Dynamic Integration of Climate Properties with Geospatial Data for Energy Applications

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Abstract— **The current energy crisis affects the whole Europe, making cross-border provision of climate data indispensable. Energy-related applications are thus becoming increasingly significant also for geospatial service development. Climate properties of the study areas are often critical for informed decisions in energy applications. Energy and climate are selected as important use cases in the GeoE3 (Geospatially Enabled Ecosystem for Europe) project involving five European countries. The cloud-based data integrations platform developed in the project facilitates harmonized access to climate properties provided by meteorological institutes in all of the participating countries. Various download and direct access methods are applied in getting the climate data to the platform, from which it is offered to the client applications via the OGC API Coverages service interface.**

Keywords-climate data; cross-border; harmonization; OGC API Coverages.

I. INTRODUCTION

Consistent cross-border delivery of harmonized climate data has become indispensable with the current energy crisis ravaging whole Europe. It is particularly important to provide access to climate properties in connection of geospatial services [1][2], for example to support energy-related decisions in spatial planning and in the construction industry. Buildings are an important factor in energy-saving endeavors and it is thus critical to provide climate properties readily connected with building data.

The Geospatially Enabled Ecosystem for Europe (GeoE3) project has been developing a cloud-based service platform for cross-border and cross-domain integration of geospatial data resources [3]. Climate data has been selected from the beginning as one of the key data sources in the project. Renewable energy is one of the three use cases of GeoE3, making buildings a central content theme for the project.

GeoE3 involves five European countries: Finland, Estonia, Norway, the Netherlands and Spain. National Mapping and Cadastral Agencies (NMCAs) of each country are participating as members of the project consortium. Cross-border access to 3D building models has been one of the main goals of the project. This goal has been quite successfully achieved, as 3D buildings from all members countries are now available from the GeoE3 integration platform [4].

The national meteorological institute is present in the project consortium only in case of Finland. However, open Application Programming Interfaces (APIs) have been made available by the Norwegian, Dutch and Spanish national meteorological institutes. Dedicated access modules have been developed for the integration platform to accommodate the varying meteorological APIs available.

Climate data is made available to client applications from the platform via the modern Open Geospatial Consortium's (OGC) OGC API Coverages access interface that also enables climate properties to be attached to individual buildings [5].

The rest of the paper is organised as follows. Section II introduces the GeoE3 integration platform. Section III discusses the solutions used for accessing climate data from the five participating countries. Section IV describes the approach applied for the harmonized provision of climate data via the OGC API Coverages service interface. The paper ends with conclusions in Section V.

II. INTEGRATION PLATFORM

The GeoE3 integration platform is a cloud-based service providing single point access to all thematic content offered by the project [6]. The platform is essentially based on pygeoapi, a Python implementation of the OGC API family of service interface standards [7]. On the GeoE3 platform, pygeoapi has been adapted to run on top of the web service development framework called Django [8]. In addition to the selected climate-related content themes: Temperature, Windspeed and Sunshine, the platform also provides harmonized access to the following themes: 2D/3D buildings, 2D/3D roads, Digital Terrain Model (DTM) and Digital Surface Model (DSM). At the moment the platform contains altogether 42 datasets/services (2D buildings: 7, 3D buildings: 7, 2D roads 4, 3D roads: 2, DTM: 6, DSM: 5, temperature: 5, windspeed: 4, sunshine: 2).

Dedicated content provider modules have been developed to access national legacy service end points providing data in national schemas. The integration platform takes care of all necessary harmonization procedures to make the content offering consistent across participating countries, and makes harmonized content available to client applications via the service interfaces conforming to the modern OGC API family of access standards. Physically the integration platform runs

 ISBN: 978-1-68558-079-7

on the cloud service environment cPouta of the Finnish IT Center for Science (CSC) in Kajaani, Finland [9].

III. Access Methods

The development for the provision of climate data service interface on the GeoE3 integration platform started with the Finnish data, as Finnish Meteorological Institute (FMI) is one of the project members [10]. Access to meteorological APIs in Norway and the Netherlands was found via the respective NMCAs. With the help of the Spanish NMCA, an API facilitating download of climate data sets from Spain was then found. A data repository maintained by the FinEst Centre for Smart Cities finally enabled provisional access also to Estonian climate data resources.

The solution for climate data access provided by FMI is based on OGC API Features implementation. The climate properties available from the FMI API include 30 years (1991-2020) averages of temperature, windspeed and yearly sunshine hours [11]. The resulting data set includes temperature values from 99 observation stations, windspeed values from 25 stations and sunshine hours from 8 stations.

From the station values and positions an interpolated grid representation is computed using Python libraries Pandas [12] and SciPy [13]. The interpolation method 'linear' is used, where observation station positions makes it possible, and the 'nearest' operation is applied for the rest of the country's area. The result is saved as a GeoTIFF image file on the integration platform. The stored image is used as the source of the platform's content provision via OGC API Coverages until the file is removed, when the FMI API is accessed again. The same base processing pipeline (see Figure 4) is followed with all the climate themes across all countries' meteorological APIs.

In the case of Norway, a custom API called Frost was used, provided by MET Norway [14]. The API requires registration and use of an API key in all data access requests. The API follows the principles established for a RESTful API and provides the results in JSON encoding. The API provides access to 30 years temperature values from 275 observation stations and windspeed values from 230 stations. Long period averages are computed by the integration platform for the period 1991-2020 and the grid representation then saved into the GeoTIFF file.

Royal Netherlands Meteorological Institute has made available a data access solution called KNMI Data Platform [15]. It offers a flexible API-based file download mechanism. At the moment temperature is the only climate property accessed from KNMI Data Platform. The value is available for 28 observation stations and represents 30 years averages (1981-2010). Values are retrieved from the downloaded NetCDF file using a Python library netCDF4, interpolated into a grid representation and stored as a GeoTIFF file to the integration platform.

The Spanish national meteorological institute Agencia Estatal de Meteorología (AEMET) provides an open access data platform AEMET OpenData [16]. After registration, an API key is provided for accessing the site. The platform offers an Open API -based access interface for retrieval of 30 years' (1981-2010) average temperature values from 105 observation stations, windspeed values from 103 stations and sunshine values from 85 stations. The values are accessed via the API by station, yearly averages are computed from monthly values, and various unit conversions are applied. The climate values are finally interpolated and saved to the GeoTIFF file.

In the case of Estonia, the service development is still ongoing. Historical weather observations are available from the FinEst Centre for Smart Cities [17]. Observation stations datasets are manually downloaded as text files. The files are then processed to retrieve temperature averages for 98 observation stations and windspeed averages for 39 stations. At the moment the Estonian dataset only covers a short period of a few months in 2022.

IV. Service Provision

On the GeoE3 integration platform, Climate data is offered to client applications via the OGC API Coverages service interface. This enables clients to retrieve grid representations for various image-based applications and analysis processes. The platform offers a basic visualization functionality for climate themes, together with simple download options (see Figure 1).

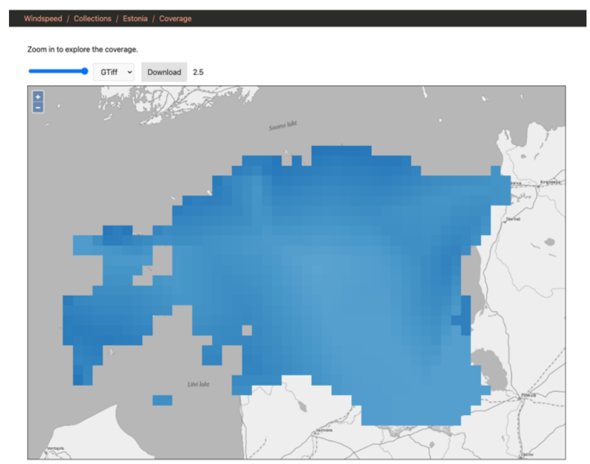

Figure 1. Climate coverage Windspeed of Estonia, visualized in the user interface of the GeoE3 integration platform.

Participating countries are treated as individual data collections inside the single theme-specific OGC API Coverages service instance. For example, the theme 'Temperature' contains currently five data collections, one for each participating country. This arrangement enables natural cross-border data integration inside a single service end point. The current availability of climate properties is shown in Table 1.

TABLE I. AVAILABILITY OF CLIMATE PROPERTIES.

	Temperature	Windspeed	Sunshine
Finland	Yes	Yes	Yes
Estonia	Yes	Yes	
Norway	Yes	Yes	
The Netherlands	Yes		
Spain	Yes	Yes	Yes

 ISBN: 978-1-68558-079-7

Via the OGC API Coverages interface, climate properties can also be queried at arbitrary point locations across the whole data extent. This enables these properties to be connected as additional attributes for example to individual building features. On the GeoE3 integration platform, this connection is made to the 2D buildings. An example of a Finnish building with climate attributes displayed is presented in Figure 2.

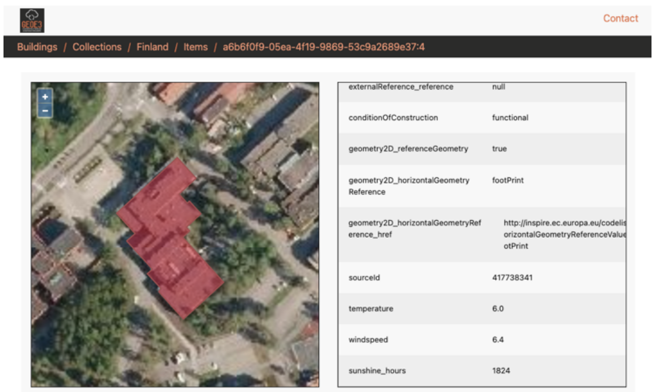

Figure 2. The selected Finnish 2D building shown with the climate-related attributes.

Map visualization of the current integration platform's user interface is based on OpenLayers library [18]. Support for OGC API Coverages has been added by custom code making use of OpenLayers source class ImageStatic.

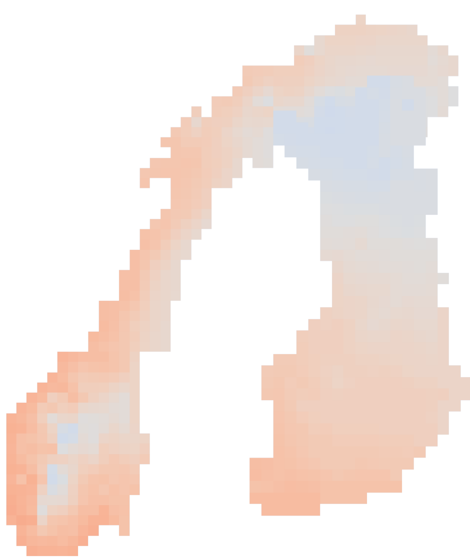

Figure 3. Integrated temperature visualization covering the area of Finland and Norway.

The so called cross-collection query mechanism facilitates cross-border content queries to be made. Currently this mechanism is officially defined only for the OGC API Features interface specification [19]. In the GeoE3 project, an experimental cross-collection query support has been developed for OGC API Coverages service. The query can be formulated as follows:

```
.../geoe3/temperature/search?
   f=png&
   collections=temperature_NO,temperature_FI&
   subset=x(396919:3888202),y(7701052:11580281)&
   scale-size=x(900),y(1000)
```

With the 'collections' parameter, the desired data collections can be identified. If the query extent, defined by the parameter 'subset', crosses a country boundary, the resulting image will be an integrated visualization of the output of the involved countries. Consistent color maps have been applied for all countries' climate themes, making the visualizations comparable across national borders. As an example, the image resulting from the above query is shown in Figure 3.

V. Conclusion

A dynamic content integration mechanism has been established on the GeoE3 integration platform. Participating countries' datasets are treated as individual data collections inside an OGC API Features or OGC API Coverages service end point. This arrangement enables natural cross-border integration of geospatial content. This kind of integrated dataset can be accessed from the platform employing the so called cross-collection query mechanism, officially defined for OGC API Features and experimentally implemented for OGC API Coverages on the GeoE3 integration platform.

Cross-domain integration has been achieved by accessing climate properties representing long period averages from various custom APIs provided by meteorological institutes. A dedicated provider module has been developed on the integration platform for each API to accommodate the differences in service protocol and content encoding. The result is stored in a GeoTIFF image as cache on the platform. Harmonized climate properties are then delivered via the OGC API Coverages interface, enabling both raster image and point value retrieval. Point values are integrated by the platform as additional attributes to the building features also available from the platform.

The cross-border and cross-domain content integration functionality offered by the GeoE3 integration platform facilitates applications requiring access to harmonized, geospatially referenced climate data across Europe. In particular, combined with building datasets, the climate properties support applications aimed at saving of energy or finding new renewable energy solutions.

Acknowledgment

The GeoE3 project is co-financed by the Connecting Europe Facility (CEF) of the European Union with the grant agreement number INEA/CEF/ICT/A2019/2063390.

The authors wish to acknowledge CSC – IT Center for Science, Finland, for computational resources.

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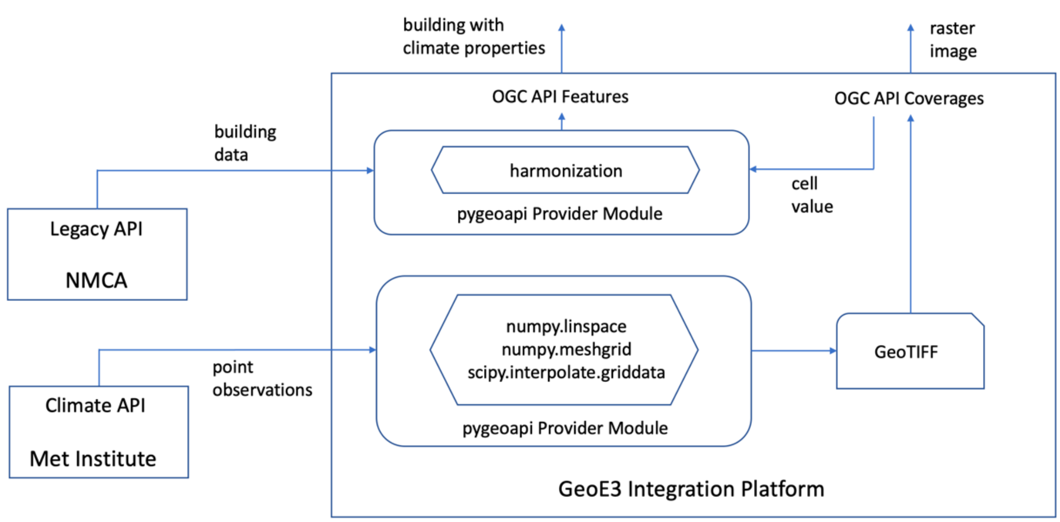

Figure 4. Processing pipeline for the OGC API Coverages-based provision of climate data on the GeoE3 integration platform.