Climate change adaptation models in Slovakia

Marián Gogola, University of Zilina, Slovakia
Daniela Durcanska, University of Zilina, Slovakia
Marta Hocova, University of Zilina, Slovakia

Occurrence of extreme weather events all over the planet invokes questions about possible future climate changes and their impacts on both global and regional scales. Therefore, contemporary climatological research pays a lot of attention to climate change scenarios with the aim of defining bounds of possible development of futureclimate. For this purpose, the numerical models of climate system are usually used. Impacts and consequences of future climate change on society and enviroment depend not only on the reaction of the climate system to different radiative forcing, but also on the reaction of human society to the new conditions by innovation in the sectors of technology, economy,life style, and policy. Hence, i tis necessary to incorporate socio-economic scenarios in the process of development of climate change projections.

Present paper provide a brief overview about what kind of information can such scenarios provide, what are their limits, how they are constructed and what are the newest findings and progress in this area.

The European Environment Agency (EEA) report presents information on past and projected climate change and related impacts in Europe, based on a range of indicators. The report also assesses the vulnerability of society, human health and ecosystems in Europe and identifies those regions in Europe most at risk from climate change.

The United Nations Framework Convention on Climate Change (UNFCCC) has agreed to limit the increase in global mean temperature since pre-industrial times to less than 2 °C, in order to prevent the most severe impacts of climate change. Current global actions to reduce greenhouse gas emissions ('mitigation') are insufficient to constrain the temperature increase to 2 °C, and global warming could be well above 2 °C by 2100. Even if the 2 °C limit is kept, substantial impacts on society, human health and ecosystems are projected to occur. Adaptation to and mitigation of climate change are therefore both needed. The European Commission has initiated various actions to integrate and mainstream adaptation into EU sectoral policies following the publication of the White Paper on adaptation to climate change in 2009. Furthermore, many countries in Europe have already adopted national adaptation strategies and some have followed up with specific action plans. The European Commission plans publishing its European Adaptation Strategy, which will include further proposals for adaptation actions across the EU.

1 About climate change

- Climate change (increases in temperature, changes in precipitation and decreases in ice and snow) is occurring globally and in Europe; some of the observed changes have established records in recent years;
- Observed climate change has already led to a wide range of impacts on environmental systems and society; further climate change impacts are projected for the future;
- Climate change can increase existing vulnerabilities and deepen socio-economic imbalances in Europe;

- Damage costs from natural disasters have increased; the contribution of climate change to these costs is projected to increase in the future;
- The combined impacts of projected climate change and socio-economic development can lead to highdamage costs; these costs can be reduced significantly by mitigation and adaptation actions;
- The causes of the most costly climate impacts are projected to differ strongly across Europe;
- On-going and planned monitoring and research at national and EU level can improve assessments of past and projected impacts of climate change, thereby enhancing the knowledge base for adaptation.

Cities fase specific climate change challenges

Three quarters of the population of Europe live in urban areas and this is where climate change will be most apparent in everyday life.

While urban areas will generally experience the same exposures to climate change as surrounding regions, the urban setting can alter this as well as any potential local impacts. The replacement of natural vegetation with artificial surfaces and buildings creates unique microclimates altering temperature, moisture, wind direction and rainfall patterns. Differences in urban design and management make cities vulnerable in different ways, even those situated in the same geographic region. Excessive amounts of rain water cannot drain into the ground where a high share of the city's area is imperviously sealed and thus generate or worsen floods. A high amount of artificial surfaces stores heat and cause raised temperatures in cities compared to the surrounding region.

Urbanisation also reduces the area available for natural flood management or increases the number of homes and businesses actually in flood-prone areas. These socio-economic changes increase the vulnerability of people, property and ecosystems under current climate conditions as long as no adaptation measures are taken (Acero, Rodríguez & Ciroth, 2014).

2 General circulation models (GCMs) and regional climate models (RCMs)

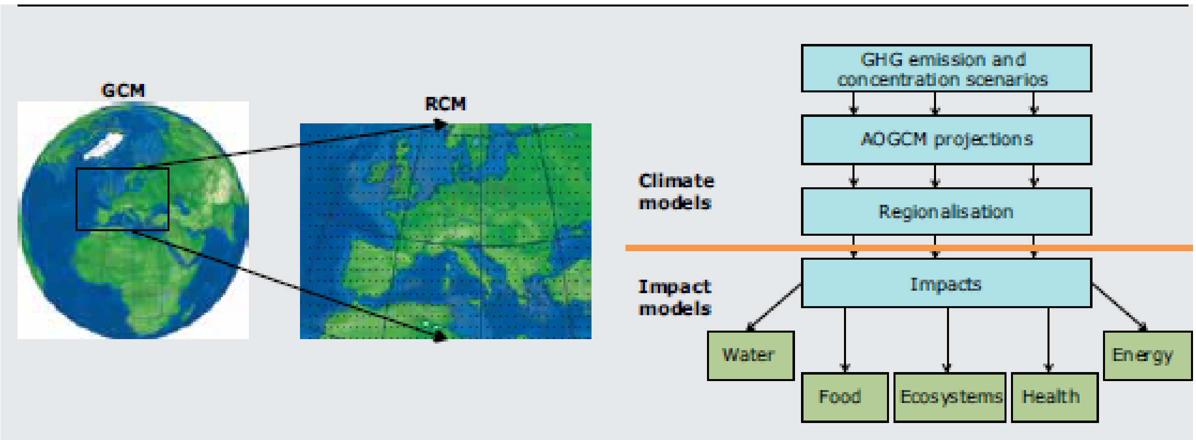
General circulation models (GCMs) are numerical models that represent key physical and chemical processes in all components of the global climate system (See Figure 1). GCMs are the most advanced tools for simulating the response of the global climate system to different emissions scenarios for GHGs and aerosols. GCMs depict the climate using a three-dimensional (3D) grid over the globe. The GCMs used in the IPCC AR4 typically simulate atmospheric processes at a horizontal resolution of between 100 and 300 km, with 20 to 60 vertical layers. Ocean processes were simulated at a horizontal resolution of between 20 and 200 km, with up to 30 vertical layers.

Some more recent GCMs have a somewhat finer horizontal resolution but their resolution is still quite coarse relative to the scale of exposure units in most climate impact assessments. ***Regional climate models*** (RCMs) can be used to bridge the coarse-resolution outputs from GCMs with the high-resolution climate data needs of regional impact assessments. RCMs cover a limited area of interest, such as Europe or an individual country (See Figure 1). They are embedded into GCMs, which prescribe the large-scale climate features. RCMs typically have a horizontal resolution of between 5 and 50 km. Their higher resolution allows for a better representation of topographic features (e.g. mountain ranges) and of regional-scale climate phenomena. As a result they can provide better projections of changes in regional precipitation patterns and in certain weather extremes. RCMs have been used to relate future climate change in specific locations to the current variability of climate within Europe.

Global and regional climate models have recognised weaknesses. Their simulations of past and current climate show some deviation from the observed climate. Furthermore, different models provide somewhat different climate projections when forced with the same emissions scenario. Nevertheless, the scientific community is confident that climate models provide credible quantitative estimates of future climate change since these models are based on fundamental physical laws and are able to reproduce the key features of observed climate change.

These models are used in Slovakia.

Figure 1: Components needed for modeling climate change and its impacts

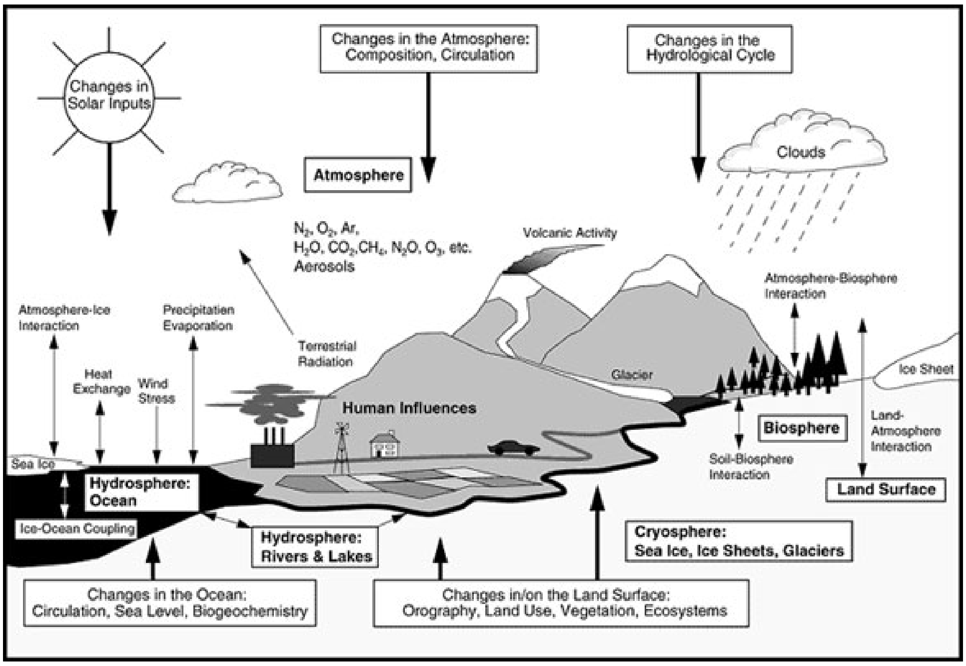


Source: Kurnik, 2012.

Human influence on the climate system

Climate denotes the statistics (average conditions and variability) of the day-to-day weather over a long time period (usually 30 years). In contrast, weather denotes the state of the atmosphere at any given time, such as the day-to-day temperature and precipitation activity. The Earth's climate system is a complex system consisting of several closely linked subsystems: the atmosphere, the hydrosphere (oceans, lakesand rivers), the cryosphere (snow and ice), and the lithosphere (soils). The climate system is closely linked to the other components of the Earth system, such as the biosphere (See Figure 2).

Figure 2: Components of the climate system

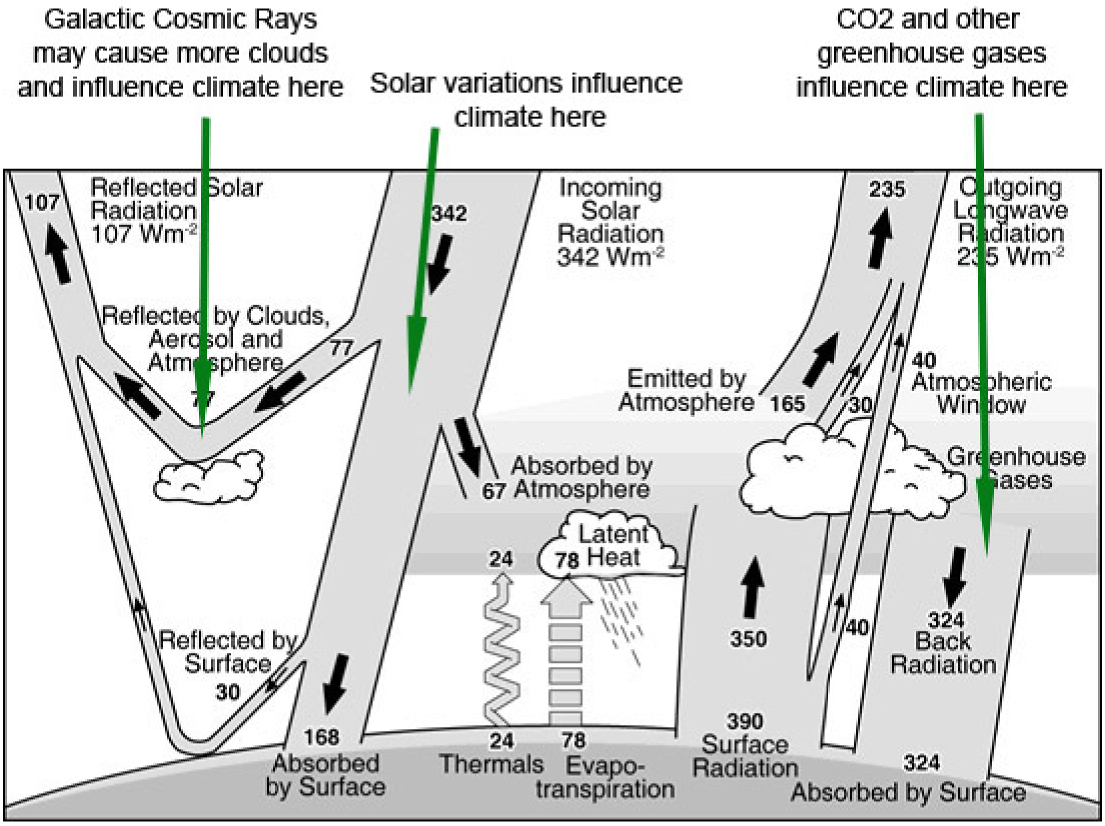


Source: IPCC, 2007.

The climate system is influenced by many factors, such as solar activity, the Earth's orbit around the Sun, atmospheric composition and volcanic activity. Climate has always been changing as a result of changes in these factors. For example, the transitions between ice ages and intermediate warm phases (interglacials) during the last one million years were triggered by predictable changes in the position of the Earth's axis with respect to the Sun, followed by an amplification of the initial changes through feedback mechanisms in the climate system. In addition to the long-term changes, the climate is characterised by substantial variability on multiple time scales. Examples include daily and seasonal cycles but also more irregular multi-year and multi-decadal phenomena such as ENSO (El Niño-Southern Oscillation), NAO (North Atlantic oscillation), PDO (Pacific decadal oscillation), and the Arctic and Antarctic oscillations.

The main pathway along which humans are affecting the global climate is by increasing the concentration of so called long-lived GHGs. These gases let visible light pass through but absorb part of the infrared radiation from the Earth, thereby keeping the heat in the system (See Figure 3).

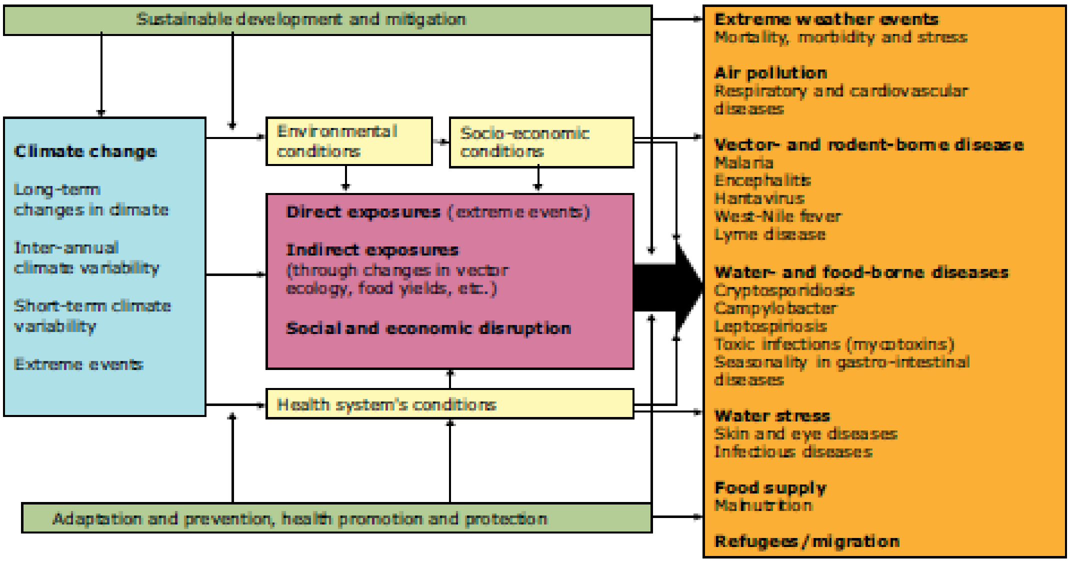
Figure 3: The Earth`s energy balance



3 Climate impacts on environmental systems

Climate change is already contributing to the global burden of disease and premature deaths. Nearly all environmental and social impacts of climate change may ultimately affect human health through altering weather patterns, changes in water and air quality, food quantity and quality, ecosystems services, livelihoods, infrastructure and migration (Figure 4). Climate change can affect existing health risks both positively and negatively, and it may introduce new health risks to previously unaffected regions. The potential health benefits from milder winters in some regions are however not expected to outweigh the risk of negative health effects through direct and indirect, immediate and delayed risks of climate change (McMichael, Montgomery & Costello, 2012).

Figure 4: Impact pathways of climate change on human health



Source: Wolf, 2011.

Climate change is one of the major environmental effects of economic activity, and one of the most difficult to handle because of its broad scale.

Existing a number of impact assessment methods, which are used to calculate impact assessment results.
In the following we present a short description of the new impact categories.

Acidification

Acidic gases such as sulphur dioxide ($SO2$) react with water in the atmosphere to form “acid rain”, a process known as acid deposition. When this rain falls, often a considerable distance from the original source of the gas (e.g. Sweden receives the acid rain caused by gases emitted in the UK), it causes ecosystem impairment of varying degree, depending upon the nature of the landscape ecosystems. Gases that cause acid deposition include ammonia ($NH3$), nitrogen oxides (NOx) and sulphur oxides (SOx).

Acidification potential is expressed using the reference unit, kg $SO2$ equivalent. The model does not take account of regional differences in terms of which areas are more or less susceptible to acidification. It accounts only for acidification caused by $SO2$ and NOx.

Climate change can be defined as the change in global temperature caused by the greenhouse effect that the release of “greenhouse gases” by human activity creates. There is now scientific consensus that the increase in these emissions is having a noticeable effect on climate. This raise of global temperature is expected to cause climatic disturbance, desertification, rising sea levels and spread of disease.

Environmental toxicity is measured as three separate impact categories which examine freshwater, marine and land. The emission of some substances, such as heavy metals, is impacts on the ecosystem. Assessment of toxicity has been based on maximum tolerable concentrations in water for ecosystems: Fresh-water aquatic ecosystems; Marine ecosystems; Terrestrial ecosystems.

Eutrophication is the build-up of a concentration of chemical nutrients in an ecosystem which leads to abnormal productivity. This causes excessive plant growth like algae in rivers which causes severe reductions in water quality and animal populations. Emissions of ammonia, nitrates, nitrogen oxides and phosphorous to air or water all have an impact on eutrophication.

Ozone-depleting gases cause damage to stratospheric ozone or the "ozone layer". There is great uncertainty about the combined effects of different gases in the stratosphere, and all chlorinated and brominated compounds that are stable enough to reach the stratosphere can have an effect. CFCs, halons and HCFCs are the major causes of ozone depletion. Damage to the ozone layer reduces its ability to prevent ultraviolet (UV) light entering the earth's atmosphere, increasing the amount of carcinogenic UVB light reaching the earth's surface. The characterisation model has been developed by the World Meteorological Organisation (WMO) and defines the ozone depletion potential of different gases relative to the reference substance.

Photochemical oxidation (Photochemical ozone creation potential)

Ozone is protective in the stratosphere, but on the ground-level it is toxic to humans in high concentration. Photochemical ozone, also called "ground level ozone", is formed by the reaction of volatile organic compounds and nitrogen oxides in the presence of heat and sunlight. The impact category depends largely on the amounts of carbon monoxide (CO), sulphur dioxide (SO2), nitrogen oxide (NO), ammonium and NMVOC (non-methane volatile organic compounds). Photochemical ozone creation potential (also known as summer smog) for emission of substances to air is calculated with the United Nations Economic Commission for Europe (UNECE) trajectory model (including fate) and expressed using the reference unit, kg ethylene (C2H4) equivalent (Martin, Perrin, Hansen & Quintana, 2000).

4 Projected costs of climate change

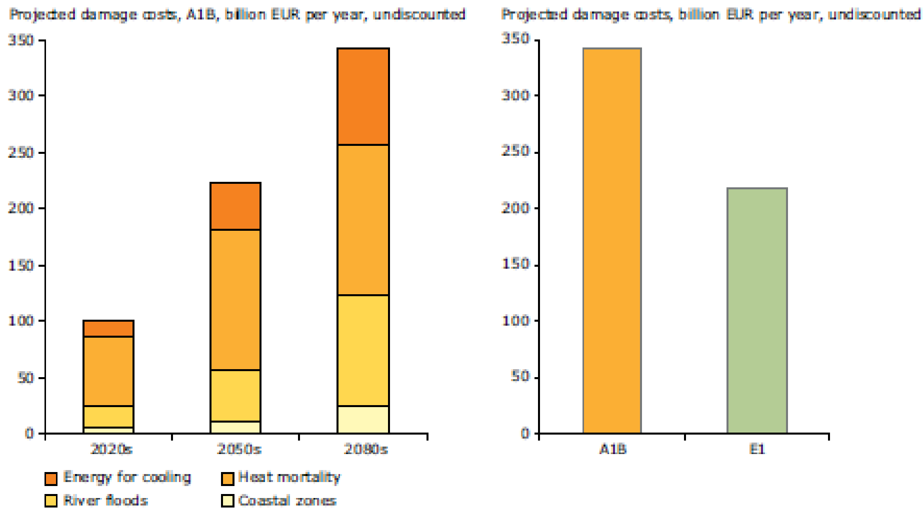
The effects of climate change, as outlined in the previous chapters and sections, will lead to wide ranging impacts on the natural and man-made environment. They will also lead to economic costs, often known as the 'costs of inaction', which are increasingly used to inform the policy debate on climate change in Europe. A number of different methods and models are being used to advance estimates of the costs of inaction.

At the European scale, a number of studies have advanced these assessments as part of consistent sectoral assessments, notably in the PESETA project (Ciscar et al, 2009; Ciscar et al, 2011) and the EU FP7-funded ClimateCost Project (Watkiss, 2011), though there are many additional studies in individual sectors. A large number of studies and estimates are also emerging at Member State level (not reported here):

- Projections suggest large increases in costs from coastal and river flooding, heat waves and energy demand (for cooling) due to the combined effects of climate change and socio-economic developments in Europe.
- There are strong geographical differences in projected costs, with pronounced damage costs in southern Europe due to increases in energy demand and heat waves, in western Europe due to coastal flooding and heat waves, in northern Europe due to coastal and river floods, and in eastern Europe due to river floods.
- Significant cost reductions can be achieved if mitigation policy would constrain climate change consistent with the EU's 2 °C objective, compared to a business-as-usual emissions scenario.

- Cost estimates have a medium to good coverage at European level for coastal and river flooding, water supply, energy demand, agriculture and human health, but cost estimates are not available or very incomplete for infrastructure, built environment, tourism, transport and forestry. Economic costs for impacts on biodiversity and ecosystems services are difficult to prepare due to the challenge of proper valuation.
- Information on the total costs of the impacts of global climate change on the European economy is lacking.

Figure 5: Projections of economic costs from climate change and socio-economic developments for four major categories



Note: Left: damage costs for the A1B scenario for energy for cooling, heat-related mortality (weighted average of Value of a Statistical Life (VSL) and Value of a Life Year Lost (VOLY)), river floods and coastal zones. Time horizon: 2010–2040, 2040–2070 and 2070–2100.
Right: A1B and E1 scenarios, 2070–2100.

Source: Watkiss, 2011.

The results of the Climate Cost project reveal potentially large costs of inaction in Europe (See Figure 5). They also show the strong geographical differences across regions. Importantly, they show the significant reductions in costs of inaction that can be achieved by mitigation policy consistent with the EU's 2 °C target, including avoiding some of the potential lower-probability, high-consequence events.

5 Climatic Change and Variability Impacts on the Transport

Land-based transport infrastructure and operation are sensitive to changes in climate, including snow and rainfall patterns, coastal and inland flooding, wind storms and heat waves. Some impacts of climate change may be positive, such as a decrease in the ice cover of oceans and rivers, but most of them will be negative (Koetse & Rietveld, 2009)10. In the Arctic, climate change is opening up new transport lanes and enables the exploitation of both natural and mineral resources. While this can be of benefit for the regional and global economy, it will also have repercussions on the Arctic's fragile environment.

Overview of potential impacts of climate change on transport infrastructure:

- Data on past climate-related impacts on transport is restricted to individual extreme events, and attribution to climate change is generally not possible.

- Information on the future risks of climate change for transport in Europe has improved recently due to several EU research projects focusing on climate change, extreme weather events and inland water transport.
- Climate change is projected to have both beneficial and adverse impacts on transport, depending on the region and the transport mode.
- Available projections suggest that rail transport will face the highest percentage increase in costs from extreme weather events. The British Islands, central Europe/France, eastern Europe and Scandinavia are projected to be most adversely impacted.

There are several areas within the sector of transportation which are indispensably linked to the weather behavior. The actions concerned are namely freak weather events (extremely high and low temperatures, intense precipitation, freak storms, heavy snow, blizzards, calamity winter weather), which all happen to cause serious complications with almost every means of transport, under all the traffic conditions. A comprehensive analysis of likely effects of the climatic changes on the traffic and transportation was conducted by (Koetse & Rietveld, 2009).

Unwanted climatic phenomena result, in relation to the traffic, in prolonged transportation times for goods being transported, prolongation of times of travel and an increased risk of accidents. There are several areas in the sector of transportation which are directly linked to the weather behavior and changes. The concerned are namely extreme weather conditions (too high and too low temperatures, intense precipitation, rainfall, heavy snow, severe or harsh winter conditions), which effectively result in serious complications with almost all the means of transport. A comprehensive analysis of likely effects in climatic changes impacting the transportation was conducted by (Koetse & Rietveld, 2009) which is, at the same time, summarized in the following survey:

Table 1: Analysis of the potential effects of climate change on transportation

Means of Transport	**Weather Conditions Impact**	**Results**
Road traffic	Extreme weather conditions (storms, flooding)	Road closures and blockages, diversions, damage to the road infrastructure, road network
	Worsened meteorological conditions (rain, snow, black ice, mist, fog, ...)	Worsened traffic flow and road safety, traffic jams, congestions,
	Worsened winter conditions (frequent snowing, wind, prolonged winter periods, duration)	Extensive requirements related to winter road maintenance, damage done to the road paving
Air traffic	Extreme weather conditions (heavy storms, freak storms, floods)	Closures of airport operations, damage done to the airport equipment, delayed flights
	Worsened meteorological conditions (rain, snow, black ice, mist, fog, ...)	Delayed flights
Rail traffic	Extreme and freak weather conditions (downpours, storms and floods)	Shutdown of lines, routes, railway closures, lockouts, damage to the infrastructure

	Worsened winter conditions (frequent snowing, heavy snowfall, wind, prolonged winter duration)	Extensive requirements related to the winter maintenance, damage to the rails, joints and switches
Sea, marine traffic	Extreme weather conditions (storms, floods)	Interruptions to the sea, marine traffic, damage to the vessels and infrastructure
	Worsened winter conditions (frequent snowing, wind, prolonged winter duration, winter periods)	Freezing of waterways, interruptions in the marine transportation corridors

Source: (Koetse & Rietveld, 2009)

Traffic Efficiency, Smooth Flow and Safety

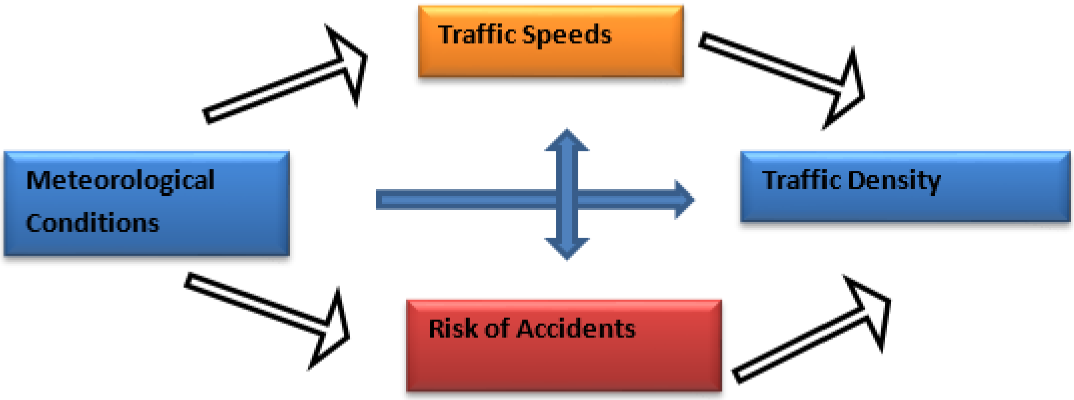
The issue of traffic safety and security, mainly on the roads and highways remains a priority when addressing and investigating the impact of weather-related phenomena on the accident rate, by virtue of having to deal with a direct jeopardy of human health and the lives of people. We may identify several meteorological parameters which are to remain significant for the course of transportation. Stern (2006) analyzed the dependency between the hot weather conditions and the accident rate on roads and worked toward the conclusion that by experiencing elevated hot weather conditions, intensity (high external temperatures and their extended duration) leads to the elevated figures of accidents, while at the same time observing, that the accidents in question are namely those of individual owners, individually- owned automobiles. Further meteorological factors mentioned in the scientific literature worth noting are fog and wind, however and undoubtedly the most significant factors to be concerned are rain and torrential downpours (in the form of rain and snow).

Koetse and Rietveld (Koetse & Rietveld, 2009) both analyzed the results under investigation having the relation to a direct interrelation of snow and rain on the accident rate (western Europe, USA, Canada) and reached the following conclusions:

- Snowfall with regard to the accident rate is more serious than the rainfall,
- with respect to the accident rate, the weather conditions shortly preceding the occurrence of either rainfall or snowfall are to be considered,
- the occurrence of accidents tends to climb predominantly with intensive rainfall or snowfall following dry weather conditions,
- frequency of accidents related to any snowfall is equally elevated, though fewer serious road accidents occur with respect to the dry weather conditions (people tend to drive at lower speeds).

On the other hand, it is obvious that the accident rate is impacted on by the whole plenitude of further factors which are consequently to have an impact on the traffic speed, flow, traffic density and such like, which may be demonstrated using the following chart (Figure 6).

Figure 6: Direct relation between the weather, road safety, speed and traffic density



Source: Koetse & Rietveld, 2009.

Further studies were focusing, in general terms, on analyzing the impact of worsened weather conditions on the conditions of road traffic. It general, they concluded that worsened meteorological conditions indispensably lead to reducing the traveling speed (within the range of 10 – 30 %) and extending the time of travel (Martin, Perrin, Hansen & Quintana, 2000; Agarwal, Maze & Souleyrette, 2005). In conclusion it may be stated that worsened weather conditions do have an elevated impact on the number of accidents occurring, lesser impact on the number of serious road accidents. At the same time, they cause, to a lesser degree, an increase in the traffic load, intensity and the time of commencing journeys. As a matter of fact, we have to state that, in spite of the fact that the effects of the weather impacting on the traffic safety are obvious, we still lack a certain number of quantitative pieces of knowledge suited for the assessment of direct or indirect impacts of the weather on the overall traffic, which requires a further detailed research and an investigation.

Fully aware of the current scenarios of climatic changes we may anticipate that the field of the traffic safety shall be impacted on in the following manner:

- More frequent presence of liquid precipitation during the winter periods may lead to rather frequently occurring instances of black ice on the roads and, as a result of this, to a heightened risk of accident rate (the areas concerned are the northern parts of the Slovak Republic and mountain regions as well), quite to the contrary in southern parts of Slovakia, this kind of risk may be slightly reduced if not eliminated,
- a more frequent occurrence of heavy rainfall, torrential downpours being accompanied by an infrequent or rare presence of hailstorms, which in the long run may lead towards the greater risk of accident rate on the roads, which may concern especially the sub-mountainous and mountainous regions.

Traffic Infrastructure

With regard to the impact of climatic changes on the traffic infrastructure, several studies have been dedicated to especially the extreme manifestations of the weather as for instance heavy storms with intensive torrential downpours, local flooding, floods and strong wind occasions (hurricanes). Demonstrations of these weather extremes are by all means different with regard to particular means of transport, in any case, though, in these cases the whole traffic systems are endangered and jeopardized, which by virtue of having the traffic infrastructure damaged results in losing the principal functionalities of the traffic infrastructure for several hours, if not days. Perhaps the most serious instances of jeopardy in relation to the traffic, transportation systems originate in conjunction with the floods and local flooding, especially in the road traffic and sea, marine traffic, bearing in mind highly frequented transportation routes as well as urban and developed areas (RAE, 2011). As an example to serve us, an instance of the traffic collapse which happened as a result of river banks bursting and a subsequent flooding in Prague, in August 2002 may be considered.

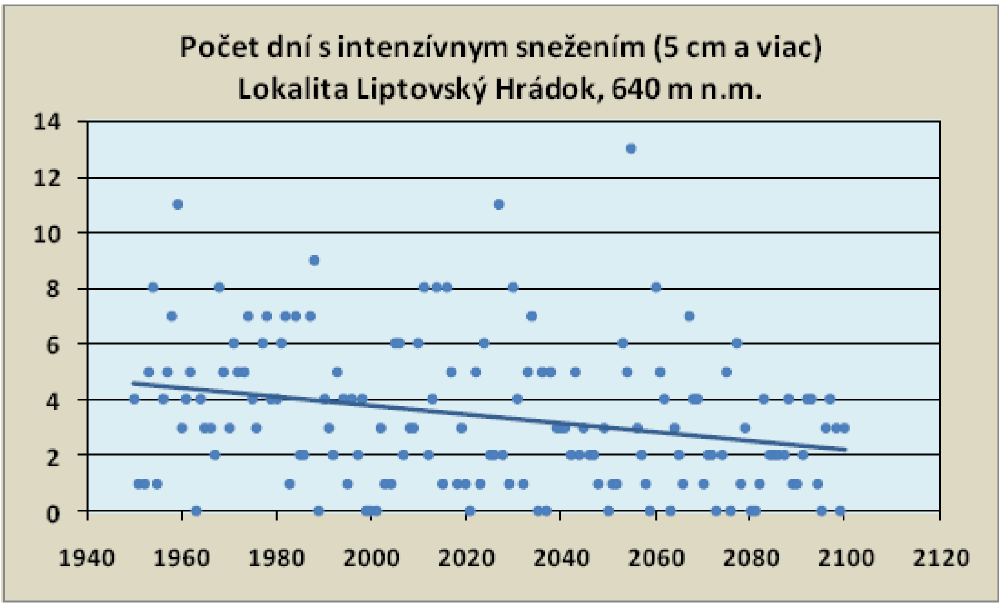
It is also indispensable to realize that extreme weather instances do not lead exclusively to the damage on the traffic infrastructure but consequently cause significant economic harm, reflecting on the economic impacts being a direct result of losing traffic functionalities and performance (delays on the way to work, delays of shipments, deliveries on hold, financial losses of forwarders and carriers, route operators, damage to the goods and such like) (AVV, 2006).

The areas of greater risk to be focused on are drainage and sewerage networks, gutters, trenches, bridges and those sections of roads which are in the very vicinity of river channels, watercourses or flowing bodies of water. Urban areas and developed areas represent a problem of significance having a high level of non-porous surfaces (tarmac, concrete), where an insufficient capacity of sewerage networks may cause “the most grievous problem” (Eichhorst, 2009) and following that a sudden flooding of road arteries and streets. A less significant problem to be considered is to be understood as a continuous damage to the road arteries and streets during the winter periods as a result of quick alternations of positive and negative temperatures, above zero and sub-zero temperatures (mechanical erosion of the top layer, paving of the road and the hard shoulder, side of the road). This kind of issue would be more significant and pronounced only at higher altitudes above 800 meters above sea level (mountain passes). A specific position is held by the river traffic on the Danube River, whence respecting the area of the watercourse and the anticipated changes in the precipitation regime or Europe, changes in the height of flow rate as well as their seasonality may occur. In this regard, the key factor to be considered is the development of precipitation-runoff relations in the Alpine region, which respecting this very standpoint are not yet easy to be identified when related to the climatic changes. A drop in the flow rate on the Danube River could possibly hamper or complicate the overall river traffic using this watercourse corridor, which is most likely during the summer months.

Winter Maintenance of Traffic Infrastructure (A case study from Slovakia)

Based on the scenarios reflecting climatic changes for the territory of the Slovak Republic, which conclude, that during the winter season the exterior, external temperature of air increases, the presence of snowfall decreases and the share of liquid precipitation goes up. These altered conditions require changes and alternations in the provision of winter maintenance as well, especially road traffic infrastructure, where the highest amount of financial means is spent. Figure 7 illustrates anticipated prospects with days of intensive snowfall, in other words days most likely to bring or induce calamity situations on the roads, where an obvious decline in such calamity situations is observable. Which, in the long run, means that it can either have a positive impact on the overall accident rate during the winter season or it may as well mean reducing the intensity (and hence the overall cost) dedicated to the winter maintenance.

Figure 7: Anticipated trend in the number of days of heavy snowfall (5 cm and more) in the location of Liptovský Hrádok town



Source: Lapin, Drinka, Kremler & Tomlain, 2008.

The scientific literature excerpts (Gregorová, 2009) do quote the conditions of the Slovak Republic observing the following conclusions with regard to impacts of the climatic changes as of the sector of transport (MINĎAŠ et al, 2011):

- road traffic within the main, backbone corridors shall be impacted in a negative way even in the future, especially during the winter periods (snow cover, frost, black ice, strong winds) in the mountain areas and elevated mountain passes of the middle and northern Slovakia, for instance the mountain passes of Donovaly, Čertovica, Besník, Šturec, Cesta Slobody /the Freedom Road/ in the Tatra Mts. Region – especially its western part from Starý Smokovec to Podbanské,
- in the highest sections of the transportation corridors around the area of Štrbské Pleso and Čertovica extensive precipitation may be anticipated as of winter months,
- considering the road traffic in the lower altitudes, lowlands a reduced snow cover may be expected as well as the number of arctic, freezing days, possibly days with frequent occurrence of black ice,
- the overall variability of climatic change impacts is to increase impacting the road traffic – from the more positive effects in the lowlands up to the negative ones at the highest elevations, altitudes,
- concerning the rail traffic, we do expect a more positive impact of the climatic change as far as the ambient air temperatures in the valleys and in the mountain areas are concerned, more negative effects may be felt by extremely high ambient air temperatures in the summer periods, especially in the in the mountains,
- concerning the rail transport and atmospheric precipitation, which may occur during the colder periods of the year in the regions situated in basins and mountain areas, bearing in mind an increased level of precipitation, this means of transport may be impacted in a negative way,
- territorial river traffic operated on the Danube River, the Morava River and the lower course of the River Váh shall be impacted in a negative way by having the water flow reduced during the summer periods,

- air transport shall be highly sensitive to the extreme weather conditions and its impacts, airports situated in the Bratislava capital and the City of Košice shall experience more positive impacts as far as the dangerous climatic phenomena in the winter periods are concerned (black icy, icy runways, snow coverage),
- an anticipated climatic change shall probably not be visible in the pipeline transport,
- as far as the overall traffic is concerned, being seen as one of the most vulnerable, reflecting the climatic changes one has to consider the road traffic as the primary one (similarly at a present day, as well),
- as far as the traffic is concerned, basins and mountain areas of the northern, central and eastern Slovakia present the most vulnerable areas of concern, when considering the regional point of view, similarly as nowadays,
- several short sections above the altitude of 1200 above sea level may be impacted in a negative way by an increased annual precipitation during the winter periods, which concerns the road traffic and, partially, several special means of transport.

6 Conclusion

Based on the results of the analysis of the up-to-now achieved results and a deep knowledge of traffic conditions and its nature , one has to view, as the most significant, the climatic change in the field of traffic and equivocally consider the issue of increased safety risks in the areas of traffic (namely road traffic) and negative impacts of climatic change on the traffic infrastructure (road and rail).

Adaptation Measures in the Field of Traffic Control have to be divided into the two groups, and that, namely the measures focusing on the reduction of health and safety risks in the road traffic as a result of extreme weather conditions and on the other hand the measures focusing on improving the road infrastructure in the risky environments, locations. The question of road safety, traffic security, even with regard to anticipated effects of the climatic change, is closely related to the implementation of the Intelligent Traffic Systems (ITS). The implementation of the Intelligent Traffic Systems may very well contribute to reducing the risks of extreme weather conditions and their impacts on the accident rate, even though we cannot consider the ITS to be a standardized and a specific adaptation measure.

References

1. Blaz Kurnik, in EAA Repor (2012) Climate change, impacts and vulnerability in Europe (EEA Technical report No 1/2012). European Environment Agency, Copenhagen. http://www.eea.europa.eu/publications/
2. Ciscar, J. C., Iglesias, A., Feyen, L., Goodess, C. M., Szabo, L., Christensen, O., Nicholls, R., Amelung, B., Watkiss, P., Bosello, F., Dankers, R., Garrote, L., Harrocks, L., Moneo, M., Moreno, A. et al. (2009) Climate change impacts in Europe. Final report of the PESETA research project (EUR 24093 EN, JRC55391). European Commission — Joint Research Centre, Institute for Prospective Technological Studies. http://ftp.jrc.es/EURdoc/JRC55391.pdf.
3. Ciscar, J.-C., Iglesias, A., Feyen, L., Szabó, L., Van Regemorter, D., Amelung, B., Nicholls, R., Watkiss, P., Christensen, O. B., Dankers, R., Garrote, L., Goodess, C. M., Hunt, A., Moreno, A., Richards, J. et al. (2011) Physical and economic consequences of climate change in Europe. Proceedings of the National Academy of Sciences. doi:10.1073/pnas.1011612108.

4. IPCC (2007) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller, eds.). Cambridge University Press, Cambridge. http://www.ipcc.ch/publications_ and_data/ar4/wg1/en/contents.html.
5. McMichael, T., Montgomery, H. and Costello, A. (2012) Health risks, present and future, from global climate change. British Medical Journal 344, e1359. doi:10.1136/bmj.e1359.
6. Acero, A. P., Rodríguez, C., Ciroth, A.: (2014) Impact assessment methods in Life Cycle Assessment and their impact categories, Greendelta, version 1.3
7. Agarwal M, Th Maze, R Souleyrette, (2005), Impacts of Weather on Urban Freeway Traffic Flow Characteristics and Facility Capacity, in: Proceedings of the 2005 Mid-Continent Transportation Research Symposium
8. AVV, (2006): Economische Waardering van Mobiliteitseffecten van een Dijkdoorbraak (Economic Valuation of Mobility Effects of a Flood), AVV, Ministry of Transport, Public Works and Water Management, Rotterdam.
9. Gregorová, B., (2009): Report on the impact of the climatic change and the assessment of territorial vulnerability in the territory of the Slovak Republic in the field of “traffic” FPV UMB Banská Bystrica, 2009.
10. Koetse, M. J., Rietveld, P. (2009): The impact of climate change and weather on transport: An overview of empirical findings. Transportation Research Part D, 14:205-221.
11. Lapin, M., Drinka, R., Kremler, M., Tomlain, J., (2008): Scenarios of Air Humidity and Potential Evapotranspiration Change for Hurbanovo, 16 pp. In: CD Proc. of the XXth Czecho-Slo-vak Bioclimatological Conference, Mikulov, Czech Republic.
12. Martin Pt, J Perrin, B Hansen, I Quintana, (2000), Inclement Weather Signal Timings, UTL Research Report MPC01-120, UTL, University of Utah, Salt Lake City.
13. MINĎAŠ, J. at al: (2011).: Impacts of the Climatic Change and Prospective Adaptation Measures in Singular Areas. EFRA Zvolen, (in Slovak).
14. RAE (2011): Infrastructure, Engineering and Climate Change Adaptation – ensuring services in an uncertain future. Published by The Royal Academy of Engineering on behalf of Engineering the Future. February 2011, ISBN 1-903496-61-6.
15. Stern. (2006): http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/stern_review_report.htm
16. Wolf, T. (2011): Assessing vulnerability to heat stress in urban areas: The example of London. LAP: LAMBERT Academic Publishing.