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Article

Development of Low-Threshold Tools and Efficient Work Processes for Data Acquisition, Processing, Evaluation, and Application by Municipalities

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Abstract: Specific climate adaptation and resilience measures can be efficiently designed and implemented at the regional and local level. Climate and environmental databases are of critical importance to achieving sustainability goals (SDGs) and for the efficient planning and implementation of suitable mitigation measures: Available databases can serve municipalities as a vital starting points to determine requirements, prioritize resources and allocate investments under consideration of commonly tight budget restrictions. High-quality geo, climate and environmental data are now available – data from remote sensing, i.e. Copernicus services will be of crucial importance. Forward-looking approaches exist to using such data to derive forecasts for urban planning process optimization for municipal administrations. On municipal level, however, the existing data have so far only been used to a limited extent, since there are no practical tools for urban planning that can be used to merge and meaningfully combine remote sensing data with local data and to further process and apply in municipal planning processes. Therefore, our project *CoKLIMAx* aims at the development of new digital products, advanced urban services and procedures, such as the development of practice-oriented technical tools that acquire various remote sensing and in-situ data sets for validation and further processing.

Keywords: climate change; city resilience; sustainable development, urban planning, remote sensing, internet of things, water management, heat islands, digital transformation, data analytics

1. Introduction

Currently, 55% of global population lives in cities - with a projected percentage of 68% in 2050 [1]. At the same time, the effects and consequences of the climate crisis are particularly striking in urban areas and are associated with a particularly high potential for damage due to the high spatial concentration of people, buildings, technical infrastructure, economic output and social and cultural activities. For example, rising summer temperatures increase heat stress, especially in cities, and can lead to increased health problems and higher numbers of heat-related deaths. More frequent and extreme storm and tempest events can cause damage to infrastructure, commercial and residential buildings [2].

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According to current scenarios and model calculations, the costs of climate damage in Germany are in the range of 0.1 - 0.6% of GDP by 2050. With investments in climate adaptation amounting to 0.1 - 0.2 % of GDP, many of the damages could be avoided and attractive additional benefits could be generated at the same time [3, 4]. Concrete measures for climate adaptation and climate resilience can be designed and implemented particularly efficient at the municipal level, so that municipal actors and their options for action, e.g. in the context of regional planning, urban land use planning, environmental planning, municipal landscaping plans, etc., play a key role in mitigating or minimizing the risks and negative consequences of the climate crisis [5].

For the viable, economical planning and implementation of appropriate measures to minimize of climate crisis-related impairments and hazards, knowledge of relevant climate and environmental climate and environmental parameters and their anticipated changes. On the basis of pertinent databases, it possible to simulate relevant scenarios and derive possible measures, so that a targeted adaptation of urban areas - in which an increasing urban areas - where the increasing majority of people live - can succeed. Thus, the timeliness, quality, suitability and availability/usability of the available climate and environmental data are determining factors for the ability of cities and municipalities to act, and of central importance for the planning and justification of climate resilience measures, which usually have to be designed and implemented under tight budget constraints and complex boundary conditions [6, 7].

Meanwhile, powerful geospatial, climate and environmental information is available in the form of Copernicus data and services as past, present and projection data and there are forward-looking approaches to its use in the context of climate and weather-related influences at the local level [8].

2. Relevant data and state-of-the-art technology

2.1. CODE-DE[1] platform

For the access to climate and environmental data by German authorities, the platform CODE-DE is available according to the current state of the art, which can also be used by municipalities in the context of the applications and tasks focused on here. CODE-DE is part of Germany's geospatial data and information strategy and offers access to remote sensing data, a virtual working environment for processing these data, and extensive information material and training to support users.

In particular, CODE-DE provides access to the Sentinel and Contributing mission data as well as to information products of the Copernicus services, offers processing capabilities and access to a portfolio of products and tools specifically designed for government applications. It is a platform that allows to manually download processed Level 1 Level 2 raster (satellite) data. An API is also available from CODE-DE. A large part of the data products available via CODE-DE originate from the CDS and have been adapted for use in Germany. CODE-DE distinguishes between the following user categories:

- Category 1: German federal authorities and their contractors
- Category 2: German state authorities, municipalities and their contractors
- Category 3: German research institutions and other non-commercial organizations
- Category 4: Anyone who does not fall into one of the other categories. Examples include non-German users, students, and private sector users.

2.2. Climate Data Store[2] (CDS)

[1] Copernicus Data and Exploitation Platform – DE; https://code-de.org/en/

[2] Copernicus Climate Data Store; https://cds.climate.copernicus.eu/#!/home

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The Climate Data Store (CDS) provides access to a multitude of climate datasets through a searchable catalog. An online toolbox is available to allow users to create workflows and applications tailored to their needs. An API is also provided for direct integration of CDS offerings and functions into software tools based on them.

2.3. Commercial software products

In addition to the above offerings, there are private sector software products such as Esri's ArcGIS platform with variants such as ArcGIS Enterprise, ArcGIS Desktop, ArcGIS Online, and many web and mobile client options. Possible application contexts include research activities as well as administrative, and most importantly, operational use. Supported are, for example:

- Spatial Analysis and Data Science
- Field Operations (citizen participation, support administrations of various institutions, companies, municipalities)
- Mapping of any kind
- 3D GIS (incl., BIM) e.g. Digital Twin and local real-time sensor technology
- Image data and remote sensing (image detection with AI, pre-processed satellite images)
- Data acquisition and management (Big Data)

2.4. Copernicus Climate Change Service[3] (C3S)

The Copernicus Climate Change Service (C3S) is carried out at the European Centre for Medium-Range Weather Forecasts (ECMWF). The aim of the C3S is to support policy development in Europe with respect to climate change, to improve the planning of climate mitigation and adaptation measures, and to promote the development of new services with added value for society. In addition to regional climate projections for Europe to the end of the 21st century, a range of observational and reanalysis data are provided. Reanalysis data are produced with models of global circulation incorporating daily observations and are thus close to the observed climate. These data are continuously provided in a very timely manner at hourly resolution. In addition to numerous atmospheric parameters such as temperature, evaporation, precipitation, radiation, etc., they also contain many data on land surfaces and land hydrology, as well as a large number of parameters for lakes.

2.5. International CORDEX[4] initiative

Within the framework of the international CORDEX initiative of the World Climate Research Program (WCRP), coordinated regional climate simulations for the 21st century are carried out for different regions worldwide. For Europe, climate change simulations have been and are being generated at a comparatively high spatial resolution of 12 km x 12 km within the EURO-CORDEX- initiative ([9, 10]). Within the Copernicus Climate Change Service (C3S) project "Producing Regional Climate Projections Leading to European Services" (PRINCIPLES, C3S_34b Lot2), further regional climate change simulations based on the global CMIP5 simulations for different emission scenarios will be generated and the ensemble of regional climate projections for Europe will be completed. The thus generated multi-model ensembles of climate projections allow the assessment of the quality of climate information by making statements about bandwidths and robustness of projected climate changes. The data of regional climate projections are provided by the Earth System Grid Federation and to a large extent also in the C3S Climate Data Store.

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[3] Copernicus Climate Change Service (C3S); https://climate.copernicus.eu/

[4] WCRD CORDEX; Coordinated Regional Climate Downscaling Experiment; https://cordex.org/

In principle, therefore, there already exists a wide range of forward-looking approaches to the use of climate and environmental data, as provided in particular by Copernicus, for the derivation of climate projections (e.g., [11-14]) and for the use of past, present, and projected data for the identification of expected climate- and weather-related challenges at the local level (e.g., [15-18].

Despite the existence of this relatively wide range of climate information and services, studies reveal that they have not yet been fully adopted in practice by municipal users ([19-21]). Since many barriers make it difficult to use climate information in the municipal decision-making process, there is also talk of barriers to use in this regard [20]. From the extensive offer of the C3S Climate Data Store, it is usually equally difficult for potential users in practice to identify the climate parameters and data sets relevant for them and to recognize their potential benefits and added values for the specific municipal applications. Therefore, it is helpful to illustrate the usefulness of existing climate parameters by their explanatory potential for past extreme events and other affectedness [22].

Other barriers and obstacles include both technical challenges to integrate the data into municipal tools and workflows, as well as the necessary knowledge on the quality of climate data and its interpretation, especially with respect to the assessment of uncertainties (e.g., [19]), and its connection to locally available data.

Coordination with regard to data format and temporal and geographic scales should also be sought. Especially for the linkage along the different spatial scales from the macro to the micro scale, solutions have to be developed and integrated into information systems. In order to develop tailor-made solutions for the respective region and local applications and to address the mentioned barriers in this process, the planning and development of applications should therefore be carried out together with municipal users in a transdisciplinary approach ('co-design'), so that climate services and their recommendations can harmonize with the institutional decision-making process, use understandable terminology and dock to the right processes at appropriate points in time ([21, 23]). As an example, regulatory barriers exist with respect to the use of climate projection data in land use planning due to the inherent uncertainties associated with these projection data. Similarly, the coordination of climate change adaptation is organizationally dispersed across several task areas and is often institutionally fragmented and usually rather weakly anchored [24].

Thus, to ensure the persistence of climate knowledge and services, institutional structures, decision-making processes, data use norms, networks, and actor constellations responsible for relevant municipal tasks should be considered, and the input of climate projection data should be closely aligned with these municipal structures and processes ([25-27]). An extended needs assessment focused on these aspects can ensure that climate services are transferred and anchored in municipal practice in a practical and sustainable manner and thus continue to be used independently after the end of the project. A positive side effect of such a transdisciplinary work process is also the capacity building of the municipal users.

3. Proposed Approach and Methods

The actual application by municipal actors has so far fallen far short of the possible and actually necessary scope. The following hurdles and challenges are known to be the reasons for the insufficient The following hurdles and challenges are known to be the reasons for the insufficient use of the system by municipalities:

- It is difficult to identify the relevant data sets in each case.
- Benefits and added value for municipal applications are not directly recognizable.
- So far, there are no easy-to-use tools for identifying and merging different Copernicus data and for processing and evaluating them (also together with local data) for use in municipal planning activities. This concerns in particular the linking along different spatial scales (macro, meso, micro scale) and the integration of data on differently resolved past or forecast periods [28, 29].

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In this context, *CoKLIMAx* aims to develop the following new products and processes:

- Practice-oriented technical tools for the determination and use of information of Copernicus data and services, merging with heterogeneous, locally available data sets and appropriate evaluation and result preparation/presentation.
- Associated technical and urban planning utilization methods, exemplified here. to be implemented for the climate resilience contexts of water (sealing and desiccation of the soil, urban storm water drainage design, flood control), heat (development planning, air flows, etc.) and vegetation (greening strategy and its spatial differentiation, vegetation monitoring/vitality).
- Establishment of best-practice local government process structures for the efficient Integration of climate and environmental data using the technical tools and urban planning Utilization methods (see above) into concrete climate resilience work of the municipality. (spatial planning, environmental planning, risk management, etc.).

4. Advanced Municipal Climate Data Store (AMCDS toolbox)

Within the scope of the objective, the conception, implementation, exemplary use and practical validation of a toolbox for the combination and use of climate and environmental data of the Copernicus services with local data will be pursued (Advanced Municipal Climate Data Store: AMCDS toolbox). Regarding the data to be merged and made usable in a practical way, the toolbox design will cover the use of Copernicus data and services, Contributing Missions data, and local data / additional attribute data of the municipality (Figure 1).

Against the background of the state of the art presented in Section 3, *CoKLIMAx* takes up the existing data offers as far as reasonable (besides access to the CDS e.g. also use of CODE-DE in categories 2 and 3). However, by researching practice-oriented solutions with a special focus on municipal requirements and possibilities, data, services, and processing and presentation tools are not only made available specifically for the municipal context, but through the interlinked R&D work on workflows, The data, services, and processing and presentation tools are not only made available specifically for the municipal context, but are also placed in a holistic context for the first time through the interlinked R&D work on workflows, work processes, and organizational/interaction characteristics of relevant municipal organizational units and task areas, directly applied in exemplary use cases, and disseminated as a completely application-suitable overall bundle of IT tools, process concepts, and application aids through application-related best-practice documentation.

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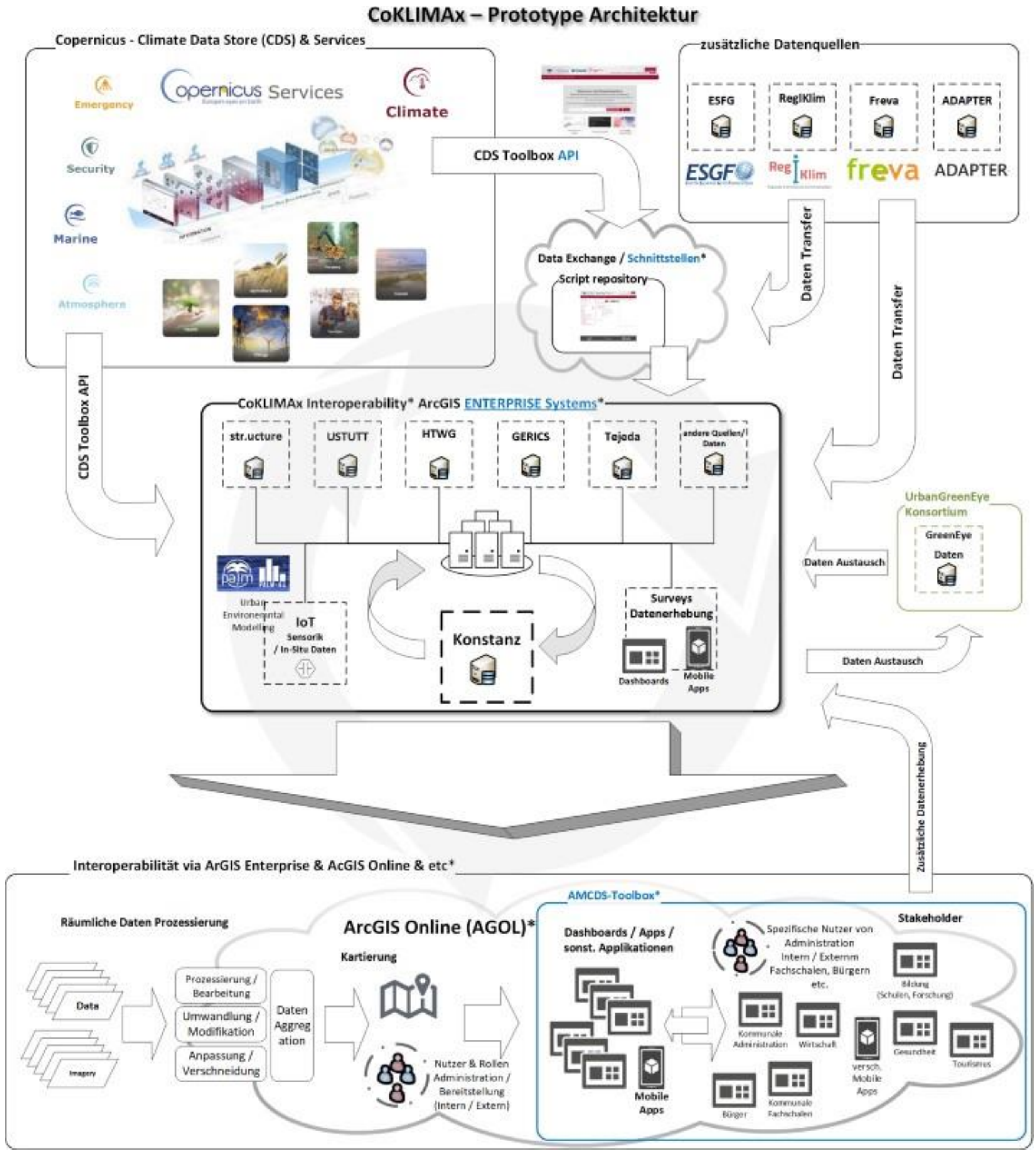

Figure 1. Data sources, data streams, and data processing functionalities in the present application context, including the AMCDS toolbox (highlighted in blue).

Local data will presently include in-situ measurements (temperature, wind, air pressure, humidity of local municipal and private/"crowd-sourced" weather stations) as well as data from the Smart Citizen Kits already widely deployed in Konstanz. Also incorporated will be existing 3D models of the city of Constance (LoD2 GIS data, 3D mesh data from georeferenced digital orthophotos of recent overflights), as well as data from LiDAR drones for point cloud modeling and LoD3+ data to be generated from these.

The AMCDS toolbox is complemented by an easy-to-use AMCDS Data Hub, which allows web browser-based searches for archived data and analyses (retrieved Copernicus data, local data and their performed merging, processing, etc.) and dynamically displays them as maps, scenes or simulations.

The implementation of the application functions of the AMCDS toolbox is planned in the form of apps, which can be combined in a modular way through standardized interfaces. The apps each cover one or a few functional steps of the process chain of data localization, combination, processing and presentation of results. This modular function structure and mechanisms that can be integrated into the apps for self-description and for ensuring that only combinations that make sense in terms of content can be put together (in each case, local checks at the corresponding combination point of function modules) result in technically low-threshold applicability and simple handling (Figure 2). In addition, the module/app design is also inherently aligned with relevant work and organizational processes of the public sector.

Figure 2. Data sources, data streams, and data processing functionalities in the present application context, including the AMCDS toolbox (highlighted in blue).

4. Discussion

The implementation will be exemplary based on the concrete local needs of the city of Constance in the above mentioned focus areas water, heat and vegetation. Relevant data and products will be developed for concrete applications in these areas and will be implemented, applied and validated in a practice-oriented manner.

With regard to the intended urban planning utilization methods and process structures, *CoKLIMAx* aims at the specification of practical work and administrative processes and their exemplary implementation to illustrate the added value and potential benefits for municipal applications that can be realized with them and by using the toolbox.

There are far-reaching synergy potentials between the data processing and software technical objectives on the one hand and the work, planning and administration process related research work on the other hand, which are to be developed in CoKLIMAx through close mutual interlocking of the associated solution approaches, work planning and consortia cooperation. In this way, it is ensured that technically efficient products and services are developed whose practical applicability and actual use are directly guaranteed and demonstrated in an exemplary manner.

As action-guiding, cross-question and result-integrating "application-practical axes

The three use cases and focus areas of water, heat and vegetation serve as action-guiding, cross-question and result-integrating "application-practical axes", on the basis of which both the data requirements and data processing, evaluation and presentation functions are examined and illustrated, as well as the municipal tasks, the resulting work processes, information chains and administrative working methods.

Beyond the scope of the project, these practical application axes established in the use cases also serve as leitmotifs and content-related technical basis for implementing and expanding the lighthouse effect of the project and a nationwide dissemination of the results and approaching further user partners and users.

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