Development of a framework for decision support in the context of climate adaptation

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Abstract: Implementing effective adaptation data that enable this knowledge transfer. For this purpose, this article presents a framework that shall simplify the development of these tools and the measures to climate change impacts concerns policymakers worldwide. At the local scale, there is a gap between scientific findings and a translation of these into concrete measures. It requires a network of tools and access to climate data. The underlying data management concept is intended to provide an infrastructure that requires only a few interventions in the operating process for both data suppliers and system administrators. Most of the infrastructure components have already been realised in the context of the ongoing research project KlimaKonform. In addition, there is an outlook on future implementations.

Keywords: Climate Change Adaptation, Climate Adaptation, SDI, Spatial Data Infrastructure, Data Management, Climate Impacts, FAIR

Addresses Sustainable Development Goal 13: Climate action

1. Project background and motivation

The impacts of climate change are a major global challenge that affect almost every region and all parts of society. Since not all climate impacts or avoidable, it is necessary to prepare and adapt to the potential risks like singular extreme weather events, potential hazards and foresee the consequences for agriculture and human health [Ip14]. It is therefore of particular importance that policymakers implement effective adaptation measures that mitigate the vulnerability of human and natural systems and, thus, pave the way to a climate-resilient future [Ip19]. Adaptation to and mitigation of climate change impacts is also addressed in one of the 13 Sustainable Development Goals (SDG; topic: Climate Change) of the United Nations (UN) [Un22]. Even though climate change impacts are in effect on a global scale, there is a need for locally tailored adaptation measures [DEA18].

In the context of the research project KlimaKonform[3], we investigate methods and decision supporting tools that aim to guide local policymakers in the process of developing adaptation measures. The study area of the project is a rural low mountain region in central

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Germany[4]. Due to the topography and demography, as well as economic particularities, the region has a special exposure to climate impacts. In the course of the project, the physical, socio-economic and ecological climate impacts in the region will be modelled based on representative examples. In addition, the adaptation capacities and costs will be investigated. Ultimately, this requires a close cooperation between scientists and local stakeholders in order to identify their needs for the development of measures. The aim is to provide tailored climate information that can be directly translated into decision-relevant knowledge. Since the landscape type of the study area is similar to wide parts of Germany, a transferability of the project insights on other regions is expected.

Due to the contribution of many scientific partners from universities and scientific institutes, such as Technische Universität Dresden (TUD[5]), Leibnitz Institut für Ökologische Raumordnung (IÖR[6]), Helmholtz-Zentrum für Umweltforschung (UFZ[7]), the project relies on a large basis of climate analysis and data. Additionally, the existing climate information platform (ReKIS[8]) shall be extended. This platform provides a variety of heterogeneous climate data that cover the study area. This data will be used for the development of climate data products. The offered data range from future climate simulations (e.g. CMIP5[9], WEREX-V[10]), reference datasets (historic data) to raw data (from weather stations).

As a starting point for the development of the climate data products, it is required to bundle these data from various sources, describe them properly (using metadata) and enable possibilities for straightforward data exchange. In recent decades, the geospatial domain has been developing concepts for data management and exchange to support the integration of multiple data sources into a harmonized and coherent data set and the data provision in Spatial Data Infrastructures (SDI) [Be14, Ya19]. In this type of distributed infrastructure, standardized web interfaces are used (mostly specified by the Open Geospatial Consortium, OGC[11]) with the objective of providing interoperable (platform-independent) data exchange. A core component of a SDI are metadata. Metadata are often defined as data about data [Ya08]. They contain important information such as contact points, access information or technical properties (e.g. spatial coverage, spatial/temporal resolution) [Ha18]. In addition, metadata increase the discoverability of datasets, ensure improved transparency and at the best enable the re-use of data [Be14, SM18]. In SDIs metadata are usually managed in a structured form using standard metadata schemas that enable machine readability [Wi16].

[4] The project focuses on selected municipalities in the districts of Burgenlandkreis (Saxony-Anhalt), Greiz (Thuringia) and Vogtlandkreis (Saxony), For more detail, see the map under: https://klimakonform.uw.tu-dresden.de/index.php/modellregion

[5] https://tu-dresden.de/

[6] https://www.ioer.de/

[7] https://www.ufz.de/

[8] https://rekis.hydro.tu-dresden.de/

[9] https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip5

[10] For further information about this model, see: [BPS16]

[11] https://www.ogc.org/

The data providers of the project and the information platform are either climate scientists or responsible employees from the federal state offices. So far, they have little or no previous knowledge to store metadata on specially designed platforms such as WebGIS servers. Experience from other projects has shown similar circumstances. Nevertheless, in order to collect as much metadata as possible, a concept is needed where data providers can store meta-information with tools they already know. In the interest of a sustainable system, this stored metadata is to be automatically applied to the various components of the SDI. The intention is to design a system that requires only minimum intervention from data providers and operators. This article describes the architecture specifics of this data management concept. With the proposed framework, we intend to create a shared and transparent data pool, which potentially closes the gap between scientific results and recommended actions for local policymakers.

2. Architecture concept

As a data management concept, we propose to implement approved elements of a spatial data infrastructure. The key component of our architecture is the existing climate information platform ReKIS. Further components are to be developed and then coupled with this platform (Fig. 1).

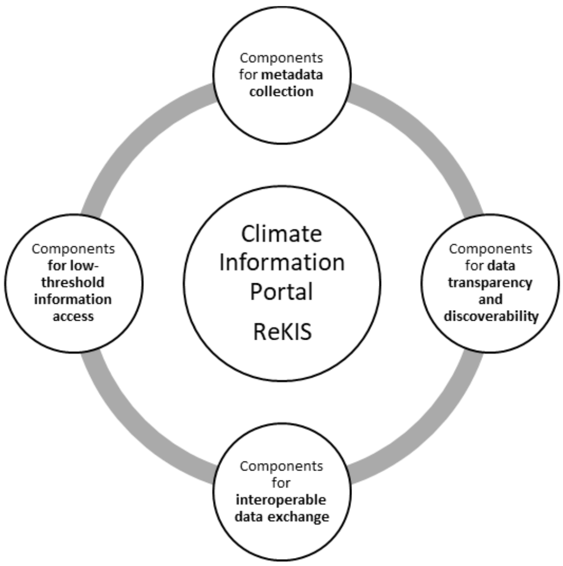

Fig. 1: New architecture components to be developed

1. Components for metadata collection:

   During the process of collection and publication of metadata in the original climate platform (ReKIS), we experienced some obstacles. Firstly, most of the data providers of our project and the ReKIS platform have no prior knowledge of standard metadata schemas or online tools for metadata collection. Therefore, they need practicable tools for metadata collection that do not add technical hurdles preventing them from depositing data and metadata.

   Hence, we decided to implement a semi-automatic approach similar to what has been presented in other works like [ATG22, No20]. This includes a simple Excel template as an easy-to-use method to collect the metadata (manually). In addition, we implemented tools that automatize the remaining process of integrating and distributing the metadata on the other (web-) components. The collected metadata is then transformed into the standardized schema GeoDCAT-AP[12] [RVR19]. GeoDCAT-AP extends the de-facto standard schema for European Open Data Portals DCAT-AP[13] with spatial properties of the standards ISO 19115[14]/19119[15] (Geographic information – Metadata / Services).

2. Components that manage and use the metadata to increase **data transparency** and **discoverability**:

   For metadata management and presentation, a catalogue service that includes all metadata records has been set up. Our catalogue is based on an open source solution called CKAN[16] (Comprehensive Knowledge Archive Network). It also supports the upload of data-supplementing resources like documentations or links to scientific publications. CKAN is an open data platform that is widely used by governments (e.g. Canada, Australia, European Data Portal) or city administrations (e.g. Berlin, Helsinki). It is extensible with own plugins and already implements features for geo-related data[17]. CKAN also provides an API (Application Programming Interface). This interface is capable of converting all records into a JSON representation and is therefore easy to integrate into other applications such as websites. We used this API to automate the process of metadata upload as well as connecting the catalogue with the main climate information platform ReKIS (see chap. ***3 Implemented functionality*** for a description of this connection).

3. Components that support inter-organizational **data exchange**:

   As mentioned earlier, the platform shall support a multitude of participating data providers and the resulting climate data products should be usable for stakeholders from many different organizations. In order to guarantee seamless data exchange over

[12] https://inspire.ec.europa.eu/good-practice/geodcat-ap
[13] https://joinup.ec.europa.eu/collection/semantic-interoperability-community-semic/solution/dcat-application-profile-data-portals-europe/release/11
[14] https://www.iso.org/standard/26020.html
[15] https://www.iso.org/standard/39890.html
[16] https://ckan.org/
[17] http://docs.ckan.org/projects/ckanext-spatial/en/latest/

the web and so build up an effective distributed information infrastructure, it is recommended to host data as a service via standardized web interfaces [Pe10]. These services can be directly connected to GIS applications (both web and local). Subsequently, the data users only stream the data content, whereas metadata and data sources are maintained by the infrastructure hosts [Eu18].

Hence, we set up an instance of GeoServer[18] that implements the open standards specified by OGC and published our geospatial data as web services. Precisely, our server hosts the following services:

a) **Web Map Service[19] (WMS)**: e.g. geographic base data such as administrative units, land use scenarios, water body layers, etc.

b) **Web Feature Service[20] (WFS)**: e.g. flood risk maps, hydro-geological overview maps, digital terrain models, etc.

c) **Web Coverage Service[21] (WCS)**: e.g. grid interpolated climate data (daily/yearly) for the federal states. These include variables like bias-corrected precipitation, mean/max/min temperatures, relative humidity, global radiation, etc.

The metadata of these services are stored in our catalogue service. The OGC community is currently working on new standards[22] that will supersede the old ones. As soon as available, it is planned to integrate these new standards via the WebGIS server as well.

4. Components that enable **low-threshold access** to data and scientific research results:

To derive decision-making tools for climate adaptation, climate information must reflect specific local climate change impacts that are tangible for the local policymakers [Ns21, Si18]. These can be examples of flood events, consequences of droughts or generally the change of the local water balance [Si18]. Especially when stakeholders are not climate experts themselves (like in our case), it is important to make the offered information easily accessible and understandable [Re18].

In order to create a low-threshold presentation of the researched climate information, we decided to add so-called story maps as a further component. In recent years, story maps have been widely used as a tool for knowledge transfer; mainly in the educational context [BHW18, Co18, Th19] but also as a suitable tool for science communication [Ou21, Vo21]. They are an illustrative method to present information with a spatial reference. They can contain interactive maps, text blocks, data visualizations, and other media content. In order not to set up another web server that

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[18] https://geoserver.org/
[19] https://www.ogc.org/standards/wms
[20] https://www.ogc.org/standards/wfs
[21] https://www.ogc.org/standards/wcs
[22] https://ogcapi.ogc.org/

has to be maintained, we decided to use the solution from ESRI[23].

The geospatial web services hosted on our WebGIS server (see 3 *Components that support inter-organizational data exchange*) are used as a layer for web maps. In turn, these web maps can be directly embedded into the story maps. When we update the data sources of the maps, no edits in the story map are necessary, because the data content is dynamically pulled via the services. This is a further detail towards building a sustainable infrastructure.

3. Implemented functionality

The developed spatial data infrastructure includes the above-described components. The current infrastructure implements a straightforward workflow from data provision to its use. For both data providers and users, there are only two points of intervention in this process (Fig. 2). Data providers need to store their data on a FTP-based server intended for this

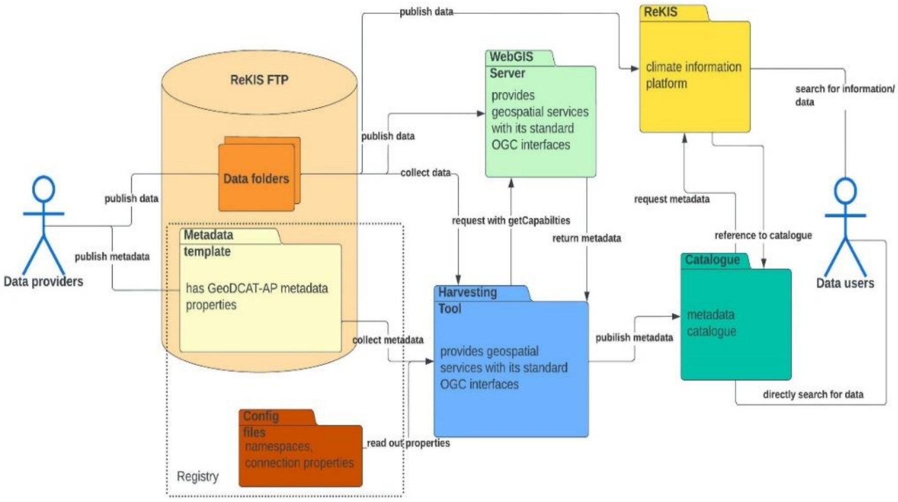

Fig. 2: Workflow from data provision to data use

purpose (see Fig. 2: ***ReKIS FTP***) and fill in a template for respective metadata (see Fig. 2: ***Metadata template***). In a next step, the data get published and available for download via a web service on the main website (see Fig. 2: ***ReKIS***). Currently the data upload data to the WebGIS Server (see Fig. 2: ***WebGIS Server***) is done manually. We are aiming to automate this step as well (c.f. chap. ***4. Conclusion and outlook***). A python-based tool

[23] https://storymaps.arcgis.com/stories

(see Fig. 2: ***Harvesting Tool***) collects metadata directly from the metadata template and from the services hosted by the WebGIS server (WMS, WFS, WCS). Comparable to ETL (Extract Transform Load) tools, the Harvesting Tool maps all the fields of the sources to the catalogue metadata schema and publishes respective metadata records. YAML based configuration files contain all mapping and connection parameters (see Fig. 2: ***Config Files***). With these configuration files, we intend to keep our tools flexible and extensible to new potential data and metadata sources. The objective is to build a data infrastructure that can be flexibly extended with new components as requirements change. Previous experiences with the climate information platform ReKIS show that such climate information platform has constantly to be adapted to the ever-growing amount of information, the technological progress as well as the evolving needs of the end users [Kr21].

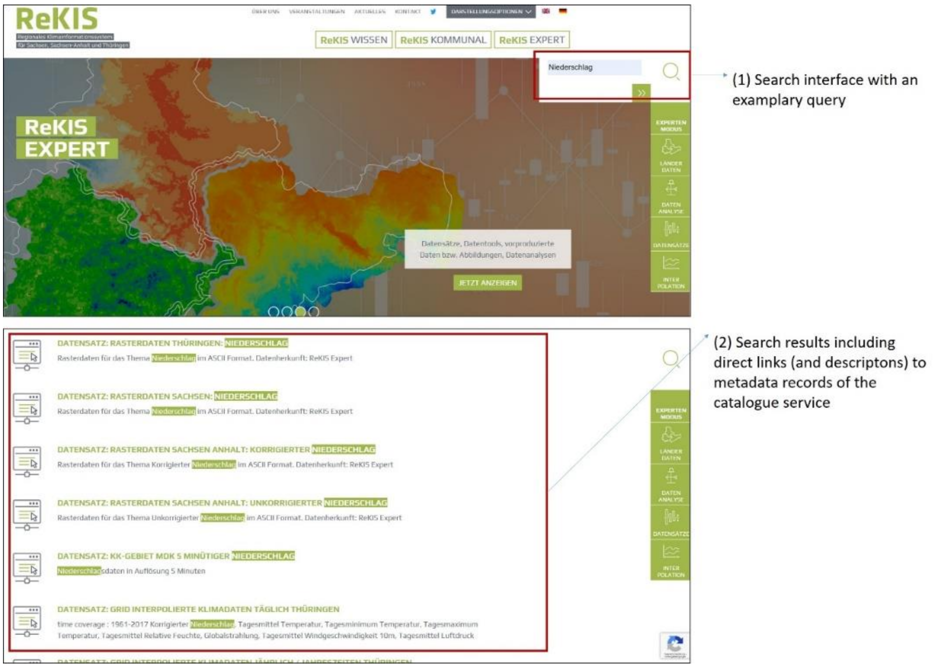

Fig. 3: Integration of the catalogue component into the search interface of the main climate information system

During the implementations, we received feedback from the ReKIS operators that platform users may not know what a metadata catalogue is. Therefore, the provision of a simple Web link to our catalogue service is not sufficient for users. We solved this by a discreet integration of the catalogue service into the search interface of ReKIS (Fig. 3). If users search for a keyword on ReKIS, a request is made to the API of the catalogue in the background. If available, the catalogue API returns metadata records and appends them to the search results page. These search results include a link and a brief description. By clicking on the search results, our catalogue opens in a new browser tab and users can find a data description and access and/or download information. As a result, the two SDI components are integrated and inexperienced users might not even recognize that the provided functionality is actually distributed between the two.

4. Conclusion and outlook

The presented infrastructure is in operational use[24] and regular feedback from the project participants is evaluated to improve the offered functionality. The extensions to the architecture primarily bring benefits for the project participants, who use it for publishing decision-supporting climate data products.

However, there are still features that have to be realized (Fig. 4) in future. As mentioned earlier, the publication of geospatial web services on our WebGIS server is still not working automatically. Further, there is currently no interface to upload the collected metadata to our WebGIS server. The server uses a GeoServer extension[25] that allows customisable configuration of metadata fields. Therefore, it was no issue to adapt the metadata fields to the schema of the metadata catalogue. Furthermore, GeoServer provides a RESTful API[26] that enables automatic upload of data and metadata. The next step is to develop a further Python module that uses this API to

- upload datasets that are stored by the data providers (on ***ReKIS FTP***, c.f. Fig. 2)
- upload/update metadata that the data providers deposit in the metadata template

To implement this, an existing python library[27] that provides methods to connect with the GeoServer-API can be used.

In addition, some of the story maps are still in a conceptual state. In order to summarize and communicate the scientific results of the climate research, the partners have yet to complete their research and environmental modelling. As mentioned earlier, we intend to use the hosted geo services in maps that are embedded in the story maps (Fig. 4). Once the story maps are finalised with content, we will integrate them into ReKIS (similar to the catalogue service).

After all new architectural components are completed and integrated, we aim to evaluate their contribution to creating an open, transparent, and easy-to-access infrastructure. It is envisaged that dedicated user surveys will be conducted for this purpose. Since the WebGIS server, the harvesting tool and the catalogue service use open interfaces, further components can be added if necessary.

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[24] URL of the catalogue service: https://klimakonform-dmp.geo.tu-dresden.de/
[25] https://docs.geoserver.org/stable/en/user/community/metadata/index.html
[26] https://docs.geoserver.org/stable/en/user/rest/
[27] https://github.com/gicait/geoserver-rest

Until the project end of KlimaKonform in April 2023, it is intended to complete the story maps and to publish them on the ReKIS plattform. Further, the functionality to automatically upload (meta-)data on the WebGIS server will be implemented. As the development of the new OGC API standards will not be completed until the end of 2023[28], these will be implemented in the WebGIS server after the end of the project.

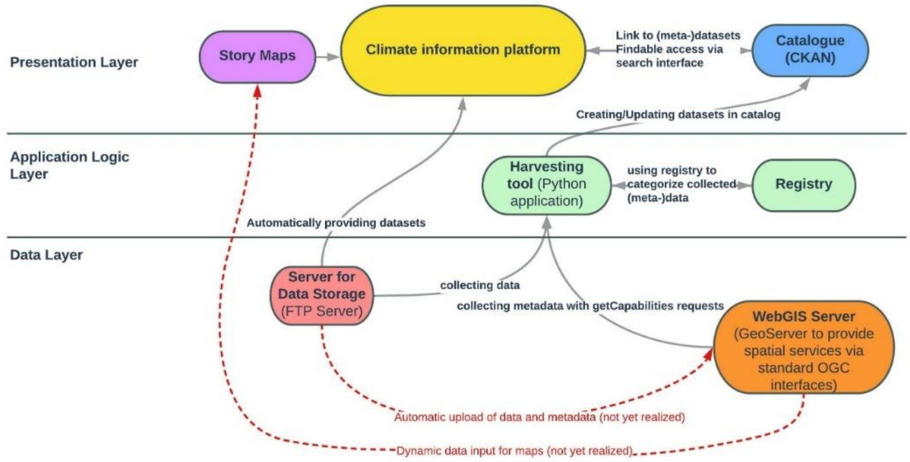

Fig. 4 Future implementation plans to be realised

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