Geo-WC: Custom Web Components for Earth Science Organizations and Agencies

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Abstract

The development of web technologies and their integration into various fields has allowed a new era in data-driven decision-making and public information accessibility, especially through their adoption of monitoring and quantification environmental data resources provided by governmental institutions. While the use of web technologies has given way to the creation of democratized applications, challenges persist in dealing with non-standardized data formats, especially considering the complexities of environmental data. To overcome these challenges and obtain up-to-date information from different institutions, we present Geo-WC: a web component framework specifically designed for earth and environmental sciences, serving as a bridge across various scientific domains. The Geo-WC utilizes a developer-friendly approach through simple HTML declarative syntax to unify information in a consolidated processing interface, allowing accessibility to users with different skill sets. The framework integrates widely used web technologies, facilitating client-side data analysis, visualization, and accessibility within web browsers.

Keywords

Hydroinformatics; web components; hydrology; environmental science; governmental agencies; FEMA; USGS; NOAA; EAUK

Software Availability

Name	Geo-Web Components (Geo-WC)
Developers	Sümeyye Kaynak, Baran Kaynak, Carlos Erazo Ramirez
Contact information	300 S. Riverside Dr., Iowa City, IA 52246 USA
Software required	Web Browser
Program language	JavaScript, HTML, CSS
Data Availability	Sample data can be found in each case study in the library's repository.
Availability and cost	The code is open-source and freely accessible on GitHub.
Code repository	https://github.com/uihilab/Geo-WC

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1. Introduction

Scientific domains like environmental sciences, disaster management, and related fields have increasingly leveraged information and communication technologies to process observational data and facilitate diverse means of public information access (Haseeb et al., 2019). This data is crucial for making well-informed decisions concerning subjects such as disaster events like floods (Li and Demir, 2022), wildfires, or establishing more comprehensive models that provide researchers and decision-makers with greater insights into particular technology-driven domain (Alabbad et al., 2024).

Considerable volume of data generated from diverse sources resides in large storage units, serving as a cornerstone for disseminating information through web interfaces like APIs (Application Programming Interface), web pages, or entities enabling access to these resources. The linkage between resources and users has transitioned from being a complicated task to a more streamlined and accessible endeavor. However, despite significant efforts to develop inclusive applications and approaches utilizing these extensive datasets, there is a challenge for users of all skill levels to understand the particulars of information technology (Cheah, 2020). Furthermore, data obtained from sources such as sensors, models, and other observational methods are oftentimes not following standardized formats, presenting difficulties in adaptation and generalization for public consumption (Horsburgh et al., 2016; Kamel Boulos et al., 2011). The end user needs to compromise between different formats and data representations (Demir and Szczepanek, 2017), removing focus from what the data is representing.

The integration of web technologies within environmental sciences stands as a fundamental push forward towards enhanced and more holistic data analysis, visualization, and accessibility (Vitolo et al., 2015; Sit et al., 2021; Erazo Ramirez et al., 2024). These technologies have allowed the creation of visualization interfaces (Sermet and Demir, 2022) and analytical frameworks operable directly within web browsers, falling under standards stipulated by web authorities facilitating the effective adoption of new technologies. Moreover, the implementation of technologies like web components (W3C, 2014) has notably removed significant obstacles in using programming languages by allowing data-driven instructions through markup language (Xiang and Demir, 2022). These introduce simple HTML declarative syntax, enabling the consolidation of information into a singular processing interface, thus removing the requirement of all connectivity aspects of a web application. This approach allows the development of applications that effectively bridge the gap between web technology and various scientific disciplines, including earth sciences.

In this study a generalized framework, Geo-Web Component (Geo-WC), has been developed to serve up-to-date data from agencies with diverse purposes and data formats through data APIs. The framework has been developed specifically for agencies within the environmental sciences, establishing a connection between web technologies and various scientific fields by consolidating information into a single user interface using a simple HTML declarative syntax. Despite the complexities of information technology, the Geo-WC framework enables easy access to a significant volume of data generated from diverse sources, making it more user-friendly for both novice and advanced users.

The paper structure is organized as follows: Section 2 provides an exploration of the technological background and related applications, along with the agencies used for the framework's development. In Section 3, we delve into the development of the Geo-WC framework, discussing its architecture and scalability. In Section 4, we present case studies illustrating the application's usage across different agencies and data types. Finally, Section 5 offers a conclusion, summarizing the application's key aspects and outlining potential future work.

2. Background

2.1. Web Components

Web development has witnessed significant advancements in recent years, with a focus on creating modular, reusable, and maintainable code. One of the key contributors to this evolution is the emergence of Web Components, a set of standardized, encapsulated components that enable developers to build powerful and efficient web applications. The rapid growth of web technologies has led to the need for more flexible and scalable solutions in web development. Web Components, consisting of custom elements, shadow DOM, HTML templates, and HTML imports, offer a standardized way to encapsulate and reuse components across different projects and frameworks (Mozilla, 2024; W3C, 2014). The technology consists of the following:

Custom Elements: Custom Elements allow developers to create and use their own HTML elements. This feature allows the development of highly modular and reusable components, promoting a more efficient and sustainable approach to web development.

Shadow DOM: The Shadow DOM (Document Object Model) is a web standard that allows developers to encapsulate and isolate the structure and style of a part of a web page within a scoped and self-contained container. It provides a way to create components with encapsulated styles and behavior, preventing these components from unintentionally affecting or being affected by styles and scripts outside of their scope.

Templates and Slots: In the context of web components, which facilitate the creation of reusable components by integrating HTML, CSS, and JavaScript, the <template> element serves to articulate the internal structure of the component, ensuring isolated style management. Furthermore, the content within the template can be dynamically cloned and utilized through JavaScript. The <slot> element in HTML is a crucial feature within web components, providing a designated area where external content can be dynamically inserted. It acts as a placeholder within the shadow DOM, allowing users of the web component to inject content into specified slots. This enables a flexible and customizable approach to content insertion, as different slots can be used to target specific regions within the component. Its ability to handle multiple slots provides a versatile mechanism for organizing and structuring content within a component, offering enhanced flexibility and customization possibilities.

2.2. Related Work

There have been numerous applications of web components since their integration into web browsers, owing to their adaptability in developing self-contained tags capable of inherent communication between other components using existing in-browser technologies. Although these applications have different purposes, they contribute to the creation of general-purpose principles and technologies for web application development. We describe different applications of web component technology in the following paragraphs.

Regarding industry uses, Salesforce Lightning Web Components showcase integrated components within the company's platform. Salesforce, a cloud-based customer software company, is built upon contemporary web development standards and structures. It incorporates web component technology to drive various applications, including the visualization of tabular data, imagery, forms, and other customer-based input data (Coenraets, 2018; Yin, 2019). Another example is Project Fugu, allowing developers to implement desktop-class productivity apps using web technologies. Web components were utilized in the creation of Paint.js.org, a web-based Microsoft Paint clone (Chromium, 2024; Liebel, 2021).

In the domain of chemistry and chem-informatics, the ChemDoodle web components represent a library working as a toolkit for generating chemically-driven graphics and facilitating molecular structure editing. It serves as an informatics solution in crystallography, material science, and related fields (Burger, 2015). In information technology, leveraging the core attributes of reactivity and state control offered by web components, Nishizu and Kamina (2022) implemented micro-frontends using signal-based components. These allow high modularity, expressing web components as signals and enabling single-page applications, thereby ensuring an effective declarative dataflow.

Instant Expert, an open-source web framework designed for building voice-enabled smart assistants or chatbots (Sajja et al., 2023), serves as a web platform employing web components as a fundamental aspect of its underlying technology. By integrating simple HTML code into an application, it enables a diverse array of customization tools for chatbots. The library contains features facilitating the parsing, processing, and modeling of both same-origin and cross-origin web pages as information resources (Sermet and Demir, 2019).

In the domains of environmental and hydrologic sciences, HydroLang-ML (Erazo Ramirez et al., 2023) stands as a web component interface within the Hydrolang.js framework (Erazo Ramirez et al., 2022), facilitating the utilization of the library via HTML-declared elements that directly translate instructions, readily accessible within the web application employing the interface. Its primary aim is to serve as a research and educational tool, allowing a smoother interaction between programming languages and web development within these fields.

Despite the widespread use of web components across various domains, existing literature shows the need for more applications leveraging web components in the earth sciences. This pertains particularly to merging data acquisition and comprehension, along with democratizing information through web-ready interfaces. Advancing scientifically driven decision-making approaches can significantly benefit from novel applications harnessing the cutting-edge technology of web components. Moreover, in the United States and globally there is a push towards data democratization through government-funded initiatives that promote data acquisition, analysis, and public distribution. These efforts allow users worldwide to make data-informed decisions. In this regard, the Geo-WC framework and library enables developers and researchers to interact with data and integrate agency resources into their applications.

2.3. Governmental and Scientific Agencies

In an effort to promote data democratization and incorporate diverse resources from a data-driven perspective, governments worldwide establish agencies to disseminate information to the public through different channels. This information serves as a critical component within a broader perspective, enabling decision-makers to formulate data-driven decisions and empowering the public for enhanced information usage. The following paragraphs delve into descriptions of some of the agencies used for the development of the framework.

The Federal Emergency Management Agency (FEMA), a US federal government-led agency established in 1979, assumes responsibility for responding to and facilitating recovery during moments of crisis within the United States (FEMA, 2024). Serving as an access point, FEMA provides information for disasters across the country, providing details that include location, nature of the disaster, dates, and related information to support disaster planning, response and recovery efforts (Alabbad and Demir, 2022; Yildirim et al., 2022).

The United States Geological Survey (USGS), working as a scientific bureau of the US government, provides scientific insights and data concerning natural hazards and the ecosystem, including water, energy, minerals, and other natural resources (USGS, 2022). It is entrusted with the collection, monitoring, analysis, and interpretation of scientific data pertaining to natural resource conditions.

The Environmental Protection Agency (EPA) is tasked with distributing information regarding significant risks and issues concerning water and air quality, flooding events, contaminant pollution, and related domains (EPA, 2022). The agency offers information through diverse channels, including maps, specified data centers, and several open-access data sources.

The National Oceanic and Atmospheric Administration (NOAA) operates with the primary objective of keeping the public informed about environmental data, including weather forecasts, severe storm warnings, and climate monitoring (NOAA, 2024). Additionally, it attempts to deepen our understanding of the natural world while safeguarding national borders through global weather monitoring. An example of information disseminated by the agency is the National Weather Service (NWS), offering comprehensive weather-related insights covering the US and abroad (NWS, 2024).

Beyond the United States, European agencies such as the Environmental Agency of the United Kingdom (EAUK) provide information regarding the country's environment, spanning waterways, fisheries, flood warnings, waste management, environmental incidents, and more (EAUK, 2024). These agencies make data accessible to the public through a variety of interfaces and public resources.

The experience gained from recent disasters, coupled with the advancements in emerging technologies and with a deeper understanding of climate change and its implications in the future has significantly increased the amount of information provided to personnel, emergency managers, and the general public. Collaborations among agencies including but not limited to NWS, USGS, EAUK, NOAA, and FEMA have enabled data distribution, monitoring, and forecasting in different and broader fields before, during, and after disasters (Wing et al., 2018). These collaborations, forming a consistent framework, allow data-driven decisions. Additionally, they facilitate active public engagement and enable the use of information for the improvement of society.

Web applications aid user access to rich data sources provided by governmental agencies, enabling meaningful data visualization. The development of a web component plays a crucial role in consolidating data from various agencies into a unified interface, providing users with easy access to information from diverse sources. The Geo-WC simplifies information usage, allowing users to explore detailed insights on their chosen topics in a centralized framework. Moreover, it promotes collaboration among agencies and contributes to information democratization, fostering a more informed and prepared society. The framework's generic structure ensures flexibility, making it easy to incorporate different agencies. This characteristic significantly expands its scope and motivational impact.

3. Methods

3.1. HydroLang.js framework

HydroLang library provides a comprehensive suite of tools and functions for developing web applications in environmental and hydrological sciences, available through a JavaScript API (Erazo Ramirez et al., 2022). It operates through four distinct modules, each designed using an object-oriented architecture and following a loosely coupled, highly modular ontology:

- <u>Data Module:</u> Establishes connections to various global data sources and types via RESTful APIs, offering tools for data transformation and manipulation.
- <u>Analyze Module:</u> Equipped with tools for data analysis, including statistical analyses, hydrological functions, and a tool for creating feed-forward shallow neural networks.
- <u>Visualize Module:</u> Created to generate visual representations like graphs and tables using Google Charts.
- <u>Maps Module:</u> Facilitates the visualization of geospatial data on a map interface within web applications.

The library's primary goal is to serve as a single resource for the development of comprehensive web applications that connect with global information data sources. Notably, the data module is a standout feature, allowing data retrieval in multiple formats such as JSON, geoJSON, XML, CSV, tabular, and binary. This enables users to give multiple parameters without requiring extensive request modifications.

3.2. System Architecture

The Geo-WC is a generic framework that integrates with various APIs to fetch real-time data and information, supporting a wide range of data formats, specifically aiming for the environmental domain. It has been designed to be used within multiple domains in environmental sciences, including but not limited to variables such as precipitation, evapotranspiration, streamflow, water and air quality, serving as a multi-purpose interface for data integration in use cases such as mapping disaster declarations or information gathering gadgets such as environmental observations. The application provides essential information such as geographic data, alerts, and flood extents, presenting outputs in formats such as maps, tables, graphs, and JSON/CSV. The system's architecture ensures adaptability, efficiency, and data integration, catering to the diverse requirements of different agencies. The processes required for displaying data on a web page from an agency is shown in Figure 1, with and without the use of Geo-WC framework. When developing the functionality for an agency using traditional methods, steps such as API connection, creation of specific requests to the API, data processing, and presentation of data in different formats needs to be implemented, through the use of web programming such as JavaScript and HTML.

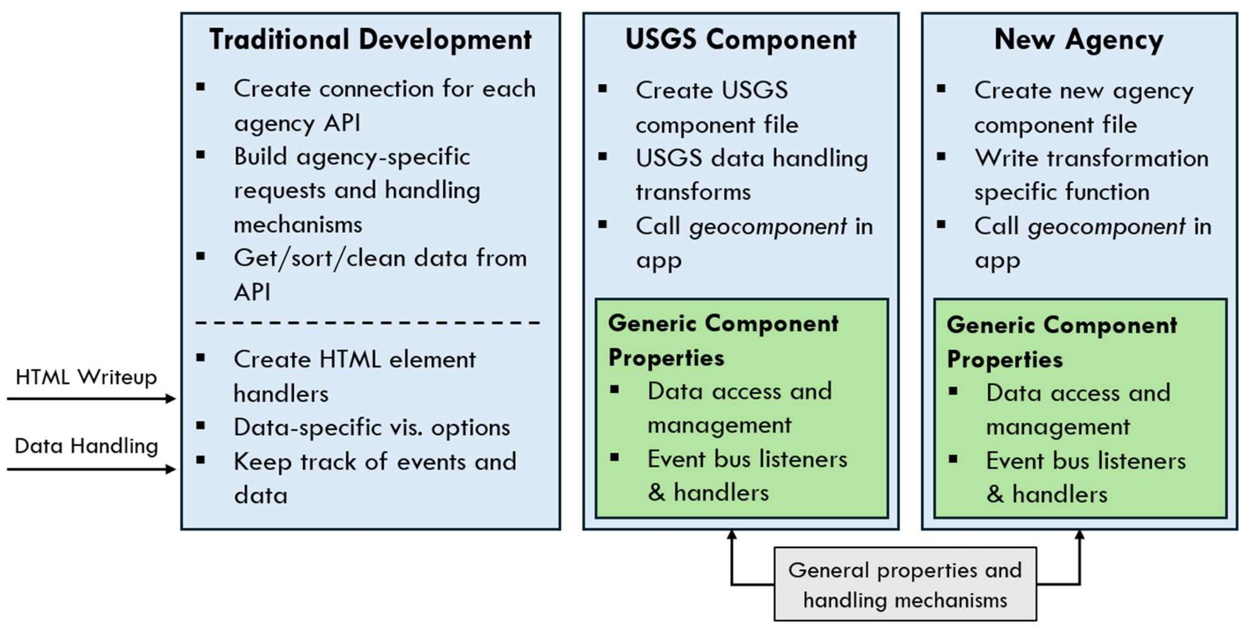


Figure 1. Traditional data request vs the approach taken in the Geo-WC library.

The use of the Geo-WC enables either the use of an existing implementation for a particular agency or a new development with minimal code interfaced through customized HTML tags. A developer can leverage pre-designed property objects through generic components for the creation of a new agency component. Consequently, it suffices for the developer to define transformation functions specific to the agency and place them within a predetermined folder.

Figure 2 illustrates the main and sub-component groups, as well as the libraries used in the Geo-WC framework. The generic component integrates HydroLang and CacheManager libraries, with CacheManager utilizing the IndexedDB API for data storage (W3C, 2023), while the map feature uses the Leaflet library (Agafonkin, 2023). The primary groups consist of agency components derived from a generic structure, enabling developers to create customized elements. Subcomponents, designed for independent functionality, stem from a sub-generic source—an HTML element leveraging the application's generic structure. The sub-generic component includes structures for other components for map, outputs, tables, and graphs. Communication between custom HTML elements within this source is facilitated through the EventBus component.

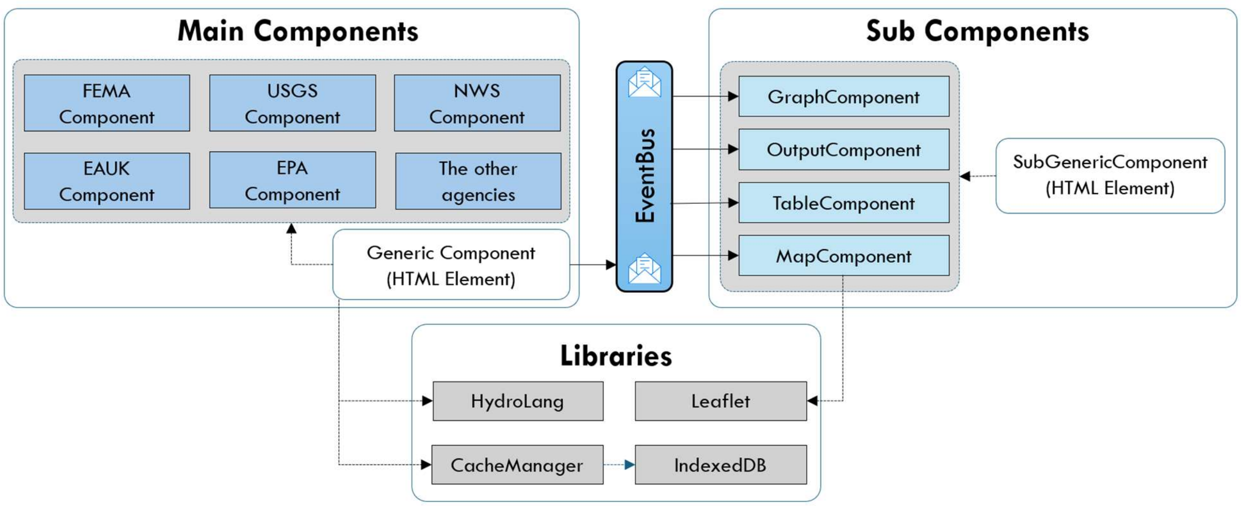


Figure 2. The generic architecture of Geo-WC framework, powered by a collection of libraries, allows integration with information globally, utilizing the user's available resources.

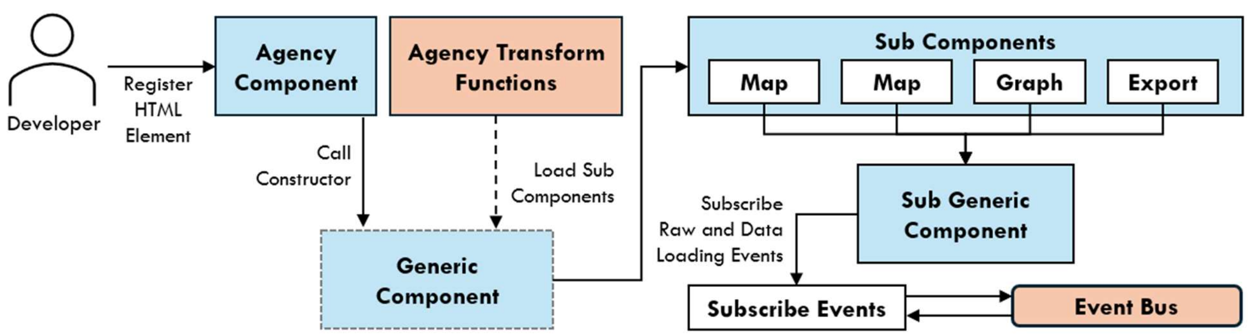


Figure 3. Flowchart of Geo-WC framework initialization and loading.

The framework's generic structure serves as the main building block for creating agency-specific web elements. As shown in the flowchart of Figure 3, users embed a custom HTML tag corresponding to the agency into a web application. This element is derived from the generic component module, which, in turn, inherits from HTMLElement, and used for creating new agency components. During the initialization of the agency element, the first constructor methods are invoked, generating a unique identifier for the loading element. This ensures that each agency element uses its designated identifier when transmitting and receiving data on the event bus, preventing unintended data mixing between different elements and efficient management of all lifecycles and sub-elements in the development of new agency elements.

Addressing the challenge of different types of agency data structures, the subcomponents are not informed of agency-specific formats, requiring a transformation function for each agency provided by the developer. This contributes to the complexity of sub-component code and makes it challenging to manage. To address this issue, a simplified approach was applied in which each agency's component encapsulates all the necessary transformation functions for its sub-components. During initialization, sub-modules receive these functions as parameters from the main component, allowing easy transfer through the sub-module loader. This process ensures that each agency's data, regardless of its format and hierarchy, can be integrated into the web component. For example, agencies like USGS and FEMA provide extensive information in JSON format with distinct hierarchical structures. Specifically, USGS agency's observation datetimes and data values are extracted from the JSON objects as shown in the following example:

```
"$.value.timeseries[0].values[0].value[*].value"
"$.value.timeseries[0].values[0].value[*].datetime"
```

Defining these paths depends on the understanding of the data structures from an agency and transformation functions provided by the developer. Derived from the sub-generic component, sub-components feature event subscription and DOM initialization functions. The event bus ensures data transfer, with subcomponents subscribing to `DataReadyRaw` and `DataLoading` events, allowing development of a loosely coupled subcomponent. The Geo-WC's data flow is illustrated in Figure 4. The agency's component builds the necessary arguments and parameters and invokes the `RunData` function on the generic component. The component checks if the cache module is active or not. If it is active, it utilizes the cache module to retrieve data from and store data to the cache. The HydroLang library manages all agency-specific API calls with the provided arguments and parameters. The data received from the HydroLang data retrieval module, or the cache module is then sent to the event bus.

All sub-components are subscribed to the event bus, allowing them to receive data and respond to other events. Upon receiving the `DataReadyRaw` event, sub-components execute transfer functions sent from the agency component as parameters. Subsequently, each sub-component runs its unique data-specific function to visualize data through graphs, maps, tables, or export the data.

The `RunData` function in the generic component follows a structured process for data retrieval. It begins by checking the status of the cache module – if active, it generates a unique key based on the data obtained from the API and relevant parameters. Afterwards, it searches for this key in IndexedDB, and upon finding it, directly retrieves the data without triggering an additional API call. In cases where the key is not found, the module initiates an API call, stores the retrieved data along with the key in IndexedDB, and disseminates the data to other components through the event bus.

In instances where the cache module is inactive, the raw data is transmitted directly to other components via the event bus ,as shown in Figure 5. To enable the cache module, the '`cache=true`' attribute should be added as a parameter. This streamlined process optimizes data retrieval within the application by mitigating unnecessary API calls, thereby enhancing responsiveness, and leveraging IndexedDB instead of local storage to accommodate potentially large datasets. Additionally, the unique identification of data for each component helps remove data conflicts, particularly when multiple components are integrated onto the same page.

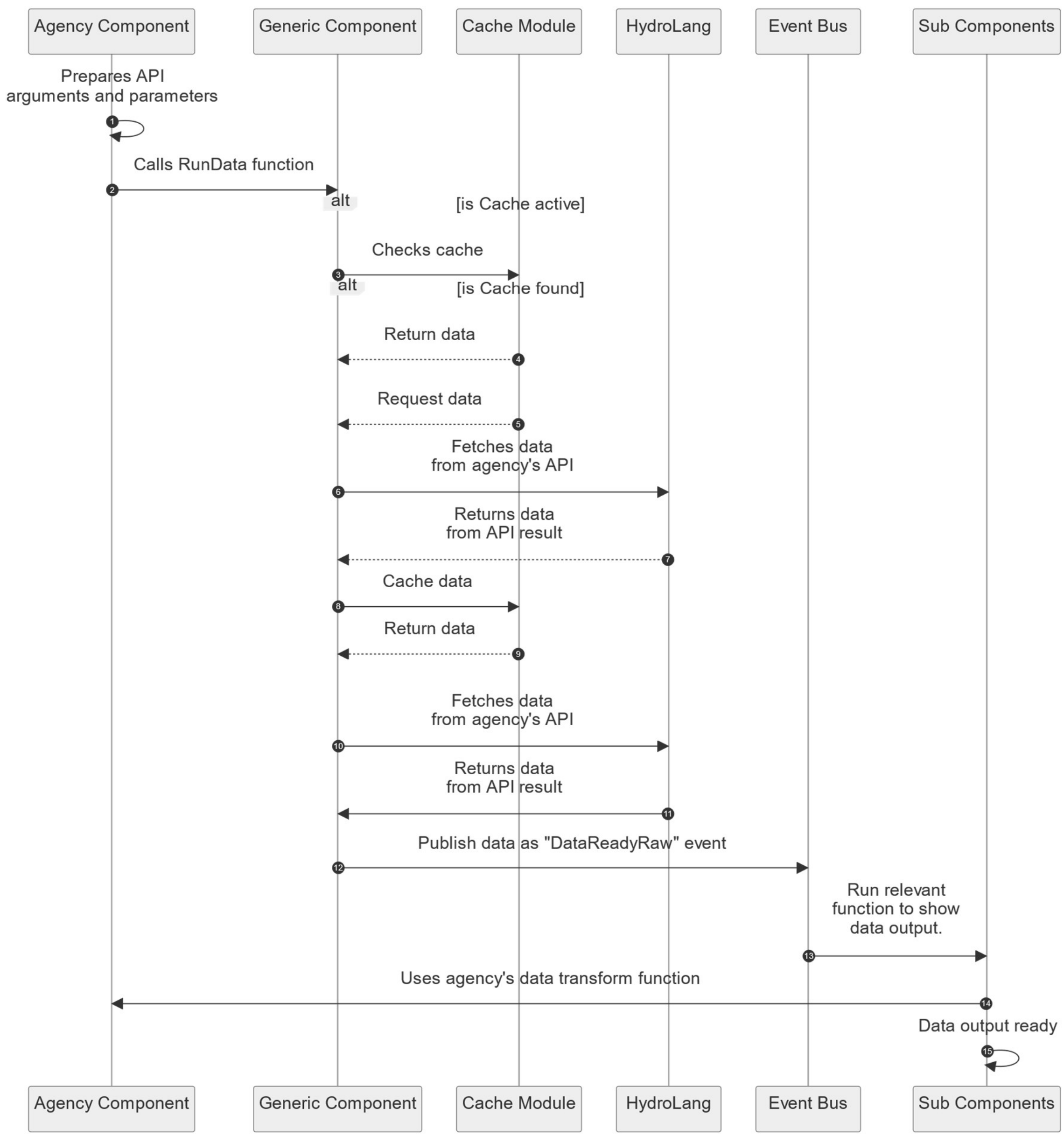


Figure 4. Sequence diagram for data flow between agency component and sub-components.

3.3. Sample Use Cases

The Geo-WC framework facilitates the display of data from agencies providing services in various fields. Leveraging the HydroLang library, the application allows for the rapid development of web components for different data providers. The generic structure enables the quick and easy development of web components tailored to different scopes and topics, supporting the download and visualization of data from various data services. Sample agencies such as USGS, FEMA, EPA, NWS, and EAUK, each serving different purposes and providing services in different data types, have been added to the application for initial development. The properties of each agency detailed in Table 1.

The declaration of an agency as a component is shown in Figure 6(a). The `'service'` parameter determines the specific service offered by the data provider. It identifies the service that the application is directed to and specifies the type of data or functionality that this service provides.

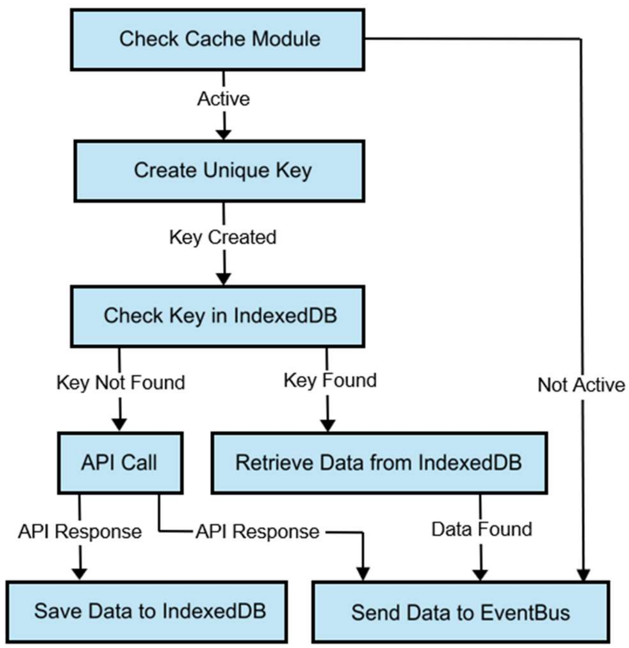


Figure 5. Data calls and database management through the cache module.

Table 1. Description of each of the agencies used for the development of the framework.

Agency	Service Type	Domain Focus	Data Type	Data Format
USGS	Observation	Streamflow	time series	JSON
FEMA	Alerts	Disaster declarations	categorical / textual	JSON
NWS	Maps and geoData	Stations	point	KML
NWS	Observations	Stations	time series	geoJSON
EPA Storet	Observations	Water Quality	time series	geoJSON
EAUK	Observations	Water Quality	time series	JSON

3.4. Data Retrieval

To retrieve data from any source, it is necessary to prepare and transmit specific request information to a web service through a set of specific parameters which vary per agency. Figure 6(b) shows how to give the request information through the API arguments component. The definition of `<api-args>` can be done in two different ways. In the first case with the flag "`raw=true`," the parameters of agencies are explicitly written in detail. In the alternative case, agencies do not need to specify their parameters explicitly and default parameters are created by the application. Parameter examples like *date* and *interval* are transformed into the date range format specific to each agency.

```
<agencyname-ml service="servicetype">
</agencyname-ml>
```

(a)

```
<agencyname-ml service="servicetype">
    <api-args raw="true" <!-- Parameters of agencies-- > </api-args>
    <api-args startDate="2023-11-01" timeInterval="1d"></api-args>
</agencyname-ml>
```

(b)

Figure 6. (a) Custom element for a generic agency, including an attribute for the service type required from the agency and (b) The definition of the API arguments for the service as multiple components appended as children of the main agency component.

3.5. Data Output Subcomponents

The Geo-WC includes sub-components developed for the web representation of data obtained from agencies with the functionalities previously mentioned. Once data has been retrieved and transformed by the agency-tailored sub-component, it is displayed in the format supported by the sub-component. Data types that can be displayed on the map include geoJSON and KML. JSON can be displayed across all sub-components based on selected features of the data. Multiple sub-components can be used simultaneously within an agency.

Displaying data in tabular format can be done using the geoweb-table component, which creates an HTML table prompt on screen, as shown in Figure 7(a) while the geoweb-map component shown in Figure 7(b) leverages the Leaflet library to create a map on screen. To display data on the graph, the HTML component for graphs is declared as shown in Figure 8(a). The geoweb-graph tag presents the relevant data graphically using the Google Charts library. Displaying graphics can be done using the geoweb-graph component with user-tailored changes passed as attributes. Finally, to download data in CSV or JSON formats for all agencies, the geoweb-output component can be used as seen in Figure 8(b).

```
<agencyname-ml service="servicetype">
    <api-args startDate="2023-11-01" timeInterval="1d"></api-args>
    <geoweb-table></geoweb-table>
</agencyname-ml>
```

(a)

```
<agencyname-ml service="servicetype">
    <api-args startDate="2023-11-01" timeInterval="1d"></api-args>
    <geoweb-map></geoweb-map>
</agencyname-ml>
```

(b)

Figure 7. (a) Use of the geo-web table and (b) the geo-web map component using data retrieved from an API.

```
<agencyname-ml service="servicetype">
    <api-args startDate="2023-11-01" timeInterval="1d"></api-args>
    <geoweb-graph></geoweb-graph>
</agencyname-ml>
```

(a)

```
<agencyname-ml service="servicetype">
    <api-args startDate="2023-11-01" timeInterval="1d"></api-args>
    <geoweb-output type="json"></geoweb-output>
    <geoweb-output type="csv"></geoweb-output>
</agencyname-ml>
```

(b)

Figure 8. (a) Geo-Web graph component and (b) Geo-Web output components from the same service.

3.6. New Agency Component

Web components, serving as a standard in web development and finding extensive use in diverse industries like social media (i.e., Twitter, Instagram), are also the pioneering technology behind frameworks such as React and other front-end libraries. This dual role showcases the versatility and foundational importance of web components in shaping the modern web landscape, both in terms of industry-specific implementations and earth sciences. The Geo-WC framework is not limited to geospatial data; it has been designed to handle various types of data available in web applications. This versatility makes it an attractive choice for developers or researchers working with diverse datasets. The flexibility of the architecture allows developers to create components tailored for specific endpoints and agency requirements. This adaptability ensures that the web component can effectively meet the unique needs of the agency or research project.

A new agency can be easily created using the generic component. The steps required to add a new agency are as follows, with sample use cases provided in the following section:

- A folder named after the agency to be added (usgs, fema, etc.) is opened under 'lib,' and within that folder, a file named agencyNameComponent.js (e.g., usgsComponent, femaComponent, etc.) is created.
- The components of agencies such as usgs, fema, nws, epa, eauk follow a standard structure. The content of any agency component can be utilized for a new agency component.
- The source and datatype information in the agencynameComponent.js file is updated for the new agency.
- Agency-specific transformation functions are provided by the developer under the agency folder. These functions are required to convert agency data into sub-components data format and transferred to the respective sub-components at runtime.
- In the `<head></head>` section of the index.html page, the newly created agencyNameComponent.js file is imported.
- The definitions for the agency are made within the `<body></body>` tags.
- Code snippets suitable for the agency's outputs are written.

4. Result and Discussion

The acquisition, downloading, and visual presentation of data play a crucial role in information-based decision-making processes, contributing valuable information for users in different sectors including sciences, business, and public-related ventures. Specifically in environmental and hydrological sciences, accurate and up-to-date data is crucial for creating effective strategies, measuring performance, and enhancing predictability (Kurtz et al., 2017). An example of how important data-driven decision-making monitoring is flooding events, such as the Midwest flood of 2008 which resulted in significant damage to several countries across the state of Iowa.

Agencies such as USGS, NOAA among others play a crucial role by having station-ready data for potential impacts and development of preventative measures, specifically in the changing nature of flooding exacerbated by climate change (Demir et al., 2022; Mallakpour & Villarini, 2015). Moreover, with the utilization of large language models (Pursnani et al., 2023) for the development and integration of climate data into conversational interfaces (Vaghefi et al., 2023; Sermet & Demir, 2021), web components can be leveraged to create more integrated and scalable web applications. Considering the latter, the framework can be used to acquire and visualize data from multiple sources with data stations easily incorporated into the framework.

An illustrative case study was conducted to demonstrate the use of the framework and demonstrate its capabilities to retrieve, process and visualize data from different domains through HTML components. Examples showcase displaying data from agencies with different domains, data types, and outputs through the usage of the generic components.

4.1. Data Retrieval

The declaration of the USGS agency component is illustrated in Figure 9(a). The provided code snippet is designed to use the '`instant-values`' service, among the other available endpoints. The code structure retrieves data from the ‘`usgs-ml`’ component, facilitating accurate setup of the service, specifying the type, with attributes such as CORS handling and cache being dealt with in the background by the generic component. Specific details related to the component are outlined within the declared tags, with additional configuration to be added as needed and a resulting output in JSON format. Other agencies follow the same structure, such as for EPA (Figure 9(b)) that has different parameters and arguments for API calls. The EPA agency produces output in GeoJSON format.

```
<usgs-ml service="instant-values">
    <api-args raw="true" site="USGS:02056000" startDt="2023-11-01" endDt="2023-11-01"
    parameterCd="00060"></api-args>
    <api-args startDate="2023-11-01" timeInterval="1d"></api-args>
</usgs-ml>
```

(a)

```
<epa-ml service="station">
    <api-args raw="true" bBox="-96.789,40.580,-89.802,43.564" characteristicName="Nitrogen"
    countycode="US:24:033" ></api-args>
    <geoweb-map></geoweb-map>
</epa-ml>
```

(b)

Figure 9. (a) Retrieval of instant values service from USGS and (b) data from EPA using the station service.

4.2. Data Output Sub-components

An example definition and table display for presenting the data from the FEMA agency in tabular form are provided in Figure 10(a) and Figure 10(b), respectively. FEMA provides categorical information about the names of disasters and the locations where disasters occurred. Just as the '`instant-value`' service request from the USGS, the component provides real-time data for a specific station along with timestamp information in JSON format. Presenting this information in a table provides a meaningful way for data visualization.

The information retrieved from an agency service can be effectively visualized on a map. Such data can be presented in various formats, including JSON, as demonstrated by agencies like USGS, FEMA, and EAUK; GeoJSON, as observed in NWS and EPA agencies; and KML, among other map-ready formats like shapefiles. These formats enable the representation of multiple locations or areas on maps, providing diverse options for visualization. The '`gridpoints`' service request from the NWS agency provides a set of grid points indicating the locations of the stations. It generates points of interest with outputs in GeoJSON format.

To display this information on the map, `<geoweb-map></geoweb-map>` tags are used. An example code snippet and map display for the service retrieved data are provided in Figures 10(a) and (b) respectively, with the code snippet being independent of the data format. Another example of map visualization is shown in Figures 11(a) and (b) for the '`stations`' service of the NWS agency that provides location information and essential details for each station and its output in KML format. The map displays multiple coordinate points for stations of different variables in Florida. A sample popup feature has been added to each station to display relevant information from when clicked.

```
<fema-ml service="disaster-declarations">
    <api-args raw="true" fipsStateCode=19></api-args>
    <geoweb-table></geoweb-table>
</fema-ml>
```

(a)

Search:

declarationtitle	placecode
0419 FIRE	99017
1707 ADKINS AVE FIRE	99005
1ST CANYON FIRE	99007
259 FIRE	99049
30TH AVENUE FIRE	99021
316 FIRE	99007
335 FIRE	99253
36 PIT FIRE	99005
36TH AVENUE FIRE	99021
412 FIRE COMPLEX	99007

Showing 1 to 10 of 1,000 entries

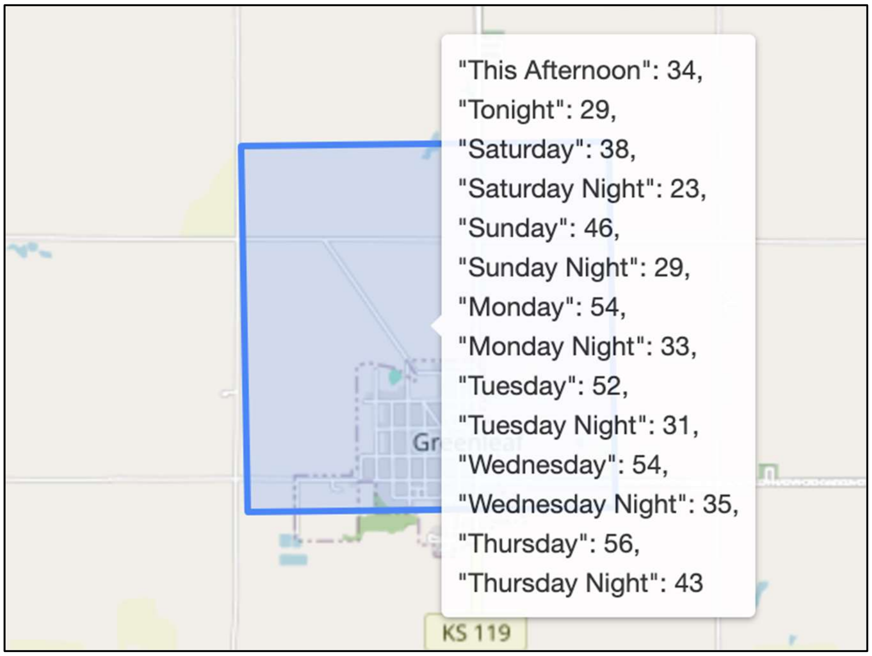
(b)

Figure 10. (a) Geo-Web table component declaration and (b) output from the rendered data.

Data retrieved can also be represented on graphs. Visualizing GeoJSON and KML data in graph form often requires the use of map drawing libraries or services specifically designed for geographic data visualization. Relevant data in data formats such as CSV, JSON, XML can be displayed on the graph. To display the information on the graph, `<geoweb-graph>` component can be used. An example code snippet and graph display for the visualization of information from the USGS "`instant-values`" service on the graph are provided in Figure 13(a) and (b) respectively. This code snippet is independent of the data format.

```
<nws-ml service="gridpoints">
    <api-args raw="true" gridX=31 gridY=80 office="TOP" ></api-args>
    <geoweb-map></geoweb-map>
</nws-ml>
```

(a)

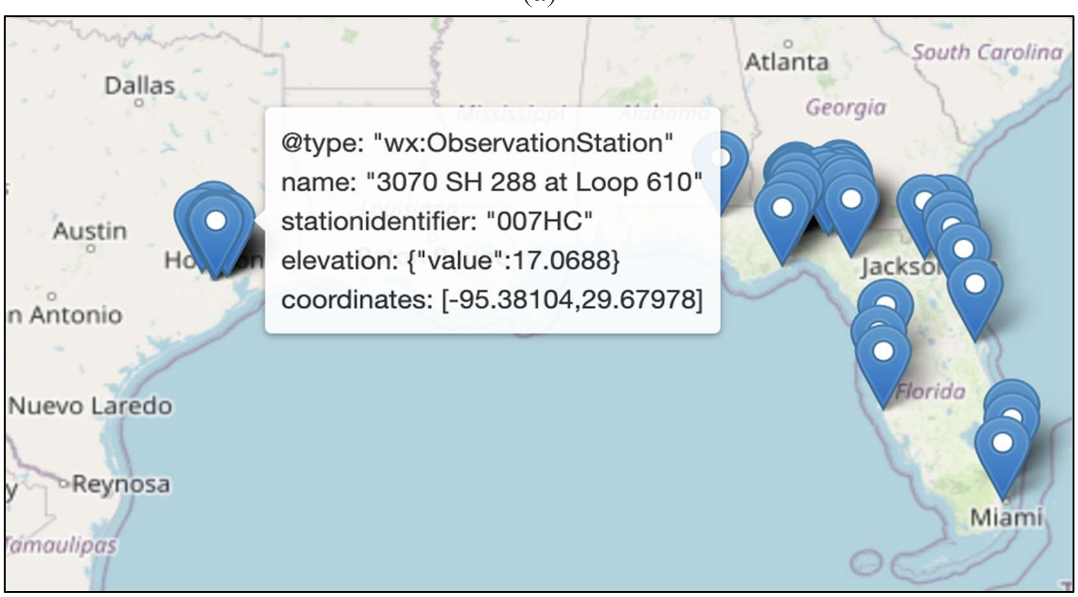


(b)

Figure 11. (a) Request of the gridpoints service of the NWS agency and (b) snippet to grid map display.

```
<nws-ml service="stations">
    <api-args raw="true" limit=100></api-args>
    <geoweb-map></geoweb-map>
</nws-ml>
```

(a)

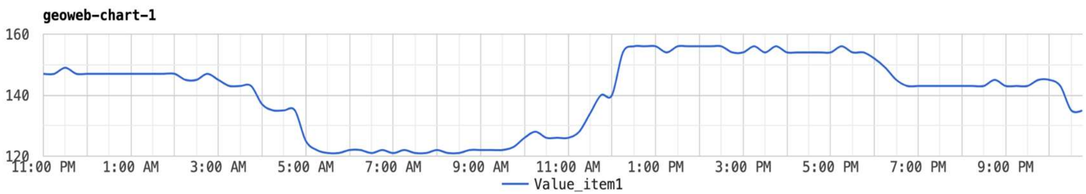


(b)

Figure 12. (a) Request to the stations service of the NWS agency and (b) map display using the retrieved data.

```
<usgs-ml service="instant-values">
    <api-args startDate="2023-11-01" timeInterval="1d"></api-args>
    <geoweb-graph></geoweb-graph>
</usgs-ml>
```

(a)



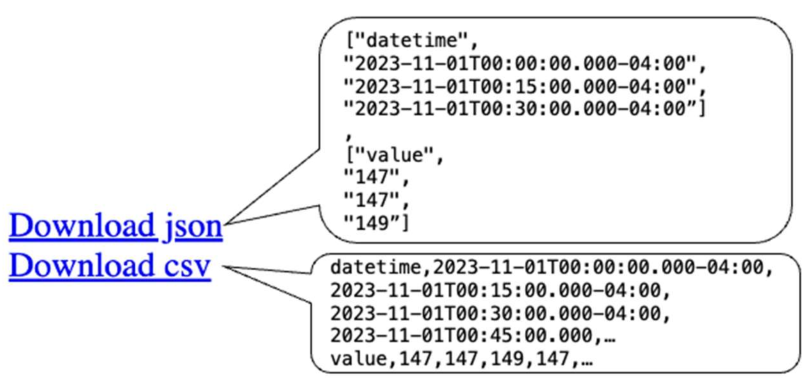
(b)

Figure 13. (a) Request to the instant-values service from USGS and (b) use the graph component with the downloaded data.

Another agency included in the Geo-Web component framework is EAUK. The agency provides information on water quality at specific interest points, presenting its output in JSON format. Similarly, as with the other agencies, this information can be visualized on maps, tables, graphs and downloaded in JSON/CSV formats. The geo-web component for output is used to download the information provided by any agency in JSON/CSV formats. As long as the proper transformation functions are written, information belonging to any agency with different domain focus, data types, and output formats can be easily downloaded in JSON/CSV formats and prepared for analysis. Regardless of the data, this process can be effortlessly accomplished with the addition of a single tag. An example code snippet can be written as shown in Figure 14(a), and its display on the screen is illustrated in Figure 14(b).

```
<eauk-ml service="data-wqsite">
    <api-args raw="true" id="NE-43500745" year="2015"></api-args>
    <geoweb-output type="json"></geoweb-output>
    <geoweb-output type="csv"></geoweb-output>
</eauk-ml>
```

(a)



(b)

Figure 14. (a) Request to the data-wqsite service of the EAUK agency and (b) output display as either a CSV or JSON file.

4. Conclusion and Future Work

The usage of web components has seen a significant increase since their release in 2016, owing to their easy and flexible architecture that incorporates several of HTML's best features. They integrate with the next-generation features of Progressive Web Applications and other emerging technologies. Web components allow developers to customize features through simple declarations, enabling the creation of complete web applications with most of the programming work handled in the background of each element through the technology's API. This means that web components can be used by entry-level programmers, researchers, and in educational settings, including high schools and universities, facilitating the process of building web pages and learning about the merge between information technologies and earth sciences.

In terms of governmental and higher-level applications, the features discussed in this manuscript represent some of the most influential and commonly used in the fields of environmental and hydrological sciences. Adopting web technologies, such as web components, facilitates better integration of publicly available data APIs to develop faster and smarter information systems. These include various interaction modalities like tables, graphs, maps, and other visual cues. The primary objective behind the Geo-Web component framework is to showcase the development and adoption of these technologies for crucial information providers such as the agencies used in the development stage. New agencies and data types/formats will be included in the future with the support from community. However, the primary purpose of the framework is that new developers can integrate agencies themselves through the instructions set within the framework and thus, promoting a larger collaboration scheme that benefits research and education.

The framework includes a limited set of subcomponents, including a graph, table, export, and map. It allows for the development of new subcomponents tailored to various scopes through its loosely coupled architecture. Additionally, to accommodate different data types such as binary streams and image data, the Geo-Web component will be expanded incorporating pertinent transformation functions and subcomponents, as well as adoption of technologies for information display already available in web environments.

The Geo-Web component attributes have been deliberately kept simple to facilitate user-friendly usage for individuals with basic programming skills. However, these attributes can also be extended to cater for diverse functions such as filtering, analyzing, or mapping data. It is noteworthy that the development of the Geo-Web component framework does not constrain the utilization of formats provided by common-use APIs. Instead, it extends beyond hydrological research, introducing new features for web-based visualizations.

Future development of the framework includes an update of the current technological stack to create an even more streamlined integration of data into web applications. Moreover, new visualization tools and modalities of integration within existing developer settings will be explored to become more user friendly. This aims to empower developers, whether enhancing the existing implementation or implementing a completely new agency using the documentation available in the framework's repository.

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