2024

Climate Snapshot

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About Us

Climate change had a profound effect on life in cities, influencing factors like habitability and overall quality of life. Urban Heat Islands (UHIs), created by changes to natural landscapes through urbanization, worsened heat stress, which threatened health, productivity, and urban systems, especially as global temperatures rose. Understanding how heat stress varied across different city areas was crucial for planning and adaptation. **CityCLIM** developed an innovative platform and high-resolution forecasting tool for European cities, combining data from various sources to provide near-real-time warnings and impact assessments. This tool aimed to guide effective mitigation strategies and involve both citizens and policymakers in addressing climate challenges.

The CityClim project comprises six consortium partners and four participating Pilot Cities that have worked together to conceptualise, develop and test the new climate services that are were main objectives of the CityCLIM project.

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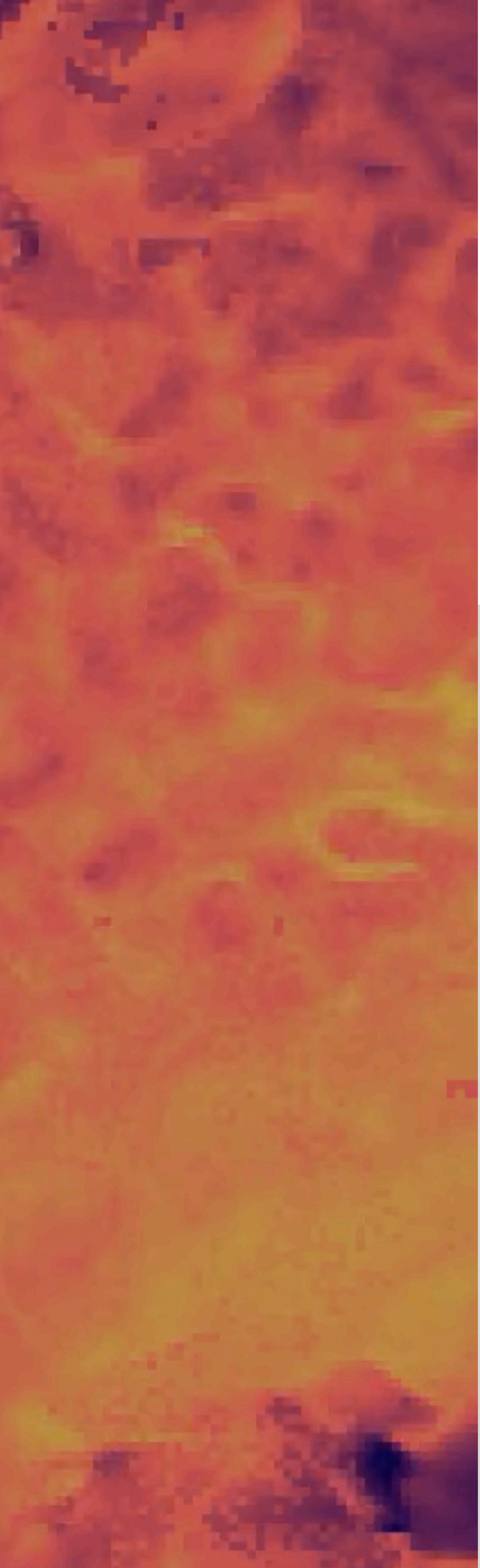


This report, part of the EU-funded CityCLIM project, analyzes the 2024 heat season and climate trends in Luxembourg, a pilot city for high-resolution weather forecasting. Using the UltraHD model, daily 48-hour forecasts identified localized weather patterns, such as around Findel Airport. The report focuses on urban heat impacts to support climate adaptation efforts.

In Short

1

In 2024, temperatures fluctuated around climate reference values, with record warmth in early January, a cooler mid-January, predominantly warm days through mid-April, normal weather until August, a warm start to September, and mild autumn conditions by October's end.

2

The summer of 2024 in Luxembourg matched the climate reference average temperature of 17.9°C, had nearly half the usual heat days, and recorded 10% less precipitation than the reference period.

Climate Report Luxembourg 2024

This report was produced in scope of the EU funded project CityCLIM. The report starts with useful information from the Climate Information Service to provide an analysis of the 2024 heat season and a general overview of the climate in the area.
As one of the four pilot cites, the city of Luxembourg and its surroundings were a testbed for one of the first operational city weather forecasts at 100m scale. The large eddy simulation model UltraHD was run for over a year on everyday basis and produced a daily prognostic forecast for 48 hours on a 50x50 km domain. The analysis of these forecasts allows the identification of areas with individual response to large-scale weather, like the heights around the airport in Findel or the valley north of Luxembourg city. The project focus was on the effects of heat within the city, therefore this report and the CityCLIM services were tailored around this topic.

Current year 2024

The annual cycle of the daily mean temperature in comparison to daily climate reference values can be seen in Figure 1. It shows a very warm record-breaking first days of 2024 followed by cooler period in the middle of January. After this period, mostly all days are above the climate reference line showing warm days until mid of April. 10 days in the end of April were colder than the average. In the following months the temperature line fluctuates around the climate reference line until end of August symbolizing normal (in climate) weather. Last days in August and a very warm start in September were followed by a very short cold period in the middle of September. The second half of October shows the red line (2014) right above the black line (climate reference) with warm weather in autumn.

The Summer 2024

The summer period 2024 in Luxembourg with an average Temperature of 17.9°C was exactly on climate reference (1991-2020) average. Luxembourg Airport station count just 4 heat days during summer 2024, which is nearly half the number of reference heat days on this station. With 199mm precipitation during the summer months it was around 10% less than in climate reference period (217mm).

Figure 2 provides a closer overview of the summer months June, July and August in 2024. One can clearly see heat wave periods in red colors. To find a typical day one can use this heatmap of hourly 2m air temperature and dewpoint. A closer look at the monthly evaluation during the summer months in 2024 shows that a smaller heatwave evolves at the end of June. But temperatures are still below 30 °C with only moderate dewpoints. In July 2024 heat wave periods occur in mid and end of month. A significant heat wave at end of month with temperature above 30°C and high dewpoints especially during nighttime where observed. A second significant heat wave on August 10th unitl August 13th with temperatures above 30°C and high dewpoints was picked as a typical summer/heat wave day in 2024. Nevertheless, slightly higher dewpoints evolve during the whole month of August. This causes, in absence of hot temperatures, also stress through humid condition.

General Climate and the Summer Season Climate Reference from 1991-2020 at Luxembourg Airport

The climate reference period 1991-2020 for Luxembourg shows monthly mean temperatures during winter (Dec., Jan., Feb.) of about 1-2°C. During summer period the monthly mean temperatures (Jun., Jul., Aug.) is about 17-19°C. Older climate reference period show lower temperatures by at least 1K. See figure 3 with the comparison of two climate reference plots.

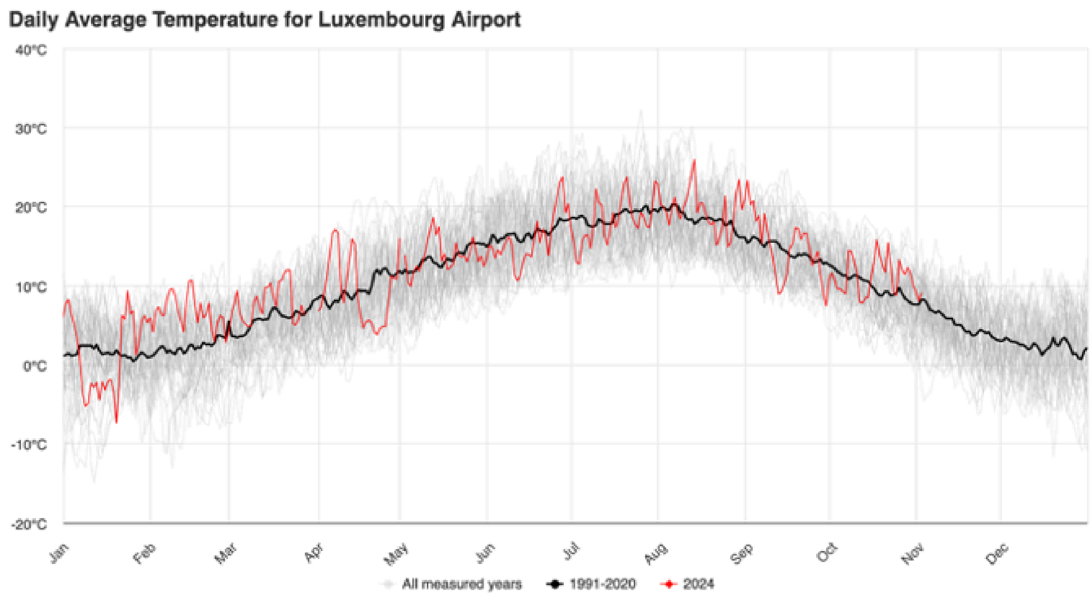
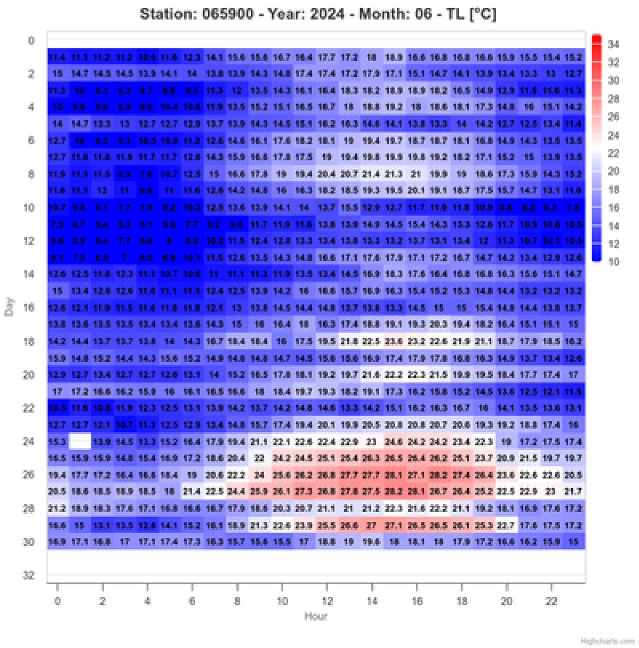
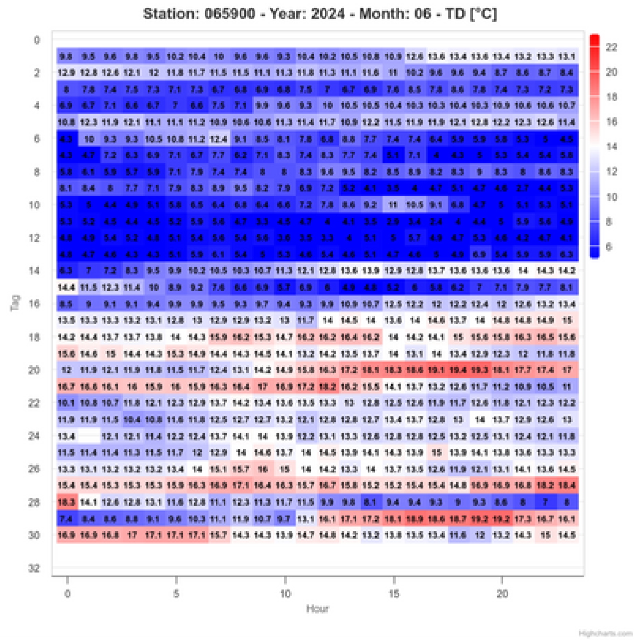
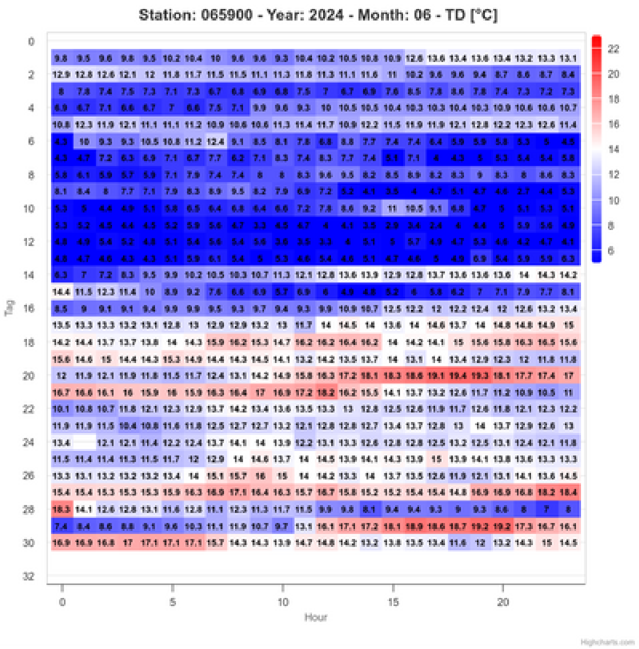
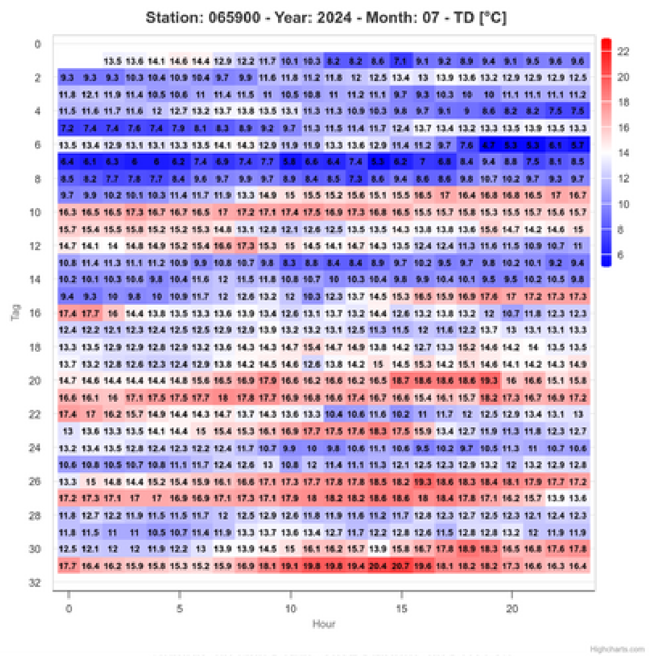


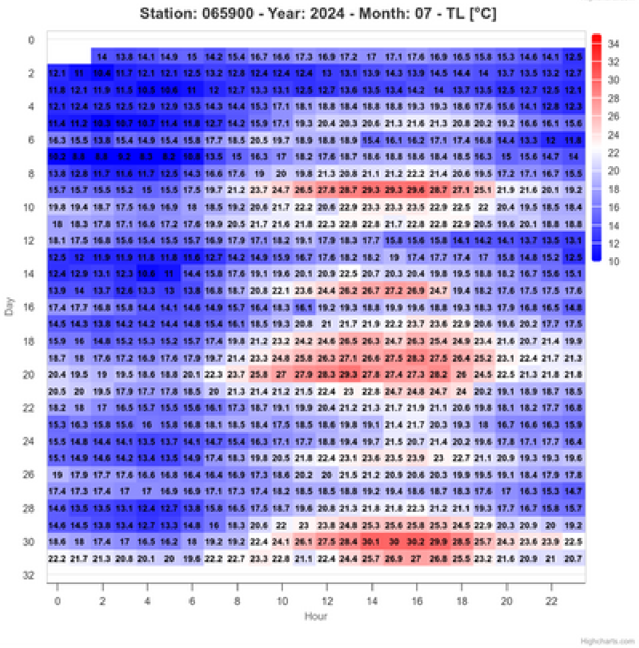
Figure 1: Annual cycle of daily mean temperature in comparison to historical years and the actual daily climate reference line.











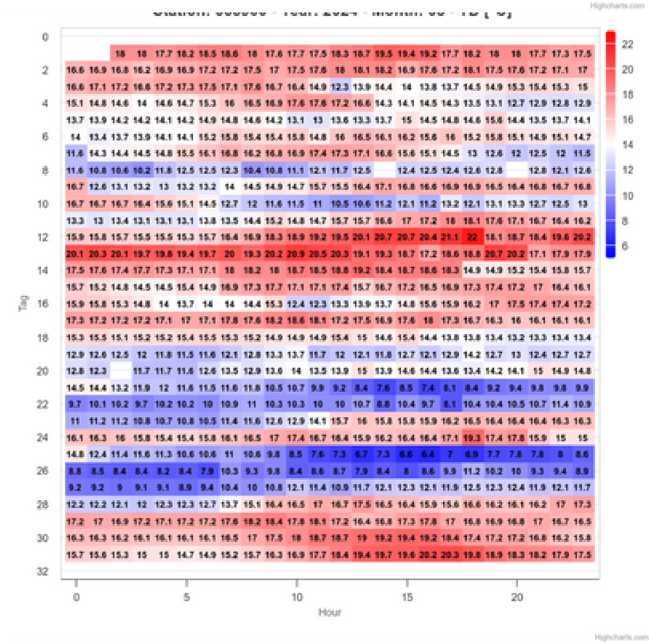


Figure 2: Hourly observed temperatures (left) and dewpoints (right) for station Luxembourg Airport of the summer months. Top: June, Mid: July, Bottom: August.

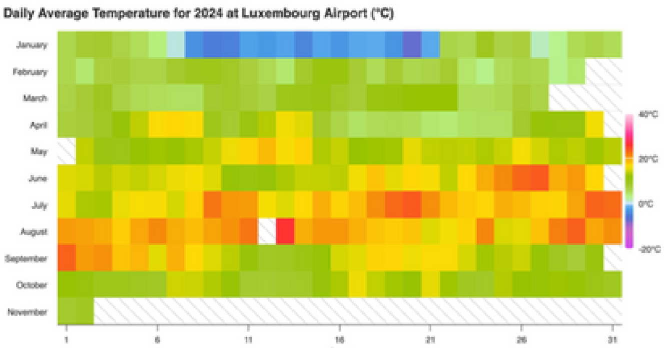


Figure 3: Daily mean temperature as heat map for the year 2024

Index days can be used to quantify local climate behavior. Summer days describe days with maximum temperatures above 25°C and heat days are days with maximum temperatures above 30°C.

During the climate period 1961-1990 Luxembourg had 3.5 heat days and 24 summer days in average. Both numbers of days increase in the climate reference period 1991-2020 to 7.5 heat days and 38 summer days. A decreasing behavior is observed for ice (maximum temperature below 0°C) and frost (minimum temperature < 0°C) days. For the climate period 1961-1990 21 ice days and 88 frost days were the average, which reduced in the current climate reference period 1991-2020 to only 14 ice days and 65 frost days.

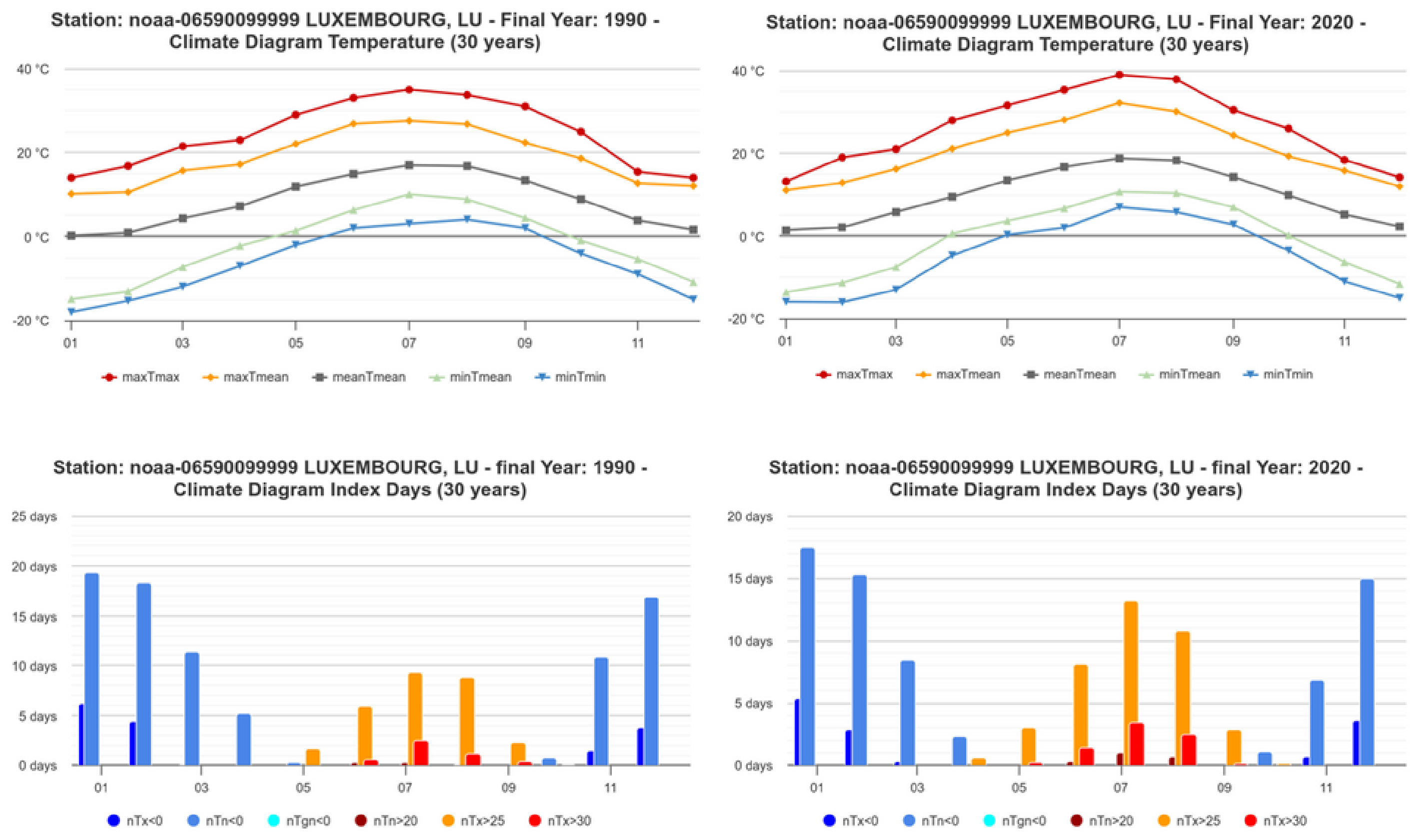


Figure 3: Climate diagram for station Luxembourg Airport for two climate reference periods. Top: Monthly mean temperature (grey), maximum of max temperatur (red), minum of max temperatur (orange), minimum of min temperature (blue), maximum of daily min temperature, Bottom: Number of ice-, frost-, summer-, heat-days, tropical nights.

The heatmaps in figure 4a show yearly mean temperatures during the last 80 years. A positive climate trend is visible with higher monthly mean temperatures in the more recent years. Figure 4b shows the yearly sums of precipitation, where no significant climate trend is visible.

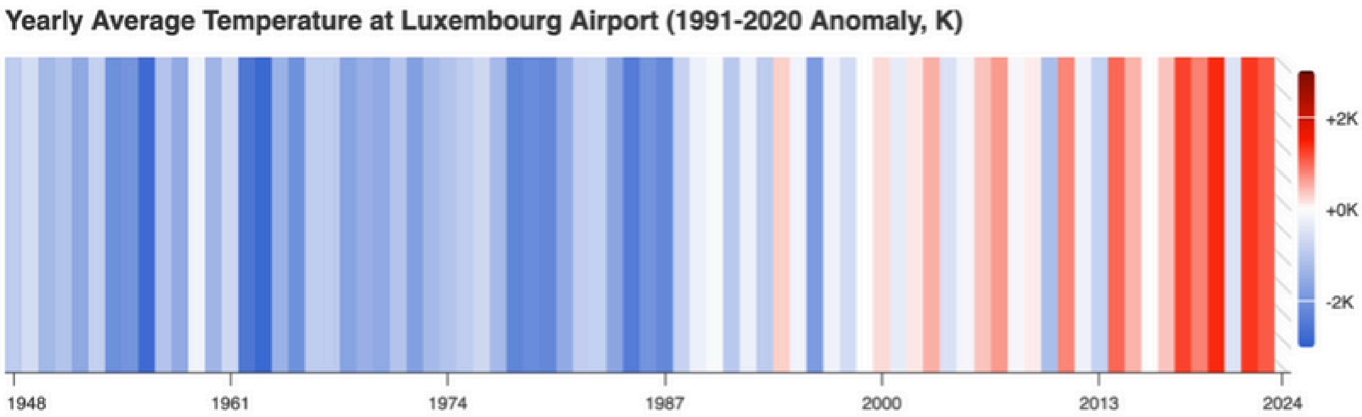


Figure 4a: Heat of average mean temperature for station Luxembourg Airport, yearly averages.

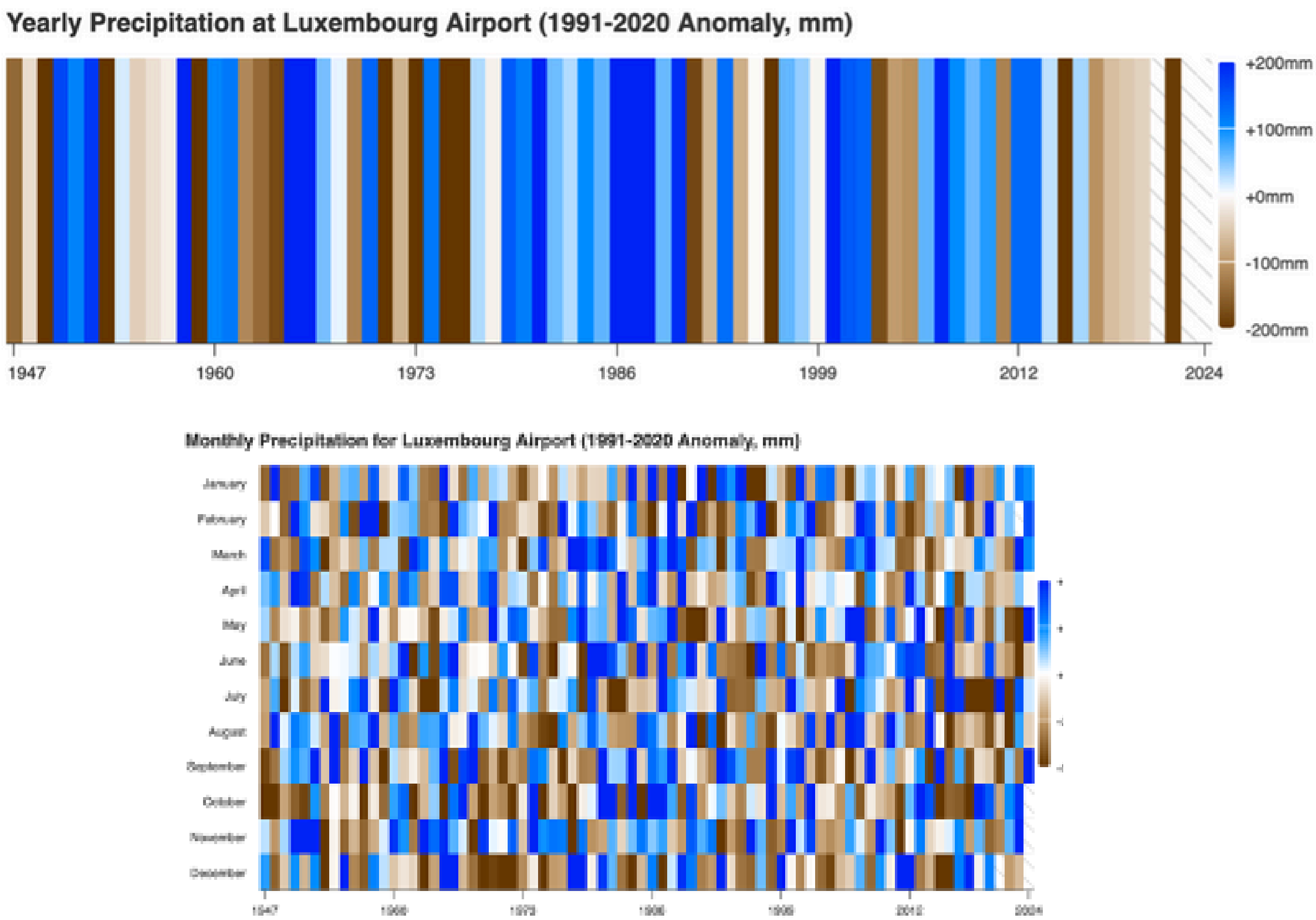


Figure 4b: Precipitation for station Luxembourg Airport, yearly and monthly averages.

UltraHD Model Analysis

The UltraHD Model developed during the CityCLIM project, is the prototype of a full featured Large Eddy Simulation model including warm and cold microphysical processes, a multilayer soil model and a three-dimensional radiative transfer model. Using latest GPU technology, it is capable of simulating everyday weather situations at a computational speed that is useful for operational weather forecast on city scale. During the CityCLIM project this weather model was run daily for a region of 50x50km around the city of Luxembourg. The necessary boundary conditions for the UltraHD were provided by the operational SuperHD model by Meteologix with a resolution of 1km. In this report results of several runs using the prototype of the UltraHD model during heat periods are presented in more detail with the focus on surface and 2m air temperature and urban heat distribution.

Detailed analysis of the heat wave 20.07

In the Days around the 20th of July 2024 a heat event occurred in the region around Luxembourg with temperatures up to 29.3 °C. The event was captured quite well in the UltraHD CityCLIM environment. One interesting aspect of this heat wave was the occurrence of a light cold front with cirrus clouds that reduced incoming radiation significantly during the afternoon. The passthrough and the radiative effects as well as some smaller previous showers were captured by the models and can be found in the In-Situ and satellite measurements within the region.

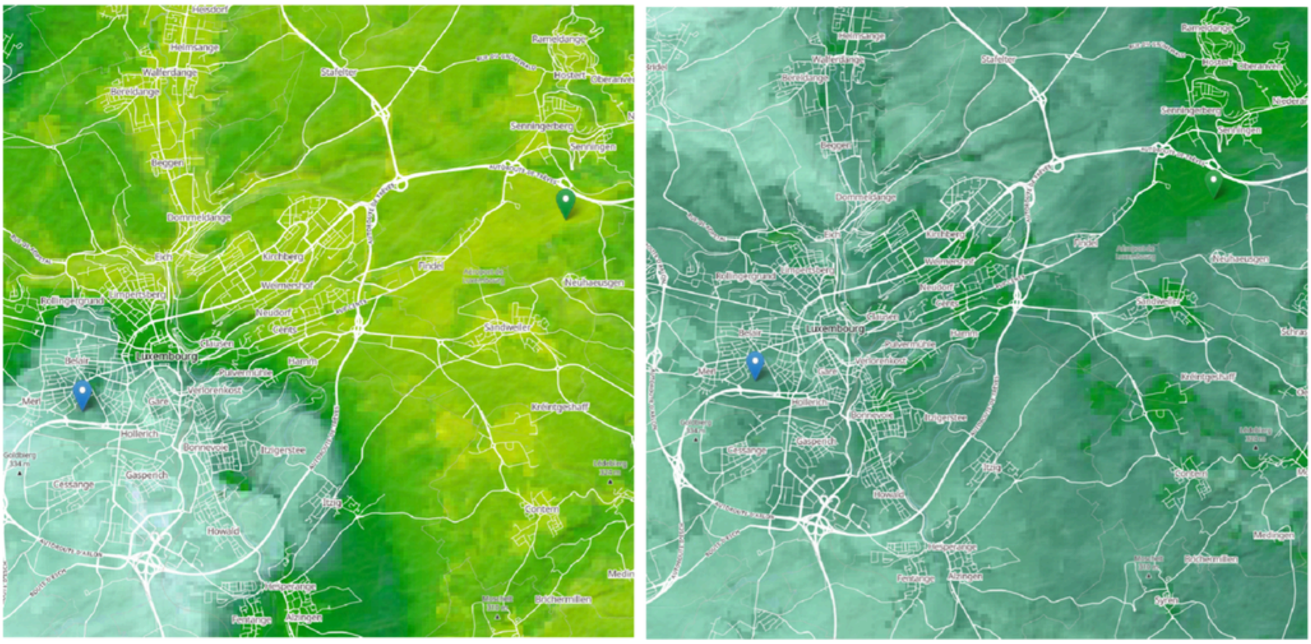


Figure 5: 2m Temperature in the Luxembourg region. Left: at 12:00z first cold pools of prefrontal clouds/showers were simulated reaching the blue pin first (station at international school) and later the green pin (station at Findel). Right: reduction of temperature during passage of frontal clouds and cirrus.

At 12:00 UTC first local showers with developed cold pools reached the blue pin, which is at the location of the station at the International School and led to a temporary decrease in the 2m temperature down to 23°C. The same temperature drop can be found about 40 minutes later at the green pin near the Findel Airport Station.

Later that day a slight cold frontal system passed thru the area from 13:50 to about 16:00 UTC. During this pass the 2m temperature drops down to 24°C and rises back to 28°C later which is in line with the measurements (see Fig.7)

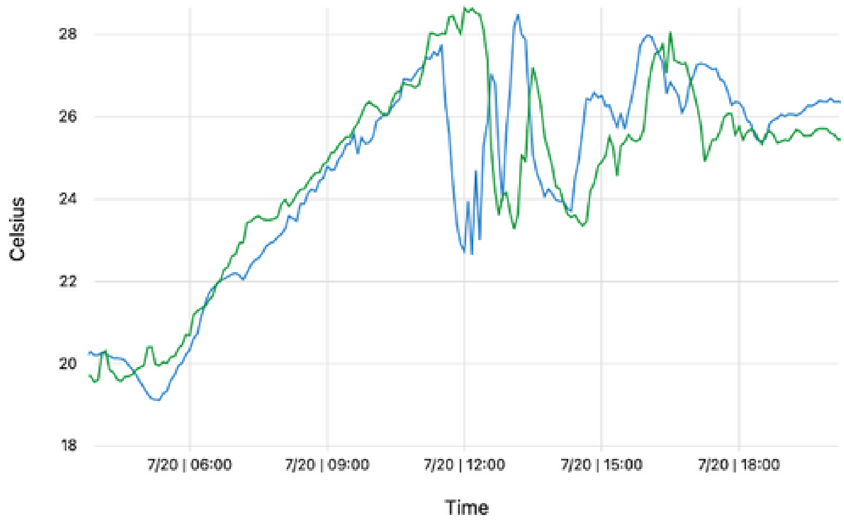


Figure 6: UltraHD model time series of the 2m temperature at two points in the Luxembourg area.
Blue: near the station at Internation School; Green: near the station at the Airport in Findel. (compare Fig. 5)

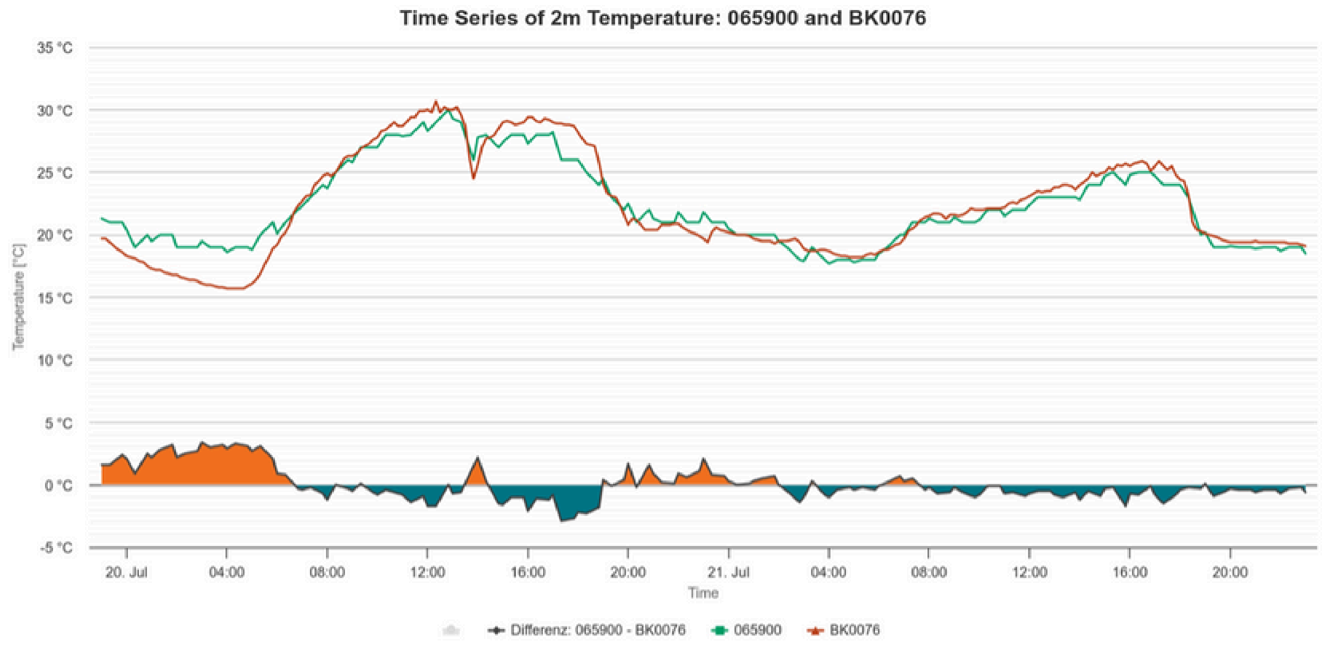


Figure 7: In-Situ measurements of the Stations at the International School (BK0076) and the Airport Findel (065900) during that day.

Although the short prefrontal temperature drop cannot be seen in the In-Situ measurements the clouds are also recognizable in the visual satellite image (Fig. 8) of that area at 12:00 UTC with a stronger cloud pixel southwest of the city where the cold pool in the UltraHD model is located. A reason for that could be an overestimation of the cold pool by the UltraHD model, e.g. by an overestimation of drizzle or the cold pool missed the station by a few meters. Except the prefrontal drop the overall afternoon temperature behavior was in good agreement with the measurement. The occurrence of the clouds in the satellite image and the model shows the ability of the model to simulate such small cloud structures even with knowledge from the 00z model run.

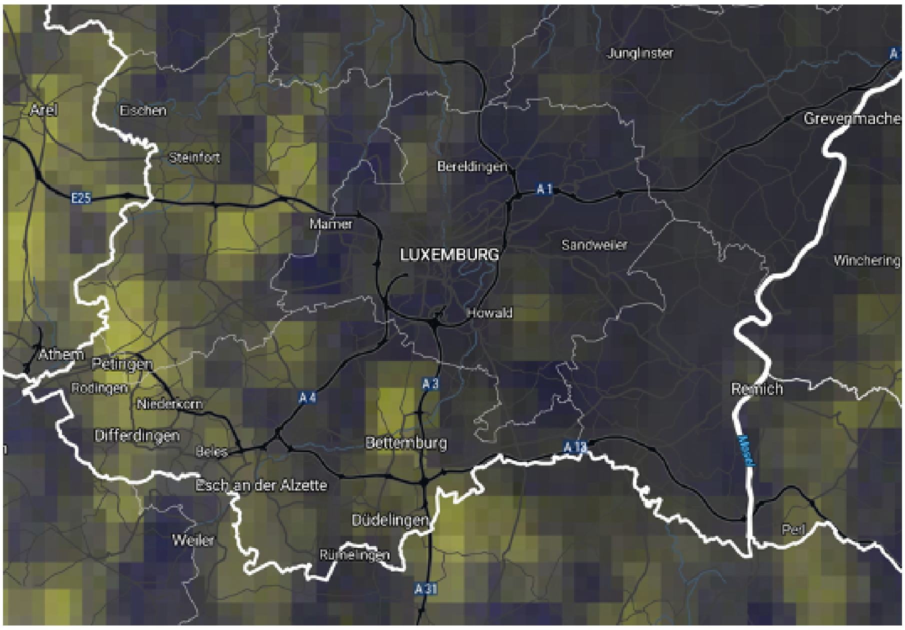


Figure 8: visible satellite image of the Luxembourg region for the 20th of July 2024 with small prefrontal convective clouds in the area.

After the passage of the cirrus and convective clouds, temperature increased again during the later afternoon and the evening. In Fig 9 the Land Surface Temperature for this date at 18:00 UTC is presented. A postfrontal Urban Surface Heat Island of up to 4 K can be easily recognized in the city area with the highest land surface temperatures in the south of the city. Cooler surface temperatures can be found in the valley north of the city or in regions that are still covered by clouds in the east.

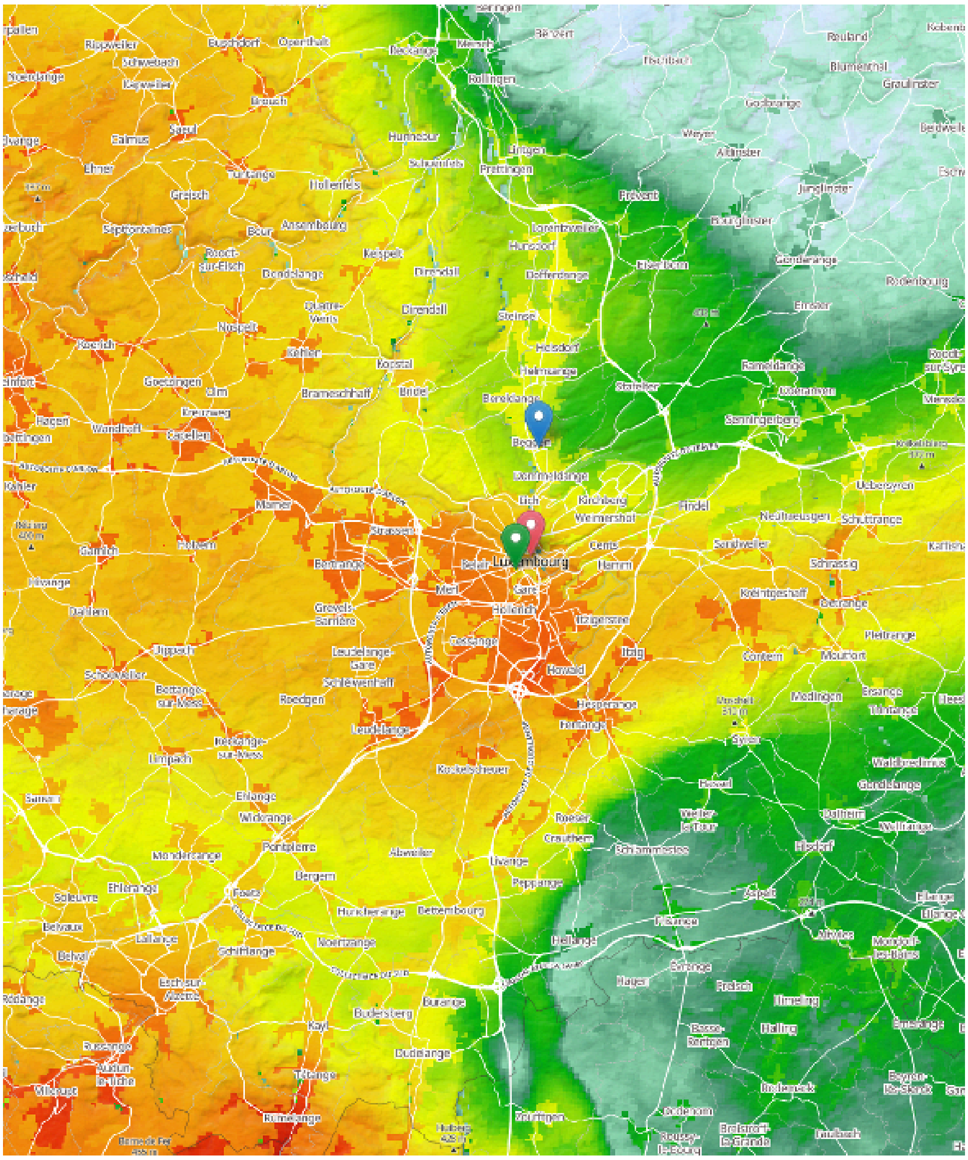


Figure 9: Land Surface Temperature (LST) for the region of Luxembourg at the 20th of July for 18:00, the areas with lower temperatures were cooled down by local showers.

Heat Wave 10-13. August 2024

The strongest heat wave for the region of Luxembourg during the year 2024 occurred from the 10th of August till the 13th of August. As presented in Figure 2, during these days the city and region gradually heated up for about 5 days with rising daily maximum temperatures up to 33.1°C and high dewpoints up to 20.9°C on the 13th of August. Fig. 10 shows the 2m temperature distribution within the UltraHD model domain for the area of interest at the maximum of the heat wave. The city of Luxembourg can be identified with slightly higher temperatures compared to the surroundings of up to 32.2°C in the center of the city. In general, the maximum of the heat wave was located more to the east and south of the larger region.

A closer look into the city (Fig. 11) shows differences in the 2m temperature of up to 2 K. During this day, areas with higher temperatures can be found in several places around the city center and in the valley north to the city. Slightly lower air temperatures can be found up the hills. The coolest spot in the city model is a small place south of Beggen, where a hill cast a shadow quite early, but also some lower lands east of Bridel.
The model shows high frequency fluctuations of the 2m Temperature caused by atmospheric turbulence, like heat plumes or smaller cold pools. On main influence is the use Land Cover description which is an important input parameter for the interpolation from model level to the 2m Temperature.

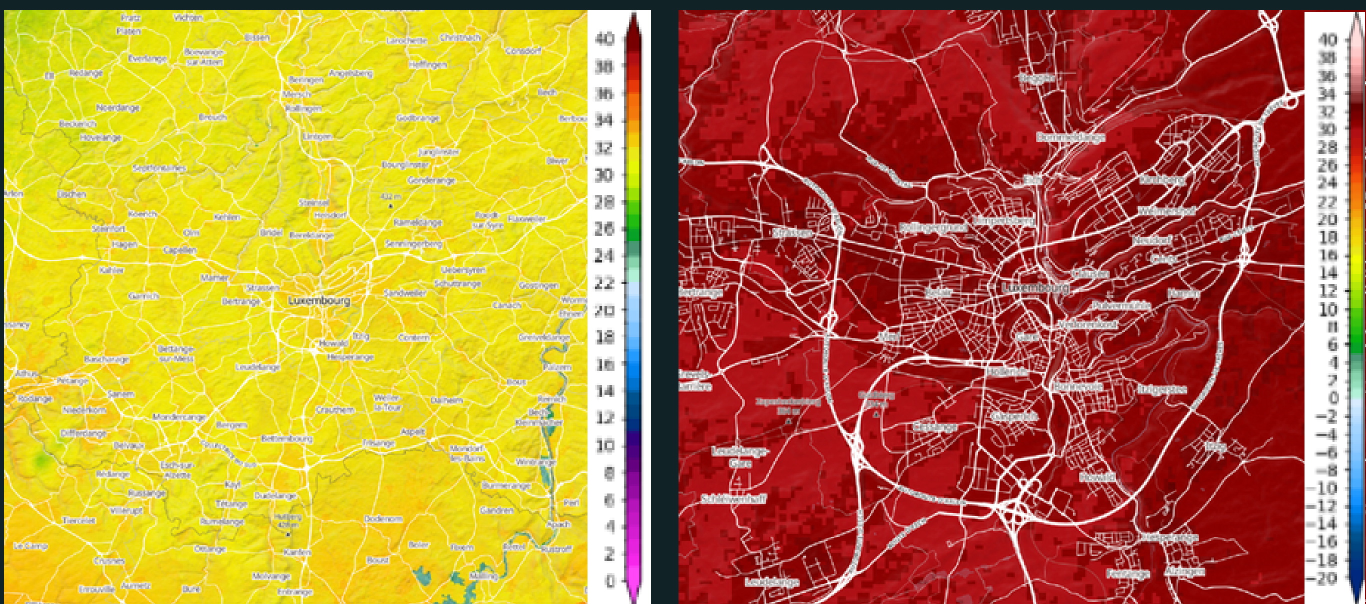


Figure 10: Left: Overview of the 2m Temperature distribution in the region covered by the UltraHD domain (13th of August 14:00z) Right: maximum 2m air temperature within the city accumulated from the 10th of August 12:00z to the 14th of August 12:00z

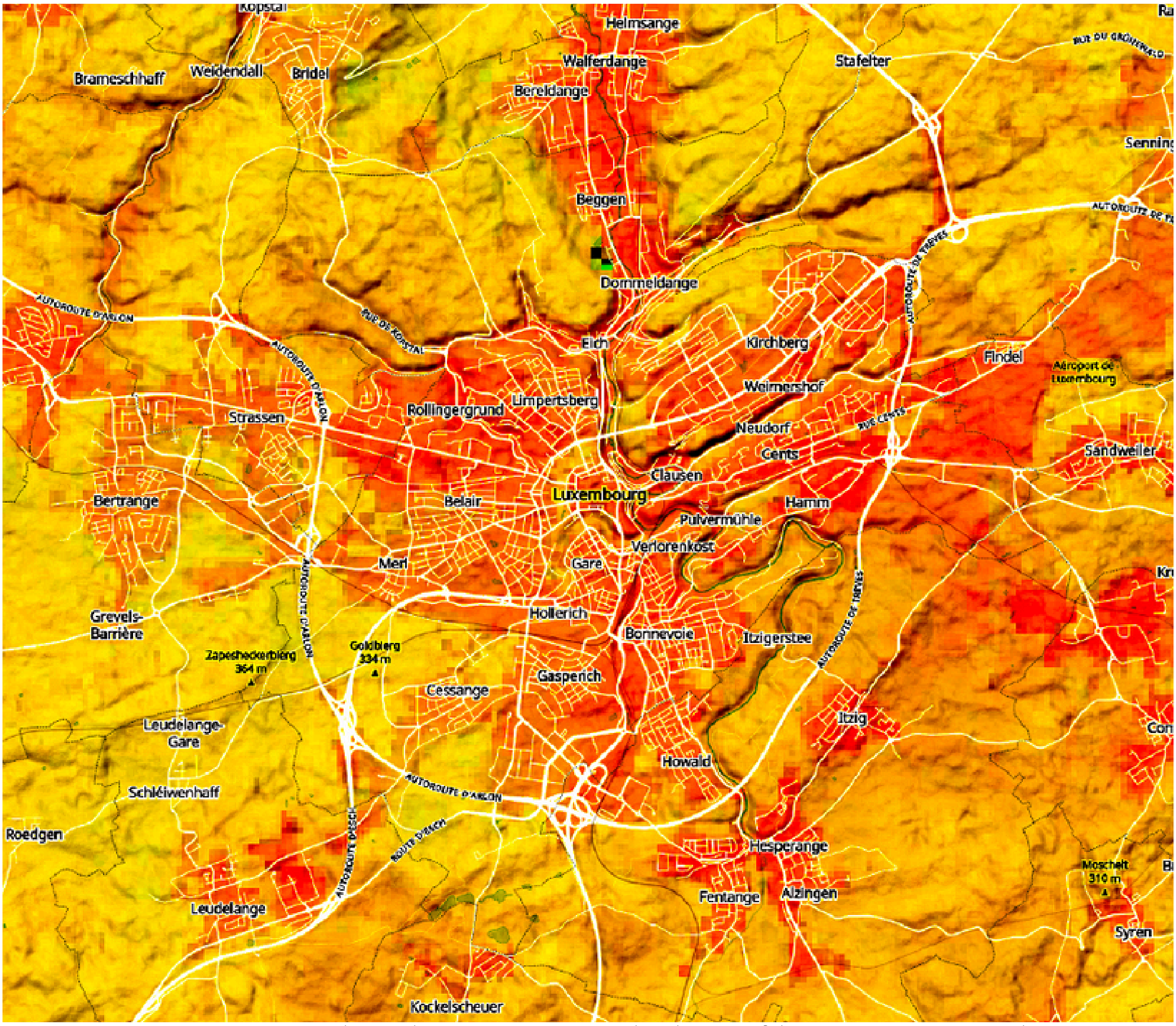
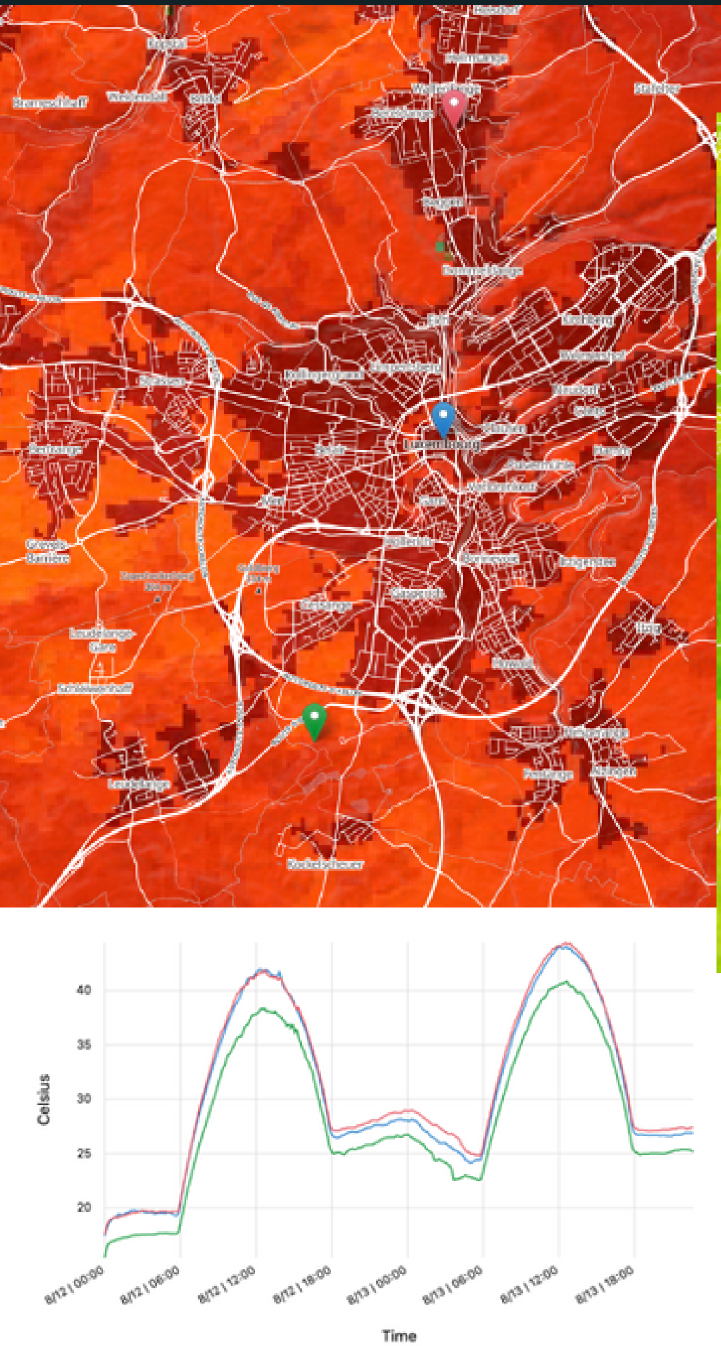


Figure 11: contrast enhanced 2m air temperature distribution of the city center region in the Luxembourg UltraHD at the 13th of August 14:00z

The surface urban heat island (SUHI) and the urban heat island (UHI) during the heat wave can be diagnosed using the UltraHD forecast for different pins within the city and its surroundings. The forecast for the land surface temperature is used for the surface urban heat island and the 2m air temperature for the urban heat island. This is presented in Fig 12 and is shows a SUHI of up to 4 K and a UHI of up to 2 K during the maximum of this heatwave. But also at a smaller scale, within the city, 2m air temperature differences of up to 2 K can be observed in the model forecast (see Fig. 13). These are mainly caused by the different orographic height and land usage between the pixels and high frequency fluctuations like heat plumes.

In general, green infrastructure, like trees or parks, lead to a decrease of the 2m air temperature. This is achieved by evaporating water vapor to regulate cell temperature. With that it increases latent heat fluxes from the soil into the atmosphere and the dewpoint.



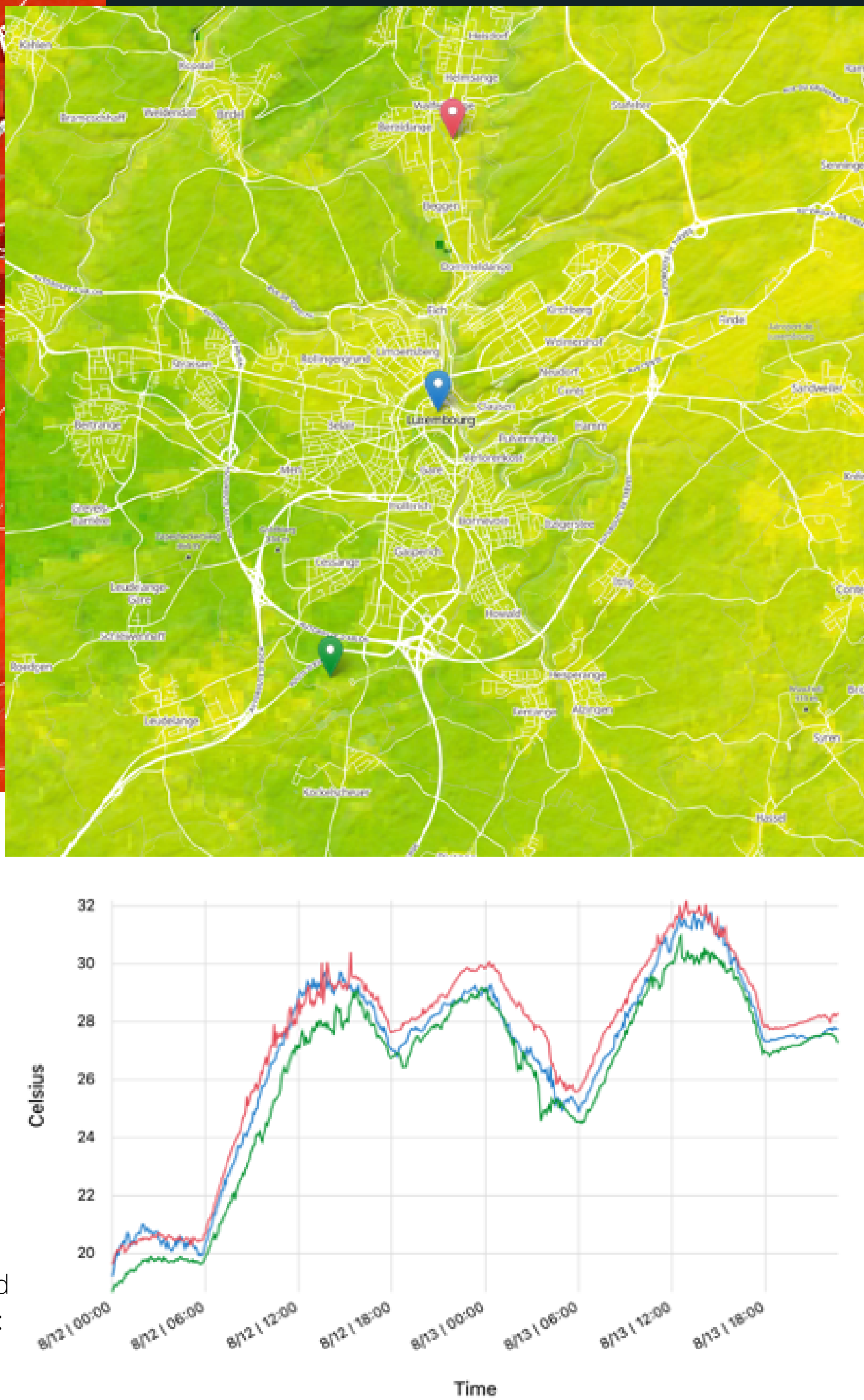


Figure 12: Illustrations for the derivation of a Surface Urban Heat Island Index (SUHI) and an Urban Heat Island Index (UHI) based on point forecasts for the region. Left: land surface temperatures show a SUHI of up to 4 K; Right: 2m air temperatures show a UHI of up to 2 K.

The dewpoint is one of the most important parameters for heat perception, especially during night hours. It is a measure for the moisture content in the air and with that for the effectiveness of body cooling through sweat. During the day within an active convective boundary layer, there is always a bit of wind, so sweat can be evaporated and transported away more easily. But during night hours, especially during high pressure weather situations like heat waves, there may be no wind at all.

In that case dewpoints above 16 °C get unpleasant. The UltraHD model provides insight in the distribution of water vapor in the atmosphere and with that on the dewpoint (Fig. 14). It can be observed that water vapor accumulates within the city and valleys during night and led to dewpoints above 16°C in certain areas during this heat wave.

Large scale usage of climate mitigation strategies like active evaporation of water using spraying devices or strongly evaporating green infrastructure will lead to higher dewpoints during night hours and will probably decrease comfort for the citizens.

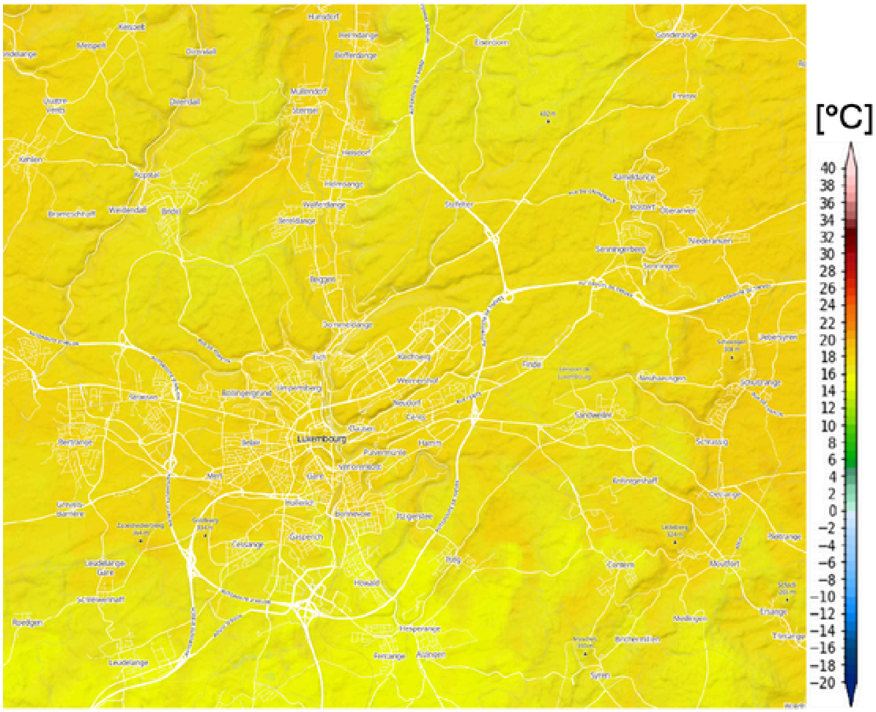


Figure 14: Distribution of 2m dewpoint in the Luxembourg city region at the morning of the 13th of August (5:30z) with dewpoints above 16 °C

Conclusion

This report presents results from the CityCLIM Project for the Pilot City Luxembourg by the Climate Information Service, the Identification Service and the UltraHD based Heat Wave and Information Service for the year 2024. During the CityCLIM project a huge number of UltraHD model runs covering almost the full year were performed. This allows detailed analysis and insight into temperature and moisture distributions within the city region during two of the most prominent heat waves for this year.

The UltraHD model also demonstrates the capability to simulate small prefrontal convective clouds and their radiative effects on surface and air temperatures at large eddy scale on an operational basis.

The **CityCLIM** frontends provide prototypical but very useful tools to access the enormous amount of model data, although at some points more flexible color scales and map options would be desirable. Also, an extension to precipitation, wind and further cloud parameters beside the urban heat context would be greatly advisable.

Check out cityclim.eu for more information!