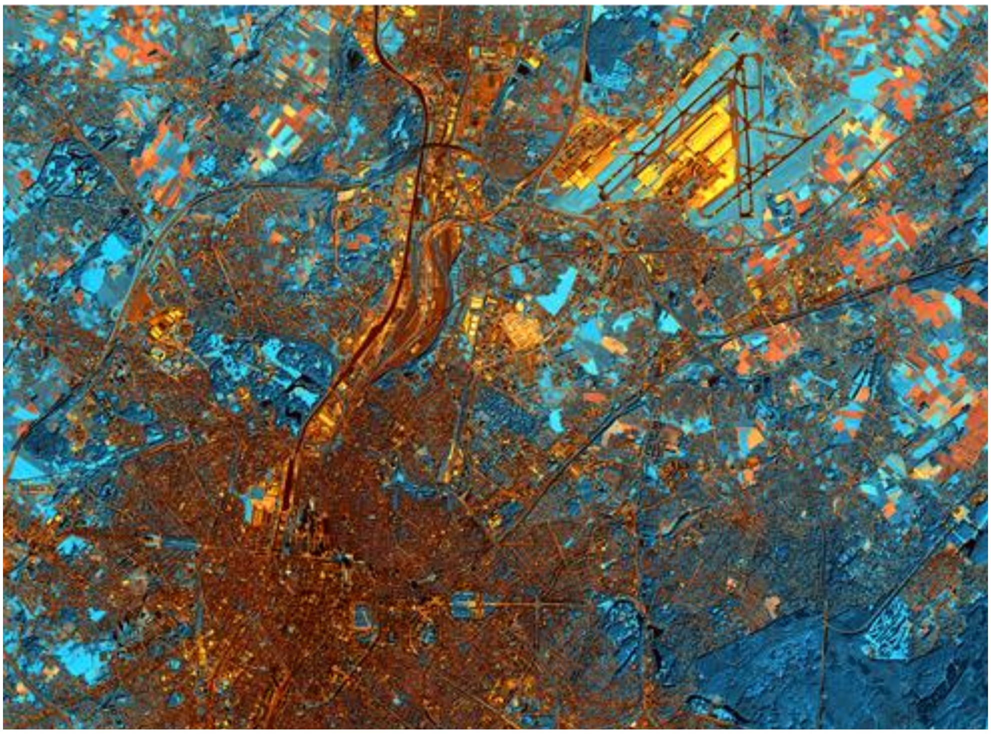

June 2021

COPERNICUS FOR URBAN RESILIENCE IN EUROPE

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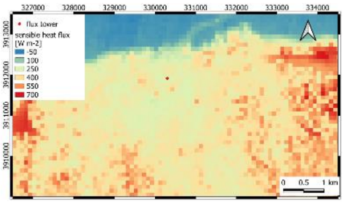

Urban Heat Emissions Monitoring Application

This application provides maps with sensible heat flux distribution in specified urban areas supporting decisions for reducing heat emissions and load.

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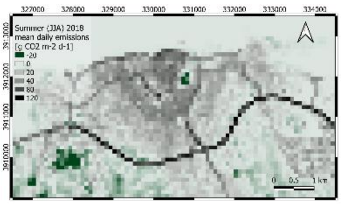

Urban CO_2 Emissions Monitoring Application

This application specifies anthropogenic carbon dioxide (CO_2) emissions in a high spatial resolution supporting strategies for reducing them.

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Urban Subsidence, Movements and Deformation Risk Application

This application informs about the localisation, extent and magnitude of exposure to slow terrain motions, as well as building or infrastructure deformations.

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Editorial

by Nektarios Chrysoulakis

CURE (Copernicus for Urban Resilience in Europe) is one of the three projects that were funded from the H2020-Space call on Copernicus evolution (LC-SPACE-04-EO-2019-2020). It is a joint effort of 10 partners that synergistically exploit Copernicus Core Services to develop an umbrella application for urban resilience (CURE System) based on DIAS (Data and Information Access Services). This system consists of 11 Cross-cutting Applications, evaluated at several European cities, for climate change adaptation/mitigation, energy and economy, as well as healthy cities and social environments.

The CURE project attempts to innovatively deploy information from Copernicus Core Services concerning atmosphere, land, climate change and emergency; in order to address the multidimensionality of urban resilience. In parallel, it exploits spatially disaggregated environmental Earth Observation (EO) data and products, which are not directly available from the Copernicus Core Services, such as data from contemporary satellite missions and in-situ observations. All the above are combined with third-party data and modelling towards coping with the required local scale.

The main project's milestones for the first half of 2021 concerned the Review Meeting and the CURE System design. More specifically, the 1st Review and the 2nd Progress Meetings were held at the beginning of 2021. The first was related to the report of first-year activities and results of the project, while the second aimed at coordinating research and innovation activities of the project partners for the third semester of the project. Furthermore, the design of the cloud-based CURE Prototype System was finalised, considering user and Cross-cutting Applications requirements as well as the exploitation of DIAS. Finally, the methodology for demonstrating CURE System and Applications to users was delineated. Users' evaluation is expected during two Demonstration Workshops.

The 3rd issue of the CURE Newsletter introduces three more CURE Cross-cutting Applications: a) Urban Heat Emissions Monitoring Application (AP03), b) Urban CO_2 Emissions Monitoring Application (AP04) and c) Urban Subsidence, Movements and Deformation Risk Application (AP06). Also, the main CURE project activities during this period are described in this issue.

Urban Heat Emissions Monitoring Application

by Christian Feigenwinter

Cities and heat emissions

Urban heat emission in the CURE AP03 refers to turbulent sensible heat flux, i.e. the heat exchange between urban surface and atmosphere. Sensible heat flux defines the amount of energy that is available for heating urban atmosphere, and it is thus closely related to air temperature. This amount of energy is strongly modified by surface properties (land cover/use, 3D geometry) and the input of heat by human activities (traffic, buildings, industry). Identifying the spatial distribution of heat emissions (in terms of sensible heat flux) will help urban planners to optimise their climate change adaptation strategies, considering also heat stress, urban green space and building development.

Quantifying urban heat emissions

This application is based on the aerodynamic resistance method (ARM) for estimating sensible heat flux (Q_H) at local scale. The ARM was successfully applied in the URBANFLUXES (URBan ANthropogenic heat FLUX from Earth observation Satellites) project for calculating citywide sensible and latent heat flux in a spatial resolution of 100 m x 100 m. In the CURE project, the ARM implementation is further developed and adapted to suit the requirements of CURE end-users, i.e. urban planners and city stakeholders. The model results are evaluated with in-situ turbulent sensible heat fluxes, measured with the Eddy Covariance (EC) method, deploying urban flux towers.

As a first step, the CURE AP03 relies mainly on local data for the first implementation of the application. As a second step, the local input data are replaced with Copernicus data, where possible.

In particular, the ARM calculates sensible heat flux in analogy to the Ohm's Law from the difference between land surface temperature (LST) and air temperature, which is then scaled with a resistance. The surface temperature is taken from CURE Local Scale Surface Temperature Dynamics Application (AP01), air temperature is measured by in-situ meteorological stations networks and (aerodynamic) resistance is calculated from wind speed and roughness parameters. The spatial distribution of roughness parameters (for calculating aerodynamic resistances) derived from urban morphology, using the Urban Multi-scale Environmental Predictor (UMEP) as implemented in the QGIS® software.

INPUT:

High resolution digital object model (DOM) for buildings and trees, deployed in the Urban Multi-scale Evironmental Predictor (UMEP) QGIS® software plugin.

OUTPUT:

Aerodynamic parameterisation for real urban surfaces:

roughness length (z_{0m}) - zero plane displacement height (z_d)

Calculating aerodynamic resistance (r_H)

The pre-processing chain for the calculating aerodynamic resistances (Coordinates: UTM 35N).

Specifying the content and source of key components

Digital Object Model (DOM)
A high resolution (1 m x 1 m) model of buildings and trees is the essential base for calculating roughness parameters and aerodynamic resistances. This information will be replaced by the Copernicus Land Monitoring Service (CLMS) building heights and street tree layer, if available.

Land Surface Temperature (LST)
The LST layer of this application relies on LST data developed and processed in the CURE Local Scale Surface Temperature Dynamics Application (AP01).

Meteorological data
Meteorological data consist of air temperature, humidity, wind velocity, wind direction, and radiation from in-situ measurements. These data will be replaced by the Copernicus Climate Change Service (C3S) atmospheric reanalysis of the global climate (ERA5) data, if applicable.

Turbulent fluxes for evaluation
Turbulent fluxes derive from in-situ measurements of urban flux towers, equipped with Eddy Covariance systems.

Interpreting urban heat emissions

The interpretation of CURE AP03 maps as presented in the right box requires basic knowledge of the urban energy balance (i.e. the partitioning of the available energy into sensible and latent heat flux and the storage term) and should also include the results of other CURE heat applications, such as the [CURE Surface Urban Heat Island Assessment Application (AP02)], the CURE Urban Thermal Comfort Application (AP08), and the CURE Urban Heat Storage Monitoring Application (AP09). The combination of all these applications provides a comprehensive overview of a city's heat load. Nevertheless, CURE AP03 already shows that higher urban air temperatures (as a result of urban-rural differences in sensible heat flux and larger heat release from the storage term) are mainly a night-time phenomenon. The slightly positive sensible heat flux during night-time in the city centre also indicates neutral to slightly unstable stratification of the urban boundary layer, in contrast to the stable rural nocturnal boundary layer (with negative sensible heat flux). Daytime heat fluxes are higher in the dry and/or open urban surroundings, where evaporation is close to zero and daytime heat storage is significantly smaller than in the high density residential and commercial areas due to the respective thermal properties of the surface materials (dry vegetation, dry soils, large low rise metal industry buildings, etc.).

CURE AP03 will be applied to the front-runner city of Heraklion and the follower city of Basel Maps of sensible heat flux are provided as GeoTiffs in a 100 m x 100 m resolution via the CURE System on DIAS. The time range and time resolution depend on the frequency of the [CURE AP01] LST products. Stakeholders are able to identify hot spots of heat emissions for different times of the day in different seasons. This will support decisions that will be taken to reduce heat emissions and heat load.

INPUT:

Aerodynamic Resistance (r_H)

Specific Heat Capacity (c_p)

Air Temperature (T_{air})

Air Density (ρ)

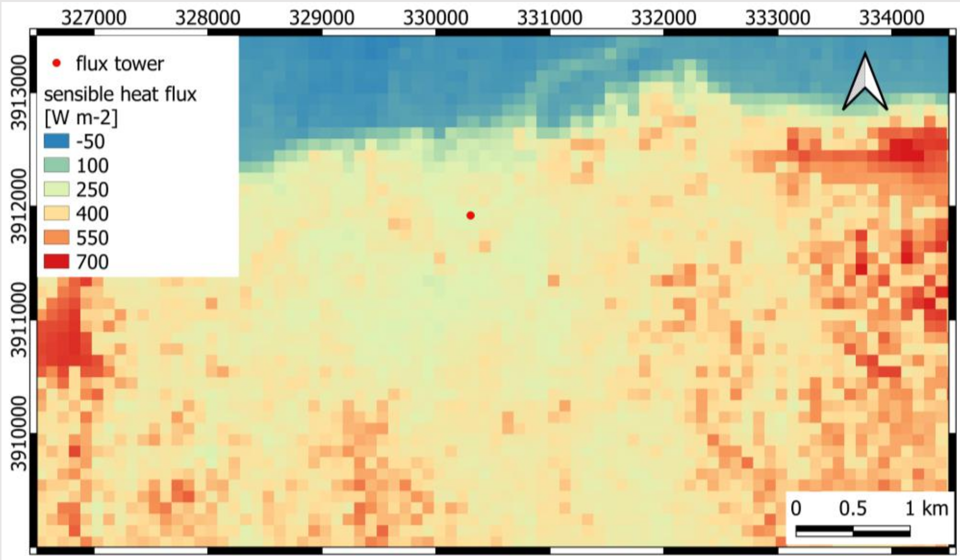
Land Surface Temperature (LST)
- Day-time
- Night-time

OUTPUT:

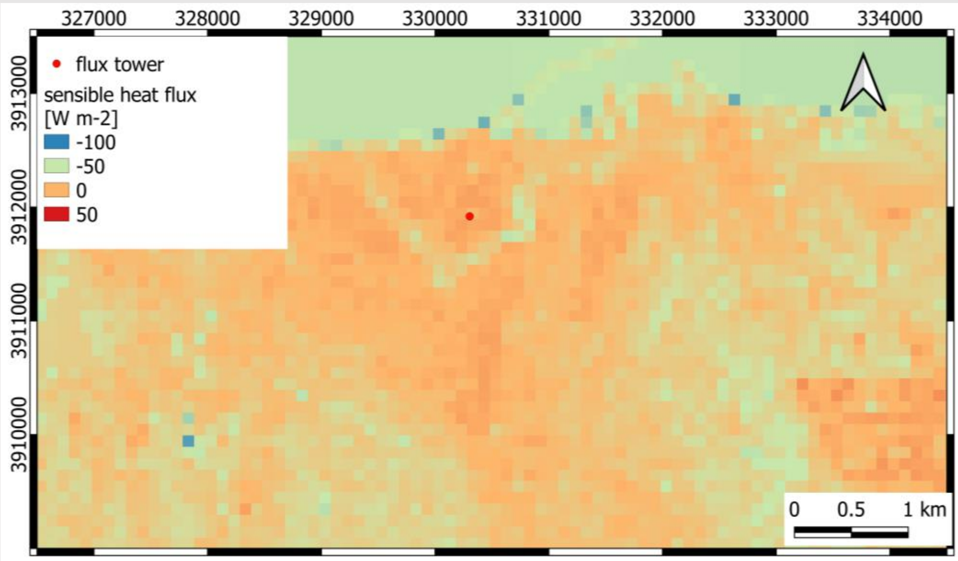
Sensible Heat Flux (Q_H)

$$Q_H = \rho c_p \frac{LST - T_{air}}{r_H}$$

day-time situation



night-time situation



The calculation output of sensible heat flux maps for CURE in a 100 m x 100 m grid for a day-time and a night-time situation of Heraklion city (Coordinates: UTM 35N).

Urban CO_2 Emissions Monitoring Application

by Christian Feigenwinter

Cities and CO_2 emissions

According to the United Nations (UN) Habitat, cities produce more than 60 per cent of greenhouse gas emissions. On the other hand, this spatial concentration of a large carbon footprint in cities also provides opportunities to reduce emissions efficiently by modifying and improving building energy systems (heating/cooling) and transport systems. The total urban CO_2 emissions have a spatial dimension due to the heterogeneity of urban land use / land cover (LULC) and urbanisation. In the CURE AP04, CO_2 emissions are partitioned into an anthropogenic (traffic, heating/cooling) and a biogenic component (urban green space). Spatial planning strategies influence urban form, and consequently affect CO_2 emissions through changes in traffic patterns, energy consumption as well as the location and extent of urban green areas. Knowing the portion of anthropogenic/biogenic components of CO_2 emissions in a high spatial resolution (neighbourhood scale) will provide urban planners with an additional decision support tool for developing emission reduction strategies.

Quantifying urban CO_2 emissions

The CURE AP04 will provide CO_2 emissions maps within city boundaries in neighbourhood scale, combining local scale CO_2 flux measurements deploying the EC method and surface parameterisation, based on LULC classification from very high resolution (VHR) satellite data and Copernicus Land Monitoring Service (CLMS) products through a turbulent flux source area model. The individual processes, contributing to the total CO_2 emissions in the source area of the flux tower, will be statistically modelled and scaled up according to the associated LULC type and environmental controls from the Copernicus Atmosphere Monitoring Service (CAMS), the Copernicus Climate Change Service (C3S) and local (non-Copernicus) data. Key datasets are LULC maps extended with road networks and related traffic data and CO_2 fluxes from urban flux towers. Additionally, high resolution Digital Object Models (DOM) of buildings and trees are the base for calculating sectorial roughness parameters, as well as standard meteorological data from in-situ measurements and/or C3S atmospheric reanalysis of the global climate (ERA5)

Seasonal mean daily total CO_2 emissions in g CO_2 m^{-2} d^{-1} for years 2017-2020 (2020 data are biased due to pandemic lockdown measures).

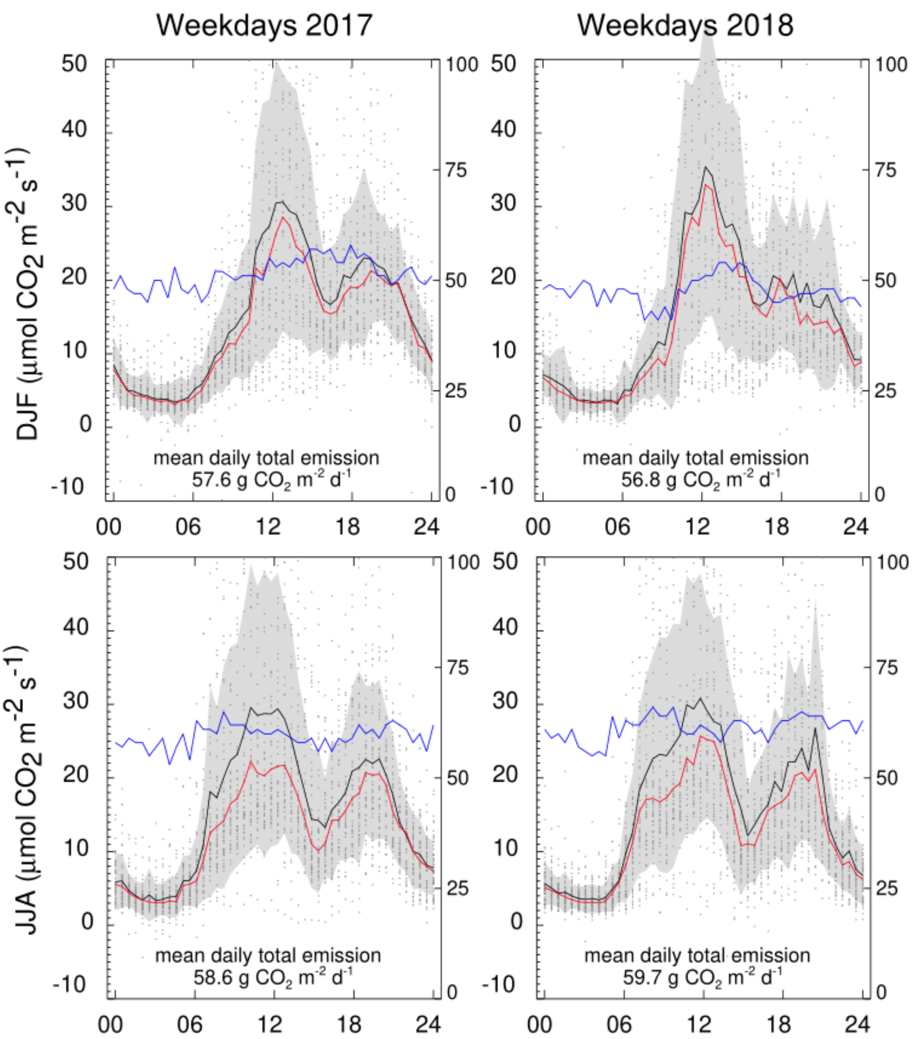
season	2017	2018	2019	2020
winter	52.2	51.2	-	43.8
spring	57.0	54.9	-	25.2
summer	51.9	51.9	46.2	38.5
autumn	49.4	46.7	43.5	41.3

The land use / land cover (LULC) map of the Heraklion city center extended with the road network, traffic data and flux footprint for spring 2018 (black dashed lines: 25%, 50% and 90% contours) at the Heraklion flux tower site (yellow dot) (Coordinates: UTM 35N).

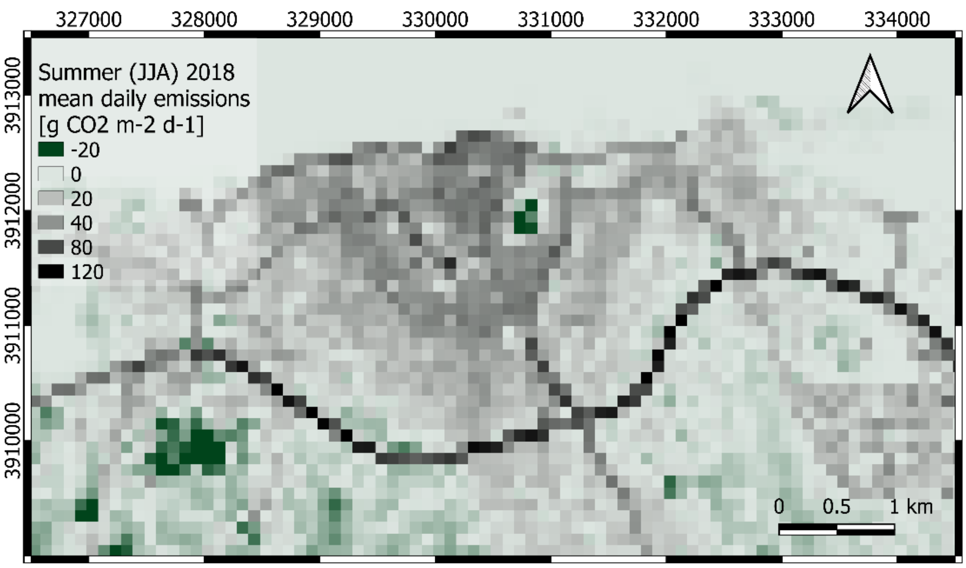
data, as input for the flux footprint model.

CO_2 fluxes measured with the EC method, deploying one of the Heraklion flux towers, are available from November 2016 to date. EC raw data (20 Hz) were processed with the EddyPro® software resulting in quality flagged half hourly CO_2 fluxes. Traffic is one of the main sources of CO_2 emissions in general, and in the front-runner city of Heraklion in particular. All the seasonal mean diurnal courses of CO_2 emissions for weekdays at the Heraklion flux tower site show the typical bi-modal shape related to morning and evening rush hours. However, the mean daily emissions do not vary significantly between seasons, which indicates that winter heating plays a minor role, as no increase of the mean daily total emission is observed. Since the vegetation fraction in the source area is very low, no significant signal from vegetation is observed (i.e. no lower emissions due to photosynthesis during the vegetation period).

The statistical modelling of urban CO_2 emissions (excluding industrial processes and point sources) analyses all the individual source and sink processes in the urban environment, i.e. emissions of fossil fuel combustion from motor vehicles and buildings (source), and the biogenic component from plant/bare soil respiration (source) and photosynthesis (sink). Local scale CO_2 flux measurements with the EC method are combined with geospatial information of urban form parameters; e.g. LULC fractions, buildings source strength (building volume and Heating Degree Days), trees source/sink strength (tree volume), human respiration (population density) through analytic source area modelling. The model results are then scaled up to the urban domain. As a first step, the seasonal mean diurnal fluxes and the corresponding averaged footprints, i.e. the footprint climatology, are analysed regarding the respective sources and sinks. The preliminary results show the importance of traffic (and road network) as a source of CO_2, besides the emissions from buildings and, to a lesser part, human respiration in the high-density residential areas. The areas with a high vegetation fraction act as a CO_2 sink during the vegetation peak period. The interpretation of CO_2 emissions may address needs of urban administration and planners to optimise their climate change mitigation and adaptation strategies towards reducing CO_2 emissions.



The mean diurnal courses of CO_2 emissions for weekdays measured at the HECKOR Heraklion flux tower, including the mean (black line), the median (red line), the standard deviation (gray shaded line), and the number of available half-hourly records (blue line, right y-axis) for weekdays in the respective season, i.e. top: winter (DJF) seasons - bottom: summer (JJA) seasons.



The mean daily CO_2 emissions for the summer season 2018, as part of the preliminary results for monitoring CO_2 emissions of the Heraklion city (Coordinates: UTM 35N).

Urban Subsidence, Movements and Deformation Risk Application

by Katerina Jupova, Jan Kolomaznik, Ivana Hlavacova and Pavel Vlach

The CURE AP06 aims to support cities with enriched information about land subsidence risk and related dangers. It can provide city authorities with both synoptic and detailed knowledge about the localisation, extent and magnitude of exposure to slow terrain motions due to subsidence or slope instability (landslide risk), and building or infrastructure deformations (due to terrain motions or maintenance failures) in urban and sub-urban areas.

The information about terrain movements and subsidence is obtained deploying means of multi-temporal Synthetic Aperture Radar Interferometry (InSAR) techniques. This information will be first gathered through the multi-temporal analysis of Sentinel-1 Synthetic Aperture Radar (SAR) imageries, but later it will come directly from the Copernicus European Ground Motion Service (EGMS). Secondly, it will be combined with information about the distribution, typology and evolution chronology of urban areas (e.g. from Copernicus Urban Atlas and World Settlement Footprint-Evolution layers).

Such analysis enables the identification of potential subsidence risk not only for urban assets, such as buildings, transportation networks (including railway tracks, highway crossings, bridges, etc.) or underground infrastructures (e.g. pipelines), but also for the inhabitants, workers and visitors in cities. This application can also help to identify relevant dangers in time, and thus serve as an effective early warning system for urban areas.

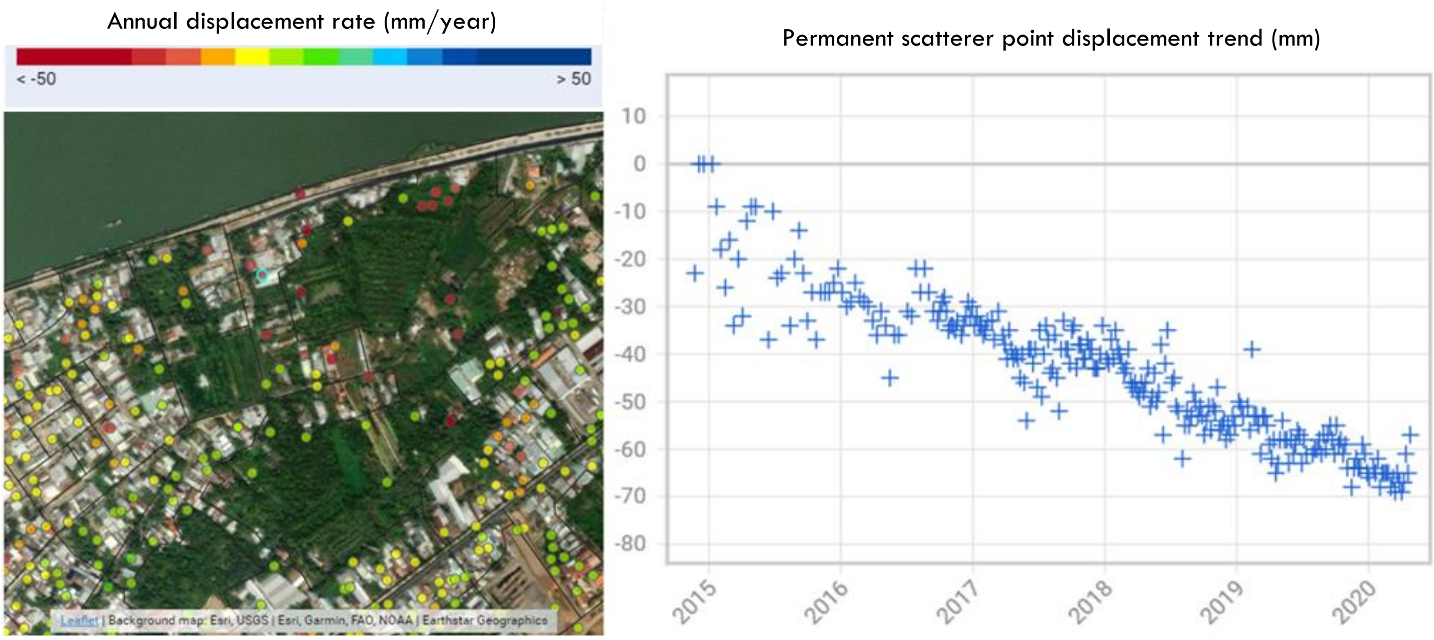
Moreover, the combination of the information about the localisation and velocity of subsidence with information about the chronology of urban blocks´ construction can be very valuable for end-users. It can help to detect potential deviations from standard multi-temporal subsidence profiles, which may reveal subsidence issues of some urban blocks. Also, it will allow to detect potential correlations between the construction age of urban blocks and their inclination to subsidence, which may unveil systematic issues in constructions.

On the other hand, timely information about subsidence in specific areas, intended for future urban development (including brownfields or patches of land without current use), may assist in predicting and thus preventing potential issues related to increased susceptibility of these areas to subsidence.

While designing the CURE AP06, emphasis is also put on integration of its results with results from the CURE Urban Flood Risk Application (AP05). This shall support the identification and assessment of potential links between land subsidence and flood risk. Typically, flood risk may deteriorate due to local terrain subsidence or, vice versa, flood events may lead to land subsidence acceleration.

Gathering information about terrain subsidence

As a first step, the information about subsidence is acquired. For this purpose, the well-proven InSAR method is applied. For over than 20 years, this method has been providing ground deformation data at centimeter



The subsidence measurements for selected permanent scatterer points in the city area classified by the velocity of movements (left) and the temporal profile of subsidence for a selected point (right).

precision. In the past decade, new ways of processing satellite radar images have been developed using Persistent Scatterer Interferometry (PSI) that allows detection and monitoring of ground movements over wide areas with even greater accuracy.

The subsidence processes are identified and monitored in a multi-temporal manner. By applying multi-temporal InSAR techniques to a series of satellite images over the same region, it is possible to detect movements of the structures on the ground in a millimeter/centimeter range. Therefore, abnormal or excessive movement can be identified, indicating potential problems requiring detailed ground investigation.

Free and routinely-available SAR data, collected with Copernicus Sentinel-1, represent a unique opportunity for applying these methods at operational level on a global scale. The dense time-series of Sentinel-1 SAR imageries allow to follow displacements of selected coherent targets - permanent scatterers points through measuring phase differences between time-series of acquisitions, and to estimate the average displacement rate.

For each of the measurement points, a temporal profile is generated, showing the trend and velocity of displacements over the observation period. Thus, the points with ongoing subsidence are detected and categorised based on the velocity of ongoing subsidence to identify the most intensive subsidence processes in the city.

Integration with information about urban land structure and evolution

As a second step, the subsidence information is integrated with the information about urban land structure and evolution in time. This step includes clustering of points with the subsidence information and spatial overlay analysis with the layers representing the development of the city structure. Thus, it leads to meaningful knowledge and understanding of the ongoing subsidence-related processes in the urban and suburban areas.

The subsidence information is converted to meaningful (functional) urban units, using primarily the geometry of the Copernicus Urban Atlas layer and applying zonal statistics, in order to obtain information about potential subsidence for each particular urban block. The Urban Atlas layer can be substituted with local urban planning maps or complemented with any custom layers; e.g. representing different types of functional urban units, for which the subsidence information should be provided. For example, in the Ostrava city-region, the users requested to perform such analysis for brownfields and downgraded areas, as potential development areas. Similar analysis can be done with linear urban features, e.g. street segments or underground infrastructures (e.g. pipelines).

To examine the relation between city development chronology and local subsidence processes, the subsidence information is combined with the Copernicus Urban Atlas change layers and the World Settlement Footprint-Evolution dataset, which shows the development of built-up areas on a yearly basis at 30 m spatial resolution between 1985 and 2015. As a result, the temporal profiles of subsidence processes can be prepared for each newly constructed unit in the city after its construction.

The results of these analyses will be presented to CURE end-users in an attractive and easy-to-understand manner through a web-based analytical portal on DIAS. This application is based on open-source components and programming languages. Hence, it allows the integration of Geographic Information System (GIS) layers, such as Web Feature Services (WFS) and Web Map Services (WMS), which enable to combine results of the CURE AP06 with any relevant local spatial data and information.

The subsidence risk exposure evaluation for all urban blocks (left) and the exposure to land subsidence for a selected urban block (right).

Project activities

1st Review Meeting

The 1st Review Meeting of the CURE project was successfully completed virtually on the 20th of January with the participation of the Project Officer, Reviewer, Advisory Board members and CURE Consortium partners. During this meeting, the progress during the first year of the project and planning of the work packages were presented by the responsible CURE partners, while discussions were carried out after each presentation. After presentations and discussions, the Project Officer and Reviewer provided their feedback.

2nd Progress Meeting

The 2nd Progress Meeting of the CURE project was held virtually on the 21st of January with the participation of the CURE Consortium partners. During this meeting, the outcomes of the 1st Review Meeting and CURE planning were outlined. Specifically, the review outcomes and planning for the next six months, concerning each of the running work packages, were presented by the responsible CURE partners, while discussions were carried out after each presentation. After presentations and discussions, the CURE Management Board convened deciding on the CURE actions regarding the next period.

CURE presentation in international scientific meetings

The CURE project was presented in the following meetings:

- 'Artificial Intelligence for Big Satellite Data – Greece at the Forefront of European Research' Online Workshop (25 February 2021) - Dr. Nektarios Chrysoulakis presented the topic of 'Big Earth Data for Urban Climate and Resilience'.
- virtual European Geophysical Union General Assembly 2021 (vEGU21) (19-30 April 2021) - Dr. Dimitris Poursanidis and Konstantinos Politakos presented studies funded by the CURE project.

All activities of the CURE project are available through the project's web-site: http://cure-copernicus.eu/news.html.

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