IMPLEMENTATION OF THE COOK INLET OPERATIONAL FORECAST SYSTEM (CIOFS) AND THE NOWCAST/FORECAST SKILL ASSESSMENT

Silver Spring, Maryland
April 2022

noaa National Oceanic and Atmospheric Administration

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

Center for Operational Oceanographic Products and Services
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

The National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) provides the National infrastructure, science, and technical expertise to collect and distribute observations and predictions of water levels and currents to ensure safe, efficient and environmentally sound maritime commerce. The Center provides the set of water level and tidal current products required to support NOS' Strategic Plan mission requirements, and to assist in providing operational oceanographic data/products required by NOAA's other Strategic Plan themes. For example, CO-OPS provides data and products required by the National Weather Service to meet its flood and tsunami warning responsibilities. The Center manages the National Water Level Observation Network (NWLON), a national network of Physical Oceanographic Real-Time Systems (PORTS®) in major U. S. harbors, and the National Current Observation Program consisting of current surveys in near shore and coastal areas utilizing bottom mounted platforms, subsurface buoys, horizontal sensors and quick response real time buoys. The Center: establishes standards for the collection and processing of water level and current data; collects and documents user requirements, which serve as the foundation for all resulting program activities; designs new and/or improved oceanographic observing systems; designs software to improve CO-OPS' data processing capabilities; maintains and operates oceanographic observing systems; performs operational data analysis/quality control; and produces/disseminates oceanographic products.

NOAA Technical Report NOS CO-OPS 096

IMPLEMENTATION OF THE COOK INLET OPERATIONAL FORECAST SYSTEM (CIOFS) AND THE NOWCAST/FORECAST SKILL ASSESSMENT

Aijun Zhang
National Ocean Service
Center for Operational Oceanographic Products and Services
Silver Spring, Maryland

April 2022

U.S. DEPARTMENT OF COMMERCE
Gina M Raimondo, Secretary

National Oceanic and Atmospheric Administration
Dr. Richard Spinrad, Assistant Secretary of Commerce for Environmental Observation and Prediction, performing the duties of Under Secretary of Commerce for Oceans and Atmosphere

National Ocean Service
Nicole LeBoeuf, Assistant Administrator

Center for Operational Oceanographic Products and Services
Richard Edwing, Director

NOTICE

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

EXECUTIVE SUMMARY

The Cook Inlet Operational Forecast System (CIOFS) became fully operational in July 2019 on the National Oceanic and Atmospheric Administration's (NOAA's) Weather and Climate Operational Supercomputing System, operated by National Centers for Environmental Prediction (NCEP) Central Operations (NCO). CIOFS uses the Regional Ocean Modeling System (ROMS) developed and supported by Rutgers University. CIOFS model grid horizontal resolution ranges from 10 meters in upper bays and estuaries and navigational channels to 3.5 kilometers near offshore waters. CIOFS vertical coordinates have 30 uniform sigma levels. CIOFS provides users with nowcasts (analysis of near present) and forecast guidance out to 48 hours of the three-dimensional (3-D) physical conditions of the Cook Inlet and its adjacent coastal area, including 3-D water currents, water temperature, salinity, and surface water levels.

CIOFS has four daily nowcast and forecast cycles at 00:00, 06:00, 12:00, and 18:00 UTC (Coordinated Universal Time), and operates within the National Ocean Service (NOS) Coastal Ocean Modeling Framework (COMF). The meteorological forcing (winds, air pressure, heat flux, etc.) for CIOFS nowcast and forecast cycles is provided by the NCEP North American Mesoscale (NAM) weather prediction model. Subtidal water level boundary conditions are derived from forecast guidance of the Extra-Tropical Storm Surge model, and other oceanographic conditions (temperature and salinity) along CIOFS' lateral boundaries on the shelf are estimated based on the guidance from the Global Real-time Ocean Forecast System. In addition, tidal open boundary conditions are derived from the ADCIRC 2003 Tidal Database. River forcing conditions for nowcast simulations are estimated from real-time discharge observations at U.S. Geological Survey river gauges. River forcing conditions for forecast simulations are consistent with the values from the most recent discharge observations.

The skill assessment results demonstrated that all water level skill metrics met or were close to NOS standard criteria. Root Mean Square Error (RMSE) at all stations were less than 10% of tide range, which is within the accepted error criteria for navigation applications. Central Frequency (CF) for both the nowcast and forecast were greater than or close to 90%, and negative outlier frequency (NOF) and positive outlier frequency (POF) were less than 1% at all stations. The surface water temperature predictions agreed well with observations. The surface temperature RMSE was below or very close to its criterion threshold (3.0 °C) in all cases. Most of the statistical variables used in skill assessment met the NOS-accepted skill assessment criteria.

The CIOFS is a collaboration between NOAA/NOS Center for Operational Oceanographic Products and Services, Office of Coast Survey, and the NOAA/National Weather Service's NCEP NCO.

This technical report documents CIOFS configuration and forcing condition generation using COMF, followed by its nowcast and forecast model skill assessment.

1. INTRODUCTION

Cook Inlet is a 180-mile-long water body; it incorporates almost every coastal use in Alaska: recreation, commercial fishing, sport fishing, subsistence, tourism, oil and gas, mining, shipping, conservation, search and rescue, and scientific research. Cook Inlet oceanography is complex. Thirty-foot tide ranges, mudflats, sea ice, and large glacial rivers all contribute to complicated circulation patterns that change hourly, daily, and seasonally. Major external factors such as the Aleutian Low (a semi-permanent, low-pressure system), the Alaska Coastal Current, and the freshwater inflow affect both the physical characteristics of the inlet and the biota that live there. Cook Inlet has strong tidal currents in proximity to the electrical grid (Okkonen, S. R. 2005, Danielson, et al, 2016). The diverse interests of those who use the inlet drive the need for understanding such an intricate and dynamic system in order to operate safely in its waters and along its coastlines. This challenge has attracted scientists from around the country.

The Cook Inlet Modeling Workshop was hosted by the Alaska Ocean Observing System (AOOS) in March 2010 (Cook Inlet Modeling and Observation Needs, Workshop Report, March 2010), which brought together modelers from state and federal agencies, academic institutions, and private and nonprofit organizations to share information on existing circulation modeling efforts and available observations. After the workshop, the National Ocean Service Coast Survey Development Laboratory (NOS/CSDL) began developing a Cook Inlet Operational Forecast System (CIOFS) in 2012 to support a tidal energy project (Lanerolle, L. et al, 2012). As its hydrodynamic core ocean prediction model, CIOFS uses the Regional Ocean Modeling System (ROMS) developed by the coastal ocean modeling community and supported by Rutgers University. ROMS is a free-surface, terrain-following, primitive equations ocean model widely used by the scientific and operational community for a diverse range of applications.

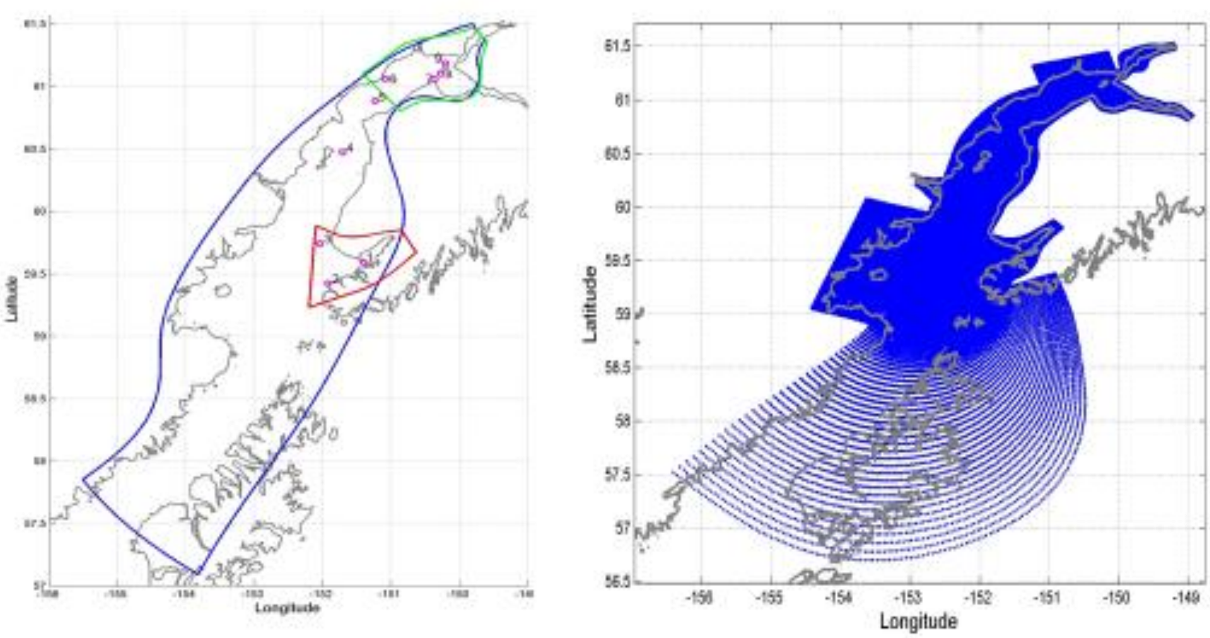


Figure 1. The first version large model domain and the two nested model domains with higher resolution (left panel) and final CIOFS domain and the model grid (right panel).

Initially CIOFS was designed as a nested system, which included a large domain with coarse resolution and two nested sub-domain models with higher resolution. Figure 1 shows the initial model domains on the left. Several sensitivity experiments demonstrated that the simulated water levels, temperature and salinity from the nested sub-domain models had larger errors (larger RMSE and phase mismatch in water levels and water temperature) than the results from the larger domain model with a coarse grid when compared with the observations. Therefore, it was decided to deploy a single model grid for the CIOFS final configuration. CIOFS final grid is shown on the right in Figure 1. CIOFS uses an orthogonal grid with horizontal dimension of 1132 × 777. Its horizontal resolution ranges from 10 meters (m) within the upper bay/estuary and navigational channels to 3.5 kilometers (km) near offshore waters. The vertical grid follows the terrain and consists of 30 uniform sigma levels. The bathymetry for the Cook Inlet model is populated from the best available data, which include NOS sounding data, National Geophysical Data Center and National Geodetic Survey shoreline data, and the U.S. Geological Survey (USGS) topography gridded product. A Digital Elevation Map (DEM) was used for the wetting/drying process of CIOFS simulations.

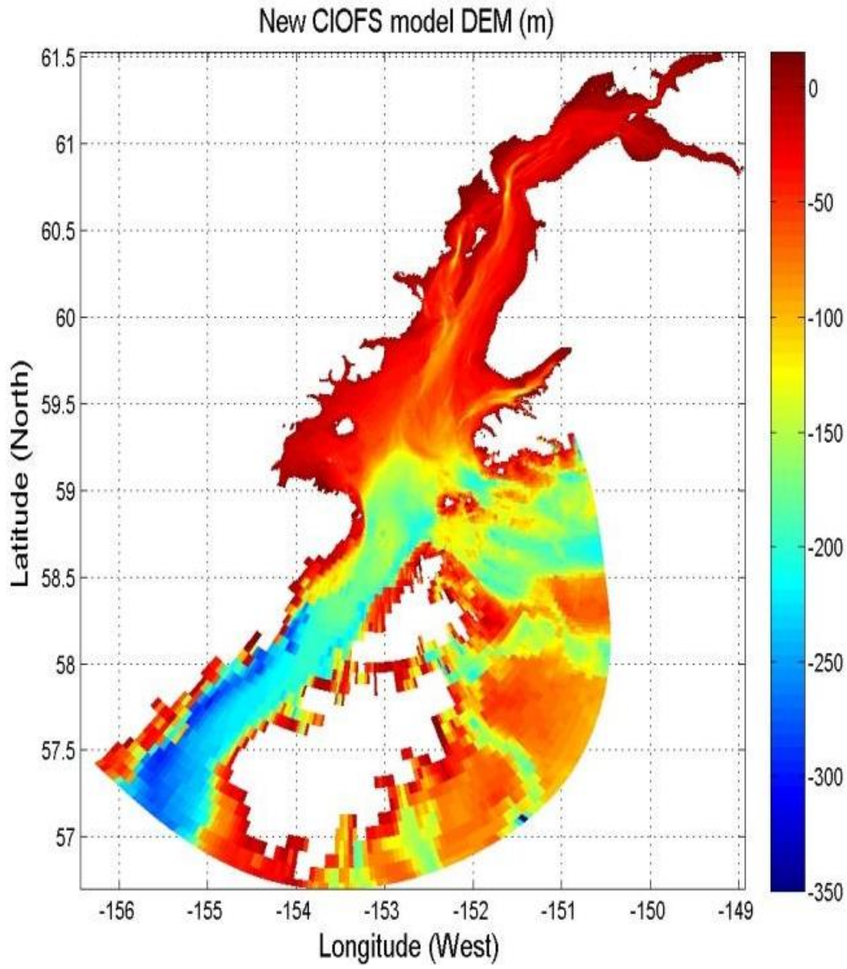


Figure 2. CIOFS model bathymetry in meters.

Several scenario simulations were conducted during the CIOFS development phase, including a tidal simulation to evaluate model performance using tidal elevation and currents predictions, and two synoptic hindcast simulations to evaluate model performance in simulating water levels, currents, water temperature, and salinity. Details on the simulation setup and related skill assessment results can be found in the National Oceanic and Atmospheric Administration (NOAA) Technical Report NOS CS 40 (Shi et al., 2021).

After CSDL completed hindcast simulations and validation, CO-OPS performed pseudo-operational simulations (nowcast and forecast in real-time mode) under the Coastal Ocean Modeling Framework (COMF) on NOAA's Weather & Climate Operational Supercomputing System (WCOSS). The surface meteorological forcing used to run CIOFS nowcasts and forecasts is based on forecast guidance from the National Weather Service's (NWS) North American Mesoscale (NAM) weather prediction model (for both nowcast and forecast). Forecast guidance from the National Centers for Environmental Prediction (NCEP) Global Forecast System is used as a backup forcing if forecast guidance from the NAM is not available. CIOFS relies on NCEP's Global Real-Time Ocean Forecast System to provide lateral open boundary temperature and salinity. NWS' Extra-Tropical Storm Surge (ETSS) model provides sub-tidal water level boundary conditions. The Advanced CIRCulation (ADCIRC) 2003 Tidal Database is used to generate CIOFS tidal forcing at the open boundaries. Additionally, near real-time observations from USGS river gauges are used to specify river discharge, temperature, and salinity at 12 major rivers in Cook Inlet.

CIOFS pseudo-operational simulations ran reliably without instability issues since the pseudo-operational nowcast/forecast runs began in November 2017. Standard model skill assessment was conducted (January 1, 2019–October 31, 2020) based on pseudo-operational simulations for targeted variables, including water level and water temperature. Due to the lack of sufficient observations of currents and salinity, nowcast and forecast skill assessments of currents and salinity were not conducted. Users can refer to Shi et al. (2021) for CIOFS performance of currents and salinity.

This technical report documents the configuration of the CIOFS operational implementation under the NOS shared Coastal Ocean Modeling Framework (COMF) on the Weather and Climate Operational Supercomputing System (WCOSS) of NOAA's High Performance Computing (HPC) System and the CIOFS performance of nowcast and forecast simulations during the period of January 1, 2019–October 31, 2020.

2. MODEL NOWCAST/FORECAST CONFIGURATION

This section describes the generation of the various forcing conditions for CIOFS nowcast/forecast predictions. All these forcing condition files are automatically generated by the HPC-COMF. A main control file (**nos.ciofs.ctl**) includes following parameters used by CIOFS.

```
export DBASE_MET_NOW=NAM
export DBASE_MET_FOR=NAM
export DBASE_WL_NOW=ETSS
export DBASE_WL_FOR=ETSS
export DBASE_TS_NOW=RTOFS
export DBASE_TS_FOR=RTOFS
export OCEAN_MODEL=ROMS
export LEN_FORECAST=48
export IGRD_MET=0
export IGRD_OBC=2
 export BASE_DATE=2016010100
export TIME_START=2016010100
export MINLON=-157.0
export MINLAT=56.0
export MAXLON=-148.0
export MAXLAT=62.0
export THETA_S=4.5d0
export THETA_B=0.91d0
export TCLINE=10.0d0
export NVTRANS=1
export NVSTR=1
export SCALE_HFLUX=1.0
export CREATE_TIDEFORCING=1
export GRIDFILE=nos.ciofs.romsgrid.nc
export HC_FILE_OBC=nos.ciofs.HC.nc
export HC_FILE_OFS=nos.ciofs.roms.tides.nc
export RIVER_CTL_FILE=nos.ciofs.river.ctl
export RIVER_CLIM_FILE=nos.ofs.river.clim.usgs.nc
export OBC_CTL_FILE=nos.ciofs.obc.ctl
export OBC_CLIM_FILE=nos.ofs.clim.WOA05.nc
export STA_OUT_CTL=nos.ciofs.stations.in
export RUNTIME_CTL=nos.ciofs.roms.in
export VARINFOFILE_ROMS=nos.ofs.roms.varinfo.dat
export HC_FILE_NWLON=nos.ofs.HC_NWLON.nc
export VGRID_CTL=nos.ciofs.vgrid.in
export NWM_REACHID_FILE=nos.ciofs.nwm.reach.dat
```

2.1 Meteorological Forcing Conditions

Meteorological forcing conditions for CIOFS are generated by the standard framework HPC-COMF, which is shared by all other existing NOS operational forecast systems. The **nos.ciofs.ctl** file in **/nosofs.vx.x.x/fix/ciofs/** defines which NOAA numerical weather prediction model output is used. For CIOFS, the forecast guidance from the NCEP NAM is used by specifying the following two parameters in the nos.ciofs.ctl control file:

export DBASE_MET_NOW=NAM
export DBASE_MET_FOR=NAM

These parameters indicate that NAM forecast guidance is used as meteorological forcing conditions for both nowcast and forecast simulations. The shell script

nos_ofs_create_forcing_met.sh

located within **/nosofs.vx.x.x/ush/** is launched to generate

nos.ciofs.met.nowcast.{yyyymmdd}.t{cc}z.nc
nos.ciofs.met.forecast.{yyyymmdd}.t{cc}z.nc

where yyyy, mm, dd, and cc indicate the year, month, day, and cycle, respectively, of the nowcast/forecast.

2.2 River Forcing Conditions

CIOFS relies on freshwater inputs at 12 USGS river gauges. Figure 3 shows the locations of the USGS river gauges. The most recent discharge rate and water temperature of each river is retrieved directly from the NCEP data tank on WCOSS. A river control file, **nos.ciofs.river.ctl**, is used by COMF to generate CIOFS river forcing conditions. Table 1 is an example of CIOFS' river control file which includes USGS and NCEP IDs of the 12 rivers, and model grid indexes where freshwater is specified.

The USGS real-time river observations, discharge, and water temperature are used only for the nowcast cycle. For the forecast cycle, the most recent river discharge and water temperature observations persist for the duration of the forecast simulation. The climatological river discharge and water temperature data (multiple-year daily mean from USGS) are used when real-time observations are not available for a given period. The climatological data for each river can be found in **nos.ofs.river.clim.usgs.nc**, which is saved in **/nosofs.vx.x.x/fix/share**.

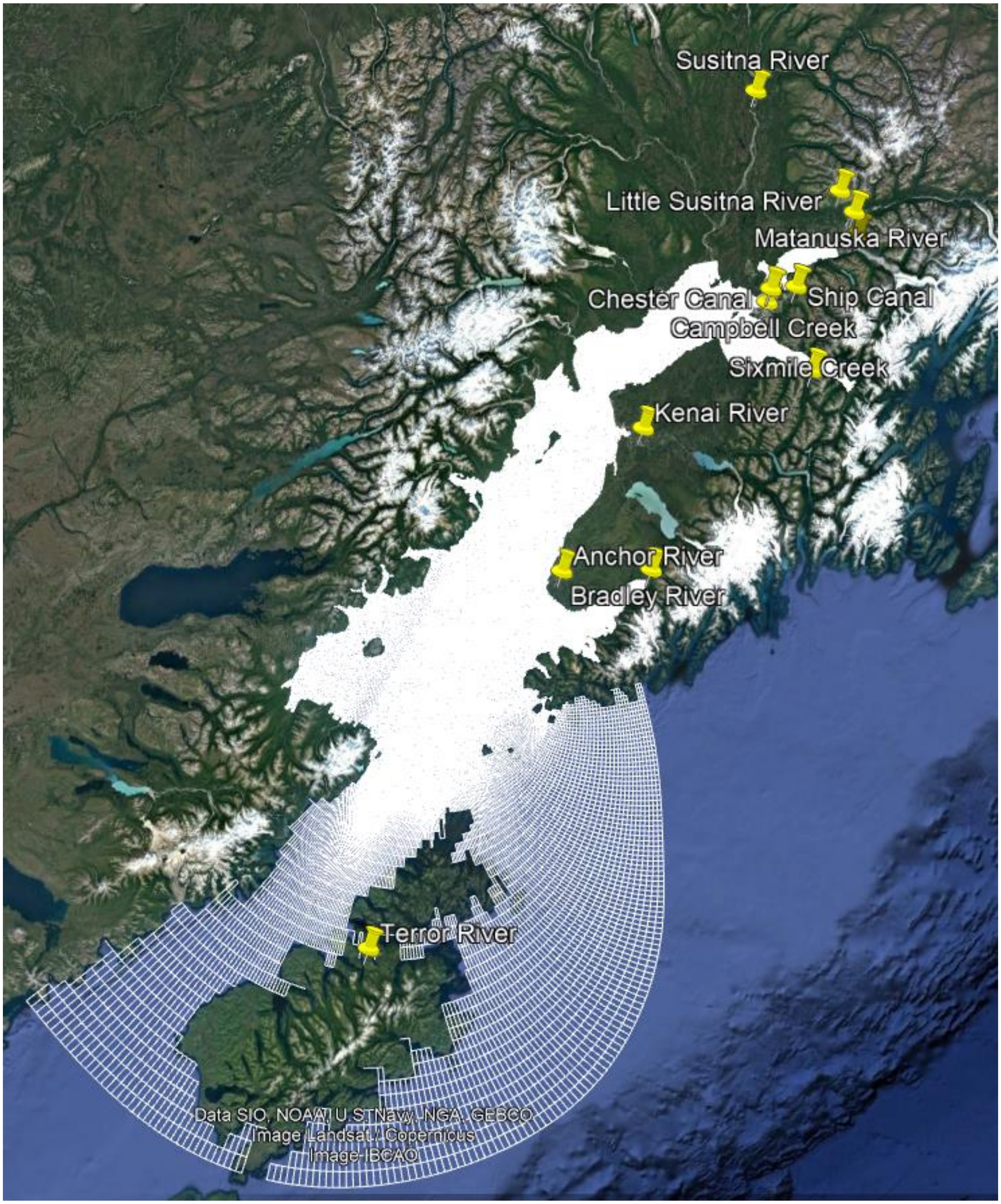


Figure 3. USGS river gauges used in CIOFS.

Table 1. A portion of the CIOFS river control file, nos.ciofs.river.ctl.

Section 1: Information about USGS rivers where real-time discharges are available.

RiverID	USGS ID	NWS ID	AGENCY ID	Q min	Q max	Q mean	T min	T max	T mean	Q Flag	TS Flag	River Station Name
1	15295700	XXXXX	USGS	0.00	136.20	8.48	-999.0	-999.0	-999.0	1	0	Terror River
2	15239070	XXXXX	USGS	0.00	49.55	4.05	0.10	15.80	4.32	1	1	Bradley River
3	15239900	XXXXX	USGS	0.00	59.47	3.95	-999.0	-999.0	-999.0	1	0	Anchor River
4	15266300	XXXXX	USGS	0.00	662.61	185.51	-999.0	-999.0	-999.0	1	0	Kenai River
5	15271000	XXXXX	USGS	0.00	103.92	20.00	-999.0	-999.0	-999.0	1	0	Sixmile Creek
6	15274600	XXXXX	USGS	0.00	14.78	1.47	-999.0	-999.0	-999.0	1	0	Campbell Creek
7	15275100	XXXXX	USGS	0.00	6.43	0.86	-999.0	-999.0	-999.0	1	0	Chester Canal
8	15276000	XXXXX	USGS	0.00	23.31	3.42	-999.0	-999.0	-999.0	1	0	Ship Canal
9	15281000	XXXXX	USGS	0.00	1384.69	402.38	-999.0	-999.0	-999.0	1	0	Knik River
10	15284000	XXXXX	USGS	0.00	577.66	184.95	-999.0	-999.0	-999.0	1	0	Matanuska River
11	15290000	XXXXX	USGS	0.00	59.75	5.95	-999.0	-999.0	-999.0	1	0	Little Susitna River
12	15292780	XXXXX	USGS	0.00	5487.81	1315.35	-999.0	-999.0	-999.0	1	0	Susitna River

Section 2: Information of ROMS grids to specify river discharges.

GRID ID	I/Xpos	J/Ypos	DIR	FLAG	RiverID Q	Q Scale	RiverID TS	TS Scale	River Basin Name
1	157	18	0	3	1	-1.000	2	1.000	Terror River at mouth near Kodiak, AK
2	506	73	1	3	2	1.000	2	1.000	Bradley River near Tidewater near Homer, AK
3	272	169	0	3	3	-1.000	2	1.000	Anchor River near Anchor Point, AK
4	266	269	0	3	4	-0.500	2	1.000	Kenai River at Soldotna, AK
5	266	270	0	3	5	-0.500	2	1.000	Kenai River at Soldotna, AK
6	594	474	1	3	6	1.000	2	1.000	Sixmile Creek near Hope, AK
7	339	517	1	3	7	-1.000	2	1.000	Campbell Creek near Spendard, AK
8	265	604	0	3	8	-1.000	2	1.000	Chester Canal at Arctic Boulevard at Anchorage
9	253	628	0	3	9	-1.000	2	1.000	Ship Canal near Anchorage, AK
10	179	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK
11	180	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK
12	181	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK
13	182	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK
14	183	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK
15	184	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK
16	185	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK
17	186	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK
18	187	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK
19	188	955	1	3	9	-0.100	2	1.000	Knik River near Palmer, AK

20	179	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
21	180	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
22	181	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
23	182	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
24	183	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
25	184	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
26	185	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
27	186	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
28	187	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
29	188	955	1	3	10	-0.100	2	1.000	Matanuska River near Palmer, AK
30	84	518	0	3	11	0.500	2	1.000	Little Susitna River near Palmer, AK
31	84	519	0	3	11	0.500	2	1.000	Little Susitna River near Palmer, AK
32	53	456	0	3	12	0.412	2	1.000	Susitna River at Sunshine, AK
33	53	457	0	3	12	0.405	2	1.000	Susitna River at Sunshine, AK
34	53	458	0	3	12	0.400	2	1.000	Susitna River at Sunshine, AK
35	53	459	0	3	12	0.394	2	1.000	Susitna River at Sunshine, AK
36	53	460	0	3	12	0.389	2	1.000	Susitna River at Sunshine, AK

2.3 Lateral Open Boundary Conditions

CIOFS lateral open boundary conditions include tidal predictions of elevations and currents using 10 tidal constituents (K1, O1, P1, Q1, M2, S2, N2, K2, M4, and M6) from the ADCIRC 2003 Tidal Database. Non-tidal water levels are generated from the ETSS forecast guidance. Water temperature, salinity, and non-tidal currents are generated from the NCEP Global Real Time Ocean Forecast System (RTOFS), and the U.S. Navy's global Hybrid Coordinate Ocean Model or HYCOM forecasts are used as a backup when RTOFS is not available. The data sources for lateral open boundary conditions are specified by the following parameters in the main control file of **nos.ciofs.ctl**,

export DBASE_WL_NOW=ETSS
export DBASE_WL_FOR=ETSS
export DBASE_TS_NOW=RTOFS
export DBASE_TS_FOR=RTOFS

Therefore, it is easy to switch data sources for sensitivity experiments and operational runs.

2.4 Initial Conditions

In COMF, **nos_ofs_read_restart.f** is used to read the ROMS-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 *ocean_time* in the initial file if the reference time is different from *${BASE_DATE}* specified in the control file, **nos.ciofs.ctl**.
(2) Re-compute the values of the variables *ocean_time* using ${BASE_DATE} as the reference time in the initial file if (1) is conducted.
(3) If the *ocean_time* is 48 hours less than ${time_nowcastend}, then the nowcast cycle is terminated. An initial condition file has to be constructed manually with zero surface elevation, zero velocity, and reasonable water temperature and salinity.

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

In the case of CIOFS, the output restart file from the nowcast of the most recent cycle is used to generate the initial condition for the nowcast of the current cycle. For example, nos.CIOFS.rst.nowcast.YYYYMMDD.t00z.nc from the nowcast at 00z is renamed nos.CIO**FS.init.nowcastYYYYMMDD.t06z.nc** for the nowcast at 06z. The restart file from the 06z cycle nowcast (**nos.CIOFS.rst.nowcast.YYYYMMDD.t06z.nc**) is then used for the 06z forecast cycle.

3. NOWCAST/FORECAST MODEL SKILL ASSESSMENT

CIOFS performed robustly, producing reasonable predictions from its nowcast and forecast (N/F) cycles for water levels, currents, water temperature, and salinity over the model's skill assessment period of January 01, 2019–September 30, 2020. This is validated visually by the cycle-by-cycle nowcast and forecast results. Figures 4 and 5 show an example of water level time series at Anchorage and Alitak. Figure 6 shows an example of a current time series plot, Figure 7 shows water temperature and salinity plots at Seldovia. To provide more scientific and objective analysis of the model performance, documented skill assessment metrics (Zhang et al., 2009) were used. 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 CIOFS nowcast and forecast skill assessment in Section 3.3.

3.1 Nowcast and Forecast Results

The latest cycle's nowcast/forecast predictions are displayed on the CIOFS operational website (https://tidesandcurrents.noaa.gov/ofs/ciofs/ciofs.html). Generally, the cycle-by-cycle results (Figures 4–7) indicate that the model typically 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. The results of the standard NOS model skill assessment and a further model evaluation for a winter storm event can be found in Section 3.3.

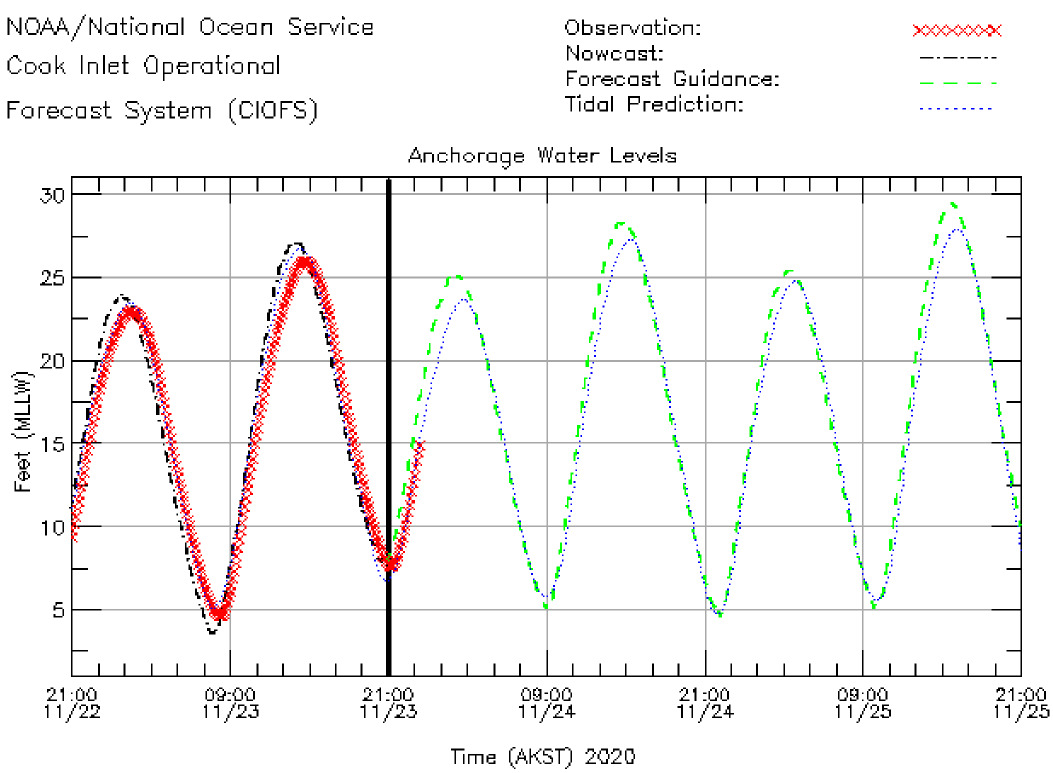


Figure 4. Examples of water level nowcast (black dashed line) and forecast (green dashed line), and tide prediction (blue line) at Anchorage, Alaska.

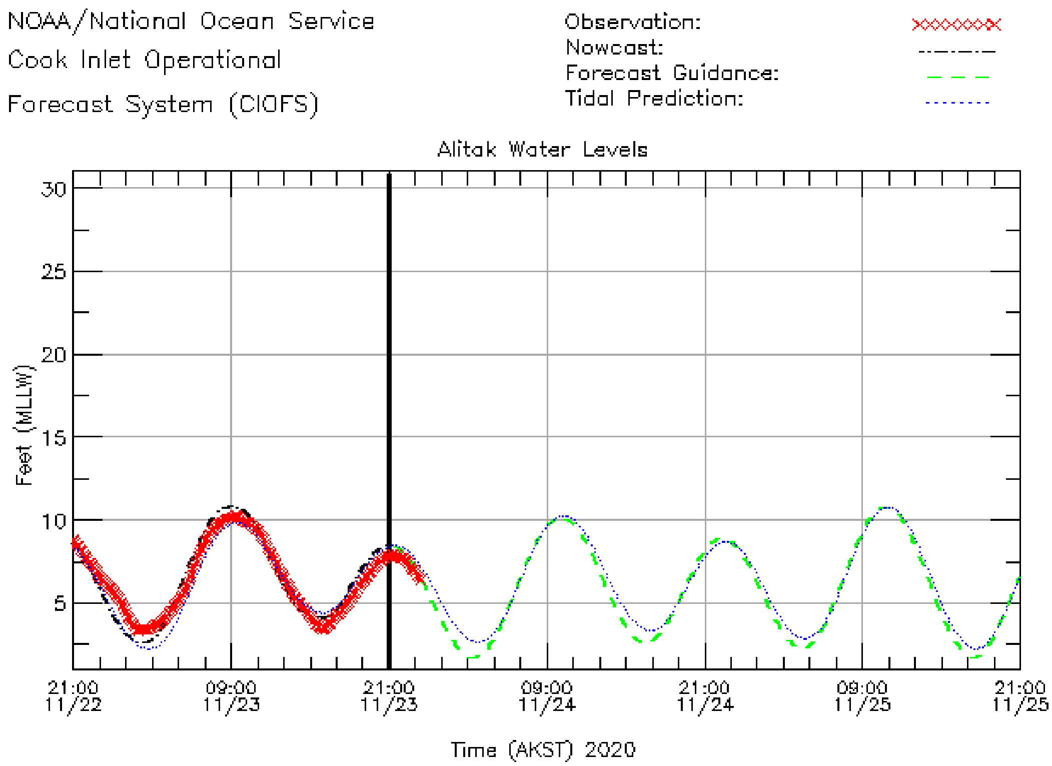


Figure 5. Examples of water level nowcast (black dashed line) and forecast (green dashed line), and tide prediction (blue line) at Alitak, Alaska.

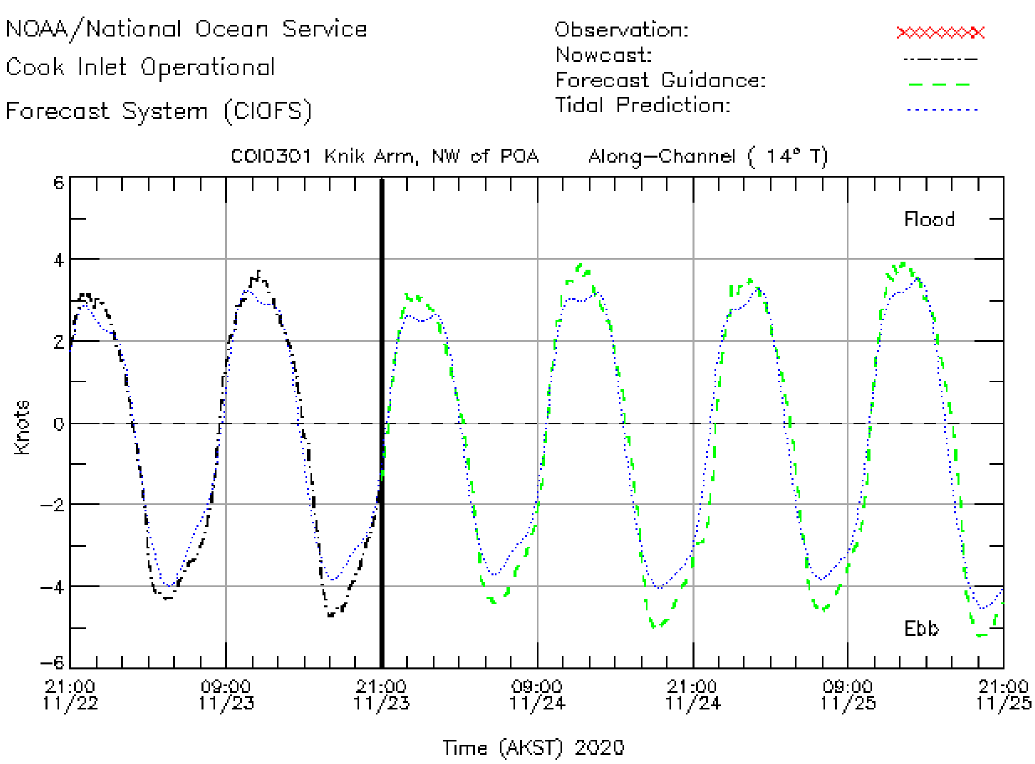


Figure 6. Examples of surface water current speed and direction nowcast (black dashed line), forecast (green dashed line), and tide current prediction (blue) at Knik Arm.

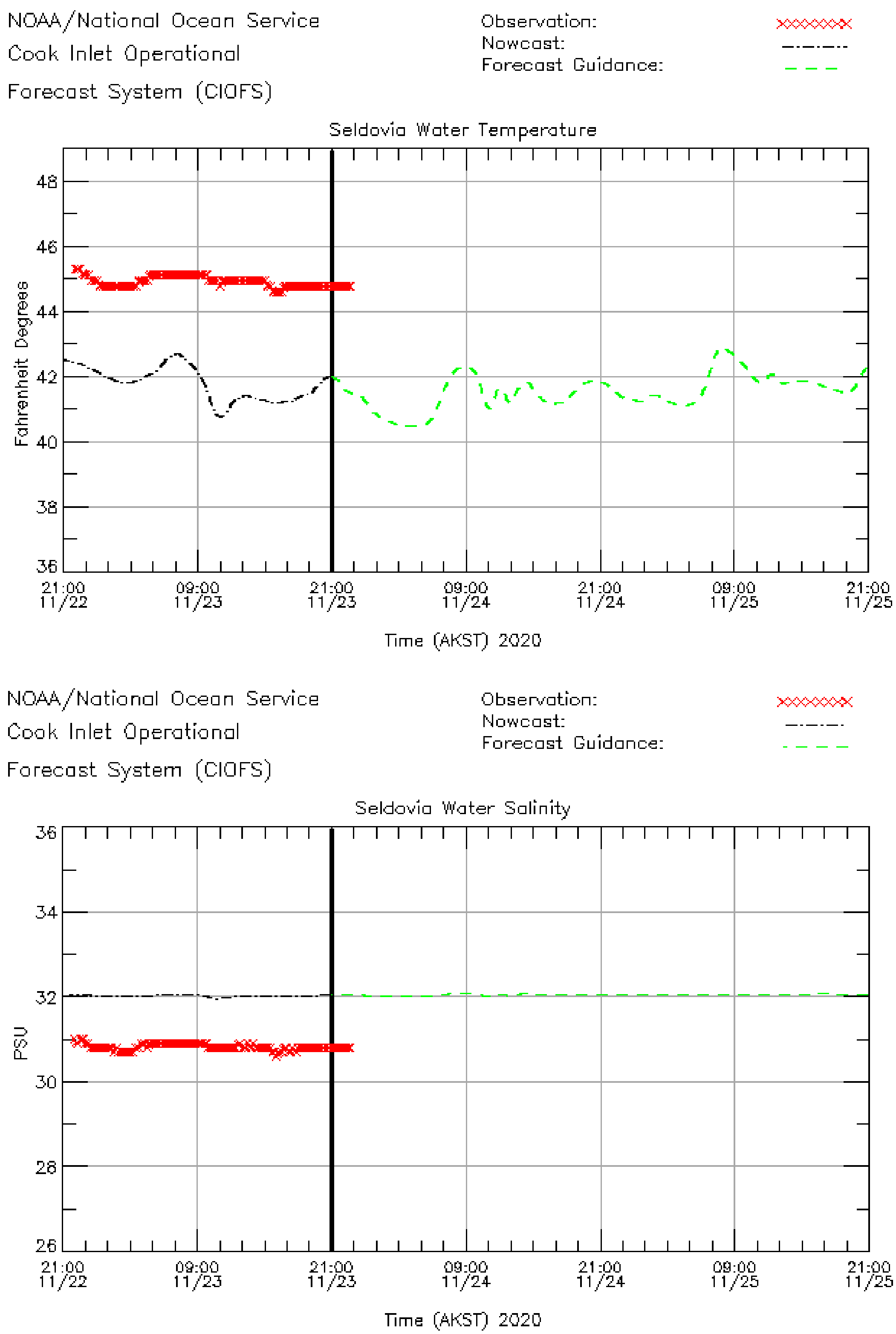


Figure 7. Examples of water surface temperature (top) and salinity (bottom) nowcast (black dashed line) and forecast (green dashed line) output at Seldovia.

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 N/F 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 N/F model results. Time series variables used in skill assessment are defined in Table 2, and a standard suite of skill assessment statistics is defined in Table 3.

Table 2. Data series groups and the variables in each. Note that upper-case letters indicate a prediction series (e.g., H) and lower-case letters (e.g., h) indicate a reference series (observation or astronomical prediction). Slack water is defined as the current speed less than ½ knot. The direction is computed only for current speeds greater than ½ knot (from Hess et al., 2003).

Group	Variable	Symbol
Group 1	Water level	H, h
(Time Series)	Current speed	U, u
	Current direction	D,d
	Salinity	S, s
	Water temperature	T,t
Group 2	Amplitude of high water	AHW,ahw
(Values at a Tidal Stage)	Amplitude of low water	ALW,ahw
	Time of high water	THW,thw
	Time of low water	TLW,tlw
	Amplitude of maximum flood current	AFC,afc
	Amplitude of maximum ebb current	AEC,aec
	Time of maximum flood current	TFC,tfc
	Time of maximum ebb current	TEC,tec
	Direction of current at maximum flood	DFC,dfc
	Direction of current at maximum ebb	DEC,dec
	Time of start of current slack before flood	TSF,tsf
	Time of end of current slack before flood	TEF, tef
	Time of start of current slack before ebb	TSE, tse
	Time of end of current slack before ebb	TEE, tee
Group 3	Water level at forecast projection time of nn hrs	Hnn, hnn
(Values from a Forecast)	Current speed at forecast projection time of nn hrs	Unn, unn
	Current direction at forecast projection time of nn hrs	Dnn, dnn
	Salinity at forecast projection time of nn hrs	Snn, snn
	Water temperature at forecast projection time of nn hrs	Tnn, tnn

Table 3. Skill assessment statistics (Hess et al., 2003).

Variable	Explanation
Error	The error is defined as the 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 ±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 2 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 2 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.
WOF(X)	Worst Case Outlier Frequency. Fraction (percentage) of errors that, given an error of magnitude exceeding X, either (1) the simulated value of water level is greater than the astronomical tide and the observed value is less than the astronomical tide, or (2) the simulated value of water level is less than the astronomical tide and observed value is greater than the astronomical tide.
SKILL	Index of Agreement (defined by Willmott and Wicks, 1980, Willmott, 1981)

$$SKILL = 1 - \frac{\sum_{i=1}^{N}(M_i - O_i)^2}{\sum_{i=1}^{N}(|M_i - \overline{M}| + |O_i - \overline{O}|)^2}$$

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

CF(X) ε90%
POF(2X) δ1%
NOF(2X) δ1%
MDPO(2X) δN
MDNO(2X) δN

The NOS-accepted error criteria (X) are:

- 15 cm or 10% of tide range for water level
- 0.26 meter per second (m/s) for surface currents
- Degree Celsius (°C) for water temperature

The accepted N (duration) is 24 hours.

In addition, a slightly different measure of model skill defined by Willmott (1981) and used by Warner et al. (2005) in a ROMS hydrodynamic simulation of the Hudson River was also computed for model comparison. Following Willmott, it takes the form:

$$Skill = 1 - \frac{\sum \left| X_{model} - X_{obs} \right|^2}{\sum \left(\left| X_{model} - \overline{X}_{obs} \right| + \left| X_{obs} - \overline{X}_{obs} \right| \right)^2}$$

where X represents the modeled variable of water level or temperature. This parameter, called the "index of agreement" by Willmott, is a relative average error and bounded measure. Perfect agreement between model results and observations will yield a skill of one and complete disagreement yields a skill of zero.

Unfortunately, no currents and salinity observations were collected during this period. Due to the large tidal range in Cook Inlet (about 10 m at Anchorage), the error criteria X is set to 10% of tide range for water levels (48 cm for Seldovia, 55 cm for Nikiski, 77 cm for Anchorage, 21 cm for Kodiak Island, and 29 cm for Alitak) for water levels, 0.26 m/s (0.5 knot) for currents, 3.0 degrees for water temperature, and 3.5 practical salinity units or PSU for salinity.

Data Sources

Observations were collected from five National Water Level Observation Network (NWLON) stations (Figure 8). Observations of water levels and water temperature from those stations are used in the skill assessment to compare with the model results.

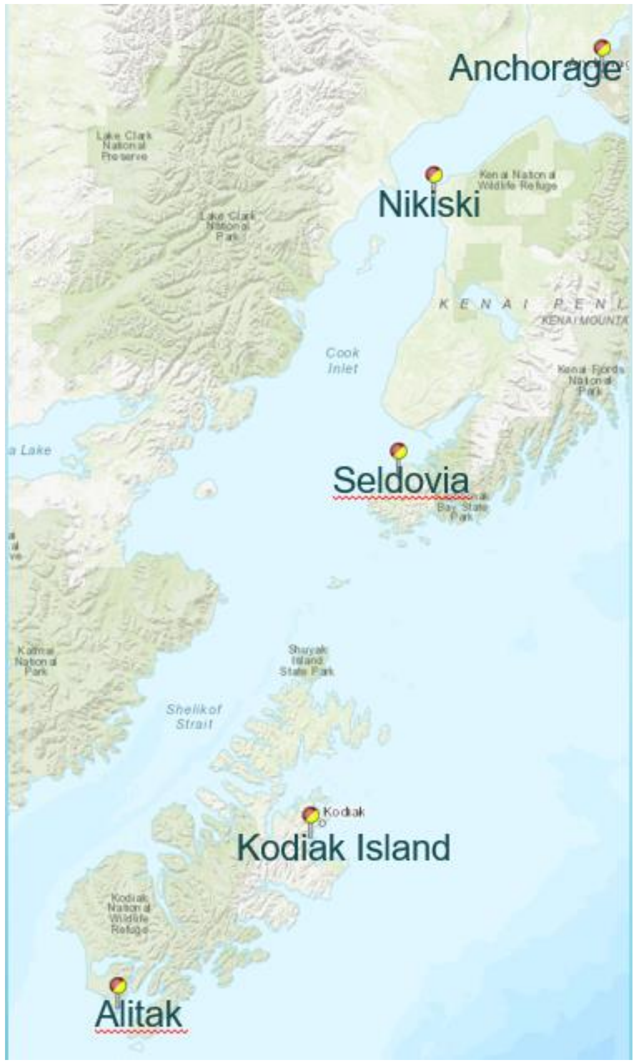


Figure 8. The locations of observation stations used for model skill assessment.

3.3 Nowcast and Forecast Skill Assessment

The skill assessment was conducted using 6-minute time series of CIOFS pseudo-operational nowcast and forecast output from January 1, 2019–October 31, 2020. Generally, RMSE, CF, NOF, POF, MDNO, and MDPO (defined in table 3) at each station satisfy the error criteria for most variables in both nowcast and forecast scenarios.

Results of Water Level Skill Assessment

Table 4 shows the NOS skill assessment statistics for water level nowcasts at five water level stations. Figure 9 shows the RMSE and CF of water level nowcasts. In general, the model performs well; skill assessment scores are close to the target criteria defined by NOS (Hess et al., 2003) for water levels at most of the stations. The Willmott's indices of agreement are close to 1.0 at all water level stations. The water level mean differences between observations and model outputs (called "bias" here) and RMSE of water levels (46.6 cm and 56.1 cm, respectively at Anchorage) are larger in the Cook Inlet upper bay. Amplitudes of high water-levels and low water-levels have a similar pattern as 6-minute water levels—with the maximum RMSE of 54.7 cm and 50.6 cm for high and low water levels at Anchorage. The timing of modeled high water-levels is generally earlier than the observations at most of the stations with a maximum high water time difference of about 24 minutes (min) at Anchorage. The time of modeled low water levels is generally very close to the observations at all stations with a maximum low water time difference of less than 10 min.

Table 4. nowcast water level skill assessment statistics: Bias (model-obs in m), RMSE (cm), CF (%), NOF (%), POF (%), and index of agreement (SKILL). NOS error criteria X (m)=10 % of tidal elevation range.

Station	X	BIAS	RMSE	NOF	CF	POF	SKILL
Anchorage							
model-obs	0.75 m	0.466	0.561	0.0	83.1	0.0	0.99
AHW-ahw	0.75 m	0.547	0.577	0.0	90.0	0.0	
ALW-alw	0.75 m	0.506	0.556	0.0	92.8	0.1	
THW-thw	0.50 hr	-0.399	0.446	0.2	60.8	0.1	
TLW-tlw	0.50 hr	-0.071	0.179	0.0	98.1	0.1	
Nikiski							
model-obs	0.54 m	0.155	0.296	0.0	93.5	0.0	0.99
AHW-ahw	0.54 m	0.290	0.321	0.0	98.1	0.0	
ALW-alw	0.54 m	-0.028	0.164	0.0	100.0	0.0	
THW-thw	0.50 hr	-0.184	0.253	0.0	92.8	0.1	
TLW-tlw	0.50 hr	-0.119	0.194	0.0	96.4	0.0	
Seldovia							
model-obs	0.47 m	0.158	0.270	0.0	92.8	0.0	0.99
AHW-ahw	0.47 m	0.270	0.304	0.0	94.9	0.0	
ALW-alw	0.47 m	0.083	0.186	0.0	99.4	0.0	
THW-thw	0.50 hr	-0.169	0.240	0.0	95.5	0.1	
TLW-tlw	0.50 hr	-0.131	0.207	0.0	96.5	0.0	
Kodiak Island							
model-obs	0.20 m	0.072	0.155	0.1	80.8	0.2	0.99
AHW-ahw	0.20 m	0.042	0.111	0.1	95.8	0.1	
ALW-alw	0.20 m	0.118	0.161	0.0	77.9	0.1	
THW-thw	0.50 hr	-0.268	0.418	1.1	72.0	0.1	
TLW-tlw	0.50 hr	-0.165	0.360	0.6	80.0	0.1	
Alitak							
model-obs	0.28 m	0.015	0.164	0.0	92.5	0.0	1.00
AHW-ahw	0.28 m	0.134	0.176	0.0	92.2	0.0	
ALW-alw	0.28 m	-0.119	0.167	0.0	91.9	0.0	
THW-thw	0.50 hr	0.066	0.224	0.1	95.0	0.0	
TLW-tlw	0.50 hr	-0.065	0.235	0.1	94.6	0.0	

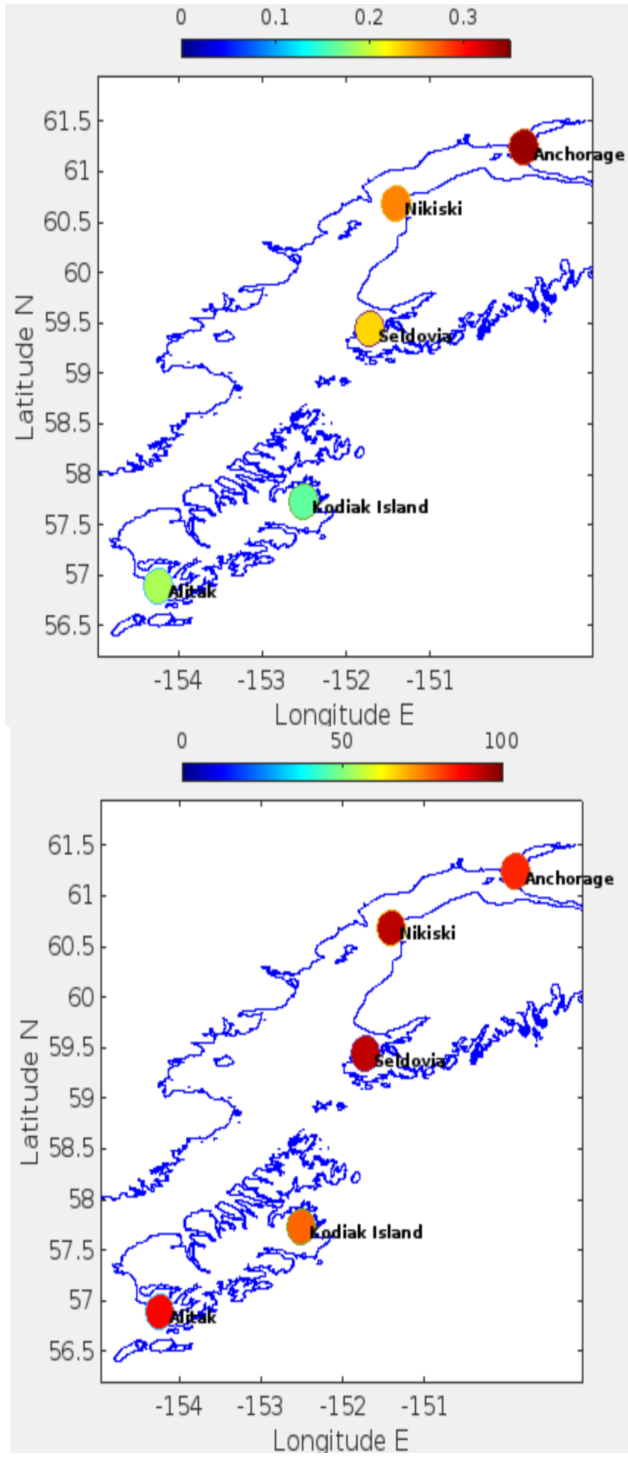


Figure 9. Root Mean Square Error (RMSE) and Central Frequency (CF) of CIOFS water level nowcasts.

Figure 10 shows RMSE and CF variations over the duration of the forecast at the five stations. As tide ranges are much larger in the upper Cook Inlet (~12 m at Anchorage) than the lower Cook Inlet (~5m at Alitak), RMSE decreases from the upper bay at Anchorage (56 cm) to the open waters at Kodiak Island (15.6 cm) and Alitak (16.4 cm). CF variations over 48 forecast hours are very close to 90% for the five stations. Neither RMSE nor CF significantly degrades over the forecast period at the five stations Since tides are dominant in Cook Inlet and non-tidal residuals are relatively small, CIOFS is able to simulate water levels very well over the entire forecast period.

Time series comparisons of modeled and observed water level at the five stations are shown in Figures 11–15. Water level nowcasts generally agree with the observations at every station in both amplitude and phase. During the assessment period, the observations at Anchorage are generally lower than the modeled water levels with an averaged difference of 46.6 cm. The offset between observations and modeled water levels is consistent over the skill assessment period, and is probably caused by different datum references for observations (Mean Sea Level) and modeled water levels (so called "model zero", which is parallel to a geoid reference such as North American Vertical Datum 1988 (NAVD88)). In general, model zero is close to Mean Sea Level in coastal and offshore waters, but notably different from Mean Sea Level in estuaries and rivers. Water level ranges in Cook Inlet vary from about 12 m in the upper bay at Anchorage to about 9 m in the middle bay at Seldovia and to about 5–6 m in the lower bay at Kodiak Island and Alitak. Thirty-day running averaged water levels are also displayed in Figures 11–15 (green for observed water levels and blue for water level nowcasts). Long-term trends of observed and modeled water levels look very similar except for the offset between them.

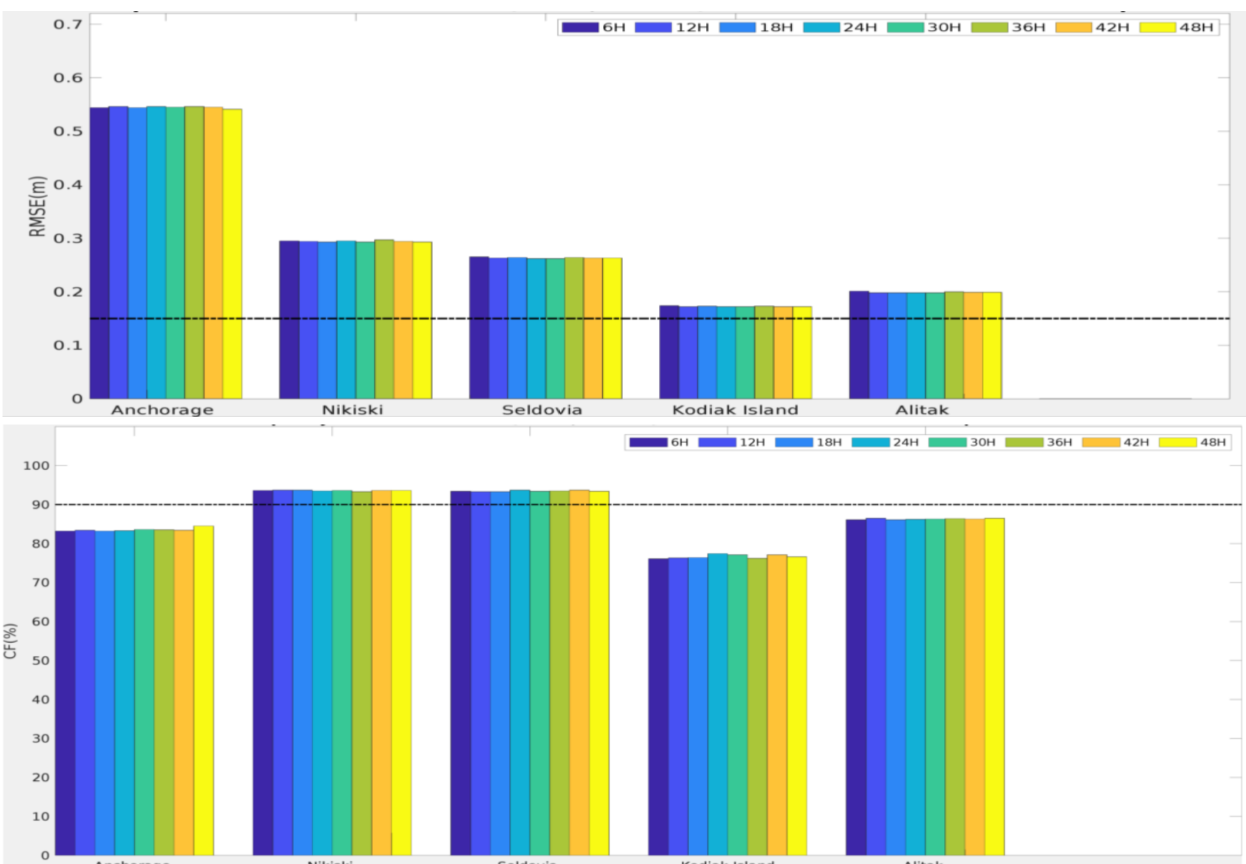


Figure 10. Root Mean Square Error (RMSE) and Central Frequency (CF) of CIOFS water level forecasts.

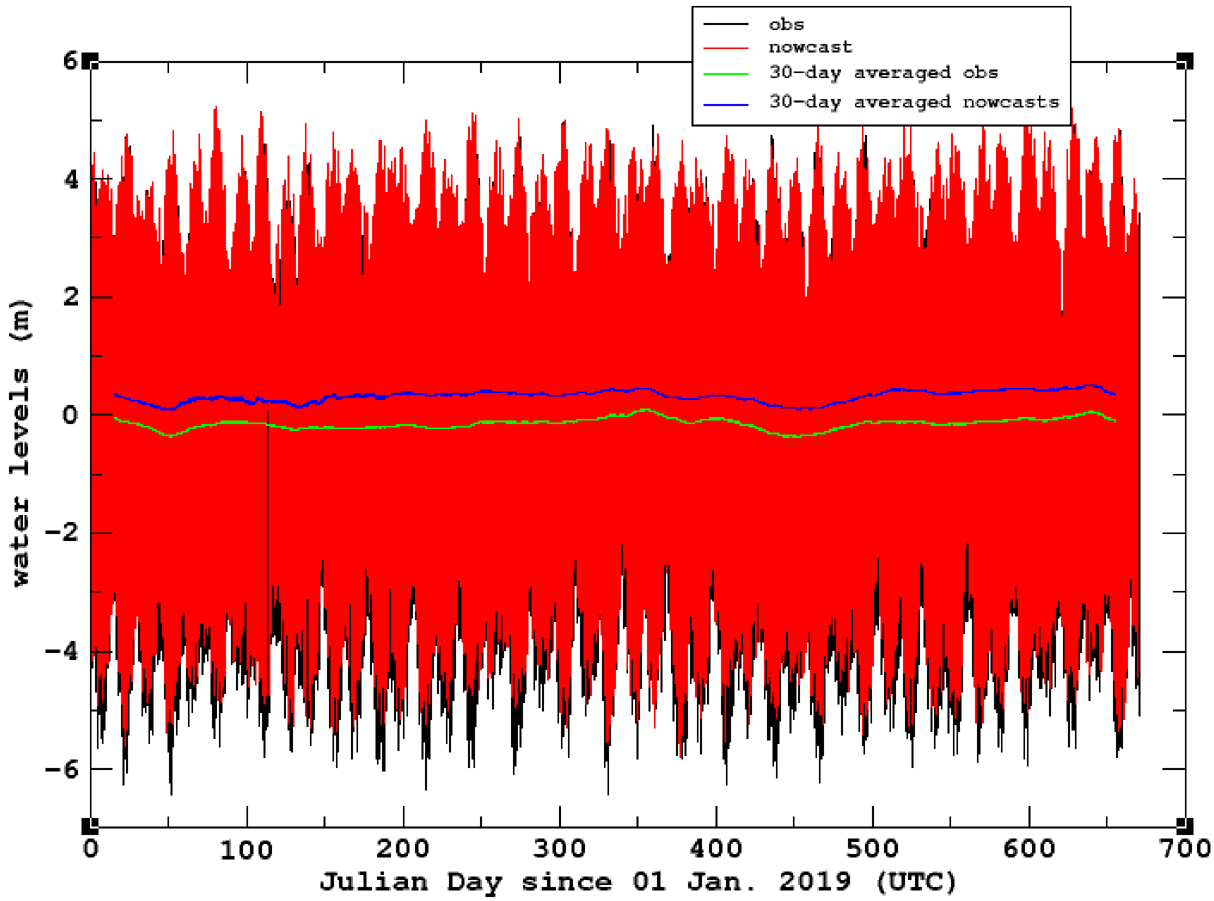


Figure 11. Comparison of water level observations and water level nowcasts at Anchorage.

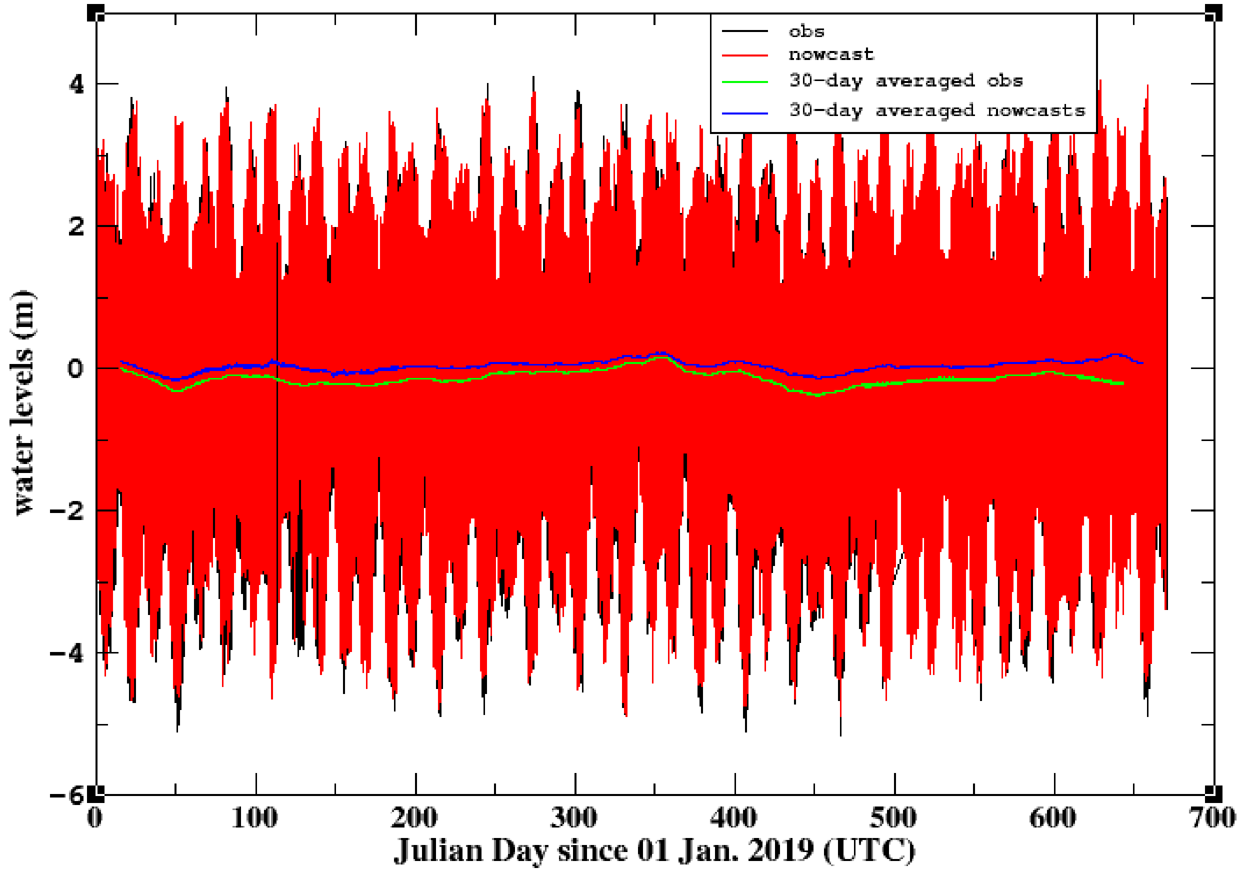


Figure 12. Comparison of water level observations and water level nowcasts at Nikiski.

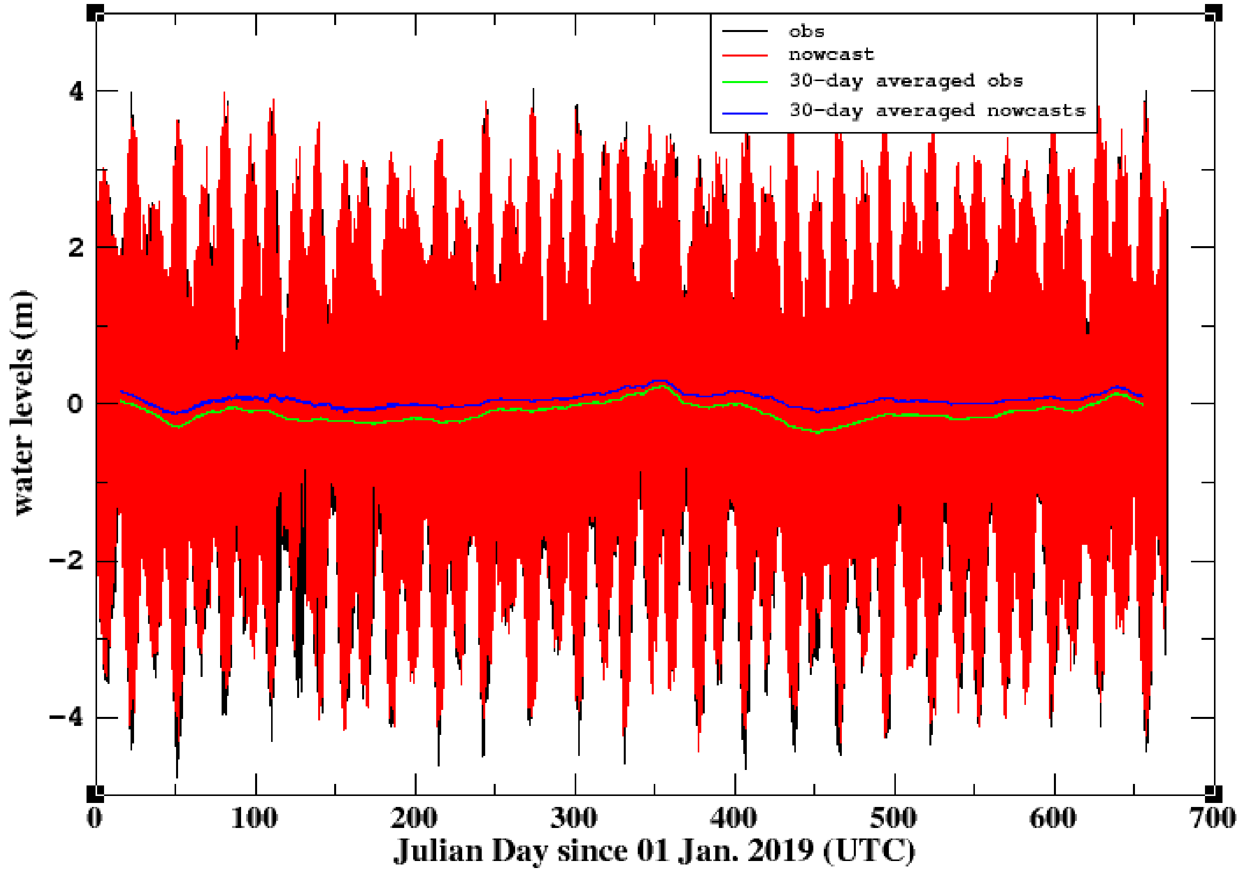


Figure 13. Comparison of water level observations and water level nowcasts at Seldovia.

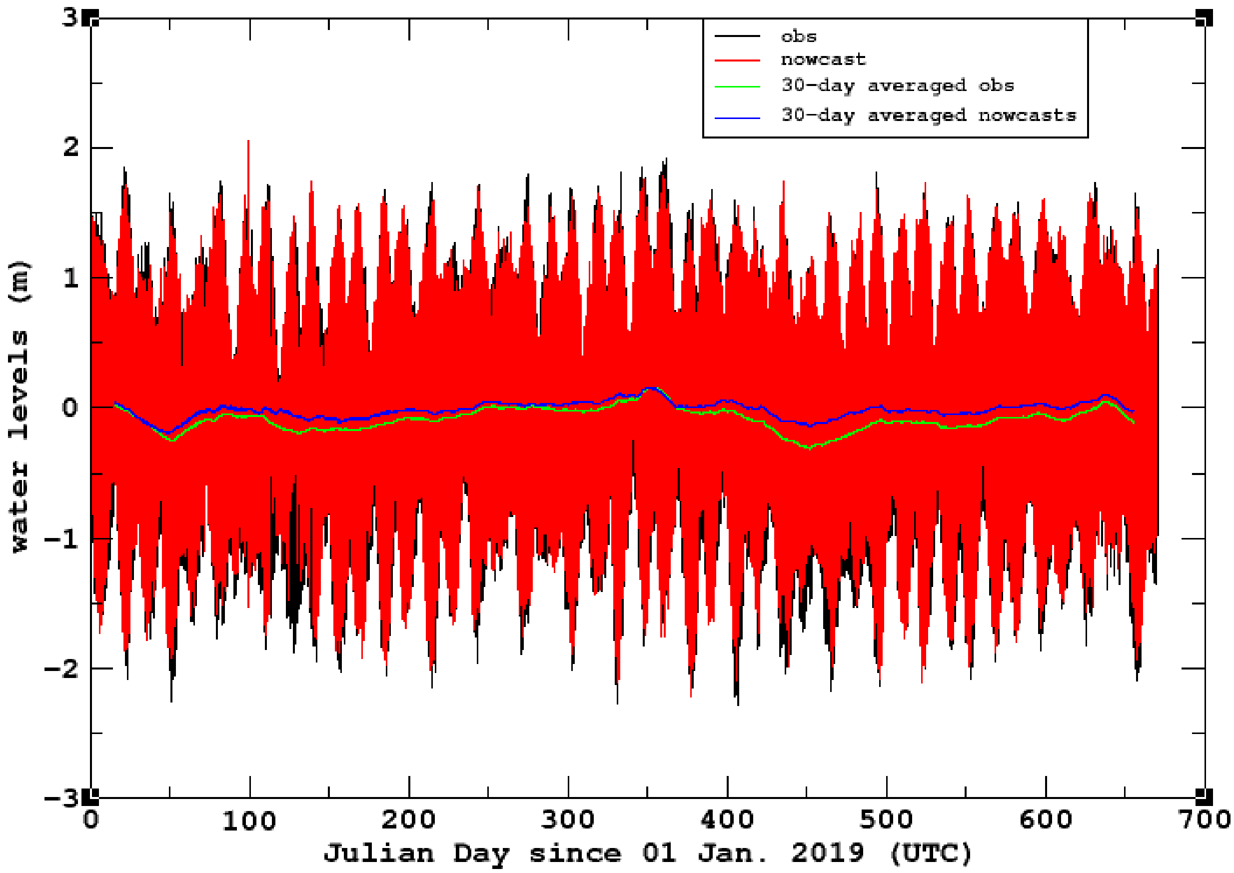


Figure 14. Comparison of water level observations and water level nowcasts at Kodiak Island.

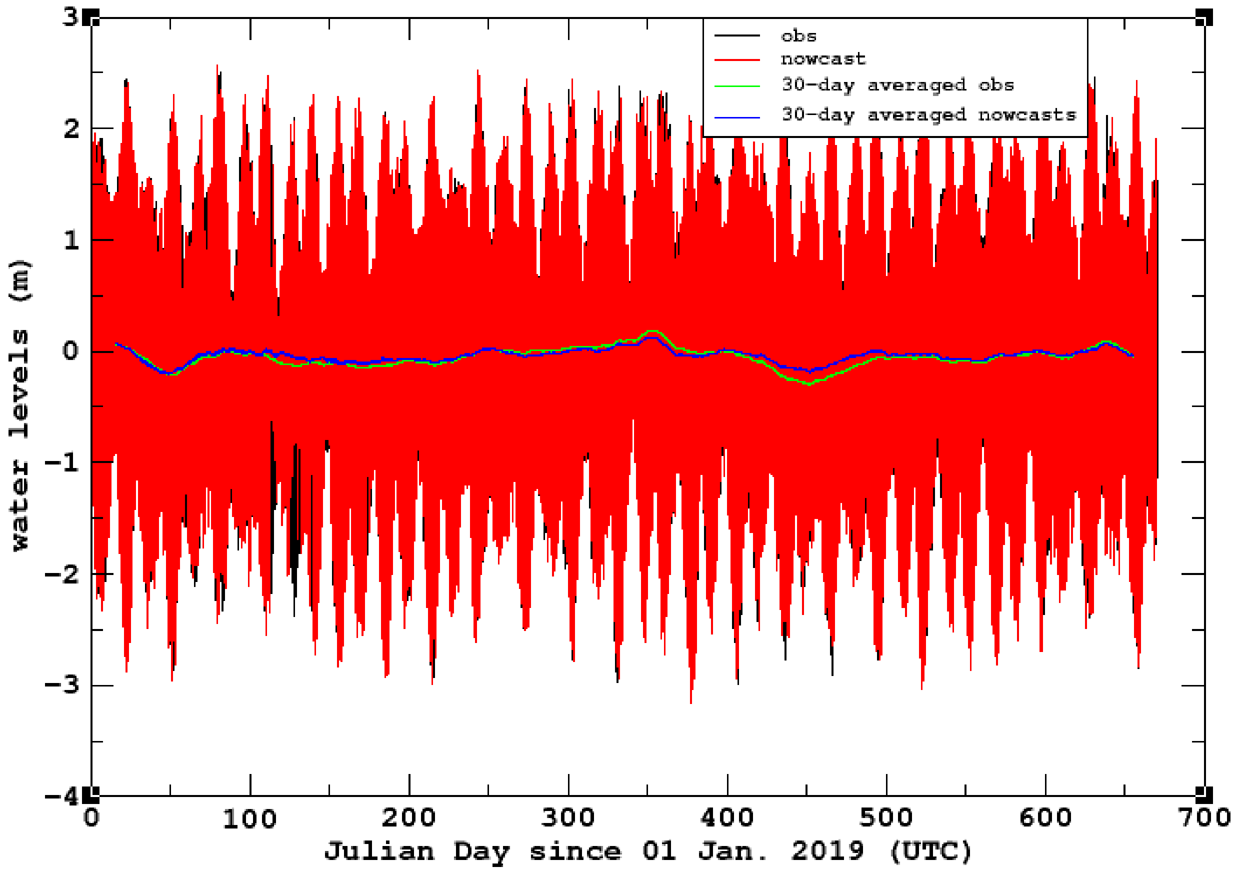


Figure 15. Comparison of water level observations and water level nowcasts at Alitak.

Tidal Constituent Comparison

Both water level observations and CIOFS water level nowcasts during the period of January 1, 2019–October 31, 2020 were harmonically analyzed using a least squared method for tidal constituents and compared with the observed tide constituents at 11 NWLON tide gauges. The tide amplitude comparison of the most significant constituents (M2, S2, N2, O1, K1, P1) are listed in Table 5. Amplitudes of all six major constituents are very close, but phase differences are large at Anchorage. The maximum difference between observed and simulated tidal constituent amplitude occurs at North Foreland with 33.1 cm for M2.

Table 5. Comparison of tidal constituent amplitudes and epochs of water levels

Station	M2		S2		N2		K1		O1		P1	
	anp	pha	anp	pha	anp	pha	anp	pha	anp	pha	anp	pha
Anchorage												
Cba.	350.5	0.0	97.7	0.1	59.7	0.1	67.1	0.1	37.1	0.0	17.6	0.0
Model	348.2	102.5	94.2	146.2	57.1	78.2	65.8	339.4	36.8	322.1	16.0	344.5
Cba-Model	2.3	-102.5	3.5	-146.1	2.6	-78.1	1.3	20.7	0.3	37.9	1.6	15.5
Nikiaki												
Cba.	250.1	32.3	86.1	63.1	49.5	1.6	64.4	307.9	38.3	291.1	18.5	308.2
Model	261.2	28.2	85.5	61.6	49.9	359.5	64.8	302.0	38.9	286.1	17.6	303.2
Cba-Model	-11.1	4.1	0.6	1.5	-0.4	2.1	-0.4	5.9	-0.6	5.0	0.9	5.0
Seldovia												
Cba.	222.6	232.9	83.2	358.0	46.1	297.8	55.9	280.0	34.4	264.2	17.6	278.0
Model	231.8	319.4	82.8	354.1	47.1	294.4	57.6	273.7	35.6	258.4	17.2	273.1
Cba-Model	-9.2	4.5	0.4	3.9	-1.0	3.4	-1.7	6.3	-1.2	5.8	0.4	4.9
Kodiak Island												
Cba.	96.5	307.4	32.4	340.9	20.0	283.4	39.7	288.5	25.7	272.7	12.6	284.2
Model	95.1	301.4	30.7	333.5	19.4	277.6	40.3	279.5	26.1	265.1	12.3	276.3
Cba-Model	1.4	6.0	1.7	7.4	0.6	5.8	-0.6	9.0	-0.4	7.6	0.3	7.9
Alitak												
Cba.	134.9	314.2	48.6	348.5	28.4	291.3	49.5	280.4	30.9	265.3	15.6	277.4
Model	145.7	310.6	50.5	346.7	29.7	288.8	50.4	277.3	32.8	261.7	14.9	274.0
Cba-Model	-10.8	3.6	-1.9	1.8	-1.3	2.5	-0.9	3.1	-1.9	3.6	0.7	3.4

Port Mackenzie												
Cba.	361.2	105.9	100.9	151.3	58.4	83.4	63.3	340.9	39.1	328.5	20.9	340.0
Model	348.8	104.4	94.1	148.5	57.0	80.2	65.7	340.3	36.9	322.7	15.9	345.4
Cba-Model	12.4	1.5	6.8	2.8	1.4	3.2	-2.4	0.6	2.2	5.8	5.0	-5.4
Fire Island												
Cba.	331.2	96.7	94.1	139.4	55.6	74.0	63.1	336.4	40.5	323.5	20.9	335.5
Model	345.2	88.5	97.2	129.4	58.2	62.5	67.5	330.9	38.6	314.0	17.1	335.5
Cba-Model	-14.0	8.2	-3.1	10.0	-2.6	11.5	-4.4	5.5	1.9	9.5	3.8	0.0
Point Possession												
Cba.	313.1	87.2	95.6	122.9	56.3	50.1	67.5	326.1	46.4	309.6	22.3	324.9
Model	338.6	77.6	97.3	116.8	58.0	50.9	67.1	324.6	38.3	307.6	17.1	328.5
Cba-Model	-25.5	9.6	-1.7	6.1	-1.7	-0.8	0.4	1.5	8.1	2.0	5.2	-3.6
North Foreland												
Cba.	248.0	75.1	74.0	108.9	44.8	39.7	59.2	327.3	36.2	313.4	19.6	326.2
Model	281.1	66.9	84.1	102.2	50.3	37.8	65.5	319.1	38.4	302.0	17.1	321.5
Cba-Model	-33.1	8.2	-10.1	6.7	-5.5	1.9	-6.3	8.2	-2.2	11.4	2.5	4.7
Kaligan Island												
Cba.	227.2	15.2	88.5	47.2	50.9	346.5	58.5	301.9	38.2	284.3	19.4	300.6
Model	240.8	11.8	84.7	44.7	48.6	343.3	63.8	295.6	39.4	279.2	18.1	295.6
Cba-Model	-13.6	3.4	3.8	2.5	2.3	3.2	-5.3	6.3	-1.2	5.1	1.3	5.0
Ninilchik												
Cba.	237.1	353.8	88.9	25.0	47.7	320.6	60.4	291.8	35.0	275.8	20.0	290.6
Model	251.3	348.3	88.7	22.7	50.5	321.9	62.3	285.0	38.3	269.5	18.0	285.2
Cba-Model	-14.2	5.5	0.2	2.3	-2.8	-1.3	-1.9	6.8	-3.3	6.3	2.0	5.4

Results of Surface Water Temperature Skill Assessment

Model evaluation and skill assessment were conducted at the five NWLON stations and three National Data Buoy Center (NDBC) buoys. Modeled surface water temperatures generally agree well with observations at all locations, and seasonal variation is simulated well. Figure 16 demonstrates RMSE (left) and CF (right) of surface water temperature nowcasts at eight stations. Table 5 lists major statistics of near-surface water temperature nowcasts. The mean differences (bias) between the observed temperature and temperature nowcasts are less than 0.5 °C at most of the stations except at Anchorage. RMSE values are less than 2 °C at all stations except Anchorage, NOF and POF are zeros at all stations, and CF values are greater than 95% except Anchorage.

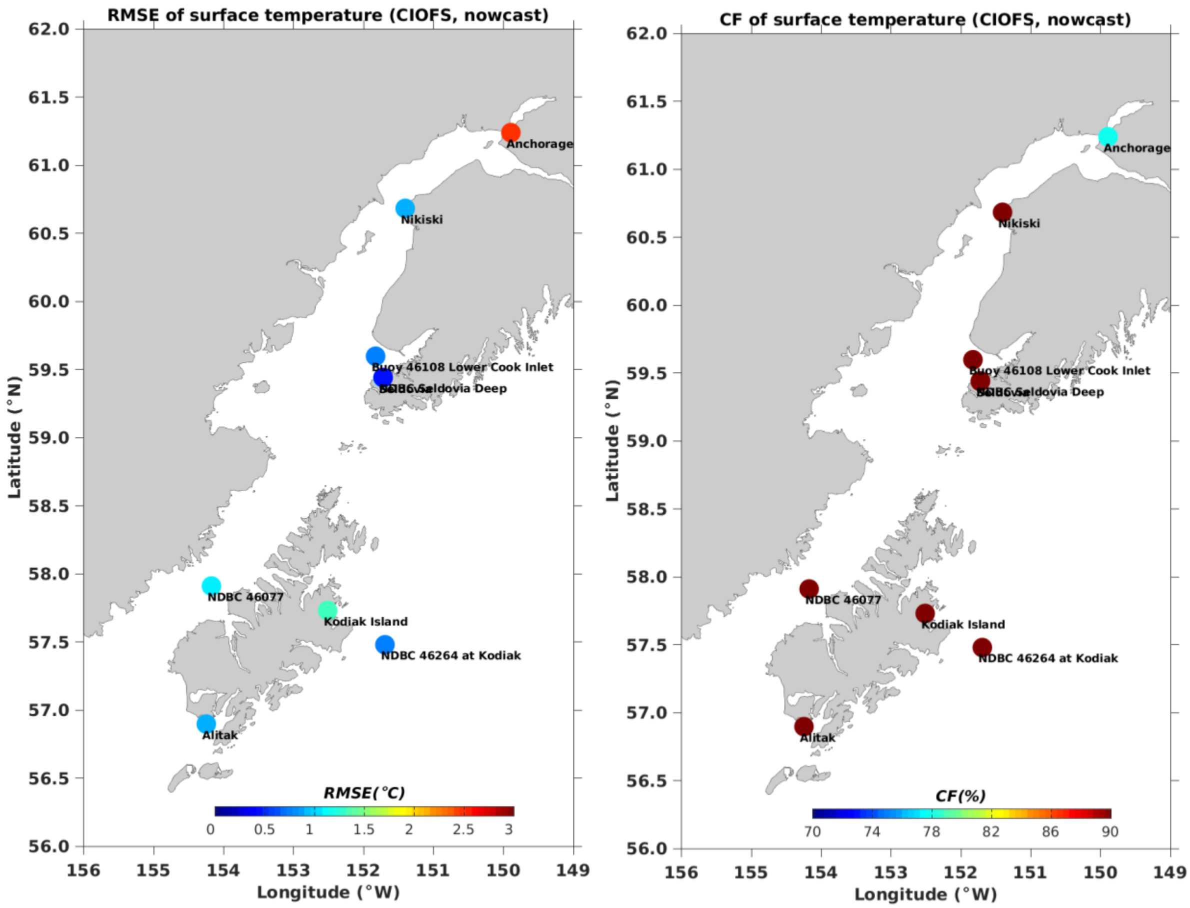
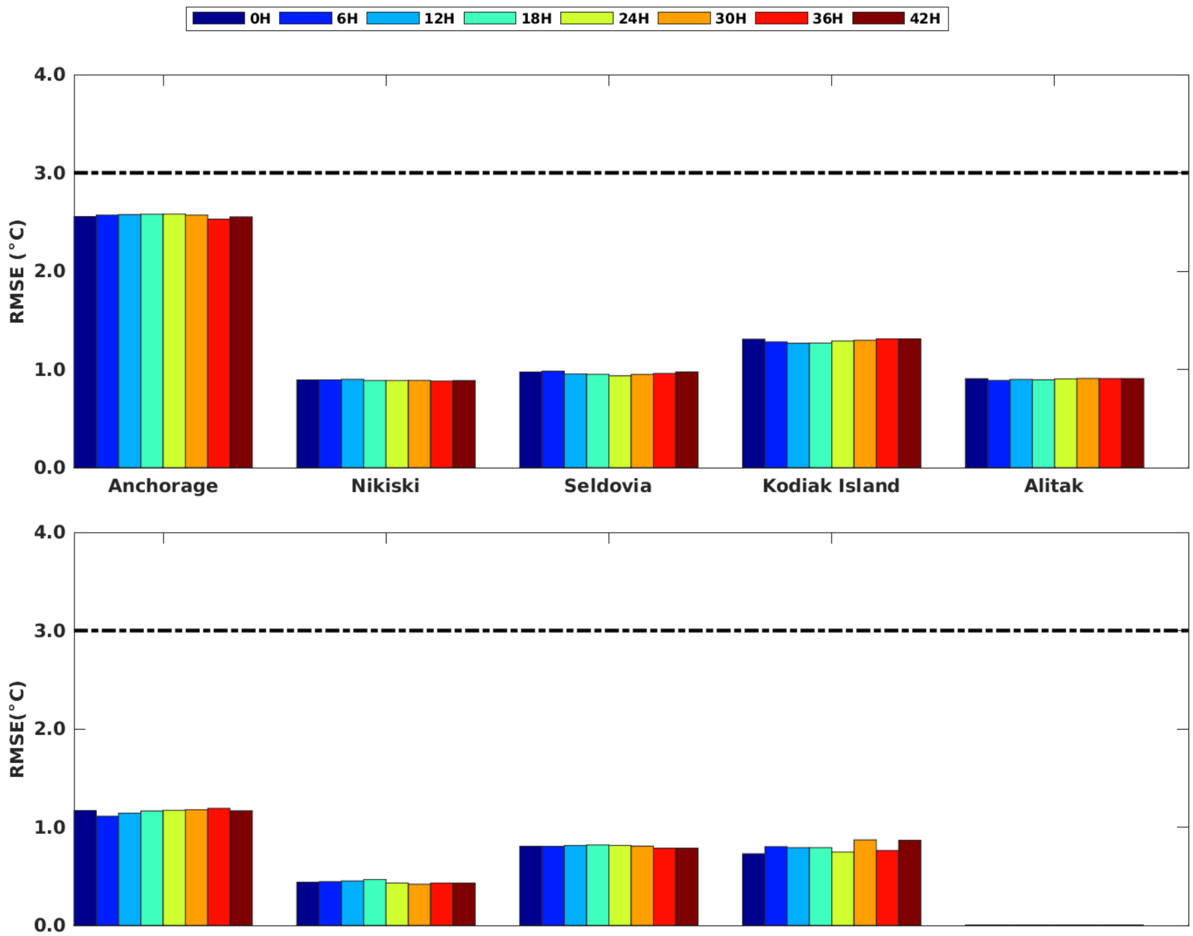


Figure 16. RMSE and CF of CIOFS water temperature nowcasts (note: Seldovia and NDBC SEQA2 are almost co-located).

Table 6. Nowcast temperature skill assessment statistics: RMSE (0 °C for temperature), CF (%), NOF (%), and POF (%), and index agreement (SKILL). NOS error criteria X=3 °C.

STATION	X	BIAS	RMSE	NOF	CF	POF	SKILL
Anchorage	3.0 c	1.236	2.281	0.0	79.2	0.9	0.98
Nikiski	3.0 c	0.261	0.792	0.0	99.9	0.0	1.00
Seldovia	3.0 c	-0.172	1.099	0.0	98.0	0.0	0.97
Kodiak Island	3.0 c	0.093	1.410	0.0	95.9	0.0	0.96
Alitak	3.0 c	-0.412	0.861	0.0	99.9	0.0	0.99
NDBC 46077	3.0 c	-0.106	1.001	0.0	98.8	0.0	0.98
NDBC SEQA2	3.0 c	-0.529	0.632	0.0	100.0	0.0	0.86
NDBC 46108	3.0 c	-0.325	0.786	0.0	99.4	0.0	0.97
NDBC 46264	3.0 c	-0.460	0.832	0.0	99.7	0.0	0.98

Figure 17 shows the variation of RMSE over 48 forecast hours at nine stations. The RMSE does not vary much over the forecast period, which means water temperature forecasts were not degraded over this 48 hour period. Figure 18 shows that the CF does not vary much over the forecast period. CF values are very close to 100 at all stations except Anchorage.



NDBC 46077 **NDBC SEQA2** **NDBC 46108** **NDBC 46264**

Figure 17. RMSE of water temperature forecasts.

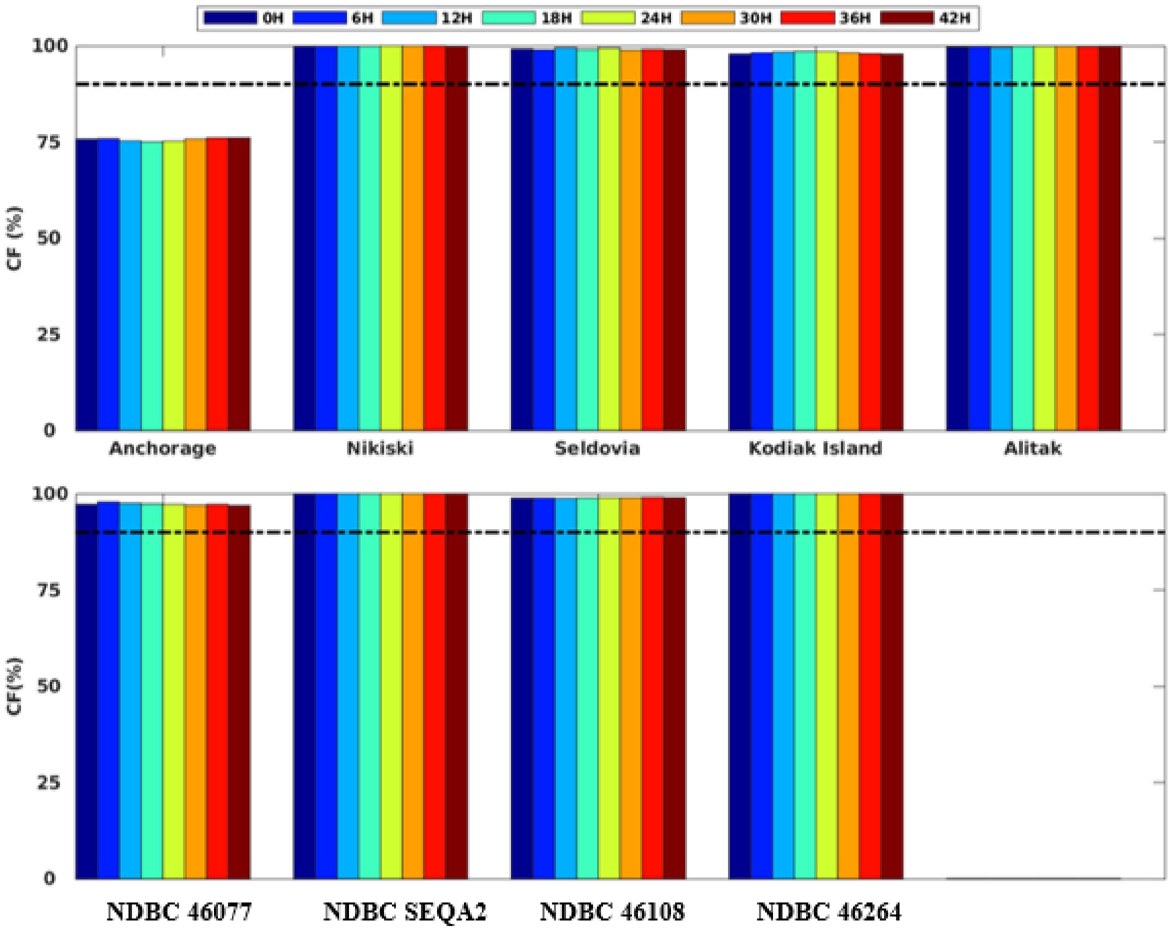


Figure 18. Central Frequency (CF) of surface water temperature forecasts over 48 forecast hours.

Further details of model skill assessment results at all stations can be found in the tables in Appendix B. As shown in the tables, all stations except Anchorage meet the NOS-required criteria for each statistic (CF, NOF, POF, MDNO and MDPO). The model was not able to sufficiently resolve the extreme tide ranges and strong tidal currents near Anchorage.

Time series comparisons of modeled nowcasts and observed water surface temperatures at all stations are shown in Figures 19–27. Modeled results generally agree with the observations for every station. CIOFS accurately simulates the annual temperature signal during the assessment period from January 1, 2019–November 1, 2020. However, at Anchorage, Figure 19 shows that CIOFS modeled water temperature is generally over-predicted (about 5 °C higher than observations) during summer, which causes the larger RMSE of 2.28.

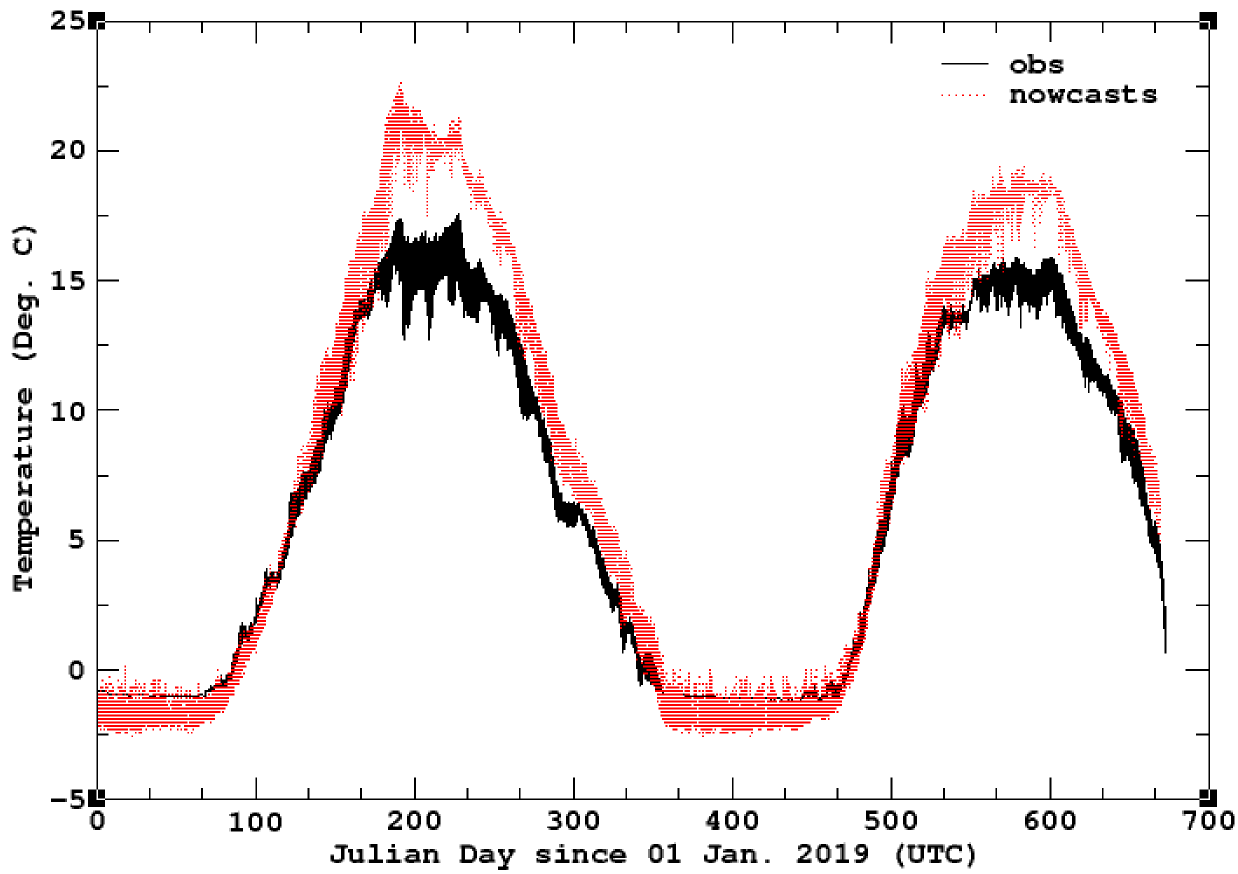


Figure 19. Comparison of water temperature observations and nowcasts at Anchorage.

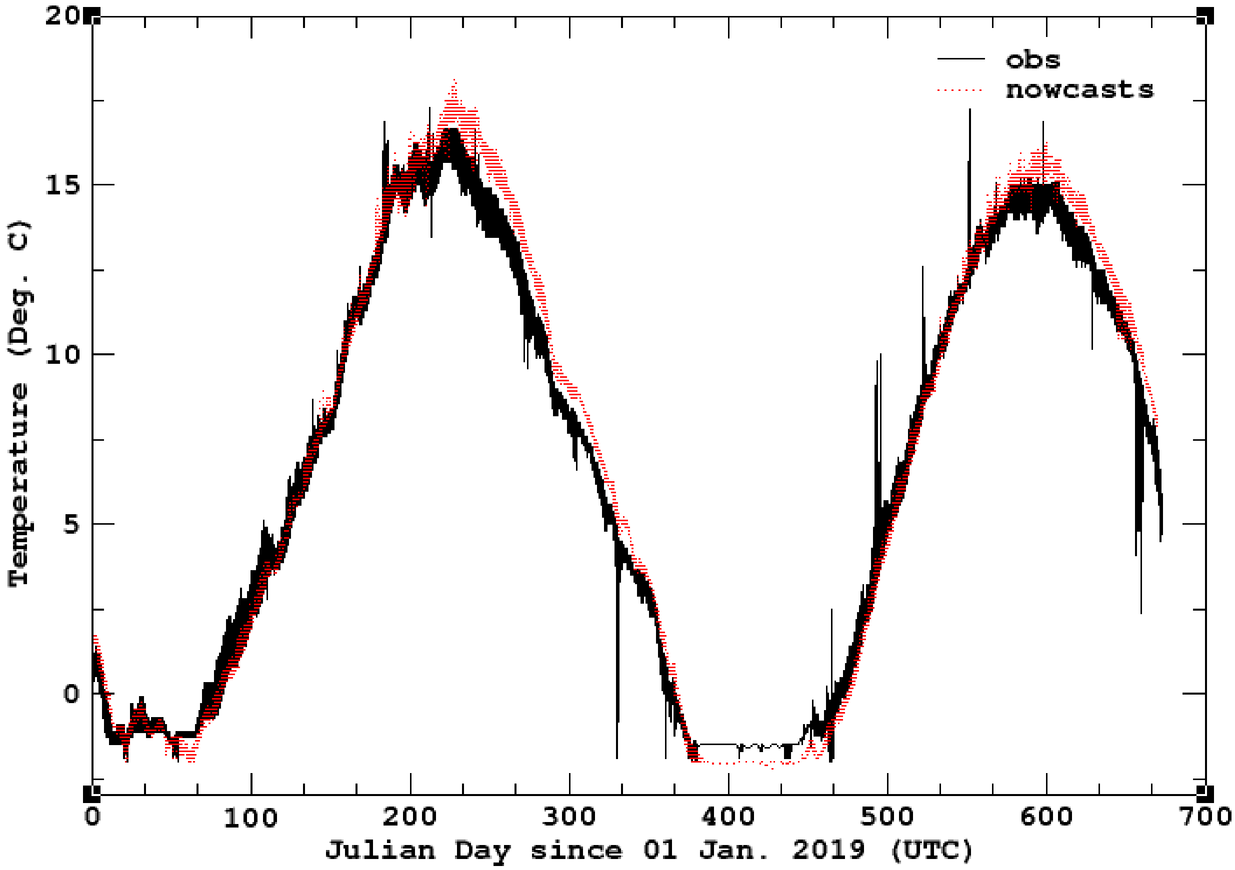


Figure 20. Comparison of water temperature observations and nowcasts at Nikiski.

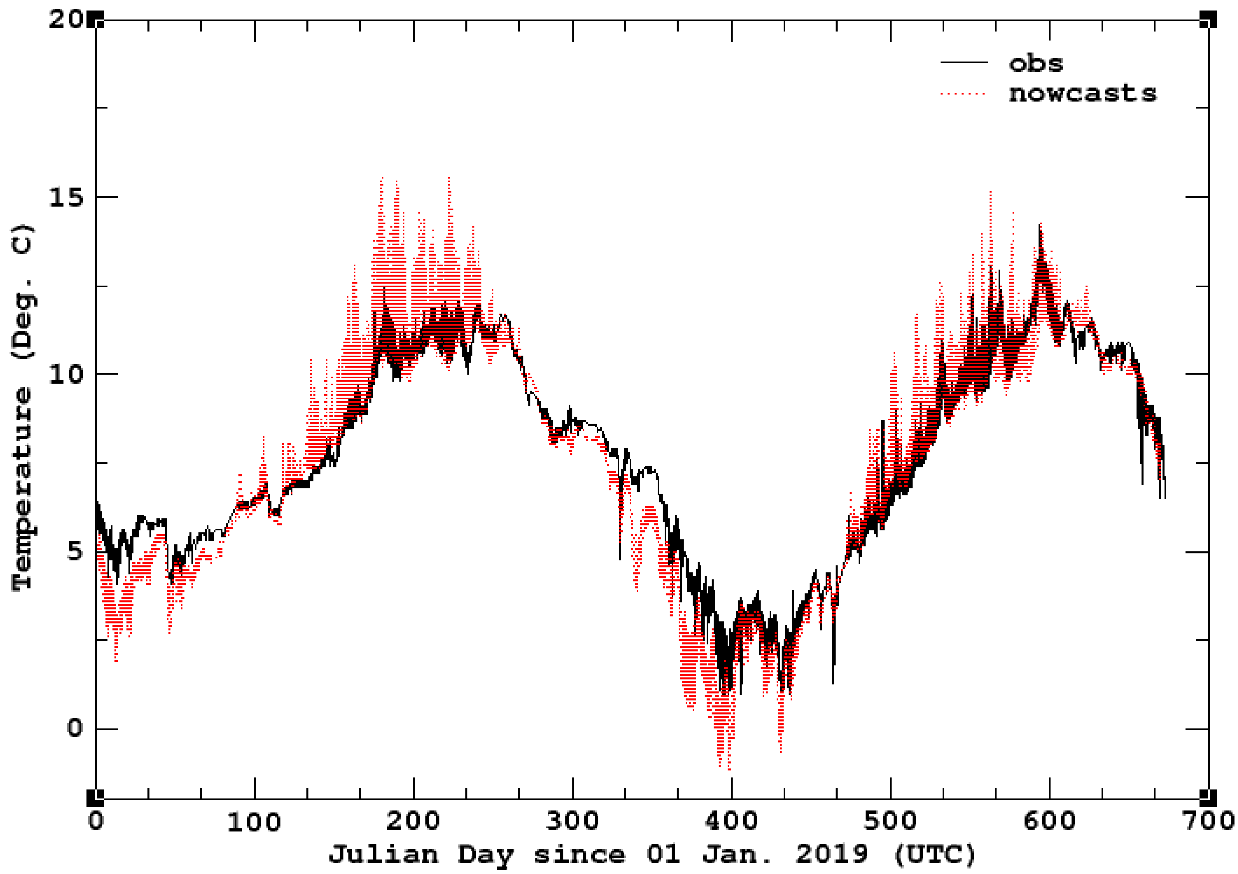


Figure 21. Comparison of water temperature observations and nowcasts at Seldovia.

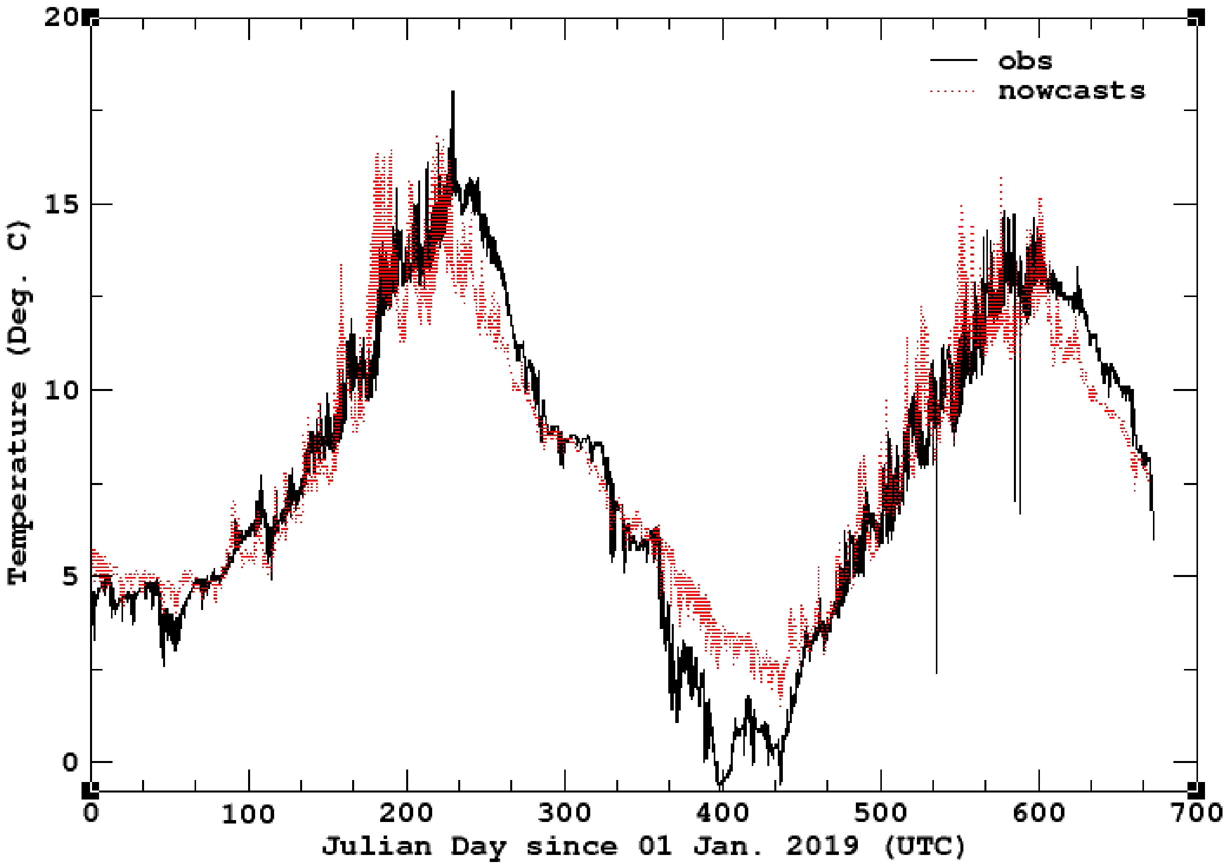


Figure 22. Comparison of water temperature observations and nowcasts at Kodiak Island.

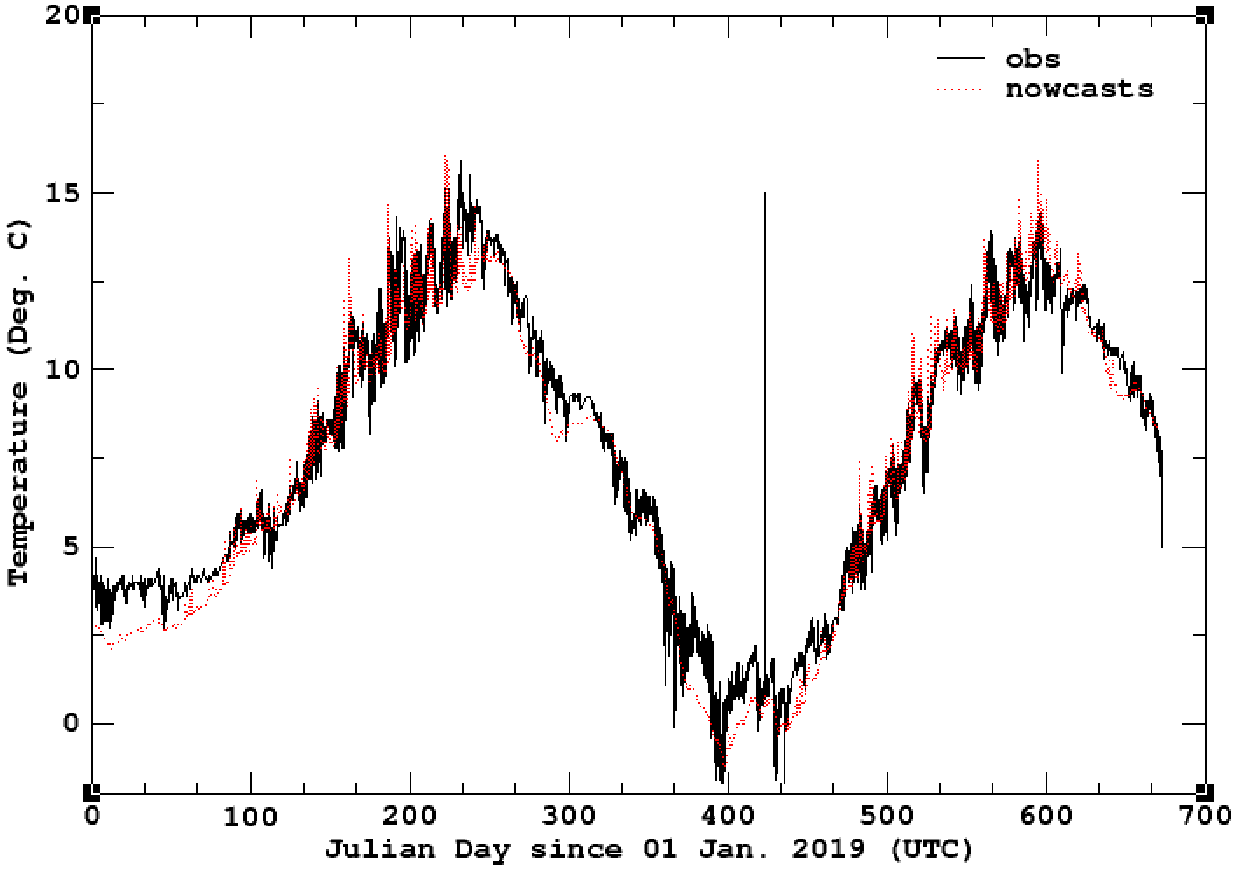


Figure 23. Comparison of water temperature observations and nowcasts at Alitak.

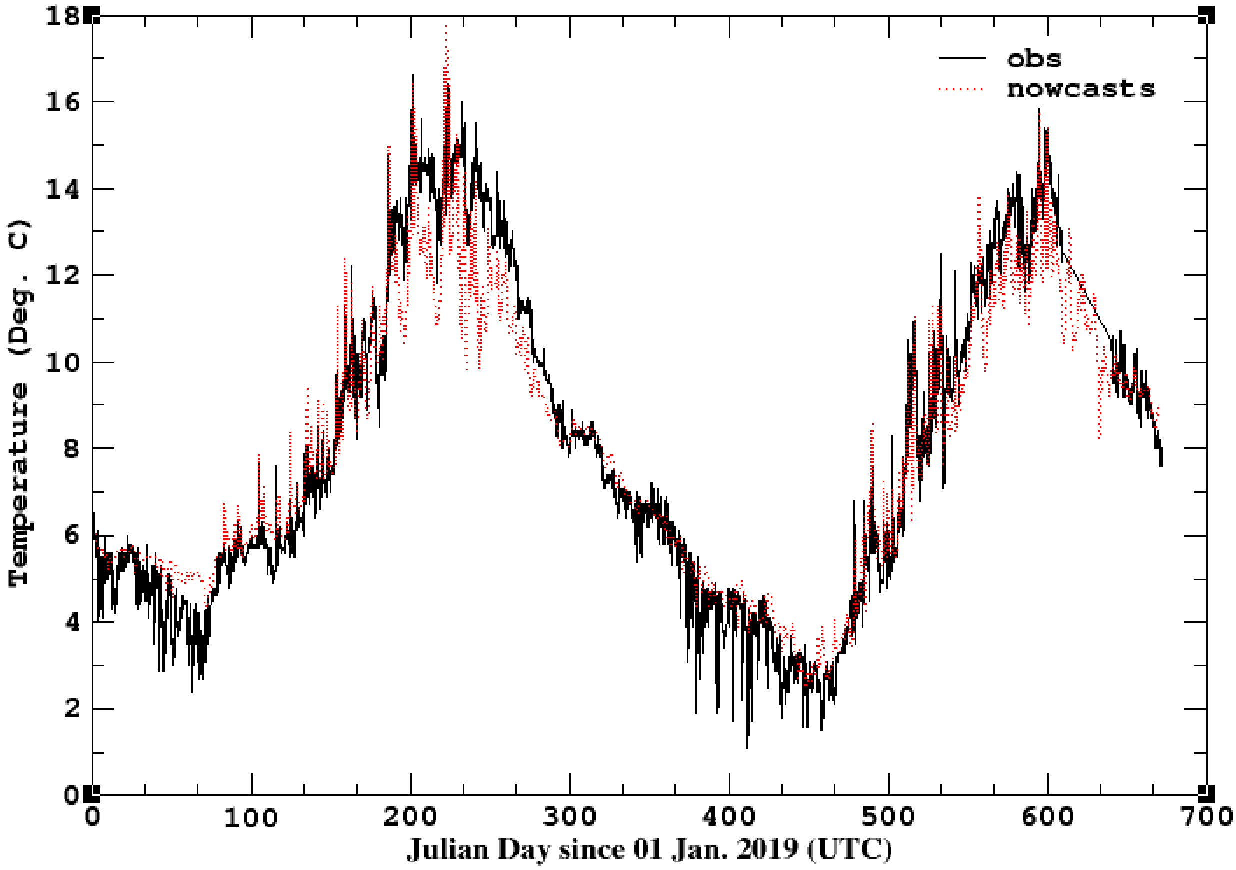


Figure 24. Comparison of water temperature observations (black) and nowcasts (red) at NDBC 46077.

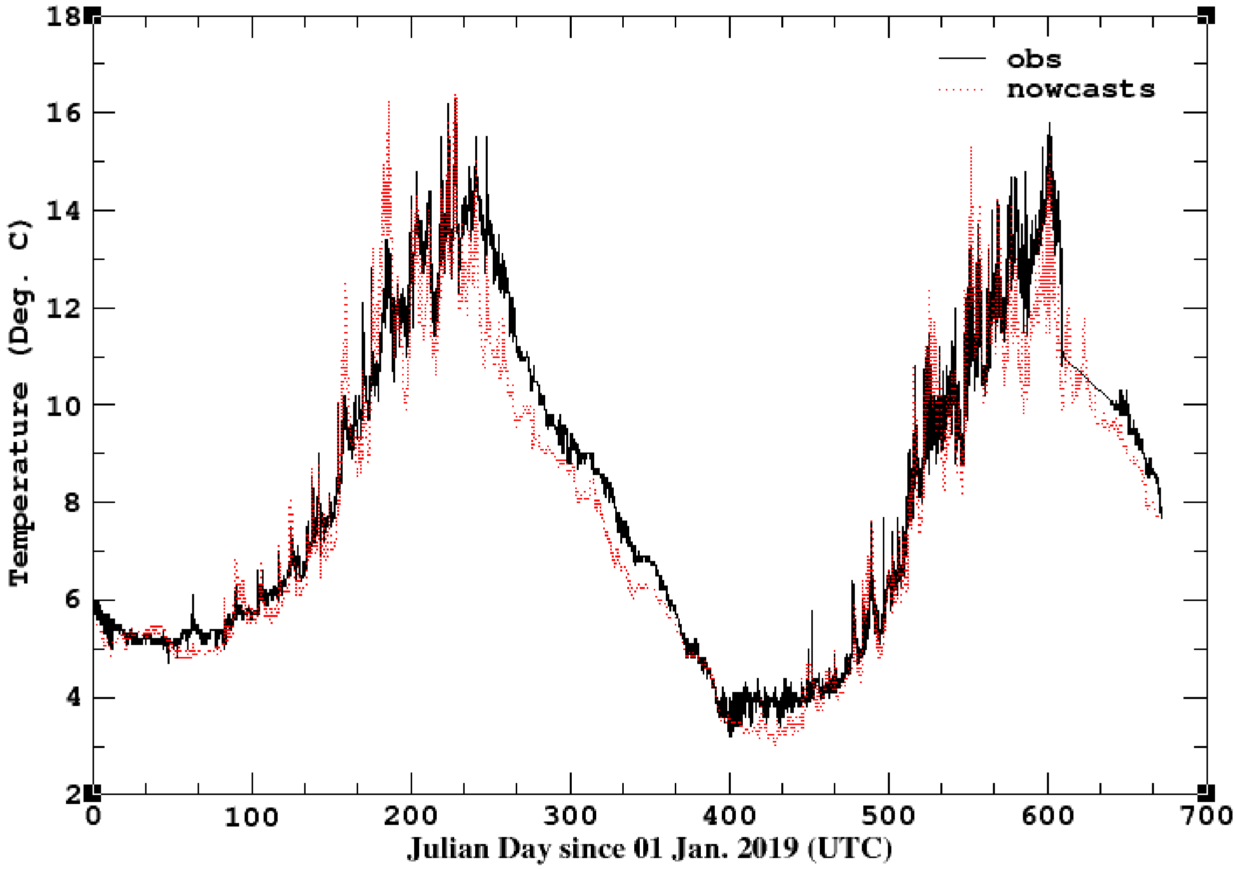


Figure 25. Comparison of water temperature observations (black) and nowcasts (red) at NDBC 46264.

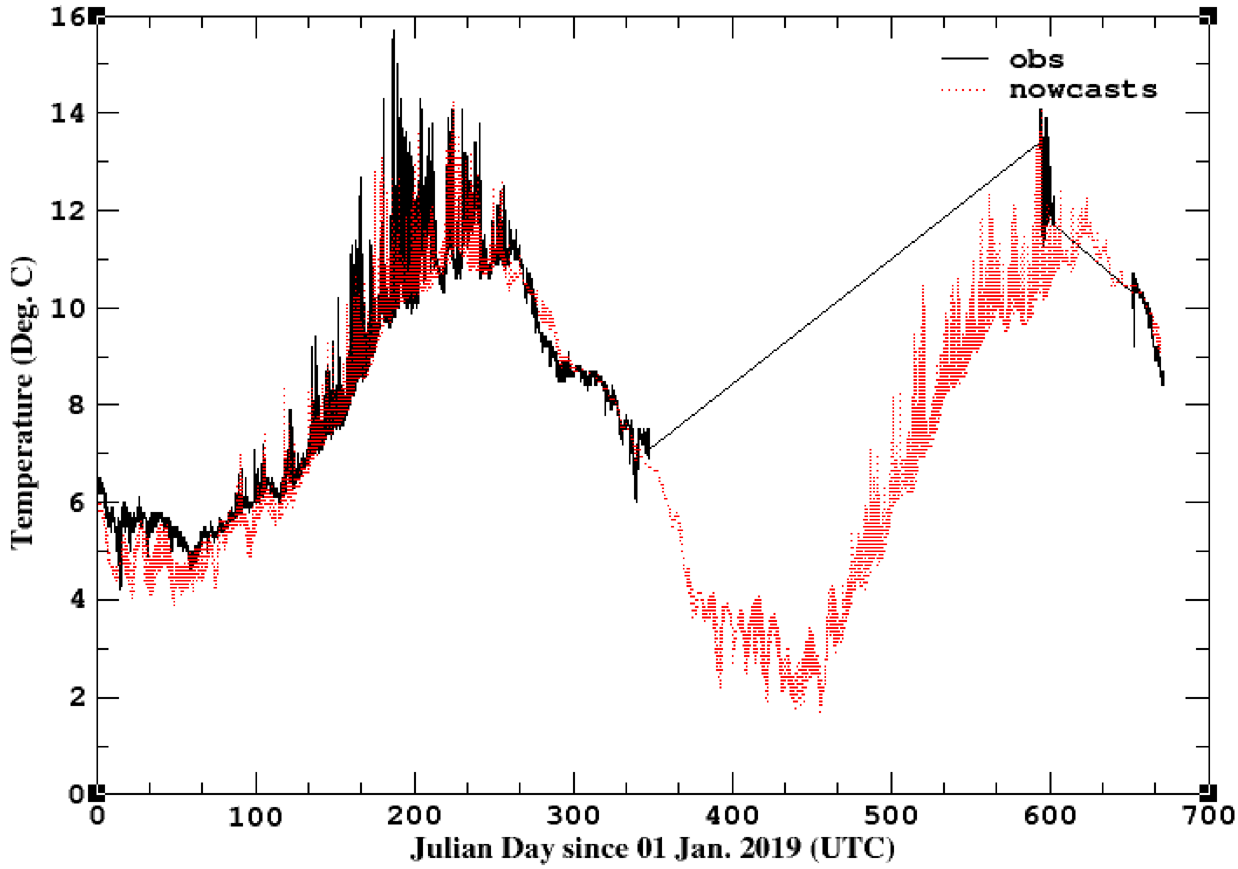


Figure 26. Comparison of water temperature observations (black) and nowcasts (red) at NDBC 46108.

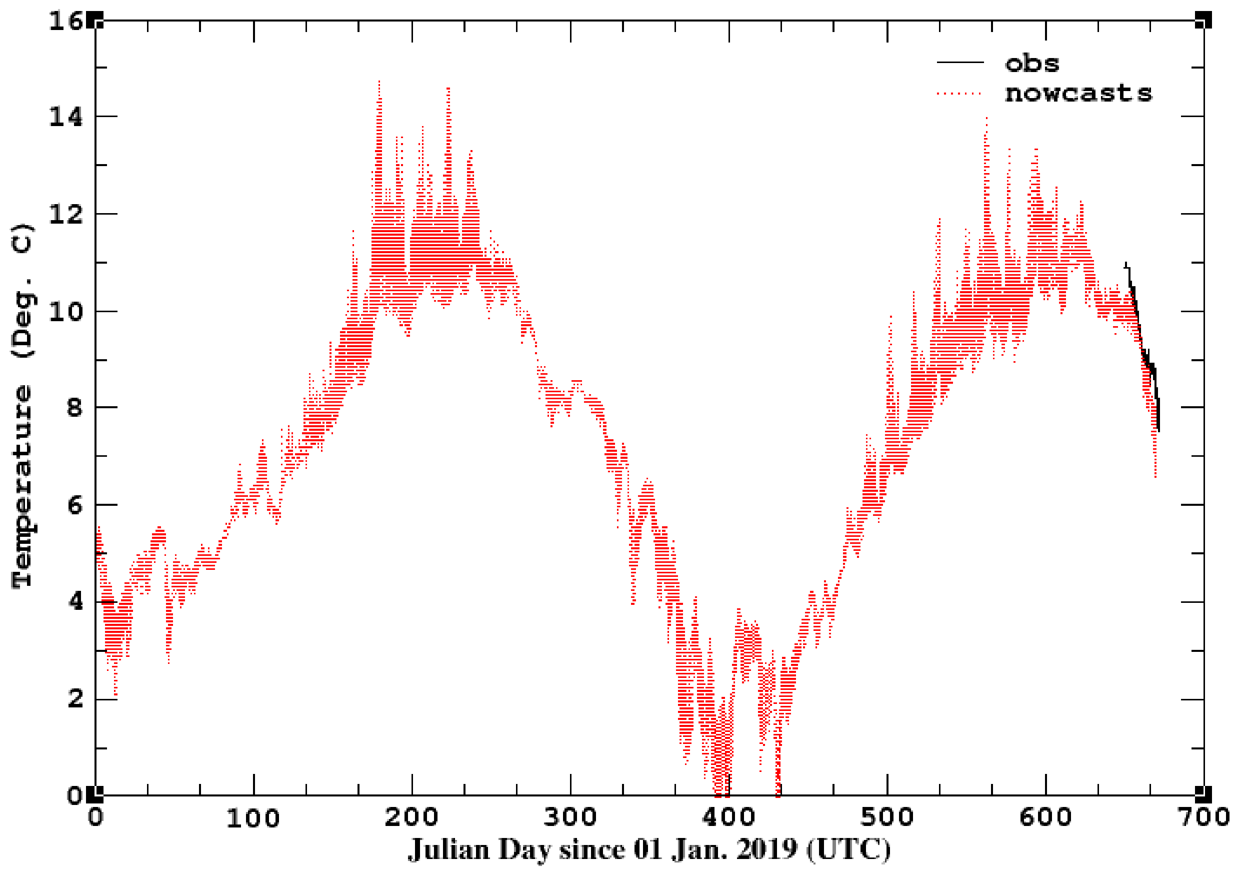


Figure 27. Comparison of water temperature observations (black) and nowcasts (red) at NDBC Seldovia Deep.

4. CONCLUSIONS

The Cook Inlet Operational Forecast System (CIOFS) became operational in July 2019, and provides the marine community with reliable forecast guidance on water levels, currents, temperature and salinity out to 48 hours. The skill assessment results based on outputs from the operational nowcast/forecast simulations during the assessment period of 2020-2021 indicated that all water level skill metrics passed or were close to NOS standard criteria. For example, RMSEs at all stations were less than 10% of the tide range of each station, which is within the accepted error criteria for navigation applications. CFs for both nowcasts and forecasts were greater than or close to 90%, and NOF and POF were less than 1% at all stations.

The surface water temperature predictions agree well with observations. For the skill assessment period, the surface temperature RMSE was below or very close to its criterion threshold (3.0 °C) in all cases. Most other variables (CF, NOF, POF, MDNO, and MDPO) met the NOS-accepted skill assessment criteria.

Skill assessment results also indicate some issues regarding CIOFS performance that can be improved in the future. Large RMSE and biases of water levels and temperature in the upper bay of Cook Inlet exist, especially at Anchorage, where it is shallow and has an extremely large tide range and strong currents. CIOFS could be improved by increasing the model resolution in this region. Updated bathymetry and topography, and freshwater inputs from National Water Model products (or coupling directly with the National Water Model) would also help improve CIOFS performance. The Alaska Coastal Current (ACC) significantly impacts the circulation of Cook Inlet, which is not considered in the present CIOFS configuration. Therefore, either extending the CIOFS model domain to incorporate the ACC or providing ACC information for the lateral open boundary conditions would also improve model performance.

As mentioned in the Technical Report NOS CS 40 (Shi et al., 2021), there are vast areas of tidal mud flats in Cook Inlet, which are dry during low tide and submerged during high tide. This is also visualized in water level animations of CIOFS. Due to the lack of accurate bathymetry, topography and high water mark observations, it is challenging to accurately simulate these tidal mud flats.

The lack of observations, especially real time currents, temperature and salinity at subsurface layers, constrain CIOFS validation and model performance evaluations. The NOS Modeling Program will continue to advocate for more observations in this region and leverage data from other observation campaigns to help assess model performance.

Finally, the present CIOFS configuration doesn’t include ice and biological parameters, which are in high-demand by the navigation and ecological communities. Adding ice and biological forecasting capability should be considered for future CIOFS upgrades.

ACKNOWLEDGEMENTS

Dr. Richard Patchen and Dr. Lyon Lanerolle initiated the CIOFS development. Dr. Lanerolle was the primary developer of CIOFS, and he conducted many sensitivity experiments. They both made tremendous contributions to the development of CIOFS.

Thanks to Lei Shi and Degui Cao. Dr. Lei Shi took over CIOFS-related development work after Dr. Lanerolle departed from NOAA. Degui Cao started the CIOFS transition and implementation work. Dr. Lianyuan Zheng investigated CIOFS model grid, and provided valuable recommendations to improve CIOFS configurations.

Special thanks to Jianbin Yang and Steven Earle of NCEP/NCO for supporting the model implementation effort.

Special thanks to Helen Worthington and Edward Davis, and Cristina Urizar for their discussions, suggestions, comments, and edits in this report. Support, guidance and encouragement from CO-OPS leadership, especially OD management team, Pat Burke, Paul Bradley, and Carolyn Lindley, during CIOFS development and implementation are critical and greatly appreciated.

REFERENCES

Danielson, S. L., K. S. Hedstrom, E. Curchitser, 2016. Cook Inlet Model Calculation, Final Report to Bureau of Ocean Energy Management, M14AC00014, OCS Study BOEM 2015-050, University of Alaska Fairbanks, AK, 149pp.

Hess, K. T. Gross, R. Schmalz, J. Kelley, F. Aikman, E. Wei, and M. Vincent (2003). NOS standards for evaluating operational nowcast and forecast hydrodynamic model systems. NOAA Technical Report NOS CS 17, Silver Spring, MD.

Lanerolle, L., C. Paternostro, G. Dusek, L. McLaughlin, and S. Skaling, 2012. An assessment of the renewable hydrokinetic energy potential in Cook Inlet, Alaska. In Proceedings of the OCEANS Conference, Virginia Beach, VA, USA, 14–19 October 2012.

NOS (2019). Service Change Notice (SCN) 19-51: Implementation of new Oceanographic Forecast Modeling Systems for the Cook Inlet and Lake Michigan and Lake Huron Effective: July 23, 2019.

Okkonen, S. R. (2005). Observations of hydrography and currents in central Cook Inlet, Alaska during diurnal and semidiurnal tidal cycles.University of Alaska Fairbanks, 32 pp.

Shi, Lei, Lyon Lanerolle, Yi Chen, Degui Cao, Richard Patchen, Aijun Zhang, and Edward P. Myers, (2021). NOS Cook Inlet Operational Forecast System: Model Development and Skill Assessment. NOAA Technical Report NOS CS 40.

Warner, J. C., W. R. Geyer, and J. A. Lerczak (2005). Numerical modeling of an estuary: A comprehensive skill assessment. Journal of Geophysical Research Atmospheres, 110(5), 1-13.

Willmott, C.J. (1981) On the Validation of Models. Physical Geography, 2, 184-194.

Zhang, A., K. Hess, E. Wei, and E. Myers (2009). Implementation of model skill assessment software for water level and current in tidal regions. NOAA Technical Memorandum NOS CS 24.

Zhang, A. and Z. Yang (2014). Coastal ocean modeling framework on NOAA's high performance computer (COMF-HPC). NOAA Technical Report NOS CO-OPS 069.

APPENDIX A. WATER LEVEL MODEL SKILL ASSESSMENT TABLES

Table A-1. Water level skill assessment at Anchorage

Station: Anchorage
Observed data time period from: / 1/ 1/2019 to /10/31/2020 with gaps of 0.00 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
H			157355	0.324									
h			157355	-0.142									
H-h	75 cm	24h	157355	0.466	0.561	0.312	0.0	83.1	0.0	2.5	2.3	0.01	0.99
AHW-ahw	75 cm	24h	1236	0.547	0.577	0.185	0.0	90.0	0.0	0.0	0.0		
ALW-alw	75 cm	24h	1235	0.506	0.556	0.231	0.0	92.8	0.1	0.0	0.0		
THW-thw	0.50 h	25h	1236	-0.399	0.446	0.198	0.2	60.8	0.1	0.0	0.0		
TLW-tlw	0.50 h	25h	1235	-0.071	0.179	0.164	0.0	98.1	0.1	0.0	0.0		
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	75 cm	24h	2491	0.469	0.560	0.306	0.0	82.9	0.0	0.0	0.0	0.00	
H012-h012	75 cm	24h	2496	0.471	0.563	0.308	0.0	82.1	0.0	0.0	0.0	0.00	
H018-h018	75 cm	24h	2496	0.472	0.563	0.307	0.0	82.0	0.0	0.0	0.0	0.00	
H024-h024	75 cm	24h	2495	0.471	0.563	0.308	0.0	82.3	0.1	0.0	0.0	0.00	
H030-h030	75 cm	24h	2494	0.471	0.561	0.305	0.0	82.7	0.0	0.0	0.0	0.00	
H036-h036	75 cm	24h	2493	0.472	0.563	0.306	0.0	82.6	0.0	0.0	0.0	0.00	
H042-h042	75 cm	24h	2492	0.474	0.563	0.304	0.0	82.5	0.1	0.0	0.0	0.00	
H048-h048	75 cm	24h	2491	0.472	0.562	0.305	0.0	82.7	0.0	0.0	0.0	0.00	
AHW-ahw	75 cm	24h	567	0.548	0.579	0.189	0.0	88.7	0.0				
ALW-alw	75 cm	24h	569	0.503	0.537	0.186	0.0	93.0	0.0				
THW-thw	0.50 h	25h	567	-0.411	0.452	0.189	0.4	66.3	0.0				
TLW-tlw	0.50 h	25h	569	-0.065	0.179	0.167	0.0	98.2	0.0				

Table A-2. Water level skill assessment at Nikiski

Station: Nikiski
Observed data time period from: / 1/ 1/2019 to /10/31/2020 with gaps of 79.28 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
H			138332	0.029									
h			138332	-0.126									
H-h	54 cm	24h	138332	0.155	0.296	0.252	0.0	93.5	0.0	2.6	0.0	0.02	0.99
AHW-ahw	54 cm	24h	1080	0.290	0.321	0.137	0.0	98.1	0.0	0.0	0.0		
ALW-alw	54 cm	24h	1083	-0.028	0.164	0.162	0.0	100.0	0.0	0.0	0.0		
THW-thw	0.50 h	25h	1080	-0.184	0.253	0.174	0.0	92.8	0.1	0.0	0.0		
TLW-tlw	0.50 h	25h	1083	-0.119	0.194	0.153	0.0	96.4	0.0	0.0	0.0		
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	54 cm	24h	2175	0.157	0.294	0.248	0.0	93.4	0.0	0.0	0.0	0.00	
H012-h012	54 cm	24h	2173	0.159	0.296	0.250	0.0	93.4	0.0	0.0	0.0	0.00	
H018-h018	54 cm	24h	2173	0.159	0.296	0.250	0.0	93.2	0.0	0.0	0.0	0.00	
H024-h024	54 cm	24h	2172	0.159	0.296	0.250	0.0	93.4	0.0	0.0	0.0	0.00	
H030-h030	54 cm	24h	2171	0.159	0.296	0.250	0.0	93.6	0.0	0.0	0.0	0.00	
H036-h036	54 cm	24h	2177	0.159	0.295	0.249	0.0	93.6	0.0	0.0	0.0	0.00	
H042-h042	54 cm	24h	2183	0.160	0.297	0.250	0.0	93.4	0.0	0.0	0.0	0.00	
H048-h048	54 cm	24h	2182	0.157	0.294	0.249	0.0	93.6	0.0	0.0	0.0	0.00	
AHW-ahw	54 cm	24h	465	0.287	0.322	0.146	0.0	97.4	0.0				
ALW-alw	54 cm	24h	464	-0.035	0.156	0.152	0.0	100.0	0.0				
THW-thw	0.50 h	25h	465	-0.171	0.251	0.183	0.0	92.9	0.0				
TLW-tlw	0.50 h	25h	464	-0.115	0.190	0.152	0.0	97.2	0.0				

Table A-3. Water level skill assessment at Seldovia

Station: Seldovia
Observed data time period from: / 1/ 1/2019 to /10/31/2020 with gaps of 0.00 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
H			157355	0.058									
h			157355	-0.101									
H-h	47 cm	24h	157355	0.158	0.270	0.219	0.0	92.8	0.0	2.2	0.0	0.02	0.99
AHW-ahw	47 cm	24h	1236	0.270	0.304	0.138	0.0	94.9	0.0	0.0	0.0		
ALW-alw	47 cm	24h	1238	0.083	0.186	0.167	0.0	99.4	0.0	0.0	0.0		
THW-thw	0.50 h	25h	1236	-0.169	0.240	0.171	0.0	95.5	0.1	0.0	0.0		
TLW-tlw	0.50 h	25h	1238	-0.131	0.207	0.161	0.0	96.5	0.0	0.0	0.0		
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	47 cm	24h	2491	0.161	0.270	0.217	0.0	92.4	0.0	0.0	0.0	0.00	
H012-h012	47 cm	24h	2496	0.161	0.271	0.218	0.0	92.5	0.0	0.0	0.0	0.00	
H018-h018	47 cm	24h	2496	0.162	0.270	0.216	0.0	92.1	0.0	0.0	0.0	0.00	
H024-h024	47 cm	24h	2495	0.162	0.270	0.217	0.0	92.6	0.0	0.0	0.0	0.00	
H030-h030	47 cm	24h	2494	0.161	0.269	0.216	0.0	92.8	0.0	0.0	0.0	0.00	
H036-h036	47 cm	24h	2493	0.161	0.269	0.216	0.0	92.6	0.0	0.0	0.0	0.00	
H042-h042	47 cm	24h	2492	0.161	0.270	0.216	0.0	92.6	0.0	0.0	0.0	0.00	
H048-h048	47 cm	24h	2491	0.160	0.268	0.216	0.0	92.5	0.0	0.0	0.0	0.00	
AHW-ahw	47 cm	24h	569	0.263	0.297	0.138	0.0	94.0	0.0				
ALW-alw	47 cm	24h	570	0.078	0.176	0.158	0.0	100.0	0.0				
THW-thw	0.50 h	25h	569	-0.169	0.235	0.164	0.0	95.6	0.0				
TLW-tlw	0.50 h	25h	570	-0.131	0.206	0.159	0.0	96.8	0.0				

Table A-4. Water level skill assessment at Kodiak Island

Station: Kodiak Island
Observed data time period from: / 1/ 1/2019 to /10/31/2020 with gaps of 0.00 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
H			157355	-0.011									
h			157355	-0.083									
H-h	20 cm	24h	157355	0.072	0.155	0.137	0.1	80.8	0.2	4.6	3.5	0.20	0.99
AHW-ahw	20 cm	24h	1230	0.042	0.111	0.103	0.1	95.8	0.1	0.0	0.0		
ALW-alw	20 cm	24h	1233	0.118	0.161	0.110	0.0	77.9	0.1	0.0	0.0		
THW-thw	0.50 h	25h	1230	-0.268	0.418	0.321	1.1	72.0	0.1	11.2	0.0		
TLW-tlw	0.50 h	25h	1233	-0.165	0.360	0.320	0.6	80.0	0.1	13.5	0.0		
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	20 cm	24h	2491	0.073	0.156	0.138	0.1	80.6	0.4	0.0	0.0	0.44	
H012-h012	20 cm	24h	2496	0.073	0.156	0.138	0.1	80.9	0.3	0.0	0.0	0.36	
H018-h018	20 cm	24h	2496	0.073	0.155	0.136	0.1	81.7	0.2	0.0	0.0	0.24	
H024-h024	20 cm	24h	2495	0.073	0.155	0.137	0.0	80.8	0.2	0.0	0.0	0.20	
H030-h030	20 cm	24h	2494	0.072	0.154	0.136	0.0	81.0	0.2	0.0	0.0	0.20	
H036-h036	20 cm	24h	2493	0.071	0.155	0.137	0.1	81.4	0.2	0.0	0.0	0.24	
H042-h042	20 cm	24h	2492	0.072	0.155	0.137	0.1	80.4	0.4	0.0	0.0	0.36	
H048-h048	20 cm	24h	2491	0.072	0.155	0.138	0.1	80.7	0.5	0.0	0.0	0.48	
AHW-ahw	20 cm	24h	568	0.036	0.108	0.102	0.0	94.4	0.0				
ALW-alw	20 cm	24h	567	0.112	0.153	0.104	0.0	80.6	0.2				
THW-thw	0.50 h	25h	568	-0.260	0.393	0.296	0.9	78.2	0.0				
TLW-tlw	0.50 h	25h	567	-0.172	0.359	0.315	0.7	81.7	0.0				

Table A-5. Water level skill assessment at Alitak

Station: Alitak
Observed data time period from: / 1/ 1/2019 to /10/31/2020 with gaps of 0.00 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
H			157355	-0.036									
h			157355	-0.051									
H-h	28 cm	24h	157355	0.015	0.164	0.164	0.0	92.5	0.0	0.4	1.4	0.03	1.00
AHW-ahw	28 cm	24h	1235	0.134	0.176	0.114	0.0	92.2	0.0	0.0	0.0		
ALW-alw	28 cm	24h	1238	-0.119	0.167	0.118	0.0	91.9	0.0	0.0	0.0		
THW-thw	0.50 h	25h	1235	0.066	0.224	0.214	0.1	95.0	0.0	0.0	0.0		
TLW-tlw	0.50 h	25h	1238	-0.065	0.235	0.226	0.1	94.6	0.0	0.0	0.0		
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	28 cm	24h	2491	0.015	0.169	0.169	0.0	91.5	0.0	0.0	0.0	0.08	
H012-h012	28 cm	24h	2496	0.015	0.169	0.168	0.0	90.9	0.0	0.0	0.0	0.08	
H018-h018	28 cm	24h	2496	0.015	0.167	0.167	0.0	91.5	0.0	0.0	0.0	0.04	
H024-h024	28 cm	24h	2495	0.015	0.167	0.167	0.0	91.3	0.0	0.0	0.0	0.00	
H030-h030	28 cm	24h	2494	0.014	0.168	0.168	0.0	91.6	0.0	0.0	0.0	0.04	
H036-h036	28 cm	24h	2493	0.013	0.168	0.168	0.0	91.7	0.1	0.0	0.0	0.12	
H042-h042	28 cm	24h	2492	0.014	0.169	0.169	0.1	91.7	0.0	0.0	0.0	0.12	
H048-h048	28 cm	24h	2491	0.014	0.167	0.167	0.0	92.0	0.1	0.0	0.0	0.08	
AHW-ahw	28 cm	24h	569	0.124	0.172	0.119	0.0	91.2	0.0				
ALW-alw	28 cm	24h	569	-0.129	0.173	0.115	0.0	91.6	0.0				
THW-thw	0.50 h	25h	569	0.060	0.221	0.213	0.0	95.3	0.0				
TLW-tlw	0.50 h	25h	569	-0.066	0.218	0.208	0.0	96.7	0.0				

APPENDIX B. SURFACE WATER TEMPERATURE SKILL ASSESSMENT TABLES

Table B-1. Water surface temperature skill assessment at Anchorage

Station: Anchorage
Observed data time period from: / 1/ 1/2019 to /11/ 2/2020 with gaps of 0.53 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			157230	7.817									
t			157230	6.582									
T-t	3.0	c 24h	157230	1.236	2.281	1.917	0.0	79.2	0.9	0.0	8.4		0.98
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	2493	1.277	2.299	1.912	0.0	78.8	0.8	0.0	5.9		
T012-t012	3.0	c 24h	2493	1.274	2.298	1.913	0.0	78.9	0.9	0.0	11.8		
T018-t018	3.0	c 24h	2493	1.279	2.309	1.923	0.0	78.9	1.1	0.0	11.8		
T024-t024	3.0	c 24h	2493	1.277	2.304	1.918	0.0	79.3	1.0	0.0	11.8		
T030-t030	3.0	c 24h	2494	1.288	2.317	1.926	0.0	78.7	1.0	0.0	11.8		
T036-t036	3.0	c 24h	2494	1.283	2.312	1.924	0.0	78.5	0.8	0.0	5.9		
T042-t042	3.0	c 24h	2494	1.275	2.309	1.925	0.0	78.1	0.8	0.0	5.9		
T048-t048	3.0	c 24h	2493	1.274	2.305	1.922	0.0	78.3	0.8	0.0	5.9		

Table B-2. Water surface temperature skill assessment at Nikiski

Station: Nikiski
Observed data time period from: / 1/ 1/2019 to /11/ 2/2020 with gaps of 0.55 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			157228	6.838									
t			157228	6.577									
T-t	3.0	c 24h	157228	0.261	0.792	0.748	0.0	99.9	0.0	0.9	1.0		1.00
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	2493	0.267	0.815	0.770	0.0	99.8	0.0	0.0	0.0		
T012-t012	3.0	c 24h	2494	0.269	0.817	0.772	0.0	99.8	0.0	0.0	0.0		
T018-t018	3.0	c 24h	2494	0.263	0.806	0.762	0.0	99.8	0.0	0.0	0.0		
T024-t024	3.0	c 24h	2494	0.261	0.810	0.767	0.0	99.8	0.0	0.0	0.0		
T030-t030	3.0	c 24h	2494	0.258	0.805	0.763	0.0	99.9	0.0	0.0	0.0		
T036-t036	3.0	c 24h	2494	0.259	0.809	0.766	0.0	99.9	0.0	0.0	0.0		
T042-t042	3.0	c 24h	2494	0.258	0.812	0.770	0.0	99.9	0.0	0.0	0.0		
T048-t048	3.0	c 24h	2493	0.263	0.818	0.775	0.0	99.8	0.0	0.0	0.0		

Table B-3. Water surface temperature skill assessment at Seldovia

Station: Seldovia
Observed data time period from: / 1/ 1/2019 to /11/ 2/2020 with gaps of 1.22 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			157066	7.522									
t			157066	7.694									
T-t	3.0 c	24h	157066	-0.172	1.099	1.086	0.0	98.0	0.0	0.0	0.0		0.97
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c	24h	2490	-0.237	1.054	1.027	0.0	98.6	0.0	0.0	0.0		
T012-t012	3.0 c	24h	2491	-0.242	1.056	1.028	0.0	98.4	0.0	0.0	0.0		
T018-t018	3.0 c	24h	2491	-0.235	1.055	1.029	0.0	98.6	0.0	0.0	0.0		
T024-t024	3.0 c	24h	2494	-0.235	1.055	1.028	0.0	98.4	0.0	0.0	0.0		
T030-t030	3.0 c	24h	2491	-0.235	1.056	1.029	0.0	98.6	0.0	0.0	0.0		
T036-t036	3.0 c	24h	2491	-0.251	1.048	1.018	0.0	98.8	0.0	0.0	0.0		
T042-t042	3.0 c	24h	2491	-0.253	1.037	1.006	0.0	99.0	0.0	0.0	0.0		
T048-t048	3.0 c	24h	2490	-0.251	1.040	1.009	0.0	98.8	0.0	0.0	0.0		

Table B-4. Water surface temperature skill assessment at Kodiak Island

Station: Kodiak Island
Observed data time period from: / 1/ 1/2019 to /11/ 2/2020 with gaps of 2.51 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			156754	7.977									
t			156754	7.884									
T-t	3.0 c	24h	156754	0.093	1.410	1.406	0.0	95.9	0.0	0.0	0.0		0.96
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c	24h	2487	0.031	1.440	1.440	0.0	95.7	0.0	0.0	0.0		
T012-t012	3.0 c	24h	2486	0.034	1.456	1.456	0.0	95.7	0.0	0.0	0.0		
T018-t018	3.0 c	24h	2486	0.035	1.449	1.449	0.0	95.7	0.0	0.0	0.0		
T024-t024	3.0 c	24h	2486	0.047	1.441	1.441	0.0	95.6	0.0	0.0	0.0		
T030-t030	3.0 c	24h	2486	0.034	1.419	1.419	0.0	96.1	0.0	0.0	0.0		
T036-t036	3.0 c	24h	2486	0.037	1.418	1.418	0.0	96.1	0.0	0.0	0.0		
T042-t042	3.0 c	24h	2486	0.021	1.412	1.413	0.0	96.1	0.0	0.0	0.0		
T048-t048	3.0 c	24h	2484	0.017	1.426	1.427	0.0	95.8	0.0	0.0	0.0		

Table B-5. Water surface temperature skill assessment at Alitak

Station: Alitak
Observed data time period from: / 1/ 1/2019 to /11/ 2/2020 with gaps of 0.50 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			157236	7.204									
t			157236	7.615									
T-t	3.0 c	24h	157236	-0.412	0.861	0.756	0.0	99.9	0.0	0.8	0.0		0.99
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c	24h	2493	-0.459	0.881	0.752	0.0	100.0	0.0	0.0	0.0		
T012-t012	3.0 c	24h	2494	-0.473	0.880	0.742	0.0	100.0	0.0	0.0	0.0		
T018-t018	3.0 c	24h	2494	-0.459	0.871	0.740	0.0	100.0	0.0	0.0	0.0		
T024-t024	3.0 c	24h	2494	-0.460	0.872	0.740	0.0	99.9	0.0	0.0	0.0		
T030-t030	3.0 c	24h	2494	-0.458	0.865	0.733	0.0	99.8	0.0	0.0	0.0		
T036-t036	3.0 c	24h	2494	-0.456	0.873	0.744	0.0	99.9	0.0	0.0	0.0		
T042-t042	3.0 c	24h	2494	-0.455	0.876	0.748	0.0	100.0	0.0	0.0	0.0		
T048-t048	3.0 c	24h	2495	-0.457	0.877	0.749	0.0	100.0	0.0	0.0	0.0		

Table B-6. Water surface temperature skill assessment at Lower Cook Inlet (46108)

Station: Buoy 46108 Lower Cook Inlet
Observed data time period from: / 1/ 1/2019 to /11/ 2/2020 with gaps of 298.80 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			85692	8.163									
t			85692	8.488									
T-t	3.0 c	24h	85692	-0.325	0.786	0.715	0.0	99.4	0.0	0.0	0.0		0.97
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c	24h	1294	-0.374	0.840	0.753	0.0	98.9	0.0	0.0	0.0		
T012-t012	3.0 c	24h	1295	-0.368	0.838	0.753	0.0	99.0	0.0	0.0	0.0		
T018-t018	3.0 c	24h	1297	-0.383	0.842	0.750	0.0	98.9	0.0	0.0	0.0		
T024-t024	3.0 c	24h	1303	-0.394	0.858	0.762	0.0	98.9	0.0	0.0	0.0		
T030-t030	3.0 c	24h	1302	-0.378	0.839	0.750	0.0	99.0	0.0	0.0	0.0		
T036-t036	3.0 c	24h	1301	-0.373	0.835	0.747	0.0	98.8	0.0	0.0	0.0		
T042-t042	3.0 c	24h	1301	-0.376	0.847	0.759	0.0	98.8	0.0	0.0	0.0		
T048-t048	3.0 c	24h	1301	-0.384	0.850	0.758	0.0	99.0	0.0	0.0	0.0		

Table B-7. Water surface temperature skill assessment at Shelikof Strait

Station: NDBC 46077
Observed data time period from: / 1/ 1/2019 to /11/ 1/2020 with gaps of 39.48 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			148074	7.845									
t			148074	7.951									
T-t	3.0 c	24h	148074	-0.106	1.001	0.996	0.0	98.8	0.0	0.0	0.0		0.98
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c	24h	2346	-0.220	1.083	1.061	0.0	98.3	0.0	0.0	0.0		
T012-t012	3.0 c	24h	2346	-0.227	1.100	1.076	0.0	98.3	0.0	0.0	0.0		
T018-t018	3.0 c	24h	2347	-0.226	1.081	1.057	0.0	98.4	0.0	0.0	0.0		
T024-t024	3.0 c	24h	2345	-0.223	1.080	1.057	0.0	98.6	0.0	0.0	0.0		
T030-t030	3.0 c	24h	2344	-0.194	1.023	1.004	0.0	98.9	0.0	0.0	0.0		
T036-t036	3.0 c	24h	2352	-0.216	1.065	1.043	0.0	98.6	0.0	0.0	0.0		
T042-t042	3.0 c	24h	2352	-0.219	1.077	1.055	0.0	98.5	0.0	0.0	0.0		
T048-t048	3.0 c	24h	2345	-0.214	1.077	1.056	0.0	98.5	0.0	0.0	0.0		

Table B-8. Water surface temperature skill assessment at Kodiak

Station: NDBC 46264 at Kodiak
Observed data time period from: / 1/ 1/2019 to /11/ 1/2020 with gaps of 325.80 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			84022	7.250									
t			84022	7.710									
T-t	3.0 c	24h	84022	-0.460	0.832	0.693	0.0	99.7	0.0	0.0	0.0		0.98
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c	24h	1399	-0.566	0.917	0.722	0.0	99.4	0.0	0.0	0.0		
T012-t012	3.0 c	24h	1400	-0.568	0.933	0.741	0.0	99.3	0.0	0.0	0.0		
T018-t018	3.0 c	24h	1400	-0.570	0.948	0.758	0.0	99.0	0.0	0.0	0.0		
T024-t024	3.0 c	24h	1398	-0.567	0.910	0.711	0.0	99.5	0.0	0.0	0.0		
T030-t030	3.0 c	24h	1403	-0.562	0.869	0.663	0.0	99.6	0.0	0.0	0.0		
T036-t036	3.0 c	24h	1411	-0.586	0.890	0.670	0.0	99.7	0.0	0.0	0.0		
T042-t042	3.0 c	24h	1416	-0.591	0.896	0.674	0.0	99.5	0.0	0.0	0.0		
T048-t048	3.0 c	24h	1405	-0.581	0.913	0.705	0.0	99.4	0.0	0.0	0.0		

Table B-9. Water surface temperature skill assessment at Seldovia Deep Buoy

Station: NDBC Seldovia Deep
Observed data time period from: /10/11/2020 to /11/ 2/2020 with gaps of 0.10 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			4779	9.146									
t			4779	9.675									
T-t	3.0 c	24h	4779	-0.529	0.632	0.345	0.0	100.0	0.0	0.0	0.0		0.86
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c	24h	81	-0.625	0.785	0.478	0.0	100.0	0.0	0.0	0.0		
T012-t012	3.0 c	24h	83	-0.577	0.700	0.399	0.0	100.0	0.0	0.0	0.0		
T018-t018	3.0 c	24h	84	-0.578	0.706	0.408	0.0	100.0	0.0	0.0	0.0		
T024-t024	3.0 c	24h	85	-0.611	0.742	0.423	0.0	100.0	0.0	0.0	0.0		
T030-t030	3.0 c	24h	86	-0.623	0.757	0.431	0.0	100.0	0.0	0.0	0.0		
T036-t036	3.0 c	24h	87	-0.631	0.764	0.433	0.0	100.0	0.0	0.0	0.0		
T042-t042	3.0 c	24h	88	-0.651	0.786	0.444	0.0	100.0	0.0	0.0	0.0		
T048-t048	3.0 c	24h	88	-0.664	0.805	0.458	0.0	100.0	0.0	0.0	0.0		

Table B-10. Water surface temperature skill assessment at Homer Dolphin Deep

Station: Buoy at Homer Dolphin Deep
Observed data time period from: /10/18/2020 to /10/20/2020 with gaps of 0.00 days
Data gap is filled by SVD method
Data are not filtered

VARIABLE	X	N	IMAX	SM	RMSE	SD	NOF	CF	POF	MDNO	MDPO	WOF	SKILL
CRITERION	-	-	-	-	-	-	<1%	>90%	<1%	<N	<N	<.5%	
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			498	9.888									
t			498	9.571									
T-t	3.0 c	24h	498	0.318	0.510	0.399	0.0	100.0	0.0	0.0	0.0		0.49
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c	24h	9	0.346	0.523	0.415	0.0	100.0	0.0	0.0	0.0		
T012-t012	3.0 c	24h	9	0.352	0.534	0.426	0.0	100.0	0.0	0.0	0.0		
T018-t018	3.0 c	24h	9	0.387	0.567	0.440	0.0	100.0	0.0	0.0	0.0		
T024-t024	3.0 c	24h	9	0.368	0.543	0.423	0.0	100.0	0.0	0.0	0.0		
T030-t030	3.0 c	24h	9	0.363	0.537	0.419	0.0	100.0	0.0	0.0	0.0		
T036-t036	3.0 c	24h	9	0.368	0.542	0.422	0.0	100.0	0.0	0.0	0.0		
T042-t042	3.0 c	24h	9	0.369	0.527	0.398	0.0	100.0	0.0	0.0	0.0		
T048-t048	3.0 c	24h	9	0.372	0.527	0.395	0.0	100.0	0.0	0.0	0.0		

ACRONYMS

ADCIRC	Advanced CIRCulation
CIOFS	Cook Inlet Operational Forecast System
CF	Central Frequency
COMF	Coastal Ocean Modeling Framework
CO-OPS	Center for Operational Oceanographic Products and Services
CSDL	Coast Survey Development Laboratory
DEM	Digital Elevation Map
ETSS	Extra-Tropical Storm Surge model
h	hour
HPC	High Performance Computing
m/s	meters per second
m	meters
MDPO	maximum duration of positive outliers
MDNO	maximum duration of negative outliers
NAM	North American Mesoscale weather prediction model
NCEP	National Centers for Environmental Prediction
NCO	NCEP Central Operations
NDBC	National Data Buoy Center
N/F	Nowcast/Forecast
NOAA	National Oceanic and Atmospheric Administration
NOF	negative outlier frequency
NOS	National Ocean Service
NWS	National Weather Service
NWLON	National Water Level Observation Network
POF	positive outlier frequency
RMSE	root mean square error
ROMS	Regional Ocean Modeling System
SM	Series mean
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time
WCOSS	Weather and Climate Operational Supercomputing System