The NANOOS Visualization System (NVS): A user-friendly, regional application for environmental data aggregation and dissemination

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A fundamental component of the U.S. Integrated Ocean Observing System (U.S. IOOS) is a network of Regional Associations that, with guidance from local stakeholders, coordinate the enhancement of regional coastal observation networks and the development of data-access products meeting regional needs. As the Pacific Northwest IOOS Regional Association, the Northwest Association of Networked Ocean Observing Systems (NANOOS) has as one key objective: the provision of integrated ocean and coastal data and user-defined products to a diverse group of end users in a timely fashion, and at spatial and temporal scales appropriate for their needs. The need for regional integration of environmental observation systems in support of diverse user communities is increasingly recognized across scientific domains, resource management agencies, and other societal sectors.

To meet this objective, NANOOS partners developed the *NANOOS Visualization System (NVS, http://nvs.nanoos.org)*, which has had ongoing enhancements since its first release in 2009 (Risien et al., 2009). NVS (Figure 1) is a web-accessible application built largely with open-source software components. It aggregates, displays and serves oceanographic, meteorological and near-coastal river data from a wide range of observation and modeling systems across coastal areas of the Pacific NW, including buoys, tide gages, river gages, weather stations, satellites and model forecasts. It offers end users a rich and user-friendly experience while integrating primarily recent and near-real-time data from a diverse set of providers, including county, state and federal agencies; private industry and regional partnerships; and academia. Regional and national feedback confirms that NVS has been well received by ocean observing and stakeholder communities alike.

NVS functionality and data coverage have greatly expanded since the original release. Currently it features time-varying tile-based map overlays (Figure 1), model-observation comparisons at observation platform sites (Figure 2), and mobile applications (Figure 2) that leverage many components from the main application, including visual elements and the data aggregation, access and plotting services. With support from the Stroud Water Research Center and the NSF Critical Zones Observatory program (NSF-CZO), the NVS framework was recently generalized, enhanced and adapted to support a watershed-based application (http://wikiwatershed-vs.org) in the Christina River Basin (CRB), a CZO site that is a tributary of the Delaware River (Figure 2).

NVS data-handling approaches favor lightweight designs, rapid development, component modularization, backend data caching, and fast data access (Mayorga et al., 2010). NVS is supported by an "asset" relational database that, together with lightweight custom web services, drives all dynamic information on the user interface. A data cache for near-real-time *in-situ* observation (30 days, soon to be expanded) is populated via dedicated Python harvesters that access and transform data from multiple sources, ingesting heterogeneous formats, data structures, semantics, and variable units. Each harvester is configured to a specific data source, an external entity offering access to data from its own observation assets or assets aggregated

from multiple providers. These data flows are continuously transformed and loaded into the NVS database in a common structure and largely homogenized semantics, including common observed-variable names and sensor-depth schemes. One of these data flows is the CUAHSI HIS WaterOneFlow (WOF) web service, which delivers data in the WaterML 1 XML encoding developed by CUAHSI HIS. The WOF harvester was developed to ingest USGS river gage data in a way that is readily expandable to other national and regional hydroclimate data sources available via the CUAHSI HIS Central system; this harvester has already been expanded for the CRB application to include the Delaware Environmental Observing System.

By avoiding onerous data-delivery requirements and instead applying a flexible policy for data ingestion, the NVS team has enabled local data providers with limited resources to have their sensor data aggregated into larger regional applications. In turn, the NVS aggregated *in-situ* data store is made available for regional programmatic access via custom, lightweight web services, and for national integration and access by IOOS and other users via standards-based data services, including Open Geospatial Consortium Sensor Observation Service (OGC SOS).

The NANOOS design and development team continually re-evaluates and enhances NVS as needs are prioritized and resources allow. Enhancements currently in planning include greater modularization of tools and data, more comprehensive and consistent management of the time dimension, and greater scalability to handle larger datasets. However, as its application expands beyond the original Pacific NW and coastal focus, NVS is incorporating richer capabilities and benefiting from effective support by other groups. A prominent example of this is an NSF-supported collaboration with the national CZO program and CUAHSI HIS partners. Expected to launch soon, this project will utilize NVS to provide user-friendly data access to time series data across all CZO sites. We look forward to further collaborations and broader community engagement.

References

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NANOOS NVS Development Partners

- Applied Physics Laboratory (APL), University of Washington
- The Boeing Company
- Center for Coastal Margin Observation & Prediction (CMOP), Oregon Health & Science University
- College of Earth, Ocean, and Atmospheric Sciences, Oregon State University (OSU)
- Oregon Department of Geology and Mineral Industries (DOGAMI)

Figures

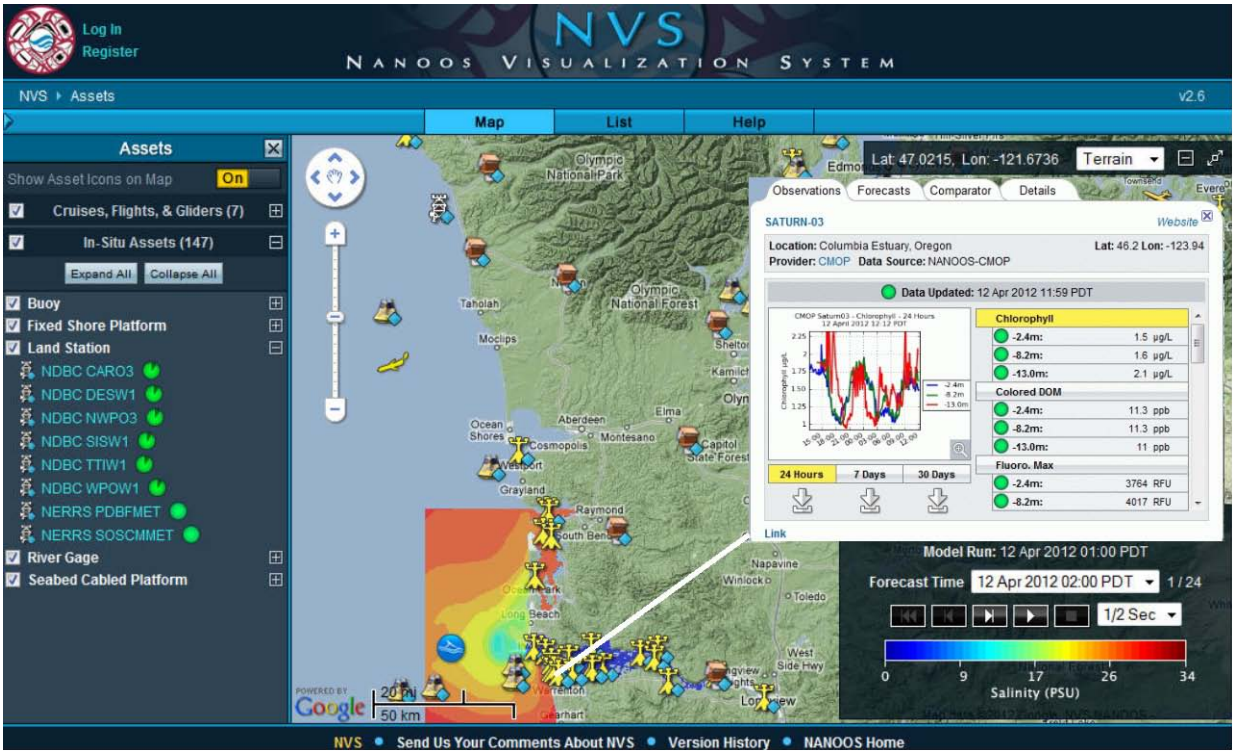

Figure 1. NVS (**http://nvs.nanoos.org**) screenshot in the Pacific NW, zoomed in to an area between the Columbia River estuary and Puget Sound. The pop-up window shows a near-real-time sensor platform at the Columbia mouth with sensors at multiple depths; Chlorophyll-a from fluorescence sensors is shown on the plot of the previous 24 hours. Salinity from a hydrodynamic estuarine circulation model is shown as a map overlay at the Columbia estuary and plume. (Note that to improve the presentation, some NVS functionality is hidden and that the pop-up window is shown as a separate screenshot inset).

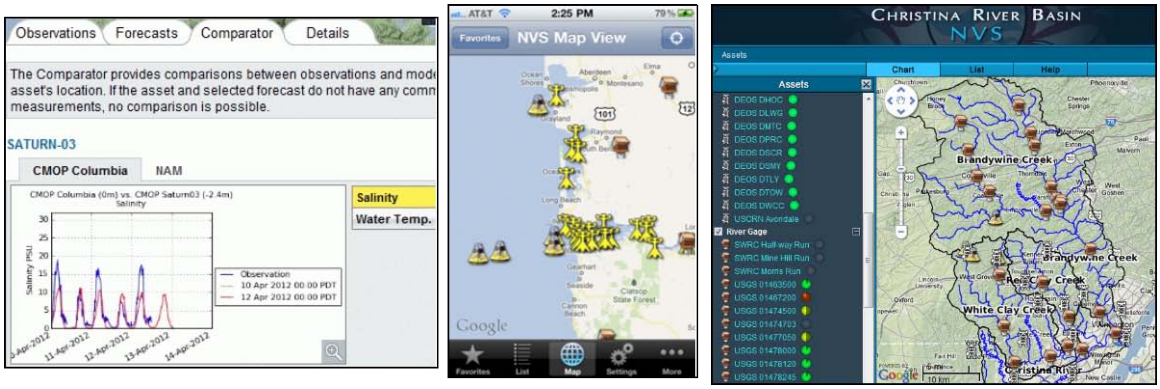

Figure 2. (Left) "Comparator" tool: Model (red) - observation (blue) salinity comparison for current and recent conditions for the site and model shown in Figure 1; (Center) iPhone NVS app (an Android app is also available); (Right) NVS adaptation to the Christina River Basin, a tributary of the Delaware River.