Long Island Sound ROMS Hydrodynamic Model Preliminary Calibration

New York City Department of Environmental Protection

DEP LIS-HWQMS Project

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PREFACE

Through a cooperative agreement, the New York City Department of Environmental Protection (DEP) and the U.S. Environmental Protection Agency (EPA) have been funding the development of a hydrodynamic and water quality model, and a Graphical User Interface/Decision Support Tool (GUI/DST) for Long Island Sound. The effort is intended to build upon, update, and improve earlier modeling efforts used for water management and Clean Water Act compliance efforts required under the 2000 LIS Total Maximum Daily Load and help guide future watershed management, planning, compliance and assessment activities using recent water quality and environmental data and the best available science. The models will also support development of management strategies at system-wide (New York Bight, New York Harbor, and LIS) and regional (e.g., LIS or New York Harbor) spatial scales.

This report, "Long Island Sound ROMS Hydrodynamic Model Preliminary Calibration," is a project deliverable that reports on an initial effort to calibrate the ROMS hydrodynamic model. Data for calendar years (CY) 2005-2006 was used to perform preliminary calibration because CY2005-2006 is a data rich time-period. The objective of the preliminary calibration report is to present a model calibration approach that can be reviewed, approved, and applied to the full model calibration time-period (i.e., CY2005-2014).

What makes this document worth reading is that it provides information about the status of the LIS hydrodynamic model calibration work. This document has been thoroughly reviewed by a peer review group referred to as the Model Evaluation Group (MEG) and staff from the U.S. Geological Survey, EPA, and DEP. Early revisions to this report addressed many reviewer comments but not all reviewer comments have been addressed in the final version of this report. In some cases, DEP has accepted responses to reviewer comments even though the reviewer comment is not addressed in this report. For example, one reviewer recommended changing the minimum water depth from 5 meters to 1 meter. In response, the Consultant, HDR, changed the minimum depth to 2.5 meters. Although this change has been implemented, it is not noted in this report. In other cases, DEP has accepted responses that effectively say "this issue will be addressed in the full model calibration report." For example, reviewers commented that the y-axis scales should be adjusted for several figures. In response, the consultant agreed to address this in the full calibration report.

Attachment 6 presents a collection of submitted reviewer comments and Consultant responses to reviewer comments. Moreover, a watermark with the word "Partial" has been added to the pages of this report to reflect the state of this report. This information is presented to provide context for reading this report.

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1 Introduction

The New York City Department of Environmental Protection (DEP) and United States Environmental Protection Agency (EPA) are funding the development of a coupled hydrodynamic/water quality model of Long Island Sound (LIS) to replace the existing System-wide Eutrophication Model (SWEM). SWEM used a combination of the Estuarine Coastal and Ocean Model (ECOM) and the Row-Column Advanced Ecological System Modeling Program (RCA). The current project is using the Regional Ocean Modeling System (ROMS) hydrodynamic model coupled with the RCA water quality model for the updated LIS model (HDR, 2021). A Quality Assurance Project Plan (QAPP) was developed for the project and is being used to guide model development (HDR, 2022).

Development of the hydrodynamic component of ROMS will be a multi-step process that includes model calibration, validation, and a post-audit. The process began with model testing using October 1994 through September 1995 data or water year 1995 (WY95) inputs from the SWEM model setup (HDR, 2023a). The WY95 testing with the ROMS hydrodynamic model generally reproduced the water elevation, current speed, temperature, and salinity data and SWEM ECOM model output. Several ROMS model tests were conducted that included sensitivities to the ROMS vertical turbulence closure schemes, the number of vertical layers, Jerlov Water Type (i.e., light attenuation), and bottom roughness length. The model testing indicated that model results were generally insensitive to the vertical turbulence closure scheme and number of vertical layers. The Jerlov Water Type and bottom roughness length model testing indicated that these model inputs can impact model results and that further evaluation should be completed during model calibration.

The second step is a preliminary calibration of ROMS using calendar years 2005 and 2006 (CY05-06) data, which is the subject of this report. This time period was selected as it is a data rich time period (i.e., includes continuous data for temperature, salinity and currents in addition to grab samples and vertical profiles). This report also provides the LIS Model Evaluation Group (MEG) an opportunity to review the preliminary calibration prior to starting the full model calibration process to the CY05-14 time period. After completing the model calibration, the ROMS hydrodynamic model will be validated for two time-periods (CY03-04 and CY15-18) and undergo post-audit modeling for CY19-22.

The ROMS hydrodynamic model inputs used for the preliminary calibration are presented in the *LIS ROMS Hydrodynamic Model Inputs and RCA Water Quality Model Load Development Approach* Memo (HDR, 2023b). This memo presents ROMS model inputs for the bottom roughness length coefficient, offshore boundary conditions, freshwater inputs, meteorologic inputs, options/constants, and the Jerlov Water Type used for the preliminary model calibration presented in this report.

It should be noted that the ROMS hydrodynamic model preliminary calibration does not represent the final model calibration and that model calibration is still in progress. The preliminary model calibration presented does represent a good level of model-data comparison both from a visual qualitative perspective and from a quantitative skill assessment perspective. This report describes the data available for model preliminary calibration and skill assessment, skill assessment metrics, results of the skill assessment, and next steps for further improvement of the model calibration for the full CY05-14 model calibration time period.

2 ROMS

The ROMS hydrodynamic model is a free-surface, terrain-following, primitive equations ocean model widely used by the scientific community for a diverse range of applications (https://www.myroms.org/). ROMS can be used to model how a waterbody responds to physical forcings such as heating, wind, and freshwater inputs. Physical schemes are based on the governing equations of mass continuity, of conservation of momentum, and for tracer-variable transport. Terrain-following vertical coordinates (sigma-layers) are used that allow for greater vertical resolution in shallow water and regions with complex bathymetry. Orthogonal curvilinear coordinates are used in the horizontal allowing for increased horizontal resolution in regions characterized by irregular coastal geometry (Moore et al., 2011). ROMS also includes several vertical mixing schemes and multiple levels of nesting grids.

ROMS is a modern and modular code written in F90/F95. ROMS was developed in the early 2000's evolving from the S-Coordinates Rutgers University Model (SCRUM). It has pre- and post-processing software for data preparation, analysis, plotting, and visualization. The entire input and output data structure of the model is via NetCDF, which facilitates the interchange of data between computers, the user community, and other independent analysis software. ROMS applications include investigations in LIS (Whitney et al., 2011, 2014, 2016; Schmidt and Whitney, 2018); the Middle Atlantic Bight (Levin et al., 2018); and Barnegat Bay (Defne et al., 2017).

3 Model Grid and Bathymetry

3.1 Grid

The new LIS model grid has finer resolution than the SWEM model grid. The SWEM model grid had 49 x 84 horizontal model segments with 10 sigma-layers. The new ROMS LIS model grid has 307 x 170 horizontal model segments and is currently using 10 sigma-layers. The model grid was designed using the RGFGRID program within the Delft-3D modeling package. RGFGRID is used for the generation and manipulation of curvilinear grids. The RGFGRID program allows for the generation of a NetCDF grid file for ROMS; this option was not used, however, since the generated file required additional manipulation in Matlab to integrate bathymetry, additional grid metrics, land masks and dummy cells. The new model grid is presented in Figure 1 that is zoomed into the LIS region.

3.2 Bathymetry

The following sources of model bathymetry were used to define model depths in the new LIS model grid.

- CUDEM (Continuously Updated Digital Elevation Model, NOAA) was used for most of the model domain. (https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ngdc.mgg.dem:999919; https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ngdc.mgg.dem:999913/html).
- CRM (US Coastal Relief Model) was applied for the southern and eastern part of the model grid (Atlantic Ocean, east of Nantucket) where CUDEM bathymetry cover was not available (https://www.ngdc.noaa.gov/mgg/coastal/crm.html).
- CONED (Coastal National Elevation Database) was used for the Connecticut River but the upper Connecticut River (north of Hartford) was adjusted to a 5-meter depth. CONED bathymetry was first applied to the Raritan River, but then a minimum depth of 5 meters was applied to most of the Raritan River (https://www.usgs.gov/special-topics/coastal-national-elevation-database-applications-project).
- Bathymetry used in the DEP Long Term Control Plan 3 (LTCP3) Open Waters Model was applied to the Upper Hudson River north of Cornwall-On-Hudson (about 5 miles north of West Point).
- Water depths from Nation Oceanic and Atmospheric Administration (NOAA) Nautical Chart #12337 (1997 edition) was applied to the Hackensack River and Passaic River areas.

For the preliminary calibration conditions, the minimum model depth was set to 5.0 meters. That is, all model depths calculated from data that are less than 5.0 meters are set equal to 5.0 meters. This will be revisited and adjusted to better reflect actual water depths during the full model calibration CY05-14 time period. All depths assigned in the model are based on the NAVD88 vertical datum. Assigned model depths for the entire grid and LIS are presented in Figures 2 and 3, respectively.

4 Model Calibration Data

The model calibration data from CY05-06 were selected for preliminary model calibration as this time period was considered to be data rich. That is, there was a significant amount of continuous data for temperature, salinity and velocity from the Long Island Sound Integrated Coastal Observing System (LISICOS) in western LIS during 2006. Most other model calibration years (CY05-14) do not have continuous data and this was considered a benefit to completing the model preliminary calibration to CY05-06. In addition, there was extensive grab sample data available in CY05-06 from CTDEEP, DEP, IEC, NJHDG, NOAA, and USGS for the model preliminary calibration.

4.1 Water Elevation

NOAA and the USGS maintain and operate several open water, tidal water elevation gages within the LIS model study area that were used for model-data comparisons. These gages are listed in Table 1 and shown in Figure 4. Data are available on an hourly or shorter time period basis.

Table 1. NOAA and USGS Gauge Locations

Owner	Gauge Location	Gauge Number	Coordinates
NOAA	Atlantic City, NJ	8534720	39° 21.4' N; 74° 25.1' W
NOAA	Sandy Hook, NJ	8531680	40° 28.0' N; 74° 0.6' W
NOAA	Bergen Point, NY	8519483	40° 38.3' N; 74° 8.8' W
NOAA	The Battery, NY	8518750	40° 42.0' N; 74° 0.9' W
NOAA	Bridgeport, CT	8467150	41° 10.4' N; 73° 10.9' W
NOAA	Montauk, NY	8510560	41° 2.9' N; 71° 57.6' W
NOAA	New London, CT	8461490	41° 22.3' N; 72° 5.7' W
NOAA	Kings Point, NY	8516945	40° 48.6' N; 73° 45.9' W
NOAA	New Haven, CT	8465705	41° 17.0' N; 72° 54.5' W
USGS	Hackensack River at Hackensack NJ	01378570	40° 52.7' N; 74° 3.4' W

4.2 Temperature and Salinity

4.2.1 Grab Sampling

Salinity and temperature data are used to assess how well the model reproduces these constituents. It is important that the model reproduces these constituents because they affect water column density, which affects vertical mixing. Vertical mixing is an important factor affecting bottom water dissolved oxygen (DO) levels. The following data sources provided grab sample temperature and salinity data:

- The New York City Harbor Survey (HS) Program dataset includes salinity and temperature data that were used for model calibration in western LIS, East River, Harlem River, Hudson River, Kill Van Kull, Jamaica Bay and the NY/NJ Harbor (see Figure 5). The monitored stations were divided into primary stations, secondary stations, and stations not considered for model calibration (generally located in small tributaries). The preliminary calibration focused on the primary and secondary stations with skill assessment statistics calculated at the primary stations.
- CTDEEP has salinity and temperature data that were used for model calibration (Water Monitoring Data Availability (ct.gov)) and has monitoring locations throughout LIS (see Figure 6). The stations were divided into primary (year-round sampling) and secondary stations (summer sampling). The preliminary calibration focused on the primary and secondary stations with skill assessment statistics calculated at the primary stations.
- The New Jersey Harbor Dischargers Group (NJHDG) dataset includes salinity and temperature data in the Hudson River and northern NJ water bodies that can

be used for model calibration. Only stations in the Hudson River and Raritan Bay are considered primary stations (see Figure 7).

- The Interstate Environmental Commission (IEC) has seasonal monitoring stations (see Figure 8) in western LIS. They are all considered secondary stations and have not yet been used for model calibration.

As the full model calibration continues model-data figures for the IEC and NJHDG will be developed.

4.2.2 Continuous Monitoring

The LISICOS program (UConn's Long Island Sound Observatory) has monitoring buoys that collect continuous salinity and temperature measurements that were used for model calibration (see Figure 9). During 2006, data were available from March through December at Execution Rocks, FB01, FB02, FB03, and the western LIS stations. These data were provided by Dr. James O'Donnell from the University of Connecticut.

4.3 Velocity

LISICOS has continuous Acoustic Doppler Current Profiler (ADCP) data (UConn's Long Island Sound Observatory) at various stations in western LIS. These data were used for model calibration. ADCP measurements during 2006 are available from late June to mid-August at Execution Rocks, FB01, FB02, FB03 and western LIS stations.

5 Model Calibration and Skill Assessment

As part of the ROMS hydrodynamic model preliminary calibration, 20 model runs were completed to test various inputs that resulted in the preliminary model calibration presented in this report. Table 2 presents a summary of the model runs completed during the preliminary calibration effort. The runs included incrementally adding model inputs, adjusting North American Regional Reanalysis (NARR) spatial output assigned as meteorological inputs, bottom roughness length (ZoB) adjustments, offshore boundary condition adjustments, use of a LIS specific Jerlov Water Type (i.e., not one of the ROMS standard Jerlov Water Types), and use of k-kl (Mellor-Yamada) vertical closure scheme. Model-data comparisons for water elevation, temperature and salinity were visually reviewed during the process to determine the impact of the change and whether the change should continue to be used or not. Run #20 represents the preliminary calibration presented in this report.

Table 2. Model Runs Completed as Part of Preliminary Calibration

Run #	Input(s) Modified	Model Results Summary
1	Boundary conditions and 2D meteorological inputs assigned (no freshwater flows)	Initial model run to evaluate boundary condition and 2D meteorological inputs
2	Same as #1 but freshwater inputs assigned and used 90% of NARR solar radiation	Improved model-data salinity comparisons and lower water temperatures but still high

Run #	Input(s) Modified	Model Results Summary
3	Same as #2 but replaced 2 NARR input stations that reflected land conditions	Improved model-data temperature comparisons in area where NARR inputs changed
4	Same as #2 but replaced 6 additional NARR stations that reflected land conditions	Improved model-data temperature comparisons in area where NARR inputs changed
5	Same as #2 but replaced all 8 additional NARR stations that reflected land conditions	Improved model-data temperature comparisons in area where NARR inputs changed
6	Same as #5 but all freshwater inputs assigned (rivers, WRRFs, CSO, SW) and model grid revisions in Jamaica Bay	Improved model-data salinity comparisons and better representation of Jamaica Bay volume
7	Same as #6 but groundwater flows added and offshore boundary elevation meteorological component added to astronomical elevations assigned	Improved model-data elevation comparisons to meteorologic driven elevation changes
8	Same as #7 but changed measurement height for air humidity and air temperature from 10 meters to 2 meters to reflect NARR output specification	Little improvement to model-data temperature comparisons, change made for consistency between NARR output and ROMS input
9	Same as #8 but ZoB changed to 0.001 meters from 0.002 meters	Slight increase in model tidal range in western LIS
10	Same as #8 but ZoB changed to 0.003 meters from 0.002 meters	Slight decrease in model tidal range in western LIS
11	Same as #8 but offshore boundary elevation M2 amplitude reduced by 10%	Slight decrease in model tidal range in western LIS
12	Same as #8 but using k-kl (Mellor-Yamada) closure instead of k-epsilon	Little change noted, use of k-kl to be consistent with prior SWEM modeling
13	Same as #12 but used 80% of NARR solar radiation	Improved model-data temperature comparisons
14	Same as #12 but used 2D ZoB (0.004 meters in Harlem/East Rivers, 0.002 meters everywhere else)	Slight decrease in model tidal range in western LIS
15	Same as #12 but offshore boundary condition salinity reduced by 2 psu	Improved model-data salinity comparisons in central/eastern LIS
16	Same as #12 but only offshore eastern boundary condition salinity reduced by 5 psu	Improved model-data salinity comparisons in central/eastern LIS
17	Same as #12 but used revised ROMS code that allows different freshwater flow input options	No change, code update only
18	Same as #12 but used LIS specific Jerlov Water Type based on LIS light attenuation data	Improved model-data temperature comparisons in LIS (surface and bottom)
19	Same as #12 but ZoB changed to 0.01 meters from 0.002 meters	Test using ZoB assigned in Stony Book ROMS modeling of LIS

Run #	Input(s) Modified	Model Results Summary
20	Same as #17 but used LIS specific Jerlov Water Type, variable offshore boundary condition temperature/salinity adjustment, used 2D ZoB (0.01 meters in Harlem/East Rivers, 0.005 meters everywhere else)	Preliminary calibration presented in this report

5.1 Water Elevation

Water elevation data are available at 10 locations for CY 2005 and 2006 model-data comparisons (Figure 4). Nine locations are NOAA gauges, and the 10^{th} is a USGS gage in the Hackensack River. Figure 10 presents model-data comparisons for two of the stations (Bridgeport and Bergen Point) during 2005 and Figure 11 presents model-data comparisons at the same stations in 2006. Additional model-data water elevation comparisons are included in Attachment 1. The model captures differences in tidal amplitude from location to location as well as the timing of changes in water elevation. Differences in water elevation during spring and neap tides are also reproduced by the model. Spring tides occur during full/new moons and result in higher high and lower low tides. Neap tides occur during half-moons and result in lower high and higher low tides. At several locations in central and western LIS (i.e., Bridgeport, New Haven, and Kings Point), the tidal range of the model exceeds the tidal range of the data; this issue will be explored further during model calibration with the full CY05-14 data. In addition, low-pass filtered water elevations will be presented in the full calibration report.

5.2 Temperature and Salinity

5.2.1 Time-series

Temperature and salinity data are available from the New York City HS Program, CTDEEP monitoring program, IEC monitoring program, and the NJHDG monitoring program. Figures 12 through 19 present examples of model-data time-series comparisons for the DEP and CTDEEP data from CY 2005 and 2006. Additional figures are included in Attachment 2. As the full model calibration continues model-data figures for the IEC and NJHDG will be developed along with model stratification figures (i.e., surface to bottom salinity and temperature differences or ΔS and ΔT).

Temperature comparisons between the model and the surface and bottom 2005 CTDEEP data are good at stations A4, C2 and C1, although the model overestimates temperature at A4 during the warmer months (Figure 12). At other eastern CTDEEP stations (Attachment 2), the model-data temperature comparisons are good but there is over-estimation of surface temperatures at some stations. The model also tends to overestimate summer temperatures at HS East River stations E7, E8 and E10 during 2005 (Figure 13). At HS stations in the Hudson River and other locations to the west, the model-data comparisons for temperature are good except for high surface and bottom temperatures at some stations. Figures 14 and 15 show that the model does a good job of reproducing the 2005 salinity data at these example stations. The model also does a good job at other CTDEEP and HS stations (Attachment 2) including stations in the Hudson River where there is greater vertical salinity stratification.

During 2006, Figures 16 and 17 show that the model overpredicts temperature data. That is, the 2006 calculations overpredict temperature more than the 2005 calculations at the same example CTDEEP and HS stations. As for salinity, it is overestimated at the example CTDEEP stations in 2006 (Figure 18) and well estimated at the example HS stations in 2006 (Figure 19).

The LISICOS continuous salinity and temperature data for 2006 were compared to model output at five locations. Further review of the data is needed to resolve some observed discrepancies (e.g., bottom salinity less than surface salinity) and some of the data were removed from the dataset before comparison to model output. Figures 20 through 23 show model versus data comparisons for temperature and salinity at these stations. In general, the model performs well and follows observed temporal patterns but overestimates temperature and salinity data during certain time periods.

Further low-pass filter analysis of the LISICOS continuous data will be completed during the full model calibration (CY05-14) and presented in the full calibration report.

5.2.2 Vertical Profiles

The temperature and salinity model output was also compared to available CTDEEP vertical profile data. Figures 24 through 27 show example comparisons for stations A4 and F2 in 2005. Additional stations are shown in Attachment 3. The model matches the vertical profiles of temperature and salinity at A4 quite well through July and reasonably well thereafter. Starting in October 2005, the model over-estimates observed temperature. For 2005, most of the vertical profile measurements at station F2 and the model output compare favorably. Again, starting in October the model overestimates observed temperature.

Model versus data comparisons at stations A4 and F2 during 2006 are presented in Figures 28 through 31. Figures for additional stations are included in Attachment 3. The model matches the salinity data at station A4 reasonably well for most of the dates. While the model comparison to the temperature profiles at station A4 is good, overall the observed temperatures are over-estimated. At station F2, the model compares very favorably to the salinity data and is also good for temperature with occasional over-estimation of the data near the surface.

The model appears to be able to reproduce the shapes of the temperature and salinity profiles quite well. That is, the model reproduced stratification and well mixed conditions. There is room for improvement in both salinity and temperature as the full calibration effort continues. It is anticipated that salinity comparisons can be improved with adjustments to model geometry, bottom roughness length coefficients and boundary conditions, while temperature comparisons can be improved with adjustments to the Jerlov Water Type or light extinction coefficients.

5.2.3 Transects

Transect figures were created for temperature and salinity from the Battery through the length of LIS. Figures were created by month including all of the data and model results within a particular month. In these figures, the data are presented as monthly averages (circles) and ranges (bars) for surface and bottom data. The monthly average surface model output are presented as solid lines with the monthly range presented as the light grey shaded areas. The monthly average bottom model output are presented as dashed lines with the monthly range presented as the dark grey shaded areas. Figures 32 and 33 are examples for July 2005 and July 2006, respectively. All 24 months from 2005 and 2006 are included in Attachment 4.

The data in the temperature panel for July 2005 shows the East River is warmer than eastern LIS at the surface and the model follows this trend although model temperatures are greater than observed temperatures. Deeper LIS waters in the center of LIS are cooler, and the model bottom average temperature generally follows the data average monthly bottom temperature. The model also captures temperature stratification between the surface and bottom waters.

The salinity data show that East River locations have lower salinity than eastern LIS locations and the model reproduces this observation. In the East River, the model salinity is greater than the data. In addition, the salinity data is less stratified than the temperature data, and the model reproduces this level of salinity stratification.

In July 2006, the surface temperature data are generally lower than the model results but fall within the range of the monthly model output in most cases. The bottom temperature data also tend to be on the lower end of the monthly model output range. The degree of temperature stratification observed in the data is reproduced by the model although the model temperature (surface and bottom) results are higher than the data.

The July 2006 surface salinity data fall within the range calculated by the model and the model reproduces the increasing trend in salinity from west to east. The model over-calculates the surface and bottom salinity data throughout LIS and the East River. The degree of salinity stratification calculated by the model is similar to that observed but generally over-calculates the observed data.

5.3 Velocity

Available 2006 LISICOS ADCP hourly velocity data were compared to hourly model output with all velocity comparison figures presented in Attachment 5. Figure 34 presents an example three-month model-data comparison for station FB02. The data show higher velocities at the surface than at the bottom and vary over a generally northeast to southwest direction over the tidal cycle. Although not as variable as the data, the modeled velocities are calculated in the same general northeast/southwest direction as the data with similar velocity magnitudes. Figure 35 presents a model-data comparison at station FB02 for a five-day period starting on 6/30/2006. The model captures the magnitude and direction of the data and shows the shift in direction between the surface and bottom. Although velocity varies at the five LISICOS ADCP stations, the model reproduces the observed data well at all locations. Nonetheless, further analysis of the LISICOS ADCP data and model output will be completed as the model calibration progresses and presented in the full calibration report. These additional analyses will include maps of residual currents, time-series of current speed and direction, tidal ellipse analysis, tidal harmonics, low-pass filtering, and presentation of vertical mixing.

5.4 East River Volume Fluxes

Monthly net (all layers), surface, and bottom water volume fluxes through the East River were calculated for the 2005 and 2006 modeling time periods. The East River transect used for these calculations extends from about 152nd Street in Whitestone to Acorn Place in Throgs Neck (Figure 36).

Figure 37 presents calculated fluxes through the East River for 2005. The net volume flux was westward (i.e., from LIS) and monthly fluxes ranged from 51 m^3/s in December to 191 m^3/s in February. The highest net volume fluxes tended to be in the first half of the year. Surface volume fluxes (top 10% of the water column) were eastward (i.e., toward LIS) and ranged from 141-306 m^3/s. Higher surface volume fluxes tended to occur during the cooler winter/spring months of the year. Bottom volume fluxes (bottom 10% of the water column) were smaller than the surface volume fluxes, ranged from 36-72 m^3/s, and were westward (i.e., from LIS).

Figure 38 presents the model calculated monthly net, surface, and bottom volume fluxes through the East River for 2006. The calculated net volume flux was westward from LIS and was lower than the 2005 volume flux ranging from 8 m^3/s (October) to 152 m^3/s (March). Surface volume fluxes were generally higher during 2006 than 2005 and ranged from 164-305 m^3/s eastward to LIS. The bottom volume fluxes were similar to 2005 and ranged from 40-73 m^3/s westward from LIS.

The westward net volume fluxes calculated by the model are in the same direction as previous studies (HydroQual, 2001), however, the magnitude of the net volume flux calculated by the model is less than that estimated in previous studies. Previous studies were conducted with a coarse spatial resolution model grid, which could cause the differences observed. Volume fluxes calculated by the model will continue to be reviewed as the full model calibration continues and presented in the full calibration report. This will include calculating the total east and west volume fluxes, use of additional transects, and presenting time-series of fluxes.

5.5 Skill Assessment Metrics

Model calibration is often accomplished through a subjective trial-and-error adjustment of model coefficients (weight of evidence approach) because many interrelated factors can influence model output. The experience and judgment of the modeler is a major factor in calibrating a model both accurately and efficiently. Although this method balances model comparison to data with the modeler’s understanding of the physical, chemical and biological characteristics of the system it does not provide a quantitative measure of the “goodness of fit.”

There is a large body of literature about coastal and estuarine modeling skill assessment (Blumberg et al., 1999; Fitzpatrick, 2009; Jolliff et al., 2009; Zhang et al., 2010; Ganju et al., 2016; and Ji, 2017). Typical measurements include relative error (RE), root mean square error (RMSE), correlation coefficient (r) and coefficient of determination (r^2). All statistical approaches have their limitations. Unfortunately, few references provide guidance as to the acceptable level of error for a satisfactory level of calibration.

It should be noted that the correlation coefficient is dependent on the range of model and data, with narrow ranges resulting in lower correlation coefficients as compared to model and data with wider ranges (https://www.bmj.com/rapid-response/2011/11/03/correlation-restricted-ranges-data-revisited, https://www.statisticshowto.com/restricted-range/). As will be seen for the salinity and temperature correlation coefficient statistics, the correlation coefficients for salinity (especially where the salinity range is small, such as in LIS) are less than those for temperature (where the annual cycle includes a large temperature range). This is an example of why a weight of evidence approach should be used when evaluating a model's goodness of fit.

Ultimately, the goal of model calibration is "not to curve fit model to data, but to describe the behavior of the data with a modeling framework of the principal mechanisms relevant to the problem" (Thomann, 1982). This ultimate goal requires a "weight of evidence" approach that balances both qualitative and quantitative skill assessment results with the model calibration guidance and acceptance provided by independent peer review.

The skill assessment metrics presented in the LIS Modeling Quality Assurance Project Plan (QAPP) (HDR, 2022) were used to perform a quantitative assessment of the model's ability to reproduce the available hydrodynamic data. It should be noted that the skill assessment approach and targets have been recently revised in Version 2.3 of the QAPP including the use of zones for compositing the metrics and will be presented in the full calibration report. The metrics included relative error, root mean square error and the correlation coefficient. Table 3 presents the targets for each metric.

- Relative error (RE): $= 100 \times \frac{|\bar{M}-\bar{O}|}{\bar{O}}$
- Root mean square error (RMSE): $= \sqrt{\sum_{i=1}^{n}\left(\frac{(M_i-O_i)^2}{n}\right)}$
- Correlation coefficient (r): $= \frac{\sum(O_i-\bar{O}) \times (M_i-\bar{M})}{\sqrt{\sum(O_i-\bar{O})^2} \times \sqrt{\sum(M_i-\bar{M})^2}}$

where: M_i – model output point

O_i – observed data point

$\bar{M}$ – model mean

$\bar{O}$ – observed data mean

n – number of observations

Table 3. Skill Assessment Metric Targets

Parameter	Relative Error	RMSE	Correlation Coefficient
Water Elevation	5-10%	< 20 cm	> 0.9
Current Speed	20-25%	< 20 cm/s	> 0.7
Salinity	10-15%	< 4.0 psu	> 0.7
Temperature	5-10%	< 2.0°C	> 0.9

5.6 Model Output Comparison to Metrics

5.6.1 Water Elevation

A tidal harmonics analysis program (Foreman, 1977) was used to assess the data and model output water elevations 10 NOAA and USGS stations (Figure 4). The five largest tidal constituents were chosen for model versus data comparisons. The constituents include M2 (principal lunar semi-diurnal), S2 (principal solar semi-diurnal), N2 (larger lunar elliptic semi-diurnal), K1 (lunar diurnal), and O1 (lunar diurnal). The standard program package analyzes 69 tidal constituents. It should be noted that the data tidal constituents are calculated for each year from the hourly elevation data and not obtained from NOAA Tides & Currents harmonic constituent analyses.

Table 4 presents the harmonic constituent analysis results for the 2005 data for tidal amplitude and tidal phase. M2 is the largest tidal constituent in the LIS region and ranges from 27.8 cm at Montauk to 115.3 cm at Kings Point. The O1 constituent is the smallest tidal contributor and ranges from about 4.2 cm at Hackensack to 7.3 cm at Atlantic City. The total tidal amplitude from these major tidal constituents ranges from 51.8 cm at Montauk to 173.8 cm at Kings Point. Table 5 presents the tidal harmonics for the 2005 model output. The model output in Table 5 compares favorably to the data tidal harmonics in Table 4.

Table 4. Tidal Harmonic Analysis for 2005 Data

	O1		K1		N2		M2		S2		Total
Station	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)
Atlantic City	7.3	97	10.8	105	12.8	196	58	210	11.6	230	100.5
Bergen Point	5	108	10.4	104	15.3	222	72.3	233	13.9	257	116.9
Battery	4.8	107	10.1	102	14	220	65.2	234	12.8	254	106.9
Hackensack	4.2	145	12.8	113	16.9	275	85.2	268	10.5	301	129.6
Kings Point	6.2	151	10.3	117	22.8	313	115.3	331	19.2	353	173.8
Bridgeport	5.9	150	9.7	116	19.5	306	99.1	325	15.7	346	149.9
Montauk	4.8	142	7.1	99	7.2	245	27.8	263	4.9	271	51.8
New Haven	5.2	151	8.8	113	16.1	307	84.1	321	12.5	341	126.7
New London	4.5	141	7.2	103	8.1	253	35.7	275	6.3	282	61.8
Sandy Hook	5	101	10.3	98	14.4	208	67.7	220	13.4	241	110.8

Table 5. Tidal Harmonic Analysis for 2005 Model Output

	O1		K1		N2		M2		S2		Total
Station	**Amp (cm)**	**Phase (deg)**	**Amp (cm)**	**Phase (deg)**	**Amp (cm)**	**Phase (deg)**	**Amp (cm)**	**Phase (deg)**	**Amp (cm)**	**Phase (deg)**	**Amp (cm)**
Atlantic City	6.5	110	8.9	98	13.2	206	56.1	219	11.1	234	95.8
Bergen Point	5.6	120	9.5	111	16.7	234	77.5	243	14.5	264	123.8
Battery	5.7	116	9.6	106	16.9	227	76.6	238	14.6	257	123.4
Hackensack	5.5	153	9.3	150	13.8	308	67.0	312	11.2	340	106.8
Kings Point	6.9	149	12.1	121	25.3	313	129.4	333	21.7	350	195.4
Bridgeport	6.7	147	11.5	118	21.2	307	108.3	326	17.8	342	165.5
Montauk	5.3	137	8.4	107	7.2	246	25.7	266	5.6	268	52.2
New Haven	6.5	145	11.1	117	18.9	303	96.5	323	15.7	338	148.7
New London	5.5	136	8.9	105	9.3	253	38.8	275	7.3	279	69.8
Sandy Hook	5.8	113	9.5	102	16.9	217	76.3	227	14.8	247	123.3

Table 6 presents some comparative statistics between the model and data results with the r values calculated using hourly data and model output. In Table 6, the amplitude difference and RE calculations are based on the sum of the five harmonic constituent amplitudes presented in Tables 4 and 5. Phase differences for the M2 tidal component are also presented in Table 6. The phase difference is calculated at the modeled minus data phase in degrees and then converted to time. The conversion is based on the M2 tide moving 360 degrees in 12.42 hours (29.0 degrees/hour). For example, at Sandy Hook the M2 phase difference is 7 degrees and when converted to time is 0.24 hours or 14.5 minutes.

The bold values in Table 6 represent skill assessment statistics that do not meet QAPP targets (RE between 5-10%, r greater than 0.9). The model predicts amplitude well at Atlantic City, Bergen Point and Montauk, but needs some improvement at other locations. It is anticipated that improvements can be obtained with adjustments to the bottom roughness length coefficient, model geometry and bathymetry in certain locations (e.g., East River, Harlem River, Hackensack River). The differences in timing between the model and data are estimated by a comparison of the M2 constituent phase, the largest constituent of tidal amplitude. A difference of 29 degrees represents a difference of one hour in the timing of the water elevations. The model timing of water elevations is good (less than one hour) with the exception of the Hackensack River, where the bathymetry is least well understood.

Table 6. Tidal Harmonics Data and Model Comparisons 2005

Station	Amplitude Difference (cm)	Amplitude RE (%)	M2 Phase Diff (min)	Model-Data r
Atlantic City	-4.7	4.7	18.6	0.97
Bergen Point	6.9	5.9	20.7	0.97
Battery	16.5	**15.4**	8.3	0.98
Hackensack	-22.8	**17.6**	91.0	**0.70**
Kings Point	21.6	**12.4**	4.1	0.99
Bridgeport	15.6	**10.4**	2.1	0.99
Montauk	0.4	0.8	6.2	0.92
New Haven	22.0	**17.4**	4.1	0.96
New London	8.0	**12.9**	0.0	0.95
Sandy Hook	12.5	**11.3**	14.5	0.98

Tables 7 through 9 present tidal harmonic calculations for the 2006 water elevation data, model output, and model and data comparisons. The bold values in Table 9 represent skill assessment statistics that do not meet QAPP targets (RE between 5-10%, r greater than 0.9). Theoretically, unless there are changes in the conditions of a water body, the tidal harmonic should be the same from year to year. While there are some minor differences between the 2005 and 2006 data results, they are essentially the same.

Table 7. Tidal Harmonic Analysis for 2006 Data

	O1		K1		N2		M2		S2		Amp
Station	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Total (cm)
Atlantic City	7.5	97	10.8	106	13	194	58.1	210	11.5	230	100.9
Bergen Point	5.1	105	10.2	105	15.4	219	72.5	233	13.6	255	116.8
Battery	5	104	9.9	104	14.3	217	65.6	234	12.5	253	107.3
Hackensack	5.3	127	12.2	129	18.9	262	84.9	268	14.1	297	135.4
Kings Point	6	152	10.1	119	23.4	311	116.7	331	19.4	353	175.6
Bridgeport	5.7	150	9.4	118	20	305	99.9	325	15.9	347	150.9

Montauk	4.3	138	6.9	106	7.3	245	28	264	5.6	268	52.1
New Haven	5.5	149	9	116	18.1	301	89.8	322	14.4	344	136.8
New London	4.5	140	6.8	106	8.2	254	35.7	275	6.3	282	61.5
Sandy Hook	5.2	100	10.2	99	14.7	206	68.2	220	13.2	240.7	111.5

Table 8. Tidal Harmonic Analysis for 2006 Model Output

	O1		K1		N2		M2		S2		Total
Station	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)	Phase (deg)	Amp (cm)
Atlantic City	6.5	110	9.1	99	13.1	206	56.1	219	11.1	235	95.9
Bergen Point	5.6	119	9.5	112	16.6	234	77.5	243	14.5	265	123.7
Battery	5.7	115	9.6	107	16.9	227	76.6	239	14.7	258	123.5
Hackensack	5.4	153	9.1	152	13.6	307	66.8	313	11.4	343	106.3
Kings Point	7.1	149	12.2	121	24.9	315	129.1	333	21.7	350	195.0
Bridgeport	6.7	147	11.5	119	20.9	309	108.1	327	17.8	343	165.0
Montauk	5.3	137	8.3	107	6.9	246	25.5	267	5.4	268	51.4
New Haven	6.5	146	11.1	118	18.6	305	96.3	323	15.7	339	148.2
New London	5.4	136	8.9	107	9.0	254	38.6	276	7.2	280	69.1
Sandy Hook	5.8	112	9.6	104	16.9	217	76.2	227	14.8	247	123.3

Table 9. Tidal Harmonics Data and Model Comparisons 2006

	Amplitude	Amplitude	M2	Model-Data
Station	Difference (cm)	RE (%)	Phase Diff (min)	r
Atlantic City	-5.0	5.0	18.6	0.97
Bergen Point	6.9	5.9	20.7	0.97
Battery	16.2	**15.1**	10.3	0.98
Hackensack	-29.1	**21.5**	93.1	**0.70**
Kings Point	19.4	**11.0**	4.1	0.99
Bridgeport	14.1	9.3	4.1	0.99

Montauk	-0.7	1.3	6.2	0.91
New Haven	11.4	8.3	2.1	0.98
New London	7.6	**12.4**	2.1	0.94
Sandy Hook	11.8	**10.6**	14.5	0.98

5.6.2 Temperature and Salinity

5.6.2.1 CTDEEP Data

Model versus data skill assessment statistics were calculated for surface and bottom temperature at CTDEEP and DEP stations. Hourly model results and grab sample data are compared. This approach may be modified for the full model calibration process. Tables 10 and 11 present the surface and bottom results for 2005 at CTDEEP primary stations. The bold values in these tables represent skill assessment statistics that do not meet the QAPP targets (RE between 10-15%, RMSE <4 psu, and r greater than 0.7 for salinity; RE between 5-10%, RMSE <2°C, and r greater than 0.9 for temperature). Except with respect to r values for salinity, the model results are within the targets specified in the QAPP and Section 5.5 of this report. Model median salinity tends to be higher than the data median with exceptions on the eastern end of LIS. Model temperatures also tend to be higher than the data.

Table 10. 2005 Model Metrics at CTDEEP Primary Stations (Surface)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
A4	16	1%	0.81	25.41	25.30	**0.44**
B3	14	2%	1.03	25.70	25.83	**0.00**
C1	16	2%	0.86	26.00	26.07	**0.44**
C2	15	2%	0.97	26.04	26.10	**0.32**
D3	15	2%	0.93	26.20	26.21	**0.26**
9	15	2%	0.78	26.11	26.14	**0.44**
E1	15	1%	0.85	26.26	26.41	**0.68**
15	14	1%	0.86	25.86	26.18	**0.58**
F2	14	1%	1.06	26.27	26.27	0.77
F3	15	1%	0.88	26.49	26.42	**0.64**
H2	15	1%	0.83	26.75	26.92	**0.59**
H4	14	1%	0.83	26.81	26.77	**0.62**

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
H6	14	2%	0.94	26.41	26.65	**0.58**
I2	13	1%	0.71	27.00	27.28	**0.67**
J2	14	2%	1.57	28.16	27.32	**0.51**
K2	12	2%	1.96	28.15	27.49	**0.55**
M3	12	2%	1.38	29.56	29.07	**0.31**
Temperature (°C)						
A4	16	6%	1.07	17.12	18.37	1.00
B3	14	9%	1.25	14.96	19.24	1.00
C1	16	7%	1.31	18.28	19.39	1.00
C2	15	8%	1.28	17.54	18.45	1.00
D3	15	7%	1.20	16.85	18.41	1.00
9	15	**10%**	1.80	15.70	17.68	0.99
E1	15	8%	1.35	16.40	17.81	1.00
15	14	8%	1.26	14.82	16.54	1.00
F2	14	9%	1.37	14.04	15.84	0.99
F3	15	5%	1.13	18.36	17.36	1.00
H2	15	7%	1.37	15.70	16.81	1.00
H4	14	9%	1.39	14.95	15.69	1.00
H6	14	8%	1.57	14.61	16.59	0.99
I2	13	4%	1.22	16.51	15.03	0.99
J2	14	5%	0.91	13.71	13.97	1.00
K2	12	6%	0.98	11.68	11.71	0.99
M3	12	8%	1.04	11.16	11.29	0.99

Table 11. 2005 Model Metrics at CTDEEP Primary Stations (Bottom)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
A4	15	2%	0.95	25.87	26.04	**0.11**
B3	15	3%	0.99	25.97	26.21	**0.15**
C1	16	1%	0.83	26.30	26.50	**0.20**
C2	15	1%	3.56	26.34	26.64	**0.29**

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
D3	16	1%	0.83	26.59	26.93	**0.29**
9	15	2%	0.86	26.14	26.56	**0.26**
E1	15	1%	0.91	26.96	27.24	**0.28**
15	14	1%	0.95	26.17	26.55	**0.34**
F2	14	1%	0.94	26.69	27.02	**0.33**
F3	15	1%	0.81	27.07	27.66	**0.41**
H2	15	1%	0.80	26.91	27.25	**0.42**
H4	14	0%	0.81	27.20	27.28	**0.44**
H6	14	1%	0.94	27.23	27.59	**0.29**
I2	14	2%	0.87	27.62	27.97	**0.44**
J2	14	1%	0.99	28.63	28.87	**0.28**
K2	12	0%	1.17	29.52	29.29	**0.07**
M3	12	1%	1.21	30.26	29.83	**0.07**
Temperature (°C)						
A4	15	**10%**	1.31	15.56	14.78	1.00
B3	15	6%	1.18	12.51	13.67	0.99
C1	16	5%	1.08	13.14	13.93	0.99
C2	15	3%	1.15	12.95	12.50	0.99
D3	16	2%	1.15	13.32	13.44	0.99
9	15	4%	1.00	13.56	13.25	1.00
E1	15	6%	1.34	13.72	14.16	0.99
15	14	0%	1.13	12.97	13.41	0.99
F2	14	7%	1.23	12.34	13.32	0.99
F3	15	7%	1.29	13.57	14.49	0.99
H2	15	9%	1.46	13.30	15.10	0.99
H4	14	7%	1.20	12.84	13.33	0.99
H6	14	6%	1.13	12.47	12.37	0.99
I2	14	5%	0.88	12.74	13.29	0.99
J2	14	5%	0.78	13.22	12.92	1.00
K2	12	9%	0.93	11.29	11.55	0.99
M3	12	8%	0.96	11.27	11.29	0.99

Tables 12 and 13 present the statistical comparisons between surface and bottom model and data for 2006 CTDEEP primary stations. The bold values in these tables represent skill assessment statistics that do not meet the QAPP targets (RE between 10-15%, RMSE <4 psu, and r greater than 0.7 for salinity; RE between 5-10%, RMSE <2°C, and r greater than 0.9 for temperature). Again, setting aside r values for salinity, the model compares favorably to the data except for over-estimation of the temperature at some locations.

Table 12. 2006 Model Metrics at CTDEEP Primary Stations (Surface)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
A4	11	1%	0.71	25.25	25.43	**0.33**
B3	11	3%	0.99	25.53	26.28	**0.22**
C1	10	4%	1.08	25.80	26.55	**0.30**
C2	12	4%	1.00	25.81	26.66	**0.32**
D3	11	3%	1.09	26.17	26.82	**0.09**
9	12	1%	0.87	26.16	26.36	0.75
E1	13	2%	0.92	26.50	26.68	**0.46**
15	13	3%	0.86	26.22	26.63	**0.35**
F2	13	1%	0.62	26.61	26.64	**0.83**
F3	13	2%	0.83	26.77	26.92	**0.52**
H2	12	2%	1.05	27.08	27.29	**0.20**
H4	12	3%	0.91	27.16	27.32	**0.37**
H6	12	2%	0.92	27.01	27.11	**0.24**
I2	8	1%	1.24	27.82	27.25	**0.17**
J2	9	1%	1.44	28.14	27.51	**0.30**
K2	8	2%	1.74	28.88	26.91	**0.56**
M3	9	2%	1.35	29.94	29.13	**0.40**
Temperature (°C)						
A4	11	**10%**	1.92	17.22	19.43	0.99
B3	11	9%	1.81	18.88	19.89	1.00
C1	10	8%	**2.12**	17.26	20.17	0.98
C2	12	**11%**	1.99	18.66	21.09	0.99
D3	11	7%	1.60	16.58	19.60	0.99
9	12	7%	**2.43**	16.54	18.98	0.98

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
E1	13	**11%**	1.74	17.71	19.89	1.00
15	13	7%	1.64	16.72	17.95	0.99
F2	13	**12%**	1.93	16.52	19.37	0.99
F3	13	**12%**	1.91	17.77	19.74	0.99
H2	12	**10%**	**2.00**	17.60	18.79	0.99
H4	12	8%	1.46	17.90	19.37	1.00
H6	12	7%	1.44	17.91	20.14	1.00
I2	8	7%	1.15	14.29	16.37	1.00
J2	9	6%	1.10	13.92	16.07	0.99
K2	8	8%	1.30	16.51	17.64	0.99
M3	9	5%	1.12	16.92	17.62	0.99

Table 13. 2006 Model Metrics at CTDEEP Primary Stations (Bottom)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
A4	11	4%	0.99	26.07	26.93	**0.09**
B3	11	3%	1.03	26.36	27.33	**0.14**
C1	10	3%	0.99	26.46	27.40	**0.03**
C2	12	3%	0.95	26.68	27.61	**0.21**
D3	11	3%	0.85	26.98	27.60	**0.20**
9	12	3%	0.94	26.42	27.13	**0.14**
E1	13	1%	0.83	27.17	27.79	**0.06**
15	13	3%	0.99	26.35	27.37	**0.06**
F2	13	2%	0.82	27.04	27.76	**0.11**
F3	13	2%	0.90	27.31	27.96	**0.11**
H2	12	2%	0.78	27.26	27.72	**0.14**
H4	12	1%	0.77	27.59	27.93	**0.02**
H6	11	1%	0.95	27.84	28.26	**0.03**
I2	8	0%	1.07	28.22	28.48	**0.35**
J2	9	2%	1.15	28.45	29.15	**0.21**
K2	8	0%	1.02	29.92	30.00	**0.46**

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
M3	8	1%	1.08	30.72	30.46	**0.17**
Temperature (°C)						
A4	11	**11%**	1.66	15.88	17.67	1.00
B3	11	9%	1.50	15.58	16.46	0.99
C1	10	9%	1.33	14.76	16.33	0.99
C2	12	4%	0.92	15.11	16.21	0.99
D3	11	4%	0.86	13.95	15.35	1.00
9	12	4%	0.94	16.08	16.41	0.99
E1	13	3%	1.04	13.82	15.22	0.99
15	13	5%	0.90	15.31	15.87	1.00
F2	13	6%	1.04	14.74	15.83	1.00
F3	13	2%	0.96	14.05	15.25	0.99
H2	12	8%	1.37	15.04	15.71	0.99
H4	12	4%	1.07	15.18	15.44	0.99
H6	11	6%	1.03	13.63	15.69	0.99
I2	8	7%	1.09	12.78	14.52	0.99
J2	9	5%	1.00	13.34	14.27	0.99
K2	8	5%	1.04	14.53	15.06	1.00
M3	8	0%	1.05	14.74	15.24	0.98

5.6.2.2 DEP Data

Skill assessment statistics for the surface and bottom model output and data for 2005 at primary DEP stations are presented in Tables 14 and 15. The bold values in these tables represent skill assessment statistics that do not meet the QAPP targets (RE between 10-15%, RMSE <4 psu, and r greater than 0.7 for salinity; RE between 5-10%, RMSE <2°C, and r greater than 0.9 for temperature). The surface salinity can change substantially over the course of a tidal cycle within the Hudson River and the surface statistical analyses, completed on an hourly comparison basis (i.e., large RE and RMSE) shows that the model does not completely capture the timing of the hourly changes in salinity. Based on the qualitative model-data comparisons, the model does capture the overall data range, but the model timing may be shifted. Further evaluation of salinity in the Hudson River will be completed as part of the full model calibration. The model does a better job of reproducing the temperature data but has an RMSE greater than the target of 2.0°C in the surface layer. The model does reproduce the DEP salinity and temperature data in the bottom layer.

Tables 16 and 17 show the model versus data statistical comparison at the DEP stations during 2006. The bold values in these tables represent skill assessment statistics that do not meet the QAPP targets (RE between 10-15%, RMSE <4 psu, and r greater than 0.7 for salinity; RE between 5-10%, RMSE <2°C, and r greater than 0.9 for temperature). The model-data surface salinity and temperature comparisons are similar to 2005 (i.e., large RE and RMSE for salinity) and will be further addressed during the full model calibration. The model does reproduce the DEP salinity and temperature data in the bottom layer at most stations.

Table 14. 2005 Model Metrics at DEP Primary Stations (Surface)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
E2	21	2%	1.56	22.75	22.67	0.81
E4	22	1%	1.37	22.91	22.93	0.74
E6	22	1%	1.23	23.10	23.57	0.85
E7	22	1%	1.15	24.00	24.20	0.76
E8	21	2%	0.96	24.12	24.78	0.70
E10	21	2%	0.97	24.68	25.28	**0.66**
H3	22	**44%**	**9.30**	17.29	9.25	**0.62**
K1	20	11%	2.72	21.02	19.24	0.87
K5A	20	8%	2.34	22.64	20.61	0.91
K6	18	4%	1.43	24.01	23.55	0.92
N1	22	**27%**	3.00	8.71	6.74	0.94
N3B	22	**20%**	3.25	11.41	9.54	0.95
N4	21	**17%**	2.95	13.89	12.58	0.96
N5	22	14%	3.38	18.32	14.79	0.95
N6	19	8%	2.59	20.65	18.96	0.83
N7	20	8%	2.63	21.30	19.91	0.90
N8	20	3%	2.21	23.10	22.35	0.78
N16	14	2%	1.03	28.96	28.30	**0.21**
Temperature (°C)						
E2	21	2%	0.98	22.07	21.84	1.00
E4	22	1%	0.99	21.51	21.03	0.99
E6	22	3%	1.09	21.00	21.50	1.00
E7	22	3%	1.03	20.27	20.21	1.00
E8	21	5%	1.12	19.22	20.31	1.00

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
E10	21	6%	1.23	20.81	20.95	1.00
H3	22	2%	1.27	23.13	23.35	0.99
K1	20	4%	1.07	21.87	21.29	0.99
K5A	20	4%	0.88	22.86	23.69	1.00
K6	18	3%	1.07	21.83	22.79	0.99
N1	22	0%	1.33	24.64	24.08	0.99
N3B	22	1%	1.12	23.89	23.63	0.99
N4	21	1%	0.95	22.82	23.41	0.99
N5	22	4%	1.07	22.42	22.61	0.99
N6	19	3%	1.12	22.10	21.83	0.99
N7	20	4%	1.12	21.98	21.86	0.99
N8	20	5%	1.17	21.65	21.33	0.99
N16	14	**11%**	**2.28**	20.35	20.94	0.97

Table 15. 2005 Model Metrics at DEP Primary Stations (Bottom)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
E2	21	0%	1.47	22.88	23.32	0.85
E4	22	4%	1.55	23.01	23.98	0.73
E6	22	3%	1.15	23.61	24.25	0.74
E7	22	4%	1.42	24.51	25.59	**0.44**
E8	21	3%	1.11	25.00	25.82	**0.32**
E10	21	1%	0.99	25.52	25.94	**0.29**
H3	22	**22%**	**5.88**	17.85	13.26	**0.56**
K1	20	1%	1.22	25.48	25.10	0.83
K5A	20	4%	1.60	23.82	23.20	0.87
K6	18	1%	1.61	24.33	25.36	**0.53**
N1	22	4%	1.70	16.55	15.24	0.94
N3B	22	0%	2.00	20.68	21.38	0.92
N4	21	2%	1.46	23.02	23.25	0.90
N5	22	3%	1.36	25.02	24.32	0.88

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
N6	19	1%	0.89	25.55	25.56	0.75
N7	20	2%	1.25	26.63	25.93	**0.66**
N8	20	2%	1.35	27.23	26.70	**0.66**
N16	14	1%	0.98	29.55	28.94	**0.01**
Temperature (°C)						
E2	21	2%	1.08	21.90	21.45	0.99
E4	22	1%	0.96	21.52	20.81	0.99
E6	22	4%	1.25	20.50	21.14	0.99
E7	22	4%	1.14	19.70	19.26	0.99
E8	21	5%	1.34	18.14	19.00	0.99
E10	21	6%	1.51	18.65	19.18	0.99
H3	22	6%	**2.02**	23.10	24.21	0.99
K1	20	7%	1.64	20.56	20.04	0.99
K5A	20	8%	1.81	21.89	23.96	1.00
K6	18	7%	1.44	21.39	22.29	0.99
N1	22	1%	1.34	22.44	22.73	0.99
N3B	22	5%	1.30	21.55	21.87	0.99
N4	21	7%	1.29	20.69	21.80	0.99
N5	22	8%	1.65	20.84	21.31	0.99
N6	19	8%	1.75	20.58	20.79	0.99
N7	20	9%	1.69	20.29	20.35	0.99
N8	20	9%	**2.11**	19.22	20.18	0.98
N16	14	**11%**	**2.39**	19.36	19.99	0.96

Table 16. 2006 Model Metrics at DEP Primary Stations (Surface)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
E2	22	1%	1.92	21.22	20.99	0.86
E4	22	1%	1.57	22.08	22.31	0.84
E6	23	1%	0.69	22.87	23.07	0.97
E7	23	1%	0.84	24.13	24.16	0.85

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
E8	22	2%	0.83	24.52	25.04	0.78
E10	21	3%	0.85	25.04	25.46	0.87
H3	20	**75%**	**11.23**	17.31	3.63	**0.66**
K1	18	**19%**	3.98	19.39	14.78	0.98
K5A	18	10%	**4.81**	21.48	19.13	**0.57**
K6	17	5%	2.08	23.22	22.27	0.90
N1	20	**66%**	3.85	6.01	1.84	0.94
N3B	20	**55%**	**4.37**	9.27	4.24	0.91
N4	20	**48%**	**4.67**	11.87	6.85	0.88
N5	20	**35%**	**5.26**	15.59	10.19	0.90
N6	18	**17%**	3.40	19.54	14.33	0.89
N7	18	14%	3.82	17.50	14.84	0.89
N8	16	4%	1.88	21.17	19.80	0.96
N16	14	2%	1.01	29.60	28.36	0.80
Temperature (°C)						
E2	22	6%	1.37	19.76	21.79	1.00
E4	22	6%	1.30	19.63	21.50	1.00
E6	23	5%	1.30	20.42	21.39	0.99
E7	23	8%	1.67	18.59	20.58	0.99
E8	22	8%	1.70	18.46	21.47	1.00
E10	21	7%	1.85	18.46	21.08	0.99
H3	20	3%	1.54	20.49	21.31	0.98
K1	18	5%	1.27	20.10	20.26	0.99
K5A	18	4%	1.44	20.68	21.28	0.99
K6	17	6%	1.32	20.13	21.01	0.99
N1	20	1%	0.72	21.94	21.65	1.00
N3B	20	2%	0.86	21.76	21.31	1.00
N4	20	3%	1.03	21.13	20.48	0.99
N5	20	6%	1.49	20.07	21.03	0.99
N6	18	6%	1.20	20.23	20.47	0.99
N7	18	5%	1.23	19.76	21.16	0.99
N8	16	6%	1.20	20.19	21.77	0.99

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
N16	14	9%	1.95	19.59	20.93	0.97

Table 17. 2006 Model Metrics at DEP Primary Stations (Bottom)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
E2	22	1%	1.00	22.01	22.14	0.86
E4	22	5%	1.38	22.15	23.46	0.87
E6	23	2%	0.92	24.06	24.13	0.81
E7	23	6%	1.57	24.66	26.28	**0.65**
E8	22	4%	1.02	25.51	26.60	**0.68**
E10	21	4%	1.00	25.95	26.93	0.77
H3	20	**29%**	**5.43**	17.43	12.23	0.77
K1	18	3%	2.66	25.54	24.57	**0.49**
K5A	18	8%	2.87	23.53	21.82	**0.54**
K6	17	1%	0.94	24.42	24.62	0.77
N1	20	10%	3.65	14.74	13.74	0.82
N3B	20	1%	2.93	19.80	20.19	**0.62**
N4	20	0%	2.37	21.90	22.01	**0.58**
N5	20	4%	1.73	24.81	24.02	**0.59**
N6	18	2%	1.45	27.06	26.15	0.71
N7	18	2%	1.71	26.39	26.31	**0.39**
N8	16	4%	1.61	28.72	27.20	0.75
N16	14	2%	1.22	30.56	29.74	**0.28**
Temperature (°C)						
E2	22	6%	1.28	19.16	21.86	1.00
E4	22	5%	1.15	19.73	21.16	1.00
E6	23	8%	1.79	18.87	21.01	0.99
E7	23	8%	1.53	17.79	19.18	0.99
E8	22	**10%**	**2.00**	16.23	19.81	0.99
E10	21	**12%**	1.93	16.29	18.40	0.99
H3	20	**11%**	2.32	20.47	22.46	0.98

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
K1	18	8%	1.52	17.73	17.48	1.00
K5A	18	9%	**2.70**	18.78	21.69	0.98
K6	17	8%	1.47	18.98	21.03	1.00
N1	20	6%	1.45	20.47	21.53	0.99
N3B	20	6%	1.44	19.16	19.65	1.00
N4	20	7%	1.57	18.35	17.55	1.00
N5	20	8%	1.83	17.33	18.83	0.99
N6	18	9%	1.57	17.25	17.34	1.00
N7	18	8%	1.43	17.74	18.62	1.00
N8	16	9%	1.95	18.64	19.45	0.99
N16	14	**10%**	1.93	17.83	19.66	0.97

5.6.2.3 LISICOS Data

Statistics were also calculated for the comparison between the model and available 2006 LISICOS continuous buoy data. Comparisons are presented in Tables 18, 19 and 20 for the surface, middle and bottom depths, respectively. The bold values in these tables represent skill assessment statistics that do not meet the QAPP targets (RE between 10-15%, RMSE <4 psu, and r greater than 0.7 for salinity; RE between 5-10%, RMSE <2°C, and r greater than 0.9 for temperature). In some cases, the bottom salinity data had significantly lower salinity than the surface data and in these cases the data was removed from the calculations. In general, the model compares well against the salinity and temperature data. The relative error for temperature is high at stations FB01 and FB03 at the surface, but these locations have relatively short durations during cold weather so small differences in temperature result in large relative error. Overall, the model comparison to the LISICOS buoy data in 2006 is good.

Table 18. 2006 Model Metrics at LISICOS Stations (Surface)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
EXRK	34,381	1%	0.58	25.39	25.36	0.82
FB01	5,607	0%	0.24	25.93	25.94	**0.66**
FB02	25,743	2%	0.97	25.60	26.11	**0.33**
FB03	6,061	0%	0.21	25.40	25.33	0.84

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
WLIS	27,259	1%	0.60	26.16	26.29	**0.69**
Temperature (°C)						
EXRK	33,865	6%	1.08	13.22	13.61	1.00
FB01	5,955	**77%**	**2.28**	2.52	4.66	0.99
FB02	25,841	6%	1.17	13.95	16.39	0.99
FB03	5,855	**46%**	1.90	3.06	4.86	0.98
WLIS	26,874	7%	1.18	13.86	15.77	0.99

Table 19. 2006 Model Metrics at LISICOS Stations (Mid-Depth)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
EXRK	20,067	3%	0.89	25.82	26.21	**0.63**
FB01	6,015	1%	0.36	25.93	26.14	0.88
FB02	14,941	3%	1.13	25.71	26.61	**0.59**
FB03	Not Available					
WLIS	16,917	3%	0.89	25.86	26.64	**0.63**
Temperature (°C)						
EXRK	20,128	6%	1.06	14.01	14.20	1.00
FB01	6,003	3%	0.55	4.06	4.12	0.98
FB02	14,098	3%	1.24	16.36	15.90	0.99
FB03	Not Available					
WLIS	14,892	5%	1.37	12.75	12.59	0.99

Table 20. 2006 Model Metrics at LISICOS Stations (Bottom)

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
Salinity (psu)						
EXRK	20,957	3%	0.90	25.82	26.44	**0.65**
FB01	5,588	1%	0.27	26.50	26.17	0.94
FB02	9,821	4%	0.97	26.39	26.90	0.86

Station	n	RE	RMSE (psu or °C)	Data Median (psu or °C)	Model Median (psu or °C)	r
FB03	6,065	2%	0.54	25.53	26.04	0.84
WLIS	8,863	0%	0.22	27.25	26.86	0.96
Temperature (°C)						
EXRK	20,771	8%	1.39	13.83	14.85	0.99
FB01	6,042	1%	0.50	4.06	3.88	0.98
FB02	9,719	**10%**	1.82	18.42	16.13	0.98
FB03	5,842	1%	0.61	4.10	4.06	0.96
WLIS	8,830	6%	1.04	16.39	14.01	1.00

5.6.3 Velocity

Model velocity versus data statistics were calculated for the LISICOS ADCP data. The ADCP data were available at multiple depths, but for the comparisons, near surface, mid-depth, and near bottom locations were chosen. Data were extracted on an hourly basis to compare to hourly model output. Results are presented in Tables 21, 22 and 23. The bold values in these tables represent skill assessment statistics that do not meet the QAPP targets (RE between 20-25%, RMSE <20 cm/s, and r greater than 0.7). The ADCP data have a median surface velocity ranging from 14 to 20 cm/s and the model has a slightly higher median surface velocity ranging from 16 to 26 cm/s. The differences in velocities resulted in some higher than desired REs. The resulting RMSE was about half the magnitude of the median velocities.

Both the model and data show decreasing velocities with depth and the model more closely reproduces the measured bottom velocities. Median bottom data velocities ranged from 12 to 15 cm/s while the model ranged from 12 to 14 cm/s. The model near-bottom velocity RE and RMSE are smaller than that calculated at the surface.

Table 21. 2006 Model Velocity Metrics at LISICOS Stations (Surface)

Station	n	RE	RMSE (cm/s)	Data Median (cm/s)	Model Median (cm/s)	r
EXRK	1,106	4%	8	14	16	**0.58**
FB01	1,202	3%	7	18	19	0.76
FB02	1,139	6%	7	19	21	0.80
FB03	1,199	**35%**	12	18	26	0.72
WLIS	1,100	21%	9	20	26	0.80

Table 22. 2006 Model Velocity Metrics at LISICOS Stations (Mid-Depth)

Station	n	RE	RMSE (cm/s)	Data Median (cm/s)	Model Median (cm/s)	r
EXRK	1,106	**26%**	7	10	13	**0.58**
FB01	1,202	4%	8	14	15	**0.64**
FB02	1,139	19%	8	13	15	0.74
FB03	1,199	**40%**	12	17	26	**0.57**
WLIS	1,100	14%	7	14	16	0.77

Table 23. 2006 Model Velocity Metrics at LISICOS Stations (Bottom)

Station	n	RE	RMSE (cm/s)	Data Median (cm/s)	Model Median (cm/s)	r
EXRK	1,106	1%	5	12	13	0.75
FB01	1,203	3%	7	13	12	**0.56**
FB02	1,139	0%	4	12	12	0.78
FB03	1,201	9%	8	15	14	0.68
WLIS	1,100	11%	6	13	14	0.66

6 Summary and Next Steps

A preliminary calibration of the LIS ROMS hydrodynamic model was conducted for CY 2005 and 2006. These are two of the data rich years of the 10-year model calibration period of CY 2005-2014. The goals of the preliminary calibration were to develop the process of creating model inputs and assessing the resulting model calibration using these approaches. Additionally, the preliminary calibration process provided an understanding of how and where the preliminary calibration may be improved during the full calibration process.

Model versus data comparisons were conducted qualitatively using visual graphical comparisons and quantitatively using skill assessment statistical metrics. Preliminary calibration included model-data comparisons to water elevation, temperature, salinity, and velocity data from CTDEEP, DEP and LISICOS data sources. The monitoring stations from these data sources included all of LIS, the Hudson River and NY/NJ Harbor. A summary of the preliminary calibration is presented below along with the next steps planned to further improve the model calibration to the full time period (CY2005-2014).

6.1 Water Elevation

The ROMS hydrodynamic model reproduces spatial variations in the magnitude and timing of available water elevation data. However, the model tends to overestimate the tidal range at most locations. Also, the model does not reproduce water elevations in the Hackensack River where the river's geometry and bathymetry are not well defined.

The planned next step to improve the model calibration involves further review and adjustment of the model geometry and bathymetry in the East River, Harlem River, Hudson River and Hackensack/Passaic Rivers. Although model sensitivities were completed to adjust the bottom roughness length coefficient spatially, limited improvements in the calculated tidal range were achieved. After adjustments to the model geometry and bathymetry, additional model sensitivities to the spatially varying bottom roughness length coefficient will be explored.

A minimum water depth of five meters was initially used to help keep the model stable and prevent model crashes. This minimum depth specification will be reviewed further as there are areas (e.g., Hackensack River) where this adjustment does not represent the local bathymetry well. Local changes in water depth and cross-sectional area are expected to improve the model water elevation calibration.

6.2 Temperature and Salinity

Time-series, vertical profile, and transect model-data comparisons for temperature and salinity show the model reproduces temperature and salinity fairly well throughout the model study area. The model also performs well against skill assessment quantitative targets. Nonetheless, there are time periods and areas in the model study area (e.g., East River, Harlem River, Hudson River) that can be further improved during the full model calibration. In general, the model over-estimates surface temperature during the spring/summertime periods at some locations, and in areas such as the East River, Harlem River and Hudson River the model-calculated salinity can be further improved to better reproduce the data.

Currently, the model uses the same LIS specific Jerlov Water Type (i.e., not one of the ROMS standard Jerlov Water Types) or light extinction coefficient throughout the model study area and is assigned as a constant in time, based on vertical PAR data and calculated light extinction coefficients in LIS. However, water clarity can vary both spatially and temporally within the study area due to changes in turbidity and chlorophyll-a levels. The planned next step to improve the model temperature calibration is to adjust, potentially spatially and temporally, the Jerlov Water Type or light extinction coefficient.

With regards to improving the model salinity calibration, it is anticipated that the model geometry and bathymetry adjustments planned to improve the model water elevation calibration will also help improve the model salinity calibration. The East River and Harlem River geometry and bathymetry changes are anticipated to improve the transport and volume flux of water between the Hudson River and the East River, which in turn are anticipated to improve the model salinity calibration and potentially the model temperature calibration.

6.3 Velocity

The model generally reproduced the magnitude of the median LISICOS ADCP velocities. While the model near-surface velocities appear to be slightly higher than the data, the model geometry and bathymetry adjustments planned to further evaluate the model water elevation and salinity calibration should help improve velocity calibration. Further evaluation of the velocity calibration will be completed as the model geometry and bathymetry are refined during the full model calibration process.

6.4 Volume Flux

The model calculated volume fluxes through the East River are in the same direction as modeled in previous studies but the magnitude of the net flux westward is smaller than calculated in previous studies. The previous modeling was completed with a coarse model grid as compared to the current LIS model and had less accurate bathymetry data, so it is not clear that the previous modeling volume fluxes were more accurate. After the model geometry and bathymetry adjustments planned to further evaluate the model water elevation and salinity calibration, the East River volume fluxes will be re-calculated and re-analyzed. In addition, volume fluxes at other East River transects will be evaluated.

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8 Figures

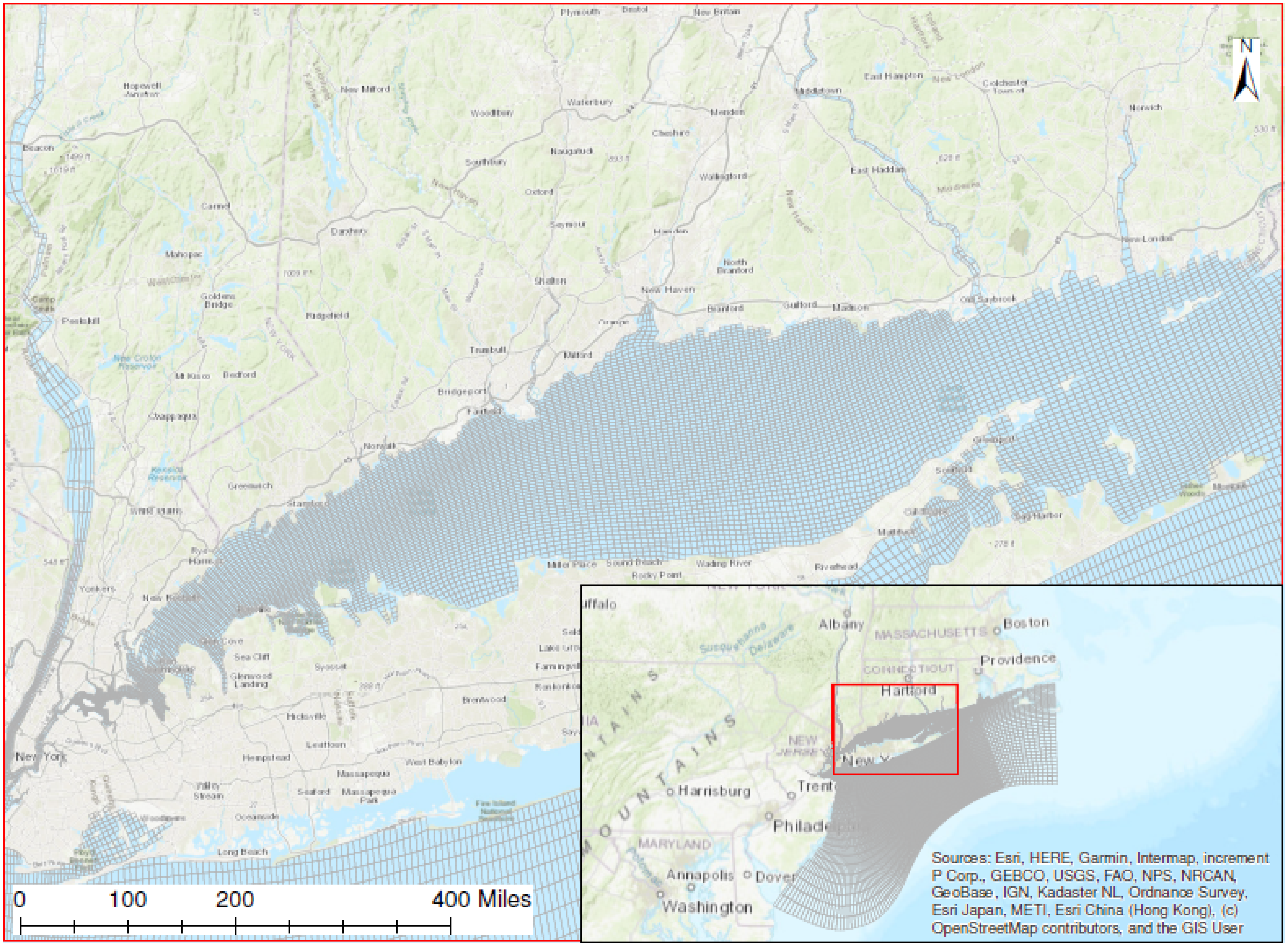


Figure 1. Project Area and Model Grid

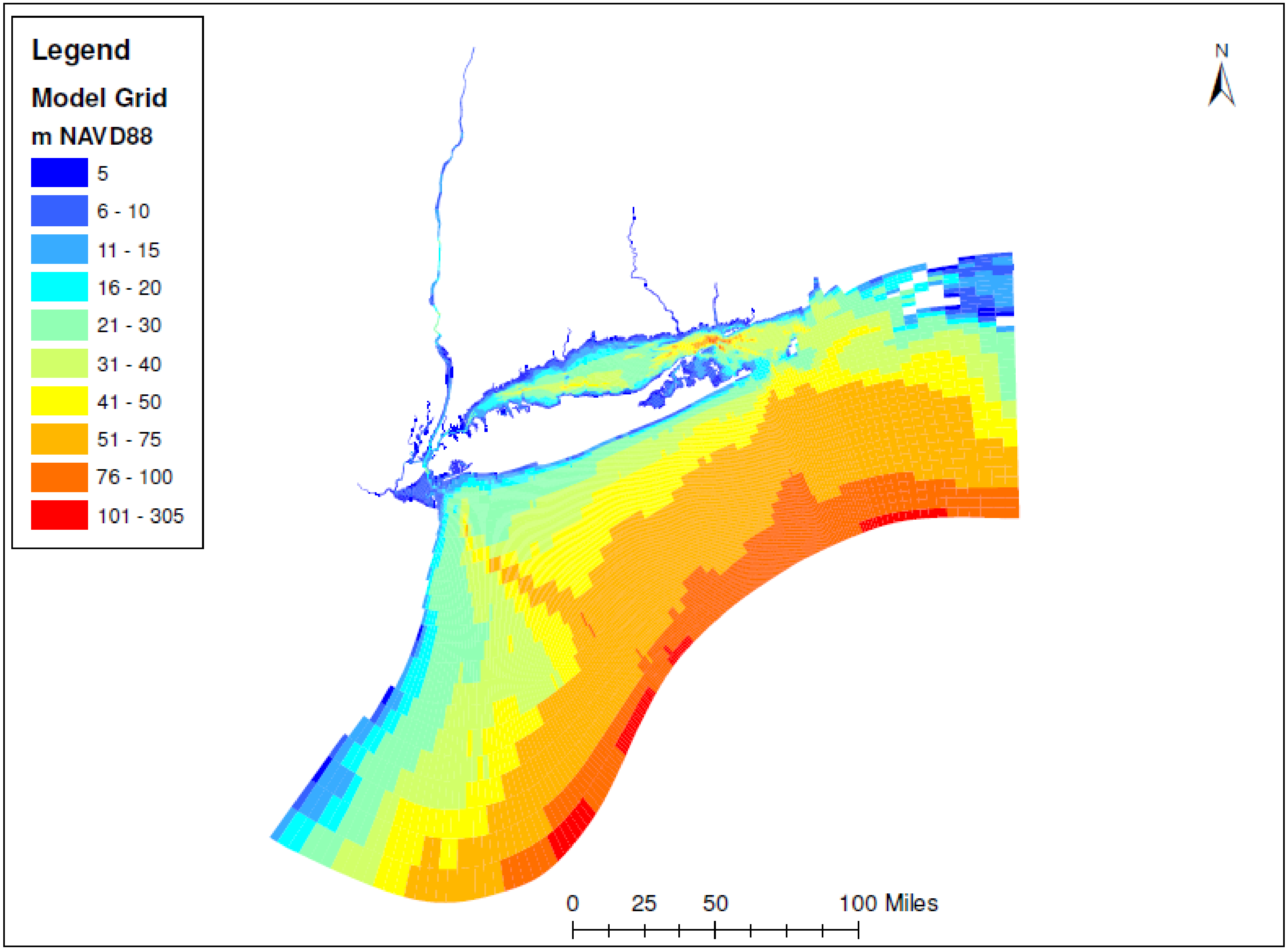


Figure 2. Model Bathymetry

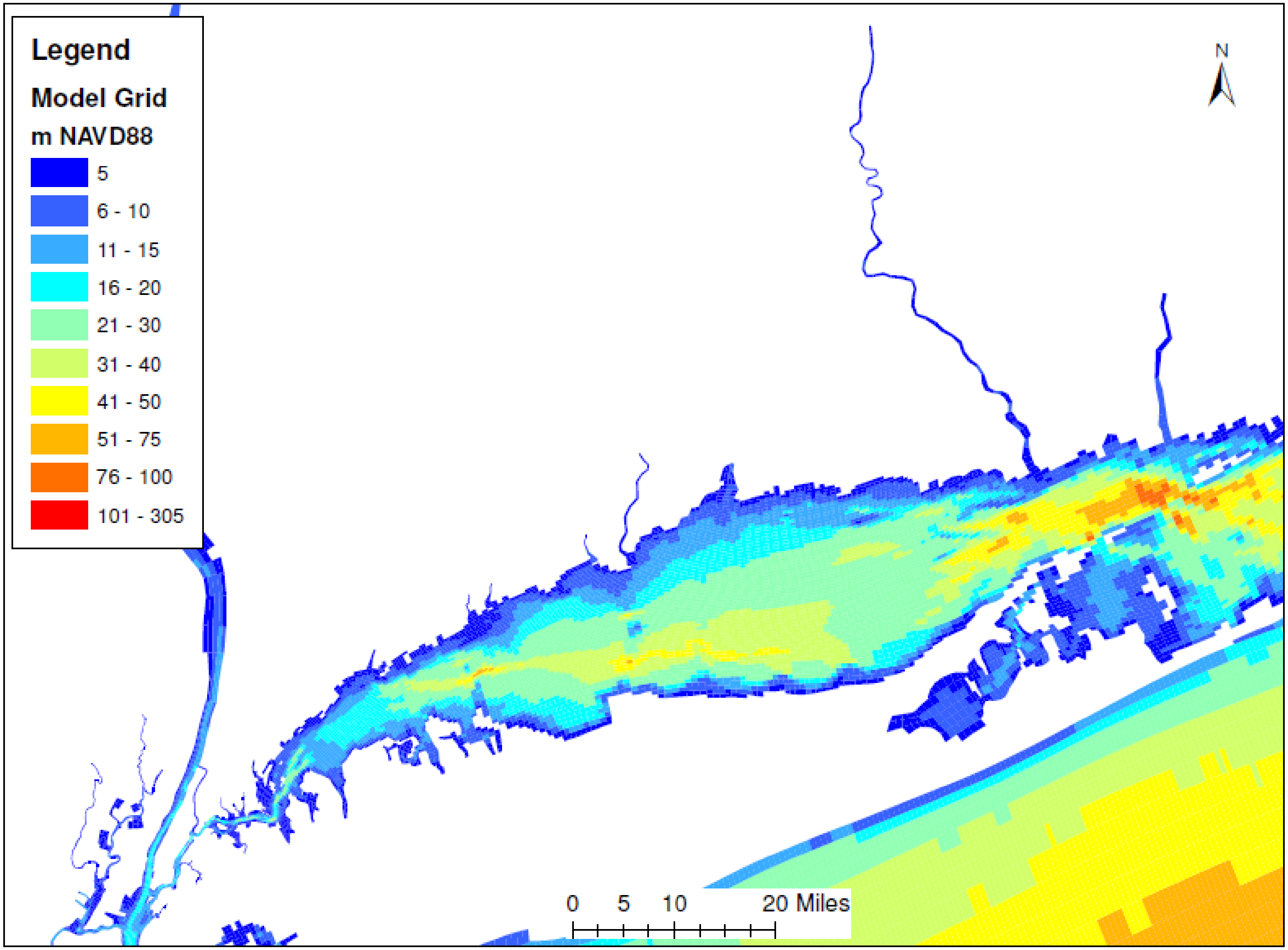


Figure 3. Model Bathymetry in LI

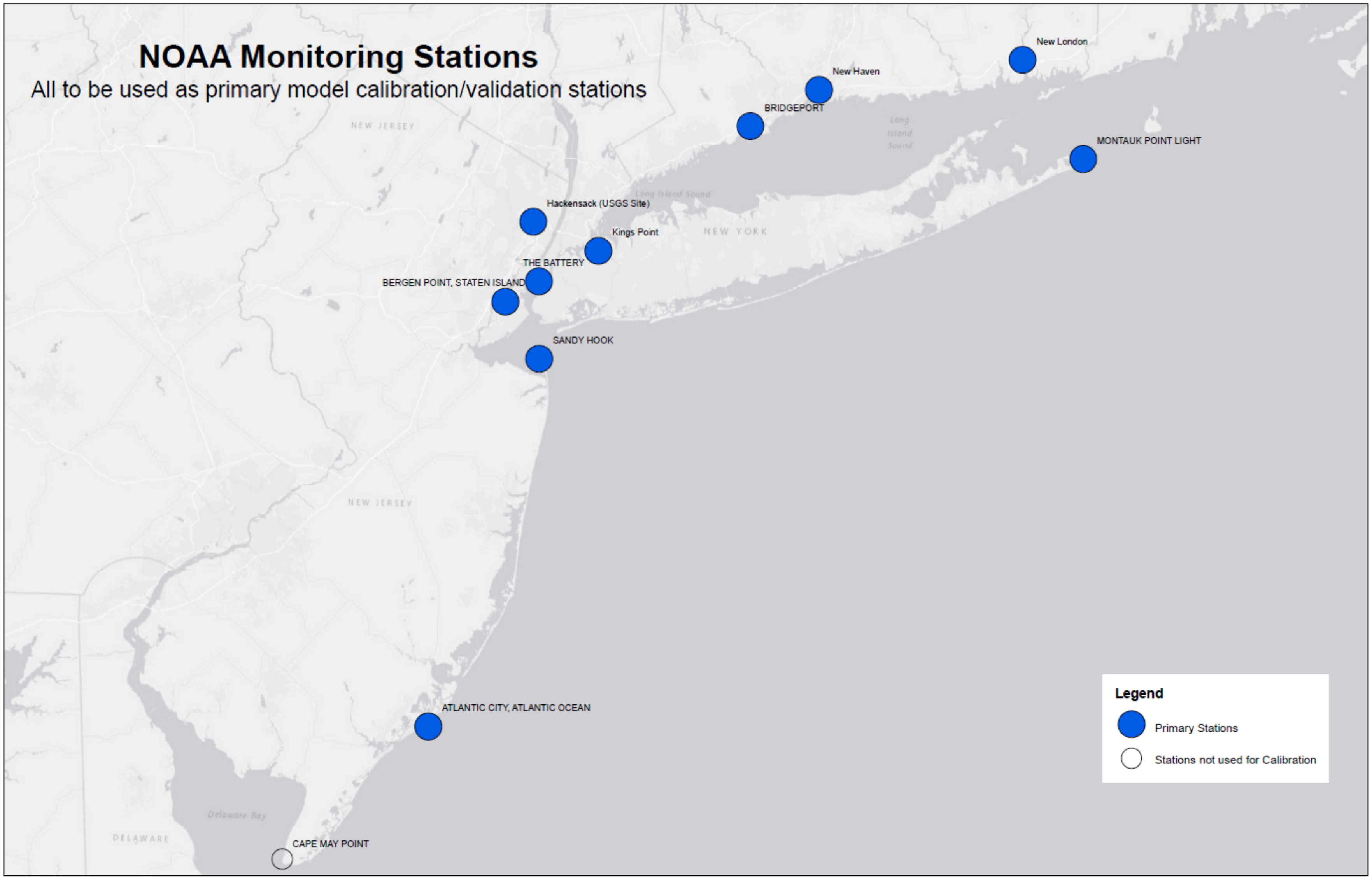


Figure 4. NOAA and USGS Water Elevation Gauge Locations

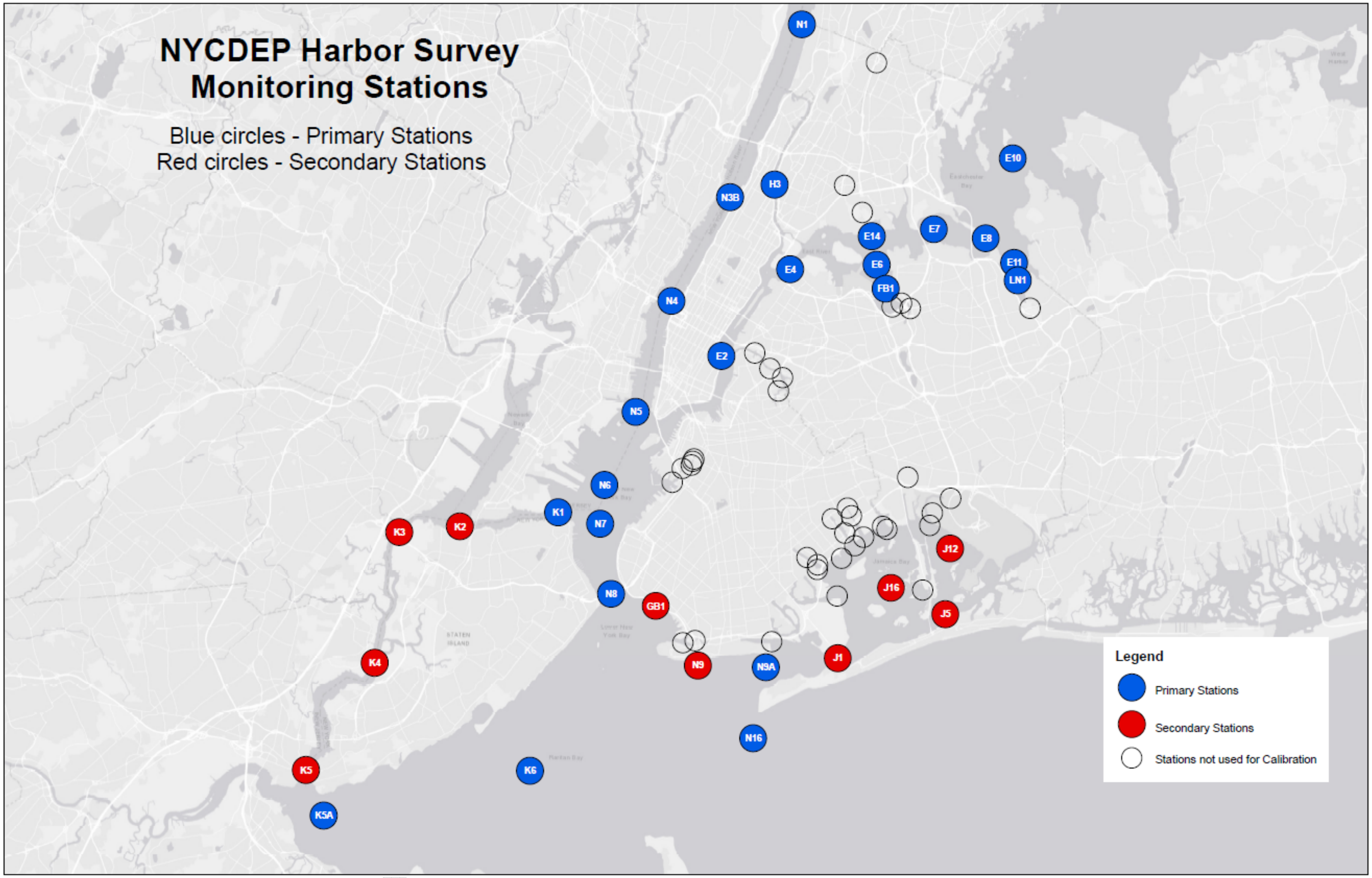


Figure 5. NYCDEP Harbor Survey Water Quality Monitoring Stations

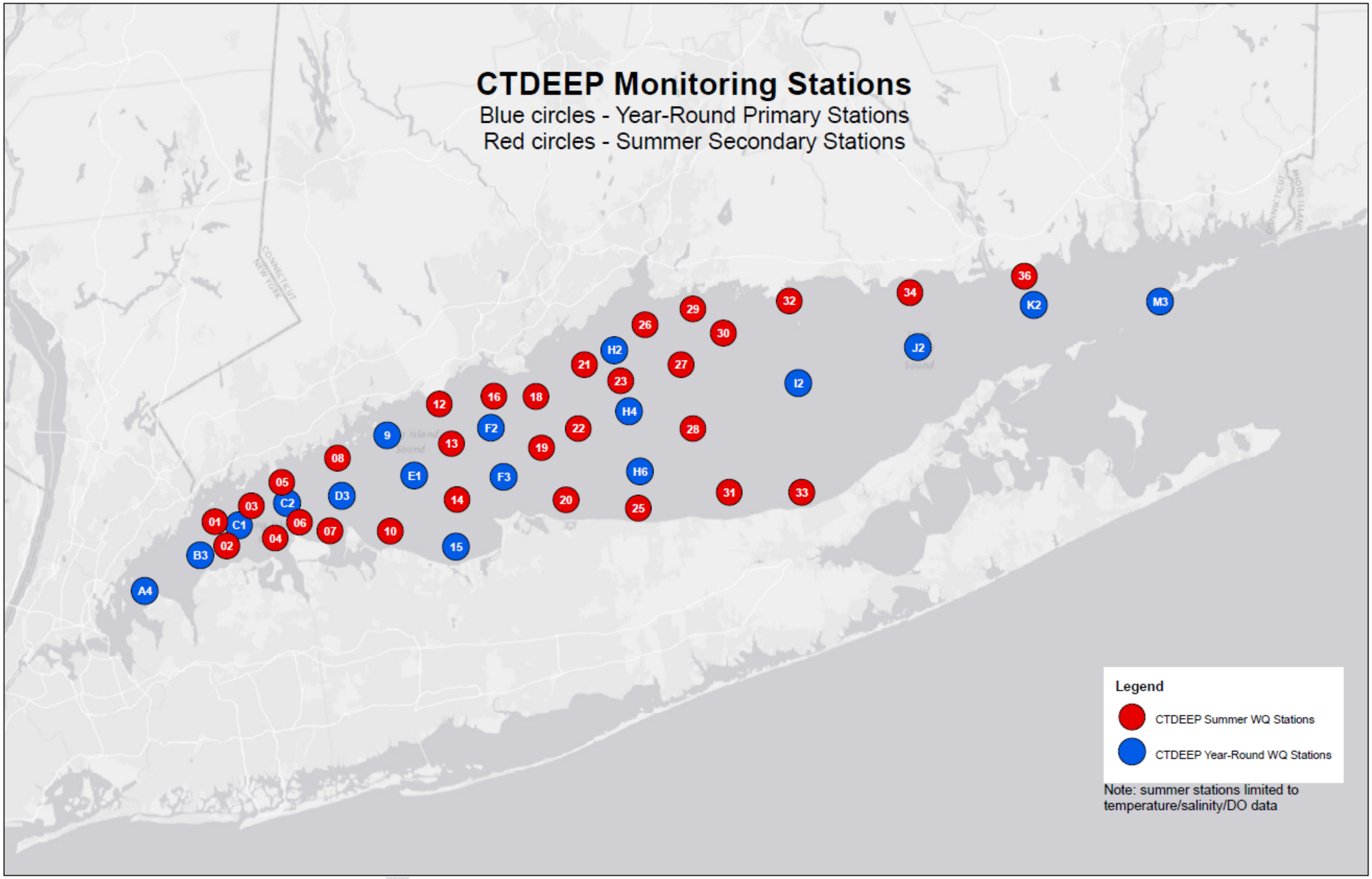


Figure 6. CTDEEP Water Quality Monitoring Stations

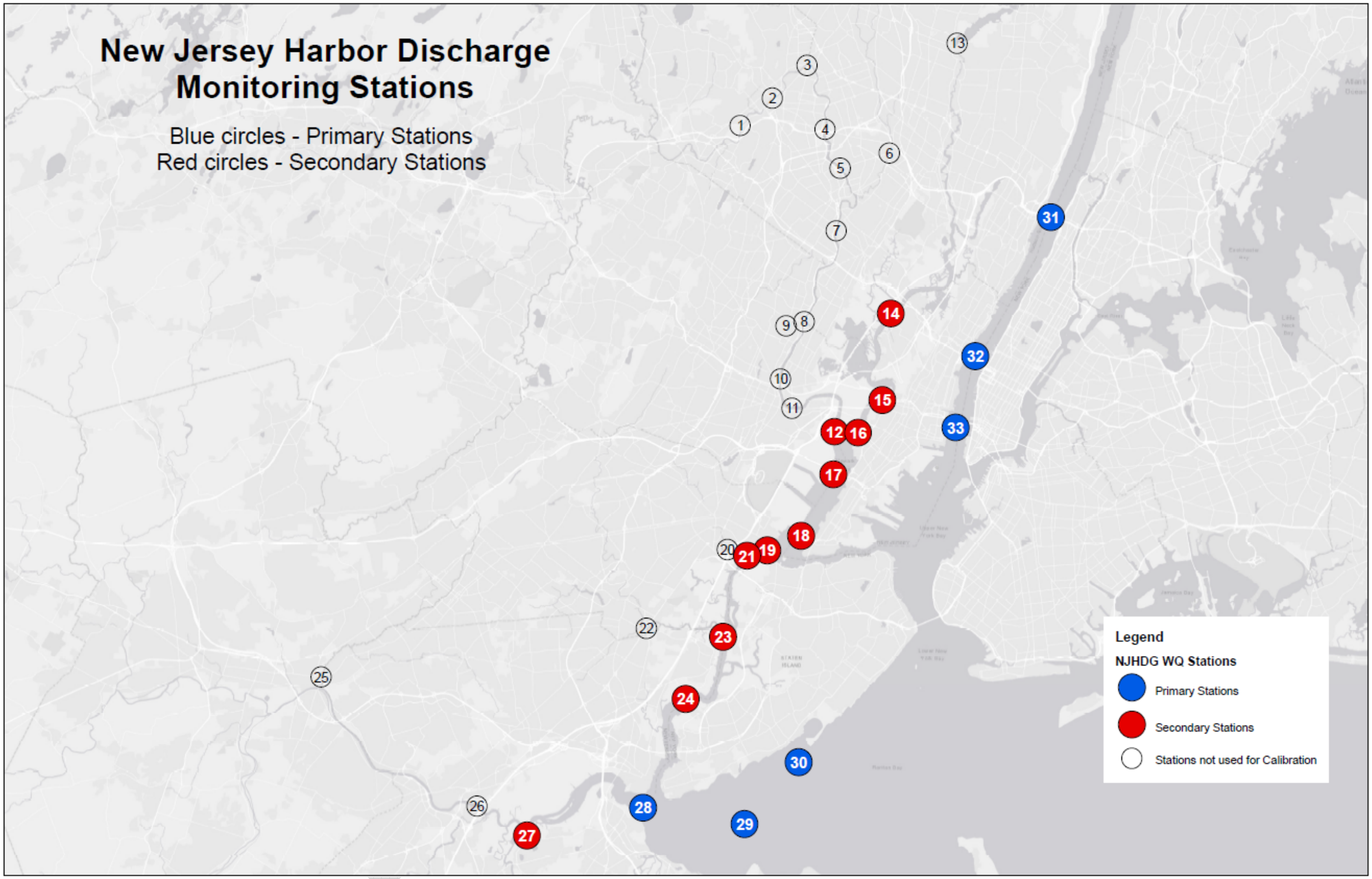


Figure 7. NJHDG Water Quality Monitoring Stations

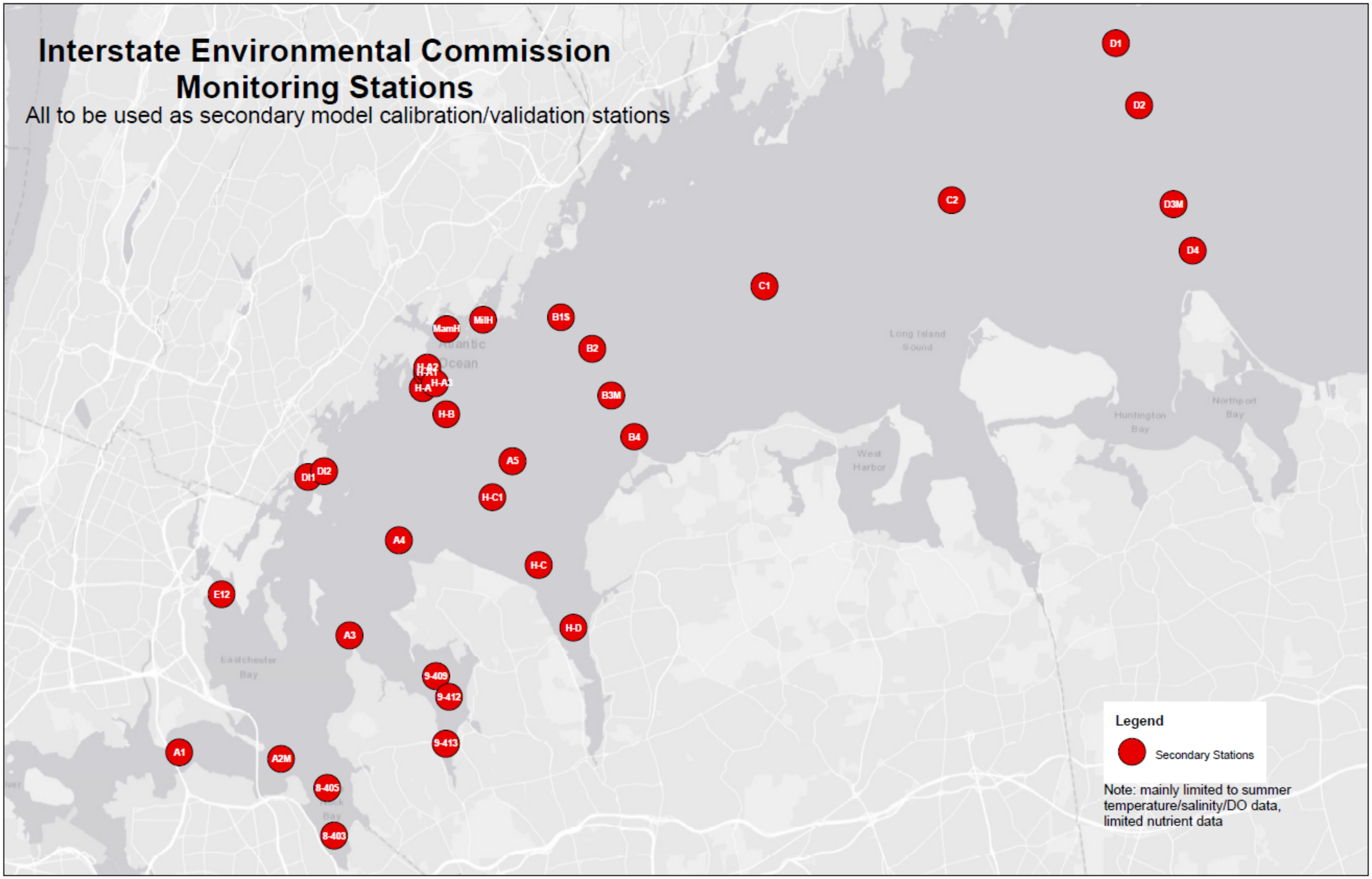


Figure 8. IEC Water Quality Monitoring Stations

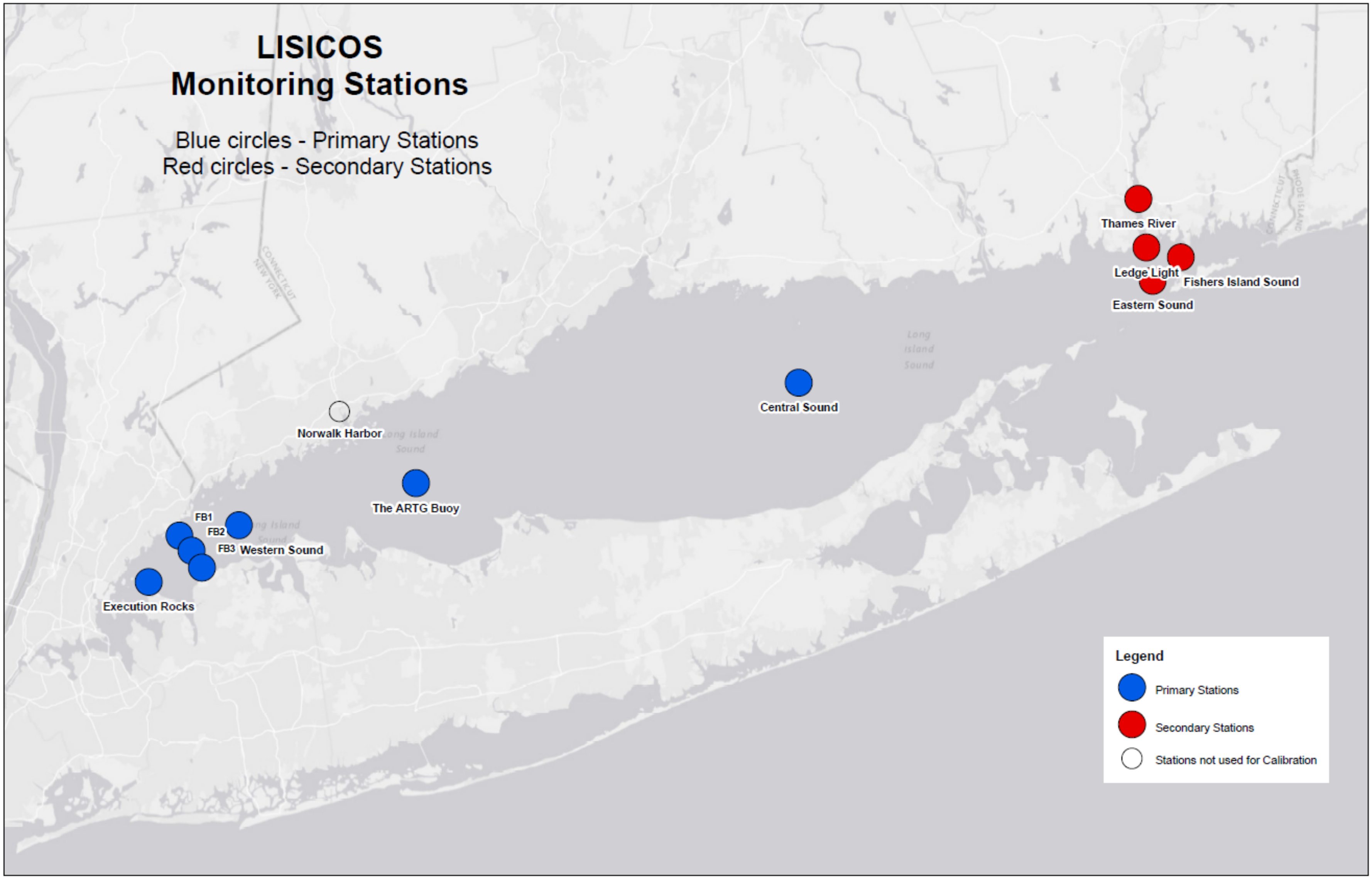


Figure 9. LISICOS Monitoring Stations

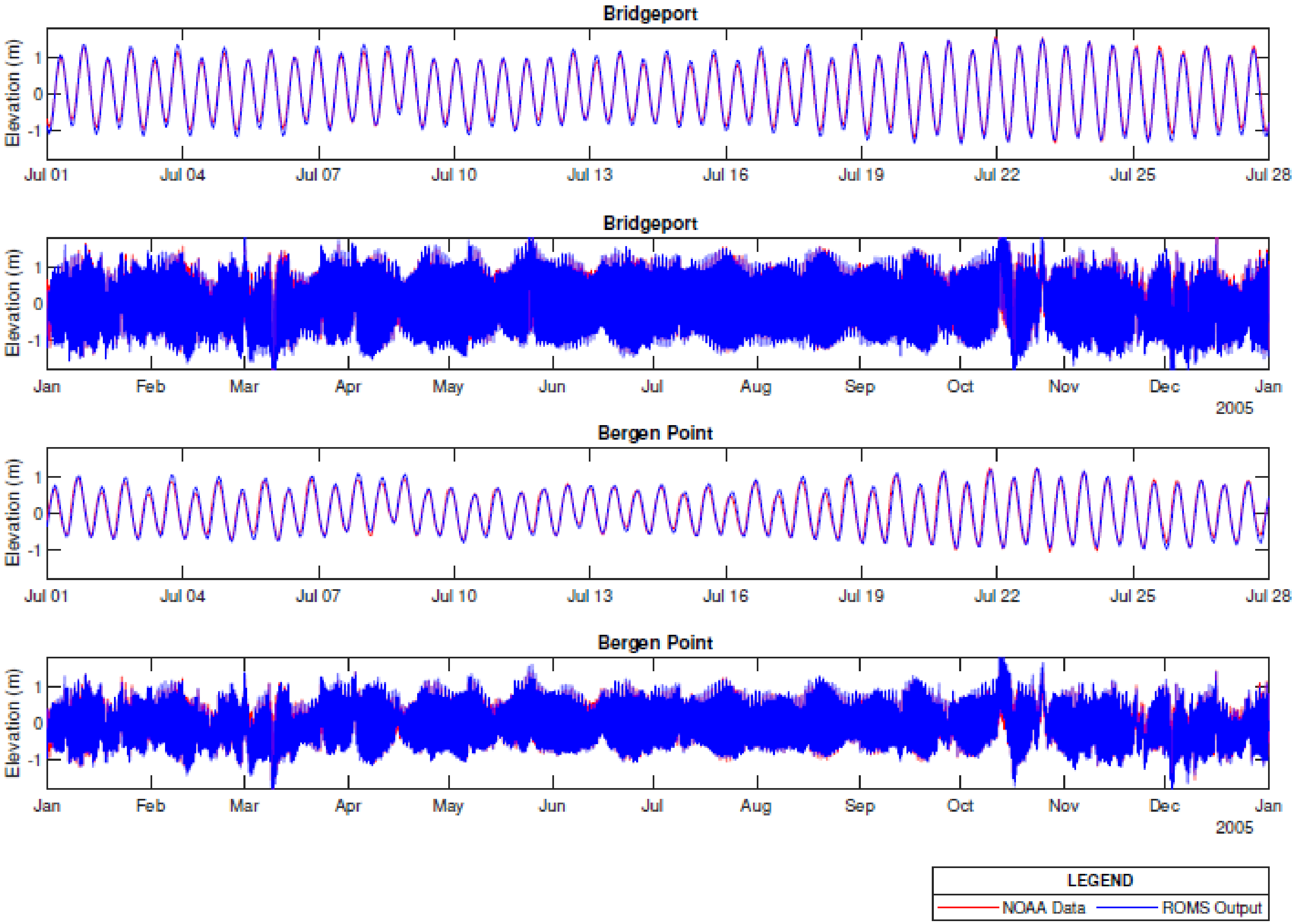


Figure 10. Water Elevation Comparisons between Model and Data at Bridgeport, CT and Bergen Point, NY in 2005

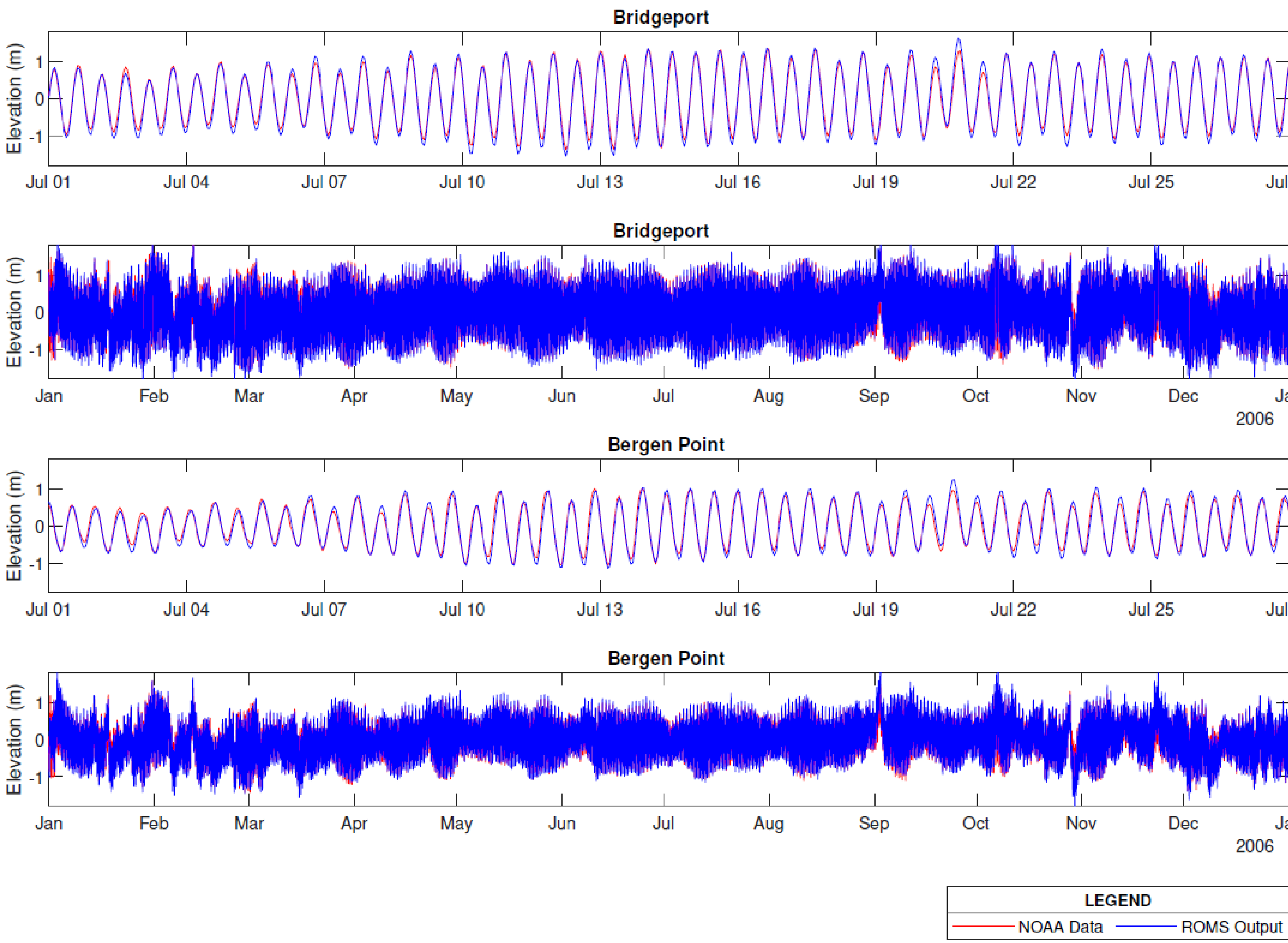


Figure 11. Water Elevation Comparisons between Model and Data at Bridgeport, CT and Bergen Point, NY in 2006

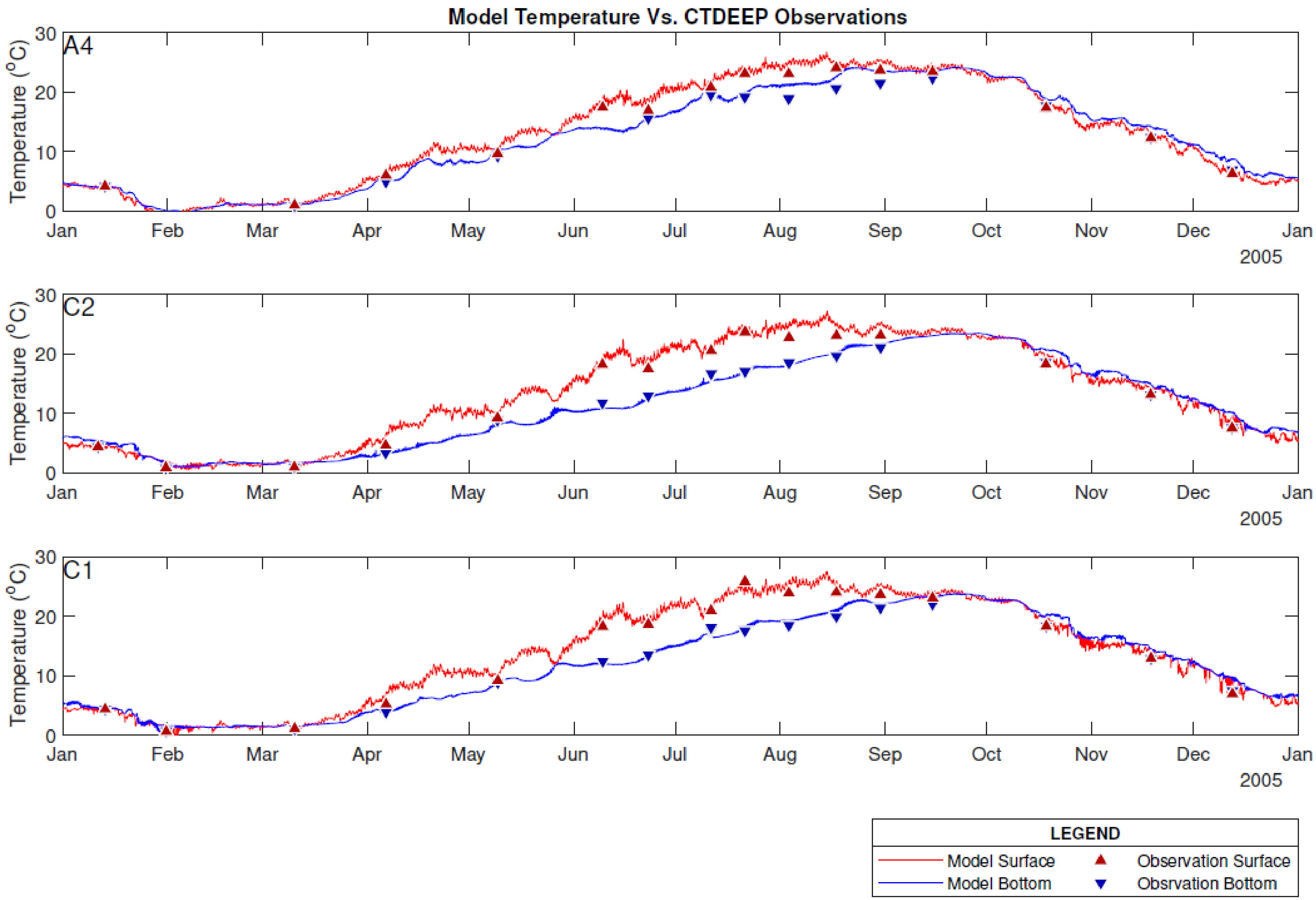


Figure 12. Temperature Comparisons between Model and Data at Western Long Island CTDEEP Stations A4, C2, and C1 in 2005

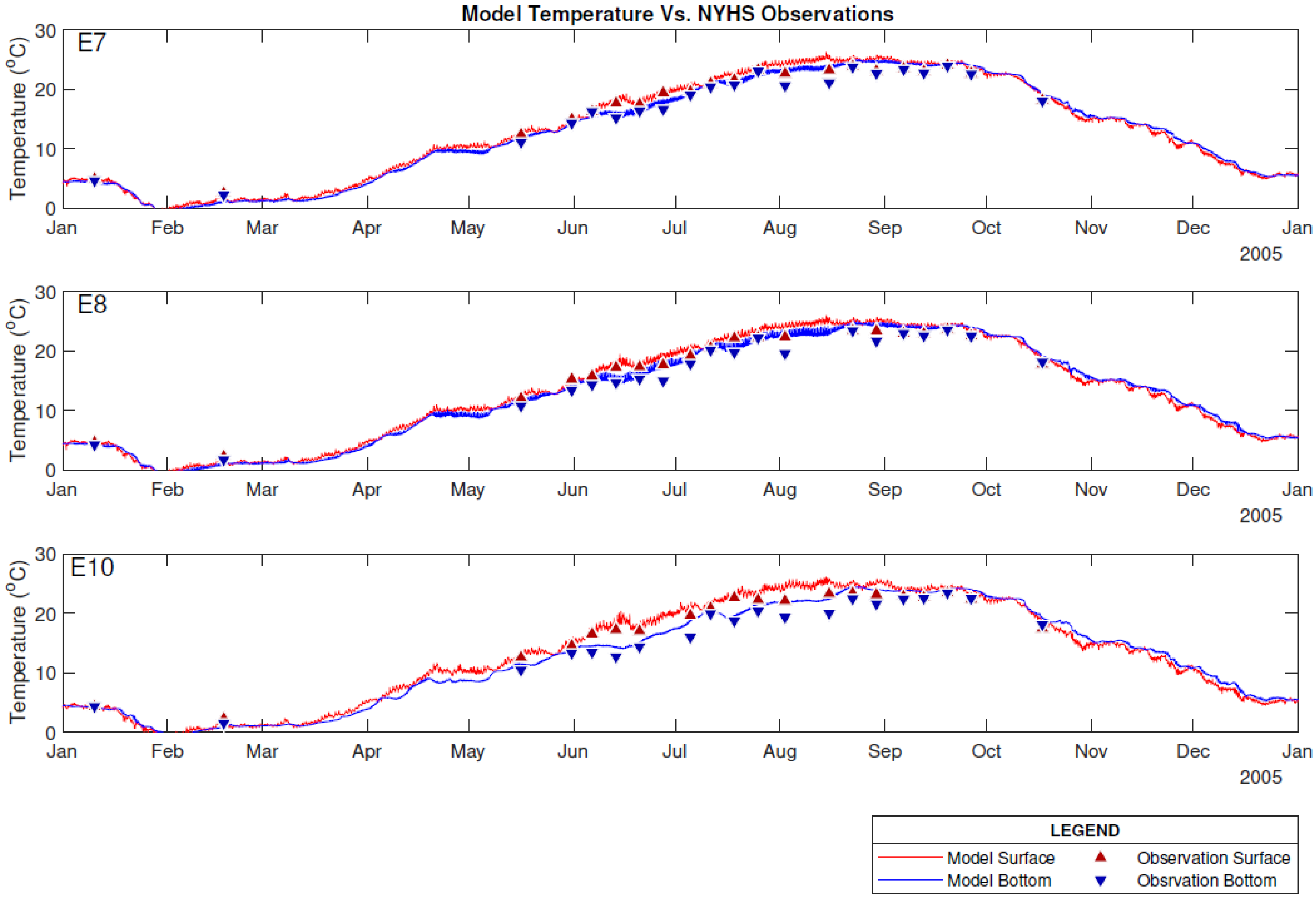


Figure 13. Temperature Comparisons between Model and Data at East River NYCDEP Stations E7, E8, and E10 in 2005

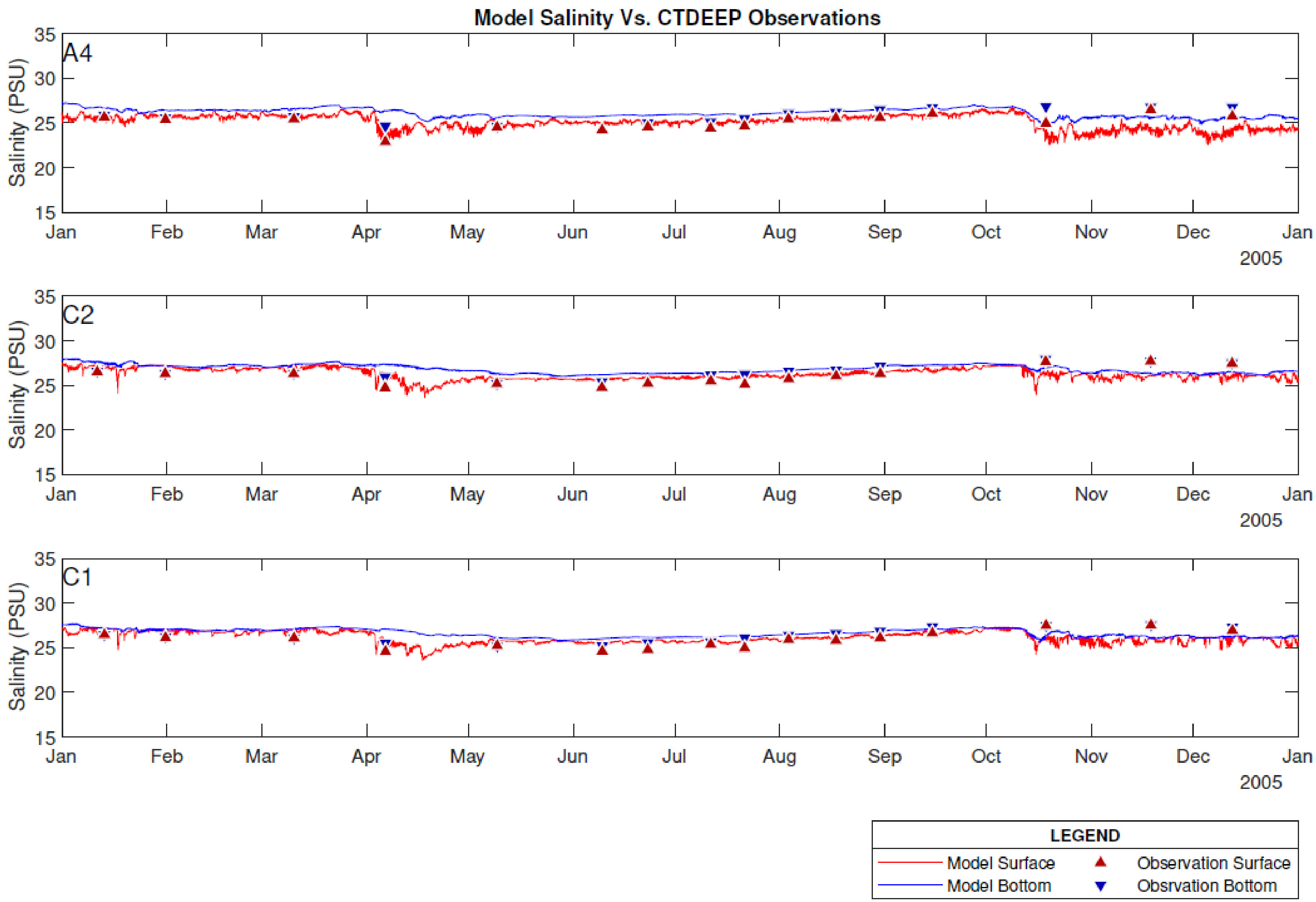


Figure 14. Salinity Comparisons between Model and Data at Western Long Island CTDEEP Stations A4, C2, and C1 in 2005

Figure 15. Salinity Comparisons between Model and Data at East River NYCDEP Stations E7, E8, and E10 in 2005

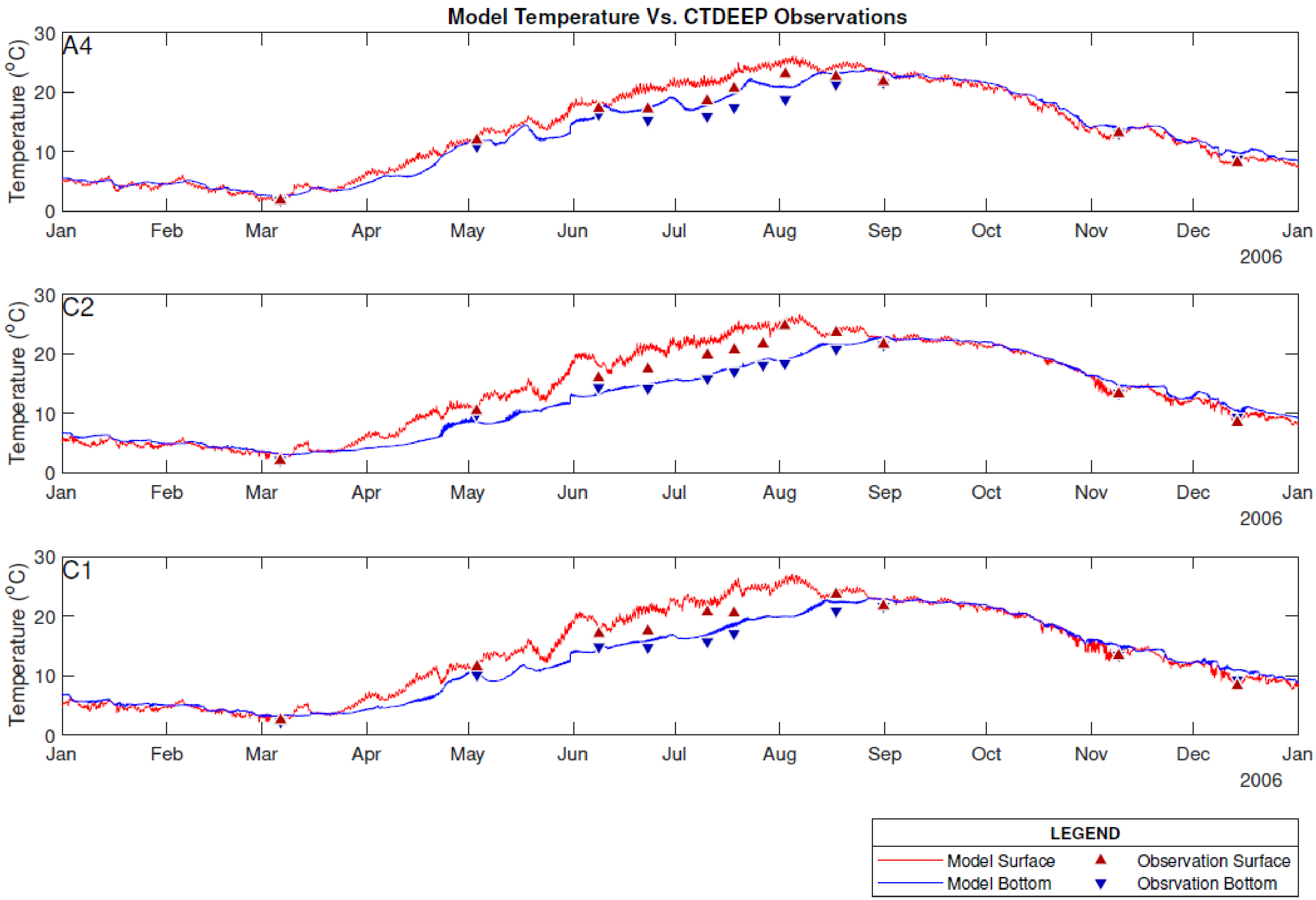


Figure 16. Temperature Comparisons between Model and Data at Western Long Island CTDEEP Stations A4, C2, and C1 in 2006

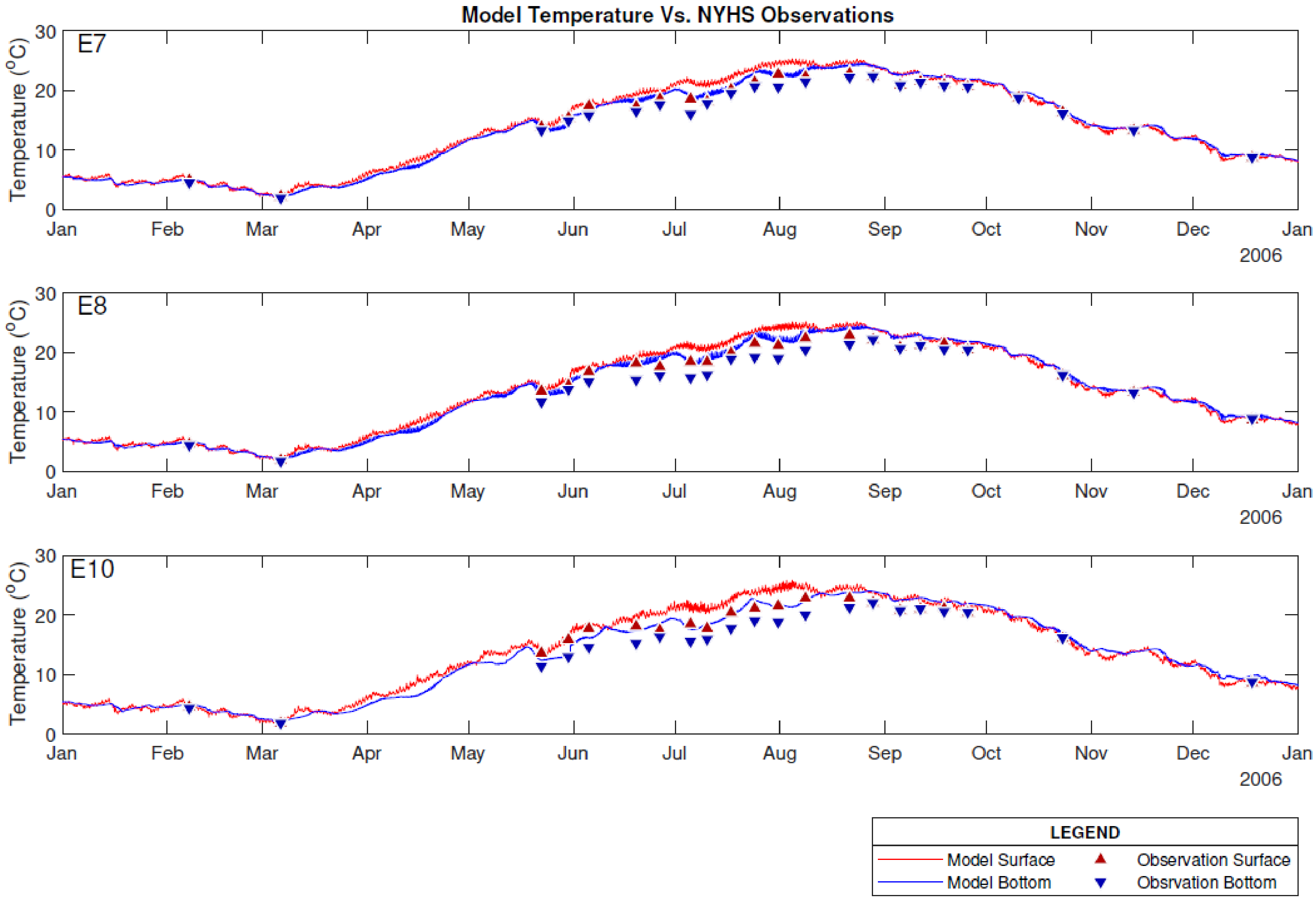


Figure 17. Temperature Comparisons between Model and Data at East River NYCDEP Stations E7, E8, and E10 in 2006

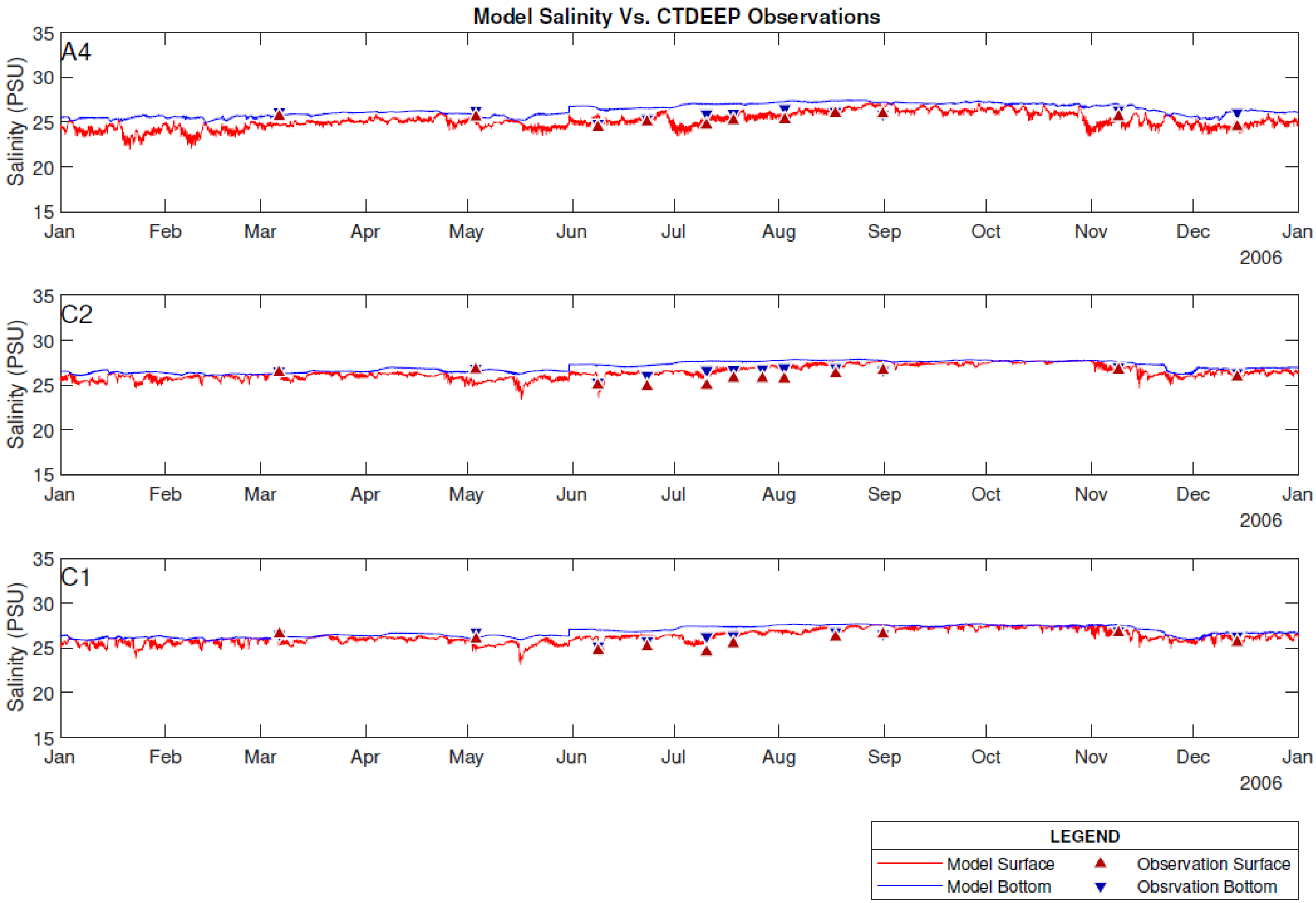


Figure 18. Salinity Comparisons between Model and Data at Western Long Island CTDEEP Stations A4, C2, and C1 in 2006

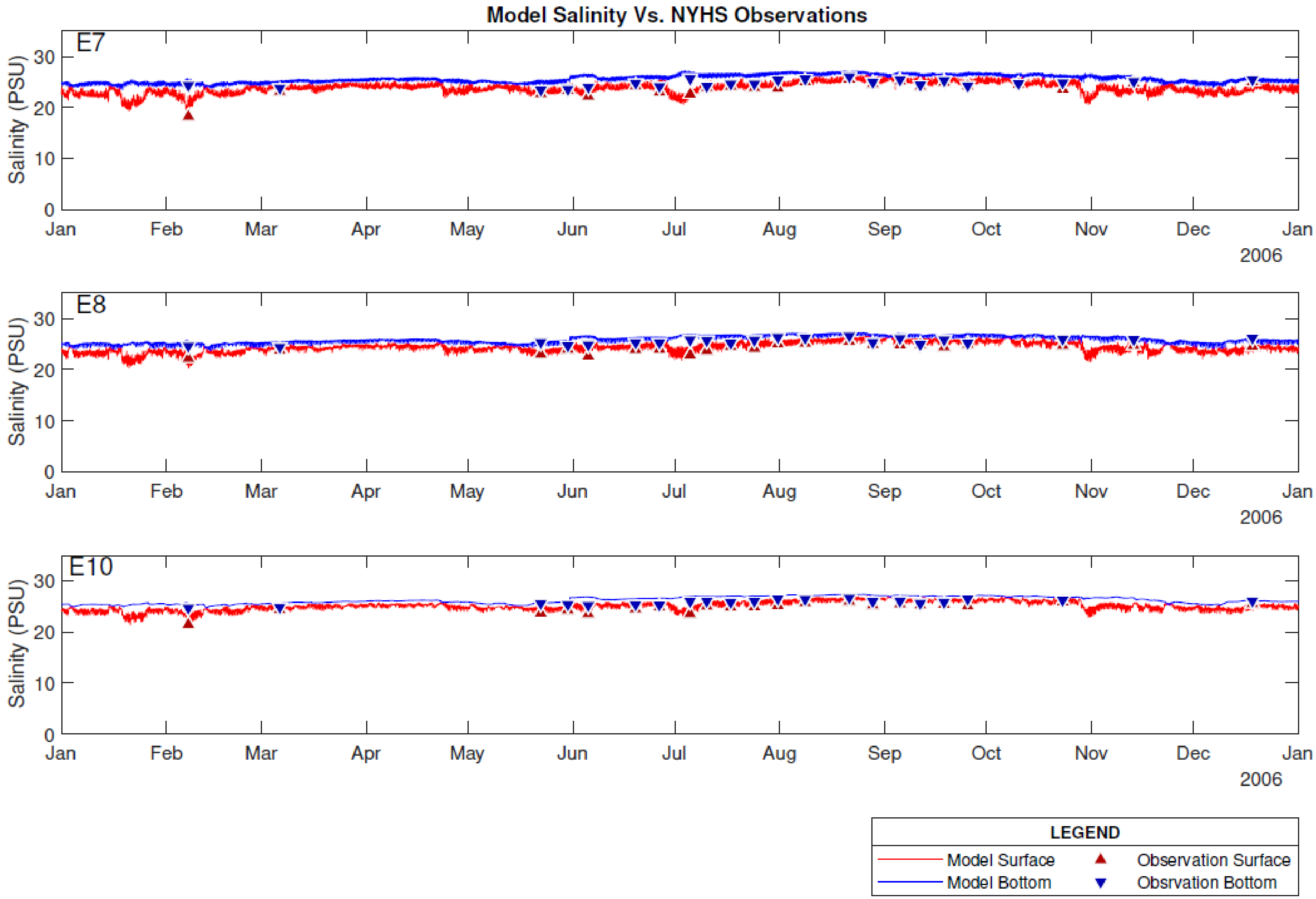


Figure 19. Salinity Comparisons between Model and Data at East River NYCDEP Stations E7, E8, and E10 in 2006

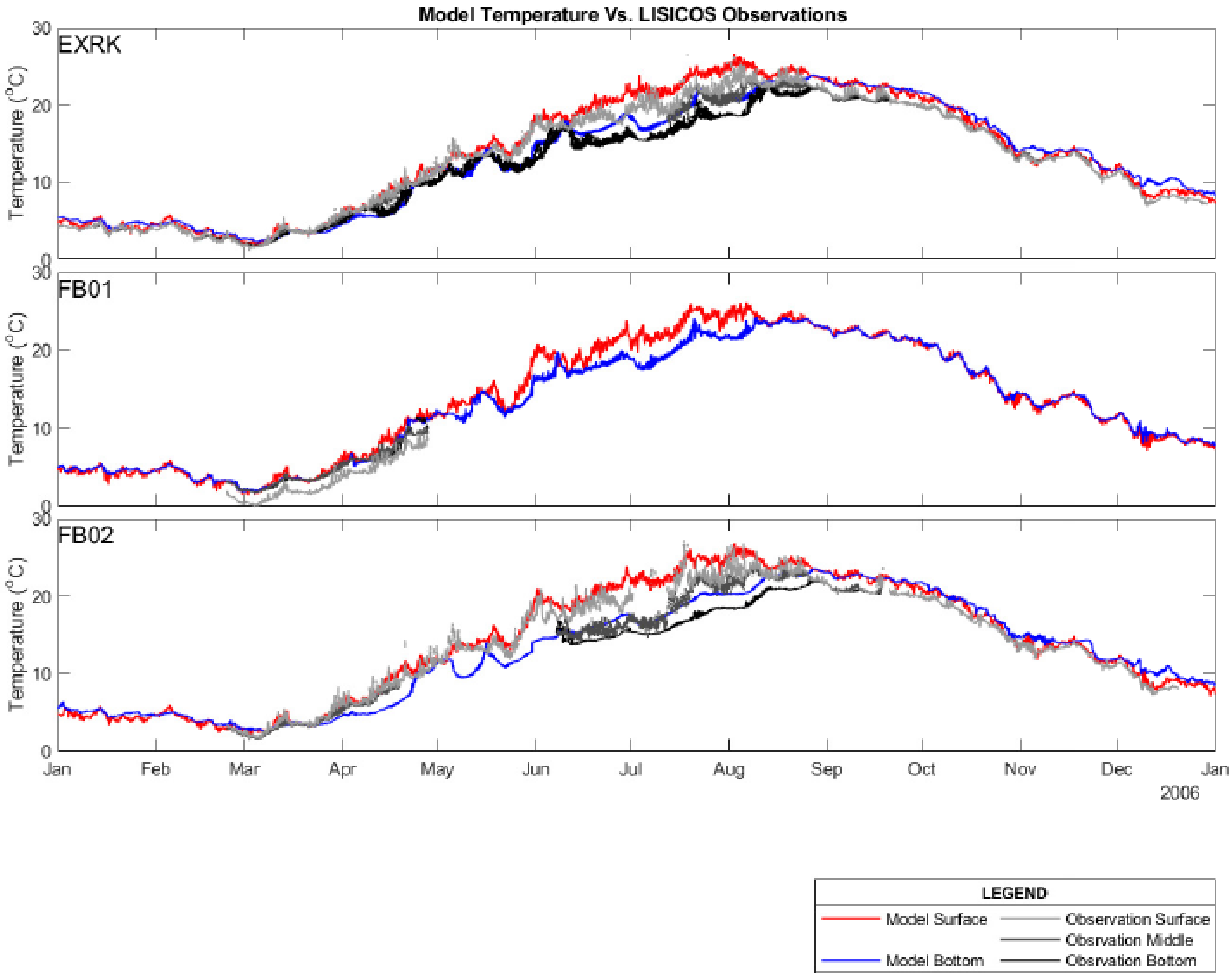


Figure 20. Temperature Comparisons between Model and Data at LISICOS Stations EXRK, FB01, and FB02 in 2006

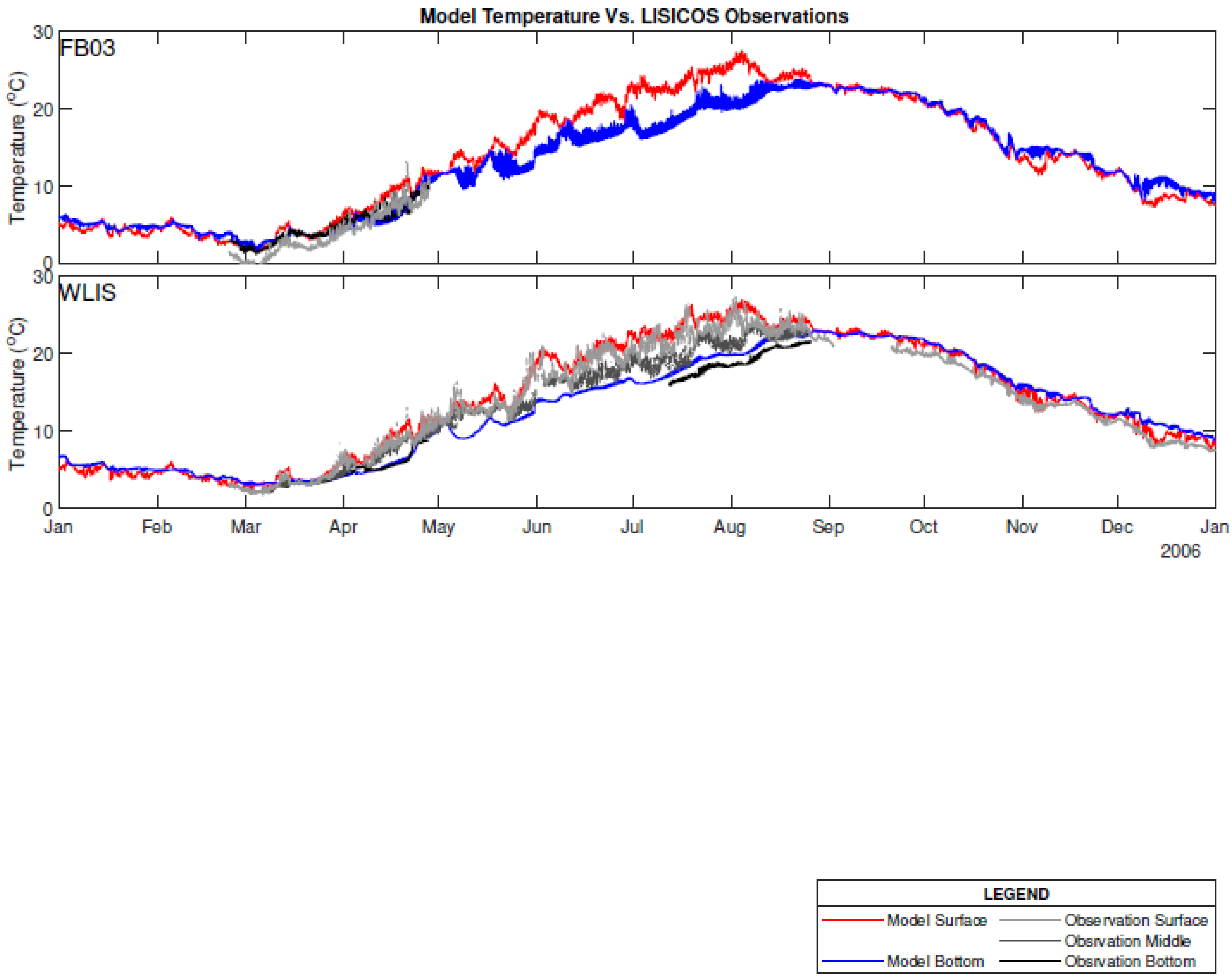


Figure 21. Temperature Comparisons between Model and Data at LISICOS Stations FB03 and WLIS in 2006

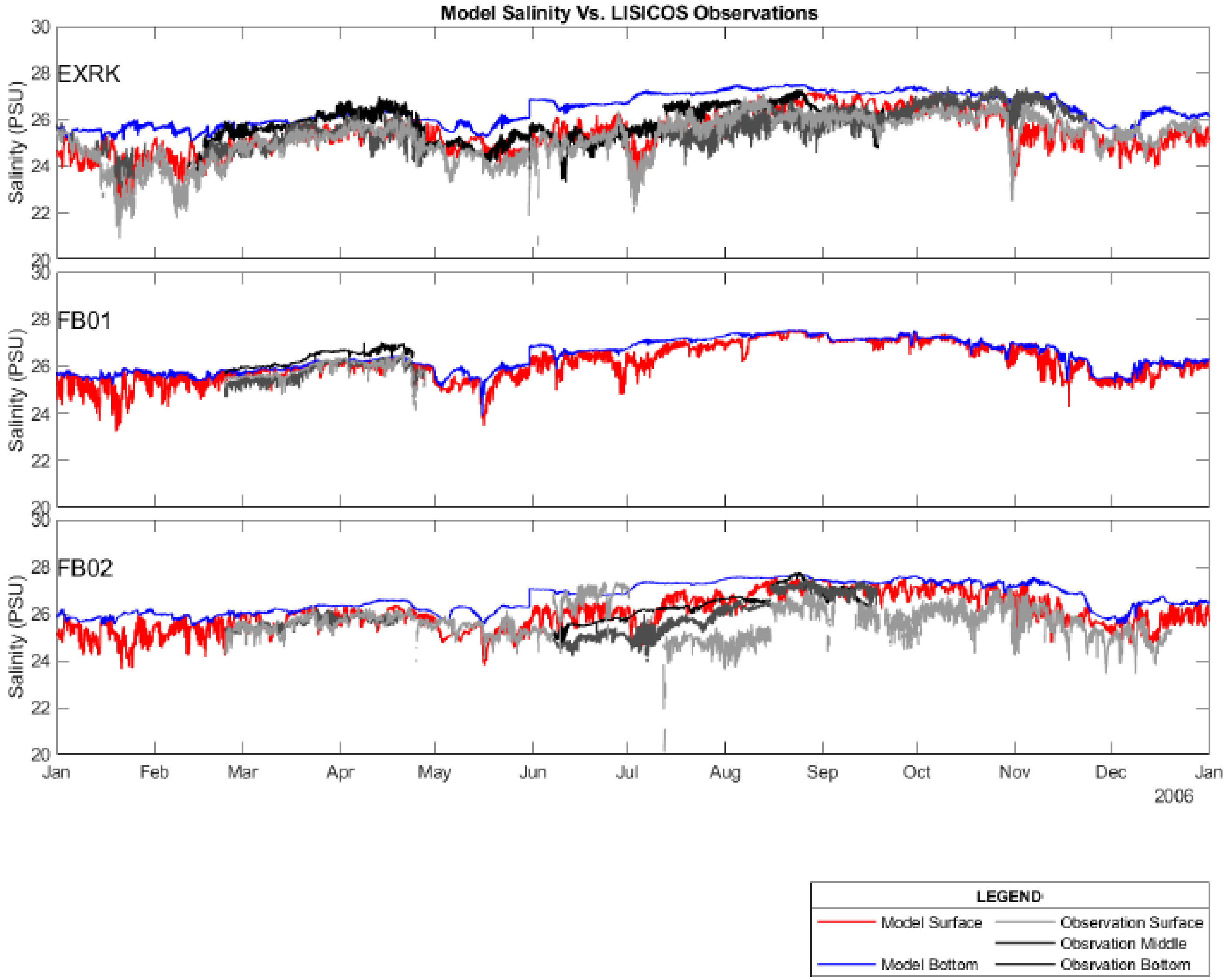


Figure 22. Salinity Comparisons between Model and Data at LISICOS Stations EXRK, FB01, and FB02 in 2006

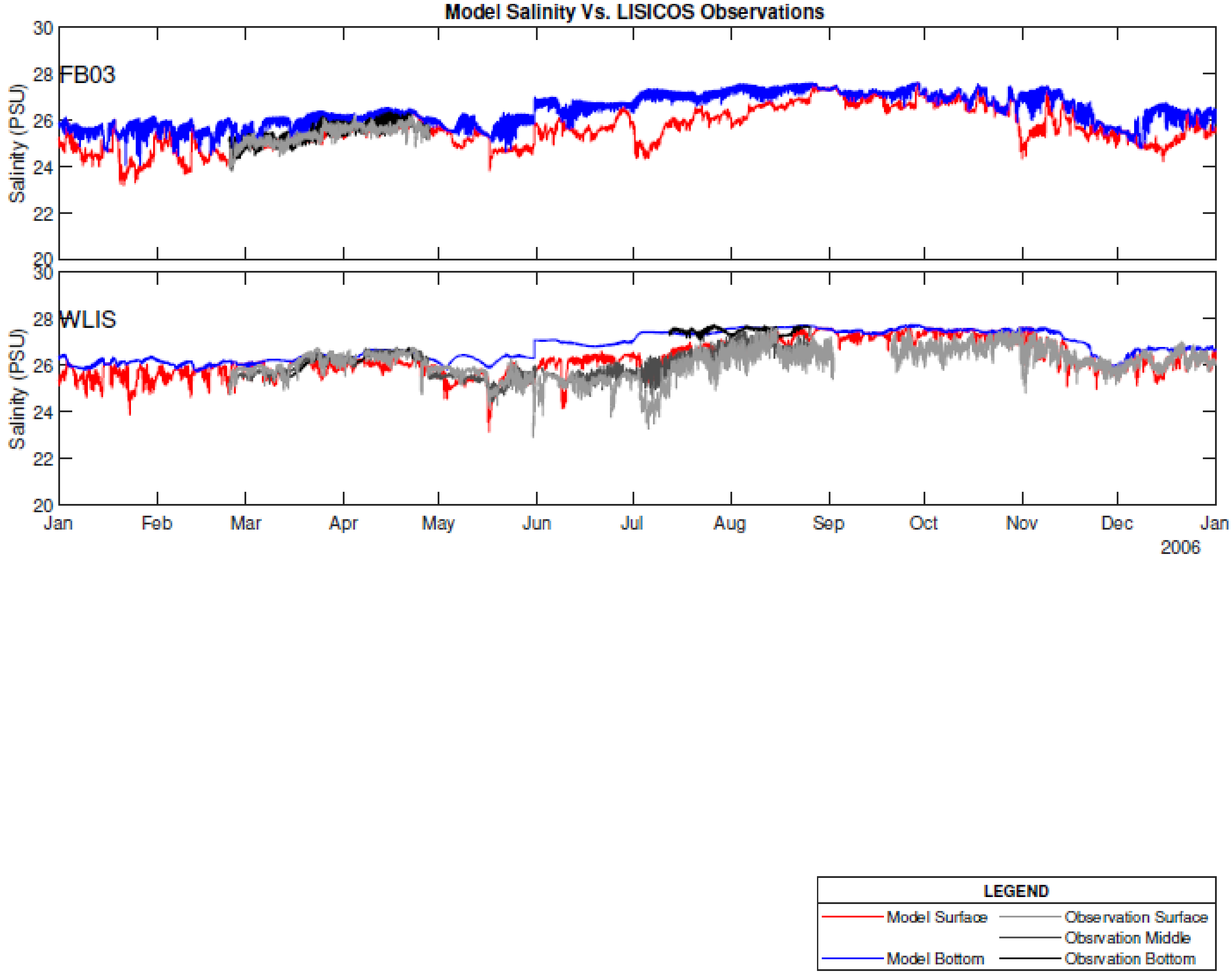


Figure 23. Salinity Comparisons between Model and Data at LISICOS Stations FB03 and WLIS in 2006

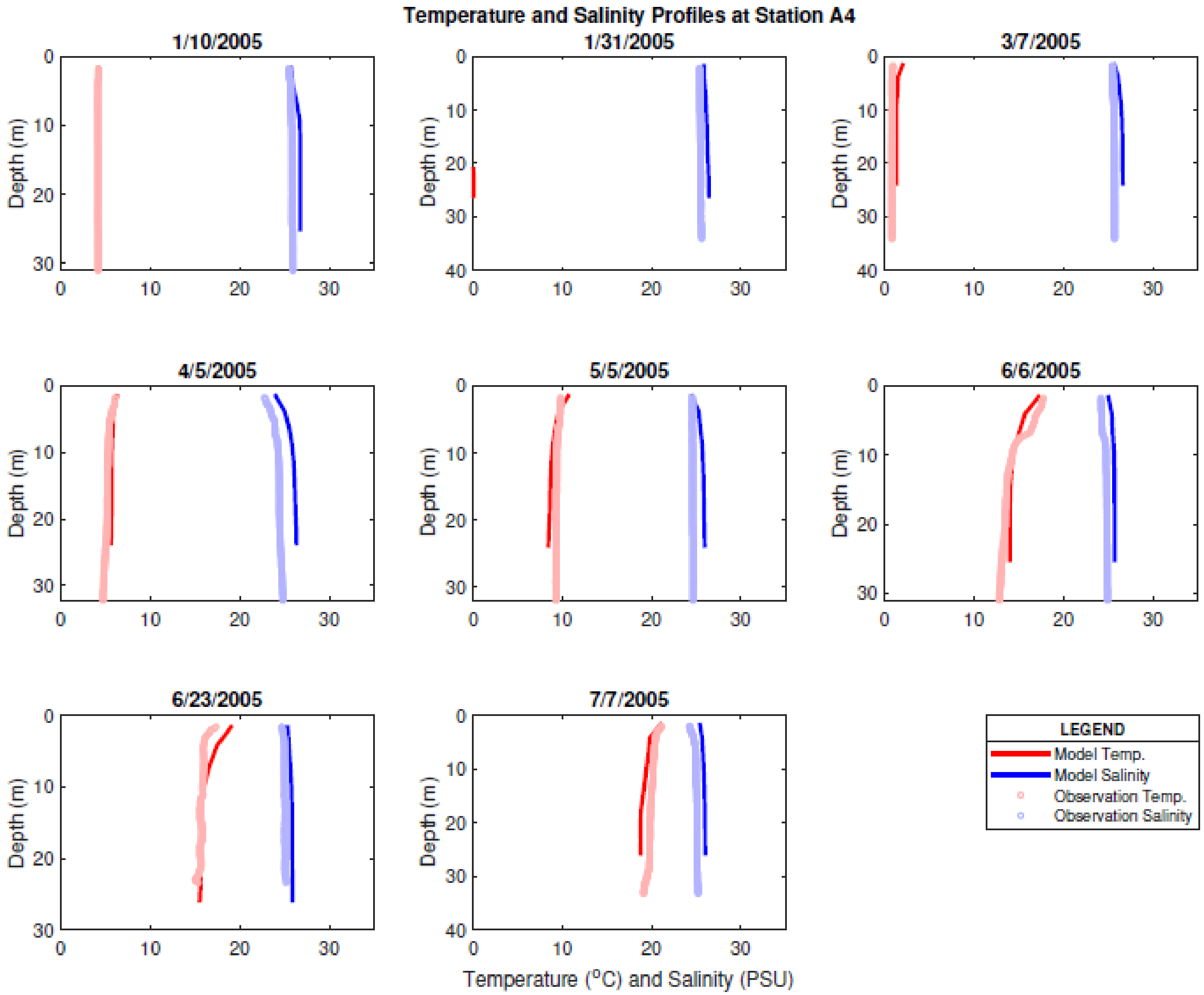


Figure 24. Temperature and Salinity Profile Comparisons between Model and Data at CTDEEP Station A4 in 2005, Part 1

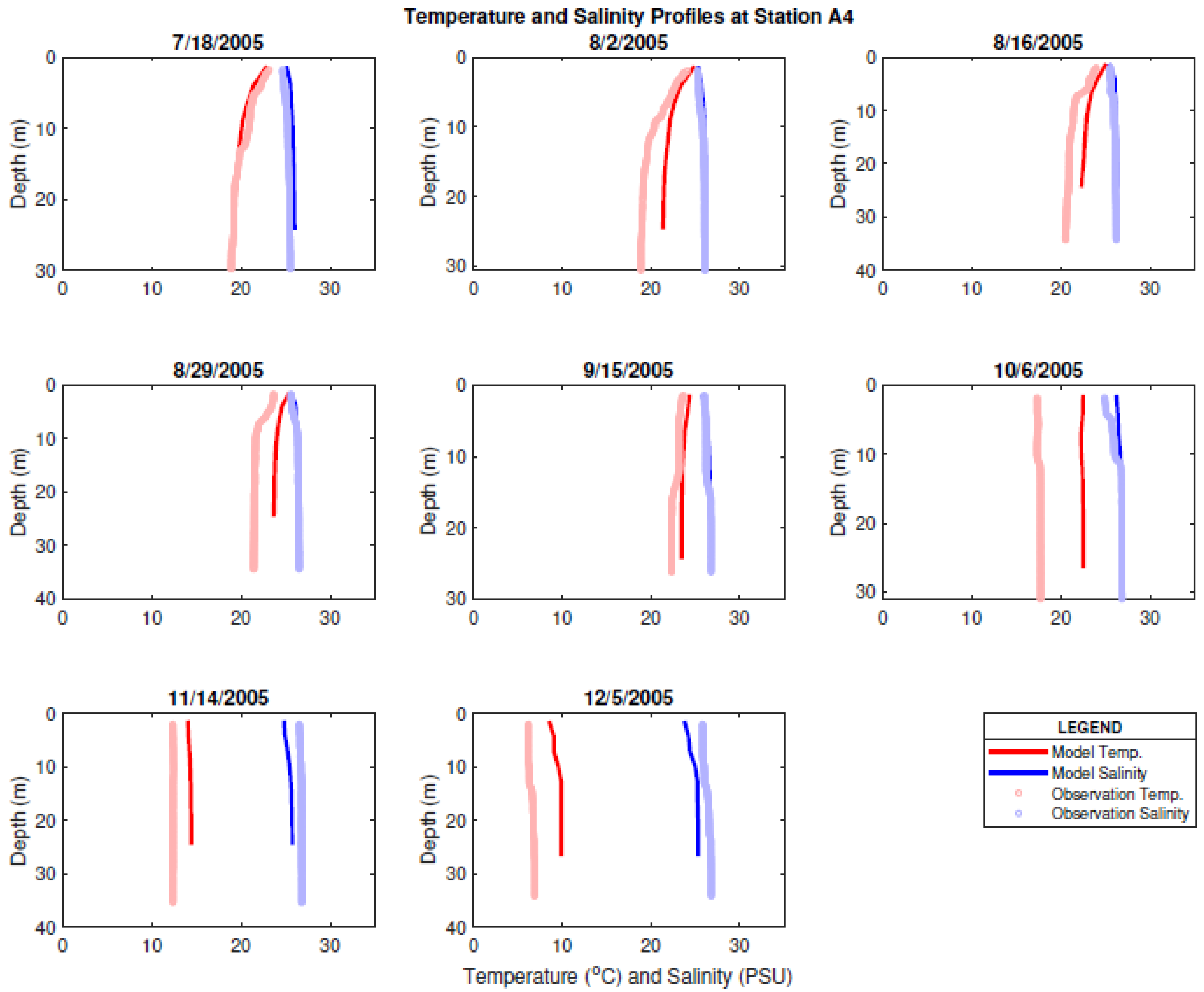


Figure 25. Temperature and Salinity Profile Comparisons between Model and Data at CTDEEP Station A4 in 2005, Part 2

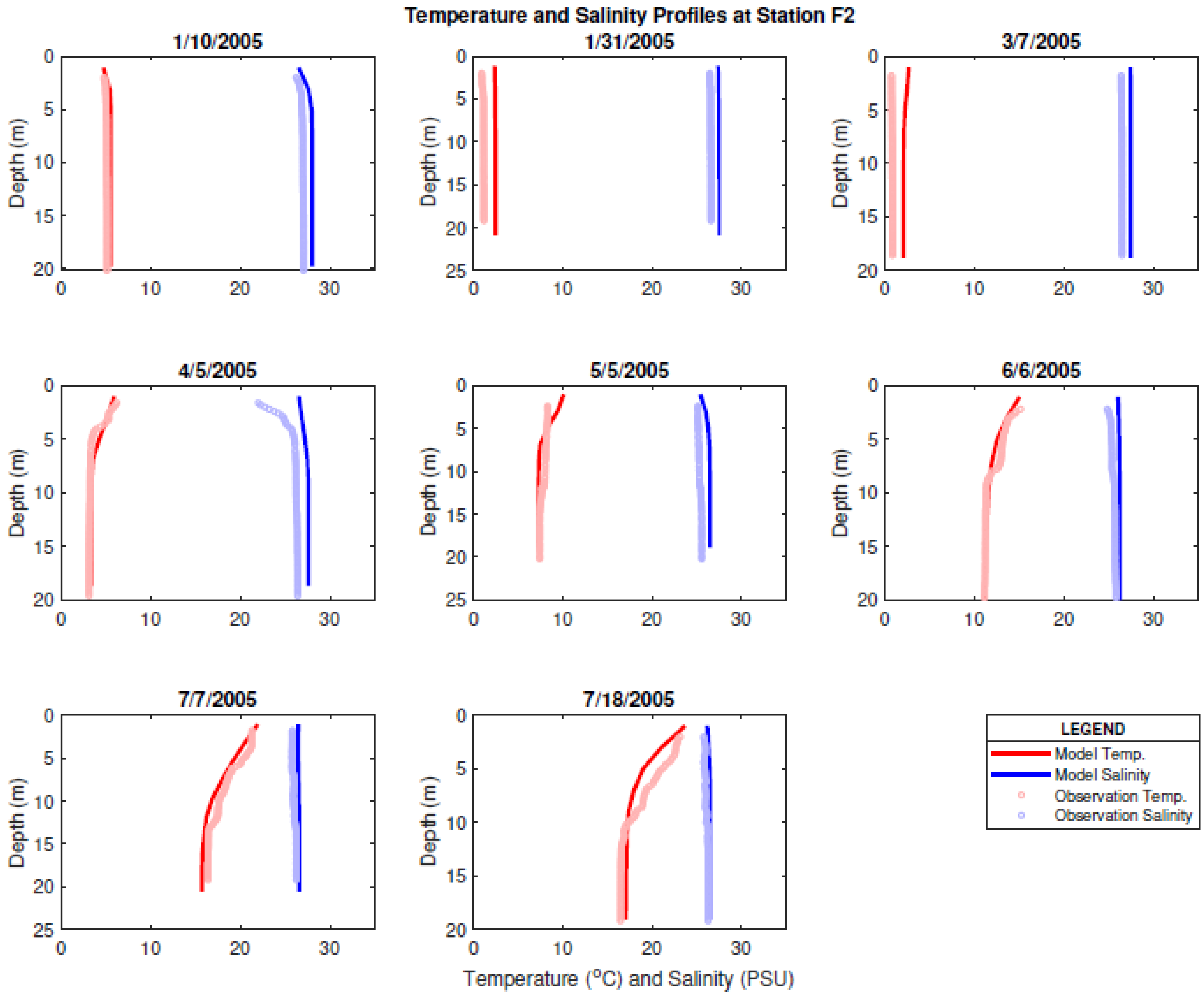


Figure 26. Temperature and Salinity Profile Comparisons between Model and Data at CTDEEP Station F2 in 2005, Part 1

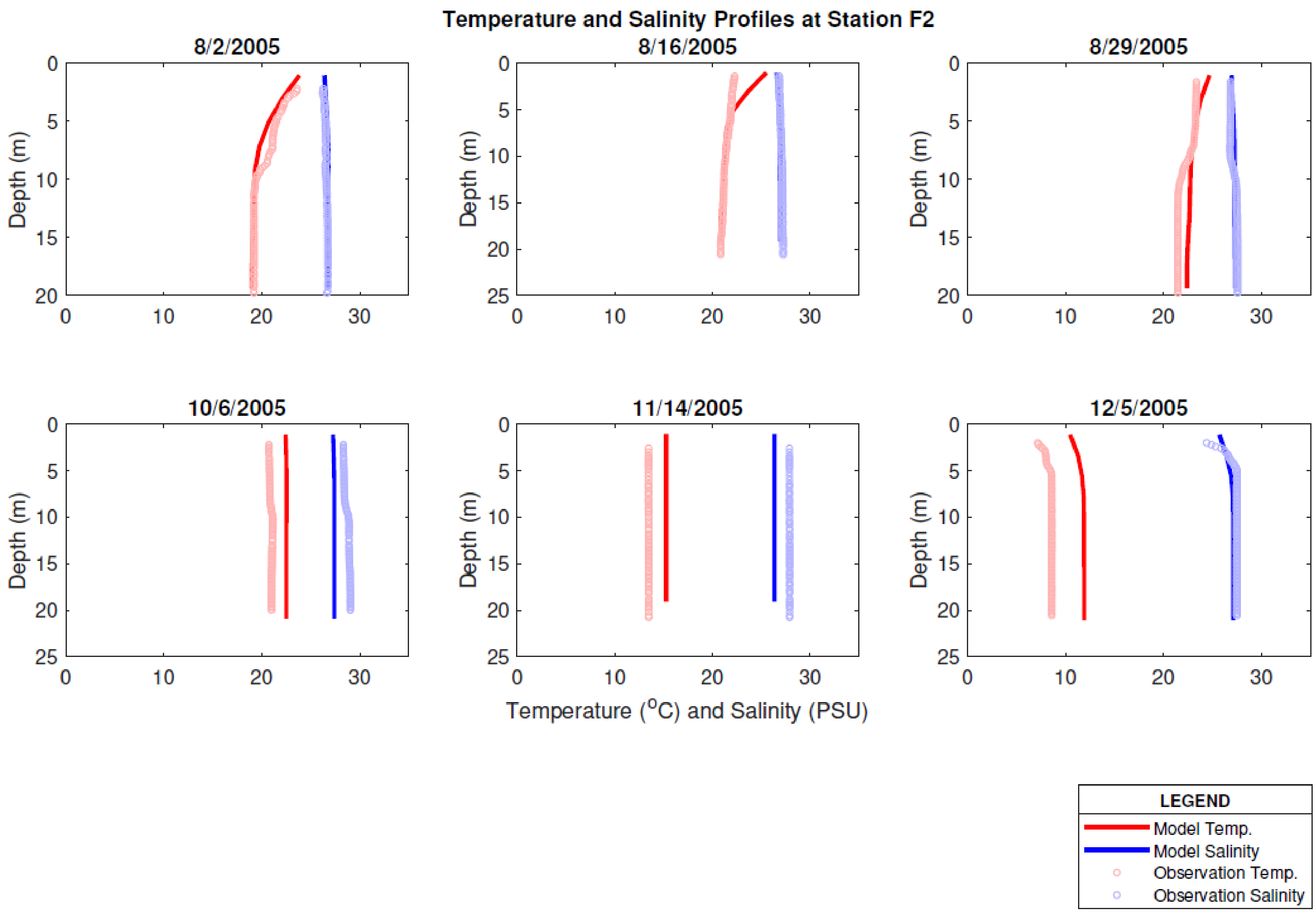


Figure 27. Temperature and Salinity Profile Comparisons between Model and Data at CTDEEP Station F2 in 2005, Part 2

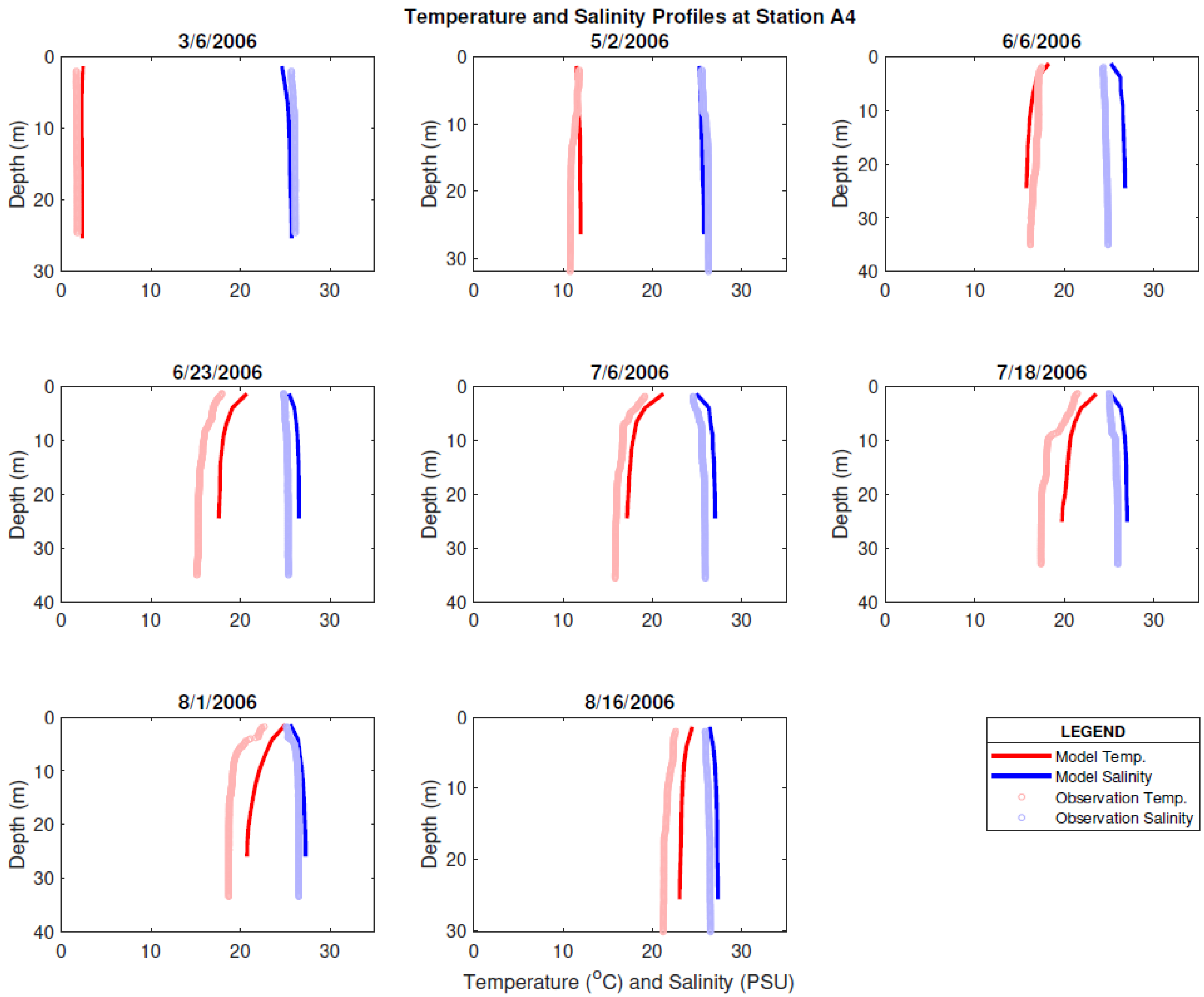


Figure 28. Temperature and Salinity Profile Comparisons between Model and Data at CTDEEP Station A4 in 2006, Part 1

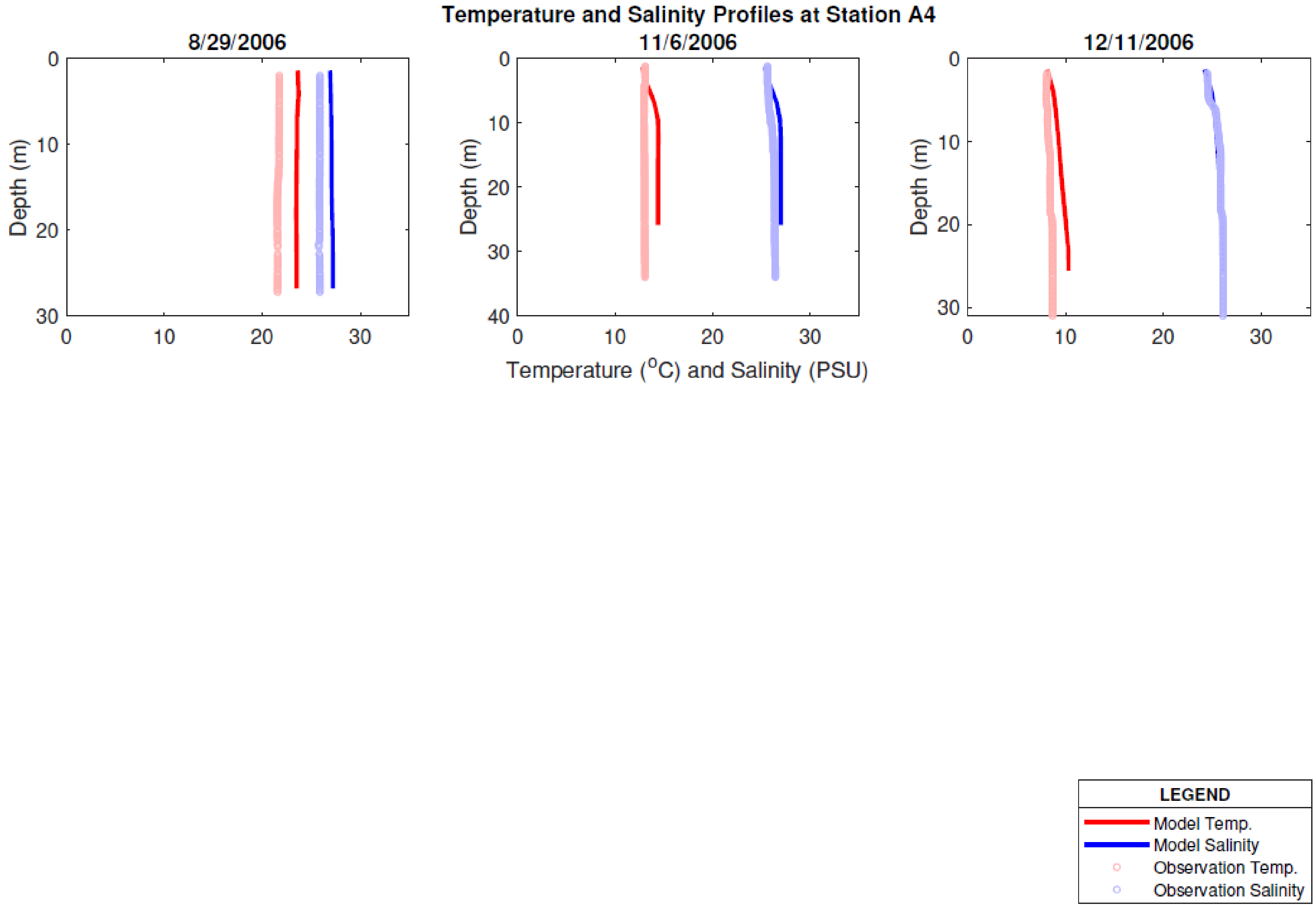


Figure 29. Temperature and Salinity Profile Comparisons between Model and Data at CTDEEP Station A4 in 2006, Part 2

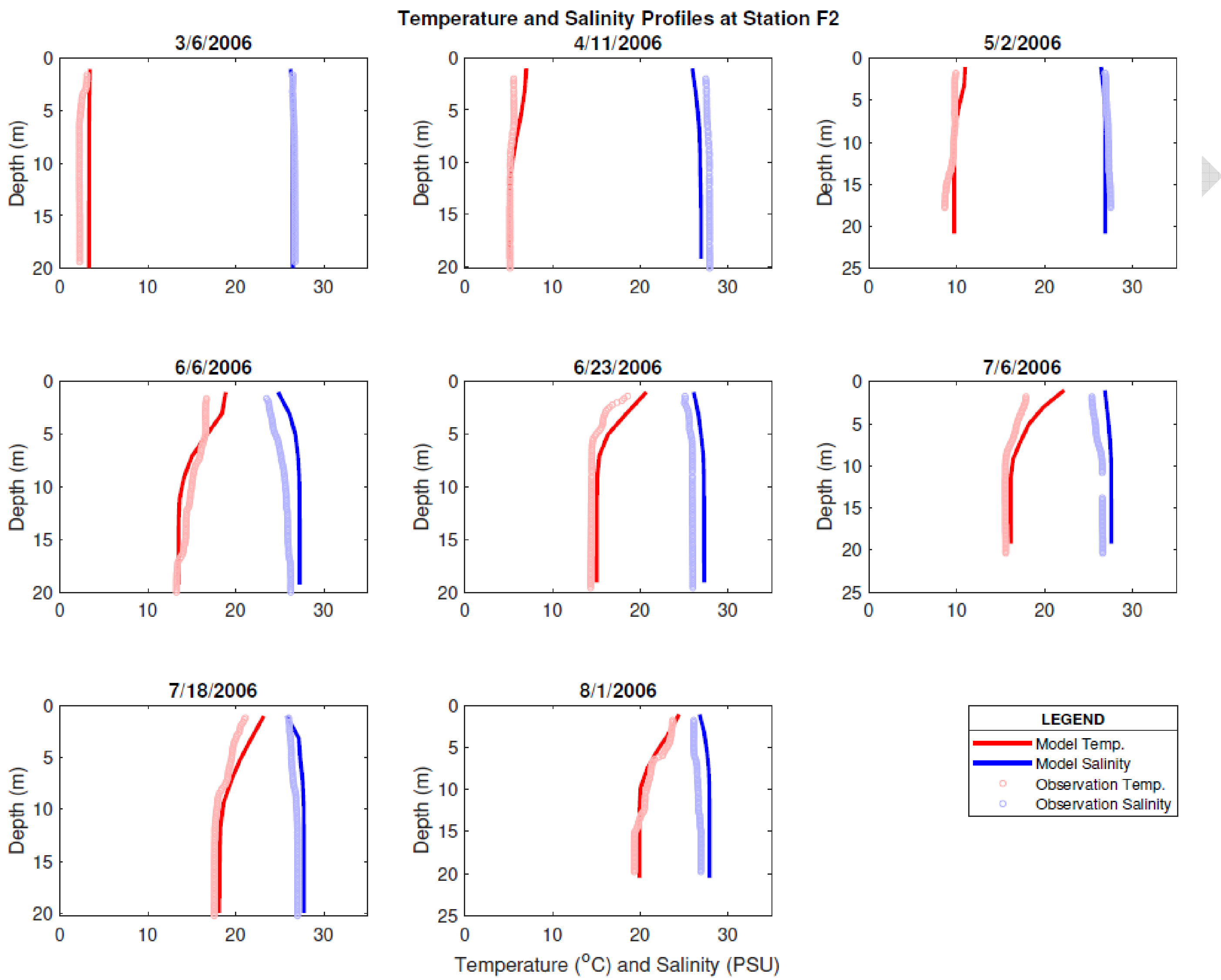


Figure 30. Temperature and Salinity Profile Comparisons between Model and Data at CTDEEP Station F2 in 2006, Part 1

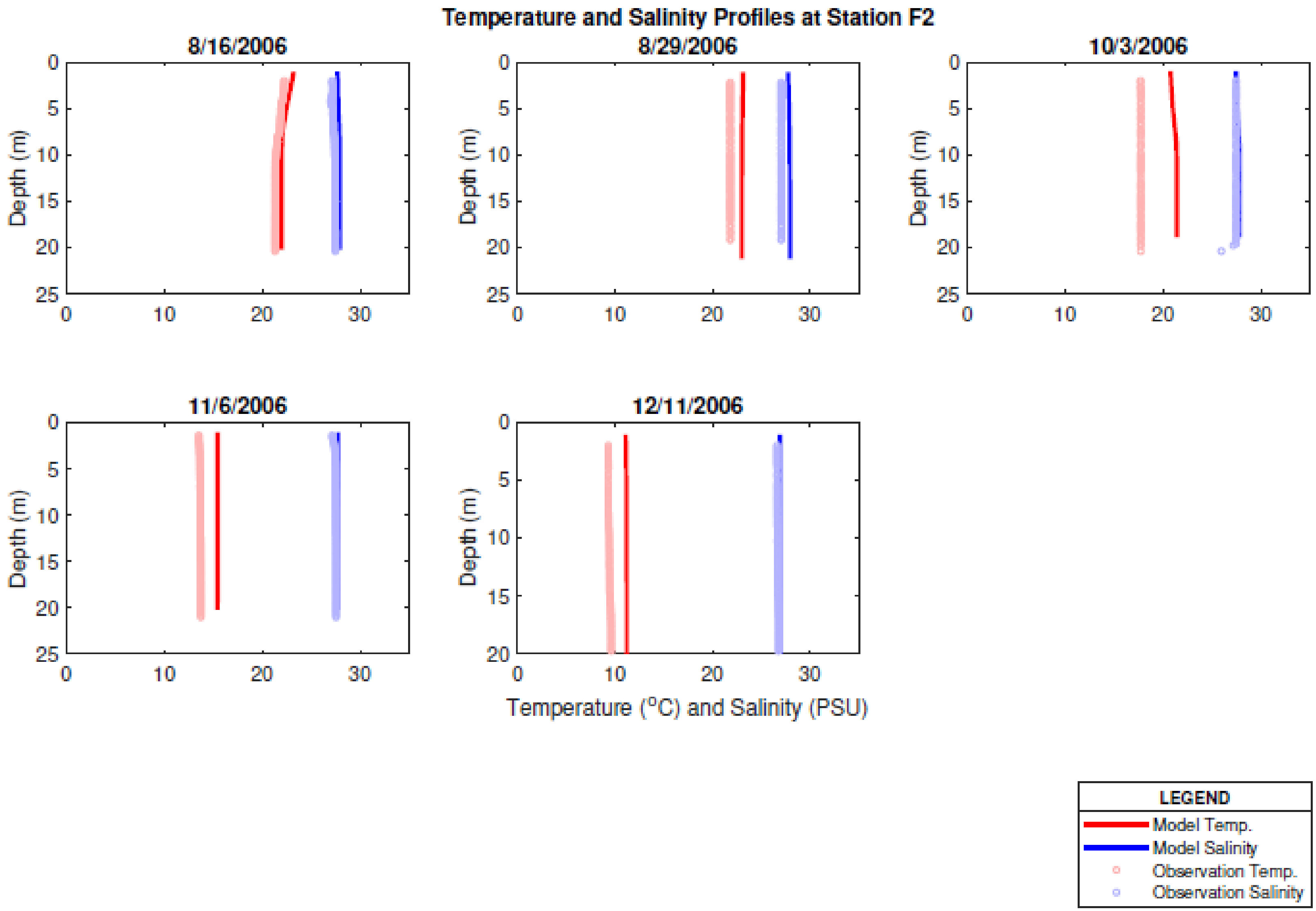


Figure 31. Temperature and Salinity Profile Comparisons between Model and Data at CTDEEP Station F2 in 2006, Part 2

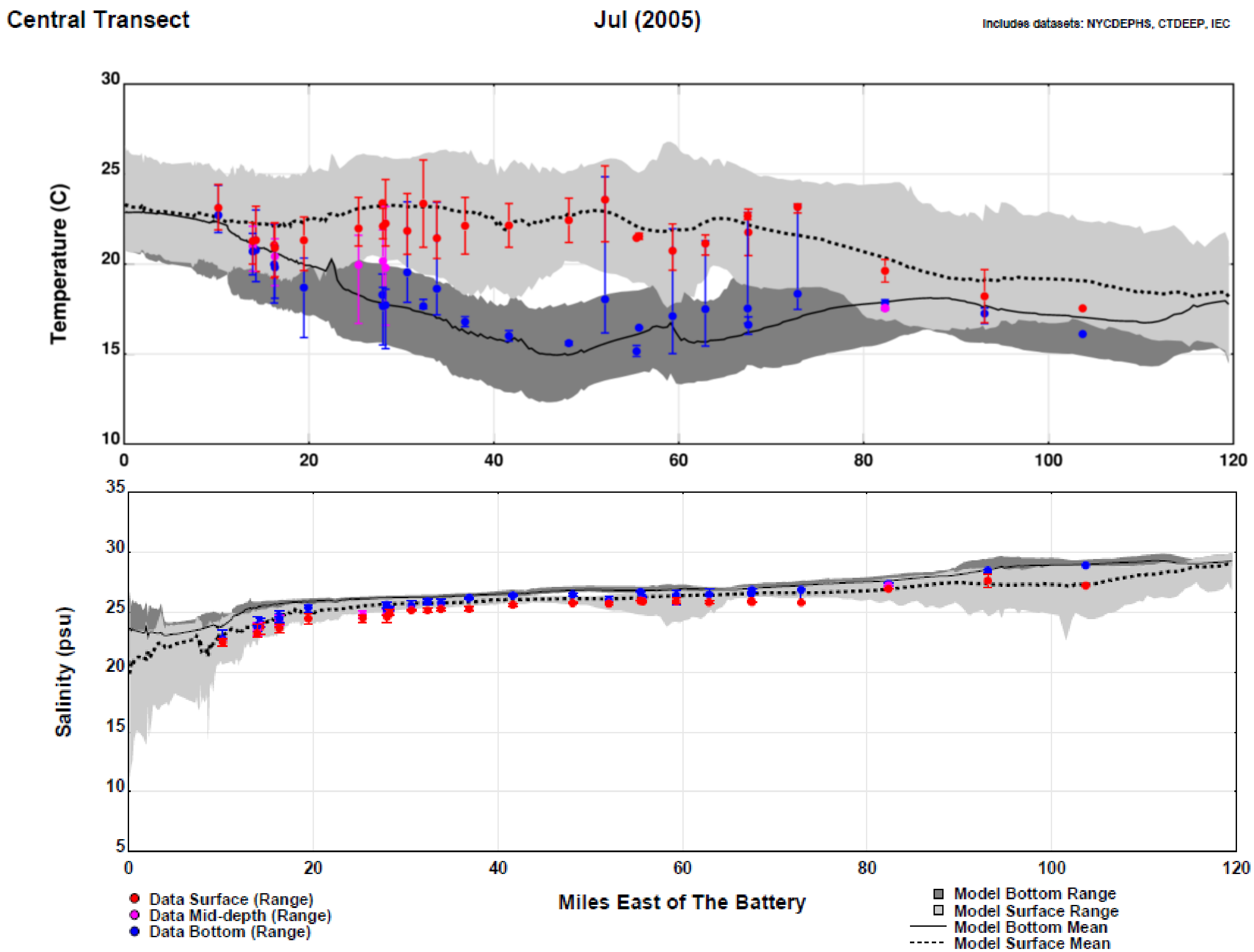


Figure 32. Temperature and Salinity Transect Comparisons between Model and Data from the Battery to Eastern LIS in July 2005

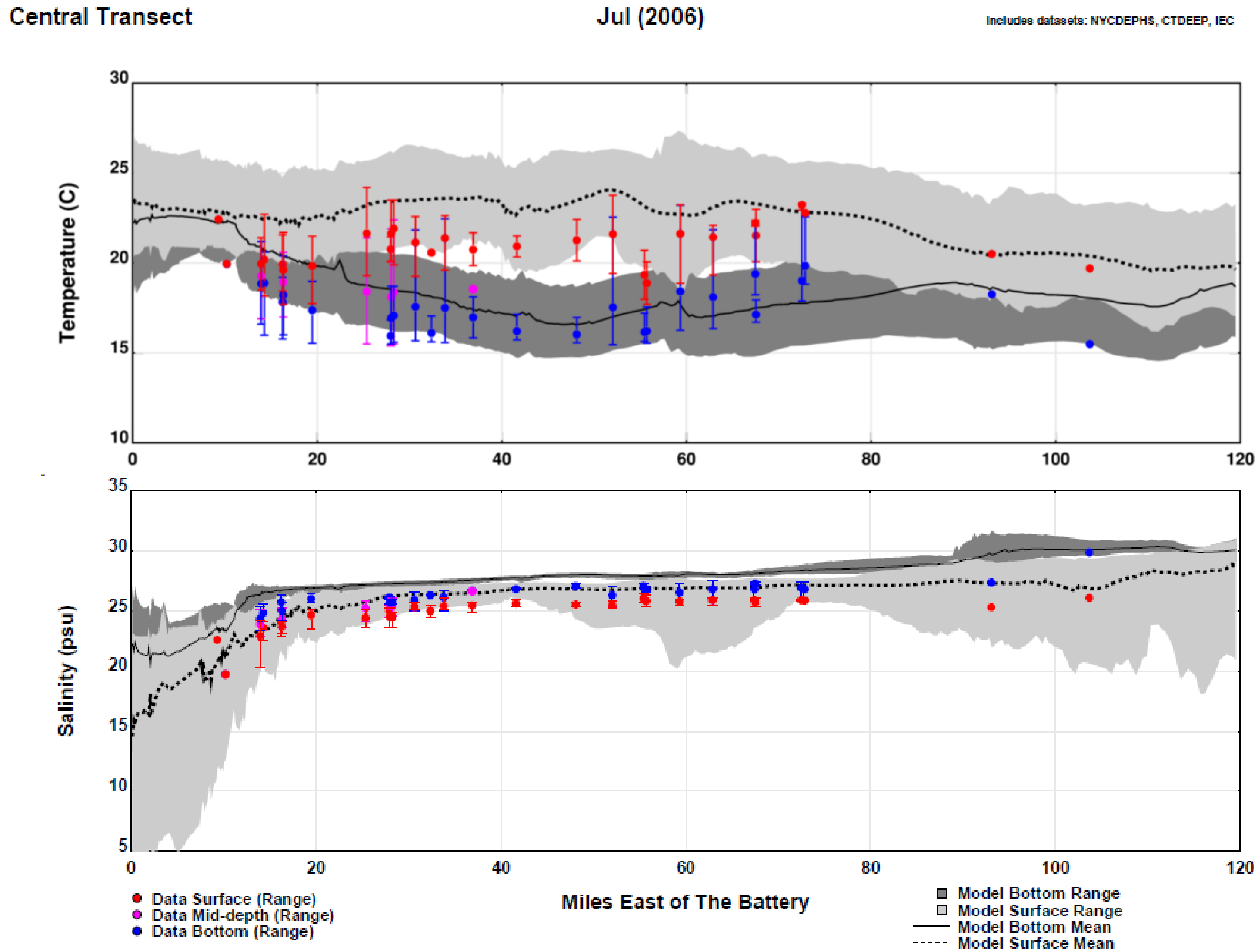


Figure 33. Temperature and Salinity Transect Comparisons between Model and Data from the Battery to Eastern LIS in July 2006

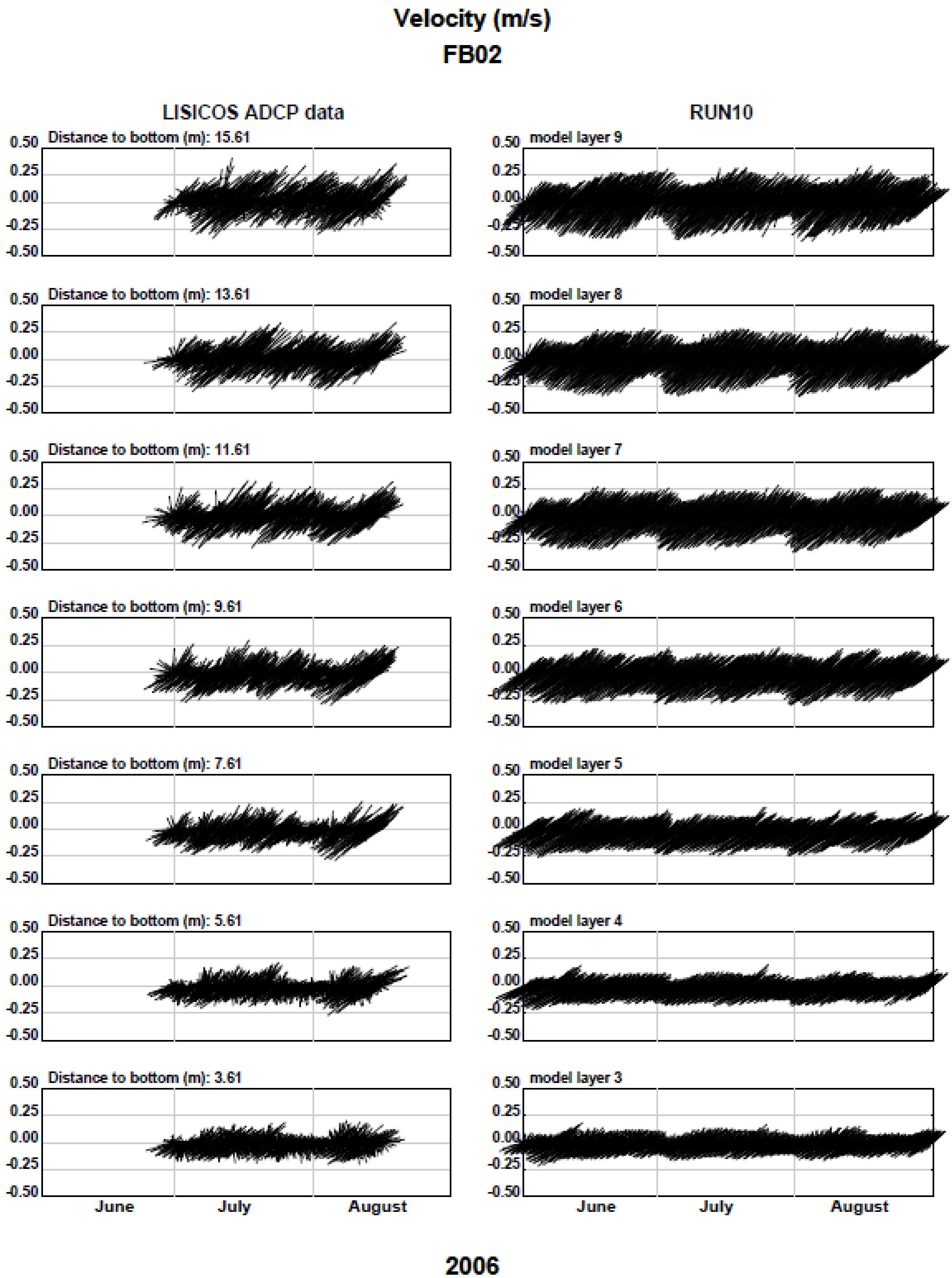


Figure 34. Hourly Current Velocity Comparisons between Model and Data at LISICOS Station FB02 for June through August 2006

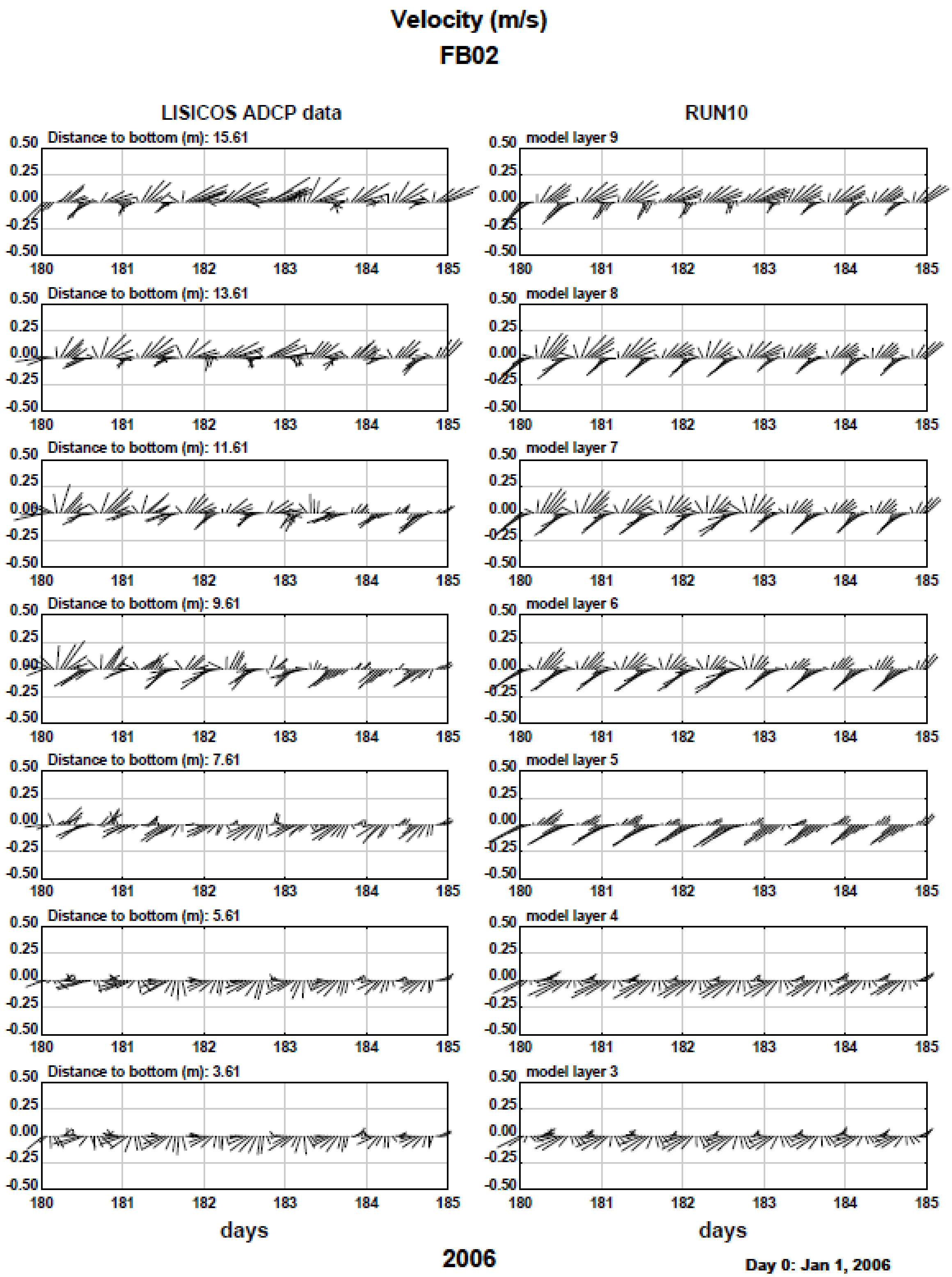


Figure 35. Hourly Current Velocity Comparisons between Model and Data at LISICOS Station FB02 for a 5-Day Period

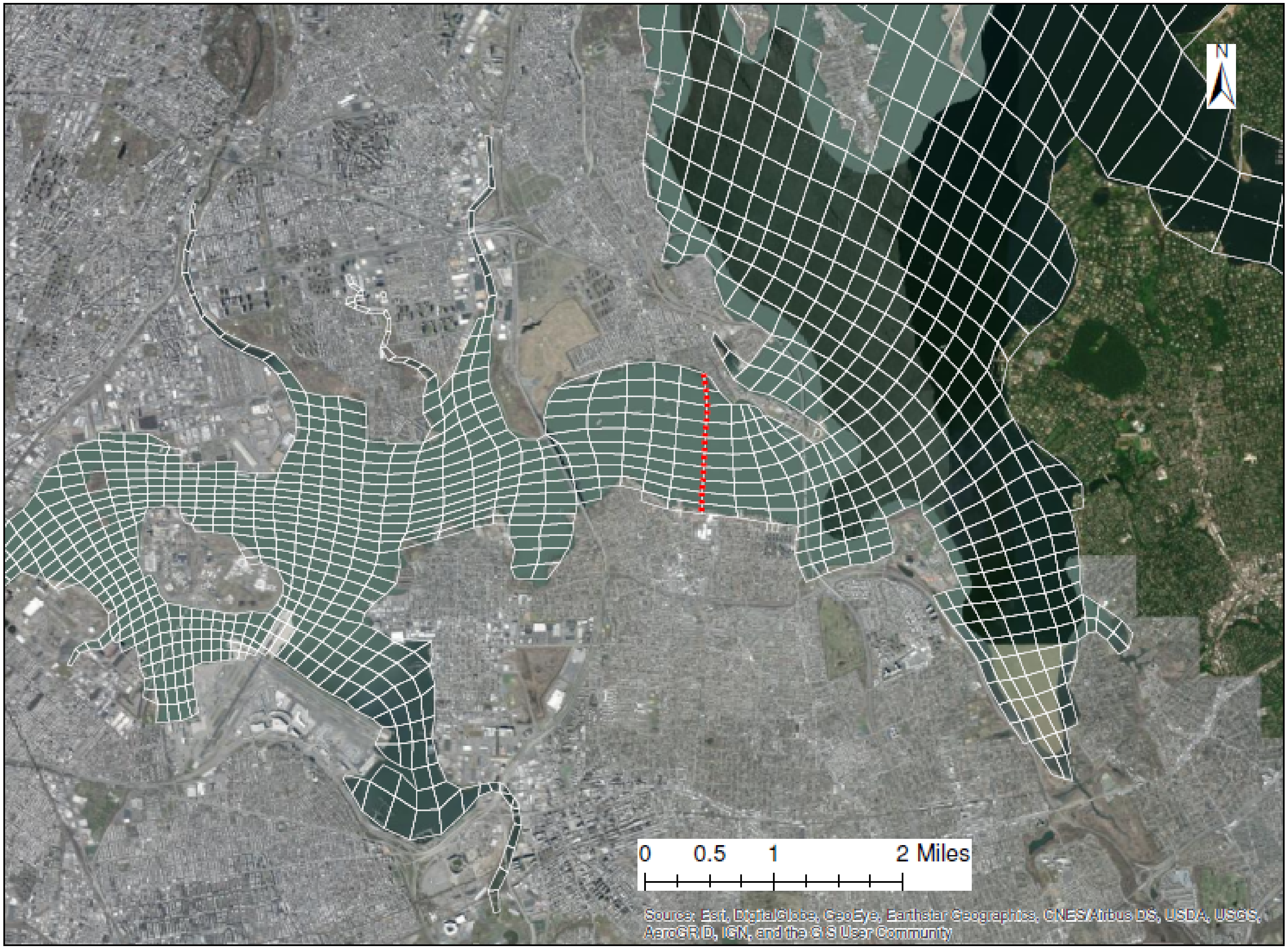


Figure 36. Flux Transect

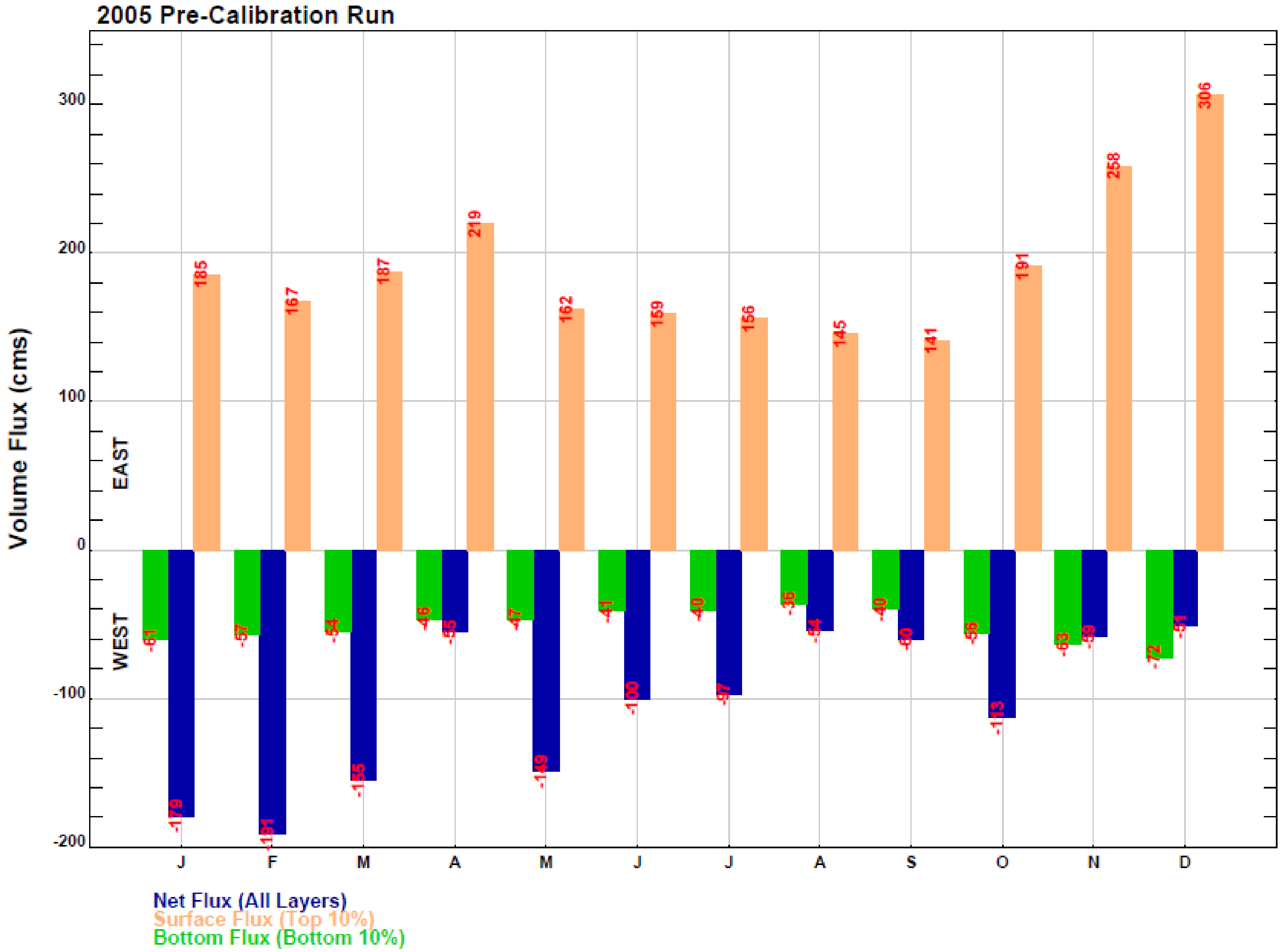


Figure 37. Model Calculated Net, Surface, and Bottom Flux through the East River in 2005

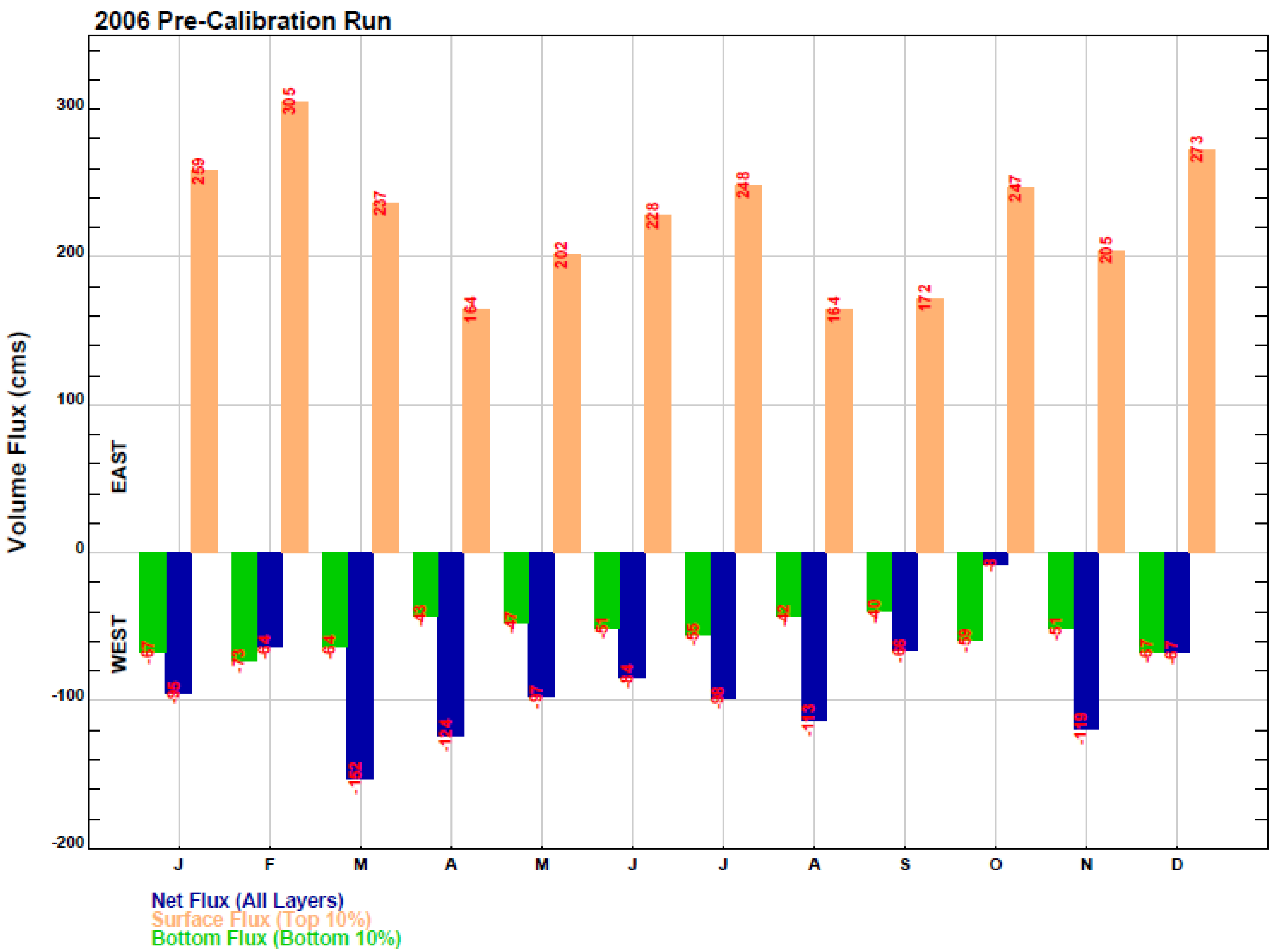
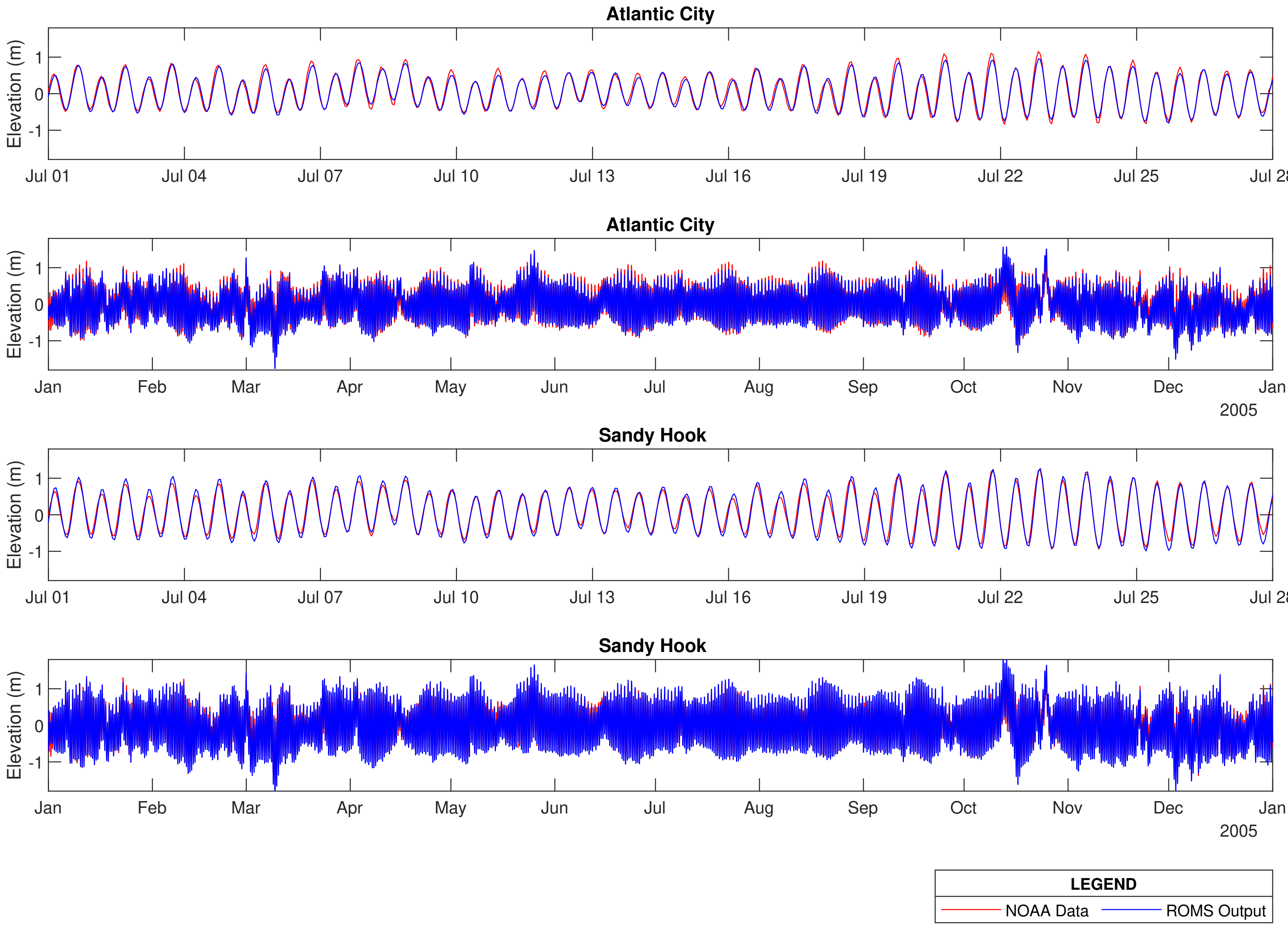


Figure 38. Model Calculated Net, Surface, and Bottom Flux through the East River in 2006

1

2005-2006 Model-Data Water Elevation Comparisons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Elevation (m)
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-1
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Jul 04
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Jul 19
Jul 22
Jul 25
Jul 28
Atlantic City
Elevation (m)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
Sandy Hook
Elevation (m)
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Jul 04
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Jul 10
Jul 13
Jul 16
Jul 19
Jul 22
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Sandy Hook
Elevation (m)
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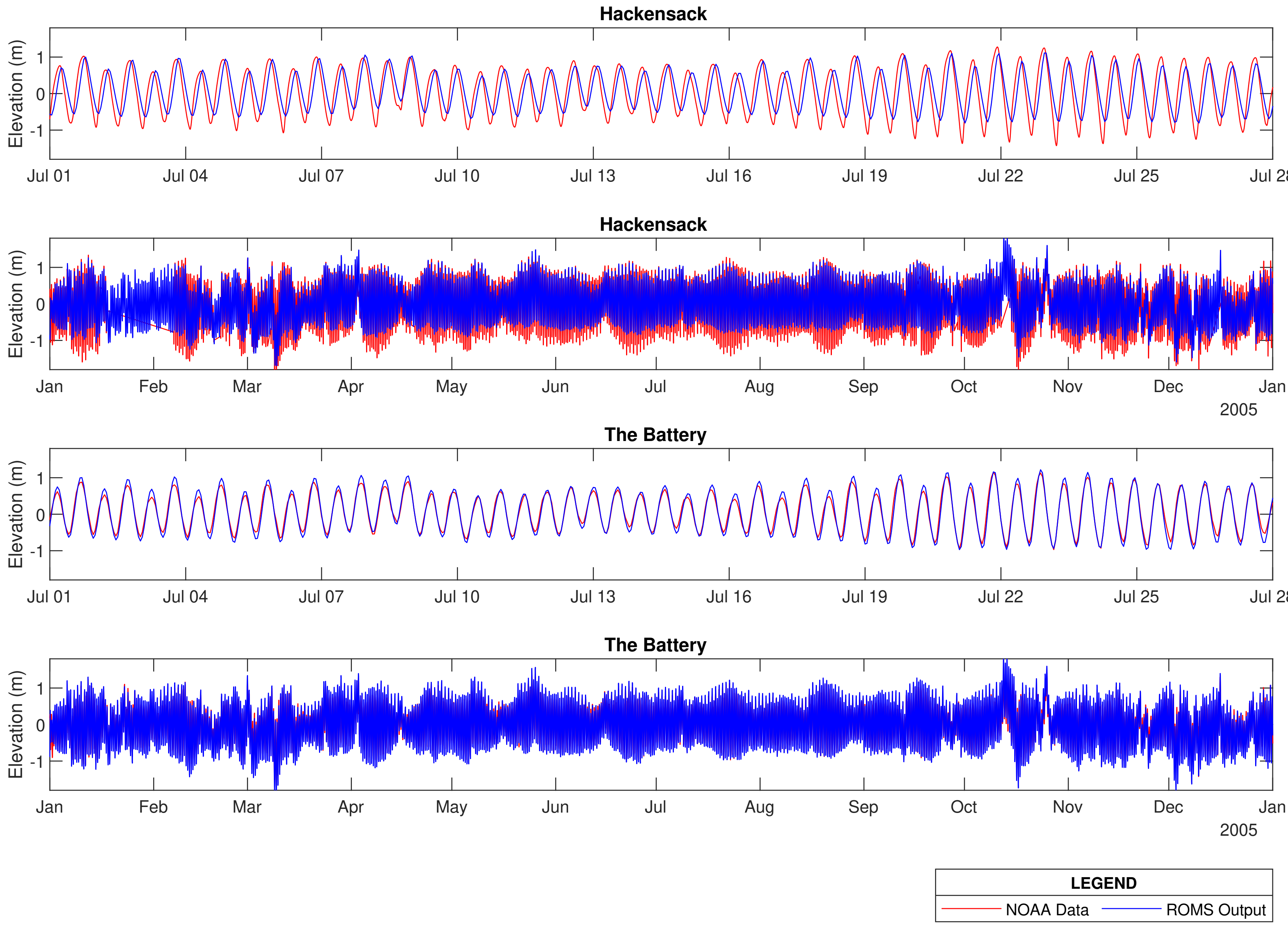
2005
LEGEND
NOAA Data
ROMS Output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The Battery
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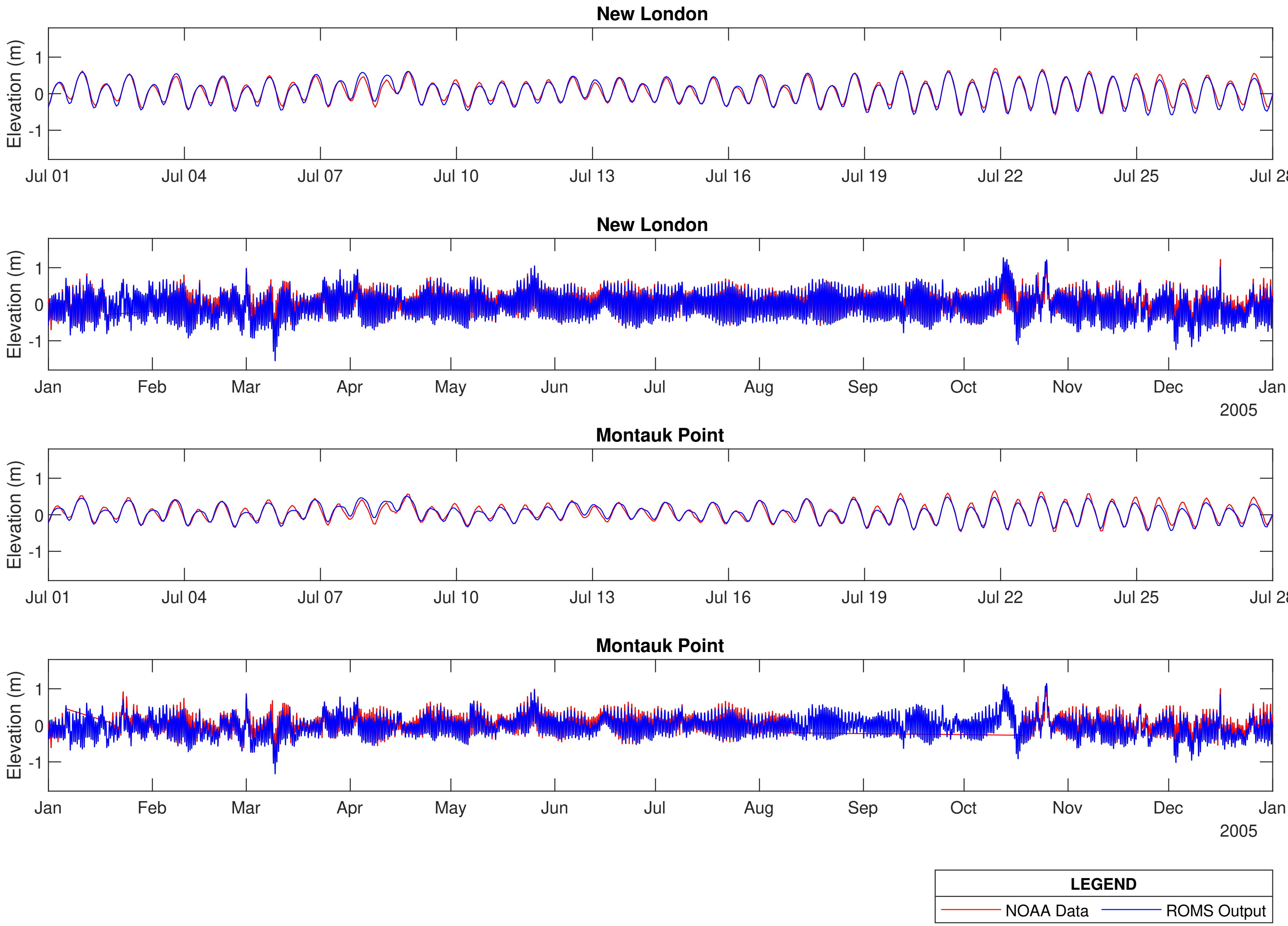
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Elevation (m)
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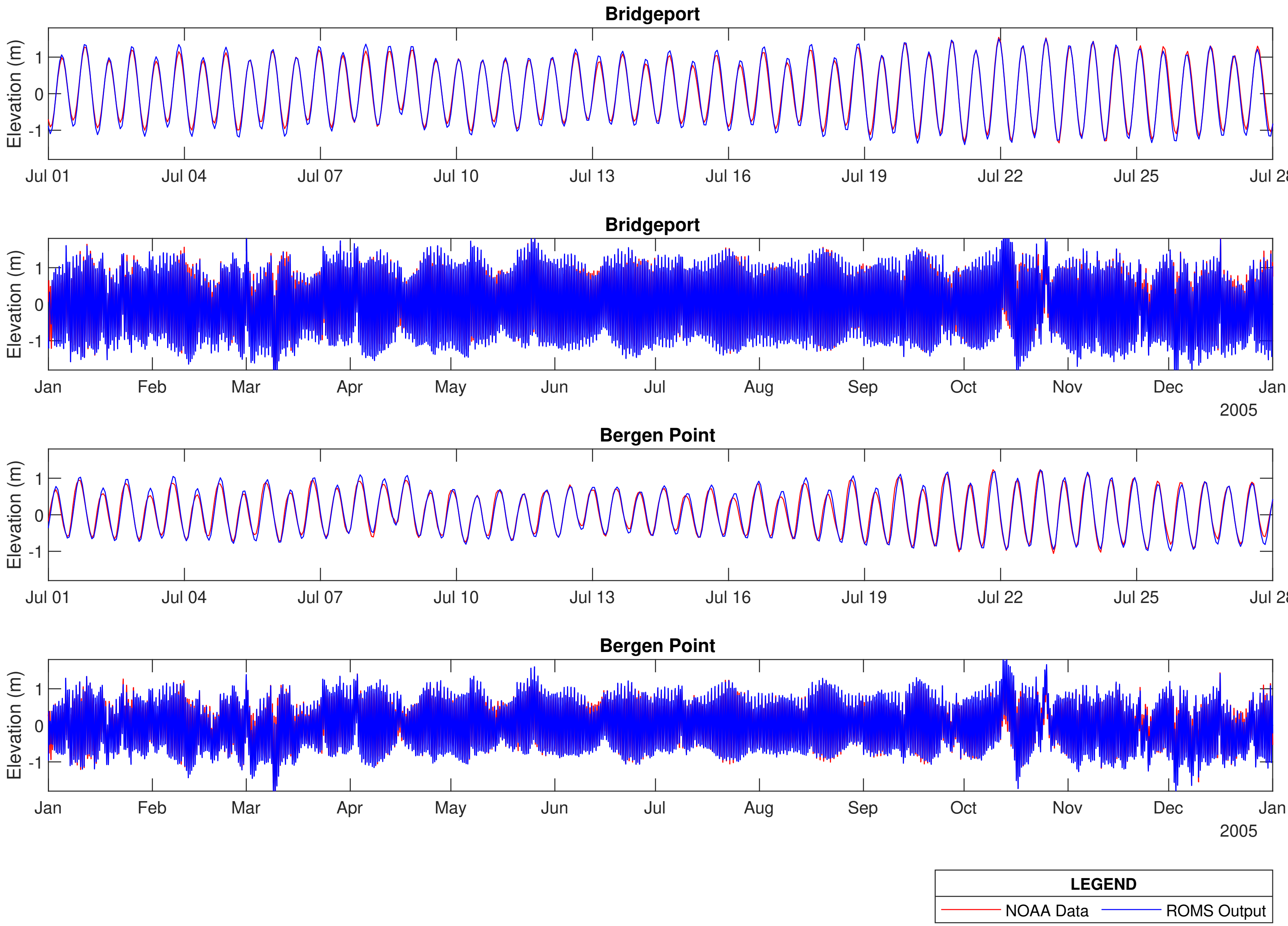
2005
Montauk Point
Elevation (m)
Montauk Point
Elevation (m)
LEGEND
NOAA Data
ROMS Output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Bergen Point
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LEGEND
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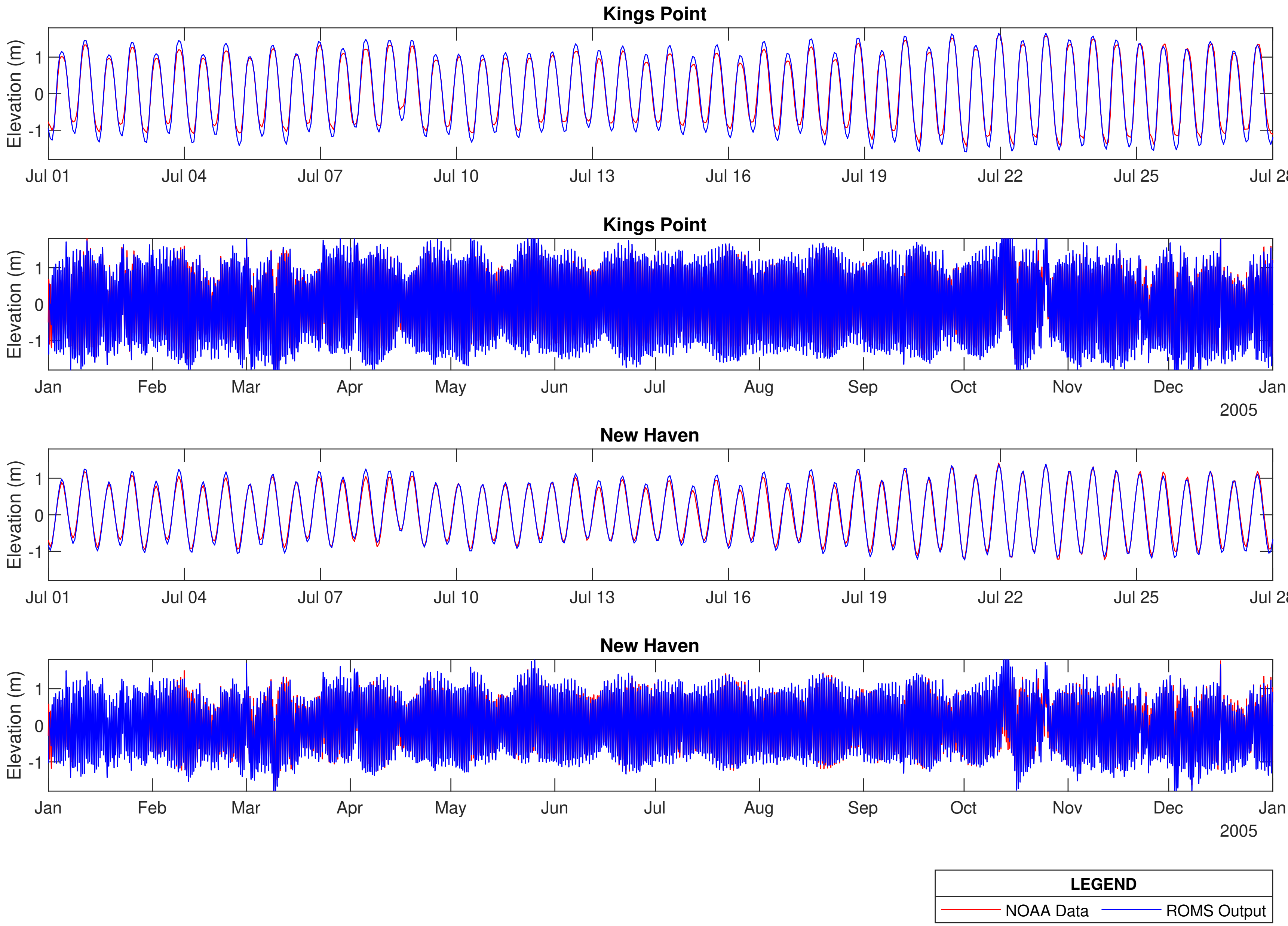

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2005
New Haven
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Elevation (m)
LEGEND
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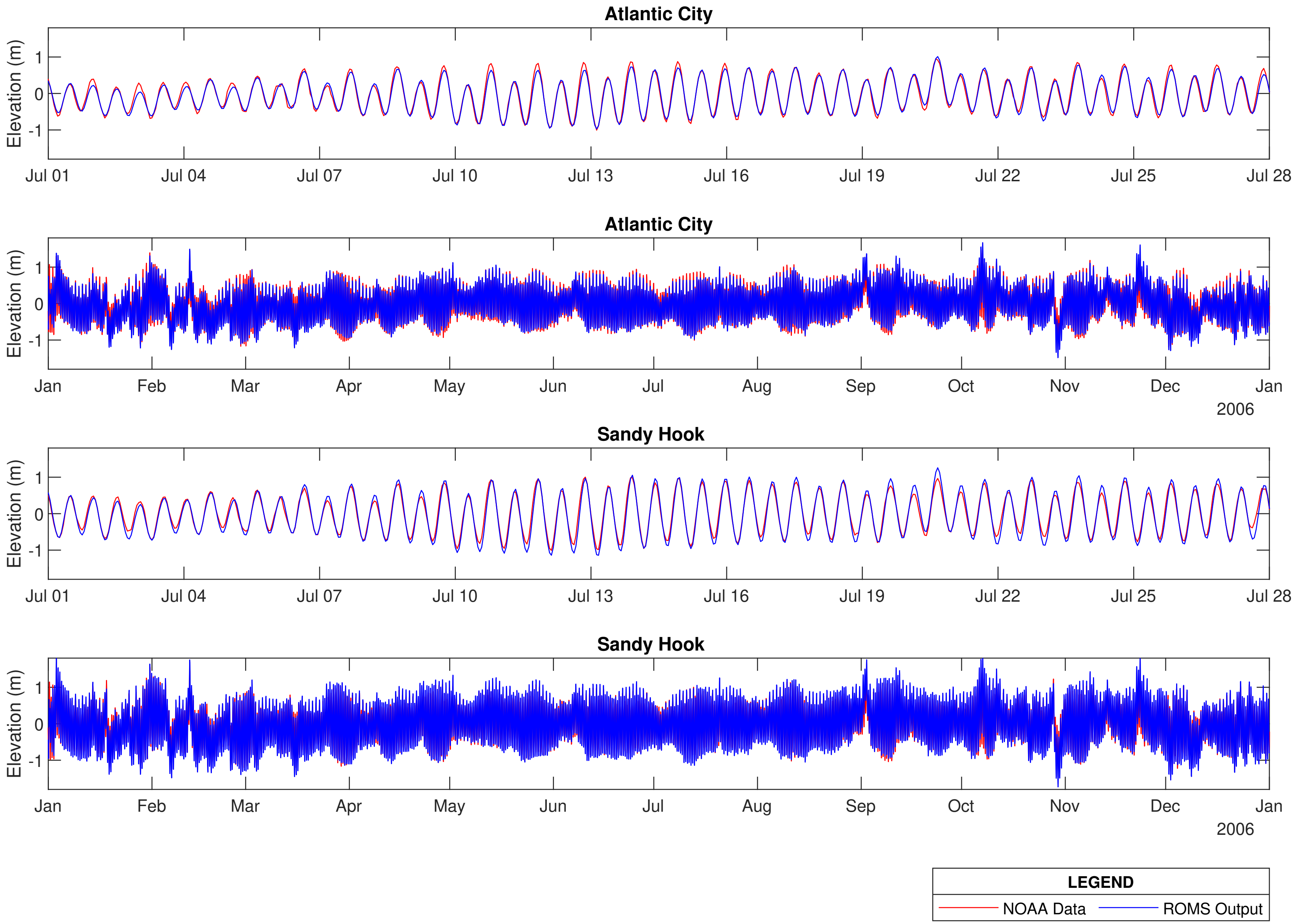
ROMS Output



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Elevation (m)
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2006
Sandy Hook
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Sandy Hook
Elevation (m)
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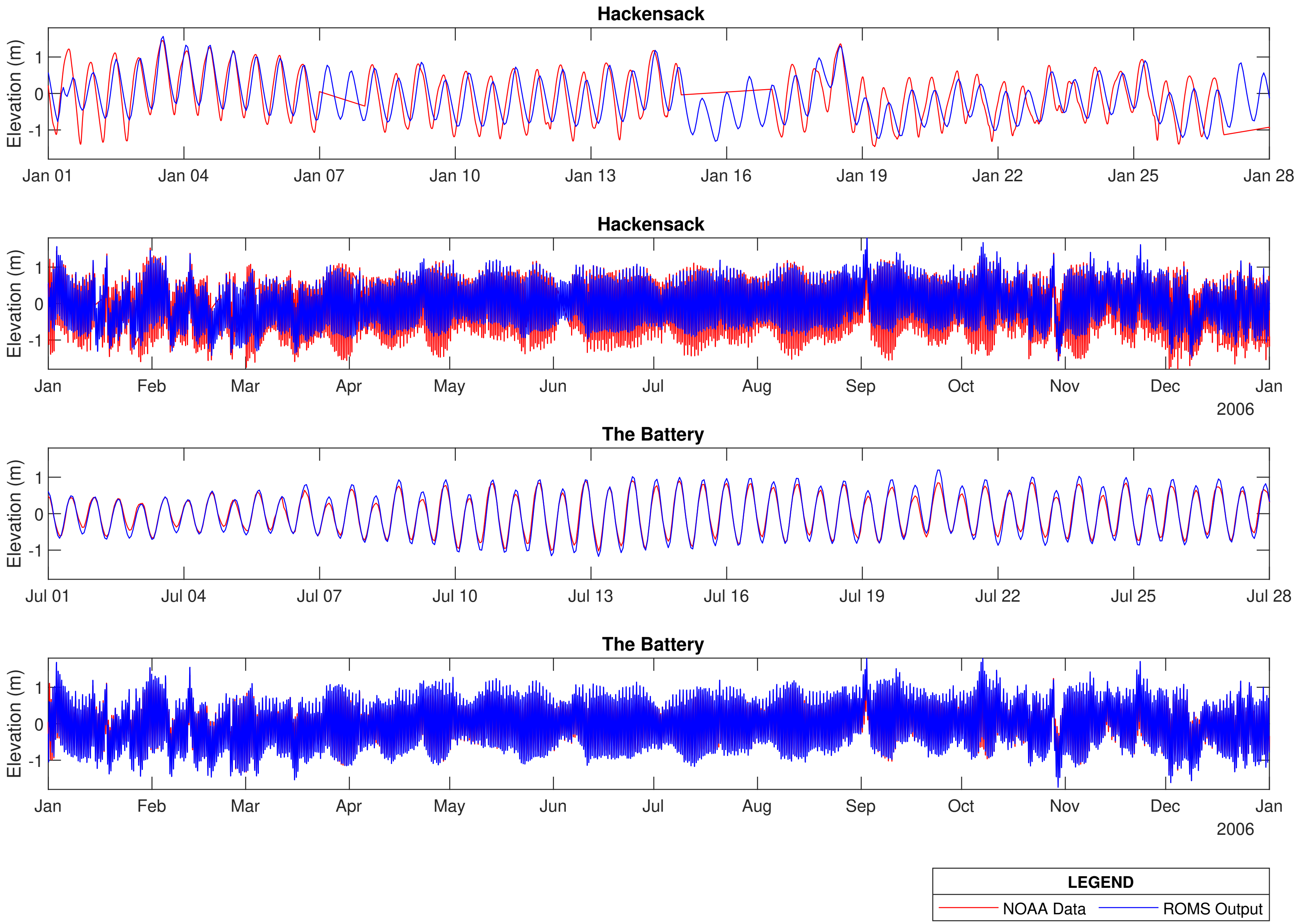

Hackensack
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Hackensack
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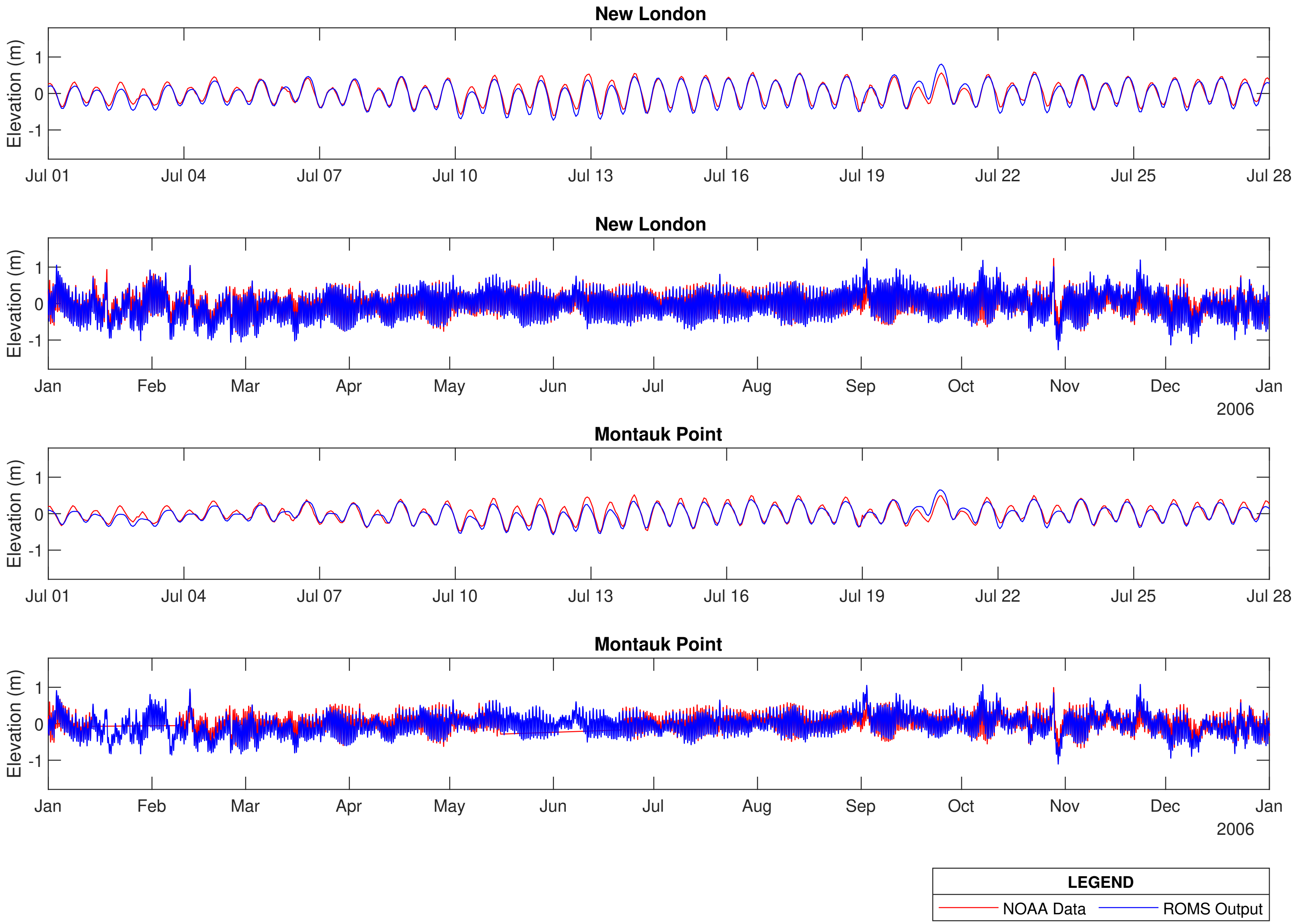
New London
Elevation (m)
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Montauk Point
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Montauk Point
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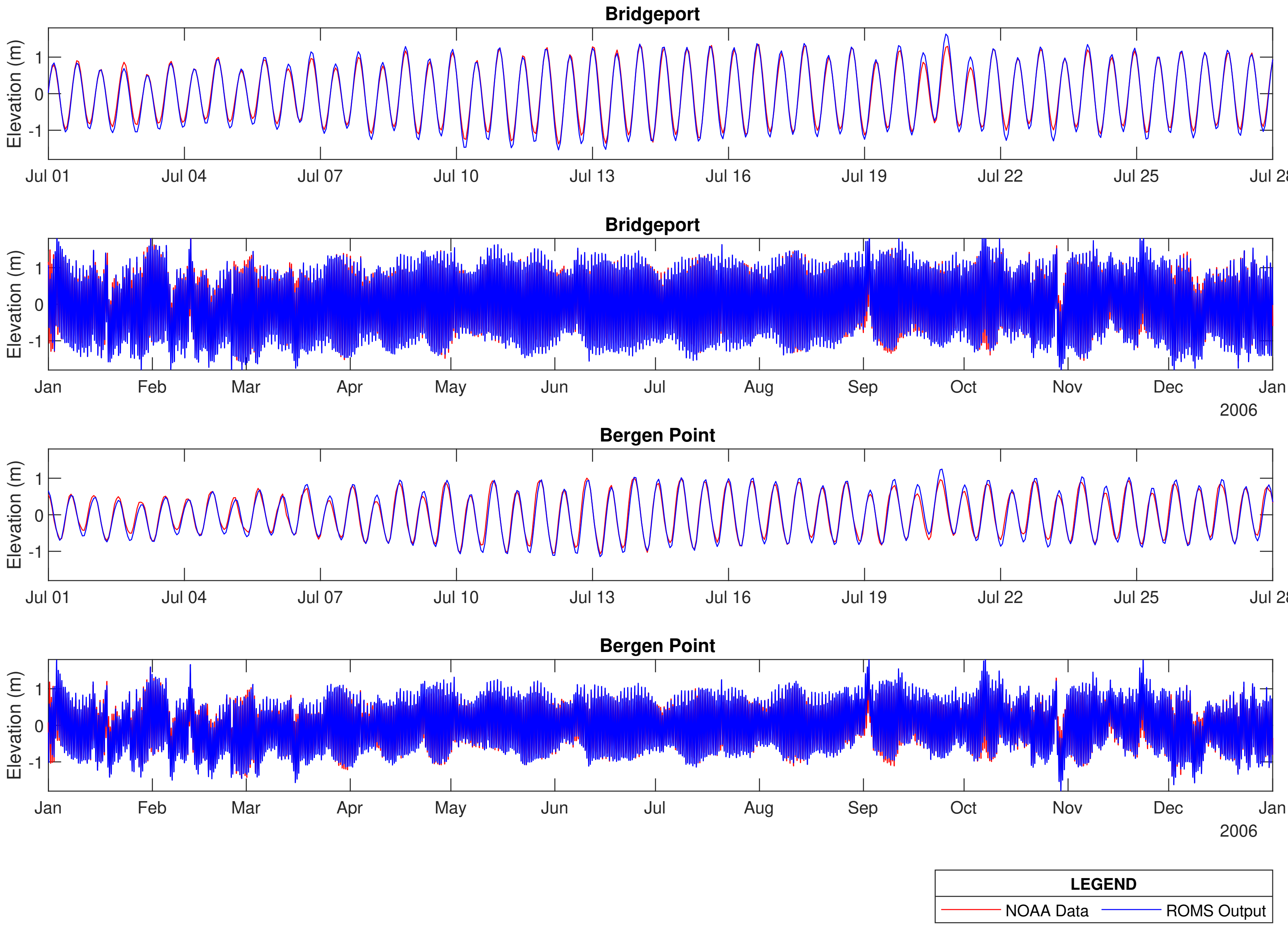

Bridgeport
Elevation (m)
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Bridgeport
Elevation (m)
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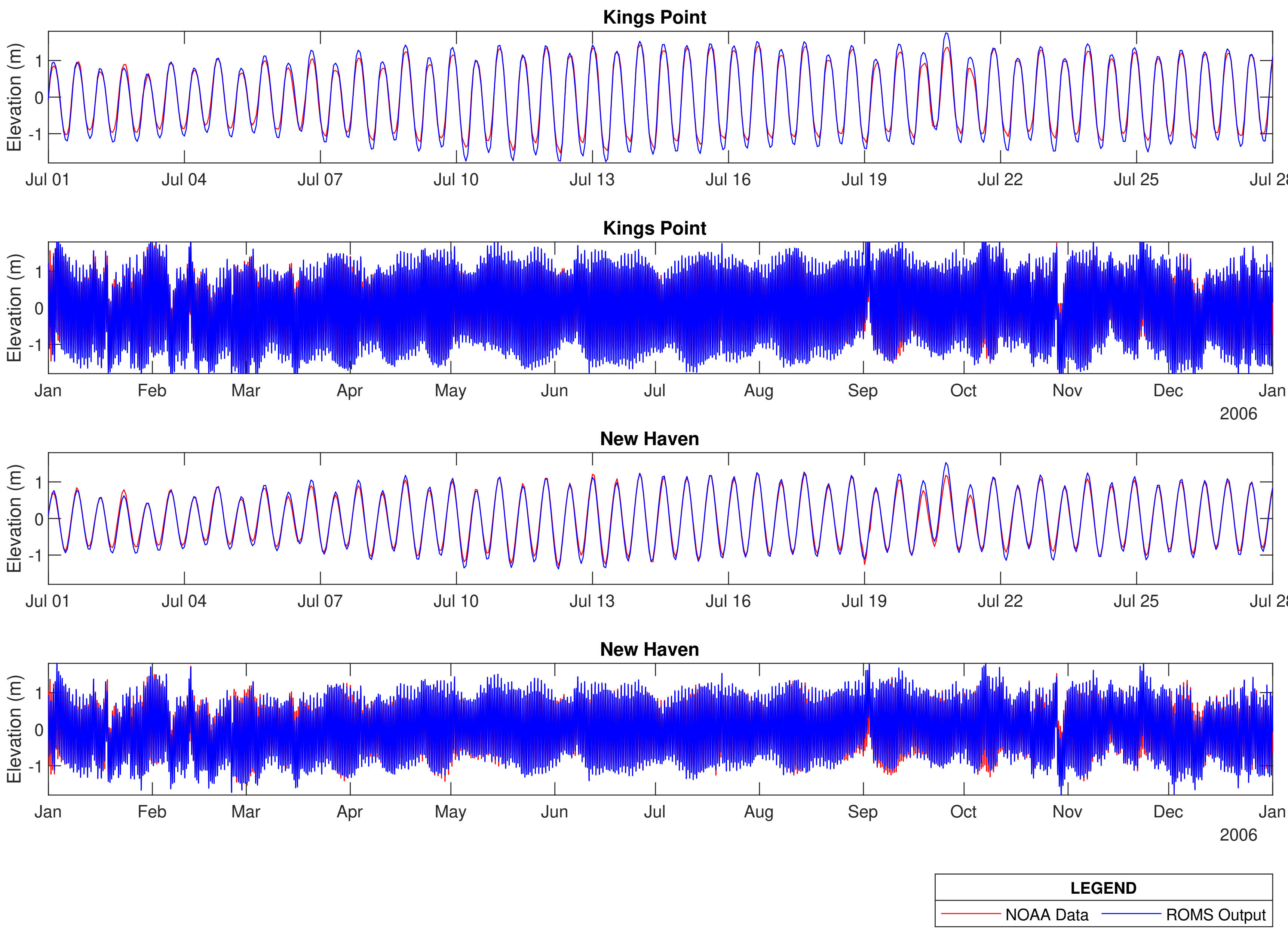
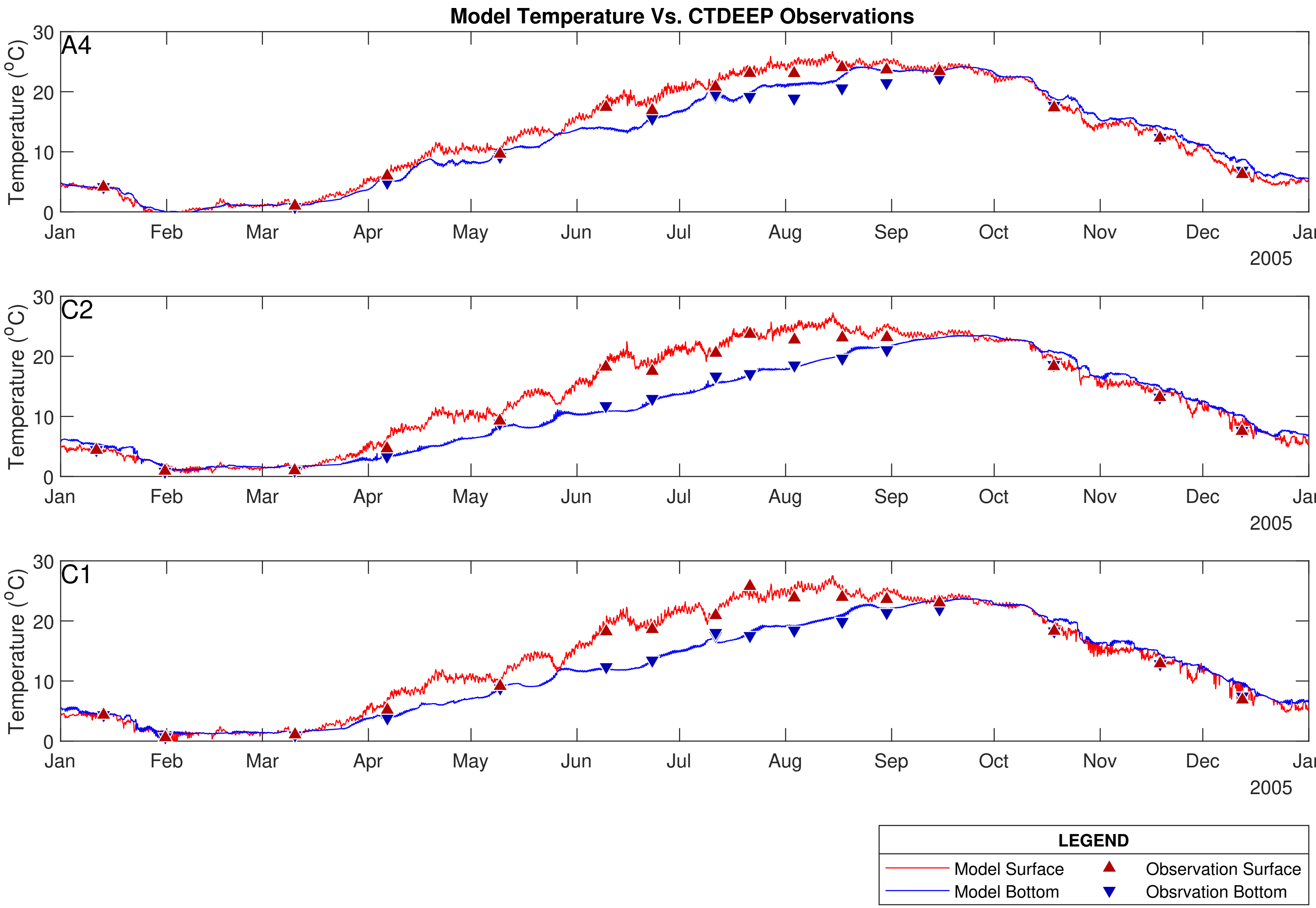
2006
Bergen Point
Elevation (m)
Jul 01
Jul 04
Jul 07
Jul 10
Jul 13
Jul 16
Jul 19
Jul 22
Jul 25
Jul 28
Bergen Point
Elevation (m)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
NOAA Data
ROMS Output

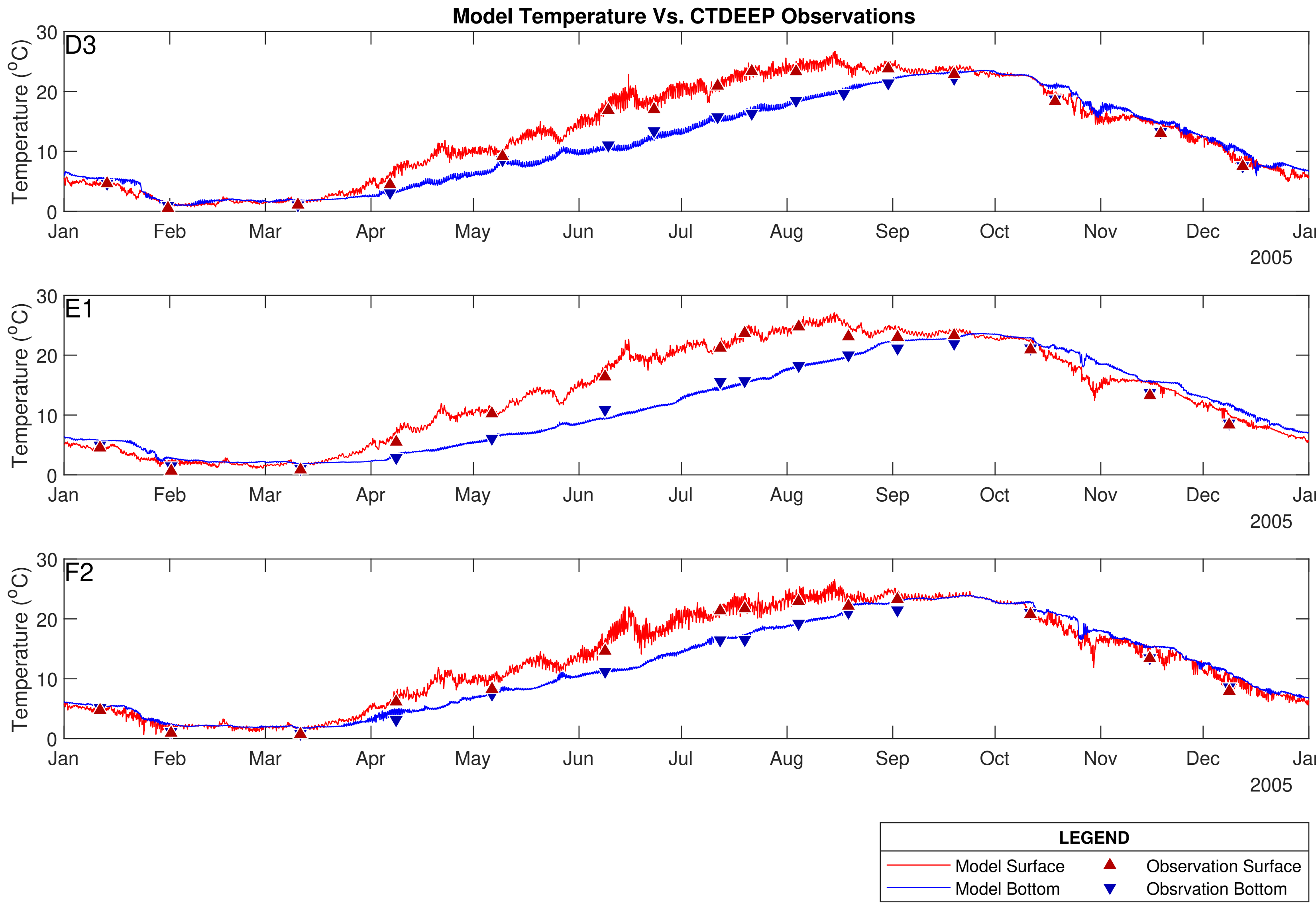

Kings Point
Elevation (m)
1
0
-1
Jul 01
Jul 04
Jul 07
Jul 10
Jul 13
Jul 16
Jul 19
Jul 22
Jul 25
Jul 28
Kings Point
Elevation (m)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
New Haven
Elevation (m)
New Haven
Elevation (m)
LEGEND
NOAA Data
ROMS Output

2

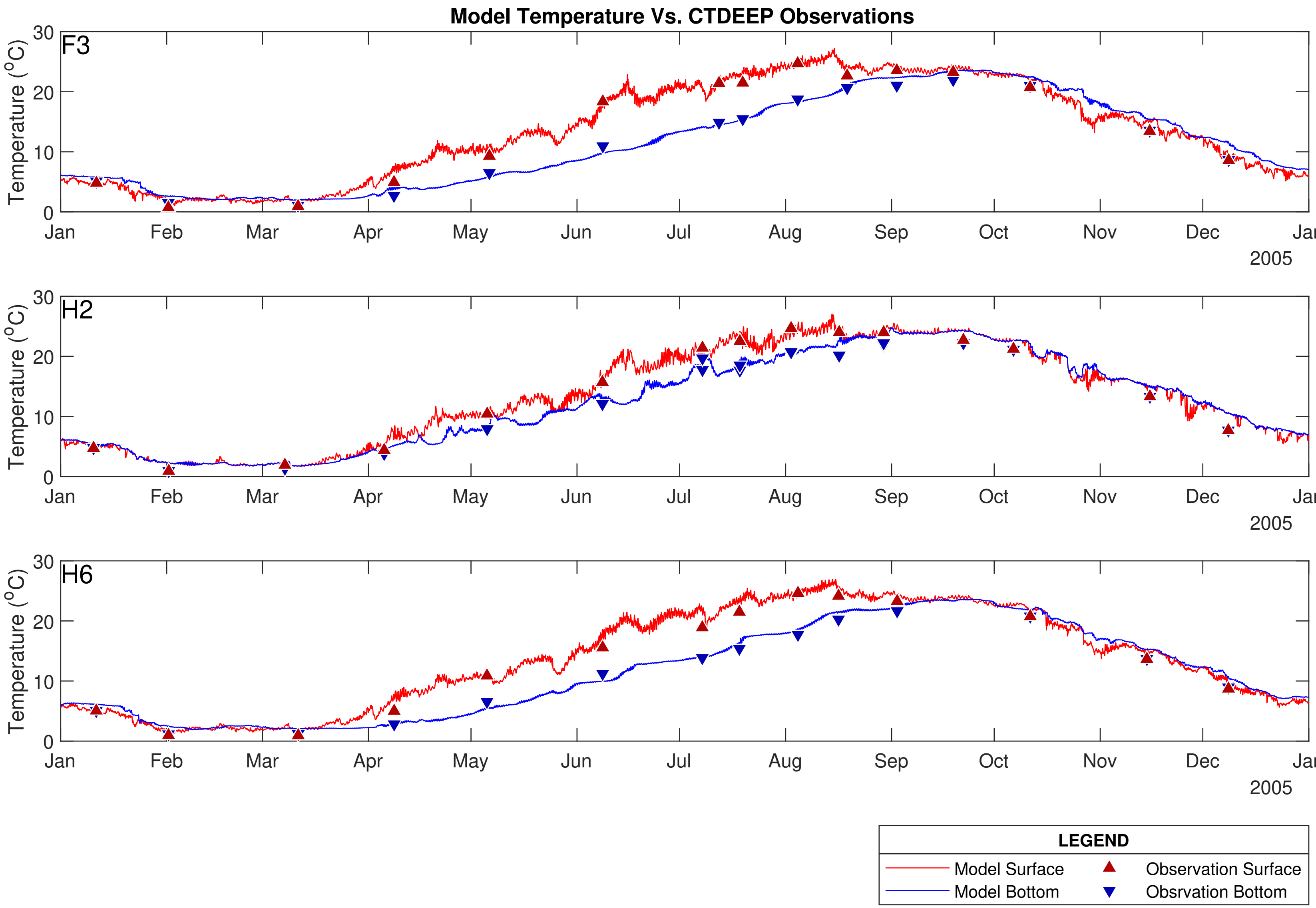
2005-2006 Model-Data Temperature/Salinity Time-Series Comparisons



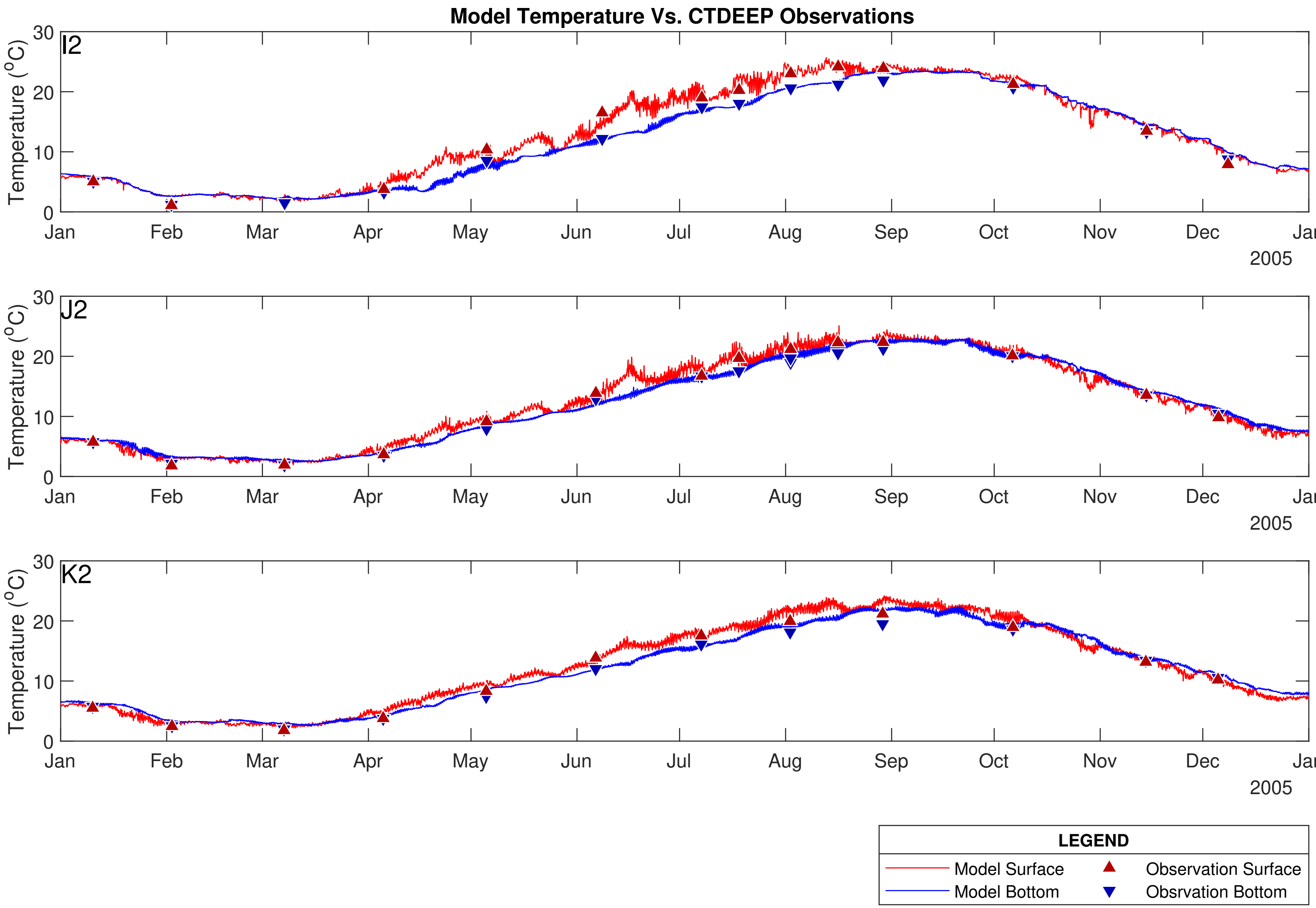
Model Temperature Vs. CTDEEP Observations
A4
C2
C1
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

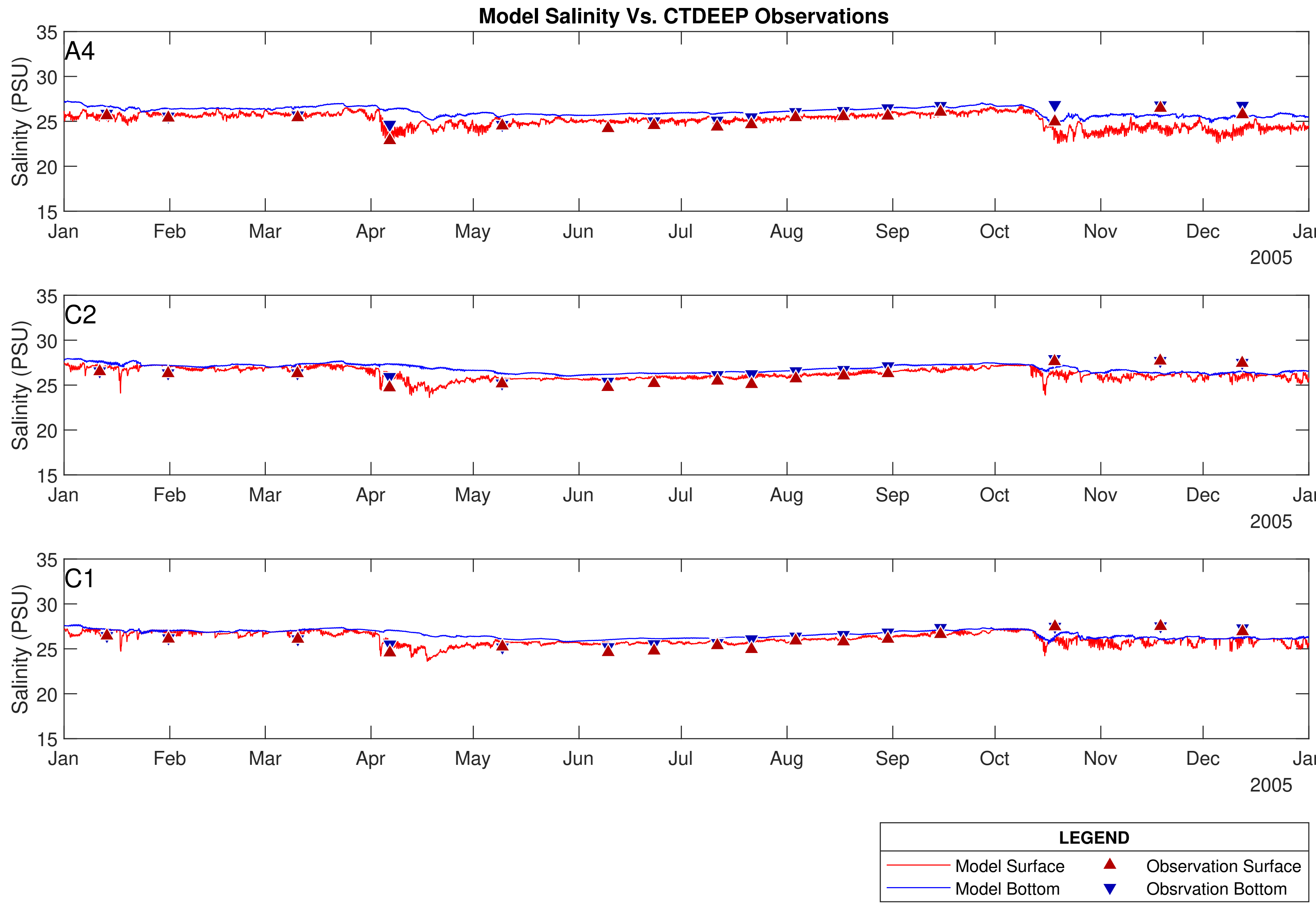


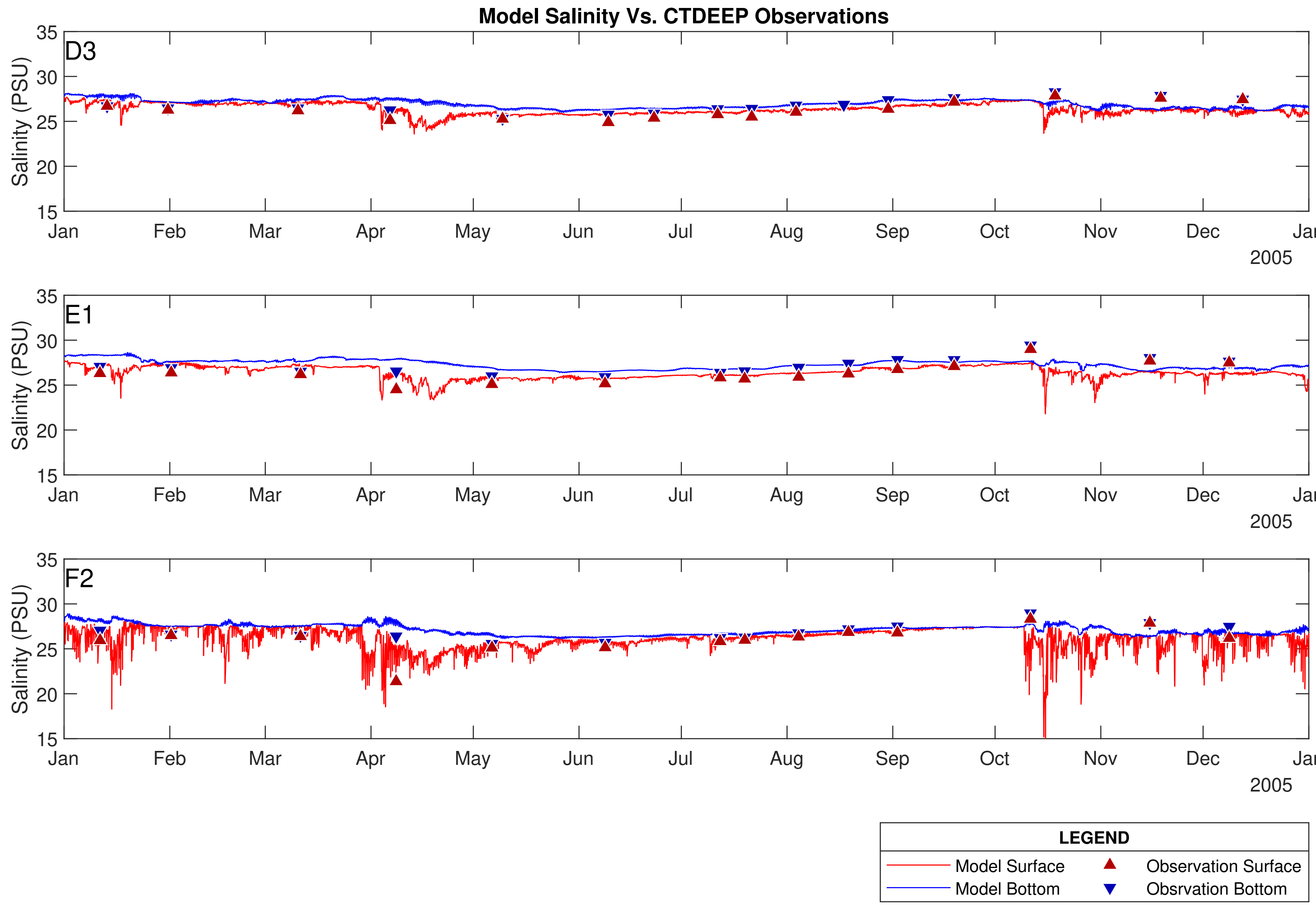
Model Temperature Vs. CTDEEP Observations
D3
E1
F2
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

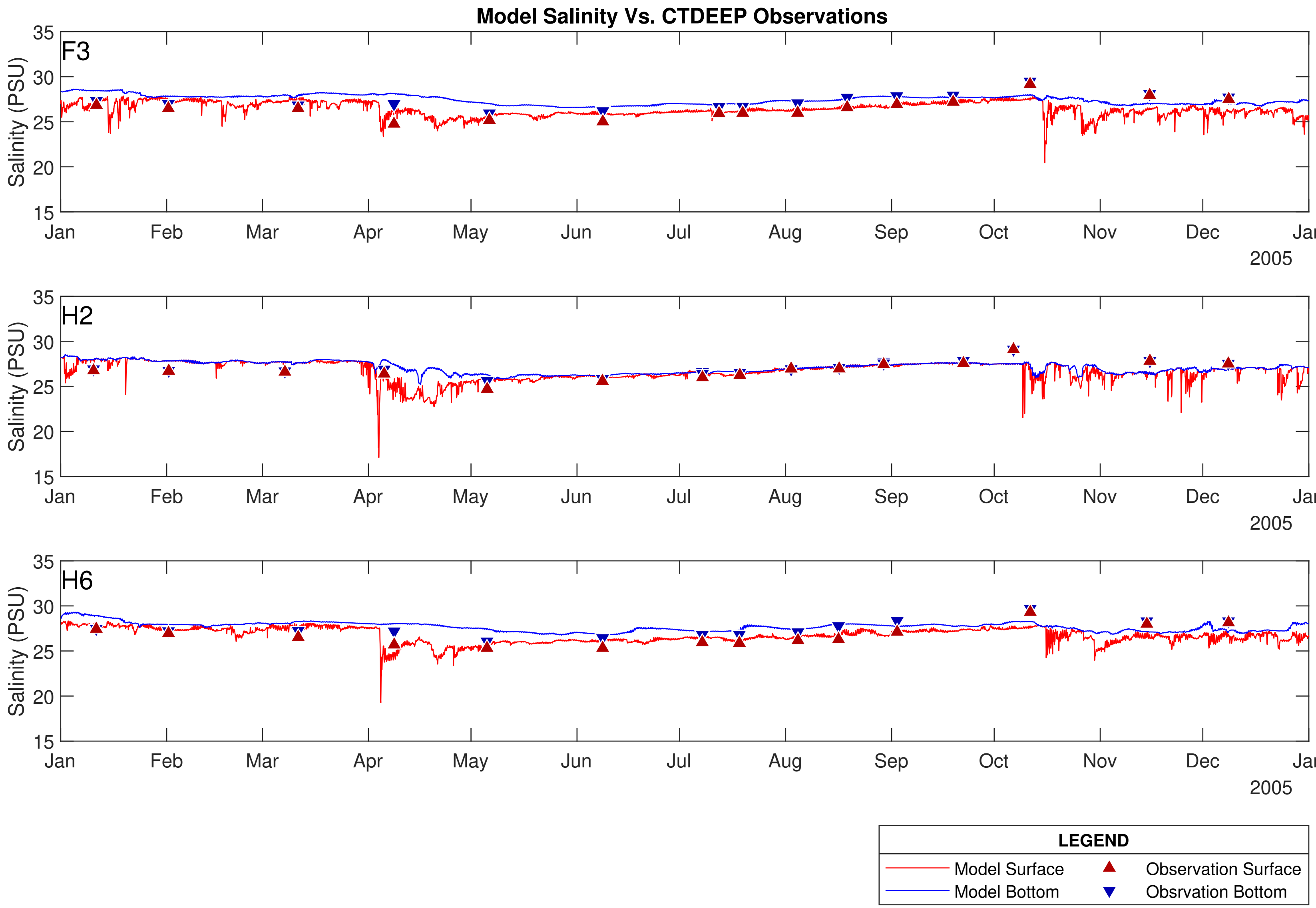


Model Temperature Vs. CTDEEP Observations
F3
H2
H6
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

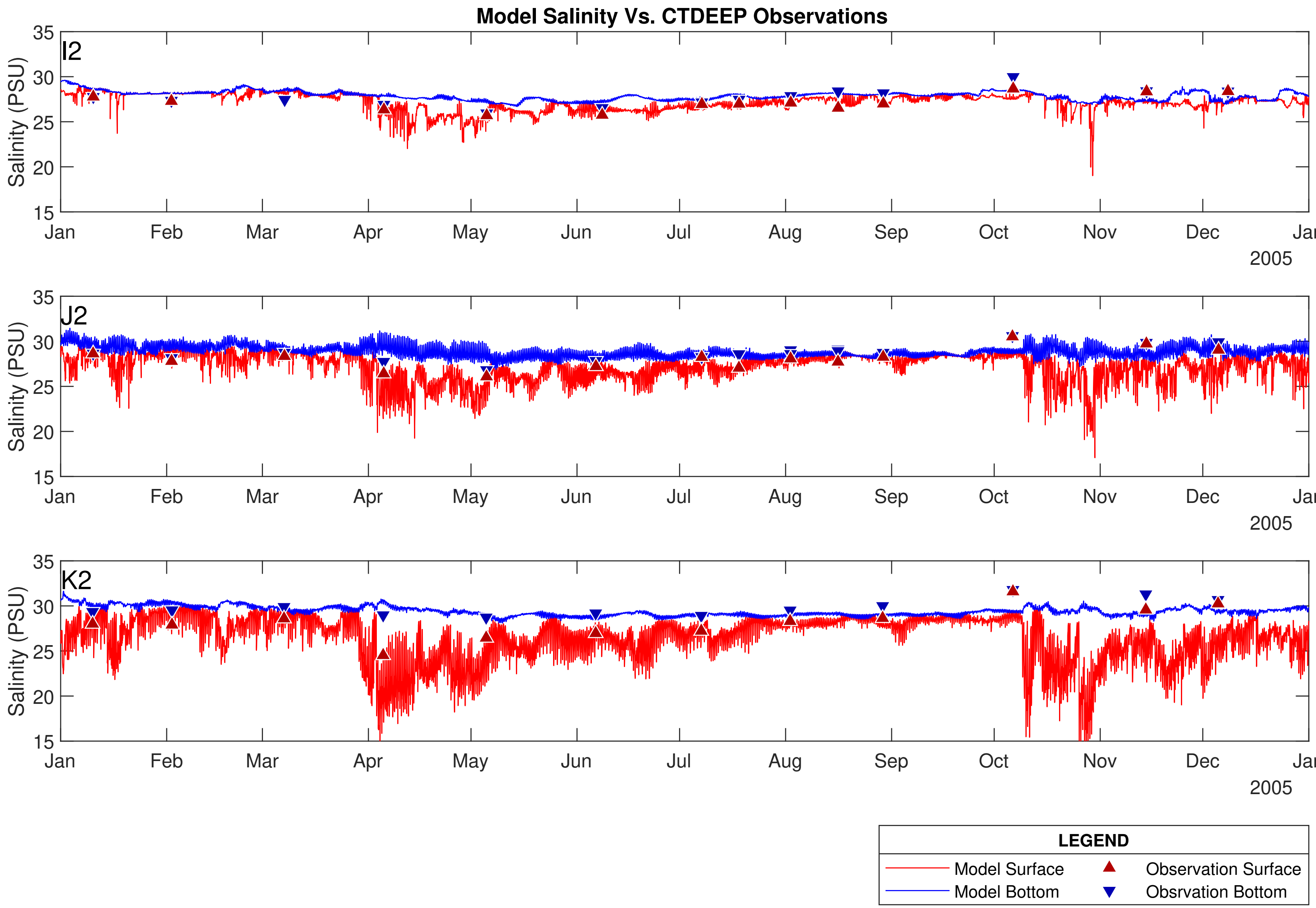

Model Temperature Vs. CTDEEP Observations
I2
J2
K2
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom


Model Salinity Vs. CTDEEP Observations
A4
C2
C1
Salinity (PSU)
35
30
25
20
15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

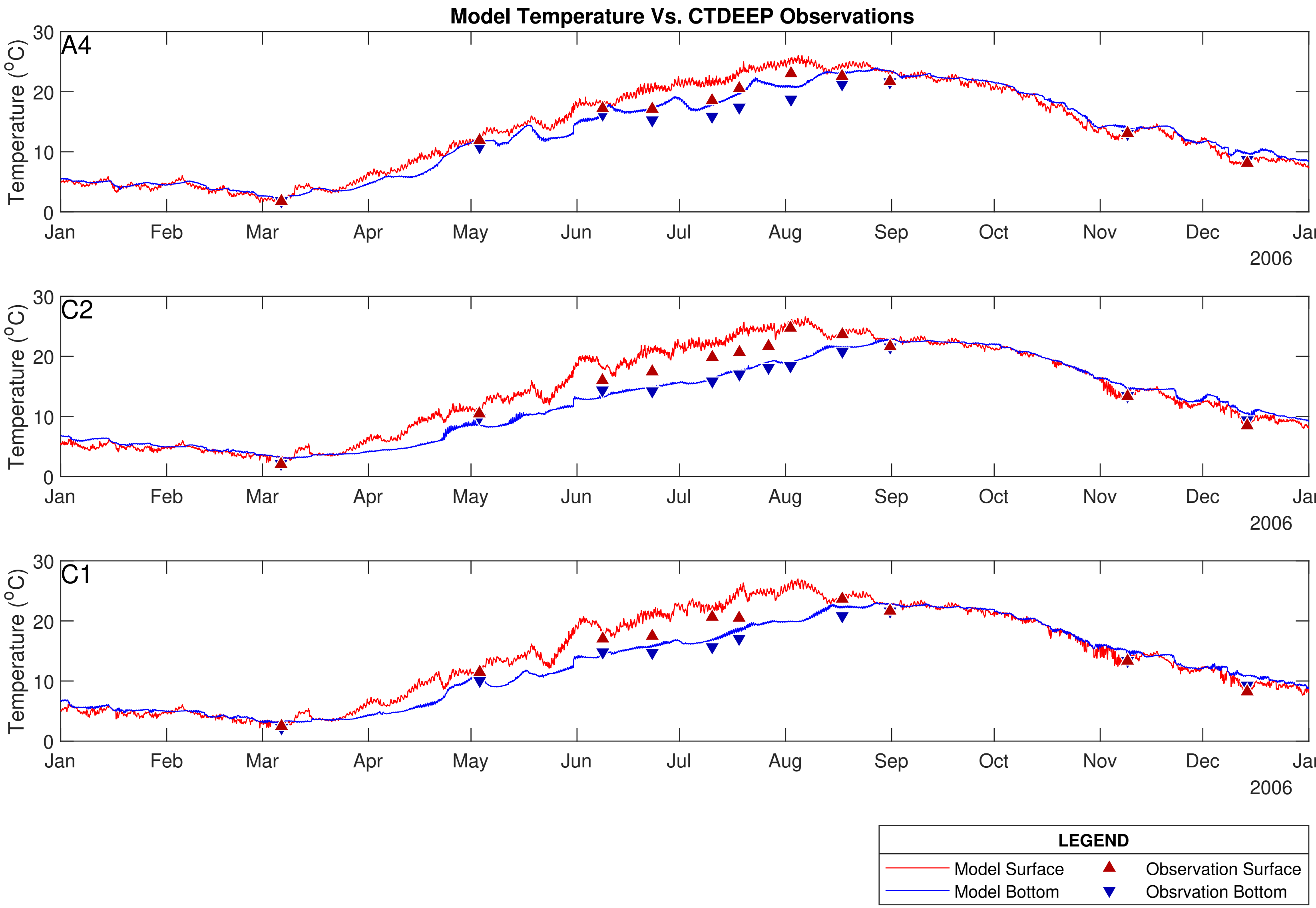

Model Salinity Vs. CTDEEP Observations
D3
E1
F2
Salinity (PSU)
35
30
25
20
15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



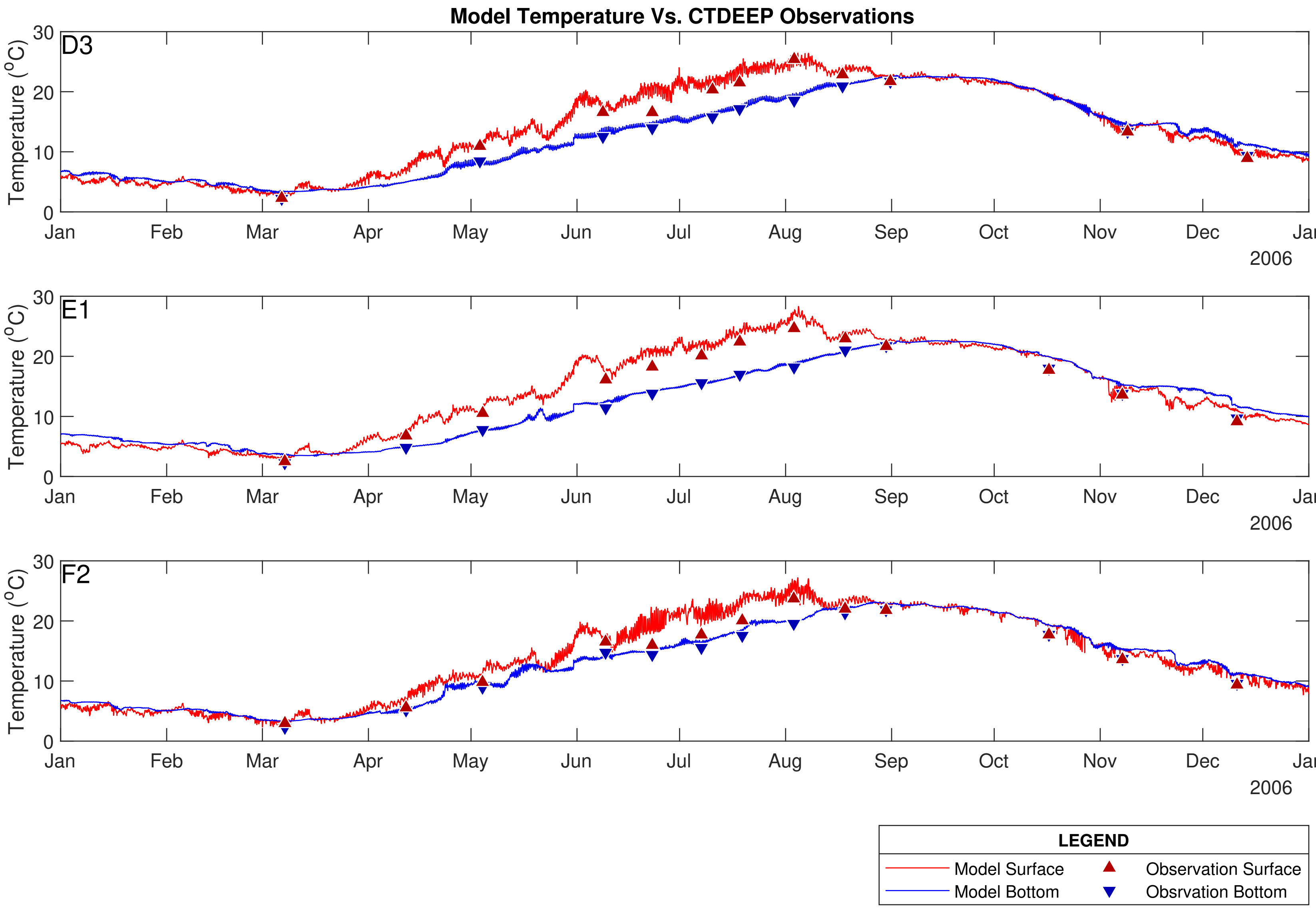
Model Salinity Vs. CTDEEP Observations
F3
H2
H6
Salinity (PSU)
35
30
25
20
15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

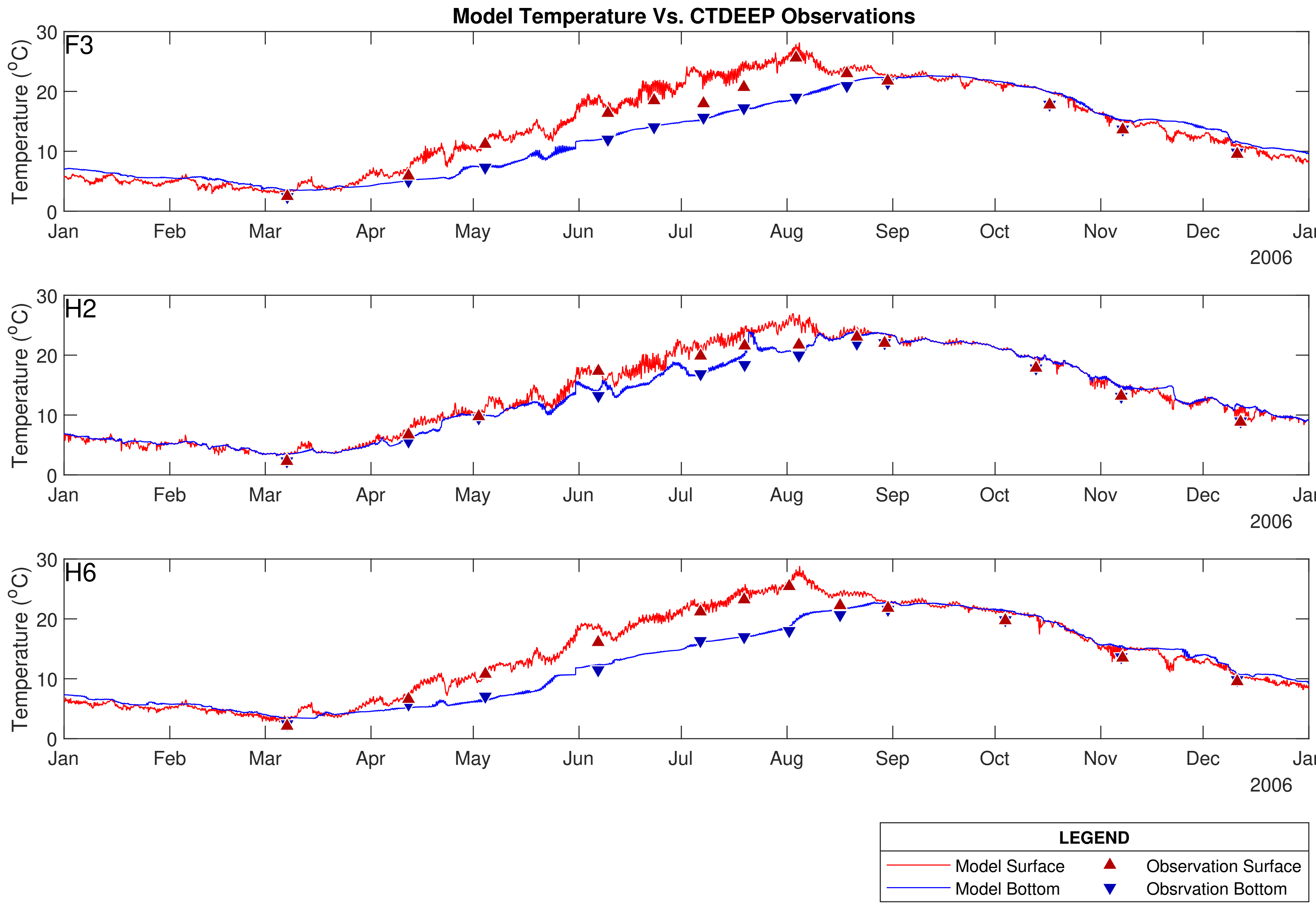


Model Salinity Vs. CTDEEP Observations
I2
J2
K2
Salinity (PSU)
35
30
25
20
15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

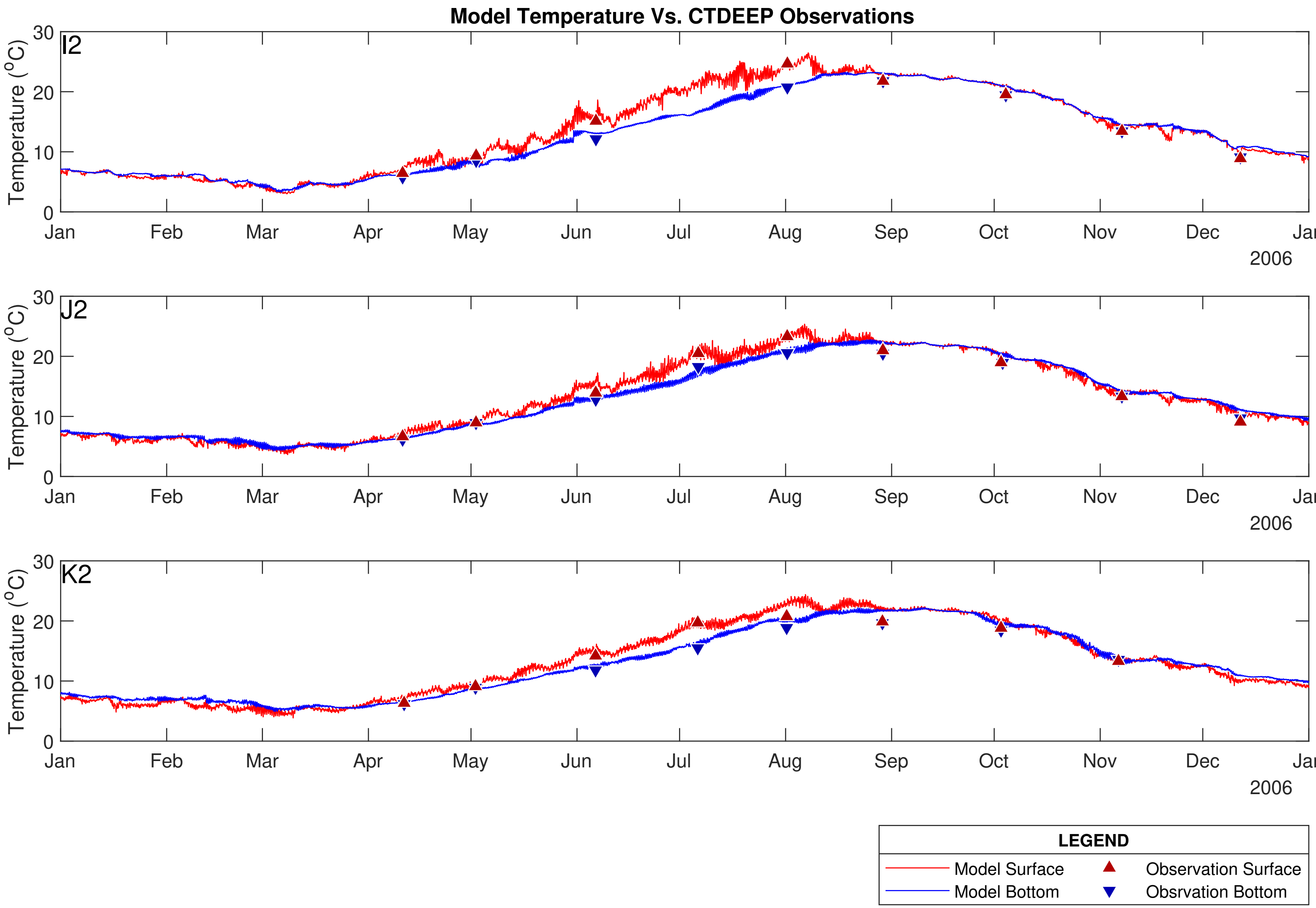


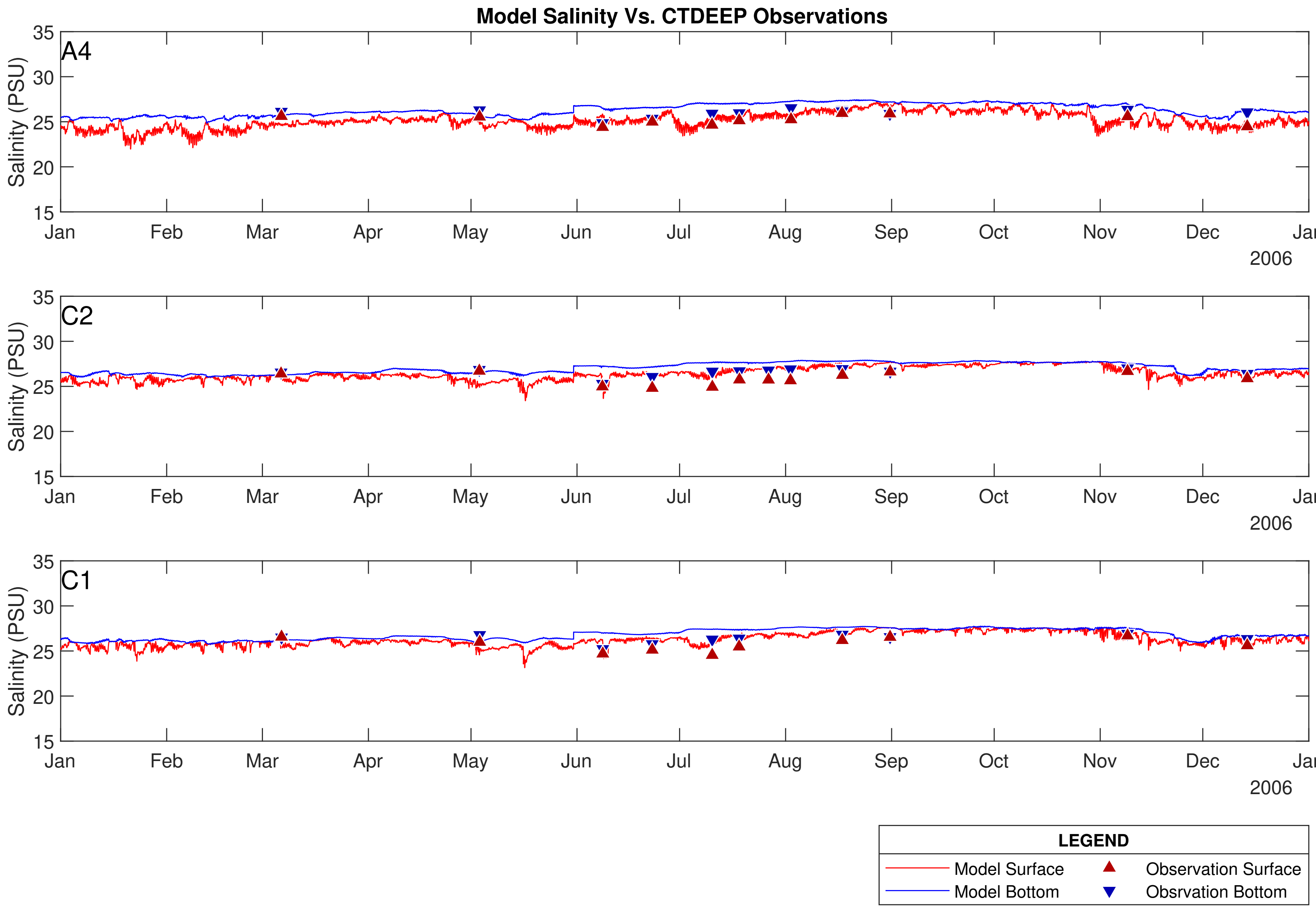
Model Temperature Vs. CTDEEP Observations
A4
C2
C1
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom


Model Temperature Vs. CTDEEP Observations
D3
E1
F2
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

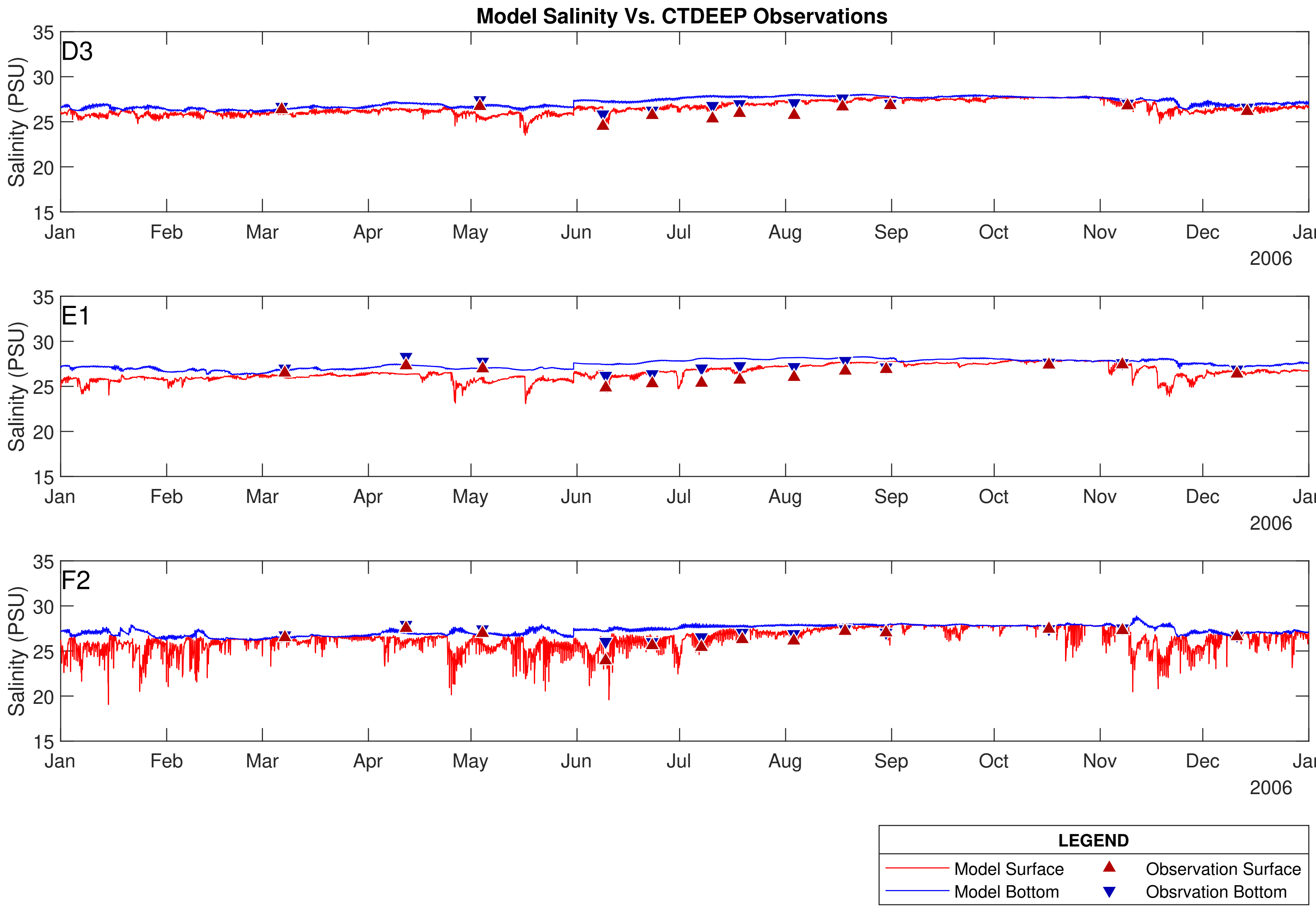


Model Temperature Vs. CTDEEP Observations
F3
H2
H6
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

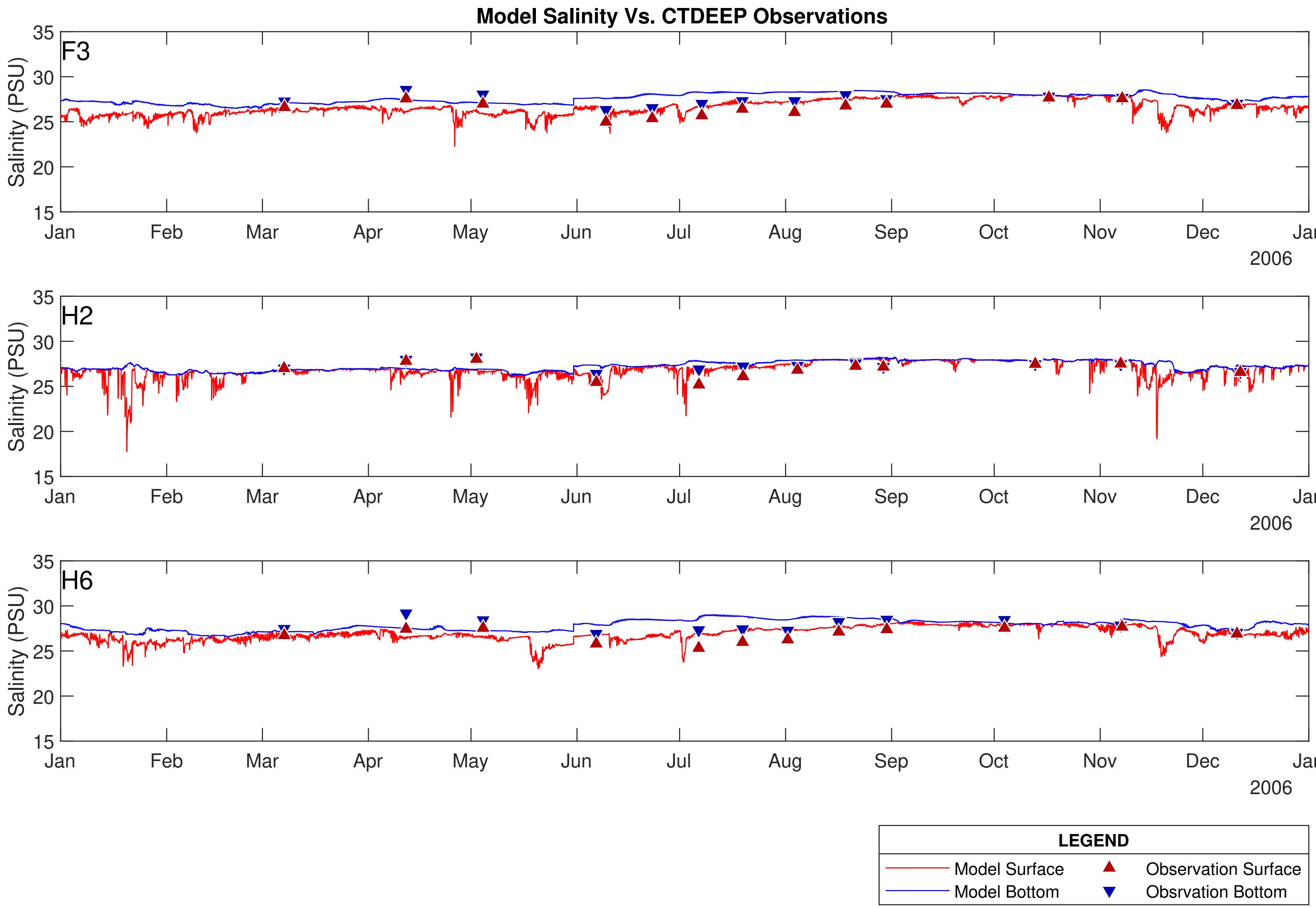

Model Temperature Vs. CTDEEP Observations
I2
J2
K2
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



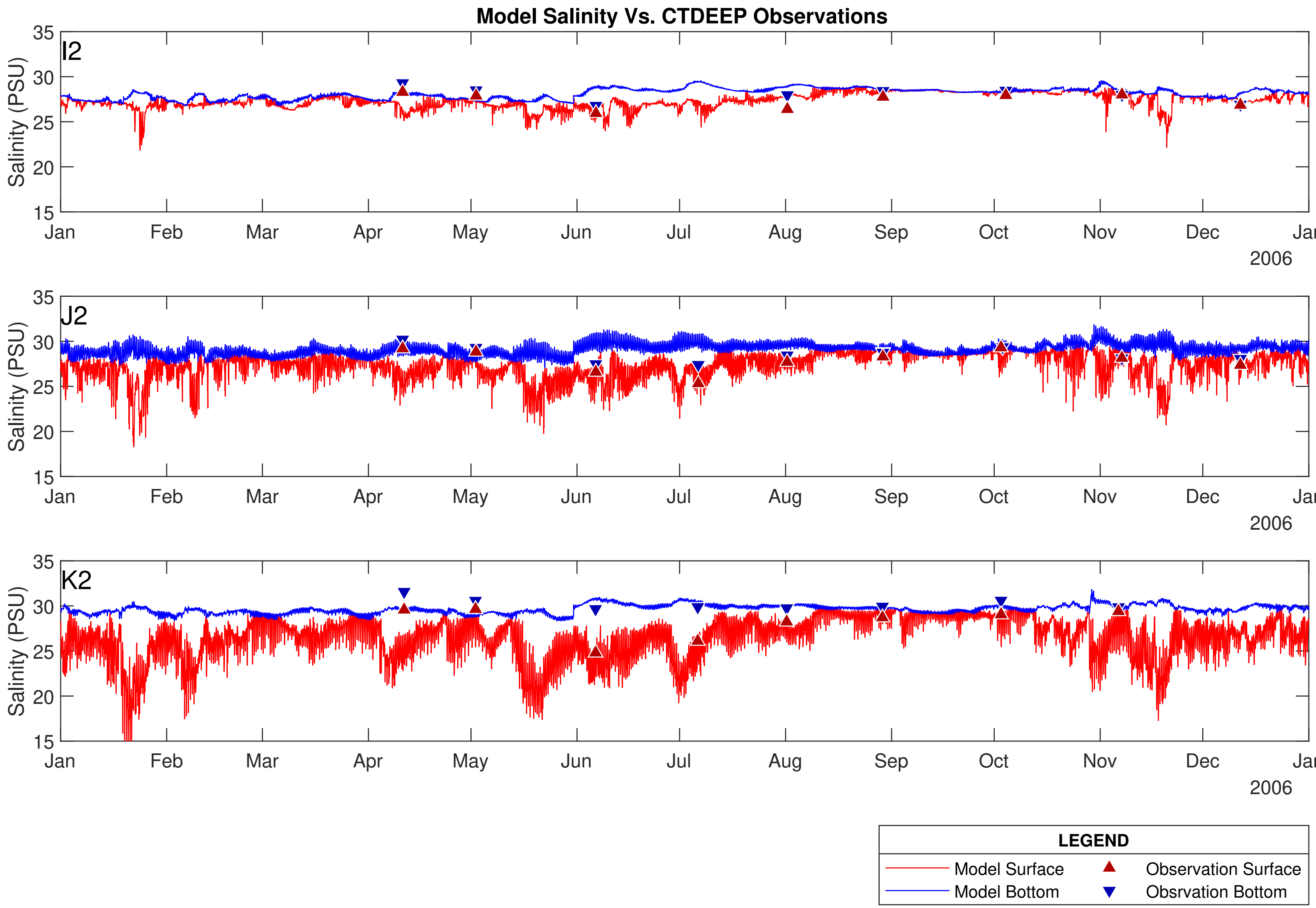
Model Salinity Vs. CTDEEP Observations
A4
C2
C1
Salinity (PSU)
35
30
25
20
15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

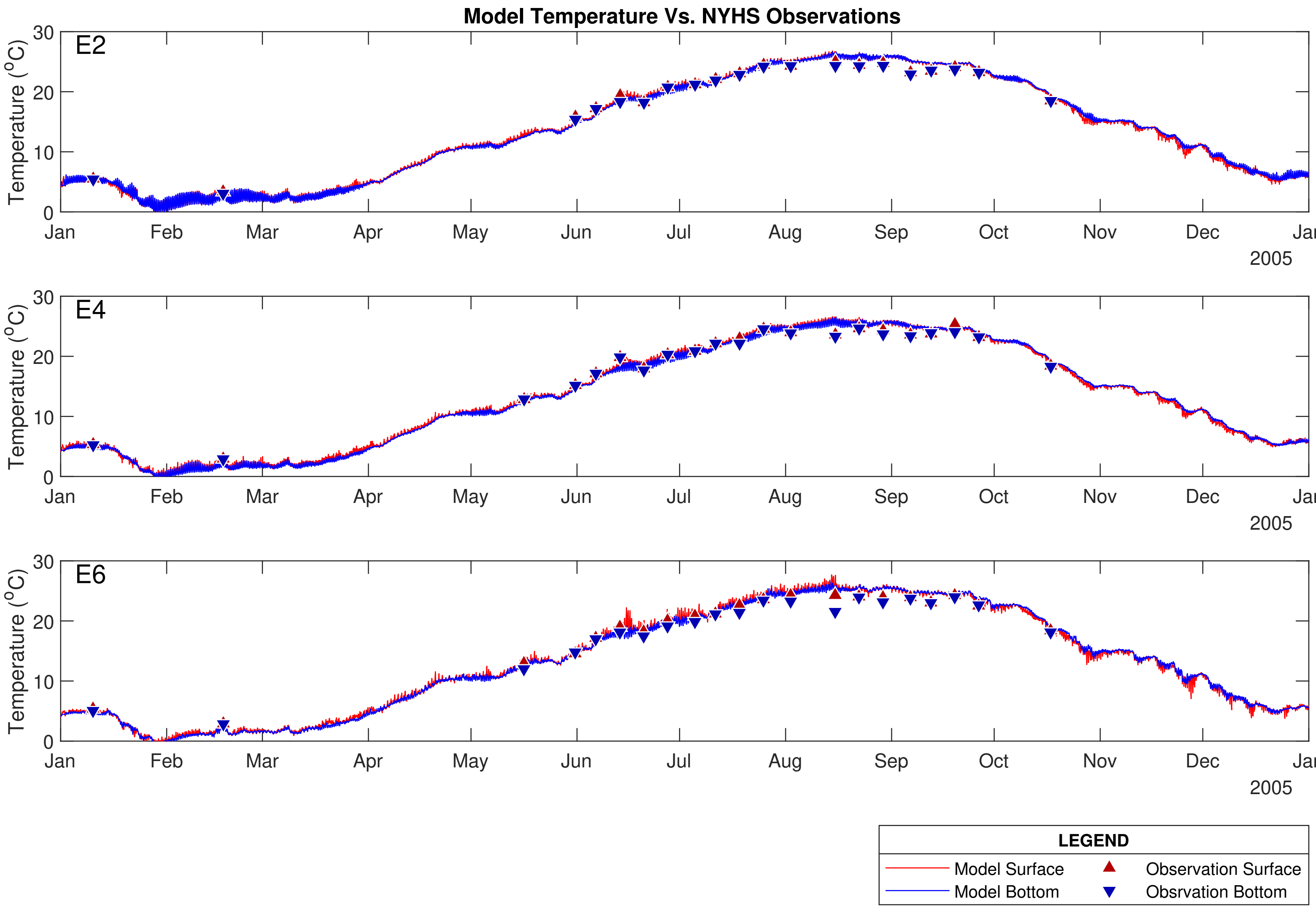


Model Salinity Vs. CTDEEP Observations
D3
E1
F2
Salinity (PSU)
35
30
25
20
15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

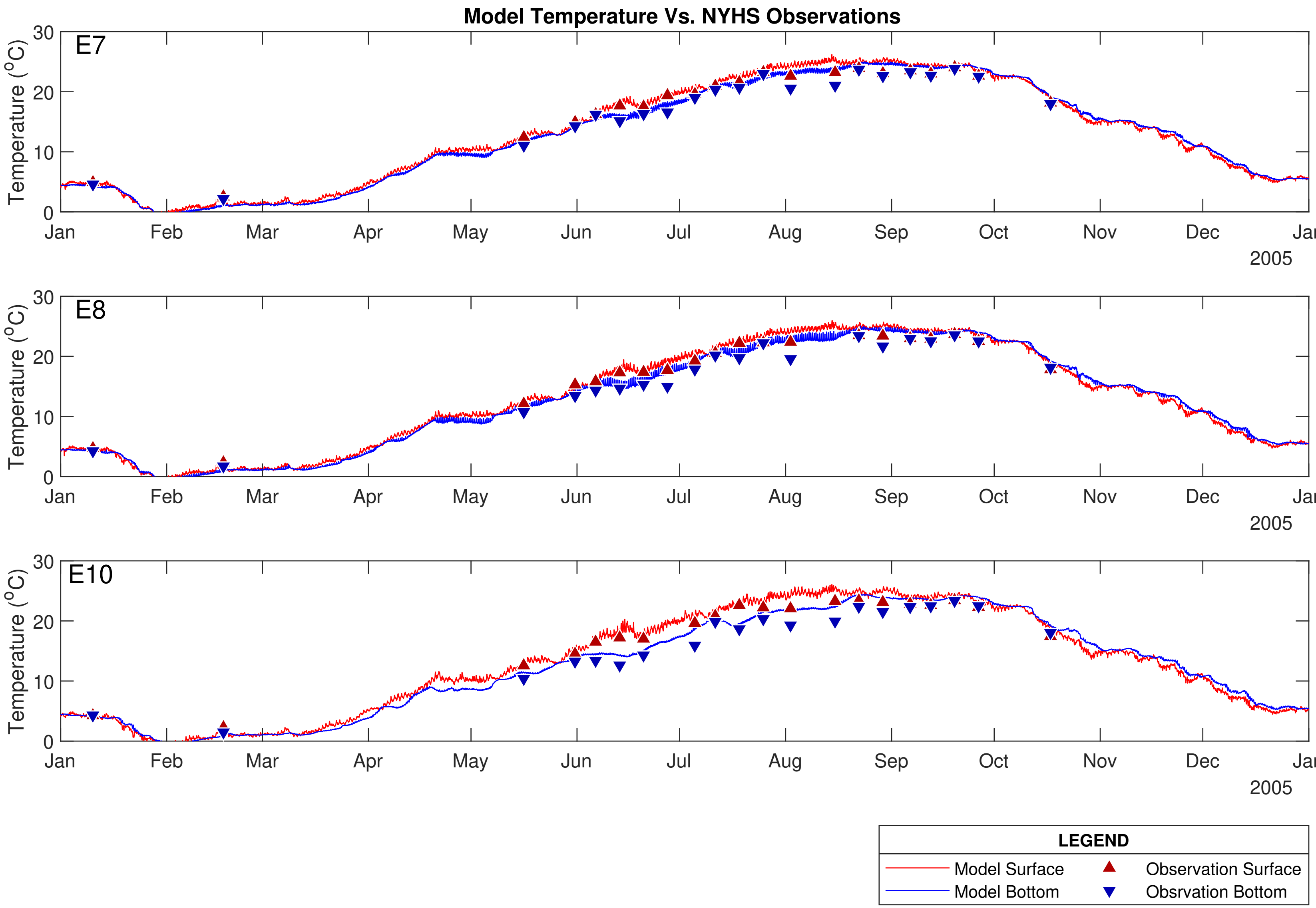


Model Salinity Vs. CTDEEP Observations
F3
H2
H6
Salinity (PSU)
35
30
25
20
15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

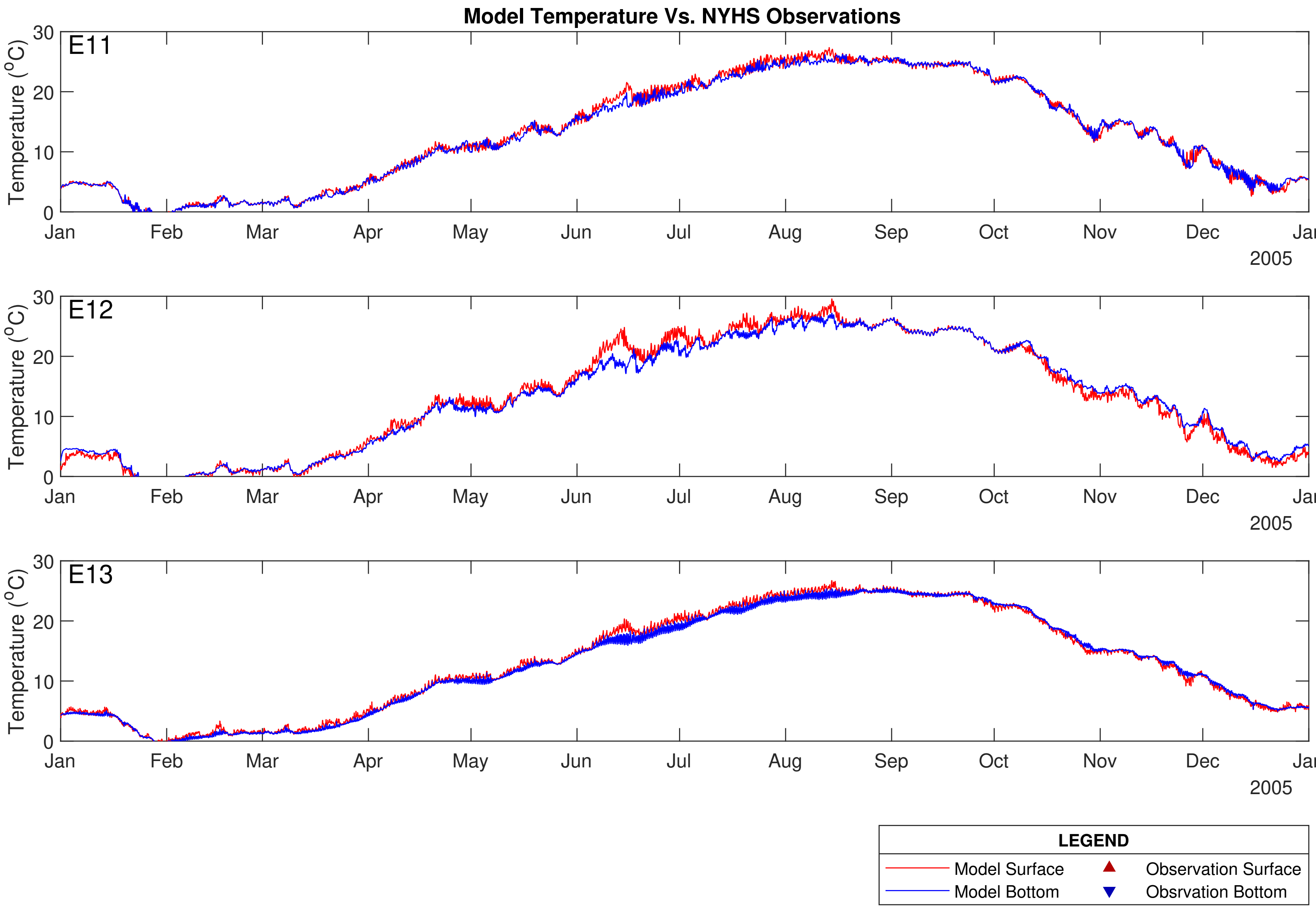

Model Salinity Vs. CTDEEP Observations
I2
J2
K2
Salinity (PSU)
35
30
25
20
15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



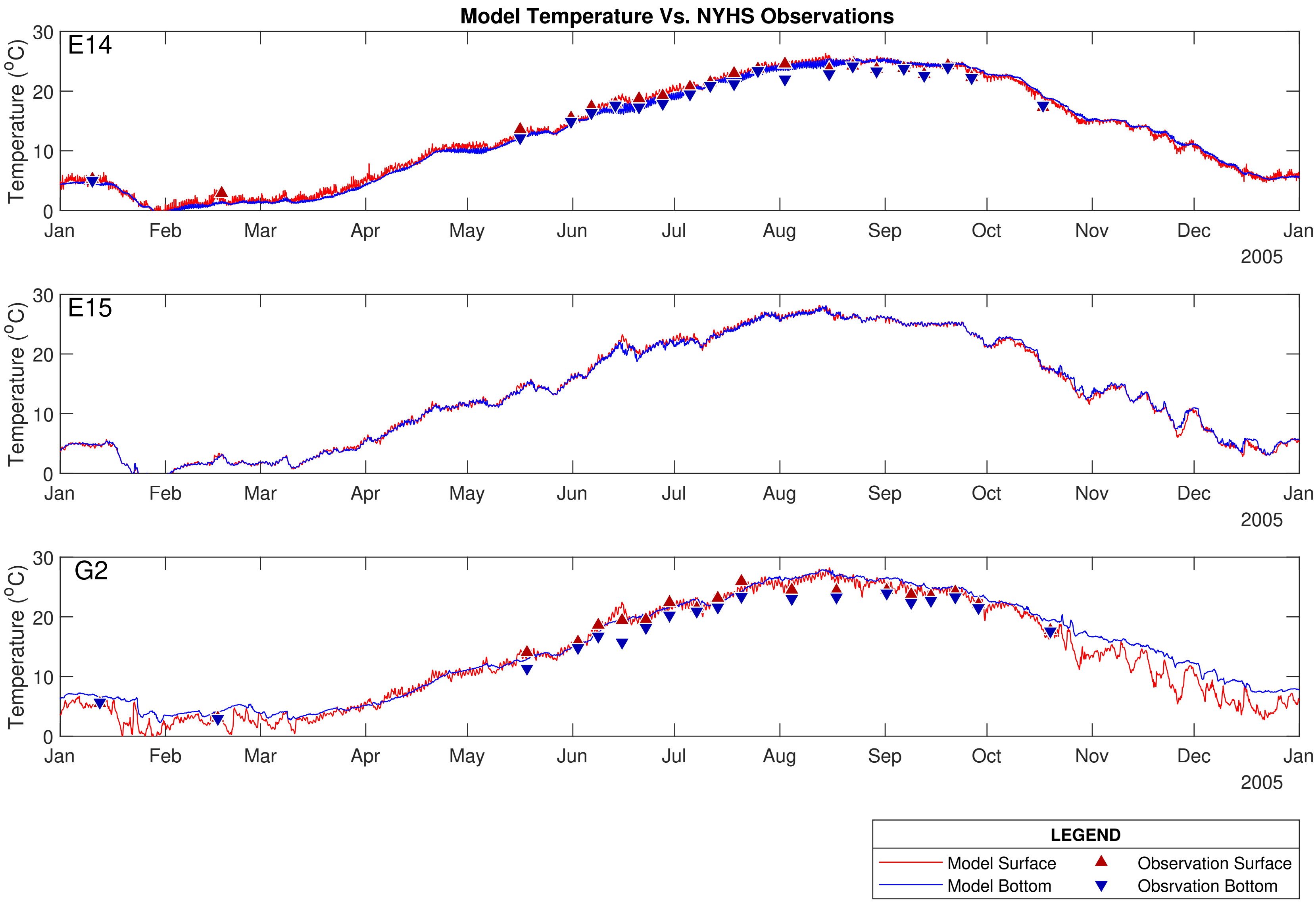
Model Temperature Vs. NYHS Observations
E2
E4
E6
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



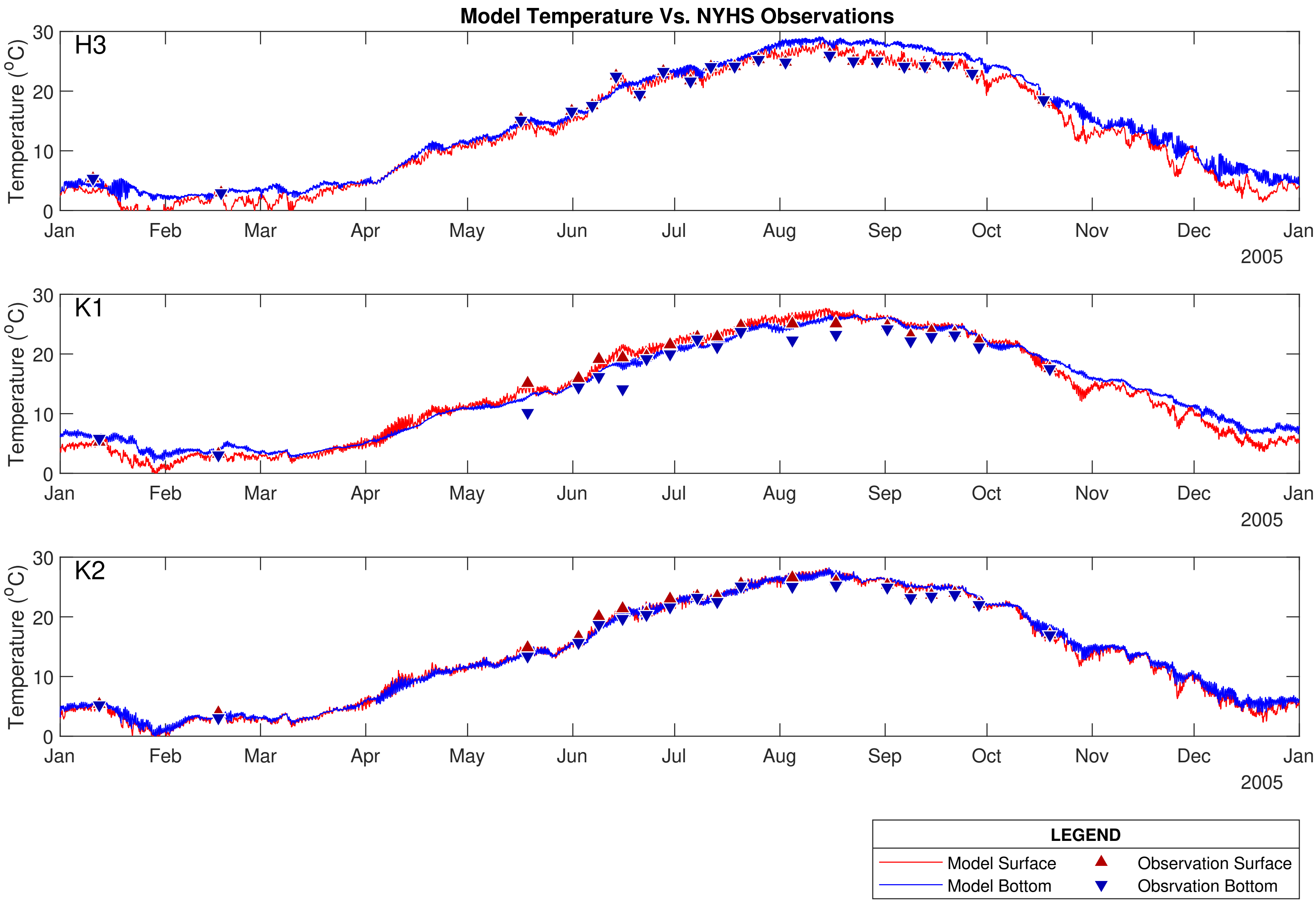
Model Temperature Vs. NYHS Observations
E7
E8
E10
Temperature (°C)
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



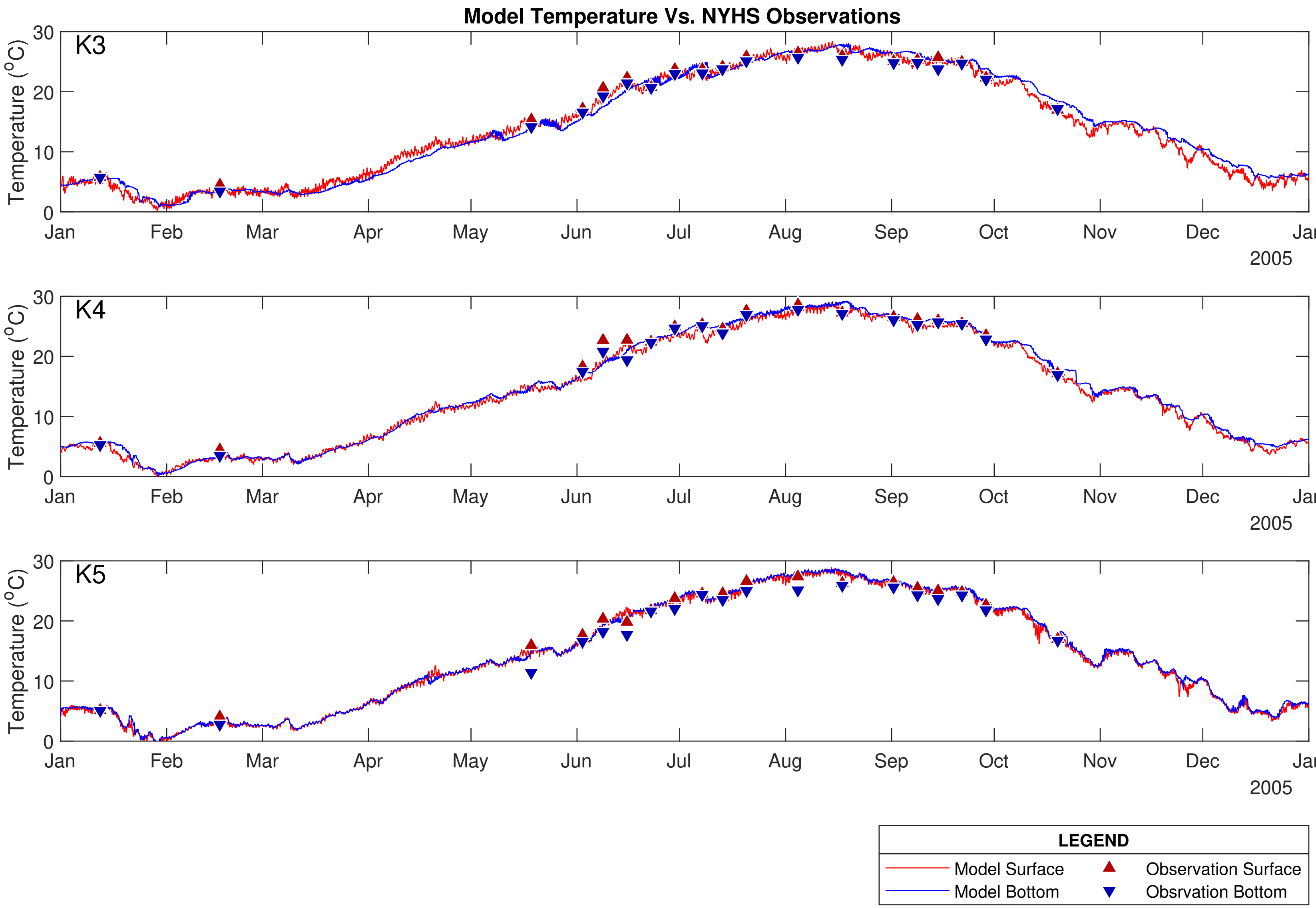
Model Temperature Vs. NYHS Observations
E11
E12
E13
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



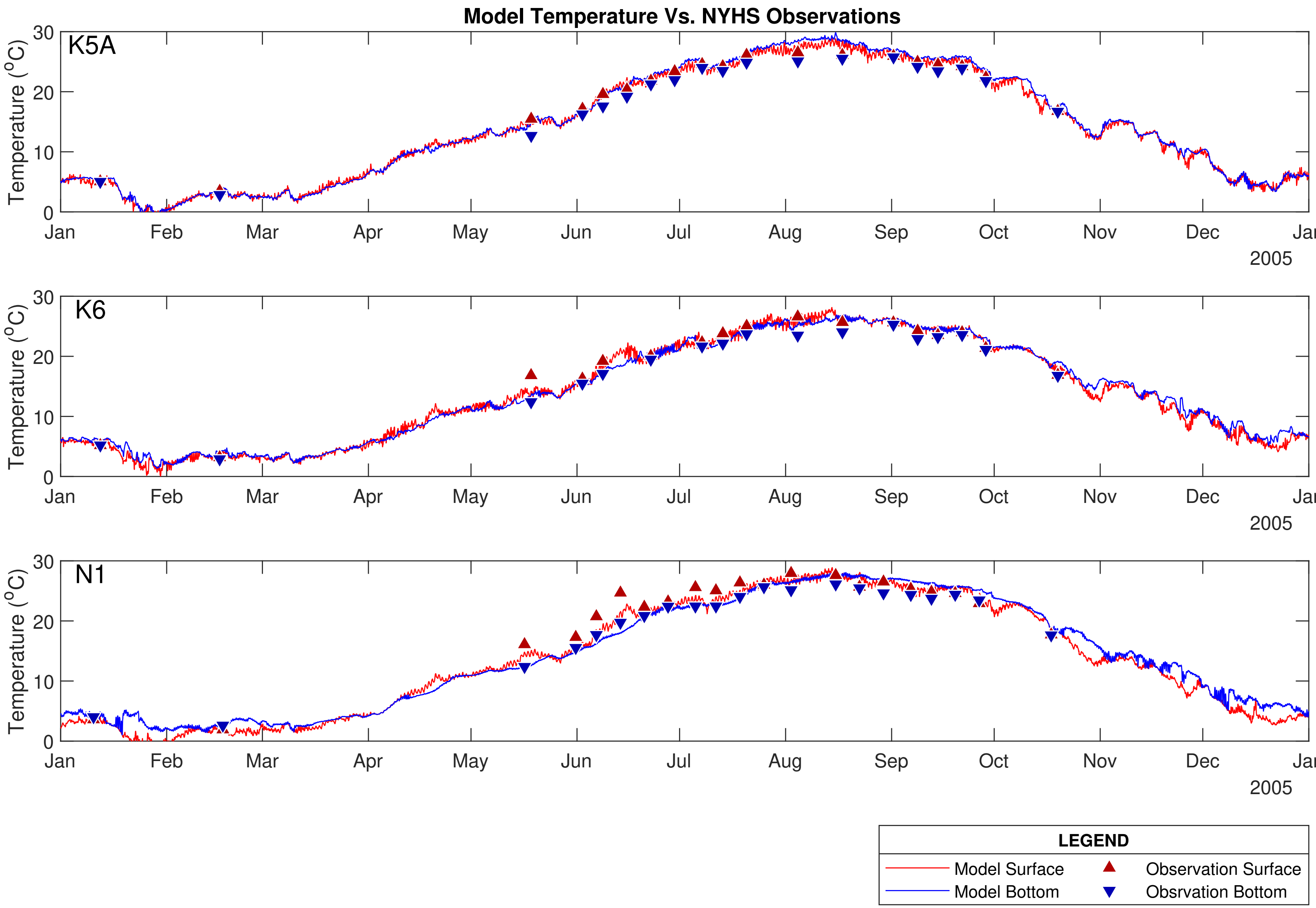
Model Temperature Vs. NYHS Observations
E14
E15
G2
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



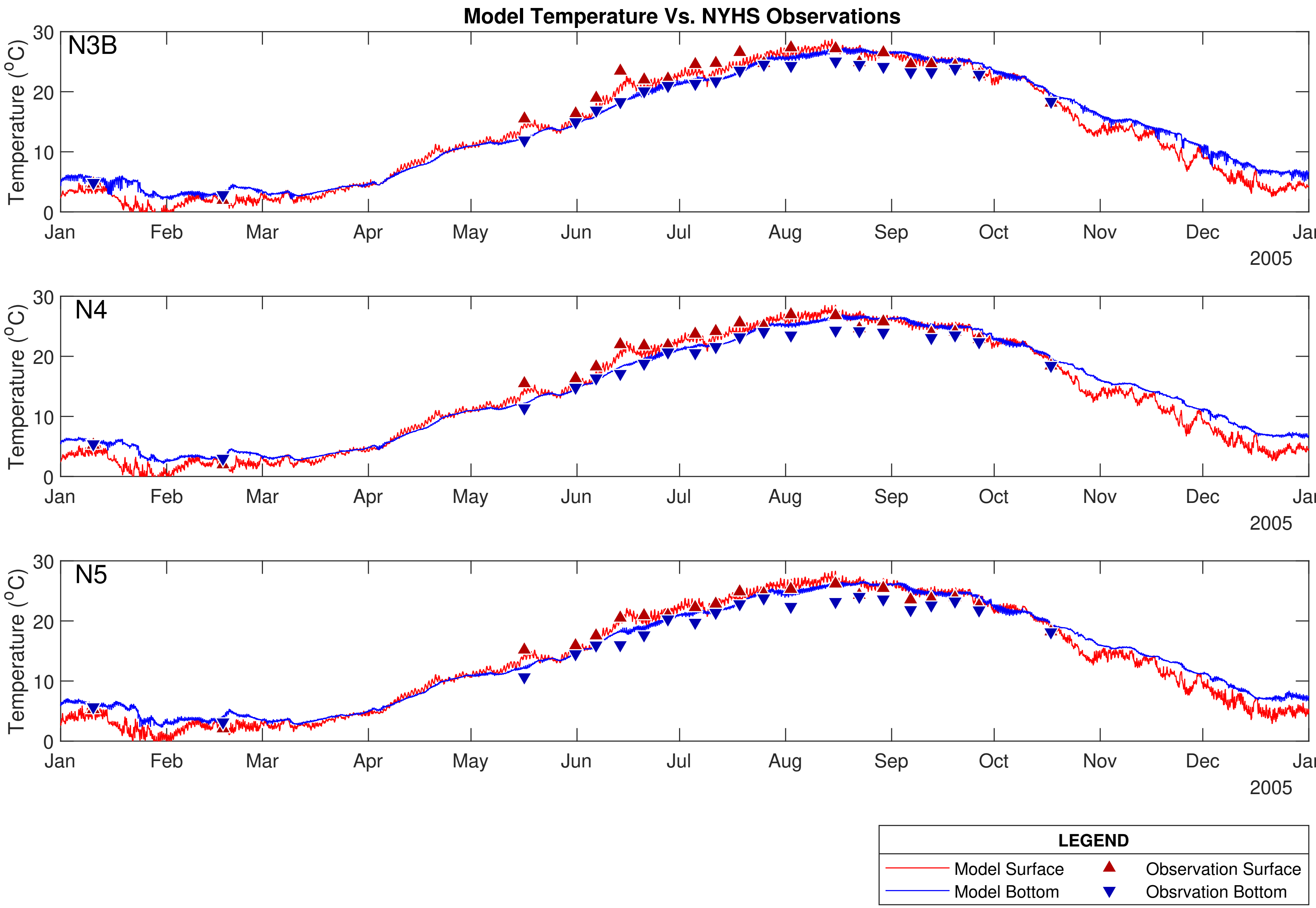
Model Temperature Vs. NYHS Observations
H3
K1
K2
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



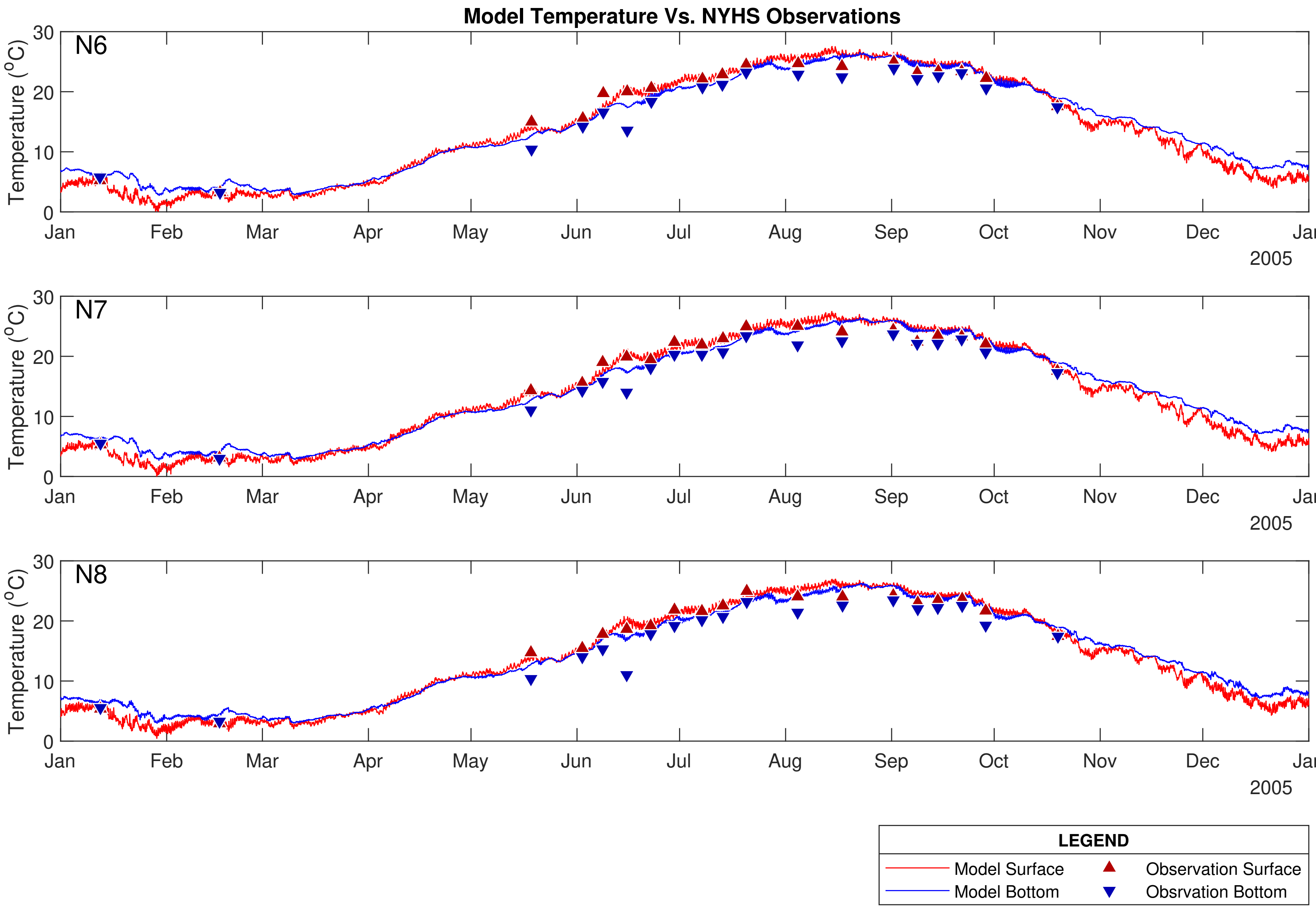
Model Temperature Vs. NYHS Observations
K3
K4
K5
Temperature (°C)
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



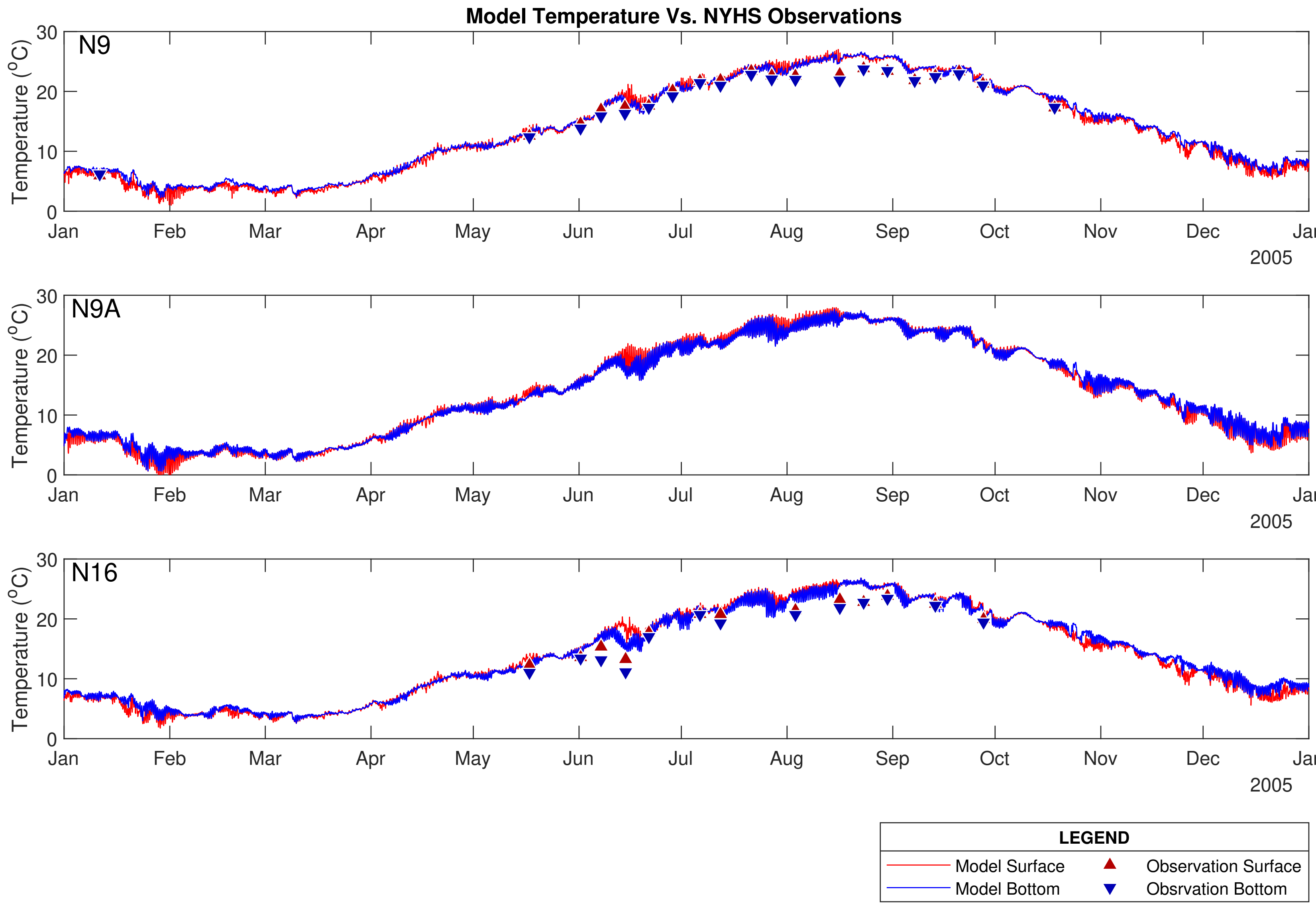
Model Temperature Vs. NYHS Observations
K5A
K6
N1
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



Model Temperature Vs. NYHS Observations
N3B
N4
N5
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

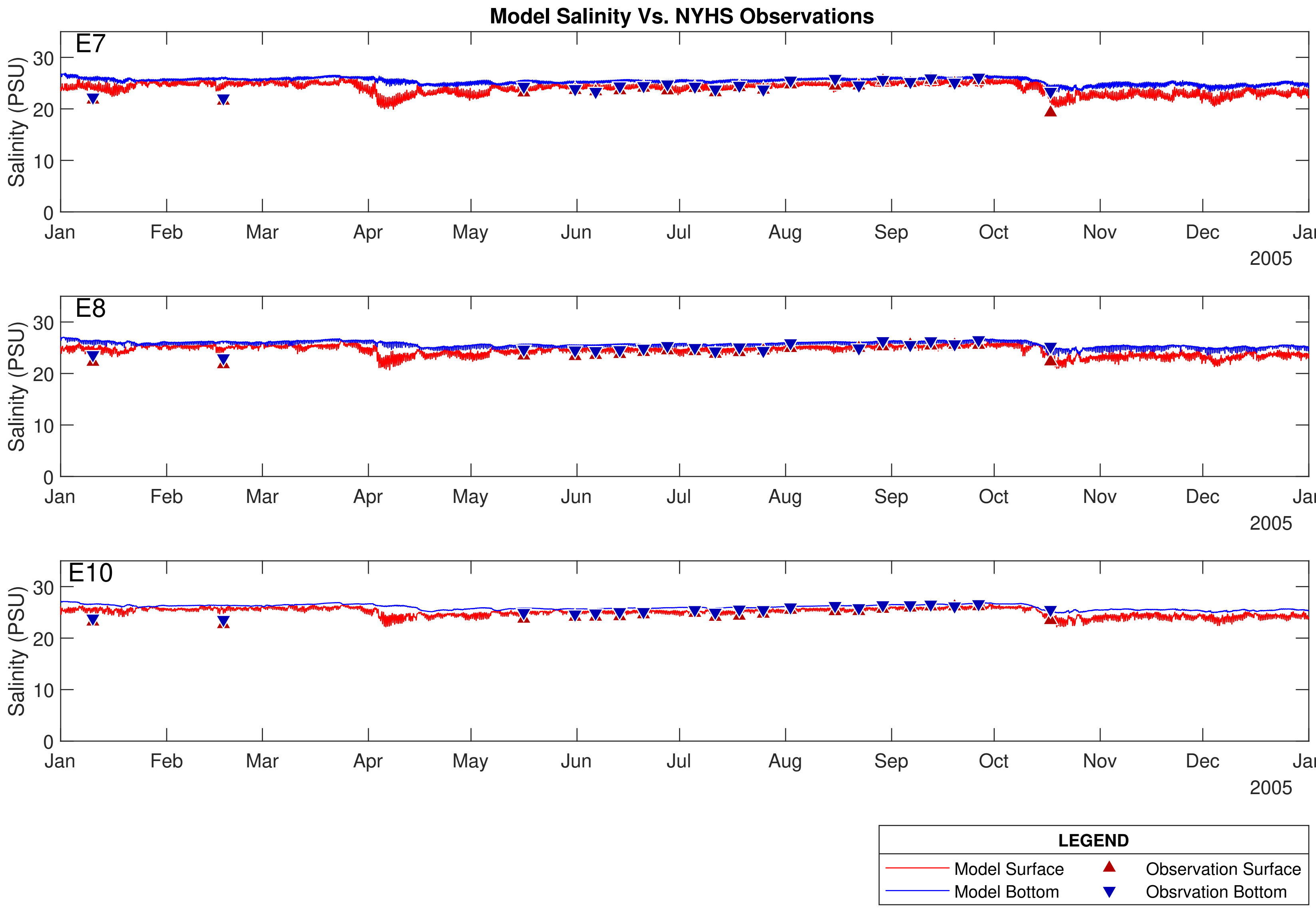


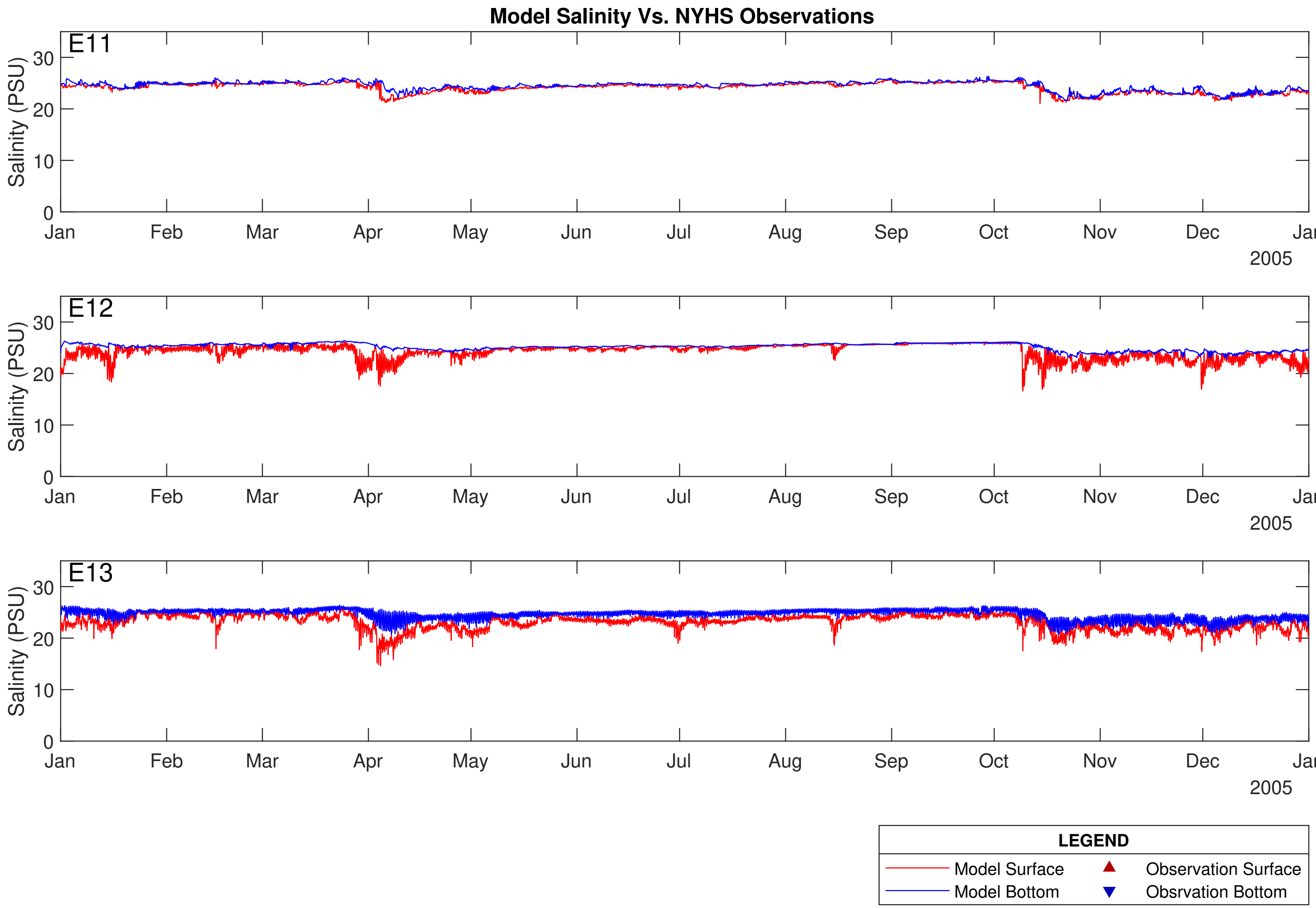
Model Temperature Vs. NYHS Observations
N6
N7
N8
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



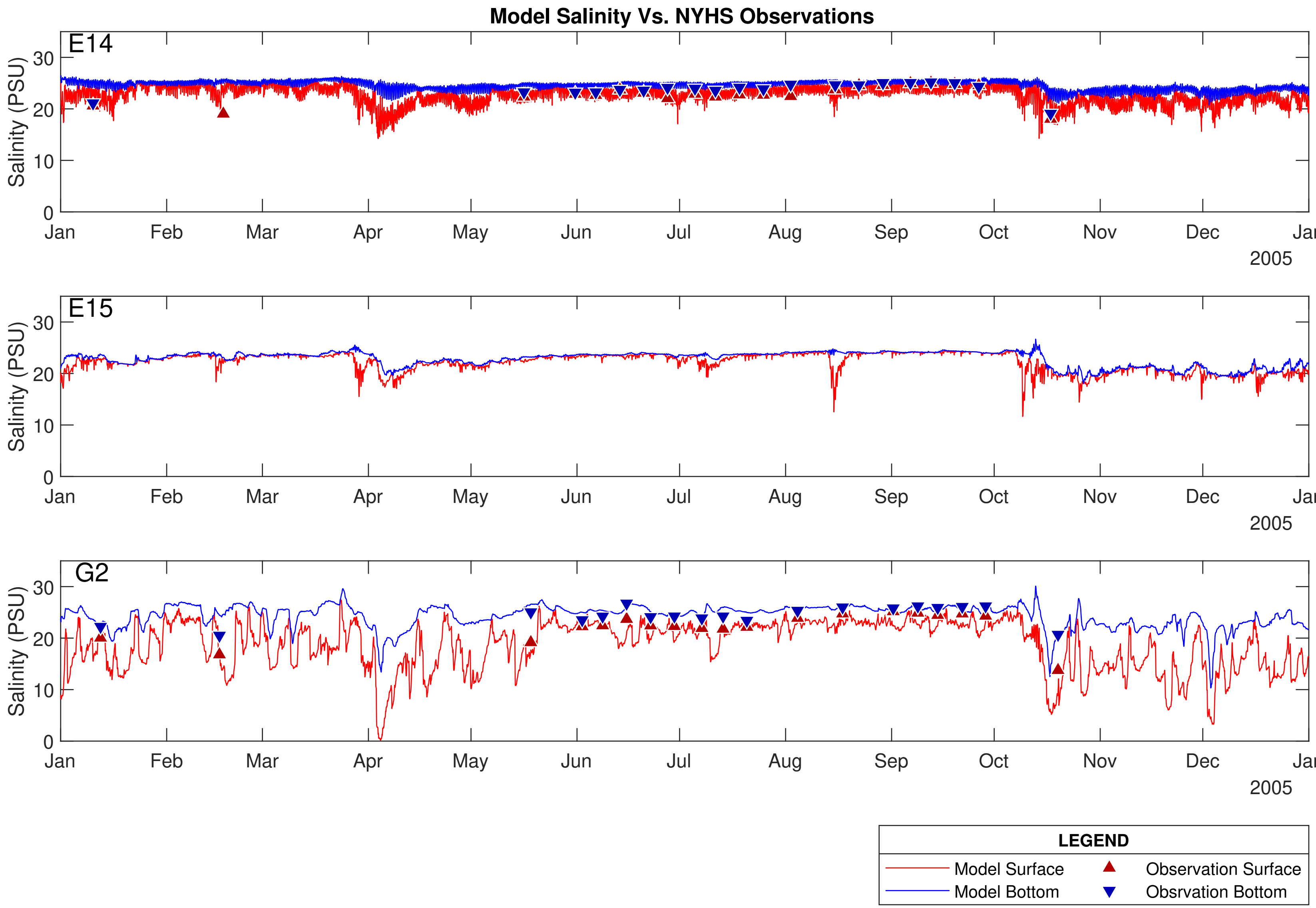
Model Temperature Vs. NYHS Observations
N9
N9A
N16
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

Model Salinity Vs. NYHS Observations
E2
E4
E6
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

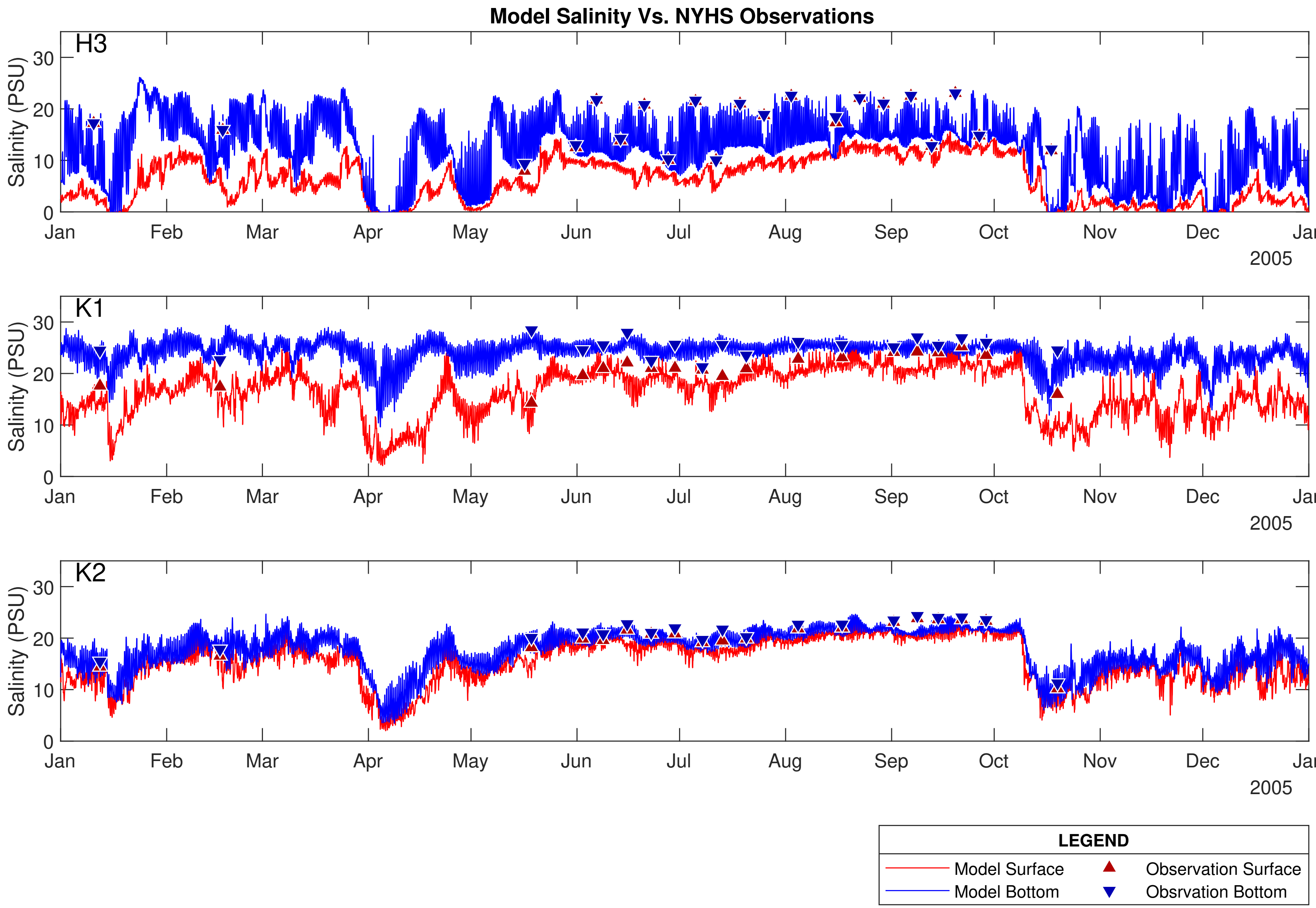

Model Salinity Vs. NYHS Observations
E7
E8
E10
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



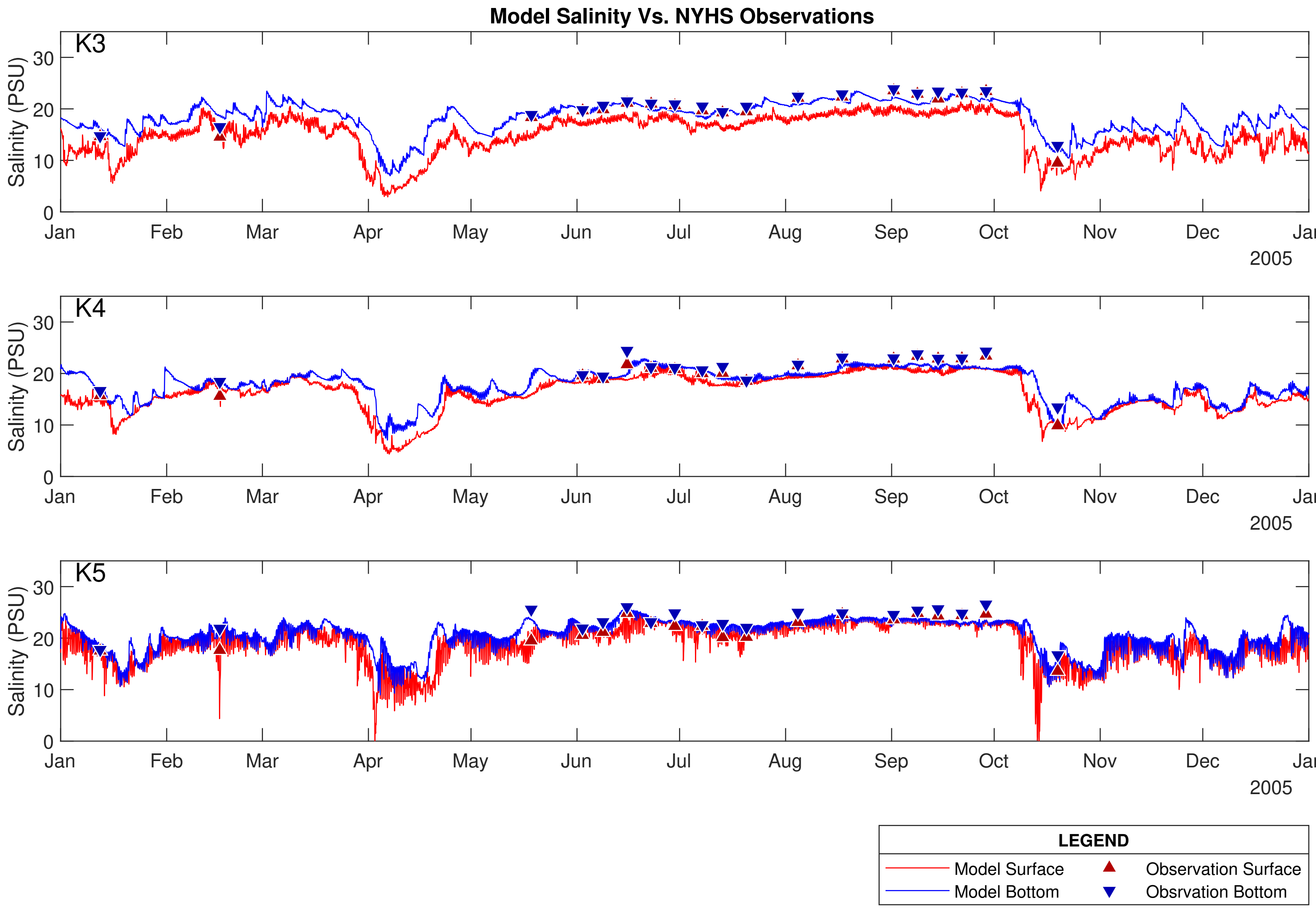
Model Salinity Vs. NYHS Observations
E11
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
E12
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
E13
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



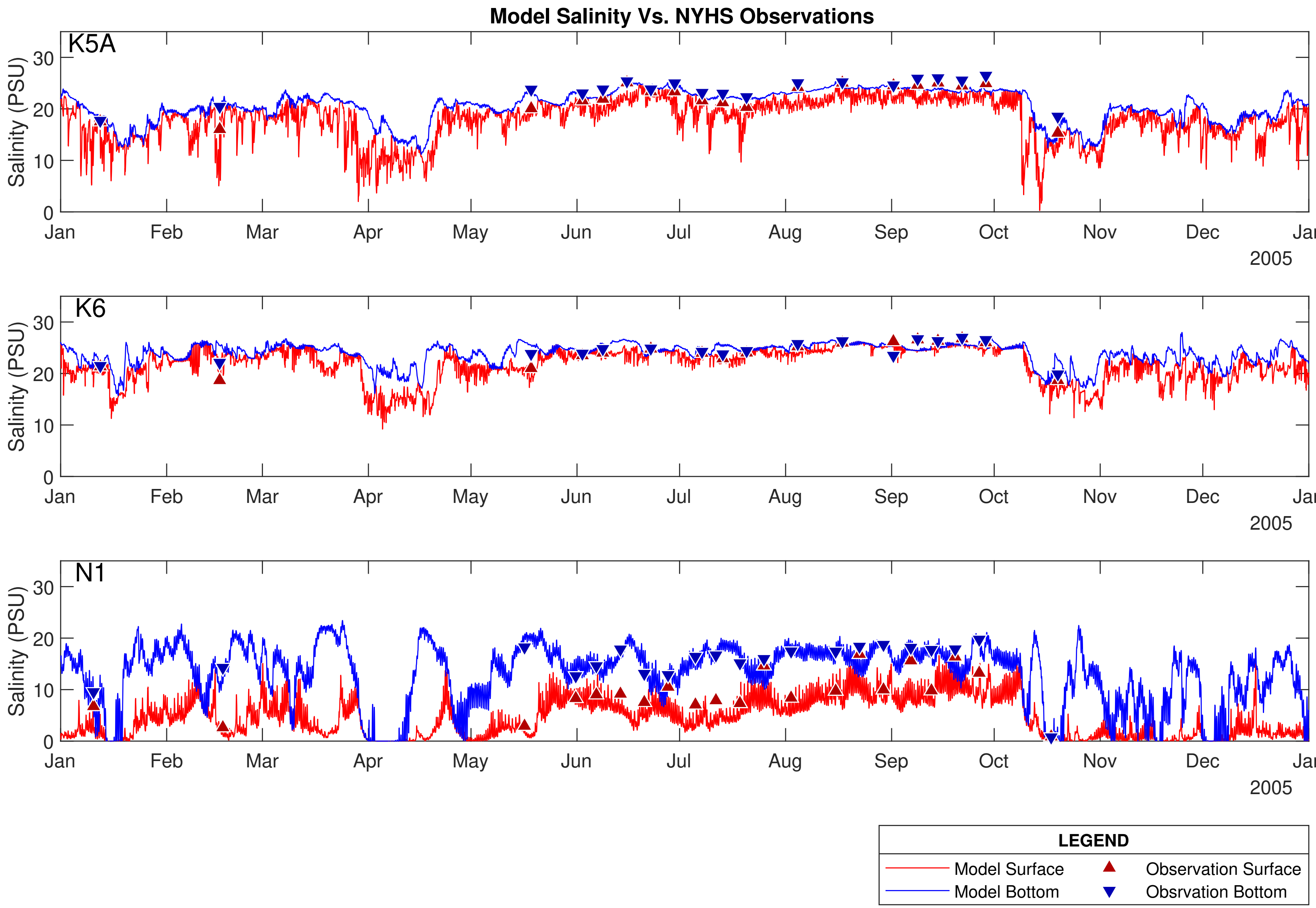
Model Salinity Vs. NYHS Observations
E14
E15
G2
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



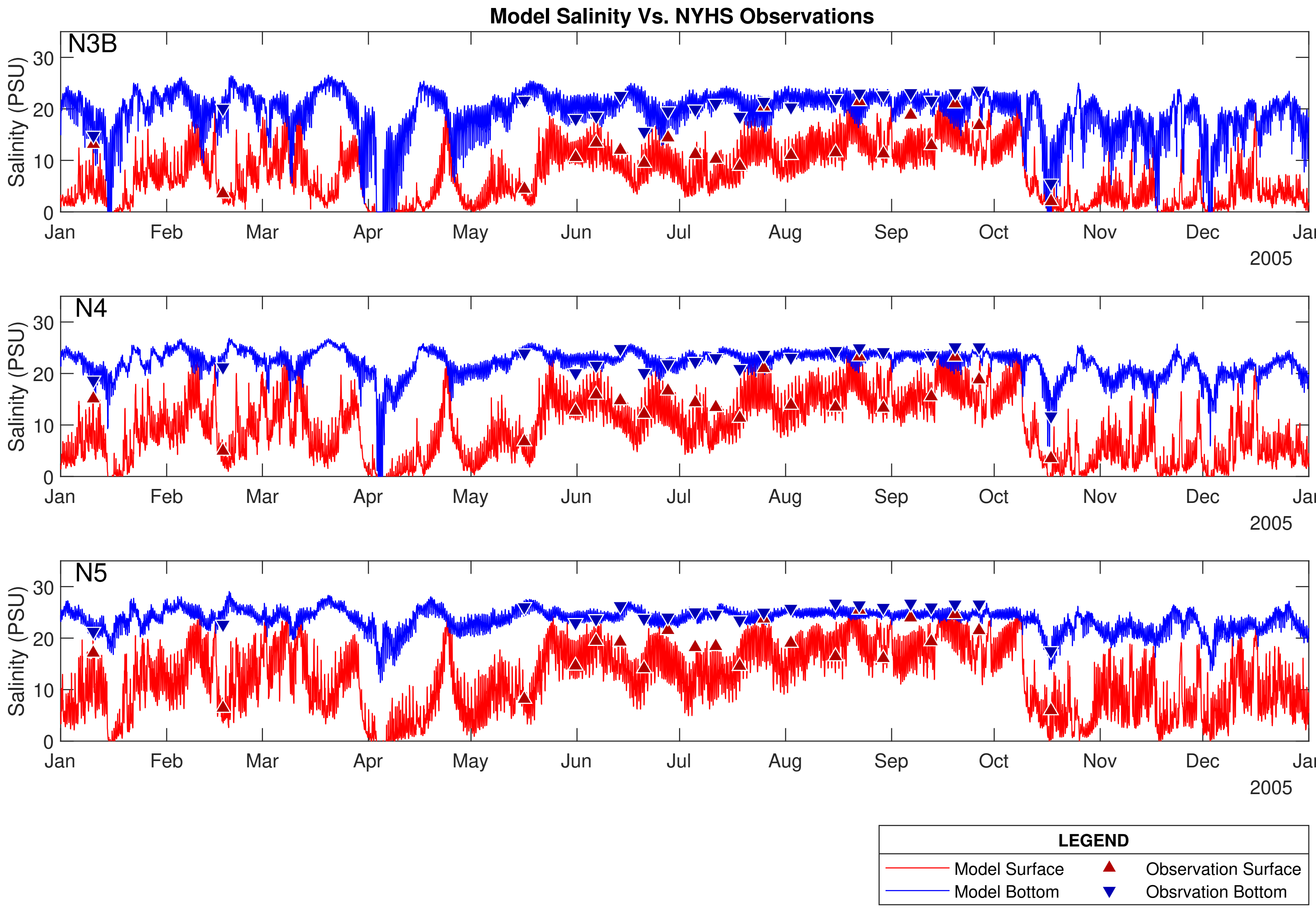
Model Salinity Vs. NYHS Observations
H3
K1
K2
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



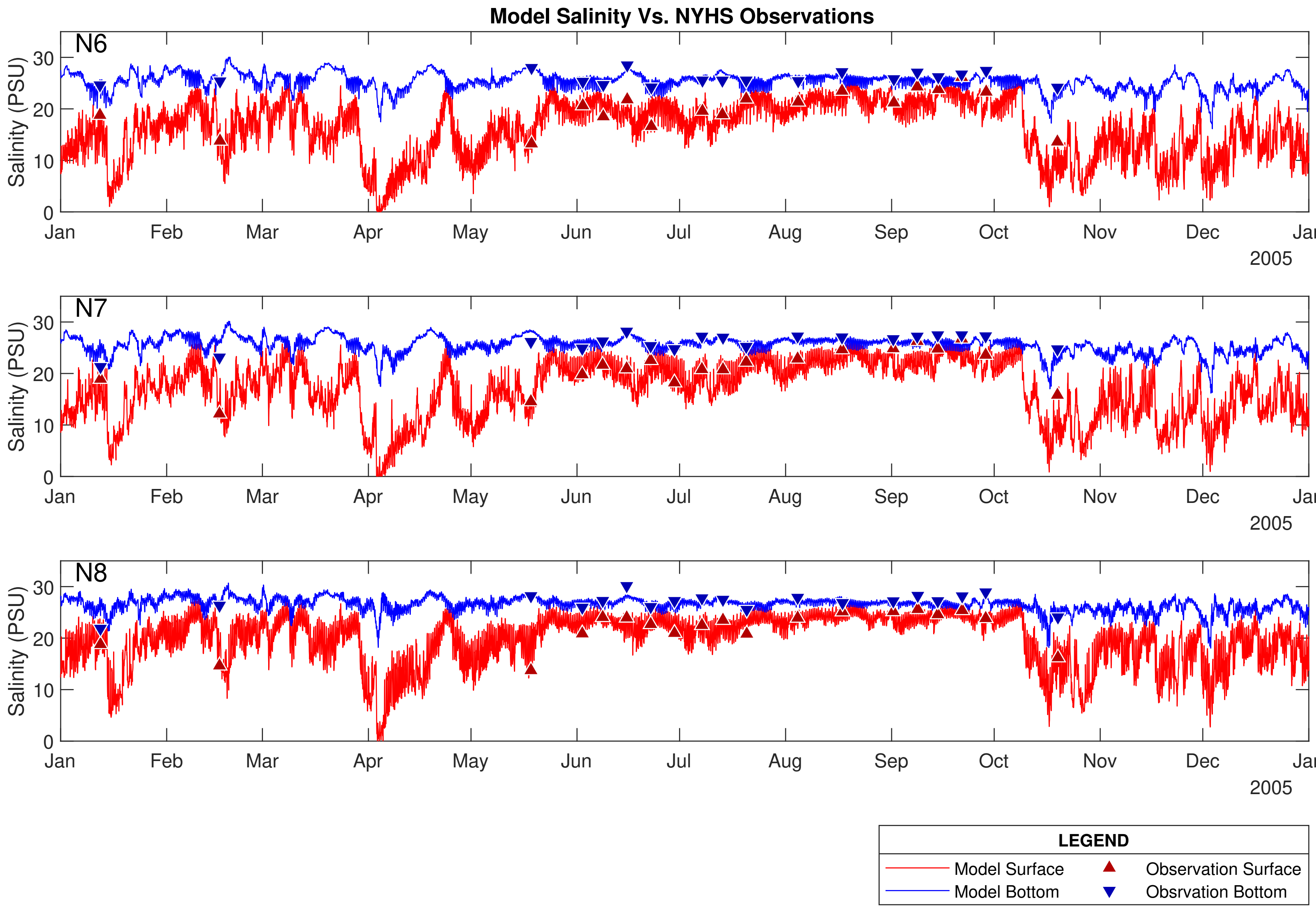
Model Salinity Vs. NYHS Observations
K3
K4
K5
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



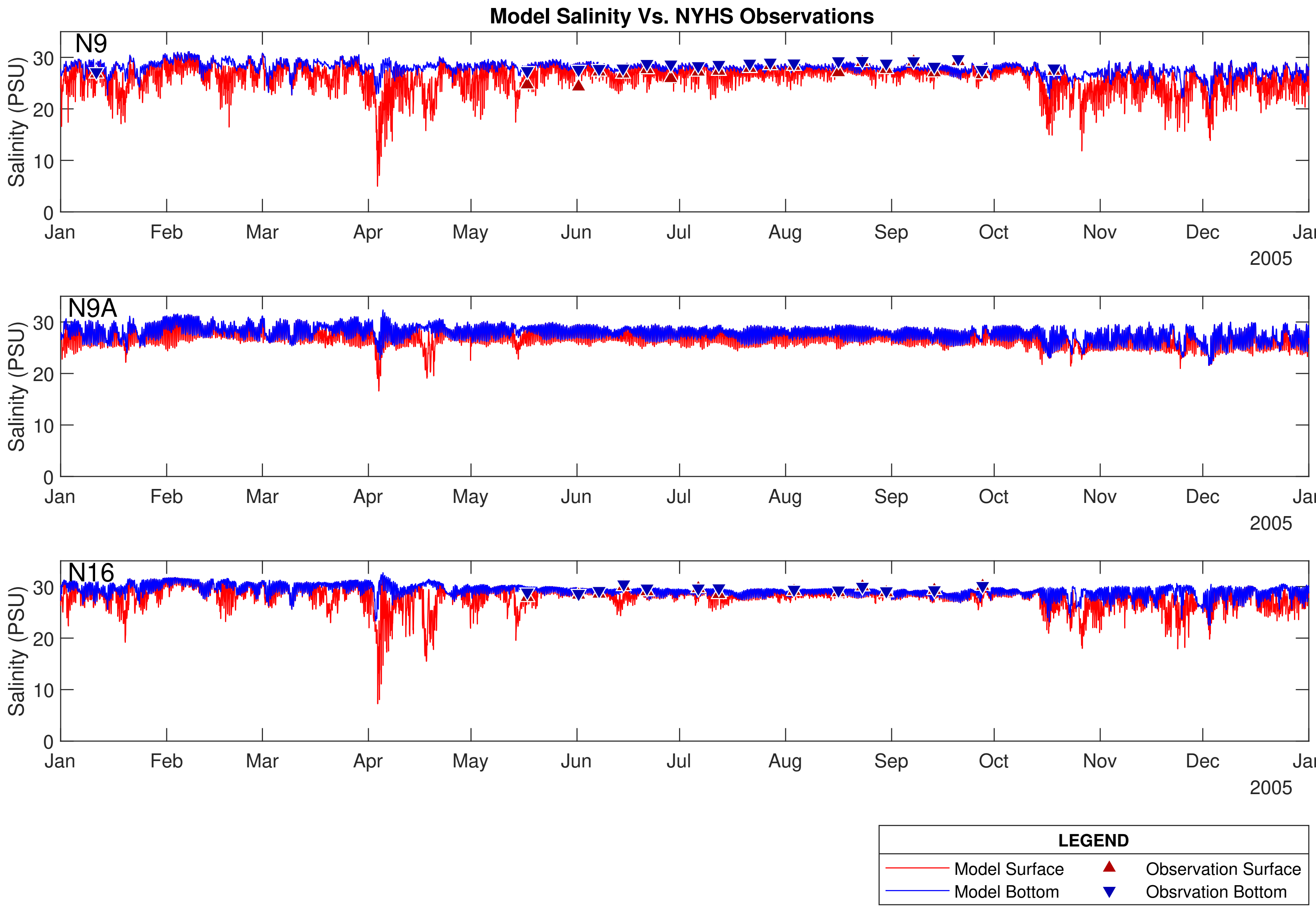
Model Salinity Vs. NYHS Observations
K5A
K6
N1
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



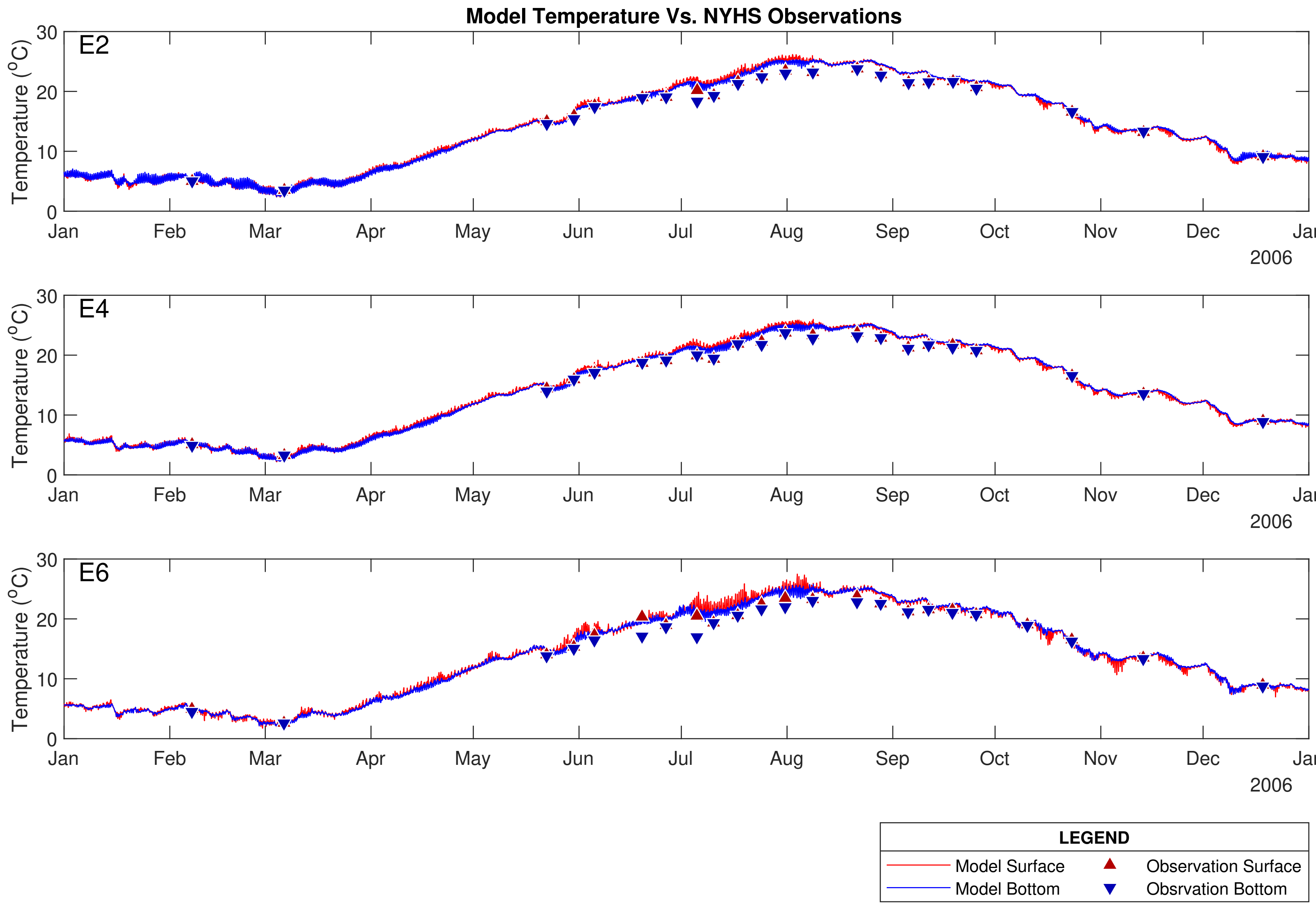
Model Salinity Vs. NYHS Observations
N3B
N4
N5
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



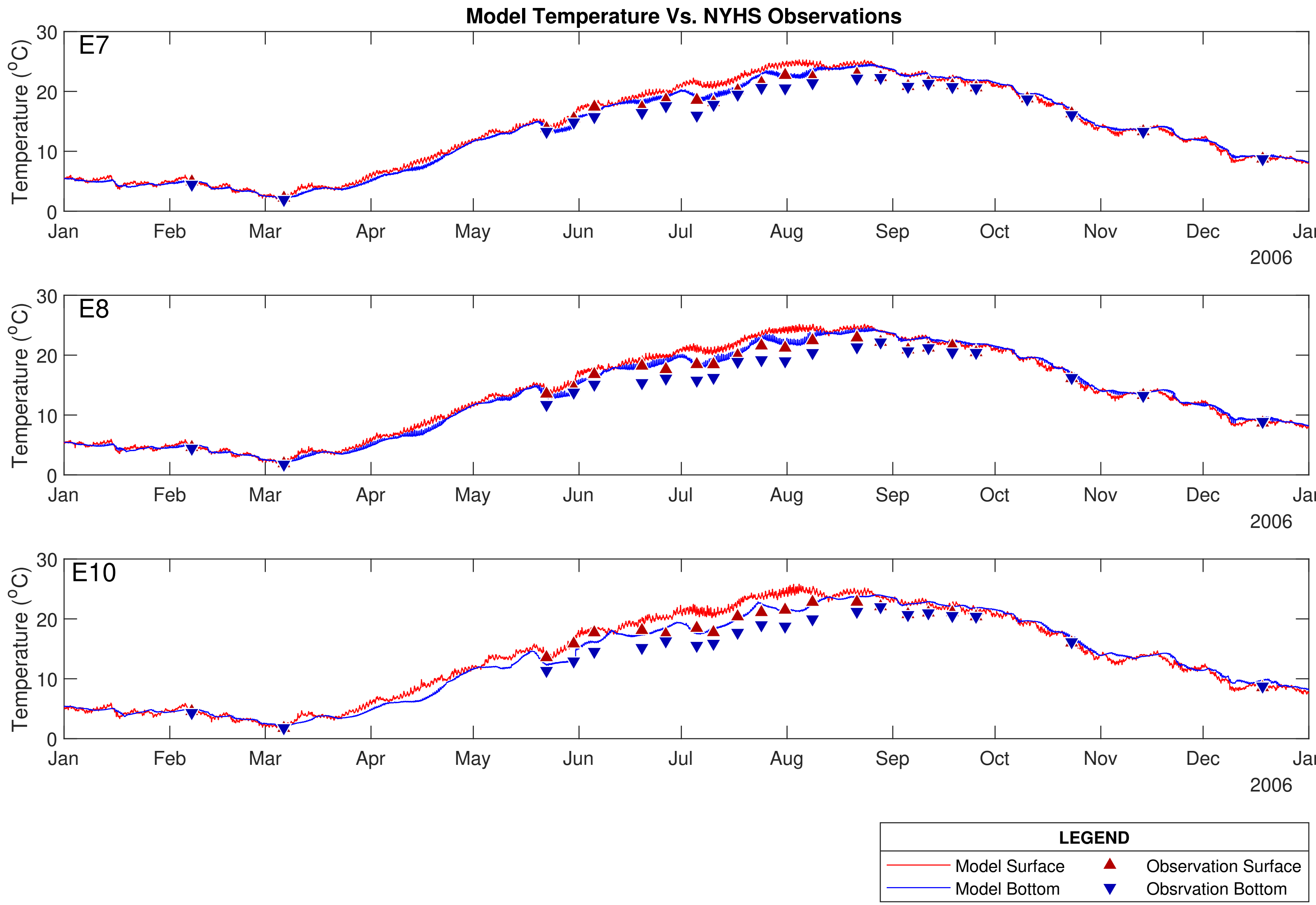
Model Salinity Vs. NYHS Observations
N6
N7
N8
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



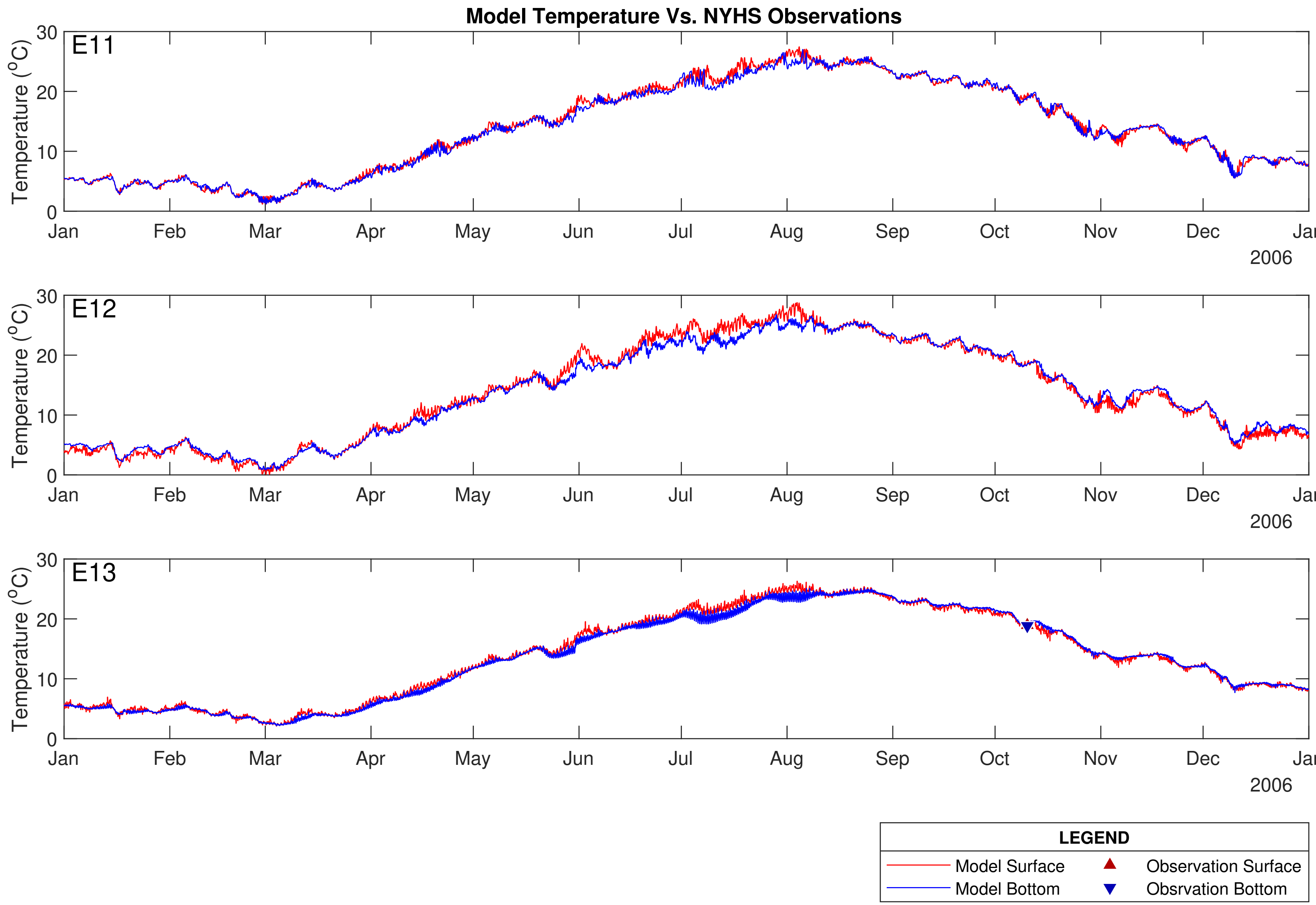
Model Salinity Vs. NYHS Observations
N9
N9A
N16
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2005
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



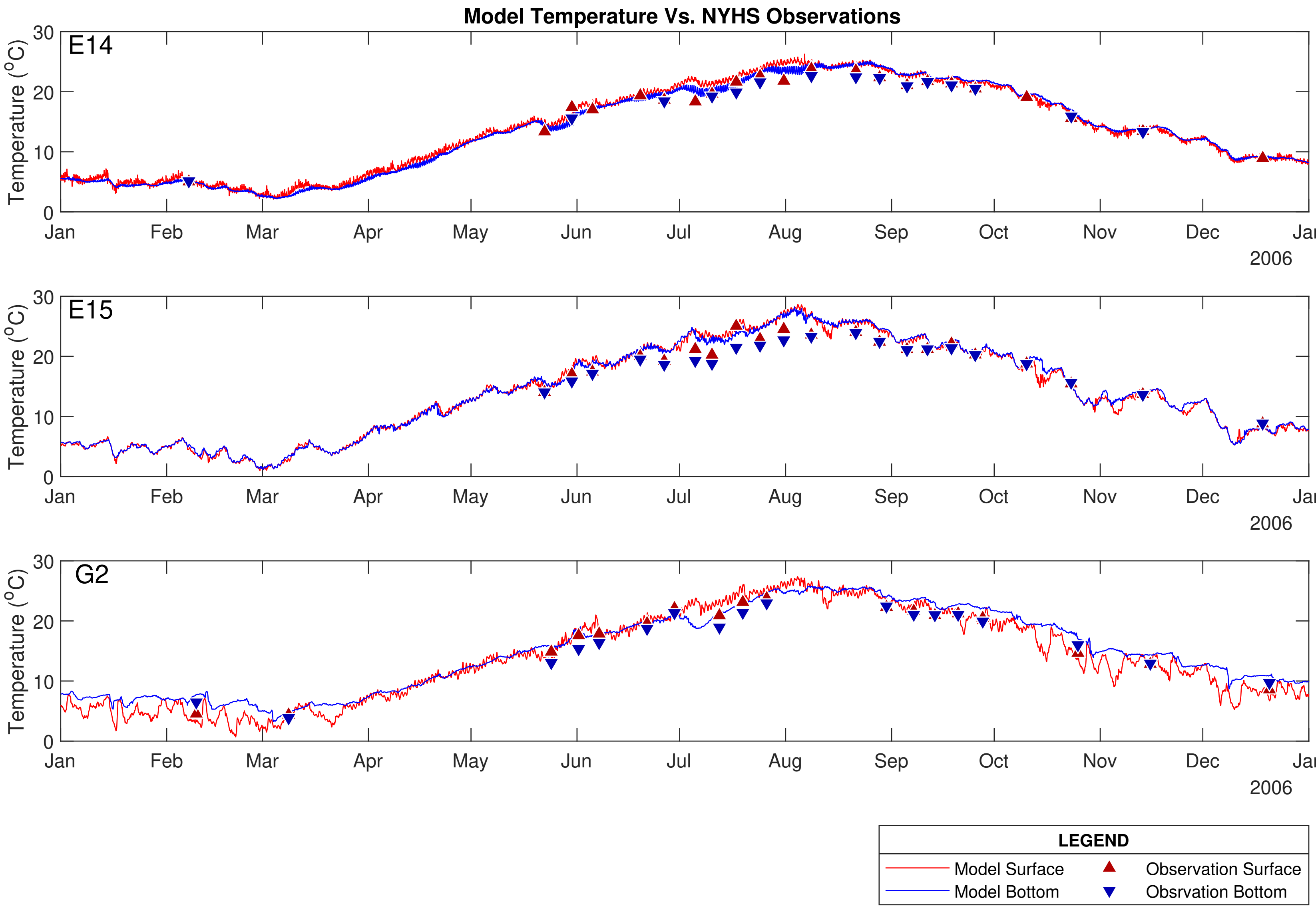
Model Temperature Vs. NYHS Observations
E2
E4
E6
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



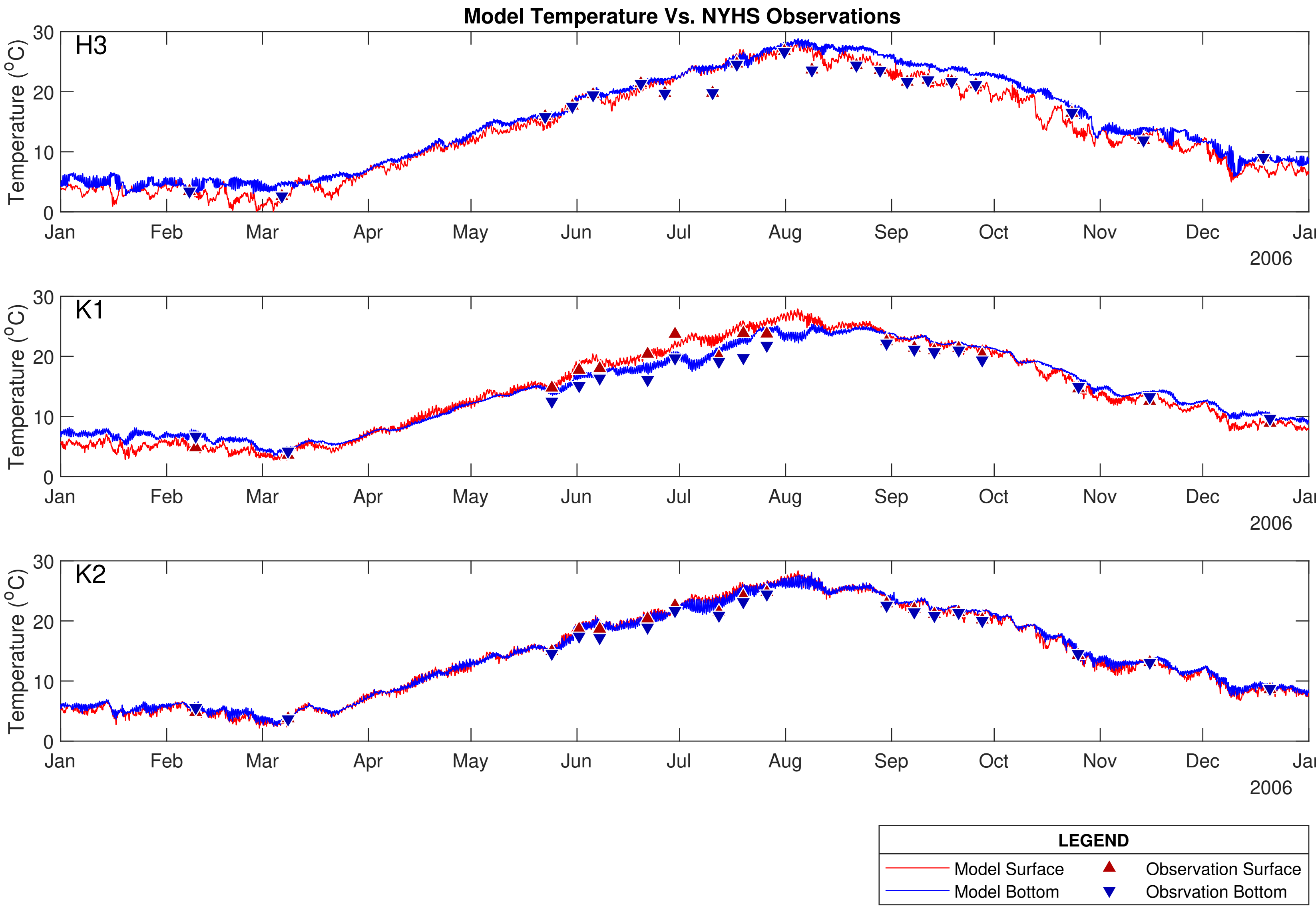
Model Temperature Vs. NYHS Observations
E7
E8
E10
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

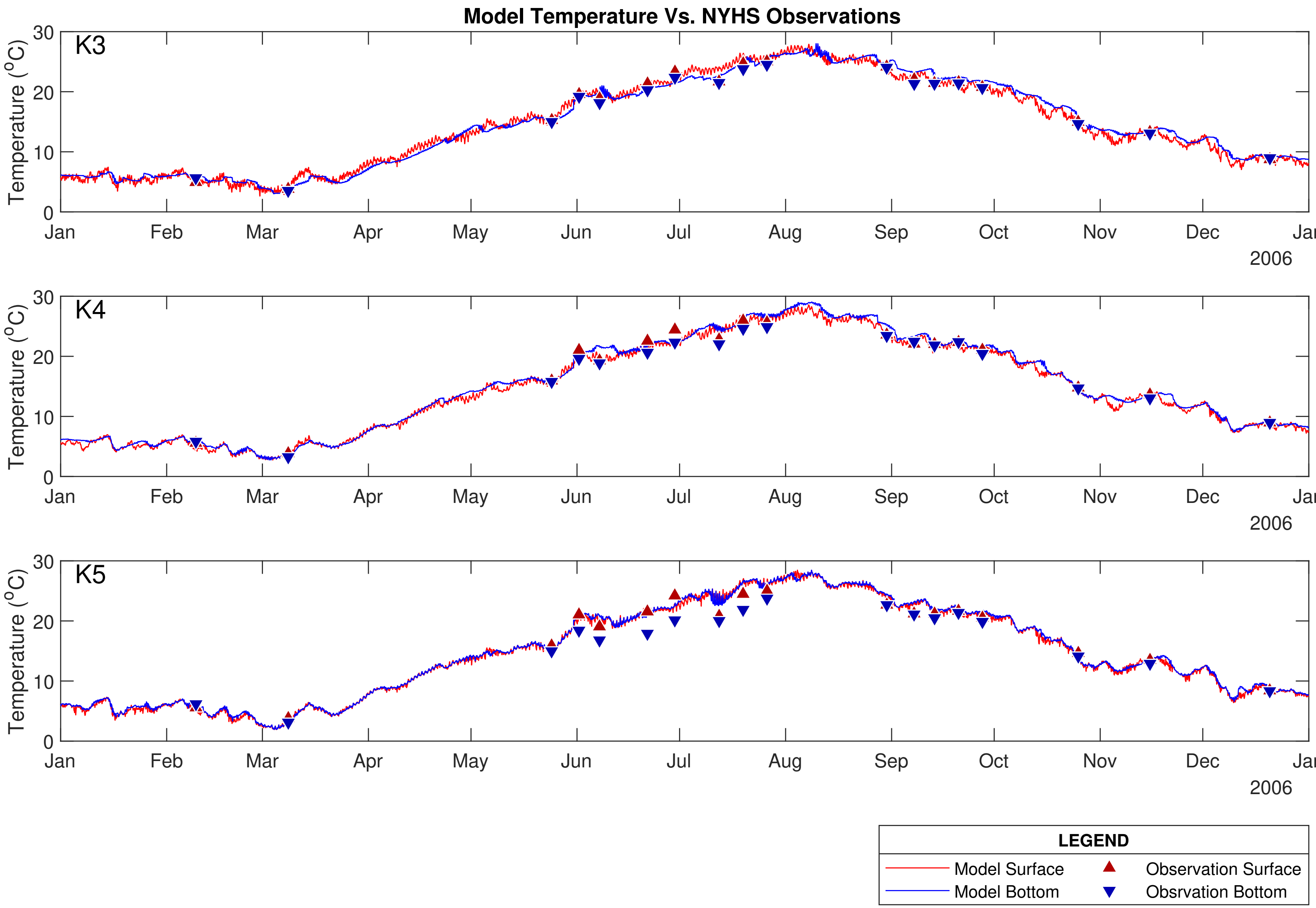


Model Temperature Vs. NYHS Observations
E11
E12
E13
Temperature (°C)
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

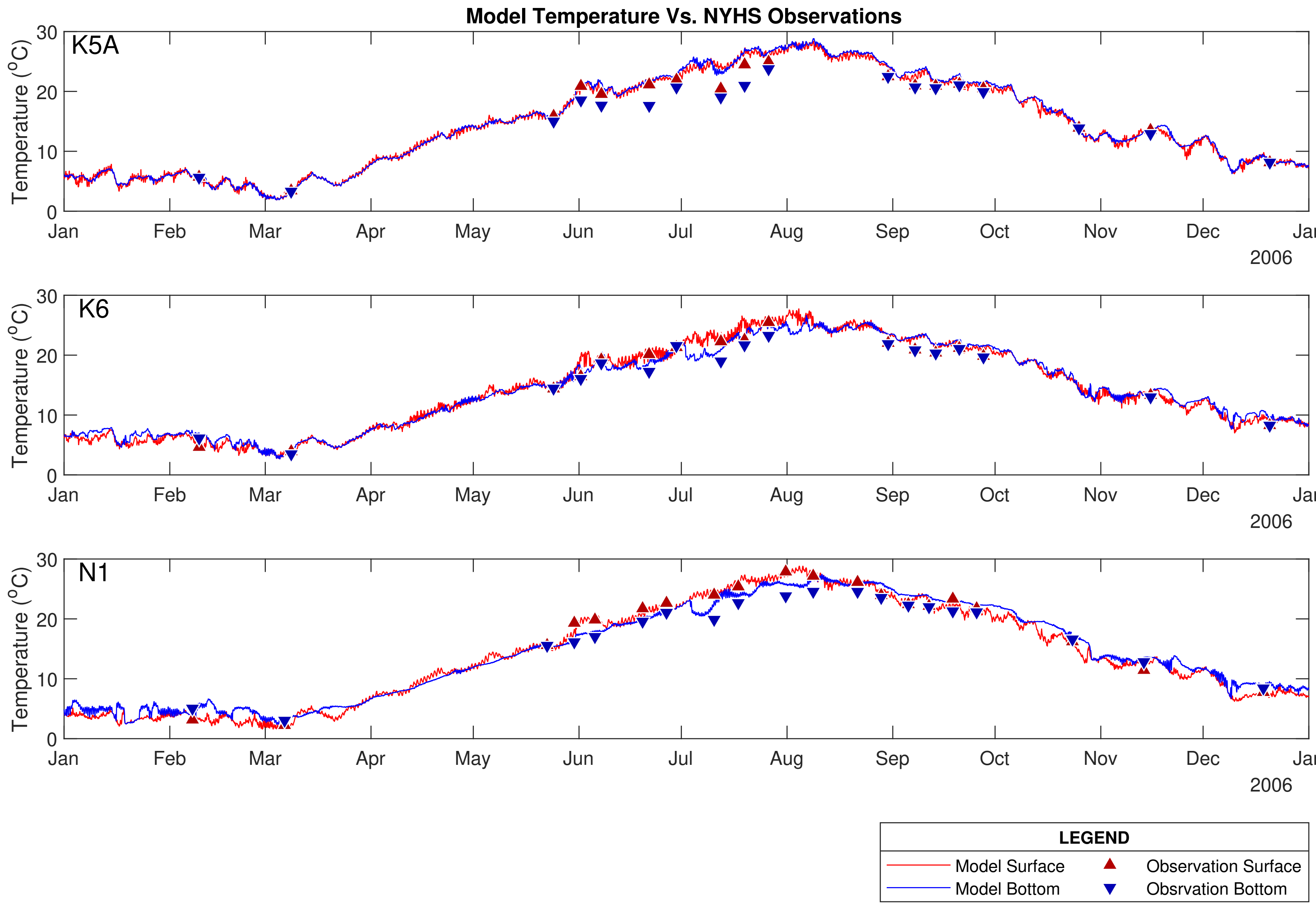


Model Temperature Vs. NYHS Observations
E14
E15
G2
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

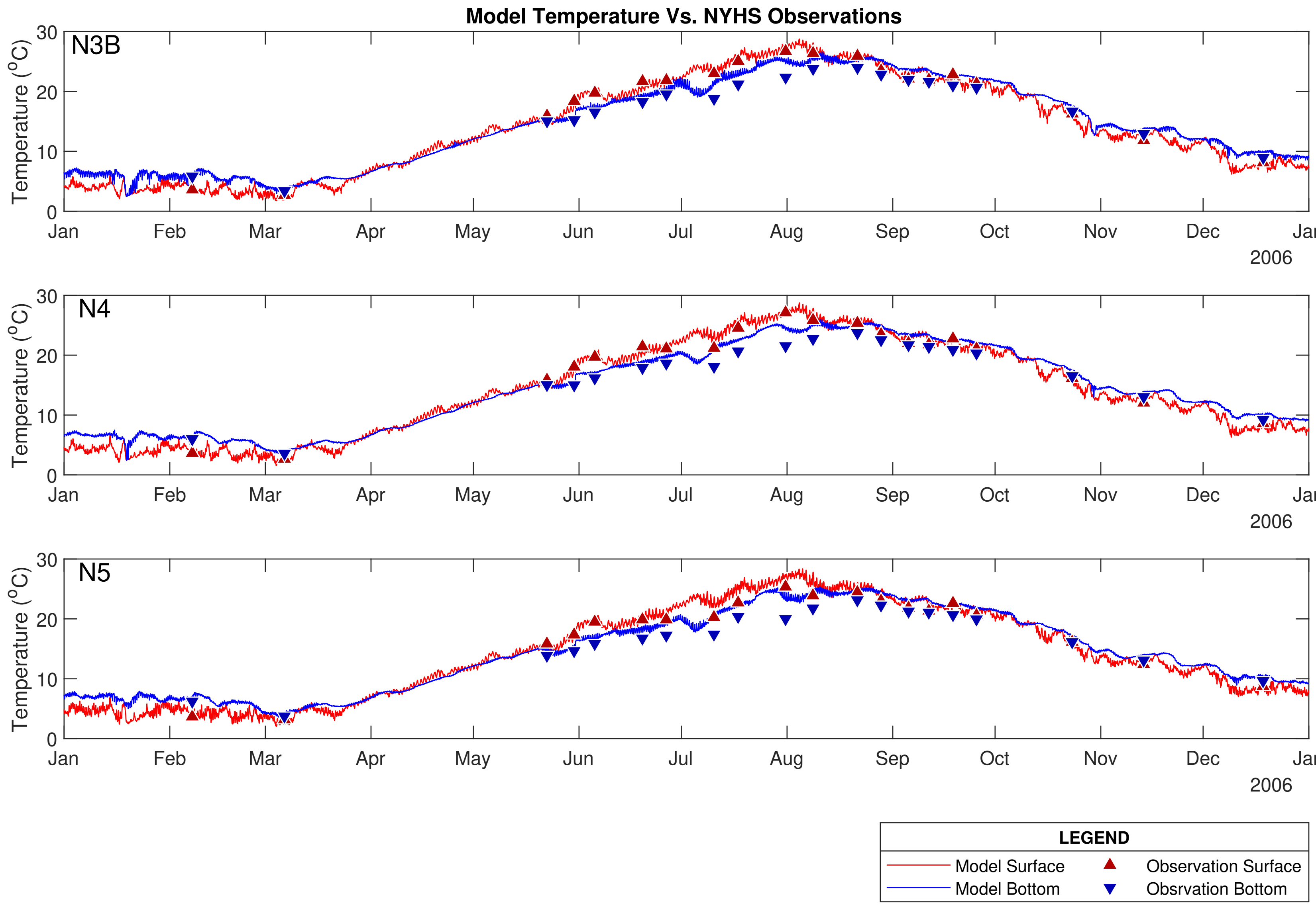

Model Temperature Vs. NYHS Observations
H3
K1
K2
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



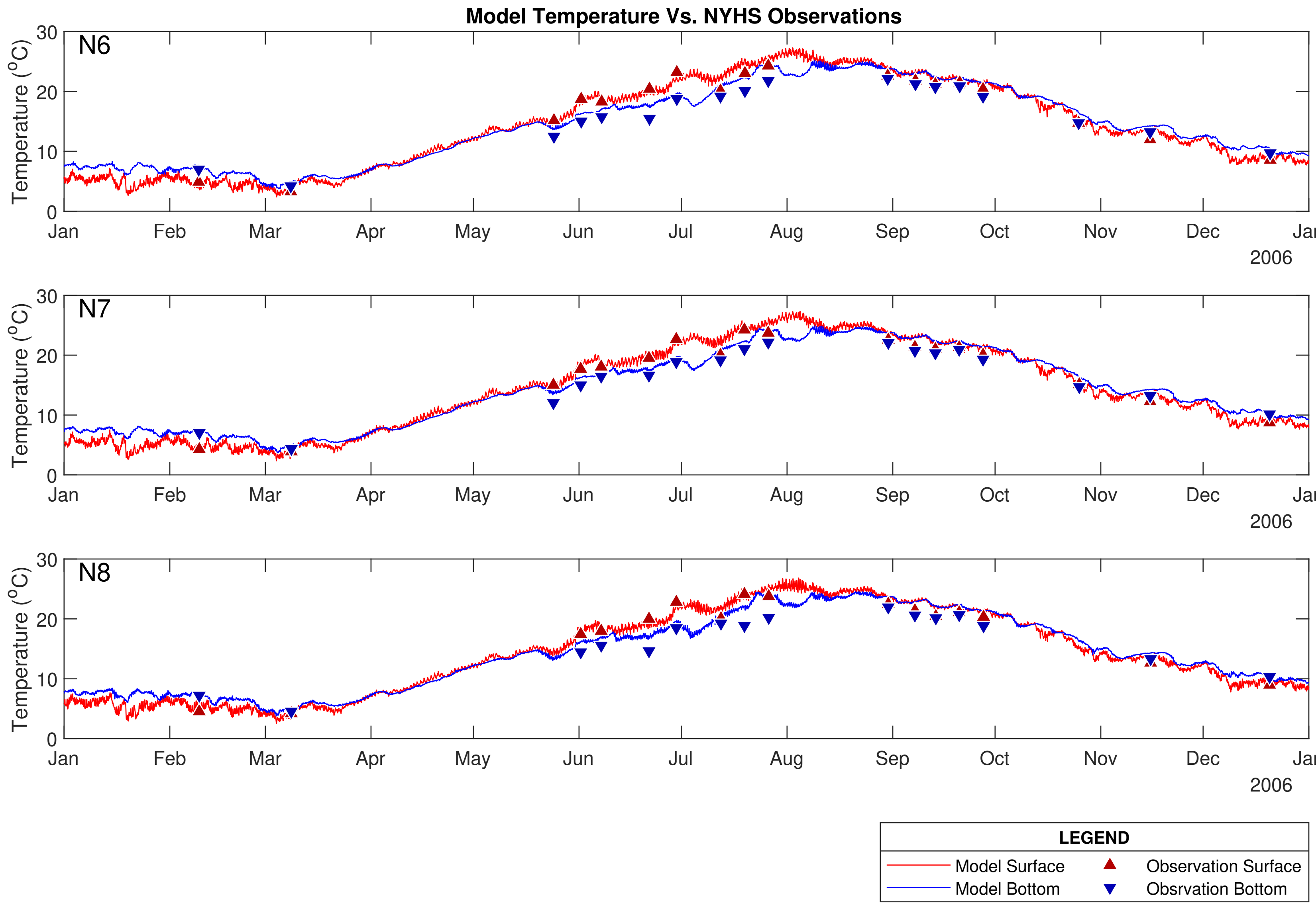
Model Temperature Vs. NYHS Observations
K3
K4
K5
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



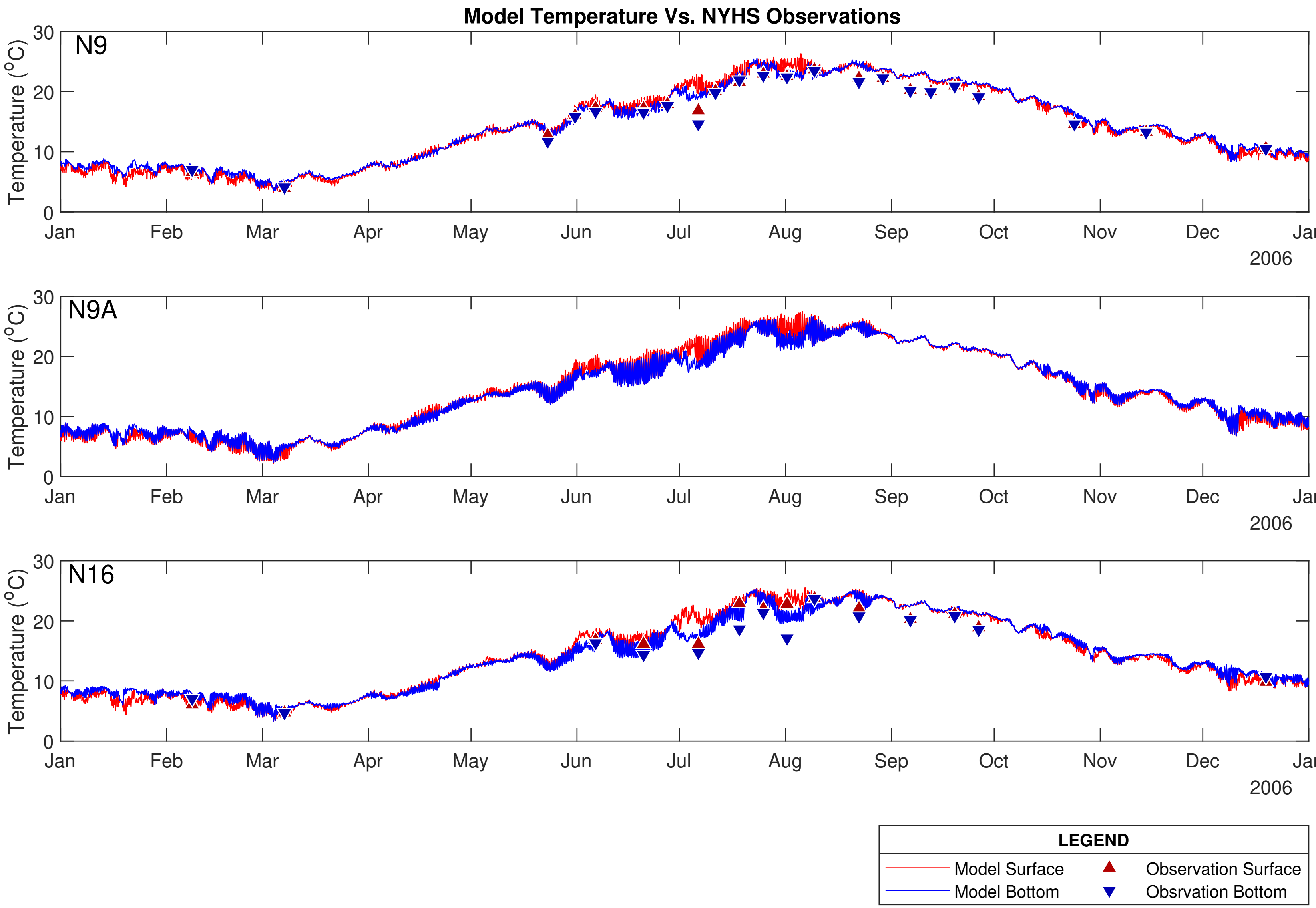
Model Temperature Vs. NYHS Observations
K5A
K6
N1
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



Model Temperature Vs. NYHS Observations
N3B
N4
N5
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

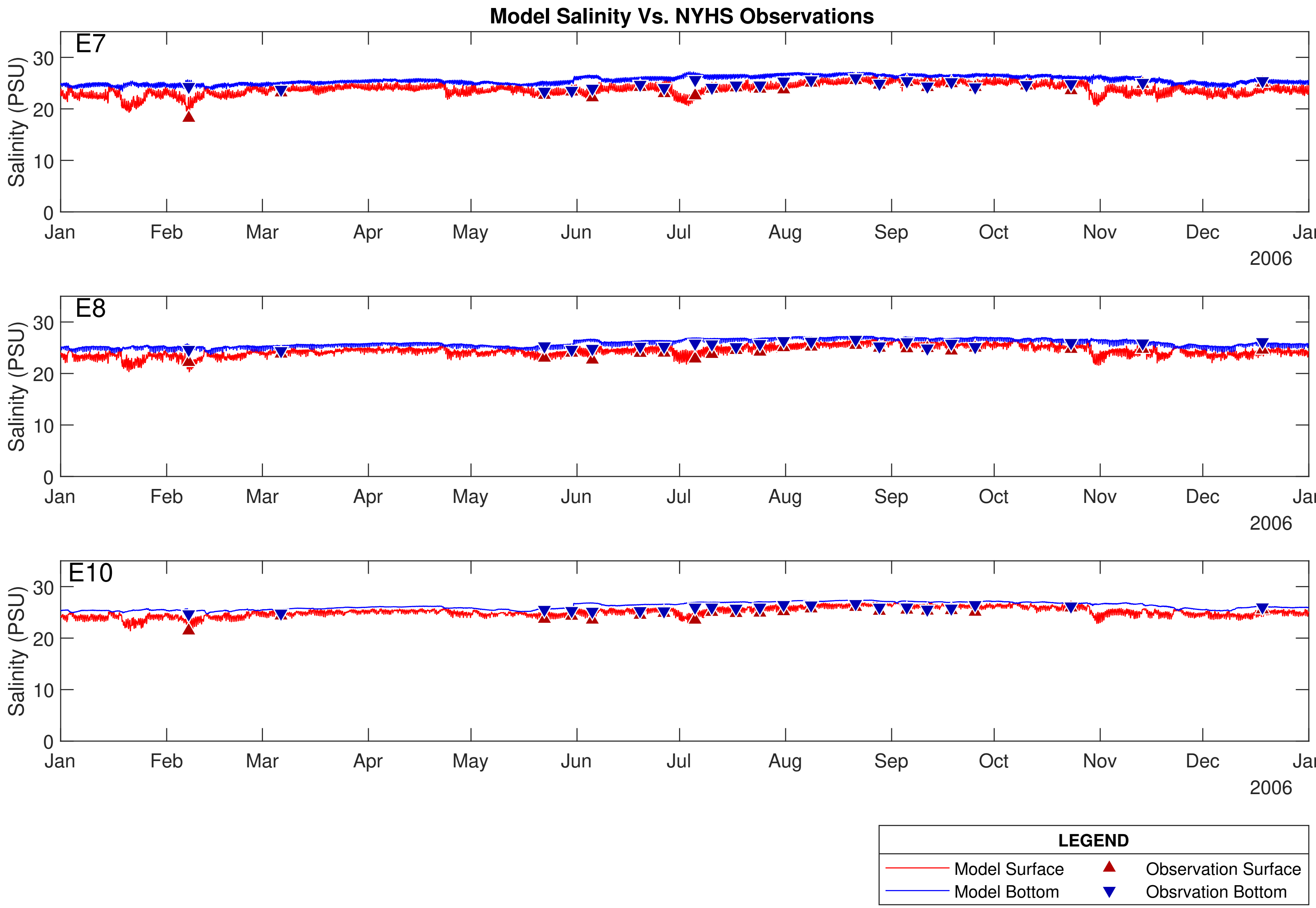


Model Temperature Vs. NYHS Observations
N6
N7
N8
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

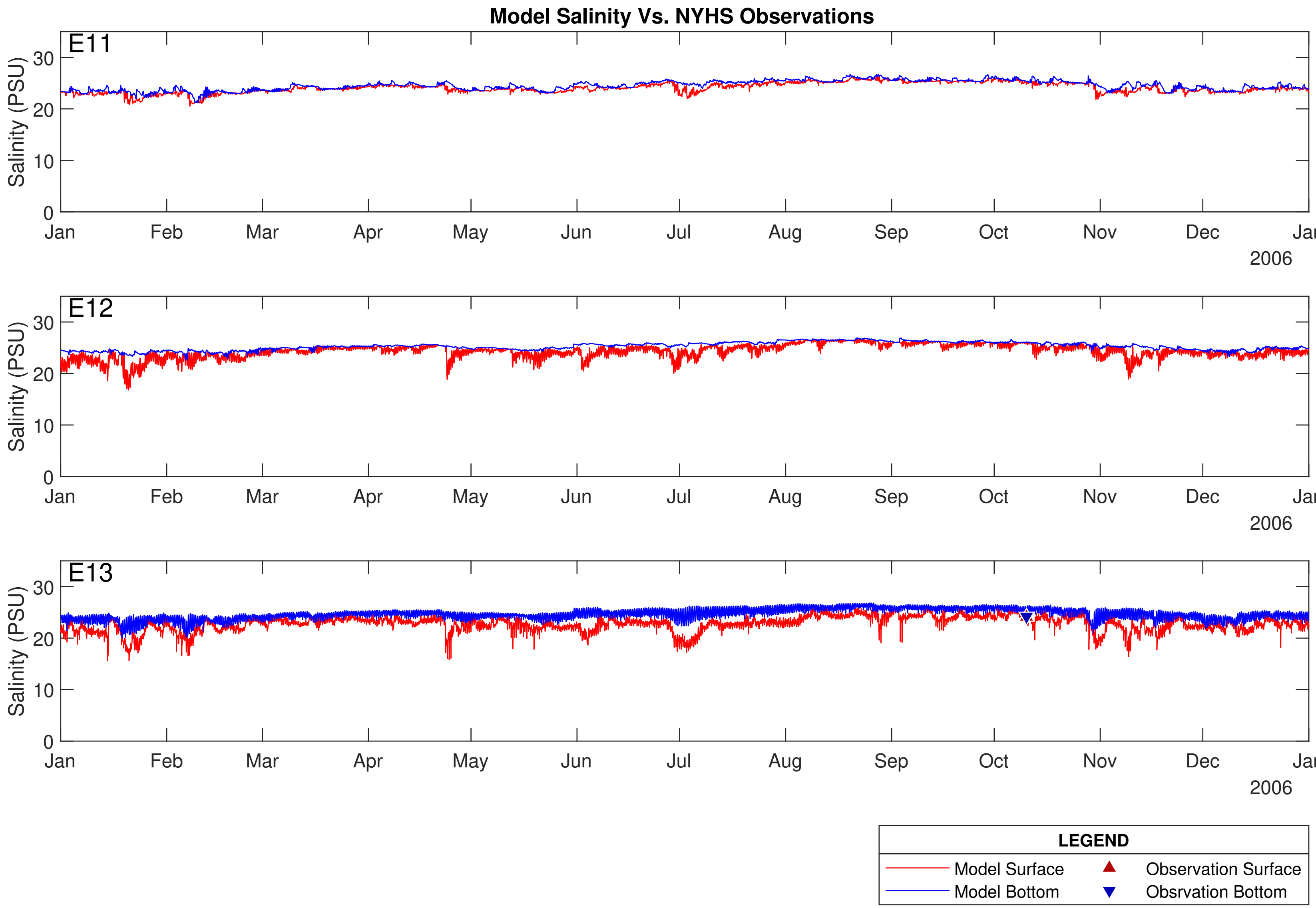


Model Temperature Vs. NYHS Observations
N9
N9A
N16
Temperature (°C)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

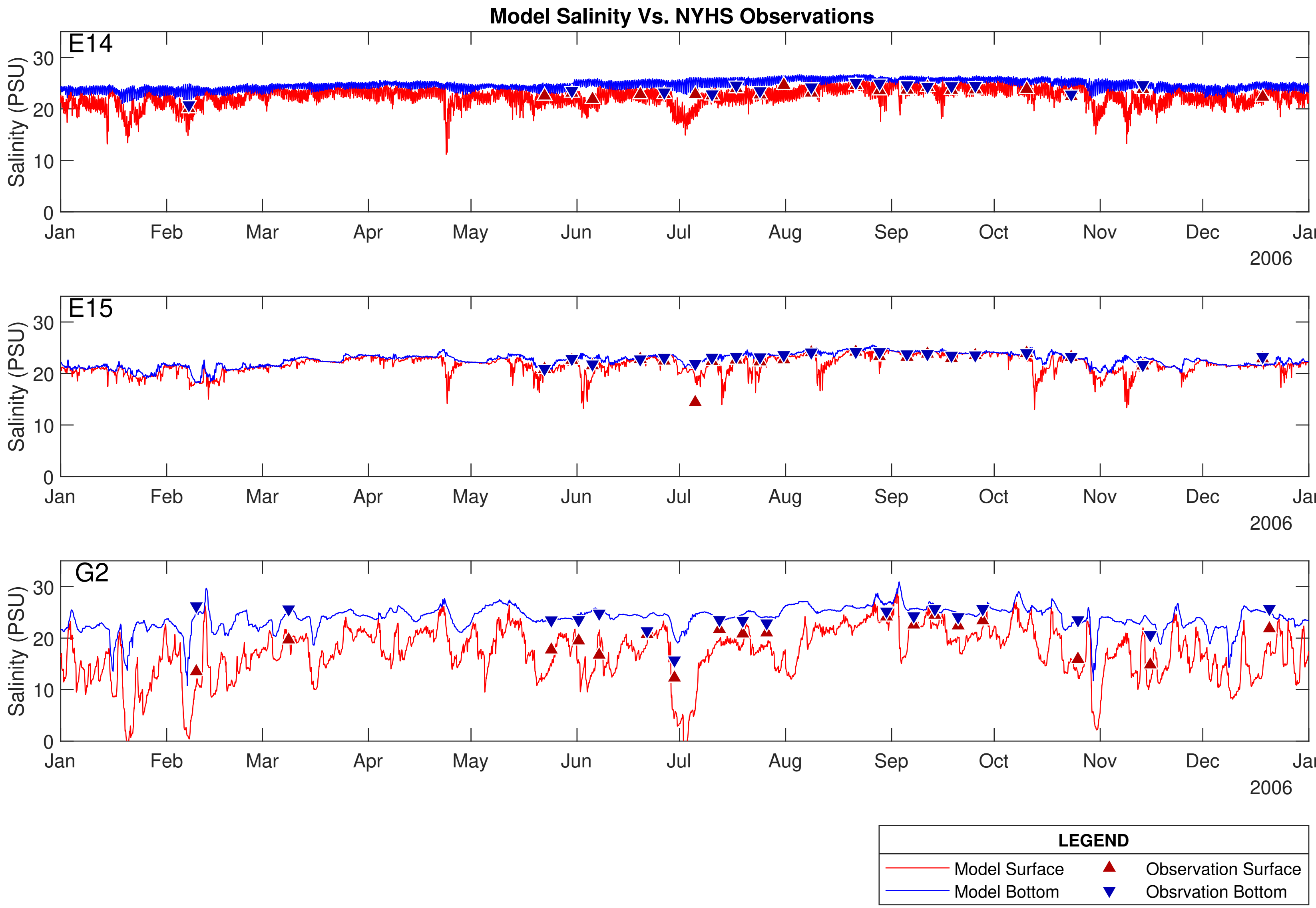
Model Salinity Vs. NYHS Observations
E2
E4
E6
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



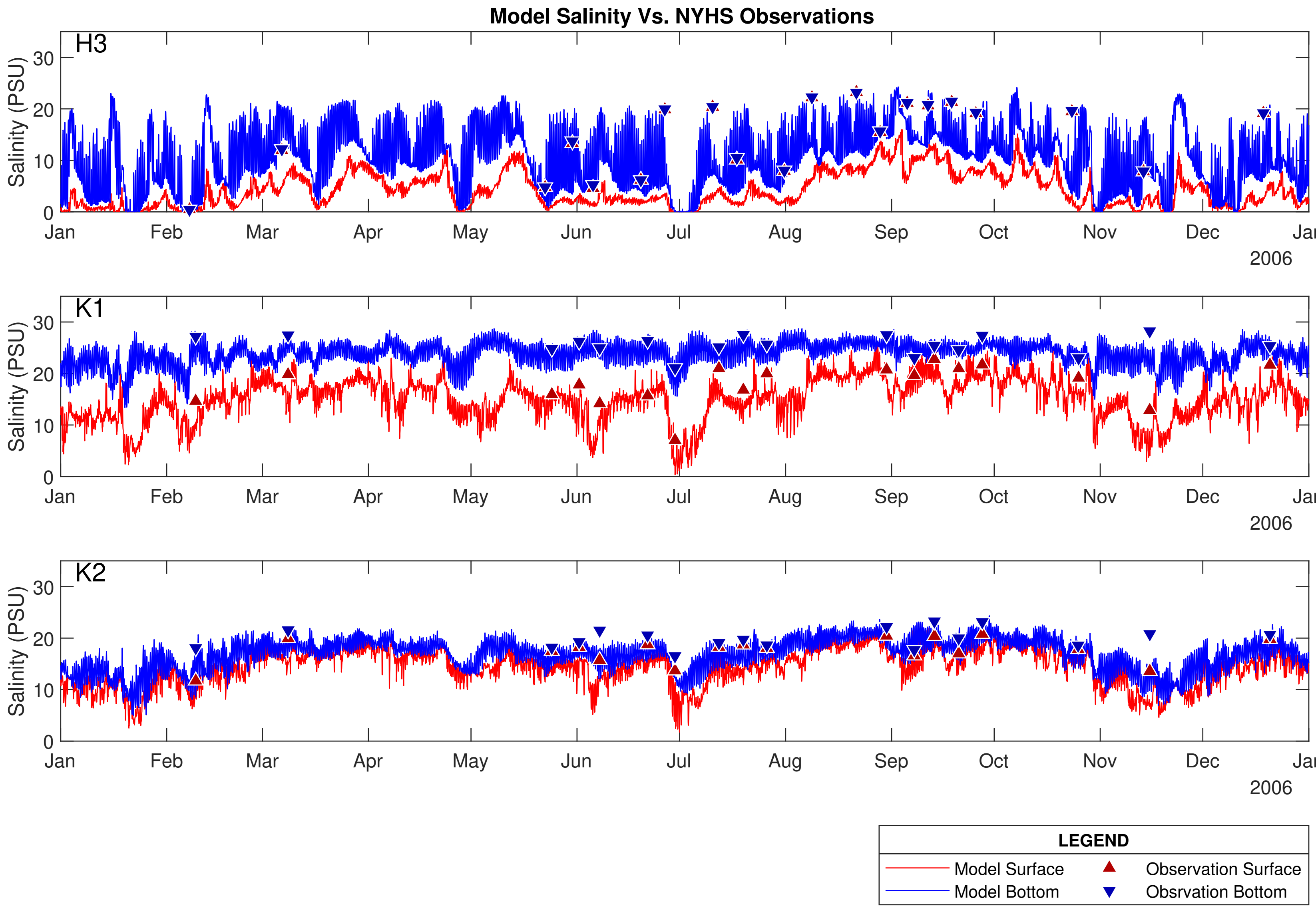
Model Salinity Vs. NYHS Observations
E7
Salinity (PSU)
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
E8
Salinity (PSU)
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
E10
Salinity (PSU)
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



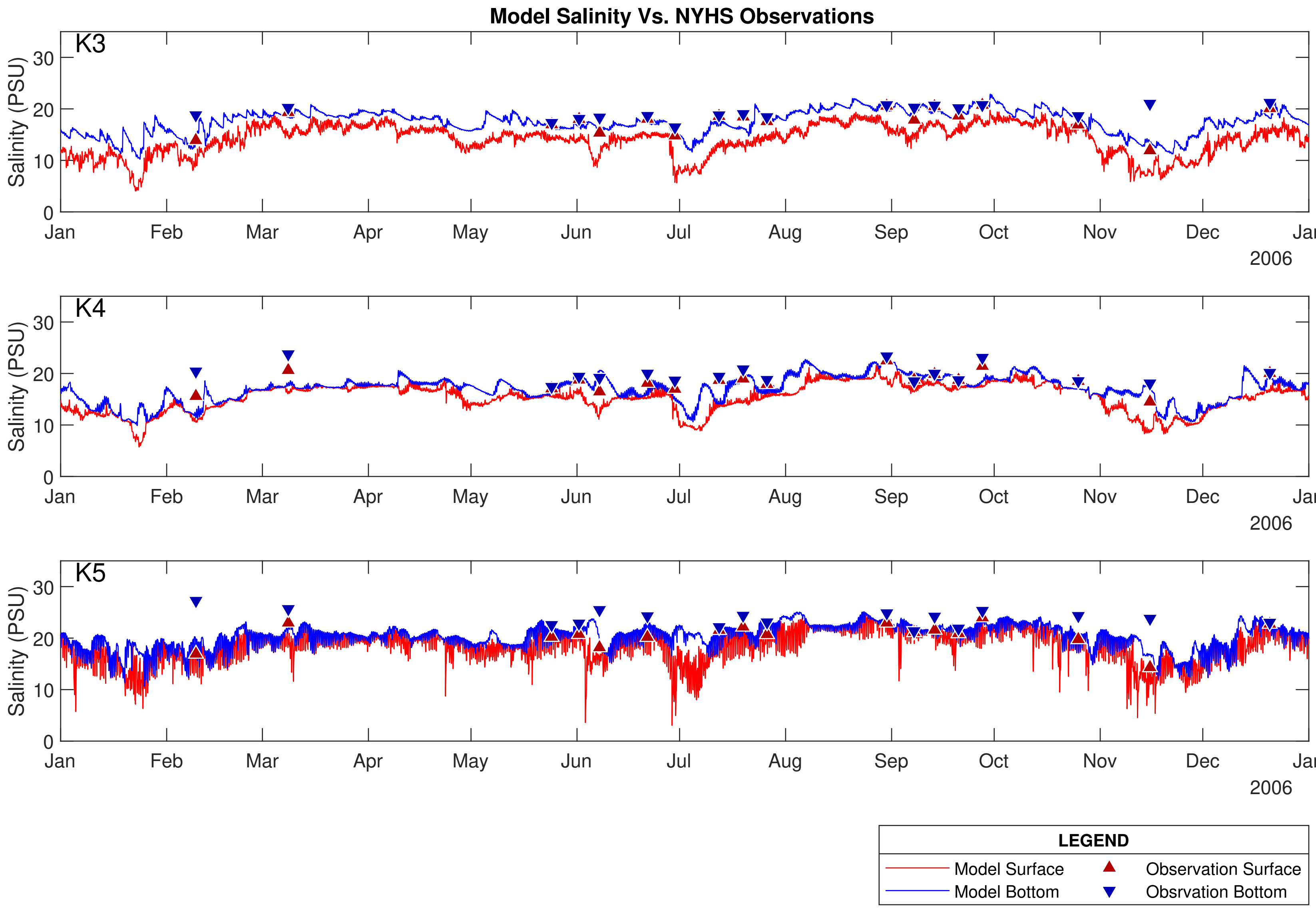
Model Salinity Vs. NYHS Observations
E11
E12
E13
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

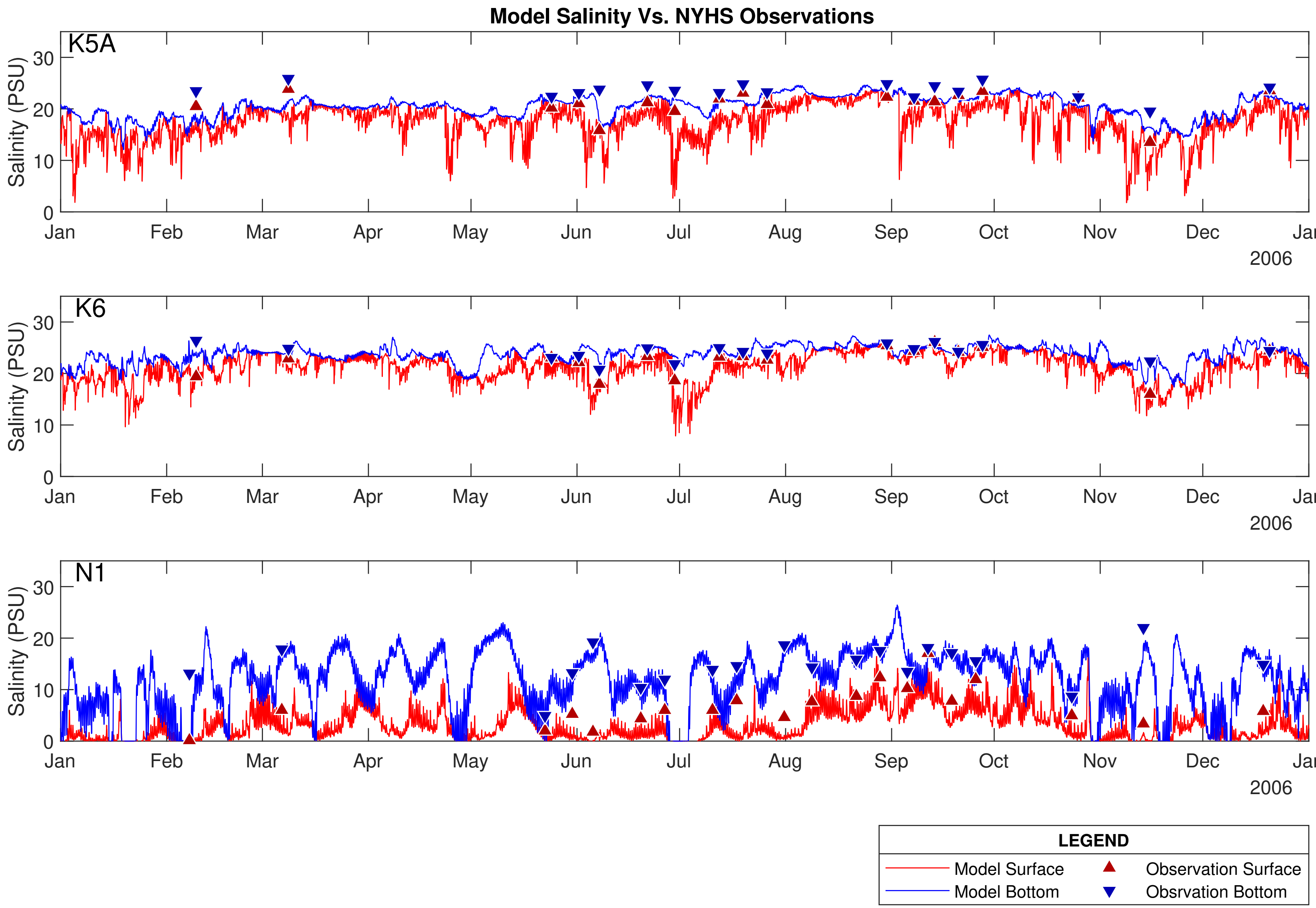


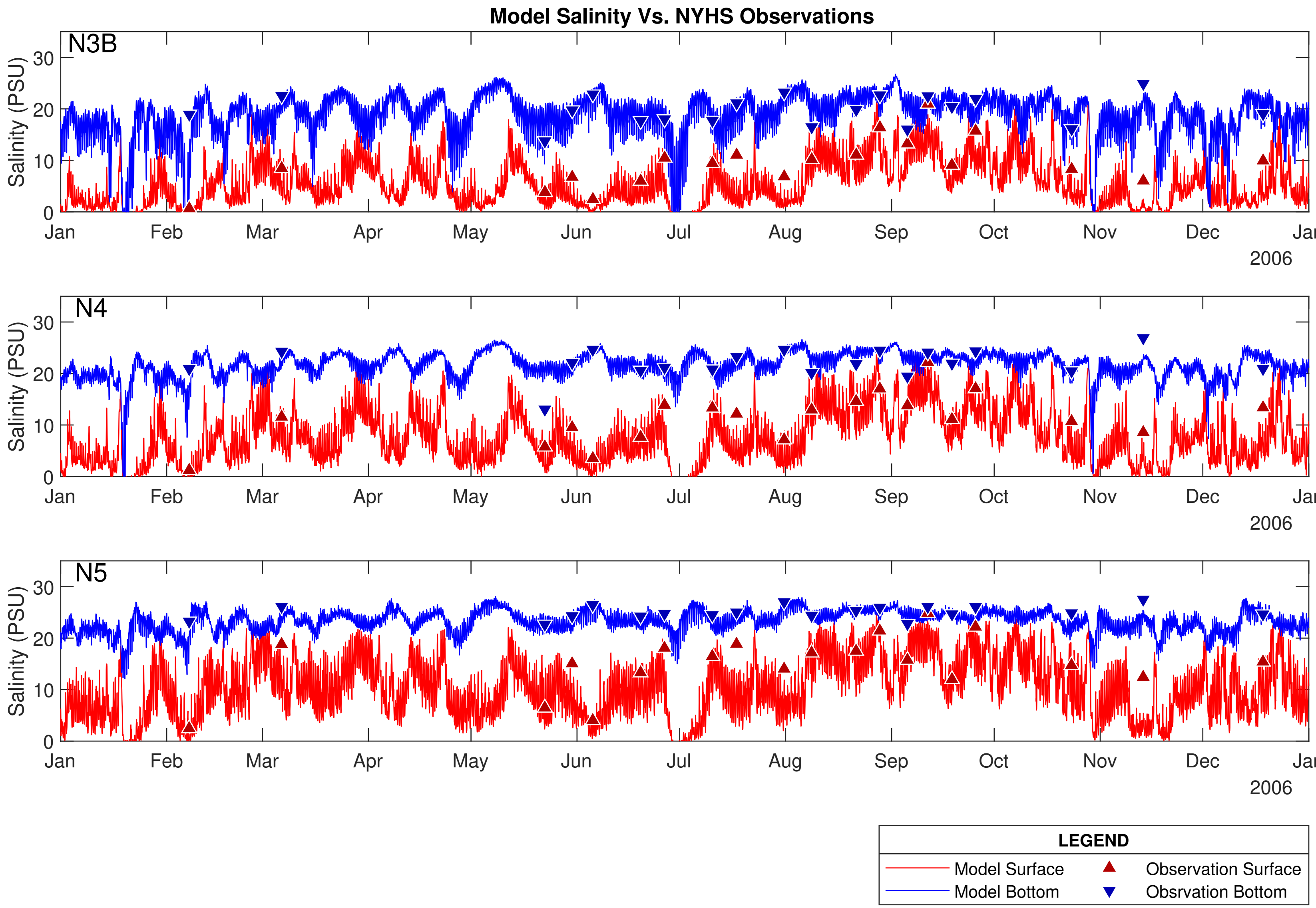
Model Salinity Vs. NYHS Observations
E14
E15
G2
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



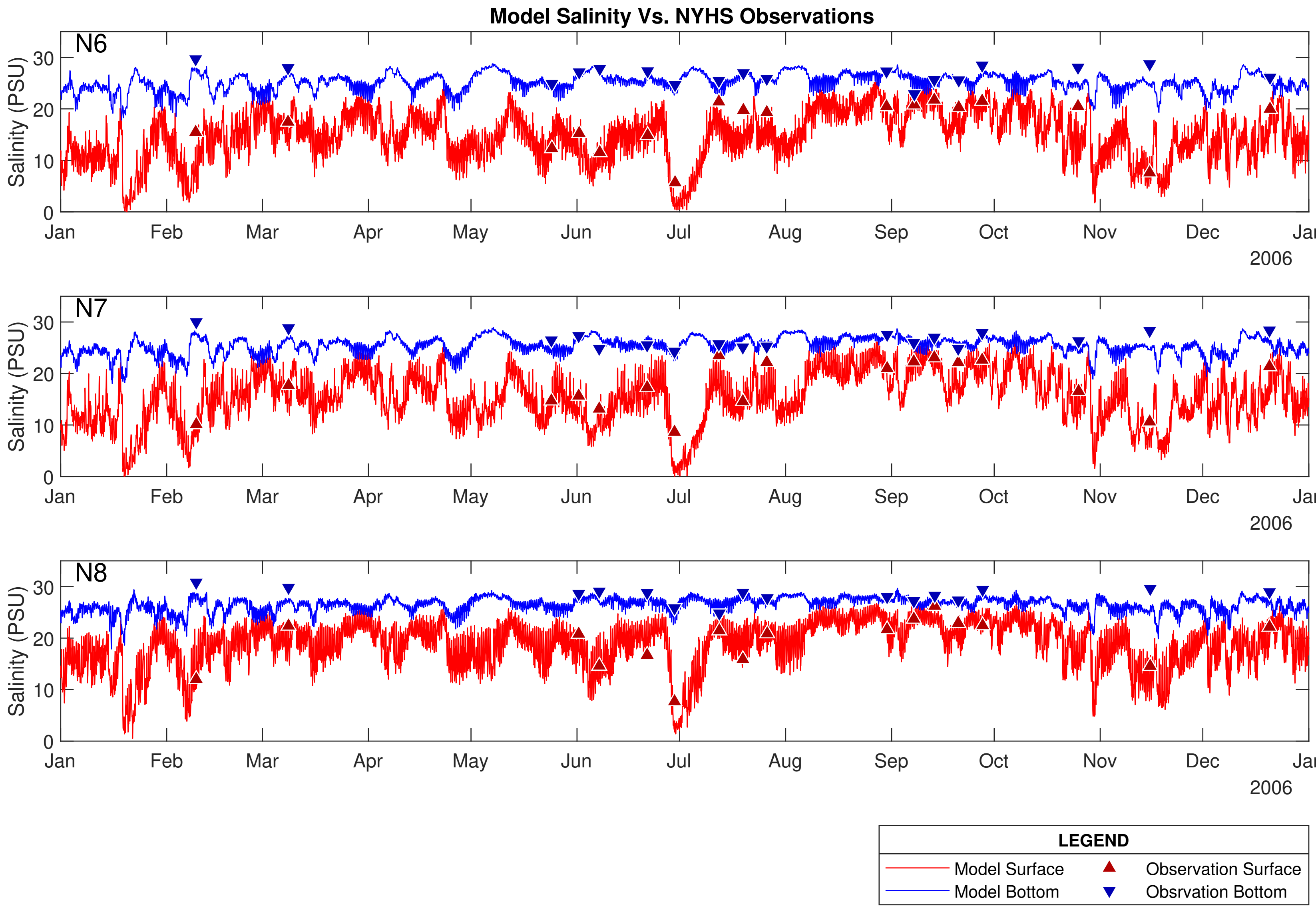
Model Salinity Vs. NYHS Observations
H3
K1
K2
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom


Model Salinity Vs. NYHS Observations
K3
K4
K5
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

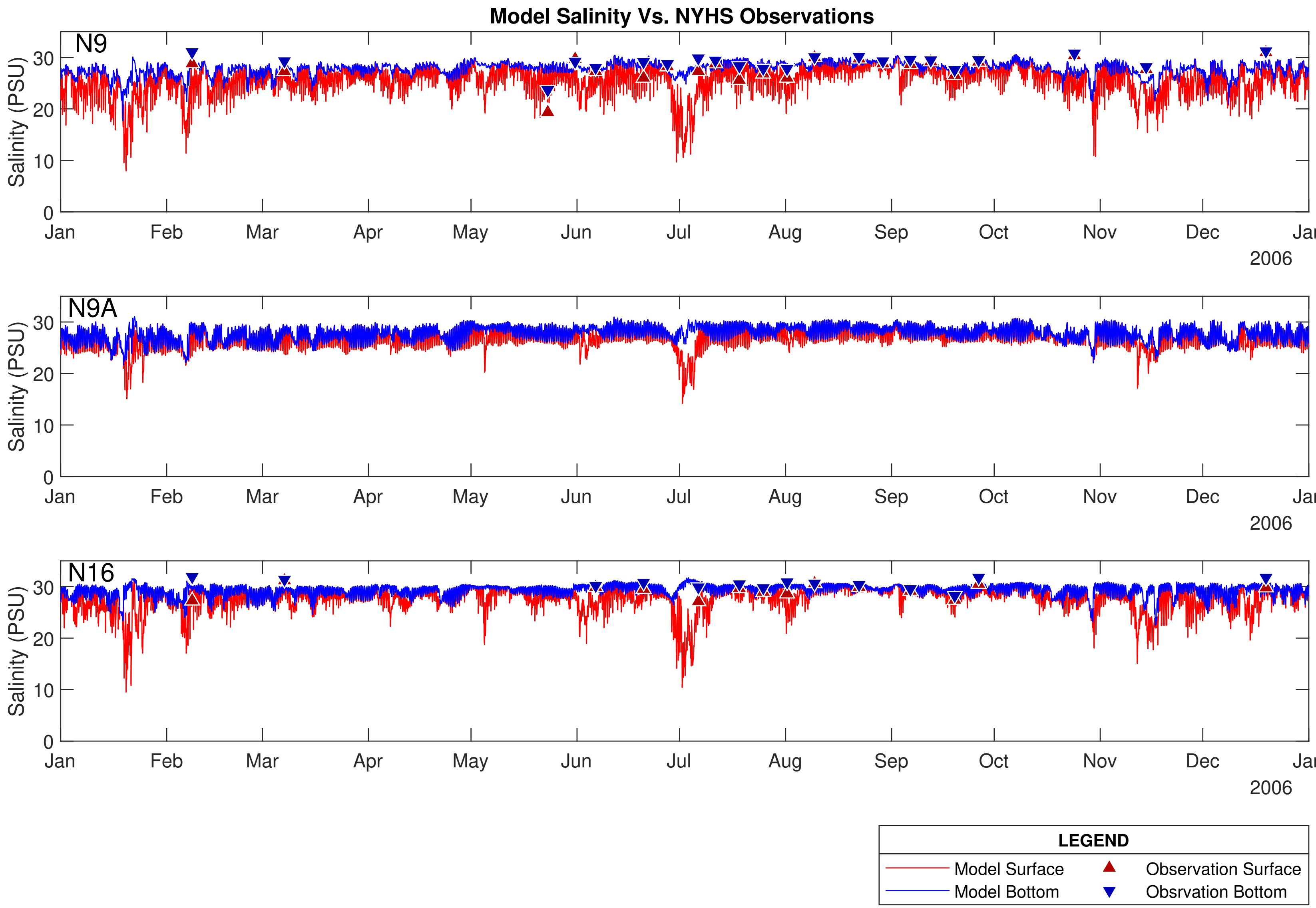

Model Salinity Vs. NYHS Observations
K5A
K6
N1
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



Model Salinity Vs. NYHS Observations
N3B
N4
N5
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



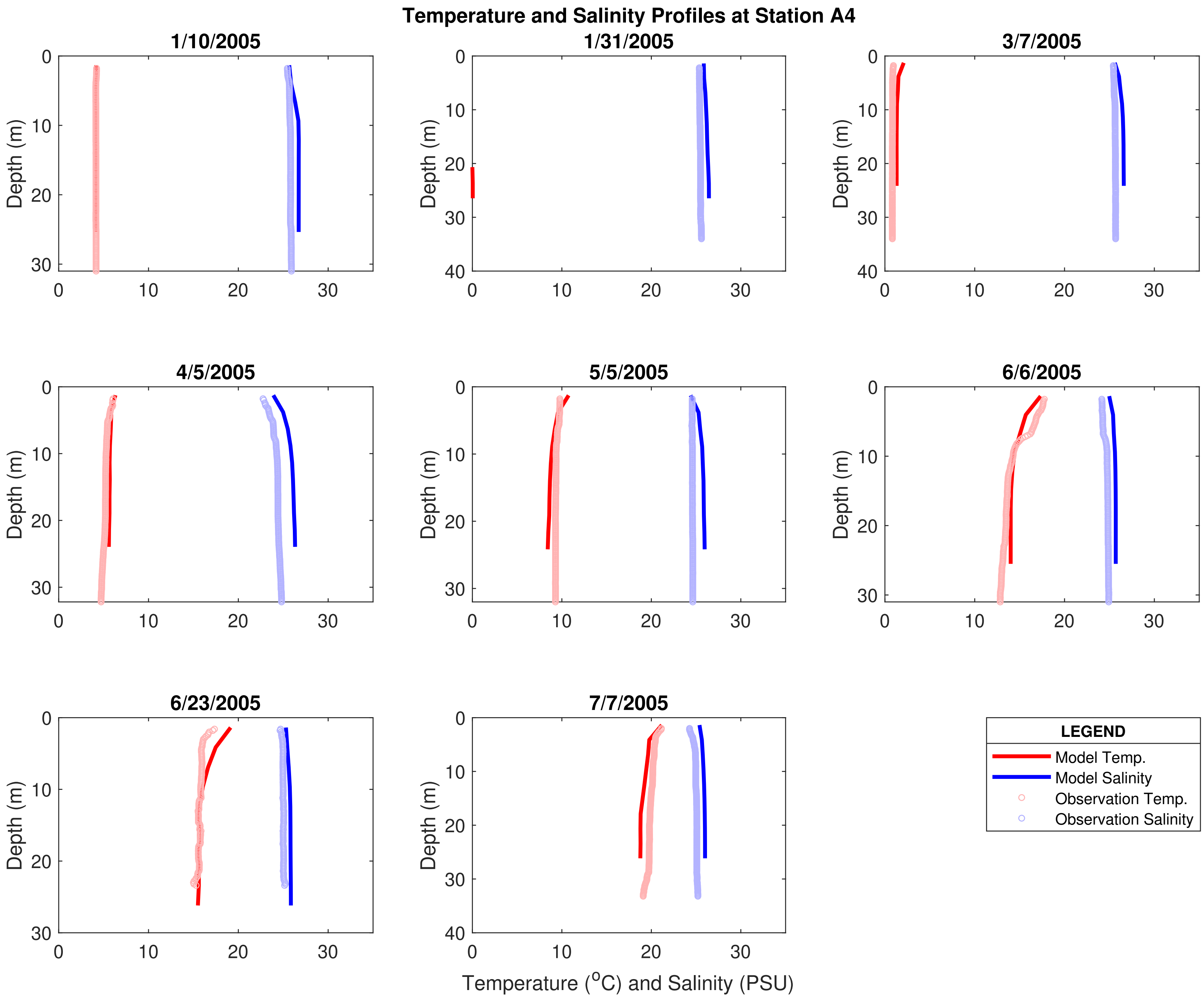
Model Salinity Vs. NYHS Observations
N6
N7
N8
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom



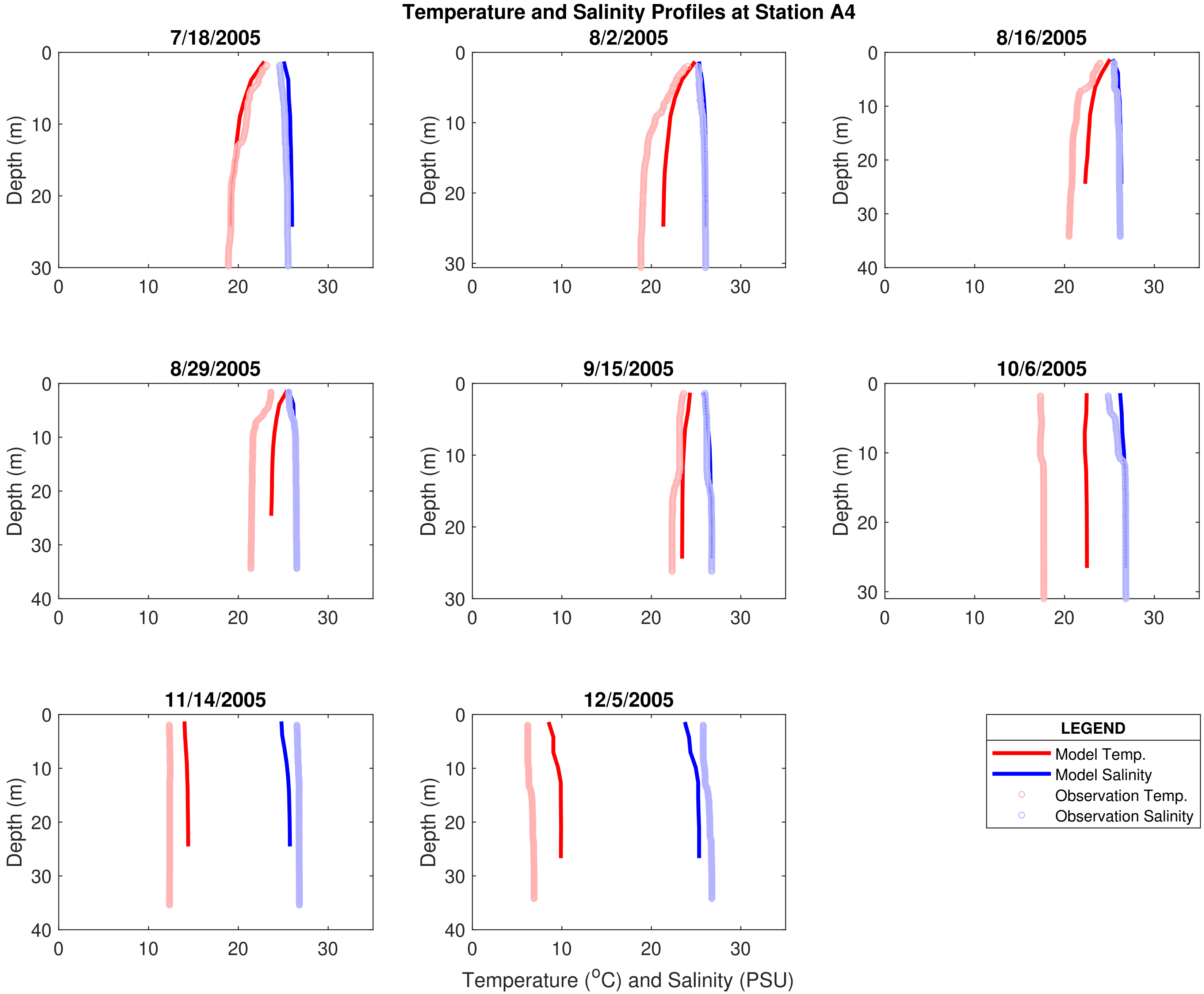
Model Salinity Vs. NYHS Observations
N9
N9A
N16
Salinity (PSU)
0
10
20
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2006
LEGEND
Model Surface
Model Bottom
Observation Surface
Obsrvation Bottom

3

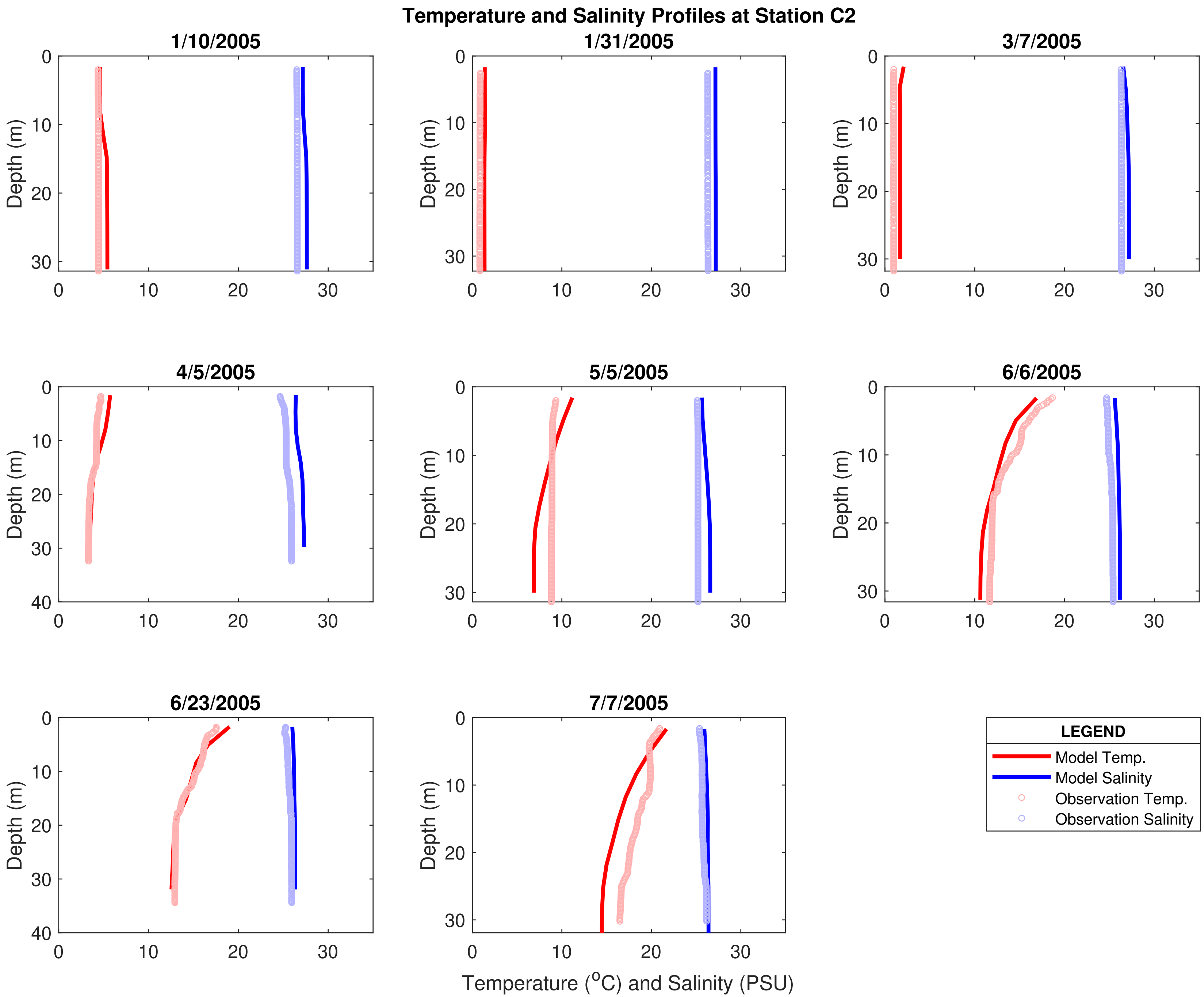
2005-2006 Model-Data Temperature/Salinity Profile Comparisons



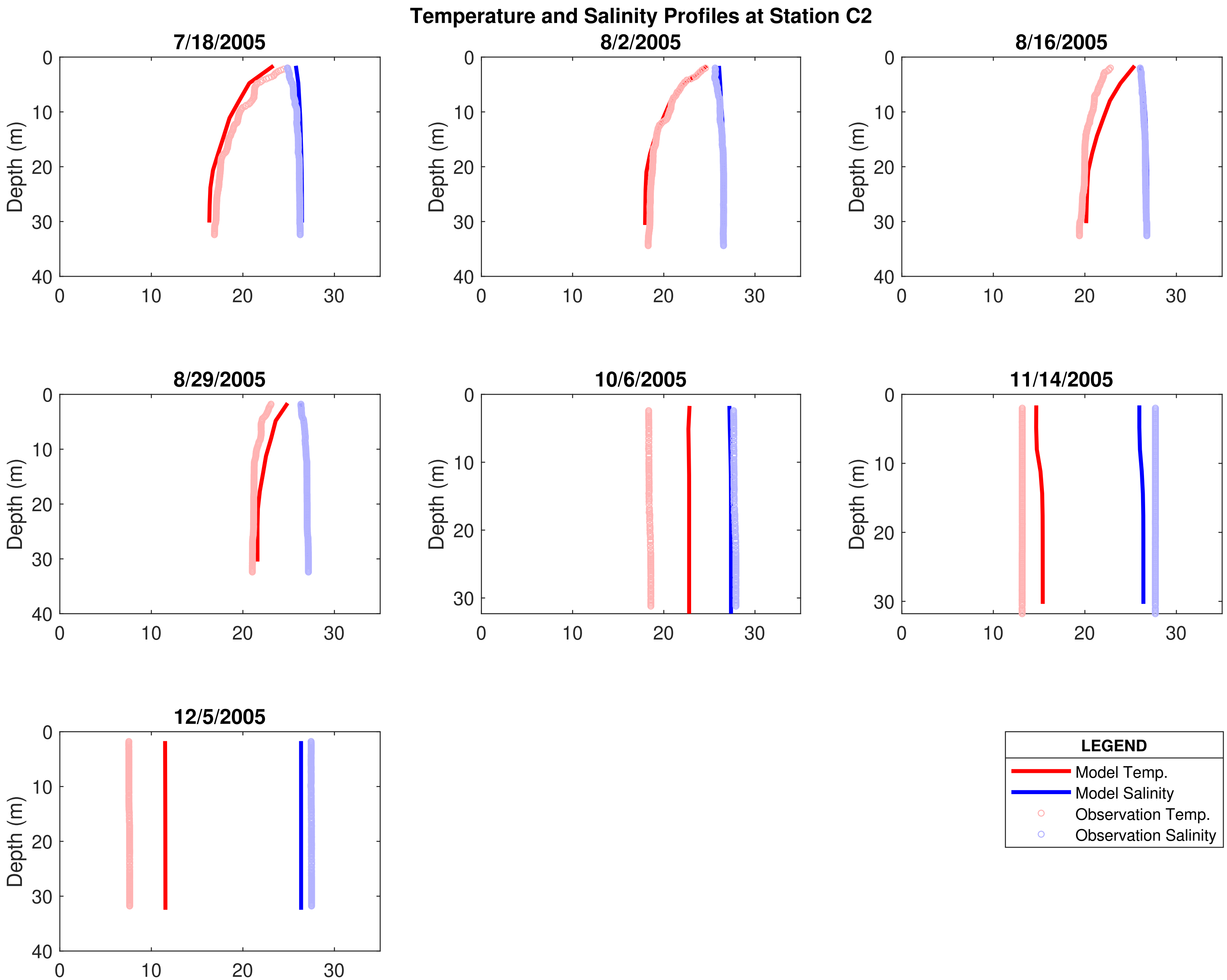
Temperature and Salinity Profiles at Station A4
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
6/23/2005
7/7/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

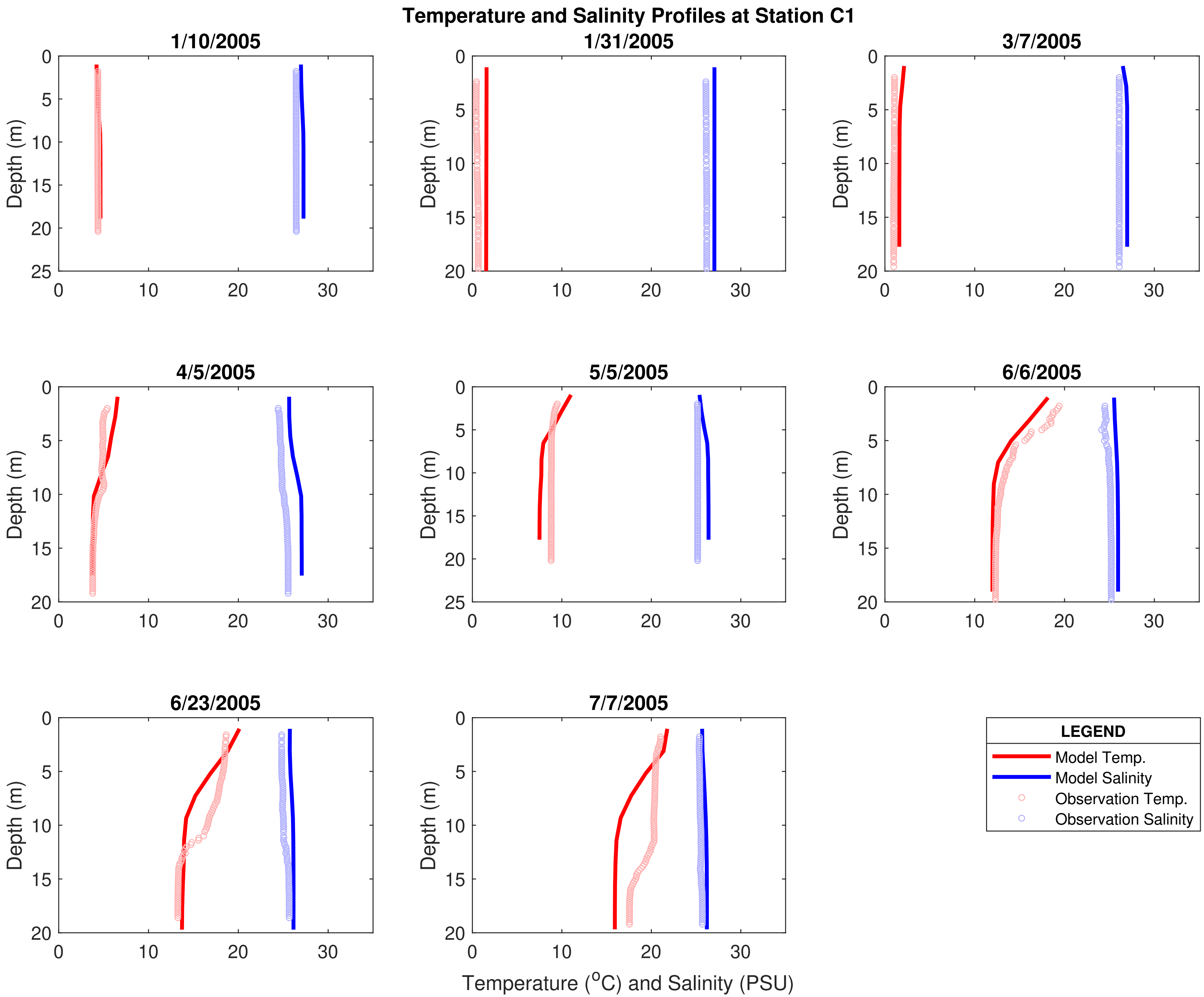


Temperature and Salinity Profiles at Station A4
7/18/2005
8/2/2005
8/16/2005
8/29/2005
9/15/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

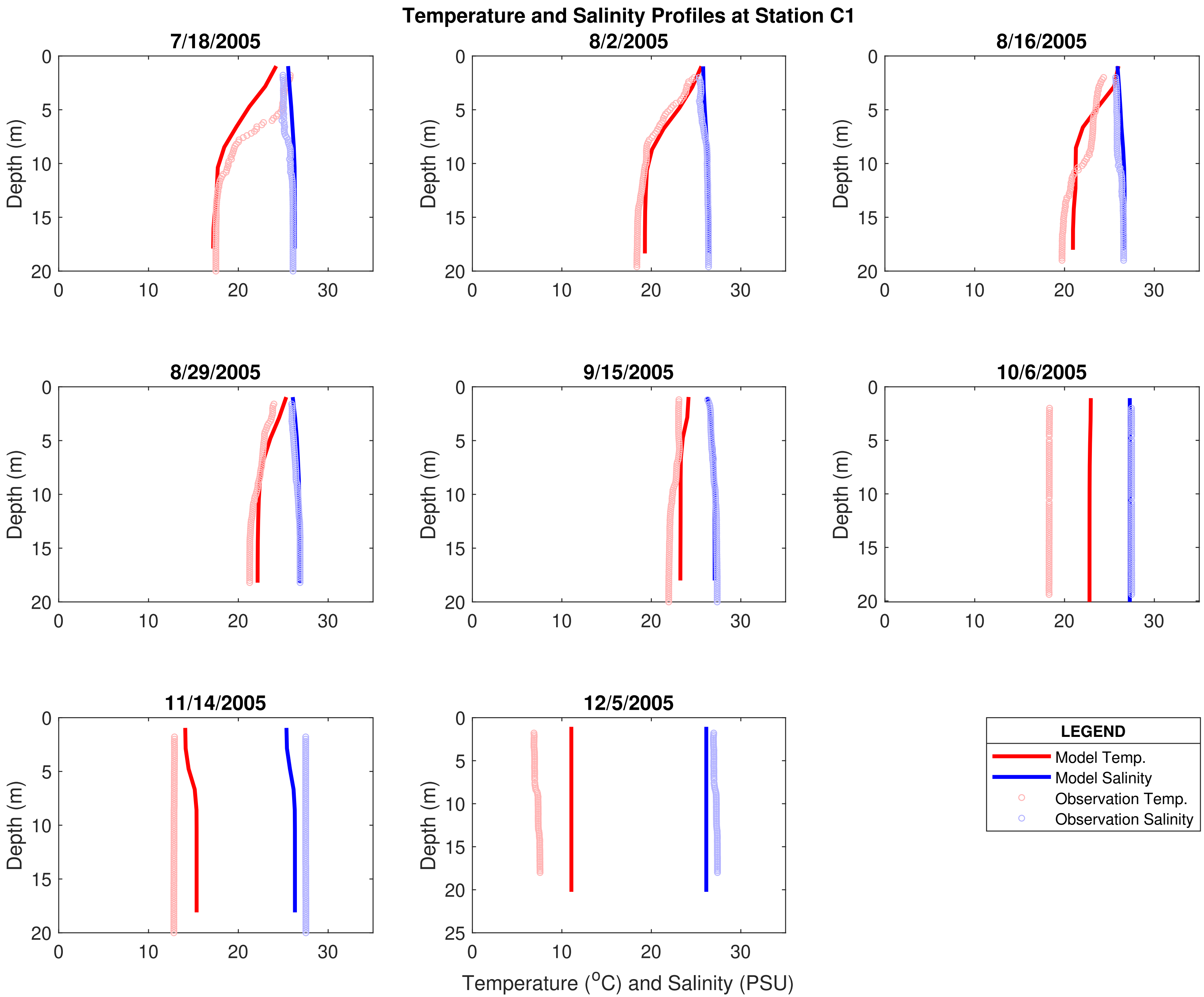


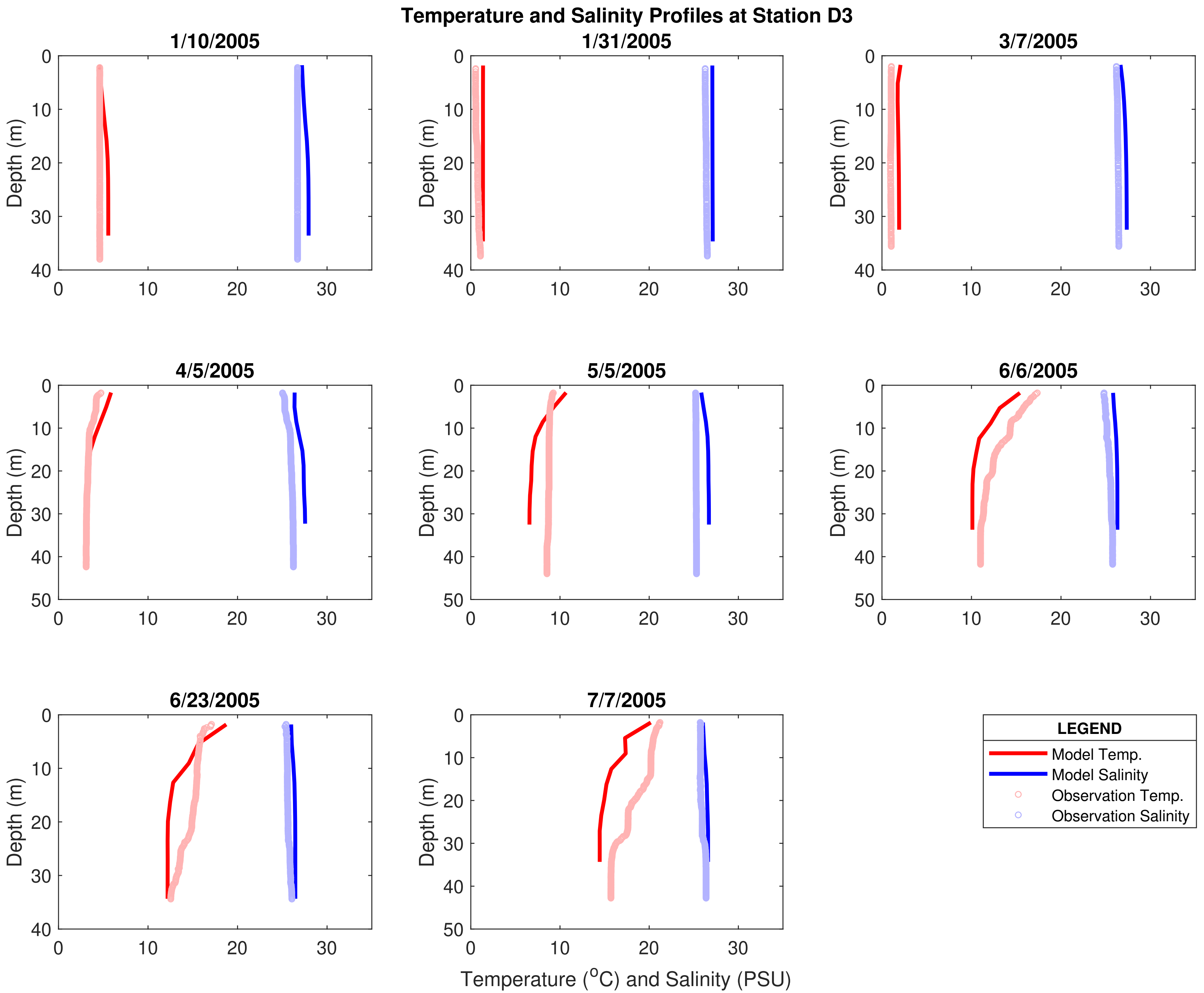
Temperature and Salinity Profiles at Station C2
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
6/23/2005
7/7/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

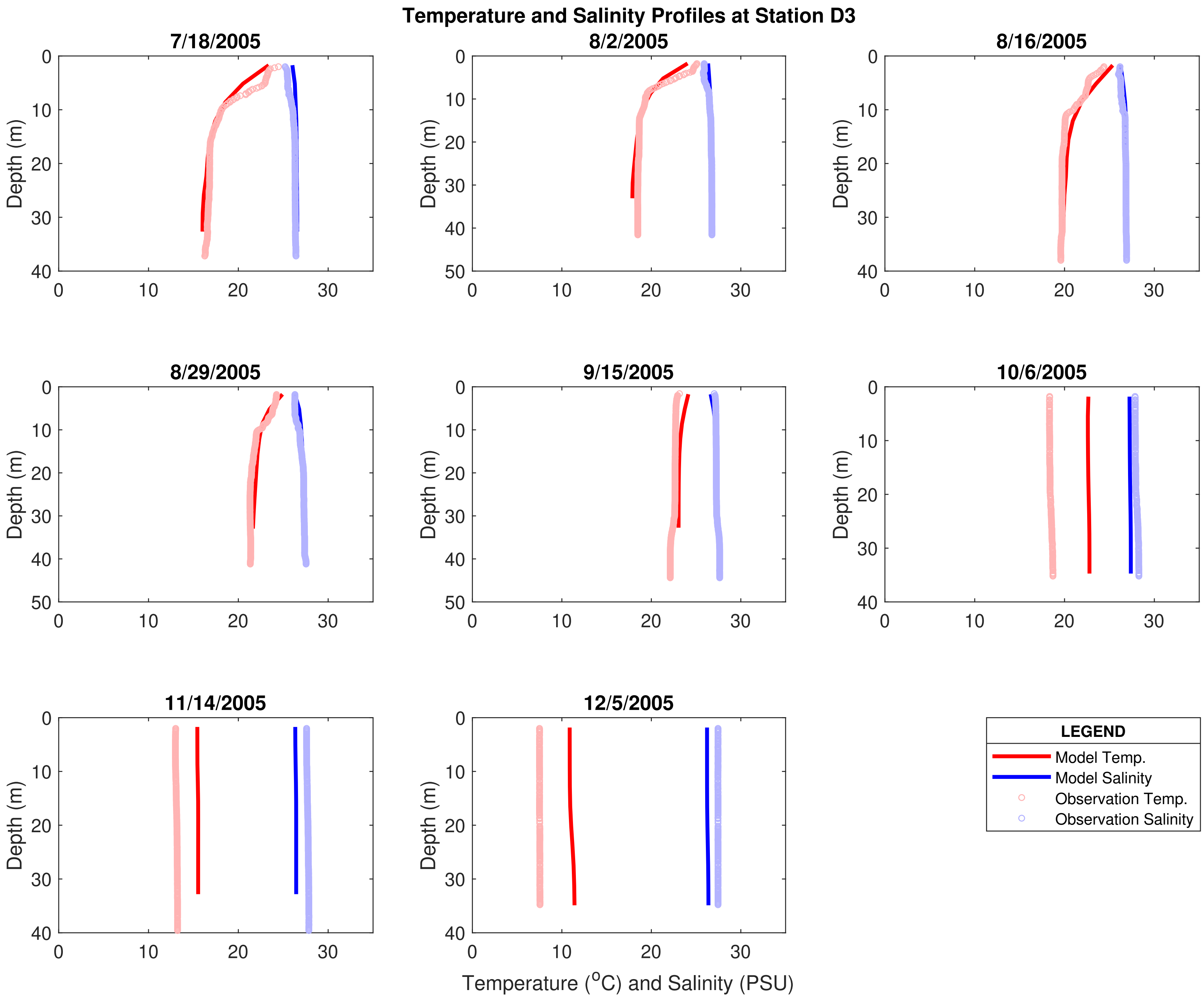

Temperature and Salinity Profiles at Station C2
7/18/2005
8/2/2005
8/16/2005
8/29/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
0
10
20
30
40
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

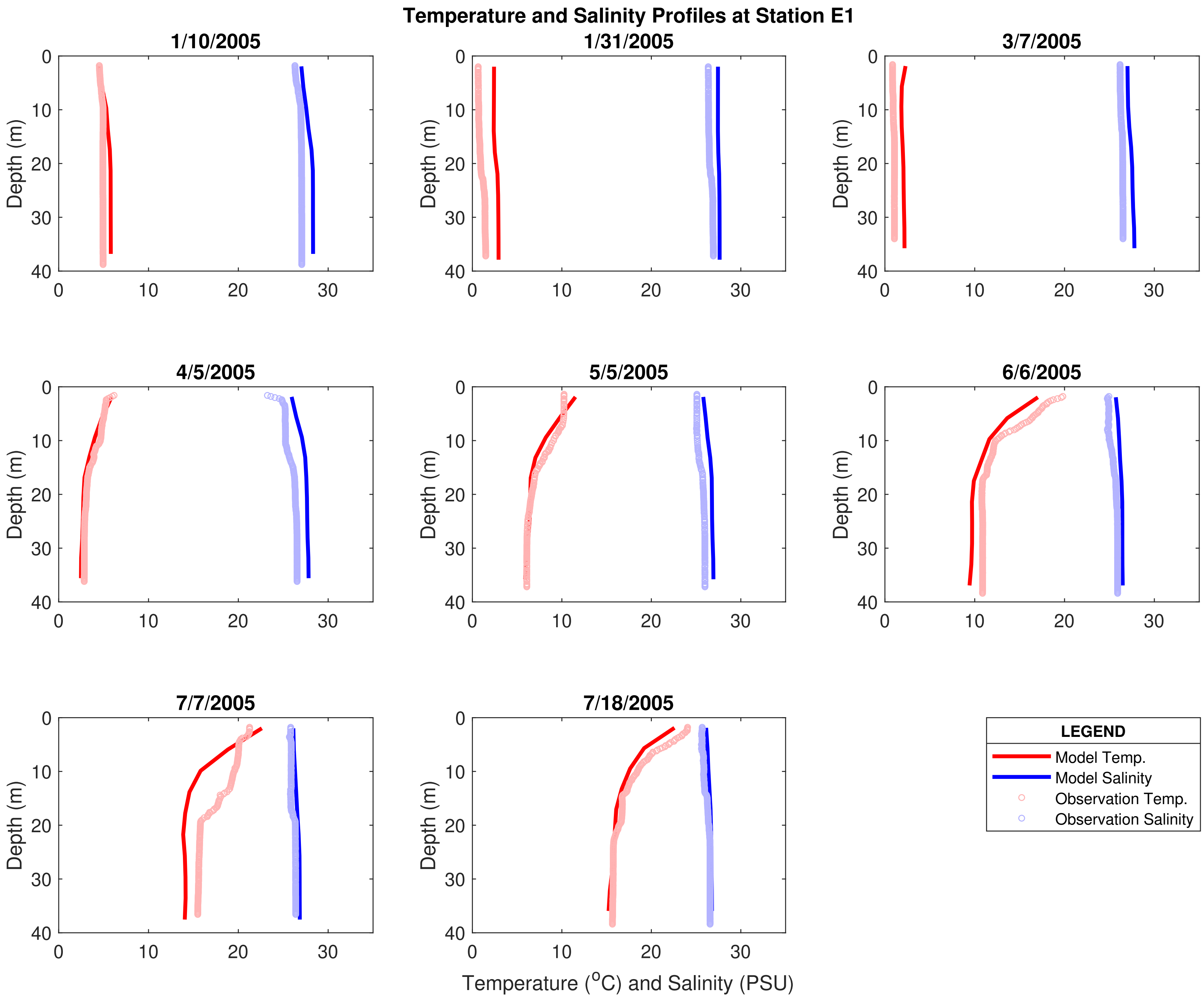


Temperature and Salinity Profiles at Station C1
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
6/23/2005
7/7/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

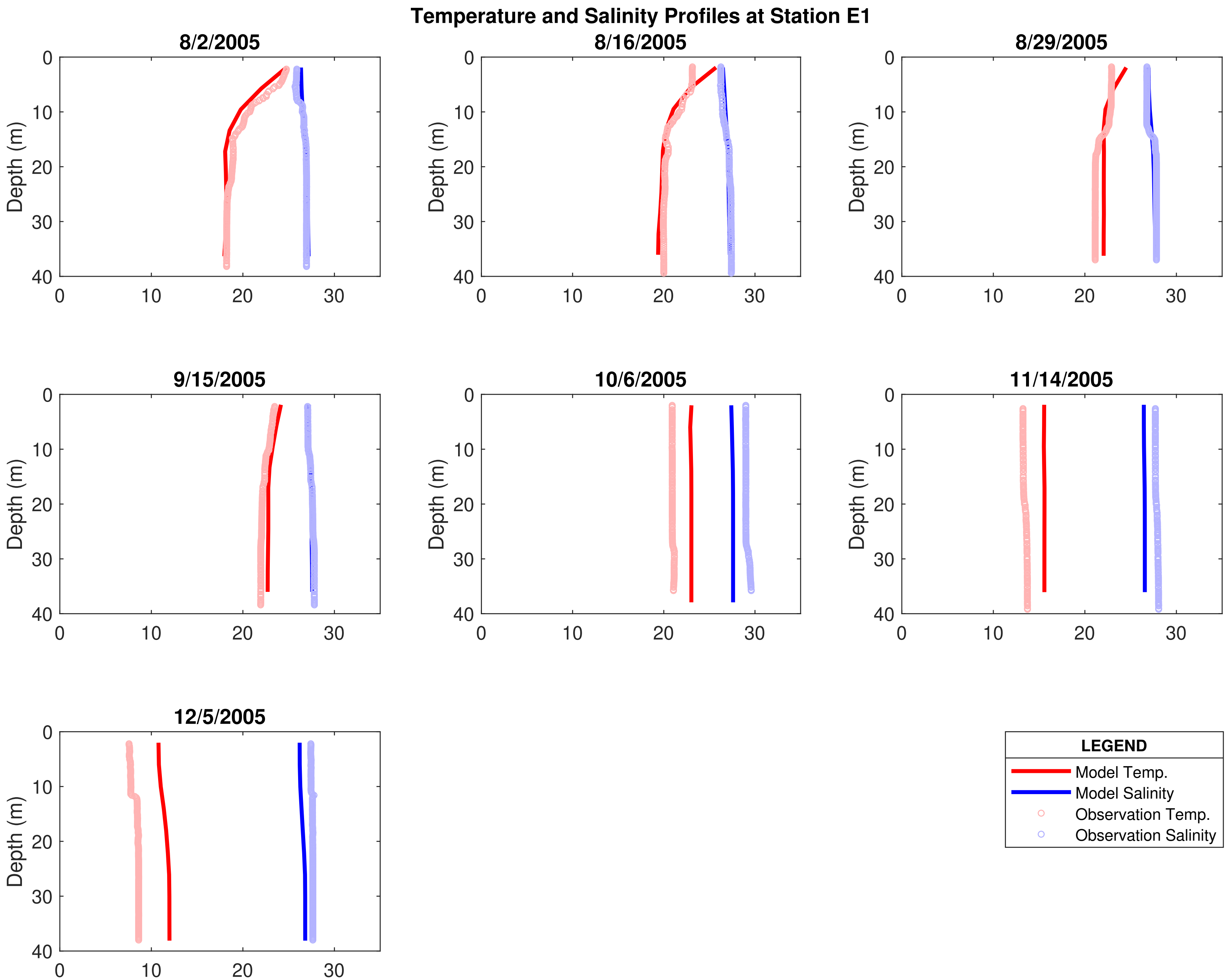

Temperature and Salinity Profiles at Station C1
7/18/2005
8/2/2005
8/16/2005
8/29/2005
9/15/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity


Temperature and Salinity Profiles at Station D3
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
6/23/2005
7/7/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

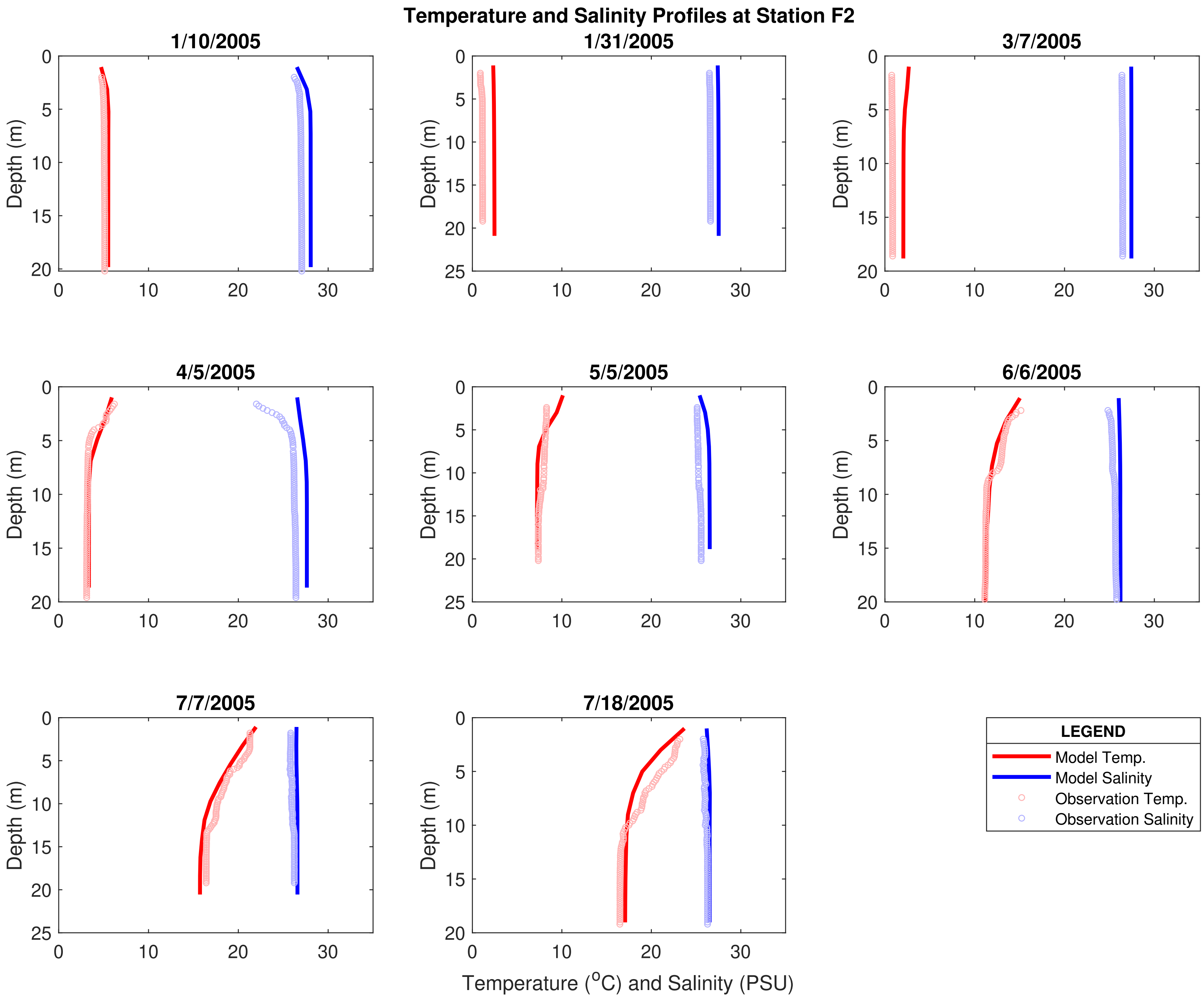

Temperature and Salinity Profiles at Station D3
7/18/2005
8/2/2005
8/16/2005
8/29/2005
9/15/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

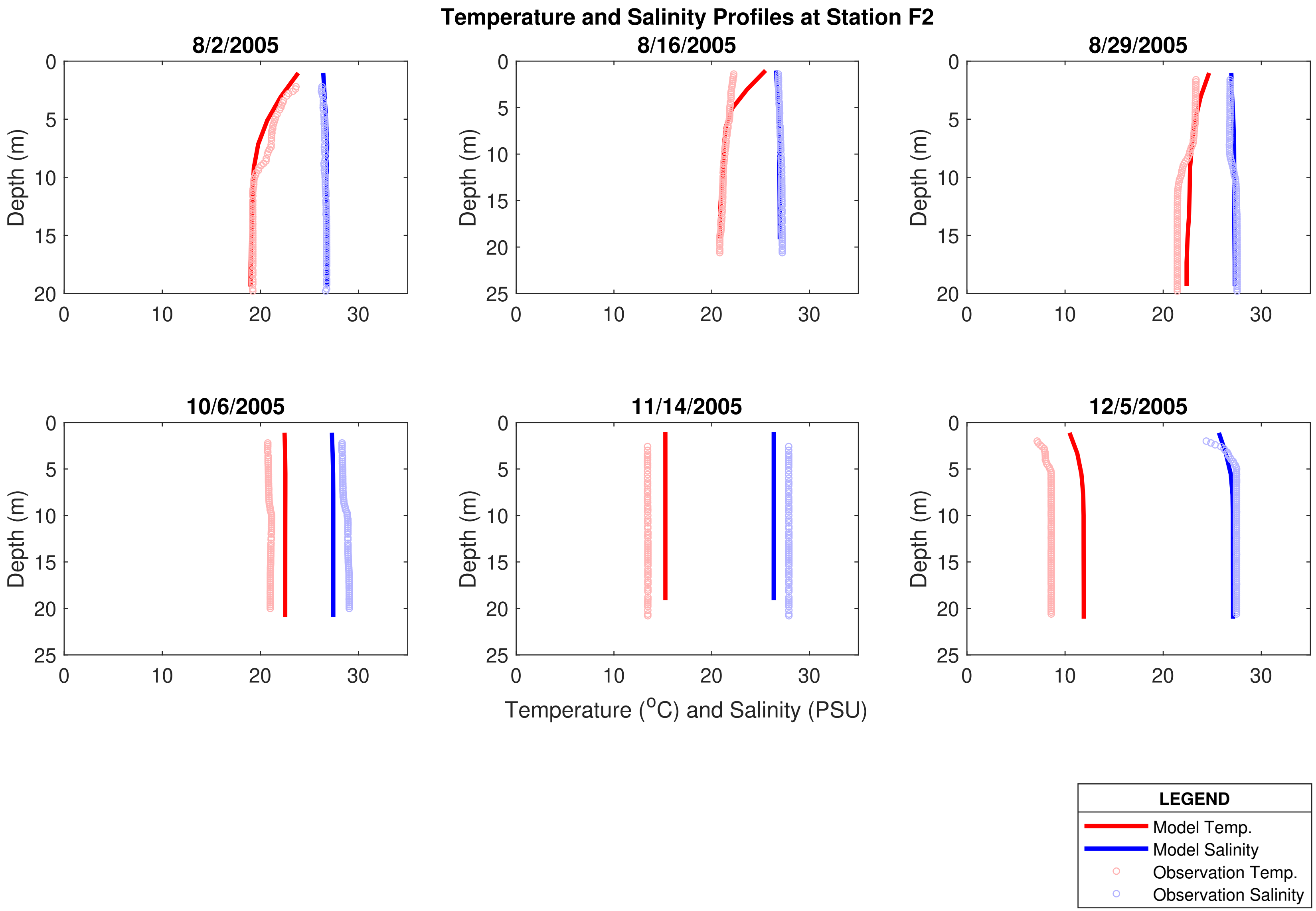


Temperature and Salinity Profiles at Station E1
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
7/7/2005
7/18/2005
Depth (m)
0
10
20
30
40
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

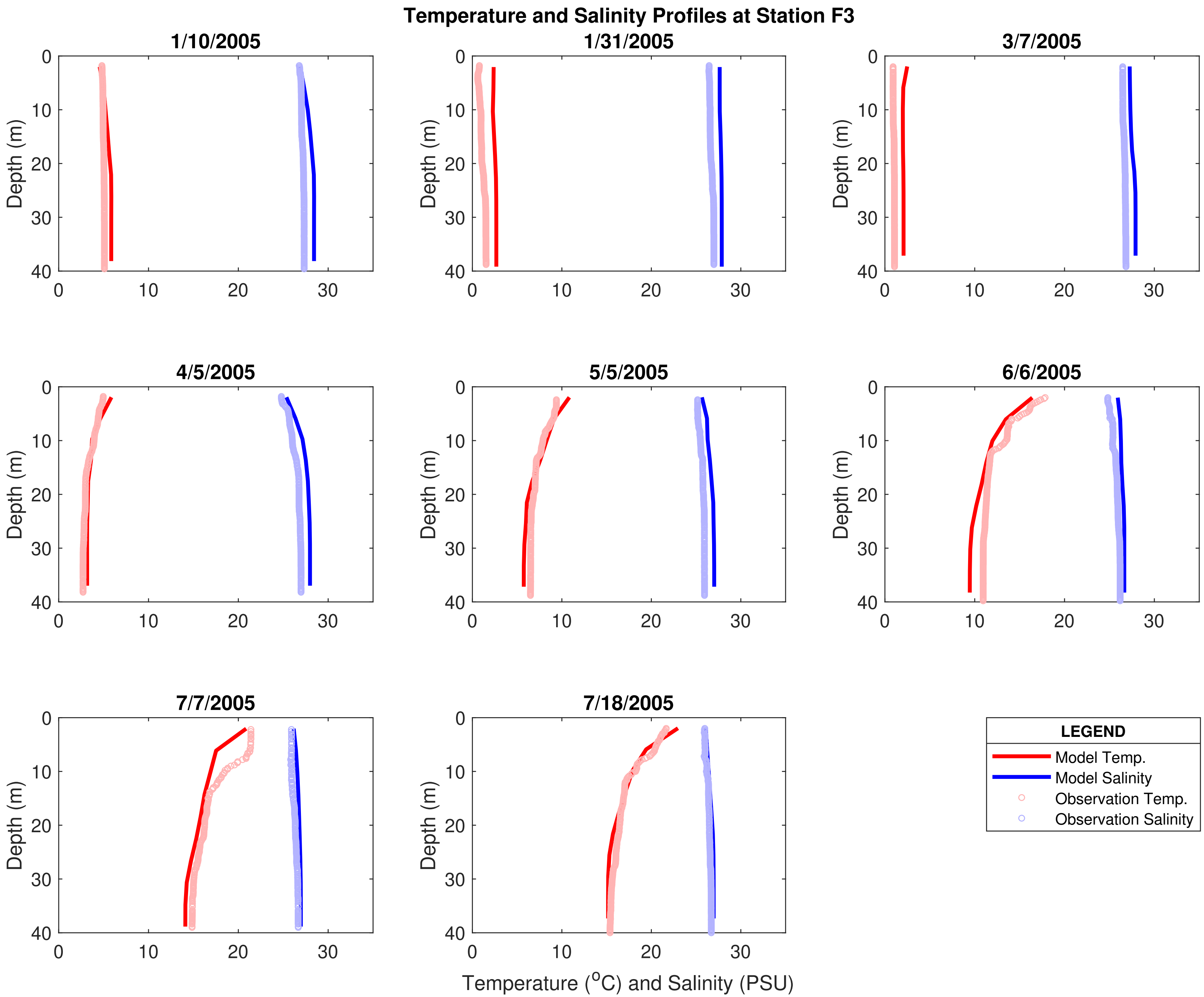


Temperature and Salinity Profiles at Station E1
8/2/2005
8/16/2005
8/29/2005
9/15/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
0
10
20
30
40
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

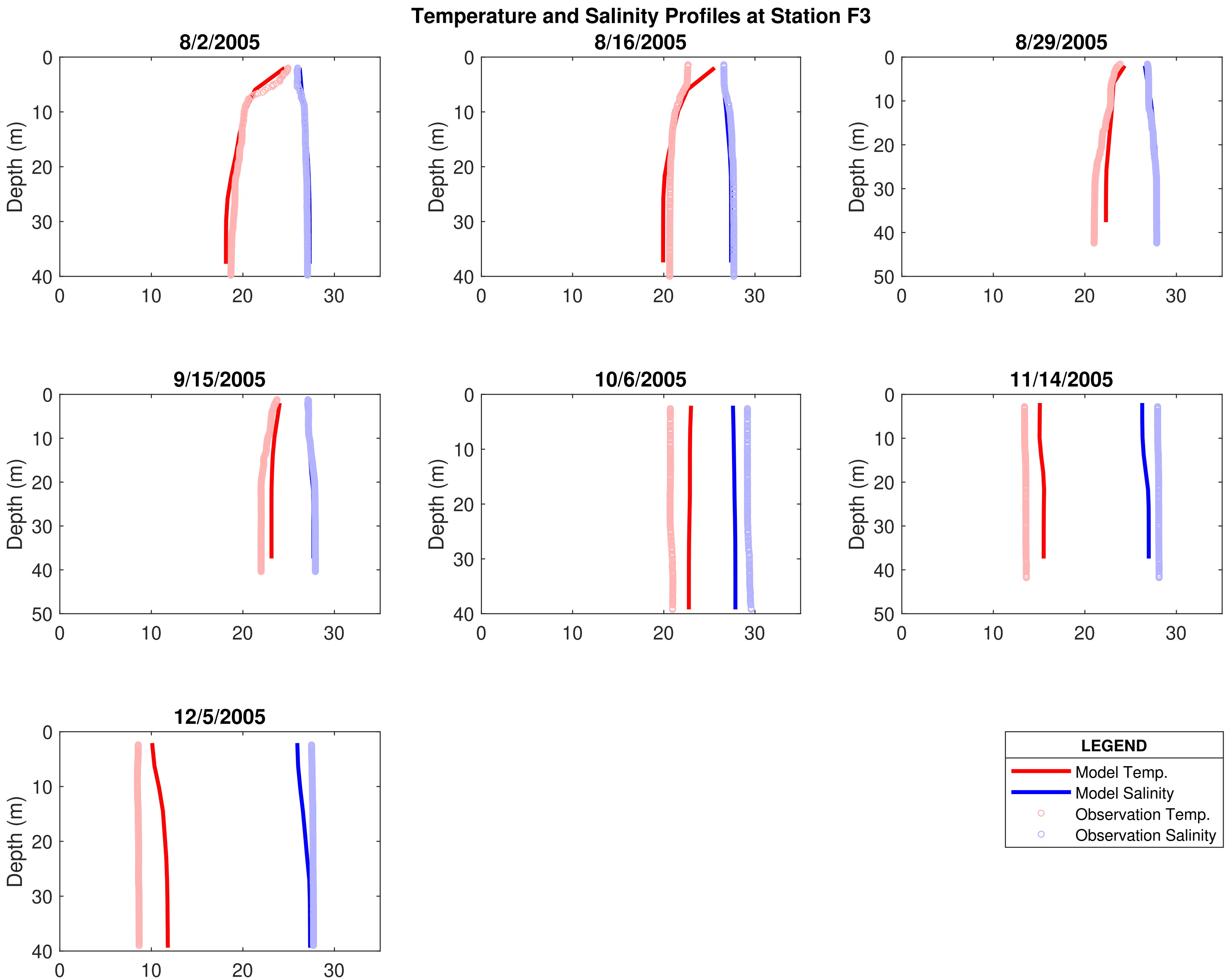

Temperature and Salinity Profiles at Station F2
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
7/7/2005
7/18/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



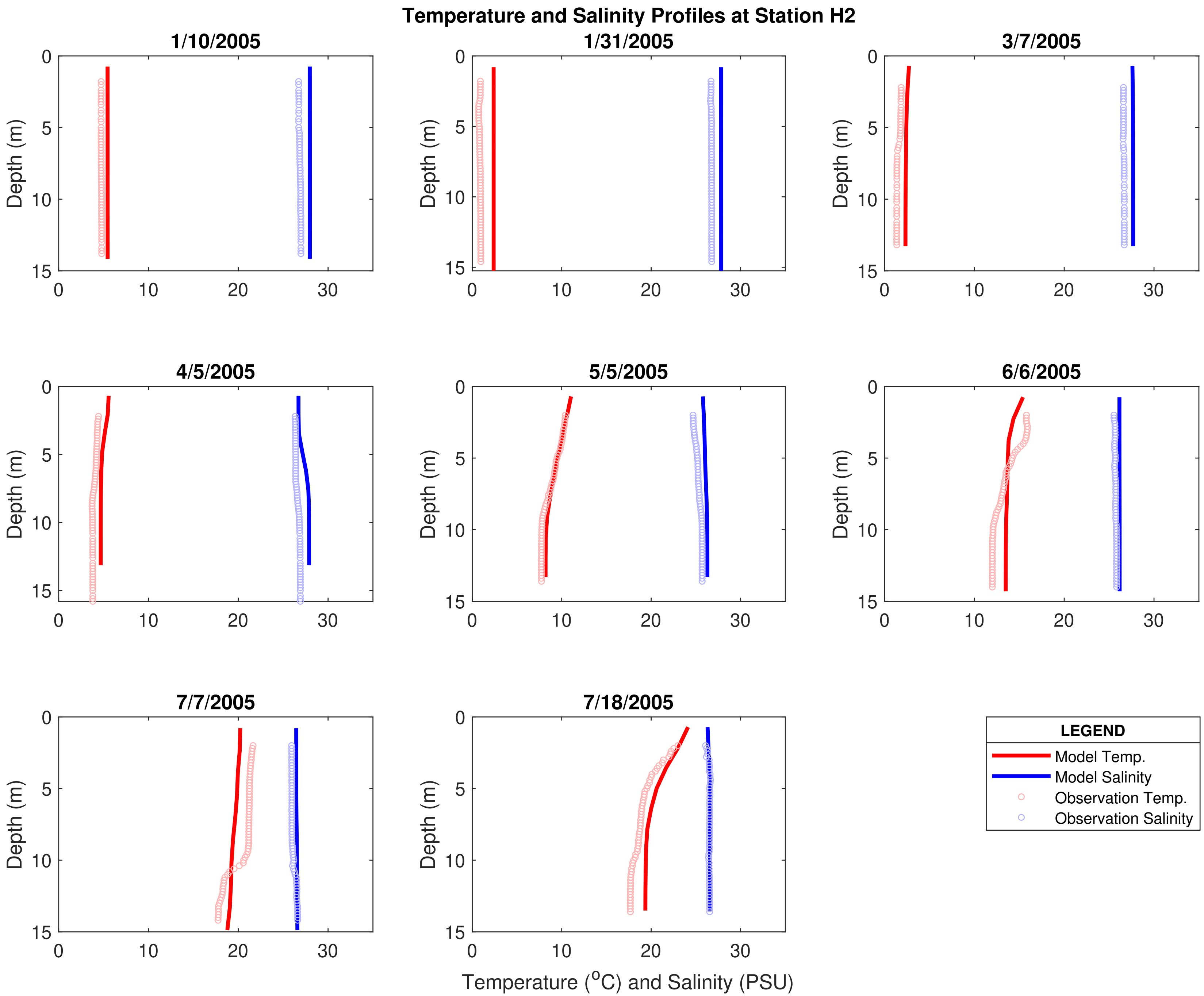
Temperature and Salinity Profiles at Station F2
8/2/2005
8/16/2005
8/29/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



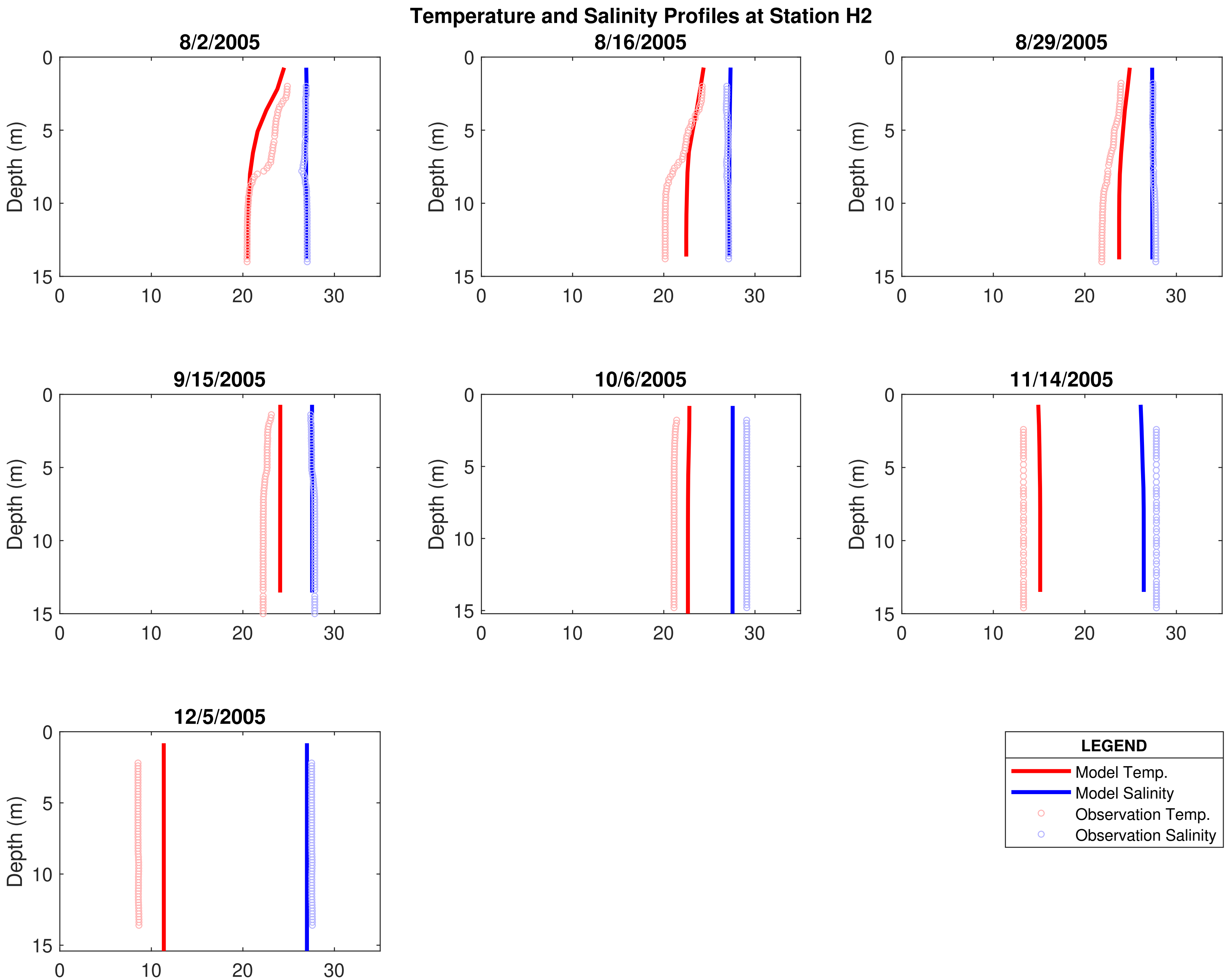
Temperature and Salinity Profiles at Station F3
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
7/7/2005
7/18/2005
Depth (m)
0
10
20
30
40
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



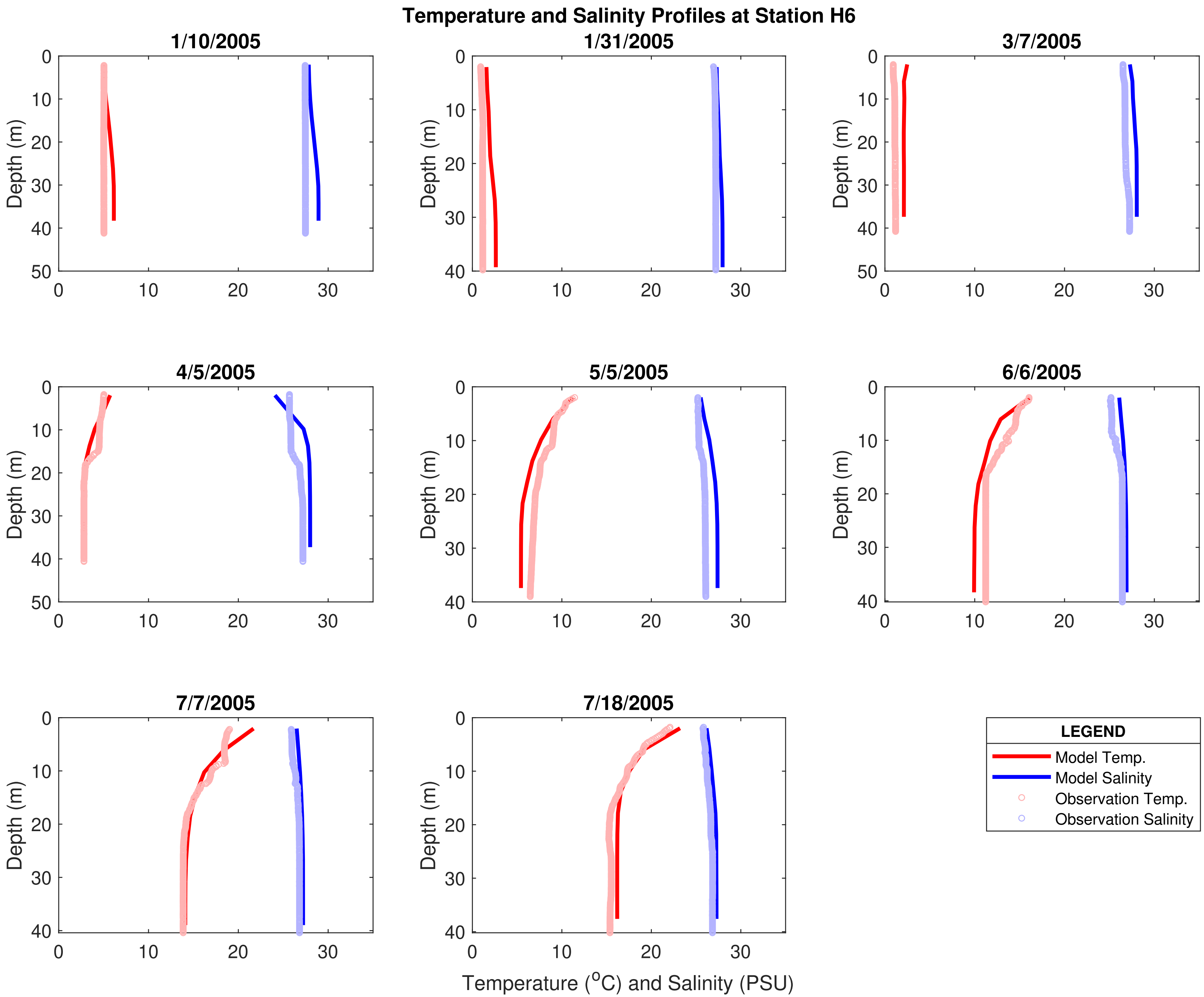
Temperature and Salinity Profiles at Station F3
8/2/2005
8/16/2005
8/29/2005
9/15/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



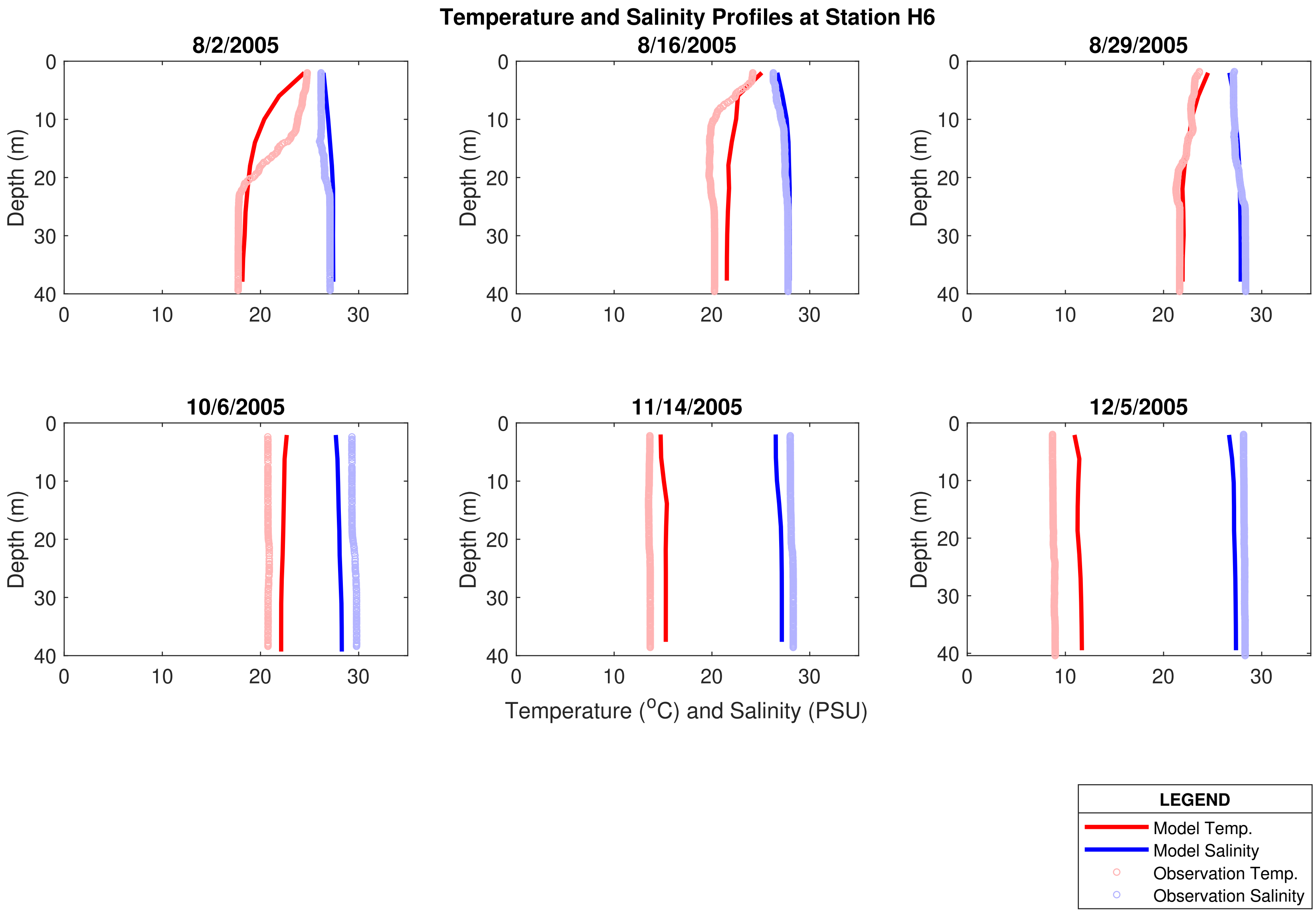
Temperature and Salinity Profiles at Station H2
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
7/7/2005
7/18/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



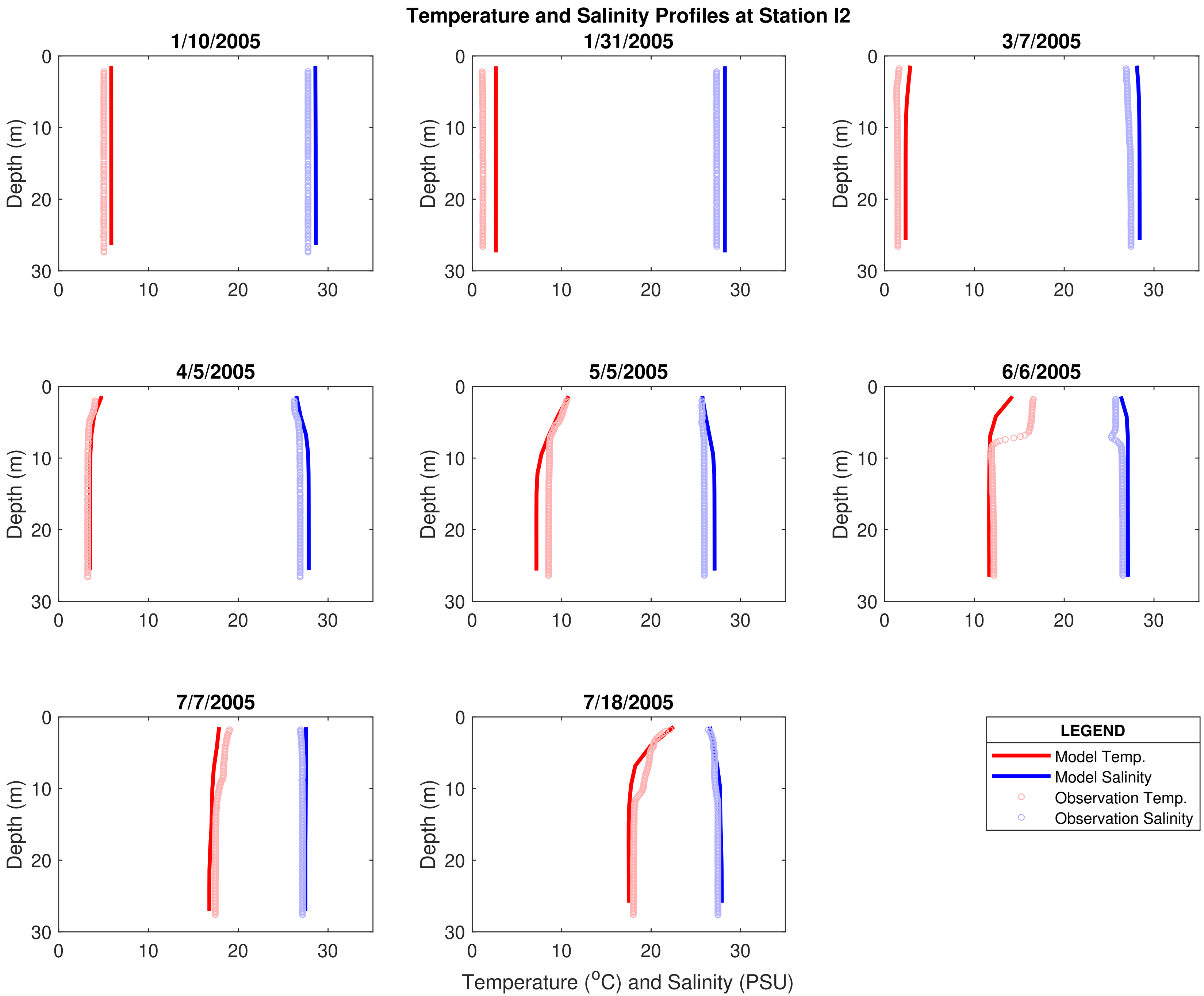
Temperature and Salinity Profiles at Station H2
8/2/2005
8/16/2005
8/29/2005
9/15/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
0
5
10
15
0
10
20
30
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



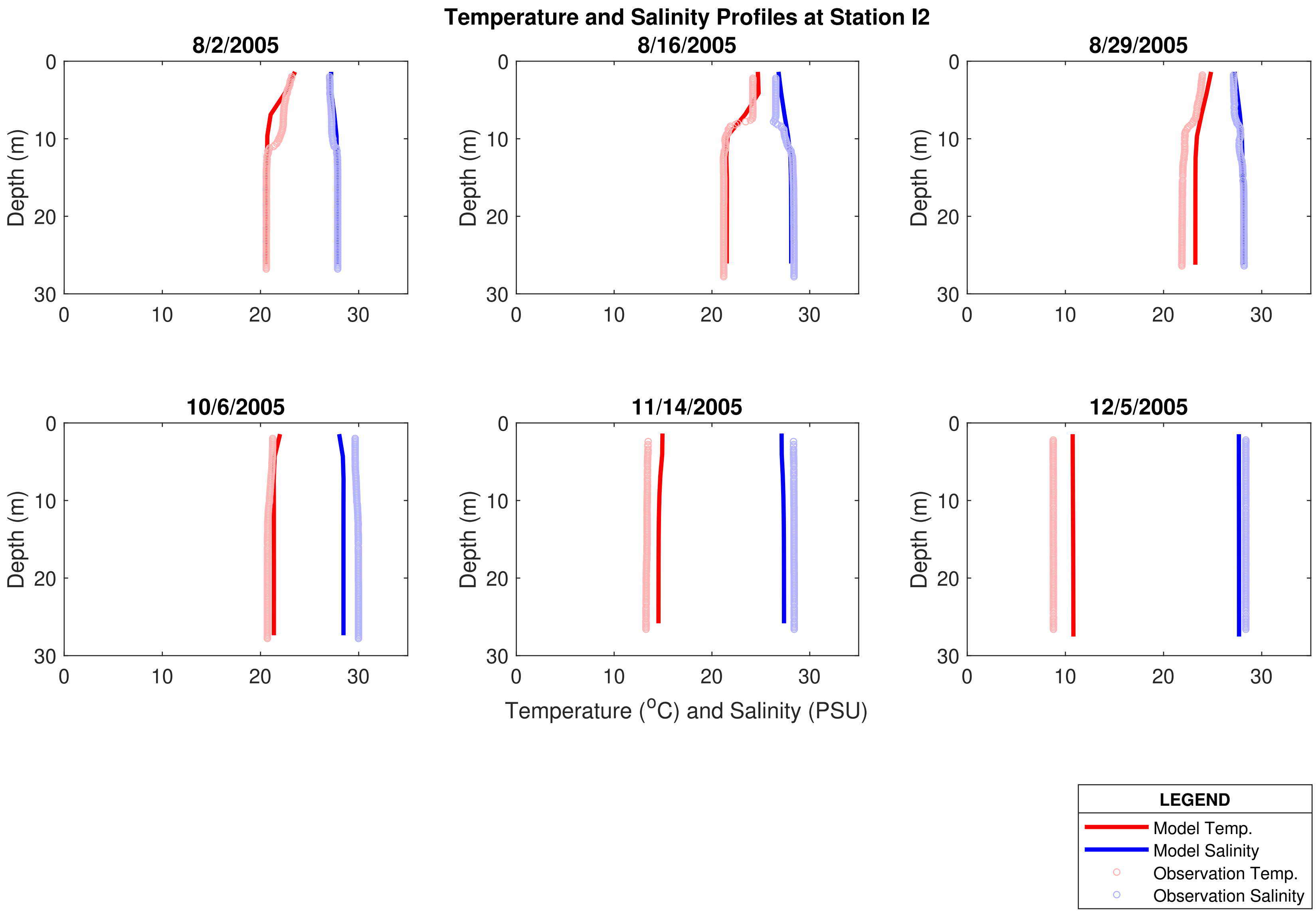
Temperature and Salinity Profiles at Station H6
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
7/7/2005
7/18/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

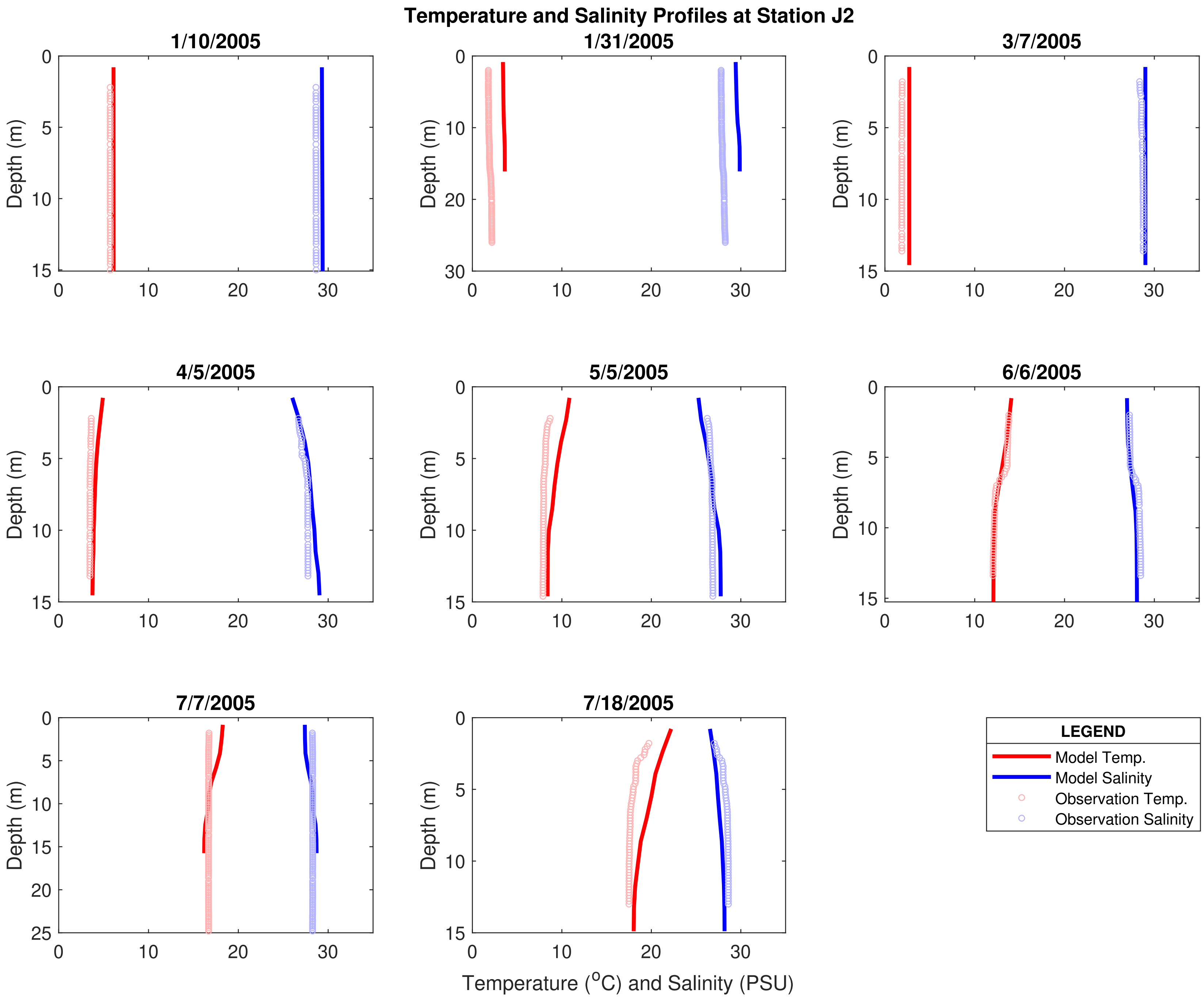


Temperature and Salinity Profiles at Station H6
8/2/2005
8/16/2005
8/29/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
0
10
20
30
40
0
10
20
30
Temperature (^{o}C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

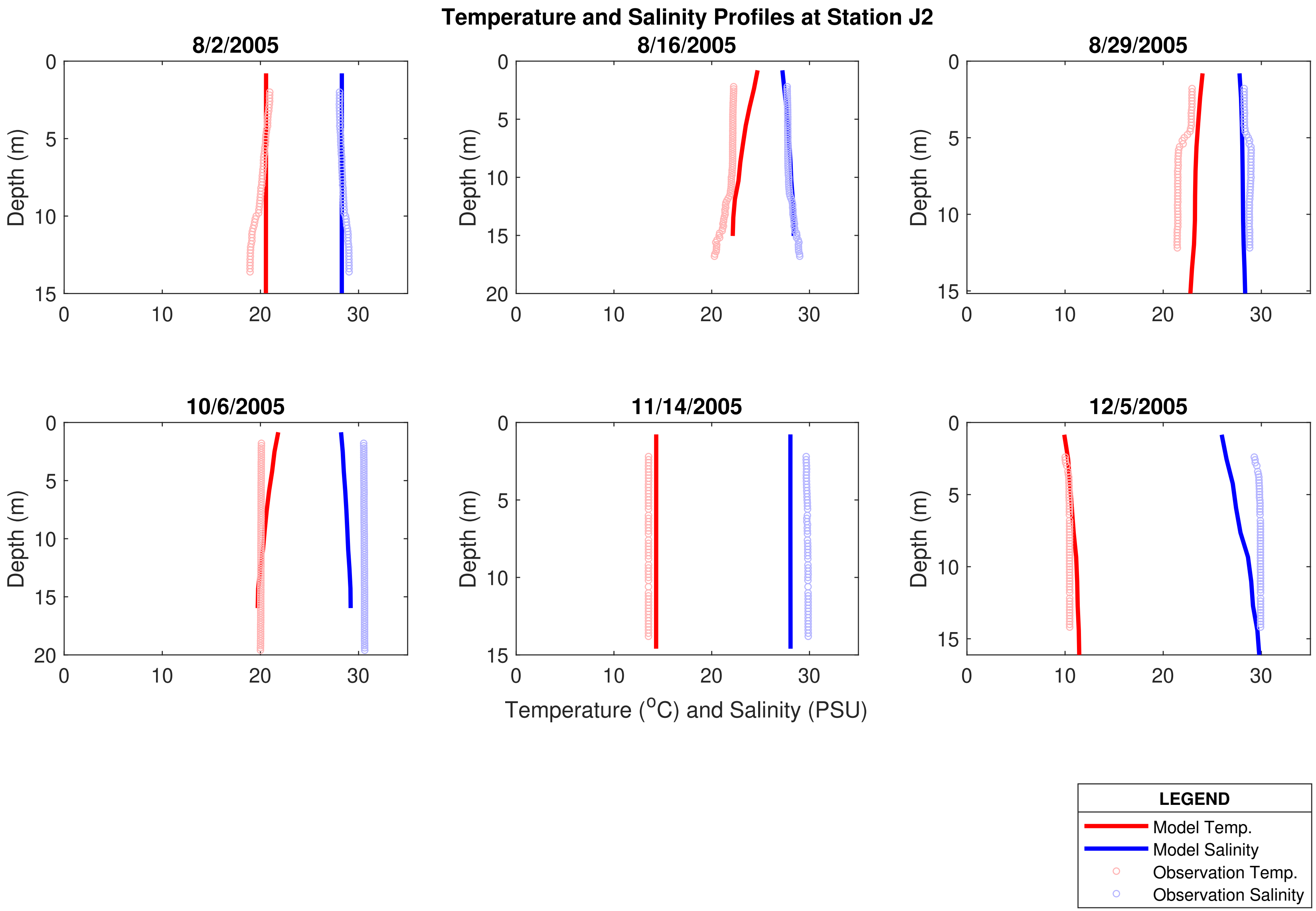


Temperature and Salinity Profiles at Station I2
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
7/7/2005
7/18/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
0
10
20
30
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

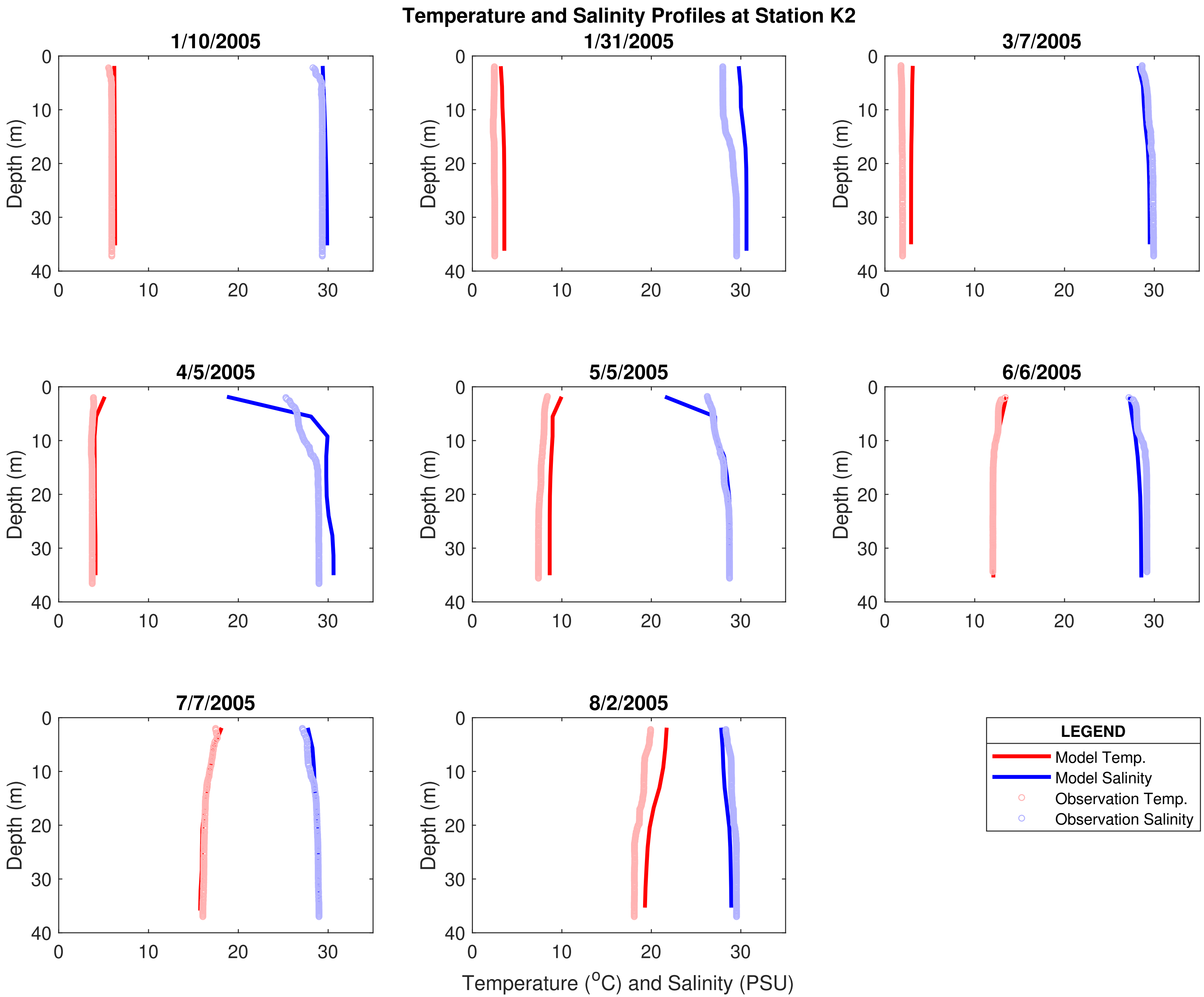

Temperature and Salinity Profiles at Station I2
8/2/2005
8/16/2005
8/29/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
0
10
20
30
Temperature (^oC) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



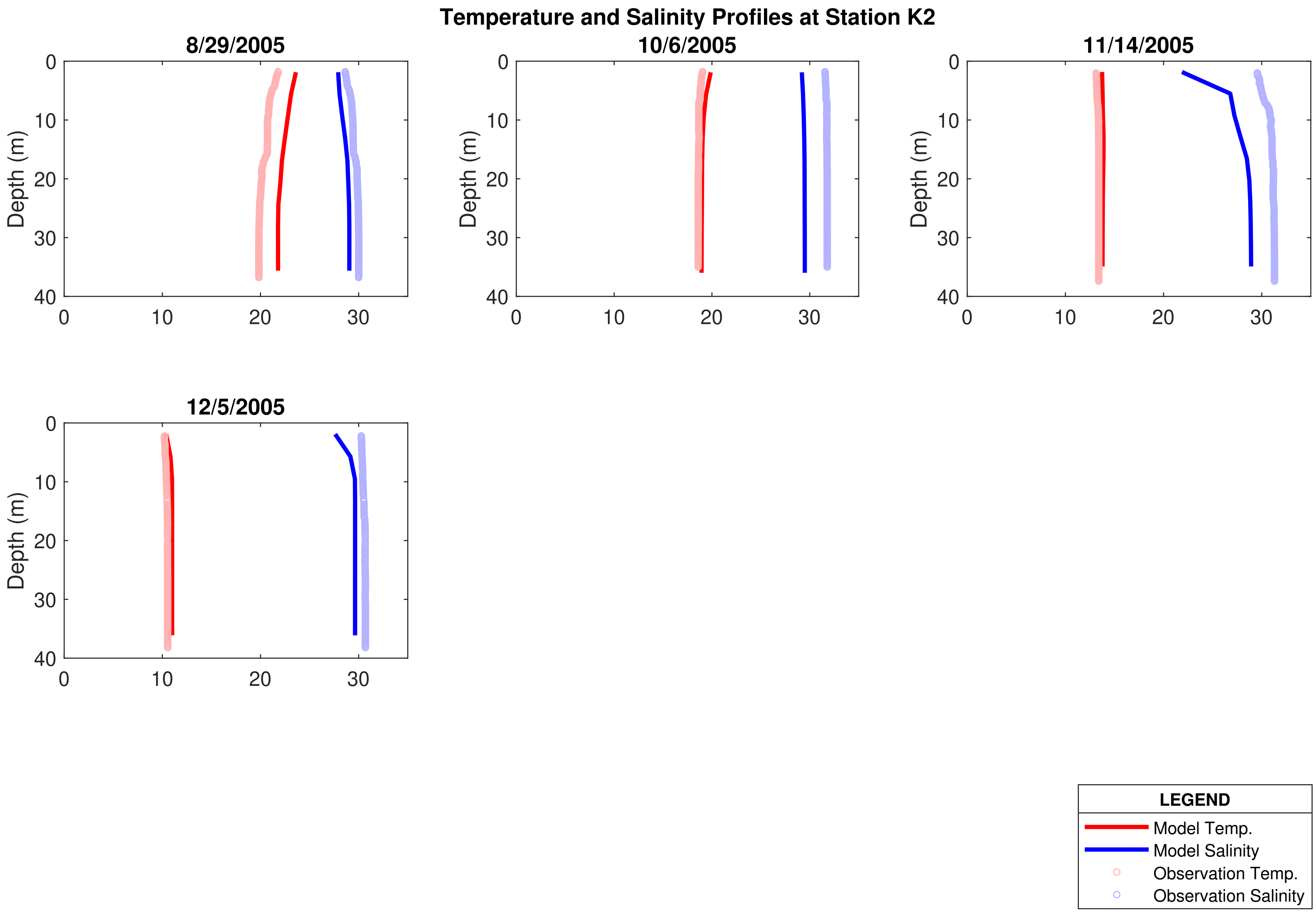
Temperature and Salinity Profiles at Station J2
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
7/7/2005
7/18/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

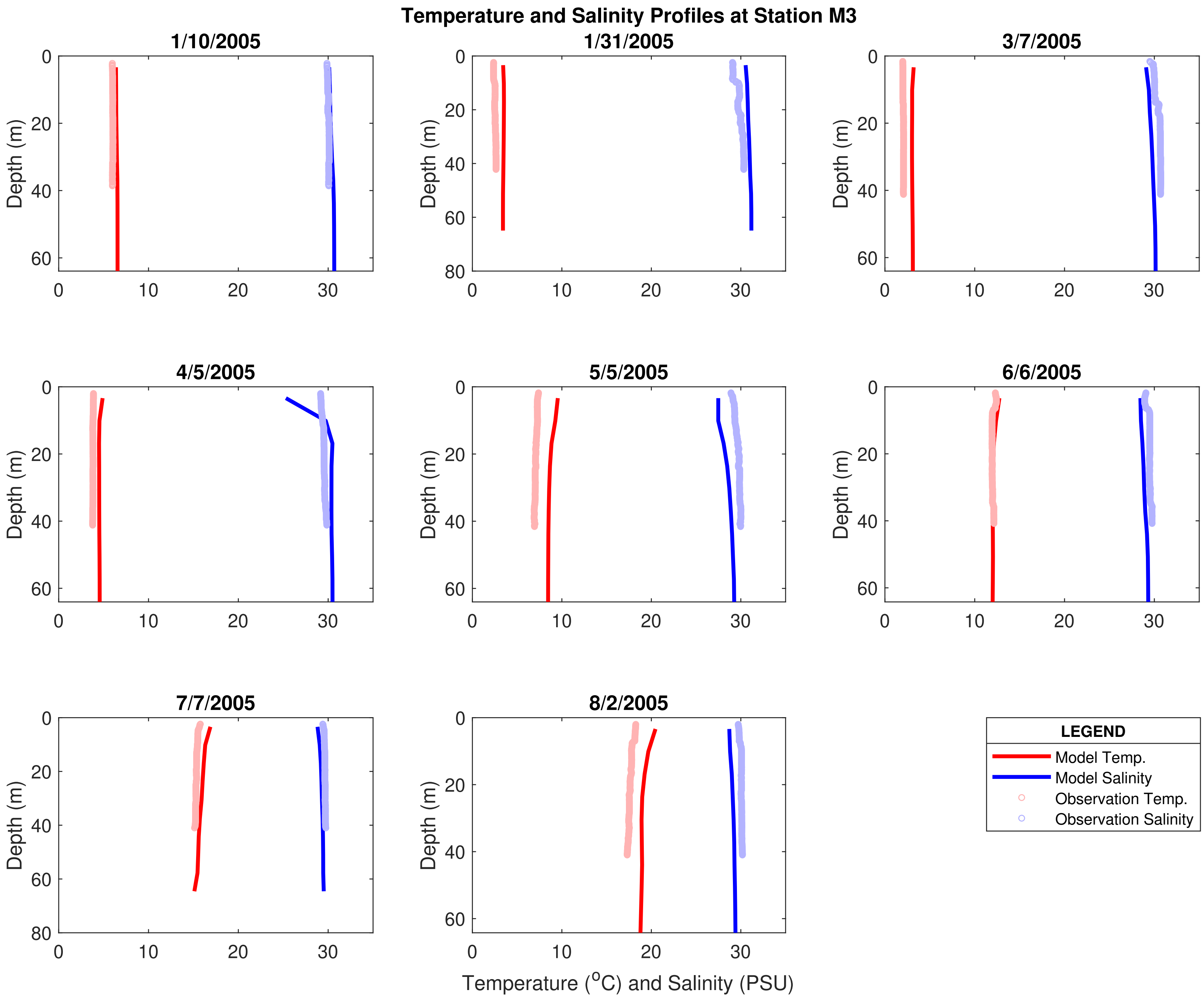


Temperature and Salinity Profiles at Station J2
8/2/2005
8/16/2005
8/29/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

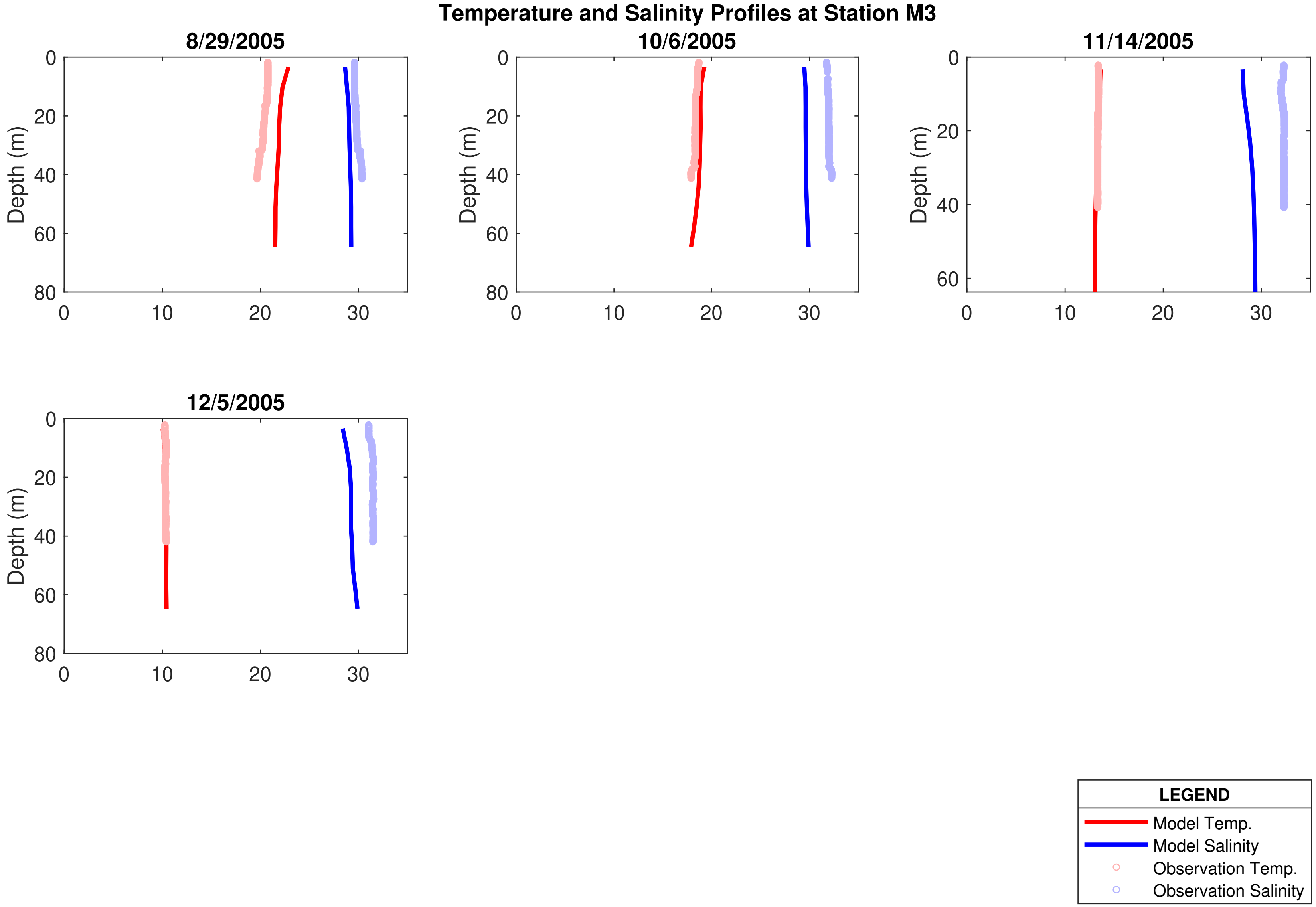


Temperature and Salinity Profiles at Station K2
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
7/7/2005
8/2/2005
Depth (m)
0
10
20
30
40
0
10
20
30
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

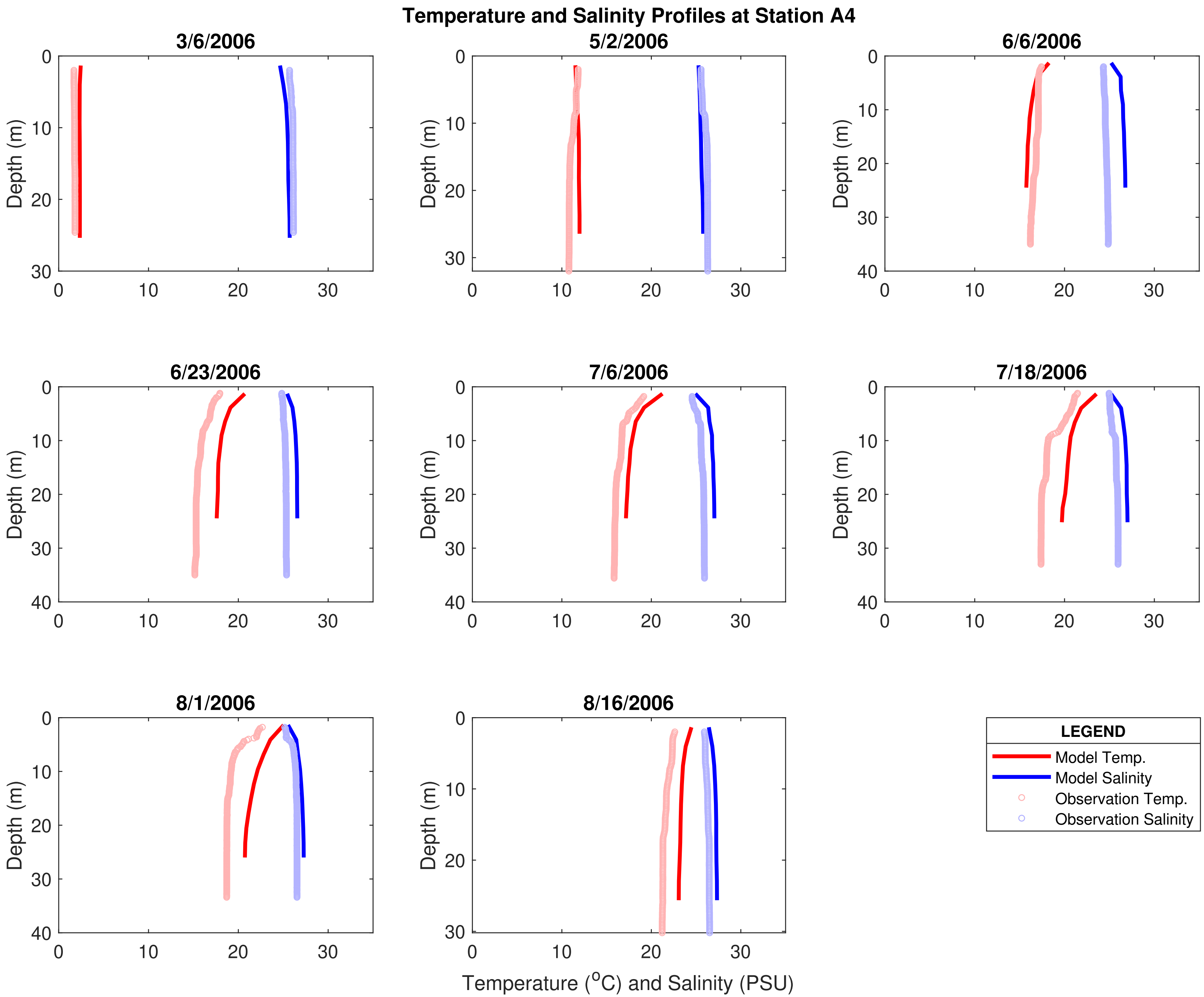

Temperature and Salinity Profiles at Station K2
8/29/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
0
10
20
30
40
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



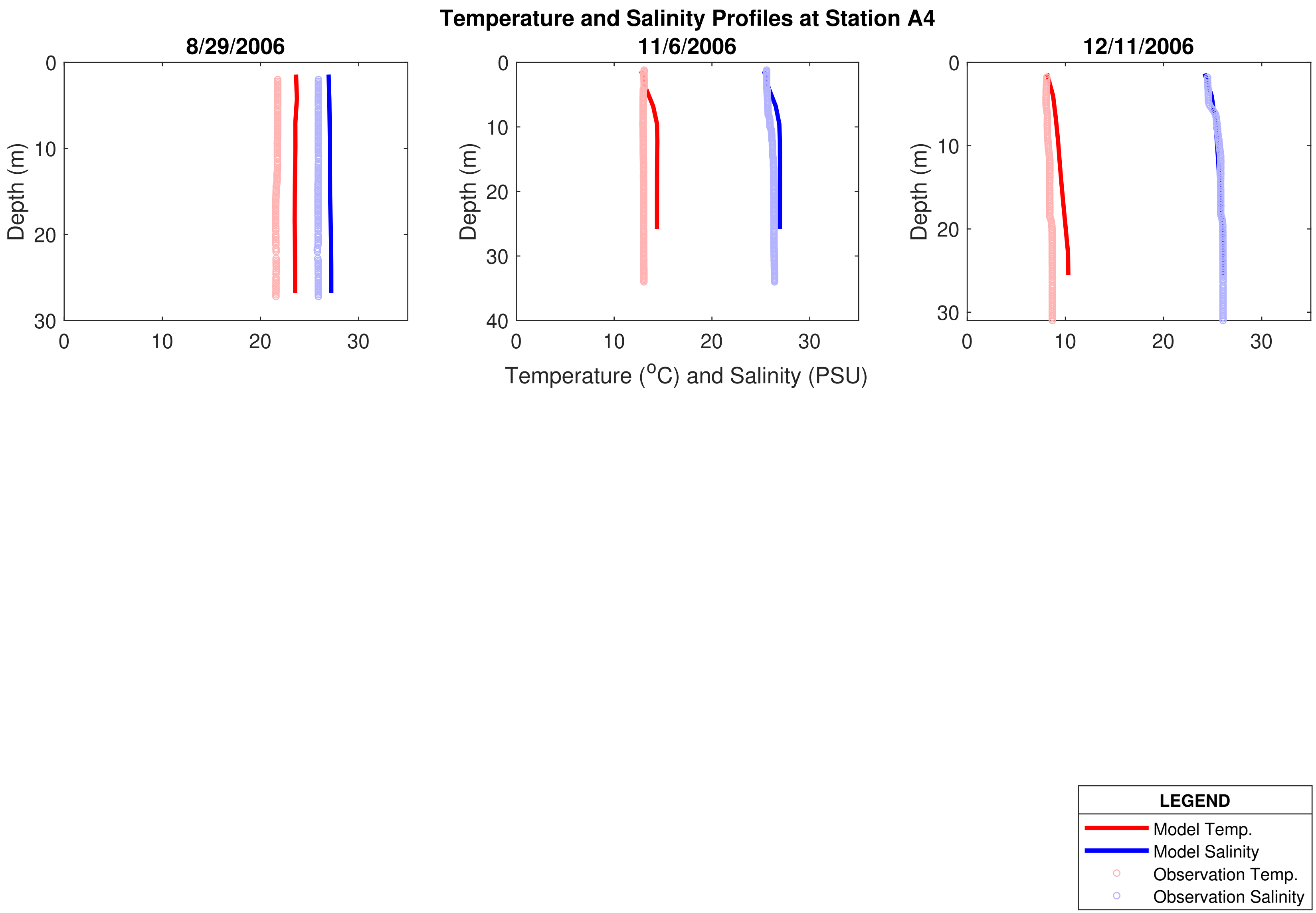
Temperature and Salinity Profiles at Station M3
1/10/2005
1/31/2005
3/7/2005
4/5/2005
5/5/2005
6/6/2005
7/7/2005
8/2/2005
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

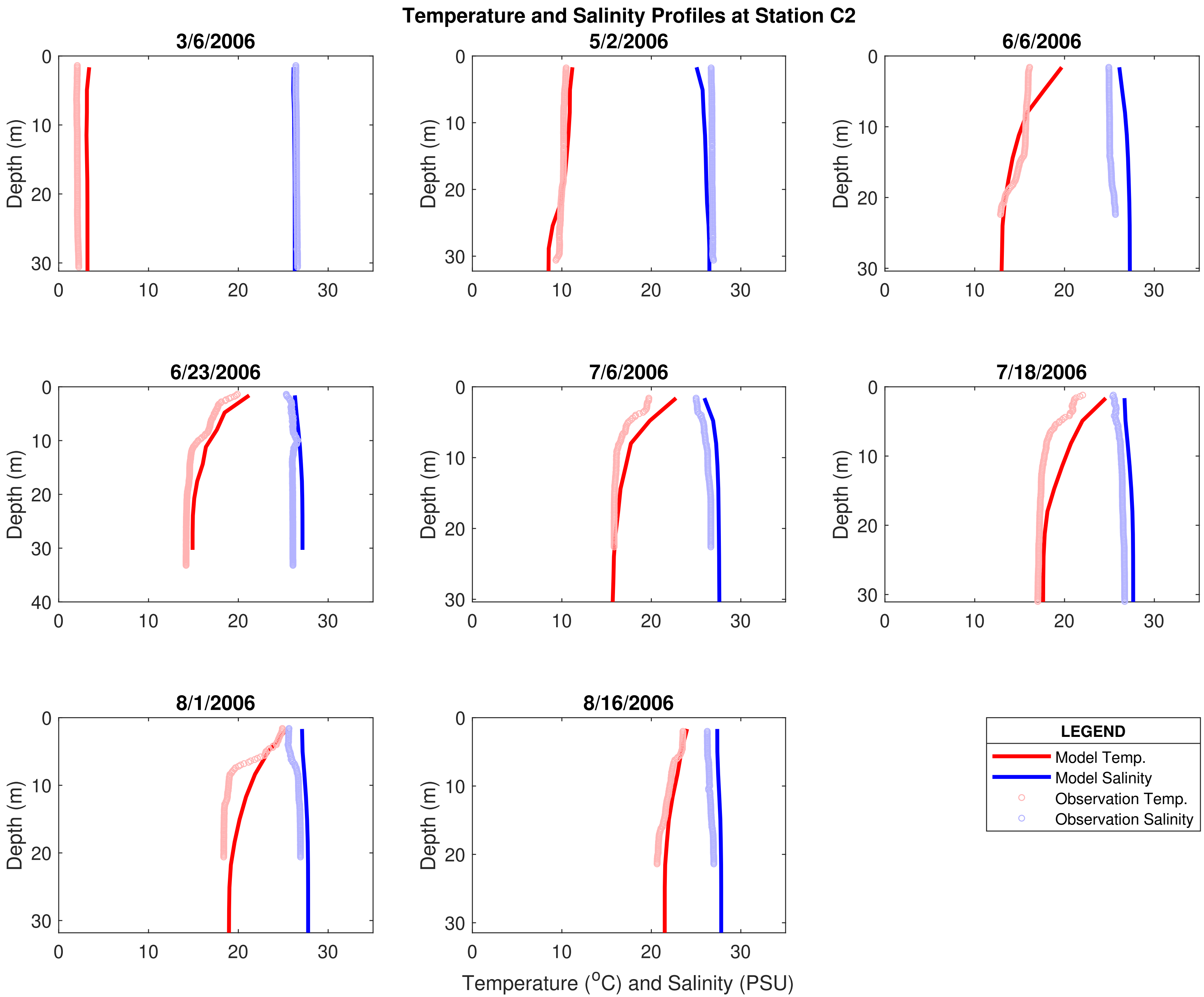


Temperature and Salinity Profiles at Station M3
8/29/2005
10/6/2005
11/14/2005
12/5/2005
Depth (m)
0
20
40
60
80
0
10
20
30
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

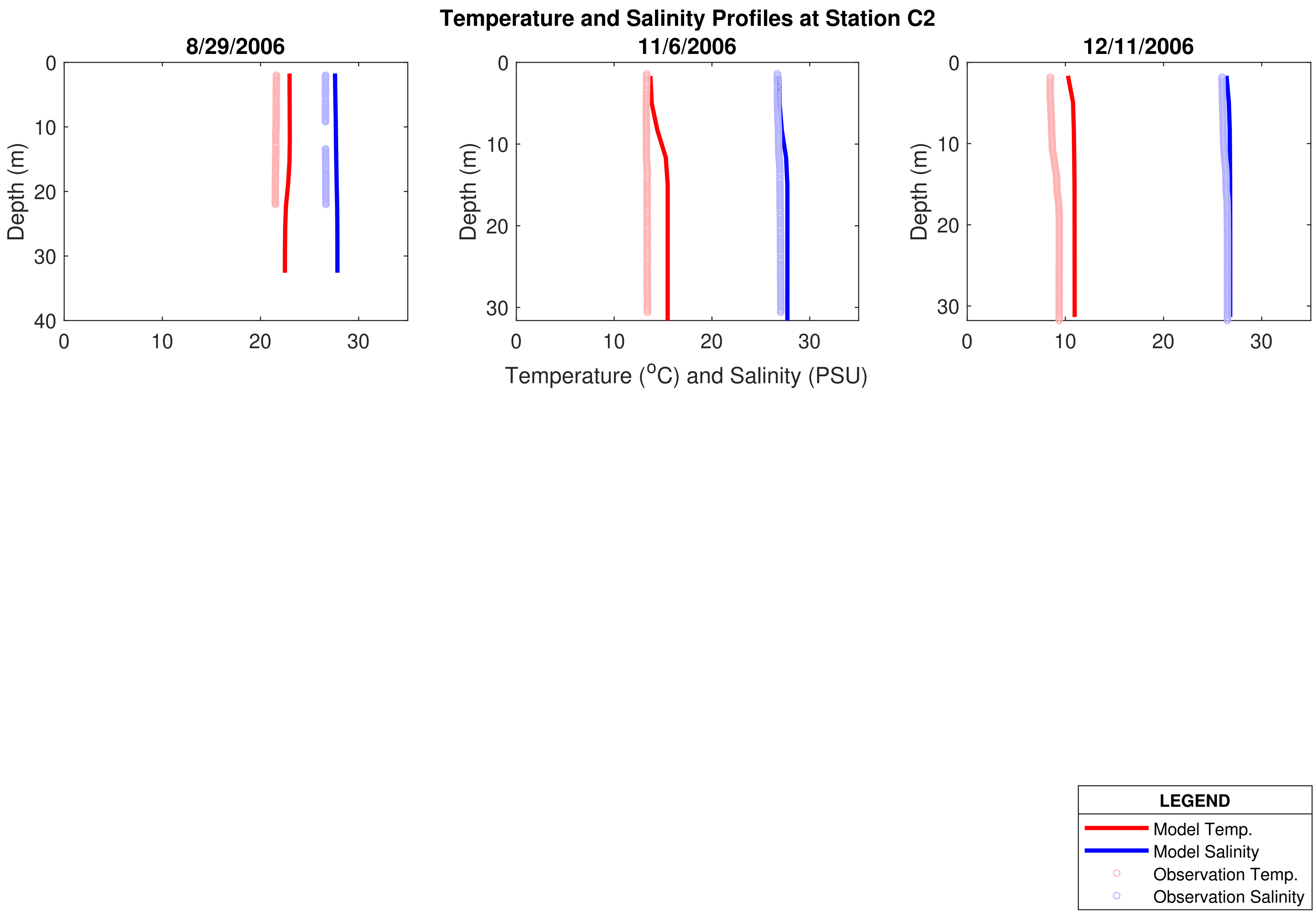


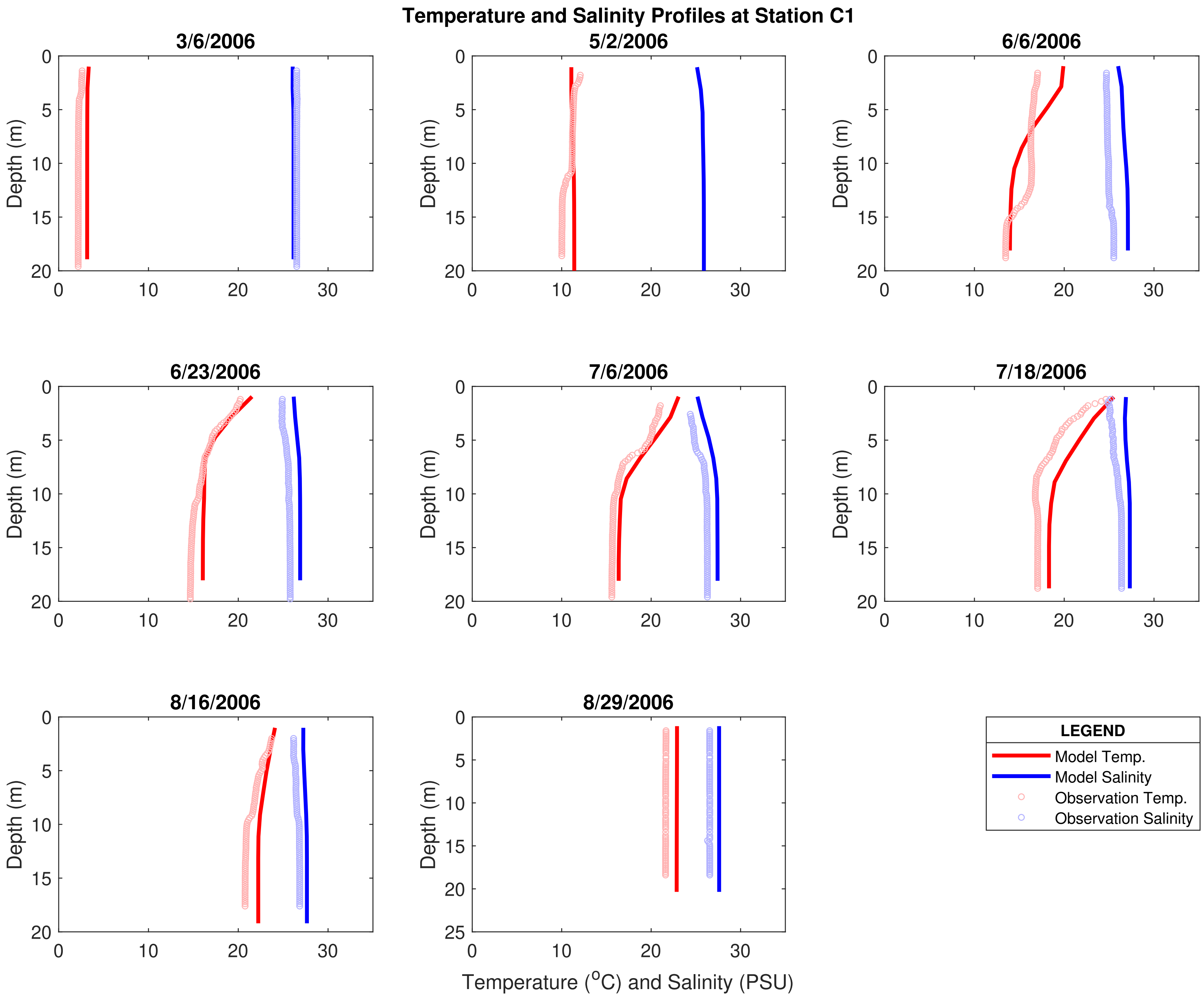
Temperature and Salinity Profiles at Station A4
3/6/2006
5/2/2006
6/6/2006
6/23/2006
7/6/2006
7/18/2006
8/1/2006
8/16/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity


Temperature and Salinity Profiles at Station A4
8/29/2006
11/6/2006
12/11/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

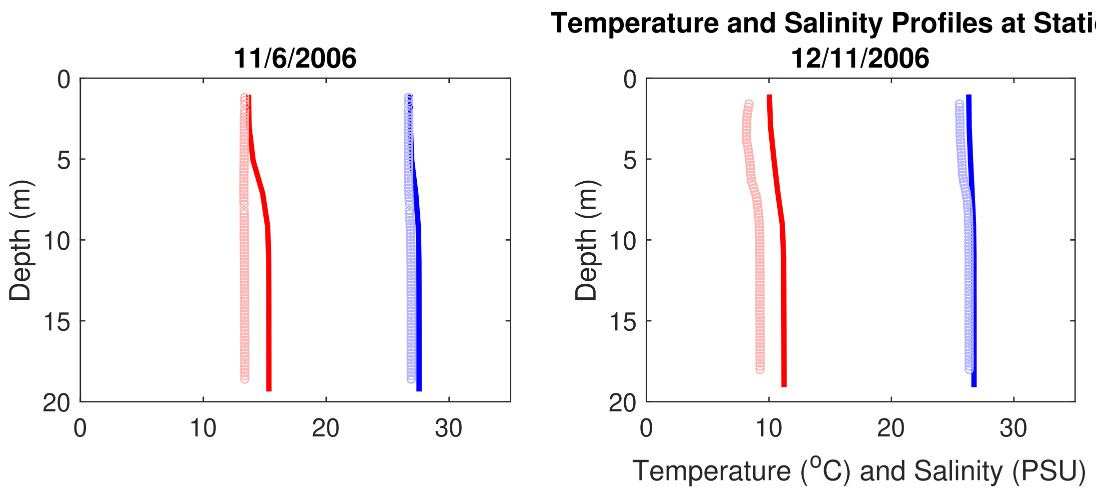


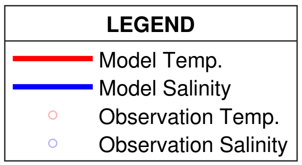
Temperature and Salinity Profiles at Station C2
3/6/2006
5/2/2006
6/6/2006
6/23/2006
7/6/2006
7/18/2006
8/1/2006
8/16/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

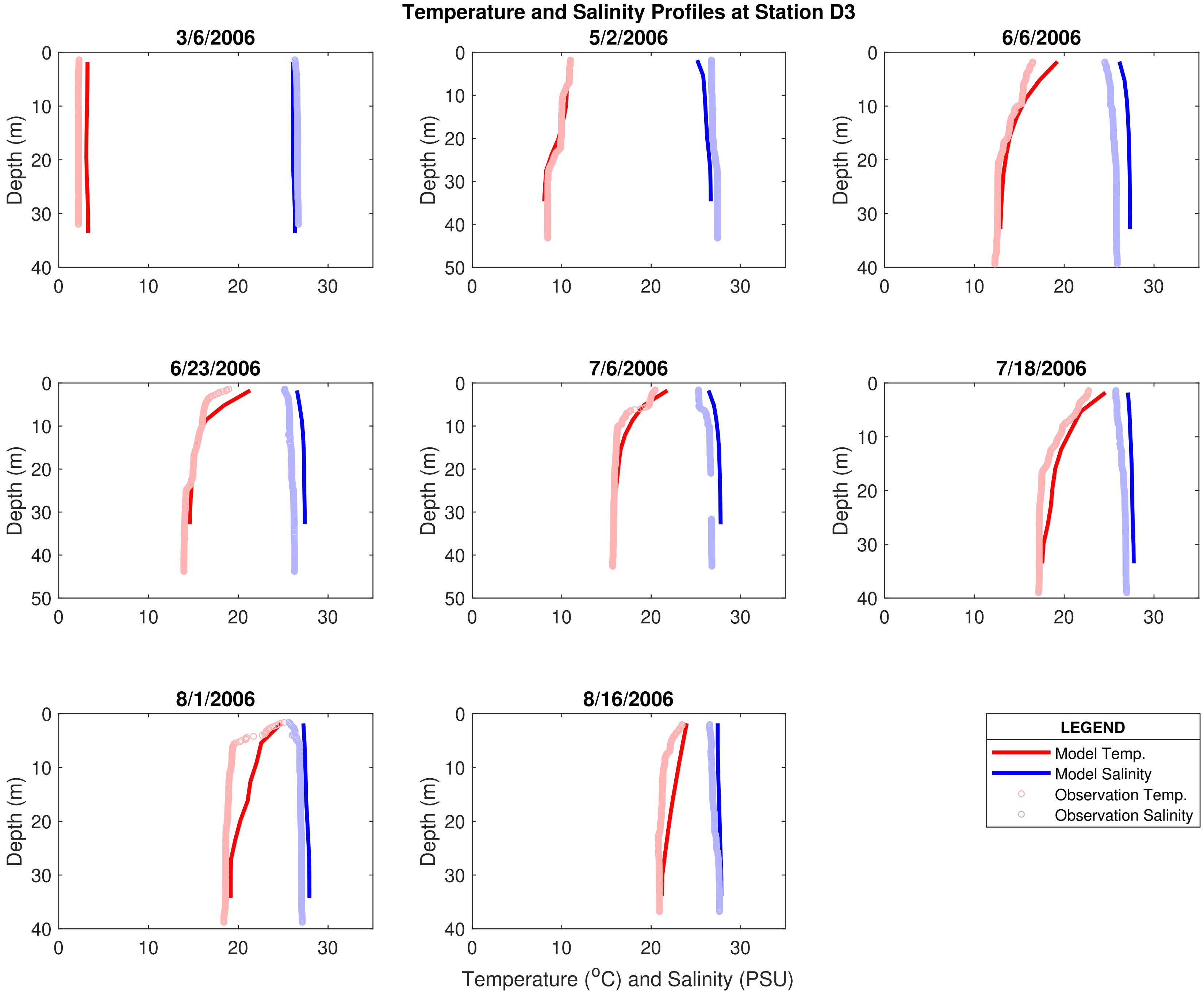

Temperature and Salinity Profiles at Station C2
8/29/2006
11/6/2006
12/11/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



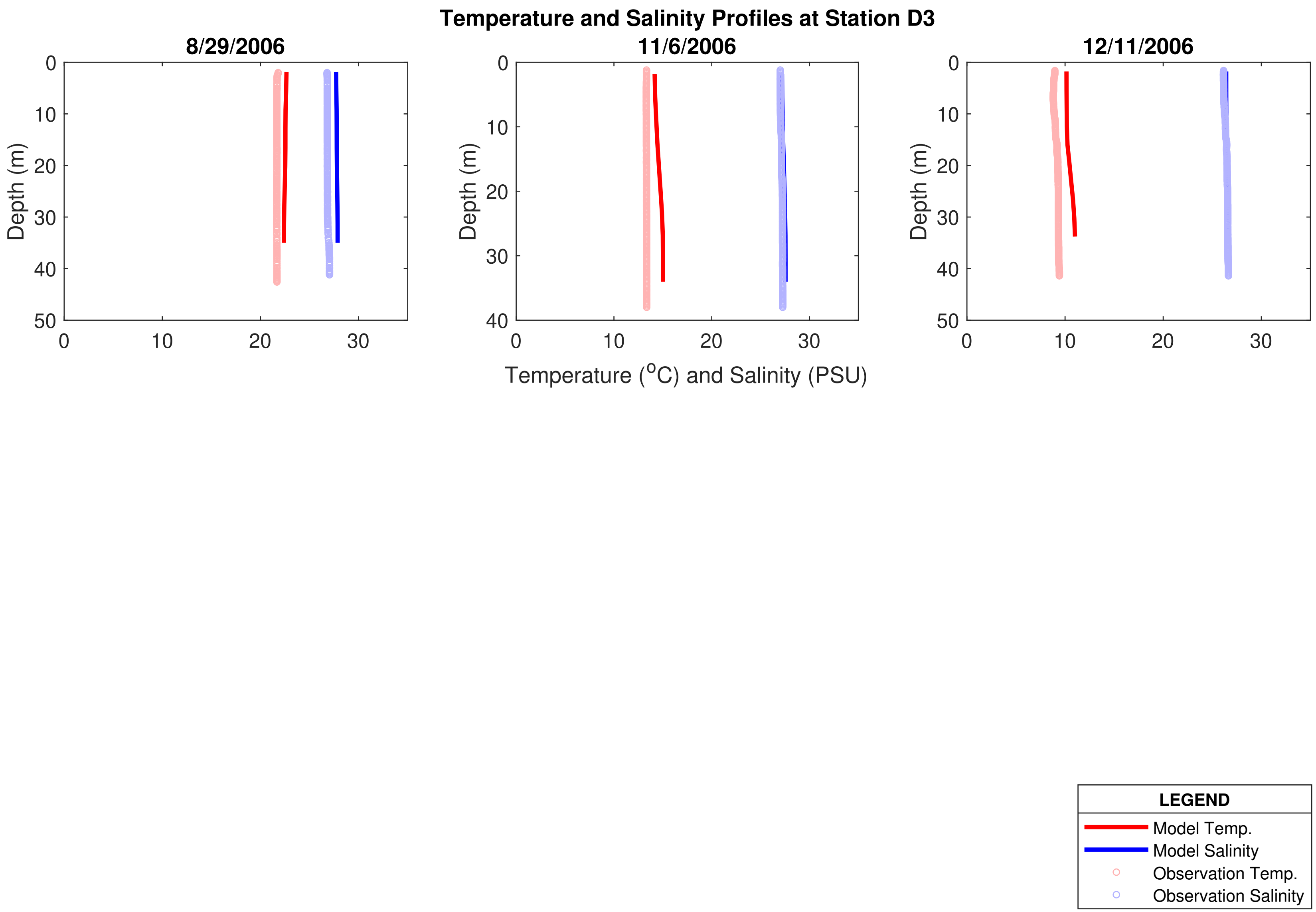
Temperature and Salinity Profiles at Station C1
3/6/2006
5/2/2006
6/6/2006
6/23/2006
7/6/2006
7/18/2006
8/16/2006
8/29/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity


Temperature and Salinity Profiles at Station C1
11/6/2006
12/11/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
0
5
10
15
20
0
10
20
30

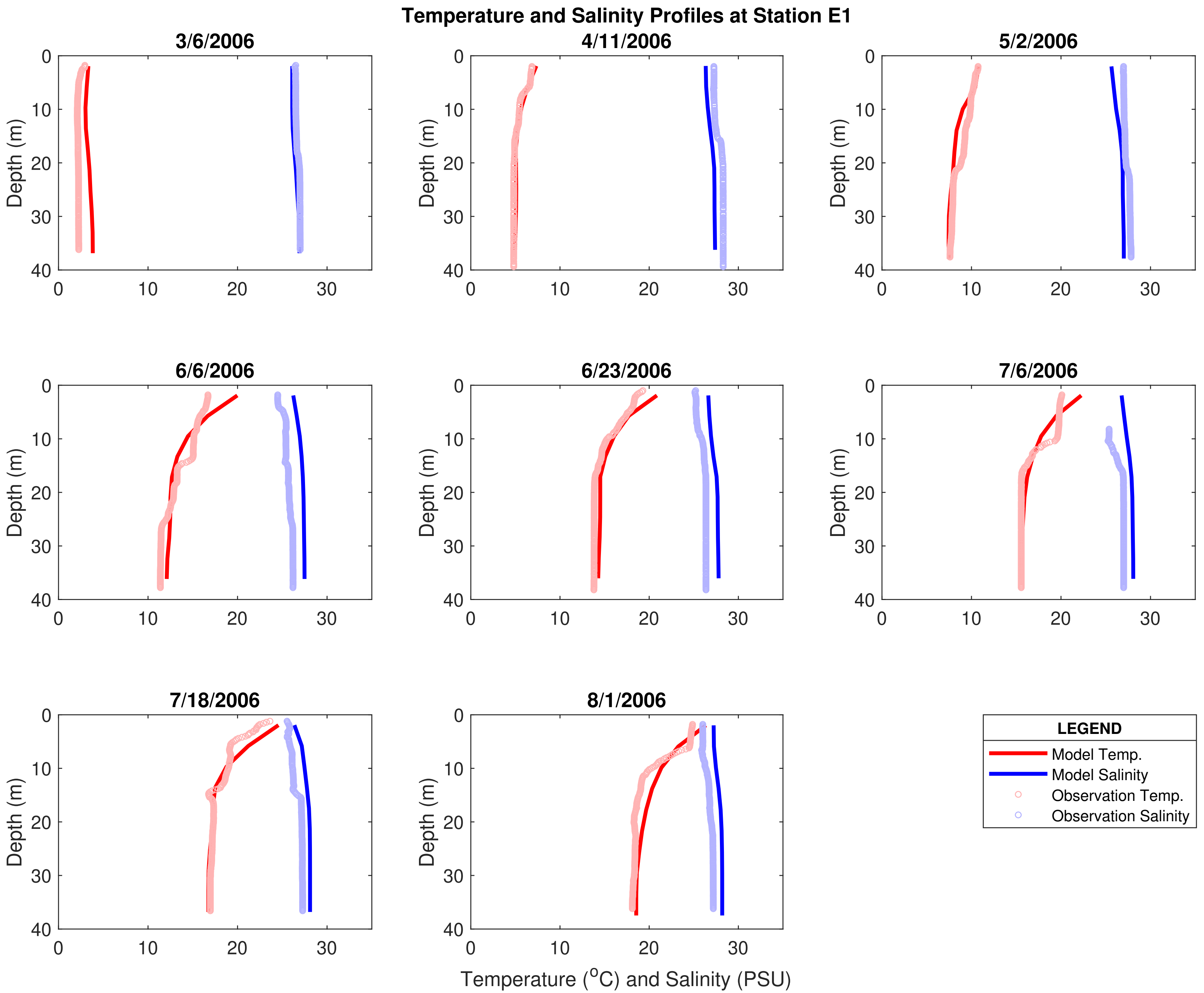

LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



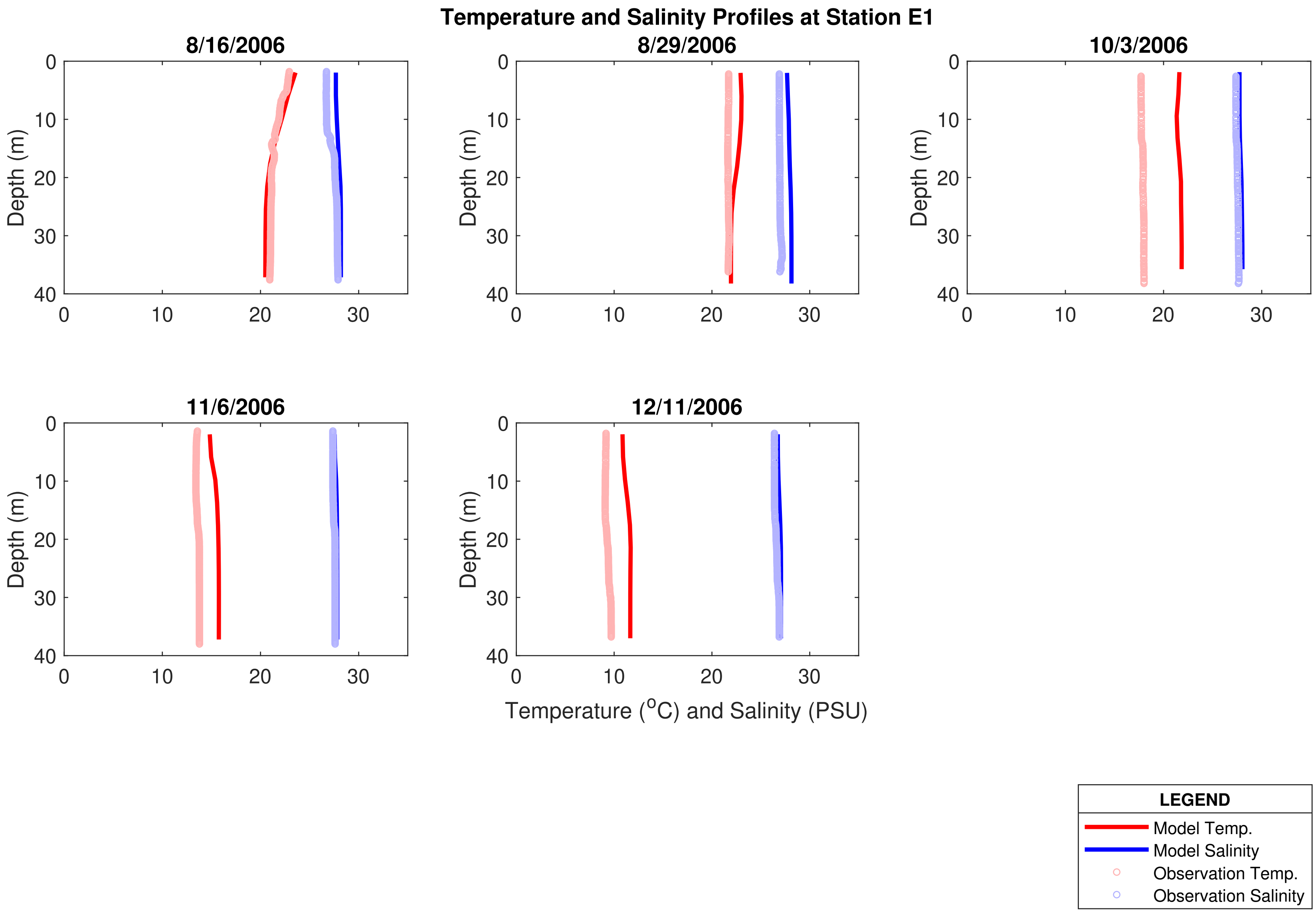
Temperature and Salinity Profiles at Station D3
3/6/2006
5/2/2006
6/6/2006
6/23/2006
7/6/2006
7/18/2006
8/1/2006
8/16/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

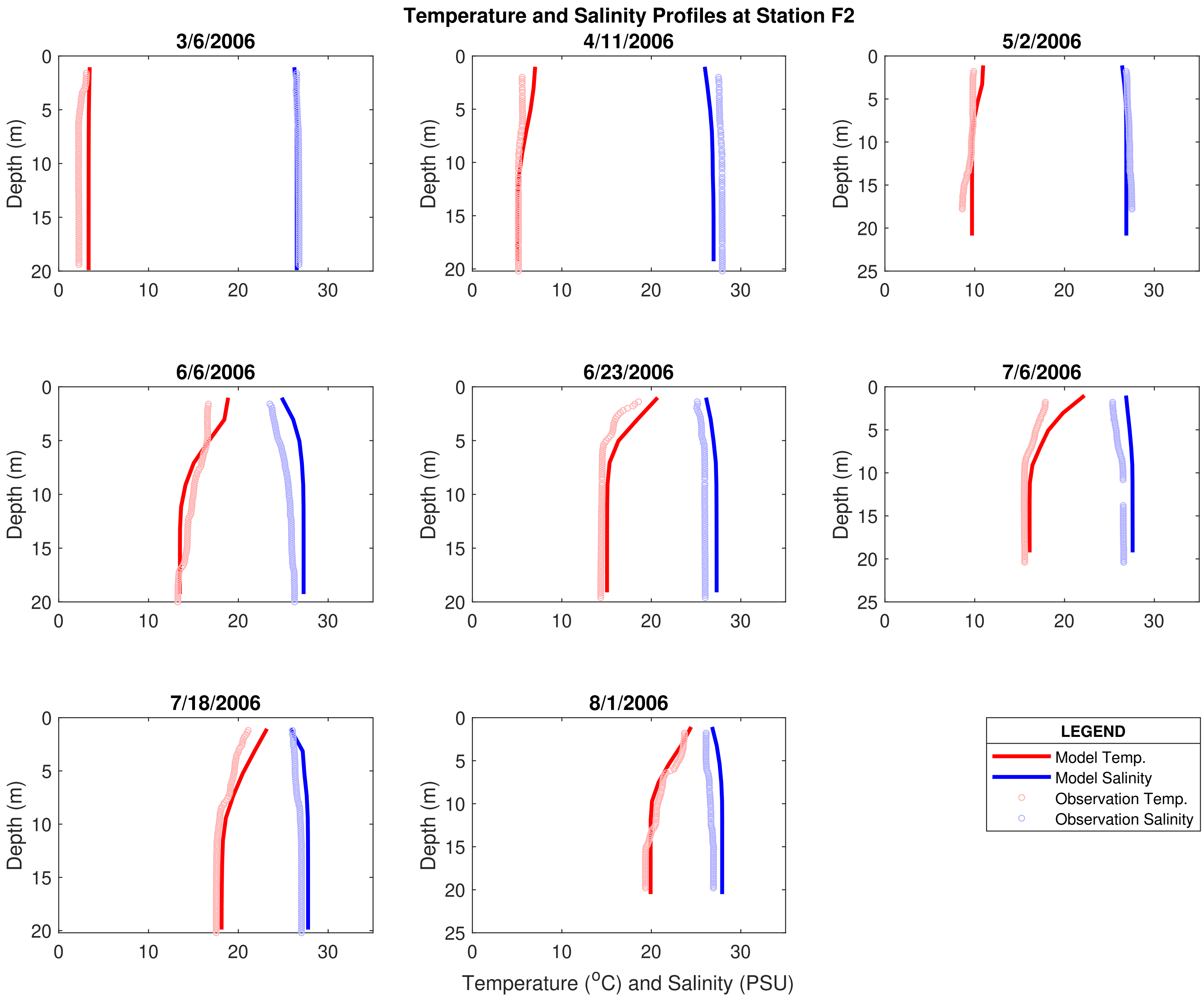


Temperature and Salinity Profiles at Station D3
8/29/2006
11/6/2006
12/11/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
0
10
20
30
40
50
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

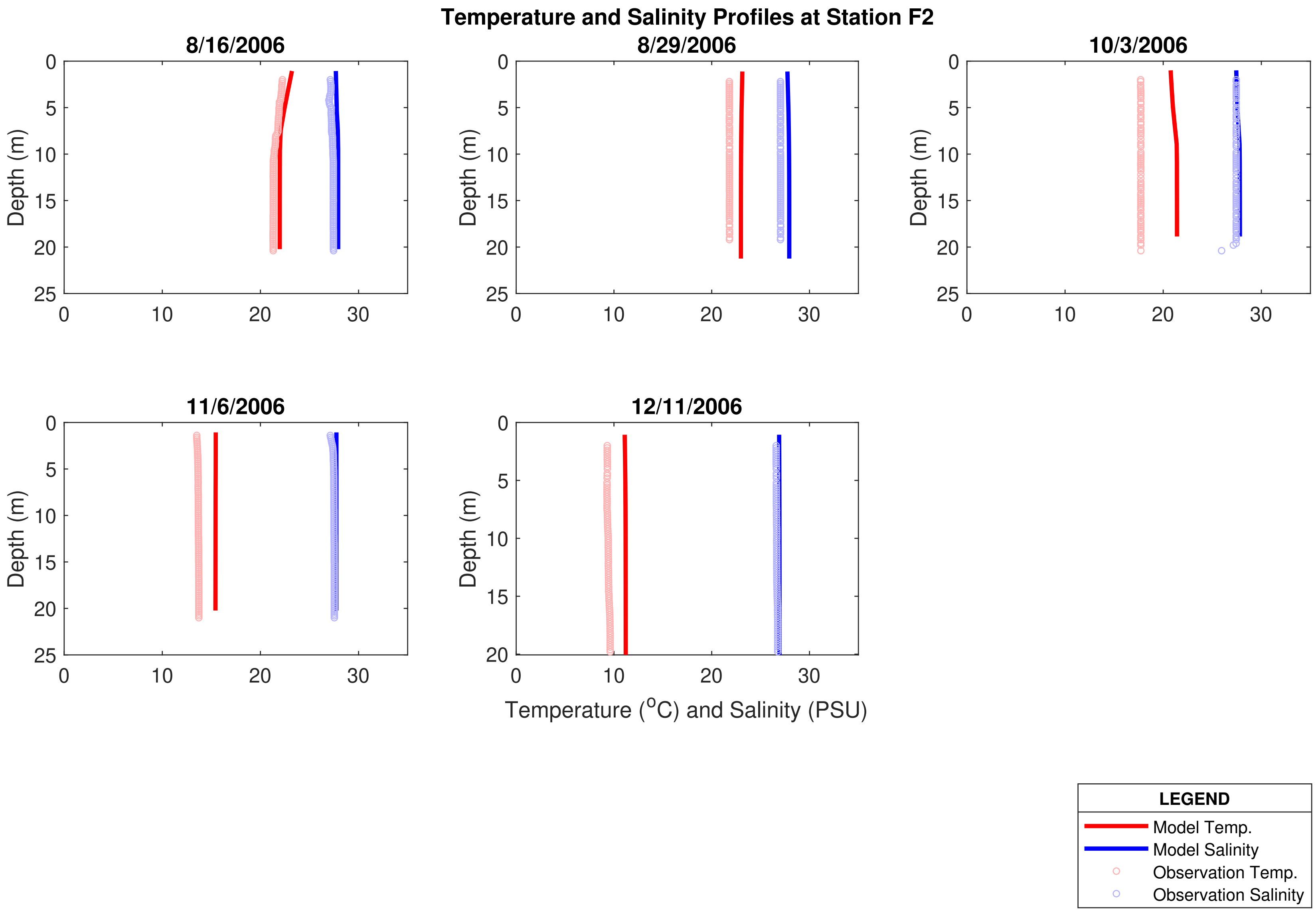


Temperature and Salinity Profiles at Station E1
3/6/2006
4/11/2006
5/2/2006
6/6/2006
6/23/2006
7/6/2006
7/18/2006
8/1/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

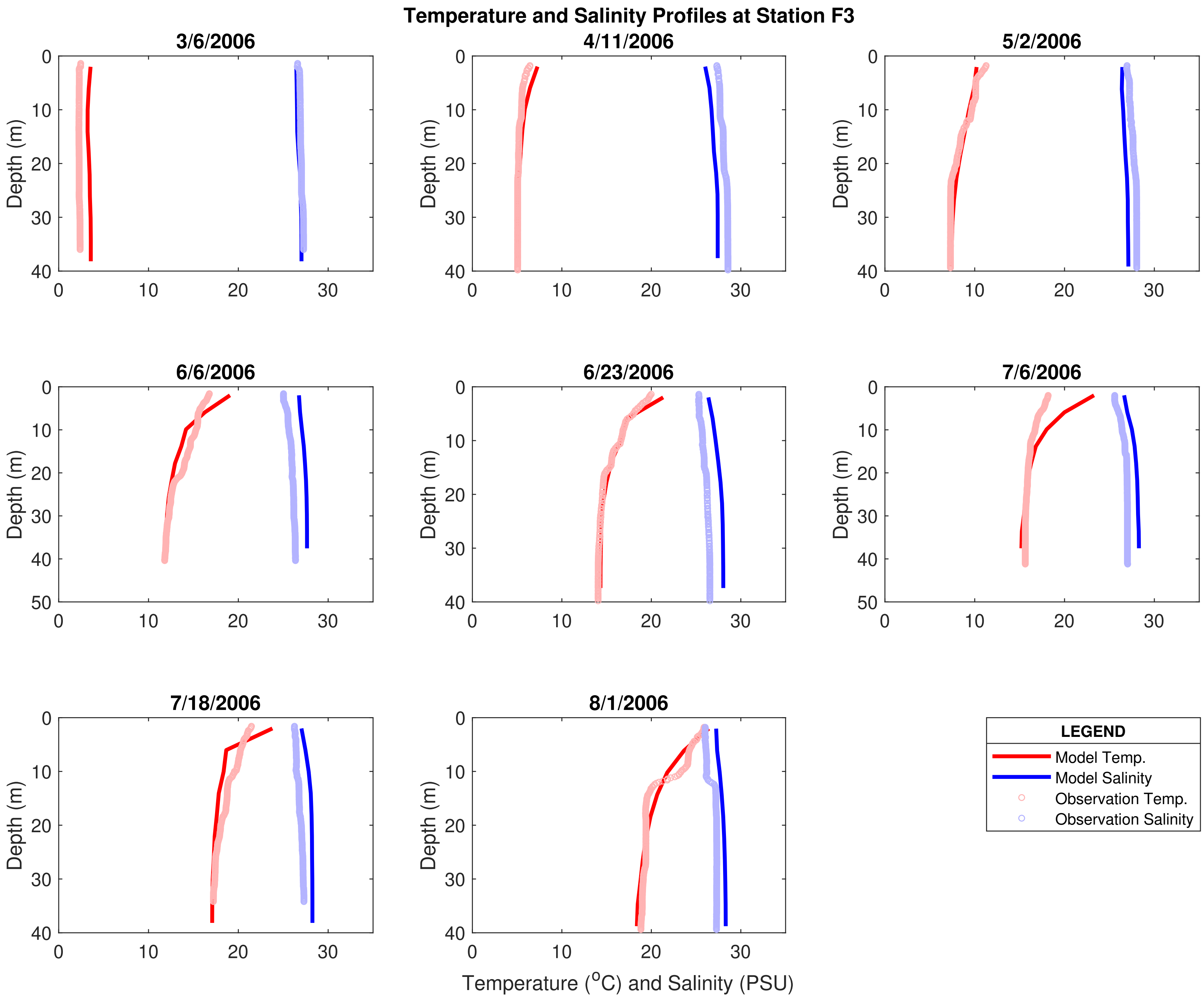

Temperature and Salinity Profiles at Station E1
8/16/2006
8/29/2006
10/3/2006
11/6/2006
12/11/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



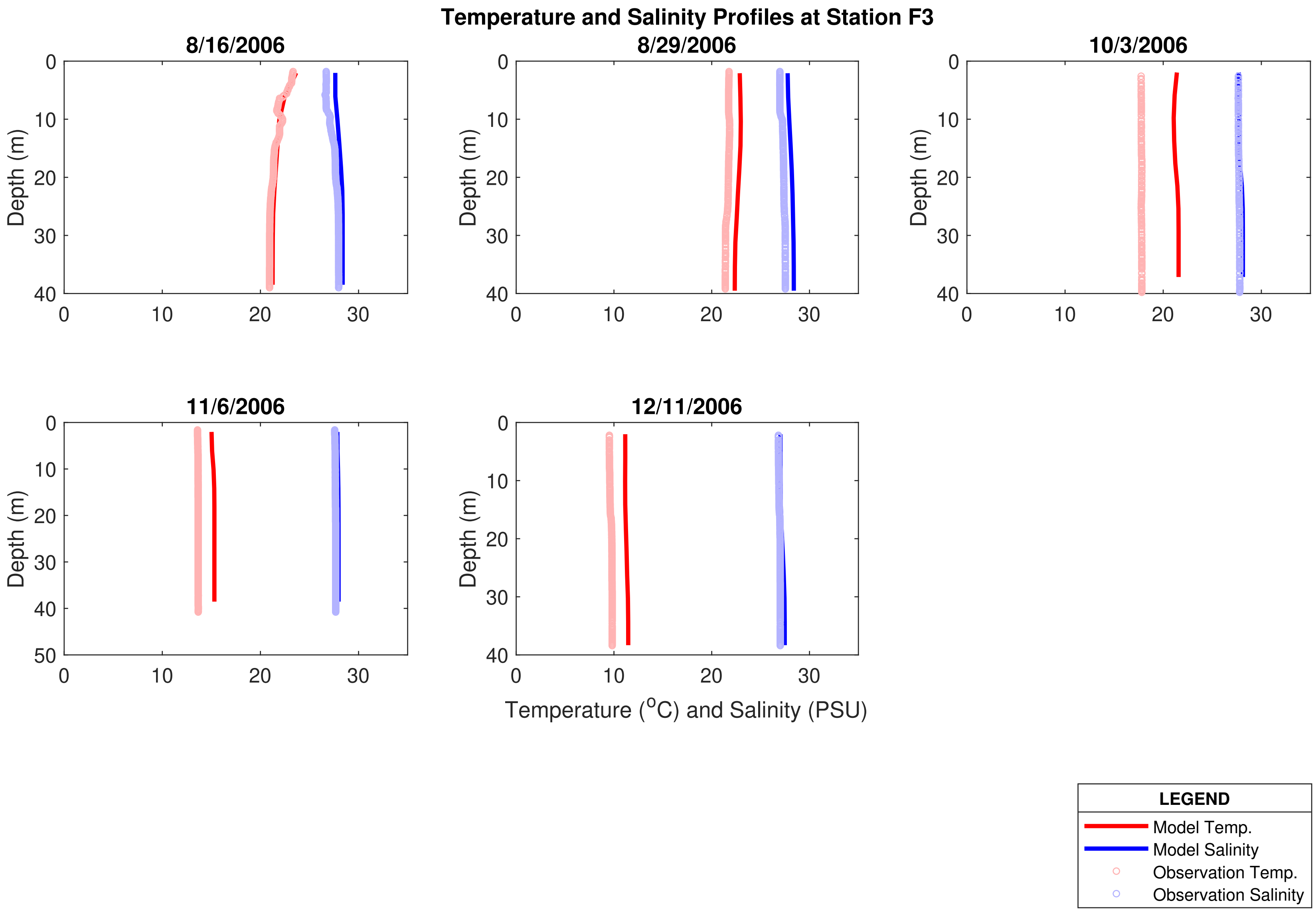
Temperature and Salinity Profiles at Station F2
3/6/2006
4/11/2006
5/2/2006
6/6/2006
6/23/2006
7/6/2006
7/18/2006
8/1/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



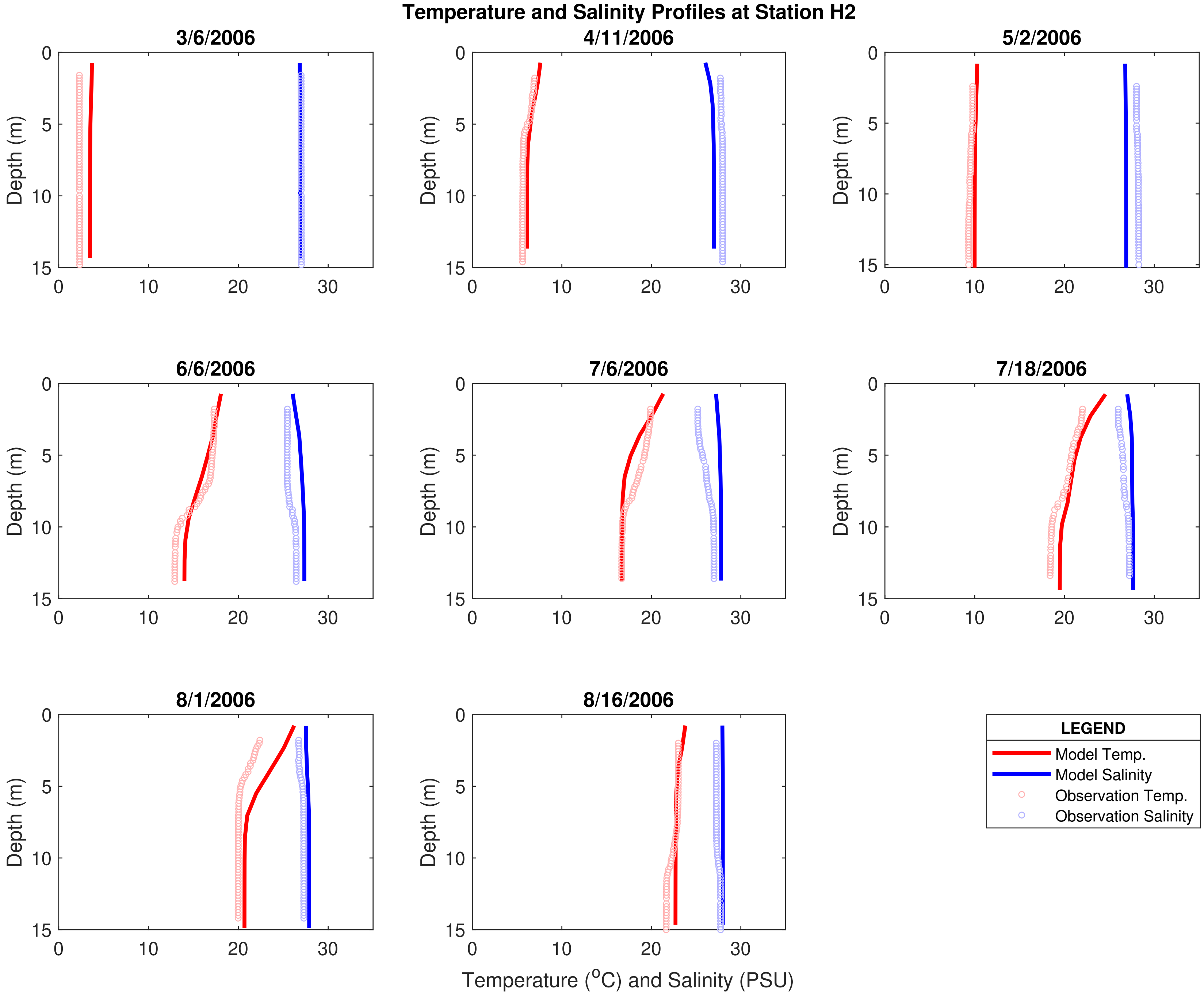
Temperature and Salinity Profiles at Station F2
8/16/2006
8/29/2006
10/3/2006
11/6/2006
12/11/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



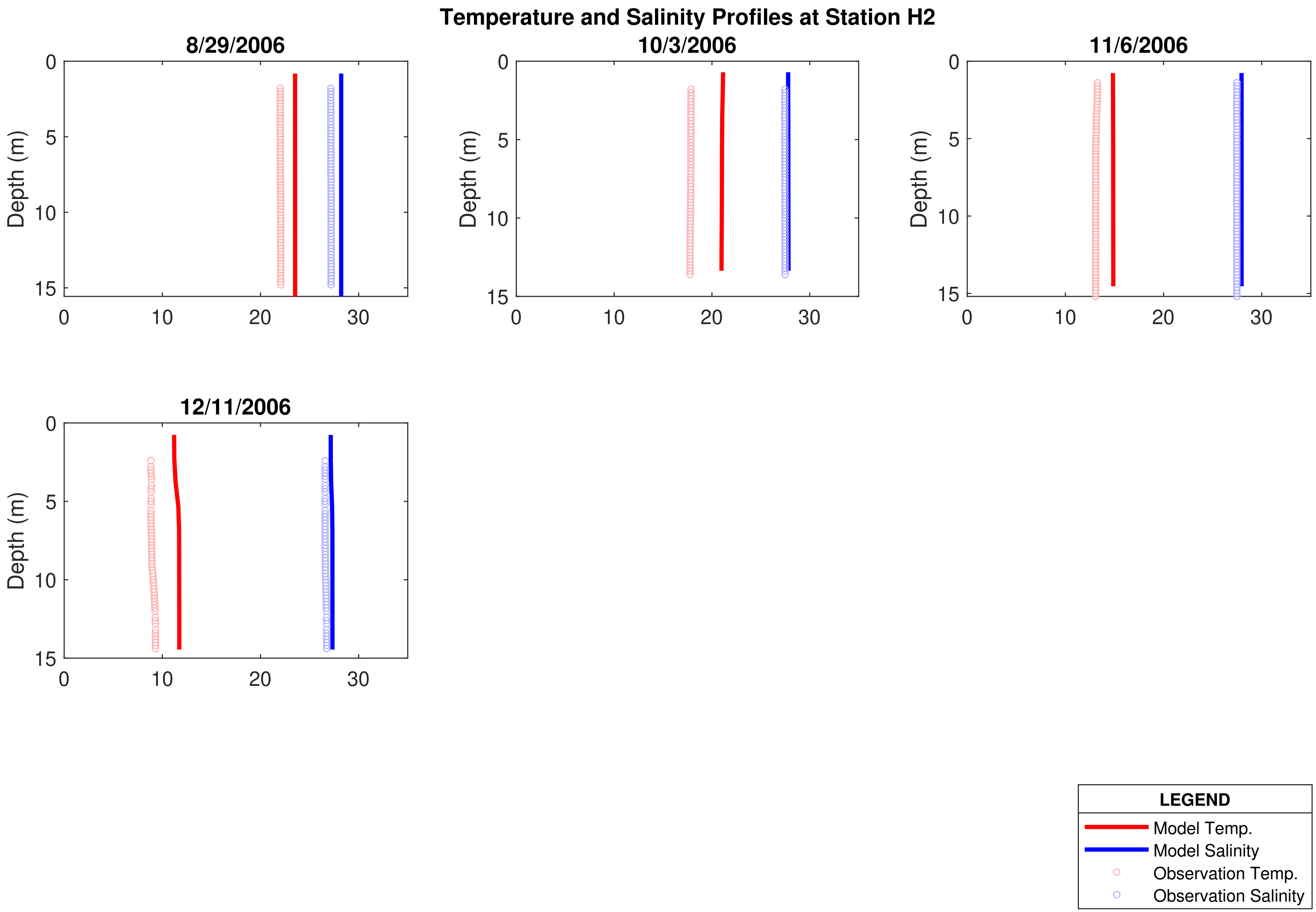
Temperature and Salinity Profiles at Station F3
3/6/2006
4/11/2006
5/2/2006
6/6/2006
6/23/2006
7/6/2006
7/18/2006
8/1/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



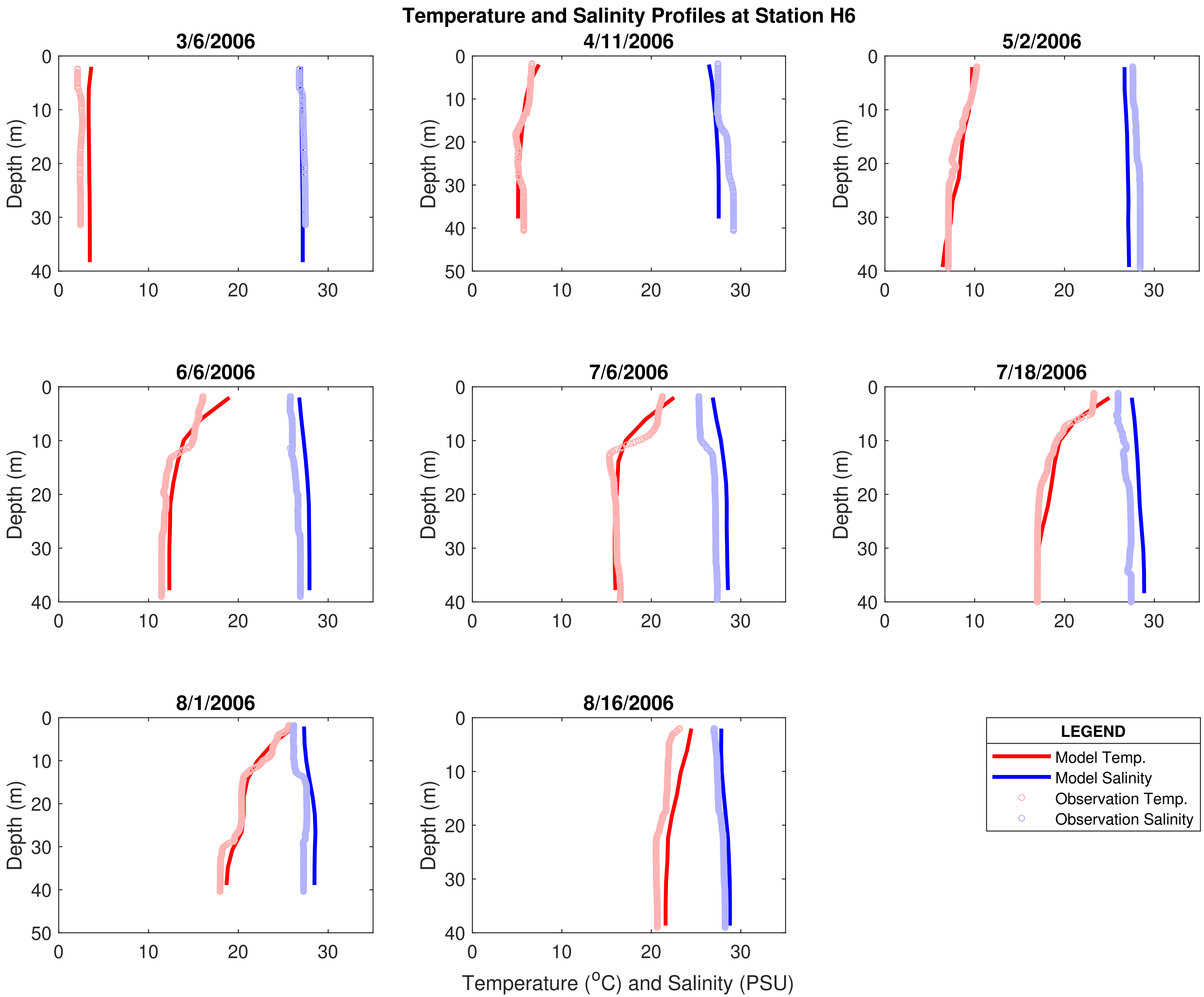
Temperature and Salinity Profiles at Station F3
8/16/2006
8/29/2006
10/3/2006
11/6/2006
12/11/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
0
10
20
30
40
50
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



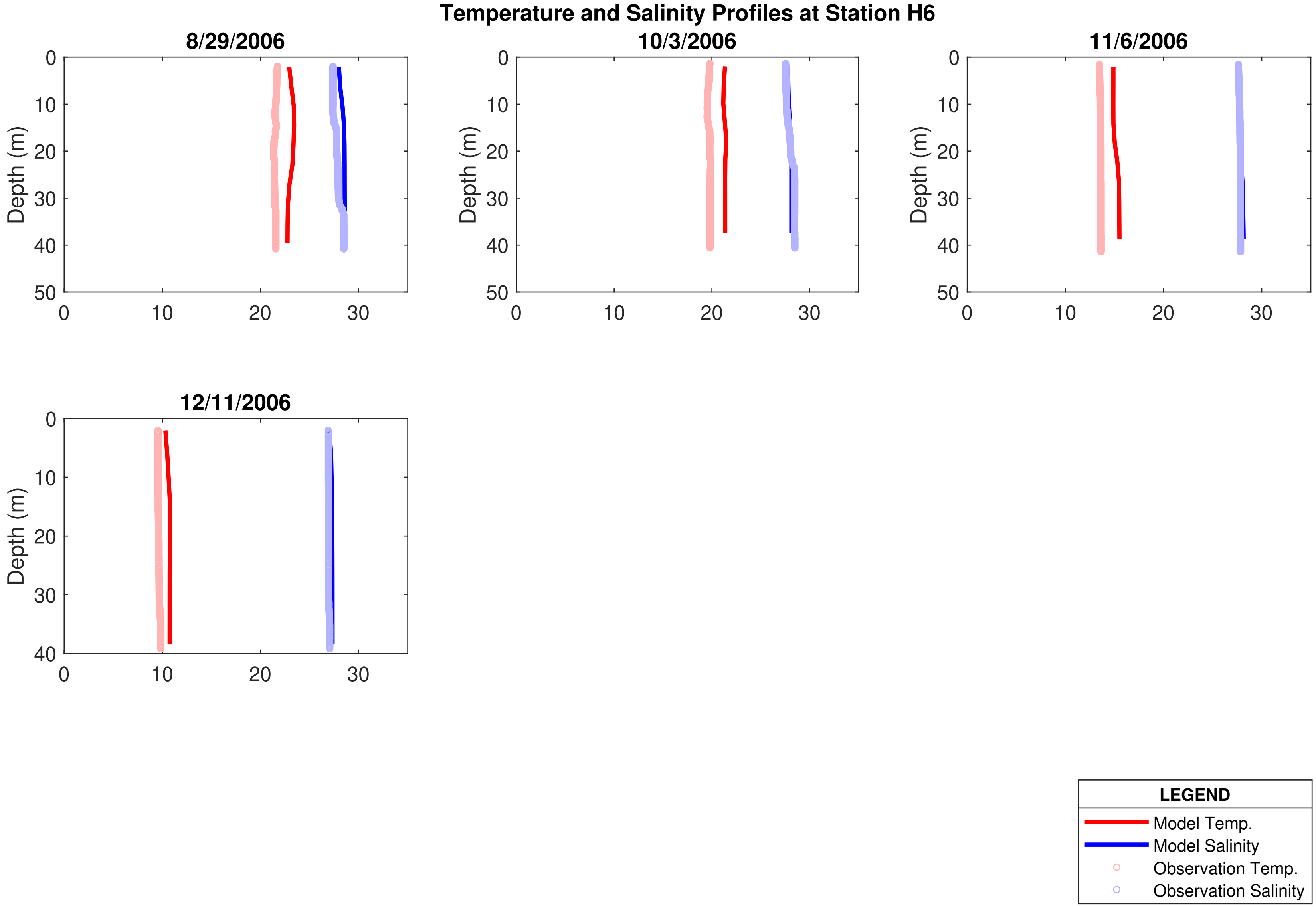
Temperature and Salinity Profiles at Station H2
3/6/2006
4/11/2006
5/2/2006
6/6/2006
7/6/2006
7/18/2006
8/1/2006
8/16/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

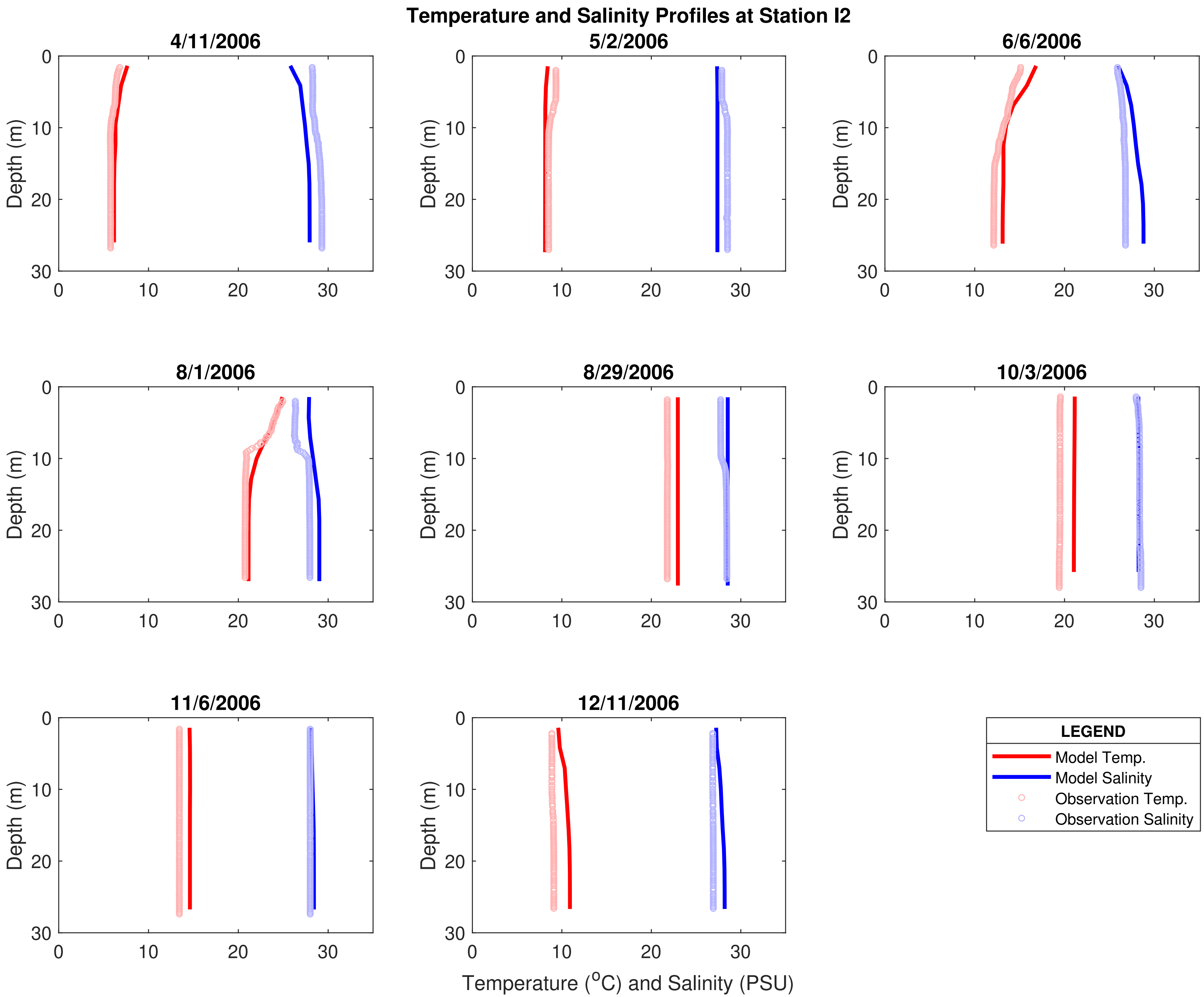


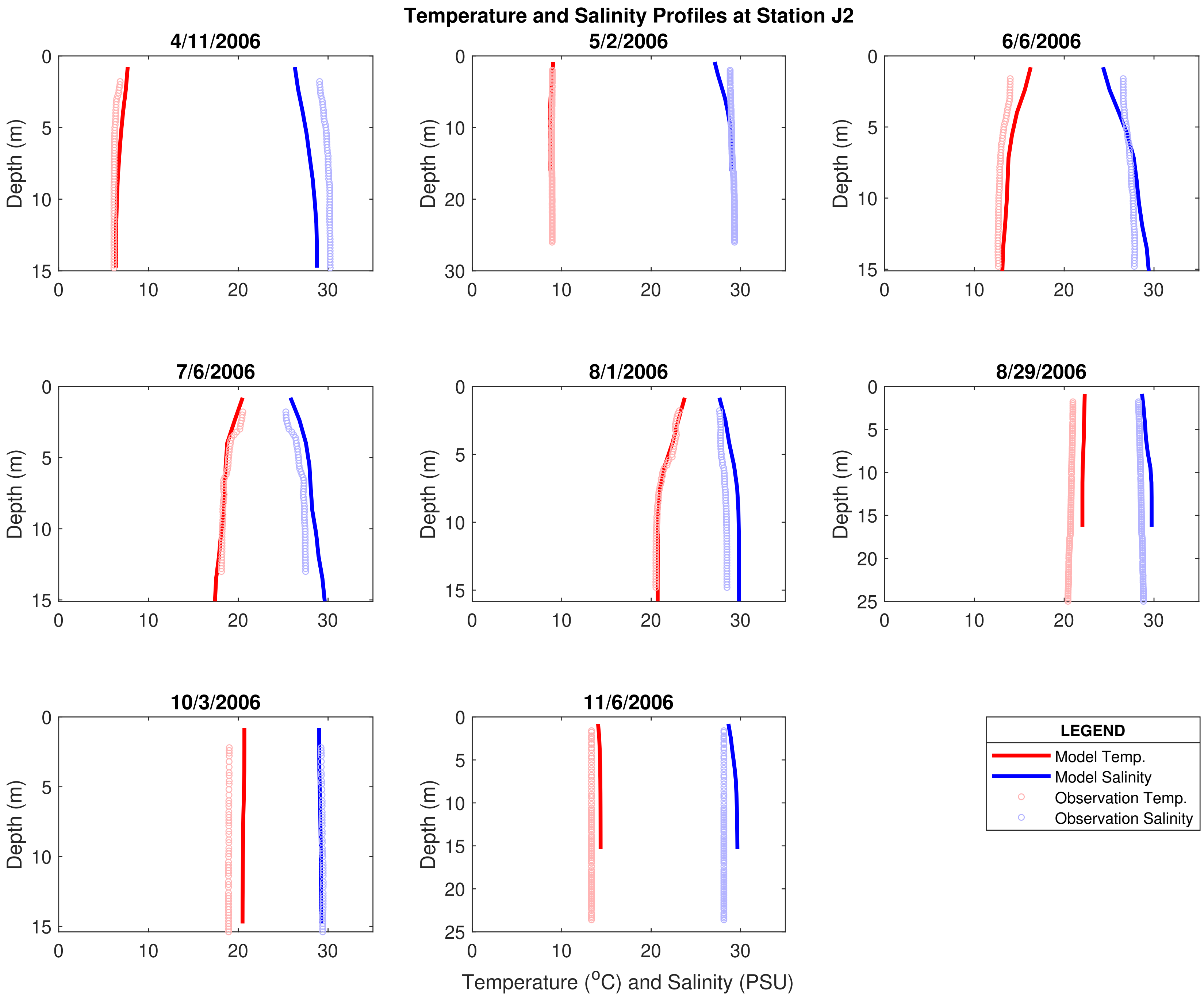
Temperature and Salinity Profiles at Station H2
8/29/2006
10/3/2006
11/6/2006
12/11/2006
Depth (m)
0
5
10
15
0
10
20
30
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



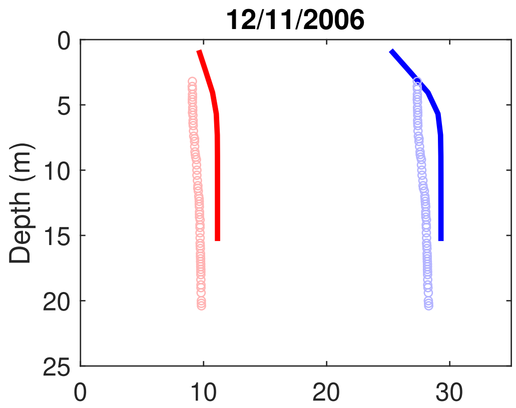
Temperature and Salinity Profiles at Station H6
3/6/2006
4/11/2006
5/2/2006
6/6/2006
7/6/2006
7/18/2006
8/1/2006
8/16/2006
Depth (m)
Temperature (^oC) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

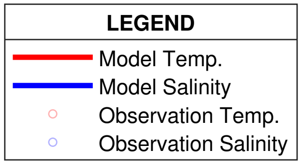

Temperature and Salinity Profiles at Station H6
8/29/2006
10/3/2006
11/6/2006
12/11/2006
Depth (m)
0
10
20
30
40
50
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

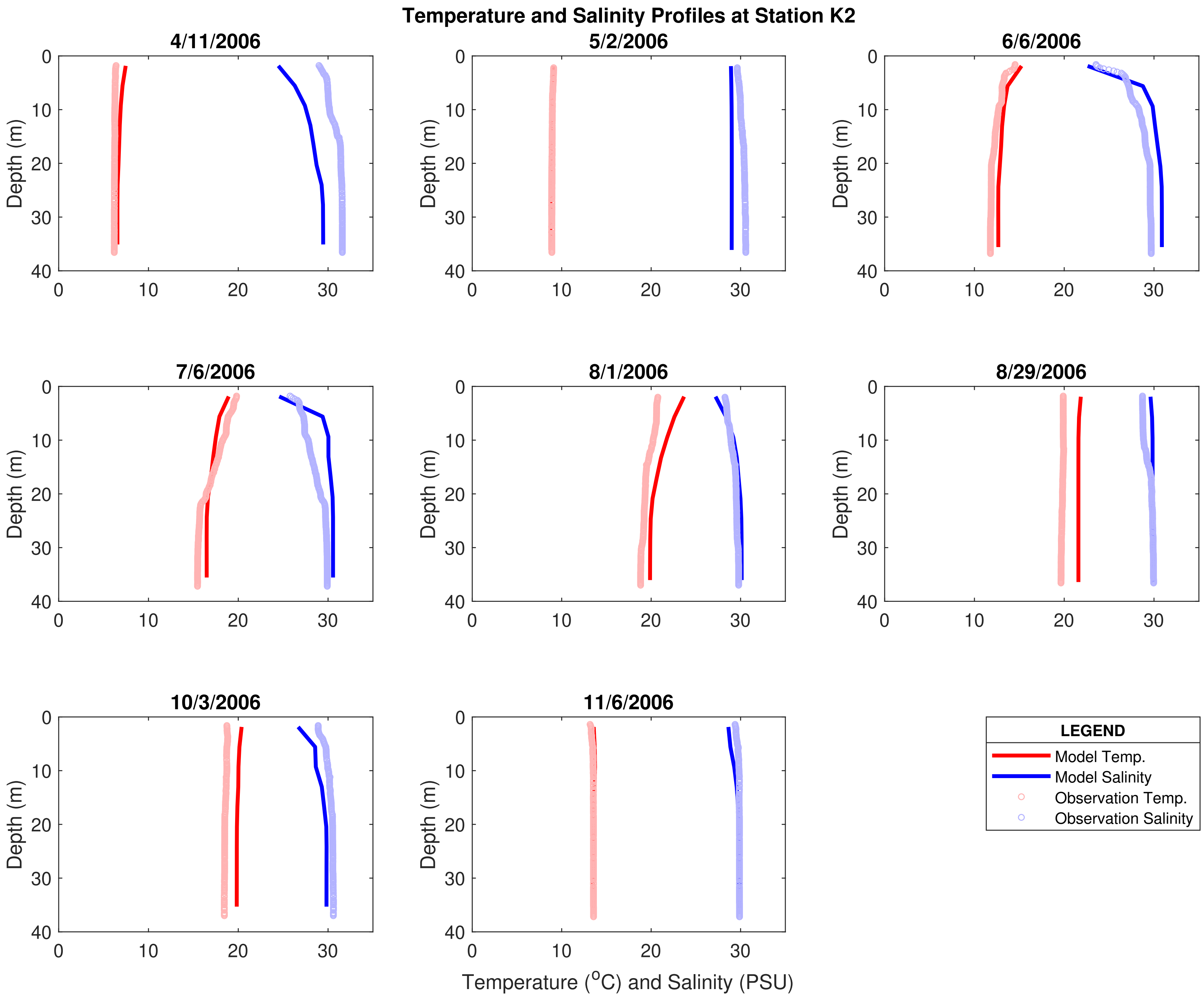

Temperature and Salinity Profiles at Station I2
4/11/2006
5/2/2006
6/6/2006
8/1/2006
8/29/2006
10/3/2006
11/6/2006
12/11/2006
Depth (m)
0
10
20
30
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



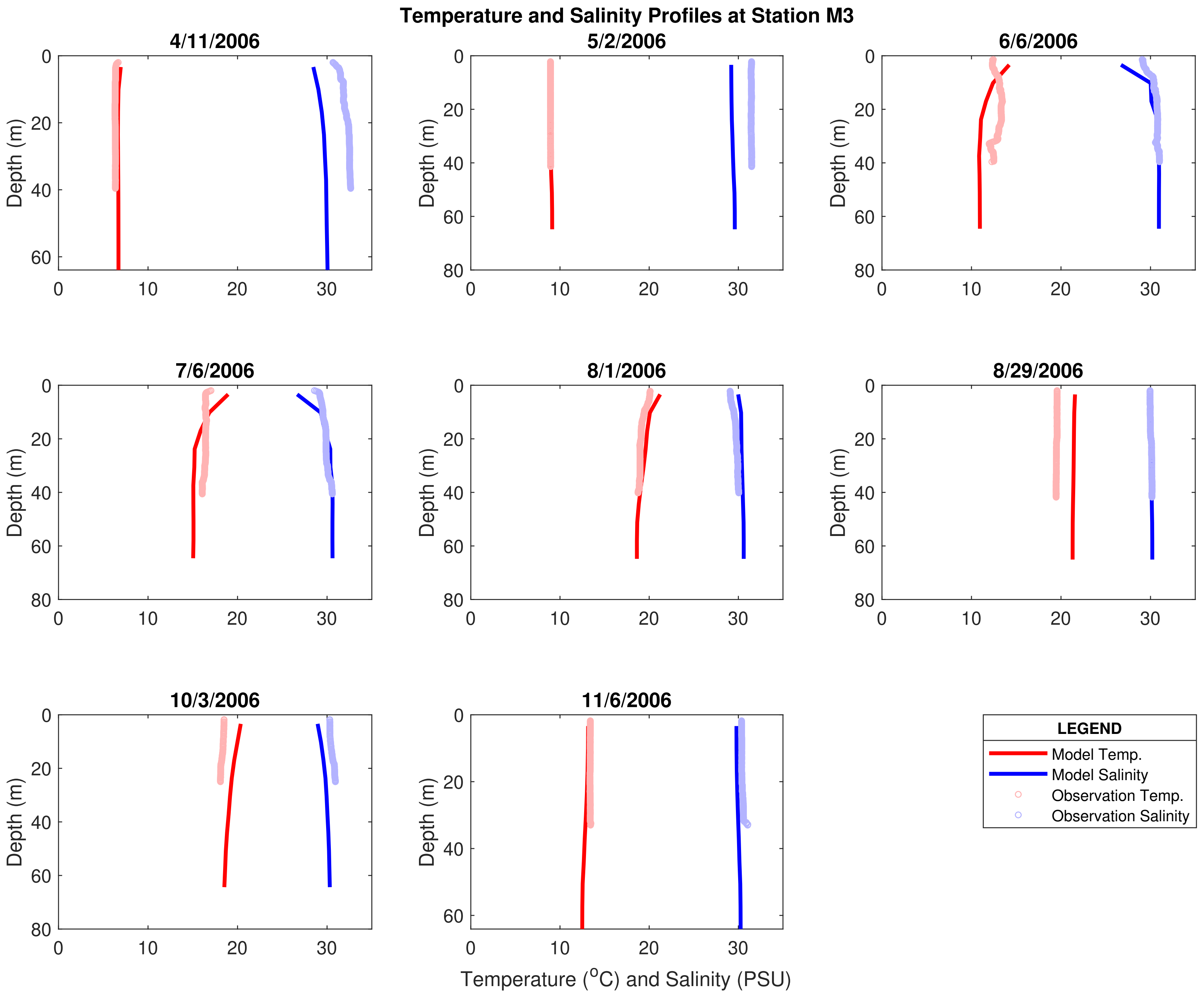
Temperature and Salinity Profiles at Station J2
4/11/2006
5/2/2006
6/6/2006
7/6/2006
8/1/2006
8/29/2006
10/3/2006
11/6/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity


12/11/2006
Depth (m)
0
5
10
15
20
25
0
10
20
30


LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity



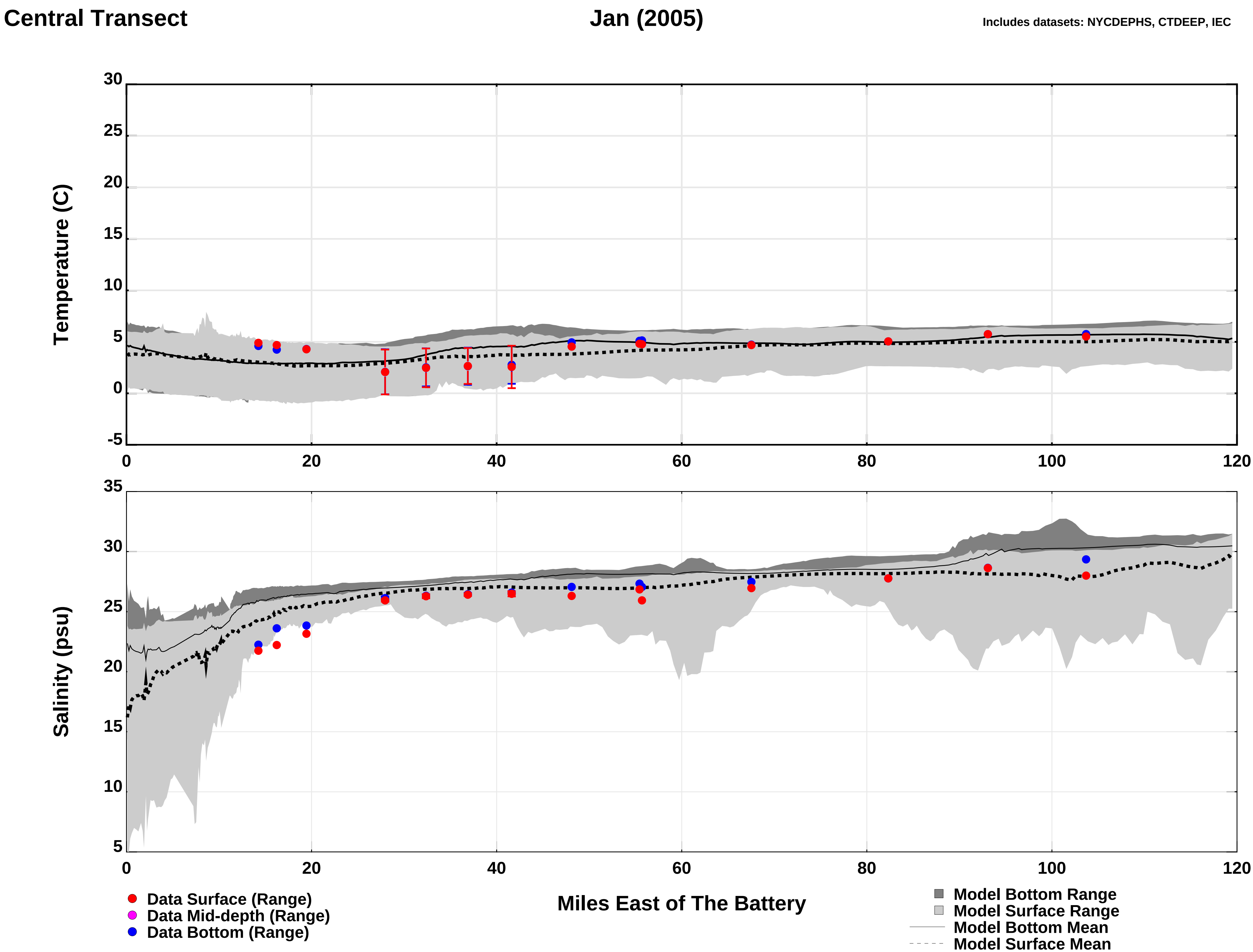
Temperature and Salinity Profiles at Station K2
4/11/2006
5/2/2006
6/6/2006
7/6/2006
8/1/2006
8/29/2006
10/3/2006
11/6/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

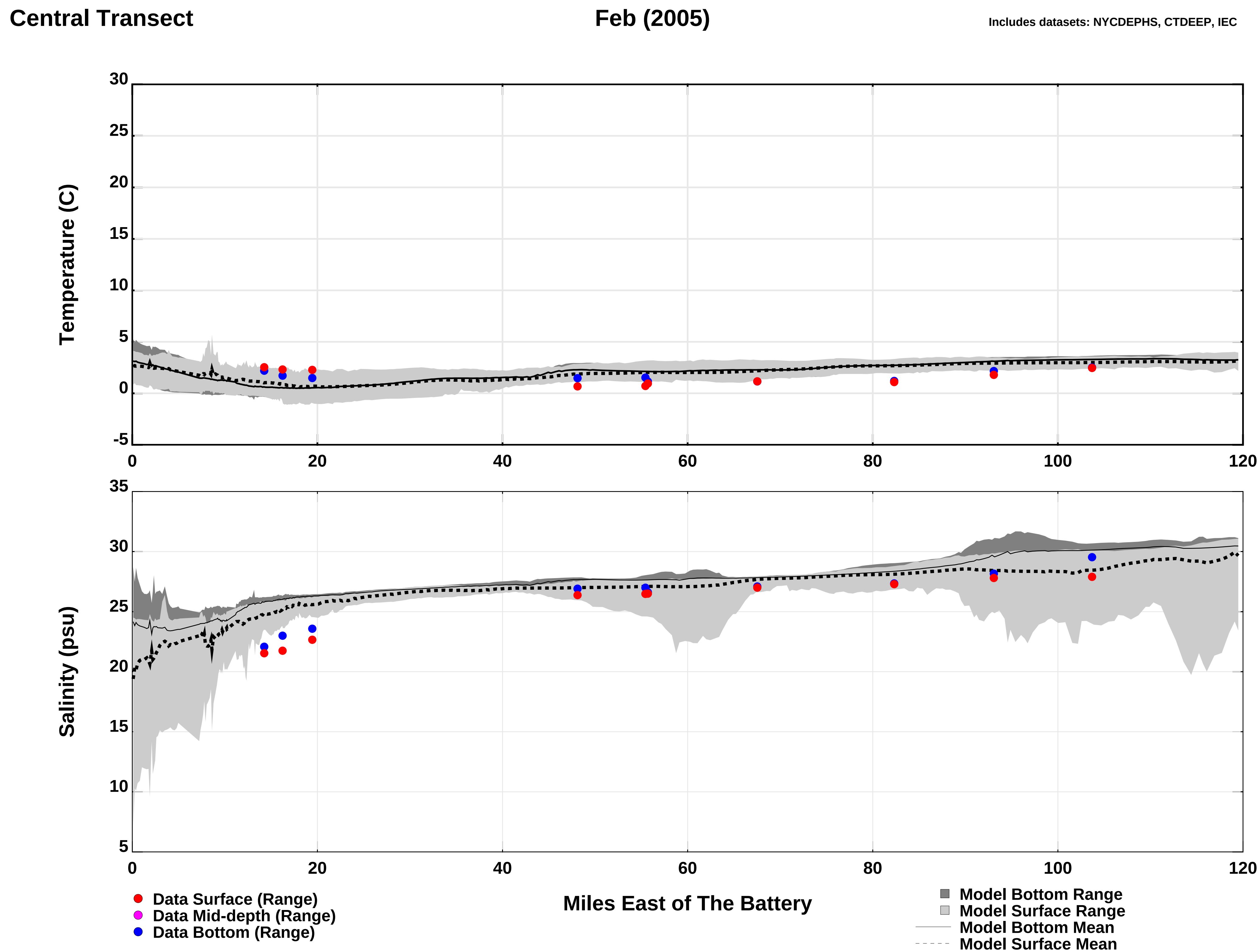


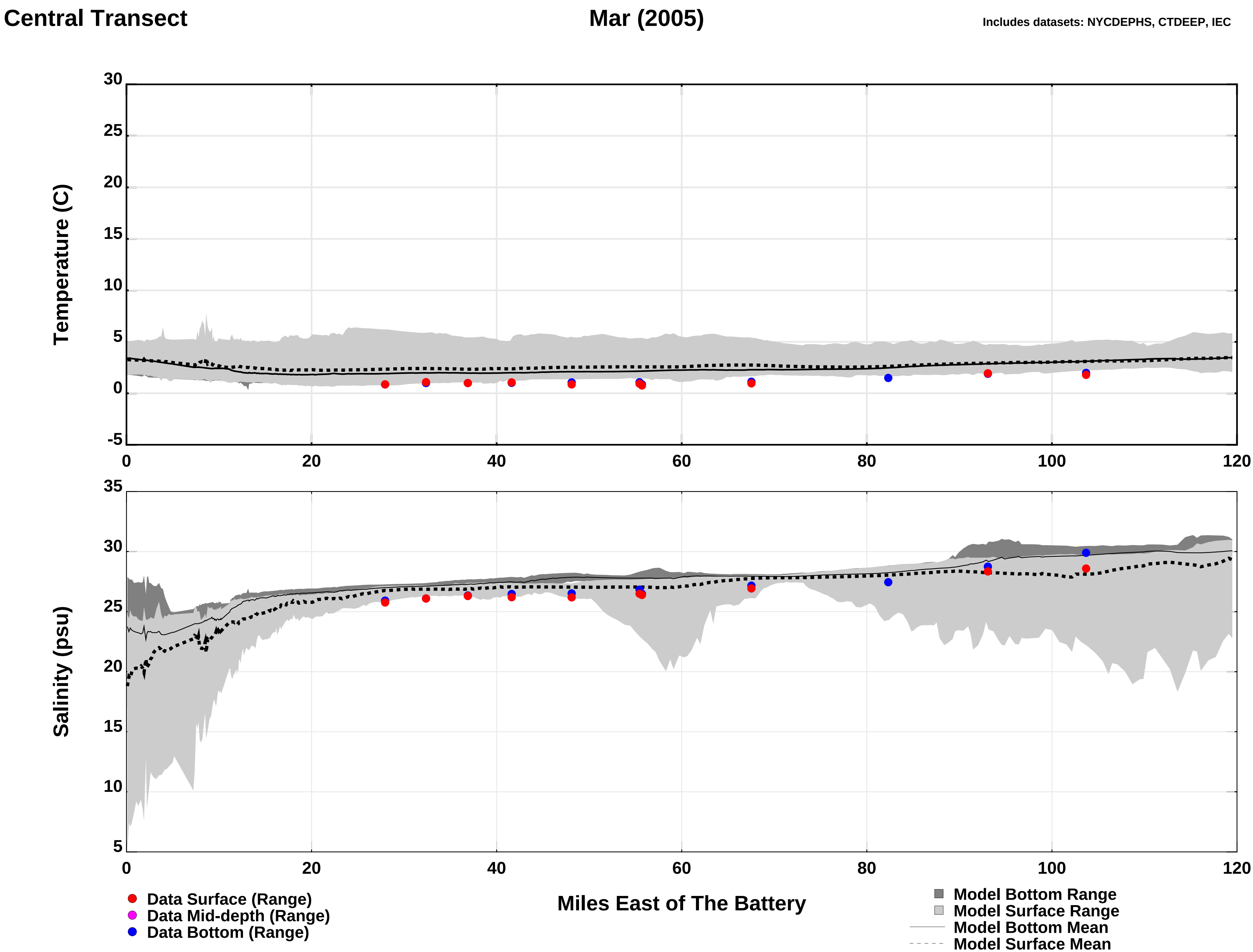
Temperature and Salinity Profiles at Station M3
4/11/2006
5/2/2006
6/6/2006
7/6/2006
8/1/2006
8/29/2006
10/3/2006
11/6/2006
Depth (m)
Temperature (°C) and Salinity (PSU)
LEGEND
Model Temp.
Model Salinity
Observation Temp.
Observation Salinity

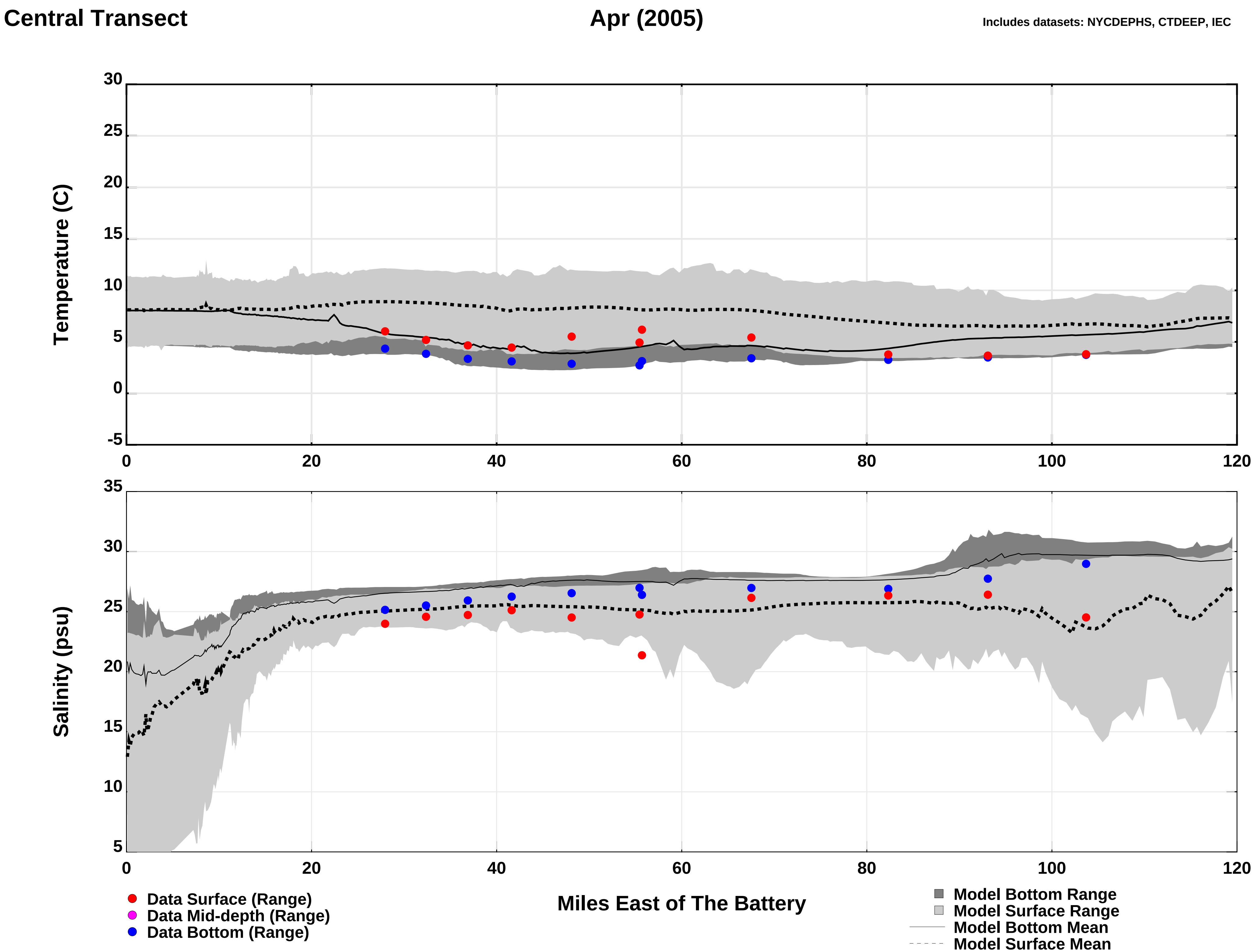
4

2005-2006 Model-Data Temperature/Salinity Transect Comparisons

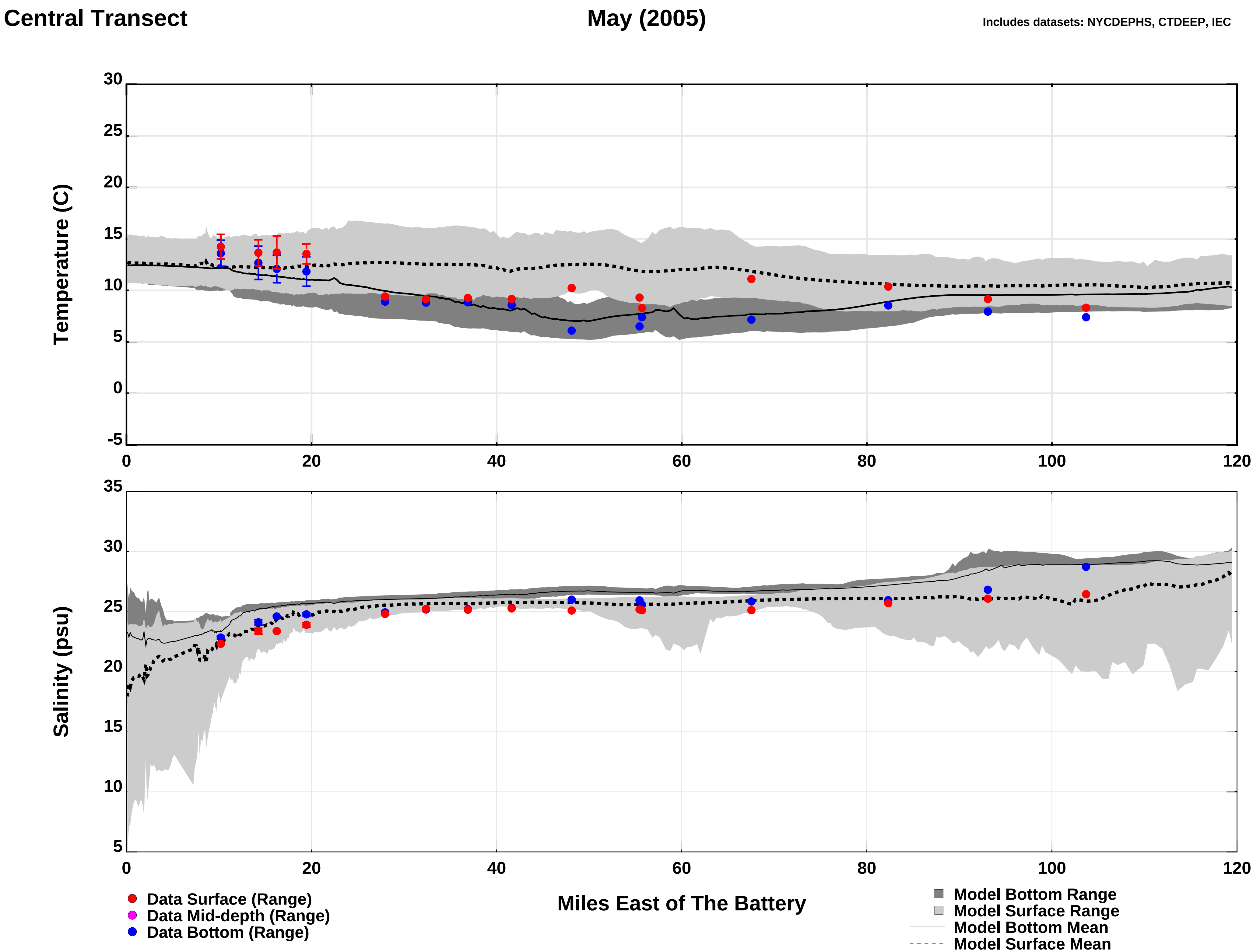

Central Transect
Jan (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean


Central Transect
Feb (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
Salinity (psu)
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean


Central Transect
Mar (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
0
20
40
60
80
100
120
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean



Central Transect
Apr (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

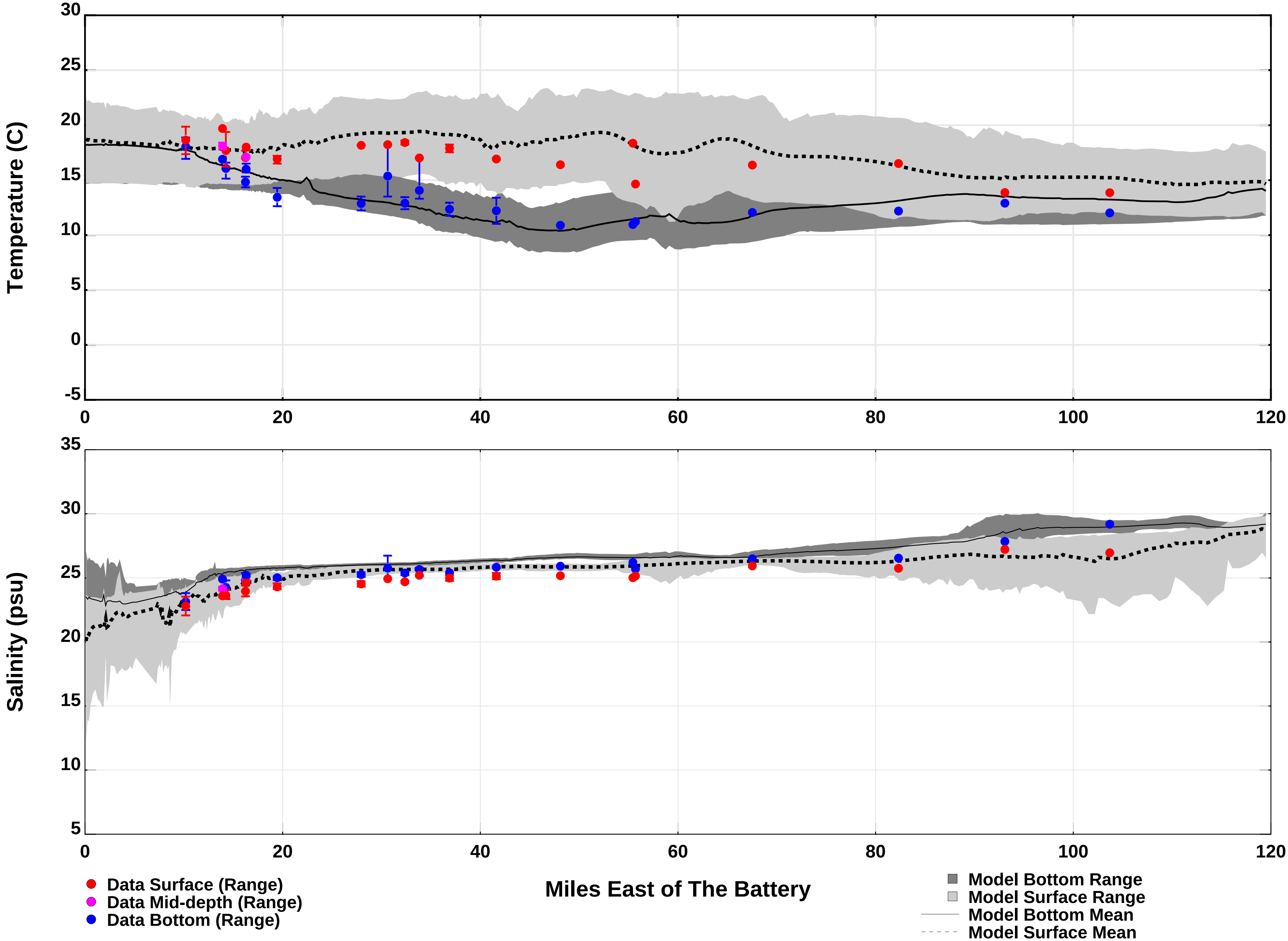


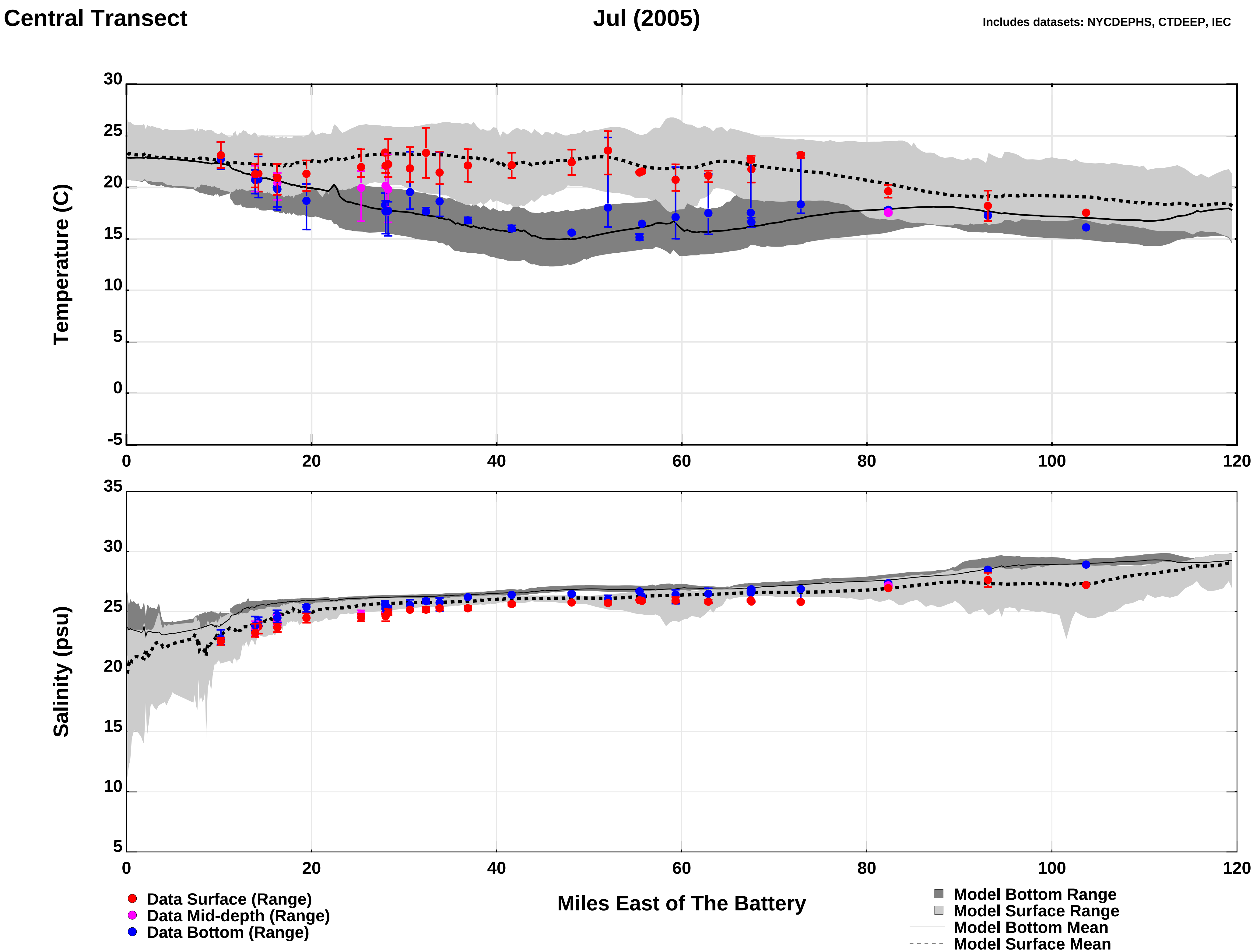
Central Transect
May (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

Central Transect

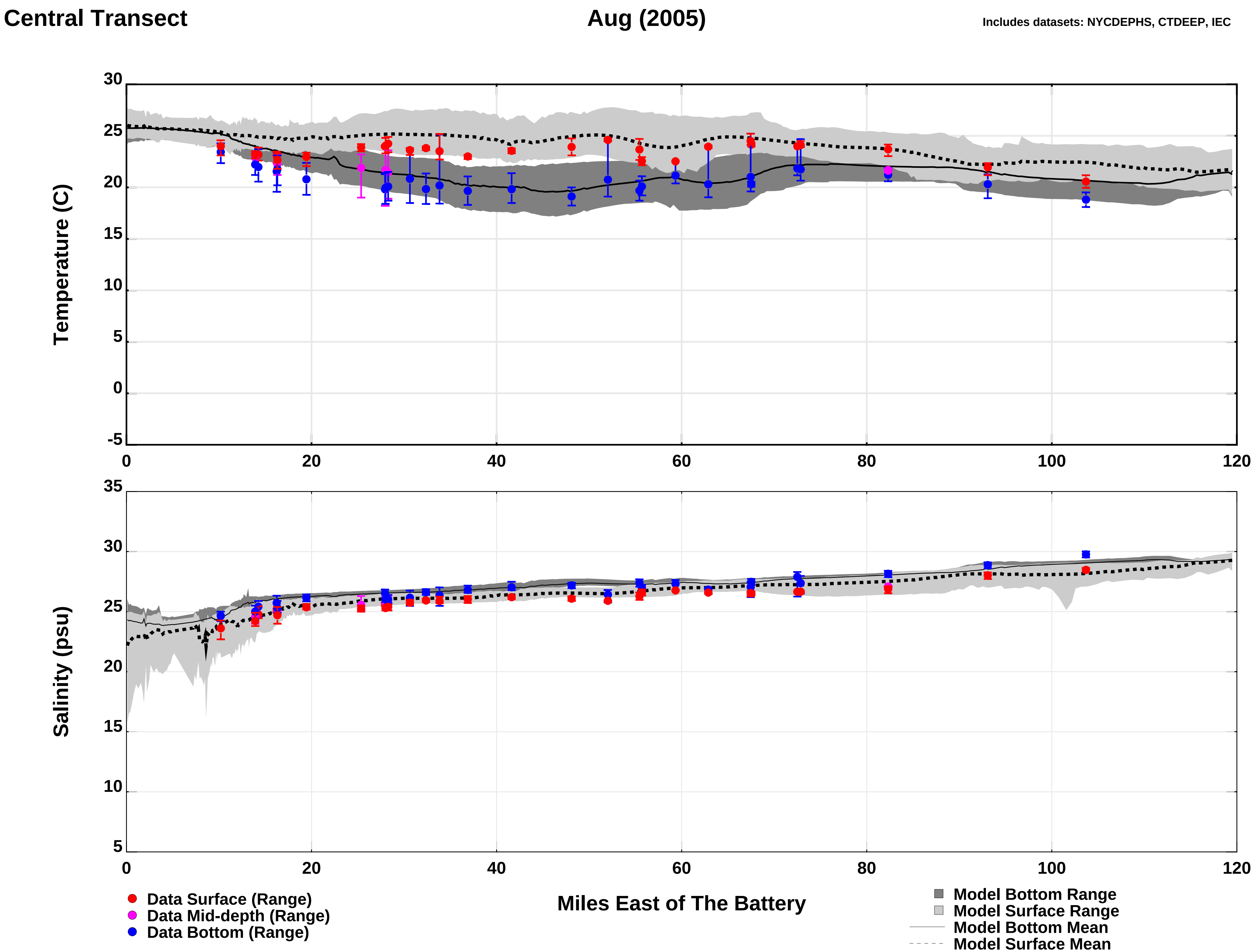
Jun (2005)

Includes datasets: NYCDEPHS, CTDEEP, IEC

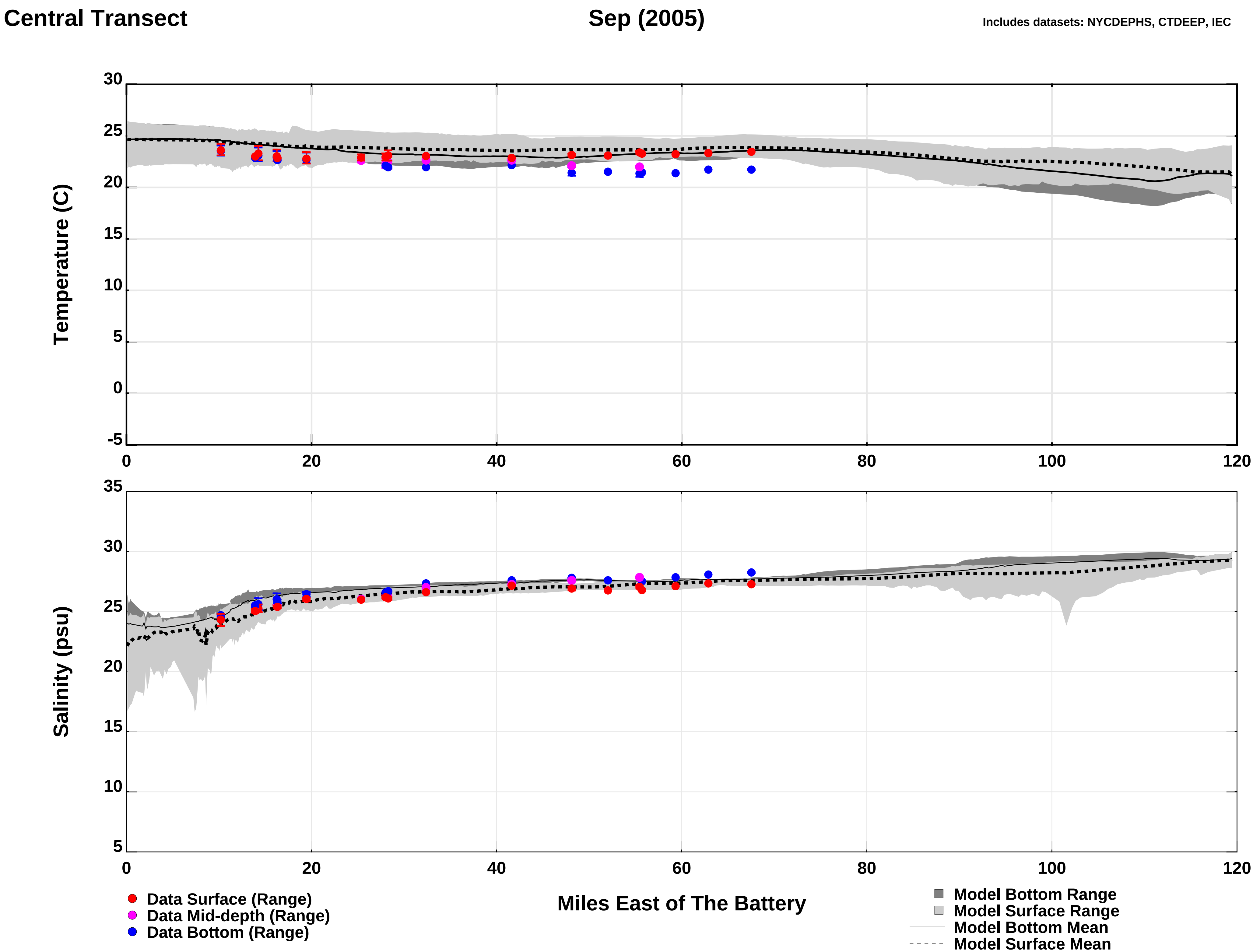




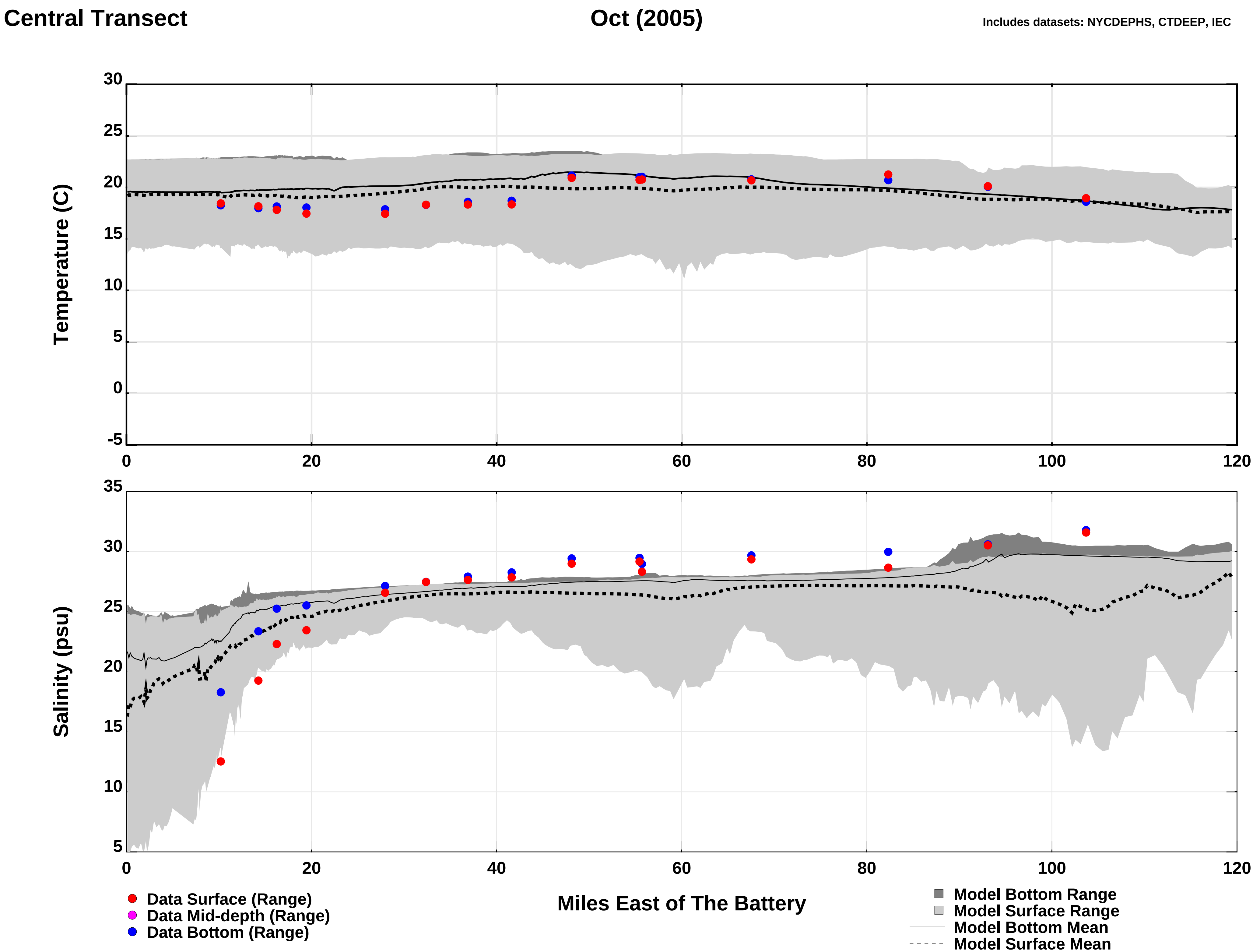
Central Transect
Jul (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean



Central Transect
Aug (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean



Central Transect
Sep (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
0
20
40
60
80
100
120
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

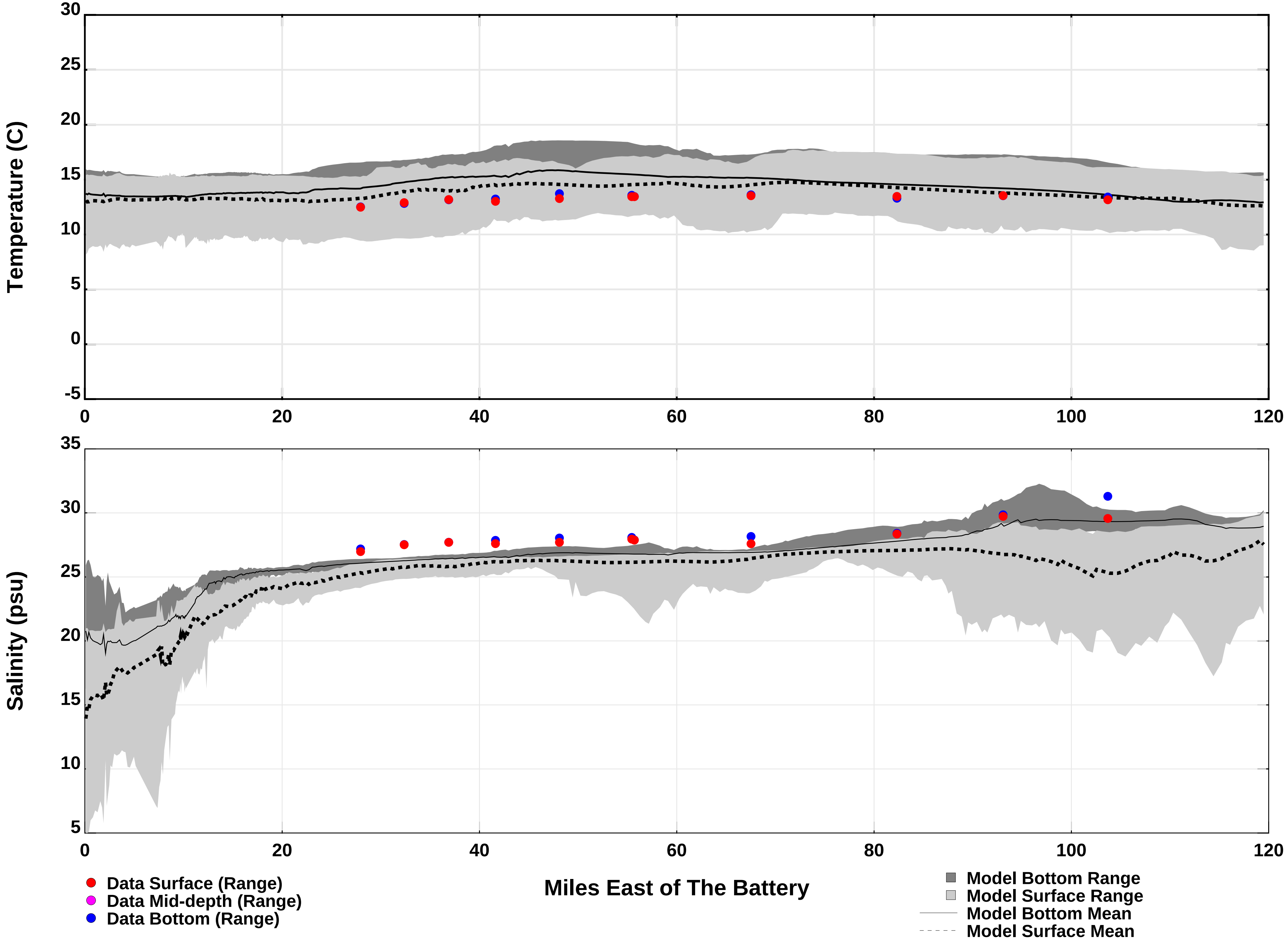


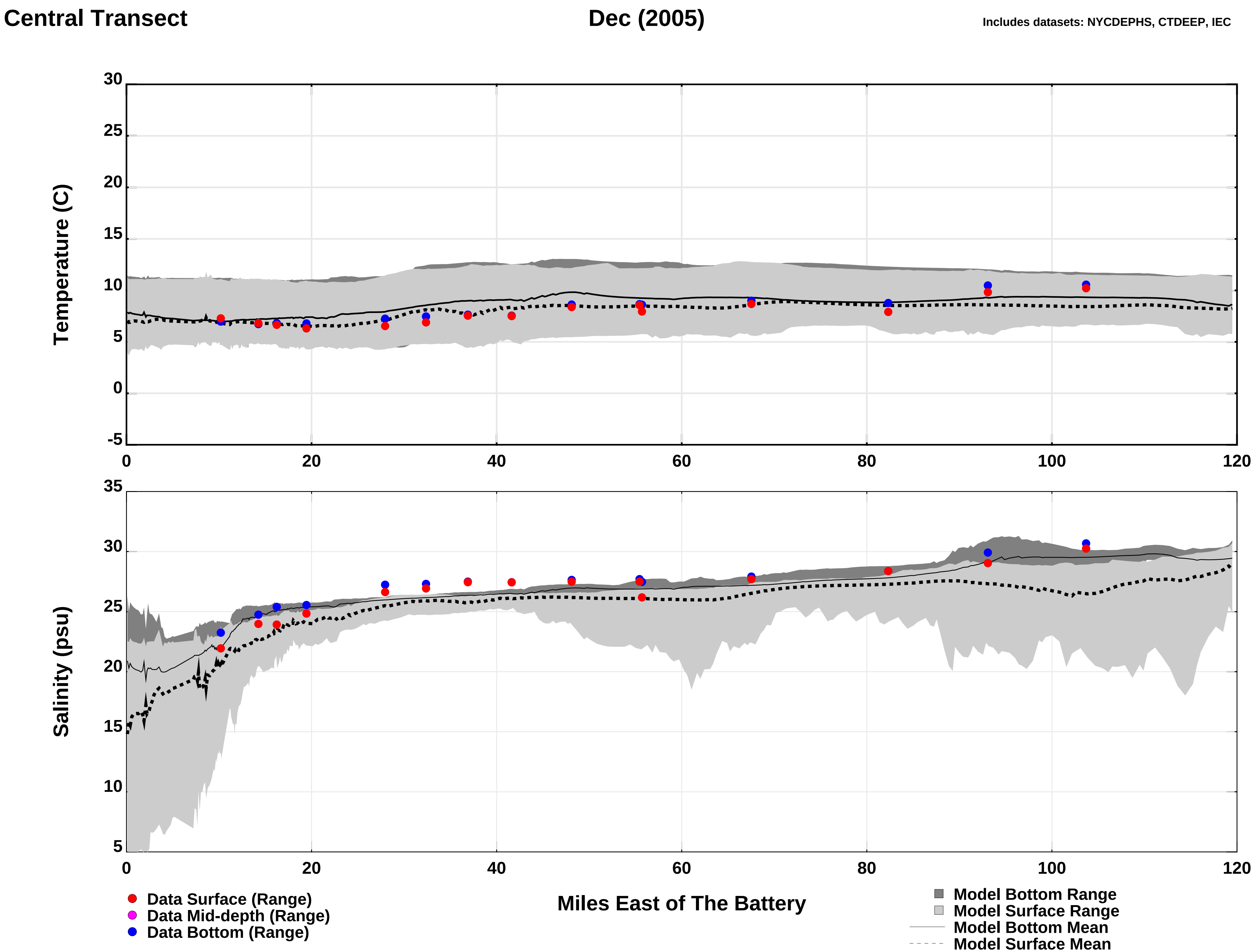
Central Transect
Oct (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

Central Transect

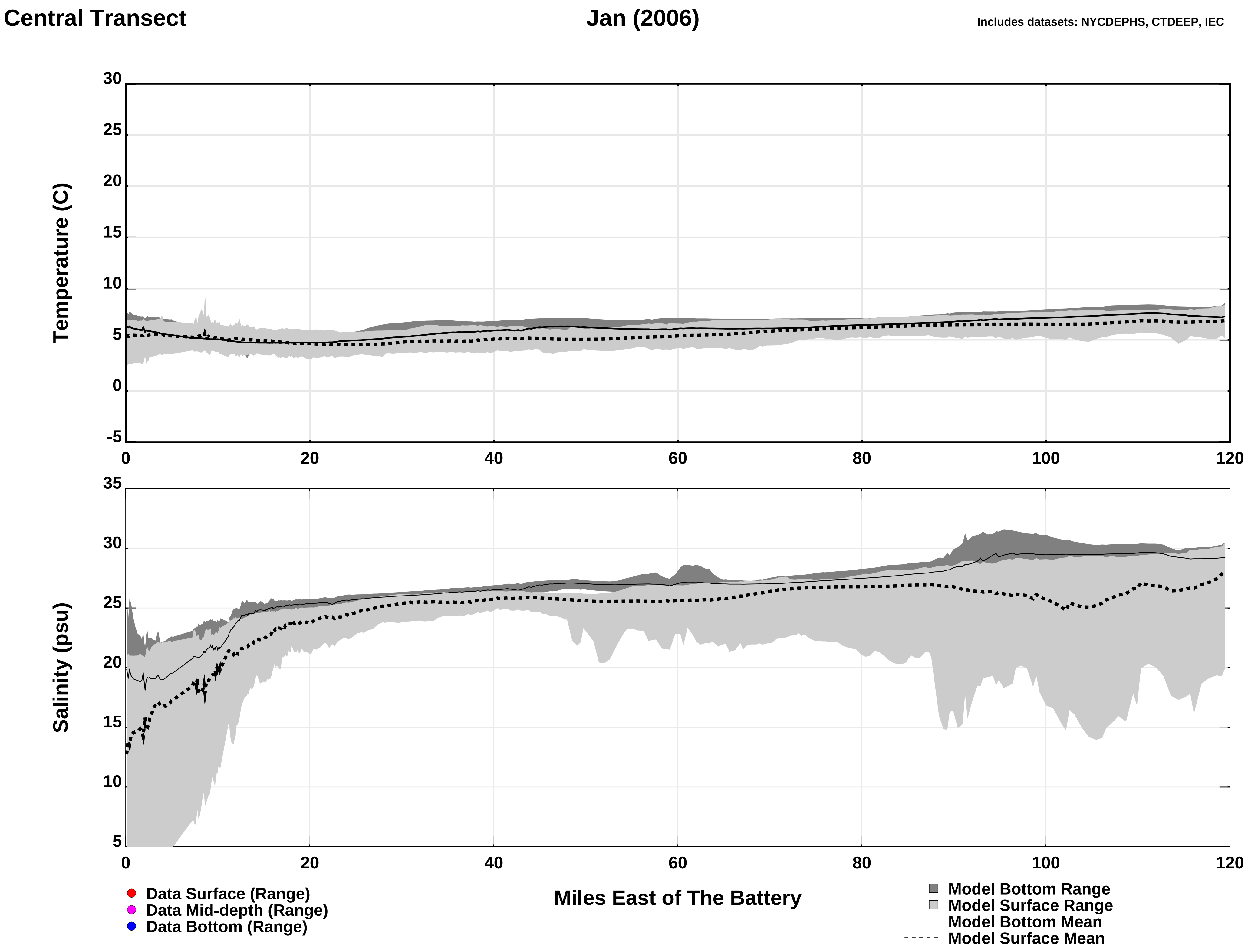
Nov (2005)

Includes datasets: NYCDEPHS, CTDEEP, IEC

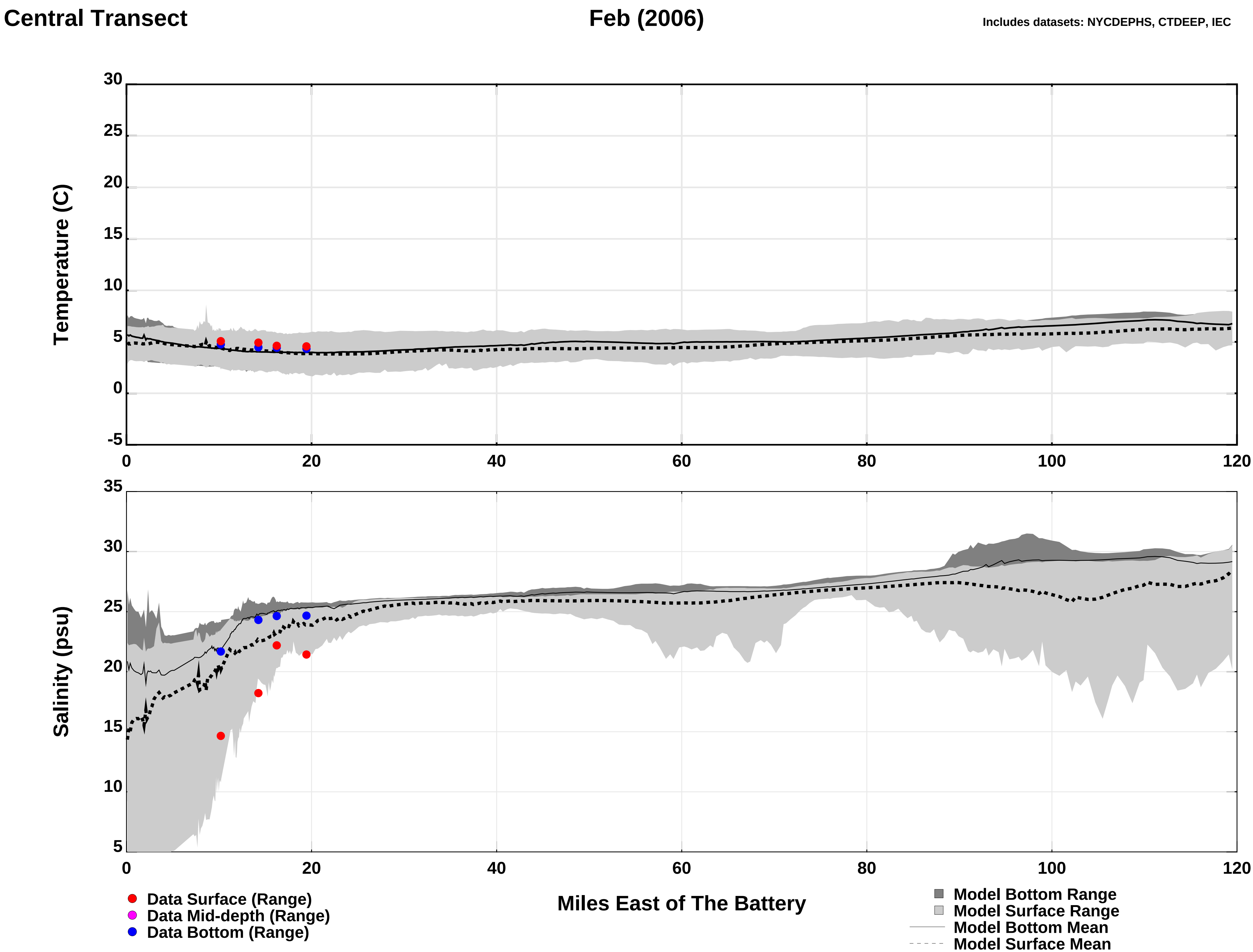




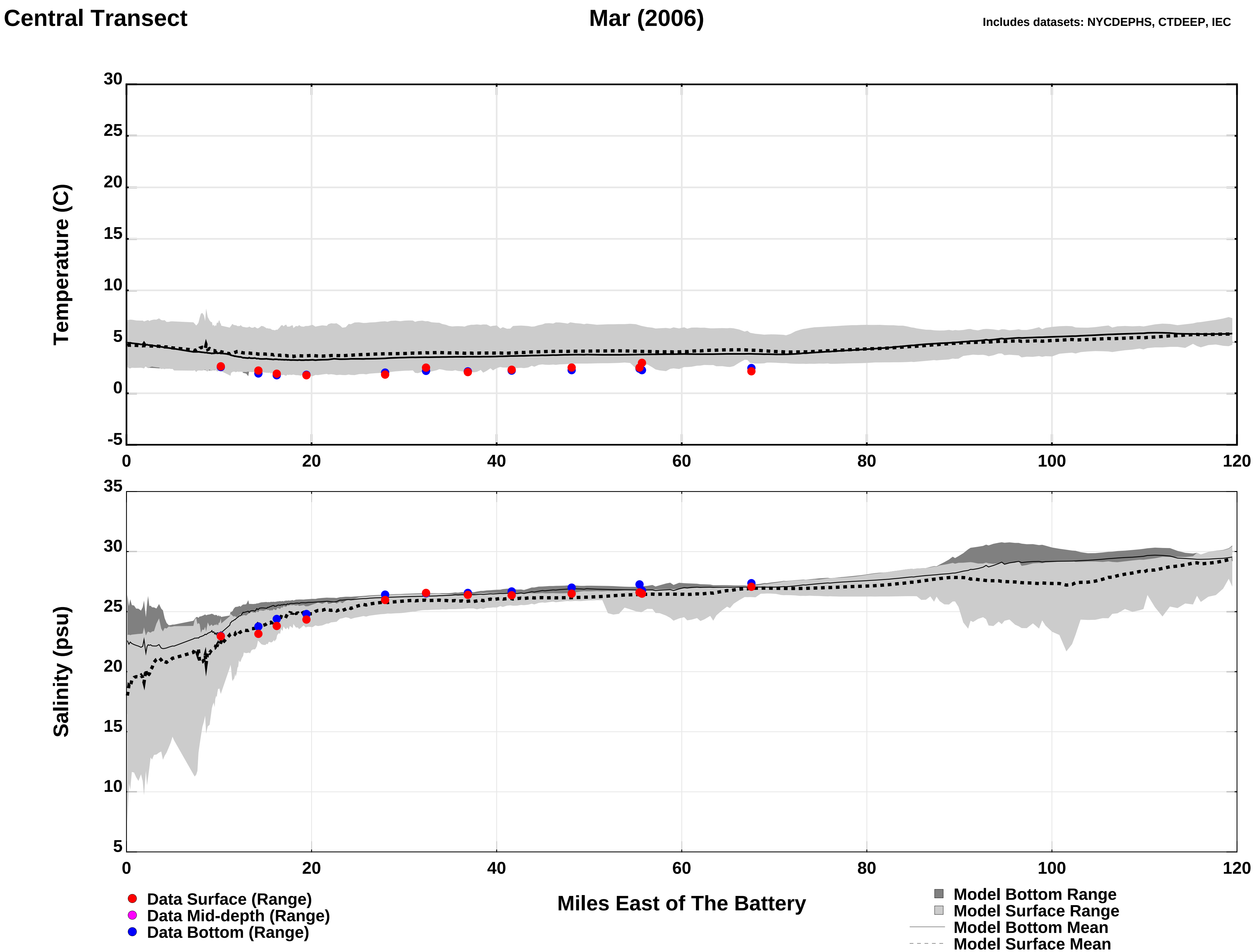
Central Transect
Dec (2005)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean



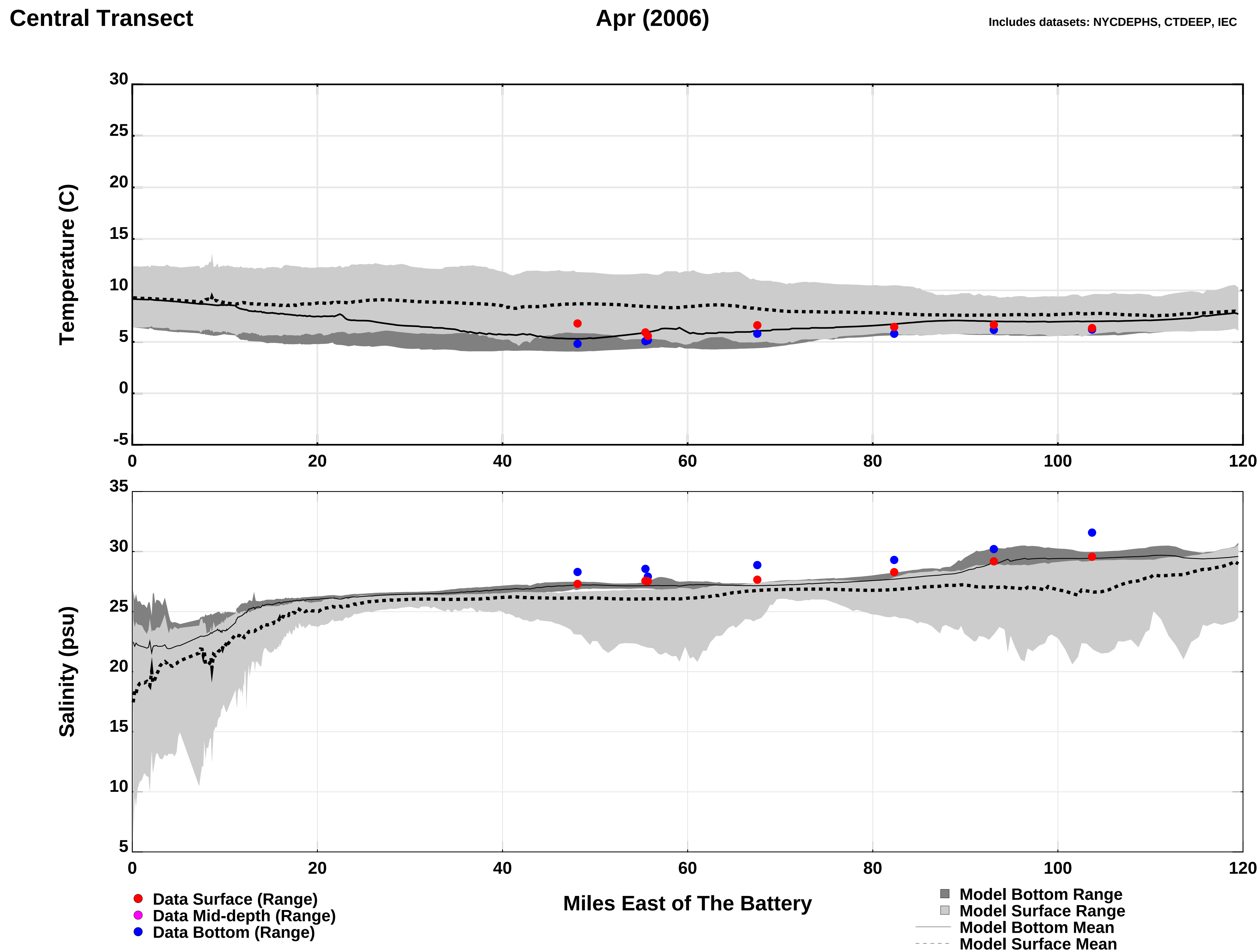
Central Transect
Jan (2006)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

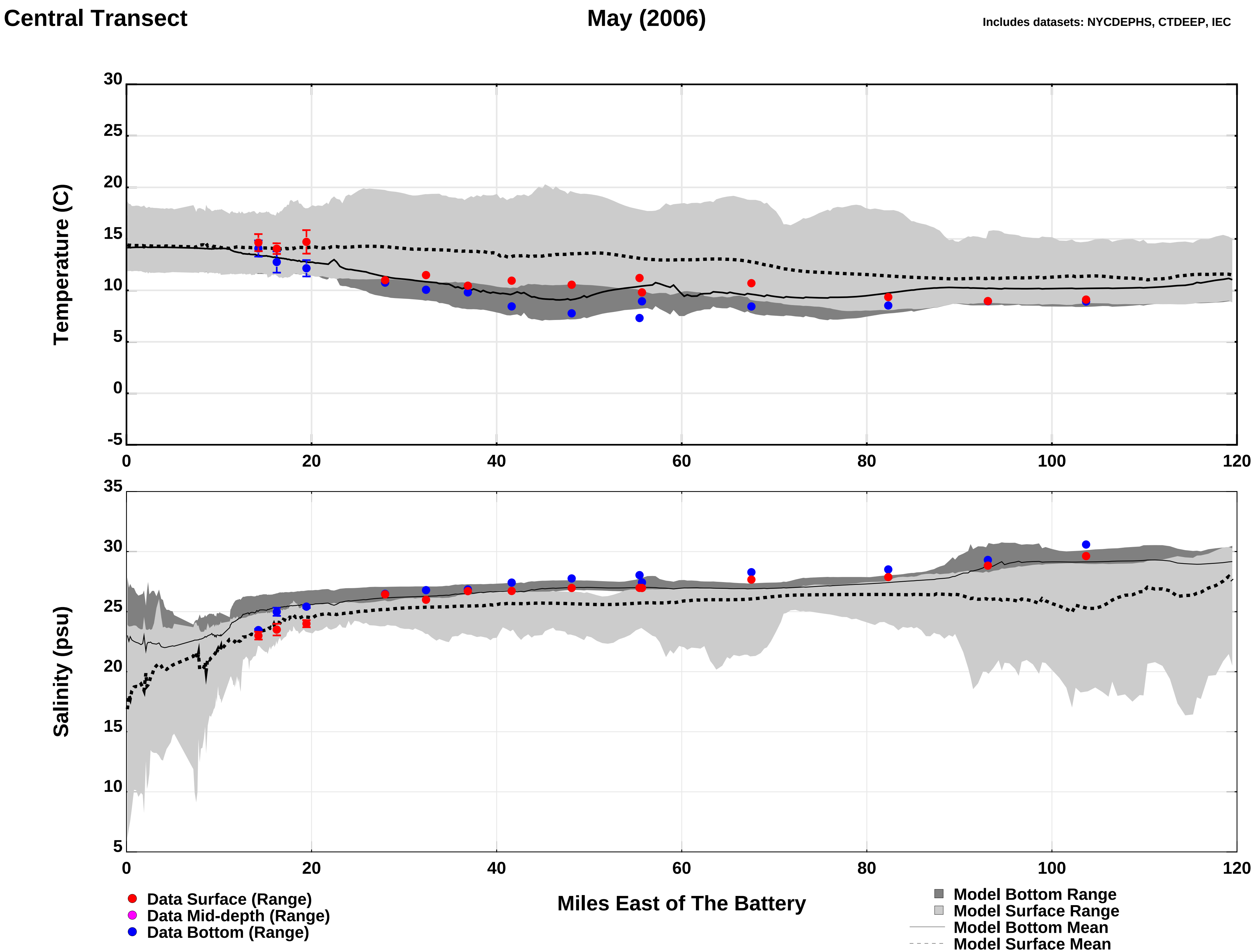


Central Transect
Feb (2006)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean



Central Transect
Mar (2006)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean


Central Transect
Apr (2006)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

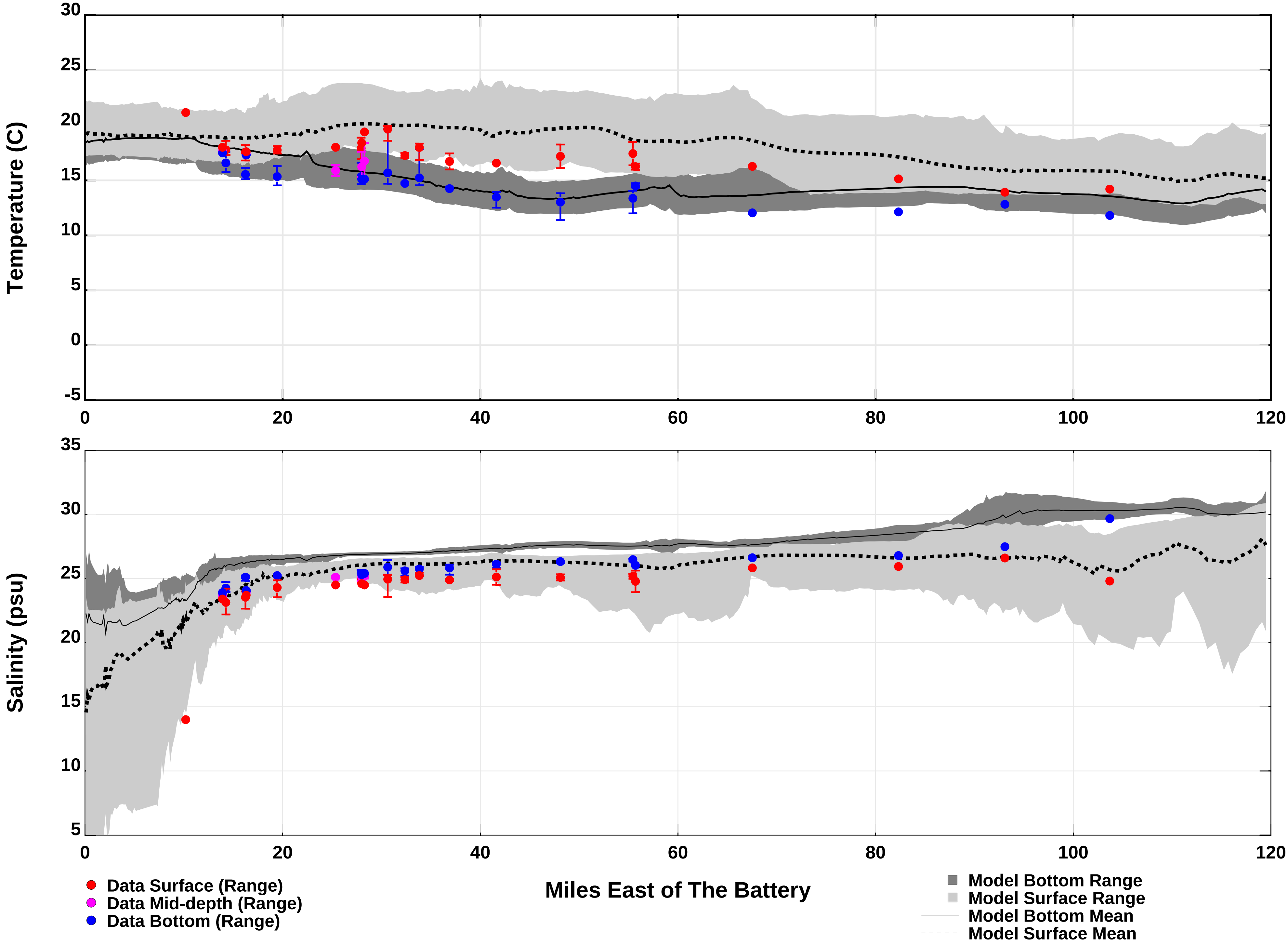


Central Transect
May (2006)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

Central Transect

Jun (2006)

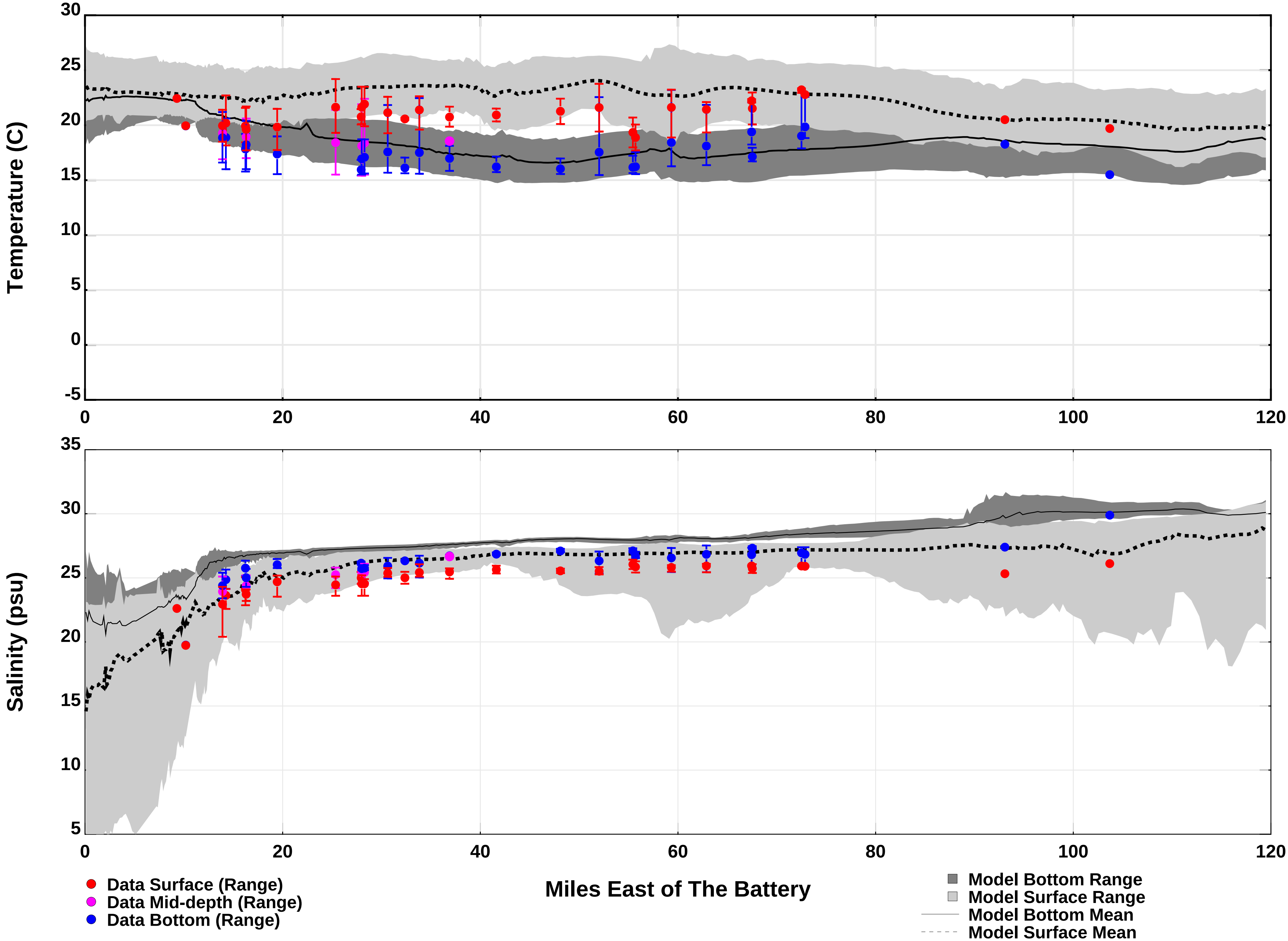
Includes datasets: NYCDEPHS, CTDEEP, IEC

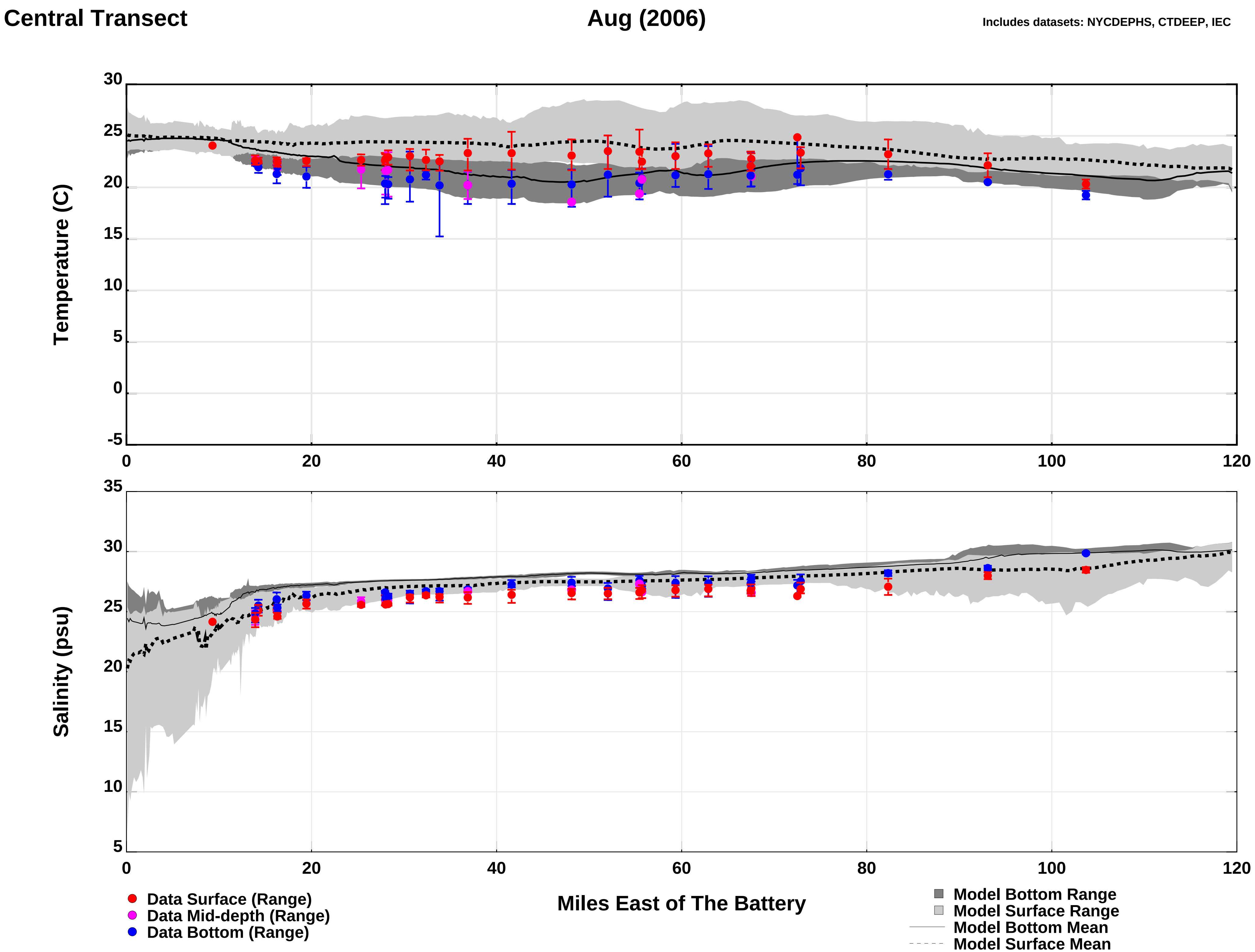


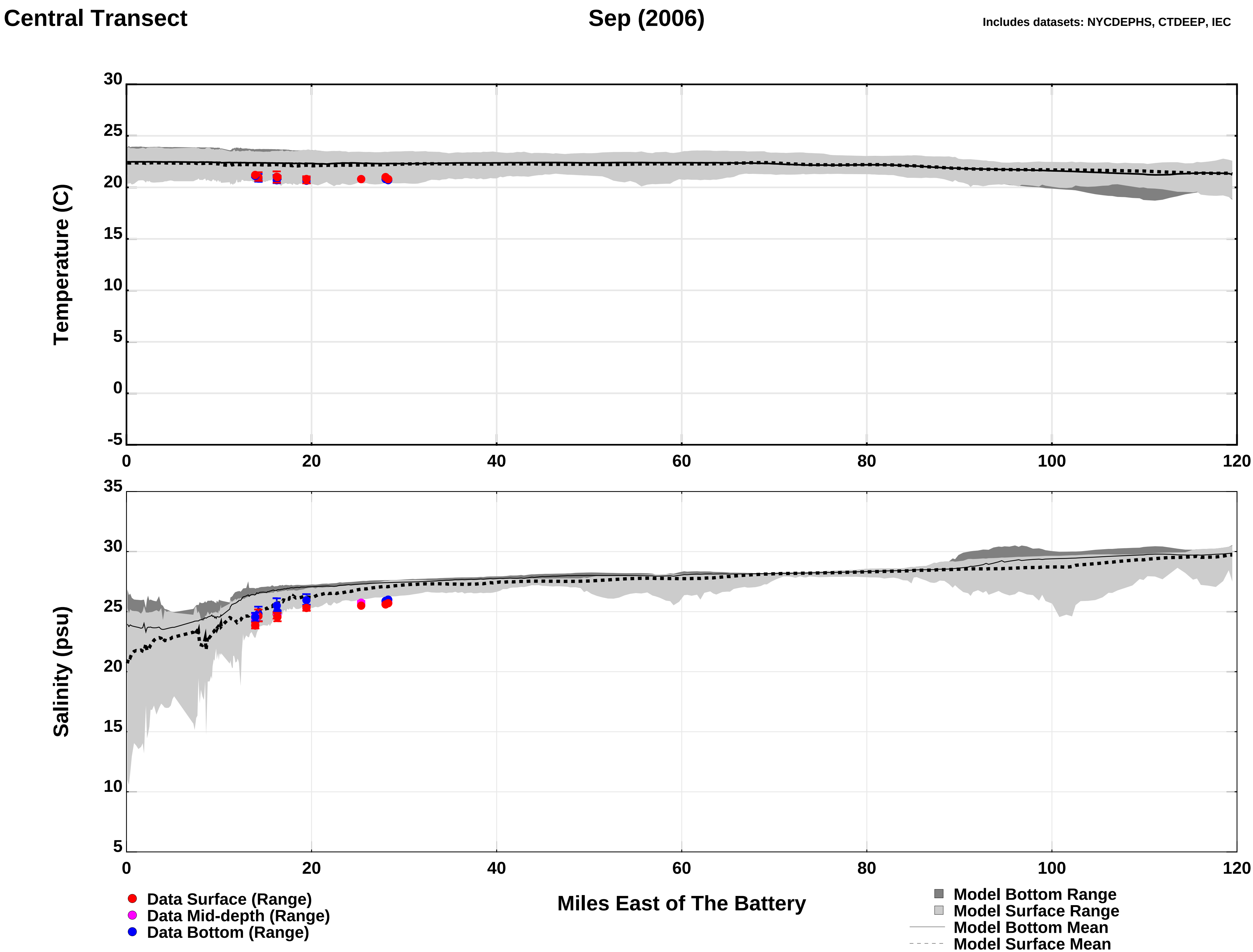
Central Transect

Jul (2006)

Includes datasets: NYCDEPHS, CTDEEP, IEC




Central Transect
Aug (2006)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
0
20
40
60
80
100
120
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

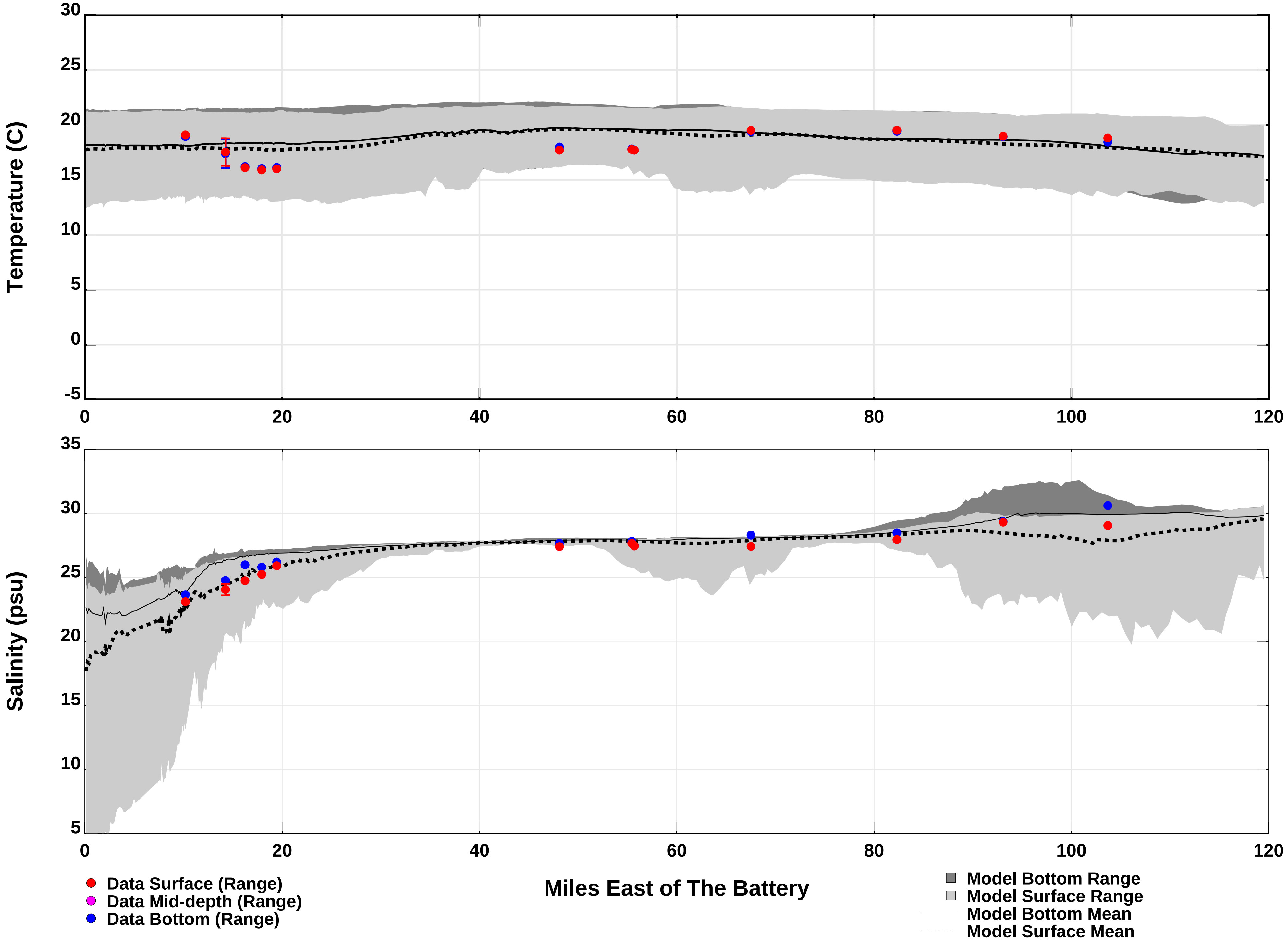


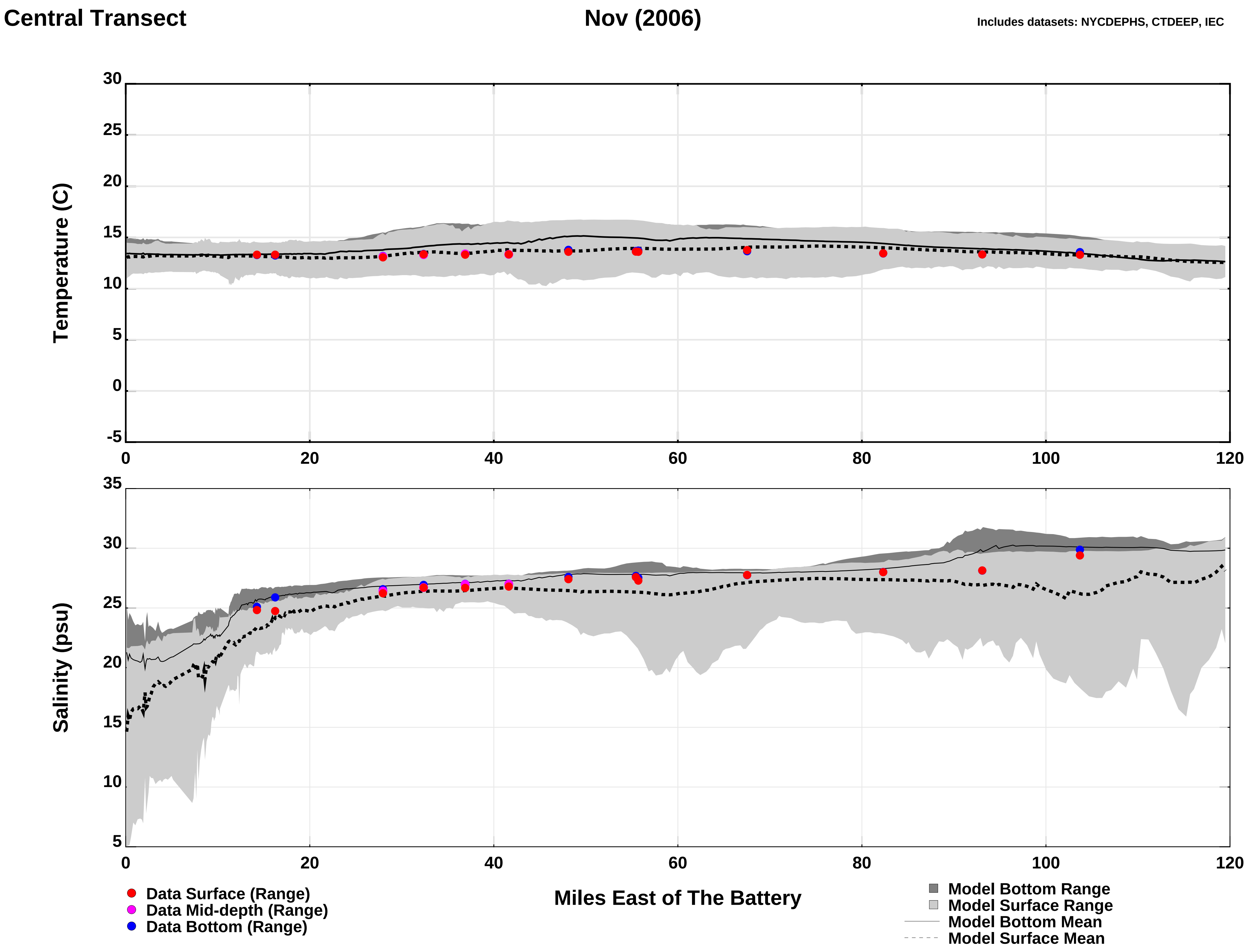
Central Transect
Sep (2006)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

Central Transect

Oct (2006)

Includes datasets: NYCDEPHS, CTDEEP, IEC



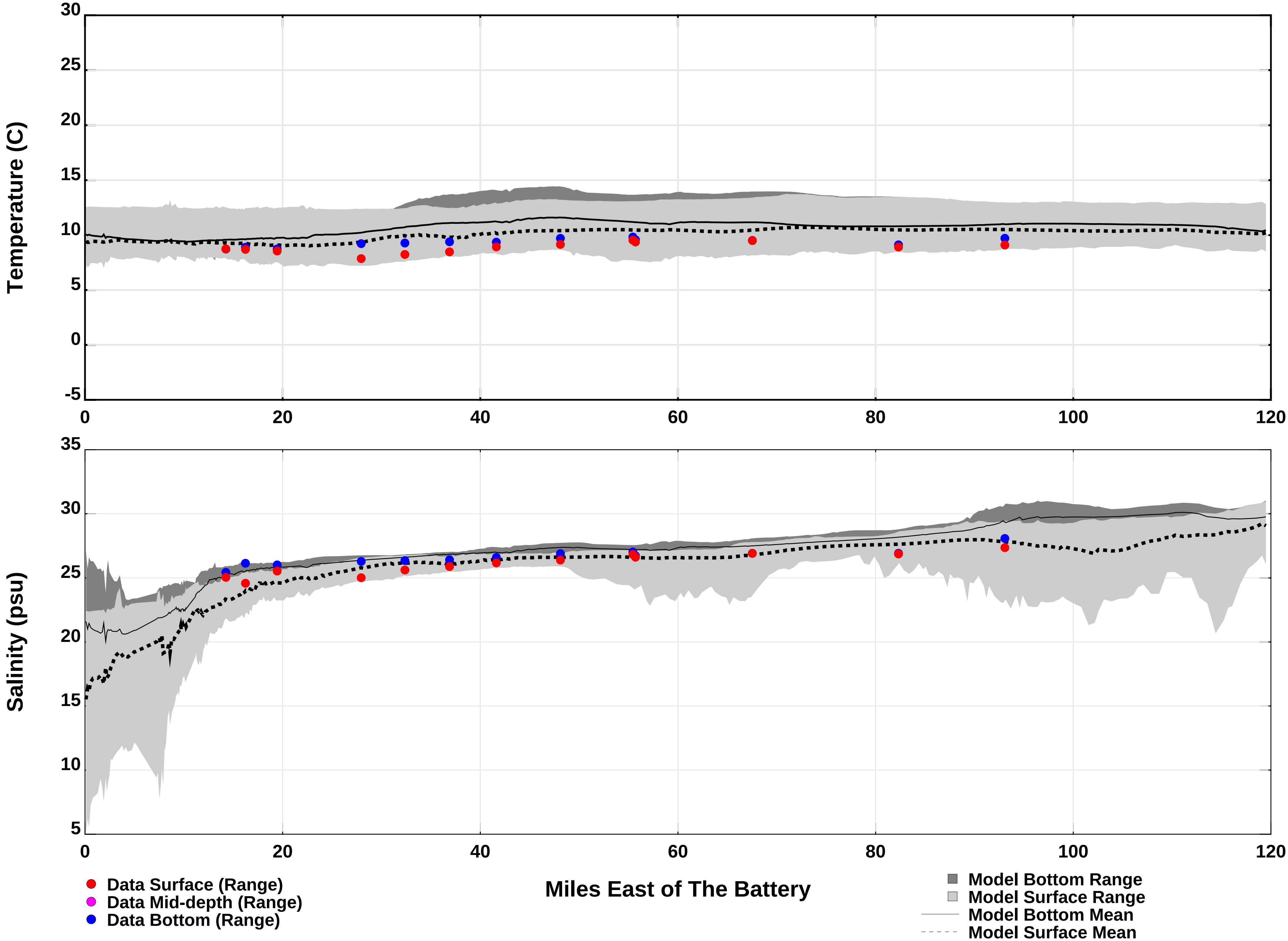


Central Transect
Nov (2006)
Includes datasets: NYCDEPHS, CTDEEP, IEC
Temperature (C)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
Salinity (psu)
35
30
25
20
15
10
5
Miles East of The Battery
Data Surface (Range)
Data Mid-depth (Range)
Data Bottom (Range)
Model Bottom Range
Model Surface Range
Model Bottom Mean
Model Surface Mean

Central Transect

Dec (2006)

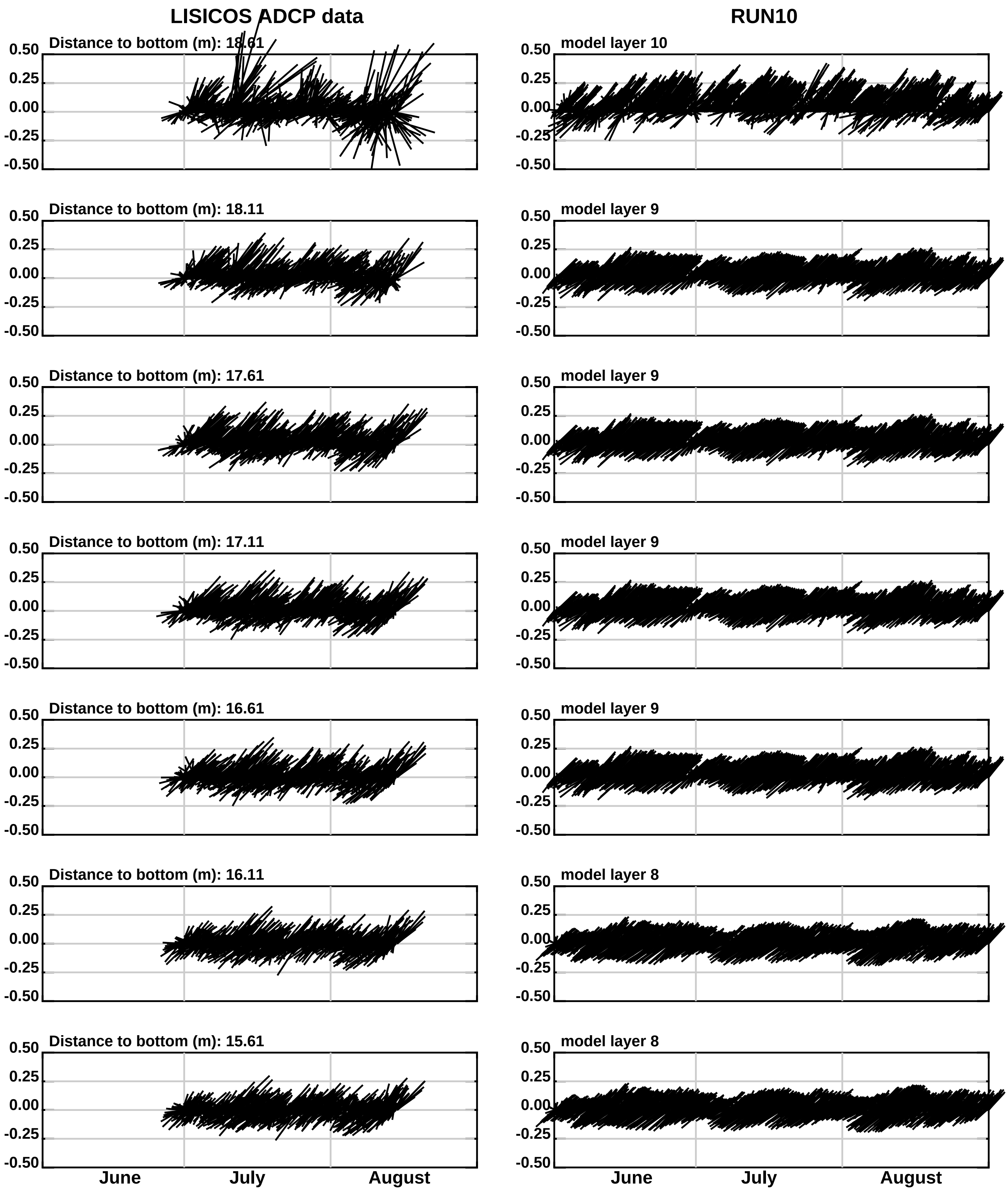
Includes datasets: NYCDEPHS, CTDEEP, IEC



5

2006 Model-Data ADCP Comparisons

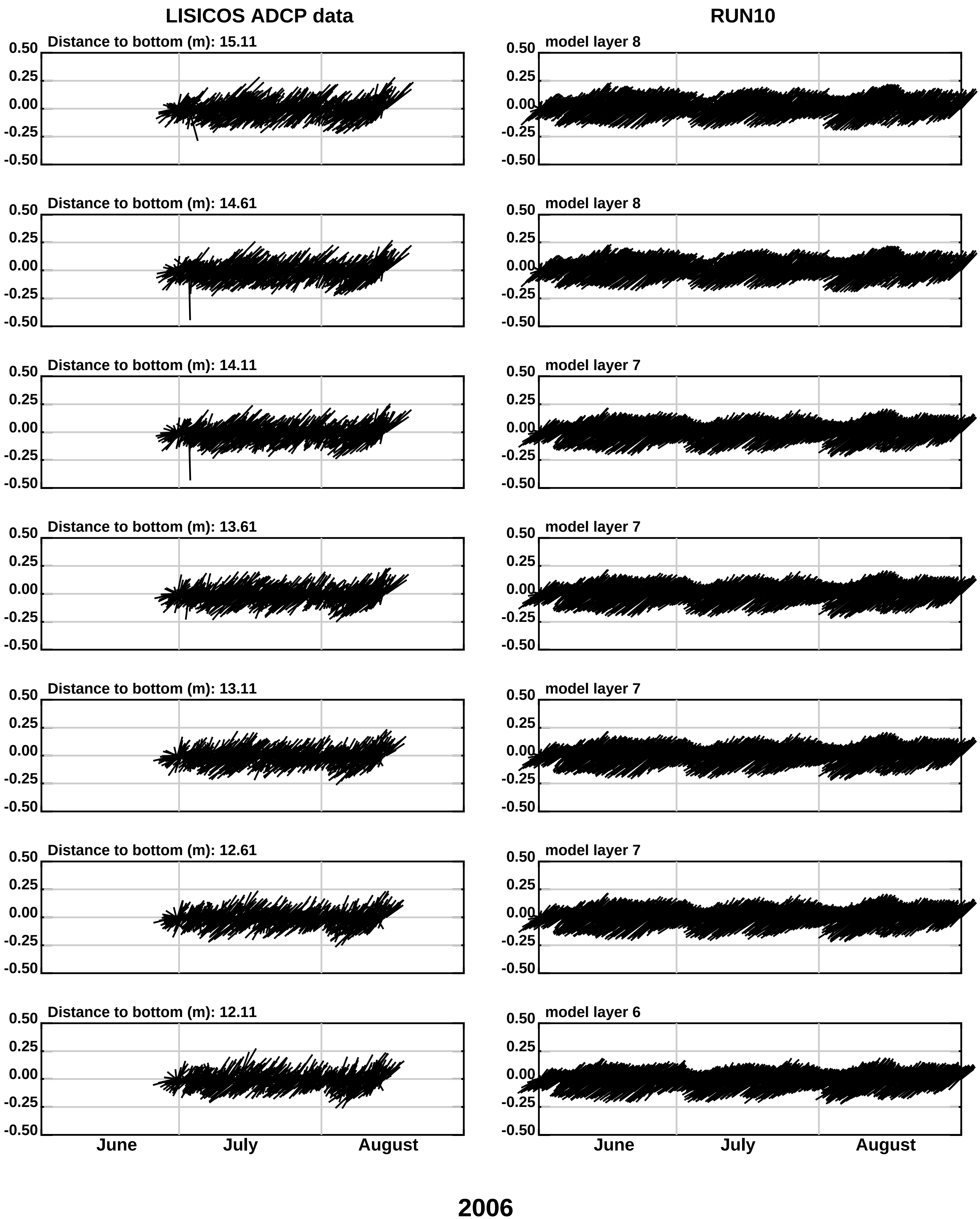
Velocity (m/s)
EXRCK001



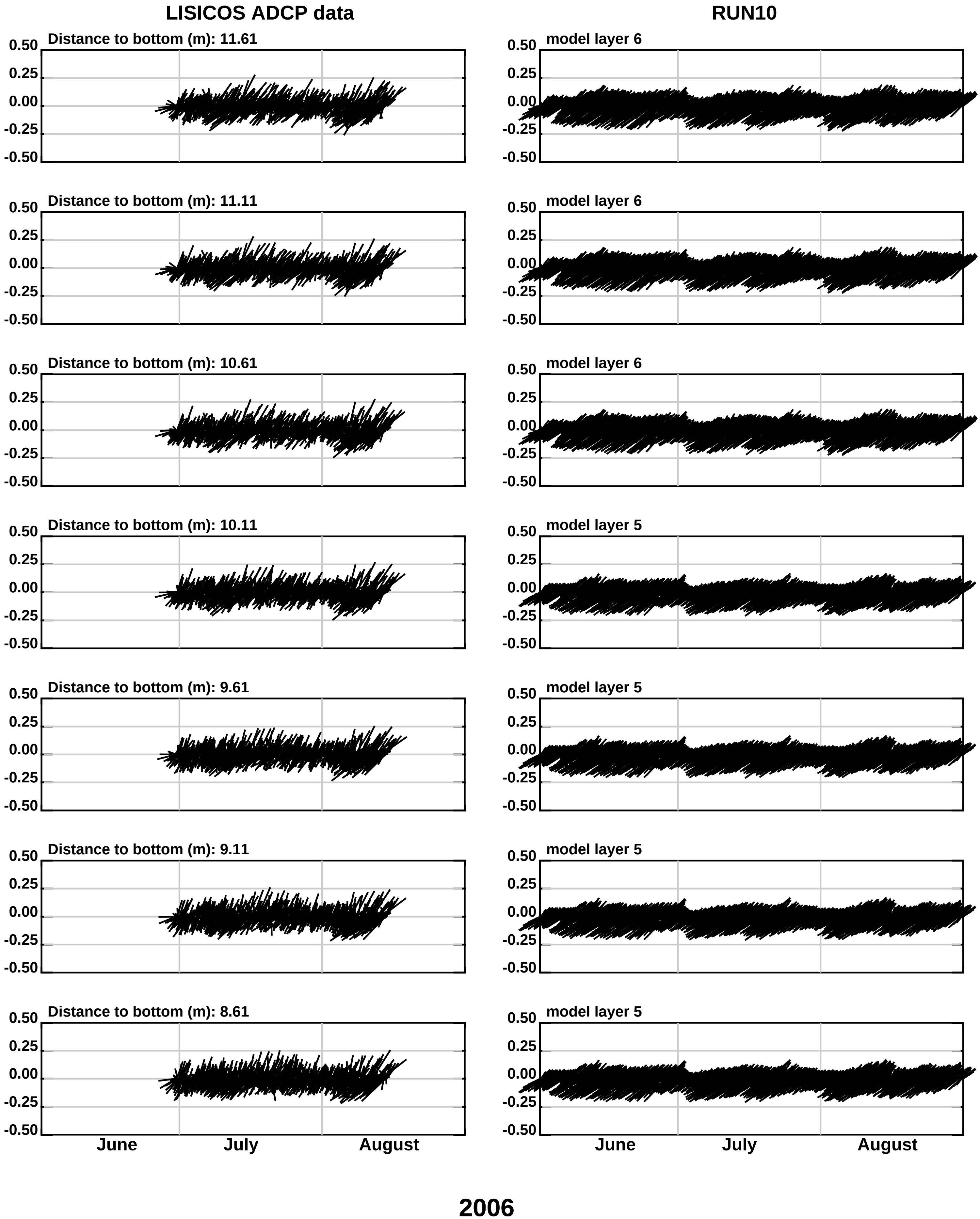
2006

Velocity (m/s)

EXRCK001

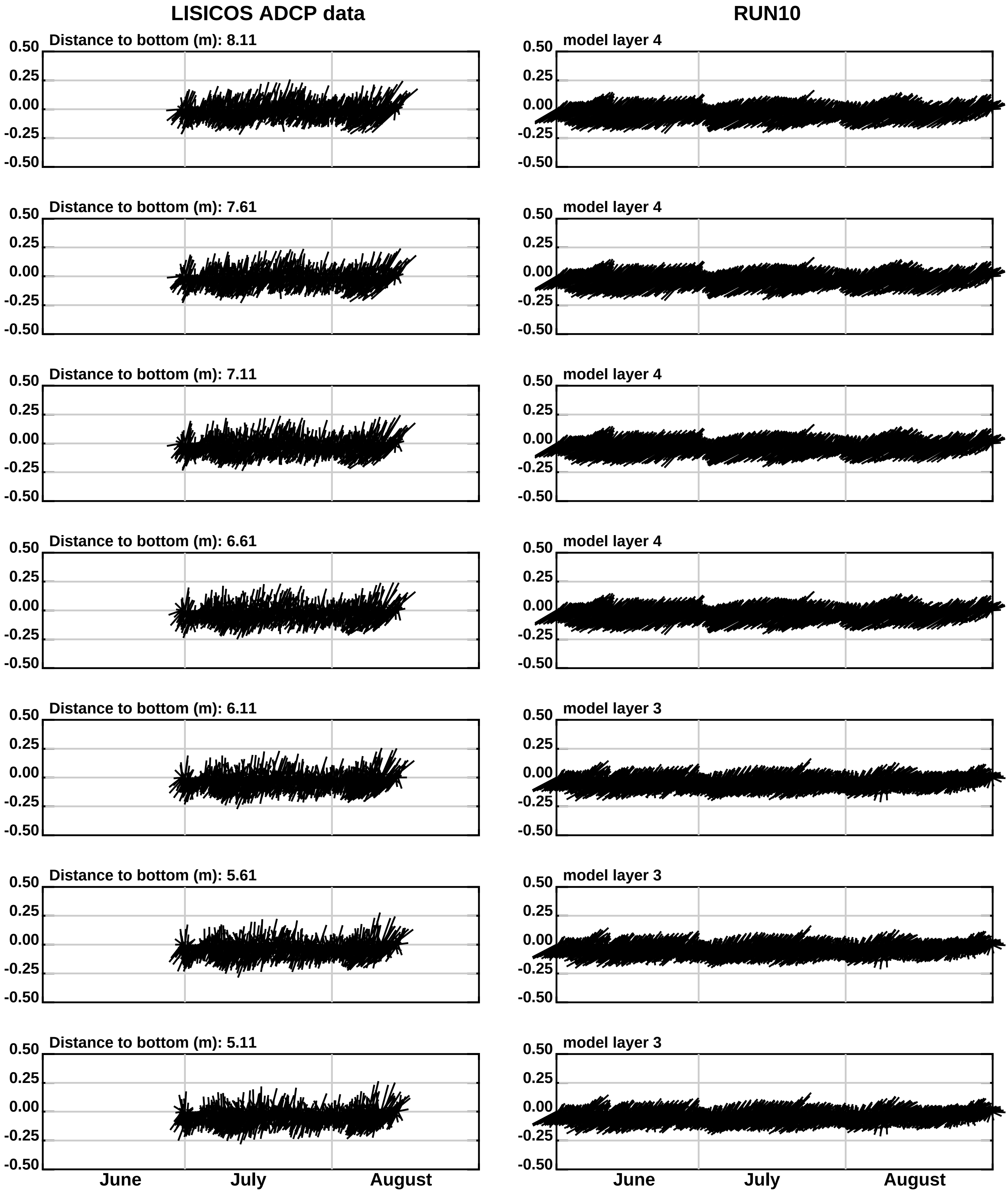


Velocity (m/s)
EXRCK001



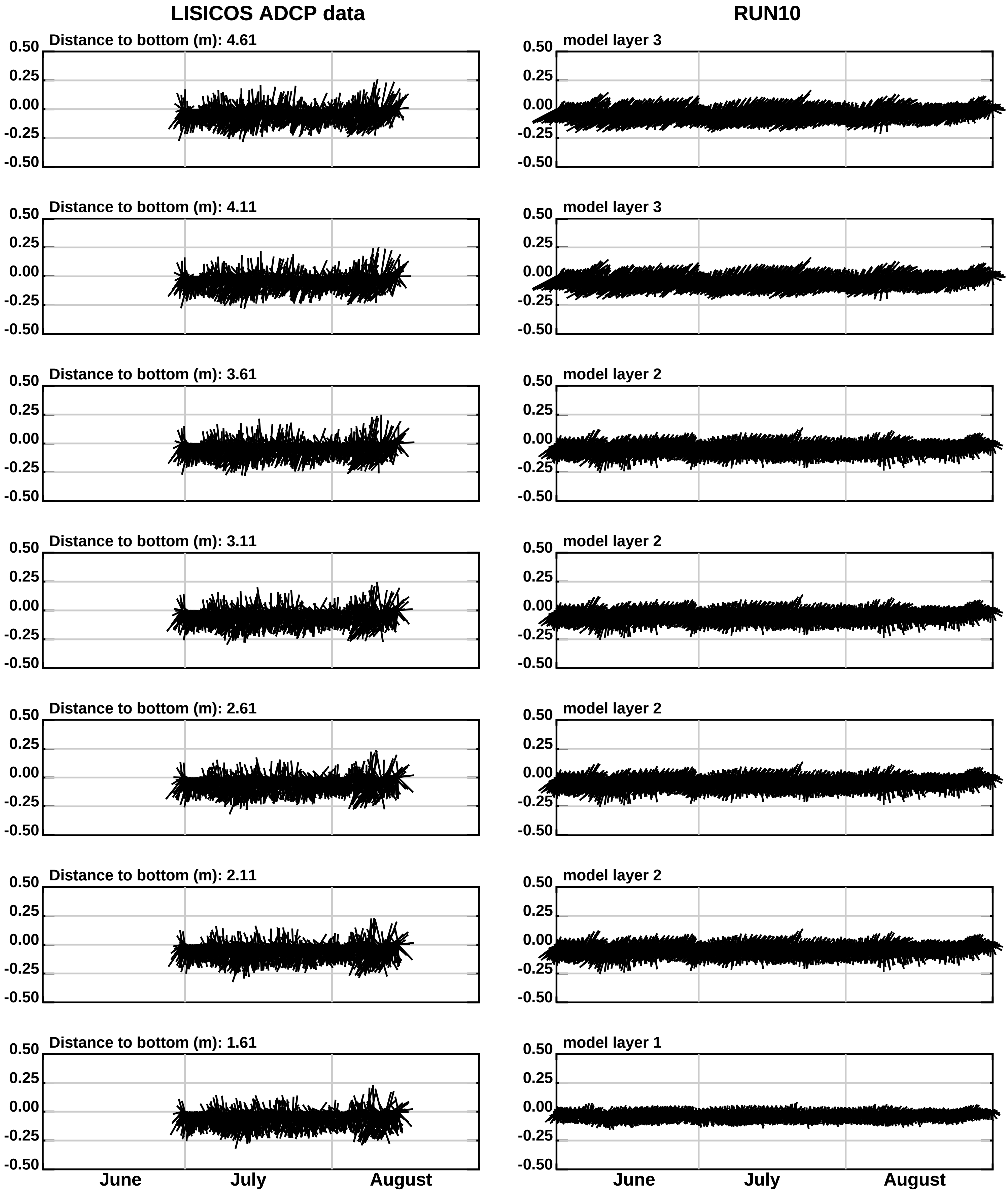
Velocity (m/s)

EXRCK001



2006

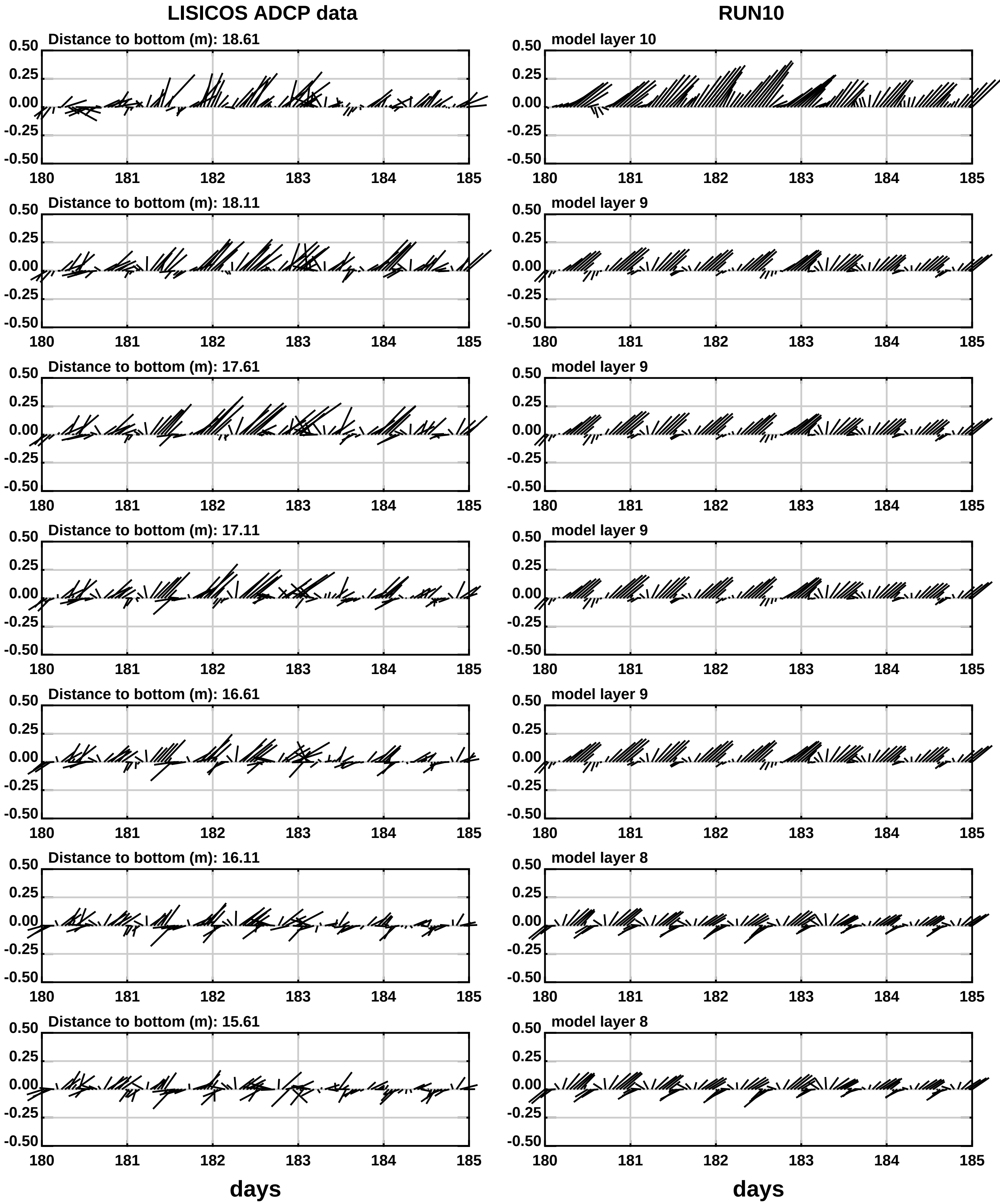
Velocity (m/s)
EXRCK001



2006

Velocity (m/s)

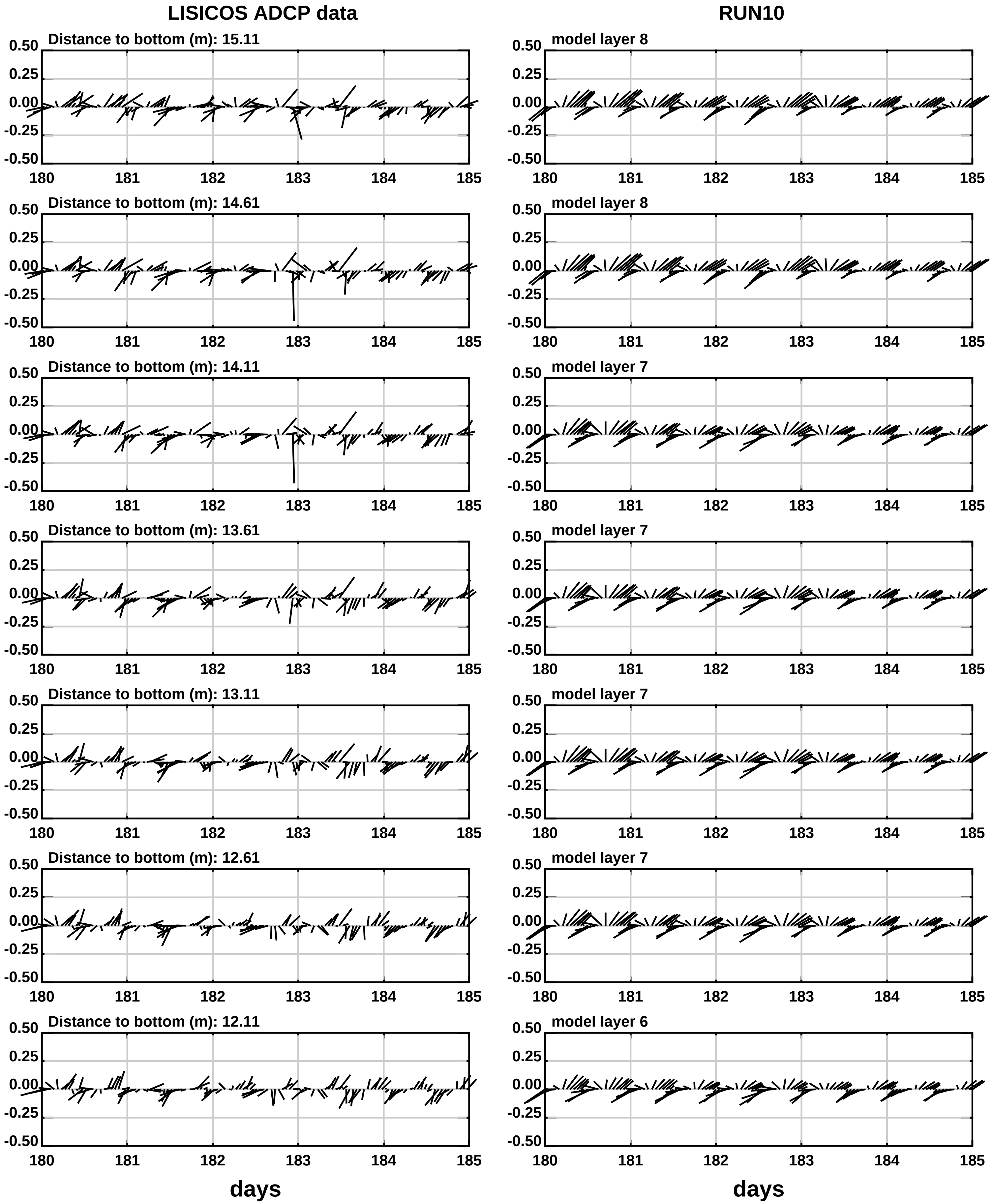
EXRCK001



2006

Day 0: Jan 1, 2006

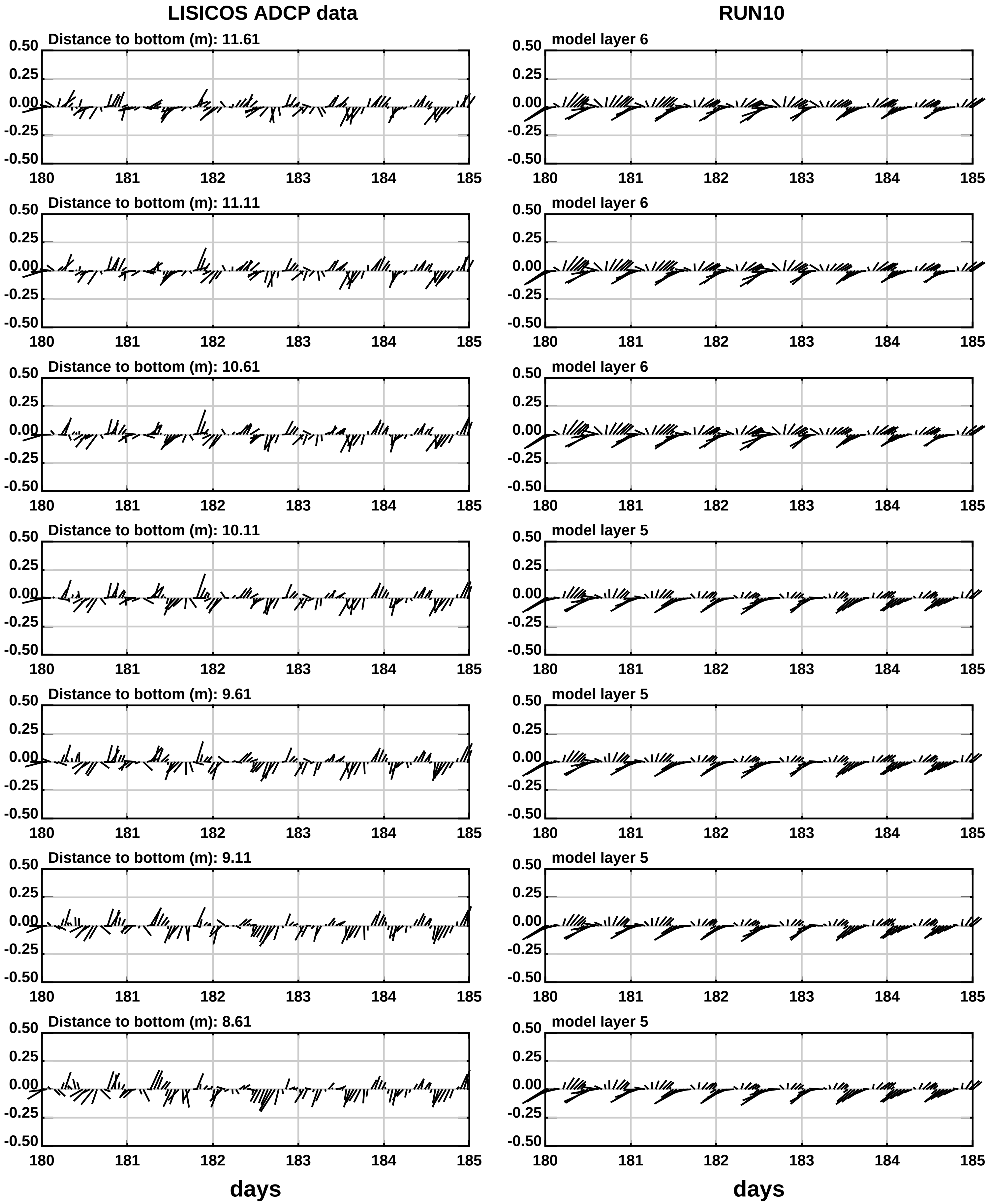
Velocity (m/s)
EXRCK001



2006

Day 0: Jan 1, 2006

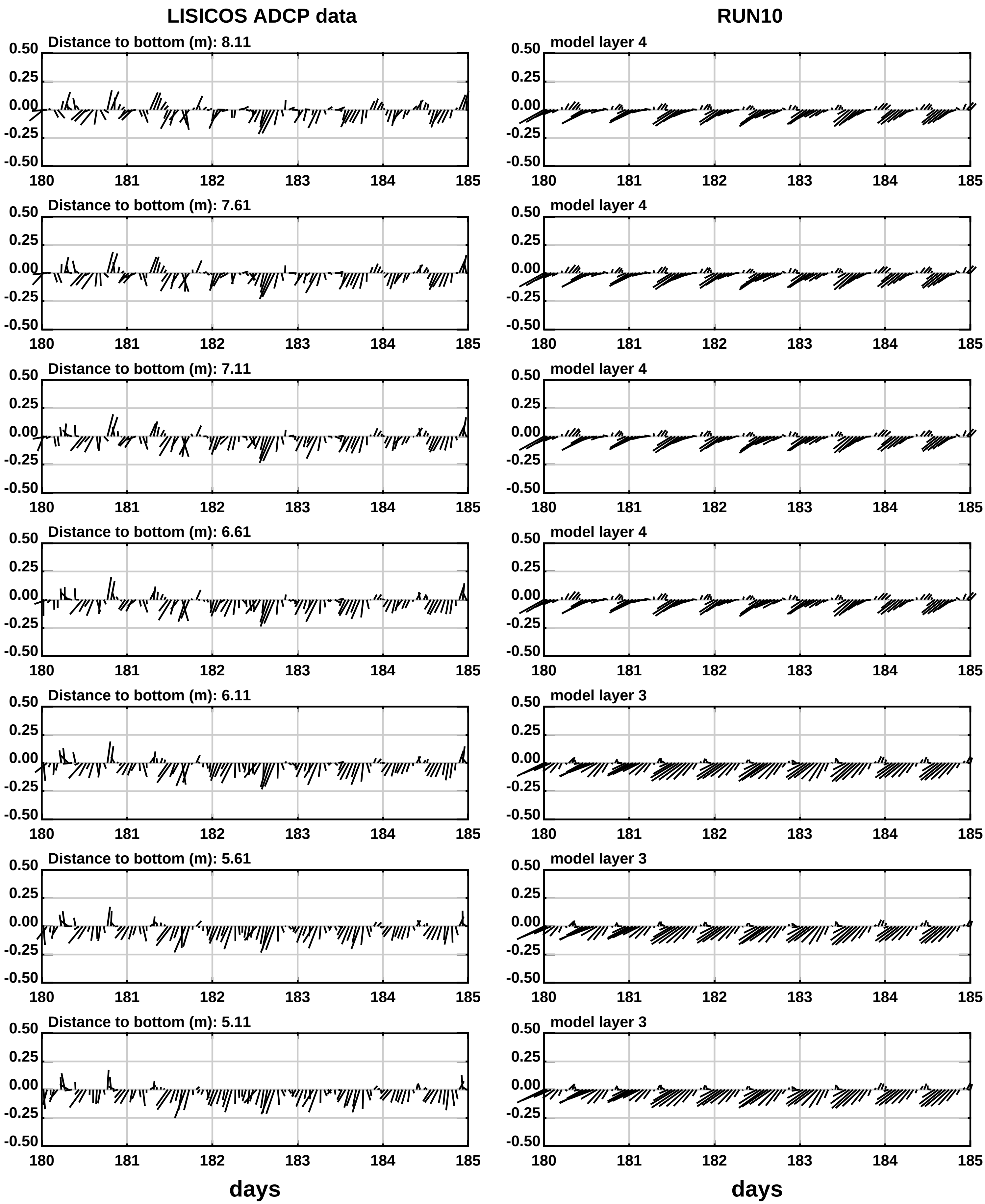
Velocity (m/s)
EXRCK001



2006

Day 0: Jan 1, 2006

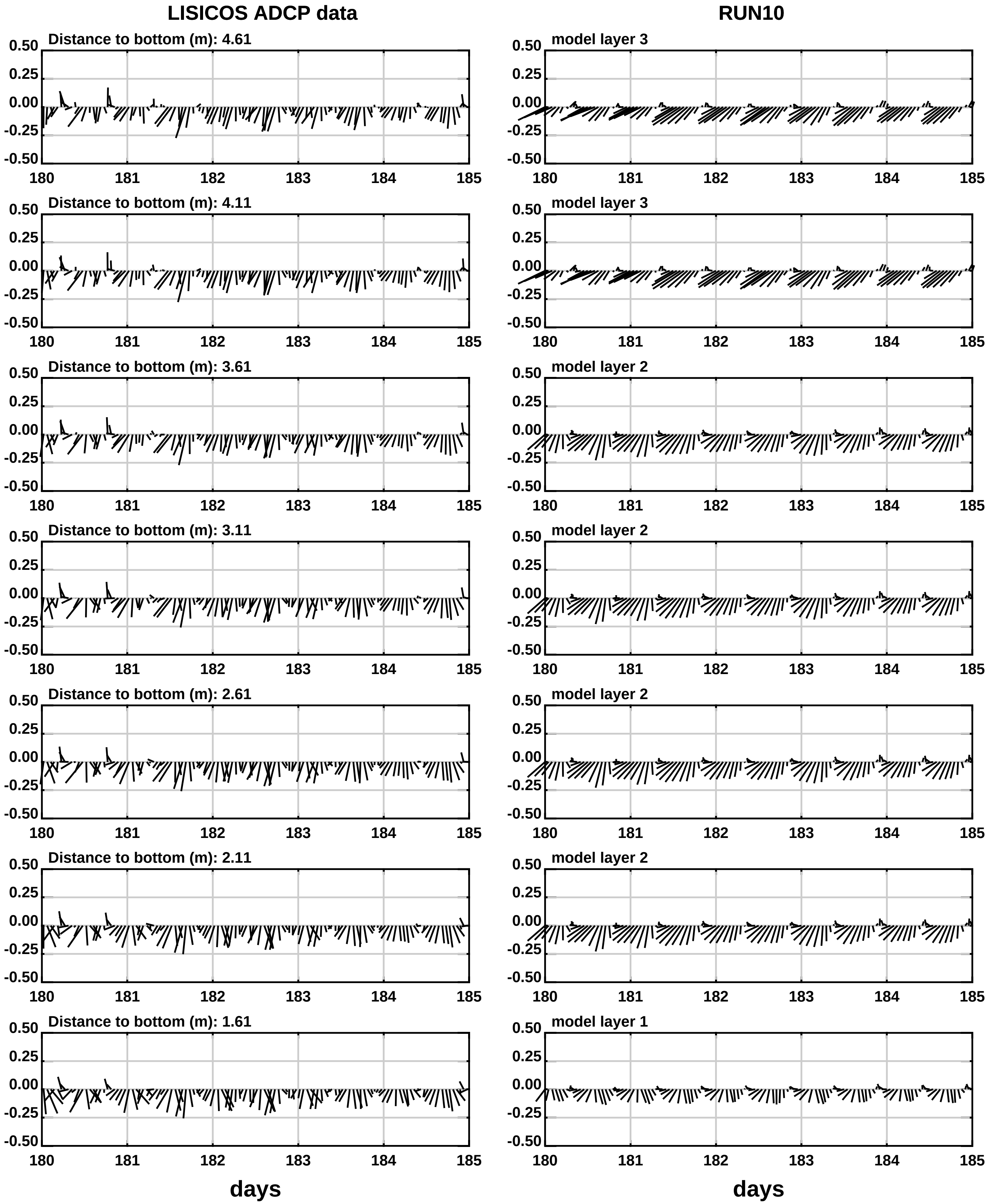
Velocity (m/s)
EXRCK001



2006

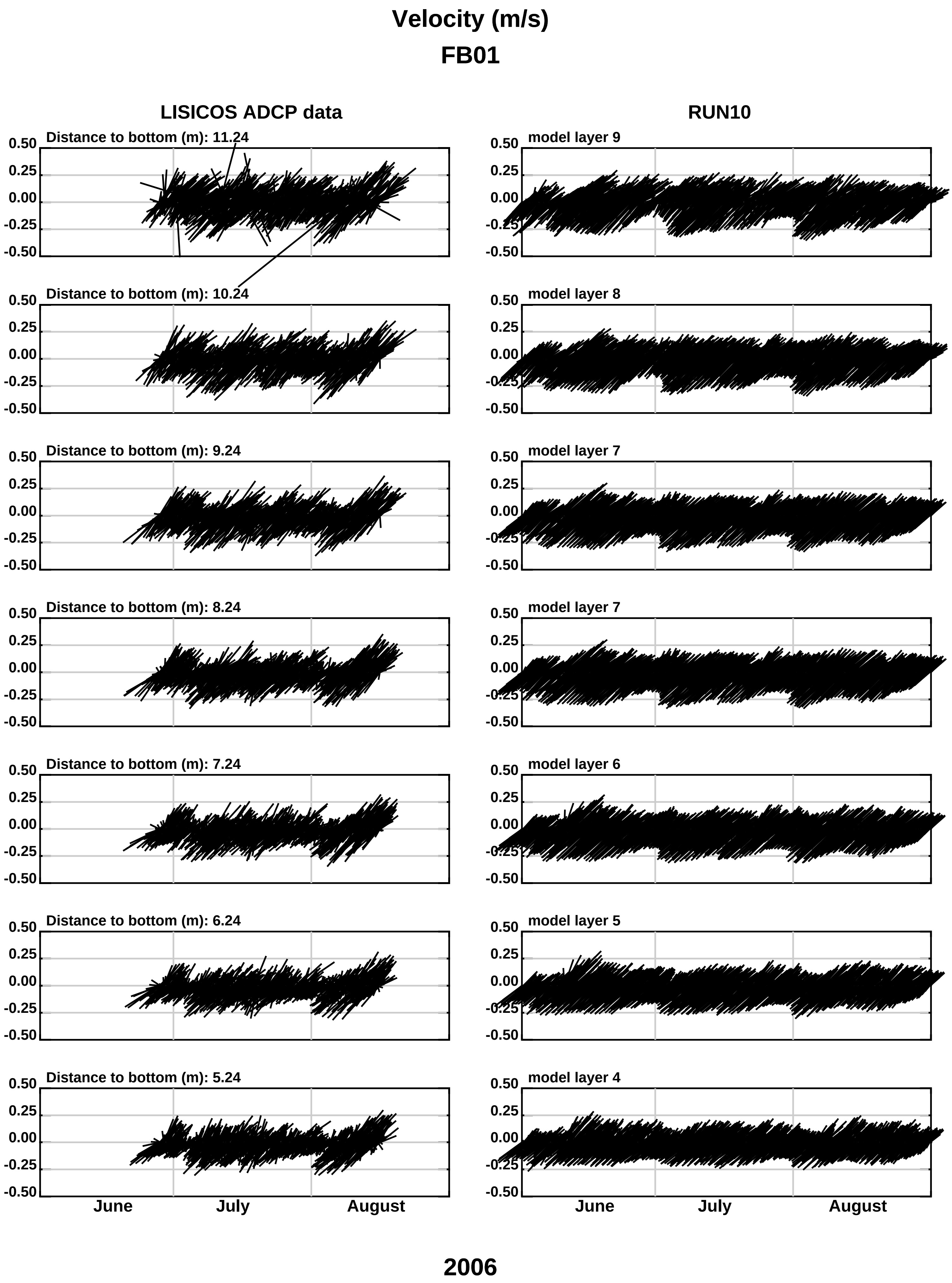
Day 0: Jan 1, 2006

Velocity (m/s)
EXRCK001



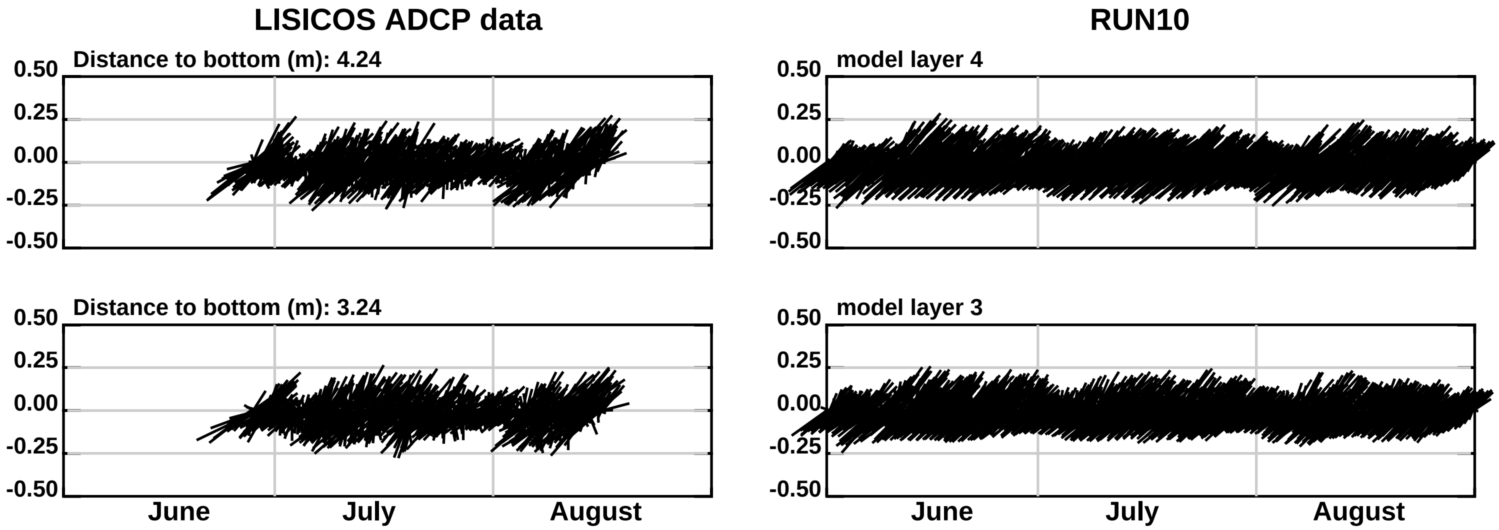
2006

Day 0: Jan 1, 2006

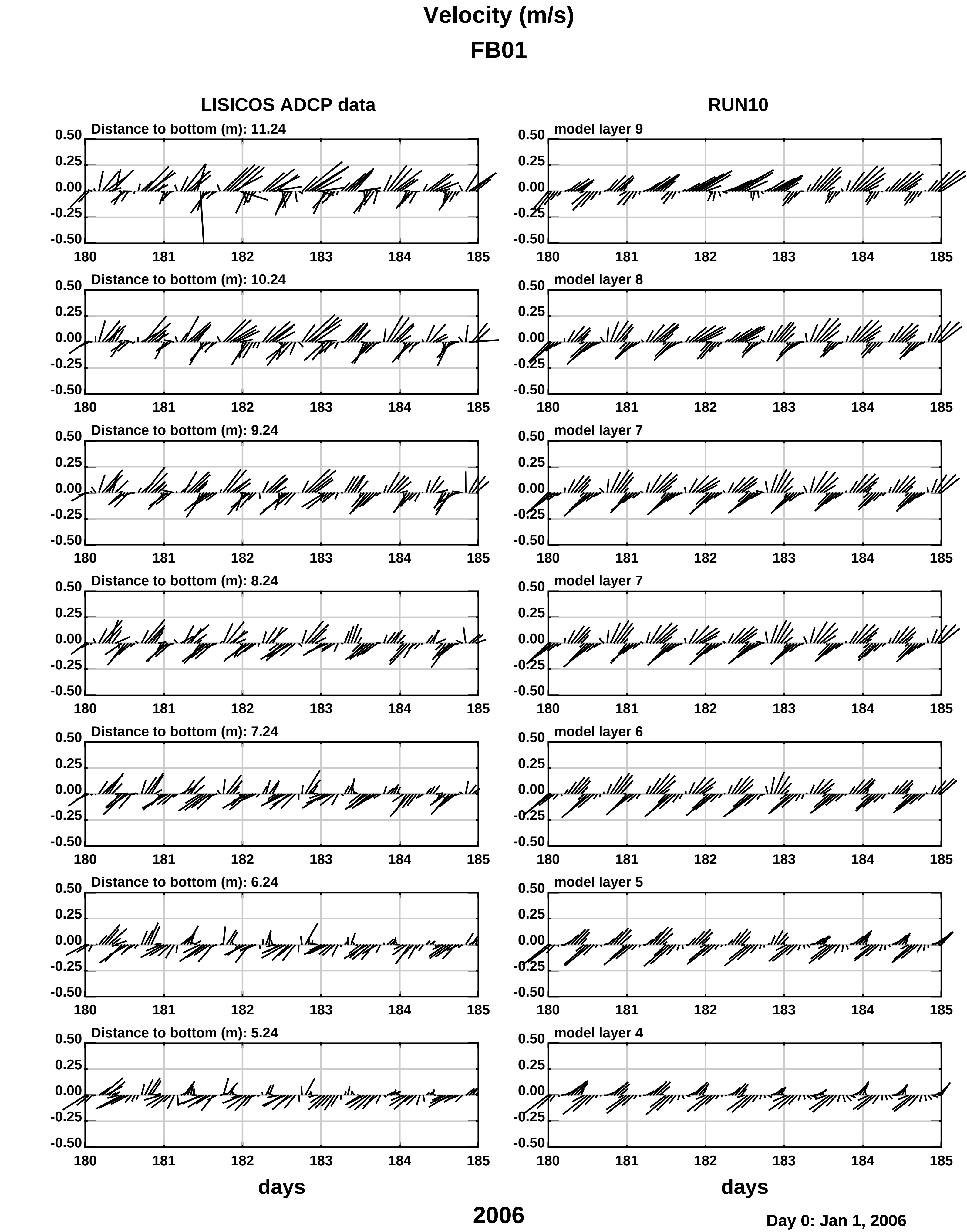


Velocity (m/s)
FB01
LISICOS ADCP data
RUN10
Distance to bottom (m): 11.24
Distance to bottom (m): 10.24
Distance to bottom (m): 9.24
Distance to bottom (m): 8.24
Distance to bottom (m): 7.24
Distance to bottom (m): 6.24
Distance to bottom (m): 5.24
model layer 9
model layer 8
model layer 7
model layer 7
model layer 6
model layer 5
model layer 4
0.50
0.25
0.00
-0.25
-0.50
June
July
August
2006

Velocity (m/s)
FB01

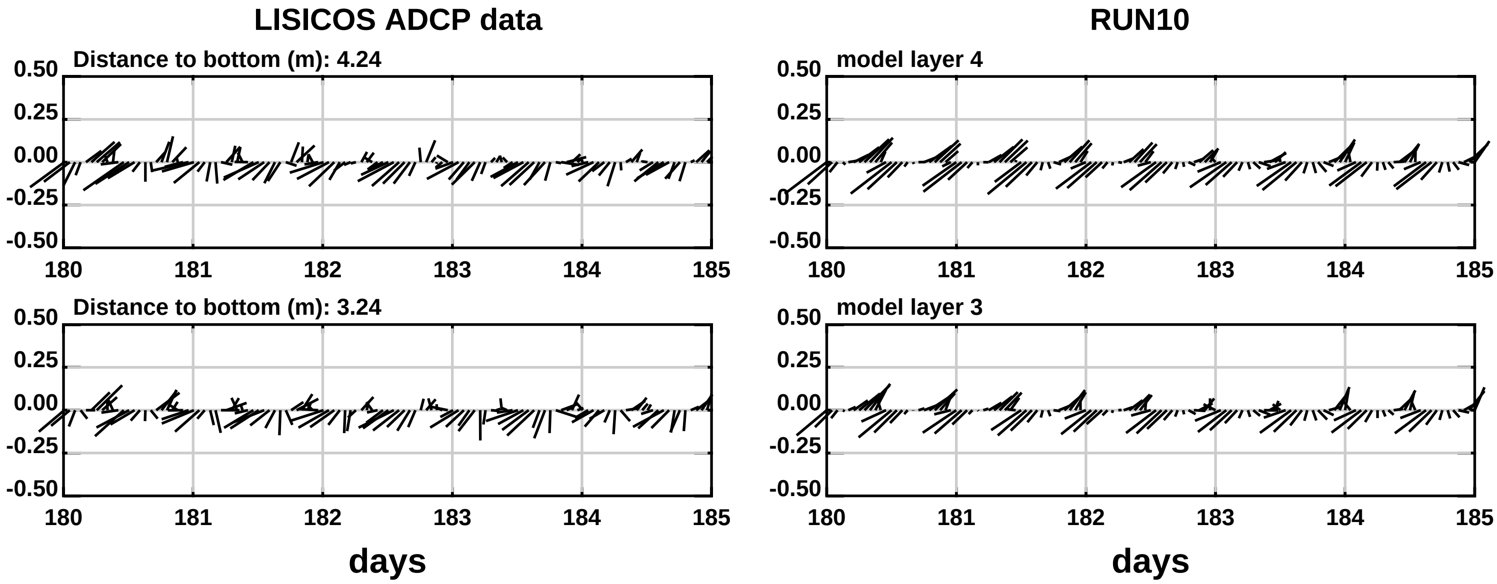


2006



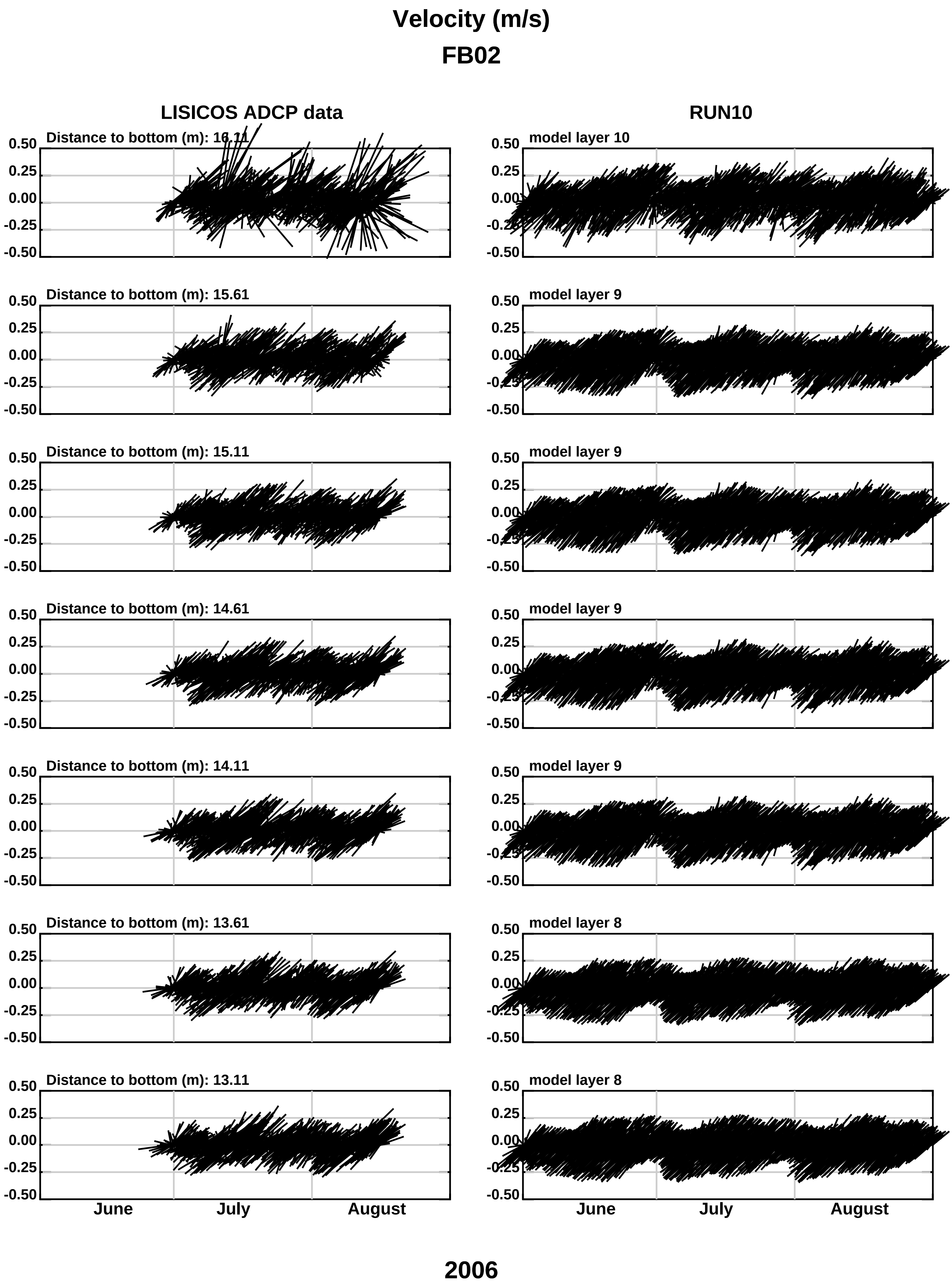
Velocity (m/s)
FB01
LISICOS ADCP data
RUN10
Distance to bottom (m): 11.24
model layer 9
Distance to bottom (m): 10.24
model layer 8
Distance to bottom (m): 9.24
model layer 7
Distance to bottom (m): 8.24
model layer 7
Distance to bottom (m): 7.24
model layer 6
Distance to bottom (m): 6.24
model layer 5
Distance to bottom (m): 5.24
model layer 4
0.50
0.25
0.00
-0.25
-0.50
180
181
182
183
184
185
days
days
2006
Day 0: Jan 1, 2006

Velocity (m/s)
FB01



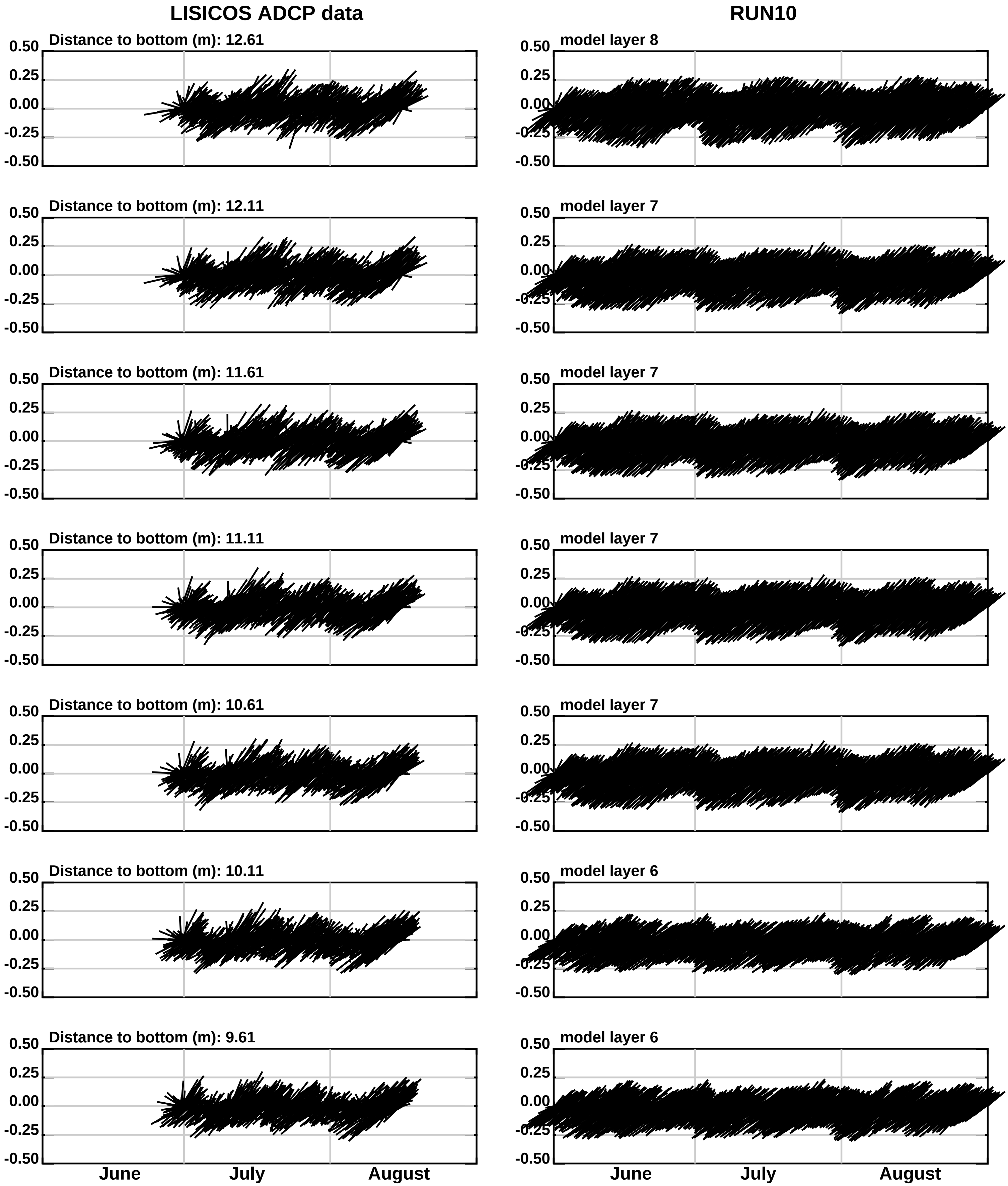
2006

Day 0: Jan 1, 2006

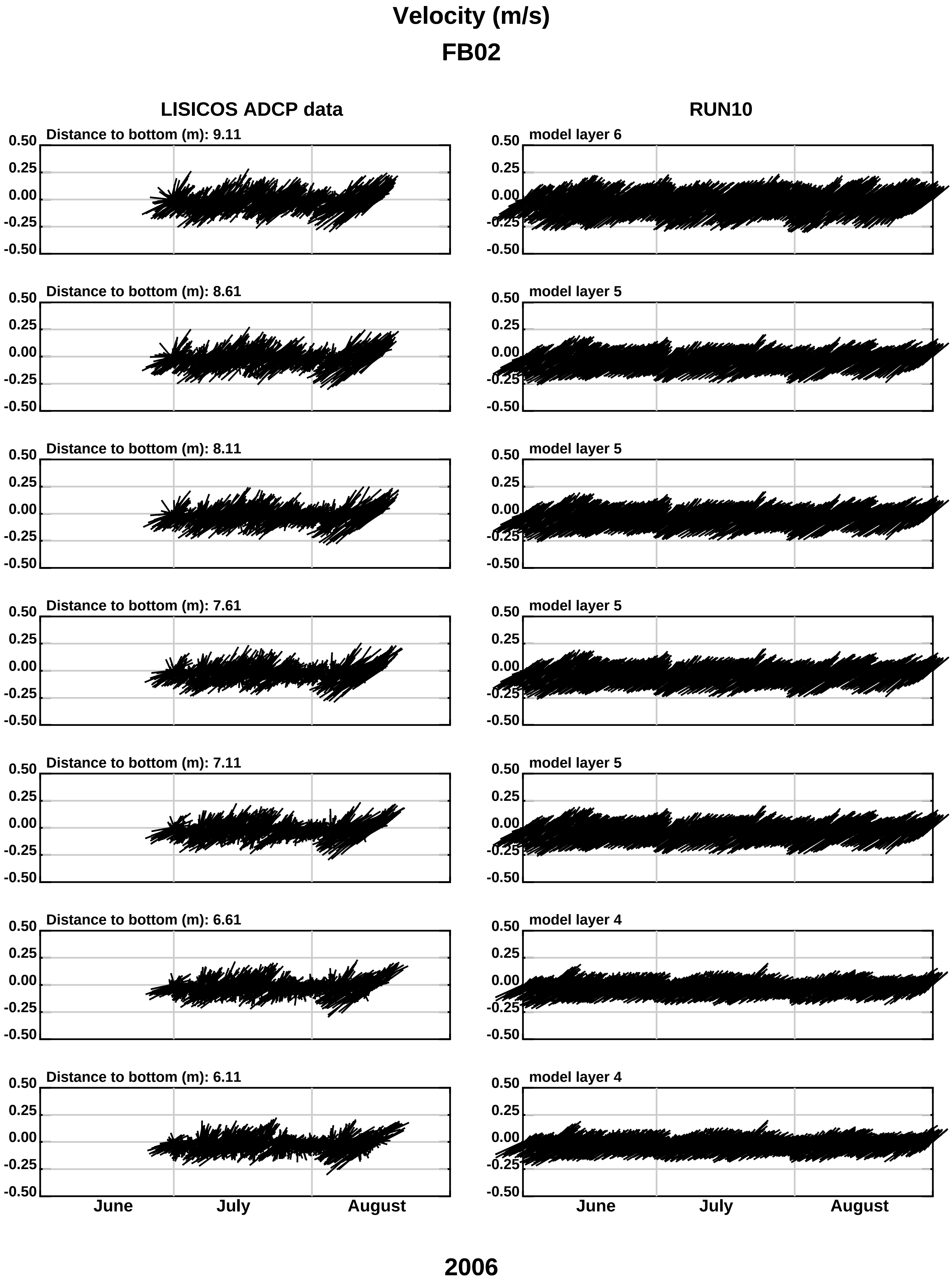

Velocity (m/s)
FB02
LISICOS ADCP data
RUN10
Distance to bottom (m): 16.11
Distance to bottom (m): 15.61
Distance to bottom (m): 15.11
Distance to bottom (m): 14.61
Distance to bottom (m): 14.11
Distance to bottom (m): 13.61
Distance to bottom (m): 13.11
model layer 10
model layer 9
model layer 9
model layer 9
model layer 9
model layer 8
model layer 8
0.50
0.25
0.00
-0.25
-0.50
June
July
August
2006

Velocity (m/s)

FB02

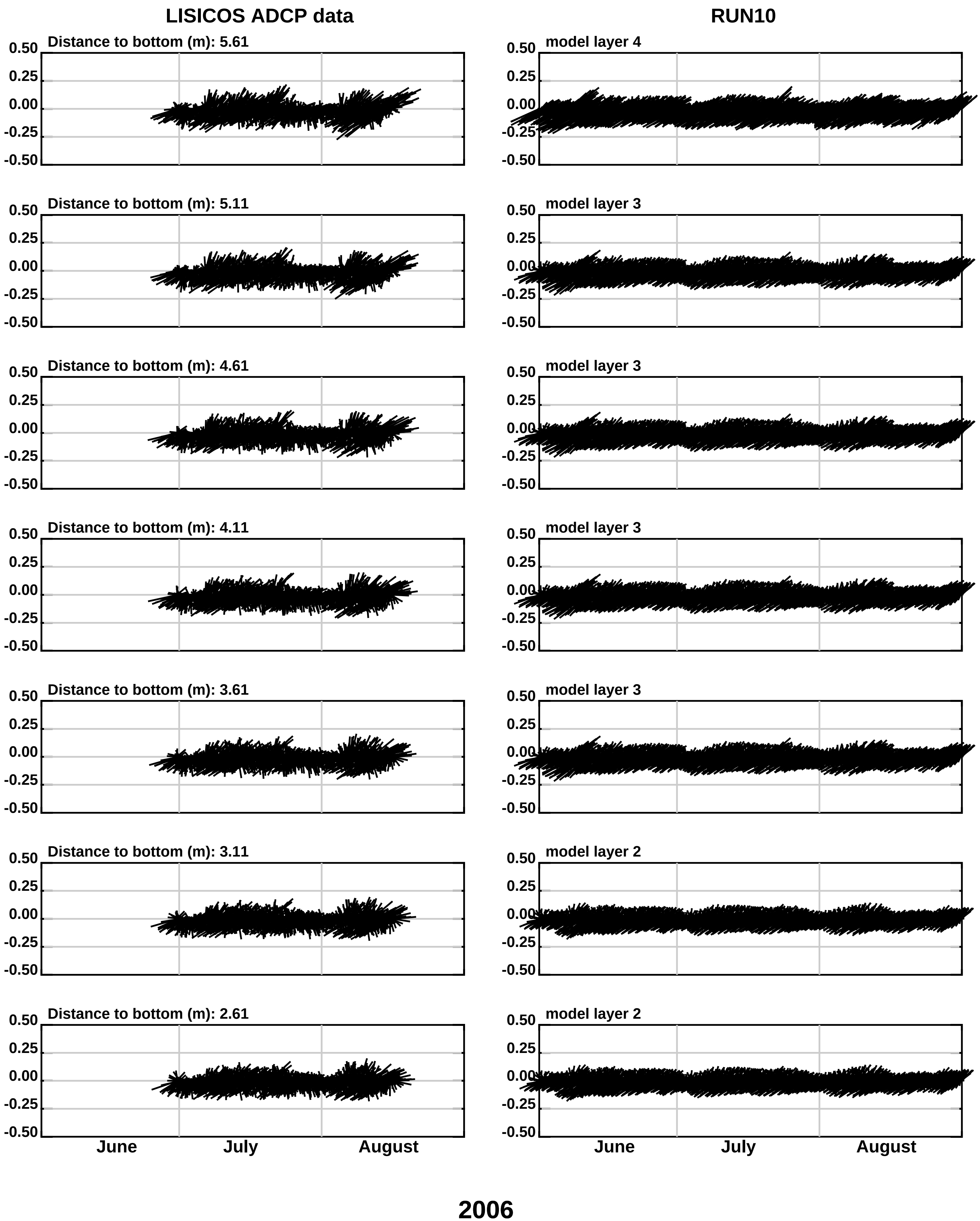


2006

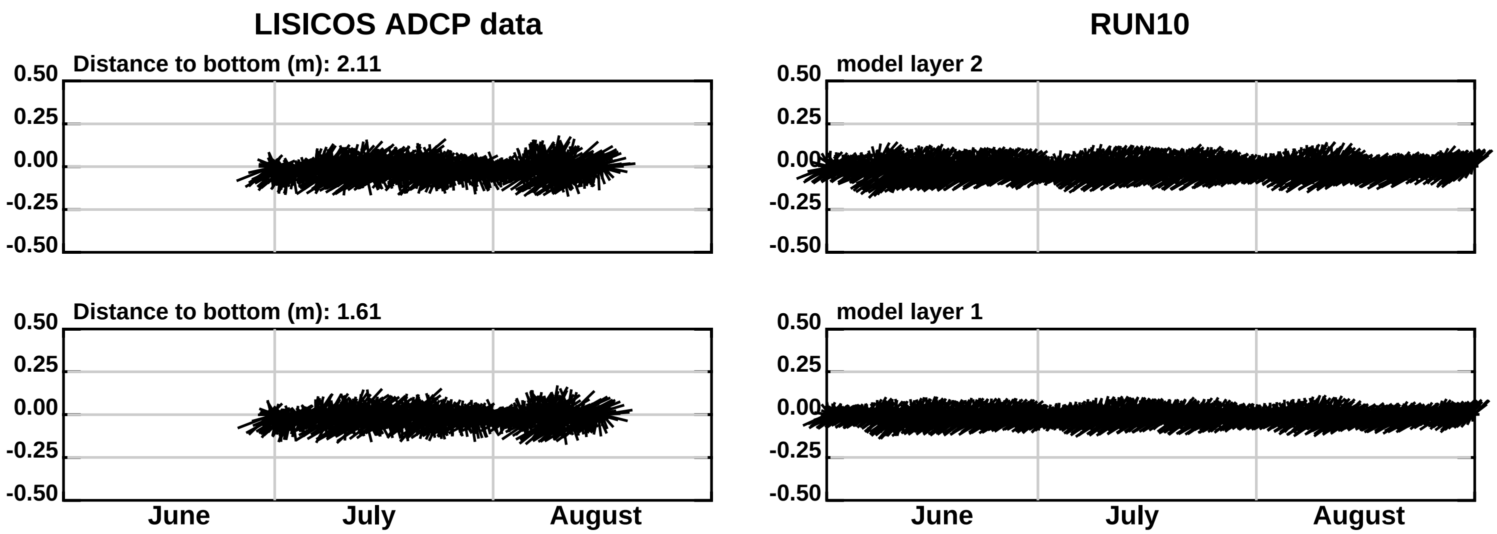

Velocity (m/s)
FB02
LISICOS ADCP data
RUN10
Distance to bottom (m): 9.11
model layer 6
Distance to bottom (m): 8.61
model layer 5
Distance to bottom (m): 8.11
model layer 5
Distance to bottom (m): 7.61
model layer 5
Distance to bottom (m): 7.11
model layer 5
Distance to bottom (m): 6.61
model layer 4
Distance to bottom (m): 6.11
model layer 4
0.50
0.25
0.00
-0.25
-0.50
June
July
August
2006

Velocity (m/s)

FB02



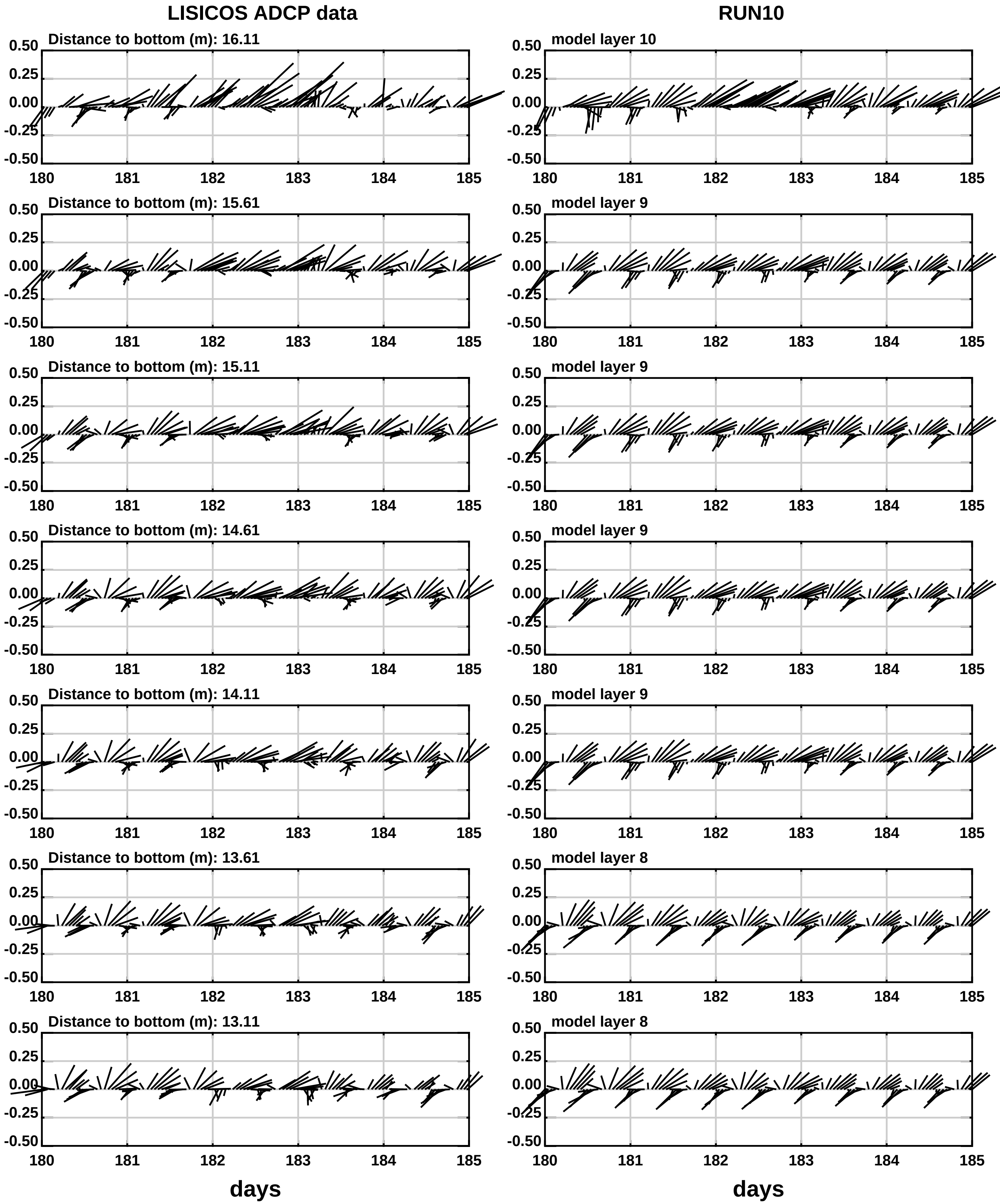
Velocity (m/s)
FB02



2006

Velocity (m/s)

FB02

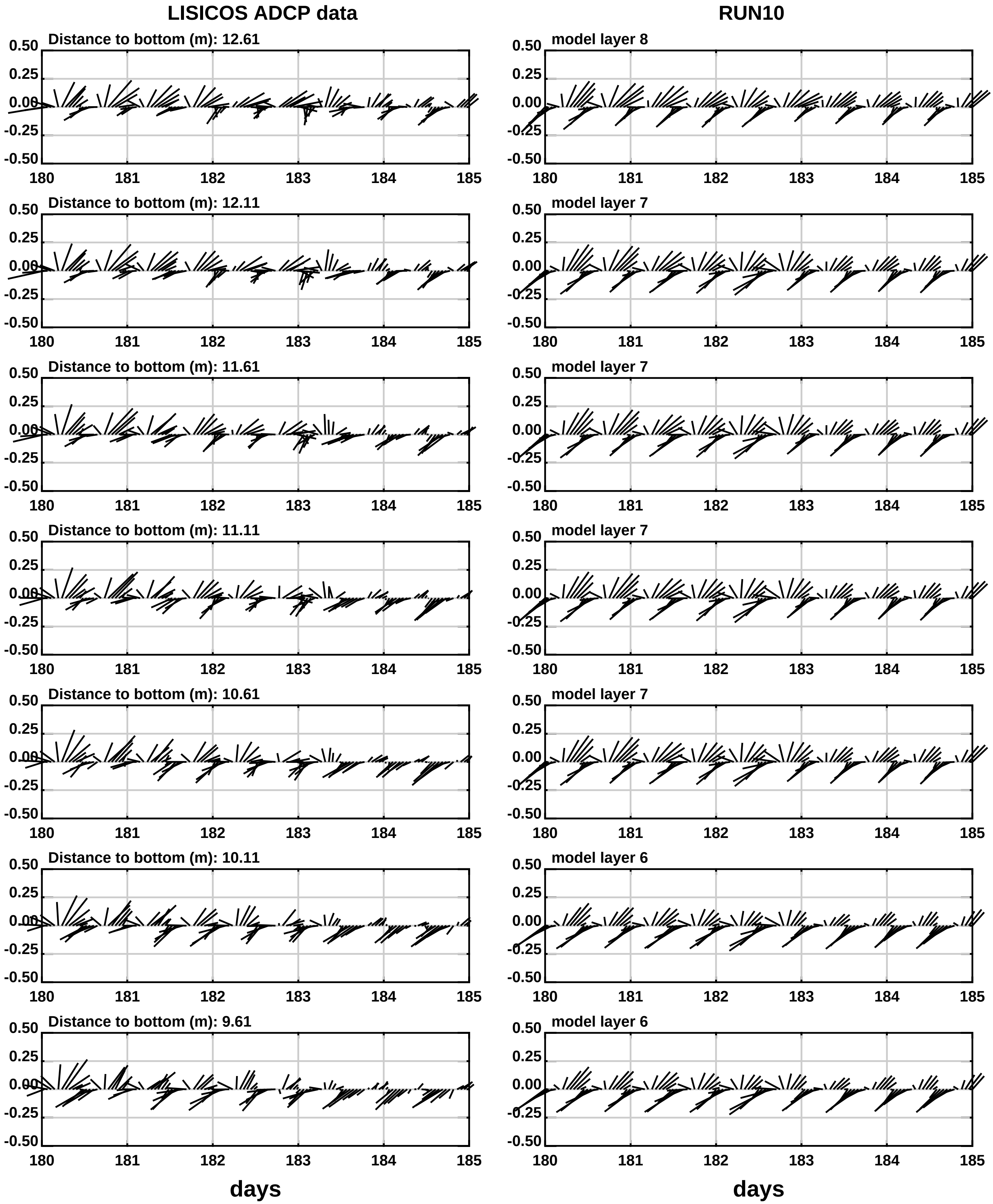


2006

Day 0: Jan 1, 2006

Velocity (m/s)

FB02

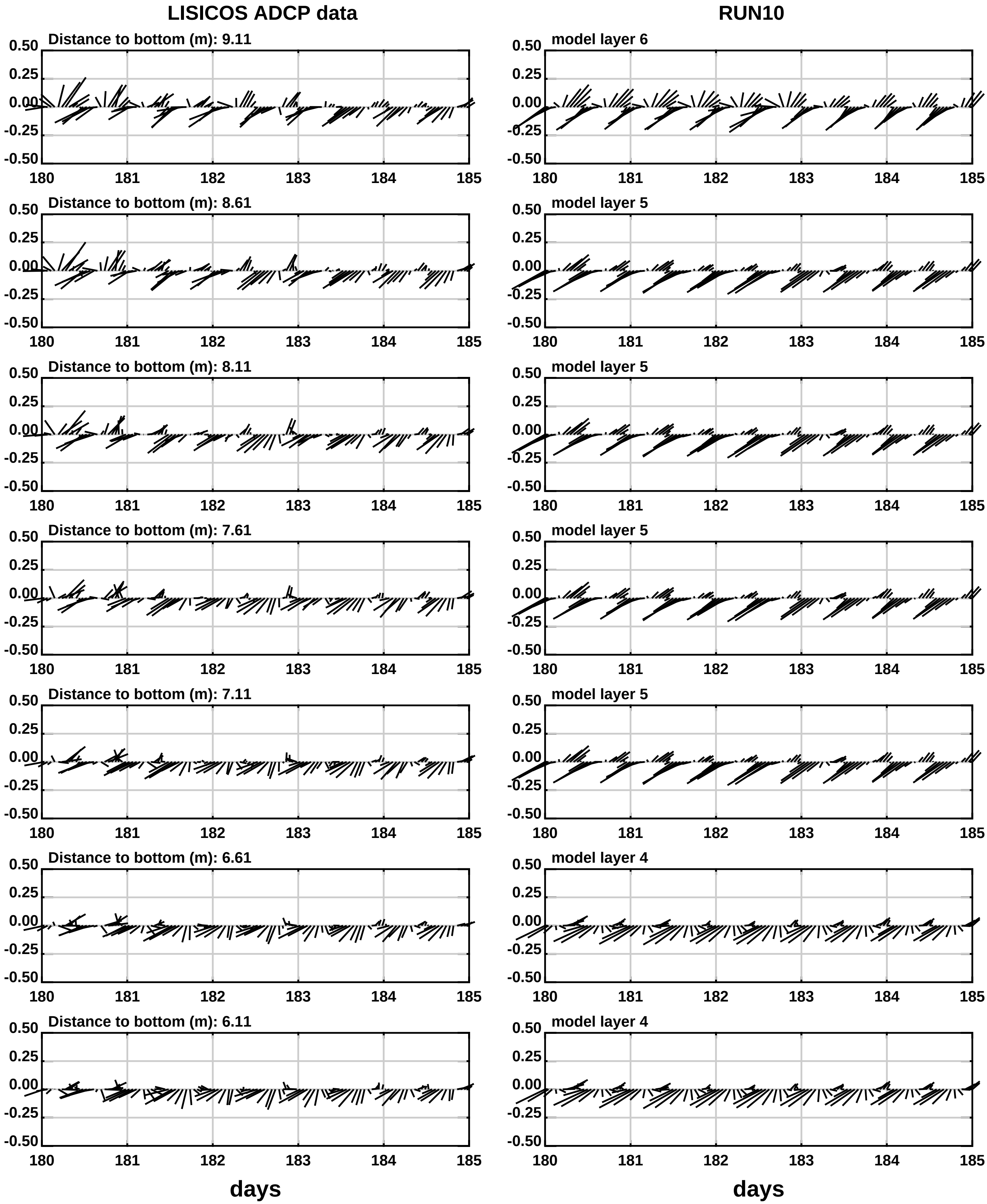


2006

Day 0: Jan 1, 2006

Velocity (m/s)

FB02

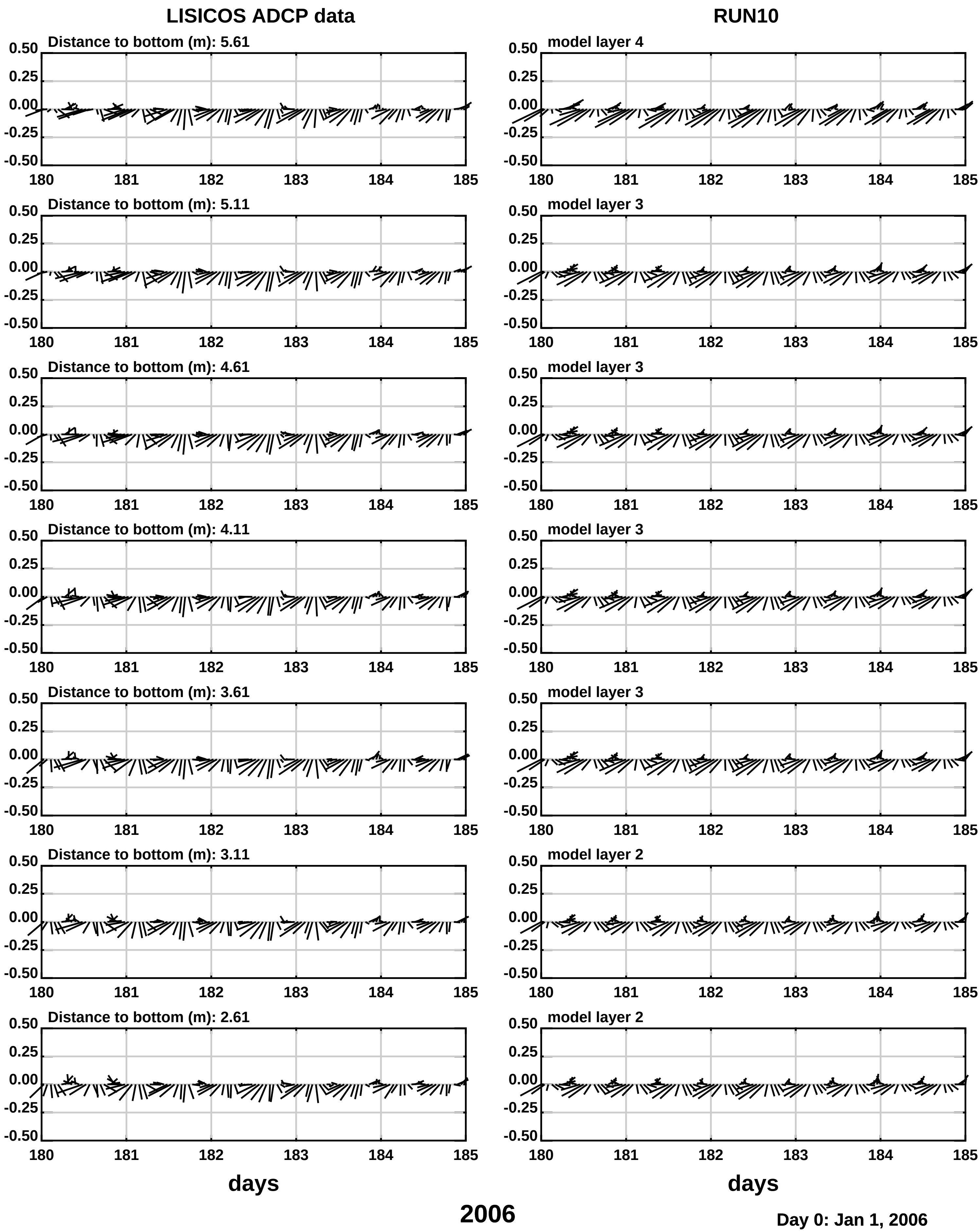


2006

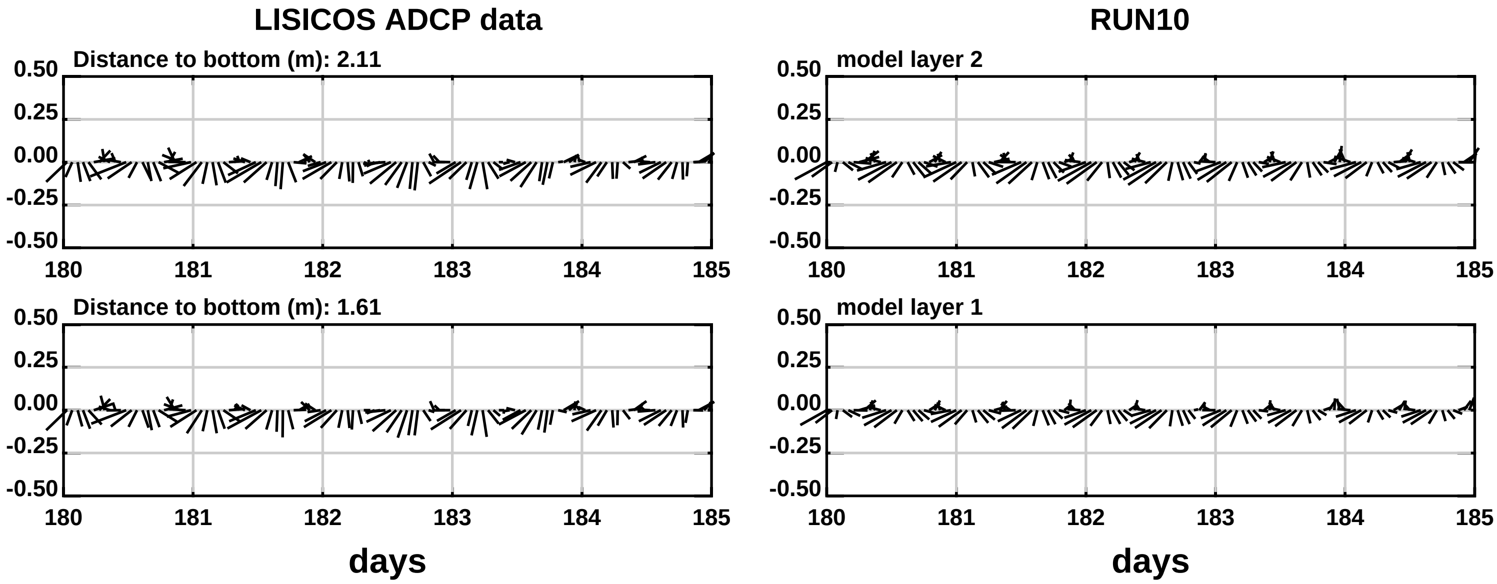
Day 0: Jan 1, 2006

Velocity (m/s)

FB02

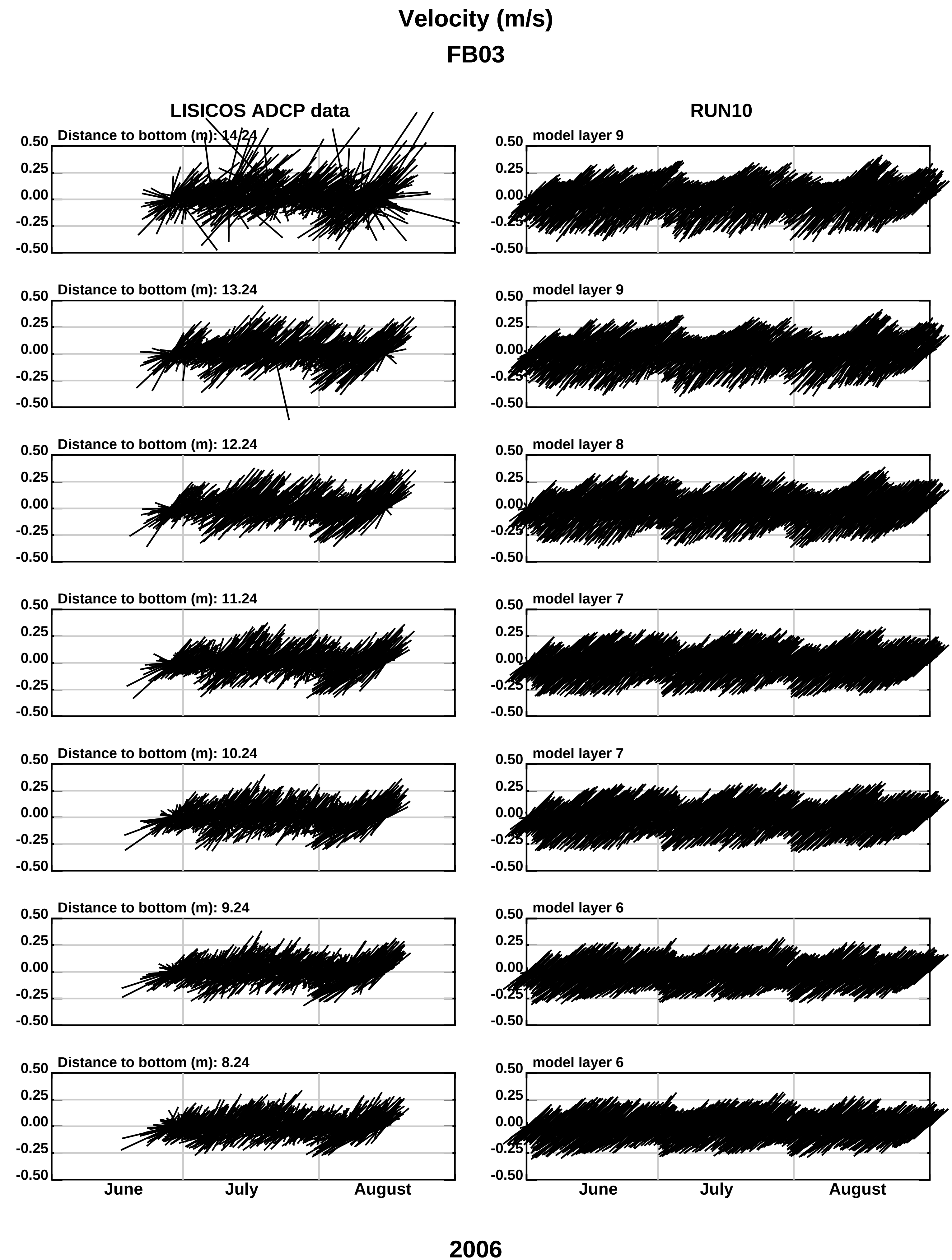


Velocity (m/s)
FB02



2006

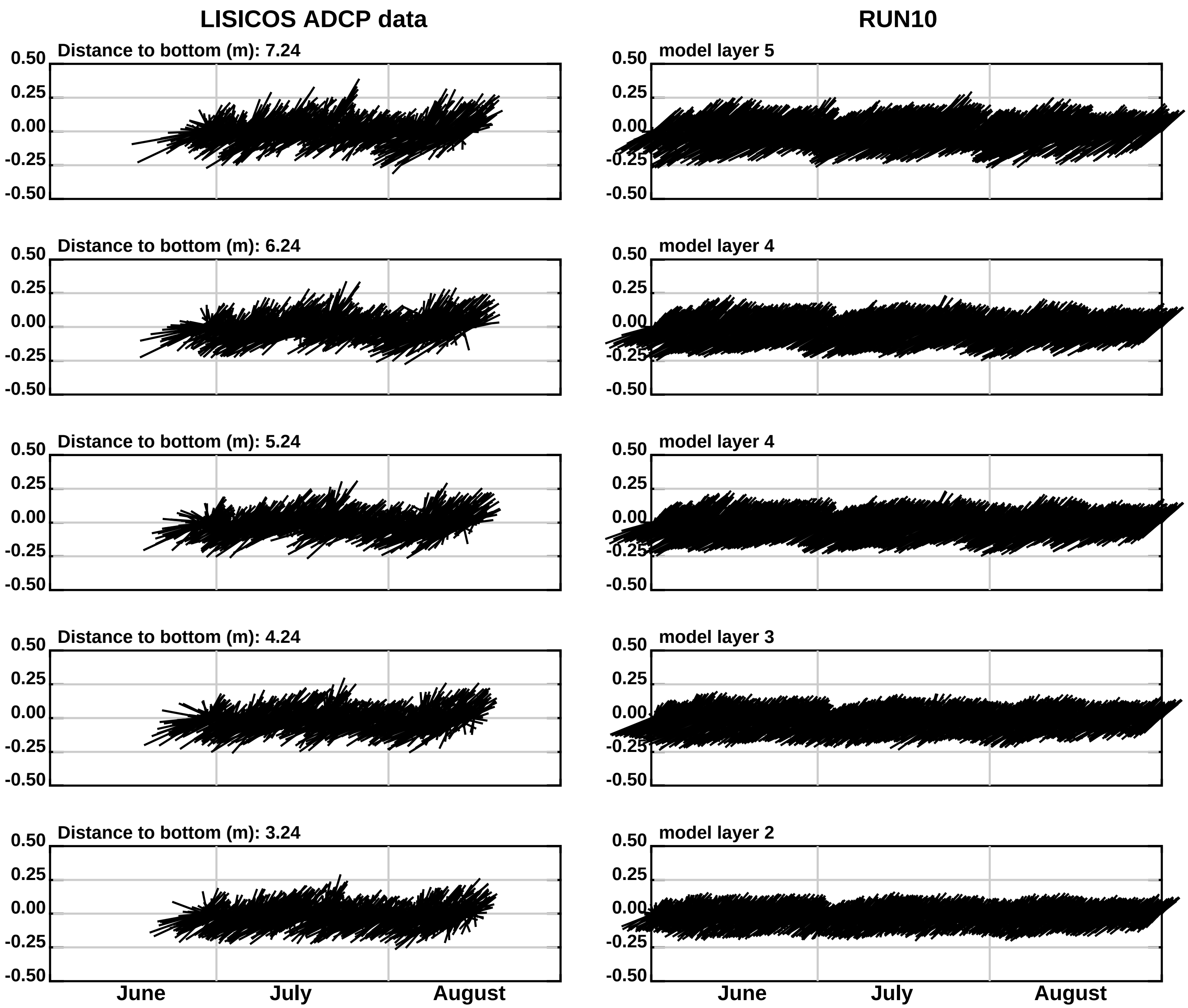
Day 0: Jan 1, 2006



Velocity (m/s)
FB03
LISICOS ADCP data
RUN10
Distance to bottom (m): 14.24
Distance to bottom (m): 13.24
Distance to bottom (m): 12.24
Distance to bottom (m): 11.24
Distance to bottom (m): 10.24
Distance to bottom (m): 9.24
Distance to bottom (m): 8.24
model layer 9
model layer 9
model layer 8
model layer 7
model layer 7
model layer 6
model layer 6
0.50
0.25
0.00
-0.25
-0.50
June
July
August
2006

Velocity (m/s)

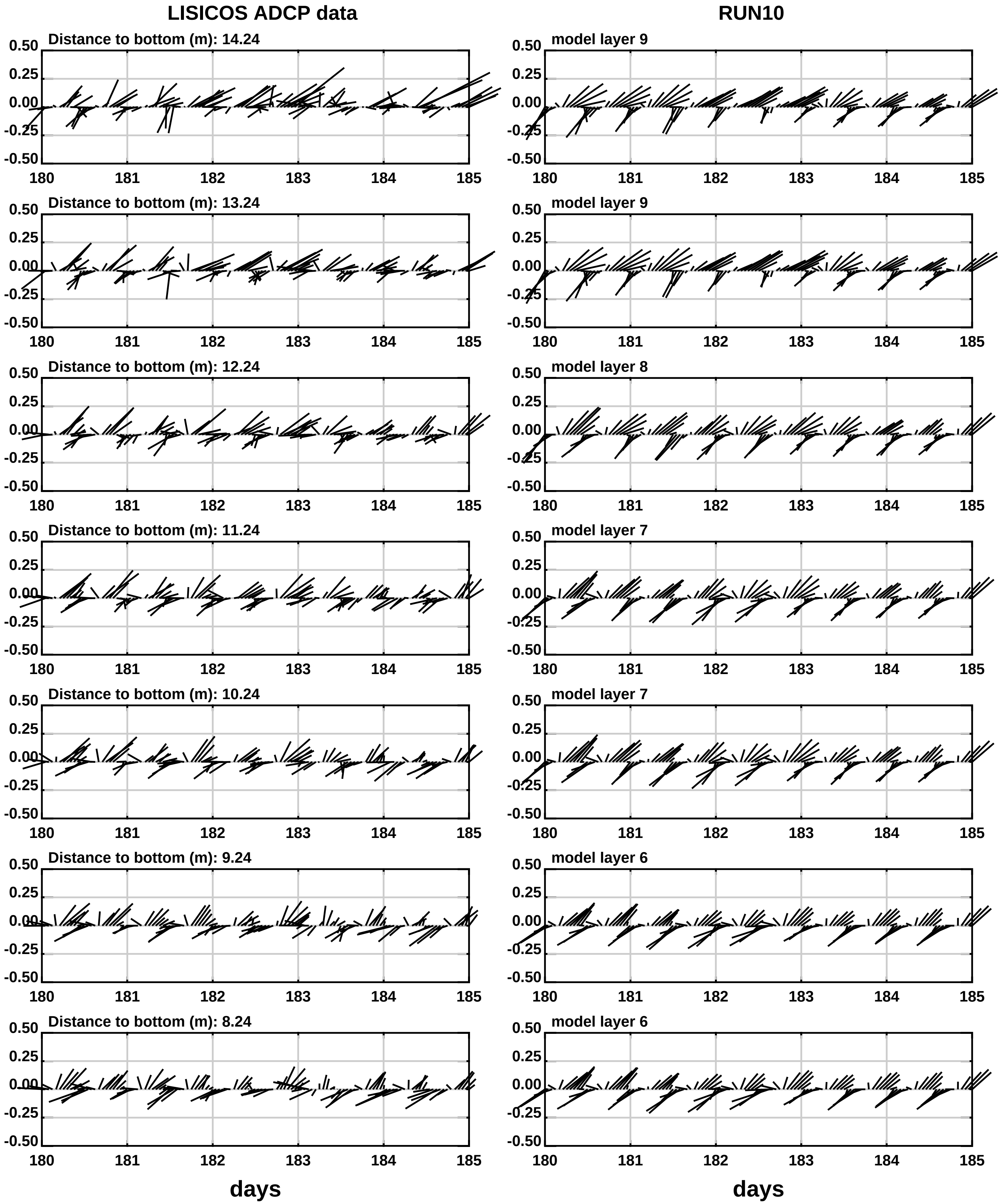
FB03



2006

Velocity (m/s)

FB03

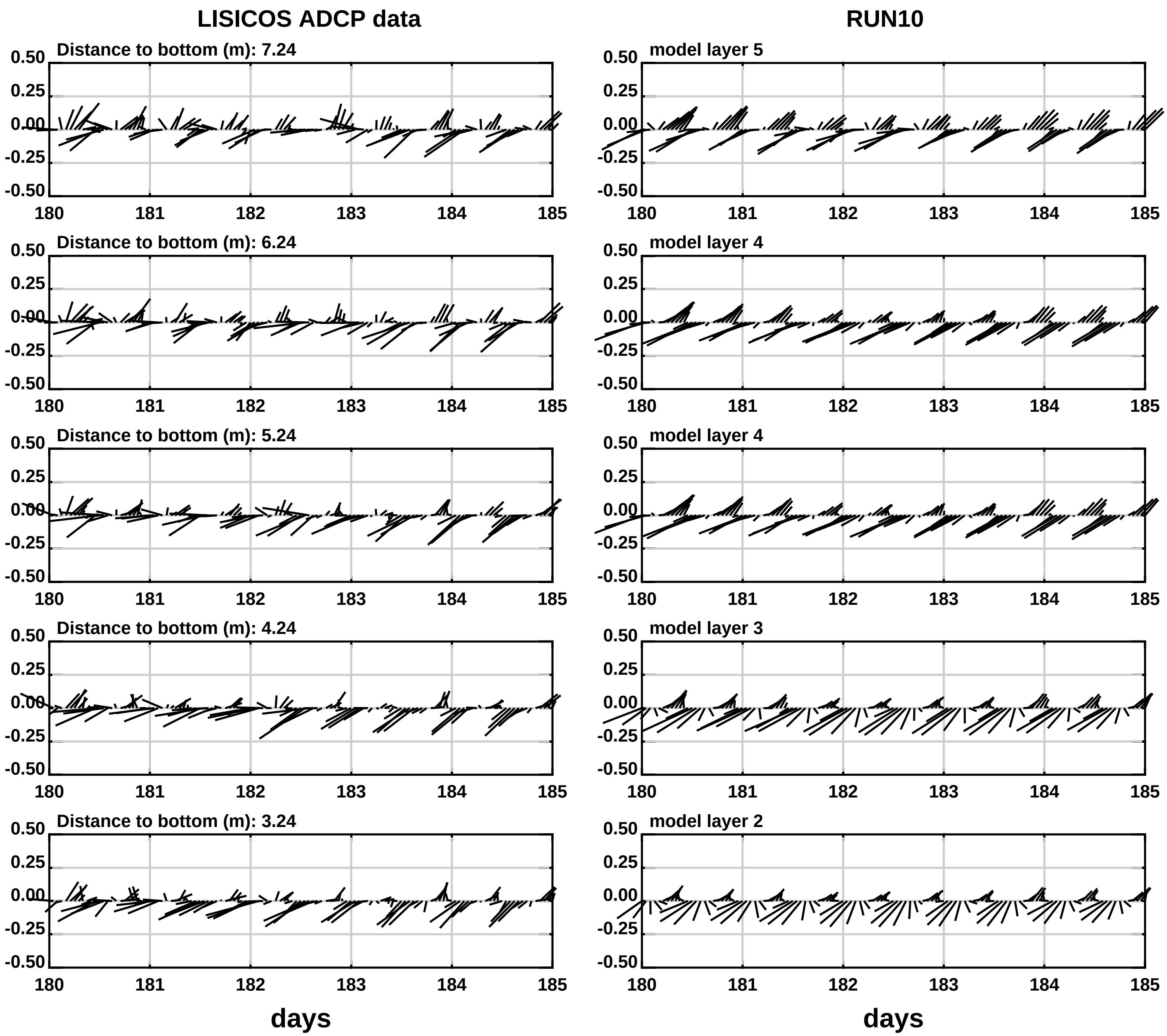


2006

Day 0: Jan 1, 2006

Velocity (m/s)

FB03



2006

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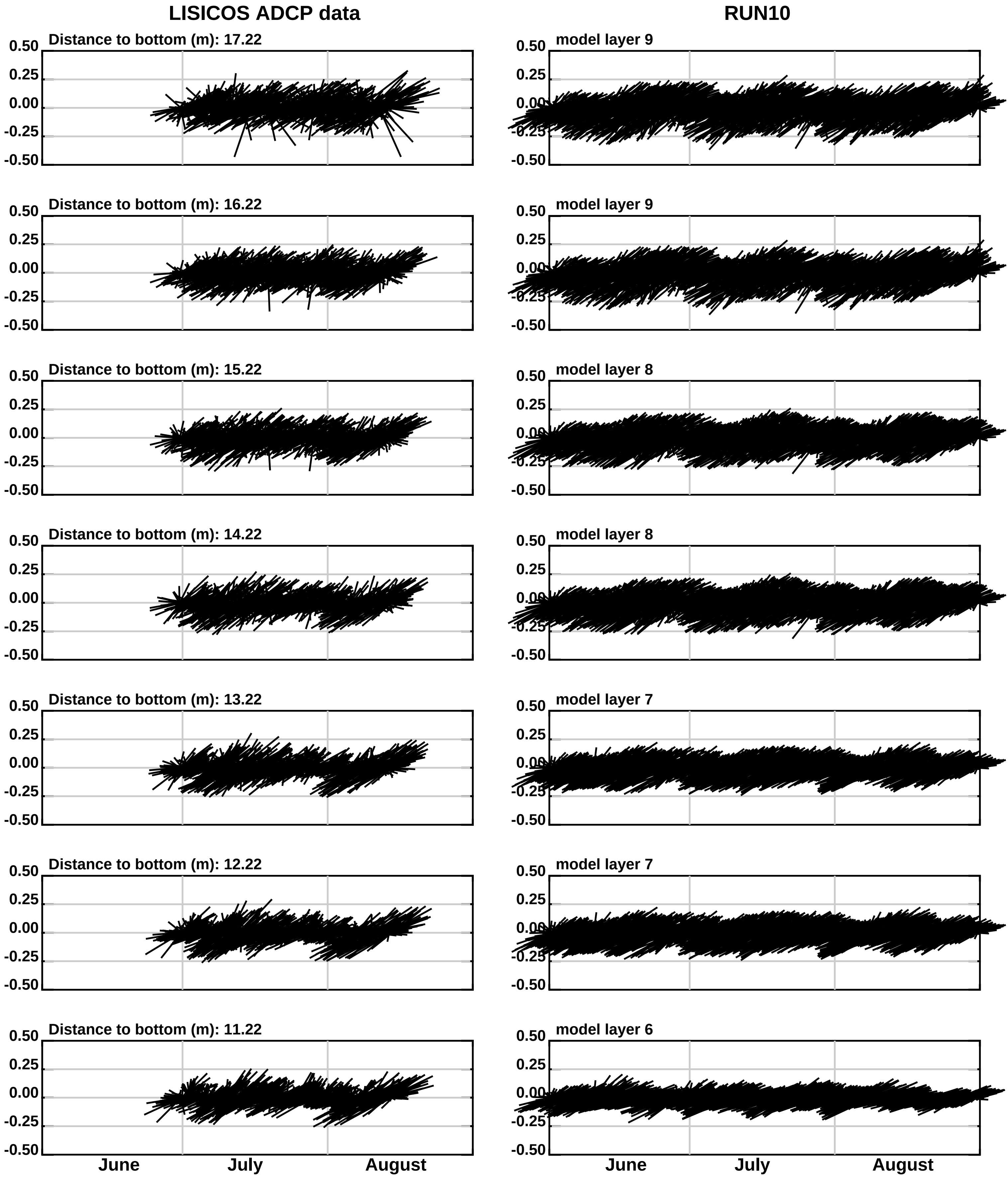
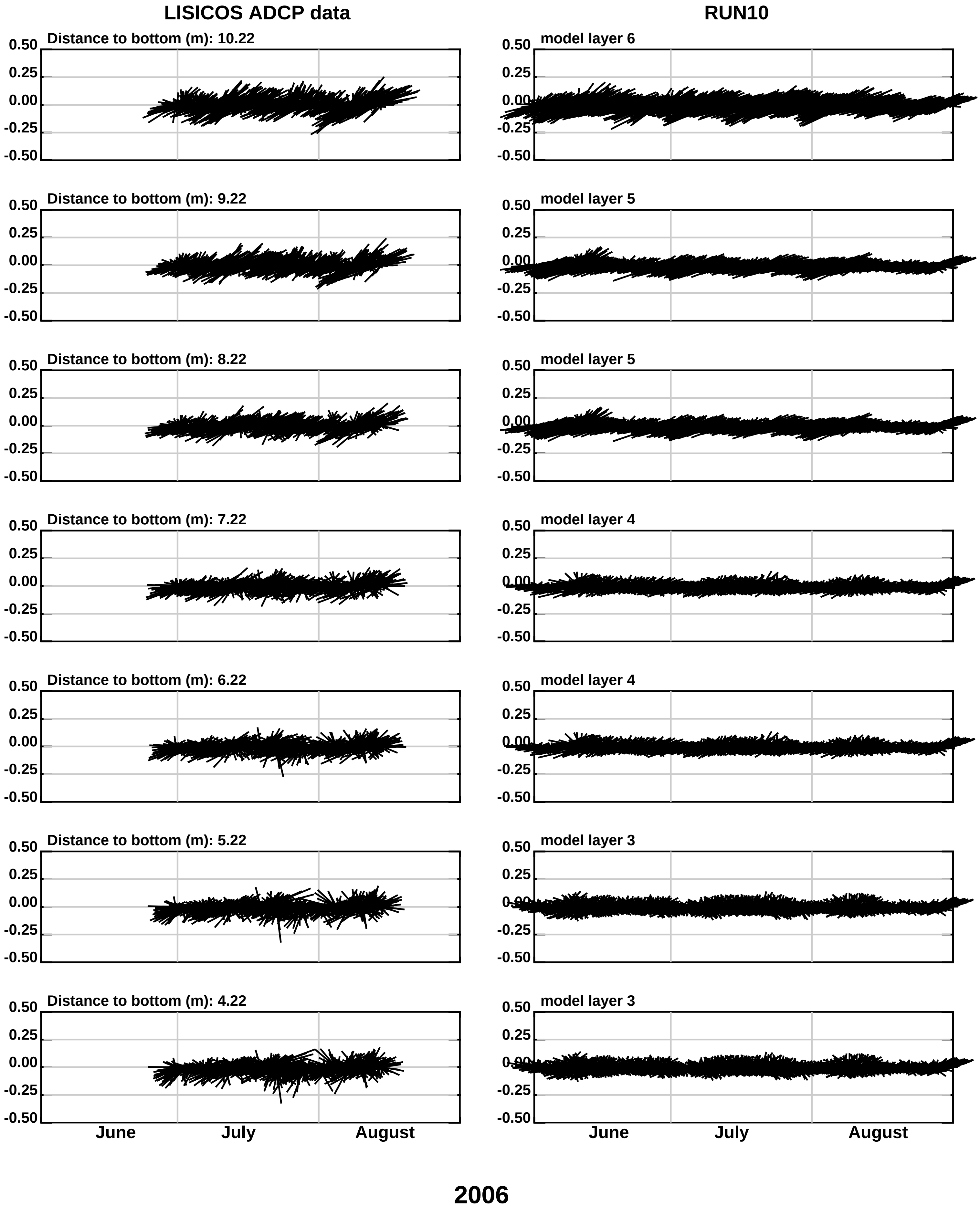
Velocity (m/s)

WLIS001



2006

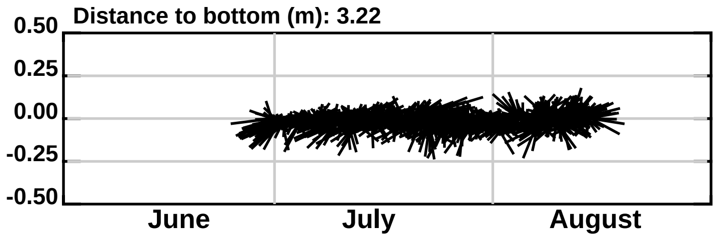
Velocity (m/s)
WLIS001



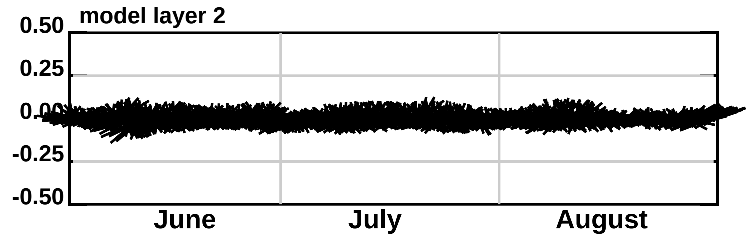
Velocity (m/s)

WLIS001

LISICOS ADCP data

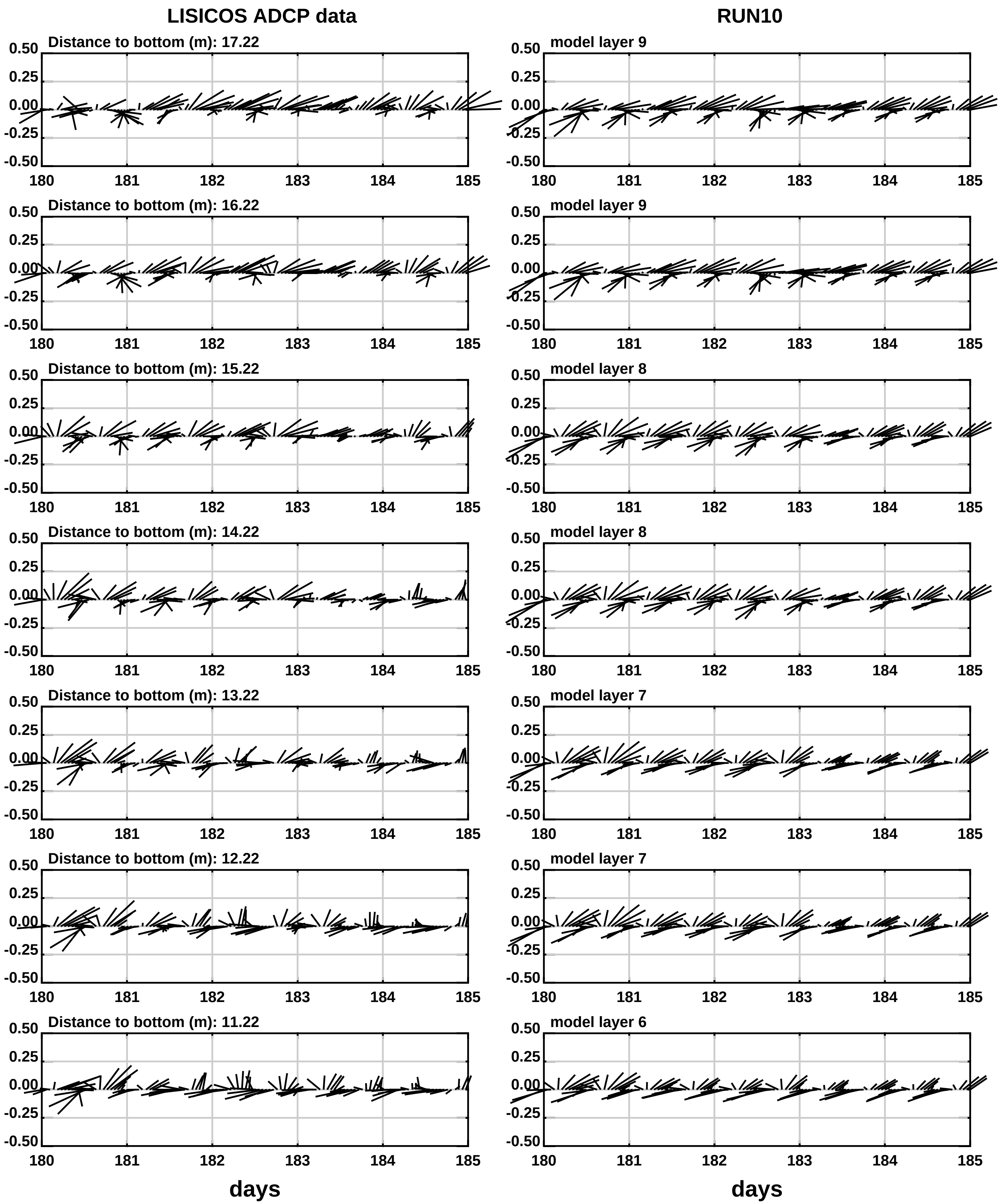


RUN10



2006

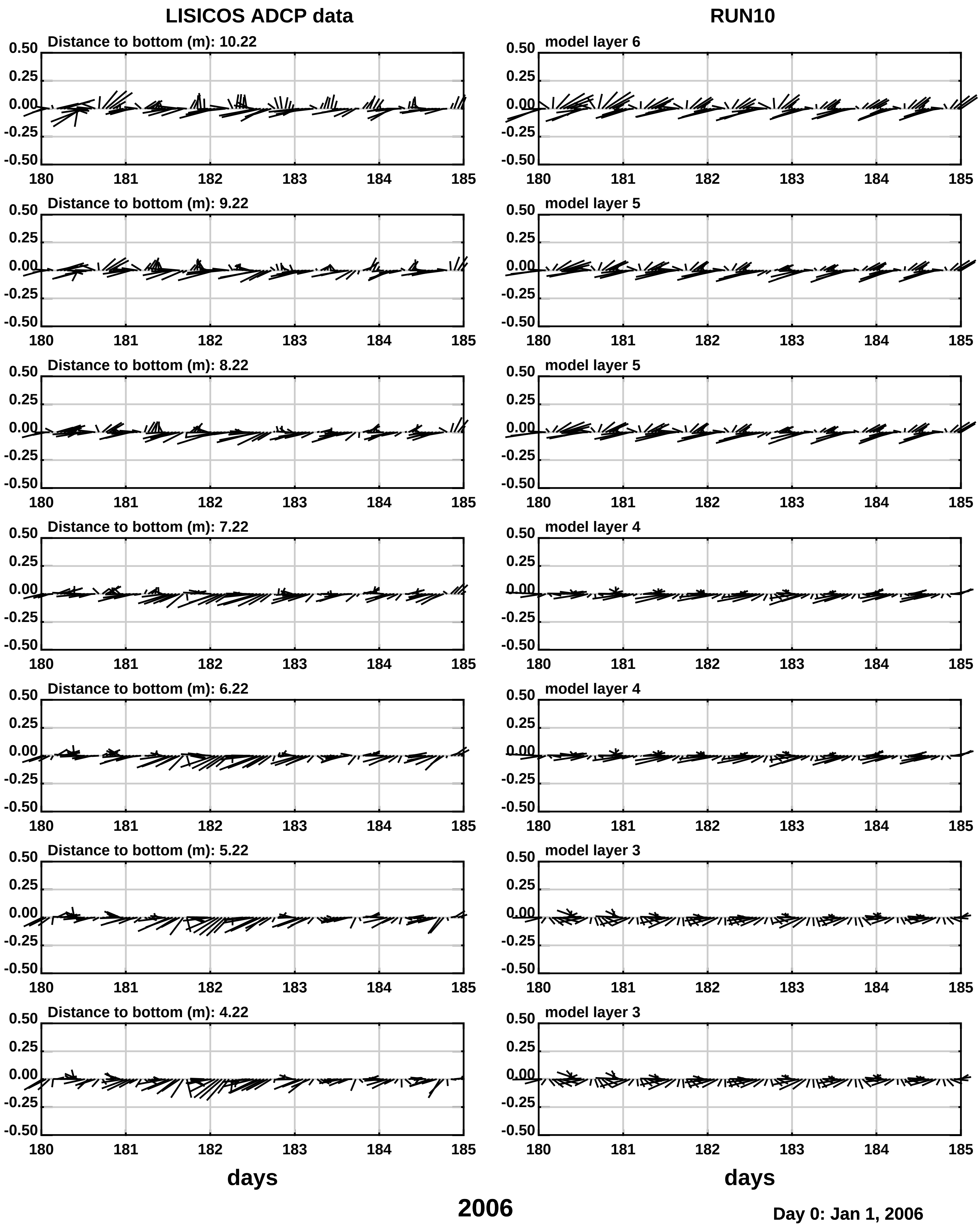
Velocity (m/s)
WLIS001



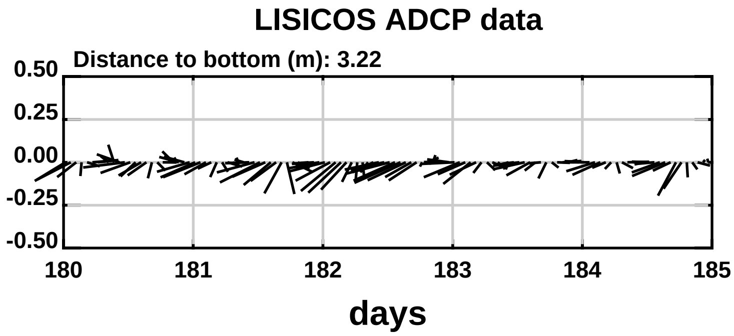
2006

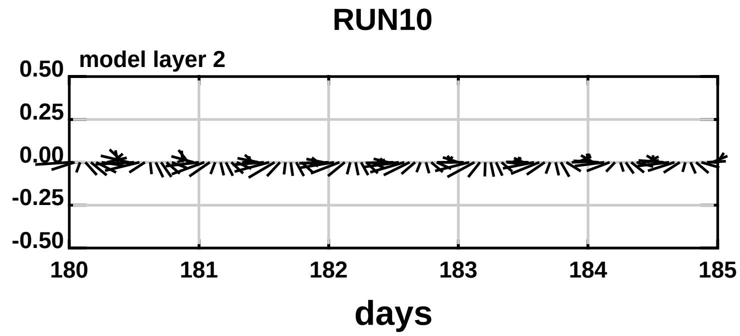
Day 0: Jan 1, 2006

Velocity (m/s)
WLIS001



Velocity (m/s)
WLIS001





2006

Day 0: Jan 1, 2006

6

Reviewer Comments and Responses

Comment No.	Section	Doc Name	Reviewer Comment	Doc Name	Response to Reviewer Comment
1	1	MEG_C1	O'Donnell – … There is much that could be done to improve the performance, but prioritizing effort would be aided by an understanding of what makes the most difference to the water quality simulations so I advise that element of the model system be added soon. There are solid arguments that getting the temperature, stratification and exchange through the East River right are important so effort applied to improving the surface exchanges with the atmosphere and assessing the simulation of the East River region would be profitable.	HDR_R1_ MEG	HDR is working on calibration of the RCA water quality model, which has further review and improvement to the ROMS hydrodynamic model calibration. Additional analyses have been completed to evaluate exchange through the East River and atmospheric exchange (e.g., net volume flux figures, model-data temperature improvements).
1	1	MEG_C1	O'Donnell – … There is much that could be done to improve the performance, but prioritizing effort would be aided by an understanding of what makes the most difference to the water quality simulations so I advise that element of the model system be added soon. There are solid arguments that getting the temperature, stratification and exchange through the East River right are important so effort applied to improving the surface exchanges with the atmosphere and assessing the simulation of the East River region would be profitable.	TL	RCA water quality model calibration is on-going and has included various improvements to the ROMS hydrodynamic model calibration.
2	1	MEG_C1	Cerco – … It is not clear why the Jerlov Water Type is introduced or what its role is in the model. Is Jerlov Water Type a model parameter? Is it in the observation database? How is it utilized? In fact, Jerlov Water Type can be empirically converted to light attenuation but why go through this complication? Why not just retain the easily understood light extinction parameter?	HDR_R1_ MEG	The ROMS source code uses the Jerlov Water Type to formulate light attenuation, which works like a two-layer light extinction coefficient. HDR is working with the existing code on this project and there are no plans to modify the formulation. Section 2.f. of the LIS ROMS Hydrodynamic Model Inputs and RCA Water Quality Model Load Development Approach (1/6/2023) describes the Jerlov Water Type formulation in model detail.
2	1	MEG_C1	Cerco – … It is not clear why the Jerlov Water Type is introduced or what its role is in the model. Is Jerlov Water Type a model parameter? Is it in the observation database? How is it utilized? In fact, Jerlov Water Type can be empirically converted to light attenuation but why go through this complication? Why not just retain the easily understood light extinction parameter?	TL	MEG was informed that use of the Jerlov Water Type is only in ROMS and that a more traditional light extinction formulation is used in RCA (i.e., light extinction as a function of chl-a and other parameters).
3	3	MEG_C1	O'Donnell – … The critical diagnosis of the accuracy of the model, and how to adjust the many choices made in the initial development has now begun and this report is an excellent step in that direction. In the following sections of my review, I critically assess the results presented and offer some suggestions on how to advance development of the model.	HDR_R1_ MEG	Acknowledged.

4	4	MEG_C1	Cerco – Key Points: The authors set a minimum water depth of 5 m throughout the system, including all shorelines. The authors note this will be revised in the final calibration. No details are included of how and where the revisions will be implemented. I want to emphasize the importance of accurately representing depth in the nearshore areas. Accurate depth nearshore is necessary for computing conventional water quality and for the eventual incorporation of living resources such as submerged aquatic vegetation and filter feeders. I think the minimum depth represented needs to go do to 1 m, at the least.	HDR_R1_ MEG	A minimum depth of 5 m was initially set to allow the model simulation to remain stable as wetting/drying is not implemented in the ROMS model. Currently, the model geometry is using a minimum depth of 2.5 m, which was the shallowest depth we could use as determined from model testing.
4	4	MEG_C1	Cerco – Key Points: The authors set a minimum water depth of 5 m throughout the system, including all shorelines. The authors note this will be revised in the final calibration. No details are included of how and where the revisions will be implemented. I want to emphasize the importance of accurately representing depth in the nearshore areas. Accurate depth nearshore is necessary for computing conventional water quality and for the eventual incorporation of living resources such as submerged aquatic vegetation and filter feeders. I think the minimum depth represented needs to go do to 1 m, at the least.	TL	MEG was informed that a min. depth of 2.5 m is used in ROMS.
5	4	MEG_C1	Warner – The report states that the minimum model depth was set at 5m. This value seems a bit high, and the model could be used at a much lower value. Perhaps a min depth of 2 m could be set.	HDR_R1_ MEG	See response to comment #4
5	4	MEG_C1	Warner – The report states that the minimum model depth was set at 5m. This value seems a bit high, and the model could be used at a much lower value. Perhaps a min depth of 2 m could be set.	TL	MEG was informed that a min. depth of 2.5 m is used in ROMS.
6	4	MEG_C1	Stoddard – Under Task 3.2, the RFP for the LIS-HWQMS project describes multiple objectives that include: … The new hydrodynamic model must also accurately represent physical transport and hydrodynamic processes throughout the larger system-wide domain of New York Harbor and the New York Bight. The MEG suggests that a few representative NYB monitoring stations within inshore, mid-shelf and offshore areas of the NJ coast be selected by HDR to demonstrate model performance for ROMS (and RCA) model calibration and validation. …	HDR_R1_ MEG	Much of the buoy data only has temperature data and the glider and WOD data provide transect data for salinity and temperature. HDR will utilize this data in New York Bight for completing model-data comparisons to the extent practicable.

6	4	MEG_C1	Stoddard – Under Task 3.2, the RFP for the LIS-HWQMS project describes multiple objectives that include: ... The new hydrodynamic model must also accurately represent physical transport and hydrodynamic processes throughout the larger system-wide domain of New York Harbor and the New York Bight. The MEG suggests that a few representative NYB monitoring stations within inshore, mid-shelf and offshore areas of the NJ coast be selected by HDR to demonstrate model performance for ROMS (and RCA) model calibration and validation. ...	TL	HDR is currently working to use the ocean buoy data and other datasets (e.g., NEFC) for model-data comparisons.
7	4	MEG_C1	Stoddard – ... As IEC and CTDEEP station data is pooled for the analysis and mapping of the spatial distribution of bottom water DO, the specific depth range above the bottom used to define “bottom” DO is a critical detail for evaluation of the maps of bottom water DO as well as assessment of surface and bottom time series and spatial transects for salinity and water temperature. Bottom water is defined by IEC’s (2018) EPA-approved QAPP as samples collected approximately 1 meter above the bottom. In contrast to IEC’s QAPP, bottom water is defined by CTDEEP’s (2017) EPA-approved QAPP as survey samples collected 3 – 5 meters above the sediment bed. The MEG would also like to know how surface and bottom survey records for grab samples are documented in the QAPP’s prepared by NYC DEP and NJ Harbor Dischargers Group (NJHDG) and how the NYC DEP and NJHDG data sets are represented in the observed data base developed by HDR for model calibration and validation. If IEC, CTDEEP, NYC DEP and/or NJHDG data sets do not report actual water depth but simply report “Bot or “B” to flag grab sample bottom measurements of DO, temperature and salinity and other water quality constituents, then it might not be correct to simply extract ROMS (or RCA) results for the bottom sigma layer for comparison to observed “bottom water” data sets.	HDR_R1_MEG	HDR will review the depths at which data are collected by the different agencies to choose the appropriate model vertical layer to compare against the data. For reference: DEP Harbor Survey reports surface data as 1m below the surface and bottom data as 1m above the bottom; CTDEEP reports surface data as 2m below the surface, bottom data as 5m above the bottom, and near-bottom data 1m above the bottom; and NJHDG reports surface data as 1m below the surface and bottom data as 1m above the bottom.

7	4	MEG_C1	Stoddard – … As IEC and CTDEEP station data is pooled for the analysis and mapping of the spatial distribution of bottom water DO, the specific depth range above the bottom used to define "bottom" DO is a critical detail for evaluation of the maps of bottom water DO as well as assessment of surface and bottom time series and spatial transects for salinity and water temperature. Bottom water is defined by IEC's (2018) EPA-approved QAPP as samples collected approximately 1 meter above the bottom. In contrast to IEC's QAPP, bottom water is defined by CTDEEP's (2017) EPA-approved QAPP as survey samples collected 3 – 5 meters above the sediment bed. The MEG would also like to know how surface and bottom survey records for grab samples are documented in the QAPP's prepared by NYC DEP and NJ Harbor Dischargers Group (NJHDG) and how the NYC DEP and NJHDG data sets are represented in the observed data base developed by HDR for model calibration and validation. If IEC, CTDEEP, NYC DEP and/or NJHDG data sets do not report actual water depth but simply report "Bot or "B" to flag grab sample bottom measurements of DO, temperature and salinity and other water quality constituents, then it might not be correct to simply extract ROMS (or RCA) results for the bottom sigma layer for comparison to observed "bottom water" data sets.	TL	HDR has reviewed the datasets surface and bottom depths for selecting which model layers to use for comparison. These adjustments will used in the full ROMS/RCA model calibration report.

8	5	MEG_C1	Warner – Comments on Table 2 •For runs 3 4 5, what is meant by “replacing NARR stations”? Are the stations grid locations on the NARR data? What were they replaced with? Or were they removed? •run 7 – how were groundwater fluxes determined and where were they assigned? •run 12 – when switch from k-e to k-kl what output components were compared? S &T? •runs ZoB changes: I ended up using ZoB = 0.002 m, and that seemed to work well for the Hudson River. I did not model LIS. So other ZoB values might work better in other areas, it is appropriate to vary the ZoB if the sea floor conditions change (i.e., from silty mud to sand, etc.). I think the ZoB = 0.005 might be too high. •Temperature and Salinity comparison – as you adjusted the NARR data, how much change did that create for the model comparisons?	HDR_R1_ MEG	HDR found meaningful meteorological data differences between NARR grid segments (stations) located on land versus over water. Some coastal segments had meteorological information more similar to land segments than water segments. These segments had inputs changed to meteorological inputs from nearby water segments. This better reflects meteorology over water and avoids significantly different inputs at locations next to each other. Section 2.d. of the LIS ROMS Hydrodynamic Model Inputs and RCA Water Quality Model Load Development Approach (1/6/2023) describes the NARR adjustments. Groundwater flows were initially estimated but are now based on annual flows from USGS groundwater models of CT and LI. Temperature and salinity model output was compared between the two runs with difference vertical closure formulations (k-e, k-kl). HDR will continue to run sensitivities with ZoB and is currently using 0.002m everywhere except in eastern LIS (0.05m). The NARR adjustments resulted in relatively small differences in the model T/S output.
8	5	MEG_C1	Warner – Comments on Table 2 •For runs 3 4 5, what is meant by “replacing NARR stations”? Are the stations grid locations on the NARR data? What were they replaced with? Or were they removed? •run 7 – how were groundwater fluxes determined and where were they assigned? •run 12 – when switch from k-e to k-kl what output components were compared? S &T? •runs ZoB changes: I ended up using ZoB = 0.002 m, and that seemed to work well for the Hudson River. I did not model LIS. So other ZoB values might work better in other areas, it is appropriate to vary the ZoB if the sea floor conditions change (i.e., from silty mud to sand, etc.). I think the ZoB = 0.005 might be too high. •Temperature and Salinity comparison – as you adjusted the NARR data, how much change did that create for the model comparisons?	TL	HDR is now using a bottom roughness length of 0.002 meters in ROMS. The other comments were addressed in the HDR responses.
9	5	MEG_C1	Cerco – In Table 2, the descriptions of Runs 9 and 10 include parameter ZoB. What is the definition of the parameter ZoB?	HDR_R1_ MEG	ZoB is the bottom roughness length (m) used in the computation of momentum stress.
9	5	MEG_C1	Cerco – In Table 2, the descriptions of Runs 9 and 10 include parameter ZoB. What is the definition of the parameter ZoB?	TL	Clarified that ZoB is the bottom roughness length.

10	5	MEG_C1	Stoddard – ...In summary, the MEG suggests that HDR should assess the value of using the NECOFS (or similar regional models) to develop both atmospheric forcing data and open water boundary conditions for salinity and temperature relative to alternative approaches which might include atmospheric forcing data obtained from Brookhaven National Lab, airport stations and coastal buoys; the MOCHA hydrographic climatology database developed by Fleming (2016); or just assimilation of SST from NOAA data products.	HDR_R1_MEG	HDR is using the NECOFS model output for open ocean T/S boundary conditions and is continuing to use NARR for the atmospheric forcing.
10	5	MEG_C1	Stoddard – ...In summary, the MEG suggests that HDR should assess the value of using the NECOFS (or similar regional models) to develop both atmospheric forcing data and open water boundary conditions for salinity and temperature relative to alternative approaches which might include atmospheric forcing data obtained from Brookhaven National Lab, airport stations and coastal buoys; the MOCHA hydrographic climatology database developed by Fleming (2016); or just assimilation of SST from NOAA data products.	TL	HDR is now using NECOFS model output to assign temperature and salinity boundary conditions.
11	5.1	MEG_C1	O'Donnell – Sea level Simulations: Figures 10 and 11 show that the model getting the amplitude of the variations in water level roughly correct. A more refined assessment is provided in the tables that compare the amplitude and phase of the tidal harmonics. I noticed that the data-based estimates are not those of the NOAA Tides and Currents program. I presume that they were computed from the single year of record used for the model simulation. This is appropriate for the evaluation, but it should be clearer in the report. Also, comparison between cells in tables on separate pages is awkward. I would like to see the amplitudes and phase estimates from data and the model in the same table. But overall, the agreement of the harmonics is fairly good in LIS and it's going to be hard to do better. Since this is not a model for navigation purposes, it is acceptable. I note that the most concise summary of these results is in the caption of the table; this information should be given in the main text.	HDR_R1_MEG	The water elevation harmonics were calculated for each year using NOAA real-time data at the associated stations. HDR will modify the way the model and data are presented in tables in the full ROMS-RCA Calibration Report along with joining amplitude model/data comparisons in one table and phase model/data comparisons in one table.

11	5.1	MEG_C1	O'Donnell – Sea level Simulations: Figures 10 and 11 show that the model getting the amplitude of the variations in water level roughly correct. A more refined assessment is provided in the tables that compare the amplitude and phase of the tidal harmonics. I noticed that the data-based estimates are not those of the NOAA Tides and Currents program. I presume that they were computed from the single year of record used for the model simulation. This is appropriate for the evaluation, but it should be clearer in the report. Also, comparison between cells in tables on separate pages is awkward. I would like to see the amplitudes and phase estimates from data and the model in the same table. But overall, the agreement of the harmonics is fairly good in LIS and it's going to be hard to do better. Since this is not a model for navigation purposes, it is acceptable. I note that the most concise summary of these results is in the caption of the table; this information should be given in the main text.	TL	Clarified that the water elevation harmonics were calculated for each year using NOAA real-time data at the associated stations and not obtained from NOAA Tides & Currents harmonic constituent analyses. HDR will modify the way the model and data are presented in tables in the full ROMS-RCA Calibration Report along with joining amplitude model/data comparisons in one table and phase model/data comparisons in one table
12	5.1	MEG_C1	Warner (Figure 11) – Water level time series look pretty good. Some slight overestimates. If this is pervasive, then it might be from the boundary. Is this why you increased Zob to 0.005? If you can compare the velocities at some locations, it will help to see if the Zob is good.	HDR_R1_ MEG	ZoB was modified to improve the model calibration to water elevation and will review the water elevation forcing at the model boundary. HDR will create figures to compare model output to velocity data. See added last sentences in Sections 5.1 and 5.3.
13	5.2	MEG_C1	Stoddard – As simulation of stratification is a critical issue for technical credibility of the hydrodynamic and water quality model, the MEG would like to see additional model-data plots for salinity and temperature to show and compare the ΔS and ΔT difference between Surface and Bottom observations and model results. ΔS and ΔT metrics for stratification should be provided for both time-series and transect plots to support seasonal and spatial transect assessments of the performance of the ROMS hydrodynamic model under stratified and well-mixed conditions.	HDR_R1_ MEG	Figures that show the model stratification (ΔS and ΔT) will be created. See added last sentence of first paragraph in Section 5.2.1.
13	5.2	MEG_C1	Stoddard – As simulation of stratification is a critical issue for technical credibility of the hydrodynamic and water quality model, the MEG would like to see additional model-data plots for salinity and temperature to show and compare the ΔS and ΔT difference between Surface and Bottom observations and model results. ΔS and ΔT metrics for stratification should be provided for both time-series and transect plots to support seasonal and spatial transect assessments of the performance of the ROMS hydrodynamic model under stratified and well-mixed conditions.	TL	HDR has created delta (surface minus bottom) temperature and salinity model-data comparison figures and will include them in the full ROMS/RCA model calibration report. See added last sentence of first paragraph in Section 5.2.1.
14	5.2	MEG_C1	Cerco (Figure 12 etc.) – The top panels in the CTDEEP figures are labelled A4 while the captions refer to A2.	HDR_R1_ MEG	A2 is a typo and will be corrected
14	5.2	MEG_C1	Cerco (Figure 12 etc.) – The top panels in the CTDEEP figures are labelled A4 while the captions refer to A2.	TL	Typos were corrected regarding labeling for CTDEEP station A2, which should have been labeled station A4.

15	5.2	MEG_C1	Warner (Figures 12 – 19) – Temperature metrics seem to be well within the expected ranges. Salinity data seems to be off. Can this be from the open boundary data? What data was used for salinity?	HDR_R1_MEG	The salinity boundary condition input was based on World Ocean Atlas climatological data. HDR is currently using NECOFS model output to assign T/S boundary conditions and salinity boundary condition inputs still need to be adjusted to improve internal salinity model-data comparisons.
15	5.2	MEG_C1	Warner (Figures 12 – 19) – Temperature metrics seem to be well within the expected ranges. Salinity data seems to be off. Can this be from the open boundary data? What data was used for salinity?	TL	HDR completed sensitivities to model boundary condition salinity adjustments to improve the ROMS model calibration.
16	5.2	MEG_C1	Cerco (Figures 20 – 23) – The use of three shades of gray for the [LISICOS] observations make the data difficult to discern. Can the authors use different symbols? Or perhaps delete the middle observations so there is less overlap?	HDR_R1_MEG	HDR will work to improve the readability of the figures.
17	5.2.1	MEG_C1	O'Donnell – Figures 12 and 13 compare the model temperature at the surface and bottom to the estimates acquired in the western Sound stations by IEC and CT DEEP. The seasonal cycle is replicated very well. The report acknowledges that the model is biased high at the surface at some stations. Clearly, there is room for improvement in the surface forcing and exchange with the atmosphere. The McCardell (2022) paper suggest that there is substantial spatial variation in the surface heat fluxes and existing atmospheric models my not be adequate. This issue deserved substantial attention. However, the comparison to the WLIS buoy data in Figure 21 is quite impressive. The low frequency signals seem to be highly correlated, though the model does seem biased high there too. It is certainly clear that there are some periods of rapid warming and cooling that are similar in both records. This is another place where low pass filtering the model and data and comparing the results might be valuable. I also note that the variance in the high frequency (the day-night variations) seems about right. Since the DEEP samples are all collected during the day, and the measurements are representative of a small volume, and these are being compared to model estimates which are averages in a box of order 3m thick and 1km2 square, it would be valuable to have error bars attached to the data points so the difference between the model and the data points can be scaled by what might be contributed by the short term variability. I think that the surface thermal forcing and exchange might need attention, but I think that effort to get the water quality model integrated is higher priority in the short term. My analysis of the interannual variability of the area of hypoxia didn't find a correlation between temperature anomalies and hypoxia so it might not be worth a lot of effort in refining the temperature simulation until we know that is a limitation.	HDR_R1_MEG	HDR agrees that further improvement to the temperature calibration is needed but the current use of the NECOFS model for assigning boundary condition inputs has improved the model-data comparisons. We do not feel that additional evaluation of atmospheric surface foricing and additional spatial variation in atmospheric model inputs is warranted as the model-data comparisons are much better with use of the NECOFS model derived boundary conditions. Further refinement is focused on vertical temperature stratification and bottom water temperatures. See last paragraph in Section 5.2.1. We are unsure how to add error bars to the CTDEEP data which are grab samples near the surface and bottom at a specific date/time.

18	5.2.1	MEG_C1	Stoddard – … In our MEG synthesis of the Jan-12 MAG meeting (see Attachment #5), the MEG focused on the coarse resolution of the NARRS atmospheric forcing data as a possible cause for over-prediction of water temperature in the ROMS model. Based on the findings of the ECOM-vs-ROMS WY95 comparison of water temperature results, however, the MEG now suggests that HDR carefully review the heat exchange formulations used in ROMS. The ECOM-ROMS testing may provide a valuable clue about a possible reason why water temperature is over-predicted in ROMS during the warmer months for the preliminary calibration years of 2005-2006.	HDR_R1_ MEG	HDR has reviewed the ROMS heat exchange formulations and although different than that used in ECOM they appear to produce similar heat flux components as ECOM. The current ROMS model temperature calibration is much improved due to continued calibration efforts and use of the NECOFS model output for assigning model T/S boundary conditions. We do not feel that additional evaluation of the ROMS heat exchange formulations and additional spatial variation in atmospheric model inputs is warranted as the model-data comparisons are much better with use of the NECOFS model derived boundary conditions.
19	5.2.1	MEG_C1	O'Donnell – The presentation graphics in Figure 14 for the salinity series is poor. … Comparison to the buoy data in Figure 22 is enlightening, but though the scale is better, the grey shades make the data difficult to discern. There is obviously some anomalous data at FB02 that should be checked. … I think that presenting the errors in tables at the end of the report is rather inconvenient. Graphs are better and numbers should be woven into the text. I think that getting the near bottom salinity and the vertical stratification due to salinity is more important that the temperature in the short term. That will be a measure of the skill in simulation of the exchange through the East River.	HDR_R1_ MEG	HDR will modify the scale for the salinity figures and look for ways to more clearly present model errors in the tables. Further effort is underway to improve the model salinity calibration including the current use of the NECOFS model output and adjustments to the salinity boundary condition inputs. HDR will revise salinity scales in these Fig. 14-15 and elsewhere.
20	5.2.1	MEG_C1	Cerco (Figures 14 – 15 and elsewhere – The vertical scale range on these salinity plots is much greater than the variation in the results being plotted. As a consequence, judging the variation and degree of agreement in the model and observations is difficult. These plots should be revised with reduced vertical scales.	HDR_R1_ MEG	HDR will revise salinity scales in these figures.

21	5.2.2	MEG_C1	O'Donnell – The vertical structure of temperature and salinity at the CT DEEP stations are shown in Figures 24-31. The presentation does not favor a very critical assessment so I can't really assess the conclusion that the comparison of model and data is favorable. I do agree that it is in the ball park and appropriate for the initial phase of calibration. I think that there should be some summary statistics of agreement her in future so we can assess whether modifications make substantial improvements. The report asserts that stratification looks good too. I think that the vertical stratification is an important metric that should be reported. I suggest that the maximum stratification and the level of the maximum be compared to the station data.	HDR_R1_ MEG	HDR will complete comparisons of stratification/maximum stratification between model and data salinity, temperature and calculated sigma-T.
22	5.2.3	MEG_C1	O'Donnell – The simulation of the variation of salinity and temperature along the axis of the Sound is assessed in Figure 32 and 33 (and others in the preliminary calibration report attachments). The axis range in Figure 33 is -5 to 30 C. This range obscures both the spatial structure of the temperature and the assessment of the differences between the model and the data … I recommend that the figures be improved in subsequent reports, and that quantitative measures of difference are developed so that we know whether, and by how much, the model is improved by modifications.	HDR_R1_ MEG	HDR will modify these figures in subsequent reports including revising y-axis ranges and legend descriptions.
23	5.2.3	MEG_C1	Cerco (Figures 32-33) – Multiple plots in this attachment show problems with computed salinity in the lower 20 km of LIS, as measured from the Battery. e.g., October 2005 and February 2006. The number of months showing similar discrepancies suggests a persistent problem in computing salinity in this area. The origin of the problem cannot be discerned from the material available. Perhaps bad open water boundary conditions? Perhaps problems in model geometry [bathymetry] in this region? In any event, this discrepancy needs to be investigated and rectified. Key Points: The "2005 – 2006 Model-Data Temperature/Salinity Transect Comparisons" appendix shows multiple instances of problems with computed salinity in the first 20 miles east of the Battery (e.g. Dec 2005, Feb 2006, July 2006). The origins of the discrepancies between model and observations are not obvious, perhaps boundary conditions, freshwater flows, or geometry. The origins of the problems should be investigated and performance in this region should be improved in the final calibration.	HDR_R1_ MEG	HDR is continuing to work on improving the salinity calibration and is further reviewing the NECOFS model salinity boundary condition inputs. In addition, HDR will work on improving the spatial model- data figures because, as presented, the figures compare monthly average model output (solid and dashed lines) to available monthly data (which may only consist of 1 or 2 grab samples). The shaded regions in these figures present the model output range over the month, which may better be used to compare model output to data (i.e., the data should fall w/in the shaded model output ranges).

24	5.2.3	MEG_C1	Cerco (Figure 32 and similar) – The legend doesn't really explain the figure and could use some revision. The legend shows colored circles for "Data Surface (Range)." Are the circles means, medians, or what? Clarification of the circles and vertical lines is necessary.	HDR_R1_ MEG	See response to comments #22 and #23.
25	5.2.3	MEG_C1	Stoddard (Figures 32-33) – Spatial transects for water temperature and salinity show the range for observed and modeled results for surface and bottom layers. Transects show mean and error bars for observed water temperature and salinity. Transects show simulated surface and bottom results for temperature and salinity as solid and dashed lines for mean values with light and dark gray bands marking the simulated range. The narrative and plot legends need to document what statistics are used to mark upper and lower (a) error bars for the observed range and (b) range of light and dark gray bands for model results. The interval used to plot the simulated results should also be documented to clarify what the plots are reporting for model results (e.g., hourly, daily snapshot, daily mean).	HDR_R1_ MEG	See response to comments #22 and #23.
26	5.2.3	MEG_C1	Stoddard (Figures 32-33) – As a follow-up to Section 1 comment about identification of representative calibration and validation stations off the NJ coast, the MEG would like to see model-data results for a new transect off the NJ coast. Transects would extend from inshore to offshore at the 200 m isobath to characterize hydrodynamic results over this area of the NY Bight. Additional transects would include time-averaged surface and bottom salinity and water temperature and ΔS and ΔT surface-bottom differences.	HDR_R1_ MEG	HDR will develop a T/ΔT and S/ΔS transects off the NJ coast and will add data where feasible. The T/S data generally available are from moving glider sampling w/ many different transect routes and sampling dates.

27	5.3	MEG_C1	O'Donnell – The velocity comparisons in Figure 34 are not very helpful in diagnosing the model performance, but Figure 35 is better. The magnitude and direction predicted is similar to that observed, which is adequate at this stage. I recommend that the tidal harmonics for the current components be computed and compared. A small phase error in the model can substantially inflate the RMSE error. Bennett et al. (2010) analyzed the same data records shown in Figure 35 (and many others). They showed that the ratio of the M6 to M2 amplitude had an unusual along Sound structure. Getting the vertical and along sound structure of the tidal current constituents correct would be a ridged test of the model. But more importantly, the vertical structure of the mean and low frequency part of the fluctuations in current should separately be assessed since it is this that plays an important role in the transport of materials. I also think that the magnitude of the vertical shear, and the level of the maximum should be compared. This, and the stratification, determine the vertical mixing rates and I would like to know that the model gets their magnitude correct.	HDR_R1_ MEG	HDR will present components for the current tidal harmonics and work on better ways to improve model-data velocity comparisons including tidal ellipses. See added last sentence in Section 5.3
28	5.3	MEG_C1	Cerco (Figure 34 and similar) – The stick plots are difficult to interpret. Is each stick a measurement in a single time interval? What is the interval? How is direction indicated and interpreted? What is positive and what is negative? Clarification is necessary or, better still, the plots should be replaced with a format that facilitates interpretation and direct comparison between model and data. This format makes it really difficult to compare model and data except in general magnitude and direction. Ordinary time series with model and data on the same plot would help a lot. One plot for current magnitude and one for direction. Or north-south and east-west components of current magnitude.	HDR_R1_ MEG	The sticks represent current vectors (with the arrow heads removed). The sticks show magnitude (length of stick) and direction (angle of stick) on an hourly basis. HDR will present the current velocity data in other formats as well as suggested. See added last sentence of Section 5.3.
29	5.3	MEG_C1	Warner (Figures 34-35) – Velocity comparisons- It is difficult to see the comparisons. Maybe show speed and direction plots?	HDR_R1_ MEG	See response to comments #28. See added last sentence of Section 5.3.

30	5.3	MEG_C1	Cerco (Figures 34-35) – I have not repeated my comments on the January 12-2023 MAG presentation (see Attachment #5). I want to emphasize, however, the importance of my request to see plots of computed tidal-average currents at multiple locations depths. Supplement the model results with tidal-average data, where available. In particular, I would like to see results in the East River and at the eastern end of the Sound.	HDR_R1_MEG	HDR will create figures for residual currents. See added last sentence of Section 5.3
30	5.3	MEG_C1	Cerco (Figures 34-35) – I have not repeated my comments on the January 12-2023 MAG presentation (see Attachment #5). I want to emphasize, however, the importance of my request to see plots of computed tidal-average currents at multiple locations depths. Supplement the model results with tidal-average data, where available. In particular, I would like to see results in the East River and at the eastern end of the Sound.	TL	HDR has created maps of residual current speed/direction by month and will include in the full ROMS/RCA model calibration report. See added last sentence of Section 5.3.
31	5.3	MEG_C1	Stoddard (Figures 34-35) – Model-data performance for velocity is given in Table 21, 22 and 23 and visual model-data comparisons are shown for velocity as stick figure time series plots for LISICOS buoys. The MEG would like to see representative surface and bottom layer maps showing observed and modeled velocity vectors for the area covered by the LISICOS buoys in western and central LIS. Vector maps could show either time-averaged model-vs-observed data conditions or hourly snapshots to show incoming and outgoing tide conditions. The MEG suggests that maps showing representative summer stratified conditions and winter well-mixed conditions would be helpful to illustrate seasonal variation in circulation patterns in this critical western area of LI Sound.	HDR_R1_MEG	Additional velocity model-data comparison figures will be developed as suggested (vector maps) will be provided in the full calibration report. See added last sentence of Section 5.3.
32	5.4	MEG_C1	O'Donnell – The volume flux in the East River is described in Figure 37 and 38. This is an important diagnostic but unfortunately, there is little data with which to evaluate the model. The estimates were compared to earlier model results. Blumberg and Pritchard (1997) did a careful analysis of this exchange transport and later evaluations should carefully compare to that result. There are a few ADCP records available from NOAA and the data and model results of O'Donnell (2023) should be available in April. These should be used in the next phase of model assessment. Again, I recommend careful attention to both the tides and low frequency variability	HDR_R1_MEG	HDR will continue to review and analyze model results for East River net tidal fluxes. See added last sentence of Section 5.4.

33	5.4	MEG_C1	Warner (Figure 37) – I like this figure but it is a bit confusing. Instead of using the top and bottom 10% of the water column to compute the east and west fluxes, can you just compute the total flux eastward and total flux westward? At each of the grid points in the transect, at each moment in time, look at the vertical profile of velocity and compute a running sum of the flow to the east and flow to the west. That might give a better representation of the transports.	HDR_R1_ MEG	HDR will modify the net tidal flux figures showing the total eastward and westward fluxes along with extending the transect further out into western LIS. HDR will compare wind speed/direction to these model flux results. See addede last sentence of Section 5.4.
33	5.5	MEG_C1	Can you make a time series plot of instantaneous (not average) volume flux vs wind? This might be outside the scope of work, but looking at what is driving that flow might help to identify transport processes in LIS.	HDR_R1_ MEG	Time-series of the fluxes will be presented in the full calibration report. See added last sentence of Section 5.4.
34	5.5	MEG_C1	Stoddard – … The MEG suggests that HDR consider the use of the Relative Root Mean Square Error as an additional model performance metric to overcome this weakness of the correlation coefficient as a metric for skill assessment for salinity.	HDR_R1_ MEG	RMSE will not be used as a model skill assessment statistic per the final skill assessment approach.
35	5.5	MEG_C1	Stoddard (Table 5) - … Statistics used to assess model performance included Relative Error, Root Mean Square Error (RMSE) and Correlation Coefficient (r). The MEG recommends that HDR provide documentation of how these targets were determined for the ROMS hydrodynamic model. NOAA NOS, for example, has published targets for operational hydrodynamic models used for PORTS forecasting (Hess et al., 2003). The MEG also recommends that HDR provide documentation of how model performance targets were determined in the calibration report for the RCA water quality model. In a literature review of mechanistic aquatic biogeochemical models, Arhonditsis and Brett (2004) compiled model performance results as correlation coefficients and relative error from ~150 published studies. Their compilation of Relative Error is shown in the Box & Whiskers plot from the journal article (see Figure 2).	HDR_R1_ MEG	The targets in the report are those presented in the modeling QAPP. The metrics are based partially on past experience and partially on literature. HDR has referred to Arhonditsis and Brett (2004) as documented in the QAPP. Arhonditsis and Brett do not perform an analysis on salinity but report a median relative error of 7% which is consistent with the 5-10% target listed. See note in Section 5.5 (fifth paragraph) regarding new skill assessment approach presented in QAPP.
36	5.5	MEG_C1	Stoddard – The equation for the correlation coefficient (page 11) uses the median value rather than the average value. Most definitions of correlation coefficient use the average value (see Ji, 2017, page 293). As the use of the median value is not typical practice for the correlation coefficient, HDR needs to provide justification for using the median value.	HDR_R1_ MEG	The report correlation coefficient equation had an error that was corrected. The description of terms should reference mean not median. The correlation coefficients in the tables were calculated with the mean.

36	5.5	MEG_C1	Stoddard – The equation for the correlation coefficient (page 11) uses the median value rather than the average value. Most definitions of correlation coefficient use the average value (see Ji, 2017, page 293). As the use of the median value is not typical practice for the correlation coefficient, HDR needs to provide justification for using the median value.	TL	The report correlation coefficient equation had an error that was corrected. The description of terms should reference mean not median. The correlation coefficients in the tables were calculated with the mean.
37	5.5	MEG_C1	Cerco – The symbols M (with an overbar) and O (with an overbar) are defined as model and observed medians. Is this correct? The formal definition of statistics such as correlation coefficient employ model and data means, not medians. Can the authors explain why median was employed? What effect does this have on the reported statistics?	HDR_R1_ MEG	See response to comments #36.
37	5.5	MEG_C1	Cerco – The symbols M (with an overbar) and O (with an overbar) are defined as model and observed medians. Is this correct? The formal definition of statistics such as correlation coefficient employ model and data means, not medians. Can the authors explain why median was employed? What effect does this have on the reported statistics?	TL	The report correlation coefficient equation had an error that was corrected. The description of terms should reference mean not median. The correlation coefficients in the tables were calculated with the mean.
38	5.6.1	MEG_C1	Cerco – I am surprised at the way the statistics are computed and employed. For example, one reported statistic is the difference in total amplitude of time series fit to the computed and observed tidal heights. I would have expected the difference in actual computed and observed tidal heights. One issue with using the fitted time series is that perturbations caused by meteorological or flow events are filtered out. It took me a while to deduce what was being done. If the authors wish to continue with these analyses, they might provide more explanation of what is being calculated.	HDR_R1_ MEG	The comparisons are presented for model and data tidal harmonics for amplitude (difference, relative error) and phase (time) based on analyses of the 2005 and 2006 model output and data. The correlation coefficients (r) presented in Tables 6 and 9 are based on hour-to-hour comparisons between model and data water elevations. Further explanation of the statistics presented in Tables 4-9 will be added to subsequent versions of the report. HDR will add comparisons of the meteorological water elevations (model and data) with the tidal components removed.
38	5.6.1	MEG_C1	Cerco – I am surprised at the way the statistics are computed and employed. For example, one reported statistic is the difference in total amplitude of time series fit to the computed and observed tidal heights. I would have expected the difference in actual computed and observed tidal heights. One issue with using the fitted time series is that perturbations caused by meteorological or flow events are filtered out. It took me a while to deduce what was being done. If the authors wish to continue with these analyses, they might provide more explanation of what is being calculated.	TL	Additional text was added to expand on the elevation comparison statistics. The comparisons are presented for model and data tidal harmonics for amplitude (difference, relative error) and phase (time) based on analyses of the 2005 and 2006 model output and data. The correlation coefficients (r) presented in Tables 6 and 9 are based on hour-to-hour comparisons between model and data water elevations.

39	5.6.1	MEG_C1	Stoddard – Table 4, 5, 6 (2005 data) and Table 7, 8 and 9 (2006 data) present model performance for tidal harmonic results for selected constituents. The report states that "Table presents the harmonic constituent analysis results for 2005 data for tidal amplitude and tidal phase". It is not clear if the Table 4 data are based on (a) actual time series harmonic analysis of observed water level records during 2005 or (b) NOAA NOS tide table constituent data for amplitude and phase used for tide predictions.	HDR_R1_ MEG	See response to comment #38. The tidal harmonics presented are calculated from the 2005 and 2006 model output and data. They are not obtained from NOAA NOS tide table constituents.
39	5.6.1	MEG_C1	Stoddard – Table 4, 5, 6 (2005 data) and Table 7, 8 and 9 (2006 data) present model performance for tidal harmonic results for selected constituents. The report states that "Table presents the harmonic constituent analysis results for 2005 data for tidal amplitude and tidal phase". It is not clear if the Table 4 data are based on (a) actual time series harmonic analysis of observed water level records during 2005 or (b) NOAA NOS tide table constituent data for amplitude and phase used for tide predictions.	TL	Additional text was added to expand on the elevation comparison statistics. The comparisons are presented for model and data tidal harmonics for amplitude (difference, relative error) and phase (time) based on analyses of the 2005 and 2006 model output and data. The correlation coefficients (r) presented in Tables 6 and 9 are based on hour-to-hour comparisons between model and data water elevations.
40	5.6.1	MEG_C1	Warner (Table 6) – seems that the tidal amplitude is too high most places, except at Hackensack. Atlantic City (AC) is too low but that is way down the coast. I suggest that instead of forcing the model with perhaps a too high of tidal range and using a large ZoB to reduce the amplitudes, you could look at reducing the tidal forcing along the open boundary and reduce the ZoB back to 0.002 or so.	HDR_R1_ MEG	HDR will look into adjusting the tidal water elevation forcing inputs at the model boundary conditions to improve model-data water elevation comparisons.
40	5.6.1	MEG_C1	Warner (Table 6) – seems that the tidal amplitude is too high most places, except at Hackensack. Atlantic City (AC) is too low but that is way down the coast. I suggest that instead of forcing the model with perhaps a too high of tidal range and using a large ZoB to reduce the amplitudes, you could look at reducing the tidal forcing along the open boundary and reduce the ZoB back to 0.002 or so.	TL	HDR will complete sensitivities to adjust boundary condition elevation inputs to improve the ROMS model calibration.

41	5.6.1	MEG_C1	Stoddard - Table 6 and Table 9 present comparisons of model results and observations. M2 constituent observed data and model results are shown for amplitude (as cm) and phase (as degrees) for 2005 (Table 4 and 5) and 2006 (Table 7 and 8). The model-data comparisons shown in Table 6 and Table 9 show amplitude, M2 and correlation coefficient. The tables need to clearly state that the amplitude difference is the sum total of the components of the observed and modeled amplitudes. Although page 12 describes how "A difference of 29 degrees represents a difference of one hour in timing of the water elevations", the report needs a better explanation of how M2 Phase Difference (reported as "min" .... minutes?) is derived from the M2 Phase (as Degrees). Finally, the report needs to explicitly document the parameter (amplitude?) used to derive the correlation coefficient (r).	HDR_R1_MEG	The text will be modified to address this comment. The amplitude is the sum of the constituents. The phases are presented for major constituents. Since M2 is the major component of the tide in LIS it can be used to assess how well the model reproduces the timing of the tide. For a M2 tide cycle, the tide moves 360 degrees in 12.42 hrs or 360/12.42 ~ 29 degrees/hr. The phase difference between the model and data divided by 29 degrees/hr multiplied by 60 gives the timing difference in minutes. Other constituents have different timing. S2, for example, moves 360 degrees in 12 hours or 30 degrees/hr. However, since M2 is the major contributor to tidal amplitude it best reflects the timing. HDR will modify the text to further describe the analyses completed. The correlation coefficient comparison is based on water elevation (model vs. data on an hourly basis).
41	5.6.1	MEG_C1	Stoddard - Table 6 and Table 9 present comparisons of model results and observations. M2 constituent observed data and model results are shown for amplitude (as cm) and phase (as degrees) for 2005 (Table 4 and 5) and 2006 (Table 7 and 8). The model-data comparisons shown in Table 6 and Table 9 show amplitude, M2 and correlation coefficient. The tables need to clearly state that the amplitude difference is the sum total of the components of the observed and modeled amplitudes. Although page 12 describes how "A difference of 29 degrees represents a difference of one hour in timing of the water elevations", the report needs a better explanation of how M2 Phase Difference (reported as "min" .... minutes?) is derived from the M2 Phase (as Degrees). Finally, the report needs to explicitly document the parameter (amplitude?) used to derive the correlation coefficient (r).	TL	Additional text was added to clarify how the elevation statistics were calculated. The amplitude is the sum of the constituents. The major M2 phase component of the tide was used to assess how well the model reproduces the timing of the tide. For an M2 tide cycle, the tide moves 360 degrees in 12.42 hrs or 360/12.42 ~ 29 degrees/hr. The phase difference between the model and data divided by 29 degrees/hr multiplied by 60 gives the timing difference in minutes. The correlation coefficient comparison is based on water elevation (model vs.data on an hourly basis).

42	5.6.1	MEG_C1	O'Donnell - There is no assessment of the skill in the non-tidal sea level simulation. This is not critical at this stage of model development but I anticipate that there will be substantial is interest the impact of storms on hypoxia and in the variability of the transport through the east river. Both issues will require that the effect of wind on sea level fluctuations is simulated adequately. McCardell et al (2023) includes a figure that illustrates what I have in mind and it is reproduced below as Figure 3. Their skill metric normalizes the variance in the model-data difference bay the variance in the data and may provide a useful benchmark for model development. My recommendation is that phase and amplitudes be summarized in a way that makes evaluation easier and these metrics be monitored as model improvements are introduced. The tidal elevation is not very sensitive to parameter choices, tidal currents should have more attention. Secondly, the model and data should be low-pass filtered to remove the high frequency tidal constituents and the series compared using the correlation and difference metrics.	HDR_R1_ MEG	HDR will add assessments of non-tidal water elevations (low-pass filtered) to the full calibration report. See added last sentence of Section 5.1.
43	5.6.2	MEG_C1	Cerco (Table 10) – Are the perfect correlations (r = 1.00) correct [for Salinity and Temperature]? Is this affected by use of medians instead of means (see CFC comment re: Page 11).	HDR_R1_ MEG	HDR used means in the correlation coefficient calculation (see response to comment #36) and will confirm the results presented and how round-off may affect the presentations. The correlations are based on hour to hour comparisons of model and data.
44	5.6.2	MEG_C1	Stoddard (Tables 10-20) – Model performance statistics tables for salinity and water temperature need to clearly define the units for each data column. The MEG also suggests that tables that combine results for salinity and temperature (e.g., Table 10) be revised so salinity and temperature are shown in separate tables. Tables shown on separate pages for salinity and temperature would make review of skill assessment data somewhat easier	HDR_R1_ MEG	HDR will modify the presentation of the skill assessment results in subsequent versions of the reports.
44	5.6.2	MEG_C1	Stoddard (Tables 10-20) – Model performance statistics tables for salinity and water temperature need to clearly define the units for each data column. The MEG also suggests that tables that combine results for salinity and temperature (e.g., Table 10) be revised so salinity and temperature are shown in separate tables. Tables shown on separate pages for salinity and temperature would make review of skill assessment data somewhat easier	TL	Units were added to the statistics tables for RMSE, data median, and model median.

45	5.6.2	MEG_C1	Stoddard (Tables 10-20) – This topic was addressed in the Jan-12-2023 MAG Meeting Synthesis Memo by the MEG (see Attachment #5). New comments are provided in this memo on the ROMS preliminary calibration report. In the Jan-12-2023 MAG presentation, skill assessment statistics were presented for CTDEEP stations as composite statistics derived from multiple stations in spatial zones of LI Sound (eastern narrows, western basin, central basin and eastern basin). The MEG liked the use of spatial zones for documentation of aggregate model performance statistics for station in selected spatial areas of the system-wide model domain. In the MAG presentation, the headings for each skill metric were described as "Median" for RE, RMS and r. As the "median" values shown for the model skill statistics are presumably computed from one or more sets of station results within each spatial zone that are presented in the preliminary calibration report, the MEG would like to see the composite CTDEEP spatial zone statistics presented at the MAG meeting included in the calibration report to provide overview descriptions of model performance summary for key spatial areas. Similar spatial zones for NY Harbor/East River could be setup to support composite model performance analysis of DEP, IEC and NJ Harbor Dischargers Group station data sets.	HDR_R1_MEG	HDR will provide composite zone statistics in subsequent versions of the reports. See note in Section 5.5 (fifth paragraph) regarding new skill assessment approach presented in QAPP.

45	5.6.2	MEG_C1	Stoddard (Tables 10-20) – This topic was addressed in the Jan-12-2023 MAG Meeting Synthesis Memo by the MEG (see Attachment #5). New comments are provided in this memo on the ROMS preliminary calibration report. In the Jan-12-2023 MAG presentation, skill assessment statistics were presented for CTDEEP stations as composite statistics derived from multiple stations in spatial zones of LI Sound (eastern narrows, western basin, central basin and eastern basin). The MEG liked the use of spatial zones for documentation of aggregate model performance statistics for station in selected spatial areas of the system-wide model domain. In the MAG presentation, the headings for each skill metric were described as "Median" for RE, RMS and r. As the "median" values shown for the model skill statistics are presumably computed from one or more sets of station results within each spatial zone that are presented in the preliminary calibration report, the MEG would like to see the composite CTDEEP spatial zone statistics presented at the MAG meeting included in the calibration report to provide overview descriptions of model performance summary for key spatial areas. Similar spatial zones for NY Harbor/East River could be setup to support composite model performance analysis of DEP, IEC and NJ Harbor Dischargers Group station data sets.	TL	HDR has generated model statistics by zones and seasons and will include in the full ROMS/RCA model calibration report. See note in Section 5.5 (fifth paragraph) regarding new skill assessment approach presented in QAPP.
46	5.6.2	MEG_C1	Stoddard (Tables 10-20) – In addition to the model performance analysis of data sets that includes all months from January through December, additional understanding about model performance might be gained if skill statistics were presented for "summer" and "winter" months to highlight model performance during critical summer stratification conditions that control hypoxia compared to well-mixed winter conditions.	HDR_R1_MEG	HDR will provide summer and winter composite statistics in subsequent versions of the reports. See note in Section 5.5 (fifth paragraph) regarding new skill assessment approach presented in QAPP.
46	5.6.2	MEG_C1	Stoddard (Tables 10-20) – In addition to the model performance analysis of data sets that includes all months from January through December, additional understanding about model performance might be gained if skill statistics were presented for "summer" and "winter" months to highlight model performance during critical summer stratification conditions that control hypoxia compared to well-mixed winter conditions.	TL	HDR has generated model statistics by zones and seasons and will include in the full ROMS/RCA model calibration report. See note in Section 5.5 (fifth paragraph) regarding new skill assessment approach presented in QAPP.

47	5.6.3	MEG_C1	Warner (Table 21-23) – Would be good to see the time series plots of velocity, especially any phase differences. You could do the same type of harmonics comparison with the velocity data as you did for the water levels.	HDR_R1_MEG	HDR will perform velocity harmonic calculations in the full calibration report. See added last sentence of Section 5.3.
48	5.6.3	MEG_C1	Stoddard (Table 21-23) – Tables 21, 22 and 23 present model-data comparisons for velocity based on the LISICOS data sets for surface, mid-depth and bottom. The narrative on page 29 refers to velocity range as cm/s. The stick plots, however, show velocity as m/sec. The tables need to document velocity units for RMSE and median values for Observed Data and Model Data.	HDR_R1_MEG	HDR will provide consistent units in subsequent versions of the reports. Tables 21-23 are corrected in the precalibration report.
48	5.6.3	MEG_C1	Stoddard (Table 21-23) – Tables 21, 22 and 23 present model-data comparisons for velocity based on the LISICOS data sets for surface, mid-depth and bottom. The narrative on page 29 refers to velocity range as cm/s. The stick plots, however, show velocity as m/sec. The tables need to document velocity units for RMSE and median values for Observed Data and Model Data.	TL	Units were added to the statistics tables for RMSE, data median, and model median. Tables 21-23 are corrected in the precalibration report.
49	6	MEG_C1	O'Donnell – Much remains to be done in the model development process, but this report shows that the HDR team has made substantial progress and is on the right track. The model seems to be showing the correct general behavior in all metrics. I think that the water quality elements of the model now need to be brought to the same level of development, i.e. to be able to reproduce the broad pattern of the seasonal cycle in nutrient concentrations and dissolved oxygen. It seems to me that forcing from the atmosphere could be improved without too much effort by using the available wind data from buoys and coastal stations, or the regional WRF product of NECOFS (see Chen, 2007). Then I advise that a more critical assessment of the delivery of freshwater, nutrients, and carbon through the East River be conducted. The tides and subtidal variations are separately important and so reports should include assessment of both.	HDR_R1_MEG	HDR is currently in the middle of the RCA water quality model calibration, which has included some of the suggested ROMS hydrodynamic model improvements from the MEG. HDR will present additional subtidal (low-pass filtering) analyses in the full calibration report. We plan to continue use of the NARR derived atmospheric model inputs as the model temperature calibration is much improved. Therefore, we will not implement use of the regional WRF NECOFS product. Volume fluxes and nutrient/carbon delivery through the East River will be presented in the full calibration report.
50	6.1	MEG_C1	Cerco – The text states "A minimum water depth of 5 meters was initially used. This minimum depth specification will be reviewed further." Once again, I remind the team that accurate representation of depth in nearshore areas is crucial to the water quality calculation.	HDR_R1_MEG	The minimum water depth in the model has been modified to 2.5m (see response to comment #4). The precalibration report will present results using a minimum water depth of 5m but the full calibration will use 2.5m.
50	6.1	MEG_C1	Cerco – The text states "A minimum water depth of 5 meters was initially used. This minimum depth specification will be reviewed further." Once again, I remind the team that accurate representation of depth in nearshore areas is crucial to the water quality calculation.	TL	MEG was informed that a min. depth of 2.5 m is used in ROMS. The precalibration report will present results using a minimum water depth of 5m but the full calibration will use 2.5m.

51	6.2	MEG_C1	Cerco – The text alludes to the effect of Jerlov Water Type (light extinction coefficient) on the temperature calculations. The text on Page 1 states tests indicated the Jerlov Water Type can impact model results. Can the authors show this in the report or elsewhere? The text states the next steps are to let water type vary spatially and perhaps temporally. In my opinion, both temporally and spatially varying light extinction are required for water quality calculations. The light extinction should also explicitly account for effects of chlorophyll on light attenuation. The report is not at all clear how Jerlov Water Type and light extinction are obtained and utilized. Does the present calibration use water type or observed extinction? Is Jerlov Water Type a model input parameter? How will chlorophyll, computed in the water quality model, be accounted for in model light extinction? Key Points: The report introduces Jerlov Water Type. Jerlov Water type is a classification, from oceanography, based on color and light transmission. Jerlov Water Type can be empirically related to light extinction. Apparently, the authors are assigning light extinction based on Jerlov Water Type. It is not clear why the authors introduced this classification. My understanding is that most observations are in the form of light extinction and the model is intended to reproduce these observations. I don't know why the complication of employing Jerlov Water Type is necessary.	HDR_R1_MEG	See response to comment #2. The water quality model (RCA) is using the more typical light extinction formulation by applying a base coefficient that is increased by effects of chl-a, TSS, and salinity (surrogate for CDOM).

51	6.2	MEG_C1	Cerco – The text alludes to the effect of Jerlov Water Type (light extinction coefficient) on the temperature calculations. The text on Page 1 states tests indicated the Jerlov Water Type can impact model results. Can the authors show this in the report or elsewhere? The text states the next steps are to let water type vary spatially and perhaps temporally. In my opinion, both temporally and spatially varying light extinction are required for water quality calculations. The light extinction should also explicitly account for effects of chlorophyll on light attenuation. The report is not at all clear how Jerlov Water Type and light extinction are obtained and utilized. Does the present calibration use water type or observed extinction? Is Jerlov Water Type a model input parameter? How will chlorophyll, computed in the water quality model, be accounted for in model light extinction? Key Points: The report introduces Jerlov Water Type. Jerlov Water type is a classification, from oceanography, based on color and light transmission. Jerlov Water Type can be empirically related to light extinction. Apparently, the authors are assigning light extinction based on Jerlov Water Type. It is not clear why the authors introduced this classification. My understanding is that most observations are in the form of light extinction and the model is intended to reproduce these observations. I don’t know why the complication of employing Jerlov Water Type is necessary.	TL	MEG was informed that use of the Jerlov Water Type is only in ROMS and that a more traditional light extinction formulation is used in RCA (i.e., light extinction as a function of chl-a and other parameters).

52	6.2	MEG_C1	Warner – The text on this page states "the model uses the same Jerlov Water Type (light extinction coefficient) through the model study area and is assigned as a constant in time." Yet Page 6, Run 20 states that site-specific Jerlov Water Type is employed in the preliminary calibration presented here. The authors need to clear up the inconsistency between the statement on Page 32 and the details presented on Page 6. Does the preliminary calibration employ uniform or spatially-varying light attenuation?	HDR_R1_MEG	The ROMS hydrodynamic model is using a spatially constant Jerlov Water Type or light attenuation coefficient. HDR will clarify the inconsistency in future reports. LIS specific Jerlov Water Type was defined in Section 5 first paragraph and Section 6 second paragraph as "LIS specific Jerlov Water Type (i.e., not one of the ROMS standard Jerlov Water Types)". Run20 results are presented in the precalibration report.
52	6.2	MEG_C1	Warner – The text on this page states "the model uses the same Jerlov Water Type (light extinction coefficient) through the model study area and is assigned as a constant in time." Yet Page 6, Run 20 states that site-specific Jerlov Water Type is employed in the preliminary calibration presented here. The authors need to clear up the inconsistency between the statement on Page 32 and the details presented on Page 6. Does the preliminary calibration employ uniform or spatially-varying light attenuation?	TL	The descriptions of the Jerlov Water Type use in the model were revised to better describe the inputs used. LIS specific Jerlov Water Type was defined in Section 5 first paragraph and Section 6 second paragraph as "LIS specific Jerlov Water Type (i.e., not one of the ROMS standard Jerlov Water Types)". Run20 results are presented in the precalibration report.
USGS1	4	JB_C1	(Barbaro) Are details of lateral inflows (freshwater inflows from rivers and groundwater) described in other documents if not here?		Described in ROMS Hydrodynamic Model Inputs and RCA Water Quality Model Load Development Approach Memo
USGS2	4.1	JB_C1	(Barbaro) Encourage distinguishing water elevation gages (offshore measuring water levels in tidal areas) from USGS streamflow gaging stations (in river reaches above tidal influence).		Added descriptive terms "open water, tidal" water elevation gages

USGS3	4.1	JB_C1	(Barbaro) Use of other USGS gages in tidally influenced waters on the CT River with data potentially available for the post audit period.		USGS tidal gages on the CT River will be reviewed for data usage for the post audit period (2019-2022)
EPA1	5.1	MD_C1	(Duvall) Are qualitative and would be better to just combine with the skill assessment section.	TL	EPA's point is noted and HDR will be mindful of it in organizing the full ROMS/RCA model calibration report.
EPA2	5.2.1	MD_C1	(Duvall) Descriptions of the model being "good" or "quite good" are qualitative and not very meaningful; suggest combining with section 5.6.2 discussion.	TL	Per EPA1, the qualitative and quantitative descriptions of the model calibration will be merged in the full calibration report.
EPA3	5.2.1	MD_C1	(Duvall) 2006 LISICOS salinity and temperature dataset should be used to calibrate the variance as a function of frequency.		High frequency variations will be evaluated during the full calibration as the T/S calibration has been improved since the preliminary calibration. Graphics will be improved to better evaluate the high frequency variations.
EPA4	5.6.2.1	MD_C1	(Duvall) Points out contradicting statement about r values for bottom and surface salinity which aren't meeting the target in QAPP.	ROMS_v3	Wording in the Sect. 5.6.2.1 of the ROMS PreCalibr report was modified to clarify that r-values for salinity do not meet the QAPP target.
EPA5	5.6.2.1	MD_C1	(Duvall) Unclear how CTDEEP surface/bottom observations are being compared to surface/bottom model layer- only using the shallowest/deepest measurements? This will impact skill and qualitative assessments, so it is important to make sure we're comparing observations to the model at the same height above bottom.		The full calibration report will compare model output and data (e.g., CTDEEP, Harbor Survey) at the same depth level. That is, the data surface and bottom depths will be mapped to specific model vertical layers by stations for model-data comparisions and skill assessment. Details are provided in the HDR memo dated 6/14/2024.
EPA6	Fig. 12	MD_C1	(Duvall) Is this a comparison between surface/bottom layer and the shallowest/deepest measurement? Agreement would likely improve if they interpolated the observations to the model layer height. The depth of the bottom measurement typically varies over time (this is obvious if you look at the figures below showing vertical profiles), which may account for some of the difference between the model and observation, particularly if the "bottom observation" doesn't fall within the bottom model layer. I would suggest that if they haven't done this they check to make sure they're comparing model to observations at the same height above bottom.		The precal report compares surface data to model layer 10 and bottom data to model layer 1. See prior comment about revisions to be made to address this issue in the full calibration report.
EPA7	Fig. 20	MD_C1	(Duvall) The height of the observations should be interpolated to the nearest model layer, which may or may not be the "surface" and "bottom". Implement in the post-processing code. Why wasn't the layer closest to the mid-depth sensor included for comparison?		See response to prior comment. The mid-depth model output was not presented to simplify presentation.

EPA8	Fig. 22	MD_C1	(Duvall) Looking at the top plot, the model is barely resolving any high-frequency variance associated with tidal exchange from the East River. This is why the salinities in the bottom layer are too high. Showing the power spectral density (variance as a function of frequency) would be more illustrative of the point above. Checking whether the model is capturing the variance at known periodicities is a better way of determining whether the model is getting the mechanics right. *Previously raised this point at a meeting in November/December as did Jim O'Donnell in the January MEG meeting*.		High frequency variations will be evaluated during the full calibration as the salinity calibration has been improved since the preliminary calibration. Power spectral density analysis will not be completed in the full calibraton report but graphics will be improved to better evaluate the high frequency variations.
EPA9	Fig. 32	MD_C1	(Duvall) Difficult to evaluate what is being shown in many of the figures because of the y-axis limits chosen. E.g., why does the temperature axis range from -5 to 30 C when the data only varies from ~12 – 26C? The model surface range is also plotted on top of the bottom surface range so you can't actually see the data. Because of this, you can't tell whether some of the "bottom" salinities observed fall within the range of modeled values. Again, they should check that the "bottom" observations fall within the bottom model layer. Also suggests station labels.		Y-axis scales for T/S will be improved in the full calibration report. Figures 32 and 33 y-scale for temperature will be revised in final precal report.
DEP1	5.1	DEP_C1a	With reference to Fig. 10 and 11, how is the reader to supposed to know when spring and neap tides are occurring? I recommend either removing this sentence or adding markers to the figures to show when these tides are occurring.	HDR_R1_DEP	Spring tides occur during full/new moons and result in higher high and lower low tides. Neap tides occur during half moons and result in lower high and higher low tides. We will add a description for these tides and add notations on the figure in future reports.
DEP2	5.2	DEP_C1a	The DEP Harbor Survey data are not being referred to in a consistent way. In Fig. 13 they are referred to as "NYHS Observations" and "Data at East River NYCDEP Stations …"	HDR_R1_DEP	We will use a consistent ref to DEP Harbor Survey data in future reports.
DEP3	5.2	DEP_C1a	I like the transects because they provide an overview and different view of how observed and predicted values compare. That said, for interpreting the transects, I think it would be useful to include a plan view that shows the path of the central transect, distance markers, and the names and locations of gages represented in the transects.	HDR_R1_DEP	Revisions to the transect maps and a spatial map locating the transects will be made in future reports. And add'l discussion and clean up of the figures will be made.
DEP4	5.2	DEP_C1a	"Deeper LIS waters of the sound are cooler …" Where is it that LIS waters are deeper? Consider referring to Figure 3 and the plan view proposed in the preceding comment.	HDR_R1_DEP	*[ROMS_v3] Wording was added to ROMS_v3 to indicate that LIS waters are deeper in the center of LIS*. [HDR_R1_DEP] Further expansion and explanation of the deeper waters of LIS will be made in future reports.
DEP5	5.2	DEP_C1a	"In addition, the salinity data is less stratified than the temperature data, and the model reproduces this level of salinity stratification." This is not true for Jan to April and Sept to Dec 2005 and in any case, because the units of measure are different for salinity and temperature, it does not seem plausible that you can compare their levels of stratification?	HDR_R1_DEP	The stratification comparison is a general statement about top to bottom differences. Revisions and add'l discussion will be provided in future reports.

DEP6	5.4	DEP_C1a	"... the magnitude of the net volume flux calculated by the model is less than that presented in the previous studies." Why raise this issue and not present representative values from the HyroQual (2001) report, that is, how much less is the earlier estimate? Also, given that no data is available for validating flux estimates, what objective is addressed in noting this discrepancy?	HDR_R1_DEP	Fluxes through the East River have been raised as an important model result to present and discuss. Although there is not contemporary estimates of fluxes from data, we have tried to compare to past estimates. We will provide further discussion of the fluxes in future reports with ref to the past data.
DEP7	6.2	DEP_C1a	"The East River and Harlem River geometry and bathymetry changes are anticipated to improve the transport and volume flux of water between the Hudson River and the East River, which in turn are anticipated to improve the model salinity calibration and potentially the model temperature calibration." I seem to recall a conversation in which it was noted that the Hudson had been dredged at time during the calibration period. Is this an issue of concern considering that the grid reflects a fixed bathymetry?	HDR_R1_DEP	Model bathymetry will be changed based on when dredging occurred. So some range of model years may use different depths than other years. This will be explained in future reports
DEP8	6.3	DEP_C1a	"... the model near-surface velocities appear to be slightly higher than the data..." Since this is deemed worthy of being mentioned in the summary, it should be mentioned and discussed in Sect 5.3 where the velocity results are presented.	HDR_R1_DEP	Add'l discussion will be added in future reports as considered necessary.
DEP9	8	DEP_C1b	In this document there are numerous comments about the figures presented in Sect. 8 and the Attachments 1 to 5 which follow Sect. 8. For example, Fig. 1 has a scale that is incorrect and uses U.S. standard units; Fig. 13, 15, 17, and 19 use "NYHS" which was decided against in comment DEP2; Fig. 32, 33, 36, use miles instead km.		The various figure units and labeling will be updated in the final calibration report.