ENVIRONMENTAL ANALYSIS OF THE GRONINGEN CITY CENTER

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TABLE OF CONTEXT

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Executive summary

Thermal comfort, climate resilient, heat stress, sustainability are topics that nowadays are notably discussed and spoken. Climate change is something real, that is outgoing and something to take care of and worry about.

From ancient history to nowadays, the importance given to this topic has gradually increased and finally, a lot of studies, articles and news speak about this topic. Climate is changing and it does not just influence to our thermal comfort but also has something to do with mortality as it is going to be shown and proved in this report.

There are so many factors to take into account when we talk about heat stress or thermal comfort such as air temperature, humidity, wind speed, material's albedo, the heat island effect, etc.

In this project, the heat stress and thermal comfort are going to be measured on the centre city of Groningen, exactly Grote Martk, since it is one of the critical points in the city. First of all, a background analysis and literature review to be aware and fully understand the problem itself in the Netherlands and all over the world. Using our own country as a reference to face heat stress, what kind of adaptations do we use, the importance of green/blue areas in a city and what benefits does it bring.

Secondly, a three layers analysis is going to be done, analysing the underground infrastructure, networks (traffic analysis, how everything is connected, etc.) and occupation (what kind of buildings and functions there are in this area and how they work together). While it is being made, we also want to know what is the people's opinion of this topic so street interviews are carried out next to Grote Markt to analyse as well their answers, and have an approach to their ideas, how they see this problem and how much do they care about it.

After being completely familiarized with the area, the problem and people's opinion, it is time to focus on the design and how it is going to affect in the result on the heat map and general temperature.

The main goal of the research is to make **people aware of this problem** and, once they are aware of it, explain how we can **adapt our urban environment** to face it. It is not a temporary problem if we do not care about it and do something about it. It is a problem which is growing day a day and acting now **may mean a huge difference in the future**.

Three proposals are done and compared between one another, taking into account public opinion, costs, maintenance, ENVImet (thermal comfort map) and design. Thus, integrating thermal comfort in our urban planning is the goal and the results are significant.

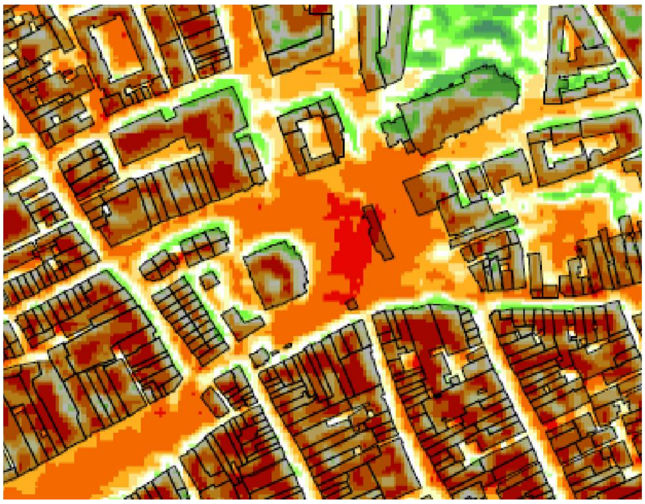
All these proposals would increase the thermal comfort in that area as it is proved in the graphs and datum. This leads to our main conclusion, which is to recommend the thermal comfort as a very important factor into our urban planning design. These might bring several advantages such as a more environmental-friendly, comfortable, attractive and, at the end, more liveable place.

1. Introduction

1.1 Background

This final thesis project is part of the research that is being carried by the Gemeente Groningen in order to make the city center more sustainable and livable. The municipality of Groningen has recently published a conceptual development plan for improving the inner-city of Groningen, this report is called "Bestemming Binnenstad 01/2016".
The main focus of this report is convert the city center to an environmental friendly downtown, reducing pollution, reroute public and private transport. The proposal gives an indication of possible green blue solutions (both design and construction details) designed to make the city center more livable and resilient resistent in order to face what will lie ahead in the future in terms of climate change.

The report lacks details on how the municipality will include the green and blue (water) improvements in the city. This is where this final thesis project will concentrate. The focus of the project is to look at the feasibility of including climate resilient options into the current plan. There are many constraints to implement green-blue solutions in the inner city. The main ones being lack of space and money. The research will investigate these issues, along with other factors.



As we can see on the right picture (heat map of Groningen), Grote Markt is one of the hottest areas from the city center, because that our research will be focus on that area, giving three different green-blue solutions for the whole area.

This three solutions will be analysis by different factors, including budget, maintenance, public opinion and 3D model.
The 3D model will be done with Revit and EnviMet.
EnviMet is a software that create a three dimensional microclimate model designed to simulate the surface plant air interactions in urban environment.
With a multi-criterial analysis including all the factors named will be choose the most successful option.

1.2 Research questions & sub questions

Main Question:

''What are the implications of including green-blue climate resilient features to the municipality of Groningen's inner-city development plan?"

To get the final answer to the main question, there are some steps that are needed to be followed. These steps are other questions (sub-questions) that can help us to have a guide and not forget anything important to being mentioned.

The sub-questions will include:

1. What are the possible green-blue options for a city like Groningen?
(Chapter 2.3; possible climate adaptations)

2. What benefit do these features give to an inner-city?
(Chapter 2.2; Benefits/Advantages to have green/blue solutions)

3. What green-blue solutions does the development plan currently include?
(Chapter 2.2; Design)

4. Which area is suitable for a more detailed study?
(Chapter 1.1; Background & Chapter 4.1; Spatial Analysis)

5. What are the alternatives for a climate resilient design for the specific urban space selected?
(Chapter 4.3; Design)

6. What are the effects of these alternatives? (we plan to use models to predict this)
(Chapter 4.4; EnviMet)

7. What are the detailed costs and benefits for the alternatives?
(Chapter 4.5.1; Budget)

8. What is the reaction from the various stakeholders to green-blue improvements based on the cost/benefit analysis? Is it worth it to invest in this area?
(Chapter 4.2; Interviews)

9. How much will cost to maintain the new green-blue possible options? Is it worth it to invest in these possible options?
(Chapter 4.5.2; Maintenance)

2 Literature review

2.1 Problem analysis

First of all there's a need to explain why heat stress and climate adaption have to be something to worry about, since, it could seem odd to talk about heat stress in a cold country such as the Netherlands.

Urban professionals understand the need for climate adaption, but they need arguments and appealing examples to convince others of the urgency to adapt to urban heat risk. In order to get the message across we read articles, reports and documentaries to give good arguments and facts.

Four terms employed extensively in this part of the report merit closer description in the form of a definition. These are the terms 'heat', 'extreme heat', 'heat stress' and 'heat strain'.

'Heat' is 'strong or excessive warmth, particularly with regard to air temperature'.

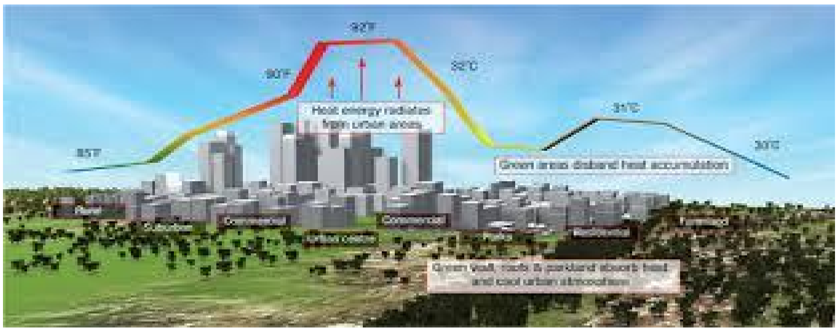
A definition of heat which uses concrete temperatures has not been found. In the Netherlands, according to the KNMI, a 'heatwave' means that the maximum temperature in De Bilt has been higher than 25ºC for at least five successive days ('summery days') and that within those five days there have been at least three days with temperatures at or above 30ºC ('tropical days').

'Extreme heat' is 'an air temperature above 36ºC (dry air) or a WBGT value greater than 28ºC'.

'Heat stress' is 'the sum of the heat generated in the body (metabolic heat) plus the heat gained from the environment (environmental heat) minus the heat lost from the body to the environment, primarily through evaporation'.

'Heat strain' is 'the bodily response to total heat stress'.

'Heat island effect' is a metropolitan area that is significantly warmer than its surrounding areas due to human activities.



According to the United States Environment Protection Agency, in a publication from 2014, for every 1 million people in a city, the temperature of the city may raise 1-3ºC compared to its surrounding areas (rural areas). Normally, the metropolitan area is warmer than the rest of the city due to human activity, land surfaces, and a high amount of buildings per km2, decreasing green-blue areas so no cooling effect from trees and vegetation.

The heat is absorbed by all materials (asphalt, roofs, facades) and, at night, all surfaces spread out all heat they absorbed, increasing the temperature at night as well. As we will explain in next points, decreasing material's albido will help with this problem.

Reasons for adaption to heat stress

There is an already existence report about the urgency for a climate-proof and water-robust in the Netherlands called Dutch Delta Programme (2015). This programme concludes that all the built-up areas may be prepared to face rising temperatures and the urban heat island effect. The impacts of heat stress given in that report are:

- A decrease in comfort and liveability of cities
- A increase in heat-related disease and mortality, especially among elderly people (75+)
- An increase in hospital admissions
- A decrease in sleep quality
- A decrease in labour productivity

Scientists have quantified these impacts, especially the impact of heat on mortality. The Netherlands has gone through two heat waves during the 21st century. The first one in 2003 resulted in 1400 to 2000 excess deaths (Garssen et al., 2005), and the second one in 2006 resulted in 1000 death people due to the heat wave (UNISDR, 2007). These figures are remarkable and consequently the heat wave in 2006 was the 4th deadliest natural disaster for 2006 (table 1).

Top 10 Natural disasters by number of deaths - 2006		
Disaster / Month	Country	Number of deaths
Earthquake, May	Indonesia	5778
Typhoon Durian, December	Philippines	1399
Landslide, February	Philippines	1112
Heat wave, July	Netherlands	1000
Heat wave, July	Belgium	940
Typhoon Bilis, July	China, P Rep	820
Tsunami, July	Indonesia	802
Cold Wave, January	Ukraine	801
Flash Flood, August	Ethiopia	498
Typhoon Samoai, August	China, P Rep	373

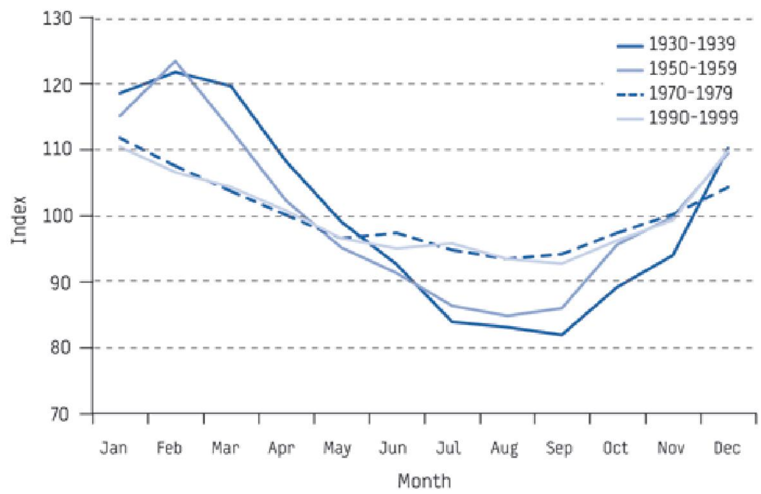
Table 1. Top 10 natural disasters 2006 (Source: UNISDR, 2007)

Moreover, the relationship between climate and excess mortality is a complex one. It can be represented in a graph, with the lowest causes of mortality rate in the Netherlands, in an average daily temperature of 16.5ºC. Summer temperatures are closer to the optimum ones which means that the mortality risk is normally below average in summer and the other way round in winter. As shown in Figure 1, between the 1950s and 1970s there was a huge change, but , since then, it hasn't had any significant change.

The indices in Figure 1 show the degree to which the monthly number of deaths in the relevant decade is higher or lower than the number that would be expected if deaths were spread over the year (a value of 110 representing a 10% higher mortality). The lower summer indices in earlier periods are largely caused by the detrimental effect of cold weather, inflating the average mortality risk. In the Netherlands, as in all other countries with mild climates, annual cold-related mortality is higher than heat-related mortality.

FIGURE 1

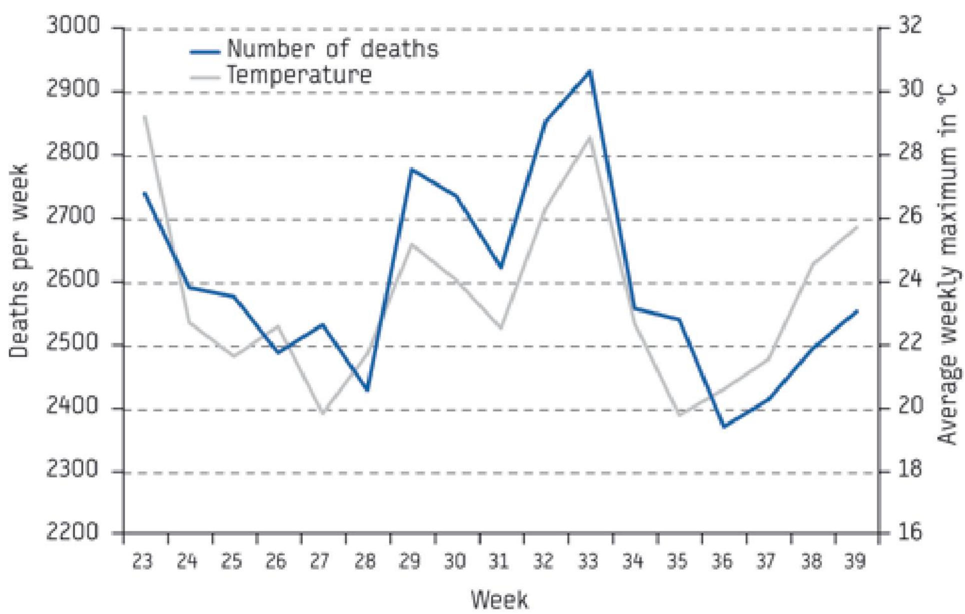
Mortality risk (all ages and causes combined) by month, various periods (monthly average = 100)



Daanen et al. (2013) quantified the economic impacts of increased temperatures in the Netherlands. The focus was on economic damage related to health and productivity. After an analysis about mortality, morbidity and productivity in the Netherlands the total economic costs were estimated at 100 million Euro per year by 2050. But the most important factor was the decrease in productivity within buildings of 2% per ºC temperature rise above 25ºC.

FIGURE 2

Mortality and average maximum temperature per week, The Netherlands, June-September 2003



Impacts of heat on comfort and liveability have not been explored in detail. Anyway, Steeneveld et al. (2011) did some preliminary investigations showing that an average of 7 heat stress days occur every year in the Netherlands and this number is being increased every year progressively.

What the future holds

While the 2003 heat wave was unusual in today's climate, Europe is highly likely to face even hotter summers more often in coming decades. Scientists estimate that human activities have already at least doubled the risk of an extreme heat wave.

Unless we make deep and swift cuts in our heat-trapping emissions, Europe could experience a heat wave similar to the one in 2003 every other year by the end of this century. A summer like that of 2003 would be considered ordinary or even cool. Summers in central Europe are expected to feel like those in southern European today.

Climatic variability in summer is projected to increase, with southern Europe experiencing more heat, less precipitation, and more frequent droughts, yet heavier rainstorms when it does rain. Northern Europe can expect more overall precipitation. Smog is also expected to rise, unless we reduce our use of fossil fuels

Ironically, people in cold regions can be most vulnerable to heat waves, because they are not acclimated to extremely hot weather, and because buildings designed for cold climates may not offer protection against extreme heat and high humidity. The elderly and those who do not have access to air-conditioning will likely be less resilient in the face of more frequent heat waves.

Some studies estimate that there are likely to be places on Earth where unprotected humans without cooling mechanisms, such as air conditioning, would die in less than six hours if global average surface temperature rises by about 12.6° F (7° C). With warming of 19.8-21.6° F (11-12° C), this same study projects that regions where approximately half of the world's people now live could become intolerable.

Even as Europeans adapt to hotter summers, rising numbers of heat-related deaths are likely. The 2003 heat wave shows that even high-income countries such as the Netherlands are not currently positioned to cope with extreme weather, a troubling prospect, as research suggests that by as early as the 2040s, if we continue on the current high emissions path, about half the summers in southern Europe are likely to be as warm as the record-breaking heat wave of 2003.

2.2 Benefits/advantages to have Green/blue areas

People find more attractive to live in Green districts than living in another places without green areas, that make us think about all the benefits that include living near nature, in fact on last years the prices of the houses in green districts or along water or areas of vegetation are higher than other places, urban vegetation and water have a direct economic value. "*The effect of attractive nature space on property prices falls from 16% for properties within 0.5 kilometers, to 1.6% for properties up to 7 kilometers away. Our findings advance existing hedonic studies by verifying that economic benefits of living near natural space extend over a larger distances. This has important implications for public policy regarding investment in natural space nearby residential areas" (Michiel N.Daams, Rethinking the economic valuation of natural Land, 2016).*

Nowadays a lot of cities around the world (such as London, Amsterdam, Rotterdam, Singapore) are working to increase and protect the actual existing nature and water spaces , that is because having more green and blue spaces improve the quality of life as well as the city's economic value.

There are some advantages to have more green and blue areas in cities and towns;

Improved flood resilience

The flood resilience can be improved if the vegetation is well structured, it can create a sponge effect on precipitations and reduce floods making it not need to be drained off, it happens the same with water areas that are designed in a way that can recollect the water

Heat alleviation

On hot days, places where is an important amount of vegetation or water areas can cooler 10 degrees than in areas with concrete floor or bricked.

Trees create shades and the ground below them is heated less, all types of green and blue solutions have the capacity to cool in a way of evaporation.

Improved biodiversity

With the addition of new green and water spaces it will be improved the biodiversity, offering habitat to many types of flora and fauna.

Food production

Nowadays the urban food production is becoming a new trend, you can notice because there is an emergence of urban agriculture, city gardening and farmer's markets. There is the necessity of know how our food is produced, the increase of sales of organic products from farmers is growing and this is good for urban farmers.

Improved air quality

There exist a lot of pollution caused by human activity and this cannot be changed, but if there are more vegetation and trees, it can absorb CO2 and sulphur dioxide and this can help to at least bring a degree of improvement. Improve air quality has a good effect on the health of the people.

Energy production from biomass and water

All the green and water areas can be useful for contribute to the town or city's energy supply using the green waste, wood from the urban forest and extracting heat from the surface water. Using these methods it can be used for fermentation or as a fuel.

Social and societal importance

Exist a really important effect of the nature in the humans, many studies has confirm that nature improve quality of life and reduce stress levels.

Green areas can be places where people go to have a nice day or do physical exercise, children can enhance their social skills and concentration in play areas, and there are many activities that public parks and green spaces offer.

Figure 1 - Community garden 'Emma's Hof' in The Hague, The Netherlands

With more vegetation and water, the towns and cities reduce health care costs and in long term it can reduces a municipality's management costs. Homes situated near green areas or water have higher price than those homes are not near of green area or water (as we have said in the introduction of this chapter).

There are a lot of benefits for the society and offering people to participle on the design and creation of new areas also create a good feeling to the citizen involvement.

2.3 Possible climate adaptations

When we think in possible options for the City of Groningen we find many possible adaptions that will work really well and could cooler the area, those climate adaptions are the following;

Porous paving materials

Any porous paving materials is suitable for paving; for example, grass concrete pavers, woodchips, shells or gravel materials and precipitation can infiltrate into the ground.

This adaption has so many advantages because it can be used for many purposes as footpaths, playgrounds, fire service roads, for aeration around trees, car parking, roads…

Figure 2 - Different types of porous paving

City trees

One very good option are trees, it offer so many advantages to cities like ; they create shade, offer coolness and also a living space for birds and insects.

The only disadvantage that it can be found is that they grow really slowly, because of this is important to protect the actual trees that are nowadays at the cities.

When we want to plant a tree we have to find a good place, it is important to think well before where it can fits better.

Figure 3 - Bolivar Square, Paris, France

Water squares

Water squares are a really good options for not only cooler the city, also it can have an important social effect as well as being a nice decoration for the inner city.

Water squares normally are uses for the inner-city areas with little room for water buffers, in cities where exist densely built-up it is difficult to find room for this and is in those areas where is most needed.

On that cities where there is difficult to find a room for it, they have design a new system, this system made the water square multifunctional, linked it to other functions like playing area, residential area or green areas.

The squares feature lower-lying areas that can be submerged in the case of heavy rainfall. The run-off from the surrounding district is connected to the square by open drains or rainwater drainage systems.
The careful, functional and aesthetic design of such water squares demands a great deal of attention. After rainfall, the lowest parts of the water square fill up first, and the water in fact remains there longest. The parts that become submerged need to be easy to clean.

Figure 4- Fountain from Illinois, USA

Water squares offer different benefits compared with another options:

- Water squares make the dynamics of water visible in the town or city and by doing so can help enhance the aesthetic value.
- Water squares can be combined with other public urban functions and as such create spaces with multiple purposes.
- Properly designed water squares allow for substantial fluctuations in water levels and as such for large volumes of water to be buffered.

One good example is the design for the Bloemhofplein square in Rotterdam. It has the same objective when is empty than when is full of water, being a part of children's game. When it is empty children can play and after the rain

Figure 5- Water square Bloemholfplein, Rotterdam, The Netherland

shower water can become part of children's game as well.

Maintenance and management are important factors, since the water reaches the square from above the ground and as such is not purified. This means that pollutants such as mud, litter, leaves and branches remain on the square after the water has been pumped away. These pollutants need to be removed as soon as the square is dry, to ensure that the square becomes attractive and usable once more *(Explain in more detail in chapter 4.5.5 Maintenance).*

Green facades

Green facades is an easy way to increase the amount of vegetation in a city and one of the best advantage is that it takes up little space in the urban area, while can cover many vertical meters from a building, the plant doesn't need some much space on the ground, but some space is required for the underground.

Figure 6- City Hall in Vitoria Street, London, United Kingdom

Vertical vegetation is not only a good way to cooling the city, it's use also to adorn the building facades.

There exist a lot of discussions about the pros and cons of green facades, it has a good effect lowering temperatures and improving the air quality, but to install green façade on buildings it can damage them and nuisance from pests is diminishing.

Evergreen plants can actually protect a building against heavy rain showers and keep the building walls dry. However, buildings which already are affected by rising humidity due to existing construction faults or damage can actually be further damaged by vegetation, as it inhibits the evaporation of moisture.

Changing materials of pavement/walls

Depends of the paving materials it has different effects on surface and air temperature in towns and cities. Paving materials cover the 30-40% of the urban surface, so depending about the type of material we have we will have different thermal comfort. In the summer, for example tarmac and concrete can reach really high temperatures between 45°C and even 70°C, the heat is trapped by the material and pass on to the ground below.

So one easy way to cooler the city is to choose the correct material of pavement, as well the materials from the walls, generally paving materials with light colours has a good influence on keeping the surface temperature down.

Light-coloured paving materials, like light clinkers and concrete stone are better than black tarmac.

Green roofs

Green roofs are increasingly used as a building block towards attaining sustainable urban development. Green roofs have many advantages. Besides being attractive, their capacity for rainwater retention, the roof itself heating up less, the underlying construction and spaces, and the surroundings are often a consideration in favour of constructing green roofs. Green roofs can also contribute to a larger biodiversity in the city and capture of particulate matter. Runoff from green roofs is cleaner.

Green roofs' is a collective term which includes moss/sedum roofs, grass/herb roofs and is used for walkable planted roofs and sloping roofs. In principle two kinds of green roofs can be discerned: extensive green roofs and intensive green roofs. The difference lies in the intensity of the required care as well as the different way of constructing. Extensive green roofs are thinner and lighter in construction and generally less costly. Extensive green roofs are easier to realise on existing buildings. Intensive green roofs vary from watered grass/herb roofs to walkable city parks on buildings.

Green roofs can be installed on roofs with slopes ranging from 1o to 35^{o}. At more than 35^{o} extra provisions are required to prevent sliding. Steeper roofs dry out faster due to the faster runoff of rainwater. If the additional provisions to counter sliding tear through the waterproofing roof membrane this will increase the risk of leaks. For rainwater retention, a slope of up to 7^{o} is most efficient.

Creating shade

Creating shade by positioning trees and vegetation strategically on the outsides of the buildings blocking the sun light can be a good way to cool the area, on this chapter we not only talk about trees creating shade, there are so many different options to create shade like temporal structures that cover the streets that we can just collocated on the hot summer days to reduce the feeling of hot (*Example in figure 9 Malaga- chapter, Ways to face heat stress in the urban environment in Spain).*

1 Methodology

1.1 Introduction

This chapter presents the methodology that has been used to answer the main question and sub questions with the help from the literature review. It can be separated in five chapters;

- Literature review (Sub questions 1,2 &3)
- Spatial analysis (sub questions 5
- Interviews (sub
- Design
- Envi-Met
- Costings

One time analyse all these chapters, with a multi-criterial analysis giving different importance to those chapter will be choose the most adequate alternative.

1.2 Envi-Met

Once the group knew about the intentions of the Gemeente to redesign the city center of Groningen in order to make it more livable and attractive our very first idea addressed the following question: How can we do a space more livable? How can we measure the livability of Grote Mart, for example?

At the beginning of the project the group had a lot of knowledge about construction and design but not about aspects such as green-blue solutions or sustainability, so we needed some help to start.

In order make up for this lack of knowledge the group attended a seminar that took place in Hanze about sustainability with exchange students from Korea. Moreover, the group did a really good job researching information and examples in other cities to get inspired. However, the turning point came when university professor Jonathan Tipping introduced ENVI-met to the group.

The goal of using ENVI-met was to show and explain in detail the environmental problems that the city center could have and present our proposals with a science-based perspective.

We chose ENVI-met for several reasons:

The program offers what we need, it fits with our necessities

It is a free software, so that means anybody can download it and get the licensed for free

We had good references about ENVI-met from one student of Hanze that helped the group in the first steps dealing with the program.

The group had a contact in Amsterdam with an expert that worked with ENVI-met and she was really useful and decisive for the project.

At the end, ENVI-met has been an extremely important tool which has given us a lot of valuable information not only about the current situation of the city center of Groningen but also about the three proposals that we found out. As a consequence, the group could compare the four different cases in order to see the differences between the current situation and the different proposals, and also in between.

To sum up this issue, ENVI-met has been very useful to us since it has enabled us to show to the Gemeente a lot of data about how they can improve the city center in environmental terms. Data related to the air temperature, the wind flows, the importance of the materials used as pavement, and the importance of green-blue solutions in the city. It is a fact that without ENVI-met it would have been impossible to demonstrate all of these data with a science-basis.

How did we work with envimet?

Since the beginning of the project the group established its own methodology in the process to be followed. The project methodology turned out to be a lengthy process. It was not easy to reach an agreement between students and professors. All in all, we can all claim it was a process worth working on, because when you work in group is necessary that all the members follow the same line and the same direction to achieve the same goal.

The group agreed on making three proposals and each proposal would included the following information:

A detailed budget with cost estimation

A maintenance project for the life time of the proposal

An ENVI-met analysis with “Air Temperature” and “Wind Speed” among other things

Once everything was clarified, it was time to start working. The process would be the following:

Draw the current situation and analyze the outputs.

Draw three proposals taking into account the current situation, and analyze the outputs.

Compare the three proposals with the current situation in order to make a ranking with scores which will be taken into account in the muti-criterial analysis.

4. Results

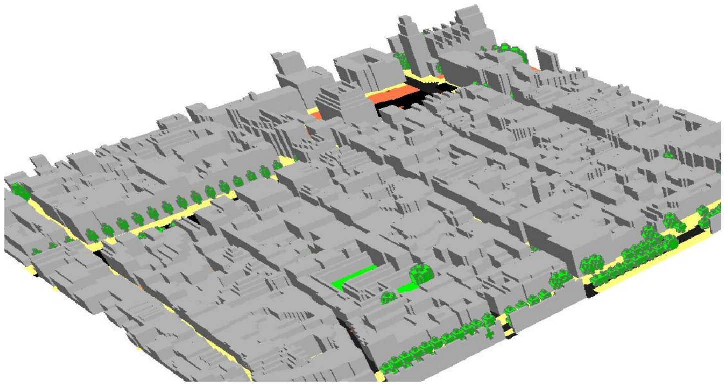
4.1 EnviMEt

Once all designs were made, next step was to simulate all proposals in envimet, to find out if the impact on climate change and heat stress was what we were expecting and how much it was. Obtaining heat maps, wind maps, albido maps, etc. (all included in appendix)

Simulation 1. Current situation

The starting point was to think for a suitable name for the project with the "Manage WorkSpaces and Projects" application and choose a work space in the computer. The project was finally called "GRONINGEN-CURRENT SITUATION".

Then, it was required to draw the area in the "Spaces" application. Tipping, Bogard and the students reached an agreement on the area chosen and its size. None of us knew in this moment that the area was extremely big to do a simulation in ENVI-met with a usual laptop.



This first idea of the area measured 500 m X 500 m X 60 m, equal to 250.000 m^2 of surface or 15.000.000 m^3 in volume. The cells of the grid had a dimension of 2 meters in each axis, which means that only the biggest version of the "ENVI-met Core" application could handle it, that was ENVI-met 250_250_30.

Some applications and web pages were used in order to draw the area accurately. The most important ones were the followings:

Google Maps: It gave us an idea about the geometry of the buildings and the streets among other important things.

Actueel Hoogtebestand Nederland: It showed us not only the height of the buildings but also the height of the streets and the trees.

Google Earth: It helped us to measure the width of the streets and buildings with a lot of precision.

The next step after drawing the area was to create a new simulation file with the application "Project Wizard". In order to create this file the following information was required:

An area input file: This is a file created by the application "Spaces" which it was already created at this point.

Select day, time and duration for the simulation: The day chosen was July, 19th 2014 because it was one of the hottest days in Groningen in the last three years. Moreover, the sky was clear the all day and the wind blew constantly in the same direction. The combination of all these features made this day perfect to be simulated. The time chosen was at 00:00 and the duration was 24 hours.

Wind features: During the day selected, the wind speed had an average of 3m/s and a wind direction of 290º.[1]

Meteorology settings: These settings make reference to the temperature and the humidity. It was necessary to include the temperature and the humidity of the day selected for each hour of the day.

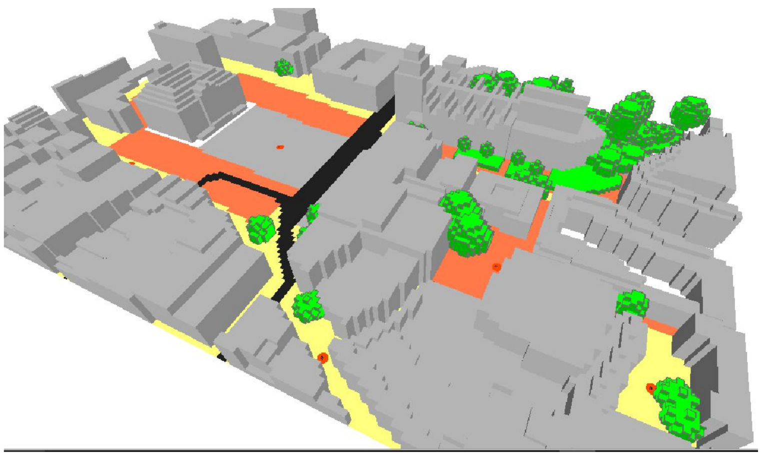
Once all these information were included in the “Project Wizard” a new simulation file was created by the application. The only thing missing was to include this file in the “ENVI-met Core” application.

When this file was loaded in “ENVI-met Core”, the application made a test looking for possible mistakes, and when everything was checked the simulation started.

A few hours later the group realized that the simulation was running very slow, in three hours talking in real time the application only had simulated 18 minutes out of 1440 minutes (24 hours), which meant that it would took around 8 days to simulate 24 hours. The group decided to stop the simulation and look for a feasible solution to finish the project on time.

Afterwards, a meeting with Tipping was arranged at Hanze to look for a solution. Several ideas came out but only two of them were viable. The first one was to run the simulations in a really big computer from the University of Groningen, but it was not a solution in the short term, so just in case this solution will not work the group turned to the second option.

The second option was to start from the beginning and reduce the area significantly. The new area measured 334 m X 214 m X 58 m, equal to 71.476 m^2 of surface or 4.145.608 m^3 in volume, more than 10 million m^3 smaller than the first area. The size of the cells was not changed, so the size continued beings 2 m each cell in the three axes.



[1] All the meteorology settings used in the simulation such as wind speed, wind direction, temperature and humidity was taken from the data base of the Groningen Airport Eelde Weather Station.

As a consequence, the grid had the following dimensions; 167_107_29. In this occasion, there were two possible options; either the simulation was run with the version 180_180_35 or with the version 250_250_30. We realized that the smallest the project was, the less time the simulation process would take.

The simulation file that was created in the last version worked with some little changes such the area input file or the folder's name, but the meteorology settings remained the same. This file was loaded in the "ENVI-met Core". It was later on checked and a few minutes later the test had finished and the simulation started.

As expected, this time the application worked quite faster, after three hours of simulation, the application had simulated around 50 minutes, which meant that in three days and a half the simulation would have been done by then, and so it was.

With the simulation finished it was time to use the application "Leonardo" in order to get the information in different kinds of maps. The "ENVI-met Core" created five types of files in different folders; "Atmosphere", "Surface", "Soil", "Radiation" and "Pollutants". In each of the folders there were 24 files which made reference to the 24 hours simulated. Depending in the type of file loaded in "Leonardo" different kind of information can be gotten.

The files used for this project has been the followings:

Surface: To get information about the surface temperature and the surface albedo.

Atmosphere: To get information about air temperature, wind speed, and flow analysis.

Simulation 2. First Proposal Groningen

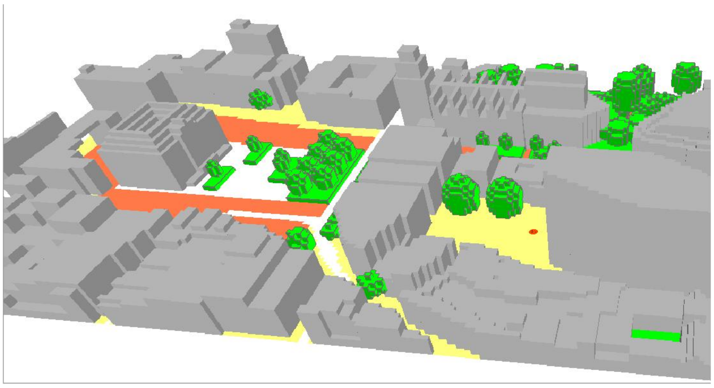
Once the simulation of the "Current Situation" finished and the outputs were analyzed with the application "Leonardo", it was then time to get the first proposal started.

It was clear that some materials had to be removed because their albedo factor was too low and the area of Grote Markt needed some green area with trees to provide shadow.[2]

The process carried out to run this simulation was the same as with the "Current Situation" simulation despite some minor changes. Moreover, the name chosen for this simulation was "First Proposal Groningen" and a new project was created as a result.

The main change was to redesign the area including the new square and the new Forum, then some materials were changed and a green area was included in Grote Markt.

[2] The "First Proposal's" results will be shown in detail in the appendix.



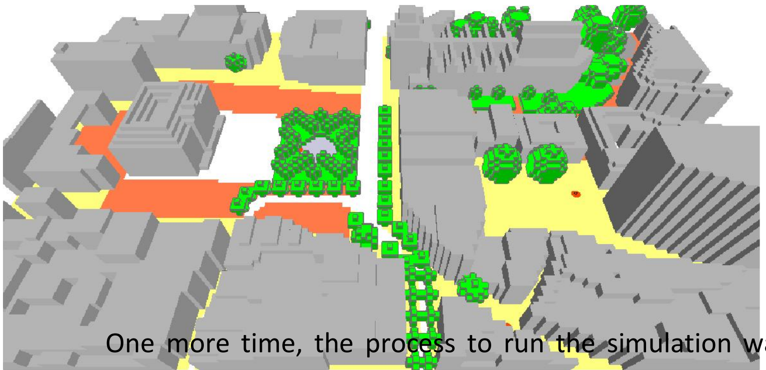
The simulation file of the “Current Situation” was used for this simulation only with one factor being changed, this is to say, the area input file. The meteorological settings remained the same.

With all of these changes already set up in the system the simulation could start and it was supposed to finish in three days, but a technical problem with the laptop which was doing the simulation appeared. As a consequence, only 16 hours out of the 24 were simulated so the group has not information from 16:00 to 24:00 hours.

Simulation 3. Second Proposal Groningen

The outcome of the “First Proposal” simulation was disappointing and it was not expected for the group. The changes in air temperature were negligible in Grote Markt, and variations in surface temperature were neither helpful.

In this situation, the only thing the group could do was to keep working and do much more changes. As a consequence, a new proposal was designed with the name “Second Proposal Groningen” including not only more green areas but also a fountain at ground level.



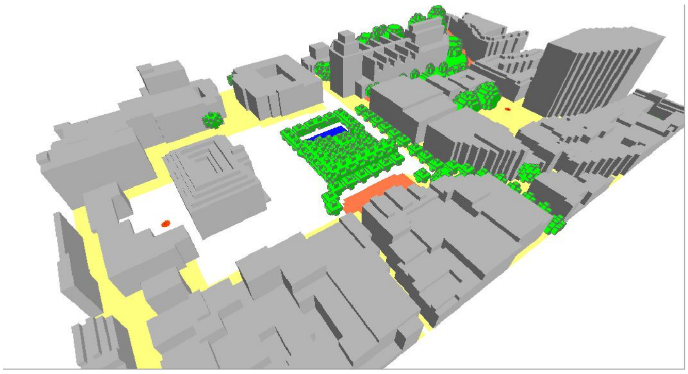
One more time, the process to run the simulation was the same as the others simulations changing only the area input file. Once the simulation finished and the files were included in “Leonardo”, the outcomes[3] showed a better result than the “First Proposal” but still insufficient. The group agreed that Grote Markt needed more shadow in order to achieve a lower temperature, this fact entailed two different feasible situation to be given; either more trees or trees with a bigger and higher crop leaf density.

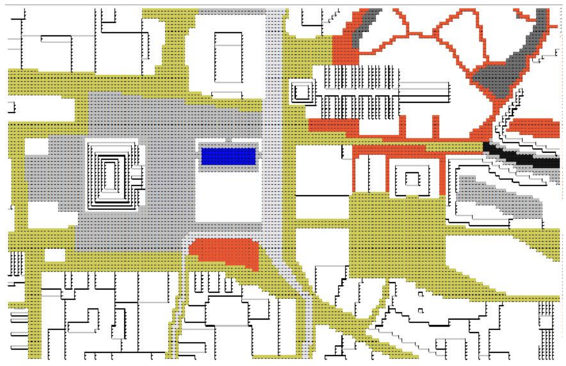
Simulation 4. Third Proposal Groningen

[3] The “Second Proposal’s” results will be shown in detail in the appendix.

The last proposal was critical because it was the last opportunity we had to achieve our goal. Consequently, this proposal introduced more changes than any other one. It keeps changes from the "Second Proposal" as well as introduces new trees, a bigger fountain and materials with higher albedo factor.

The name of this proposal was "Third Proposal Groningen" and the simulation file remained the same with the only change of the area input file. When the changes were finished and everything was checked, the simulation started.





For the first time, the results[4] were very good and significantly relevant for the achievement of our project, being compared with the other proposals, especially with the current situation.

A description of all materials used, how the program works all the results of each simulation with all graphs and all other matters of interest are described and included in the Appendix.

[4] The "Third Proposal's" results wil be shown in detail in the appendix.

5. Conclusion

5.1 Remarks

This project goal is to make people realize how climate is changing which can affect to our citizens and their thermal comfort and life as well as giving some solutions to the city centre of Groningen as adaptations on thermal comfort in urban planning and design.

When we were selected to do this project, we were surprised by the topic, since speaking about heat stress and heat waves in the Netherlands, which is a northern country, may sound weird. But honestly, we won interest as we were moving on. As it was intended, the literature review made us realize the importance of climate change even in northern countries so it was not something to worry about just in heat extreme countries.

It was easy to find articles and studies about this problem. Some of them with reliable datum and with very interesting points of view, so reading about this problem was the most important part to successfully carry out this project. Once the literature review was done, so the problem was identified, it was time to investigate options and adaptations. It is interesting not just to focus on the Netherlands but world-width. Since understanding the problem as world-width brings more solutions and it is easier to determine vulnerabilities.

As reference, we observed how our own country, Spain, faces this problem. In particular, Valencia, which is our city, and we came up with lots of solutions such as temporary tents from roof to roof to create shade along some streets, green spaces, water vaporizers, green facades/roofs, or simply using materials with higher albedo.

Nonetheless, it was just the beginning. Once the problem was identified as well as vulnerabilities and options/adaptations it was time to find out how much worth it is to invest in this problem and, at the same time, if people is up to help.

The idea was to interview some random people around the city center to find out how much do they care about this problem, if they are aware of it and it is worth it to invest on it from their point of view. At the same time, one of the questions showed some options and green spaces that are already constructed so they could evaluate and rank them. We were happy about the results. Everyone showed interest for this problem, they are down for helping and they think it is important to invest in something like that and take care of our environment and, at a larger scale, of our planet. After all interviews, it can be stated that people gives a lot of importance to environment and thermal comfort, and they do not see it as a single problem about temperature, but it affects people in physiological terms as well. According to their opinion, it can be said that including green spaces in the city centre and along streets, as well as pedestrian streets transforms the city centre in a much liveable place, cosy and it makes people feel connected with nature, which leads, somehow, even to a stress reduction in their lifes.

From this interview, the next step was to design three proposals, which could improve thermal comfort. So far, we had people’s opinion and how countries face this problem so we had all things needed to design our proposals.

First of all, a three layers analysis was made. This part was kind of difficult since we needed plans of infrastructure, which are owned by the municipality, and meeting the urban planner or just getting these information attached on an e-mail was a bit messed up. Even though, thanks to our educational supervisor and some other people involved in this project we managed to get it. Nonetheless, it was in Dutch, which is not a language we speak, so we needed help to understand it, and again thanks to Jonathan we got to understand it and took advantage of that information, although we might have gone deeper on this information if it were in English. Nevertheless, the underground surface and distribution of infrastructure such as pipes, cables, etc made feasible all proposals we wanted to do, because, even though there are some infrastructures that could hinder our construction process and increment the final budget, it was not a very circulated area.

Once the three proposal were designed, a study of thermal comfort for each one with the program ENVImet was decisive to be sure that all proposal had an impact on what we were looking for. ENVImet is a program we have never used before so, first weeks we worked on it simulating an easy designed square to get familiarized with the program, and we met some people who was already in touch with this program that helped us on the first steps.

Finally, all proposal were designed and the thermal comfort analysis for all of them was done. It showed interesting data, so it was reliable that what we had done has a real effect in thermal comfort, achieving by it the goals we set for this project.

As conclusion, global warming is happening and we have to keep in mind that a change is needed. There is no doubt that it is something worth it to invest on, since what we change now, either remodelling our cities or changing the following urban planning to make it more sustainable and environmentally friendly, will remain in the future. If it is not now or not us, our future generations will have a bigger problem so in a large scale and long-term it is completely worth it. Even though it is a huge process that we have to go through, the whole world is worried about it and if we all do something, the difference is enormous. So definitely, thermal comfort is linked to living standards and healthy/comfortable living environments, so it has to be a important point to take into account in our urban design and planning. Even though, more research have to be done in the future about this topic.

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7. Appendix

Annexes IV: Envi-Met

-Information programme

-Simulation actual

-Simulation 1

-Simulation 2

-Simulation 3

Outcomes' analysis

This section provides all the information required to understand deeply the changes done in the different proposals as well as it shows a detailed analysis of the outcomes and their advantages.

First of all, the areas will be shown to do a visual analysis of their differences such as materials, green areas, trees and arrangement of buildings.

Secondly, being aware of the different areas will be easier to understand the outcomes which will be later shown in the following order:

- Figure 1: Surface temperature of the four scenarios at 07:00, 11:00, 15:00, 19:00 and 23:00.

- Figure 2: Surface albedo of the four scenarios.

- Figure 3: Air temperature at one meter high of the four scenarios at 11:00, 15:00 and 19:00.

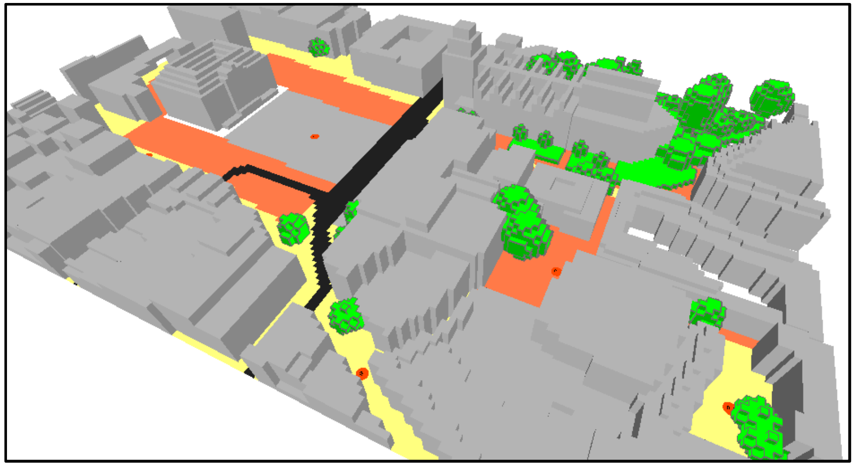
- Figure 4: Wind speed and flow analysis at one meter high of the four scenarios at 11:00

Finally, some charts related with temperature at different height will be shown. These charts have been obtained from a receptor located in the model area. The receptors get a lot of information such as; date, time, height, temperature each 3 meters high, humidity, radiation… just in the place they are located.

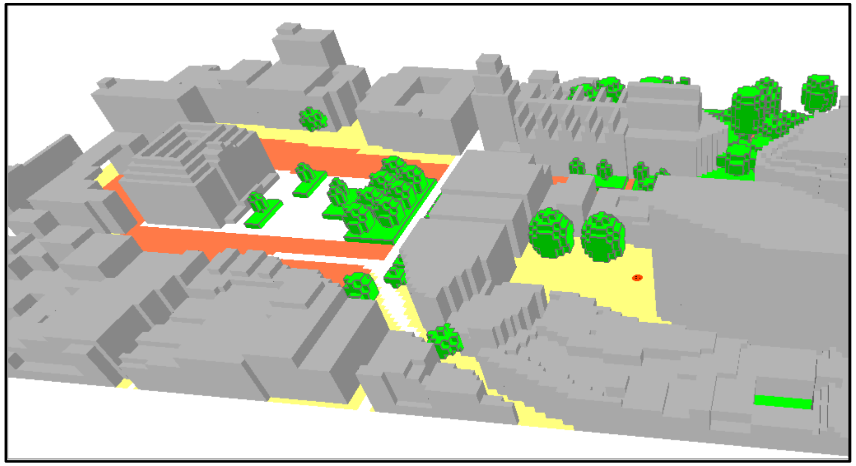
This project is made up of 10 receptors but only the receptor number 3 is useful due to its location and the most useful information is the temperature at 0,00m and 1,00m high. The location of this receptor is in the middle of Grote Mark and it is visible in the 3D model as a red dot.

VISUAL ANALYSIS OF THE FOUR SCENARIOS

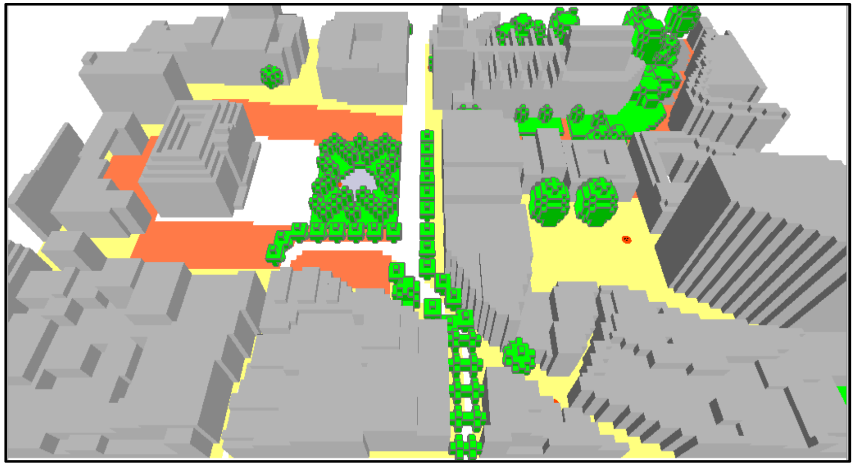
3D MODEL VIEW



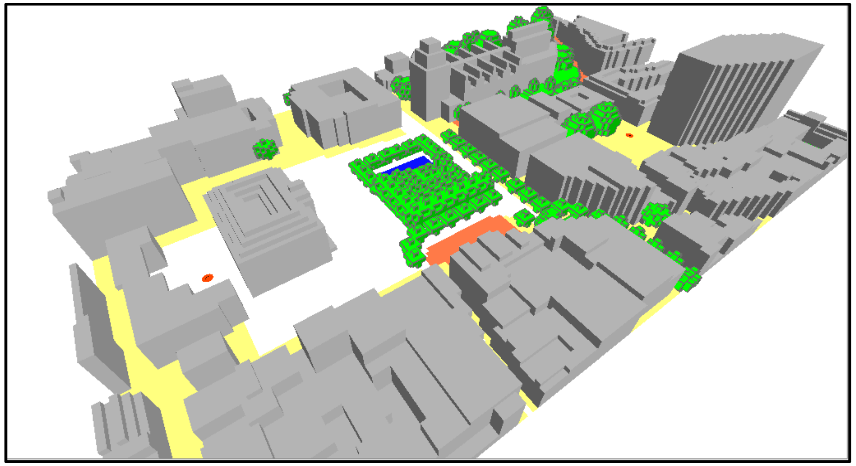
GRONINGEN CURRENT SITUATION



GRONINGEN FIRST PROPOSAL



GRONINGEN SECOND PROPOSAL



GRONINGEN THIRD PROPOSAL

OUTCOMES’ ANALYSIS

SURFACE TEMPERATURE

FIGURE 1: GRONINGEN-CURRENT SITUATION 07:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

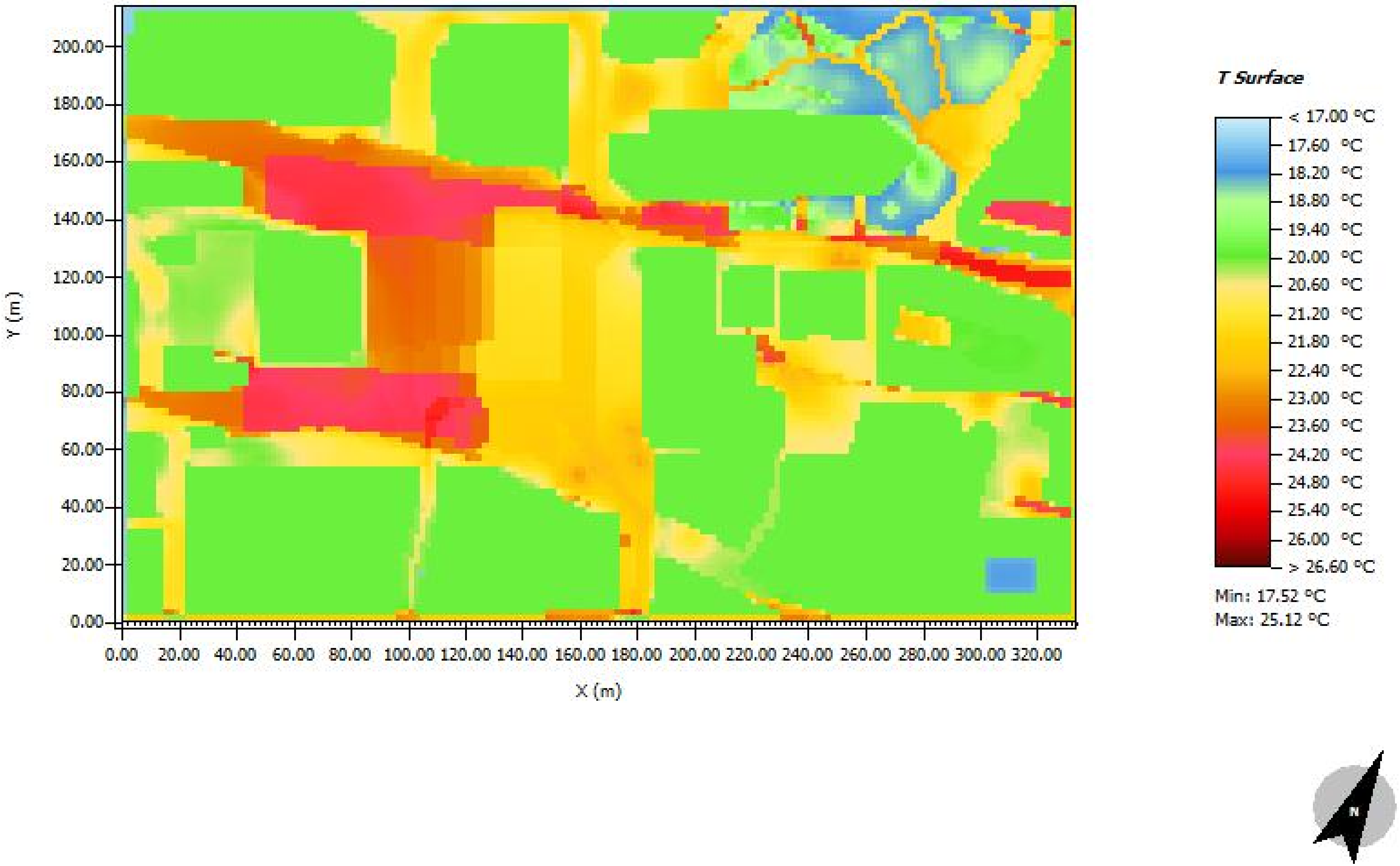
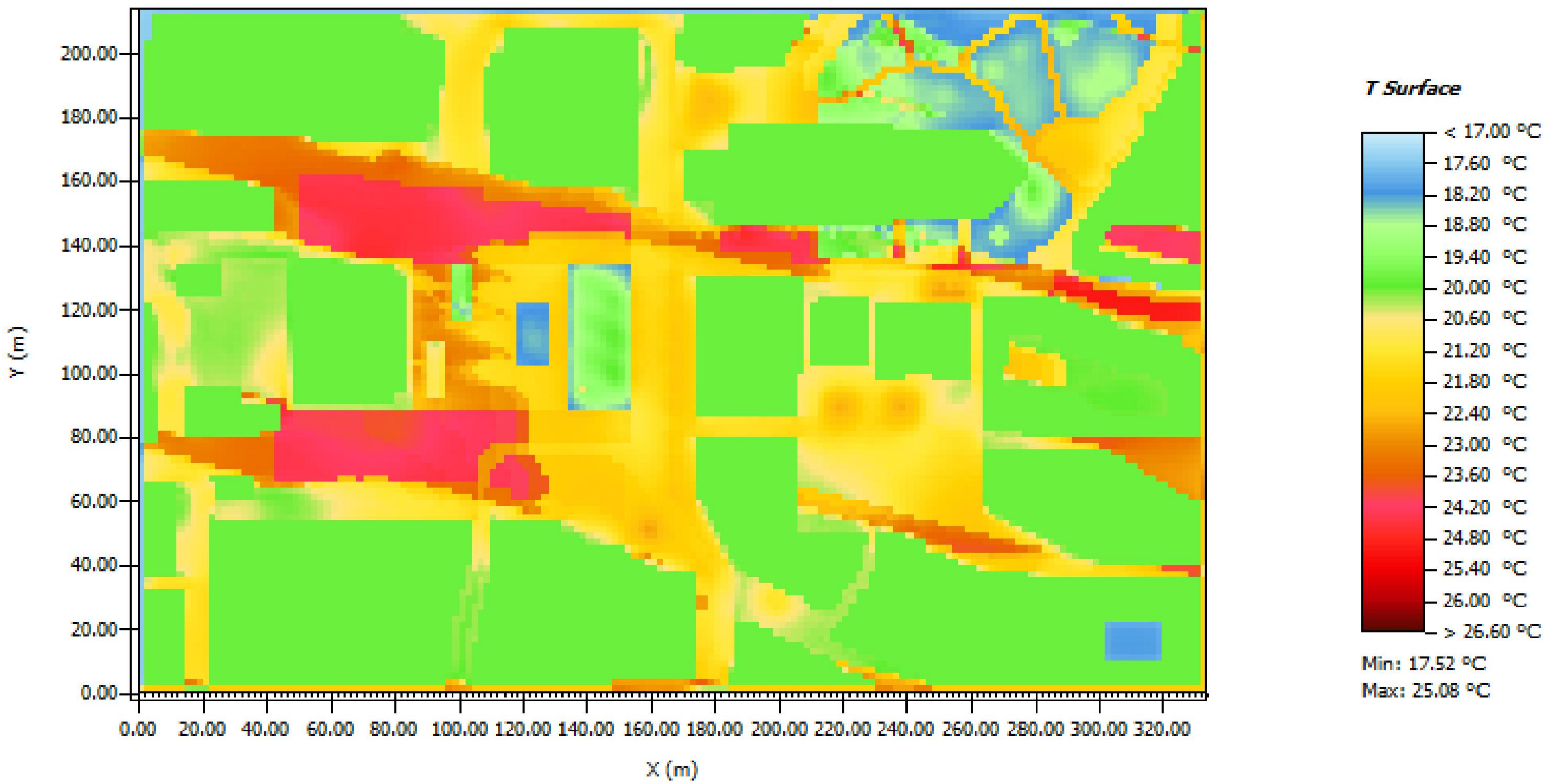


FIGURE 1: GRONINGEN-FIRST
PROPOSAL 07:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)



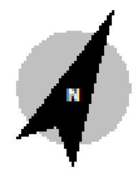


FIGURE 1: GRONINGEN-SECOND PROPOSAL 07:00:01 19.07.2014

SURFACE TEMPERATURE (z=0 m)

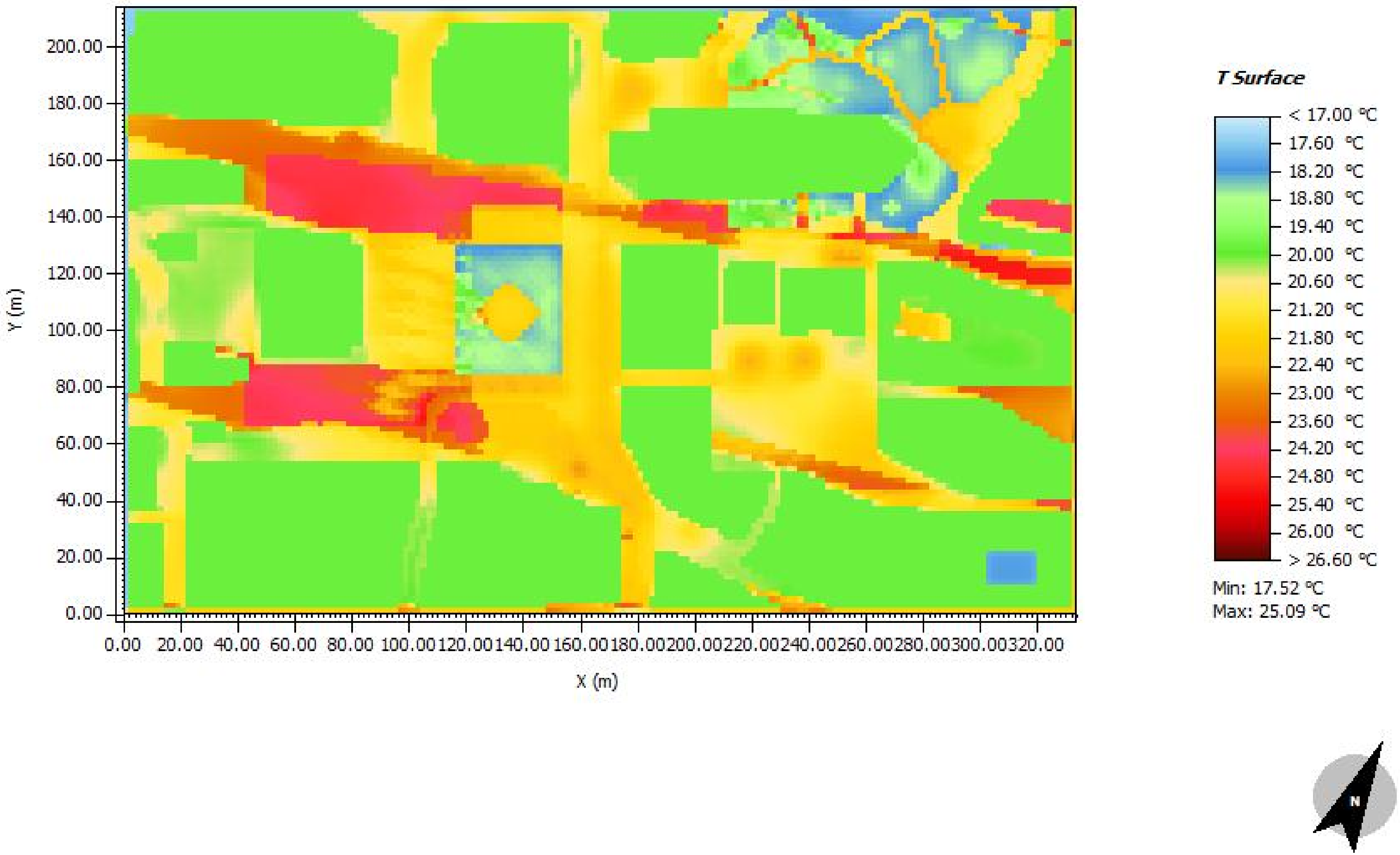


FIGURE 1: GRONINGEN-THIRD PROPOSAL 07:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

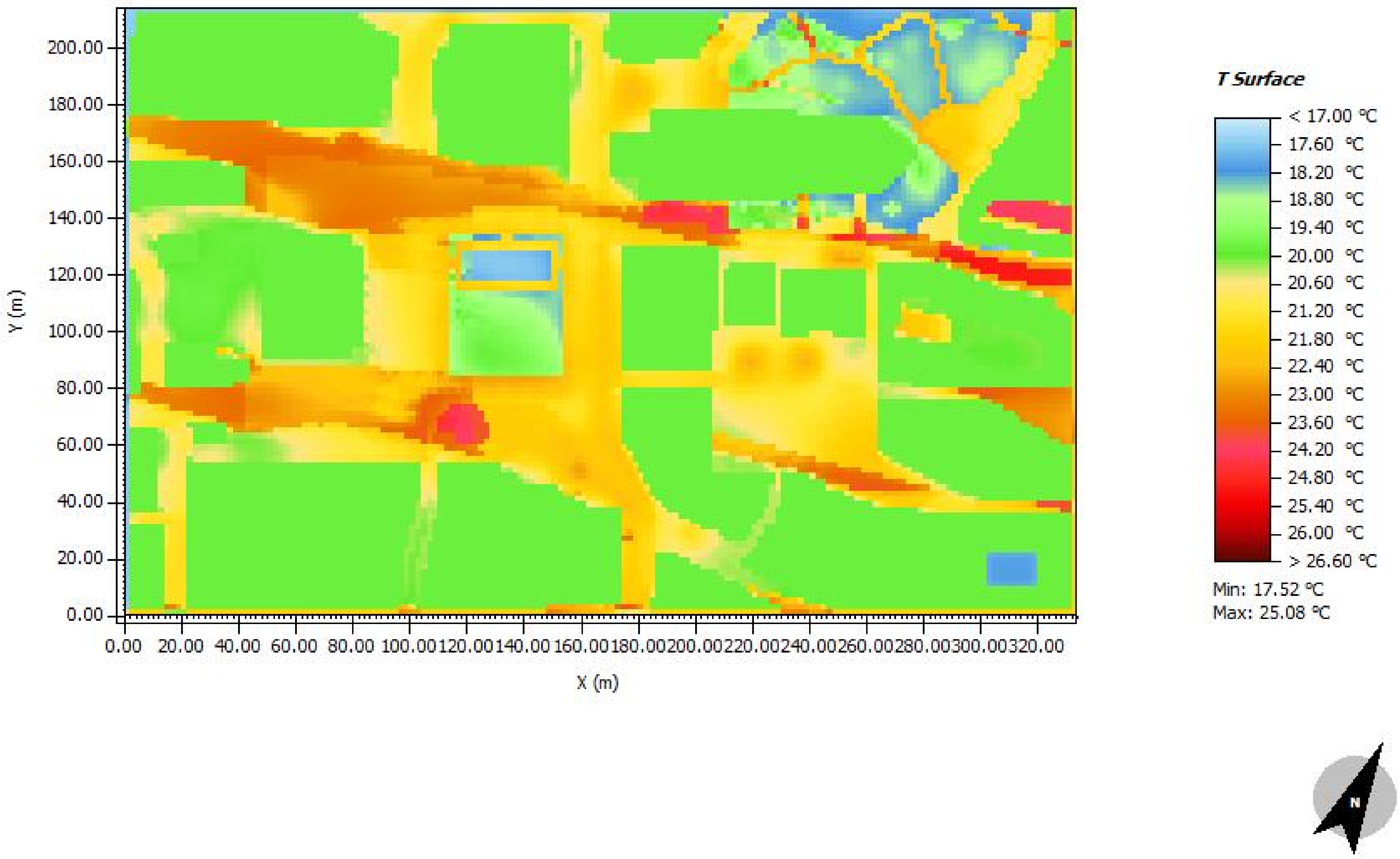


FIGURE 1: GRONINGEN-CURRENT SITUATION 11:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

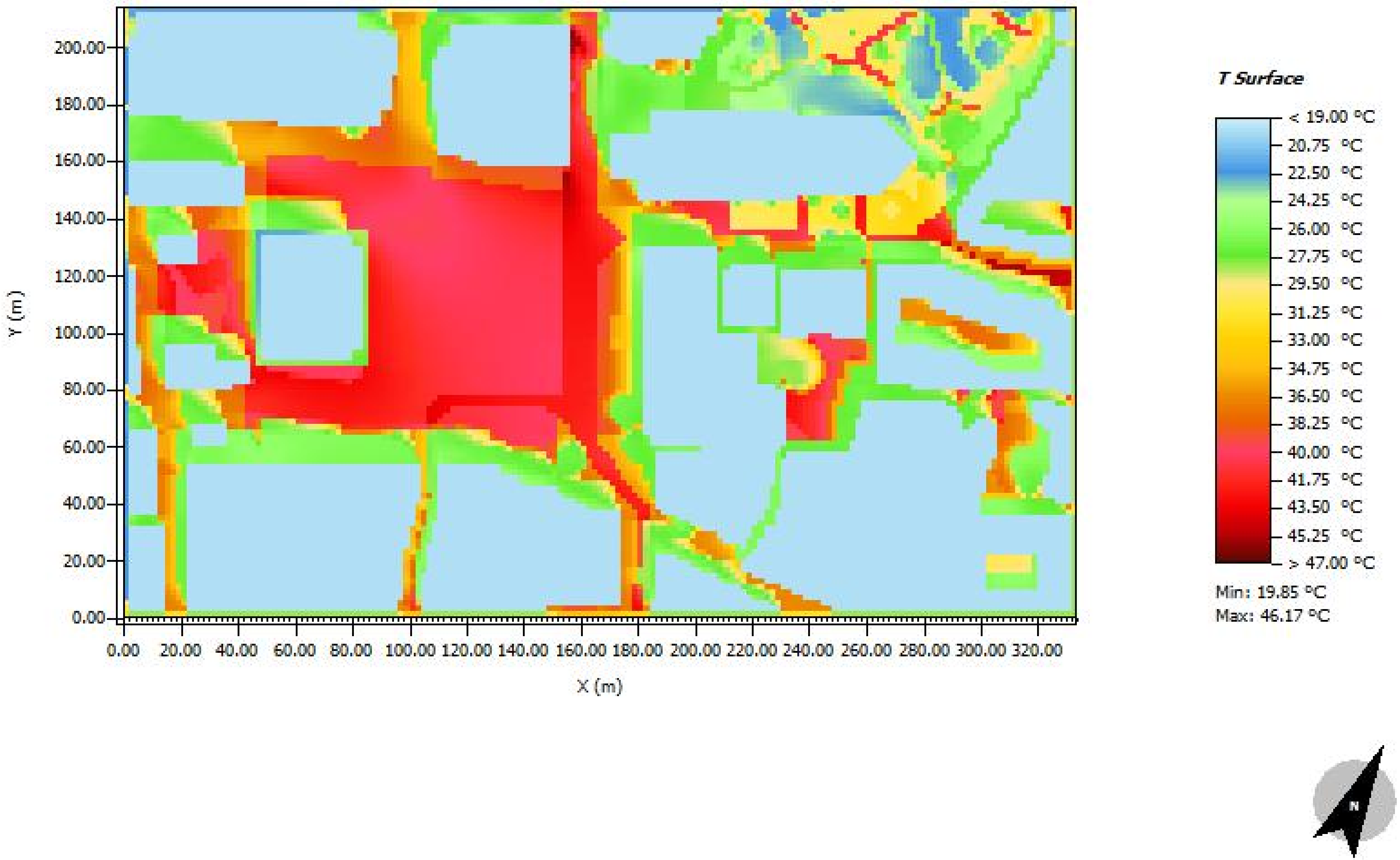


FIGURE 1: GRONINGEN-FIRST PROPOSAL 11:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

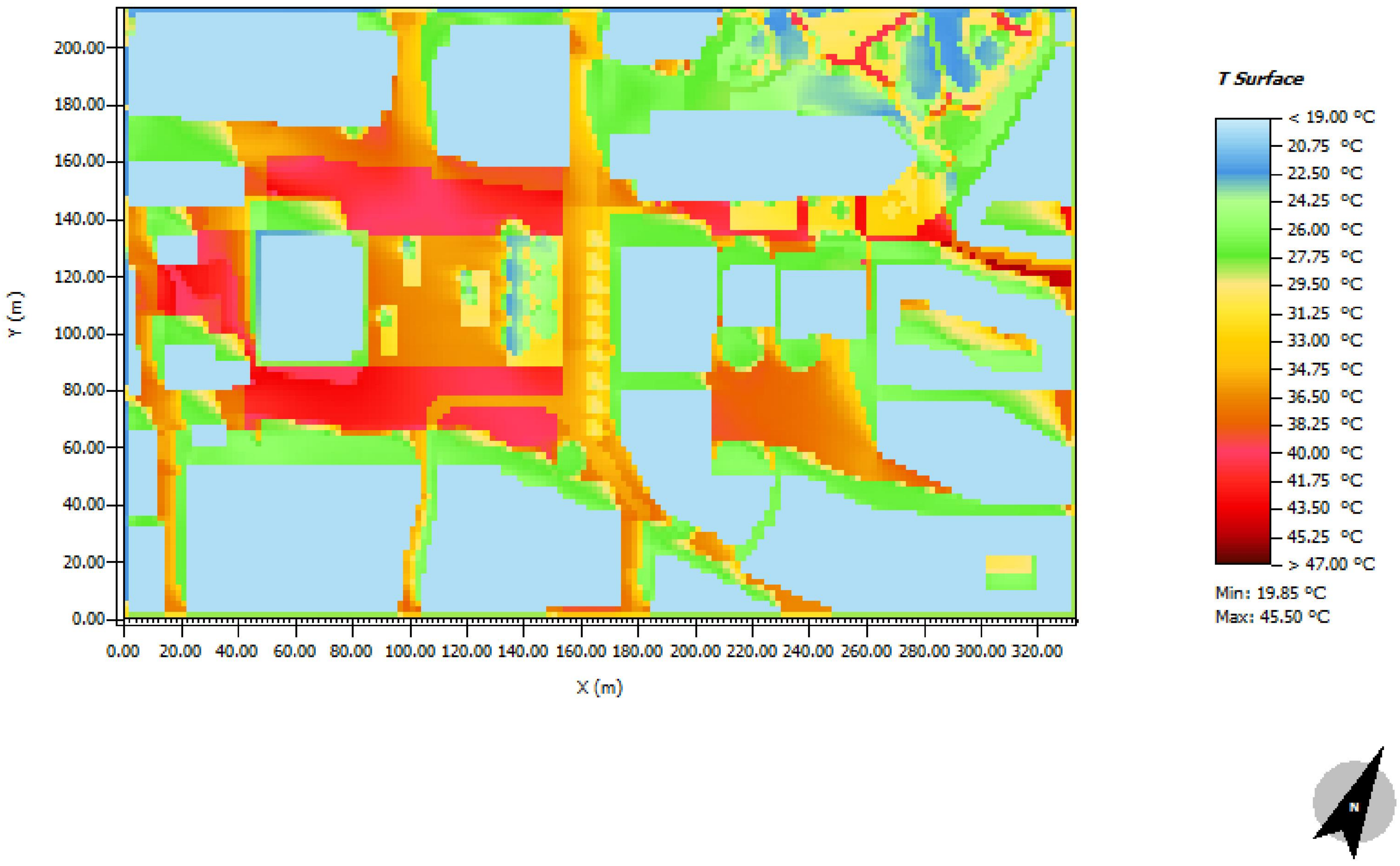


FIGURE 1: GRONINGEN-SECOND PROPOSAL 11:00:01 19.07.2014

SURFACE TEMPERATURE (z=0 m)

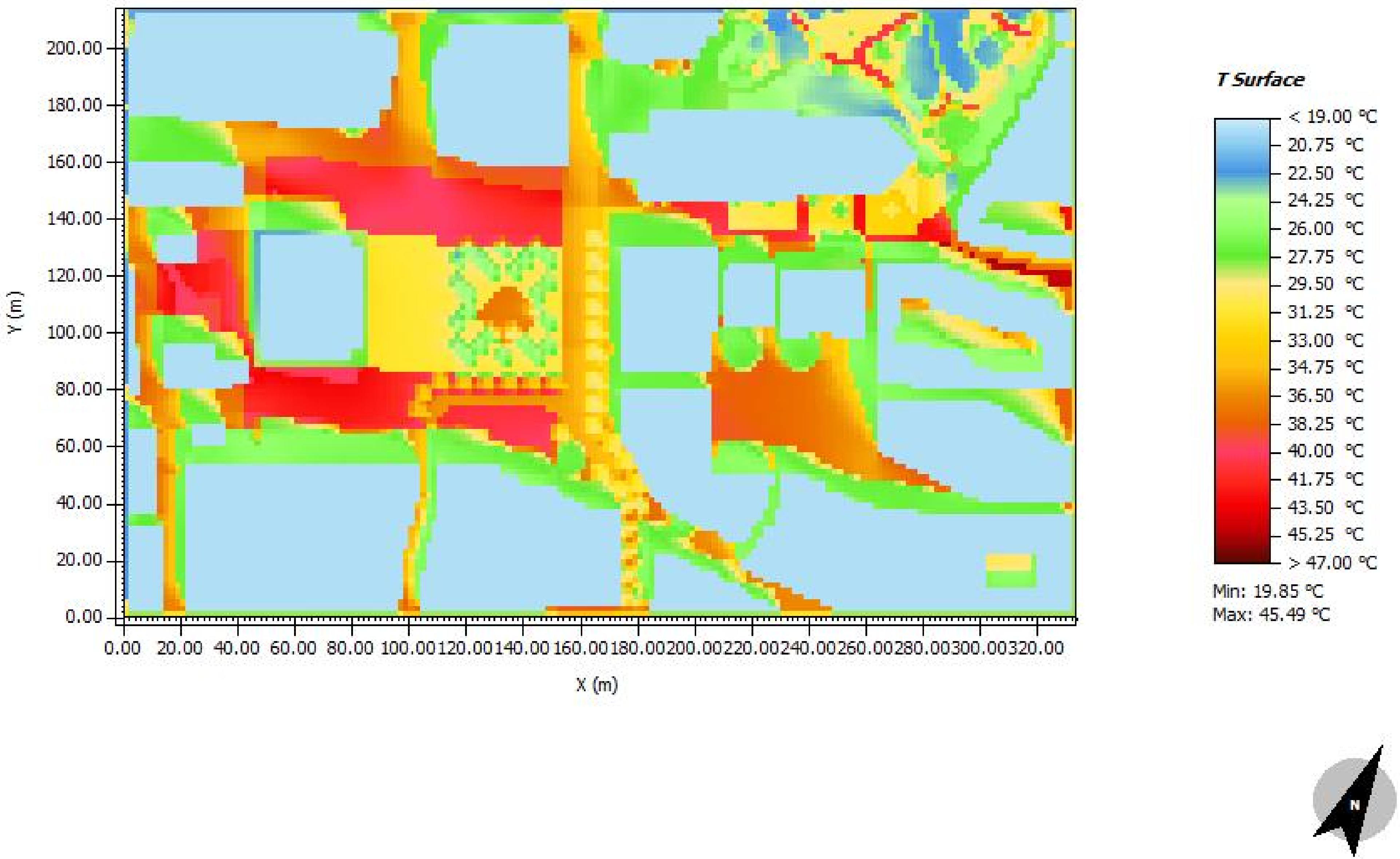


FIGURE 1: GRONINGEN-THIRD PROPOSAL 11:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

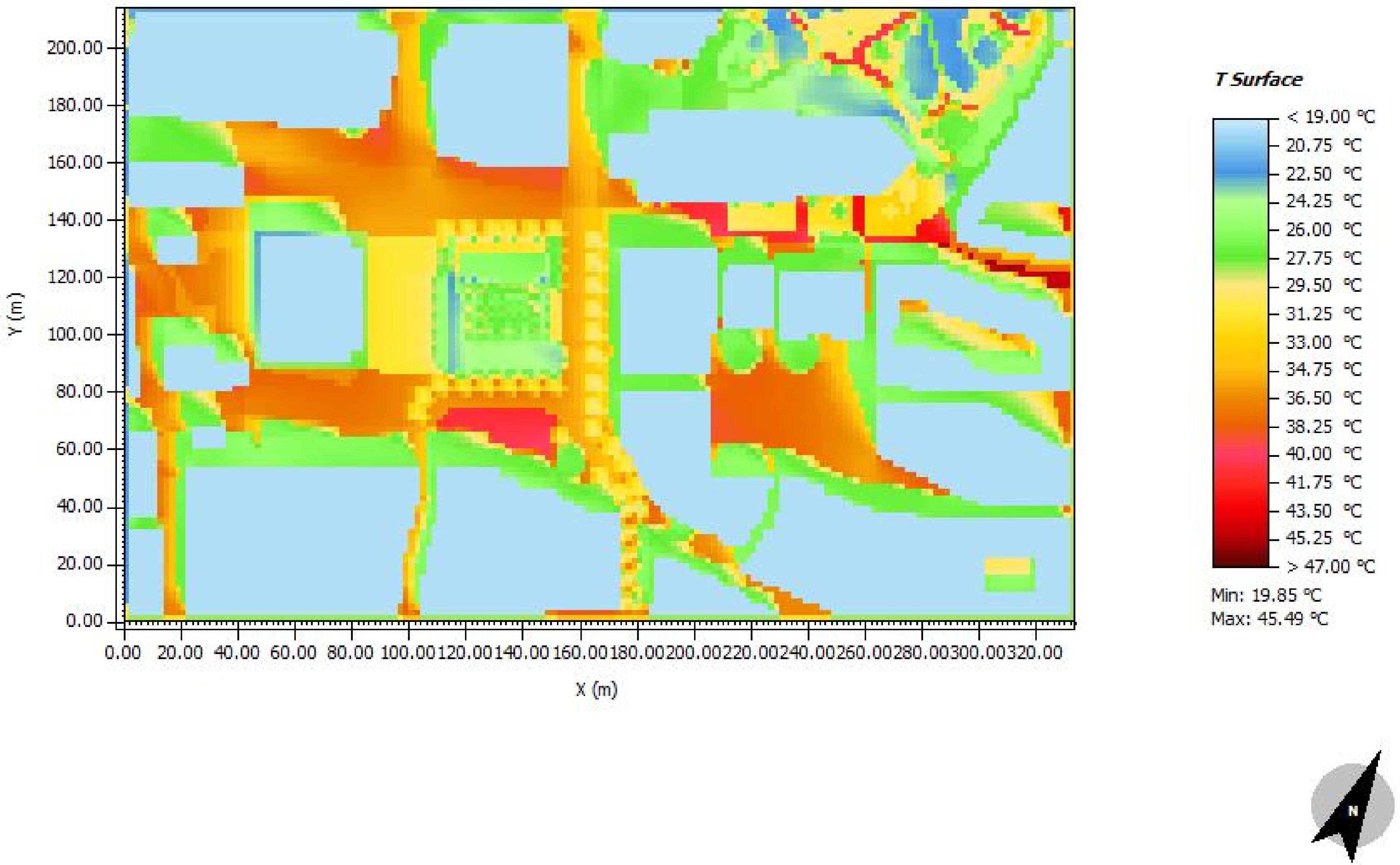


FIGURE 1: GRONINGEN-CURRENT SITUATION 15:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

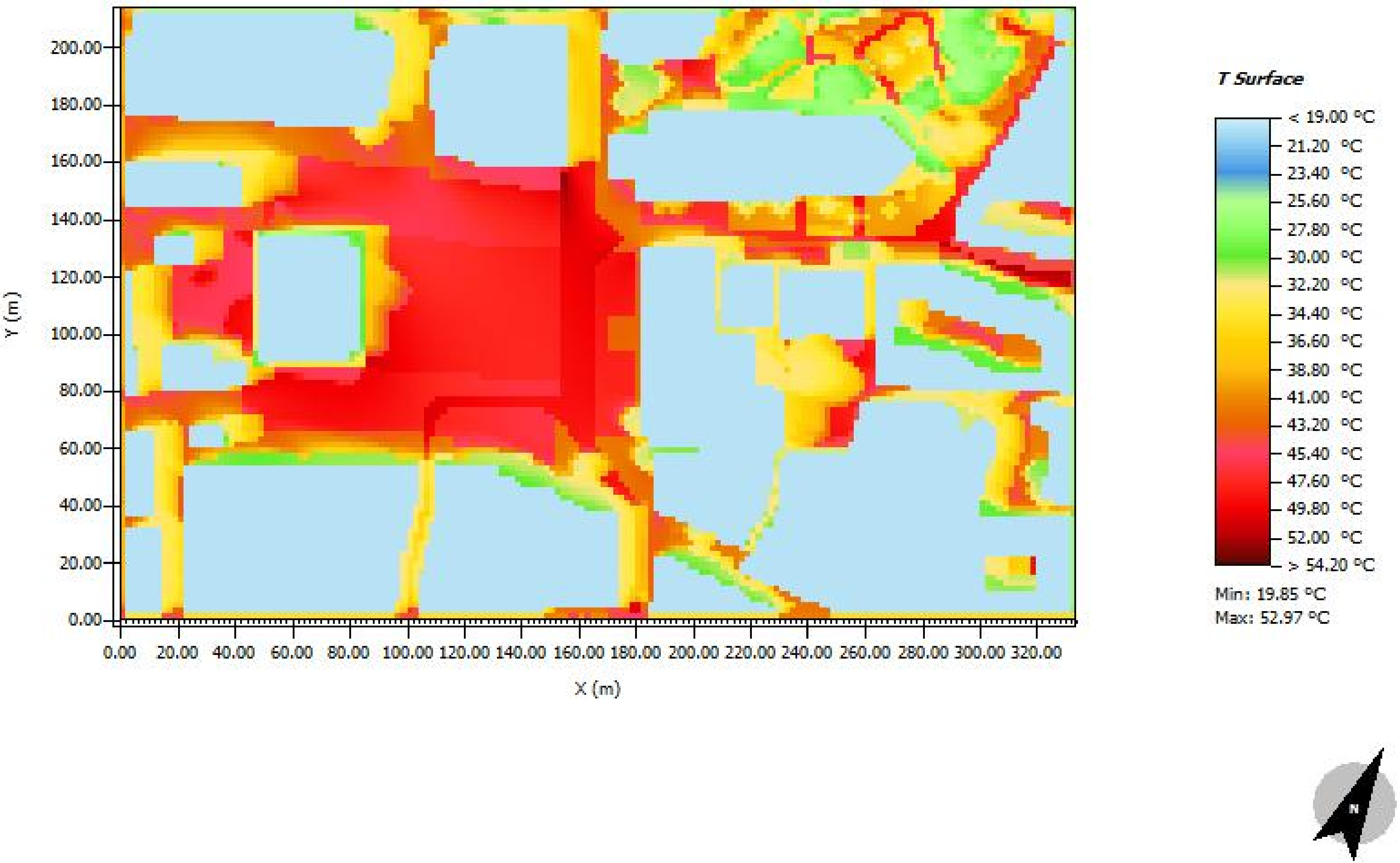


FIGURE 1: GRONINGEN-FIRST PROPOSAL 15:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

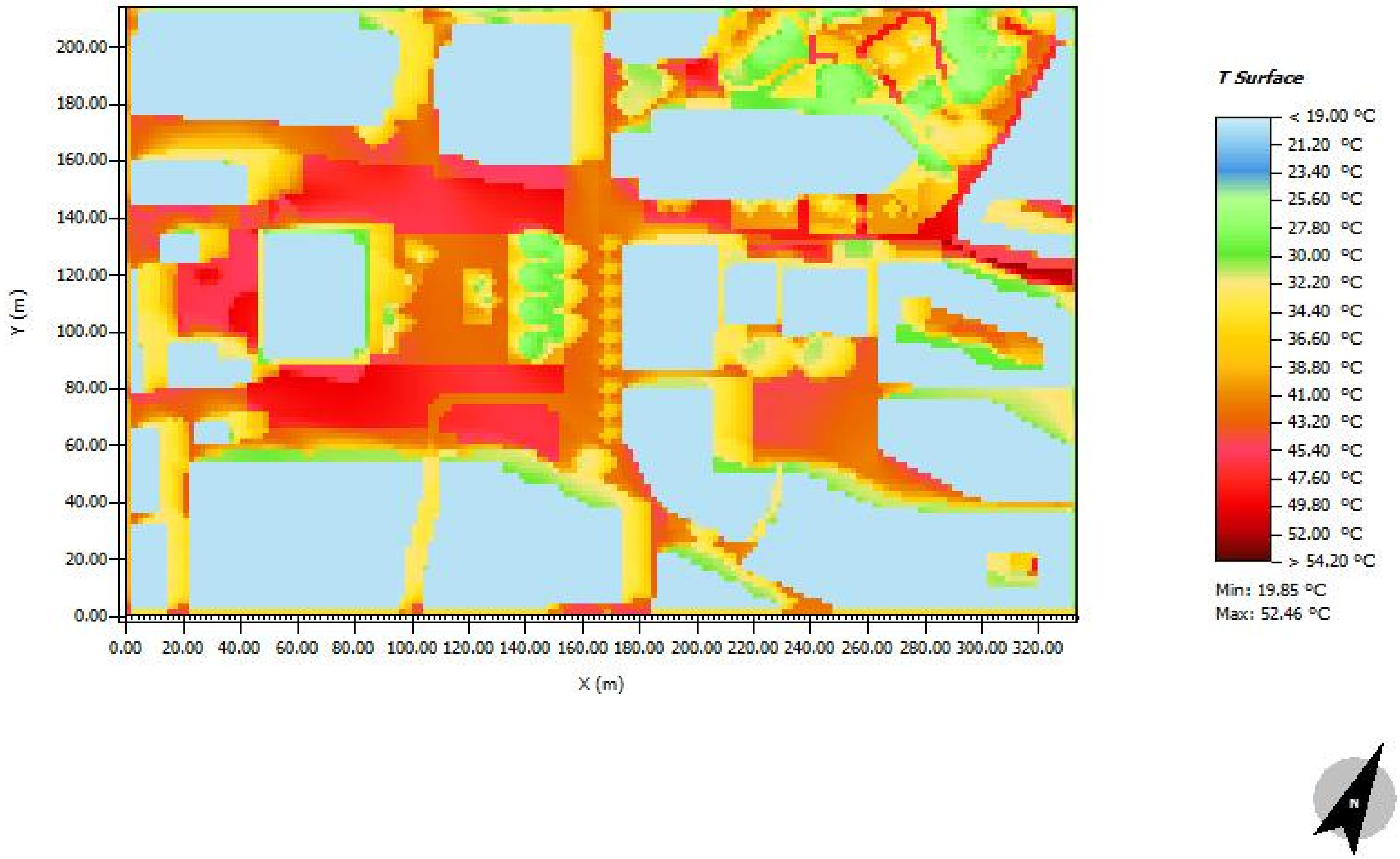


FIGURE 1: GRONINGEN-SECOND PROPOSAL 15:00:01 19.07.2014

SURFACE TEMPERATURE (z=0 m)

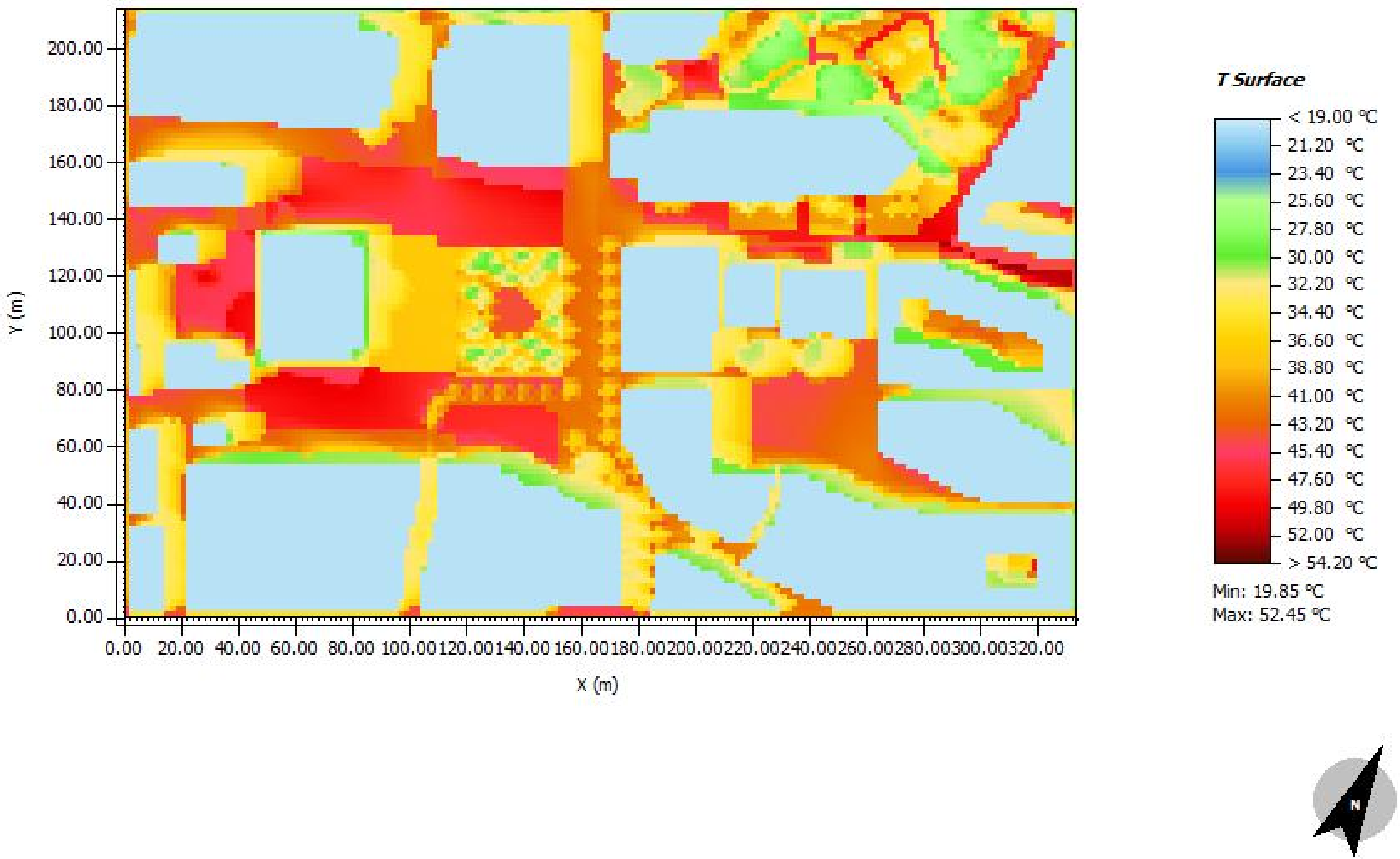


FIGURE 1: GRONINGEN-THIRD PROPOSAL 15:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

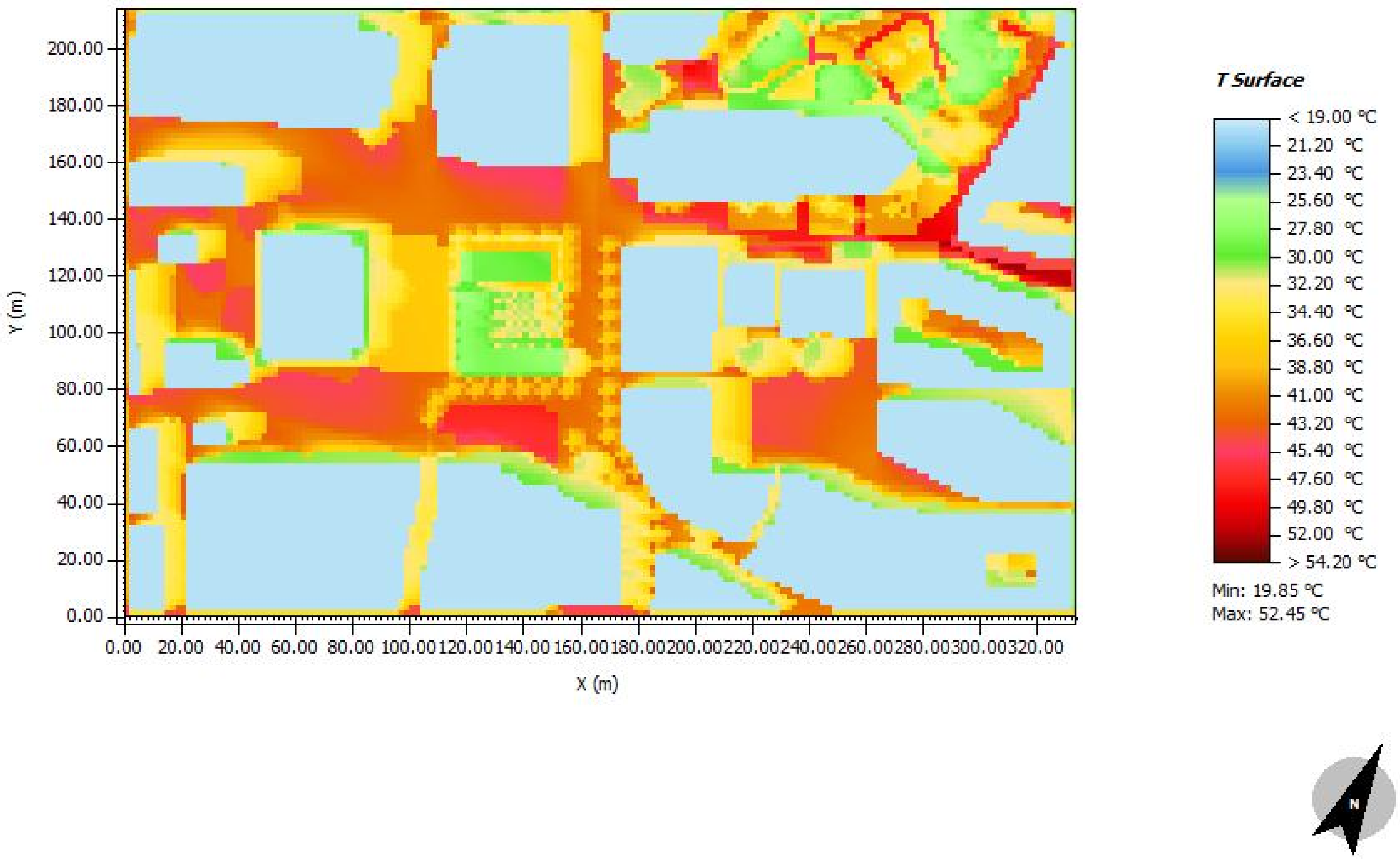


FIGURE 1: GRONINGEN-CURRENT SITUATION 19:00:01 19.07.2014

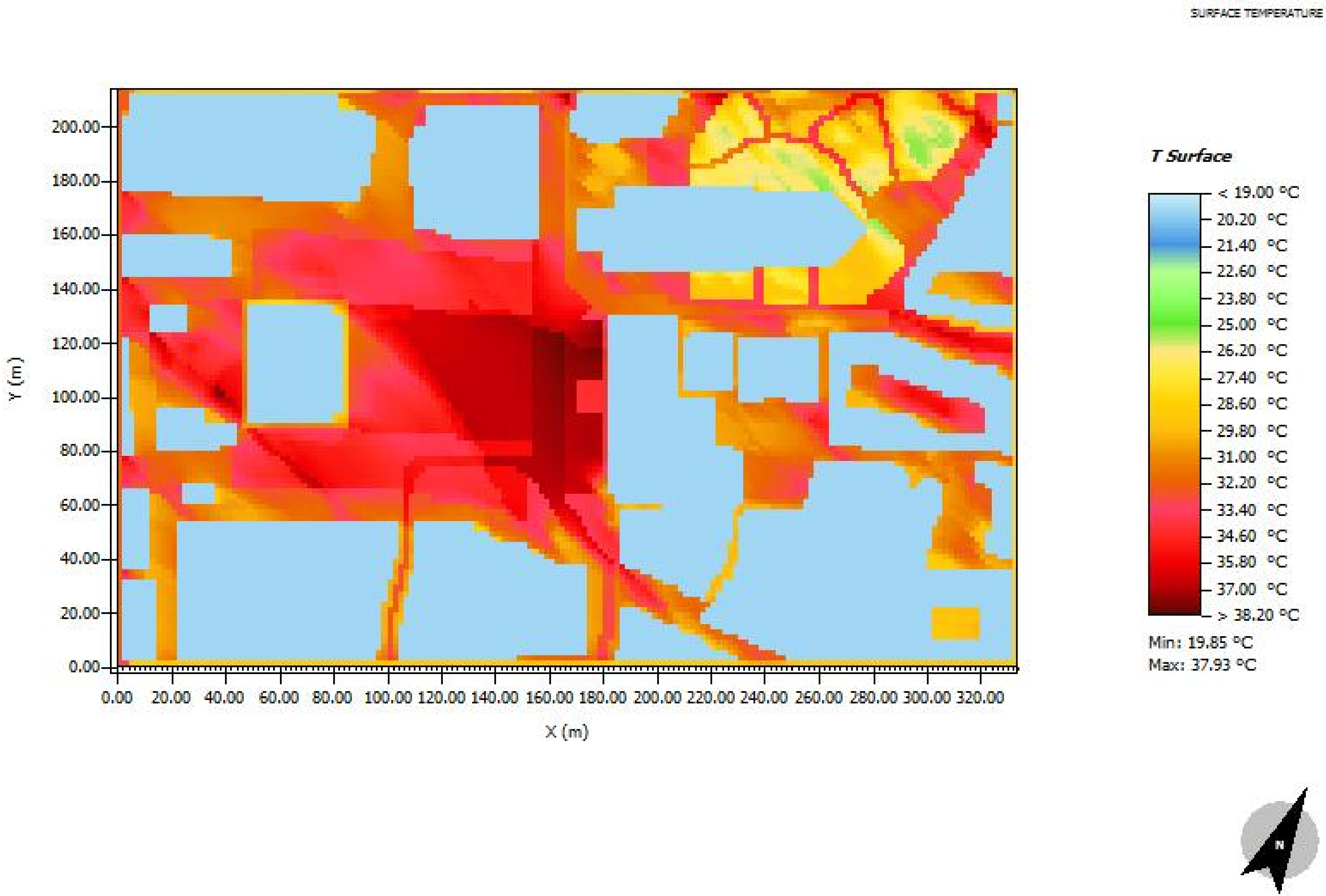


FIGURE 1: GRONINGEN-SECOND PROPOSAL 19:00:01 19.07.2014

SURFACE TEMPERATURE(z=0 m)

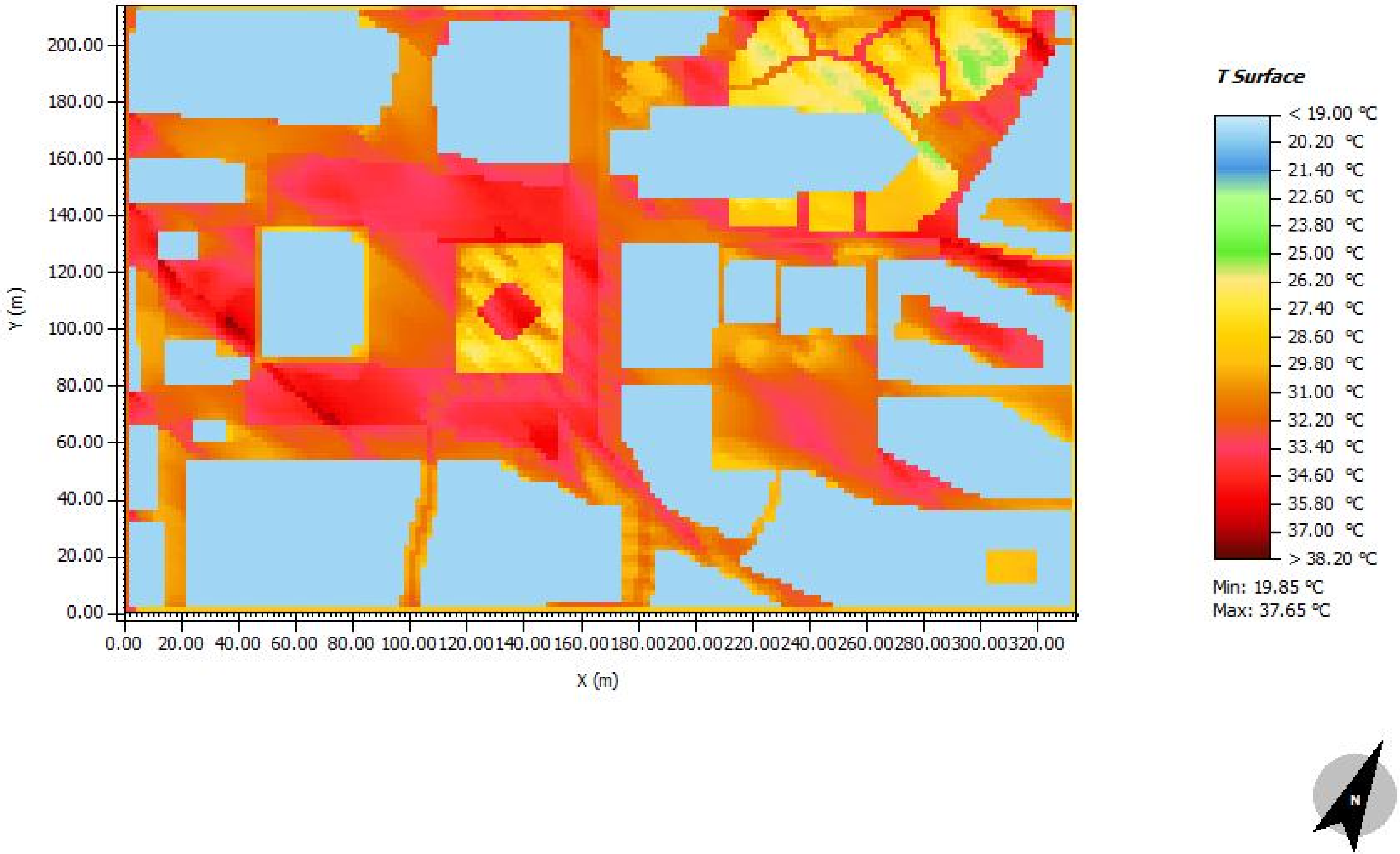


FIGURE 1: GRONINGEN-THIRD PROPOSAL 19:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

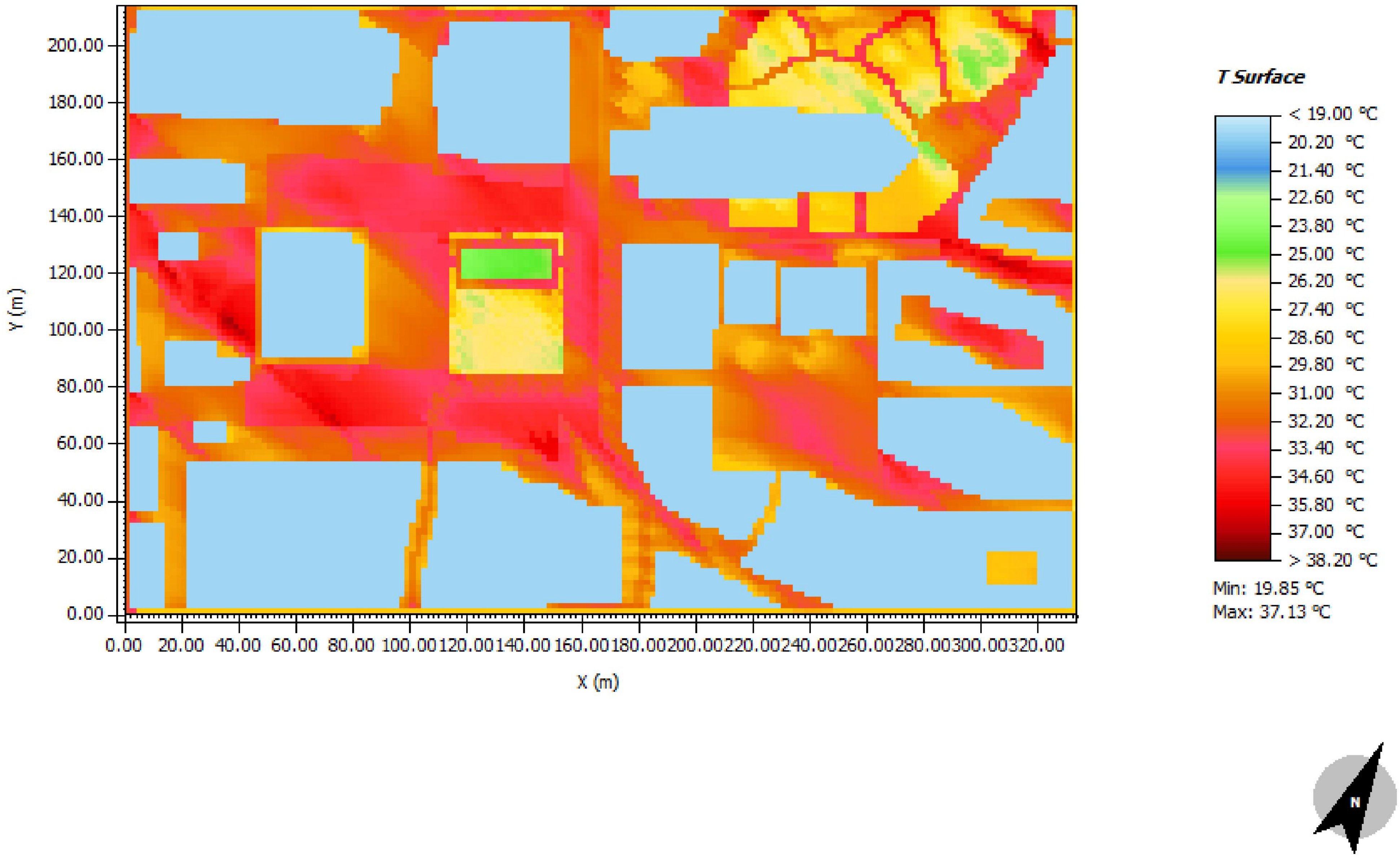


FIGURE 1: GRONINGEN-CURRENT SITUATION 23:00:01 19.07.2014

SURFACE TEMPERATURE (z=0m)

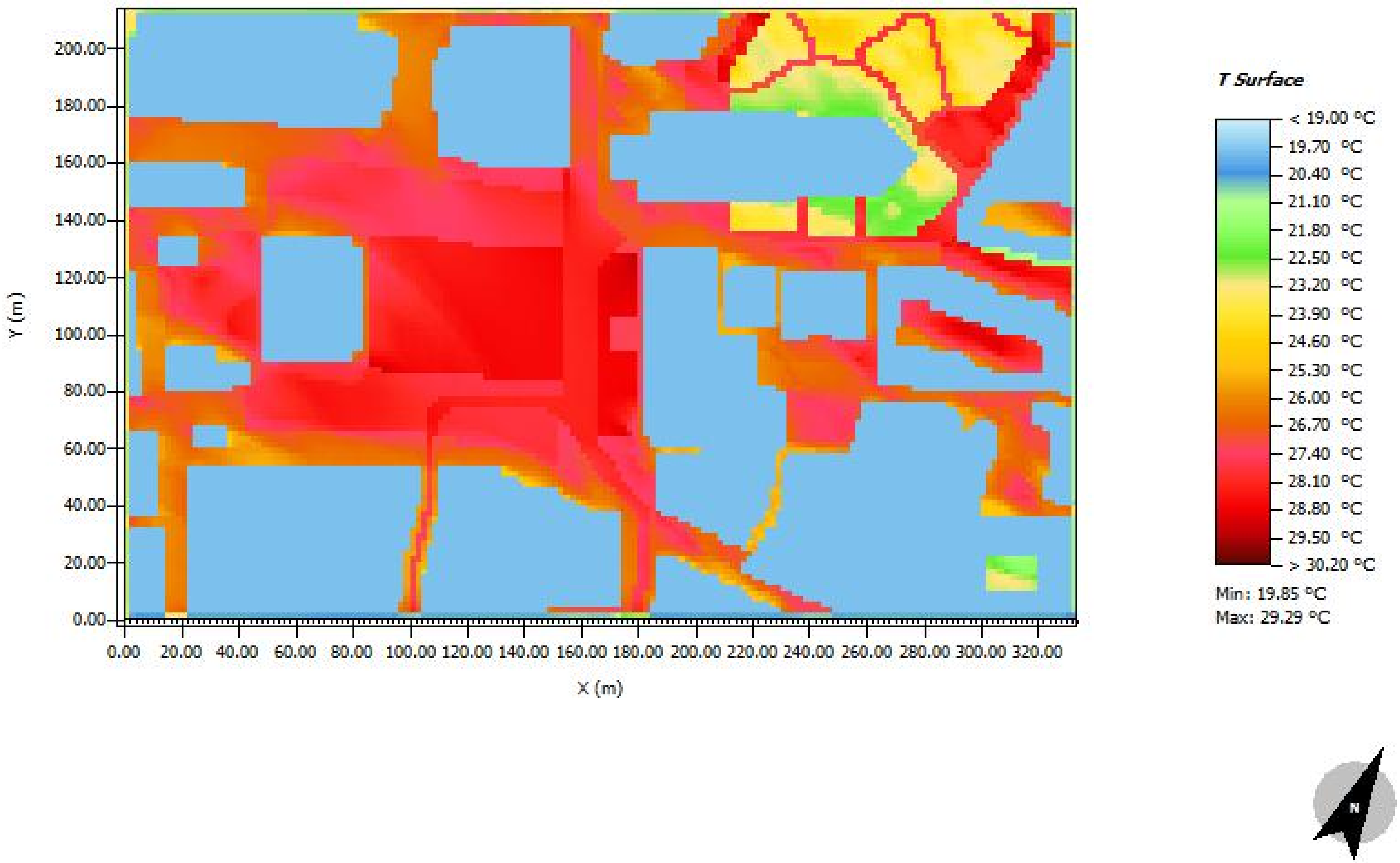


FIGURE 1: GRONINGEN-SECOND PROPOSAL 23:00:01 19.07.2014

SURFACE TEMPERATURE (z=0 m)

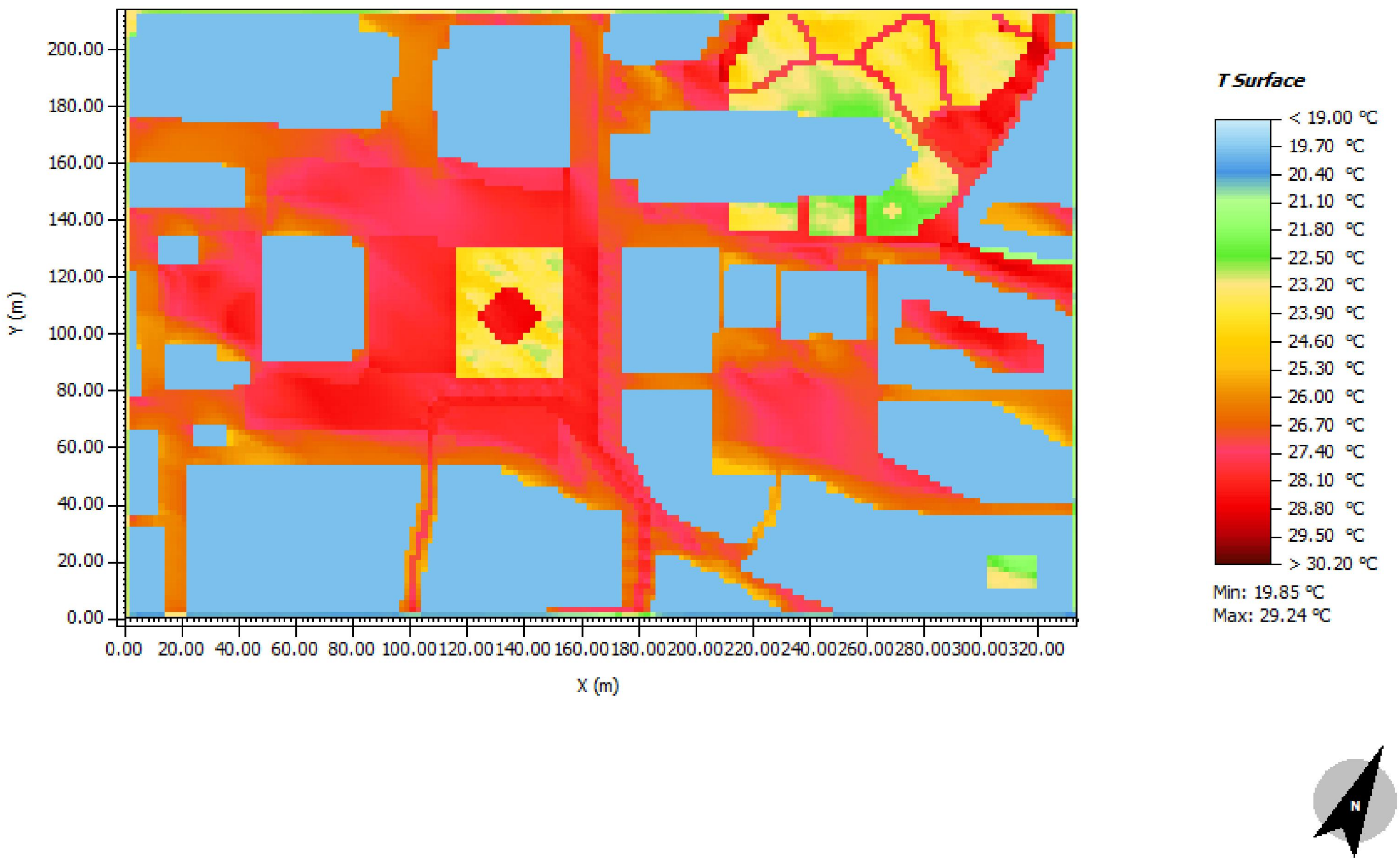
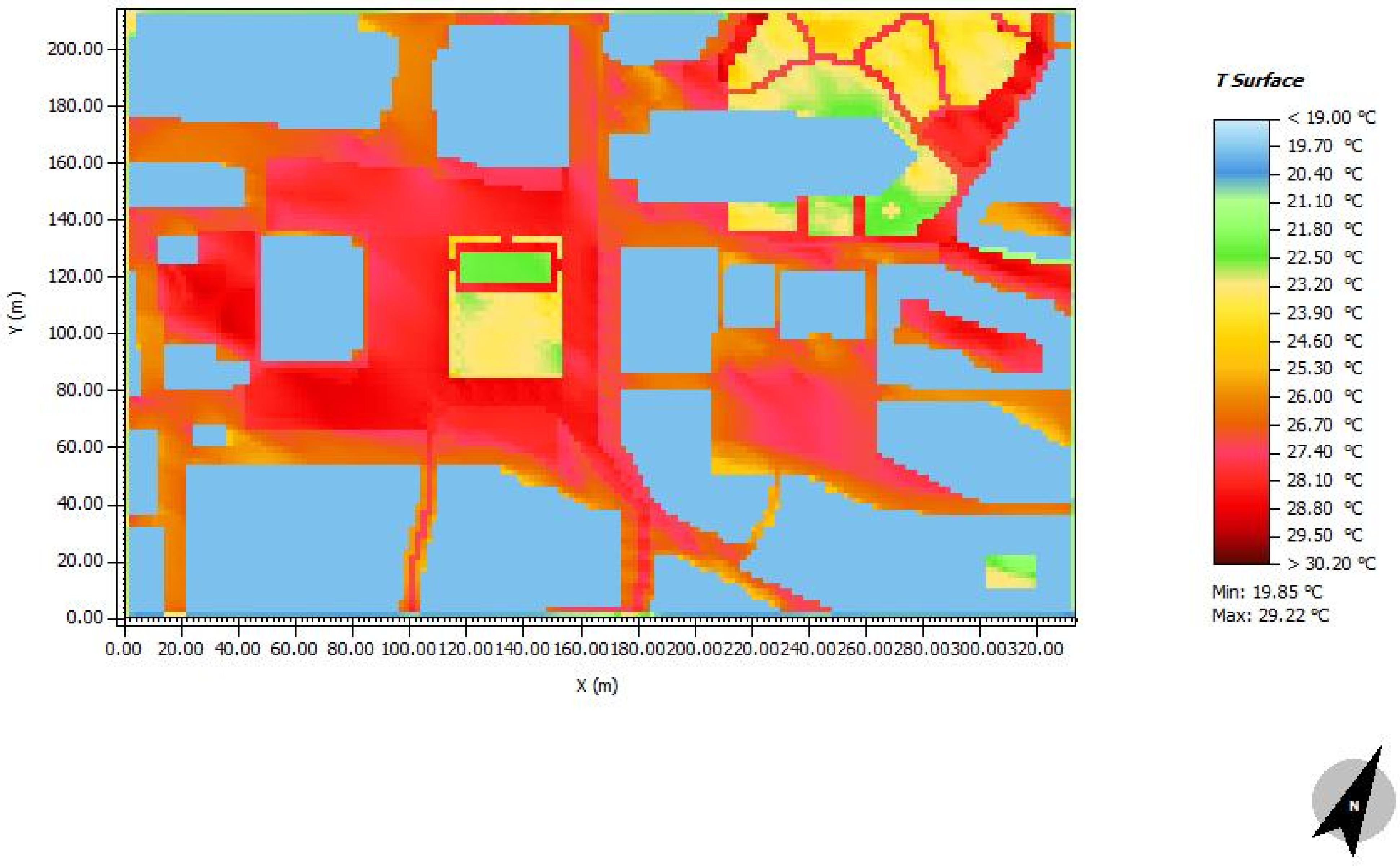


FIGURE 1: GRONINGEN-THIRD PROPOSAL 23:00:01 19.07.2014

SURFACE TEMEPERATURE (z=0m)



CONCLUSIONS

SURFACE TEMPERATURE

The analysis about surface temperature was done taking into account 5 different hours during the day, more specifically at 07:00, at 11:00, at 15:00, at 19:00 and at 23:00 hours. The reason of this distribution is due to the fact that surface temperature varies greatly not only during the day but also during the night.

As the heat maps show, the surface temperature is mainly related with the albedo factor. As a consequence, it is possible to distinguish between different materials.

At 07:00 it is possible to observe that surface temperature in any of the three proposals can reach a minimum temperature of 17.30 ºC in Grote Markt whereas in the current situation the minimum temperature is 20.60 ºC.

At 11:00 the average surface temperature in Grote Markt is around 40.00 ºC in the current situation. However, in the third proposal is around 26.00 ºC, the change is very significant.

At 15:00 the difference between the current situation and the proposals reach the maximum difference in surface temperature. The current situation shows an average of 47.60 ºC whereas the third proposal presents an average of 27.80 ºC. It is very significant the fact that between 11:00 and 15:00 the average surface temperature has increased 7.6 ºC in the current situation, but in the third proposal only 1.80 ºC.

At 19:00 the maps show a drop in surface temperature especially in the areas where buildings provide shadow. It is possible to observe in the four scenarios the shadow created by the city hall in Grote Markt due to the sunset.

At 23:00 it is possible to detect the cooling rate of the materials. For instance, the water temperature in the third proposal has decreased only 2.50 ºC. However, the material behind the city hall in the same proposal has decrease 6.30 ºC.

As a general conclusion about surface temperature, it could be said that the albedo factor plays a very important role. Moreover, as it will be later show, the surface temperature has a direct influence in the temperature at 1 meter high, thus having a great impact in thermal comfort.

OUTCOMES’ ANALYSIS

SURFACE ALBEDO

FIGURE 2: GRONINGEN-CURRENT SITUATION 19.07.2014

SURFACE ALBEDO (z=0m)

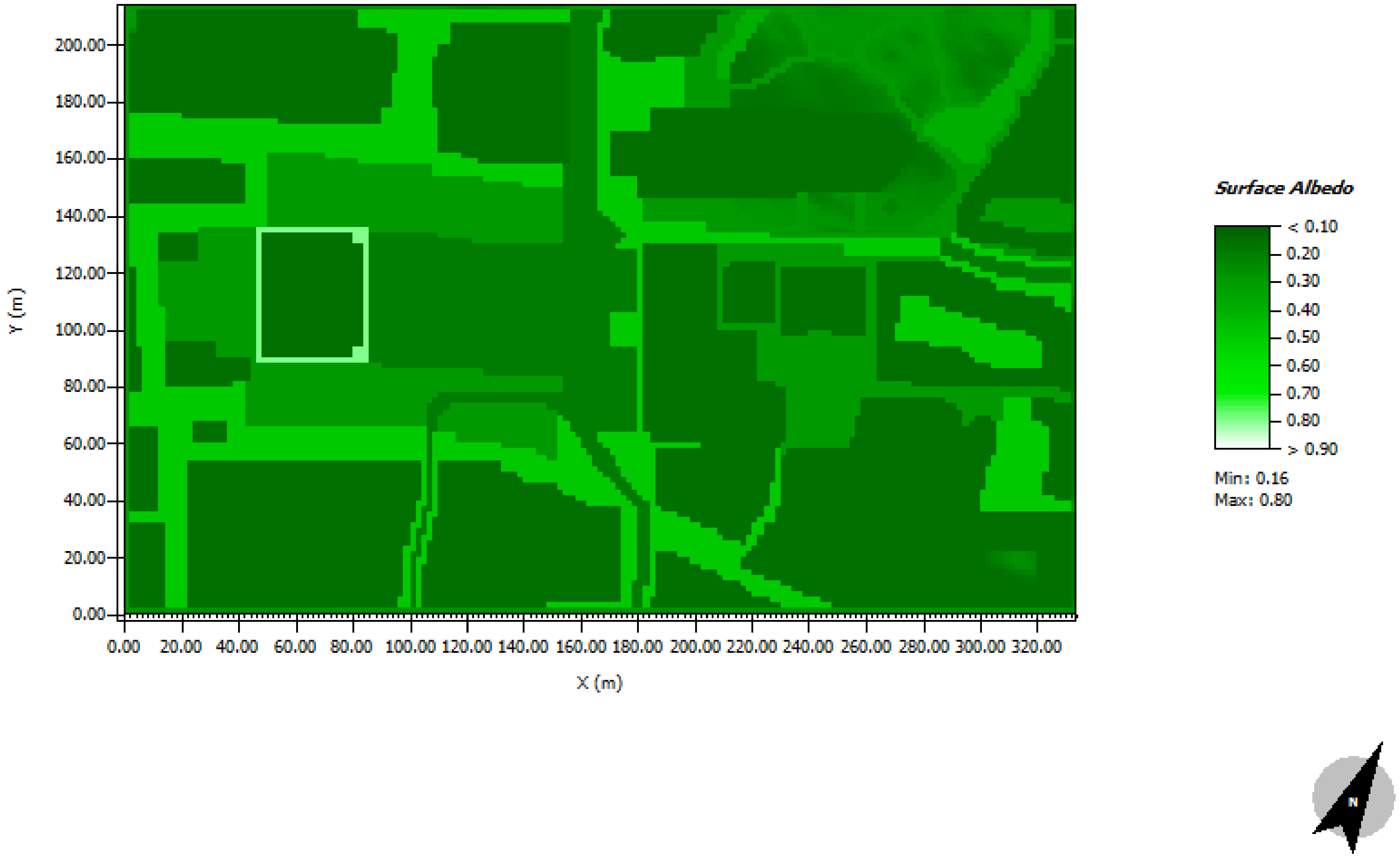


FIGURE 2: GRONINGEN-FIRST PROPOSAL 19.07.2014

SURFACE ALBEDO (z=0m)

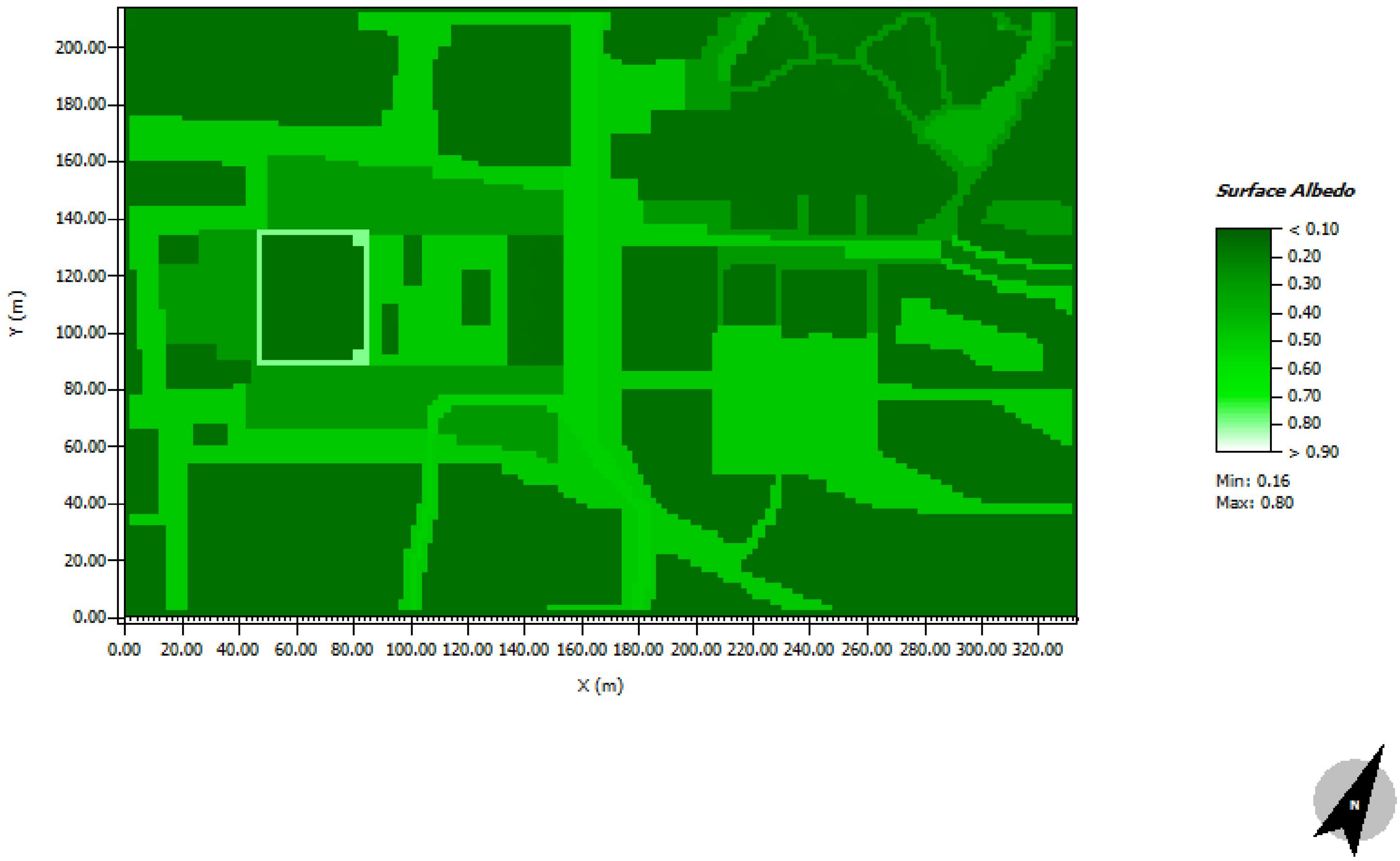


FIGURE 2: GRONINGEN-SECOND PROPOSAL 23:00:01 19.07.2014

SURFACE ALBEDO(z=0 m)

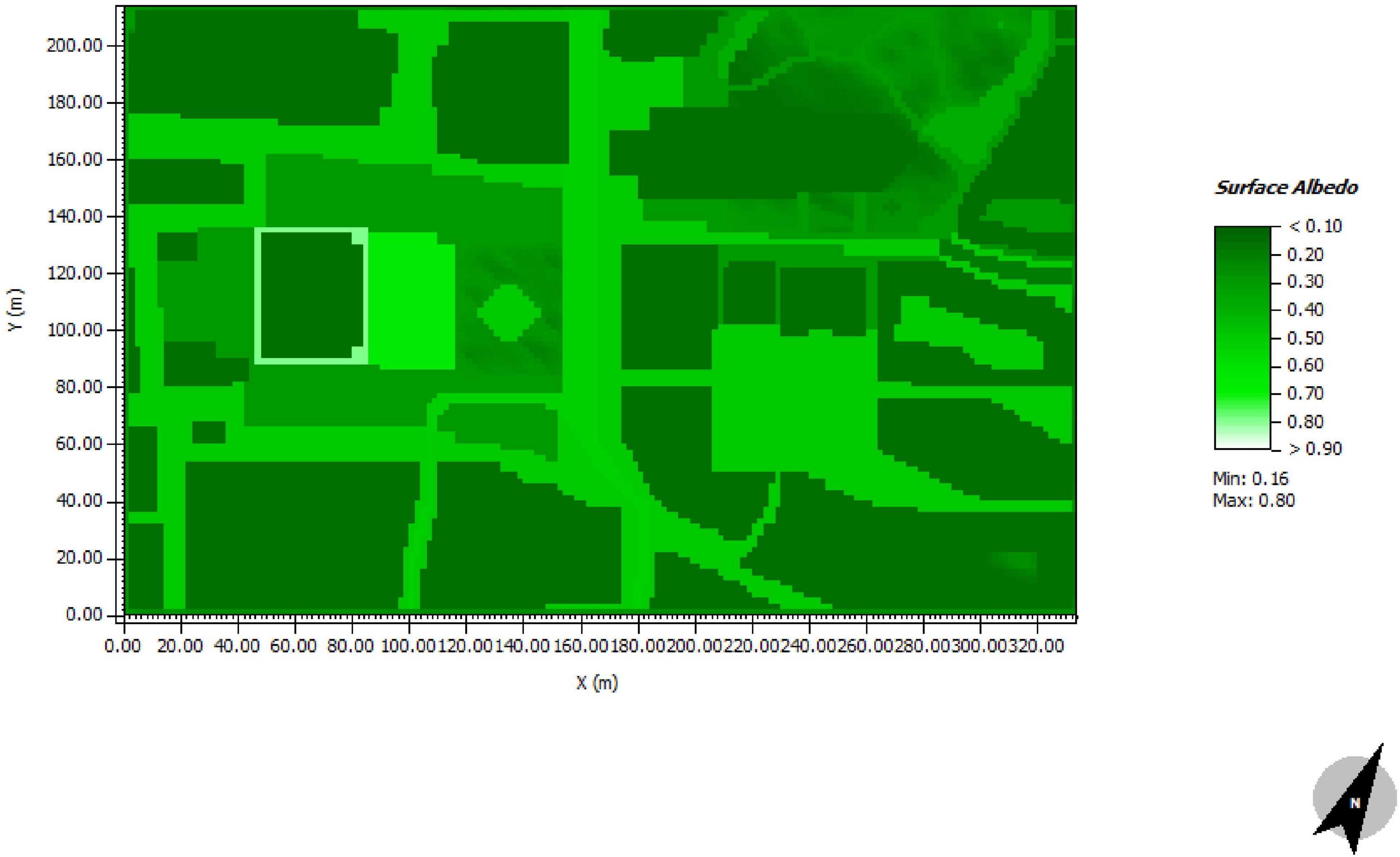
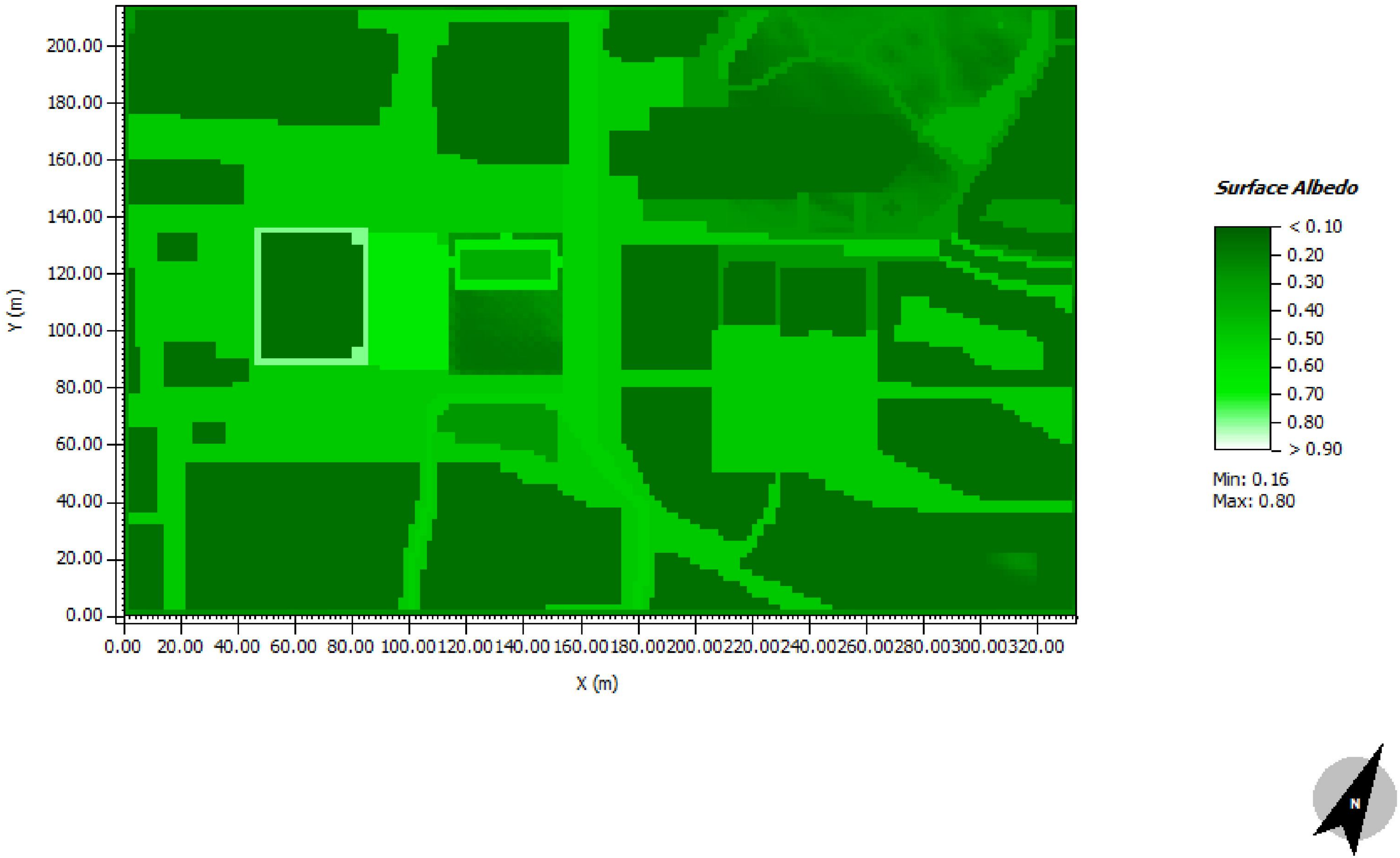


FIGURE 2: GRONINGEN-THIRD PROPOSAL 19.07.2014

SURFACE ALBEDO (z=0 m)



CONCLUSION

SURFACE ALBEDO

With regard to surface albedo it was not necessary to choose different times during the day because it does not depend on the moment of the day. The reflectivity of each material is a characteristic which remains the same, it is unchanging.

The legend shows values from 0.10 to 0.90 which means the following:

- The closest to the value 1.00, the less radiation will be absorbed
- The closest to the value 0.00, the less radiation will be reflected

As the analysis shows, the colors in the current situation are darker than in the other scenarios. This fact demonstrates that the current situation absorbs more radiation, so it is heated more easily.

As a conclusion, the scenario with the highest average of reflectivity coefficient is the third one, followed by the second one and finally the first one.

OUTCOMES' ANALYSIS

AIR TEMPERATURE

FIGURE 3: GRONINGEN-CURRENT SITUATION 11:00:01 19.07.2014

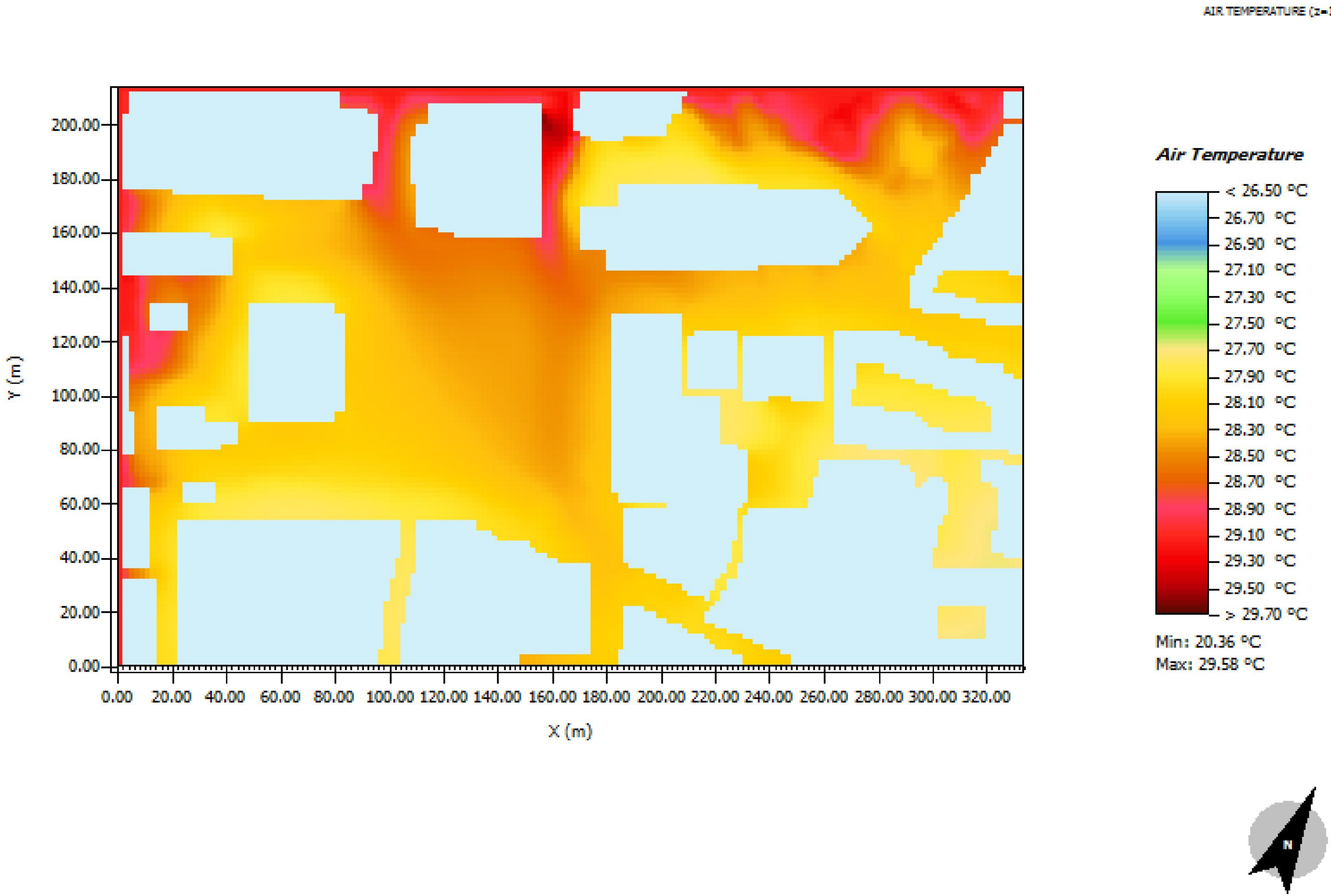


FIGURE 3: GRONINGEN-FIRST PROPOSAL 11:00:01 19.07.2014

AIR TEMPERATURE (z=1.00 m)

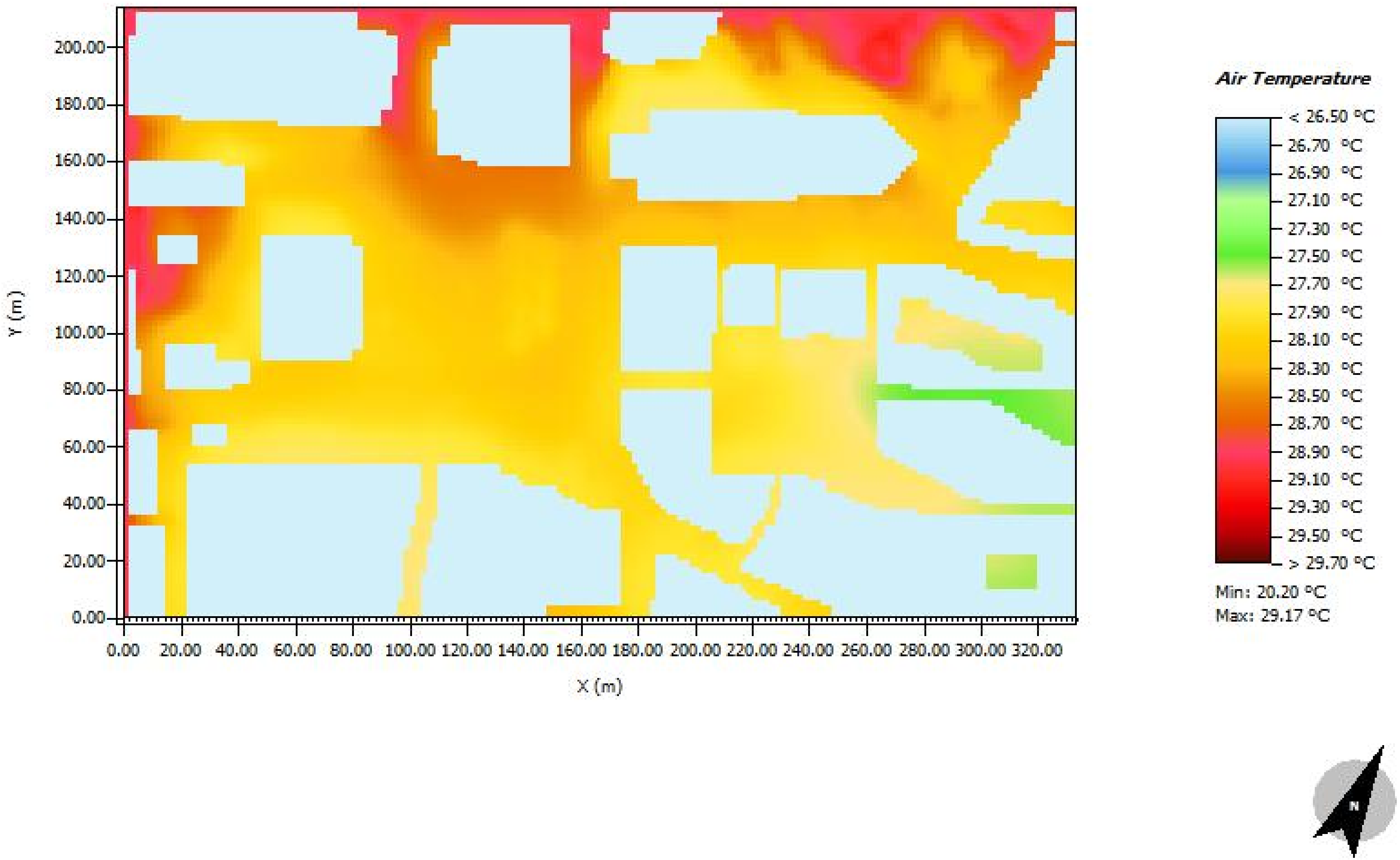


FIGURE 3: GRONINGEN-SECOND PROPOSAL 11:00:01 19.07.2014

AIR TEMPERATURE (z=1.00 m)

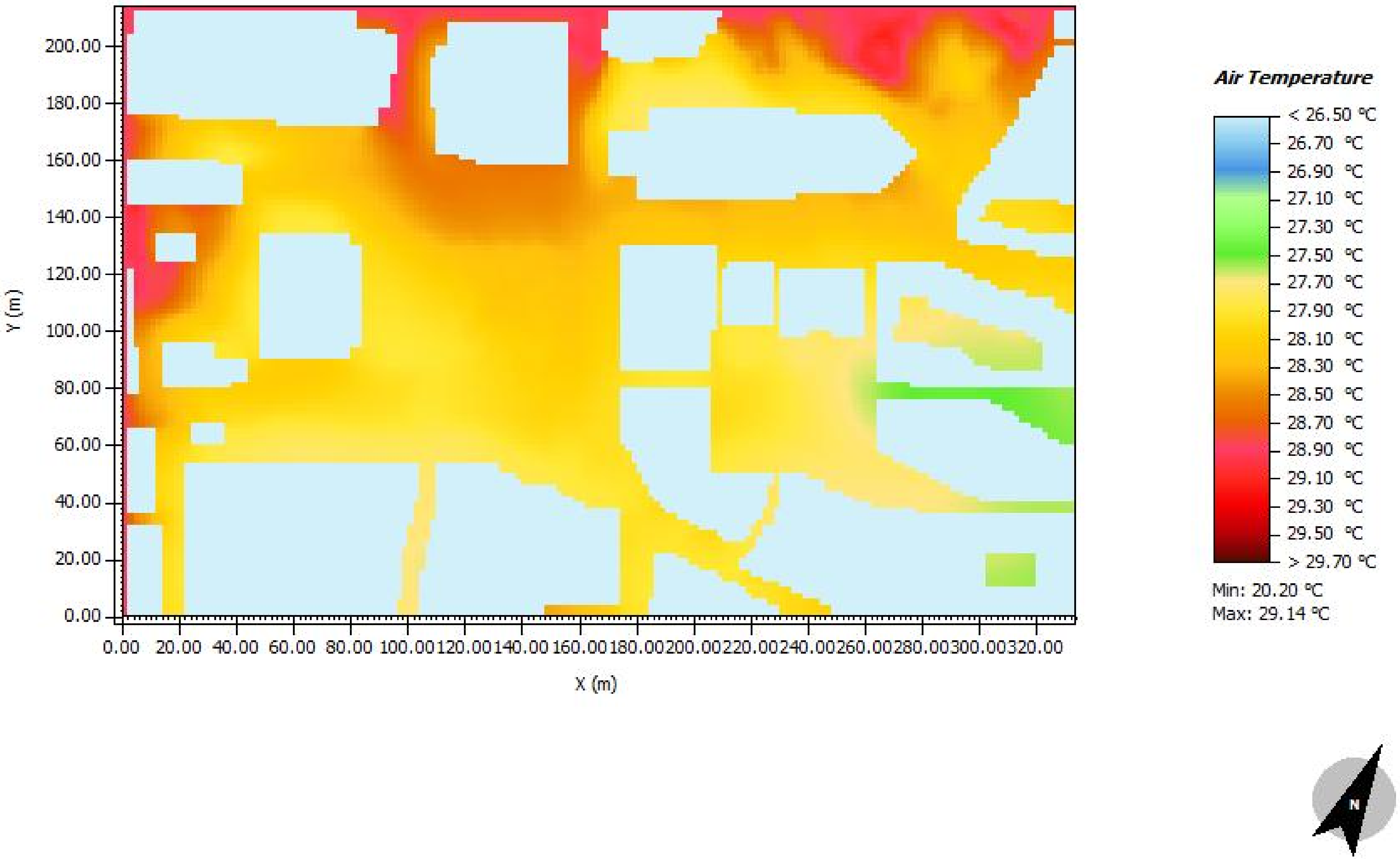


FIGURE 3: GRONINGEN-THIRD PROPOSAL 11:00:01 19.07.2014

AIR TEMPERATURE (z=1.00 m)

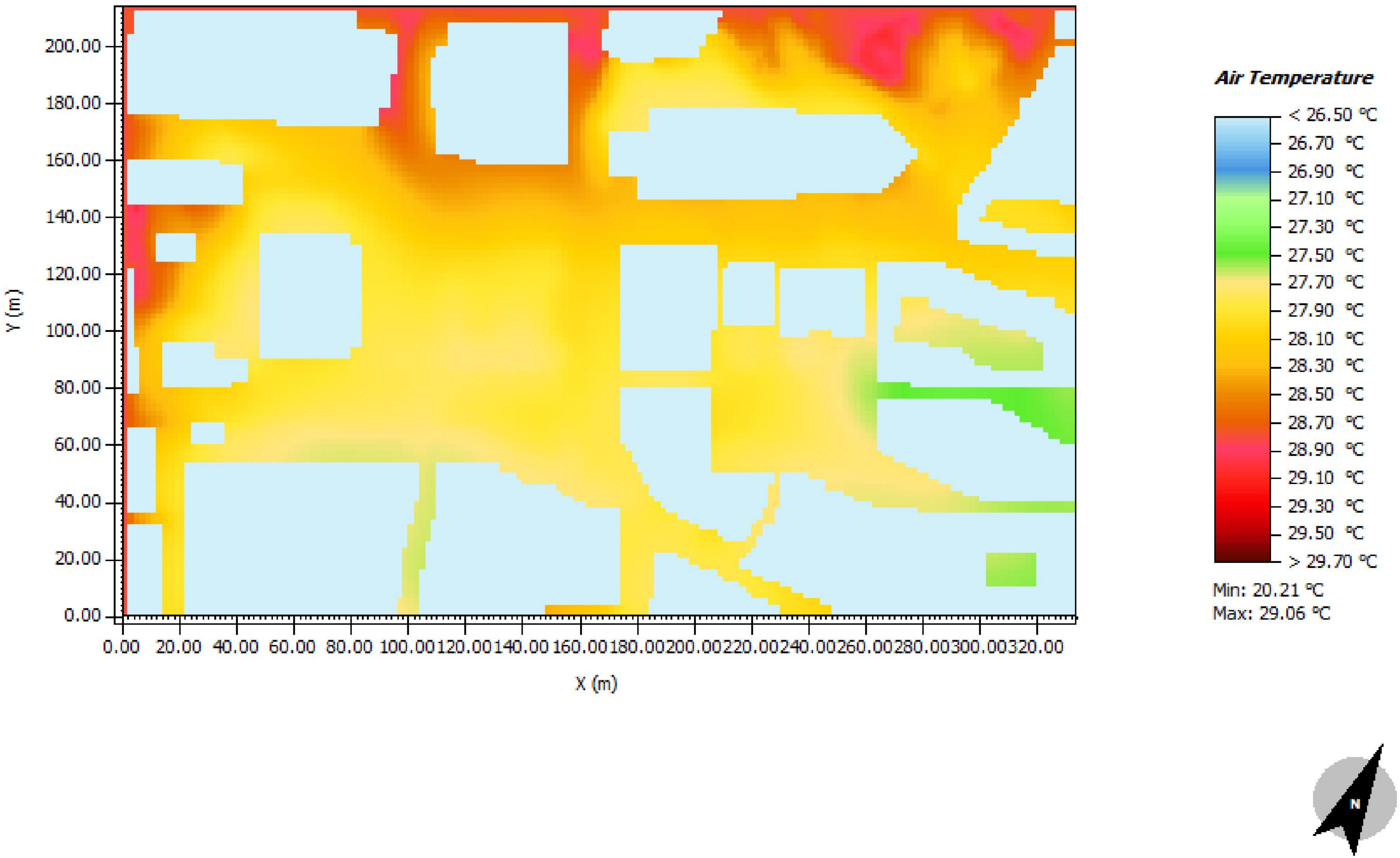


FIGURE 3: GRONINGEN-CURRENT SITUATION 15:00:01 19.07.2014

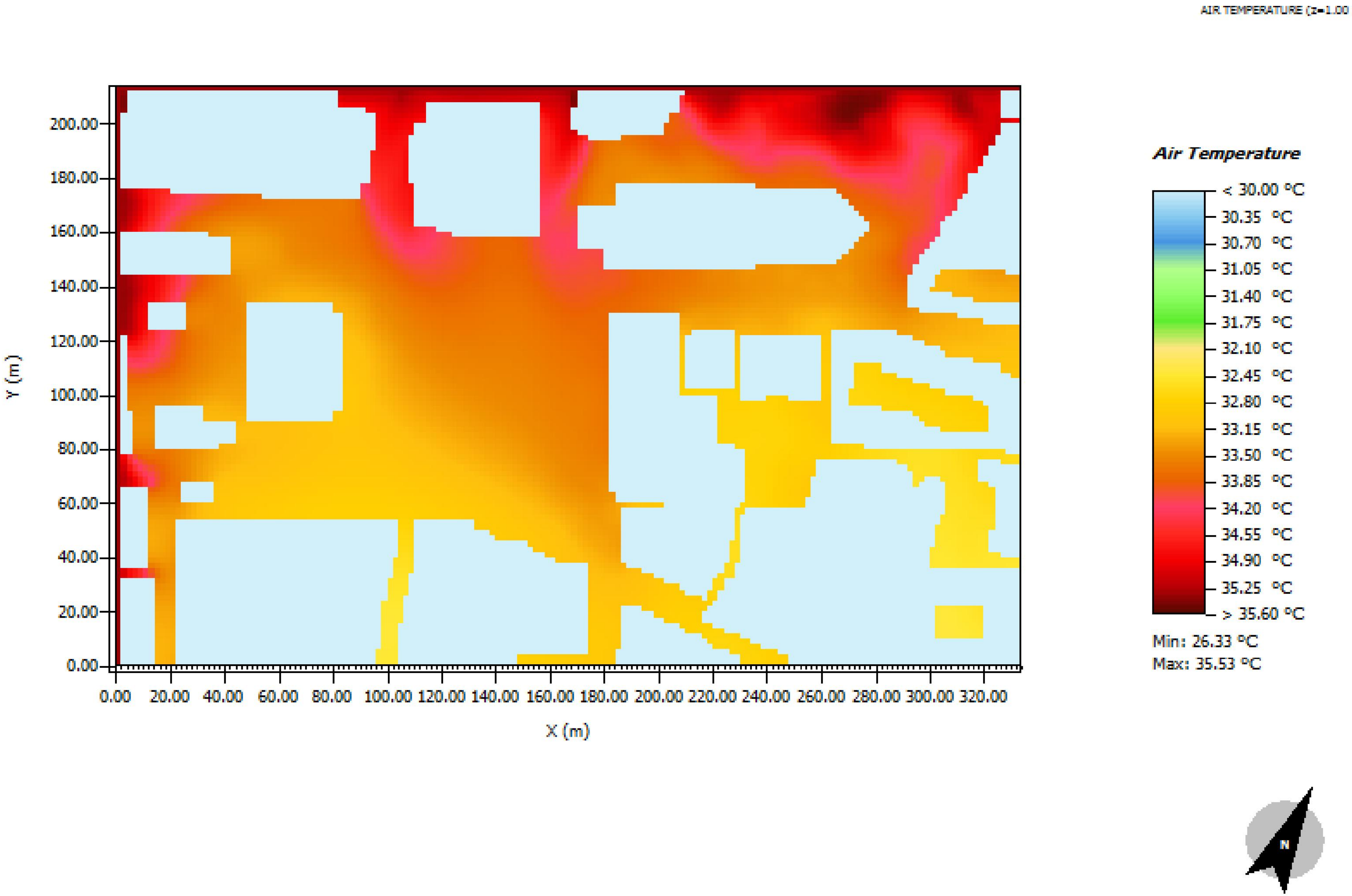


FIGURE 3: GRONINGEN-FIRST
PROPOSAL 15:00:01 19.07.2014

AIR TEMPERATURE (z=1.00 m)

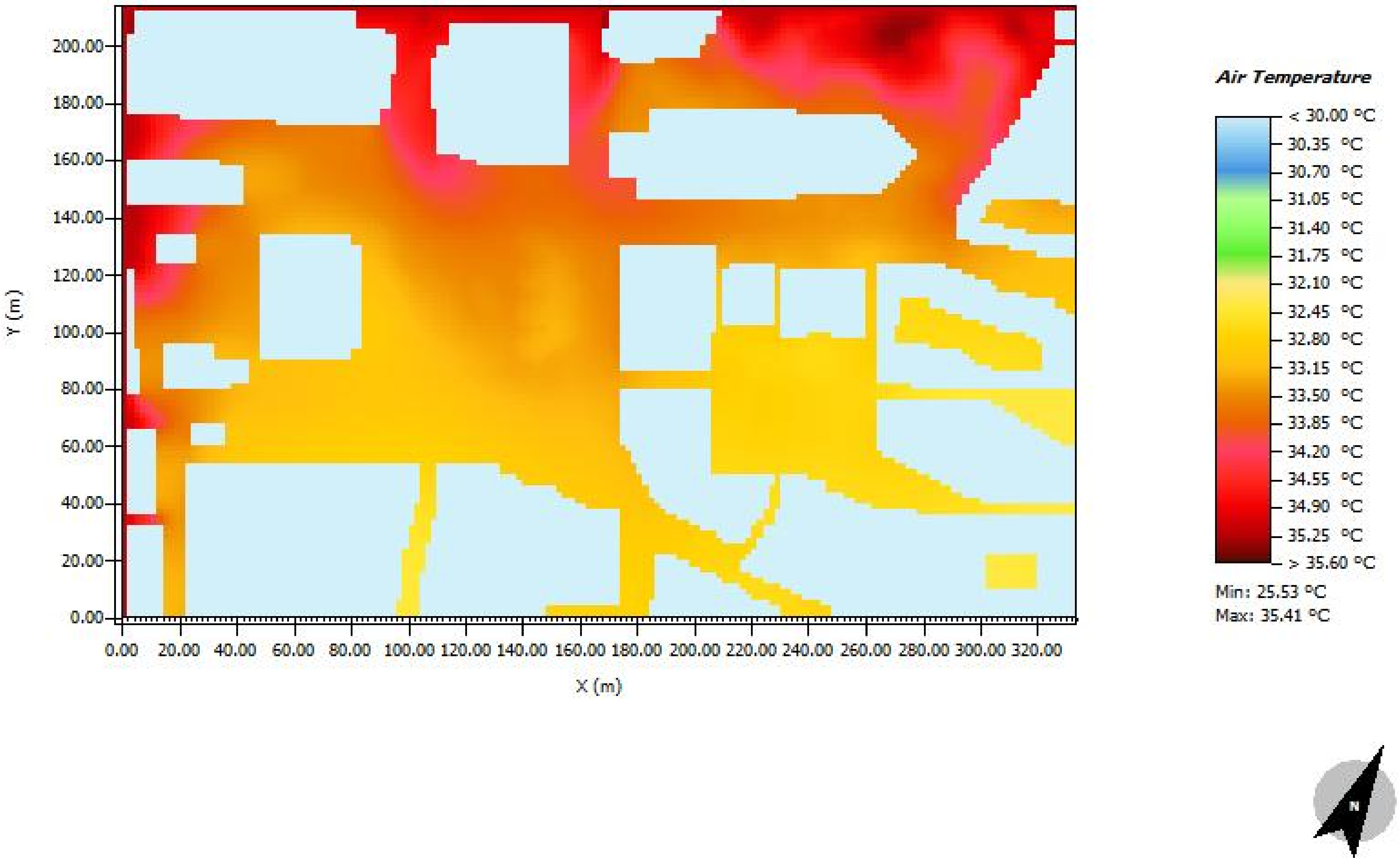


FIGURE 3: GRONINGEN-SECOND PROPOSAL 15:00:01 19.07.2014

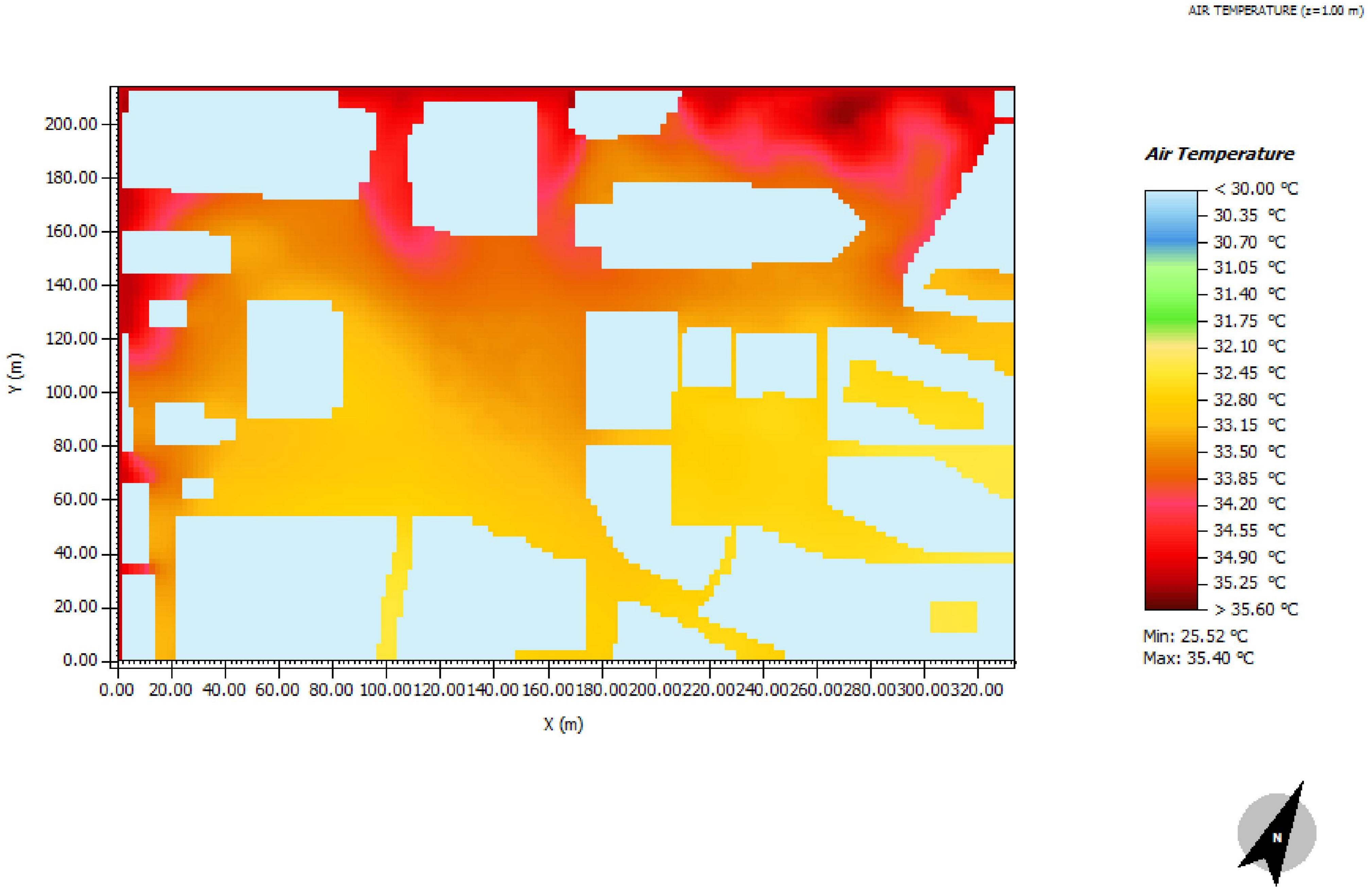


FIGURE 3: GRONINGEN-THIRD PROPOSAL 15:00:01 19.07.2014

AIR TEMPERATURE (z=1.00 m)

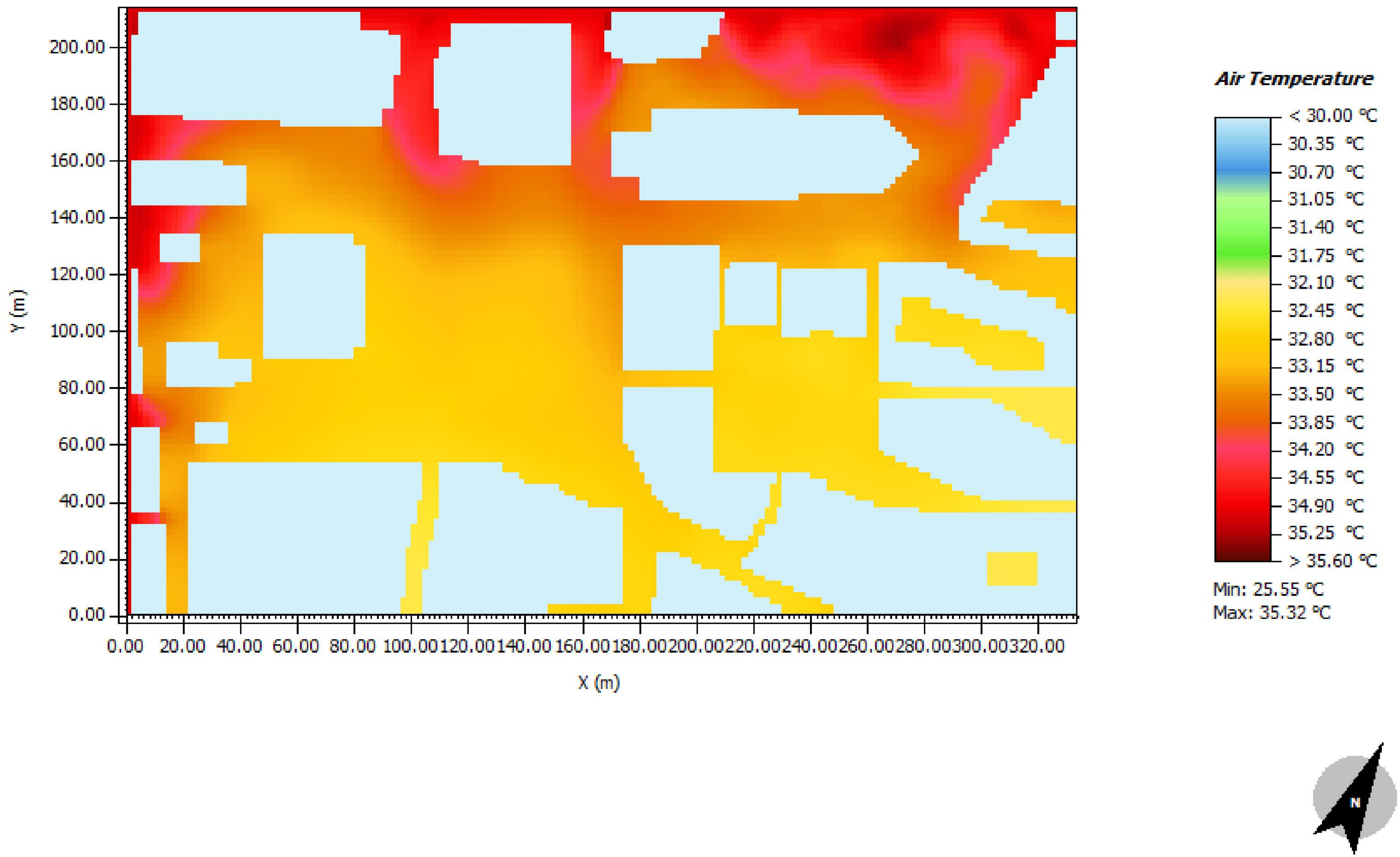


FIGURE 3: GRONINGEN-CURRENT SITUATION 19:00:01 19.07.2014

AIR TEMPERATURE (z=1.00 m)

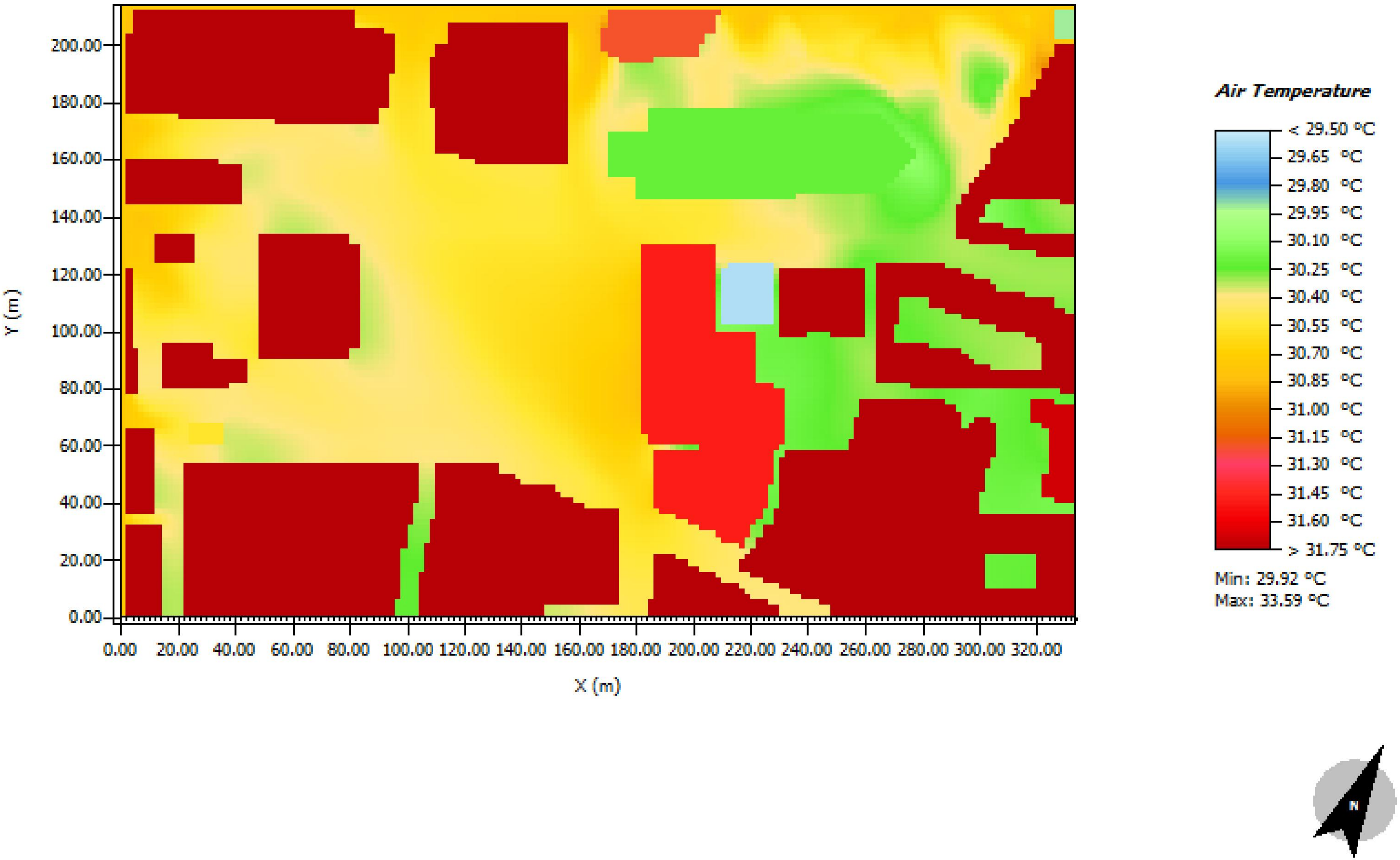


FIGURE 3: GRONINGEN-SECOND PROPOSAL 19:00:01 19.07.2014

AIR TEMPERATURE (z=1.00 m)

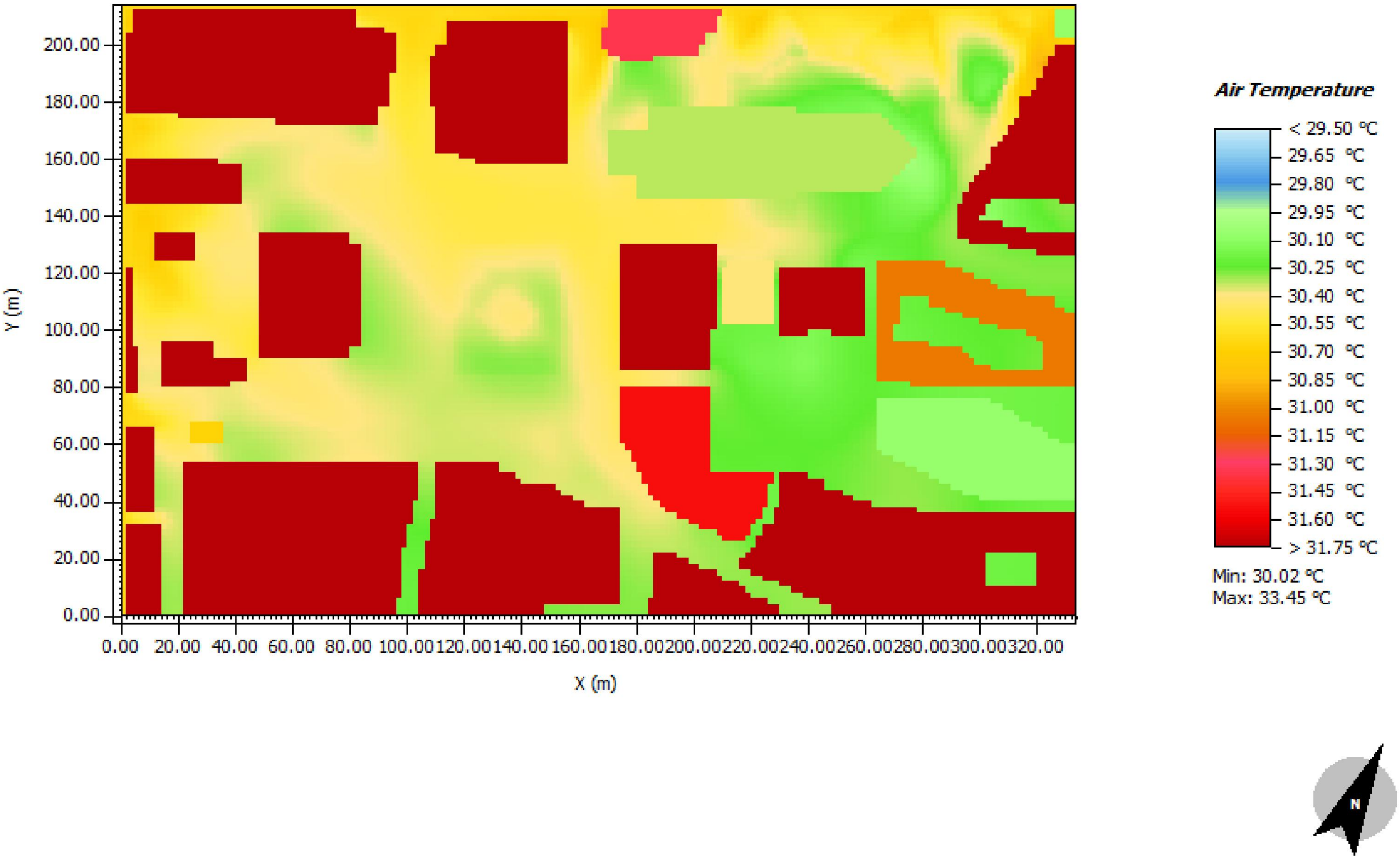
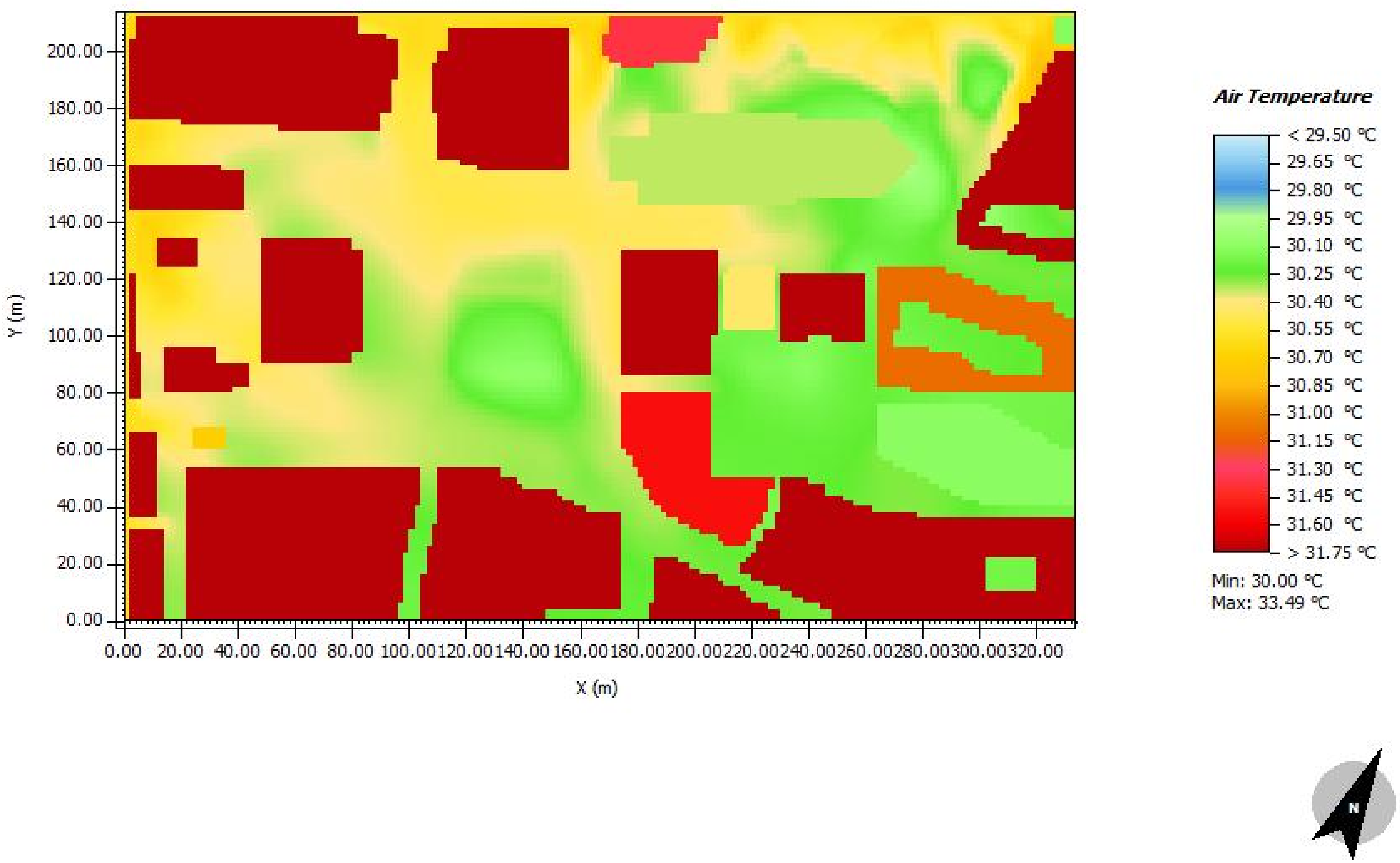


FIGURE 3: GRONINGEN-THIRD PROPOSAL 19:00:01 19.07.2014

AIR TEMPERATURE (z=1.00 m)



CONCLUSION

AIR TEMPERATURE

Air temperature is the most important factor to be considered in order to improve the thermal comfort in a particular area. It can be measured at different heights, the most common ones are between one and two meters high.

This feature was measured three times during the day, at 11:00, at 15:00 and at 19:00. Before 11:00 and after 19:00 the variation in the air temperature is insignificant.

At 11:00 the outcomes show that the average air temperature in Grote Markt is around 28.50 ºC at 1 meter high whereas in the third proposal is around 27.90 ºC. The difference is 0.60 ºC which seems little but in fact it is an important significant difference.

At 15:00 air temperature reach its maximum value. The average in Grote Mark in the current situation is around 33.50 ºC whereas in the third proposal is 32.70 ºC increasing the difference until 0.8 ºC. This difference is due to the green-blue solutions present in the third proposal, especially the trees which provide shadow but also the grass that has a higher albedo factor that the actual material in Grote Mark.

At 15:00 it is also possible to see the difference in the materials used in the ground. Behind the city hall in the current situation the average air temperature is around 33.50 ºC whereas in the third proposal is 33.00 ºC. It is a difference of 0.50 ºC only changing the surface material.

At 19:00 the maps show a drop in the air temperature due to the sunset and the difference between the current situation and the third proposal is around 0.60 ºC.

As a conclusion, it has been achieved a significant reduction in temperature in Grote Mark using green-blue solutions. The difference is not as significant as it was in the surface temperature. However, air temperature has a greater effect in thermal comfort, especially at 1 meter high.

OUTCOMES’ ANALYSIS

WIND SPEED AND FLOW ANALYSIS

FIGURE 4: GRONINGEN-CURRENT SITUATION 11:00:01 19.07.2014

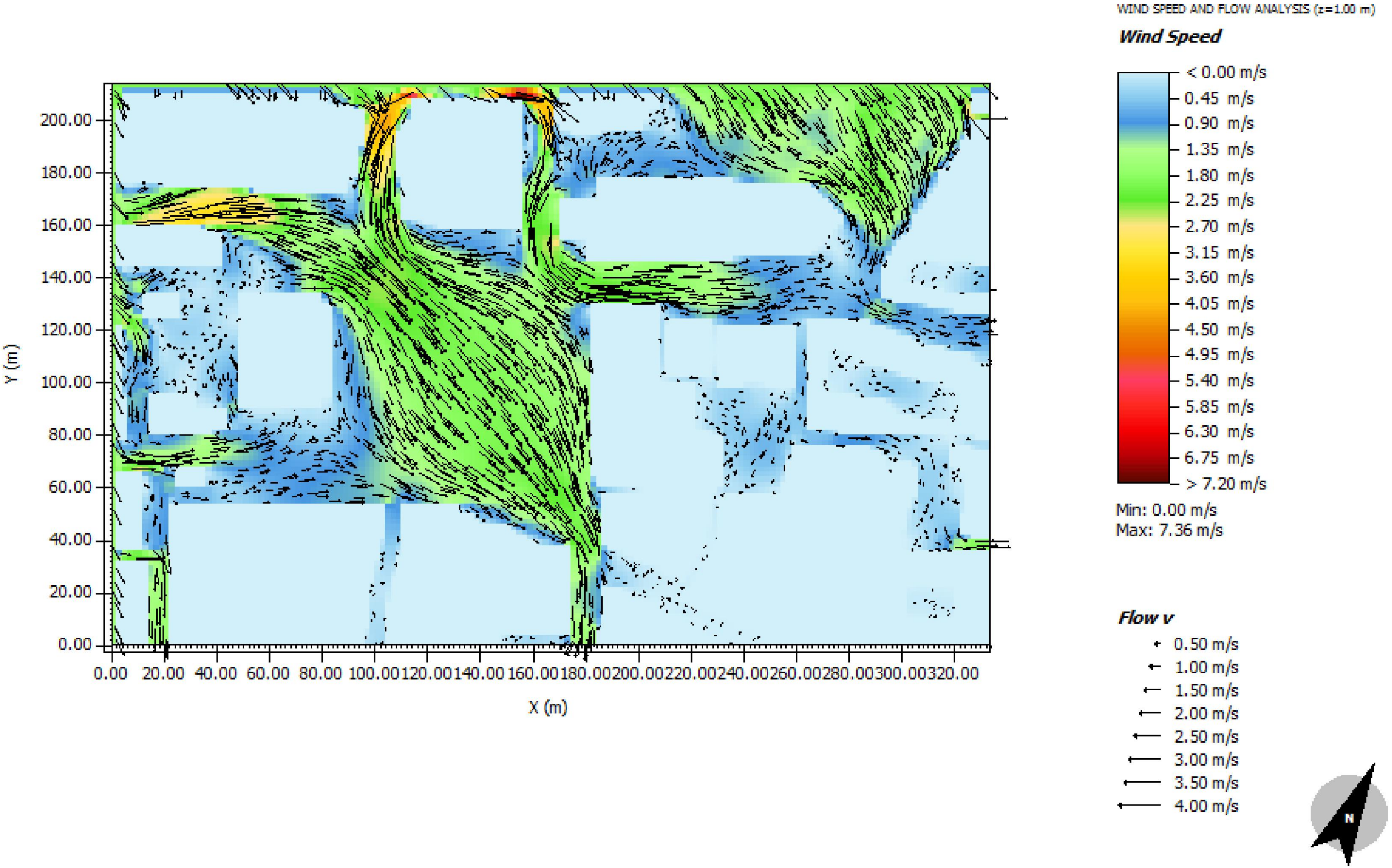


FIGURE 4: GRONINGEN-FIRST
PROPOSAL 11:00:01 19.07.2014

AIR TEMPERATURE AND FLOW ANALYIS (z=1.00 m)

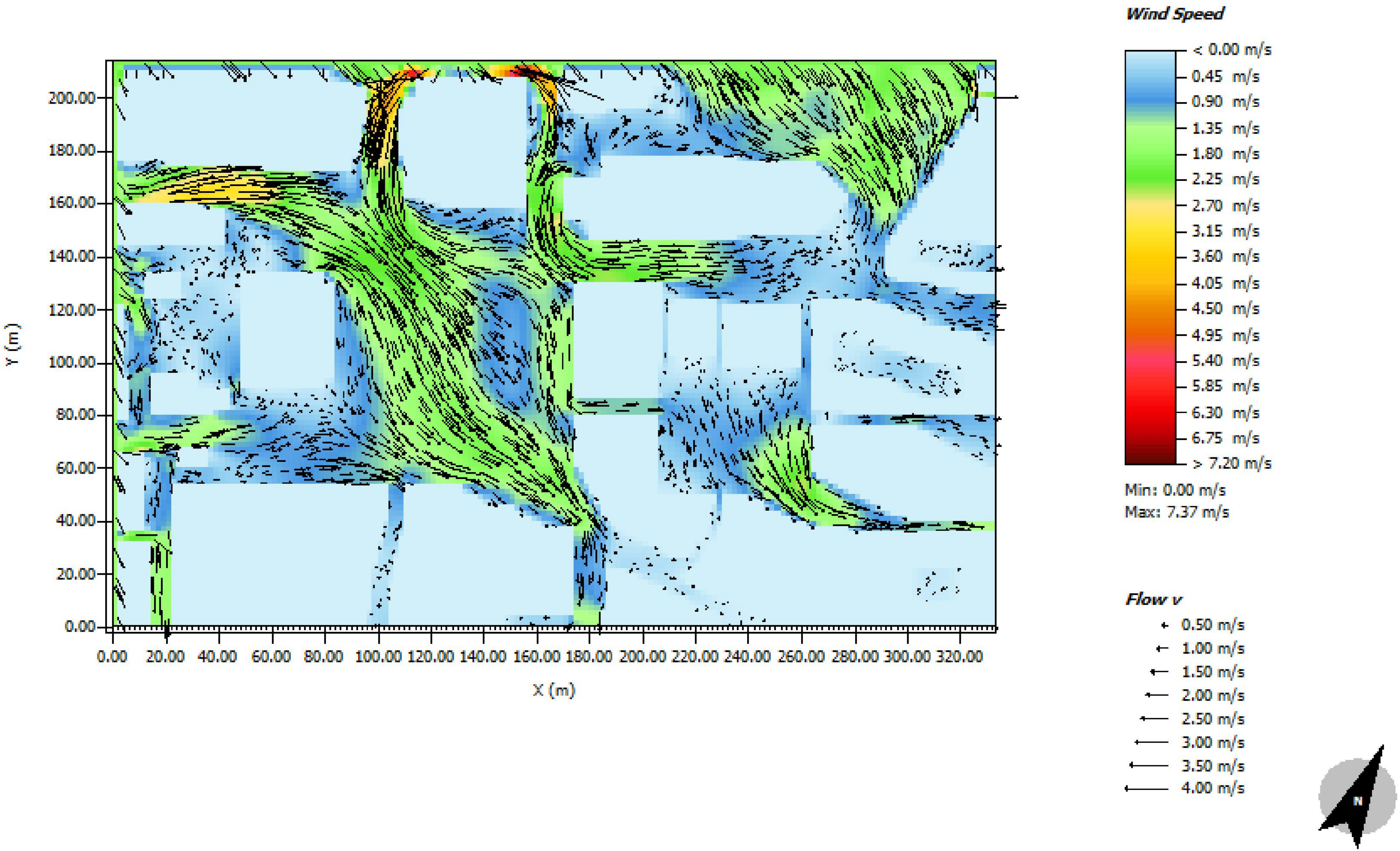


FIGURE 4: GRONINGEN-SECOND PROPOSAL 11:00:01 19.07.2014

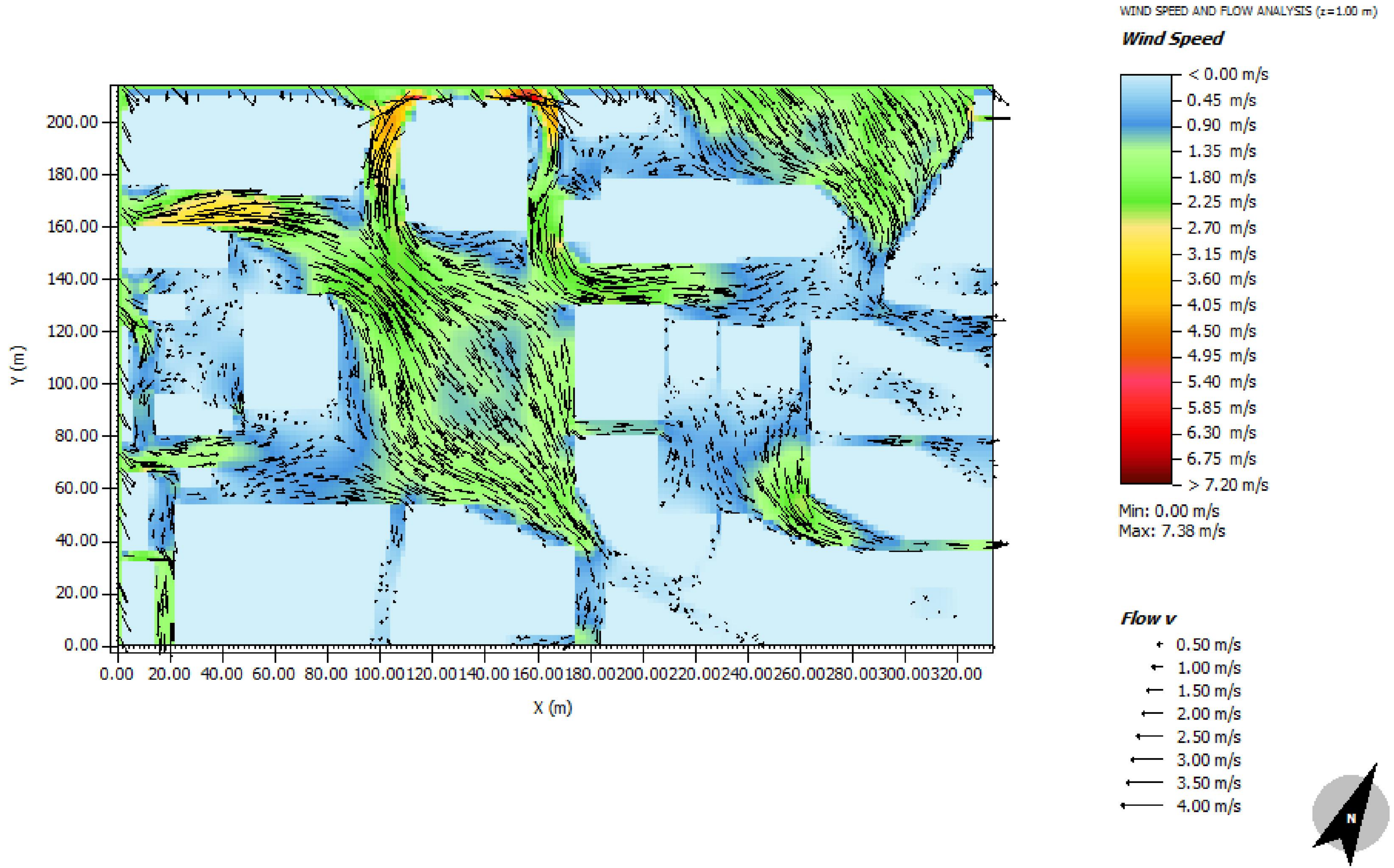
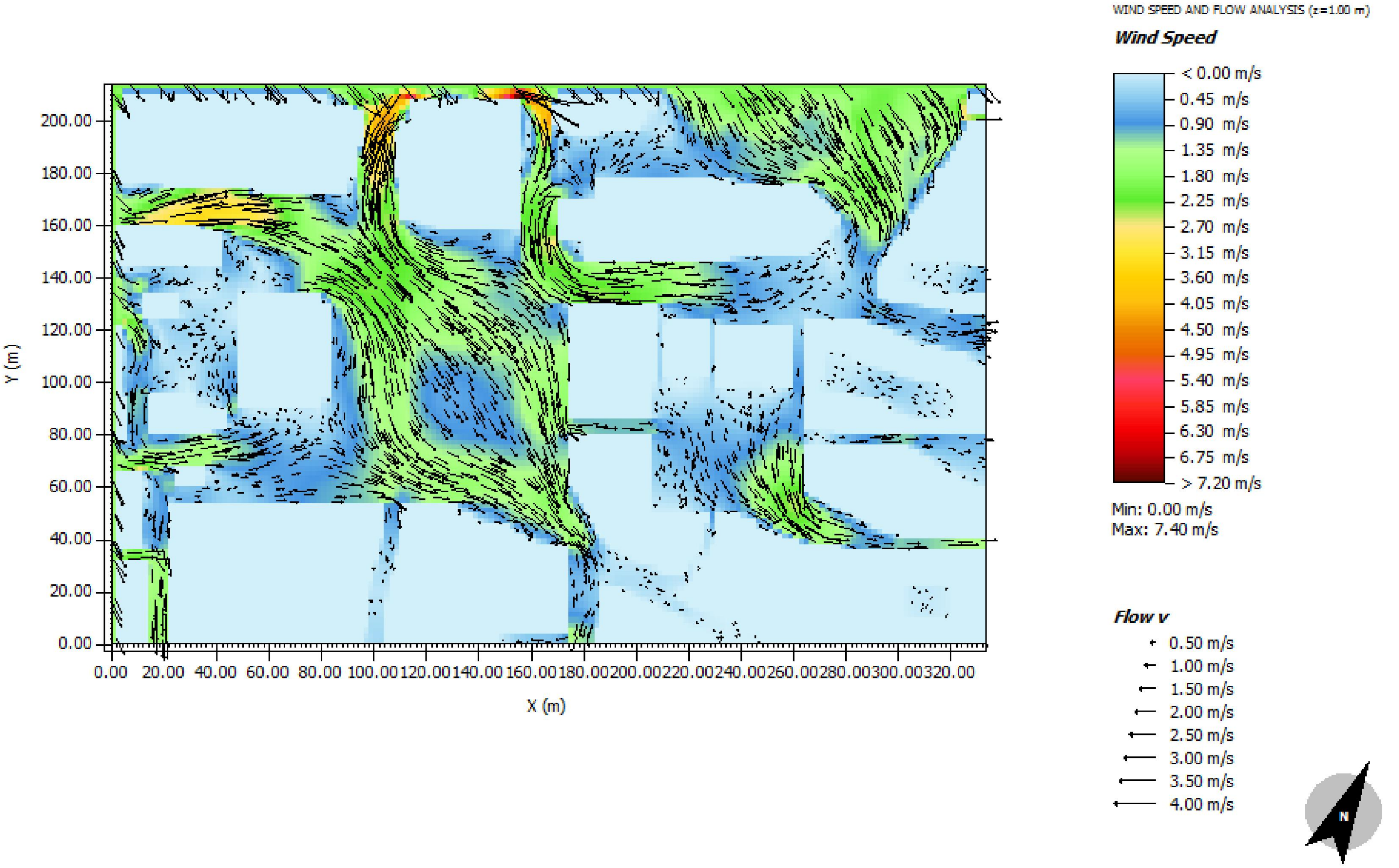


FIGURE 4: GRONINGEN-THIRD PROPOSAL 11:00:01 19.07.2014



CONCLUSION

WIND SPEED AND FLOW ANALYSIS

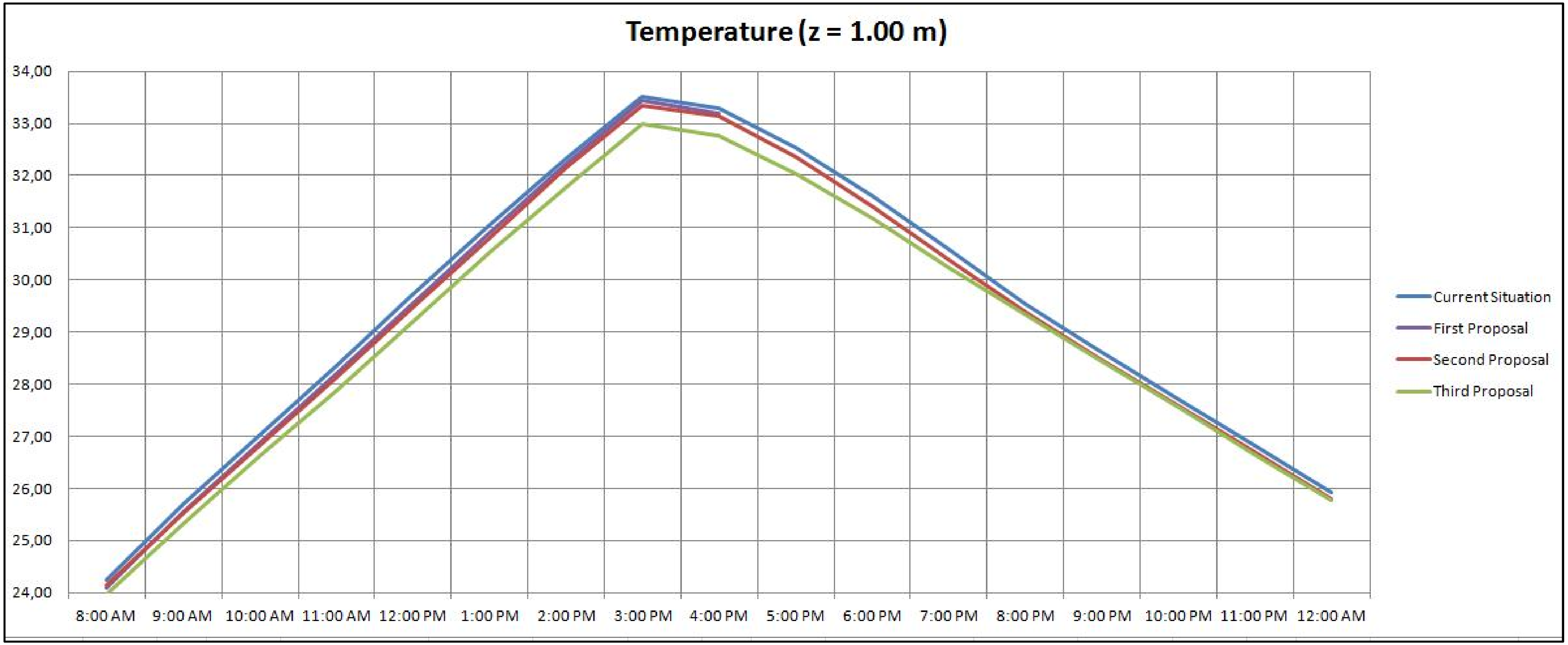
Wind speed in not as important as air temperature but it provides very valuable data. Only one map has been obtained for each scenario since the variation along the day is insignificant.

The outcomes show that in the current situation the wind flows constant and unobstructed. The average wind speed in Grote Markt is 2.25 m/s. However, in the first proposal wind speed in the green area has a value close to 0.00 m/s.

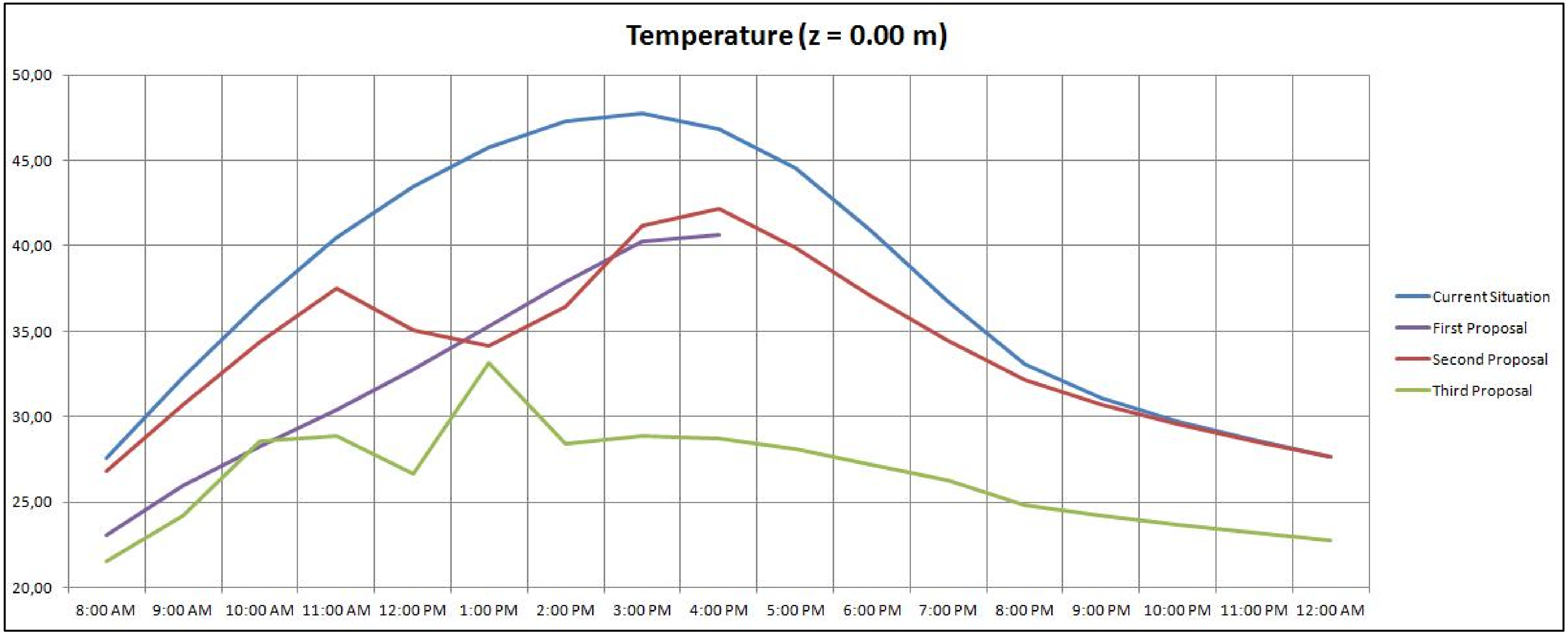
As a conclusion, it is obvious that obstacles such as trees or building have an important effect when it comes to the wind speed. Furthermore, if there had been a big difference in wind speed, it could have directly affected the air temperature.

OUTCOMES' ANALYSIS

RECEPTOR 3



This chart shows the air temperature of the four scenarios at 1 meter high in the middle of Grote Markt. The maximum difference between scenarios is 0.50 ºC and it takes place at 15:00. It would have been better to place more receptors in Grote Markt in order to get more specific data.



This chart shows the difference in surface temperature also in the middle of Grote Markt. The current situation presents a constant curve which reaches its maximum value at 15:00.The first proposal also shows a regular line but the other two proposals are irregular. That is because the receptor is located close to a tree that provides shadow, so depending on the position of the sun and the tree in relation to the receptor the temperature change sharply.