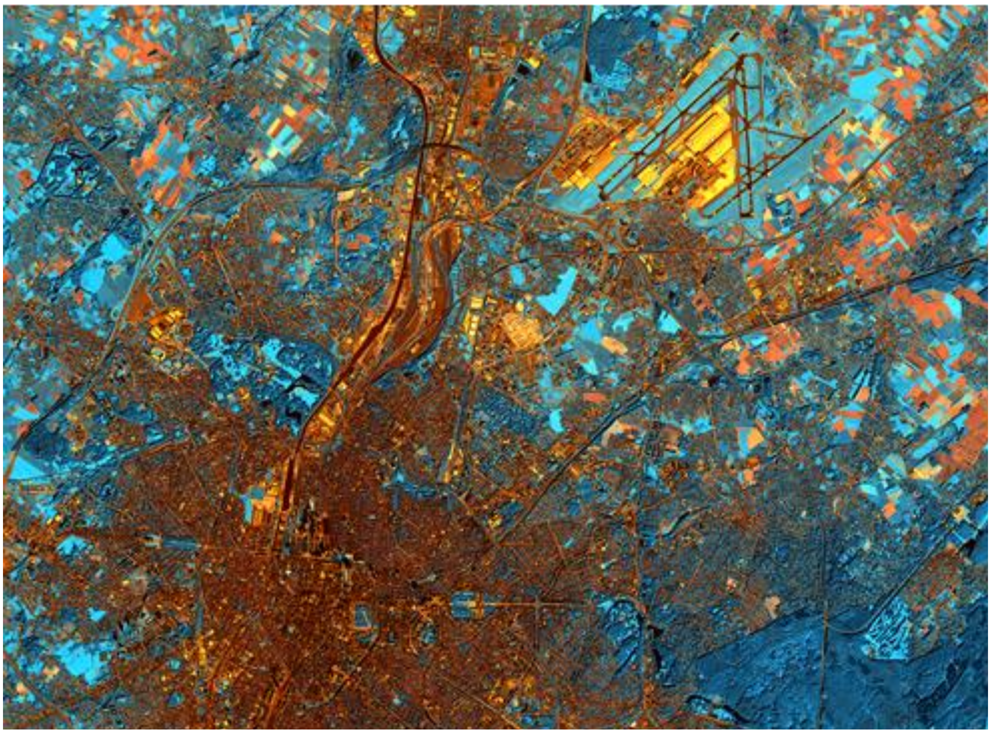


CURE

January 2021

COPERNICUS FOR URBAN RESILIENCE IN EUROPE

Editorial

by Nektarios Chrysoulakis

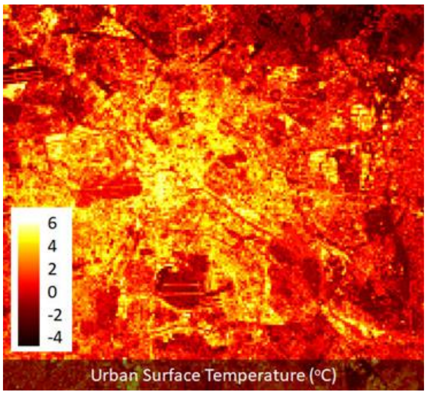
CURE (Copernicus for Urban Resilience in Europe) is one of the three projects that were funded from the H2020-Space call on Copernicus evolution (LC-SPACE-04-EO-2019-2020). It is a joint effort of 10 partners that synergistically exploit Copernicus Core Services to develop a DIAS (Data and Information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

CURE 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, CURE 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.

During the first year of the CURE project, many remarkable R&I activities were completed. Firstly, the Kick-off and the 1st Progress Meetings were conducted, coordinating the research and innovation (R&I) activities of the project partners. Also, a series of meetings and interviews were utilised for specifying users' requirements regarding the CURE prototype and its applications. Another significant milestone was the operation of the relevant web-site, informing about the CURE system, as well as the news, publications and consortium of the project. Last but not least, the Copernicus Core Services Interface (CCSI) was completed.

The 2nd issue of the CURE Newsletter presents the progress and the main achievements of the project during the last semester of 2020. In this issue, users' requirements are included, CCSI and the relevant data portfolio guide are introduced, as well as CURE applications regarding 'Local Scale Surface Temperature Dynamics' and 'Surface Urban Heat Island Assessment' are presented. Finally, CURE communication and dissemination activities during this period are described.

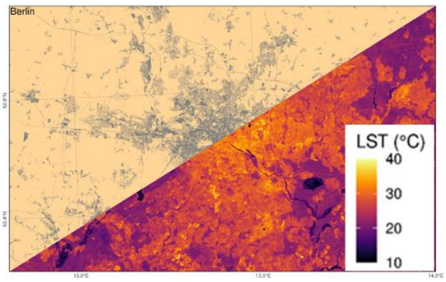
IN THIS ISSUE



Local Scale Surface Temperature Dynamics Application

This CURE application is developing time series of urban surface temperature maps of 100 m x 100 m resolution (local scale). The maps represent the skin temperature (°C), i.e. the temperature of the surface elements at the time of the satellite acquisition.

Page 4



Surface Urban Heat Island Assessment Application

This CURE application provides a framework to objectively quantify the Surface Urban Heat Island Indicator through regression analysis of the land surface temperature and the density of the urban fabric.

Page 6

Users' Requirements

by David Ludlow

Needs of Urban Areas

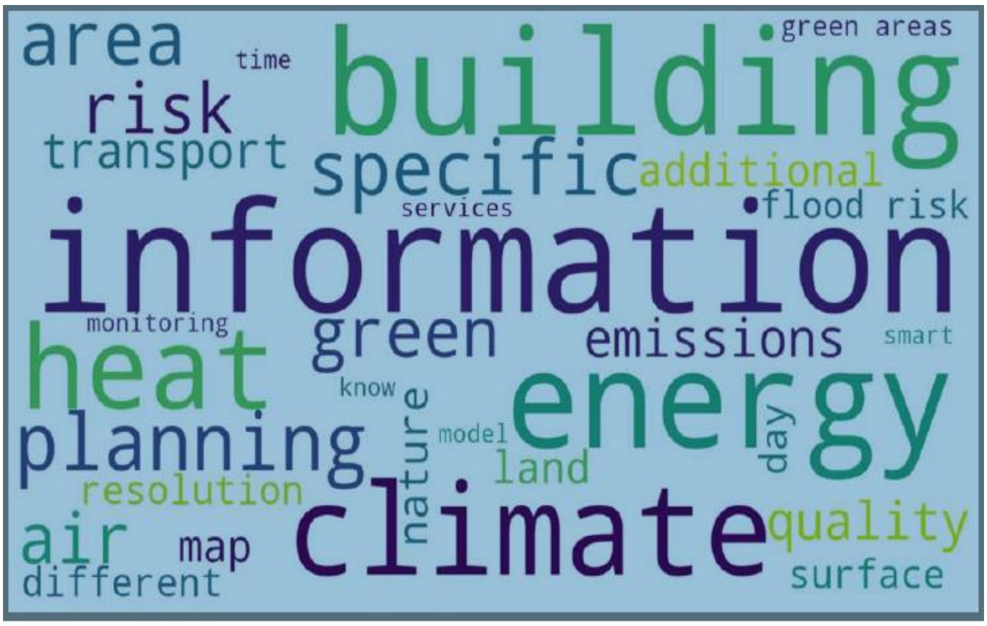
CURE stakeholder needs and requirements shape the development of CURE cross-cutting applications, informed by specifications of user requirements in urban resilience and spatial planning derived from the CURE front-runner pilot cities. This requirements gathering process, recently completed by the CURE team, aims to: a) develop an understanding of different user expectations of Copernicus based data, and b) identify commonalities that can be useful for the development of generic products applied to other European cities.

CURE city stakeholder requirements derive from the objective of urban planning to manage the territory delivering the sustainability policy targets of European cities, concerning climate change, urban health, economic development, biodiversity loss, etc. This management is specified in a variety of policy strategies including climate mitigation and adaptation actions that enhance the resilience of cities, and support the definition of transition pathways to sustainable and carbon neutral cities. These policy strategies require sound understanding and quantification of the drivers of urban transition, to support effective policy responses defined in various policy commitments including the European Union Urban Agenda, and the Sustainable Development Goals (SDGs).

This context includes major challenges for urban planners and policy/decision makers, as cities are extremely complex systems; and the various drivers of change, impacts and responses are strongly interrelated with each other. Indeed, the effective governance of the cities and city-regions of Europe today is potentially undermined by this urban complexity, whereby the high degree of interconnectedness and multiple interactions between socio-economic and environmental factors in the territorial context create barriers to the effective implementation of sustainable urban development.

Dealing with Urban Requirements

Complex and interconnected urban ecosystems require integrated assessment of spatial impacts in terms of socio-economic and environmental factors to secure the essential "win-win" policy co-benefits, central to the delivery of the transformation agenda adopted by policy/decision makers globally. An integrated approach looks at complementarities and trade-offs across multiple policy objectives in urban planning, and takes full advantage of potential synergies and co-benefits.



Policies targeting climate resilience, compact cities and enhancing urban quality of life can deliver these major climate co-benefits. For instance, the promotion of active travel via cycling and walking improves air quality and reduces fossil fuel emissions, creating accompanying positive health and environmental benefits.

These city requirements define a major opportunity for the EO community to promote the innovative exploitation of Copernicus derived data, tools and methodologies in dealing with the multi-dimensional problem of urban sustainability. Central to this opportunity is the need for cross-cutting tools, methods and innovation, linking the complex socio-economic and environmental dimensions of urban sustainability in urban planning. This enhanced intelligence helps cities assess the efficacy of policy actions and causation between the policy action and climate co-benefits. Also, these tools allow local authorities to test 'what if' scenarios, for example, concerning the reduction of air pollution to estimate the health cost savings of low-carbon transport policies. Similar tools for other co-benefits assessment can aid the incorporation of co-benefit considerations in the decision making process, such as tools to quantify the estimated health benefits and savings associated with active travel and nature-based solutions.

CURE applications support the delivery of spatially disaggregated intelligence for decision makers, operative at different city scales from neighbourhood to city-region. CURE promotes information capacity presenting the current state of cities against drivers (climate change and socio-economic transformation) and pressures (pollution and emissions), addressing the overall impact (quality of life, social cohesion) that enables cities to prepare an evidence and knowledge-based response (better plans, local actions and policies) for urban resilient and sustainable cities.

CURE Data Needs and Interface Concept

by Katerina Jupova and Michal Opletal

Copernicus Datasets

The main type of input data for the CURE cross-cutting applications is represented by datasets from the Copernicus programme. These data products are typically available for multiple time horizons or even in dense time-series, with pan-European coverage or at least covering larger European cities in a fully harmonized form. This assures high level of robustness of the CURE cross-cutting applications and their replicability in the future, for both additional cities and time-horizons.

First, products acquired by Copernicus satellite missions – Sentinels – represent one of the most important inputs for the CURE applications. While Sentinel-3 provides the information about the land surface temperatures (LST) in 1 km x 1 km resolution, Sentinel-2 based information about the land cover structure (in particular on impervious surfaces and vegetation) will be used to downscale this LST information to higher level of spatial detail. Additionally, Sentinel-1 imageries will be exploited for monitoring land subsidence.

Second, data from Copernicus Core Services - i.e. CLMS (Copernicus Land Monitoring Service), C3S (Copernicus Climate Change Service), CAMS (Copernicus Atmosphere Monitoring Service), EMS (Copernicus Emergency Management Service) and later also from EGMS (European Ground Motion Service) - will serve as the other crucial input for the CURE applications. The CLMS offers data on land cover structure. The high-resolution (HR) imperviousness layer with pan-European coverage will provide information about sealed surfaces. The Urban Atlas (UA) will serve as a source of information about the internal structure of urban areas. The UA Building Heights will be used to gather 3D information about city structure, while the UA Street Tree layer shows distribution of rows or patches of trees in cities. These datasets will be used to downscale the information from Sentinel imageries or Copernicus Core Services to significantly higher level of spatial detail, taking into consideration both distribution of built-up land and internal structure of the city. The CLMS also offers the European Image Mosaics in HR and VHR (very high-resolution) and the Digital Elevation Model over Europe (EU-DEM). From the global component of the CLMS, specific datasets illustrating vegetation features will be used. From the C3S, the European daily gridded (E-OBS) meteorological data and the reanalysis (ERA5) hourly estimates for various atmospheric (e.g. water vapor) quantities will be exploited. The CAMS offers air quality data showing concentrations of different pollutants (COX, NOX, O3, PMs, etc.) or surface solar irradiation data. The EMS will provide the flood-related indicators and forecasts. The data on ground motions from EGMS will be used from the next year on, when this service becomes operational.

These Copernicus datasets will be supplemented by third-party datasets, where needed or requested by the end-users. Such third-party datasets will be typically represented by local city open data, usually providing higher level of spatial detail in particular city areas than the pan-European Copernicus datasets. In some cases, third-party datasets with global coverage will be integrated, most often from OpenStreetMap or World Settlement Footprint layer.

CURE Copernicus Core Services Interface

To facilitate fully automated access to all of these types of input data products stored in different remote repositories, the CURE CCSI has been set-up. This platform provides functionalities for the CURE system and CURE cross-cutting applications in order to interact with relevant input data for each developed service and pilot area. This Interface provides a search Application Programming Interface (API), adopting Open Geospatial Consortium (OGC) OpenSearch specification. It is used for standard service, facilitating the aggregation of results between disparate data providers and collections. By this API, all registered catalogues can be searched. All received feeds for a given search query are parsed and returned in a standardized form; containing product metadata, geographic information and links for downloadable or mountable content. The application does not provide only the search over cloud-based platforms of DIAS, through which most of the Copernicus datasets are accessible; but allows also to search in third-party resources such as local city open data APIs upon their registration into the CCSI. Such APIs can be integrated into the CCSI in the semi-automatic process, if they meet required specification. Further extension of the CCSI into semantic based search, using urban resilience ontology as dedicated transversal service for service providers, is considered.

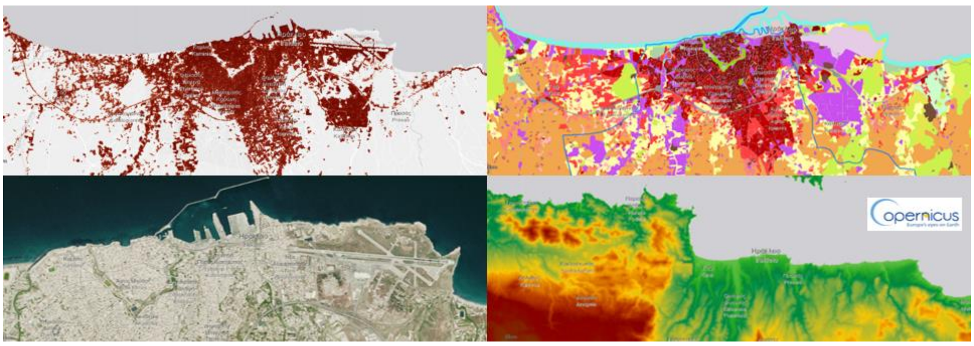
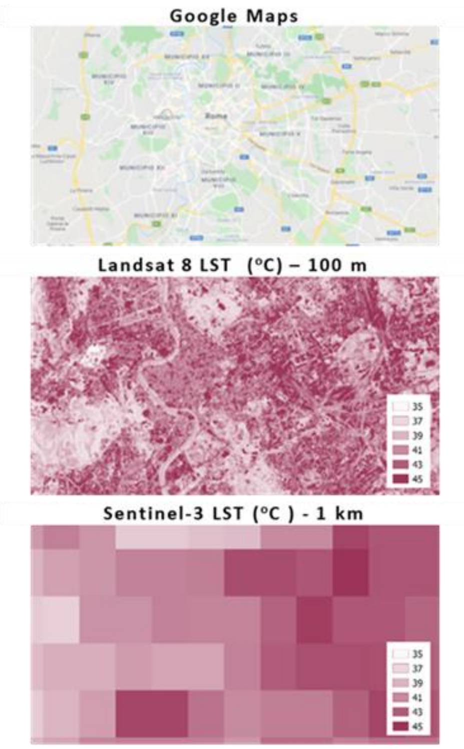


Illustration of different types of CLMS data products available for Heraklion city area (HR Imperviousness Density, UA, VHR Image Mosaic and EU-DEM)

Local Scale Surface Temperature Dynamics Application

by Zina Mitraka and Giannis Lantzanakis



Rome, Italy, July 09, 2018

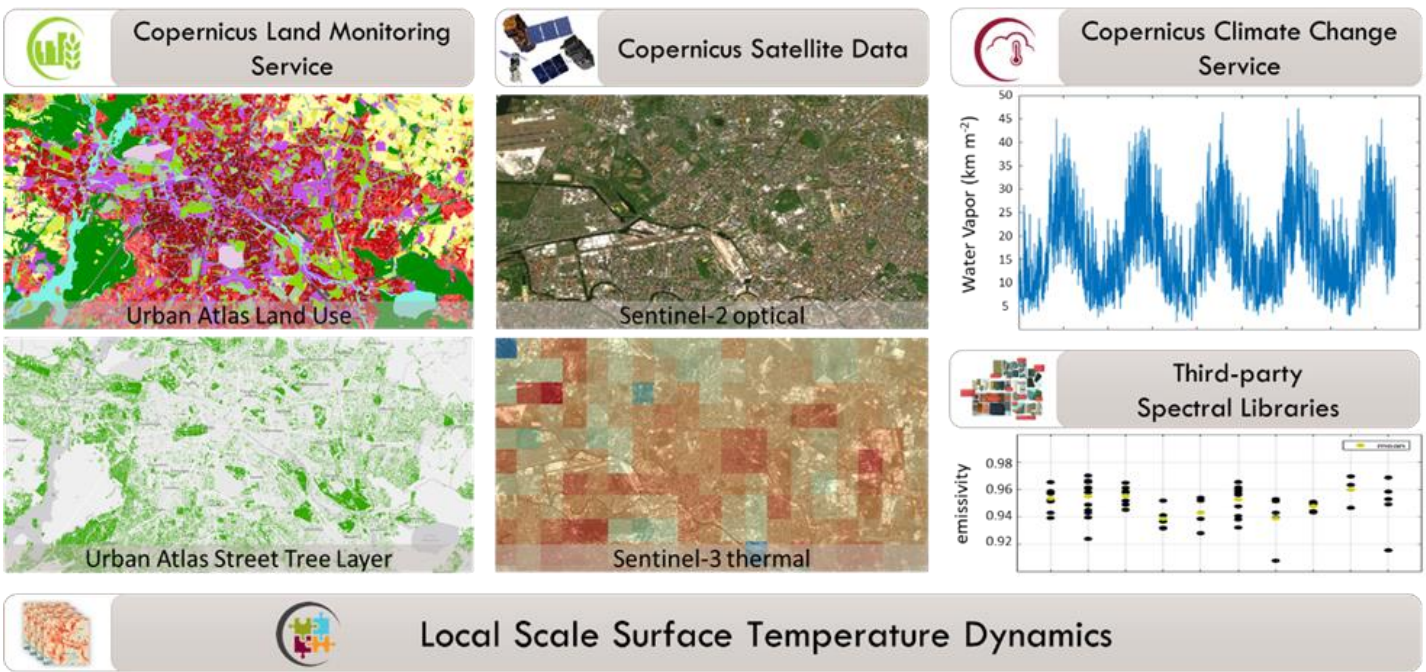
Cities and Temperature

Temperature is one of the most important variables in climate monitoring. The LST refers to the skin temperature, namely the temperature of the surface elements (ºC). Surface temperature helps describing the processes of the urban energy and water balance, meaning the exchange of energy and water between the land surface and the atmosphere. Therefore, accurately quantifying the spatial and temporal evolution of cities' surface temperature helps to understand and evaluate the land surface – atmosphere exchange processes and draw conclusions about the urban climate.

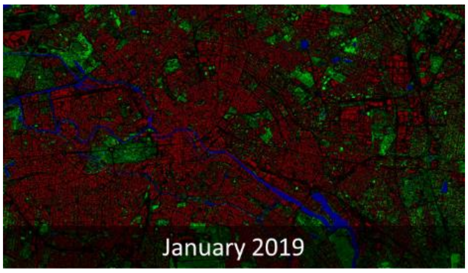
Frequent, accurate and detailed information of the urban surface temperature is a fundamental information source for capturing and monitoring the Surface Urban Heat Island (SUHI) phenomenon and for assessing the heat emissions and the heat storage of a city, which are addressed in separate CURE applications. The heat emissions refer to the turbulent sensible heat flux densities that describe the mechanism of energy exchanging between the urban surface and atmosphere. This is in practice the heat that is emitted by the urban surface and tends to increase the air temperature, and therefore to deteriorate the thermal comfort of people. The heat storage refers to rate, at which the urban surface stores and releases energy and it is the main cause of the Urban Heat Island (UHI) phenomenon, since the cities usually release heat slower than natural surfaces. The spatio-temporal distribution of urban surface temperature at neighbourhood scale is a prerequisite for quantifying the SUHI phenomenon as well as the heat emissions and storage.

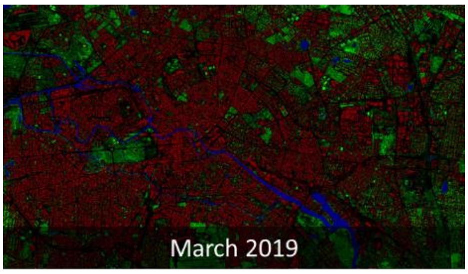
Urban Surface Temperature from Space

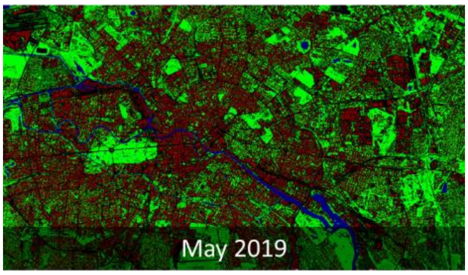
Thermal satellite sensors allow the estimation of surface temperature from space, and (regarding the European Constellation of Sentinel missions) Sentinel-3 is imaging in the thermal infrared four times per day with a spatial resolution of 1 km x 1 km. The respective LST products are made available by the European Space Agency (ESA), allowing continuity for the respective Advanced Along-Track Scanning Radiometer (AATSR) archive LST data; and the ESA Climate Change Initiative LST project is currently homogenizing these global LST time series over the past 20-25 years. On

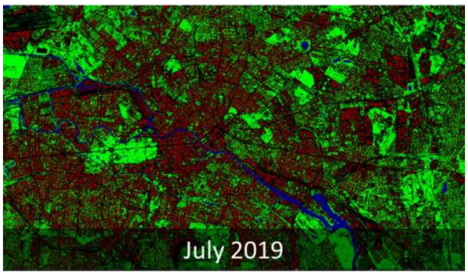


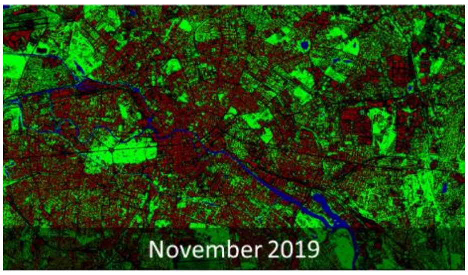
the other hand, in the biophysical parameters of the CLMS, a LST product is available at 5 km from geostationary satellites, covering 2010 - present.

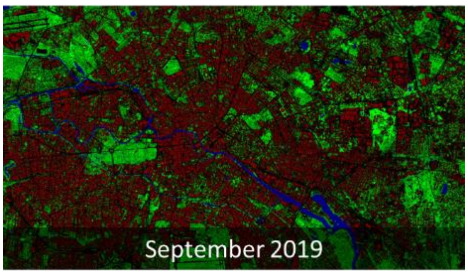












Nevertheless, cities present great variation in surface temperature, because of the unique urban surface properties and the highly inhomogeneous geometry of the urban setting. Thus, the spatial scale of the surface temperature products is important in order to assess the temperature differences between different features.

Surface temperature in cities is a dynamically changing parameter with diurnal and seasonal variations, presenting distinct characteristics, attributed to the highly variable urban surface properties and the unique 3D nature of the urban surface. The particular urban surface geometric and radiative properties affect the physical processes occurring in the urban canyons. Geometric properties, including the buildings orientation and urban surface openness to sun and sky, provide a strong control on urban temperature. By day, the highest temperature occurs on facets that maximize the local irradiance (e.g. facets with no shade, well exposed at small local zenith angles to the solar beam); while nighttime maximum urban temperature extremes are mostly governed by the radiative and thermal properties of the scene. Facets with low albedo favour shortwave absorption and therefore present higher temperatures, whereas those with high albedo lead to lower temperature. There is an almost infinite mix of these properties in an urban area, so spatial patterns of temperature in cities are extremely varied, especially by day; and the temporal variability of surface temperature in cities is much greater than that of the air temperature. Thus, in order to draw conclusions about a city's surface temperature behaviour, having detailed information on its spatial pattern in a single snapshot is not sufficient, but monitoring its evolution through time is an emerging need.

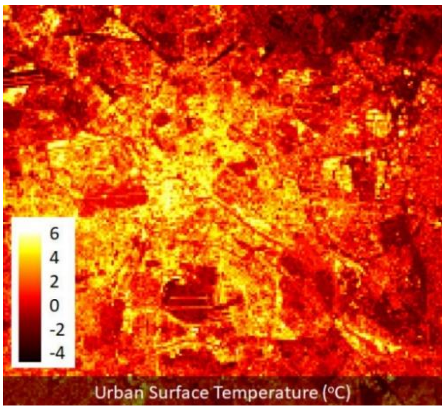
Surface Temperature and the Copernicus Services

CURE is putting together information from: two Copernicus Services (CLMS and C3S), two Copernicus Satellite missions (Sentinel-2 and Sentinel-3) and some ancillary spectral libraries in order to achieve the monitoring of the urban surface temperature dynamics at local scale.

Data from CLMS are used to achieve the surface characterization and Sentinel-2 acquisitions, twice per week, allowing the dynamic monitoring of the urban surface with great spatial detail (10 m x 10 m spatial resolution). This detailed information provides a good basis for achieving accurate surface temperature maps at local scale. Sophisticated downscaling approaches are used to achieve a 100 m x 100 m spatial resolution from the original 1 km x 1 km resolution of the Sentinel-3 thermal imagery, and data from C3S are used for the atmospheric correction of the thermal measurements. Ancillary information from spectral libraries is used in combination with the dynamic land cover maps to estimate the surface emissivity at local scale, which is necessary to be known for surface temperature retrieval from the thermal measurements. The CURE surface temperature products will be validated against in-situ measured temperatures for the cities of Heraklion and Basel, where these data are available from FORTH and UNIBAS, respectively.

Products

The CURE Local Scale Surface Temperature Dynamics Application (AP01) is developing time series of urban surface temperature maps of 100 m x 100 m resolution (local scale). The maps represent the skin temperature (°C), i.e. the temperature of the surface elements at the time of the satellite acquisition.



Local scale urban surface temperature for Berlin corresponding to 24 July 2019, 21:26 local time, as derived from AP01

Surface Urban Heat Island Assessment Application

by Benjamin Leutner and Mattia Marconcini

Human well-being in urban environments is, among others, strongly driven by local climatic conditions, in particular temperature; and is expected to be impacted heavily by recent and forecasted temperature variability and increase due to climate change. CURE Surface Urban Heat Island Assessment Application (AP02) provides an objective way to estimate the degree, to which a city's temperature regime is driven by its artificial land cover.

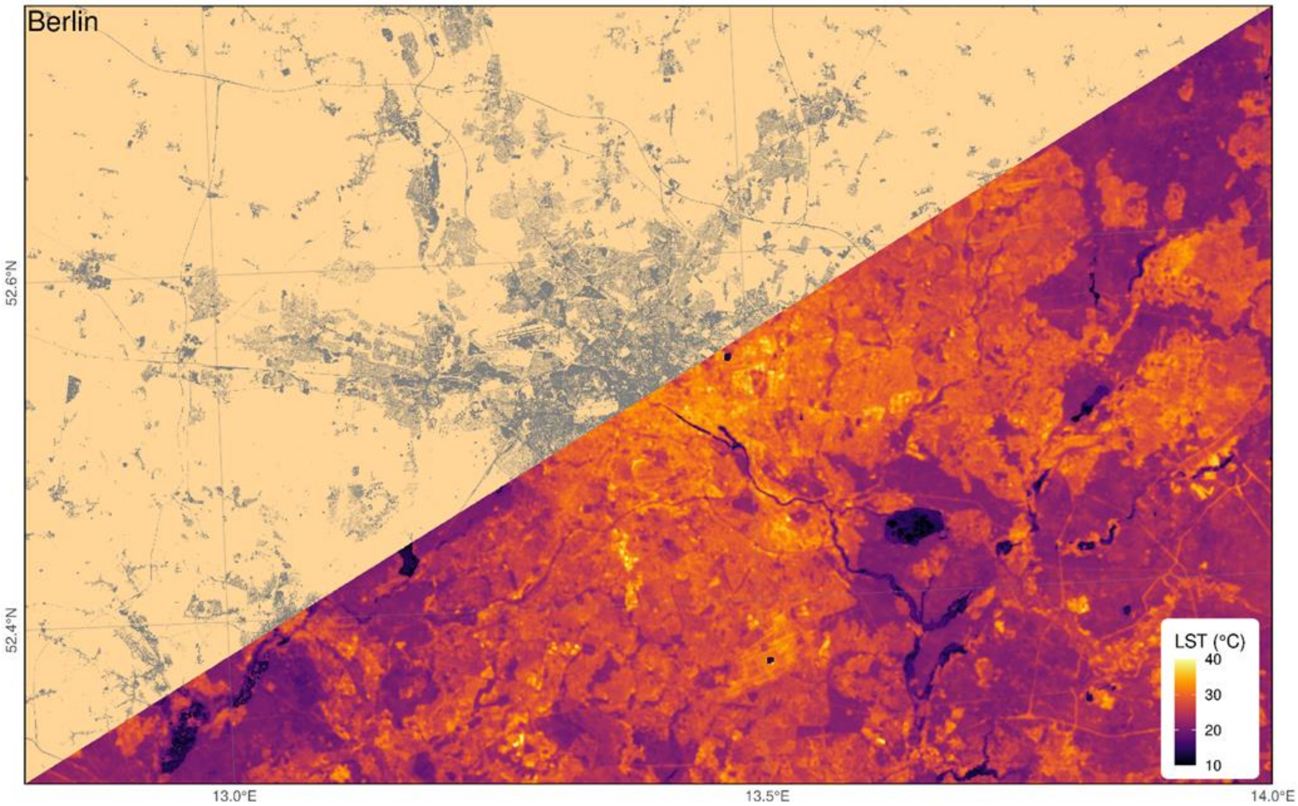
Urban Heat Island Effect

In general, urban or metropolitan areas are warmer than their rural surroundings due to the thermal properties of the built-up environment, as well as the excess heat produced by human activities. This phenomenon is commonly referred to as the UHI effect. As the population of cities grows, they commonly experience an expansion of the impervious area at the cost of formerly vegetated areas. In consequence, urban temperatures rise. Increasing temperature in the urban environment directly affects human well-being through heat stress, it decreases air quality by increasing the production of pollutants such as ozone, it decreases water quality as warmer water flows into area streams, it increases energy consumption, and puts stress on the remaining urban vegetation.

Attempts to mitigate the UHI effect are manifold, still often costly. On the one hand, solutions include the expansion of vegetated areas, such as parks or green roofs within cities; which exhibit a cooling effect through the process of evapotranspiration. On the other hand, attempts include structural construction planning, targeting improved ventilation and hence heat exchange with the surroundings (e.g. through ventilation corridors such as straight roads); or the utilization of thermally reflective surfaces (e.g. light-coloured materials), which reflect more solar irradiation and absorb less heat.

Quantifying the Surface-Driven Heat Island Effect

Cities differ strongly in how pronounced the UHI effect plays out. This is due to complex interactions of local and regional climatic conditions with the urban fabric, such as roads and buildings but also vegetation and their respective spatial arrangement. The AP02 of the CURE project will provide a quantitative way to assess the intensity of the surface-driven heat island effect at the city level. Such a quantitative characterisation of the UHI effect can both contribute to the evaluation of potential heat risks of Europe's cities and guide the planning of resilient urban development in the face of global climate change.



Data utilized for CURE AP02. Example city: Berlin. Upper left: CLMS imperviousness HR layer. Lower right: Landsat 8 derived median LST over the summer-period.

The quantification of the UHI effect has historically been accomplished based on weather stations inside and outside of cities, which were used to derive measures of thermal contrast. Given the costliness of in-situ measurements, this meant that such indicators were strongly dependent on few observations and their relative placement.

With CURE AP02, the potential of EO is utilized to provide objective and robust indicators derived from repeated remotely sensed measurements of cities' temperatures, as well as maps of the distribution of impervious areas derived from remote sensing. CURE AP02 will provide a so-called Surface Urban Heat Island Indicator (SUHII). Specifically, AP02 provides a framework to objectively quantify the SUHII through regression analysis of LST and the density of the urban fabric. The SUHII could be derived automatically for any European city and will be demonstrated for the four front-runner cities of Berlin, Copenhagen, Sofia and Heraklion.

CURE AP02 deploys frequent LST measurements acquired through the space-borne thermal sensors of the American Landsat 8 mission and the European Copernicus Sentinel-3 mission. Thermal data are pre-processed via CURE AP01 and serve as the main input for CURE AP02. An example for such an LST measurement, averaged over the summer months for the city of Berlin, can be seen in the lower right section of Figure in page 6. The UHI effect is clearly identifiable through increased thermal emissions, originating from the urban highly impervious centre of Berlin. Contrastingly to the warm urban areas in the centre, the surrounding suburban areas experience lower temperatures. The suburban areas are followed by rural areas, which are dominated by vegetation and exhibit significantly colder temperatures (similar to water bodies and streams).

The Impact of Imperviousness

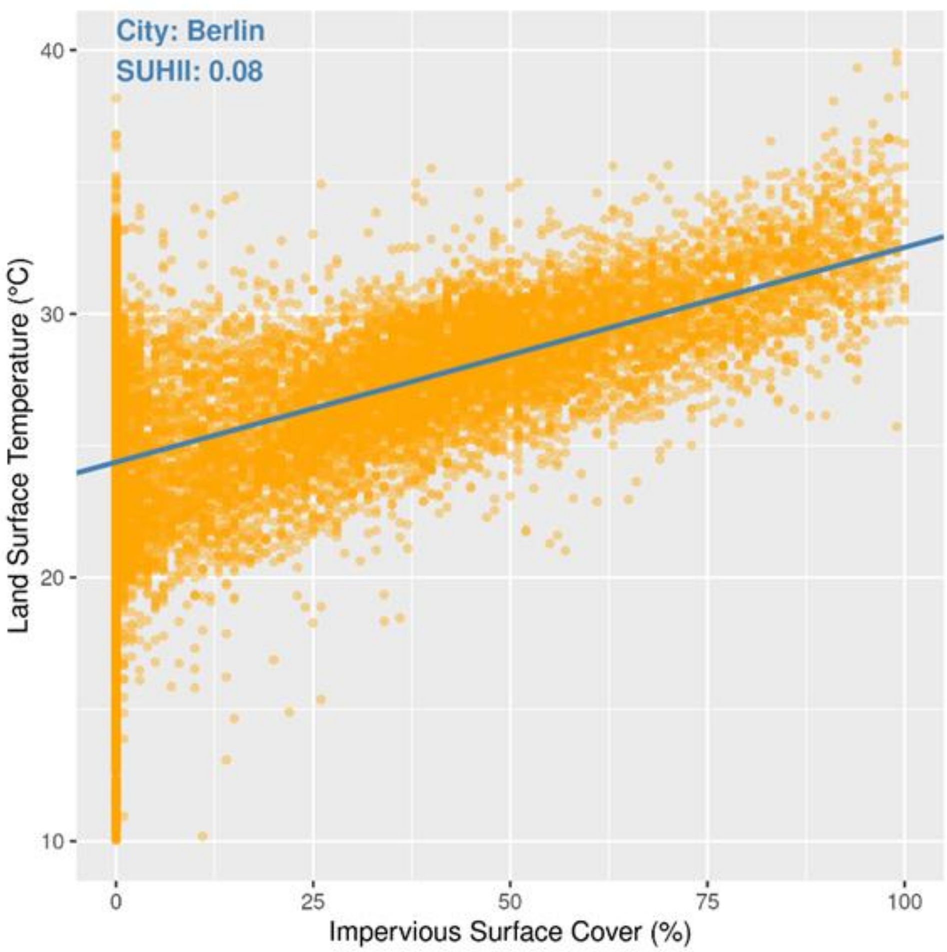
In addition, CURE AP02 uses existing HR urban imperviousness layers of the CLMS (upper left section of Figure in page 6); which, by definition, result from the substitution of the original natural land cover or water surface with an artificial, often impervious, cover. After a data-driven delineation of the urban thermal footprint based on the distribution of imperviousness, AP02 will then provide the city-specific dependency of LST on percentage cover of impervious surfaces.

Figure of page 7 shows an example of the relationship between the percentage of the impervious area and LST during the summer months for the city of Berlin. Clearly visible is the systematic relationship between both factors, which is almost perfectly linear on average in the case of Berlin. Thus, by utilizing a regression model to identify the underlying trend, a simple, but objective, measurement of the SUHII is obtained and can be provided for any city, given the availability of imperviousness and thermal remote sensing data.

Products

The outputs of this application will be the estimated SUHII value per city per year available for download. By utilizing thermal EO data also from past years, in combination with previous years' CLMS imperviousness layers, CURE AP02 will not only be able to provide a recent estimate of the SUHII; but also trace its temporal development, and hence allow to monitor and compare SUHII temporal trajectories of cities. Building on top of the existing CLMS imperviousness products, CURE will provide SUHII estimates for all cities for the years 2006, 2009, 2012, 2015 and 2018.

Interpreting these SUHII values will then allow for a relative ranking of cities (e.g. at national level) deploying their thermal characteristics. Consequently, this advancement will enable an assessment of vulnerability to urban heat stress, which may allow to focus efforts on the most affected cities and steer urban development. Thus, CURE AP02 can address identified stakeholder needs of both policy/decision makers and urban planners, optimizing their adaptation strategies with regard to heat stress aiming at urban resilience.

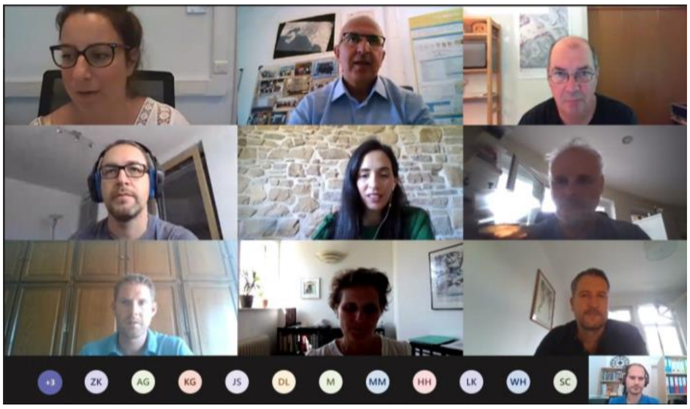


Relationship between impervious surface and LST for Berlin. The blue line is a linear model fit, based on which the SUHII is derived.

Project Activities

1st Progress Meeting

The 1st Progress Meeting of the CURE project was successfully completed on the 25th of June with the participation of the Project Officer, members of the Advisory Board and the CURE Consortium. The Meeting was held virtually due to the Covid-19 pandemic. During the Meeting, presentations, discussions and planning of the CURE actions regarding the next months were accomplished.



CURE Presentation in International Scientific Meetings

The CURE project was presented in the following meetings:

- SPIE Remote Sensing Digital Forum 2020 (21–25 September 2020) - Dr. Nektarios Chrysoulakis (FORTH) was invited and presented the CURE project concept and idea in “Session 1: Urban Air Quality and Climate”.
- 2020 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) (26 September - 2 October 2020) - Dr. Nektarios Chrysoulakis (FORTH) presented the CURE project concept and idea in “MO2.R12: Urban Remote Sensing I” Session.
- 4th SmartBlueCity Euro-Mediterranean Conference-Exhibition (Athens, 9-10 October 2020) - Giorgos Somarakis (FORTH) presented the CURE project focusing on its cross-cutting applications in Session 9 “Technological Innovations, Planning Approaches and Data Considerations for Managing Cities and Insular Communities in the MED”.
- Space for Cities: From Innovation to Operation Workshop (27 October 2020) - Dr. Birgitte Holt Andersen (CWare) and David Ludlow (UWE) presented the CURE project focusing on the topic ‘Enhancing Urban Health with Satellite Data’ in Session ‘Using Satellite Data to Monitor Urban Health’.

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

CURE

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