NANOOS Data Management Plan

Version Tracking

Date	Persons	Change Description
2023-04-14	Roxanne Carini	Updated for NANOOS Recertification
2020-11-20	Craig Risien	Updated for inclusion in the NANOOS 2021-2026 Proposal
2020-08-16	Emilio Mayorga	Certification Approved
2018-02-22	Emilio Mayorga	Response to IOOS Request for Additional Information: - Added Version Tracking section and Table of Contents - Enhanced Archiving and Quality Control descriptions, including timelines - Clarified roles of NANOOS “internal” providers vs NANOOS DAC - Added citation (Seaton et al., 2018)
2017-07-11	Emilio Mayorga	Initial version, submitted with Certification Application

A. Background

The NANOOS Data Management and Cyberinfrastructure (DMAC) effort involves a collaboration of several NANOOS partners who are responsible for developing and maintaining a regional Data Assembly Center (DAC) for robust, operational data aggregation, management, quality control, distribution and archiving; and informative, user-friendly products encompassing the web portal and interactive data access and visualization applications online and on mobile platforms. NANOOS DMAC integrates and manages data from a variety of sources and types of assets that include in-situ observations, remote sensing observations and products, processed data products (such as climatologies), and numerical model nowcasts and forecasts.

NANOOS organizes the broad DMAC effort into two overlapping committees or teams, with overlapping members and regular cross-communication: DMAC and User Products (UPC) Committees. The DMAC Committee oversees DAC operations, including compliance with IOOS DMAC functional roles, while the UPC oversees web portal and user product development, prioritizing and assessing usability for new features, and user engagement. The UPC strives to create innovative and transformative user-defined products and services for Pacific Northwest stakeholders, sustaining innovations with the NANOOS Visualization System (NVS) to succeed in this vital translation: meaningful and informative data products that connect with user applications and serve society. NVS, including its supporting data and metadata stores and integrated visualization products, play a central role in NANOOS DMAC and UPC efforts. Weekly "tag-up" calls of these two committees plus a third, the Engagement & Outreach (E&O) Committee, comprise a team, the NANOOS Tri-Com, who collectively produce and review enhancements and development of our data products and services to meet user needs. Annual Tri-Com meetings are used to review progress and set priorities for the coming year.

The goals of the DAC system are to provide the functional six core capabilities described in the "Guidance for Implementation of the Integrated Ocean Observing System (IOOS) Data Management and Cyberinfrastructure Subsystem" document (https://ioos.noaa.gov/data/contribute-data/), and to support the data and metadata needs of NANOOS user applications that serve a range of partners and consumers including government (local, state, federal and tribal), industry, education sectors, non-profits and the general public. These goals are carried out at the Applied Physics Laboratory at the University of Washington (APL-UW) by the DMAC co-leads, heavily advised by NANOOS collaborators at the Oregon Department of Geology and Mineral Industries (DOGAMI) and the Columbia River Inter-Tribal Fish Commission (CRITFC).

Data for in-situ observations and metadata for all asset types are integrated, managed, and centralized on APL-UW servers to support user access via the NVS application and the NANOOS ERDDAP server and programmatic access to asset inventories. This integration encompasses "internal" data from NANOOS-funded assets as well as "external" data from other regional assets and federal and Canadian assets. NANOOS submits glider and High Frequency (HF) Radar data to the corresponding national DACs for national integration and distribution, while also consuming those data streams in our user applications. In addition to direct observation data, NANOOS integrates and manages data from other types of assets, including gridded data from models and processed data products. These are currently consumed by internal applications and displayed in NVS, and some are distributed by NANOOS PIs to external partners.

The NANOOS DMAC team keeps abreast of U.S. IOOS Program Office data management activities via regular communication with Program Office personnel, other Regional Association (RA) DMAC teams, and community-based discussions. It maintains communication particularly with West Coast RA's through common participation in NOAA West Watch (https://www.noaa.gov/westwatch), the West Coast Ocean Data Portal (https://portal.westcoastoceans.org, a component of the West Coast Ocean Alliance), the IOOS Pacific Region Ocean Acidification (IPACOA) Data Portal (http://www.ipacoa.org), and other cross-regional initiatives. It also maintains international engagement via collaborations with Canadian partners (particularly in British Columbia, but also nationally) and technical leadership in the Global Ocean Acidification Observation Network (GOA-ON) Data Portal (http://portal.goa-on.org). (NANOOS DMAC regional, cross-regional, and international collaborations on ocean acidification are discussed in Mayorga et al., 2016, and Newton et al., 2012).

B. Roles and Responsibilities

This section meets Certification Requirements described in §997.23 (f) (1). NANOOS DMAC and UPC teams include personnel from APL-UW, OSU, CRITFC and DOGAMI (Oregon Department of Geology and Mineral Industries). The DMAC Committee oversees DAC operations, including compliance with IOOS DMAC functional roles, while UPC oversees web portal and user product development, prioritizing and assessing usability for new features, and user engagement. NANOOS E&O Committee provides oversight on usability. UW leads DAC efforts: implementation and operational activities involving centralized NANOOS resources, the NANOOS web portal, and NVS. However, prioritization and definition of enhancements and new capabilities are arrived at collaboratively among these NANOOS partners. In addition, data and visualization product development, multi-source data assembly, and IOOS protocol or functional capability implementation are all activities carried out jointly by these partners in support of NANOOS DMAC efforts.

Troy Tanner (UW), co-leads the NANOOS DMAC Committee with Roxanne Carini, ensuring that all data collected by the program are timely, properly preserved, and made available via IOOS standard services. Coordinates and leads the implementation of IOOS DMAC functional capabilities involving data integration, management, quality control, distribution, and archiving. Leads NANOOS web portal and user application development, including mobile applications. Lead developer for NVS, including plot and map rendering capabilities such as map tile generation from gridded data. Coordinates integration of distributed data products into cohesive and user-friendly user applications. Also coordinates NVS metadata and data store development and maintenance. Supervises staff who perform system administration for all UW NANOOS servers, including those

supporting DAC capabilities.
Roxanne Carini (UW), co-leads the NANOOS DMAC Committee with Troy Tanner. Coordinates DAC activities among NANOOS DAC partners and serves as primary point of contact between NANOOS, the DAC team, data providers, peer RA DMAC teams, and the IOOS Program Office DMAC team. Also provides coordination with other relevant cyberinfrastructure and data initiatives regionally, nationally and internationally.

Jonathan Allan (DOGAMI), NANOOS UPC Chair. Coordinates UPC activities to seek user feedback and prioritizing of user product development and enhancements. Also provides and oversees direct data product development in his areas of expertise, including shoreline observations, near-shore bathymetry, tsunami hazards, and climatology.

NANOOS selected these individuals based on their achievements, qualifications, and regional knowledge. All are known experts in their respective fields. Each of these NANOOS leads provides performance reports to the Executive Director and are part of NANOOS reviews. Additionally, all are subjected to the annual review processes of their home institutions. UW and DOGAMI each have a process in place for personnel evaluation. All personnel listed have received excellent evaluations that are on file with their respective Human Resources departments.

CVs for the DMAC and UPC personnel:
https://www.nanoos.org/documents/certification/NANOOS-CVs-2023.pdf

C. Implementation of Data Management Protocols

This section meets Certification Requirements described in §997.23 (f) (5). NANOOS DMAC personnel maintain regular communication with the U.S. IOOS Program Office through a variety of mechanisms including in-person meetings, phone calls & webinars, email conversations, and GitHub repositories. This communication ensures that the DMAC team is aware of all new practices and protocols, as promulgated by the IOOC and the IOOS Program Office and understands how and when to implement them. NANOOS DMAC personnel also play active roles in IOOS DMAC projects, contributing to software development, implementation of standards, and system documentation.

The NANOOS servers and data management software are maintained by the NANOOS DMAC team so data management protocols can be applied as soon as practicable, limited only by resource restrictions (personnel time, budget, or server capabilities). The NANOOS DMAC team plans to implement all new protocols as soon as possible and within one year of adoption by IOOS. Once the new protocol is received by the DMAC lead, an implementation plan, including a more detailed schedule, will be outlined, and executed by the DMAC team.

D. Computing Infrastructure

This section meets Certification Requirements described in §997.23 (f) (3). DAC operations and user applications are supported by servers primarily at **APL-UW**. The servers are located in a secure, dedicated server room equipped with redundant network access and power protection. APL-UW servers run Ubuntu and are comprised of over a dozen physical and virtual servers. These servers host Apache and Tomcat web servers, MySQL and PostgreSQL relational databases, and various web applications. Data harvesting is accomplished with a purpose-built software suite named BlueHarvest. Overlays are created and served by a purpose-built application named EIS. NANOOS generated platform data is made publicly available via the NANOOS ERDDAP server. NANOOS servers and applications are monitored by a third-party monitoring application named Nagios. All data and application software are backed up daily to an external server.

E. Data Streams

This section meets Certification Requirements described in §997.23 (f) (2-6). NANOOS DMAC integrates and manages data from a variety of sources and types of assets that include in-situ observations, remote sensing observations and products, processed data products (such as climatologies and anomalies), and numerical model nowcasts and forecasts. **Variables** handled encompass meteorology; physical, biogeochemical, and biological oceanographic properties; and nearshore geomorphology. For "internal" (NANOOS funded) data streams (E.1.), the specific variables and data types produced by each observational asset are described in the **individual provider Data Management Plans (DMP's)** (see DMP links in Table 1); variables for all integrated assets are provided by the asset inventory; descriptions of **NANOOS asset inventories** are available at https://www.nanoos.org/about_nanoos/documents.php under the "Kay Documents" and "Certification 2023" sections.

All data flows from instrument platforms to shore-side servers are managed by platform operators, both for "internal" (NANOOS) and "external" data streams. These data streams encompass **internal data** from NANOOS-funded assets (managed by operators – NANOOS Principal Investigators (PIs) – who are an integral part of NANOOS) as well as **external data** from other regional assets, larger scale observation systems, and federal and Canadian assets. Federal sources of in-situ observation data (NOAA NDBC, NOAA CO-OPS, NOAA PMEL, USGS, CDIP, etc.) are managed by federal partners and are not discussed further in this document. Data from all providers is downloaded by a new NANOOS data harvester named "BlueHarvest". BlueHarvest facilitates the access, integration, centralization, and management of data streams. Data for all variables are converted to common units set by NANOOS DMAC. Data and metadata from internal platforms are pushed to the NANOOS ERDDAP server to facilitate standardized discovery and data access. NANOOS PIs operating gliders and High Frequency Radars (HFR) submit their data to the corresponding national DACs for national integration and distribution using previously defined DAC standards.

NVS (https://nvs.nanoos.org/) serves DAC functions as a central integrator and distributor of data, asset metadata, graphical products (time series plots, map overlays, section plots, etc.) and related information available to users in a consistent fashion (Mayorga et al., 2010). Its data flows and components are illustrated in Figure 1, though emphasizing fixed-location in-situ assets. Hosted on UW servers, the NVS asset data and metadata are maintained in a relational database. The database relies on consistent categories of platform types, measured variables (labeled as "measurements") and units, data types, etc., and mapping and translation between heterogeneous source metadata and this consistent metadata. In situ observational data, particularly for – but not limited to – fixed- location assets (including depth profilers), are also integrated into this database and leverages this asset metadata as well as a coherent, harmonized representation of time, location, depth/altitude, and units; transformations from original source formats, encodings and conventions are performed using the BlueHarvest data harvesting suite. These transformations and checks **represent a base level of Quality Control (QC) applied by the DAC** to all in situ observational data streams. More thorough QC of each dataset is carried out by the platform operators. QC details for internal data can be found in the individual provider DMPs linked in Table 1. NVS also provides a custom, lightweight set of RESTful HTTPS web services that return readily parsed JSON responses. Map overlays, such as currents from HF Radar, are Google Map-compatible tiles created by the NANOOS tile server, EIS.

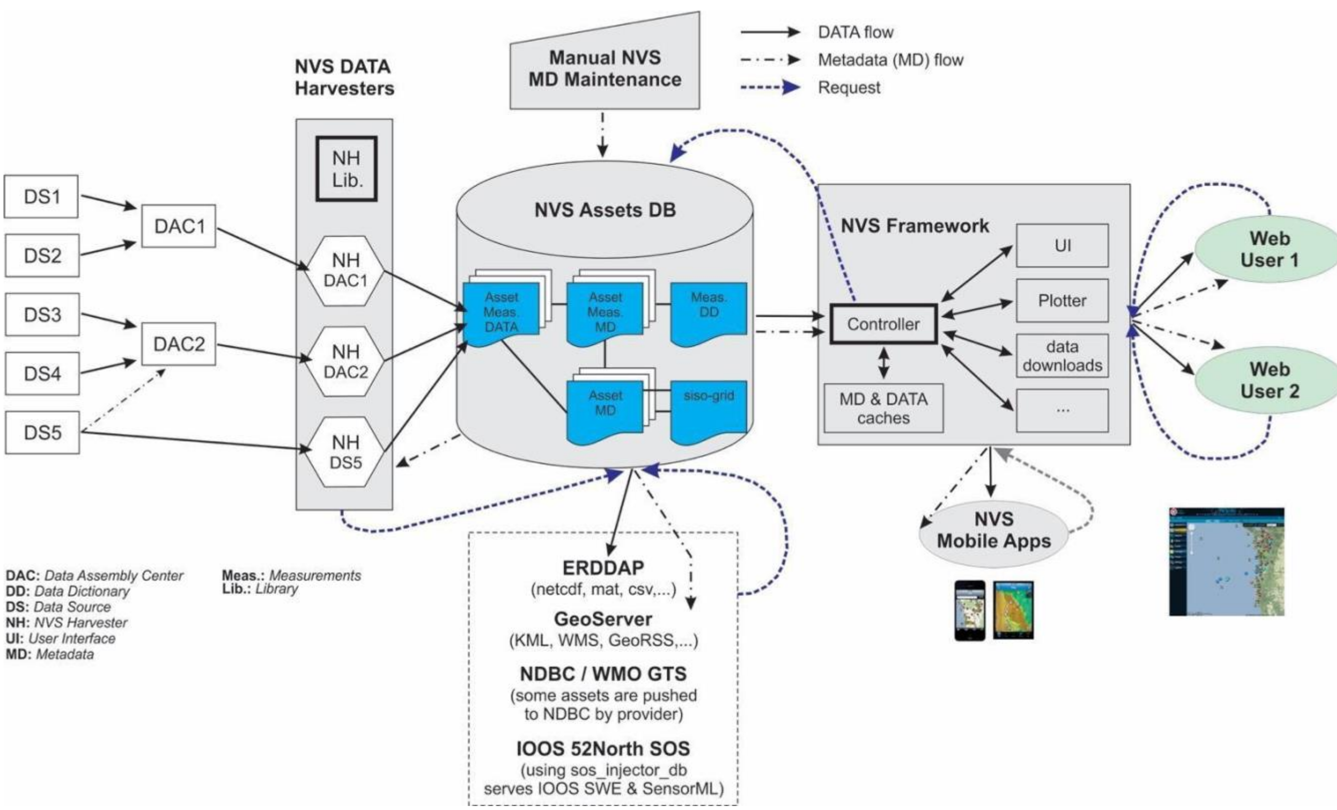

Figure 1. NVS data flows and components, emphasizing fixed-location in-situ assets (platforms). The NVS Assets Database contains the NANOOS DAC metadata store for all asset types and time series data store for fixed-location and some mobile in-situ assets. Shaded blocks represent broad NVS components. DAC1 and DAC2 illustrate complementary functionality served by NANOOS DMAC partners (e.g., OSU) in aggregating data from a few sources and redistributing them in a common form for easier access by the centralized DAC. Data flows from instrument platforms to operator shore-side servers (which in turn serve as NVS data sources) are not shown here. DAC (Data Assembly Center), DD (Data Dictionary), DS (Data

Source), Lib. (Code Library), MD (Metadata), Meas. (Measurements), NH (NVS Harvester), UI (User Interface). Adapted from Mayorga et al. (2010).

1. NANOOS (Internal) Data Streams

Table 1 provides a summary of NANOOS-funded (internal) observational data streams, including important data management and data distribution services or capabilities in place as they pertain to each data stream. Each of the 15 data streams is grouped into four categories that share many characteristics:

1. Surface Currents and Waves
2. Fixed-location Sensor Platforms
3. Gliders and Ferries
4. Beach and Shoreline Observations

These categories generally correspond to those in the NANOOS Strategic Operational Plan.

For each data stream category, this section describes these functional capabilities:

1. Data Ingestion and Management (See also individual DMP Sections 1-4 and 5.1)
2. Quality Control (See also individual DMP Sections 5.2)
3. Data Access and Sharing (See also individual DMP Sections 6-7)
4. Archiving (See also individual DMP Section 8)

Each provider (operator) manages its own data flow from sensors to shore-side servers, computer infrastructure, and instrument logs for its data files before integration into the NANOOS DAC. The descriptions below include brief summaries of actions performed by NANOOS providers for assets under their responsibility (gleaned from the individual DMPs, Table 1), as well as broader, across-the-board actions performed by the NANOOS DAC. The latter are indicated explicitly. Variables measured by each asset are listed in the individual DMPs, Section 1.6.

**** Surface Currents and Waves***

HF Radar and *Port X-Band Radar* provide complementary but distinct capabilities for observing surface currents and waves, respectively. As the *HF Radar* technology is more mature, procedures for data management, quality control, data access and sharing, and archiving are more standardized and agreed upon nationally compared to *Port X-Band Radar*. NANOOS follows national HF Radar best practices, as referenced in the “National Surface Current Mapping Plan”.

Data Ingestion and Management. Details for each asset type are described in its individual DMP (Table 1). *HF Radar* data are submitted to the National HF Radar Network (DAC) according to DAC specifications. *Port X Band Radar* data, representing radar backscatter intensity as a function of range, azimuth, and time, are recorded on-site and processed on a workstation either on-site or at OSU. Raw data are stored in NetCDF files that include all necessary metadata for making the data meaningful as well as other useful information pertaining to the recordings: Radar antenna elevation, Radar zero heading, Radar antenna location (latitude/longitude or UTM coordinates), Recording year, Recording UTC offset, and the “donut”, or number of range bins that should be removed from each radar pulse in order to correctly map the data. The backscatter intensity data are rectified to geographic coordinates and used to create mean images (time exposures) and bulk wave parameters (peak directions and frequencies). Processed data is generally stored as MATLAB MAT files. Imagery is stored as PNG files that are generally available on the website for use by NVS within one hour of the end of the recording.

Quality Control (QC). Details for each asset type are described in its individual DMP (Table 1, section I.3). *HF Radar* QC procedures adhere to the National HF Radar Network (DAC) according to DAC specifications. There is no established standardized protocol for *Port X-Band Radar* image data. However, times when data are not available are flagged.

Data Access and Sharing. *HF Radar:* As it is distributed to the National HF Radar Network, these data are openly and readily available via web services and download capabilities provided by the National DAC. The DAC also makes the data available to the WMO GTS for use in national forecast capabilities. In addition, NANOOS produces its own gridded product from subsetting and reprocessing National DAC products; these are accessible for browsing and visualization as map overlays on NVS. *Port X-Band Radar:* Custom plots of single rotation, average intensity, wavenumber spectra are created by the provider and integrated into NVS for the port site. NVS also serves times series of peak wave direction, peak wave period, and peak wavelength. Raw data are available upon request from the provider; community data standards for encoding and delivery of this data type are not available.

Archiving. *HF Radar* data are archived on NCEI by the National DAC. *Port X-Band Radar* raw data (with metadata) are currently not archived nationally but are preserved by the provider (OSU) in either raw or NetCDF format using local redundant HDD storage. Discussions between NCEI, the provider and NANOOS will be required to lay There are several data products that have historically been produced and served from **OSU servers** in the College of Earth, Ocean, and Atmospheric Sciences (CEOAS). APL-UW has assumed production for many of these. A few were deemed legacy products and will be retired. NANOOS DMAC anticipates the remaining products will be fully transitioned to APL-UW by the end of 2023. out appropriate options for long-term, national archiving.

**** Fixed-location Sensor Platforms***

Data for this asset type is generated from 5 datasets (*Washington Shelf Buoys, Oregon Shelf Buoy, Puget Sound ORCA Buoy Program, CMOP SATURN network, and South Slough Estuary Observations*) managed by 4 providers (Table 1). Platform types span shelf and estuarine moorings, profiling moorings, and sensors attached to piers or other coastal fixed structures. Variables handled encompass meteorology as well as physical and biogeochemical oceanographic properties. *South Slough Estuary Observations* are also part of the National Estuarine Research Reserves (NERR) network and follow NERR System-Wide Monitoring Program (SWMP) data management, processing, QA/QC and distribution procedures established by the NERR Centralized Data Management Office (CDMO). These procedures are described or pointed to in the individual DMP for this data stream (Table 1), taken from the SWMP network DMP; therefore, specific procedures will not be discussed in detail below, except as noted.

Data Ingestion and Management. Details for each asset type are described in its individual DMP (Table 1). Initial raw and pre-processed data are assembled by the data providers and made available for near real-time integration (harvesting) by the NANOOS DAC via data pulls, typically from a provider web server, using a variety of access protocols and data encodings. Procedures for harvesting and DAC management generally follow the workflow described in the introduction to Section E, including Figure 1, and include substantial data and metadata harmonization, including conversion to common metric units. The NVS data store currently maintains the most recent 60 days of data, though the lifting of this limitation is being incrementally explored . The NANOOS ERDDAP server archives a subset of the fixed-location sensor platform data for harvest by NDBC and links to full datasets archived via other ERDDAP servers maintained by individual NANOOS PIs.

Quality Control (QC). All NANOOS providers follow best practices for QA/QC procedures, as documented in the individual DMPs (Table 1). The current NANOOS DAC QC process for all fixed-station assets, in addition to what is described in Section E, includes syntax checks to reject malformed data sources, location (latitude & longitude) validation after each deployment, and feed/continuity monitoring to alert the DAC team when data are lagging well behind the expected schedule so that appropriate action can be taken.

NANOOS DMAC has participated actively in QARTOD implementation discussions, including the IOOS DMAC QARTOD Working Group and contributions to several QARTOD manuals. We initiated a QARTOD flagging pilot on the NVS data store in Winter 2017 using the *ioos_qartod* Python package. In addition, CRITFC took steps to implement QARTOD flagging on the *SATURN network* data in 2018 (Seaton et al., 2018) in coordination with the NANOOS DAC (see the individual DMP), the *Puget Sound ORCA Buoy Program* implemented relevant QARTOD manuals in 2022-2023, and King County – an external regional partner – is already implementing QARTOD-based flagging on their data streams (see Section E.2.). NANOOS is also building regional climatologies and historical records that may help establish QARTOD ranges. When available from the platform operator/NANOOS PI, and to the extent possible and practical for useability, NANOOS DMAC will display QARTOD flags along with the data for a given variable in NVS. The QARTOD flags will also be made available as part of the datasets archived on the NANOOS ERDDAP server.

Data Access and Sharing. As described above in the introduction to Section E, data are available for browsing and visualization on NVS, as well as download or programmatic access via NVS, NDBC / GTS, and ERDDAP.

Archiving. NANOOS started archiving data with NCEI in Spring 2017. In this initial stage, the *SATURN network* data (Table 1) from OHSU-CMOP (now CRITFC) was used as a pilot to develop metadata conventions, file segmentation and archival procedures that can be readily adapted to fixed-location in-situ data streams from other NANOOS sources. Nearly all historical data have been submitted, and all current data is being submitted monthly starting on the 15th (Available datasets on NCEI OneStop: https://data.noaa.gov/onestop/collections?q=Oceanographic%20data%20Center%20for%20Coastal%20Margin%20Observation%20and%20Prediction and CMOP directory at: https://www.ncei.noaa.gov/data/oceans/ioos/nanoos/ohsucmop/). Archival files are in the NCEI NetCDF Templates v2.0 format and follow ACDD and CF conventions. The NANOOS DAC automatically stages monthly incremental archive updates on the 10th of the month at https://data.nanoos.org/ncei/ohsucmop/, and these are automatically downloaded (pulled) by NCEI by the 15th of the month. The NCEI Submission Agreement (SA) is provided as the Appendix document https://www.nanoos.org/documents/certification/DMP/NANOOS-NCEI-Submission_Agreement_2017-03-13T19-51-12.pdf. The SA has extensive technical details about the archiving procedures. Below are relevant fragments from the SA:

Submission Information Packages (SIP) will be organized into 'bags'. Each 'bag' will contain data, metadata, and manifest files which fully document the files intended to be submitted. The 'bags' will be folders on http://data.nanoos.org/ncei/ohsucmop/ which correspond to the name of the platform. E.g. abpoa/, riverrad/, saturn01/, etc. Within the station folder (or 'bag') there will be four standard files with the following names: bag- into.txt, bagit.txt, manifest-sha256.txt, and tagmanifest-sha256.txt as well as a data/ directory which will contain folders for all of the netCDF files to be submitted. Each of the folders within the data/ directory represent an instrument/instrument deployment.

NCEI will organize the Archival Information Packages (AIP) by station. Each time a new station arrives, a new AIP will be generated. If a station follows the 'bag' convention and has a name which matched a previously submitted package, NCEI will update the AIP and append the data from the new submission.

If the new submission has files with the same name as what we previously submitted, NCEI will assume that the most recent submission should replace the previous submission. Only the files that have the same name will be replaced with the newly submitted file.

NANOOS DMAC will work with other NANOOS-funded providers to develop plans for NCEI archival following the conventions and procedures developed for the NANOOS *SATURN network* dataset. Some providers may choose to archive only delayed-mode, post-processed data within a couple of months after mooring or sensor recovery after each deployment (typically every 6 months in the case of *Washington and Oregon Shelf Buoys*). Data from *South Slough Estuary Observations* are expected to be archived with NCEI via separate arrangements between NERR CDMO and NCEI.

*** Gliders and Ferries**
NANOOS supports three gliders, *Northern CA Shelf Trinidad Head Glider* (a Seaglider,

collaboration between NANOOS and CeNCOOS), *WA Shelf Glider* (a Slocum glider), and *LaPush Glider* (a Seaglider). All historical transect deployments from all three gliders have been submitted to the national Glider DAC, and data from regular deployments are submitted automatically to the national Glider DAC. *Victoria Clipper Ferry* collects near real-time geo-referenced environmental data during daily transits of the private passenger ferry vessel, Victoria Clipper IV, as it travels between Seattle, WA and Victoria, BC (Canada). WDOE collaborates in the management of this data stream with APL-UW and with Integral Consulting, Inc.

Data Ingestion and Management. Details for each asset type are described in its individual DMP (Table 1). For *Northern CA Shelf Trinidad Head Glider* and *WA Shelf Glider*, data are received and automatically processed by OSU using standard procedures described in the individual DMPs. The processed deployment files are then automatically transformed into the Glider DAC NetCDF template and pushed to the Glider DAC, and the *N CA Trinidad Head Glider* files are shared with CeNCOOS. *La Push Glider* data are received and automatically processed by APL-UW using standard procedures described in the individual DMP. The processed deployment file is then automatically transformed into the Glider DAC NetCDF template and pushed to the Glider DAC. *Victoria Clipper Ferry* data are transmitted daily from the ferry vessel to a Digital Ocean cloud server for data processing and dissemination.

Quality Control (QC). Details for each asset type are described in its individual DMP (Table 1). All QC procedures are currently applied by the providers. *All Gliders:* The data processing and quality-control procedures for profile data are defined in the Seaglider Quality Control Manual document and by the national Glider DAC. *Victoria Clipper Ferry:* Data from the sensors are run through a set of automated and manual (staff-driven) quality control procedures based on criteria developed from QARTOD guidance, sensor manufacturer recommendations, in conjunction with location specific and climatology tests to ensure that measurements meet and pass these tests.

Data Access and Sharing. *Glider data* are archived and near real-time glider data are available via the Glider DAC, making these data readily available via web services and download capabilities provided by the national DAC. The DAC also makes the data available to the WMO GTS for use in national forecast capabilities. In addition, NANOOS has developed user-friendly NVS glider applications (https://nvs.nanoos.org/GliderTrinidadHead, https://nvs.nanoos.org/GliderWashingtonShelf, https://nvs.nanoos.org/GliderLaPush) for data visualization and access to past and current near real-time data, with links to the Glider DAC for data download. *Victoria Clipper Ferry* data are openly accessible from the Cloud, as Raw and NetCDF files, and from a THREDDS server for "Level 1" processed data; details are found in the individual DMP (Table 1). A subset of sensors is also available on NVS.

Archiving. *Glider data* from active deployments are submitted to the Glider DAC in near real-time and from there it is archived at NCEI. *Victoria Clipper Ferry* data are currently not archived nationally but are preserved by the provider on a cloud service. Discussions between NCEI, the provider and NANOOS will be required to lay out appropriate options for long-term, national archiving of this trajectory data.

*** Beach and Shoreline Observations***

NANOOS collects information on the morphodynamics of beaches along the coasts of OR and WA in order to document the seasonal, interannual, and long-term changes taking place at multiple beach study sites and at a range of spatial scales, in support of hazard mitigation. Data collected include beach profiles, and topographic, shoreline and bathymetric mapping, generated from three programs: *Oregon (OR) Shoreline Observations*, *Washington (WA) Shoreline Observations*, *and Nearshore Bathymetry*.

Data Ingestion and Management. Details for each asset type are described in its individual DMP (Table 1). For all data programs, field survey data are collected using Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) and downloaded back in the program lead's office, where post-processing and QA/QC procedures are applied, and the data files are managed as described in the DMPs. For *OR & WA Shoreline Observations* a consistent set of beach profile plots are created and distributed for wider use via NVS and other outlets.

Quality Control (QC). Details for each asset type are described in its individual DMP (Table 1). *OR & WA Shoreline Observations* use nearly identical QA/QC procedures, developed collaboratively, to ensure locational and elevation accuracy, removal of spurious elevation values, and characterization of uncertainties. Similar approaches are used for the *Nearshore Bathymetry* data. QARTOD manuals do not currently exist for these data types.

Data Access and Sharing. *OR & WA Shoreline Observations:* Typically, data are made available after they have been collected with a lag of approximately 1-2 weeks for OR and 1-2 months for WA. The data are disseminated as plots via the NVS Beach and Shoreline Changes App, see http://nvs.nanoos.org/BeachMapping. Data files are available upon request as Excel and matlab files for OR, and ASCII files for WA. *Nearshore Bathymetry* data are available upon request.

Archiving. *OR & WA Shoreline Observations* data are archived at their respective state agencies following state data preservation directives. *Nearshore Bathymetry* data are currently stored with backups at OSU servers. The providers and NANOOS worked with the IOOS program office and NCEI to assemble all required components for archiving Oregon shoreline data at NCEI. This initial dataset now sits in the NCEI queue for processing, with no estimated date for action. Once established, additional data will be archived after each collection campaign. Upon NCEI finishing the archiving process for Oregon shoreline data, NANOOS will leverage this work to develop the process for archiving Washington shoreline data at NCEI.

*** Nowcast and Forecast Numerical Models***

NANOOS supports the *UW LiveOcean model* (coastal WA, OR and BC, and the Salish Sea), the *OSU ROMS model* (coastal WA and OR), and the *CRITFC Virtual Columbia River model* (Columbia River estuary and shelf). These regional scale models include circulation and biogeochemical fields that are used internally by NANOOS data product applications and for investigation of OA, hypoxia, and HABs by shellfish growers and resource managers, among other things. These numerical models run daily at the respective institutions. NANOOS also serves model output from researchers that are not supported directly by NANOOS. This includes biogeochemical model output from *Canada's Salish Sea Cast* (Susan Allen, UBC), and the seasonal forecast *J-SCOPE biogeochemical model* (Samantha Siedlecki, U Conn). NANOOS has also tested service of high resolution currents from *PNNL's Salish Sea and Columbia R estuary models* (Tarang Khangaokar, PNNL/UW).

Data Ingestion and Management. NANOOS-funded model output is managed by individual PIs. Forecast results and value-added products are made available daily via NVS. These fields are used internally as results are incorporated into several NVS applications including Data Explorer, Tuna Fishers, and Seacast, as well as the "Forecast" and "Comparator" tabs associated with particular fixed-location sensor platforms, and by external partners such as researchers, NOAA's Office of Response and Restoration (OR&R) and the IOOS EDS Model Viewer. NANOOS also serves (on an APL-UW server) several daily files of various *LiveOcean* outputs fields accessed by other modelers to use for boundary conditions and forcings.

Quality Control (QC). Model validation and quality control is the responsibility of individual PIs.

Data Access and Sharing. *Nowcast and forecast fields* are made available within two hours of the model run completing, via NVS and on an open-access APL-UW server: https://liveocean.apl.uw.edu/output/.

Archiving. Archiving of model results is the responsibility of the individual PIs and institutions running the models, though NANOOS DMAC does assist in the distribution of daily products that are then retained archivally (https://liveocean.apl.uw.edu/output/).

2. External Data Streams

The NANOOS DAC also integrates external data streams (not funded by NANOOS) from other regional assets, large-scale observation systems, and federal and Canadian assets. Data from US federal or Canadian federal (currently Environment Canada) sources are not discussed further, as they are managed by their respective agencies. Remaining observational data streams are **primarily fixed-location in-situ assets** similar to the NANOOS Fixed-location Sensor Platforms described in Section E.1. They include shelf and estuarine moorings, benthic cabled platforms, sensors attached to piers or other coastal fixed structures, sensors on pumped water intakes at shellfish hatcheries and other facilities. Currently active providers are described in Table 2. The range of variables measured is similar to those from NANOOS Fixed-location Sensor Platforms.

Data Ingestion and Management. These providers range from small groups managing a single platform to ONC and OOI, which are large, long-term observation systems with highly established and documented data and asset management procedures and highly capable data distribution systems. Metadata and near real-time data streams from these sources are integrated into the NANOOS DAC using the same procedures as for NANOOS Fixed-location Sensor Platforms as described in Section E.1. As with those assets, data are provided in heterogeneous formats, data access mechanisms, and encodings. Data from these external sources are currently integrated only in a "pass through" basis where the NVS data store retains the most recent 60 days. This limitation may be lifted on a case-by-case basis based on data assessments, partnership strengthening, and increasing NANOOS capabilities.

Several providers, particularly those in the shellfish aquaculture community with ocean acidification (OA) concerns, maintain their sensors and data in collaboration with NANOOS partners (Newton et al., 2012). That community has developed common, shared approaches for data management around the Burke-o-lator OA sensor and related sensors, based on collaborations between industry and academic and federal scientists. In addition, NANOOS DMAC provides data management guidance to external partners, based on requests and needs.

Quality Control (QC). Several providers already apply robust and well-documented QA/QC procedures. King County is implementing QC adapted from QARTOD. ONC and OOI have their own robust, published QC procedures. Providers using Burke-o-lator sensors share and continue to develop common best practices developed by that collaborative community. Public QC documentation for a substantial subset of providers is available as follows (refer to Table 2 for provider codes):

- Hakai: https://data.hakai.org/home/sensor-network
- King County: https://kingcounty.gov/services/environment/water-and-land/puget-sound-marine/marine-mooring/data%20quality%20control.aspx
- ONC: https://www.oceannetworks.ca/data/data-quality/
- OOI: https://oceanobservatories.org/quality-control/
- WADOH: https://doh.wa.gov/community-and-environment/shellfish/commercial-shellfish/vibrio-control-plan/temperature-data

In addition, the NANOOS DAC applies to external-provider data streams the same set of base-level harmonization and QC checks described in the Quality Control sub-section above under E.1, *Fixed-location Sensor Platforms*.

Data Access and Sharing. All data streams listed in Table 2 are publicly available via NVS for graphical browsing and data downloads. NWIC data is also redistributed to NDBC / WMO GTS. In addition, several providers maintain their own robust, open data distribution mechanisms, including Hakai Institute, King County, ONC, and OOI.

Archiving. ONC and OOI have their own published, long-term data preservation plans and mechanisms. The other external providers are not currently archiving data with NCEI or a national archive. NANOOS DMAC plans to engage these partners to discuss such archiving, once the mechanisms for regular NCEI archiving of all NANOOS internal assets have been put in place.

F. Web Portal and User Applications

The **NANOOS web portal** (https://www.nanoos.org/) provides access to a wide range of resources about NANOOS, its members, IOOS and other organizations. The Products page (https://www.nanoos.org/products/products.php) provides user-friendly access to relevant web resources, user applications and products from both NANOOS and other organizations.

NVS (https://nvs.nanoos.org/) serves as the primary data browsing, visualization, and access application provided by NANOOS to its user community (Risien et al., 2009; Risien et al., 2019). In order to better serve a wide range of users, NVS provides customized "Apps" targeted to specific user communities that share a common user interface for enhanced usability and typically draw from the same common data stores. Custom Apps include the *Tsunami Evacuation Zones App* (see Martin et al., 2011), *Boaters App*, *Tuna Fishers App*, *Climatology App*, and others (Figure 2). The NVS infrastructure has been generalized into a software framework labeled "vizer" that has been adapted to other applications such as the thematic ocean acidification IPACOA and GOA-ON data portals described earlier (Section A).

The *NVS Data Explorer App* (Figure 3) provides NVS' richest and most comprehensive – but often the most complex – access to data assets integrated by NANOOS, including site time series, depth profile section plots, glider section visualizations, site comparisons between observed and modeled variables, map overlays (rendered as map tiles) from model forecasts, and gridded data products, such as remote sensing, and climatological map overlays. These are accessible from an interactive, central "timeline" selector tool.

The **CMOP Data Explorer with NANOOS Data** enables advanced users to generate and combine different kinds of plots using multiple sites and variables (e.g. winds, waves, temperature) obtained via web service access from the harmonized NVS data and metadata store for fixed-location site time series. It is a collaborative effort between CRITFC-CMOP and APL-UW that adapted the pre-existing "CMOP Data Explorer" tool (Baptista et al., 2015) to Pacific NW data distributed via the JSON-based, REST, light-weight web services provided by NVS. It's hosted by CRITFC-CMOP at: https://cmop.critfc.org/datamart/observation-network/data-explorer/nanoos/ Figure 4 shows a sample plot from this application combining two sites and two variables over a common time period.

Finally, NANOOS hosts other online user products that leverage NVS components or other NANOOS data integration activities. Prominent examples include **J-SCOPE**, the JISAO Seasonal Coastal Ocean Prediction of the Ecosystem (https://www.nanoos.org/products/j-scope/); and **Real-Time HABs**, Real-time Information About Harmful Algal Blooms (https://www.nanoos.org/products/habs/real-time/home.php).

Figure 2. NVS (V6.3) Apps at https://nvs.nanoos.org/.

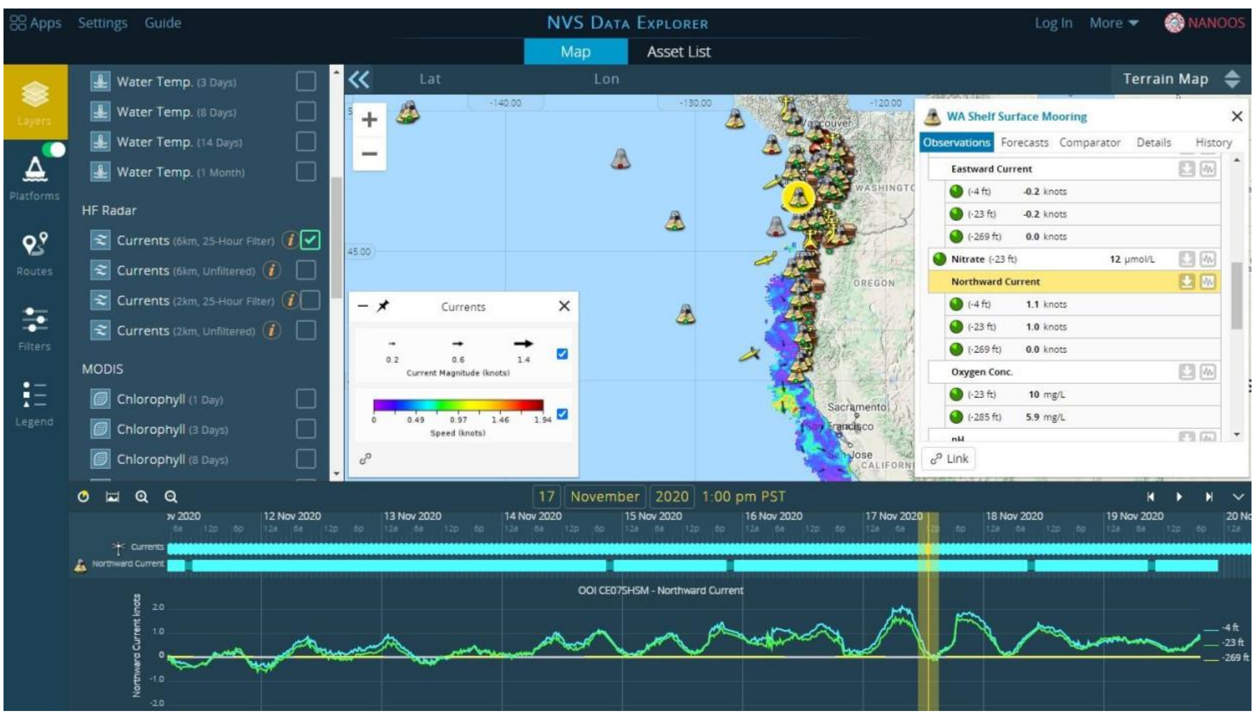

Figure 3. NVS Data Explorer App (https://nvs.nanoos.org/Explorer) showing multi-depth salinity time series at an OOI asset that also includes meteorological observations; and a surface currents map overlay from HF Radar.

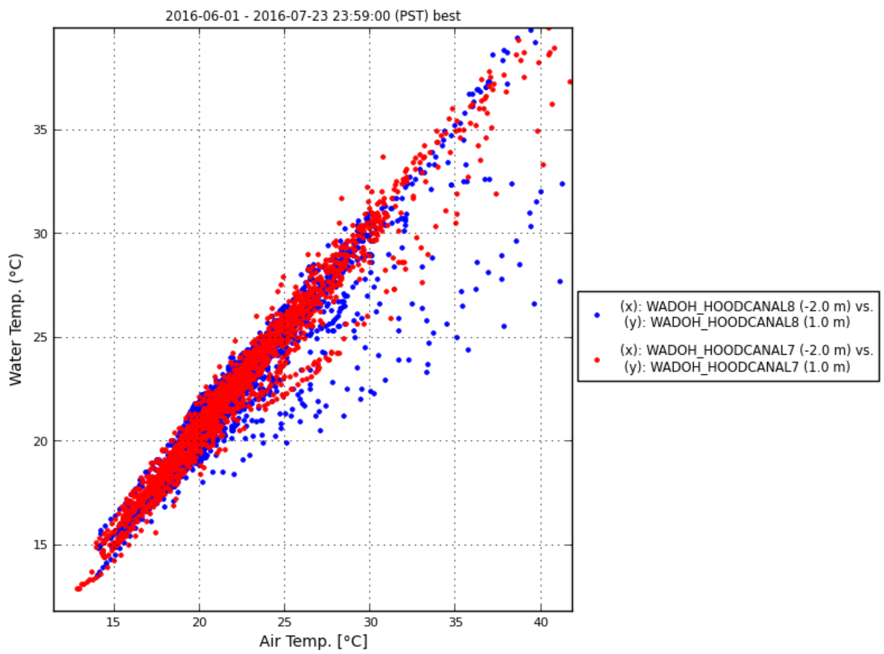

Figure 4. Sample plot from the "CMOP Data Explorer with NANOOS Data" application combining two sites (Hood Canal 7 [red] and Hood Canal 8 [blue] from WA Department of Health) and two variables (air and near-surface water temperature) over a common time period (2016-06-01 to 2016-07-23).

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Table 1. Data Management summary for NANOOS-supported (internal) assets; for additional, detailed information on each asset, see the corresponding Data Management Plan (DMP) file(s).

System	Operator	Asset Count	NVS Metadata	NVS Access*	NANOOS ERDDAP	NDBC WMO GTS	Archiving	DMP File
Surface Currents and Waves								
HF Radar (currents)	OSU	12#	X	Plot		X	National DAC, NCEI	DMP HF Radar
Port X-band Radar (waves)	OSU	1#	X	All			PI	DMP Port X-band Radar
Fixed-location Sensors								
WA Shelf Buoys	APL-UW	2	X	All	==		NCEI~	DMP WA Shelf Buoys
OR Shelf Buoy	OSU	1	X	All	X	X	NCEI~	DMP OR Shelf Buoy DMP OR Shelf Buoy OA Data
Puget Sound, ORCA Buoy Program	APL-UW	6	X	All	X	X	NCEI~	DMP Puget Sound ORCA Buoys
Columbia River estuary & plume SATURN network	CRITFC	14+	X	All	=	X	NCEI	DMP CMOP Network
South Slough Estuary Obs.	SSNERR	6+	X	All	==		NCEI	DMP NERR South Slough
Gliders and Ferries								
Trinidad Head Glider	OSU	1	X	Plot	=		National DAC, NCEI	DMP Trinidad Head Glider
WA Shelf Glider	OSU, CRITFC	1	X	Plot	=		National DAC, NCEI	DMP WA Shelf Glider
La Push Glider	APL-UW	1	X	Plot	=		National DAC, NCEI	DMP La Push Glider
Victoria Clipper Ferry	WDOE	1x	X	All			State Agency	DMP Victoria Clipper Ferrybox
Beach and Shoreline Observations								
OR Shoreline Obs.	DOGAMI	N/A	X	Plot			State Agency, NCEI~	DMP OR Shoreline Obs
WA Shoreline Obs.	WDOE	N/A	X	Plot			State Agency	DMP WA Shoreline Obs
Nearshore Bathymetry	OSU	N/A	X				PI	DMP Nearshore Bathymetry

* For NVS Access, "All" represents both data download and graphic presentation, and "Plot" only includes graphic presentation; # Number of radar sites; = Already in another ERDDAP and will be linked to NANOOS ERDDAP in near future; == Will be added to NANOOS ERDDAP in near future; ~ NANOOS will work with NCEI and PI to get dataset archived using existing pathways as templates/ entry submitted to NCEI, but not yet processed due to long queue; + Several stations are currently inactive but may be redeployed as resources allow; x Not currently deployed, pending ferry operations.

Table 2. External, fixed-location in-situ data streams other than those from federal or Canadian federal agencies. These assets are integrated into the NANOOS DAC and NVS.

Provider	Name & URL	Type	Contact Name & Email	Asset Count	Notes
Hakai Institute	Hakai Institute	Academic	Wiley Evans, wiley.evans@hakai.org	2	Canadian. Burke-o-lator (OA)
King County	King County	County	Kim Stark, Kimberle.Stark@kingcounty.gov	4	Implementing QARTOD-based QC flagging.
NWIC	Northwest Indian College	Academic	Misty Peacock, mpeacock@nwic.edu	1+	Close partnership with NANOOS, UW
ONC	Ocean Networks Canada	Academic	Reyna Jenkyns, reyna@oceannetworks.ca	5+	Canadian. Large, long-term observation system.
OOI	Ocean Observatories Initiative	Academic	Edward Dever, edward.dever@oregonstate.edu	6	Large, long-term observation system. Using Endurance Array platforms.
PennCoveShellfish	Penn Cove Shellfish	Industry	Ian Jefferds, ian@penncoveshellfish.com	1+	
PSI	Pacific Shellfish Institute	Non-Profit	Andy Suhrbier, suhrbier@pacshell.org	5+	Includes one Burke-o-lator (OA). Close partnership with NANOOS.
TaylorShellfish	Taylor Shellfish	Industry	Benoit Eudeline, BenoitE@taylorshellfish.com	1+	Burke-o-lator (OA). Close partnership with NANOOS.
WADOH	Washington Department of Health	State	Clara Hard, clara.hard@doh.wa.gov	20	Seasonal network (late Spring to early Fall). Currently offline.
WhiskeyCrShelfish	Whiskey Creek Shellfish Hatchery	Industry	Alan Barton, alan_barton22@yahoo.com	1+	Burke-o-lator (OA). Close partnership with NANOOS.

All assets are in the NVS Metadata Store and all provide data and graphic access on NVS. OA: Ocean Acidification, where the Burke-o-lator is a specialized OA sensor. + Station currently inactive but may be redeployed as resources allow.