IMPLEMENTATION OF THE LAKE MICHIGAN AND HURON OPERATIONAL FORECAST SYSTEM (LMHOFS) AND THE NOWCAST/FORECAST SKILL ASSESSMENT

Silver Spring, Maryland
August 2019

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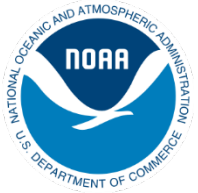

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Lakes Michigan and Huron Operational Forecast System (LMHOFS), with the Finite Volume Community Ocean Model (FVCOM) as its hydrodynamic core, has been implemented to provide users with nowcasts (analyses of near present) and forecast guidance of the three-dimensional (3-D) physical conditions of Lakes Michigan and Huron, including surface water levels and 3-D water currents and water temperature, out to 120 hours. By combining Lakes Michigan and Huron into one model grid and invoking advanced model schemes and algorithms, LMHOFS is expected to provide more accurate predictions than the previous National Ocean Service (NOS) Lake Michigan OFS (LMOFS) and Lake Huron OFS (LHOFS), which had separate model domains based on the Princeton Ocean Model (POM).

The LMOFS and LHOFS were based on the Great Lakes Forecasting System developed by Ohio State University and the National Oceanic and Atmospheric Administration Office of Oceanic and Atmospheric Research's (OAR) Great Lakes Environmental Research Laboratory (GLERL) in the late 1980s and 1990s, using a customized POM for each of the Great Lakes.

LMHOFS has been running reliably with no instability issues since the nowcast/forecast runs started in March 2018. Standard model skill assessment of the 10-month (June 17, 2018–April 17, 2019) semi-operational runs indicates that all targeted variables meet the NOS model skill criteria. The successful implementation of LMHOFS on the Weather and Climate Operational Supercomputing System (WCOSS) provides reliable forecast guidance on water levels, currents, and water temperatures to support NOS navigation customers and will serve as the hydrodynamic basis for operational ice modeling and other applications in the region.

This technical report documents how the Center for Operational Oceanographic Products and Services builds the control and static files for the High Performance Computing-Coastal Ocean Modeling Framework and then generates the required model forcing files that drive LMHOFS. The nowcast and forecast model skill assessment is then presented.

1.0 INTRODUCTION

Lakes Michigan and Huron are joined through the 8.0 kilometer (km)-wide open-water Straits of Mackinac. The water depth is over 60 meters (m) in some places along the straits. Lakes Michigan and Huron are hydrologically one body of water because the flow of water through the straits keeps their water levels in near-equilibrium. When treated as one body of water, with a surface area of 117,300 km^2, Lakes Michigan and Huron is the largest freshwater lake in the world (Kelley and Chen, 2019).

There were two separate National Ocean Service (NOS) operational forecast systems, LMOFS and LHOFS, for Lake Michigan and Lake Huron, respectively, before the implementation of the new Lakes Michigan and Huron Operational Forecast System (LMHOFS). They used the Great Lakes version of the Princeton Ocean Model (POMGL) and had four daily nowcast and forecast cycles, which generated forecasts out to 60 hours. The horizontal grid resolution used for both LMOFS and LHOFS was 5 km. The nowcast cycles were forced by surface meteorological analyses of near-real-time meteorological observations from over water and over land platforms, which were used to provide heat and radiation fluxes and wind stress to POMGL. The forecast cycles were forced by gridded surface wind and air temperature forecasts (2.5 km resolution) from the National Weather Service (NWS) National Digital Forecast Database (NDFD).

The LMOFS and LHOFS nowcast and forecast guidance of water levels generally met the NOS-accepted criteria, which will be elaborated in Section 3.2. However, due to low resolutions of model grid and bathymetric data, LMOFS and LHOFS under-predicted water levels at certain locations. In addition, they could not fully reproduce water levels under severe weather conditions for a nowcast cycle, because the complexity of a weather system could not be completely represented given the low density of the meteorological observations. Generally, the surface water temperature nowcasts of LMOFS and LHOFS exhibited an unrealistic high-frequency oscillation possibly due to the coarse model grid resolution.

In 2013, NOS and the Great Lakes Environmental Research Laboratory (GLERL) began a project to update each of the OFS for the Great Lakes to provide improved lake predictions and guidance out to 120 hours. The Finite Volume Community Ocean Model (FVCOM) was selected as the core ocean model due to its unstructured grid design that would allow for higher horizontal resolution along the shore and its incorporation of more advanced algorithms to improve heat flux boundary conditions.

The new LMHOFS combines Lake Michigan and Lake Huron into one model grid (Figure 1) and invokes more advanced model schemes and algorithms, e.g., COARE2.6 Bulk Algorithm (Fairall et al., 1996) for heat flux. NOAA 3 arc-second bathymetry data are applied to delineate the land boundary. The horizontal model grid (Figure 2) is composed of 170,000 triangular elements and 90,000 nodes. The resolution varies from approximately 100 m near the shore to about 2.5 km offshore.

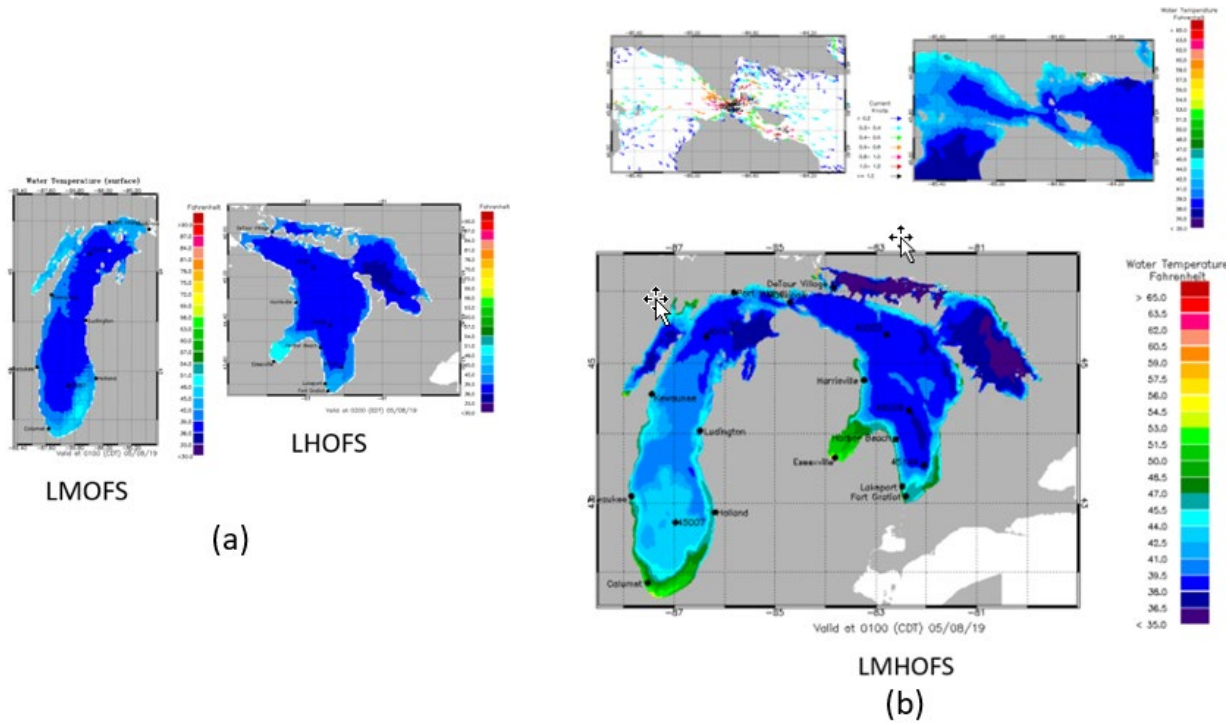


Figure 1. The a) separate LMOFS and LHOFS domains and b) combined LMHOFS domain.

Figure 2. LMHOFS model grid.

The grid generation module of the Surface-Water-Modeling System software was used by GLERL to generate the unstructured model grid. The model bathymetry was obtained by interpolating the GLERL digital bathymetry onto each unstructured FVCOM model grid node, referenced to the International Great Lakes Datum. The model bathymetry is shown in Figure 3.

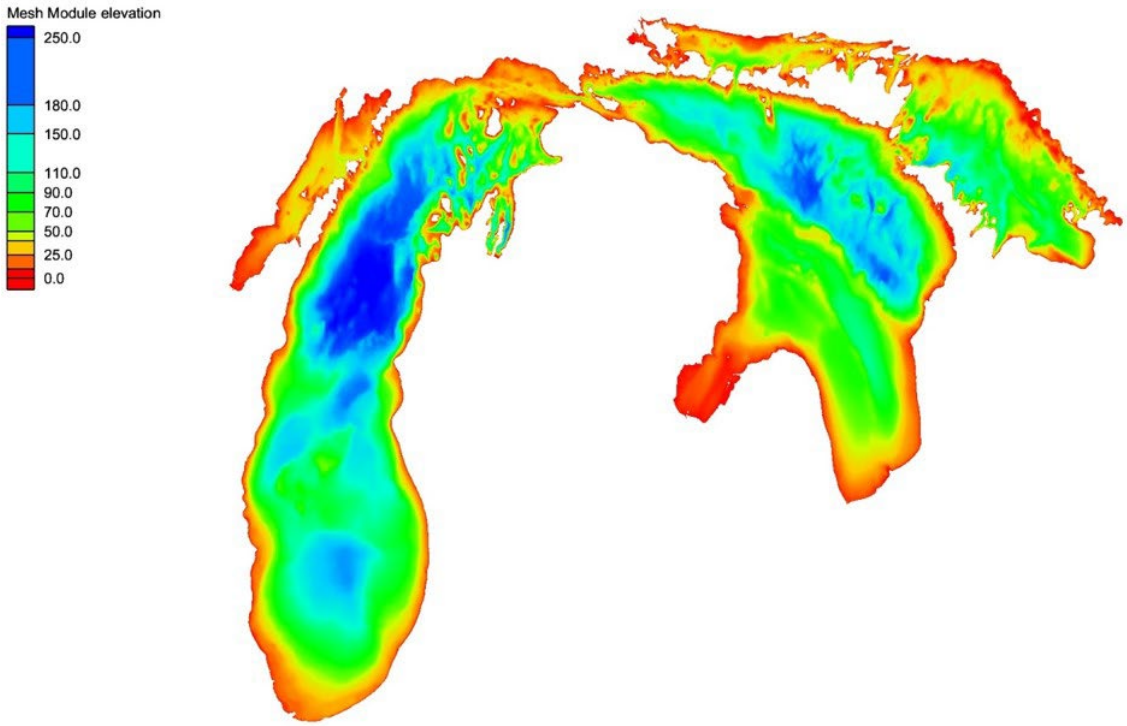


Figure 3. LMHOFS bathymetry in meters.

LMHOFS generates more accurate predictions than the previous LMOFS and LHOFS. The successful implementation and operation of LMHOFS provides more reliable information to help pilots and mariners safely and efficiently navigate through Lakes Michigan and Huron and also provides support for coastal zone management and hazard mitigation in this Great Lakes region.

LMHOFS has been running reliably with no instability issues since the semi-operational nowcast/forecast runs started in March 2018. Standard model skill assessment based on ten months (June 17, 2018–April 17, 2019) indicates that predictions have improved for all targeted variables, including water level, surface currents, and water temperature.

This technical report documents how the NOS Center for Operational Oceanographic Products and Services (CO-OPS) created the control and static files for the High Performance Computing-Coastal Ocean Modeling Framework (HPC-COMF), which supports LMHOFS and other NOS forecast systsms and then generates the required model forcing files that drive LMHOFS (Section 2). Nowcast and forecast skill assessment for the period of June 17, 2018–April 17, 2019 is then presented (Section 3).

2.0 MODEL NOWCAST/FORECAST CONFIGURATION

This section describes the generation of 1) the meteorological surface forcing conditions, 2) the river forcing conditions, 3) the lateral open ocean boundary conditions, and 4) the initial conditions for LMHOFS nowcast/forecast predictions. All these forcing condition files are automatically generated by the HPC-COMF.

2.1 Meteorological Forcing Conditions

Meteorological forcing conditions for LMHOFS are generated by the HPC-COMF similar to other existing NOS operational forecast systems. The **nos.lmhofs.ctl** file in /**nosofs.vx.x.x/fix/lmhofs/** controls which NOAA numerical weather prediction model output is used. For LMHOFS, the High Resolution Rapid Refresh (HRRR) and Global Forecast System (GFS) with 0.25 degree resolution (GFS25) are used by specifying the following two parameters in the **nos.lmhofs.ctl** control file:

export DBASE_MET_NOW=HRRR
export DBASE_MET_FOR=GFS25

These control files indicate that HRRR is used for the nowcast and GFS25 for the forecast meteorological forcing conditions. The shell script **nos_ofs_create_forcing_met.sh** within **/nosofs.vx.x.x/ush/** can be launched to generate **nos.lmhofs.met.nowcast.yyyymmdd.tccz.nc** and **nos.lmhofs.met.forecast.yyyymmdd.tccz.nc** (where yyyy, mm, dd, and cc in "tccz" indicate respectively the year, month, day, and cycle of the nowcast/forecast). The required HRRR and GFS25 model output files exist in the Weather and Climate Operational Supercomputing System (WCOSS) data tank.

NDFD was initially planned to be used to generate forecast meteorological forcing as in the previous LMOFS/LHOFS. Unfortunately, sea surface air pressure, the variable that is required by LMHOFS to generate the meteorological forcing conditions, is not available in NDFD.

2.2 River Forcing Conditions

LMHOFS relies on freshwater inputs at four United States Geological Survey (USGS) river gauges: St. Mary's River (04127885), St. Clair River (04159130), Saginaw River (04157005) and Fox River (040851385) as shown in Figure 4. The most recent discharge rate and water temperature of each river can be retrieved directly from the National Centers for Environmental Prediction (NCEP) data tank on WCOSS. Table 1 is part of the river control file of **nos.lmhofs.river.ctl** showing the locations of the four rivers and the discharge scales of these rivers at given grid points.

Figure 4. River systems of LMHOFS.

Table 1. LMHOFS river control file nos.lmhofs.river.ctl.

```
Section 1: Information about USGS or NOS gages where real-time discharges and/or water temperature observations are available
 12   5  1.0  !! 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     04127885   XXXXX    USGS     0.0  5000.0 3115.0   0.0    28.0    12.0      1      1     "ST MARY'S RIVER AT SAULT STE. MARIE,ONTARIO    "
  2     04159130   XXXXX    USGS     0.0  6003.0 4955.0   0.0    28.0    12.0      1      1     "ST. CLAIR RIVER AT PORT HURON, MI"
  3     04157005   XXXXX    USGS     0.0   365.0  114.0   0.0    28.0    12.0      1      1     "SAGINAW RIVER AT SAGINAW "
  4     040851385  XXXXX    USGS     0.0   271.0  125.0   0.0    28.0    12.0      1      1     "FOX RIVER AT GREEN BAY, WI"
  5     9076070    SWPM4    COOPS -9999.   9999.  9999.   0.0    28.0    12.0      3      1     "use for ST Mary river temperaure"
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      95709   95709   0       3      1         0.50      5         1.0        "ST MARY'S RIVER AT SAULT STE. MARIE,ONTARIO    "
  2      96378   96378   0       3      1         0.50      5         1.0        "ST MARY'S RIVER AT SAULT STE. MARIE,ONTARIO    "
  3     120667  120667   0       3      2        -0.33      2         1.0        "ST. CLAIR RIVER AT PORT HURON, MI"
  4     120665  120665   0       3      2        -0.33      2         1.0        "ST. CLAIR RIVER AT PORT HURON, MI"
  5     120662  120662   0       3      2        -0.33      2         1.0        "ST. CLAIR RIVER AT PORT HURON, MI"
  6     171375  171375   0       3      3         0.25      3         1.0        "SAGINAW RIVER AT SAGINAW "
  7     171369  171369   0       3      3         0.25      3         1.0        "SAGINAW RIVER AT SAGINAW "
  8     171360  171360   0       3      3         0.25      3         1.0        "SAGINAW RIVER AT SAGINAW "
  9     171348  171348   0       3      3         0.25      3         1.0        "SAGINAW RIVER AT SAGINAW "
 10          6       6   0       3      4         0.33      4         1.0        "FOX RIVER AT GREEN BAY, WI"
 11          4       4   0       3      4         0.33      4         1.0        "FOX RIVER AT GREEN BAY, WI"
 12          1       1   0       3      4         0.33      4         1.0        "FOX RIVER AT GREEN BAY, WI"
```

Since the USGS river data represent real-time observations, river discharge and water temperature cover only the nowcast cycle. For the forecast cycle, the most recent river discharge and water temperature observations are used for the 120-hour duration of the cycle. 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 time period. The climatological data for each river can be found in **nos.ofs.river.clim.usgs.nc**, which is in **/nosofs.vx.x.x/fix/share**.

Water temperature is not measured at the St. Mary's station (USGS 04127885); therefore, the measured value from the nearby S.W. Pier station (CO-OPS 9076070) is used at this location (Table 1).

2.3 Water Level Boundary Conditions

The water level boundary conditions include both the surface low-frequency water level and the lateral boundary condition at the St. Mary's River. As documented in the LMHOFS hindcast technical report (Kelley and Chen, 2019), the calculation of the low-frequency water level has been an ongoing challenge in modeling the Great Lakes accurately. While the inflow and outflow of LMHOFS can be obtained from observed discharge at the St. Mary's River and the St. Clair River, and the two main tributaries' discharge can be obtained from observations at the Saginaw River and Fox River, there are still some unmeasurable water sources and sinks in the system. The unaccounted inflow/outflow is due to a combination of inflow from other small tributaries, runoff, and over-lake precipitation and evaporation. It can be represented by the term, $Q_{residual}$.

$$Q_{residual} = Area \times dH/dt - \left(Q_{St.Mary's\ River} + Q_{Tributaries} - Q_{St.Clair\ River}\right) \quad (1)$$

where *dH/dt* is calculated by averaging the observed water level change over the previous five days at the following four NOS/CO-OPS water level gauges: Milwaukee, Wisconsin (9087057), Ludington, Michigan (9087023), Mackinaw City, Michigan (9075080), and Harbor Beach, Michigan (9075014). $Q_{St.Mary's\ River}$, $Q_{Tributaries}$, and $Q_{St.Clair\ River}$ are respectively the inflow at the St. Mary's River, the total discharge of the two tributaries that are considered, and the outflow at the St. Clair River. *Area* is the surface area of Lakes Michigan and Huron.

The residual water level change is calculated by the following formula:

$$H_{residual} = Q_{residual}/Are$$

$H_{residual}$ is then added to LMHOFS via the precipitation/evaporation in the forcing files **nos.lmhofs.met.nowcast.yyyymmdd.tccz.nc** and **nos.lmhofs.met.forecast.yyyymmdd.tccz.nc**.

The above methodology was initially designed by GLERL. Here, however, CO-OPS uses a simplified version to calculate $H_{residual}$ as in the following equation:

$$H_{residual} = HO_{average} - HM_{average} \quad (2)$$

where $HO_{average}$ and $HM_{average}$ are the averaged measured water level at those four stations and the averaged model water level at all grid points.

There are two reasons for this simplification. One is that the new method directly nudges the modeled water level to the observation, avoiding potential mistakes in obtaining inflow, outflow, and tributaries whose values are not required for the model. The other is that (2) implies that the model water level simulation results are independent of the water level correctness in the initial file. Even without a sound restart file, nowcast/forecast (N/F) running with (2) will bring the model water level close to the observation value within a few cycles.

A new subdirectory, **nos_ofs_residual_water_calculation.fd**, has been added into COMF under **/nosofs.vx.x.x/sorc**, where **nos_ofs_residual_water_calculation.f** can be found. This Fortran code, along with its control file, **nos.lmhofs.wl.calculation.ctl** (which is generated from **nos_ofs_residual_water_calculation.sh),** will be used to calculate the $H_{residual}$. The Figure 5 flow chart shows how to obtain residual data and insert the value into the LMHOFS meteorological forcing files, **nos.lmhofs.met.nowcast.yyyymmdd.tccz.nc** and **nos.lmhofs.met.forecast.yyyymmdd.tccz.nc.**

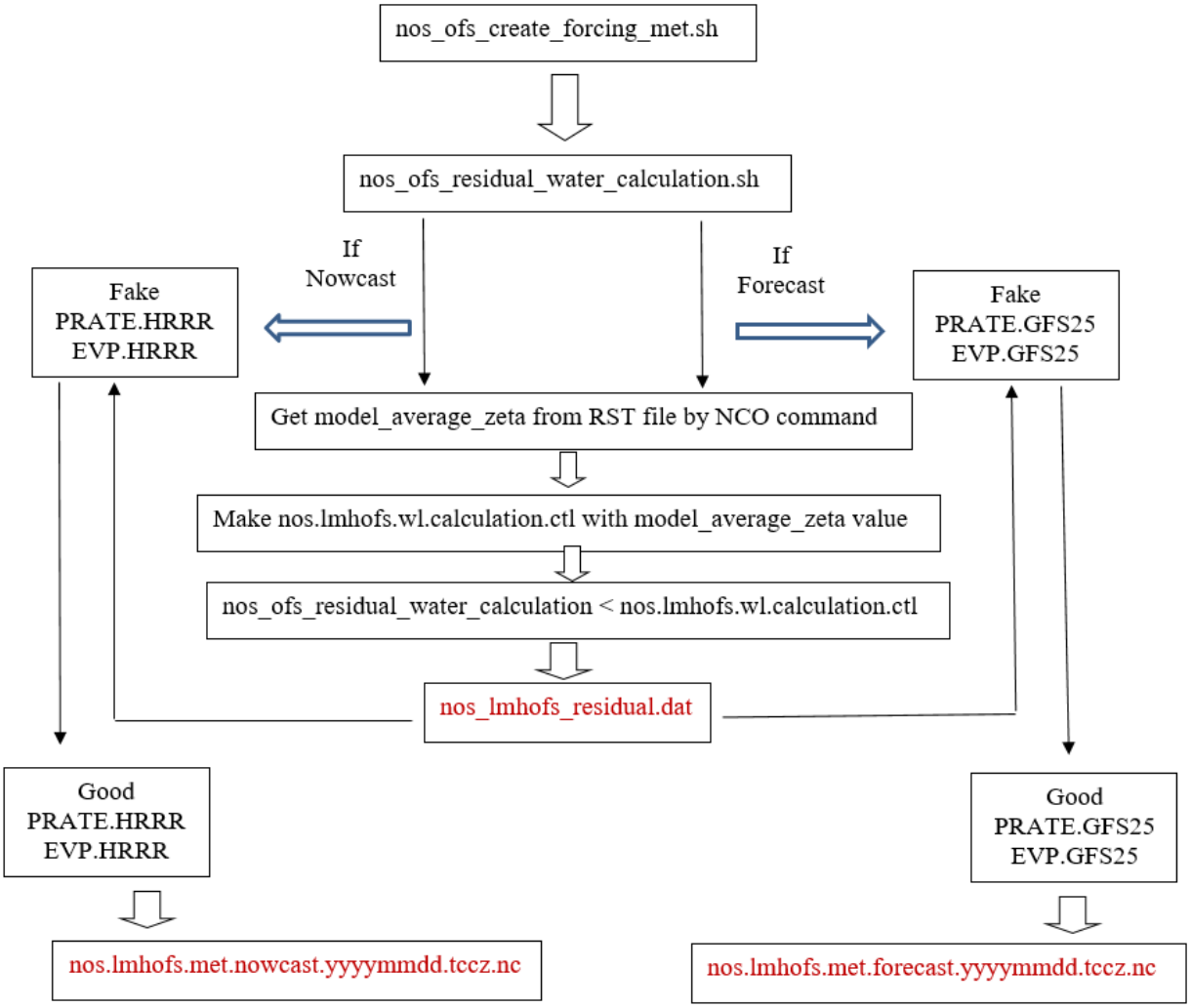


Figure 5. Flow chart to obtain lake residual data and insert it into meteorological forcing files.

The residual water can be distributed to the **nos.lmhofs.met.nowcast.yyyymmdd.tccz.nc** and **nos.lmhofs.met.forecast.yyyymmdd.tccz.nc** files. However, in practice, the residual water is evenly distributed into the nowcast meteorological forcing, **nos.lmhofs.met.nowcast.yyyymmdd.tccz.nc**. The **nos.lmhofs.met.forecast.yyyymmdd.tccz.nc,** therefore, contains no precipitation/evaporation adjustment.

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.lmhofs.ctl**", etc.

(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 zero surface elevation, zero velocity, and reasonable water temperature and salinity.

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

In the case of LMHOFS, the output restart file from the nowcast of the last cycle is used to generate the initial condition for the nowcast of the current cycle. For example, **nos.lmhofs.rst.nowcast.YYYYMMDD.t00z.nc** from the nowcast at 00z will be renamed (after minor "time" and "Itime" related revision) to **nos.lmhofs.init.nowcastYYYYMMDD.t06z.nc** for the nowcast at 06z. The restart file from the 06z cycle nowcast (**nos.lmhofs.rst.nowcast.YYYYMMDD.t06z.nc**) will be used for the 06z forecast cycle.

3.0 NOWCAST/FORECAST MODEL SKILL ASSESSMENT

LMHOFS performed robustly, producing reasonable predictions from its nowcast and forecast (N/F) cycles for water level, currents, and temperature over the model's skill assessment period of June 17, 2018–April 17, 2019. This is visually validated by the cycle-by-cycle nowcast and forecast results as shown in Figures 6–8. However, 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 LMHOFS 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 LMHOFS operational website (Tides and Currents, 2019). Generally, the cycle-by-cycle results (Figures 6–8) 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.

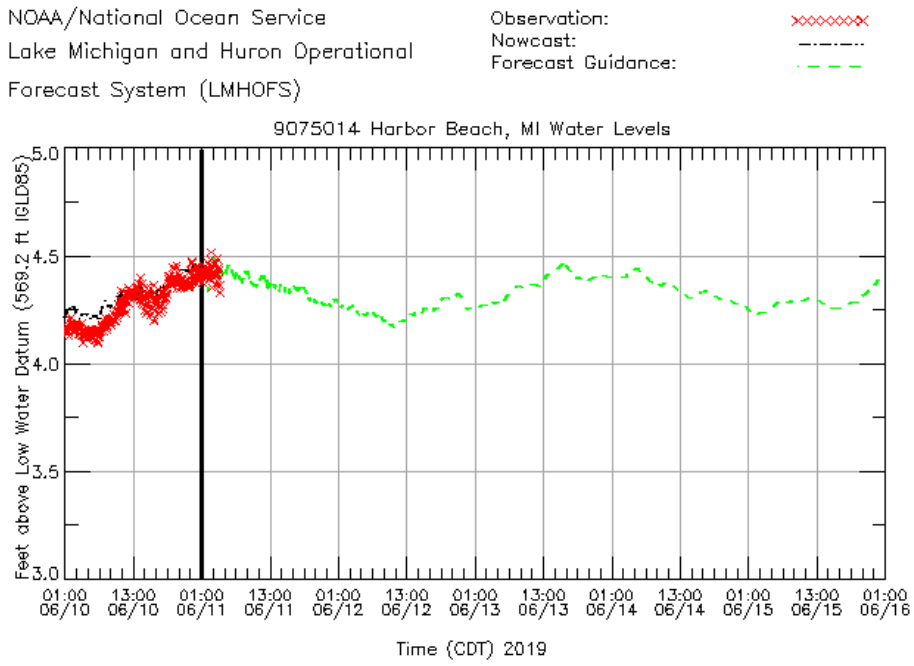


Figure 6. Example of water level nowcast (black dashed line) and forecast (green dashed line) output at Harbor Beach, MI.

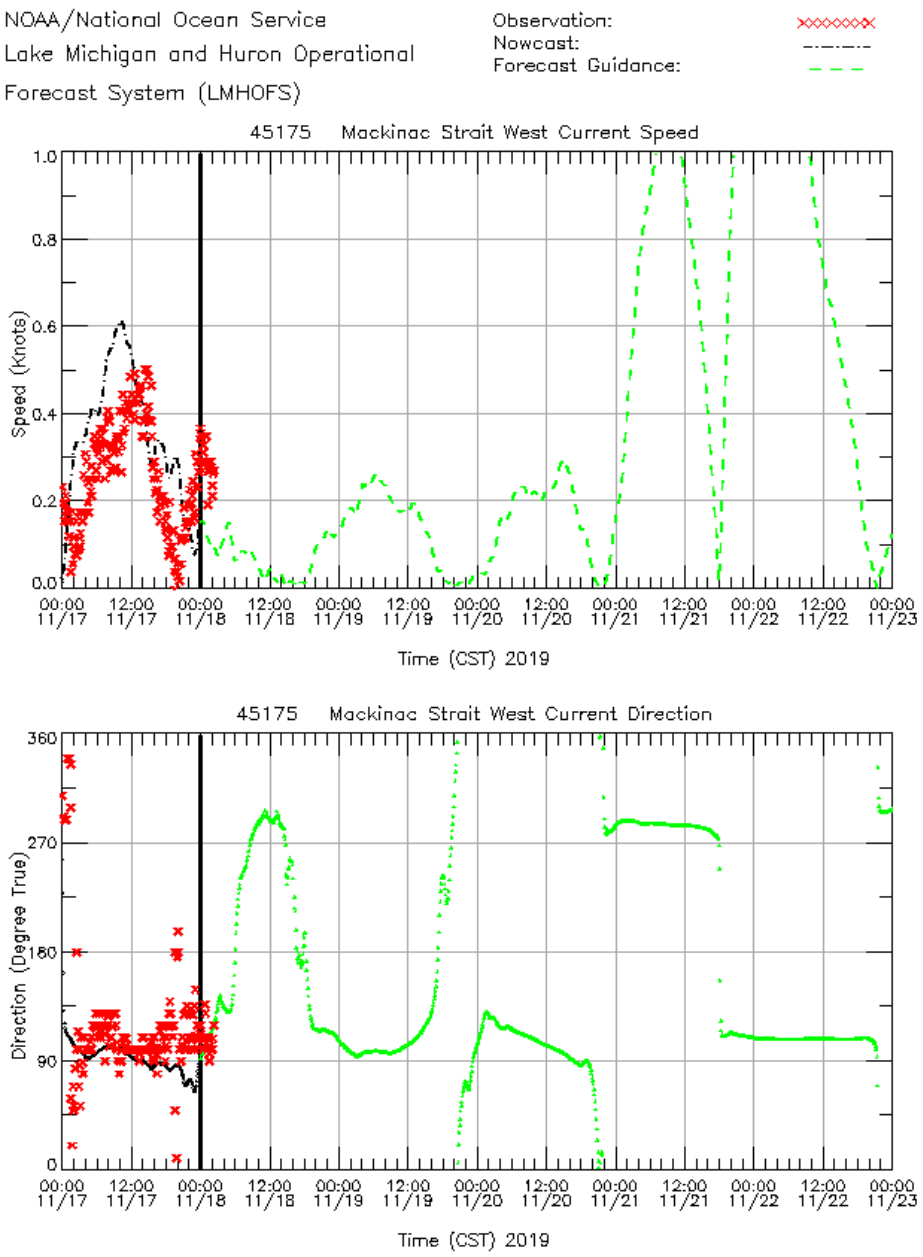


Figure 7. Example of surface water current speed and direction nowcast (black dashed line) and forecast (green dashed line) output at Mackinac Strait West.

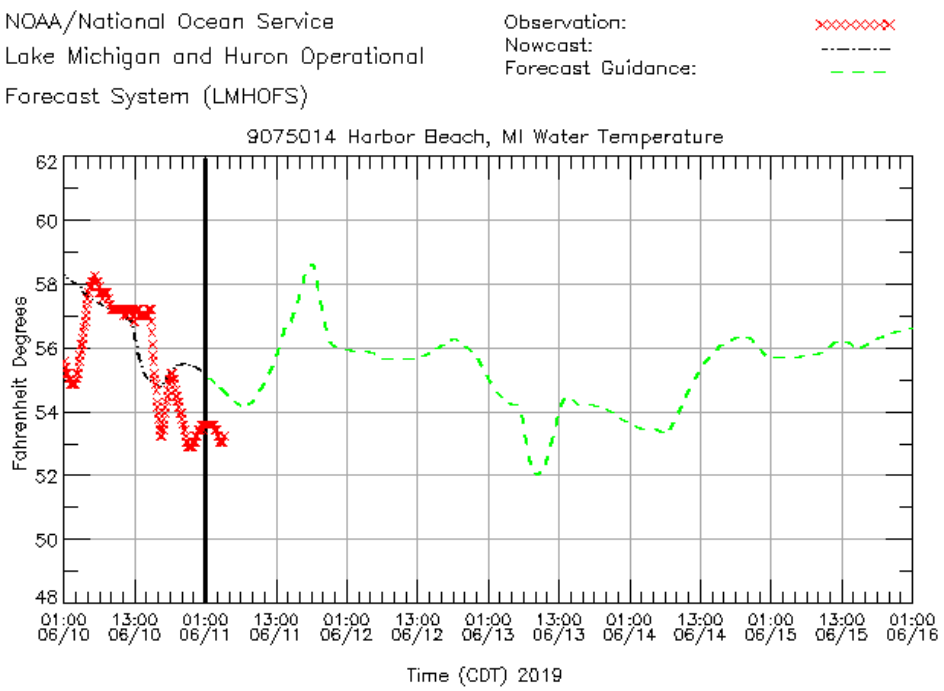


Figure 8. Example of water surface temperature nowcast (black dashed line) and forecast (green dashed line) output at Harbor Beach, MI.

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. A standard suite of skill assessment statistics is defined in Table 2.

Table 2. 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 ±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:

$$CF(X) \geq 90\%, \quad POF(2X) \leq 1\%, \quad NOF(2X) \leq 1\%, \quad MDPO(2X) \leq N, \quad MDNO(2X) \leq N$$

The NOS-accepted error criteria (X) are: 0.15 m for water level, 3.0 °C for water temperature, and 0.26 meters per second (m/s) for surface currents. The accepted N (duration) is 24 hours.

Data sources

As shown in Table 3 and Figure 9, the observed data were collected from two NOAA entities - CO-OPS and the NWS National Data Buoy Center (NDBC). To conduct the skill assessment, CO-OPS retrieved real-time measurements of water level, surface currents, and surface water temperature to compare with the model results. 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, C and D. Note: two NDBC stations, Muskegon Buoy and Saginaw Bay Buoy, are maintained by GLERL.

Table 3. The observation stations used for skill assessment of LMHOFS. In the table, WL, CU and T respectively represent water level, water current and water temperature. The two NDBC stations with * label are maintained by GLERL.

Owner	Station ID	Lat	Lon	Station Name	Variables
CO-OPS	9087031	42.79	-86.20	Holland, MI	WL, T
CO-OPS	9087023	43.95	-86.44	Ludington, MI	WL
CO-OPS	9087096	45.97	-85.87	Port Inland, MI	WL, T
CO-OPS	9075080	45.78	-84.72	Mackinaw, MI	WL, T
CO-OPS	9087044	41.73	-87.54	Calumet, MI	WL
CO-OPS	9087068	44.46	-87.50	Kewaunee, WI	WL
CO-OPS	9087057	43.00	-87.89	Milwaukee	WL
CO-OPS	9075099	45.99	-83.90	De Tour Village, MI	WL, T
CO-OPS	9087072	44.80	-87.31	Sturgeon Bay Canal	WL
CO-OPS	9075035	43.64	-83.85	Essexville, MI	WL
CO-OPS	9075014	43.85	-82.64	Harbor Beach, MI	WL, T
CO-OPS	9075002	43.14	-82.49	Lakeport, MI	WL
CO-OPS	9014098	43.01	-82.42	Fort Gratiot, MI	WL
NDBC	45014	44.80	-87.76	South Green Bay, WI	CU, T
NDBC	45002	45.34	-86.41	North Michigan	T
NDBC	45013	43.10	-87.85	Atwater Park, WI	T
NDBC	45024	43.98	-86.56	Ludington Buoy, MI	T
NDBC	45007	42.67	-87.03	South Michigan	T
*NDBC	45161	43.18	-86.36	Muskegon Buoy, MI	CU, T
NDBC	45174	42.14	-87.66	Wilmette Buoy, IL	T
NDBC	45029	42.90	-86.27	Holland Buoy, MI	T
NDBC	45170	41.76	-86.97	Michigan City Buoy	T
NDBC	45168	42.40	-86.33	South Haven Buoy, MI	T
NDBC	45175	45.83	-84.77	Mackinac Strait West	CU, T
NDBC	45003	45.35	-82.84	North Huron	T
NDBC	45162	44.98	-83.27	Thunder Bay Buoy, MI	T
*NDBC	45163	43.99	-83.6	Saginaw Bay Buoy, MI	CU, T
NDBC	45008	44.28	-82.42	South Huron	T

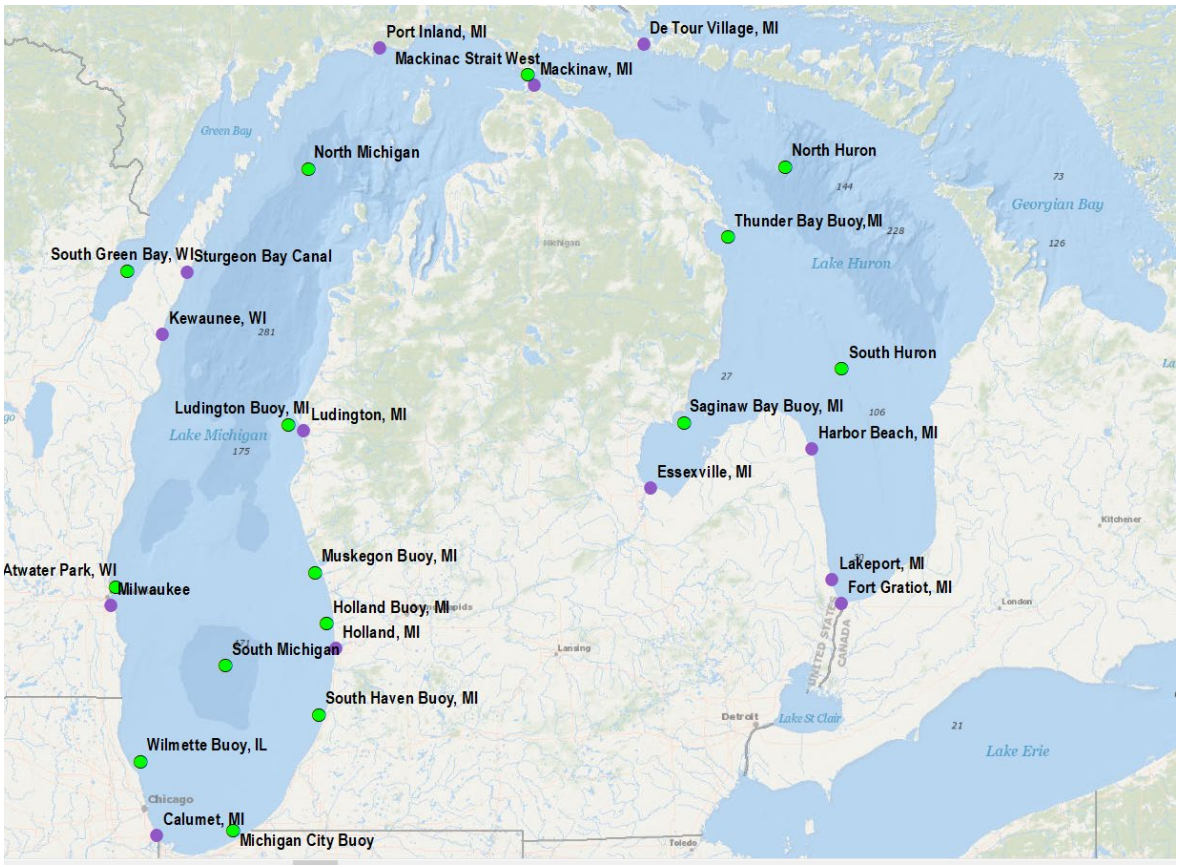


Figure 9. The locations of observation stations used for model skill assessment. CO-OPS stations are in purple, NDBC stations are in green. Muskegon Buoy and Saginaw Bay Buoy are maintained by GLERL.

3.3. Nowcast and Forecast Skill Assessment

The LMHOFS semi-operational nowcast and forecast assessment period was from June17, 2018-April 17, 2019, and the results from these simulations were organized into time series for analysis using the skill assessment software. Generally, RMSE, CF, NOF, POF, MDNO, and MDPO at each station satisfy the error criteria for most variables in both nowcast and forecast scenarios. The results of the skill assessment for water level, surface currents, and temperature are discussed in the following subsections.

Results of water level skill assessment

The skill assessment used thirteen water level stations (Table 3 and Figure 9), seven at Lake Michigan and six at Lake Huron. Modeled water levels generally agree well with observations. A typical cycle of N/F results is shown in Figure 6.

The RMSEs of nowcast water level at all stations are less than 0.15 m, the accepted error criteria for navigation applications. The RMSE results are shown in Figure 10. Figure 11 shows the forecast RMSE values at different forecast lead times from 6 hours to 120 hours. In general, forecasts out to 120 hours are all within accepted error limits (i.e., ≤0.15 m).

The tables in Appendix A show details of water elevation model skill assessment results at all stations for all skill metrics. Generally, nowcast and forecast CF values at all locations range from 91.4% to 100.0% (where ≥90% is the accepted error criteria). High CF values are due to the

nudging technique that was employed in the model. NOF and POF are less than 1% (the NOS accepted error criteria) at all stations for both nowcast and forecast scenarios. Both MDNO and MDPO at all stations are less than the required 24-hour criteria for both scenarios. The Essexville station did not perform as well as the rest of the stations, where the POF range is from 0.0–0.7% and the MDPO reaches 11.8 hours for the forecasts. Relatively poor model performance at Essexville might be due to the location of the station, which is at the head of the Saginaw Bay, where meteorological model output (HRRR and GFS25), which are used to drive LMHOFS, could not provide realistic meteorological forcings. This will be discussed later in this report where a winter storm event is investigated.

Time series comparisons of modeled and observed water level at all thirteen stations are shown in Appendix B. Modeled results generally agree with the observations at every station. During the assessment period, the observation at Port Inland is one month short. For consistency, the time series at this station is retained in the report.

Water level error comparisons were also made between LMHOFS and the previous POM-based LMOFS/LHOFS. Figure 12 shows the nowcast RMSE comparisons at twelve stations. LMHOFS significantly outperformed POM-based models at ten stations. For example, the LMHOFS water level nowcast at Essexville is ~0.04 m better than the LHOFS nowcast. Only at Calumet and De Tour Village does LMHOFS show lower water level skill than LMOFS or LHOFS.

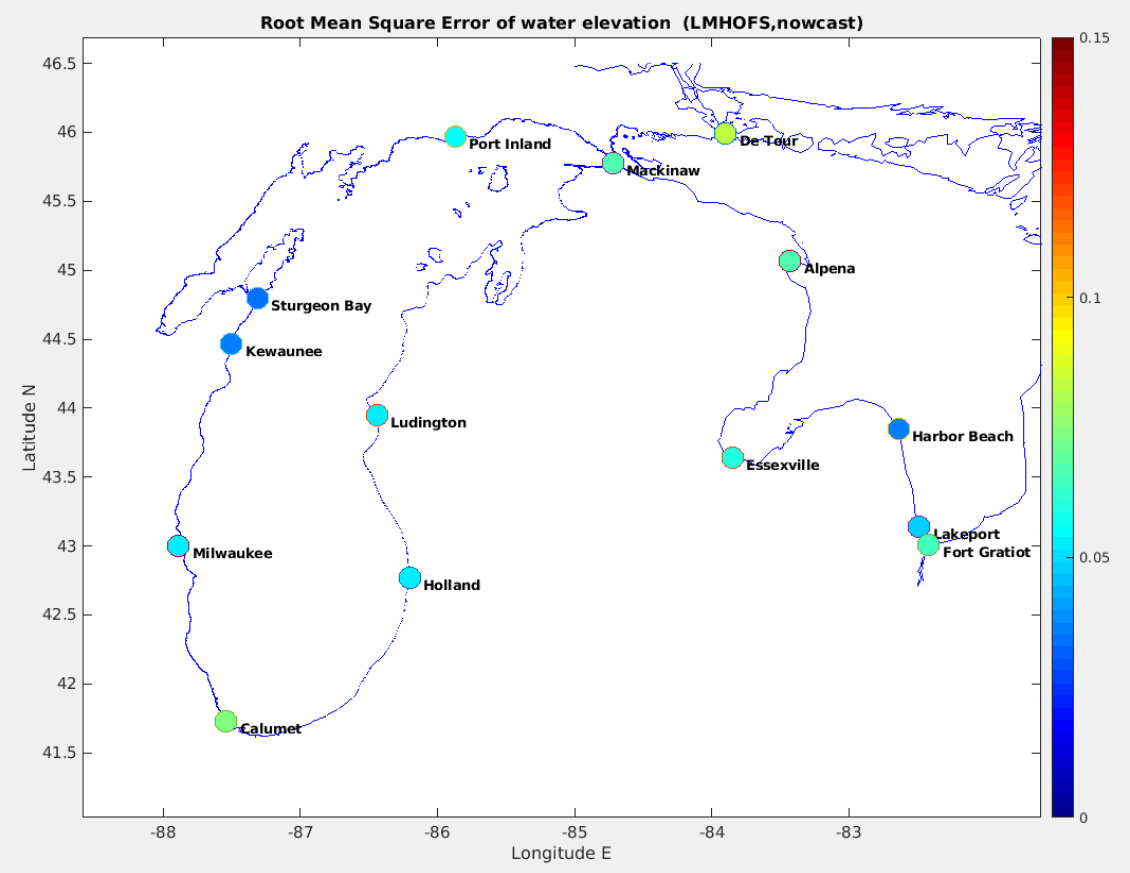
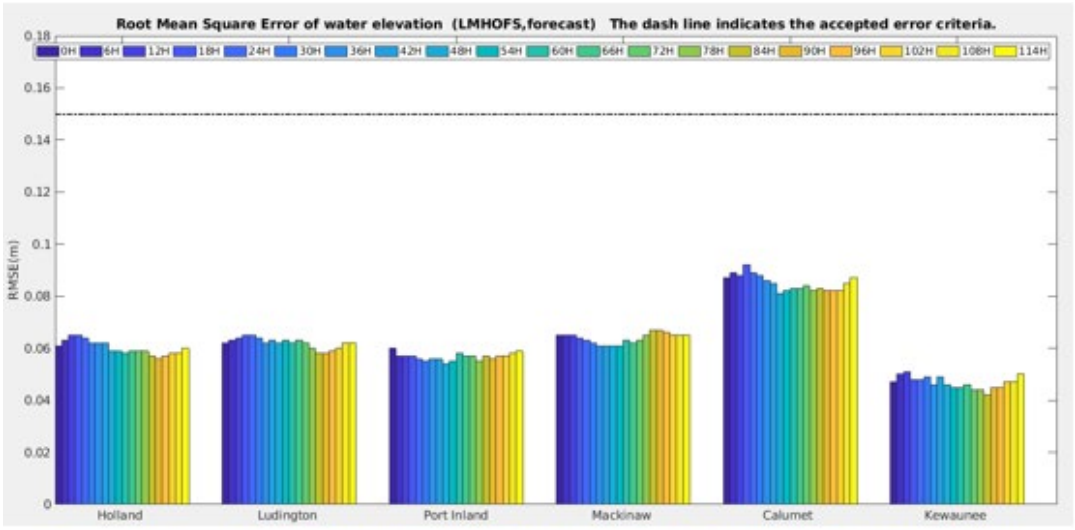
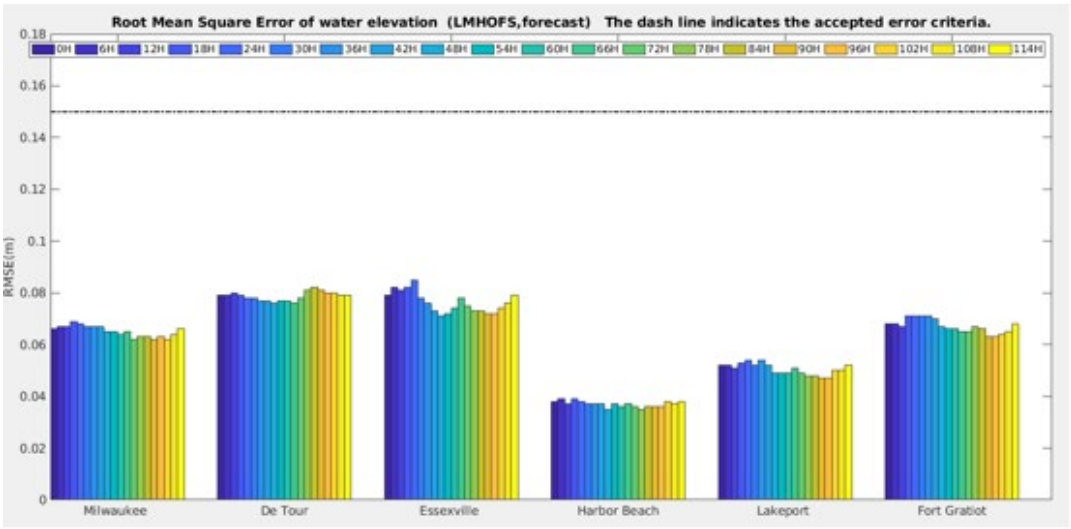


Figure 10. Nowcast RMSE of water level.





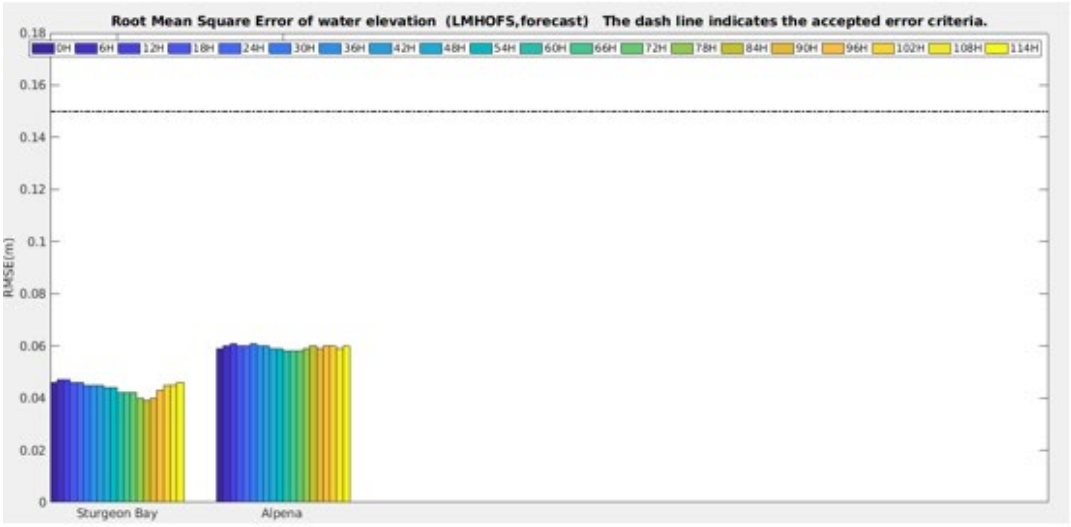


Figure 11. Forecast RMSE of water level.

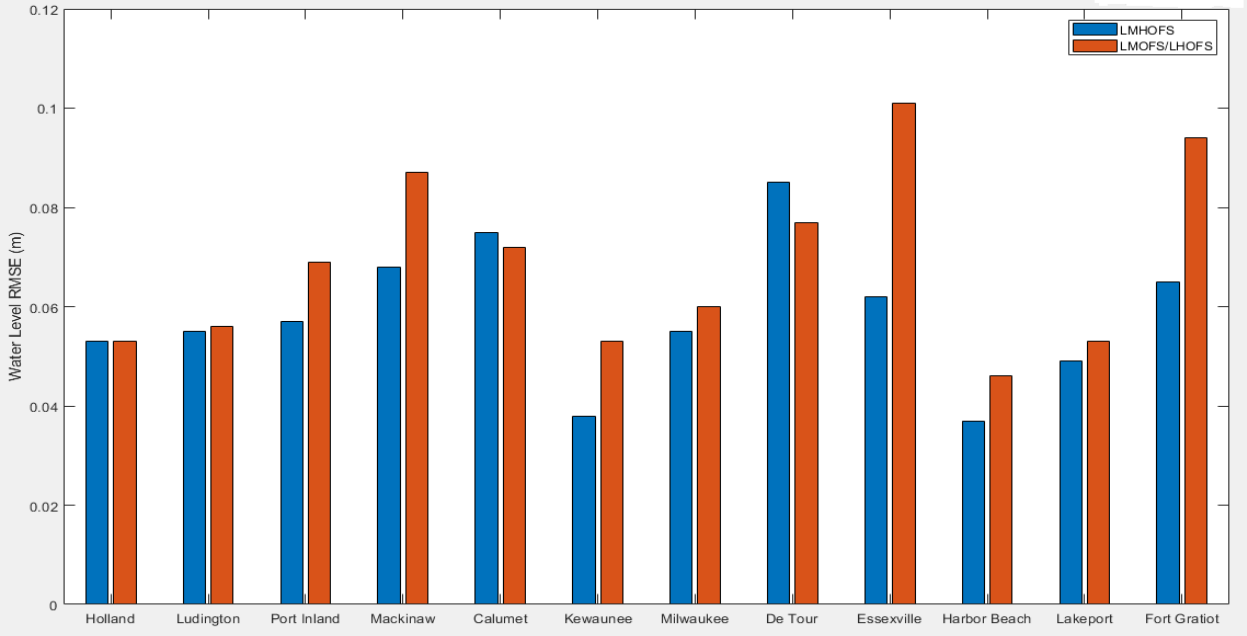


Figure 12. Nowcast water level RMSE comparison between LMHOFS (blue) and LMOFS/LHOFS (red).

Results of surface water currents skill assessment

The skill assessment used four water current stations (Table 3 and Figure 9). Modeled surface water currents generally agree well with observations at all currents stations. A typical cycle of N/F results is shown in Figure 7.

The RMSE of surface current speed for the nowcast and forecast results are shown in Figures 13 and 14. All stations meet NOS error criteria for navigation applications of 0.26 m/s. The details of surface current speed skill assessment results of all stations can be found in the tables in Appendix C. The RMSE values of surface current speed range from 0.049 m/s at South Green Bay to 0.143 m/s at Mackinac Strait West. The model is highly accurate in predicting water current speed, due largely to the FVCOM model physics and accuracy of HRRR and GFS winds, which offer reasonable meteorological forcing for LMHOFS. High skill in CF is also attained.

NOS model skill assessment software only accepts currents (faster than 0.26 m/s) to calculate the current direction skill metrics. Since the means of surface current speeds (shown in Tables C-1–C-4) are slower than 0.26 m/s for all stations, the current direction skill assessment results in Tables C-5–C-8 are not reliable (and cannot be considered when assessing model performance) and are retained only for informational purposes. Thus, the current speed error criterion of 0.26 m/s might be too tolerant to assess the model performance in the Great Lakes or other inland water bodies where currents are generally slower than in coastal regions.

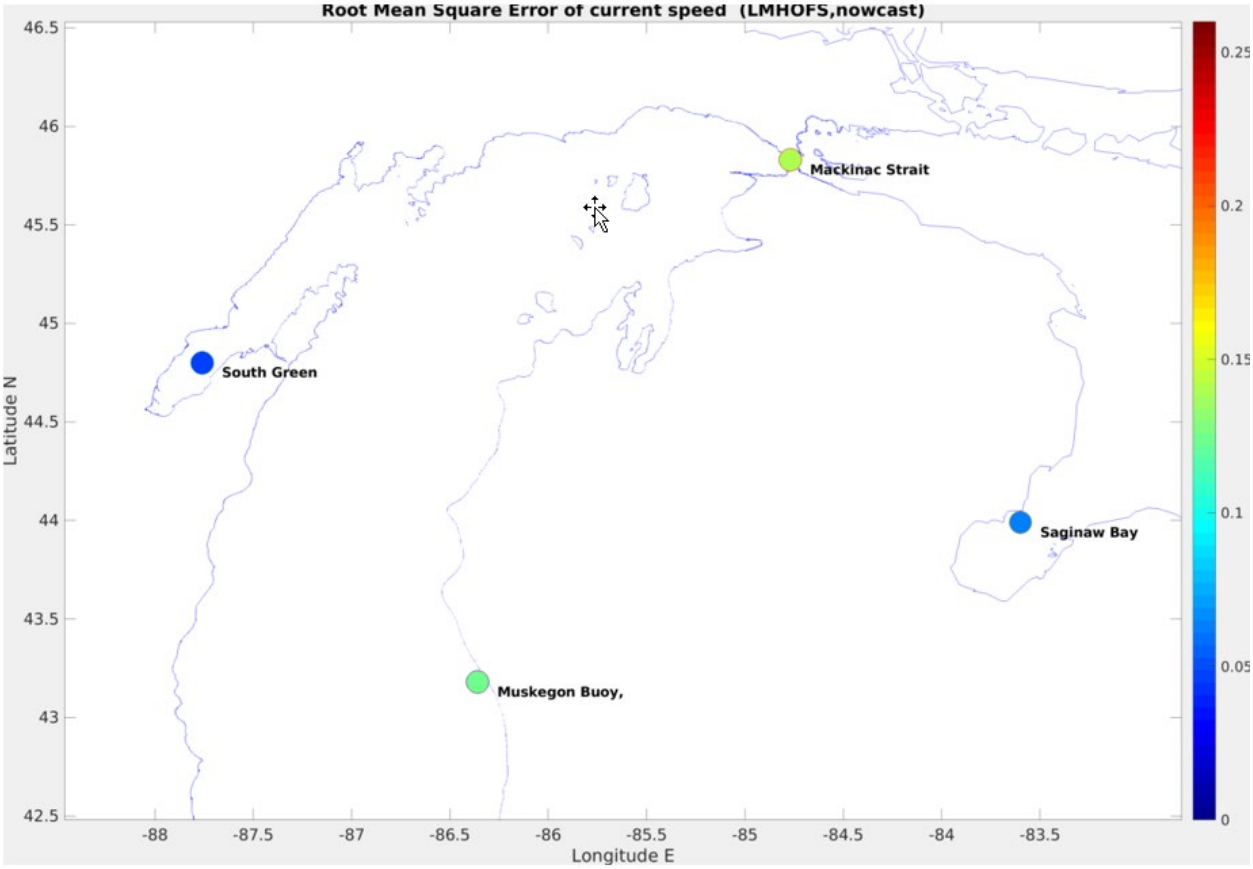


Figure 13. Nowcast RMSE of surface water current speed.

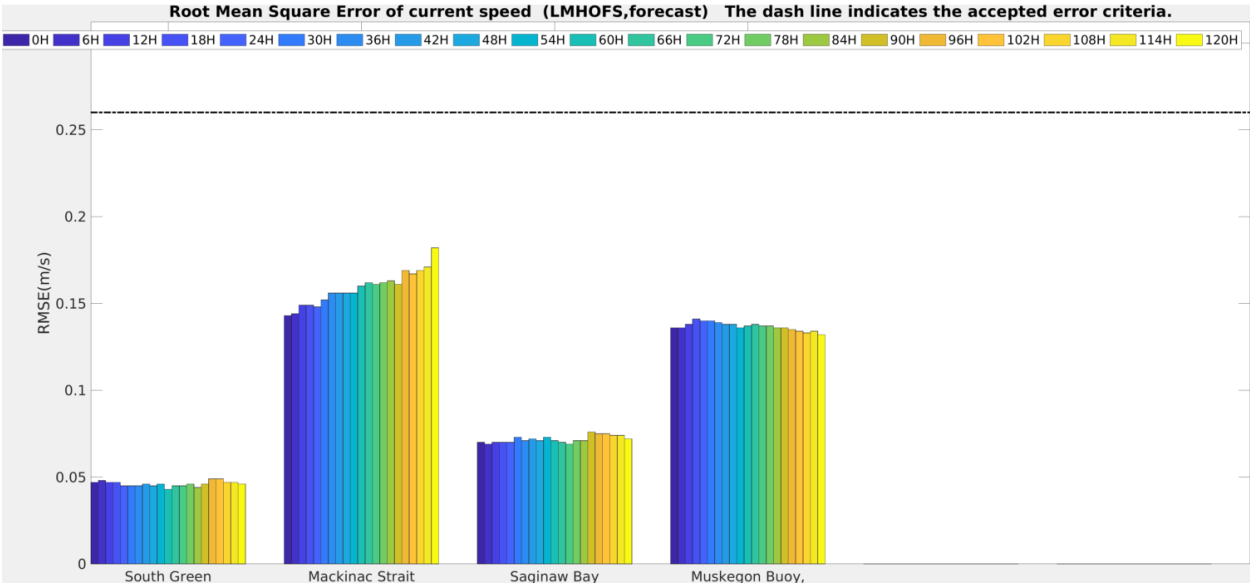


Figure 14. Forecast RMSE of surface water current speed.

Results of surface water temperature skill assessment

Model evaluation and skill assessment were conducted at twenty stations for surface water temperature. Five are CO-OPS year-round National Water Level Observation Network

(NWLON) stations, while the other fifteen are NDBC seasonal buoys (Table 3 and Figure 9). Modeled surface water temperatures generally agree well with observations at all locations. Figure 8 shows representative N/F results at the Harbor Beach station.

Nowcast and forecast RMSEs of surface water temperature are illustrated, respectively, in Figures 15 and 16. By comparison, the model's skill in predicting water temperature is not as good as the water level skill as described previously. The error at most stations is less than 3.0 °C, which is the NOS water temperature accepted error criteria for navigation applications. The nowcast RMSE at three stations, however, is larger than the criteria (Appendix D). The errors are lowest at Saginaw Bay and North Michigan, whose RMSE values are near1.7 °C. In contrast, the nowcast RMSE is highest at North Huron (i.e., exceeds criterion), where the RMSE is ~ 3.6 °C.

Further details of model skill assessment results at all stations can be found in the tables in Appendix D. As shown in the tables, CF did not meet the required 90% criterion at most stations, most notably at De Tour Village (59.2%). NOF and POF did not meet the criterion at some stations. The value of POF at Holland Buoy, for instance, was 6.7% for the nowcast and ≤11.6% for the forecast. MDNO and MDPO also exceeded the required 24-hour criteria at some stations. For example, MDNO and MDPO exceeded 100 hours at some stations, such as at Holland and Holland Buoy.

At some stations (Figure 16), like Muskegon Buoy, the nowcast (at 0h) RMSE values are higher than the values at some forecast lead times (06h and over). These unusual results might stem from the residual water approach described in Section 2.3. Since the residual water-induced water level adjustment is performed on the nowcast cycle only, the precipitate flux of water into/out of the system might create unrealistic results of water level and temperature, and therefore higher RMSE. This is the same reason that higher RMSE of water level can also be found at 0H for some stations in Figure 11.

Time series comparisons of modeled and observed water surface temperature at all stations are shown in Appendix E. Modeled results generally agree with the observations for every station, although the skill assessment indicates that the acceptable error thresholds were not attained at certain locations as previously mentioned. During the assessment period, only four CO-OPS NWLON stations (Holland, Mackinaw, De Tour Village, and Harbor Beach) collected data for the entire assessment period. All NDBC stations and one CO-OPS station (Port Inland) have observations only for 2018. These stations did not collect temperature measurements for the winter season.

Water temperature comparisons were also made between LMHOFS and LMOFS/LHOFS. Figure 17 shows the nowcast RMSE comparisons at five stations. LMHOFS outperforms POM-based models at all stations with the greatest improvement at Holland station, where RMSE improves about 1 °C.

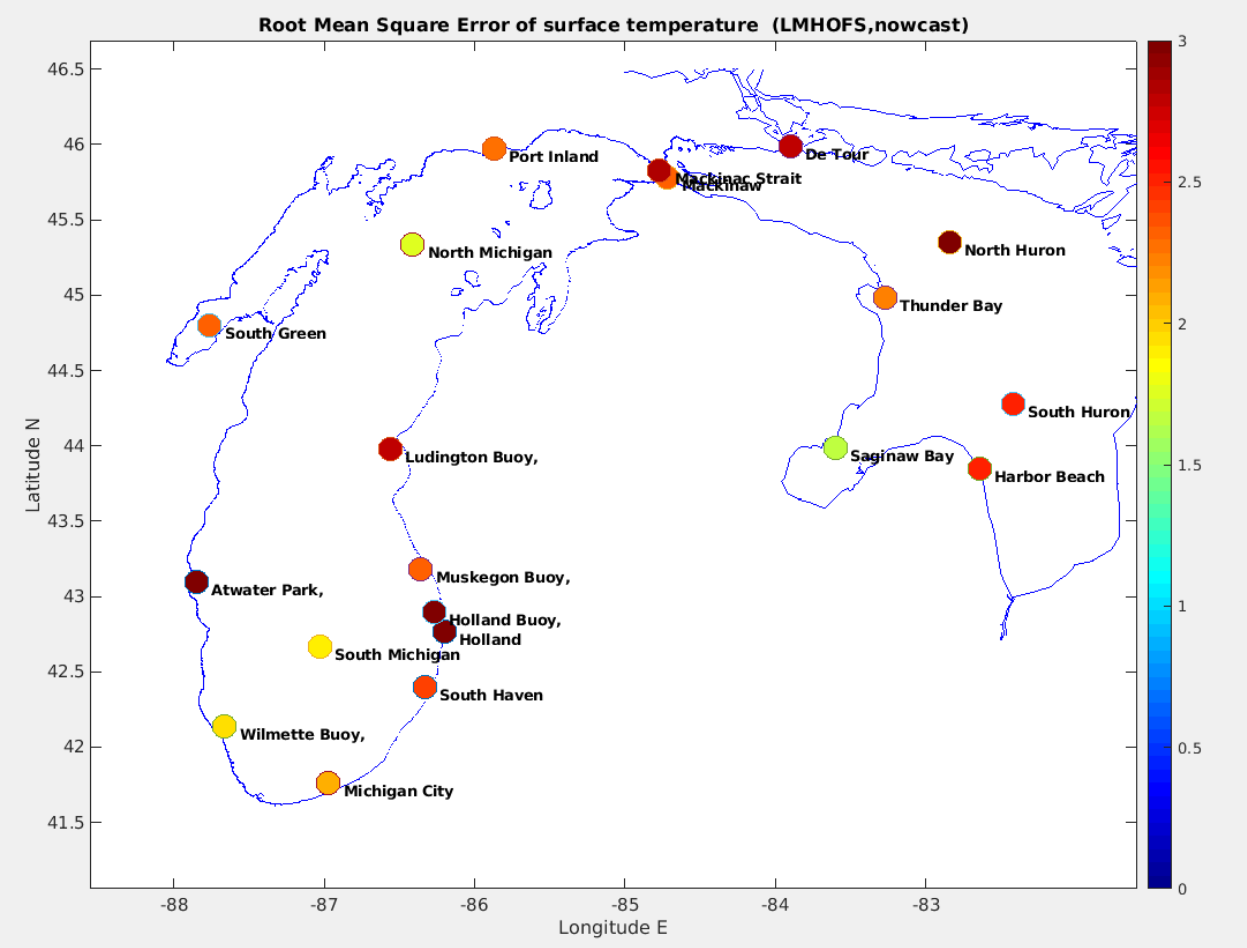


Figure 15. Nowcast RMSE of surface water temperature.

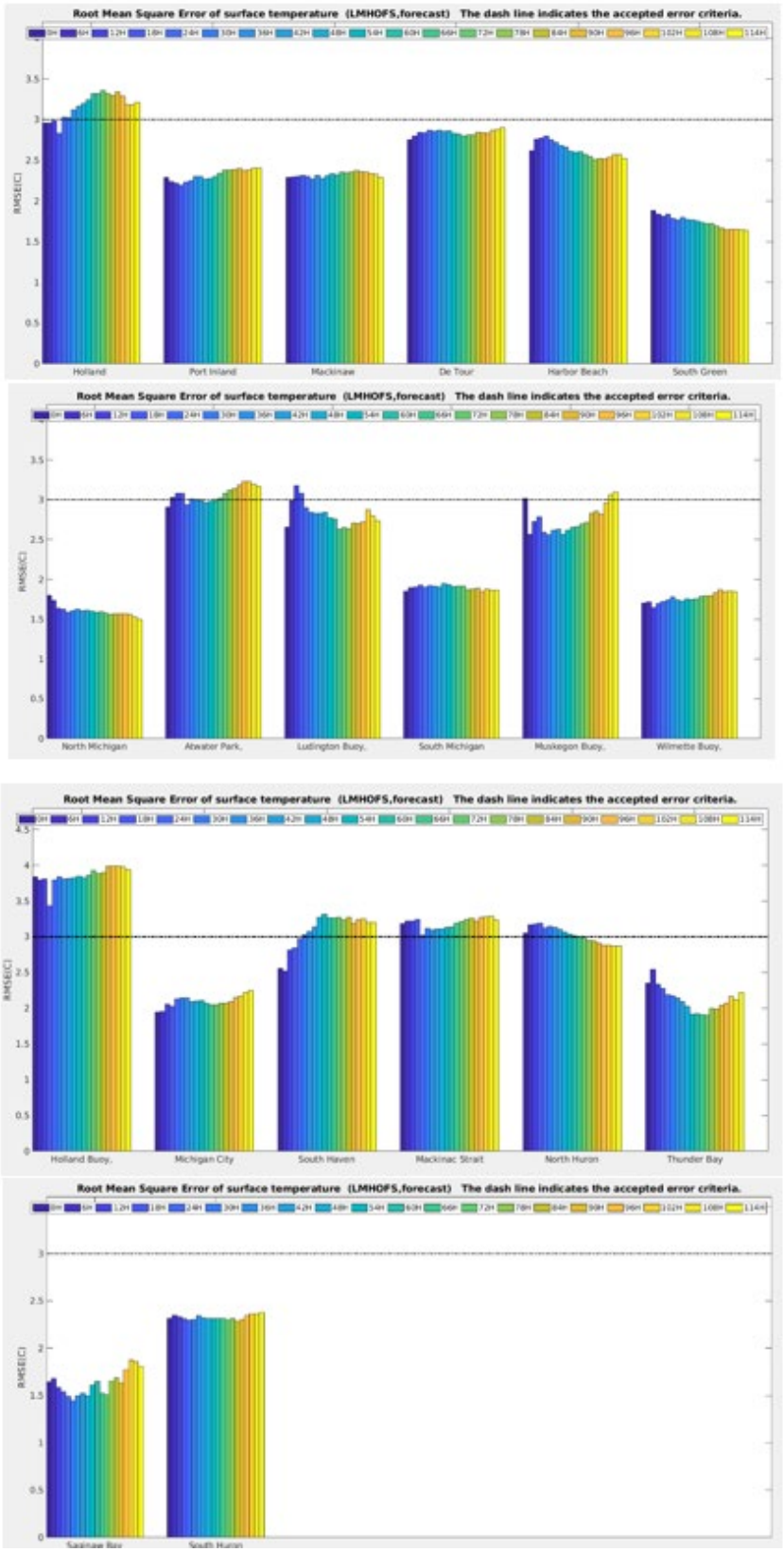


Figure 16. Forecast RMSE of surface water temperature.

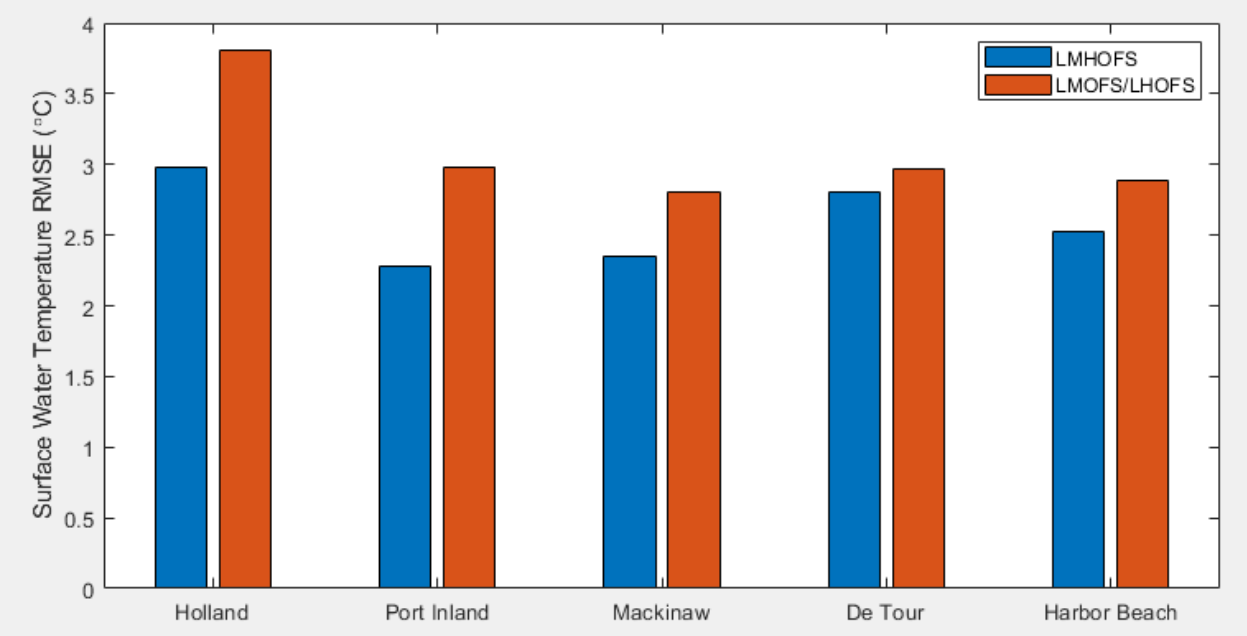


Figure 17. Nowcast surface water temperature RMSE comparison between LMHOFS (blue) and LMOFS/LHOFS (red).

Further model evaluation during a winter storm event

As previously described, CO-OPS evaluated LMHOFS' performance of water level, surface current, and surface temperature compared with the POM-based LMOFS/LHOFS. The comparative performance of LMHOFS, LMOFS, and LHOFS was also investigated for a strong winter storm event.

The Great Lakes area experienced a severe winter storm on February 24–26, 2019. Figures 18 and 19 show the comparisons of LMHOFS and LHOFS/LMOFS water level difference at Essexville and Port Inland. Observed water levels at these two stations are also shown in the figures.

Figure 18 indicates LHOFS over-predicted the drop in water level at Essexville. At 2/25/00Z the difference of model prediction and observation was almost 1.0 m. LMHOFS produced better water level results and slightly under-predicted the drop in water level. Its overall water level error during this event was less than 0.2 m.

Figure 19 shows much-improved skill at Port Inland for LMHOFS compared to LMOFS. LMOFS under-predicted both the observed water level rise and subsequent fall during this event.

Improved wind forcings for LMHOFS is the reason for the improvement in water level prediction at the Essexville station. As mentioned previously, LHOFS/LMOFS used observations from coastal and buoy stations, as well as the interpolated wind forcing, to drive the model nowcast. LMHOFS, however, uses HRRR output as the wind-forcing. The HRRR provides higher resolution (3 km) winds and is updated hourly.

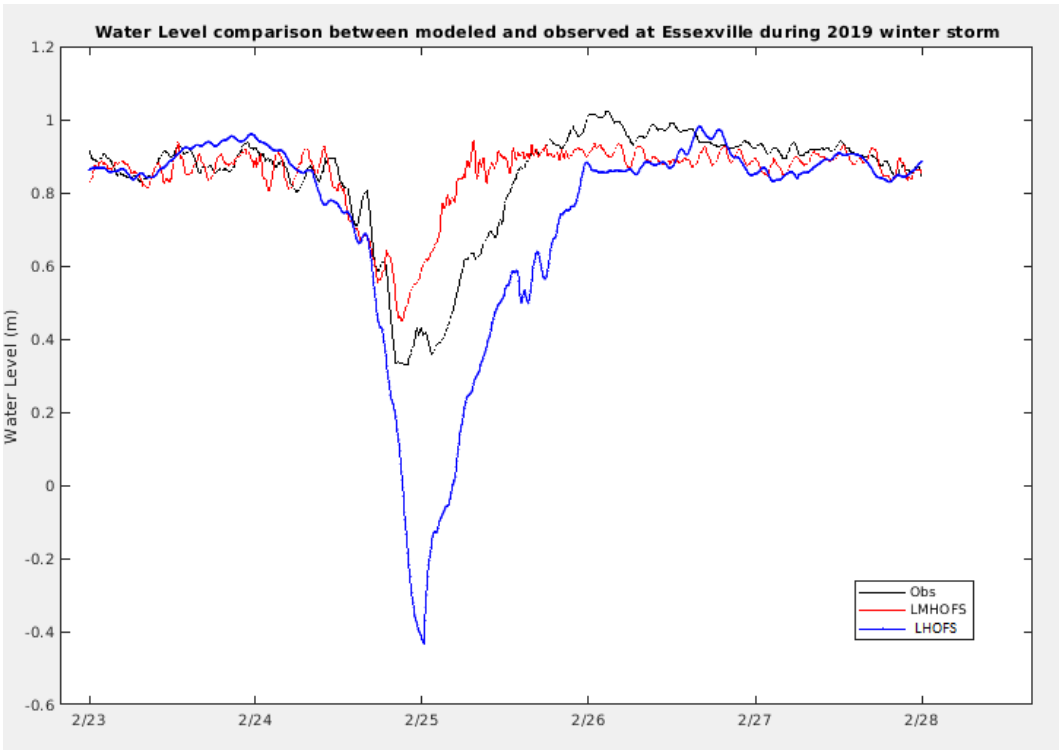


Figure 18. LMHOFS (red) and LHOFS (blue) water level difference compared to observations (black) at Essexville during the winter storm event.

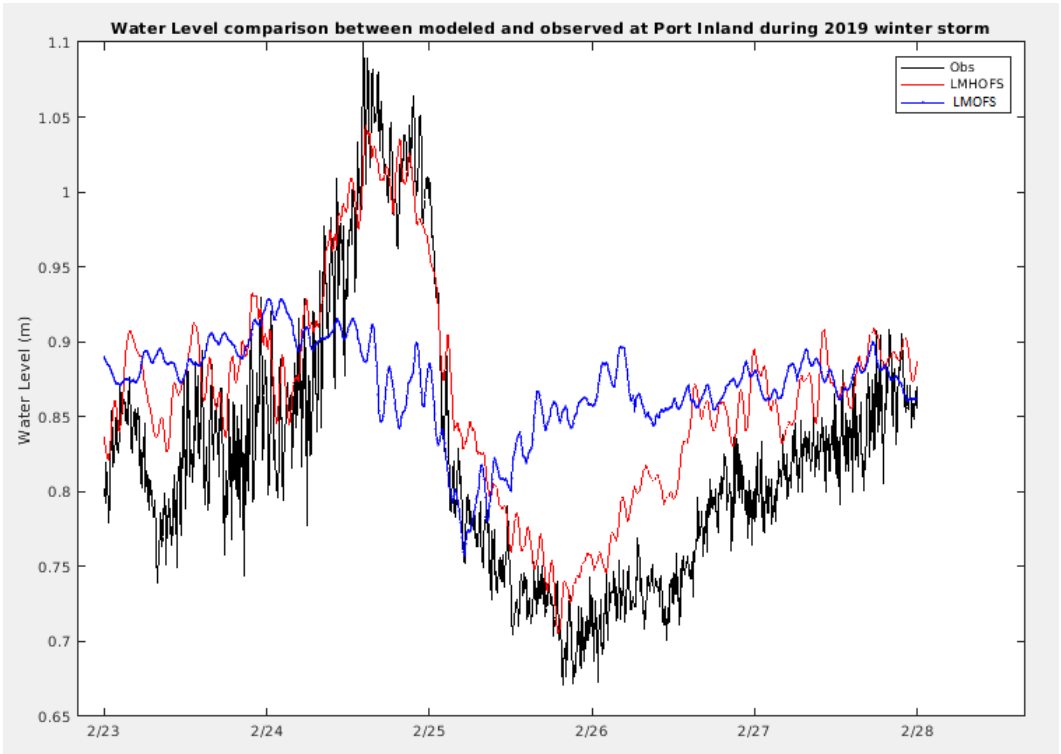


Figure 19. LMHOFS (red) and LMOFS (blue) water level difference compared to observations (black) at Port Inland during the winter storm event.

Figure 20 shows LMHOFS and LHOFS winds at Essexville during the winter storm event. When the wind reached its peak on February 25, LHOFS used the interpolated wind speed of ~23 m/s and LMHOFS used a wind speed of ~13 m/s. The lower HRRR winds used for LMHOFS improved the model skill compared to the higher interpolated winds used in LHOFS.

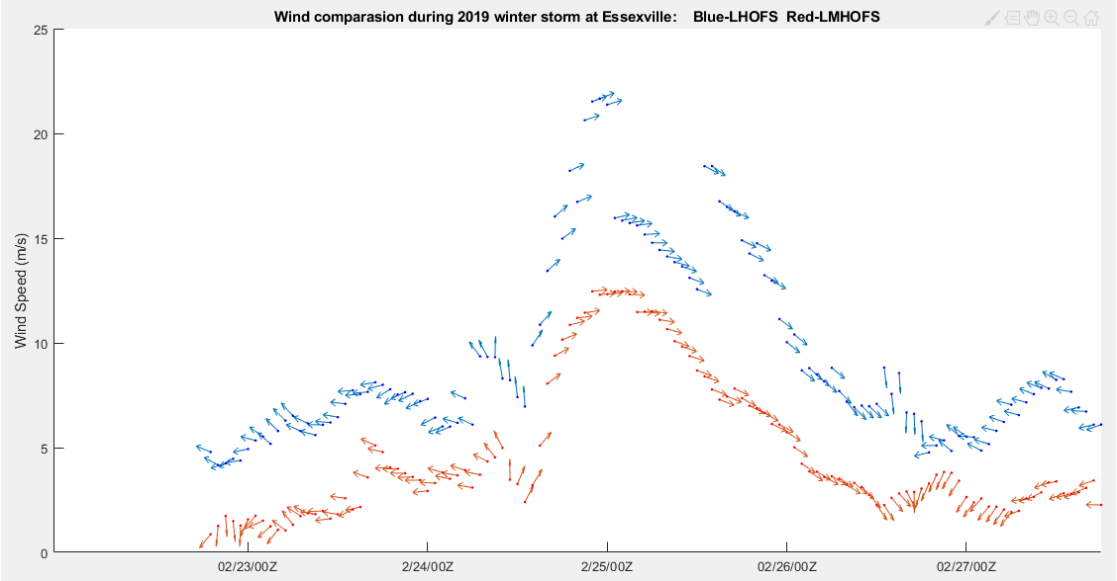


Figure 20. LMHOFS (red) and LHOFS (blue) wind difference at Essexville.

Similarly, wind differences of the two OFSs at Port Inland are shown in Figure 21. There is no clear indication at this station that the local wind was solely responsible for the different water level response of LMHOFS and LMOFS. The overall design of LMHOFS to be a higher resolution, integrated (combined LMOFS and LHOFS) FVCOM-based model was also a large contributing factor to the observed improvement in performance during this storm event.

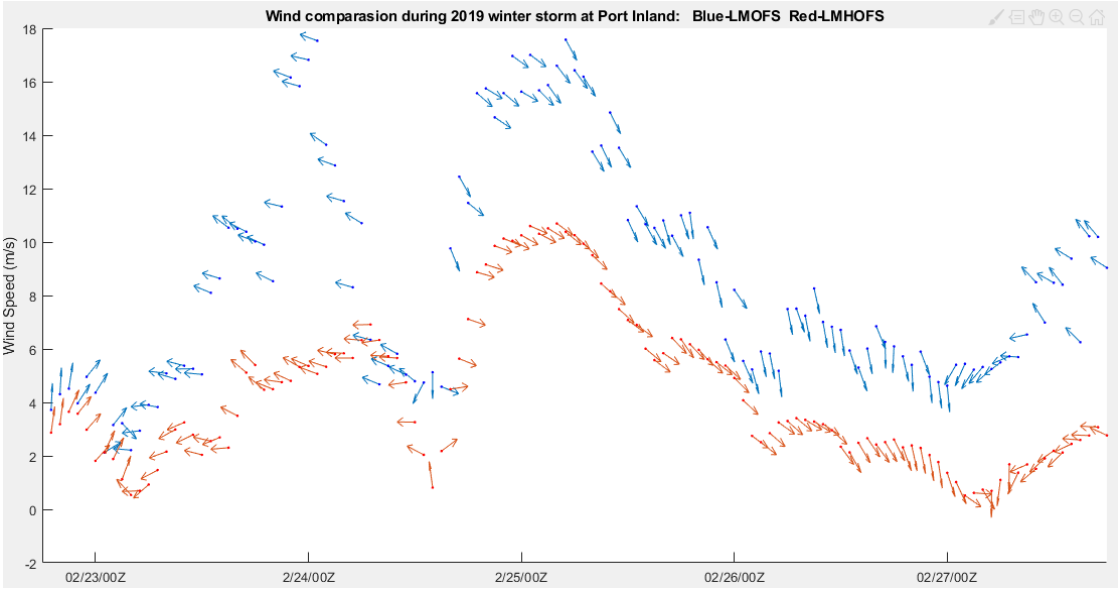


Figure 21. LMHOFS (red) and LMOFS (blue) wind difference at Port Inland.

4.0 CONCLUSIONS

GLERL developed and tested the LMHOFS, and NOS/Office of Coast Survey conducted hindcast skill assessment (Kelley and Chen, 2019). CO-OPS successfully implemented this OFS using the HPC-COMF on WCOSS. The COMF automatically generates all necessary forcing files for nowcast and forecast predictions in real-time mode. The LMHOFS nowcast/forecast runs began in March 2018, and its outputs for the period of June 17–April 17, 2019 were used for the LMHOFS N/F skill assessment.

The results indicate that all water level skill metrics passed NOS assessment criteria. For example, RMSEs at all stations were less than 0.15 m, the accepted error criteria for navigation applications. CFs for both nowcast and forecast were larger than 90.0%, and NOF and POF were less than 1% at all stations.

The RMSE of surface current speed for the nowcast and forecast results met NOS error criterion of 0.26 m/s. CF of water current speed was also within acceptable error tolerances. The current direction skill assessment was not reliable due to the lower current speeds typically occurring in the Great Lakes region.

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 ^{o}C) in all cases. Most other variables (CF, NOF, POF, MDNO, and MDPO) met the NOS-accepted skill assessment criteria.

Water level and surface temperature comparisons were made between LMHOFS and the POM-based LMOFS/LHOFS. LMHOFS outperformed LMOFS/LHOFS at all stations for water temperature prediction and at almost all stations for water level prediction.

Also, LMHOFS outperformed LMOFS/LHOFS in water level prediction during a strong winter storm within the skill assessment period. The design of the FVCOM-based system, and high resolution HRRR wind forcing were contributing factors.

LMHOFS became operational on WCOSS in July 2019 (NOS, 2019). The successful implementation of this new OFS provides reliable forecast guidance on water level, currents, and temperature to support NOS' navigation customers and will serve as the hydrodynamic basis for future operational ice modeling and other applications in the region.

ACKNOWLEDGEMENTS

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REFERENCES

Fairall, C. W., E. F. Bradley, D. P. Rogers, J. B. Edson, and G. S. Young, 1996, Bulk parameterization of air–sea fluxes in TOGA COARE. J. Geophys. Res., 101, 3747–3767.

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.

Kelley, J and Y. Chen (2019), Upgrade of NOS Lake Michigan and Lake Huron Operational Forecast Systems to FVCOM: Model Development and Hindcast Skill Assessment. NOAA Technical Report NOS CS xx, Silver Spring, MD.

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.

Tides and Currents (2019). Lake Michigan and Huron Operational Forecast System (LMHOFS). Retrieved from https://tidesandcurrents.noaa.gov/ofs/lmhofs/lmhofs.html

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.

LIST OF APPENDICES

APPENDIX A. WATER LEVEL MODEL SKILL ASSESSEMENT TABLES

Table A-1. Water level skill assessment at Holland

Station: Holland
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68572	0.907									
h			68572	0.944									
H-h	15	cm 24h	68572	-0.037	0.053	0.038	0.1	99.0	0.0	1.8	0.0	0.00	0.88
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15	cm 24h	953	-0.042	0.061	0.043	0.0	98.1	0.0	0.0	0.0		
H012-h012	15	cm 24h	952	-0.043	0.063	0.046	0.0	97.9	0.0	0.0	0.0		
H018-h018	15	cm 24h	951	-0.045	0.065	0.047	0.0	97.6	0.0	0.0	0.0		
H024-h024	15	cm 24h	950	-0.047	0.065	0.045	0.0	97.8	0.0	0.0	0.0		
H030-h030	15	cm 24h	949	-0.047	0.064	0.044	0.0	98.0	0.0	0.0	0.0		
H036-h036	15	cm 24h	948	-0.046	0.062	0.042	0.0	98.1	0.0	0.0	0.0		
H042-h042	15	cm 24h	947	-0.045	0.062	0.043	0.0	97.7	0.0	0.0	0.0		
H048-h048	15	cm 24h	946	-0.045	0.062	0.044	0.0	97.9	0.0	0.0	0.0		
H054-h054	15	cm 24h	945	-0.043	0.059	0.040	0.0	98.6	0.0	0.0	0.0		
H060-h060	15	cm 24h	944	-0.043	0.059	0.040	0.0	98.1	0.0	0.0	0.0		
H066-h066	15	cm 24h	943	-0.042	0.058	0.039	0.0	98.3	0.0	0.0	0.0		
H072-h072	15	cm 24h	942	-0.043	0.059	0.041	0.0	98.3	0.0	0.0	0.0		
H078-h078	15	cm 24h	941	-0.043	0.059	0.040	0.0	98.7	0.0	0.0	0.0		
H084-h084	15	cm 24h	940	-0.043	0.059	0.041	0.0	98.7	0.0	0.0	0.0		
H090-h090	15	cm 24h	939	-0.042	0.057	0.040	0.0	99.0	0.0	0.0	0.0		
H096-h096	15	cm 24h	957	-0.040	0.056	0.040	0.0	99.2	0.0	0.0	0.0		
H102-h102	15	cm 24h	956	-0.039	0.057	0.041	0.0	99.2	0.0	0.0	0.0		
H108-h108	15	cm 24h	955	-0.040	0.058	0.042	0.0	98.7	0.0	0.0	0.0		
H114-h114	15	cm 24h	954	-0.041	0.058	0.041	0.0	99.0	0.0	0.0	0.0		
H120-h120	15	cm 24h	953	-0.042	0.060	0.044	0.0	98.3	0.0	0.0	0.0		

Table A-2. Water level skill assessment at Ludington

Station: Ludington
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68572	0.907									
h			68572	0.949									
H-h	15	cm 24h	68572	-0.042	0.055	0.035	0.1	99.3	0.0	0.9	0.0	0.00	0.88
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15	cm 24h	953	-0.047	0.062	0.041	0.0	98.5	0.0	0.0	0.0		
H012-h012	15	cm 24h	952	-0.049	0.063	0.041	0.0	98.7	0.0	0.0	0.0		
H018-h018	15	cm 24h	951	-0.049	0.064	0.040	0.0	98.7	0.0	0.0	0.0		
H024-h024	15	cm 24h	950	-0.052	0.065	0.040	0.0	98.3	0.0	0.0	0.0		
H030-h030	15	cm 24h	949	-0.052	0.065	0.040	0.0	98.1	0.0	0.0	0.0		
H036-h036	15	cm 24h	948	-0.051	0.064	0.039	0.0	98.5	0.0	0.0	0.0		
H042-h042	15	cm 24h	947	-0.049	0.062	0.039	0.0	98.3	0.0	0.0	0.0		
H048-h048	15	cm 24h	946	-0.049	0.063	0.040	0.0	98.5	0.0	0.0	0.0		
H054-h054	15	cm 24h	945	-0.048	0.062	0.039	0.0	98.3	0.0	0.0	0.0		
H060-h060	15	cm 24h	944	-0.049	0.063	0.040	0.0	98.2	0.0	0.0	0.0		
H066-h066	15	cm 24h	943	-0.049	0.062	0.039	0.0	98.3	0.0	0.0	0.0		
H072-h072	15	cm 24h	942	-0.050	0.063	0.038	0.0	98.6	0.0	0.0	0.0		
H078-h078	15	cm 24h	941	-0.049	0.062	0.038	0.0	99.0	0.0	0.0	0.0		
H084-h084	15	cm 24h	940	-0.047	0.060	0.037	0.0	99.0	0.0	0.0	0.0		
H090-h090	15	cm 24h	939	-0.045	0.058	0.035	0.0	99.8	0.0	0.0	0.0		
H096-h096	15	cm 24h	957	-0.045	0.058	0.036	0.0	99.6	0.0	0.0	0.0		
H102-h102	15	cm 24h	956	-0.045	0.059	0.038	0.0	99.3	0.0	0.0	0.0		
H108-h108	15	cm 24h	955	-0.046	0.060	0.039	0.0	99.1	0.0	0.0	0.0		
H114-h114	15	cm 24h	954	-0.047	0.062	0.040	0.0	98.8	0.0	0.0	0.0		
H120-h120	15	cm 24h	953	-0.046	0.062	0.041	0.0	98.4	0.0	0.0	0.0		

Table A-3. Water level skill assessment at Port Inland

Station: Port Inland
Observed data time period from: / 6/17/2018 to /12/ 2/2018
Data gap is filled using 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			63506	0.923									
h			63506	0.881									
H-h	15 cm	24h	63506	0.042	0.057	0.038	0.0	99.3	0.0	1.0	0.0	0.00	0.89
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15 cm	24h	886	0.034	0.060	0.049	0.0	98.4	0.0	0.0	0.0		
H012-h012	15 cm	24h	884	0.031	0.057	0.048	0.0	98.9	0.0	0.0	0.0		
H018-h018	15 cm	24h	882	0.031	0.057	0.047	0.0	98.3	0.0	0.0	0.0		
H024-h024	15 cm	24h	880	0.031	0.057	0.048	0.0	98.6	0.1	0.0	0.0		
H030-h030	15 cm	24h	878	0.030	0.056	0.047	0.0	99.1	0.0	0.0	0.0		
H036-h036	15 cm	24h	876	0.029	0.055	0.047	0.0	98.7	0.0	0.0	0.0		
H042-h042	15 cm	24h	874	0.030	0.056	0.048	0.0	99.0	0.0	0.0	0.0		
H048-h048	15 cm	24h	872	0.031	0.056	0.047	0.0	99.1	0.0	0.0	0.0		
H054-h054	15 cm	24h	881	0.031	0.054	0.044	0.0	99.5	0.0	0.0	0.0		
H060-h060	15 cm	24h	885	0.032	0.055	0.046	0.0	98.9	0.0	0.0	0.0		
H066-h066	15 cm	24h	873	0.034	0.058	0.047	0.0	98.7	0.0	0.0	0.0		
H072-h072	15 cm	24h	872	0.031	0.057	0.048	0.0	98.9	0.0	0.0	0.0		
H078-h078	15 cm	24h	871	0.032	0.057	0.047	0.0	99.2	0.0	0.0	0.0		
H084-h084	15 cm	24h	870	0.034	0.055	0.044	0.0	99.4	0.0	0.0	0.0		
H090-h090	15 cm	24h	870	0.037	0.057	0.043	0.0	99.3	0.0	0.0	0.0		
H096-h096	15 cm	24h	889	0.036	0.056	0.043	0.0	99.3	0.0	0.0	0.0		
H102-h102	15 cm	24h	889	0.035	0.057	0.044	0.0	99.3	0.0	0.0	0.0		
H108-h108	15 cm	24h	889	0.035	0.057	0.046	0.0	99.1	0.0	0.0	0.0		
H114-h114	15 cm	24h	888	0.034	0.058	0.048	0.0	98.6	0.0	0.0	0.0		
H120-h120	15 cm	24h	887	0.034	0.059	0.048	0.0	98.6	0.0	0.0	0.0		

Table A-4. Water level skill assessment at Mackinaw

Station: Mackinaw
Observed data time period from: / 9/18/2018 to / 4/ 2/2019
Data gap is filled using 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			68513	0.915									
h			68513	0.857									
H-h	15 cm	24h	68513	0.057	0.068	0.037	0.0	98.7	0.0	0.0	0.3	0.00	0.83
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15 cm	24h	952	0.052	0.065	0.039	0.0	98.9	0.0	0.0	0.0		
H012-h012	15 cm	24h	951	0.051	0.065	0.040	0.0	98.8	0.0	0.0	0.0		
H018-h018	15 cm	24h	950	0.051	0.065	0.039	0.0	98.8	0.0	0.0	0.0		
H024-h024	15 cm	24h	950	0.050	0.064	0.039	0.0	98.8	0.0	0.0	0.0		
H030-h030	15 cm	24h	948	0.050	0.063	0.038	0.0	99.3	0.0	0.0	0.0		
H036-h036	15 cm	24h	947	0.050	0.062	0.037	0.0	99.0	0.0	0.0	0.0		
H042-h042	15 cm	24h	946	0.049	0.061	0.037	0.0	99.5	0.0	0.0	0.0		
H048-h048	15 cm	24h	945	0.049	0.061	0.037	0.0	99.3	0.0	0.0	0.0		
H054-h054	15 cm	24h	944	0.049	0.061	0.036	0.0	99.6	0.0	0.0	0.0		
H060-h060	15 cm	24h	943	0.050	0.061	0.036	0.0	99.6	0.0	0.0	0.0		
H066-h066	15 cm	24h	942	0.051	0.063	0.036	0.0	99.7	0.0	0.0	0.0		
H072-h072	15 cm	24h	941	0.050	0.062	0.037	0.0	99.4	0.0	0.0	0.0		
H078-h078	15 cm	24h	940	0.050	0.063	0.037	0.0	99.3	0.0	0.0	0.0		
H084-h084	15 cm	24h	939	0.053	0.065	0.039	0.0	98.6	0.0	0.0	0.0		
H090-h090	15 cm	24h	938	0.055	0.067	0.039	0.0	98.7	0.0	0.0	0.0		
H096-h096	15 cm	24h	956	0.054	0.067	0.039	0.0	98.5	0.0	0.0	0.0		
H102-h102	15 cm	24h	955	0.054	0.066	0.038	0.0	98.4	0.0	0.0	0.0		
H108-h108	15 cm	24h	954	0.053	0.065	0.038	0.0	98.5	0.0	0.0	0.0		
H114-h114	15 cm	24h	953	0.052	0.065	0.039	0.0	98.4	0.0	0.0	0.0		
H120-h120	15 cm	24h	952	0.052	0.065	0.039	0.0	98.7	0.0	0.0	0.0		

Table A-5. Water level skill assessment at Calumet

Station: Calumet
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68582	0.900									
h			68582	0.952									
H-h	15 cm	24h	68582	-0.052	0.075	0.054	0.1	96.4	0.0	1.3	0.0	0.00	0.85
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15 cm	24h	953	-0.058	0.087	0.066	0.4	94.5	0.0	0.0	0.0		
H012-h012	15 cm	24h	952	-0.062	0.089	0.064	0.3	91.8	0.0	5.9	0.0		
H018-h018	15 cm	24h	951	-0.062	0.088	0.063	0.2	94.1	0.0	0.0	0.0		
H024-h024	15 cm	24h	950	-0.063	0.092	0.067	0.4	92.7	0.0	0.0	0.0		
H030-h030	15 cm	24h	949	-0.062	0.089	0.064	0.2	92.7	0.0	0.0	0.0		
H036-h036	15 cm	24h	948	-0.063	0.088	0.062	0.3	93.4	0.0	5.9	0.0		
H042-h042	15 cm	24h	947	-0.059	0.086	0.062	0.2	93.2	0.0	0.0	0.0		
H048-h048	15 cm	24h	946	-0.059	0.085	0.061	0.4	94.2	0.0	5.9	0.0		
H054-h054	15 cm	24h	945	-0.056	0.081	0.059	0.3	95.0	0.0	0.0	0.0		
H060-h060	15 cm	24h	944	-0.057	0.082	0.058	0.3	94.8	0.0	0.0	0.0		
H066-h066	15 cm	24h	943	-0.058	0.083	0.059	0.2	94.0	0.0	0.0	0.0		
H072-h072	15 cm	24h	942	-0.058	0.083	0.059	0.4	94.2	0.0	0.0	0.0		
H078-h078	15 cm	24h	941	-0.058	0.084	0.061	0.3	92.9	0.0	0.0	0.0		
H084-h084	15 cm	24h	940	-0.058	0.082	0.058	0.2	94.8	0.0	0.0	0.0		
H090-h090	15 cm	24h	939	-0.058	0.083	0.060	0.3	95.0	0.0	0.0	0.0		
H096-h096	15 cm	24h	957	-0.057	0.082	0.059	0.3	94.8	0.0	0.0	0.0		
H102-h102	15 cm	24h	956	-0.057	0.082	0.060	0.3	94.2	0.0	0.0	0.0		
H108-h108	15 cm	24h	955	-0.056	0.082	0.061	0.3	95.5	0.0	0.0	0.0		
H114-h114	15 cm	24h	954	-0.057	0.085	0.063	0.3	93.7	0.0	0.0	0.0		
H120-h120	15 cm	24h	953	-0.058	0.087	0.064	0.4	93.7	0.0	0.0	0.0		

Table A-6. Water level skill assessment at Kewaunee

Station: Kewaunee
Observed data time period from: /10/ 9/2018 to / 4/ 2/2019
Data gap is filled using 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			68046	0.902									
h			68046	0.919									
H-h	15 cm	24h	68046	-0.018	0.038	0.034	0.0	99.6	0.0	0.4	0.0	0.00	0.94
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15 cm	24h	944	-0.025	0.047	0.040	0.0	99.6	0.0	0.0	0.0		
H012-h012	15 cm	24h	943	-0.026	0.050	0.043	0.0	99.3	0.0	0.0	0.0		
H018-h018	15 cm	24h	942	-0.027	0.051	0.043	0.0	99.4	0.0	0.0	0.0		
H024-h024	15 cm	24h	941	-0.026	0.048	0.040	0.0	99.4	0.0	0.0	0.0		
H030-h030	15 cm	24h	940	-0.027	0.048	0.039	0.0	99.5	0.0	0.0	0.0		
H036-h036	15 cm	24h	942	-0.028	0.049	0.040	0.0	99.0	0.0	0.0	0.0		
H042-h042	15 cm	24h	942	-0.025	0.046	0.039	0.0	99.6	0.0	0.0	0.0		
H048-h048	15 cm	24h	941	-0.029	0.049	0.039	0.0	99.3	0.0	0.0	0.0		
H054-h054	15 cm	24h	940	-0.025	0.046	0.039	0.0	99.6	0.0	0.0	0.0		
H060-h060	15 cm	24h	939	-0.025	0.045	0.038	0.0	99.8	0.0	0.0	0.0		
H066-h066	15 cm	24h	938	-0.024	0.045	0.039	0.0	99.4	0.0	0.0	0.0		
H072-h072	15 cm	24h	937	-0.024	0.046	0.039	0.0	99.3	0.0	0.0	0.0		
H078-h078	15 cm	24h	935	-0.022	0.044	0.038	0.0	99.7	0.0	0.0	0.0		
H084-h084	15 cm	24h	933	-0.023	0.044	0.038	0.0	99.5	0.0	0.0	0.0		
H090-h090	15 cm	24h	931	-0.021	0.042	0.036	0.0	99.8	0.0	0.0	0.0		
H096-h096	15 cm	24h	948	-0.023	0.045	0.039	0.0	99.5	0.0	0.0	0.0		
H102-h102	15 cm	24h	947	-0.024	0.045	0.038	0.0	99.7	0.0	0.0	0.0		
H108-h108	15 cm	24h	946	-0.024	0.047	0.040	0.0	99.4	0.0	0.0	0.0		
H114-h114	15 cm	24h	945	-0.024	0.047	0.041	0.0	99.6	0.0	0.0	0.0		
H120-h120	15 cm	24h	944	-0.025	0.050	0.043	0.0	98.9	0.0	0.0	0.0		

Table A-7. Water level skill assessment at Milwaukee

Station: Milwaukee
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68582	0.901									
h			68582	0.942									
H-h	15 cm	24h	68582	-0.041	0.055	0.037	0.0	99.2	0.0	0.3	0.0	0.00	0.89
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15 cm	24h	953	-0.050	0.066	0.043	0.0	98.0	0.0	0.0	0.0		
H012-h012	15 cm	24h	952	-0.052	0.067	0.043	0.0	98.2	0.0	0.0	0.0		
H018-h018	15 cm	24h	951	-0.052	0.067	0.043	0.0	98.2	0.0	0.0	0.0		
H024-h024	15 cm	24h	950	-0.052	0.069	0.045	0.0	97.5	0.0	0.0	0.0		
H030-h030	15 cm	24h	949	-0.052	0.068	0.044	0.0	97.6	0.0	0.0	0.0		
H036-h036	15 cm	24h	948	-0.051	0.067	0.044	0.0	97.4	0.0	0.0	0.0		
H042-h042	15 cm	24h	947	-0.051	0.067	0.043	0.0	97.6	0.0	0.0	0.0		
H048-h048	15 cm	24h	946	-0.052	0.067	0.042	0.0	97.9	0.0	0.0	0.0		
H054-h054	15 cm	24h	945	-0.051	0.065	0.040	0.0	98.1	0.0	0.0	0.0		
H060-h060	15 cm	24h	944	-0.049	0.065	0.042	0.0	98.2	0.0	0.0	0.0		
H066-h066	15 cm	24h	943	-0.047	0.064	0.043	0.0	98.2	0.0	0.0	0.0		
H072-h072	15 cm	24h	942	-0.048	0.065	0.044	0.0	97.1	0.0	0.0	0.0		
H078-h078	15 cm	24h	941	-0.046	0.062	0.042	0.0	98.4	0.0	0.0	0.0		
H084-h084	15 cm	24h	940	-0.046	0.063	0.043	0.0	98.4	0.0	0.0	0.0		
H090-h090	15 cm	24h	939	-0.046	0.063	0.043	0.0	98.3	0.0	0.0	0.0		
H096-h096	15 cm	24h	957	-0.046	0.062	0.041	0.0	98.4	0.0	0.0	0.0		
H102-h102	15 cm	24h	956	-0.047	0.063	0.041	0.0	98.4	0.0	0.0	0.0		
H108-h108	15 cm	24h	955	-0.047	0.062	0.041	0.0	98.6	0.0	0.0	0.0		
H114-h114	15 cm	24h	954	-0.048	0.064	0.043	0.0	98.4	0.0	0.0	0.0		
H120-h120	15 cm	24h	953	-0.049	0.066	0.044	0.1	98.0	0.0	0.0	0.0		

Table A-8. Water level skill assessment at De Tour Village

Station: De Tour Village
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68572	0.919									
h			68572	0.841									
H-h	15 cm	24h	68572	0.078	0.085	0.035	0.0	97.4	0.1	0.0	2.2	0.00	0.75
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15 cm	24h	953	0.070	0.079	0.036	0.0	97.4	0.0	0.0	0.0		
H012-h012	15 cm	24h	952	0.070	0.079	0.037	0.0	97.0	0.0	0.0	0.0		
H018-h018	15 cm	24h	951	0.071	0.080	0.038	0.0	96.8	0.0	0.0	0.0		
H024-h024	15 cm	24h	950	0.069	0.079	0.038	0.0	96.9	0.0	0.0	0.0		
H030-h030	15 cm	24h	949	0.069	0.078	0.037	0.0	97.4	0.0	0.0	0.0		
H036-h036	15 cm	24h	948	0.069	0.078	0.036	0.0	97.8	0.0	0.0	0.0		
H042-h042	15 cm	24h	947	0.068	0.077	0.036	0.0	97.8	0.0	0.0	0.0		
H048-h048	15 cm	24h	946	0.068	0.077	0.036	0.0	98.2	0.0	0.0	0.0		
H054-h054	15 cm	24h	945	0.068	0.076	0.036	0.0	98.5	0.0	0.0	0.0		
H060-h060	15 cm	24h	944	0.068	0.077	0.036	0.0	98.9	0.0	0.0	0.0		
H066-h066	15 cm	24h	943	0.069	0.077	0.033	0.0	98.9	0.0	0.0	0.0		
H072-h072	15 cm	24h	942	0.068	0.076	0.035	0.0	98.9	0.0	0.0	0.0		
H078-h078	15 cm	24h	941	0.069	0.078	0.035	0.0	98.5	0.0	0.0	0.0		
H084-h084	15 cm	24h	940	0.072	0.081	0.037	0.0	97.8	0.2	0.0	0.0		
H090-h090	15 cm	24h	939	0.073	0.082	0.035	0.0	97.4	0.0	0.0	0.0		
H096-h096	15 cm	24h	957	0.073	0.081	0.034	0.0	97.9	0.1	0.0	0.0		
H102-h102	15 cm	24h	956	0.073	0.080	0.035	0.0	98.1	0.0	0.0	0.0		
H108-h108	15 cm	24h	955	0.072	0.080	0.034	0.0	98.1	0.0	0.0	0.0		
H114-h114	15 cm	24h	954	0.071	0.079	0.035	0.0	97.5	0.0	0.0	0.0		
H120-h120	15 cm	24h	953	0.071	0.079	0.036	0.0	97.3	0.0	0.0	0.0		

Table A-9. Water level skill assessment at Essexville

Station: Essexville
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68572	0.910									
h			68572	0.924									
H-h	15	cm 24h	68572	-0.014	0.062	0.060	0.2	97.2	0.1	0.0	3.3	0.00	0.91
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15	cm 24h	953	-0.017	0.079	0.077	0.0	94.3	0.3	0.0	5.9		
H012-h012	15	cm 24h	952	-0.017	0.082	0.080	0.2	92.5	0.5	0.0	5.9		
H018-h018	15	cm 24h	951	-0.018	0.081	0.079	0.1	93.9	0.7	0.0	5.9		
H024-h024	15	cm 24h	950	-0.021	0.082	0.080	0.3	94.3	0.7	5.9	5.9		
H030-h030	15	cm 24h	949	-0.021	0.085	0.082	0.3	94.2	0.6	0.0	5.9		
H036-h036	15	cm 24h	948	-0.021	0.078	0.075	0.5	95.6	0.7	5.9	5.9		
H042-h042	15	cm 24h	947	-0.020	0.076	0.074	0.4	95.2	0.4	0.0	0.0		
H048-h048	15	cm 24h	946	-0.017	0.073	0.071	0.3	94.6	0.1	0.0	0.0		
H054-h054	15	cm 24h	945	-0.017	0.071	0.069	0.1	94.9	0.0	0.0	0.0		
H060-h060	15	cm 24h	944	-0.017	0.072	0.070	0.1	95.1	0.1	0.0	0.0		
H066-h066	15	cm 24h	943	-0.016	0.074	0.072	0.1	95.0	0.5	0.0	5.9		
H072-h072	15	cm 24h	942	-0.015	0.078	0.076	0.2	94.8	0.6	0.0	11.8		
H078-h078	15	cm 24h	941	-0.015	0.075	0.074	0.1	95.3	0.5	0.0	5.9		
H084-h084	15	cm 24h	940	-0.016	0.073	0.071	0.1	95.0	0.1	0.0	0.0		
H090-h090	15	cm 24h	939	-0.015	0.073	0.071	0.2	95.2	0.2	0.0	0.0		
H096-h096	15	cm 24h	957	-0.014	0.072	0.070	0.0	95.3	0.1	0.0	0.0		
H102-h102	15	cm 24h	956	-0.015	0.072	0.071	0.1	94.6	0.1	0.0	0.0		
H108-h108	15	cm 24h	955	-0.016	0.074	0.072	0.1	95.3	0.3	0.0	0.0		
H114-h114	15	cm 24h	954	-0.016	0.076	0.074	0.1	95.1	0.4	0.0	5.9		
H120-h120	15	cm 24h	953	-0.017	0.079	0.077	0.2	93.9	0.6	0.0	11.8		

Table A-10. Water level skill assessment at Harbor Beach

Station: Harbor Beach
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68572	0.912									
h			68572	0.906									
H-h	15	cm 24h	68572	0.006	0.037	0.036	0.0	99.6	0.0	0.0	0.0	0.00	0.94
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15	cm 24h	953	0.005	0.038	0.038	0.0	99.9	0.0	0.0	0.0		
H012-h012	15	cm 24h	952	0.006	0.039	0.038	0.0	99.7	0.0	0.0	0.0		
H018-h018	15	cm 24h	951	0.005	0.037	0.037	0.0	99.8	0.0	0.0	0.0		
H024-h024	15	cm 24h	950	0.002	0.039	0.039	0.0	99.5	0.0	0.0	0.0		
H030-h030	15	cm 24h	949	0.001	0.038	0.038	0.0	99.8	0.0	0.0	0.0		
H036-h036	15	cm 24h	948	0.003	0.037	0.037	0.0	99.8	0.0	0.0	0.0		
H042-h042	15	cm 24h	947	0.003	0.037	0.037	0.0	99.7	0.0	0.0	0.0		
H048-h048	15	cm 24h	946	0.005	0.037	0.037	0.0	99.9	0.0	0.0	0.0		
H054-h054	15	cm 24h	945	0.004	0.035	0.035	0.0	100.0	0.0	0.0	0.0		
H060-h060	15	cm 24h	944	0.003	0.037	0.037	0.0	99.7	0.0	0.0	0.0		
H066-h066	15	cm 24h	943	0.004	0.036	0.036	0.0	99.8	0.0	0.0	0.0		
H072-h072	15	cm 24h	942	0.005	0.037	0.037	0.0	99.7	0.0	0.0	0.0		
H078-h078	15	cm 24h	941	0.005	0.036	0.036	0.0	99.9	0.0	0.0	0.0		
H084-h084	15	cm 24h	940	0.005	0.035	0.035	0.0	100.0	0.0	0.0	0.0		
H090-h090	15	cm 24h	939	0.007	0.036	0.036	0.0	100.0	0.0	0.0	0.0		
H096-h096	15	cm 24h	957	0.007	0.036	0.035	0.0	99.9	0.0	0.0	0.0		
H102-h102	15	cm 24h	956	0.007	0.036	0.036	0.0	100.0	0.0	0.0	0.0		
H108-h108	15	cm 24h	955	0.007	0.038	0.037	0.0	99.9	0.0	0.0	0.0		
H114-h114	15	cm 24h	954	0.007	0.037	0.036	0.0	99.9	0.0	0.0	0.0		
H120-h120	15	cm 24h	953	0.006	0.038	0.038	0.0	99.9	0.0	0.0	0.0		

Table A-11. Water level skill assessment at Lakeport

Station: Lakeport
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68572	0.912									
h			68572	0.909									
H-h	15 cm	24h	68572	0.003	0.049	0.049	0.0	98.7	0.0	0.8	0.0	0.00	0.92
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15 cm	24h	953	-0.000	0.052	0.052	0.0	98.1	0.0	0.0	0.0		
H012-h012	15 cm	24h	952	-0.000	0.052	0.052	0.0	97.7	0.0	0.0	0.0		
H018-h018	15 cm	24h	951	-0.002	0.051	0.051	0.0	98.4	0.0	0.0	0.0		
H024-h024	15 cm	24h	950	-0.004	0.053	0.053	0.0	97.4	0.0	0.0	0.0		
H030-h030	15 cm	24h	949	-0.003	0.054	0.054	0.1	98.1	0.0	0.0	0.0		
H036-h036	15 cm	24h	948	-0.002	0.052	0.052	0.1	98.7	0.0	0.0	0.0		
H042-h042	15 cm	24h	947	-0.003	0.054	0.054	0.0	98.6	0.0	0.0	0.0		
H048-h048	15 cm	24h	946	-0.001	0.052	0.052	0.0	98.4	0.0	0.0	0.0		
H054-h054	15 cm	24h	945	-0.002	0.049	0.049	0.0	98.7	0.0	0.0	0.0		
H060-h060	15 cm	24h	944	-0.001	0.049	0.049	0.0	99.0	0.0	0.0	0.0		
H066-h066	15 cm	24h	943	-0.001	0.049	0.049	0.0	98.4	0.0	0.0	0.0		
H072-h072	15 cm	24h	942	0.001	0.051	0.051	0.0	98.2	0.0	0.0	0.0		
H078-h078	15 cm	24h	941	-0.001	0.049	0.049	0.0	98.4	0.0	0.0	0.0		
H084-h084	15 cm	24h	940	-0.002	0.048	0.048	0.1	98.6	0.0	0.0	0.0		
H090-h090	15 cm	24h	939	-0.001	0.048	0.048	0.1	98.7	0.0	0.0	0.0		
H096-h096	15 cm	24h	957	-0.000	0.047	0.047	0.0	99.2	0.0	0.0	0.0		
H102-h102	15 cm	24h	956	0.001	0.047	0.047	0.0	98.7	0.0	0.0	0.0		
H108-h108	15 cm	24h	955	0.001	0.050	0.050	0.0	98.8	0.0	0.0	0.0		
H114-h114	15 cm	24h	954	-0.000	0.050	0.050	0.0	98.6	0.0	0.0	0.0		
H120-h120	15 cm	24h	953	-0.001	0.052	0.052	0.0	98.2	0.0	0.0	0.0		

Table A-12. Water level skill assessment at Fort Gratiot

Station: Fort Gratiot
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68572	0.809									
h			68572	0.844									
H-h	15 cm	24h	68572	-0.035	0.065	0.054	0.1	97.2	0.0	1.2	0.0	0.00	0.87
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15 cm	24h	953	-0.039	0.068	0.056	0.1	96.6	0.0	0.0	0.0		
H012-h012	15 cm	24h	952	-0.039	0.068	0.056	0.1	97.0	0.0	0.0	0.0		
H018-h018	15 cm	24h	951	-0.040	0.067	0.055	0.1	97.3	0.0	0.0	0.0		
H024-h024	15 cm	24h	950	-0.042	0.071	0.057	0.1	96.7	0.0	0.0	0.0		
H030-h030	15 cm	24h	949	-0.041	0.071	0.058	0.1	96.6	0.0	0.0	0.0		
H036-h036	15 cm	24h	948	-0.041	0.071	0.058	0.2	97.3	0.0	5.9	0.0		
H042-h042	15 cm	24h	947	-0.041	0.071	0.058	0.2	96.3	0.0	0.0	0.0		
H048-h048	15 cm	24h	946	-0.038	0.070	0.058	0.1	96.6	0.0	0.0	0.0		
H054-h054	15 cm	24h	945	-0.038	0.067	0.055	0.0	96.1	0.0	0.0	0.0		
H060-h060	15 cm	24h	944	-0.037	0.066	0.055	0.1	96.2	0.0	0.0	0.0		
H066-h066	15 cm	24h	943	-0.039	0.066	0.054	0.1	96.2	0.0	0.0	0.0		
H072-h072	15 cm	24h	942	-0.037	0.065	0.053	0.1	97.2	0.0	0.0	0.0		
H078-h078	15 cm	24h	941	-0.039	0.065	0.052	0.3	97.2	0.0	0.0	0.0		
H084-h084	15 cm	24h	940	-0.040	0.067	0.054	0.3	97.2	0.0	0.0	0.0		
H090-h090	15 cm	24h	939	-0.039	0.066	0.053	0.3	97.4	0.0	0.0	0.0		
H096-h096	15 cm	24h	957	-0.037	0.063	0.051	0.2	98.2	0.0	0.0	0.0		
H102-h102	15 cm	24h	956	-0.037	0.063	0.051	0.1	98.2	0.0	0.0	0.0		
H108-h108	15 cm	24h	955	-0.036	0.064	0.053	0.3	98.5	0.0	5.9	0.0		
H114-h114	15 cm	24h	954	-0.037	0.065	0.053	0.2	98.0	0.0	0.0	0.0		
H120-h120	15 cm	24h	953	-0.038	0.068	0.056	0.3	96.7	0.0	5.9	0.0		

Table A-13. Water level skill assessment at Sturgeon Bay Canal

Station: Sturgeon Bay Canal
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68582	0.908									
h			68582	0.922									
H-h	15	cm 24h	68582	-0.014	0.034	0.031	0.0	99.7	0.0	0.3	0.0	0.00	0.95
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15	cm 24h	953	-0.024	0.046	0.039	0.0	99.8	0.0	0.0	0.0		
H012-h012	15	cm 24h	952	-0.026	0.047	0.039	0.0	99.8	0.0	0.0	0.0		
H018-h018	15	cm 24h	951	-0.025	0.047	0.040	0.0	99.8	0.0	0.0	0.0		
H024-h024	15	cm 24h	950	-0.026	0.046	0.038	0.0	99.7	0.0	0.0	0.0		
H030-h030	15	cm 24h	949	-0.027	0.046	0.038	0.0	99.9	0.0	0.0	0.0		
H036-h036	15	cm 24h	948	-0.026	0.045	0.036	0.0	99.9	0.0	0.0	0.0		
H042-h042	15	cm 24h	947	-0.026	0.045	0.037	0.0	99.7	0.0	0.0	0.0		
H048-h048	15	cm 24h	946	-0.026	0.045	0.037	0.0	99.4	0.0	0.0	0.0		
H054-h054	15	cm 24h	945	-0.026	0.044	0.036	0.0	99.8	0.0	0.0	0.0		
H060-h060	15	cm 24h	944	-0.025	0.044	0.036	0.0	99.6	0.0	0.0	0.0		
H066-h066	15	cm 24h	943	-0.023	0.042	0.035	0.0	99.8	0.0	0.0	0.0		
H072-h072	15	cm 24h	942	-0.024	0.042	0.035	0.0	99.9	0.0	0.0	0.0		
H078-h078	15	cm 24h	941	-0.022	0.042	0.035	0.0	99.8	0.0	0.0	0.0		
H084-h084	15	cm 24h	940	-0.021	0.040	0.034	0.0	99.9	0.0	0.0	0.0		
H090-h090	15	cm 24h	939	-0.020	0.039	0.033	0.0	100.0	0.0	0.0	0.0		
H096-h096	15	cm 24h	957	-0.021	0.040	0.034	0.0	99.7	0.0	0.0	0.0		
H102-h102	15	cm 24h	956	-0.023	0.043	0.036	0.0	99.8	0.0	0.0	0.0		
H108-h108	15	cm 24h	955	-0.025	0.045	0.038	0.0	99.4	0.0	0.0	0.0		
H114-h114	15	cm 24h	954	-0.025	0.045	0.038	0.0	99.6	0.0	0.0	0.0		
H120-h120	15	cm 24h	953	-0.024	0.046	0.038	0.0	99.8	0.0	0.0	0.0		

Table A-14. Water level skill assessment at Alpena

Station: Alpena
Observed data time period from: / 6/17/2018 to / 4/ 2/2019
Data gap is filled using 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			68572	0.919									
h			68572	0.868									
H-h	15	cm 24h	68572	0.051	0.067	0.042	0.0	98.2	0.0	0.0	0.5	0.00	0.82
SCENARIO: SEMI-OPERATIONAL FORECAST													
H006-h006	15	cm 24h	953	0.042	0.059	0.041	0.0	98.7	0.0	0.0	0.0		
H012-h012	15	cm 24h	952	0.043	0.060	0.042	0.0	99.2	0.0	0.0	0.0		
H018-h018	15	cm 24h	951	0.045	0.061	0.041	0.0	98.8	0.0	0.0	0.0		
H024-h024	15	cm 24h	950	0.044	0.060	0.041	0.0	99.1	0.0	0.0	0.0		
H030-h030	15	cm 24h	949	0.044	0.060	0.041	0.0	98.5	0.0	0.0	0.0		
H036-h036	15	cm 24h	948	0.045	0.061	0.042	0.0	98.5	0.0	0.0	0.0		
H042-h042	15	cm 24h	947	0.044	0.060	0.042	0.0	99.2	0.0	0.0	0.0		
H048-h048	15	cm 24h	946	0.044	0.060	0.041	0.0	98.5	0.0	0.0	0.0		
H054-h054	15	cm 24h	945	0.043	0.059	0.041	0.0	99.5	0.0	0.0	0.0		
H060-h060	15	cm 24h	944	0.043	0.059	0.040	0.0	99.3	0.0	0.0	0.0		
H066-h066	15	cm 24h	943	0.043	0.058	0.039	0.0	99.4	0.0	0.0	0.0		
H072-h072	15	cm 24h	942	0.043	0.058	0.039	0.0	98.9	0.0	0.0	0.0		
H078-h078	15	cm 24h	941	0.043	0.058	0.039	0.0	99.1	0.0	0.0	0.0		
H084-h084	15	cm 24h	940	0.044	0.059	0.040	0.0	99.1	0.1	0.0	0.0		
H090-h090	15	cm 24h	939	0.045	0.060	0.040	0.0	99.6	0.1	0.0	0.0		
H096-h096	15	cm 24h	957	0.045	0.059	0.038	0.0	98.7	0.0	0.0	0.0		
H102-h102	15	cm 24h	956	0.045	0.060	0.040	0.0	99.0	0.0	0.0	0.0		
H108-h108	15	cm 24h	955	0.044	0.060	0.041	0.0	99.2	0.0	0.0	0.0		
H114-h114	15	cm 24h	954	0.043	0.059	0.041	0.0	99.0	0.0	0.0	0.0		
H120-h120	15	cm 24h	953	0.042	0.060	0.042	0.0	98.7	0.0	0.0	0.0		

APPENDIX B. TIME SERIES OF MODELED WATER LEVEL VERSUS OBSERVATIONS

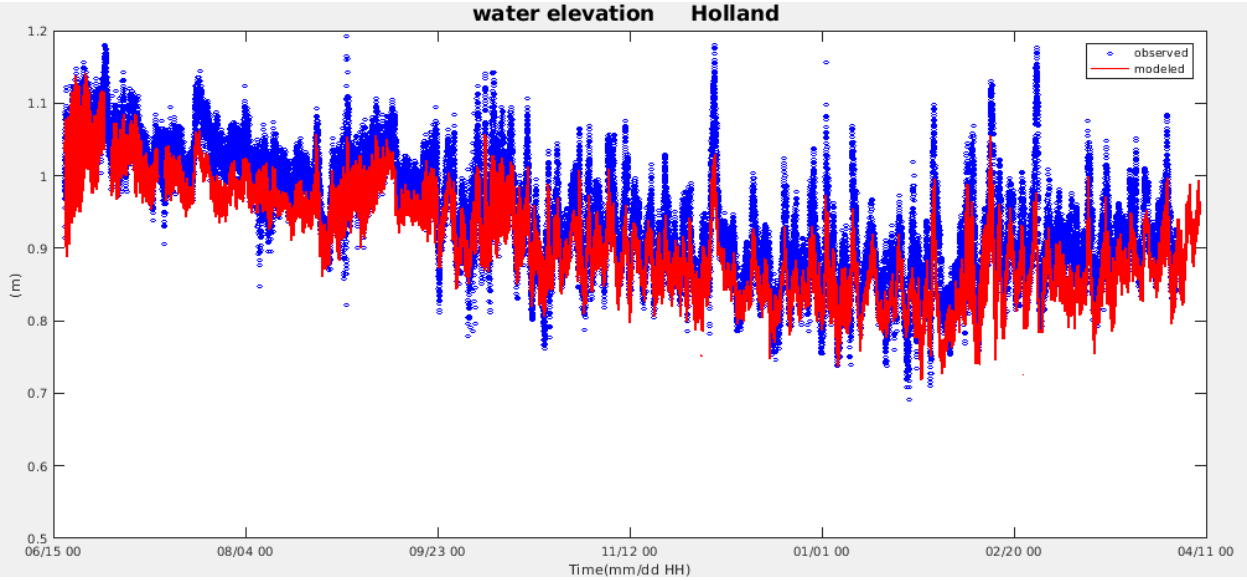

Figure B-1. Modeled (red) versus observed (blue) water level at Holland

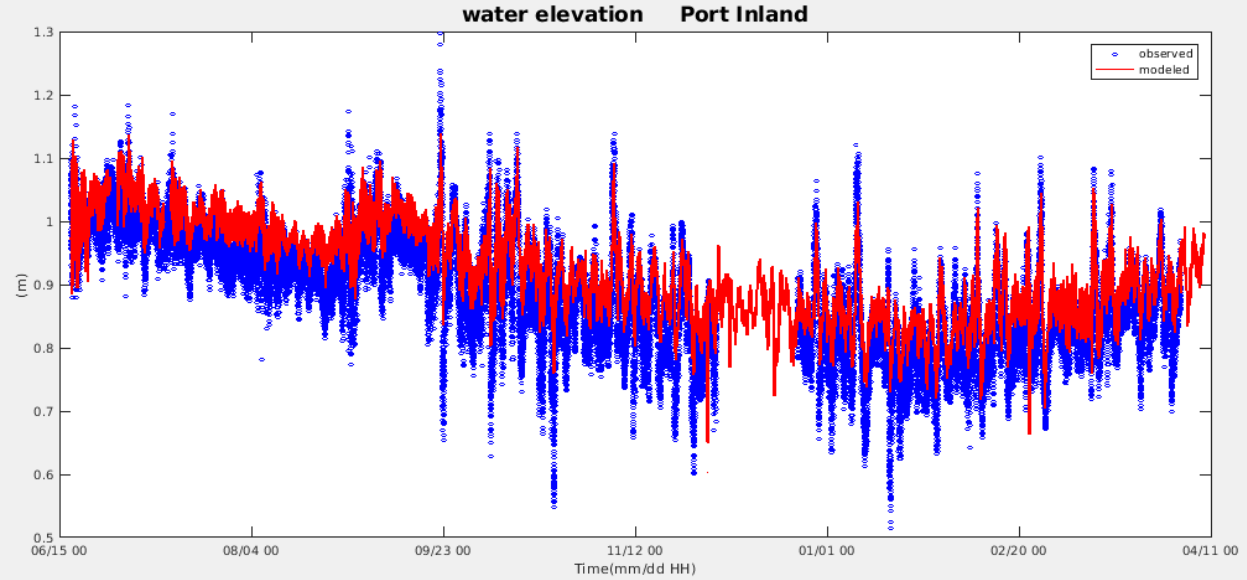

Figure B-2. Modeled (red) versus observed (blue) water level at Port Inland. Note there was a one-month data gap in the water level record.

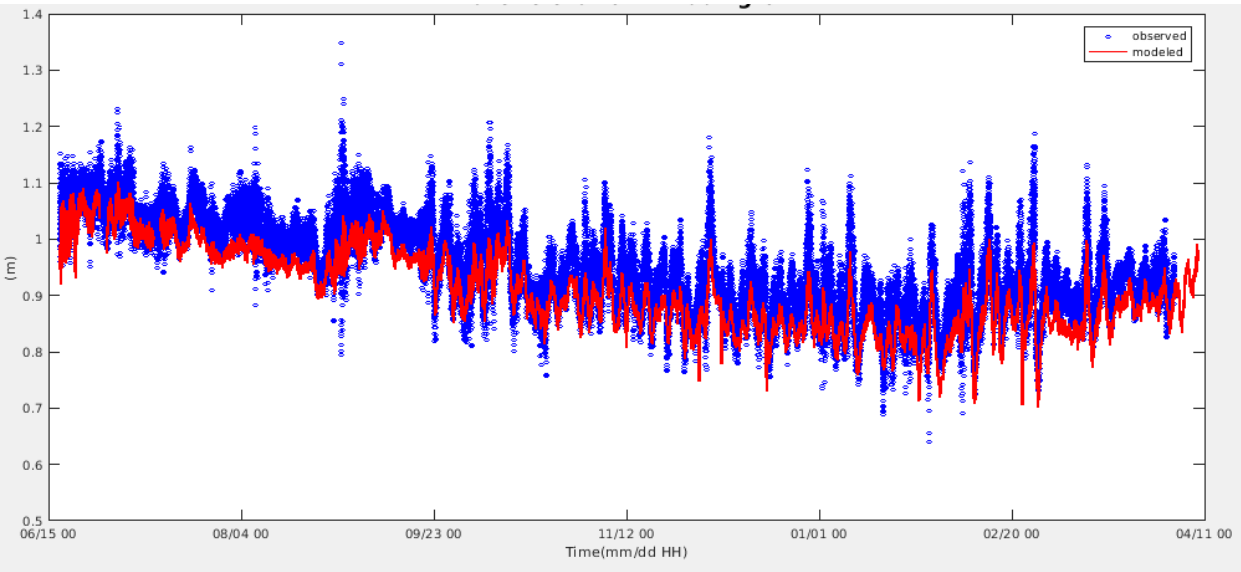

Figure B-3. Modeled (red) versus observed (blue) water level at Ludington

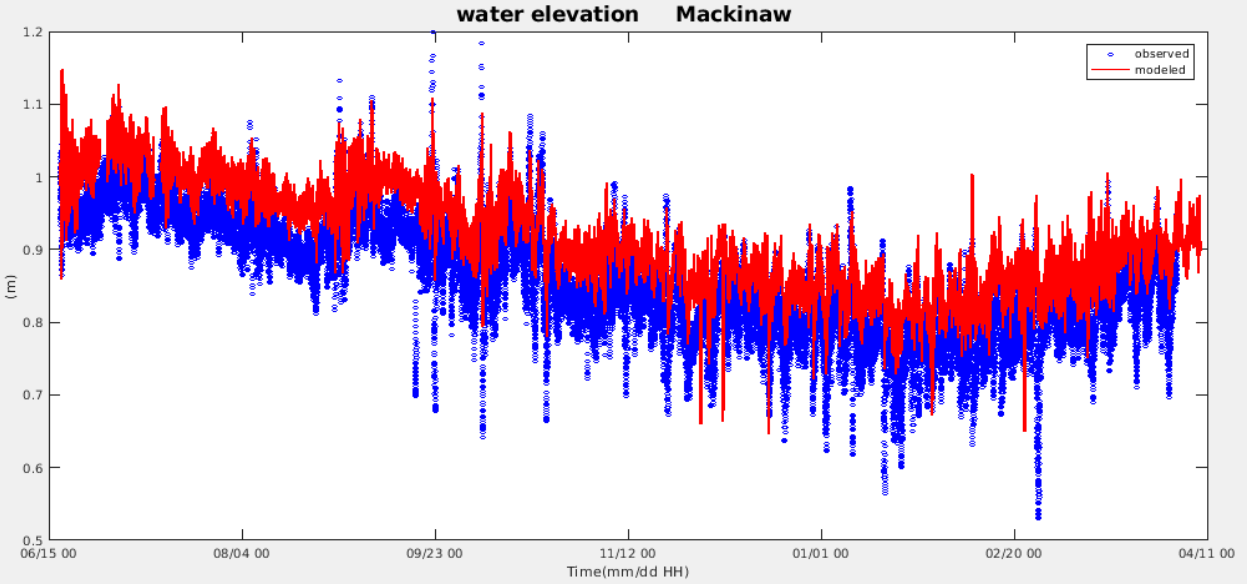

Figure B-4. Modeled (red) versus observed (blue) water level at Mackinaw

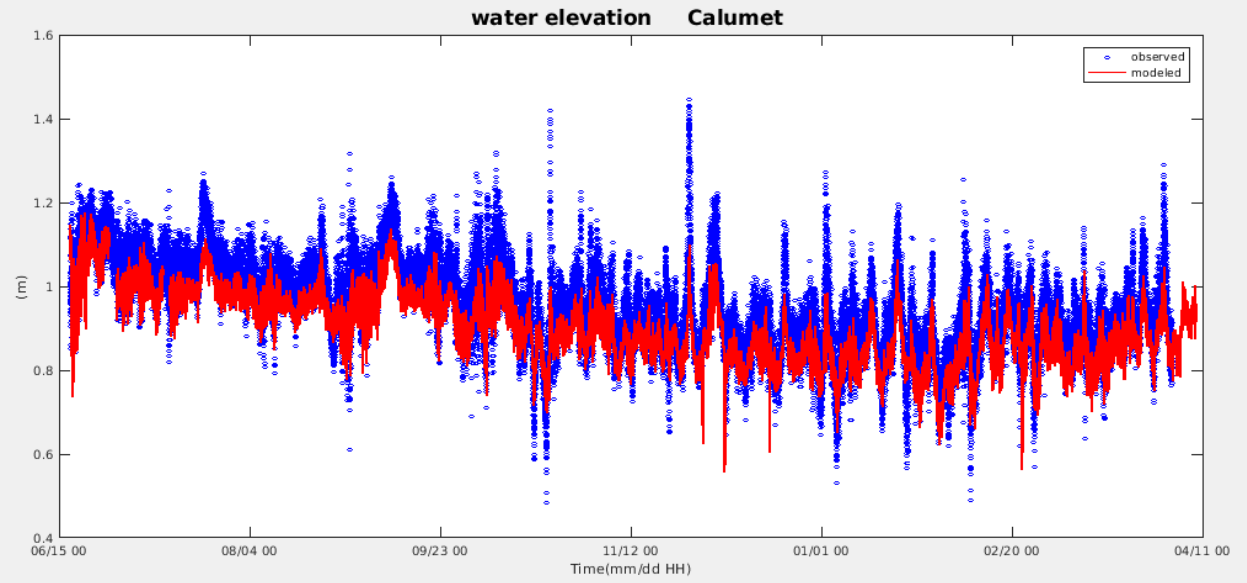

Figure B-5. Modeled (red) versus observed (blue) water level at Calumet

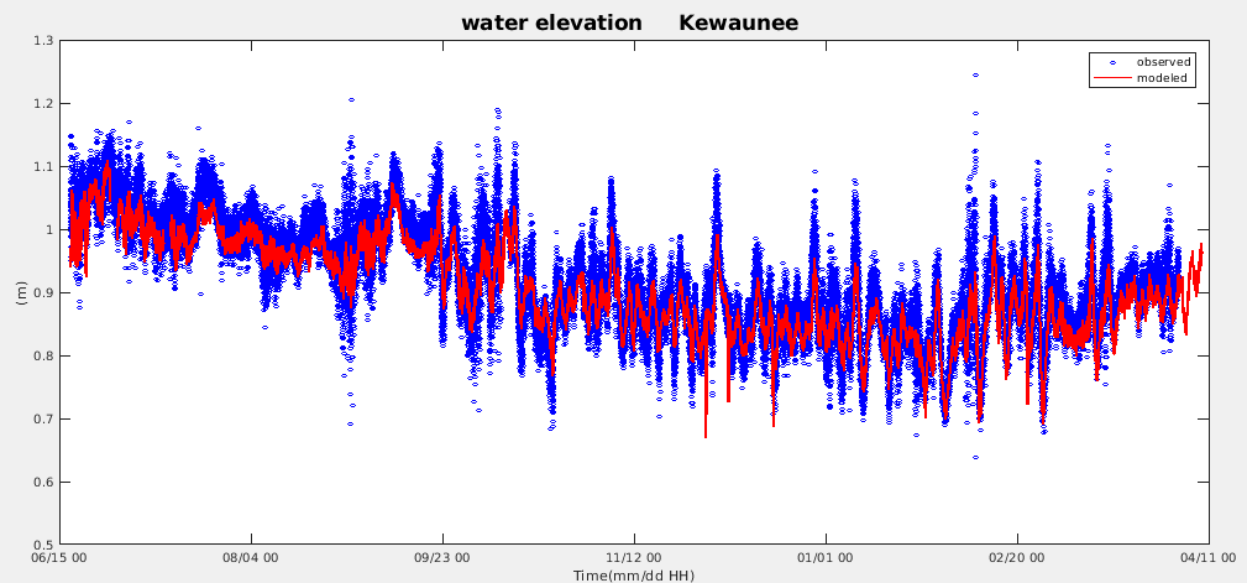

Figure B-6. Modeled (red) versus observed (blue) water level at Kewaunee

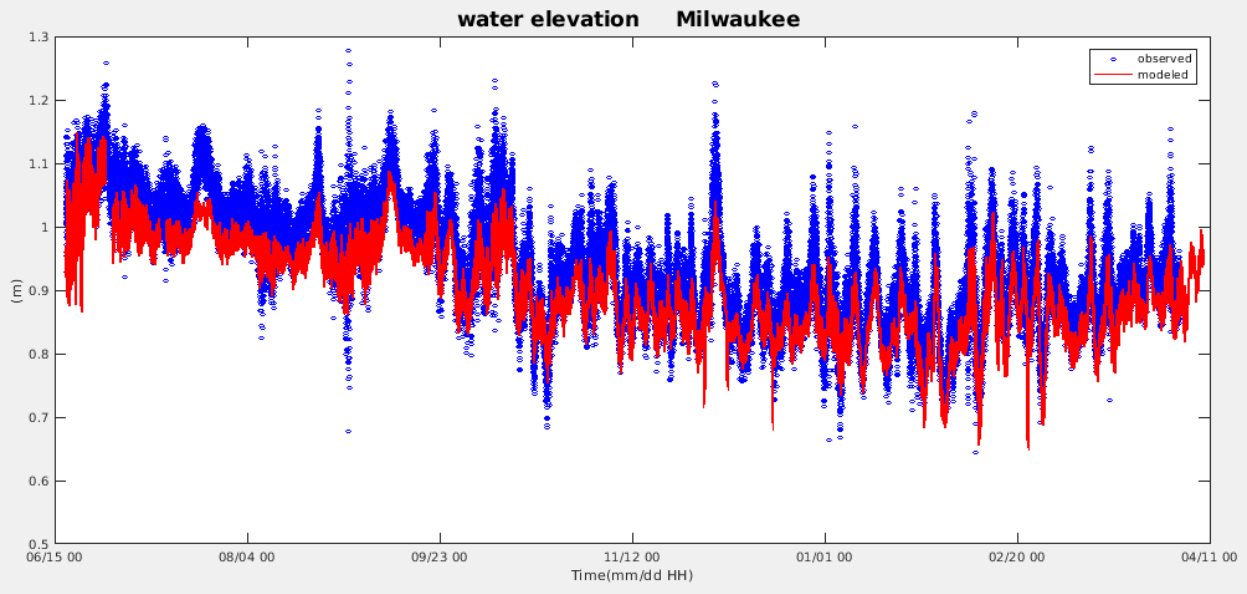

Figure B-7. Modeled (red) versus observed (blue) water level at Milwaukee

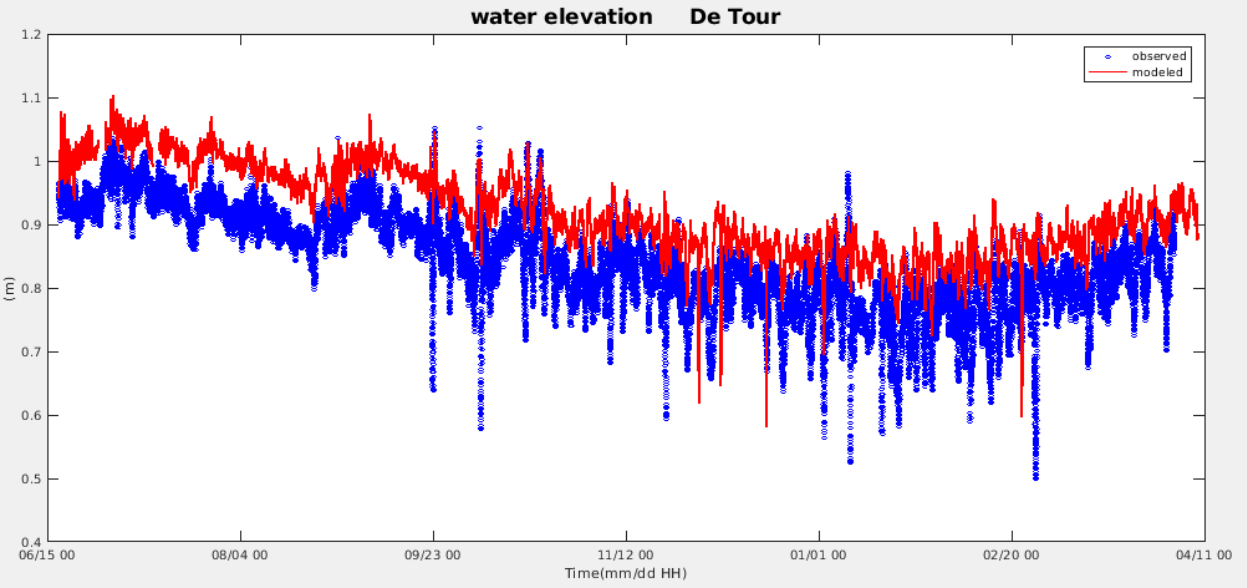

Figure B-8. Modeled (red) versus observed (blue) water level at De Tour Village

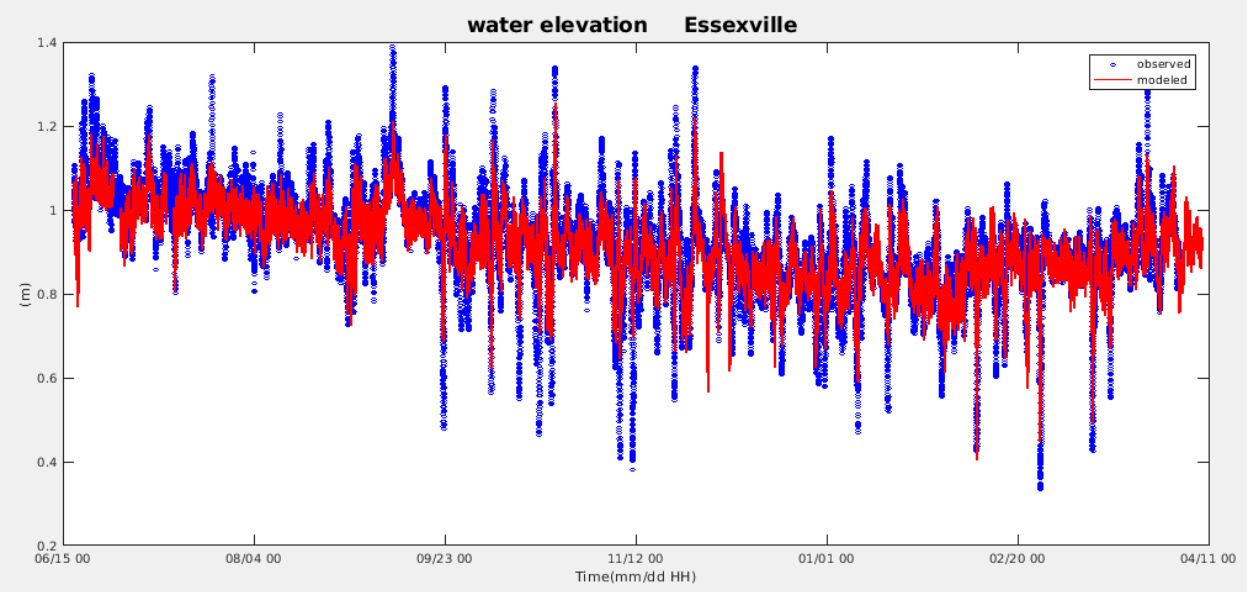

Figure B-9. Modeled (red) versus observed (blue) water level at Essexville

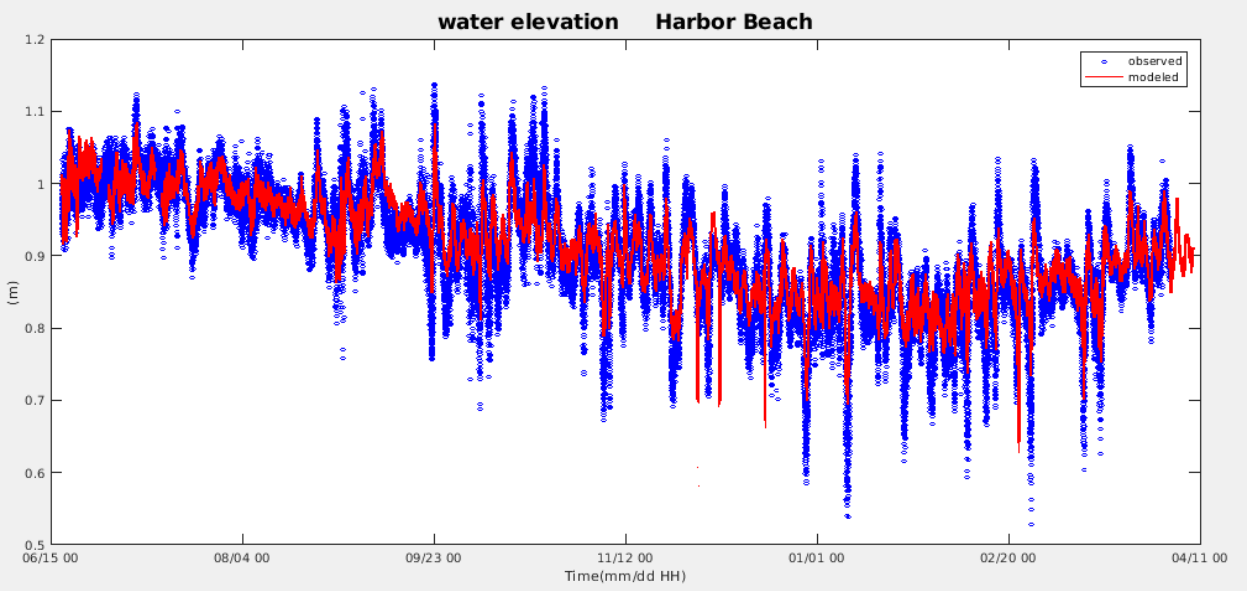

Figure B-10. Modeled (red) versus observed (blue) water level at Harbor Beach

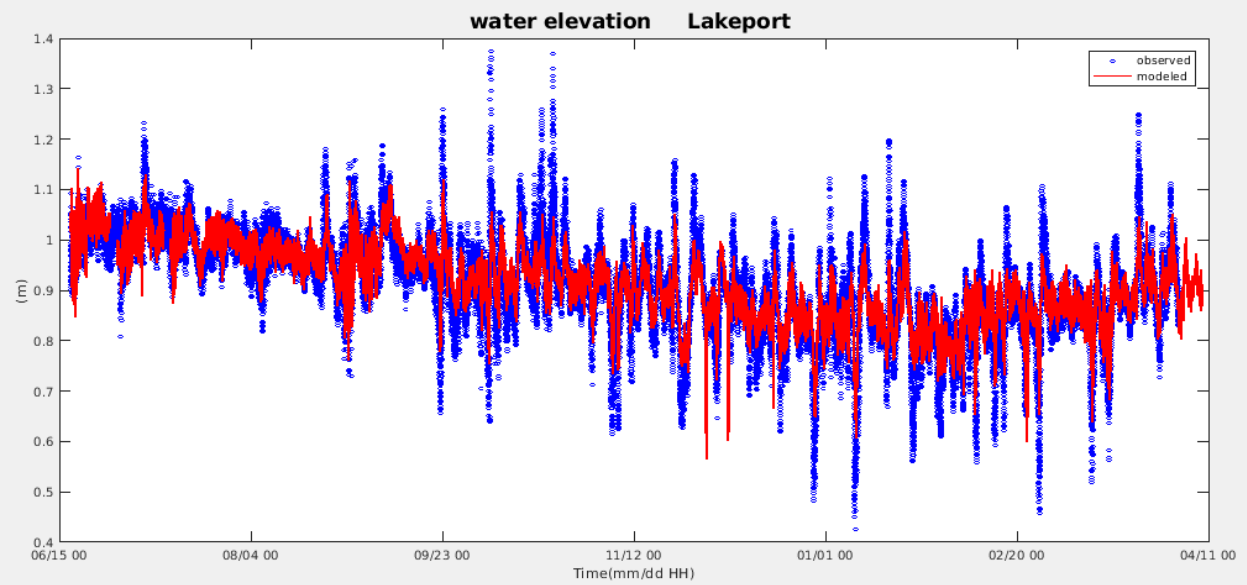

Figure B-11. Modeled (red) versus observed (blue) water level at Lakeport

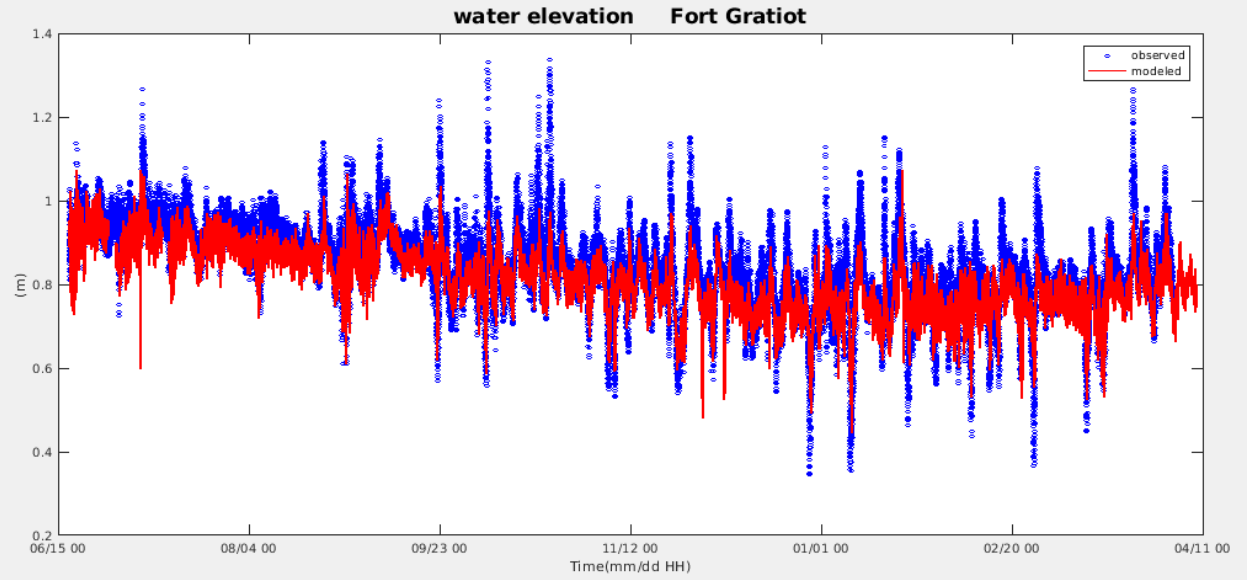

Figure B-12. Modeled (red) versus observed (blue) water level at Fort Gratiot

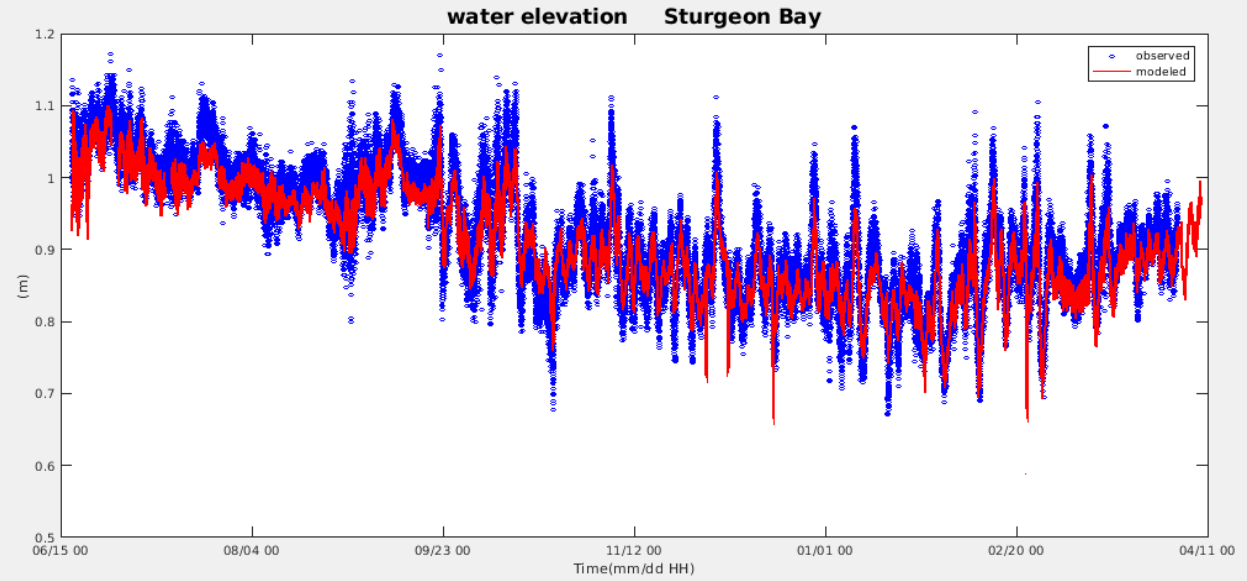

Figure B-13. Modeled (red) versus observed (blue) water level at Sturgeon Bay

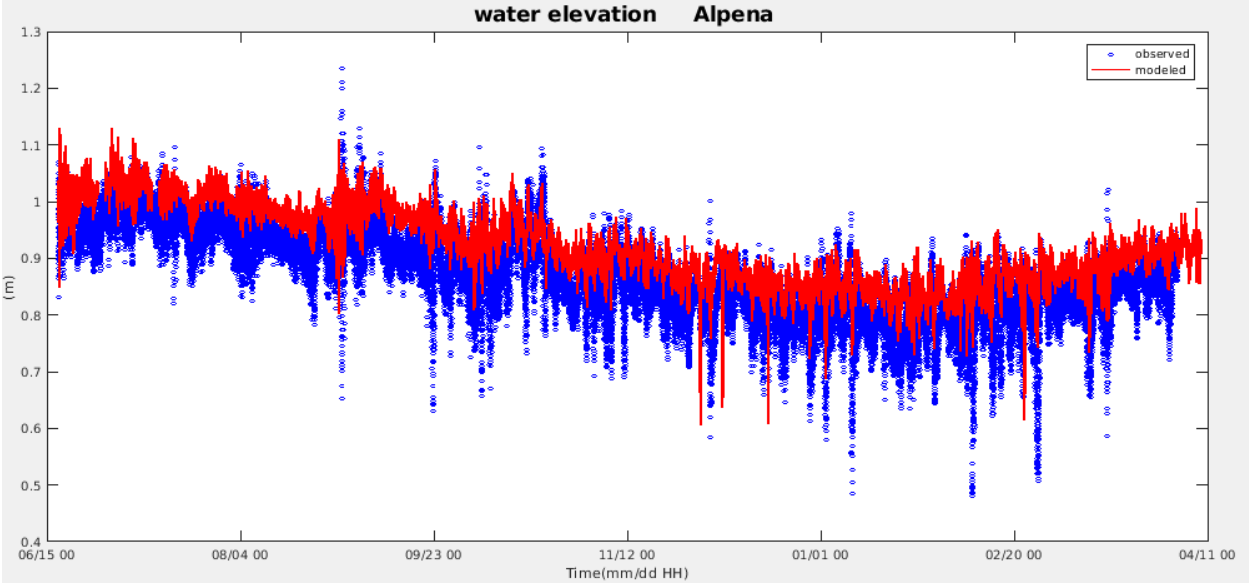

Figure B-14. Modeled (red) versus observed (blue) water level at Alpena

APPENDIX C. SURFACE CURRENTS MODEL SKILL ASSESSMENT TABLES

Table C-1. Water surface current speed skill assessment at South Green Bay

Station: South Green Bay, WI
Observed data time period from: / 6/20/2018 to / 8/ 2/2018
Data gap is filled using 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													
U			23583	0.058									
u			23583	0.063									
U-u	26	cm/s 24h	23583	-0.005	0.049	0.049	0.0	100.0	0.0	0.0	0.0		0.49
SCENARIO: SEMI-OPERATIONAL FORECAST													
U000-u000	26	cm/s 24h	304	-0.006	0.047	0.046	0.0	100.0	0.0	0.0	0.0		
U006-u006	26	cm/s 24h	304	-0.005	0.048	0.048	0.0	100.0	0.0	0.0	0.0		
U012-u012	26	cm/s 24h	304	-0.008	0.047	0.046	0.0	100.0	0.0	0.0	0.0		
U018-u018	26	cm/s 24h	304	-0.010	0.047	0.046	0.0	100.0	0.0	0.0	0.0		
U024-u024	26	cm/s 24h	302	-0.007	0.045	0.044	0.0	100.0	0.0	0.0	0.0		
U030-u030	26	cm/s 24h	301	-0.010	0.045	0.044	0.0	100.0	0.0	0.0	0.0		
U036-u036	26	cm/s 24h	300	-0.010	0.045	0.044	0.0	100.0	0.0	0.0	0.0		
U042-u042	26	cm/s 24h	300	-0.010	0.046	0.045	0.0	100.0	0.0	0.0	0.0		
U048-u048	26	cm/s 24h	301	-0.008	0.045	0.044	0.0	100.0	0.0	0.0	0.0		
U054-u054	26	cm/s 24h	303	-0.009	0.046	0.045	0.0	100.0	0.0	0.0	0.0		
U060-u060	26	cm/s 24h	304	-0.008	0.043	0.043	0.0	100.0	0.0	0.0	0.0		
U066-u066	26	cm/s 24h	305	-0.007	0.045	0.045	0.0	100.0	0.0	0.0	0.0		
U072-u072	26	cm/s 24h	307	-0.010	0.045	0.044	0.0	100.0	0.0	0.0	0.0		
U078-u078	26	cm/s 24h	308	-0.009	0.046	0.045	0.0	100.0	0.0	0.0	0.0		
U084-u084	26	cm/s 24h	309	-0.011	0.044	0.042	0.0	100.0	0.0	0.0	0.0		
U090-u090	26	cm/s 24h	309	-0.012	0.046	0.044	0.0	100.0	0.0	0.0	0.0		
U096-u096	26	cm/s 24h	307	-0.013	0.049	0.047	0.0	100.0	0.0	0.0	0.0		
U102-u102	26	cm/s 24h	305	-0.016	0.049	0.047	0.0	100.0	0.0	0.0	0.0		
U108-u108	26	cm/s 24h	303	-0.016	0.047	0.044	0.0	100.0	0.0	0.0	0.0		
U114-u114	26	cm/s 24h	301	-0.015	0.047	0.045	0.0	100.0	0.0	0.0	0.0		
U120-u120	26	cm/s 24h	299	-0.014	0.046	0.044	0.0	100.0	0.0	0.0	0.0		

Table C-2. Water surface current speed skill assessment at Mackinac Strait West

Station: Mackinac Strait West
Observed data time period from: / 8/ 1/2018 to / 9/21/2018
Data gap is filled using 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													
U			27942	0.129									
u			27942	0.209									
U-u	26	cm/s 24h	27942	-0.080	0.143	0.118	0.0	92.8	0.0	0.0	0.0		0.69
SCENARIO: SEMI-OPERATIONAL FORECAST													
U000-u000	26	cm/s 24h	366	-0.078	0.143	0.120	0.0	92.9	0.0	0.0	0.0		
U006-u006	26	cm/s 24h	366	-0.077	0.144	0.122	0.0	93.2	0.0	0.0	0.0		
U012-u012	26	cm/s 24h	365	-0.081	0.149	0.125	0.5	93.4	0.0	0.0	0.0		
U018-u018	26	cm/s 24h	364	-0.083	0.149	0.123	0.3	94.0	0.0	0.0	0.0		
U024-u024	26	cm/s 24h	362	-0.085	0.148	0.122	0.6	92.0	0.0	0.0	0.0		
U030-u030	26	cm/s 24h	360	-0.086	0.152	0.126	0.6	91.7	0.0	0.0	0.0		
U036-u036	26	cm/s 24h	359	-0.087	0.156	0.129	0.6	91.4	0.0	0.0	0.0		
U042-u042	26	cm/s 24h	358	-0.086	0.156	0.130	0.6	91.3	0.0	0.0	0.0		
U048-u048	26	cm/s 24h	357	-0.081	0.156	0.134	0.6	90.5	0.0	0.0	0.0		
U054-u054	26	cm/s 24h	356	-0.081	0.156	0.133	0.8	91.9	0.0	0.0	0.0		
U060-u060	26	cm/s 24h	355	-0.083	0.160	0.137	0.8	90.7	0.0	0.0	0.0		
U066-u066	26	cm/s 24h	354	-0.087	0.162	0.137	0.8	90.1	0.0	0.0	0.0		
U072-u072	26	cm/s 24h	353	-0.085	0.161	0.137	0.6	89.2	0.0	0.0	0.0		
U078-u078	26	cm/s 24h	352	-0.081	0.162	0.141	0.9	89.8	0.0	0.0	0.0		
U084-u084	26	cm/s 24h	351	-0.073	0.163	0.146	1.1	91.5	0.0	6.0	0.0		
U090-u090	26	cm/s 24h	351	-0.071	0.161	0.144	1.4	90.3	0.0	6.0	0.0		
U096-u096	26	cm/s 24h	351	-0.078	0.169	0.150	1.1	89.2	0.0	6.0	0.0		
U102-u102	26	cm/s 24h	350	-0.074	0.167	0.150	1.1	88.6	0.0	6.0	0.0		
U108-u108	26	cm/s 24h	349	-0.072	0.169	0.153	0.6	89.1	0.0	0.0	0.0		
U114-u114	26	cm/s 24h	347	-0.071	0.171	0.156	0.9	89.0	0.0	6.0	0.0		
U120-u120	26	cm/s 24h	345	-0.066	0.182	0.170	1.4	86.7	0.0	0.0	0.0		

Table C-3. Water surface current speed skill assessment at Saginaw Bay Buoy

Station: Saginaw Bay Buoy, MI
Observed data time period from: / 6/17/2018 to / 9/18/2018
Data gap is filled using 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													
U			21616	0.063									
u			21616	0.093									
U-u	26	cm/s 24h	21616	-0.030	0.064	0.056	0.0	100.0	0.0	0.0	0.0		0.48
SCENARIO: SEMI-OPERATIONAL FORECAST													
U000-u000	26	cm/s 24h	263	-0.040	0.070	0.058	0.0	100.0	0.0	0.0	0.0		
U006-u006	26	cm/s 24h	262	-0.038	0.069	0.058	0.0	100.0	0.0	0.0	0.0		
U012-u012	26	cm/s 24h	261	-0.036	0.070	0.060	0.0	100.0	0.0	0.0	0.0		
U018-u018	26	cm/s 24h	260	-0.035	0.070	0.061	0.0	100.0	0.0	0.0	0.0		
U024-u024	26	cm/s 24h	259	-0.037	0.070	0.060	0.0	100.0	0.0	0.0	0.0		
U030-u030	26	cm/s 24h	258	-0.037	0.073	0.063	0.0	100.0	0.0	0.0	0.0		
U036-u036	26	cm/s 24h	257	-0.035	0.071	0.062	0.0	100.0	0.0	0.0	0.0		
U042-u042	26	cm/s 24h	256	-0.038	0.072	0.062	0.0	100.0	0.0	0.0	0.0		
U048-u048	26	cm/s 24h	255	-0.036	0.071	0.062	0.0	100.0	0.0	0.0	0.0		
U054-u054	26	cm/s 24h	254	-0.039	0.073	0.062	0.0	100.0	0.0	0.0	0.0		
U060-u060	26	cm/s 24h	253	-0.036	0.071	0.062	0.0	100.0	0.0	0.0	0.0		
U066-u066	26	cm/s 24h	252	-0.036	0.070	0.060	0.0	100.0	0.0	0.0	0.0		
U072-u072	26	cm/s 24h	251	-0.032	0.069	0.061	0.0	100.0	0.0	0.0	0.0		
U078-u078	26	cm/s 24h	250	-0.033	0.071	0.063	0.0	100.0	0.0	0.0	0.0		
U084-u084	26	cm/s 24h	249	-0.034	0.071	0.063	0.0	100.0	0.0	0.0	0.0		
U090-u090	26	cm/s 24h	248	-0.038	0.076	0.066	0.0	100.0	0.0	0.0	0.0		
U096-u096	26	cm/s 24h	247	-0.037	0.075	0.065	0.0	100.0	0.0	0.0	0.0		
U102-u102	26	cm/s 24h	246	-0.040	0.075	0.064	0.0	100.0	0.0	0.0	0.0		
U108-u108	26	cm/s 24h	245	-0.037	0.074	0.064	0.0	100.0	0.0	0.0	0.0		
U114-u114	26	cm/s 24h	244	-0.044	0.074	0.059	0.0	100.0	0.0	0.0	0.0		
U120-u120	26	cm/s 24h	243	-0.039	0.072	0.060	0.0	100.0	0.0	0.0	0.0		

Table C-4. Water surface current speed skill assessment at Muskegon Buoy

Station: Muskegon Buoy, MI
Observed data time period from: / 6/17/2018 to /10/19/2018
Data gap is filled using 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													
U			28683	0.095									
u			28683	0.165									
U-u	26 cm/s	24h	28683	-0.071	0.127	0.106	0.0	94.6	0.0	0.0	0.0		0.54
SCENARIO: SEMI-OPERATIONAL FORECAST													
U000-u000	26 cm/s	24h	376	-0.077	0.136	0.112	0.0	93.1	0.0	0.0	0.0		
U006-u006	26 cm/s	24h	376	-0.077	0.136	0.112	0.0	92.8	0.0	0.0	0.0		
U012-u012	26 cm/s	24h	375	-0.078	0.138	0.114	0.0	93.3	0.0	0.0	0.0		
U018-u018	26 cm/s	24h	374	-0.080	0.141	0.117	0.0	93.0	0.0	0.0	0.0		
U024-u024	26 cm/s	24h	373	-0.079	0.140	0.116	0.0	93.0	0.0	0.0	0.0		
U030-u030	26 cm/s	24h	372	-0.077	0.140	0.117	0.0	92.7	0.0	0.0	0.0		
U036-u036	26 cm/s	24h	371	-0.075	0.139	0.117	0.0	93.0	0.0	0.0	0.0		
U042-u042	26 cm/s	24h	370	-0.074	0.138	0.117	0.0	93.0	0.0	0.0	0.0		
U048-u048	26 cm/s	24h	369	-0.072	0.138	0.118	0.0	92.4	0.0	0.0	0.0		
U054-u054	26 cm/s	24h	368	-0.070	0.136	0.117	0.0	93.8	0.0	0.0	0.0		
U060-u060	26 cm/s	24h	367	-0.068	0.137	0.119	0.0	92.9	0.0	0.0	0.0		
U066-u066	26 cm/s	24h	366	-0.067	0.138	0.121	0.0	92.9	0.0	0.0	0.0		
U072-u072	26 cm/s	24h	365	-0.067	0.137	0.120	0.0	93.7	0.0	0.0	0.0		
U078-u078	26 cm/s	24h	364	-0.068	0.137	0.119	0.0	92.9	0.0	0.0	0.0		
U084-u084	26 cm/s	24h	363	-0.067	0.136	0.119	0.0	93.4	0.0	0.0	0.0		
U090-u090	26 cm/s	24h	362	-0.069	0.136	0.117	0.0	93.9	0.0	0.0	0.0		
U096-u096	26 cm/s	24h	361	-0.071	0.135	0.115	0.0	93.6	0.0	0.0	0.0		
U102-u102	26 cm/s	24h	360	-0.070	0.134	0.114	0.0	94.2	0.0	0.0	0.0		
U108-u108	26 cm/s	24h	359	-0.072	0.133	0.112	0.0	93.9	0.0	0.0	0.0		
U114-u114	26 cm/s	24h	358	-0.074	0.134	0.112	0.0	93.9	0.0	0.0	0.0		
U120-u120	26 cm/s	24h	357	-0.069	0.132	0.112	0.0	94.7	0.0	0.0	0.0		

Table C-5. Water surface current direction skill assessment at South Green Bay

Station: South Green Bay, WI
Observed data time period from: / 6/20/2018 to / 8/ 2/2018
Data gap is filled using 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													
D			23583	179.241									
d			23583	142.282									
D-d	22.5 dg	24h	23583	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		0.37
SCENARIO: SEMI-OPERATIONAL FORECAST													
D000-d000	22.5 dg	24h	304	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D006-d006	22.5 dg	24h	304	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D012-d012	22.5 dg	24h	304	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D018-d018	22.5 dg	24h	304	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D024-d024	22.5 dg	24h	302	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D030-d030	22.5 dg	24h	301	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D036-d036	22.5 dg	24h	300	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D042-d042	22.5 dg	24h	300	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D048-d048	22.5 dg	24h	301	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D054-d054	22.5 dg	24h	303	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D060-d060	22.5 dg	24h	304	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D066-d066	22.5 dg	24h	305	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D072-d072	22.5 dg	24h	307	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D078-d078	22.5 dg	24h	308	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D084-d084	22.5 dg	24h	309	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D090-d090	22.5 dg	24h	309	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D096-d096	22.5 dg	24h	307	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D102-d102	22.5 dg	24h	305	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D108-d108	22.5 dg	24h	303	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D114-d114	22.5 dg	24h	301	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D120-d120	22.5 dg	24h	299	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		

Table C-6. Water surface current direction skill assessment at Mackinac Strait West

Station: Mackinac Strait West
Observed data time period from: / 8/ 1/2018 to / 9/21/2018
Data gap is filled using 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													
D			27942	183.669									
d			27942	174.127									
D-d	22.5 dg 24h		27942	-0.356	3.656	3.638	0.0	99.3	0.0	0.7	0.0		0.73
SCENARIO: SEMI-OPERATIONAL FORECAST													
D000-d000	22.5 dg 24h		366	-0.186	3.228	3.227	5.5	90.4	3.8	6.0	6.0		
D006-d006	22.5 dg 24h		366	-0.026	3.661	3.666	5.5	89.3	5.2	6.0	12.0		
D012-d012	22.5 dg 24h		365	-0.083	3.522	3.526	4.7	91.2	4.1	12.0	6.0		
D018-d018	22.5 dg 24h		364	0.024	3.033	3.038	4.1	91.8	4.1	6.0	6.0		
D024-d024	22.5 dg 24h		362	-0.047	3.100	3.104	4.7	92.0	3.3	6.0	6.0		
D030-d030	22.5 dg 24h		360	-0.154	4.207	4.210	5.3	90.8	3.9	6.0	6.0		
D036-d036	22.5 dg 24h		359	0.227	3.421	3.419	3.6	91.9	4.2	6.0	6.0		
D042-d042	22.5 dg 24h		358	-0.110	3.058	3.060	4.2	92.5	3.1	6.0	6.0		
D048-d048	22.5 dg 24h		357	-0.056	2.847	2.850	4.5	92.4	3.1	6.0	6.0		
D054-d054	22.5 dg 24h		356	0.370	9.594	9.600	4.2	92.4	3.4	6.0	6.0		
D060-d060	22.5 dg 24h		355	0.345	9.779	9.787	4.2	92.7	2.8	6.0	6.0		
D066-d066	22.5 dg 24h		354	0.442	9.914	9.918	3.7	93.2	3.1	12.0	6.0		
D072-d072	22.5 dg 24h		353	0.152	13.646	13.665	3.1	92.4	4.2	12.0	6.0		
D078-d078	22.5 dg 24h		352	0.751	10.028	10.014	2.0	94.0	4.0	6.0	6.0		
D084-d084	22.5 dg 24h		351	-0.417	16.814	16.832	3.7	92.0	4.0	6.0	6.0		
D090-d090	22.5 dg 24h		351	-1.946	19.342	19.272	4.8	90.6	4.0	12.0	6.0		
D096-d096	22.5 dg 24h		351	-0.329	19.499	19.524	4.0	92.6	3.4	6.0	6.0		
D102-d102	22.5 dg 24h		350	-0.008	14.164	14.184	2.9	93.4	3.4	6.0	6.0		
D108-d108	22.5 dg 24h		349	1.442	17.203	17.167	3.7	92.0	4.3	12.0	6.0		
D114-d114	22.5 dg 24h		347	-0.987	19.341	19.344	4.0	91.6	4.3	6.0	6.0		
D120-d120	22.5 dg 24h		345	-0.005	13.918	13.938	2.6	94.8	2.6	0.0	6.0		

Table C-7. Water surface current direction skill assessment at Saginaw Bay Buoy

Station: Saginaw Bay Buoy, MI
Observed data time period from: / 6/17/2018 to / 9/18/2018
Data gap is filled using 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													
D			21616	187.542									
d			21616	144.763									
D-d	22.5 dg 24h		21616	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		0.49
SCENARIO: SEMI-OPERATIONAL FORECAST													
D000-d000	22.5 dg 24h		263	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D006-d006	22.5 dg 24h		262	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D012-d012	22.5 dg 24h		261	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D018-d018	22.5 dg 24h		260	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D024-d024	22.5 dg 24h		259	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D030-d030	22.5 dg 24h		258	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D036-d036	22.5 dg 24h		257	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D042-d042	22.5 dg 24h		256	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D048-d048	22.5 dg 24h		255	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D054-d054	22.5 dg 24h		254	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D060-d060	22.5 dg 24h		253	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D066-d066	22.5 dg 24h		252	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D072-d072	22.5 dg 24h		251	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D078-d078	22.5 dg 24h		250	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D084-d084	22.5 dg 24h		249	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D090-d090	22.5 dg 24h		248	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D096-d096	22.5 dg 24h		247	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D102-d102	22.5 dg 24h		246	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D108-d108	22.5 dg 24h		245	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D114-d114	22.5 dg 24h		244	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		
D120-d120	22.5 dg 24h		243	0.000	0.000	0.000	0.0	100.0	0.0	0.0	0.0		

Table C-8. Water surface current direction skill assessment at Muskegon Buoy

Station: Muskegon Buoy, MI
Observed data time period from: / 6/17/2018 to /10/19/2018
Data gap is filled using 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													
D			28683	207.888									
d			28683	184.169									
D-d	22.5	dg 24h	28683	-0.178	2.451	2.445	0.0	99.6	0.0	0.3	0.0		0.56
SCENARIO: SEMI-OPERATIONAL FORECAST													
D000-d000	22.5	dg 24h	376	-0.054	2.661	2.664	1.1	97.9	1.1	0.0	0.0		
D006-d006	22.5	dg 24h	376	-0.075	2.788	2.790	1.1	97.6	1.1	0.0	0.0		
D012-d012	22.5	dg 24h	375	-0.124	2.797	2.798	1.6	97.6	0.8	0.0	0.0		
D018-d018	22.5	dg 24h	374	-0.016	2.389	2.392	0.8	98.1	1.1	0.0	0.0		
D024-d024	22.5	dg 24h	373	-0.024	2.466	2.470	0.8	98.1	1.1	0.0	0.0		
D030-d030	22.5	dg 24h	372	-0.093	2.770	2.773	1.1	98.1	0.8	0.0	0.0		
D036-d036	22.5	dg 24h	371	-0.172	3.245	3.245	1.3	98.1	0.5	0.0	0.0		
D042-d042	22.5	dg 24h	370	-0.135	2.915	2.916	1.1	97.8	0.8	0.0	0.0		
D048-d048	22.5	dg 24h	369	-0.164	2.923	2.922	1.6	97.3	0.8	0.0	0.0		
D054-d054	22.5	dg 24h	368	-0.117	2.701	2.702	1.1	97.8	1.1	0.0	0.0		
D060-d060	22.5	dg 24h	367	-0.085	2.874	2.877	1.1	97.8	1.1	0.0	0.0		
D066-d066	22.5	dg 24h	366	-0.014	2.843	2.847	1.1	97.8	1.1	0.0	0.0		
D072-d072	22.5	dg 24h	365	-0.182	3.684	3.684	1.4	97.8	0.8	0.0	0.0		
D078-d078	22.5	dg 24h	364	-0.119	2.516	2.516	1.1	98.4	0.5	0.0	0.0		
D084-d084	22.5	dg 24h	363	-0.119	2.504	2.505	1.1	98.1	0.8	0.0	0.0		
D090-d090	22.5	dg 24h	362	-0.305	3.616	3.608	1.7	97.5	0.6	0.0	0.0		
D096-d096	22.5	dg 24h	361	-0.282	2.828	2.818	1.1	98.6	0.3	0.0	0.0		
D102-d102	22.5	dg 24h	360	-0.181	2.140	2.136	1.4	98.1	0.6	0.0	0.0		
D108-d108	22.5	dg 24h	359	-0.150	1.968	1.965	1.1	98.3	0.6	0.0	0.0		
D114-d114	22.5	dg 24h	358	-0.184	2.099	2.094	0.8	98.9	0.3	0.0	0.0		
D120-d120	22.5	dg 24h	357	0.049	1.481	1.482	0.3	99.2	0.6	0.0	0.0		

APPENDIX D. SURFACE WATER TEMPERATURE SKILL ASSESSMENT TABLES

Table D-1. Water surface temperature skill assessment at Holland

Station: Holland
Observed data time period from: / 9/10/2018 to / 4/ 7/2019
Data gap is filled using 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			69477	10.000									
t			69477	9.106									
T-t	3.0	c 24h	69477	0.894	2.983	2.846	1.4	78.5	4.5	17.0	51.3		0.97
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	971	0.870	2.959	2.830	1.8	82.5	4.2	64.9	59.0		
T012-t012	3.0	c 24h	970	0.848	2.960	2.837	1.9	80.5	4.6	29.5	59.0		
T018-t018	3.0	c 24h	969	0.785	2.988	2.884	2.0	81.1	3.8	29.5	41.3		
T024-t024	3.0	c 24h	968	0.642	2.831	2.759	2.8	82.0	2.9	53.1	35.4		
T030-t030	3.0	c 24h	968	0.693	3.032	2.953	2.5	81.5	3.9	53.1	41.3		
T036-t036	3.0	c 24h	968	0.667	3.026	2.953	2.6	82.5	4.0	53.1	76.7		
T042-t042	3.0	c 24h	968	0.685	3.124	3.050	2.9	81.7	4.0	112.1	70.8		
T048-t048	3.0	c 24h	968	0.681	3.166	3.094	3.0	82.3	4.2	147.5	59.0		
T054-t054	3.0	c 24h	968	0.671	3.200	3.131	2.9	82.4	4.3	141.6	59.0		
T060-t060	3.0	c 24h	968	0.743	3.242	3.157	2.9	80.6	4.2	141.6	59.0		
T066-t066	3.0	c 24h	968	0.785	3.322	3.230	2.9	80.8	4.5	141.6	76.7		
T072-t072	3.0	c 24h	968	0.789	3.321	3.227	3.1	81.2	4.1	147.5	59.0		
T078-t078	3.0	c 24h	968	0.824	3.359	3.258	3.1	81.0	4.0	147.5	76.7		
T084-t084	3.0	c 24h	968	0.803	3.318	3.221	2.4	80.1	4.2	118.0	76.7		
T090-t090	3.0	c 24h	967	0.802	3.297	3.200	2.5	80.8	4.3	118.0	59.0		
T096-t096	3.0	c 24h	966	0.790	3.342	3.249	2.7	81.2	4.6	135.7	76.7		
T102-t102	3.0	c 24h	974	0.827	3.287	3.183	2.6	80.3	4.5	64.9	59.0		
T108-t108	3.0	c 24h	973	0.821	3.184	3.078	2.5	80.5	4.3	64.9	59.0		
T114-t114	3.0	c 24h	972	0.819	3.180	3.074	2.7	80.3	3.7	59.0	35.4		
T120-t120	3.0	c 24h	971	0.827	3.212	3.105	3.0	80.7	4.5	59.0	41.3		

Table D-2. Water surface temperature skill assessment at Port Inland

Station: Port Inland
Observed data time period from: / 6/17/2018 to /11/27/2018
Data gap is filled using 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			38482	13.831									
t			38482	15.198									
T-t	3.0	c 24h	38482	-1.368	2.279	1.823	1.5	82.7	0.0	31.8	0.0		0.96
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	520	-1.303	2.288	1.882	2.1	81.0	0.0	17.7	0.0		
T012-t012	3.0	c 24h	519	-1.275	2.236	1.839	1.7	83.0	0.0	11.8	0.0		
T018-t018	3.0	c 24h	518	-1.281	2.217	1.811	0.8	80.9	0.0	5.9	0.0		
T024-t024	3.0	c 24h	517	-1.262	2.191	1.793	1.0	84.1	0.0	11.8	0.0		
T030-t030	3.0	c 24h	516	-1.321	2.232	1.801	1.9	84.1	0.0	11.8	0.0		
T036-t036	3.0	c 24h	515	-1.390	2.253	1.775	1.9	83.7	0.0	11.8	0.0		
T042-t042	3.0	c 24h	514	-1.343	2.304	1.874	2.1	83.3	0.0	17.7	0.0		
T048-t048	3.0	c 24h	513	-1.321	2.300	1.885	2.3	83.0	0.2	17.7	0.0		
T054-t054	3.0	c 24h	532	-1.288	2.269	1.870	1.9	82.5	0.2	23.6	0.0		
T060-t060	3.0	c 24h	531	-1.312	2.279	1.865	1.9	82.1	0.2	29.5	0.0		
T066-t066	3.0	c 24h	530	-1.348	2.305	1.871	2.5	82.5	0.2	35.4	0.0		
T072-t072	3.0	c 24h	529	-1.389	2.341	1.886	2.5	81.5	0.2	35.4	0.0		
T078-t078	3.0	c 24h	528	-1.421	2.381	1.912	3.2	82.2	0.2	47.2	0.0		
T084-t084	3.0	c 24h	527	-1.429	2.378	1.903	2.3	81.0	0.2	35.4	0.0		
T090-t090	3.0	c 24h	526	-1.427	2.388	1.917	2.3	79.5	0.2	41.3	0.0		
T096-t096	3.0	c 24h	525	-1.422	2.397	1.931	2.3	80.6	0.2	29.5	0.0		
T102-t102	3.0	c 24h	524	-1.418	2.371	1.901	2.3	80.7	0.2	29.5	0.0		
T108-t108	3.0	c 24h	523	-1.423	2.377	1.907	2.3	79.5	0.2	29.5	0.0		
T114-t114	3.0	c 24h	522	-1.425	2.407	1.941	2.5	78.4	0.2	11.8	0.0		
T120-t120	3.0	c 24h	521	-1.413	2.405	1.947	2.1	79.5	0.2	5.9	0.0		

Table D-3. Water surface temperature skill assessment at Mackinaw

Station: Mackinaw
Observed data time period from: / 9/18/2018 to / 4/ 7/2019
Data gap is filled using 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			69724	8.311									
t			69724	8.967									
T-t	3.0	c 24h	69724	-0.657	2.346	2.252	0.6	84.8	0.0	23.1	0.0		0.98
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	975	-0.511	2.288	2.231	0.3	85.2	0.0	5.9	0.0		
T012-t012	3.0	c 24h	974	-0.524	2.295	2.236	0.9	86.1	0.0	11.8	0.0		
T018-t018	3.0	c 24h	973	-0.555	2.304	2.237	0.7	85.5	0.0	11.8	0.0		
T024-t024	3.0	c 24h	972	-0.574	2.314	2.243	0.7	85.0	0.0	5.9	0.0		
T030-t030	3.0	c 24h	972	-0.598	2.302	2.224	0.5	85.6	0.0	5.9	0.0		
T036-t036	3.0	c 24h	972	-0.634	2.273	2.184	0.2	85.8	0.0	0.0	0.0		
T042-t042	3.0	c 24h	972	-0.597	2.314	2.236	0.4	84.3	0.0	0.0	0.0		
T048-t048	3.0	c 24h	972	-0.634	2.280	2.191	0.1	85.1	0.0	0.0	0.0		
T054-t054	3.0	c 24h	972	-0.596	2.307	2.230	0.0	83.0	0.0	0.0	0.0		
T060-t060	3.0	c 24h	972	-0.590	2.332	2.258	0.1	82.5	0.0	0.0	0.0		
T066-t066	3.0	c 24h	972	-0.578	2.323	2.251	0.0	82.7	0.0	0.0	0.0		
T072-t072	3.0	c 24h	972	-0.549	2.354	2.290	0.3	81.9	0.0	0.0	0.0		
T078-t078	3.0	c 24h	972	-0.546	2.349	2.286	0.1	82.5	0.0	0.0	0.0		
T084-t084	3.0	c 24h	972	-0.548	2.357	2.294	0.3	82.4	0.0	0.0	0.0		
T090-t090	3.0	c 24h	971	-0.561	2.375	2.309	0.4	81.9	0.0	5.9	0.0		
T096-t096	3.0	c 24h	970	-0.560	2.360	2.293	0.3	82.8	0.0	5.9	0.0		
T102-t102	3.0	c 24h	978	-0.566	2.352	2.284	0.3	82.6	0.0	5.9	0.0		
T108-t108	3.0	c 24h	977	-0.557	2.336	2.270	0.5	83.3	0.0	17.7	0.0		
T114-t114	3.0	c 24h	976	-0.562	2.330	2.262	0.3	84.3	0.0	0.0	0.0		
T120-t120	3.0	c 24h	975	-0.530	2.289	2.228	0.3	85.1	0.0	5.9	0.0		

Table D-4. Water surface temperature skill assessment at De Tour Village

Station: De Tour Village
Observed data time period from: / 6/17/2018 to / 4/ 7/2019
Data gap is filled using 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			69785	8.630									
t			69785	8.281									
T-t	3.0	c 24h	69785	0.349	2.801	2.790	0.0	59.2	2.9	0.0	76.0		0.97
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	976	0.034	2.752	2.753	0.0	64.1	0.6	0.0	0.0		
T012-t012	3.0	c 24h	975	0.071	2.797	2.798	0.0	63.6	1.9	0.0	59.0		
T018-t018	3.0	c 24h	974	0.129	2.842	2.841	0.0	62.5	2.1	0.0	59.0		
T024-t024	3.0	c 24h	973	0.112	2.837	2.836	0.0	63.0	1.6	0.0	76.7		
T030-t030	3.0	c 24h	972	0.142	2.869	2.866	0.0	62.2	1.7	0.0	64.9		
T036-t036	3.0	c 24h	971	0.118	2.854	2.853	0.0	62.4	1.8	0.0	53.1		
T042-t042	3.0	c 24h	970	0.133	2.867	2.866	0.0	63.1	1.8	0.0	59.0		
T048-t048	3.0	c 24h	970	0.232	2.857	2.849	0.0	63.2	1.5	0.0	29.5		
T054-t054	3.0	c 24h	970	0.233	2.861	2.853	0.0	62.7	1.8	0.0	11.8		
T060-t060	3.0	c 24h	970	0.245	2.832	2.822	0.0	63.5	1.4	0.0	11.8		
T066-t066	3.0	c 24h	970	0.234	2.823	2.815	0.0	64.2	1.5	0.0	29.5		
T072-t072	3.0	c 24h	971	0.265	2.801	2.790	0.0	64.2	1.4	0.0	29.5		
T078-t078	3.0	c 24h	970	0.229	2.810	2.802	0.0	64.9	1.3	0.0	29.5		
T084-t084	3.0	c 24h	970	0.223	2.810	2.802	0.0	64.7	1.3	0.0	11.8		
T090-t090	3.0	c 24h	970	0.173	2.841	2.837	0.0	62.7	1.1	0.0	11.8		
T096-t096	3.0	c 24h	968	0.078	2.839	2.839	0.0	63.4	1.3	0.0	11.8		
T102-t102	3.0	c 24h	979	0.070	2.834	2.834	0.0	64.2	1.6	0.0	11.8		
T108-t108	3.0	c 24h	978	0.094	2.872	2.872	0.0	63.3	2.2	0.0	11.8		
T114-t114	3.0	c 24h	977	0.113	2.877	2.876	0.0	63.6	2.7	0.0	29.5		
T120-t120	3.0	c 24h	976	0.131	2.900	2.898	0.0	62.5	2.5	0.0	29.5		

Table D-5. Water surface temperature skill assessment at Harbor Beach

Station: Harbor Beach
Observed data time period from: /10/ 1/2018 to / 4/12/2019
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%	SKILL
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			69711	7.542									
t			69711	9.068									
T-t	3.0	c 24h	69711	-1.526	2.524	2.267	7.0	81.1	0.0	135.4	0.0		0.96
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	977	-1.133	2.620	2.364	4.5	87.5	0.0	23.6	0.0		
T012-t012	3.0	c 24h	977	-1.182	2.760	2.495	4.8	86.6	0.0	59.0	0.0		
T018-t018	3.0	c 24h	977	-1.239	2.775	2.484	4.8	85.4	0.0	64.9	0.0		
T024-t024	3.0	c 24h	977	-1.259	2.797	2.500	5.5	85.2	0.0	53.1	0.0		
T030-t030	3.0	c 24h	980	-1.345	2.754	2.404	5.1	84.2	0.0	53.1	0.0		
T036-t036	3.0	c 24h	979	-1.336	2.719	2.370	5.3	84.3	0.0	53.1	0.0		
T042-t042	3.0	c 24h	978	-1.289	2.681	2.351	5.3	84.8	0.0	59.0	0.0		
T048-t048	3.0	c 24h	977	-1.265	2.663	2.344	5.1	85.6	0.0	64.9	0.0		
T054-t054	3.0	c 24h	976	-1.228	2.613	2.307	4.7	86.6	0.0	47.2	0.0		
T060-t060	3.0	c 24h	977	-1.177	2.601	2.320	4.5	86.9	0.0	41.3	0.0		
T066-t066	3.0	c 24h	977	-1.169	2.606	2.331	4.7	86.4	0.0	53.1	0.0		
T072-t072	3.0	c 24h	977	-1.096	2.575	2.331	4.4	86.8	0.0	47.2	0.0		
T078-t078	3.0	c 24h	977	-1.100	2.549	2.301	4.7	86.4	0.0	41.3	0.0		
T084-t084	3.0	c 24h	978	-1.082	2.507	2.263	3.8	86.0	0.0	35.4	0.0		
T090-t090	3.0	c 24h	976	-1.111	2.524	2.267	3.4	85.2	0.0	29.5	0.0		
T096-t096	3.0	c 24h	975	-1.099	2.514	2.262	4.2	86.1	0.0	23.6	0.0		
T102-t102	3.0	c 24h	977	-1.107	2.532	2.278	4.2	87.2	0.0	17.7	0.0		
T108-t108	3.0	c 24h	977	-1.103	2.573	2.326	4.2	86.9	0.0	29.5	0.0		
T114-t114	3.0	c 24h	977	-1.097	2.572	2.327	5.0	87.6	0.0	29.5	0.0		
T120-t120	3.0	c 24h	977	-1.063	2.525	2.291	4.0	87.7	0.0	29.5	0.0		

Table D-6. Water surface temperature skill assessment at South Green Bay

Station: South Green Bay, WI
Observed data time period from: / 9/ 8/2018 to /11/ 1/2018
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%	SKILL
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			30285	19.113									
t			30285	19.340									
T-t	3.0	c 24h	30285	-0.227	2.328	2.317	1.4	80.9	0.0	14.4	1.2		0.92
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	395	-0.007	1.886	1.888	0.8	88.9	0.0	0.0	0.0		
T012-t012	3.0	c 24h	397	0.034	1.842	1.844	0.8	89.4	0.0	0.0	0.0		
T018-t018	3.0	c 24h	394	0.040	1.816	1.818	0.5	89.6	0.0	0.0	0.0		
T024-t024	3.0	c 24h	393	0.157	1.838	1.834	0.5	89.3	0.0	0.0	0.0		
T030-t030	3.0	c 24h	392	0.157	1.790	1.785	0.0	90.3	0.0	0.0	0.0		
T036-t036	3.0	c 24h	390	0.172	1.770	1.763	0.0	91.3	0.0	0.0	0.0		
T042-t042	3.0	c 24h	398	0.256	1.800	1.784	0.0	91.2	0.0	0.0	0.0		
T048-t048	3.0	c 24h	403	0.271	1.772	1.753	0.0	91.8	0.0	0.0	0.0		
T054-t054	3.0	c 24h	401	0.264	1.767	1.750	0.0	90.8	0.0	0.0	0.0		
T060-t060	3.0	c 24h	399	0.261	1.757	1.739	0.0	91.5	0.0	0.0	0.0		
T066-t066	3.0	c 24h	399	0.248	1.738	1.722	0.0	91.2	0.0	0.0	0.0		
T072-t072	3.0	c 24h	399	0.237	1.723	1.709	0.0	91.5	0.0	0.0	0.0		
T078-t078	3.0	c 24h	399	0.230	1.721	1.707	0.0	92.0	0.0	0.0	0.0		
T084-t084	3.0	c 24h	400	0.225	1.691	1.678	0.0	93.0	0.0	0.0	0.0		
T090-t090	3.0	c 24h	400	0.220	1.666	1.653	0.0	93.0	0.0	0.0	0.0		
T096-t096	3.0	c 24h	400	0.204	1.645	1.634	0.0	93.2	0.0	0.0	0.0		
T102-t102	3.0	c 24h	400	0.185	1.650	1.642	0.0	94.0	0.0	0.0	0.0		
T108-t108	3.0	c 24h	399	0.179	1.654	1.646	0.0	94.5	0.0	0.0	0.0		
T114-t114	3.0	c 24h	397	0.170	1.646	1.640	0.0	94.5	0.0	0.0	0.0		
T120-t120	3.0	c 24h	396	0.175	1.638	1.630	0.0	94.2	0.0	0.0	0.0		

Table D-7. Water surface temperature skill assessment at North Michigan

Station: North Michigan
Observed data time period from: / 6/17/2018 to /11/13/2018
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%	SKILL
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			35056	16.248									
t			35056	16.372									
T-t	3.0	c 24h	35056	-0.124	1.782	1.778	0.0	93.5	3.6	0.0	79.9		0.96
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	462	-0.379	1.799	1.761	0.0	95.7	3.2	0.0	53.1		
T012-t012	3.0	c 24h	461	-0.331	1.737	1.707	0.0	95.9	3.0	0.0	53.1		
T018-t018	3.0	c 24h	460	-0.242	1.639	1.623	0.0	96.5	3.0	0.0	59.0		
T024-t024	3.0	c 24h	459	-0.224	1.627	1.614	0.0	96.3	3.3	0.0	70.8		
T030-t030	3.0	c 24h	458	-0.164	1.591	1.584	0.0	96.3	3.3	0.0	76.7		
T036-t036	3.0	c 24h	457	-0.174	1.605	1.598	0.0	96.1	3.3	0.0	82.6		
T042-t042	3.0	c 24h	456	-0.198	1.629	1.619	0.0	96.1	3.5	0.0	88.5		
T048-t048	3.0	c 24h	475	-0.206	1.609	1.597	0.0	95.8	3.2	0.0	82.6		
T054-t054	3.0	c 24h	474	-0.243	1.614	1.598	0.0	95.4	3.0	0.0	76.7		
T060-t060	3.0	c 24h	473	-0.280	1.602	1.579	0.0	95.3	2.7	0.0	70.8		
T066-t066	3.0	c 24h	472	-0.317	1.591	1.560	0.0	94.7	2.5	0.0	64.9		
T072-t072	3.0	c 24h	471	-0.365	1.595	1.554	0.0	94.7	2.3	0.0	59.0		
T078-t078	3.0	c 24h	470	-0.406	1.575	1.524	0.0	94.0	2.1	0.0	53.1		
T084-t084	3.0	c 24h	469	-0.441	1.561	1.499	0.0	94.5	1.9	0.0	47.2		
T090-t090	3.0	c 24h	468	-0.495	1.571	1.492	0.0	94.7	1.7	0.0	41.3		
T096-t096	3.0	c 24h	467	-0.547	1.570	1.474	0.0	93.1	1.5	0.0	35.4		
T102-t102	3.0	c 24h	465	-0.582	1.571	1.461	0.0	93.3	1.3	0.0	29.5		
T108-t108	3.0	c 24h	464	-0.608	1.562	1.441	0.0	94.2	1.3	0.0	29.5		
T114-t114	3.0	c 24h	463	-0.629	1.532	1.398	0.0	94.0	1.1	0.0	23.6		
T120-t120	3.0	c 24h	462	-0.654	1.500	1.352	0.0	93.5	0.6	0.0	11.8		

Table D-8. Water surface temperature skill assessment at Atwater Park

Station: Atwater Park, WI
Observed data time period from: / 7/18/2018 to / 8/15/2018
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%	SKILL
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			29263	16.143									
t			29263	17.152									
T-t	3.0	c 24h	29263	-1.009	3.039	2.866	6.2	69.9	0.1	45.2	2.5		0.86
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	370	-0.845	2.907	2.785	4.6	74.6	1.1	11.8	5.9		
T012-t012	3.0	c 24h	370	-0.975	3.031	2.873	4.3	71.6	1.1	17.7	5.9		
T018-t018	3.0	c 24h	373	-1.114	3.081	2.877	4.0	68.1	1.3	11.8	5.9		
T024-t024	3.0	c 24h	375	-0.999	3.082	2.920	5.3	68.3	0.0	17.7	0.0		
T030-t030	3.0	c 24h	376	-0.810	2.938	2.828	5.6	72.9	0.3	17.7	0.0		
T036-t036	3.0	c 24h	374	-0.894	3.013	2.881	5.3	71.9	0.3	23.6	0.0		
T042-t042	3.0	c 24h	373	-0.889	3.003	2.872	4.8	71.0	0.0	23.6	0.0		
T048-t048	3.0	c 24h	385	-0.799	2.995	2.890	6.2	71.9	0.0	23.6	0.0		
T054-t054	3.0	c 24h	385	-0.768	2.969	2.871	6.5	74.0	0.0	29.5	0.0		
T060-t060	3.0	c 24h	382	-0.746	2.979	2.888	6.8	76.4	0.0	35.4	0.0		
T066-t066	3.0	c 24h	381	-0.758	2.994	2.900	6.0	76.4	0.3	35.4	0.0		
T072-t072	3.0	c 24h	378	-0.741	3.017	2.929	6.9	76.7	0.0	59.0	0.0		
T078-t078	3.0	c 24h	378	-0.783	3.082	2.985	7.4	76.2	0.3	59.0	0.0		
T084-t084	3.0	c 24h	377	-0.784	3.118	3.021	8.2	76.4	0.3	53.1	0.0		
T090-t090	3.0	c 24h	376	-0.845	3.143	3.032	7.4	74.5	0.3	47.2	0.0		
T096-t096	3.0	c 24h	373	-0.861	3.186	3.072	7.8	74.0	0.3	47.2	0.0		
T102-t102	3.0	c 24h	371	-0.862	3.230	3.118	8.6	73.9	0.3	41.3	0.0		
T108-t108	3.0	c 24h	370	-0.846	3.228	3.119	8.4	73.5	0.5	35.4	0.0		
T114-t114	3.0	c 24h	367	-0.823	3.198	3.095	7.6	73.6	0.5	23.6	0.0		
T120-t120	3.0	c 24h	367	-0.780	3.167	3.074	7.1	74.1	1.1	23.6	5.9		

Table D-9. Water surface temperature skill assessment at Ludington Buoy

Station: Ludington Buoy, MI
Observed data time period from: / 8/ 1/2018 to /10/ 2/2018
Data gap is filled using 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			24914	20.195									
t			24914	18.842									
T-t	3.0	c 24h	24914	1.352	2.806	2.458	0.1	78.1	5.2	1.9	21.1		0.82
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	304	1.450	2.654	2.226	0.0	79.3	4.9	0.0	11.8		
T012-t012	3.0	c 24h	304	1.779	2.989	2.406	0.3	76.6	6.9	0.0	17.7		
T018-t018	3.0	c 24h	303	1.727	3.180	2.675	0.0	72.3	7.9	0.0	29.5		
T024-t024	3.0	c 24h	302	1.703	3.080	2.570	0.0	73.5	6.3	0.0	23.6		
T030-t030	3.0	c 24h	301	1.450	2.903	2.520	0.0	77.4	6.3	0.0	23.6		
T036-t036	3.0	c 24h	314	1.496	2.841	2.419	0.0	76.8	5.1	0.0	23.6		
T042-t042	3.0	c 24h	312	1.510	2.832	2.400	0.0	77.9	5.4	0.0	17.7		
T048-t048	3.0	c 24h	311	1.520	2.830	2.391	0.3	79.4	5.8	0.0	11.8		
T054-t054	3.0	c 24h	310	1.529	2.841	2.398	0.0	78.4	3.9	0.0	5.9		
T060-t060	3.0	c 24h	310	1.528	2.771	2.315	0.0	76.5	4.2	0.0	5.9		
T066-t066	3.0	c 24h	310	1.556	2.759	2.283	0.0	79.0	3.9	0.0	5.9		
T072-t072	3.0	c 24h	310	1.559	2.631	2.123	0.0	80.3	3.9	0.0	5.9		
T078-t078	3.0	c 24h	310	1.596	2.652	2.121	0.0	79.4	5.2	0.0	17.7		
T084-t084	3.0	c 24h	309	1.600	2.635	2.098	0.0	79.3	4.2	0.0	23.6		
T090-t090	3.0	c 24h	308	1.612	2.711	2.183	0.3	78.2	4.2	0.0	29.5		
T096-t096	3.0	c 24h	307	1.583	2.701	2.192	0.0	78.8	4.2	0.0	11.8		
T102-t102	3.0	c 24h	307	1.569	2.720	2.225	0.0	81.4	3.9	0.0	41.3		
T108-t108	3.0	c 24h	306	1.608	2.879	2.392	0.3	80.4	4.2	0.0	35.4		
T114-t114	3.0	c 24h	305	1.626	2.801	2.284	0.0	81.0	5.2	0.0	23.6		
T120-t120	3.0	c 24h	304	1.567	2.736	2.246	0.0	79.9	4.6	0.0	29.5		

Table D-10. Water surface temperature skill assessment at South Michigan

Station: South Michigan
Observed data time period from: / 7/11/2018 to / 9/ 2/2018
Data gap is filled using 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			38822	19.740									
t			38822	17.956									
T-t	3.0	c 24h	38822	1.784	1.930	0.738	0.0	96.6	0.0	0.0	0.0		0.97
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	525	1.664	1.854	0.820	0.0	97.1	0.0	0.0	0.0		
T012-t012	3.0	c 24h	524	1.718	1.894	0.797	0.0	97.7	0.0	0.0	0.0		
T018-t018	3.0	c 24h	523	1.768	1.905	0.712	0.0	97.9	0.0	0.0	0.0		
T024-t024	3.0	c 24h	522	1.806	1.930	0.680	0.0	97.5	0.0	0.0	0.0		
T030-t030	3.0	c 24h	521	1.778	1.904	0.683	0.0	97.5	0.0	0.0	0.0		
T036-t036	3.0	c 24h	521	1.796	1.920	0.681	0.0	97.1	0.0	0.0	0.0		
T042-t042	3.0	c 24h	518	1.783	1.916	0.701	0.0	97.3	0.0	0.0	0.0		
T048-t048	3.0	c 24h	517	1.769	1.904	0.705	0.0	97.3	0.0	0.0	0.0		
T054-t054	3.0	c 24h	536	1.805	1.947	0.729	0.0	97.6	0.0	0.0	0.0		
T060-t060	3.0	c 24h	535	1.792	1.936	0.734	0.0	97.4	0.0	0.0	0.0		
T066-t066	3.0	c 24h	535	1.763	1.912	0.741	0.0	97.8	0.0	0.0	0.0		
T072-t072	3.0	c 24h	534	1.759	1.919	0.767	0.0	97.2	0.0	0.0	0.0		
T078-t078	3.0	c 24h	533	1.741	1.915	0.797	0.0	97.6	0.2	0.0	0.0		
T084-t084	3.0	c 24h	532	1.703	1.874	0.784	0.0	98.1	0.0	0.0	0.0		
T090-t090	3.0	c 24h	531	1.697	1.880	0.811	0.0	97.4	0.0	0.0	0.0		
T096-t096	3.0	c 24h	530	1.686	1.890	0.854	0.0	97.9	0.2	0.0	0.0		
T102-t102	3.0	c 24h	528	1.658	1.848	0.817	0.0	98.3	0.2	0.0	0.0		
T108-t108	3.0	c 24h	527	1.667	1.878	0.867	0.0	97.9	0.2	0.0	0.0		
T114-t114	3.0	c 24h	526	1.652	1.866	0.869	0.0	97.0	0.2	0.0	0.0		
T120-t120	3.0	c 24h	525	1.653	1.868	0.871	0.0	97.7	0.2	0.0	0.0		

Table D-11. Water surface temperature skill assessment at Muskegon Buoy

Station: Muskegon Buoy, MI
Observed data time period from: / 6/17/2018 to / 6/17/2018
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%	SKILL
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			14551	20.214									
t			14551	19.108									
T-t	3.0	c 24h	14551	1.107	2.351	2.074	0.9	86.3	1.1	0.0	0.0		0.91
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	187	0.910	3.015	2.882	3.7	81.8	1.1	47.2	0.0		
T012-t012	3.0	c 24h	190	1.166	2.570	2.297	1.1	80.5	1.1	17.7	0.0		
T018-t018	3.0	c 24h	190	1.138	2.728	2.486	1.1	81.6	1.6	17.7	17.7		
T024-t024	3.0	c 24h	189	1.233	2.787	2.506	1.6	81.5	2.6	23.6	17.7		
T030-t030	3.0	c 24h	186	1.053	2.591	2.374	1.6	84.4	1.1	23.6	17.7		
T036-t036	3.0	c 24h	190	1.039	2.559	2.345	1.6	88.4	1.1	23.6	17.7		
T042-t042	3.0	c 24h	191	1.001	2.621	2.429	2.1	87.4	1.0	41.3	17.7		
T048-t048	3.0	c 24h	195	1.027	2.633	2.430	2.1	87.7	1.5	41.3	0.0		
T054-t054	3.0	c 24h	190	0.947	2.568	2.393	2.1	85.8	1.1	41.3	0.0		
T060-t060	3.0	c 24h	190	0.942	2.617	2.448	2.6	86.3	0.5	47.2	0.0		
T066-t066	3.0	c 24h	190	0.881	2.656	2.513	2.6	84.2	0.5	47.2	0.0		
T072-t072	3.0	c 24h	187	0.768	2.661	2.554	2.7	83.4	0.0	47.2	0.0		
T078-t078	3.0	c 24h	188	0.926	2.694	2.537	3.2	80.9	0.5	53.1	0.0		
T084-t084	3.0	c 24h	186	0.920	2.713	2.559	3.2	82.8	0.5	64.9	0.0		
T090-t090	3.0	c 24h	186	0.904	2.834	2.693	2.7	82.8	1.6	47.2	0.0		
T096-t096	3.0	c 24h	185	0.914	2.857	2.715	3.8	82.7	0.5	70.8	0.0		
T102-t102	3.0	c 24h	186	0.948	2.817	2.660	3.2	82.3	0.5	47.2	0.0		
T108-t108	3.0	c 24h	185	0.988	2.963	2.800	3.2	80.5	1.6	64.9	0.0		
T114-t114	3.0	c 24h	184	0.931	3.061	2.924	3.3	78.8	0.5	29.5	0.0		
T120-t120	3.0	c 24h	182	0.845	3.093	2.983	4.4	81.3	0.5	47.2	0.0		

Table D-12. Water surface temperature skill assessment at Wilmette Buoy

Station: Wilmette Buoy, IL
Observed data time period from: / 7/29/2018 to /11/15/2018
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%	SKILL
SCENARIO: SEMI-OPERATIONAL NOWCAST													
T			34134	18.909									
t			34134	18.745									
T-t	3.0	c 24h	34134	0.164	1.980	1.973	1.8	88.1	0.0	23.4	0.0		0.95
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	455	0.101	1.701	1.700	0.9	91.6	0.0	0.0	0.0		
T012-t012	3.0	c 24h	452	0.134	1.719	1.715	0.4	88.3	0.0	0.0	0.0		
T018-t018	3.0	c 24h	450	0.268	1.647	1.627	0.7	90.2	0.0	0.0	0.0		
T024-t024	3.0	c 24h	448	0.337	1.700	1.668	0.0	88.6	0.0	0.0	0.0		
T030-t030	3.0	c 24h	446	0.390	1.726	1.683	0.4	89.5	0.0	0.0	0.0		
T036-t036	3.0	c 24h	444	0.375	1.744	1.705	0.5	88.1	0.0	0.0	0.0		
T042-t042	3.0	c 24h	442	0.354	1.784	1.751	0.5	87.6	0.0	0.0	0.0		
T048-t048	3.0	c 24h	456	0.352	1.745	1.711	0.2	87.3	0.0	0.0	0.0		
T054-t054	3.0	c 24h	459	0.358	1.730	1.695	0.0	87.6	0.0	0.0	0.0		
T060-t060	3.0	c 24h	459	0.360	1.757	1.721	0.2	88.0	0.0	0.0	0.0		
T066-t066	3.0	c 24h	459	0.340	1.746	1.714	0.2	88.2	0.0	0.0	0.0		
T072-t072	3.0	c 24h	460	0.349	1.755	1.722	0.4	87.6	0.0	0.0	0.0		
T078-t078	3.0	c 24h	460	0.339	1.789	1.759	0.2	87.2	0.0	0.0	0.0		
T084-t084	3.0	c 24h	460	0.311	1.793	1.768	0.2	88.7	0.0	0.0	0.0		
T090-t090	3.0	c 24h	460	0.256	1.793	1.776	0.4	87.6	0.0	5.9	0.0		
T096-t096	3.0	c 24h	460	0.243	1.835	1.820	0.4	87.2	0.2	5.9	0.0		
T102-t102	3.0	c 24h	460	0.255	1.874	1.859	0.7	86.5	0.7	11.8	0.0		
T108-t108	3.0	c 24h	460	0.272	1.847	1.829	0.7	87.2	0.7	11.8	5.9		
T114-t114	3.0	c 24h	460	0.296	1.849	1.827	0.2	87.8	0.2	0.0	0.0		
T120-t120	3.0	c 24h	461	0.349	1.846	1.815	0.4	87.4	0.4	0.0	0.0		

Table D-13. Water surface temperature skill assessment at Holland Buoy

Station: Holland Buoy, MI
Observed data time period from: / 6/17/2018 to /10/25/2018
Data gap is filled using 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			30491	20.960									
t			30491	19.114									
T-t	3.0 c 24h		30491	1.846	3.394	2.848	0.6	73.7	6.7	9.3	120.6		0.79
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c 24h		389	1.986	3.837	3.288	2.6	69.9	11.3	23.6	129.8		
T012-t012	3.0 c 24h		388	2.194	3.794	3.099	0.5	68.0	11.6	0.0	129.8		
T018-t018	3.0 c 24h		387	2.096	3.809	3.185	1.3	68.2	10.9	23.6	112.1		
T024-t024	3.0 c 24h		386	1.782	3.433	2.938	1.3	72.3	7.0	11.8	64.9		
T030-t030	3.0 c 24h		385	1.959	3.794	3.253	1.0	69.9	8.6	5.9	118.0		
T036-t036	3.0 c 24h		384	1.966	3.841	3.304	2.1	70.1	8.6	17.7	118.0		
T042-t042	3.0 c 24h		398	1.928	3.808	3.288	1.8	70.6	8.8	17.7	118.0		
T048-t048	3.0 c 24h		397	1.905	3.814	3.308	2.0	70.5	9.1	17.7	118.0		
T054-t054	3.0 c 24h		396	1.893	3.826	3.329	2.3	70.7	9.8	29.5	118.0		
T060-t060	3.0 c 24h		395	1.865	3.849	3.372	2.8	69.9	9.6	53.1	118.0		
T066-t066	3.0 c 24h		394	1.873	3.823	3.337	2.8	70.8	9.9	53.1	118.0		
T072-t072	3.0 c 24h		393	1.872	3.864	3.385	2.8	70.0	10.2	47.2	118.0		
T078-t078	3.0 c 24h		392	1.850	3.927	3.468	3.3	70.9	9.7	64.9	118.0		
T084-t084	3.0 c 24h		391	1.898	3.880	3.389	3.3	70.6	9.5	59.0	94.4		
T090-t090	3.0 c 24h		390	1.894	3.899	3.412	3.1	70.8	10.5	64.9	94.4		
T096-t096	3.0 c 24h		389	1.897	3.983	3.506	3.3	71.5	11.3	64.9	129.8		
T102-t102	3.0 c 24h		388	1.938	3.984	3.485	3.1	70.1	10.8	59.0	106.2		
T108-t108	3.0 c 24h		388	1.977	3.988	3.468	3.6	70.9	11.1	70.8	106.2		
T114-t114	3.0 c 24h		388	1.983	3.978	3.453	3.6	70.6	10.3	70.8	106.2		
T120-t120	3.0 c 24h		388	2.014	3.936	3.386	2.8	70.4	10.8	23.6	129.8		

Table D-14. Water surface temperature skill assessment at Michigan City

Station: Michigan City Buoy
Observed data time period from: / 6/17/2018 to /11/ 5/2018
Data gap is filled using 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			33045	20.947									
t			33045	19.913									
T-t	3.0 c 24h		33045	1.035	2.132	1.865	1.5	89.2	0.2	27.5	2.9		0.93
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c 24h		429	0.893	1.949	1.734	1.6	92.1	0.0	35.4	0.0		
T012-t012	3.0 c 24h		428	0.777	1.957	1.798	1.9	91.6	0.0	41.3	0.0		
T018-t018	3.0 c 24h		427	0.810	2.054	1.890	1.9	89.5	0.0	41.3	0.0		
T024-t024	3.0 c 24h		426	0.963	2.025	1.784	1.9	88.7	0.0	41.3	0.0		
T030-t030	3.0 c 24h		424	0.824	2.129	1.966	2.1	87.5	0.0	23.6	0.0		
T036-t036	3.0 c 24h		423	0.796	2.147	1.996	2.4	86.3	0.2	23.6	0.0		
T042-t042	3.0 c 24h		422	0.785	2.147	2.000	1.7	86.7	0.2	23.6	0.0		
T048-t048	3.0 c 24h		440	0.793	2.094	1.941	1.4	88.0	0.2	23.6	0.0		
T054-t054	3.0 c 24h		439	0.759	2.103	1.964	1.4	88.6	0.2	23.6	0.0		
T060-t060	3.0 c 24h		438	0.752	2.109	1.973	1.4	88.6	0.2	23.6	0.0		
T066-t066	3.0 c 24h		437	0.757	2.071	1.929	1.6	89.0	0.2	35.4	0.0		
T072-t072	3.0 c 24h		436	0.750	2.053	1.913	1.6	89.7	0.2	35.4	0.0		
T078-t078	3.0 c 24h		435	0.757	2.050	1.908	1.6	90.8	0.2	35.4	0.0		
T084-t084	3.0 c 24h		434	0.783	2.071	1.920	1.6	89.9	0.2	35.4	0.0		
T090-t090	3.0 c 24h		433	0.769	2.075	1.929	1.6	89.4	0.2	35.4	0.0		
T096-t096	3.0 c 24h		433	0.762	2.098	1.957	2.1	88.7	0.2	41.3	0.0		
T102-t102	3.0 c 24h		432	0.772	2.153	2.012	2.1	89.1	0.2	41.3	0.0		
T108-t108	3.0 c 24h		431	0.767	2.169	2.031	2.3	90.5	0.2	41.3	0.0		
T114-t114	3.0 c 24h		430	0.756	2.217	2.086	2.1	90.2	0.2	35.4	0.0		
T120-t120	3.0 c 24h		429	0.774	2.251	2.117	2.3	89.7	0.2	41.3	0.0		

Table D-15. Water surface temperature skill assessment at South Haven Buoy

Station: South Haven Buoy, MI
Observed data time period from: / 8/15/2018 to /10/25/2018
Data gap is filled using 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			29503	19.690									
t			29503	19.422									
T-t	3.0	c 24h	29503	0.268	2.417	2.402	2.4	81.6	0.1	50.0	3.9		0.91
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	376	0.666	2.561	2.476	2.7	85.1	0.5	47.2	0.0		
T012-t012	3.0	c 24h	384	0.594	2.521	2.453	3.4	82.3	0.8	59.0	0.0		
T018-t018	3.0	c 24h	370	0.526	2.815	2.769	3.5	77.0	1.1	59.0	5.9		
T024-t024	3.0	c 24h	369	0.418	2.845	2.818	4.3	78.9	0.8	82.6	0.0		
T030-t030	3.0	c 24h	368	0.080	2.967	2.970	4.9	79.1	0.5	88.5	0.0		
T036-t036	3.0	c 24h	367	0.019	3.030	3.034	5.4	80.4	1.1	88.5	5.9		
T042-t042	3.0	c 24h	381	0.062	3.074	3.077	5.0	80.3	1.3	82.6	5.9		
T048-t048	3.0	c 24h	380	0.069	3.142	3.145	5.3	80.3	1.8	82.6	11.8		
T054-t054	3.0	c 24h	379	0.082	3.272	3.275	6.9	79.9	2.1	82.6	11.8		
T060-t060	3.0	c 24h	378	0.092	3.319	3.322	6.6	79.6	1.6	94.4	11.8		
T066-t066	3.0	c 24h	377	0.162	3.263	3.263	5.3	81.7	1.3	70.8	0.0		
T072-t072	3.0	c 24h	376	0.240	3.263	3.259	5.1	81.4	1.3	64.9	5.9		
T078-t078	3.0	c 24h	375	0.319	3.274	3.263	5.1	79.5	1.3	70.8	0.0		
T084-t084	3.0	c 24h	374	0.372	3.234	3.216	5.3	78.6	0.8	59.0	5.9		
T090-t090	3.0	c 24h	373	0.376	3.270	3.253	5.4	78.8	1.6	82.6	5.9		
T096-t096	3.0	c 24h	372	0.441	3.195	3.168	4.8	79.8	1.3	47.2	0.0		
T102-t102	3.0	c 24h	372	0.508	3.246	3.210	5.4	79.6	1.3	59.0	0.0		
T108-t108	3.0	c 24h	372	0.524	3.251	3.213	5.6	78.2	0.5	88.5	0.0		
T114-t114	3.0	c 24h	373	0.547	3.198	3.155	5.1	76.4	1.6	59.0	5.9		
T120-t120	3.0	c 24h	374	0.568	3.201	3.154	5.1	77.3	0.8	41.3	5.9		

Table D-16. Water surface temperature skill assessment at Mackinac Strait West

Station: Mackinac Strait West
Observed data time period from: / 8/ 1/2018 to /10/15/2018
Data gap is filled using 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			31104	16.671									
t			31104	19.006									
T-t	3.0	c 24h	31104	-2.335	2.882	1.689	1.7	65.2	0.0	29.5	0.0		0.80
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	395	-2.685	3.186	1.717	3.0	60.5	0.0	29.5	0.0		
T012-t012	3.0	c 24h	395	-2.748	3.223	1.686	3.5	56.5	0.0	23.6	0.0		
T018-t018	3.0	c 24h	394	-2.771	3.221	1.644	3.0	55.6	0.0	23.6	0.0		
T024-t024	3.0	c 24h	393	-2.822	3.246	1.606	3.3	56.5	0.0	23.6	0.0		
T030-t030	3.0	c 24h	392	-2.648	3.021	1.456	2.0	59.7	0.0	23.6	0.0		
T036-t036	3.0	c 24h	397	-2.771	3.119	1.434	2.3	57.7	0.0	23.6	0.0		
T042-t042	3.0	c 24h	410	-2.734	3.094	1.450	2.2	58.3	0.0	23.6	0.0		
T048-t048	3.0	c 24h	409	-2.736	3.108	1.477	1.7	57.9	0.0	11.8	0.0		
T054-t054	3.0	c 24h	408	-2.736	3.113	1.486	2.2	59.1	0.0	23.6	0.0		
T060-t060	3.0	c 24h	407	-2.756	3.129	1.484	2.2	58.5	0.0	23.6	0.0		
T066-t066	3.0	c 24h	406	-2.763	3.138	1.489	2.2	58.9	0.0	23.6	0.0		
T072-t072	3.0	c 24h	405	-2.804	3.191	1.524	2.5	56.8	0.0	23.6	0.0		
T078-t078	3.0	c 24h	403	-2.832	3.213	1.519	2.2	57.6	0.0	23.6	0.0		
T084-t084	3.0	c 24h	402	-2.853	3.242	1.542	2.0	55.2	0.2	11.8	0.0		
T090-t090	3.0	c 24h	401	-2.871	3.256	1.538	2.7	53.6	0.0	23.6	0.0		
T096-t096	3.0	c 24h	400	-2.828	3.222	1.546	2.5	57.0	0.0	23.6	0.0		
T102-t102	3.0	c 24h	399	-2.855	3.273	1.601	3.0	54.9	0.0	23.6	0.0		
T108-t108	3.0	c 24h	398	-2.842	3.278	1.634	3.5	58.5	0.0	29.5	0.0		
T114-t114	3.0	c 24h	397	-2.845	3.288	1.650	3.5	57.2	0.3	29.5	0.0		
T120-t120	3.0	c 24h	396	-2.793	3.234	1.631	3.3	57.6	0.3	29.5	0.0		

Table D-17. Water surface temperature skill assessment at North Huron

Station: North Huron
Observed data time period from: / 7/ 3/2018 to /11/ 7/2018
Data gap is filled using 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			35672	16.893									
t			35672	14.204									
T-t	3.0	c 24h	35672	2.690	3.594	2.384	0.0	76.3	10.1	0.0	245.1		0.89
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	472	2.205	3.055	2.118	0.0	85.0	6.4	0.0	88.5		
T012-t012	3.0	c 24h	471	2.335	3.172	2.149	0.0	79.6	6.6	0.0	88.5		
T018-t018	3.0	c 24h	470	2.379	3.179	2.112	0.0	80.4	6.4	0.0	88.5		
T024-t024	3.0	c 24h	469	2.444	3.191	2.053	0.0	81.0	6.2	0.0	88.5		
T030-t030	3.0	c 24h	468	2.333	3.123	2.078	0.0	81.0	6.0	0.0	88.5		
T036-t036	3.0	c 24h	467	2.369	3.144	2.069	0.0	80.1	5.8	0.0	88.5		
T042-t042	3.0	c 24h	467	2.356	3.133	2.067	0.0	80.9	5.6	0.0	88.5		
T048-t048	3.0	c 24h	479	2.338	3.106	2.046	0.0	82.5	5.4	0.0	88.5		
T054-t054	3.0	c 24h	484	2.292	3.065	2.038	0.0	82.9	5.4	0.0	88.5		
T060-t060	3.0	c 24h	483	2.265	3.037	2.025	0.0	83.9	5.4	0.0	88.5		
T066-t066	3.0	c 24h	481	2.231	3.013	2.028	0.0	85.2	5.2	0.0	88.5		
T072-t072	3.0	c 24h	480	2.208	2.997	2.028	0.0	85.2	5.2	0.0	88.5		
T078-t078	3.0	c 24h	479	2.193	2.993	2.038	0.0	86.2	5.2	0.0	88.5		
T084-t084	3.0	c 24h	478	2.161	2.951	2.012	0.0	87.2	5.2	0.0	88.5		
T090-t090	3.0	c 24h	477	2.156	2.941	2.002	0.0	86.6	5.2	0.0	88.5		
T096-t096	3.0	c 24h	476	2.125	2.915	1.998	0.0	88.0	5.3	0.0	88.5		
T102-t102	3.0	c 24h	475	2.093	2.883	1.986	0.0	88.0	5.1	0.0	88.5		
T108-t108	3.0	c 24h	474	2.096	2.884	1.982	0.0	88.0	5.3	0.0	88.5		
T114-t114	3.0	c 24h	473	2.074	2.870	1.985	0.0	87.7	5.5	0.0	88.5		
T120-t120	3.0	c 24h	472	2.076	2.875	1.991	0.0	87.5	5.7	0.0	88.5		

Table D-18. Water surface temperature skill assessment at Thunder Bay Buoy

Station: Thunder Bay Buoy,MI
Observed data time period from: / 6/17/2018 to / 9/17/2018
Data gap is filled using 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			21403	18.392									
t			21403	18.526									
T-t	3.0	c 24h	21403	-0.134	2.246	2.242	0.4	86.5	3.1	4.2	10.2		0.84
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0	c 24h	243	-0.160	2.349	2.349	0.8	84.0	3.7	5.9	11.8		
T012-t012	3.0	c 24h	242	-0.015	2.547	2.552	0.4	85.1	5.0	0.0	11.8		
T018-t018	3.0	c 24h	241	0.147	2.335	2.335	0.4	85.9	4.6	0.0	11.8		
T024-t024	3.0	c 24h	240	0.004	2.278	2.283	0.0	86.7	3.3	0.0	11.8		
T030-t030	3.0	c 24h	258	-0.179	2.191	2.188	0.4	87.2	2.3	0.0	5.9		
T036-t036	3.0	c 24h	257	-0.180	2.172	2.168	0.8	87.2	3.1	0.0	5.9		
T042-t042	3.0	c 24h	256	-0.163	2.146	2.144	0.4	88.3	2.7	0.0	5.9		
T048-t048	3.0	c 24h	255	-0.186	2.094	2.090	0.0	86.7	2.4	0.0	5.9		
T054-t054	3.0	c 24h	254	-0.150	2.026	2.024	0.0	88.2	1.6	0.0	0.0		
T060-t060	3.0	c 24h	253	-0.113	1.919	1.919	0.0	88.9	1.6	0.0	0.0		
T066-t066	3.0	c 24h	252	-0.173	1.923	1.919	0.0	88.5	1.2	0.0	0.0		
T072-t072	3.0	c 24h	251	-0.206	1.911	1.904	0.0	90.8	1.2	0.0	0.0		
T078-t078	3.0	c 24h	250	-0.188	1.900	1.895	0.4	91.2	1.2	0.0	0.0		
T084-t084	3.0	c 24h	249	-0.158	2.001	1.999	0.4	89.6	1.6	0.0	0.0		
T090-t090	3.0	c 24h	248	-0.083	1.994	1.997	0.0	86.7	2.0	0.0	5.9		
T096-t096	3.0	c 24h	247	-0.016	2.042	2.046	0.0	89.5	2.8	0.0	5.9		
T102-t102	3.0	c 24h	246	0.002	2.070	2.075	0.0	89.4	2.4	0.0	5.9		
T108-t108	3.0	c 24h	245	-0.009	2.168	2.172	0.4	86.5	2.0	0.0	5.9		
T114-t114	3.0	c 24h	244	0.004	2.116	2.121	0.0	88.1	2.0	0.0	5.9		
T120-t120	3.0	c 24h	243	0.095	2.219	2.222	0.4	86.8	2.5	0.0	5.9		

Table D-19. Water surface temperature skill assessment at Saginaw Bay Buoy

Station: Saginaw Bay Buoy, MI
Observed data time period from: / 6/17/2018 to / 6/17/2018
Data gap is filled using 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			10427	21.962									
t			10427	22.904									
T-t	3.0 c 24h		10427	-0.942	1.690	1.403	0.0	89.6	0.0	0.0	0.0		0.77
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c 24h		120	-0.946	1.643	1.349	0.0	92.5	0.0	0.0	0.0		
T012-t012	3.0 c 24h		120	-0.863	1.683	1.451	0.0	93.3	0.0	0.0	0.0		
T018-t018	3.0 c 24h		120	-0.751	1.586	1.403	0.0	93.3	0.0	0.0	0.0		
T024-t024	3.0 c 24h		119	-0.899	1.546	1.263	0.0	93.3	0.0	0.0	0.0		
T030-t030	3.0 c 24h		127	-0.761	1.491	1.288	0.0	96.1	0.0	0.0	0.0		
T036-t036	3.0 c 24h		127	-0.746	1.444	1.241	0.0	96.9	0.0	0.0	0.0		
T042-t042	3.0 c 24h		127	-0.776	1.497	1.286	0.0	95.3	0.0	0.0	0.0		
T048-t048	3.0 c 24h		126	-0.833	1.526	1.284	0.0	96.0	0.0	0.0	0.0		
T054-t054	3.0 c 24h		125	-0.808	1.498	1.267	0.0	92.8	0.0	0.0	0.0		
T060-t060	3.0 c 24h		125	-0.747	1.608	1.430	0.0	93.6	0.0	0.0	0.0		
T066-t066	3.0 c 24h		125	-0.766	1.656	1.474	0.0	91.2	0.0	0.0	0.0		
T072-t072	3.0 c 24h		124	-0.819	1.527	1.294	0.0	94.4	0.0	0.0	0.0		
T078-t078	3.0 c 24h		123	-0.769	1.509	1.304	0.0	95.1	0.0	0.0	0.0		
T084-t084	3.0 c 24h		123	-0.737	1.652	1.485	0.0	91.9	0.8	0.0	0.0		
T090-t090	3.0 c 24h		123	-0.826	1.687	1.477	0.0	90.2	0.0	0.0	0.0		
T096-t096	3.0 c 24h		122	-0.883	1.636	1.383	0.0	91.0	0.0	0.0	0.0		
T102-t102	3.0 c 24h		121	-0.909	1.776	1.532	0.8	88.4	0.0	0.0	0.0		
T108-t108	3.0 c 24h		121	-0.824	1.873	1.689	0.0	88.4	0.8	0.0	0.0		
T114-t114	3.0 c 24h		121	-0.834	1.859	1.668	0.0	88.4	0.8	0.0	0.0		
T120-t120	3.0 c 24h		120	-0.912	1.810	1.570	0.0	88.3	0.0	0.0	0.0		

Table D-20. Water surface temperature skill assessment at South Huron

Station: South Huron
Observed data time period from: / 7/ 8/2018 to / 9/13/2018
Data gap is filled using 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			35572	18.195									
t			35572	15.968									
T-t	3.0 c 24h		35572	2.227	2.538	1.217	0.0	81.7	1.1	0.0	32.2		0.94
SCENARIO: SEMI-OPERATIONAL FORECAST													
T006-t006	3.0 c 24h		470	1.984	2.318	1.201	0.0	86.2	0.9	0.0	0.0		
T012-t012	3.0 c 24h		469	2.025	2.348	1.190	0.0	84.2	0.9	0.0	0.0		
T018-t018	3.0 c 24h		468	2.036	2.335	1.144	0.0	84.4	0.6	0.0	0.0		
T024-t024	3.0 c 24h		469	2.020	2.310	1.122	0.0	85.9	0.6	0.0	0.0		
T030-t030	3.0 c 24h		468	2.015	2.295	1.099	0.0	84.8	0.2	0.0	0.0		
T036-t036	3.0 c 24h		467	2.023	2.303	1.101	0.0	85.7	0.4	0.0	5.9		
T042-t042	3.0 c 24h		464	2.083	2.343	1.073	0.0	85.6	0.9	0.0	17.7		
T048-t048	3.0 c 24h		477	2.046	2.320	1.094	0.0	86.8	1.3	0.0	23.6		
T054-t054	3.0 c 24h		481	2.018	2.315	1.135	0.0	87.1	1.2	0.0	23.6		
T060-t060	3.0 c 24h		480	2.003	2.311	1.154	0.0	88.5	1.7	0.0	35.4		
T066-t066	3.0 c 24h		479	1.992	2.319	1.188	0.0	87.7	1.7	0.0	35.4		
T072-t072	3.0 c 24h		478	1.977	2.316	1.208	0.0	88.9	1.9	0.0	41.3		
T078-t078	3.0 c 24h		478	1.954	2.302	1.219	0.0	89.1	2.1	0.0	41.3		
T084-t084	3.0 c 24h		477	1.957	2.310	1.229	0.0	89.7	2.1	0.0	47.2		
T090-t090	3.0 c 24h		476	1.953	2.289	1.195	0.0	89.9	2.1	0.0	47.2		
T096-t096	3.0 c 24h		475	1.943	2.304	1.239	0.0	90.3	2.5	0.0	53.1		
T102-t102	3.0 c 24h		473	1.970	2.347	1.278	0.0	88.8	2.5	0.0	47.2		
T108-t108	3.0 c 24h		473	1.976	2.368	1.306	0.0	89.4	2.5	0.0	53.1		
T114-t114	3.0 c 24h		472	1.957	2.360	1.320	0.0	89.4	2.8	0.0	59.0		
T120-t120	3.0 c 24h		471	1.965	2.378	1.340	0.0	89.0	2.5	0.0	59.0		

APPENDIX E. TIME SERIES OF MODELED SURFACE WATER TEMPERATURE VERSUS OBSERVATIONS

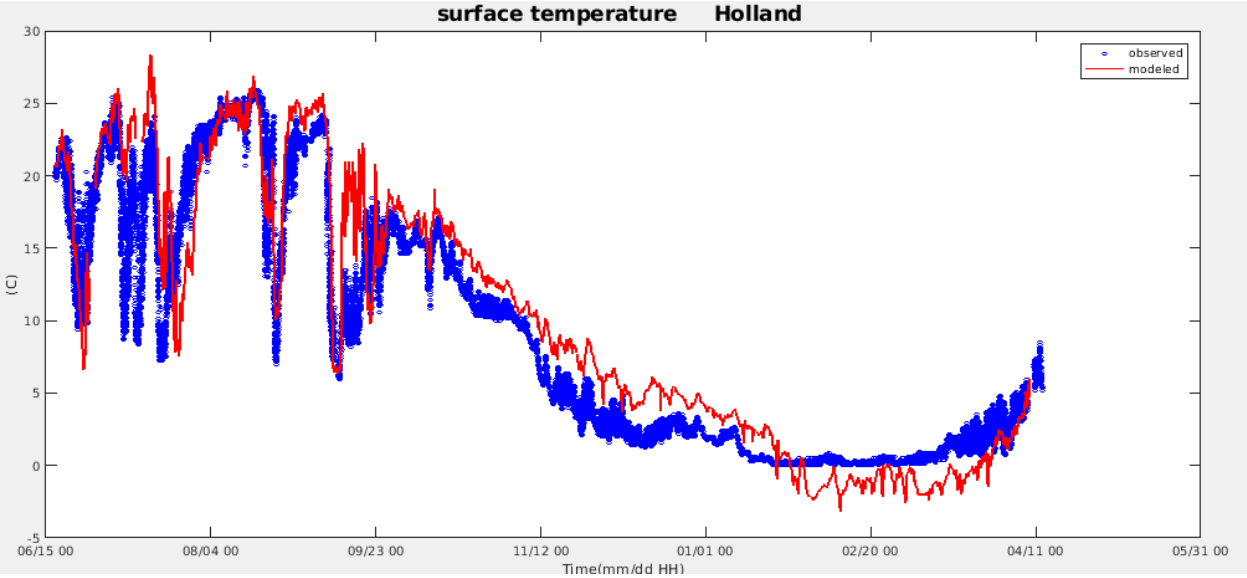

Figure E-1. Modeled (red) versus observed (blue) surface water temperature at Holland

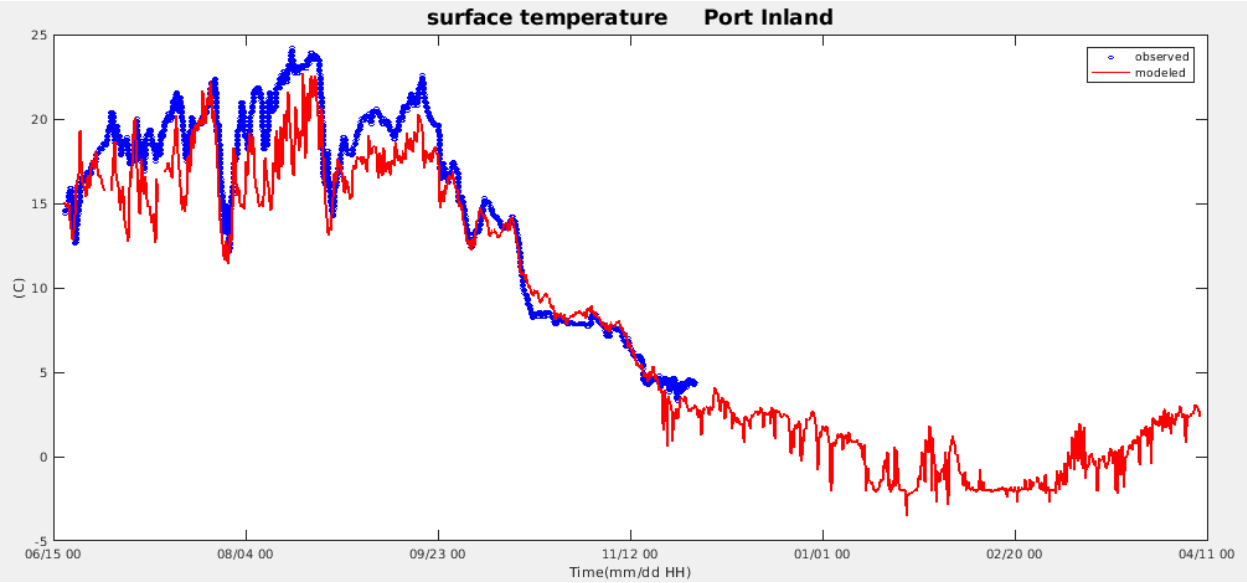

Figure E-2. Modeled (red) versus observed (blue) surface water temperature at Port Inland. Note there was no water temperature observation in the winter season.

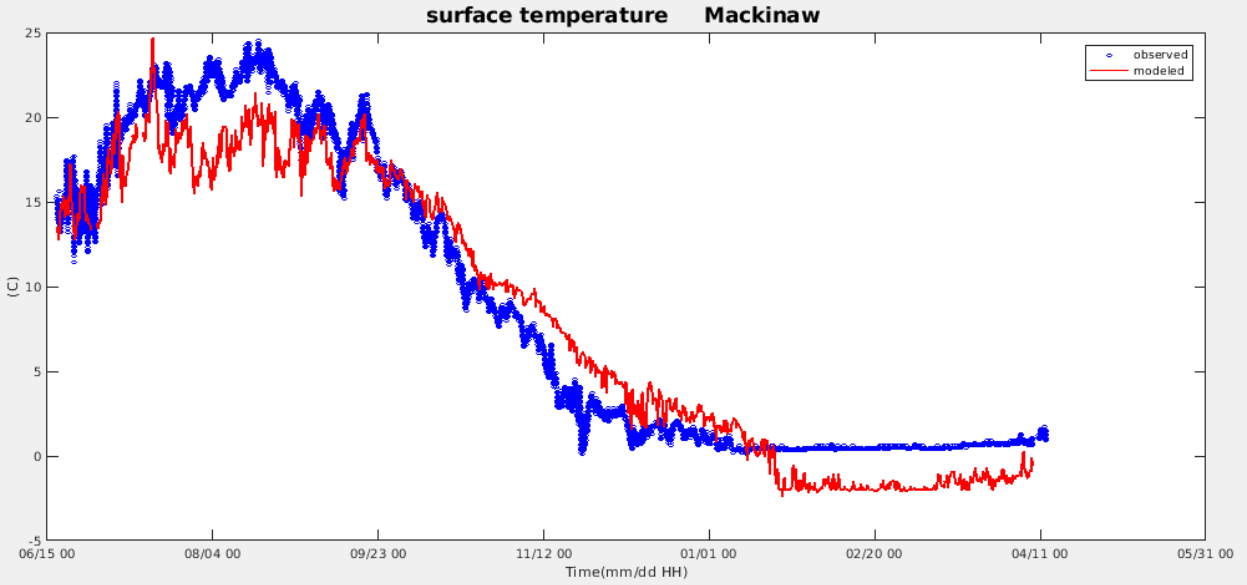

Figure E-3. Modeled (red) versus observed (blue) surface water temperature at Mackinaw

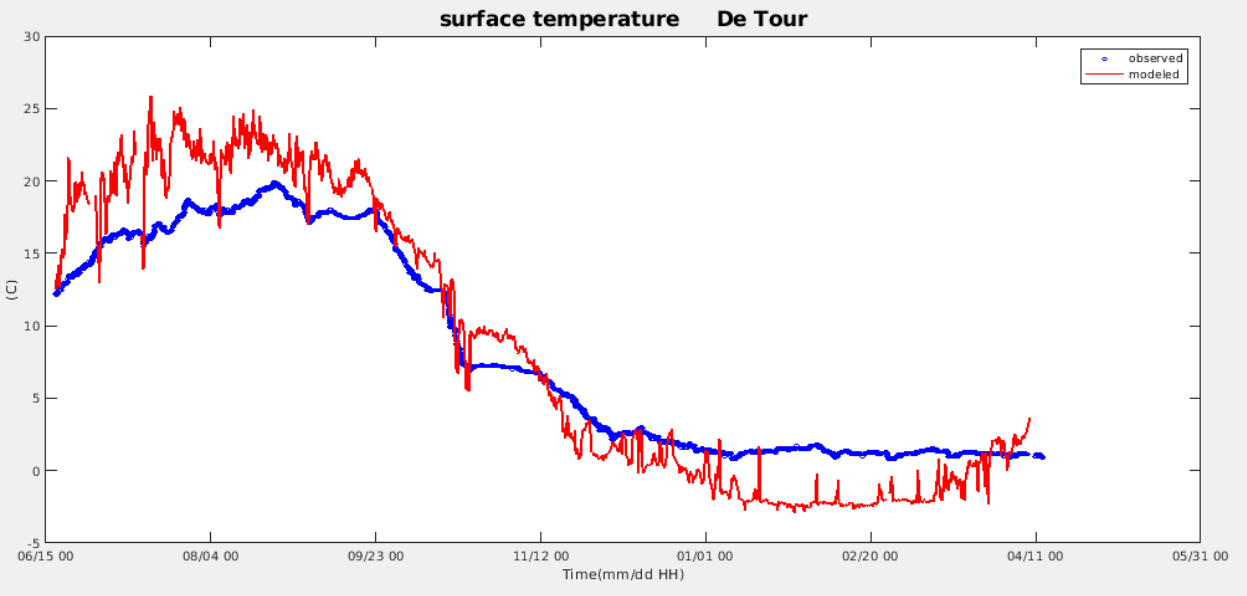

Figure E-4. Modeled (red) versus observed (blue) surface water temperature at De Tour Village

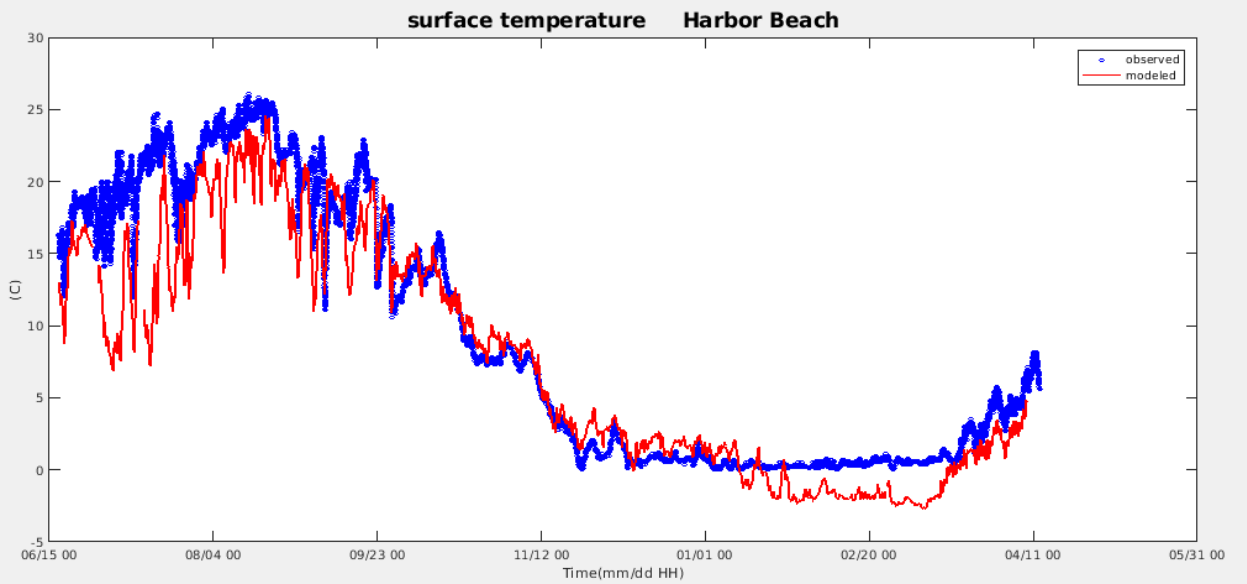

Figure E-5. Modeled (red) versus observed (blue) surface water temperature at Harbor Beach

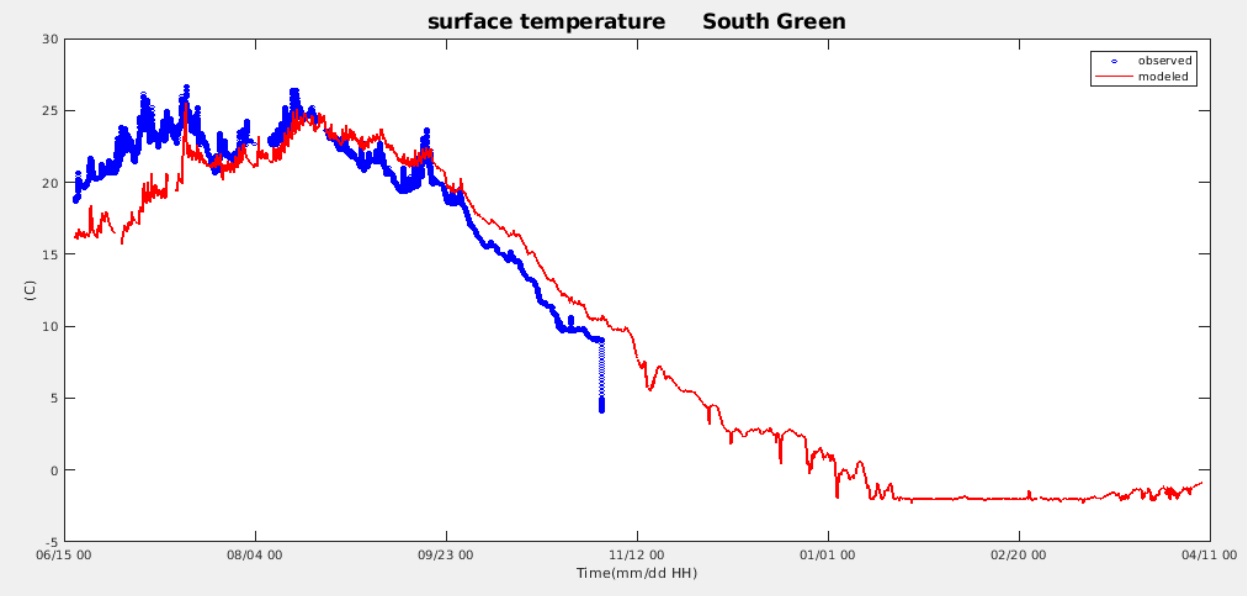

Figure E-6. Modeled (red) versus observed (blue) surface water temperature at South Green. Note there was no water temperature observation in the winter season.

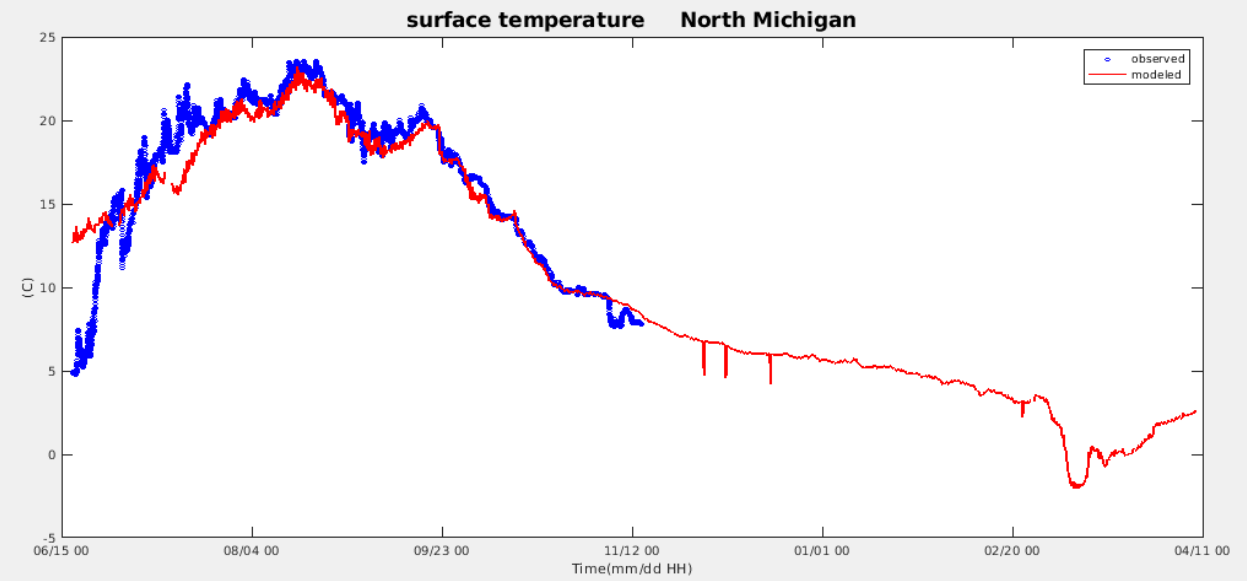

Figure E-7. Modeled (red) versus observed (blue) surface water temperature at North Michigan. Note there was no water temperature observation in the winter season.

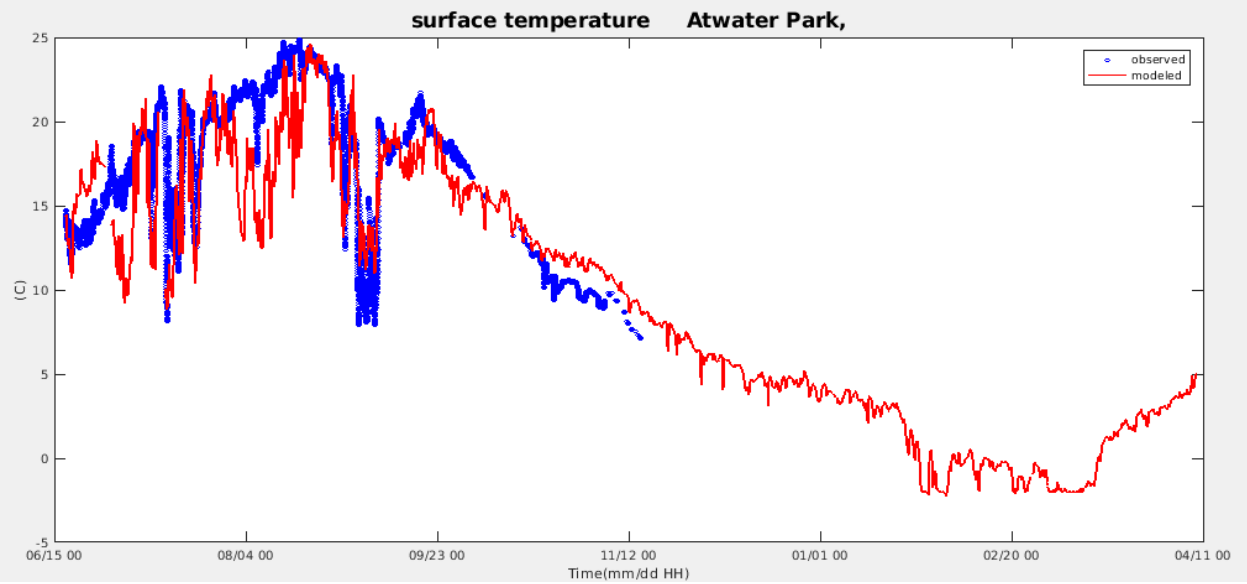

Figure E-8. Modeled (red) versus observed (blue) surface water temperature at Atwater Park. Note there was no water temperature observation in the winter season.

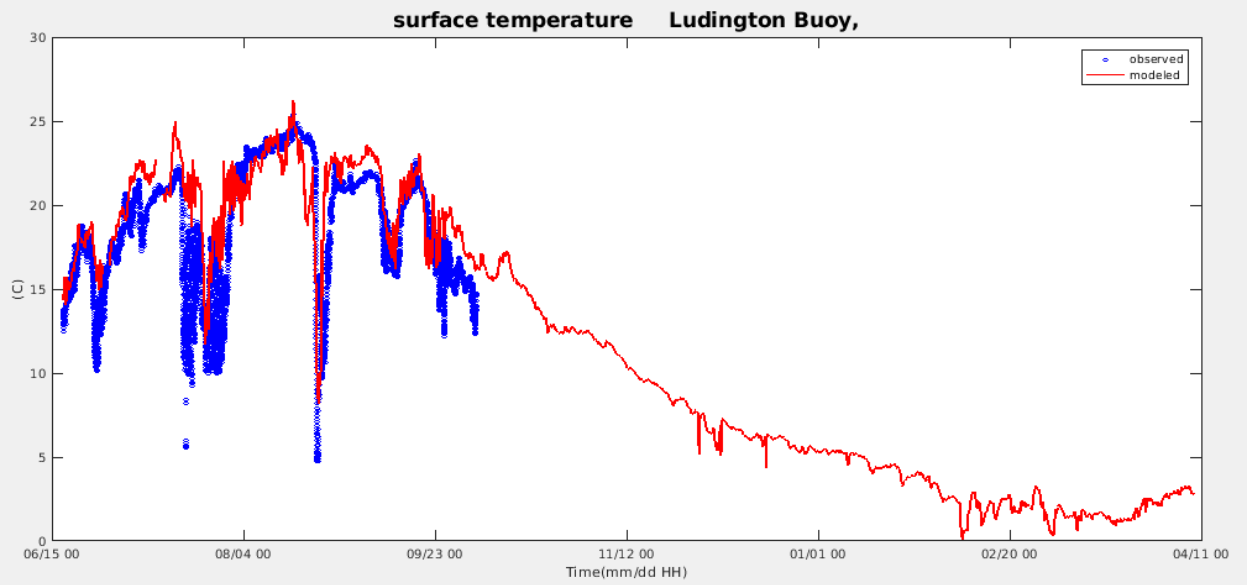

Figure E-9. Modeled (red) versus observed (blue) surface water temperature at Ludington Buoy. Note there was no water temperature observation in the winter season.

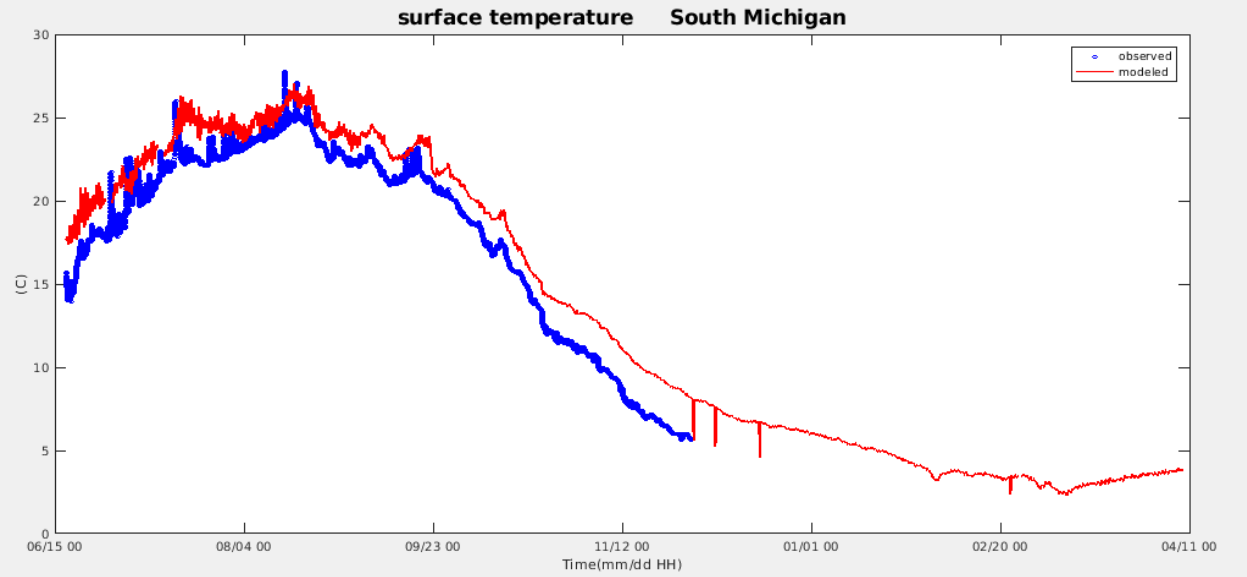

Figure E-10. Modeled (red) versus observed (blue) surface water temperature at South Michigan. Note there was no water temperature observation in the winter season.

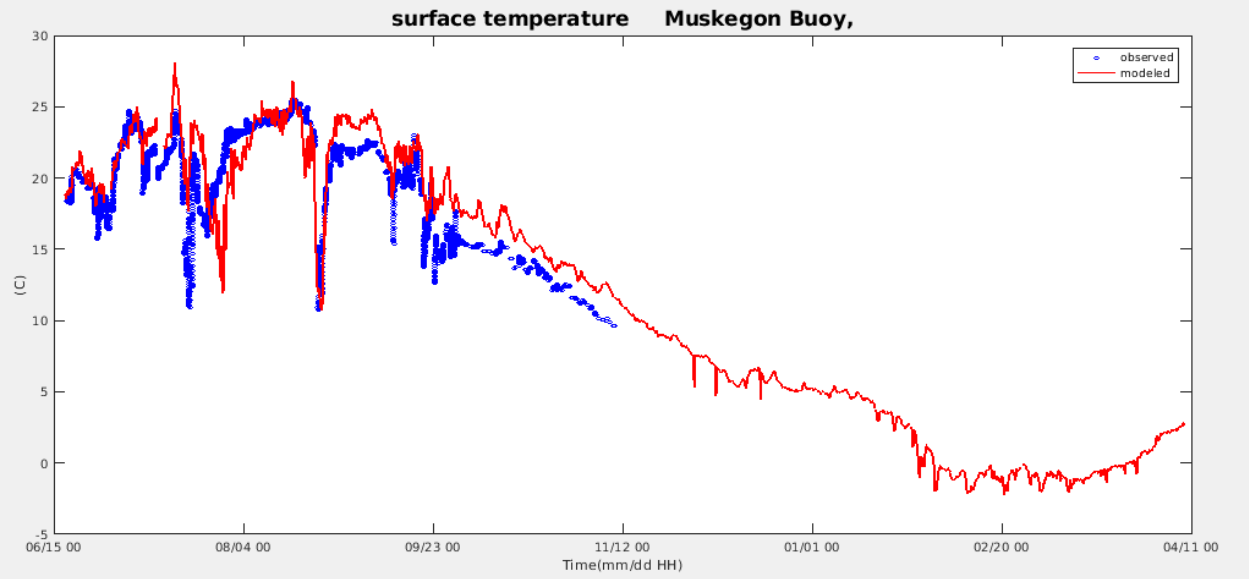

Figure E-11. Modeled (red) versus observed (blue) surface water temperature at Muskegon Buoy. Note there was no water temperature observation in the winter season.

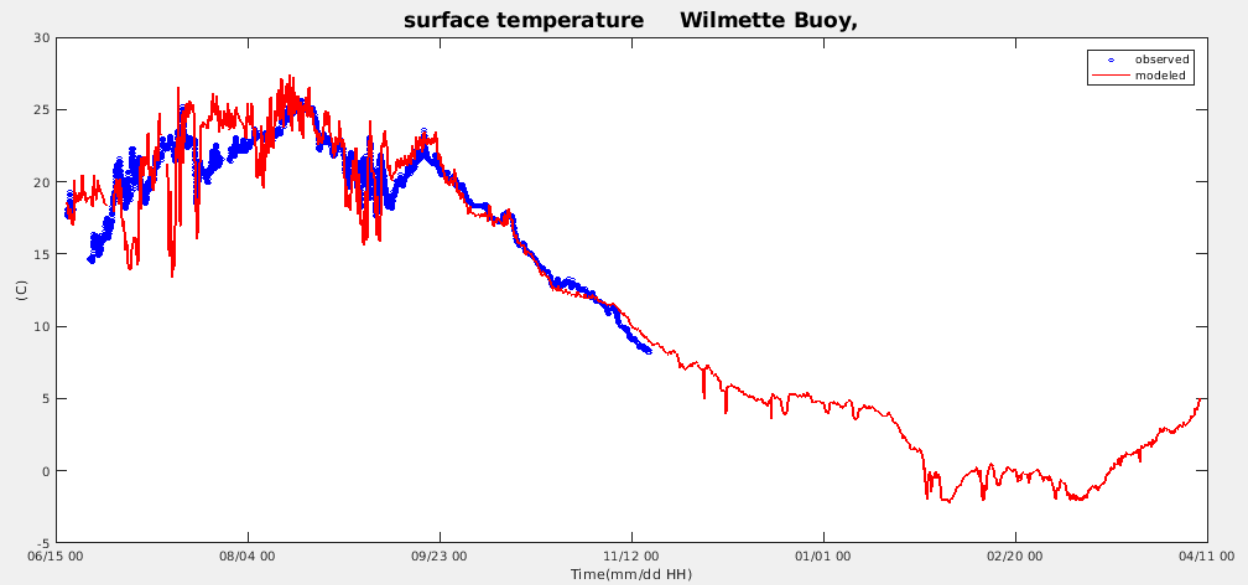

Figure E-12. Modeled (red) versus observed (blue) surface water temperature at Wilmette Buoy. Note there was no water temperature observation in the winter season.

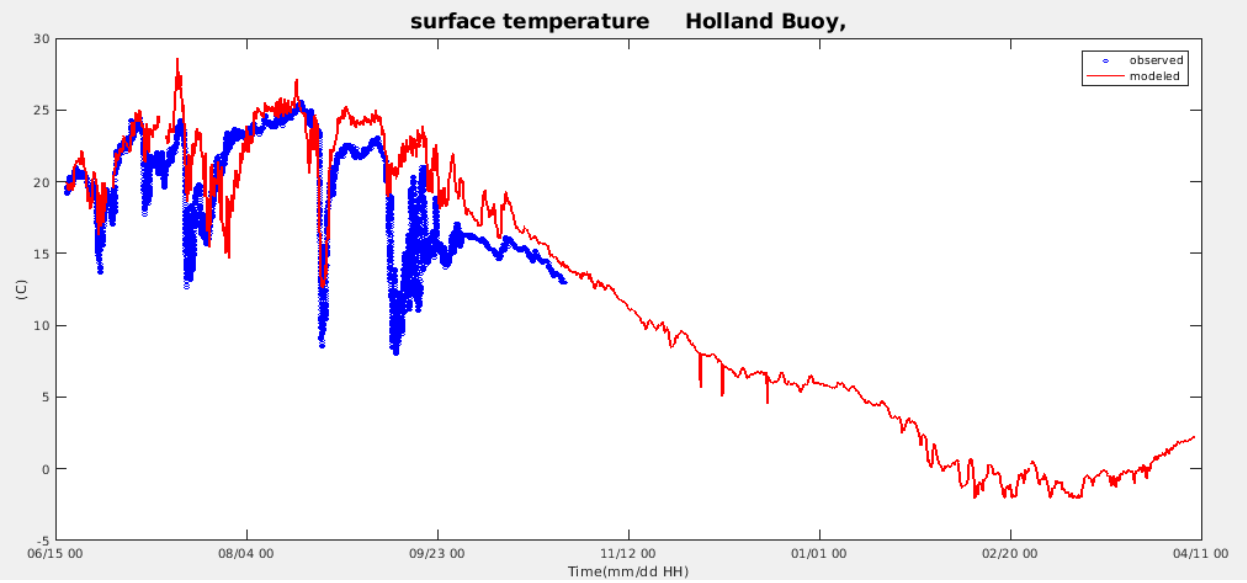

Figure E-13. Modeled (red) versus observed (blue) surface water temperature at Holland Buoy. Note there was no water temperature observation in the winter season.

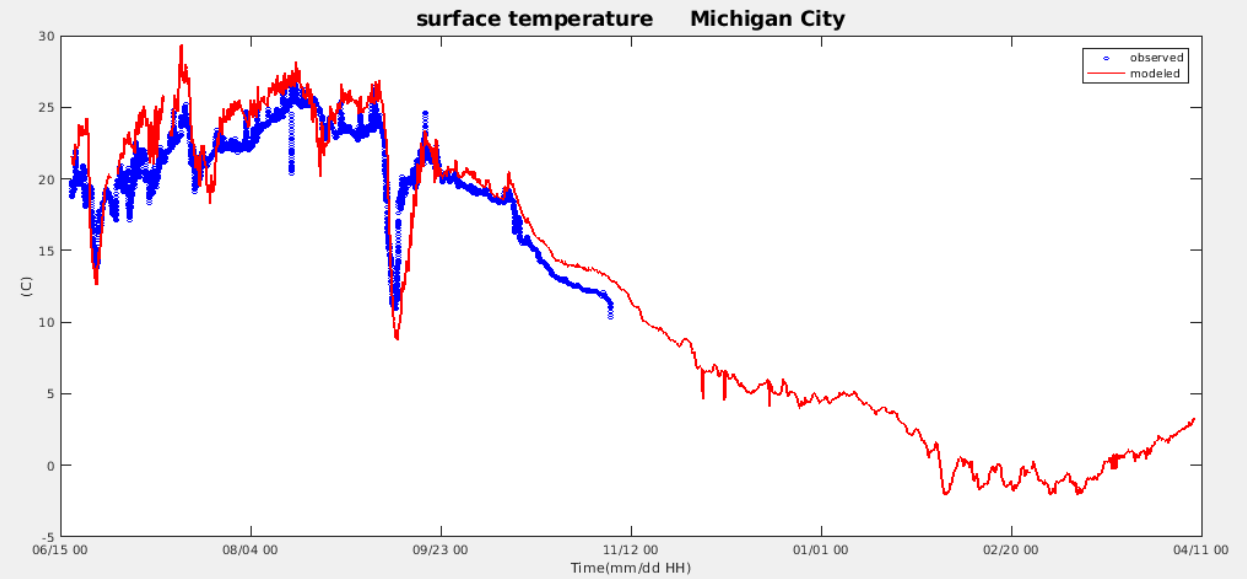

Figure E-14. Modeled (red) versus observed (blue) surface water temperature at Michigan City. Note there was no water temperature observation in the winter season.

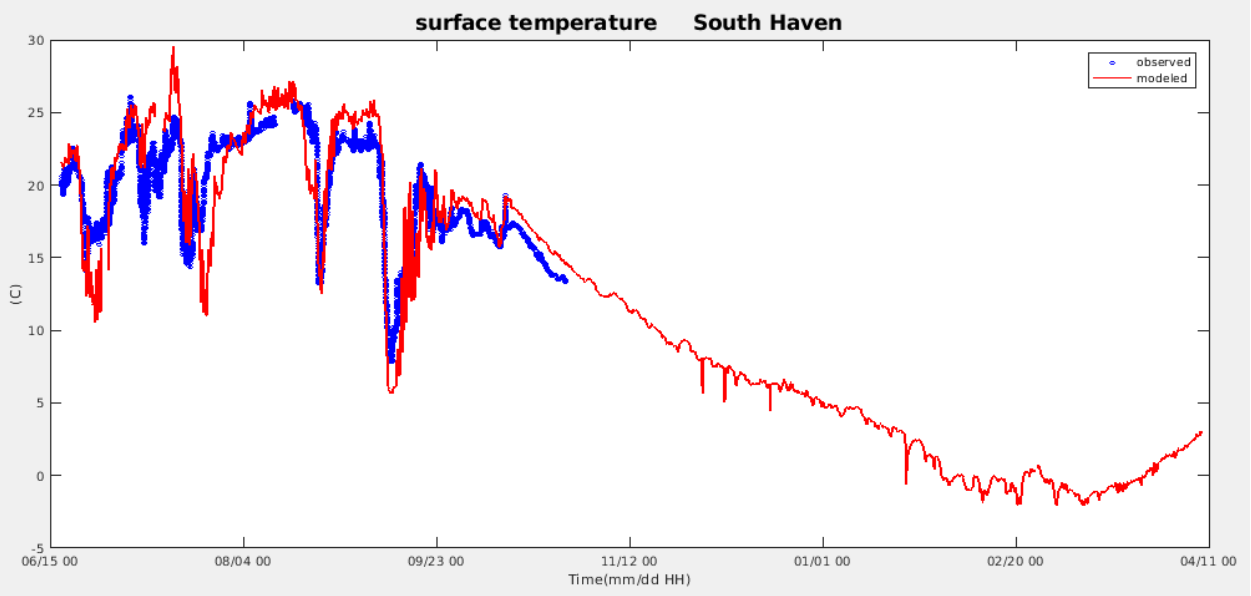

Figure E-15. Modeled (red) versus observed (blue) surface water temperature at South Haven. Note there was no water temperature observation in the winter season.

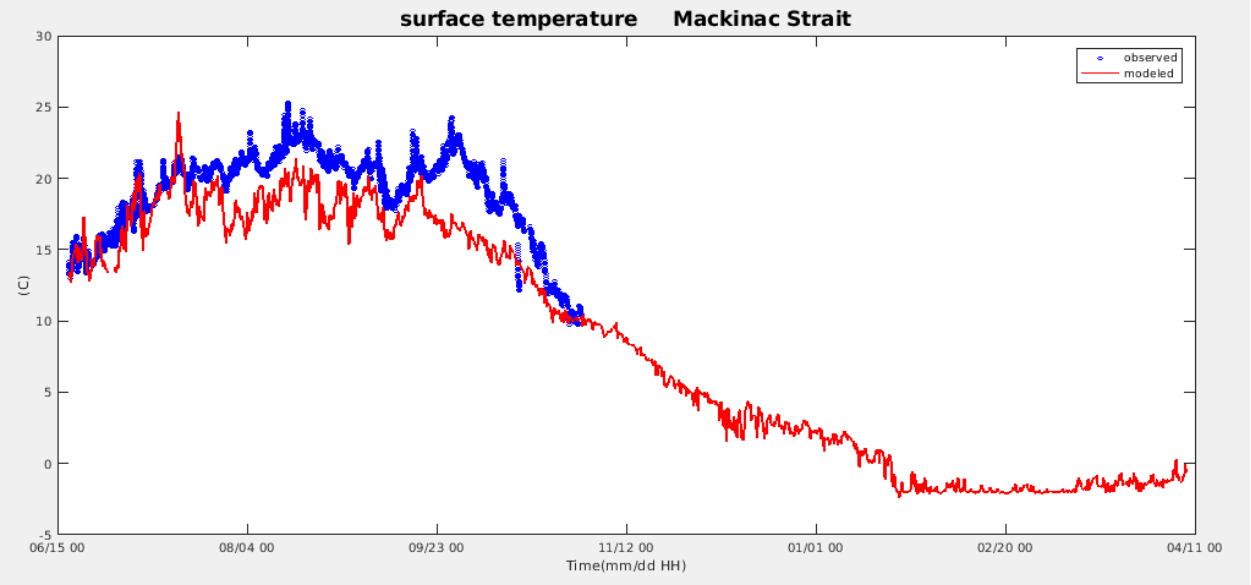

Figure E-16. Modeled (red) versus observed (blue) surface water temperature at Mackinac Strait. Note there was no water temperature observation in the winter season.

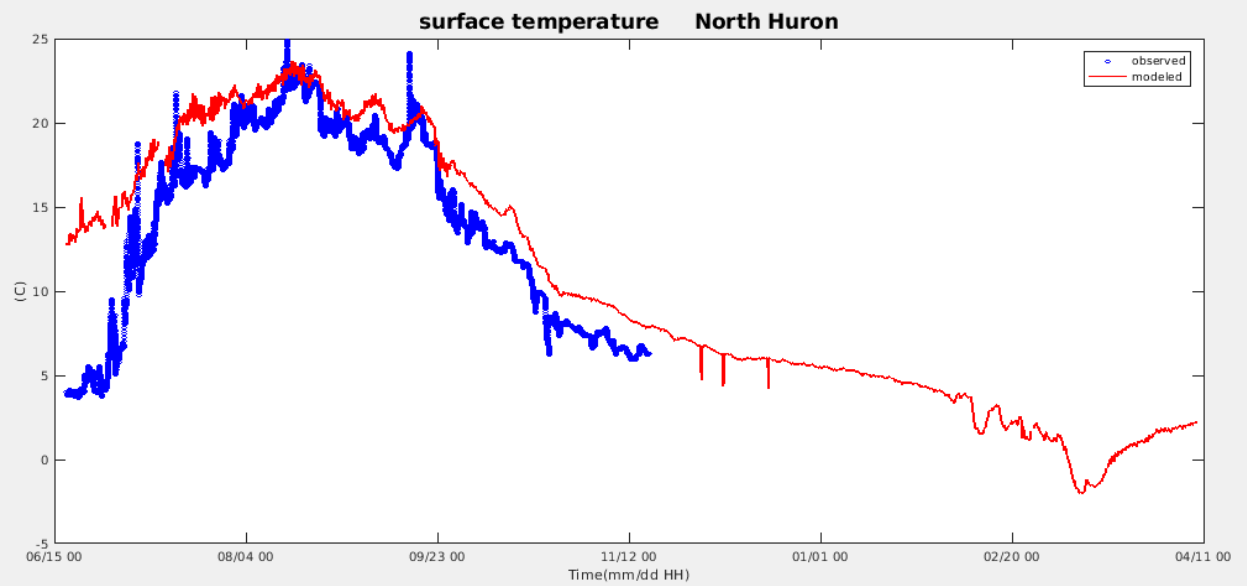

Figure E-17. Modeled (red) versus observed (blue) surface water temperature at North Huron. Note there was no water temperature observation in the winter season.

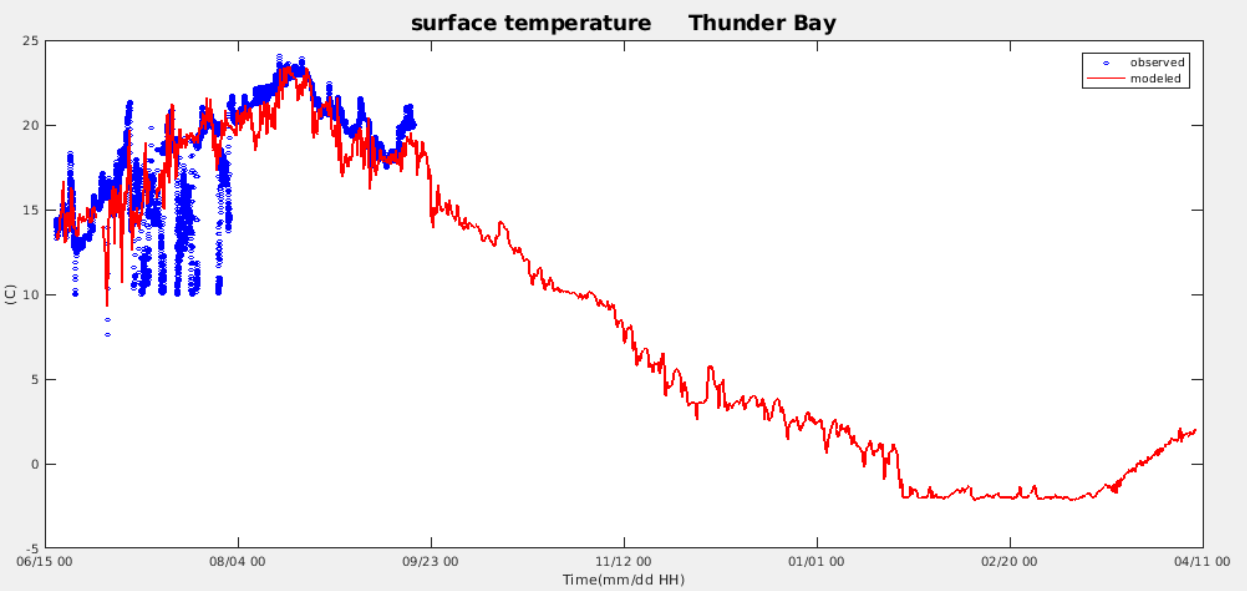

Figure E-18. Modeled (red) versus observed (blue) surface water temperature at Thunder Bay. Note there was no water temperature observation in the winter season.

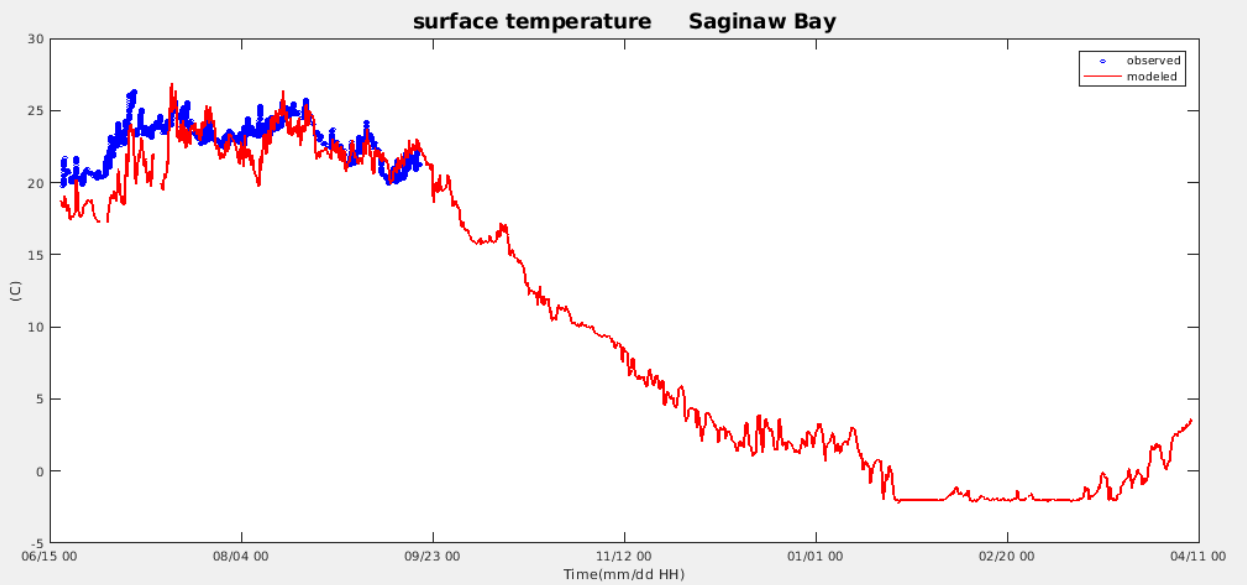

Figure E-19. Modeled (red) versus observed (blue) surface water temperature at Saginaw Bay. Note there was no water temperature observation in the winter season.

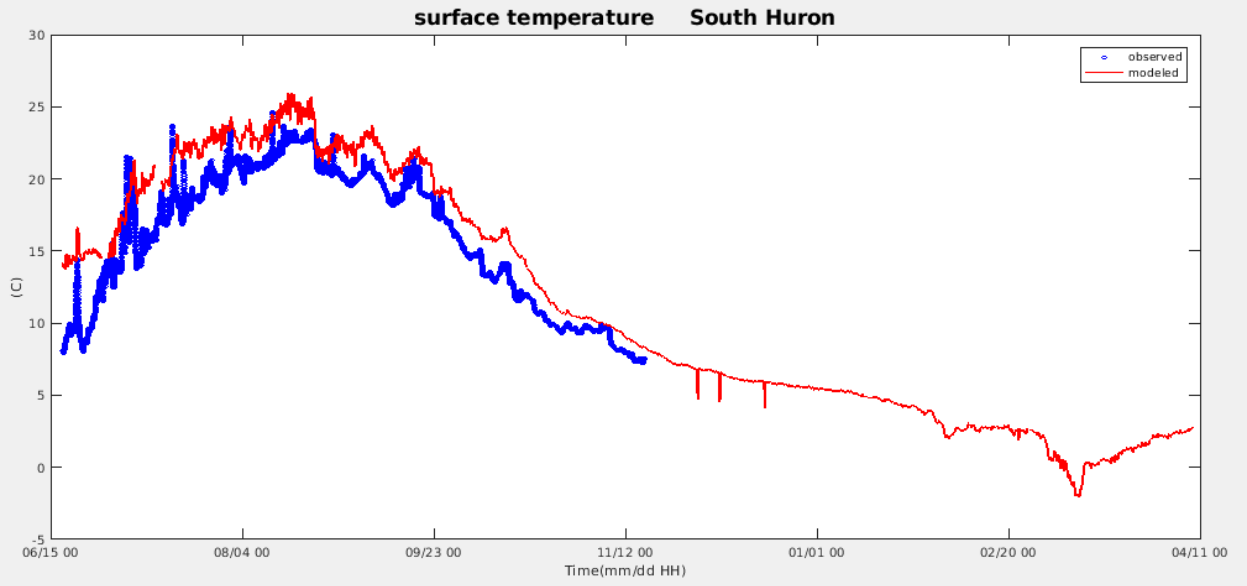

Figure E-20. Modeled (red) versus observed (blue) surface water temperature at South Huron. Note there was no water temperature observation in the winter season.

ACRONYMS

CF	central frequency
COMF	Coastal Ocean Modeling Framework
CO-OPS	Center for Operational Oceanographic Products and Services
COARE	Coupled Ocean Atmosphere Response Experiment
FVCOM	Finite Volume Community Ocean Model
GFS	Global Forecast System
GLERL	Great Lakes Environmental Research Laboratory
h	hour
HPC	High Performance Computing
HRRR	High Resolution Rapid Refresh
LHOFS	Lake Huron Operational Forecast System
LMHOFS	Lakes Michigan and Huron Operational Forecast System
LMOFS	Lake Michigan Operational Forecast System
m/s	meters per second
m	meters
MDPO	maximum duration of positive outliers
MDNO	maximum duration of negative outliers
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
NWS	National Weather Service
POF	positive outlier frequency
POM	Princeton Ocean Model
POMGL	Great Lakes version of the Princeton Ocean Model
RMSE	root mean square error
SM	series mean
USGS	U.S. Geological Survey
WCOSS	Weather and Climate Operational Supercomputing System