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Urban SIS
D441.6.5 Use case manual for public use and understanding of Urban SIS products

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1. Introduction

The Urban SIS results consist of urban climate data in the form of downscaled *Essential Climate Variables* (ECVs) and from those determined impact indicators. There are data sets over three urbanized 110x110 km^2 domains available under the Urban SIS portal that include the cities of Stockholm, Bologna and Amsterdam/Rotterdam. Urban SIS climate information over a city is provided as three data sets, each based on 5 years of hourly gridded 1×1 km^2 data representing:

- A historical period of specific years: 2006, 2007, 2012, 2013, 2014
- 5-years of data taken from a climate scenario, representing present conditions (1980-2010)
- 5-years of data taken from a climate scenario, representing future conditions (2030-2065)

For the historical period the data should be as close as possible to the reality and the quality of the downscaling has, for the most important ECVs, been evaluated against observations (deliverables C3S_D441.5.1-3). The data set representing present conditions of the climate scenario is also given names of historical years, but they have no connection to "true" conditions for particular years and can only be compared in terms of statistics e.g. long term period averages or maxima.

The purpose of this manual is to guide a new user how to access, visualize and download urban climate data through the Urban SIS portal. The procedure is similar for all ECVs and impact indicators, so detailed examples will be given for some selected variables – air temperature and four air quality variables – that have been decided for upload also in the *Copernicus Data Store* (CDS) database. The user can easily switch to other ECVs and impact indicators, using the same functionality as described in the two use case examples.

2. Communicating the quality of Urban SIS data

The data displayed in Urban SIS can, as a result of how they were produced and which input data were used, be associated with three quality aspects:

a) Downscaling model performance (named "Model")
b) Determination of impact indicators (named "Indicator")
c) Climate scenario uncertainties (named "Scenario")

Some data have only one aspect (e.g. an ECV for the historical period), some two aspects (e.g. an impact indicator for the historical period or an ECV for the future scenario) and some will be associated to three aspects (e.g. an impact indicator for the future scenario).

The quality is communicated to the end user as three levels:

- ***GOOD*** quality, suggesting that the end user can use the information directly and have confidence in the information being relevant and in line with alternative inforamtion (measurements or other model generated data). **Message: Go ahead!**
- ***MEDIUM*** quality, indicating that the results are useful, but that the user must be aware of certain limitations/restrictions. **Message: Caution!**

- ***POOR*** quality, indicating results that are only partly useful. The end user must be fully aware of the limitations before using this data. **Message: Warning!**

Important note: An Urban SIS data set will have the quality of the poorest quality given to any of the aspects associated to the variable or impact indicator selected.

The full framework for communicating the quality of Urban SIS data is given in the deliverable C3S_D441.5.4.2. It is there indicated that the quality should be visualized as a colored button, as soon as the data are selected for visualization over the map. This feature has yet not been implemented in the present version of the Urban SIS portal. This manual will give the quality classification of the data sets used in the examples and show, through references to some key documents, how to access the corresponding quality information of all Urban SIS data.

3. ECVs and impact indicators available

Table 3.1 lists the ECVs provided in the Urban SIS portal. Urban SIS facilitates, except for the hourly time series, also statistics like monthly/yearly means and extreme values (for all ECVs at ground level). For precipitation there are also gridded data with a 15 min resolution available for download.

Table 3.1 Urban SIS ECVs and their units

Name	Unit
Air temperature* (T2M)	K
Air temperature* (T2Murban)	K
Air temperature* (T2Mnature)	K
Air temperature* (T layer 1)	K
Air temperature* (T layer 2)	K
Air temperature* (T layer 3)	K
Precipitation (15 min)	mm
Precipitation (hourly)	mm
Relative humidity*	%
Wind* (at 10 m)	m/s
Gustiness	m/s
Boundary layer height	m
Snowfall	mm
O3 concentration	µg/m3
NO2 concentration	µg/m3
PM10 concentration	µg/m3
PM2,5 concentration	µg/m3
Global radiation	w/m2
Direct shortwave radiation	w/m2
Diffuse shortwave radiation	w/m2
Local runoff	mm/h
Surface runoff	mm/h
Evapotranspiration	mm
River discharge	m^3/h
Soil moisture	mm
Snow cover	m

Table 3.2 show an aggregated list of the impact indicators elaborated with the ECVs as a base. Wherever complementary data are required – e.g. population data – those have been searched as open data, available on the web.

Table 3.2 Overview of Urban SIS impact indicators, organized after sectors and type of impact.

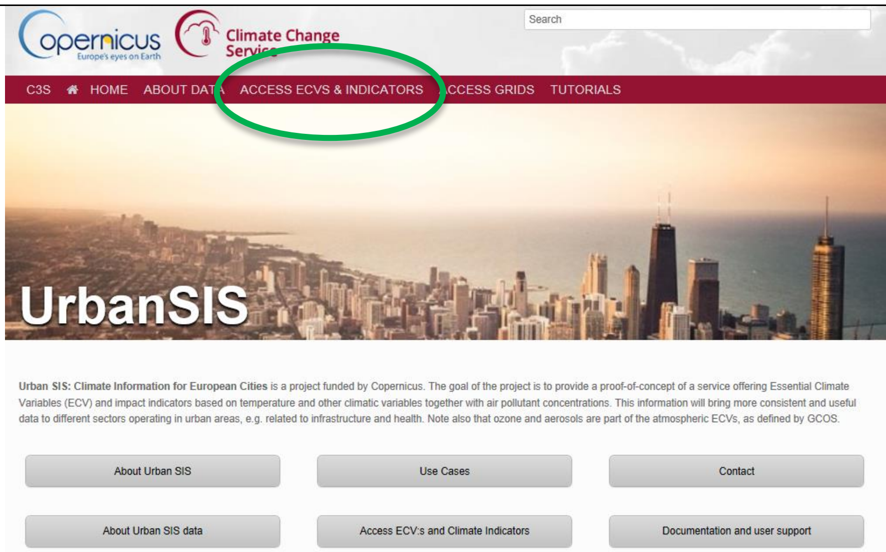
sector	indicator area	indicator type	indicators
Health indicators	***Air quality***	EU limit values: concentrations	7
		EU limit/WHO guideline values: exposure	10
		Mortality long-term exposure	6
		Mortality short-term exposure	2
	Heat stress	Number of hot days	1
		Heat wave duration	1
		Heat induced mortality	2
	Discomfort	Thom Discomfort index	2
		Universal Thermal Climate Index	2
		Frequency of tropical nights	1
Energy indicators	***Energy consumption***	Heating degree days	1
		Cooling degree days	1
	Solar energy	Monthly shortwave solar insolation	1
Infrastructure indicators	***Flooding***	Extreme precipitation	8
		Extreme precipitation intensity/duration	10
	Green infrastructure	Growing season length	3
	Transport infrastructure	Frost days	1
		Ice days	1
		Zero-crossings	1
Non-sector specific indicators		Daily max/min/mean air temperature	4

4. Example: Air temperatures in Bologna

In this section we will access and analyse present and future air temperatures in Bologna. Please use the hyperlinks wherever introduced as part of the text.

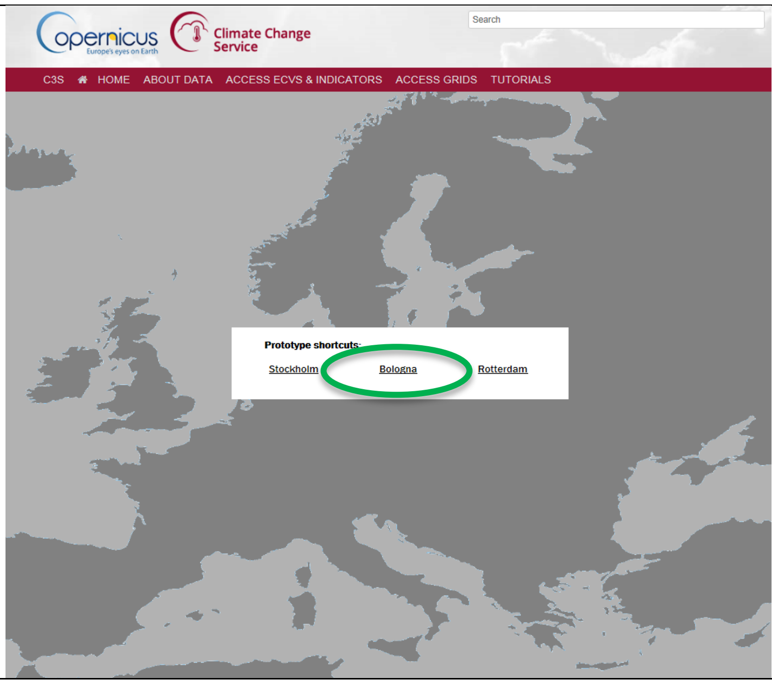
Access Urban SIS portal

- *Click the text "ACCESS ECVS & INDICATORS"*



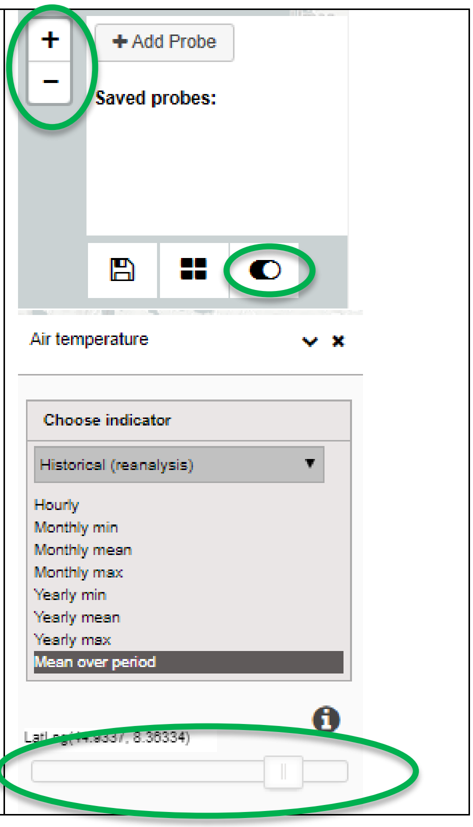
Access ECVs & Indicators

- *Select the "Bologna" domain*



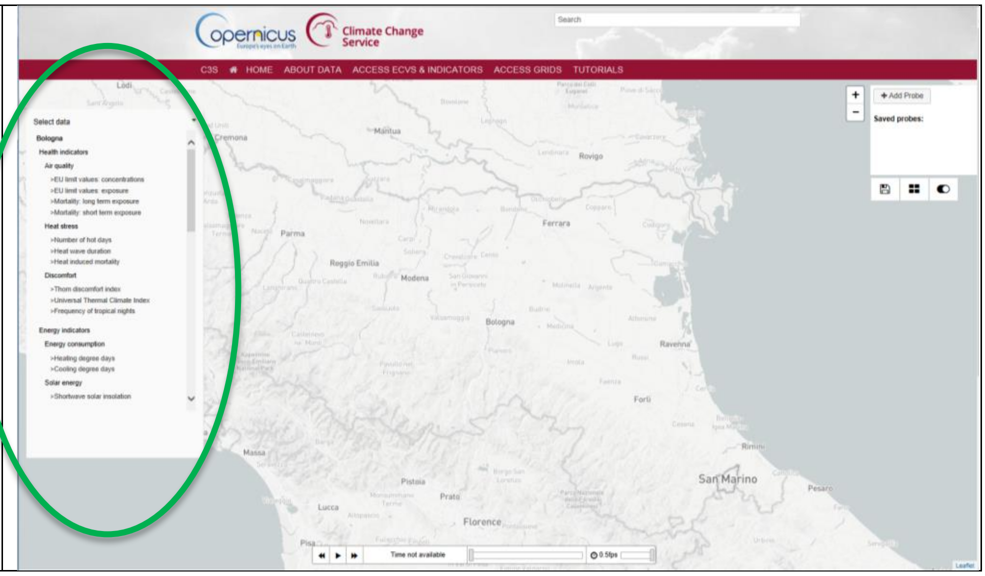
Navigate in the map

- *To zoom in the map, use the + and – buttons to the upper right in the window. It is also possible to zoom using the mouse scroll wheel or by holding down shift and the left mouse button to select an area of interest.*
- *Menus can be toggled on and off in order to leave more space for the map by using the leftmost button under the probe windows.*
- *To pane in the map, hold down the left mouse button and move the map to the desired position.*
- *The data layer can be made transparent by using the opacity slider at the bottom of the data selection panel to the left in the widow. (This is not possible if you are in the ACCESS grids application GRIDS)*



Select data (1)

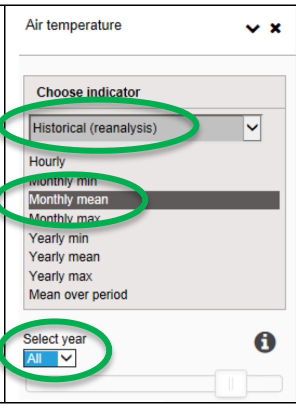
Select under “Temperature” the ECV “Air temperature” (ECVs are found in the end of the list of available data grids)



Select data (2)

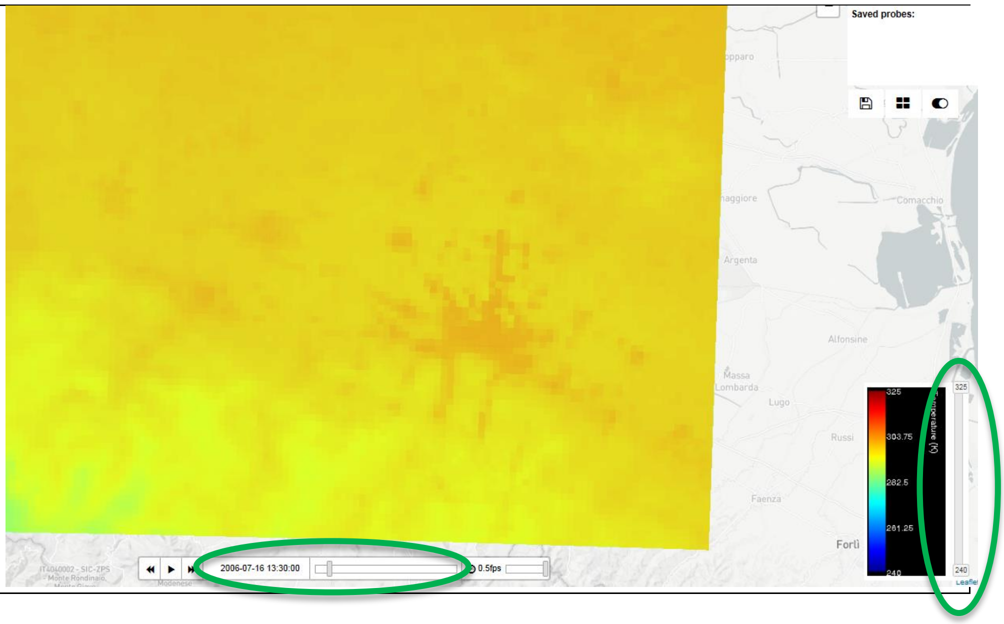
Select "Historical (reanalysis)", "Monthly mean" and finally "All" years (will select monthly data from all 5 years 2006, 2007, 2012, 2013 and 2014).

Note that you have redo all three selections in order to update the map with a new data set!



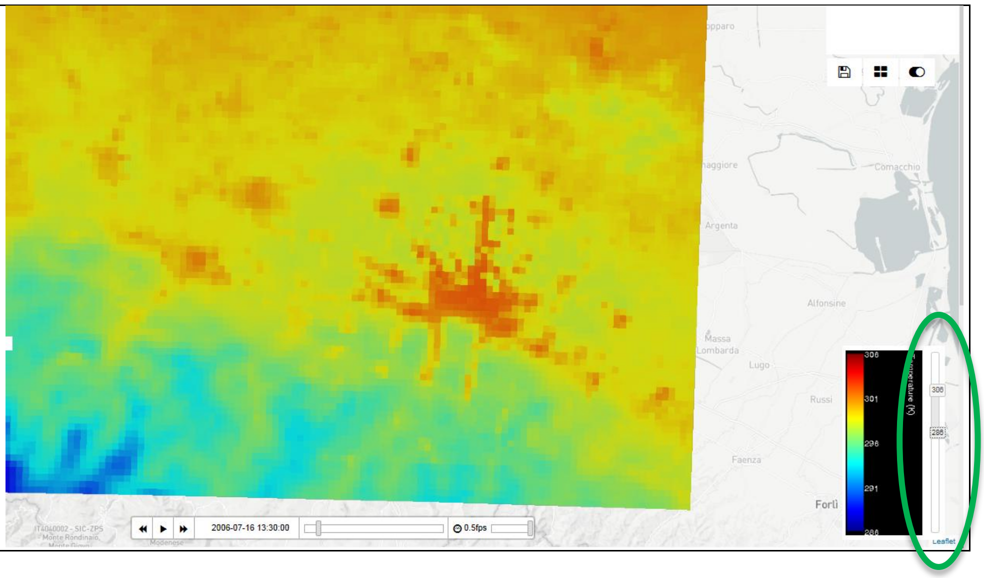
Select which monthly grid to visualize

The slide bar can be used to advance the monthly grids to a summer month of high temperatures, here July 2006. The Urban Heat Island (UHI) effect over Bologna is visible.
The colour scale can be adjusted through the vertical bar to the right.



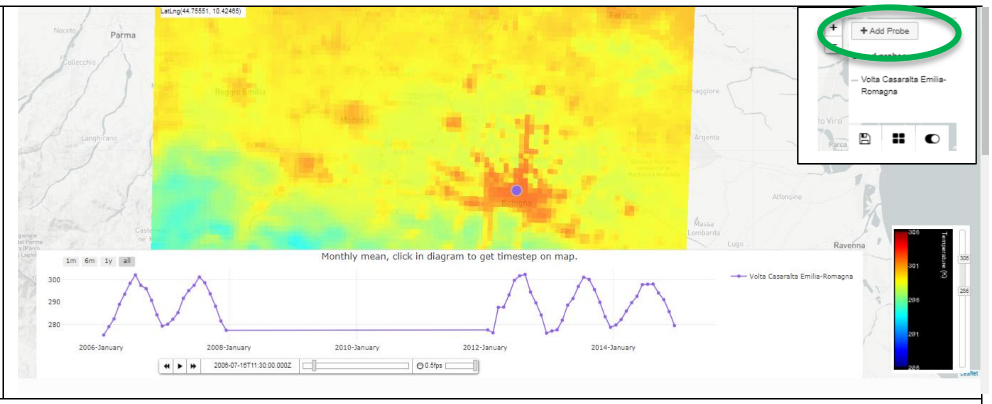
Select which monthly grid to visualize

Here the colour scale is adjusted to go from 286 K (blue) to 306 K (red).



Add Probe

Add a receptor point to display the time series of monthly temperatures. The location can be given by a click over the map, or it can be given as lat/long under "Add Probe".



It is possible to add many Probes. The numeric values of the displayed time series of ECV or impact indicator values at Probe locations are shown by moving the cursor to a specific date along the curves.

Store current view, download

The current view can be stored by first clicking on the "Store" icon and the click on the "Show saved views" icon.

After this storing procedure, the data can be downloaded.

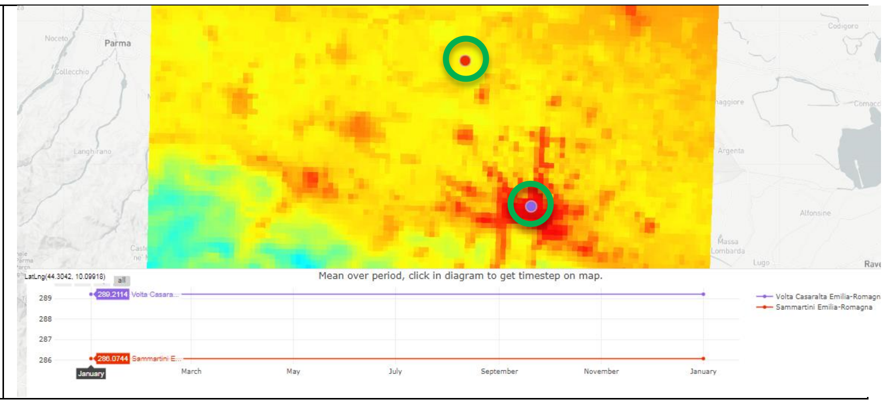
Downloaded data

The format of the downloaded monthly data (after unzipping). For hourly data the time stamp is local hour, indicating the difference to UCT. Various receptor points can be downloaded simultaneously.

```
,Bologna Emilia-Romagna
Lat,44.5160932228493
Lng,11.34338378906250
2006-01-16T12:30:00+01:00,275.3534
2006-02-15T00:30:00+01:00,279.0915
2006-03-16T12:30:00+01:00,282.5266
2006-04-16T01:30:00+02:00,289.04953
2006-05-16T13:30:00+02:00,293.5519
.....
.....
```

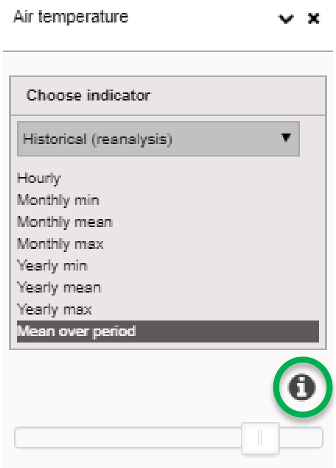
Quantification of the Bologna Urban Heat Island effect

A simple comparison of the mean temperature over all 5 years for a location inside Bologna (289 K) and another rural location in the Po valley (286.1 K).

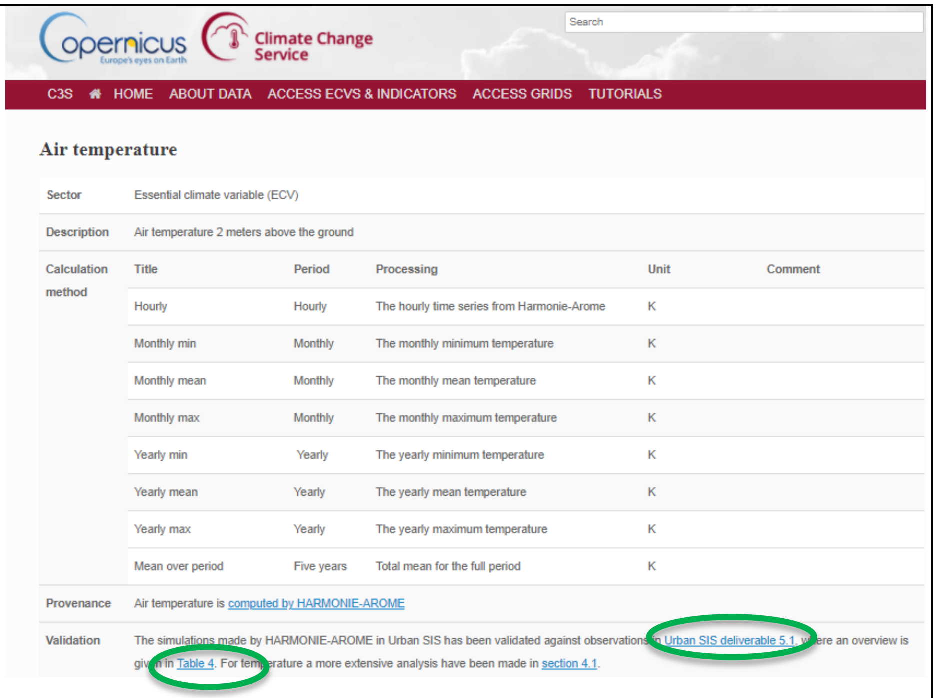


Information and quality of the Urban SIS data visualized[1]

Information of the data and how it was produced can be found under the information button:



.

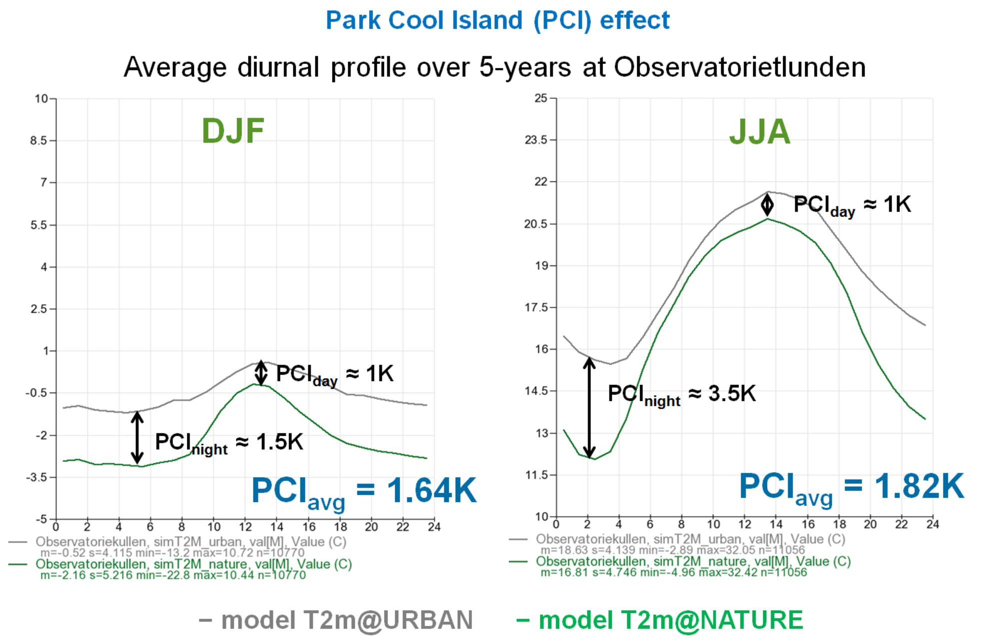


For the historical period the deliverable D5.1 gives a comparison of Urban SIS climate data against measurements. Results for temperature are found in Table 4.
*The quality of air temperature in Bologna, for the historical period, is classified as **GOOD** in Table 2.3 of the deliverable C3S_D441.5.4.2.*
There is only one quality aspect, model performance, for which the percentage error of the mean is <1°C and for the standard deviation of hourly data the percentage error <10%.

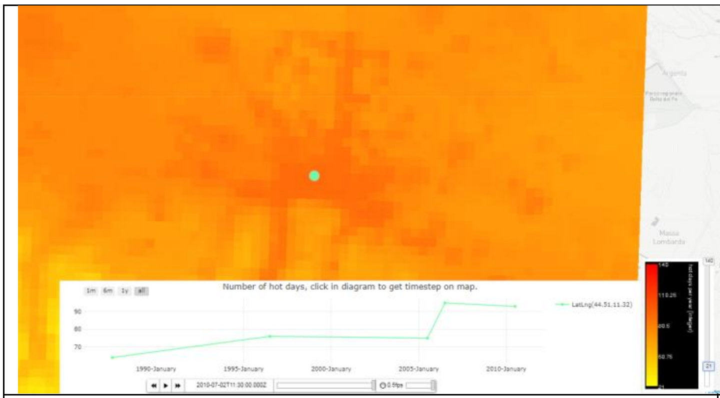
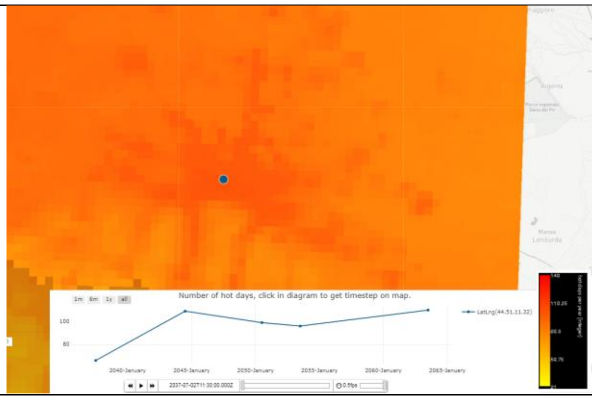
We have so far analysed the first of four Temperature ECVs in Urban SIS, the ***air temperature*** which is the average temperature at 2 m level over the 1x1 km^2 cell. The three others Temperature ECVs are:

- ***Urban air temperature***: The temperature 2 m level over built up surfaces within the 1x1 km^2 cell, e.g. over streets/paved areas and around buildings.
- ***Nature air temperature***: The temperature at 2 m level over vegetated surfaces e.g. within parks and other green areas of the 1x1 km^2 cell. The figure below shows an example of how it can be used to assess the cooling impact of green infrastructure in a city.
- ***Higher level air temperatures***: The temperatures of the three lowest vertical layers of the model output are available, however only as hourly data. They are representative of temperatures in at 12, 38 and 50 m height, respectively.

[1] The quality should be communicated through a colored button that will appear as soon as a data set has been selected for visualization, however yet not implemented. See C3S_D441.5.4.2 for further details.

Analysis using Urban and Nature air temperatures *The graphs shows an analysis of the Park Cool Island effect in Stockholm, comparing the Urban (grey) and Nature (green) temperatures within a 1x1 km² cell.*	

We will now visualize some of the impact indicators that are based on air temperatures. They are aimed for assessing how heat stress affects health and comfort among the urban population. Obviously an interesting question is how the climate change will affect the impact in the future. A recommendation to the end user is to open two windows and display the same types of graphs for the present (left window) and future (right window) conditions. The first example is for the Number of hot days, comparing the impact under present and future climate conditions:

	
Present conditions (1980-2010)	*Future conditions (2030-2065)*

The Probe (receptor point) is inside Bologna at 44.51°N and 11.32 °E. The range of this indicator at that location goes, during present conditions, from 64 to 95 days with daily mean temperatures over the 75th percentile of summer temperatures. With the same threshold for future conditions, the range is 66 to 110 days at the same location. With the colour scale adjusted in the same way, it is also possible to see the difference between the two gridded indicator maps.

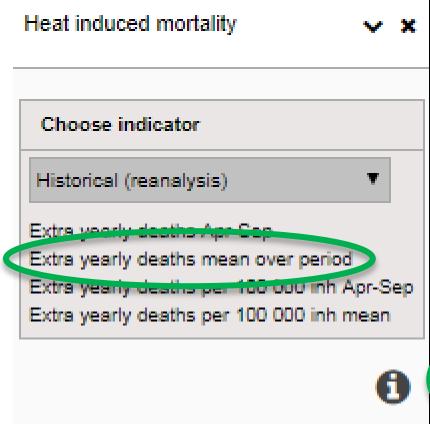
For this indicator there are three quality aspects to consider (as said before the lowest quality of the up to three aspects should be used for judging the overall quality of the data presented). Here:

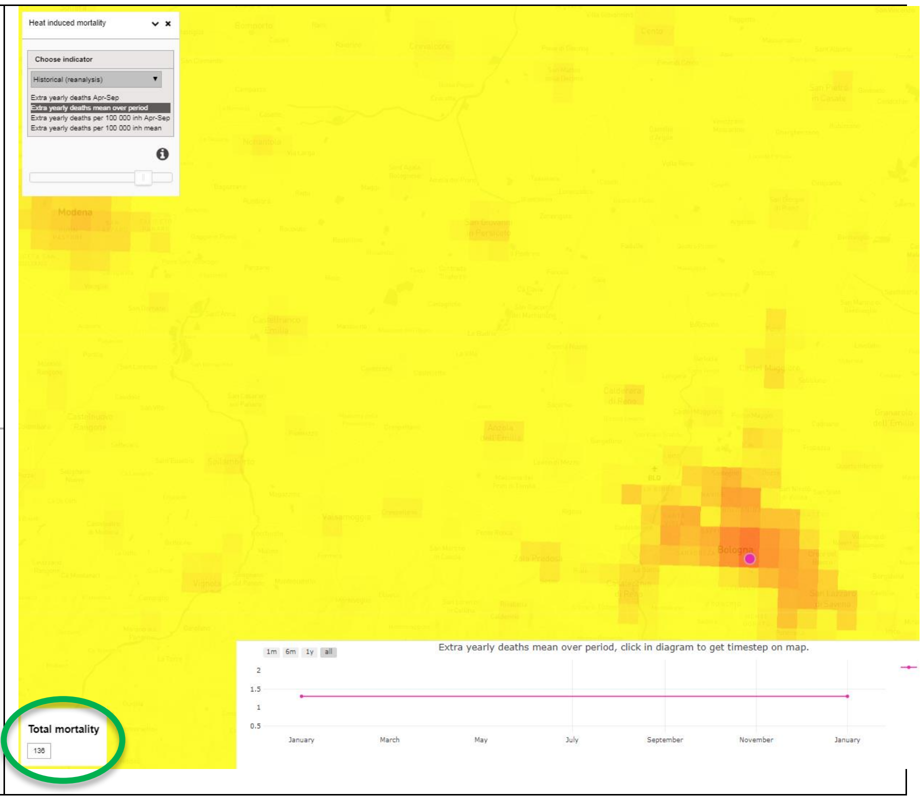
- Model performance: ***GOOD*** as already stated for temperatures in Bologna, see Table 2.3
- Determination of indicator: ***GOOD*** as indicated by Table 2.5 (the indicator is just a statistical elaboration of the temperature data, no other input data involved).
- Climate scenario uncertainties: ***MEDIUM*** as indicated by Table 2.13. Important to note that the Urban SIS climate scenario is based on an emission development according to a RCP8.5 scenario, which means high emissions and a strong heating of surface temperatures.

Since the lowest classification is of ***MEDIUM*** quality, this will also be the overall characterization of the displayed impact indicator.

Next impact indicator to analyse will be mortality caused by heat stress. Heat induced mortality is an advanced impact indicator and it is important to understand the way it is calculated. In the following example we will assess the heat induced mortality calculated from temperature of the historical data set.

Select under the "Heat stress indicators" the "Heat induced mortality" and "Historical (reanalysis)" data set. There are four results that can be accessed (see list below). Select the mean value for all five years of the historical period!





The gridded map displays the expected number of extra deaths per year due to heat stress, as an average for the 2006, 2007, 2012, 2013 and 2014. In total over the 110x110 km^2 domain the mortality is increased with 136 deaths, while the number of expected premature deaths within a 1x1 km^2 in the city center is 1.3 per year (from the Probe diagram).

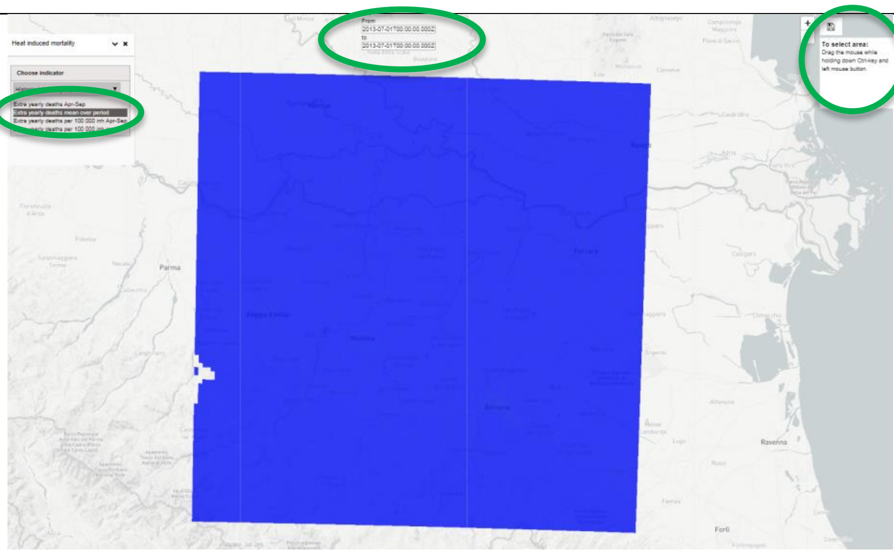
As before the model performance is of ***GOOD*** quality (based on temperature Table 2.3), and since the population data is also considered to be representative for historical and present conditions, also the indicator aspect is given ***GOOD*** quality, see Table 2.5. For the historical period the overall quality is thus ***GOOD***, however if the same indicator is presented for the future conditions, more caution must be used since both population data and land-use may have changed considerably (the calculation uses the same land-use and the same population for both present and future conditions). The quality of this impact indicator will thus be ***MEDIUM*** for future conditions, see Table 2.13.

The last exercise for temperature will be to download the heat induced mortality grid representing the mean conditions during the historical period. For that we switch to the ACESS GRIDS functionality:

ACCESS GRIDS

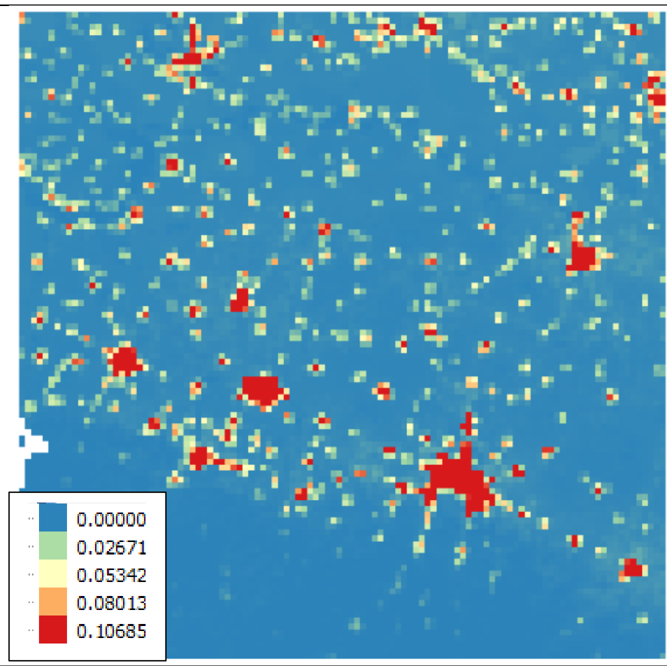
Select as before the Heat induced mortality data for the "Historical (reanalysis)" period and the data set ***Extra yearly deaths mean over period****.*

Here you can also select the period (from date 1 to date 2), however since the grid we access is the mean over the 5 years, there is only one unique grid/date.



The download is made by a click on the icon up in the right corner. The default is to download the entire 110x110 km² grid, but there is also a possibility to select area by draging the mouse while holding down Ctrl-key and left mouse button, marking on the map a specific area within the model domain.

The format of the download file is NetCDF. To the right QGIS, with a plug-in "NetCDF Browser", has been used to display the grid. What can be difficult sometimes while downloading grids is to correctly transform to a new platform the geographical coordinates (the THREADS server has shown to alter the projection information during data export). If the NetCDF download exported from the portal does not work properly in the end user's platform in terms of geographical information, it is recommended to download the original NetCDF file directly, following the instructions in C3S_D441.7.3.



5. Example: Air pollution in the Amsterdam/Rotterdam area

We will now explore an air pollution example. Urban SIS offers four of the regulated air pollutants: NO_2, O_3, $PM_{2.5}$ and PM_{10}. The hourly data that constitute the basis for statistics and impact indicators are, as all Urban SIS variables, given as gridded data with a spatial resolution of 1x1 km^2. This means that Urban SIS output reflect the urban background data, typically found at roof level or over parks and other open areas, thus lacking the hot spot concentrations found close to streets and traffic emissions.

Access ECVs & Indicators

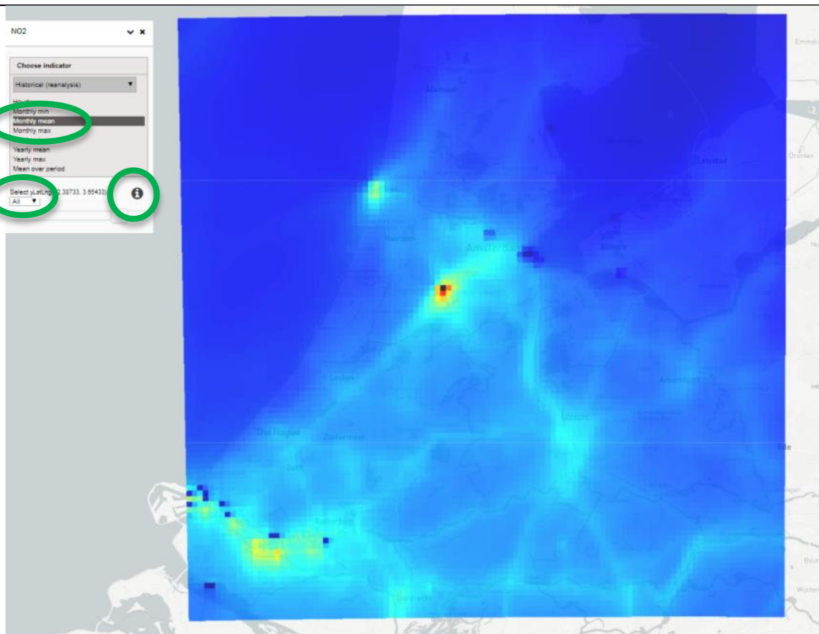
- *Select the "Rotterdam" domain (Amsterdam and Rotterdam are within the same 110x110 km^2 domain).*

Select data

Select under "Air quality" the ECV "NO2" (ECVs are found in the end of the list of available data grids), the "Historical (reanalysis)" period and the ***Monthly mean*** *ECV and visualize for all years.*

An information page is opened while clicking on the ⓘ symbol.

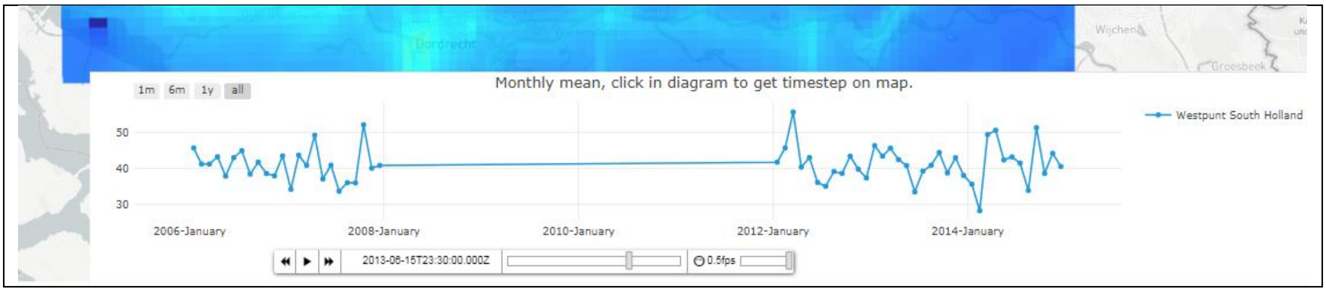
Adjust the colour scale to span the range 0-50 µg/m³ which allows the display of the spatial gradients, with higher concentrations in cities and along major roads.



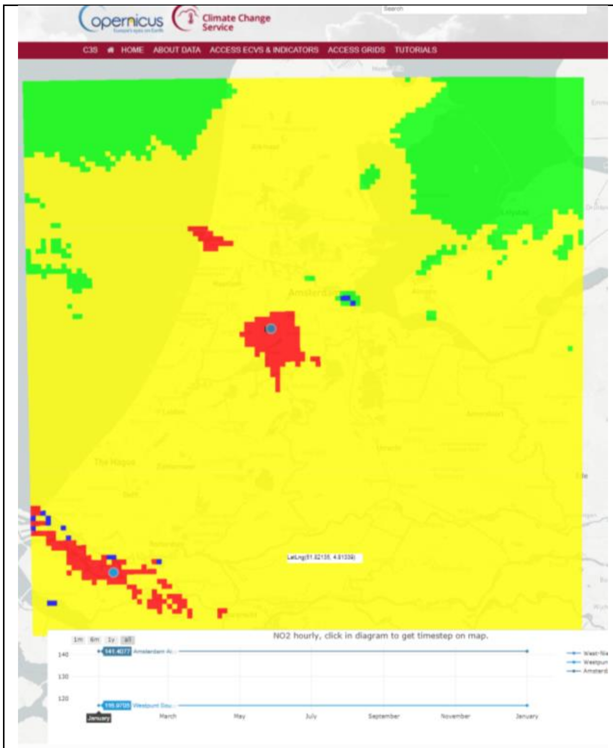
The quality of the model results have been assessed in the C3S_D441.5.2 report, see Table 3 and for NO_2 also Figure 3. Model performance for NO_2 has been classified as ***GOOD***, see Table 2.4 in the

[C3S_D441.5.4.2](#) report on how to communicate quality to users of Urban SIS data. Note that model results have some grids with zero values (appears as isolated blue pixels). This error was due to a postprocessing of the data over grid cells with both water and land, however they do not affect the values of neighbouring cells (and they are absent in the NO_2 output present and future conditions).

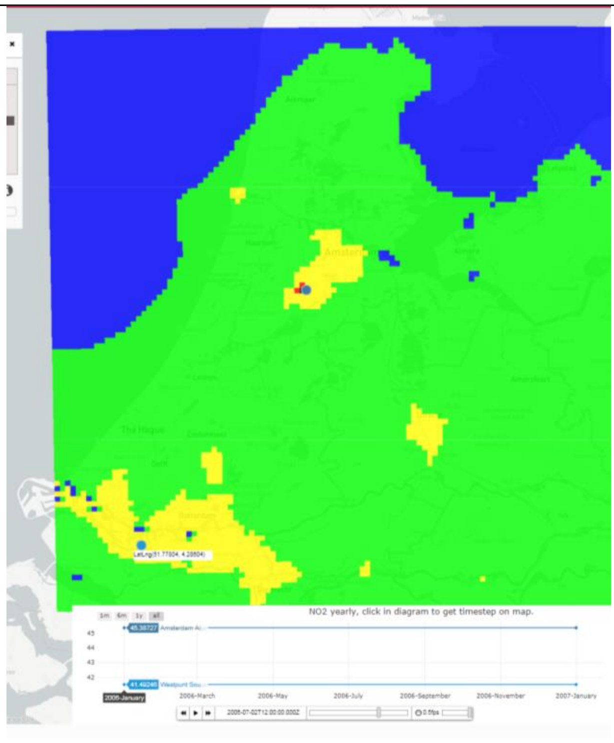
By locating a Probe in the Rotterdam city centre it is possible to follow the monthly mean levels of NO_2 in the Rotterdam urban background, ranging from 28.3 (February 2014) to 55.7 (March 2012) $\mu g/m^3$.



We now switch to an impact indicator calculated from the NO_2 data, the "EU limit values concentrations". There are two indicators: "NO_2 hourly" and "NO_2 yearly".



"NO_2 hourly"



"NO_2 yearly"

The highest hourly NO_2 values are found around Amsterdam, along the Rotterdam harbour and close to energy plant located at the coast. There are no exceedances of the limit value for hourly data (200 $\mu g/m^3$), the highest being around 140 $\mu g/m^3$. For the yearly limit value there are a couple of 1x1 km^2 cells in Amsterdam/Schiphol where the concentration levels exceed the EU limit value (40 μg/m^3), raising up to 40-45 μg/m^3. Since this indicator is only a statistical processing of the NO_2 data for the historical period, the quality remains ***GOOD***. Note however that Urban SIS output urban background concentrations and that the NO_2 concentrations may be considerably higher in hot spots close to highways, major roads and sources in the Rotterdam harbour.

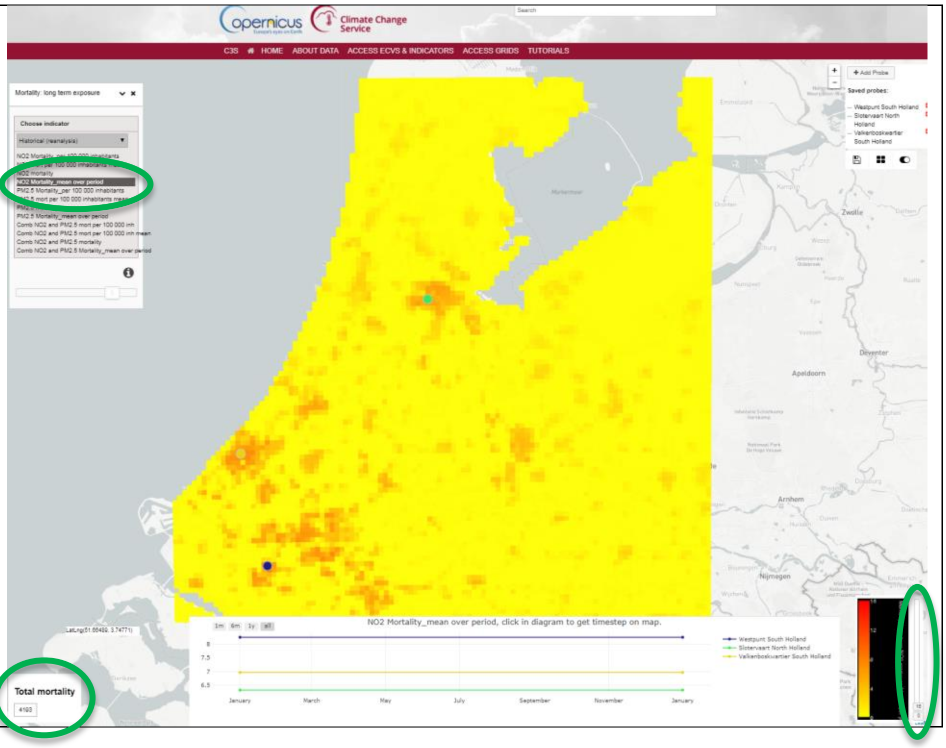
The next analysis of the NO_2 air pollution in the Amsterdam/Rotterdam area concerns the premature mortality expected to be caused by long-term exposure to NO_2 levels. For this we select the "Mortality long term exposure" data.

NO2 mortality per year (mean 2006-2007-2012-2013-2014).

Adjust colour scale for the range 0-16 deaths/year.

Total mortality over the whole 110x110 km^2 domain: 4193 per year.

Mortality in some selected 1x1 km^2 cells (Probes) in Rotterdam: 8.3 per year, Amsterdam: 6.3 per year and in Hague: 7.0 per year.



The quality for this indicator is based on the model performance aspect, which is ***GOOD*** according to Table 2.4, and the determination of the indicator aspect, which is also ***GOOD*** according to Table 2.5. The total quality is thus ***GOOD*** for this estimation of premature death due to NO_2 exposure.

It is possible also to calculate the health impact of $PM_{2.5}$ exposure, as well as the summed health impact of NO_2 and $PM_{2.5}$ exposure. The latter yields more than 10,000 premature deaths per year. Note however that the Urban SIS $PM_{2.5}$ data have a model performance quality ***MEDIUM***, see Table 2.4, which thus indicate a higher uncertainty also for the indicators based on $PM_{2.5}$.

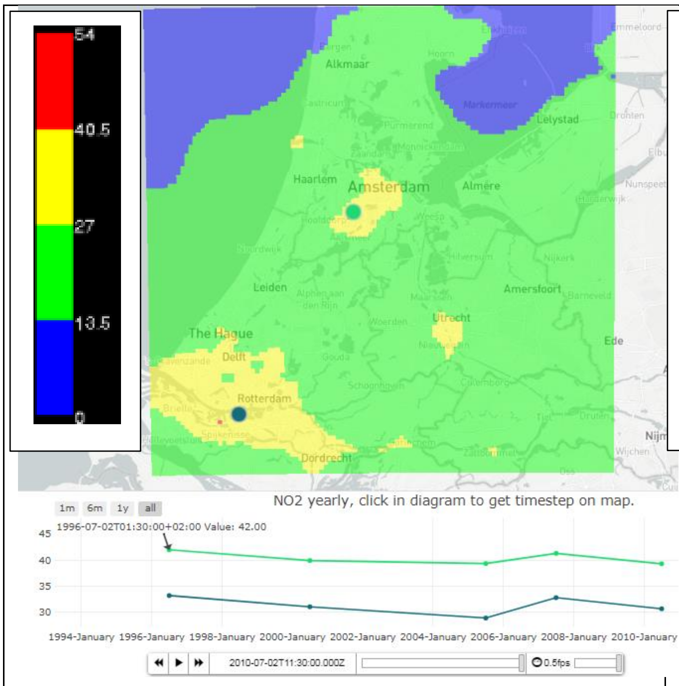
The final analysis for the air pollution will be to assess the expected changes in NO_2 and O_3 exposures between present (1980-2010) and future (2030-2065) conditions. We will use two indicators:

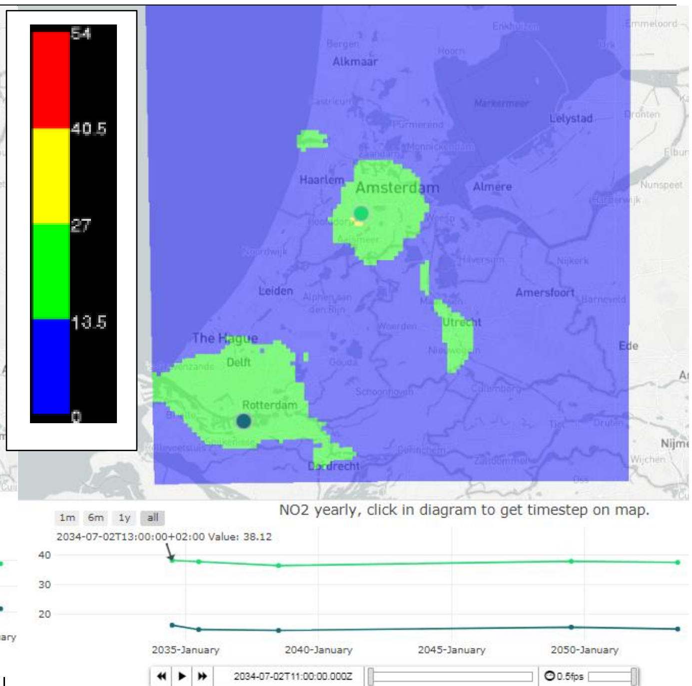
- For NO_2 the simple annual mean values, in Urban SIS named "EU limit values concentrations" used for comparisons with EU limit values and also for the mortality calculation (which involves population data). The EU limit value for NO_2 yearly mean is 40 µg/m^3.

- For O_3 the 93.15 percentile of maximum running 8-hour averages (limit value 120 µg/m^3).

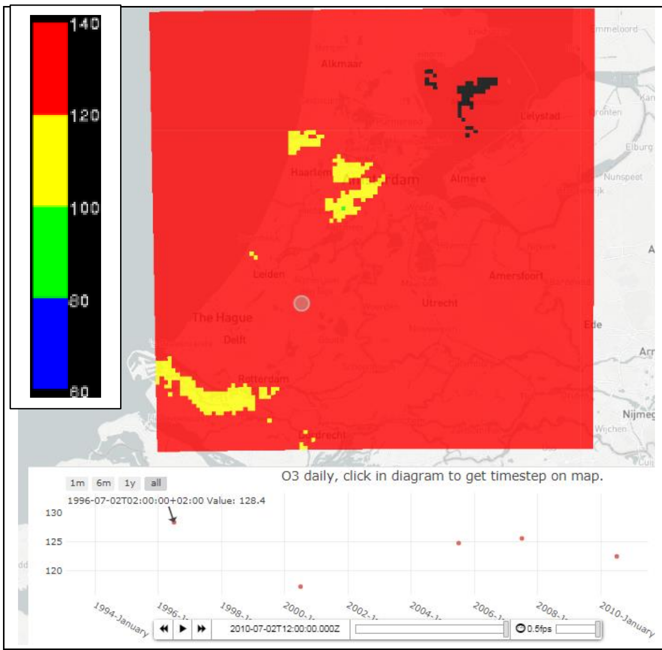
The comparison present versus future is made with coloured maps and with concentrations at two receptor locations, one in Amsterdam and the other in Rotterdam. While analysing the differences it is good to know the background to the climate scenario and the different conditions assumed between the present and the future windows:

- The climate scenario is based on RCP8.5 emissions, which means that it is a rather strong climate signal especially in terms of temperature.
- The air pollution emissions in Europe, affecting the long-range contributions arriving to the Amsterdam/Rotterdam area, follow an ECLIPSE scenario of *Current Legislation* (CLE) where there are rather strong reductions in NOx and PM emissions between present and future.
- The present emissions inside the 110x110 km^2 domain have been modified to the future time window, according to official projections for the Netherlands. In general the future emissions are in the range 60-100% of present emissions, see Table 7 and Figure 6 of the deliverable C3S_D441.3.5.

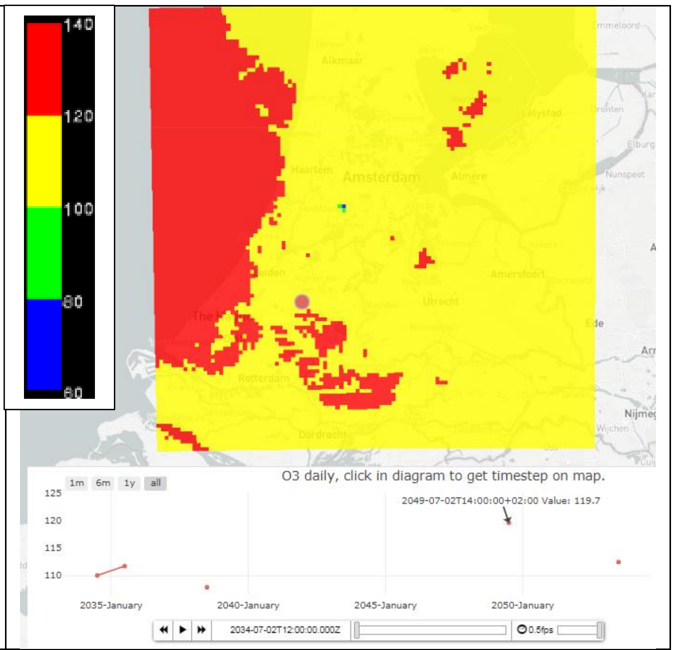




*Yearly mean NO_2 concentrations for **present** conditions.* *Amsterd.:* 39-42 µg/m^3, Rotterd.: 29-33 µg/m^3 *Quality: **GOOD***	*Annual mean NO_2 concentrations for **future** conditions.* *Amsterd.:* 37-39 µg/m^3, Rotterd.: 15-16 µg/m^3 *Quality: **MEDIUM***



O_3 daily for ***present*** *conditions.*
Alphen aan den Rijn: 117-128 µg/m^3.
Quality: ***MEDIUM***



O_3 daily for ***future*** *conditions.*
Alphen aan den Rijn: 108-120 µg/m^3.
Quality: ***MEDIUM***

Conclusions from the analysis:

- NO_2 yearly mean for present conditions: At and above EU limit (40 µg/m^3) in a few cells around Amsterdam/Schiphol. Rotterdam well below EU limit.
- NO_2 in the future: Considerably lower concentrations – around half of present conditions - in most of the domain. For smaller areas affected by dominant local sources, like Amsterdam/Schiphol, the concentrations are only marginally lowered.
- O_3 daily for present conditions: Concentrations exceeding the EU limit value (120 µg/m^3) at many places outside Amsterdam and Rotterdam. Note however that Urbana SIS model performance is only of ***MEDIUM*** quality, giving higher O_3 levels as compared to measurements according to Table 3 in C3S_D441.3.5.2.
- O_3 daily in the future: a clear tendency of lowered concentrations, likely eliminating most of the O_3 exceedances over land (especially if we take into account the tendency for the model to overestimate also present ozone levels).

The Amsterdam/Rotterdam domain will face lower long-range contributions of NO_2 and O_3 in the future, which, together with emission reductions also locally, will contribute to lower population exposure and health impacts. For certain smaller areas some local sources of NO_x may play a larger role than the long-range NO_2 contributions for what will happen in the future. If local NO_x emissions are not reduced, NO_2 concentrations will continue high and close to the EU limit in those areas. Changes in meteorological variables – i.e. climate change – play a minor role for future air pollution levels and their effect is included in the analysis.

6. Concluding remarks

The Urban SIS proof-of-concept project has developed a framework and a prototype for an urban climate service for different sectors acting in the urban environment and for which the spatial and temporal resolution of existing climate services are not sufficient. From end users' viewpoint it stands clear that there is a need both for information representing the conditions of today, as well as information of what is likely to happen in the future.

For ECVs related to health and comfort, e.g. temperature and air pollution, there have been considerable achievements of delivering data with good quality. However, Urban SIS has not been able to deliver downscaled precipitation with sufficient quality. Even if there are examples of simulations which successfully describe intense rainfall events, the overall precipitation has failed in magnitude with large sub-estimations. This has had strong negative implications for the subsequent hydrological modeling and it has contributed to a low quality of both long-term precipitation and hydrological ECVs.

The way Urban SIS has introduced climate projections, using only one specific realization of a global climate model with subsequent regional downscaling, implies limitations in how end users can rely on the long-term temporal trends in the climate variables. The uncertainties given by the use of a single-scenario approach are especially critical for precipitation, for which different climate models show a larger variability, and may invalidate any conclusion of future trends. For precipitation the uncertainty of future conditions adds to the shortcomings in the simulation of the conditions of today, so that we can state that the long-term data of precipitation from Urban SIS are not useful for urban planning. However, the high spatial and temporal resolution of Urban SIS precipitation can support valuable insights on how intense rainfall and urban flooding develop, a fact that has been positively referenced in the project's use case reports. Clearly there is a need to further develop both the urban downscaling of precipitation, as well as to achieve a better representation of the variability of climate projections, as compared to a single-scenario.

For temperature, with its spatial gradients over urbanized areas and for which there is a clear increasing trend towards the future, as well as for air quality, where climate change is only one and not a dominating driver of future air pollution, the Urban SIS information can be useful for both short-term and long-term planning. For air quality there are plans to add scenarios and combinations of European-scale emissions and local emissions that allow the end users to isolate the effect of climate change, emissions outside the city area and local emissions inside on current and future air pollution concentrations.

With this as a background, we encourage end users to explore the Urban SIS portal ECVs and impact indicators, not only following the examples of this user manual, but also experimenting with other variables and indicators.

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