Adaptation in cities

The art of lateral thinking

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GERICS
Climate Service Center Germany
An institution of Helmholtz-Zentrum Geesthacht

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Introduction

The Climate Service Center Germany (GERICS) was initiated by the German Federal Government in 2009 as a fundamental part of the German high-tech strategy for climate protection. Since June 2014, GERICS has been a scientific organisational entity of the Helmholtz-Zentrum Geesthacht – Zentrum für Material- und Küstenforschung GmbH.

GERICS delivers scientifically-sound products, advisory services and decision-relevant information to help support government, administration, and business in their efforts to adapt to climate change. We are located in the historic "Chilehaus" in Hamburg and employ an interdisciplinary team of natural and social scientists.

The Director of GERICS is meteorologist and climate scientist Prof. Dr. Daniela Jacob.

Adaptation in cities – the art of lateral thinking

How to succeed in adaptation at city level

Adaptation of urban areas and its surroundings requires the consideration of many factors and drivers, including their interactions. Additionally, a large number of interests from key players such as administration (from local to regional), politics, and companies as well as state of the art scientific knowledge have to be included. Aside from the individual scope and strategic objectives, regional to local climate change information is one of the important corner stones in estimating possible future climate change impacts and the related hot spots in the area under investigation.

Before the development of an individual adaptation strategy for a city, the following steps have to be kept in mind:

1. The urban system is complex. It comprises parts of the climate system, the water cycle, the material cycle and numerous of value chains.

2. With regard to future developments, the climate system is complex too. In other words, a change in one component generally results in (often non-linear) changes of other system components such as water levels, wind velocities or air humidity.

3. In the whole urban system there are many dynamic processes with moving targets. This requires flexible solutions that need to be harmonised with existing administrative / planning processes and structures.

4. Before entering the planning phase of adaptation it is necessary to understand the whole system, which includes the knowledge of the most important drivers – including not only climatic but also non-climatic drivers such as new socio-economic trends or land-use change.

5. Interactions of one or more of these drivers have to be taken into account, all in all leading to potentially very different impacts in a city or region.

6. Possible cascading effects need to be addressed appropriately.

7. Adaptation actions can range from short-term to longer-term activities and address different temporal and spatial dimensions.

8. There is no "one-size-fits-all" adaptation solution. Each aspect has to be addressed individually. The more precise the problem, the more accurate the solution. But, it is also important to understand what the changing aspect means for the system.

Our experience with regard to climate change impacts and associated adaptation measures in cities shows the necessity for a flexible tool that addresses a whole range of actions. This ensures the applicability in all regions and scales, independent of specific settings such as the environmental framework, the existing degree of information or the most pressing challenges. All these requirements are addressed by GERICS' innovative toolkit concept. This concept was – and currently is – tested in different types of cities, ranging from small municipalities to state capitals. The locations are all over Germany including cities on the sea as well as densely populated areas inland. The main goal of our activities in all cases is the support of adaptation processes. This includes techniques for a systematic assessment of current and future opportunities and vulnerabilities due to climate change impacts.

The idea behind the adaptation toolkit for cities (German product name: GERICS-Stadtbaukasten) is to have numerous independent but easy-to-connect and easy-to-use modules, which address different important aspects – e.g. the vulnerability against urban, river or groundwater flooding or the climate proofing of compensation measures – relevant to represent and to understand the respective systems such as the climate resilience of the critical infrastructure from administration as well as other stakeholder perspectives. Depending on the initial question(s), the relevant modules can be selected and combined individually. One key component is the distilling of all relevant presently available climate information to design tailor-made solutions.

The biggest advantage of the toolkit approach is its transferability to other regions all over the world regardless of the available information or the complexity of the system under consideration.

Adaptation to climate impacts is not a new challenge

It is widely accepted that cities are key players with respect to climate change. They are not only main contributors; they will also be affected by expected climate change impacts. Most cities are well aware of climate change mitigation. With regard to climate change adaptation, however, there exist some ambiguities. The most common misjudgments of municipal representatives are a) mitigation and adaptation measures are the same, b) there is no willingness to pay for local measures now when the future effects can not directly be quantified or even seen, and c) the belief that developing and implementing an adaptation strategy without further action is sufficient. Nevertheless, many municipalities are already aware of the most important hydro-meteorological hazards – such as extreme precipitation, heat waves, droughts or river floods – relevant for their city or region (as illustrated in figure 1). And often there exist plans how to avoid system failures or breakdowns, for example with respect to critical infrastructure.

For the development of practicable adaptation actions, impacts on different urban sectors have to be taken into account. Based on experience gained from case studies and survey evaluations it became clear that the starting point for all further activities is the connection of state-of-the-art regional climate information, and regional or local socio-economic and environmental information connected with local expert knowledge.

The whole process of using the adaptation toolkit with cities starts with the elaboration of the toolkit-frame according to the individual needs of the municipality, and by taking a holistic view. This approach is necessary in order to identify the specific opportunities and challenges arising from climate change for a city, and to therefore be able to understand all potential risks related to climate change throughout the entire urban adaptation process. Hence, the focus of all related activities has to be on the whole system instead of single elements, to avoid misleading actions in sectors that would have been overlooked or otherwise not considered.

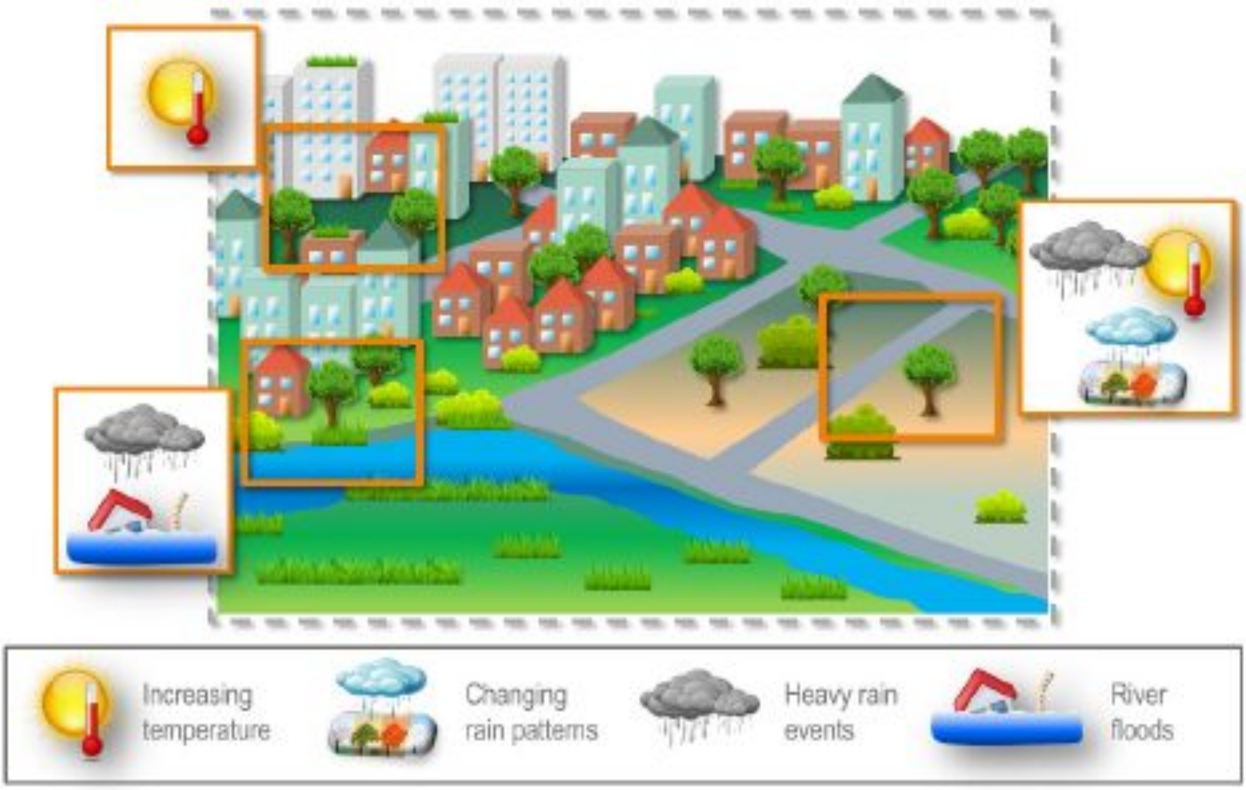

Fig.1. Examples of the most important hydro-meteorological hazards and typical areas for city adaptation

The toolkit-frame comprises all relevant modules including the necessary interfaces to support the overall adaptation process. The intended modules are tailored to the individual needs. This means the modification of the given methodology with regard to the city size, the existing level of information, legislative framework or the climatic conditions.

Since climate impacts cause considerable stress to the urban population and infrastructure, it is necessary to adapt to local and regional projected climate impacts at an early stage. These impacts need to be considered in planning and design processes to positively influence the quality of life and the resilience of infrastructure in the future. Therefore, another important step is the development of a strategy to integrate the actions carried out as part of the city toolkit application into existing process chains such as environmental audits or development plans. As a further benefit, modules can be used as a bridge between two or more workflows, creating and using available synergies. Finally, it is necessary to consider mitigation and adaptation jointly and equally when developing and Implementing adaptation action.

Even though effective adaptation measures are known, such as the preservation and expansion of green areas and water elements or the use of climate-sensitive construction materials, there is often still a gap between the approaches in theory and in practice due to administrative barriers and lack of understanding.

In the following, we show three examples, already carried out in practice, to provide some insights on how the work with the adaptation toolkit for cities looks like.

The need to also compensate future impacts

Growing urban population is directly associated with growing need for building land and site development. As a results of this development green spaces or other unbuilt land is rededicated to construction land. For the protection of the environment in urban areas and its surroundings the law on nature conservation and landscape conservation (Federal Nature Conservation Act - BNatSchG) was created, which, for example, defines environmental impacts as changes in the shape or use of the ground that significantly reduce the performance and functionality of the natural environment or landscape. The perpetrators of these interventions are obliged to compensate for or replace unavoidable damage to nature and landscape with measures of nature conservation and landscape management.

The implementation of related compensation measures is common practice for cities and carried out countless times. But, up to now the consideration of future changes such as the various climate impacts is still missing. For example, for the first afforestation, renaturation or the building of a biotope plant growth basically depends on climate factors such as temperature (mean values as well as heatwaves) and precipitation (heavy rain events and annual precipitation patterns). An increase in temperature, especially in northern latitudes, has an impact on plants and organisms, which leads to an impairment of biodiversity. Additionally, the spread of invasive species is supported.

As a result, entire ecosystems are facing new challenges and there is a risk that the planned ecological objectives may not be met by compensation measures in the future. With regard to the projected climatic changes, the functional efficiency of the compensation measures must be estimated with foresight. For this purpose, a new method was developed by GERICS, examining currently planned compensation measures against the background of climate change. The aim is to evaluate compensation measures and their functionality under climatically changing conditions and to evaluate how they can achieve and maintain their originally intended function.

The most important element is the appropriate use of available regional climate projections. The comparison of two methods – using one climate projection only and using an ensemble of 34 climate projections – shows that the first more simple approach is not sufficient to fully cover all possible future developments. Rather single trends are identified that may imply incorrect adaptation measures. Only by using the entire range of possible future climatic changes is it possible to develop suitable gradual management strategies.

For the case study regions located in the area of the state capital Kiel (Schleswig-Holstein, Germany) projected climate change signals are relatively weak. This means rather small climatic changes with minor effects are to be expected. The combination of these results with local environmental expert knowledge result in a differing future picture for the investigated compensation areas.

For the formation of new forests or forest development through initial afforestation and the development of the semi-open pasture landscape there will be no significant effects in the future. It can therefore be assumed that the overall goals will be achieved. This also means that under climate change conditions the expected forest areas, fens, reed beds, sedge beds and a semi-open pasture landscape will sufficiently keep the functionality of the currently planned compensation measure until 2050.

On the other hand, the (independent) development of small wet biotopes, such as ponds, brooks, low moor areas and partially alluvial meadows, can be partly endangered. Due to expected higher average temperatures and changing precipitation patterns, insufficient water columns can occur temporarily, especially in summer. Low water levels lead to higher nutrient concentrations due to a lower dilution effect. This favours the growth of weeds, pests and pathogens, which altogether counteracts the achievement of the planned objective of the compensation measures. In order to meet these objectives, it is necessary to support the functionality under climate change conditions, for example by using maintenance or post-strengthening measures. However, a case-by-case analysis is necessary to identify the individually best combination of measures to pave the way for the planned functionality under changing climate conditions.

In addition, it is recommended that the development process of the compensation measures should be accompanied by a long-term monitoring programme. This allows the prompt onset of targeted countermeasures in order to minimize the risk of undesirable developments. Typical procedures are random sample monitoring or continuous monitoring, where city authorities, landscape conservation associations or other institutions could check the development status of the compensation measures from time to time.

Permanent thermal comfort in the city

The growing urban population and demographic change are two important challenges for cities of the future. Growing cities need free space for further building activities, but this space is increasingly rare. Each new building reduces the green spaces that are important for the urban climate, biodiversity, recovery, retention of precipitation, the maintenance of fresh air corridors, or the reduction of the urban heat island.

Due to improved living conditions and health care, average life expectancy in Germany has been rising for many decades. According to the Federal Statistical Office, the proportion of the total population over 65 will increase from 21% (2009) to 29% (2030) and 34% (2060) respectively. As the number of elderly people increases, so does the number of people affected by physical heat stress caused by heat waves. Against the background of projected global warming, the threat is increasing, so that adaptation actions are needed to optimize the thermal comfort under climate change conditions.

By the middle of the 21st century, most people living in major cities will have to adjust to an increase in the annual average temperature and the higher number of summer days, heat days and tropical nights. However, climate-friendly and climate-adapted urban planning gives people the opportunity to reduce the negative effects of climate change on the urban climate and to influence the inner-city microclimate in such a way that overheating can be reduced.

With regard to the increasing heat in cities, two major challenges can be identified in urban climatology: 1) unfavourable interactions between the building structure and local wind conditions, and 2) a critical thermal situation caused by the lack of evaporation possibilities and a high heat storage capacity of building and soil surfaces.

To raise the awareness of these challenges an important step is the visualization of current and future hot spots in city districts. One helpful tool for this approach are urban climate models. This approach is particularly suitable for visualizing future hot spots and for demonstrating the effectiveness of adaptation measures to increase the thermal well-being in a district. The focus is not on the exact extent of temperature reduction through individual measures, but rather on identifying potential challenges and possible solutions, and to raise awareness in order to pave the way for integrating adaptation into future city planning activities.

To identify hot spots and to simulate the effects of new building structures or additional blue and green infrastructure we used a common software based climate model. The investigation site – an urban district or several street blocks – with typical city structure elements including developed and undeveloped areas can be used to show the typical temperature related challenges of today and in the future. The results are also expected to be applied to other districts of the city with similar structural elements.

The focal point of the approach is the use of open- or easy-to-access-information to build the model. Even though the scientific standard is not on the highest possible level, the biggest advantage of this approach is its high user-friendliness. It guarantees the application for nearly all municipalities. The information included were taken from online available maps – such as Google Maps, Bing Maps, Open Street Maps – as well as from urban development plans. For the digitization of the vegetation, the most suitable standard trees of the model database have been used. Where no precise information on surfaces and floor types was available, the proven standard materials within the model have been used.

The meteorological input variables are 24-hour profiles of air temperature (at a height of 2 m) and relative humidity, as well as wind direction and wind speed for "today" and for the "future scenario" in 2050. The calculation is based on observational and regional climate model data.

The results of the model simulations showed the temperature effects by day and night with and without adaptation measures. Most of the selected adaptation measures are "minimally invasive" – new tree plantations or the creation of new water elements. Hence, city planners are able to learn from the simulations which measures might be helpful to adapt existing buildings to climate change impacts and which structures should be avoided in further urban development.

Heavy rain and flash floods – be prepared to avoid wet surprises

Climate change is one of the most important drivers that can heavily influence the urban water cycle. Main impacts will happen at the extremes – long lasting drought periods and heavy rain events. One of the most important aspects for cities (and its inhabitants) is the knowledge of the system weaknesses and its most vulnerable parts. This can be addressed by creating hot spot maps and basing the development of protection concepts on these maps. Depending on the location of the city and the environmental framework the focus can be different – river floods, high groundwater levels, flash floods. It includes the strengthening of local administration protection actions as well as the self-care of landowners.

Heavy precipitation events have already affected cities and municipalities all over Germany, and the perceived increase of heavy rain events enhances the pressure on local administrations to react. As an example, in our investigation site in the Elbtalaue (Lower Saxony) two heavy rain events in 2016 and three in 2017 caused flooding of streets and cellars. In some parts of the city, culverts and the sewage system were filled with sediment, which intensified the flooding in upstream areas.

After these events the need to flush the rainwater inlets and pipes highlighted the need for further consideration of adaptation measures, because it was obvious for the local administration that infrastructures created in the last few decades were partly no longer able to drain the current amount of rainwater. Furthermore, regional climate projections for the region show that fall, winter and spring will see rather more precipitation. Currently, no clear statements can be made on future changes in frequency and intensity of heavy rain events. Initial observations and calculations show, nevertheless, that the amount of precipitation is increasing during heavy rainfall. This is expected to lead to an increased risk of damage from heavy rain events.

The last flooding events showed that the city is well experienced in handling river floods from the Elbe river. But it became clear that there is still little experience on heavy rain events. Together with GERICS, the city decided not only to work on the symptoms, but to develop a sensitive urban development with regard to urban flooding.

As a main area of interest, the city administration selected the city centre that has already been drained by a small creek during heavy rain events in the past. For the visualization of flood effects we used a GIS-tool to swamp the city area virtually with the equivalent of sixty litres per square metre. The final maps show the accumulation areas of the water and potential bottlenecks for the flow. All results were evaluated with a survey of historical events based on an inquiry of inhabitants in the affected urban areas as well as field data provided by the fire brigade.

It should be noted, however, that actual hazards depend essentially on detailed local conditions. Therefore, standardized recommendations are not helpful. The improvement of infrastructure elements and the development of adaptation options has to be carried out individually and city-specific. However, further possible measures can be highlighted.

For endangered buildings there exist a high number of measures for technical flood protection or structural precaution. In our example, one important option is the intensification of the maintenance of the small draining creek in the city centre and other drainage pathways including the culverts. All of these elements must be kept clear for surface runoff. This means the cleaning of the culverts and removal of growing plants and waste in the creek.

On the other hand, the expected run-off behaviour can already be taken into account in the planning phase of new residential areas or the additional integration of rainwater retention basin. Furthermore, the house owners should be provided with better information on heavy rain events and on what to do to be well-prepared. For this purpose, a freely available information flyer has been developed by GERICS.

The shades of adaptation

Adaptation in cities can be very diverse just like projected climate change impacts. Each city has its own vulnerable sectors, places and infrastructure elements depending on the climatic, environmental and socio-economic frame. The key for successful adaptation are scientifically based regional climate information and a holistic system understanding. Other important components for adaptation are: existing pressure, city needs, available knowledge, and the accessible city specific information.

An excellent tool to support adaptation actions and to integrate regional climate information into the existing environmental framework is the GERICS adaptation toolkit for cities. The modules can be adapted easily to the respective conditions to deal with challenges related to climate change impacts caused by, for example, longer heatwaves, more intense heavy rain events, or changed annual rain patterns. To

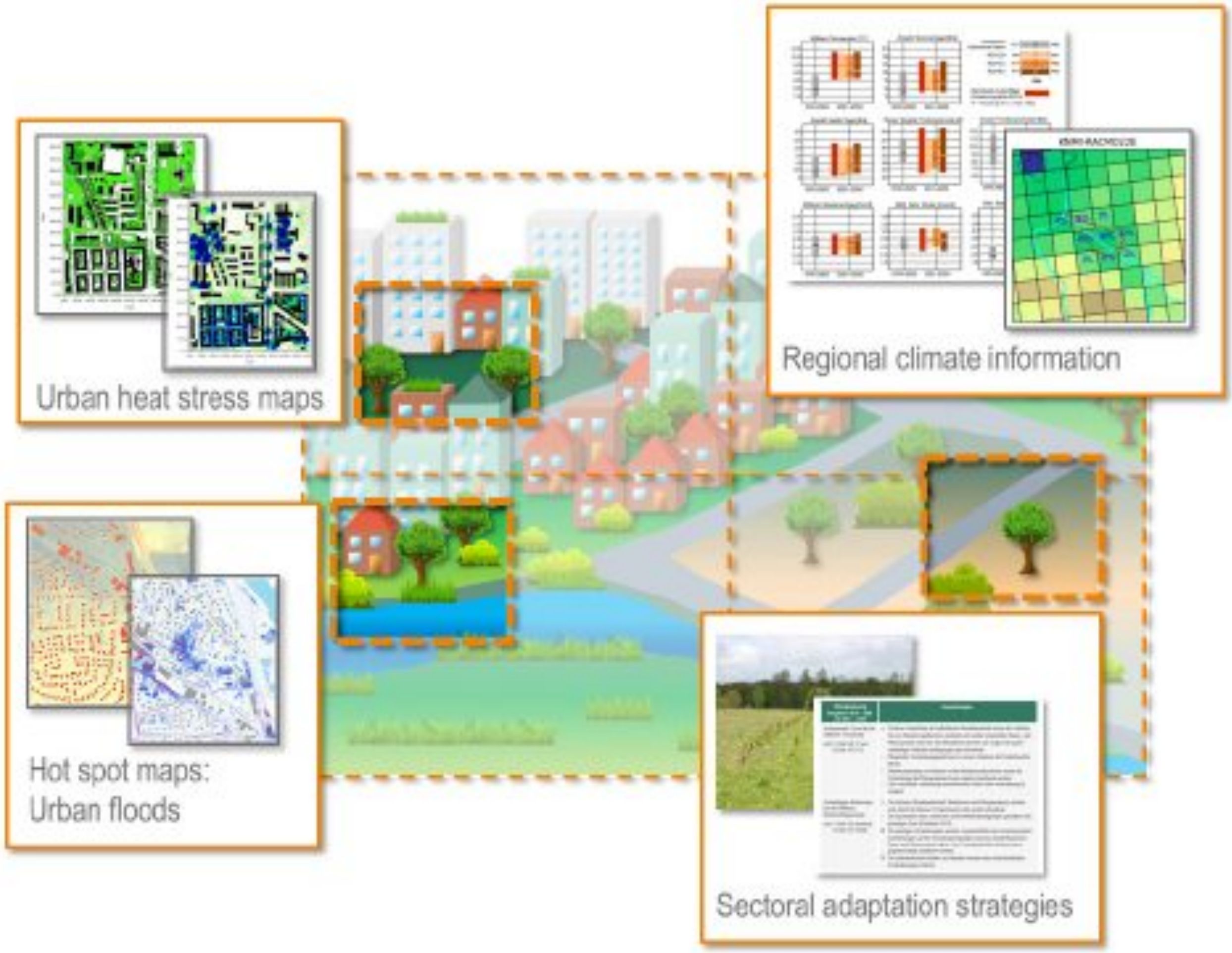

Fig.2. Examples from the GERICS adaptation toolkit for cities in a nutshell

describe the practical use of our city toolkit we highlighted three examples which are based on state-of-the art regional climate information and resulted in urban heat stress maps, hot spot maps for urban floods, as well as sectoral adaptation strategies regarding compensation measures, as illustrated in figure 2.

But adaptation is more than creating hot spot maps or developing adaptation strategies. For successful adaptation, communication is key. Therefore, only through the co-development and co-design with local decision-makers and local experts (such as urban planners, water and energy suppliers, etc.), the inclusion of local knowledge can be ensured. Communication is also the best tool to improve integrative system understanding, since the various expertise from all necessary areas can be incorporated. This not only benefits the success of the project but is also expected to increase the acceptance due to its local and individual character.

Further information and contact:

https://www.gerics.de/products_and_publications/toolkits/index.php.en

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