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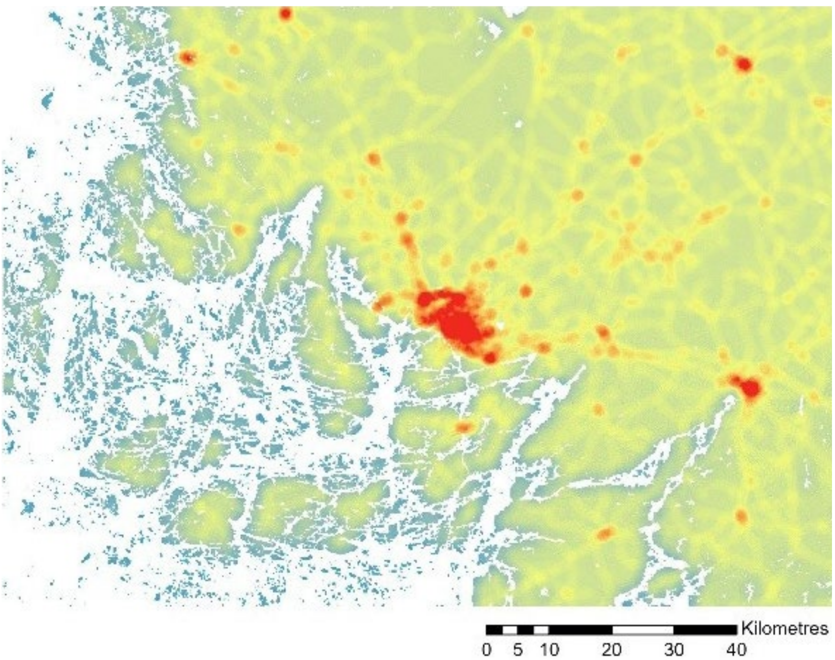
SEASONAL AND DIURNAL CHARACTERISTICS OF SPATIAL TEMPERATURE VARIABILITY IN TURKU, SW FINLAND

A Case Study of 2021



Juuso Suomi, Krista Väätäinen & Jukka Käyhkö

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Turku 2025
University of Turku
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CONTENTS

ABSTRACT

This study examines local climate and presents local climate information from the coastal city of Turku and its surroundings in southwestern Finland. The study area consists of urban and rural land cover types, with a specific focus on the Turku Student Village area, approximately 2 kilometres northeast of the Turku city centre. The study is based on 80 temperature and relative humidity (T/RH) loggers of the Turku Urban Climate Research Group (TURCLIM) of the Geography Division at the Department of Geography and Geology at the University of Turku. The study is conducted in the context of the RESPONSE research project (https://h2020response.eu/) funded by the European Commission's Horizon 2020 Framework Programme. Before the RESPONSE project, Turku Student Village had only one T/RH logger, but at the beginning of the RESPONSE project, nine additional loggers were installed in the Turku Student Village area, resulting in a dense local cluster of loggers in that area. This enables the examination of spatio-temporal temperature differences around Turku Student Village. The study is based on half-hour interval temperature observations of a full calendar year 2021. The study consists of analyses on observed temperatures and spatially continuous temperature maps produced by a linear regression model and open-access GIS data. The observed temperatures are studied on a monthly and diurnal basis in the spatial scales of the whole Turku region and the Turku Student Village region. The spatially continuous temperature maps and the related regression model results are interpreted on the scale of the whole Turku area. The weather conditions of the study year 2021 are related to the climatic conditions of the Turku region during the climatic reference period 1991–2020.

Regarding the monthly average temperatures and monthly averages of daily minimum and maximum temperatures, spatial temperature variability was largest in summer. The seasonal pattern of largest momentary spatial temperature differences was opposite, as the differences were largest in winter. The patterns were similar for the temperatures of the Turku area as a whole and for the Student Village area only. The season of the smallest spatial temperature differences depended on the temperature variable and the area. Among the environmental factors, land cover and water bodies had the strongest impact on spatial temperature differences. The urban-type land cover had a warming effect throughout the year. The direction of the impact of water bodies varied; regarding the monthly average temperatures and monthly average of daily minimum temperatures, the impact of water bodies was warming throughout the year, whereas for monthly average of daily maximum temperature and momentary situations, its impact was cooling in spring, and for daily maxima also in summer. During late autumn and early winter, the warming effect of the water bodies was even stronger than that of the urban land cover. Of the environmental factors studied, the impact of elevation was clearly weakest, and manifested as proneness of low-lying sites to cold-air drainage during the times of daily minimum temperatures and occasionally also at the times of largest month-specific momentary temperature differences.

Keywords: urban heat island, spatial temperature differences, regression model, topography, land cover, water bodies

1
THEORETICAL BACKGROUND

Urban areas exhibit distinct local climates compared to their rural surroundings. Perhaps the most studied and well-documented phenomenon of urban climate is the urban heat island (UHI) effect, which describes the relative warmth of urban areas compared to adjacent rural areas (Oke, 1987). A key factor contributing to the UHI is the solar heat stored by urban buildings and pavements (Swamy et al., 2024). This stored heat is released during the evening and nighttime, causing slower cooling in cities compared to rural areas. Other contributors to the UHI effect include anthropogenic heat sources such as vehicle traffic, building heating, and human metabolic activity, as well as reduced evapotranspiration in urban areas relative to rural landscapes. Additionally, environmental factors such as topography and proximity to coastlines influence the specific characteristics of the UHI in different cities (Reinwald et al., 2024). Beyond the UHI, other aspects of urban climate include increased precipitation, driven by the UHI effect and atmospheric aerosols (Lalonde et al., 2023), and reduced average wind speeds due to urban structures (Liu et al., 2023). This study investigates the influence of elevation, water bodies, and land cover on UHI intensity and examines the spatial characteristics of the UHI effect.

2
STUDY AREA

Turku is a mid-sized city (204,618 inhabitants at the end of August 2024) located in southwest Finland (Figure 1). To the southwest of the city, Turku is surrounded by the brackish Baltic Sea and an extensive archipelago. The coordinates of the city centre are 60°27′ N, 22°16′ E. The city centre has been built around River Aura that runs from Oripää eskers and discharges into the Baltic Sea. The River Aura and the proximity of the Baltic Sea influence the climate around the coastal city.

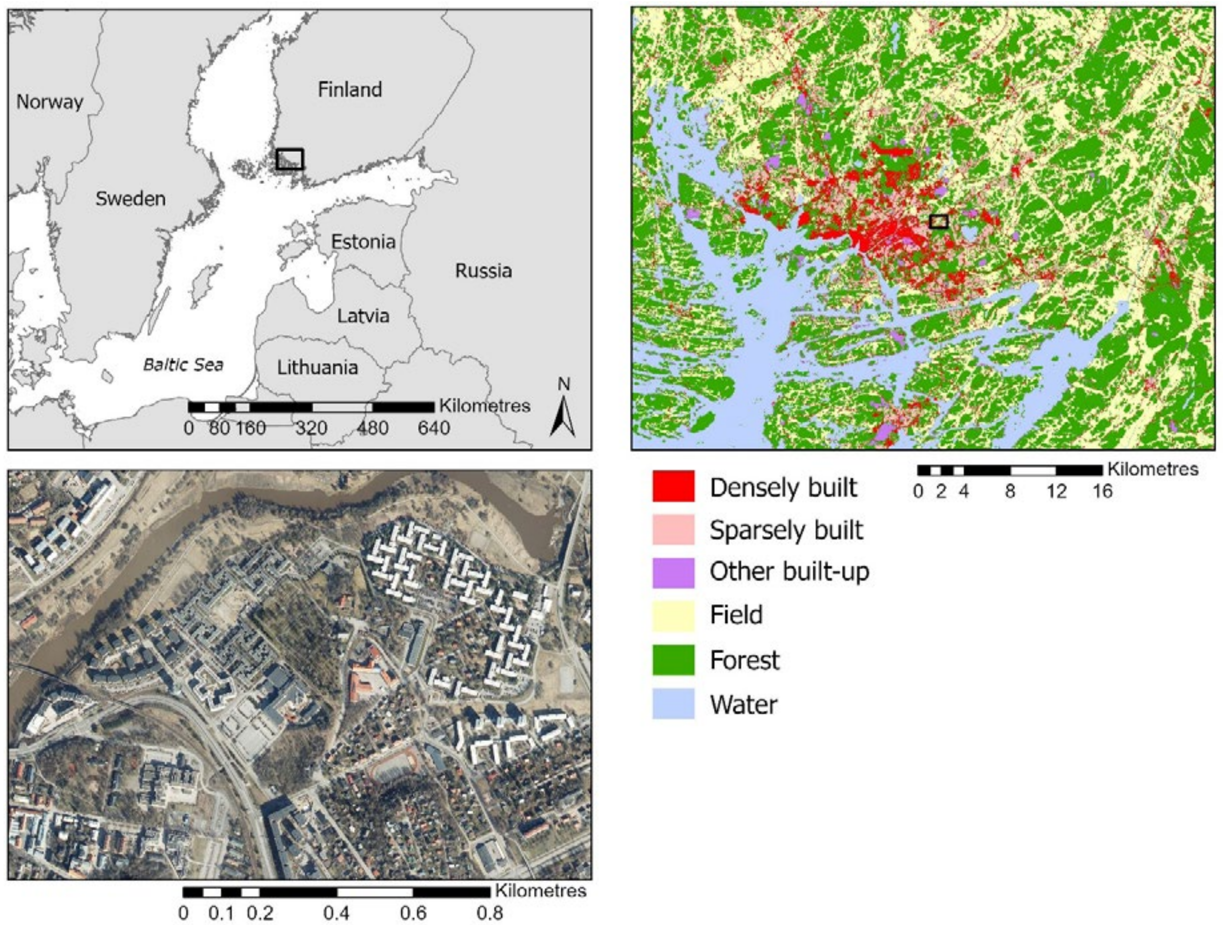

Figure 1. The study area presenting the geographical location of southwest Finland (upper left), the land cover of southwest Finland and Turku region with Turku Student Village's geographical location indicated (upper right) and an ortho aerial photo of the Turku Student Village area (bottom left). The land cover map is based on the CORINE Land Cover 2018 dataset. The aerial photo is produced by the National Land Survey of Finland.

According to Köppen's climate classification, Turku belongs to the Dfb climate, meaning that it has a humid continental climate with a warm summer and no significant precipitation differences between seasons. During the climatic reference period 1991–2020, the average temperature at Turku airport was 5.8 ˚C (Jokinen et al., 2021). The coldest month is February with an average temperature of –4.5 ˚C and the warmest July with an average temperature of 17.5 ˚C. Mean annual rainfall is 684 mm. The rainiest month was July (74 mm) and the driest month was April (32 mm). Annual average wind speed was 3.4 m/s. The windiest month on average was December with an average wind speed of 3.7 m/s and the least windy months were July, August, and September with wind speed averages of 3.1 m/s.

3
DATA AND METHODS

This study is based on half-hour interval temperature observations of the TURCLIM (Turku Urban Climate Research Group) local climate observation network of the Geography Division of the University of Turku. The TURCLIM observation network includes 85 observation sites in the city of Turku and neighbouring municipalities (Figures 2 & 3). In this study, the data on 80 observation sites of the year 2021 were used. Those 80 loggers include nine new loggers that were installed in the Turku Student Village area in December 2020 to densify the observation network in the RESPONSE project target area that only had 1 logger before the project (Figure 4). The TURCLIM data enables versatile re-

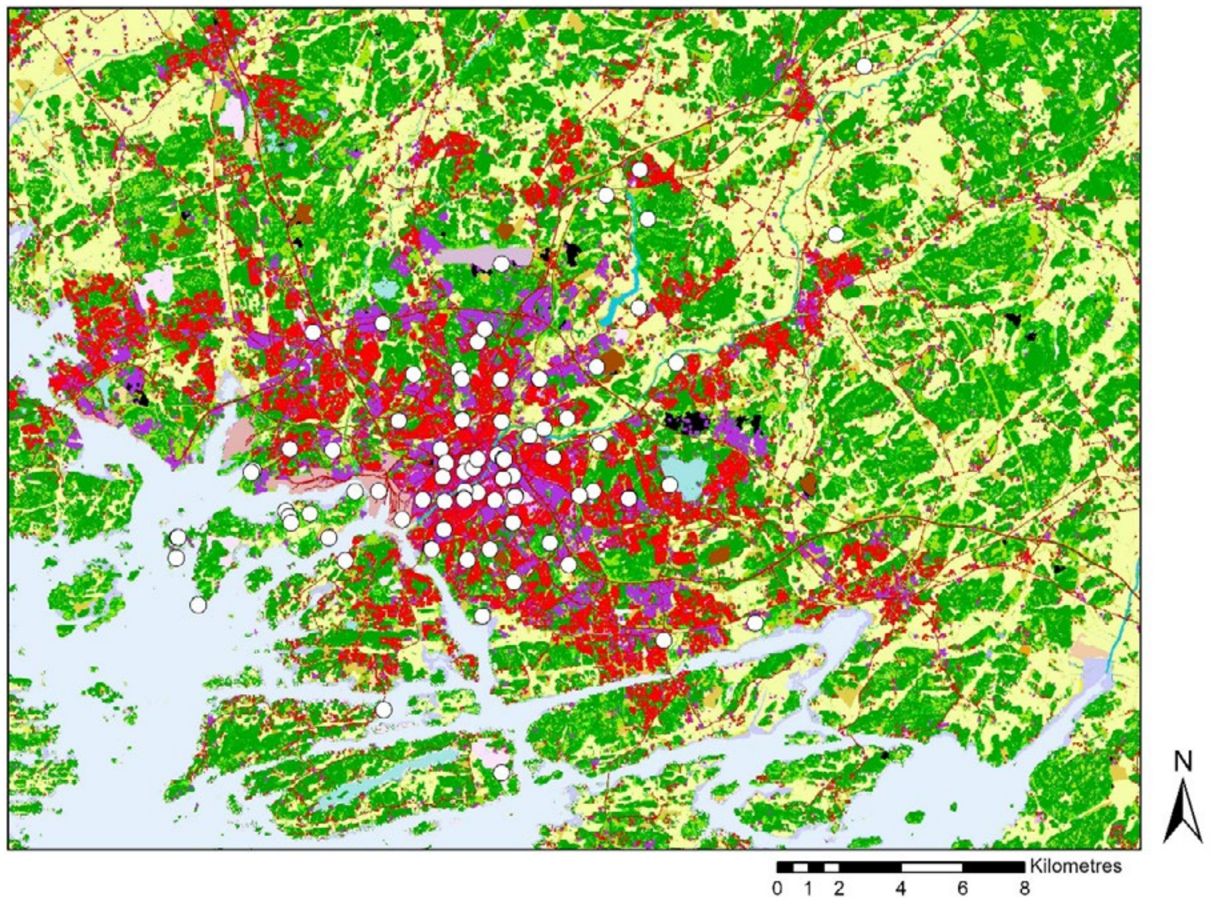

Figure 2. The TURCLIM logger locations (white circles) in and around the city of Turku. Background map: CORINE Land Cover 2018. For information on CORINE level 4 classes and respective colours, used in this Figure and subsequent CORINE based Figures, see Suomi et al. 2024, Appendix A.

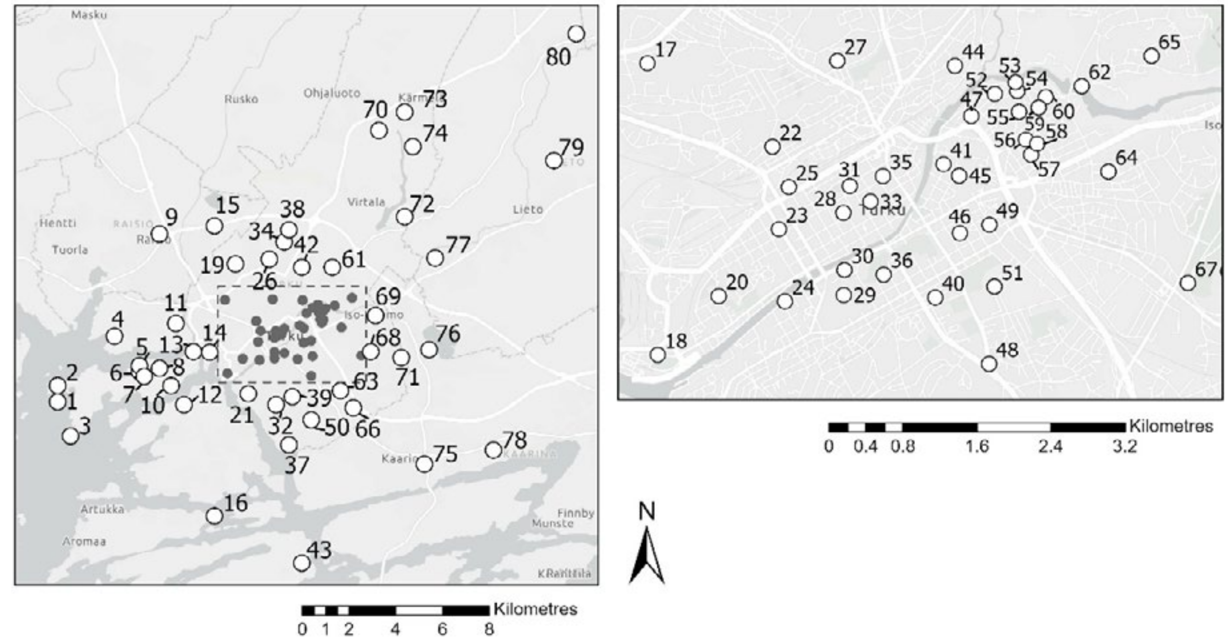

Figure 3. Zoomed view of the TURCLIM logger network. The loggers are numbered consecutively based on the eastern coordinate. For information on the observation site elevation and land cover, see Table 1.

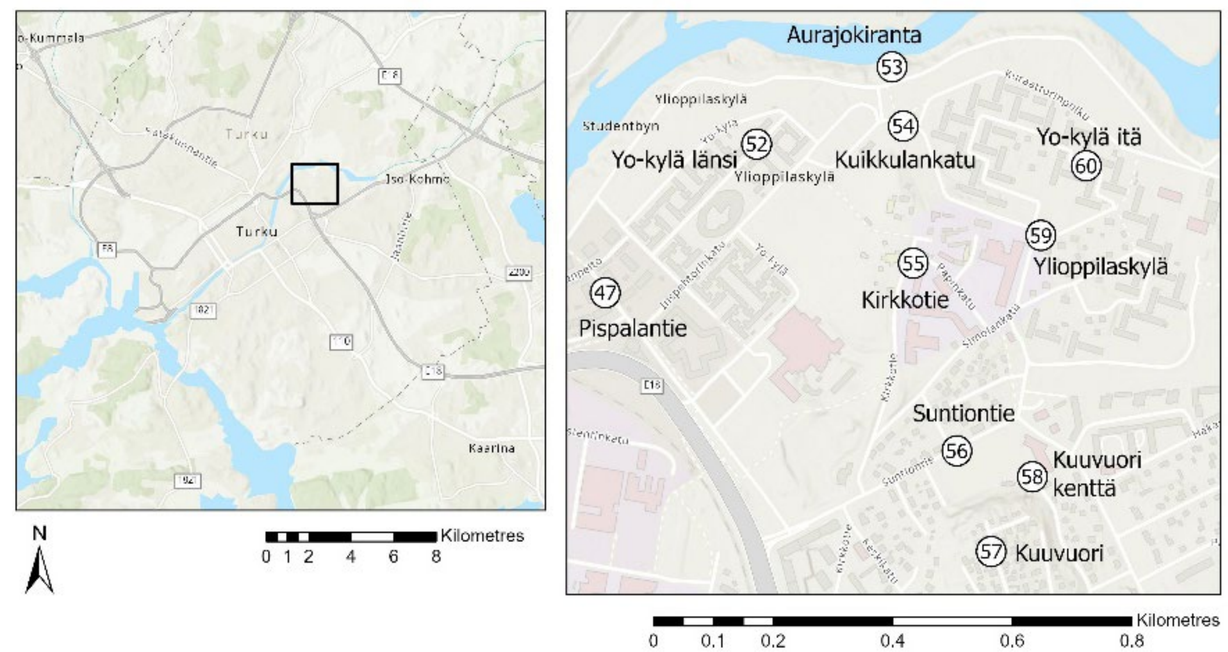

Figure 4. Loggers of the Turku Student Village area. For information on the observation site elevation and land cover, see Table 1.

Table 1. Elevation and urban land cover proportion in the surroundings of the TURCLIM observation sites.

No	Logger Name	Elevation (m)*	Urban land cover proportion (%)**
1	Kolkka	0.5	0.0
2	Camping	1.4	19.8
3	Kuuva	4.8	0.0
4	Pansio	3.5	0.0
5	Hiiriluoto ranta	0.5	0.0
6	Hiiriluoto mäki	36.3	0.0
7	Hiiriluoto manner	17.3	0.0
8	Kasvitieteellinen	4.6	0.0
9	Raisio	14.5	95.1
10	Ruissalo	1.0	0.0
11	Messukeskus	6.0	85.2
12	Hirvensalo	0.8	0.0
13	Marjaniemi	17.0	56.8
14	Vapaavarasto	2.5	25.9
15	Mylly	20.8	76.5
16	Satava	1.2	12.3
17	Suikkila	22.1	70.4
18	Linna	2.3	49.4
19	Metsäkyla	22.4	3.7
20	Kakola	18.0	49.4
21	Heikkilänkasarmi	4.1	25.9
22	Kähäri	20.9	32.1
23	Mikaelinkirkko	9.8	76.5
24	Martti	2.5	55.6
25	Rautatieasema	9.7	84.0
26	Impivaara	31.1	0.0
27	Rieskalähde	31.4	28.4
28	Betel	16.9	100.0
29	Urheilupuisto	23.3	0.0
30	Virastotalo	7.2	77.8
31	Puolalanmäki	28.9	86.4
32	Ispoinen	16.5	1.2
33	Kauppatori	7.7	97.5
34	Runosmäki	37.6	98.8
35	Puutori	18.1	100.0
36	Luostarivuori	33.5	81.5
37	Katariina	6.5	0.0
38	Vahdontie	40.1	45.7
39	Luolavuori	43.5	0.0
40	Saarnitie	16.8	16.0
41	Piispankatu	9.7	25.9
42	Valkiasvuori	29.7	21.0
43	Kakskerta	16.3	0.0
44	Alfa	21.0	28.4
45	Yliopistonmäki	35.6	70.4
46	Kerttuli	23.0	87.7
47	Pispalantie	10.9	98.8
48	Uudenmaantie	24.0	58.0
49	Sirkkala	23.1	86.4
50	Ryhmäpuutarha	13.8	0.0
51	Kupittaa	17.3	37.0
52	Yo-kylä länsi	10.0	69.1
53	Aurajokiranta	9.8	8.6
54	Kuikkulankatu	11.4	46.9
55	Kirkkotie	23.0	54.3
56	Suntiontie	15.8	4.9
57	Kuuvuori	43.6	1.2
58	Kuuvuori kenttä	16.2	32.1
59	Ylioppilaskylä	15.2	55.6
60	Yo-kylä itä	10.7	66.7
61	Kristillinen	21.8	27.2
62	Halinen	7.5	32.1
63	Hautausmaa	24.9	28.4
64	Nummi	29.9	11.1
65	Liponkuja	22.7	0.0
66	Huhkola	18.8	0.0
67	Pääskyvuori WS	15.2	21.0
68	Pääskyvuori	47.7	21.0
69	Kurala	13.5	0.0
70	Ylijoki	33.8	0.0
71	Varissuo	46.2	80.2
72	Metsämäki	21.3	0.0
73	Jäkärlä	56.6	69.1
74	Niuskala	32.4	0.0
75	Kaarina	17.3	56.8
76	Rauhanniemi	39.7	0.0
77	Vanhalinna	22.2	9.9
78	Tuorla	14.1	14.8
79	Lieto	30.8	0.0
80	Sikilä	43.3	16.0

* Metres above sea level.
** Urban land cover proportion is calculated within a 100 metre radius around the observation site. Urban land cover consists on the following three CORINE Land Cover 2018 classes: blocks of flats areas, commercial areas and road and rail networks and associated lands.

search on spatio-temporal temperature variability. The observation sites cover different kinds of environments (Table 1) that enable, together with various GIS data, estimation of the impacts of environmental factors, such as topography, land cover, and proximity of sea areas, on spatial temperature differences during different seasons and weather conditions. Multiple linear regression models with these environmental factors as explanatory variables and temperature as the response variable were completed for each month. The explanatory variable on land cover was formulated based on the CORINE Land Cover 2018 dataset (spatial resolution 20 × 20 m) (Syke, 2024), the explanatory variable on topography was based on the elevation model (spatial resolution 10 × 10 m) (National Land Survey of Finland, 2019), and the explanatory variable on water bodies was based on the SLICES 2010 land use classification (spatial resolution 10 × 10 m) (National Land Survey of Finland, 2020). The explanatory variable on land use represents the proportion of urban land cover area divided by the area of the buffer as a whole. The urban land cover consists of three original CORINE Land Cover classes; block of flat areas, commercial areas, and road and rail networks and associated lands. The explanatory variable on water bodies represents the proportion of water body areas divided by the area of the buffer as a whole, and the explanatory variable on topography represents the relative elevation of the site that is calculated by the formula in which the average elevation of the buffer surrounding the observation site is reduced from the observation site's elevation, which means that hill-top type sites get positive variable values and valley-bottom type sites get negative values. The temperature measured by the TURCLIM observation network acted as a response variable. The explanatory variables were applied in the regression models with case-specific and variable-specific optimal buffer zone sizes that were determined based on the Pearson's correlation coefficients between the variables and temperatures (Table 2). Regression models were also utilized in creating spatially continuous high-resolution (100 m) temperature maps on each studied case. The regression models were calibrated with Enter setting meaning that all explanatory variables were included in the regression model despite their statistical significance. In interpretation of the model results, the significance level of $p \leq 0.05$ was applied.

The data used in the comparison of monthly temperatures of 2021 to the average temperatures during the 30-year climatic reference period 1991–2020 were retrieved from the Finnish Meteorological Institute's climate report (Jokinen et al., 2021). The Finnish Meteorological Institute (FMI) has observation sites in the Turku municipality area in Artukainen, Turku airport, and Rajakari. The temperatures of the 30-year reference period represent the temperatures of Turku airport. CORINE Land Cover 2018 data and ortho-aerial photographs of Turku provided by the National Land Survey of Finland have been used for visualization in the maps. Maps representing the 500 hectopascal geopotential height and air pressure at the ground level retrieved from Wetterzentrale CFS and TheWeatherOutlook NCEP reanalyses were included for the available time periods (Wetterzentrale, 2024; TheWeatherOutlook, 2025). The maps of Wetterzentrale were primarily used, and if they were not available, the maps of TheWeatherOutlook were applied. Wetterzentrale and TheWeatherOutlook provide these maps for time stamps of 00.00, 06.00, 12.00, and 18.00 UTC. Since the temperature

Table 2. The radii of the optimal buffer sizes of explanatory variables applied in the multiple linear regression models. The optimal buffer sizes were determined based on the Pearson's correlation coefficients between the variable and temperature.

	Monthly average temperature			Monthly averages of daily minimums			Monthly averages of daily maximums			Momentary maximum temperature range		
Month	**Land cover**	**Water body**	**Elevation**	**Land cover**	**Water body**	**Elevation**	**Land cover**	**Water body**	**Elevation**	**Land cover**	**Water body**	**Elevation**
January	700 m	500 m	200 m	400 m	5 km	300 m	400 m	500 m	100 m	400 m	2 km	500 m
February	700 m	500 m	300 m	700 m	5 km	500 m	400 m	500 m	100 m	100 m	2 km	500 m
March	700 m	1500 m	100 m	700 m	500 m	300 m	400 m	2 km	500 m	1000 m	2 km	100 m
April	1000 m	2 km	200 m	1000 m	300 m	300 m	1000 m	2 km	500 m	1000 m	2 km	100 m
May	1000 m	2 km	200 m	1000 m	300m	300 m	1000 m	1500 m	100 m	1000 m	1 km	100 m
June	700 m	2 km	300 m	400 m	500 m	500 m	200 m	2 km	200 m	1000 m	2 km*	100 m
July	700 m	2 km	300 m	400 m	500 m	500 m	1000 m	2 km	300 m	100 m	2 km*	500 m
August	400 m	500 m	300 m	100 m	2 km	500 m	200 m	2 km*	500 m	100 m	2 km	500 m
September	1000 m	500 m	300 m	100 m	2 km	500 m	200 m	2 km*	500 m	700 m	2 km	500 m
October	400 m	500 m	100 m	700 m	2 km	300 m	400 m	500 m	500 m	100 m	1500 m	300 m
November	400 m	2 km*	300 m	100 m	500 m	500 m	400 m	700 m	100 m	700 m	2 km	500 m
December	700 m	2 km	300 m	700 m	500 m	300 m	400 m	700 m	100 m	1000 m	2 km	500 m

* The square root of the original value has been applied.

data is in UTC+2 format, the time difference has been considered when retrieving the pressure maps from Wetterzentrale and The WeatherOutlook. The maps closest to the momentary maximum temperature range times have been used. Wind speed and cloudiness data for the maximum temperature range moments are also presented. The data are retrieved from the FMI's Turku Artukainen station and the values have been presented as an average of the half-an-hour period preceding the time of the largest momentary temperature range. The wind speed is reported in metres per second (m/s) and cloudiness with an okta scale from 0 (clear) to 8 (cloudy).

4 RESULTS

4.1 Monthly summaries of temperature variability

4.1.1 January

At the FMI weather station at the Turku airport, the average temperature of January 2021 was -4.1 °C, which is 0.3 °C colder than the average January temperature during the climate period 1991–2020 (Jokinen et al., 2021).

Regarding the TURCLIM observation sites, the warmest and coldest monthly average temperatures in January 2021 were measured in Sikilä and Kuuva, respectively (Figure 5). In Sikilä, the average temperature was -4.5 ˚C, and in Kuuva -3.0 ˚C. The warmest and coldest monthly averages of daily minimum temperatures were also measured in Kuuva (-5.0 ˚C) and Sikilä (-7.0 ˚C). The warmest and coldest monthly averages of daily maximum temperatures were measured in the same sites Kuuva (-1.1 ˚C) and Sikilä (-2.3 ˚C). The maximum momentary temperature range, 10.3 °C, was observed between the loggers in Sikilä and Kuuva on the 31st of January at 22.00, when the temperature in Kuuva was -7.4 ˚C and in Sikilä -17.7. A possible reason for the difference is the local warming effect of the sea in Kuuva.

When taking a closer look at the Turku Student Village area and its ten observation sites in January, the highest and lowest monthly average temperatures occurred in Pispalantie -3.6 ˚C and both in Kuuvuori and Kuikkulankatu -3.9 ˚C, respectively (Figure 6). The highest and lowest monthly averages of daily minimum temperatures were -5.9 ˚C in Pispalantie and Yo-kylä itä, and -6.3 ˚C in Aurajokiranta and Kuikkulankatu, respectively. The highest and lowest monthly averages of daily maximum temperatures were -1.6 ˚C in Pispalantie, Suntiontie and Yo-kylä länsi and -1.8 ˚C in Kuuvuori and Kuikkulankatu, respectively. The momentary maximum temperature range was 4.6 ˚C between the observation sites Kuuvuori and Aurajokiranta. The largest range occurred on the 31st of January at 19.30. Possible reasons for the difference can be the inversion conditions, when the impact of elevation between the hilltop site Kuuvuori logger and the low-lying site Aurajokiranta next to the river are emphasized.

For the monthly average temperatures, the explanatory power of the regression model (Adjusted R Square) is 0.631 and of the explanatory variables, water bodies and land cover were statistically significant (Table 3). The tables follow the SPSS format. The variable v1_3_5_700 stands for proportion of urban land cover (apartment building areas, service areas and traffic areas) in a 700-metre radius. The variable tkuwaters_500m stands for the proportion of water bodies in a 500-metre radius. The variable relelev_200 stands for relative elevation, i.e. the elevation of the observation site minus the average elevation of a 200-metre radius buffer around the observation site. All the explanatory variables had a slight warming effect. The water bodies had the strong-

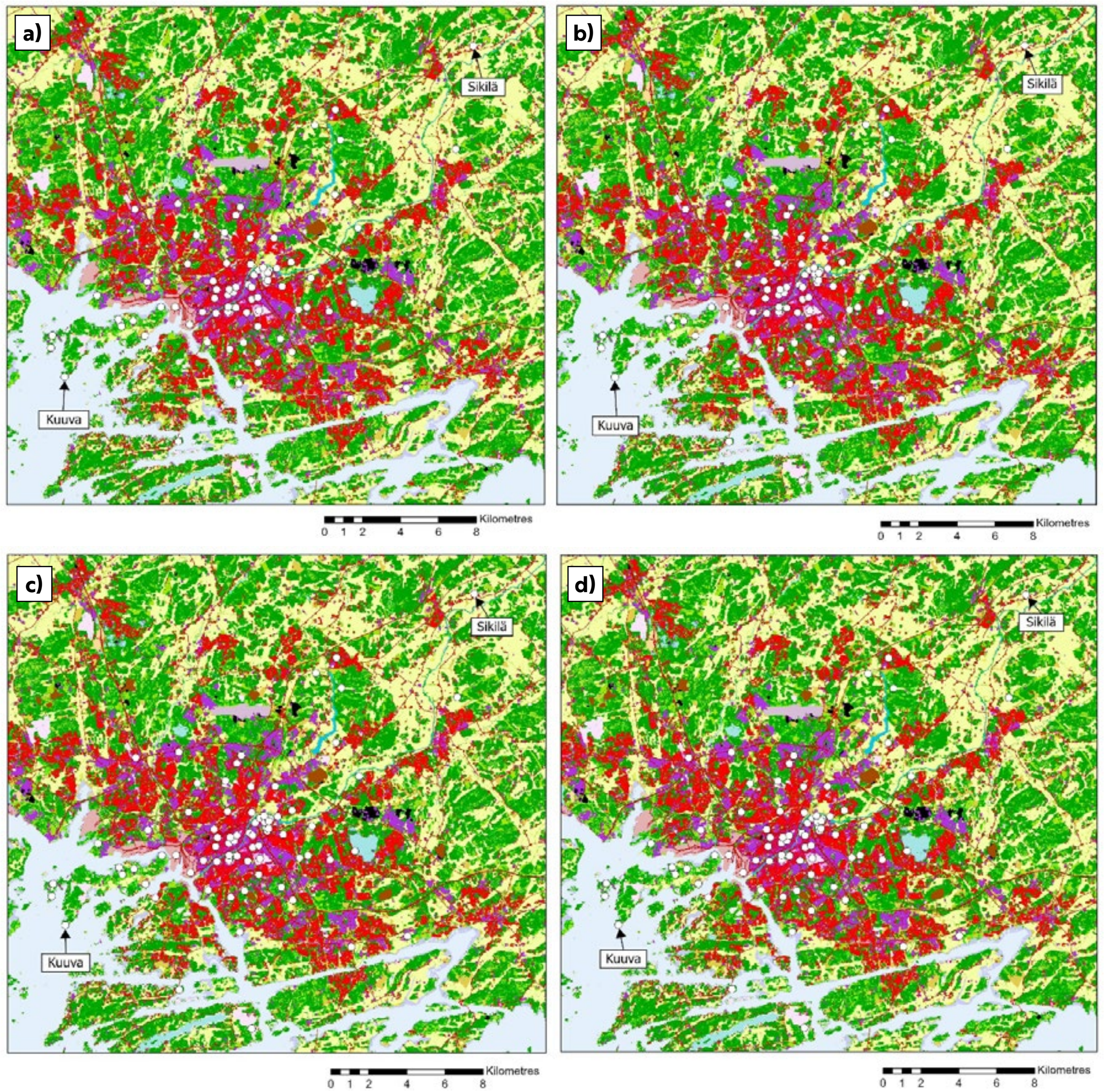

Figure 5. The locations of the observation sites of the highest and lowest a) monthly average temperatures (Kuuva -3.0 ˚C, Sikilä -4.5 ˚C), b) monthly averages of daily minimum temperatures (Kuuva -5.0 ˚C, Sikilä -7.0 ˚C), c) monthly averages of daily maximum temperatures (Kuuva -1.1 ˚C, Sikilä -2.3 ˚C) and d) momentary maximum temperature range on January 31st at 22.00 with the difference of 10.3 ˚C (Kuuva -7.4 ˚C, Sikilä -17.7 ˚C) on the CORINE Land Cover 2018 dataset in January 2021.

est warming effect, but the land cover had a relatively strong effect as well. The same applies for the monthly averages of daily minimum temperatures but with the explanatory power of 0.722 (Table 4) and for the monthly averages of daily maximum temperatures but with the explanatory power of 0.534 (Table 5). In the case of daily maximum temperatures, the relative elevation had practically no impact on temperature. The momentary maximum temperature range's explanatory power is 0.629 and all the explanatory variables were statistically significant (Table 6). All the explanatory variables had a warming effect, but the water bodies had the strongest along with the land cover.

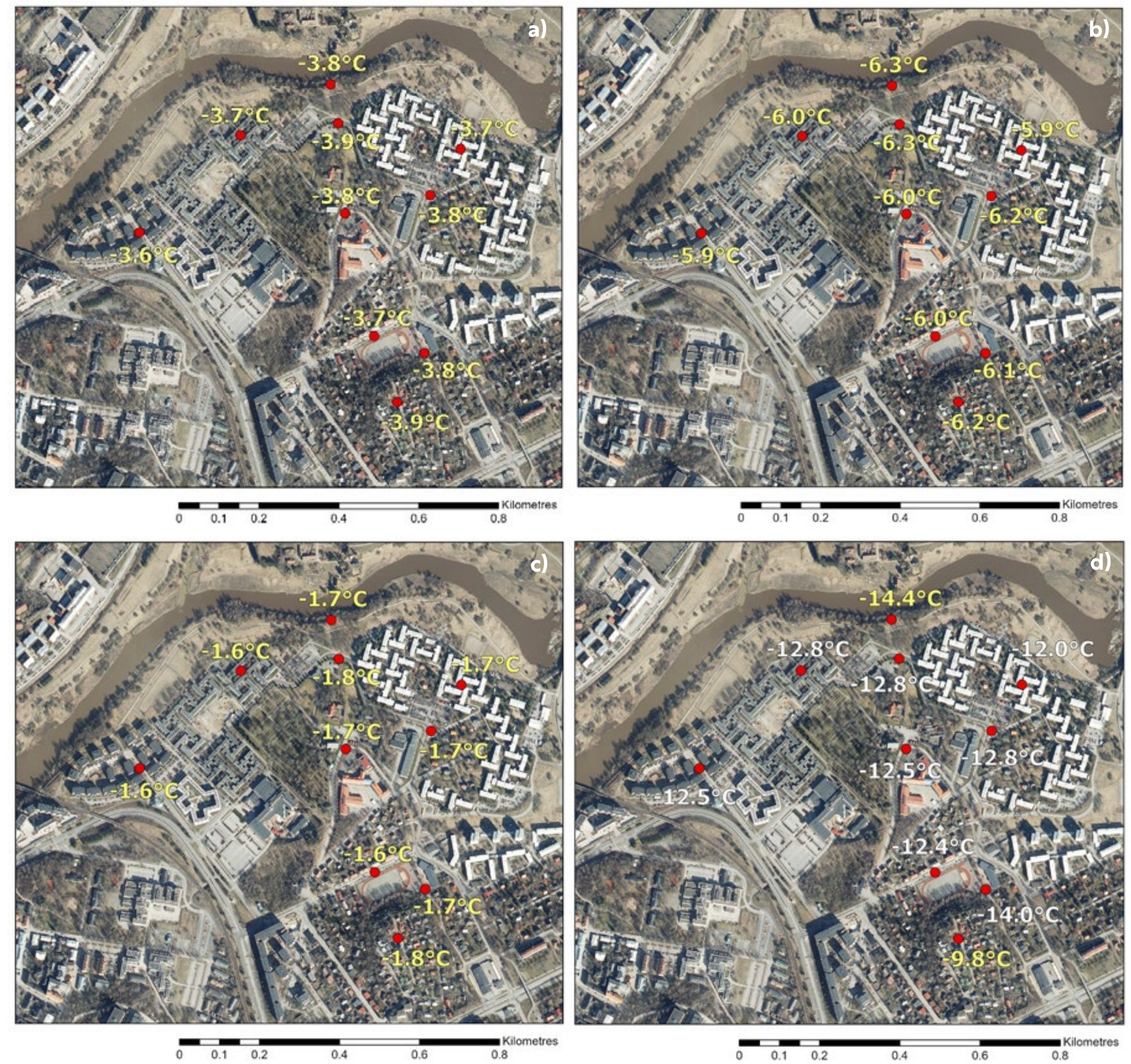

Figure 6. The Student Village observation sites with a) monthly average temperatures, b) monthly averages of daily minimum temperatures, c) monthly averages of daily maximum temperatures and d) the momentary maximum temperature range on January 31st at 19.30 in 2021 with the difference of 4.6 ˚C between Kuuvuori and Aurajokiranta. For individual observation site names, see Figure 4.

Areas adjacent to the shoreline appear warmer than the areas further inland in the monthly average temperature map (Figure 7). The UHI in the Turku city centre is also distin-

Table 3. The regression model for the monthly average temperatures in January 2021. vl_3_5_700 = proportion of urban land cover inside a 700-metre radius buffer, tkuwaters_500m = proportion of water bodies inside a 500-metre radius buffer, relelev_200 = elevation of the observation site minus the average elevation of the 200-metre radius buffer around the observation site. The variable abbreviations of the other respective tables follow the same nomination principles.

R Square	0.646	
Adjusted R Square	0.631	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_700m	0.714	<0.001
tkuwaters_500m	0.735	<0.001
relelev_200m	0.040	0.594

Table 4. The regression model for the monthly averages of daily minimum temperatures in January 2021.

R Square	0.734	
Adjusted R Square	0.722	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.727	<0.001
tkuwaters_5km	0.785	<0.001
relelev_300m	0.134	0.041

Table 5. The regression model for the monthly averages of daily maximum temperatures in January 2021.

R Square	0.554	
Adjusted R Square	0.534	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.646	<0.001
tkuwaters_500m	0.700	<0.001
relelev_100m	-0.001	0.992

Table 6. The regression model for the momentary maximum temperature range of January 2021.

R Square	0.645	
Adjusted R Square	0.629	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.600	<0.001
tkuwaters_2km	0.687	<0.001
relelev_500m	0.332	<0.001

guishable. Bigger roads and biggest residential areas can also be recognized as warmer areas as reflecting the impact of anthropogenic heat. The monthly averages of the daily minimum temperatures follow a similar pattern to the monthly average temperatures, but the warming effect of the sea extends further inland. The distribution of the maxima reminds that of the monthly average temperatures. Regarding the momentary maximum temperature ranges, the mainland does not stand out as the coldest area as in the average temperature cases, but the impact of topography is emphasized, and consequently, the lowland areas appear to be the coldest. In this map, the human-induced, from a regional perspective, exceptionally large topographic variability of the limestone quarry in Parainen distorts the temperature range. Consequently, the limestone quarry and temperatures of that area have been presented in black. In other maps of January, the impact of topography is smaller, and the limestone quarry area is presented normally. Similar to the other maps, the coastal areas are also the warmest in the map depicting the momentary maximum temperature range. The lowest temperature outside the quarry was -16.33 ˚C.

The map containing sea level air pressure and height of the 500 hectopascal pressure level on the 31st of January at 18.00 UTC depicts the large-scale weather conditions during the momentary maximum temperature range situation of Turku Student Village and the whole Turku area (Figure 8). At that time, the Turku area and southern Finland were under a low-pressure centre. The 500 hPa pressure surface height in the area is around 504–508 decametres. The average wind speed at around January 31st at 22.00 was 0.425 m/s, whereas the average cloudiness was 1.75. At 19.30, i.e. at the time of maximum range for the Student Village, the wind speed was 0.375 m/s and cloudiness 6.5.

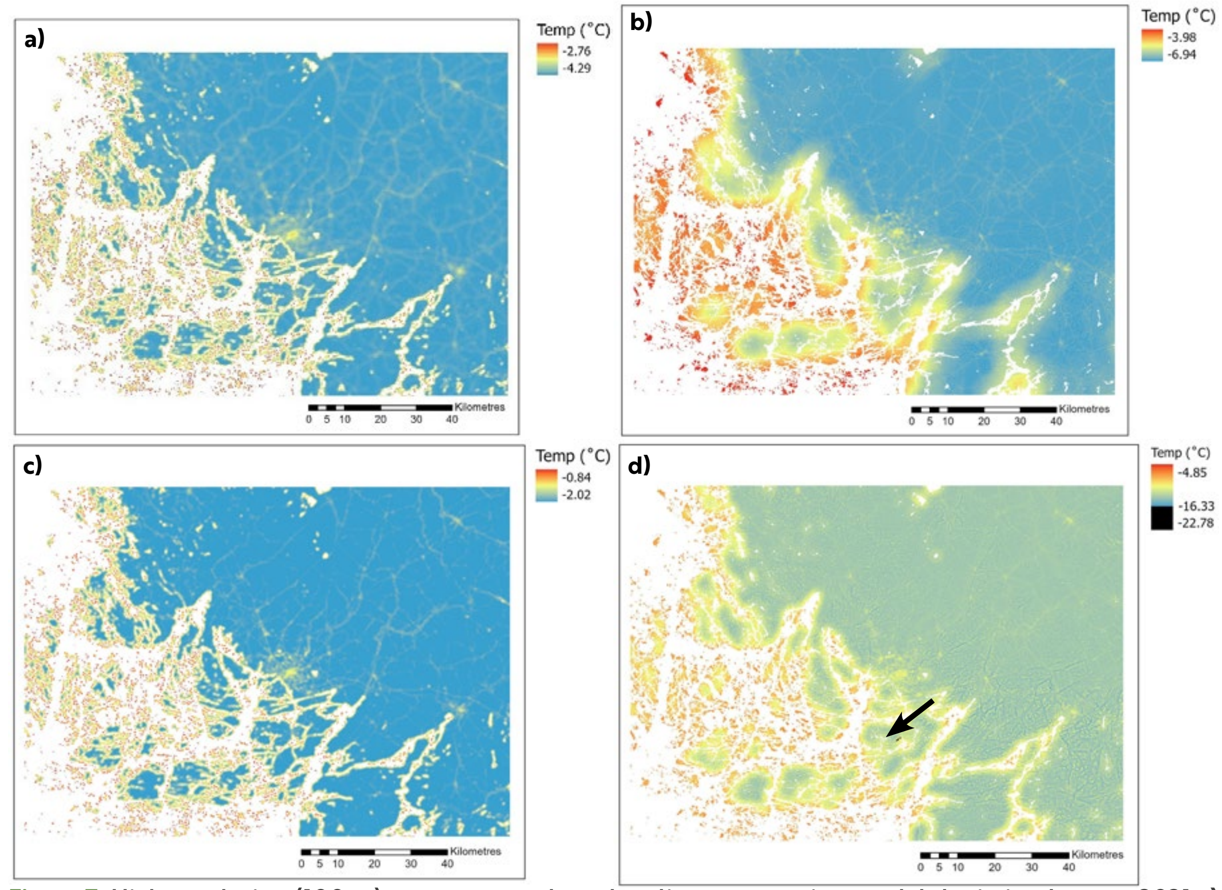

Figure 7. High-resolution (100 m) temperatures based on linear regression model depicting January 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on January 31st, 2021, at 22.00. The abnormally low temperature area in the limestone quarry located in Parainen is marked in black (arrow).

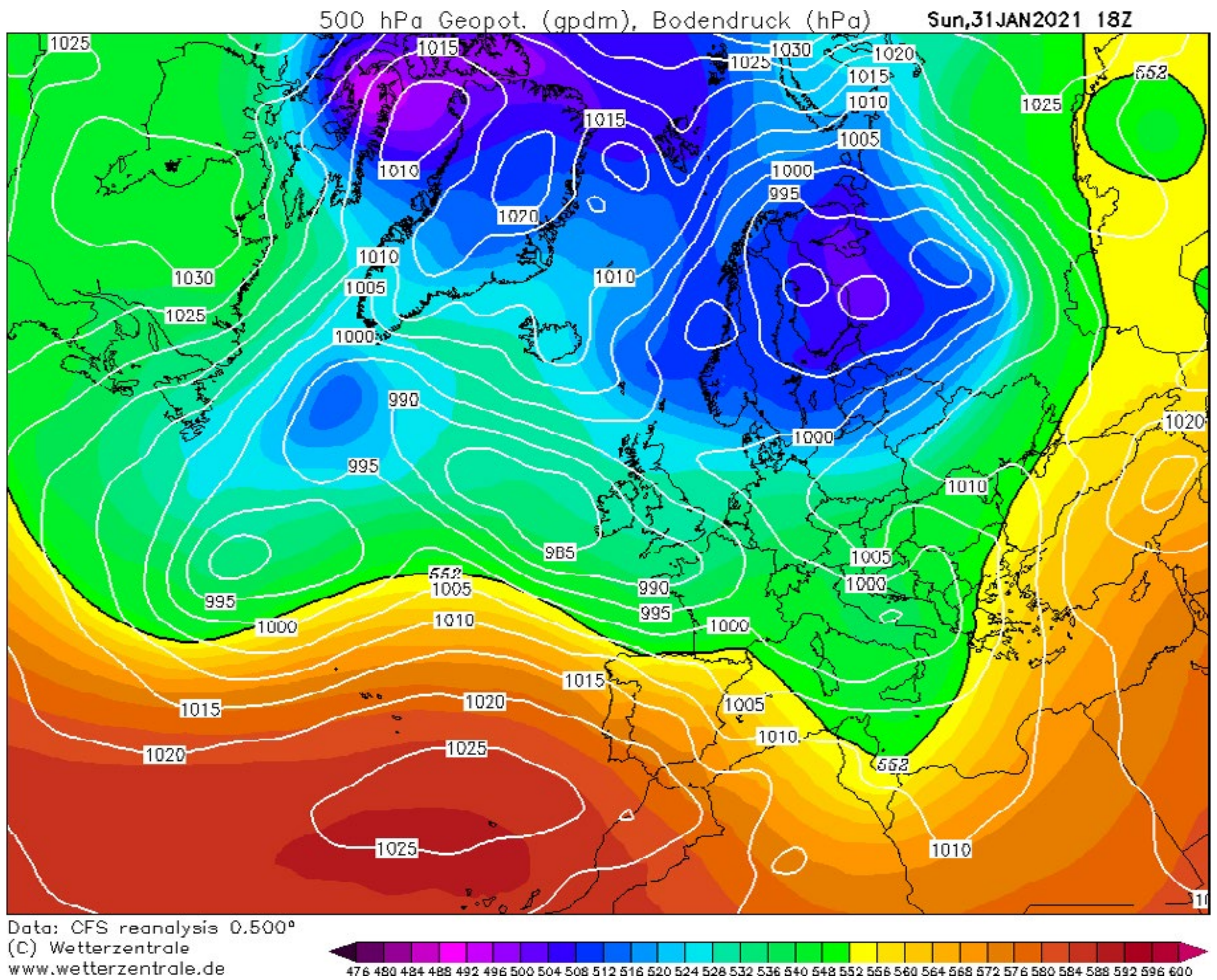

Figure 8. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for January 31st at 18.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

4.1.2 February

February 2021 was colder than average in the Turku area. In the Turku airport, the average temperature was -6.4 ˚C in 2021, whereas during the climate period 1991–2020, the respective temperature was -4.5 ˚C, resulting in a cold anomaly of 1.9 ˚C in February 2021 (Jokinen et al., 2021).

Regarding the TURCLIM observation network, the highest monthly average temperature was -5.0 ˚C, measured in Betel in the city centre and the lowest monthly average temperature was -7.2 ˚C, measured in Niuskala (Figure 9). The highest and lowest monthly averages of daily minimum temperatures were recorded in Betel and Niuskala. In Betel, the daily minima were on average -8.4 ˚C and in Niuskala -11.9 ˚C. The highest and lowest monthly averages for the daily maximum temperatures were measured in Kauppatori (-1.7 ˚C) and Sikilä (-3.3 ˚C).

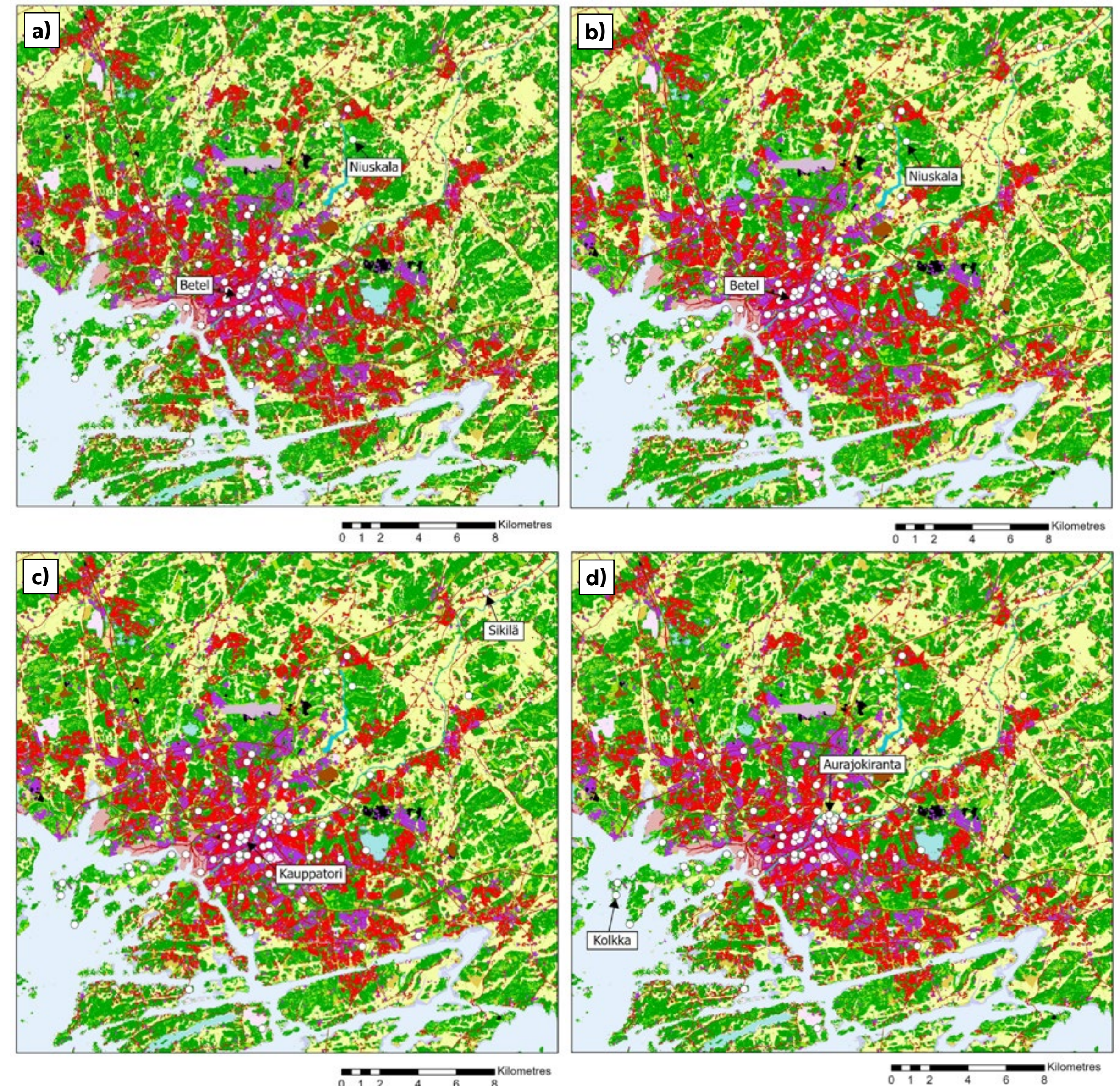

Figure 9. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Betel –5.0 ˚C, Niuskala –7.2 ˚C), **b)** monthly averages of daily minimum temperatures (Betel –8.4 ˚C, Niuskala –11.9 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori –1.7 ˚C, Sikilä –3.3 ˚C) and **d)** momentary maximum temperature range on February 13th at 00.30 with the difference of 10.7 ˚C (Kolkka –3.9 ˚C, Aurajokiranta –14.6 ˚C) on the CORINE Land Cover 2018 dataset in February 2021.

The maximum temperature range was measured between Kolkka and Aurajokiranta on the 13th of February at 00.30, the difference being 10.7 ˚C. In Kolkka, the temperature was -3.9 ˚C and Aurajokiranta -14.6 ˚C. The difference is probably mainly due to the wintertime warming effect of the sea in the coastal area around Kolkka. The Aurajokiranta logger is located next to the lowland river bench, and inversion conditions and related cold-air pooling may al-

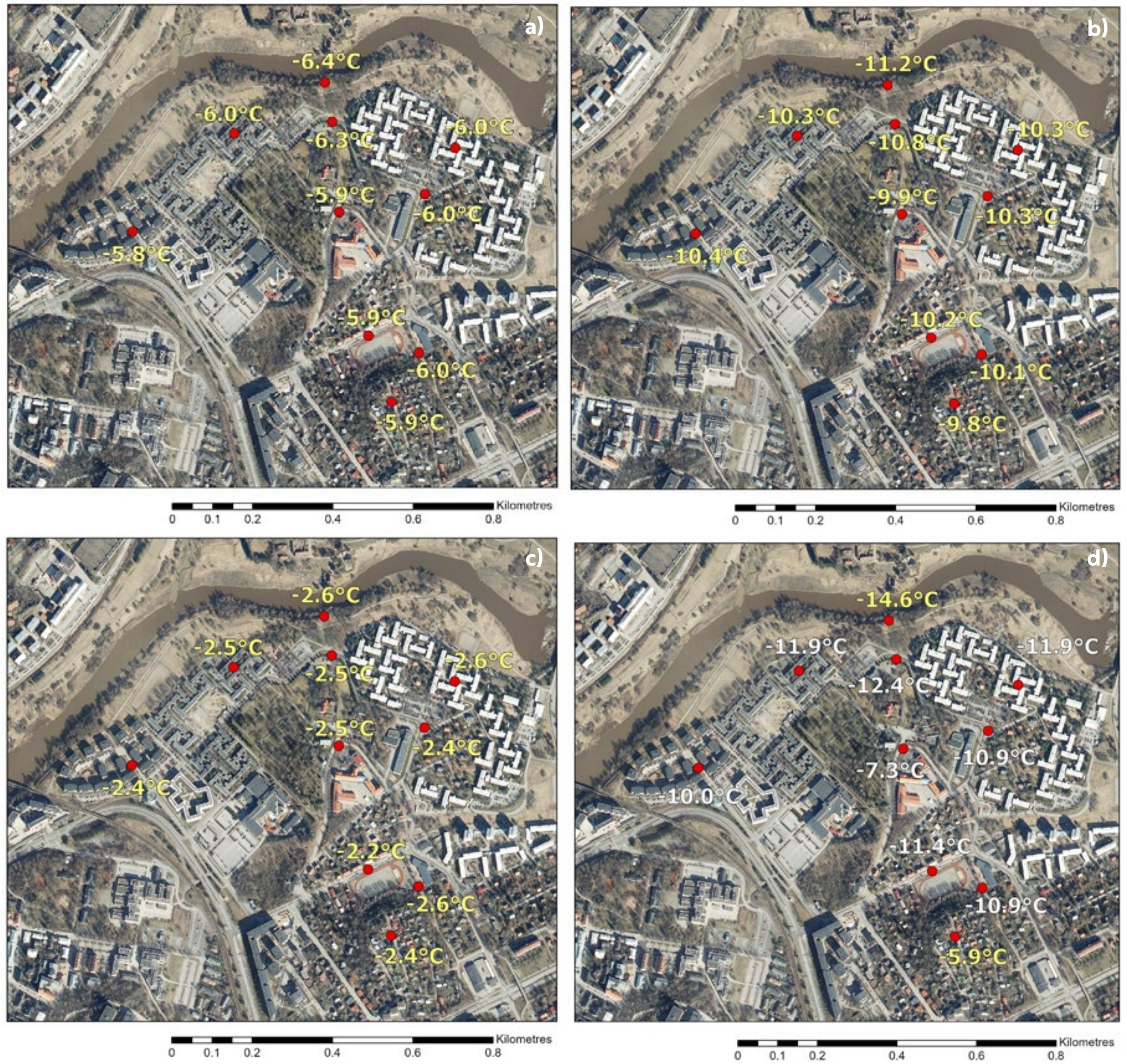

Figure 10. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on February 13th at 00.30 in 2021 with the difference of 8.7 °C between Kuuvuori and Aurajokiranta. For individual observation site names, see Figure 4.

so have played a role behind the large difference.

For the Turku Student Village area, the highest and lowest monthly average temperatures were -5.8 °C in Pispalantie and -6.4 °C in Aurajokiranta (Figure 10). The highest monthly average of daily minimum temperatures was -9.8 °C in Kuuvuori and the lowest in -11.2 °C in Aurajokiranta. For the maxima, the highest temperature was -2.2 °C in Suntiontie and the lowest -2.6 °C in Aurajokiranta, Yo-kylä itä, and Kuuvuori kenttä. The maximum temperature range occurred between Aurajokiranta and Kuuvuori on the 13th of February at 00.30,

Table 7. The regression model for the monthly average temperatures in February 2021.

R Square	0.675	
Adjusted R Square	0.661	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_700m	0.829	<0.001
tkuwaters_500m	0.499	<0.001
relelev_300m	0.146	0.044

Table 8. The regression model for the monthly averages of daily minimum temperatures in February 2021.

R Square	0.755	
Adjusted R Square	0.744	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_700m	0.827	<0.001
tkuwaters_5km	0.604	<0.001
relelev_500m	0.259	<0.001

Table 9. The regression model for the monthly averages of daily maximum temperatures in February 2021.

R Square	0.466	
Adjusted R Square	0.442	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.738	<0.001
tkuwaters_500m	0.400	<0.001
relelev_100m	-0.090	0.325

Table 10. The regression model for the momentary maximum temperature range of February 2021.

R Square	0.396	
Adjusted R Square	0.369	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_100m	0.405	<0.001
tkuwaters_2km	0.362	<0.001
relelev_500m	0.400	<0.001

when the difference was 8.7 °C. This was the highest temperature difference recorded in the Student Village during 2021. Inversion conditions and related enhanced impact of elevation may explain the large temperature difference.

In February's monthly average temperature regression model, the explanatory power of the regression model is 0.661 (Table 7). All the explanatory variables were statistically significant, and they had a warming effect on temperatures. Based on the model, the land cover had the strongest effect and the elevation the weakest. In the case of the monthly averages of daily minimum temperatures, the explanatory power is 0.744 and all the explanatory variables were statistically significant (Table 8). The land cover had the strongest effect and elevation the weakest. For the maxima, the explanatory power is 0.442 (Table 9). Only the land cover and water bodies were statistically significant explanatory variables. Land cover had the strongest effect. In the case of the momentary maximum temperature range, the explanatory power is 0.369 and all explanatory variables were statistically significant (Table 10). All had a warming effect, and the effect of land cover was the strongest.

In February, the city centre and the coasts are on average the warmest areas (Figure 11). This can be explained by the urban heat effect and the warming impact of the sea. As a consequence of strengthened sea ice cover, the relative warmth of coastal areas is not as clear as in January. The continental areas are relatively cool. The same pattern is detectable also in the monthly averages of daily maximum temperatures. In the monthly averages of daily minimum temperatures, the coast and is-

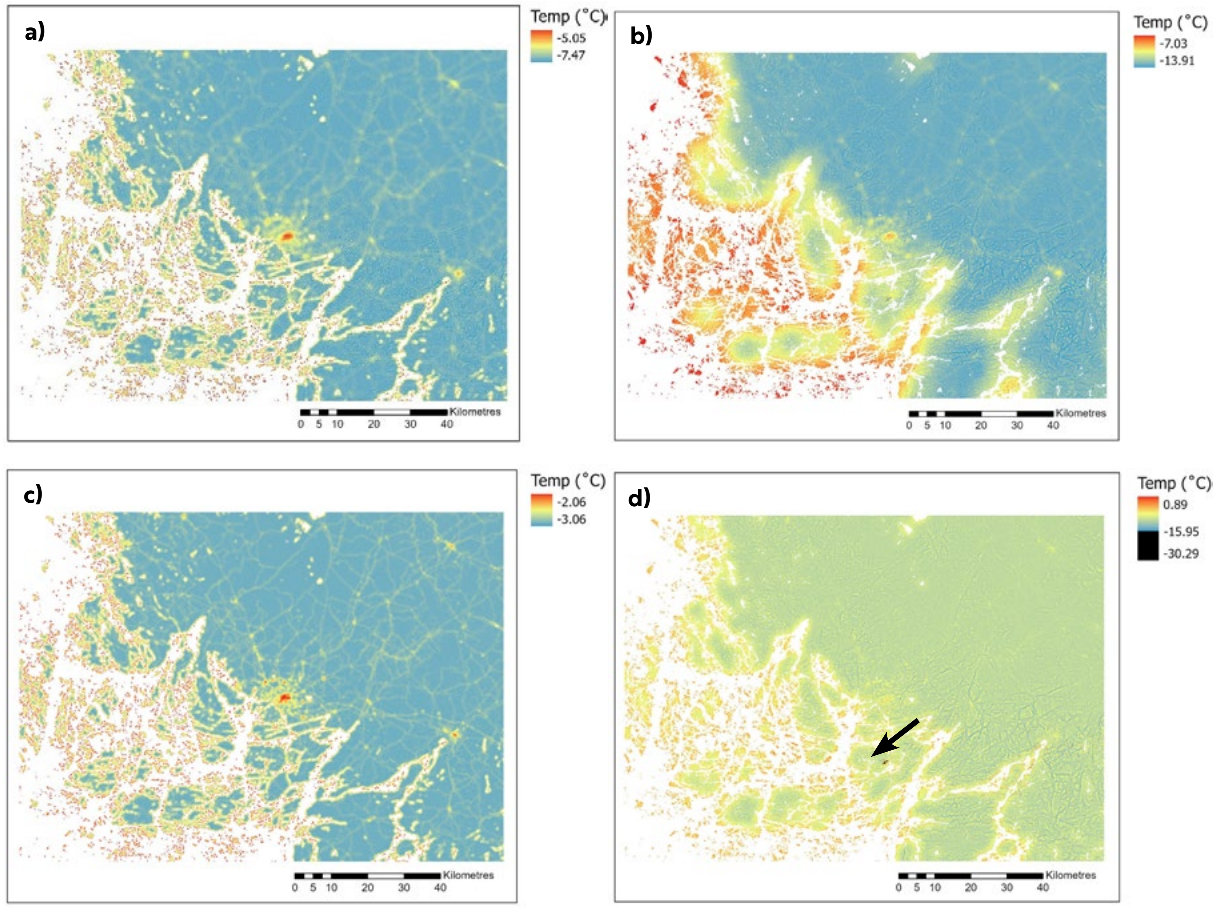

Figure 11. High-resolution (100 m) temperatures based on linear regression model depicting February 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on February 13th, 2021, at 00.30. The abnormally low temperature area in the limestone quarry located in Parainen is marked in black (arrow).

lands are clearly the warmest areas, but the UHI is present. In the momentary maximum temperature range map, the lowlands are the coolest and coastal areas the warmest. Similar to January, the effect of the limestone quarry in Parainen is also highlighted, and temperatures of that area are presented in black colour. The lowest temperature outside the quarry is -15.95 ˚C.

For February's momentary maximum temperature range moments in the Student Village area and the whole Turku region, the area is on the eastern side of the high-pressure centre located in Denmark and southwestern Norway (Figure 12). Low-pressure centres are located in the Svalbard region to the north of Finland and in the Moscow region to the southeast of Finland. The 500 hPa pressure surface is located at around 532–536 decametres height in the Turku region. The map represents the situation at 00.00 UTC. At the time of maximum temperature difference, February 13th at 00.30, the wind speed was 1.95 m/s and cloudiness was 0.

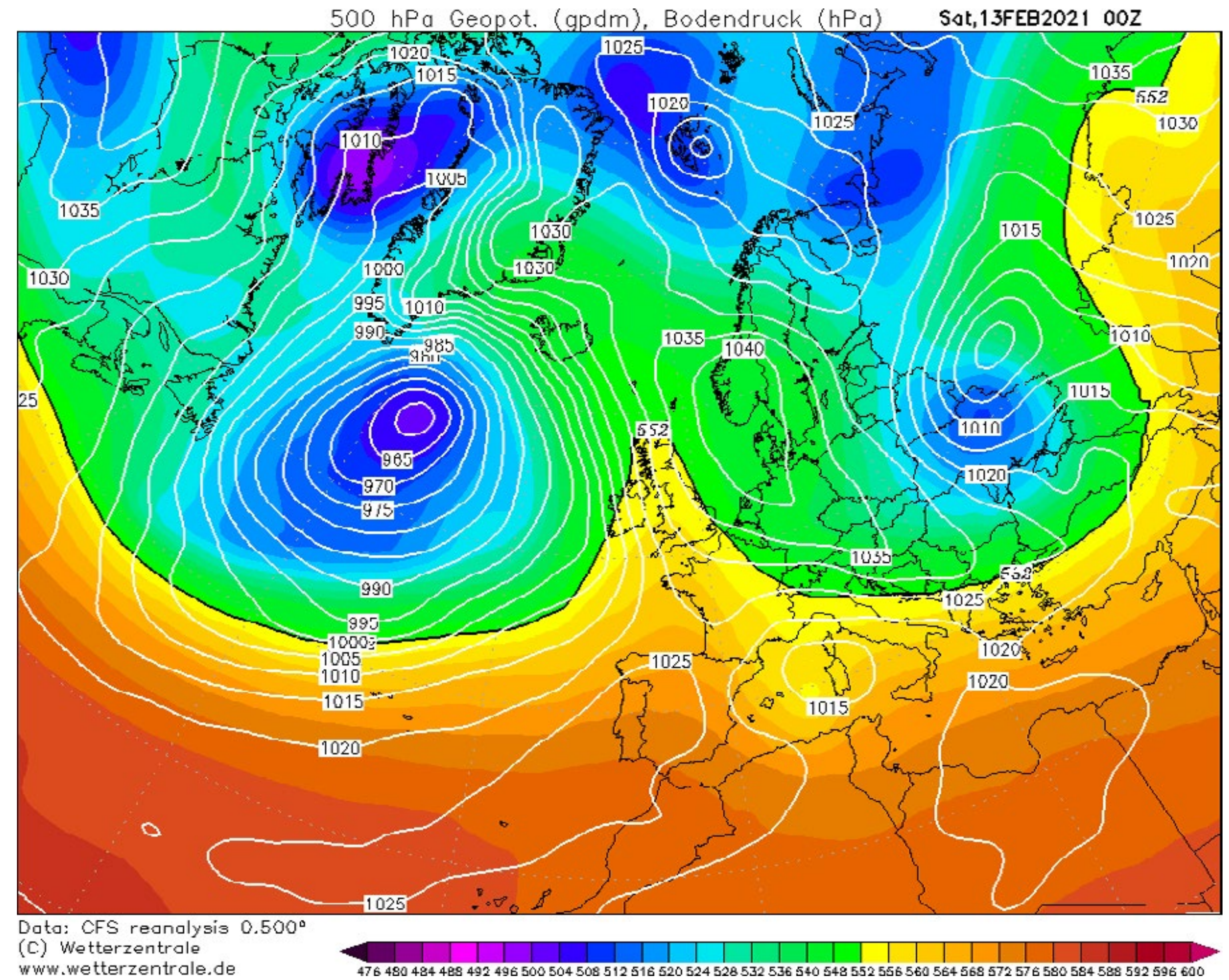

Figure 12. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for February 13th at 00.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

4.1.3 March

In March 2021, the average temperature at the Turku airport was 0.1 ˚C. During the climatic period 1991–2020, the respective temperature was -1.3 ˚C (Jokinen et al., 2021), meaning that March 2021 was 1.4 °C warmer than average.

Regarding the TURCLIM observation network, the highest and lowest monthly average temperatures were measured in Kauppatori (1.2 ˚C), located in the city centre, and in Niuskala (-0.3 ˚C), a rural site located approximately 10 km northeast of the city centre (Figure 13). The highest and lowest monthly averages of daily minimum temperatures were measured in Betel (-1.7 ˚C) and Niuskala (-4.4 ˚C). For the maxima, the respective averages were 4.6 ˚C, measured in Kauppatori, and 3.1 ˚C, measured in Kolkka. The maximum temperature range was observed between Kauppatori and Kuuva on

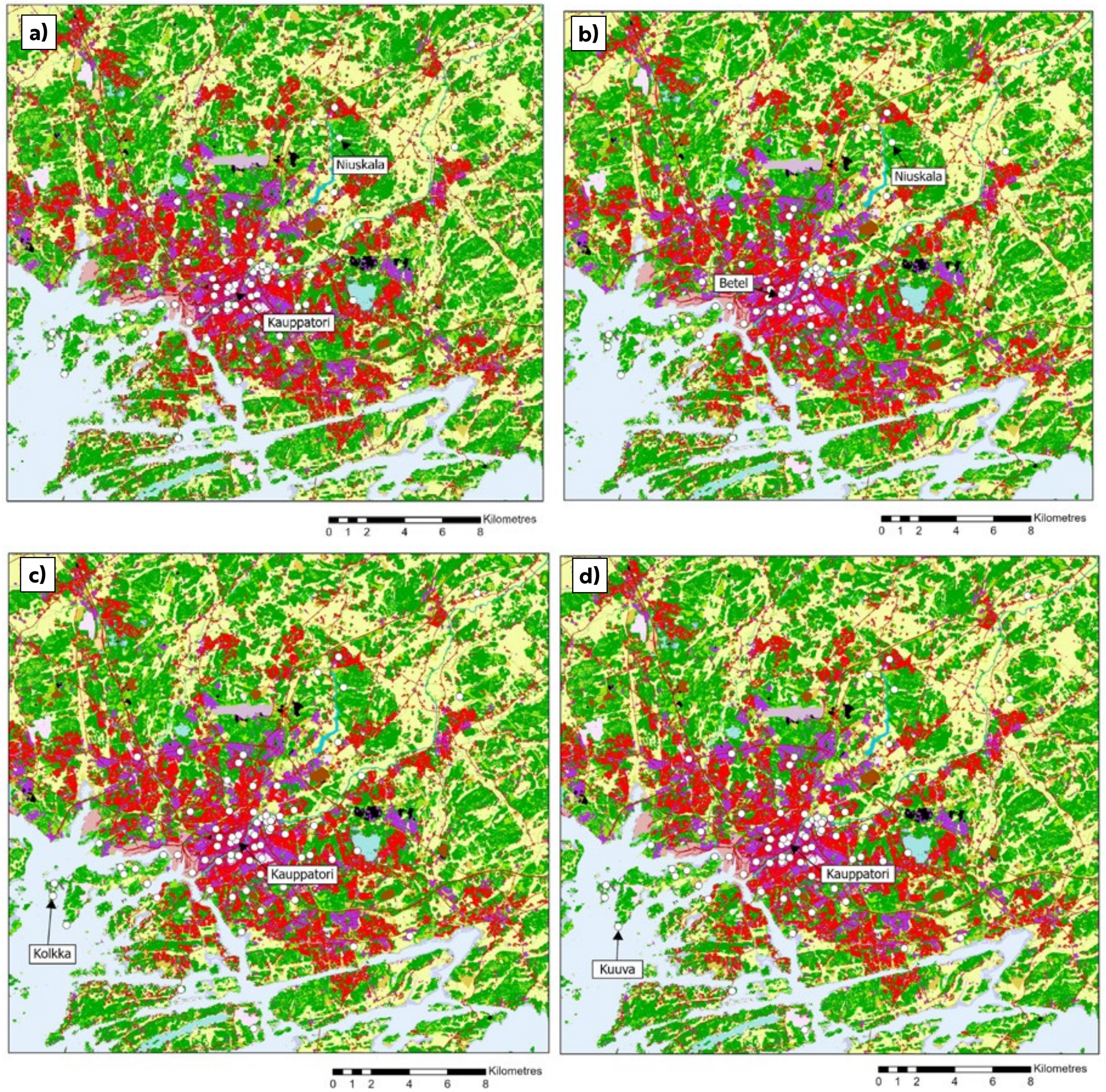

Figure 13. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kauppatori 1.2 ˚C, Niuskala -0.3 ˚C), **b)** monthly averages of daily minimum temperatures (Betel -1.7 ˚C, Niuskala -4.4 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori 4.6 ˚C, Kolkka 3.1 ˚C) and **d)** momentary maximum temperature range on March 26th at 14.30 with the difference of 9.5 ˚C (Kauppatori 11.3 ˚C, Kuuva 1.8 ˚C) on the CORINE Land Cover 2018 dataset in March 2021.

the 26th of March at 14.30. In Kauppatori, the temperature was 11.3 ˚C and in Kuuva 1.8 ˚C, resulting in a difference of 9.5 ˚C. Potential reasons behind the large difference may be the local cooling effect of the sea, foggy conditions on the coast compared to the sunny conditions in the city centre, plus the impact of UHI.

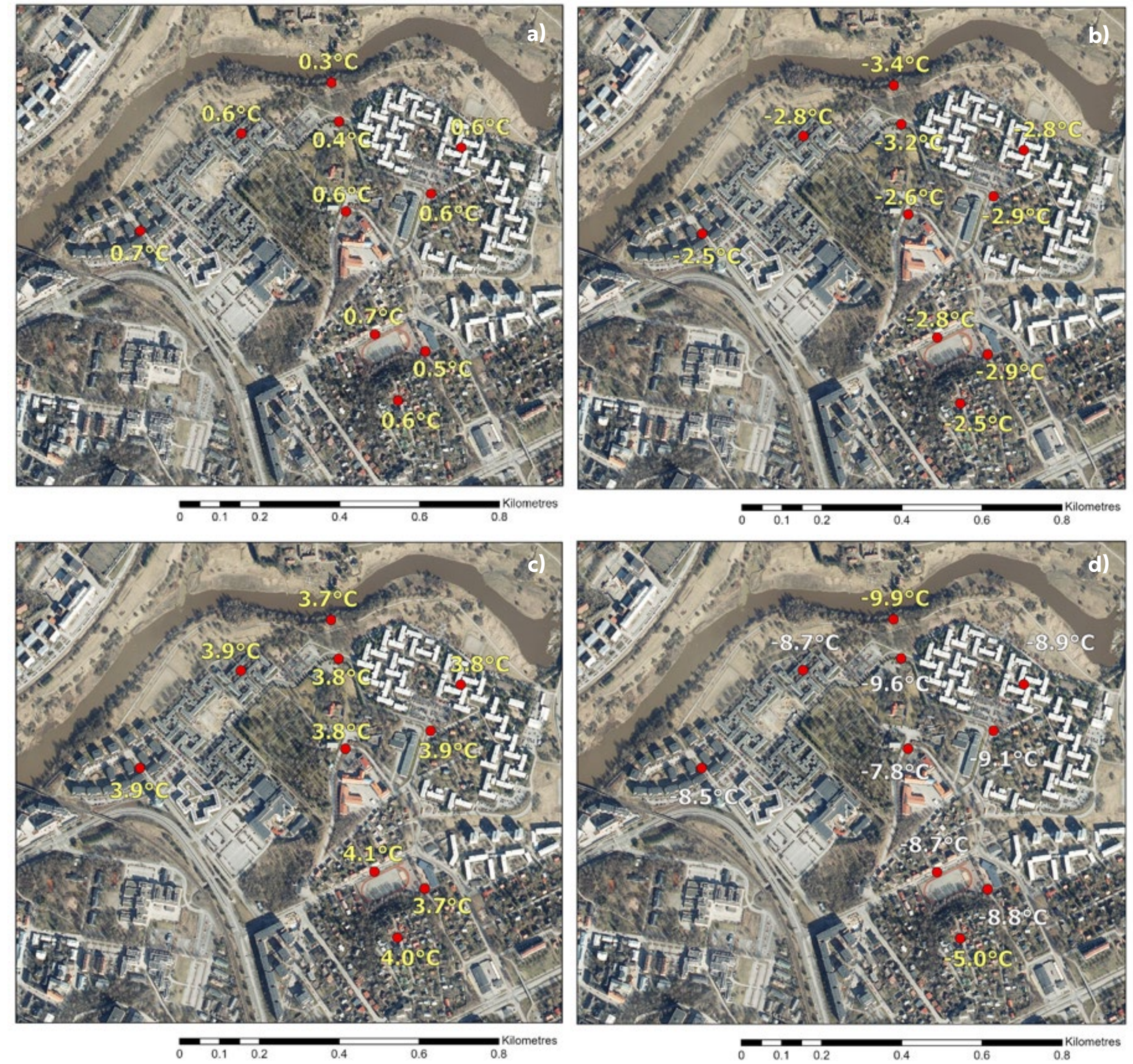

Figure 14. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on March 5th at 03.30 in 2021 with the difference of 4.9 ˚C between Kuuvuori and Aurajokiranta. For individual observation site names, see Figure 4.

In the Turku Student Village, the highest and lowest monthly average temperatures occurred in Pispalantie and Suntiontie, 0.7 ˚C, and in Aurajokiranta, 0.3 ˚C, respectively (Figure 14). The highest monthly average of daily minimum temperatures, -2.5 °C, was recorded in Pispalantie and Kuuvuori, whereas the lowest respective temperature, -3.4 ˚C, was recorded in Aurajokiranta. In the case of the daily maxima, the highest and lowest averages occurred in Suntiontie, 4.1 ˚C, and Aurajokiranta and Kuuvuori kenttä, 3.7 ˚C. The maximum

Table 11. The regression model for the monthly average temperatures in March 2021.

R Square	0.664	
Adjusted R Square	0.649	
Variable	Standardized Coefficients Beta	Significance
Constant		0.501
vl_3_5_700m	0.931	<0.001
tkuwaters_1500m	0.352	<0.001
relelev_100m	-0.013	0.860

Table 12. The regression model for the monthly averages of daily minimum temperatures in March 2021.

R Square	0.702	
Adjusted R Square	0.689	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_700m	0.807	<0.001
tkuwaters_500m	0.503	<0.001
relelev_300m	0.227	0.001

Table 13. The regression model for the monthly averages of daily maximum temperatures in March 2021.

R Square	0.346	
Adjusted R Square	0.317	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.408	<0.001
tkuwaters_2km	-0.247	0.029
relelev_500m	-0.195	0.055

Table 14. The regression model for the momentary maximum temperature range of March 2021.

R Square	0.857	
Adjusted R Square	0.851	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_1000m	0.038	0.487
tkuwaters_2km	-0.907	<0.001
relelev_100m	-0.018	0.715

temperature range was observed on the 5th of March at 03.30 between Aurajokiranta and Kuuvuori. The inversion conditions and related enhanced impact of elevation could explain the 4.9 ˚C temperature difference.

In the regression model for March, the explanatory power for the monthly average temperatures is 0.649 (Table 11). Of the explanatory variables, the land cover and water bodies were statistically significant, both having a warming effect. Based on the model, the land cover had a much stronger effect than the water bodies. For the monthly averages of daily minima, the explanatory power is 0.689 with all explanatory variables being statistically significant (Table 12). All explanatory variables had a warming effect. The impact of land cover was the strongest and that of the elevation the weakest. For monthly averages of daily maximum temperatures, the explanatory power is 0.317 (Table 13). Of the explanatory variables, the land cover and water bodies were statistically significant. The land cover had a warming effect and the water bodies a cooling effect. The momentary maximum temperature range's explanatory power is 0.851 (Table 14). Of the explanatory variables, only water bodies were statistically significant, indicating a strong cooling effect.

The coastal areas appear warmer than the continental areas in the monthly average temperature map just like in January and February (Figure 15). Also, the Turku city centre, smaller residential areas, and main roads appear as relatively warm areas. The minimum temperature map reminds the monthly average temperature map, but the impact of cold air pooling is also visible. For the daily maxima, the coastal areas are the coldest, whereas the built-up areas in the mainland, especially the Turku city centre, are the warmest. The momentary maximum temperature range map depicts the coast and islands as the coolest areas and the mainland the warmest.

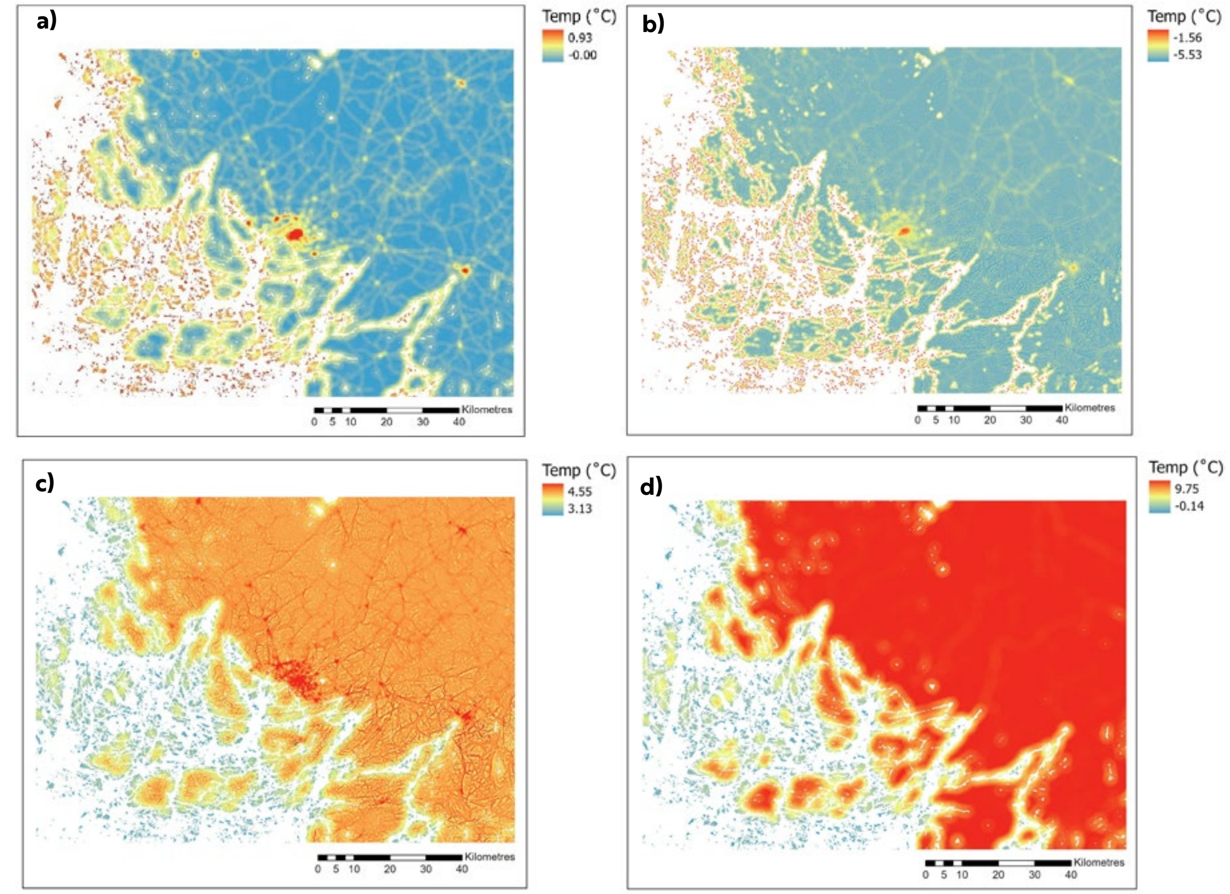

Figure 15. High-resolution (100 m) temperatures based on linear regression model depicting March 2021 a) monthly average temperatures, b) monthly averages of daily minimum temperatures, c) monthly averages of daily maximum temperatures and d) temperatures of momentary maximum temperature range on March 26th, 2021, at 14.30.

During the momentary maximum temperature range of the whole Turku area on the 26th of March at 14.30, Turku was located on the northern edge of the high-pressure ridge (Figure 16). A relatively strong low-pressure centre prevailed over Iceland. The 500 hPa pressure surface height was 540–548 decametres over the Turku area. The map represented the situation at 12.00 UTC. For the maximum temperature range moment of the Student Village, the area was between the low-pressure in Russia in the east and the high-pressure in the British Isles in the west (Figure 17). The 500 hPa pressure surface height was 512–516 decametres and the map represents the situation at 00.00 UTC. The average wind speed on March 26th at 14.30 was 3.35 m/s and cloudiness 0. On March 5th at 03.30, the wind speed was 1.05 m/s and cloudiness 3.25.

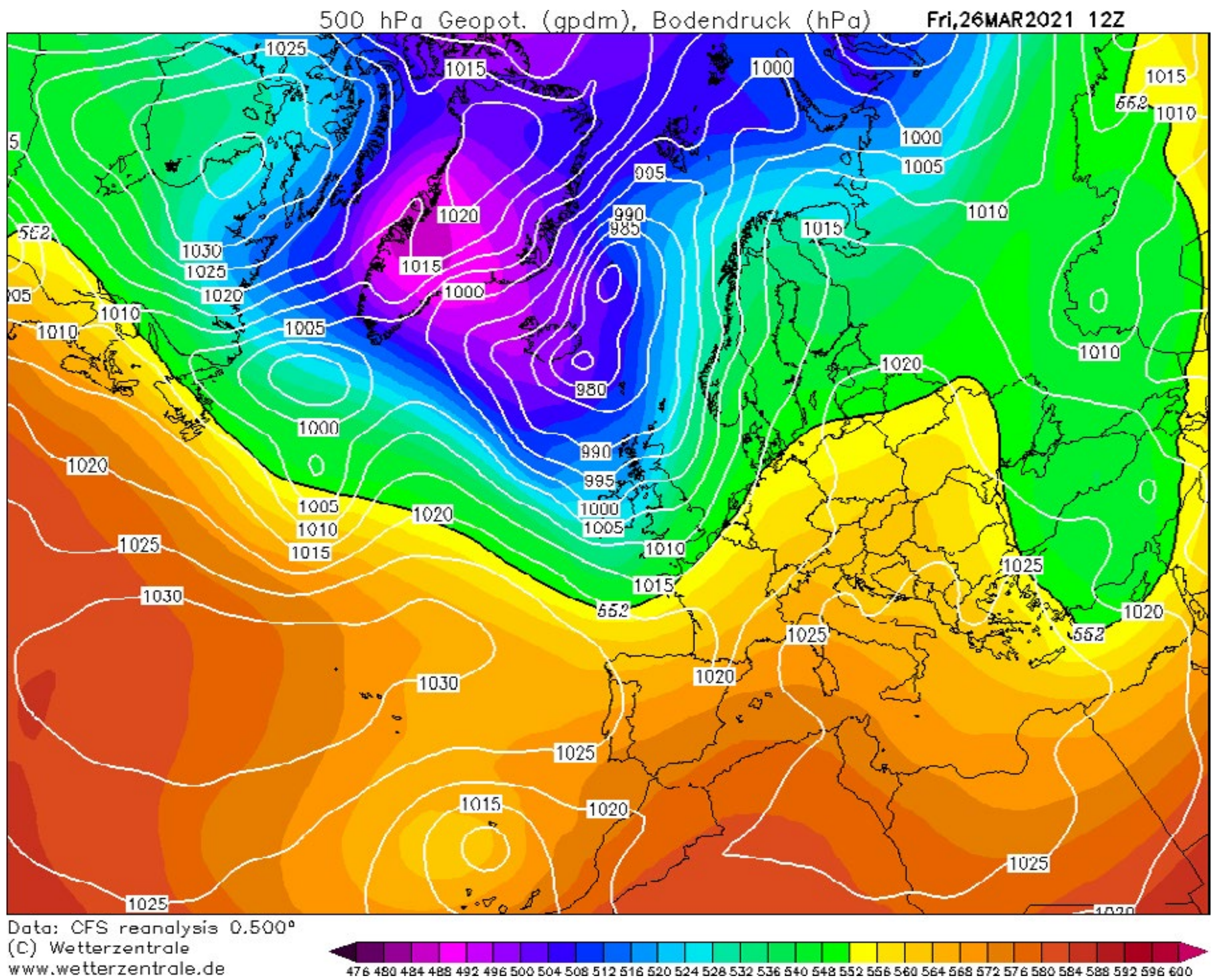

Figure 16. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for March 26th at 12.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

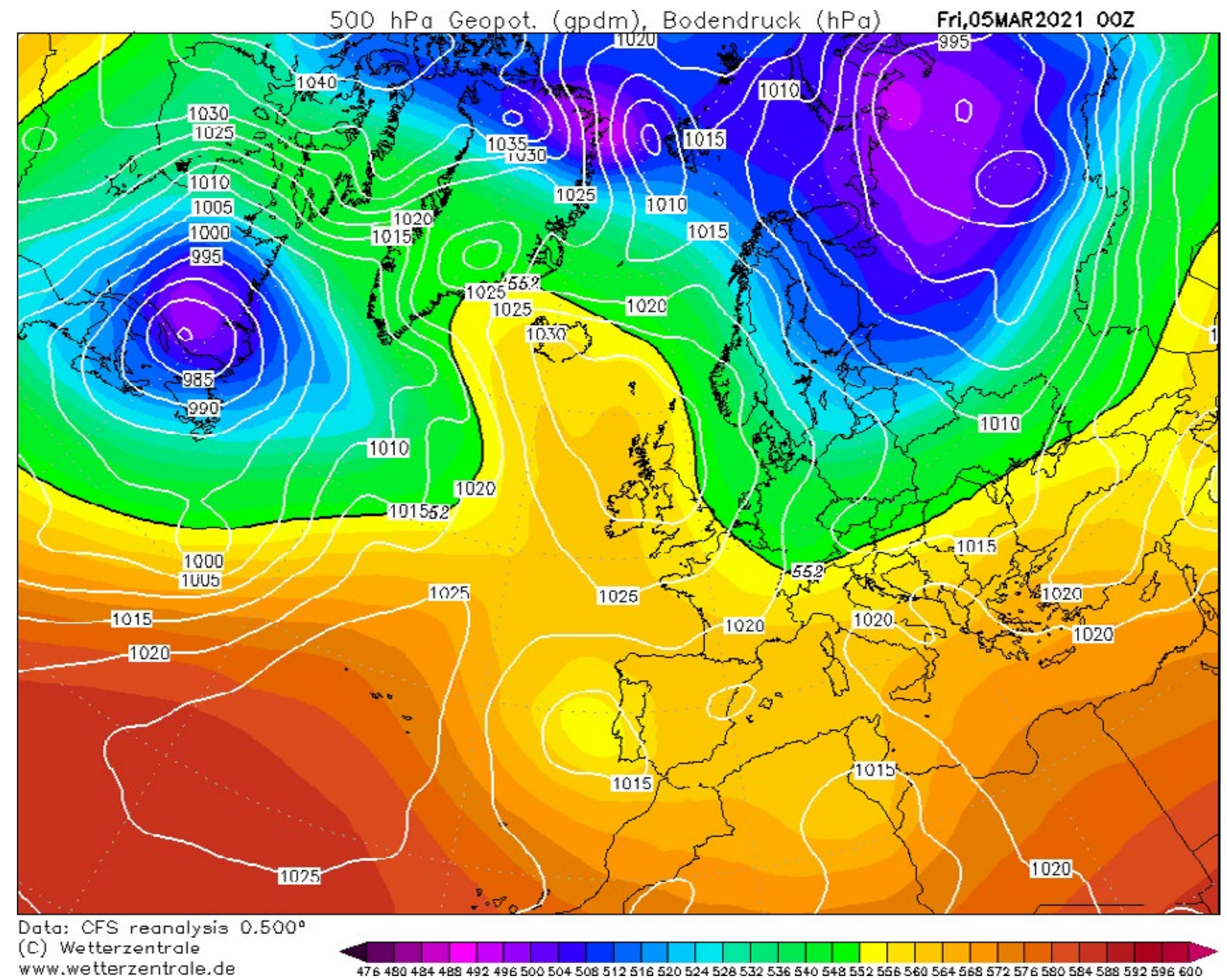

Figure 17. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for March 5th at 00.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

4.1.4 April

In April 2021, the average temperature at the Turku airport was 4.7 ˚C. The month was 0.6 °C warmer than during the climatic period 1991–2020, when the average temperature for April was 4.1 °C (Jokinen et al., 2021).

Regarding the TURCLIM observation network, in April 2021 the highest monthly average temperature (5.4 ˚C) was measured in Kauppatori and the lowest (3.7 ˚C) in Niuskala (Figure 18). The highest and lowest monthly averages of daily minimum temperatures, 1.5 ˚C and -1.5 ˚C, were measured in Betel and Niuskala, respectively. The highest and lowest monthly averages of daily maximum temperatures were recorded in Kauppatori (9.5 ˚C) and Kolkka (7.8 ˚C). The momentary maximum temperature range, 8.8 ˚C, was measured between Betel and Kuuva; on the 19th of April at 16.00, the tem-

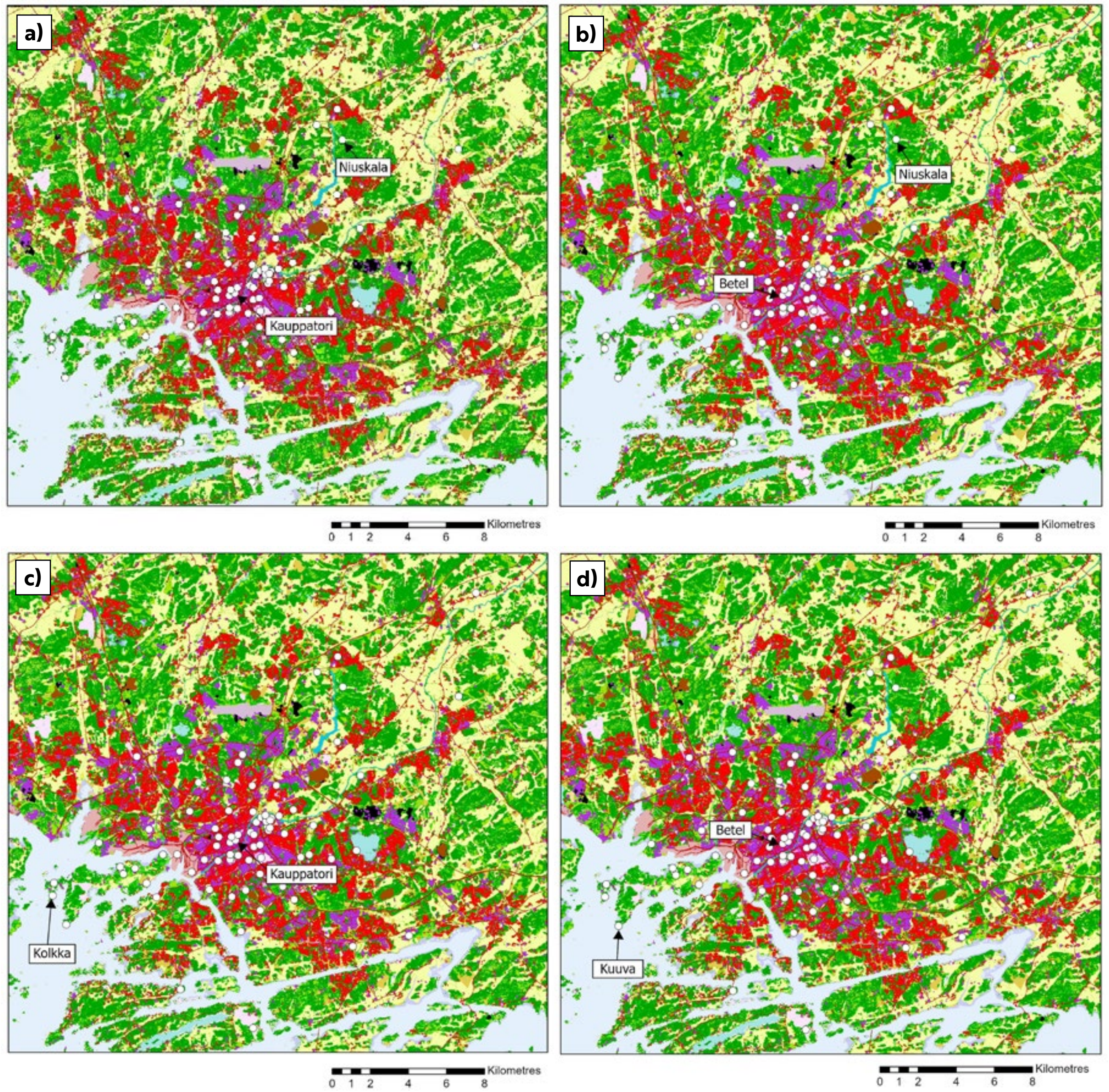

Figure 18. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kauppatori 5.4 ˚C, Niuskala 3.7 ˚C), **b)** monthly averages of daily minimum temperatures (Betel 1.5 ˚C, Niuskala -1.5 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori 9.5 ˚C, Kolkka 7.8 ˚C) and **d)** momentary maximum temperature range on April 19th at 16.00 with the difference of 8.8 ˚C (Betel 17.8 ˚C, Kuuva 9.0 ˚C) on the CORINE Land Cover 2018 dataset in April 2021.

perature was 17.8 ˚C in Betel and 9.0 ˚C in Kuuva. The difference is mainly caused by the cooling effect of the relatively cold sea in the coastal site Kuuva.

The highest monthly average temperature in the Turku Student Village area was 4.8 ˚C in Pispalantie, Suntiontie, and Yo-kylä itä (Figure 19). The lowest monthly aver-

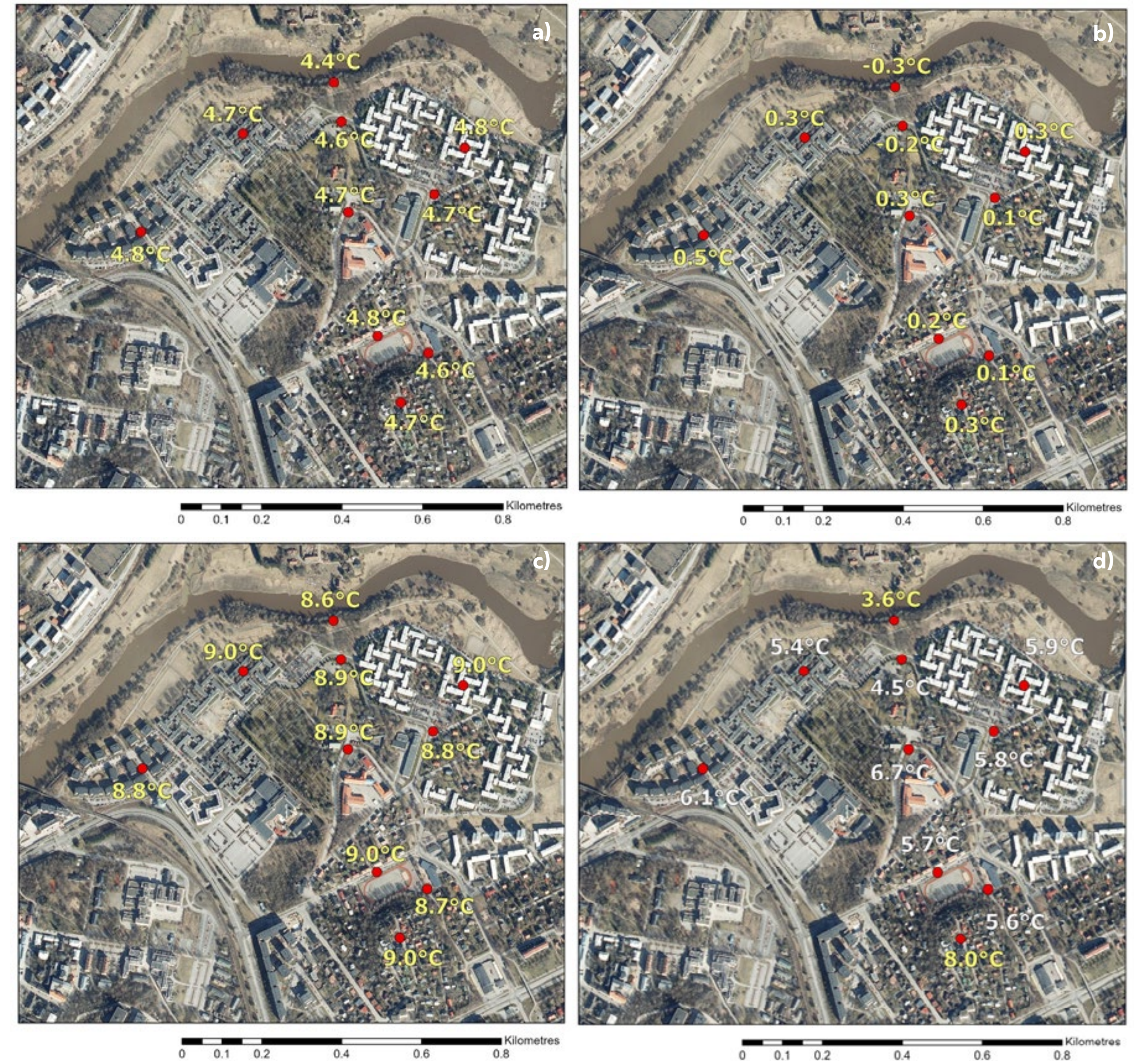

Figure 19. The Student Village observation sites with a) monthly average temperatures, b) monthly averages of daily minimum temperatures, c) monthly averages of daily maximum temperatures and d) the momentary maximum temperature range on April 18th at 23.30 in 2021 with the difference of 4.4 ˚C between Kuuvuori and Aurajokiranta. For individual observation site names, see Figure 4.

age temperature was 4.4 ˚C, measured in Aurajokiranta. The highest monthly average of daily minimum temperatures, 0.5 ˚C, was measured in Pispalantie, whereas the lowest respective temperature, -0.3 ˚C, was recorded in Aurajokiranta. The highest monthly average of daily maximum temperatures, 9.0 ˚C, was measured at four sites: Kuuvuori, Suntiontie, Yo-kylä länsi, and Yo-kylä itä. The lowest respective temperature, 8.6 ˚C, was recorded in Aurajokiranta. The momentary maximum temperature range, 4.4 ˚C, oc-

Table 15. The regression model for the monthly average temperatures in April 2021.

R Square	0.756	
Adjusted R Square	0.745	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_1000m	0.954	<0.001
tkuwaters_2km	0.245	<0.001
relelev_200m	0.036	0.569

Table 16. The regression model for the monthly averages of daily minimum temperatures in April 2021.

R Square	0.673	
Adjusted R Square	0.658	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_1000m	0.764	<0.001
tkuwaters_300m	0.432	<0.001
relelev_300m	0.236	0.002

Table 17. The regression model for the monthly averages of daily maximum temperatures in April 2021.

R Square	0.386	
Adjusted R Square	0.359	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_1000m	0.200	0.082
tkuwaters_2km	-0.477	<0.001
relelev_500m	-0.159	0.111

Table 18. The regression model for the momentary maximum temperature range of April 2021.

R Square	0.688	
Adjusted R Square	0.674	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_1000m	-0.014	0.860
tkuwaters_2km	-0.835	<0.001
relelev_100m	-0.094	0.190

curred between Kuuvuori and Aurajokiranta. This was measured on the 18th of April at 23.30, when the temperature was 8.0 ˚C in Kuuvuori and 3.6 ˚C in Aurajokiranta. The difference may be explained by the inversion and cold air drainage.

In the regression model for April's monthly average temperatures, the explanatory power is 0.745. Of the explanatory variables, land cover and water bodies were statistically significant (Table 15). Both had a warming effect, and the land cover's influence was stronger. In the case of monthly averages of daily minimum temperatures, the explanatory power is 0.658 (Table 16). All explanatory variables were statistically significant with a warming effect. Elevation had the weakest effect and land cover the strongest. For the maxima, the explanatory power is 0.359 and only the water bodies are statistically significant explanatory variables, having a moderate cooling effect (Table 17). For the maximum temperature range, the explanatory power is 0.674 (Table 18). Only the water bodies are statistically significant explanatory variables, indicating a strong cooling effect.

In April's monthly average temperature map, the coast is warmer than the mainland (Figure 20). The UHI is clear and covers the Turku city centre and densely built areas in its vicinity. In the map for monthly averages of daily minimum temperatures, the effect of the urban areas appears weaker. For the monthly averages of daily maximum temperatures, the mainland is clearly the warmest and coastal area the coolest, reflecting the cooling impact of the sea.

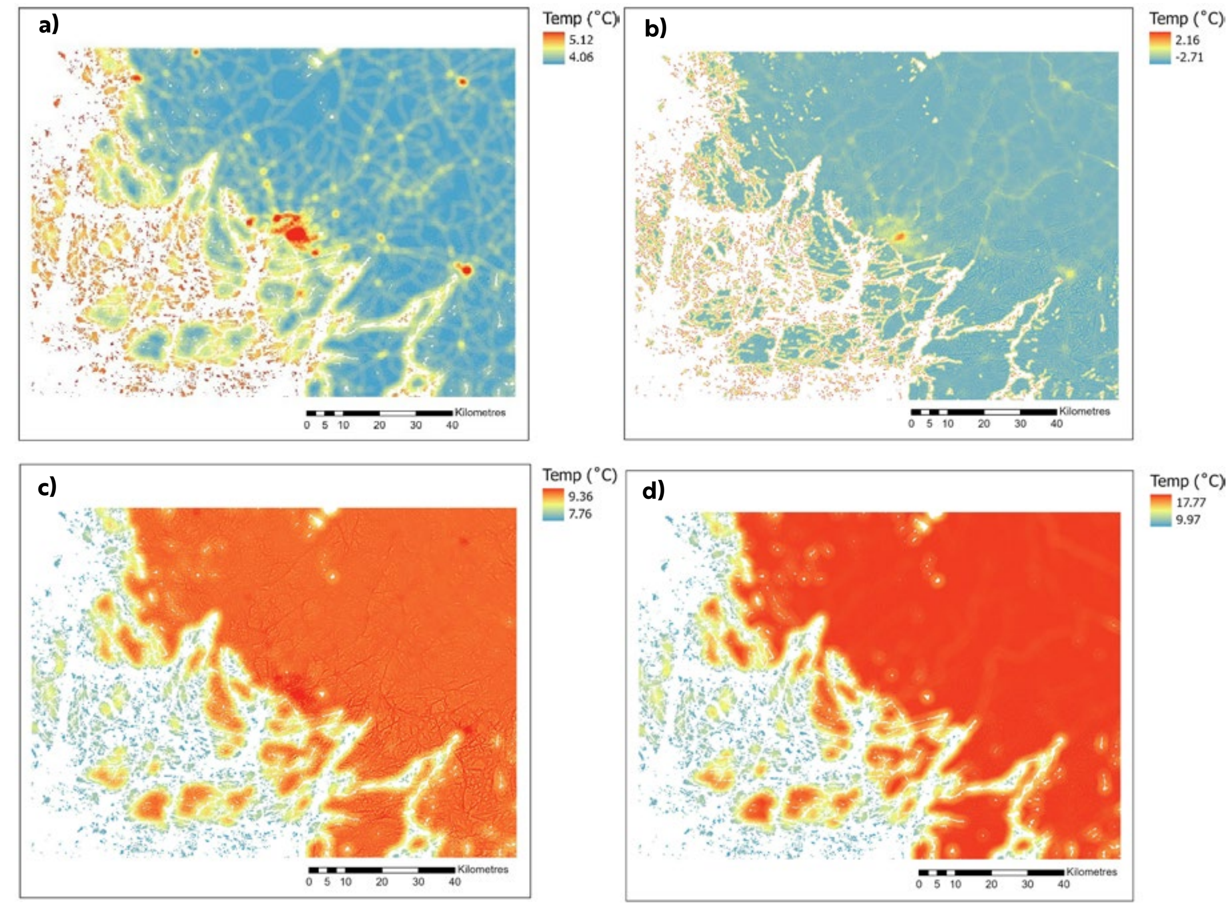

Figure 20. High-resolution (100 m) temperatures based on linear regression model depicting April 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on April 19th, 2021, at 16.00.

In April, during the momentary maximum temperature range for the whole Turku region, the area is under the impact of high-pressure centred over eastern Russia (Figure 21). The map represents the situation at 12.00 UTC. The 500 hPa pressure surface height over the Turku area is 560–564 decametres. In the case of the maximum temperature range of the Turku Student Village area, the situation is analogous (Figure 22). The map represents the situation at 18.00 UTC and the 500 hPa pressure surface height is around 560–564 decametres. On April 19th at 16.00, i.e. at the time of the maximum temperature range for the whole Turku region, the wind speed was 2.225 m/s and cloudiness 0, whereas at the time of the maximum temperature range of the Turku Student Village area, the 18th at 23.30, the wind speed was 0.15 m/s and cloudiness 0.

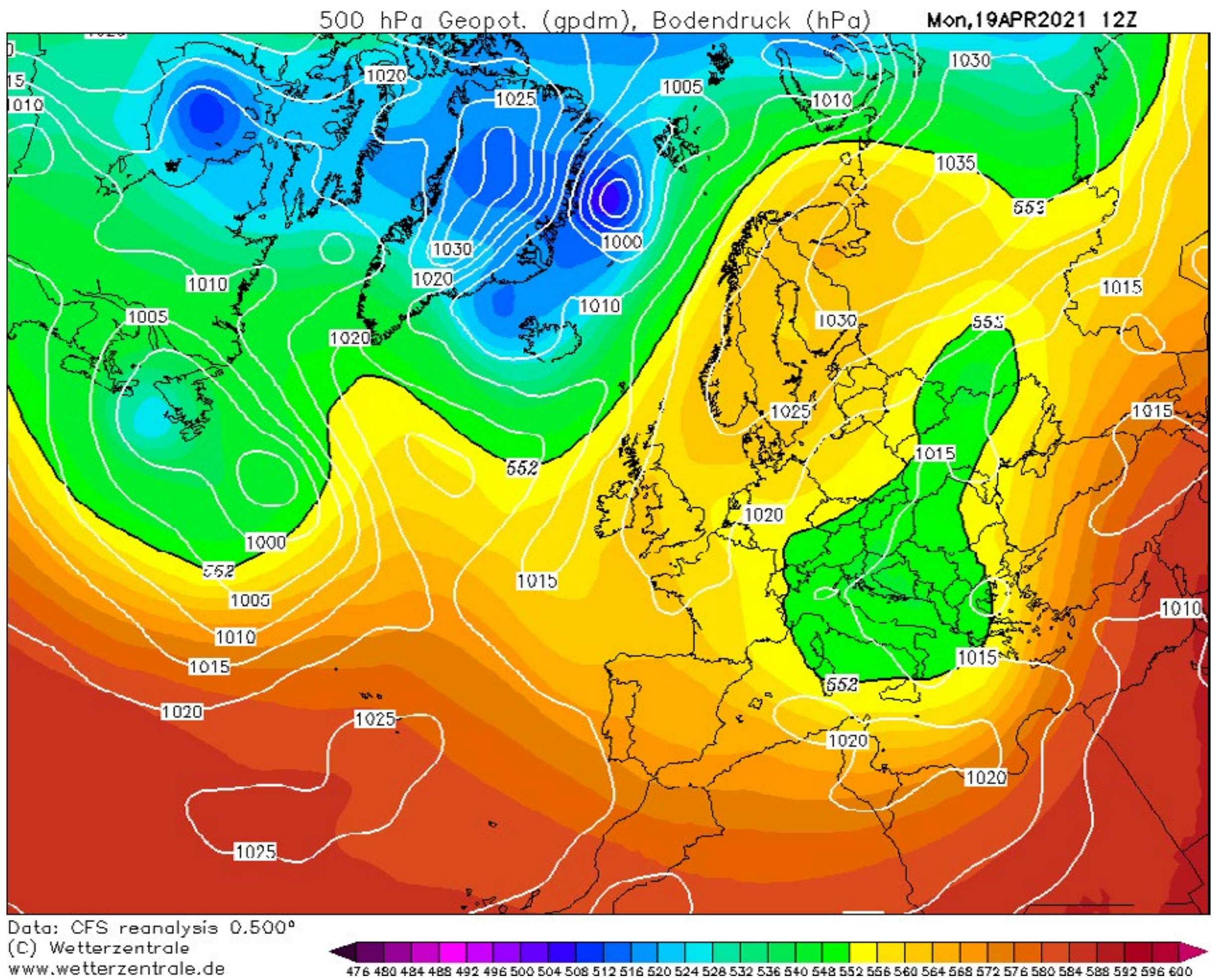

Figure 21. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for April 19th at 12.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

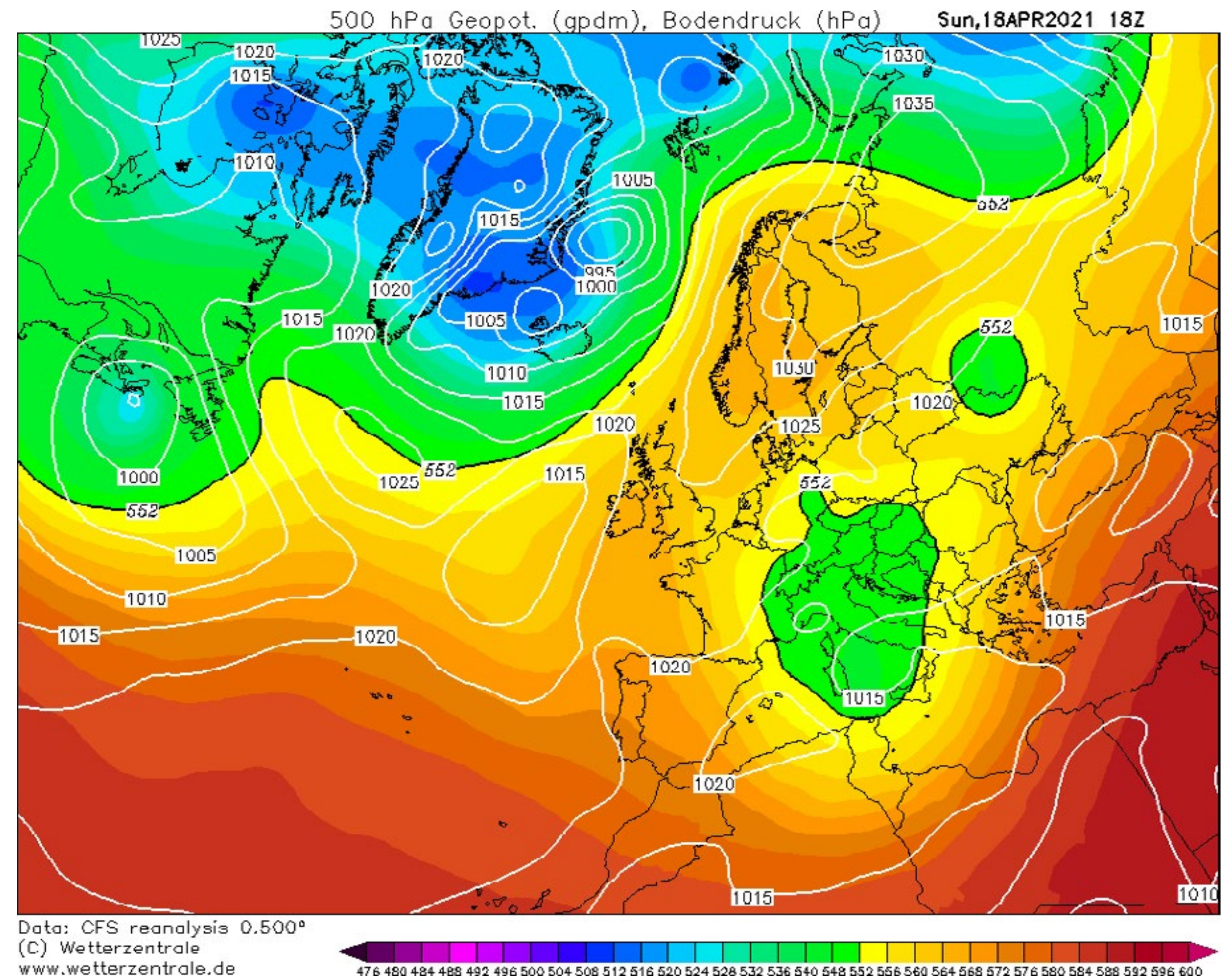

Figure 22. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for April 18th at 18.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

4.1.5 May

In May 2021, the average temperature at the Turku airport was 9.9 ˚C, whereas during the climate period 1991–2020 the respective temperature was 10.0 ˚C (Jokinen et al., 2021).

Regarding the TURCLIM observation network, in May 2021 the highest and lowest monthly average temperatures were measured in Kauppatori (11.1 ˚C) and in Kuuva (9.6 ˚C) (Figure 23). The highest and lowest monthly averages of daily minimum temperatures were measured in Betel with an average of 6.8 ˚C and in Niuskala with an average of 3.6 ˚C. For the daily maxima, the averages were 15.5 ˚C in Kauppatori and 13.4 ˚C in Kolkka. The maximum temperature range was measured between Sikilä and Pääskyvuori Weather Station on the 13th of May at 16.00, when the Pääskyvuori WS recorded 27.4 ˚C and Sikilä 19.0 ˚C, resulting in a difference of 8.4 ˚C. The difference could be due to a local shower in Sikilä.

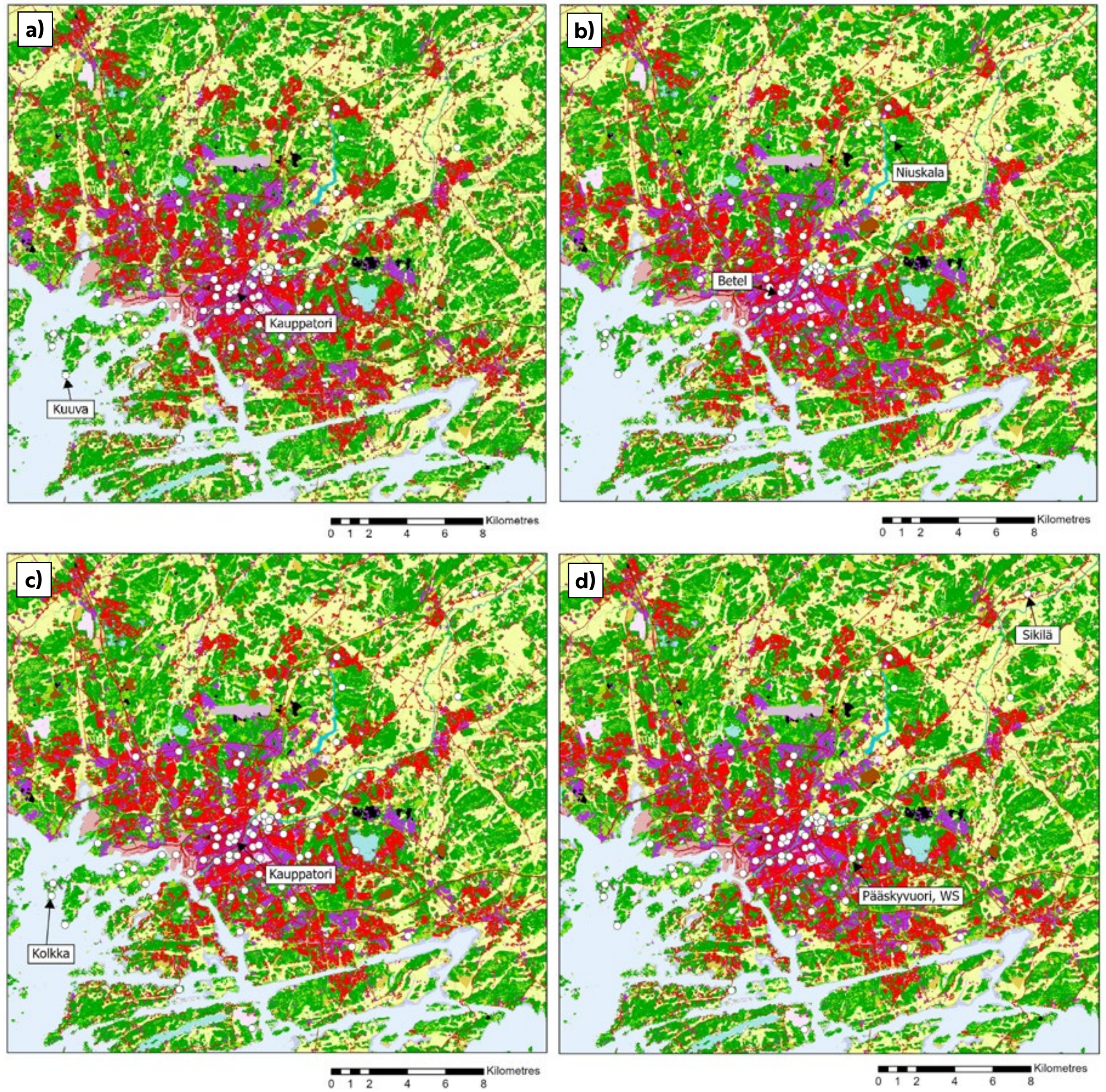

Figure 23. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kauppatori 11.1 ˚C, Kuuva 9.6 ˚C), **b)** monthly averages of daily minimum temperatures (Betel 6.8 ˚C, Niuskala 3.6 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori 15.5 ˚C, Kolkka 13.4 ˚C) and **d)** momentary maximum temperature range on May 13th at 16.00 with the difference of 8.4 ˚C (Pääskyvuori WS 27.4 ˚C, Sikilä 19.0 ˚C) on the CORINE Land Cover 2018 dataset in May 2021.

For the Turku Student Village area, the highest monthly average temperature was 10.6 ˚C at five sites: Pispalantie, Suntiontie, Kirkkotie, Yo-kylä länsi, and Yo-kylä itä (Figure 24). The lowest average temperature was 10.1 ˚C, measured in Aurajokiranta. The highest and lowest monthly averages of daily minimum temperatures were measured in Pispalantie (5.9 ˚C) and Aurajokiranta (4.9 ˚C). The highest monthly average of daily maximum temperatures was 15.1 ˚C measured in Kuuvuori, Kirkkotie, Yo-kylä länsi, and Yo-kylä itä. The lowest respective temperature was 14.8 ˚C, measured in Aurajokiranta. The momentary maximum temperature range, 6.7 ˚C, was detected between Aurajokiranta and

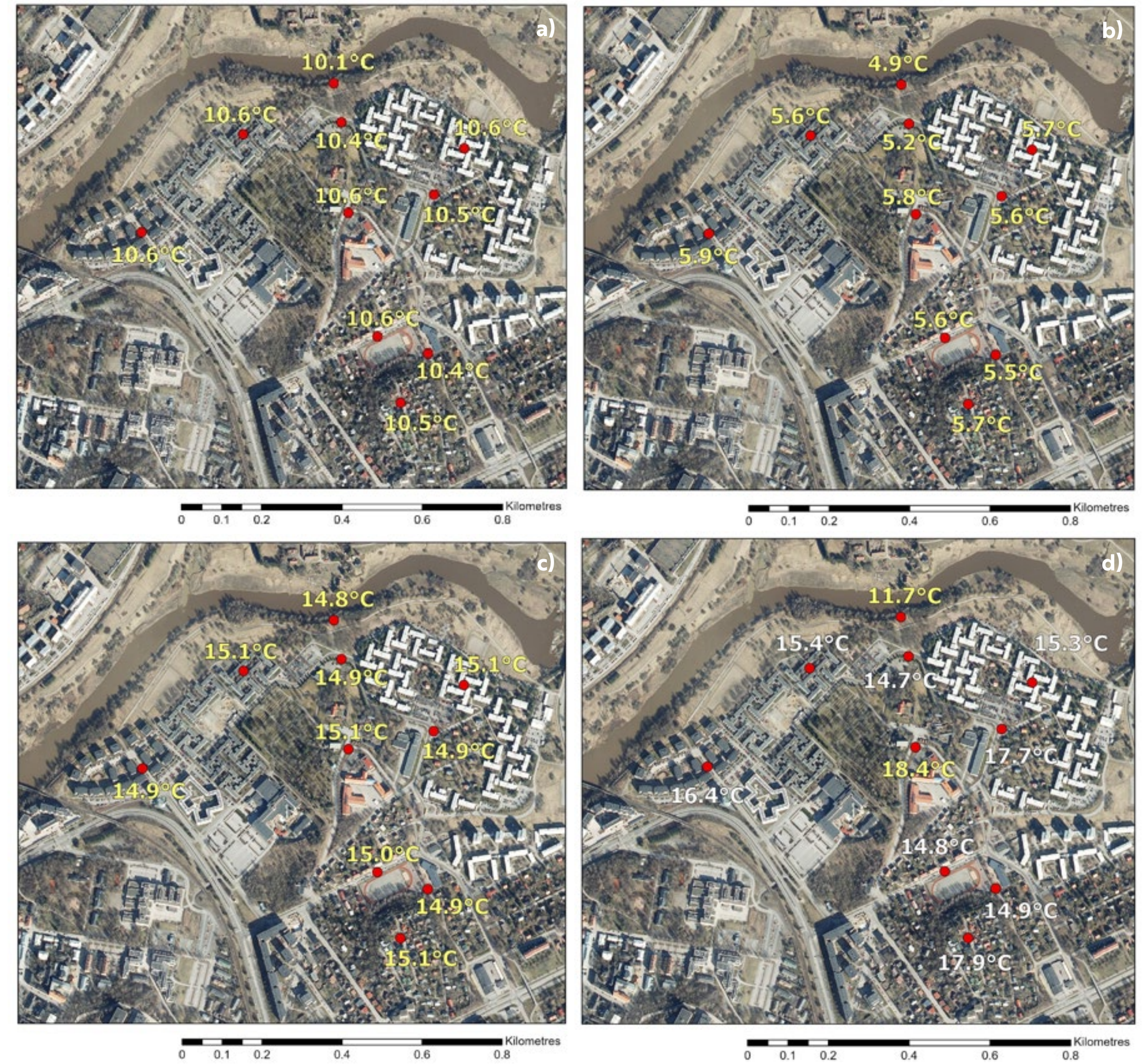

Figure 24. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on May 12th at 23.30 in 2021 with the difference of 6.7 ˚C between Kirkkotie and Aurajokiranta. For individual observation site names, see Figure 4.

Table 19. The regression model for the monthly average temperatures in May 2021.

Variable	Standardized Coefficients Beta	Significance
R Square	0.777	
Adjusted R Square	0.767	
Constant		<0.001
vl_3_5_1000m	0.819	<0.001
tkuwaters_2km	-0.102	0.131
relelev_200m	0.026	0.661

Table 21. The regression model for the monthly averages of daily maximum temperatures in May 2021.

Variable	Standardized Coefficients Beta	Significance
R Square	0.607	
Adjusted R Square	0.590	
Constant		<0.001
vl_3_5_1000m	0.240	0.011
tkuwaters_1500m	-0.636	<0.001
relelev_100m	-0.126	0.115

Table 20. The regression model for the monthly averages of daily minimum temperatures in May 2021.

Variable	Standardized Coefficients Beta	Significance
R Square	0.681	
Adjusted R Square	0.667	
Constant		<0.001
vl_3_5_1000m	0.775	<0.001
tkuwaters_300m	0.375	<0.001
relelev_300m	0.246	<0.001

Table 22. The regression model for the momentary maximum temperature range of May 2021.

Variable	Standardized Coefficients Beta	Significance
R Square	0.250	
Adjusted R Square	0.217	
Constant		<0.001
vl_3_5_1000m	0.506	<0.001
tkuwaters_1000m	-0.018	0.883
relelev_100m	-0.124	0.259

Kirkkotie. The difference was measured on the 12th of May at 23.30.

The explanatory power of the regression model for the monthly average temperatures is 0.767. Of the explanatory variables, only the land cover was statistically significant (Table 19), indicating a warming effect. For the monthly averages of daily minimum temperatures, the explanatory power is 0.667 and all explanatory variables are statistically significant (Table 20). All variables had a warming effect; the land cover strongest and the elevation weakest. For daily maxima, the explanatory power is 0.590. Of the explanatory variables, land cover and water bodies were statistically significant (Table 21). Land cover had a warming effect and the water bodies a cooling effect. For the momentary temperature range, the explanatory power is 0.217 and only the land cover was statistically significant, indicating a warming effect (Table 22).

In May, the coast is cooler than the mainland in the monthly average temperature map (Figure 25). On the mainland, the urban areas appear as warmest. In the monthly averages of daily minimum temperatures map, the mainland is cooler and the coast and the Turku city centre appear to be the warmest. For the monthly averages of daily maximum temperatures, the mainland is the warmest and coastal area the coolest. In the temperature map of the momentary maximum temperature range, the urban areas are clearly the warmest. The coolest areas lie scattered on the coasts and low-lying areas.

In May, the maps containing sea level pressure and the height of the 500 hPa pressure level for the momentary maximum temperature ranges remind each other (Figures 26 & 27). The Turku area is located between the high-pressure of western Russia and weak low-pressure over the British Isles. The maps are time-stamped at 12.00 UTC with the 500 hPa pressure surface height located around 560–564 decametres and 00.00 UTC with the 500 hPa pressure surface height at around 568–572 decametres. The wind speed was 4.15 m/s and cloudiness 1.5 during May 13th at 16.00. On the 12th at 23.30, the wind speed was 2.55 m/s and cloudiness 0 on average.

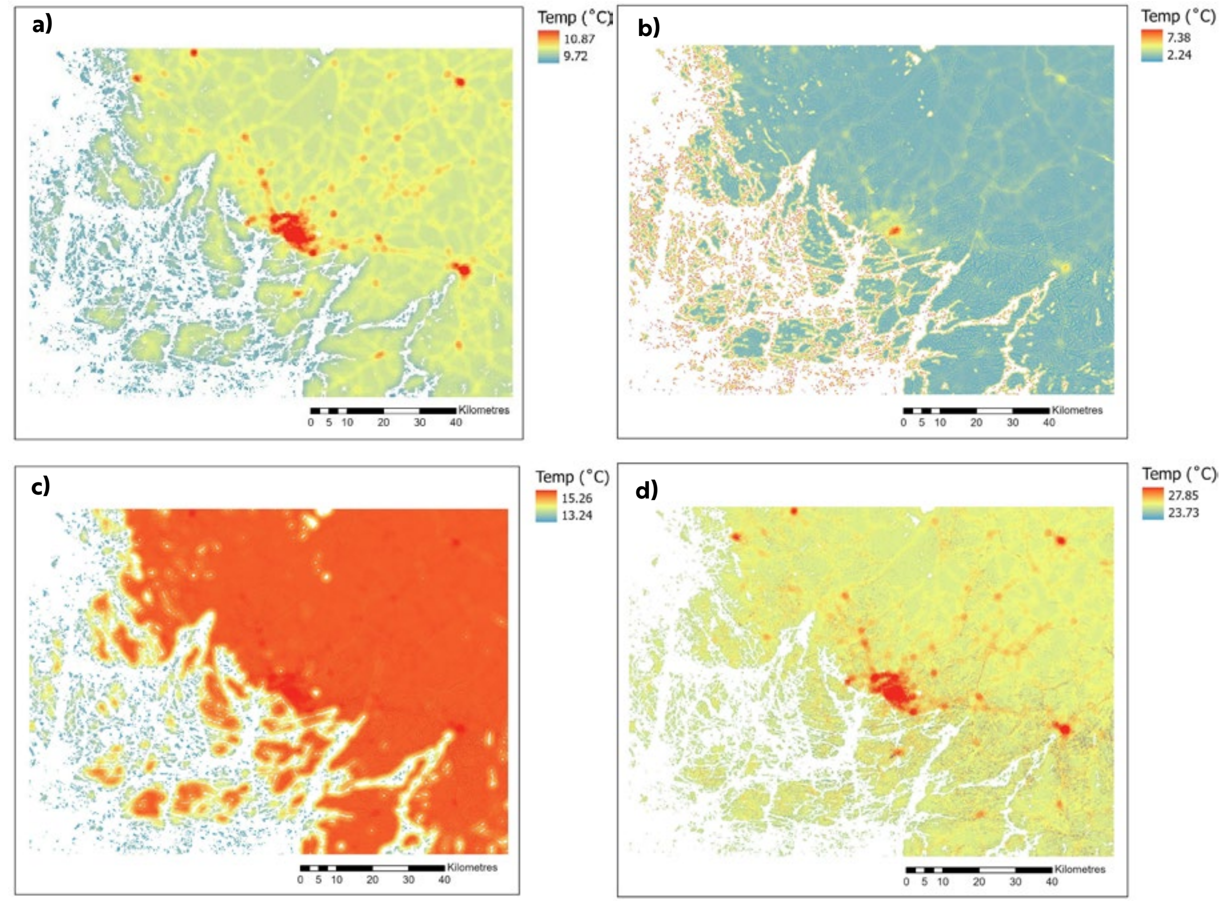

Figure 25. High-resolution (100 m) temperatures based on linear regression model depicting May 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on May 13th, 2021, at 16.00.

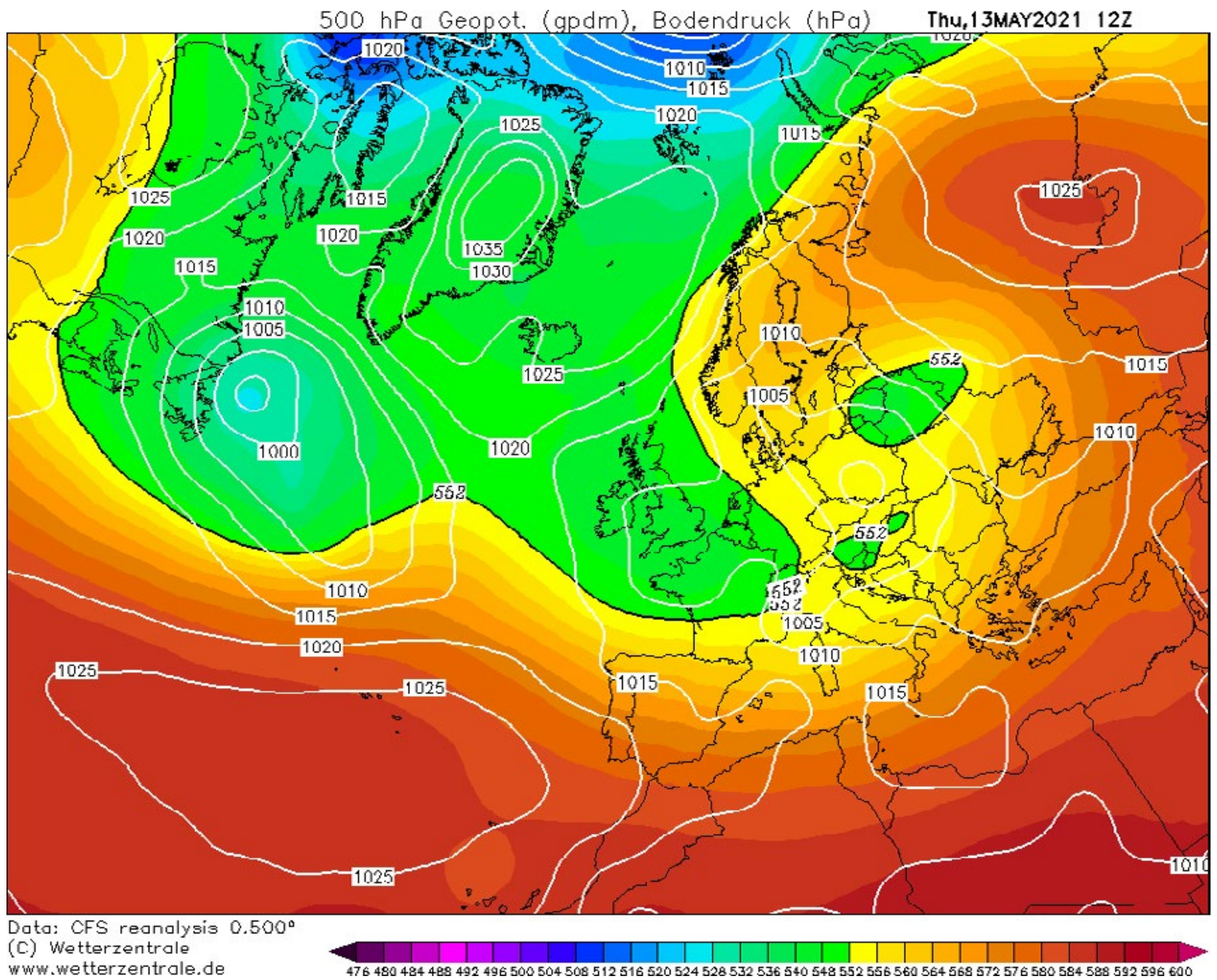

Figure 26. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for May 13th at 12.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

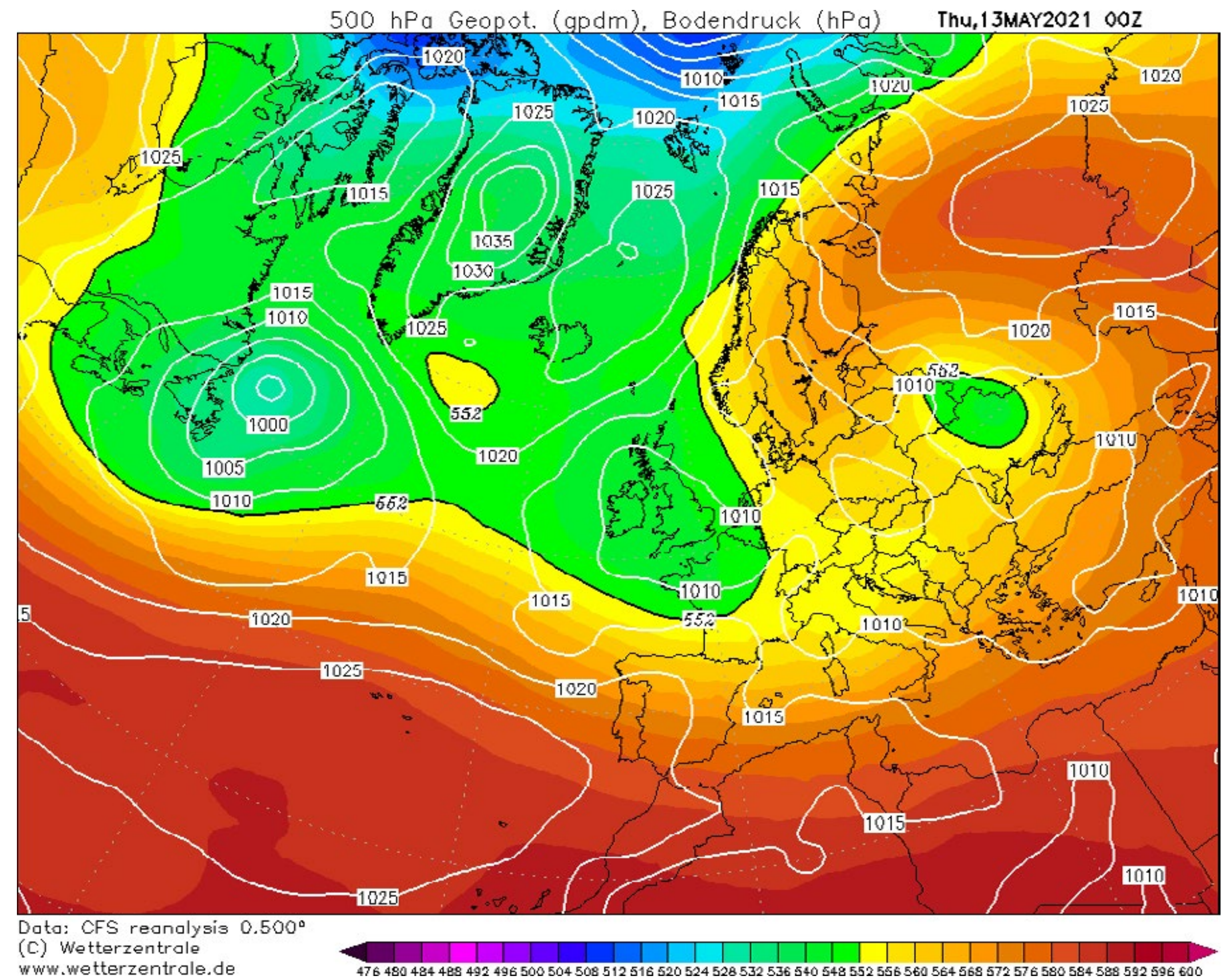

Figure 27. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for May 13th at 00.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

4.1.6 June

In June 2021, the average temperature at the Turku airport was 18.4 ˚C, as the June average temperature in 1991–2020 was 14.4 ˚C (Jokinen et al., 2021). Consequently, June 2021 was 4 ˚C warmer than average.

Regarding the TURCLIM observation network, the monthly average temperature of June 2021 was highest, 20.1 ˚C, in Kauppatori and lowest, 17.6 ˚C, in Niuskala (Figure 28). The highest and lowest monthly averages of daily minimum temperatures were obtained in Betel and Sikilä. In Betel, daily minima were on average 15.0 ˚C and in Sikilä 10.9 ˚C. The highest and lowest monthly averages of daily maximum temperatures were 24.8 ˚C in Kauppatori and 22.1 ˚C in Kolkka. The momentary maximum temperature range was observed between Kuuva and Valkiasvuori on the 7th of June at 15.00, the difference between the loggers being 10.3 ˚C. In Kuuva, the tem-

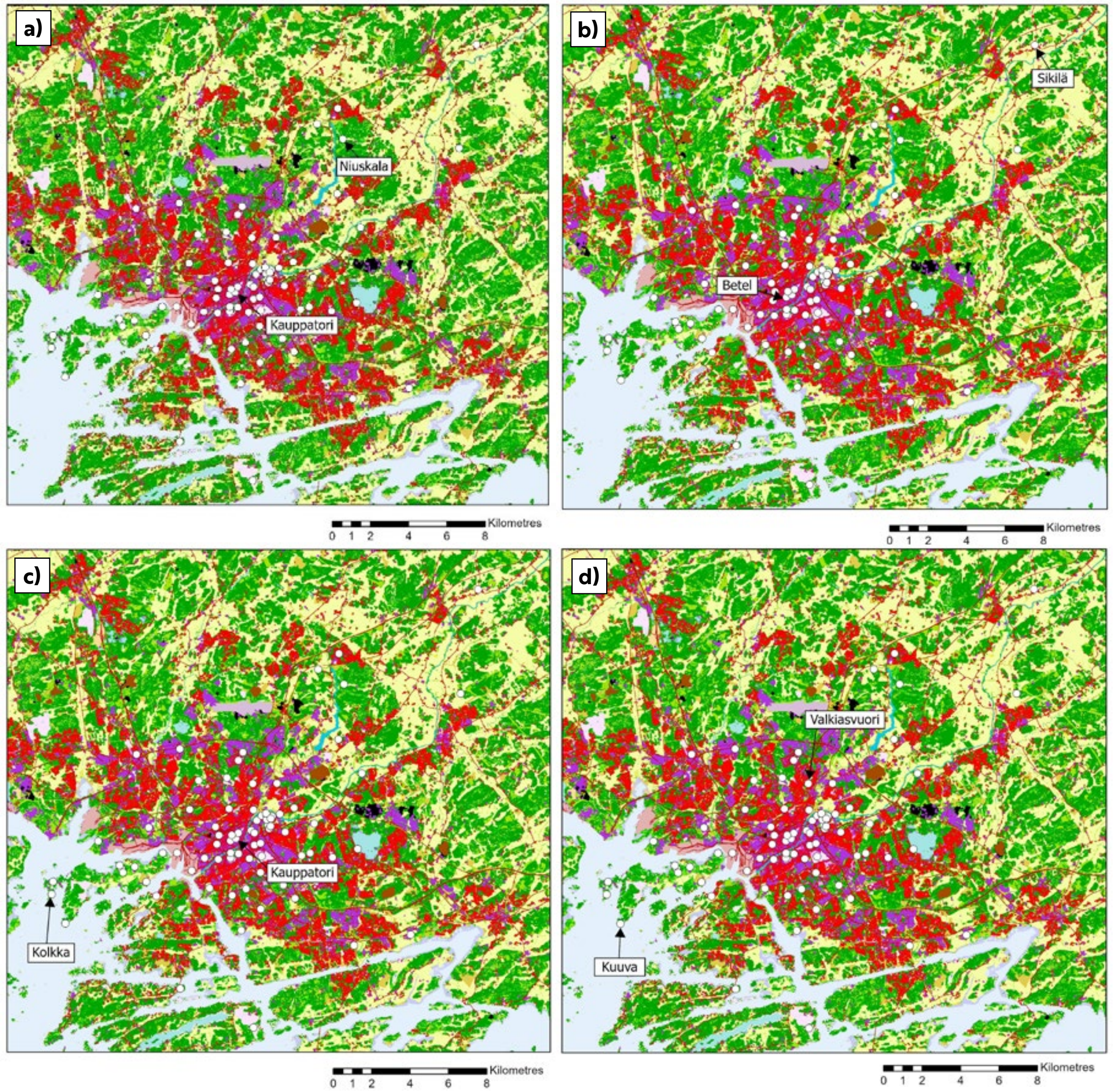

Figure 28. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kauppatori 20.1 ˚C, Niuskala 17.6 ˚C), **b)** monthly averages of daily minimum temperatures (Betel 15.0 ˚C, Sikilä 10.9 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori 24.8 ˚C, Kolkka 22.1 ˚C) and **d)** momentary maximum temperature range on June 7th at 15.00 with the difference of 10.3 ˚C (Kuuva 26.9 ˚C, Valkiasvuori 16.6 ˚C) on the CORINE Land Cover 2018 dataset in June 2021.

perature was 26.9 ˚C, whereas in Valkiasvuori it was 16.6 ˚C. The difference may be due to a local shower and related temperature drop in Valkiasvuori.

The highest and lowest monthly average temperatures in the Turku Student Village area were measured in Pispalantie, Yo-kylä itä, and Suntiontie (19.3 ˚C) and Aurajokiranta (18.4 ˚C)

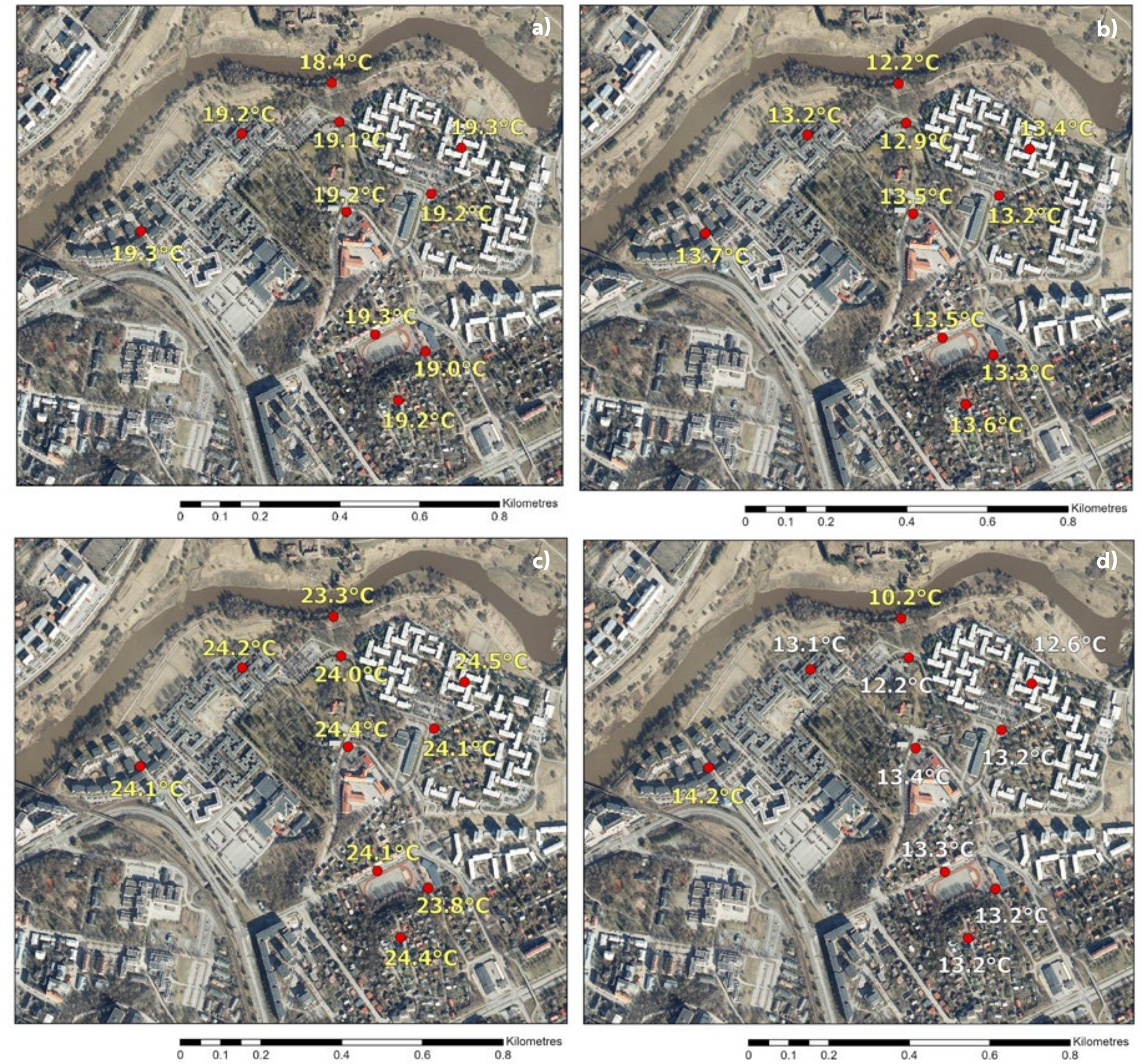

Figure 29. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on June 6th at 02.00 in 2021 with the difference of 4.0 ˚C between Pispalantie and Aurajokiranta. For individual observation site names, see Figure 4.

(Figure 29). The highest and lowest monthly averages of daily minimums were 13.7 ˚C in Pispalantie and 12.2 ˚C in Aurajokiranta. Regarding the daily maxima, the warmest was Yo-kylä itä with an average of 24.5 ˚C, whereas the coldest was Aurajokiranta with an average of 23.3 ˚C. The maximum temperature range occurred between Aurajokiranta and Pispalantie on the 6th of June at 02.00. The difference between the loggers was 4.0 ˚C. In this situation, the low-lying River Aura bench explains the coldness of the Aurajokiranta observation site,

Table 23. The regression model for the monthly average temperatures in June 2021.

R Square	0.718	
Adjusted R Square	0.705	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_700m	0.818	<0.001
tkuwaters_2km	0.019	0.800
relelev_300m	0.137	0.044

Table 24. The regression model for the monthly averages of daily minimum temperatures in June 2021.

R Square	0.665	
Adjusted R Square	0.650	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.779	<0.001
tkuwaters_500m	0.393	<0.001
relelev_500m	0.321	<0.001

Table 25. The regression model for the monthly averages of daily maximum temperatures in June 2021.

R Square	0.603	
Adjusted R Square	0.585	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_200m	0.228	0.009
tkuwaters_2km	-0.656	<0.001
relelev_200m	0.028	0.722

Table 26. The regression model for the momentary maximum temperature range of June 2021.

R Square	0.469	
Adjusted R Square	0.445	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_1000m	-0.183	0.094
tkuwaters_2kmsqrt	0.575	<0.001
relelev_100m	0.021	0.825

whereas the warming effects of the highly trafficked road and blocks of flats close to the Pispalantie observation site are detectable as its relative warmth.

The monthly average temperature regression model's explanatory power is 0.705 (Table 23). The land cover and elevation were statistically significant, both having a warming effect. Land cover had a stronger effect. For the monthly averages of daily minimum temperatures, the explanatory power is 0.650 and all explanatory variables were statistically significant and had a warming effect (Table 24). The land cover's effect was the strongest and elevation's the weakest. For the maxima, the explanatory power is 0.585 and the land cover and water bodies were statistically significant (Table 25). The land cover had a warming effect, and the water bodies a cooling effect. In the case of the momentary maximum temperature range, the explanatory power is 0.445, and of the explanatory variables, only water bodies were statistically significant (Table 26). The impact was warming. The variable tkuwat2kmsqrt means the square root of the proportion of water bodies inside a 2-kilometre radius buffer around the observation site.

In the monthly average temperature map of June, the low-lying areas are the coldest, whereas the Turku city centre and other densely built-up areas are the warmest (Figure 30). The main road network is also warmer than its surroundings. The average daily minimum temperature map appears similar, but the relative warmth of residential areas is less clear, and coastal areas are relatively warmer than in the average temperature map. The limestone quarry in Parainen affects the tempera-

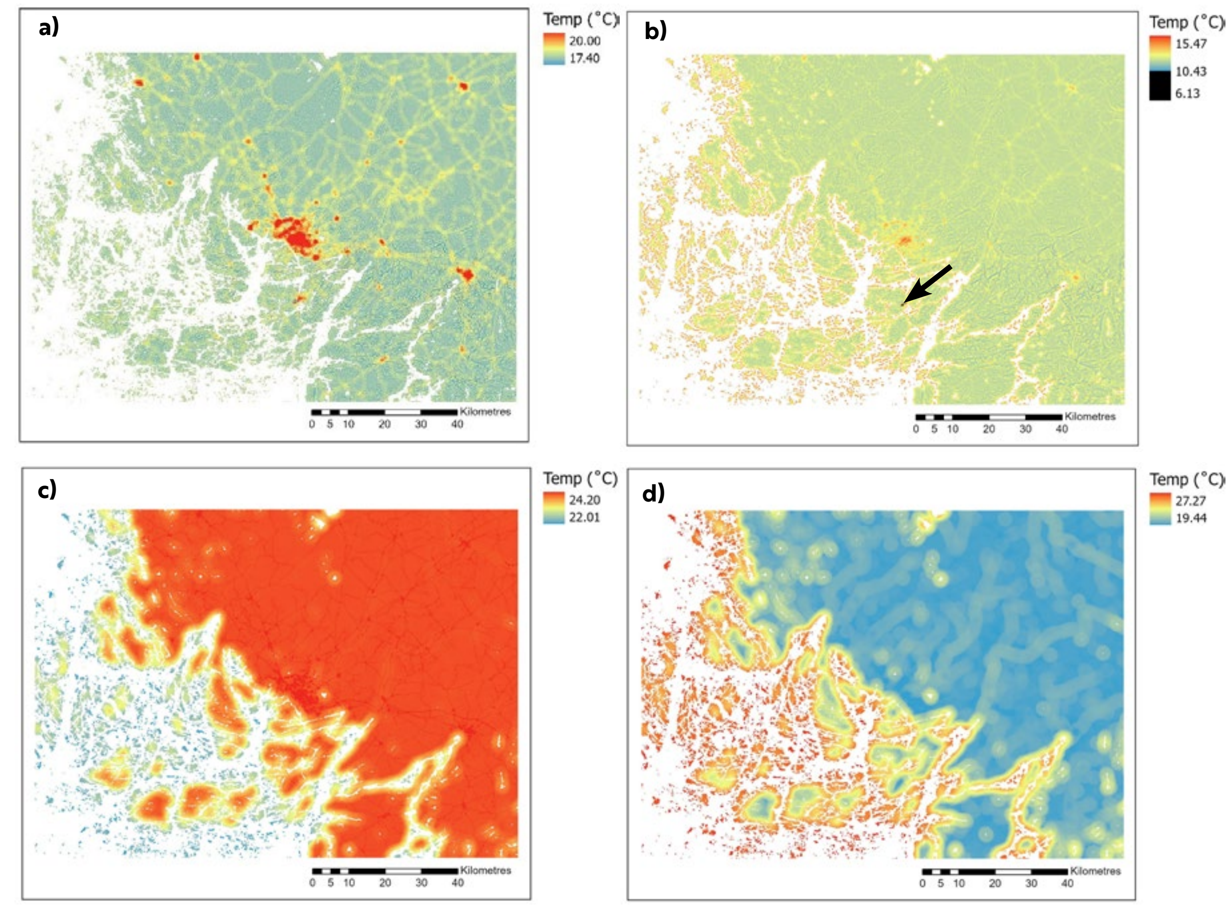

Figure 30. High-resolution (100 m) temperatures based on linear regression model depicting June 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on June 7th, 2021, at 15.00. The abnormally low temperature area in the limestone quarry located in Parainen is marked in black (arrow).

ture range of daily minima. The lowest average daily minimum temperature outside the quarry is 10.43 °C. In the daily maximum temperature map, the mainland is the warmest and the coast the coolest. For the maximum temperature range map, the situation is the opposite; the coastal areas are the warmest and the mainland the coolest, probably reflecting the higher shower-sensitivity of inland areas.

Based on the maps of sea level air pressure and height of the 500 hPa pressure level on the moments of maximum temperature variability of June, the 500 hPa height is approximately between 570 and 580 decametres (Figures 31 & 32). At the time of the maximum temperature range of the whole Turku area, the high-pressure centre lies over Kola Peninsula and a weak low-pressure centre over Iceland. At the time of the maximum temperature range of the Turku Student Village area, the high-pressure centre lied over northern Norway, while weak low-pressures lied over the Atlantic Ocean to the southwest of Iceland and over eastern Europe. At the moment of the momentary maximum temperature range of the Turku area as a whole, i.e., on June 7th at 15.00, the wind speed was 3.925 m/s and cloudiness 7. At the respective moment of the Turku Student Village area, i.e., on the 6th of June at 02.00, the wind speed was 1.4 m/s and cloudiness 0 on average.

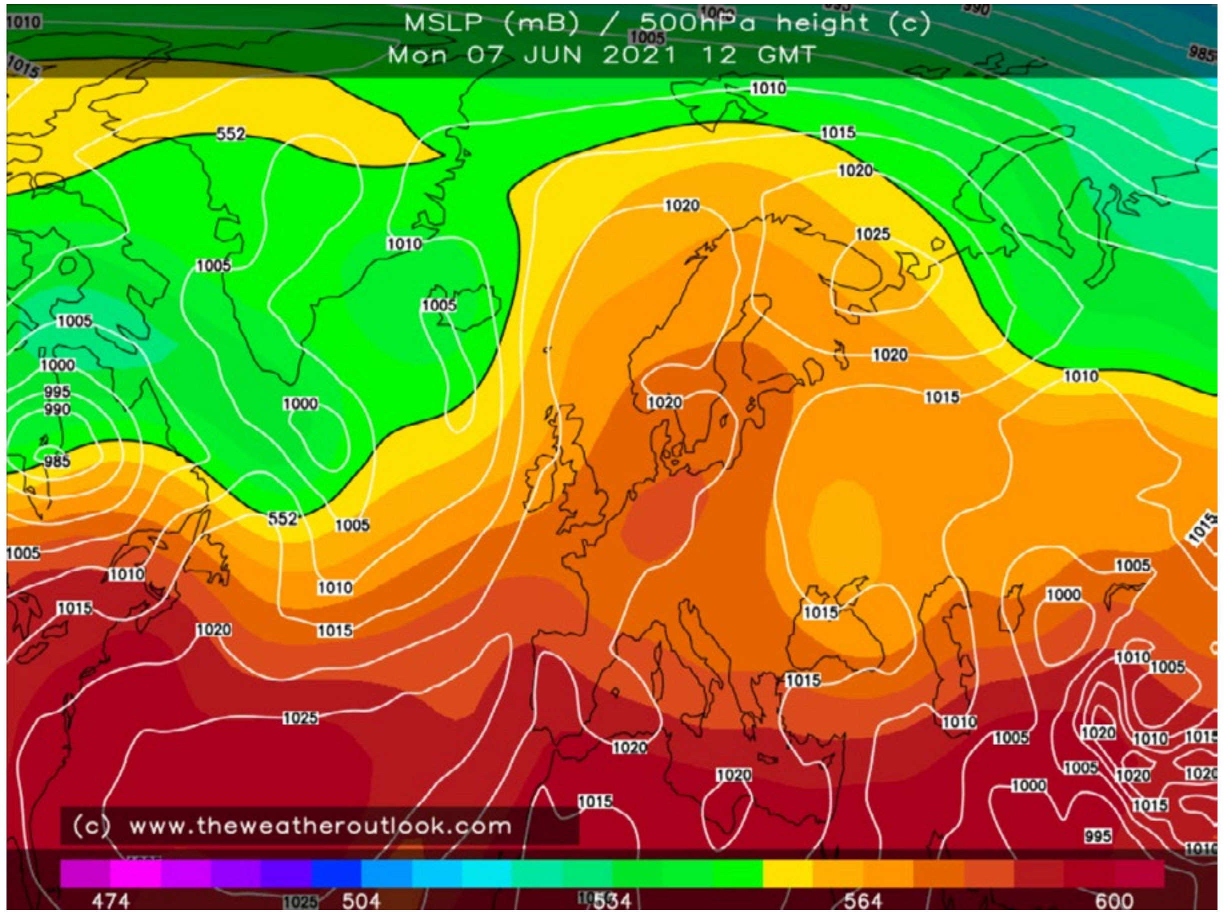

Figure 31. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for June 7th at 12.00 UTC. Retrieved from TheWeatherOutlook (https://www.theweatheroutlook.com/twodata/reanalysis.aspx).

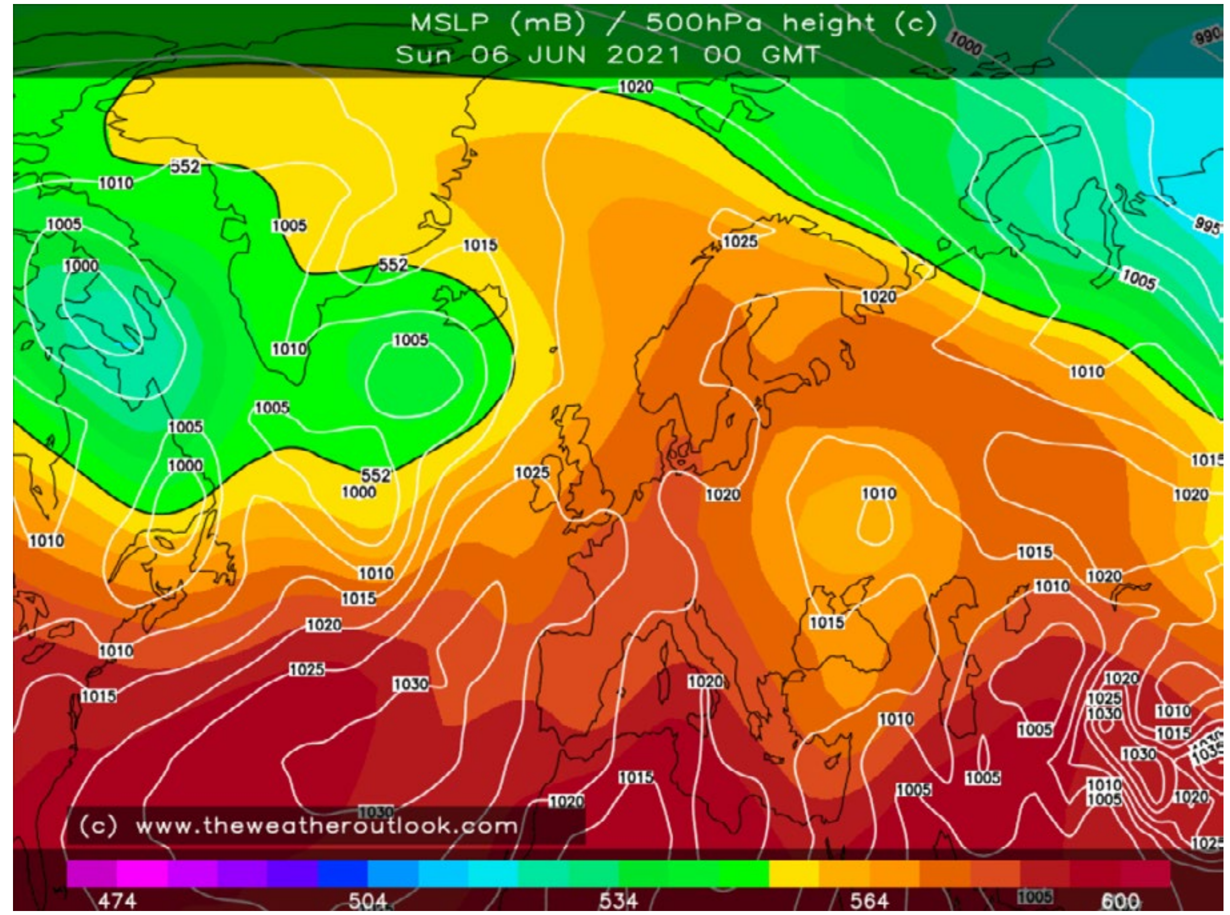

Figure 32. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for June 6th at 00.00 UTC. Retrieved from TheWeatherOutlook (https://www.theweatheroutlook.com/twodata/reanalysis.aspx).

4.1.7 July

In July 2021, the average temperature at the Turku airport was 20.3 ˚C, which is almost three degrees warmer than the average temperature of 17.5 ˚C during the climate period 1991–2020 (Jokinen et al., 2021).

Regarding the TURCLIM observation network, in July 2021 the highest and lowest monthly average temperatures were 22.1 ˚C, measured in Kauppatori, and 19.0 ˚C, measured in Niuskala (Figure 33). The lowest monthly average of daily minimum temperatures, 12.4 ˚C, also occurred in Niuskala, whereas the highest respective temperature, 17.0 ˚C, took place in Betel. The highest and lowest monthly averages of daily maximum temperatures were measured in the same locations as the highest and lowest monthly average temperatures. In Kauppatori, daily maxima were on average 26.6 ˚C, and in Niuskala 24.3 ˚C. The maximum temperature range was 9.1 ˚C and it was measured between Kuuva and Niuskala on the 20th of July at 05.00, when the temperature in Kuuva was 17.2 ˚C and in Niuska-

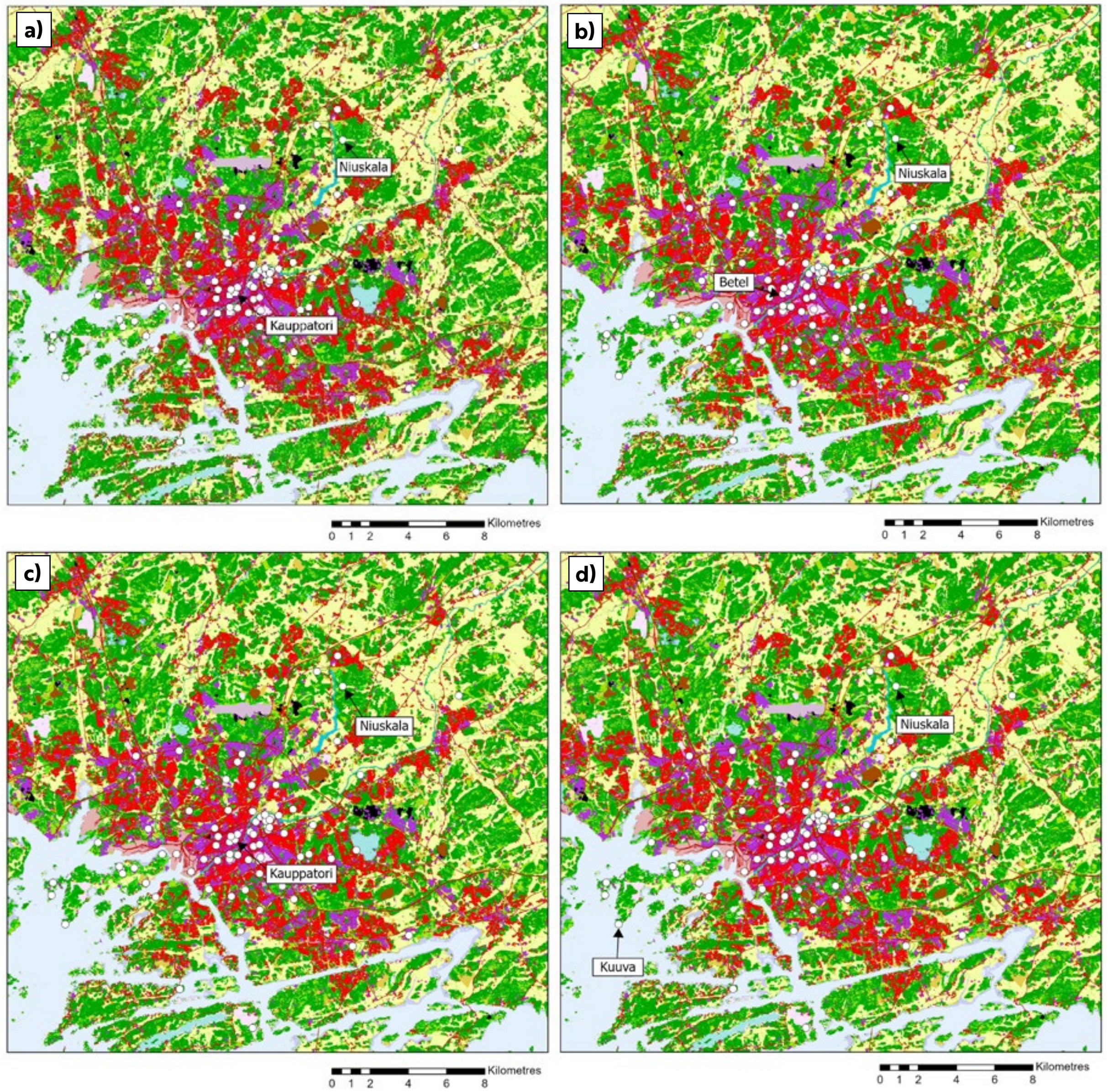

Figure 33. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kauppatori 22.1 ˚C, Niuskala 19.0 ˚C), **b)** monthly averages of daily minimum temperatures (Betel 14.0 ˚C, Niuskala 12.4 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori 26.6 ˚C, Niuskala 24.3 ˚C) and **d)** momentary maximum temperature range on July 20th at 05.00 with the difference of 9.1 ˚C (Kuuva 17.2 ˚C, Niuskala 8.1 ˚C) on the CORINE Land Cover 2018 dataset in July 2021.

la 8.1 ˚C. The difference can be explained by the warming effect of the sea in the Kuuva region and effective nighttime cooling in the rural site Niuskala.

In the Turku Student Village area, the highest monthly average temperature was 21.4 ˚C, reached in the Kuuvuori and Yo-kylä itä sites (Figure 34). The lowest monthly average temperature, 20.4 ˚C, existed in Aurajokiranta. The lowest monthly average of daily minimum temperatures, 14.4 ˚C, was observed in Aurajokiranta. The highest was in Pispalantie with an average of 15.7 ˚C. For the daily maxima, the highest and lowest monthly averages were 26.5 ˚C in Kuuvuori and 25.1 ˚C in Aurajokiranta. The momentary maximum temperature range was 4.9 ˚C between Pispalantie and Aurajokiranta. This was measured on the 4th of July at 23.00. The possible warming effect of the highly trafficked road and blocks of flats close

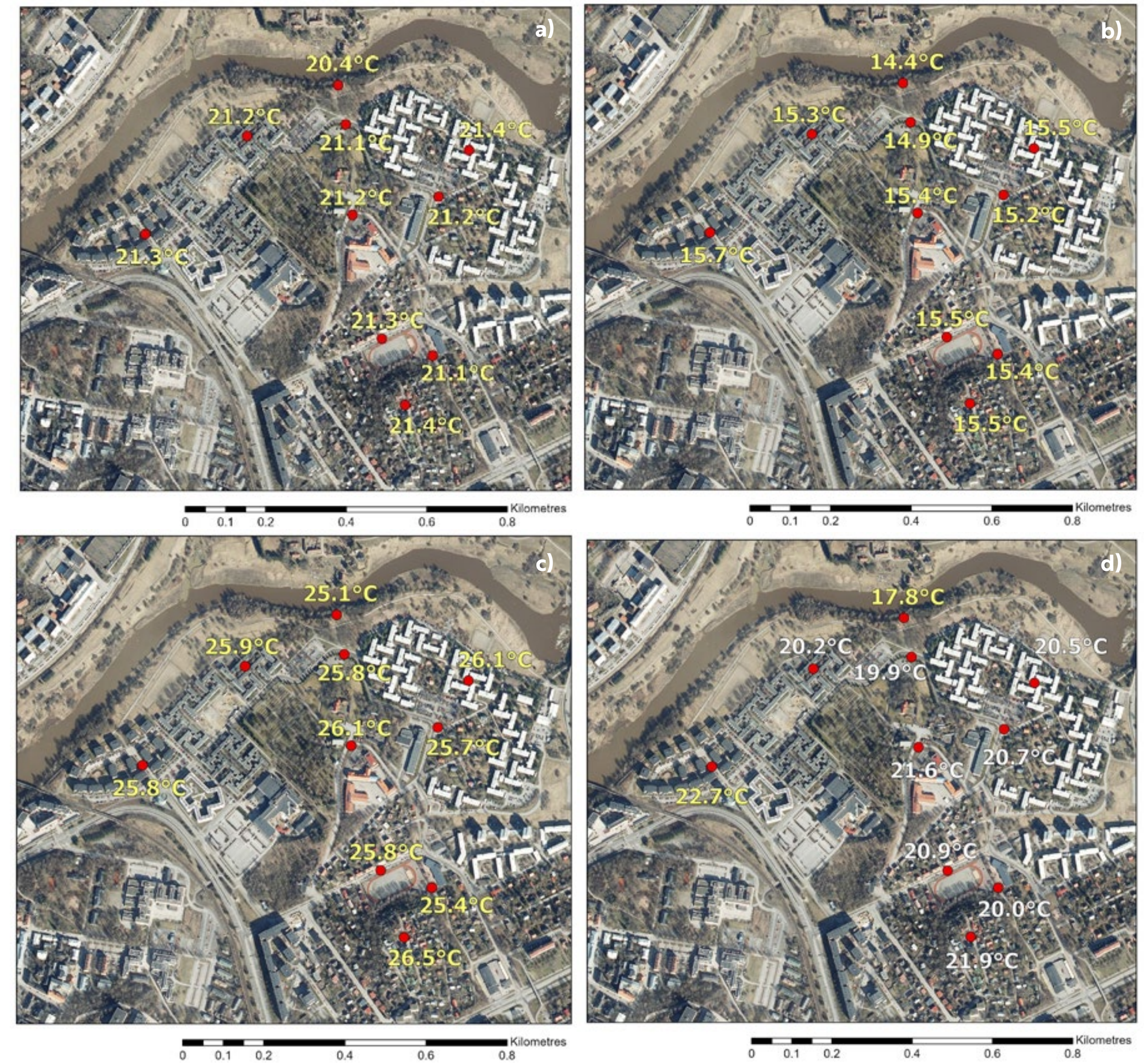

Figure 34. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on July 4th at 23.00 in 2021 with the difference of 4.9 ˚C between Pispalantie and Aurajokiranta. For individual observation site names, see Figure 4.

Table 27. The regression model for the monthly average temperatures in July 2021.

Variable	Standardized Coefficients Beta	Significance
R Square	0.650	
Adjusted R Square	0.634	
Constant		<0.001
vl_3_5_700m	0.852	<0.001
tkuwaters_2km	0.280	0.001
relelev_300m	0.153	0.044

Table 28. The regression model for the monthly averages of daily minimum temperatures in July 2021.

Variable	Standardized Coefficients Beta	Significance
R Square	0.628	
Adjusted R Square	0.612	
Constant		<0.001
vl_3_5_400m	0.736	<0.001
tkuwaters_500m	0.498	<0.001
relelev_500m	0.301	<0.001

Table 29. The regression model for the monthly averages of daily maximum temperatures in July 2021.

Variable	Standardized Coefficients Beta	Significance
R Square	0.399	
Adjusted R Square	0.372	
Constant		<0.001
vl_3_5_1000m	0.313	0.008
tkuwaters_2km	-0.403	<0.001
relelev_300m	0.071	0.476

Table 30. The regression model for the momentary maximum temperature range of July 2021.

Variable	Standardized Coefficients Beta	Significance
R Square	0.623	
Adjusted R Square	0.606	
Constant		<0.001
vl_3_5_100m	0.522	<0.001
tkuwaters_2kmsqrt	0.746	<0.001
relelev_500m	0.208	0.008

to Pispalantie explain the warmth of that site, and the lowland river bench where the Aurajokiranta logger is located may have received cold air drainage.

In the regression model for the monthly average temperatures, the explanatory power is 0.634 and all explanatory variables are statistically significant, having a warming effect (Table 27). The land cover had the strongest effect and elevation the weakest. For the monthly average of daily minima, the explanatory power is 0.612 and all explanatory variables were statistically significant (Table 28). The land cover's effect was strongest and elevation's weakest. For the maxima, the explanatory power is 0.372 with land cover and water bodies being statistically significant (Table 29). The water bodies had a cooling effect and land cover a warming effect. In the case of the maximum temperature range, the explanatory power is 0.606 and all explanatory variables were statistically significant (Table 30). All had a warming effect, but the water bodies had the strongest and elevation the weakest.

In the monthly average temperature map, the coasts along with the Turku city centre and other densely-built areas appear as the warmest (Figure 35). The main roads can also be detected as slightly warmer than their surroundings. The daily minimum temperature map reminds the average temperature map, but the relative warmth of the Turku city centre is less clear. The lowland areas can be detected as the coolest areas due to cold air drainage. In the daily maxima map, the mainland area is relatively warm, and the phenomenon is enhanced in the urban areas. During the time of maximum temperature range, the coast is the warmest and the mainland the coolest. The limestone quarry affects the temperature ranges in the daily minimum

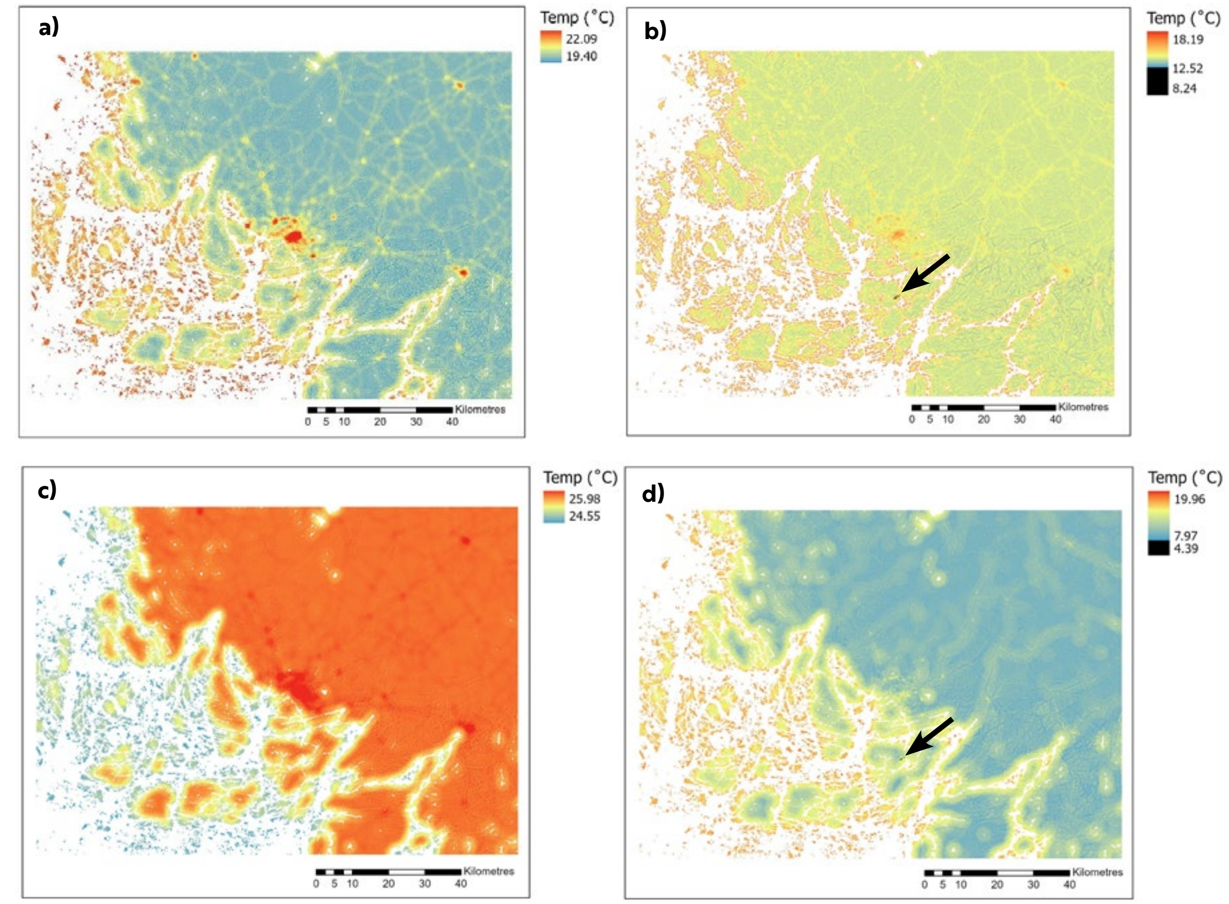

Figure 35. High-resolution (100 m) temperatures based on linear regression model depicting July 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on July 20th, 2021, at 05.00. The abnormally low temperature areas in the limestone quarry located in Parainen are marked in black (arrow).

temperature map and the momentary maximum temperature range map. The lowest temperatures outside the quarry are 12.52 ˚C in the minimum temperatures map and 7.97 ˚C in the momentary maximum temperature range map.

The map of sea level air pressure and the height of the 500 hPa pressure level at the moment of maximum temperature range of the whole Turku region in July 2021 illustrates a low-pressure centre in the Barents Sea, to the northwest of Novaya Zemlya, and a high-pressure in the vicinity of the British Isles (Figure 36). The 500 hPa pressure surface was situated at approximately 565 decametres over Turku. In the case of the Turku Student Village, a weak low-pressure was located to the west of the British Isles, while Finland was under the impact of weak high-pressure (Figure 37). The 500 hPa pressure surface was at approximately 580 decametres. At the time of the momentary maximum temperature range on July 20th at 05.00, the wind speed was 1.775 m/s and cloud cover was 6.75. On the 4th at 23.00, the wind speed averaged 1.275 m/s, with no cloud cover.

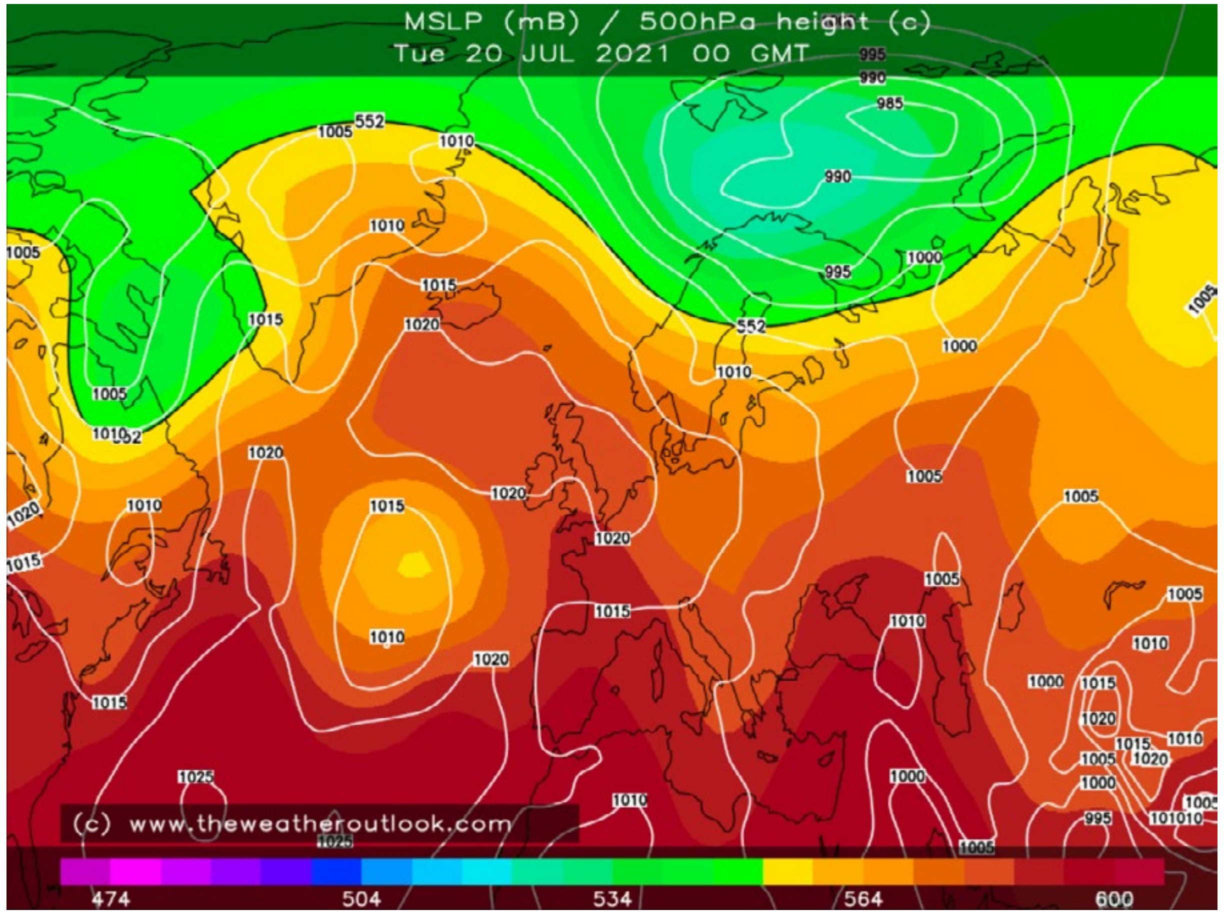

Figure 36. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for July 20th at 00.00 UTC. Retrieved from TheWeatherOutlook (https://www.theweatheroutlook.com/twodata/reanalysis.aspx).

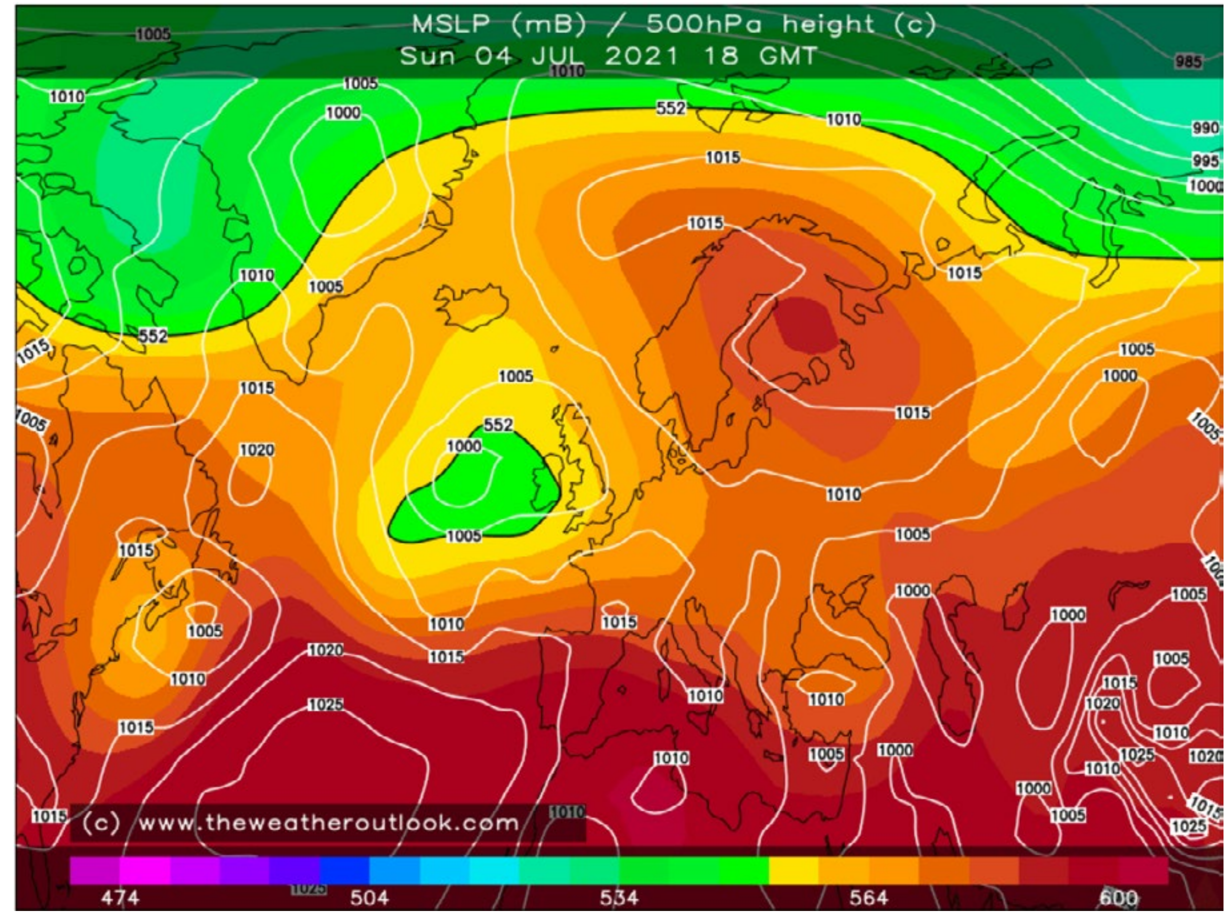

Figure 37. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for July 4th at 18.00 UTC. Retrieved from TheWeatherOutlook (https://www.theweatheroutlook.com/twodata/reanalysis.aspx).

4.1.8 August

August 2021 was 1 ˚C colder than average; the average temperature at the Turku airport was 15.2 ˚C, whereas during the climate period 1991–2020, the respective temperature was 16.2 ˚C (Jokinen et al., 2021).

Regarding the TURCLIM observation network, the highest and lowest monthly average temperatures occurred in Kauppatori and Niuskala (Figure 38). In Kauppatori, the average temperature was 16.7 ˚C and in Niuskala 14.4 ˚C. The highest and lowest monthly averages of daily minimum temperatures, 13.6 ˚C and 10.4 ˚C, respectively, were measured in Kuuva and Ylijoki. For the daily maxima, the averages varied between Kauppatori's 20.6 ˚C and Niuskala's 18.3 ˚C. The momentary maximum temperature range was 9.2 ˚C and it was measured between Kolkka and Ylijoki on the 4th of August at 04.30, when the temperature was 14.6 ˚C in Kolkka and 5.4 ˚C in Ylijoki. The difference is probably explained by the local heating effect of the sea in a coastal site Kolkka, and local inversion in the inland observation site Ylijoki.

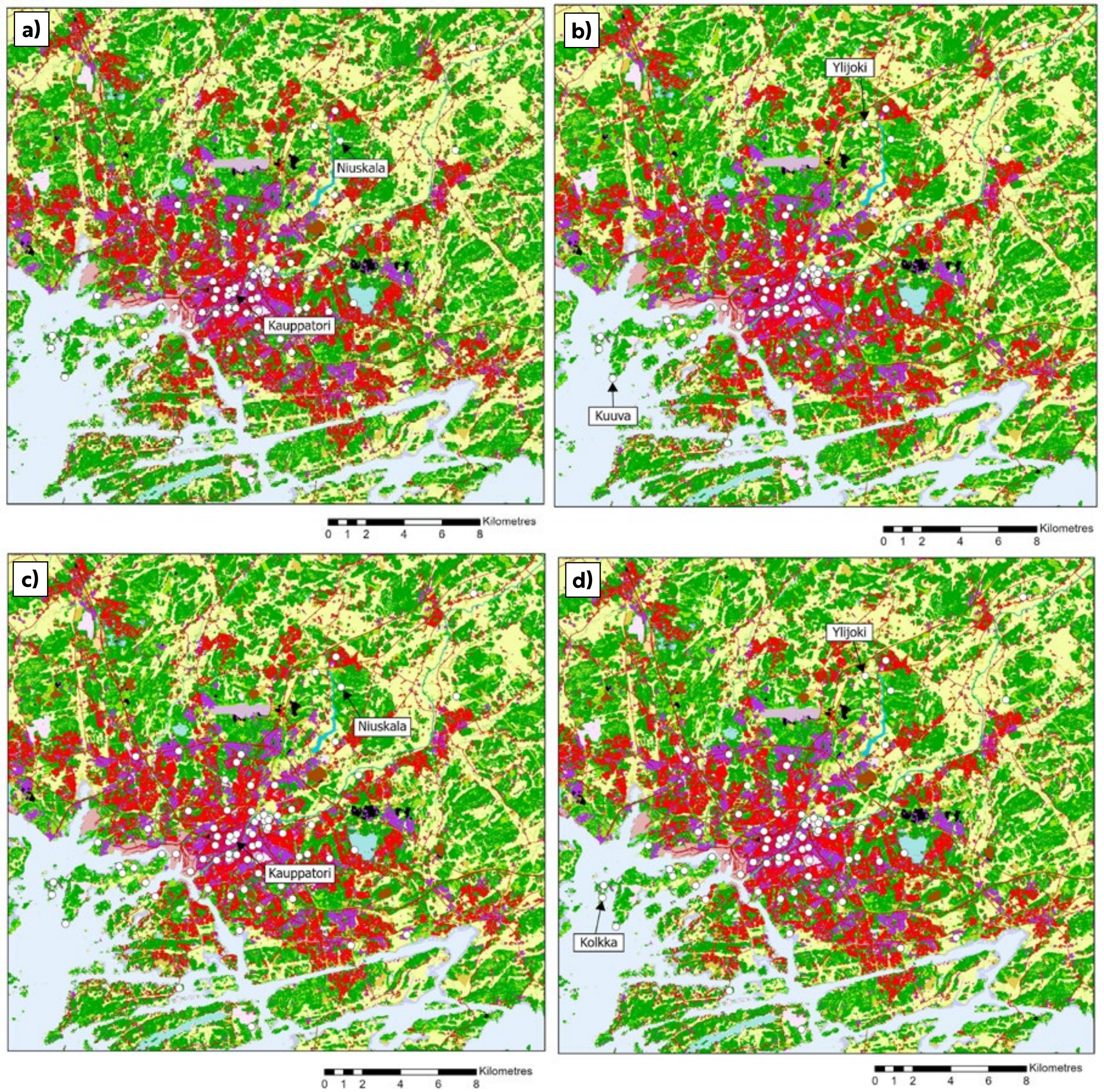

Figure 38. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kauppatori 16.7 ˚C, Niuskala 14.4 ˚C), **b)** monthly averages of daily minimum temperatures (Kuuva 13.6 ˚C, Ylijoki 10.4 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori 20.6 ˚C, Niuskala 18.3 ˚C) and **d)** momentary maximum temperature range on August 4th at 04.30 with the difference of 9.2 ˚C (Kolkka 14.6 ˚C, Ylijoki 5.4 ˚C) on the CORINE Land Cover 2018 dataset in August 2021.

The highest monthly average temperature in the Turku Student Village area was reached in Pispalantie with an average of 16.0 ˚C (Figure 39). The lowest monthly average temperature, 15.3 ˚C, was measured in Aurajokiranta. The highest and lowest monthly averages of daily minimum temperatures were observed in Pispalantie and Kuuvuori (12.5 ˚C) and Aurajokiranta (11.7 ˚C). In the case of the daily maxima, the highest and lowest were 19.8 ˚C, measured in Kuuvuori, and 18.9 ˚C, measured in Aurajokiranta. The momentary maximum temperature range was observed on the 4th of August at 05.30 between the hill-top site Kuuvuori and the river valley site Aurajokiranta. The difference was 4.8 ˚C. Inversion conditions and related cold air drainage could explain the observed temperature difference.

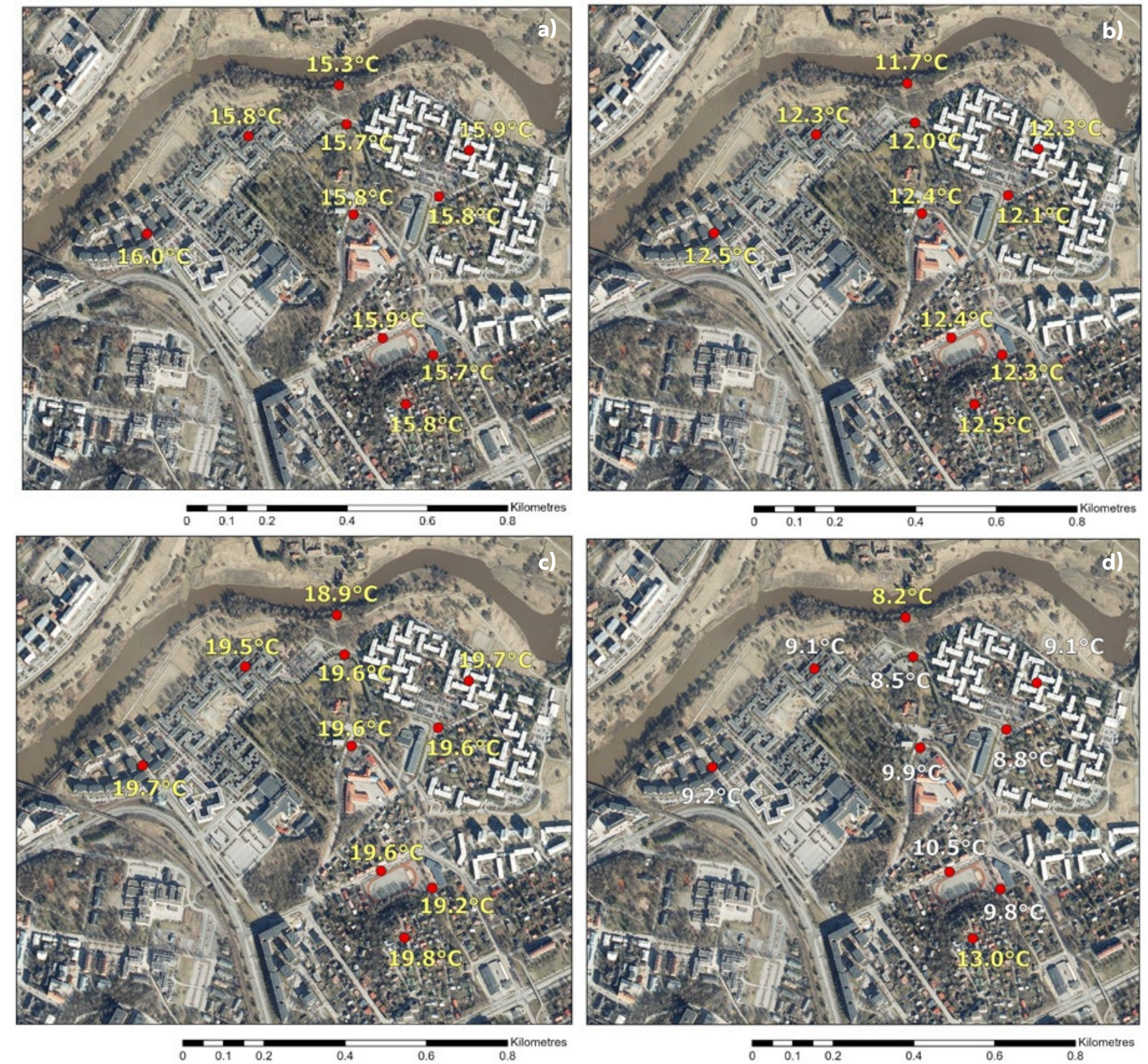

Figure 39. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on August 4th at 05.30 in 2021 with the difference of 4.8 ˚C between Kuuvuori and Aurajokiranta. For individual observation site names, see Figure 4.

The monthly average temperatures' regression model's explanatory power is 0.596 with

Table 31. The regression model for the monthly average temperatures in August 2021.

R Square	0.613	
Adjusted R Square	0.596	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.766	<0.001
tkuwaters_500m	0.552	<0.001
relelev_300m	0.150	0.055

Table 32. The regression model for the monthly averages of daily minimum temperatures in August 2021.

R Square	0.619	
Adjusted R Square	0.602	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_100m	0.692	<0.001
tkuwaters_2km	0.597	<0.001
relelev_500m	0.228	0.004

Table 33. The regression model for the monthly averages of daily maximum temperatures in August 2021.

R Square	0.291	
Adjusted R Square	0.259	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_200m	0.537	<0.001
tkuwaters_2kmsqrt	-0.012	0.915
relelev_500m	-0.036	0.729

Table 34. The regression model for the momentary maximum temperature range of August 2021.

R Square	0.680	
Adjusted R Square	0.665	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_100m	0.573	<0.001
tkuwaters_2km	0.653	<0.001
relelev_500m	0.369	<0.001

the land cover and water bodies as statistically significant explanatory variables (Table 31). Both had a warming effect, and the impact of land cover was stronger. In the case of the monthly averages of daily minimum temperatures, the explanatory power is 0.602 (Table 32). All explanatory variables were statistically significant and had a warming effect. The land cover's influence was the strongest and elevation's the weakest. For the average daily maxima, the explanatory power is 0.259. Of the explanatory variables, only land cover was statistically significant, and the impact was warming (Table 33). For the momentary maximum temperature range, the explanatory power is 0.665 and all explanatory variables were statistically significant and had a warming effect (Table 34). The water bodies had the strongest effect and elevation the weakest.

In the monthly average temperature map, the coastal areas and the Turku city centre appear as the warmest (Figure 40). The mainland is relatively cool. Moderately built-up areas and main roads are slightly warmer than their natural surroundings. The minimum temperature map reminds the average temperature map, but the warming impact of water bodies extends further inland. In the map on average daily maximum temperature, the relatively warm residential areas are clearly detectable, but it is good to notice that the absolute temperature differences are small. The coast is the coolest area. In the momentary maximum temperature range map, the coast is the warmest and the heat of urban areas is not that strong. Here the limestone quarry in Parainen has a slight effect on the temperature range. The lowest temperature outside the quarry is 3.93 ˚C.

The map of sea level air pressure and height of the 500 hPa pressure level representing the

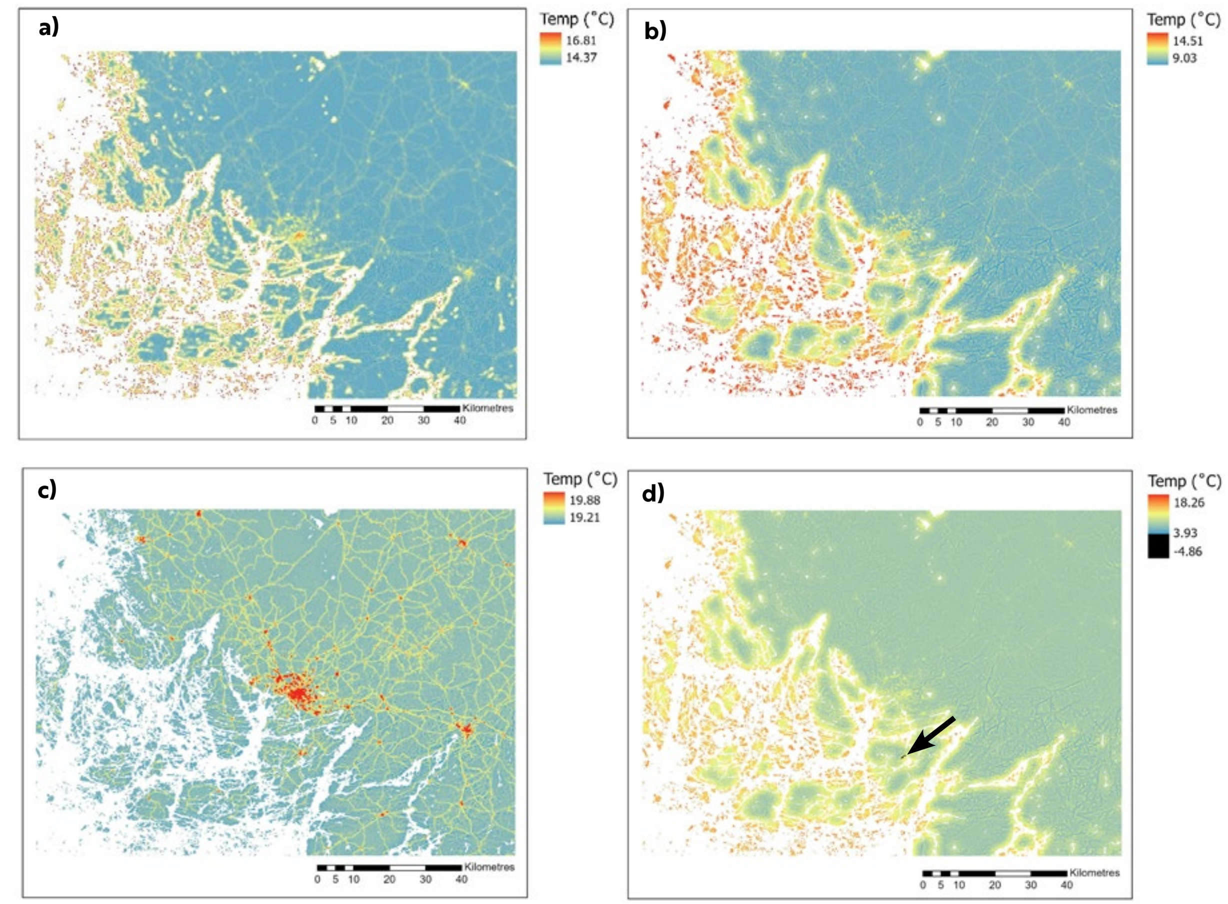

Figure 40. High-resolution (100 m) temperatures based on linear regression model depicting August 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on August 4th, 2021, at 04.30. The abnormally low temperature area in the limestone quarry located in Parainen is marked in black (arrow).

time of maximum temperature range of the whole Turku area depicts a relatively strong low-pressure over the Kola Peninsula (Figure 41). Over the Atlantic Ocean, a low-pressure was located south of Cape Farewell, Greenland, while a strong high-pressure was positioned further south in the Azores region. The 500 hPa pressure surface was at approximately 550 decametres, with the map timestamped at 00.00 UTC. Six hours later, at 06.00 UTC - representing the moment of the maximum temperature range in the Turku Student Village area, the air pressure pattern remained largely unchanged (Figure 42). The high- and low-pressure centres remained in approximately the same locations, though the low-pressure centre south of Cape Farewell had shifted slightly eastward. The 500 hPa pressure surface remained at around 550 decametres. On August 4th at 04.30, the wind speed was 1.1 m/s with no cloud cover. By 05.30, the wind speed had increased to 1.575 m/s, and cloudiness was 0.5.

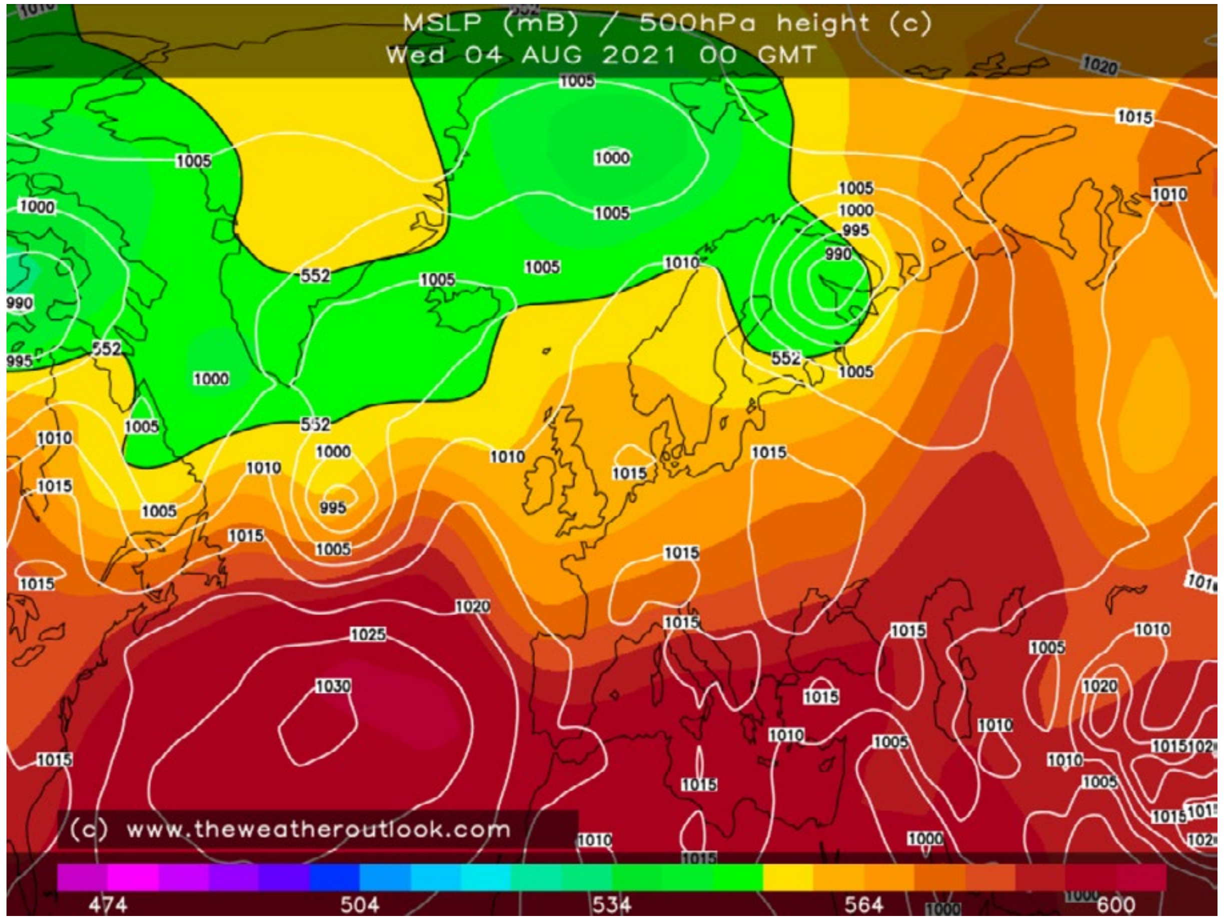

Figure 41. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for August 4th at 00.00 UTC. Retrieved from TheWeatherOutlook (https://www.theweather-outlook.com/twodata/reanalysis.aspx).

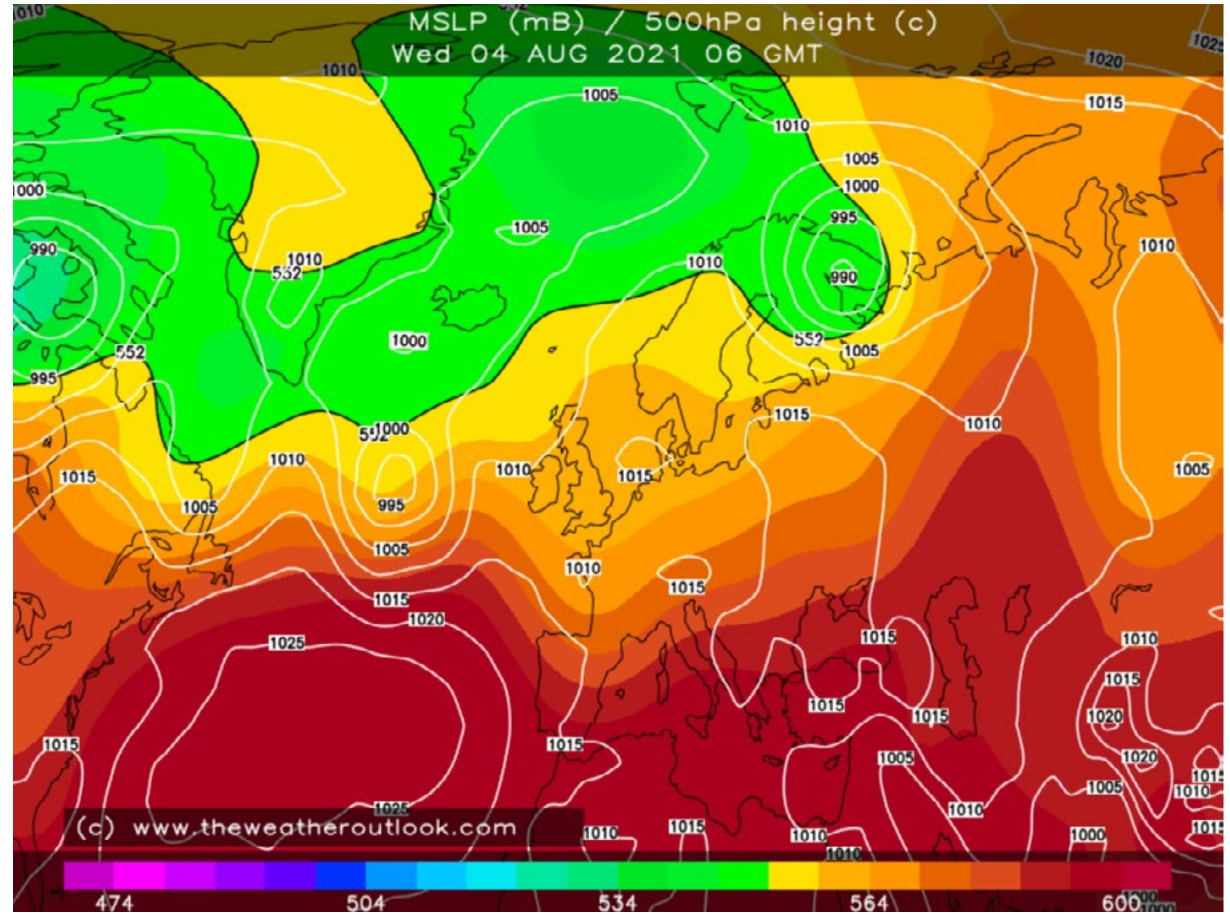

Figure 42. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for August 4th at 06.00 UTC. Retrieved from TheWeatherOutlook (https://www.theweather-outlook.com/twodata/reanalysis.aspx).

4.1.9 September

Similar to August 2021, September 2021 was colder than average. At the Turku airport, the average temperature of September 2021 was 9.7 ˚C, whereas the respective temperature during the climate period of 1991–2020 was 11.3 ˚C (Jokinen et al., 2021).

Regarding the TURCLIM observation network, September's highest and lowest monthly average temperatures, 11.1 ˚C and 9.0 ˚C, were measured in Kauppatori and Niuskala, respectively (Figure 43). The lowest monthly average of daily minimum temperatures, 5.0 ˚C, was also measured in Niuskala, whereas the highest respective temperature, 8.3 ˚C, was measured in Kuuva. For the daily maxima, the highest and lowest averages were measured in Kauppatori (14.8 ˚C) and Niuskala (13.1 ˚C). The maximum temperature range, 8.8 ˚C, was measured between Kuuva and Ylijoki on the 7th of September at 05.30. In Kuuva, the temperature was 11.5 ˚C and in Ylijoki 2.7 ˚C. The difference is probably explained by the local warming effect of the sea in a coastal site Kolkka, and local inversion in the inland observation site Ylijoki.

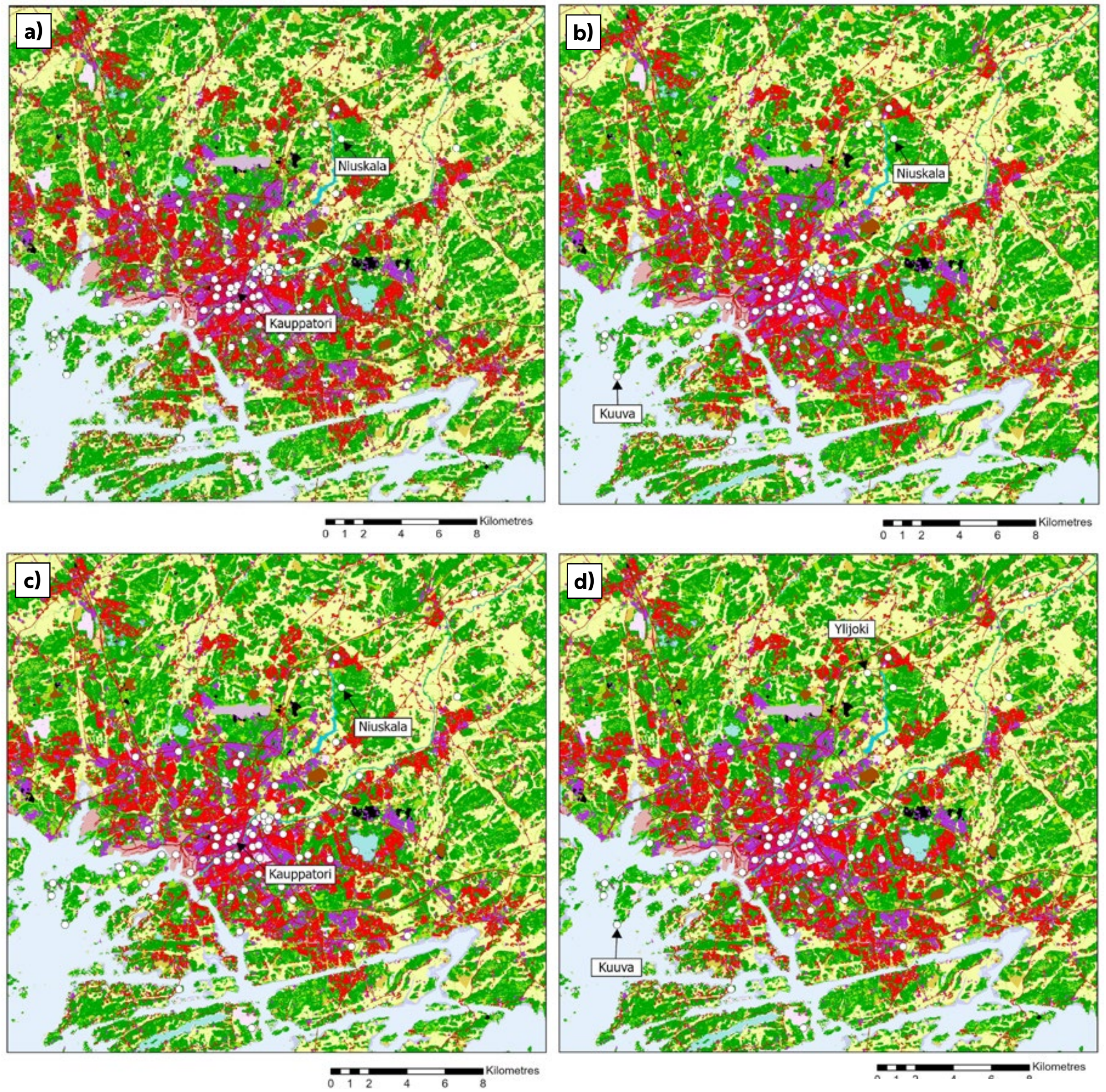

Figure 43. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kauppatori 11.1 ˚C, Niuskala 9.0 ˚C), **b)** monthly averages of daily minimum temperatures (Kuuva 8.3 ˚C, Niuskala 5.0 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori 14.8 ˚C, Niuskala 13.1 ˚C) and **d)** momentary maximum temperature range on September 7th at 05.30 with the difference of 8.8 ˚C (Kuuva 11.5 ˚C, Ylijoki 2.7 ˚C) on the CORINE Land Cover 2018 dataset in September 2021.

In the Turku Student Village area, the highest and lowest monthly average temperatures were measured in Pispalantie, Suntiontie (10.4 °C) and Aurajokiranta (9.7 ˚C) (Figure 44). The highest and lowest monthly averages of daily minimum temperatures, 6.9 ˚C and 5.9 ˚C, were observed in Pispalantie and Aurajokiranta, respectively. Regarding the daily maxima,

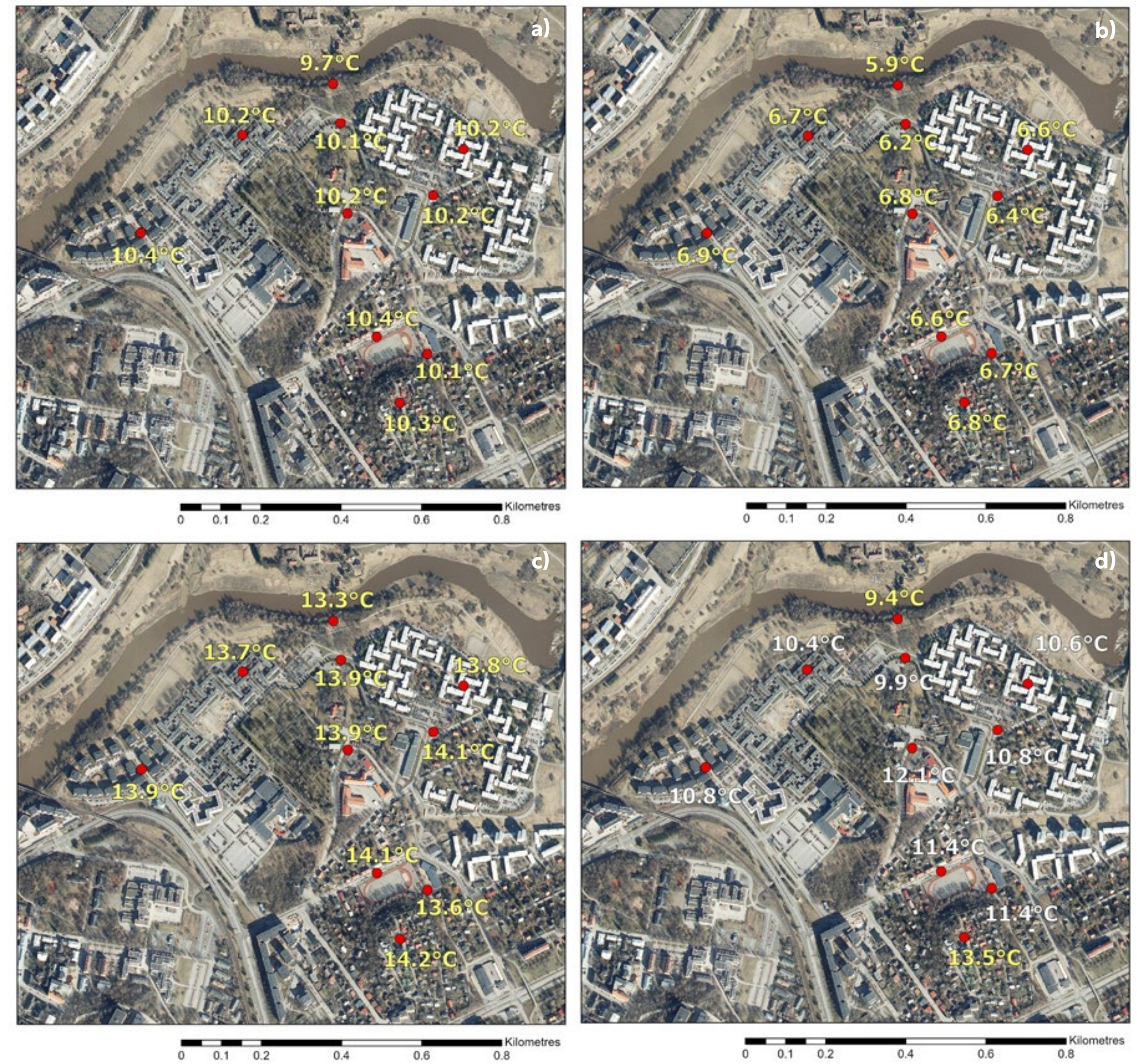

Figure 44. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on September 9th at 03.30 in 2021 with the difference of 4.1 ˚C between Kuuvuori and Aurajokiranta. For individual observation site names, see Figure 4.

the warmest site, 14.2 ˚C, was Kuuvuori, and the coldest site, 13.3 °C, was Aurajokiranta. The momentary maximum temperature range, 4.1 ˚C, was measured on the 9th of September at 03.30, when the warmest site, 13.5 ˚C, was Kuuvuori and the coldest site, 9.4 ˚C, was Aurajokiranta. The difference may be mostly explained by the inversion and related cold air pooling.

The explanatory power of the regression model for the monthly average temperatures is 0.648. Of the explanatory variables, land cover and water bodies were statistically significant

Table 35. The regression model for the monthly average temperatures in September 2021.

R Square	0.663	
Adjusted R Square	0.648	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_1000m	0.772	<0.001
tkuwaters_500m	0.627	<0.001
relelev_300m	0.128	0.084

Table 36. The regression model for the monthly averages of daily minimum temperatures in September 2021.

R Square	0.616	
Adjusted R Square	0.599	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_100m	0.639	<0.001
tkuwaters_2km	0.633	<0.001
relelev_500m	0.253	0.002

Table 37. The regression model for the monthly averages of daily maximum temperatures in September 2021.

R Square	0.237	
Adjusted R Square	0.203	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_200m	0.453	<0.001
tkuwaters_2kmsqrt	-0.067	0.562
relelev_500m	-0.124	0.254

Table 38. The regression model for the momentary maximum temperature range of September 2021.

R Square	0.754	
Adjusted R Square	0.743	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_700m	0.635	<0.001
tkuwaters_2km	0.801	<0.001
relelev_500m	0.330	<0.001

(Table 35). They both had a warming effect, and the effect of land cover was stronger. In the regression model for the average daily minima, the explanatory power is 0.599 and all explanatory variables were statistically significant (Table 36). All of them had a warming effect. The effect of land cover was strongest and that of elevation the weakest. In the regression model of the average daily maxima, the explanatory power is 0.203. Of the explanatory variables, only the land cover was statistically significant (Table 37). It had a slight warming effect. For the momentary maximum temperature range, the explanatory power is 0.743 and all explanatory variables were statistically significant and their impact was warming (Table 38). The water bodies had the strongest and elevation the weakest effect.

In the monthly average temperature map, the coastal area is the warmest (Figure 45). The Turku city centre is also warmer than its rural surroundings. The rest of the land areas are cooler, but weak UHIs of some residential areas are detectable. In the monthly averages of daily minimum temperature map, the coast is warm and the inland areas are cool. A weak UHI in the Turku city centre is also detectable. In the map on the average daily maxima, the land areas are the warmest, and therein the densely built residential areas and main roads appear as warmest. The coastlines in the maximum temperature range map seem to be the warmest and the inland areas the coolest. The effect of the limestone quarry is also visible and has been marked in black in the map. The lowest temperature outside the quarry is 0.96 ˚C.

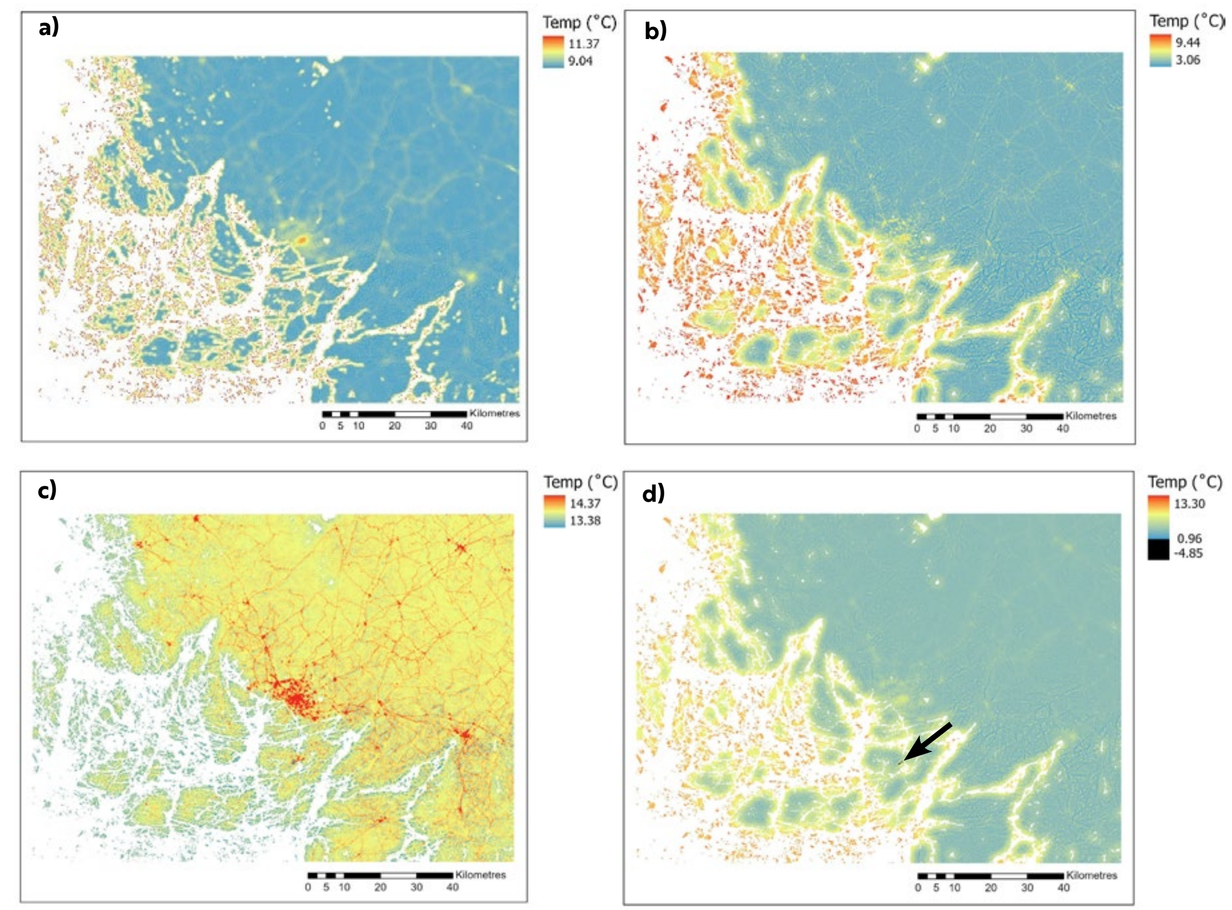

Figure 45. High-resolution (100 m) temperatures based on linear regression model depicting September 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on September 7th, 2021, at 05.30. The abnormally low temperature area in the limestone quarry located in Parainen is marked in black (arrow).

During the momentary maximum temperature range, Turku was on the northwestern side of high-pressure, whose centre was in Ukraine (Figure 46). Low-pressure centres lay in the Novaya Zemlya region in northern Russia and on the eastern side of Greenland. The 500 hPa pressure surface height was around 560–564 decametres. The map is time-stamped at 06.00 UTC. At the time of the Student Village momentary maximum temperature range, the high- and low-pressures appeared approximately in the same locations as at the time of maximum momentary temperature range of the Turku area as a whole (Figure 47). The 500 hPa pressure surface height is around 568–572 decametres and the map's time stamp is 00.00 UTC. The average wind speed was 0.25 m/s and cloudiness 7.75 on the 7th of September at 05.30. On the 9th at 03.30, the wind speed was 1 m/s and cloudiness 2.25 on average.

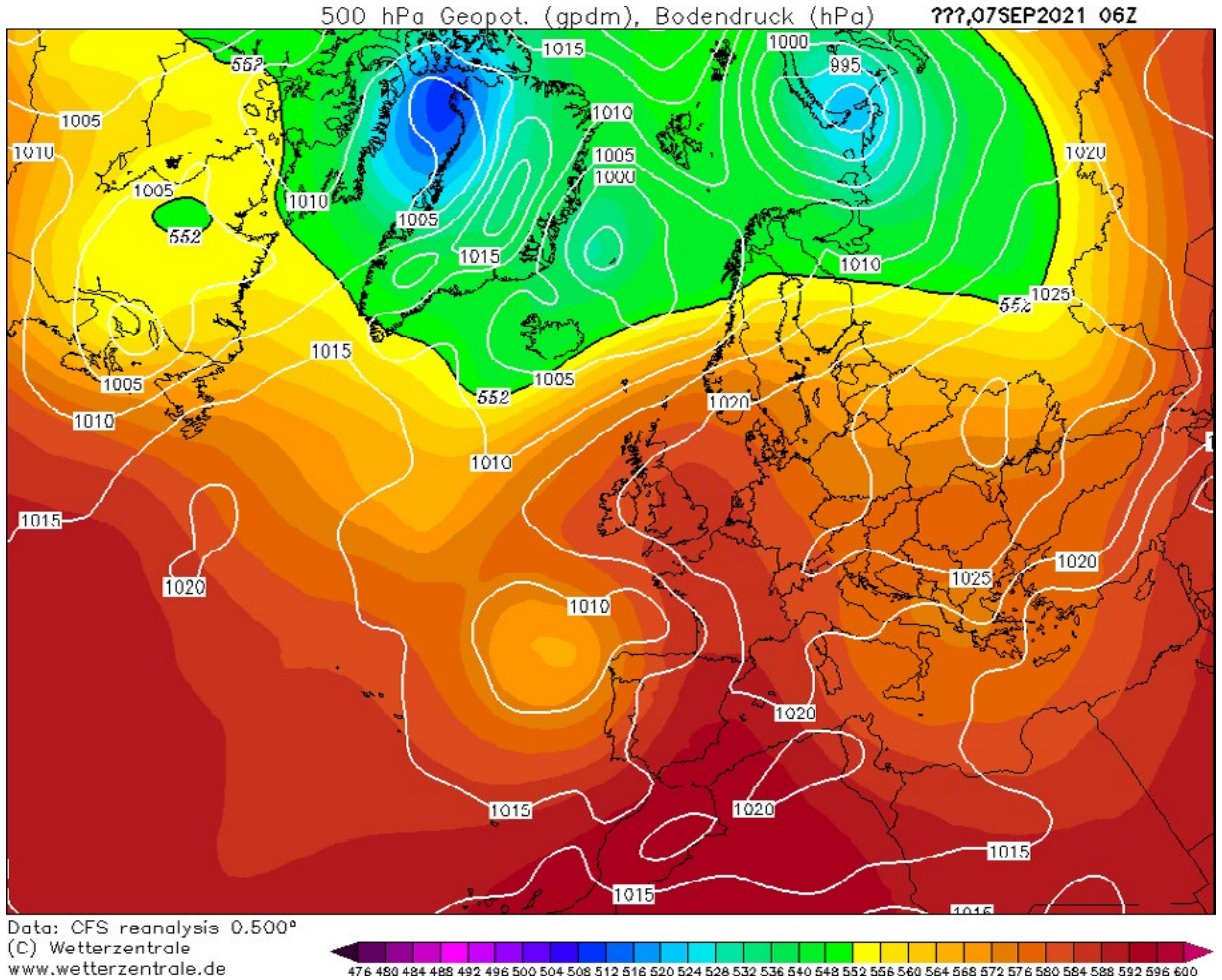

Figure 46. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for September 7th at 06.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

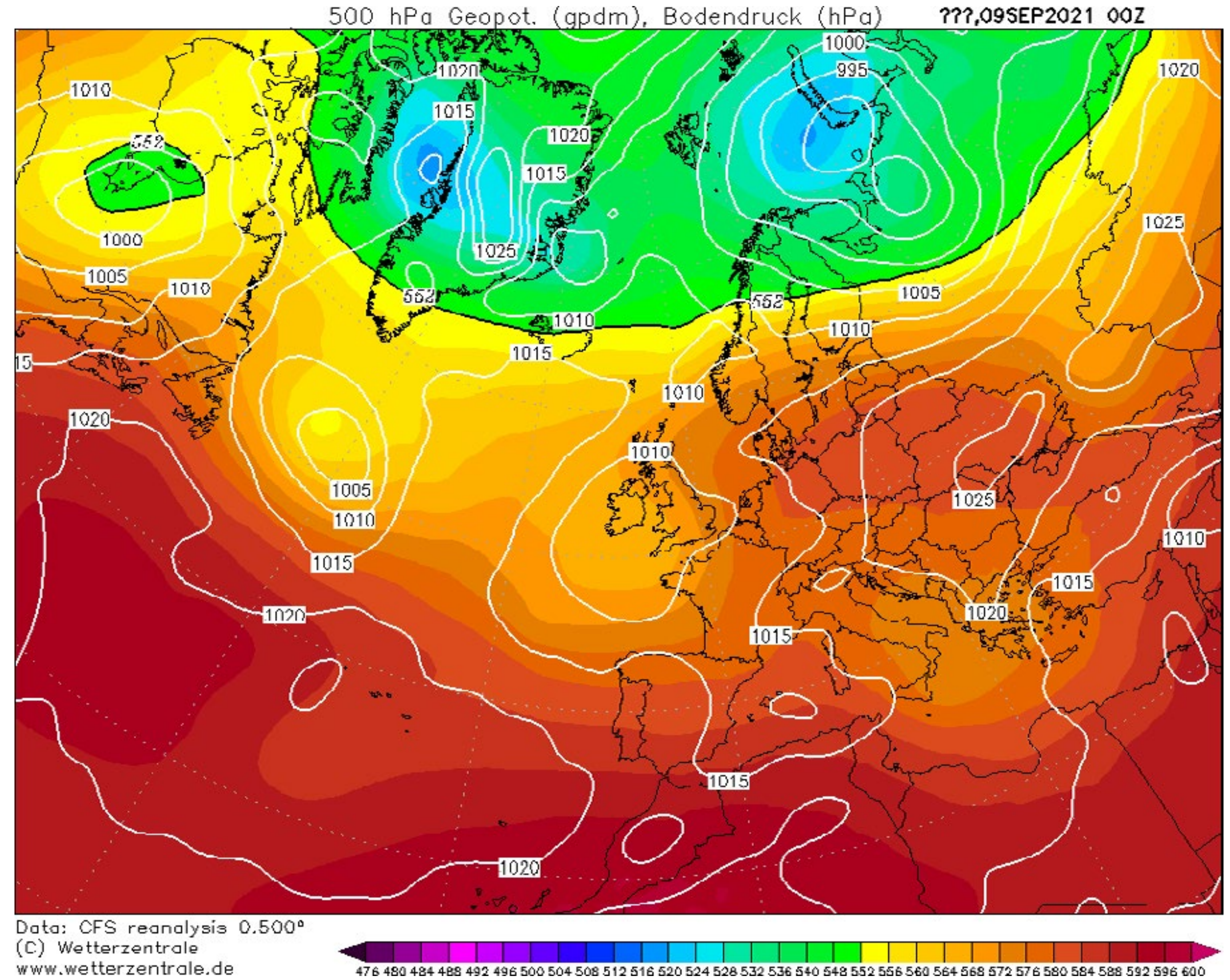

Figure 47. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for September 9th at 00.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

4.1.10 October

In October 2021, the average temperature at the Turku airport was 8.1 ˚C, whereas during the climate period 1991–2020 it was 5.7 ˚C, meaning that October 2021 was 2.4 ˚C warmer than average (Jokinen et al., 2021).

Regarding the TURCLIM observation network, in October 2021 the highest and lowest monthly average temperatures were measured in Kauppatori and Sikilä (Figure 48). In Kauppatori, the average temperature was 9.1 ˚C, whereas in Sikilä it was 7.8 ˚C. The highest and lowest monthly averages of daily minimum temperatures were measured in Kolkka (7.2 ˚C) and Sikilä (5.1 ˚C). The highest and lowest monthly averages of daily maximum temperatures were measured in Kauppatori (11.2 ˚C) and Hiiriluoto mäki (10.2 ˚C). The momentary maximum temperature range was observed between Kuuva and Ylijoki on the 14th of October at 08.30, when the temperature was 8.2 ˚C in Kuuva and -1.5 ˚C in Ylijoki, i.e., the difference between the sites was 9.7 ˚C.

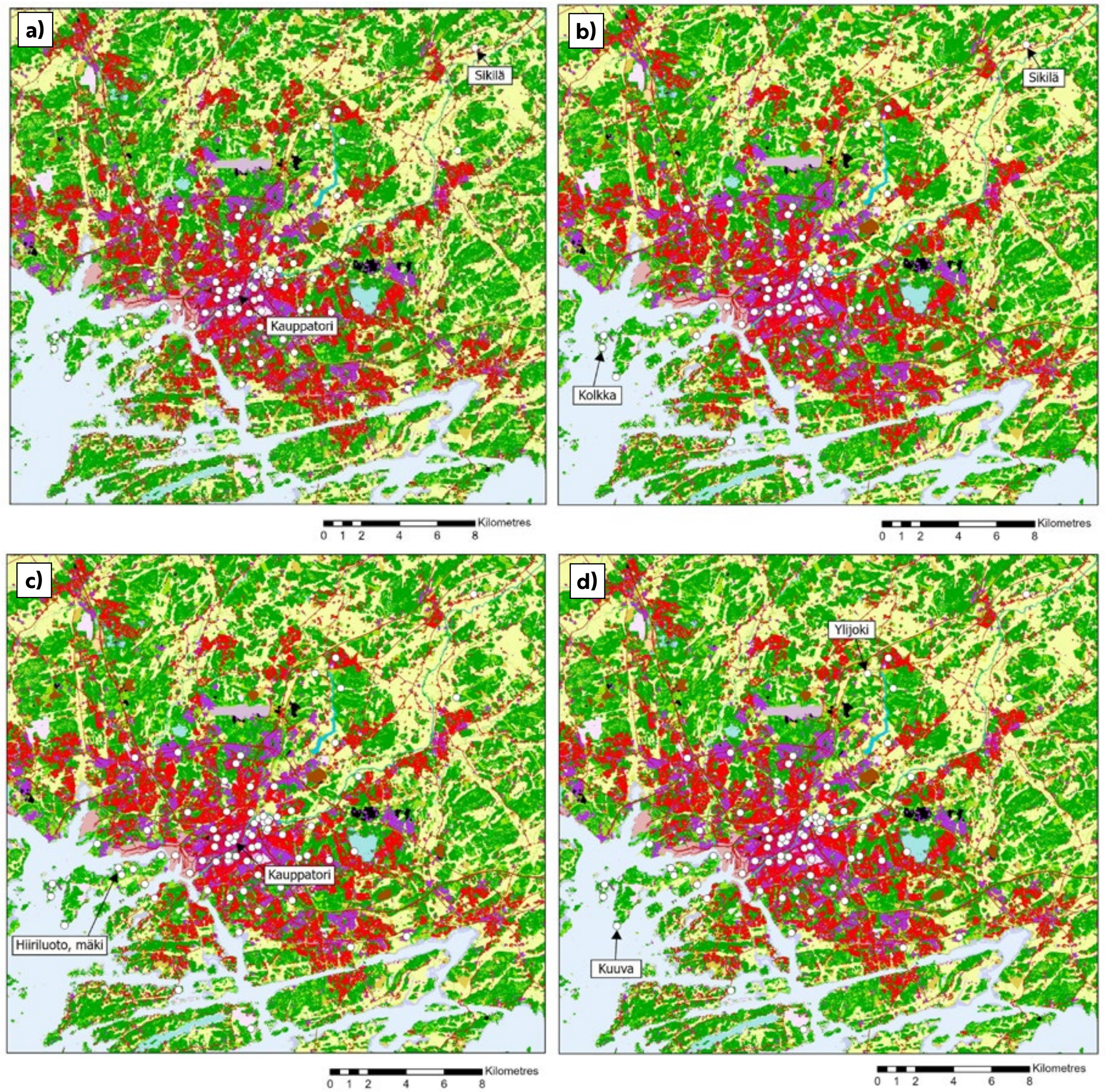

Figure 48. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kauppatori 9.1 ˚C, Sikilä 7.8 ˚C), **b)** monthly averages of daily minimum temperatures (Kolkka 7.2 ˚C, Sikilä 5.1 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori 11.2 ˚C, Hiiriluoto mäki 10.2 ˚C) and **d)** momentary maximum temperature range on October 14th at 08.30 with the difference of 9.7 ˚C (Kuuva 8.2 ˚C, Ylijoki -1.5 ˚C) on the CORINE Land Cover 2018 dataset in October 2021.

In October 2021 in the Turku Student Village area, the highest and lowest monthly average temperatures were 8.7 ˚C, measured in Pispalantie and Suntiontie, and 8.4 ˚C, measured in Aurajokiranta (Figure 49). The highest monthly average of daily minimum temperatures, 6.3 °C, was observed in Pispalantie and Kuuvuori, whereas the lowest respective temperature, 5.8 ˚C, occurred in Aurajokiranta. The highest and lowest monthly averages of daily maximum temperatures were reached in Suntiontie with an average of 10.8 ˚C and in Aurajokiranta with an average of 10.5 ˚C. The maximum temperature range occurred between Aurajokiranta and Kuuvuori on the 28th of October at 06.30, when the temperature was 6.7 °C in Kuuvuori and 1.0 °C in Aurajokiranta, resulting in a difference of 5.7 ˚C. The difference could be explained by inversion conditions and related cold air drainage.

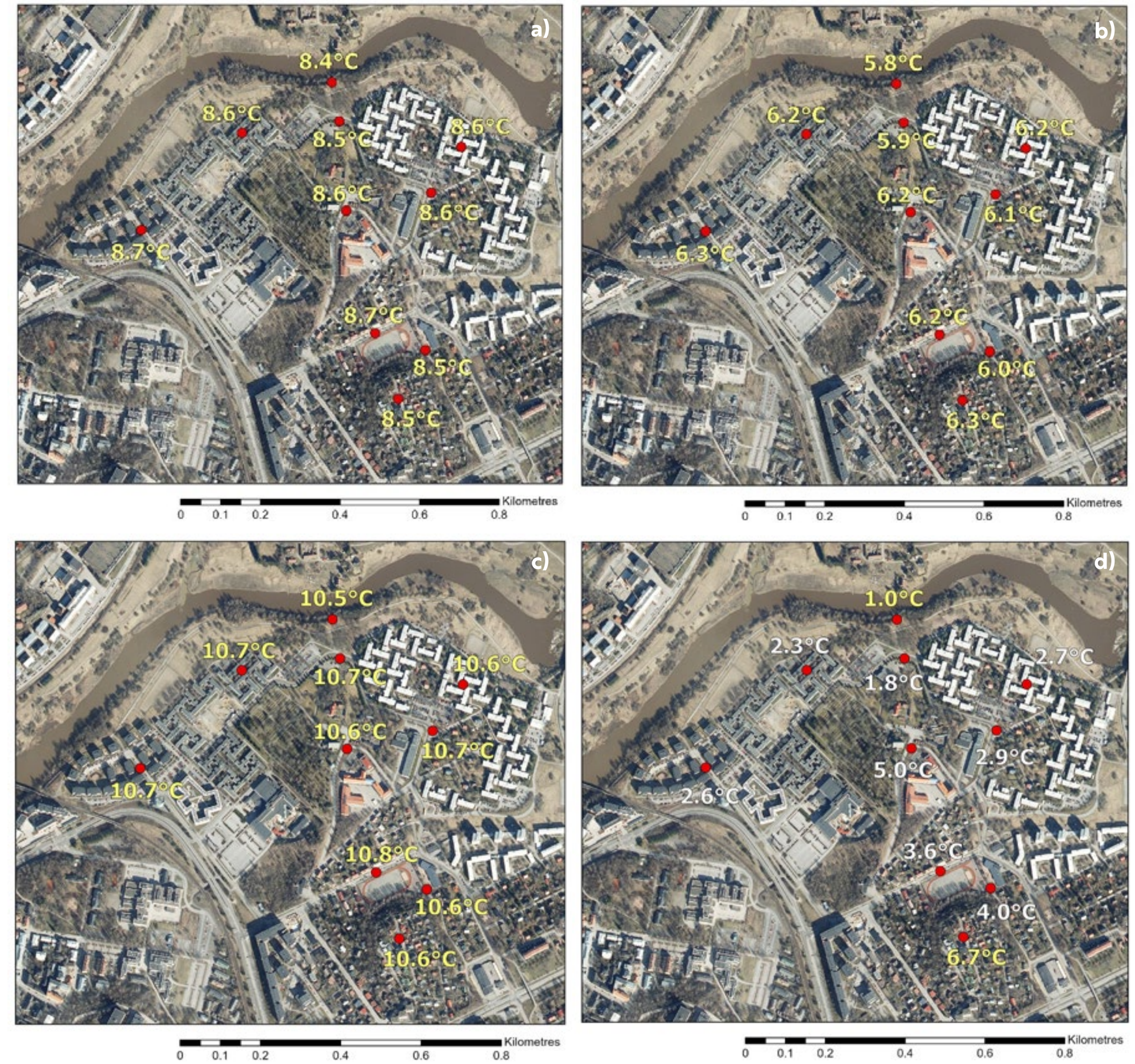

Figure 49. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on October 28th at 06.30 in 2021 with the difference of 5.7 ˚C between Kuuvuori and Aurajokiranta. For individual observation site names, see Figure 4.

Table 39. The regression model for the monthly average temperatures in October 2021.

R Square	0.597	
Adjusted R Square	0.579	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.700	<0.001
tkuwaters_500m	0.690	<0.001
relelev_100m	0.036	0.647

Table 41. The regression model for the monthly averages of daily maximum temperatures in October 2021.

R Square	0.410	
Adjusted R Square	0.383	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.645	<0.001
tkuwaters_500m	0.413	<0.001
relelev_500m	-0.232	0.016

Table 40. The regression model for the monthly averages of daily minimum temperatures in October 2021.

R Square	0.794	
Adjusted R Square	0.785	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_700m	0.813	<0.001
tkuwaters_2km	0.839	<0.001
relelev_300m	0.165	0.005

Table 42. The regression model for the momentary maximum temperature range of October 2021.

R Square	0.672	
Adjusted R Square	0.657	
Variable	Standardized Coefficients Beta	Significance
Constant		0.017
vl_3_5_100m	0.495	<0.001
tkuwaters_1500m	0.788	<0.001
relelev_300m	0.254	<0.001

The explanatory power of the regression model for the monthly average temperatures is 0.579 (Table 39). Of the explanatory variables, land cover and water bodies were statistically significant. Both had a warming effect, and that of land cover was slightly stronger. For the daily minima, the explanatory power is 0.785 and all explanatory variables are statistically significant (Table 40). The water bodies had the strongest and elevation the weakest warming effect. For the daily maxima, the explanatory power is 0.383 and all explanatory variables are statistically significant (Table 41). The land cover and water bodies had a warming effect, and that of land cover was stronger. The elevation had a cooling effect that was weaker than the warming effects of land cover and water bodies. In the case of the momentary maximum temperature range, the explanatory power is 0.657 (Table 42). All explanatory variables were statistically significant and had a warming effect. The water bodies had the strongest effect and elevation the weakest.

In the average temperature map of October, the coastal areas are the warmest, and the UHI in the city centre is also detectable (Figure 50). The other mainland areas are clearly cooler with some exceptions in the densely populated areas and in the vicinity of main roads. In the map on average daily minima, the coastal areas are warm, and the warming impact of the sea extends further inland. The densely built-up areas are also warmer than the rural areas in the mainland. In the map of average daily maxima, the lowlands seem to be the coolest and the Turku city centre the warmest. The coastal areas are warm compared to the mainland areas. The momentary maximum temperature range map seems to have a similar spatio-thermal pattern to the daily minimum temperature map, even if the absolute temperatures differ between the situations. The limestone quarry in Parainen has an effect on the momentary maximum temperature range map. The lowest temperature outside the quarry is –1.38 ˚C.

At the moment of maximum temperature variation for the Turku region, two low-pressure zones are evident: one near the coast of Norway over the Norwegian Sea, and the other southeast of Svalbard over the Barents Sea (Figure 51). A high-pressure zone is positioned over France. The 500 hPa pressure surface is located at approximately 540 decametres, with the map timestamped at 06.00 UTC. In the case of Turku Student Village in October, Turku is located on the northern side of the high-pressure that is extending to central Europe from the Caspian Sea area (Figure 52). The low-pressure centres are located in northwestern Siberia and on the southwestern side of Iceland.

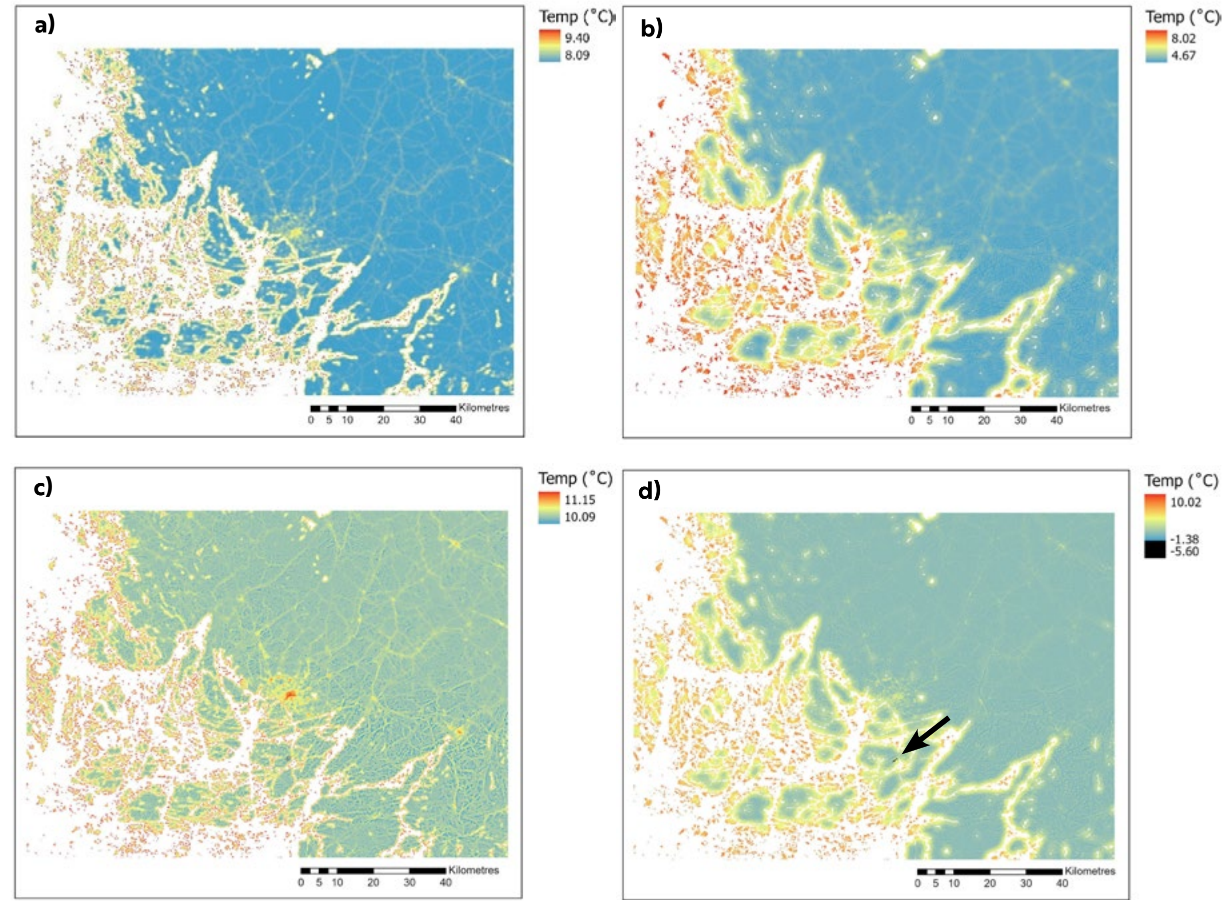

Figure 50. High-resolution (100 m) temperatures based on linear regression model depicting October 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on October 14th, 2021, at 08.30. The abnormally low temperature area in the limestone quarry located in Parainen is marked in black (arrow).

The 500 hPa pressure surface height is around 552-556 decametres. The map is timestamped at 06.00 UTC. For the Turku region on the 14th of October at 08.30, the average wind speed was 1.1 m/s and average cloudiness 0.25. On the 28th at 06.30 for the Student Village, the average wind speed was 1.375 m/s and average cloudiness 4.67.

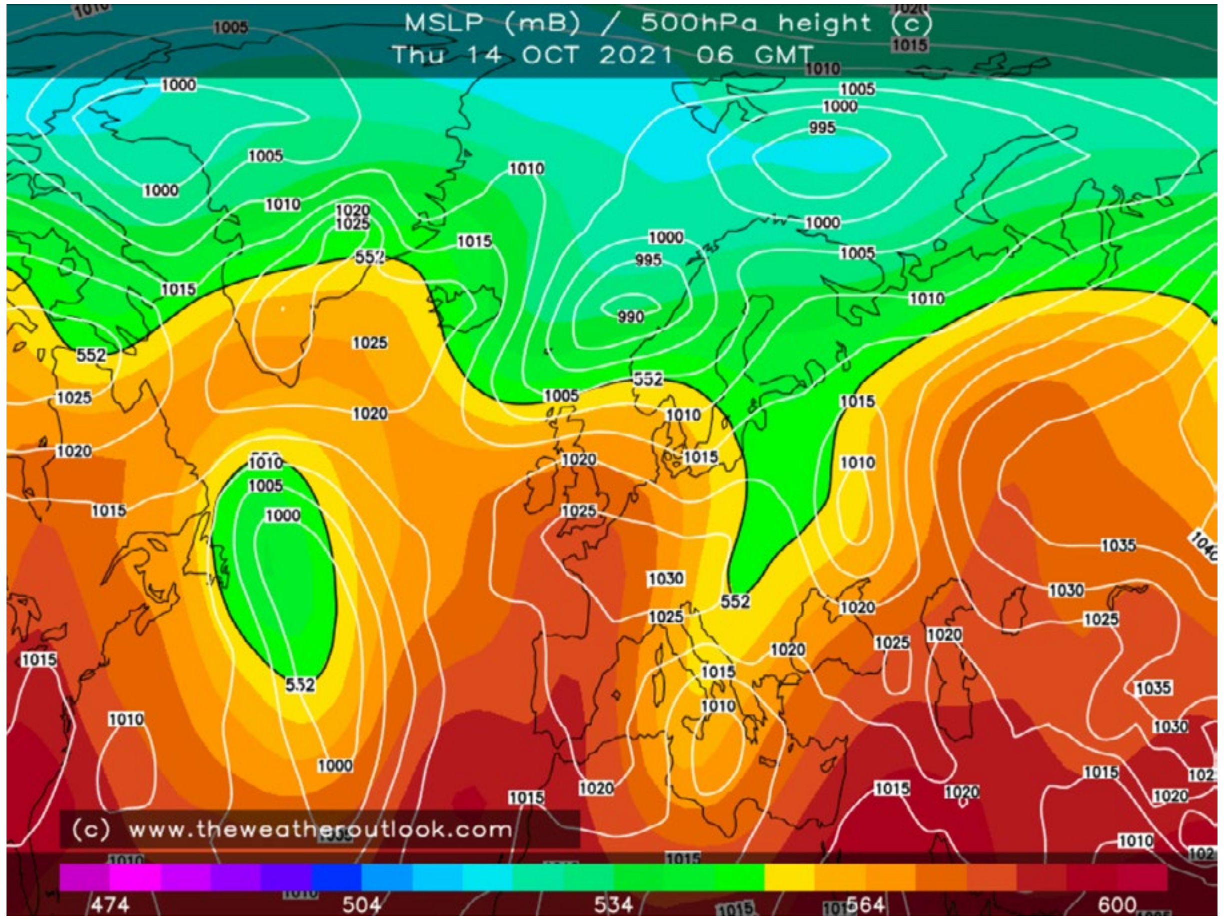

Figure 51. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for October 14th at 06.00 UTC. Retrieved from TheWeatherOutlook (https://www.theweather-outlook.com/twodata/reanalysis.aspx).

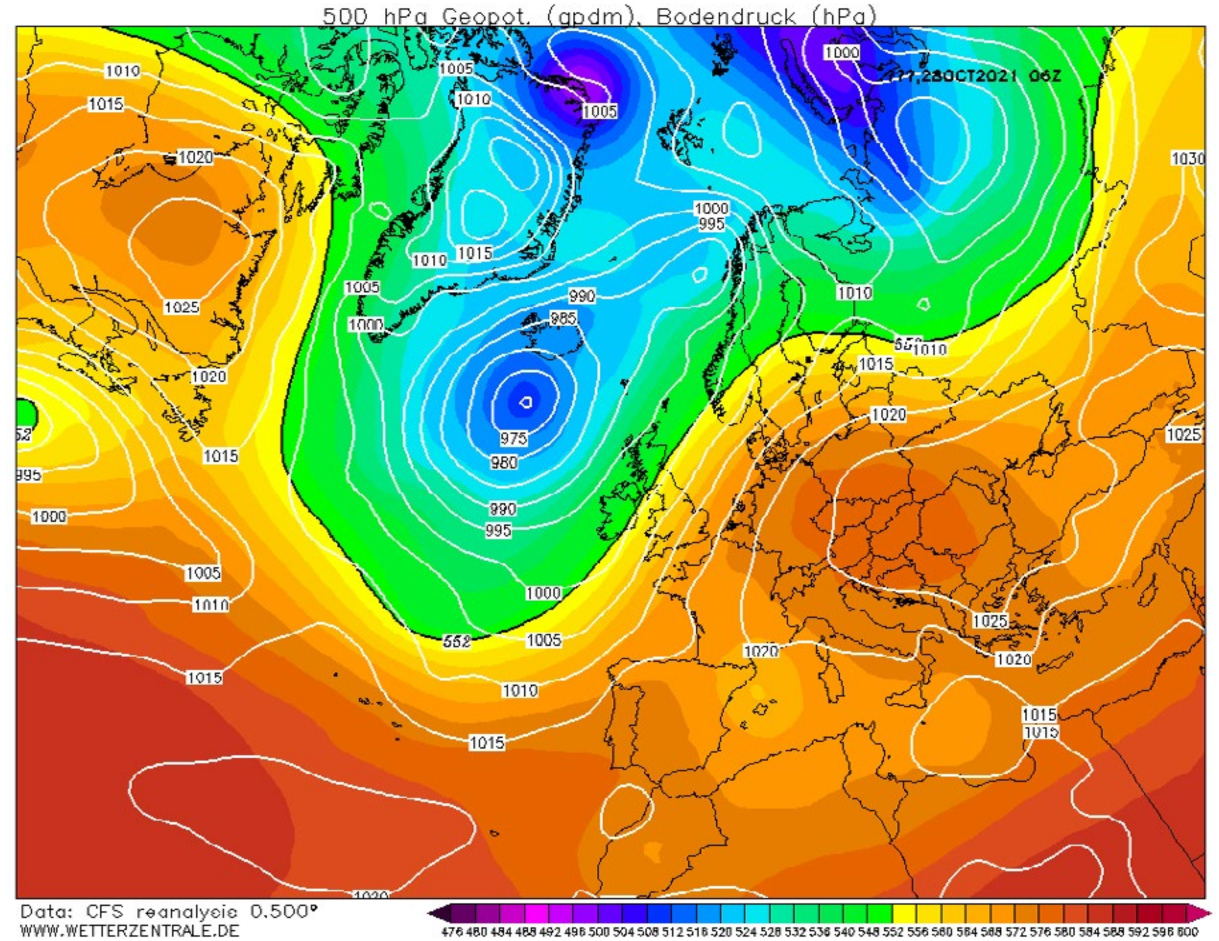

Figure 52. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for October 28th at 06.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

4.1.11 November

In November 2021, the average temperature at the Turku airport was 1.4 ˚C, whereas during the climate period 1991–2020 the respective temperature was 1.5 ˚C (Jokinen et al., 2021), i.e., November 2021 was practically normal in terms of temperature.

Regarding the TURCLIM observation network, the highest and lowest monthly average temperatures in November 2021, 2.9 ˚C and 1.0 ˚C, were measured in Kolkka and Niuskala, respectively (Figure 53). The highest monthly average of daily minimum temperatures, 0.9 ˚C, was recorded in Betel and the lowest monthly average temperature, -2.0 ˚C, in Niuskala. For the average daily maxima, Kaupatori was the warmest (5.0 ˚C) and Niuskala the coldest (3.5 ˚C). The momentary maximum temperature range, 8.5 ˚C, was measured between Kolkka and Huhkola on the 22nd of November at 09.00, when the temperature was 1.2 ˚C in Kolkka and -7.3 ˚C in Huhkola.

The highest monthly average temperature in the Turku Student Village, 2.2 ˚C,

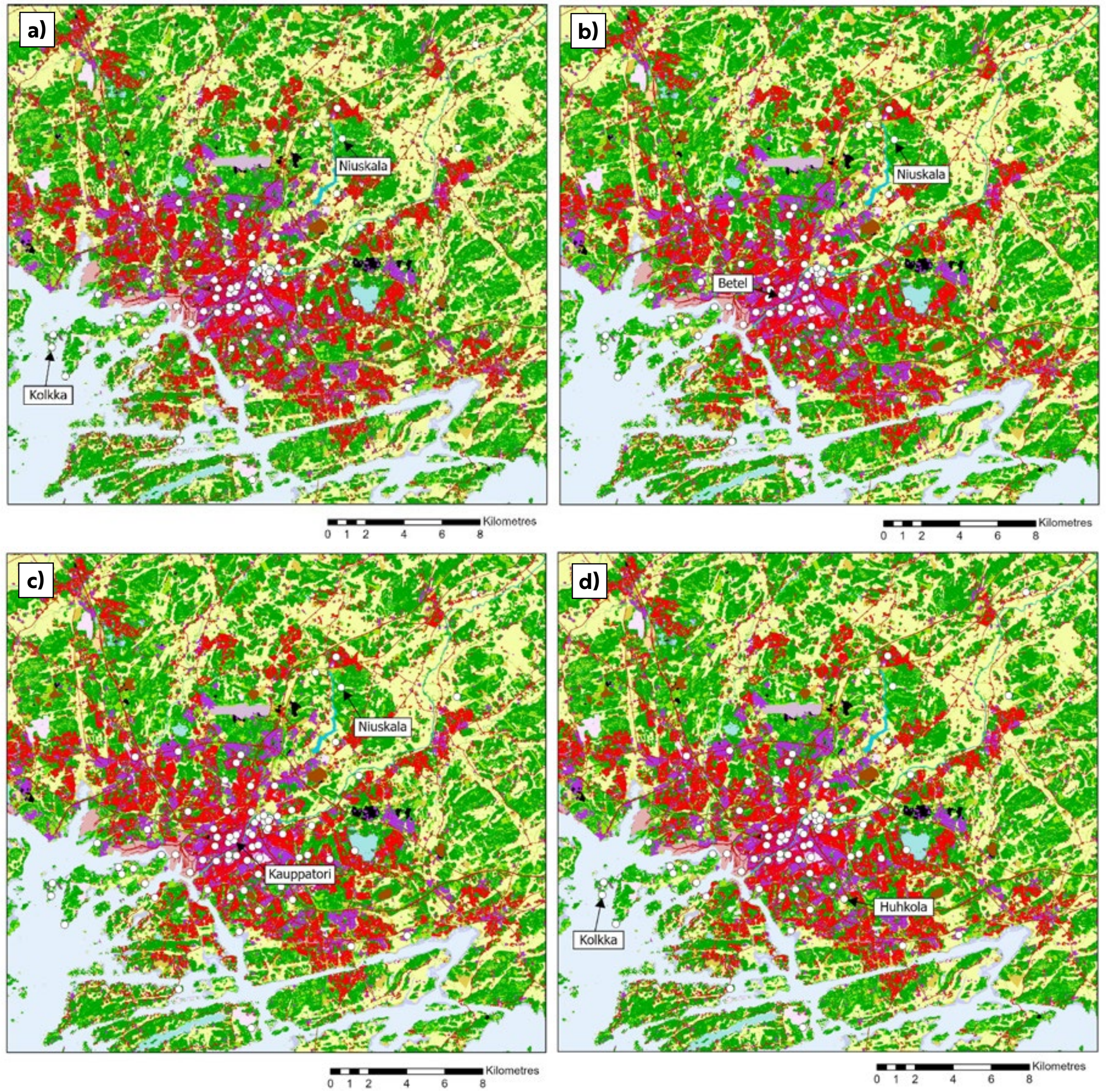

Figure 53. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kolkka 2.9 ˚C, Niuskala 1.0 ˚C), **b)** monthly averages of daily minimum temperatures (Betel 0.9 ˚C, Niuskala -2.0 ˚C), **c)** monthly averages of daily maximum temperatures (Kauppatori 5.0 ˚C, Niuskala 3.5 ˚C) and **d)** momentary maximum temperature range on November 22nd at 09.00 with the difference of 8.5 ˚C (Kolkka 1.2 ˚C, Huhkola -7.3 ˚C) on the CORINE Land Cover 2018 dataset in November 2021.

was measured in Pispalantie (Figure 54). The lowest respective temperature, 1.8 ˚C, was measured in Aurajokiranta. The lowest monthly average of daily minimum temperatures, -1.1 ˚C, was also recorded in Aurajokiranta and the highest, -0.2 ˚C, in Kuuvuori. Regarding the average daily maxima, the warmest sites, 4.5 ˚C, were Pispalantie and Suntiontie, and the coldest sites, 4.2 ˚C, Kuuvuori and Aurajokiranta. The momentary maximum temperature range occurred on the 22nd of November at 10.00, when the temperature difference between Kuuvuori and Kuikkulankatu was 5.5 ˚C, as the temperature was -0.8 ˚C in a hilltop site Kuuvuori and -6.3 ˚C in a relatively low-lying site Kuikkulankatu. Inversion conditions and topographical differences between Kuuvuori and Kuikkulankatu may explain the observed temperature difference.

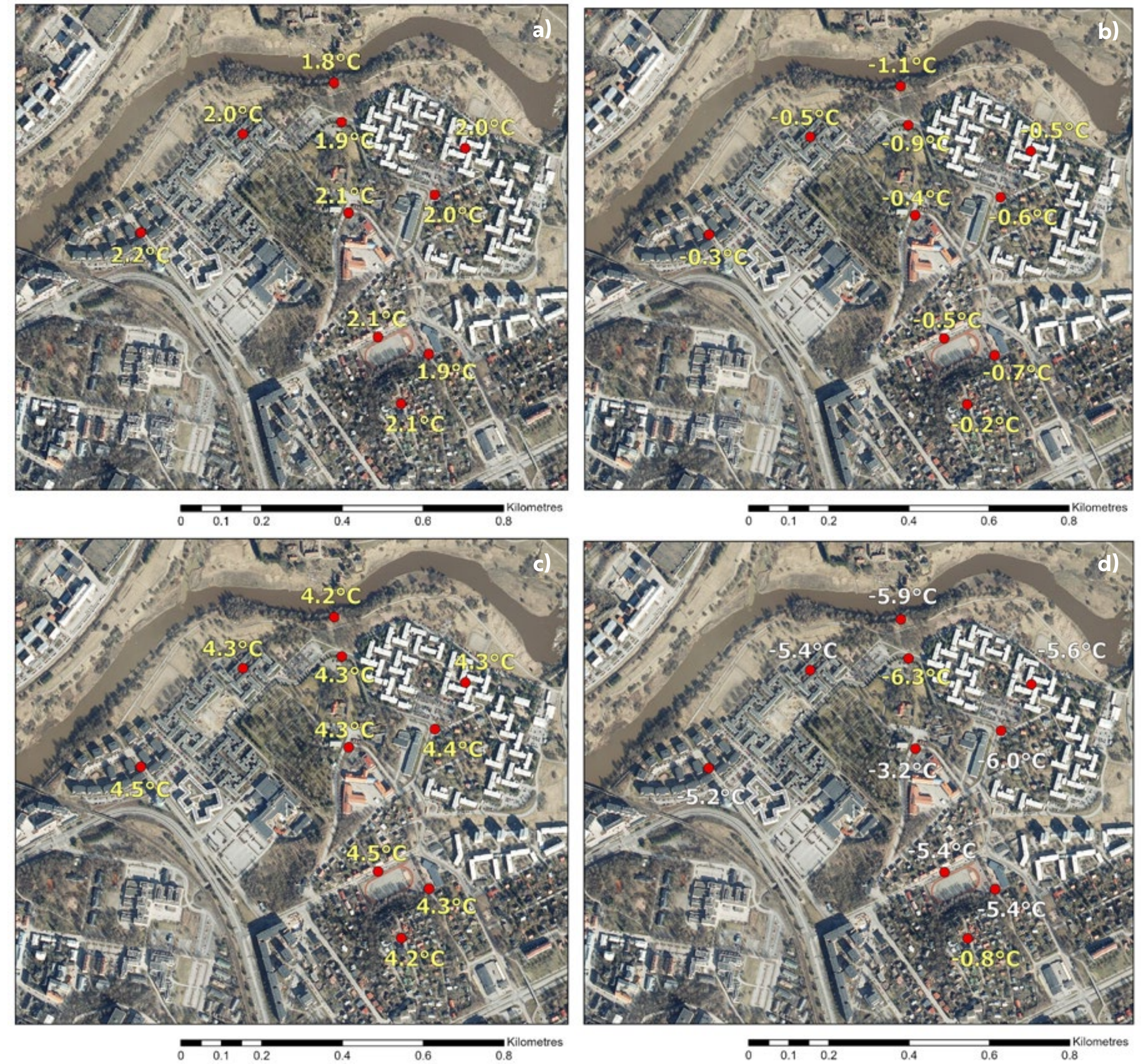

Figure 54. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on November 22nd at 10.00 in 2021 with the difference of 5.5 ˚C between Kuuvuori and Kuikkulankatu. For individual observation site names, see Figure 4.

Table 43. The regression model for the monthly average temperatures in November 2021.

R Square	0.670	
Adjusted R Square	0.655	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.698	<0.001
tkuwaters_2kmsqrt	0.790	<0.001
relelev_300m	0.101	0.161

Table 44. The regression model for the monthly averages of daily minimum temperatures in November 2021.

R Square	0.578	
Adjusted R Square	0.559	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_100m	0.546	<0.001
tkuwaters_500m	0.587	<0.001
relelev_500m	0.328	<0.001

Table 45. The regression model for the monthly averages of daily maximum temperatures in November 2021.

R Square	0.532	
Adjusted R Square	0.511	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_400m	0.626	<0.001
tkuwaters_700m	0.733	<0.001
relelev_100m	-0.056	0.512

Table 46. The regression model for the momentary maximum temperature range of November 2021.

R Square	0.644	
Adjusted R Square	0.628	
Variable	Standardized Coefficients Beta	Significance
Constant		<0.001
vl_3_5_700m	0.578	<0.001
tkuwaters_2km	0.705	<0.001
relelev_500m	0.347	<0.001

In the regression model of the monthly average temperatures, the explanatory power is 0.655. Of the explanatory variables, land cover and water bodies were statistically significant (Table 43). Both had a warming effect, and that of the water bodies was stronger. In the case of the monthly averages of daily minimum temperatures, the explanatory power of the regression model is 0.559 and all explanatory variables are statistically significant (Table 44). The water bodies had the strongest and elevation the weakest warming effect. For the average daily maxima, the explanatory power is 0.511 and the land cover and water bodies are statistically significant (Table 45). The water bodies had a stronger warming effect than the land cover. For the maximum temperature range, the explanatory power is 0.628 and all explanatory variables are statistically significant (Table 46). The water bodies had the strongest warming effect and elevation the weakest.

In the monthly average temperature map, the coastal areas and outer archipelago are the warmest (Figure 55). The warming effect of the sea extends quite far from the coastline. The UHI of the Turku city centre and a few other densely-built areas can also be detected. The map of daily maxima reminds the map of average temperature, but the effect of the warm sea does not extend as far inland as in the monthly average temperature map. The maps of average daily minima and the maximum temperature range remind each other; the low-lying valleys are the coolest and the coastal areas the warmest. The UHIs

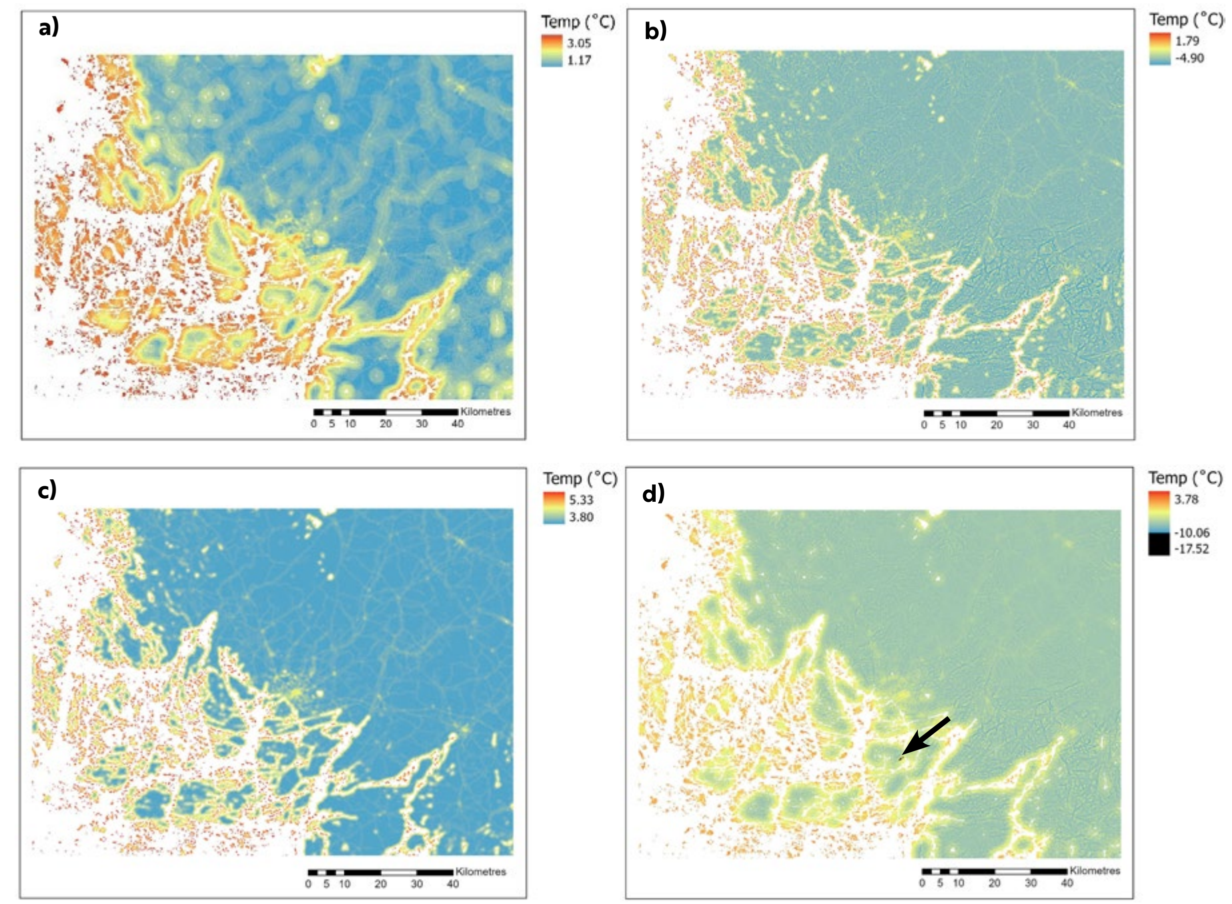

Figure 55. High-resolution (100 m) temperatures based on linear regression model depicting November 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on November 22nd, 2021, at 09.00. The abnormally low temperature area in the limestone quarry located in Parainen is marked in black (arrow).

of the Turku city centre and other densely-built areas are warmer than the sparsely-built mainland areas. The quarry's effect on the temperature range is marked in black. The lowest temperature outside the quarry is –10.06 ˚C.

At the times of momentary maximum temperature ranges in the Turku region and the Turku Student Village in November, Turku was located between the low-pressure of central Russia and a high-pressure of the Atlantic Ocean somewhat to the northwest of the British Isles (Figure 56). The 500 hPa pressure surface height is around 524-528 decametres. The map is timestamped at 06.00 UTC. On November 22nd at 09.00, the average wind speed was 1.225 m/s and average cloudiness 0. At 10.00, the wind speed was 1.8 m/s and cloudiness 0 on average.

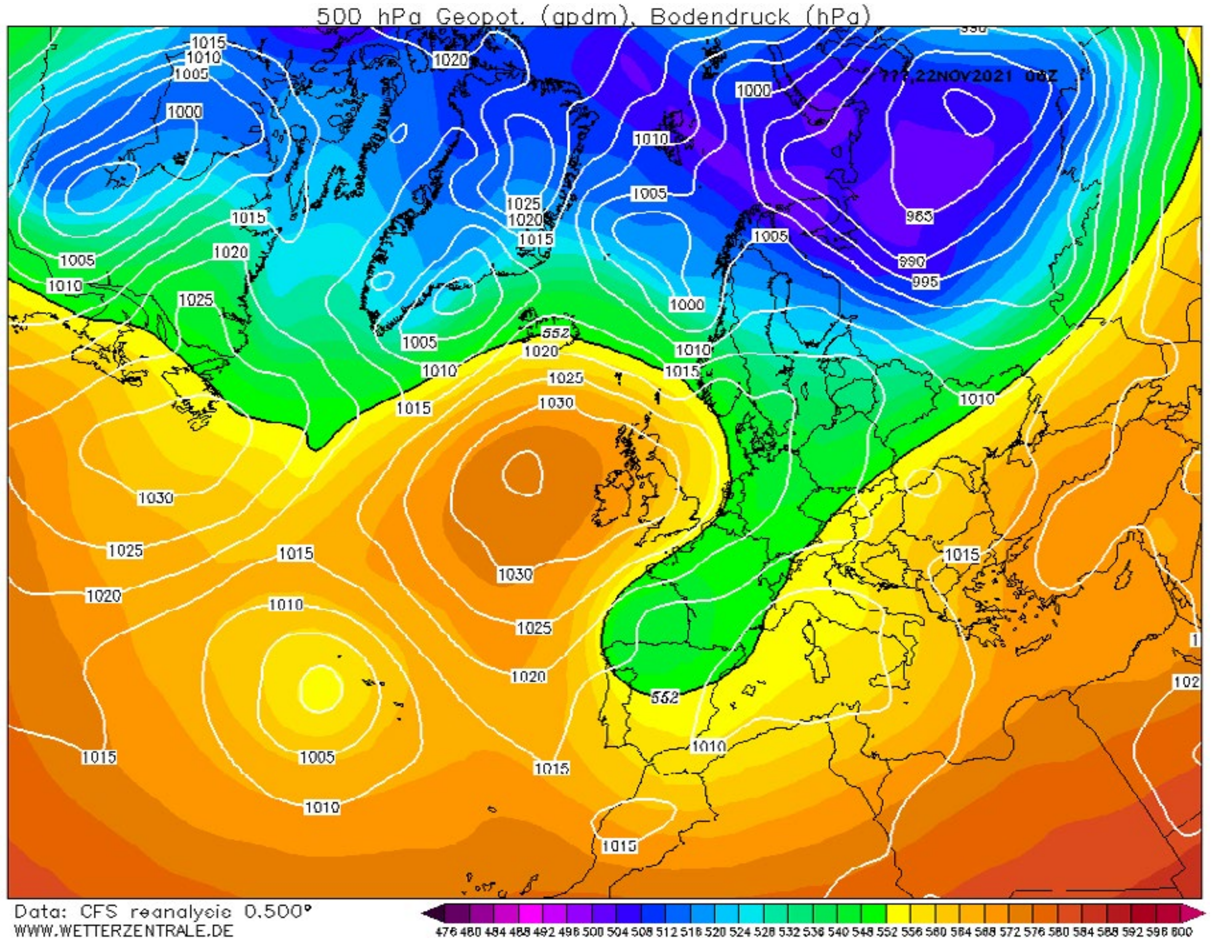

Figure 56. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for November 22nd at 06.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

4.1.12 December

December 2021 was clearly colder than average. At the Turku airport, the average temperature in 2021 was -5.9 ˚C, whereas during the climate period 1991–2020 it was -1.5 ˚C (Jokinen et al., 2021).

Regarding the TURCLIM observation network, the highest and lowest monthly average temperatures, -4.3 ˚C and -6.4 ˚C, were measured in Kuuva and Niuskala, respectively (Figure 57). The lowest monthly average of daily minimum temperatures, -9.4 ˚C, was also measured in Niuskala, and the highest respective temperature, -6.8 ˚C, was measured in Betel. The highest and lowest monthly averages for daily maximum temperatures, -1.9 ˚C and -3.4 ˚C, were measured in Kuuva and Niuskala, i.e., in the same sites as the highest and lowest monthly average temperatures. The maximum temperature range occurred between Kuuva and Ylijoki. The difference was 11.6 ˚C and it was measured on the 22nd of December at 20.00, when the temperature was -3.8 ˚C in

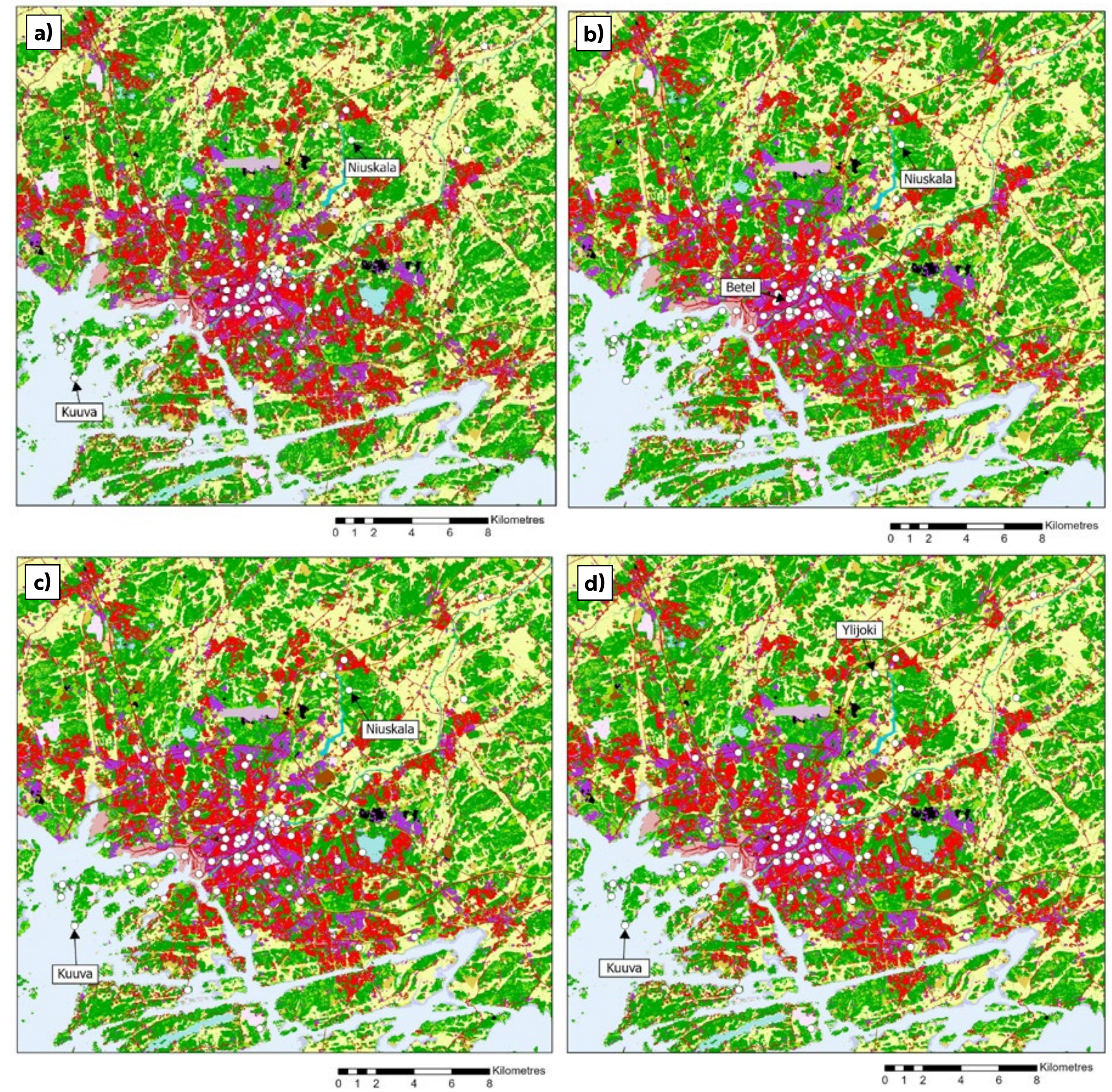

Figure 57. The locations of the observation sites of the highest and lowest **a)** monthly average temperatures (Kuuva -4.3 ˚C, Niuskala -6.4 ˚C), **b)** monthly averages of daily minimum temperatures (Betel 6.8 ˚C, Niuskala -9.4 ˚C), **c)** monthly averages of daily maximum temperatures (Kuuva -1.9 ˚C, Niuskala -3.4 ˚C) and **d)** momentary maximum temperature range on December 22nd at 20.00 with the difference of 11.6 ˚C (Kuuva -3.8 ˚C, Ylijoki -15.4 ˚C) on the CORINE Land Cover 2018 dataset in December 2021.

Kuuva and-15.4 ˚C in Ylijoki. This was the highest temperature difference recorded in the Turku region during the year 2021. The difference can be explained by the heating impact of the sea in Kuuva, which is located in the southwestern parts of the Ruissalo island. The difference was enhanced by the change in weather, as a relatively warm air mass that reached the

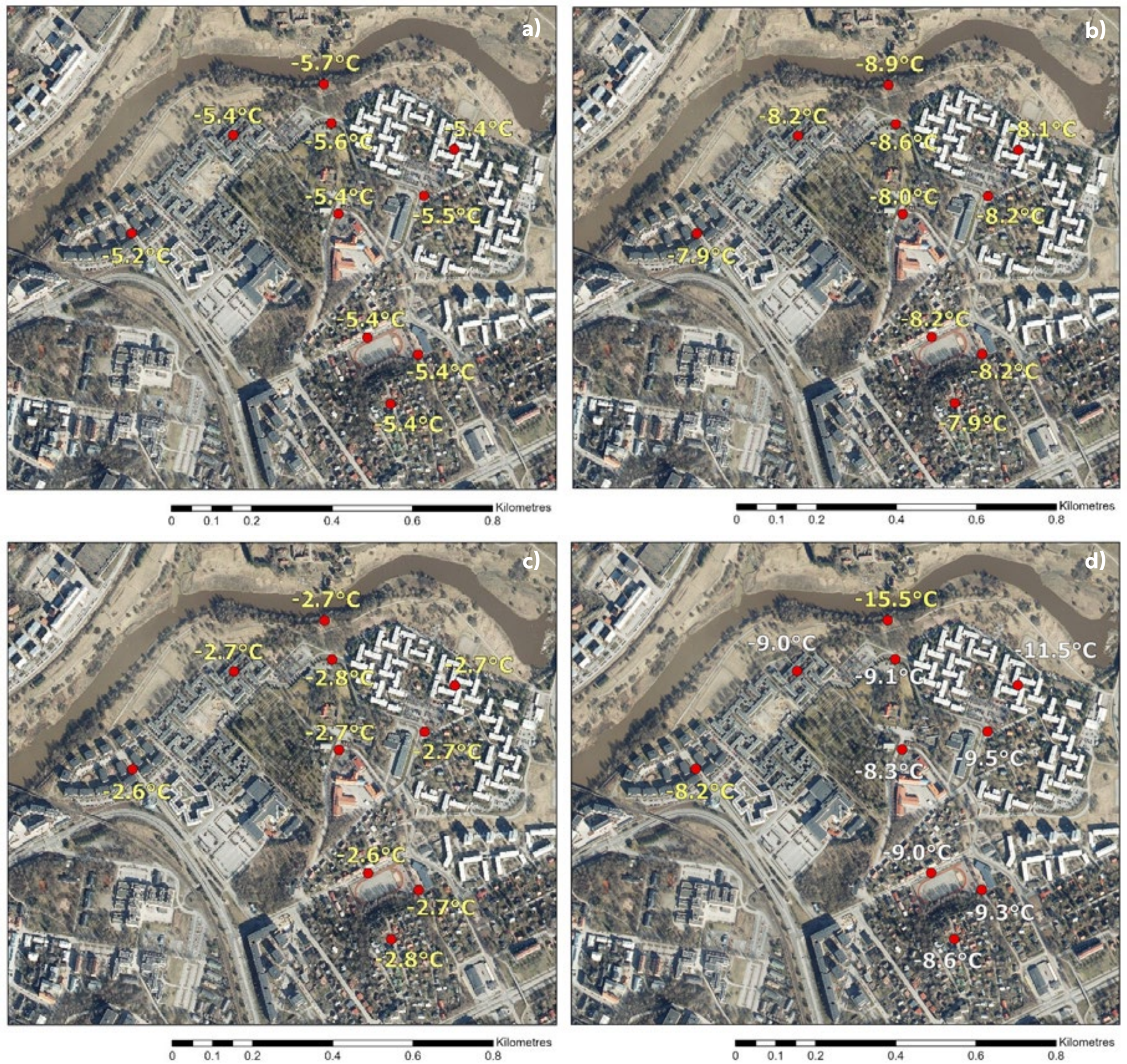

Figure 58. The Student Village observation sites with **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** the momentary maximum temperature range on December 25th at 18.00 in 2021 with the difference of 7.3 ˚C between Pispalantie and Aurajokiranta. For individual observation site names, see Figure 4.

study area from the southwest first reached the southwestern parts of the Ruissalo island. The Ylijoki site is more continental, located over 10 kilometres from the shoreline.

In the Turku Student Village area, the highest and lowest monthly average temperatures were -5.2 ˚C, measured in Pispalantie, and -5.7 ˚C, measured in Aurajokiranta (Figure 58). The highest and lowest monthly averages of daily minimum temperatures were measured in Pispalantie and Kuuvuori (-7.9 ˚C) and the lowest in Aurajokiranta (-8.9 ˚C).

Table 47. The regression model for the monthly average temperatures in December 2021.

R Square	0,808	
Adjusted R Square	0,799	
Variable	**Standardized Coefficients Beta**	**Significance**
Constant		<0.001
vl_3_5_700m	0,861	<0.001
tkuwaters_2km	0,878	<0.001
relelev_300m	0,057	0,310

Table 48. The regression model for the monthly averages of daily minimum temperatures in December 2021.

R Square	0,700	
Adjusted R Square	0,686	
Variable	**Standardized Coefficients Beta**	**Significance**
Constant		<0.001
vl_3_5_700m	0,734	<0.001
tkuwaters_500m	0,666	<0.001
relelev_300m	0,218	0,002

Table 49. The regression model for the monthly averages of daily maximum temperatures in December 2021.

R Square	0,616	
Adjusted R Square	0,598	
Variable	**Standardized Coefficients Beta**	**Significance**
Constant		<0.001
vl_3_5_400m	0,697	<0.001
tkuwaters_700m	0,759	<0.001
relelev_100m	0,006	0,937

Table 50. The regression model for the momentary maximum temperature range of December 2021.

R Square	0,730	
Adjusted R Square	0,718	
Variable	**Standardized Coefficients Beta**	**Significance**
Constant		<0.001
vl_3_5_1000m	0,668	<0.001
tkuwaters_2km	0,818	<0.001
relelev_500m	0,265	<0.001

The average daily maxima were highest, -2.6 ˚C, in Pispalantie and Suntiontie, and lowest, -2.8 ˚C, in Kuuvuori and Kuikkulankatu. The momentary maximum temperature range, 7.3 ˚C, occurred between Aurajokiranta and Pispalantie. The difference was measured on the 25th of December at 18.00, when the temperature was -8.2 °C in Pispalantie and -15.5 °C in Aurajokiranta. The warming effect of blocks of flats along Pispalantie and cold-air drainage to the low-lying river bench of the Aurajokiranta logger could explain the observed temperature difference.

The explanatory power of the regression model for the monthly average temperatures is 0.799. Of the explanatory variables, land cover and water bodies were statistically significant (Table 47). Both had a warming effect, and that of the water bodies was slightly stronger. In the case of the monthly averages of daily minimum temperatures, the explanatory power is 0.686 and all explanatory variables were statistically significant (Table 48). All had a warming effect. The impact of land cover was strongest and the impact of elevation weakest. For the average daily maxima, the explanatory power is 0.598. Of the explanatory variables, the impacts of land cover and water bodies were statistically significant and warming (Table 49). The effect of water bodies was stronger. For the momentary maximum temperature range, the explanatory power is 0.718 with all explanatory variables being statistically significant (Table 50). All had a warming effect, and the effect of water bodies was strongest and that of elevation weakest.

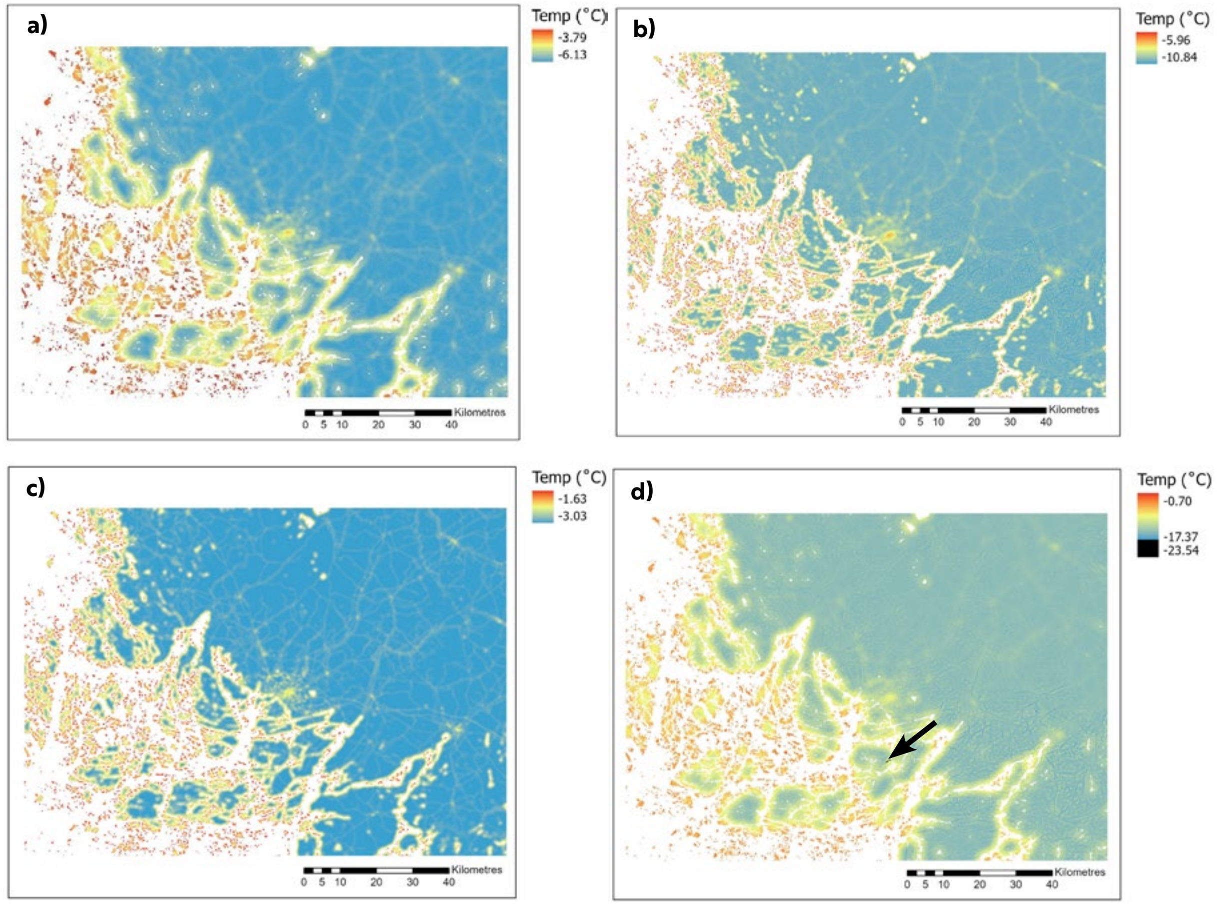

Figure 59. High-resolution (100 m) temperatures based on linear regression model depicting December 2021 **a)** monthly average temperatures, **b)** monthly averages of daily minimum temperatures, **c)** monthly averages of daily maximum temperatures and **d)** temperatures of momentary maximum temperature range on December 22[nd], 2021, at 20.00. The abnormally low temperature area in the limestone quarry located in Parainen is marked in black (arrow).

In the monthly average temperature map, the coastal zone is the warmest in addition to the city centre (Figure 59). The UHI of the Turku city centre is also detectable. The map on the average daily maximum temperatures map reminds the monthly average temperatures map, even if temperatures differ in absolute terms between the maps. The monthly averages of daily minimum temperatures map and the temperature range map also remind each other with relative coldness of low-lying sites and relative warmth of coastal areas. In the map of average daily minima, the UHI of the Turku city centre and other densely built areas can be detected. The limestone quarry in Parainen and its temperature range has been marked in black. The lowest temperature outside the quarry area is -17.37 ˚C.

In December, at the time of the momentary maximum temperature range of the Turku region, the high-pressure centre prevails in southeastern Europe and a low-pressure centre in the Barents Sea in the northeastern side of Finland (Figure 60). The 500 hPa pressure surface is at around 528-532 decametres' height. The map's timestamp is 18.00 UTC. At the time of the maximum momentary temperature range of the Turku Student Village area, the low-pressure centre lies over southeastern Finland (Figure 61). At that time, the 500 hPa pressure surface is around 496-500 decametres' height. The map is timestamped at 18.00 UTC. The wind speed was 1 m/s and cloudiness 5.25 on average on the 22[nd] at 20.00. On the 25[th] at 18.00, the wind speed was 2.475 m/s and cloudiness 0 on average.

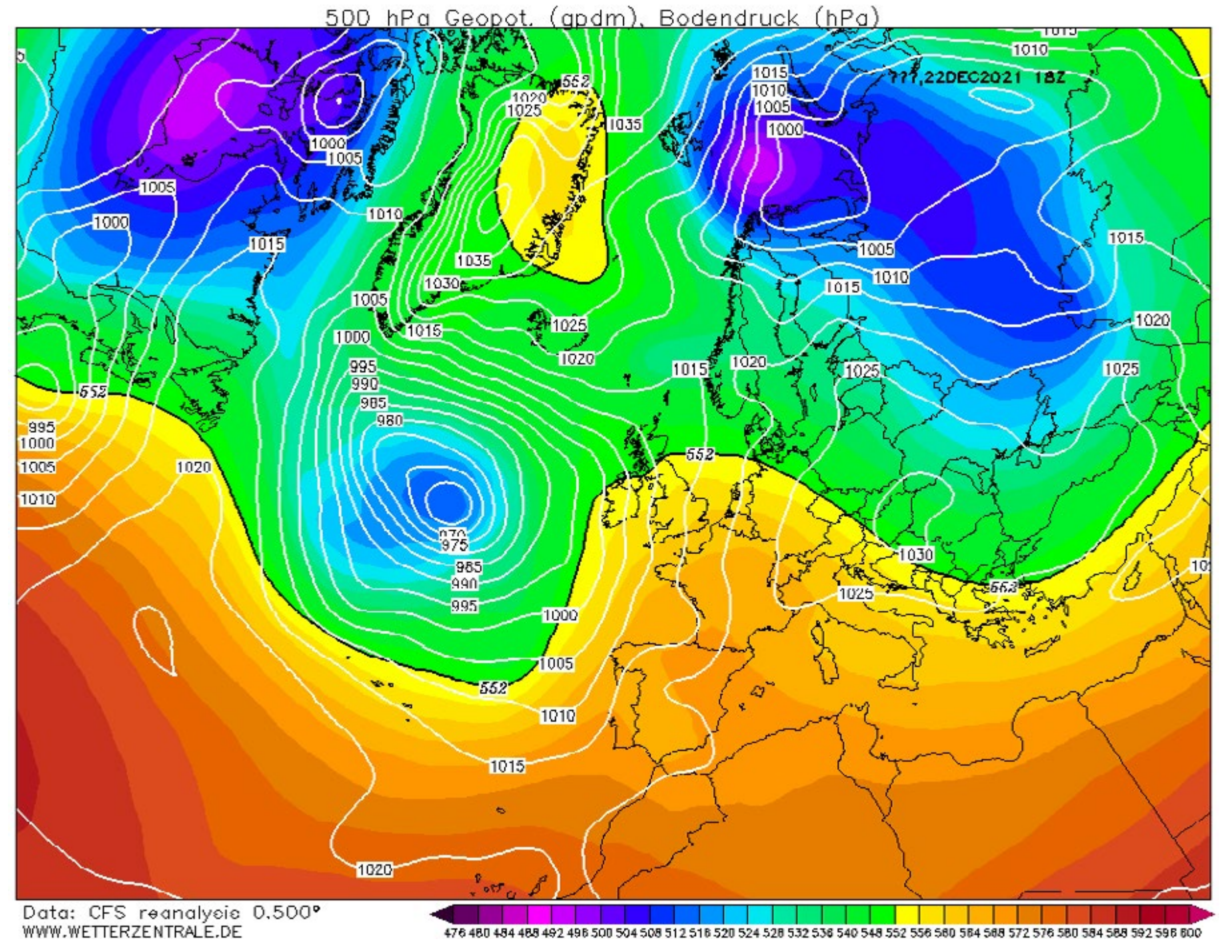

Figure 60. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for December 22nd at 18.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

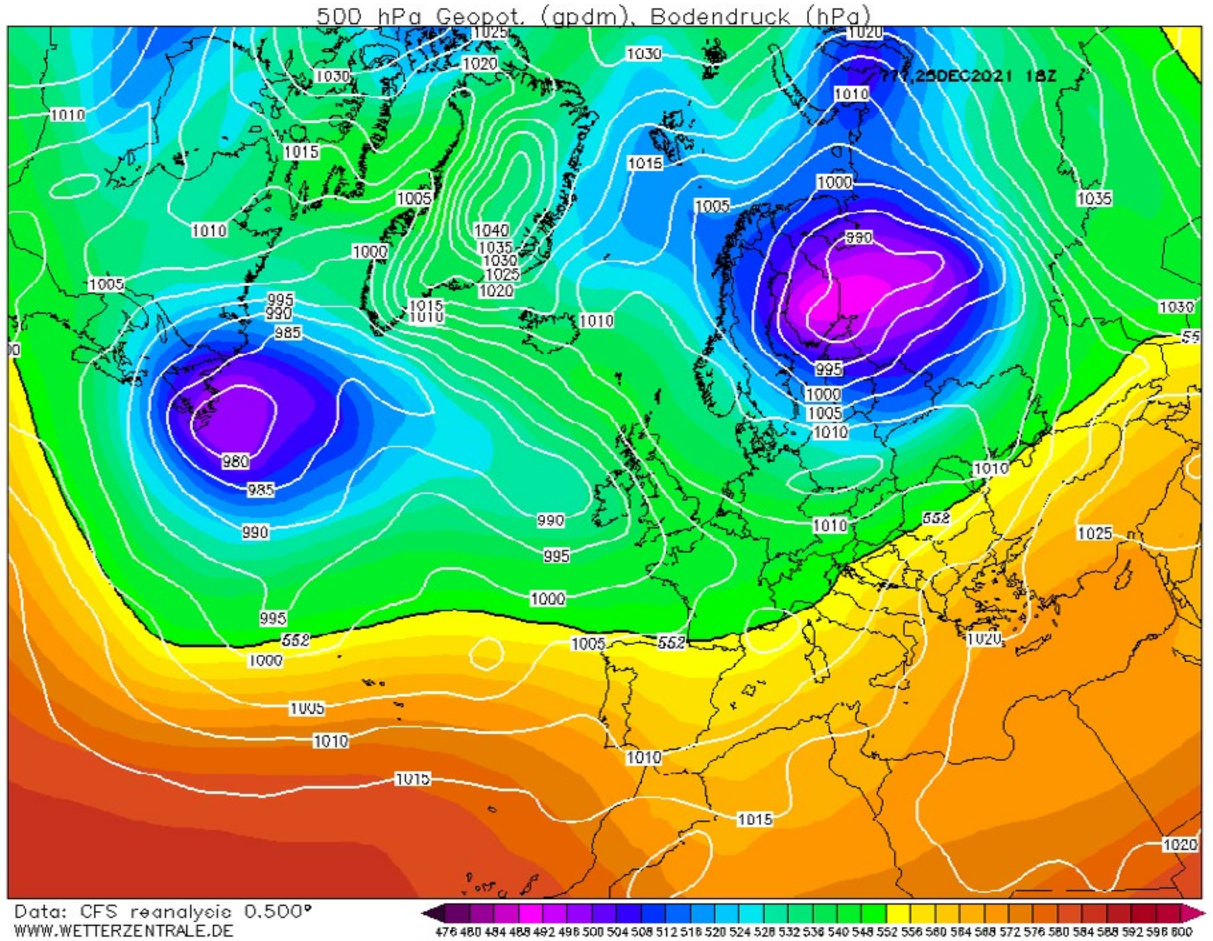

Figure 61. Sea level air pressure (white contours) and height of 500 hectopascal pressure level in decametres (colour ramp) for December 25th at 18.00 UTC. Retrieved from Wetterzentrale (https://www.wetter-zentrale.de/en/reanalysis.php?model=cfsr).

4.2 Annual overview

In the observed year 2021, a temperature difference of 1.9 °C was recorded between the sites with the highest and lowest annual average temperatures in the Turku region. The highest annual average temperature, 7.3 °C, was measured at the Kauppatori site, while the lowest, 5.4 °C, was recorded at Niuskala. Regarding annual averages of daily minimum temperatures, the lowest value of 1.0 °C was observed in Niuskala, whereas the highest, 4.1 °C, was recorded in Betel, resulting in a difference of 3.1 °C. For annual averages of daily maximum temperatures, the difference between the highest and lowest values was 1.3 °C, with Kauppatori registering the highest value at 10.7 °C and Niuskala the lowest at 9.4 °C.

In the Student Village area, the highest annual average temperature, 6.7 °C, was recorded at the Pispalantie observation site, while the lowest, 6.2 °C, was measured at Aurajokiranta, yielding a difference of 0.5 °C. The highest annual average of daily minimum temperatures was 3.0 °C in Pispalantie, whereas the lowest was 2.1 °C in Aurajokiranta, corresponding to a difference of 0.9 °C. The highest annual average of daily maximum temperatures was observed in Kuuvuori, at 10.1 °C, while the lowest occurred in Aurajokiranta, at 9.7 °C, with a difference of 0.4 °C between the sites.

5 SYNTHESIS

In the study year 2021, based on the observations at the Turku airport, February was the coldest month with an average temperature of -6.4 ˚C, whereas July was the warmest with an average temperature of 20.3 ˚C. Compared to the average temperature of the climate period 1991–2020, the largest warm anomaly occurred in June, which was 4 ˚C warmer than average. The largest cold anomaly occurred in December, which was 4.4 ˚C colder than average.

Regarding the warmest and coldest sites of the whole network, for the monthly average temperatures, the monthly averages of daily minima and maxima, and the momentary maximum temperature range, the warmest sites were often located around the city centre and the coastal areas (Tables 51–54). Especially the warmth of Kauppatori was highlighted during the summer months, but Betel, Kolkka, and Kuuva were also warmest in some months. The impact of the city on temperatures is warming throughout the year. In late autumn and winter, the sea is relatively warm, which is seen as the warmth of the coastal sites, such as Kolkka and Kuuva. On the contrary, the same sites appear as the coldest during the daytime in spring, when the sea areas are relatively cold. The rural inland sites Sikilä and Niuskala were often the coldest.

In the Turku Student Village area, Aurajokiranta was mainly the coldest site (Tables 55–58). The coldness was emphasized during the maximum spatial temperature range situations. The relatively low temperatures of Aurajokiranta could be explained by its low-lying location and related proneness to cold air drainage at the bank of the River Aura. The river bank on the site dips steeply towards the north, and related unfavourable radiative conditions may also play a role in the site's relative coldness. The Aurajokiranta site surroundings have plenty of

Table 51. Highest and lowest monthly average temperatures in the Turku region in 2021.

	Monthly average temperature				
Month	Highest temp. (˚C)	Lowest temp. (˚C)	Difference (˚C)	Highest temp. site	Lowest temp. site
January	-3.0	-4.5	1.5	Kuuva	Sikilä
February	-5.0	-7.2	2.2	Betel	Niuskala
March	1.2	-0.3	1.5	Kauppatori	Niuskala
April	5.4	3.7	1.7	Kauppatori	Niuskala
May	11.1	9.6	1.5	Kauppatori	Kuuva
June	20.1	17.6	2.5	Kauppatori	Niuskala
July	22.1	19.0	3.1	Kauppatori	Niuskala
August	16.7	14.4	2.3	Kauppatori	Niuskala
September	11.1	9.0	2.1	Kauppatori	Niuskala
October	9.1	7.8	1.3	Kauppatori	Sikilä
November	2.9	1.0	1.9	Kolkka	Niuskala
December	-4.3	-6.4	2.1	Kuuva	Niuskala

Table 52. Highest and lowest monthly averages of daily minimum temperatures in the Turku region in 2021.

	Monthly averages of daily minimums				
Month	Highest temp. (˚C)	Lowest temp. (˚C)	Difference (˚C)	Highest temp. site	Lowest temp. site
January	-5.0	-7.0	2.0	Kuuva	Sikilä
February	-8.4	-11.9	3.5	Betel	Niuskala
March	-1.7	-4.4	2.7	Betel	Niuskala
April	1.5	-1.5	3.0	Betel	Niuskala
May	6.8	3.6	3.2	Betel	Niuskala
June	15.0	10.9	4.1	Betel	Sikilä
July	17.0	12.4	4.6	Betel	Niuskala
August	13.6	10.4	3.2	Kuuva	Ylijoki
September	8.3	5.0	3.3	Kuuva	Niuskala
October	7.2	5.1	2.1	Kolkka	Sikilä
November	0.9	-2.0	2.9	Betel	Niuskala
December	-6.8	-9.4	2.6	Betel	Niuskala

Table 53. Highest and lowest monthly averages of daily maximum temperatures in the Turku region in 2021.

	Monthly averages of daily maximums				
Month	Highest temp. (˚C)	Lowest temp. (˚C)	Difference (˚C)	Highest temp. site	Lowest temp. site
January	-1.1	-2.3	1.2	Kuuva	Sikilä
February	-1.7	-3.3	1.6	Kauppatori	Sikilä
March	4.6	3.1	1.5	Kauppatori	Kolkka
April	9.5	7.8	1.7	Kauppatori	Kolkka
May	15.5	13.4	2.1	Kauppatori	Kolkka
June	24.8	22.1	2.7	Kauppatori	Kolkka
July	26.6	24.3	2.3	Kauppatori	Niuskala
August	20.6	18.3	2.3	Kauppatori	Niuskala
September	14.8	13.1	1.7	Kauppatori	Niuskala
October	11.2	10.2	1.0	Kauppatori	Hiiriluoto, mäki
November	5.0	3.5	1.5	Kauppatori	Niuskala
December	-1.9	-3.4	1.5	Kuuva	Niuskala

Table 54. Highest and lowest temperatures of month-specific momentary maximum temperature ranges in the Turku region in 2021.

		Momentary maximum temperature range				
Month	Date and time (GMT+2)	Highest temp. (˚C)	Lowest temp. (˚C)	Difference (˚C)	Highest temp. site	Lowest temp. site
January	31st, 22.00	-7.4	-17.7	10.3	Kuuva	Sikilä
February	13th, 00.30	-3.9	-14.6	10.7	Aurajokilaakso	Kolkka
March	26th, 14.30	11.3	1.8	9.5	Kauppatori	Kuuva
April	19th, 16.00	17.8	9.0	8.8	Betel	Kuuva
May	13th, 16.00	27.4	19.0	8.4	Pääskyvuori WS	Sikilä
June	7th, 15.00	26.9	16.6	10.3	Kuuva	Valkiasvuori
July	20th, 05.00	17.2	8.1	9.1	Kuuva	Niuskala
August	4th, 04.30	14.6	5.4	9.2	Kolkka	Ylijoki
September	7th, 05.30	11.5	2.7	8.8	Kuuva	Ylijoki
October	14th, 08.30	8.2	-1.5	9.7	Kuuva	Ylijoki
November	22nd, 09.00	1.2	-7.3	8.5	Kolkka	Huhkola
December	22nd, 20.00	-3.8	-15.4	11.6	Kuuva	Ylijoki

Table 55. Highest and lowest monthly average temperatures in the Student Village in 2021. In the cases in which multiple observation sites are either warmest or coldest with 0.1 °C accuracy, the warmest or coldest site, determined by multiple decimal accuracy, is reported. This pattern is followed in this Table and Tables 56–58.

	Monthly average temperature				
Month	Highest temp. (°C)	Lowest temp. (°C)	Difference (°C)	Highest temp. site	Lowest temp. site
January	-3.6	-3.9	0.3	Pispalantie	Kuuvuori
February	-5.8	-6.4	0.6	Pispalantie	Aurajokiranta
March	0.7	0.3	0.4	Pispalantie	Aurajokiranta
April	4.8	4.4	0.4	Suntiontie	Aurajokiranta
May	10.6	10.1	0.5	Yo-kylä itä	Aurajokiranta
June	19.3	18.4	0.9	Pispalantie	Aurajokiranta
July	21.4	20.4	1.0	Yo-kylä itä	Aurajokiranta
August	16.0	15.3	0.7	Pispalantie	Aurajokiranta
September	10.4	9.7	0.7	Pispalantie	Aurajokiranta
October	8.7	8.4	0.3	Pispalantie	Aurajokiranta
November	2.2	1.8	0.4	Pispalantie	Aurajokiranta
December	-5.2	-5.7	0.5	Pispalantie	Aurajokiranta

Table 56. Highest and lowest monthly averages of daily minimum temperatures in the Student Village in 2021.

	Monthly averages of daily minimums				
Month	Highest temp. (°C)	Lowest temp. (°C)	Difference (°C)	Highest temp. site	Lowest temp. site
January	-5.9	-6.3	0.4	Pispalantie	Kuikkulankatu
February	-9.8	-11.2	1.4	Kuuvuori	Aurajokiranta
March	-2.5	-3.4	0.9	Pispalantie	Aurajokiranta
April	0.5	-0.3	0.8	Pispalantie	Aurajokiranta
May	5.9	4.9	1.0	Pispalantie	Aurajokiranta
June	13.7	12.2	1.5	Pispalantie	Aurajokiranta
July	15.7	14.4	1.3	Pispalantie	Aurajokiranta
August	12.5	11.7	0.8	Pispalantie	Aurajokiranta
September	6.9	5.9	1.0	Pispalantie	Aurajokiranta
October	6.3	5.8	0.5	Kuuvuori	Aurajokiranta
November	-0.2	-1.1	0.9	Kuuvuori	Aurajokiranta
December	-7.9	-8.9	1.0	Kuuvuori	Aurajokiranta

Table 57. Highest and lowest monthly averages of daily maximum temperatures in the Student Village in 2021.

	Monthly averages of daily maximums				
Month	Highest temp. (°C)	Lowest temp. (°C)	Difference (°C)	Highest temp. site	Lowest temp. site
January	-1.6	-1.8	0.2	Suntiontie	Kuuvuori
February	-2.2	-2.6	0.4	Suntiontie	Yo-kylä itä
March	4.1	3.7	0.4	Suntiontie	Kuuvuori kenttä
April	9.0	8.6	0.4	Suntiontie	Aurajokiranta
May	15.1	14.8	0.3	Kuuvuori	Aurajokiranta
June	24.5	23.3	1.2	Yo-kylä itä	Aurajokiranta
July	26.5	25.1	1.4	Kuuvuori	Aurajokiranta
August	19.8	18.9	0.9	Kuuvuori	Aurajokiranta
September	14.2	13.3	0.9	Kuuvuori	Aurajokiranta
October	10.8	10.5	0.3	Suntiontie	Aurajokiranta
November	4.5	4.2	0.3	Pispalantie	Kuuvuori
December	-2.6	-2.8	0.2	Pispalantie	Kuuvuori

Table 58. Highest and lowest temperatures of month-specific momentary maximum temperature ranges in the Student Village in 2021.

		Momentary maximum temperature range				
Month	Date and time (GMT+2)	Highest temp. (°C)	Lowest temp. (°C)	Difference (°C)	Highest temp. site	Lowest temp. site
January	31st, 19.30	-9.8	-14.4	4.6	Kuuvuori	Aurajokiranta
February	13th, 00.30	-5.9	-14.6	8.7	Kuuvuori	Aurajokiranta
March	5th, 03.30	-5.0	-9.9	4.9	Kuuvuori	Aurajokiranta
April	18th, 23.30	8	3.6	4.4	Kuuvuori	Aurajokiranta
May	12th, 23.30	18.4	11.7	6.7	Kirkkotie	Aurajokiranta
June	6th, 02.00	14.2	10.2	4.0	Pispalantie	Aurajokiranta
July	4th, 23.00	22.7	17.8	4.9	Pispalantie	Aurajokiranta
August	4th, 05.30	13.0	8.2	4.8	Kuuvuori	Aurajokiranta
September	9th, 03.30	13.5	9.4	4.1	Kuuvuori	Aurajokiranta
October	28th, 06.30	6.7	1.0	5.7	Kuuvuori	Aurajokiranta
November	22nd, 10.00	-0.8	-6.3	5.5	Kuuvuori	Kuikkulankatu
December	25th, 18.00	-8.2	-15.5	7.3	Pispalantie	Aurajokiranta

vegetation, which may, together with the proximity of the river, enhance evapotranspiration, which may for its part lower the sensible temperature in the area. There are neither buildings nor artificial surfaces in the vicinity of the Aurajoki site, which further supports its coldness. The warmest site in the Turku Student Village region varied depending on the month and time of the day, but rather often either Kuuvuori or Pispalantie was the warmest. Kuuvuori's warmth can mostly be explained by its hill-top location, and the site is often warmest during the inversion situations at the moments of largest spatial temperature ranges. The relative warmth of Pispalantie is probably due to the proximity of blocks of flats and related local heat release by them.

Of the explanatory variables of the month-specific regression model, the land cover and the water bodies were often statistically significant. The impact of land cover was warming throughout the year (Table 59). The impact of water bodies varied between the seasons and time of the day; in daytime in spring and summer, the impact of water bodies was cooling, whereas otherwise its impact was mostly warming. In late autumn and early winter, the warming impact of water bodies was even stronger than that of the land cover. Of the explanatory variables, elevation was rarely statistically significant, but when it was, it had a slight warming effect, indicating cold temperatures in relatively low-lying sites.

In the temperature maps produced based on the regression models, archipelago and coastal areas of the mainland appear as relatively warm areas in many cases. In spring and summer in daytime, these areas are the coldest. Both phenomena can be explained by the large specific heat capacity of water and its capability to store heat in a thick layer. As a consequence, land areas warm and cool more quickly than the water bodies, which can be seen as relative coldness of the coastal areas in daytime in spring and summer, and on the other hand, as relative warmth of the coastal areas in autumn and early winter, especially at night. The warmth of the city centre and other densely built areas can also be detected from the majority of the maps. These UHIs are due to good heat storage capacity of the buildings and other urban construction materials. The urban con-

Table 59. Monthly adjusted R square values and standardized coefficients for each statistically significant ($p \leq 0.05$) explanatory environmental variables (land cover, water bodies, elevation) of the multiple linear regression models applied for the temperature data of 2021.

		Monthly average temperature		Monthly averages of daily minimums		Monthly avergaes of daily maximums		Momentary maximum temperature range	
Month	Variable	Adjusted R Square	Standardized coefficients Beta	Adjusted R Square	Standardized coefficients Beta	Adjusted R Square	Standardized coefficients Beta	Adjusted R Square	Standardized coefficients Beta
January		0.631		0.799		0.534		0.629	
	Land cover		0.714		0.861		0.646		0.600
	Water body		0.735		0.878		0.700		0.687
	Elevation								0.332
February		0.661		0.744		0.442		0.369	
	Land cover		0.829		0.827		0.738		0.405
	Water body		0.499		0.604		0.400		0.362
	Elevation				0.259				0.400
March		0.649		0.689		0.317		0.851	
	Land cover		0.931		0.807		0.408		
	Water body		0.352		0.503		-0.247		-0.907
	Elevation				0.227				
April		0.745		0.658		0.359		0.674	
	Land cover		0.954		0.764				
	Water body		0.245		0.432		-0.477		-0.835
	Elevation				0.236				
May		0.767		0.667		0.590		0.217	
	Land cover		0.819		0.775		0.240		0.506
	Water body				0.375		-0.636		
	Elevation				0.246				
June		0.705		0.650		0.585		0.445	
	Land cover		0.818		0.779		0.228		
	Water body		0.019		0.393		-0.656		0.575
	Elevation				0.321				0.021
July		0.634		0.612		0.372		0.606	
	Land cover		0.852		0.736		0.313		0.522
	Water body		0.280		0.498		-0.403		0.746
	Elevation		0.153		0.301				0.208
August		0.596		0.602		0.259		0.665	
	Land cover		0.766		0.692		0.537		0.573
	Water body		0.552		0.597				0.653
	Elevation				0.228				0.369
September		0.648		0.599		0.203		0.743	
	Land cover		0.772		0.639		0.453		0.635
	Water body		0.627		0.633				0.801
	Elevation				0.253				0.330
October		0.579		0.785		0.383		0.657	
	Land cover		0.700		0.813		0.645		0.495
	Water body		0.690		0.839		0.413		0.788
	Elevation				0.165		-0.232		0.254
November		0.655		0.559		0.511		0.628	
	Land cover		0.698		0.546		0.626		0.578
	Water body		0.790		0.587		0.733		0.705
	Elevation				0.328				0.347
December		0.799		0.686		0.598		0.718	
	Land cover		0.861		0.734		0.697		0.668
	Water body		0.878		0.666		0.759		0.818
	Elevation				0.218				0.265

Table 60. The average wind speed and average cloudiness in the FMI's Turku Artukainen station at the times of month-specific momentary maximum temperature ranges of the Turku region and of the Turku Student Village area in 2021. The values represent the averages of previous half-an-hour observations including the observation of the time of the momentary maximum temperature range.

Turku				
Moment of maximum temp. range				
Month	**Day**	**Time**	**Average wind speed (m/s)**	**Cloudiness [1/8]**
January	31	21.30–22.00	0.425	1.75
February	13	0.00–0.30	1.95	0
March	26	14.00–14.30	3.35	0
April	19	15.30–16.00	2.225	0
May	13	15.30–16.00	4.15	1.5
June	7	14.30–15.00	3.925	7
July	20	4.30–5.00	1.775	6.75
August	4	4.00–4.30	1.1	0
September	7	5.00–5.30	0.25	7.75
October	14	8.00–8.30	1.1	0.25
November	22	8.30–9.00	1.225	0
December	22	19.30–20.00	1	5.25
Average			1.87	2.52

Student Village				
Moment of maximum temp. range				
Month	**Day**	**Time**	**Average wind speed (m/s)**	**Cloudiness [1/8]**
January	31	19.00–19.30	0.375	6.5
February	13	0.00–0.30	1.95	0
March	5	3.00–3.30	1.05	3.25
April	18	23.00–23.30	0.15	0
May	12	23.00–23.30	2.55	0
June	6	1.30–2.00	1.4	0
July	4	22.30–23.00	1.275	0
August	4	5.00–5.30	1.575	0.5
September	9	3.00–3.30	1	2.25
October	28	6.00–6.30	1.375	4.67
November	22	9.30–10.00	1.8	0
December	25	17.30–18.00	2.475	0
Average			1.41	1.43

struction materials store heat during daytime and release it during the evening and night, which slows down the cooling of the urban areas, thus promoting the formation of UHI, which is often strongest at night. Anthropogenic heat release by, for example, traffic and differences in evapotranspiration between the urban and rural areas also explain the UHI. Of the built-up areas, main roads can also be detected on most of the maps as warmer than their surroundings.

The limestone quarry located to the southwest of the Parainen city centre had, under certain circumstances, a notable local impact on the modelled temperature (cf. e.g., Figs. 7d and 11d). This was due to the depth of the quarry and related exceptionally large topographic variability of the area compared to other temperature variability of the Turku region. This was manifested as doubtfully low temperatures during inversion conditions that were rather common during the momentary maximum temperature range situations. The effect was obvious also in the daily minimum temperatures of June and July.

The land use and water bodies have a clear effect on local temperature differences in the Turku area. The water bodies principally diminish seasonal and diurnal temperature variability in the coastal areas but, on the other hand, under certain circumstances, are a crucial factor behind large spatial temperature differences. The effect of land use is mostly seen as the relative warmth of densely-built areas in the form of UHI. Societally, UHI is connected, for example, to the heat-related health risks during summertime heatwaves and, on the other hand, to the energy efficiency of the buildings.

In early and mid-winter, the largest momentary spatial temperature range situations were characterized by low-pressure located close to southern Finland and the Turku region. At the times of maximum temperature range situations of spring and early summer, the study area was affected by high-pressure in the nearby areas of southern Finland. Otherwise, during the maximum momentary temperature range situations, the study area was mostly between the low- and high-pressure centres, and the pressure gradient in the area was rather moderate. The average wind speed during the momentary maximum temperature ranges was the highest in spring and summer in the case of the Turku region and in summer and late autumn in the case of Turku Student Village. The lowest values were reached in autumn and winter in the case of the Turku region and during winter and spring in the case of Turku Student Village. For the momentary maximum temperature ranges of the whole Turku region, the July and September situations were most cloudy, whereas in the case of the Turku Student Village, the conditions were most cloudy at the times of January and October maximum ranges. The clearest conditions occurred in both cases at the times of maximum ranges of spring months. On average, the wind speed at the moments of month-specific maximum temperature ranges of the Turku region was 1.87 m/s, which was slightly higher than the respective average for the Turku Student Village, 1.41 m/s (Table 60). The cloudiness was also on average higher for the month-specific maximum temperature ranges of the whole Turku region (2.52) than for the Turku Student Village area (1.43).

Knowledge on spatial temperature differences could be increasingly utilized in urban planning. Heat-related health risks are promoted by UHI, which can be mitigated by increasing green infrastructure in urban areas. High-albedo building materials can also for their part mitigate the UHI, but on the other hand, they may increase the heating demand during winter. In winter, the information on spatial temperature differences can be used to identify areas prone to slipperiness and to estimate spatial differences in heating demand.

6
CONCLUDING REMARKS

This study systematically documented the spatio-temporal variability of temperature in the Turku region throughout 2021, utilising a dense network of T/RH loggers from the TURCLIM observation system and supplemented by large-scale atmospheric reanalysis data. The Turku city centre is locally the warmest area in the Turku region. The difference in 2021 annual average temperature between the warmest (Kauppatori) and coldest (Niuskala) sites was in the order of 1.9 °C, which happens to be same as for the longer term average (Suomi & Käyhkö, 2012; Suomi, 2014). The main factors causing spatial temperature differences are land cover, water bodies and elevation, of which the impact of land cover and water bodies are the most significant.

The main findings are summarised as follows:

- **Urban land cover** consistently exerted a warming effect on all temperature metrics studied, confirming the existence of an urban heat island in Turku under a variety of weather conditions.
- **Proximity to water bodies** demonstrated seasonally variable effects: a warming influence during cold seasons, especially on minimum temperatures, and a cooling effect during late spring and summer on daily maximum temperatures.
- **Elevation** influenced temperature variability primarily during nocturnal inversion conditions, contributing to colder temperatures at low-lying sites reflecting cold-air drainage and pooling.
- **Seasonal differences** in spatial temperature variability were evident, with the strongest spatial contrasts during winter months (for momentary temperature differences) and summer months (for all three monthly average temperature metrics).
- **Large-scale atmospheric conditions**, particularly the dominance of high-pressure systems, played a crucial role in intensifying local spatial temperature differences, especially through their impact on wind speed and cloudiness.

The results underscore the importance of fine-scale environmental heterogeneity in shaping urban and regional climates. They also highlight the need for integrated urban planning that considers the combined effects of land cover, topography, and proximity to water in mitigating urban heat stress, particularly under future climate warming scenarios.

Future research should further examine temporal dynamics using higher-frequency observations, incorporate additional environmental variables such as vegetation cover and soil moisture, and expand analyses to include extreme weather events.

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