

HydroLang Markup Language: Community-Driven Web Components for Hydrological Analyses

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Highlights

- HTML-based computational framework for hydrology research and education.
- Provides an effortless interface for environmental and hydrological analyses.
- Architecture-agnostic web components for reusability through web platforms.
- Modular design involving a powerful core engine and 3rd party geospatial tools.

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Abstract

We introduce HydroLang Markup Language (HL-ML), a programming interface that uses markup language to perform environmental analyses using the hydrological and environmental framework HydroLang. The software acts as a self-contained interface that uses HTML tags powered by the web components specification to generate simple hydrological computations that enable data analysis, visualization and manipulation via semantically driven instructions. It enables hydrological researchers and professionals to use markup language to retrieve, analyze, visualize, and map data without the need for a programming experience. The components' adaptability enables users to run analytical routines that perform simple and complex analyses on the client side. We present the implementation details of the approach, the use of custom elements in web technologies and academia, and share sample usages to demonstrate the simplicity of use of the human-readable and computer-executable framework.

Keywords

Scientific visualization; hydrological analysis; software libraries; web frameworks; web components

Software availability

| | |
|-----------------------|---|
| Name | HL-ML |
| Developers | Carlos Erazo Ramirez, Yusuf Sermet, Ibrahim Demir |
| Contact information | 300 S. Riverside Dr., Iowa City, IA 52246, USA |
| Software required | Web browser |
| Program language | JavaScript, HTML, CSS |
| Availability and cost | The framework is open-source and free to use. The repository can be accessed on GitHub. |
| Code repository | https://github.com/uihilab/HydroLang-ML |

1 Introduction

Environmental analysis is inextricably tied to enormous volumes of data and monitoring efforts (Muste et al., 2017). The formats, structure, and requirements of these datasets differ depending on the domain and the scope of the research. To maintain a degree of integrity and dependability necessary to undertake an analysis, appropriate deuration procedures must be used. Thus, computational tools have been implemented for decades to circumvent the latter, allowing for better data analysis and workflows, producing accurate and appropriate outcomes. These tools have been used to gather information, clean and process, display, modify, and run mathematical models. Nonetheless, professionals in both academia and industry have faced several obstacles in keeping up with the plethora of programming languages, libraries, and standards that emerge on a regular basis. Studies show using programming languages might present hurdles for researchers who lack the essential knowledge or time to learn how to properly apply scripts to perform their jobs (López Pimentel et al., 2021; Bosse & Gerosa, 2017).

Several programming languages and applications have been used to create better and more efficient computing tools in the environmental domain. MATLAB, R, and Python are three of the most commonly used programming languages in academia. MATLAB is frequently used for signal processing as a completely mathematical construct with a variety of arrays and modules that use simple syntax for

matrix operations, but is restricted because of its proprietary agreements. Both R and Python are extensively used scripting languages for comprehensive scientific computing, with R being primarily used by academics for statistical and probabilistic research, and Python being widely used for GIS, data manipulation and integration, and even web development. Moreover, the recently launched platform, Jupyter Notebooks, provides an expansion on the programming language, Python, to perform computationally intensive tasks both on the client and server side through a cell-based interface for visualization and computation.

The environmental sciences have made extensive use of web technologies for analysis and communication needs. In particular, web development tools have been successfully used in real-time flood mapping systems (Hu and Demir, 2021; Li et al., 2022), ethical decision making (Ewing et al., 2021), disaster mitigation analytics (Yildirim and Demir, 2021; Alabbad et al., 2022), decision support systems (Teague et al., 2021), geovisual data analytics (Xu et al., 2019; Sit et al., 2021), and immersive virtual reality applications in environmental science and hydrology (Sermet & Demir, 2020). Specifically, markup languages and similar ontologies have been used in many environmental studies (Yesilkoy et al., 2022) including generation of comprehensive flood event specifications (Haltas et al., 2021), and markup language for flood information, forecast and alerts (Xiang & Demir, 2022). Even while it is straightforward to create full systems that function using JavaScript as the primary programming language, there is still room for additional advancement in terms of user adoption, such as the deployment of HTML-like libraries.

Many paradigms have been implemented and explored to create optimum performance and execution of tasks in web platforms focusing on computation libraries (Sit et al., 2019) and novel data structures (Demir and Szczepanek, 2017). One of the most popularized approaches is the use of component-based models, which is a branch of software engineering emphasizing the separation of concerns throughout an application to create a reusable approach to definitions, implementations, and extendibility (Mraz, 2019). Recently standardized, the use of web components provides an integrative approach to component-based development. This relatively new web technology is a set of standards that enable reusable custom elements for web applications, allowing for cross-platform functionality and the creation of reusable code that can be rendered in any web browser adhering to industry standards.

The literature review identifies a substantial gap for a web component application that performs hydrological and environmental analysis to download, clean, analyze, and visualize data through the use of web components. HL-ML is an open-source integrated programming interface that supports research and education in hydrology and environmental sciences, powered by the HydroLang framework (Erazo et al., 2021) through the use of web component technology. It was developed using a component-based UI architecture to integrate the modular assembly of HydroLang.js through the usage of semantic structures to provide an easier and more intuitive platform to perform strong analysis through web browsers. The technology allows the usage of all the modules and components of the HydroLang framework with added integrative data manipulation using the local storage memory allocation of web browsers to manipulate data according to the user's needs.

Throughout the article, Section 2 discusses web components as a technology, how they have been implemented and used across web platforms, and the associated applications the technology has had in industry and academia. Section 3 goes into the architectural design process and implementation methods used, as well as the relationship between the interface and the HydroLang.js framework, demonstrating how the interface is used in an HTML element to access each module within HydroLang. With an example of how the interface is used for retrieving, cleaning, and displaying hydrological data,

Section 4 displays the results and discussions, emphasizing the necessity for semantic development of web components for hydrological analysis. Finally, Section 5 discusses the conclusions and future research.

2 Background

2.1 Web Components

Microsoft HTML Components (Microsoft, 2013) and Mozilla XBL (W3C, 2012) were the first attempts to establish web components as a standard across web platforms. This first began in 1998 with the intention of expanding the DOM by adding new properties that could aid in changing behaviors through the use of various tags that relied on JavaScript or VBScript. The components' implementation was limited, and Microsoft abandoned the feature after multiple tries, deprecating it with Internet Explorer 10 in 2011. The second started in 2001 with the goal of extending default DOM tags to provide customized behavior, but despite the fact that the additions worked across all Mozilla products, it was deprecated and abandoned in 2012.

Angular (Google, 2022) and React (Facebook, 2022) web frameworks were developed by Google and Facebook in 2009 and 2013, respectively. Angular provided improved semantics in web apps by allowing developers to design customizable tags, and React is being used to address the demand for reusable widgets, allowing many companies around the world to leverage the platform's implementation.

The W3C web components specification (W3C, 2014) introduced a definition for expanded DOM usage in 2012, with the goal of standardizing the idea of customized and reusable tags across all web browsers without any vendor library restrictions. The components are made up of four different principles that work around each other:

Custom Elements: It allows the construction of custom tags and determine their usage, attributes, how they interact with different events, and rendering alternatives.

Shadow DOM: It allows to expand an enclosed version of the DOM tree, including an HTML script which is not available through the Light DOM.

HTML Template: The template tag enables the rendering of any stated tags within the DOM tree, allowing for element mutability and extensibility.

Following the release of the web component standard, various third-party libraries were created to provide users with an easy-to-use development environment. Stencil (Rotman, 2022), Litcomponent (Lit, 2022), Material, and Polymer (Polymer, 2020) are some of the most popular frameworks. These front-end frameworks have been frequently used as alternatives to web components because of their ability to develop quick and simple components that act similarly to standard components, but with the drawback that they are not portable and are bound to certain contexts.

Despite the fact that the usage of framework-based components has grown in the previous decade, the constant requests made to servers by clients and applications decrease response times and, as a result, degrade application performance. The key benefits of adopting the W3C web components API are the robustness of the applications built, as well as the ease with which they can be maintained and changed to fit into any workflow, and their extensibility to be recoupled into new browsers or apps (Krishna, 2022). Some of the disadvantages of using components stem from their restrictions on styling, particularly Cascading Style Sheets (CSS), and incompatibility with native elements. In addition to the fact that the components are not fully supported on all browsers, they are also misunderstood and misapplied because of the lack of information on usage in comparison to other frameworks, with the possibility of problems arising from nested functionality.

2.2 Related Work

An increasing interest in the creation of applications in academics has emerged in addition to industry-driven applications that leverage web components to create tools for social media and mass communication, with examples including use cases in both natural and social sciences. For instance, since 2009, the ChemDoodle library (Burger, 2015) has been available, and it is the first chemistry toolkit to view and modify data using just web component via the Common Web Clients (CWC) standards. It is mostly used for generating 2D and 3D chemical graphics, as well as changing molecular data by putting it into a JSON file, which is then displayed using HTML-specific technology. In the field of genomics, MetExploreViz (Chazalviel et al., 2018) is a web component library that provides features aimed at visualizing metabolic networks and pathways in biochemical context. The application was developed on a modular architecture that is embedded into a website and available through a basic graphical user interface (GUI). It leverages on external libraries like D3.js to create high quality scalable vector graphics (SVG). Executable HTML (Batalas et al., 2021) is a collection of custom HTML elements in psychology that allow authors to write and execute procedural logic in HTML5 through web components, with the primary goal of manipulating subtrees added as questionnaires, which are reproducible and accessible to users with little experience with web technologies and programming in general. Its main goal is to evaluate the use of ambulatory assessments from the standpoint of a non-programming expert.

Web components have been employed in GIS in the same way as in other web technologies to build widgets and apps that can be replicated across several interfaces. Calcite Design System serves as an example (ArcGIS, 2022) being a set of design and development resources for the development of attractive and simple-to-use mapping apps. Instant Expert (Sermet & Demir, 2021) is an open-source semantic web framework that is based on integrated voice-enabled smart assistants through any online platform, independent of domain or technology, using the extendibility and reproducibility of web components. It is adaptable to a variety of study topics and uses both machine learning algorithms and web components for natural language processing to allow non-technical domain experts to add operational helpers.

Educational studies have also benefited from the use of web components, particularly in libraries and bookkeeping systems. The comparison between the reusability of custom elements and the use of widgets for displaying options for library patrons and control for librarians with little to no programming experience has been researched by (Wusteman, 2019), highlighting how the use of web components can drastically change interoperability within the library setting and allow for better control of the interactivity required from computer-based searching and sorting operations. Additionally, the web component standards have also helped in the development of loosely coupled server and client-side components that allow real time communication between front and backend interfaces, due to the isomorphic nature of JavaScript and the asynchronous behavior of web applications (Triglianos, 2015).

Despite the growing number of applications focusing on hydrological applications, there is a gap in the literature of studies using web components in the field, providing an opportunity to explore the usage of the web component technology to address the needs of research in hydroinformatics.

3 Methods

3.1 HydroLang Markup Language

HL-ML was created in response to the need for simple, easy-to-use frameworks for performing analysis using web technologies. The majority of programming interfaces have their own ontological design that follows specific criteria for an analysis based on the user's needs. Though this is still true for this project, being supported by the powerful computational engine of HydroLang.js, it makes use of

standardized technologies to generate object-relational arguments that can later be passed onto the aforementioned framework to perform the required analysis via semantically driven instructions. It allows researchers, educators, and members of the general public with limited or no programming experience and an environmental analysis interest to use markup language to retrieve, clean, analyze, and visualize information on the client-side with little or no further manipulation required. Furthermore, it enables users to manipulate data from the web browser's local storage, providing full Create-Read-Update-Delete (CRUD) operations that may be readily scaled into other databases if necessary. The project's major goals and contributions can be summarized up as follows.

- Create environmental-specific HTML tags for computational tasks using standardized versions of web components adopted by major web technology providers.
- Provide a user interface that enables semantically driven instructions to be easily written using a stepwise ontology.
- Leverage the use of common standards for storing information via web browsers to save data manipulated directly by instructions provided in an HTML file.
- Improve the usability and accessibility of the majority of the functions integrated into the HydroLang.js core framework.
- Develop a high-level abstraction for the use of computational frameworks and libraries that can be readily copied and changed to fit any required context.

3.2 HydroLang.js Framework

HydroLang.js is an open source and community-driven computational framework to help with hydrological research and education. It consists of four primary core modules, each serving a distinct purpose while keeping a low level of cohesiveness. These modules are: (1) Data, specifically for retrieving data from different data source APIs, data transformation, uploading and downloading; (2) Visualize, module for data visualization using the Google Charts API as well as JSON object renderers; (3) Maps, used for creating maps rendered on the browser to view georeferenced data and data selection; and (4) Analyze, containing 3 main components for performing hydrological subroutines used in academia and industry (hydro), performing statistical analysis on data (stats), and creating simple neural network models (NN) (Figure 1). While deep learning applications becoming popular in recent years for hydrology and water resources applications (Gautam et al., 2020; Demiray et al., 2021), web based neural network libraries and platforms (Sit and Demir, 2022) making access to these models easier for domain experts. The library was developed using JavaScript, considering the advantages the programming language has for the development of web applications, integration with other open-source libraries, usage of standards, and lexical instructions that aids on learning. HydroLang significantly reduces the amount of programming required to perform any of the subroutines implemented, allowing users to perform analysis in a few lines of code as a one stop workplace.

The latest version of the framework adopted the ES6 standardized functional destructured parameters to access all the methods, leveraging the adoption of the features in major web browsers like Chrome, Firefox and Edge. The usage of JavaScript's object-oriented nature allows for integration of the commonly used separation of interests within each function. Since the methods included in HydroLang often require several types of instructions and data, the destructuring set for development can be found in Table 1.

This information was adopted to enable a more efficient development process for extensibility and reliability, standardizing how the community approach should follow the usage and implementation phases while maintaining a modular architecture. The documentation for each of the methods included

in HydroLang.js, as well as case studies with full implementation of most methods of the framework, can be found in the software’s repository (Erazo et al., 2020).

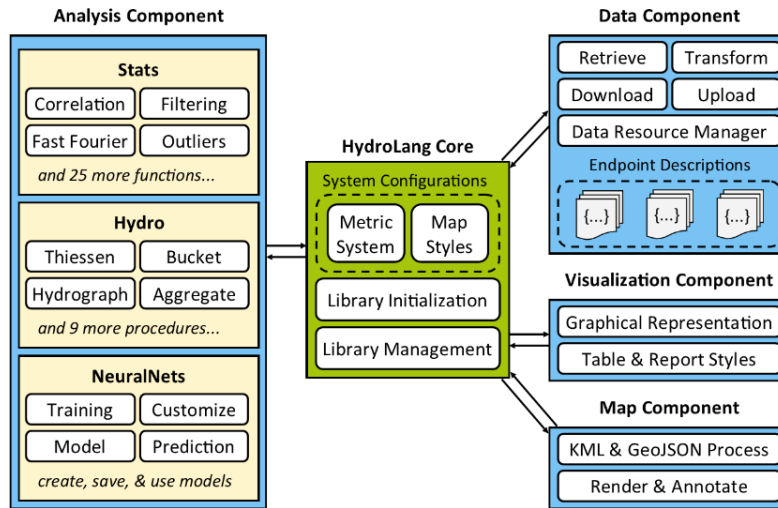


Figure 1. Architecture and components of the HydroLang framework (Erazo et al., 2021)

Table 1. Structures for functional usage in HydroLang.

| Structure | Description |
|------------|---|
| Parameters | Information for calculations, calling data source API’S and basic steering functional conditions. |
| Arguments | Additional information required for functional usage. Specificities explicitly described for each function. |
| Data | Arrays, objects, strings, numbers, and any other type of data driven driven. |

3.3 System Architecture

HL-ML was built with the primary focus on data integration and manipulation by combining the capabilities of web components using a semantic approach that triggers instructions based on information fed by the users. Five separate custom elements that seek to register, alter, and control data are used to manipulate the given information and create a direct link with the HydroLang.js library, serving as an abstraction of the framework and main interface for easier usage (Table 2).

Table 2. Descriptions of web components in HL-ML.

| Web Element | Description |
|---------------|---|
| maincomponent | The hl-ml software's main component. It includes driver methods for registering, retrieving, modifying, and downloading data. Also acts as a constructor for any other element that has to be registered. |
| hydrolangml | Element constructor to be used as parent for each of the sub-elements. Contains slots available for each of the subsequent element. |
| analyzmod | Element constructor for dealing with the analyze module. |
| datamod | Element constructor serving the data module. |
| visualizemod | Element constructor serving the visualize module. |
| mapmod | Element constructor serving the map module |

These subcategories are considered custom elements in and of themselves, maintaining the same structural development throughout their lifecycles as described in Figure 2. Being built on top of HydroLang.js, the user should be familiar with the requirements of methods that will be used to pass appropriate parameters and data.

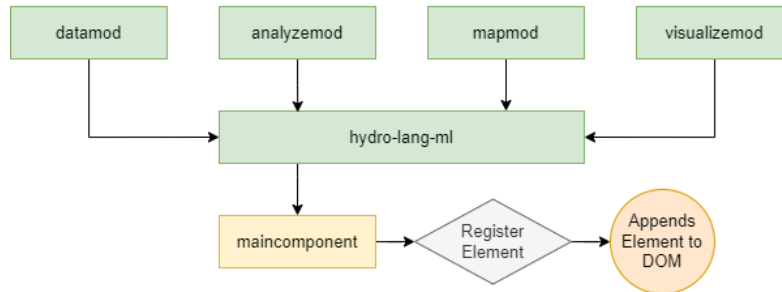


Figure 2. Connection between the elements, main component and DOM.

The components were created using an object-oriented design that focuses on calling a primary component element with methods for data manipulation, local storage access, and allocating a HydroLang.js instance for the property function requested by the user, as depicted in Figure 3. Inputs serve as information gateways for linking and abstracting parameters, arguments, and data required for functional calling, keeping the same argumentative ontology used throughout the HydroLang framework. The attributes of the parameter elements are used as connectors for the local storage. If the property "input" is used and there are no data components in the request, HL-ML will get the data from local storage. If the user adds the property "output," it represents either an object produced from the results of a HydroLang.js method or data input fed directly by the user and is saved in the local storage using the attribute's value.

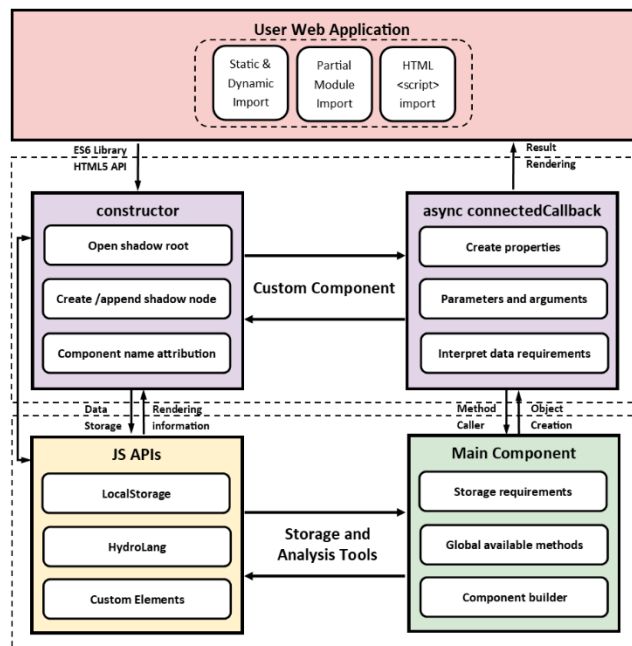


Figure 3. HL-ML architecture

The modules are accessed via the component's declaration in the DOM tree, which is itself a part of the HL-ML component. The main component then registers each element by calling the custom elements API, and setting the names and types of components created—parent and child component. As shown in Figure 4, the tag names and attributes provided to the components determine their functionality. The parameters, arguments, and data ontology of HydroLang.js must be used to build the child elements allocated to each component.

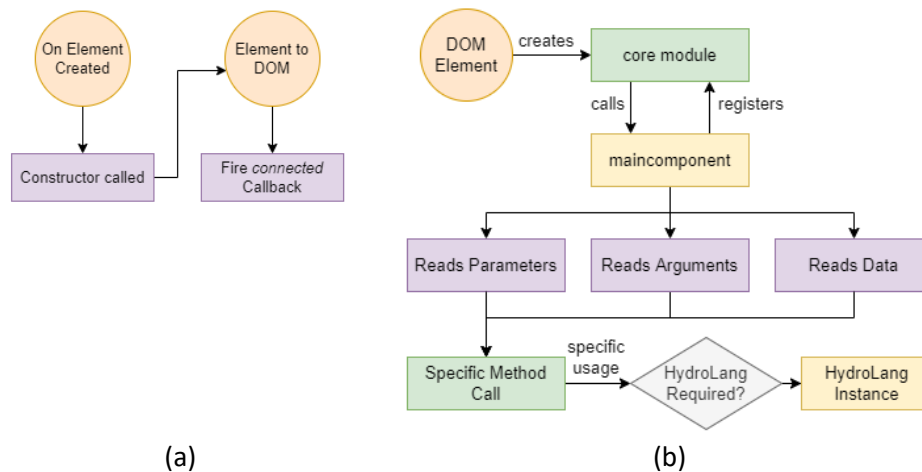


Figure 4. (a) Element lifecycles and (b) element connection to main components and supporting API's.

Following the creation of the element, it inherits the functions from the main component based on the given attributes, thus calling the HydroLang instance. The main component accesses the local storage API for data manipulation if the function's output is presented as a certain data type—JSON, array, XML, or geoJSON—and the user supplies the tag for local storage access. The data is read from local storage and displayed on screen if the function requires rendering options such as visualization or mapping. The general flowchart that each component follows during its existence is depicted in Figure 5.

Deferred routines to manage data reading and writing have been added to the main component methods to handle the asynchronous behavior of most data queries provided in HydroLang, as well as the static nature of HTML. Because HTML does not execute sequentially driven code, any process handling is done inside the functions of the main component. The deferral routines included use the type of instruction the user is sending within a component to adopt the processes to be awaited. For example, if a user retrieves data from any of the available sources, the data will be saved in local storage with a name specified by the user or automatically generated.

Following that, the user must refer to the data using the specified name for additional analytical purposes. This must be done while waiting for the procedure to be completed. If the named object is still inaccessible on the local storage, an error message will be displayed indicating the reason. Furthermore, the modules follow the same pattern for data processing, accessing HydroLang instances, visualization modules, and any other requests. The use of the dynamic refresh feature of web pages and browsers has also been integrated into the design.

Each element was built using a reusable taxonomy that adapts to the expected growth of the HydroLang framework, with the ability to add new functionalities and modules to give stronger and reliable analysis. Other implemented modules will be accessible through the HL-ML API as the framework expands, allowing for continued adoption of easy-to-use software.

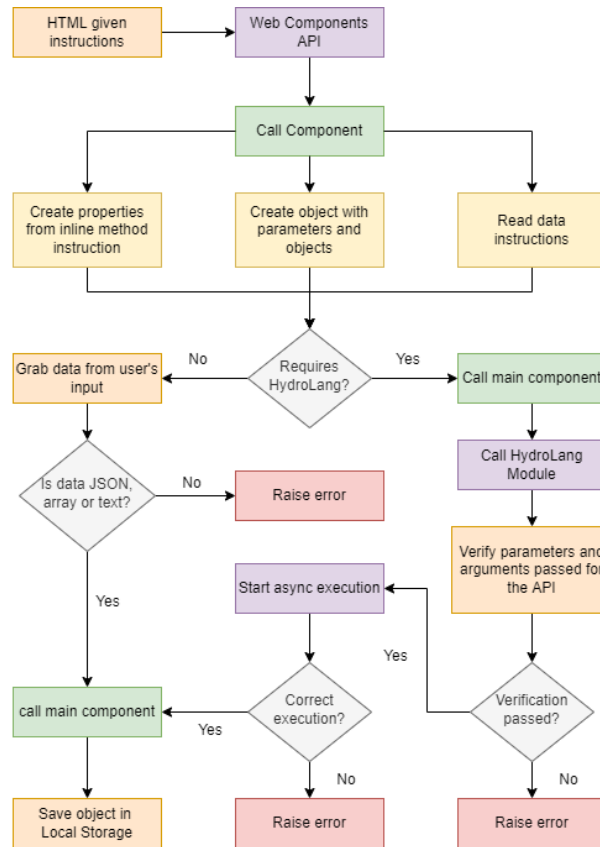


Figure 5. General component flowchart.

3.4 Use Cases

3.4.1 Library Initialization

The script element is used to load HydroLang.js into an HTML page, which can then be used in the console of a web browser. This is done by either inserting another script element into the HTML or using the console to call the library. The user must provide variables as JavaScript datatypes to use as parameters, arguments, and data in each module's methods. Using HL-ML, there is no need to specify variables beyond the scope of the HTML page. The custom names assigned to the web components make the library accessible. The tags, which are put within an additional divisor tag on the HTML script, include all modules once the page goes live in order to preserve order throughout the DOM tree.

```

<head>
  <link rel="stylesheet" href="./modules/css/hydrolang.css">
  <script type="module" src="./hydrolang-ml/main.js"></script>
  <title>HydroLang-ML Example</title>
</head>
<body>
  <div id="hydrolang">
    <hydrolang-ml>
      <!--All the modules that are required to be accessed are declared
      within the hydrolang-ml component-->
    </hydrolang-ml>
  </div>
</body>
  
```

Figure 6. Declaration and usage of HL-ML.

3.4.2 HydroLang Module Usage

Data Module: The retrieval of data from any source requires specific request information to be sent to a web service. For example, if the data required is from the USGS API, the user needs to create an object that declares all the information to be later passed as a GET request through the HydroLang data module. The retrieved information is prompted as a local variable that can be accessed through the console of the web browser and is lost after the page is refreshed. HL-ML creates the request from the given tags passed by the user, with the results being downloaded and saved in the web browser's local storage with the name from the "output" tag, serialized and saved as a string. Data manipulation (such as transformation, analysis, visualization, or deletion) is made possible with HL-ML within the browser's environment by saving data in the local storage.

```
<hydrolang-ml>
  <data-mod method="retrieve">
    <parameters source="data_source" dataType="somedata_type" proxyurl="https://proxy-server.name"
      output="some_name"></parameters>
    <arguments someSite="SITE:0000" format="json" startdate="YYYY-MM-DD" enddate="YYYY-MM-DD"
      additionalArg="someVal"></arguments>
  </data-mod>
</hydrolang-ml>
```

Figure 7. Example usage for data retrieval.

Visualizing Modules: Data visualization through HydroLang.js is done synchronously through the *visualize* and *maps* modules. With no stored object available, any visualization dataset should be declared before it is passed to the visualize functions. Using HL-ML, if there is data stored in the local storage that contains a specific name passed by the user, then it will be rendered to the screen, circumventing the asynchrony of the required APIs.

```
<hydrolang-ml>
  <visualize-mod method="draw">
    <parameters type="chart" name="Visualize_Example"></parameters>
    <arguments charttype="scatter"></arguments>
    <dataset>[[0,1,2,3,4,5,6,7,8,9,10],[0.1,2,0.52,0.2,0.69,8,98,8,10,11,5]]</dataset>
  </visualize-mod>
  <map-mod method="Layers">
    <parameters layer="tile" output="OpenStreetMap"></parameters>
  </map-mod>
  <map-mod method="Layers">
    <parameters layer="marker" output="examplemarker"></parameters>
    <dataset>[14.035344,-87.192993]</dataset>
  </map-mod>
</hydrolang-ml>
```

Figure 8. Chart and map rendering through HL-ML.

Analysis Module: Along with the *data* module, the *analyze* module contains several methods for the creation of powerful hydrological, statistical, and machine learning analyses. Well-known routines used by experts in the field, as well as novel approaches highlighting the capabilities of new technologies and methodologies, have been implemented within the module. Most methods contain several parameters required to drive a computation, and through the usage of HL-ML the information in place is significantly reduced. The data is accessed by any function using the name of the output results recorded in the local storage.

```
<hydrolang-ml>
  <analyze-mod component="hydro" method="syntheticalc">
    <parameters type="SCS" unit="si" output="synthetic_calc"></parameters>
    <arguments L= 4000 slope= 10 cn= 82></arguments>
  </analyze-mod>
</hydrolang-ml>
```

Figure 9. Example usage for the analyze module components.

4 Results and Discussion

HL-ML incorporates HydroLang.js's powerful architecture to provide users with a seamless instruction-based interface that allows for easy to use and powerful commands for analysis in hydrology and environmental sciences. It allows for the visualization of many types of data (JSON, XML, map rendering, charts and tabular structures), the retrieval of data from various sources throughout the world, and the execution of hydrological and hydraulic analysis. All of this is done through markup language, requiring little to no additional knowledge of programming.

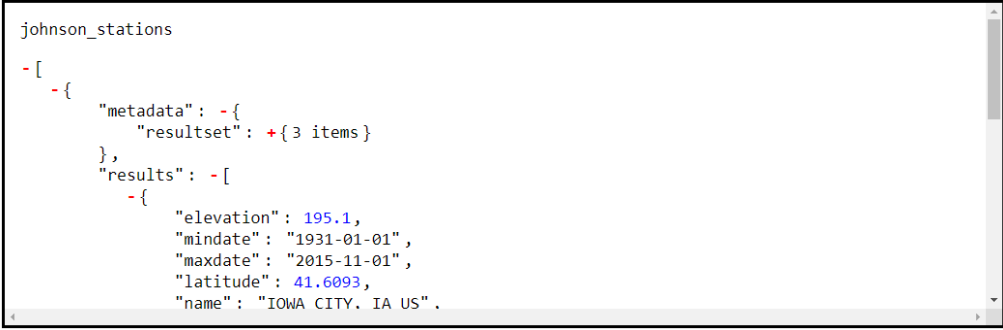
The web component standard's quality assurance allows a greater interpretation of the technology's scalability and its potential to become a high-level standard for web development. Studies have assessed the quality of information during user testing on web applications, highlighting that the W3C standardized web components provide a greater sense of understanding on usage and implementation (Lizcano et al., 2020). This paves the way for applications such as HL-ML to be scaled for public technological outreach. Furthermore, aside from research, the ease of use of the framework creates opportunities in most levels of academia, from high schools to university classrooms, with a tool that enables students to gain an understanding of web applications and high-level programming applied to environmental sciences.

4.1 Case Study

To highlight the ease of use of HL-ML, a case study was carried out for the retrieval, cleaning, and visualization of rainfall data from sources included within the framework. The flood events of June and July 2008 in the Midwest created severe damage throughout several counties in the state of Iowa. Using the NOAA and USGS data sources, the available data stations were obtained for the dates prior to the flooding event to see data availability. The result request was saved and afterwards rendered using the visualization component. From there on, a station in Iowa City was selected to retrieve hourly precipitation data obtained through volumetric weighting. The dataset contained records between May and July 2008, with most of the records being lost when the flooding event happened.

```
<data-mod method="retrieve">
  <parameters source="noaa" datatype="availablestations" output="johnson_stations"
    token="gNUkMgFH..."></parameters>
  <arguments locationid="FIPS:19103" startdate="2008-05-30" enddate="2008-06-30"
    limit="1000"></arguments>
</data-mod>

<visualize-mod method="draw">
  <parameters type="json" input="all"></parameters>
</visualize-mod>
```



```
johnson_stations
- [
  - {
    "metadata": - {
      "resultset": + {3 items}
    },
    "results": - [
      - {
        "elevation": 195.1,
        "mindate": "1931-01-01",
        "maxdate": "2015-11-01",
        "latitude": 41.6093,
        "name": "IOWA CITY, IA US" .
      }
    ]
  }
]
```

Figure 10. Request for stations in Johnson County. The retrieved object was rendered on screen as an expandable JSON object for exploration.

```

<data-mod method="retrieve">
  <parameters source="usgs" datatype="instant-values" output="iowacity_streamflow_halfhour"
    proxyurl="https://some-proxy.server/"></parameters>
  <arguments site="USGS:05454500" startDt="2008-04-02" endDt="2008-06-30"
    format="json"></arguments>
</data-mod>

<data-mod method="retrieve">
  <parameters source="noaa" datatype="prec-hourly" output="iowacity_rainfall_hourly"
    token="gNukMgf."></parameters>
  <arguments stationid="COOP:134101" startdate="2008-04-02" enddate="2008-07-30"
    limit="1000"></arguments>
</data-mod>

```

(a)

```

<data-mod method="transform">
  <parameters input="iowacity_streamflow_halfhour" save="value"
    output="cleaned_iowacity_streamflow_halfhour"></parameters>
  <arguments type="ARR" keep=["datetime", "value"]></arguments>
</data-mod>

<data-mod method="transform">
  <parameters input="iowacity_rainfall_hourly" save="results"
    output="cleaned_iowacity_rainfall_hourly"></parameters>
  <arguments type="ARR" keep=["date", "value"]></arguments>
</data-mod>

```

(b)

```

Cleaned_iowacity_streamflow_halfhour
-[
+ [4290 items],
+ [4290 items]
]
johnson_stations
-[
+ [2 items]
]
iowacity_streamflow_halfhour
-[
+ [7 items]
]
cleaned_iowacity_rainfall_hourly
-[
+ [138 items],
+ [138 items]
]

```

(c)

Figure 11. (a) Requesting data from the gauge station USGS:05454500 and the rainfall station COOP:134101, (b) removing dates and values from the downloaded data using the data module's transform function, saving with appropriate naming and (c) cleaned data to the browser's local storage are all examples of data requests.

The recovered data was stripped from any additional information that was not useful for the analysis, and afterwards saved as a new variable in the local storage with an appropriate nametag, storing the date and value for each record. The data was afterwards analyzed applying basic statistic functions within the framework, calling the stats component. The result of the analysis was afterwards rendered as tables to screen.

```

<analyze-mod component="stats" method="basicstats">
  <parameters input="cleaned_iowacity_rainfall_hourly"
    output="basic_stats_rainfall"></parameters>
</analyze-mod>

<visualize-mod method="draw">
  <parameters type="table" input="basic_stats_rainfall"
    name="table_rainfall_data"></parameters>
</visualize-mod>

```

(a)

```

<analyze-mod component="stats" method="basicstats">
  <parameters input="cleaned_iowacity_streamflow_halfhour"
    output="basic_stats_streamflow"></parameters>
</analyze-mod>

<visualize-mod method="draw">
  <parameters type="table" input="basic_stats_streamflow"
    name="table_streamflow_data"></parameters>
</visualize-mod>

```

(b)

| | |
|--------------------|---------|
| Number of values | 137 |
| Minimum Value | 0 |
| Maximum value | 140 |
| Sum | 2,530 |
| Mean | 18.467 |
| Median | 10 |
| Standard deviation | 17.957 |
| Variance | 324.839 |

(c)

| | |
|--------------------|----------------|
| Number of values | 4,289 |
| Minimum Value | 1,810 |
| Maximum value | 41,100 |
| Sum | 57,720,190 |
| Mean | 13,457.727 |
| Median | 10,100 |
| Standard deviation | 8,538.265 |
| Variance | 72,918,976.198 |

(d)

Figure 12. (a) and (b) Performing basic statistical analysis on the cleaned data along with rendering data to screen, and (c) and(d) output results.

The results from the data cleaning were passed into the visualization options to be rendered as both columns for the rainfall, and polyline for the streamflow as shown in Figure 13.

```

<visualize-mod method="draw">
  <parameters type="chart" input="cleaned_iowacity_rainfall_hourly"
    name="cleaned_iowacity_rainfall_hourly_mm"></parameters>
  <arguments charttype="column"></arguments>
</visualize-mod>

<visualize-mod method="draw">
  <parameters type="chart" input="cleaned_iowacity_streamflow_halfhour"
    name="cleaned_iowacity_streamflow_halfhour_cfs"></parameters>
  <arguments charttype="line"></arguments>
</visualize-mod>

```

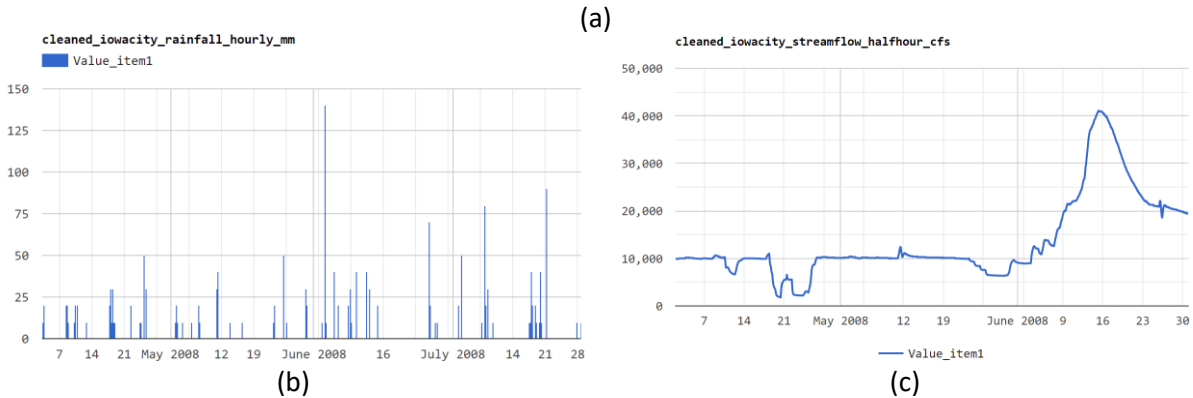


Figure 13. (a) Using the visualize module to render the cleaned data for both stations, (b) screen output for the rainfall within the requested dates in mm, and (c) stream discharge in cfs.

The locations inside Iowa City were included in the metadata for each station. Figure 13 shows a map with the relevant markers denoting the position of the stations projected to screen using the map module. The map engine component needs to be firstly rendered before the addition of markers.

```

<map-mod method="render">
  <parameters type="tile" lat="41.6572" lon="-91.5414"></parameters>
</map-mod>

<map-mod method="Layers">
  <parameters type="marker" output="COOP:134101"></parameters>
  <dataset>[41.60930, -91.50510]</dataset>
</map-mod>

<map-mod method="Layers">
  <parameters type="marker" output="USGS:0545500"></parameters>
  <dataset>[41.65667, -91.540833]</dataset>
</map-mod>

```

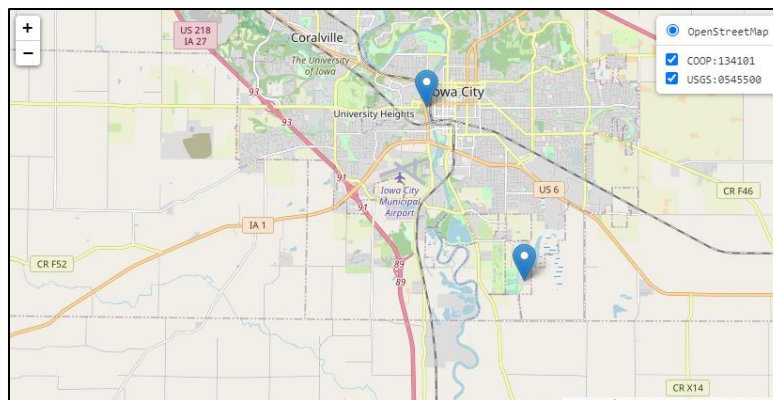


Figure 14. Code and rendered map for streamflow (top marker) and rainfall (lower marker) stations in the area of interest.

5 Conclusions and Future Work

Web components are used for a wide range of purposes, from social media to information applications to the academic community. The main goal of this project is to introduce the technology behind web components in environmental and hydrological sciences to allow users with no or limited programming experience to easily process, analyze and visualize data through the use of an intuitive HTML design linked to a powerful engine deployed only using browser technologies. The design's ontology allows for future growth of the HydroLang.js framework to be directly used within HL-ML, allowing for greater framework capabilities and a better user experience.

The use of HL-ML will allow the expansion of the community of users for the HydroLang.js framework, complementing its development in a circular loop with the integration of new modules and the possibility to expand through a community-driven approach. By integrating visual plug-and-play programming and analytics platforms serving intelligent hydrological modeling, HL-ML acts as a step forward for future releases of HydroLang.js. Furthermore, it is the first step in the development of components for environmental and hydrological platforms that can use the technology to undertake various sorts of analysis via the replication of instructions in self-contained declared objects.

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