Competences for a sustainable city development: Qualification scheme for Climate Adaptation in Construction, Architecture and Planning

Clim-CAP

Deliverable 4.2

Content Collection

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Competences for a sustainable city development: Qualification scheme for Climate Adaptation in Construction, Architecture and Planning

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1. Description of purpose and overall content of each module

1.1 Module 1 - Basic scientific knowledge about urban climate processes

In module 1 all relevant basic scientific knowledge about urban climate processes is taught and made available for the course participants. The general learning goal of module 1 is *understanding urban climate processes.* This learning goal is subdivided according to themes concerning temperature in the city, wind in the city, water in the city and combined urban climate phenomena. Sub learning goals are:

- Obtaining knowledge about climate change and climate change scenario's containing the IPCC scenarios for all climate issues;
- Obtaining knowledge about the impact of climate change on urban areas including temperature, wind and storm water;
- Obtaining scientific knowledge about temperature and heat as part of the urban climate containing themes as: Short wave radiation and albedo, Long wave-radiation and emissivity, air temperature, Urban Heat Islands, Evapo(transpi)ration, Concept of human thermal perception;
- Obtaining scientific knowledge about wind as part of the urban climate, containing themes as: Wind streaming patterns and Wind speed around buildings and more complex urban environments;
- Obtaining scientific knowledge about water as part of the urban climate, containing themes as: Water cycle, Evaporation rates, Rainfall patterns, Catchment areas, the influence of land use on drainage of storm water and flood risks;
- Understanding the interactions between water and temperature and the relation of temperature and wind.

The study load for Module 1 is 25 hours (including the hours of the face to face meeting, studying at home and making the online test).

1.2 Module 2 - Analyses techniques for urban climate

In module 2 Analysis techniques for urban climate are taught with the general learning goal: *analysing and predicting urban climate processes*. Also the overall learning goal for module 2 is subdivided according to themes concerning temperature in the city, wind in the city, water in the city and combined urban climate phenomena. Sub learning goals are that the course participant:

- Know several types of measurements (methods for measuring temperature and wind in the city) and know how to access available data;
- Is able to carry out non-expert shadow analyses;
- Is able to read and interpret expert measurements on temperature;
- Is able to read and interpret expert surface temperature maps and urban heat maps;
- Is able to carry out educated guesses (non-expert analyses) on wind;
- Is able to interpret expert maps with run off patterns and flood risk assessments;

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- Is able to integrate all aforementioned knowledge and skills to analyse and predict urban climate processes;
- Is able to carry out a non-expert analyses on urban climate by drafting a climatope map.

The study load for Module 2 is 40 hours (including the hours of the face to face meeting, studying on the new knowledge at home and practising the new skills in the assignments belonging to module 2).

1.3 Module 3 - Smaller scale adaptation measures

Module 3 is all about integration of smaller scale adaptation measures into an integral design solution for adaptation on the smaller scale (neighbourhood and around a building). The general learning goal of module 3 is expressed as follows: consciously creating urban climate adaptation solutions on small scale, subdivided according to themes concerning temperature and wind control and integrated solutions. The scale of intervention lies between a neighbourhood down to street / single building level. Divided in sublearning goals, the course participant:

- Know small scale adaptation measures subdivided according to the themes concerning temperature, wind control and water. This entails solutions such as:
    - Facade material adjustments,
    - Shading elements,
    - Choice of Pavement materials,
    - Green walls,
    - Building and street orientation,
    - Vegetation in gardens and parks,
    - Evaporative cooling,
    - Boosting ventilation in open space,
    - Wind protection in open space.
- Is able to make an integral analyses of urban climate around the building/on neighbourhood scale;
- Is able to create an integral climate adaptive design for a retrofitting of an existing urban block using a selection of small scale adaptation measures;
- Is able to create an integral climate adaptive design for a new small urban neighbourhood.

The study load for Module 3 is 30 hours (including the hours of the face to face meeting, joining the excursion, studying the new knowledge at home and applying these competences in the design exercises belonging to module 3).

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1.4 Module 4 - Larger scale urban planning implementation

The purpose of module 4 is to integrate all knowledge, skills and competences from the foregoing modules and apply it on the larger scale of urban planning focused on the implementation of climate adaptation on this scale. The content for this module depend on the planning systems in different countries and different strategies to implement urban climate adaptation will be chosen. In some countries strategies that rely on top-down processes prevail and in other countries bottom-up processes prevail. Accordingly the content is extended with communication and soft skills, raising community awareness and fostering bottom – up initiatives. The general learning goal is: integrally creating urban climate adaptation on large scale (city- district). Divided in sublearning goals, this mainly entails that the course participant:

- Has knowledge of and is able to implement large scale climate adaptation measures;
- Is able to create integrated recommendations for urban climate planning based on a climatope map;
- Can apply the national planning directives to implement adaptation, including the policy instruments of legislation, subsidies and communication;
- Is able to make a stakeholder analyses and a communication strategy based upon that;
- Apply this communication strategy for example for fostering bottom – up initiatives and community awareness;
- Is able to combine these competences in an overall implementation strategy (including communication and stimulation) for a recommendation map.

The study load for Module 4 is 55 hours (including the hours of the face to face meeting, studying the new content at home and applying all knowledge, skills and competences of all 4 modules in the assignments belonging to module 4).

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2. Content guideline – result of WP4

In WP4 also guidelines for teacher and student accompanying all powerpoint lectures were produced. These guidelines are presented in this chapter.

2.1 Module 1 – Lectures

Module 1 consists of the following lectures:

- Lecture 1a: Lecture about regional climate change scenarios
- Lecture 1b: Lecture about climate change impacts
- Lecture 2: Lecture about urban climate - heat
- Lecture 3: Lecture about urban climate – wind and ventilation
- Lecture 4: Lecture about urban climate – water

2.1.1 Module 1 – Lecture 1a: Lecture about regional climate change scenarios

The climate system
Short introduction to the climate system,
Explain interactions between the different spheres briefly,
point out the very strong complexity and interdependence
Result: Difficult predictability

Radiation budget of the earth
Simple and schematic explanation of the greenhouse effect:
There is a balance between the short-wave solar radiation on the earth and the short (reflection) and long-wave radiation from the Earth's surface. This balance is necessary, otherwise the earth would get hotter or colder permanently.
As a small proportion of long-wave radiation is reflected by the atmosphere to the earth, nevertheless occurs an energy profit. This is used to heat the air and for evaporation and thus to drive the hydrological cycle. The global average temperature of the Earth (15 °C) would otherwise be -18 °C. This greenhouse effect is thus to be seen generally positive, but it is currently significantly enhanced by the human-induced change in the composition of the atmosphere.

Global average radiative forcing (Increase in energy balance)
Global average radiative forcing (column: RF values) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (column**: spatial scale**) of the forcing and the assessed level of scientific understanding (column: LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple

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addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. The range for linear contrails does not include other possible effects of aviation on cloudiness. Cit.: IPCC 2007

Observed changes
Observed changes in (a) global average surface temperature, (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961–1990. Smoothed curves represent decadal average values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). Cit.: IPCC 2007

Comparison of observed changes in temperature with results simulated by climate models using natural and anthropogenic forcing
Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. Cit.: IPCC 2007

Multi-model global averages of surface warming for the scenarios A2, A1B, B1
Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six marker scenarios. The assessment of the best estimate and likely ranges in the grey bars includes the Atmosphere-Ocean General Circulation Models (AOGCMs) in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. Cit.: IPCC 2007

Projected surface temperature changes for the early and late 21st century for B1 (top), A1B (middle) and A2 (bottom) scenarios
Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the AOGCM multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over the decades 2020–2029 (centre) and 2090–2099 (right). The left panels show corresponding uncertainties as the relative probabilities of estimated global average warming from several different AOGCM and Earth System Model of Intermediate Complexity studies for the same periods. Some studies

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present results only for a subset of the SRES scenarios, or for various model versions. Therefore the difference in the number of curves shown in the left-hand panels is due only to differences in the availability of results. Cit.: IPCC 2007

Relative changes in precipitation
Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. Cit.: IPCC 2007

Global Trends of Climate Change
Main global impacts of climate change

"National slides" of climate change

Last slide: Reasons of investigation
Connection to the next Presentation about the impact of climate change to urban areas

2.1.2 Module 1 – Lecture 1b: Lecture about climate change impacts

Slide 2: Reasons of investigation
Urban climate and climate change together request an adaptation to climate in the future

Slide 3 - 4: Optional introduction to the subject
- no climate at all in Paradise
- reality with fire (CO_2-production) and caves (adaptation to climate, housing area)

Part 1: Impact of Heat

Slide 5: Impact of heat
The frequencies of the daily maximum temperatures change due to the climate change:
- higher mean temperatures
- more variations ➔ higher standard deviation

➔ new climate with more heat and extreme heat

Slide 6: Hot Summer 2003 – standard for the future ?
Extreme summer situation with a very long heat wave (nearly 2 weeks) could be the normal summer situation in the future

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Slide 7: Vulnerability over heat waves in agglomerations

Slide 8: Urban heat island depending on the number of city population ?
For the example of cities in North Rhine-Westphalia the maximum temperature differences between the city centre and the rural surrounding increases with the number of inhabitants. In Cologne the differences in cloudless summer nights can reach more than 8 Kelvin, even in smaller towns with around 30.000 inhabitants the differences add up over 6 Kelvin.

Slide 9: Impact of heat stress: discomfort, circulatory complaints, death
- comfort temperature (lowest death rate) in Athens: 24 °C, in London: 20 °C
- **high-risk group**: the elderly, sick persons, very young children, women
- **persistence** of heat waves: now: 2 – 4 days, in future more than 5 – 7 days
- **time of the year**: heat early in springtime is more vulnerable than at the end of the summer
- **time of the day**: heat in nighttimes (regeneration) is more vulnerable than in daytimes

Slide 10 - 13: Vulnerability over heat waves
Step 1: defining the areas of the urban heat islands (climatope map or building density map)
Step 2: classification of the population density
Step 3: classification of the rate of habitants older than 65 years
Result : different categories of vulnerability in a city depending on thermal stress, population density and the rate of elderly people.

Part 2: Impact of Water

Slide 14: Examples of damage caused by heavy rainfall in an urban area

Slide 15: Increase of heavy rainfall events during a lifetime
As a result of statistical calculations the probabilities of heavy rainfall events change dramatically in the next 100 years. So-called 100-year events that occur now only once in a lifetime, will happen every 10 - 20 years in the future climate and are therefore to be considered as a regular event in a lifetime. They can not any longer be classified as a natural disaster. Instead, the urban structures have to be adapted to such events. Future 100-year events will bring significantly higher amounts of precipitation and continue to be regarded as a natural disaster.

Slide 16 - 17: Rainfall on sealed surfaces in urban areas
In urban areas the flow regime in relation to rainfall is significantly modified compared to the surrounding countryside. Instead of draining locally to the ground and therefore contribute to groundwater recharge, the precipitation in the city is mainly derived on the surface and thus shortened available for groundwater recharge and evaporation, while at the same time the risk of intra-urban flooding caused by heavy rain events increases.

Example: destruction of the asphalt surface by running water

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Slide 18 - 19: Bochum after a heavy rainfall event, summer 2013
Please add an example on national level.

Discussion

2.1.3 Module 1 – Lecture 2: Lecture about urban climate - heat

Slide 2, 3, 4: Urban climate characteristics compared to the unbuilt area
Changes in the levels of radiation and energy budget, the thermal conditions and bioclimate in urban areas compared to the surrounding.
The sunlight is attenuated by the urban haze resulting from anthropogenic trace gas entries in the town atmosphere. The ultraviolet radiation leads to favorable, in high doses also to adverse health effects (induction of erythema and skin cancer). It is filtered preferably in the polluted city atmosphere and has, particularly in winter, significantly lower values in comparison with the surrounding area. As a result of changes in energy balance urban average annual air temperatures are increased by 1 to 2 K compared to the region and thus represent an urban heat island. However, city size and structure, weather and season determine substantial deviations from these values, which can be quite 10 K to 15 K in individual cases and for a short time at night.
Temperature differences are indicated in Kelvin !

Slide 5, 6: Heat balance
The composition of the urban atmosphere, the horizon constraints of urban buildings and the properties of building materials change the energy balance of a city. The turbulent currents of the sensible heat and the latent heat, expended for evaporation, are modified significantly in urban areas. On average the sensible heat flux (for the warming of the air) outweighs the latent heat flux, since the absence of surface water and vegetation occurs less evaporation.
Sunshine duration is shortened in urban street canyons due to the larger shading caused by the buildings. Extreme values are achieved by unfavorable orientation, height and density of buildings. The global radiation energy is absorbed by the urban development and stored as heat. In contrast to the values of the solar radiation directed toward the bottom longwave atmospheric radiation values are generally increased.

Different types of temperatures:

Air temperature
Slide 7
24h – mean diurnal variations of air temperature for two climate stations (one city station, one rural station) in summer and winter during a cloudless period:

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- similar air temperatures during the day
- at night significantly higher air temperatures at the inner-city climate station, since the cooling after sunset is greatly attenuated by heat supply from the buildings.

Surface temperature
Slide 8
Example of a thermal image (recording in early summer, afternoon) on a residential street with trees, differences in the surface temperatures of up to 10 Kelvin between shaded and sunlit road surfaces.
Soil temperature
Slide 9
4 days diurnal variations of air and soil temperature in Bochum during a cloudless period (autumn):
The deeper measured in the ground the flatter the temperature curves are. The daily maximum soil temperatures in increasing depth occur with an increasing time delay after the daily maximum air temperatures. In 50 cm soil depth almost no diurnal variation is evident.

PMV – Bioclimate Model
Slide 10 - 12
The thermal impact complex deals with the heat balance of humans and the associated possibilities for heat emission of the body for given meteorological conditions. An optimal thermoregulation of man is only guaranteed within certain narrowly defined climatic parameters. Variation of these parameters affect the organism as thermal stress. It can manifest itself as heat stress in summer or cold stress in winter. Mainly the meteorological parameters global radiation, air temperature, humidity and wind speed are important for the thermal comfort. High air temperatures can complicate the heat emission through the skin. High humidity can also affect the thermal comfort when the vapour pressure gradient between the skin and the atmosphere is too low. Low temperatures and high wind speeds, however, increase heat loss from the body. Direct sunlight warms the body surface and may reduce the cooling effect of low air temperatures and wind. The effect of these meteorological parameters on thermal comfort can be integrated and objectively evaluate on various metrics, whereat a differentiation according to the degree of exposure is possible.
For the prediction of thermal comfort for the people in a model area the PMV – Bioclimate model is used. It is the most famous Bioclimate model and takes into account the personal comfort level of average people. The values of the PMV-scale range between -4, which corresponds to a feeling of "very cold" to +4 ("very warm"). A PMV value of 0 corresponds to a neutral, so comfortable thermal situation (not too cold and not too warm).
A case study in the Bochum city centre shows the bioclimatic situation in the surrounding of an urban space on a hot day in summer. Shaded areas (building and tree shadows) show a comfortable bioclimatic situation, all other areas are very hot (values over 3.0 PMV).

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Air temperature – Urban heat island
Slides 13 – 24
S 13: Air temperatures on four different climate stations in Düsseldorf during a 5-day-heatwave in summer 2009, station 1 is a city climate station, stations 2-4 are rural.
The differences in night time temperatures increase day by day from 2 Kelvin at the beginning of the heat-wave up to 4.4 Kelvin after 4 days of heat. Reason is the increasing heat storage in the built-up surrounding of station 1 (city).

S14: Results of a mobile climate measurement in Düsseldorf, night time, summer.
The air temperatures on the measurement route through Düsseldorf differ up to 10 Kelvin. The warmest areas are located in the city of Düsseldorf, the coldest in the unbuild surrounding. Here the air temperatures at 0.5 m height are lower than at 2 m height, because the cold ground surface cools the air from below. In urban areas the situation is reversed, the boundary layer air are kept warm from below (hot asphalt surfaces of roads).
S15: xy-chart of air temperatures against cooling rates
The different land use patterns of a city show a typical temperature behaviour respectively.
- Rural areas (blue) are cold at night and have a high cooling rate.
- Riverside areas (dark green) have average nightly air temperatures and average cooling rates.
- Forest areas (green) are average warm up to slightly over-heated at night and have a very low cooling rate, since they remain very cool during the day.
- Suburban areas (yellow) are average warm to slightly hot at night time and have an average cooling rate (about 6 Kelvin in the time from 14.00 to 23.00).
- urban areas (red) are strongly overheated at night with a very low cooling rate.

S 16: Isoplethen chart of temperature differences between an urban and a rural climate station in Essen in daily and seasonal cycle.
Up: differences between a courtyard station and the rural station
Down: differences between a street canyon station and the rural station
During summer, the street canyon station shows higher temperatures than the courtyard station, particularly in the afternoon and beginning night. The greening of the courtyard reduces the urban heat island by shadowing the surface and cooling by evapotranspiration of the vegetation.

S 17: The annual average temperature rises per 10% sealing of surfaces at about 0.08 °C

S 18: Maximum temperature differences between the city centre and the rural surrounding for cities in NRW
The climatic characteristics of a city derive partly from the degree of sealing and city size. This chart shows the relationship between the the heat island effect and the size of the city for various cities in North Rhine-Westphalia. It is clear that the maximum temperature difference between the big city centers and the surrounding countryside is up to 9 Kelvin. It is also seen that even in smaller cities under 100,000 inhabitants a measurable heat island effect can occur.

S 19: Example of an air temperature distribution map
The warmest areas during a clear and warm summer night are located in the inner city of Arnhem. Up to 10 Kelvin lower air temperatures occur in the depths of the valleys. Cold air is heavier than warm air and therefore flows downhill and accumulates in depressions and valleys.

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S 20: Example of the urban heat island in Bochum, current situation and expansion of the heat island in the future scenario
Yellow. Below-average population density, e.g. CBD
Orange: average population density
Red: above average population density
Purple: above average number of elderly people over 65 years

S 21 - 24: Example of the hot summer 2003

- Temperature deviations from the mean summer values (mean June, July, August 1961–1990) in Germany, 2003 was the hottest summer since 1856
- number of summer days (≥ 25℃) and hot days (≥ 30℃) in the year 2003, in June 2003, in July 2003 and in August 2003 compared to the mean values (1912-2007) in Bochum
- Frequencies of daily maximum temperatures: The increase of mean and variance leads to a sharp increase on hot days in the future climate.

Surface temperature
Slides 25 - 32
Every body, every surface with a temperature> 0 Kelvin (= -273.16 ℃) emits radiation. This is purely thermally stimulated and thus a function of the absolute temperature of the surface. This relationship is described by the "Stefan-Boltzmann law". By non-contact measurement of these heat radiation (IR) the surface temperature of a body can be detected.

Example of the thermal image of Bochum, day and night situation: Rural areas are cooler in day- and night-time (green to blue colours). Water is, compared to other surfaces, cold during the day and relatively warm in the night. The heat island of the city of Bochum is visible in the night-time image. All sealed surfaces are in orange to red colours with temperatures above 18 ℃.

Detailed image of the city centre of Bochum: all buildings and streets are warmer than the unsealed surrounding.

Detailed images (photo and thermal image) of the Opel factory in Bochum: very high temperatures of this completely sealed area.

Detailed image of two different roofs: green roof in the foreground, normal roof with a tree shadow in the background.

Detailed images (thermal image and photo) of an urban square: lower surface temperatures on the water body, between the cobblestones. Wrong temperatures measured on metallic surfaces (the average emission coefficient used for IR measurements is not usable for metallic surfaces).
Detailed images (thermal image and photo) of an street canyon: lower surface temperatures on the cobblestone areas. Different temperatures are based on different surface and house facade colours.

Traffic areas with bright surfaces: bright concrete warms up to 13 Kelvin less than dark asphalt.

Last slide 33: Climatope map of the Ruhr-District, Germany
Region with connected cities, areas of heat island, most cities without a rural surrounding, instead surrounded by the sealed, built-up areas of neighboring cities.

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2.1.4 Module 1 – Lecture 3: Lecture about urban climate – wind and ventilation

Slide 2: Vertical wind speed distribution over rural and urban terrain

The average wind speed is lower in cities compared to the surrounding areas, because the increase in the surface roughness due to the development slows down the flow. This means, for example, that anthropogenic micropollutants and the warm air can hardly be discharged through the urban canyons. However, the gustiness is increased at building edges and in vortices behind buildings, while the wind direction varies highly. Starting from the fact that in urban areas both the thermal and air quality stress for the population can be very high, an effective atmospheric exchange in the city would be beneficial, so that a removal of over-heated air and pollutants can occur.

However, the urban development of large parts of the urban surfaces leads to negative urban climatic effects. The urban structure with its buildings is a flow obstacle, resulting in a reduction of the ground-level wind speed.

Slide 3: Stable and unstable atmospheric conditions

Weather conditions with inversion (stable condition) avoid an vertical air exchange. The cooling rate for air is 1°C per 100 m, the surrounding air in the case of stable atmospheric condition is warmer than the ascending air package and therefore no vertical air rise is possible. With unstable weather conditions the ascending air is always warmer than the surrounding and therefore continues rising (convection).

Temperature inversions lead to unfavorable emission climatic conditions. That lead to a lack of ventilation and especially in valleys with existing issuers the air falls off in quality.

Slide 4 - 5: Modifications of the wind field by building structures

At prominent locations within the urban development, the gusts of the wind increases. This applies in particular to channelling and jet effects within the range of building necks and street canyons. Since these effects are highly localized, they have - in relation to the weak atmospheric exchange in the city as a whole, - no positive influence. This wind flows can also lead to nuisance up to dangerous situations, especially in coastal regions with higher wind speeds.

The predetermined flow direction by the gradient wind undergoes strong modifications in the city, which manifest themselves in particular in near-surface deflection effects and lead to channelling and nozzle effects in the field of urban canyons and building gaps.

Slide 6 - 7: Modifications of the wind field by building structures

- annual mean wind speeds in the City of Bottrop

Wind field analysis: low wind speeds and bad conditions for ventilation in the dense building zone. The wind speeds in the city centre average less than 1 m/s, in the rural surrounding they are many times higher, up to 4 m/s.

- annual mean wind distribution in the City of Essen

Not only the wind speed but also the wind direction is highly modified by the direct surrounding of a climate station. A street canyon in the city centre of Essen switches the wind from

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predominant southwest directions (rural station Essen-Mülheim) to a dominant wind flow from the south with significantly lower wind speeds because of the surrounding buildings.

Slide 8 - 10: Local breeze system caused by the urban heat island
Furthermore, urban areas with sufficient warmth are able to form an independent local breeze system by rising hot air over cities, which leads to compensation by the influx of cooler, surface air from the surrounding area. Such ground-level, intermittently occurring air flow is therefore referred to as “local breeze system” (or UHI circulation). Since this wind system is weak, it occurs particularly when the parent flow is low or suppressed (< 3 m/s), especially during autochthonous cloudless nights.

Slide 11: Local breeze system caused by the urban heat island or cold air drainage
Another factor inhibiting the exchange can be seen in the effect of high and dense vegetation (shrubs and trees) to block the flow in the area of green space and ventilation corrodors. There, the vegetation leads to a reduction of ground-level wind speed ("wind catchers"), so that the exchange can be difficult. A particular disadvantage gives this effect to nocturnal, often only poorly developed drainage flows.

Slide 12 - 14: Ventilation corridors
One of the urban climate investigations objectives is, to detect ventilation paths between the city and surrounding areas. Cold or fresh air can flow from the surrounding countryside into the city during low wind weather conditions. Such air exchange arise themically driven as “local breeze system” or in relief terrain by gravitational drive. The depth of penetration in the urban area depends on the strength of the drive and the roughness of the ventilation path.
Railway lines or highways are typical ventilation corridors, the latter transporting potentially polluted air. But also open green areas can guide the fresh airflows.

Slide 15: Relief induced air circulation
The relief inside and outside a city body also influences the near-surface wind field and can have positive as well as negative influences on the urban climate. The relief may result in the case of valleys to channeling effects. This allows fresh, cool air from the surrounding area to flow far into the body of the city. In cloudless nights, even with opposite flow in the free atmosphere, ground-level cold air flows down the slope and penetrates the built-up area. In hot summer nights, this can lead to a local cooling in the urban area. Negative effects of the relief are expected when the valley floor and the valley slopes have buildings or dense forests. These can reduce ground-level ventilation. In the worst case, structures perpendicular to the valley axis or along the slope form a flow bolt which can, with weak surface winds, impair the ventilation of leeward buildings.

Slide 16: Relief induced air circulation: cold air flows in the city of Arnhem
Example of the city of Arnhem:
relief induced cold air flows downward the hills and cumulates in the valley floors. They use the valleys as flow corridors and penetrate the urban areas.

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Slide 17 - 18: Air flow in street canyons
Street canyon: air flow without and with trees
Two schematic displays of the vertical circulation of air in a street canyon without and with trees.
➔ Reduction of vertical transport of air and pollutants due to the treetop layer.

Slide 19 - 20: Air flow in street canyons
Examples photos of two streets with a dense treetop layer:
- street with heavy traffic, potential of a high pollution rate in the street under the trees
- pedestrian zone, no pollution potential

Discussion

2.1.5 Module 1 – Lecture 4: Lecture about urban climate – water

Slide 2: Global introduction to „water“
Projection of CO2 emissions and corresponding climate: no stabilisation of sea-level rise in the next 1000 years
Sea-level rise due to thermal expansion and to ice melting will be the main problem of global climate change in the next centuries to millennia!
But this presentation will deal with “**Water in Cities**”, mainly with heavy rainfall events.

Slide 3: Water bodies in urban areas
Cities are generally characterized by a low relative and absolute humidity compared to undeveloped hinterland. While low exchange weather conditions, particularly in clear and wind calm summer nights, the humidity levels within the built-up areas are temporarily higher than in the surrounding areas. This effect is called „Urban Moisture Excess“ (UME).
The reasons for the occurrence of the UME are:
- due to the partial overheating in cities a failure or at a later occurrence of dew setting occurs
- evapotranspiration persists even at night compared to the much cooler surrounding

In general, it can be assumed that in Central Europe approximately one-third of the total annual hours, especially in the second half of the night, have an UME.
Through the construction of more water and green spaces in cities evapotranspiration is increased and thus the latent heat flux is raised at the expense of the sensible heat flux. This ensures that the expended energy amount for the evaporation of water of about 2.4 MJ / kg is not available for the heating of the air.

Slide 4: The Physiological Equivalent Temperature as a function of air temperature and air humidity
By increasing the evaporation heat stress could rise by frequent occurrence of sultriness. A model study shows, however, that these fears are unfounded. For the results shown in the graph the physiological equivalent temperature (PET) was calculated depending on the air temperature and relative humidity.

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The increase in physiological equivalent temperature PET is almost independent of the air humidity conditions, but follows the rise in air temperature. Thus, it can be assumed that the heat load caused by increased evaporation in the urban area is lower than the cooling effect of energy consumption by evaporation.

Slide 5: Increase in heavy rainfall events per human lifetime
Rainfall is particularly increased in the lee of urban areas.
Usually the urban drainage systems are designed to cope with heavy rainfall events with a probability of 10 years. As a result of statistical calculations the probabilities of heavy rainfall events change dramatically in the next 100 years. So-called 100-year events that occur now only once in a lifetime, will happen every 10 - 20 years in the future climate and are therefore to be considered as a regular event in life. They can not any longer be classified as a natural disaster. Instead, the urban structures have to be adapted to such events. Future 100-year events will bring significantly higher amounts of precipitation and continue to be regarded as a natural disaster.

Slide 6 - 7: intense rainfall events
Different examples of heavy rainfall events in the past (records of a rain gauge in Bochum, 1910) and present (> 50 mm in Essen, 2009). On 26/07/2008 Dortmund had within a few hours up to 200 mm rainfall, representing nearly a quarter of the mean annual precipitation sum.

Slide 8: Forecasts for the precipitation trends
Country specific data

Slide 9: Direct and indirect effects of extreme rainfall events
Extreme rainfall event ➔ fast and large runoff ➔ overloading of the drainage systems ➔ soil erosion and high risk of flooding ➔ contamination by mud and scree material, increased health risk, harm to infrastructure and private property

Slide 10 - 11: Urban water cycle
In urban areas the flow regime in relation to rainfall is significantly modified compared to the surrounding countryside. Instead of draining locally to the ground and therefore contribute to groundwater recharge, the precipitate in the city is mainly derived on the surface and thus shortened available for groundwater recharge and evaporation, while at the same time the risk of intra-urban flooding caused by heavy rain events increases.

Slide 12 - 14: Example of Bochum, heavy rainfall event in June 2013
- flooding of a street on the bottom of a small valley, up to 1.40 m water depth
- destruction of the asphalt surface by running water
- points (red) of all efforts of the fire brigade after the extreme rainfall concentrated in the eastern part of Bochum

Slide 15 - 16: Drainage network

This project has been funded with support from the European Commission.

- normal case: only the water from all sealed surfaces runs into the sewer network, rainfall over unsealed areas infiltrate into the soil or runs into existing water bodies
- heavy rainfall with flooding: rainwater from all areas, sealed and unsealed, tries to run into the sewer network with the result of overloading and flooding

Slide 17: Drainage network: calculation bases DIN / EN 752
The sewer system has to work correctly with rainfall events up to an annuality of 2 to 5 years, depending on the urban structure. Higher rainfall events can cause overloading, but flooding are allowed only with 20 to 30years events or higher rainfall.

Slide 18: Risk assessment: pluvial flow path map
For an example, rural and urban areas of Soest, the pluvial surface runoff lines are shown in this map. Basis for this calculations are the topography of the region and the occurrence of natural or artificial sinks. The runoff lines are classified depending on the amount of merged rainwater from the surrounding areas.

Slide 19: Risk assessment: topography of the catchment area
Settlement areas in hillside situation or below slopes can be overrun by wild runoff water from above-lying areas. Particularly at risk are residential areas which are located under highly sealed areas because slope drains can lead to an impounding or overloading of the sewerage system. Downhill roadways and streets forward the slope runoff to be directed towards the populated area. Already flat inclined slopes, embankments and other surfaces can be equal effective during heavy rainfall.
Is a settlement in a trough position or a part of the settlement in a hollow, with an unfavorable effect of road directions the slope drain can meet at the lowest point, potentially causing great damage to adjacent properties and buildings and overloading the sewer system temporarily.

Slide 20: Risk assessment: rate of surface sealing
The hazard potential of a sub-basin increases with the size of the outflow effective areas and the degree of outflow activity. The higher these two values, the less restraint potential the area has and the more rain water is fed to the drainage facilities without delay or goes into the surface runoff.
In areas with medium or high surface sealing rates a risk to the population, buildings and infrastructure by aboveground flash floods and congested channels is very likely to occur during localised extreme rainfalls at very high intensities.

Slide 21: Risk assessment: overload areas in cities
Gullies and smaller streams often have no significant flood control facilities. In general, there is no information on flow behaviour, profile course or other waterways data for small bodies of water. Excessive amounts of water can flood settlement areas. Channel systems, that are not rated for such quantities of water, can be overloaded. Flood discharge of rivers can also cause a backlog in the rain water inlets of drains or damage the sewage treatment plant by flooding.

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Slide 22 - 23: Risk assessment: existence of bottlenecks in the drainage network
A congestion of drains has not only the consequence that rain water cannot drain, but backwater from the sewer system can flow into underlying cellar rooms. Also affected are underground car parks, subways and other which can be flooded with poorly sized drains.
The mass transfer at a slope drain and overflow of streams (gravel, sediment, leaves / branches and other entrained solids) can affect the functioning of the drainage systems significantly due to blockage of road gullies, enemas open flumes and streams in cased sections and other cross-cutting constraints (despite assurance with rake). Water can sputter out of road gullies instead of draining off.
Water collects after heavy and extreme precipitation often in deeper points of the urban area, such as underpasses or tunnels, because the local drainage can not cope with the invading water masses. A hazard is due to such flooded bottlenecks if a passage is temporarily not possible for intervention or emergency personnel because of the water masses or break down vehicles.

Slide 24: Risk assessment: river flooding
High-water marks are useful to remember past flood events and display the altitude reached. They are a way of raising the awareness of the existing flood risk in vulnerable areas.

Discussion

This project has been funded with support from the European Commission.

2.2 Module 2 – Lectures

Module 2 consists of the following lectures:

- Lecture 1: Lecture about urban analysis – Measurements and Data Availability
- Lecture 2: Urban climate analysis – Climatope maps
- Assignment: Climatope Map of Neuss

2.2.1 Module 2 – Lecture 1: Lecture about urban analysis – Measurements and Data Availability

Slides 3 – 11 Data base

Country specific data

Small-scale data

German Climate Atlas of the German Weather Service (DWD)

- Retrievable climate elements divided by sector:
  General: air temperature, Climatological characteristic days, precipitation, vegetation beginning, Forest Fire Index
  Agriculture: for example - Soil moisture, frost penetration, etc.
  Forestry: for example - Bark beetle (beginning of infestation)
  Soil protection: for example - Maximum surface temperature
  Energy: air temperature, precipitation
  Transport: for example - Ice days, frost days, etc.
- Cartographic representations, diagrams
- Comparison normal values / actual values
- Presentation of climatic scenarios

Figure in the presentation:

Germany-wide representation of the temperature averages in March 1961 to 1990 and the current temperature deviation of the same month

Climate Atlas of North Rhine-Westphalia

- - Divided into text part and maps with data and future projections

Maps:

Division into levels: government departments, districts, municipalities, use of different scales (1: 500,000, 1: 250,000, 1: 100,000)

Different categories (eg, air temperature, precipitation, solar radiation) can be selected with different categories (eg, minimum temperature, total precipitation, sunshine duration) in freely definable periods

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Bioclimate Map of Germany
Representation of stressful climatic situations, "subjective" representation of qualitative detectable climatic elements

Slide 12
Air temperature distribution
Map of the relative temperature distribution of the city of Bochum
- The figure shows a map of the relative air temperatures (temperature deviations) of Bochum
- For climate analysis, the absolute air temperatures are of a high significance, as these reflect the urban structures,
- Absolute temperatures are strongly time-variable
- The representation of the relative air temperatures refers to a summer day with undisturbed radiation, the temperatures are at 2m height above ground
- The level of the individual temperature class depends on the span of temperatures in the urban area and allows an assessment of the heat dominated areas
- Data is provided by the cities, often the data collection is the basis of a climate analysis
- Data collection is carried out selectively by climate stations and with suitable measurement vehicles (bus, car, bicycle)

Possible representation as a vector or raster data: GIS

Slides 13 - 16
Data base – Measurements
Measurement bus of the Ruhr-University Bochum
- Measurement setup is mounted at the front (air temperature, humidity, IR surface temperature)
- Pneumatic mast for wind speed and wind direction (three-component wind measurement)
- Temperatures and humidity can be measured continuously, possibility of measuring and comparing large-scale urban areas
- Wind measurements of interesting points possible, for example, for the detection of fresh air tracks
- -In principle various measuring platforms, such as car or bike, are also suitable
- IMPORTANT: no influence on the measurements by elements of the measurement platform (eg waste heat from the engine)

Climate Station on a brownfield site
- Measurements can provide data for longer periods
- Variable Sensors
- Measurements serve as reference and for the calibration of mobile measurement campaigns

Representation of the continuously recorded air temperatures by the example of the City of Soest
- Data is measured with the previously shown measurement bus

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- Data must be processed before it can be displayed in a map (time correction, statistical classes)
- to produce a comprehensive map, experts must extrapolate the linear recorded values to the area,

especially in this case, the factors to be consider are land use and terrain elevation.

Slides 17 - 21
Surface temperatures
IR-surface temperatures of the urban area of the Cit y of Bochum

- Taken with a multispectral scanner (aircraft)
- This type of scanner measurment allows high resolutions (here 7.5 m)
- Sometimes this kind of data is available through the municipalities, but the costs of the data collection are significant
- Aerial survey usually takes place during an undisturbed radiation day in summer, one aerial survey is made during daytime, another at night
- Important for the interpretation of the data:
- There are only surface temperatures shown (roofs, treetops)
- Materials with strongly differing emission coefficients are represented incorrectly, this can lead to errors in the interpretation (ex .: metal roofs are shown as too cold)

Surface temperatures
Landsat 8 Panchromatic and LANDSAT-8 TIR

- Examples of free satellite data (Landsat 8)
- The panchromatic channel has a resolution of 15 m and shows detailed structures
- The light clouds can be seen in this figure, they don't disturb the interpretation of the data
- The TIR channel has a resolution of 100 m
- Urban structures are only dimly discernible, use-related temperatures are no longer to be made out - yet suitable for estimating the urban heat island
- In this example, however, the cloud cover is clearly visible and restricts the image evaluation
- The search for suitable, cloud-free satellite images often proves to be very time consuming

Slides 22 - 23
Land use
Real land use for the city of Bochum

- Map is a rough overview and represents the level of detail of the land-use classification of the city of Bochum, the legend shows the individual classes
- For an assessment of the urban climate a high level of detail is essential

Land use mapping by the example of the City of Soest

- Another example of a land use classification
- A lower but sufficient level of detail

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- Land-use keys vary greatly from municipality to municipality, recording the real land-use is often done by external service providers

Slides 24 - 26
Elevation model
Height map layers for the City of Bochum (15 meters)
- Representation of a digital terrain model in classified height layers with a class size of 15 m
- Original data is in TXT format (xyz records) with a horizontal resolution of 1 x 1 m and a vertical resolution in the cm range
- Provisioned by the Ordnance Survey NRW, you have to pay a fee or receive it through the contracting community
- GIS processing of the raw data necessary

Elevation model
Shuttle Radar Topography Mission (SRTM)

- Free alternative to the data of the Ordnance Survey
- Global data set
- Horizontal resolution in the range of 90 x 90 m

Elevation model
Elevation model of Bochum with superimposed building plans
- combination of digital terrain model with building footprints from the solar register
- Elevation models of the Ordnance Survey also include such records, the necessary spatial data processing requires a profound knowledge of GIS Systems
- Data is required for the computation of flow paths and flood areas

Slide 27
Population data
Representation of the population by building blocks for Bochum
- Data exists in german municipalities or may be obtained from external service providers in the spatial data and geomarketiung sector (eg: infas GEOdaten) but not with this level of accuracy
- Data will be used for vulnerability analysis

Discussion

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2.2.2 Module 2 – Lecture 2: Urban climate analysis – Climatope maps

Slide 2

Climatope Map for the City of Bochum

- Shown is a climatope map for the entire city of Bochum
- Because of the dark red color, parts of the city are striking the eye
- These areas have the highest heat stress and are corresponding to the urban heat island
- Other minor areas are colored equally, eg Bochum-Wattenscheid (north-western city area)
- Smaller heat islands are suited here in the highly compacted areas of districts (Wattenscheid was a separate municipality until 1975 with an independent community planning)
- These are areas that should be given special consideration under urban climate / planning aspects
- The red areas are part of the Climatope of the City, characterized through compacted land use structures, the air exchange is limited and the temperatures are significantly higher than in the open land climatope
- Most of the parts of the developed are of the municipaity belong to the class of the climatope with medium building density, those land use structures are less dense than in Climatope of the City, the rate of the vegetation is higher, the temperatures are moderately higher than in the open land climatope
- Especially the north-western settlement areas belong to the class of the Climatopes with low building density, here the microclimatic conditions are indeed affected by the land use structures, but this influence is small, thermal stress is not given
- the open land climatope is considered to be a very positive area under the aspect of heat stress and air hygiene
- Connections of this area with dense built-up urban areas, either directly or through green areas are to be kept absolutely free of disturbing influences because of the possible air exchange
- Urban parks and forests are considered to be relevant air channels, due to the usually lower plant density and less undergrowth, parks are better air channels than forests
- Large bodies of water (lakes and major rivers) can affect the air exchange conditions and, due to its high heat capacity, have a strong influence on the local temperatures, They temper the climate, but can also give an extra warming at nighttime
- A climatope map provides important information from a climate perspective on urban planning
- It is the basis for further, more detailed maps that are aimed directly at the city planners (eg vulnerability maps)

Slide 3

Summary of the advantages of a climatope map

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Slide 4

General definition of climatopes

- A climatope represents areas with the same micro-climatic characteristics (temperature, wind, humidity), usually determined by the land use structures
- The first group of climatopes (climatopes by definition) is described by the land use, no further consideration of other factors must be included
- The group of calculated climatopes cannot be assigned as easily, although the building structure affects the climatope classificationr, large-scale climatic or orographic factors (altitude, proximity to large bodies of water, distinct air channels) can, however, influence the assignment to a climatope in a positive or negative way (in the thermal sense).

Slides 5 - 7

Presentation of open land climatope with its advantages and disadvantages

- This CLIMATOPE is formed mainly by agricultural land (arable land, meadows)

Slides 8 - 10

Presentation of the water climatope with its advantages and disadvantages

Slides 11 - 13

Presentation of the forest climatope with its advantages and disadvantages

Slides 14 - 16

Presentation of park climatope with its advantages and disadvantages and Photos

Slides 17 - 19

Representation of the climatope with low building density with their advantages and disadvantages and Photos

Slides 20 - 22

Representation of the climatope with medium building density with their advantages and disadvantages and Photos

- In principle, the advantages and disadvantages of both climatopes (low and medium building density) are very similar, but the climatope with low building density has little negative effects on the air flow and thermal stress

Slides 23 - 25

Presentation of the climatope of the city with its advantages and disadvantages

Slides 26 - 28

Presentation of climatope of the inner city with its advantages and disadvantages and photos

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Slides 29 - 32
Representation of commercial and industrial climatopes with their advantages and disadvantages

The following slides shows the required data basis for the creation of an expert climatope map, and the necessary steps are described.

Slide 33
Land use data
- Shown is the very fine real use classification of the city of Bochum
- The figure shows only a small part of the urban area and therefore only a small part of the total land use classes
- An assignment to climatopes with such a detailed land use key is only possible by using the computer, a manual classification is not exactly feasible
- Therefore, a reduction in the number of classes by an assignment in climate-related land use classes is performed (see next slide)

Slide 34
- Here the land useclasses have been reclassified in climate-related land use classes, which land use class belongs to which climate relevant class requires knowledge of the appearance of the respective land use in the case of built-up areas (site visit, photo documentation, etc.), forests, parks, waters and others are easily reclassed by the respective land use class
- A cartographic illustration of this classification shows structures that are very similar to the climatopes and is a rough climatic assessment, with this maps the planning of further steps (eg measurement campaigns) is suitable

Slide 35
Map of the relative air temperature distribution at 2 m height
- This map must be designed by experts on the basis of measurements and the consideration of building structures, orography and measurements of air temperature, wind, etc., a program for the modeling of air temperatures over the entire city is unknown (the urban scale is usually between the regular scales of climate modeling programs such as METRAS (University of Hamburg) which is focused on the mesoscale (regional) and does not adequately consideres the different building structures,on the microscale level the existing program ENVI-metworks on a too large scale (the model size of this program is 400 x 400 m)
- Illustrated in the map on this slide are not absolute temperatures, but the average deviations from the surrounding temperatures

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Lifelong Learning Programme

CLIMCAP — Qualification Scheme for Climate Adaptation in Construction, Architecture and Planning

Competences for sustainable city development

Slide 36

Map of the mobile measured air temperature at 2 m height for the city of Soest

- Unfortunately we do not have any measurements for Bochum,shown in the previous slide is the existing air temperature distribution map from a previous urban climate analysis
- Temperatures are recorded continuously with a measuring bus, but other measuring platforms are also suitable
- Measured temperatures must be time corrected, since the natural diurnal variation of air temperature affects the measurement during the measurement campaign
- The best information of the influence from the country or the buildings on the air temperature is obtained in the nightly hours, there is no more incoming solar radiation and the structures themselfes determine the evolution of the temperatures

Slide 37

Height layers map of Bochum (15m)

- The altitude can affect the temperature of particular types of land use classes significantly
- Since a climatope basically reflects the situation at night, the gravitational processes of air dynamics dictated by the orography have to be taken into account
- Cold air masses are relatively heavier than warm air packages and should therefore, if the climate situation does not interfere with air flow (wind speeds must be less than 0.5 m / s) glide down the slopes
- Valley areas are thus supplied with cold air, in hollows cold air may accumulate (pool of cold air), it is noticeable by the expression of a distinct inversion layer, the temperatures are, compared to the environment, significantly lower
- Peaks occur much warmer at night since cold air masses move downhill

Slide 38

Classified Thermal Map of Bochum

- Thermal maps often provide a high-resolution image of the surface temperatures
- In the normal appearance they are difficult to interpret in terms of a meaningful climatope classification
- A classified thermal map provides a much better overview and directly show urban climate advantages and disadvantages
- In the GIS-based calculation of a climatope map high-resolution classified thermal maps provide pixel-precise assignment to individual climatopes, but climatopes always describe a summary of land use patterns,so the first calculation results must be generalized again (at a resolution of 7.5 x 7.5 m, not every Pixel can represent a different climatope), as a result, the accuracy of the calculated climatopes is significantly higher than a manually designed map or a map that is based solely on the classification by the type of land use, the transition regions between different climatopes is very good represented (the borders are no longer displayed as a sharp separation but will go into each other)

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- The calculation of such a map does not have to be made by the students, but the knowledge of the method is very useful for the understanding of the map
- How is the classified thermal map calculated?
    - o What is needed is a image of the day and a image of the situation by night
    - o The average temperature between those two images is calculated for each pixel
    - o The temperature difference between day and night is calculated, this represents the nocturnal cooling for each pixel
    - o Average temperature and the cooling are each divided into meaningful classes, as shown by the legend, the number of classes for the mean values is 3 and the number of classes for the nocturnal colling is 4
    - o These two maps are then cross-classified, i.e. all possible class combinations have to be formed and mapped as classified thermal map
    - o The legend shows the result of this cross-classification:
        - The y-axis shows gradations whether it is a cold air producing area or a heat island
        - The x-axis describes the intensity of the cold air production or heat area

Slide 39
How to draft a comprehensive Climatope Map
- The first step is the creation of the map of the relative air temperature distribution by experts
- The input data for this purpose, the input data sets are required
- With temperature deviation map, the climatope map can be created in the next step in combination with the other input data

Discussion

2.2.3 Module 2 – Assignment: Climatope Map of Neuss

Task Description:
The participants should independently draw a climatope map on the city map of Neuss on the basis of previously acquired knowledge and based on the maps provided. All maps will be available on the Blackboard.

Slide 2
Image of the process of creating a climatope map (optimal way for experts)

For the assignment:
The map of the temperature distribution is prepared by experts, it must not be designed by the participants due to the great expertise this would presuppose

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Slide 3
Citymap of Neuss
- This map is used as a drawing basis

Slide 4 - 6
Temperatures by night at 2 m above ground in the summer

The Map of the air temperature distribution

Take note : This map was made by using a computerized interpolation of measured points, this approach is prone to error, the map of the Measurements by the RUB and measurements from 1994 and the map of the height levels should be considered in the interpretation and use of this map when creating the climatopes

Slide 7
Map of height layers with water bodies

Slide 8
Map of land use types with description

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2.3 Module 3 – Lectures

Module 3 consists of the following lectures:

- Lecture 1: Adaptation to Heat
- Lecture 2: Adaptation to Water
- Lecture 3: Adaptation to Wind

2.3.1 Module 3 – Lecture 1: Adaptation to Heat

Slide 2

Future city

Introduction to the topic:

- Adaptation to heat in mediterranian cities
- Planning with water
- redevelopment on former industrial areas
- redevelopment in housing areas

Slide 3 - 4

The direct and indirect consequences of the regional impacts of climate change on any system (= municipality, watershed, region, facility, sector, company) on 4 levels of intervention

I. basic condition of the system
II. stresses and strains / sensitivities of the system
III. malfunction or non-function of the system
IV. potential for damage in the system

This allows for each load (exposure), sensitivity (susceptibility), missing / non-functional (system failure) or other adverse effects that would be considered as part of a threat analysis (left side of figure) a "system-specific” adaptation solution (right side of the figure).
Adaptation solutions are in accordance with the 4-layer system, three different groups of adjustment potentials (levels I - III) and the harm reduction potential (level IV). In this way the legal and financial responsibilities (government, operators, private land owners, etc.) depending on the different levels can be considered.

From level I to level IV the degree of vulnerability of a system increases in such a way that the risks to the system increase and at the same time the possibilities of the system to countersteer are reduced. So for example, hazards at the level III and IV need significantly more complex and usually more expensive adaptation or protective measures, without implying any failure- or loss potentials are excluded.

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Slides 5 -44
As a result of the threat analysis an action plan of adaptation to climate change can be established.
The following slides show examples of the **action plan for the "impact of heat"** for the different levels of intervention from the threat analysis.

Slides 7 - 11
The use of microclimate models can calculate the benefit of adaptation measures and therefore is a good option to discuss the possibilities of different measures

Slides 12 - 24
Example for the adaptation measure "greening of Streets":
Slides 14 – 18: air temperature reduction by green (grass, bushes and trees) in an urban street canyon
Slides 19 – 20: risk of air pollution under the treetop layer in streets with car traffic
Slides 21 – 23: Examples for trees in urban areas
Slide 24: Examples of trees with low (suitable for urban areas) and high (not suitable for the use in urban areas) emission of biogenic hydrocarbon, because this emissions enables a higher production of harmful ozone in urban streets.

Slides 25 - 34
Examples for the adaptation measures "green roofs" and "green facades"

Slides 35 - 43
Examples for the adaptation measures "building materials and colours"

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2.3.2 Module 3 – Lecture 2: Adaptation to Water

Slide 2 -3

Urban water cycle

In urban areas the flow regime in relation to rainfall is significantly modified compared to the surrounding countryside. Instead of draining locally to the ground and therefore contribute to groundwater recharge, the precipitate in the city is mainly derived on the surface and thus shortened available for groundwater recharge and evaporation, while at the same time the risk of intra-urban flooding caused by heavy rain events increases.

Slide 4 - 9

Water bodies in urban areas

Examples for using water bodies for cooling the urban air by increasing the evaporation

Slides 10

Direct and indirect effects of extreme rainfall in urban areas

Slides 11 - 17

Adaptation measures for heavy rainfall

Examples for local retention and infiltration on public and private grounds and on green roofs

The use of microclimate models can calculate the benefit of adaptation measures and therefore is a good option to discuss the possibilities of different measures

Slides 18

Conclusion on effective adaptation measures against heavy rainfalls

Slides 19 - 24

Examples for Germany, Ruhr district, on water conversion areas

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2.3.3 Module 3 – Lecture 3: Adaptation to Wind

Slide 2 - 4

Modification of the urban wind field

Two main problems connected to urban wind fields:

- **high wind speeds with the risk of damage and discomfort**
    - canalisation of wind flows
    - passage and venturi effects
    - high turbulence
- **low wind speeds because of the higher roughness in urban areas**
    - poor air ventilation
    - poor air quality
    - risk of heat accumulation

Slide 5 - 11

1. Adaptation measures for high wind speeds (damage and discomfort)

Examples for the following measures:

- protect urban squares against draught
- protect pedestrian areas near high-rise buildings against "downwash"
- equipe open spaces with wind breaking elements
- use movable street furniture, which can be changed to the downwind side

Slides 12 -18

2. Adaptation measures for low wind speeds with poor ventilation in urban areas

Examples for the following measures:

- Relief induced air circulation
- Local breeze system caused by the urban heat island
- Ventilation corridors
- Air flow in street canyons (risk of air pollution under the treetop layer in streets with car traffic)

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2.4 Module 4 – Lectures

Module 4 consists of the following lectures:

- Lecture 1: Large scale adaptation measures
- Lecture 2: Climate recommendation map

2.4.1 Module 4 – Lecture 1: Large scale adaptation measures

Slide 2

Action plan for climate adaptation

While there have always been climate-adapted cities (z. B. narrow streets with shading the house walls, bright surfaces) in the hot climates of the earth, a rethink is necessary in our regions, in order to achieve an adaptation to the impacts of climate change. There needs to be a transformation of the city and building architecture to achieve a reduction in the future additional heat stress in summer. Primary it is about reducing the direct summer heat entry. A secondary strategy is to ensure good ventilation with their cooling effect. This measures apply to the city level apart from small scale adaptation.
Long term measures to be implemented fall within the scope of open space planning. Due to the very slow rate of sustainable urban redevelopment there is a great need for action for urban planning. Adaptation to changes that arise in the future have to start today

Slide 3

Relative air temperature distribution of Bochum

To detect the areas with heat stress during hot periods in summer, a air temperature map for a city is usefull. The example of Bochum shows the clearly hotter areas in the city center. This places are during nighttimes up to 5 Kelvin warmer than the rural surrondings.

Slide 4

Action plan for adaptation at city level

The following slides show examples for the adaptation measures on city level. Malfunctions of the system "city" such as "lack of cooling in nighttimes", "poor ventilation" and "heavy rainfall runoff" demand measures like:

- building area limits
- fresh air areas
- cold air corridors
- permeable hillside development
- municipal hazard and risk maps for urban flooding and flash floods

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Examples for these measures will be given in the following slides.

Slides 5 - 6
Fix building area limits
In order to ensure sufficient ventilation even with weak currents, a small extend and density of development of the settlement body is required. Thus, significantly mitigated by the introduce of fresh and cold air from the environment the heat load in the inner cities and the air hygiene situation can be improved there.
In the surrounding area of a city should therefore sufficient open space be available for the air exchange with the inner city. In particular, if only a few open spaces exist as a buffer space between closely spaced cities or can be expected by further construction with a restriction of the supply of fresh air, building limits should be set in the outskirts. Thus the preservation of climatically valuable areas can be secured and a sprawl of the city area can be counteracted.

Between the reservation of unsealed inner-city areas and the aims of climate-friendly urban development often conflicts of aim occure. A development of open spaces leads to compact settlement structures that are transport and energy saving. On the other hand by the compression of the development the heat island effect is enhanced. Therefore, efforts should be made at least as a compromise, to seek development boundaries. Careful design of the remaining inner-city open spaces can counteract the negative effects of compaction.

Slides 7 - 8
Create, save fresh air areas
Fresh-air producing areas can be vegetation dominated open spaces such as forests and parks and urban settlements with a high proportion of green space and a low degree of sealing. The generation of cold and fresh air over a natural surface is determined by the thermal properties of the surface substrate. Field and meadow areas cool off more and thus produce more cold air than woodlands.
In addition, the effectiveness of fresh air areas is highly dependent on their size. Through the preservation and creation of additional fresh air producing areas and their networking, an enhancing of their effectiveness can be achieved. The connection of the innercity areas to fresh air areas contributes to the interruption or reduction of heat islands and creates urban climate relevant regeneration areas. This connection via ventilation lanes and fresh air corridors should take place without enrichment with pollutants.

Slides 9 - 11
Create, save cold air corridors
Fresh air corridors and ventilation lanes connect cold air production areas or fresh air areas with the city center and are thus an important part of urban air exchange. Especially in low-exchange weather conditions they are relevant to the climate, as they are transported over lower-laden air masses in the polluted areas of the city.

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City Climatically relevant ventilation lanes can be grouped into three categories:
• **Ventilation corridors** ensure a mass air transport, irrespective of the thermal or air pollution caracteristic.
• **Cold air corridors** transport cool, but not closer in terms of air quality situation specified air masses.
• **Fresh air corridors** direct hygienic unencumbered, but thermally unspecified air masses.

In cloudless summer nights near ground cold air can flow downhill and entry into the building even with opposite flow in the free atmosphere. In hot summer nights, this can lead to a local cooling in the area of urban development.
An exchange inhibiting factor can be seen in the effects of high and dense vegetation (shrubs and trees) to block the flow in the range of ventilation lanes. Here the vegetation leads to the reduction of ground-level wind speed ("wind catchers"), so that the exchange can be difficult.

Slides 12
Permeable hillside development
Large open space with cold air production and valleys with flow towards the city center are regarded as particularly sensitive areas of the city ventilation, contributing even with light wind to a city ventilation by cold air transportation. This fresh air can reach even with weak wind flows from the outside into the city, the building must not form bar building belts on the outskirts. The slopes along the cold air paths should be kept free from hang parallel bars building.

Slides 13 - 15
Municipal hazard and risk maps for urban flooding and flash floods
Risk assessment: rate of surface sealing
The hazard potential of a sub-basin increases with the size of the outflow effective areas and the degree of outflow activity. The higher these two values, the less restraint potential the area has and the more rain water is fed to the drainage facilities without delay or goes into the surface runoff.
In areas with medium or high surface sealing rates a risk to the population, buildings and infrastructure by aboveground flash floods and congested channels is very likely to occur during localised extreme rainfalls at very high intensities.

Risk assessment: pluvial flow path map
For an example, rural and urban areas of Soest, the pluvial surface runoff lines are shown in this map. Basis for this calculations are the topography of the region and the occurrence of natural or artificial sinks. The runoff lines are classified depending on the amount of merged rainwater from the surrounding areas.

Risk assessment: overload areas in cities
Gullies and smaller streams often have no significant flood control facilities. In general, there is no information on flow behaviour, profile course or other waterways data for small bodies of water. Excessive amounts of water can flood settlement areas. Channel systems, that are not rated for such quantities of water, can be overloaded. Flood discharge of rivers can also cause a backlog in the rain water inlets of drains or damage the sewage treatment plant by flooding.

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2.4.2 Module 4 – Lecture 2: Climate recommendation map

Slide 2 - 3

Climate recommendation map

The climatope map forms the basis for the derivation of planning recommendations and the need for action with the aim to reduce or dismantle existing stress potential and secure and protect the quality of life and living. In addition, favorable conditions will be highlighted and positive correlations will be shown.
The climatope map forms the basis for the division of the urban area in load and compensation areas and to derive spatially concrete planning instructions. While the climatope map is created objectively by means of GIS calculations and represents the current state of the urban area, the climate recommendation map is created from a combination of GIS analysis and expertise.

The planning priorities are hereby set on the basis of load and compensation areas and are labeled using leads for local measures and for air exchange. The planning recommendations contained in the map are frameworks that should serve as a guide to town planning. They are derived from the analysis of the climatic situation of a city with the aim of stabilizing positive spatial structures and the improvement of stressed areas.
It should be noted here that only the environmental aspect “climate” was used to deviate planning recommendations. A consideration with other environmental or spatial development serving requirements is necessary.

Slide 4 - 8

Compensation areas

Compensation areas are predominantly undeveloped or only loosely built open spaces of varying size and function. Here regional significant compensation areas, water and forest areas, which are important from a bioclimatic point of view, as well as urban green spaces that divide the settlement area, will be distinguished and explained on the following slides (5 – 8).

Many areas in the city fulfil due to their size and equipment a compensation function to climatic and air quality pressures. These include in particular larger green and open spaces in the urban area.
Specifically, the following positive characteristics of these areas should be highlighted:

- low emissions and the ability to bind and filter air pollutants,
- low surface roughness that improves the ventilation situation,
- production of fresh and cold air by strong night cooling during warm and hot days.

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Slide 9 - 13

Load areas

Load areas are the built spaces in the city. They are divided into three different load areas according to the density and height of the building and into the load area of the commercial and industrial areas. A coherent spatial unit is called “Load area”, if any thermal and / or air pollution burden on the population occurs.

Climatically, the following loads may arise:

- thermal loads by particularly strong warming during the day and / or attenuated cooling at night
- thermal-hygro stress by heating with addition of increased humidity
- significant changes in the wind field, with areas with a significant reduction of air exchange or zones of increased turbulence and gusts

From air-hygienic point of view, a load space is defined by the fact that the emissions lead to a local increase in pollutant emissions or to significant regional and national enrichment effects.

The different load areas will be explained on the following slides (10 – 13).

Slides 14 - 16

Local measures

In the climate recommendation map local measures for defined areas are proposed. These small-scale recommendations to complement the general recommendations for individual regions consider measures relating to building structure, recommendations for particularly sensitive areas and various measures of greening.

Firstly, they relate to the preservation and protection of climatically favorable conditions, so there is a need for action in terms of planning restrictions and measures to avoid a deterioration of the situation. The second area of recommendations include the elimination of existing deficits and exposure through climate-related measures.

Slides 15 – 16 give an overview of these local measures.

Slides 17 - 20

Air exchange

In the climate recommendation map areas are recognized, which are of particular importance for the exchange of air. To this, planning guidance is provided with respect to the ventilation situation and to maintain or improve the fresh and cold air flow.

A good ventilation situation in the city contributes significantly to the quality of their microclimate. By having an efficient air exchange, over-heated air masses can be removed from the city and

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replaced by cooler air from the surrounding area. Further air masses enriched with pollutants can be replaced by fresh air and the vertical mixing of air can be increased.

Two factors are crucial for air exchange:

- the mean wind speed, which means the strength of air exchange controls the mass of pre-transported and removed air
- the vertical mixing. In addition to the drive by the wind field, the ground-roughness, the heating at the ground and possible cold air formations contribute to the vertical exchange. In the inner-city also at night a vertical exchange of air is maintained, which is driven by convection due to the urban overheating.

Slides 18 – 20 give an overview of the icons concerning the ventilation situation and the preservation or improvement of the fresh and cold air supply.

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