D5.1
Urban primary data need analysis
Deliverable 5.1
Related Work Package: WP5
Deliverable lead: VITO
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Instrument: HORIZON 2020
Start date of the project: 01 June 2017
Duration of the project: 30 months
Website: www.climate-fit.city

Abstract
In the first stage of the PUCS/Climate-fit.city project, climate data providers, climate service providers and end-users are involved in the co-design of six concrete sectoral cases of an urban climate service: Climate & Health, Building Energy, Emergency Planning, Urban Planning, Active Mobility, and Cultural Heritage.

After the workshops involving local stakeholders, described in Deliverable 2.1, the climate service providers listed the specific climate data needs for their urban climate service. These needs were discussed with the climate data providers (VITO and KULeuven) and adjusted where necessary to ensure the feasibility and timing of data delivery.

The present deliverable documents this process of collection, discussion and adjustment of all climate service providers' data needs. In addition, potential links, synergies and overlaps between the sectoral cases are identified.

Dissemination level of the document

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1. Introduction

This document is developed as part of the PUCS (Pan-European Climate Service) project, which has received funding from the European Union’s Horizon 2020 Research and Innovation programme, under the Grant Agreement number 730004\(^1\). For marketing purposes, the project name is changed to ‘Climate-fit.city’ for internal usage and communication to end-users and stakeholders. The "Urban primary data need analysis" represents Deliverable 5.1 of Work Package 5 (WP5) – Urban climate data platform. The objective of PUCS is to establish services that translate the best available scientific urban climate data into relevant information for public and private end-users operating in cities. This will be achieved by demonstrating the benefits of urban climate information to end-users, considering the sectors of health, energy, emergency planning, urban planning, mobility, and cultural heritage.

In the framework of the initial service demonstration cases (WP2), the climate service providers and end-users have organized workshops to co-design six concrete sectoral cases, to be implemented in Barcelona, Bern, Antwerp, Prague/Ostrava/Hodonín, Vienna, and Rome. One of the outcomes of these workshops are the concrete urban climate data needs to set up the service. In a next step, these data needs were to be collected, analysed and discussed in terms of feasibility and timing with the primary climate data providers VITO and KULeuven. The present deliverable documents this process of data needs collection and analysis.

This analysis focusses on the data specifications in terms of spatial and temporal resolution, time horizons, climate change scenarios, the selection of the required variables, and data file formats. Although every service provider has different data needs, the objective of this analysis is to classify the different needs in terms of climate data so that an optimized production environment can be set up, in collaboration with the service providers.

The final goal of WP5 is to make these data available through a dedicated web-based platform, not only targeting the use within PUCS by project partners, but also the use by a larger group of potential climate service purveyors after the ending of the H2020 funding. Therefore we are gathering and documenting as much information as possible from both the climate service providers and their end-users and stakeholders by means of online questionnaires and individual follow-up meetings.

The structure of the present deliverable is as follows: Chapter 2 introduces the urban climate data providers. Chapter 3 contains a description of the process applied to collect the service providers’ data needs, including the template of the online questionnaire that is used. In Chapter 4 the specific data needs for each of the six sectoral cases are listed. Chapter 5 identifies potential links, synergies and overlaps between the sectoral cases. The original questionnaire responses from the six sectoral cases are attached in Annex A, and Annex B provides information on the climate data providers’ models and tools.

\(^1\) SCS-01-2016-2017: Exploiting the added value of climate services – a) Demonstration of climate services (2016 – Innovation Action – IA)
2. Climate data providers

In this project, the urban climate data will be delivered by two primary data providers, VITO and KULeuven. VITO will focus with its urban climate model ‘UrbClim’ on heat stress and related meteorological variables and indicators, while KULeuven will apply its rainfall downscaling statistics method to focus on precipitation and flooding. Prior to the workshops in WP2, both partners provided the service providers in this project with an overview of their modelling methods and the climate data that could be delivered, in order to ensure that the service providers had a good idea of the possibilities and limitations of the data. Both documents are included in Annex B.

3. Service providers data needs collection process

The data needs collection process is tackled in a two-step approach: 1) In a first step, VITO and KULeuven designed an online questionnaire (Google form) to be filled in by all climate service providers as a solid first base for discussion. In this way, the data needs are listed uniformly, making it easy to document and analyse them. 2) In a second step, the responses were discussed individually with all the climate service providers during a technical meeting, skype conference or via email. During these discussions, the details of the data needs were clarified and a clear working plan and timeline was set up for the delivery of the needed input data for each climate service.

The designed questionnaire maps the service providers’ data needs regarding location, historical time frames and climate scenarios, meteorological parameters and their temporal and spatial resolution, data types and formats, and leaves room for additional feedback. Moreover, the service providers are asked to first fill in their minimal data requirements to set up their service, so the data providers can start focussing on these and make sure that all the services can be developed within the timing of this project. Secondly, they are asked to fill in any additional ‘nice to have’ data according to their ideas or the ideas that came out of the workshops with the end-users and stakeholders from WP2. This could be valuable information to improve the service in the future and take into account when designing the Urban Climate Data Platform.

The resulting questionnaire is shown in Figure 1. All the questionnaires filled in by the service providers can be found in Annex A.
Figure 1: Online questionnaire to be filled in by service providers

Questionnaire Urban Climate Data Platform

The answers to this questionnaire will be used in determining the needs for the Urban Climate Data Platform. During the questionnaire, a distinction between the (minimal) requirements of the service provider and the wish list of the stakeholders will be made. You can supply information per (type of) stakeholder if you prefer.

Thank you very much!

Institute name *

Minimal requirements of service provider

Please add your minimal requirements as a service provider on this page.

Location

Which city or cities are required? *

Time frames and climate scenarios

Which historical time frame is required? *

- 1970-1980
- 1981-1990
- 1991-2000
- 2001-2010
- 2011-2017
- Other: ____________________________
Which future time frame is required? *

☐ 2026-2035
☐ 2036-2045
☐ 2046-2055
☐ 2056-2065
☐ 2066-2075
☐ 2076-2085
☐ 2086-2095
☐ 2096-2100
☐ Other: _____________________

Which climate scenario is required? *

☐ RCP2.6
☐ RCP4.5
☐ RCP6.0
☐ RCP8.5
☐ Other: _____________________
Meteorological parameters

Which meteorological parameters are required and at which temporal resolution?

<table>
<thead>
<tr>
<th></th>
<th>Minute</th>
<th>Hour</th>
<th>Daily mean</th>
<th>Monthly mean</th>
<th>Yearly mean</th>
<th>Mean over long time (&gt; 20 years)</th>
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What spatial resolution is required?

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<th>Map at 1m resolution</th>
<th>Map at 10m resolution</th>
<th>Map at 100m resolution</th>
<th>Map at 250m resolution</th>
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<th>Map at 5km resolution</th>
<th>Mean over city</th>
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Do you require any other meteorological parameters? At which temporal and spatial resolution?
What spatial extent is required? *
- Small scale (domain <100m)
- Neighbourhood (100m < domain < 2km)
- City District (2km < domain < 10km)
- Entire city (> 10km)
- Other: ___________________________

Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

Which data format is required? *
- Text files (comma or tab separated)
- NetCDF
- GIS-format (GeoTiff)
- Other: ___________________________

Additional feedback

Do you have any additional feedback?

Do you want to add another stakeholder? *
4. Identified service providers’ data needs

4.1. Sectoral case Climate & Health

**Minimal data requirements**

This service will focus on the broader Barcelona metropolitan area, a domain about 40 x 40 km large. Data for a 30-year historical period are required (1987-2016), and climate projections for all years up to 2100. Ideally, all climate scenarios are included, but we will start with RCP8.5 and RCP4.5 and see how much time and budget is left after that. Daily data of air temperatures (minimum, mean and maximum) and humidity (dew point temperatures and relative humidity) are needed, as well as a thermal comfort indicator (Wet Bulb Globe Temperature). These indicators are needed at a spatial resolution of 100 m. Also local rainfall projections will be provided, but the temporal and spatial resolution of these will be discussed in a later stage. The data will be delivered in a Netcdf format, including the lat/lon grid and the daily time series of the variables.

**Additional feedback from the end-users**

The end user of this service (the Barcelona Public Health Agency) would like to have the model simulations being set up with their own local land use map, which will be delivered by the beginning of December 2017. This is OK for VITO, as long as the delivery is on time so that the project timing is not compromised.

There is concern from the service provider that the local effect of the sea breeze in Barcelona is not correctly included in the standard driving ERA-Interim data. Therefore, VITO will first do a validation exercise with local measurements, also using the more accurate ERA5 data, to evaluate model performance. This exercise should be done by the end of December 2017.

4.2. Sectoral case Building Energy

**Minimal data requirements**

This service will first focus first on the city of Bern. A historical period from 2000-2017 is required based on ERA5 data, and climate projections for the 20-year period including 2051-2070. Ideally RCP6.0 is used, but we will start with RCP4.5 and RCP8.5. Hourly data of air temperatures, humidity, wind speed, rainfall and thermal comfort (Wet Bulb Globe Temperature) will be provided at a spatial resolution of 100 m for the entire city of Bern. The data will be delivered in Netcdf format.

**Additional feedback from the end-users**

The service provider and end-user are also interested in similar data for the other cities of the project (and outside of the project). This will be discussed in a later phase. Also, there is interest from the end-users in high-resolution (<25 m) thermal comfort and wind speed
maps. When the minimal required data are ready, we will see how much time and budget is left to focus on these additional data. There is concern from the service provider that the local effect of drainage flows in Bern are not correctly included in the model chain.

4.3. Sectoral case Emergency Planning

Minimal data requirements

This service will be set up for the city of Antwerp, using as long as possible historical rainfall records. Climate projections are needed for 10-year periods around the years 2030, 2050 and 2100, using RCP4.5 and RCP8.5 scenarios. The focus is solely on rainfall data, which are to be processed in design rain storms for return periods of 2, 5 and 20 years. The data format will be text files.

Additional feedback from the end-users

No additional feedback was received from the end users.

4.4. Sectoral case Urban Planning

Minimal data requirements

This service will be set up for three cities in the Czech Republic: Prague, Ostrava and Hodonin. A recent historical 10-year period (2007-2016) is required, and climate projections for 10-year periods around the years 2030 and 2050 for two RCP scenarios (RCP4.5 and RCP8.5). Hourly time series of air temperatures, humidity, wind speeds and rainfall are needed, at a horizontal resolution of 100 m. From these meteorological variables, indicator maps (Urban Heat Island, number of Heat Wave Days,...) will be calculated. For at least one city, a high-resolution (1 m) thermal comfort map will be calculated for a selected warm day/period. The data will be delivered in Netcdf format and some indicator maps in GIS (geotiff) format.

Additional feedback from the end-users

The end-users and stakeholders of this service are very interested in high-resolution maps and the possibility to play around themselves with urban planning scenarios. The quality of the data is very important to them, so we will see if the time and budget allows for a validation exercise.

4.5. Sectoral case Active Mobility

Minimal data requirements

The focus is here on the broader metropolitan region of Vienna. A 30-year historical period (1987-2016) is required, as well as climate projections for the years 2036-2065 with both
the RCP4.5 and RCP8.5 scenarios. Hourly time series of air temperatures, humidity, wind speed and direction, rainfall and thermal comfort (Wet Bulb Globe Temperature) are needed, as well as global radiation and snowfall. Since the models of the data providers do not include the latter ones, they will be derived from ERA-Interim and ERA5 data. These data will be provided for a horizontal resolution of 100 m. For selected days, high-resolution (<10 m) maps will be calculated, focussing on wind speeds and thermal comfort. The data will be provided in Netcdf format.

Additional feedback from the end-users

The city of Vienna, a stakeholder of this service, is also very interested in short-term forecasts of these variables.

4.6. Sectoral case Cultural Heritage

Minimal data requirements

This service will be set up for an area in and around the city of Rome. A 30-year historical period (1987-2016) is required, as well as climate projections for 10-year periods around the years 2030 and 2050 with scenarios RCP4.5 and RCP8.5. The focus is on daily thermal comfort data, but also hourly rainfall data are requested. The thermal comfort data will be provided at a horizontal resolution of 100 m. Also air quality and pollen data are needed, which will be derived from other data sources (to be discussed). The data will be provided in Netcdf format.

Additional feedback from the end-users

The end users and stakeholders of this service are interested in pluvial flooding and water levels in the Tiber river. We will see if the time and budget allows for additional work in this area. The city of Rome is also interested in the results for the other RCP scenarios and would like to have the results in GIS format.
5. Identification of links, synergies and overlaps

This section presents an identification of links, synergies and overlaps between the data needs of the sectoral cases. It can serve as starting point for further in-depth discussions about the Urban Climate Data Platform during the upcoming General Assembly meeting (December 2017), where the topic will be addressed in more detail.

First of all, regarding the time frames, all cases ask for a period of at least 10 years of the most recent historical data (Figure 2). Three of them (“Climate & Health”, “Active Mobility” and “Cultural Heritage”) need a 30-year reference period (1987-2016) and only the “Emergency Planning” service will look for data dating further in the past (not specified).

Figure 2: Questionnaire responses for the required historical time frames

Regarding the future climate data, most services are only interested in the near future (up to 2050), as only the “Climate & Health” and “Emergency Planning” cases indicate needs for far-future data (Figure 3). Climate scenarios RCP4.5 and RCP8.5 are most popular, as only the “Building Energy” case had a clear and sole interest in RCP6.0 (Figure 4). A lot of services see the other scenarios as ‘nice to have’.

Secondly, the proposed meteorological variables are all interesting for most cases, and some requested even additional data (“Active Mobility” and “Cultural Heritage”). Especially thermal comfort (5 cases) and rainfall (5 cases) are popular. Most services require hourly data, for some (“Climate & Health” and “Cultural Heritage”) daily data are sufficient. A spatial resolution of 100m is needed in all cases, and some cases ask for additional high-resolution (10m or less) data (“Building Energy”, “Urban Planning” and “Active Mobility”). There is also a lot of additional interest from end-users and stakeholders in these high-resolution maps. All cases need the data for the entire city, or even the whole metropolitan area.
In 5 of the 6 cases, the requested data format is Netcdf (Figure 5). Only for the “Emergency Planning” case a different data format and post-processing of the data is requested.
Figure 5: Questionnaire responses for the required data format

Which data format is required?

6 reactions

- Text files (comma separated): 1 (18.7%)
- NetCDF: 5 (83.3%)
- GIS-format (Geographic): 1 (18.7%)
A Annex Questionnaire responses

A.1 Questionnaire response – Climate & Health

Questionnaire Urban Climate Data Platform

The answers to this questionnaire will be used in determining the needs for the Urban Climate Data Platform. During the questionnaire, a distinction between the (minimal) requirements of the service provider and the wish list of the stakeholders will be made. You can supply information per (type of) stakeholder if you prefer.

Thank you very much!

Institute name *

Joan Ballester (ISGlobal) ____________

Minimal requirements of service provider

Please add your minimal requirements as a service provider on this page.

Location

Which city or cities are required? *

Barcelona (and metropolitan area) __________________________________________

Time frames and climate scenarios

https://docs.google.com/forms/d/1XNT0Hz_0wESJSAG6xg3q-ibLEYcR-aXllPwK...  23/11/2017
Which historical time frame is required? *

- □ 1970-1980
- □ 1981-1990
- □ 1991-2000
- □ 2001-2010
- □ 2011-2017

☑ Anders: 1986-2017

Which future time frame is required? *

- □ 2026-2035
- □ 2036-2045
- □ 2046-2055
- □ 2056-2065
- □ 2066-2075
- □ 2076-2085
- □ 2086-2095
- □ 2096-2100

☑ Anders: Until 2100

https://docs.google.com/forms/d/1XNTtJHZ_0wESJSAG6xlgzq-hhEYcR-sX1lPwK... 23/11/2017
Which climate scenario is required? *

- RCP2.6
- RCP4.5
- RCP6.0
- RCP8.5

Anders: __________________________

Meteorological parameters

Which meteorological parameters are required and at which temporal resolution?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minute</th>
<th>Hour</th>
<th>Daily mean</th>
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https://docs.google.com/forms/d/1XNTJHZ_0wESJSAG6xdgqzq-hhEYeR-aX1IPwK...  23/11/2017
What spatial resolution is required?

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<th>10m resolution</th>
<th>100m resolution</th>
<th>250m resolution</th>
<th>1km resolution</th>
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<td>Air temperatures</td>
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<td>Relative humidity</td>
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<td>Thermal comfort</td>
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</tr>
</tbody>
</table>

Do you require any other meteorological parameters? At which temporal and spatial resolution?

No

What spatial extent is required? *

- [ ] Small scale (domain <100m)
- [ ] Neighbourhood (100m < domain < 2km)
- [ ] City District (2km < domain < 10km)
- [ ] Entire city (> 10km)
- [ ] Anders: ___________________________

https://docs.google.com/forms/d/1XNTJHZ_0wESJ5AG6xlgzq-llhFyYcR-aXHpwK...  23/11/2017
Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

Daily Longitude/Latitude/Time files

Which data format is required? *

- Text files (comma or tab separated)
- NetCDF
- GIS-format (GeoTiff)
- Anders: ____________________________

Additional feedback

Do you have any additional feedback?

If resolutions, domains and periods are too much, we can discuss what to change

Stakeholder wish list

https://docs.google.com/forms/d/1XNTjJHZ_0wESJSAQ6xлггzq-lhEYcR-aX1lPwK... 23/11/2017
A.2 Questionnaire response – Building Energy

Questionnaire Urban Climate Data Platform

The answers to this questionnaire will be used in determining the needs for the Urban Climate Data Platform. During the questionnaire, a distinction between the (minimal) requirements of the service provider and the wish list of the stakeholders will be made. You can supply information per (type of) stakeholder if you prefer.

Thank you very much!

Institute name *

Meteotest

Minimal requirements of service provider

Please add your minimal requirements as a service provider on this page.

Location

Which city or cities are required? *

Bern, Antwerp

Time frames and climate scenarios

https://docs.google.com/forms/d/1XNTuJHZ_0wE8ja8G6xgq-bbEYeR-aXHwK... 23/11/2017
Which historical time frame is required? *

- [ ] 1970-1980
- [ ] 1981-1990
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- [x] 2001-2010
- [ ] 2011-2017
- [ ] Anders: ________________________________

Which future time frame is required? *

- [ ] 2026-2035
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- [ ] Anders: ________________________________

https://docs.google.com/forms/d/1XNTjHZ_0wESJSA6xdlgqJ-bhEYcR-sXi11PwK... 23/11/2017
Which climate scenario is required? *

- [ ] RCP2.6
- [ ] RCP4.5
- [x] RCP6.0
- [ ] RCP8.5
- [ ] Anders: ______________________

 Meteorological parameters

Which meteorological parameters are required and at which temporal resolution?

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https://docs.google.com/forms/d/1XNTjJHZ_0wESJSAG6xlgzq-llhEYcR-sX1IPwK...  23/11/2017
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Do you require any other meteorological parameters? At which temporal and spatial resolution?

What spatial extent is required? *

- Small scale (domain <100m)
- Neighbourhood (100m < domain < 2km)
- City District (2km < domain < 10km)
- Entire city (> 10km)

https://docs.google.com/forms/d/1XNTJHZ_0wESJSAG6xldgqzq-lhEYcR-sX11PwK... 23/11/2017
Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

time series (we will build tmys by ourself)

Which data format is required? *

☐ Text files (comma or tab separated)

☑ NetCDF

☐ GIS-format (GeoTiff)

☐ Anders: ______________________________

Additional feedback

Do you have any additional feedback?

------------------------------------------------------------------------------------

Stakeholder wish list

https://docs.google.com/forms/d/1XNTdJHZ_J0wESJSAG6xq-hlhEYeR-9X1IPwK... 23/11/2017
Questionnaire Urban Climate Data Platform

Please add the wishlist of first stakeholder (or type of stakeholders) that was present during the workshops on this page.

Stakeholder information

Describe the stakeholder *

Building simulation users

Location

Which city or cities are required? *

Bern, Antwerp, Barcelona or Roma, eventually also other partner cities

Time frames and climate scenarios

Which historical time frame is required? *

☐ 1970-1980
☐ 1981-1990
☒ 1991-2000
☒ 2001-2010
☐ 2011-2017
☐ Anders: ________________________________

https://docs.google.com/forms/d/1XNTjHJZ 0wESJSAG6xlgzq-lhhEYcR-sX1jpWk... 23/11/2017
Which future time frame is required? *

- [ ] 2026-2035
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- [ ] 2096-2100

- [ ] Anders: ______________________________________

Which climate scenario is required? *

- [ ] RCP2.6
- [ ] RCP4.5
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- [ ] RCP8.5

- [ ] Anders: ______________________________________

Meteorological parameters

https://docs.google.com/forms/d/1XNTjHZ_0wESJSAG6xlgzq-hhEYcR-sX1lPwK... 23/11/2017
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https://docs.google.com/forms/d/1XNToIHZ_0weE5jSAQ6xdlgqL-hhEYcR-sXJlPwK... 23/11/2017
Do you require any other meteorological parameters? At which temporal and spatial resolution?

What spatial extent is required? *

- Small scale (domain <100m)
- Neighbourhood (100m < domain < 2km)
- City District (2km < domain < 10km)
- Entire city (> 10km)

Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

- time series

https://docs.google.com/forms/d/1XNTvHZ_0wESJSAG6xdgzq-IhEYcRaXIIpWwK... 23/11/2017
Which data format is required? *

- Text files (comma or tab separated)
- NetCDF
- GIS-format (GeoTiff)
- Anders: __________________________

Additional feedback

Do you have any additional feedback?

-------------------------------------------------------------------------------------

Do you want to add another stakeholder? *

No

Stakeholder II wish list

Please add the wishlist of the second stakeholder that was present during the workshops on this page.

Stakeholder information

https://docs.google.com/forms/d/1XNTjHZ_0wESJSAG6xdgzcj-hhEYeR-aX1IPwK... 23/11/2017
A.3 Questionnaire response – Emergency Planning

Questionnaire Urban Climate Data Platform

The answers to this questionnaire will be used in determining the needs for the Urban Climate Data Platform. During the questionnaire, a distinction between the (minimal) requirements of the service provider and the wish list of the stakeholders will be made. You can supply information per (type of) stakeholder if you prefer.

Thank you very much!

Institute name *

KU Leuven

Minimal requirements of service provider

Please add your minimal requirements as a service provider on this page.

Location

Which city or cities are required? *

Antwerp

Time frames and climate scenarios

https://docs.google.com/forms/d/1XNTuJHZ_0wE8JSAG6xdgqMbhEYcR-aXIIpK... 23/11/2017
Which historical time frame is required? *

- [ ] 1970-1980
- [ ] 1981-1990
- [ ] 1991-2000
- [ ] 2001-2010
- [ ] 2011-2017

☑ Anders:
We use historical time series data (as long as possible, but bounded by the data availability)

Which future time frame is required? *

- [ ] 2026-2035
- [ ] 2036-2045
- [ ] 2046-2055
- [ ] 2056-2065
- [ ] 2066-2075
- [ ] 2076-2085
- [ ] 2086-2095
- [ ] 2096-2100

☑ 2096-2100

Anders: ________________________________
Which climate scenario is required? *

- RCP2.6
- RCP4.5
- RCP6.0
- RCP8.5

Anders: ____________________________

Meteorological parameters

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- Air temperatures
- Relative humidity
- Wind speed and direction
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- Thermal comfort

Do you require any other meteorological parameters? At which temporal and spatial resolution?

What spatial extent is required? *

- [ ] Small scale (domain <100m)
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- [x] Entire city (> 10km)
- [ ] Anders: _________________________________

https://docs.google.com/forms/d/1XNTfJHZ_0wESJSAG6xdgzzq-hhEYcR-sXilPwK...  23/11/2017
Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

design rain storms for return periods of 2, 5, 20 years

Which data format is required? *

☑ Text files (comma or tab separated)

☐ NetCDF

☐ GIS-format (GeoTiff)

☐ Anders: ________________________________

Additional feedback

Do you have any additional feedback?

______________________________

Stakeholder wish list

https://docs.google.com/forms/d/1XNT1HZ_0wESJ8AG6xdgzcq-hhFYcR-aX11PwK...  23/11/2017
Please add the wishlist of first stakeholder (or type of stakeholders) that was present during the workshops on this page.

**Stakeholder information**

Describe the stakeholder *

City of Antwerp & other partners involved in emergency planning

**Location**

Which city or cities are required? *

Antwerp

**Time frames and climate scenarios**

Which historical time frame is required? *

- [ ] 1970-1980
- [ ] 1981-1990
- [ ] 1991-2000
- [ ] 2001-2010
- [ ] 2011-2017

☑ Anders: No need; current design storms

---

https://docs.google.com/forms/d/1XNTjHZ_0wESJSAG6xdgzoq-hhEYcR-aXIIPwK... 23/11/2017
Which future time frame is required? *

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Anders: ___________________________

Which climate scenario is required? *

- [ ] RCP2.6
- [x] RCP4.5
- [ ] RCP6.0
- [x] RCP8.5

Anders: ___________________________

Meteorological parameters

https://docs.google.com/forms/d/1XNTJHZ_0wESJSAG6xgzyc-hhEYcR-axX1PlwK... 23/11/2017
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Design storms for return periods of 2, 5, 20 years
Which data format is required? *

- Text files (comma or tab separated)
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- Anders: ____________________________

Additional feedback

Do you have any additional feedback?

----------------------------------------------------------

Do you want to add another stakeholder? *

No ▼

Stakeholder II wish list

Please add the wishlist of the second stakeholder that was present during the workshops on this page.

Stakeholder information

https://docs.google.com/forms/d/1XNTjHZ_0wESiSAG6xldgqz-lhEYcR-sX1lPwK...  23/11/2017
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Thank you very much!

Institute name *

GISAT

Minimal requirements of service provider

Please add your minimal requirements as a service provider on this page.

Location

Which city or cities are required? *

Prague, Ostrava, Hodonin

Time frames and climate scenarios

https://docs.google.com/forms/d/1XNTUHZ_0wESlSAG6xldgzzq-bhEyEcR-aXIIiPwK...  23/11/2017
Which historical time frame is required? *

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- [x] RCP4.5
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<td>Air temperatures</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Relative humidity</td>
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<td>✓</td>
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<td>Rainfall</td>
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<tr>
<td>Dew point temperature</td>
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<td>✓</td>
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<td></td>
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<td>✓</td>
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</tr>
</tbody>
</table>

Do you require any other meteorological parameters? At which temporal and spatial resolution?

------------------------------------------------------------------------------------------------------------------

## What spatial extent is required? *

- [ ] Small scale (domain <100m)
- [ ] Neighbourhood (100m < domain < 2km)
- [ ] City District (2km < domain < 10km)
- [✓] Entire city (> 10km)
- [ ] Others: ___________________________________________________________

https://docs.google.com/forms/d/1XNTUHJZ_0weEJSJAG6xldgzq-lhEYcR-sXIIpWfK...  23/11/2017
Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

time-average maps

Which data format is required? *

- Text files (comma or tab separated)
- NetCDF
- GIS-format (GeoTiff)
- Anders: ____________________________

Additional feedback

Do you have any additional feedback?

___________________________________________

Stakeholder wish list

https://docs.google.com/forms/d/1XNTjHZ_0wESJSAG6xdgzzp-hhEYcR-aX1IPwK... 23/11/2017
Please add the wishlist of first stakeholder (or type of stakeholders) that was present during the workshops on this page.

Stakeholder information

Describe the stakeholder *

City administrations (Prague, Ostrava)

Location

Which city or cities are required? *

Prague, Ostrava

Time frames and climate scenarios

Which historical time frame is required? *

- [ ] 1970-1980
- [ ] 1981-1990
- [ ] 1991-2000
- [ ] 2001-2010
- [ ] 2011-2017

https://docs.google.com/forms/d/1XNTjHZ_0wE8JSA6xqBhYcR-aX1lPwK... 23/11/2017
Which future time frame is required? *

- [x] 2026-2035
- [ ] 2036-2045
- [x] 2046-2055
- [ ] 2056-2065
- [ ] 2066-2075
- [ ] 2076-2085
- [ ] 2086-2095
- [ ] 2096-2100

Anders: ____________________________

Which climate scenario is required? *

- [ ] RCP2.6
- [x] RCP4.5
- [ ] RCP6.0
- [x] RCP8.5

Anders: ____________________________

Meteorological parameters

https://docs.google.com/forms/d/1XNTjHZ_0wESJSAG6xdlgzoq-hhEYcR-sX1lPwK... 23/11/2017
Which meteorological parameters are required and at which temporal resolution?

<table>
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<tr>
<th>Parameter</th>
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https://docs.google.com/forms/d/1XNTfHZ_0wESJSAG6xdgzzq-hhEYcR-aX11PwK... 23/11/2017
Do you require any other meteorological parameters? At which temporal and spatial resolution?
Flooding and air quality are also issues, the higher spatial resolution the better.

What spatial extent is required? *

- [ ] Small scale (domain <100m)
- [ ] Neighbourhood (100m < domain < 2km)
- [ ] City District (2km < domain < 10km)
- [x] Entire city (> 10km)
- [ ] Anders: ____________________________

Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

time-average maps

https://docs.google.com/forms/d/1XNTjHZ_0wESJSAG6xdgzoq-hhEYcR-aXiIPwK...

23/11/2017
Which data format is required? *

☐ Text files (comma or tab separated)

☐ NetCDF

☑ GIS-format (GeoTiff)

☐ Andens: __________________________

Additional feedback

Do you have any additional feedback?

Model validation is important, demonstrate reliability, Prague is expert user, use of thermal satellite imagery

Do you want to add another stakeholder? *

No

Stakeholder II wish list

Please add the wishlist of the second stakeholder that was present during the workshops on this page.

Stakeholder information

https://docs.google.com/forms/d/1XNTiJHZ_0wESJSAG6xlGzq-lhIEycR-aX1HpwK... 23/11/2017
A.5 Questionnaire response – Active Mobility

Questionnaire Urban Climate Data Platform

The answers to this questionnaire will be used in determining the needs for the Urban Climate Data Platform. During the questionnaire, a distinction between the (minimal) requirements of the service provider and the wish list of the stakeholders will be made. You can supply information per (type of) stakeholder if you prefer.

Thank you very much!

Institute name *

JOANNEUM RESEARCH

Minimal requirements of service provider

Please add your minimal requirements as a service provider on this page.

Location

Which city or cities are required? *

Vienna

Time frames and climate scenarios

https://docs.google.com/forms/d/1XNT0HZ_0wESJSAG6xdgcp-hhEYeRe-sX1PwK...  23/11/2017
Which historical time frame is required? *

- [ ] 1970-1980
- [x] 1981-1990
- [x] 1991-2000
- [x] 2001-2010
- [x] 2011-2017

Anders: __________________________

Which future time frame is required? *

- [ ] 2026-2035
- [x] 2036-2045
- [x] 2046-2055
- [x] 2056-2065
- [ ] 2066-2075
- [ ] 2076-2085
- [ ] 2086-2095
- [ ] 2096-2100

Anders: __________________________
Which climate scenario is required? *

- [ ] RCP2.6
- [x] RCP4.5
- [ ] RCP6.0
- [x] RCP8.5
- [x] Anders: Note: two RCPs would be great, but one suffices for the start

Meteorological parameters

Which meteorological parameters are required and at which temporal resolution?

<table>
<thead>
<tr>
<th></th>
<th>Minute</th>
<th>Hour</th>
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<tr>
<td>Wind speed and direction</td>
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</tbody>
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https://docs.google.com/forms/d/1XNTtJHZ_0wESJSAq6xdgqzQllhEYcR-sXl1PwK...  23/11/2017
Questionnaire Urban Climate Data Platform

What spatial resolution is required?

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</table>

Do you require any other meteorological parameters? At which temporal and spatial resolution?

Snowfall (daily sum; mean over city) and solar radiation (hourly; mean over city) would be interesting.

What spatial extent is required? *

- [ ] Small scale (domain <100m)
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- [x] Entire city (> 10km)

Anders: ________________________________

https://docs.google.com/forms/d/1XNtJHZ_0wE5JSA6x5drgq-l5dEYcR-sX11FwK... 23/11/2017
Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

time series, typical meteorological years

Which data format is required? *

☐ Text files (comma or tab separated)
☐ NetCDF
☐ GIS-format (GeoTiff)
☐ Anders: ______________________________

Additional feedback

Do you have any additional feedback?

Stakeholder wish list

https://docs.google.com/forms/d/1XNTtjHZ_0wESJSAGxGxTdgt2zWYY-rrX1lPwK...  23/11/2017
Please add the wishlist of first stakeholder (or type of stakeholders) that was present during the workshops on this page.

Stakeholder information

Describe the stakeholder *

City of Vienna

Location

Which city or cities are required? *

Vienna

Time frames and climate scenarios

Which historical time frame is required? *

☐ 1970-1980

☐ 1981-1990

☐ 1991-2000

☐ 2001-2010

☐ 2011-2017

☐ Anders: ________________________________

https://docs.google.com/forms/d/1XNTiJHZ_0wESjSAG6xlgzq-lhEY7cR-sXHpwK... 23/11/2017
Which future time frame is required? *

- 2026-2035
- 2036-2045
- 2046-2055
- 2056-2065
- 2066-2075
- 2076-2085
- 2086-2095
- 2096-2100

☑️ Anders: No particular time frame mentioned; stakeholders would also be interested in short-term forecasts (hours-days)

Which climate scenario is required? *

- RCP2.6
- RCP4.5
- RCP6.0
- RCP8.5

☑️ Anders: No particular scenario mentioned

Meteorological parameters

https://docs.google.com/forms/d/1XNTfJHZ_0wE5JSAG6xlgzq-lhEYcR-siX1lPwK... 23/11/2017
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https://docs.google.com/forms/d/1XNTlJHZ_0wESJSAG6xdgqzq-hhEYcR-aX1IPwK...  23/11/2017
Do you require any other meteorological parameters? At which temporal and spatial resolution?

What spatial extent is required? *

☐ Small scale (domain <100m)
☐ Neighbourhood (100m < domain < 2km)
☐ City District (2km < domain < 10km)
☑ Entire city (> 10km)
☐ Anders: __________________________

Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

No particular requirements __________________________

https://docs.google.com/forms/d/1XNTUHZ_0wESjSAG6xdgzeq-bhFYeR-aX1IPwK... 23/11/2017
Which data format is required? *

☐ Text files (comma or tab separated)

☐ NetCDF

☐ GIS-format (GeoTiff)

☑ Anders: No particular requirements

Additional feedback

Do you have any additional feedback?

Do you want to add another stakeholder? *

No

Stakeholder II wish list

Please add the wishlist of the second stakeholder that was present during the workshops on this page.

Stakeholder information

https://docs.google.com/forms/d/1XNT0JHZ_0wESJSAG6xldgzq-lhEYcR-sX1lPwK...  23/11/2017
A.6 Questionnaire response – Cultural Heritage

Questionnaire Urban Climate Data Platform

The answers to this questionnaire will be used in determining the needs for the Urban Climate Data Platform. During the questionnaire, a distinction between the (minimal) requirements of the service provider and the wish list of the stakeholders will be made. You can supply information per (type of) stakeholder if you prefer.

Thank you very much!

Institute name *

VITO

------------------------------------------------------------

Minimal requirements of service provider

Please add your minimal requirements as a service provider on this page.

Location

Which city or cities are required? *

Rome

------------------------------------------------------------

Time frames and climate scenarios

https://docs.google.com/forms/d/1XNTUHJZ_0wE8JSAG6xdgzoq-hhEYeR-aX1IPwK...

23/11/2017
Which historical time frame is required? *

- [x] 1970-1980
- [ ] 1981-1990
- [ ] 1991-2000
- [ ] 2001-2010
- [x] 2011-2017

Which future time frame is required? *

- [x] 2026-2035
- [ ] 2036-2045
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- [ ] 2076-2085
- [ ] 2086-2095
- [ ] 2096-2100
- [ ] Anders: ____________________
Which climate scenario is required? *

- [ ] RCP2.6
- [x] RCP4.5
- [ ] RCP6.0
- [x] RCP8.5
- [ ] Anders: _______________________

Meteorological parameters

Which meteorological parameters are required and at which temporal resolution?

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Questionnaire Urban Climate Data Platform

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<td>Thermal comfort</td>
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</tbody>
</table>

Do you require any other meteorological parameters? At which temporal and spatial resolution?

What spatial extent is required? *

☐ Small scale (domain <100m)

☐ Neighbourhood (100m < domain < 2km)

☐ City District (2km < domain < 10km)

☑ Entire city (> 10km)

☐ Anders: ____________________________________________

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Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

Time series

Which data format is required? *

☐ Text files (comma or tab separated)

☑ NetCDF

☐ GIS-format (GeoTiff)

☐ Anders: _________________________________

Additional feedback

Do you have any additional feedback?

Also pollen and air quality data should be included

Stakeholder wish list

https://docs.google.com/forms/d/1XNT1HZ_0wESISAG6x6dqz-DhEYcR-aXi1PwK... 23/11/2017
Please add the wishlist of first stakeholder (or type of stakeholders) that was present during the workshops on this page.

Stakeholder information

Describe the stakeholder *

City of Rome, archeological site managers

Location

Which city or cities are required? *

Rome

Time frames and climate scenarios

Which historical time frame is required? *

- 1970-1980
- 1981-1990
- 1991-2000
- 2001-2010
- 2011-2017

https://docs.google.com/forms/d/1XNTjHZ_0wESJSAG6xdgzzq-hhEYeR-aX1HPwK... 23/11/2017
Which future time frame is required? *

- [x] 2026-2035
- [ ] 2036-2045
- [x] 2046-2055
- [ ] 2056-2065
- [ ] 2066-2075
- [ ] 2076-2085
- [ ] 2086-2095
- [ ] 2096-2100

Anders: ______________________________

Which climate scenario is required? *

- [x] RCP2.6
- [x] RCP4.5
- [x] RCP6.0
- [x] RCP8.5

Anders: ______________________________

Meteorological parameters

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### Questionnaire Urban Climate Data Platform

**Which meteorological parameters are required and at which temporal resolution?**

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<th>Parameter</th>
<th>Minute</th>
<th>Hour</th>
<th>Daily mean</th>
<th>Monthly mean</th>
<th>Yearly mean</th>
<th>Mean over long time (&gt;20 years)</th>
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<tbody>
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<td>Relative humidity</td>
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<td>Rainfall</td>
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<td>Dew point temperature</td>
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<td>Thermal comfort</td>
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<td>✓</td>
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</tbody>
</table>

**What spatial resolution is required?**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Point data (i.e. location of measurement station, building...)</th>
<th>Map at 1m resolution</th>
<th>Map at 10m resolution</th>
<th>Map at 100m resolution</th>
<th>Map at 250m resolution</th>
<th>Map at 1km resolution</th>
<th>Map at 5km resolution</th>
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<td>Air temperatures</td>
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<td>Rainfall</td>
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<td>Thermal comfort</td>
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Do you require any other meteorological parameters? At which temporal and spatial resolution?

What spatial extent is required? *

☐ Small scale (domain <100m)

☐ Neighbourhood (100m < domain < 2km)

☐ City District (2km < domain < 10km)

☑ Entire city (> 10km)

☐ Anders: __________________________________________

Data

What type of processing is required? For example: time series, time-average maps, typical meteorological years, composite rainfall events, IDF curves, design rain storms = rain storms for given return periods (which return periods?), other statistics (which ones?), other types of additional post-processing of the spatio-temporal data? *

No specifications

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Which data format is required? *

☐ Text files (comma or tab separated)

☐ NetCDF

☑ GIS-format (GeoTiff)

☐ Anders: __________________________________________

Additional feedback

Do you have any additional feedback?

Interest in flooding events, water height in Tiber

______________________________________________________

Do you want to add another stakeholder? *

No

Stakeholder II wish list

Please add the wishlist of the second stakeholder that was present during the workshops on this page.

Stakeholder information

https://docs.google.com/forms/d/1XNTiHfZ_0wESJSAG6xdgqo-hhjEcReYcK-wx1IwK/... 23/11/2017
B.1 VITO – Data available from the UrbClim model

UrbClim is the urban climate model developed by VITO, see De Ridder et al. (2015) for details. Lauwaet et al. (2015, 2016, 2017) and García-Diez et al. (2016) present examples of model applications.

In this document, an overview is given of (potentially) available UrbClim model output data. It should be noted that the information presented here is necessarily limited; a more complete understanding may be obtained by getting in touch with VITO staff – who will gladly provide more details.

At the end of this document we provide references to relevant scientific papers and reports, but also to a few movies / webinars explaining urban heat island effects, and the use of modelling.

1. Model basics

This section gives a rough overview of certain aspects of the model that affect simulation duration and storage requirements. This is important for gaining a proper understanding of model constraints and limitations.

UrbClim is a so-called deterministic numerical urban climate model. In such models, a simulation domain is covered with a 3D raster (grid) that is composed of small cells (cubes); in each of those, the equations of atmospheric physics are solved, using advanced numerical-mathematical techniques, eventually yielding the required quantities such as temperature, humidity, wind speed, etc. in each of the grid cells.

Here, we won’t bother too much about these technicalities, but as a user of model output it is important to be aware of the fact that running (conducting a simulation with) the UrbClim model, even though it was designed to run fast, requires a large computational and storage effort. For example, consider a domain composed of 300 x 300 grid cells horizontally, with a spatial resolution of 100 m, thus covering a domain of 30 km wide, which is typically used for a medium-size city; about one full month of wall clock time is needed on a single computer processor (CPU) for a simulation covering the May-September (= extended summer) period of a given year. (Fortunately, at VITO we have access to a large number of computer processors that can be set to work simultaneously.)

A lower spatial resolution (larger grid cells, i.e., less spatial detail) effectively reduces the duration of a simulation. To take the example of the previous paragraph, in case we run the same domain at 300 m resolution instead of 100 m, the time gain is almost a factor 30, i.e., simulating a five-month summer period would last approximately a day instead of a month.
Conversely, long-term climate simulations, typically covering 30 years rather than a single summer season, heavily increase the amount of computer time needed, but here also we can take advantage of using a large number of computer processors simultaneously, running each summer period on a different processor.

So, whenever we conduct UrbClim simulations, we will have to consider the trade-off between spatial resolution, domain size, the number of years simulated, the number of cities, the number of climate scenarios, etc... For instance, in case you would like to obtain simulation results for many cities and many climate scenarios, we will necessarily have to reduce the spatial resolution in order to keep things manageable.

In terms of storage, consider as a benchmark that, for the $300 \times 300$ cells domain mentioned above, when storing two variables (say, 2-m temperature and humidity) for the 2D grid covering the surface, at an hourly time step and covering 20 summer seasons each containing 5 months (May-Sep), would give rise to around 50 Gb of data per scenario. Obviously, every additional climate or land use change scenario adds to the data storage volume.

Finally, it is important to be aware of the fact that UrbClim does not resolve buildings explicitly. Instead, urban surfaces are represented as a rough concrete ‘slab’, and simplified parameters are used to describe its aggregate behavior such as roughness, reflectivity, etc... As a result, the spatial resolution cannot be higher than approximately 100 m. (In fact, technically we could use a higher resolution than this, but that wouldn't make any sense as the model was not designed to properly deal with individual obstacles such as buildings and trees.) We do have a possibility to add some finer detail, though, for certain variables (mainly thermal comfort indicators), see a later section for more information.

2. Input data

Again, while it is not necessary to understand all the input data requirements, it may help appreciate certain possibilities and limitations of the UrbClim model.

- **Large-scale atmospheric model output.** Weather and climate evolve at scales much larger than domains typically covered by UrbClim, the latter generally being a few tens of kilometres. Therefore, UrbClim is ‘steered’ (forced) by output from a large-scale – regional or global – atmospheric model. The latter contain large-scale weather and climate features, but are much too coarse to contain any urban detail, which is why models such as UrbClim are required.

- **Terrain data** constitute another group of input data. UrbClim needs the specification of a number of parameters that characterize the underlying terrain. Among these, an important one is land cover (e.g., CORINE land cover for Europe). The model also requires raster fields containing the ‘degree of soil sealing’ (percentage of impermeable surfaces – which is typically high in built-up areas), and vegetation abundance (percentage of green vegetation, most often taken from satellite imagery containing a vegetation index).

3. Output data

UrbClim raw output data consists of
2D gridded fields with a spatial resolution of between one hundred and a few hundred metres (i.e., features with a spatial extent smaller than this cannot be 'seen' – they aren't present in the data)

- covering domains extending over a few tens of kilometres (depending mainly on the size of the considered city), and therefore consisting of up to several hundred grid cells horizontally
- for (normally) the following quantities, taken at 2 m (or another level – to be specified) above the ground:
  - temperature
  - absolute humidity
  - wind speed vector components
- for periods typically covering a few tens of summer seasons, either
  - historic periods (e.g., 1986-2015)
  - climate projections (e.g., 2081-2100 for a given IPCC scenario such as RCP8.5)
  - possibly also seasonal forecasts (to be tested, though)
- at an hourly time step, and written to NetCDF (commonly used scientific format) files.

Even though the raw output consists of hourly data files, at the post-processing stage a host of derived / aggregated quantities can be produced from it rather flexibly, for example:

- daily Tmin/Tmax
- relative instead of absolute humidity
- wind speed and direction instead of vector components
- number of tropical days
- number of heat wave days
- cooling degree days
- thermal comfort indicators such as the wet-bulb globe temperature (WBGT), which combine temperature, humidity, radiation, and wind speed.

All this information can be delivered in a number of formats (GeoTIFF, GIS formats, ...). In fact, a considerable portion of the co-design work between the data providers (VITO & KU Leuven) and the service providers will consist of agreeing on these derived variables and output file formats.

Note also that the variables listed above (temperature, humidity, wind speed) constitute the standard output. But the model calculates a lot of other quantities as well, most of which we could in principle also add to the output, such as soil moisture content, soil (or vegetation) temperature, precipitation runoff, surface heat flux, surface evaporation flux, leaf stomatal resistance, etc... It should be noted, though, that many of these variables generally have not undergone thorough validation, hence they are to be considered as experimental and are to be used with caution. Radiation (short- and longwave) and precipitation variables can also be included, but since these are not calculated within UrbClim (instead they are taken from the large-scale model used to drive the UrbClim simulation), these quantities will not contain any urban detail.
Regarding the future climate projections, another issue arises. Basically, in its most complete form, urban climate projection simulations are achieved by forcing the UrbClim model with GCM/RCM output instead of historic Re-analysis data such as those of the ECMWF ERA Interim archives. Now, in order to account for GCM/RCM uncertainty, we apply the ensemble approach, meaning that urban climate projection simulations are repeated a number of times (typically around ten), each time using output from a different GCM/RCM to provide the forcing, and thus introducing an inter-model related uncertainty.

However, that leads to a tenfold increase in an already computation-intensive procedure, thus severely limiting the number of cases-cities-periods that can be considered. To remedy this, VITO has developed a statistical technique that, stated simply, adds the climate change effect contained in the GCM/RCM projections to a ‘reference’ (i.e., representative for present-day conditions) urban climate result. Yet, this technique involves the use of statistical coefficients that are specific for each variable and, so far, has been applied solely to 2-m temperature.

Once again we would like to stress that, given the high computational and storage cost associated with UrbClim simulations, it is of paramount importance to proceed with a judicious selection of periods, scenarios (IPCC, land use, ...), and look for compromises whenever required, including lowering the spatial resolution to allow more scenario simulations. Also, in most situations, in order to cut the number of Giga- or Terabytes of required storage, the output will only contain a limited number of quantities selected beforehand.

In the list above, more specifically in the specification of the time periods available (historic, climate projection, seasonal forecast), you may be struck by the absence of the forecast time horizon, i.e., the 1-10 day range that typically comes with weather forecasts. While this is intentionally so (forecasts are within the realm of the national weather services, and are generally kept out of the climate services), in some cases a workaround is possible. For instance, when discussing the Rome case study, a possible solution would consist of including the forecast time horizon by first generating historic climate information (e.g., 1986-2015); whenever forecast information is available to the user (e.g., from the regular weather forecast), we can then identify, within the historic data, the day that best corresponds to the forecast day, and subsequently use the information of this particular historic day as a proxy.

4. High-resolution

As mentioned previously, the spatial resolution of UrbClim output is limited to approximately 100 m. Most of the time this is more than suitable, especially considering that quantities such as temperature and humidity have a fairly diffuse spatial distribution, i.e., they do not exhibit very sharp spatial gradients. The situation is very different, though, when considering radiation, especially shortwave (solar) radiation. Indeed, during sunny days, the spatial pattern of solar radiation generally varies over very short distances, due to the shade that is generated by obstacles such as buildings and trees. At the same time, during the day, radiation has a large impact on human thermal comfort.

---

2 Global Climate Model / Regional Climate Model
In order to account for this, VITO has developed a hybrid procedure, which combines regular UrbClim output fields (temperature, humidity, wind speed) with separately calculated metre-scale fields of short- and longwave (thermal infrared) radiation, an approach that is capable of generating maps containing a thermal comfort indicator for an entire city with a spatial resolution of a few metres.

However, two caveats apply:

- this procedure requires the availability of suitable high-resolution 3D cadastral data for the domain of interest, with a spatial resolution of a few metres and containing all buildings, trees, and other relevant obstacles;
- given the high computational intensity of calculating radiation patterns for an entire city at a few metres resolution, this procedure can only be used for short periods, typically of the order of one or a few days.

In the examples shown below, a few high-resolution cases have been included towards the end.

5. Examples

Below, we produce a number of figures showing UrbClim output fields generated in past projects, to demonstrate what sort of output, aggregations and post-processing can be achieved.
Hourly maps of the average daily cycle of the urban heat island intensity for Antwerp for a recent summer period. Every time in this mosaic is obtained as the average of the temperature for the particular hour in the day. For instance, the tile labeled ‘21u’ is obtained by averaging all the maps occurring at 21 GMT within the considered summer period.
Wet-bulb globe temperature (WBGT, which is a thermal comfort indicator based on air temperature and humidity, short- and longwave radiation, and wind speed) for a hot day in the summer of 2015, for the city of Ghent (Belgium). The cooler areas (blue-green) generally result from shading by trees or buildings. For more information on the WBGT, see for instance https://en.wikipedia.org/wiki/Wet-bulb_globe_temperature.
Average urban heat island intensity for the Brussels area at 23 GMT, for the summers (June-July-August) of the 1986-2005 period.
Potentially lost working hours for heavy outdoor work, as a consequence of high levels of heat stress occurring in the (hot) summer months (June-July-August) of 2003, for the City of Brussels.
Number of heat wave days (based on exceedance of the 98th percentiles of Tmin and Tmax) For the Berlin area, for 1986-2005 (left), and for 2081-2100 under the IPCC scenario RCP8.5 (right). Notice the nearly tenfold increase in the number of heat wave days towards the end of the century.

The annual average number of cooling degree days for Brussels, for the period 1986-2005, superimposed on a Google Earth background map. The number of cooling degree days in a given period equals the number of hours during which the temperatures exceeds 25°C, multiplied by the temperature excess above 25°C. This is an international standard to estimate cooling energy demand.
Simulated average 12:00 UT (left) and 00:00 UT (right) surface turbulent sensible heat flux for Toulouse and surroundings, for the period June-July 2004.

The mean radiant temperature (MRT – a thermal comfort indicator) for a hot day in the summer of 2012, near central Antwerp. The blue areas indicate the cooling effect of tree shade (urban parks). To generate this information, standard UrbClim output is combined with very high-resolution (few metres) calculations of radiation exposure (both solar and thermal infrared radiation). This approach requires a high-resolution 3-D urban cadastre, containing individual buildings.
The mean wet bulb globe temperature (WBGT) on 12 August 2003 for the entire Brussels area (left), with a zoom on the center of the city (right). The yellow colours generally correspond to building shade, and the blue areas mostly correspond to thermal comfort conditions underneath trees within urban parks. For this sort of data, UrbClim output is combined with very high-resolution (few metres) calculations of radiation exposure (both solar radiation and thermal infrared or so-called 'heat radiation'). This approach requires the availability of a high-resolution 3-D urban cadastre, containing individual buildings.
REFERENCES

García-Díez, M., D. Lauwaet, H. Hooyberghs, J. Ballester, K. De Ridder, and X. Rodó, 2016. Advantages of using a fast urban boundary layer model as compared to a full mesoscale model to simulate the urban heat island of Barcelona. Geoscientific Model Development, 9, 4439–4450.

SCIENTIFIC REPORTS FROM RECENT FP7 PROJECTS CONTAINING URBCLIM DESCRIPTIONS / RESULTS

FP7-RAMSES (www.ramses-cities.eu)
D4.1 Validation of agglomeration-scale climate simulations
D4.2 Agglomeration-scale urban climate and air quality projections
D4.3 Urban adaptation effects on urban climate

FP7-NACLIM (www.naclim.eu)
D42.20 The first subset of urban climate simulation results
D42.33 The final urban climate simulation results
D42.42 The impact of predicted climate on urban societies

MORE GENERAL INTRODUCTIONS TO URBAN HEAT ISLAND EFFECTS AND MODELLING

- [https://www.youtube.com/watch?v=Uvel09o4uQO](https://www.youtube.com/watch?v=Uvel09o4uQO), a link to a webinar in which our colleague Hans presents between 14:35 and 32:37
- [https://www.youtube.com/watch?v=p5WmZsHF5hE&list=PLoqC0y5-eTV5g6Bm_aJERRS0dBy4Xibg2&index=3](https://www.youtube.com/watch?v=p5WmZsHF5hE&list=PLoqC0y5-eTV5g6Bm_aJERRS0dBy4Xibg2&index=3) is another short movie (featuring colleague Dirk)
- VITO’s urban climate service website: [www.urban-climate.eu/](http://www.urban-climate.eu/)
- A general source of information regarding the urban climate is available from the following link: [http://www.urban-climate.org/documents/UHI_Canopy.pdf](http://www.urban-climate.org/documents/UHI_Canopy.pdf).
KU Leuven will be responsible in the project for the rainfall downscaling (for all city cases and services that need data on rainfall changes due to climate change). KU Leuven will also be in charge of the urban flood impact modelling for the 2 cases that demand such modelling (the Antwerp – Emergency planning case and a second case still to be determined).

**Climate scenarios for (extreme) rainfall**

The generation of climate scenarios for extreme rainfall will use a novel method of statistical downscaling (Willems et al., 2012) where all publicly available global and regional climate model outputs will be considered and downscaled to the local scale of a European city.

![Scheme summarizing the process of statistical downscaling of the ensembles of publicly available global, regional and local climate model outputs. Climate scenarios for (extreme) rainfall will be obtained that are applicable for local impact analysis at the scale of European cities.](image)

Local time series of measured precipitation intensity available for specific locations in Europe (i.e. cities) will be perturbed according to climate change signals obtained from the climate model outputs. This will done based on the ensembles (groups of climate models) of publicly available outputs from global climate models (GCMs; CMIP5 database) and European regional climate models (RCMs; EURO-CORDEX database) and the quantile perturbation
method (Willems 2013a; Willems & Vrac, 2011; Ntegeka et al., 2014) for further downscaling. This downscaling method intrinsically involves bias correction (removal of any systematic difference between the climate model outputs and the historical observations). If local area models (LAMs), which are high resolution climate models but for limited areas, are also available, these will be considered to validate and fine-tune the statistical downscaling assumptions. For Belgium, for instance, local area models with fine spatial resolutions of 2.8 to 4 km are currently being simulated within the CORDEX.be project. Also the UrbClim model by VITO can be classified as a LAM.

The climate change signals that will be derived and downscaled for this project involve changes in rainfall intensities in relation to the severity level (exceedance probability or return period), the number of wet and dry days, and this for each month of the year. These changes will be applied to the local historical precipitation time series using a stochastic modelling procedure. The local historical time series can be of any time scale (monthly, daily, hourly, 15-minutes, ...). The time scale that is required for the local impact analysis or climate service depends on the type of impact and service, and may be determined during the stakeholder workshop.

**Future rainfall products and options**

The result of the perturbation based statistical downscaling are precipitation time series of the same length and time scale modified (perturbed) time series but following future climate conditions. Different options can be considered here as follows:

- Different climate horizons: e.g. 2030, 2050, 2100, but any other time horizon between now and 2100 may be considered;
- Different greenhouse scenarios: RCP8.5 (business-as-usual scenario reg. greenhouse gas emissions), RCP 6.0, RCP 4.5 (medium scenarios) and RCP 2.6 (strong mitigation scenario), or all RCP-scenarios combined, given that the likelihood of each scenario cannot be determined;
- Different time scales: same time step as the original historical precipitation series, or aggregated over coarser time scales.
- Different climate models: Because of the uncertainties in the future climate projections, it is important that these uncertainties are taken into account in the impact analysis. This can be done in different ways. One way is to consider an ensemble of future perturbed rainfall time series: one for each of the different climate models. This, however, leads to a large set of time series to be considered (in some cases more than 200 !). That is why we propose the use of a reduced set of “climate scenarios” where the full ensemble of future climate projections of all the climate models is statistically post-processed in order to obtain few scenarios that approximately span the full ensemble range. In Belgium, we use three climate scenarios: high, mean and low; these represent future changes on the higher end, the middle and the lower end of the full range of future changes in rainfall.

For the historical precipitation time series, local time series need to be collected and provided, or we have to search for available precipitation time series in public databases. However, note that such public databases most often do not provide precipitation data with
high temporal resolution. The time step is often daily or even monthly, which may be too coarse for the PUCCS impact analysis or climate service.

The historical and future (perturbed) rainfall series can also be further processed in order to obtain rainfall statistics, such as:
- Extreme rainfall intensities for given probabilities or return periods, e.g. 5-year, 20-year or 100-year rainfall intensities;
- Rainfall intensity-duration-frequency (IDF) curves, which are typically used for the design of urban drainage systems; or for impact analysis on urban flooding (i.e. construction of urban flood hazard maps);
- Etc... In principle every statistic that can be obtained from the historical precipitation time series can also be derived for the future conditions.

Few examples

Hereafter, few examples are shown of extreme rainfall statistics and their use within specific (urban flood related) applications.

Changes in mean monthly precipitation

Monthly changes in precipitation depth, where the boxplots indicate the ranges of relative changes based on the full ensemble of climate models (around 200 runs in this case for Belgium). One can see that the higher the RCP scenario (the higher the greenhouse gas concentrations) the stronger the changes. Winter months show increasing future rainfall amounts for Belgium; the summer months decreasing future rainfall amounts. Most climate models show such increasing or decreasing patterns. The precise % change is, however, uncertain as is indicated by the box-plots. We note in the figure that the winter rainfall may increase up to about 30% or more; the summer rainfall may decrease down to about -50% or more.
**Changes in extreme rainfall intensity-duration-frequency (IDF) curves**

IDF curves for Uccle, Belgium, representing how the rainfall intensity depends on the time scale (aggregation level = time duration over which the rainfall intensity is averaged) and the return period (probability of occurrence). By overlaying the IDF curves for the historical and future climate, it can be seen that a 100-year storm in the current climate may become a 10-year storm in the future climate 2071-2100. The lines in the plot are for return periods of 1 month (lowest red lines), 1 year (pink lines), 10 years (green lines) and 100 years (dark green line).

**Changes in design storms**

Changes in one of the storms that is used for the design of urban drainage systems in Belgium (2-year storm in the figure). One can see the increase in peak intensity of the storm from the historical (=current) climate to the future climate according to the mean and high climate scenarios.
Spatial maps showing the changes in extreme rainfall intensities (in the figure for the example of the 5-year 15-min rainfall intensity) from the current to the future climate (high climate scenario) over the city of Antwerp.
**Trends and multi-decadal climate oscillations**

Next to climate change, it may be important to look at the presence of trends in historical rainfall time series. Based on an anomaly indicator for extreme rainfall intensities, long-term temporal trends and multi-decadal oscillations have been detected for extreme rainfall in Europe (Ntegeka & Willems, 2008; Willems, 2013b, 2013c).

Temporal evolution in the occurrence of extreme rainfall intensities (intensities which potentially may lead to urban flooding) at Uccle, Belgium, being a combination of a long-term gradual trend (probably due to global warming) and oscillations at multi-decadal time scales around that trend.

Correlations (for nearby areas) and anti-correlations (between Northern and Southern Europe) of the temporal anomaly patterns in extreme rainfall across Europe and the Middle East.
Changes in (urban) floods

For analyzing the changes in sewer or river flows and (urban) floods, the rainfall time series needs to be propagated in a hydrological and/or hydraulic model of the water system (i.e. urban drainage system, river system). This can be done for the historical rainfall time series and repeated for the future (perturbed) rainfall time series. When the impact results after use of both types of time series are compared, the changes in impacts can be assessed.

For impact analysis on urban floods, the impact models may consist of detailed full hydrodynamic models or surrogate, conceptual models. KU Leuven developed both types of models to transfer the rainfall (and temperature/evapotranspiration) changes to changes in urban flood risks. A conceptual urban hydrology model has been developed (Wolfs and Willems, 2017; De Vleeschauwer et al., 2014), consisting of a 2-D overland flow part integrated with a below ground part build-up of reservoirs. The below ground part of the model represents the sewer system as well as other networks, such as tunnels or metro networks, that can drain or store run-off.

Hybrid urban flood modelling concept where the bi-directional interactions between the above ground (overland) and below ground (sewer network and underground stores) are considered

Nested 2D surface inundation modelling approach, where 2D computational meshes with different resolutions (depending on how flood prone the area is) are combined to limit the computational burden
Examples of urban inundation model results

Changes in urban flood hazard for the city of Antwerp, from the current (2015) climate to the future climate (2030, 2050, 2100, for high climate scenario). The coloured areas show the areas where inundations of the sewer system occur for return periods of 2, 5 and 20 years (water on the street or with “door step” margin of 20 cm).
Flood maps for different return periods (probabilities of occurrence)
100-year flood maps before and after climate change (high climate scenario)
Some references

On statistical downscaling and quantile perturbation method:


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