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News

The Urban Climate Services URCLIM project

Cities and climate

While already just over 50% of the world population lives in cities, it is expected that on balance practically all population growth up to 2050 is in cities, amounting to 3 billion extra urban inhabitants amounting to a total urban population of 6.5 billion people (Revi et al., 2014). Cities are particularly vulnerable to climate change because of their high concentration of population, goods, capital stock, and infrastructures. Heat waves in particular, enhanced locally by the so-called *Urban Heat Island* (UHI) lead to an above-normal mortality rate in cities (Wong et al., 2013; Shaposhnikov et al., 2014). Intense precipitation in urban areas, on the other hand, cause more easily floods with dire consequences because of the impermeability of the urban surfaces (Muis et al., 2015; Yin et al., 2016). Air quality conditions in cities are recurrently and often even continuously exceeding health limits. Furthermore, cities are strong emitters of greenhouse-gases, as the high concentration of human activities, like transport and industry, entails high levels of energy consumption.

Therefore, city actors, especially planners, are facing numerous and sizeable climate change related challenges, while having to manage and plan their city development in a sustainable and climate proof way. In such a complex multi-dimensional and multi-objective decision environment pertinent, clear and decision-relevant information is indispensable for urban planners and related stakeholders. However, climate information is mostly provided by climate models at spatial scales much larger than the (sub)urban scales at which mitigation and adaptation measures are to be realized. Recognizing the increasing climate and environmental challenges faced by cities but also the maturity of urban modelling, Integrated Urban Services (IUS) (Grimmond et al., 2020) have been identified by the World Meteorological Organization (WMO) as an applied field of research, aiming "*to assist decision makers and end-users on capabilities and services*" and that "*it is important not to wait for a disaster to act*" (WMO, 2018). Analysis of action in several cities showed that "*engagement of multidisciplinary teams is more common in the provision of climate services with clear benefits*" (WMO, 2019).

Access to data, comparable in space and in time, at global and local level, is a key requirement for our globalized society in order to define common objectives at all scales - local, national, continental, global - and to elaborate policies and perform objective monitoring. To date, spatio-temporal data availability has strongly increased due to the widespread use of sensors and due to a strong push for open-data policies. However, this brings along challenges, for instance for designing workflows to efficiently harvest the existing data and to reach common data standards.

Goal of URCLIM

The goal of the URCLIM project (www.urclim.eu) is to prove a concept: the realization of Integrated Urban Climate Services (IUCS) for urban planners and related stakeholders using local urban and climate data from multiple open-data sources. A general methodology to produce UCS and to evaluate the associated uncertainties is being developed within the URCLIM project.

In order to achieve the project goal, the project has 4 scientific objectives:

1) to develop a methodology for the creation of high-resolution maps of urban parameters for climate studies,
2) to analyze the propagation of uncertainty from regional climate models to urban-scale climate models and local impact models,
3) to evaluate multi-criteria impacts and various types of adaptation strategies,
4) to define pertinent Urban Climate Services in cooperation with stakeholders, and using a visualization interface.

Consortium and methodology

The European interdisciplinary research consortium is composed of research centers of five national meteorological services (Météo-France, France; Royal Meteorological Institute of Belgium, Belgium; Finnish

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Meteorological Institute, Finland; Météo-Ro, Romania; KNMI, The Netherlands), laboratories in meteorology and in spatial data sciences (CNRS, France), and the French national mapping agency (IGN).

Apart from specialists in regional climate and urban climate and air quality, the URCLIM consortium also encompasses specialists of geomatics and urban mapping, socio-economics and researchers having long experiences of collaborative works on urban planning and health impact studies.

Fig. 1 presents the overall methodology of the project, and how the 4 objectives are reached. One of the scientific challenges is to be able, in the end, to design IUCS that are both scientifically robust (and with uncertainties evaluations) and that are relevant for stakeholders, both in terms of scope and spatio-temporal scale. This implies, for instance, to be able to produce impacts and evaluate strategies at neighborhood and eventually street scales. In order to achieve this goal, the first half of the project has focused on developing generic methodologies to obtain high-resolution urban maps (at urban block scale) suitable for urban atmospheric models, and, to downscale from regional climate models towards such fine scales. The current second half of the project focuses on strategies of adaptation and development and smart visualization for IUCS.

Several case study cities have also been chosen, each located in a different climate zone over Europe, influenced by different geographical features, and with a different urban history and structure (Fig. 2). This allows to evaluate several kinds of IUCS, some that are common to all cities, such as the support of Urban Heat Islands mitigation and heat-wave risk reduction and the support of adaptation measures for pluvial flooding. Other impacts are more specific, such as road and sidewalk icing in Helsinki.

Importantly, the objective is to establish the basis of *generic* IUCS methodologies in the sense that these methodologies can be applied on

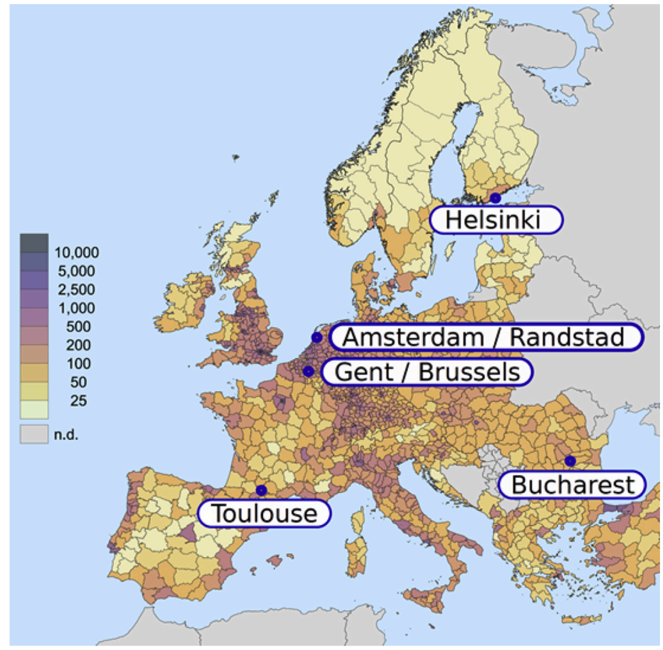

Fig. 2. Population density in Europe (inhabitants per square kilometer) and the URCLIM case study cities: Toulouse, Paris, Ghent, Brussels, The Randstad (The Hague, Amsterdam, Rotterdam, Utrecht), Helsinki, Bucharest. Figure adopted and adjusted from https://commons.wikimedia.org/wiki/File:Population_density_by_NUTS_3_region_(2017).svg.

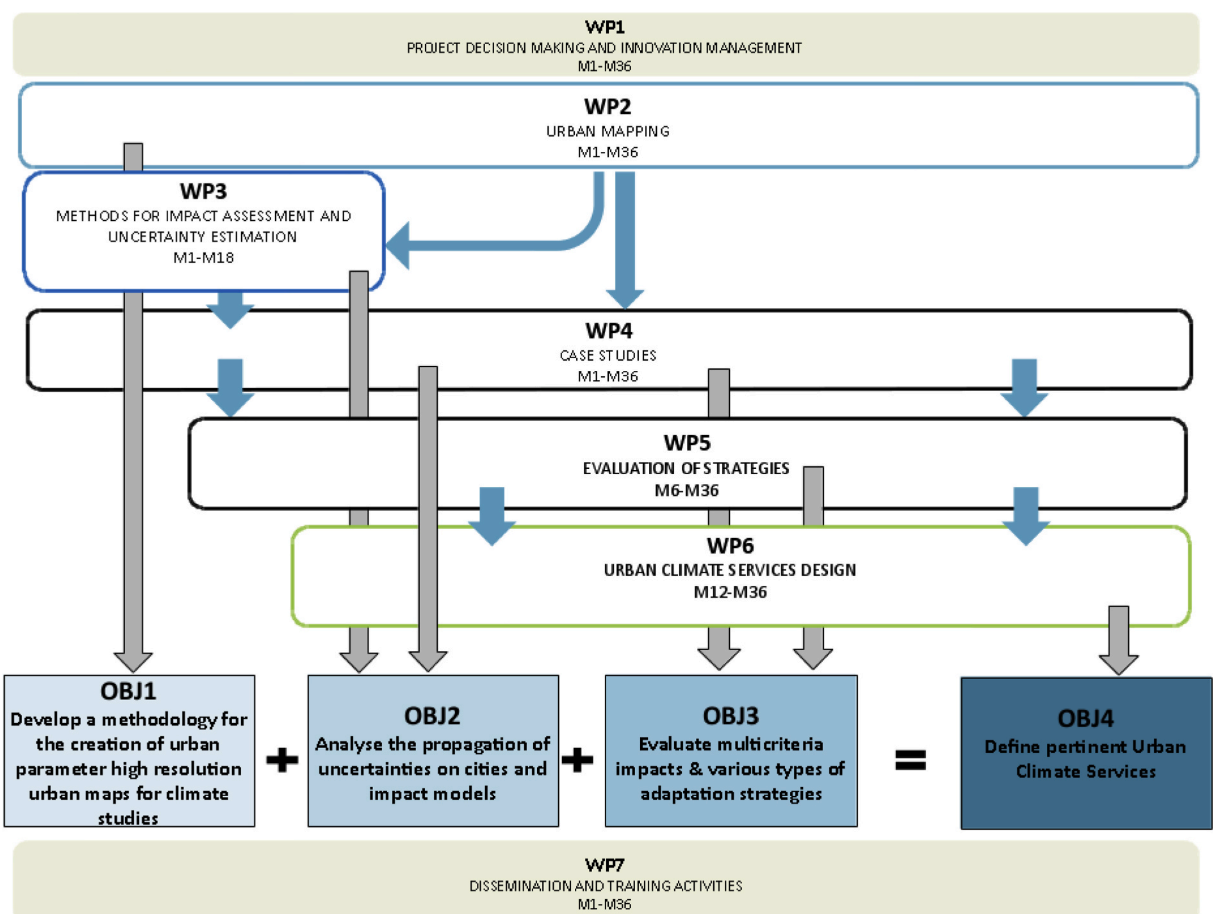

Fig. 1. Project workflow.

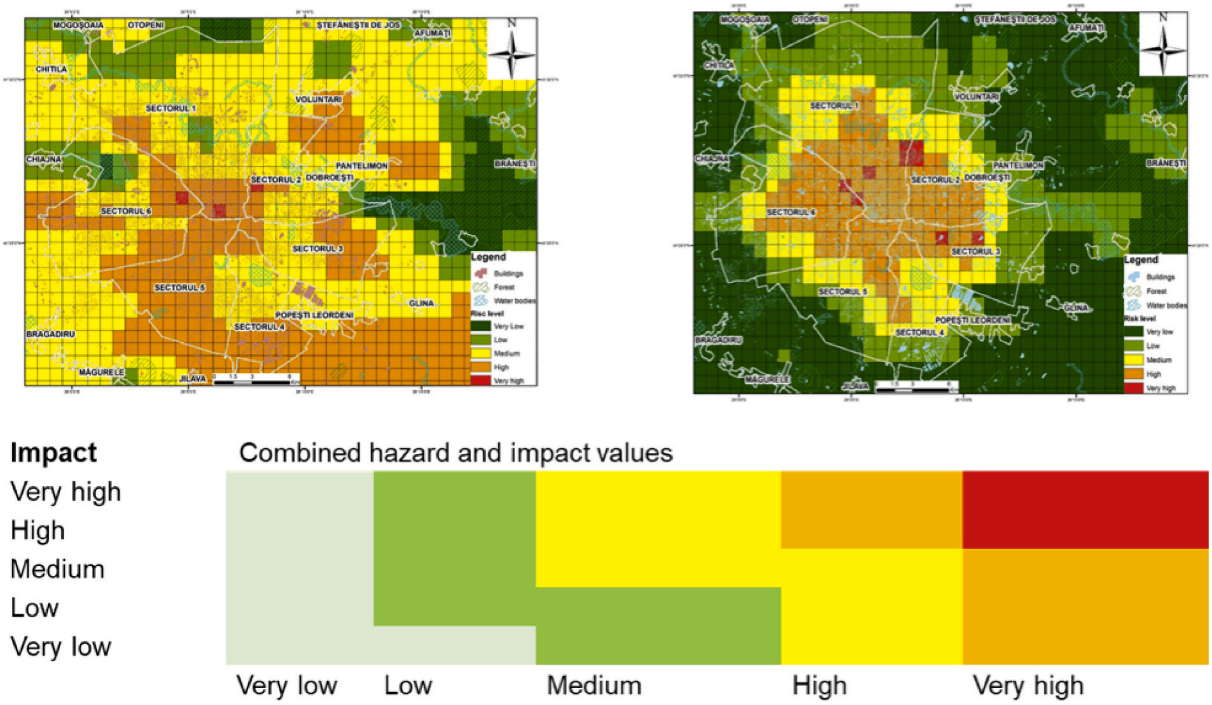

Fig. 3. Heat wave risk map during day (left) and night (right) for Bucharest, and risk matrix (below). These are obtained by combining data from para-medical interventions and surface temperatures from satellite observations.

any city. This is achieved by building tools based on open urban data, by the use of identical atmospheric and urban climate models among the partners and by the documentation of metadata to allow people outside the consortium to reuse the developments to design their own services.

Early results

In order to share knowledge among participants and outside, an URCLIM collaborative web platform has been set up (http://geometadatalabs.eu/Infolab_URCLIM). A QGIS plugin allows to upload information. It can interrogate Copernicus catalogues. The quality of the Open Street Map (OSM) database has also been analyzed, as well as the means how to enrich it. The most relevant geospatial variables used by the Town Energy Balance Model (Masson 2000; Lemonsu et al., 2012; Schoetter et al., 2017) have been identified, and methodologies to compute the climate indicators and extract and transform OSM data (Mooney and Minghini, 2017) to a set of GIS layers, have been developed. The GIS layers are then processed to compute urban indicators that will feed the TEB model. The code source of the algorithms is distributed in GPL and available on a public repository: https://github.com/orbisgis/geoclimate/issues

Another important part of the project focused on developing generic methods for impact assessment and uncertainty estimation in an urban context. For instance, in order to investigate the Urban Heat Island in a future climate techniques were designed for computationally-cheap statistical-dynamical downscaling of EURO-CORDEX regional climate simulations to the urban scale. Different sources of uncertainties were quantified, such as those related to model and observation errors, downscaling techniques, urban surface description, and health impacts. For future projections the uncertainty propagation from the global scale climate models (GCM) over the regional scale (RCM) up to the city scale models was addressed, as well as the greenhouse-gas-scenario uncertainty. For air quality assessment, the uncertainties investigated include the ones associated with air quality models, climate models, emission changes and downscaling to urban scales. Methodologies to study impact on road icing changes and for real Estate (including an urban extension model) were finalized and methodologies for evaluating simulated sub-daily precipitation extremes were developed. Thanks to local expertise of researchers of the consortium, IUCS on health impact studies or cross-related impacts of urban and climate change were also developed for some of the cities (see Fig. 3).

Societal impacts and the collaborations with the stakeholders

All URCLIM partners have involved local city and territories stakeholders and these include mostly environmental and climate plan services, but also others are engaged for risks issues (e.g. on floods or health). IGN, the French national mapping agency, also implies its sister organizations in Europe as well as pan European organization like Eurogeographics, to disseminate URCLIM work on the issues linked to urban mapping and data for IUCS. Stakeholders so far have participated to special sessions during the general assemblies of the project. Hence the URCLIM project provides major advances on Climate Services for stakeholders, especially urban planners and city administrations. The services are aimed to provide pertinent climate information on a multitude of impacts and risks.

The generic approach followed by the consortium enables further deployment for cities (at least in Europe but possibly anywhere in the world), because

- the high-resolution urban maps for these IUCS are based on open data[1]
- the World Climate Research Program EURO-CORDEX is used as input climate data
- the methodologies are open-access, carefully documented, and the technical developments are open-source
- a smart visualization tool is associated to the Urban Climate Services
- the Urban Climate Services are developed in common with stakeholders supported by case studies.

[1] including data not yet open but due to become so as targeted by European legislation on open data and the re-use of public sector information, i.e. high resolution geographical, meteorological and statistical data.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Valéry Masson[a,*], Erwan Bocher[b], Bénédicte Bucher[c], Zenaida Chitu[d], Sidonie Christophe[c], Carl Fortelius[e], Rafiq Hamdi[f], Aude Lemonsu[a], Adriaan Perrels[e], Bert Van Schaeybroeck[f], Ben Wichers Schreur[g], Liliana Velea[d], Yasmina Beddar[a], Jean-Christophe Calvet[a], Andy Delcloo[f], Arsène Druel[a], François Duchêne[f], Guillaume Dumas[a], Alexandru Dumitrescu[d], Jacques Gautier[c], Marine Goret[a], Matti Horttanainen[e], Rostislav Kouznetsov[e], Arnaud Le Bris[c], Shirley Lecorre[a], Benjamin Le Roy[a], Yuliia Palamarchuk[e], Gwendall Petit[b], Reija Ruuhela[e], Olli Saranko[e], Mikhail Sofiev[e], Pilvi Siljamo[e], Hans Van de Vyver[f], Peter van Velthoven[g], Athanasios Votsis[e]

[a] *Centre National de Recherches Météorologiques, Université de Toulouse, Météo-France & CNRS, France*
[b] *LabSTICC, CNRS, France*
[c] *LASTIG, Univ Gustave Eiffel, IGN, ENSG, France*
[d] *Meteo Romania, Romania*
[e] *Finnish Meteorological Institute, Finland*
[f] *Royal Meteorological Institute of Belgium (RMI), Belgium*
[g] *Koninklijk Nederlands Meteorologisch Instituut, Netherlands*

[*] Corresponding author. CNRM, GMME, 42 avenue Coriolis, 31057, Toulouse, France.
E-mail address: valery.masson@meteo.fr (V. Masson).