# hf_hydrodata: A Python package for accessing hydrologic simulations and observations across the United States

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Summary

The field of hydrologic modeling, or modeling of the terrestrial hydrologic cycle, is very data intensive. Models require many inputs to define topography, geology and atmospheric conditions. Additionally, in situ observations such as streamflow rate and depth to groundwater can be used to evaluate model outputs and calibrate input parameters. There are many public organizations and research groups in the United States which produce and make freely available parts of this required data. However, the data have a wide range of spatiotemporal resolutions, file types, and methods of access. This makes finding and accessing all the data required for analysis a very time-consuming part of most hydrologic studies. The hf_hydrodata package is designed to simplify this data acquisition process by providing access to a broad array of variables, all of which have been pre-processed for consistency.

Statement of need

hf_hydrodata is a Python package that provides a streamlined, uniform syntax for accessing hydrologic data. Spanning the Continental United States, hf_hydrodata serves both gridded data and site-level point observations from the HydroData catalog. The package allows users to add filters to obtain data for only certain geographic areas and/or time periods of interest. This package was developed with hydrologists in mind, to facilitate the collection of domain-specific model inputs and validation data.

This package includes three main types of data. First we provide access to point observations that are compiled from public sources. Sources include the United States Geological Survey (USGS), the Snow Telemetry Network (SNOTEL), Soil Climate Analysis Network (SCAN), AmeriFlux, and the National Oceanic and Atmospheric Administration (NOAA). All point observation data are continuously updated to the HydroData Database and are pre-processed for consistency.

We also provide access to a national geofabric of hydrologically processed topography, land cover and hydrogeology land cover datasets that were developed from the national ParFlow model (i.e. the ParFlow CONUS model, e.g. Maxwell & Condon (2016); O'Neill et al. (2021); Yang et al. (2023)). Simulation outputs generated from the first (ParFlow CONUS1.0) and second (ParFlow CONUS2.0) generation of the ParFlow CONUS model are also available through this interface.

The HydroData catalog also contains atmospheric forcing datasets that can be used to drive hydrologic models. These large gridded datasets can be difficult to download and use in their entirety. Our interface makes it possible to easily subset just the forcings needed for a local simulation without ever downloading the entire dataset.

The aim of the hf_hydrodata package is to provide a "one-stop shop" for all of a hydrologists' data needs and to eliminate the burden of each researcher needing to learn multiple syntaxes in order to obtain the data relevant for their study area. It also aims to facilitate the sharing of open-source hydrologic data across research groups. hf_hydrodata requires a simple yet flexible set of parameters to be able to include a new offering. This keeps the barrier to entry low for members of the hydrologic community to add additional data sources to the package and keeps hf_hydrodata relevant as new datasets are created.

State of the Field

The hf_hydrodata package spans multiple agencies, and includes both site-level observations and national gridded datasets. This allows users to interact with data from many sources with a single API call. Existing packages such as the dataRetrieval R package (DeCicco et al., 2024) provide some similar capabilities allowing users to access a breadth of hydrologic site-level surface water and groundwater observations from the USGS. However, the dataRetreival package is limited to USGS sources and is designed for R users. Our package goes beyond this to provide access to data from multiple agencies (for example the SNOTEL and FluxNet observation networks). The hf_hydrodata package provides a common syntax for acquiring such observations so that the user need not spend valuable research time learning multiple syntaxes to get all data relevant for their watershed. Additionally, the hf_hydrodata package provides users access to a wide selection of gridded data products. Many of these gridded data products, such as inputs and outputs from the national ParFlow model and multiple gridded atmospheric forcing datasets, are not publicly available by other means.

Functionality

Complete documentation of the hf_hydrodata package including available datasets, example workflows, and the full API reference is available on Read the Docs.

The hf_hydrodata API contains distinct modules for accessing gridded data and site-level point observations. The output data structure is designed to align with the data type: gridded data gets returned as a NumPy array (Walt et al., 2011) while point data gets returned in a pandas DataFrame (The pandas development team, 2020) (to connect site identifiers to time series in a straightforward manner). However the API is structured to take in compatible input parameters (where applicable), in order to make the data querying process as seamless as possible across the different data types.

For example, if a user wanted to obtain gridded ParFlow CONUS1 daily simulated water table depth data for the latitude/longitude bounding box of [38.749, -106.207, 41.485, -100.695] for October 1, 2003 - May 1, 2004, they would use the following syntax to get relevant data and metadata.

```python
import hf_hydrodata

gridded_parameters = {'dataset': 'conus1_baseline_mod',
                      'variable': 'water_table_depth',
                      'temporal_resolution': 'daily',
                      'aggregation': 'mean',
                      'grid': 'conus1',
                      'latlng_bounds': [38.749, -106.207, 41.485, -100.695],
```

```
                            'start_time': '2003-10-01', 'end_time': '2004-05-01'
                           }

gridded_data = hf_hydrodata.get_gridded_data(gridded_parameters)
gridded_metadata = hf_hydrodata.get_catalog_entry(gridded_parameters)
```

If they also wanted to query observational water table depth data from USGS wells for the same geography and time period, they would use the following syntax. A subset of each of the output DataFrames produced is shown in Figure 1.

```python
import hf_hydrodata

point_parameters = {'dataset': 'usgs_nwis',
                    'variable': 'water_table_depth',
                    'temporal_resolution': 'daily',
                    'aggregation': 'mean',
                    'latitude_range': (38.749, 41.485),
                    'longitude_range': (-106.207, -100.695),
                    'date_start': '2003-10-01', 'date_end': '2004-05-01'
                   }

point_data = hf_hydrodata.get_point_data(point_parameters)
point_metadata = hf_hydrodata.get_point_metadata(point_parameters)
```

	date	393358103454800	393902103554000	393902103554001	393902103554003
0	2003-10-01	2.941320	3.392424	3.617976	3.557016
1	2003-10-02	2.932176	3.386328	3.605784	3.547872
2	2003-10-03	2.950464	3.392424	3.605784	3.557016
3	2003-10-04	2.953512	3.389376	3.608832	3.553968
4	2003-10-05	2.956560	3.392424	3.605784	3.553968

	site_id	site_name	site_type	agency	state	latitude	longitude	first_date_data_available	last_date_data_available	record_count
0	393358103454800	SC00605703BAB DTX5 BEAVER CREEK	groundwater well	USGS	CO	39.566111	-103.763333	2000-02-24	2005-06-13	1923
1	393902103554000	SC00505806BBD DTX9 MUDDY CREEK	groundwater well	USGS	CO	39.650556	-103.927778	2000-04-26	2014-09-29	4104
2	393902103554001	SC00505806BBD1 DTX10A MUDDY CREEK	groundwater well	USGS	CO	39.650556	-103.927778	2000-04-26	2024-01-27	6944
3	393902103554003	SC00505806BBD3 DTX11 MUDDY CREEK	groundwater well	USGS	CO	39.650556	-103.927778	2000-04-26	2014-09-29	4126

Figure 1: Image of example site-level point observations DataFrame and select site-level attributes, as returned by the provided example function calls.

This streamlined syntax showcases the advantage of the `hf_hydrodata` package, to allow users to access a wide variety of hydrologic data from a simple Python interface.

Acknowledgements

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