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# Urban SIS: Use case urban air quality Bologna D441.6.4.1

## Status report

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# Introduction

The Po Valley (northern Italy) represents an important non attaining zone for PM, NO2 and O3 with respect to the air quality limit values established in the EU Air Quality Directive. This zone covers the territory of the regions in Northern Italy and includes several urban agglomerates such as Milan, Turin, Venice and Bologna. The area is densely populated and heavily industrialized. About 450.000 tons of NOx, 90.000 tons of PM and 250.000 tons per year of NH3 are emitted in the atmosphere by a wide variety of pollution sources mainly related to traffic, domestic heating, industry and energy production sectors. Another important pollution source is related to the nitrogen and ammonia cycle, coming mainly from fertilizers, breeding and farming activities. Meteorological conditions and the transport and dispersion of pollutants are strongly influenced by the morphological characteristics of the Po Valley and the northern Adriatic Basin. The transport of pollutants is limited by the Alps, the Apennines and the Dynaric Alps. Pollutants are transported across the Adriatic sea, which influences the atmospheric circulation and the photochemical processes representing main drivers of ozone and secondary PM. Due both to the meteorological conditions and the morphologic characteristics of the Po valley, the rural background concentration of pollutants are often high, while a large part of the PM is due to secondary production, as several studies report. As a matter of fact, the Emilia Romagna region has recently approved the Regional Air Quality Plan (PAIR2020) and is the coordinator of PREPAIR Life-Integrated project 2015. PREPAIR will implement the measures foreseen in the regional plans and in the Po Valley agreement at a larger scale so to strengthen the sustainability and durability of results: the geographical coverage of the project is not only the Po Valley with the regions and cities that mainly influence air quality in the basin, but it also be extended to Slovenia in order to assess and reduce pollutants transportation across the Adriatic sea.

An improved knowledge of present and future climate and emission scenarios represent a crucial issue for Europe, due to significant impacts on health status quality registered during the recent decades. Each of the last three decades have been successively warmer at global scale than any previous decade since 1850, and an increase in extreme events of temperature (hot days, tropical nights, heat waves) have been registered since 1950 (IPCC, 2013). The signal of temperature increase is evident at different spatial scale: global, regional and local, even if the magnitude is different. As concerns precipitation, an increase of intense precipitation and dry events have been registered. The distribution and amount of precipitation is projected to be affected differently all over Europe by global heating. Local and general patterns like thermal inversion and turbulence can cause diverse conditions for pollution distribution and air quality levels.

The present deliverable is focused on urban area of Bologna, Emilia-Romagna region. Emilia Romagna experienced very high temperatures after 2000, for example on 2003, 2006, 2012, 2013, 2015 when daily maximum temperature exceeded 34°C peaking at 39-40°C and minimum temperature exceeded 20°-25°C (for example Bologna in July 2013). These high temperatures contribute to high ozone concentration in summer time.

# 1. Purpose of the study

Knowledge of present and future emission scenarios as well as meteorological data at local level are requested to describe the air quality in terms of pollutant concentrations. An evaluation of future air quality, taking into account not only emission scenarios due to Air Quality Plan but also to climate change is often requested by end-users, by the municipality and other Local Governments. To this aim and in the framework of the present deliverable, Urban SIS produced simulations with a resolution of $1x1km^2$, covering a domain that includes Bologna and other cities in Emilia Romagna, will be explored. Different years have been selected for the historical period used to validate the model, namely: 2006, 2007, 2012, 2013 and 2014. The Urban SIS output of interest for this use case concerns both air pollution concentrations (ECVs) as well as postprocessed concentrations forming impact indicators for the health sector.

## 1.1 High pollution episodes

The historical years to be simulated and produced in Urban SIS have been selected in order to include winters with very high pollution episodes that occurred in the Emilia Romagna region. An example of such episode took place February 2012 in the Po Valley region, with daily PM10 average concentrations exceeding 150 $\mu g/m^3$ (Fig. 1). It's the second highest concentration among the last 12 years maximum values. The pollution episode also affected the other regions of northern Italy. The analysis of the meteorological situation revealed the stagnation of a cold air mass due to persistent thermal inversion even during daytime hours (Fig 2). On Monday 20th, the transit of a depression system to central-northern Italy led to moderate precipitation, disappearance of inversion and consequent replacement of air mass.

Figure 1- Emilia Romagna average and daily maximun urban background PM10 and PM25 concentrations

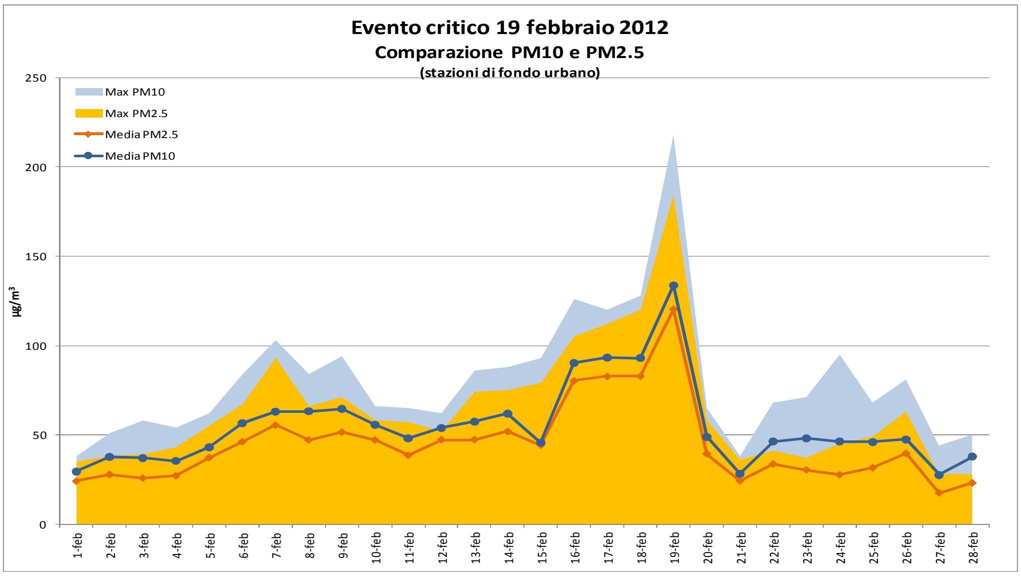
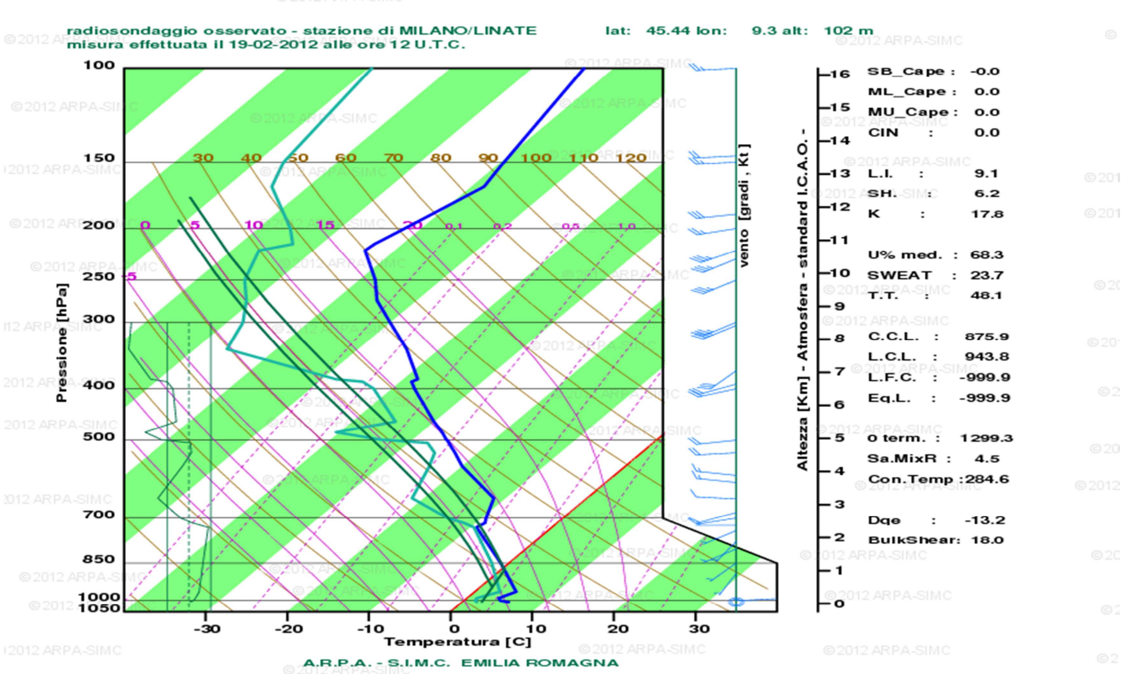


Figure 2 Thermal inversion naer surface from radiosounding at Milano Linate at 12UTC 19th February with very low wind




Strong inversions are common during winter time meteorological conditions and contribute to extremely unfavourable atmospheric dispersion. They develop close to the ground, wind speeds are low under the inversion which forces pollutants to accumulate close to the ground, also allowing the formation of large quantities of secondary aerosols.

In Emilia Romagna as well as in Po Valley the limit value for daily PM10 is exceeded almost every year at roadside stations; in worst years it is exceeded also at background stations. During extreme years also the limit of annual average (40 µg/m$^3$) is exceeded roadside stations. The limit value for PM2.5 is usually not exceeded.

Figure 3 - PM10, number of days in a year with daily average > 50 µg/m$^3$ in Bologna (legislation limit is 35 exceedances per year)

**$PM_{10}$ – numero giorni di superamento del valore limite giornaliero (50 µg/m$^3$) 2005 – 2015**

| *Stazione* | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PORTA SAN FELICE | 100 | 109 | 104 | 68 | 50 | 63 | 69 | 73 | 57 | 23 | 38 |
| SAN LAZZARO | - | - | - | - | - | 35 | 50 | 43 | 25 | 20 | 35 |
| GIARDINI MARGHERITA | - | - | - | 19 | 20 | 29 | 42 | 33 | 10 | 14 | 23 |
| VIA CHIARINI | - | - | - | - | - | - | 40 | 40 | 18 | 19 | 25 |
| DE AMICIS | 52 | 69 | 49 | 38 | 32 | 43 | 44 | 38 | 19 | 15 | 19 |
| SAN PIETRO CAPOFIUME | - | - | - | - | 16 | 29 | 43 | 40 | 19 | 21 | 26 |
| CASTELLUCCIO | - | - | - | - | - | - | - | 1 | 1 | 0 | 0 |

In summer time the frequent condition of high temperature, stagnating high pressure systems, making episodes of high tropospheric ozone. The ozone concentrations show great variability over the years due to weather variability as showed in Fig. 4.

Figure 4 - O3, number of days in a year with 8h average > 120 µg/m3 in Bologna (legislation limit is 25 exceedances per year)

| $O_3$ obiettivo a lungo termine – numero giorni di superamento max media 8 h (120 µg/m$^3$) 2005 – 2015 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Stazione* | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| GIARDINI MARGHERITA | 25 | 17 | 39 | 47 | 42 | 15 | 66 | 58 | 75 | 44 | 45 |
| VIA CHIARINI | - | - | - | - | - | - | 73 | 70 | 52 | 25 | 55 |
| SAN PIETRO CAPOFIUME | 63 | 69 | 68 | 57 | 70 | 58 | 83 | 58 | 40 | 16 | 39 |
| CASTELLUCCIO | - | - | - | - | - | - | 0 | 12 | 5 | 2 | 14 |

## 2. Status of the use case

For the Emilia-Romagna area, including the city of Bologna, there are routinely operated model simulations for air quality running on a daily basis. The model NINFA (Northern Italy Network to Forecast Aerosol pollution) is based on the Chimere chemical transport model driven by the meteorological model COSMO-I7. The model provides concentration maps of PM10, PM2.5, ozone and NO2, for the previous day (hindcast) and the following 72 hours (forecast). There is also an air quality assessment system in Emilia-Romagna named PESCO (Postprocessing and Evaluation with Statistic Techniques of the Chimere Output) which allows the reconstruction of the Regional map of ozone ground concentration, PM10, PM2.5 and nitrogen dioxide by performing a statistical post-processing of the NINFA output together with observed concentrations from the monitoring network. PESCO corrects both the analysis and the NINFA forecasts.

The availability of NINFA and PESCO daily air quality maps for Bologna puts the city in a more privileged situation as compared to most other European cities. The Urban SIS historical air quality maps of air pollutant concentrations will thus not represent something new for the authorities in the area. The Bologna use case will take advantage of the NINFA and PESCO output to assess the quality of the Urban SIS PM10, PM2.5, NO2 and O3 outputs, also in terms of exceedances of the EU limit values. What is new information in Urban SIS is the output of gridded meteorological variables, consistent with the air quality ECVs. The use case will take advantage of this by using the meteorological ECVs to calculate ventilation or stagnation indices, for present and future conditions, e.g. to see if future meteorology is supposed to contribute to changes in air pollution levels (with source emissions being as today). The Urban SIS meteorological and urban scale air quality concentrations can also be used as input and background concentrations for urban scale dispersion models (i.e. ADMS urban, etc.). What will also be explored in Urban SIS are the health impact indicators for air quality.

## 3. What have been accomplished so far?

Simulations available in the Urban SIS portal have been downloaded at hourly and monthly time scales. The monthly means for NO2 (Fig. 5) and PM10 (Fig. 6) show different spatial distribution and also seasonal variation.

Figure 5 Monthly average values of NO2 for January 2013. The time series graph show the monthly averages in the center of Bologna during 2013.
The color scales goes between 0 (blue) and 56 µg/m³ (red).

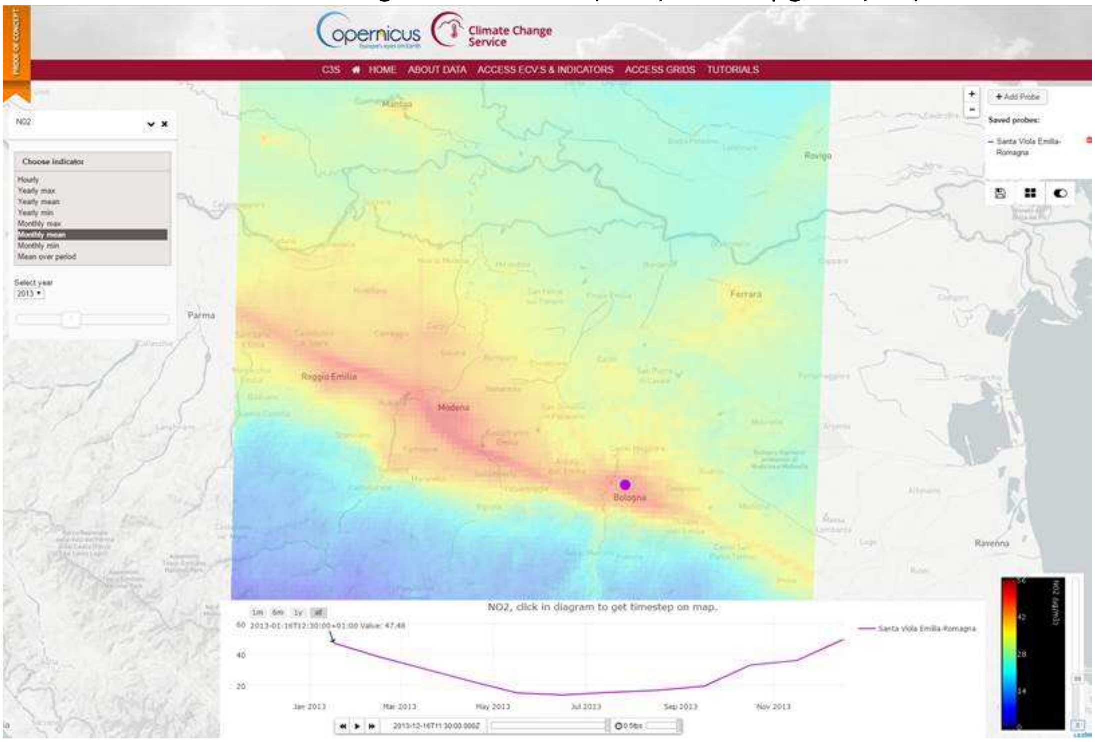
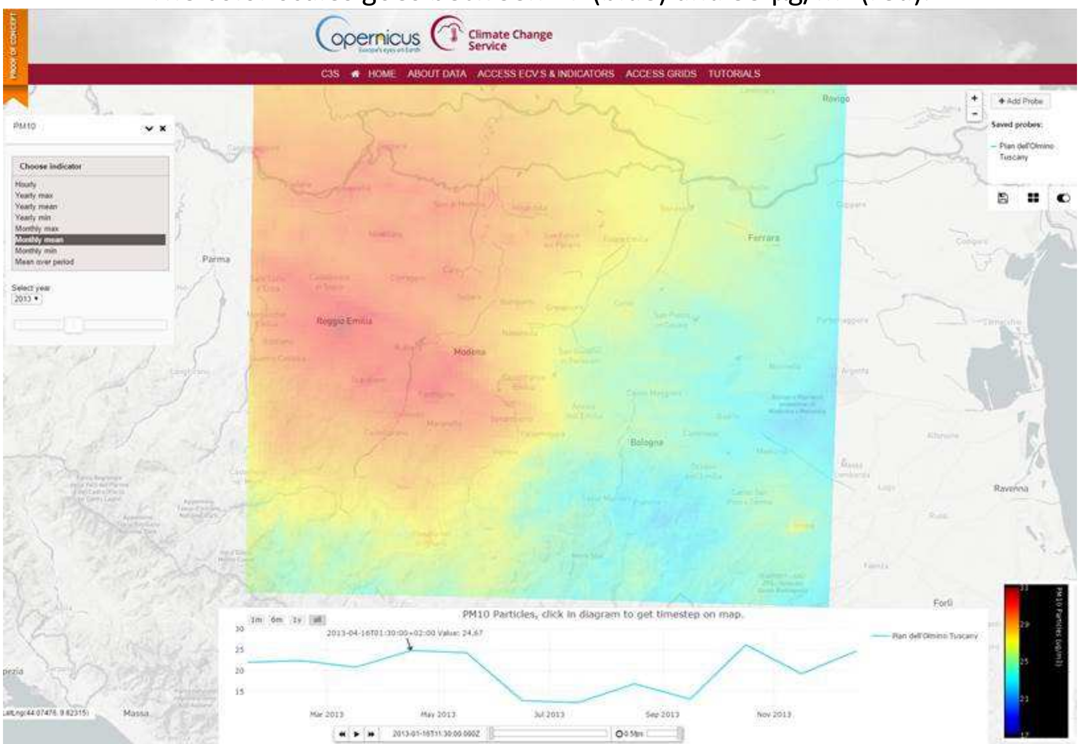
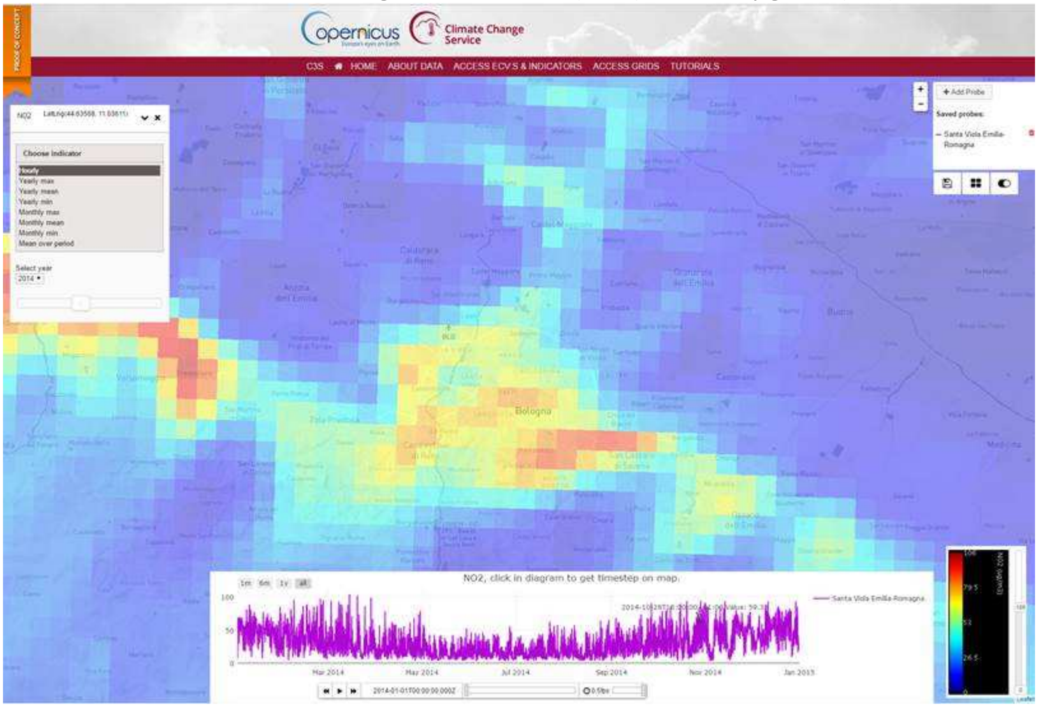



Figure 6 Monthly average values of PM10 for April 2013. The time series graph show the monthly averages in the center of Bologna during 2013.
The color scales goes between 17 (blue) and 33 µg/m³ (red).



An example of hourly averaged NO2 concentrations over the Bologna city is given in Fig. 7, together with a time series graph of the urban background NO2 levels from the city centre, covering the entire year 2013.

Figure 6 Hourly data of NO2 concentration displayed for 28th October 2013, at 19:00 hours. The time series graph show NO2 hourly concentration for the whole year 2013. The color scales goes between 0 (blue) and 105 µg/m3 (red).




Downloading of meteorological ECVs has also started, to be used to calculate ventilation/stagnation indices. Of particular interest for air quality concentrations are the following ECVs:

- air temperature at ground level (T2M) and wind speed at 10 m
- air temperature and wind speed at model level 1, 2, 3 (allowing certain vertical information)
- boundary layer height
- Relative humidity
- Precipitation
- Snowfall
- Global radiation

At project start, local and regional health authorities were involved as stakeholders and end users in the identification of useful health impact indicators, as well as to assure an engagement process to follow project development and the final results. Their feedbacks on what Urban SIS will provide in terms of health impact indicators have, so far, been highly positive. Of the impact indicators, some come from pure statistical postprocessing to allow a direct comparison with EU limit values and WHO guideline levels. There will also be various types of impact indicators where population data are included:

- Number of persons in each 1x1 $km^2$ cell exposed to urban background concentrations above an EU limit value or WHO guideline value
- Number of premature death due to long-term exposure of NO2 and PM2.5 (individually and in combination)
- Number of preterm births due to short-term exposure to ozone

Up to the submission of this report, the health impact indicators have not been available in the Urban SIS portal.

# 4. What is envisioned for the near future

Future work will be done on assessing the quality and testing the usefulness of the air quality ECVs and indicators that will be available for visualisation and download in the Urban SIS portal. This will take place both for the historical data, as well as for the climate projections driven by a RCP8.5 scenario that will be available for the Emilia Romagna domain during the second half of 2017.

ECVs data can be used and will be tested as input and background concentrations for urban scale dispersion models (eg. ADMS urban, gaussian model, etc.).

Qualitative estimates of how climate change will affect air quality will be carried out using synthetic meteorological indicators, for example “stagnation indices” derived from meteorological ECVs; Tmax as proxy for ozone.

The local and regional health authorities involved in the definition of health impact indicators (e.g. as participants in the WP4 workshop realised in February 2016) will be presented the Urban SIS final indicators of health impacts from air pollution and their comments will be documented.

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