

# **SCI-WMS:Python based Web Mapping Service for Visualizing Geospatial Data**

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**Abstract** SCI-WMS is an open-source python implementation of an OGC WMS [1] service for qualitatively assessing society-critical atmospheric and oceanographic applications including: forecasting, risk assessment, model comparison and algorithmic/parameter selection. The modular cross-platform implementation of SCI-WMS allows the service to keep pace with the rapid developments in the geospatial data science community and to produce visualizations for numerous types of model outputs with transparent support for both structured and unstructured geo-referenced topologies. This article outlines the implementation and technology stack for visualizing geospatial Climatological and Forecasting (CF) data using SCI-WMS<sup>1</sup> and details the deployment of SCI-WMS for visualizing model data and simulations within the scope of the U.S. IOOS Coastal and Ocean Modeling Testbed project [2].

## **1 Motivation**

With the explosion of atmospheric, oceanographic, climate and weather data, federated datasets may span petabytes of geospatial information comprised of millions of files in different generated by multiple organizations located across the globe, it is no longer feasible to replicate such externally hosted, but semantically related data in a centralized repository for processing and visualization. SCI-WMS is a visualization tool specifically designed for federated data that maintains a local database

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<sup>1</sup> <https://github.com/asascience-open/sci-wms>

of meta-data about each externally hosted dataset to avoid data-replication while providing rapid generalization of visualizations.

The U.S. Integrated Ocean Observing System (IOOS) Coastal and Ocean Modeling Testbed (COMT) was formed to unify otherwise disparate entities in government, academia and industry to leverage the proliferation of oceanographic data and modeling techniques to combat natural and man-made coastal stressors by accelerating the turnaround from research and development to operational application of society-critical applications including: forecasting, model comparison, model skill assessment, and algorithmic/parameterization improvements [2]. Key to the U.S. IOOS COMT mission is an extensible and universally available tool for quickly visualizing and assessing a diverse set of coastal modeling data. SCI-WMS is a general OGC WMS solution for serving rasterized visualizations of geospatial data which has been deployed for the COMT project to provide visualizations of a wide range of scientific data.

## 2 SCI-WMS

SCI-WMS is an open-source implementation of the Open Geospatial Consortium’s (OGC) Web Map Service (WMS) standard which specifies an HTTP interface for generating rasterized visualizations of geospatial data [1]. SCI-WMS is implemented in Python using the Django<sup>2</sup> web framework and standard cross-platform numerical software, NumPy [3] and Matplotlib [4] for generating visual content. Additionally, the open-source python implementation provides a cross-platform WMS solution which can leverage the suite of tools developed by the geospatial data analysis community such as pyugrid<sup>3</sup> to maintain pace with the latest geospatial software and standards developments such as unstructured grid support and CF-UGrid Compliance<sup>4</sup>.

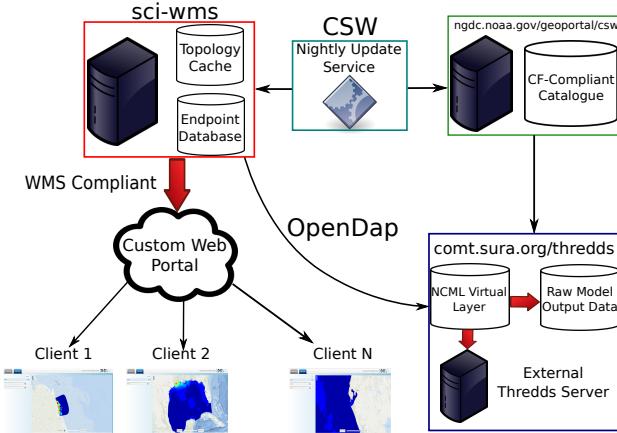
Vital to the efficiency of SCI-WMS is the abstraction of a dataset into two entities: a topology, defined as a geo-referenced spatial structure and numerical model output as visualized in Figure 2. SCI-WMS creates a local topology cache for efficiently computing spatial neighborhoods with respect to topology structure. For storage efficiency, model output is not replicated locally but referenced via OGC compliant web-services. Because geospatial WMS requests are commonly restricted to a subset of the Earth’s surface, SCI-WMS uses the local topology to compute the subset of model data needed to fulfill each request prior to accessing the external data. Furthermore, by classifying topologies as either regular or unstructured, efficient algorithms and data structures are exploited to optimize the computation of relevant model data subsets.

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<sup>2</sup> <https://www.djangoproject.com/>

<sup>3</sup> <https://github.com/pyugrid/pyugrid>

<sup>4</sup> <https://github.com/ugrid-conventions/ugrid-conventions/blob/v0.9.0/ugrid-conventions.md>



**Fig. 1** Overview of the SCI-WMS deployment for the U.S. IOOS COMT project. SCI-WMS updates its topology and endpoint database via a nightly service which queries CF-Compliant datasets catalogued by NGDC. Model data is hosted on an external web server exposed by an NcML facade as a single NetCDF data structure accessible to SCI-WMS via OPeNDAP. SCI-WMS responds to http clients interfacing through a custom built web portal.

Topology	OpenDap Endpoint
	<a href="http://...">http://...</a>
	<a href="http://...">http://...</a>
$\vdots$	$\vdots$
	<a href="http://...">http://...</a>

**Fig. 2** SCI-WMS topology and endpoint data store. Typologies are classified as c-grid and u-grid for efficient geospatial queries and remote model data access.

### 3 Deploying SCI-WMS for the U.S. IOOS COMT Testbed

While SCI-WMS is a general software solution for geospatial visualization, it is a key component in realizing the U.S. IOOS COMT mission, facilitating qualitative model comparisons and aggregation through a unified visualization framework. Figure 1 outlines the cyberinfrastructure behind the deployment of SCI-WMS for the COMT project.

The NOAA<sup>5</sup>–NGDC<sup>6</sup> Geoportal indexes public geophysical datasets and provides an OGC Catalogue Web Service (CSW) to query datasets by their metadata at-

<sup>5</sup> National Oceanic and Atmospheric Administration

<sup>6</sup> National Geophysical Data Center

tributes. SCI-WMS queries the NGDC Geoportal at regular intervals updating both the topologies and OPeNDAP links for all new or modified datasets.

Raw coastal data is hosted by the Southeastern Universities Research Association (SURA) on a dedicated server for the COMT project [5]. Each data set may consist of multiple files in different formats, and may be the result of very different models run by various institutions with disparate computing resources. However, accompanying each dataset is an NcML virtual layer which exposes each dataset as a single NetCDF object which may be accessed via OPeNDAP<sup>7</sup>. Furthermore, the NcML facade presents a consistent set of meta information in accordance to CF-Conventions [6] providing services like SCI-WMS access to the raw data through a uniform interface.

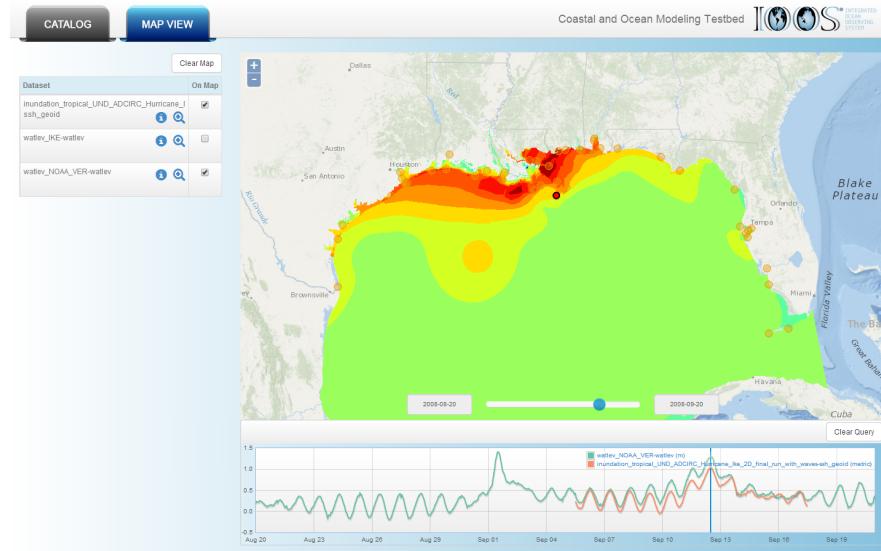
Currently, SCI-WMS is used to visualize data from the first phase groups of IOOS COMT program: *estuarine hypoxia, shelf hypoxia and coastal inundation* [2]. For each modeling group, SCI-WMS successfully generates visualizations from ADCIRC, FVCOM, SELFE and SLOSH models and serves as a use-case of how SCI-WMS can be leveraged as a scalable solution for delivering consistent visualizations of scientific data to a diverse community.

## 4 Results

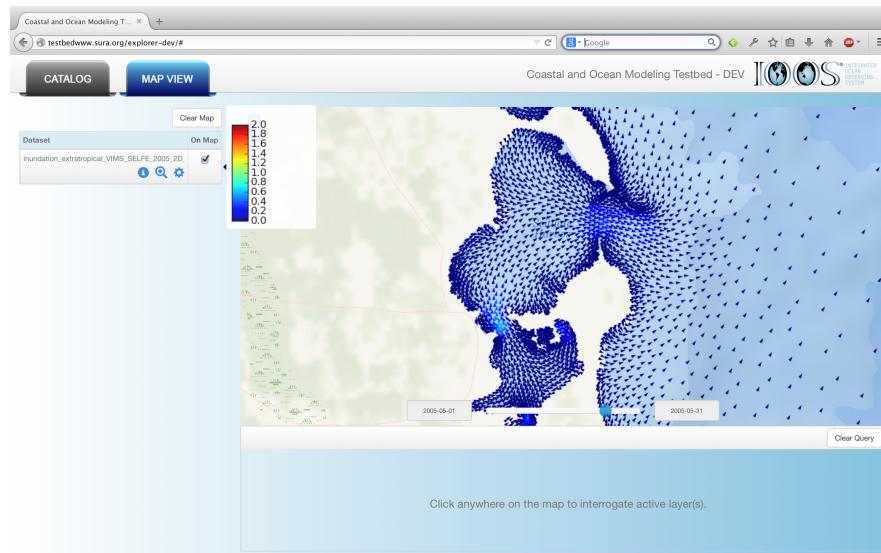
Figure 3 shows a web portal utilizing the SCI-WMS backend to compare ADCIRC model output for Hurricane Ike with water levels observed by NOAA stations. On-going development is in progress for SCI-WMS to support emerging geophysical datasets such as ensemble model output and to provide clear visual support for the assessment and quantification of model skill and performance metrics.

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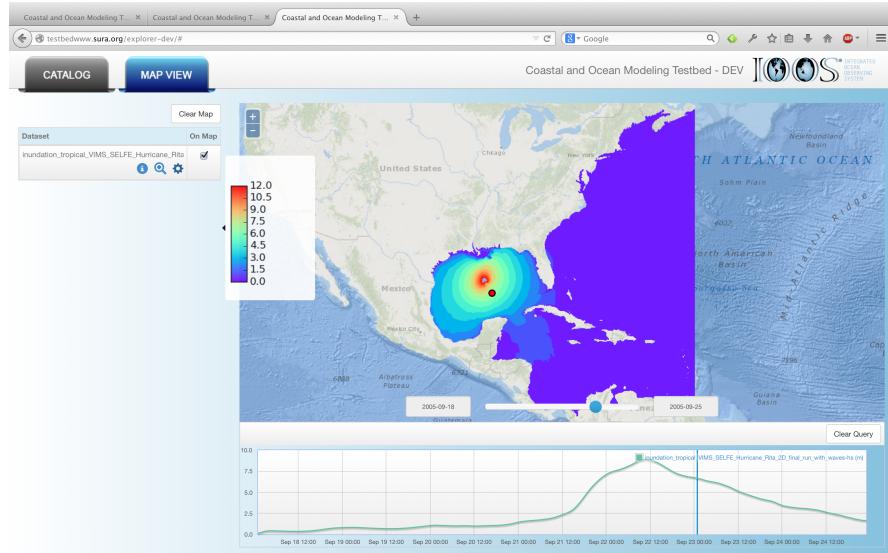
<sup>7</sup> <http://www.opendap.org/>



**Fig. 3** Comparison of ADCIRC (unstructured topology) model results with observed water levels in the Northern Gulf of Mexico for Hurricane Ike. Verified observed water levels are from NOAA's Station 8760922 (red dot on map). The map shows modeled water levels (in meters above the geoid) at the peak of the storm in southern Louisiana. The time series plot shows both the modeled (green) and observed (orange) water levels. The vertical blue line in the time series plot corresponds to the current time of the map.



**Fig. 4** SELFE model of current direction and speed in the Chesapeake Bay area.



**Fig. 5** Visualizing SELFE model of significant sea surface wave height along the eastern coast of the United States. The underlying topology is an unstructured grid with over 5 million nodes which SCI-WMS can handle in real time.

## References

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