NOAA Technical Report NOS CO-OPS 111

# IMPLEMENTATION OF THE SALISH SEA AND COLUMBIA RIVER OPERATIONAL FORECAST SYSTEM AND THE SEMI-OPERATIONAL NOWCAST/FORECAST SKILL ASSESSMENT

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U.S. DEPARTMENT OF COMMERCE
**National Ocean Service**
**Center for Operational Oceanographic Products and Services**

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**National Ocean Service**
**National Oceanic and Atmospheric Administration**
**U.S. Department of Commerce**

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# EXECUTIVE SUMMARY

The Salish Sea and Columbia River Operational Forecast System (SSCOFS), with the Finite Volume Community Ocean Model (FVCOM) as its hydrodynamic core, has been developed and implemented into operations to provide users with 6-hour nowcasts (analyses of near present) and 72-hour forecast guidance of the 3-D physical conditions of Salish Sea and Columbia River estuary regions—including surface water levels, 3-D water currents, water temperature, and salinity.

The development and implementation of SSCOFS was the result of a collaborative project between Pacific Northwest National Laboratory (PNNL), the National Ocean Service's (NOS) Office of Coast Survey (OCS), Center for Operational Oceanographic Products and Services (CO-OPS), and National Weather Service's (NWS) National Centers for Environmental Prediction Central Operations (NCO). This is the first time that a Coastal and Ocean Modeling Testbed (COMT)-funded project was transitioned from research to operation.

The successful implementation of SSCOFS decommissioned NOS's prior Columbia River Estuary Operational Forecast System (CREOFS) whose hydrodynamic core was the Semi-Implicit Eulerian-Lagrangian Finite Element (SELFE) model, which is obsolete and no longer supported by its developers. SSCOFS's model domain is larger and fully envelops CREOFS's domain.

To the date of publication of this report, SSCOFS has been running robustly without any instability issues since February of 2024 when the last version of the model started running in quasi-operational mode. Skill assessment based on half-year (Feb-Aug, 2024) model outputs indicates that NOS's hydrodynamic model skill assessment standard criteria are met or close to met for all target variables, and the model's water level outperforms CREOFS's in the middle and upper Columbia River. The successful implementation of this model fulfills NOS's mission by providing more reliable forecast guidance on water levels, currents, water temperatures, and salinity to maritime communities to aid in services such as navigation management and emergency responses. It also serves as the hydrodynamic basis for other coastal applications, such as ecological modeling, fishery and climate studies in this region.

This technical report documents how CO-OPS built the conventional static control files for the High-Performance Computing (HPC) Coastal Ocean Modeling Framework (COMF) on Weather and Climate Operational Supercomputing System-2 (WCOSS2) to generate the required model forcing files to drive SSCOFS. This is followed by a list of some specific model treatments and, lastly, the presentation of nowcast and forecast guidance skill assessment results.

# 1.0 INTRODUCTION

The “Graveyard of the Pacific” is a very dangerous region for maritime navigation along the northwest coast of the United States. It stretches from around Tillamook Bay on the Oregon Coast northward past the treacherous Columbia Bar and the Strait of Juan de Fuca, up the rocky western coast of Vancouver Island to Cape Scott. Unpredictable weather conditions, including storms and fog, and dangerous coastal elements, including shifting sandbars, tidal rips, and rocky reefs and shorelines, have caused thousands of ships to wreck in the area since European exploration of the region began in earnest in the 18th century (Wikipedia contributors 2024).

To face this navigation challenge, the Columbia River Estuary Operational Forecast System (CREOFS) was implemented in 2012 as a result of a joint work of the National Ocean Service (NOS) and Oregon Health & Science University (OHSU). CREOFS, with a hydrodynamic core of Semi-Implicit Eulerian-Lagrangian Finite Element (SELFE), covered the “Graveyard of the Pacific” area. Unfortunately, SELFE is not supported any longer by its developer at OHSU. As a result, CREOFS has to be decommissioned, and a new Operational Forecast System (OFS), with a sustainable hydrodynamic core, should be implemented to replace it. As navigational safety is also a big concern in the adjacent Puget Sound, the San Juan Islands, the Strait of Georgia, and the Strait of Juan de Fuca, the new model should have a larger domain to include these areas.

The Salish Sea and Columbia River Operational Forecast System (SSCOFS) serves just such a purpose (Figure 1). This model was initially developed by Pacific Northwest National Laboratory (PNNL) in collaboration with the Northwest Association of Networked Ocean Observing Systems (NANOOS), an Integrated Ocean Observing System (IOOS) regional association. Recognizing the need to leverage the expertise of the external modeling community to support its modeling program, NOS has adopted a community modeling vision that relies on the contributions from more inclusive modeling communities. SSCOFS was first transitioned to the Office of Coast Survey (OCS) to perform a 1-year hindcast and evaluation to ensure that the model meets the minimum performance metrics for navigation as documented in the NOS Skill Assessment Technical Report (Hess et al. 2003).

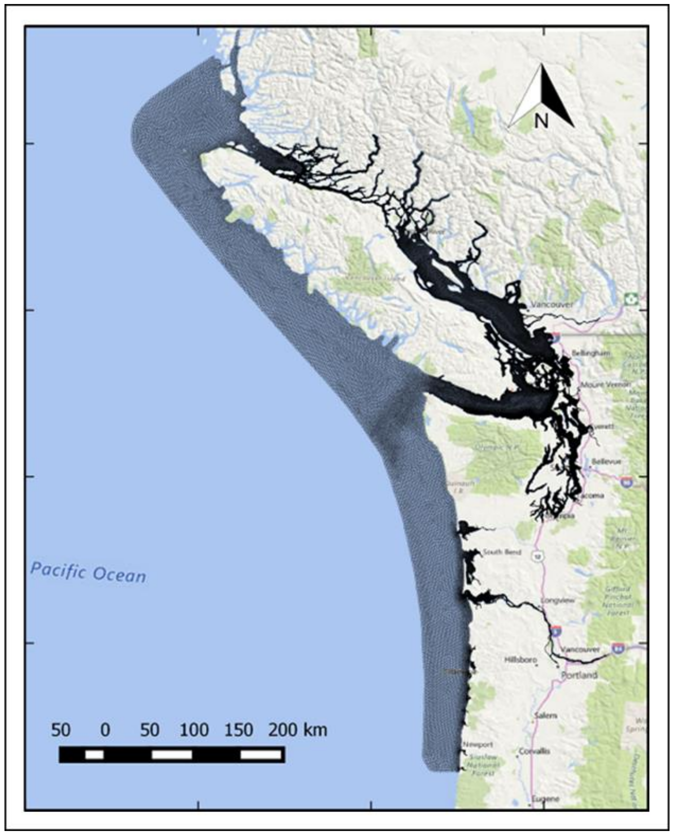


**Figure 1.** The SSCOFS model domain.

After successful hindcast evaluation (Shi et al. 2025), SSCOFS was transitioned to the Center for Operational Oceanographic Products and Services (CO-OPS) to be integrated into the Coastal Ocean Modeling Framework (COMF) for model running in quasi-operational or Nowcast/Forecast (N/F) mode. The model's N/F skill assessment was then conducted to evaluate the model's performance in a quasi-operational environment to ensure the model runs robustly and reliably. Finally, the model code package was delivered to the National Centers for Environmental Prediction (NCEP) Central Operations (NCO) to be implemented on the Weather and Climate Operational Supercomputing System-2 (WCOSS2).

The SSCOFS model domain encompasses the Puget Sound, the San Juan Islands, the Strait of Georgia, and the Strait of Juan de Fuca, and extends south along the Pacific Coast to include the Columbia River estuary. The hydrodynamic core of SSCOFS is the Finite Volume Community Ocean Model (FVCOM), which is supported by the University of Massachusetts Dartmouth (UMASSD). The model has horizontal unstructured triangular mesh grids (Figure 1) with 239,734 nodes and 433,410 elements. The vertical grid follows the terrain and consists of 10 spatially varying sigma layers. The model's horizontal resolution ranges from 100 m along the shoreline to 500 m in deeper parts of Puget Sound and the Georgia Basin, and to 10,000 m over the continental shelf. Resolution in the Columbia River varies between 100 and 200 m. Water depth in the model references to xGEOID20b datum.

The output from NCEP's North American Mesoscale (NAM), with Global Forecast System (GFS) as its backup, provides meteorological forcing for the model. The primary river forcing is from National Water Model (NWM) output, with United States Geological Survey (USGS) observation and climatological daily river discharge data as its backup. Along the open boundaries, tidal forcing is from the ADvanced CIRCulation (ADCIRC [ENPAC15]) tidal database, and the Global Real-Time Ocean Forecast System (G-RTOFS) provides the subtidal water levels and vertical profiles of water temperature and salinity.

The model codes were finalized on February 7, 2024, when the last NWM river-reach-ID related final revision was made, and the model has since been running reliably in near real-time mode with no instability issues. The model skill assessment, based on model results in a half-year period, indicates that all target variables, including water levels, surface water temperature, salinity, and currents, meet or are close to the NOS accepted error criteria. The water level outperforms the decommissioned CREOFS in the middle and upper Columbia River thanks to the establishment of a new USGS river discharge station and more accurate bottom friction distributions in the Columbia River. The model forecast horizon increases from 48 hours of CREOFS to 72 hours.

Section 2 documents how CO-OPS created the control and static files for the High-Performance Computing-Coastal Ocean Modeling Framework (HPC-COMF), which supports SSCOFS and other NOS forecast systems to generate the model forcing files that are required to drive the model. Some special non-conventional model treatments and features to improve the model performance are also listed in Section 2. A nowcast and forecast skill assessment for the period of February 15-August 15, 2024, is then presented in Section 3. Finally, conclusions are made in Section 4.

# 2.0 MODEL NOWCAST/FORECAST CONFIGURATION

This section describes the generation of (1) meteorological surface forcing conditions, (2) river forcing conditions, (3) lateral open boundary conditions, and (4) initial conditions for the SSCOFS nowcast/forecast predictions. All these forcing condition files are automatically generated by the HPC-COMF. Some non-conventional model features are also listed in this section.

## 2.1 Meteorological Forcing Conditions

Meteorological forcing conditions for SSCOFS are generated by the HPC-COMF, similar to other existing NOS operational forecast systems. The **sscofs.ctl** file in **/nosofs.vx.x.x/fix/sscofs/** controls which NOAA numerical weather prediction model (or models) is used. For SSCOFS, the model outputs of the NAM Forecast System with 12 km resolution is used by specifying the following 2 parameters in the **sscofs.ctl** control file:

```
export DBASE_MET_NOW=NAM
export DBASE_MET_FOR=NAM
```

These control parameters indicate that the NAM product is used for both nowcast and forecast meteorological forcing conditions. NAM 4-km was initially planned to be used to drive the model. Its variable of “air pressure,” however, has some issues in the northern area outside of United States territory. The initial plan, therefore, was abandoned.

The shell scripts **exnos_ofs_prep.sh** within **/nosofs.vx.x.x/scripts/** and **nos_ofs_create_forcing_met.sh** within **/nosofs.vx.x.x/ush/** are launched to generate **sscofs.tccz.yyyymmdd.met.nowcast.nc** and **sscofs.tccz.yyyymmdd.met.forecast.nc** (where yyyy, mm, dd, and cc in “tccz” indicate the year, month, day, and cycle of the nowcast/forecast, respectively). The required NAM model output files exist in the WCOSS2 data tank. The GFS model output files will be used as backup if NAM is not available.

## 2.2 River Forcing Conditions

The 19 rivers considered in SSCOFS are the Columbia, Skagit, Stillaguamish, Snohomish, Willamette, Nooksack, Samish, Green, Nisqually, Puyallup, Skokomish, Deschutes, Chehalis, Elwha, Dungeness, Duckabush, Lewis, and Cowlitz Rivers in the U.S. and the Fraser River in Canada.

The NWS's NWM analyses and predictions are, by default, used for SSCOFS river forcing conditions for both the nowcast and forecast cycles. The NWM analyses are used for the nowcast cycles while the NWM predictions are used for the forecast cycles. Real-time river discharge observations at a USGS gauge are used as backup in the nowcast cycle when NWM predictions are not available for a river. This is true for the rivers in the U.S. The Fraser River is outside the U.S. territory. Therefore, it has no NWM output support. Fortunately, this river's real time observed discharge data are available in WCOSS2 data tank for nowcast cycles. For forecast, the river discharge persists with the value from the most recent observation.

To make the river data process more organized, the **nos_ofs_create_forcing_river** Fortran executable is called 2 times from **nos_ofs_create_forcing_river.sh**. One is for the 18 rivers in the U.S. and the other is for the Fraser River in Canada. The input files of the two calls are **sscofs.river.ctl** and **sscofs.river.canada.ctl**, respectively.

The first section of the **sscofs.river.ctl** shows the 18 rivers in the U.S. and their IDs.

```
Section 1: Information about USGS or NOS gages where real-time discharges and/or water temperature observations are available
  36  18    1 !! NIJ NRIVERS DELT
RiverID STATION_ID NWS_ID AGENCY_ID Q_min Q_max Q_mean T_min T_max  T_mean  Q_Flag TS_Flag   River_Name

 1   14144700   XXXXX  USGS   304.0  35000.0   7500.0     1.00    23.20    12.09      1       1 "USGS 14144700 COLUMBIA RIVER AT VANCOVOR, OR"
 2   12200500   XXXXX  USGS    86.0   5100.0    468.0     1.00    18.00     8.00      1       1 "USGS 12200500 SKAGIT RIVER NEAR MOUNT VERNON, WA"
 3   12167000   XXXXX  USGS     5.21   705.09    59.05    1.00    18.00     8.0       1       1 "USGS 12167000 NF STILLAGUAMISH RIVER ARLINGTON, WA"
 4   12150800   XXXXX  USGS    36.53  1713.17   288.98    1.00    18.00     8.0       1       1 "USGS 12150800 SNOHOMISH RIVER NEAR MONROE, WA"
 5   14211720   XXXXX  USGS   183.21  3992.68  1157.71    1.00    18.00     8.0       1       1 "USGS 14211720 WILLAMETTE RIVER AT PORTLAND, OR"
 6   12213100   XXXXX  USGS    13.20  1360.00   108.00    1.00    18.00     8.0       1       1 "Nooksack River at Ferndale, WA"
 7   12201500   XXXXX  USGS     0.62    142.00     6.90   1.00    18.00     8.0       1       1 "Samish River Near Burlington, WA"
 8   12113000   XXXXX  USGS     2.30    800.00    37.00   1.00    18.00     8.0       1       1 "Green River Near Auburn, WA"
 9   12089500   XXXXX  USGS    13.00   1120.00    41.00   1.00    18.00     8.0       1       1 "NISQUALLY RIVER AT MCKENNA, WA"
10   12101500   XXXXX  USGS    11.00   1600.00    93.80   1.00    18.00     8.0       1       1 "Puyallup River at Puyallup, WA"
11   12061500   XXXXX  USGS    20.00    820.00    34.30   1.00    18.00     8.0       1       1 "Skokomish River Near Potlatch, WA"
12   12080010   XXXXX  USGS    68.00   1990.00   164.90   1.00    18.00     8.0       1       1 "DESCHUTES RIVER AT E ST BRIDGE AT TUMWATER, WA"
13   12031000   XXXXX  USGS    12.00   1300.00   181.90   1.00    18.00     8.0       1       1 "Chehalis River at Porter, WA"
14   12045500   XXXXX  USGS     0.28   1180.00    42.70   1.00    18.00     8.0       1       1 "ELWHA RIVER AT MCDONALD BR NEAR PORT ANGELES, WA"
15   12048000   XXXXX  USGS     0.20    300.00    20.00   1.00    18.00     8.0       1       1 "DUNGENESS RIVER NEAR SEQUIM, WA"
16   12054000   XXXXX  USGS    20.00    220.00    20.00   1.00    18.00     8.0       1       1 "Duckabush River Near Brinnon, WA"
17   14220500   XXXXX  USGS    20.00    220.00    60.00   1.00    18.00     8.0       1       1 "Lewis River at Ariel, WA"
18   14243000   XXXXX  USGS    50.00   1120.00   150.00   1.00    18.00     8.0       1       1 "Cowlitz River at Castle Rock, WA"
```

**Figure 2.** First section of river control file for the 18 rivers in the U.S.

The second section of the **sscofs.river.ctl** shows the node-ID of a river and the river's discharge scale (Q_Scale). All rivers in this model have 2 node points, and the Q_Scale is 0.5 at each point to split the entire river discharge.

Section 2: Information of FVCOM grids/locations to specify river inputs

| GRID_ID | NODE_ID | ELE_ID | DIR | FLAG | RiverID_Q | Q_Scale | RiverID_T | T_Scale | River_Basin_Name |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 239733 | 1 | 0 | 3 | 1 | 0.5 | 1 | 1.00 | "Columbia R" |
| 2 | 239734 | 2 | 0 | 3 | 1 | 0.5 | 1 | 1.00 | "Columbia R" |
| 3 | 170844 | 3 | 0 | 3 | 2 | 0.5 | 2 | 1.00 | "Skagit R" |
| 4 | 170845 | 4 | 0 | 3 | 2 | 0.5 | 2 | 1.00 | "Skagit R" |
| 5 | 178359 | 5 | 0 | 3 | 3 | 0.5 | 3 | 1.00 | "Stillaguamish R " |
| 6 | 178360 | 6 | 0 | 3 | 3 | 0.5 | 3 | 1.00 | "Stillaguamish R" |
| 7 | 219657 | 7 | 0 | 3 | 4 | 0.5 | 4 | 1.00 | "Snohomish R" |
| 8 | 219549 | 8 | 0 | 3 | 4 | 0.5 | 4 | 1.00 | "Snohomish R" |
| 9 | 237760 | 9 | 0 | 3 | 5 | 0.5 | 5 | 1.00 | "Willamette R" |
| 10 | 237747 | 10 | 0 | 3 | 5 | 0.5 | 5 | 1.00 | "Willamette R" |
| 11 | 177345 | 11 | 0 | 3 | 6 | 0.5 | 6 | 1.00 | "Nooksack R" |
| 12 | 177346 | 12 | 0 | 3 | 6 | 0.5 | 6 | 1.00 | "Nooksack R" |
| 13 | 150166 | 13 | 0 | 3 | 7 | 0.5 | 7 | 1.00 | "Samish R" |
| 14 | 150167 | 14 | 0 | 3 | 7 | 0.5 | 7 | 1.00 | "Samish R" |
| 15 | 196372 | 15 | 0 | 3 | 8 | 0.5 | 8 | 1.00 | "Green R" |
| 16 | 196210 | 16 | 0 | 3 | 8 | 0.5 | 8 | 1.00 | "Green R" |
| 17 | 220352 | 17 | 0 | 3 | 9 | 0.5 | 9 | 1.00 | "Nisqually R" |
| 18 | 220353 | 18 | 0 | 3 | 9 | 0.5 | 9 | 1.00 | "Nisqually R" |
| 19 | 211522 | 19 | 0 | 3 | 10 | 0.5 | 10 | 1.00 | "Puyallup R" |
| 20 | 211523 | 20 | 0 | 3 | 10 | 0.5 | 10 | 1.00 | "Puyallup R" |
| 21 | 212313 | 21 | 0 | 3 | 11 | 0.5 | 11 | 1.00 | "Skokomish R" |
| 22 | 212314 | 22 | 0 | 3 | 11 | 0.5 | 11 | 1.00 | "Skokomish R" |
| 23 | 230080 | 23 | 0 | 3 | 12 | 0.5 | 12 | 1.00 | "Deschutes R" |
| 24 | 230081 | 24 | 0 | 3 | 12 | 0.5 | 12 | 1.00 | "Deschutes R" |
| 25 | 51662 | 25 | 0 | 3 | 13 | 0.5 | 13 | 1.00 | "Chehalis R" |
| 26 | 51663 | 26 | 0 | 3 | 13 | 0.5 | 13 | 1.00 | "Chehalis R" |
| 27 | 47401 | 27 | 0 | 3 | 14 | 0.5 | 14 | 1.00 | "Elwha R" |
| 28 | 47402 | 28 | 0 | 3 | 14 | 0.5 | 14 | 1.00 | "Elwha R" |
| 29 | 72609 | 29 | 0 | 3 | 15 | 0.5 | 15 | 1.00 | "Dungeness R" |
| 30 | 72610 | 30 | 0 | 3 | 15 | 0.5 | 15 | 1.00 | "Dungeness R" |
| 31 | 188050 | 31 | 0 | 3 | 16 | 0.5 | 16 | 1.00 | "Duckabush R" |
| 32 | 188051 | 32 | 0 | 3 | 16 | 0.5 | 16 | 1.00 | "Duckabush R" |
| 33 | 223882 | 33 | 0 | 3 | 17 | 0.5 | 17 | 1.00 | "Lewis R" |
| 34 | 223883 | 34 | 0 | 3 | 17 | 0.5 | 17 | 1.00 | "Lewis R" |
| 35 | 202619 | 35 | 0 | 3 | 18 | 0.5 | 18 | 1.00 | "Cowlitz R" |
| 36 | 202726 | 36 | 0 | 3 | 18 | 0.5 | 18 | 1.00 | "Cowlitz R" |

**Figure 3.** Second section of the river control file for the 18 rivers in the U.S.

Based on the location of each river's node-ID, the corresponding river's reach ID in NWM products can be found on the NWM webpage https://water.noaa.gov/map. A river's reach ID layer needs to be activated by clicking on Layers-National Water Model-Stream Reach-Enabled. The corresponding river reach ID for the 18 rivers in the U.S. can be found in the following screenshot of the **sscofs.nwm.reach.dat** file.

```
REACH_ID FLAG (1: IN NWM DOMAIN  0: OUTSIDE NWM DOMAIN)
                        18
                 23735707 1
                 24270288 1
                 24274329 1
                 24279014 1
                 23735689 1
                 23955772 1
                 24534280 1
                 23977616 1
                 24281964 1
                 23980375 1
                 24285492 1
                 23990859 1
                 23856601 1
                 23997022 1
                 23997334 1
                 24287052 1
                 24241627 1
                 24521980 1
```

**Figure 4.** Reach ID of the rivers in the U.S.

The screenshot of the river control file for the Fraser River of Canada can be found in Figure 5. The river's station ID, 08MF005, and its real-time observed discharge values are encoded in the **/lfs/h1/ops/prod/dcom/yyyymmdd/b001/xx022** BUFR file in the WCOSS2 data tank.

```
Section 1: Information about USGS or NOS gages where real-time discharges and/or water temperature observations are available
  2   1     1 !! NIJ NRIVERS DELT
RiverID STATION_ID NWS_ID AGENCY_ID Q_min Q_max Q_mean T_min T_max  T_mean  Q_Flag TS_Flag   River_Name
 1     08MF005    XXXXX    WSC    626.5  17000.0   3475.0     1.00     19.00     9.88      1       1 "WSC 08MF005 FRASER RIVER AT HOPE"

Section 2: Information of FVCOM grids/locations to specify river inputs
GRID_ID NODE_ID ELE_ID DIR     FLAG RiverID_Q  Q_Scale RiverID_T    T_Scale           River_Basin_Name
   1   178006     1     0       3       1        0.5       1         1.00               "Fraser R"
   2   178007     2     0       3       1        0.5       1         1.00               "Fraser R"
```

**Figure 5.** The river control file for Canadian Frazer River.

Real-time river discharge observations at a USGS river gauge are used as backup in the nowcast cycle for the 18 U.S. rivers when NWM predictions are not available for a river. In the forecast cycle, persistent river discharge and river water temperature will be used with the corresponding latest measured value. If neither NWM nor measured data is available, climatological river discharge and water temperature will be employed for this river.

## 2.3 Open Boundary Conditions

The purpose of **nos_ofs_create_forcing_obc_fvcom.f** of COMF is to generate lateral open boundary forcing files for FVCOM-based OFS, such as SSCOFS. Tides, generated from the ADCIRC (ENPAC15) tidal database, are provided by PNNL model developers. Nontidal water levels and vertical profiles of water temperature and salinity are all derived from G-RTOFS. Correspondingly, in the SSCOFS main control file, **sscofs.ctl**, all the following variables are set to "RTOFS":

export DBASE_WL_NOW=RTOFS
export DBASE_WL_FOR=RTOFS
export DBASE_TS_NOW=RTOFS

export DBASE_TS_FOR=RTOFS

The shell scripts **exnos_ofs_prep.sh** within **/nosofs.vx.x.x/scripts/** and **nos_ofs_create_forcing_obc.sh** within **/nosofs.vx.x.x/ush/** are launched to generate a model-required lateral open boundary condition (OBC) file **sscofs.tccz.yyyymmdd.obc.nc** (where yyyy, mm, dd, and cc in "tccz" indicate the year, month, day, and cycle, respectively). The required RTOFS model output files exist in the WCOSS2 data tank. NOS's West Coast Operational Forecast System (WCOFS) with higher resolution than RTOFS might be a better option for open boundary conditions. But it is not considered in this implementation due to lack of comparison and evaluation between RTOFS and WCOFS.

## 2.4 Initial Conditions

In COMF, **nos_ofs_read_restart_fvcom.f** is used to read the FVCOM-based OFS model initial/restart file. If the values and attributes of the variable "time" are correct, then the initial file is not changed. Otherwise, the following actions may be conducted if needed:

(1) Change the reference time (the attribute of "units" in the initial NetCDF file) of the variables "time" and "Itime" in the initial file if the reference time is different from ${BASE_DATE} specified in the control file, such as "**nos.sscofs.ctl**."
(2) Recompute the values of the variables "time" and "Itime" using ${BASE_DATE} as the reference time in the initial file if (1) is conducted.
(3) If the "time" is 48 hours less than ${time_nowcastend}, then the nowcast cycle is terminated. An initial condition file has to be constructed manually with 0 surface elevation, 0 velocity, and reasonable water temperature and salinity.

For additional information, see Zhang and Yang (2014).

In the case of the SSCOFS, the output restart file from the previous nowcast cycle is used to generate the initial condition for the nowcast of the current cycle. For example, **sscofs.t03z.YYYYMMDD.rst.nowcast.nc** from the nowcast at 03z will be renamed (after minor "time" and "Itime" related revision) to **sscofs.t09z.YYYYMMDD.init.nowcast.nc** for the nowcast at 09z. The restart file from the 09z cycle nowcast, **sscofs.t09z.YYYYMMDD.rst.nowcast.nc** will be used for the 09z cycle forecast, and so on.

The above 4 subsections are "conventional" model setups which are similar from one OFS to another. The following are special model setups and features that are configured for SSCOFS only, which can be called "non-conventional."

## 2.5 Thermal vertical constraint on the open boundary

G-RTOFS's water temperature at the lower water column was found to be lower than observation along the open boundary by PNNL model developers. During the hindcast test, PNNL found that a simple vertical thermal constraint can improve water temperature simulation by up to 1.5 °C. The constraint is that at any mesh grid point along the open boundary, the water temperature at any vertical water column below 125 m takes the temperature value at the 125 m depth. As the model's vertical layers are in sigma coordinates, a python code **nos_ofs_obc_cut.py** was developed to find the corresponding sigma layer to 125 m at each boundary mesh grid to carry out this thermal constraint. The python code can be found under **/nosofs.vx.x.x/ush/pysh**. Two sets of temperature results from 2 model versions—one with this thermal constraint and the other without—will be evaluated and compared in the next section.

## 2.6 Bottom friction determination in the Columbia River

Bottom friction, parameterized by bottom roughness length scale $z_0$, is a very sensitive forcing term in hydrodynamic models to modulate not only the overall water level but also the tidal range for a tidal river. For the Columbia River, PNNL in the early phase of the model development suggested a $z_0$ distribution in the lower, middle, and upper Columbia River as shown in Figure 6. CO-OPS validated this $z_0$ distribution by comparing measured and modeled current profiles at different times and locations along the river. The measured currents are from a CO-OPS Columbia River currents survey completed in 2023 and from the USGS Columbia River station at Vancouver (14144700). During the $z_0$ validation period, the river discharge value at the NWM River Reach ID 23735707 agreed well with USGS measured data at 14144700.

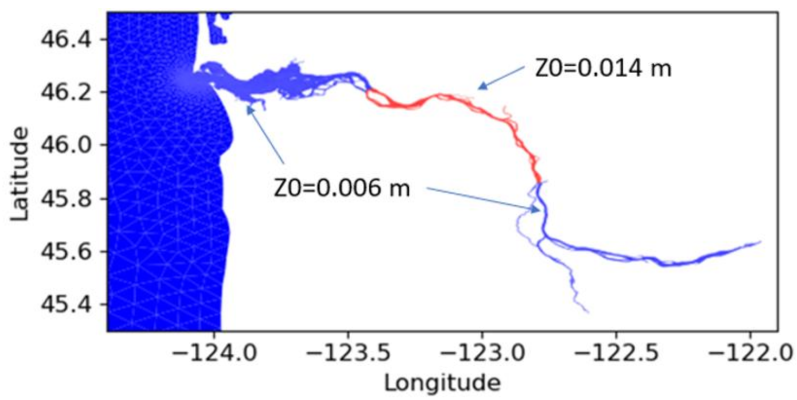


**Figure 6.** Bottom roughness length scale distribution in the Columbia River.

Instead of providing 2-dimensional $z_0$ distribution in the model as in SSCOFS, then using the following formula to calculate the bottom drag coefficient $C_d$ which is based on the ratio of the height of grid point nearest to the bottom $z_{ab}$ to $z_0$, the decommissioned CREOFS model directly provided 2-dimensional $C_d$ from an input file.

$$C_d = max\{ [(\frac{1}{\kappa} ln(\frac{z_{ab}}{z_0})]^{-2} , 0.0025 \} \ (k \ is \ von \ Karman's \ constant)$$

CREOFS's $C_d$ value distribution in a portion of the Columbia River is shown in Figure 7. The values are much smaller than the calculated $C_d$ in SSCOFS. The more reasonable $z_0$ and the subsequent $C_d$ in SSCOFS improves the model's water level performance in the middle and upper Columbia River, which will be discussed in detail in the next section.

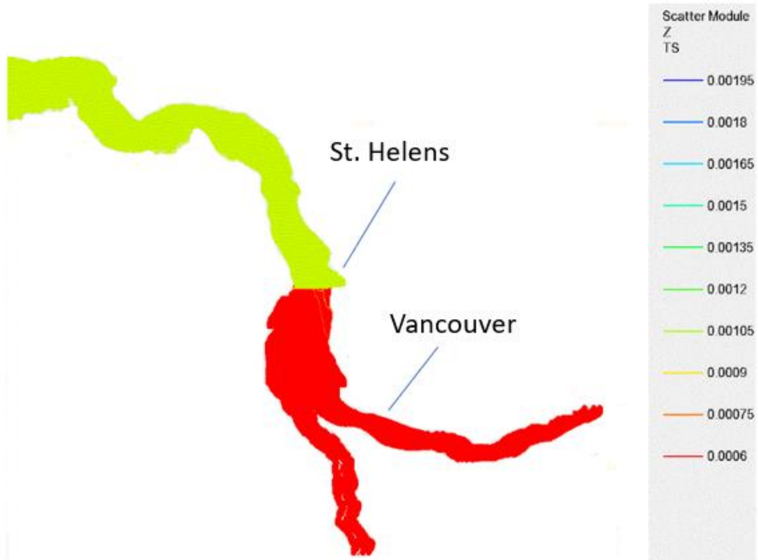


**Figure 7.** Columbia River Estuary Operational Forecast System (CREOFS) bottom drag coefficient distribution in the Columbia River.

## 2.7 Vertical datums in the Columbia River

Vertical datums are important to any OFS, especially for SSCOFS. This is because, in addition to finding the relationships between tidal datums (such as mean lower low water [MLLW] and mean sea level [MSL]) and non-tidal datums (such as NAVD88 and xGEOID20b) at every mesh point, we also have to find their relationships to the special Columbia River Datum (CRD), which is critical for safe navigation along the river.

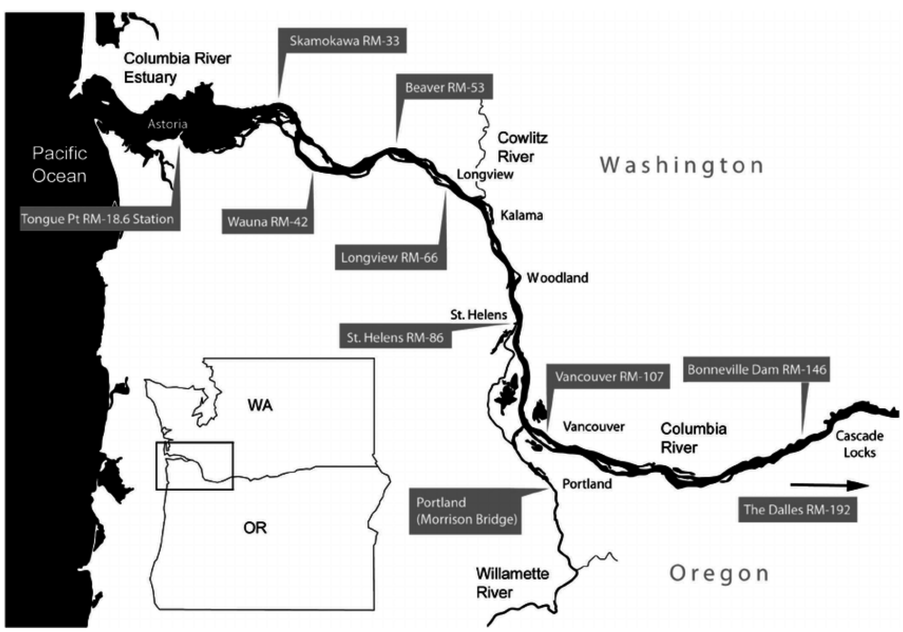


**Figure 8.** Columbia River water level stations and their river miles (from Jay 2011).

For navigation safety, the CRD was established as a non-tidal datum based on an observational study by the U.S. Army Corps of Engineers (USACE) in 1912. This datum is an adopted low water reference plane that runs from River Mile 23 to Bonneville Dam at River Mile 146. It also extends up the Willamette River (Figure 8). The CRD reference 0 was set at water level gauge locations such that the datum was below the average low water but not as low as the lowest record for a long period which resulted from a combination of circumstances that seldom occur. Historically, the CRD was originally defined relative to the National Geodetic Vertical Datum of 1929 (NGVD 29), later to North American Vertical Datum of 1988 (NAVD88), and more recently to Experimental Geoid Models 2020b (xGEOID20b) at distinct river miles with linear interpolation applied between defined locations.

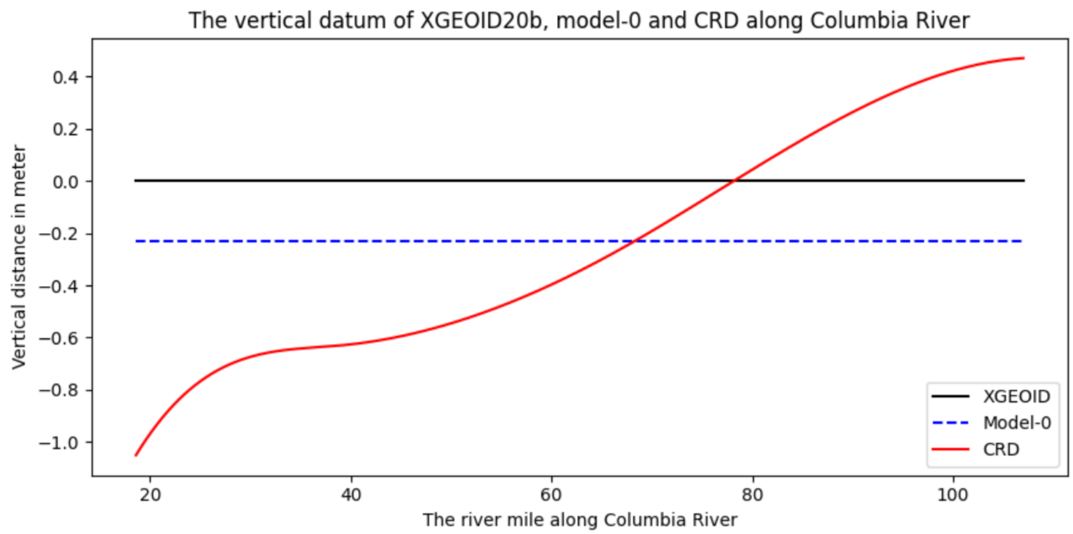


**Figure 9.** The relative vertical positions of Experimental Geoid Models 2020b (xGEOID20b), model-0 and the Columbia River Datum (CRD) along Columbia River.

As xGEOID20b is a geoid vertical datum, which is theoretically parallel to the model-0 surface, the bathymetry referencing to this datum in the model, rather than non-geoid datum like NAVD88, reflects a more hydrodynamic reality of the domain. Figure 9 shows the relative positions of xGEOID20b and CRD along a portion of the Columbia River (from river mile 18 to 107), which is derived from the data available at https://vdatum.noaa.gov/vdatumweb/. The CRD relative to xGEOID20b at all model mesh nodes of the middle and upper river can be found in the standard OFS datum file **sscofs_vdatums.nc**, which is provided by OCS.

The dash line in the figure is the model-0 surface which is about 0.23 m below xGEOID20b. Model-0 surface is determined by matching the modeled water level with the observed CRD water level at Astoria, Skamokawa, Wauna, Longview, St. Helens, and Vancouver. The consistency of 0.23 m between xGEOID20b and model-0 surface at all stations indicates XGEOID20b parallels well to a geoid surface, model-0, in this section of the Columbia River.

As SSCOFS uses RTOFS's model output to provide the subtidal water level on the lateral open boundary, the model-0 surface should coincide with the long-term averaged water level along the boundary. Ideally, COMF should have been revised to add 0.23 m to process SSCOFS's OBC files so that model-0 and xGEOID20b coincide at the same level to secure bathymetry soundness. However, this value held true for less than 1 year, and a longer-term investigation should be made to verify that 0.23 m is valid for all seasons. After longer-term validation, a reasonable RTOFS water level adjustment height should be imposed on the open boundary for SSCOFS in the next COMF package upgrade.

## 2.8 Open boundary water level interval

During the early phase of N/F model setup, pseudo-high-frequency water level oscillation, dubbed as water level "squiggle" in the SSCOFS project team, was found at many locations.

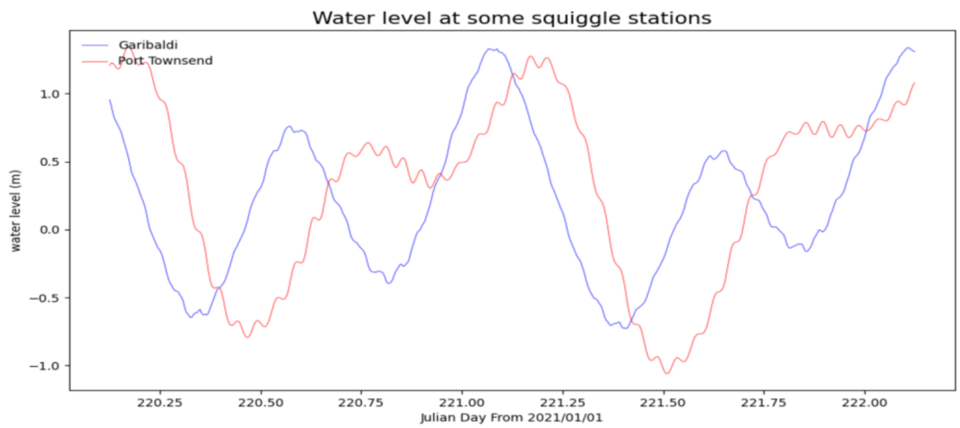


**Figure 10.** Water level squiggles at Port Townsend and Garibaldi.

Figure 10 shows water level squiggles at Port Townsend and Garibaldi. There were about 50 stations experiencing such squiggles in the total 300-plus stations in the model. Some squiggles, like at Port Townsend, were worse than the others, like at Garibaldi. In the worst case, the squiggle range could be as high as 0.2 m.

Identifying the root cause of the issue, COMF's conventional 1-hour water level interval in the OBC file, was time consuming. If we decrease the interval to 15 minutes, no squiggles were found in all stations. For safety, we set the water level interval in the model's OBC control file to six minutes in the latest COMF package to ensure no squiggles exist in the operational SSCOFS model results.

The team was motivated to investigate why a 1-hour water level input on open boundaries works well for other OFSs but not for SSCOFS. Six ideal domains with different shapes, coastal angles, and bathymetry distributions were constructed for the purpose of this investigation (Figure 11). Each domain can be considered as a test case with its eastern end having similar geographic features of the Salish Sea subregion and with its western end having similar geographic features of SSCOFS's open boundary subregion. These ideal cases were loaded into COMF to run 10 days in quasi-operational mode. The cycle-by-cycle meteorological and open boundary forcing files then were concatenated to run the model offline in a static directory, where different bathymetry slopes were tested for each case. Hundreds of offline tests indicate that water level squiggles exist for all 6 ideal cases as long as a relatively large bathymetry slope is applied along the western open boundary. The slope of 1/75 is big enough for all 6 ideal cases to get pseudo-squiggles somewhere in their domains. This slope is equivalent to the assumption that the bathymetry increases 1000 m from east to west across 1 longitude degree distance (the latitude at the Strait of Juan de Fuca is considered when the distance is calculated) near the open boundary of an ideal case. In reality, the largest bathymetry slope is around 1/30 to the west of the Strait of Juan de Fuca.

We found that the large bathymetry slope near the open boundary plays a major role in generating pseudo-water level squiggle. The tests also suggest that the shoreline shape of the domain might be a minor contributor to the intensity of the squiggles. The lessons learned here will be useful for future OFS development.

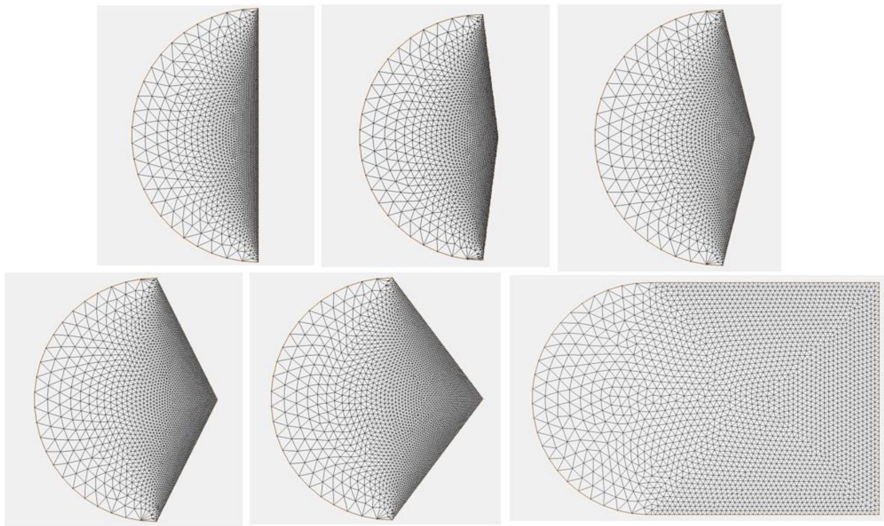

**Figure 11.** Ideal domains designed to investigate the water level squiggles.

# 3.0 NOWCAST/FORECAST MODEL SKILL ASSESSMENT

The SSCOFS has performed robustly and produced reasonable predictions from its nowcast and forecast cycles for water level, temperature, salinity, and currents since the model's final version was fixed on February 7, 2024. This is visually validated by the cycle-by-cycle nowcast and forecast results compared with observations as shown in Figure 12. Standard model skill assessment metrics (Zhang et al. 2009), however, have to be conducted to provide more scientific and objective analysis of the model performance.

The initial planned skill assessment period was from mid-July 2023, when a false model "final" version was launched, to mid-July 2024. However, during the 2023-2024 winter season, the model's Columbia River discharge input was found unreasonable compared with USGS's measured value at Vancouver, WA 14144700. Due to seasonal man-controlled dam discharge modulation, the original river reach ID 23736129, which is located in the upper side of the Bonneville Dam, could not provide correct river discharges to the model. Communications with NWM development team determined that river reach ID 23735707 should be used to provide the discharge of Columbia River. The final river reach ID correction considerably changes the discharge and the subsequent water level and flow in the Columbia River. The model needs about 1 week to spin up to reach equilibrium in the river before the model skill assessment can be started.

In this report, the model skill assessment period is from February 15 to August 15, 2024, which satisfies the minimum time period (half-year) requirement for NOS standard model skill assessment. Section 3.1 describes the cycle-by-cycle nowcast and forecast results. Section 3.2 briefly reviews the basics of skill assessment statistics, followed by the results of the SSCOFS nowcast and forecast skill assessment in Section 3.3.

## 3.1 Nowcast and Forecast Results

The latest cycle's nowcast and forecast predictions are displayed on the SSCOFS website: https://tidesandcurrents.noaa.gov/ofs/sscofs/sscofs.html. Generally, the cycle-by-cycle results (Figures 12) indicate that the model meets NOS navigation requirements for water level, surface currents, and water temperature in nowcast and forecast time windows at all stations where measurements are available. Permanent and consistent salinity observation is scanty in the whole model domain compared to other variables. Salinity cycle-by-cycle visual validation, therefore, is not available on the website. Periodic salinity measurement, however, did exist at 6 stations during the model skill assessment period, and the standard salinity skill assessment results at these stations will be illustrated in Section 3.3.

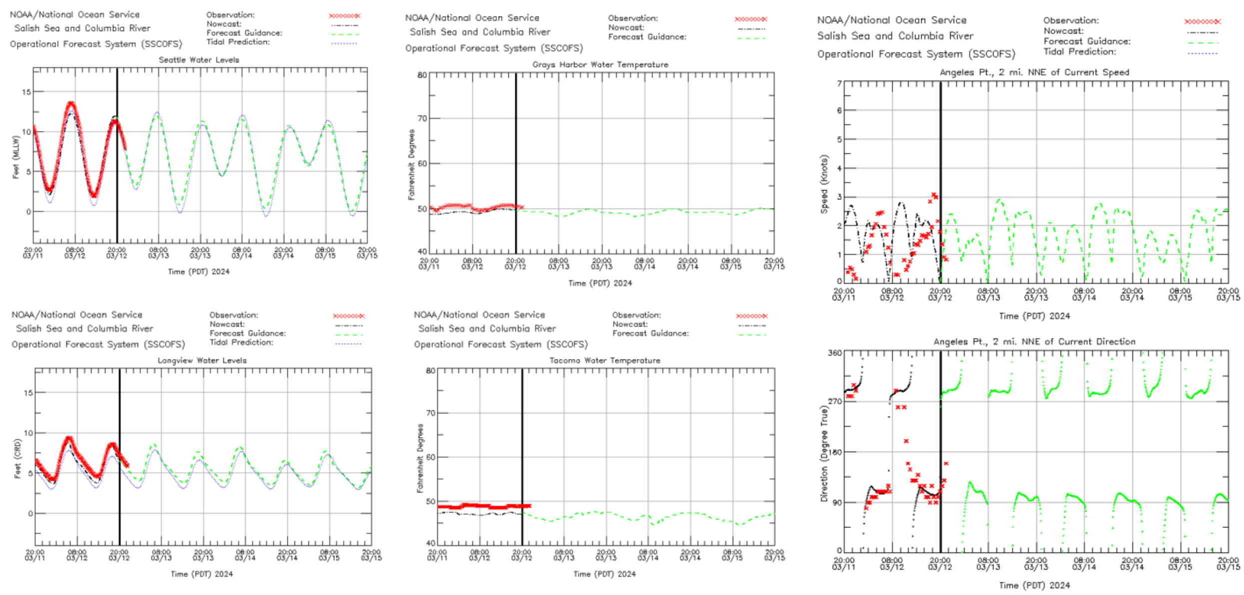


**Figure 12.** Examples of time series of water level, surface water temperature, and surface current speed and direction at selected stations.

## 3.2 Skill Assessment Software System and Data Source

This section provides an overview of the NOS model skill assessment statistics and software, and discusses the data sources used for the nowcast and forecast model skill assessment.

**Skill assessment statistics**

Skill assessment is an objective measurement of the performance of a model when systematically compared with observations. NOS skill assessment criteria were created for evaluating the performance of circulation models (Hess et al. 2003), and a software package was subsequently developed to compute these criteria using standard file format output from the models (Zhang et al. 2009). The software computes the skill assessment scores automatically using files containing observations and nowcast and forecast model results. A standard suite of skill assessment statistics is defined in Table 1.

**Table 1.** Skill assessment statistics (Hess et al. 2003).

| Variable | Explanation |
|---|---|
| Error | The error is defined as the predicted value, p, minus the reference (observed or astronomical tide value, r : $e_i = p_i - r_i$. |
| SM | Series Mean. The mean value of a series y. Calculated as: $\bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$ . |
| RMSE | Root Mean Square Error. Calculated as: $RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} e_i^2}$ . |
| SD | Standard Deviation. Calculated as: $SD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N} (e_i - \bar{e})^2}$ |
| CF(X) | Central Frequency. Fraction (percentage) of errors that lie within the limits $\pm$X. |
| POF(X) | Positive Outlier Frequency. Fraction (percentage) of errors that are greater than X. |
| NOF(X) | Negative Outlier Frequency. Fraction (percentage) of errors that are less than -X. |
| MDPO(X) | Maximum Duration of Positive Outliers. A positive outlier event is two or more consecutive occurrences of an error greater than X. MDPO is the length of time (based on the number of consecutive occurrences) of the longest event. |
| MDNO(X) | Maximum Duration of Negative Outliers. A negative outlier event is two or more consecutive occurrences of an error less than -X. MDNO is the length of time (based on the number of consecutive occurrences) of the longest event. |

The target frequencies of the associated statistics based on navigation requirements are:

CF(X) ≥90%, POF(2X) ≤1%, NOF(2X) ≤1%, MDPO(2X) ≤ N, MDNO(2X) ≤ N

The NOS accepted error criteria (X) are 0.15 m for water level, 3.0 °C for surface water temperature, 3.5 PSU for salinity, 0.26 m per second (m/s) for current speed, and 22.5 degrees for current direction. The accepted N (duration) is 24 hours.

**Data sources**

As shown in Tables 2-4 and Figures 13-15, the observed water level data are all from CO-OPS. The observed water temperature data are from CO-OPS, the NWS National Data Buoy Center (NDBC), and USGS. The observed water salinity and currents are from Coastal Margin Observation and Prediction (CMOP), the University of Washington (UW), NDBC, CO-OPS, and USGS. Real-time measurements of water level, surface temperature, salinity, and currents were compared with the model results, and model skill assessments were performed to evaluate the model skill statistics. Observed data at some stations were not available for certain periods. The missing data periods (in days) are indicated in the headers of the corresponding model skill assessment tables in Appendices A, B, D, F, and G.

Model output of 6-minute station files which support this technic report can be found at https://noaa-nos-ofs-pds.s3.amazonaws.com/index.html#sscofs/netcdf/2024mm/ where mm is from 02 to 08.

**Table 2.** The water level observation stations used for skill assessment of the Salish Sea and Columbia River Operational Forecast System (SSCOFS).

| Owner | Station ID | Lat | Lon | Station Name | Variables |
|---|---|---|---|---|---|
| CO-OPS | 9449424 | 48.863 | -122.759 | Cherry Point | WL |
| CO-OPS | 9444900 | 48.113 | -122.758 | Port Townsend | WL |
| CO-OPS | 9447130 | 47.601 | -122.340 | Seattle | WL |
| CO-OPS | 9446484 | 47.269 | -122.415 | Tacoma | WL |
| CO-OPS | 9444090 | 48.125 | -123.442 | Port Angeles | WL |
| CO-OPS | 9442396 | 47.908 | -124.637 | La Push | WL |
| CO-OPS | 9437540 | 45.570 | -123.956 | Garibaldi | WL |
| CO-OPS | 9435380 | 44.610 | -124.086 | South Beach | WL |
| CO-OPS | 9439040 | 46.207 | -123.768 | Astoria | WL |
| CO-OPS | 9440569 | 46.267 | -123.452 | Skamokawa | WL |
| CO-OPS | 9439099 | 46.160 | -123.405 | Wauna | WL |
| CO-OPS | 9440422 | 46.105 | -122.953 | Longview | WL |
| CO-OPS | 9439201 | 45.865 | -122.797 | St. Helens | WL |
| CO-OPS | 9440083 | 45.632 | -122.697 | Vancouver | WL |

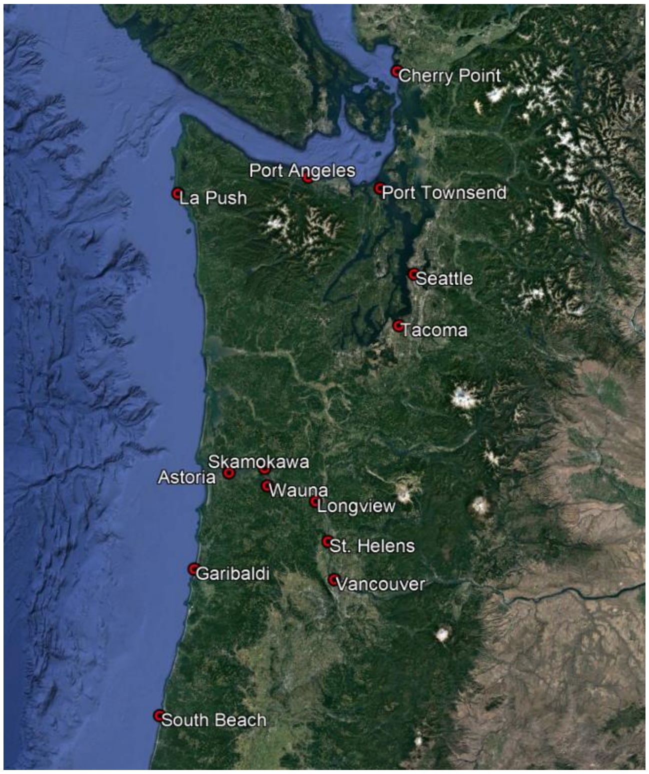


**Figure 13.** The water level observation stations used for the Salish Sea and Columbia River Operational Forecast System (SSCOFS) skill assessment.

**Table 3.** The water temperature observation stations used for the Salish Sea and Columbia River Operational Forecast System (SSCOFS) skill assessment.

| Owner | Station ID | Lat | Lon | Station Name | Variables |
|---|---|---|---|---|---|
| CO-OPS | 9449880 | 48.545 | -123.012 | Friday Harbor | SST |
| CO-OPS | 9444900 | 48.108 | -122.755 | Port Townsend | SST |
| CO-OPS | 9446484 | 47.267 | -122.413 | Tacoma | SST |
| CO-OPS | 9444090 | 48.125 | -123.440 | Port Angeles | SST |
| CO-OPS | 9443090 | 48.368 | -124.605 | Neah Bay | SST |
| CO-OPS | 9442396 | 47.908 | -124.637 | La Push | SST |
| NDBC | 46211 | 46.857 | -124.244 | Grays Harbor | SST |
| NDBC | 46248 | 46.133 | -124.667 | Astoria Canyon | SST |
| CO-OPS | 9437540 | 45.570 | -123.956 | Garibaldi | SST |
| CO-OPS | 9440422 | 46.105 | -122.953 | Longview | SST |
| USGS | 14211720 | 45.519 | -122.667 | Willamette Portland | SST |

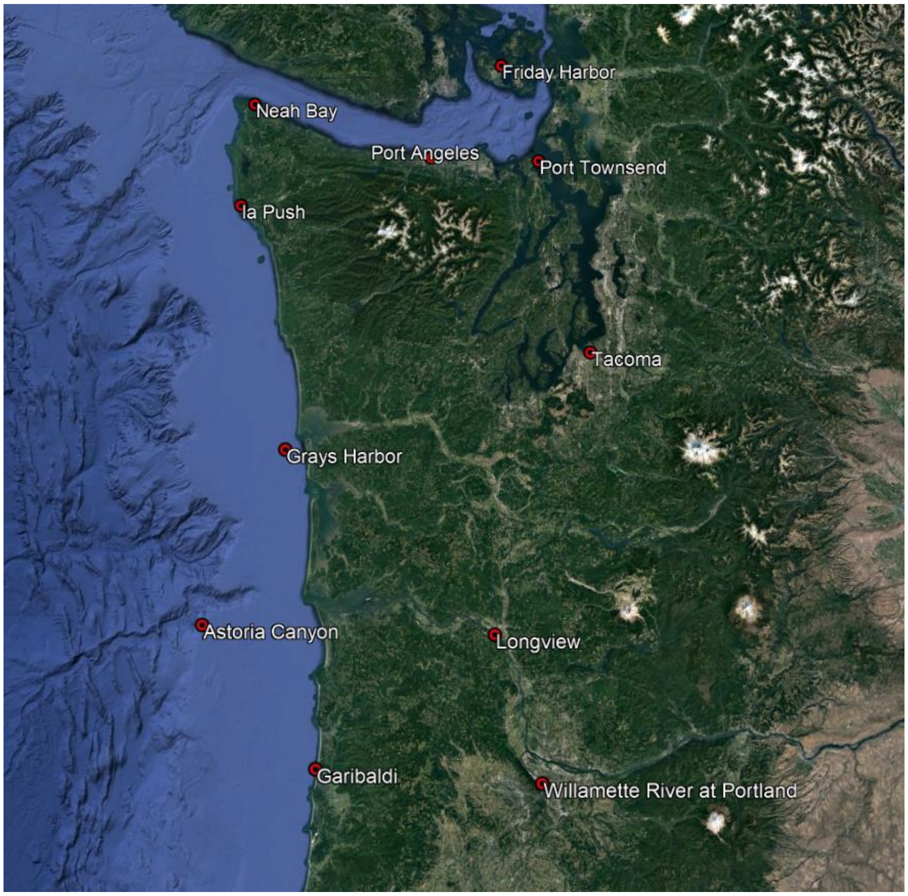


**Figure 14.** The water temperature observation stations used for the Salish Sea and Columbia River Operational Forecast System (SSCOFS) skill assessment.

**Table 4.** The water salinity and currents observation stations used for the Salish Sea and Columbia River Operational Forecast System (SSCOFS) skill assessment.

| Owner | Station ID | Lat | Lon | Station Name | Variables |
|---|---|---|---|---|---|
| CMOP | saturn7 | 46.28581 | -124.014999 | Saturn-07 | SSS |
| UW | npby1 | 47.28 | -122.73 | NPBY1 | SSS |
| UW | npby2 | 47.7612 | -122.3972 | NPBY2 | SSS |
| UW | orca3 | 47.9073 | -122.627 | ORCA3 | SSS |
| UW | orca4 | 47.8034 | -122.8029 | ORCA4 | SSS |
| UW | orca2 | 47.4218 | -123.1126 | ORCA2 | SSS |
| NDBC | 46267 | 48.173 | -123.607 | Angeles Point | CU |
| CO-OPS | ks0101 | 47.59406 | -122.5423 | Rich Passage | CU |
| CO-OPS | ks0201 | 47.75788 | -122.7303 | Bangor Hood Canal | CU |
| USGS | 14144700 | 45.63117 | -122.69580 | USGS-Van | CU |

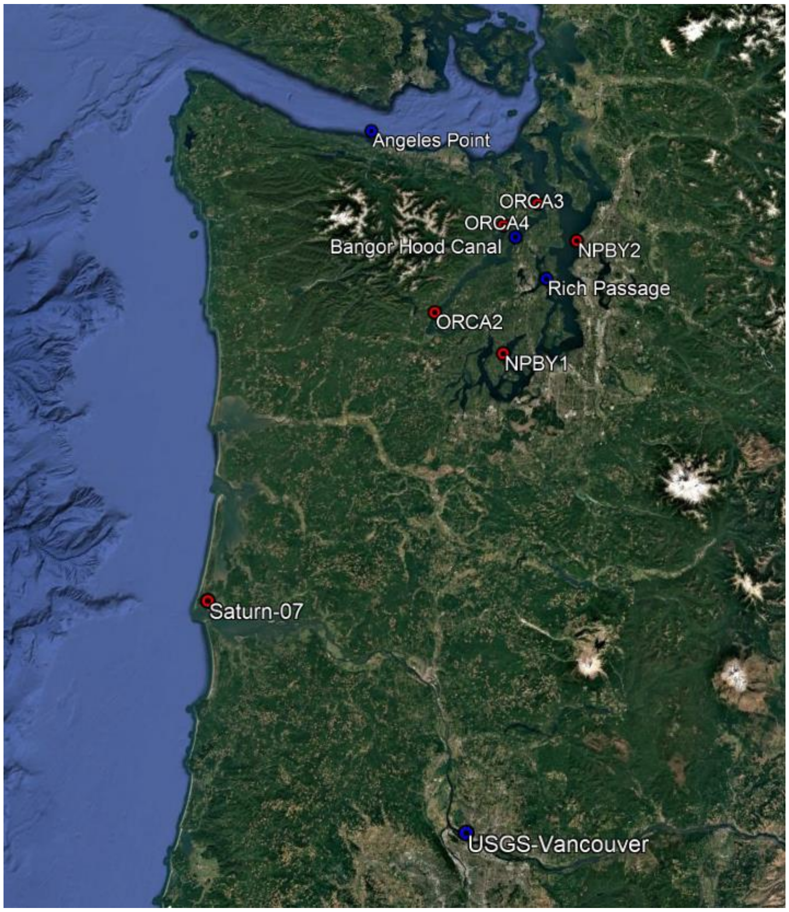


**Figure 15.** The salinity and currents observation stations used for the Salish Sea and Columbia River Operational Forecast System (SSCOFS) skill assessment. Red is for salinity, and blue for currents.

## 3.3. Nowcast and Forecast Skill Assessment

The SSCOFS semi-operational nowcast and forecast assessment period was from February 15-August 15, 2024, and the results from model simulations during this period were concatenated into time series for analysis using the skill assessment software. The observed original salinity data from UW and river flow data from USGS were manually processed by python and shell scripts to change to the required standard format.

Generally, root mean square error (RMSE), central frequency (CF), negative outlier frequency (NOF), positive outlier frequency (POF), maximum duration of negative outliers (MDNO), and maximum duration of positive outliers (MDPO) at each station meet or are close to the NOS accepted error criteria for most variables in both nowcast and forecast scenarios. The results of the skill assessment for water level, temperature, salinity, and currents are discussed in the following subsections.

**Results of water level skill assessment**

Among CO-OPS's 14 National Water Level Observation Network (NWLON) stations, model water levels generally agree well with observations. A typical cycle of N/F results is shown in Figure 12.

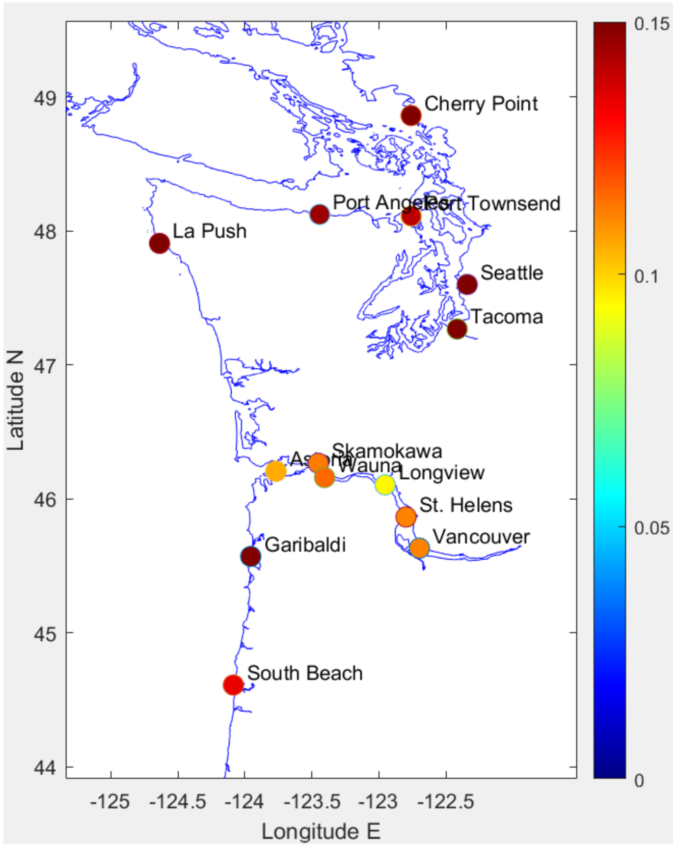


**Figure 16.** Nowcast root mean square errors (RMSEs) of water level (in meters) for the Salish Sea and Columbia River Operational Forecast System (SSCOFS).

The RMSEs of nowcast water levels at most stations are less than or close to 0.15 m, the accepted error criteria for navigation applications (Figure 16). More skill assessment details can be found in Appendix A Tables A-1 to A-14. The only exception is at Garibaldi (station ID 9437540) where the RMSE is about 0.21 m. This is because the model mesh can't resolve the complicated coastline where station 9437540 is located. The node point where the modeled water levels are compared with observations is about 200 m from the observation location. More importantly, 2 man-made piers, one of which accommodates 9437540, are not resolved in the model grid.

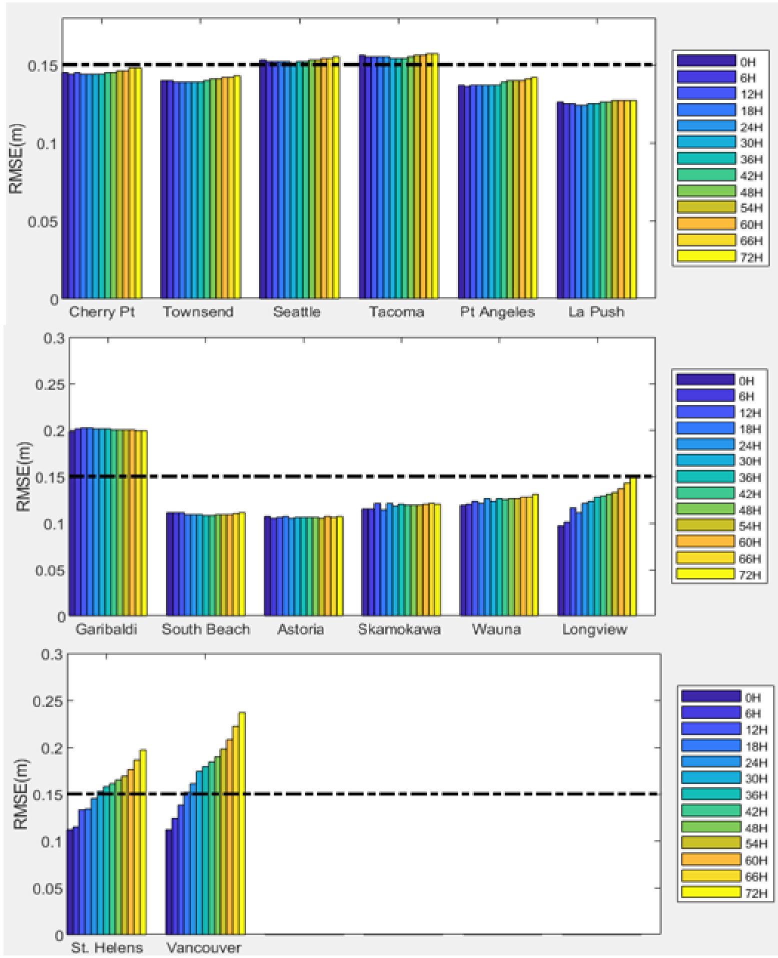


**Figure 17.** Forecast root mean square errors (RMSEs) of water level (in meters) at different lead times for the Salish Sea and Columbia River Operational Forecast System (SSCOFS).

The RMSEs of forecast water levels at all stations are also less than or close to the NOS accepted error criteria. For any numerical model, the RMSEs of its target variables generally increase as the model's forecast lead time goes up. This is the same for SSCOFS water levels. However, in the middle and upper Columbia River, this trend is extremely striking as shown in Figure 17. For example, the RMSE at Vancouver increases dramatically from 0.11 m at 0 H to 0.24 m at 72 H lead time scenario (see Table A-14 for the values). This rapid RMSE increase with forecast lead time might be attributed to the inaccuracy of NWM's river discharge in the forecast as data assimilation effect tapers off. Such dramatic degradation of water level performance in forecast cycles has never been found in the other existing OFS skill assessments.

The SSCOFS's water level outperforms the decommissioned CREOFS's in the middle and upper Columbia River in nowcast and short forecast lead time scenarios, which is demonstrated by the comparison of Figures 18 and 19 with the same 6 Columbia River stations in Figures 16 and 17. The nowcast water level RMSEs from CREOFS operational runs at Longview, St. Helens, and Vancouver are all above 0.15 m, much worse than those of SSCOFS. In forecast, the CREOFS's RMSEs also increase with forecast lead time but far less intensely than in SSCOFS.

Two factors might be the players behind better water level performance of SSCOFS than CREOFS. One is the correct river reach ID 23735707 is used in the model to obtain NWM's data-assimilation-considered river discharge near USGS 14144700 station, which started to measure and disseminate river discharge in 2016, 6 years after CREOFS was implemented. The second factor is more accurate bottom friction distribution is considered as mentioned previously.

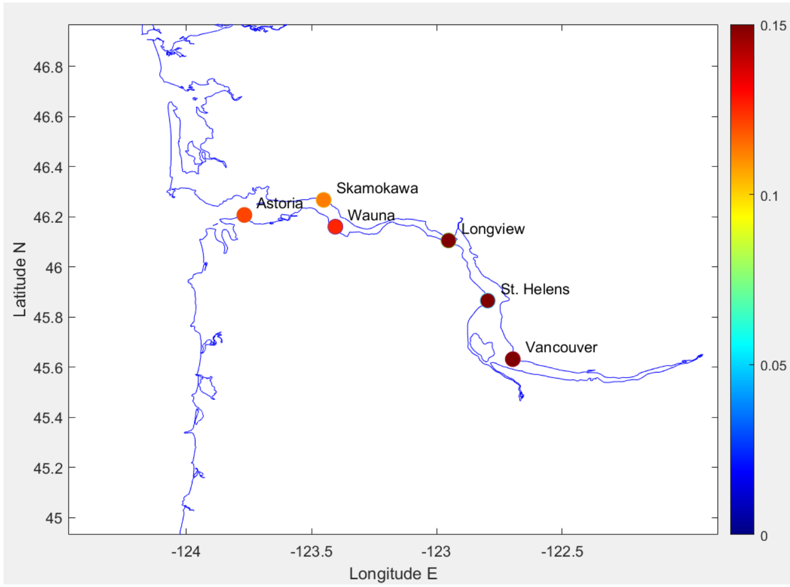


**Figure 18.** Nowcast root mean square errors (RMSEs) of water level (in meters) for the Columbia River Estuary Operational Forecast System (CREOFS).

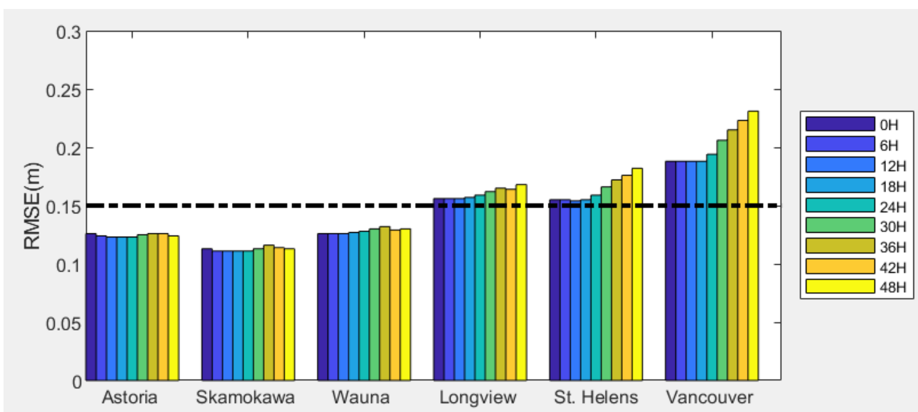


**Figure 19.** Forecast root mean square errors (RMSEs) of water level (in meters) at different lead times for the Columbia River Estuary Operational Forecast System (CREOFS).

The tables in Appendix A show a full set of water level model skill assessment results for all skill statistical metrics at all stations. Generally, nowcast and forecast CF values at all locations range from 50.1% to 89.8% which does not meet the accepted criteria (CF ≥90%). The lowest CF is found at Garibaldi, where the model can't resolve the subarea well, as mentioned before. The unsatisfying low CF is due to the high energy of tide and river flow in the model domain and the subsequent relatively large water level RMSEs, as shown previously.

NOF and POF are close to or less than 1% (the NOS accepted error criteria) at most stations for both nowcast and forecast scenarios. But at Garibaldi, the nowcast water level NOF and POF are as high as 10.4% and 4.9%, respectively, due to the large water level RMSE. For the forecast, the worst cases are in the middle and upper Columbia River when lead time goes up. In the Vancouver H72 scenario, for instance, the forecast water level NOF and POF are 9.5% and 11.0%, respectively, which are associated with the large water level RMSEs in the long lead times, as mentioned before.

Both MDNO and MDPO at all ocean and lower Columbia River stations are much less than the accepted 24-hour criteria for all scenarios. From Longview to the upper Columbia River, both MDNO and MDPO increase. One interesting thing is that the MDNO is longer than MDPO in those upper river stations. MDNO at Longview is 13.3 hours for nowcast and 66.0 hours for H72 forecast lead time, while MDPO for all scenarios except for H72 forecast is 0.0 hours. At Vancouver, nowcast MDNO and MDPO are 21.6 and 0.0 hours, respectively. But as forecast lead time increases, MDPO nonlinearly increases. For the forecast H72 scenario, the MDPO has increased to as high as 90 hours, though still less than its MDNO value.

The correlation coefficient (CORR) of water levels for all open ocean stations is very high, either 0.99 or 1.0. This indicates that modeled water level over the analysis period is well in phase with observations, largely due to the accuracy of modeled tidal phases in most subregions where the tide is very strong. Even for those middle and upper Columbia River stations where the tidal range is small, the CORR is still above 0.97 for nowcast scenarios. As river influence becomes more important compared with the tide, the CORR decreases as the lead time increases in the upper Columbia River due to worse river discharge input, as mentioned previously. For example, at Vancouver, the CORR is 0.94 in the H06 scenario and decreases to 0.78 in the H72 scenario.

**Results of surface water temperature skill assessment**

Model evaluation and skill assessment for surface water temperature were conducted at 11 stations. Their locations can be found in Table 3 and Figure 14. Eight are CO-OPS's NWLON stations, 2 are NDBC buoys, and 1 is a USGS station. The water temperature sensor depth ranges from 0.5 to 2.8 m of the 11 stations, and the model temperature output at corresponding grid points has been interpolated to the corresponding sensor depth. Similar vertical interpolation holds true in both salinity and currents model data processes that will be discussed in the next subsections.

Nowcast RMSEs of surface water temperature are illustrated in Figure 20, and forecast RMSEs at different lead times are shown in Figure 21. By comparison, the model's skill in predicting water temperature is relatively better than the water level skill described previously. The RMSEs of all stations are far less than 3.0°C, the NOS accepted error criteria. Two stations have interesting RMSE slopes as forecast lead time increases. One is Willamette Portland, where RMSEs increase sharply with lead time. This is similar to the water level RMSE slope in the middle and upper Columbia River, due largely to the NWM river discharge forecast inaccuracy, as mentioned previously. More interesting is station La Push where the RMSEs of water temperature decrease as forecast lead time increases, a "negative" distribution which is quite uncommon. There are 2 major factors in the model to determine water temperature. One is the temperature profile derived from RTOFS in the lateral open boundary, and the other is the local heat flux in NAM. The latter is more likely the culprit. This is because water temperature is conservative and stable along the lateral open boundary where water depth is so deep. The huge change of nearly 0.5°C RMSE from the 0-hour to 72-hour scenario can only come from NAM. Apparently, local heat flux measurement/calculation and land-sea boundary determinations in the data assimilation process in NAM may have some issues in the nowcast cycle which leads to the bad-nowcast and good-forecast phenomenon.

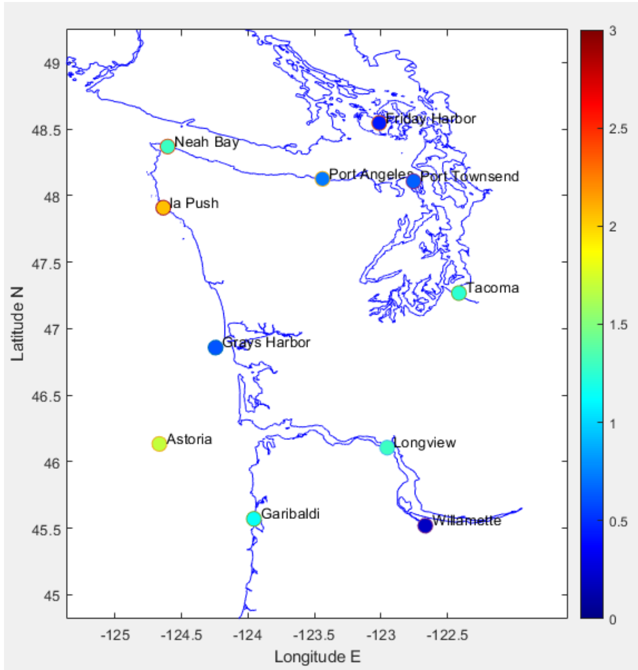


**Figure 20.** Nowcast root mean square errors (RMSEs) of surface water temperature (in °C) for Salish Sea and Columbia River Operational Forecast System (SSCOFS).

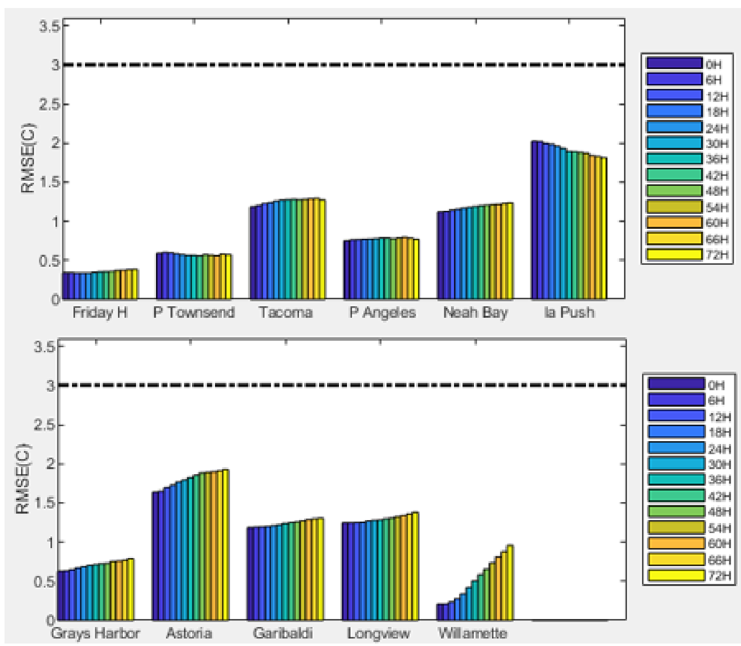


**Figure 21.** Forecast root mean square errors (RMSEs) of surface temperature (in °C) at different lead times for the Salish Sea and Columbia River Operational Forecast System (SSCOFS).

Further details of model skill assessment results at all stations can be found in the tables in Appendix B. As shown in the tables, CF meets the accepted 90% criterion at all stations for nowcast scenarios except for La Push, which has a value of 84.5%. CF in forecast scenarios at all stations also have very high values. Both NOF and POF meet the 1% criterion at all stations for nowcast and forecast scenarios. Actually, they are all perfectly 0.0% except for La Push, where

NOF is 0.5% in some forecast lead times (H60, H66, and H72). The values of MDPO and MDNO are perfectly 0.0 hour at all stations (including La Push) and for all nowcast and forecast scenarios.

The surface water temperature time series comparison between model and observation at all stations are illustrated in Appendix C. The observations are not complete within the entire evaluation window at some stations.

As mentioned in Section 2.4, SSCOFS has an arbitrary thermal vertical constraint on the lateral open boundary, such that, “at any mesh grid point on the boundary, the water temperature at any vertical water column below 125 m takes the temperature value at the 125 m level.” To evaluate its effect, the model without this thermal constraint was also quasi-operationally running during the skill assessment period. This no-thermal-constraint model skill assessment indicates that there is slightly worse temperature performance compared with thermal-constraint model. Generally, no noticeable RMSE change is found on the Pacific coast of Oregon and Washington. RMSEs are about 0.2°C higher at the stations in the Salish Sea subregion. The worst station is Neah Bay, which has about 0.5°C RMSE increase. During the model skill assessment period, the vertical thermal constraint did not bring a 1.5°C improvement as PNNL found in their hindcast study.

**Results of surface water salinity skill assessment**

Model evaluation and skill assessment for surface water salinity were conducted at 6 buoy stations. Their locations can be found in Table 4 and Figure 15. One station is maintained by CMOP, and the others are owned and maintained by UW. The salinity measurement depth is 1.0 m at Saturn-07 and 5.0 m at all other stations.

Nowcast RMSEs of surface water salinity are illustrated in Figure 22, and forecast RMSEs at different lead times are shown in Figure 23. The salinity model performance, similar to water temperature, is acceptable at all stations. The RMSEs of all stations are less than 3.5 practical salinity units (PSU), the NOS accepted error criterion. The RMSEs at NPBY1 and NPBY2 are outstanding at less than 0.5 PSU. CF ranges from 80.0% at Saturn-07 to 100.0% at NPBY1 and NPBY2.

Appendices D and E, respectively, show the details of salinity skill assessment results at each station and the modeled versus observation time series graphics at each station. The model’s salinity depends largely on the lateral open boundary salinity profile derived from RTOFS, as well as on the river discharges if the place of interest is in the vicinity of a river mouth. For example, given its location, the model’s salinity performance at Saturn-07 depends on both the open boundary salinity and the fresh water discharge of Columbia River. Table D-1 indicates that POF is 0.0% and MDPO is 0.0 hours for nowcast and all forecast scenarios. NOF and MDNO are 3.7% and 24 hours in the worst scenario, which indicates the model has moderate low salinity intendancy that likely stems from slightly high discharge estimation from NWM. This result can be confirmed by Figure E-1 which illustrates that during the skill assessment period, the modeled salinity is less than observation. For example, the observed salinity is more than 5.0 PSU larger than the modeled salinity around July 18, 2024.

As observed salinity data are from different sources and their data temporal resolution ranges from 2 minutes at Saturn-07 to 1 day at some Oceanic Remote Chemical Analyzer (ORCA) stations, the observed data is marked as a black “dot” in all Appendix E figures for better visual evaluations.

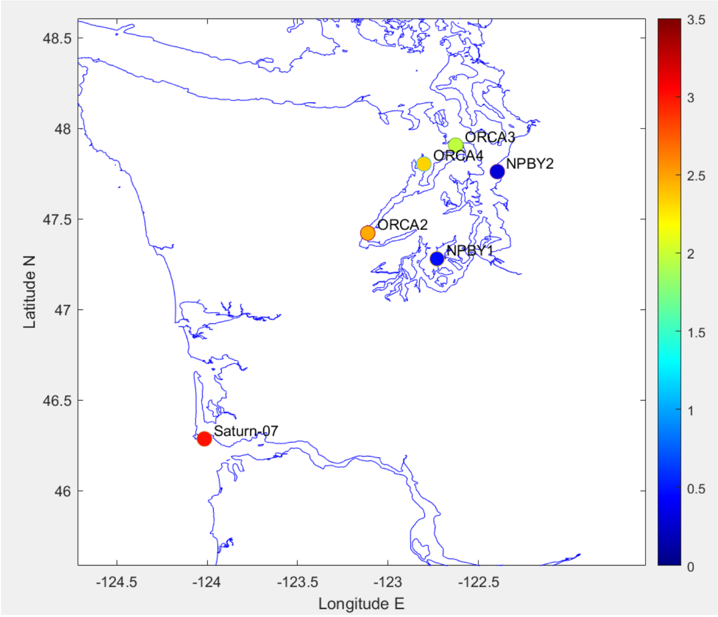


**Figure 22.** Nowcast root mean square error (RMSE) of surface water salinity (in practical salinity units [PSU]) for the Salish Sea and Columbia River Operational Forecast System (SSCOFS).

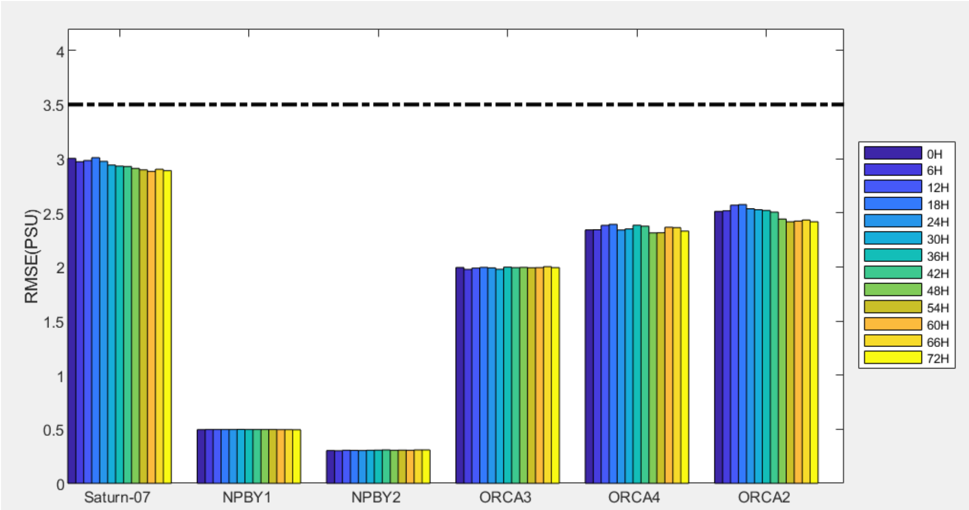


**Figure 23.** Forecast root mean square error (RMSE) of surface water salinity (in practical salinity units [PSU]) at different lead times for the Salish Sea and Columbia River Operational Forecast System (SSCOFS).

## Results of water currents skill assessment

As shown in Table 4 and Figure 15, there are 4 currents observation stations used for the skill assessment, 2 of which are from CO-OPS, 1 from NDBC, and 1 from USGS. A typical cycle of N/F results of current speed and direction can be found in Figure 12. In most cases, both modeled current speed and direction match well with the observations.

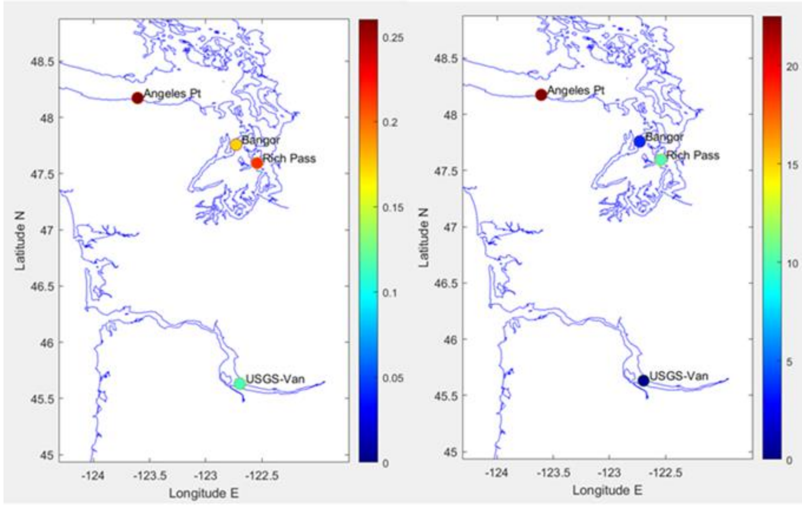


**Figure 24.** Nowcast root mean square error (RMSE) of current speed in m/s (left) and direction in degree (right) for the Salish Sea and Columbia River Operational Forecast System (SSCOFS).

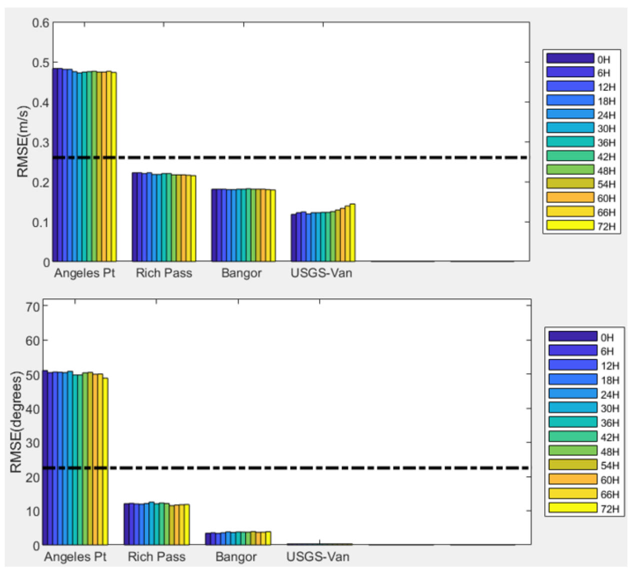


**Figure 25.** Forecast root mean square error (RMSE) of current speed in m/s (upper) and direction in degree (lower) at different lead times for the Salish Sea and Columbia River Operational Forecast System (SSCOFS).

The sensor depths at Angeles Point, Rich Passage, and Bangor Hood Canal are 1.0 m, 13.7 m, and 56.0 m, respectively, below sea surface. USGS-Van provides measured vertically averaged river flow rather than flow at a certain depth. The river flow vertical profile is the assumed liner from surface to bottom at this station, so the mid-layer currents at the corresponding model output station are used to compare with the observations. The main purpose of model assessment at USGS-Van is to evaluate the validity of SSCOFS's modeled river flow, which coherently reflects the soundness of NWM's Columbia River discharge. Furthermore, the accuracy of the modeled river flow is a critical basis to find and validate the correct bottom friction distributions as discussed in Section 2.6.

The RMSEs of current speeds for nowcast and forecast can be found in the left panel of Figure 24 and upper panel of Figure 25. All stations meet the NOS accepted error criteria except for Angeles Point, where the RMSE of current speed is about 0.48 m/s, much higher than 0.26 m/s, the NOS accepted error criteria. Similar results can be found for the RMSEs of current directions from the right panel of Figure 24 and lower panel of Figure 25. At the other 3 stations, RMSEs meet the NOS required 22.5°, but the directions at Angeles Point are larger than 50.0° for the nowcast and all forecast lead time scenarios. The details of the current skill assessment results at all stations can be found in the tables in Appendices F and G.

The reason behind poor current performance at Angeles Point is the location difference between the observation and model outputs. The model mesh point, which is nearest to NDBC Angeles Point, is not listed in the model's output control file. Instead, the mesh grid which is closest to Angeles Pt., 2 mi. NNE of (PUG1639) is mistakenly listed in the control file to represent NDBC at Angeles Point. The distance is about 5.9 km between the 2 locations, as shown in Figure 26.

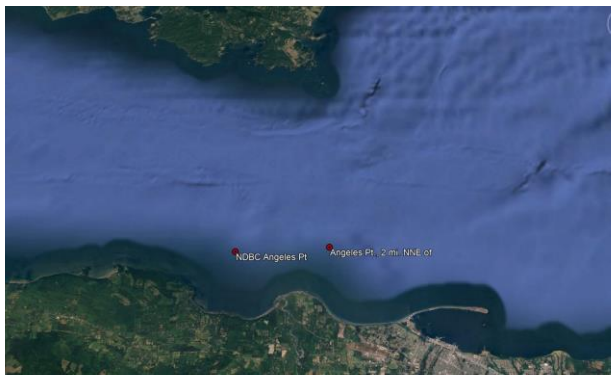


**Figure 26.** The locations of the National Data Center Buoy (NDBC) buoy at Angeles Point and the model grid point 2 miles NNE of Angeles Point (PUG1639).

If the Strait of Juan de Fuca had parallel north and south shores and had the same water depth of 50 m everywhere in the channel, for example, the 5.9 km location difference should not have made a considerable RMSE difference. This is because the only difference, hydrodynamically, between the 2 locations in the ideal case should come from the tidal phase, which is about 4 minutes given the assumed water depth and the resulting gravity wave speed. In reality, however, the water depth at Angeles Pt., 2 mi. NNE of (PUG1639) is 25 m, much shallower than the 75 m of NDBC at Angeles Point. As a result, the water currents at the former location, modulated by the continuity equation in the model, should be larger than at the latter. In addition, the coastline is meandering as shown in Figure 26, which makes the major current direction different at the 2 locations.

In light of the above analysis, model currents from the element which is nearest to the NDBC at Angeles Point were extracted from hourly nowcast fields files to reassess the model performance. Node point 38739 is found to be the nearest to the NDBC buoy station. Based on the locations of this node and the NDBC buoy, shown in the left panel of Figure 27, and the relative locations of the node's surrounding elements, as shown in the right panel of Figure 27, the element 72139 is selected to extract the model surface currents to compare with the observations.

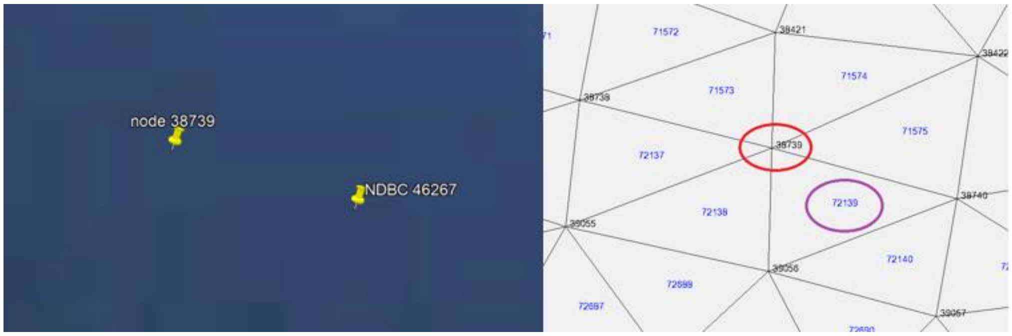


**Figure 27.** The relative location of the National Data Buoy Center (NDBC) buoy and its nearest model node, 38739 (left). The selected element where modeled currents are extracted from nowcast hourly fields files to compare with observations (right).

The RMSE of nowcast surface current speed decreases to 0.33 m/s, which is much lower than the original 0.48 m/s though still over the NOS accepted error criteria. Similarly, the RMSE of current direction decreases to 37.6° from the original 50.7° due largely to a more accurate current direction at the correct model output location.

No historical forecast field files were archived in the skill assessment period to support forecast skill reassessment at the new correct model location. Even for the nowcast, the hourly modeled currents are too temporally coarse to be employed to conduct standard model skill assessment. The above model reassessments on current speed and direction at the correct location are not the official results and only serve as reference.

# 4.0 CONCLUSIONS

The SSCOFS, with the FVCOM as its hydrodynamic core, has been implemented to provide users with nowcast and forecast guidance of the 3-D physical conditions of the Salish Sea and Columbia River estuary regions—including surface water levels, 3-D water currents, water temperature, and salinity—out to 72 hours. The quasi-operational run of the SSCOFS with its final version began on February 7, 2024, and their outputs for the period of February 15-August 15, 2024, were used for the model nowcast and forecast skill assessment.

The model skill assessment results indicate that all water level metrics pass or are close to the NOS accepted error criteria. For example, RMSEs of water level at all stations are less than or close to 0.15 m, the acceptance for navigation applications, except for Garibaldi, where the model mesh grids can’t resolve the complicated coastline. CFs range from 50.1% to 89.8% which does not meet the accepted criteria (CF ≥90%) due largely to high vitality of tides and Columbia River flow in the model domain. NOF and POF are close to or less than 1% (the NOS accepted error criteria) at most stations for both nowcast and forecast scenarios. Both MDNO and MDPO at all ocean and lower Columbia River stations are much less than the required 24-hour criteria for both scenarios.

The SSCOFS nowcast water level outperforms the decommissioned CREOFS in the middle and upper Columbia River thanks to the establishment of a new USGS river discharge station and more accurate bottom friction distributions in the Columbia River. However, the SSCOFS’s water level RMSEs in the middle and upper Columbia River increase linearly with forecast lead times, which suggests NWM’s river discharge forecast performance decreases as lead time increases.

Another advantage of SSCOFS, not mentioned in Section 3, is that unlike CREOFS, it does not need any water level adjustment based on the difference between the model and observation of previous cycles to predict water level of the current cycle, thanks largely to the new establishment of a USGS river discharge station.

The surface water temperature skill assessment results indicate that water temperature RMSEs are far less than 3ºC at all available stations. CFs meet the accepted 90% criterion at almost all stations for nowcast scenarios. Both NOF and POF meet the 1% criterion at all stations for nowcast and forecast scenarios. The value of MDPO and MDNO is perfectly 0.0 hours at all stations for all nowcast and forecast scenarios.

The special vertical thermal constraint did not have substantial model enhancement on water temperature performance during the skill assessment period. Generally, there is no noticeable water temperature enhancement on the Pacific coast of Oregon and Washington. There is, however, tangible water temperature improvement, attributed to the thermal constraint, in the Salish Sea subregions and the Strait of Juan De Fuca, with the largest improvement at Neah Bay where a 0.5°C RMSE enhancement is found.

The surface water salinity skill assessment results indicate that salinity RMSEs at all stations are less than 3.5 PSU, the NOS accepted error criteria. The RMSEs at NPBY1 and NPBY2, located in the Salish Sea, are outstanding at less than 0.5 PSU. The model's salinity performance depends largely on the open boundary salinity profile derived from RTOFS and also on river discharges if the place of interest is in the vicinity of a river mouth. Given its location, the model's salinity performance at Saturn-07 depends on both the open boundary salinity and the fresh water discharge of Columbia River. NOF and MDNO values indicate the model has moderate low salinity intendancy that likely stems from slightly high river discharge estimation from NWM.

The RMSEs of current speed for nowcast and forecast meet NOS accepted error criteria at all stations except for Angeles Point, where the RMSE of current speed is about 0.48 m/s, which is over the NOS accepted error criterion. Similar results are found for the RMSEs of current direction. At the other 3 stations, RMSEs are less than the accepted error criterion. But the values at Angeles Point are larger than 50.0° for the nowcast and all forecast scenarios. The reason behind such poor current performance at this station is due to an incorrect model output location. Model currents from the correct mesh element were extracted from hourly nowcast fields files to reassess the model performance. Both RMSEs of current speed and direction are improved substantially at this station.

# ACKNOWLEDGEMENTS

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# ACRONYMS

| | |
|---|---|
| ADCIRC | ADvanced CIRCulation |
| CF | central frequency |
| CMOP | Coastal Margin Observation and Prediction |
| COMF | Coastal Ocean Modeling Framework |
| CO-OPS | Center for Operational Oceanographic Products and Services |
| CRD | Columbia River Datum |
| CREOFS | Columbia River Estuary Operational Forecast System |
| FVCOM | Finite Volume Community Ocean Model |
| GFS | Global Forecast System |
| HPC | High Performance Computing |
| IOOS | Integrated Ocean Observing System |
| MDPO | maximum duration of positive outliers |
| MDNO | maximum duration of negative outliers |
| NAM | North American Mesoscale Forecast System |
| NANOOS | Northwest Association of Networked Ocean Observing Systems |
| NCEP | National Centers for Environmental Prediction |
| NDBC | National Data Buoy Center |
| N/F | Nowcast/Forecast |
| NOAA | National Oceanic and Atmospheric Administration |
| NOF | negative outlier frequency |
| NOS | National Ocean Service |
| NWM | National Water Model |
| NWLON | National Water Level Observation Network |
| NWS | National Weather Service |
| NPAC | North Pacific |
| OCS | Office of Coast Survey |
| OHSU | Oregon Health & Science University |
| PNNL | Pacific Northwest National Laboratory |
| POF | positive outlier frequency |
| RMSE | root mean square error |
| RTOFS | Real-Time Ocean Forecast System |
| SELFE | Semi-implicit Eulerian-Lagrangian Finite Element |
| SM | series mean |
| SSCOFS | Salish Sea and Columbia River Operational Forecast System |
| UMASSD | University of Massachusetts Dartmouth |
| USGS | U.S. Geological Survey |
| UW | University of Washington |
| WCOSS | Weather and Climate Operational Supercomputing System |

# LIST OF APPENDICES

# APPENDIX A. WATER LEVEL MODEL SKILL ASSESSMENT TABLES

**Table A-1.** Water level skill assessment at Cherry Point.

| Station: | Cherry Point | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | -0.129 | | | | | | | | | | |
| h | | | 40201 | -0.129 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | -0.001 | 0.144 | 0.144 | 1.1 | 70.2 | 2.2 | 6.3 | 7.4 | 0.0 | 0.99 | 0.99 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | 0.001 | 0.145 | 0.145 | 1.5 | 71.1 | 2.3 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H006-h006 | 15 cm | 24h | 611 | 0.000 | 0.144 | 0.144 | 1.3 | 70.9 | 2.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H012-h012 | 15 cm | 24h | 610 | -0.001 | 0.145 | 0.145 | 1.5 | 70.7 | 2.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H018-h018 | 15 cm | 24h | 609 | -0.001 | 0.144 | 0.144 | 1.1 | 71.1 | 2.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H024-h024 | 15 cm | 24h | 608 | -0.001 | 0.144 | 0.144 | 1.3 | 71.4 | 2.3 | 6.0 | 0.0 | -99.9 | 1.0 | |
| H030-h030 | 15 cm | 24h | 607 | -0.001 | 0.144 | 0.144 | 1.2 | 70.7 | 2.5 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H036-h036 | 15 cm | 24h | 606 | -0.001 | 0.144 | 0.144 | 1.2 | 71.0 | 2.3 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H042-h042 | 15 cm | 24h | 605 | -0.003 | 0.145 | 0.145 | 1.3 | 71.2 | 2.3 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H048-h048 | 15 cm | 24h | 604 | -0.003 | 0.145 | 0.145 | 1.3 | 71.7 | 2.3 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H054-h054 | 15 cm | 24h | 603 | -0.003 | 0.146 | 0.146 | 1.2 | 70.6 | 2.2 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H060-h060 | 15 cm | 24h | 602 | -0.003 | 0.146 | 0.146 | 1.2 | 71.6 | 2.2 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H066-h066 | 15 cm | 24h | 601 | -0.004 | 0.148 | 0.148 | 1.3 | 71.0 | 2.8 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H072-h072 | 15 cm | 24h | 600 | -0.004 | 0.148 | 0.148 | 1.7 | 70.5 | 2.5 | 6.0 | 6.0 | -99.9 | 1.0 | |

**Table A-2.** Water level skill assessment at Port Townsend.

| Station: | Port Townsend | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | 0.012 | | | | | | | | | | |
| h | | | 40201 | 0.012 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.138 | 0.138 | 0.7 | 72.6 | 2.1 | 5.1 | 7.1 | 0.0 | 0.99 | 0.99 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | 0.002 | 0.140 | 0.140 | 0.5 | 71.7 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H006-h006 | 15 cm | 24h | 611 | 0.002 | 0.140 | 0.140 | 0.5 | 70.9 | 2.3 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H012-h012 | 15 cm | 24h | 610 | 0.002 | 0.139 | 0.140 | 0.5 | 71.6 | 2.3 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H018-h018 | 15 cm | 24h | 609 | 0.002 | 0.139 | 0.140 | 0.2 | 71.1 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H024-h024 | 15 cm | 24h | 608 | 0.001 | 0.139 | 0.140 | 0.3 | 71.1 | 2.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H030-h030 | 15 cm | 24h | 607 | 0.001 | 0.139 | 0.140 | 0.3 | 72.2 | 2.3 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H036-h036 | 15 cm | 24h | 606 | 0.001 | 0.139 | 0.140 | 0.2 | 71.1 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H042-h042 | 15 cm | 24h | 605 | 0.000 | 0.140 | 0.140 | 0.2 | 71.7 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H048-h048 | 15 cm | 24h | 604 | -0.001 | 0.141 | 0.141 | 0.5 | 71.2 | 2.8 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H054-h054 | 15 cm | 24h | 603 | 0.000 | 0.141 | 0.142 | 0.5 | 70.1 | 3.0 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H060-h060 | 15 cm | 24h | 602 | 0.000 | 0.142 | 0.142 | 0.5 | 70.4 | 2.7 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H066-h066 | 15 cm | 24h | 601 | -0.001 | 0.142 | 0.142 | 0.5 | 71.0 | 2.8 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H072-h072 | 15 cm | 24h | 600 | -0.002 | 0.143 | 0.143 | 0.8 | 70.3 | 2.8 | 0.0 | 0.0 | -99.9 | 1.0 | |

**Table A-3.** Water level skill assessment at Seattle.

| Station: | Seattle | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | 0.047 | | | | | | | | | | |
| h | | | 40201 | 0.047 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.151 | 0.151 | 1.2 | 66.4 | 2.9 | 8.0 | 9.3 | 0.0 | 0.99 | 1 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | 0.001 | 0.153 | 0.153 | 1.5 | 64.1 | 2.5 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H006-h006 | 15 cm | 24h | 611 | 0.000 | 0.152 | 0.152 | 1.5 | 64.0 | 2.1 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H012-h012 | 15 cm | 24h | 610 | 0.000 | 0.152 | 0.153 | 1.5 | 63.6 | 2.1 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H018-h018 | 15 cm | 24h | 609 | -0.001 | 0.152 | 0.153 | 1.6 | 64.4 | 2.1 | 6.0 | 0.0 | -99.9 | 1.0 | |
| H024-h024 | 15 cm | 24h | 608 | -0.001 | 0.152 | 0.152 | 1.5 | 64.0 | 2.0 | 6.0 | 0.0 | -99.9 | 1.0 | |
| H030-h030 | 15 cm | 24h | 607 | -0.001 | 0.151 | 0.152 | 1.3 | 65.4 | 2.1 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H036-h036 | 15 cm | 24h | 606 | -0.001 | 0.152 | 0.152 | 1.3 | 65.2 | 2.1 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H042-h042 | 15 cm | 24h | 605 | -0.002 | 0.152 | 0.152 | 1.2 | 64.6 | 2.1 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H048-h048 | 15 cm | 24h | 604 | -0.003 | 0.153 | 0.153 | 1.3 | 64.7 | 2.5 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H054-h054 | 15 cm | 24h | 603 | -0.003 | 0.153 | 0.154 | 1.0 | 65.0 | 2.5 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H060-h060 | 15 cm | 24h | 602 | -0.002 | 0.154 | 0.154 | 1.2 | 65.3 | 2.7 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H066-h066 | 15 cm | 24h | 601 | -0.003 | 0.154 | 0.154 | 1.3 | 65.2 | 3.0 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H072-h072 | 15 cm | 24h | 600 | -0.003 | 0.155 | 0.155 | 1.3 | 66.0 | 3.0 | 0.0 | 6.0 | -99.9 | 1.0 | |

**Table A-4.** Water level skill assessment at Tacoma.

| Station: | Tacoma | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKIL<br>L |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | 0.042 | | | | | | | | | | |
| h | | | 40201 | 0.042 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.155 | 0.155 | 1.4 | 64.4 | 3.2 | 6.8 | 9.3 | 0.0 | 0.99 | 1 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | 0.001 | 0.156 | 0.156 | 1.6 | 62.7 | 2.6 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H006-h006 | 15 cm | 24h | 611 | 0.001 | 0.155 | 0.155 | 1.6 | 63.3 | 2.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H012-h012 | 15 cm | 24h | 610 | 0.002 | 0.155 | 0.155 | 1.6 | 62.8 | 2.5 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H018-h018 | 15 cm | 24h | 609 | 0.001 | 0.155 | 0.155 | 1.3 | 63.5 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H024-h024 | 15 cm | 24h | 608 | 0.002 | 0.155 | 0.155 | 1.3 | 63.0 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H030-h030 | 15 cm | 24h | 607 | 0.002 | 0.154 | 0.155 | 1.0 | 64.1 | 2.6 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H036-h036 | 15 cm | 24h | 606 | 0.002 | 0.154 | 0.154 | 1.0 | 64.5 | 2.8 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H042-h042 | 15 cm | 24h | 605 | 0.001 | 0.154 | 0.154 | 0.8 | 64.0 | 2.6 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H048-h048 | 15 cm | 24h | 604 | 0.001 | 0.155 | 0.155 | 1.5 | 64.4 | 2.8 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H054-h054 | 15 cm | 24h | 603 | 0.001 | 0.156 | 0.156 | 1.2 | 64.3 | 3.3 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H060-h060 | 15 cm | 24h | 602 | 0.001 | 0.156 | 0.156 | 0.8 | 64.5 | 3.3 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H066-h066 | 15 cm | 24h | 601 | 0.000 | 0.157 | 0.157 | 1.3 | 64.2 | 3.2 | 0.0 | 6.0 | -99.9 | 1.0 | |
| H072-h072 | 15 cm | 24h | 600 | 0.000 | 0.157 | 0.157 | 1.2 | 64.0 | 3.0 | 0.0 | 6.0 | -99.9 | 1.0 | |

**Table A-5.** Water level skill assessment at Port Angeles.

| Station: | Port Angeles | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | -0.023 | | | | | | | | | | |
| h | | | 40201 | -0.023 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.139 | 0.139 | 1.1 | 73.5 | 2.0 | 5.5 | 6.3 | 0.0 | 0.98 | 0.99 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | 0.000 | 0.137 | 0.137 | 0.5 | 72.7 | 1.6 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H006-h006 | 15 cm | 24h | 611 | 0.002 | 0.136 | 0.136 | 0.5 | 73.0 | 2.0 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H012-h012 | 15 cm | 24h | 610 | 0.001 | 0.137 | 0.137 | 0.5 | 73.0 | 2.3 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H018-h018 | 15 cm | 24h | 609 | 0.000 | 0.137 | 0.137 | 1.0 | 73.4 | 2.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H024-h024 | 15 cm | 24h | 608 | 0.000 | 0.137 | 0.137 | 0.8 | 73.0 | 2.0 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H030-h030 | 15 cm | 24h | 607 | 0.001 | 0.137 | 0.137 | 0.7 | 72.5 | 2.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H036-h036 | 15 cm | 24h | 606 | 0.000 | 0.137 | 0.138 | 0.7 | 72.6 | 2.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H042-h042 | 15 cm | 24h | 605 | -0.001 | 0.139 | 0.139 | 0.7 | 71.6 | 2.3 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H048-h048 | 15 cm | 24h | 604 | -0.001 | 0.140 | 0.140 | 1.0 | 71.9 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H054-h054 | 15 cm | 24h | 603 | -0.001 | 0.140 | 0.140 | 0.8 | 71.6 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H060-h060 | 15 cm | 24h | 602 | -0.001 | 0.140 | 0.141 | 0.8 | 71.1 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H066-h066 | 15 cm | 24h | 601 | -0.002 | 0.141 | 0.141 | 1.0 | 70.9 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H072-h072 | 15 cm | 24h | 600 | -0.002 | 0.142 | 0.142 | 1.0 | 70.3 | 2.5 | 0.0 | 0.0 | -99.9 | 1.0 | |

**Table A-6.** Water level skill assessment at La Push.

| Station: | La Push | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | -0.058 | | | | | | | | | | |
| h | | | 40201 | -0.058 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.125 | 0.125 | 2.0 | 80.2 | 0.5 | 7.8 | 4.8 | 0.0 | 0.99 | 0.99 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | -0.001 | 0.126 | 0.126 | 2.1 | 81.2 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H006-h006 | 15 cm | 24h | 611 | -0.002 | 0.125 | 0.125 | 2.0 | 81.3 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H012-h012 | 15 cm | 24h | 610 | -0.002 | 0.125 | 0.125 | 2.1 | 81.1 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H018-h018 | 15 cm | 24h | 609 | -0.003 | 0.124 | 0.124 | 2.1 | 81.8 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H024-h024 | 15 cm | 24h | 608 | -0.003 | 0.124 | 0.124 | 2.3 | 80.8 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H030-h030 | 15 cm | 24h | 607 | -0.003 | 0.125 | 0.125 | 2.5 | 81.2 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H036-h036 | 15 cm | 24h | 606 | -0.003 | 0.125 | 0.125 | 2.3 | 80.0 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H042-h042 | 15 cm | 24h | 605 | -0.003 | 0.126 | 0.126 | 2.3 | 80.7 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H048-h048 | 15 cm | 24h | 604 | -0.004 | 0.126 | 0.126 | 2.3 | 80.8 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H054-h054 | 15 cm | 24h | 603 | -0.003 | 0.127 | 0.127 | 2.5 | 80.6 | 0.3 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H060-h060 | 15 cm | 24h | 602 | -0.004 | 0.127 | 0.127 | 2.5 | 80.1 | 0.5 | 12.0 | 0.0 | -99.9 | 1.0 | |
| H066-h066 | 15 cm | 24h | 601 | -0.004 | 0.127 | 0.127 | 2.8 | 80.0 | 0.5 | 36.0 | 0.0 | -99.9 | 1.0 | |
| H072-h072 | 15 cm | 24h | 600 | -0.004 | 0.127 | 0.127 | 2.8 | 80.2 | 0.5 | 24.0 | 0.0 | -99.9 | 1.0 | |

**Table A-7.** Water level skill assessment at Garibaldi.

| Station: | | | Garibaldi | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | -0.019 | | | | | | | | | | |
| h | | | 40201 | -0.019 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.215 | 0.215 | 10.4 | 50.7 | 4.9 | 5.7 | 6.2 | 0.0 | 0.96 | 0.98 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | -0.006 | 0.198 | 0.198 | 9.0 | 52.8 | 3.8 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H006-h006 | 15 cm | 24h | 611 | 0.000 | 0.201 | 0.202 | 8.8 | 50.1 | 4.4 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H012-h012 | 15 cm | 24h | 610 | -0.002 | 0.202 | 0.202 | 8.7 | 50.7 | 3.9 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H018-h018 | 15 cm | 24h | 609 | -0.001 | 0.202 | 0.202 | 8.9 | 50.4 | 4.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H024-h024 | 15 cm | 24h | 608 | -0.003 | 0.201 | 0.201 | 9.0 | 50.2 | 4.1 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H030-h030 | 15 cm | 24h | 607 | -0.003 | 0.201 | 0.201 | 8.9 | 50.6 | 4.0 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H036-h036 | 15 cm | 24h | 606 | -0.004 | 0.201 | 0.201 | 8.7 | 50.8 | 4.3 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H042-h042 | 15 cm | 24h | 605 | -0.003 | 0.200 | 0.200 | 8.4 | 51.6 | 3.8 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H048-h048 | 15 cm | 24h | 604 | -0.003 | 0.200 | 0.200 | 8.9 | 50.8 | 4.0 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H054-h054 | 15 cm | 24h | 603 | -0.003 | 0.200 | 0.200 | 8.8 | 51.1 | 3.3 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H060-h060 | 15 cm | 24h | 602 | -0.003 | 0.200 | 0.200 | 9.0 | 51.2 | 3.8 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H066-h066 | 15 cm | 24h | 601 | -0.003 | 0.199 | 0.199 | 8.7 | 51.6 | 3.3 | 0.0 | 0.0 | -99.9 | 1.0 | |
| H072-h072 | 15 cm | 24h | 600 | -0.003 | 0.199 | 0.200 | 9.0 | 52.2 | 4.0 | 0.0 | 0.0 | -99.9 | 1.0 | |

**Table A-8.** Water level skill assessment at South Beach.

| Station: | | | South Beach | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | -0.003 | | | | | | | | | | |
| h | | | 40201 | -0.003 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.113 | 0.113 | 0.8 | 83.0 | 0.3 | 4.3 | 1.8 | 0.0 | 0.99 | 0.99 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | 0.001 | 0.111 | 0.111 | 1.0 | 83.7 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H006-h006 | 15 cm | 24h | 611 | -0.001 | 0.111 | 0.111 | 1.0 | 83.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H012-h012 | 15 cm | 24h | 610 | -0.002 | 0.111 | 0.111 | 1.0 | 83.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H018-h018 | 15 cm | 24h | 609 | -0.003 | 0.109 | 0.109 | 1.0 | 84.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H024-h024 | 15 cm | 24h | 608 | -0.004 | 0.109 | 0.109 | 1.0 | 84.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H030-h030 | 15 cm | 24h | 607 | -0.004 | 0.109 | 0.109 | 0.8 | 83.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H036-h036 | 15 cm | 24h | 606 | -0.004 | 0.108 | 0.108 | 0.8 | 84.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H042-h042 | 15 cm | 24h | 605 | -0.004 | 0.108 | 0.108 | 0.8 | 84.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H048-h048 | 15 cm | 24h | 604 | -0.004 | 0.109 | 0.109 | 0.8 | 83.9 | 0.2 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H054-h054 | 15 cm | 24h | 603 | -0.004 | 0.109 | 0.109 | 1.0 | 84.4 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H060-h060 | 15 cm | 24h | 602 | -0.004 | 0.109 | 0.109 | 1.0 | 83.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H066-h066 | 15 cm | 24h | 601 | -0.005 | 0.110 | 0.110 | 1.2 | 84.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H072-h072 | 15 cm | 24h | 600 | -0.005 | 0.111 | 0.111 | 1.3 | 84.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |

**Table A-9.** Water level skill assessment at Astoria.

| Station: | | Astoria | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | | | | | | | | | | | | |
| h | | | 40201 | -0.047 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.106 | 0.106 | 0.3 | 84.4 | 0.1 | 3.1 | 2.9 | 0.0 | 0.99 | 1 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | -0.002 | 0.107 | 0.107 | 0.3 | 84.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H006-h006 | 15 cm | 24h | 611 | 0.001 | 0.105 | 0.106 | 0.2 | 84.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H012-h012 | 15 cm | 24h | 610 | 0.000 | 0.106 | 0.106 | 0.2 | 84.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H018-h018 | 15 cm | 24h | 609 | 0.000 | 0.107 | 0.107 | 0.3 | 85.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H024-h024 | 15 cm | 24h | 608 | -0.002 | 0.105 | 0.105 | 0.3 | 85.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H030-h030 | 15 cm | 24h | 607 | -0.001 | 0.106 | 0.106 | 0.2 | 85.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H036-h036 | 15 cm | 24h | 606 | -0.003 | 0.106 | 0.106 | 0.2 | 85.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H042-h042 | 15 cm | 24h | 605 | -0.003 | 0.106 | 0.106 | 0.0 | 85.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H048-h048 | 15 cm | 24h | 604 | -0.004 | 0.106 | 0.106 | 0.2 | 85.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H054-h054 | 15 cm | 24h | 603 | -0.003 | 0.105 | 0.105 | 0.2 | 86.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H060-h060 | 15 cm | 24h | 602 | -0.003 | 0.107 | 0.107 | 0.2 | 85.7 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H066-h066 | 15 cm | 24h | 601 | -0.003 | 0.106 | 0.106 | 0.3 | 86.4 | 0.0 | 6.0 | 0.0 | -99.9 | 0.99 | |
| H072-h072 | 15 cm | 24h | 600 | -0.003 | 0.107 | 0.107 | 0.2 | 85.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |

**Table A-10.** Water level skill assessment at Skamokawa.

| Station: | | Skamokawa | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | 0.030 | | | | | | | | | | |
| h | | | 40201 | 0.030 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.113 | 0.113 | 0.6 | 82.0 | 0.1 | 4.2 | 2.9 | 0.0 | 1.0 | 0.99 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | -0.001 | 0.115 | 0.115 | 0.7 | 81.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H006-h006 | 15 cm | 24h | 611 | 0.001 | 0.115 | 0.115 | 0.7 | 81.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H012-h012 | 15 cm | 24h | 610 | -0.003 | 0.121 | 0.121 | 1.0 | 79.7 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H018-h018 | 15 cm | 24h | 609 | 0.000 | 0.114 | 0.114 | 0.5 | 81.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H024-h024 | 15 cm | 24h | 608 | -0.005 | 0.121 | 0.121 | 1.0 | 78.0 | 0.2 | 0.0 | 0.0 | -99.9 | 0.98 | |
| H030-h030 | 15 cm | 24h | 607 | -0.004 | 0.118 | 0.118 | 0.5 | 78.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H036-h036 | 15 cm | 24h | 606 | -0.007 | 0.120 | 0.120 | 1.0 | 78.7 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H042-h042 | 15 cm | 24h | 605 | -0.006 | 0.119 | 0.119 | 0.8 | 77.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H048-h048 | 15 cm | 24h | 604 | -0.007 | 0.119 | 0.119 | 0.7 | 78.5 | 0.2 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H054-h054 | 15 cm | 24h | 603 | -0.006 | 0.119 | 0.119 | 0.5 | 78.4 | 0.2 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H060-h060 | 15 cm | 24h | 602 | -0.005 | 0.120 | 0.120 | 0.5 | 76.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.98 | |
| H066-h066 | 15 cm | 24h | 601 | -0.004 | 0.121 | 0.121 | 1.0 | 78.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.98 | |
| H072-h072 | 15 cm | 24h | 600 | -0.002 | 0.120 | 0.121 | 0.8 | 79.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.98 | |

**Table A-11.** Water level skill assessment at Wauna.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station: | Wauna | | | | | | | | | | | | | |
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | 0.060 | | | | | | | | | | |
| h | | | 40201 | 0.060 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.116 | 0.116 | 1.0 | 80.7 | 0.1 | 5.2 | 1.7 | 0.0 | 1.0 | 1.0 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | -0.001 | 0.119 | 0.119 | 1.3 | 80.1 | 0.2 | 0.0 | 0.0 | -99.9 | 0.98 | |
| H006-h006 | 15 cm | 24h | 611 | 0.001 | 0.120 | 0.120 | 1.0 | 79.1 | 0.2 | 0.0 | 0.0 | -99.9 | 0.98 | |
| H012-h012 | 15 cm | 24h | 610 | -0.004 | 0.123 | 0.123 | 1.5 | 79.3 | 0.0 | 6.0 | 0.0 | -99.9 | 0.98 | |
| H018-h018 | 15 cm | 24h | 609 | 0.000 | 0.121 | 0.121 | 1.0 | 76.8 | 0.3 | 6.0 | 0.0 | -99.9 | 0.98 | |
| H024-h024 | 15 cm | 24h | 608 | -0.007 | 0.126 | 0.126 | 1.3 | 75.0 | 0.3 | 0.0 | 0.0 | -99.9 | 0.98 | |
| H030-h030 | 15 cm | 24h | 607 | -0.006 | 0.123 | 0.123 | 1.0 | 76.4 | 0.5 | 0.0 | 0.0 | -99.9 | 0.98 | |
| H036-h036 | 15 cm | 24h | 606 | -0.009 | 0.126 | 0.125 | 1.5 | 75.9 | 0.3 | 12.0 | 0.0 | -99.9 | 0.98 | |
| H042-h042 | 15 cm | 24h | 605 | -0.009 | 0.125 | 0.125 | 1.2 | 76.4 | 0.3 | 12.0 | 0.0 | -99.9 | 0.98 | |
| H048-h048 | 15 cm | 24h | 604 | -0.010 | 0.126 | 0.126 | 1.2 | 76.2 | 0.3 | 12.0 | 0.0 | -99.9 | 0.98 | |
| H054-h054 | 15 cm | 24h | 603 | -0.007 | 0.126 | 0.126 | 1.5 | 76.5 | 0.5 | 12.0 | 0.0 | -99.9 | 0.98 | |
| H060-h060 | 15 cm | 24h | 602 | -0.005 | 0.128 | 0.128 | 1.2 | 75.6 | 0.5 | 12.0 | 0.0 | -99.9 | 0.98 | |
| H066-h066 | 15 cm | 24h | 601 | -0.003 | 0.128 | 0.128 | 1.5 | 76.0 | 0.7 | 12.0 | 0.0 | -99.9 | 0.98 | |
| H072-h072 | 15 cm | 24h | 600 | 0.000 | 0.131 | 0.131 | 1.8 | 75.3 | 1.2 | 0.0 | 0.0 | -99.9 | 0.98 | |

**Table A-12.** Water level skill assessment at Longview.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station: | Longview | | | | | | | | | | | | | |
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | 0.234 | | | | | | | | | | |
| h | | | 40201 | 0.234 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.095 | 0.095 | 1.0 | 89.8 | 0.0 | 13.3 | 0.0 | 0.0 | 0.98 | 1.0 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | 0.000 | 0.097 | 0.097 | 1.1 | 89.1 | 0.0 | 18.0 | 0.0 | -99.9 | 0.97 | |
| H006-h006 | 15 cm | 24h | 611 | 0.002 | 0.101 | 0.101 | 1.1 | 86.7 | 0.0 | 12.0 | 0.0 | -99.9 | 0.97 | |
| H012-h012 | 15 cm | 24h | 610 | -0.007 | 0.116 | 0.115 | 2.0 | 83.1 | 0.0 | 24.0 | 0.0 | -99.9 | 0.96 | |
| H018-h018 | 15 cm | 24h | 609 | -0.005 | 0.111 | 0.111 | 1.3 | 82.8 | 0.2 | 24.0 | 0.0 | -99.9 | 0.97 | |
| H024-h024 | 15 cm | 24h | 608 | -0.013 | 0.121 | 0.120 | 2.1 | 80.6 | 0.3 | 30.0 | 0.0 | -99.9 | 0.96 | |
| H030-h030 | 15 cm | 24h | 607 | -0.015 | 0.123 | 0.122 | 1.6 | 78.4 | 0.5 | 42.0 | 0.0 | -99.9 | 0.96 | |
| H036-h036 | 15 cm | 24h | 606 | -0.017 | 0.128 | 0.127 | 2.1 | 76.9 | 0.8 | 36.0 | 0.0 | -99.9 | 0.95 | |
| H042-h042 | 15 cm | 24h | 605 | -0.018 | 0.129 | 0.128 | 2.6 | 77.2 | 0.7 | 54.0 | 0.0 | -99.9 | 0.95 | |
| H048-h048 | 15 cm | 24h | 604 | -0.018 | 0.131 | 0.130 | 2.5 | 77.3 | 0.8 | 60.0 | 0.0 | -99.9 | 0.95 | |
| H054-h054 | 15 cm | 24h | 603 | -0.015 | 0.133 | 0.133 | 2.5 | 75.6 | 1.2 | 48.0 | 0.0 | -99.9 | 0.95 | |
| H060-h060 | 15 cm | 24h | 602 | -0.009 | 0.137 | 0.136 | 2.5 | 74.9 | 1.2 | 66.0 | 0.0 | -99.9 | 0.95 | |
| H066-h066 | 15 cm | 24h | 601 | -0.005 | 0.143 | 0.143 | 3.3 | 72.0 | 1.3 | 66.0 | 0.0 | -99.9 | 0.94 | |
| H072-h072 | 15 cm | 24h | 600 | -0.001 | 0.150 | 0.150 | 3.0 | 69.8 | 2.3 | 66.0 | 6.0 | -99.9 | 0.94 | |

**Table A-13.** Water level skill assessment at St. Helens.

| Station: | | | St. Helens | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE | X | N | IMAX | SM | RMSE | SD | NOF | CF | POF | MDNO | MDPO | WOF | CORR | SKILL |
| CRITERION | - | - | - | - | - | - | <1% | >90% | <1% | <N | <N | <.5% | | |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | 0.335 | | | | | | | | | | |
| h | | | 40201 | 0.335 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.112 | 0.112 | 1.7 | 83.9 | 0.0 | 21.3 | 0.2 | 0.0 | 0.95 | 1.0 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | -0.001 | 0.112 | 0.112 | 2.0 | 83.2 | 0.0 | 24.0 | 0.0 | -99.9 | 0.95 | |
| H006-h006 | 15 cm | 24h | 611 | -0.001 | 0.115 | 0.115 | 2.1 | 82.5 | 0.0 | 18.0 | 0.0 | -99.9 | 0.94 | |
| H012-h012 | 15 cm | 24h | 610 | -0.008 | 0.133 | 0.133 | 2.8 | 74.6 | 0.5 | 18.0 | 0.0 | -99.9 | 0.92 | |
| H018-h018 | 15 cm | 24h | 609 | -0.015 | 0.134 | 0.134 | 2.5 | 75.0 | 0.3 | 12.0 | 0.0 | -99.9 | 0.92 | |
| H024-h024 | 15 cm | 24h | 608 | -0.018 | 0.145 | 0.144 | 3.3 | 70.4 | 0.7 | 18.0 | 12.0 | -99.9 | 0.91 | |
| H030-h030 | 15 cm | 24h | 607 | -0.024 | 0.153 | 0.151 | 4.3 | 66.9 | 0.8 | 12.0 | 12.0 | -99.9 | 0.90 | |
| H036-h036 | 15 cm | 24h | 606 | -0.025 | 0.158 | 0.156 | 5.1 | 67.0 | 0.7 | 18.0 | 12.0 | -99.9 | 0.90 | |
| H042-h042 | 15 cm | 24h | 605 | -0.027 | 0.161 | 0.159 | 5.5 | 66.9 | 1.3 | 30.0 | 12.0 | -99.9 | 0.89 | |
| H048-h048 | 15 cm | 24h | 604 | -0.026 | 0.165 | 0.163 | 5.8 | 66.9 | 2.0 | 18.0 | 12.0 | -99.9 | 0.89 | |
| H054-h054 | 15 cm | 24h | 603 | -0.021 | 0.169 | 0.168 | 6.0 | 65.2 | 2.2 | 42.0 | 12.0 | -99.9 | 0.88 | |
| H060-h060 | 15 cm | 24h | 602 | -0.012 | 0.176 | 0.175 | 5.6 | 64.1 | 2.8 | 54.0 | 12.0 | -99.9 | 0.87 | |
| H066-h066 | 15 cm | 24h | 601 | -0.006 | 0.186 | 0.186 | 5.7 | 59.2 | 4.5 | 54.0 | 36.0 | -99.9 | 0.85 | |
| H072-h072 | 15 cm | 24h | 600 | 0.000 | 0.197 | 0.197 | 6.2 | 55.2 | 6.5 | 54.0 | 42.0 | -99.9 | 0.83 | |

**Table A-14.** Water level skill assessment at Vancouver.

| Station: | | | Vancouver | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE | X | N | IMAX | SM | RMSE | SD | NOF | CF | POF | MDNO | MDPO | WOF | CORR | SKILL |
| CRITERION | - | - | - | - | - | - | <1% | >90% | <1% | <N | <N | <.5% | | |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| H | | | 40201 | 0.420 | | | | | | | | | | |
| h | | | 40201 | 0.420 | | | | | | | | | | |
| H-h | 15 cm | 24h | 40201 | 0.000 | 0.112 | 0.112 | 1.7 | 84.4 | 0.0 | 21.6 | 0.0 | 0.0 | 0.95 | 0.97 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 15 cm | 24h | 612 | -0.002 | 0.112 | 0.112 | 1.5 | 85.6 | 0.0 | 12.0 | 0.0 | -99.9 | 0.95 | |
| H006-h006 | 15 cm | 24h | 611 | -0.003 | 0.124 | 0.124 | 2.8 | 81.2 | 0.0 | 12.0 | 0.0 | -99.9 | 0.94 | |
| H012-h012 | 15 cm | 24h | 610 | -0.007 | 0.138 | 0.138 | 3.0 | 72.0 | 0.5 | 12.0 | 12.0 | -99.9 | 0.93 | |
| H018-h018 | 15 cm | 24h | 609 | -0.024 | 0.152 | 0.150 | 5.4 | 71.1 | 0.5 | 12.0 | 12.0 | -99.9 | 0.91 | |
| H024-h024 | 15 cm | 24h | 608 | -0.020 | 0.161 | 0.160 | 5.6 | 67.6 | 1.3 | 24.0 | 12.0 | -99.9 | 0.90 | |
| H030-h030 | 15 cm | 24h | 607 | -0.031 | 0.174 | 0.171 | 8.2 | 65.2 | 1.6 | 48.0 | 18.0 | -99.9 | 0.89 | |
| H036-h036 | 15 cm | 24h | 606 | -0.031 | 0.179 | 0.177 | 7.9 | 63.4 | 2.0 | 48.0 | 18.0 | -99.9 | 0.88 | |
| H042-h042 | 15 cm | 24h | 605 | -0.033 | 0.184 | 0.181 | 8.6 | 64.3 | 2.5 | 78.0 | 42.0 | -99.9 | 0.87 | |
| H048-h048 | 15 cm | 24h | 604 | -0.031 | 0.190 | 0.188 | 9.1 | 63.7 | 2.5 | 54.0 | 24.0 | -99.9 | 0.86 | |
| H054-h054 | 15 cm | 24h | 603 | -0.023 | 0.198 | 0.197 | 8.3 | 60.4 | 4.1 | 66.0 | 30.0 | -99.9 | 0.85 | |
| H060-h060 | 15 cm | 24h | 602 | -0.012 | 0.208 | 0.208 | 8.5 | 57.6 | 6.1 | 90.0 | 78.0 | -99.9 | 0.83 | |
| H066-h066 | 15 cm | 24h | 601 | -0.003 | 0.222 | 0.222 | 8.7 | 52.6 | 8.2 | 66.0 | 84.0 | -99.9 | 0.81 | |
| H072-h072 | 15 cm | 24h | 600 | 0.004 | 0.237 | 0.237 | 9.5 | 51.3 | 11.0 | 99.0 | 90.0 | -99.9 | 0.78 | |

# APPENDIX B. SURFACE WATER TEMPERATURE SKILL ASSESSMENT TABLES

**Table B-1.** Surface water temperature skill assessment at Friday Harbor.

| Station: | | Friday Harbor | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 43533 | 10.030 | | | | | | | | | | |
| t | | | 43533 | 9.926 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 43533 | 0.104 | 0.449 | 0.437 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | 0.97 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 668 | 0.160 | 0.342 | 0.303 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.96 | |
| H006-h006 | 3 C | 24h | 668 | 0.157 | 0.342 | 0.304 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.96 | |
| H012-h012 | 3 C | 24h | 668 | 0.151 | 0.338 | 0.303 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.96 | |
| H018-h018 | 3 C | 24h | 668 | 0.144 | 0.337 | 0.305 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.96 | |
| H024-h024 | 3 C | 24h | 668 | 0.132 | 0.336 | 0.309 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.96 | |
| H030-h030 | 3 C | 24h | 668 | 0.122 | 0.346 | 0.324 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.96 | |
| H036-h036 | 3 C | 24h | 668 | 0.114 | 0.353 | 0.334 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.96 | |
| H042-h042 | 3 C | 24h | 668 | 0.108 | 0.355 | 0.338 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.96 | |
| H048-h048 | 3 C | 24h | 668 | 0.098 | 0.358 | 0.344 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.95 | |
| H054-h054 | 3 C | 24h | 667 | 0.097 | 0.371 | 0.358 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.95 | |
| H060-h060 | 3 C | 24h | 666 | 0.089 | 0.373 | 0.363 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.95 | |
| H066-h066 | 3 C | 24h | 665 | 0.085 | 0.382 | 0.372 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.95 | |
| H072-h072 | 3 C | 24h | 664 | 0.077 | 0.385 | 0.378 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.95 | |

**Table B-2.** Surface water temperature skill assessment at Port Townsend.

| Station: | | Port Townsend | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 43533 | 10.523 | | | | | | | | | | |
| t | | | 43533 | 10.161 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 43533 | 0.362 | 0.651 | 0.541 | 0.0 | 99.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | 0.94 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 668 | 0.340 | 0.589 | 0.481 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H006-h006 | 3 C | 24h | 668 | 0.342 | 0.600 | 0.493 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H012-h012 | 3 C | 24h | 668 | 0.342 | 0.596 | 0.488 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H018-h018 | 3 C | 24h | 668 | 0.320 | 0.582 | 0.486 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.92 | |
| H024-h024 | 3 C | 24h | 668 | 0.312 | 0.571 | 0.479 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H030-h030 | 3 C | 24h | 668 | 0.312 | 0.563 | 0.470 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H036-h036 | 3 C | 24h | 668 | 0.310 | 0.562 | 0.469 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H042-h042 | 3 C | 24h | 668 | 0.303 | 0.556 | 0.467 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H048-h048 | 3 C | 24h | 668 | 0.310 | 0.572 | 0.482 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H054-h054 | 3 C | 24h | 667 | 0.307 | 0.566 | 0.476 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | |
| H060-h060 | 3 C | 24h | 666 | 0.296 | 0.559 | 0.474 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | |
| H066-h066 | 3 C | 24h | 665 | 0.296 | 0.578 | 0.496 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H072-h072 | 3 C | 24h | 664 | 0.300 | 0.571 | 0.486 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | |

**Table B-3.** Surface water temperature skill assessment at Tacoma.

| Station: | | | Tacoma | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 43533 | 11.281 | | | | | | | | | | |
| t | | | 43533 | 11.098 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 43533 | 0.182 | 1.252 | 1.239 | 0.0 | 98.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | 0.9 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 668 | 0.083 | 1.187 | 1.185 | 0.0 | 99.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H006-h006 | 3 C | 24h | 668 | 0.096 | 1.202 | 1.199 | 0.0 | 99.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H012-h012 | 3 C | 24h | 668 | 0.100 | 1.227 | 1.223 | 0.0 | 98.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H018-h018 | 3 C | 24h | 668 | 0.098 | 1.238 | 1.235 | 0.0 | 99.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H024-h024 | 3 C | 24h | 668 | 0.101 | 1.257 | 1.254 | 0.0 | 99.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H030-h030 | 3 C | 24h | 668 | 0.104 | 1.270 | 1.267 | 0.0 | 98.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H036-h036 | 3 C | 24h | 668 | 0.086 | 1.274 | 1.272 | 0.0 | 98.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H042-h042 | 3 C | 24h | 668 | 0.065 | 1.280 | 1.279 | 0.0 | 98.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H048-h048 | 3 C | 24h | 668 | 0.055 | 1.275 | 1.275 | 0.0 | 98.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H054-h054 | 3 C | 24h | 667 | 0.048 | 1.278 | 1.278 | 0.0 | 98.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H060-h060 | 3 C | 24h | 666 | 0.035 | 1.289 | 1.289 | 0.0 | 98.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H066-h066 | 3 C | 24h | 665 | 0.034 | 1.292 | 1.293 | 0.0 | 98.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H072-h072 | 3 C | 24h | 664 | 0.032 | 1.273 | 1.274 | 0.0 | 97.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |

**Table B-4.** Surface water temperature skill assessment at Port Angeles.

| Station: | | | Port Angeles | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 43285 | 10.360 | | | | | | | | | | |
| t | | | 43285 | 9.934 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 43285 | 0.426 | 0.732 | 0.595 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.90 | 0.92 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 664 | 0.445 | 0.751 | 0.606 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H006-h006 | 3 C | 24h | 664 | 0.455 | 0.764 | 0.614 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H012-h012 | 3 C | 24h | 664 | 0.454 | 0.768 | 0.620 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H018-h018 | 3 C | 24h | 664 | 0.451 | 0.771 | 0.626 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H024-h024 | 3 C | 24h | 664 | 0.444 | 0.773 | 0.633 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H030-h030 | 3 C | 24h | 664 | 0.443 | 0.778 | 0.640 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H036-h036 | 3 C | 24h | 664 | 0.438 | 0.786 | 0.653 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H042-h042 | 3 C | 24h | 664 | 0.431 | 0.787 | 0.659 | 0.0 | 99.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H048-h048 | 3 C | 24h | 664 | 0.420 | 0.779 | 0.657 | 0.0 | 99.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H054-h054 | 3 C | 24h | 663 | 0.419 | 0.787 | 0.666 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.89 | |
| H060-h060 | 3 C | 24h | 662 | 0.415 | 0.795 | 0.678 | 0.0 | 99.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.88 | |
| H066-h066 | 3 C | 24h | 661 | 0.403 | 0.785 | 0.674 | 0.0 | 99.7 | 0.0 | 0.0 | 0.0 | -99.9 | 0.88 | |
| H072-h072 | 3 C | 24h | 660 | 0.387 | 0.771 | 0.667 | 0.0 | 99.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.88 | |

**Table B-5.** Surface water temperature skill assessment at Neah Bay.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station: | | Neah Bay | | | | | | | | | | | | |
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 42601 | 9.746 | | | | | | | | | | |
| t | | | 42601 | 10.416 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 42601 | -0.669 | 1.300 | 1.114 | 0.0 | 97.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.47 | 0.54 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 653 | -0.544 | 1.122 | 0.982 | 0.0 | 99.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.47 | |
| H006-h006 | 3 C | 24h | 653 | -0.550 | 1.127 | 0.984 | 0.0 | 99.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.47 | |
| H012-h012 | 3 C | 24h | 653 | -0.569 | 1.142 | 0.991 | 0.0 | 98.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.46 | |
| H018-h018 | 3 C | 24h | 653 | -0.585 | 1.153 | 0.994 | 0.0 | 99.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.45 | |
| H024-h024 | 3 C | 24h | 653 | -0.604 | 1.169 | 1.001 | 0.0 | 99.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.44 | |
| H030-h030 | 3 C | 24h | 653 | -0.620 | 1.177 | 1.002 | 0.0 | 99.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.44 | |
| H036-h036 | 3 C | 24h | 653 | -0.636 | 1.188 | 1.005 | 0.0 | 99.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.43 | |
| H042-h042 | 3 C | 24h | 653 | -0.643 | 1.199 | 1.012 | 0.0 | 98.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.42 | |
| H048-h048 | 3 C | 24h | 653 | -0.653 | 1.207 | 1.016 | 0.0 | 98.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.41 | |
| H054-h054 | 3 C | 24h | 652 | -0.664 | 1.212 | 1.014 | 0.0 | 98.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.41 | |
| H060-h060 | 3 C | 24h | 651 | -0.674 | 1.218 | 1.015 | 0.0 | 98.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.40 | |
| H066-h066 | 3 C | 24h | 650 | -0.689 | 1.228 | 1.018 | 0.0 | 98.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.39 | |
| H072-h072 | 3 C | 24h | 649 | -0.701 | 1.235 | 1.017 | 0.0 | 98.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.39 | |

**Table B-6.** Surface water temperature skill assessment at La Push.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station: | | La Push | | | | | | | | | | | | |
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 43533 | 11.685 | | | | | | | | | | |
| t | | | 43533 | 10.409 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 43533 | 1.276 | 2.064 | 1.622 | 0.1 | 84.5 | 0.1 | 3.1 | 4.0 | -99.9 | 0.60 | 0.68 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 668 | 1.224 | 2.024 | 1.613 | 0.3 | 85.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.61 | |
| H006-h006 | 3 C | 24h | 668 | 1.214 | 2.020 | 1.616 | 0.3 | 85.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.60 | |
| H012-h012 | 3 C | 24h | 668 | 1.185 | 1.996 | 1.607 | 0.3 | 86.5 | 0.1 | 0.0 | 0.0 | -99.9 | 0.61 | |
| H018-h018 | 3 C | 24h | 668 | 1.151 | 1.985 | 1.618 | 0.4 | 87.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.60 | |
| H024-h024 | 3 C | 24h | 668 | 1.107 | 1.960 | 1.619 | 0.4 | 88.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.60 | |
| H030-h030 | 3 C | 24h | 668 | 1.062 | 1.930 | 1.613 | 0.3 | 89.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.60 | |
| H036-h036 | 3 C | 24h | 668 | 1.012 | 1.893 | 1.602 | 0.3 | 90.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.60 | |
| H042-h042 | 3 C | 24h | 668 | 0.987 | 1.892 | 1.615 | 0.4 | 90.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.59 | |
| H048-h048 | 3 C | 24h | 668 | 0.954 | 1.881 | 1.622 | 0.4 | 90.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.58 | |
| H054-h054 | 3 C | 24h | 667 | 0.928 | 1.871 | 1.626 | 0.3 | 90.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.58 | |
| H060-h060 | 3 C | 24h | 666 | 0.898 | 1.840 | 1.607 | 0.5 | 91.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.59 | |
| H066-h066 | 3 C | 24h | 665 | 0.878 | 1.829 | 1.605 | 0.5 | 91.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.59 | |
| H072-h072 | 3 C | 24h | 664 | 0.850 | 1.811 | 1.600 | 0.5 | 91.4 | 0.0 | 0.0 | 0.0 | -99.9 | 0.59 | |

**Table B-7.** Surface water temperature skill assessment at Grays Harbor.

| Station: | | Grays Harbor | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 37273 | 11.289 | | | | | | | | | | |
| t | | | 37273 | 11.534 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 37273 | -0.245 | 0.626 | 0.576 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | 0.96 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 608 | -0.265 | 0.627 | 0.569 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | |
| H006-h006 | 3 C | 24h | 608 | -0.272 | 0.632 | 0.571 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | |
| H012-h012 | 3 C | 24h | 608 | -0.303 | 0.648 | 0.573 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | |
| H018-h018 | 3 C | 24h | 608 | -0.333 | 0.669 | 0.581 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H024-h024 | 3 C | 24h | 608 | -0.357 | 0.685 | 0.585 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H030-h030 | 3 C | 24h | 608 | -0.390 | 0.702 | 0.585 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H036-h036 | 3 C | 24h | 608 | -0.409 | 0.712 | 0.584 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | |
| H042-h042 | 3 C | 24h | 608 | -0.426 | 0.722 | 0.583 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | |
| H048-h048 | 3 C | 24h | 608 | -0.434 | 0.728 | 0.585 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.94 | |
| H054-h054 | 3 C | 24h | 607 | -0.450 | 0.753 | 0.604 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H060-h060 | 3 C | 24h | 606 | -0.465 | 0.761 | 0.603 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H066-h066 | 3 C | 24h | 605 | -0.477 | 0.770 | 0.605 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H072-h072 | 3 C | 24h | 604 | -0.493 | 0.790 | 0.618 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |

**Table B-8.** Surface water temperature skill assessment at Astoria Canyon.

| Station: | | Astoria Canyon | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 38768 | 11.660 | | | | | | | | | | |
| t | | | 38768 | 13.005 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 38768 | -1.345 | 1.703 | 1.045 | 0.0 | 90.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.87 | 0.78 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 589 | -1.269 | 1.638 | 1.038 | 0.0 | 90.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.88 | |
| H006-h006 | 3 C | 24h | 590 | -1.277 | 1.650 | 1.046 | 0.0 | 91.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.88 | |
| H012-h012 | 3 C | 24h | 591 | -1.323 | 1.696 | 1.063 | 0.0 | 90.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.87 | |
| H018-h018 | 3 C | 24h | 592 | -1.356 | 1.724 | 1.065 | 0.0 | 90.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.88 | |
| H024-h024 | 3 C | 24h | 593 | -1.393 | 1.766 | 1.087 | 0.0 | 89.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.87 | |
| H030-h030 | 3 C | 24h | 594 | -1.428 | 1.794 | 1.087 | 0.0 | 88.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.87 | |
| H036-h036 | 3 C | 24h | 595 | -1.453 | 1.823 | 1.102 | 0.0 | 88.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.87 | |
| H042-h042 | 3 C | 24h | 596 | -1.481 | 1.854 | 1.116 | 0.0 | 85.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.86 | |
| H048-h048 | 3 C | 24h | 597 | -1.506 | 1.881 | 1.127 | 0.0 | 85.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.86 | |
| H054-h054 | 3 C | 24h | 597 | -1.518 | 1.891 | 1.129 | 0.0 | 85.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.86 | |
| H060-h060 | 3 C | 24h | 597 | -1.535 | 1.898 | 1.117 | 0.0 | 85.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.86 | |
| H066-h066 | 3 C | 24h | 597 | -1.550 | 1.910 | 1.116 | 0.0 | 84.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.86 | |
| H072-h072 | 3 C | 24h | 597 | -1.568 | 1.927 | 1.121 | 0.0 | 85.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.86 | |

**Table B-9.** Surface water temperature skill assessment at Garibaldi.

| Station: | | Garibaldi | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 31062 | 10.472 | | | | | | | | | | |
| t | | | 31062 | 11.320 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 31062 | -0.849 | 1.311 | 0.999 | 0.0 | 95.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.55 | 0.64 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 503 | -0.849 | 1.317 | 1.008 | 0.0 | 95.4 | 0.0 | 0.0 | 0.0 | -99.9 | 0.55 | |
| H006-h006 | 3 C | 24h | 502 | -0.857 | 1.324 | 1.010 | 0.0 | 95.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.55 | |
| H012-h012 | 3 C | 24h | 501 | -0.872 | 1.339 | 1.017 | 0.0 | 95.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.54 | |
| H018-h018 | 3 C | 24h | 500 | -0.890 | 1.343 | 1.006 | 0.0 | 95.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.55 | |
| H024-h024 | 3 C | 24h | 499 | -0.928 | 1.366 | 1.003 | 0.0 | 95.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.55 | |
| H030-h030 | 3 C | 24h | 498 | -0.948 | 1.377 | 0.999 | 0.0 | 94.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.56 | |
| H036-h036 | 3 C | 24h | 497 | -0.960 | 1.385 | 0.999 | 0.0 | 95.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.56 | |
| H042-h042 | 3 C | 24h | 496 | -0.987 | 1.405 | 1.001 | 0.0 | 94.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.56 | |
| H048-h048 | 3 C | 24h | 495 | -0.996 | 1.410 | 0.999 | 0.0 | 95.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.56 | |
| H054-h054 | 3 C | 24h | 494 | -1.017 | 1.432 | 1.010 | 0.0 | 94.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.55 | |
| H060-h060 | 3 C | 24h | 493 | -1.042 | 1.460 | 1.024 | 0.0 | 94.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.53 | |
| H066-h066 | 3 C | 24h | 492 | -1.049 | 1.479 | 1.044 | 0.0 | 94.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.52 | |
| H072-h072 | 3 C | 24h | 492 | -1.046 | 1.484 | 1.053 | 0.0 | 93.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.51 | |

**Table B-10.** Surface water temperature skill assessment at Longview.

| Station: | | Longview | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 43449 | 12.642 | | | | | | | | | | |
| t | | | 43449 | 13.839 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 43449 | -1.197 | 1.306 | 0.523 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | 0.99 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 666 | -1.141 | 1.245 | 0.498 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H006-h006 | 3 C | 24h | 666 | -1.142 | 1.246 | 0.500 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H012-h012 | 3 C | 24h | 666 | -1.144 | 1.249 | 0.500 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H018-h018 | 3 C | 24h | 666 | -1.149 | 1.251 | 0.495 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H024-h024 | 3 C | 24h | 666 | -1.167 | 1.267 | 0.492 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H030-h030 | 3 C | 24h | 666 | -1.179 | 1.277 | 0.491 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H036-h036 | 3 C | 24h | 666 | -1.186 | 1.282 | 0.486 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H042-h042 | 3 C | 24h | 666 | -1.203 | 1.296 | 0.483 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H048-h048 | 3 C | 24h | 666 | -1.217 | 1.308 | 0.481 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H054-h054 | 3 C | 24h | 665 | -1.236 | 1.326 | 0.481 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H060-h060 | 3 C | 24h | 664 | -1.249 | 1.340 | 0.485 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H066-h066 | 3 C | 24h | 663 | -1.268 | 1.358 | 0.486 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| H072-h072 | 3 C | 24h | 662 | -1.287 | 1.378 | 0.492 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |

**Table B-11.** Surface water temperature skill assessment at Willamette River at Portland.

| Station: | | Willamette River at Portland | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/15/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE | X | N | IMAX | SM | RMSE | SD | NOF | CF | POF | MDNO | MDPO | WOF | CORR | SKILL |
| CRITERION | - | - | - | - | - | - | <1% | >90% | <1% | <N | <N | <.5% | | |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| T | | | 10022 | 8.358 | | | | | | | | | | |
| t | | | 10022 | 8.415 | | | | | | | | | | |
| T-t | 3.0 C | 24h | 10022 | -0.057 | 0.199 | 0.191 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | 0.99 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3 C | 24h | 164 | -0.059 | 0.208 | 0.200 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H006-h006 | 3 C | 24h | 164 | -0.060 | 0.209 | 0.201 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H012-h012 | 3 C | 24h | 163 | -0.067 | 0.234 | 0.225 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.99 | |
| H018-h018 | 3 C | 24h | 162 | -0.086 | 0.278 | 0.265 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.98 | |
| H024-h024 | 3 C | 24h | 161 | -0.107 | 0.336 | 0.319 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.97 | |
| H030-h030 | 3 C | 24h | 160 | -0.129 | 0.421 | 0.402 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.95 | |
| H036-h036 | 3 C | 24h | 159 | -0.148 | 0.506 | 0.485 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.93 | |
| H042-h042 | 3 C | 24h | 158 | -0.164 | 0.582 | 0.560 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.91 | |
| H048-h048 | 3 C | 24h | 157 | -0.184 | 0.654 | 0.630 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.88 | |
| H054-h054 | 3 C | 24h | 156 | -0.203 | 0.734 | 0.707 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.85 | |
| H060-h060 | 3 C | 24h | 155 | -0.226 | 0.810 | 0.780 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.82 | |
| H066-h066 | 3 C | 24h | 154 | -0.248 | 0.881 | 0.848 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.78 | |
| H072-h072 | 3 C | 24h | 153 | -0.269 | 0.958 | 0.923 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.74 | |

# APPENDIX C.  TIME SERIES OF MODELED SURFACE WATER TEMPERATURE VERSUS OBSERVATIONS

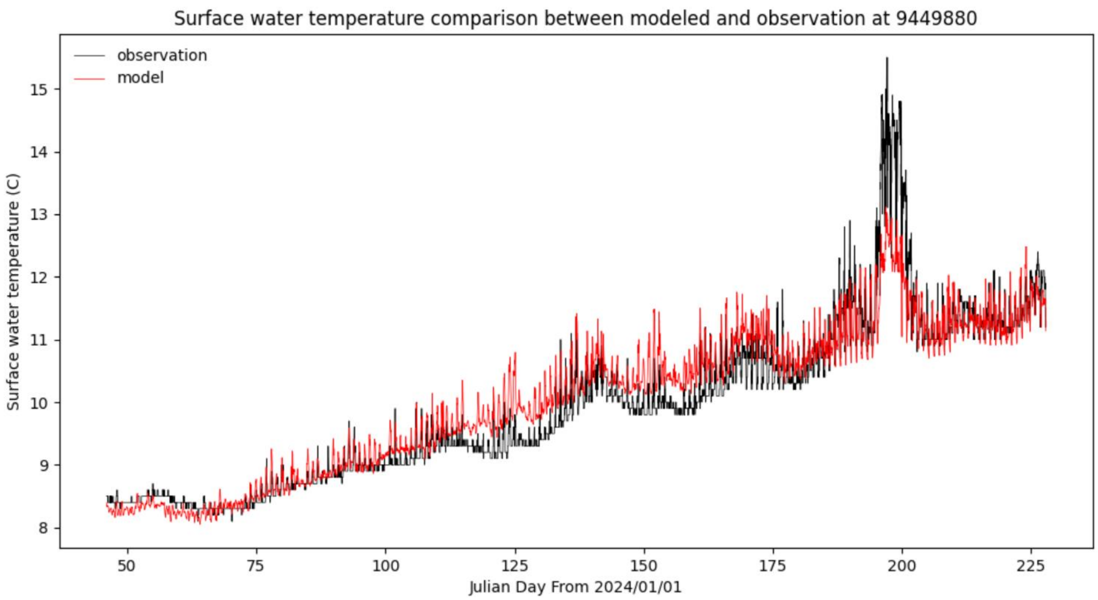


**Figure C-1.**  SSCOFS modeled surface water temperature versus observations at Friday Harbor.

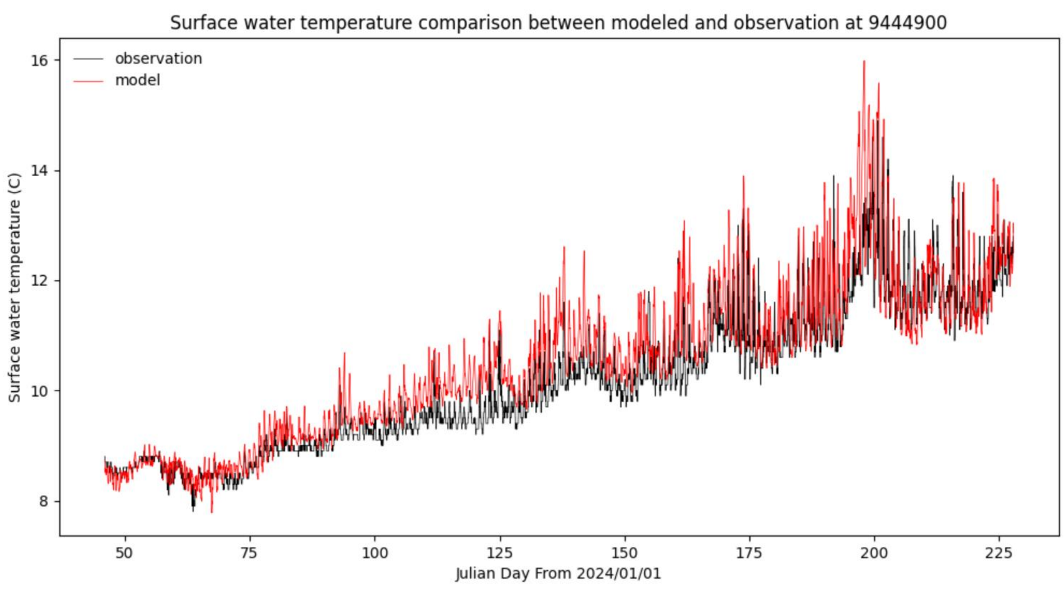


**Figure C-2.**  SSCOFS modeled surface water temperature versus observations at Port Townsend.

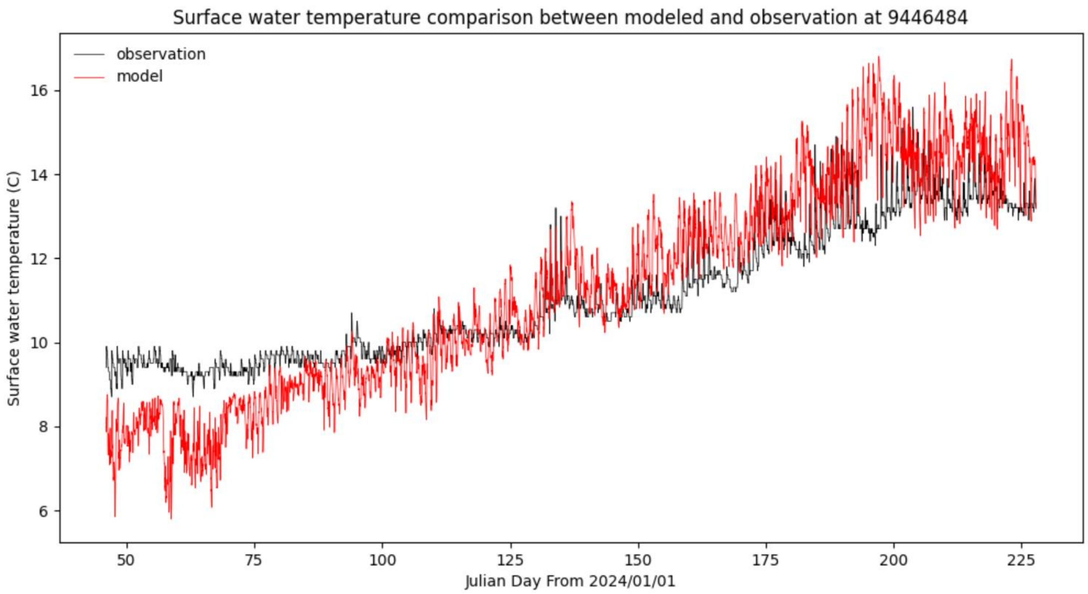


**Figure C-3.** SSCOFS modeled surface water temperature versus observations at Tacoma.

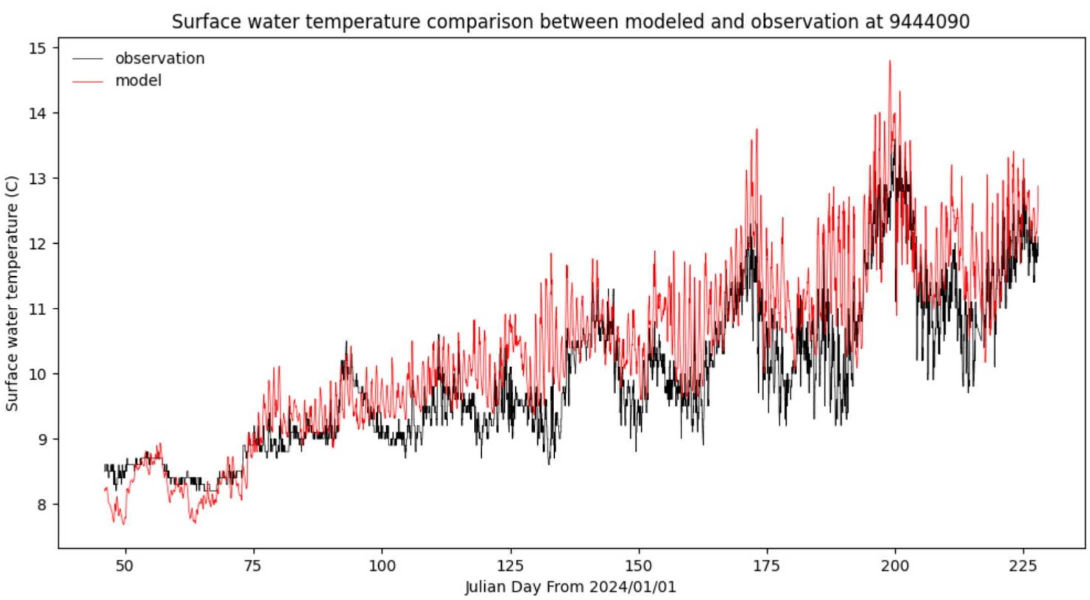


**Figure C-4.** SSCOFS modeled surface water temperature versus observations at Port Angeles.

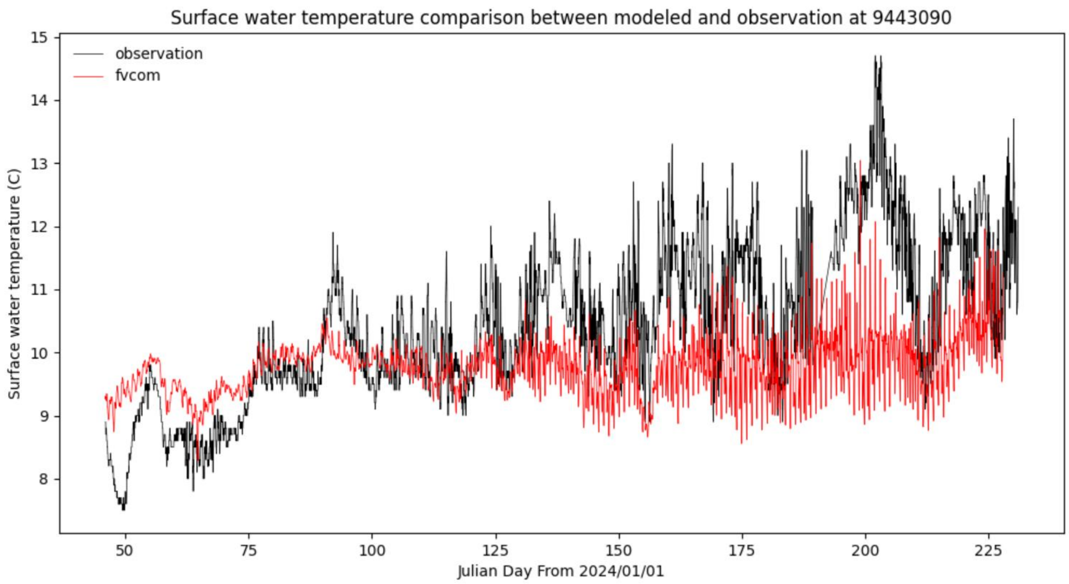


**Figure C-5.** SSCOFS modeled surface water temperature versus observations at Neah Bay.

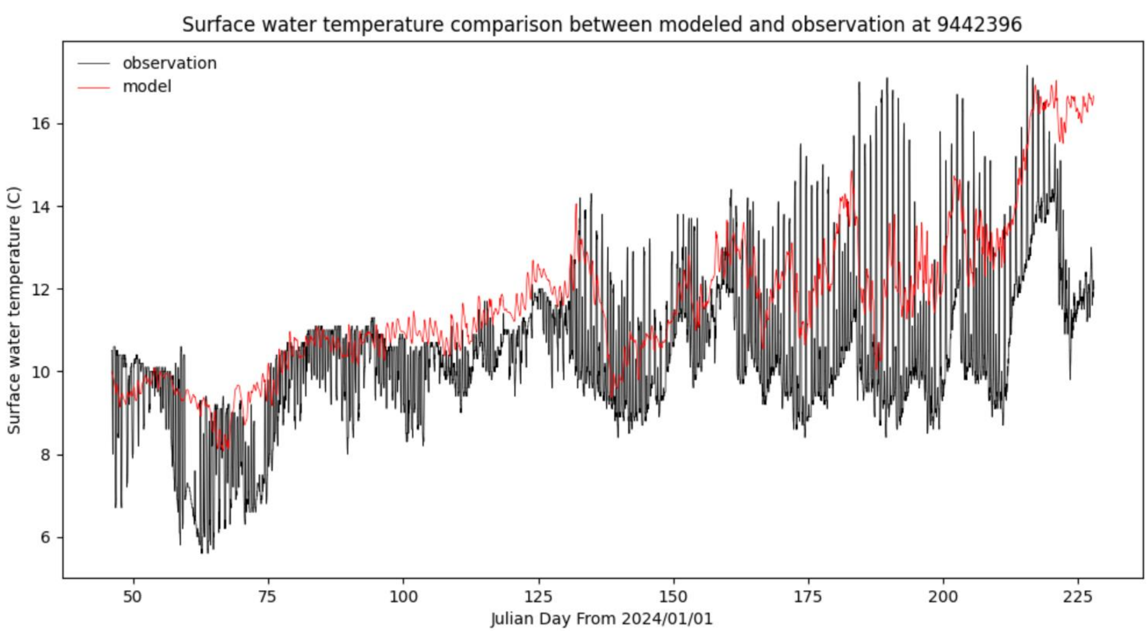


**Figure C-6.** SSCOFS modeled surface water temperature versus observations at La Push.

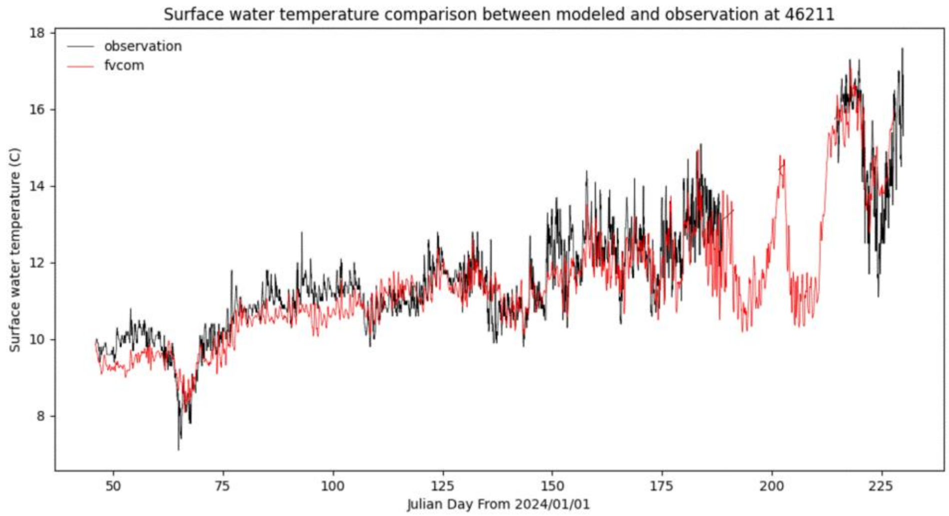


**Figure C-7.** SSCOFS modeled surface water temperature versus observations at Grays Harbor.

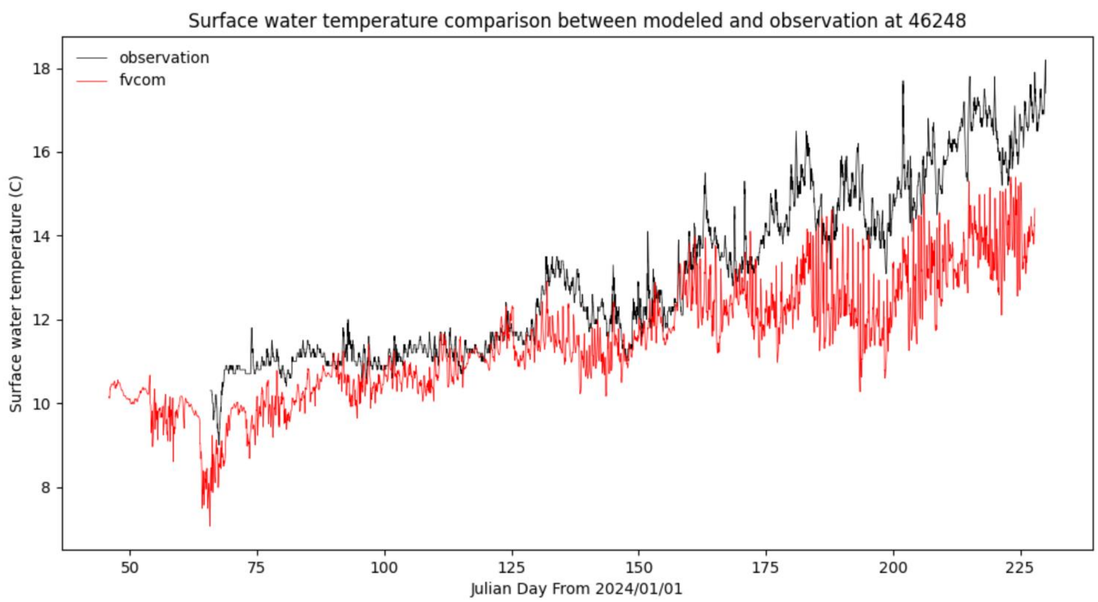


**Figure C-8.** SSCOFS modeled surface water temperature versus observations at Astoria Canyon.

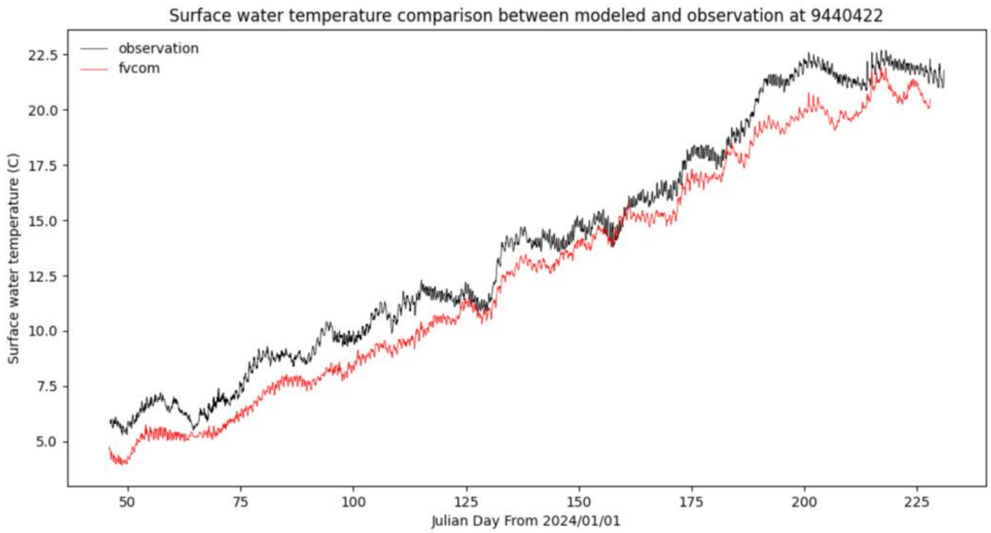


**Figure C-9.** SSCOFS modeled surface water temperature versus observations at Garibaldi.

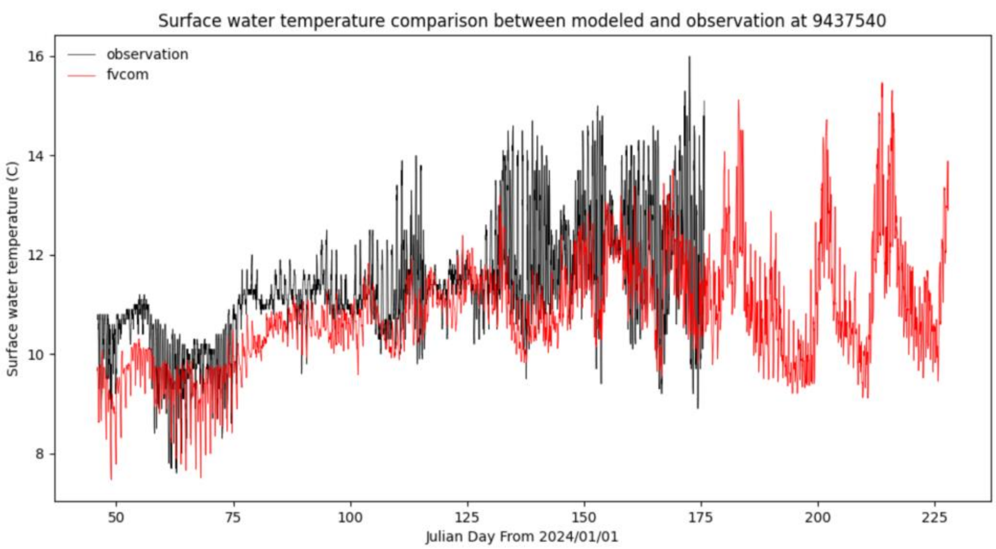


**Figure C-10.** SSCOFS modeled surface water temperature versus observations at Longview.

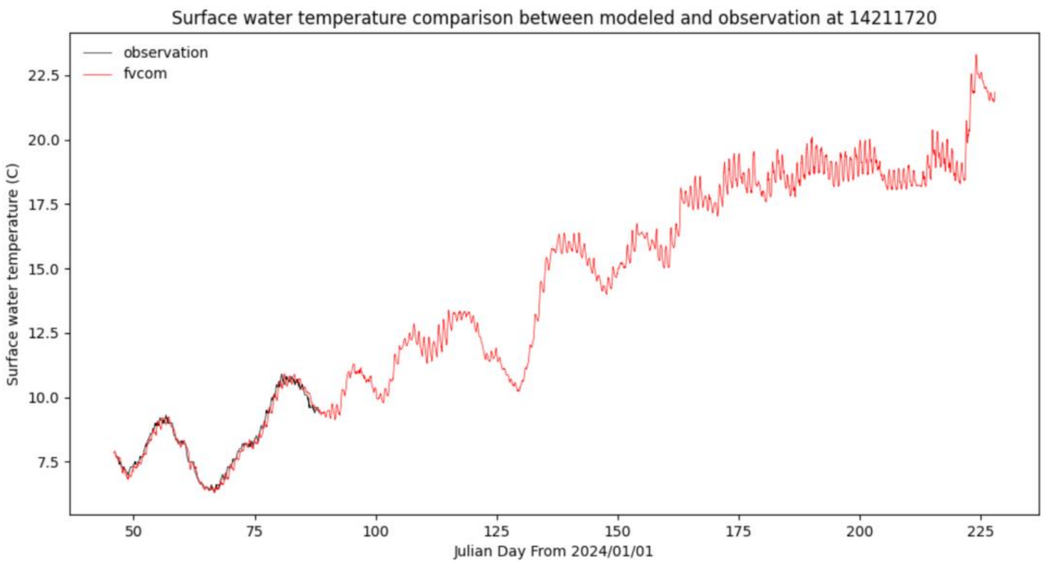


**Figure C-11.** SSCOFS modeled surface water temperature versus observations at Willamette Portland.

# APPENDIX D. SURFACE WATER SALINITY SKILL ASSESSMENT TABLES

**Table D-1.** Surface water salinity skill assessment at Saturn-07.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station: | Saturn-07 | | | | | | | | | | | | | |
| Observed data time period from / 3/23/2024 to / 6/ 3/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| S | | | 41593 | 7.348 | | | | | | | | | | |
| S | | | 41593 | 8.500 | | | | | | | | | | |
| S-s | 3.5 psu | 24h | 41593 | -1.152 | 3.002 | 2.772 | 3.7 | 80.6 | 0.0 | 4.8 | 0.9 | -99.9 | 0.50 | 0.66 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3.5 psu | 24h | 636 | -1.102 | 3.002 | 2.794 | 3.6 | 81.1 | 0.0 | 24.0 | 0.0 | -99.9 | 0.47 | |
| H006-h006 | 3.5 psu | 24h | 636 | -1.042 | 2.971 | 2.785 | 3.6 | 81.9 | 0.0 | 24.0 | 0.0 | -99.9 | 0.47 | |
| H012-h012 | 3.5 psu | 24h | 636 | -0.987 | 2.982 | 2.816 | 3.0 | 80.7 | 0.0 | 24.0 | 0.0 | -99.9 | 0.46 | |
| H018-h018 | 3.5 psu | 24h | 636 | -0.965 | 3.009 | 2.852 | 3.3 | 81.0 | 0.0 | 24.0 | 0.0 | -99.9 | 0.44 | |
| H024-h024 | 3.5 psu | 24h | 636 | -0.951 | 2.975 | 2.821 | 3.1 | 80.5 | 0.0 | 24.0 | 0.0 | -99.9 | 0.44 | |
| H030-h030 | 3.5 psu | 24h | 636 | -0.891 | 2.940 | 2.804 | 2.5 | 80.7 | 0.0 | 24.0 | 0.0 | -99.9 | 0.45 | |
| H036-h036 | 3.5 psu | 24h | 636 | -0.925 | 2.931 | 2.783 | 3.1 | 81.3 | 0.0 | 24.0 | 0.0 | -99.9 | 0.46 | |
| H042-h042 | 3.5 psu | 24h | 636 | -0.880 | 2.927 | 2.794 | 2.2 | 80.7 | 0.0 | 12.0 | 0.0 | -99.9 | 0.45 | |
| H048-h048 | 3.5 psu | 24h | 636 | -0.879 | 2.910 | 2.777 | 2.8 | 80.5 | 0.0 | 12.0 | 0.0 | -99.9 | 0.46 | |
| H054-h054 | 3.5 psu | 24h | 637 | -0.898 | 2.896 | 2.755 | 2.5 | 81.2 | 0.0 | 6.0 | 0.0 | -99.9 | 0.47 | |
| H060-h060 | 3.5 psu | 24h | 636 | -0.839 | 2.882 | 2.760 | 2.8 | 81.0 | 0.0 | 6.0 | 0.0 | -99.9 | 0.47 | |
| H066-h066 | 3.5 psu | 24h | 636 | -0.864 | 2.902 | 2.773 | 2.8 | 80.0 | 0.0 | 6.0 | 0.0 | -99.9 | 0.46 | |
| H072-h072 | 3.5 psu | 24h | 636 | -0.815 | 2.889 | 2.774 | 2.7 | 79.9 | 0.0 | 6.0 | 0.0 | -99.9 | 0.45 | |

**Table D-2.** Surface water salinity skill assessment at NPBY1.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station: | NPBY1 buoy | | | | | | | | | | | | | |
| Observed data time period from 2/15/2024 to / 7/28/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| S | | | 39312 | 29.391 | | | | | | | | | | |
| S | | | 39312 | 29.028 | | | | | | | | | | |
| S-s | 3.5 psu | 24h | 39312 | 0.363 | 0.485 | 0.322 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.75 | 0.63 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3.5 psu | 24h | 597 | 0.372 | 0.496 | 0.327 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.70 | |
| H006-h006 | 3.5 psu | 24h | 596 | 0.374 | 0.497 | 0.328 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.70 | |
| H012-h012 | 3.5 psu | 24h | 595 | 0.374 | 0.497 | 0.327 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.70 | |
| H018-h018 | 3.5 psu | 24h | 594 | 0.374 | 0.497 | 0.328 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.70 | |
| H024-h024 | 3.5 psu | 24h | 593 | 0.374 | 0.497 | 0.328 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.70 | |
| H030-h030 | 3.5 psu | 24h | 592 | 0.375 | 0.498 | 0.328 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.69 | |
| H036-h036 | 3.5 psu | 24h | 591 | 0.374 | 0.497 | 0.328 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.70 | |
| H042-h042 | 3.5 psu | 24h | 590 | 0.374 | 0.497 | 0.327 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.69 | |
| H048-h048 | 3.5 psu | 24h | 589 | 0.375 | 0.497 | 0.327 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.69 | |
| H054-h054 | 3.5 psu | 24h | 588 | 0.375 | 0.497 | 0.327 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.69 | |
| H060-h060 | 3.5 psu | 24h | 587 | 0.374 | 0.496 | 0.327 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.69 | |
| H066-h066 | 3.5 psu | 24h | 586 | 0.373 | 0.496 | 0.327 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.69 | |
| H072-h072 | 3.5 psu | 24h | 585 | 0.372 | 0.495 | 0.327 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.69 | |

**Table D-3.** Surface water salinity skill assessment at NPBY2.

| Station: | NPBY2 buoy | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| S | | | 43532 | 29.159 | | | | | | | | | | |
| S | | | 43532 | 29.076 | | | | | | | | | | |
| S-s | 3.5 psu | 24h | 43532 | 0.083 | 0.298 | 0.286 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.75 | 0.83 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3.5 psu | 24h | 668 | 0.092 | 0.303 | 0.289 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H006-h006 | 3.5 psu | 24h | 668 | 0.093 | 0.301 | 0.287 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H012-h012 | 3.5 psu | 24h | 668 | 0.090 | 0.305 | 0.292 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H018-h018 | 3.5 psu | 24h | 668 | 0.088 | 0.304 | 0.291 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H024-h024 | 3.5 psu | 24h | 668 | 0.096 | 0.303 | 0.288 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H030-h030 | 3.5 psu | 24h | 668 | 0.098 | 0.305 | 0.289 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H036-h036 | 3.5 psu | 24h | 668 | 0.094 | 0.307 | 0.293 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H042-h042 | 3.5 psu | 24h | 668 | 0.095 | 0.309 | 0.294 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H048-h048 | 3.5 psu | 24h | 668 | 0.100 | 0.306 | 0.290 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H054-h054 | 3.5 psu | 24h | 667 | 0.101 | 0.307 | 0.290 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H060-h060 | 3.5 psu | 24h | 666 | 0.105 | 0.306 | 0.288 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H066-h066 | 3.5 psu | 24h | 665 | 0.107 | 0.309 | 0.290 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.73 | |
| H072-h072 | 3.5 psu | 24h | 664 | 0.109 | 0.309 | 0.289 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.72 | |

**Table D-4.** Surface water salinity skill assessment at ORCA2.

| Station: | ORCA2 buoy | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| S | | | 43527 | 26.113 | | | | | | | | | | |
| S | | | 43527 | 27.809 | | | | | | | | | | |
| S-s | 3.5 psu | 24h | 43527 | -1.696 | 2.479 | 1.808 | 1.9 | 88.2 | 0.0 | 21.8 | 0.0 | -99.9 | 0.42 | 0.42 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3.5 psu | 24h | 668 | -1.809 | 2.513 | 1.746 | 1.9 | 88.2 | 0.0 | 36.0 | 0.0 | -99.9 | 0.47 | |
| H006-h006 | 3.5 psu | 24h | 668 | -1.818 | 2.518 | 1.743 | 1.8 | 88.0 | 0.0 | 36.0 | 0.0 | -99.9 | 0.48 | |
| H012-h012 | 3.5 psu | 24h | 668 | -1.856 | 2.570 | 1.780 | 2.4 | 88.5 | 0.0 | 36.0 | 0.0 | -99.9 | 0.47 | |
| H018-h018 | 3.5 psu | 24h | 668 | -1.863 | 2.575 | 1.778 | 2.2 | 88.5 | 0.0 | 36.0 | 0.0 | -99.9 | 0.47 | |
| H024-h024 | 3.5 psu | 24h | 668 | -1.843 | 2.537 | 1.745 | 1.9 | 88.0 | 0.0 | 36.0 | 0.0 | -99.9 | 0.47 | |
| H030-h030 | 3.5 psu | 24h | 668 | -1.843 | 2.528 | 1.732 | 1.8 | 88.0 | 0.0 | 36.0 | 0.0 | -99.9 | 0.46 | |
| H036-h036 | 3.5 psu | 24h | 668 | -1.835 | 2.521 | 1.731 | 2.1 | 88.5 | 0.0 | 36.0 | 0.0 | -99.9 | 0.46 | |
| H042-h042 | 3.5 psu | 24h | 668 | -1.835 | 2.506 | 1.709 | 1.9 | 88.8 | 0.0 | 30.0 | 0.0 | -99.9 | 0.46 | |
| H048-h048 | 3.5 psu | 24h | 668 | -1.796 | 2.442 | 1.656 | 1.5 | 88.2 | 0.0 | 24.0 | 0.0 | -99.9 | 0.46 | |
| H054-h054 | 3.5 psu | 24h | 667 | -1.785 | 2.417 | 1.631 | 1.3 | 88.8 | 0.0 | 18.0 | 0.0 | -99.9 | 0.46 | |
| H060-h060 | 3.5 psu | 24h | 666 | -1.795 | 2.423 | 1.629 | 0.9 | 88.6 | 0.0 | 12.0 | 0.0 | -99.9 | 0.46 | |
| H066-h066 | 3.5 psu | 24h | 665 | -1.796 | 2.433 | 1.644 | 1.4 | 88.4 | 0.0 | 12.0 | 0.0 | -99.9 | 0.46 | |
| H072-h072 | 3.5 psu | 24h | 664 | -1.782 | 2.417 | 1.634 | 1.5 | 88.3 | 0.0 | 18.0 | 0.0 | -99.9 | 0.45 | |

**Table D-5.** Surface water salinity skill assessment at ORCA3.

| Station: | ORCA3 buoy | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| S | | | 43523 | 28.135 | | | | | | | | | | |
| S | | | 43523 | 29.877 | | | | | | | | | | |
| S-s | 3.5 psu | 24h | 43523 | -1.742 | 1.972 | 0.924 | 0.0 | 96.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | 0.15 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3.5 psu | 24h | 668 | -1.766 | 1.994 | 0.925 | 0.0 | 96.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.20 | |
| H006-h006 | 3.5 psu | 24h | 668 | -1.752 | 1.976 | 0.915 | 0.0 | 96.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H012-h012 | 3.5 psu | 24h | 668 | -1.767 | 1.989 | 0.914 | 0.0 | 96.4 | 0.0 | 0.0 | 0.0 | -99.9 | 0.22 | |
| H018-h018 | 3.5 psu | 24h | 668 | -1.770 | 1.995 | 0.920 | 0.0 | 96.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H024-h024 | 3.5 psu | 24h | 668 | -1.766 | 1.991 | 0.920 | 0.0 | 96.4 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H030-h030 | 3.5 psu | 24h | 668 | -1.753 | 1.978 | 0.916 | 0.0 | 96.4 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H036-h036 | 3.5 psu | 24h | 668 | -1.764 | 1.997 | 0.936 | 0.0 | 96.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H042-h042 | 3.5 psu | 24h | 668 | -1.764 | 1.993 | 0.929 | 0.0 | 96.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H048-h048 | 3.5 psu | 24h | 668 | -1.766 | 1.995 | 0.928 | 0.0 | 96.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H054-h054 | 3.5 psu | 24h | 667 | -1.764 | 1.992 | 0.926 | 0.0 | 96.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H060-h060 | 3.5 psu | 24h | 666 | -1.760 | 1.993 | 0.936 | 0.0 | 96.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H066-h066 | 3.5 psu | 24h | 665 | -1.770 | 2.002 | 0.936 | 0.0 | 95.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |
| H072-h072 | 3.5 psu | 24h | 664 | -1.764 | 1.993 | 0.929 | 0.0 | 96.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.21 | |

**Table D-6.** Surface water salinity skill assessment at ORCA4.

| Station: | ORCA4 buoy | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| S | | | 43530 | 25.917 | | | | | | | | | | |
| S | | | 43530 | 27.622 | | | | | | | | | | |
| S-s | 3.5 psu | 24h | 43530 | -1.704 | 2.335 | 1.595 | 1.4 | 92.5 | 0.0 | 4.8 | 0.0 | -99.9 | 0.42 | 0.49 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| H000-h000 | 3.5 psu | 24h | 668 | -1.770 | 2.342 | 1.535 | 1.2 | 91.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.44 | |
| H006-h006 | 3.5 psu | 24h | 668 | -1.773 | 2.343 | 1.533 | 1.2 | 91.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.44 | |
| H012-h012 | 3.5 psu | 24h | 668 | -1.802 | 2.383 | 1.561 | 1.3 | 91.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.45 | |
| H018-h018 | 3.5 psu | 24h | 668 | -1.812 | 2.392 | 1.562 | 1.3 | 91.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.45 | |
| H024-h024 | 3.5 psu | 24h | 668 | -1.782 | 2.34 | 1.518 | 1.0 | 91.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.45 | |
| H030-h030 | 3.5 psu | 24h | 668 | -1.792 | 2.35 | 1.522 | 1.0 | 92.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.46 | |
| H036-h036 | 3.5 psu | 24h | 668 | -1.821 | 2.385 | 1.541 | 1.2 | 91.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.46 | |
| H042-h042 | 3.5 psu | 24h | 668 | -1.823 | 2.376 | 1.525 | 1.2 | 91.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.46 | |
| H048-h048 | 3.5 psu | 24h | 668 | -1.789 | 2.314 | 1.469 | 1.2 | 91.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.47 | |
| H054-h054 | 3.5 psu | 24h | 667 | -1.790 | 2.315 | 1.470 | 1.2 | 91.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.47 | |
| H060-h060 | 3.5 psu | 24h | 666 | -1.819 | 2.366 | 1.514 | 1.4 | 91.4 | 0.0 | 0.0 | 0.0 | -99.9 | 0.46 | |
| H066-h066 | 3.5 psu | 24h | 665 | -1.831 | 2.363 | 1.495 | 1.4 | 91.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.47 | |
| H072-h072 | 3.5 psu | 24h | 664 | -1.803 | 2.331 | 1.479 | 1.1 | 91.7 | 0.0 | 0.0 | 0.0 | -99.9 | 0.47 | |

# APPENDIX E. TIME SERIES OF MODELED SURFACE WATER SALINITY VERSUS OBSERVATIONS

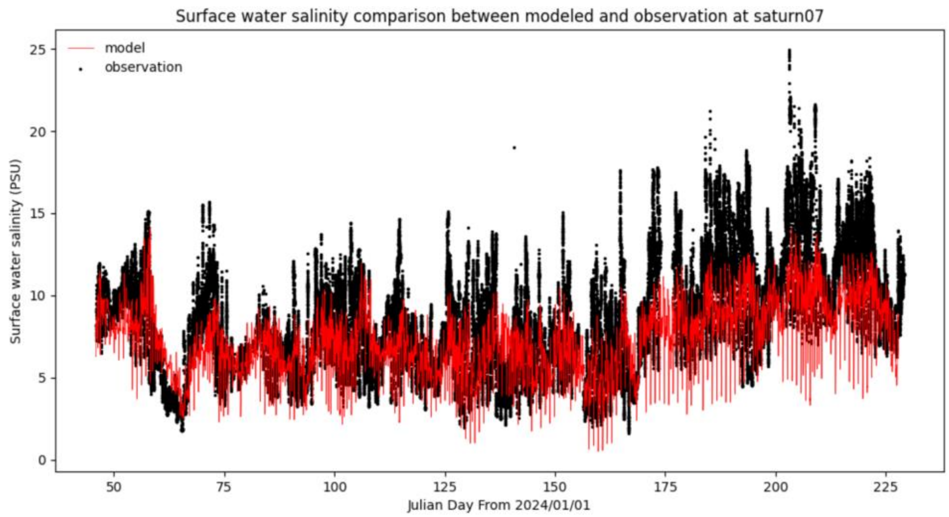


**Figure E-1.** SSCOFS modeled surface water salinity versus observations at Saturn-07.

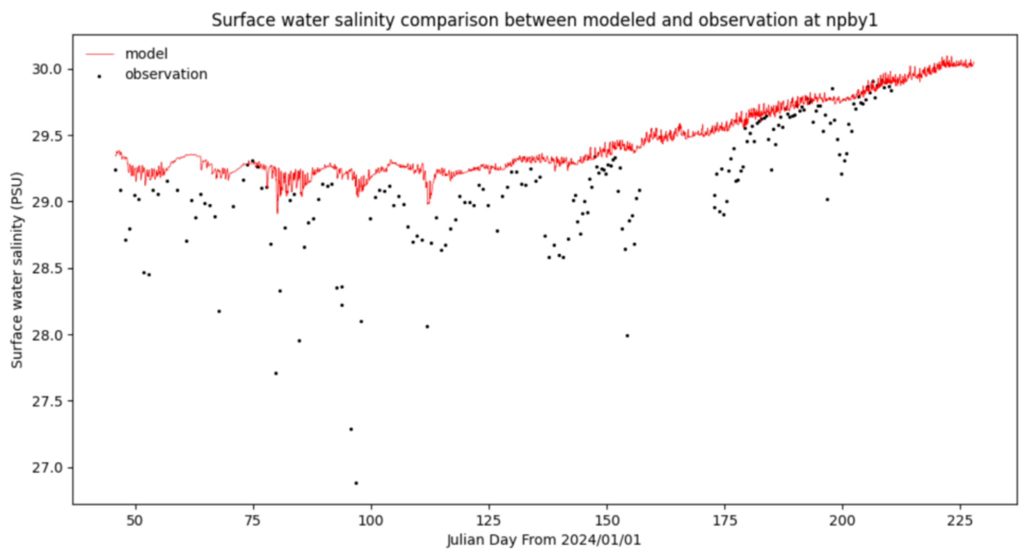


**Figure E-2.** SSCOFS modeled surface water salinity versus observations at NPBY1.

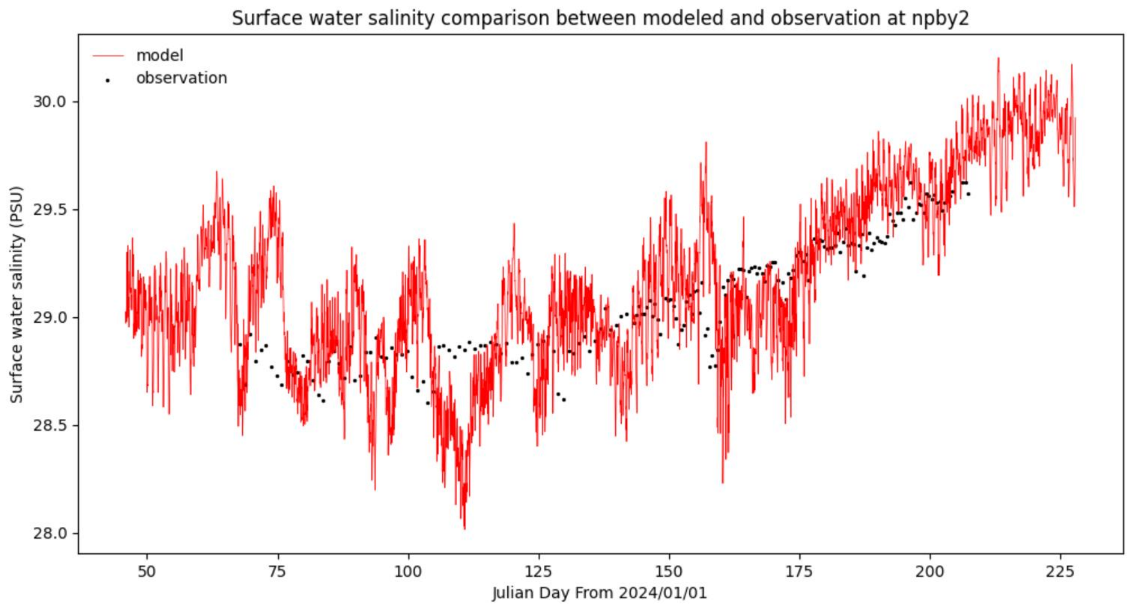


**Figure E-3.** SSCOFS modeled surface water salinity versus observations at NPBY2.

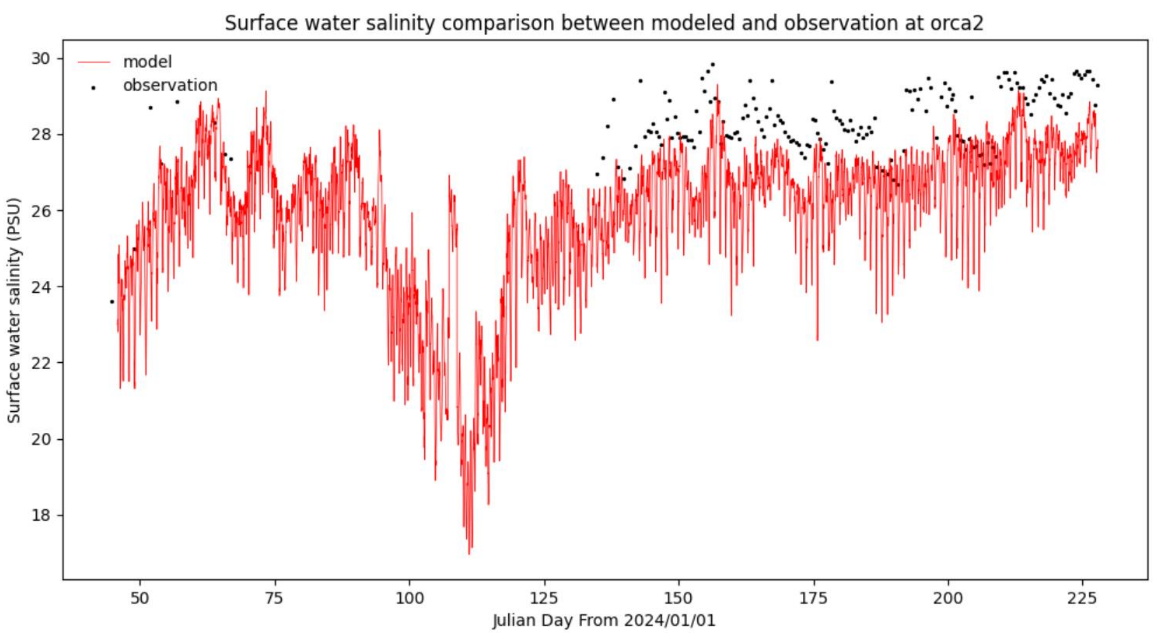


**Figure E-4.** SSCOFS modeled surface water salinity versus observations at ORCA2.

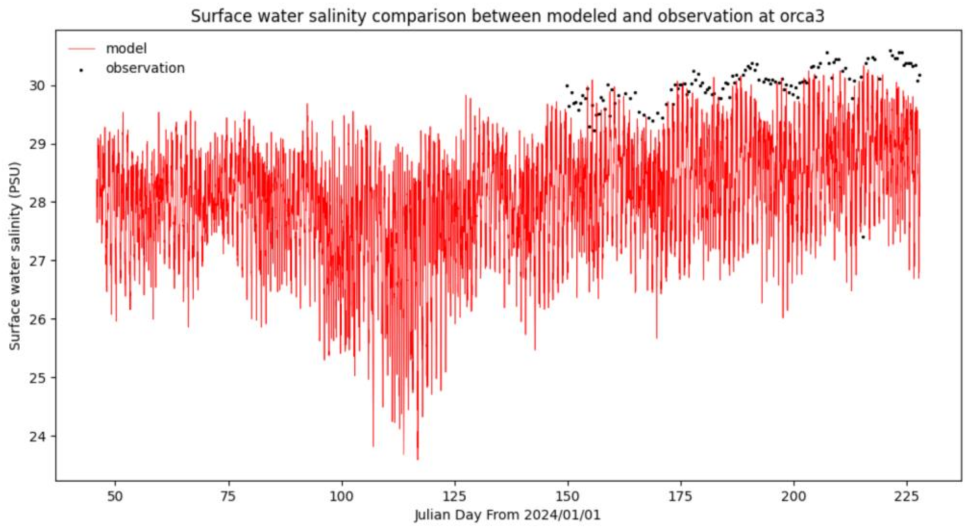


**Figure E-5.** SSCOFS modeled surface water salinity versus observations at ORCA3.

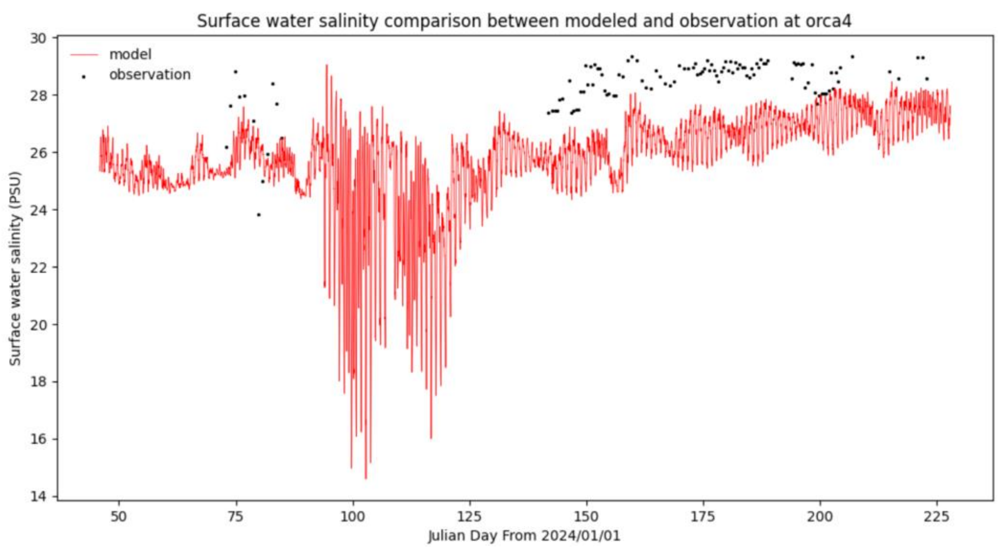


**Figure E-6.** SSCOFS modeled surface water salinity versus observations at ORCA4.

# APPENDIX F. WATER CURRENTS SPEED SKILL ASSESSMENT TABLES

**Table F-1.** Water currents speed skill assessment at NDBC Angeles Point (1.0 m level).

| Station: | NDBC Angles Point | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| U | | | 32096 | 0.738 | | | | | | | | | | |
| u | | | 32096 | 0.465 | | | | | | | | | | |
| U-u | 0.26m/s | 24h | 32096 | 0.273 | 0.474 | 0.364 | 0.8 | 45.3 | 25.5 | 2.7 | 6.7 | -99.9 | 0.41 | 0.57 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| U000-u000 | 0.26m/s | 24h | 529 | 0.300 | 0.476 | 0.371 | 1.7 | 39.9 | 28.4 | 0.0 | 78.0 | -99.9 | 0.42 | |
| U006-u006 | 0.26m/s | 24h | 529 | 0.300 | 0.480 | 0.374 | 1.7 | 39.3 | 28.5 | 0.0 | 78.0 | -99.9 | 0.42 | |
| U012-u012 | 0.26m/s | 24h | 528 | 0.299 | 0.479 | 0.374 | 1.7 | 39.0 | 28.6 | 0.0 | 78.0 | -99.9 | 0.41 | |
| U018-u018 | 0.26m/s | 24h | 528 | 0.297 | 0.479 | 0.376 | 1.5 | 39.2 | 28.4 | 0.0 | 78.0 | -99.9 | 0.41 | |
| U024-u024 | 0.26m/s | 24h | 529 | 0.291 | 0.473 | 0.374 | 1.5 | 39.9 | 28.0 | 0.0 | 78.0 | -99.9 | 0.42 | |
| U030-u030 | 0.26m/s | 24h | 529 | 0.288 | 0.472 | 0.375 | 1.9 | 40.3 | 27.8 | 0.0 | 78.0 | -99.9 | 0.42 | |
| U036-u036 | 0.26m/s | 24h | 529 | 0.287 | 0.472 | 0.375 | 1.7 | 40.1 | 27.8 | 0.0 | 78.0 | -99.9 | 0.42 | |
| U042-u042 | 0.26m/s | 24h | 529 | 0.290 | 0.474 | 0.376 | 1.9 | 39.7 | 27.2 | 0.0 | 78.0 | -99.9 | 0.42 | |
| U048-u048 | 0.26m/s | 24h | 528 | 0.286 | 0.473 | 0.377 | 1.9 | 39.6 | 27.3 | 0.0 | 78.0 | -99.9 | 0.42 | |
| U054-u054 | 0.26m/s | 24h | 527 | 0.285 | 0.471 | 0.375 | 1.9 | 40.4 | 26.9 | 0.0 | 78.0 | -99.9 | 0.42 | |
| U060-u060 | 0.26m/s | 24h | 526 | 0.284 | 0.471 | 0.376 | 1.9 | 41.1 | 27.2 | 0.0 | 78.0 | -99.9 | 0.42 | |
| U066-u066 | 0.26m/s | 24h | 525 | 0.288 | 0.473 | 0.376 | 2.1 | 40.4 | 27.2 | 0.0 | 60.0 | -99.9 | 0.42 | |
| U072-u072 | 0.26m/s | 24h | 524 | 0.287 | 0.472 | 0.375 | 1.7 | 41.2 | 27.5 | 0.0 | 78.0 | -99.9 | 0.42 | |

**Table F-2.** Water current speed skill assessment at Rich Passage (13.7 m level).

| Station: | Rich Passage | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| U | | | 43457 | 0.290 | | | | | | | | | | |
| u | | | 43457 | 0.439 | | | | | | | | | | |
| U-u | 0.26m/s | 24h | 43457 | -0.149 | 0.215 | 0.155 | 2.4 | 78.4 | 0.0 | 2.5 | 0.0 | -99.9 | 0.84 | 0.81 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| U000-u000 | 0.26m/s | 24h | 667 | -0.146 | 0.222 | 0.167 | 2.8 | 76.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.80 | |
| U006-u006 | 0.26m/s | 24h | 667 | -0.145 | 0.222 | 0.167 | 3.0 | 76.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.80 | |
| U012-u012 | 0.26m/s | 24h | 667 | -0.145 | 0.220 | 0.165 | 2.8 | 76.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.81 | |
| U018-u018 | 0.26m/s | 24h | 667 | -0.146 | 0.222 | 0.167 | 2.8 | 76.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.80 | |
| U024-u024 | 0.26m/s | 24h | 667 | -0.145 | 0.218 | 0.164 | 2.1 | 76.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.81 | |
| U030-u030 | 0.26m/s | 24h | 666 | -0.145 | 0.218 | 0.163 | 2.3 | 77.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.81 | |
| U036-u036 | 0.26m/s | 24h | 665 | -0.145 | 0.220 | 0.165 | 2.4 | 75.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.80 | |
| U042-u042 | 0.26m/s | 24h | 664 | -0.145 | 0.220 | 0.165 | 2.6 | 76.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.80 | |
| U048-u048 | 0.26m/s | 24h | 663 | -0.144 | 0.217 | 0.162 | 2.1 | 76.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.81 | |
| U054-u054 | 0.26m/s | 24h | 662 | -0.143 | 0.217 | 0.163 | 2.0 | 76.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.81 | |
| U060-u060 | 0.26m/s | 24h | 661 | -0.145 | 0.217 | 0.161 | 1.8 | 75.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.81 | |
| U066-u066 | 0.26m/s | 24h | 660 | -0.143 | 0.216 | 0.162 | 1.7 | 76.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.81 | |
| U072-u072 | 0.26m/s | 24h | 659 | -0.143 | 0.215 | 0.161 | 1.5 | 77.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.82 | |

**Table F-3.** Water currents speed skill assessment at Bangor, Hood Canal (56.0 m level).

| Station: | Bangor, Hood Canal | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE | X | N | IMAX | SM | RMSE | SD | NOF | CF | POF | MDNO | MDPO | WOF | CORR | SKILL |
| CRITERION | - | - | - | - | - | - | <1% | >90% | <1% | <N | <N | <.5% | | |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| U | | | 33213 | 0.137 | | | | | | | | | | |
| u | | | 33213 | 0.245 | | | | | | | | | | |
| U-u | 0.26m/s | 24h | 33213 | -0.109 | 0.174 | 0.136 | 0.4 | 85.7 | 0.0 | 2.6 | 0.0 | -99.9 | 0.51 | 0.57 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| U000-u000 | 0.26m/s | 24h | 498 | -0.115 | 0.181 | 0.139 | 0.6 | 84.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.49 | |
| U006-u006 | 0.26m/s | 24h | 498 | -0.116 | 0.181 | 0.139 | 0.4 | 84.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.50 | |
| U012-u012 | 0.26m/s | 24h | 498 | -0.116 | 0.181 | 0.139 | 0.4 | 84.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.50 | |
| U018-u018 | 0.26m/s | 24h | 498 | -0.115 | 0.180 | 0.139 | 0.6 | 84.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.50 | |
| U024-u024 | 0.26m/s | 24h | 498 | -0.116 | 0.180 | 0.138 | 0.6 | 84.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.51 | |
| U030-u030 | 0.26m/s | 24h | 497 | -0.116 | 0.181 | 0.139 | 0.6 | 84.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.50 | |
| U036-u036 | 0.26m/s | 24h | 496 | -0.116 | 0.181 | 0.139 | 0.6 | 84.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.49 | |
| U042-u042 | 0.26m/s | 24h | 495 | -0.117 | 0.182 | 0.140 | 0.6 | 83.8 | 0.0 | 0.0 | 0.0 | -99.9 | 0.49 | |
| U048-u048 | 0.26m/s | 24h | 494 | -0.116 | 0.181 | 0.139 | 0.6 | 83.4 | 0.0 | 0.0 | 0.0 | -99.9 | 0.49 | |
| U054-u054 | 0.26m/s | 24h | 493 | -0.116 | 0.181 | 0.139 | 0.6 | 84.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.49 | |
| U060-u060 | 0.26m/s | 24h | 492 | -0.115 | 0.181 | 0.139 | 0.6 | 83.9 | 0.0 | 0.0 | 0.0 | -99.9 | 0.49 | |
| U066-u066 | 0.26m/s | 24h | 491 | -0.115 | 0.180 | 0.139 | 0.6 | 84.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.49 | |
| U072-u072 | 0.26m/s | 24h | 490 | -0.113 | 0.179 | 0.139 | 0.6 | 84.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.49 | |

**Table F-4.** Water currents speed skill assessment at USGS-Vanc (vertical average).

| Station: | USGS-Vanc | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE | X | N | IMAX | SM | RMSE | SD | NOF | CF | POF | MDNO | MDPO | WOF | CORR | SKILL |
| CRITERION | - | - | - | - | - | - | <1% | >90% | <1% | <N | <N | <.5% | | |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| U | | | 43532 | 0.744 | | | | | | | | | | |
| u | | | 43532 | 0.644 | | | | | | | | | | |
| U-u | 0.26m/s | 24h | 43532 | 0.100 | 0.117 | 0.060 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.96 | 0.87 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| U000-u000 | 0.26m/s | 24h | 668 | 668 | 668 | 668 | 668 | 668 | 668 | 668 | 668 | -99.9 | 0.96 | |
| U006-u006 | 0.26m/s | 24h | 668 | 0.098 | 0.122 | 0.072 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 0.91 | |
| U012-u012 | 0.26m/s | 24h | 668 | 0.091 | 0.124 | 0.085 | 0.0 | 99.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.91 | |
| U018-u018 | 0.26m/s | 24h | 668 | 0.089 | 0.119 | 0.079 | 0.0 | 99.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.88 | |
| U024-u024 | 0.26m/s | 24h | 668 | 0.083 | 0.122 | 0.089 | 0.0 | 99.1 | 0.0 | 0.0 | 0.0 | -99.9 | 0.87 | |
| U030-u030 | 0.26m/s | 24h | 668 | 0.084 | 0.122 | 0.089 | 0.0 | 98.7 | 0.0 | 0.0 | 0.0 | -99.9 | 0.86 | |
| U036-u036 | 0.26m/s | 24h | 667 | 0.083 | 0.123 | 0.091 | 0.0 | 98.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.85 | |
| U042-u042 | 0.26m/s | 24h | 666 | 0.083 | 0.123 | 0.090 | 0.0 | 98.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.85 | |
| U048-u048 | 0.26m/s | 24h | 665 | 0.085 | 0.125 | 0.091 | 0.0 | 98.6 | 0.0 | 0.0 | 0.0 | -99.9 | 0.84 | |
| U054-u054 | 0.26m/s | 24h | 664 | 0.091 | 0.129 | 0.092 | 0.0 | 97.3 | 0.0 | 0.0 | 0.0 | -99.9 | 0.84 | |
| U060-u060 | 0.26m/s | 24h | 663 | 0.099 | 0.133 | 0.090 | 0.0 | 96.5 | 0.0 | 0.0 | 0.0 | -99.9 | 0.84 | |
| U066-u066 | 0.26m/s | 24h | 662 | 0.105 | 0.139 | 0.091 | 0.0 | 95.2 | 0.0 | 0.0 | 0.0 | -99.9 | 0.84 | |
| U072-u072 | 0.26m/s | 24h | 661 | 0.109 | 0.144 | 0.094 | 0.0 | 94.4 | 0.0 | 0.0 | 0.0 | -99.9 | 0.83 | |

# APPENDIX G. WATER CURRENTS DIRECTION SKILL ASSESSMENT TABLES

**Table G-1.** Water currents direction skill assessment at NDBC Angles Point (1.0 m level).

| Station: | | NDBC Angles Point | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| D | | | 32096 | 209.9 | | | | | | | | | | |
| d | | | 32096 | 183.9 | | | | | | | | | | |
| D-d | 22.5 dg | 24h | 32096 | 6.4 | 50.3 | 49.9 | 7.7 | 59.5 | 13.7 | 2.8 | 3.7 | -99.9 | 0.50 | 0.71 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| D000-d000 | 22.5 dg | 24h | 529 | 2.1 | 51.0 | 51.0 | 24.0 | 35.2 | 40.5 | 12.0 | 42.0 | -99.9 | 0.48 | |
| D006-d006 | 22.5 dg | 24h | 529 | 2.3 | 50.4 | 50.4 | 24.4 | 35.5 | 40.1 | 12.0 | 42.0 | -99.9 | 0.48 | |
| D012-d012 | 22.5 dg | 24h | 528 | 2.5 | 50.6 | 50.5 | 23.9 | 35.6 | 40.5 | 12.0 | 42.0 | -99.9 | 0.49 | |
| D018-d018 | 22.5 dg | 24h | 528 | 2.6 | 50.5 | 50.5 | 23.7 | 35.6 | 40.5 | 12.0 | 42.0 | -99.9 | 0.48 | |
| D024-d024 | 22.5 dg | 24h | 529 | 2.6 | 50.4 | 50.4 | 23.8 | 35.2 | 40.8 | 12.0 | 42.0 | -99.9 | 0.48 | |
| D030-d030 | 22.5 dg | 24h | 529 | 3.1 | 50.8 | 50.7 | 23.6 | 35.7 | 40.6 | 12.0 | 42.0 | -99.9 | 0.47 | |
| D036-d036 | 22.5 dg | 24h | 529 | 2.5 | 49.7 | 49.7 | 23.4 | 36.1 | 40.3 | 12.0 | 42.0 | -99.9 | 0.47 | |
| D042-d042 | 22.5 dg | 24h | 529 | 2.6 | 49.7 | 49.7 | 23.4 | 35.7 | 40.6 | 12.0 | 42.0 | -99.9 | 0.47 | |
| D048-d048 | 22.5 dg | 24h | 528 | 1.7 | 50.3 | 50.3 | 23.5 | 35.6 | 40.9 | 12.0 | 42.0 | -99.9 | 0.46 | |
| D054-d054 | 22.5 dg | 24h | 527 | 1.6 | 50.5 | 50.5 | 23.5 | 35.3 | 41.0 | 12.0 | 42.0 | -99.9 | 0.48 | |
| D060-d060 | 22.5 dg | 24h | 526 | 2.5 | 49.9 | 49.9 | 23.6 | 35.0 | 40.9 | 12.0 | 42.0 | -99.9 | 0.49 | |
| D066-d066 | 22.5 dg | 24h | 525 | 2.6 | 50.0 | 49.9 | 23.0 | 35.8 | 40.8 | 12.0 | 42.0 | -99.9 | 0.49 | |
| D072-d072 | 22.5 dg | 24h | 524 | 3.1 | 48.8 | 48.7 | 22.7 | 36.3 | 40.8 | 12.0 | 42.0 | -99.9 | 0.47 | |

**Table G-2.** Water currents direction skill assessment at Rich Passage (13.7 m level).

| Station: | | Rich Passage | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE<br>CRITERION | X<br>- | N<br>- | IMAX<br>- | SM<br>- | RMSE<br>- | SD<br>- | NOF<br><1% | CF<br>>90% | POF<br><1% | MDNO<br><N | MDPO<br><N | WOF<br><.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| D | | | 43457 | 189.9 | | | | | | | | | | |
| d | | | 43457 | 195.1 | | | | | | | | | | |
| D-d | 22.5 dg | 24h | 43457 | -0.906 | 10.2 | 10.1 | 0.2 | 93.8 | 0.0 | 0.5 | 0.0 | -99.9 | 0.80 | 0.90 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| D000-d000 | 22.5 dg | 24h | 667 | -0.6 | 12.1 | 12.1 | 24.6 | 52.6 | 22.2 | 66.0 | 54.0 | -99.9 | 0.82 | |
| D006-d006 | 22.5 dg | 24h | 667 | -0.5 | 12.2 | 12.2 | 23.7 | 52.0 | 23.4 | 66.0 | 54.0 | -99.9 | 0.82 | |
| D012-d012 | 22.5 dg | 24h | 667 | -0.8 | 12.0 | 12.0 | 25.0 | 52.0 | 22.3 | 66.0 | 54.0 | -99.9 | 0.83 | |
| D018-d018 | 22.5 dg | 24h | 667 | -0.8 | 11.9 | 11.9 | 25.0 | 52.3 | 22.3 | 66.0 | 54.0 | -99.9 | 0.81 | |
| D024-d024 | 22.5 dg | 24h | 667 | -0.8 | 12.1 | 12.1 | 25.9 | 51.7 | 22.0 | 66.0 | 54.0 | -99.9 | 0.81 | |
| D030-d030 | 22.5 dg | 24h | 666 | -0.8 | 12.5 | 12.5 | 24.6 | 52.0 | 22.1 | 66.0 | 54.0 | -99.9 | 0.82 | |
| D036-d036 | 22.5 dg | 24h | 665 | -0.8 | 12.0 | 12.0 | 24.5 | 52.3 | 22.4 | 66.0 | 54.0 | -99.9 | 0.81 | |
| D042-d042 | 22.5 dg | 24h | 664 | -0.7 | 12.3 | 12.3 | 24.5 | 52.3 | 22.7 | 60.0 | 54.0 | -99.9 | 0.81 | |
| D048-d048 | 22.5 dg | 24h | 663 | -0.7 | 12.1 | 12.1 | 24.6 | 52.9 | 22.2 | 54.0 | 54.0 | -99.9 | 0.82 | |
| D054-d054 | 22.5 dg | 24h | 662 | -0.9 | 11.5 | 11.5 | 24.0 | 53.9 | 21.6 | 48.0 | 30.0 | -99.9 | 0.83 | |
| D060-d060 | 22.5 dg | 24h | 661 | -0.9 | 11.7 | 11.7 | 24.7 | 53.9 | 20.4 | 42.0 | 30.0 | -99.9 | 0.81 | |
| D066-d066 | 22.5 dg | 24h | 660 | -0.8 | 11.8 | 11.7 | 23.6 | 53.0 | 22.3 | 36.0 | 30.0 | -99.9 | 0.83 | |
| D072-d072 | 22.5 dg | 24h | 659 | -0.9 | 11.8 | 11.8 | 24.1 | 54.5 | 21.1 | 30.0 | 30.0 | -99.9 | 0.82 | |

**Table G-3.** Water currents direction skill assessment at Bangor, Hood Canal (56.0 m level).

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station: | Bangor, Hood Canal | | | | | | | | | | | | | |
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| D | | | 33213 | 134.2 | | | | | | | | | | |
| d | | | 33213 | 109.0 | | | | | | | | | | |
| D-d | 22.5 dg | 24h | 33213 | -0.6 | 3.6 | 3.6 | 0.0 | 99.3 | 0.0 | 0.8 | 0.0 | -99.9 | 0.23 | 0.57 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| D000-d000 | 22.5 dg | 24h | 498 | -0.7 | 3.4 | 3.4 | 6.4 | 93.4 | 0.2 | 6.0 | 0.0 | -99.9 | 0.20 | |
| D006-d006 | 22.5 dg | 24h | 498 | -0.8 | 3.6 | 3.5 | 6.8 | 93.0 | 0.2 | 6.0 | 0.0 | -99.9 | 0.19 | |
| D012-d012 | 22.5 dg | 24h | 498 | -0.7 | 3.4 | 3.3 | 6.2 | 93.6 | 0.2 | 6.0 | 0.0 | -99.9 | 0.21 | |
| D018-d018 | 22.5 dg | 24h | 498 | -0.8 | 3.6 | 3.5 | 6.6 | 93.2 | 0.2 | 6.0 | 0.0 | -99.9 | 0.20 | |
| D024-d024 | 22.5 dg | 24h | 498 | -0.8 | 3.8 | 3.7 | 6.8 | 93.0 | 0.2 | 6.0 | 0.0 | -99.9 | 0.19 | |
| D030-d030 | 22.5 dg | 24h | 497 | -0.8 | 3.7 | 3.6 | 6.2 | 93.6 | 0.2 | 6.0 | 0.0 | -99.9 | 0.18 | |
| D036-d036 | 22.5 dg | 24h | 496 | -0.8 | 3.8 | 3.7 | 6.5 | 93.3 | 0.2 | 6.0 | 0.0 | -99.9 | 0.18 | |
| D042-d042 | 22.5 dg | 24h | 495 | -0.8 | 3.8 | 3.7 | 6.9 | 92.9 | 0.2 | 6.0 | 0.0 | -99.9 | 0.18 | |
| D048-d048 | 22.5 dg | 24h | 494 | -0.8 | 3.7 | 3.7 | 6.5 | 93.3 | 0.2 | 6.0 | 0.0 | -99.9 | 0.18 | |
| D054-d054 | 22.5 dg | 24h | 493 | -0.8 | 3.9 | 3.8 | 7.1 | 92.7 | 0.2 | 6.0 | 0.0 | -99.9 | 0.20 | |
| D060-d060 | 22.5 dg | 24h | 492 | -0.8 | 3.7 | 3.6 | 6.5 | 93.3 | 0.2 | 6.0 | 0.0 | -99.9 | 0.17 | |
| D066-d066 | 22.5 dg | 24h | 491 | -0.8 | 3.7 | 3.7 | 6.5 | 93.3 | 0.2 | 6.0 | 0.0 | -99.9 | 0.19 | |
| D072-d072 | 22.5 dg | 24h | 490 | -0.8 | 3.9 | 3.8 | 6.7 | 93.1 | 0.2 | 6.0 | 0.0 | -99.9 | 0.19 | |

**Table G-4.** Water currents direction skill assessment at USGS-Vanc (vertical average).

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station: | USGS-Vanc | | | | | | | | | | | | | |
| Observed data time period from 2/15/2024 to / 8/16/2024 | | | | | | | | | | | | | | |
| Data gap is filled using SVD method | | | | | | | | | | | | | | |
| Data are not filtered | | | | | | | | | | | | | | |
| VARIABLE CRITERION | X - | N - | IMAX - | SM - | RMSE - | SD - | NOF <1% | CF >90% | POF <1% | MDNO <N | MDPO <N | WOF <.5% | CORR | SKILL |
| SCENARIO: SEMI-OPERATIONAL NOWCAST | | | | | | | | | | | | | | |
| D | | | 43532 | 306.7 | | | | | | | | | | |
| d | | | 43532 | 307.0 | | | | | | | | | | |
| D-d | 22.5 dg | 24h | 43532 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | 1.00 |
| SCENARIO: SEMI-OPERATIONAL FORECAST | | | | | | | | | | | | | | |
| D000-d000 | 22.5 dg | 24h | 668 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D006-d006 | 22.5 dg | 24h | 668 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D012-d012 | 22.5 dg | 24h | 668 | -0.3 | 0.3 | 0.1 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D018-d018 | 22.5 dg | 24h | 668 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D024-d024 | 22.5 dg | 24h | 668 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D030-d030 | 22.5 dg | 24h | 668 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D036-d036 | 22.5 dg | 24h | 667 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D042-d042 | 22.5 dg | 24h | 666 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D048-d048 | 22.5 dg | 24h | 665 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D054-d054 | 22.5 dg | 24h | 664 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D060-d060 | 22.5 dg | 24h | 663 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D066-d066 | 22.5 dg | 24h | 662 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |
| D072-d072 | 22.5 dg | 24h | 661 | -0.3 | 0.3 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | -99.9 | 1.00 | |