tourists hardly changes due to climate change, individual countries may face dramatic impacts that grow rapidly over time. According to the model, currently colder countries will see an increase in domestic tourism; warmer countries will see a reduction.

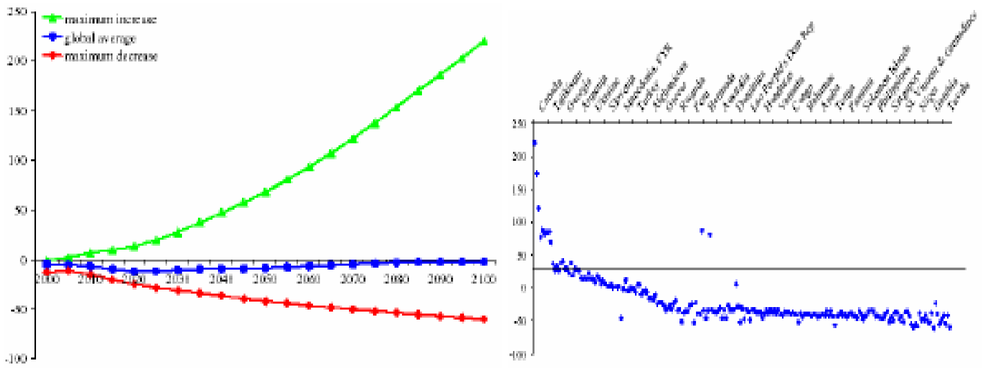


Figure 3 - The effect of climate change on international tourist arrivals, as a percentage of the numbers without climate change; top panel: world average, maximum increase, and maximum decrease; bottom panel: impact in 2100, countries ranked to their annual average temperature in 1961-1990.

Figure 3 shows the impact of climate change on international tourism arrivals, both over time and over space as predicted by the Hamburg Tourism Model. Aggregate international tourism falls because of climate change, reaching a maximum decrease of 10% below the scenario without climate change around 2025, and edging towards zero after that.

Aggregate international tourism falls because more tourists stay in their home country, particularly tourists from Germany and the UK, who make up a large part of international tourism. By 2100, for individual countries, international arrivals may fall by up to 60% of the base value or increase by up to 220% of the base value. Climate change increases the attractiveness of cooler countries, and reduces that of warmer ones.

According to the model world aggregate expenditures hardly change, first rising slightly and then falling slightly. The relationship between current climate and impacts of climate change, however, is a lot noisier for expenditures than for international arrivals and domestic tourists.

3. Expected impacts in Europe

The majority of tourists in central and eastern European countries are attracted by the culturally important cities, such as Prague, Budapest, Warsaw, Moscow, St Petersburg and the Baltic capitals.

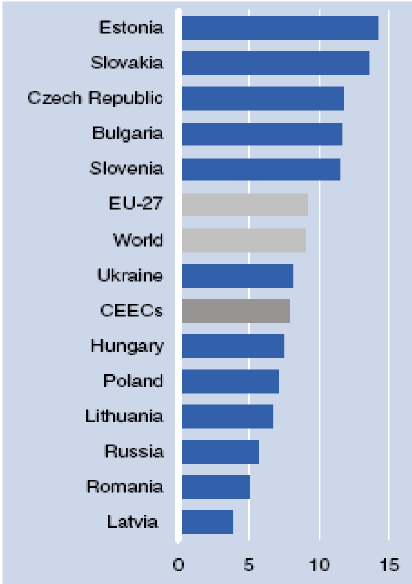


Figure 4 – Dependency on tourism differs in Eastern Europe; % of GDP from tourism, 2007

From this point of view, the region is less sensitive to climate change. However, with rising incomes, tourist centres are increasingly being built and expanded in favourable geographic locations.

Parts of these regions will experience climate change. In the future, for instance, the Baltic States – so far characterised by cultural and rural tourism – could attract more seaside tourists. The Polish coast could also benefit. Countries bordering the Black Sea (Bulgaria, Romania and the Ukraine) could also expect beneficial effects from climate change for their regions. Primarily, they could attract seaside holidaymakers away from the hot eastern Mediterranean area – e.g. Greece and Turkey. Low prices will help this. Climatic conditions will also improve in Russia, which attracted more than 20 million foreign tourists in 2006 – as many as Austria. Nevertheless, it is usually dominated by types of travel that are highly insensitive to climate.

The summer convalescence and health tourism in lake and mountain landscapes is the second most important in Eastern Europe. Lake Balaton in Hungary – the largest lake in central Europe – is, for instance, an immensely important tourist destination in the country. However, rising temperatures and reduced amounts of precipitation represent a risk for the very shallow lake: increased evaporation would make it even shallower. In the long term, this could interfere with water sports.

Winter sports tourism is widespread in a few areas of the Carpathians. However, many of the skiing areas in these countries are at such low altitudes that, like parts of Austria, they could have problems with snow reliability by 2030. Nevertheless, winter sports tourism represents only a small part of the total revenues from tourism.

Overall, climate change could increase the touristic appeal of the central and eastern European countries. Only minor effects are expected from climate change though, as cultural tourism, which is not dependent on climate, is more important. Increasing summer temperatures will result in a positive effect for northern regions like the Baltic. However, in many regions summer tourism is still in its infancy.

Negative climatic consequences always have particularly serious effects (Heymann E., 2008) where climate-sensitive tourism has a large economic weighting (figure 5). In Europe this is in Malta, Cyprus, Spain, Austria and Greece. In the Caribbean, this category includes e.g. the Bahamas and Jamaica. In Asia this applies to Thailand and Malaysia; in Africa to Tunisia and Morocco. Countries particularly dependent on (climate-sensitive) tourism are the island states in the South Pacific and even more so those in the Indian Ocean (primarily the Maldives and the Seychelles). Even though the climatic effects will not be "life threatening" there until 2030, the message is however clear: if climate change means that the tourists stay away, there are considerable negative effects on the whole economy.

Among the countries that will experience positive climatic effects by 2030, Estonia (partly because of its proximity to Finland), Slovakia, Switzerland and New Zealand are the most dependent on tourism. In the European countries, in Canada and in the USA, tourism is of below average significance. Due to the expected substitution effects, the significance of the tourism industry in many "winning" countries could, however, increase in the coming decades as a consequence of climate change.

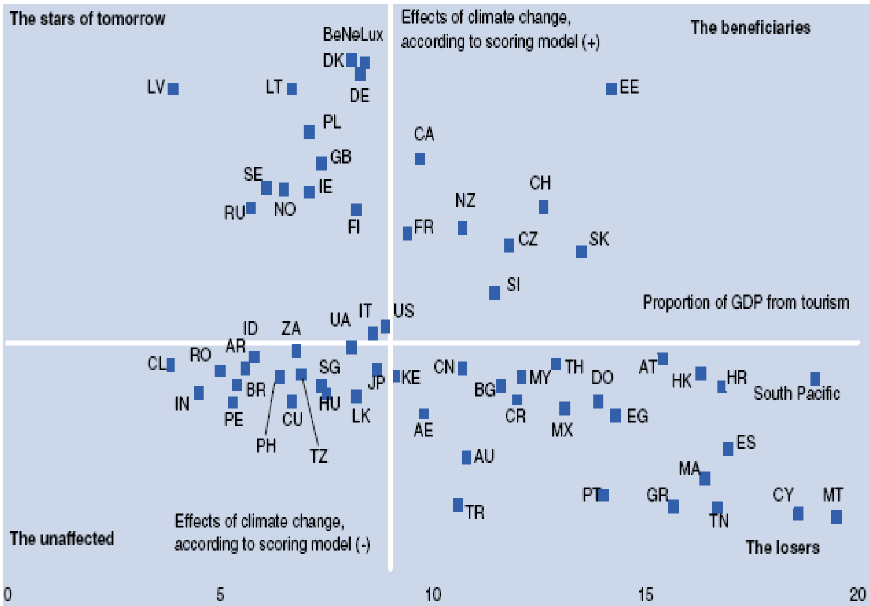


Figure 5 - More losers than winners from climate change

Assessment based on the effects of climate change according to the DBR scoring model (ordinate) and % of GDP from tourism (abscissa: global average: 9%)

The graphic shows all the countries that we have investigated in our scoring model, with the exception of the island states in the Indian Ocean (Mauritius, the Seychelles and the Maldives), Jamaica and the Bahamas. These five countries are also in the group of losers.

They are negatively affected by climate change and have a particularly high economic dependence on tourism. For reasons of scale we have not included them in the graphic.

According to our survey, other gainers include the Czech Republic, Slovakia and Estonia. It must be pointed out that the predominant forms of travel in these countries are less climate-sensitive than for instance in the Mediterranean countries.

The Hamburg Tourism Model predicts drastic differences across the countries in the world. Thus, a closer look on expected impacts in Europe is necessary. There are studies about the whole continent, as well as about specific regions (mainly the Alps and Mediterranean) covering both the effect on summer and winter tourism. The major effects that could be expected are summarised in Table 1.

Table 1 - Potential effects of climate change on economic activity in the tourism sector

Geographical location	Main climatic drivers	Expected potential impacts on economic activity	Level of confidence
Nordic regions, Eastern Europe	Rising temperature, changes in precipitation	Positive impact on tourism demand	Medium
Mediterranean regions, costal resorts	Rising temperature, changes in precipitation, sea level rise	Negative impact on tourism demand during summer	Medium
	Rising temperature in summer	Negative impact on tourism demand during summer, positive impact in spring and autumn	Medium-low
Low altitude mountain resorts	Rising temperature, changes in precipitation	Negative impact on winter tourism activities	Medium-high
High altitude mountain resorts	Rising temperature, changes in precipitation	Possible positive impact on snow-related activities	Medium

There are no specific studies about the economic impacts on the tourism sector in Bulgaria; however, we can draw some general conclusions from the table above. It is quite probable that the traditional mountain winter resorts at low altitudes and summer destinations on the Black sea will suffer from uncomfortable tourist conditions, while new destinations in the countryside offering alternative forms of tourism and summer mountain vacations might benefit from climate change.

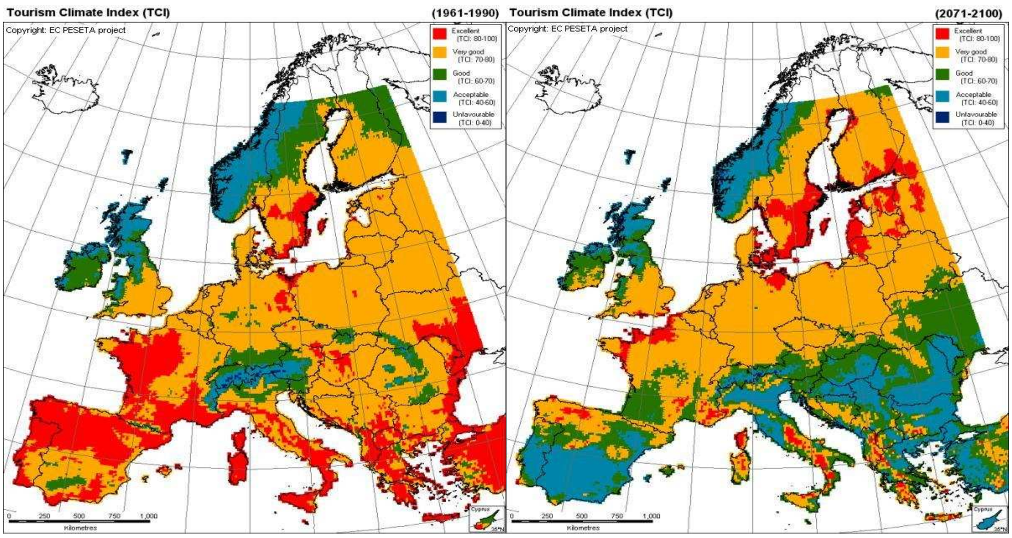


Figure 6 - Simulated conditions for summer tourism in Europe for 1961-1990 (left) and 2071-2100 (right) according to a high-emissions scenario (IPCC A2); climate data from PRUDENCE project

The expected adverse effects on the beach tourism on the Black sea are confirmed also by the PESETA project[1]. The project makes a multi-sectoral assessment of the impacts of climate change in Europe for the 2011-2040 and 2071-2100 time horizons, firstly, by assessing the physical impacts and, secondly, by valuing them in monetary terms. However, the purpose of the study is not to give single values of damage or impact of climate change, but to explore the plausible ranges of climate change impacts. Preliminary results are shown on Figure 6. The tourism study aims at modelling the major flows of tourism in Europe so that the influence of the climate is explicitly considered.

Coastal tourism, a dominant segment of the tourism market, has a marked seasonal and spatial concentration. In PESETA project the climatic suitability for general summer tourism purposes is expressed as an index, the Tourism Climate Index (TCI), comprising the climate features temperature, humidity, sunshine, rain and wind. Monthly climate data is used with a spatial resolution of 12 km. The maps represent summer conditions (June, July, August). The main information these maps provide is the direction of these shifts. Some regions see their climatic attractiveness improve in summer, with other regions (such as the Balkans) facing deterioration. The TCI for the Black Sea is projected to decrease by four degrees from Excellent TCI: 80-100 to Acceptable TCI: 40-60. The maps indicate significant shifts in the climatic suitability for tourism, with the belt of excellent summer conditions moving from the Mediterranean towards northern Europe. In the shoulder seasons (spring and autumn, not shown here), TCI scores are generally projected to increase throughout Europe.

The authors point out that the maps only provide projections of climatic suitability patterns, and not of the economic significance of climate change for tourism. The study is based on only one emission scenario and one climate scenario, also does not take into account extreme weather events.

Winter tourism is a special topic of research interest. Studies show that there is a statistically significant trend in snow-cover reduction in the Alps over the recent years. A number of authors study the impacts of climate change on winter tourism especially in Austria and Switzerland.

Breiling and Charamza (1999) have studied the seasonal snow cover depth related to altitude and develop a regionalised model for Austrian snow conditions. The snow model covers three steps. In the first step the authors have modelled the relation of snow to temperature and precipitation at each snow station under consideration. In the second step they have modelled the best fit of all stations to a regional dependence of snow cover and altitude. In the third step they have used a scenario for temperature and precipitation change and computed a new snow-cover depth. Then they have looked at what altitude they find this snow-cover depth today. At about 2000 m altitude a warming of 2°C does not seem problematic concerning the amount of snow. The authors predict that at this degree of warming almost half of the annual values of snow will remain in the range of 1965 to 1995 values. Thus, in Austria they could occasionally find good winter seasons, but they cannot count on a regular appearance like during 1965 and 1995. In fact, according to the authors it is the frequency of good and bad seasons that will determine the future of resorts. The development of Austrian winter tourism and skiing infrastructure during the last 30 years was changing in accordance with the decade temperature variation. The period 1965-1985

[1] PESETA (Projection of Economic impacts of climate change in Sectors of the European Union based on boTtom-up Analysis) – see details and preliminary results on http://peseta.jrc.es/index.html

was a relatively cold one. At that time an expansion of ski lifts occurred. The period 1985-1995 was considerably warmer. Most winter resorts had snow problems during this time, many of them serious ones. Artificial snow making became popular. Breiling and Charamza point out that just 0.8 °C warming necessitated strong adaptation and the impact of 2 °C warming could leave only a few locations suitable for winter tourism and skiing – restricted to high altitudes.

The impacts of snow-deficient winters at the end of the 1980s on the winter tourism industry in Switzerland have been examined by Koenig and Abegg (1997). The study shows that ski areas in lower areas suffered severe consequences. The authors assess the snowreliability of ski areas assuming the 100-day rule. This rule states that to operate a ski area with profit, snow cover sufficient for skiing (i.e. 30cm) should last at least 100 days per season (between the first of December and the end of April). Different studies showed that most of the Swiss ski areas above 1200m have matched the 100 days-rule in the past and that a minimum altitude of 1200m ('line of snow-reliability') is required in order to operate a financially viable ski industry under current climate conditions in Switzerland. If significant atmospheric warming were to take place (+2ºC) the snowline in the Central Alps would rise by 300m. The study shows that 85% (195 of 230) of the ski areas in Switzerland are snowreliable at present. If climate change should occur as outlined above, the number of snowreliable ski areas would drop to 144 (= 63%). The corresponding figures for single ski-lifts are 40% and 9% respectively. On a regional level stronger consequences could be expected.

This is likely to threaten the regionally balanced economic growth in Switzerland which winter tourism has provided.

A number of studies cover also other climate related consequences that are likely to affect tourist flows, e.g. water shortages in southeast Mediterranean, threats to cultural heritage, biodiversity (see summary in EEA, 2007).

4. CLAVIER project – expected results

The nations in Central and Eastern Europe (CEE) face triple challenges of the ongoing economic and political transition, continuing vulnerability to environmental hazards, and longer term impacts of global climate change. Literature reviews have shown that although there are useful studies on a European level, studies based on detailed regionalized climate models for CEE (incl. Romania and considering especially the economic impacts of climate change are lacking. CLAVIER project (Mishev P., Mochurova M., 2008).

The CLAVIER project is supported by the European Commission's 6th Framework Programme as a 3 year Specific Targeted Research Project from 2006 to 2009 under the Thematic Sub-Priority "Global Change and Ecosystems". Researchers from six countries and different disciplines investigate linkages between climate change and its impact on Central and Eastern Europe (CEE). Three representative countries are studied in detail: Romania, Hungary and Bulgaria (figure 7).

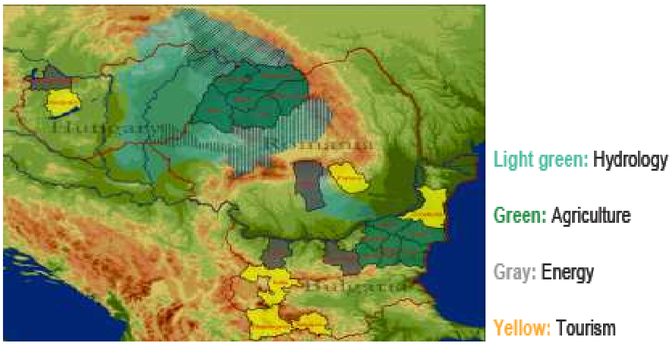


Figure 7 - CLAVIER target regions

The project is coordinated by Max Planck Institute for Meteorology, Germany.

Partners from Romania are the National Institute of Hydrology and Water INHGA Romania Management, Bucharest, the Babes-Bolyai University of Cluj and the Institute of Geography of the Romanian Academy.

CLAVIER addresses the following three scientific goals:

- Investigation of ongoing and future climate changes and their associated uncertainties in Central and Eastern European Countries (CEEC)
- Analyses of possible impact of climate changes in CEEC on weather pattern and extremes, air pollution, human health, natural ecosystems, forestry, agriculture and infrastructure as well as water resources
- Evaluation of the economic impacts of climate changes on CEEC economies, concentrating on four economic sectors, which are agriculture, tourism, energy supply and the public sector.

In the framework of CLAVIER, ongoing and future climate changes are analysed based on existing data and climate projections with very high detail to fulfil the needs of local and regional impact assessments.

CLAVIER project is divided into eight work packages (WP). Seven of these WPs are research topics introduced in detail below. WP0 covers a set of horizontal activities, including the internal co-ordination of the project and communication with external stakeholders.

WP1: Climate change simulations and assessment of uncertainties

The first work package of CLAVIER is designed to perform climate change simulations, to assess uncertainties and to provide relevant future climate scenarios for impact communities. The mandatory experiments to be performed consist of an ensemble of 8 simulations covering the period 1951 to 2050. This ensemble is the cross product of 2 greenhouse-gas-emission scenarios (A1B and B1 from IPCC), 2 global ocean-atmospherecoupled models (MPI-M and IPSL), and 2 regionally-oriented climate models (REMO from MPI-M and LMDZ from IPSL).

WP2: Optimized input data for climate impact studies from regional climate models

CLAVIER is conducted by an interdisciplinary team involving scientists with very different methodological backgrounds. A crucial part of the project is the establishment of an effective interface between the project participants, particularly those from the climate modelling and the climate impact assessment communities. Climate model – climate impact interfaces are realised by dynamical and statistical techniques.

WP3x: Impact studies

The objectives of different WP3x are to make impact studies – weather regimes and their implication to air pollution levels; impact of climate change on extreme events, incl. the summer drying problem; changes in the hydrological regime of various catchments and in riverine flood characteristics; impacts on ecosystems (lowland and wetland damages, migration of invasive species, pests, insects); local air quality; infrastructure; human health.

WP4 Economic Vulnerability of CEE societies and economic impact assessment

The main objective of WP4 is to evaluate the economic impacts of climate change in Romania, Hungary and Bulgaria on tourism, agriculture, energy and the public sector. The Romania are going to study climate change impacts on winter tourism at the Carpathians and summer tourism at Constantza. The Bulgaria takes part in the WP4 with the task to investigate climate change impacts on winter tourism in the resort of Bankso, Borovets and Pamporovo and on the development of the regions where the resorts are located. The Hungary are engaged in study the tourism impact Lake Balaton.

In the CLAVIER project, three different regional climate models are used to form a small model ensemble: two versions of the REMO model – figure 8, (REMO5.0 operated at the Hungarian Meteorological Service, REMO5.7 developed at the Max-Planck Institute for Meteorology in Hamburg) and the LMDZ model from CNRS in Paris.

With each of these models, a simulation of a past period from 1961 to 2000 and a long transient simulation for the hundred years of 1951 to 2050 were carried out. Such an exhaustive combination is designed to evaluate the uncertainties existing in the different stages of regional climate change information. Figure 8 shows as example the difference between simulated summer temperatures and the CRU observational dataset [New et al. 2002] for the model simulations performed at the Max-Planck Institute for Meteorology by the regional climate model REMO.

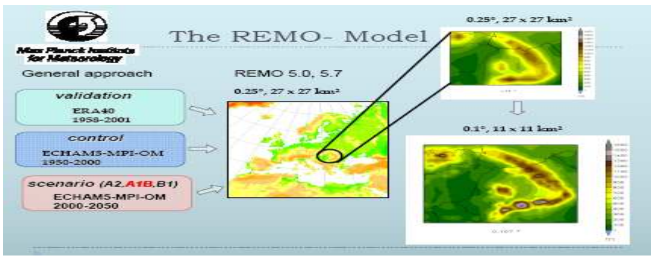


Figure 8 – The REMO Model

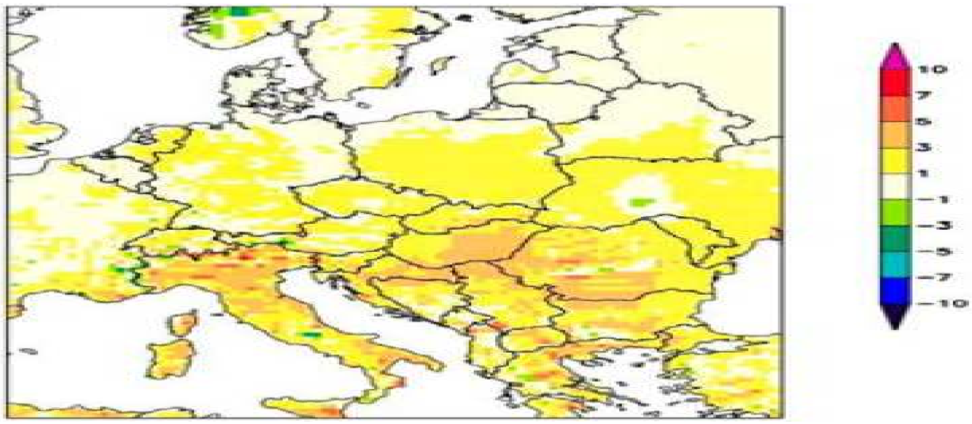


Figure 9 - Difference of the summer mean (2m) temperature (in degree Celsius) between the model results and the CRU dataset for the period of 1961–2000 (JJA mean). The REMO 5.7 experiment was driven by the ERA40 reanalyses

A crucial part of the project is the establishment of an effective interface between the project participants, particularly those from the climate modelling and the climate impact assessment communities. Thus, empirical-statistical methodologies for bridging the "scale-gap" between modelling data and the needs of particular impact studies and for mitigating climate model errors are evaluated and further developed by Wegener Center for Climate and Global Change, University of Graz, Austria (WegCenter). Figure 10 shows the effect of two different empirical-statistical post-processing methods for daily temperature (upper panel) and precipitation errors (lower panel) of a REMO hindcast simulation (black) over Hungary compared to the gridded observational dataset of the ECA&D project [Haylock et al., 2008].

Median errors are displayed together with the 25/75 and the 5/95 quantiles of the errors for the individual seasons and the entire year. While both methods – a multilinear regression approach (MLR, red) and a quantile mapping approach (QM, green) – are very successful in reducing temperature errors, the linear nature of the MLR approach limits the performance of the method with respect to daily precipitation. QM shows good performance for both parameters. Weather regimes are believed to be a main factor in organizing the local weather and climate of Central and Eastern Europe. They are associated with significant anomalies of temperature, precipitation and wind.

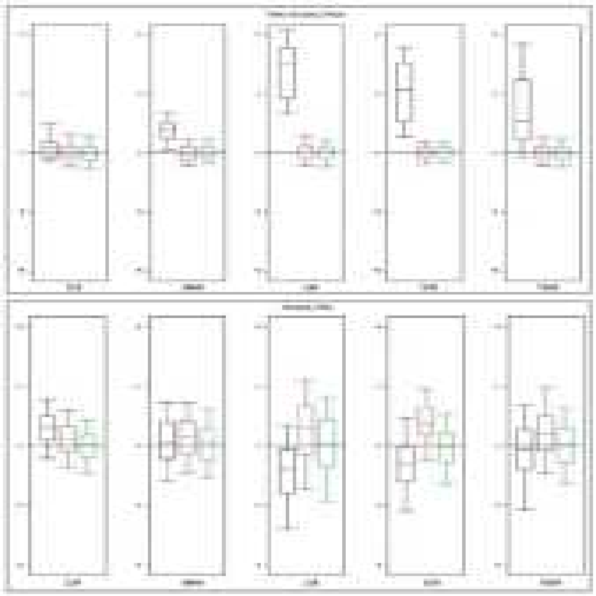


Figure 10 - Seasonal and annual differences between daily temperatures (upper panel) and daily precipitation sums (lower panel) of a REMO simulation (1961-2000) driven by the ERA-40 reanalysis over Hungary (black).

The median, 25/75 quantiles, and the 5/95 quantiles are indicated. The differences after post-processing using and multi-linear regression and a quantile mapping approach are shown in red and green, respectively

Therefore, one CLAVIER objective is to make a complete analysis of weather regimes for the selected region including the study of ongoing and future changes as well as their implication to air pollution levels. Figure 11 illustrates how relative frequency of macro-circulation patterns changes in the last 40 years over the Central-European region.

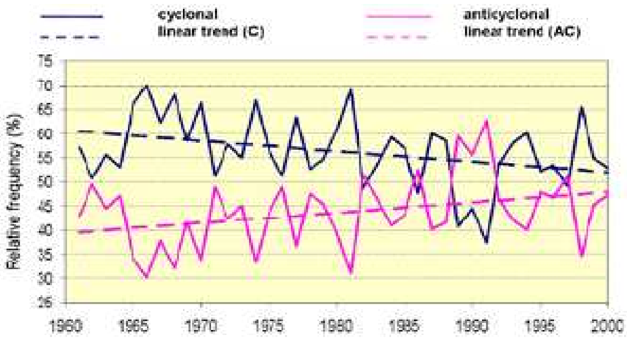


Figure 11 - Annual relative frequency of cyclonic (dark blue) and anticyclonic (pink) Hess-Brezowsky macro-synoptic types and linear trends for the period 1961-2000 over the Central-European region)

These calculations are performed by the Hungarian Meteorological Service (OMSZ) in Budapest. It is generally expected within the climate research community that the frequency of extreme events will be significantly modified under climate change conditions. It could be heavy extra-tropical storms or heavy precipitation events. In the framework of CLAVIER, 24 indices for extreme events have been identified based on the STARDEX definitions and on the requirements of the project partners. They are typical for the CLAVIER study area and mainly based on temperature, precipitation and wind speed. Based on the output of regional climate models mentioned above, CLAVIER aims at the production of future hydrological and agricultural scenarios.

Analysis of the simulation results received from hydrological models serves as direct or indirect input to water management decision support systems. Within the project, the transboundary Tisza Basin and Arges catchments as well as the hydrological regime of Lake Balaton are studied in detail. One example of this study is presented in Figure 12 and shows estimated annual evaporation rates for Lake Balaton. The comparison between observational and simulated data has been done by the Budapest University of Technology and Economics (BUTE).

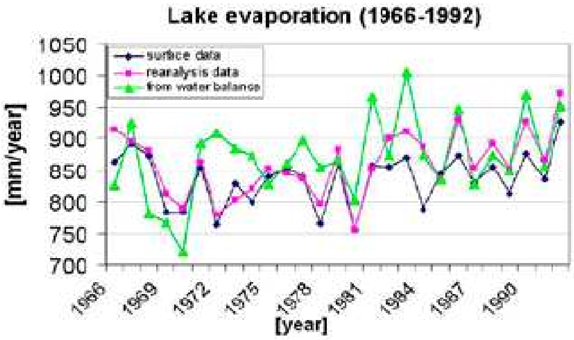


Figure 12 - Estimated annual evaporation rates for Lake Balaton

As it was already mentioned above, one of the main objectives of CLAVIER is to evaluate the economic impacts of climate changes in Romania, Hungary, and Bulgaria. Four economic sectors are of particular interest of CLAVIER: agriculture, tourism, energy supply and the public sector. In addition, the risk transfer mechanisms and institutional settings that can deal with economic risks, e.g. from flood events or droughts, are analysed.

Based on the findings of the case studies, the influence of climate change scenarios on the national economies will be estimated and conclusions on the overall macroeconomic relevance of the studied phenomena will be drawn. Figure 13 shows the case study areas selected in Romania for winter tourism (the Prahova Valley and the limitrophe mountain region Bucegi Mts) and for summer tourism (Southern littoral region, between Constanța and Vama Veche – Constanța County).

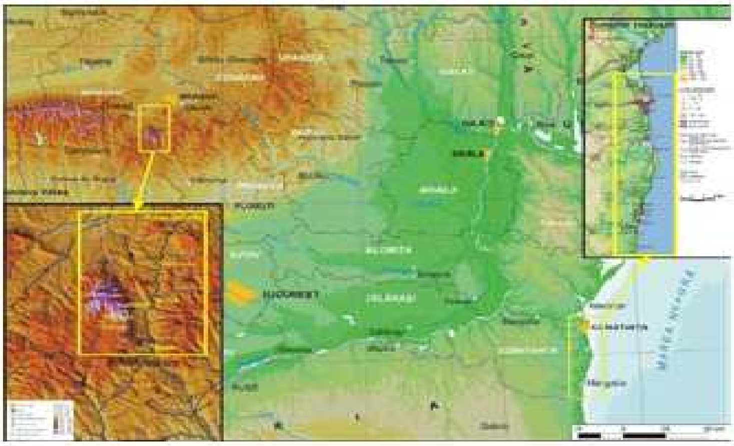


Figure 13 - Case study areas selected in Romania for winter and summer tourism

5. Conclusion

While the world aggregate number of domestic tourists hardly changes due to climate change, individual countries may face dramatic impacts that grow rapidly over time. A number of studies have shown that climate change could negatively affect countries and regions that depend heavily on incomes from tourism and could also bring benefits to places that are currently not popular with tourists.

The economic and societal relevance of climate change for tourism will crucially depend on adaptation strategies. This calls first all, for more detailed studies about economic costs of climate change and the costs of adaptations on local level (region, municipality, single tourist resort) and secondly – for developing new policy frameworks at a European leve and regional level. However, despite the challenges sufficient information is available to start with action now.

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