Attachment 1

DSM2 Recalibration for Bay-Delta Conservation Plan

DSM2 Recalibration

Prepared for

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October 2009

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Acronyms and Abbreviations

1D	one dimensional
2D	two dimensional
BDCP	Bay Delta Conservation Plan
BLTM	Branched Lagrangian Transport Model
CDEC	California Data Exchange Center
CCWD	Contra Costa Water District
CVP	Central Valley Project
DCC	Delta Cross Channel
DICU	Delta Island Consumptive Use
DSM2	Delta Simulation Model 2
DSM2PWT	Delta Simulation Model Project Work Team
DWR	California Department of Water Resources
EC	electrical conductivity
HEC-DSS	Hydrologic Engineering Center Data Storage System
HYDRO	DSM2 Hydrodynamics Module
IEP	Interagency Ecological Program
MWDSC	Metropolitan Water District of Southern California
NAVD88	North Atlantic Vertical Datum 1988
NGVD29	National Geodetic Vertical Datum 1929
QUAL	DSM2 Water Quality Module
RMSE	root mean squared error
SWP	State Water Project
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
WDL	Water Data Library
WY	Water Year

SECTION 1
Introduction

1.1 Background

Delta Simulation Model (DSM2) is a one-dimensional (1D) model capable of simulating hydrodynamics and water quality in Sacramento – San Joaquin Delta. The model was developed by California Department of Water Resources (DWR). DSM2 was originally calibrated and validated in 1997 (DWR, 1997). In 2000, a group of agencies, water users, and stakeholders recalibrated and validated DSM2 in an open process resulting in a model that could replicate the observed data more closely than the 1997 version (DSM2PWT, 2001). DSM2 is frequently used to ascertain impacts of potential changes in Delta conditions (salinity, flow, and water level) associated with changes in flow patterns caused by variations in boundary conditions such as river inflows, exports, diversions, or gate operations.

The Bay Delta Conservation Plan (BDCP) is considering several conservation strategies to restore habitat for Delta fisheries while continuing reliable water supply. Federal and state agencies, environmental organizations, fishery agencies, water agencies, and other organizations are working together to develop the Plan. DSM2 is one of the core analytical tools that will be used in the BDCP to evaluate the changes to Delta hydrodynamics and water quality associated with the elements of the Plan.

1.2 Purpose of DSM2 Recalibration

During the development of preliminary DSM2 modeling analyses for the BDCP analyses, several shortcomings were identified in the DSM2's capability of accurately simulating tidal flows in the Sacramento River and Cache Slough region. Several permanent morphological changes such as island flooding (Liberty Island) have occurred in the Delta since the previous DSM2 calibration in 2000. Updated bathymetric data were collected in parts of the Delta since the last calibration. In addition, new flow, stage, and electrical conductivity (EC) monitoring data are available since the last calibration providing a better spatial and temporal depiction of the hydrodynamics and water quality. The BDCP is considering the construction and operation of the new diversion intakes on the Sacramento River and large-scale restoration of tidal marsh in the Cache Slough region. The ability to accurately simulate tidal flows and salt transport in this region is of particular importance for the BDCP. These factors have called for recalibration of DSM2 to reflect the most recent configuration and data availability. A limited recalibration of DSM2 was undertaken to ensure adequacy of DSM2 for BDCP analyses and other applications. DWR is currently in the preparatory phase of a broader recalibration process based on the outcome of this recalibration effort.

1.3 Scope of DSM2 Recalibration

The main goal of this DSM2 recalibration is to rectify specific shortcomings in DSM2 that are critical for its use in BDCP analyses. The following primary objectives were set at the outset of the calibration effort:

- Accurate representation of tidal prism in DSM2 under the current physical conditions in the Delta
- Accurate simulation of tidal flows at Rio Vista, Jersey Point and Threemile Slough, in terms of magnitude and phase
- Adequate simulation of EC at Collinsville, Emmaton, Jersey Point, Rio Vista and in Rock Slough
- Identify and disclose strengths and weakness of DSM2 model, particularly as it relates to the BDCP process.

The scope of this recalibration is mainly focused on these primary objectives. For other locations in the Delta, the objective was established that the calibration should be consistent or better than that from the 2000 calibration.

SECTION 2

Model Configuration and Boundary Conditions

2.1 DSM2 Overview

DSM2 contains two modules, HYDRO and QUAL, that simulate Delta hydrodynamics and salt transport, respectively (DWR, 1997). The HYDRO module is a one-dimensional, implicit, four-point finite difference model developed originally by Lew DeLong of the USGS in Reston, Virginia (DeLong et. al., 1992). DWR adapted the model to the Sacramento-San Joaquin Delta by revising the input-output system, adapting Delta bathymetry, including open water elements, and incorporating water project facilities such as gates, barriers, and Clifton Court Forebay. The salt transport model, QUAL, is adapted from the Branched Lagrangian Transport Model (BLTM) model developed by Harvey Jobson of USGS, Reston Virginia (Jobson, 1980).

The spatial domain of DSM2 includes the river channels, sloughs, reservoirs and other open water areas within the Delta bounded by Sacramento, Vernalis and Martinez as shown in Figure 2-1. The spatial resolution of the model varies with channel lengths ranging from a few hundred feet to a few miles. Several cross-sections define the bathymetry within each DSM2 channel. The cross-section information is interpolated to provide adequate representation for the computation method.

Boundary conditions to the DSM2-HYDRO model are river inflows, exports, diversions, drainage, and tidal stage. In addition, several internal boundary conditions such as operable gates and permanent rock barriers are included. Boundary conditions to the DSM2-QUAL model are water quality of the river inflows, drainage, and the seawater at the downstream boundary. The boundary conditions in the historical model were updated from 1990 through 2008 to incorporate the most recently available information. The DSM2 model is most commonly simulated with a 15-minute computational time step. Sensitivity studies performed as part of the 2000 calibration indicate that the model results were insensitive to 3-, 5- or 15-minute time steps.

The sections that follow describe the physical changes, bathymetric updates, and boundary condition review that were conducted as the first step in the model calibration effort.

2.2 Physical Changes

This section provides a short description of the changes made to DSM2 grid before starting the calibration process. The grid modifications included a representation of the flooded Liberty Island, modification of channel lengths in the Sacramento River, inclusion of new bathymetry in Sacramento River channels, and extension of the rigid wall boundary on the Sacramento River further upstream. Figure 2-2 identifies the modifications performed to DSM2 grid. This section also discusses the rationale behind the changes and their impact on the DSM2 results.

2.2.1 Liberty Island Flooding

Liberty Island is an inundated island encompassing approximately 5,209 acres and located in Yolo and Solano counties, in the northern Sacramento-San Joaquin Delta adjacent to Prospect Island and Little Holland Tract. It is the southern outlet of the Yolo Bypass. Liberty Island has been flooded since 1998 when levees were breached during high flows through the bypass. The levees were not repaired by the landowners and the island has remained inundated and under tidal influence (USFWS, 2008). In the early 2000, the levee adjacent to Cache Slough failed, which significantly impacted the tidal prism in Cache Slough and the Sacramento River. The change in tidal prism can be visualized from the tidal flows measured in Sacramento River at Rio Vista just downstream of the confluence with Cache Slough. The tidal flow range has increased by approximately 25,000 cfs at Rio Vista as shown in the Figure 2-3. The existing DSM2 model grid did not include the flooded Liberty Island. This caused the model to under-predict the tidal prism significantly in the north Delta and impacted the hydrodynamics in the Sacramento River and many of the north Delta channels.

A representation of the flooded Liberty Island was incorporated into the DSM2 model. Due to the one-dimensional nature of the DSM2 model, open water bodies are simulated through a reservoir construct connected to the adjacent channels. A reservoir with a surface area of 5,209 acres was included in the DSM2 model (node 322) on Cache Slough to simulate the flooded Liberty Island as shown in Figure 2-2. The coefficients that govern the amount of flow entering and exiting the reservoir are set to 10,000 and 7,500 respectively. These coefficients were derived to best represent the observed change in tidal flows in the Sacramento River at Rio Vista. Comparisons were also performed between simulated and observed tidal flows on Cache Slough.

2.2.2 Extension of Model Boundaries on Sacramento River

Peak ebb tidal flows simulated in DSM2 near to the upstream boundary on the Sacramento River were attenuated as compared to the observed data. It was hypothesized, that one of the reasons for the ebb attenuation may be the proximity of the rigid upstream boundary on the Sacramento River, which is located at the City of Sacramento in the DSM2. The daily averaged flow measured at the Freeport gage south of the city is used as the inflow boundary for Sacramento River. At times of low inflow, tidal variation in stage and flow extend upstream beyond Sacramento. Therefore, the inflow boundary condition that is constant over a 24-hour period does not account for the effects of the miles of channels above the upstream boundary that are under tidal influence. In addition, since DSM2 does not allow propagation of tidal waves at the boundary, an incoming tidal wave would be reflected at the boundary rather than to continue propagating upstream and be dissipated. The reflected wave could lead to errors in simulated stage and flow near the upstream end of the Sacramento River (Shum, 2006).

In an effort to reduce the reflective wave issue, the rigid boundary on Sacramento River was extended upstream while keeping the location of the boundary inflow unchanged in DSM2 as shown in Figure 2-2. Four new channels of 10,000 feet each were added to the existing DSM2 grid. The channel cross-sections for this 40,000-foot reach were derived from the 2002 Comprehensive Study Sacramento River UNET model (USACE, 2002). This modification to the grid was found to partly mitigate the errors caused due to the reflected wave and allowed improvement in the simulation of peak ebb tide flows in Sacramento River channels around Hood as shown in the Figure 2-4.

2.2.3 Updated Sacramento River Grid

The DSM2 grid was refined in the north delta in anticipation of the need to simulate proposed diversion intakes. The highlighted nodes in Figure 2-2 on the Sacramento River were relocated. Table 2-1 shows the modified channel lengths resulted from the relocation of DSM2 nodes to match the proposed points of diversion. In this process the total length of the river channel from City of Sacramento to the Sutter Slough confluence was ensured to be unchanged.

In DSM2, bathymetry of a channel is represented by irregular cross-sections spaced over the length of the channel. DSM2 requires an optimum number of irregular cross-sections defined in a channel to accurately represent the bathymetry of the channel and for the accuracy in computations. This number depends on the length of the channel. With the channel lengths modified, the number of the irregular cross-sections within each channel was reviewed in the channels upstream of Delta Cross Channel (DCC). Additional cross-sections were added to the channels, when the number was fewer than the optimum. The new cross-sections were extracted using the Cross-Section Development Program (CSDP) based on the recent bathymetry data collected by DWR in 2008. More information about the recent bathymetry data is presented in the Section 2.2.4. Table 2-2 shows the existing and modified cross-section locations in the DSM2 grid. The cross-section location within a channel is shown as a fraction of the channel length measured from the upstream end of the channel. The new cross-sections that were added to the existing grid are shown with an asterisk (*) on the cross-section location distance.

The definitions provided in DSM2 (translations) for the locations along the Sacramento River (e.g. RSAC101) in the model falling between nodes 332 and 339 were modified to reflect the changes in channel lengths. The resulting Sacramento River flows were compared between the two simulations with existing and modified grids. The comparison showed that the changes in the flows and stage in Sacramento River channels were minor (less than 1 percent), mainly around the modified channels. No changes were found further downstream.

2.2.4 Updated Sacramento River Bathymetry

DWR collected bathymetry data on the upper Sacramento River between Sacramento and the Walnut Grove in 2008 (DWR, 2008). This recent bathymetric dataset was compared to the existing DSM2 bathymetry using CSDP. Figure 2-5 shows the extent and the resolution of the bathymetric data in the two datasets. On the whole, the two datasets showed no differences in terms of the channel cross-sections. Therefore, existing DSM2 cross-sections were not updated with the recent bathymetry data. However, the data in the existing bathymetry, is very sparse upstream of Sutter Slough junction. Therefore, the new bathymetry was used to extract the new irregular cross-sections to improve the resolution in the channels upstream of Sutter Slough on the Sacramento River, as described in the previous section.

2.3 Boundary Condition Review

The time series data used for the inflow, export, and stage boundary conditions in the existing DSM2 model were verified using the observed gage data collected from different sources for water years (WYs) 2001 to 2004. Existing inflow and exports data at each boundary were compared to the observed gage data on a daily time step for Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras Rivers; Banks Pumping Plant, Jones Pumping Plant, Contra Costa Water District Rock Slough, and Old River Intakes. Boundary conditions were modified to ensure accuracy with the observations for the days when the absolute difference was greater than 1 percent. Stage boundary data at Martinez were verified by comparing the model simulated stage output with the observed gage data. EC boundary condition data were not verified using gage data. Table 2-3 shows the boundary locations where the existing time series data were compared with the observed gage data and the number of days the data has been replaced with the observed data.

In summary, most of the existing boundary condition data matched the observed records. The mismatched data were mainly in fall and winter months of WY 2001 for the Sacramento River and the Mokelumne River inflows. For Calaveras boundary, existing data is different than observed data for 31 days. These differences are mainly in the WY 2004, from February through May, and were corrected to match observed flows.

Tables

TABLE 2-1
Comparison of Existing and Modified Channel Lengths

DSM2 Channel #	DSM2 Node at d/s of the Channel	DSM2 Existing Channel Lengths (ft)	DSM2 Modified Channel Lengths (ft)
411	332	18,620	18,620
412	333	14,386	17,340
413	334	14,323	11,828
414	335	17,612	24,177
415	336	12,285	6,300
416	337	17,389	25,418
417	338	12,716	6,133
418	339	16,047	13,562

TABLE 2-2
Translation of Existing Cross-section Locations to Modified Cross-section Locations

Existing Irregular Cross-section Locations			Modified Irregular Cross-section Locations		
DSM2 Channel	**Channel Length (ft)**	**Cross-section Location**	**DSM2 Channel**	**Channel Length (ft)**	**Cross-section Location**
412	14,386	0.27053	412	17,340	0.22444
		0.58263			0.48337
		0.87590			0.72668
413	14,323	0.05145			0.87214
		0.19211			0.98833
		0.55768	413	11,828	0.42557
		0.83269			0.75859
414	17,612	0.03831	414	24,177	0.00892
		0.30709			0.20472
		0.41170			0.28092
		0.66276			0.46381
		0.86416			0.61052
		0.95902*			0.67962*
415	12,285	0.11477			0.76779
		0.40885			0.91722
		0.60497	415	6,300	0.06477
		0.90451			0.64887
416	17,389	0.18735	416	25,418	0.08729
		0.28725*			0.15564*
		0.37797			0.21770
		0.64429			0.39990
		0.77274			0.48777
		0.84153*			0.53483*
417	12,716	0.01444*			0.65047*
		0.28395			0.78530
		0.49394			0.89035
		0.63939*			0.96312*
		0.78870*	417	6,133	0.15672*
418	16,047	0.02079*			0.64922*
		0.26257*	418	13,562	0.12745*
		0.53364			0.44819
		0.78081			0.74065
		0.98668			0.98424

* New cross-sections defined using 2008 DWR bathymetry.

TABLE 2-3
Boundary Locations Where the Existing Data is Replaced by Observed Data

Location ID	Description	Parameter	Gage Data Source	Number of Days Data Replaced by Gage Data
RSAC155	Sacramento River at Freeport	Flow	IEP (DWR-OM-JOC-DSM2)	16
RSAN112	San Joaquin River at Vernalis	Flow	IEP (DWR-OM-JOC-DSM2)	3
RCSM075	Cosumnes River	Flow	IEP (DWR-OM-JOC-DSM2)	5
RMKL070	Mokelumne River at Woodbridge	Flow	IEP (DWR-OM-JOC-DSM2)	128
RCAL009	Calaveras River at Stockton	Flow	IEP (DWR-OM-JOC-DSM2)	31
BYOLO040	Yolo Bypass	Flow	IEP (DWR-OM-JOC-DSM2)	0
CHSWP003	Clifton Court Forebay	Exports	IEP (DWR-OM-JOC-DSM2) IEP (DWR-OM-JOC) CDEC (CLC)	0
CHDMC004	Delta Mendota Canal	Exports	IEP (DWR-OM-JOC-DSM2) IEP (DWR-OM-JOC) CDEC (DMC)	2
ROLD034	Old River near Byron	Diversions	IEP (DWR-OM-JOC-DSM2)	1
CHCCC006	Delta Mendota Canal at Tracy Pumping Plant	Diversions	IEP (DWR-OM-JOC-DSM2)	2
SLBAR002	Barker Slough	Diversions	IEP (DWR-OM-JOC-DSM2) IEP (DWR-OM-JOC)	0

Figures

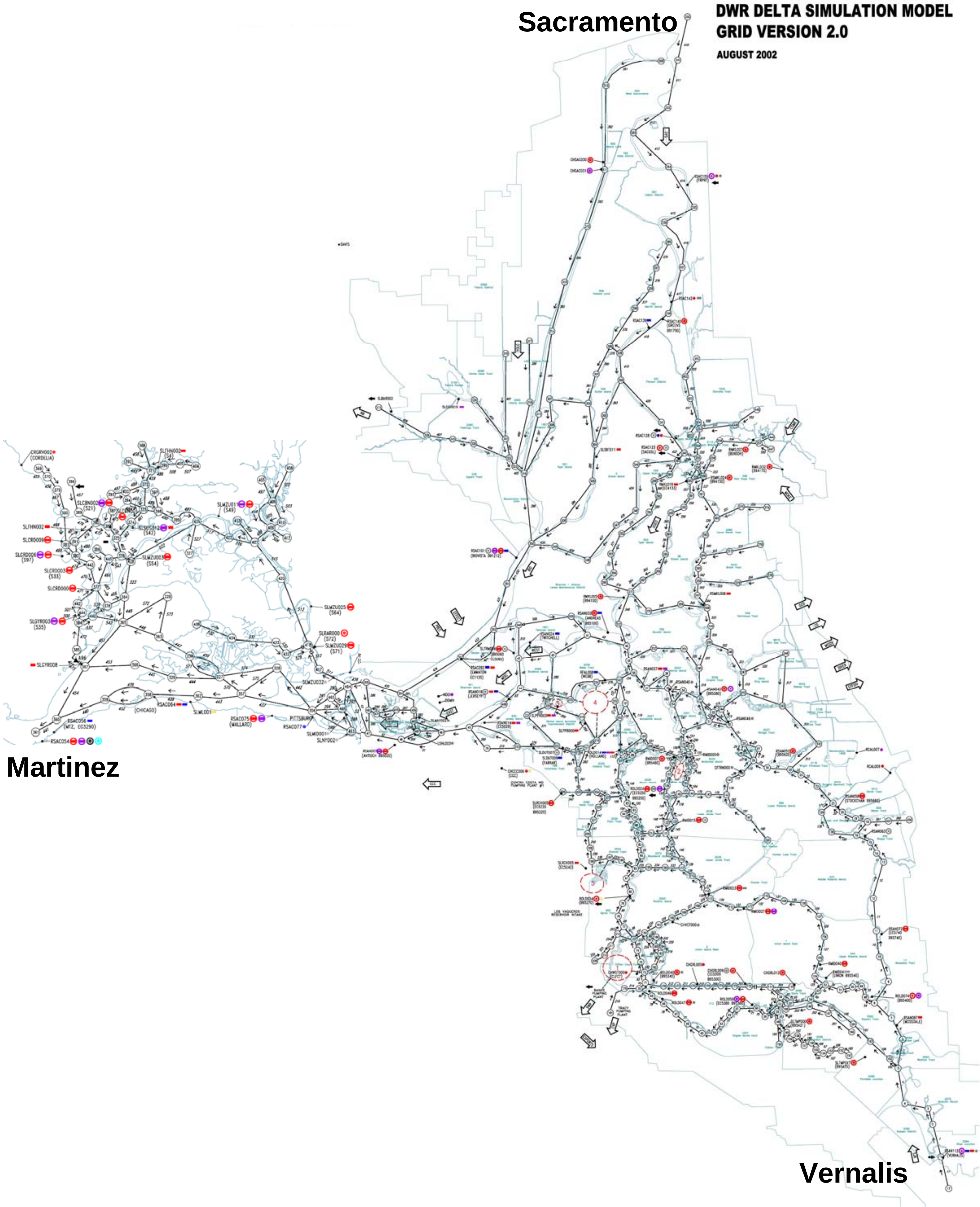


FIGURE 2-1
Spatial Domain of the DSM2 Model

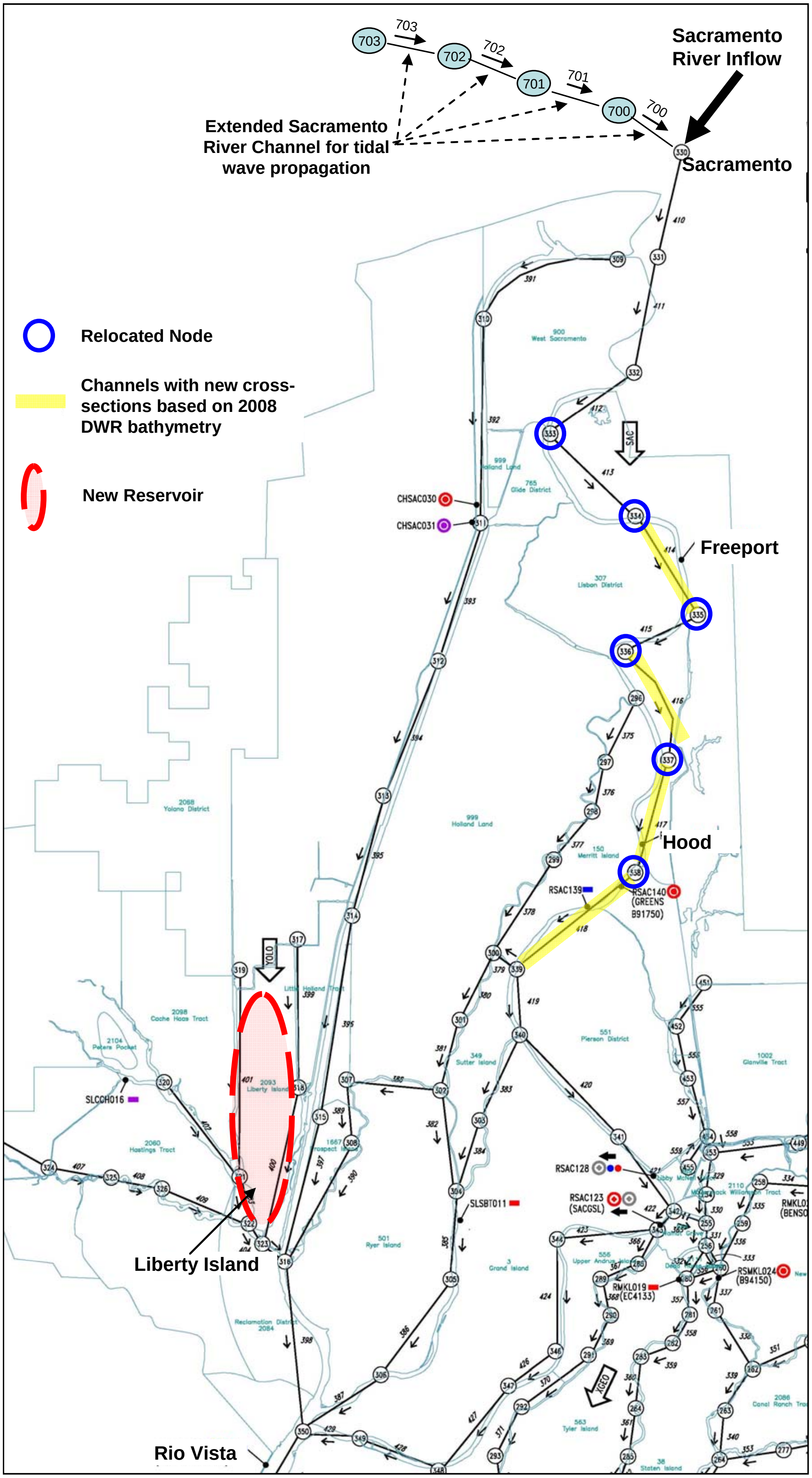


FIGURE 2-2
DSM2 Model Grid in the North Delta Showing the Grid Modifications Performed as Part of the Recalibration Effort

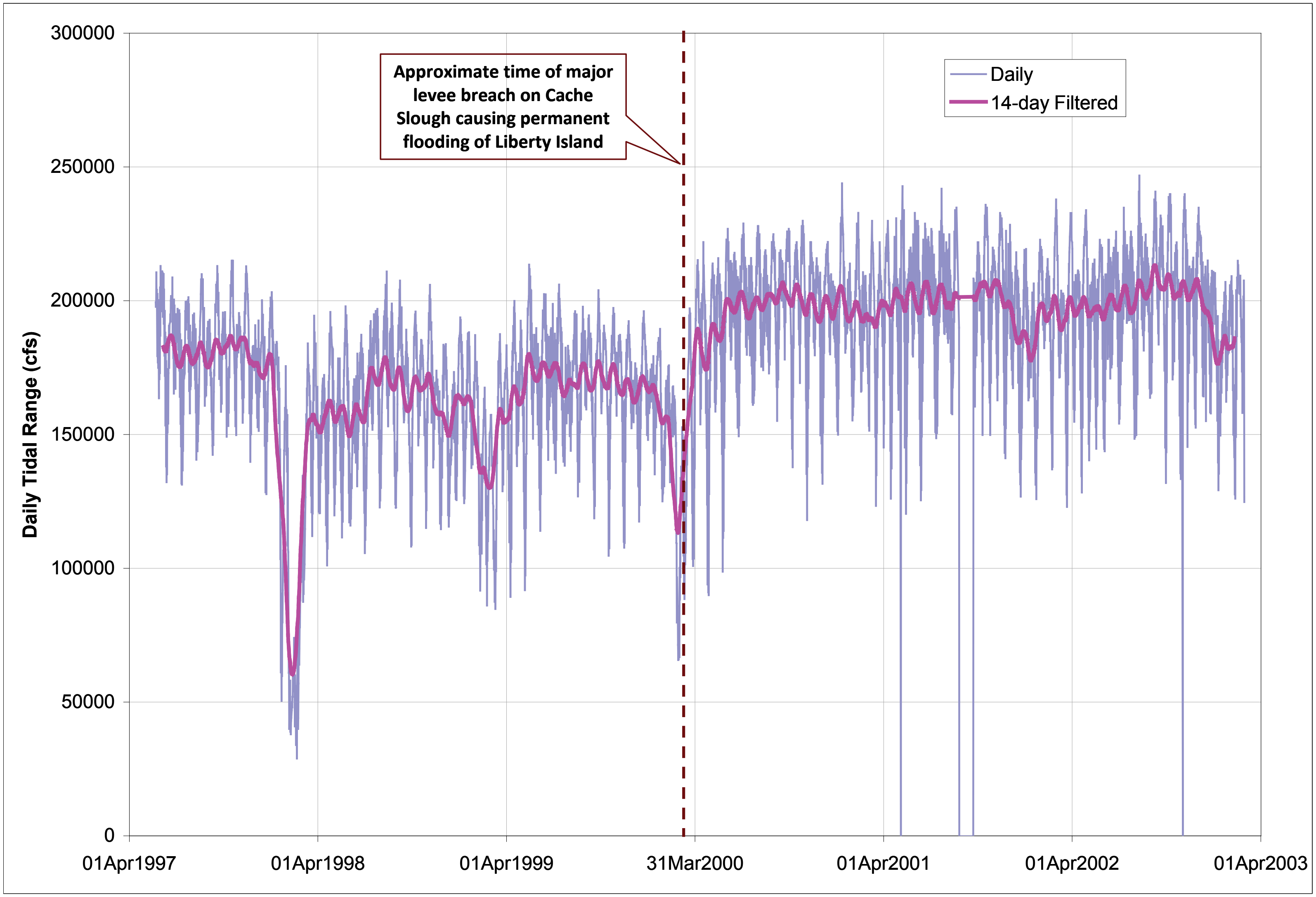


FIGURE 2-3
Observed Tidal Flow Range in Sacramento River at Rio Vista

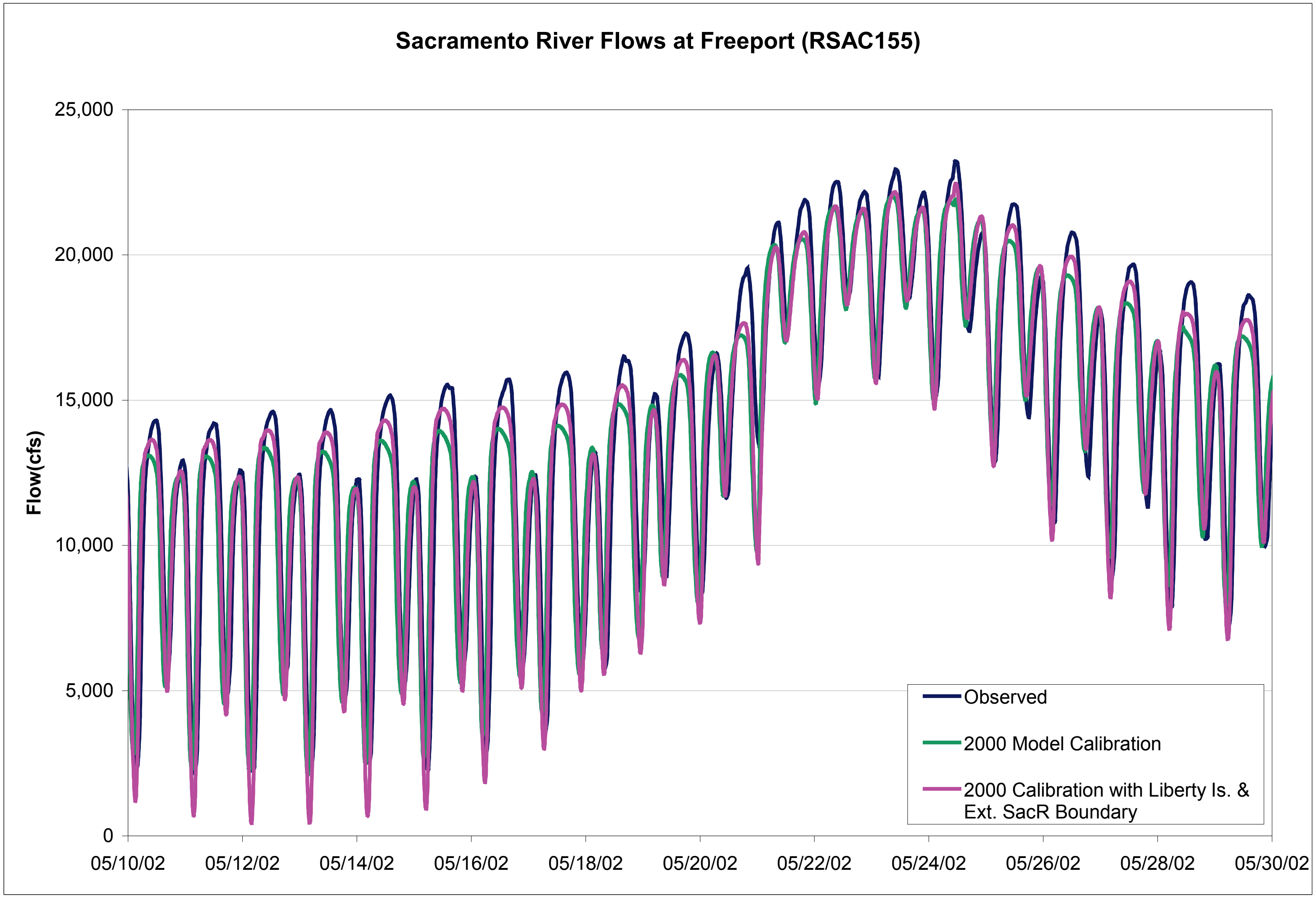


FIGURE 2-4
Simulated and Observed Tidal Flow in Sacramento River at Freeport With and Without Extended Channels Upstream of Sacramento River Boundary

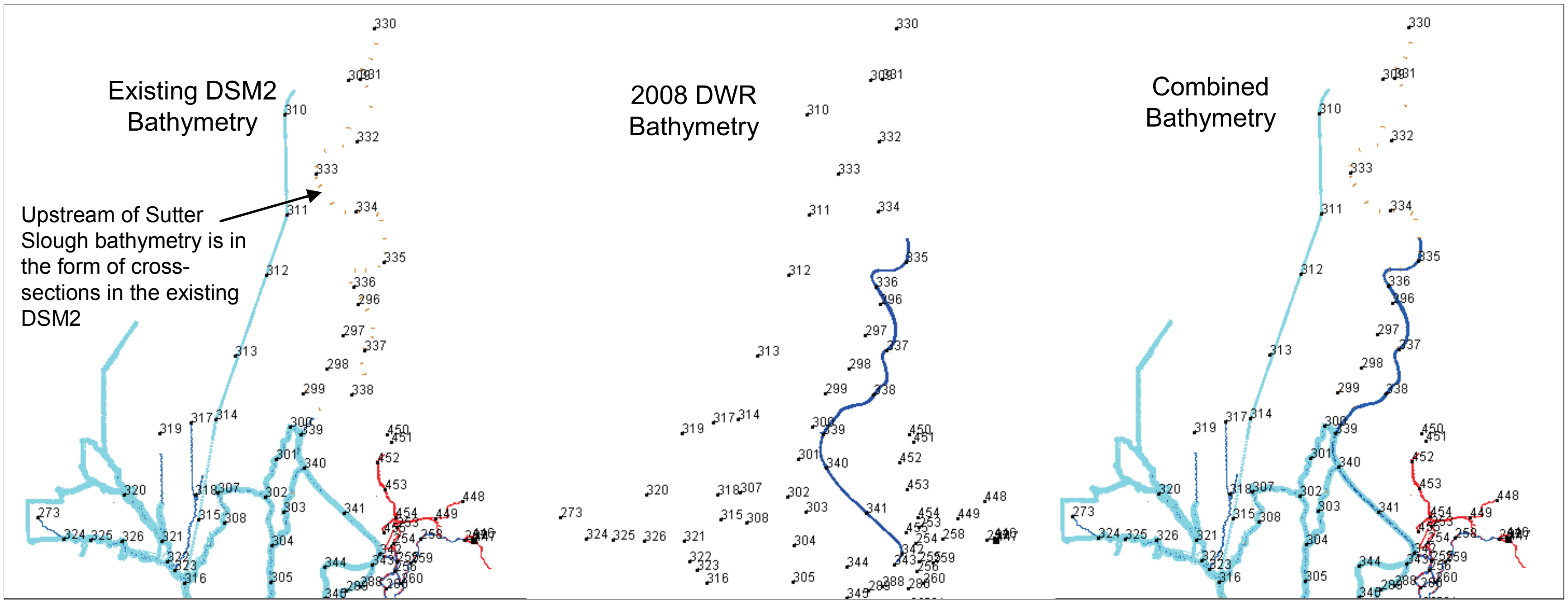


FIGURE 2-5
DSM2 and DWR Bathymetry Extent in Delta

SECTION 3

Calibration Details

3.1 Observed Data

An observed dataset was compiled for the purpose of evaluating the simulated model results. The dataset contains 15-minute average and hourly average data of flow, stage, and electrical conductivity (EC). The data has been collected at several locations in the Delta that were determined to be critical to the evaluation of performance of the model.

The sources for the observed data included United States Geological Survey (USGS), United States Bureau of Reclamation (USBR), DWR's California Data Exchange Center (CDEC), Interagency Ecological Program (IEP), and DWR's Water Data Library (WDL).

The model was calibrated based on the goodness of fit measures computed using the observed dataset. Hence, the accuracy of the observed data is very critical for evaluating the performance of the model. To ensure the accuracy of the collected observed dataset, quality assurance has been performed. Each time series dataset was visually inspected for anomalies in the data that were eliminated.

Table 3-1 is the inventory of the datasets collected for the purpose of DSM2 model calibration. The table lists the source of each data record, which sometimes is the agency maintaining the gage, gage identification number, location of the measurement, the parameters measured and the period of available data for every record in the observed dataset.

3.2 Period Selection

The calibration and validation periods for this DSM2 calibration effort was selected such that a variety of conditions were included in terms of the hydrology, exports and gate operations within the identified period. In addition, the period was selected such that it represented the existing structure of the Delta and had sufficient observed flow, stage, and EC data collected at various locations in the Delta. These criteria are generally consistent with the recommendations by USGS (Ruhl, 2007). A brief description of the key factors used in deciding the calibration and validation periods is provided below.

1. Current physical conditions: Representation of current structural configuration of the Delta in DSM2 is important from using the model for future planning efforts. The permanent flooding of Liberty Island that occurred in early 2000 was a significant change to the Delta configuration since the previous calibration. Therefore, based on this factor, any period after WY 2000 is desirable for current DSM2 calibration.

2. Hydrology: Periods with low flows are desirable for calibration of hydrodynamic and water quality models in estuaries. At low flows the tides are the dominant process determining the hydrodynamics and the transport in the Delta. Based on this factor,

Table 3-2 shows that WYs 2001, 2002, 2004, 2007, and 2008 are reasonable years for calibration.

3. Exports: Periods with variable export regimes would provide contrast in terms of the hydrodynamics and water quality in the South and Central Delta. Based on this criterion, WYs 2001, 2002, 2004, 2007, and 2008 are good for the calibration as shown in the Table 3-2.

4. Availability of observed data: The availability of observed flow, stage, and EC data at various locations in the Delta is critical for the calibration. In addition to the daily average data, availability of some instantaneous data is important. As shown in the Table 3-2, WYs 2002 through 2008 have abundant observed flow, stage, and EC data. Based on the availability of both daily and instantaneous data at key locations identified for the calibration, it was decided which year was fair, good or sparse.

Based on the above four factors it was determined that the WYs 2001 to 2008 would be an appropriate period for the calibration and validation of DSM2. The selection of calibration versus validation periods is discussed separately under the Sections 4 through 6.

3.3 Calibration Metrics

The success of calibration was evaluated based on a combination of quantitative metrics and the qualitative assessment. Goodness-of-fit measures were computed both on a tidal scale and on a net daily scale for hydrodynamics. However, for EC simulation, the computed measures were limited to daily and monthly scales, since significant uncertainty exists in the agricultural drainage inputs at the tidal scales.

The evaluation of calibration and validation performance for flow and stage were summarized through the following metrics:

- **Time series inspection of tidal flow and stage.** 15-minute modeled and observed time series data are plotted over one month to visually judge the model performance. This plot provides an initial sense of the quality of the calibration or validation on a tidal scale, in terms of amplitude, phase, and mean.

- **Bias in simulated peak ebb and peak flood.** This metric allows assessing any bias in the modeled tidal highs or tidal lows compared to the observed data. The scatter plot shows the goodness-of-fit between the observed and simulated tidal peak ebbs and lows for the entire calibration or validation period. This plot does not account for the phase error that may exist between the modeled and observed data. The slope of the linear trend line through the scatter indicates the bias.

- **Error in Tidal amplitude.** This metric is a measure of the difference in the modeled and observed tidal amplitude or range. A percent error histogram is plotted for the modeled and observed tidal range over the entire calibration or validation period, which provides an indication of the bias in the simulated tidal range. An average amplitude error is also computed over the full calibration or validation period.

- **Error in Tidal phase.** This metric is a measure of the difference in the modeled and observed timing of the peak tidal ebbs or floods. An error histogram is plotted for the phase difference in minutes, between the modeled and observed flow and stage over the entire calibration or validation period. The histogram provides an indication of whether the model data is leading or lagging the observed data most often. An average phase error is also computed over the full calibration or validation period.

- **Time series inspection of tidally-averaged flow and stage.** Tidally filtered daily averages of the modeled and observed data are plotted as a time series over the full calibration or validation period. This plot gives an indication of how well the model is simulating the flows and stages on a net basis. The net flow is especially important, because it is an indicator of the transport of water quality constituents. Since the observed stage data often exhibits erroneous datum shifts due to subsidence of the monitoring sites, comparing the modeled and observed net stage data is not very useful for evaluating stage calibration.
- **Mean Error in tidally-averaged flow and stage.** Mean error is computed as the difference between the long-term average of the modeled and observed tidally filtered net daily data, over the full calibration or validation period. Mean error is a good measure to show any bias in the modeled net flows compared to the observed data. The mean error, however, averages both positive (over-prediction) and negative errors (under-prediction), and can lead to a smaller computed error than through other metrics or seasonal analysis.
- **Root Mean Squared Error (RMSE) in tidally-averaged flow and stage.** RMSE is computed using the tidally filtered daily modeled and observed data over the full calibration period. RMSE provides an indication of the error variance including the errors in the magnitude and time shift. RMS error provides a more realistic measure of prediction errors, and is not subject to balancing positive and negative errors as described above. However, the RMS error does not discern between over- and under-predictions.

The goodness-of-fit measures for flow and stage outputs were summarized on a set of plots that are specific to each location, as shown in the Figure 3-1. The top panel compares the observed and simulated time series of tidal flow (or stage) for several days within the calibration period. The middle panel includes three plots that allow analysis of the model performance on a tidal scale. The scatter plot shows the goodness-of-fit between the observed and simulated tidal peak ebbs and lows for the entire calibration period. The two error histograms show the amplitude errors as a percentage and the phase errors in minutes between the simulated and observed data within each tidal cycle over the calibration period. The bottom panel shows the tidally filtered daily average flow (or stage) time series comparison over the full calibration period. The Root Mean Squared Error (RMSE) and the means computed using the daily modeled and observed data over the full calibration period are included as an inset on the bottom plot. Due to the known datum issues in the observed stage data, the RMSE and the mean error are not very useful for evaluating stage calibration. Therefore, only the metrics computed on the tidal scale were used for evaluating the stage calibration.

Figure 3-2 shows the definition of the average amplitude and phase error computations used in this process. In general, both the amplitude and the phase error were computed between the modeled and observed data for each tidal cycle and averaged over the full calibration period.

The evaluation of calibration performance for EC was summarized through the following metrics:

- **Bias in simulated monthly averaged EC.** This metric allows assessing any bias in the modeled monthly averaged EC compared to the observed data. The scatter plot shows the goodness-of-fit between the observed and simulated monthly averaged EC for the entire calibration period. The slope of the linear trend line through the scatter indicates the bias.
- **Error in monthly averaged EC.** This metric is a measure of the difference in the modeled and observed monthly averaged EC. A percent error histogram is plotted for the modeled and observed monthly averaged EC over the entire calibration period. The histogram is an additional indicator of the bias in the simulated monthly averaged EC. A long-term average error is also computed over the full calibration.
- **Time series inspection of tidally-averaged EC.** Tidally filtered daily averages of the modeled and observed EC data are plotted as a time series over the full calibration period. This plot gives an indication of how well the model is simulating the EC on a net basis. It also shows any seasonal bias in the simulated data.
- **Mean Error in tidally-averaged EC.** Mean error is computed as the difference between the long-term averages of the modeled and observed tidally filtered net daily EC data, over the full calibration period. Mean error is a good measure to show an overall bias in the modeled daily EC compared to the observed data. The mean error, however, averages both positive (over-prediction) and negative errors (under-prediction), and can lead to a smaller computed error than through other metrics or seasonal analysis.
- **Root Mean Squared Error (RMSE) in tidally-averaged EC.** RMSE is computed using the tidally filtered daily modeled and observed EC data over the full calibration period. As noted earlier, RMSE is an indicator of the error variance including the errors in the magnitude and time shift. RMS error provides a more realistic measure of prediction errors, and is not subject to balancing positive and negative errors as described above. However, the RMS error does not discern between over and under-predictions.

The goodness-of-fit measures for EC were summarized on location-specific plots similar to the one shown in Figure 3-3. The two plots in the top panel summarize the performance of the simulated EC in comparison to the observed values on a monthly scale. The scatter plot compares the monthly averaged simulated EC with the observed EC. The histogram shows the error between the monthly averaged simulated and observed EC as percentage. The bottom plot shows a time series comparison of the tidally-filtered daily averaged simulated and observed EC. The RMSE and the mean averages computed over the full period of QUAL calibration between the simulated and observed daily EC values are shown as an inset in the bottom plot.

Tables

TABLE 3-1
Inventory of the Collected Observed Data in Delta

S.No.	Location ID	Description	Agency/ID	Parameter	Time Step	Period Available
1	RSAC155	Sacramento River at Freeport	IEP/RSAC155	FLOW	1HOUR	04/01/2000 – 01/01/2008
			CDEC/FPT	STAGE	15MIN	12/01/1983 – 11/01/2008
2	RSAC139	Sacramento River at Green's Landing	CDEC/GLN	EC	1HOUR	04/01/1999 – 10/01/2003
3	RSAC128	Sacramento River above Delta Cross Channel	USGS/11447890	FLOW	15MIN	12/01/1991 – 02/01/2003
			IEP/RSAC128	FLOW	15MIN	02/01/2003 – 10/01/2004
			CDEC/SDC	FLOW	15MIN	09/01/2003 – 08/01/2008
			USGS/11447890	STAGE	15MIN	12/01/1992 – 02/01/2003
			CDEC/SDC	STAGE	15MIN	02/01/2003 – 11/01/2004
4	RSAC123	Sacramento River below Georgiana Slough	IEP/RSAC123	FLOW	15MIN	01/01/1993 – 10/01/2004
			CDEC/GES	FLOW	15MIN	05/01/2006 – 06/01/2009
			IEP/RSAC123	STAGE	15MIN	01/01/1993 – 10/01/2004
5	RSAC101	Sacramento River at Rio Vista	IEP/RSAC101	FLOW	15MIN	04/01/1995 – 02/01/2003
			CDEC/SRV	FLOW	15MIN	10/01/2003 – 12/01/2008
			IEP/RSAC101	STAGE	15MIN	04/01/1995 – 02/01/2003
			WDL/B91212	STAGE	15MIN	02/01/2003 – 10/01/2004
			CDEC/RIV	EC	1HOUR	03/01/1988 – 02/01/2009
6	RSAC092	Sacramento River at Emmaton	IEP/RSAC092	EC	1HOUR	04/01/2000 – 01/01/2008
7	RSAC081	Sacramento River at Collinsville	IEP/RSAC081	EC	1HOUR	04/01/2000 – 01/01/2008
8	RSAC064	Sacramento River at Port Chicago	IEP/RSAC064	EC	1HOUR	04/01/2000 – 01/01/2008
9	RSAC054	Sacramento River at Martinez	IEP/RSAC054	STAGE	15MIN	08/01/1988 – 09/01/2002
			CDEC/MRZ	STAGE	1HOUR	06/01/1994 – 10/01/2008
			CDEC/MRZ	EC	1HOUR	06/01/1994 – 10/01/2008
10	RSAN112	San Joaquin River at Vernalis	IEP/RSAN112	EC	1HOUR	04/01/2000 – 01/01/2008
11	RSAN087	San Joaquin River at Mossdale	IEP/RSAN112	STAGE	1HOUR	01/01/1999 – 12/01/2005
			CDEC/MSD	EC	1HOUR	04/01/2002 – 02/01/2009
12	RSAN072	San Joaquin River at Brandt Bridge	CDEC/BDT	EC	15MIN	04/01/2005 – 02/01/2009
13	RSAN063	San Joaquin River at Stockton	IEP/RSAN063	FLOW	15MIN	07/01/1995 – 02/01/2003
			CDEC/SJG	FLOW	15MIN	08/01/2003 – 07/01/2009
			IEP/RSAN063	STAGE	15MIN	07/01/1995 – 02/01/2003
			CDEC/SJG	STAGE	15MIN	08/01/2003 – 10/01/2004
14	RSAN058	San Joaquin River at Burns Cutoff	CDEC/RRI	STAGE	15MIN	12/01/2000 – 11/01/2008
			CDEC/RRI	EC	15MIN	11/01/2002 – 10/01/2008

TABLE 3-1
Inventory of the Collected Observed Data in Delta

S.No.	Location ID	Description	Agency/ID	Parameter	Time Step	Period Available
15	RSAN032	San Joaquin River at San Andreas Landing	IEP/RSAN032	STAGE	15MIN	08/01/1982 – 10/01/2004
			CDEC/SAL	EC	1HOUR	03/01/1988 – 02/01/2009
16	RSAN018	San Joaquin River at Jersey Point	IEP/RSAN018	FLOW	15MIN	05/01/1994 – 02/01/2003
			CDEC/SJJ	FLOW	15MIN	12/01/2003 – 07/01/2009
			IEP/RSAN018	STAGE	15MIN	05/01/1994 – 02/01/2003
			IEP/RSAN018	EC	1HOUR	04/01/2000 – 01/01/2008
17	RSAN007	San Joaquin River at Antioch	CDEC/ANH	STAGE	1HOUR	12/01/1983 – 11/01/2008
			CDEC/ANH	EC	1HOUR	09/01/1999 – 06/01/2009
18	SLTRM004	Three Mile Slough	IEP/SLTRM004	FLOW	15MIN	01/01/1997 – 02/01/2003
			CDEC/TSL	FLOW	15MIN	01/01/2008 – 12/01/2008
			WDL/B95060	STAGE	15MIN	09/01/2001 – 10/01/2004
			CDEC/TMS	EC	15MIN	03/01/1999 – 02/01/2009
19	ROLD074	Old River at Head	CDEC/OH1	STAGE	15MIN	07/01/2000 – 11/01/2008
20	ROLD059	Old River at Tracy Boulevard	CDEC/OLD	STAGE	1HOUR	08/01/2001 – 10/01/2004
			CDEC/OLD	EC	15MIN	08/01/2006 – 06/01/2009
21	ROLD047	Old River near Delta Mendota Canal	IEP/ROLD047	STAGE	15MIN	09/01/1991 – 01/01/2003
			IEP/ROLD047	STAGE	15MIN	09/01/1999 – 12/01/2002
			CDEC/OBD	STAGE	15MIN	08/01/2001 – 10/01/2004
22	ROLD034	Old River near Byron (Highway 4)	USGS/11313405	FLOW	15MIN	01/01/2000 – 02/01/2003
			CDEC/OH4	FLOW	15MIN	10/01/2003 – 10/01/2004
			IEP/ROLD034	STAGE	15MIN	08/01/1982 – 01/01/2003
			WDL/B95270	STAGE	15MIN	01/01/2003 – 10/01/2004
23	ROLD024	Old River at Bacon Island	IEP/ROLD024	FLOW	15MIN	01/01/1987 – 02/01/2003
			CDEC/OBI	FLOW	15MIN	02/01/2003 – 10/01/2004
			IEP/ROLD024	STAGE	15MIN	01/01/1987 – 02/01/2003
			WDL/B95270	STAGE	15MIN	02/01/2003 – 10/01/2004
			IEP/ROLD024	EC	1HOUR	04/01/2000 – 01/01/2008
24	ROLD014	Old River at Holland Cut	CDEC/HLL	EC	1HOUR	03/01/1988 – 10/01/2008
25	RMID040	Middle River at Mowery Bridge	CDEC/UNI	EC	1HOUR	12/01/1999 – 06/01/2009
26	RMID027	Middle River at Tracy Blvd	CDEC/MTB	EC	1HOUR	10/01/1999 – 06/01/2009
27	RMID023	Middle River at Borden Highway	IEP/RMID023	STAGE	15MIN	09/01/1982 – 01/01/2003
			CDEC/MTB	STAGE	15MIN	01/01/2003 – 10/01/2004
			IEP/RMID023	EC	1HOUR	01/01/2000 – 05/01/2005

TABLE 3-1
Inventory of the Collected Observed Data in Delta

S.No.	Location ID	Description	Agency/ID	Parameter	Time Step	Period Available
28	RMID015	Middle River at Middle River	USGS/11312676	FLOW	15MIN	01/01/1987 – 06/01/2002
			CDEC/MDM	FLOW	15MIN	10/01/2003 – 10/01/2004
			WDL/B95468	EC	15MIN	10/01/2000 – 10/01/2008
29	RMKL019	Mokelumne River at Snodgrass Slough	IEP/RMKL019	EC	15MIN	10/01/1982 – 08/01/2004
30	CHGRL009	Grant Line Canal	IEP/CHGRL009	FLOW	15MIN	05/01/1999 – 02/01/2003
			CDEC/GLC	FLOW	15MIN	02/01/2003 – 10/01/2004
			IEP/CHGRL009	STAGE	15MIN	05/01/1999 – 02/01/2003
			WDL/B95300	STAGE	15MIN	02/01/2003 – 10/01/2004
			WDL/B95300	EC	15MIN	01/01/2000 – 09/01/2008
31	SLMZU011	Montezuma Slough at Beldons	CDEC/BDL	STAGE	1HOUR	01/01/1987 – 03/01/2009
			CDEC/BDL	EC	1HOUR	09/01/1988 – 02/01/2008
32	CHSWP003	Clifton Court Forebay	CDEC/CLC	EC	1HOUR	12/01/2000 – 02/01/2009
33	CHDMC006	Delta Mendota Canal at Tracy Pumping Plant	CDEC/DMC	EC	15MIN	04/01/1999 – 02/01/2009
34	SLDUT007	Dutch Slough	IEP/SLDUT007	FLOW	15MIN	02/01/1996 – 02/01/2003
			CDEC/FRP	FLOW	15MIN	02/01/2003 – 10/01/2004
			IEP/SLDUT007	STAGE	15MIN	02/01/1996 – 02/01/2003
			CDEC/FRP	STAGE	15MIN	02/01/2003 – 10/01/2004
			CDEC/FRP	EC	1HOUR	02/01/1999 – 06/01/2009
35	GEORG_SL	Georgiana Slough at Sacramento River	IEP/GEORG_SL	FLOW	15MIN	08/01/2001 – 12/01/2002
			CDEC/GSS	FLOW	15MIN	07/01/2004 – 12/01/2008
			IEP/GEORG_SL	STAGE	15MIN	08/01/2001 – 09/01/2003
			CDEC/GSS	STAGE	15MIN	09/01/2003 – 10/01/2004
36	STMBT_SL	Steamboat Slough	CDEC/SSS	FLOW	15MIN	09/25/2003 – 10/01/2008
37	SUTR_SL	Sutter Slough at Courtland	CDEC/SUT	FLOW	15MIN	05/30/2006 – 10/01/2008
38	CACHE_SL	Cache Slough at Ryer Island	CDEC/RYI	FLOW	15MIN	05/01/2006 – 10/01/2008

TABLE 3-2
Selection of Calibration Period Based on Hydrology, Exports, and Observed Data Availability

Water Year	Sacramento Valley[a]	Annual Exports (cfs)[b]	Data Availability[c]		
			Flow	Stage	EC
2001	D	7,067	Sparse	Sparse	Good
2002	D	7,698	Good	Good	Good
2003	AN	8,734	Good	Good	Good
2004	BN	8,464	Fair	Fair	Good
2005	AN	8,936	Fair	Fair	Good
2006	W	8,722	Fair	Fair	Good
2007	D	8,020	Good	Good	Good
2008	C	5,146	Good	Good	Good

[a] Based on CDEC data (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)
[b] Based on DAYFLOW data from IEP website (http://www.iep.water.ca.gov/dayflow/output/index.html)
[c] Based on data availability from IEP, CDEC and USGS at several locations in the Delta

Figures

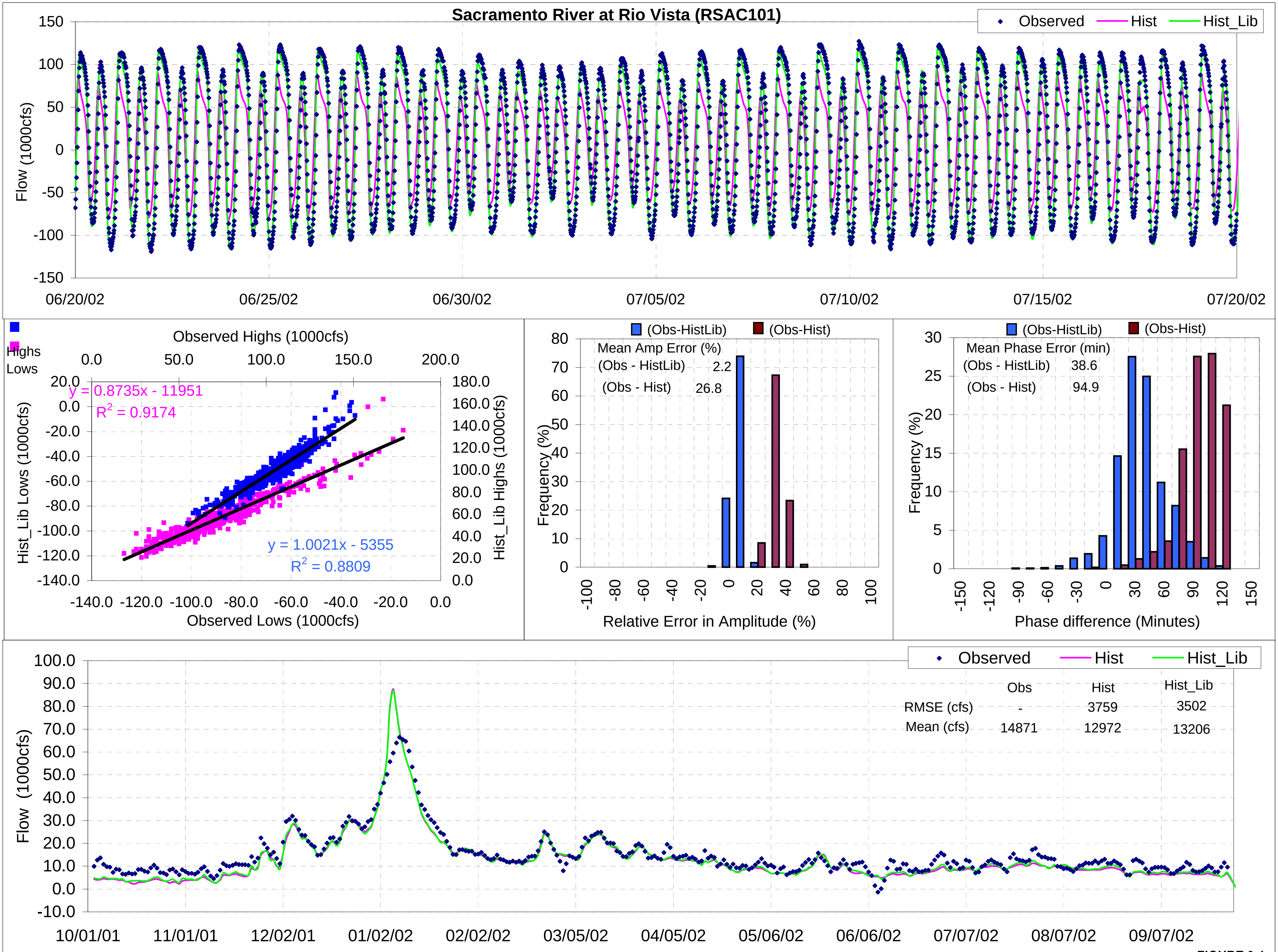
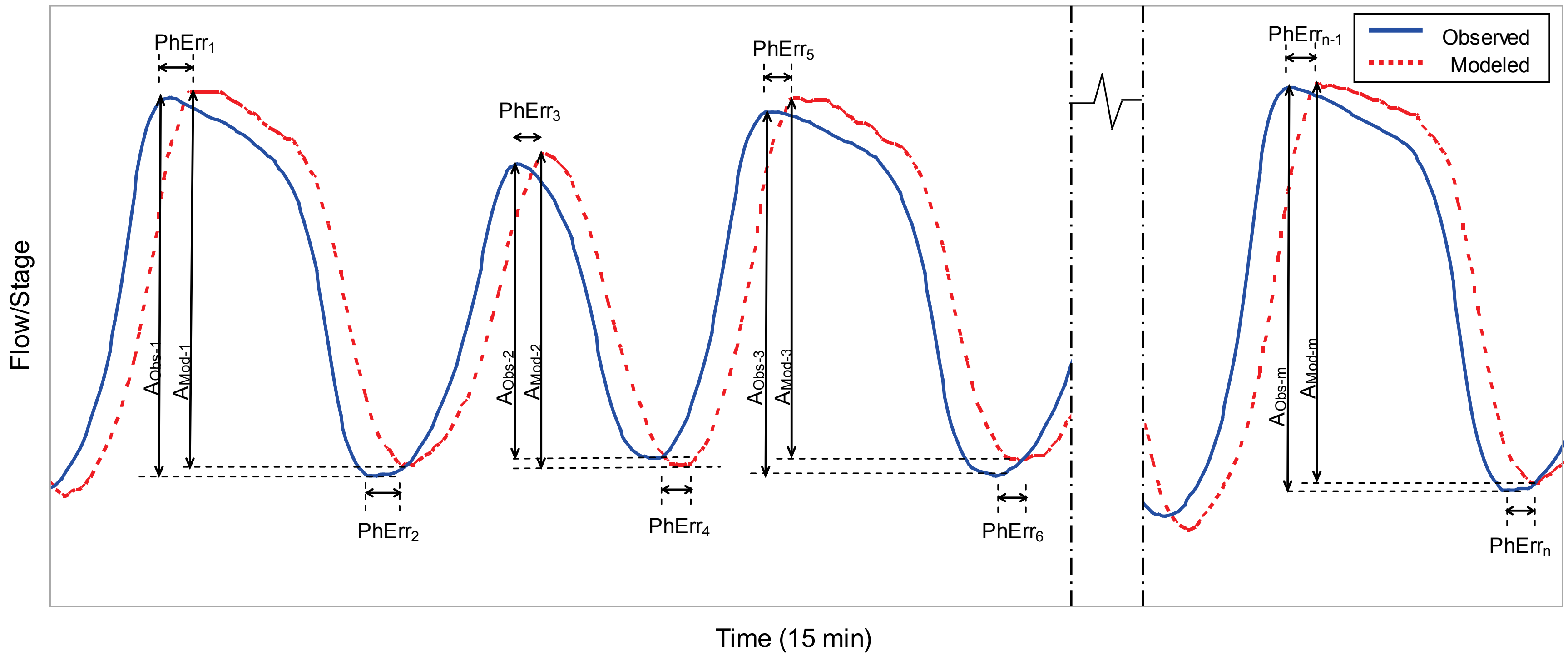


FIGURE 3-1

Sample Plot Showing the Metrics for Evaluating HYDRO Calibration



$$AvgAmplitudeError = \left\{ \frac{(A_{MOD-1} - A_{OBS-1}) + (A_{MOD-2} - A_{OBS-2}) + (A_{MOD-3} - A_{OBS-3}) + \ldots (A_{MOD-m} - A_{OBS-m})}{m} \right\}$$

$$AvgPhaseError = \left\{ \frac{PhError_1 + PhError_2 + PhError_3 + \ldots PhError_{n-1} + PhError_n}{n} \right\}$$

FIGURE 3-2
Definition of Average Amplitude Error and Average Phase Error

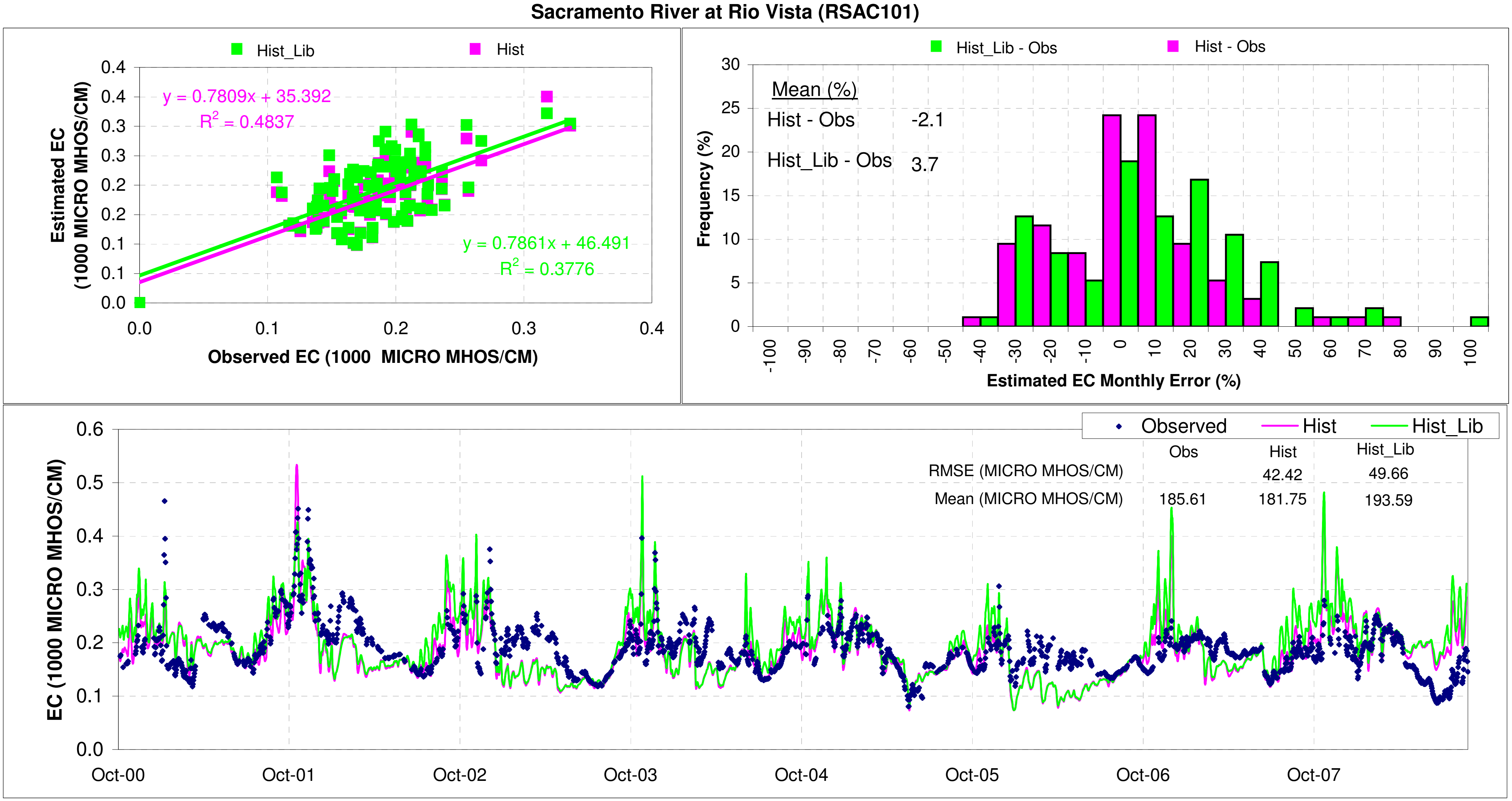


FIGURE 3-3

Sample Plot Showing the Metrics for Evaluating EC Calibration

SECTION 4

Hydrodynamics Calibration

4.1 Calibration Period

HYDRO was calibrated for one year period, using the data from WY 2002 (October 2001 to September 2002). WY 2002 was a dry year and has flow and stage data available at most locations in the Delta. Table 4-1 shows the summary of rim flows and the gate operations for this one year. Figure 4-1 shows the daily inflows and exports for WY 2002.

4.2 Key Calibration Parameters

4.2.1 Manning's n

Manning's roughness coefficient or Manning's n was the main calibration parameter used in the Hydro calibration. In 2000 calibration, DSM2PWT divided the Delta into regions of common roughness and modified the roughness regionally in the calibration process. This approach implies that the errors in the model are only associated with channel roughness; all other model errors, such as improper representation of the physical Delta in the model or the model's inability to simulate momentum at channel junctions, are only addressed to the extent the channel friction can address these limitations. In the current calibration, changes were made to both channel friction and the structural representation of the Delta. Starting from the final roughness map from 2000 calibration, Manning's n was modified in key channels to improve the DSM2's ability to simulate the observed hydrodynamics. Table 4-2 shows the list of channels with the modified Manning's n value in the current calibration.

4.2.2 Geometry Modifications

In 2000 calibration, DSM2PWT modified the channel geometry in a few key channels to get the best agreement with the observed data. These changes were justified since there were dramatic variations in the channel cross-sections within the datasets from multiple bathymetric surveys. Moreover, the process of fitting a cross-section to bathymetric data is very subjective and if there are significant changes in the data from one survey to the other, then it may lead to different interpretations of what would be a best fit for a cross-section. One of the final steps in the 2000 calibration was to decrease the Threemile Slough cross-sectional area by 20 percent at the Sacramento end and increase the area by 20 percent on the San Joaquin end.

In the current calibration, based on the discussions with DWR staff, it was decided that the cross-sections in the existing Delta channels may be modified, if necessary. The Threemile Slough cross-section at the Sacramento end was modified to provide a better fit with the bathymetry compared to the 2000 calibration. Figure 4-2 shows the cross-section profiles assumed in the 2000 calibration and current recalibration for the Threemile Slough at Sacramento River. This modification led to an increase in cross-sectional area by 16 percent compared to the 2000 calibration. It was found that increasing the area of this cross-section also helped the overall calibration in the Delta and especially in Threemile Slough. Apart from this one geometric change, the existing channels have not been modified as part of calibration process.

4.3 Key Steps in the Calibration

HYDRO calibration was started with the physical and boundary condition changes incorporated into the 2000 calibration model, as described in Section 2. The roughness coefficient was modified progressively based on the goodness-of-fit with observed data at each step. The key steps in the calibration included:

- Decreased Manning's n in
  - Sacramento River channels upstream of Sutter Slough confluence
  - San Joaquin River channels from Threemile Slough to Antioch
- Increased Threemile Slough cross-sectional area at the Sacramento River end by approximately 16 percent
- Decreased Manning's n in
  - Georgina Slough channels from Sacramento River to Mokelumne River
  - Delta Cross Channel
- Increased Manning's n in Sacramento River channel between Delta Cross Channel and Georgiana Slough to match with upstream and downstream channels

A total of 15 runs were required to get the best goodness-of-fit metrics. At the end of Run 15, it was clearly evident that the hydrodynamic results from Run 15 were improved as compared to the 2000 version.

4.4 Hydrodynamics Calibration Locations

Figure 4-3 shows the locations where the performance of DSM2 HYDRO was assessed in simulating flow and stage. A total of 12 locations for flow and 22 locations for stage were selected. Table 4-3 lists the locations including their short names used in the results discussion in the following section.

4.5 Results

Results of the hydrodynamic recalibration effort are presented below. Plots contain various metrics that were used to compare the results from the current calibration to both the observed data and to the previous calibration effort. These plots reflect model performance for WY 2002. Statistics for the 2000 calibration are included for reference and to demonstrate areas of improvement and locations where the errors increased in the current recalibration runs as compared to the previous calibration. The detailed hydrodynamics calibration results for all the locations in the Delta are included in the Appendix A.

4.5.1 Flow Calibration Metrics

The DSM2 grid modifications performed in the recalibration effort are located in the north Delta region. The inclusion of flooded Liberty Island showed the biggest impact on the tidal dynamics in this region. The result of this change can be seen in the flow metrics for Sacramento River at Rio Vista location, in Figure 4-4. On an average the simulated flow range is less than the observed data by 2.2 percent. This is a significant improvement compared to the 2000 calibration, which was under-predicting the flow range by 26.8 percent. The simulated peak flood tide flows at Rio Vista are slightly less than the observed in the latest calibration. The simulated tidal flow is lagging the observed data by 38 minutes in the current calibration compared to the 95 minutes in 2000 calibration. The simulated net flows at Rio Vista did not significantly change compared to the 2000 calibration. The RMSE is 3,502 cfs and the mean error is 1,665 cfs, which are slightly lower than the 2000 calibration.

The inclusion of Liberty Island also impacted the DSM2 performance in Georgiana Slough. The modification of channel roughness in Sacramento River upstream of Rio Vista may also have contributed to the improvements at Georgiana Slough. The flow metrics for Georgiana Slough are shown in Figure 4-5. The error in the tidal flow range, though still high, has dropped from 78 percent in 2000 calibration to 30 percent. The mean error in phase has dropped to 0.8 minutes compared from 16 minutes in the 2000 calibration. Again, the simulated net flows did not change significantly from 2000 calibration, with mean error at 211 cfs and the RMSE at 330 cfs in the current calibration.

The extension of the rigid boundary on the Sacramento River along with other channel roughness changes, improved the simulated tidal flows in Sacramento River at Freeport as shown in the Figure 4-6. The biggest concern in this reach was under prediction of peak ebb flows in DSM2. In the current calibration, the mean error in the tidal flow range has dropped to 2.5 percent from 12 percent in the 2000 calibration. Similarly, the mean phase error was reduced by nearly half from 60 minutes in the 2000 calibration. The net flows did not change as expected, because of the proximity to the boundary. However, the RMSE has increased slightly in the current calibration from 268 to 388 cfs, which is still only 2 percent of the mean flow.

The changes in the north Delta (grid and the channel roughness) resulted in better representation of the net Cross Delta flow. Cross Delta flow is the flow exiting from the Sacramento River through Georgiana Slough and the DCC, and is measured as the change in the Sacramento River flow from upstream of the DCC to downstream of Georgiana Slough. Figure 4-7 shows the calibration metrics for the Cross Delta flows. The mean error has decreased from 259 to 188 cfs and the RMSE dropped from 217 to 156 cfs in the current calibration compared to the 2000 calibration.

Figure 4-8 shows four plots with a summary of the key flow calibration metrics at several locations in the north Delta region. The plots in the top panel (a, b) present summary of the tidal flow metrics. The mean amplitude errors at all the locations in the north Delta is less than 5 percent except in Georgiana Slough. The mean phase error at all the locations in the north Delta is less than 40 minutes. Overall tidal metrics from current calibration show a significant reduction in the errors compared to the 2000 calibration at all the locations in the north Delta. The plots in the bottom panel (c, d) present summary of net flow metrics, which did not change significantly from the 2000 calibration. Slight improvements can be seen in mean error at Freeport, Rio Vista and Cross Delta flows and slight increases in locations around Georgiana Slough. RMSE has decreased for the locations downstream of DCC and increased very slightly upstream. These improvements are a direct result of increasing the tidal prism in Cache Slough via the addition of Liberty Island.

The inclusion of Liberty Island in DSM2 also impacted the flow results in west Delta region and, to a limited extent, in central Delta locations. However, modification of the Threemile Slough cross-section resulted in the largest change in these two regions of the Delta. Figure 4-9 shows the flow metrics for Threemile Slough near San Joaquin River. The mean error in tidal flow range is around 1 percent compared to 14.5 percent in 2000 calibration. The mean phase error is 24 minutes and did not appreciably change from 2000 calibration. The simulated net flow in Threemile Slough is approximately 1,000 cfs more than the observed and about 100 cfs more than the 2000 calibration. The RMSE increased from 1,015 cfs in the 2000 calibration to 1,185 cfs. Accurate simulation of the tidal flows in Threemile Slough was considered more important than net flows due to the relative magnitude of tidal flows compared to the net flows (up to 10 times the net flows).

The flow metrics for San Joaquin River at Jersey Point are shown in Figure 4-10. The errors in tidal flow range (1.6 percent) and phase (15 minutes) are very small. However, the errors in the tidally-averaged flows are relatively high at this location. The mean error is 1,287 cfs and the RMSE is 2,979 cfs, which are significant compared to the mean flow. However, comparable errors in tidally-averaged flow at Jersey Point were also present in the 2000 calibration. It is important to note that tidal flows at Jersey Point are roughly 150,000 cfs; nearly 100 times the tidally-averaged.

Figure 4-11 shows the summary of flow metrics in the central and western Delta regions. Plots a and b show the tidal metrics. The mean error in the flow range has reduced significantly in Threemile Slough and Dutch Slough and slightly increased at Jersey Point compared to the 2000 calibration. However, the errors at all three locations are less than 7 percent. The mean phase error at all the three locations is less than 30 minutes. The mean phase error increased at Jersey Point and in Dutch Slough and remained unchanged in Threemile Slough compared to the 2000 calibration. Plot c and d show the net flow metrics. Again, the changes compared to the 2000 calibration are minimal. However, the errors in the net flow are high at all the locations. The simulated net flow in Dutch Slough is in the opposite direction to the observed, although the observed net average flow in this channel is only 13 cfs.

The summary of flow metrics in the South Delta are shown in the Figure 4-12. The net flow metrics remained nearly unchanged in the South Delta and on the upper San Joaquin River compared to the 2000 calibration. Both the RMS errors and mean errors show minimal differences between the two calibration efforts. This is expected, since the changes incorporated in the recalibration effort were focused on improving model results in the north Delta. The amplitude errors, though slightly higher than 2000 calibration in the South Delta, remained low. The phase errors in the 2000 calibration effort were generally small; the recalibration results indicate slightly larger phase errors in the South Delta, but the errors remained less than 20 minutes.

4.5.2 Stage Calibration Metrics

In addition to predicted flows, the recalibration effort also included analysis of predicted stages at key locations in the Delta. The recalibration effort attempted to reduce amplitude and phase errors in predicted stage. While RMS errors in tidally-averaged water level were analyzed, potential discrepancies in datum data lessened the importance of this parameter.

The recalibration process resulted in improved DSM2 stage predictions at all the locations in the north Delta. Figure 4-13 shows the stage metrics for Rio Vista location. The mean error in tidal range has dropped from 46 percent in the 2000 calibration to 11 percent. Similarly, the mean phase error in the recalibrated DSM2 has dropped from 17 to 4 minutes. However, the mean tidally-averaged stage is 0.66 foot lower than the observed data. These results are not significantly different from the 2000 calibration, which had an error of 0.71 foot. It is uncertain whether this error is related to any datum issues. In Georgiana Slough the mean error in tidal range is at 10 percent compared to the 36 percent in the 2000 calibration as shown in Figure 4-14. The mean phase error decreased from 26 minutes in the 2000 calibration to 15 minutes. Georgiana Slough is a good example to show how the discrepancies in datum result in high RMSE and mean error even though the tidal metrics show significant improvement. Therefore, tidally-averaged metrics were not used as the key metric in assessing the stage calibration.

Figure 4-15 summarizes the tidal stage metrics for several locations in the north Delta. Plot a shows the mean error in the tidal range as percentage of the mean observed tidal range for the current recalibration and the 2000 calibration. The mean error in the tidal range is less than 13 percent at all the locations in the north Delta with significant improvements compared to the 2000 calibration. Similarly, the mean phase error has decreased significantly at all the locations in the north Delta compared to 2000 calibration, with the highest error of 32 minutes at Freeport.

Figure 4-16 shows the summary of tidal metrics for stage at several locations in the western and central Delta. Again, the mean error in the tidal range has reduced significantly compared to 2000 calibration with the highest error at 17 percent. With the exception of Antioch, the mean phase error has also reduced at all the locations with highest error at 5 minutes. At Antioch, the error has increased by 5 minutes compared to 2000 calibration to 25 minutes.

The mean error in the tidal range for all the locations in the South Delta and upper San Joaquin River have slightly reduced compared to 2000 calibration as shown in the plot a of Figure 4-17. However, the phase errors have increased in the current recalibration with the maximum error of 32 minutes at the Head of Old River.

Overall, the recalibration effort yielded consistent improvements in the predicted tidal range over the previous calibration, with the most notable improvements seen on the Sacramento River. Changes in the South Delta show only minor improvements, as expected, considering the changes to the model were confined to the North Delta. The improvements on the Sacramento River are considerable in terms of the phase difference in the predicted stage, but the improvements are not consistent as they were for tidal amplitude. Phase errors increase slightly on Old River and the upper San Joaquin River, but remain below 35 minutes and average less than 20 minutes.

Tables

TABLE 4-1
Summary of Period-Averaged Boundary Flows and Gate Operations Over the Calibration Period

Boundary Inflows, Exports and Gate Operations	Calibration Period (Oct 01, 2001 – Sep 30, 2002)
Sacramento River	18,091 cfs
San Joaquin River	1,935 cfs
Total Exports	7,433 cfs
Delta Cross Channel	Variable
Old River at Head Barrier	Installed from October to mid-November in 2001 and mid-April to mid-May in 2002
South Delta Agricultural Barriers	Gates are removed from mid-November 2001 to mid-April 2002 and installed from mid-April to end of September, 2002. (Grant Line Canal barrier was installed from mid-June)

TABLE 4-2
List of Channels with Modified Manning's Roughness Coefficient in the Current Calibration

DSM2 Channel Number	Manning's n from 2000 Calibration	Manning's n from Current Calibration
48	0.026	0.022
49	0.026	0.022
50	0.026	0.022
51	0.026	0.022
83	0.026	0.022
284	0.026	0.022
365	0.028	0.022
366	0.030	0.028
367	0.030	0.028
368	0.030	0.028
369	0.030	0.028
370	0.030	0.028
371	0.030	0.028
372	0.030	0.028
373	0.030	0.028
374	0.030	0.028
410	0.033	0.028
411	0.033	0.028
412	0.033	0.028
413	0.033	0.028
414	0.033	0.028
415	0.033	0.028
416	0.033	0.028
417	0.033	0.028
418	0.033	0.028
422	0.022	0.028

TABLE 4-3
List of Hydrodynamics Calibration Locations

Location	Short Name	Flow	Stage
Sacramento River at Freeport	RSAC155	✓	✓
Sacramento River above Delta Cross Channel	RSAC128	✓	✓
Sacramento River downstream from Georgiana Slough	RSAC123	✓	✓
Sacramento River at Rio Vista	RSAC101	✓	✓
Sacramento River at Martinez	RSAC054		✓
San Joaquin River at Mossdale	RSAN087		✓
San Joaquin River at Stockton	RSAN063	✓	✓
Stockton Ship Channel at Burns Cutoff	RSAN058		✓
San Joaquin River at San Andreas Landing	RSAN032		✓
Three Mile Slough	SLTRM004	✓	✓
San Joaquin River at Jersey Point	RSAN018	✓	✓
San Joaquin River at Antioch	RSAN007		✓
Old River at Head	ROLD074		✓
Old River at Tracy Boulevard	ROLD059		✓
Old river near Delta Mendota Canal	ROLD047		✓
Old River at Highway 4 (near Byron)	ROLD034	✓	✓
Old River at Bacon Island	ROLD024	✓	✓
Middle River at Borden Highway	RMID023		✓
Grant Line Canal at Tracy Boulevard Bridge	CHGRL009	✓	✓
Georgiana Slough	GEORG_SL	✓	✓
Montezuma Slough at Beldons	SLMZU011		✓
Dutch Slough	SLDUT007	✓	✓
Cross Delta Flow (RSAC128 - RSAC123)	X-Delta Flow	✓	

Figures

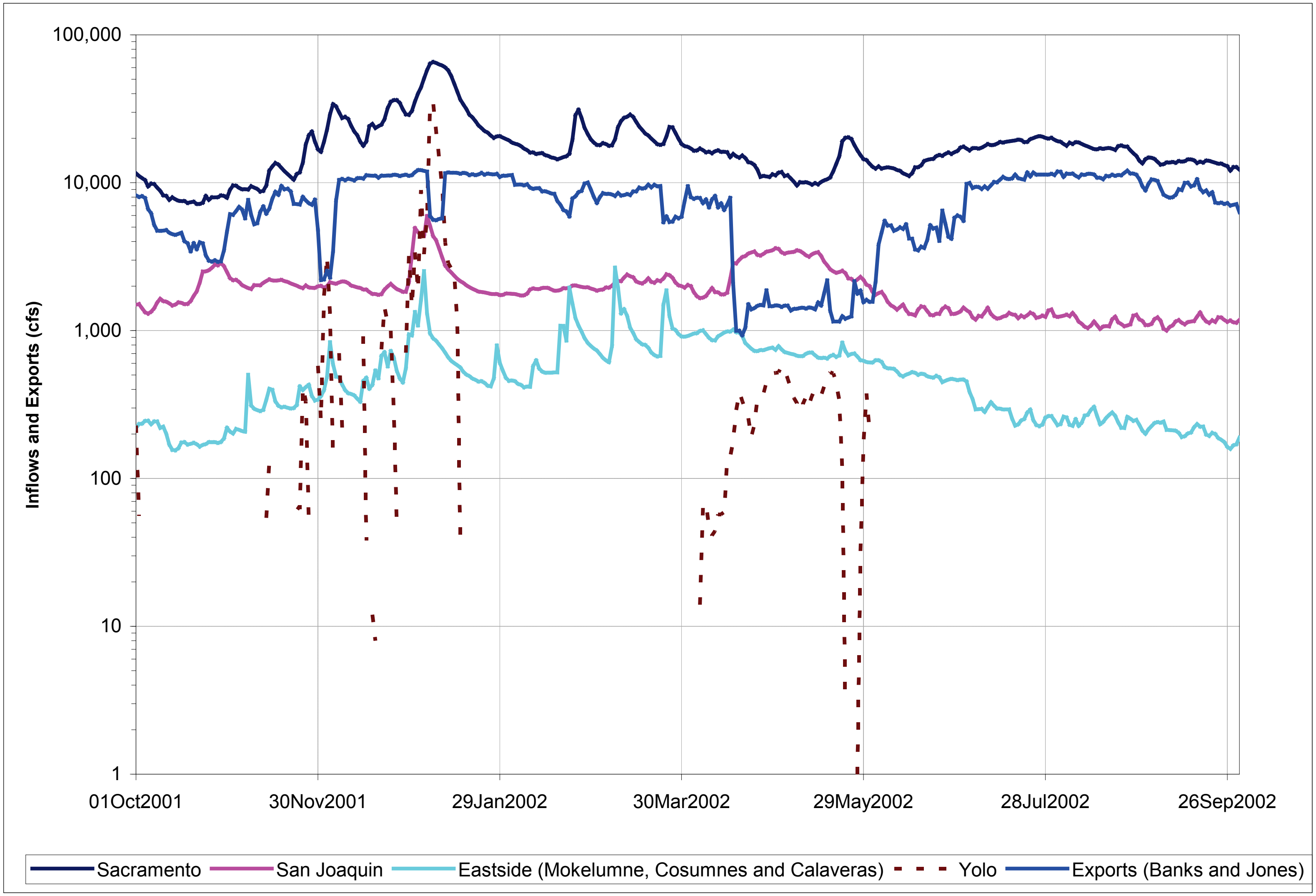


FIGURE 4-1
Daily Time Series of Boundary Inflows and Exports over the Calibration Period (WY 2002)

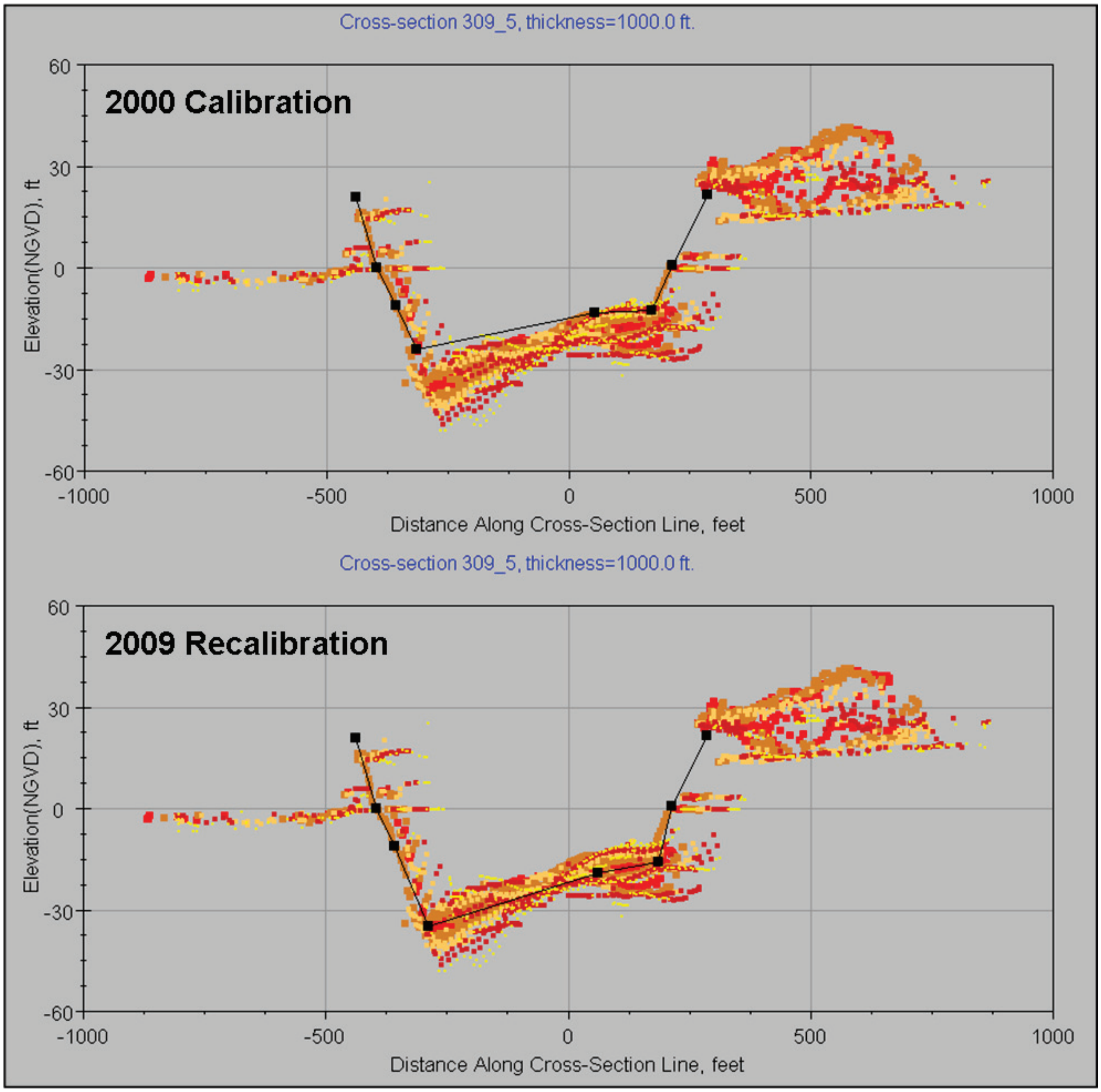


FIGURE 4-2
Comparison of Cross-section Profiles for Threemile Slough at Sacramento River, Between 2000 Calibration and 2009 Recalibration

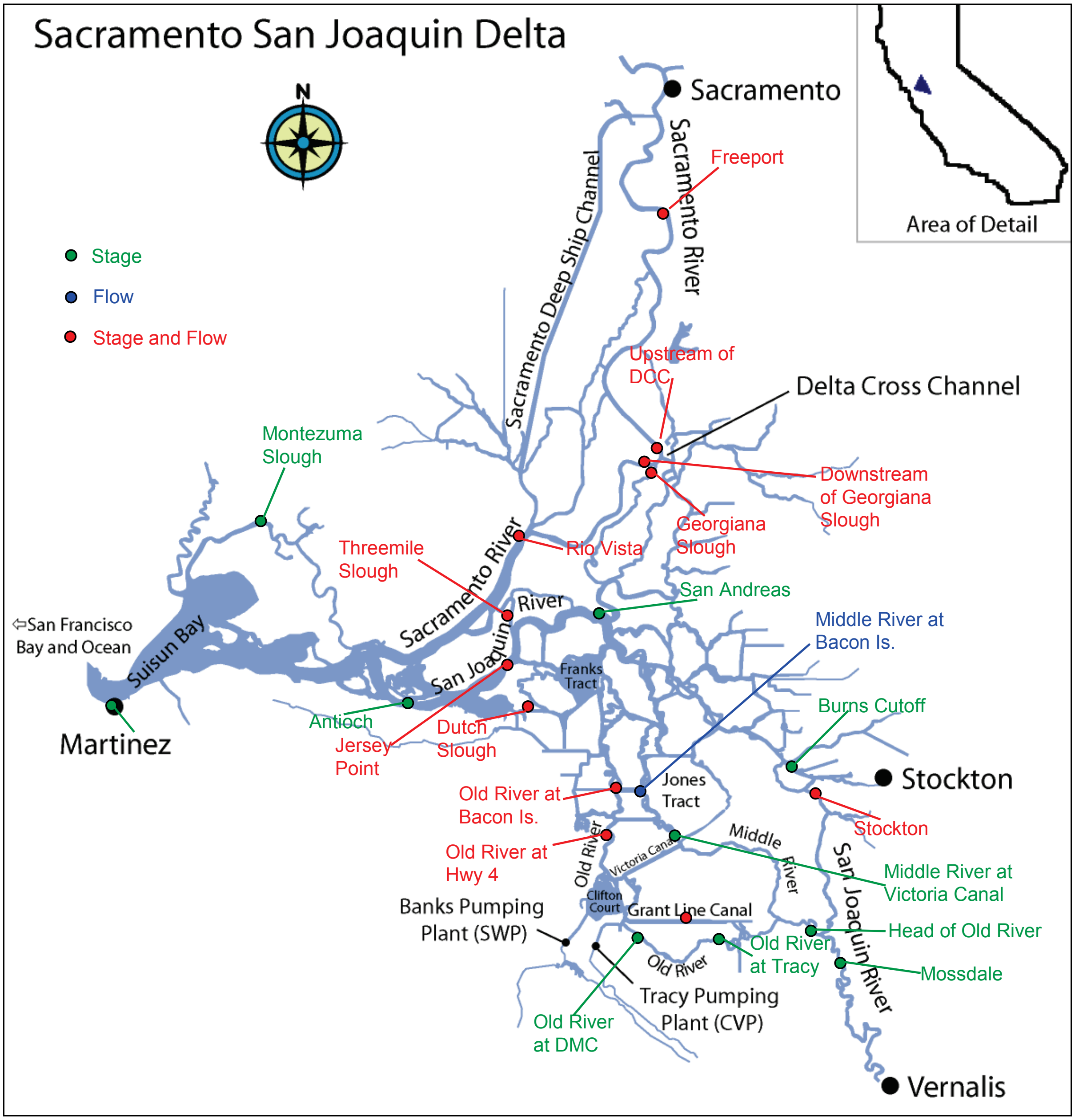


FIGURE 4-3
Map Showing Hydrodynamics Calibration Locations

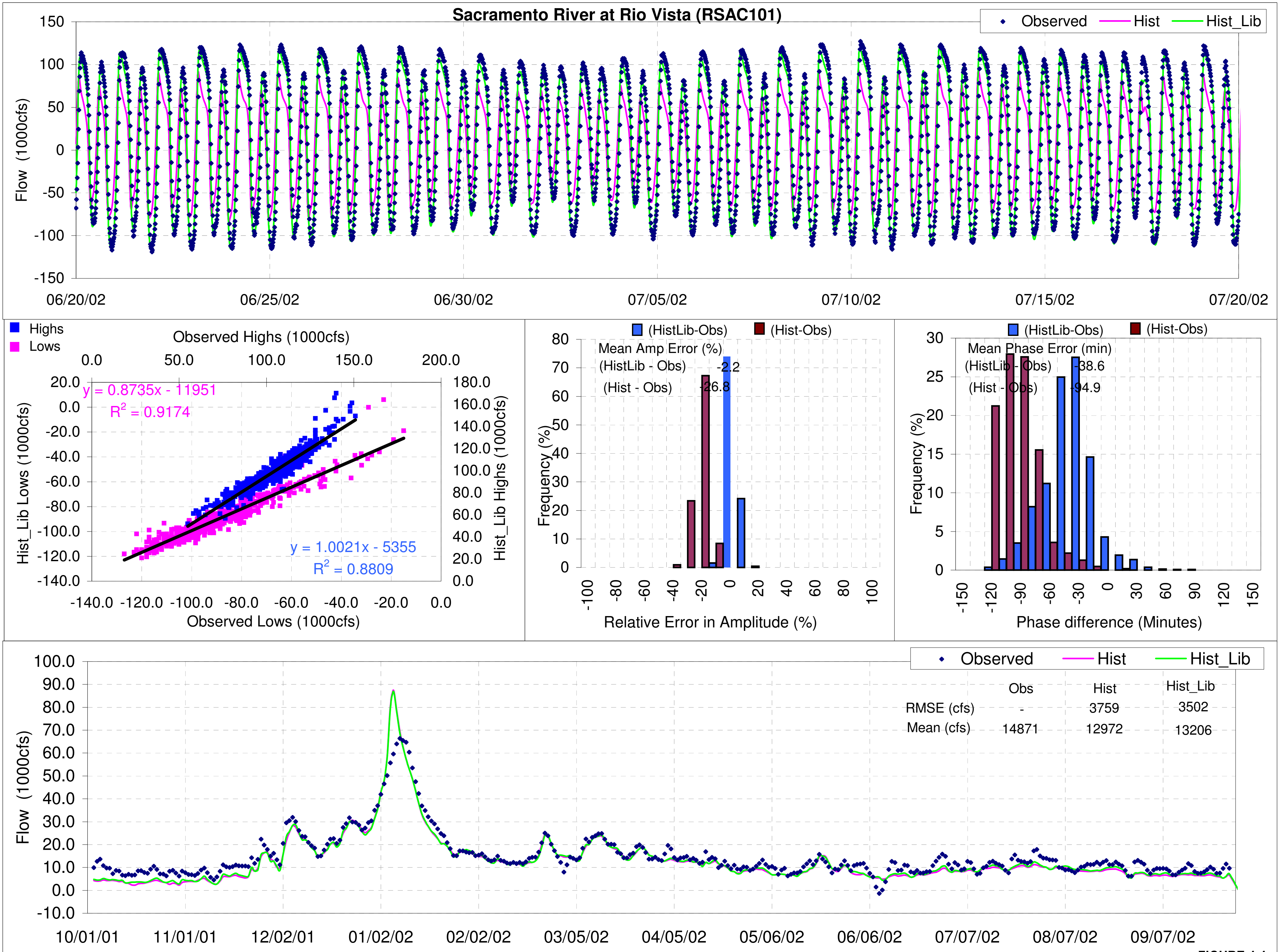


FIGURE 4-4

Flow Calibration Metrics for Sacramento River at Rio Vista

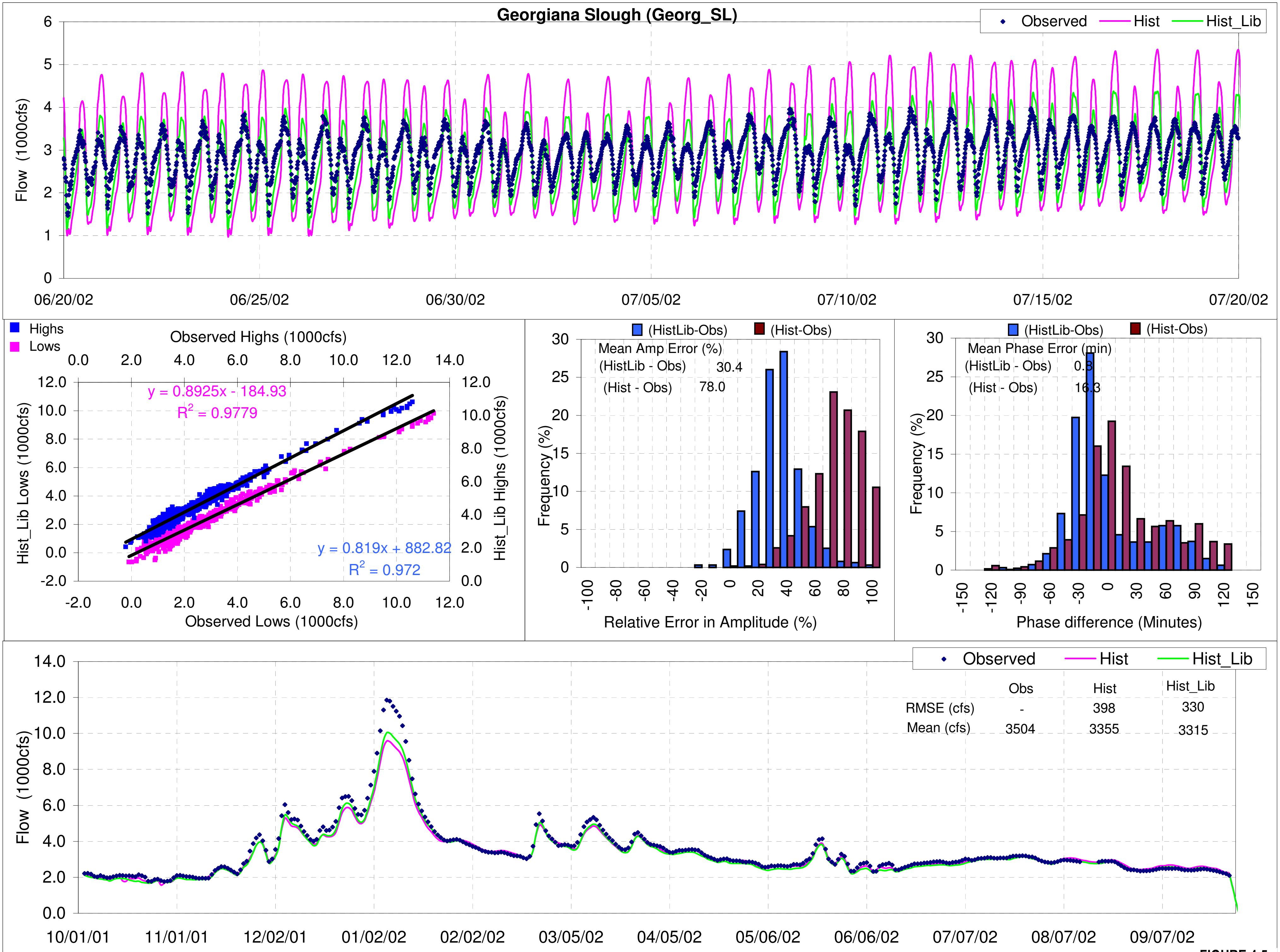


FIGURE 4-5

Flow Calibration Metrics for Georgiana Slough

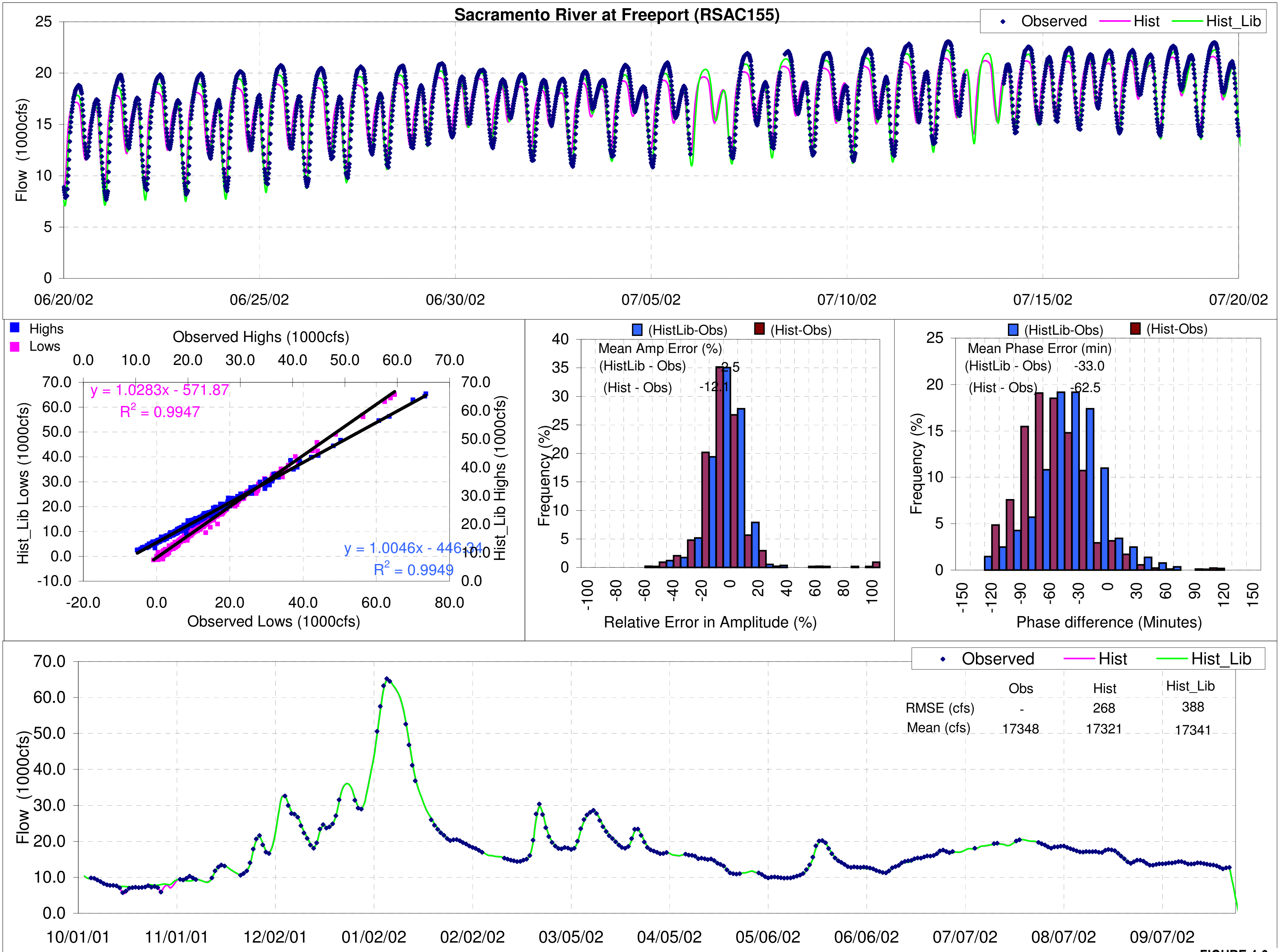


FIGURE 4-6

Flow Calibration Metrics for Sacramento River at Freeport

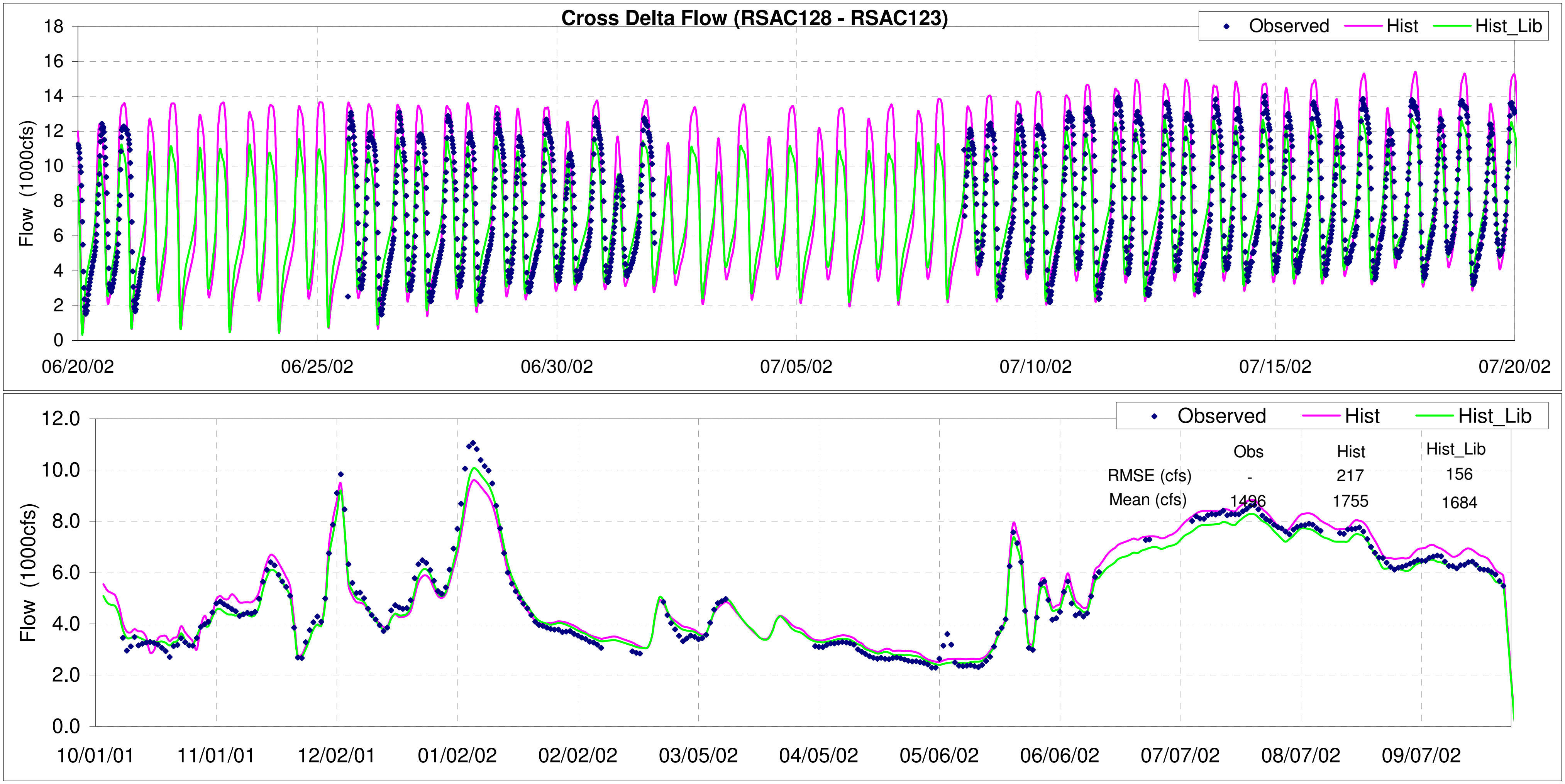


FIGURE 4-7
Flow Calibration Metrics for Cross Delta Flow (Total Flow Exiting from Sacramento River through DCC and Georgiana Slough)

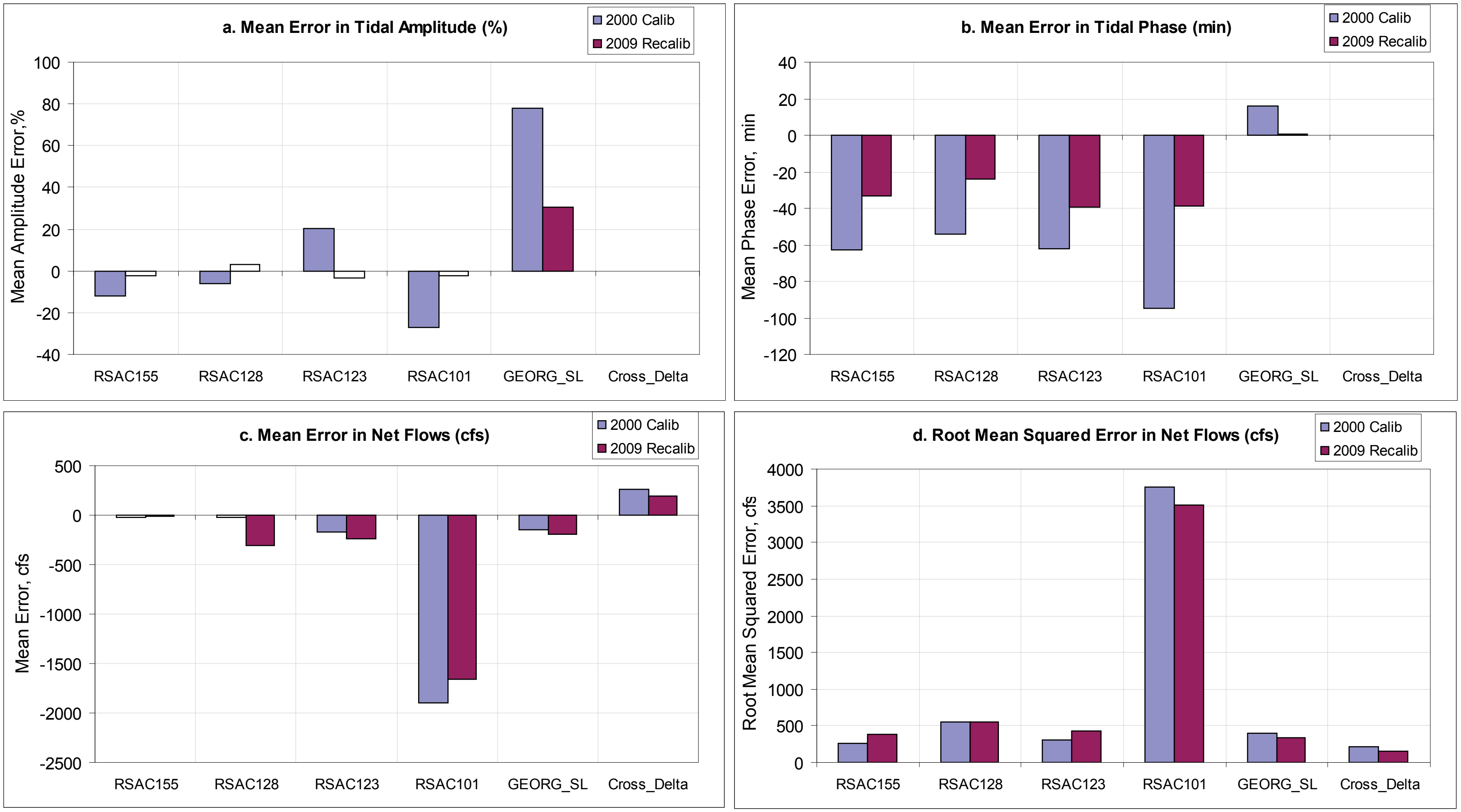


FIGURE 4-8
Summary of Flow Calibration Metrics for Locations in the North Delta Region

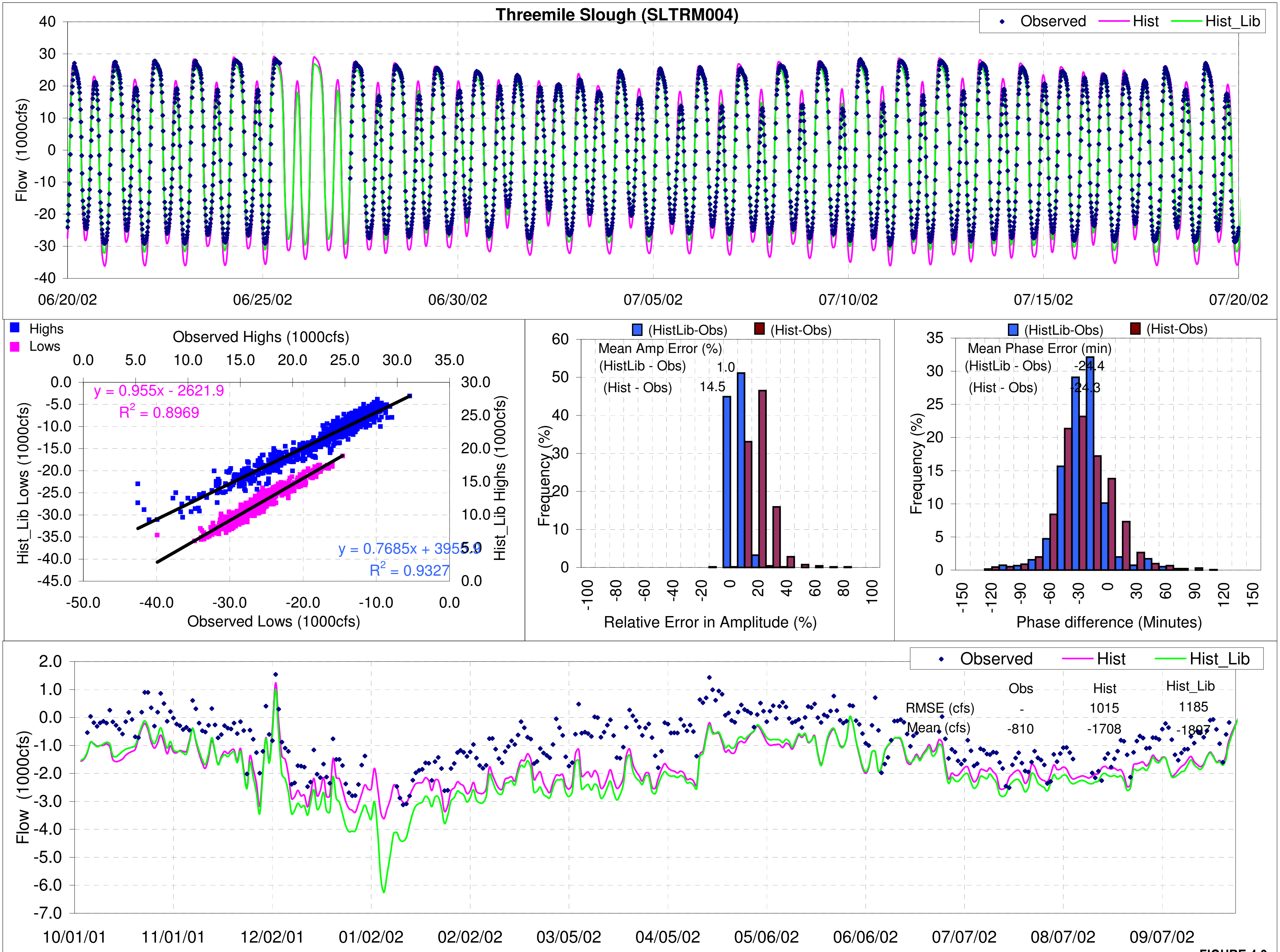


FIGURE 4-9

Flow Calibration Metrics for Threemile Slough near San Joaquin River

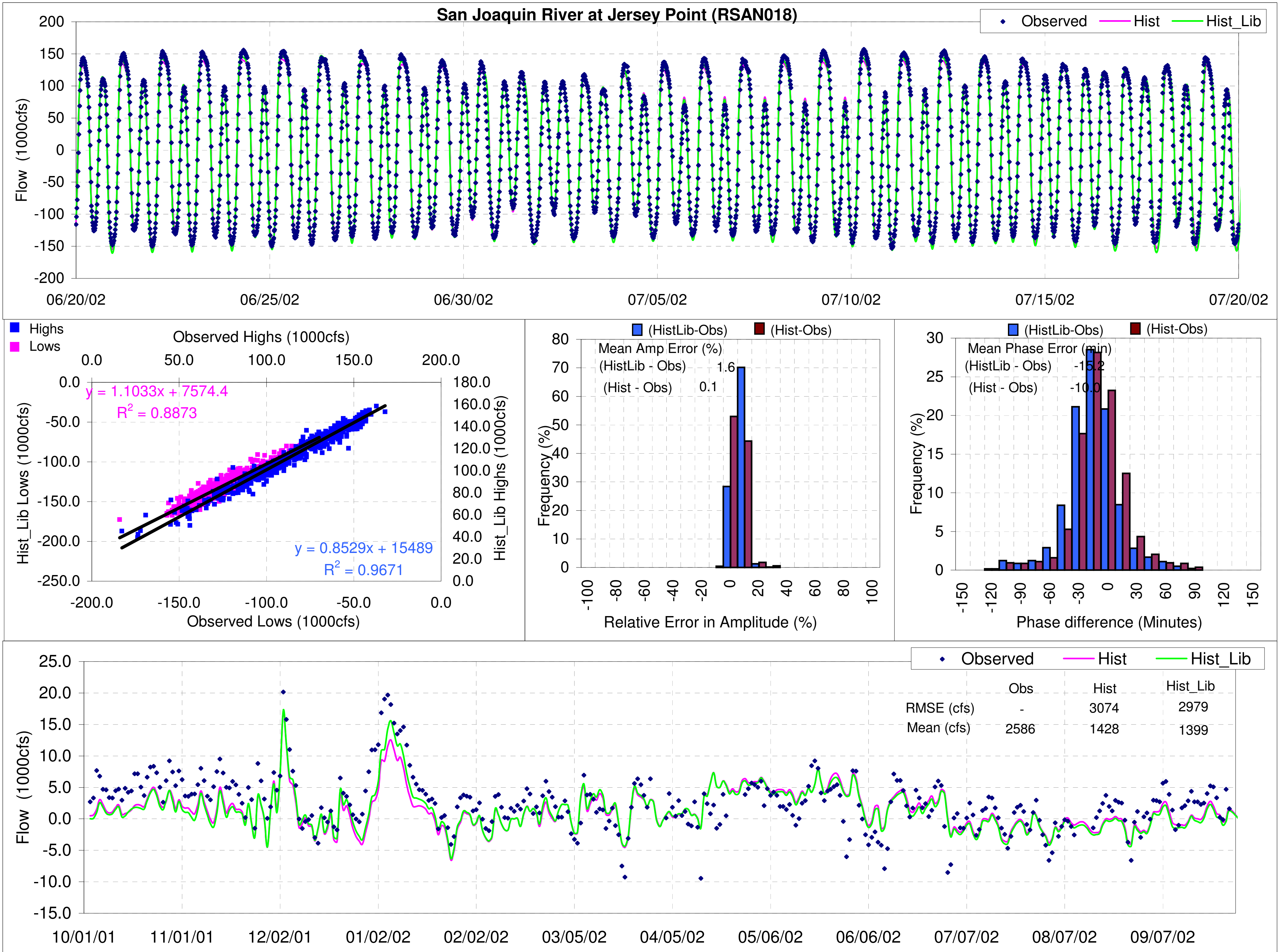


FIGURE 4-10

Flow Calibration Metrics for San Joaquin River at Jersey Point

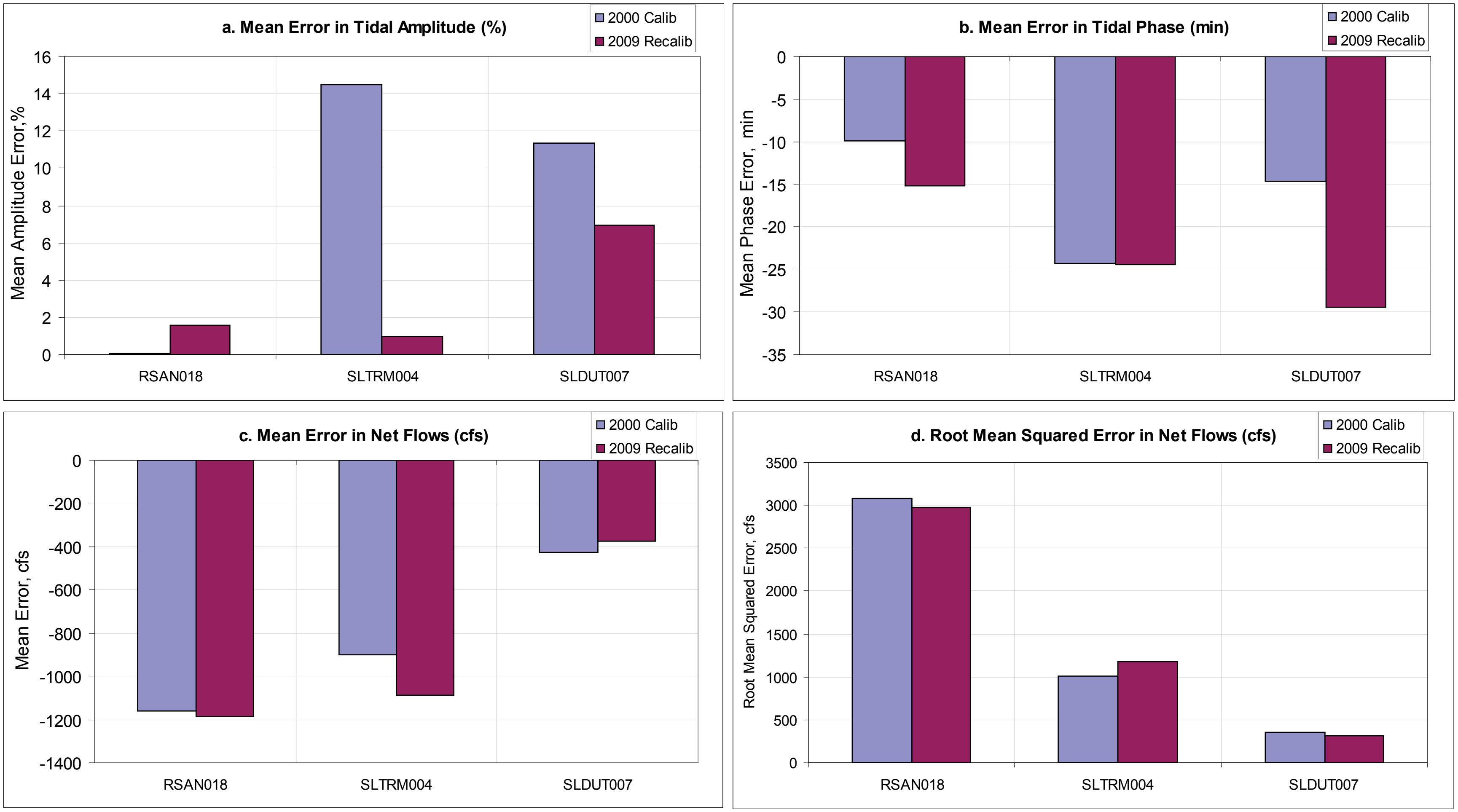


FIGURE 4-11
Summary of Flow Calibration Metrics for Locations in the Western and Central Delta Regions

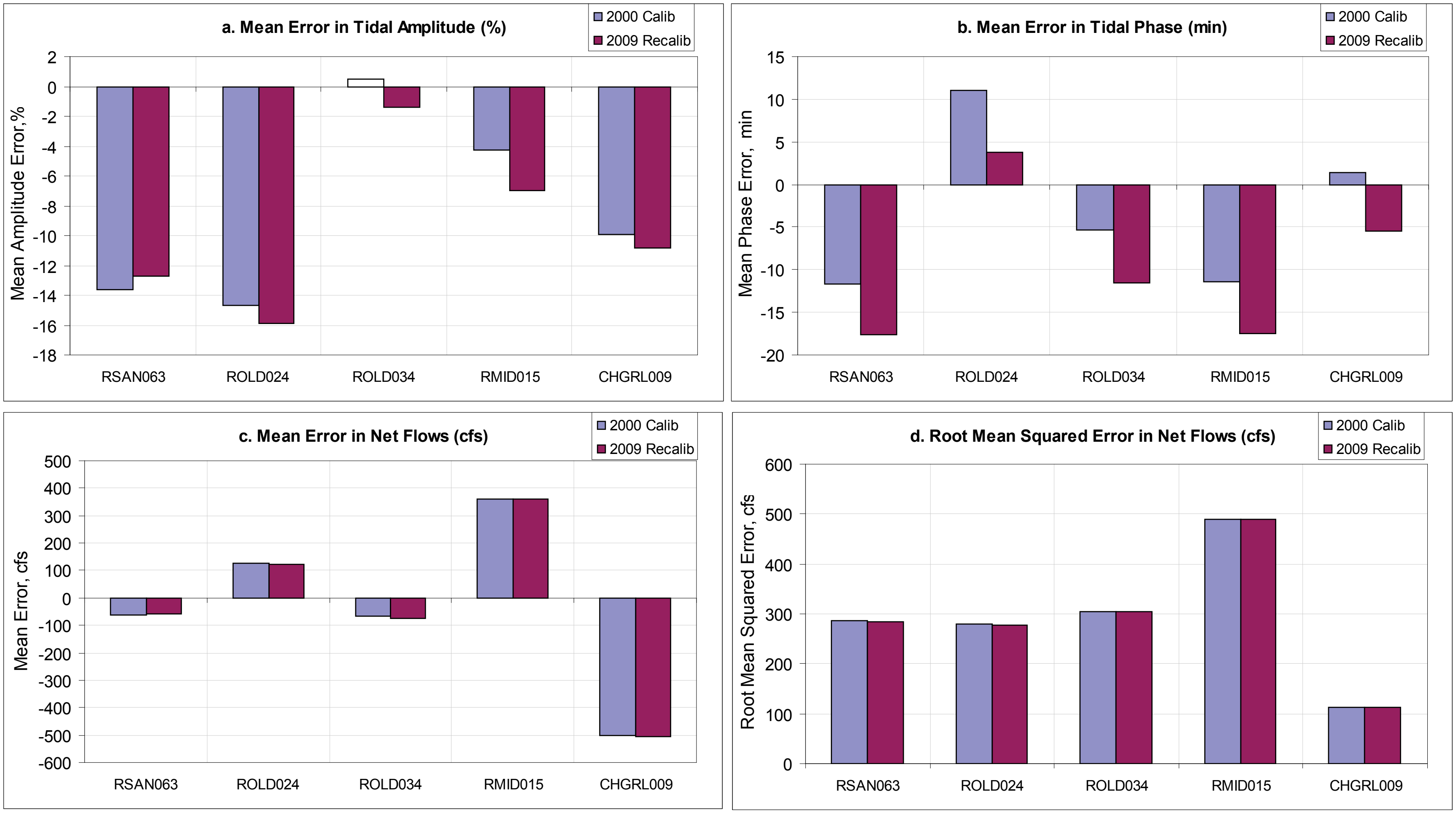


FIGURE 4-12
Summary of Flow Calibration Metrics for Locations in the South Delta Region

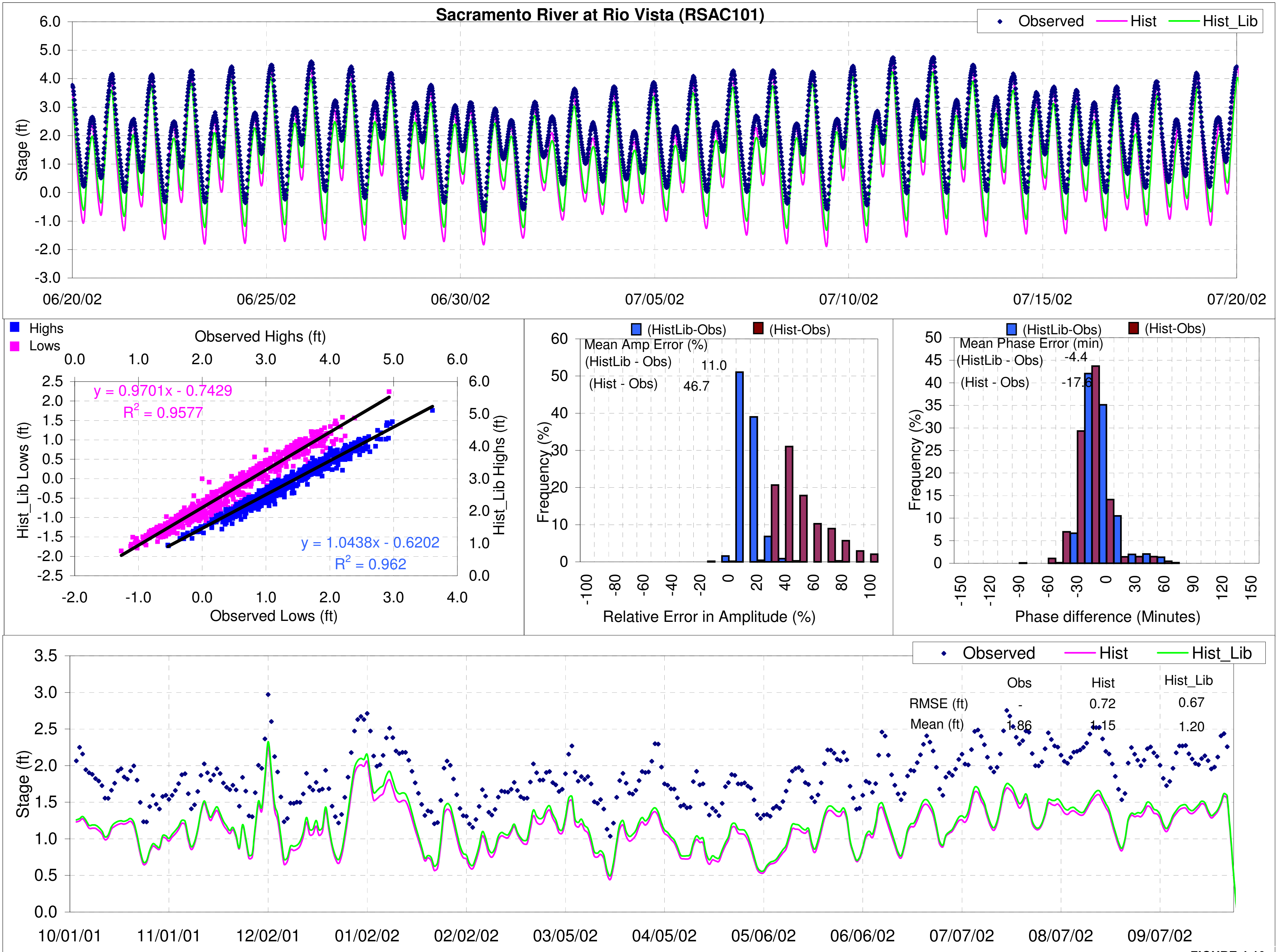


FIGURE 4-13

Stage Calibration Metrics for Sacramento River at Rio Vista

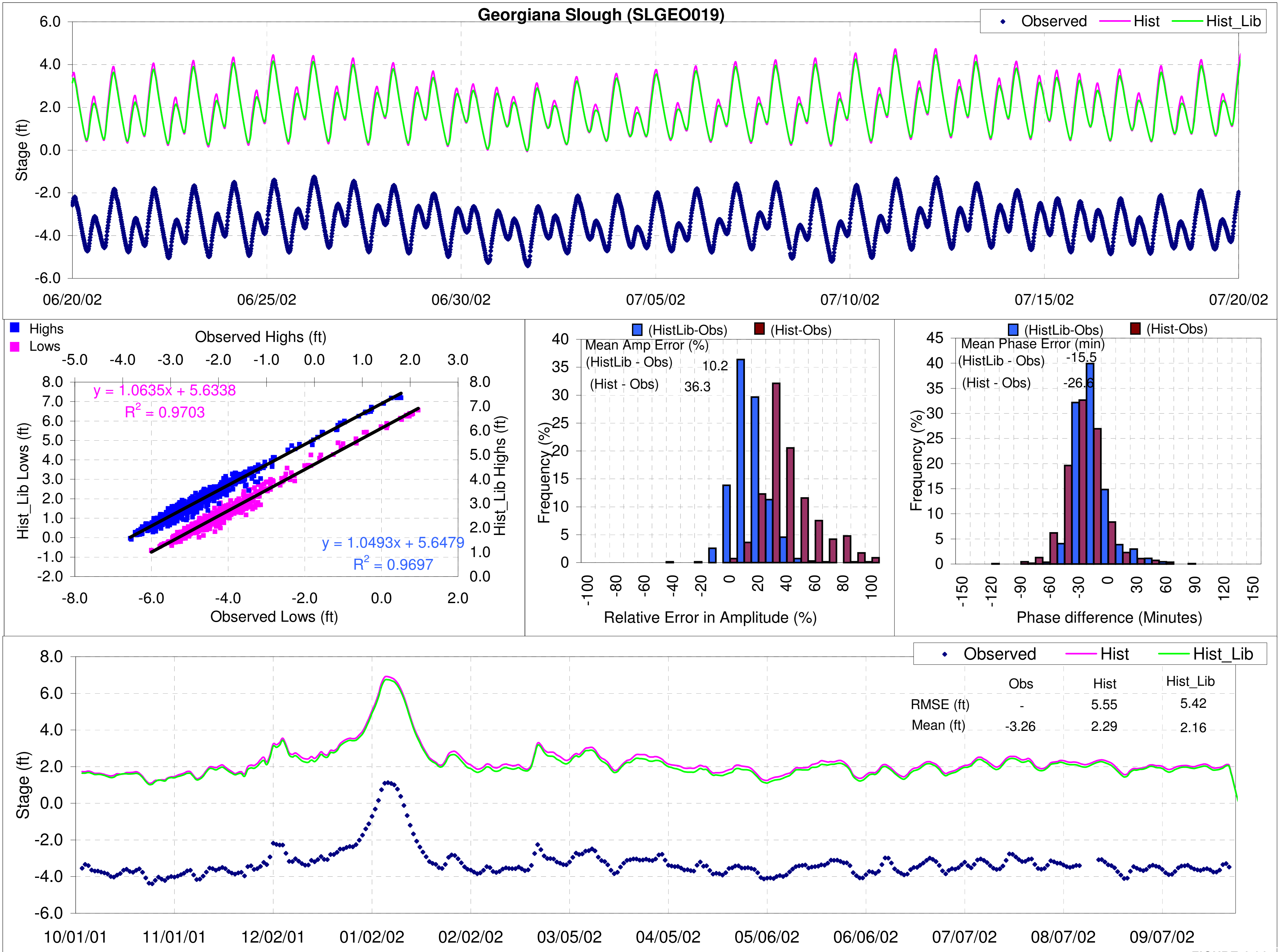


FIGURE 4-14

Stage Calibration Metrics for Georgiana Slough

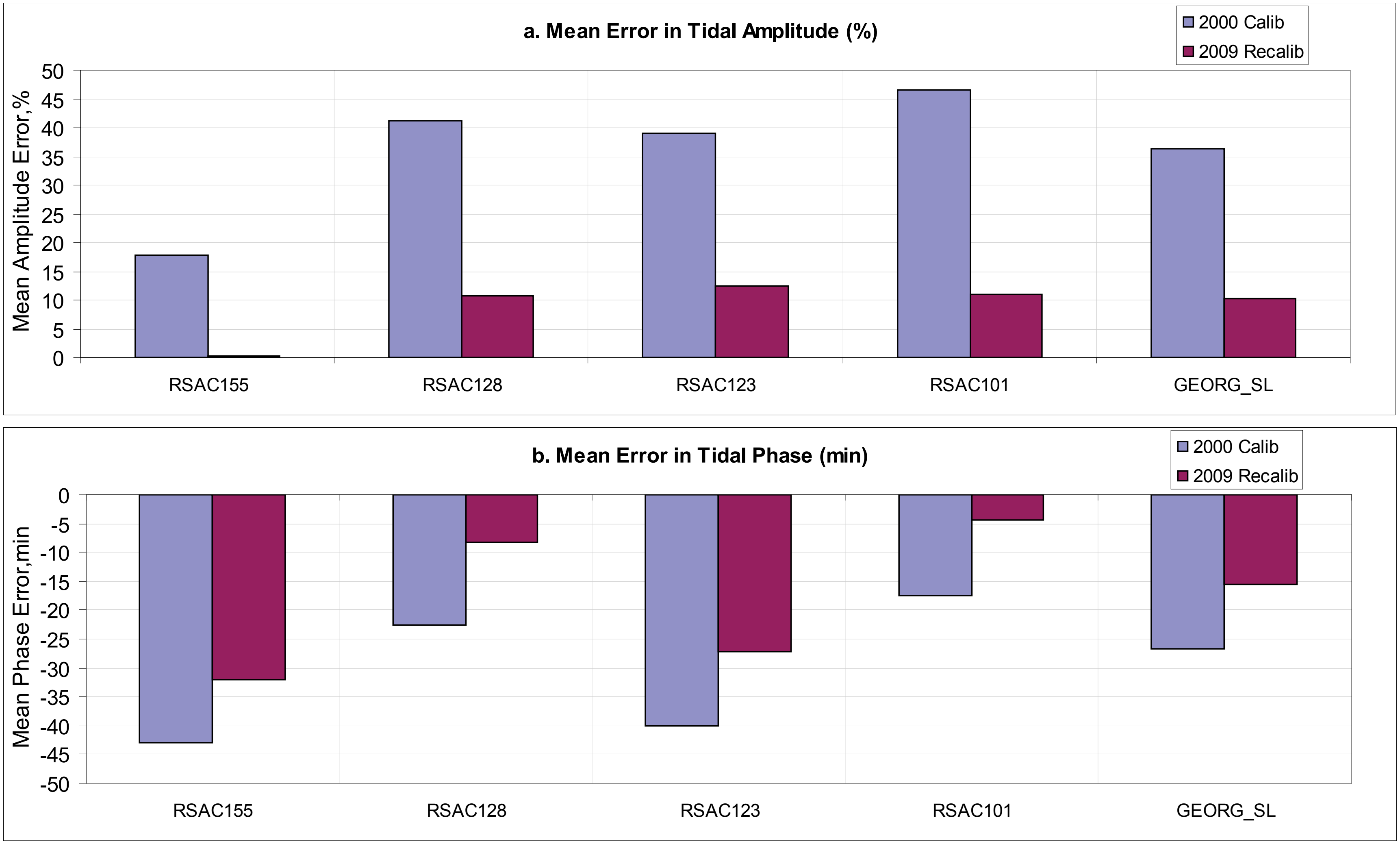
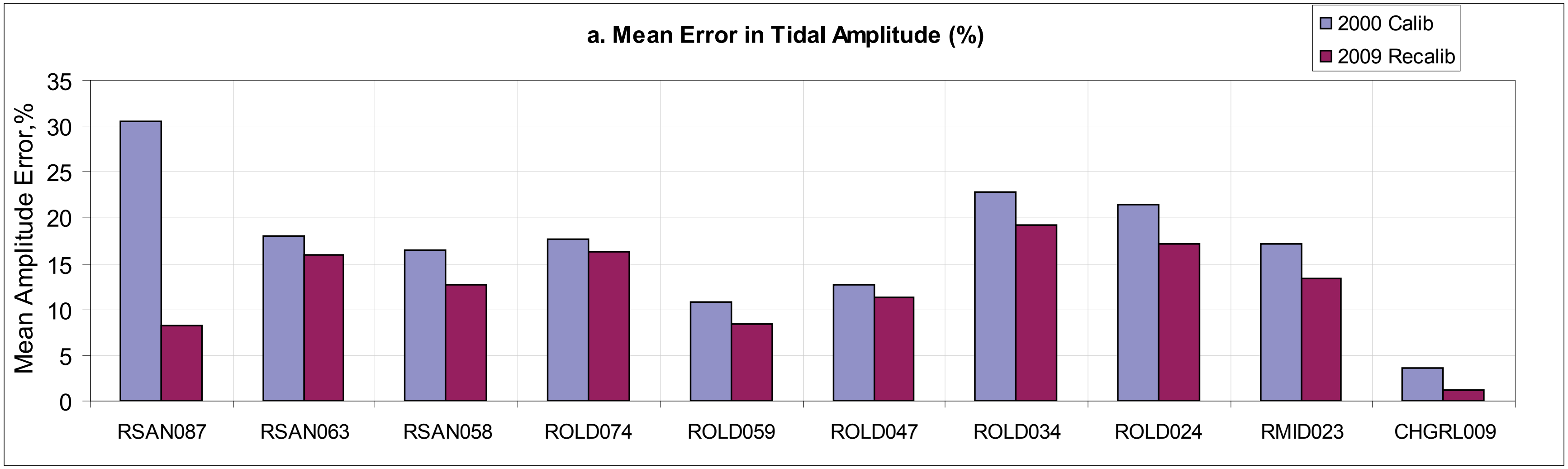


FIGURE 4-15
Summary of Stage Calibration Metrics for Locations in the North Delta Region

FIGURE 4-16
Summary of Stage Calibration Metrics for Locations in the Western and Central Delta Regions



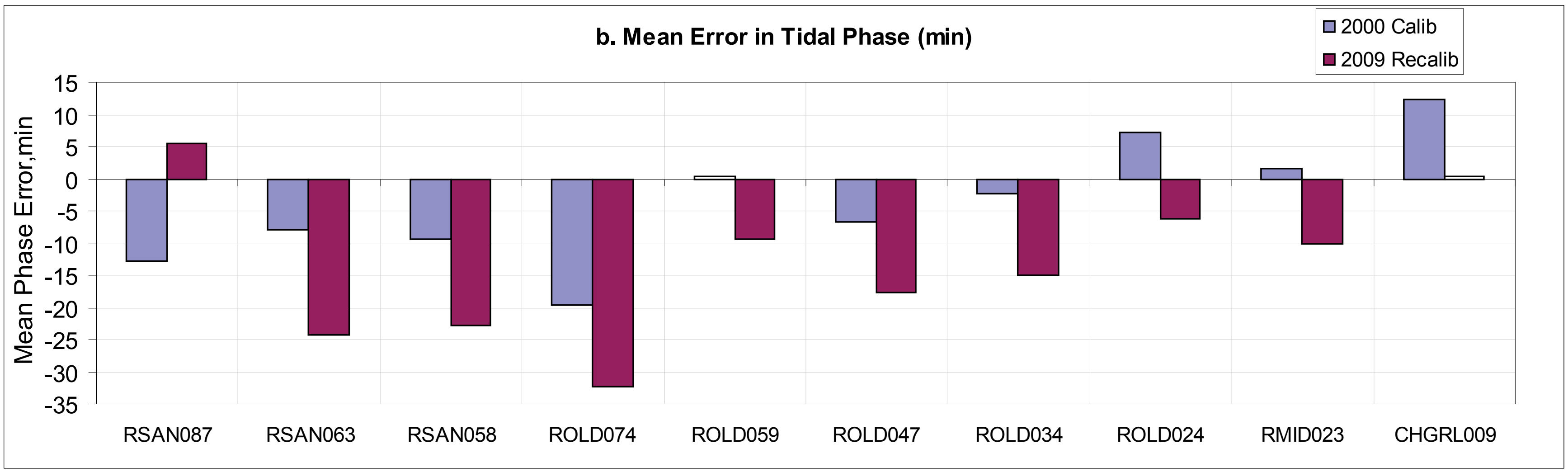


FIGURE 4-17
Summary of Stage Calibration Metrics for Locations in the South Delta Region

SECTION 5
Hydrodynamics Validation

5.1 Validation Period

Two validation runs were performed for DSM2 HYDRO. HYDRO was validated for a two year period from WY 2003 to WY 2004. HYDRO was also validated for an 8-year period from WY 2001 through WY 2008 to cover a wider variety of conditions in the Delta. The 8-year validation period included the calibration period (WY 2002). The model parameters were unchanged from calibration Run 15 for the validation simulations.

5.2 Hydrodynamics Validation Locations

Figure 5-1 shows the locations where the performance of DSM2 HYDRO was validated in simulating flow and stage. A total of 15 locations for flow and 22 locations for stage were selected. Table 5-1 lists the locations including their short names used in the results discussion in the following section.

5.3 Results

The flow and stage validation metrics are summarized in this section. The results for the flow validation are presented from the 8-year simulation. The results for the stage validation are presented from the 2-year simulation. The results from the two validation runs are compared to the results from equivalent simulations based on the 2000 calibration. The detailed hydrodynamics validation results for all the locations in the Delta are included in the Appendix B.

Figure 5-2 shows the summary of flow validation metrics for various locations in the North Delta region. Both the tidal and net flow metrics show similar trend compared to the calibration results. Three additional locations in the North Delta are included in the validation metrics: Steamboat Slough (STMBT_SL), Sutter Slough (SUTR_SL), and Cache Slough (CacheSl). The key flow metrics have improved compared to the validation results based on the 2000 calibration.

Flow validation metrics for Threemile Slough and Dutch Slough are similar to the calibration as shown in Figure 5-3. However, for Jersey Point, the results from validation did not hold the same trends as the calibration; the error in tidal flow range has decreased while the mean phase error has increased. In the net flow metrics, both the mean error and RMSE are very similar to the calibration.

In the south Delta and the upper San Joaquin River, the flow calibration trends are held in the net flow metrics from the validation simulation as shown in the Figure 5-4. However, the tidal metrics show small incremental errors at most locations, unlike the calibration results. Peak phase errors remain under 15 minutes, and peak flow amplitude errors remain under 15 percent.

Statistics were calculated for flow metrics on the 8-year validation period. Figures are presented below comparing the RMS error, mean amplitude error, and mean phase error at all the locations in the Delta where the model performance was assessed. Two plots are shown for each statistic, the first compares the results of the 1-year recalibration to the 8-year validation, and the second compares results from the 8-year validation of the recalibration to results of an 8-year validation simulation of the previous calibration effort conducted by DWR in 2000. The extended validation period contains a larger range in hydrologic influences than the 1-year calibration period, and thus RMS errors are generally expected to be larger for the validation period.

Figure 5-5 compares the RMS errors in the net flows, for WY 2002 recalibration and the corresponding 8-year validation simulations. In general, the RMS errors are larger for the longer validation simulation. The RMS errors in the upper Sacramento River are noticeably smaller for WY 2002 as compared to the 8-year period. The validation simulation actually lowered the RMS error slightly at Rio Vista and Threemile Slough.

Figure 5-6 compares the RMS error in tidally averaged flow for the two 8-year validation runs based on the 2000 calibration and the 2009 recalibration. Although the RMS errors are higher in the validation period, the relative performance of the validation simulations is similar to that presented for the WY 2002 simulations. Improvements in RMS error are seen at Rio Vista, Jersey Point, Georgiana Slough, and Cross Delta flow.

Figures 5-7 and 5-8 compare the mean errors in flow amplitude. Figure 5-7 shows the variations in mean flow amplitude errors between the one year recalibration and the 8-year validation simulations. On average, the mean percent errors are lower for the validation period as compared to the one year recalibration period; the average absolute percent error at the 13 locations in Figure 5-7 is reduced from 16 percent in the 2002 recalibration to 7 percent in the eight year validation.

Figure 5-8 compares mean errors in tidal flow range for the two validation simulations based on 2000 calibration and current recalibration. The recalibration simulation has significantly lower errors than the 2000 calibration simulation over the 8-year period. The reductions are similar to those presented for the one year calibration period. The recalibration simulation achieved considerable reductions in mean amplitude error on the Sacramento River and its side channels, including Georgiana Slough, Steamboat Slough, Sutter Slough, and Cache Slough. This is of critical performance for proper simulation of the effects of diversions off the Sacramento River and the new tidal marsh in the North Delta region proposed under BDCP.

The errors in the phasing of the predicted tidal flow are compared in Figures 5-9 and 5-10. The phase errors are similar for the one year and eight year simulations with the recalibrated model (Figure 5-9). Errors in phase are higher on the Sacramento River in general than in the South Delta. When compared to the results from 8-year validation based on the 2000 calibration, the validation results from the recalibrated model show consistent improvement throughout the Delta. Errors in the Sacramento River are cut in half in the recalibrated model, and show even greater improvement in channels branching off of the Sacramento River in the North Delta.

The improvement in the DSM2's ability to reproduce the measured daily range in water levels is summarized in Figure 5-11. Over the eight year validation period, the average errors in predicted tidal range are reduced by over 40 percent in the recalibrated model as compared to the previous calibration.

Table

TABLE 5-1
List of Hydrodynamics Validation Locations

Location	Short Name	Flow	Stage
Sacramento River at Freeport	RSAC155	✓	✓
Sacramento River above Delta Cross Channel	RSAC128	✓	✓
Sacramento River downstream from Georgiana Slough	RSAC123	✓	✓
Sacramento River at Rio Vista	RSAC101	✓	✓
Sacramento River at Martinez	RSAC054		✓
San Joaquin River at Mossdale	RSAN087		✓
San Joaquin River at Stockton	RSAN063	✓	✓
Stockton Ship Channel at Burns Cutoff	RSAN058		✓
San Joaquin River at San Andreas Landing	RSAN032		✓
Three Mile Slough	SLTRM004	✓	✓
San Joaquin River at Jersey Point	RSAN018	✓	✓
San Joaquin River at Antioch	RSAN007		✓
Old River at Head	ROLD074		✓
Old River at Tracy Boulevard	ROLD059		✓
Old river near Delta Mendota Canal	ROLD047		✓
Old River at Highway 4 (near Byron)	ROLD034	✓	✓
Old River at Bacon Island	ROLD024	✓	✓
Middle River at Bacon Island	RMID015	✓	✓
Middle River at Borden Highway	RMID023		✓
Grant Line Canal at Tracy Boulevard Bridge	CHGRL009	✓	✓
Georgiana Slough	GEORG_SL	✓	✓
Montezuma Slough at Beldons	SLMZU011		✓
Dutch Slough	SLDUT007	✓	✓
Cross Delta Flow	X-Delta Flow	✓	
Steamboat Slough	STEAMBT_SL	✓	
Sutter Slough	SUTTER_SL	✓	
Cache Slough at Ryer Island	CACHE	✓	

Figures

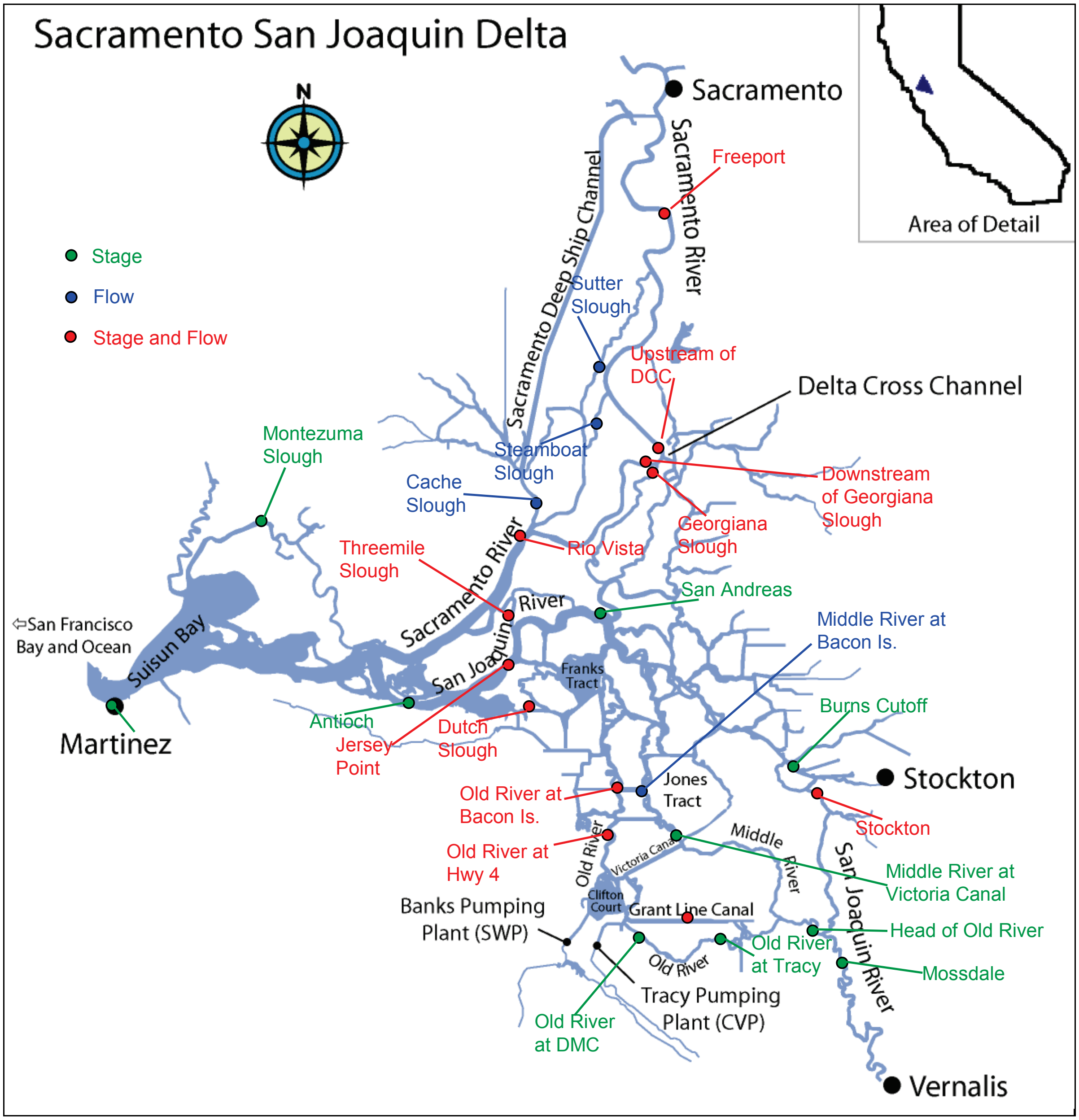


FIGURE 5-1
Map Showing Hydrodynamics Validation Locations

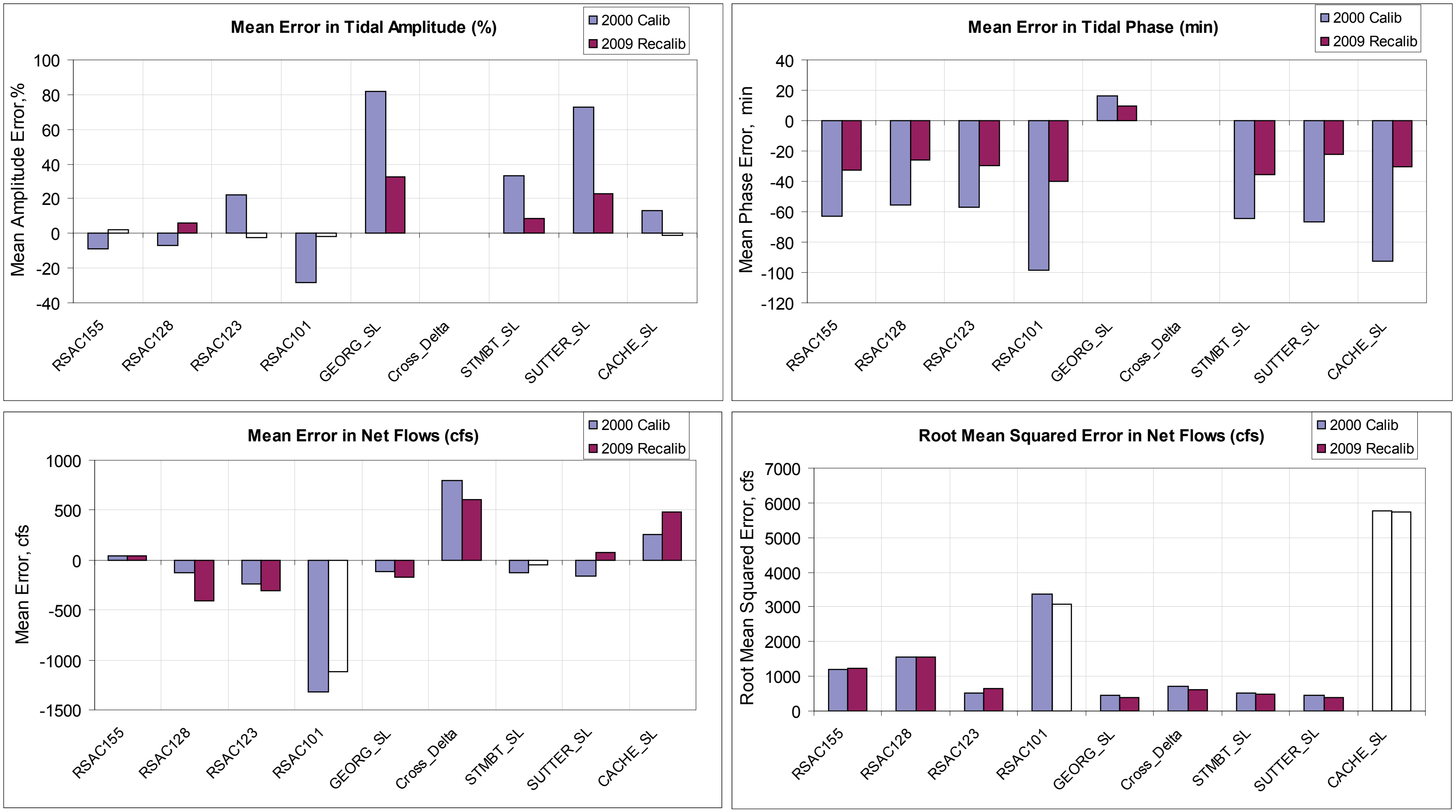


FIGURE 5-2
Summary of Flow Validation Metrics for Locations in the North Delta Region

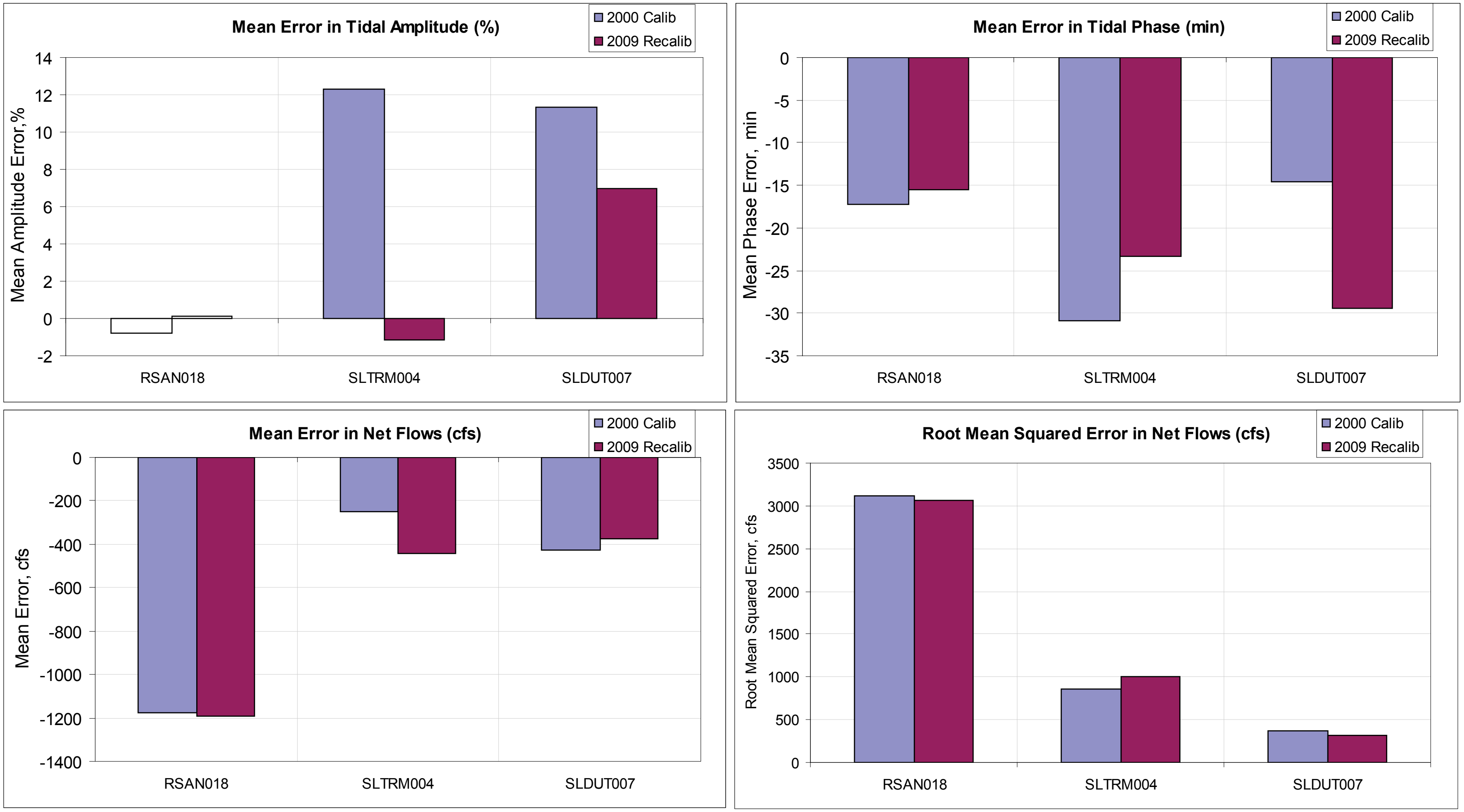


FIGURE 5-3
Summary of Flow Validation Metrics for Locations in the Western and Central Delta Regions

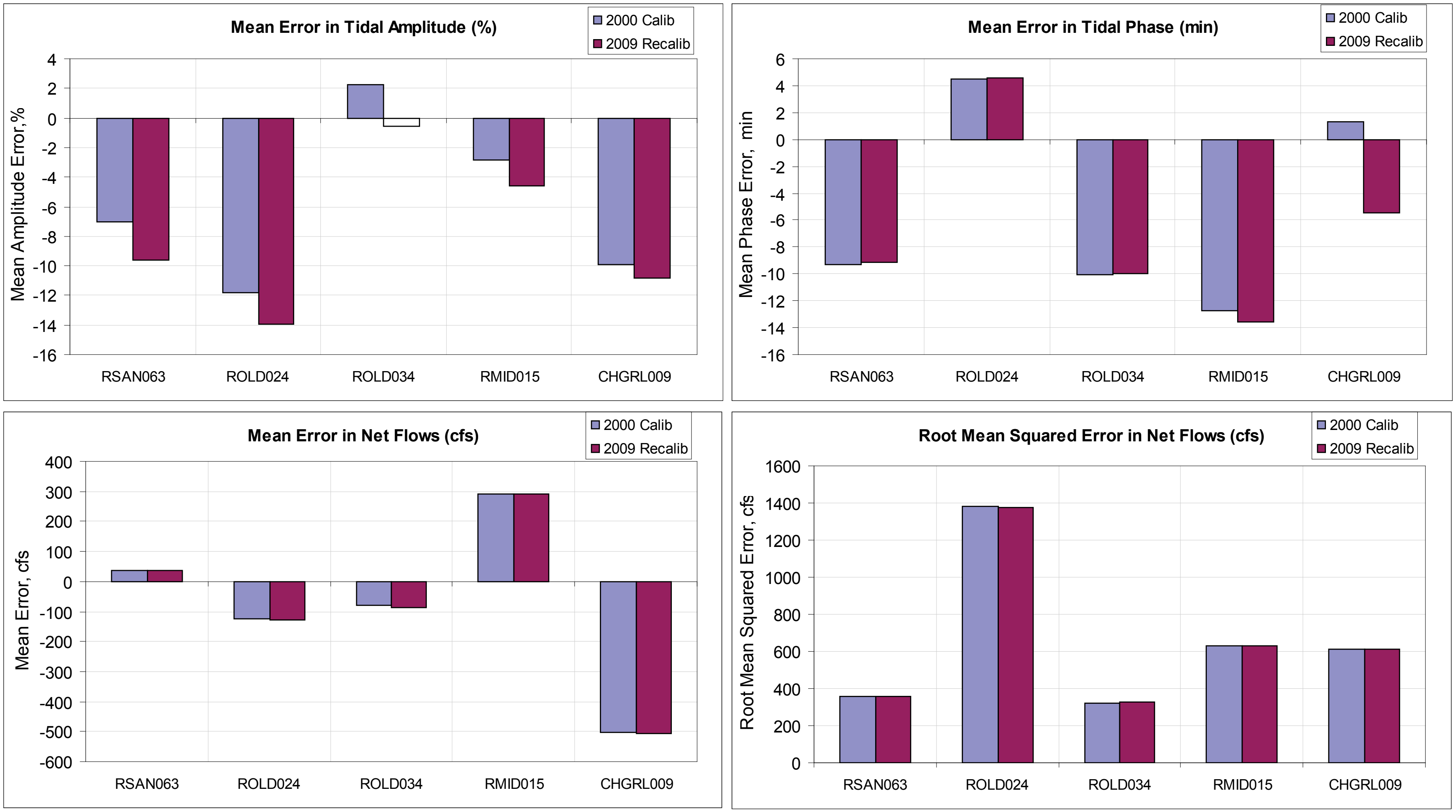


FIGURE 5-4
Summary of Flow Validation Metrics for Locations in the South Delta Region

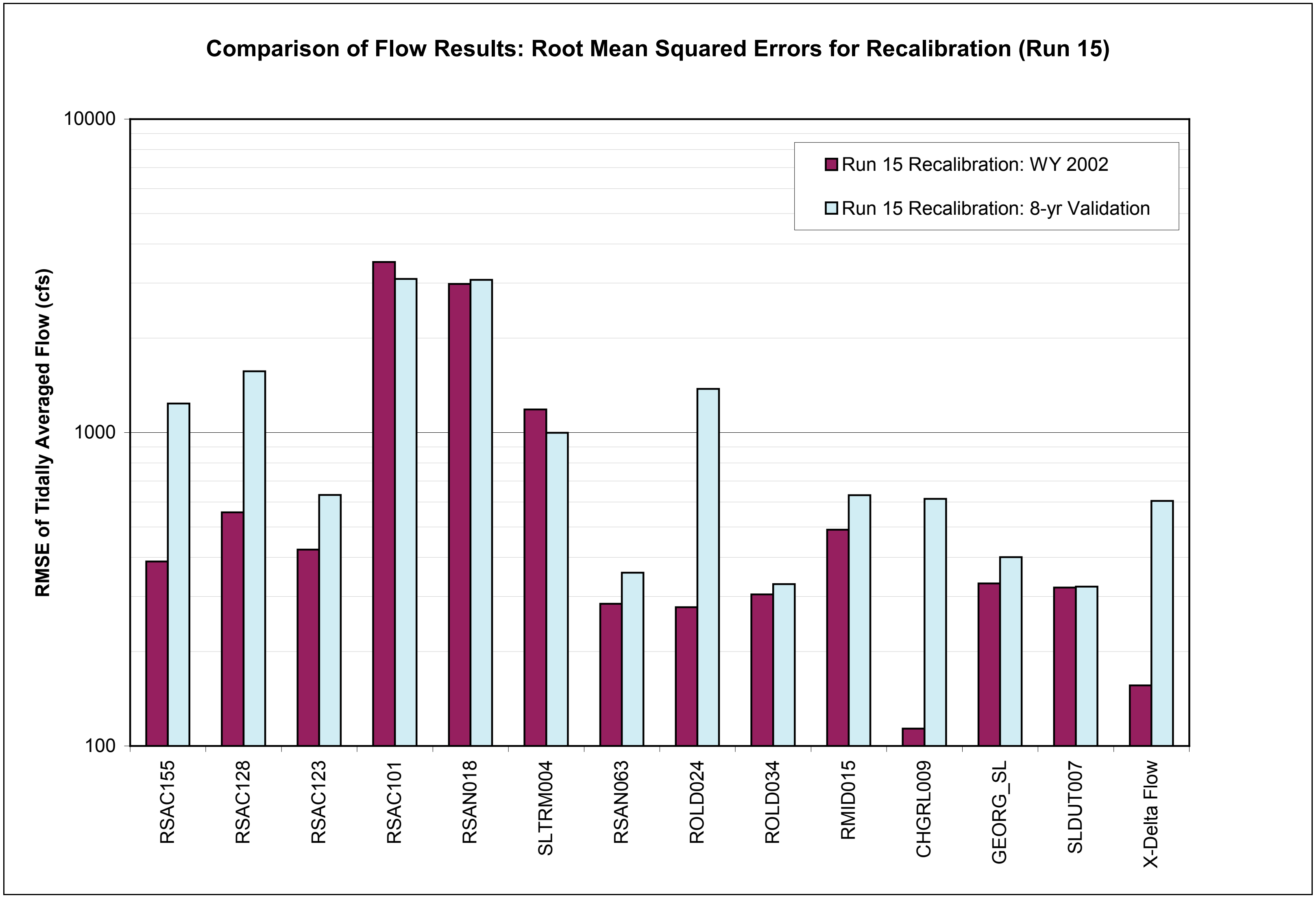


FIGURE 5-5
Comparison of RMS Errors in Flow for Recalibration and Extended Validation

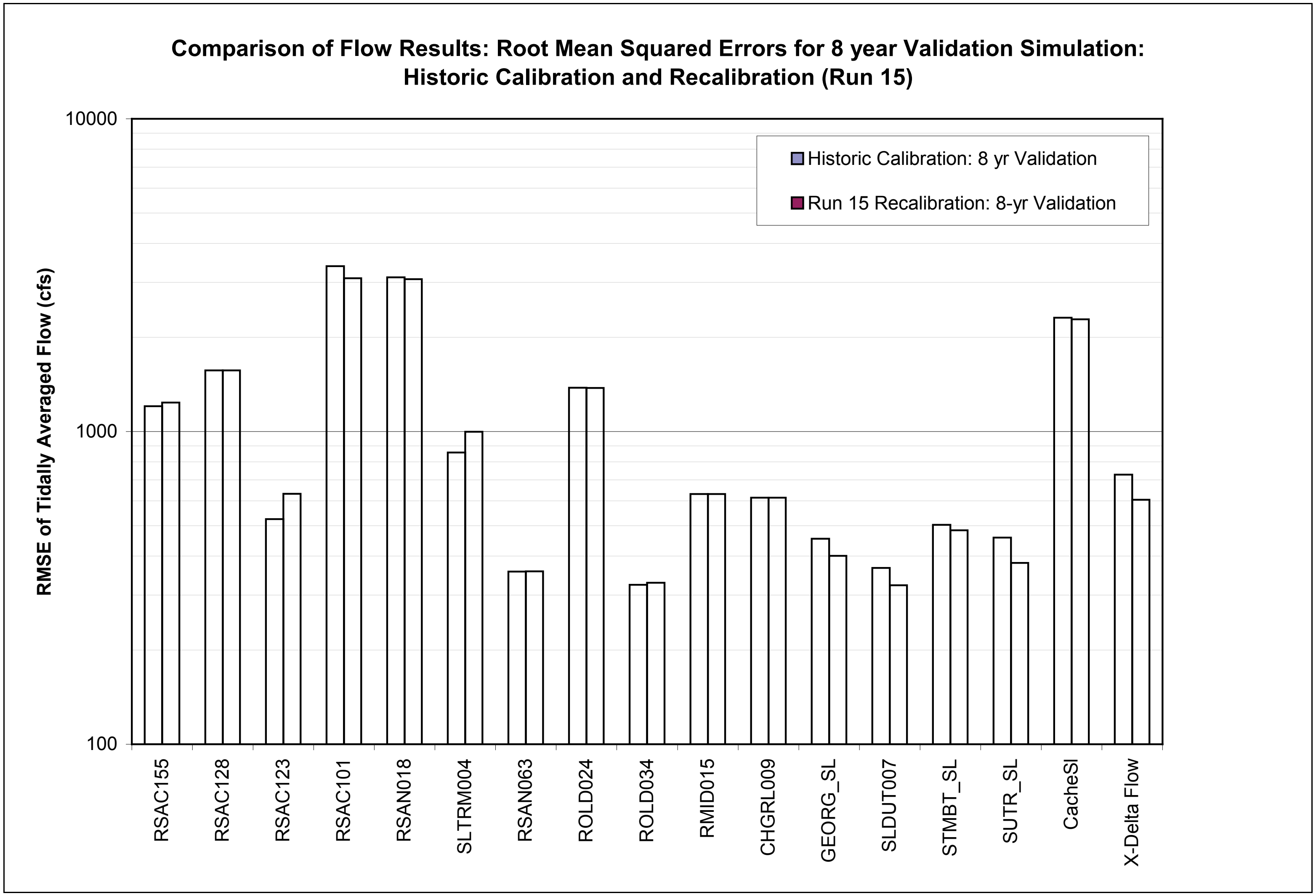


FIGURE 5-6
Comparison of RMS Errors in Flow for Extended Validation Period
(2000 Calibration and 2009 Recalibration Simulations)

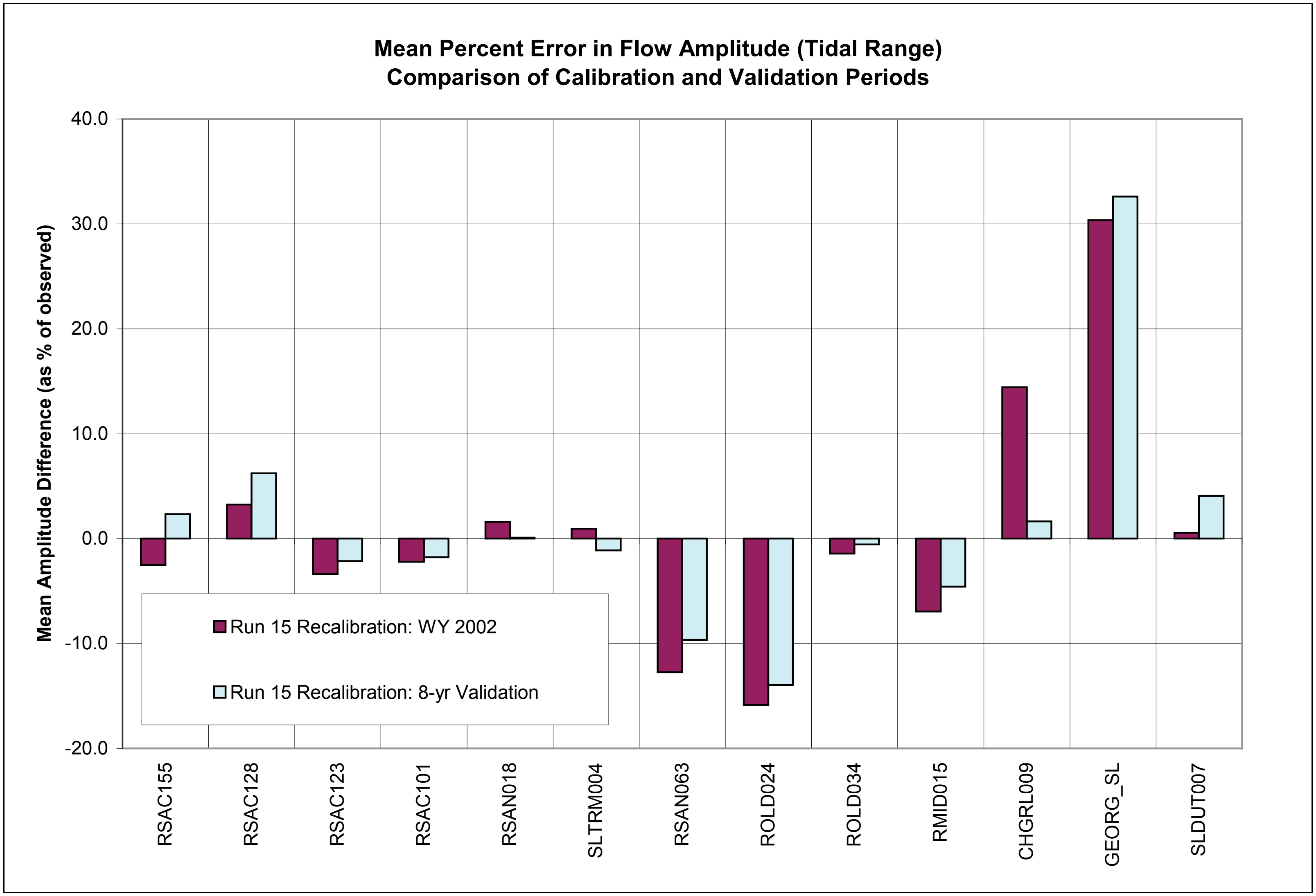


FIGURE 5-7
Comparison of Mean Amplitude Errors in Flow for Recalibration and Extended Validation

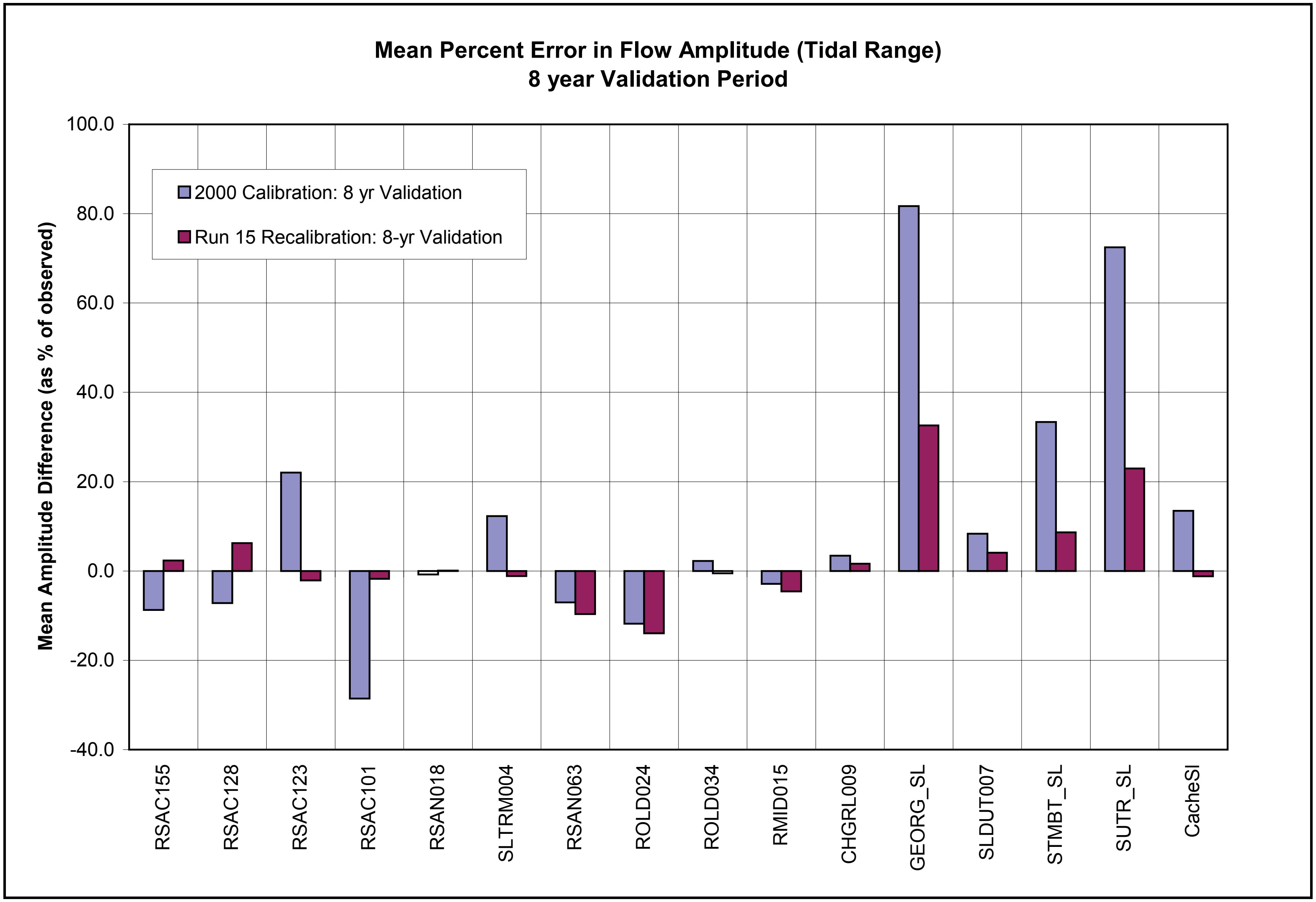


FIGURE 5-8
Comparison of RMS Errors in Flow for Extended Validation Period
(2000 Calibration and 2009 Recalibration Simulations)

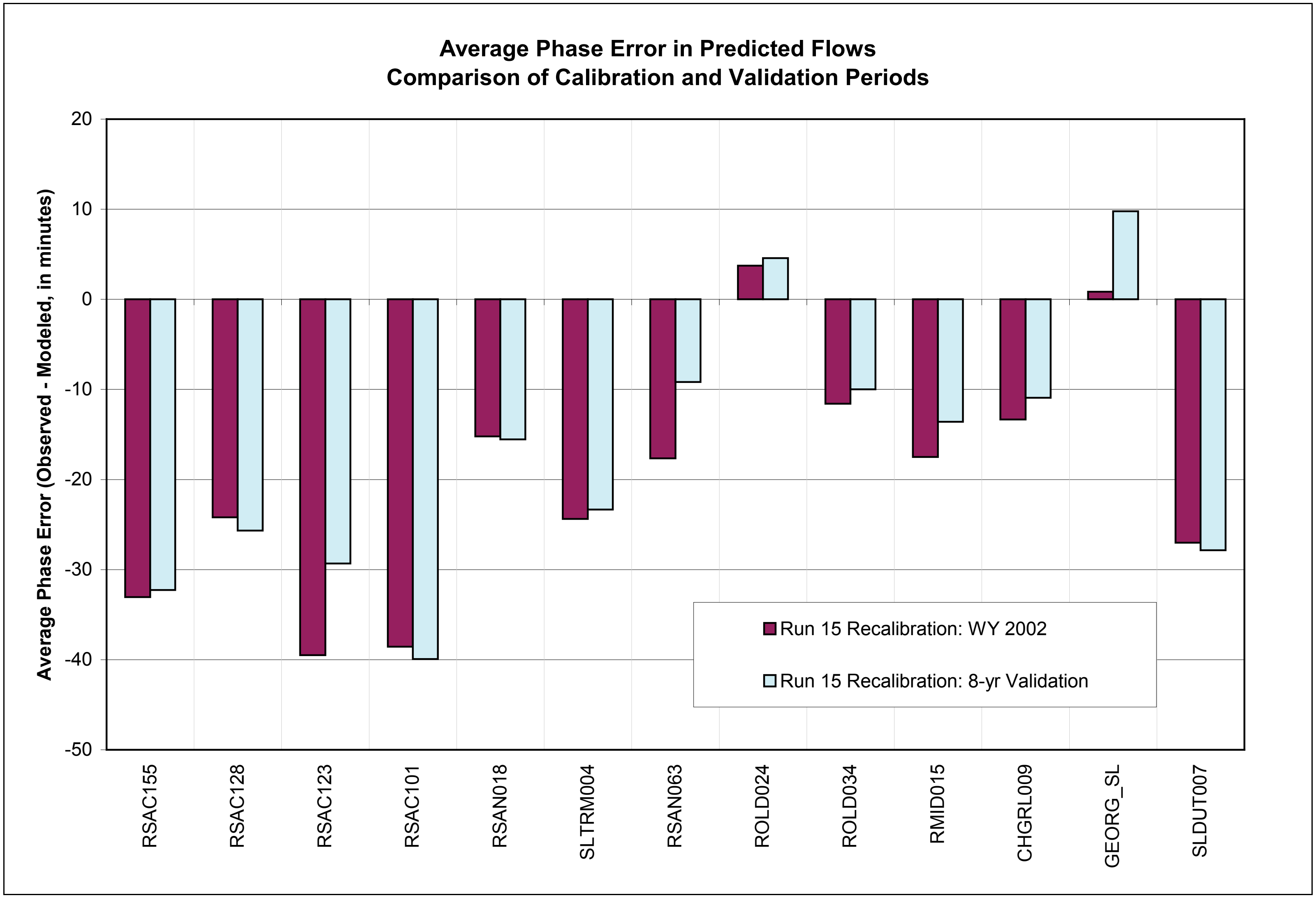


FIGURE 5-9
Comparison of Mean Phase Errors in Flow for Recalibration and Extended Validation

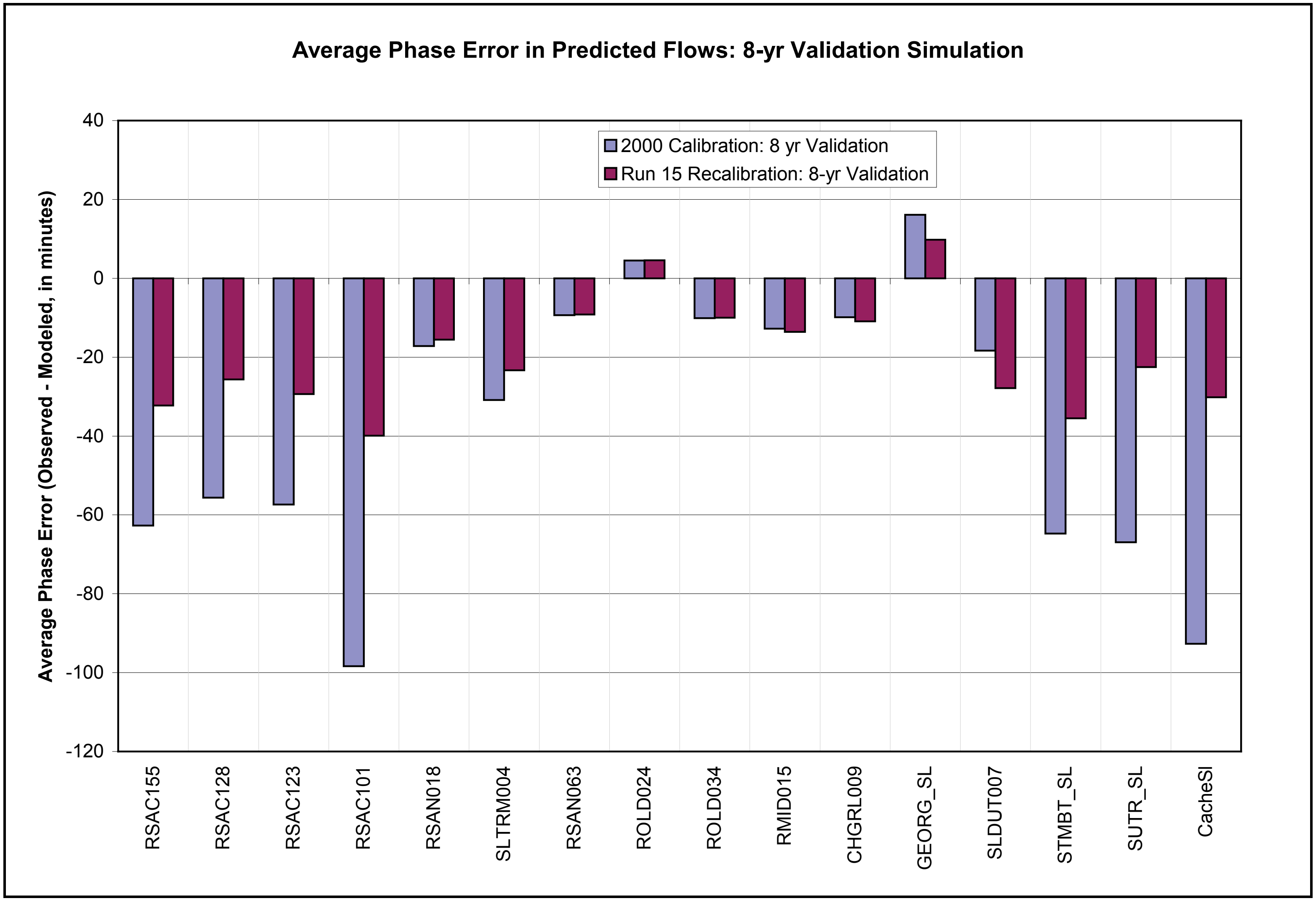


FIGURE 5-10
Comparison of RMS Errors in Flow for Extended Validation Period
(2000 Calibration and 2009 Recalibration Simulations)

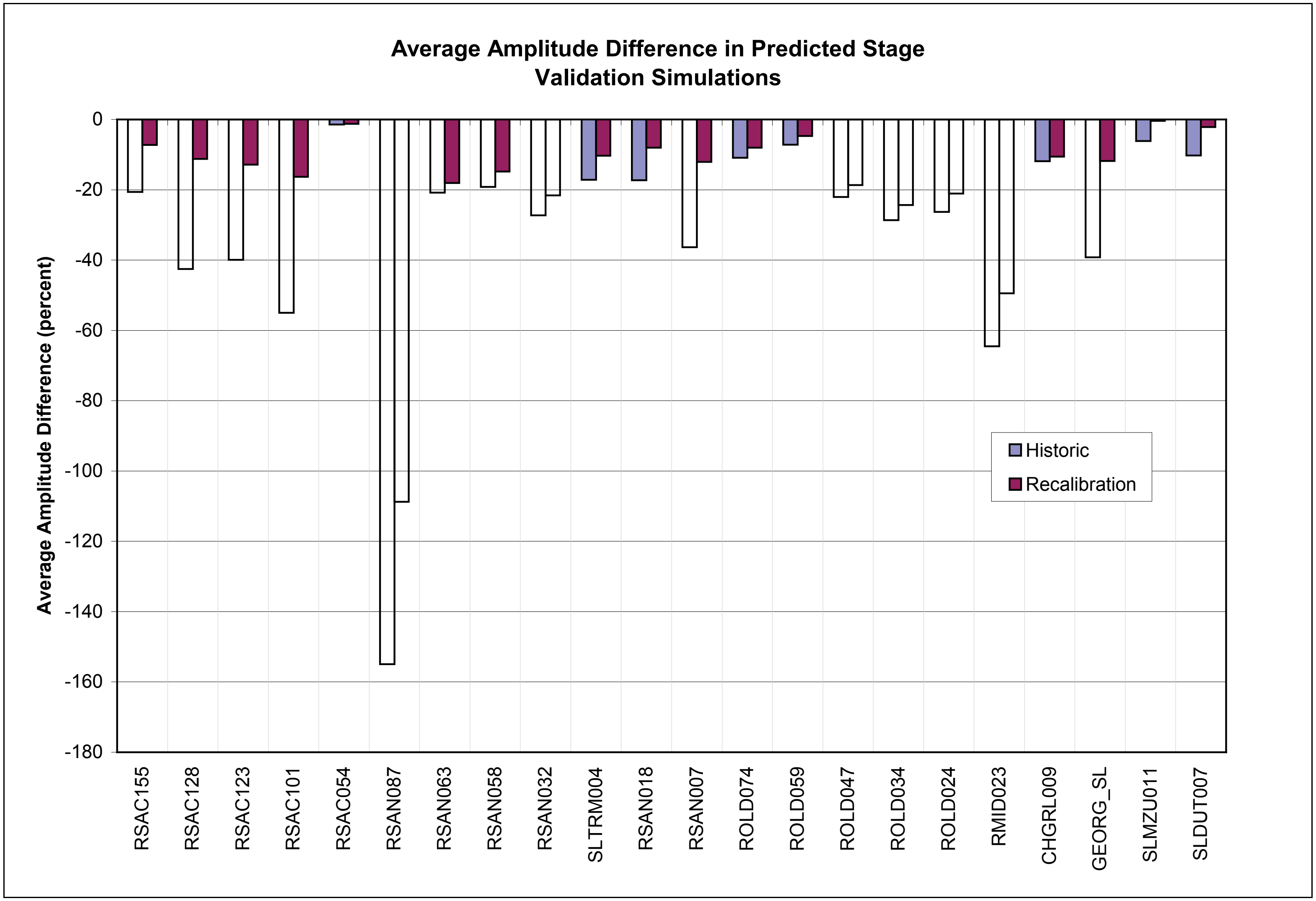


FIGURE 5-11
Comparison of Errors in Predicted Tidal Amplitude (Stage) for 2-year Validation Period
(2000 Calibration and 2009 Recalibration Simulations)

SECTION 6

Water Quality Calibration and Validation

6.1 Calibration Period

Based on the discussions with DWR staff, it was decided that the QUAL calibration period should be as long as practical and contain recent dry periods. During the dry periods the salinity intrusion occurs in the Delta and the salinity varies significantly in the interior of the Delta. It is important that the model can predict the EC well for these periods. Therefore, the 8-year period used for the HYDRO validation, WY 2001 through WY 2008, was used for the QUAL calibration. This period included five below-normal, dry, or critical years when high-salinity intrusions were recorded. A separate validation period was not developed since sufficient observed EC data was not available beyond the long EC calibration period.

6.2 Key Calibration Parameters

Channel dispersion factors were the calibration parameter used in the QUAL calibration. Increased dispersion allows higher mixing in the channels, which translates to higher salinity transport. This is especially true when high salinity gradients exist. The dispersion factor in QUAL is a ratio of dispersion to advection within a channel. In the 2000 calibration, the Delta was divided into 22 regions, each containing several channels with the same dispersion factor. In the current calibration, starting with the final dispersion map from 2000 calibration, the dispersion factors were adjusted in key channels to achieve the best match with the observed data. Table 6-1 lists the channels where dispersion factors were modified in the current calibration.

6.3 Key Steps in the Calibration

QUAL calibration used the output from the 8-year HYDRO validation run, which was based on the calibration Run 15. With the dispersion factors unchanged from 2000 calibration, the results from the first QUAL run showed consistent over prediction of EC in both Sacramento and San Joaquin Rivers. The key changes made as part of the QUAL calibration include:

- Dispersion factors were reduced in Sacramento River channels from Rio Vista to Chipps Island
- Dispersion factors were increased in San Joaquin River channels from Mokelumne River to Broad Slough
- Dispersion factors were increased in Dutch Slough near San Joaquin River
- Dispersion factors were reduced in Sacramento River channels from Port Chicago to Martinez

A total of 18 runs were simulated to get the best match with the observed data at all locations in the Delta. Run EC_3L_15 was the final QUAL calibration run.

6.4 EC Calibration Locations

Figure 6-1 shows the locations where the performance of DSM2 QUAL in simulating EC was evaluated in the current recalibration. A total of 27 locations were selected. Table 6-2 lists the locations including their short names used in the results discussion in the following section.

6.5 Results

The improvements made in the recalibration of Delta hydrodynamics are expected to carry over into the water quality modeling. By more accurately representing the tidal hydrodynamics in the system, the errors in water quality predictions should be reduced to the extent that the errors are related to the hydrodynamics and not other boundary conditions such as DICU.

The recalibration effort focused on improving predictions at several key locations in the Delta, including Emmaton and Jersey Point (two water quality compliance locations). In general, the thesis behind the recalibration effort was that by improving model predictions on the lower Sacramento and San Joaquin Rivers, conditions in the South Delta and other interior locations would also improve.

Figures 6-2 to 6-6 show the detailed EC calibration metrics for Collinsville, Emmaton, Rio Vista, Jersey Point, and Old River at Rock Slough (Bacon Island). The results show that the simulated EC at Emmaton and Jersey Point match well with the observed data and have improved compared to the 2000 calibration. The errors in the mean EC at Collinsville and Rio Vista are slightly higher in the current recalibration compared to 2000 calibration, especially in the fall months, although, the errors are less than 7 percent. The detailed EC calibration metrics for all the locations in the Delta are included in the Appendix C.

Figure 6-7 compares the average percent change in EC from observed data for both the 2000 calibration and the current recalibration simulations. Negative numbers indicate the model is producing lower EC values than observed data, and positive numbers indicate the model is predicting saltier conditions than those measured in the field. The largest improvements came at the targeted locations, namely Emmaton and Jersey Point. Antioch also saw a considerable reduction in average error. Errors in the recalibration run increased from the previous calibration at Old River at Holland Cut and at the South Delta export locations. Despite the considerable hydrodynamic improvements at Rio Vista, the EC results indicate slightly worse performance compared to the previous calibration. The increase in dispersion coefficients required to improve EC predictions at Emmaton (Run 3G_15) brought more salt to Rio Vista. To address this, the dispersion coefficients in channels 430 and 431 were lowered to 0.05. This improved EC predictions at Rio Vista, but the model still predicts higher salinity at Rio Vista in the summer and fall months. The final dispersion coefficients used in the Sacramento River have a low point in the vicinity of Rio Vista; this may not be justifiable from a physics standpoint, and should be addressed in subsequent analyses. Even though, the 2000 calibration resulted in slightly better EC values at Rio Vista compared to the current calibration, it is important to note that the current calibration has accurate hydrodynamics unlike the 2000 calibration.

Model performance at the lower Sacramento River stations should be viewed as a group. Average error in the tidally averaged EC for the recalibration simulation is 4.3 percent at Rio Vista, 0.3 percent at Emmaton, and 7.0 percent at Collinsville. Note that there is no consistent bias, in that the lowest error is in the middle of the three stations.

Figure 6-8 presents the RMS errors in predicted EC for both the 2000 calibration and the 2009 recalibration. The RMS errors vary considerably throughout the Delta, with elevated errors seen in the western Delta and in Suisun Marsh. In general, the RMS errors are higher on the Sacramento River than on the San Joaquin River and in the South Delta. Significant improvements are seen at Emmaton, Jersey Point, Antioch, and Old River at Bacon Island. Errors increased compared to the 2000 calibration run at Rio Vista, Clifton Court, Old River at Holland Cut, and Threemile Slough.

There is considerable variation in the RMS errors when viewed on a monthly basis, as demonstrated in Figures 6-9 through 6-11, which present more detailed model results at Emmaton, Rio Vista, and Jersey Point. In general, the RMS errors are higher in the summer and fall months and lower in the winter and spring months. Errors in these three plots are presented as percent errors normalized by the average EC at a given station.

At Emmaton, the peak errors in the summer months have been reduced considerably in the recalibration simulation. The months of July through September are generally when the EC is steadily increasing in the central Delta. The reduction in RMS error during these months indicates that the model is more accurately predicting the build up of EC in the summer months. The average RMS errors decrease in the winter and spring months. The recalibration effort improves the average errors during the 6 months span from January to June, but from a low error to start with.

Figure 6-10 presents the average monthly performance at Rio Vista. Here, the performance is more uniform throughout the year, without the strong seasonal pattern seen at Emmaton. Errors in the summer and fall months are higher in the recalibration simulation than in the previous calibration effort, for reasons discussed above.

The performance at Jersey Point is shown in Figure 6-11. The seasonal pattern visible at Emmaton is also seen here, with peak errors in the summer months and small errors in the spring. The peak errors in July through October are reduced considerably in the recalibration simulation.

An overview of the monthly model performance at eight key locations is provided in Figure 6-12. There is a general seasonal trend visible in the model results, where the model underestimates the salinity in the winter and spring months and overestimates the salinity in the summer and fall months. This pattern is influenced through the specification of dispersion coefficients in the model, and the optimization of model performance was primarily conducted through the adjustment of this parameter. However, given the general trend seen in the results, it is not possible to continue to correct both the overestimation of salt in the summer/fall period and the underestimation of salt in the winter/spring period by adjusting the dispersion coefficient. A decrease in the dispersion coefficient could lower the salt transport into the Delta during the low flow months, but would likely lead to increased errors during the winter/spring period when the model is already underestimating the salt content.

The performance of DSM2 regionally in predicting the EC is shown in Figures 6-13 to 6-15. The tidally averaged mean error and RMSE are plotted for both the 2000 calibration and the current recalibration for North Delta, Western and Central Delta, and South Delta regions. The mean errors in the North Delta are less than 4 percent in the current recalibration with RMSE as high as 45 percent as shown in Figure 6-13. Compared to the 2000 calibration, the performance is inconsistent in the current calibration, with significant improvement at Emmaton, slight degradation at Rio Vista and unchanged EC at Green's Landing. Figure 6-14 summarizes the mean error and RMSE in the tidally averaged EC for the western and central Delta locations. The mean errors are less than 10 percent in the western Delta locations with RMSE up to 45 percent. With exception of Mokelumne River (25 percent), the mean error in the central Delta locations is less than 15 percent. Compared to the 2000 calibration, the changes in the errors are fairly minimal at most locations; however, the change is inconsistent. As noted earlier, while Threemile Slough shows slight degradation, Jersey Point and Antioch show significant improvements. The summary of EC performance for south Delta is shown in Figure 6-15. For the most part, the EC predictions remain unchanged from 2000 calibration. Noticeable improvements in Old River at Bacon Island EC exist, while slightly higher EC is seen at the pumps. Except for Old River at Tracy (25 percent), Holland Cut (15 percent) and Grant Line Canal (15 percent), all the errors are around 10 percent in the South Delta. The upper San Joaquin locations show errors up to 15 percent.

Figure 6-16 presents a summary of the recalibration effort as compared to the previous calibration. For a select set of locations, Figure 6-16 shows the percent change in tidally average RMS error in predicted EC for the recalibration simulation, relative to the RMSE from the previous calibration. The RMS error increases by more than 10 percent at Rio Vista (17 percent) and Old River at Holland Cut (12 percent). The RMS error decreases by more than 10 percent at Collinsville, Martinez, Antioch, Jersey Point, Old River at Bacon Island, and Dutch Slough. Overall, the improvements outweigh the locations where the errors increased in the recalibration effort. Table 6-3 shows the numerical values used to generate Figure 6-16.

Figure 6-17 compares model performance by water year for the 8-year extended validation simulations. There is considerable variation in model performance in different water years. The average errors are highest in WY 2007, and second highest in the hydro calibration year (2002). The recalibration provided the largest reduction errors in these 2 years, which were both classified as dry years. The best performance for both the previous calibration and the recalibration simulation was in 2008, a critical year with average annual exports of only 5,100 cfs. Although the eight year period is a small sample set, it appears that the model performance may be influenced by water year type.

Two series of eight plots each have been developed to demonstrate the annual patterns in model predicted EC. These plots were developed to provide insight into the seasonal performance of the model such that future calibration efforts can address months with larger errors. The first set of plots (Figures 6-18 to 6-25) shows average monthly EC at eight key locations in the Delta. The bar charts include observed data, results from the 2000 calibration simulation, and results from the recalibrated model. The second set of plots (Figures 6-26 to 6-33) presents the average percent error in the monthly EC for both the 2000 calibration and the 2009 recalibration. Locations presented include:

- Collinsville
- Emmaton
- Rio Vista
- Antioch
- Jersey Point
- Old River at Rock Slough (Bacon Island)
- Old River at Clifton Court (Banks Pumping Plant)
- Jones Pumping Plant (CVP)

Tables

TABLE 6-1
List of Channels with Modified Dispersion Factor in the Current Calibration

DSM2 Channel Number	Dispersion Factor from 2000 Calibration	Dispersion Factor from Current Calibration
45	0.5	0.7
46	0.5	0.7
47	0.5	0.7
48	0.05	0.07
49	0.05	0.07
50	0.05	0.07
51	0.05	0.07
52	0.05	0.07
53	0.05	0.07
83	0.05	0.07
215	0.6	0.75
260	0.6	0.75
274	0.6	0.75
275	0.6	0.75
284	0.05	0.07
285	0.05	0.07
286	0.05	0.07
290	0.8	0.3
291	0.8	0.3
300	0.05	0.07
430	0.4	0.05
431	0.4	0.05
432	0.4	0.2
433	0.4	0.2
434	1.0	0.5
435	1.0	0.5
436	0.8	0.3
439	1.5	1.3
440	1.5	1.3
452	1.5	1.3

TABLE 6-2
List of EC Calibration Locations

Location	Short Name
Sacramento River at Greens Landing	RSAC139
Sacramento River at Rio Vista	RSAC101
Sacramento River at Emmaton	RSAC092
Sacramento River at Collinsville	RSAC081
Sacramento River at Port Chicago	RSAC064
Sacramento River at Martinez	RSAC054
San Joaquin River at Vernalis	RSAN112
San Joaquin River at Mossdale	RSAN087
San Joaquin River at Brandt Bridge	RSAN072
Stockton Ship Channel at Burns Cutoff	RSAN058
San Joaquin River at San Andreas Landing	RSAN032
San Joaquin River at Jersey Point	RSAN018
San Joaquin River at Antioch	RSAN007
Old River at Tracy Road	ROLD059
Old River at Bacon Island	ROLD024
Old River at Holland Cut	ROLD014
Middle River at Mowery Bridge	RMID040
Middle River at Tracy Boulevard	RMID027
Middle River at Borden Highway	RMID023
Middle River at Middle River	RMID015
Mokelumne River at Snodgrass Slough	RMKL019
Grant Line Canal at Tracy Boulevard Bridge	CHGRL009
Montezuma Slough at Beldons	SLMZU011
Old River at Clifton Court Forebay	CHSWP003
Delta Mendota Canal at Tracy Pumping Plant	CHDMC006
Three Mile Slough at San Joaquin River	SLTRM004
Dutch Slough	SLDUT007

TABLE 6-3
Comparison of RMS Error between the 2000 Calibration and 2009 Recalibration

Location	Tidal Average RMSE (micro mhos/cm)		Percent Change in RMSE vs. Historical
	Historical	Recalibration 3L_15	
RSAC101	42	50	17.1
RSAC092	350	307	-12.3
RSAC081	796	796	0.0
RSAC064	2,849	2,887	1.3
RSAC054	1,913	1,621	-15.3
RSAN032	72	72	0.6
RSAN018	322	270	-16.3
RSAN007	686	585	-14.7
ROLD024	89	79	-10.7
ROLD014	105	118	12.1
RMID023	62	65	4.9
RMID015	52	54	2.5
SLMZU011	1,740	1,706	-2.0
CHSWP003	64	69	7.6
CHDMC006	63	63	-0.7
SLTRM004	216	223	3.0
SLDUT007	190	165	-13.4

= reduced error vs. historical (yellow)
= increased error vs. historical (red)
= negligible change vs. historical (light blue)

Figures

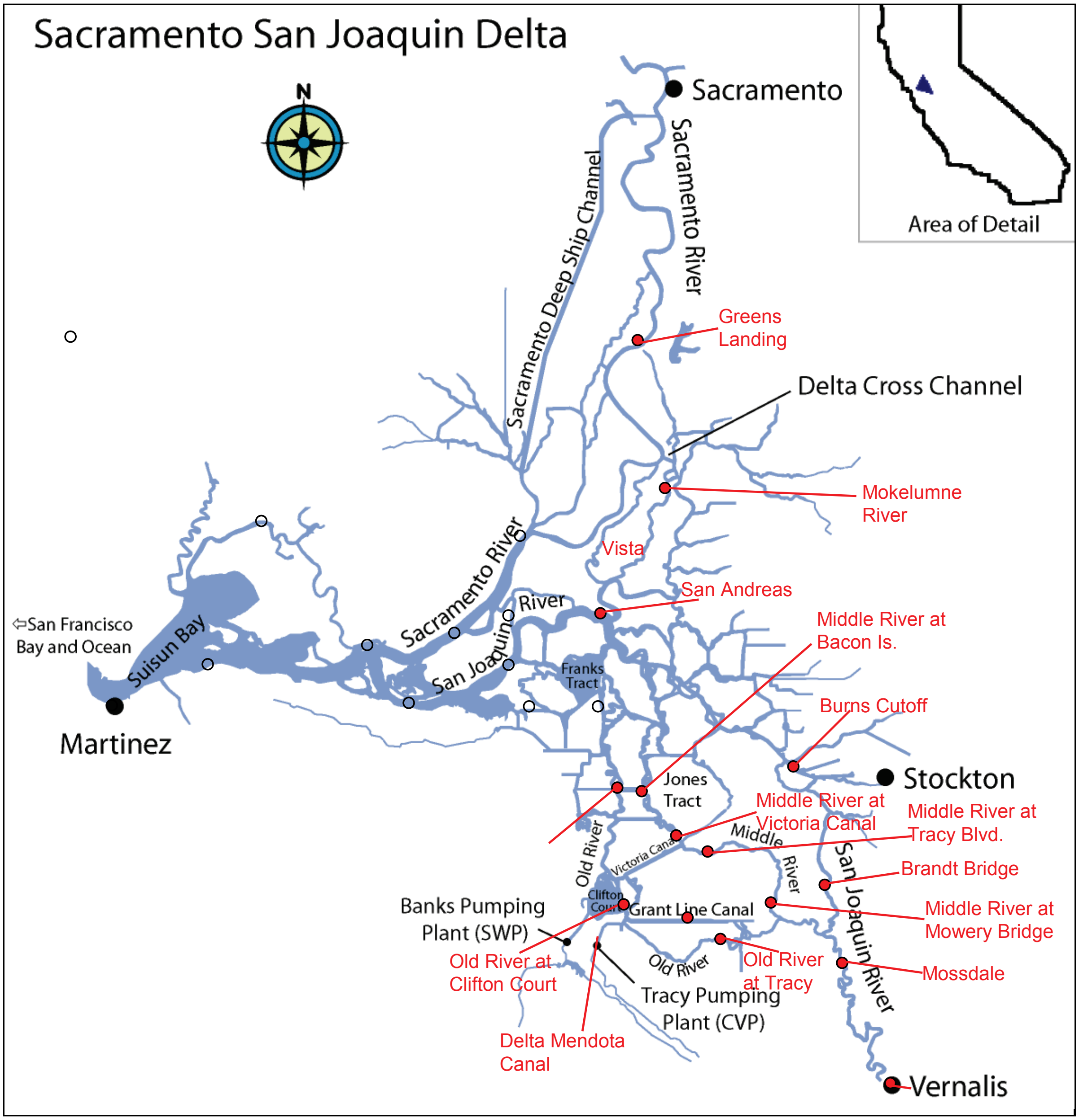


FIGURE 6-1
Map Showing EC Calibration Locations

Sacramento River at Collinsville (RSAC081)

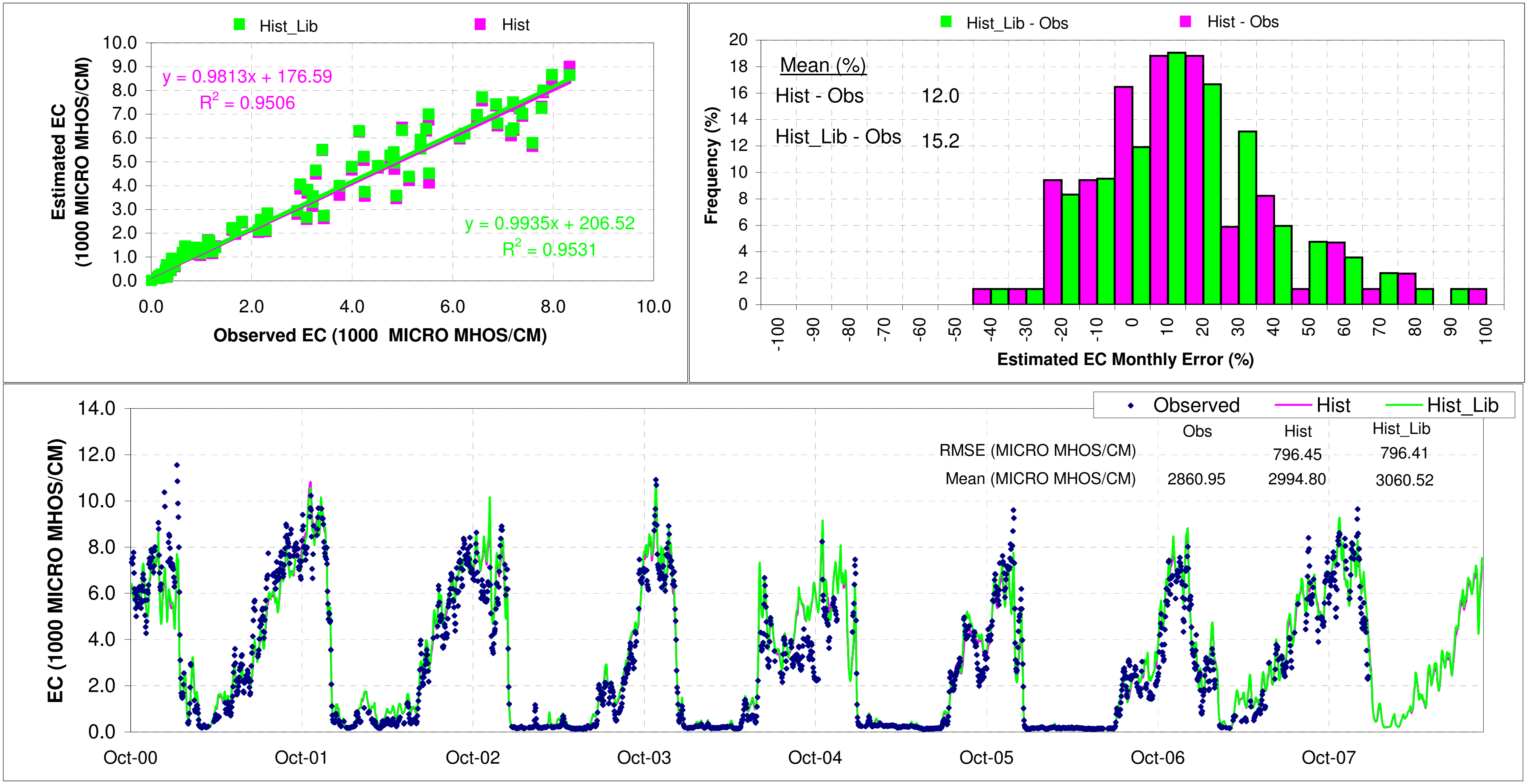
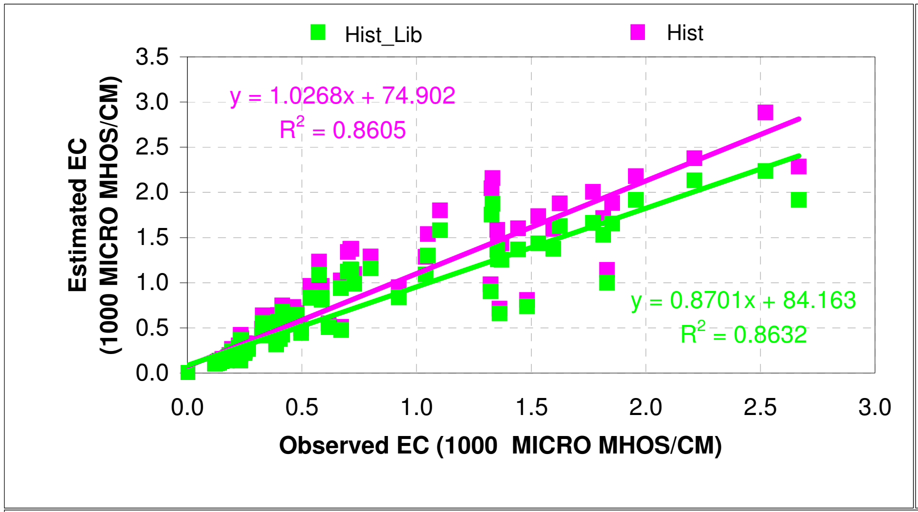
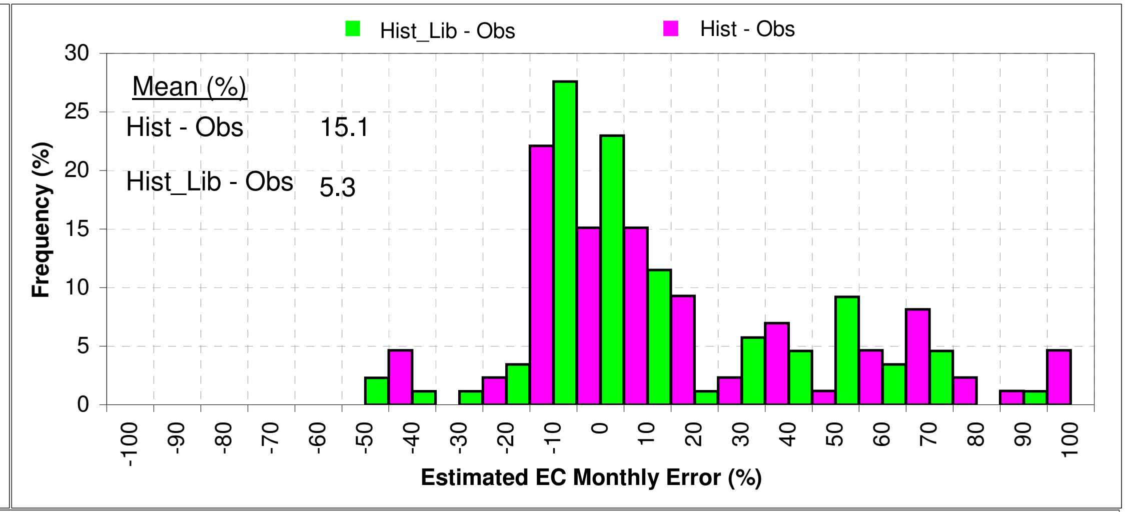


FIGURE 6-2
EC Calibration Metrics for Sacramento River at Collinsville

Sacramento River at Emmaton (RSAC092)





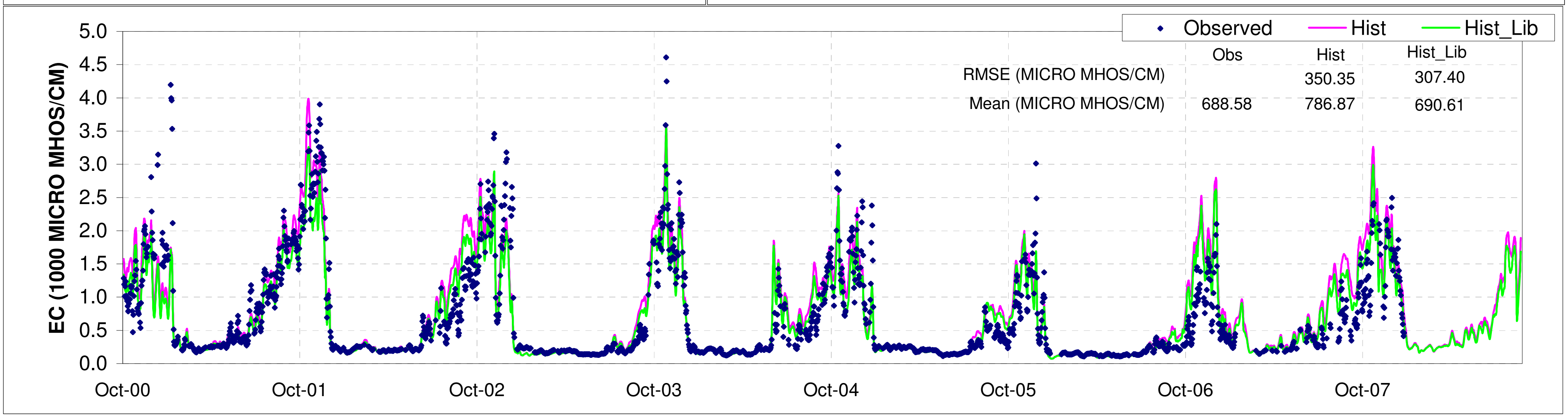


FIGURE 6-3
EC Calibration Metrics for Sacramento River at Emmaton

Sacramento River at Rio Vista (RSAC101)

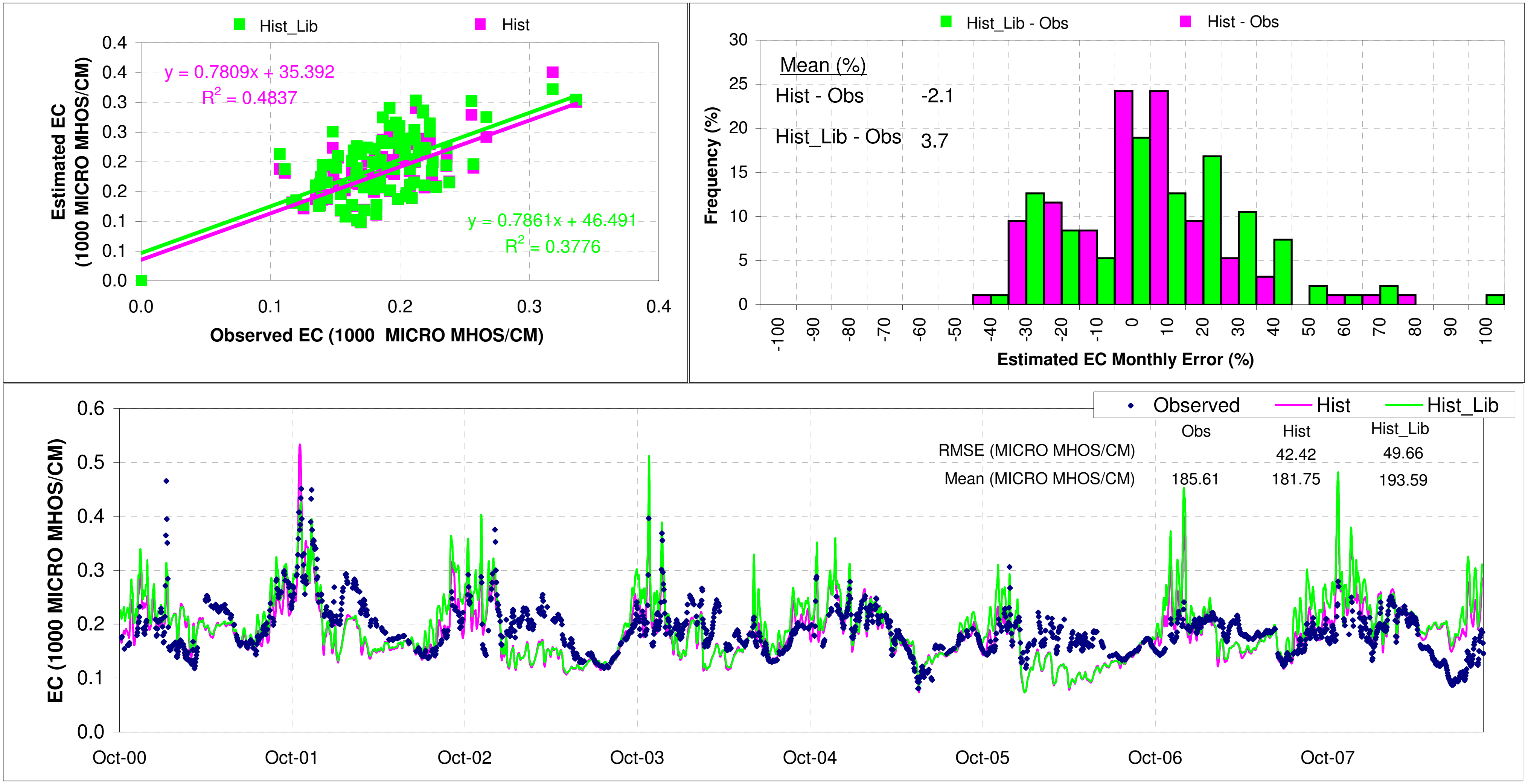


FIGURE 6-4
EC Calibration Metrics for Sacramento River at Rio Vista

San Joaquin River at Jersey Point (RSAN018)

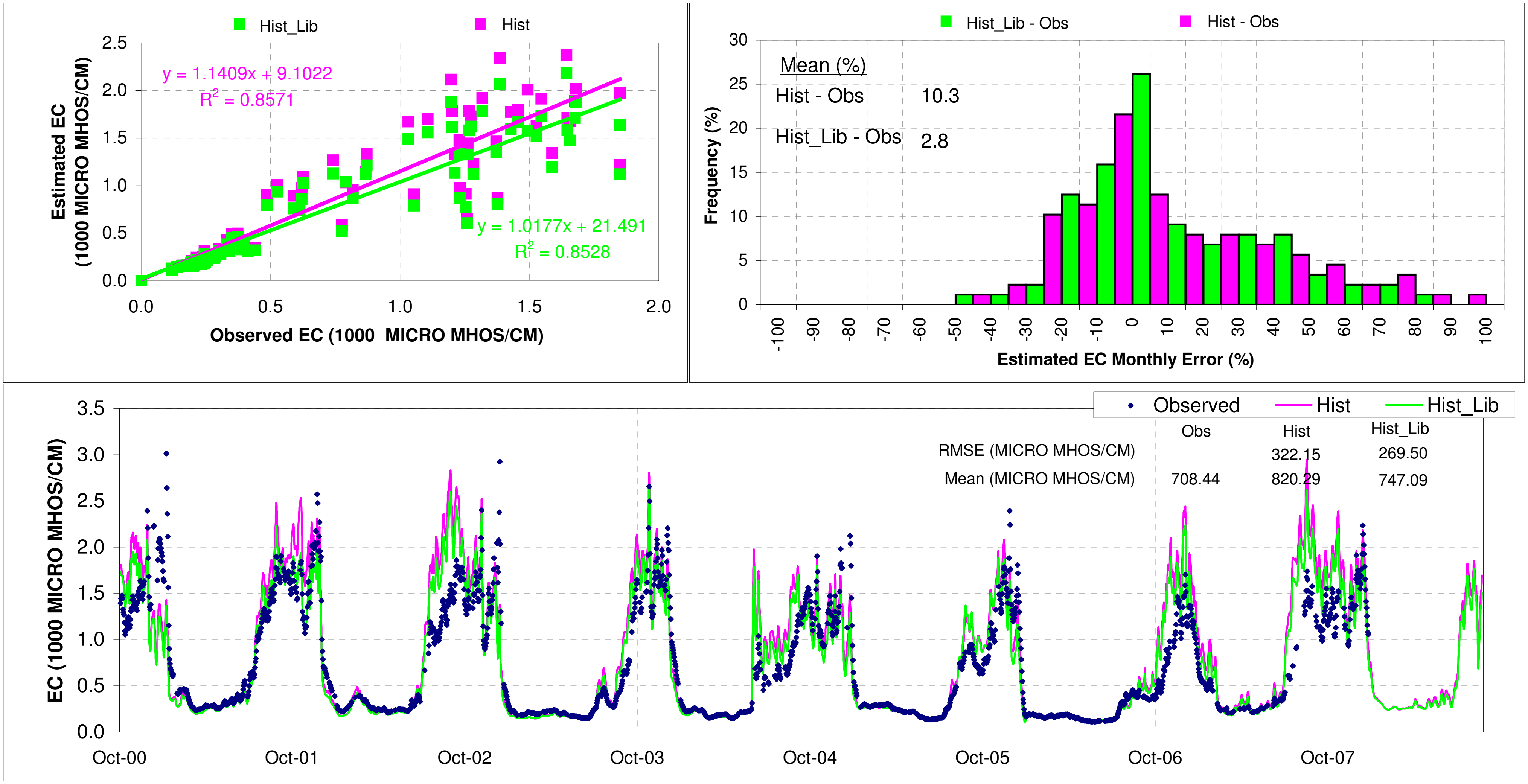


FIGURE 6-5
EC Calibration Metrics for San Joaquin River at Jersey Point

Old River at Bacon Island (ROLD024)

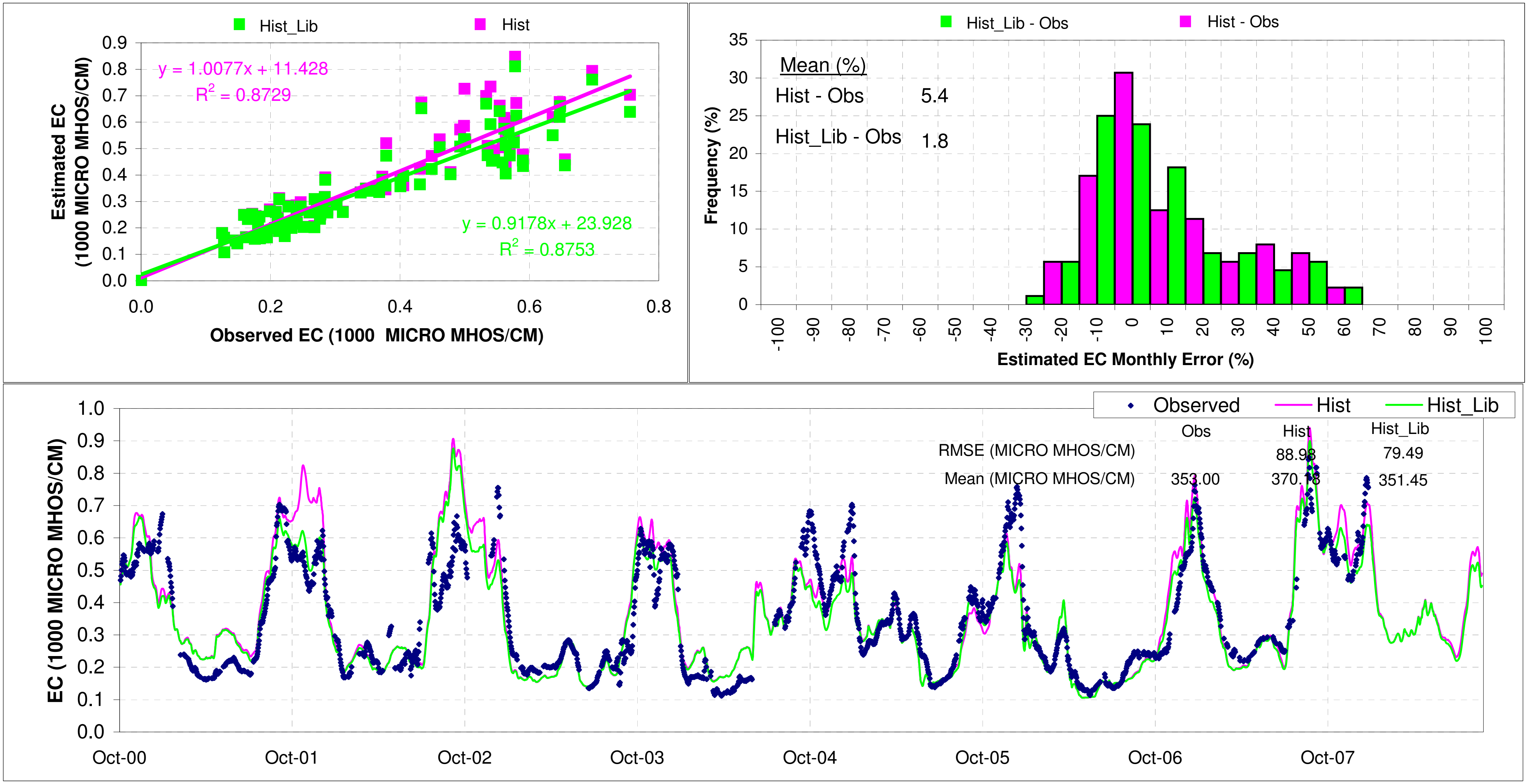


FIGURE 6-6
EC Calibration Metrics for Old River at Rock Slough (Bacon Island)

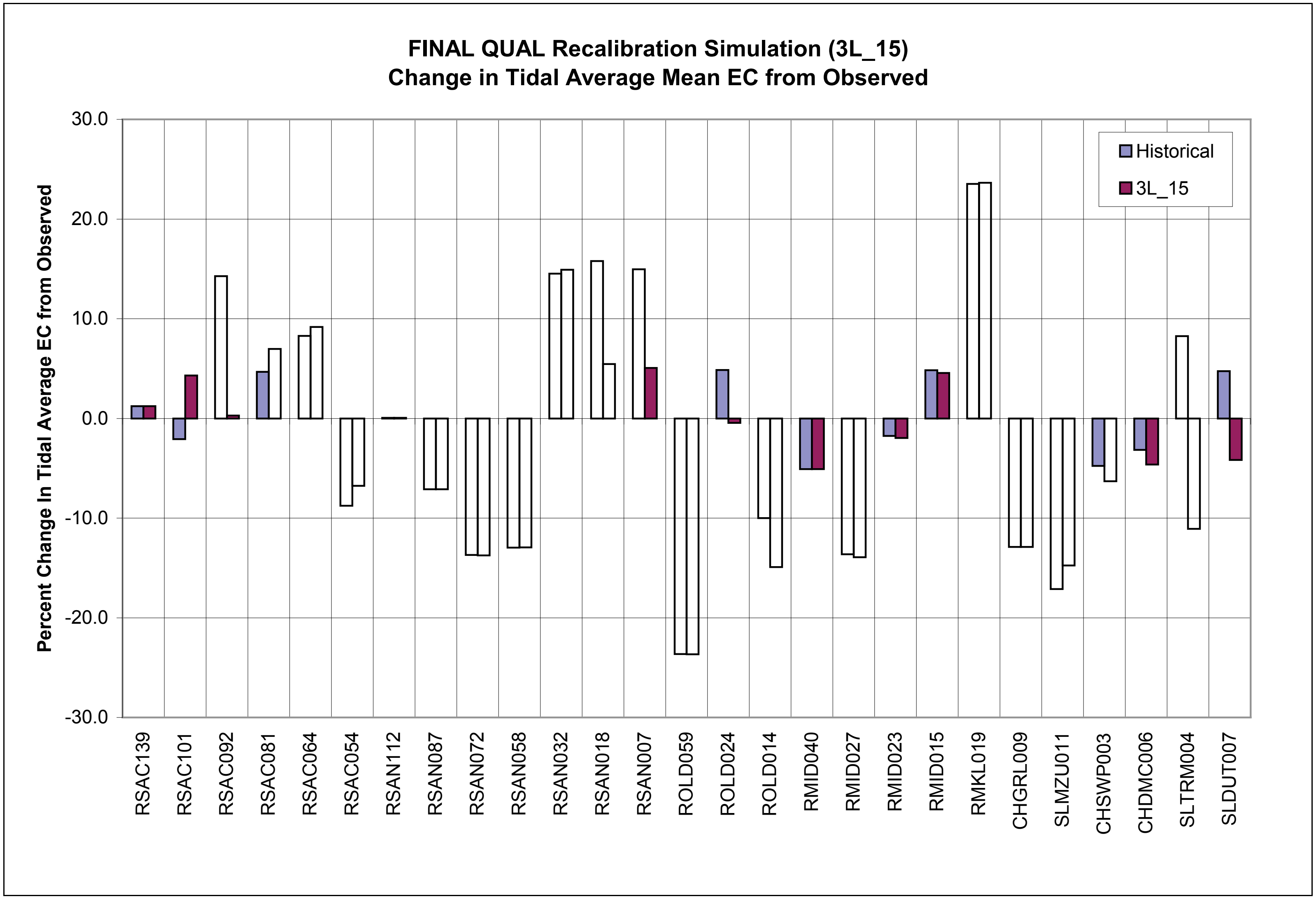


FIGURE 6-7
Comparison of Average Percent Difference in Predicted EC for 2000 Calibration Model and 2009 Recalibrated Model (Run 3L_15)

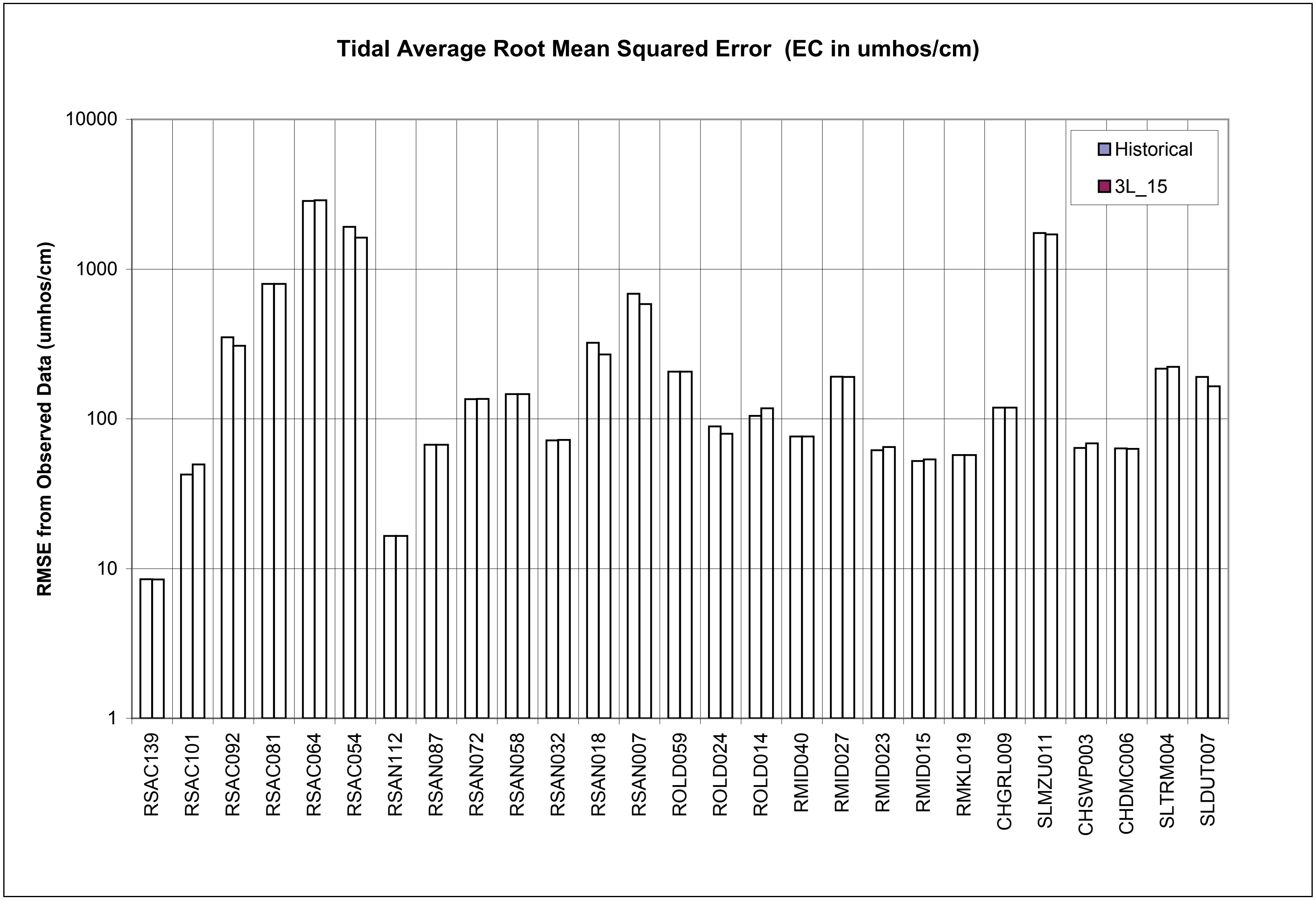


FIGURE 6-8
Comparison of RMS Error in Predicted EC for 2000 Calibration and 2009 Recalibration

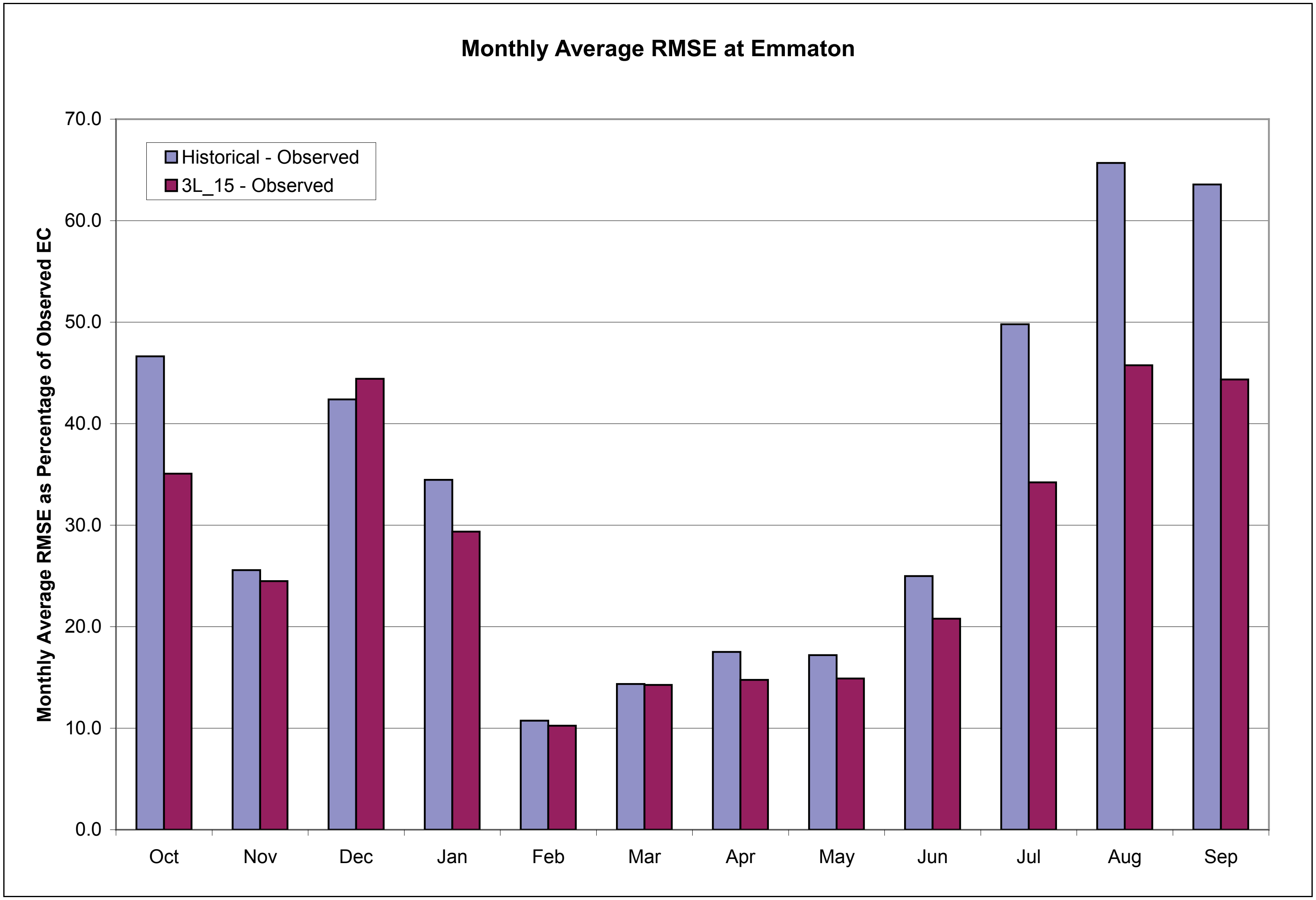


FIGURE 6-9
Monthly Average RMS Errors at Emmaton

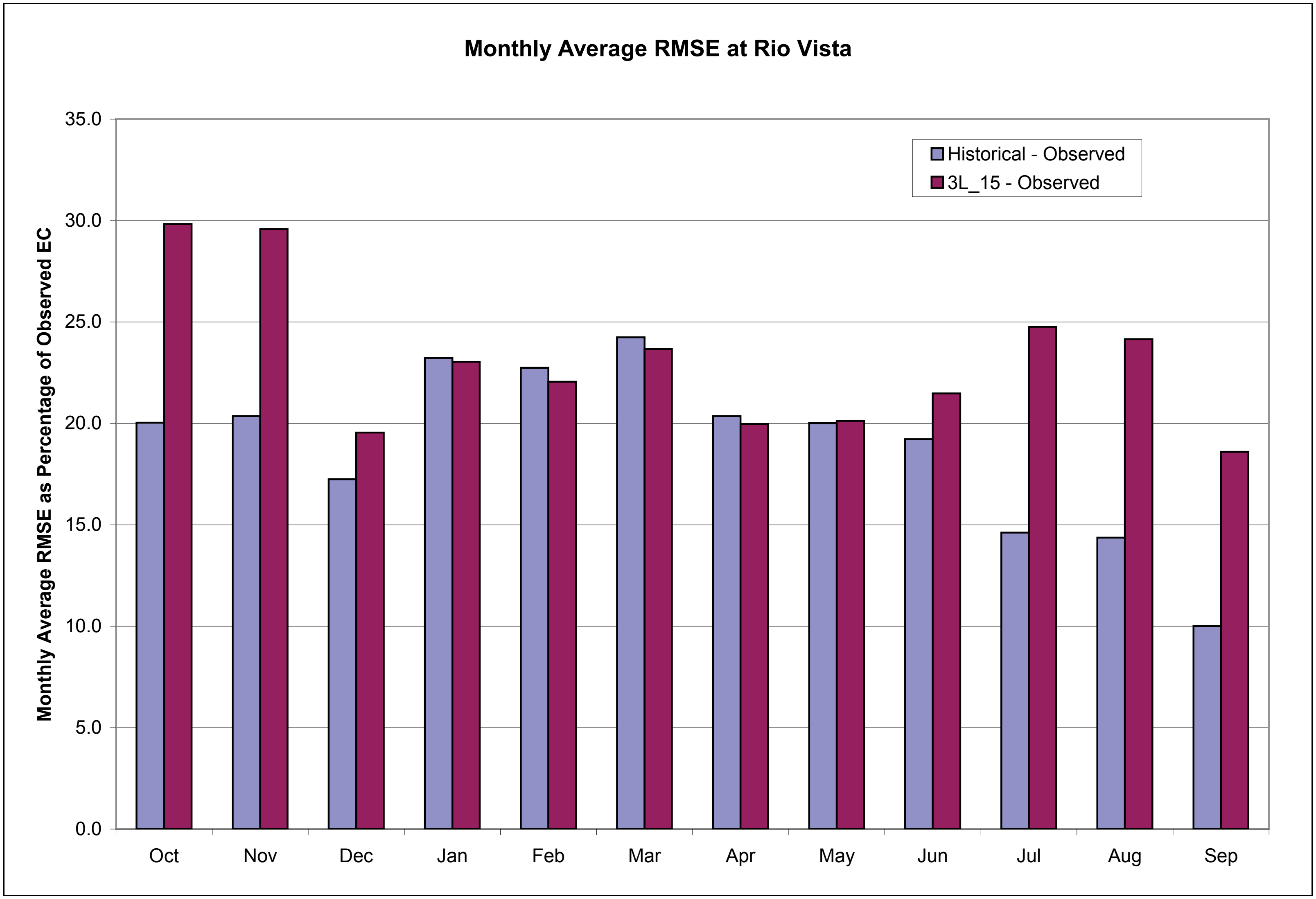


FIGURE 6-10
Monthly Average RMS Errors at Rio Vista

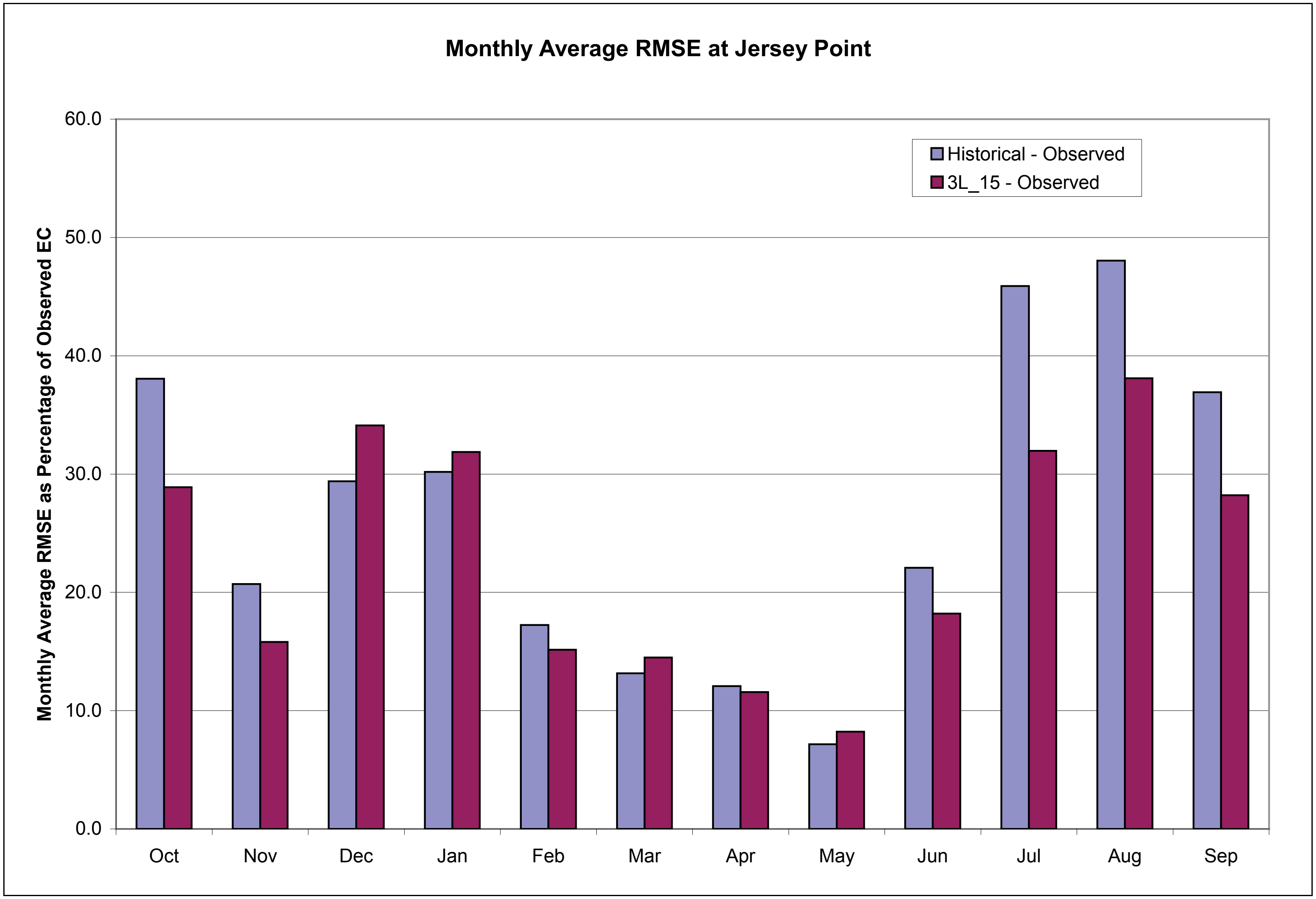


FIGURE 6-11
Monthly Average RMS Errors at Jersey Point

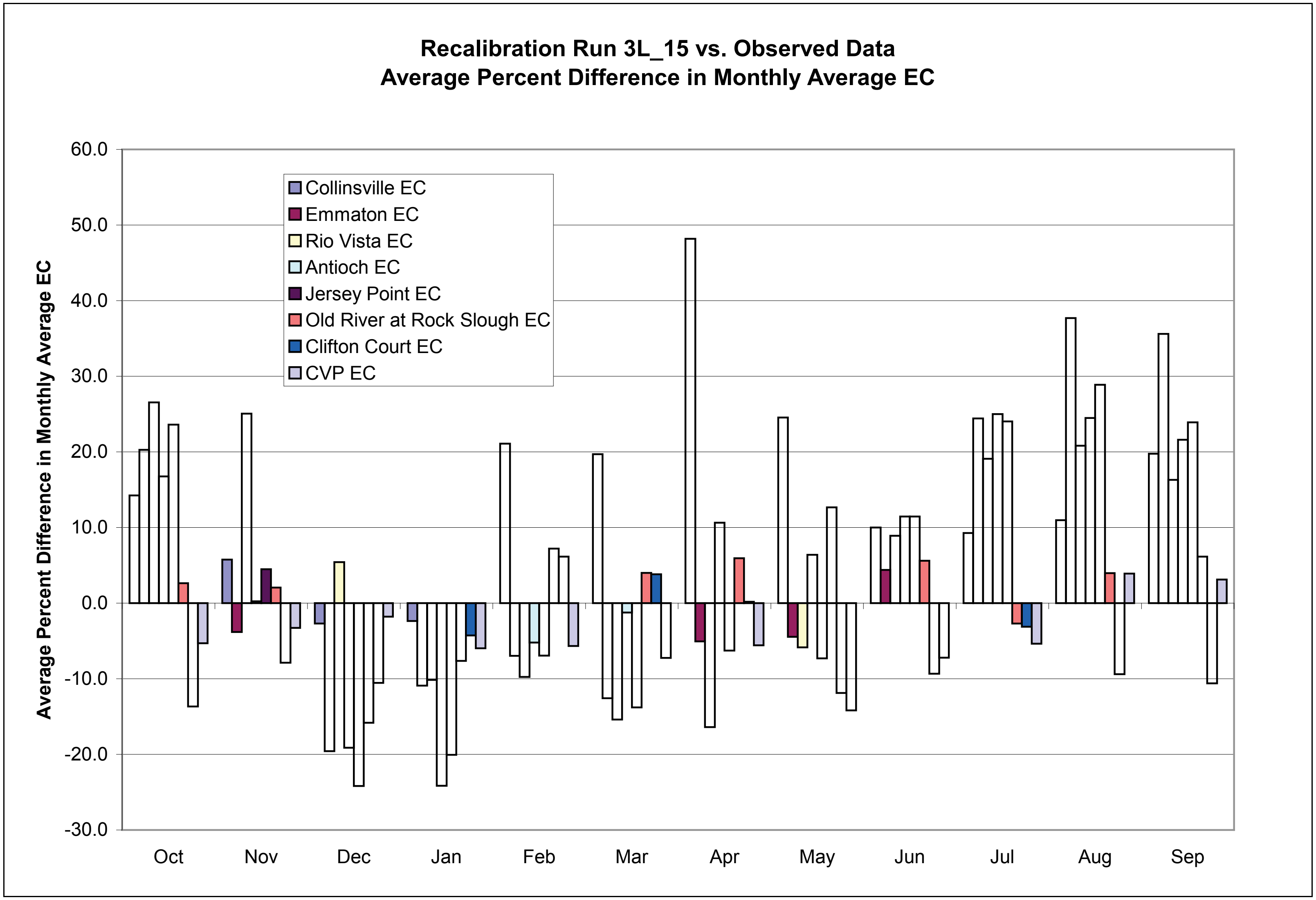


FIGURE 6-12
Overview of Monthly Model Performance – Recalibration

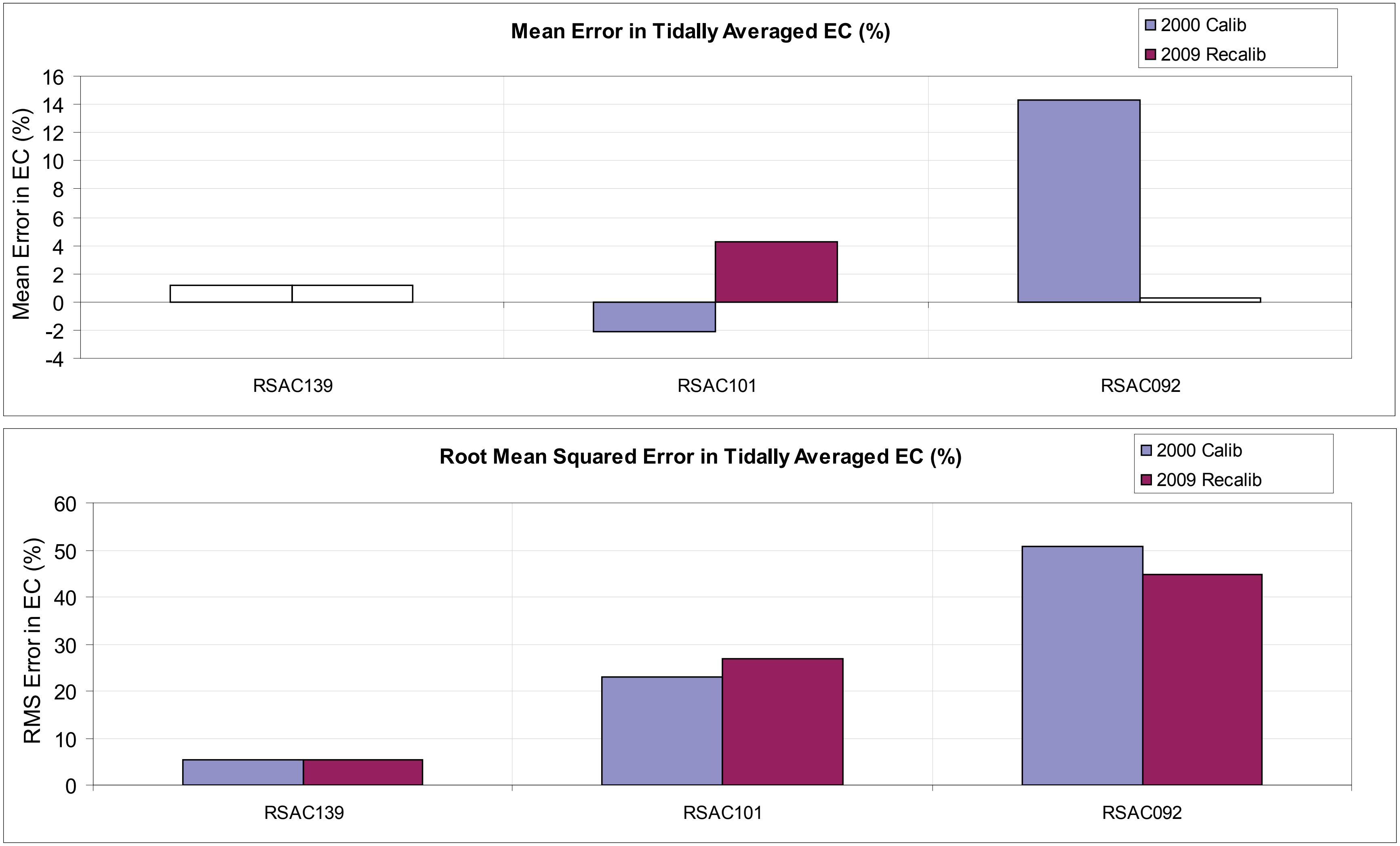
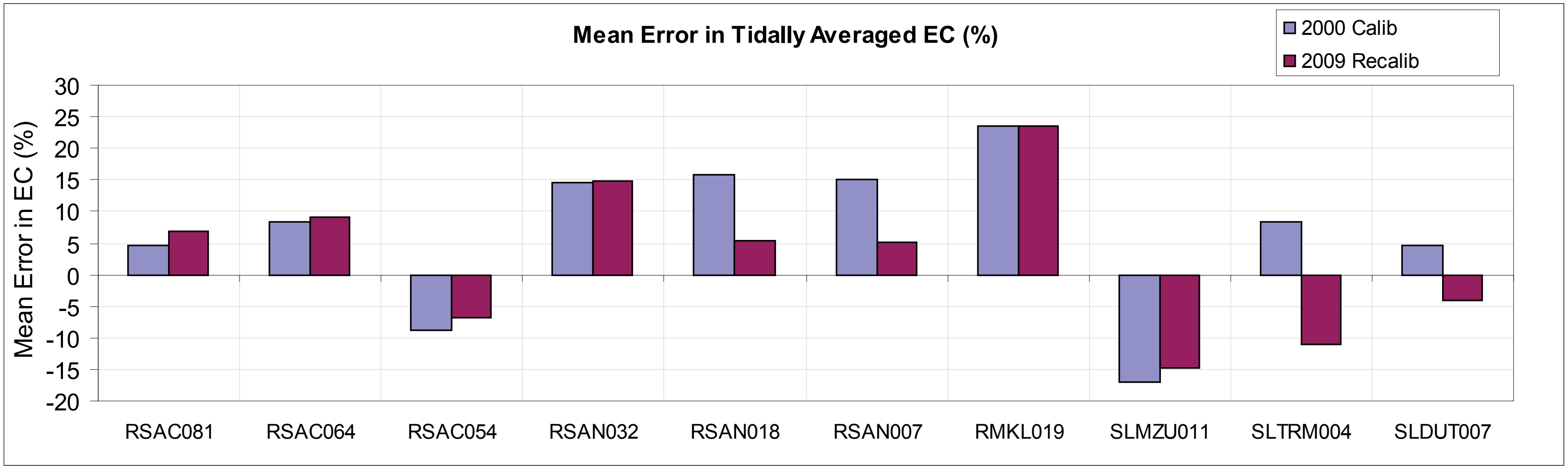


FIGURE 6-13
Summary of EC Calibration Metrics for Locations in the North Delta Region



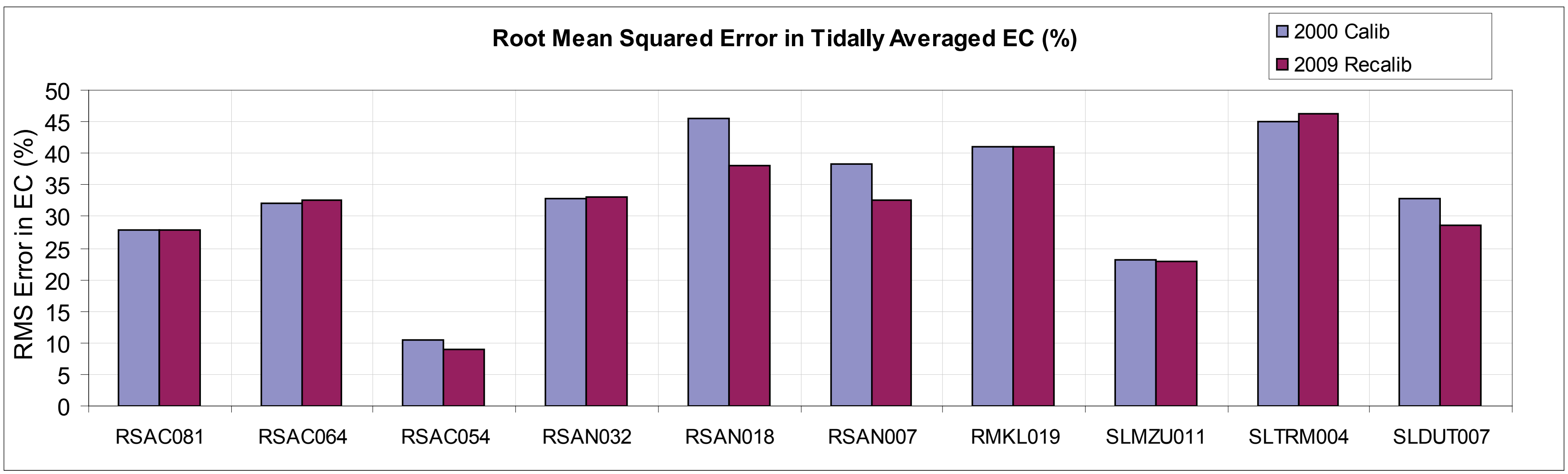
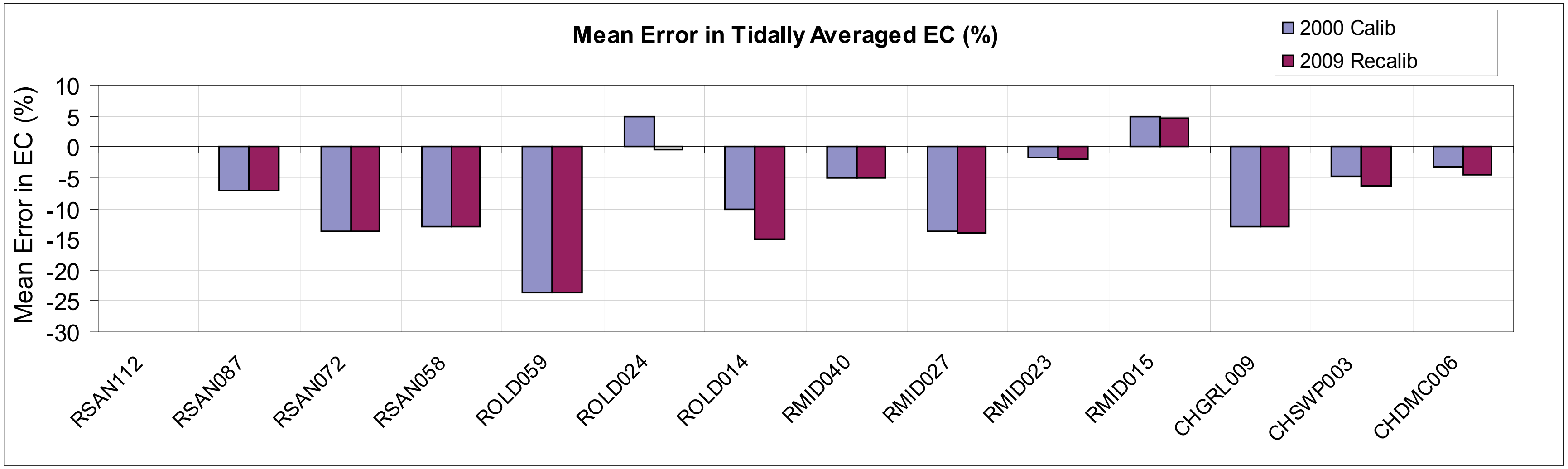


FIGURE 6-14
Summary of EC Calibration Metrics for Locations in the Western and Central Delta Regions



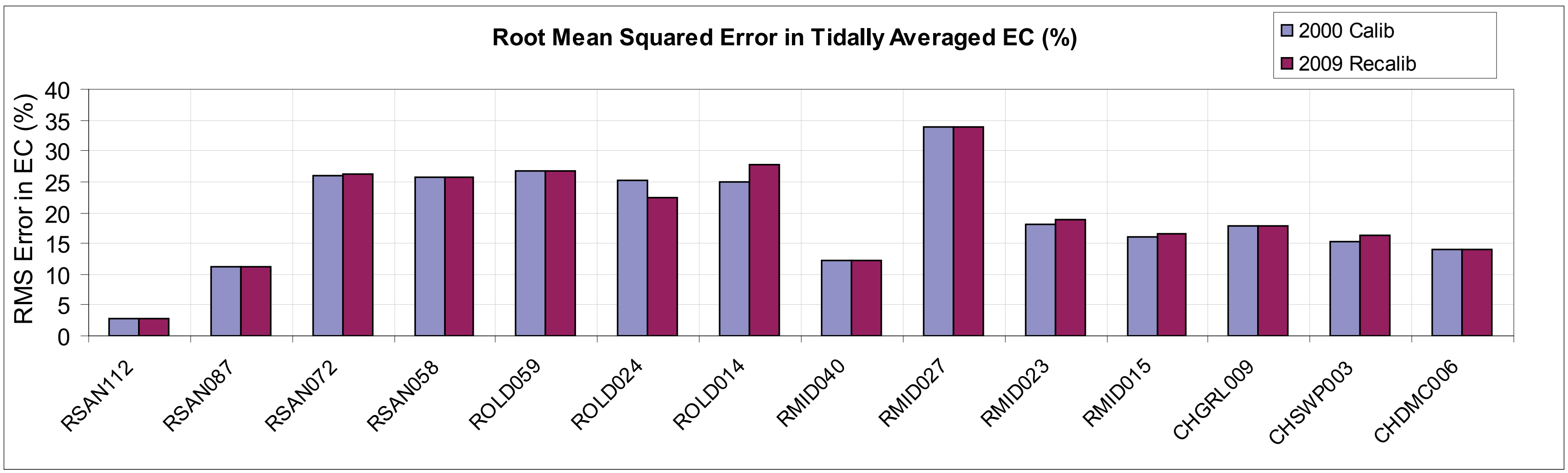


FIGURE 6-15
Summary of EC Calibration Metrics for Locations in the South Delta Region

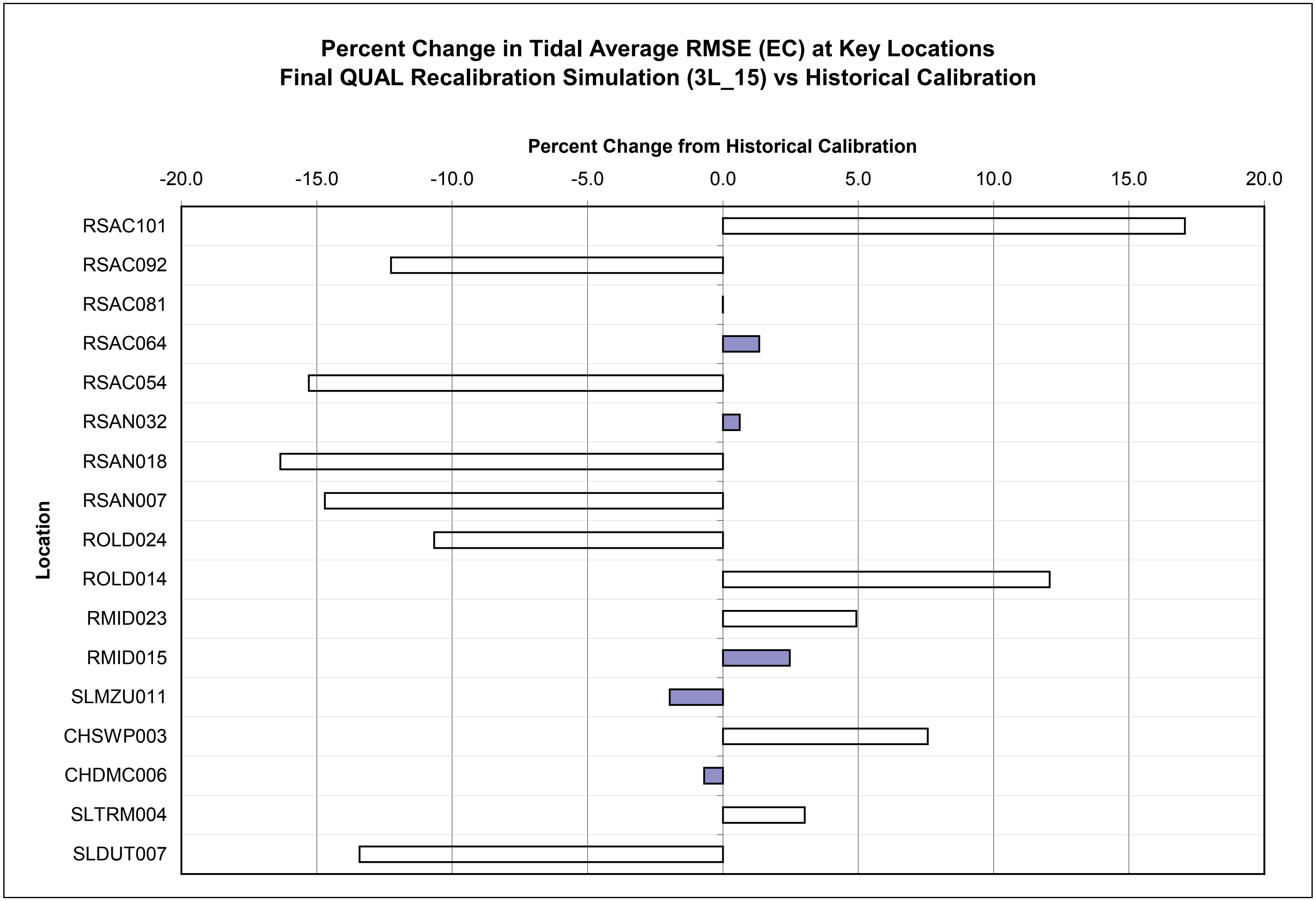


FIGURE 6-16
Percent Change in RMS Error (EC) between Recalibrated Model and 2000 Calibration

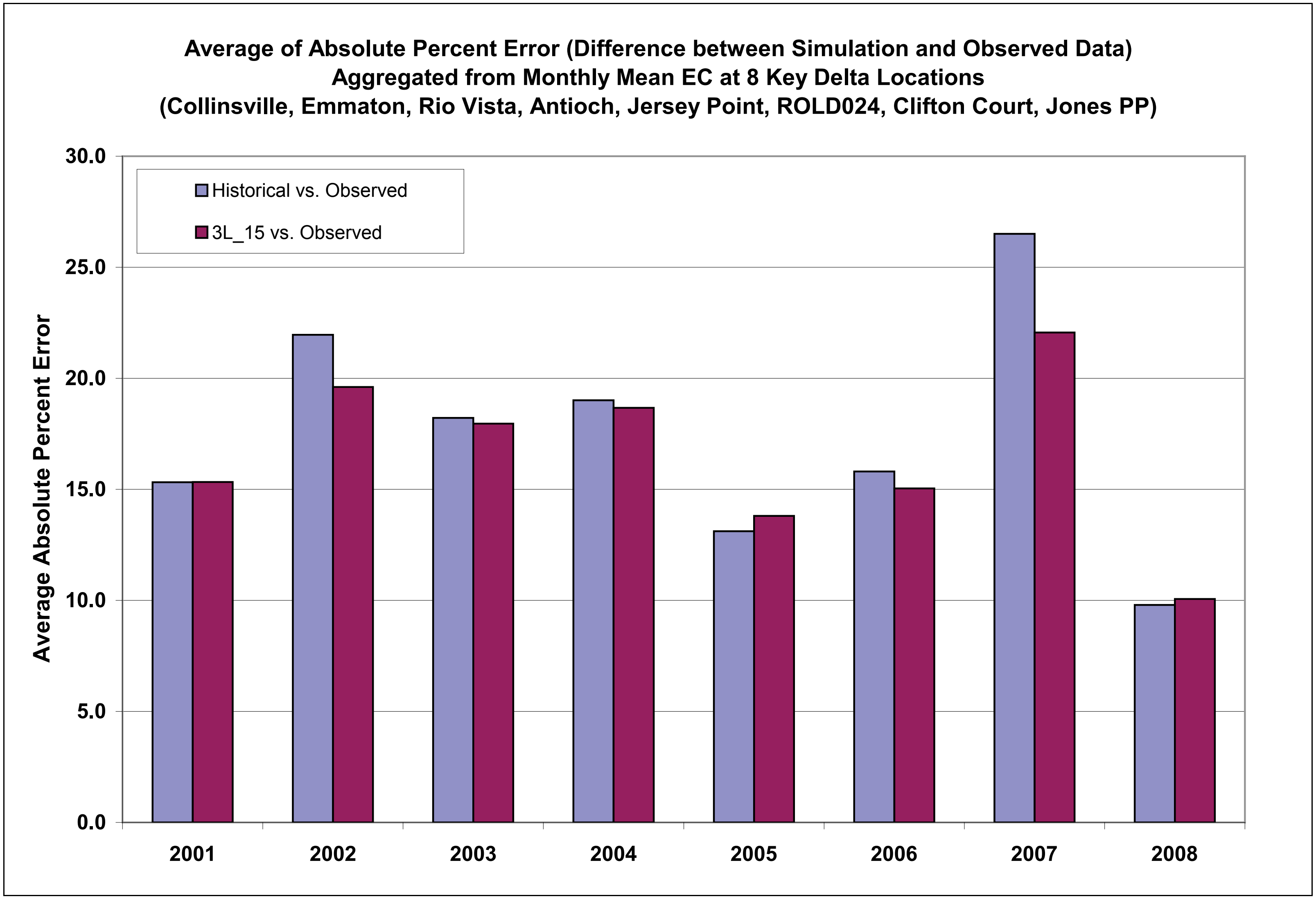


FIGURE 6-17
Model Performance by Water Year

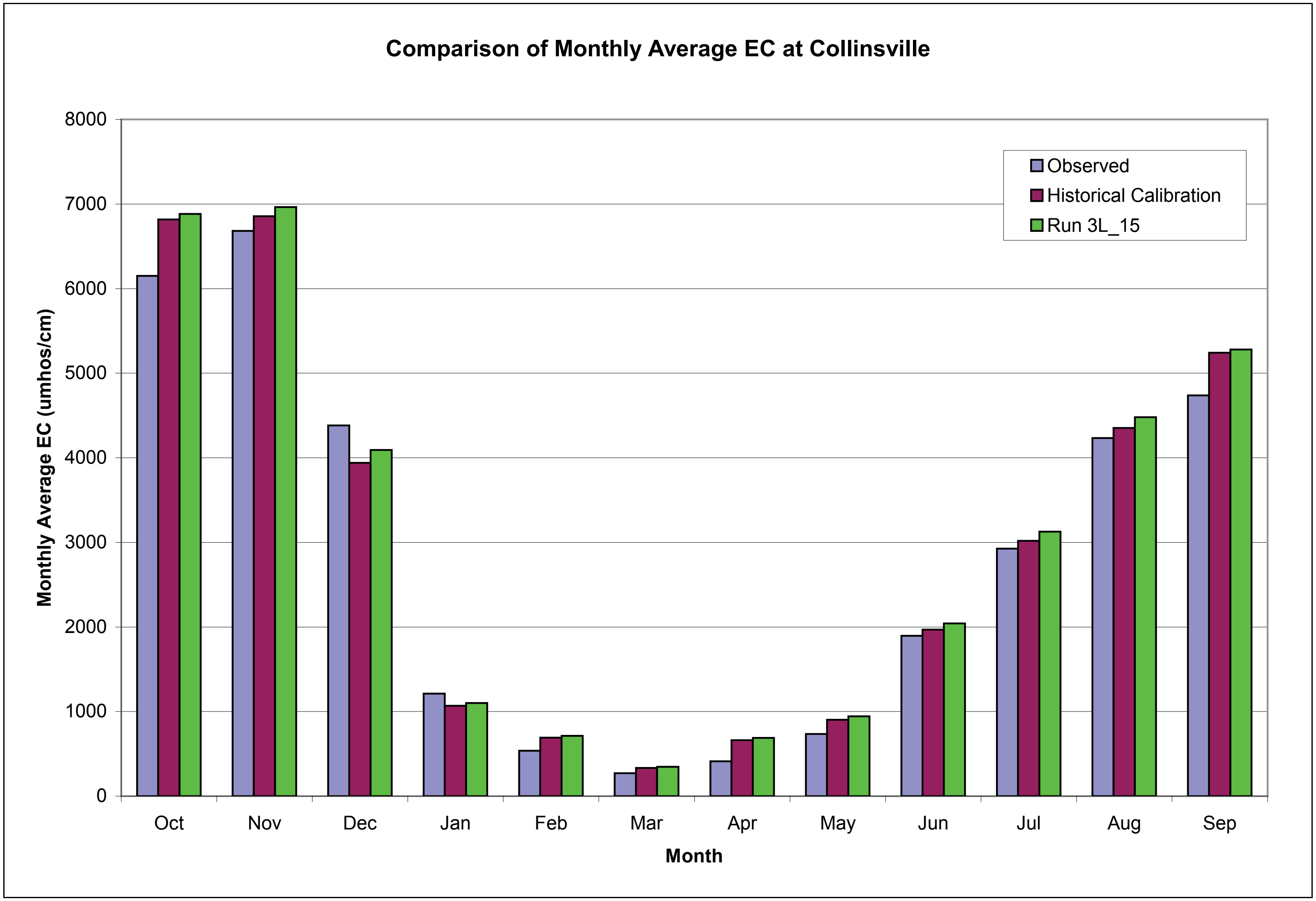


FIGURE 6-18
Monthly Average EC at Collinsville

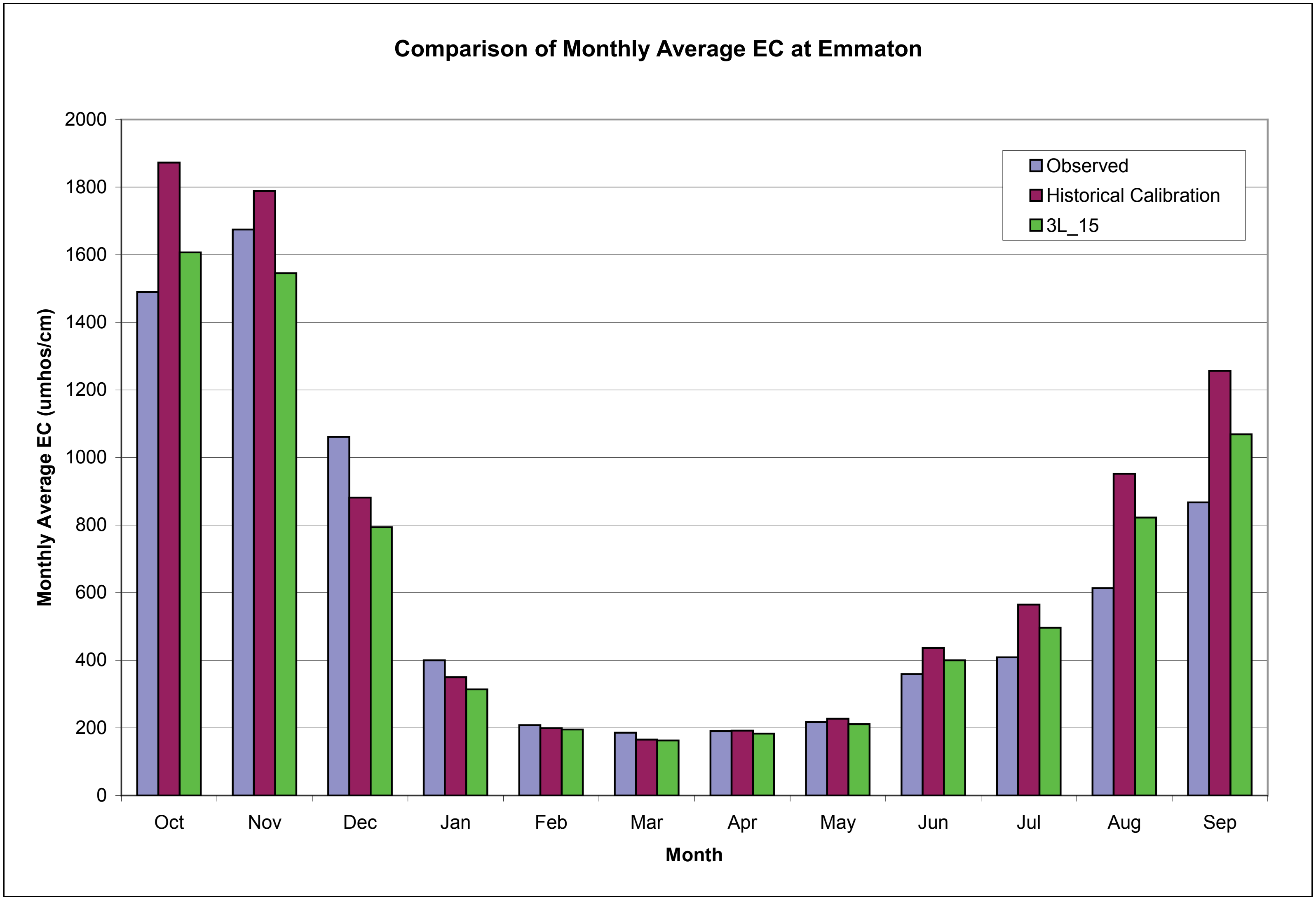


FIGURE 6-19
Monthly Average EC at Emmaton

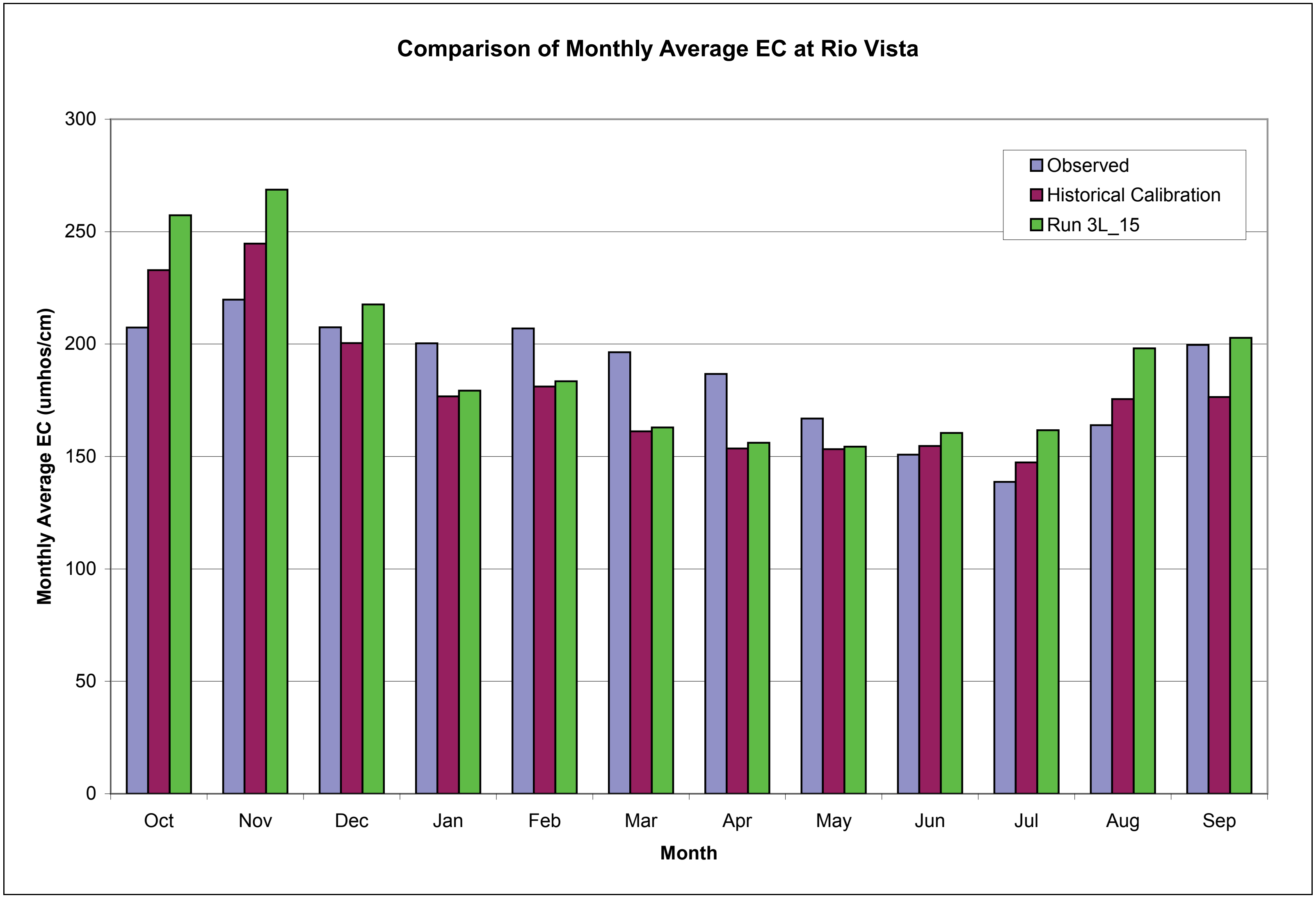


FIGURE 6-20
Monthly Average EC at Rio Vista

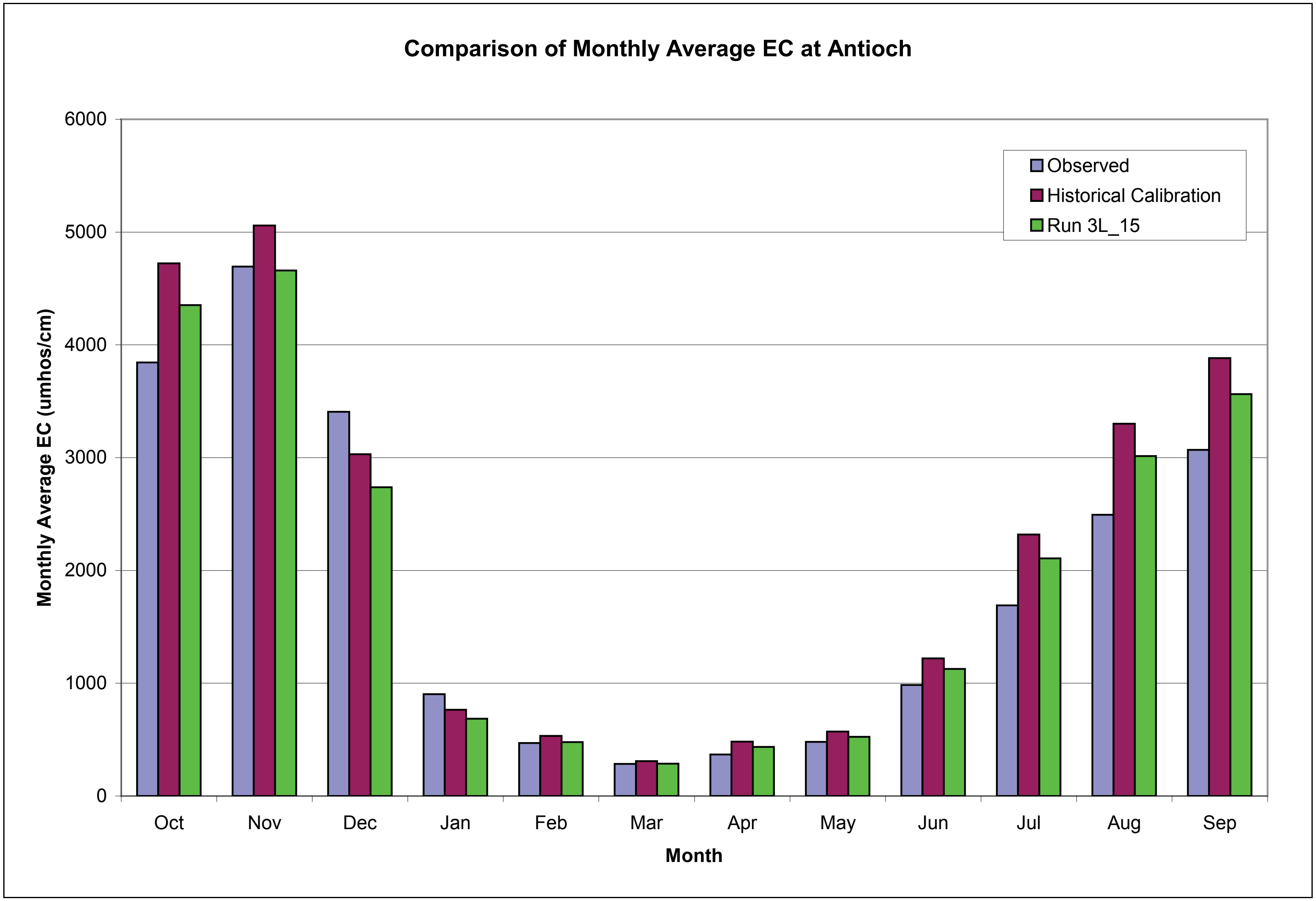


FIGURE 6-21
Monthly Average EC at Antioch

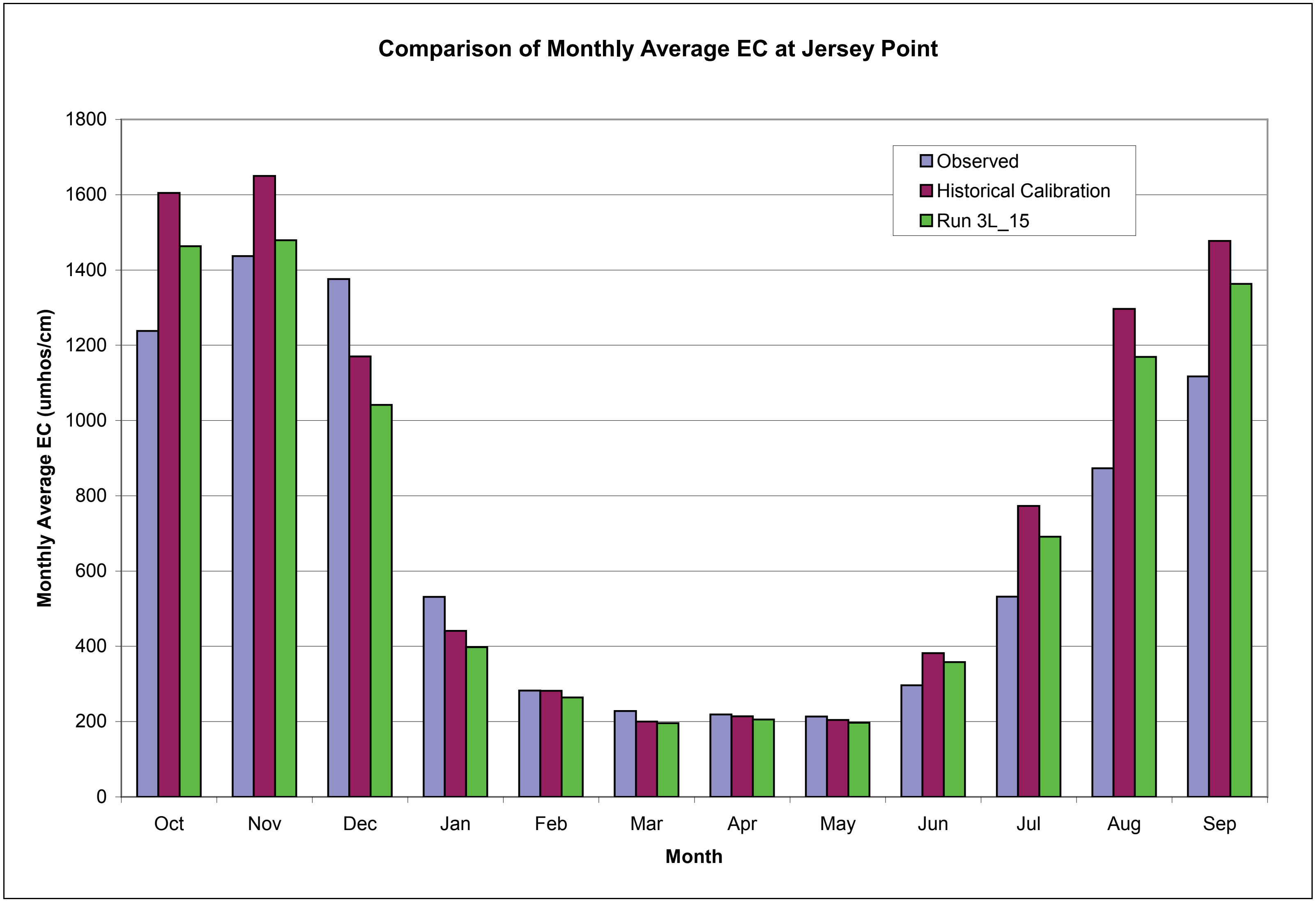


FIGURE 6-22
Monthly Average EC at Jersey Point

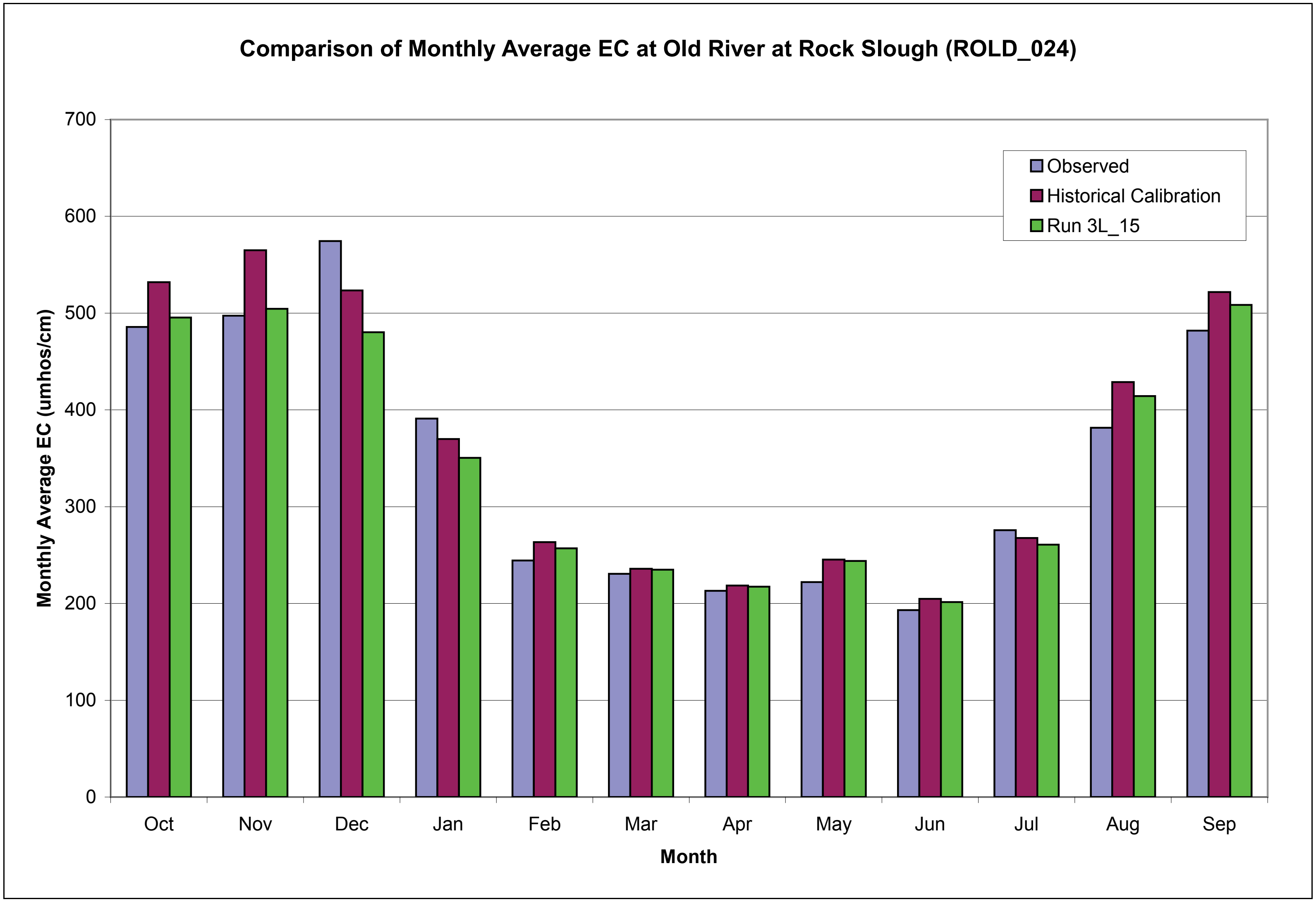


FIGURE 6-23
Monthly Average EC at Old River (ROLD024)

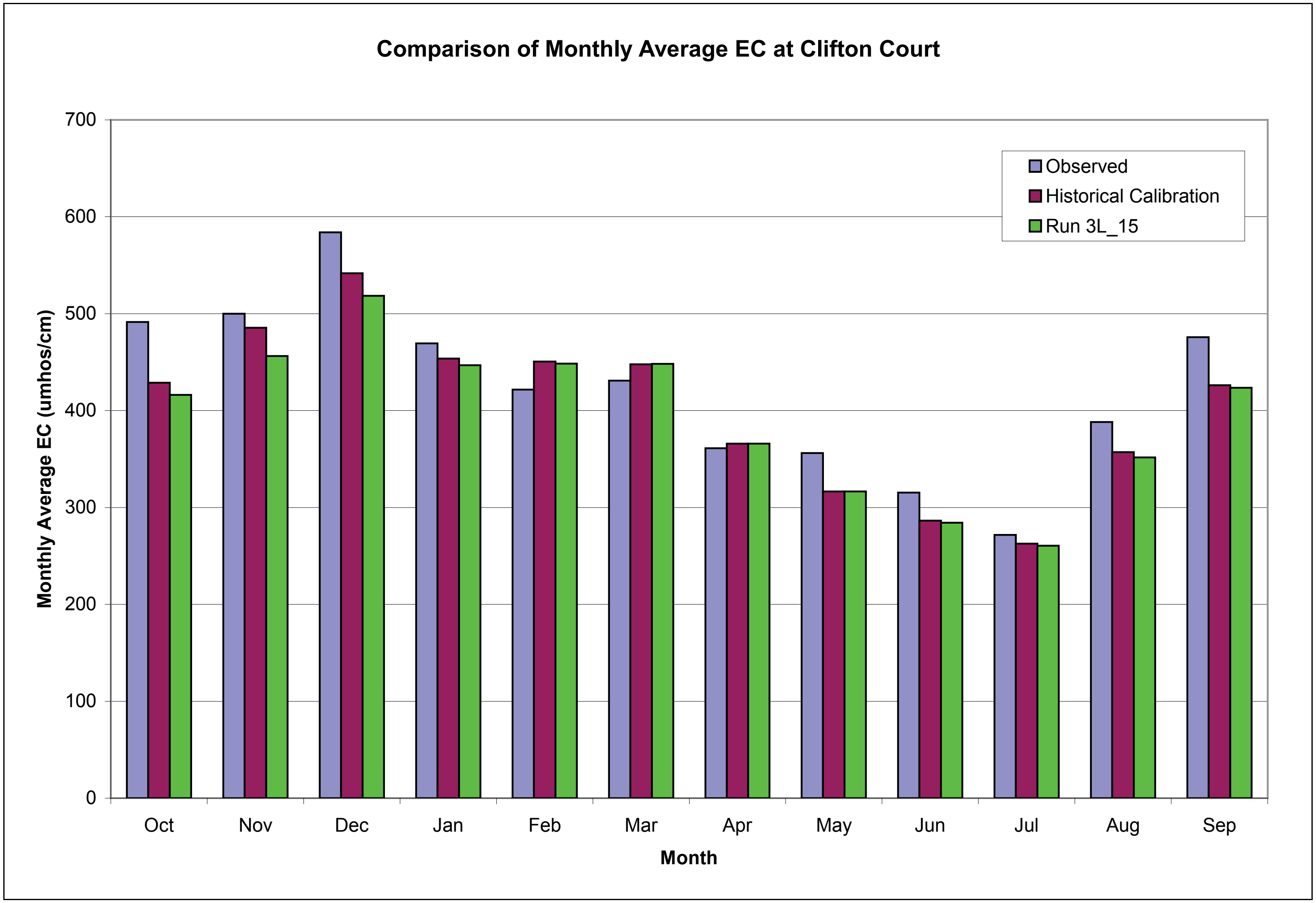


FIGURE 6-24
Monthly Average EC at Old River at Clifton Court

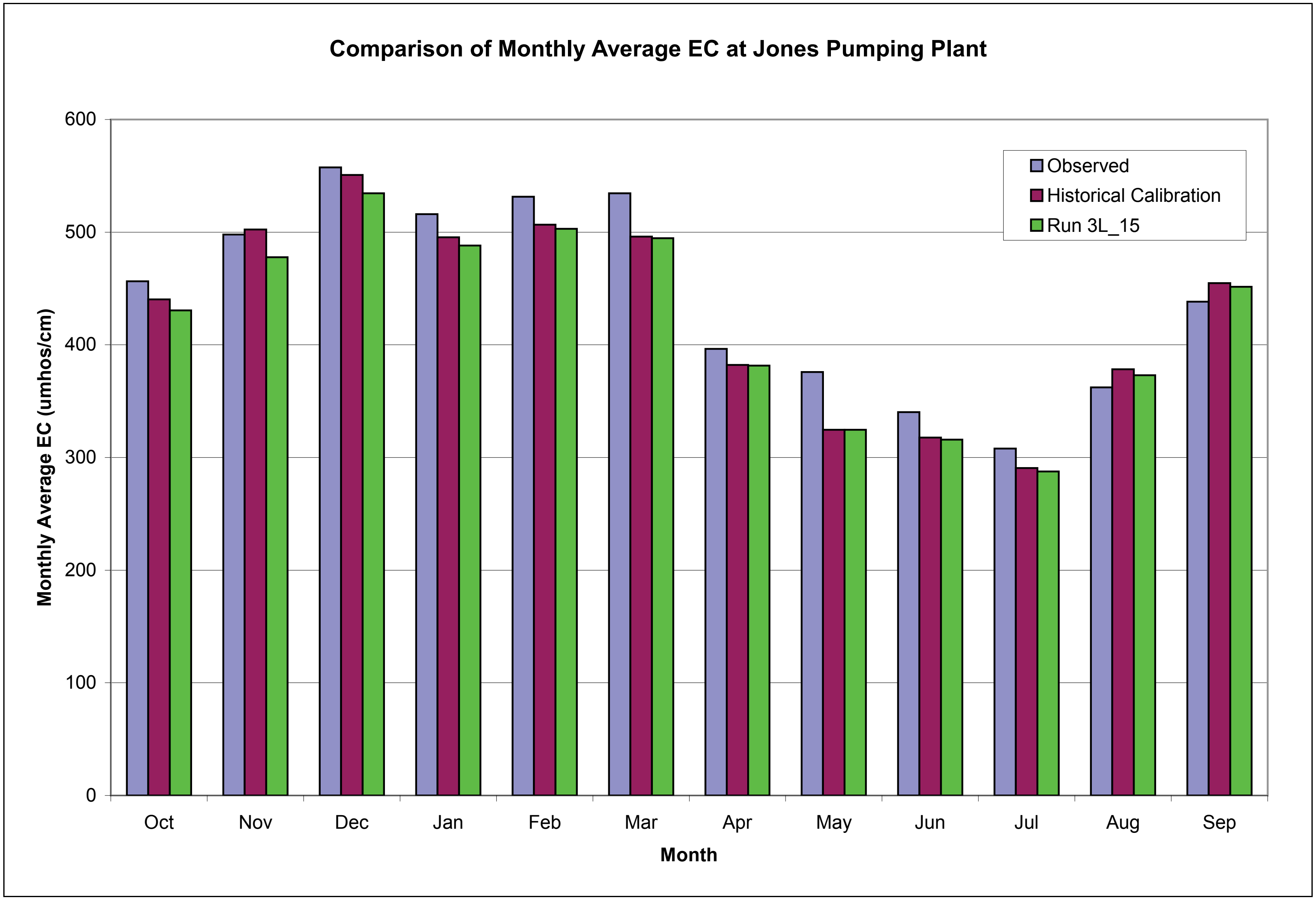


FIGURE 6-25
Monthly Average EC at Jones Pumping Plant

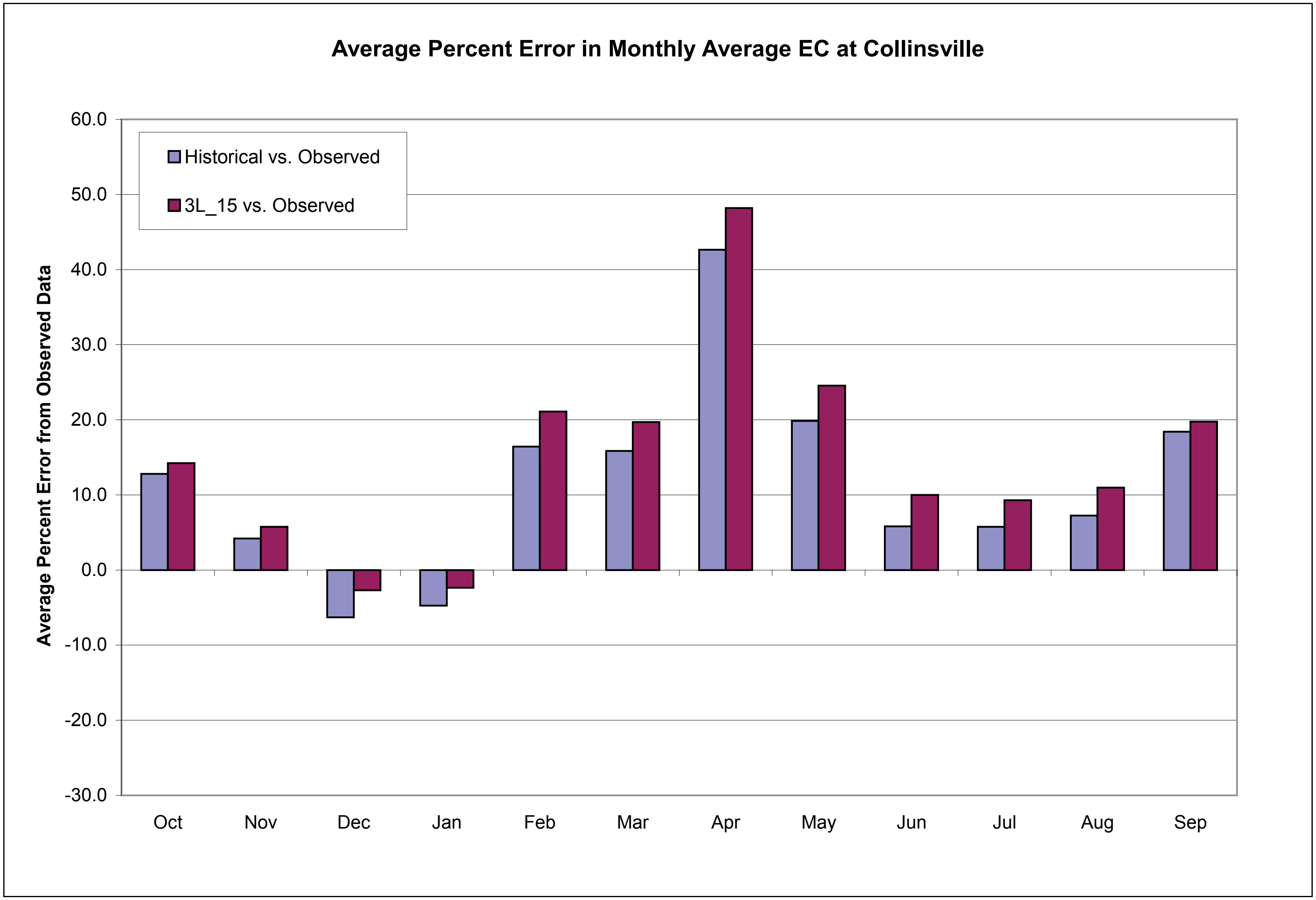


FIGURE 6-26
Monthly Percent Error in Predicted EC at Collinsville

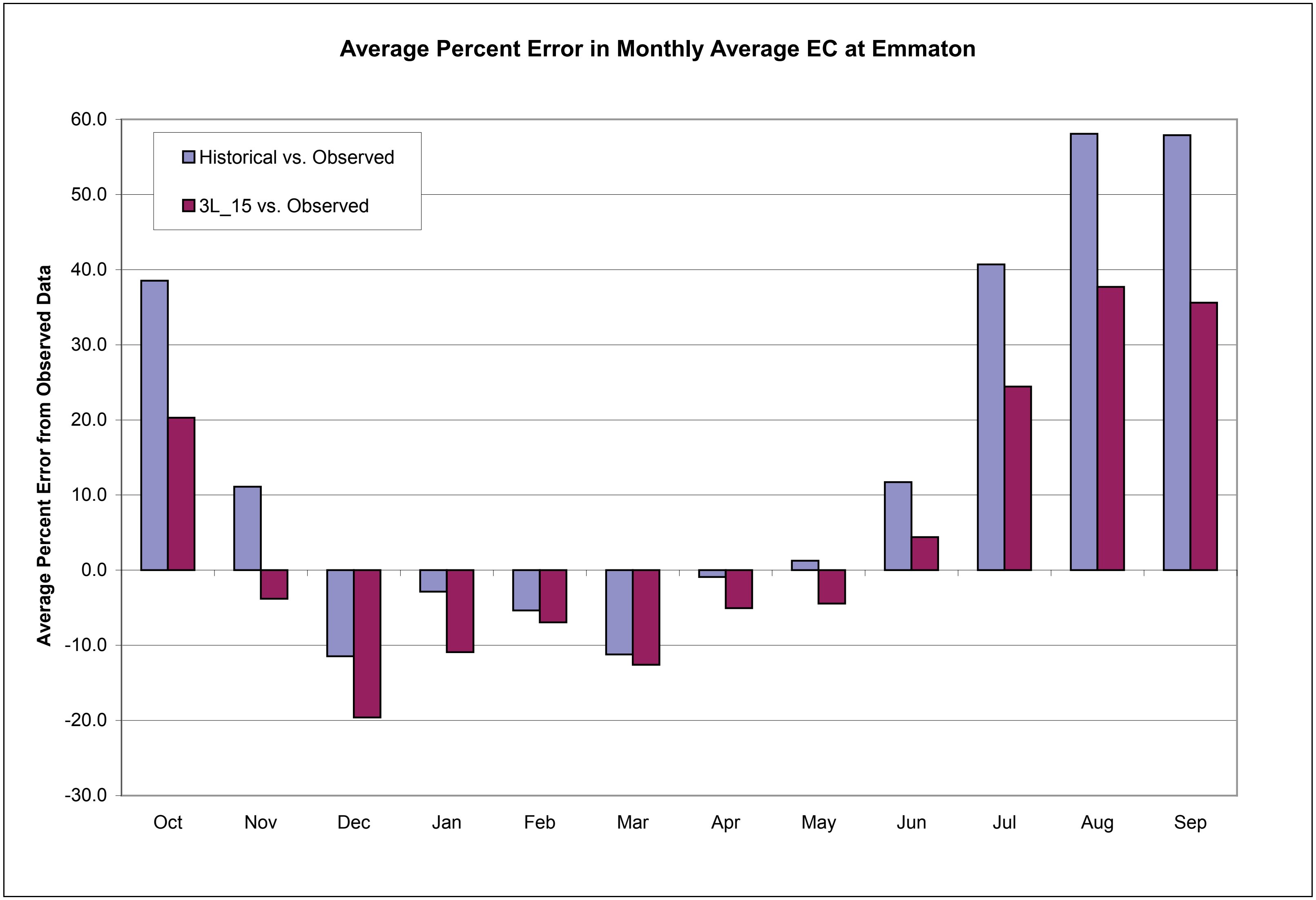


FIGURE 6-27
Monthly Percent Error in Predicted EC at Emmaton

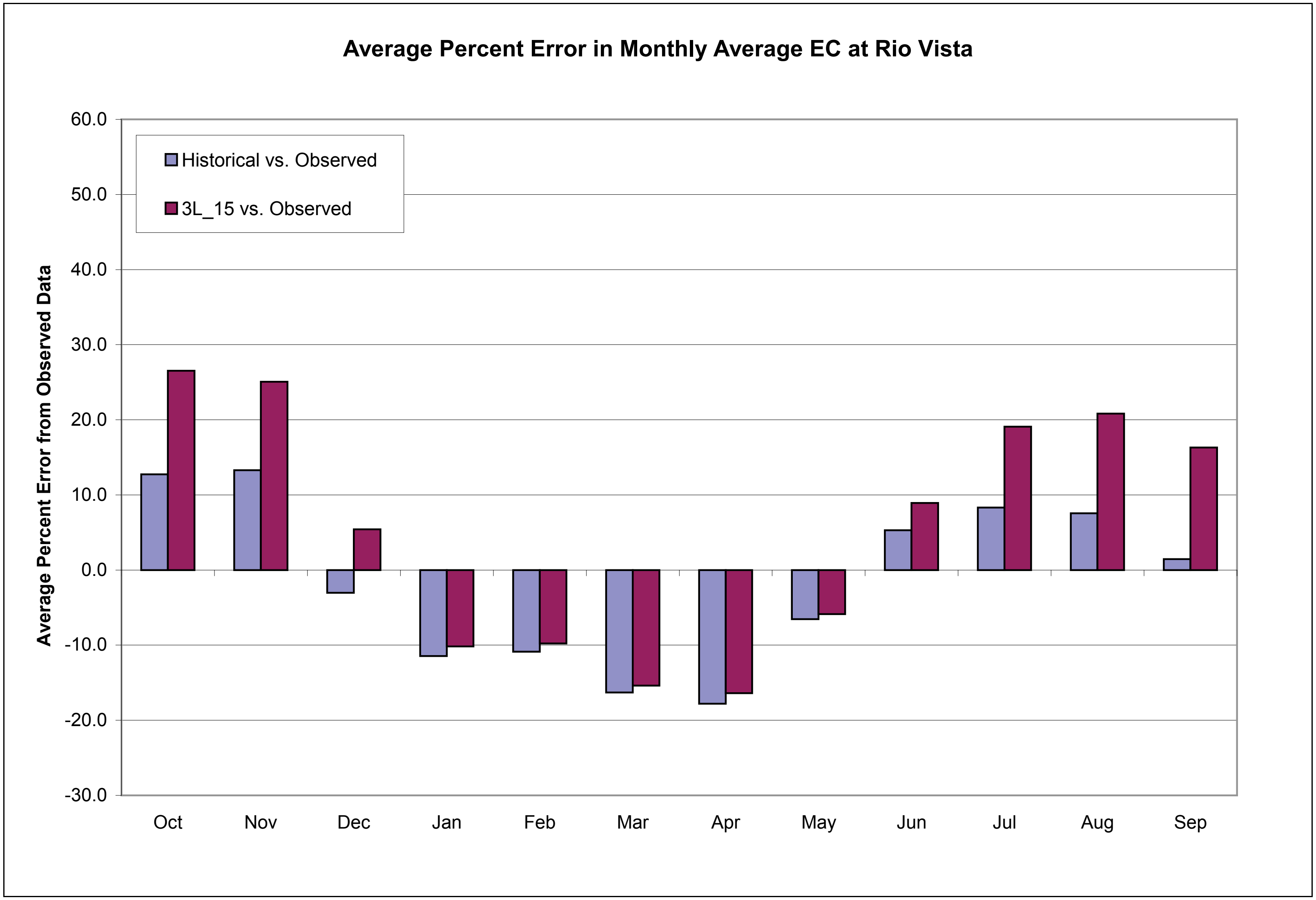


FIGURE 6-28
Monthly Percent Error in Predicted EC at Rio Vista

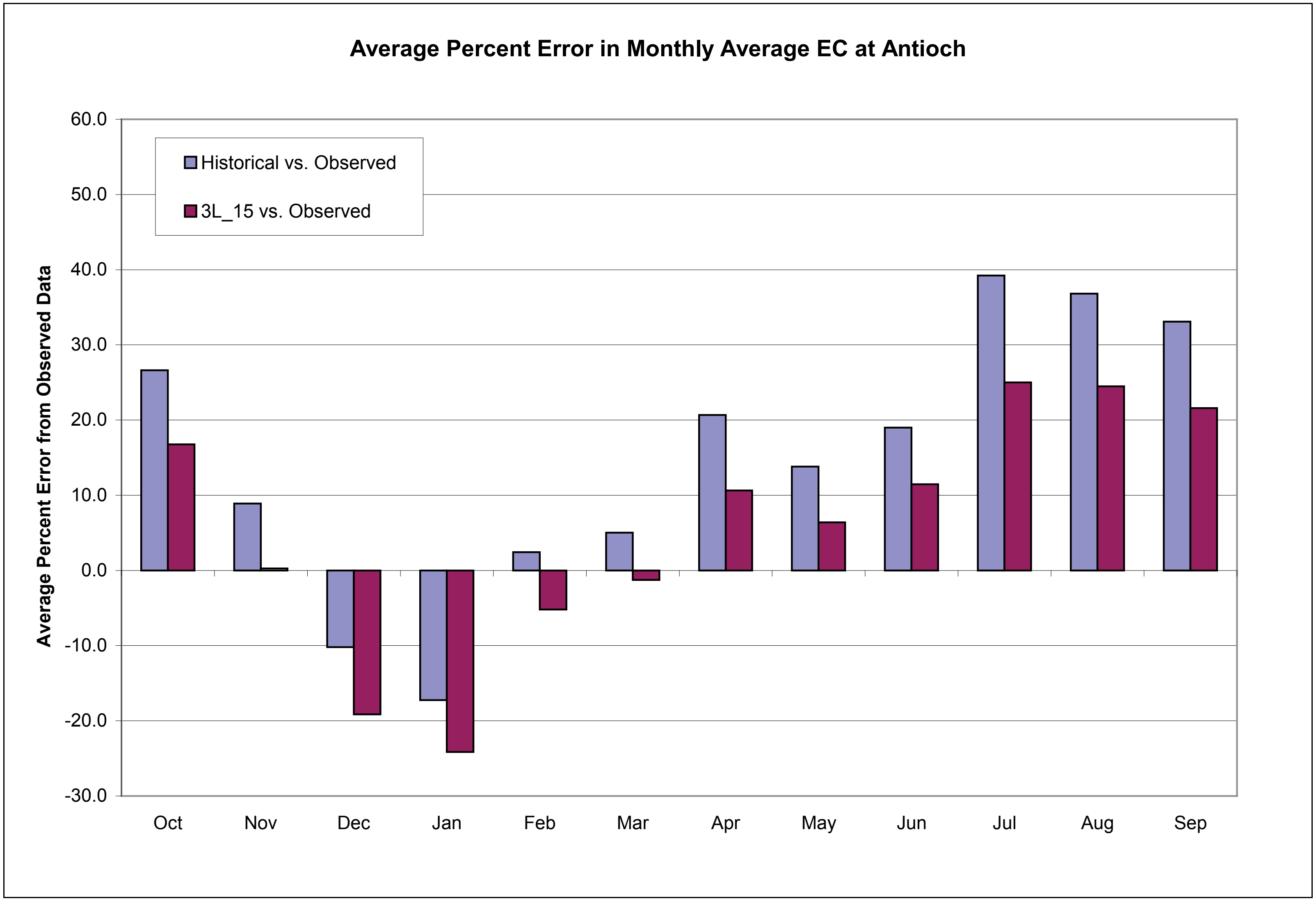


FIGURE 6-29
Monthly Percent Error in Predicted EC at Antioch

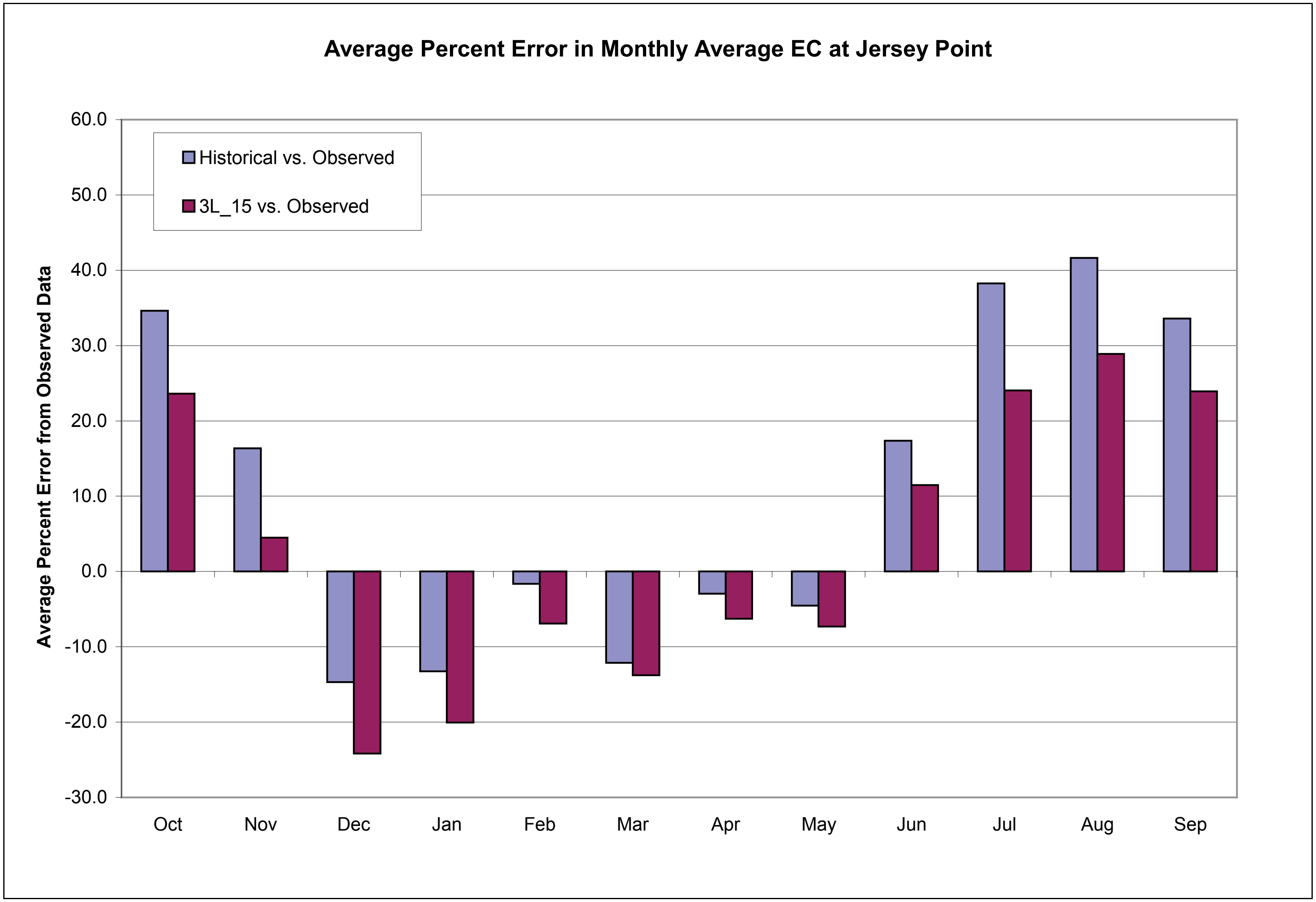


FIGURE 6-30
Monthly Percent Error in Predicted EC at Jersey Point

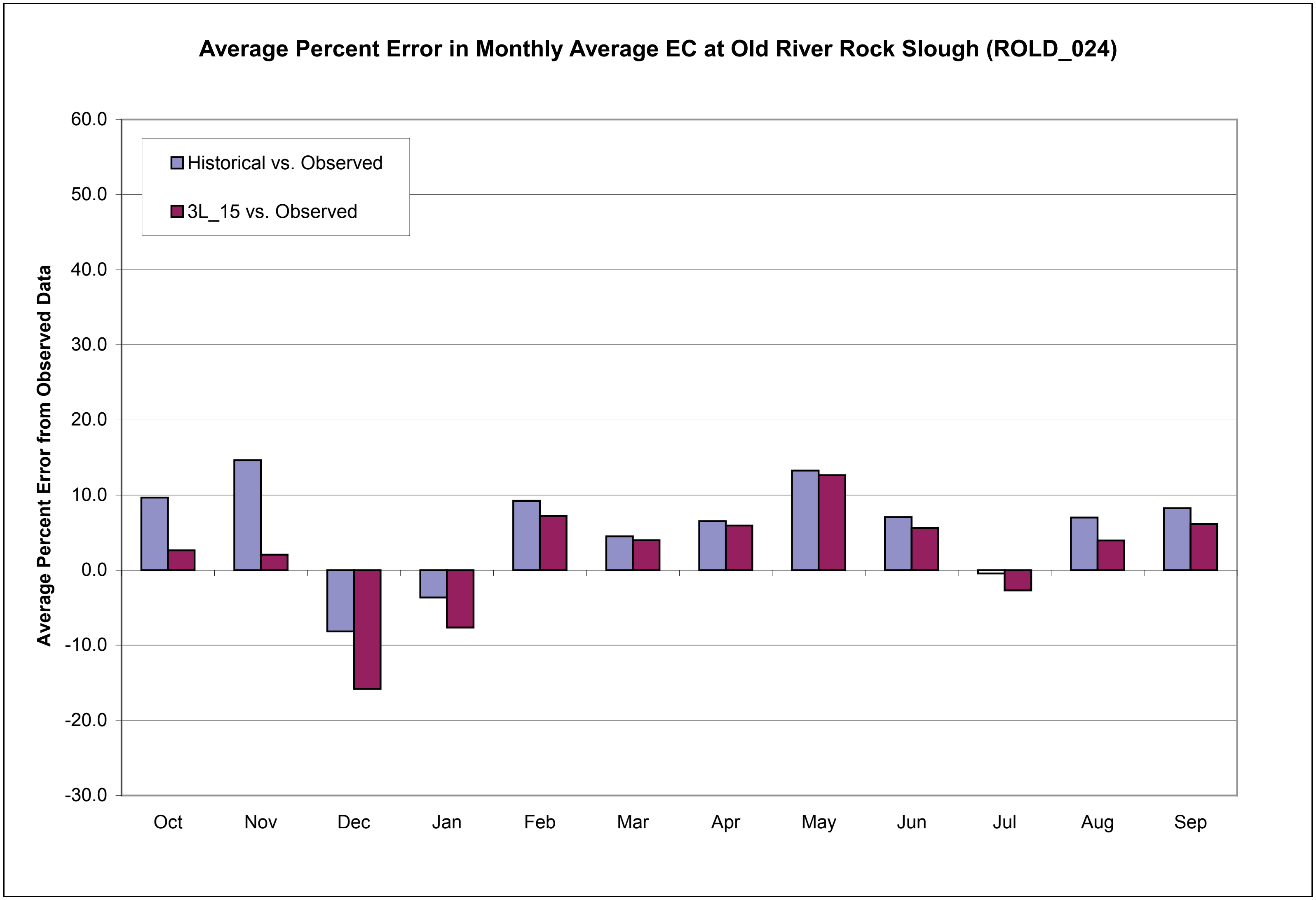


FIGURE 6-31
Monthly Percent Error in Predicted EC at Old River (ROLD024)

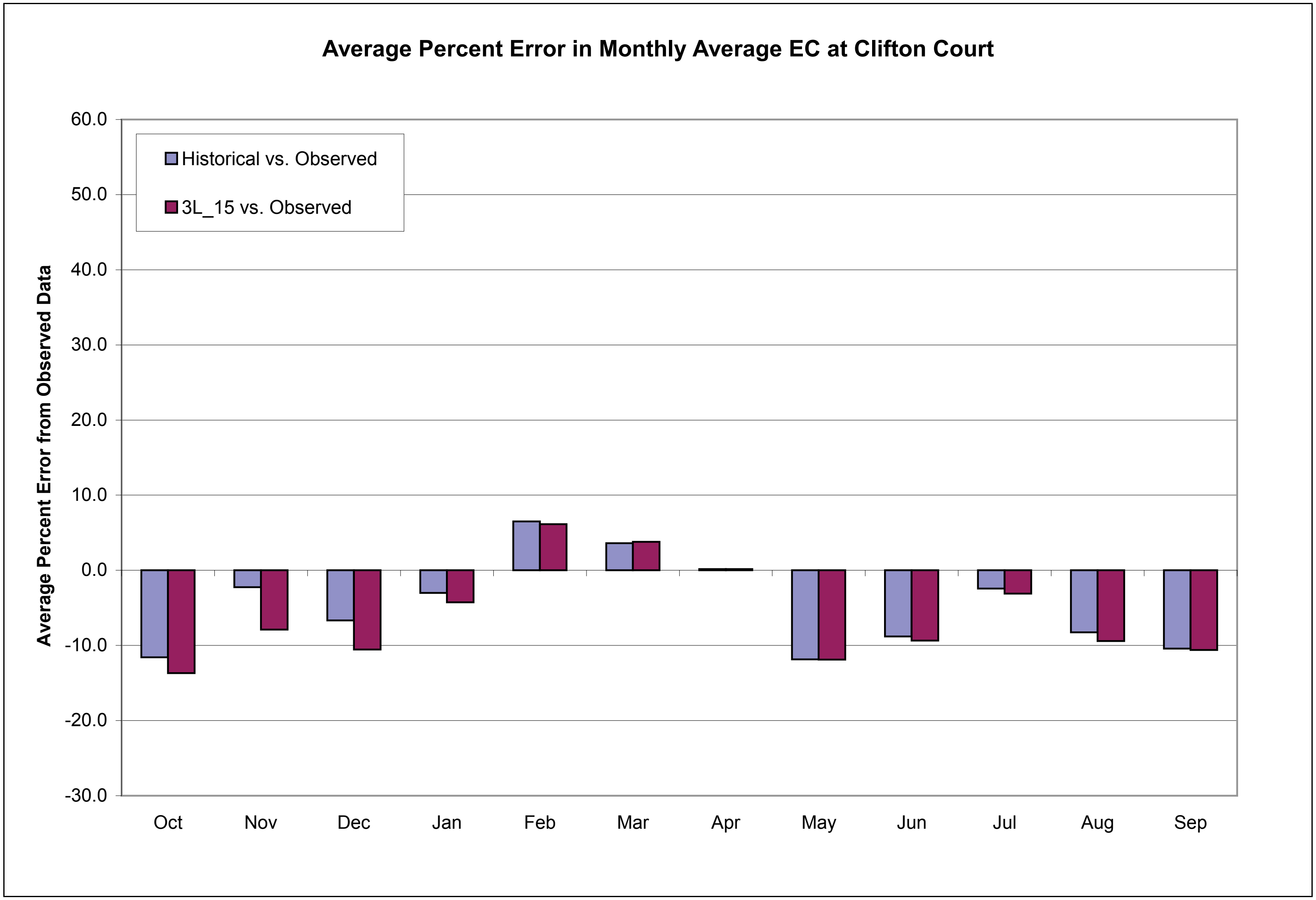


FIGURE 6-32
Monthly Percent Error in Predicted EC at Clifton Court

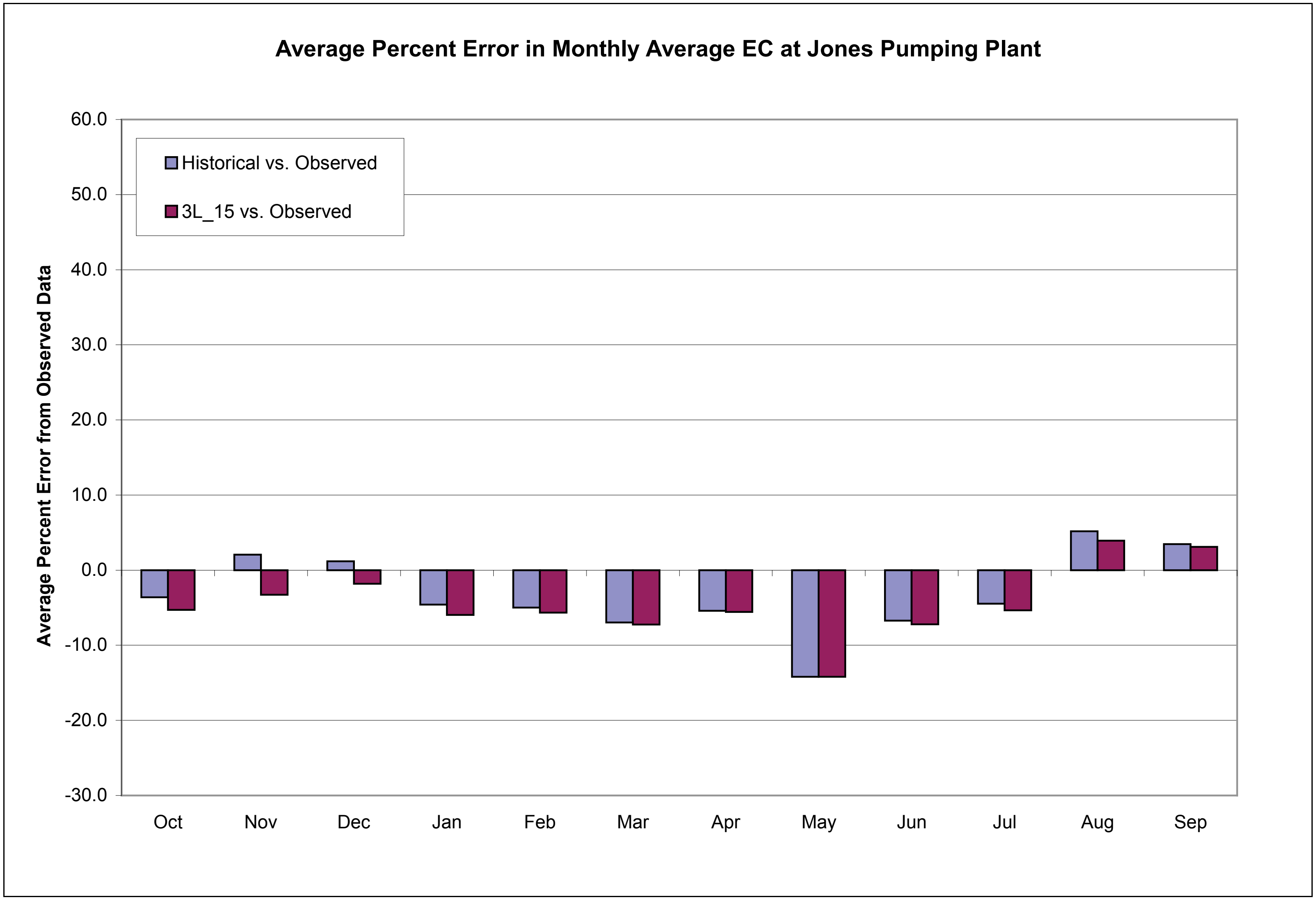


FIGURE 6-33
Monthly Percent Error in Predicted EC at Jones Pumping Plant

SECTION 7

Conclusions and Recommendations

7.1 Conclusions

The current recalibration of DSM2 was undertaken for two main reasons: Liberty Island flooding caused noticeable impact on the hydrodynamics in the north Delta and the 2000 DSM2 calibration did not include this morphological change and therefore do not accurately simulate hydrodynamics in the north Delta. This recalibration was started with an objective to improve the performance of DSM2 in simulating hydrodynamics and water quality at Emmaton, Rio Vista, Jersey Point and Threemile Slough.

The DSM2 model from the 2000 calibration was modified to incorporate the physical changes and boundary condition changes as described in earlier sections. The DSM2-HYDRO with the modified grid was then successfully calibrated with the observed flow and stage data for WY 2002, by mainly modifying Manning's roughness coefficient in the channels. The recalibrated DSM2-HYDRO was then successfully validated for an 8-year period (WY 2001 to WY 2008). DSM2-QUAL was calibrated for WY 2001 to WY 2008 using the results from HYDRO validation. The channel dispersion factors were modified to simulate EC accurately.

At the end of this process, the results from recalibrated DSM2 model have better agreement with observed data than the 2000 calibration overall in the Delta and specifically at the key locations identified in the objectives, in terms of tidal hydrodynamics. It is important to note that the simulated hydrodynamics in the Cache Slough and Steamboat Slough have significantly improved in the recalibrated DSM2. The simulated net flows in Sacramento River at Rio Vista and the Cross Delta flows have improved compared to the 2000 calibration. However, the net flows in Threemile Slough from the Sacramento River to the San Joaquin River in the recalibrated DSM2 are higher than the 2000 calibration. Net flows in Dutch Slough have improved with recalibration; however, they still continue to be in the wrong direction compared to the observed data.

The recalibration process yielded improvement in the QUAL results at Jersey Point, Emmaton and Rock Slough, along with many other locations throughout the Delta. The RMSE is slightly worse at Rio Vista and Threemile Slough for the recalibrated model than the 2000 calibration. The simulated EC is slightly lower in Old River at Holland Cut and near Clifton Court Forebay. Analysis of the calibration metrics indicates that the model performs better during dry and critical years.

Overall, this recalibration effort resulted in a marked improvement in the performance of DSM2-HYDRO and DSM2-QUAL compared to the 2000 calibration.

7.2 Recommendations

A somewhat common pattern in the model results is to over-predict salinity in the summer and fall and under-predict salinity in the winter and spring. The model generally predicts EC in the late summer that rises too quickly compared to the observed data. This is clearly evident at Rio Vista and Jersey Point. This may indicate that the model is over-predicting the tidal mixing or that the dispersion values are too high during periods of low flow. Currently, the dispersion values prescribed for a given channel are held constant for the simulation in DSM2, irrespective of changes in flow. The ability to use a variable dispersion coefficient may improve model predictions. It is recommended that the evaluation and implementation of variable dispersion coefficients to improve seasonally-biased model predictions be considered in the future.

The dispersion values adopted in the final calibration simulation can have significant step changes from one channel to the next. It is hard to justify such a change from a physics perspective. The targeted adjustments of dispersion values required to improve the calibration may indicate that other factors aside from the dispersion coefficients are controlling the errors. The errors may stem from errors in the hydrodynamic predictions, or errors in internal loads (DICU). In future, it is recommended that the Delta agricultural diversion and drainage flow data be obtained from a more realistic model than DICU.

The calibration process is quite complex in that model predictions are generally not consistently biased. For example, predicted fall EC at Rio Vista is higher than observed values in most years, but in 2002, the model predictions are below measured EC. Efforts made to improve conditions at one location or for a certain period can end up making conditions worse at other locations or during other time periods. Future analyses could investigate correlations between predicted errors and other variables such as net flows and average EC, to see if any relationships can be seen that could be used to improve model predictions.

7.3 Limitations

DSM2 is a 1D model with inherent limitations in simulating hydrodynamic and transport processes in a complex estuarine environment such as the Sacramento – San Joaquin Delta. DSM2 assumes that velocity in a channel can be adequately represented by a single average velocity over the channel cross-section, meaning that variations both across the width of the channel and through the water column are negligible. DSM2 does not have the ability to model short-circuiting of flow through a reach, where a majority of the flow in a cross-section is confined to a small portion of the cross-section. DSM2 does not conserve momentum at the channel junctions and does not model the secondary currents in a channel. DSM2 also does not explicitly account for dispersion due to flow accelerating through channel bends. It cannot model the vertical salinity stratification in the channels. For open water bodies DSM2 assumes uniform and instantaneous mixing over entire open water area. Thus it does not account for the any salinity gradients that may exist within the open water bodies. Significant uncertainty exists in flow and EC input data related to in-Delta agriculture, which leads to uncertainty in the simulated EC values. Caution needs to be exercised when using EC outputs on a sub-monthly scale.

SECTION 8

References

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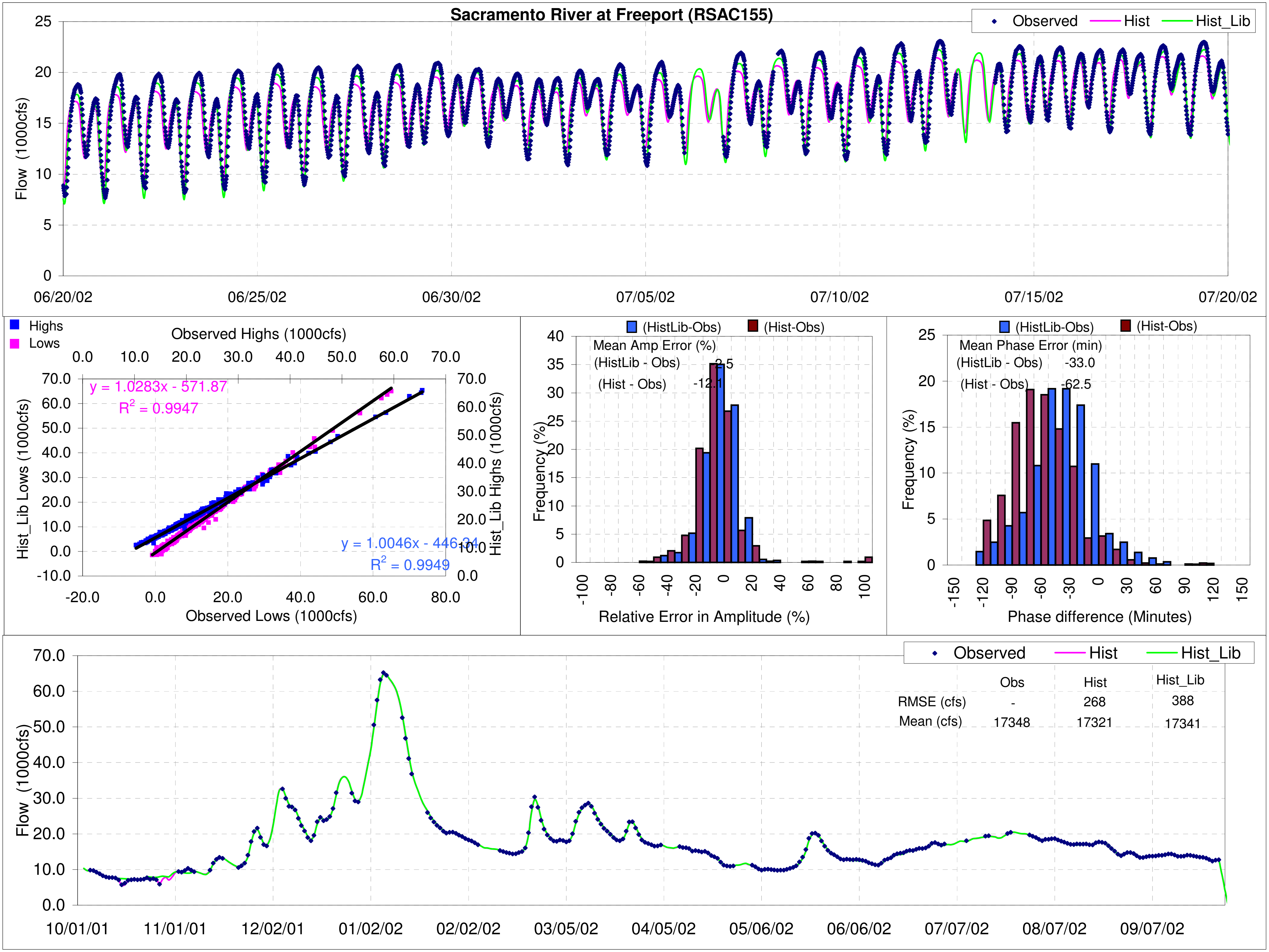
Appendix A
Detailed HYDRO Calibration Results


Sacramento River at Freeport (RSAC155)
Observed
Hist
Hist_Lib
Flow (1000cfs)
0
5
10
15
20
25
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
y = 1.0283x - 571.87
R^2 = 0.9947
y = 1.0046x - 446.34
R^2 = 0.9949
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
-10.0
-20.0
80.0
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 2.5
(Hist - Obs) -12.1
Frequency (%)
-100
-80
-60
-40
-20
0
20
40
60
80
100
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -33.0
(Hist - Obs) -62.5
-150
-120
-90
-60
-30
0
30
60
90
120
150
Phase difference (Minutes)
Observed
Hist
Hist_Lib
Flow (1000cfs)
Obs
Hist
Hist_Lib
RMSE (cfs) - 268 388
Mean (cfs) 17348 17321 17341
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
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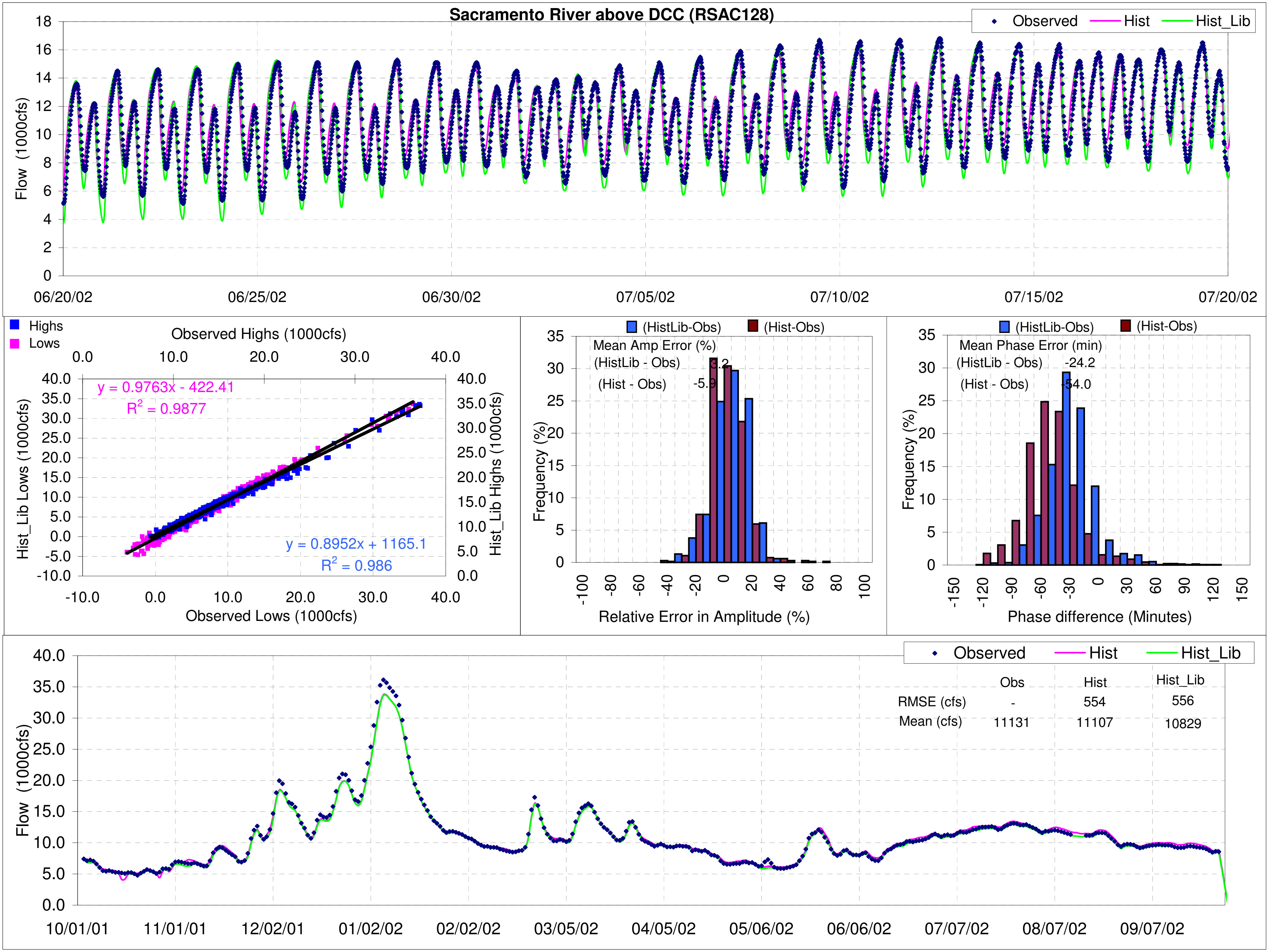
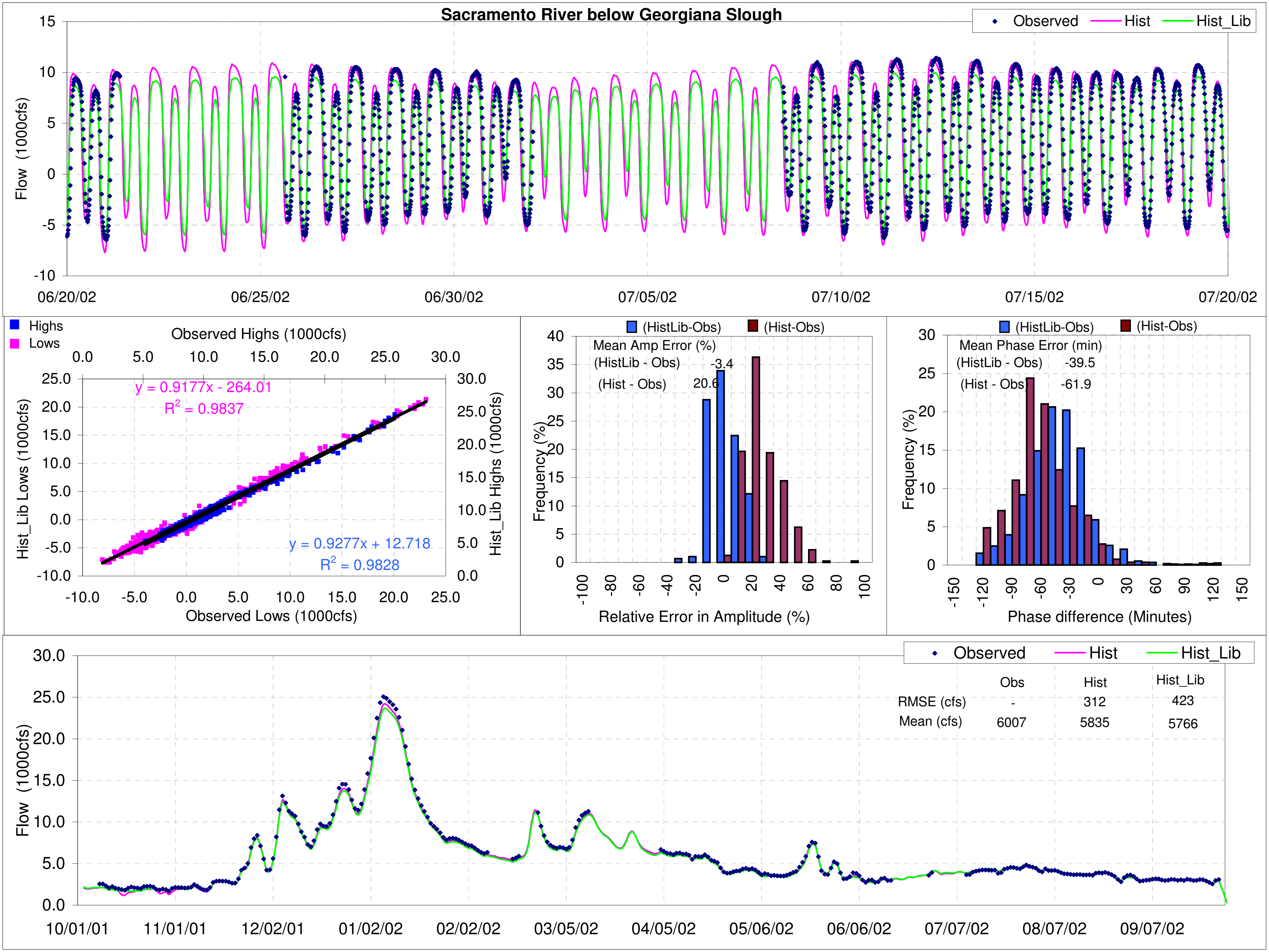
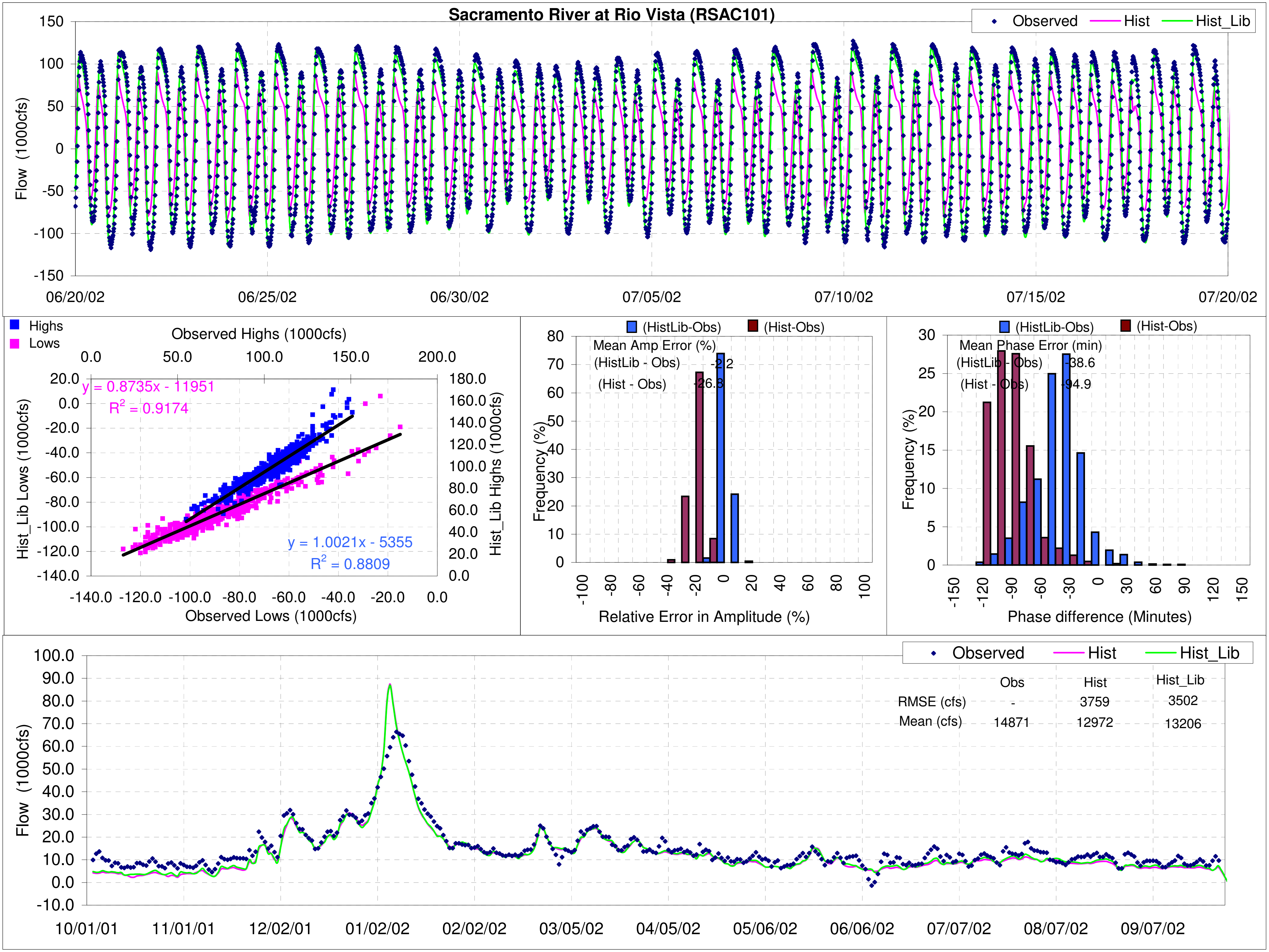
07/07/02
08/07/02
09/07/02

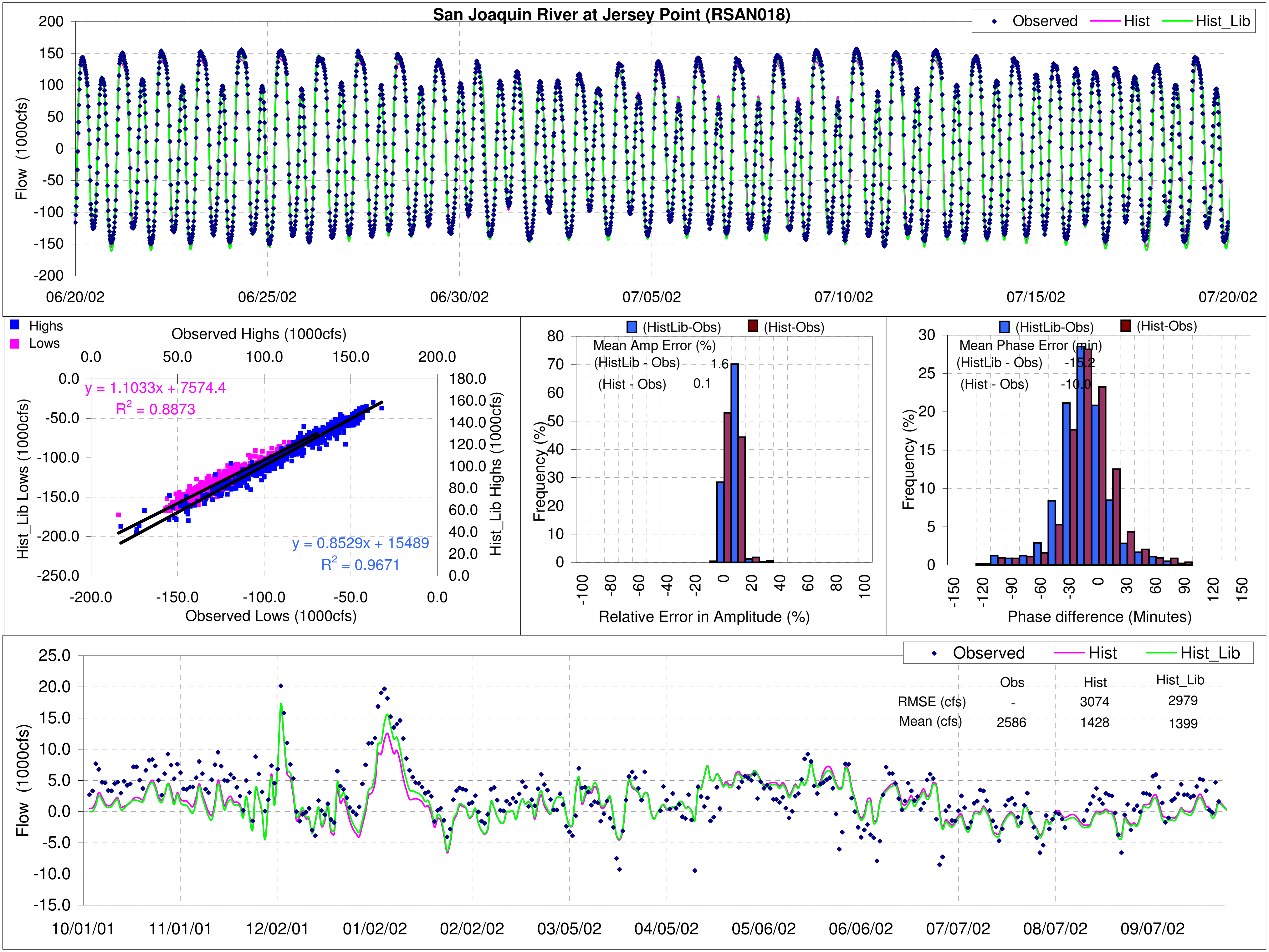


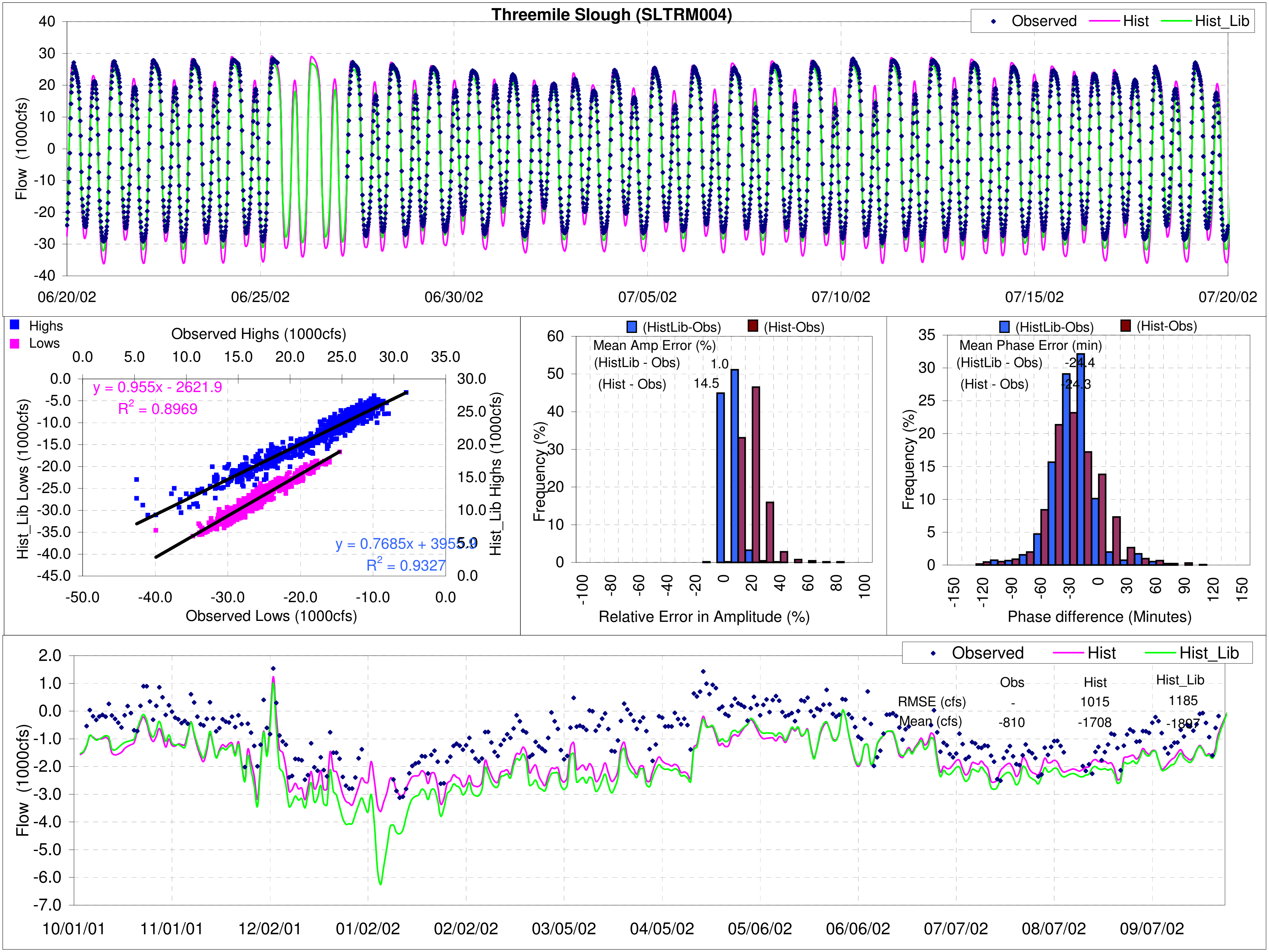
Sacramento River above DCC (RSAC128)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 0.9763x - 422.41
R2 = 0.9877
y = 0.8952x + 1165.1
R2 = 0.986
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 3.2
(Hist - Obs) -5.9
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -24.2
(Hist - Obs) -54.0
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 554 556
Mean (cfs) 11131 11107 10829
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

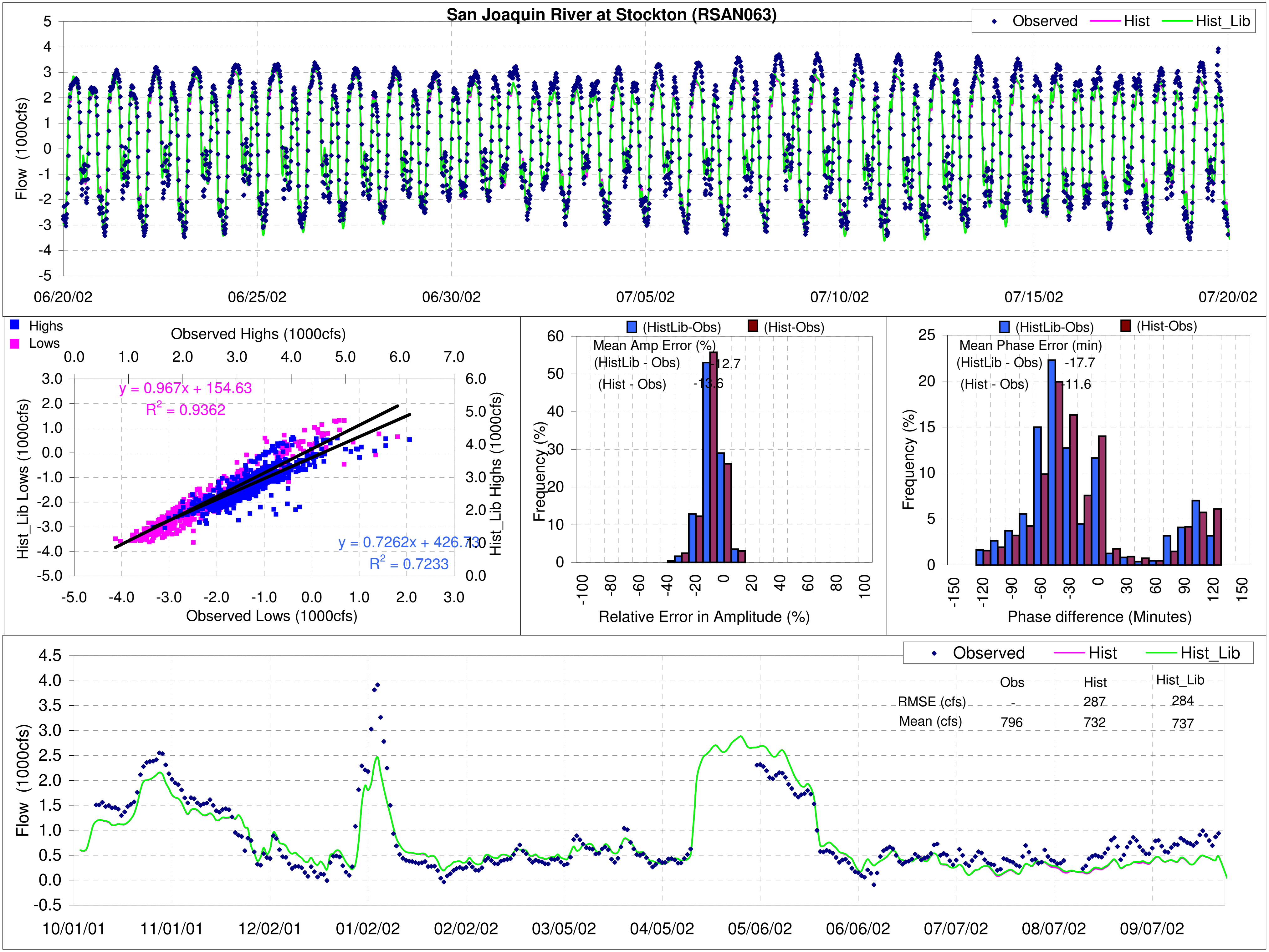


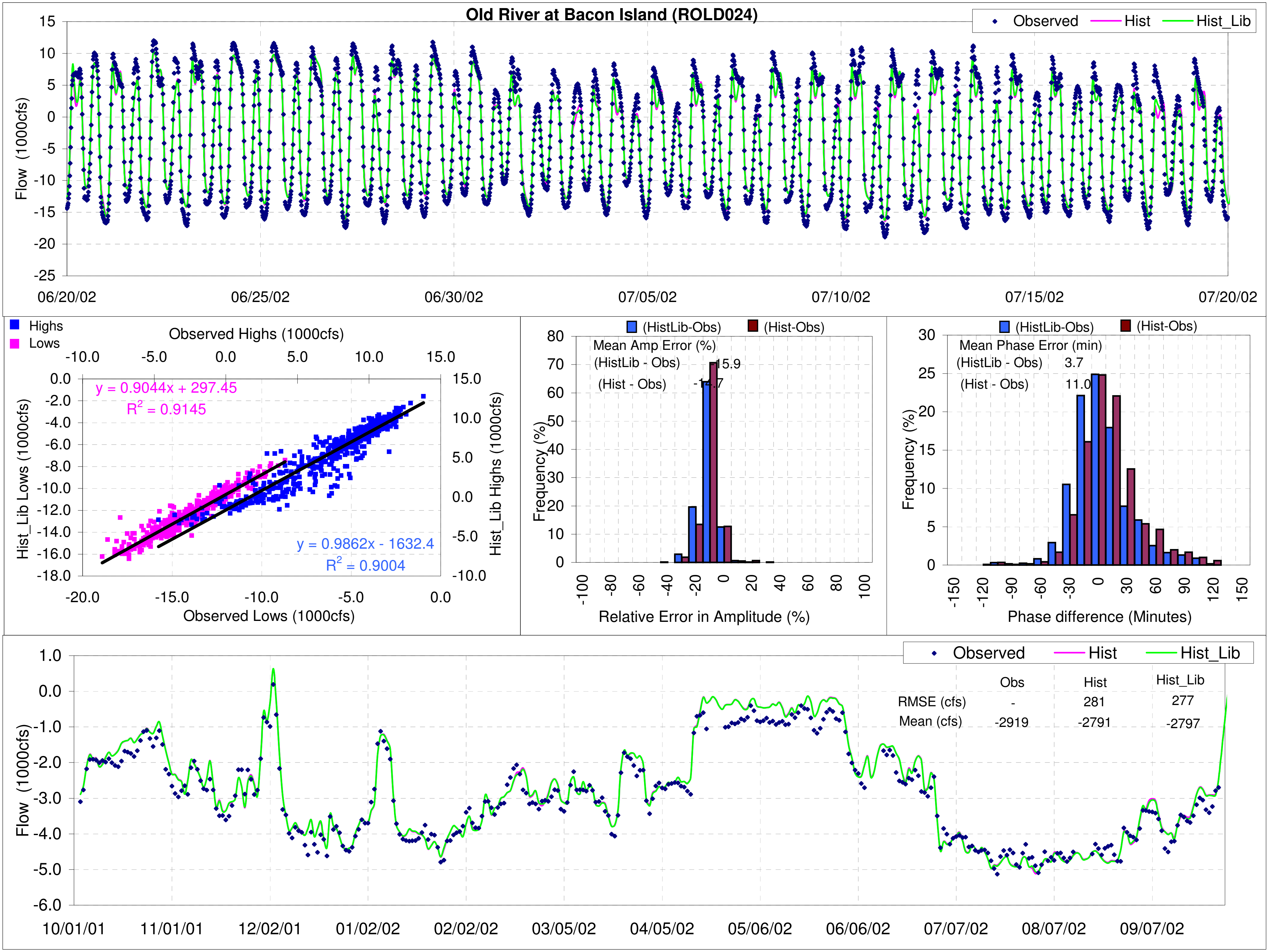
Sacramento River below Georgiana Slough
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 0.9177x - 264.01
R2 = 0.9837
y = 0.9277x + 12.718
R2 = 0.9828
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -3.4
(Hist - Obs) 20.6
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -39.5
(Hist - Obs) -61.9
Frequency (%)
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 312 423
Mean (cfs) 6007 5835 5766
Flow (1000cfs)
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02


Sacramento River at Rio Vista (RSAC101)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 0.8735x - 11951
R^2 = 0.9174
y = 1.0021x - 5355
R^2 = 0.8809
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -2.2
(Hist - Obs) -26.8
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -38.6
(Hist - Obs) -94.9
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 3759 3502
Mean (cfs) 14871 12972 13206
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

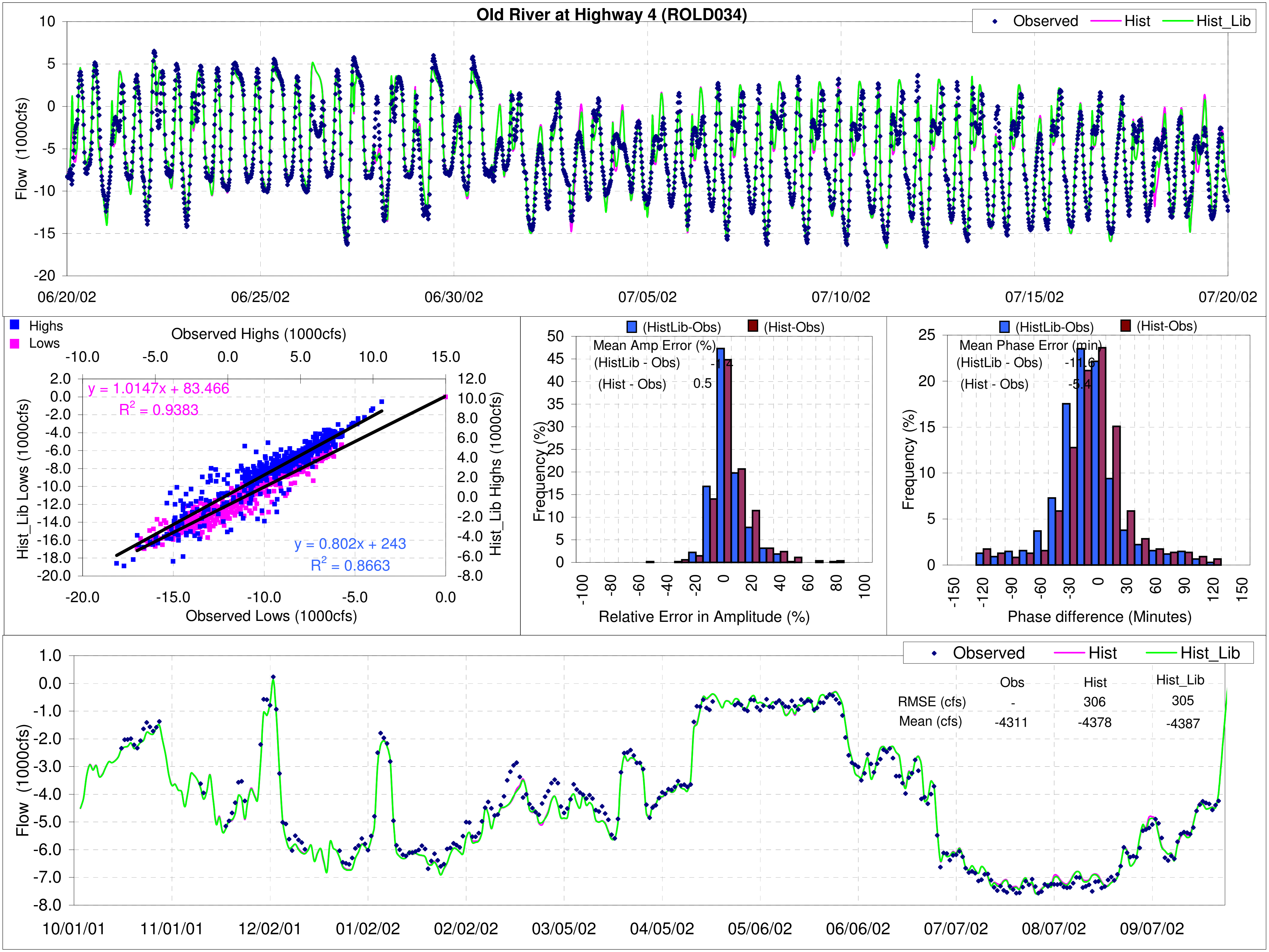

San Joaquin River at Jersey Point (RSAN018)
Observed
Hist
Hist_Lib
Flow (1000cfs)
200
150
100
50
0
-50
-100
-150
-200
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
0.0
50.0
100.0
150.0
200.0
y = 1.1033x + 7574.4
R^2 = 0.8873
y = 0.8529x + 15489
R^2 = 0.9671
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
-200.0
-150.0
-100.0
-50.0
0.0
-250.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 1.6
(Hist - Obs) 0.1
Frequency (%)
Relative Error in Amplitude (%)
-100
-80
-60
-40
-20
0
20
40
60
80
100
Mean Phase Error (min)
(HistLib - Obs) -15.2
(Hist - Obs) -10.0
Phase difference (Minutes)
-150
-120
-90
-60
-30
0
30
60
90
120
150
Obs
Hist
Hist_Lib
RMSE (cfs) - 3074 2979
Mean (cfs) 2586 1428 1399
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02


Threemile Slough (SLTRM004)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 0.955x - 2621.9
R2 = 0.8969
y = 0.7685x + 3955.9
R2 = 0.9327
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 1.0
(Hist - Obs) 14.5
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -24.4
(Hist - Obs) -24.3
Phase difference (Minutes)
Observed
Hist
Hist_Lib
Obs Hist Hist_Lib
RMSE (cfs) - 1015 1185
Mean (cfs) -810 -1708 -1807
Flow (1000cfs)
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

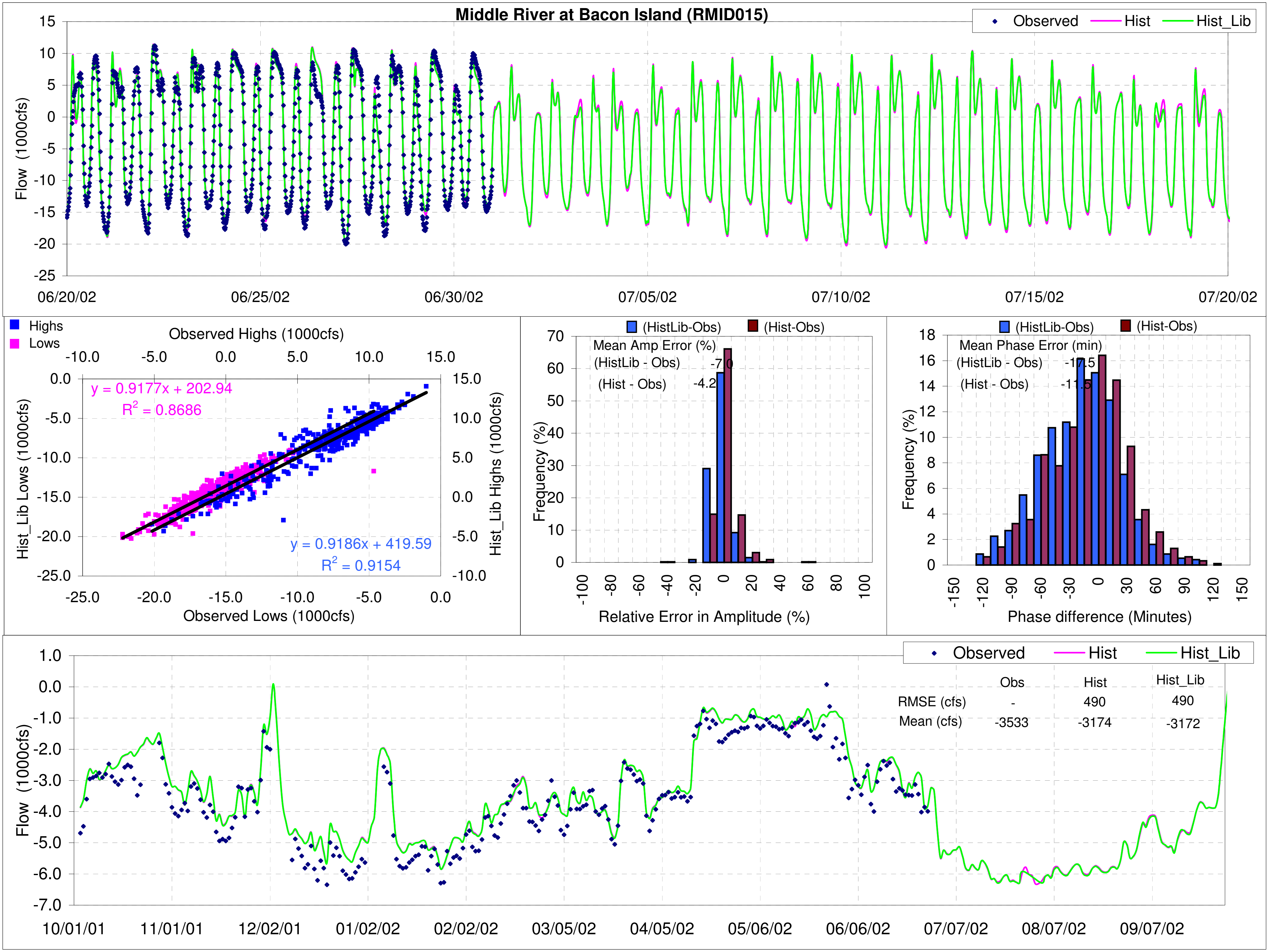

San Joaquin River at Stockton (RSAN063)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 0.967x + 154.63
R2 = 0.9362
y = 0.7262x + 426.73
R2 = 0.7233
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -12.7
(Hist - Obs) -13.6
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -17.7
(Hist - Obs) -11.6
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (cfs) - 287 284
Mean (cfs) 796 732 737
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02



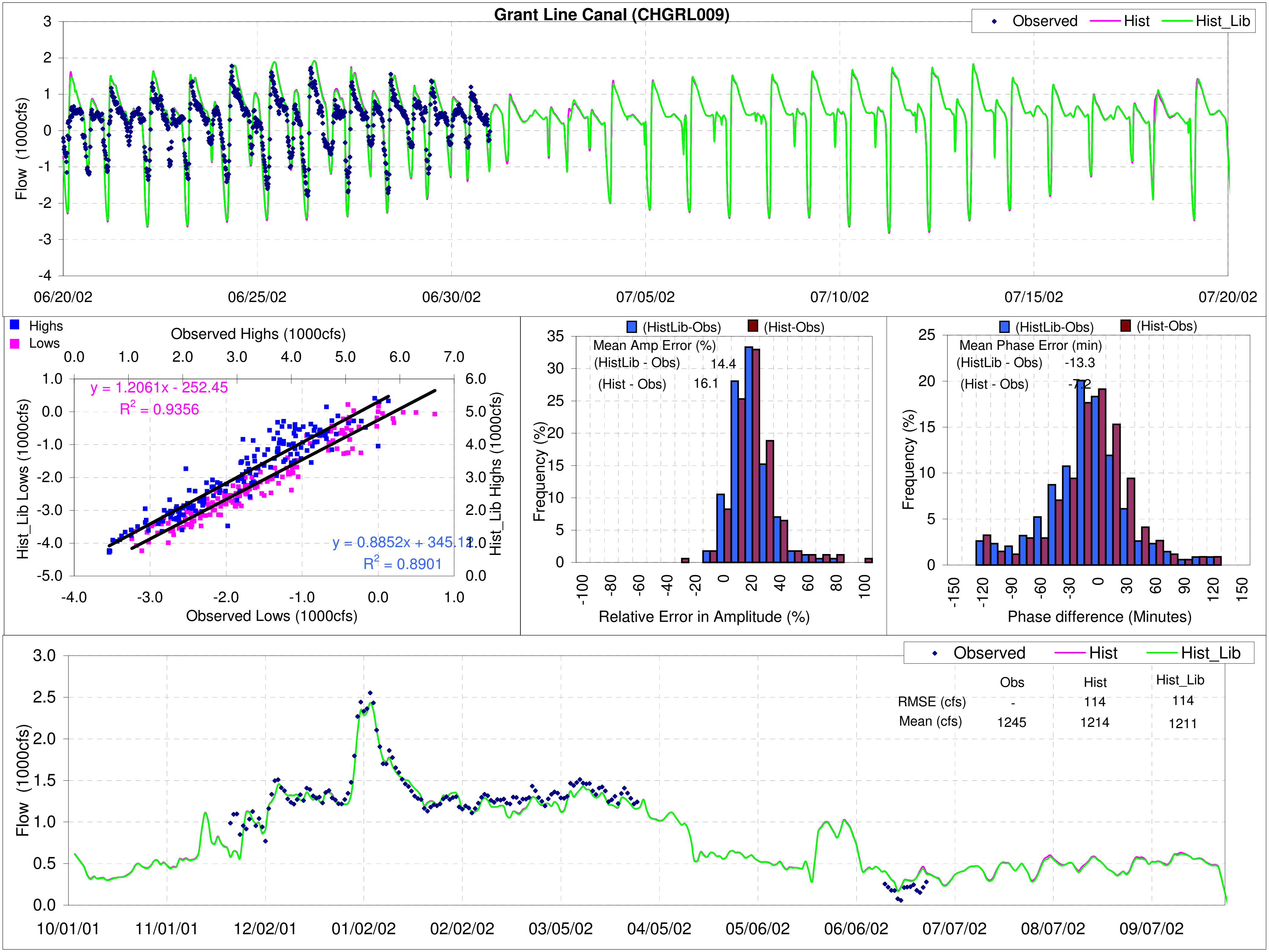
Old River at Bacon Island (ROLD024)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 0.9044x + 297.45
R^2 = 0.9145
y = 0.9862x - 1632.4
R^2 = 0.9004
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -15.9
(Hist - Obs) -14.7
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 3.7
(Hist - Obs) 11.0
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 281 277
Mean (cfs) -2919 -2791 -2797
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02



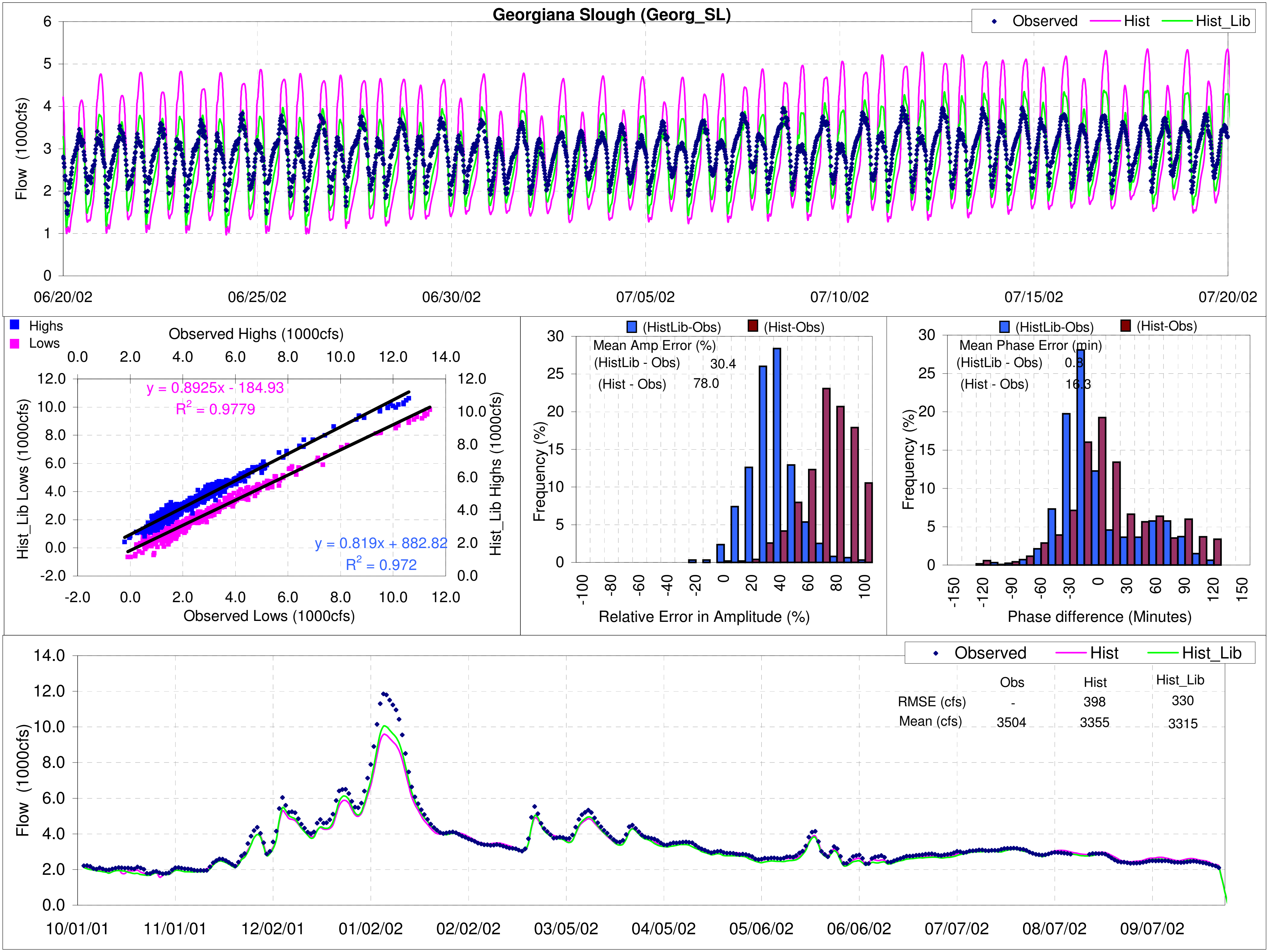
Old River at Highway 4 (ROLD034)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 1.0147x + 83.466
R2 = 0.9383
y = 0.802x + 243
R2 = 0.8663
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -1.4
(Hist - Obs) 0.5
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -11.6
(Hist - Obs) -5.4
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 306 305
Mean (cfs) -4311 -4378 -4387
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02



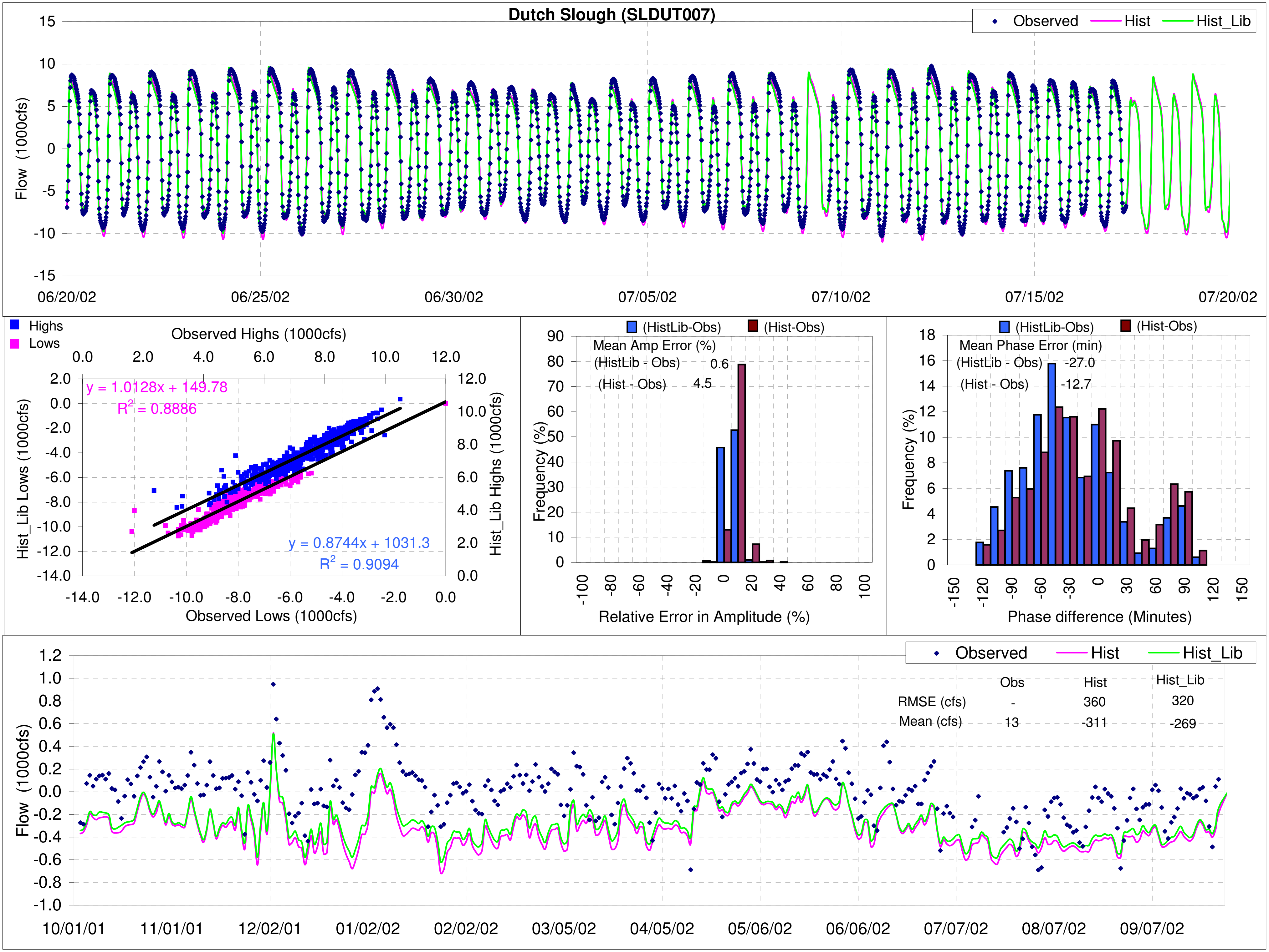
Middle River at Bacon Island (RMID015)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 0.9177x + 202.94
R^2 = 0.8686
y = 0.9186x + 419.59
R^2 = 0.9154
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -7.0
(Hist - Obs) -4.2
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -17.5
(Hist - Obs) -11.5
Frequency (%)
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 490 490
Mean (cfs) -3533 -3174 -3172
Flow (1000cfs)
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

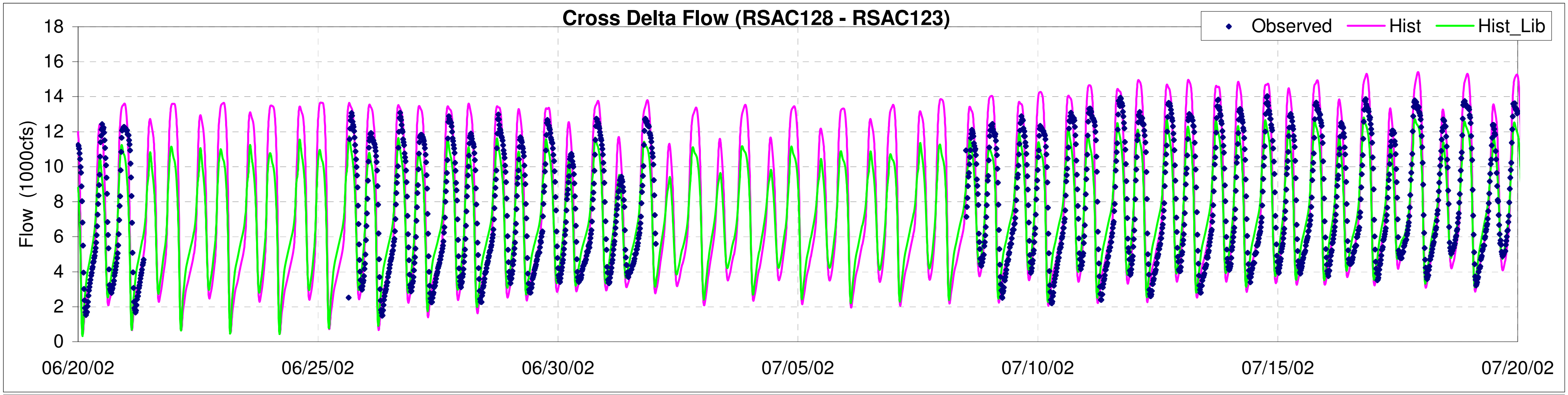


Grant Line Canal (CHGRL009)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 1.2061x - 252.45
R2 = 0.9356
y = 0.8852x + 345.12
R2 = 0.8901
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 14.4
(Hist - Obs) 16.1
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -13.3
(Hist - Obs) -7.2
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (cfs) - 114 114
Mean (cfs) 1245 1214 1211
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

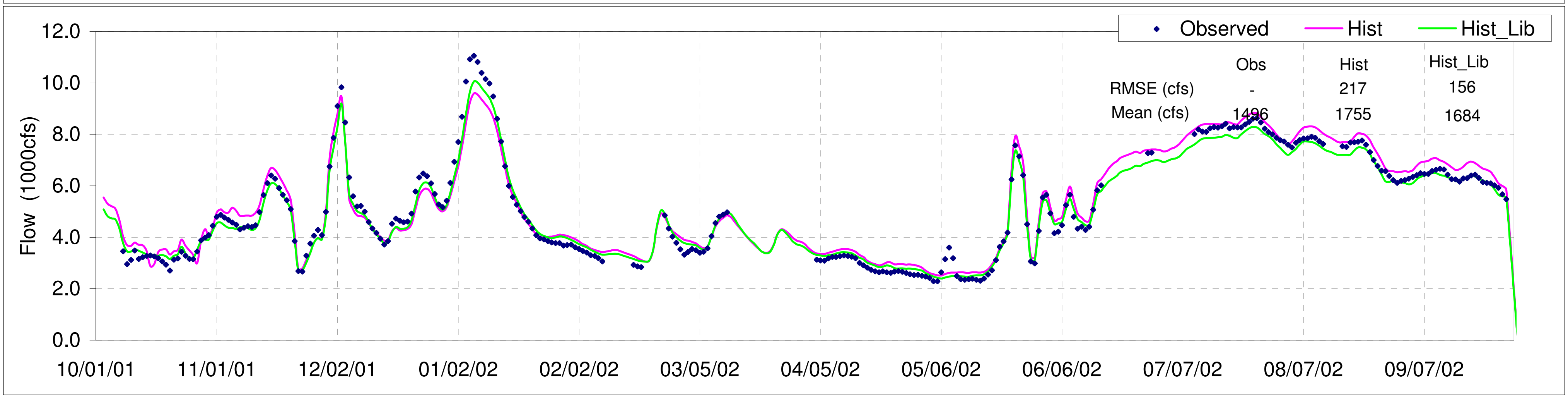


Georgiana Slough (Georg_SL)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 0.8925x - 184.93
R^2 = 0.9779
y = 0.819x + 882.82
R^2 = 0.972
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 30.4
(Hist - Obs) 78.0
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 0.3
(Hist - Obs) 16.3
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 398 330
Mean (cfs) 3504 3355 3315
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

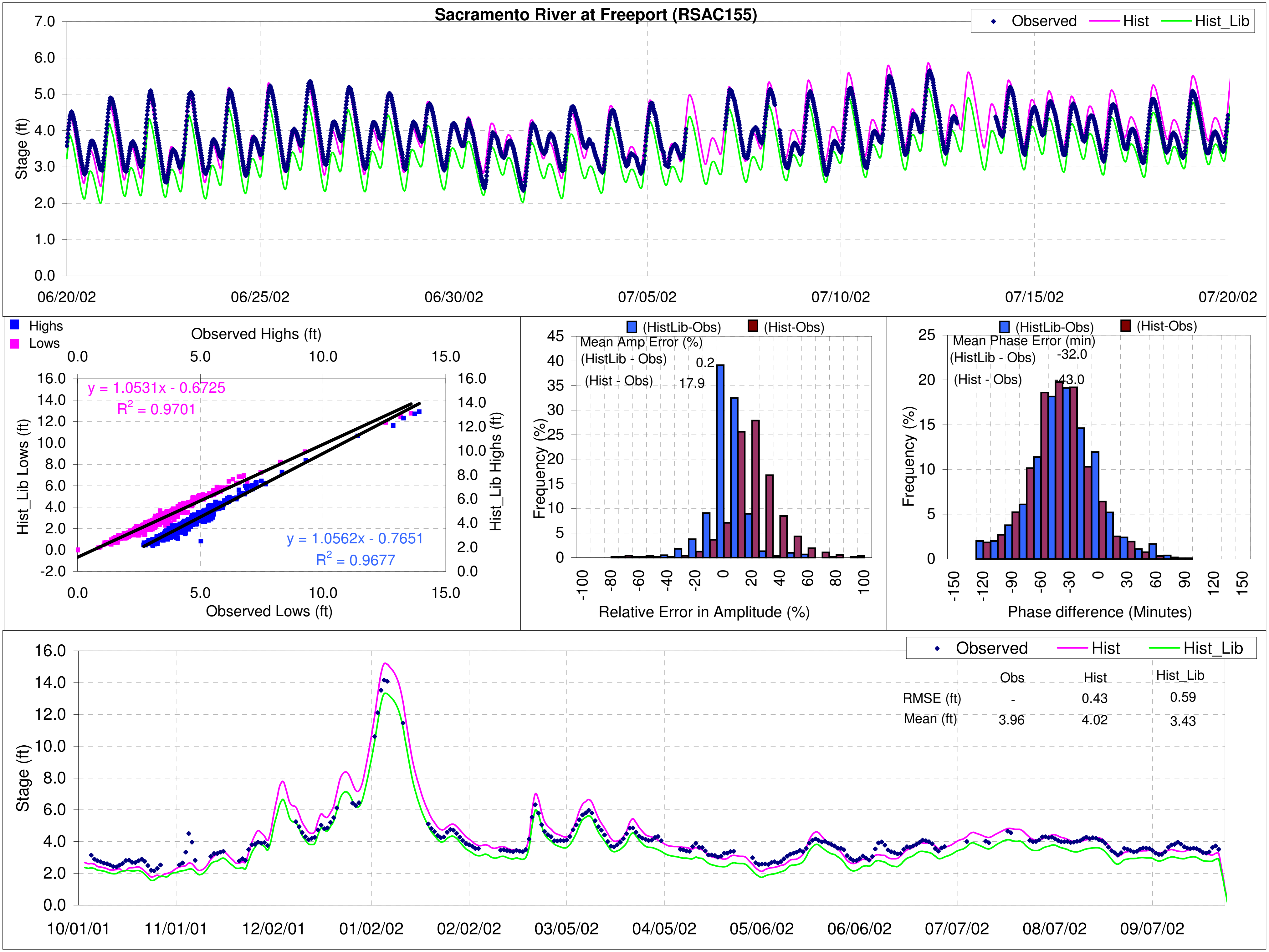

Dutch Slough (SLDUT007)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (1000cfs)
y = 1.0128x + 149.78
R^2 = 0.8886
y = 0.8744x + 1031.3
R^2 = 0.9094
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 0.6
(Hist - Obs) 4.5
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -27.0
(Hist - Obs) -12.7
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 360 320
Mean (cfs) 13 -311 -269
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

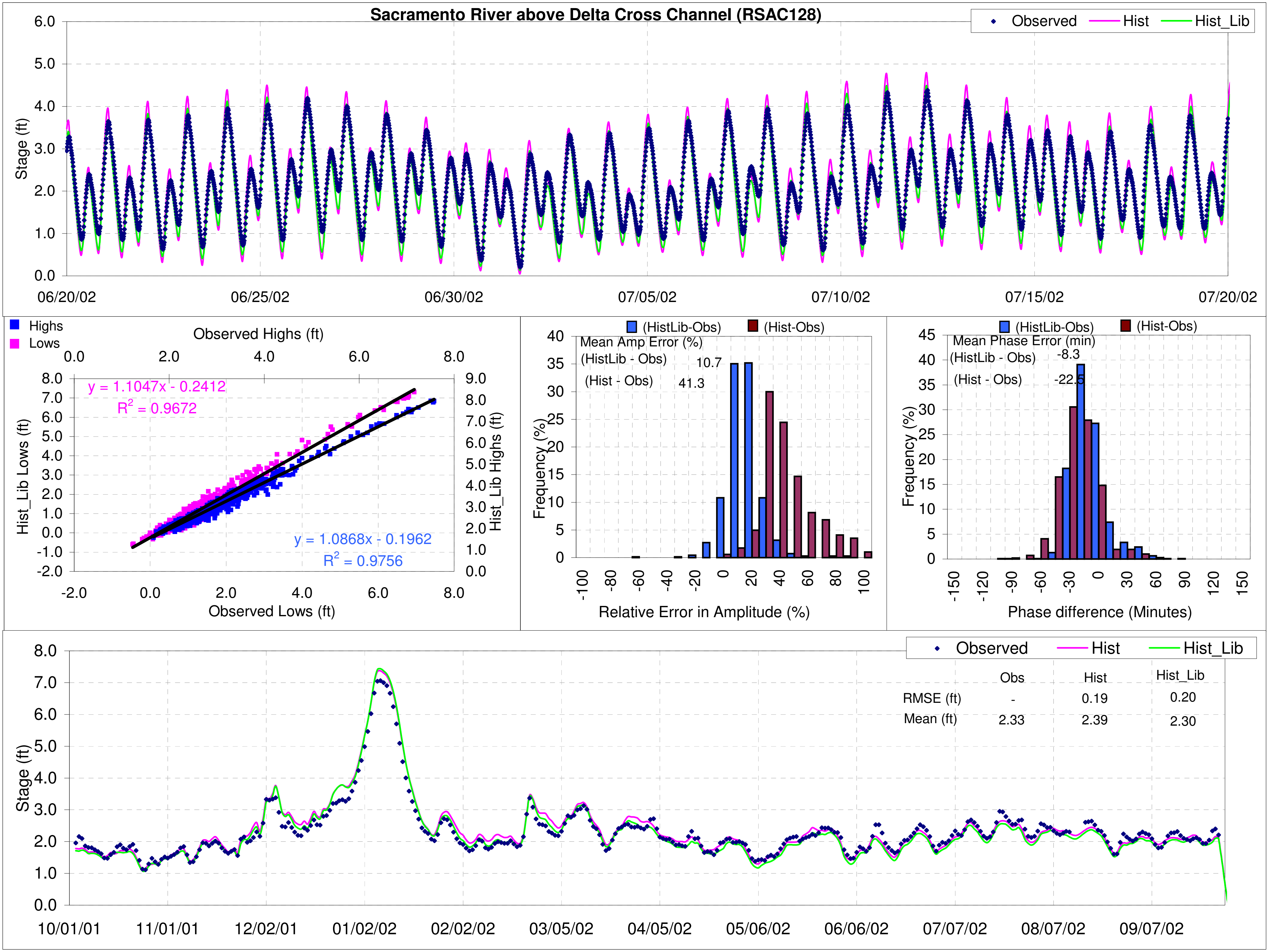


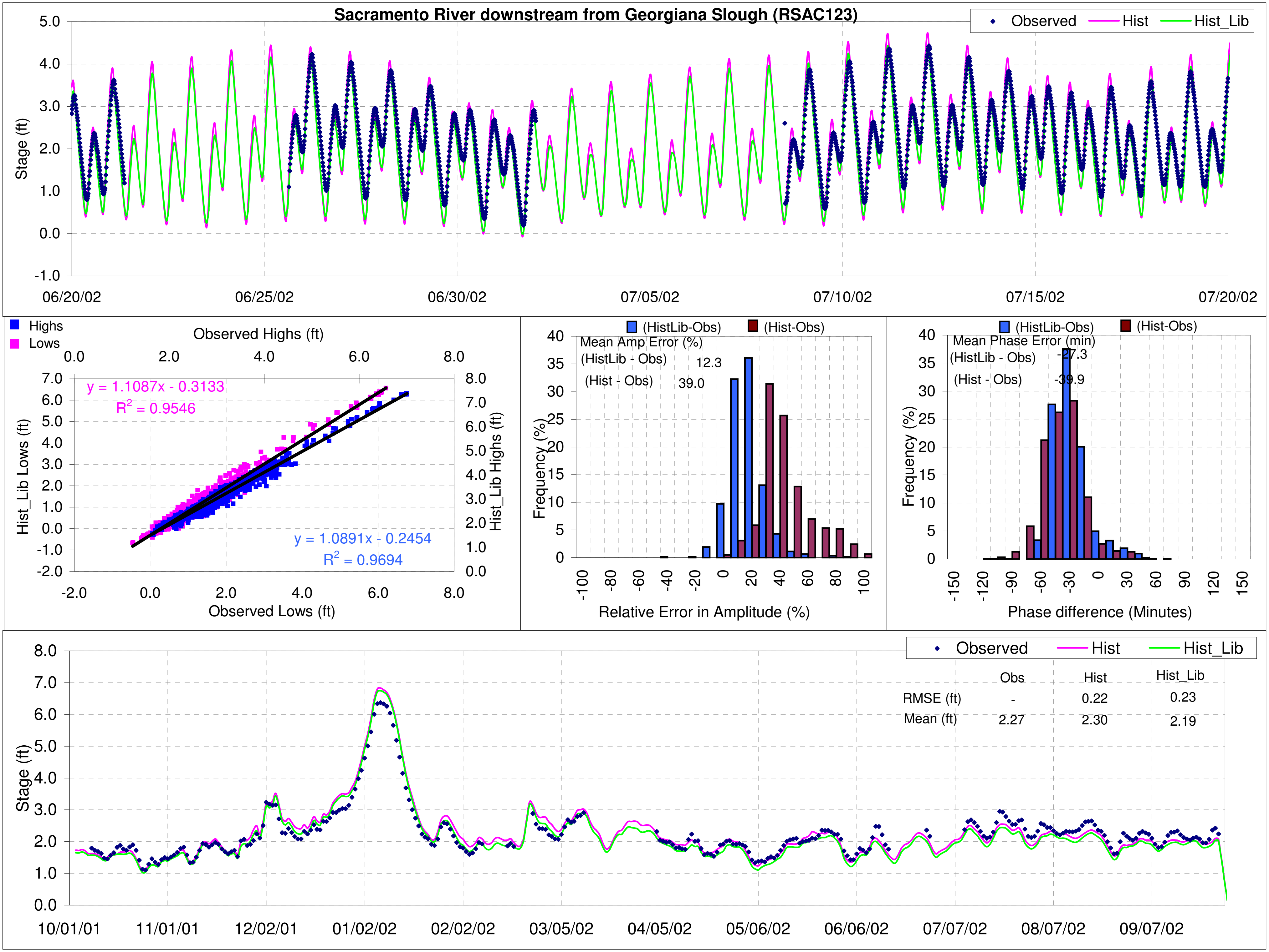
Cross Delta Flow (RSAC128 - RSAC123)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02

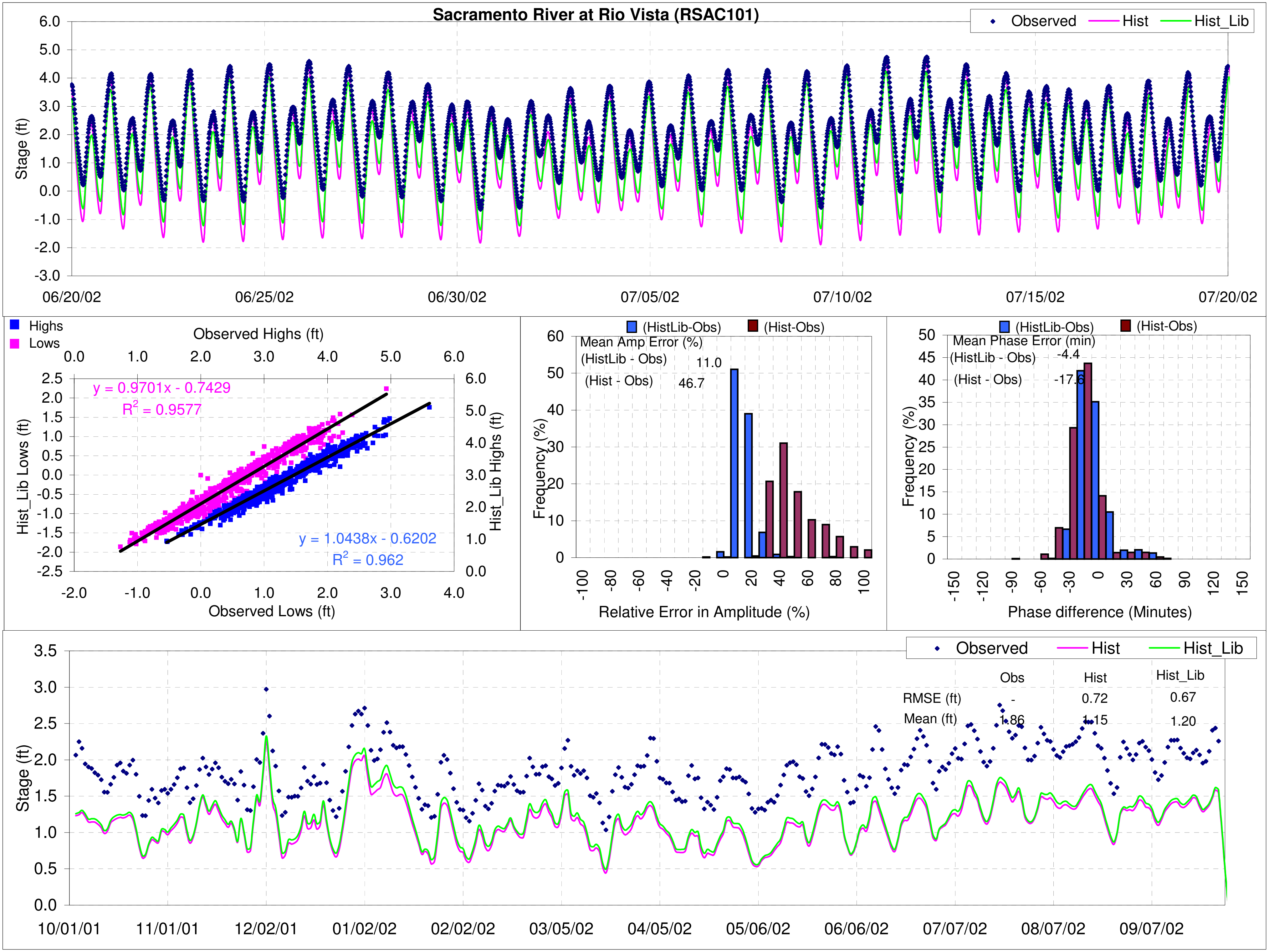


Observed
Hist
Hist_Lib
Obs
Hist
Hist_Lib
RMSE (cfs)
-
217
156
Mean (cfs)
1496
1755
1684
Flow (1000cfs)
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

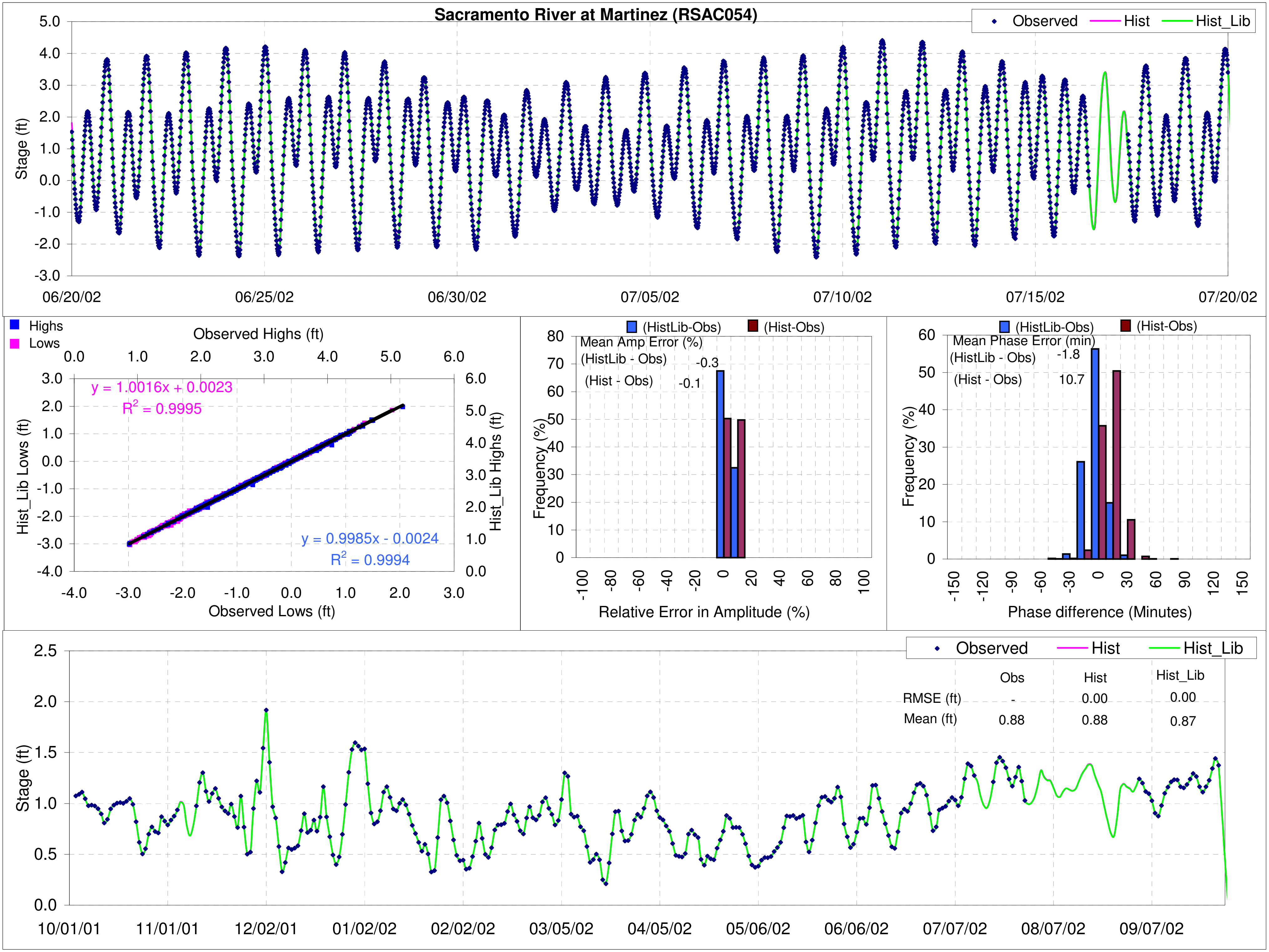

Sacramento River at Freeport (RSAC155)
Observed
Hist
Hist_Lib
Stage (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
0.0
5.0
10.0
15.0
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
y = 1.0531x - 0.6725
R2 = 0.9701
y = 1.0562x - 0.7651
R2 = 0.9677
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 0.2
(Hist - Obs) 17.9
Frequency (%)
45
40
35
30
25
20
15
10
5
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -32.0
(Hist - Obs) -43.0
-150
-120
-90
-60
-30
0
30
60
90
120
150
Phase difference (Minutes)
Stage (ft)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02
Obs Hist Hist_Lib
RMSE (ft) - 0.43 0.59
Mean (ft) 3.96 4.02 3.43

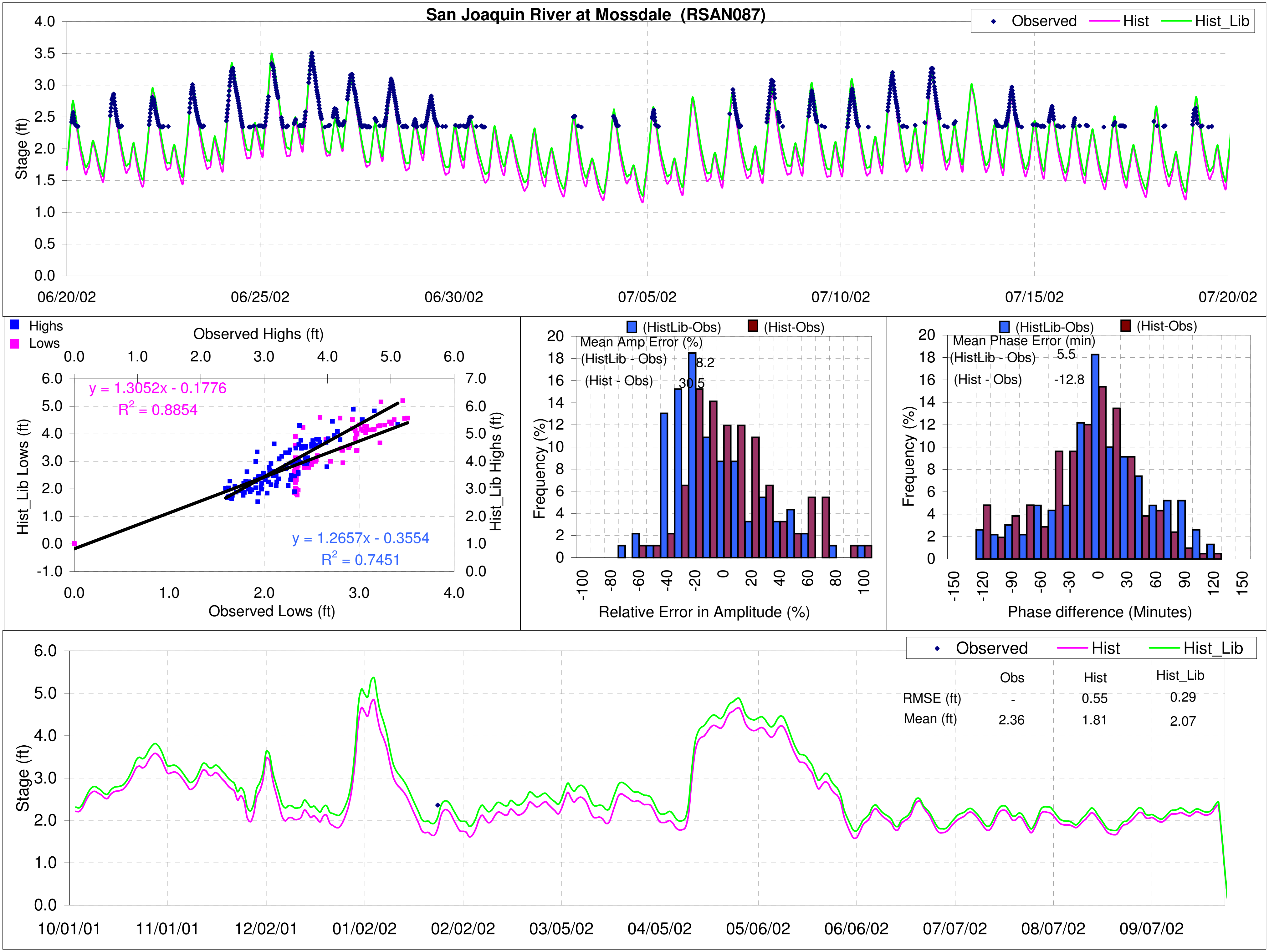

Sacramento River above Delta Cross Channel (RSAC128)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 1.1047x - 0.2412
R^2 = 0.9672
y = 1.0868x - 0.1962
R^2 = 0.9756
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 10.7
(Hist - Obs) 41.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -8.3
(Hist - Obs) -22.5
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (ft) - 0.19 0.20
Mean (ft) 2.33 2.39 2.30
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

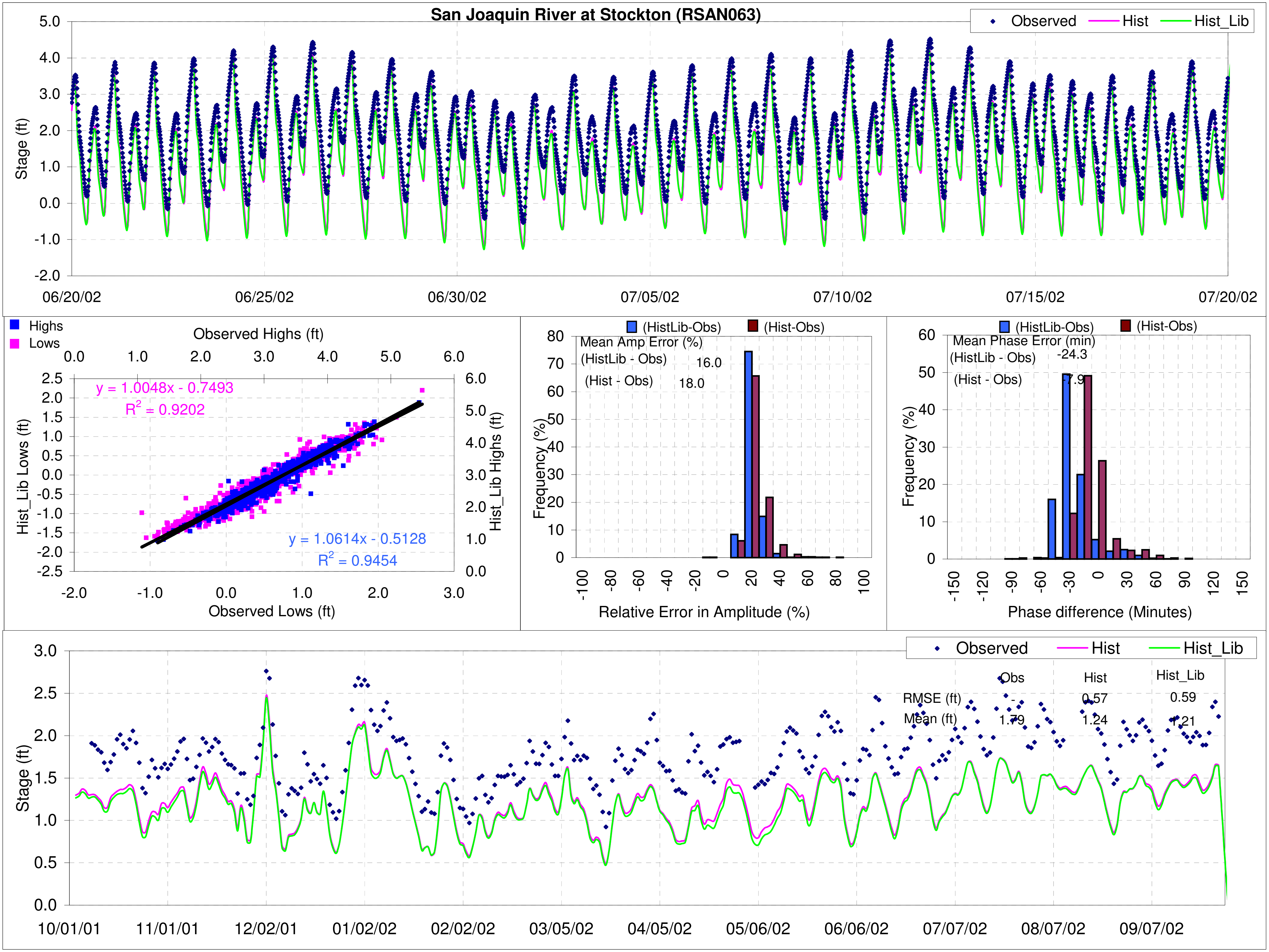

Sacramento River downstream from Georgiana Slough (RSAC123)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 1.1087x - 0.3133
R^2 = 0.9546
y = 1.0891x - 0.2454
R^2 = 0.9694
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 12.3
(Hist - Obs) 39.0
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -27.3
(Hist - Obs) -39.9
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (ft) - 0.22 0.23
Mean (ft) 2.27 2.30 2.19
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

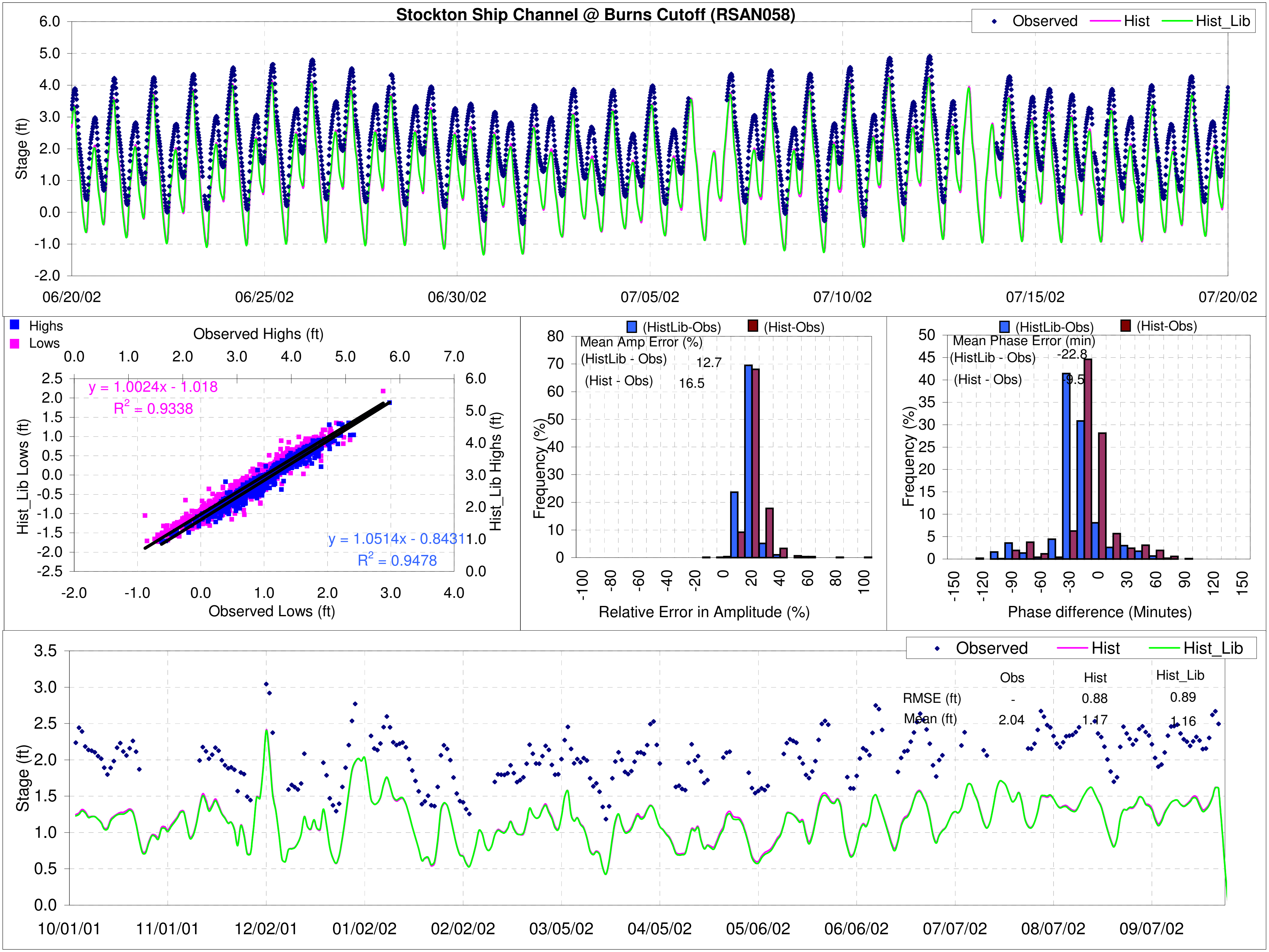


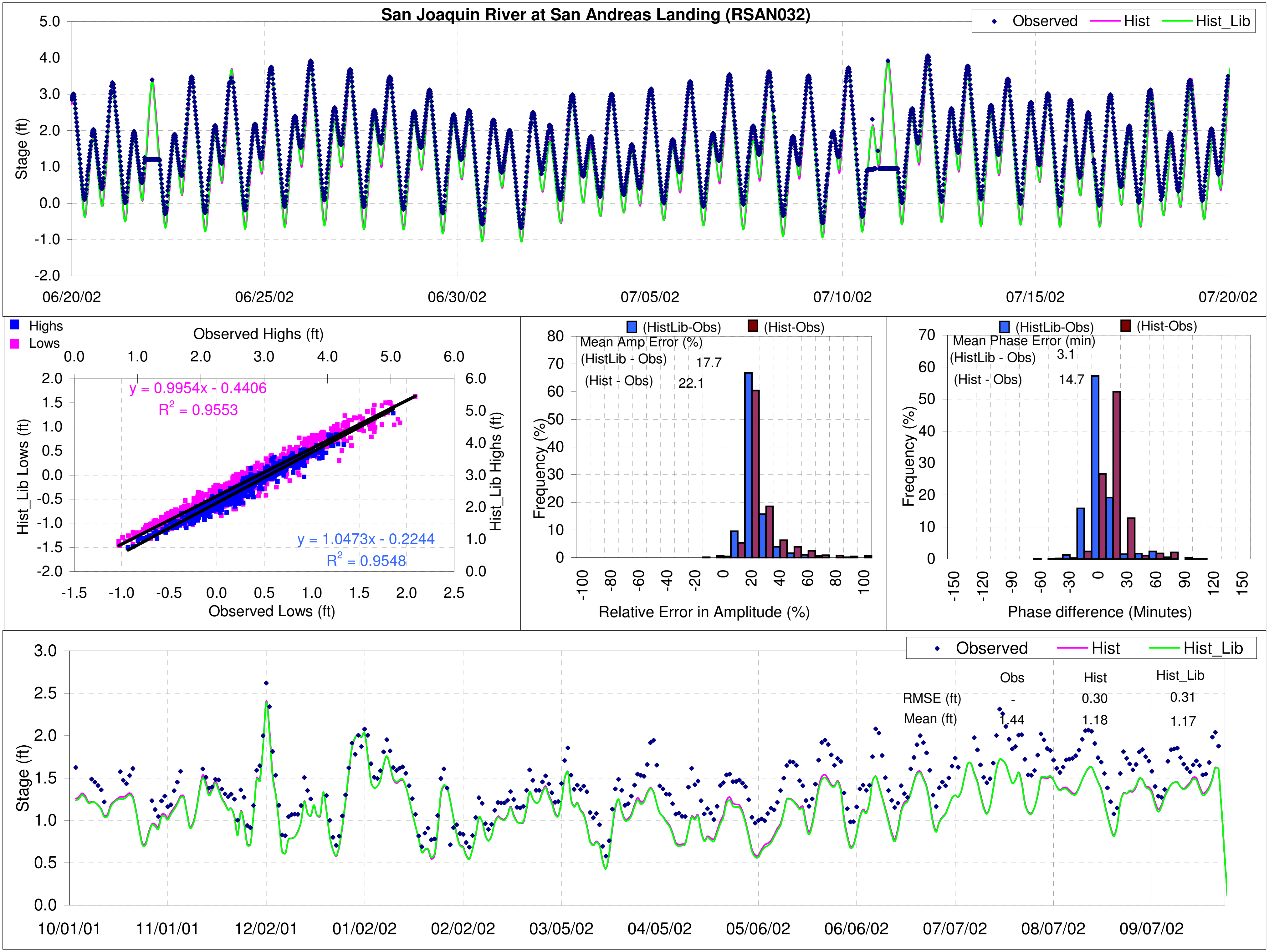
Sacramento River at Rio Vista (RSAC101)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 0.9701x - 0.7429
R^2 = 0.9577
y = 1.0438x - 0.6202
R^2 = 0.962
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 11.0
(Hist - Obs) 46.7
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -4.4
(Hist - Obs) -17.6
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.72 0.67
Mean (ft) 1.86 1.15 1.20
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

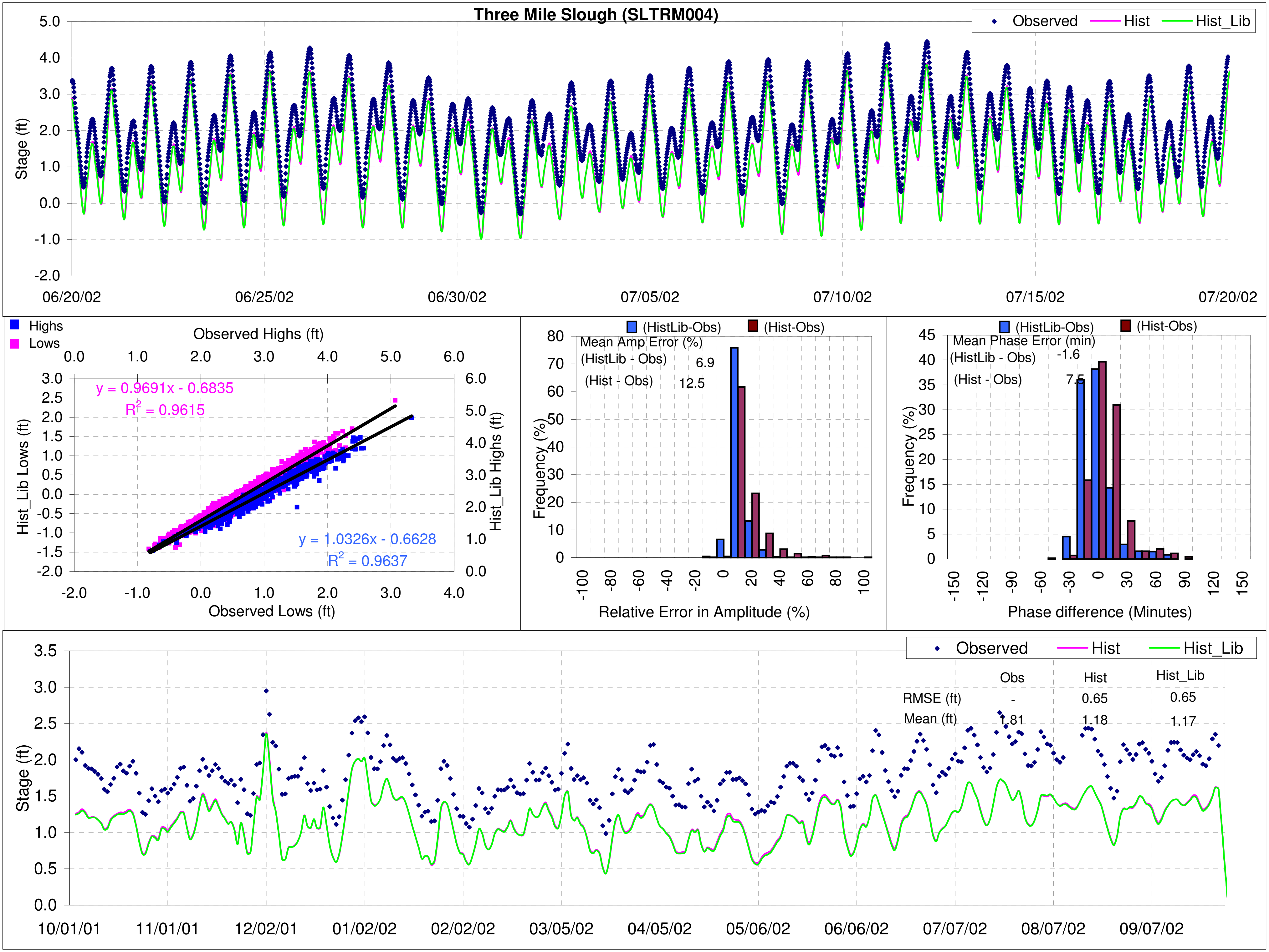

Sacramento River at Martinez (RSAC054)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
y = 1.0016x + 0.0023
R^2 = 0.9995
y = 0.9985x - 0.0024
R^2 = 0.9994
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -0.3
(Hist - Obs) -0.1
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -1.8
(Hist - Obs) 10.7
Phase difference (Minutes)
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02
Obs Hist Hist_Lib
RMSE (ft) - 0.00 0.00
Mean (ft) 0.88 0.88 0.87

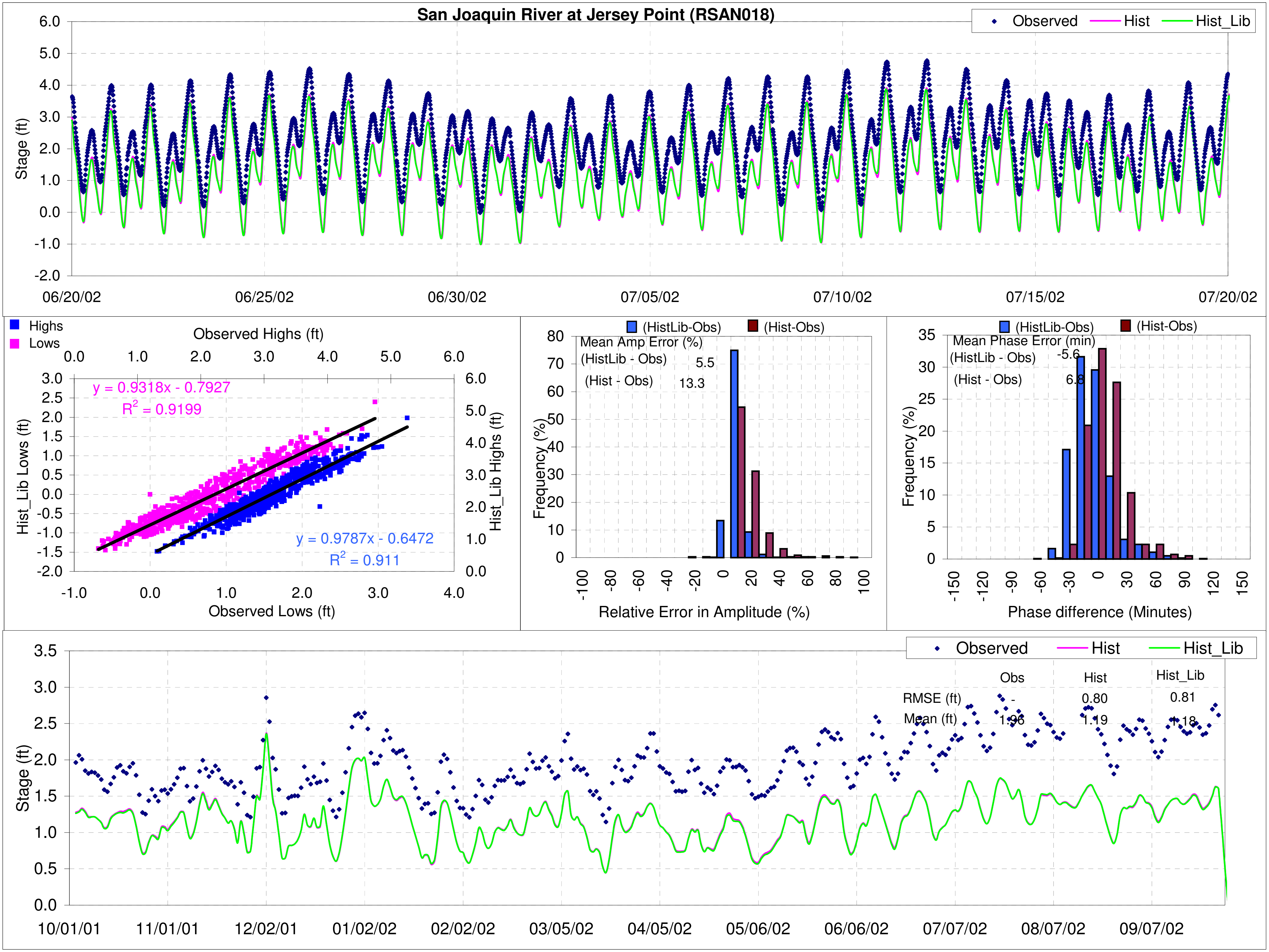

San Joaquin River at Mossdale (RSAN087)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
y = 1.3052x - 0.1776
R2 = 0.8854
y = 1.2657x - 0.3554
R2 = 0.7451
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 8.2
(Hist - Obs) 30.5
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 5.5
(Hist - Obs) -12.8
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.55 0.29
Mean (ft) 2.36 1.81 2.07
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

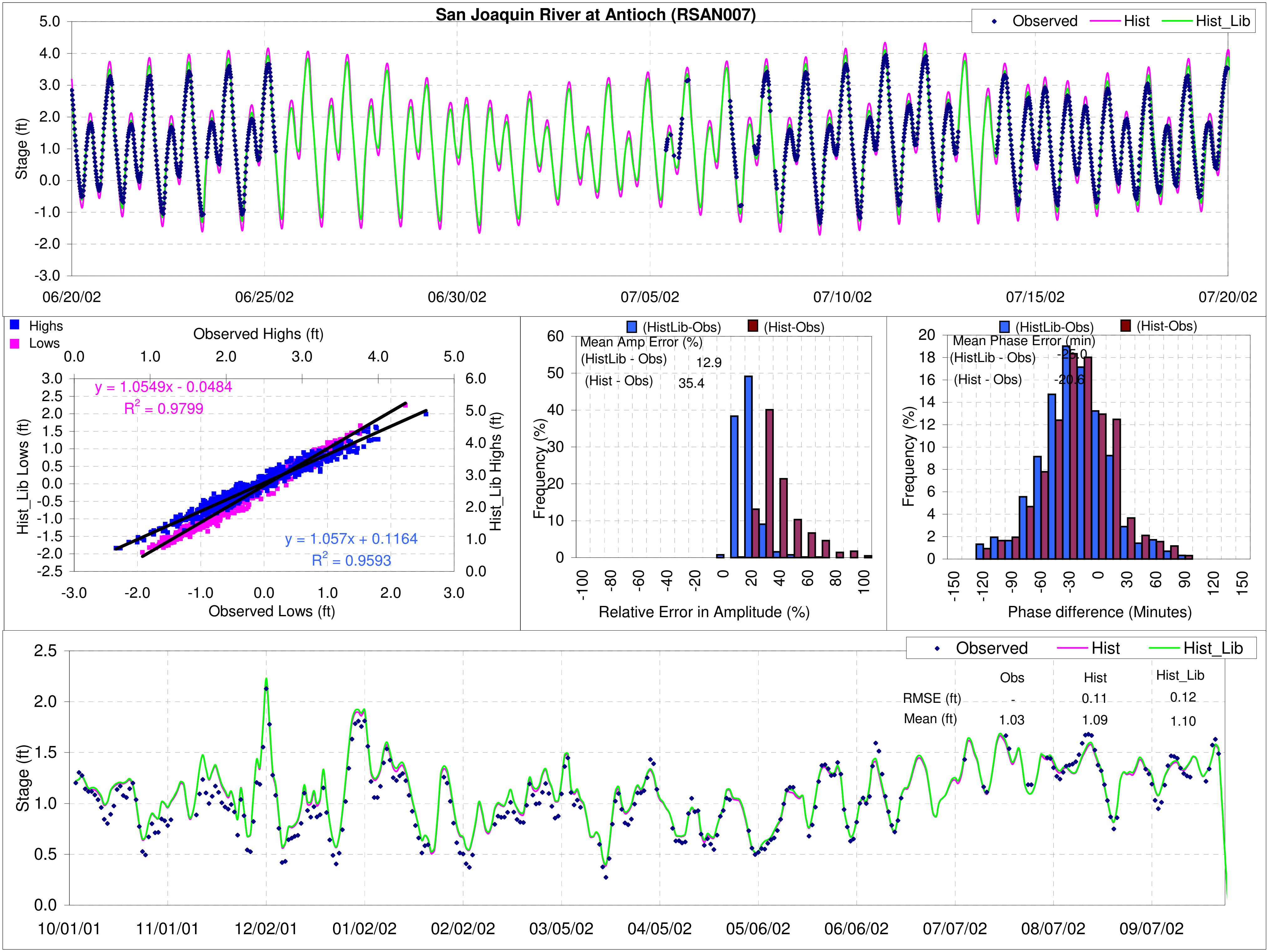

San Joaquin River at Stockton (RSAN063)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 1.0048x - 0.7493
R^2 = 0.9202
y = 1.0614x - 0.5128
R^2 = 0.9454
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 16.0
(Hist - Obs) 18.0
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -24.3
(Hist - Obs) -7.9
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (ft) - 0.57 0.59
Mean (ft) 1.79 1.24 1.21
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

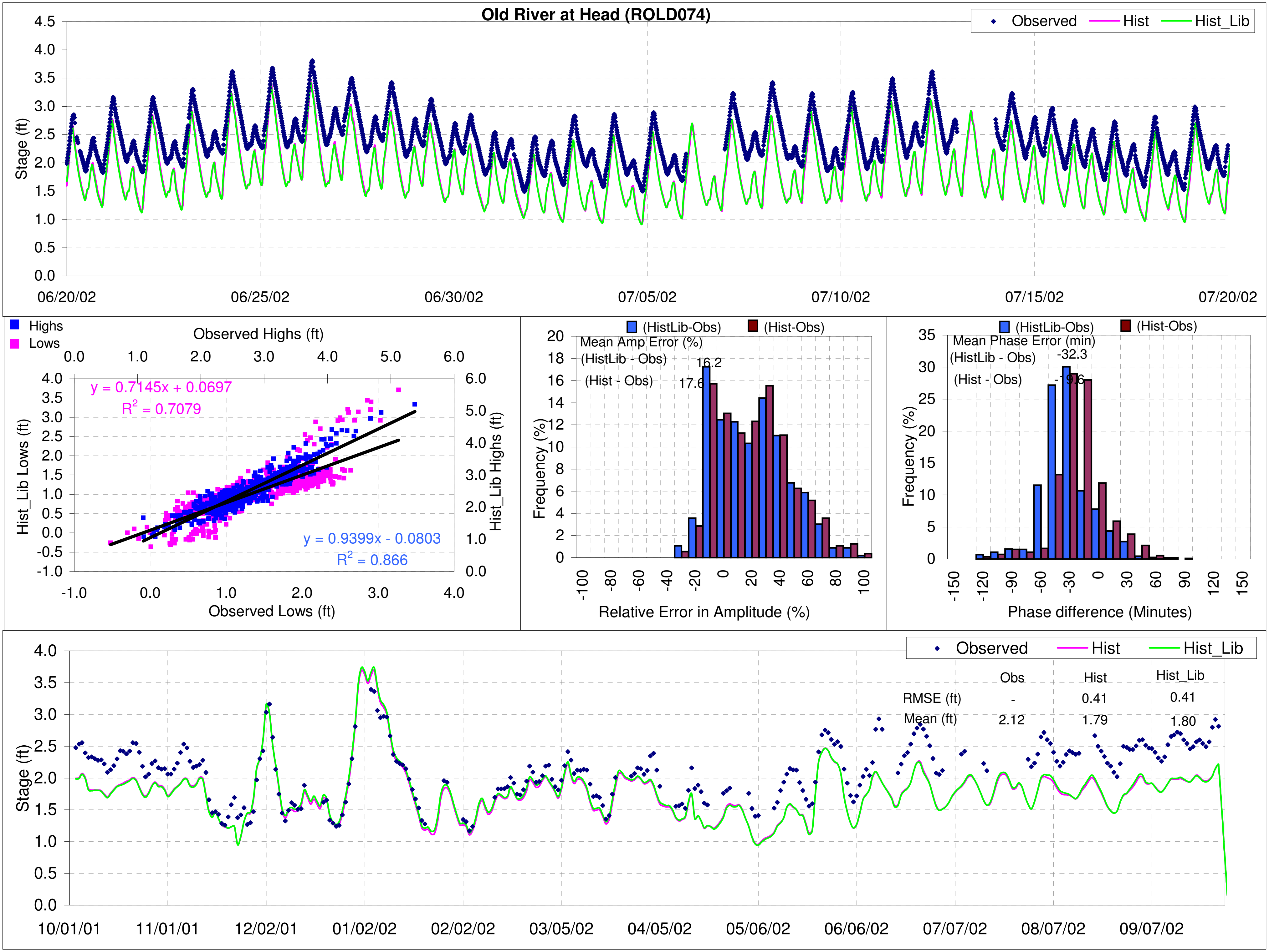

Stockton Ship Channel @ Burns Cutoff (RSAN058)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 1.0024x - 1.018
R^2 = 0.9338
y = 1.0514x - 0.8431
R^2 = 0.9478
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 12.7
(Hist - Obs) 16.5
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -22.8
(Hist - Obs) -9.5
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.88 0.89
Mean (ft) 2.04 1.17 1.16
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02


San Joaquin River at San Andreas Landing (RSAN032)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
y = 0.9954x - 0.4406
R² = 0.9553
y = 1.0473x - 0.2244
R² = 0.9548
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 17.7
(Hist - Obs) 22.1
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 3.1
(Hist - Obs) 14.7
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.30 0.31
Mean (ft) 1.44 1.18 1.17
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

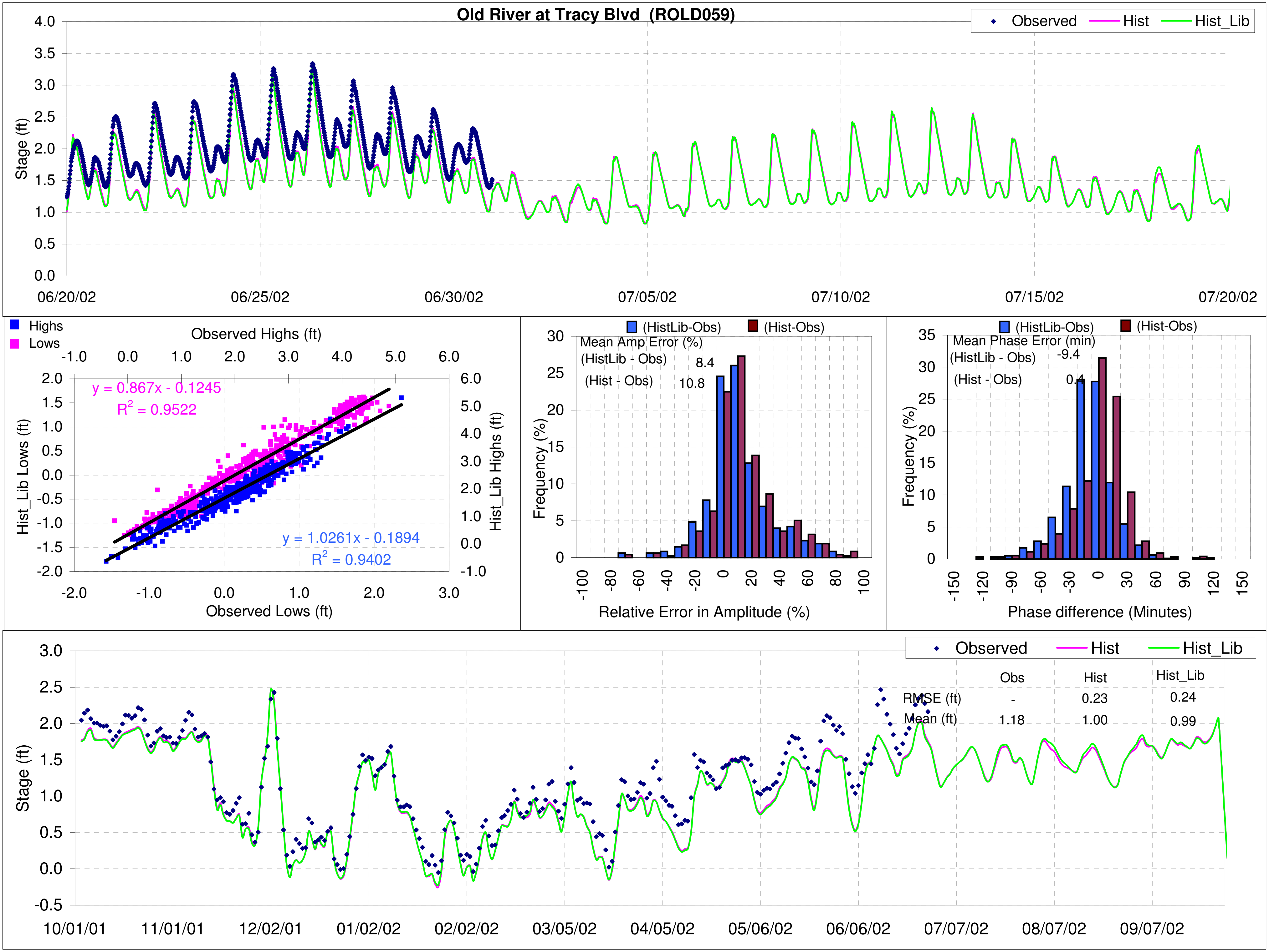

Three Mile Slough (SLTRM004)
Observed
Hist
Hist_Lib
Stage (ft)
5.0 4.0 3.0 2.0 1.0 0.0 -1.0 -2.0
06/20/02 06/25/02 06/30/02 07/05/02 07/10/02 07/15/02 07/20/02
Highs
Lows
Observed Highs (ft)
0.0 1.0 2.0 3.0 4.0 5.0 6.0
y = 0.9691x - 0.6835
R^2 = 0.9615
y = 1.0326x - 0.6628
R^2 = 0.9637
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5 -2.0
6.0 5.0 4.0 3.0 2.0 1.0 0.0
-2.0 -1.0 0.0 1.0 2.0 3.0 4.0
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 6.9
(Hist - Obs) 12.5
Frequency (%)
80 70 60 50 40 30 20 10 0
-100 -80 -60 -40 -20 0 20 40 60 80 100
Relative Error in Amplitude (%)
(HistLib-Obs)
(Hist-Obs)
Mean Phase Error (min)
(HistLib - Obs) -1.6
(Hist - Obs) 7.5
Frequency (%)
45 40 35 30 25 20 15 10 5 0
-150 -120 -90 -60 -30 0 30 60 90 120 150
Phase difference (Minutes)
Observed
Hist
Hist_Lib
Obs Hist Hist_Lib
RMSE (ft) - 0.65 0.65
Mean (ft) 1.81 1.18 1.17
Stage (ft)
3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
10/01/01 11/01/01 12/02/01 01/02/02 02/02/02 03/05/02 04/05/02 05/06/02 06/06/02 07/07/02 08/07/02 09/07/02


San Joaquin River at Jersey Point (RSAN018)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 0.9318x - 0.7927
R2 = 0.9199
y = 0.9787x - 0.6472
R2 = 0.911
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 5.5
(Hist - Obs) 13.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -5.6
(Hist - Obs) 6.8
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.80 0.81
Mean (ft) 1.96 1.19 1.18
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

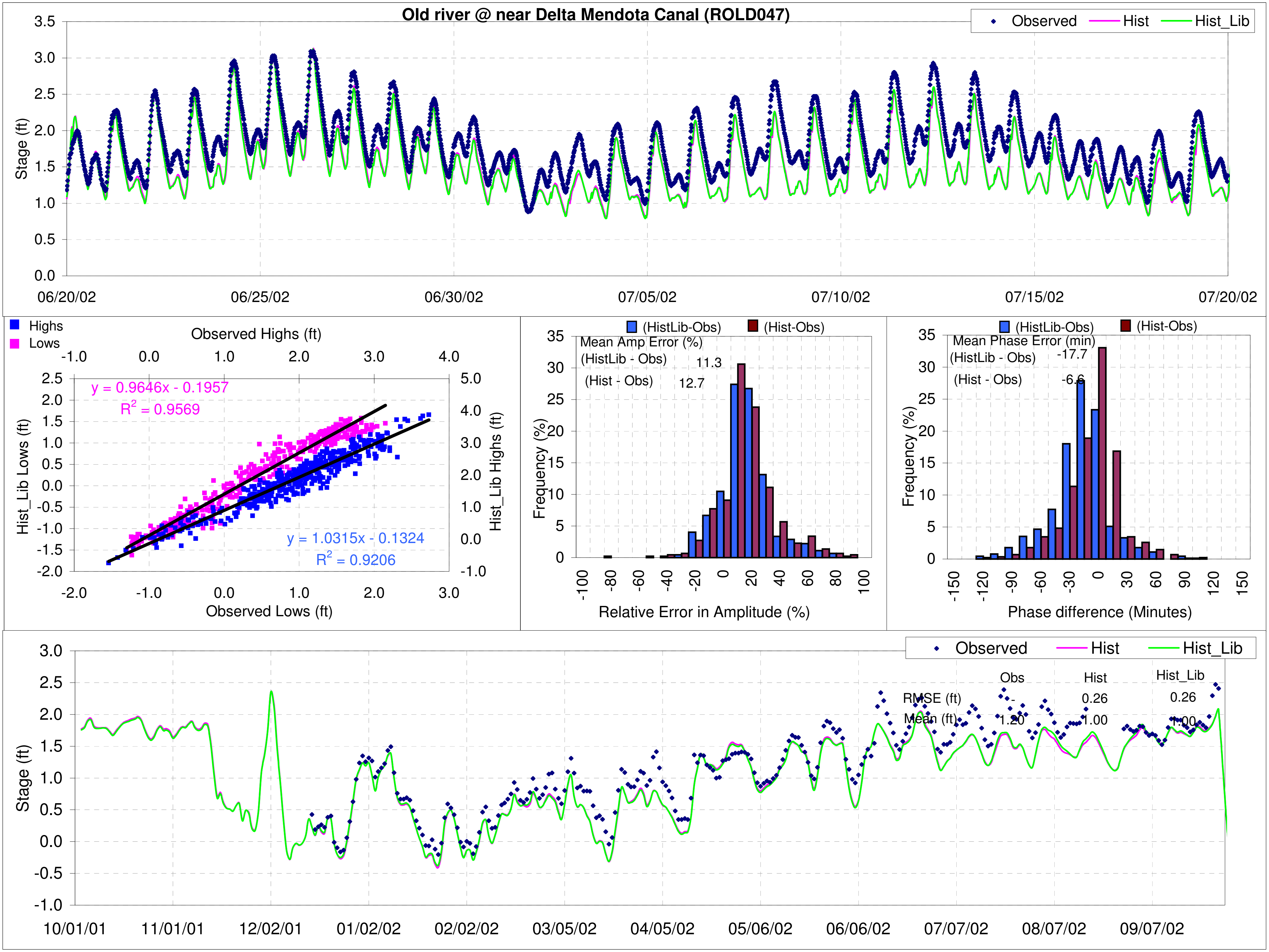

San Joaquin River at Antioch (RSAN007)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 1.0549x - 0.0484
R2 = 0.9799
y = 1.057x + 0.1164
R2 = 0.9593
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 12.9
(Hist - Obs) 35.4
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -25.0
(Hist - Obs) -20.6
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.11 0.12
Mean (ft) 1.03 1.09 1.10
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02



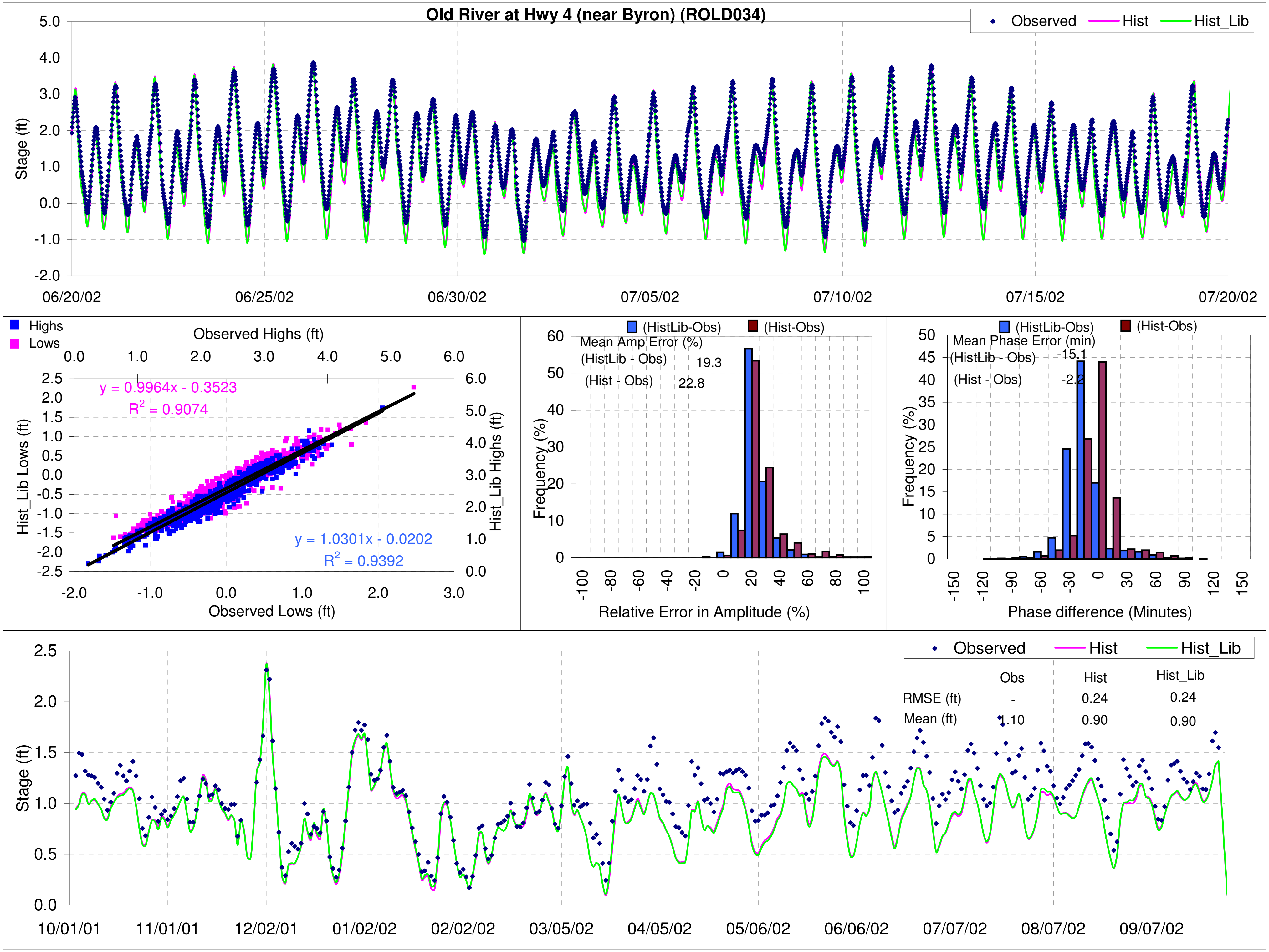
Old River at Head (ROLD074)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 0.7145x + 0.0697
R2 = 0.7079
y = 0.9399x - 0.0803
R2 = 0.866
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs)
16.2
(Hist - Obs)
17.6
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs)
-32.3
(Hist - Obs)
-19.6
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft)
-
0.41
0.41
Mean (ft)
2.12
1.79
1.80
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02



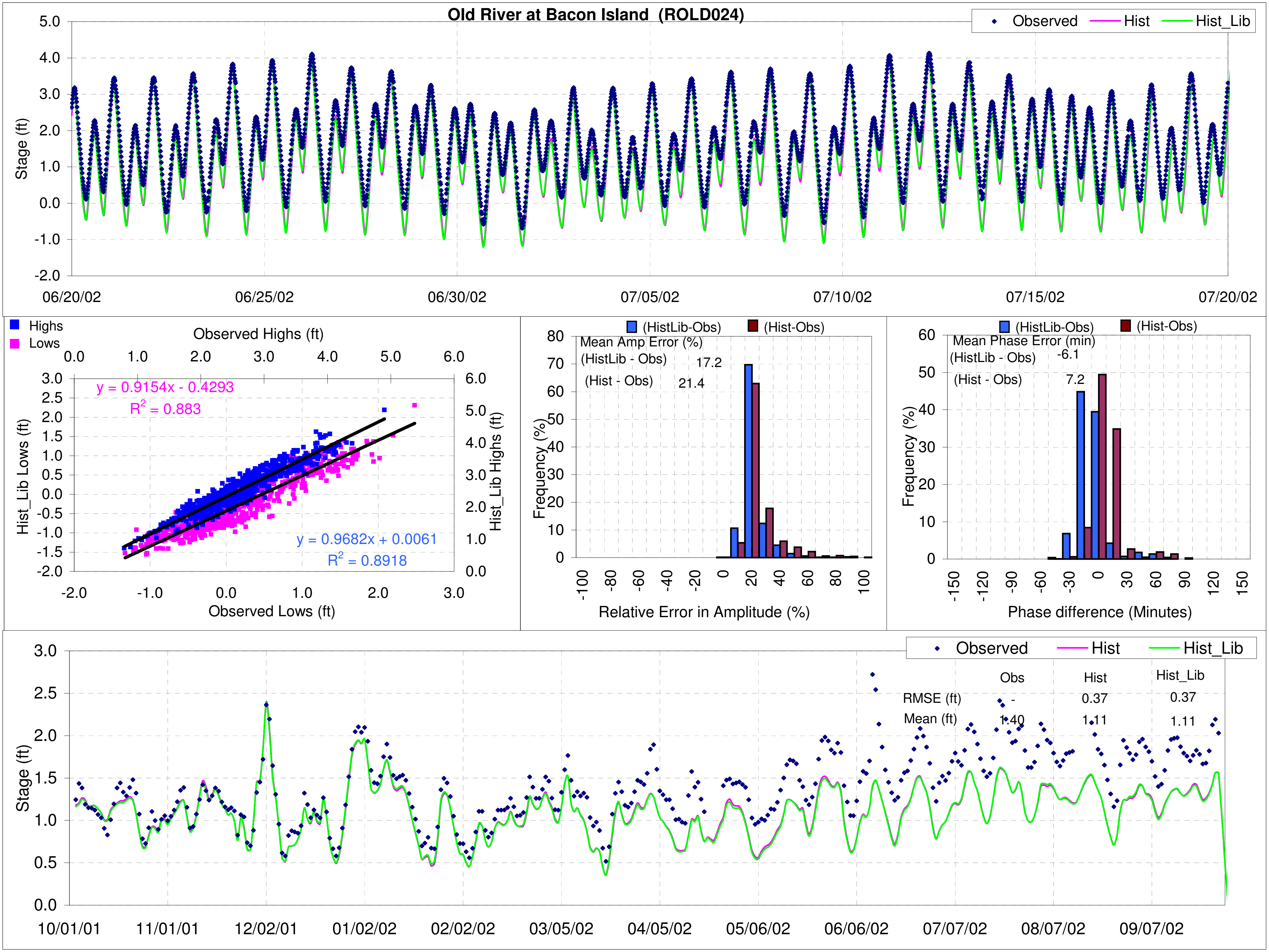
Old River at Tracy Blvd (ROLD059)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
Observed Lows (ft)
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
y = 0.867x - 0.1245
R^2 = 0.9522
y = 1.0261x - 0.1894
R^2 = 0.9402
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 8.4
(Hist - Obs) 10.8
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -9.4
(Hist - Obs) 0.4
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.23 0.24
Mean (ft) 1.18 1.00 0.99
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02



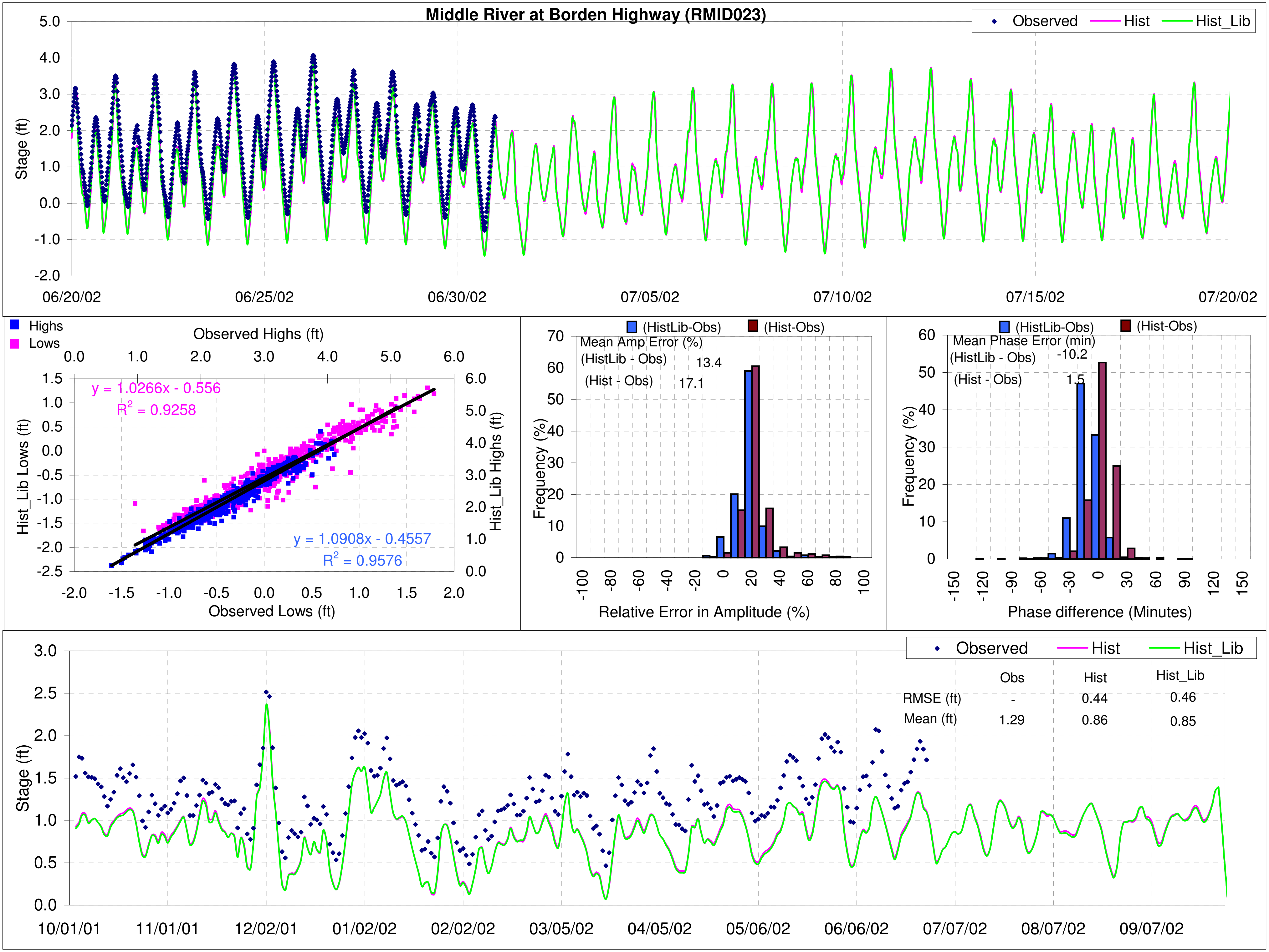
Old river @ near Delta Mendota Canal (ROLD047)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 0.9646x - 0.1957
R2 = 0.9569
y = 1.0315x - 0.1324
R2 = 0.9206
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 11.3
(Hist - Obs) 12.7
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -17.7
(Hist - Obs) -6.6
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.26 0.26
Mean (ft) 1.20 1.00 1.00
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

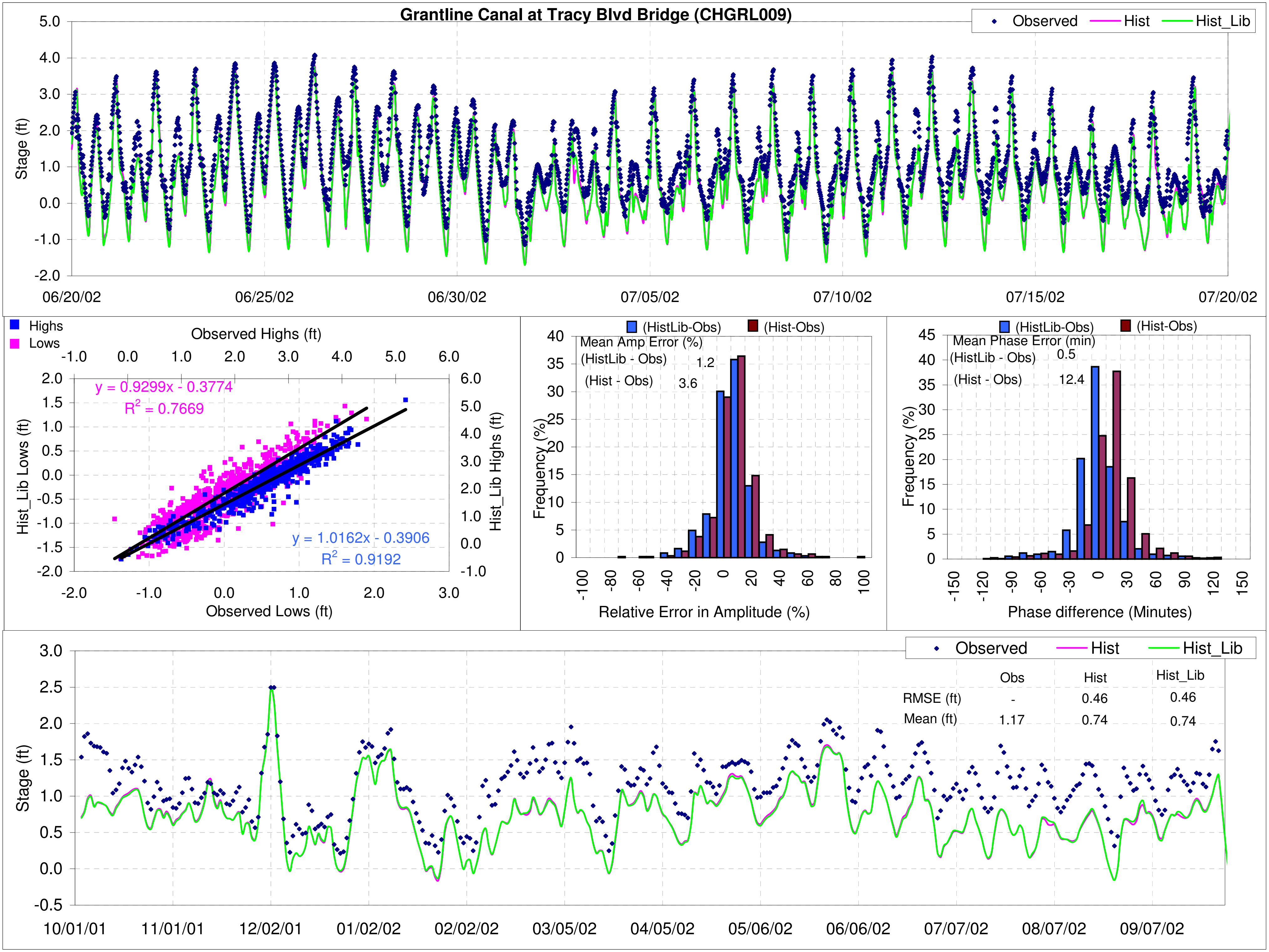


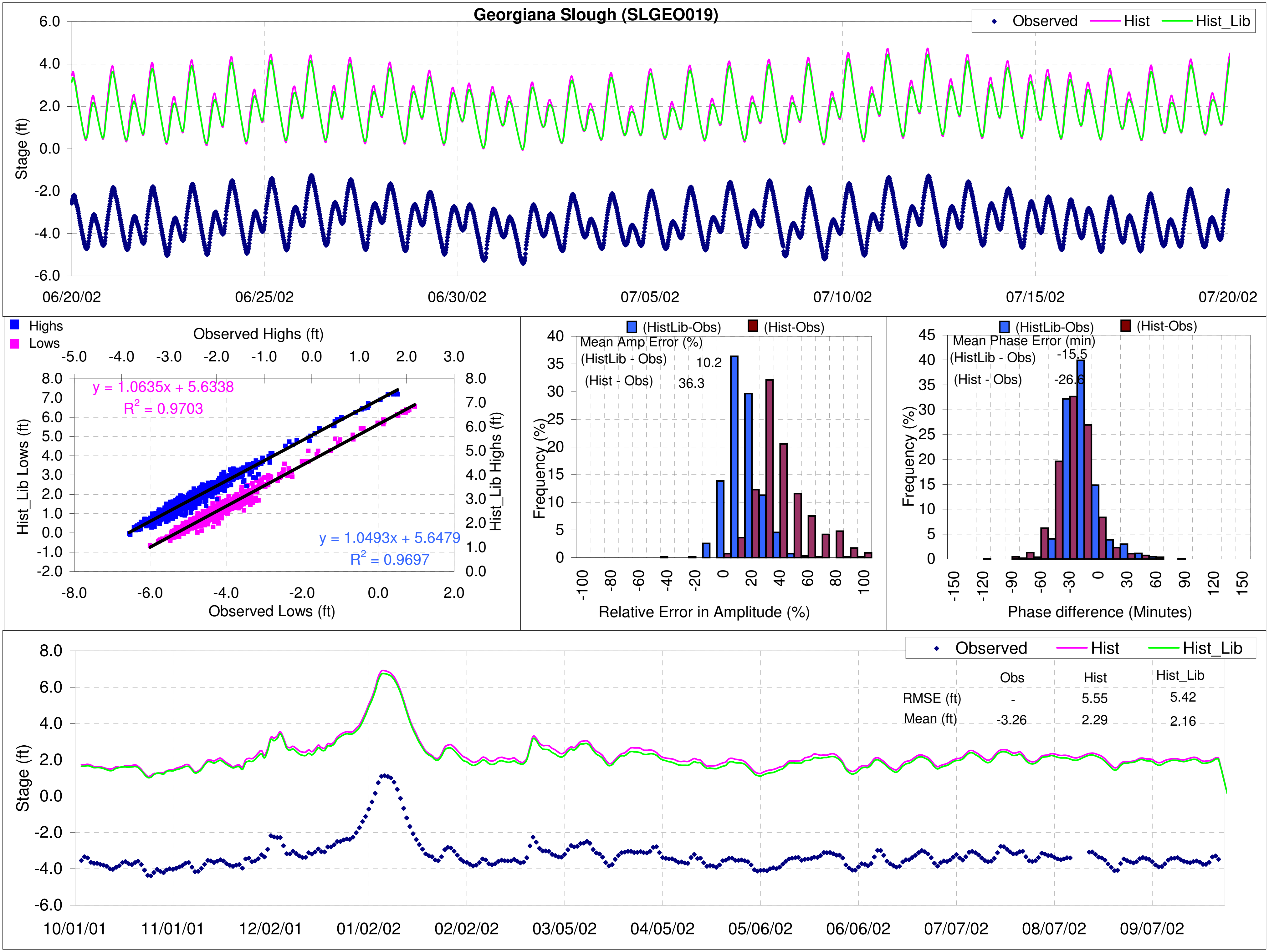
Old River at Hwy 4 (near Byron) (ROLD034)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 0.9964x - 0.3523
R2 = 0.9074
y = 1.0301x - 0.0202
R2 = 0.9392
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 19.3
(Hist - Obs) 22.8
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -15.1
(Hist - Obs) -2.2
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.24 0.24
Mean (ft) 1.10 0.90 0.90
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

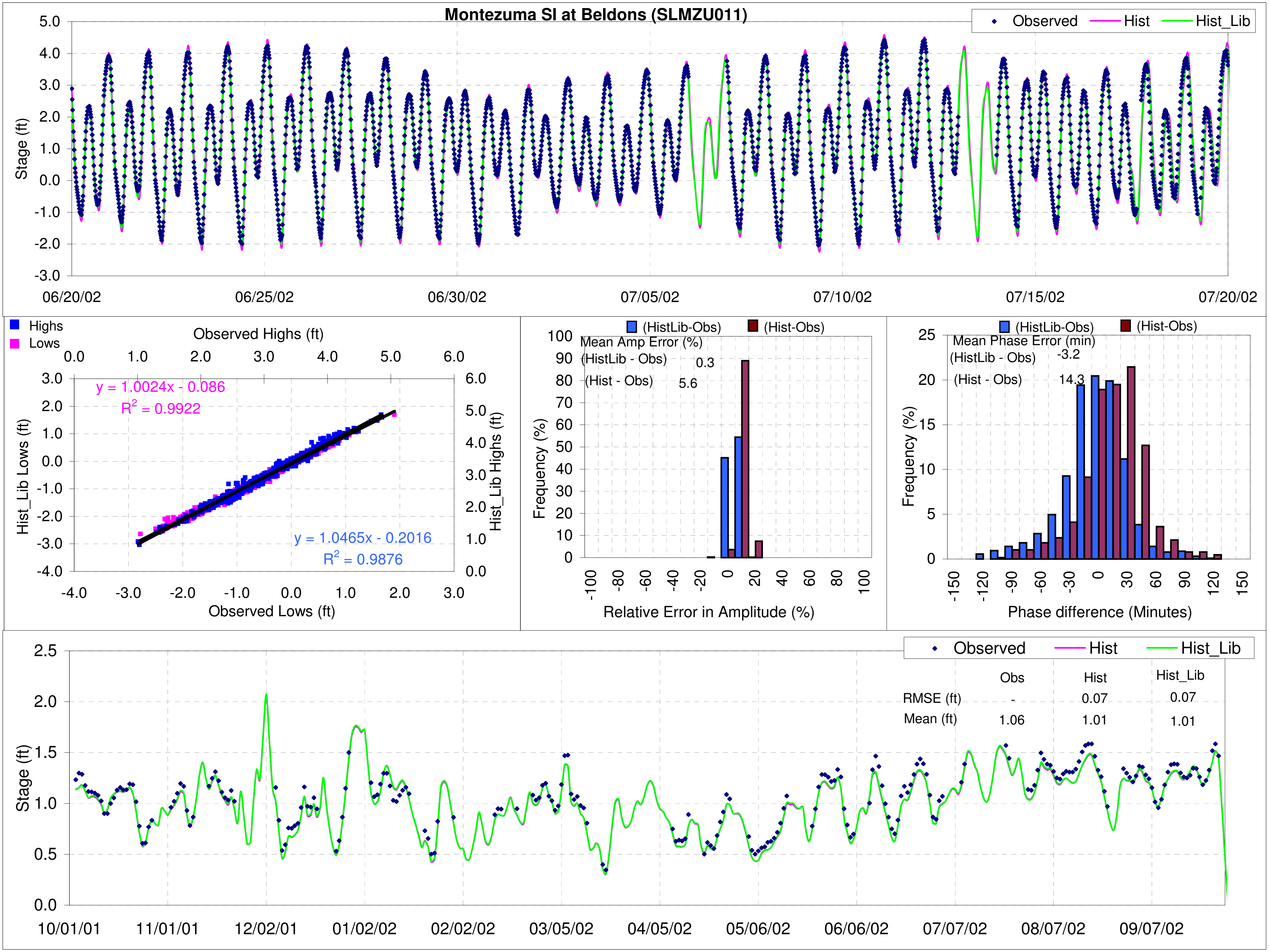


Old River at Bacon Island (ROLD024)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 0.9154x - 0.4293
R^2 = 0.883
y = 0.9682x + 0.0061
R^2 = 0.8918
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 17.2
(Hist - Obs) 21.4
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -6.1
(Hist - Obs) 7.2
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.37 0.37
Mean (ft) 1.40 1.11 1.11
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

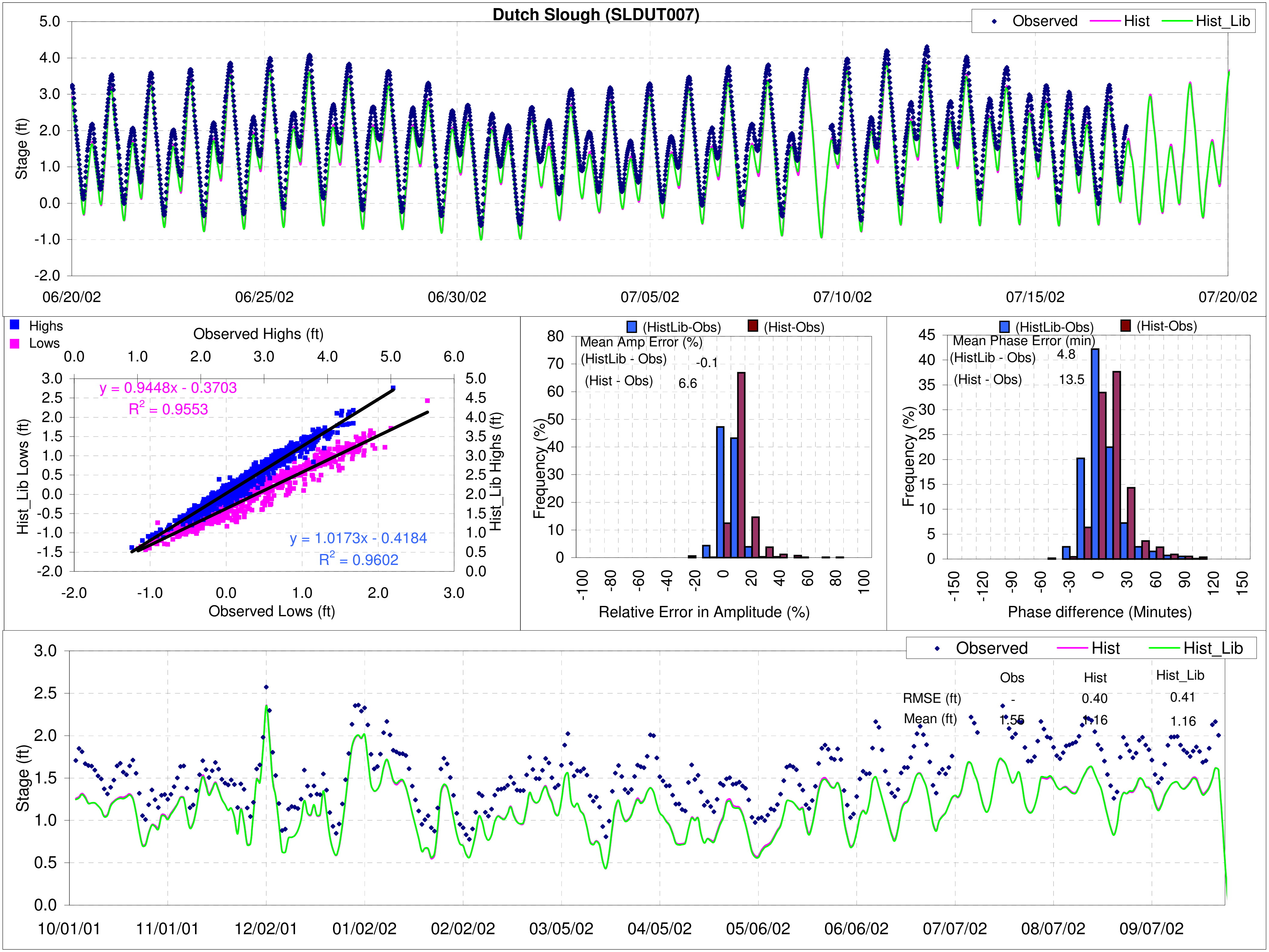

Middle River at Borden Highway (RMID023)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 1.0266x - 0.556
R^2 = 0.9258
y = 1.0908x - 0.4557
R^2 = 0.9576
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 13.4
(Hist - Obs) 17.1
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -10.2
(Hist - Obs) 1.5
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.44 0.46
Mean (ft) 1.29 0.86 0.85
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02


Grantline Canal at Tracy Blvd Bridge (CHGRL009)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 0.9299x - 0.3774
R2 = 0.7669
y = 1.0162x - 0.3906
R2 = 0.9192
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 1.2
(Hist - Obs) 3.6
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 0.5
(Hist - Obs) 12.4
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.46 0.46
Mean (ft) 1.17 0.74 0.74
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02


Georgiana Slough (SLGEO019)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 1.0635x + 5.6338
R2 = 0.9703
y = 1.0493x + 5.6479
R2 = 0.9697
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 10.2
(Hist - Obs) 36.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -15.5
(Hist - Obs) -26.6
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 5.55 5.42
Mean (ft) -3.26 2.29 2.16
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

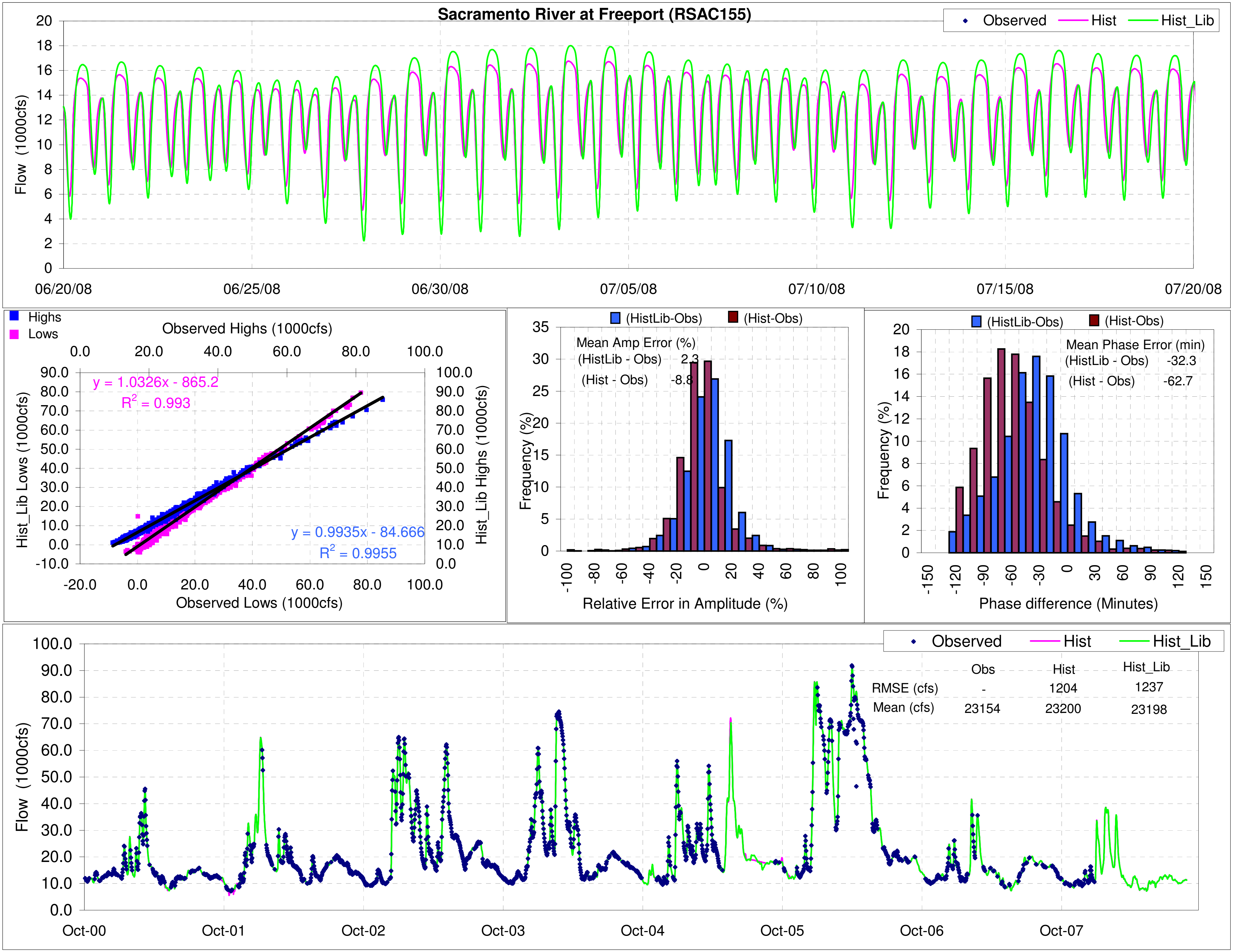


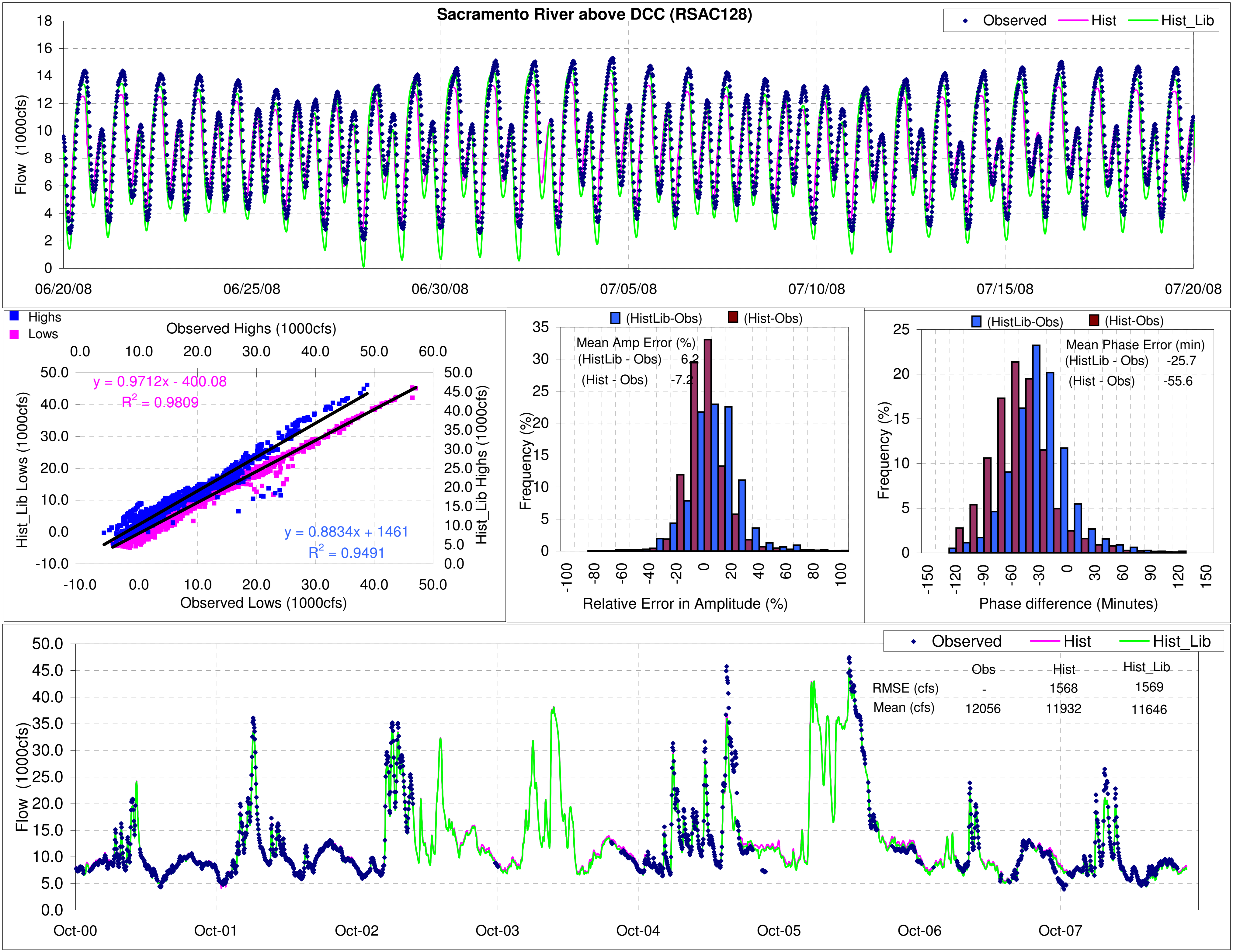
Montezuma Sl at Beldons (SLMZU011)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
y = 1.0024x - 0.086
R2 = 0.9922
y = 1.0465x - 0.2016
R2 = 0.9876
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 0.3
(Hist - Obs) 5.6
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -3.2
(Hist - Obs) 14.3
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.07 0.07
Mean (ft) 1.06 1.01 1.01
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

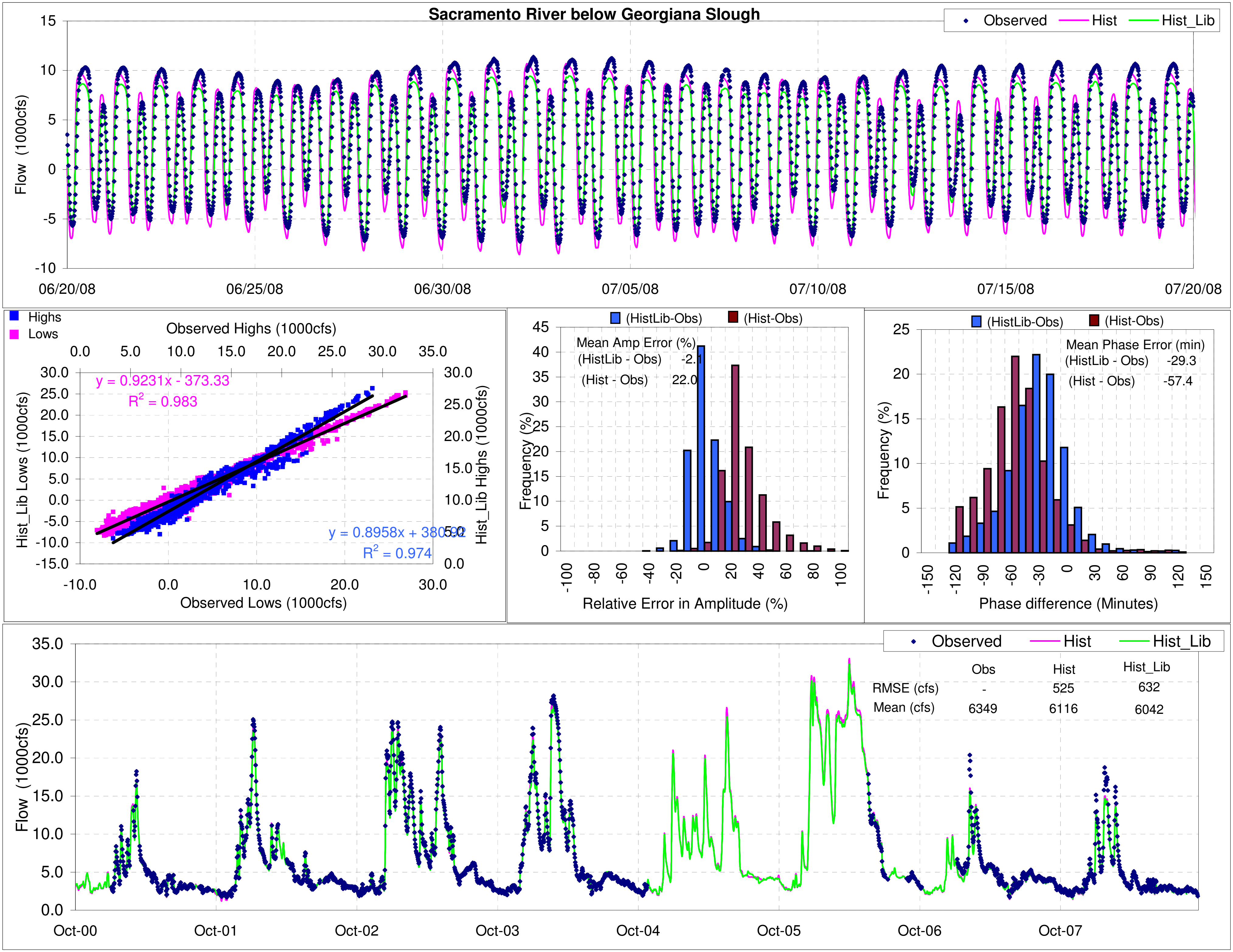


Dutch Slough (SLDUT007)
Observed
Hist
Hist_Lib
Stage (ft)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
06/20/02
06/25/02
06/30/02
07/05/02
07/10/02
07/15/02
07/20/02
Highs
Lows
Observed Highs (ft)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
y = 0.9448x - 0.3703
R^2 = 0.9553
y = 1.0173x - 0.4184
R^2 = 0.9602
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -0.1
(Hist - Obs) 6.6
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 4.8
(Hist - Obs) 13.5
Phase difference (Minutes)
Observed
Hist
Hist_Lib
Obs
Hist
Hist_Lib
RMSE (ft) - 0.40 0.41
Mean (ft) 1.55 1.16 1.16
Stage (ft)
10/01/01
11/01/01
12/02/01
01/02/02
02/02/02
03/05/02
04/05/02
05/06/02
06/06/02
07/07/02
08/07/02
09/07/02

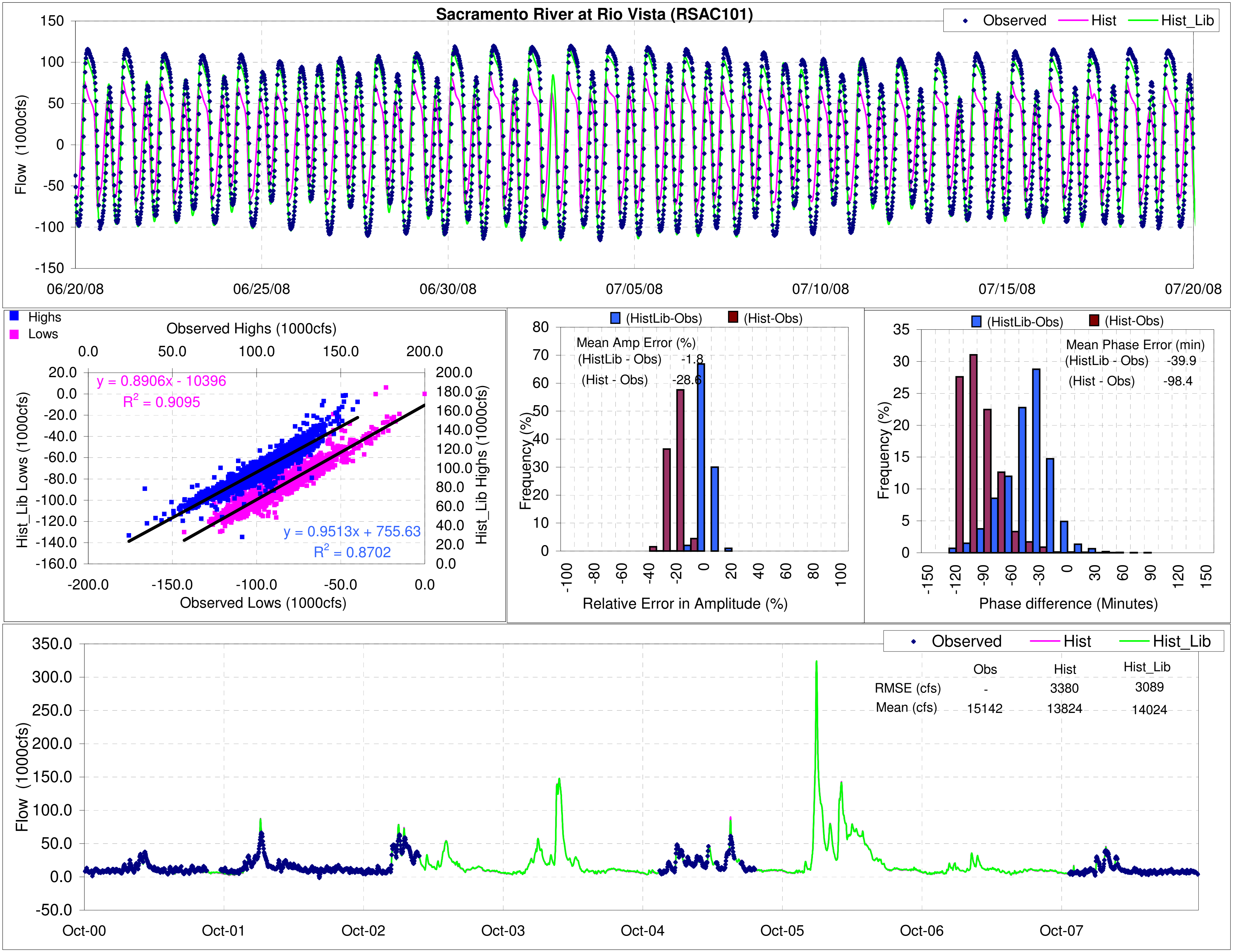
Appendix B
Detailed HYDRO Validation Results


Sacramento River at Freeport (RSAC155)
Observed
Hist
Hist_Lib
Flow (1000cfs)
0
2
4
6
8
10
12
14
16
18
20
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
0.0
20.0
40.0
60.0
80.0
100.0
y = 1.0326x - 865.2
R^2 = 0.993
y = 0.9935x - 84.666
R^2 = 0.9955
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 2.3
(Hist - Obs) -8.8
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -32.3
(Hist - Obs) -62.7
Phase difference (Minutes)
Observed
Hist
Hist_Lib
Obs
Hist
Hist_Lib
RMSE (cfs)
-
1204
1237
Mean (cfs)
23154
23200
23198
Flow (1000cfs)
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

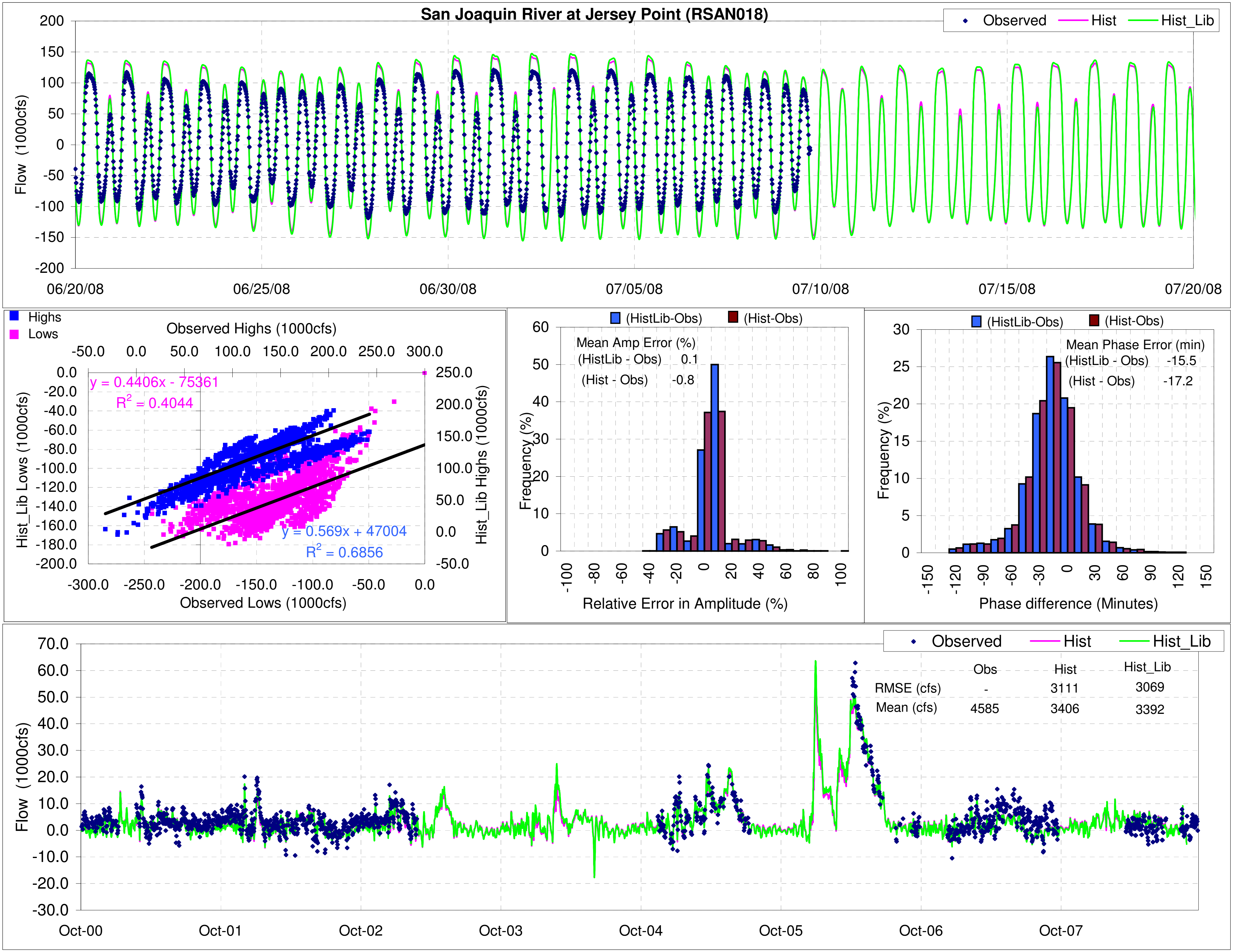

Sacramento River above DCC (RSAC128)
Observed
Hist
Hist_Lib
Flow (1000cfs)
18
16
14
12
10
8
6
4
2
0
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
y = 0.9712x - 400.08
R^2 = 0.9809
y = 0.8834x + 1461
R^2 = 0.9491
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 6.2
(Hist - Obs) -7.2
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -25.7
(Hist - Obs) -55.6
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 1568 1569
Mean (cfs) 12056 11932 11646
Flow (1000cfs)
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

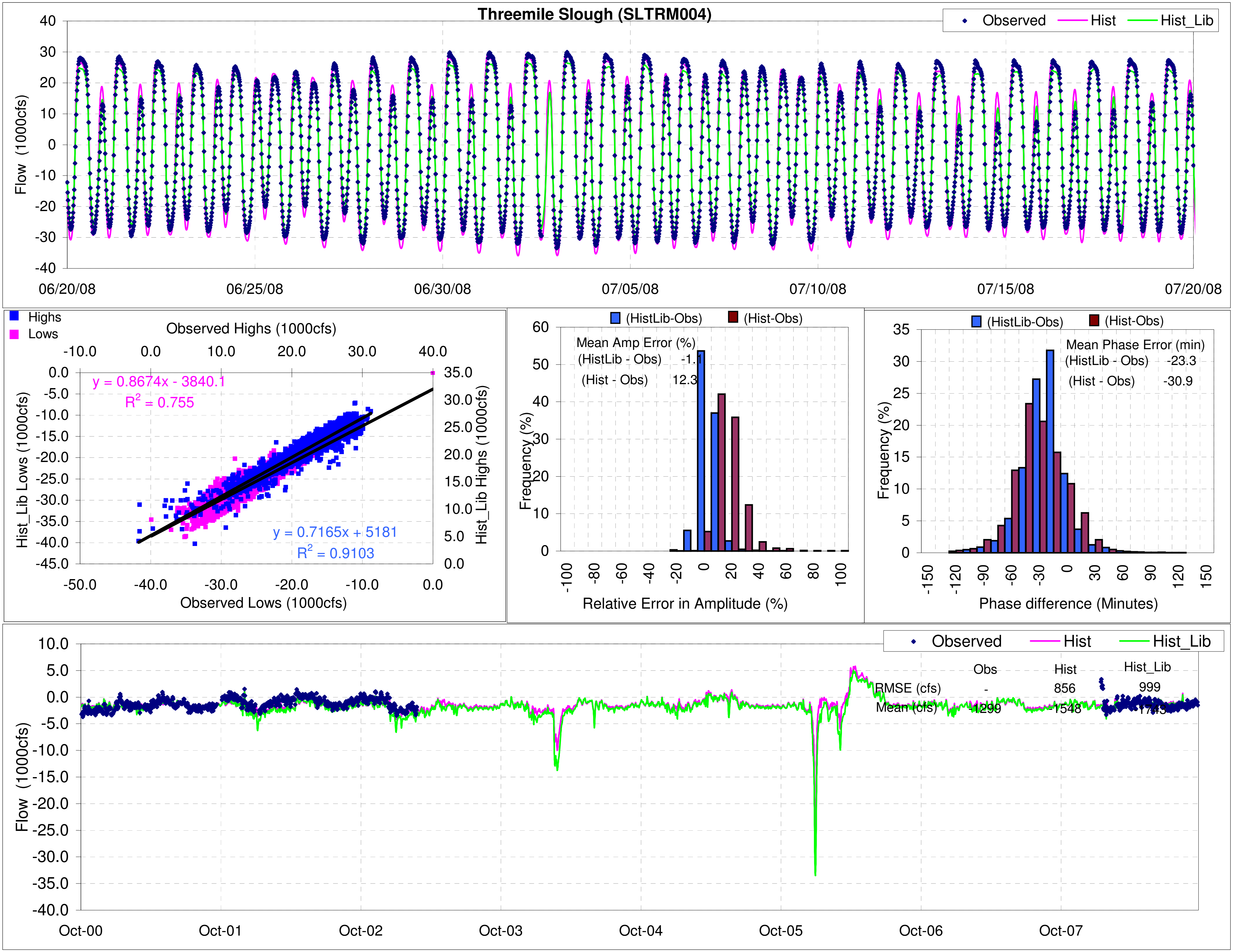


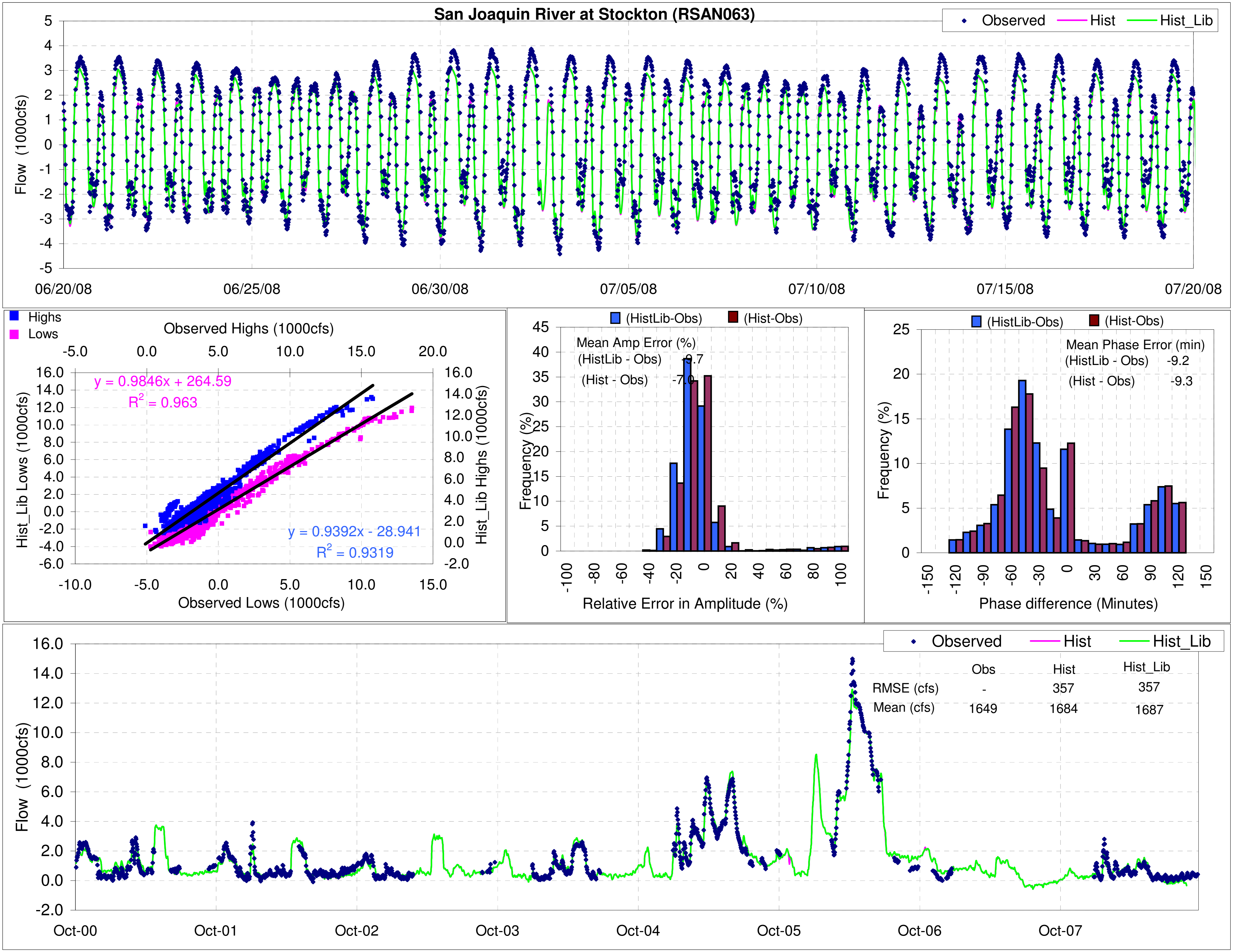
Sacramento River below Georgiana Slough
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
Observed Lows (1000cfs)
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
y = 0.9231x - 373.33
R2 = 0.983
y = 0.8958x + 380.92
R2 = 0.974
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -2.1
(Hist - Obs) 22.0
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -29.3
(Hist - Obs) -57.4
Phase difference (Minutes)
Flow (1000cfs)
Obs
Hist
Hist_Lib
RMSE (cfs)
-
525
632
Mean (cfs)
6349
6116
6042
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

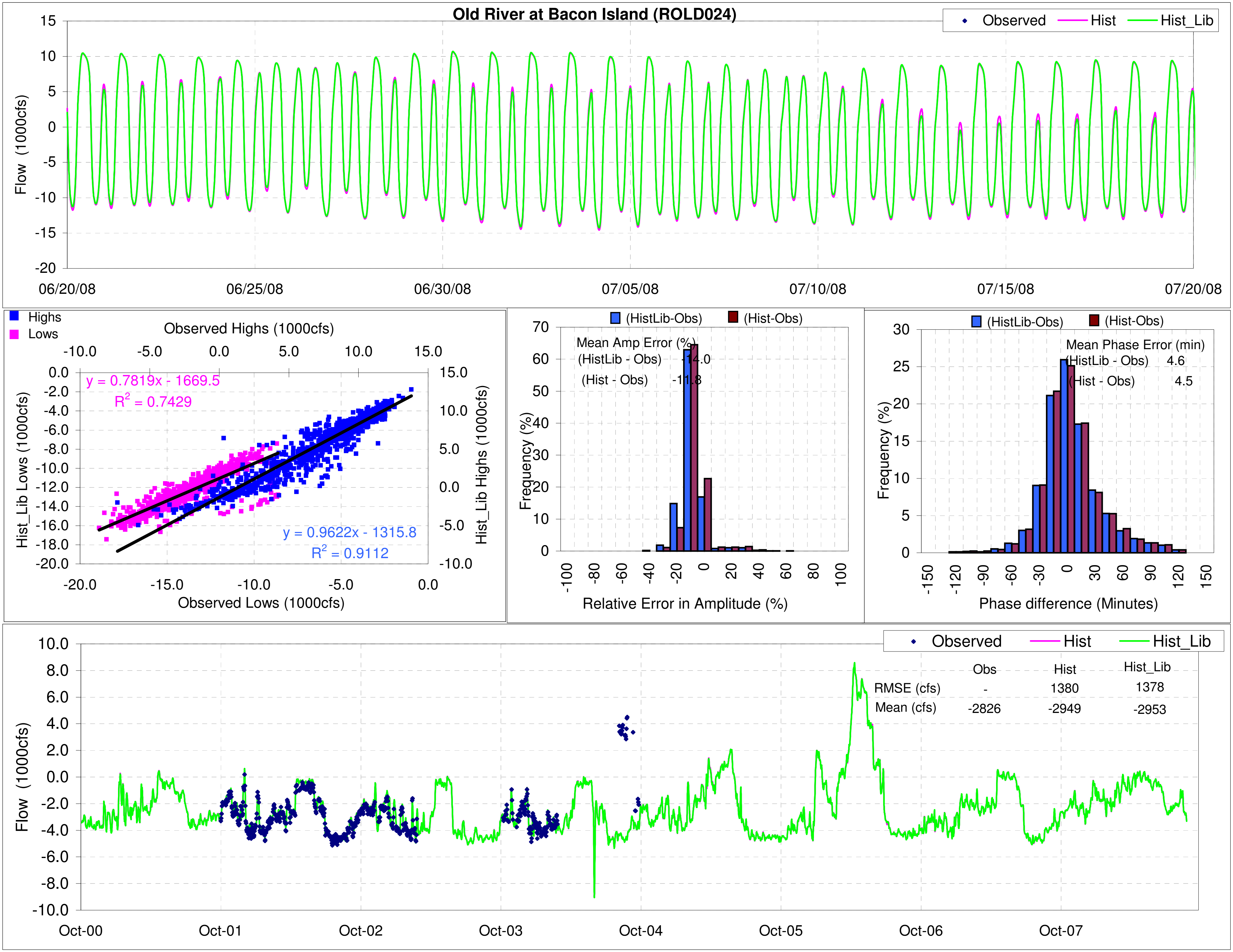


Sacramento River at Rio Vista (RSAC101)
Observed
Hist
Hist_Lib
Flow (1000cfs)
150
100
50
0
-50
-100
-150
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
0.0
50.0
100.0
150.0
200.0
y = 0.8906x - 10396
R² = 0.9095
y = 0.9513x + 755.63
R² = 0.8702
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
-200.0
-150.0
-100.0
-50.0
0.0
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -1.8
(Hist - Obs) -28.6
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -39.9
(Hist - Obs) -98.4
Phase difference (Minutes)
Observed
Hist
Hist_Lib
Obs
Hist
Hist_Lib
RMSE (cfs)
-
3380
3089
Mean (cfs)
15142
13824
14024
Flow (1000cfs)
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
-50.0
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

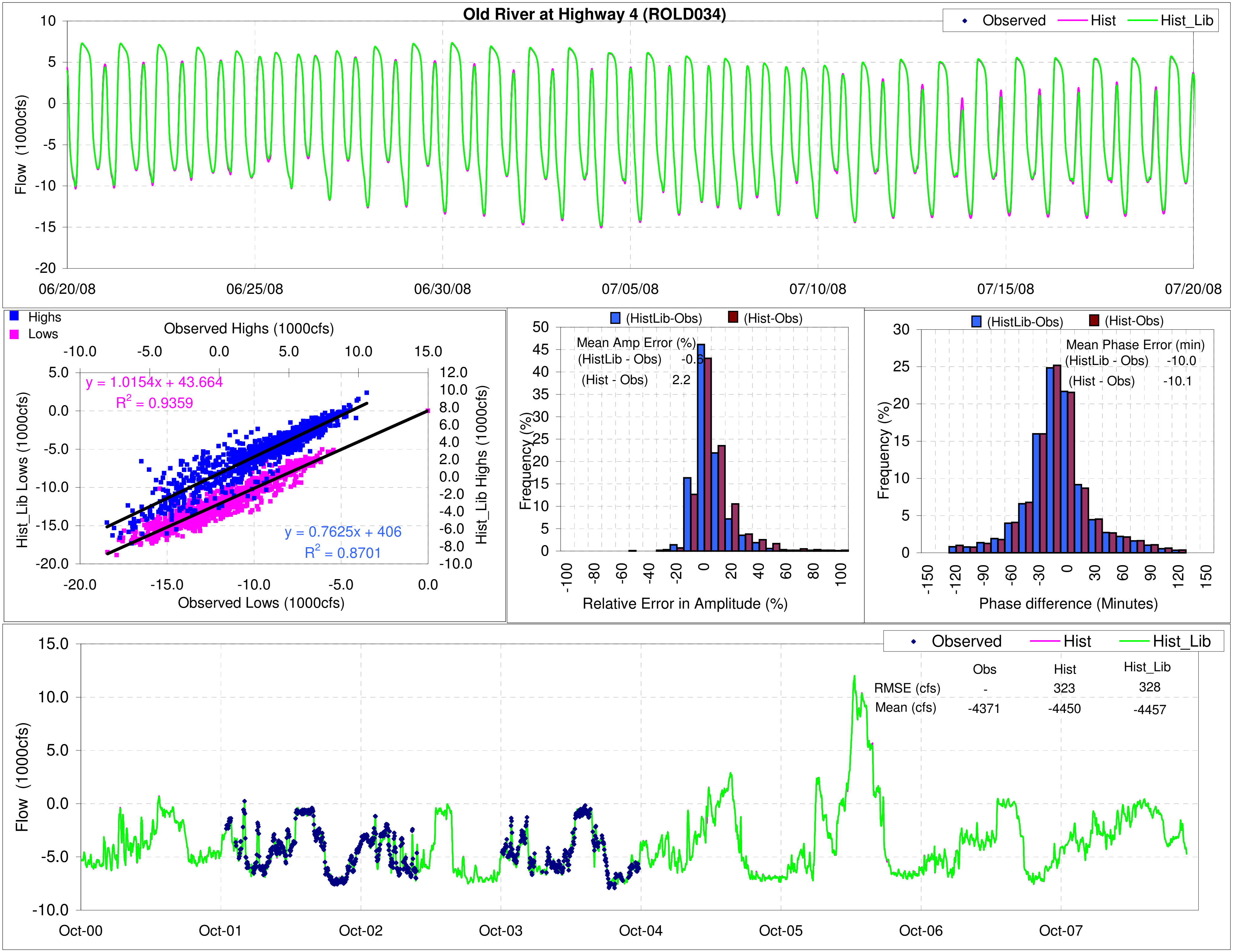

San Joaquin River at Jersey Point (RSAN018)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
y = 0.4406x - 75361
R2 = 0.4044
y = 0.569x + 47004
R2 = 0.6856
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 0.1
(Hist - Obs) -0.8
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -15.5
(Hist - Obs) -17.2
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 3111 3069
Mean (cfs) 4585 3406 3392
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

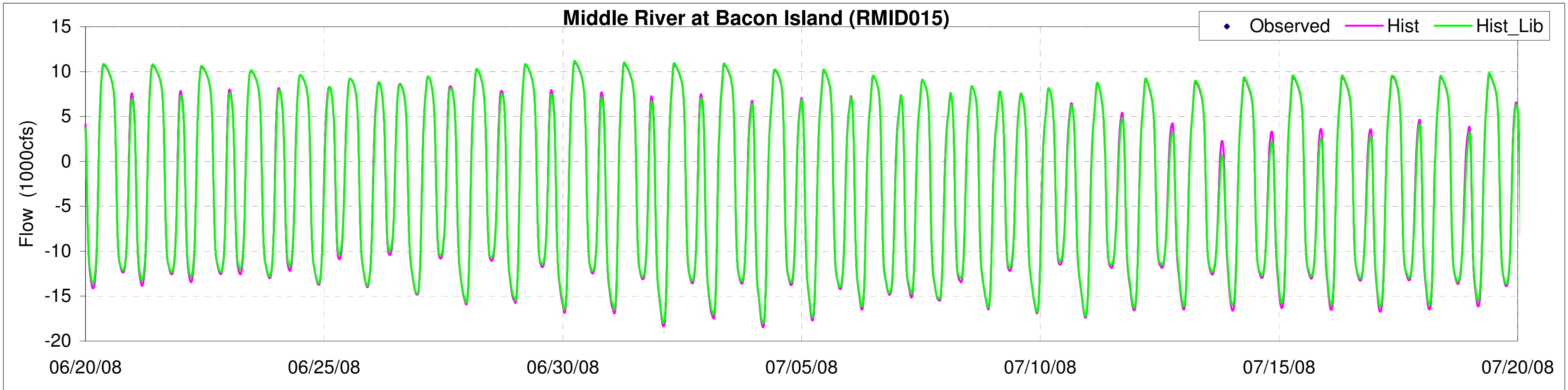

Threemile Slough (SLTRM004)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
y = 0.8674x - 3840.1
R^2 = 0.755
y = 0.7165x + 5181
R^2 = 0.9103
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -1.1
(Hist - Obs) 12.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -23.3
(Hist - Obs) -30.9
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs)
-
856
999
Mean (cfs)
-1299
-1548
-1743
Flow (1000cfs)
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

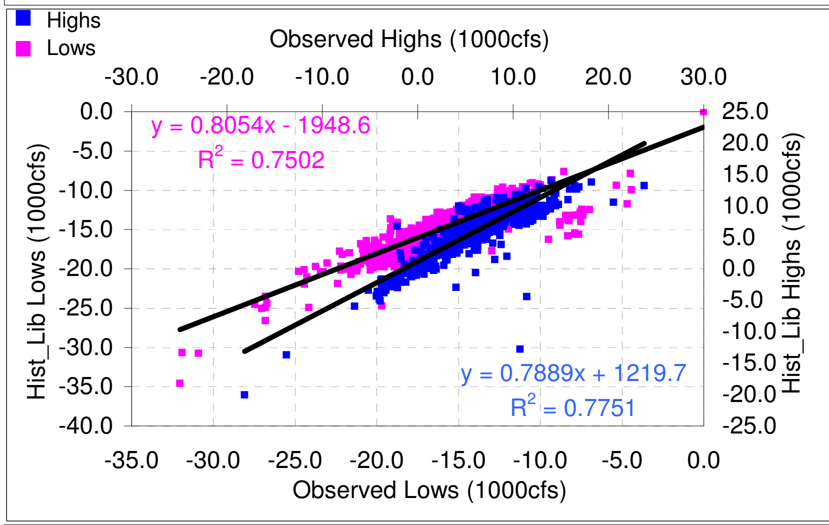

San Joaquin River at Stockton (RSAN063)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
y = 0.9846x + 264.59
R² = 0.963
y = 0.9392x - 28.941
R² = 0.9319
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -9.7
(Hist - Obs) -7.0
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -9.2
(Hist - Obs) -9.3
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 357 357
Mean (cfs) 1649 1684 1687
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

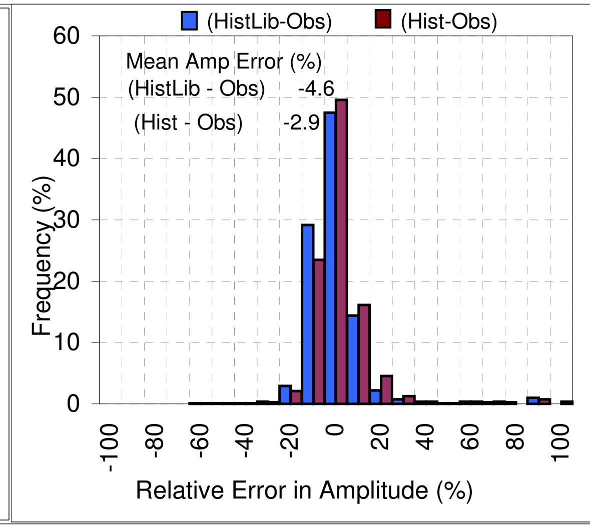


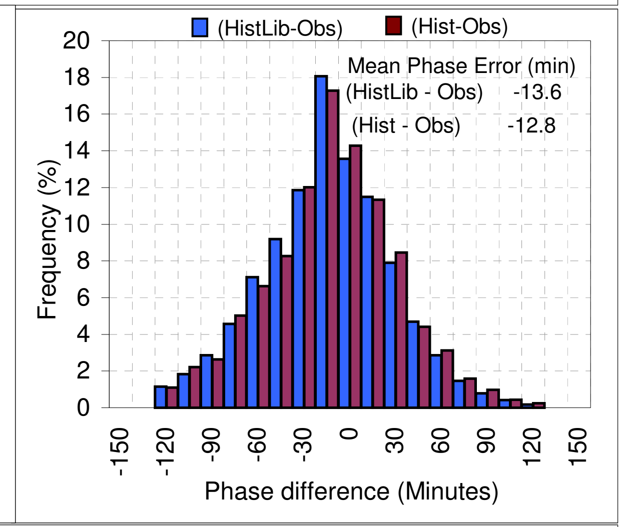
Old River at Bacon Island (ROLD024)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
y = 0.7819x - 1669.5
R^2 = 0.7429
y = 0.9622x - 1315.8
R^2 = 0.9112
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -14.0
(Hist - Obs) -11.8
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 4.6
(Hist - Obs) 4.5
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs)
-
1380
1378
Mean (cfs)
-2826
-2949
-2953
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

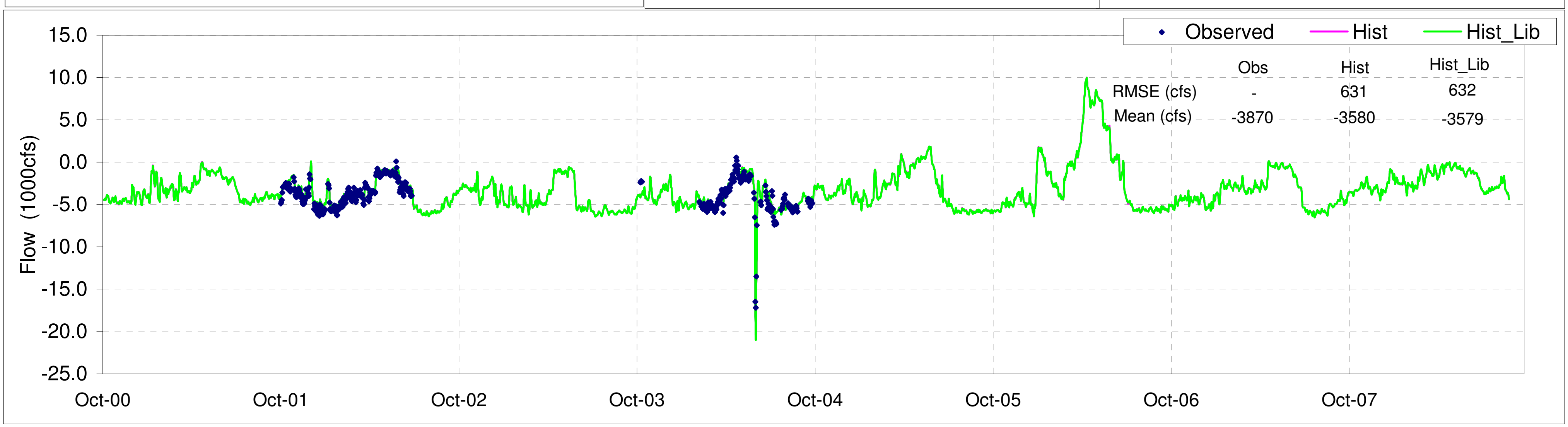

Old River at Highway 4 (ROLD034)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
y = 1.0154x + 43.664
R2 = 0.9359
y = 0.7625x + 406
R2 = 0.8701
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -0.6
(Hist - Obs) 2.2
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -10.0
(Hist - Obs) -10.1
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs)
-
323
328
Mean (cfs)
-4371
-4450
-4457
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

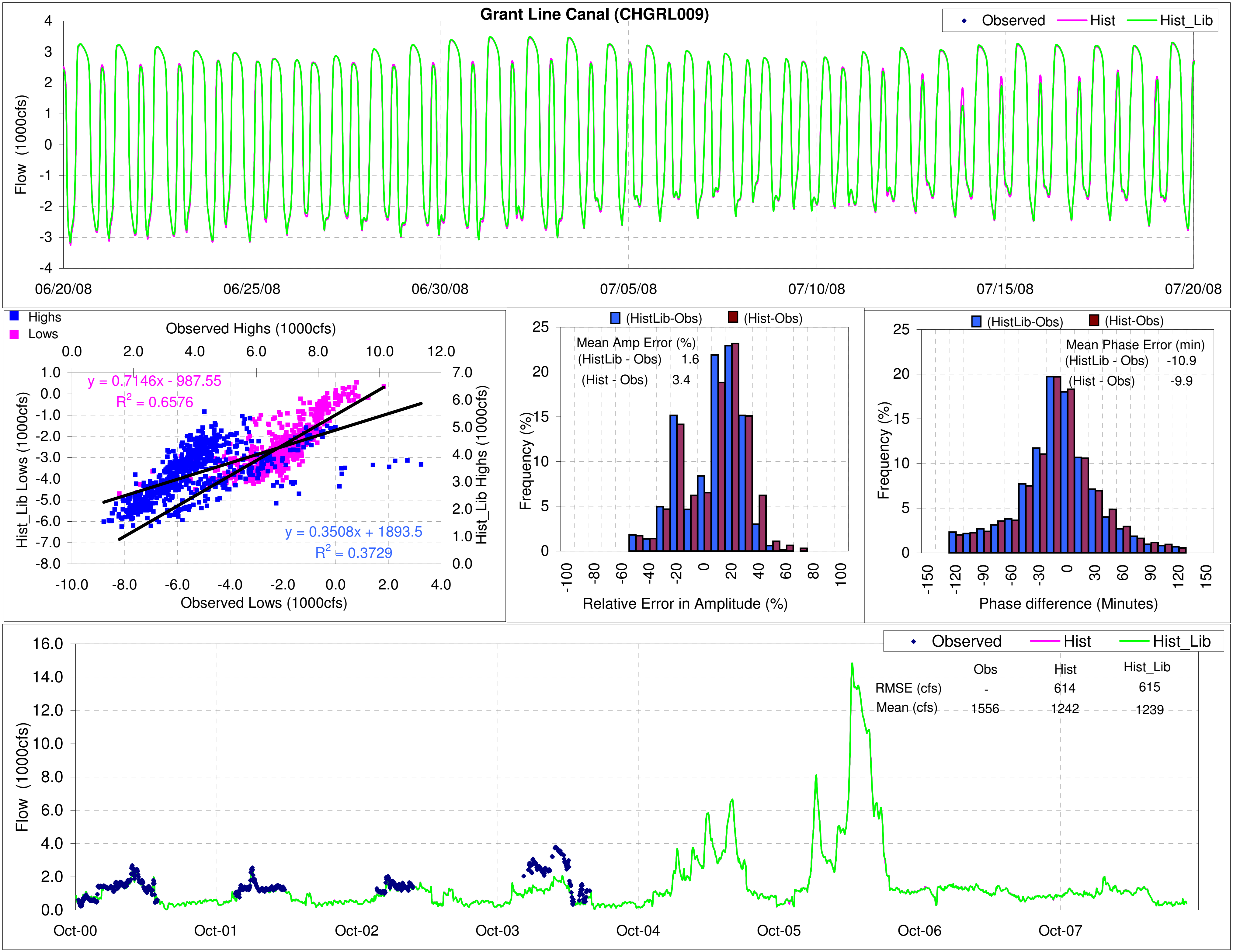

Middle River at Bacon Island (RMID015)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08


Highs
Lows
Observed Highs (1000cfs)
y = 0.8054x - 1948.6
R^2 = 0.7502
y = 0.7889x + 1219.7
R^2 = 0.7751
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)

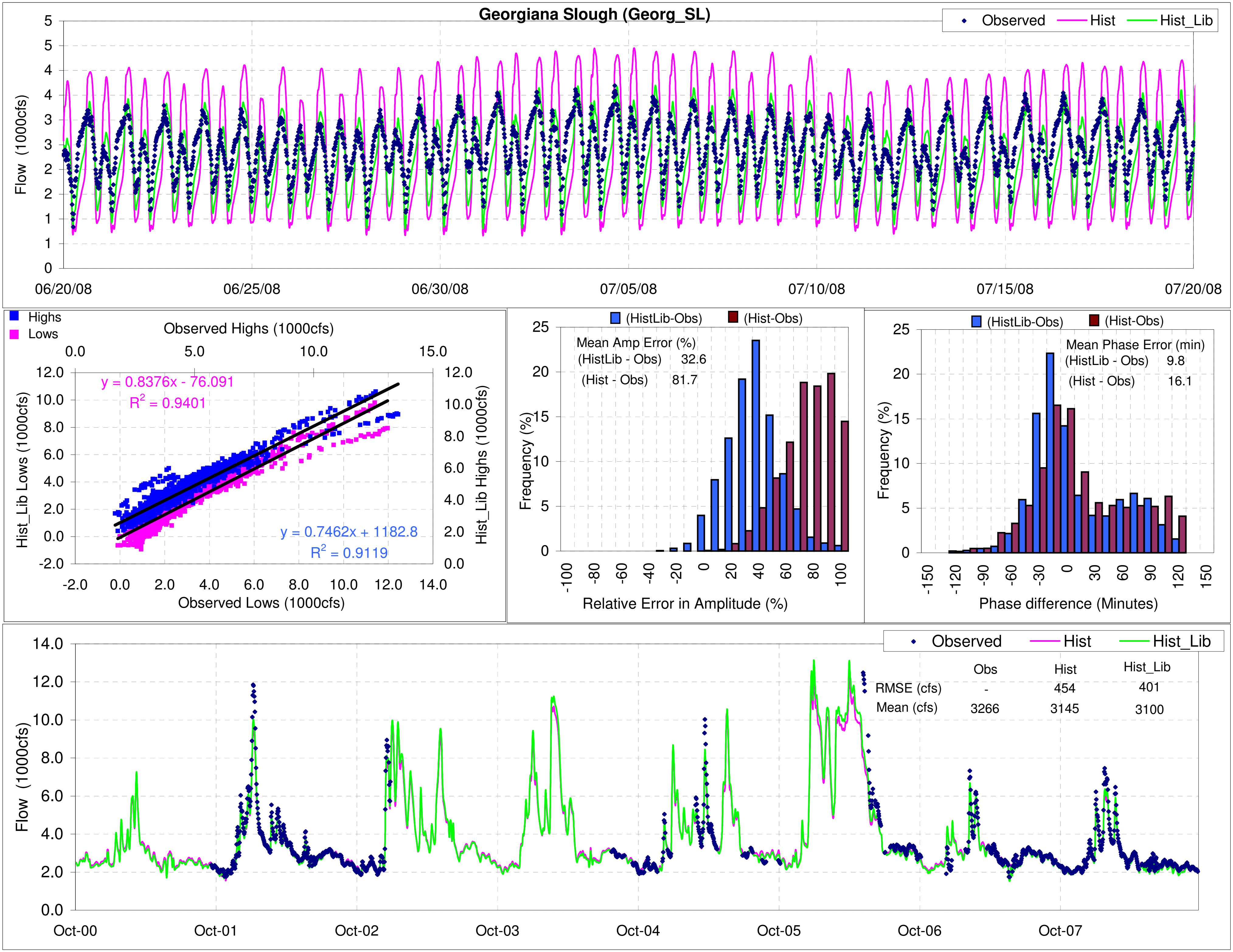

(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -4.6
(Hist - Obs) -2.9
Frequency (%)
Relative Error in Amplitude (%)

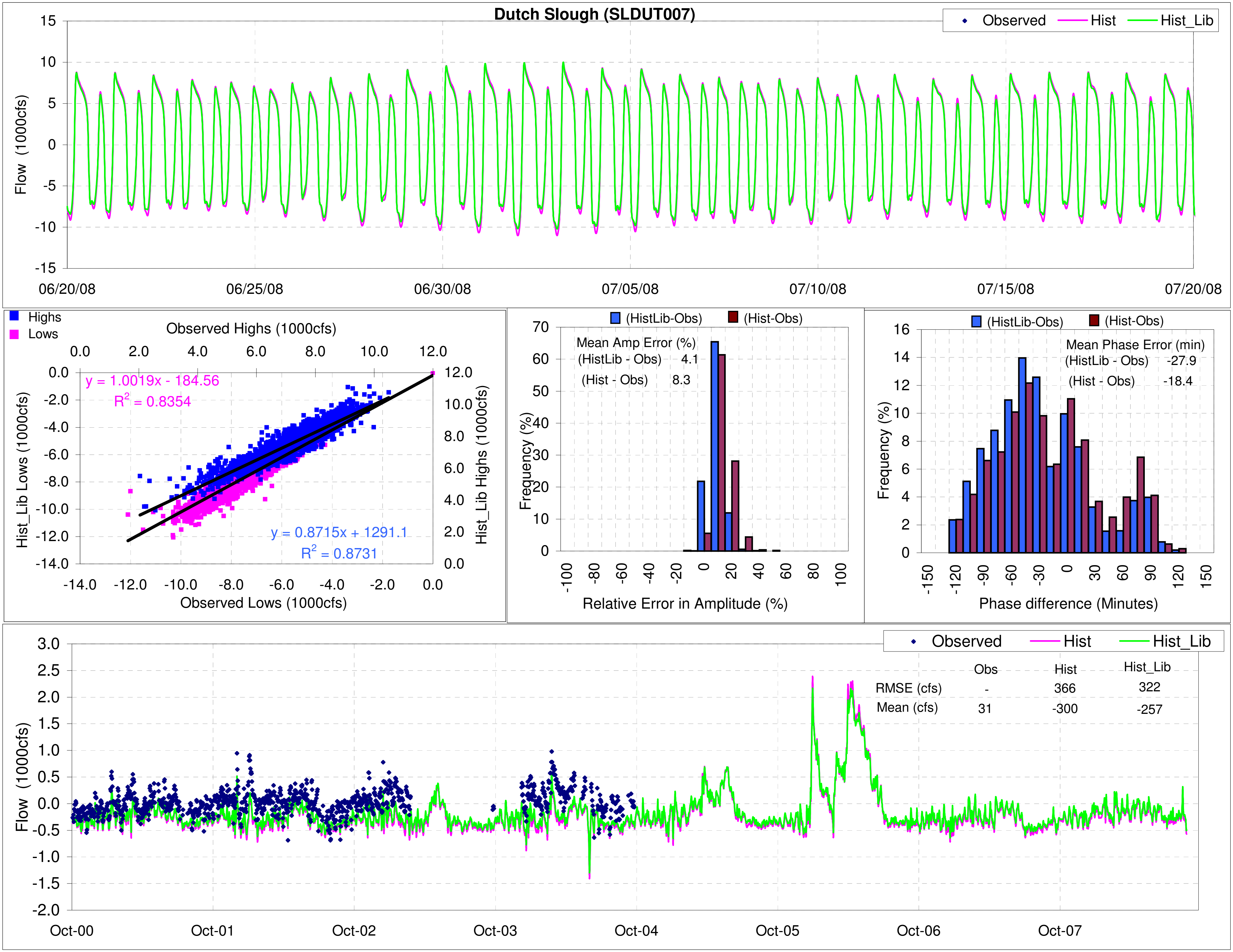

(HistLib-Obs)
(Hist-Obs)
Mean Phase Error (min)
(HistLib - Obs) -13.6
(Hist - Obs) -12.8
Frequency (%)
Phase difference (Minutes)

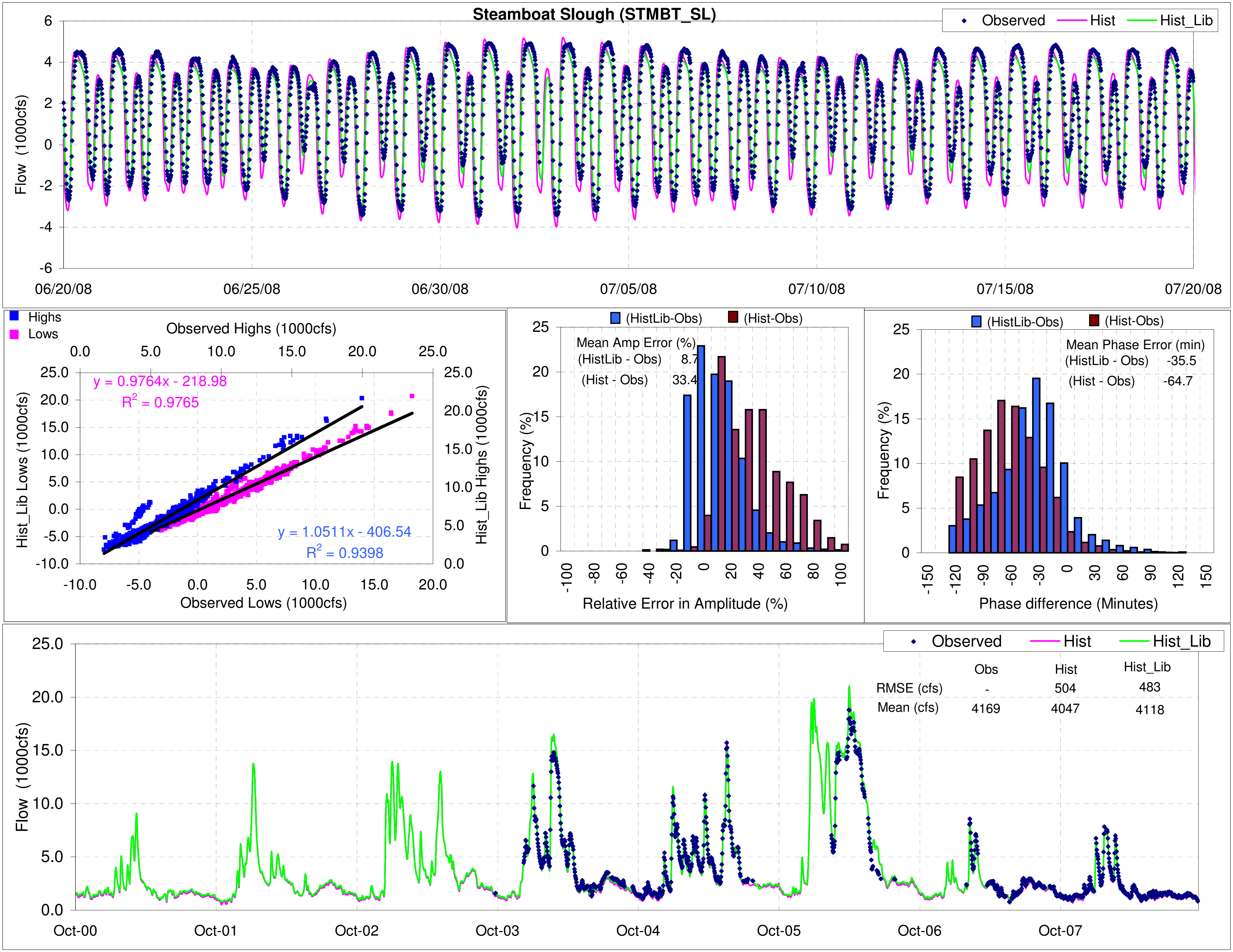

Observed
Hist
Hist_Lib
Obs
Hist
Hist_Lib
RMSE (cfs)
-
631
632
Mean (cfs)
-3870
-3580
-3579
Flow (1000cfs)
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

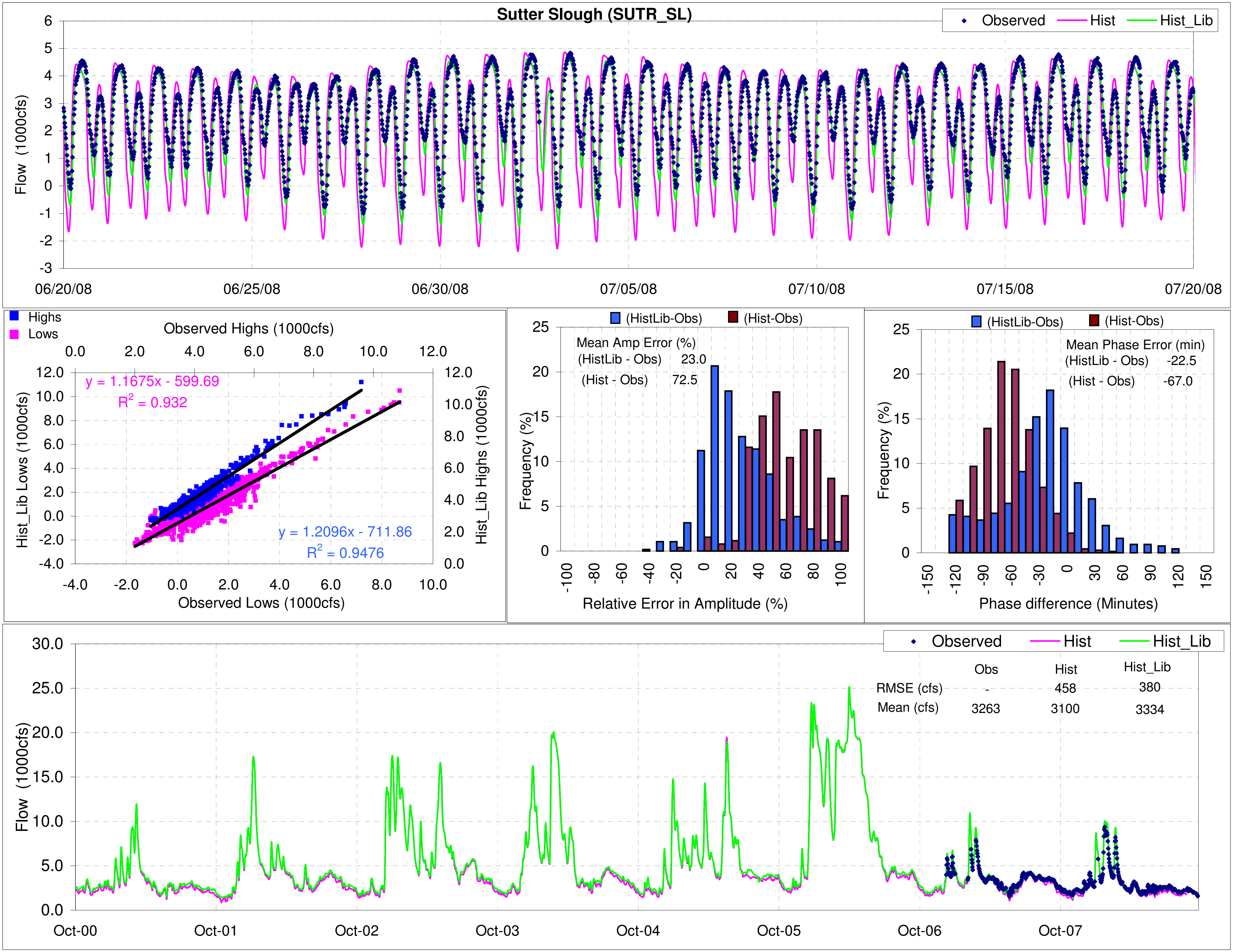


Grant Line Canal (CHGRL009)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
y = 0.7146x - 987.55
R2 = 0.6576
y = 0.3508x + 1893.5
R2 = 0.3729
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 1.6
(Hist - Obs) 3.4
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -10.9
(Hist - Obs) -9.9
Phase difference (Minutes)
Observed
Hist
Hist_Lib
Obs Hist Hist_Lib
RMSE (cfs) - 614 615
Mean (cfs) 1556 1242 1239
Flow (1000cfs)
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

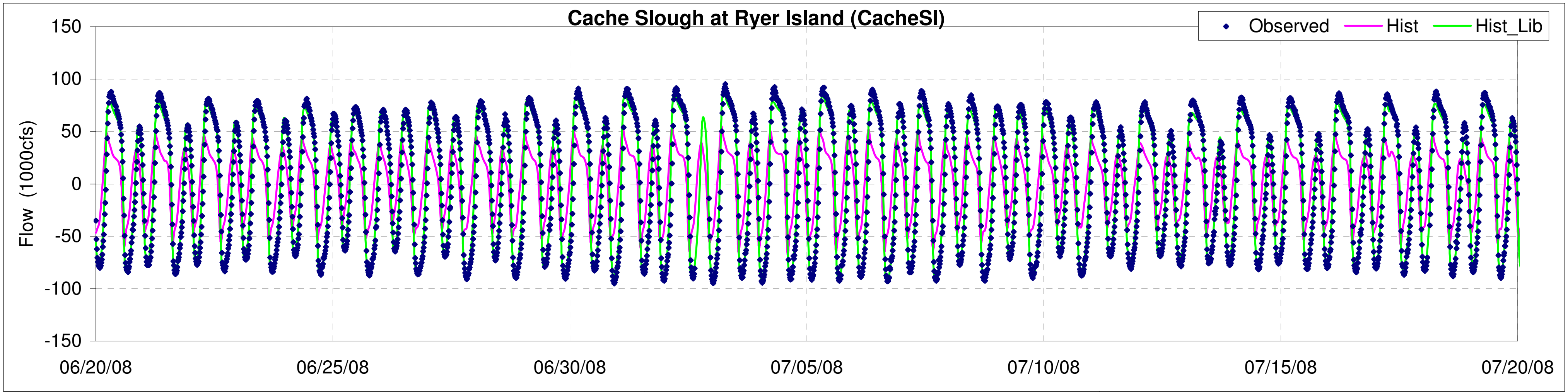

Georgiana Slough (Georg_SL)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
y = 0.8376x - 76.091
R^2 = 0.9401
y = 0.7462x + 1182.8
R^2 = 0.9119
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 32.6
(Hist - Obs) 81.7
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 9.8
(Hist - Obs) 16.1
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 454 401
Mean (cfs) 3266 3145 3100
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

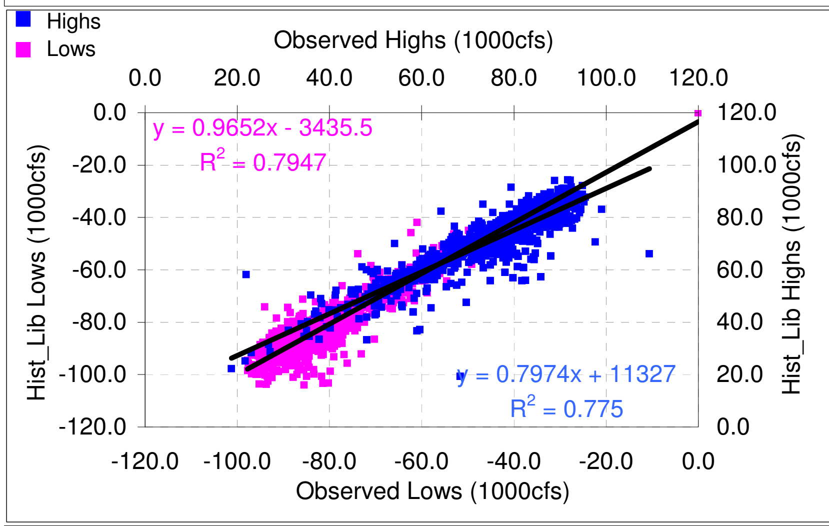

Dutch Slough (SLDUT007)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
y = 1.0019x - 184.56
R2 = 0.8354
y = 0.8715x + 1291.1
R2 = 0.8731
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 4.1
(Hist - Obs) 8.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -27.9
(Hist - Obs) -18.4
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 366 322
Mean (cfs) 31 -300 -257
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

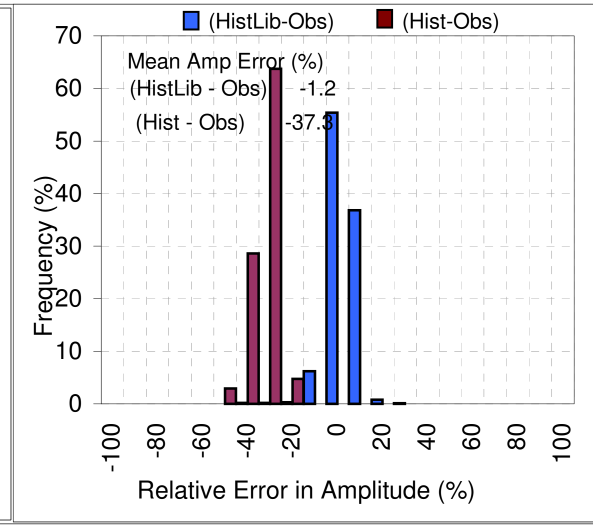

Steamboat Slough (STMBT_SL)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
y = 0.9764x - 218.98
R2 = 0.9765
y = 1.0511x - 406.54
R2 = 0.9398
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 8.7
(Hist - Obs) 33.4
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -35.5
(Hist - Obs) -64.7
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 504 483
Mean (cfs) 4169 4047 4118
Flow (1000cfs)
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

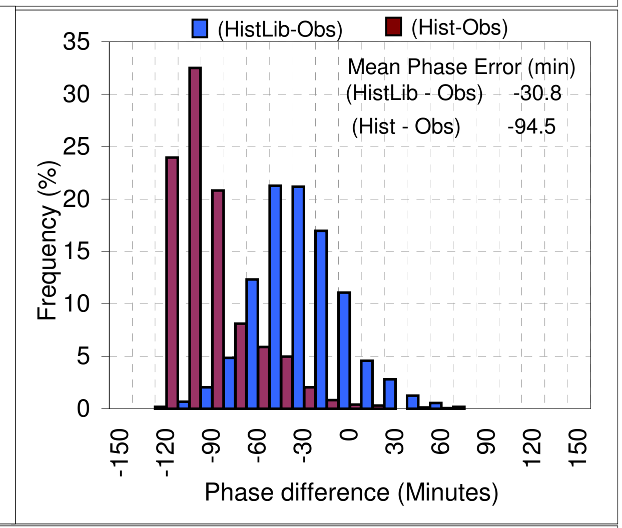


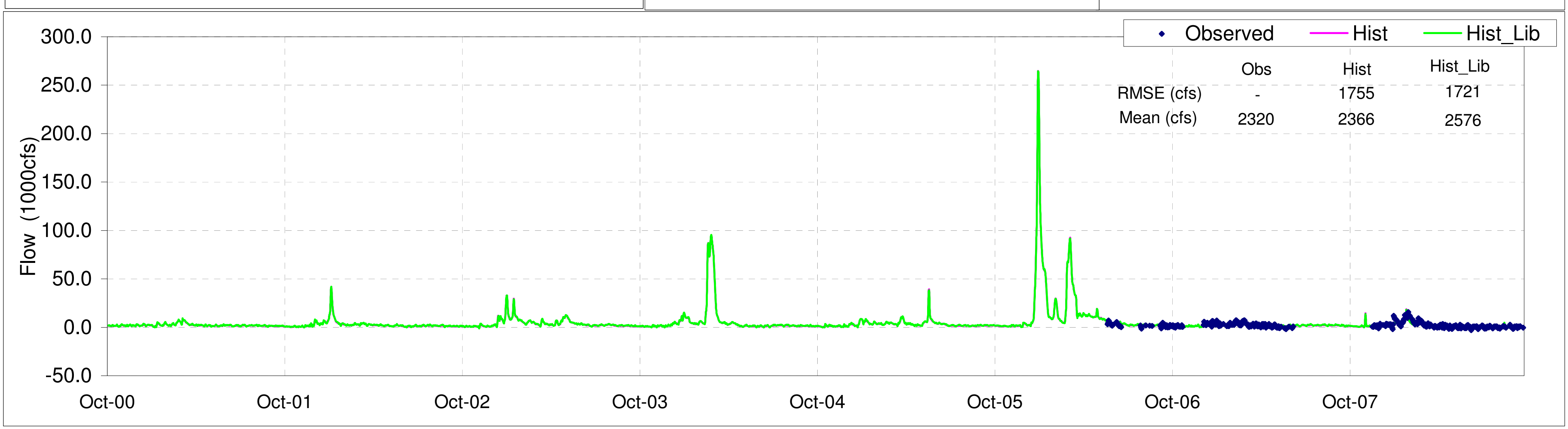
Sutter Slough (SUTR_SL)
Observed
Hist
Hist_Lib
Flow (1000cfs)
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08
Highs
Lows
Observed Highs (1000cfs)
y = 1.1675x - 599.69
R2 = 0.932
y = 1.2096x - 711.86
R2 = 0.9476
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
Observed Lows (1000cfs)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 23.0
(Hist - Obs) 72.5
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -22.5
(Hist - Obs) -67.0
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (cfs) - 458 380
Mean (cfs) 3263 3100 3334
Flow (1000cfs)
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

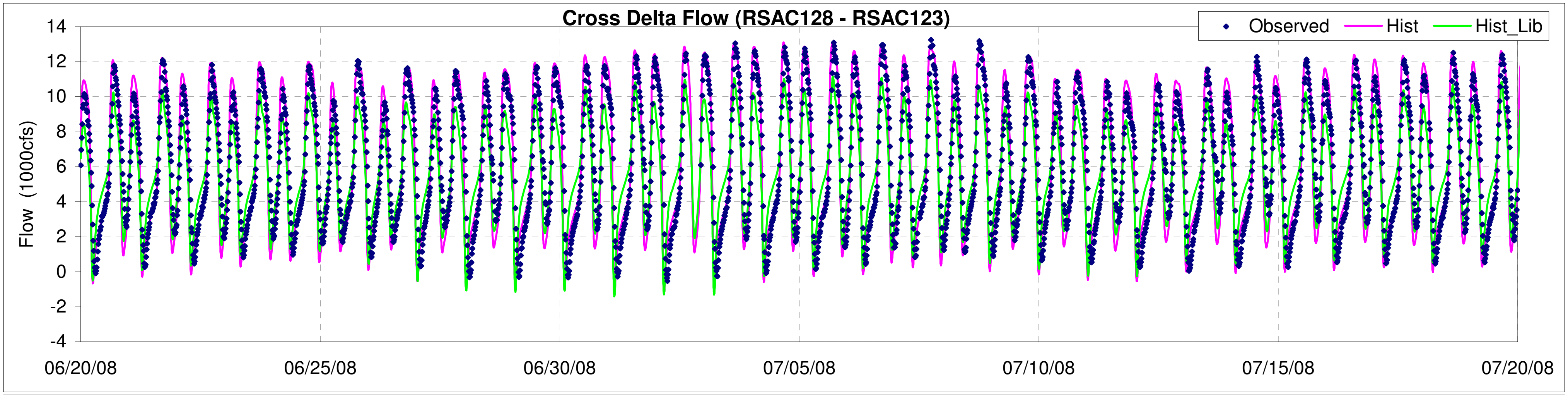

Cache Slough at Ryer Island (CacheSI)
Observed
Hist
Hist_Lib
Flow (1000cfs)
150
100
50
0
-50
-100
-150
06/20/08
06/25/08
06/30/08
07/05/08
07/10/08
07/15/08
07/20/08

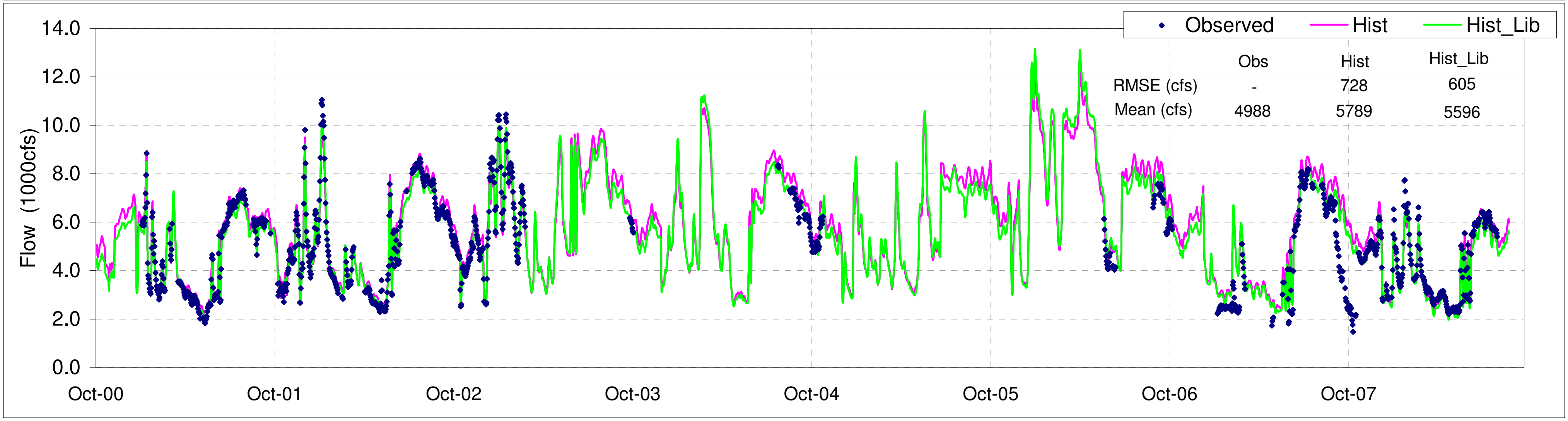

Highs
Lows
Observed Highs (1000cfs)
0.0 20.0 40.0 60.0 80.0 100.0 120.0
y = 0.9652x - 3435.5
R2 = 0.7947
y = 0.7974x + 11327
R2 = 0.775
Hist_Lib Lows (1000cfs)
Hist_Lib Highs (1000cfs)
0.0 -20.0 -40.0 -60.0 -80.0 -100.0 -120.0
120.0 100.0 80.0 60.0 40.0 20.0 0.0
-120.0 -100.0 -80.0 -60.0 -40.0 -20.0 0.0
Observed Lows (1000cfs)


(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) -1.2
(Hist - Obs) -37.3
Frequency (%)
70 60 50 40 30 20 10 0
-100 -80 -60 -40 -20 0 20 40 60 80 100
Relative Error in Amplitude (%)

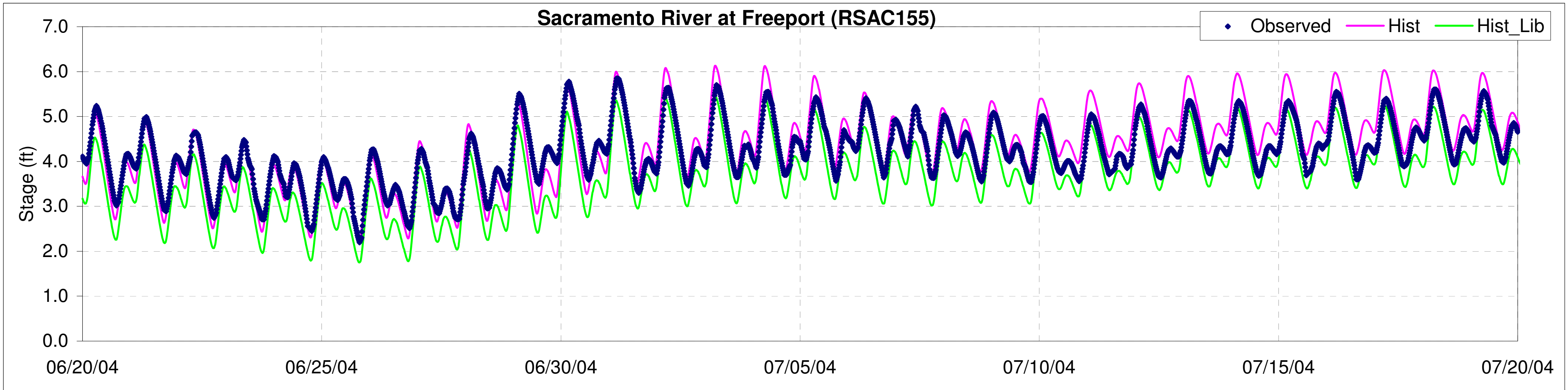

(HistLib-Obs)
(Hist-Obs)
Mean Phase Error (min)
(HistLib - Obs) -30.8
(Hist - Obs) -94.5
Frequency (%)
35 30 25 20 15 10 5 0
-150 -120 -90 -60 -30 0 30 60 90 120 150
Phase difference (Minutes)

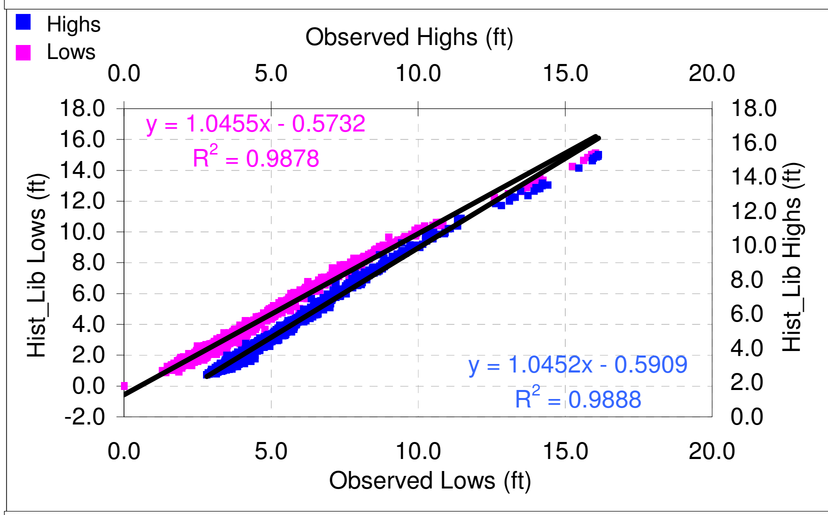

Observed
Hist
Hist_Lib
Obs Hist Hist_Lib
RMSE (cfs) - 1755 1721
Mean (cfs) 2320 2366 2576
Flow (1000cfs)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
-50.0
Oct-00
Oct-01
Oct-02
Oct-03
Oct-04
Oct-05
Oct-06
Oct-07

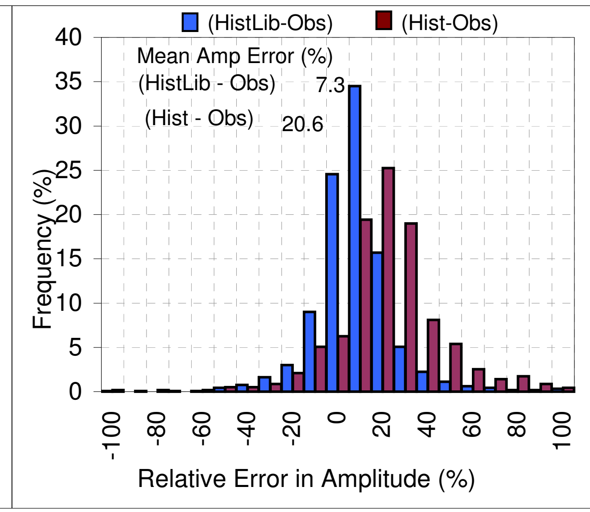


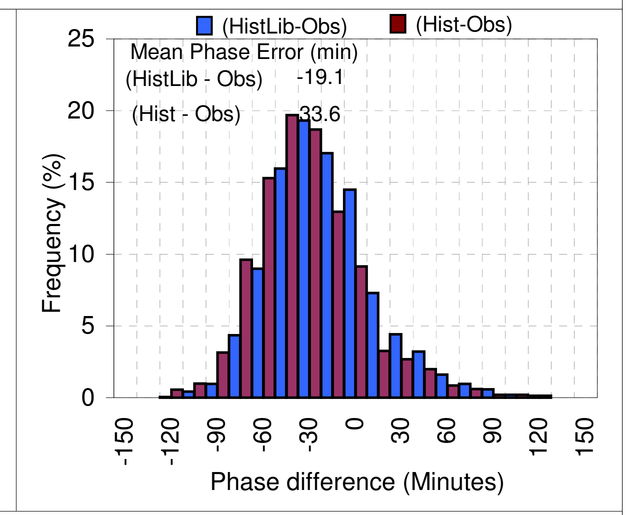


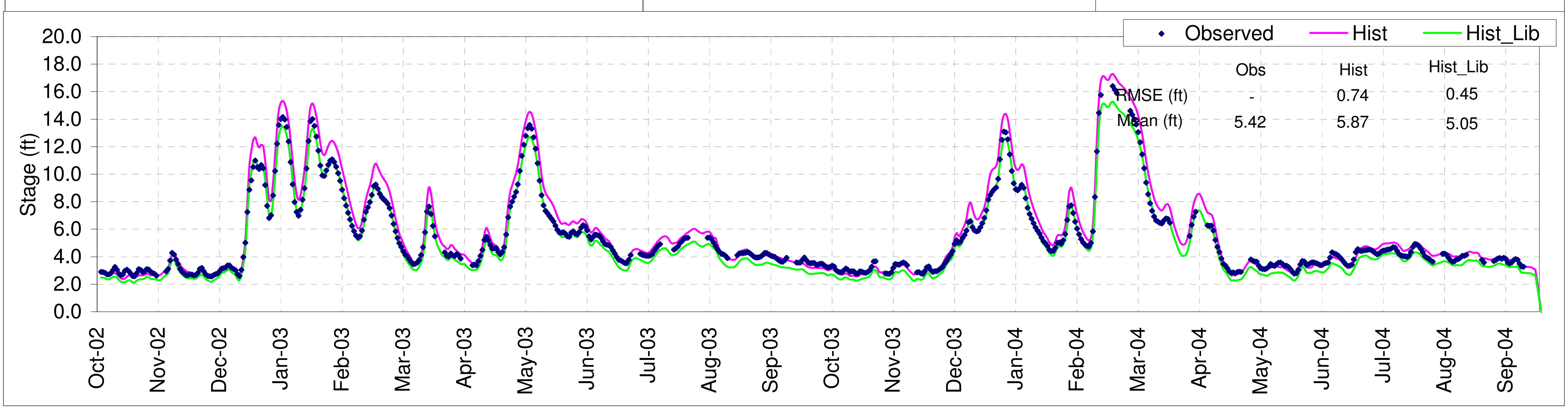
	Obs	Hist	Hist_Lib
RMSE (cfs)	-	728	605
Mean (cfs)	4988	5789	5596

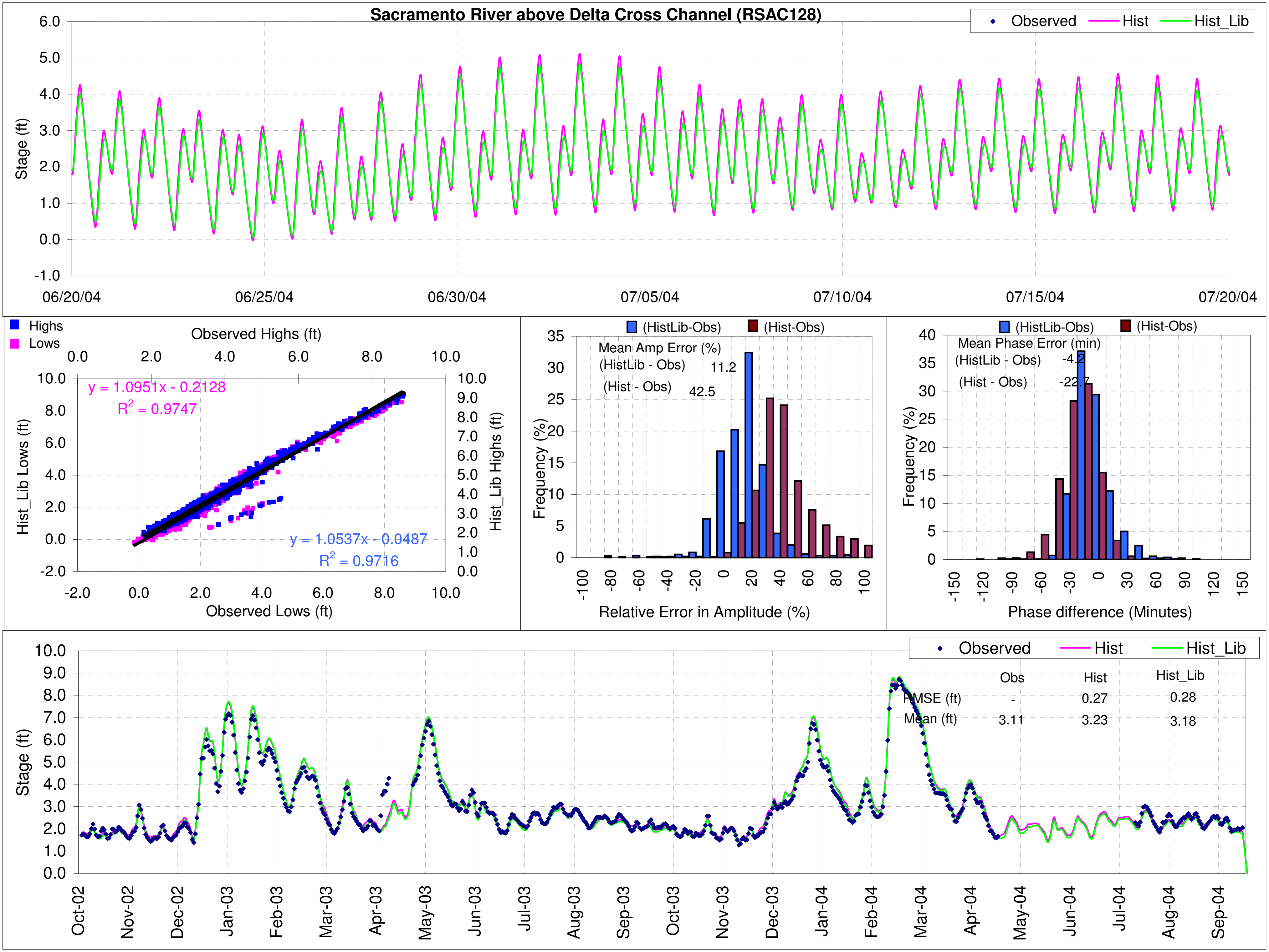

Sacramento River at Freeport (RSAC155)
Observed
Hist
Hist_Lib
Stage (ft)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04


Highs
Lows
Observed Highs (ft)
y = 1.0455x - 0.5732
R^2 = 0.9878
y = 1.0452x - 0.5909
R^2 = 0.9888
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
0.0
5.0
10.0
15.0
20.0

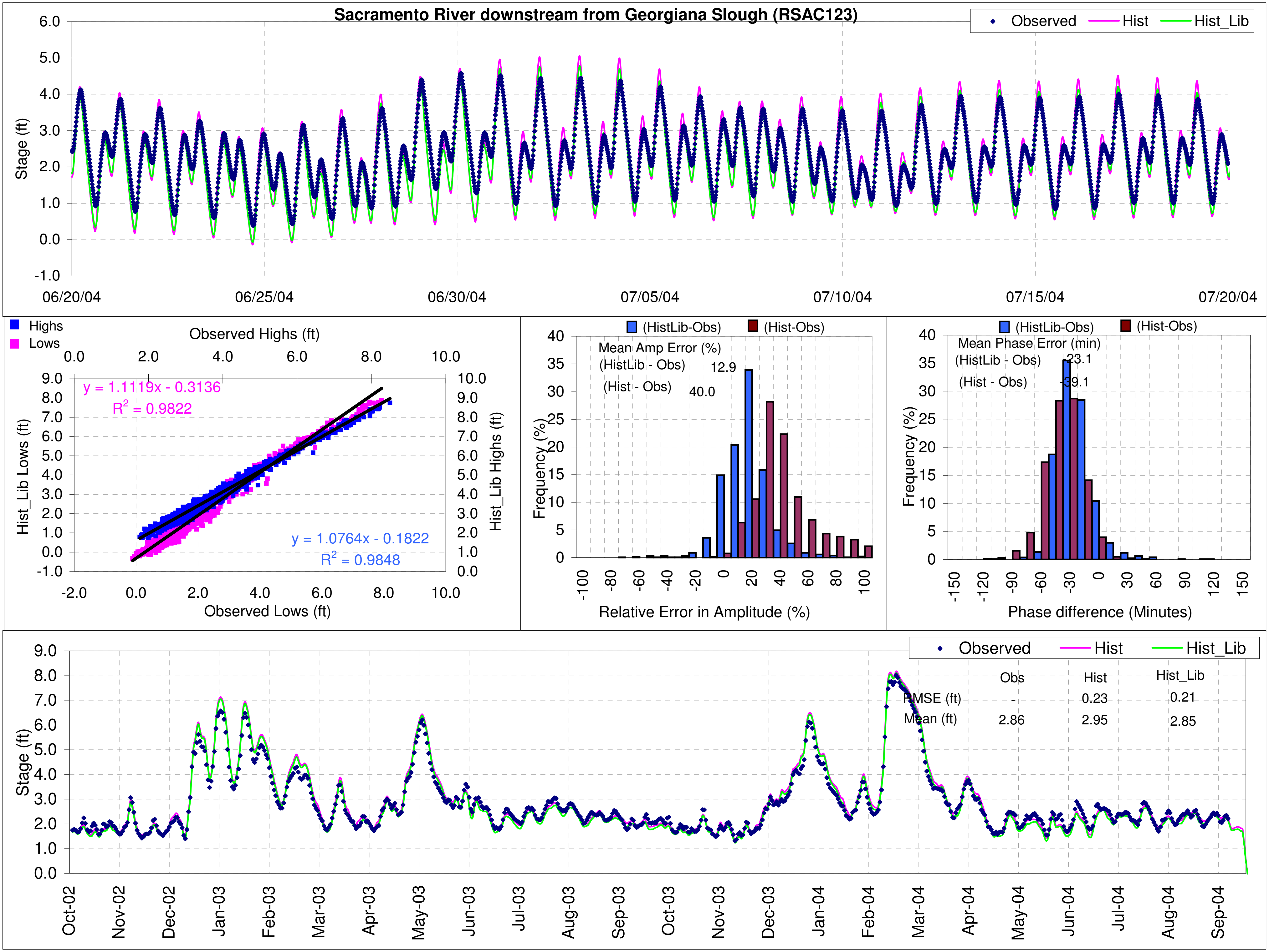

(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 7.3
(Hist - Obs) 20.6
Frequency (%)
Relative Error in Amplitude (%)

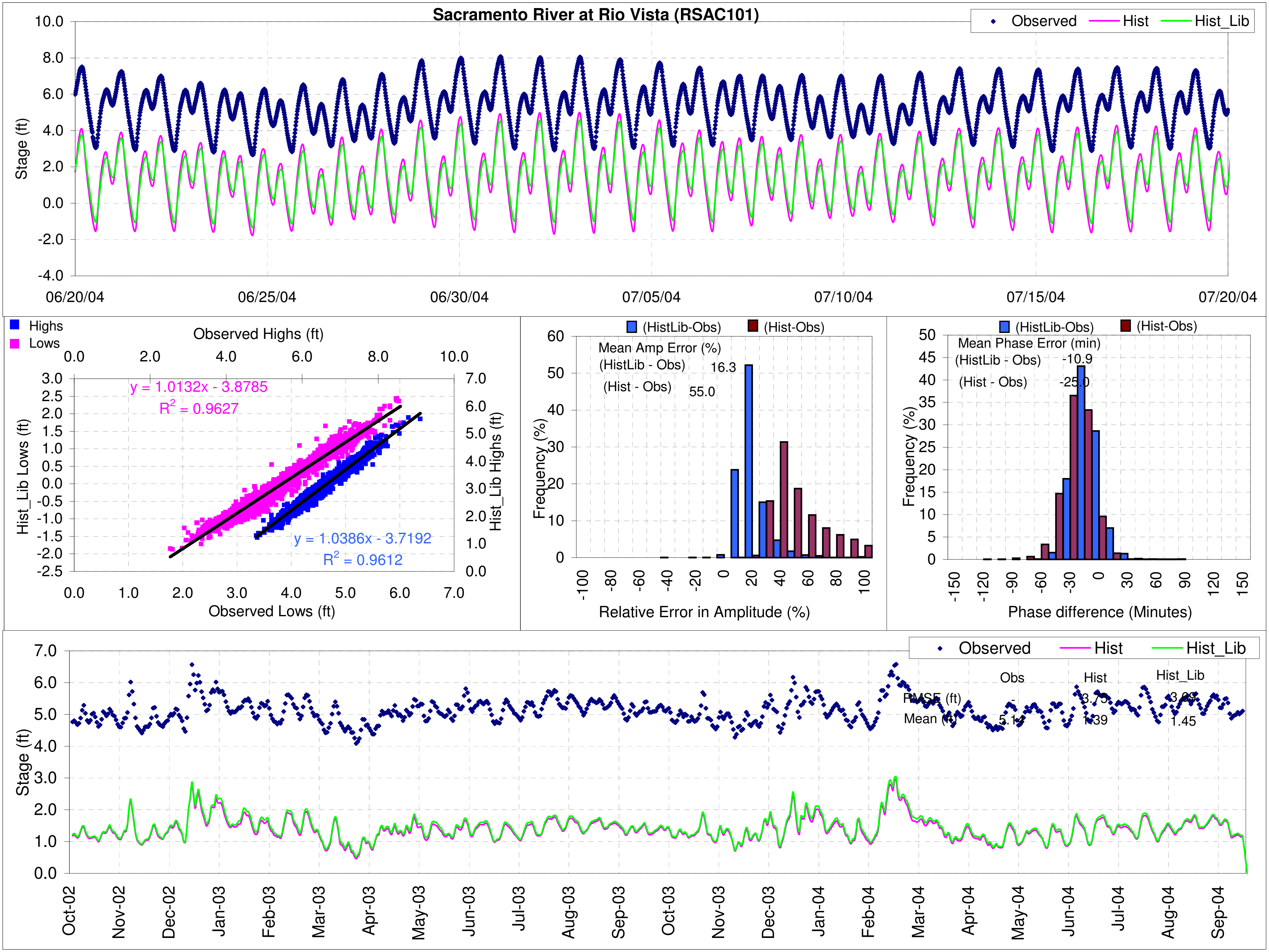

(HistLib-Obs)
(Hist-Obs)
Mean Phase Error (min)
(HistLib - Obs) -19.1
(Hist - Obs) 33.6
Frequency (%)
Phase difference (Minutes)


Observed
Hist
Hist_Lib
Obs
Hist
Hist_Lib
RMSE (ft)
-
0.74
0.45
Mean (ft)
5.42
5.87
5.05
Stage (ft)
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

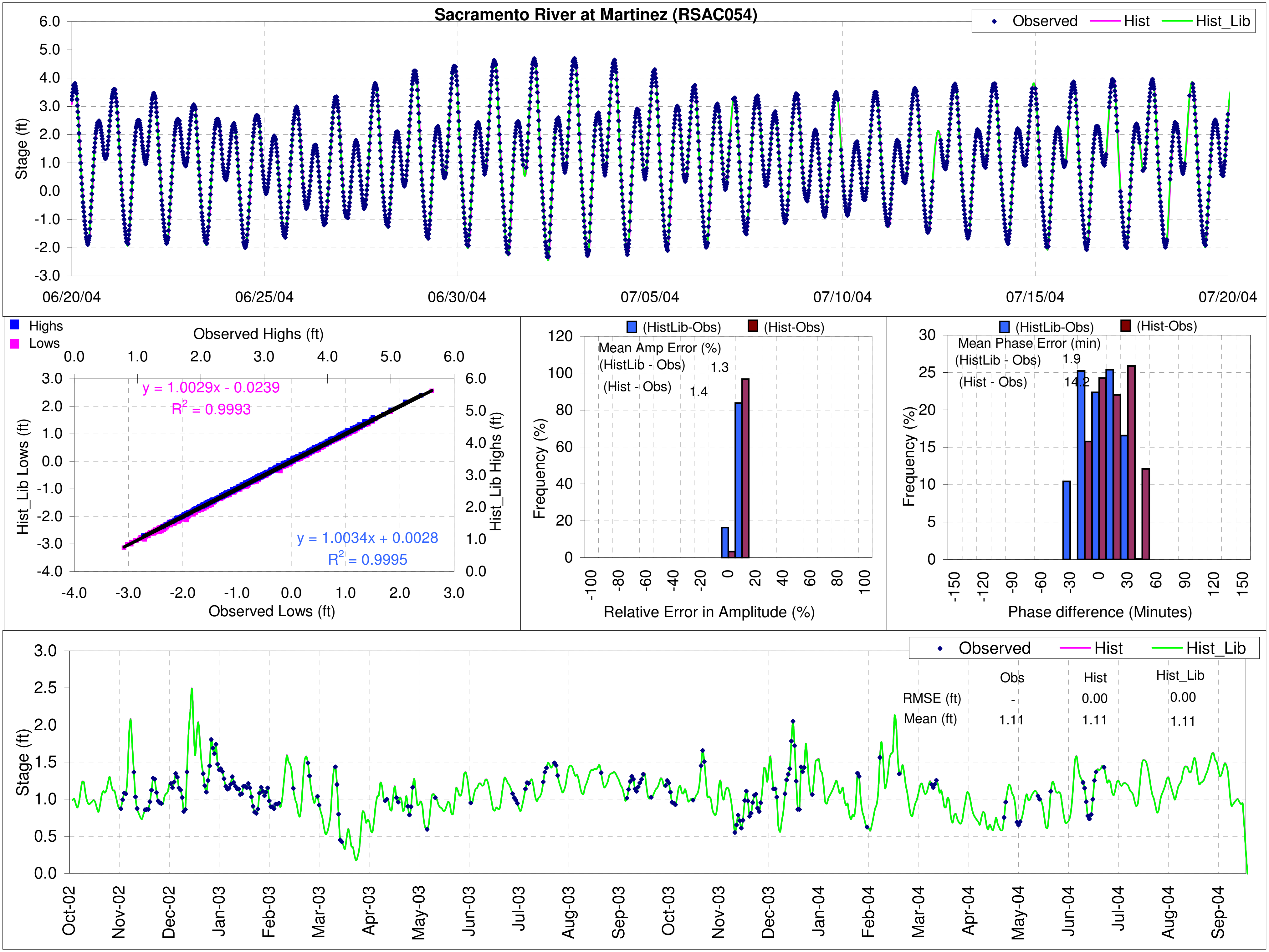


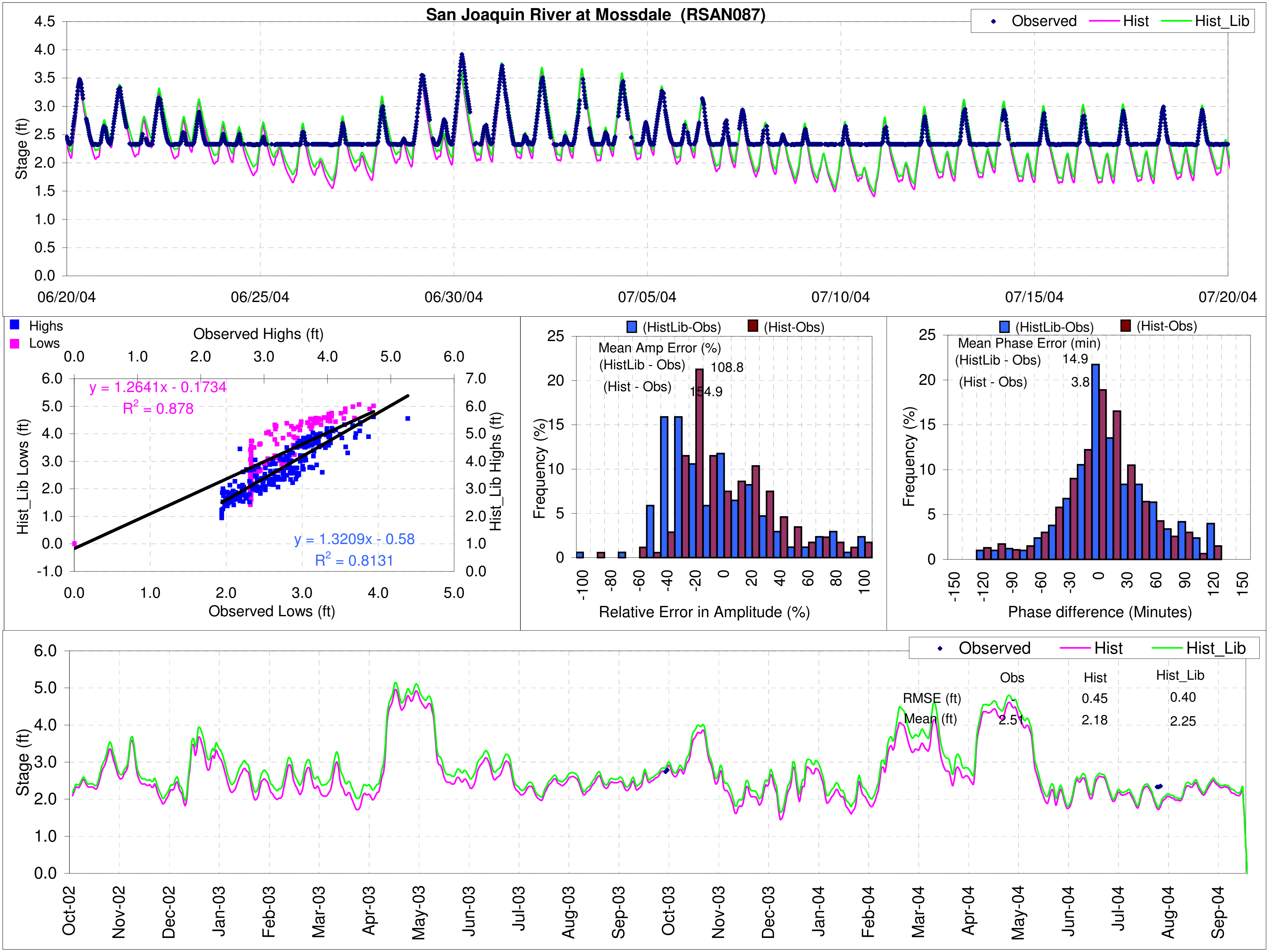
Sacramento River above Delta Cross Channel (RSAC128)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 1.0951x - 0.2128
R2 = 0.9747
y = 1.0537x - 0.0487
R2 = 0.9716
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 11.2
(Hist - Obs) 42.5
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -4.2
(Hist - Obs) -22.7
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (ft) - 0.27 0.28
Mean (ft) 3.11 3.23 3.18
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04


Sacramento River downstream from Georgiana Slough (RSAC123)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
Observed Lows (ft)
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
y = 1.1119x - 0.3136
R² = 0.9822
y = 1.0764x - 0.1822
R² = 0.9848
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 12.9
(Hist - Obs) 40.0
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -23.1
(Hist - Obs) -39.1
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.23 0.21
Mean (ft) 2.86 2.95 2.85
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

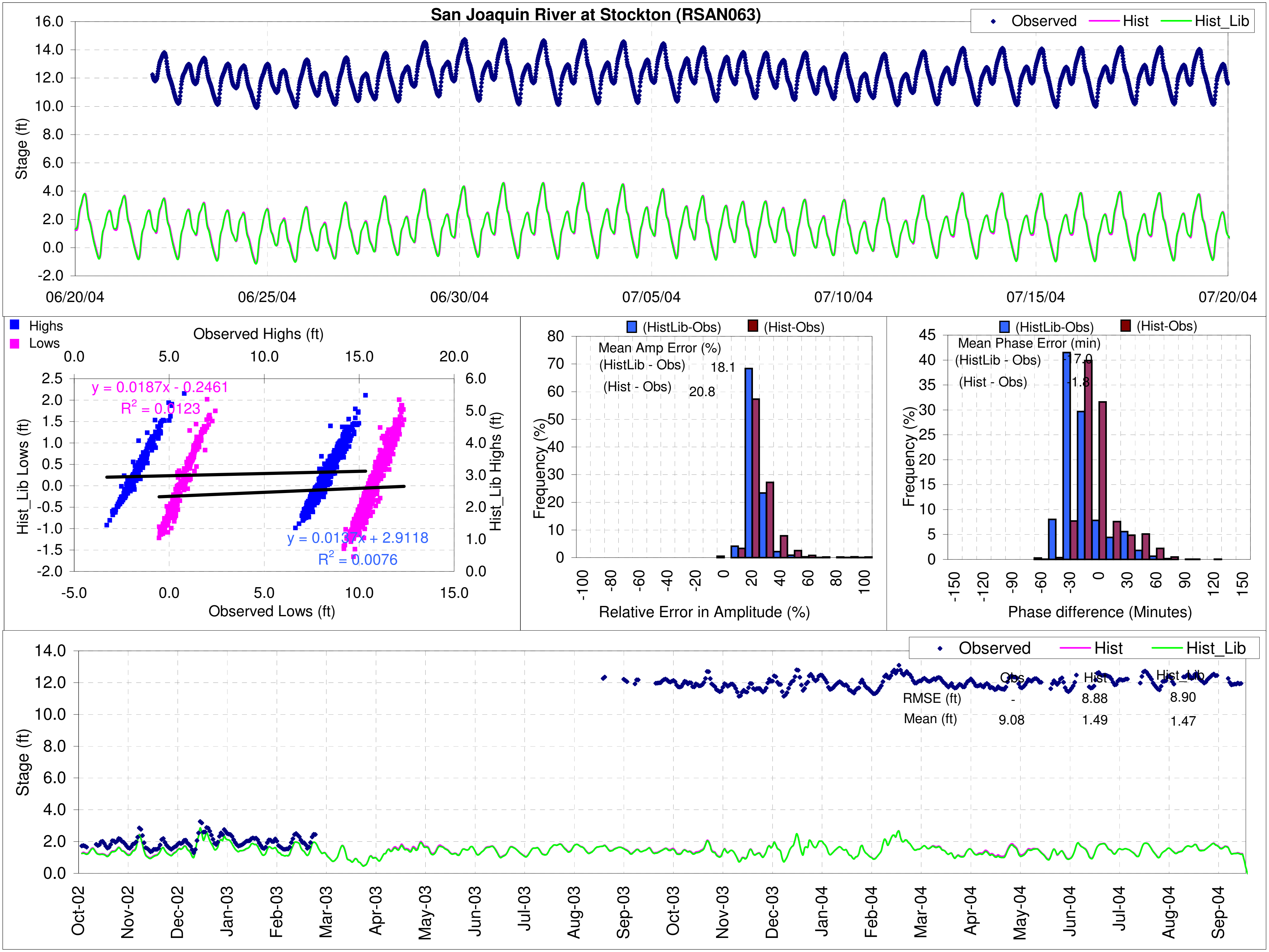


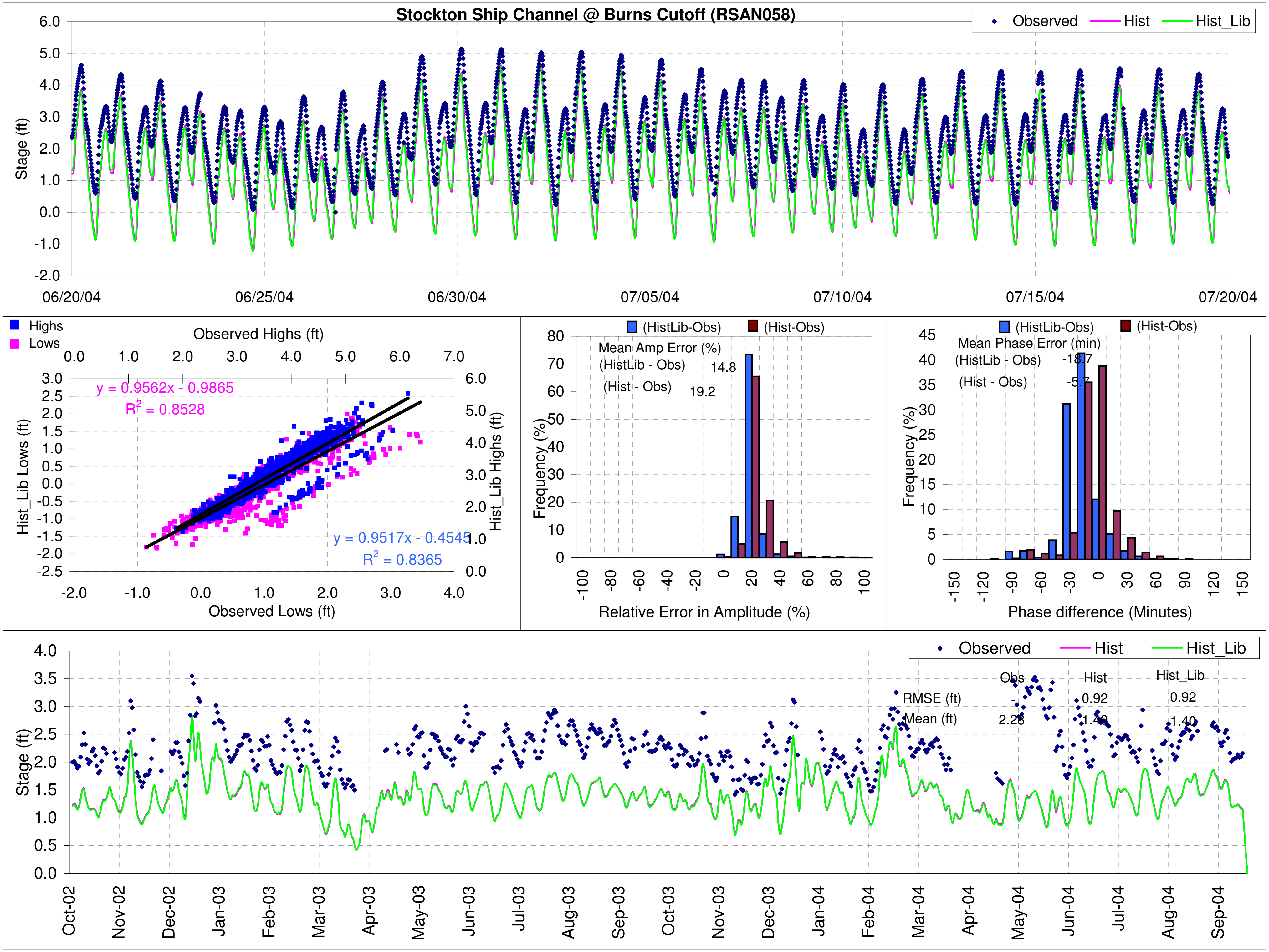
Sacramento River at Rio Vista (RSAC101)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 1.0132x - 3.8785
R2 = 0.9627
y = 1.0386x - 3.7192
R2 = 0.9612
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 16.3
(Hist - Obs) 55.0
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -10.9
(Hist - Obs) -25.0
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 3.75 3.69
Mean (ft) 5.14 1.39 1.45
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

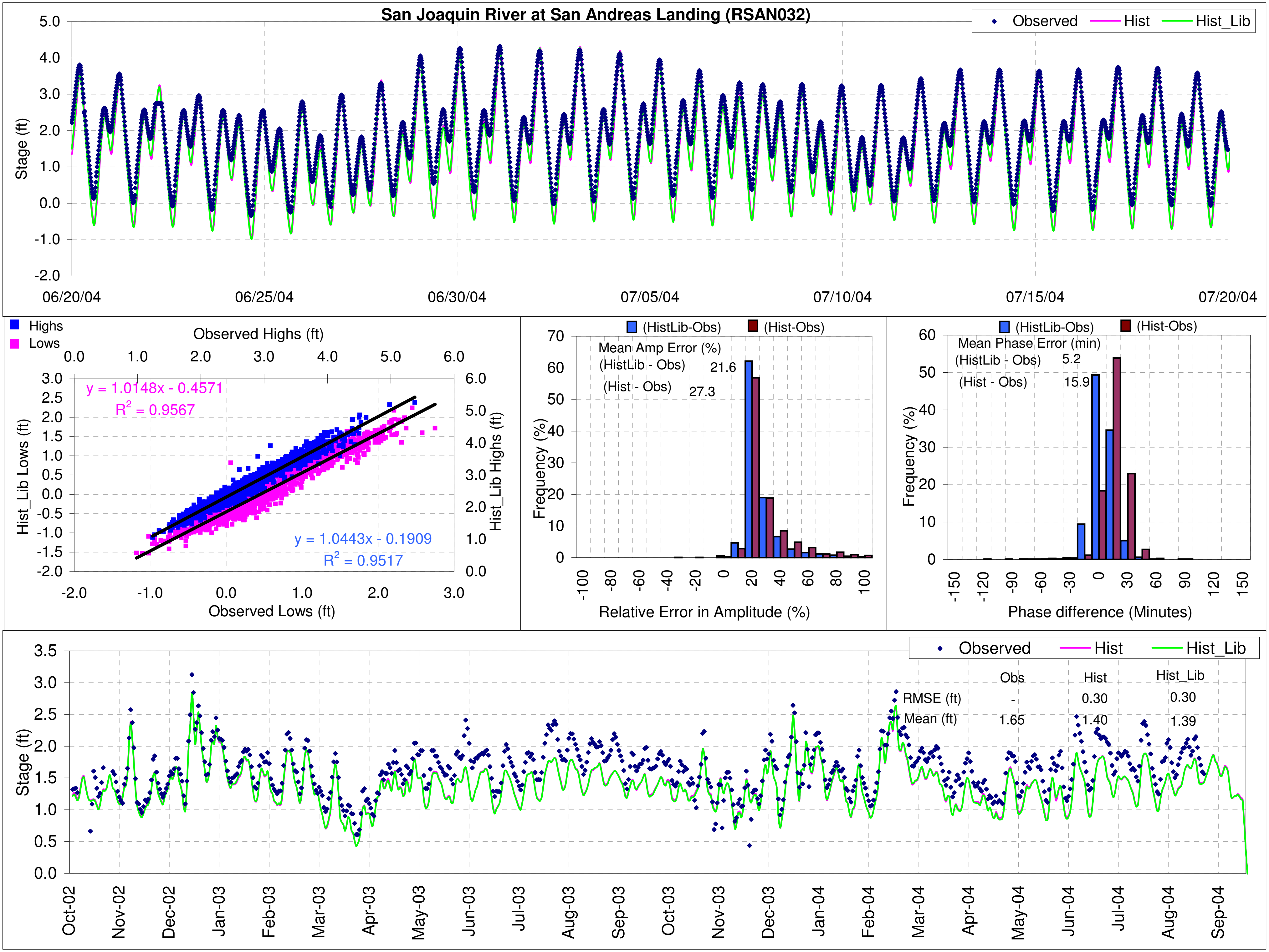

Sacramento River at Martinez (RSAC054)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 1.0029x - 0.0239
R² = 0.9993
y = 1.0034x + 0.0028
R² = 0.9995
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 1.3
(Hist - Obs) 1.4
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 1.9
(Hist - Obs) 14.2
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.00 0.00
Mean (ft) 1.11 1.11 1.11
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

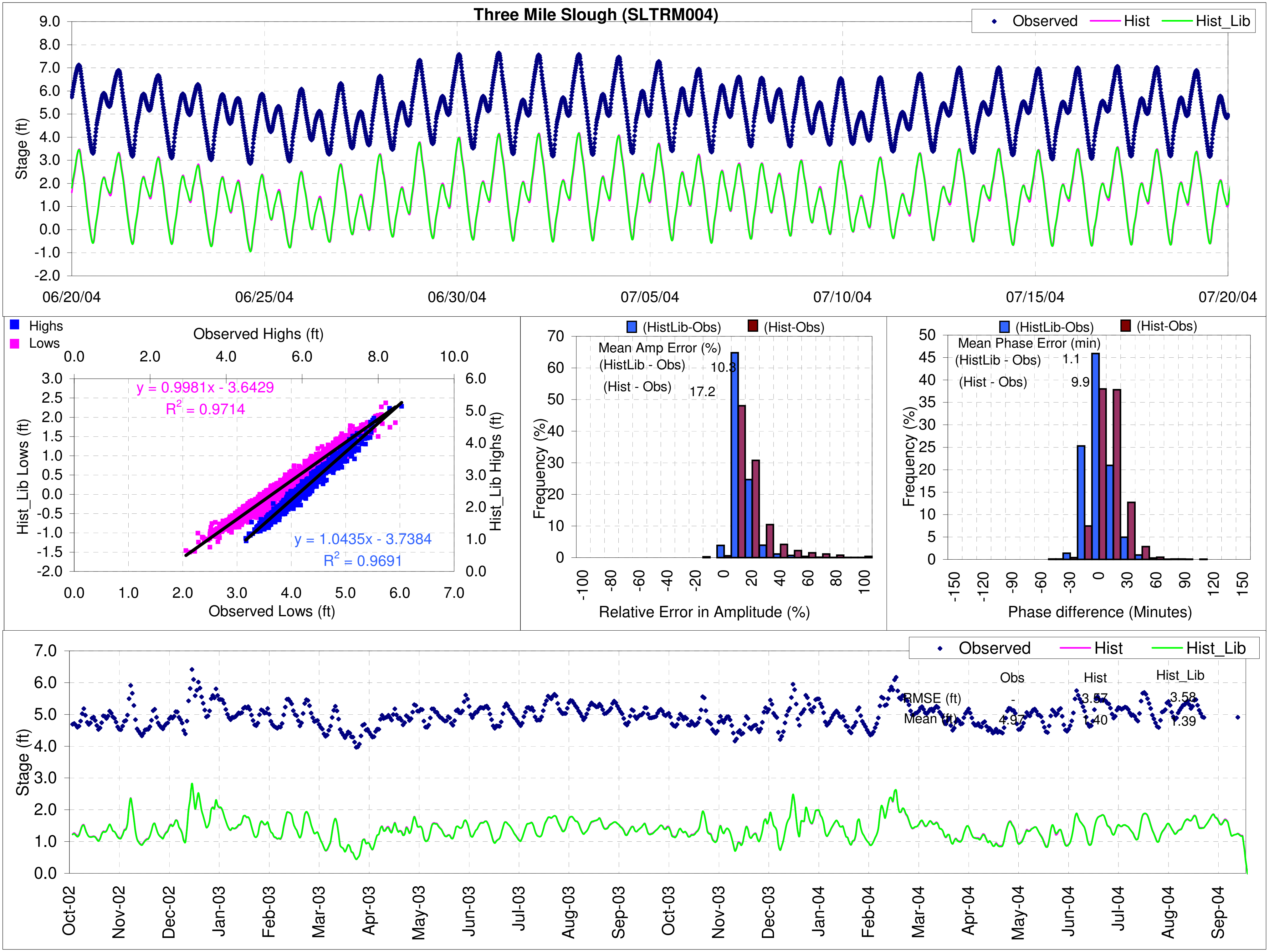


San Joaquin River at Mossdale (RSAN087)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 1.2641x - 0.1734
R^2 = 0.878
y = 1.3209x - 0.58
R^2 = 0.8131
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 108.8
(Hist - Obs) 154.9
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 14.9
(Hist - Obs) 3.8
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) 0.45 0.40
Mean (ft) 2.51 2.18 2.25
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

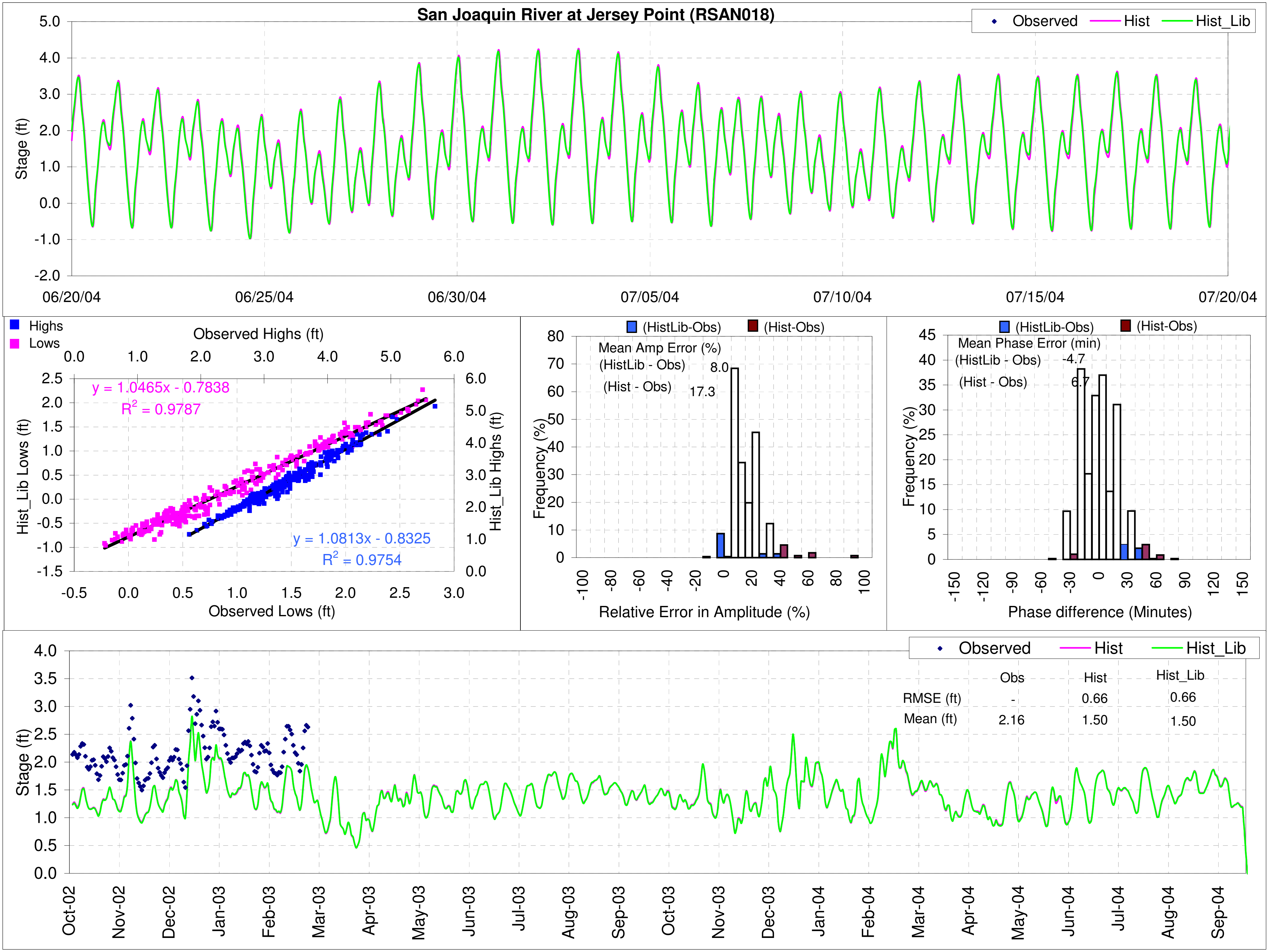

San Joaquin River at Stockton (RSAN063)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 0.0187x - 0.2461
R^2 = 0.0123
y = 0.0137x + 2.9118
R^2 = 0.0076
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 18.1
(Hist - Obs) 20.8
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -17.0
(Hist - Obs) -1.8
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (ft) - 8.88 8.90
Mean (ft) 9.08 1.49 1.47

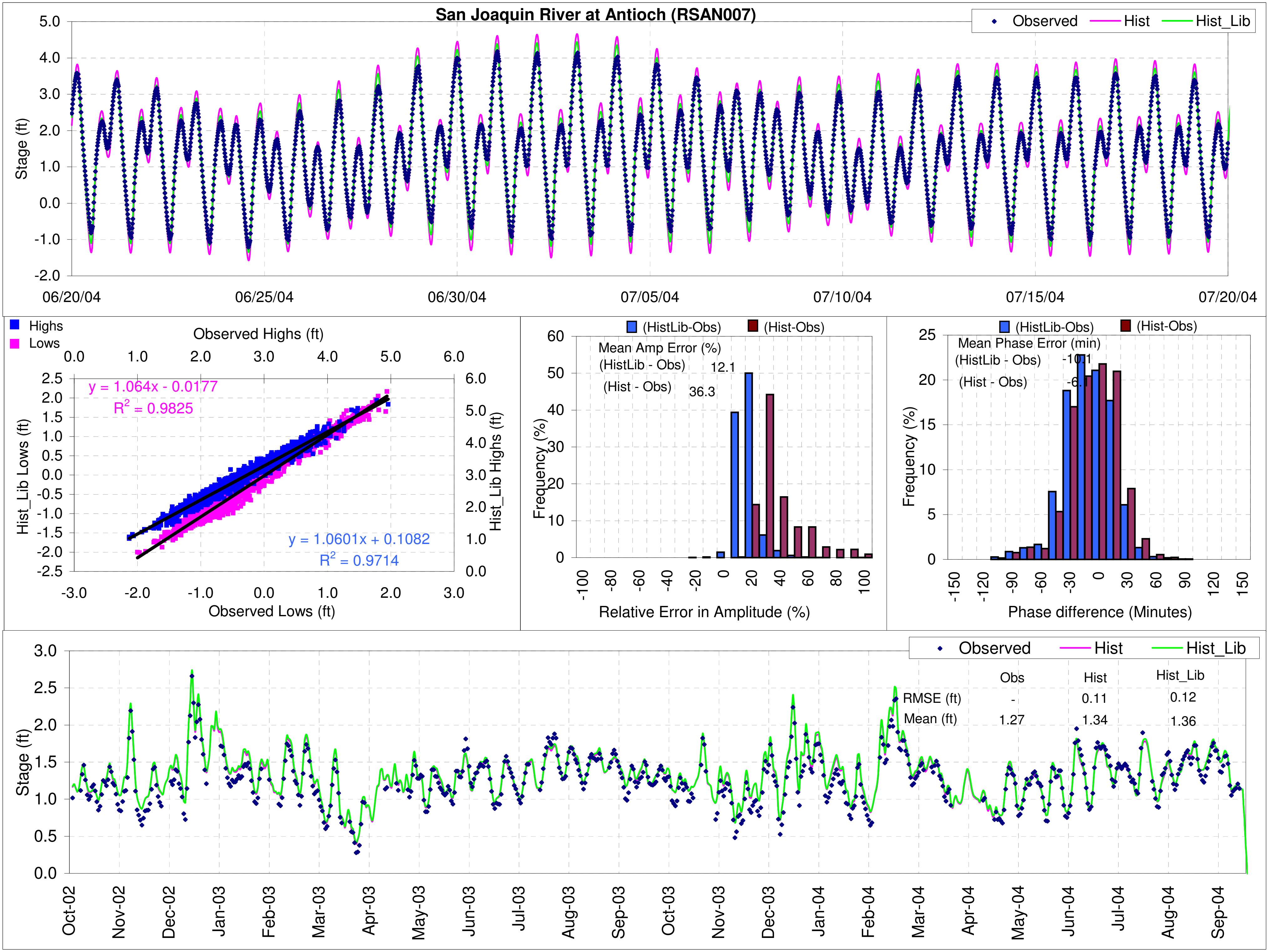

Stockton Ship Channel @ Burns Cutoff (RSAN058)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 0.9562x - 0.9865
R^2 = 0.8528
y = 0.9517x - 0.4545
R^2 = 0.8365
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 14.8
(Hist - Obs) 19.2
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -18.7
(Hist - Obs) -5.7
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.92 0.92
Mean (ft) 2.28 1.40 1.40
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04


San Joaquin River at San Andreas Landing (RSAN032)
Observed
Hist
Hist_Lib
Stage (ft)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
y = 1.0148x - 0.4571
R2 = 0.9567
y = 1.0443x - 0.1909
R2 = 0.9517
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 21.6
(Hist - Obs) 27.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 5.2
(Hist - Obs) 15.9
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.30 0.30
Mean (ft) 1.65 1.40 1.39
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

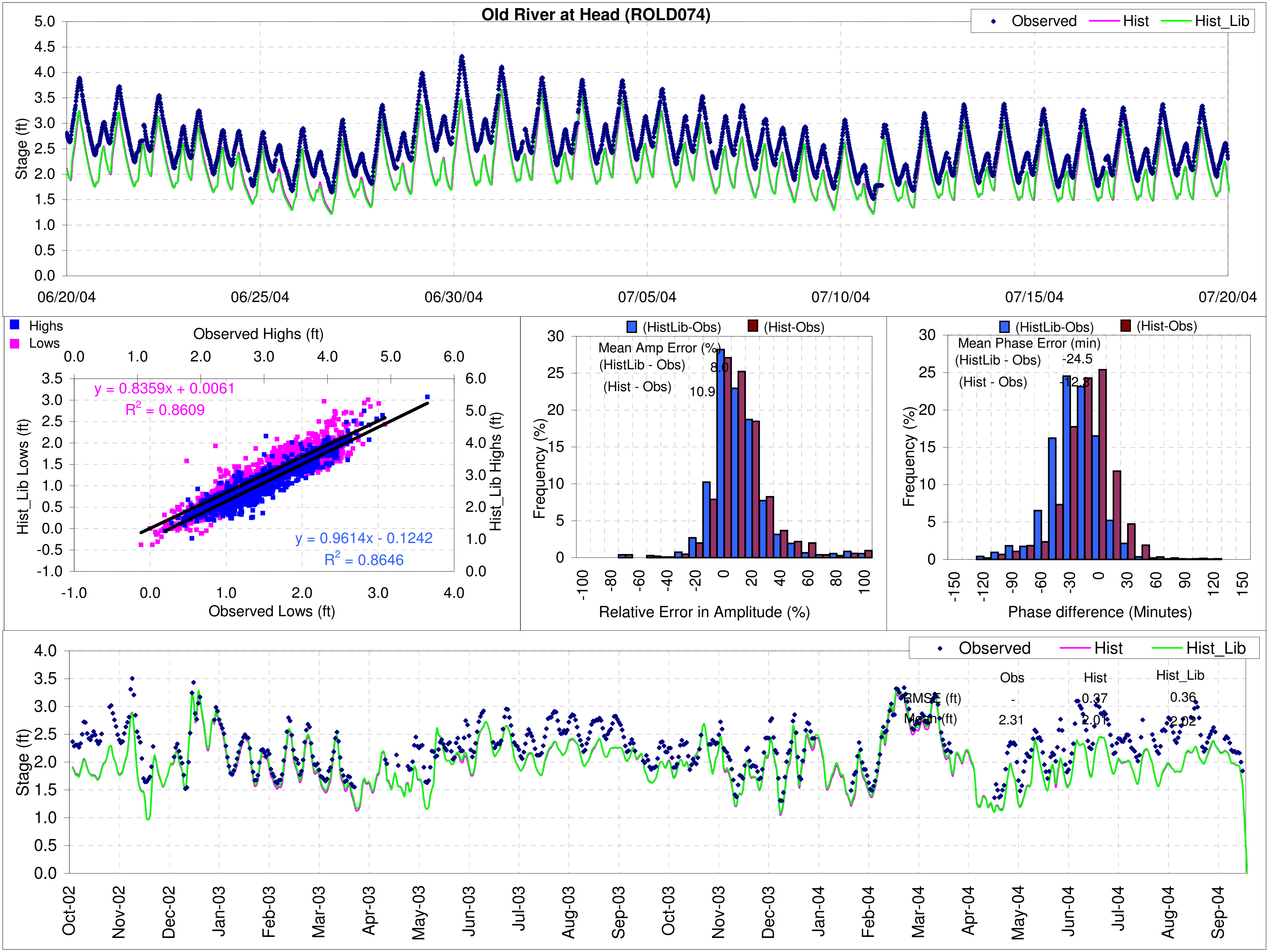


Three Mile Slough (SLTRM004)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 0.9981x - 3.6429
R2 = 0.9714
y = 1.0435x - 3.7384
R2 = 0.9691
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 10.3
(Hist - Obs) 17.2
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 1.1
(Hist - Obs) 9.9
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 3.57 3.58
Mean (ft) 4.97 1.40 1.39
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

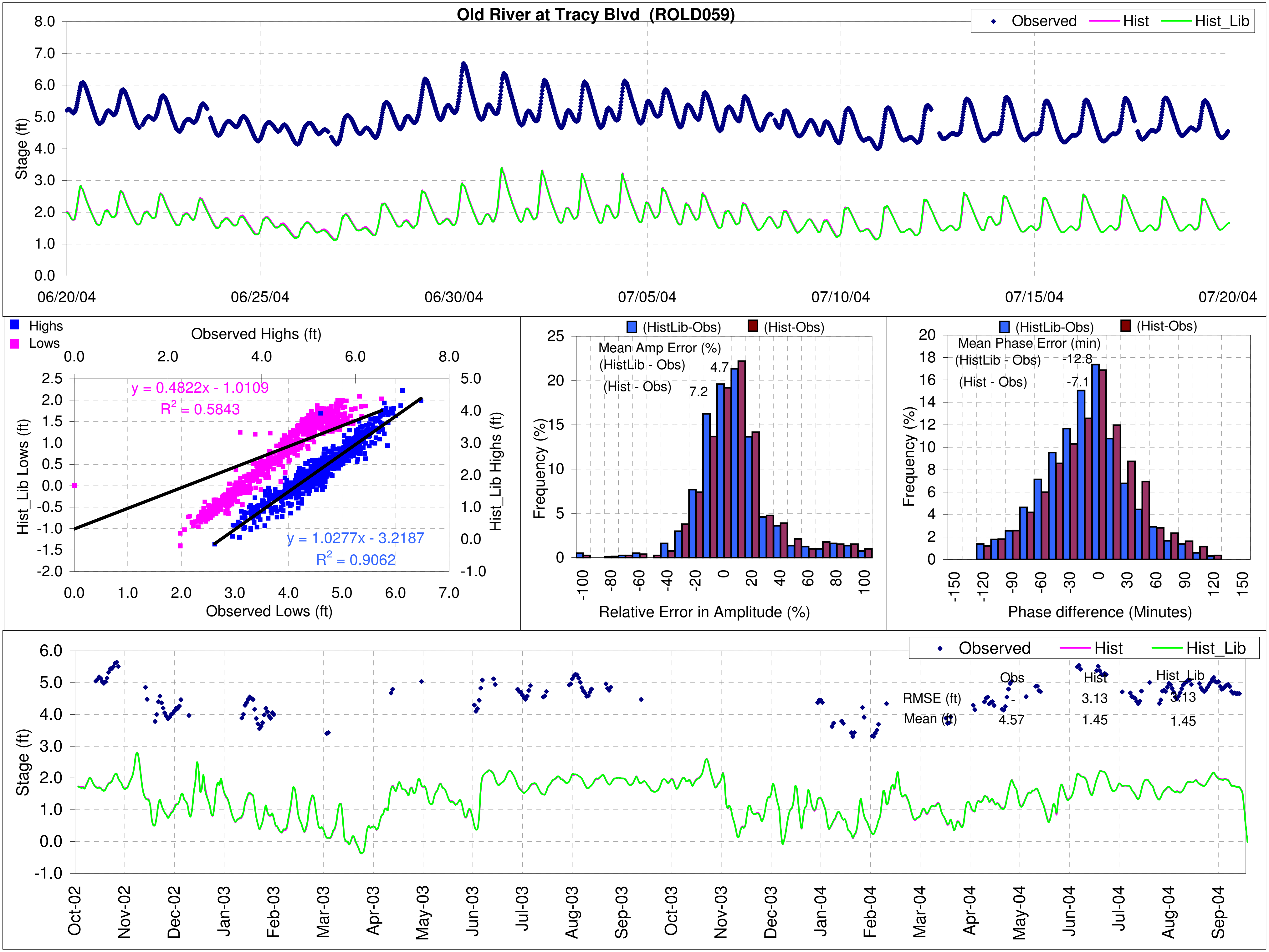

San Joaquin River at Jersey Point (RSAN018)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 1.0465x - 0.7838
R^2 = 0.9787
y = 1.0813x - 0.8325
R^2 = 0.9754
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 8.0
(Hist - Obs) 17.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -4.7
(Hist - Obs) 6.7
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (ft) - 0.66 0.66
Mean (ft) 2.16 1.50 1.50
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

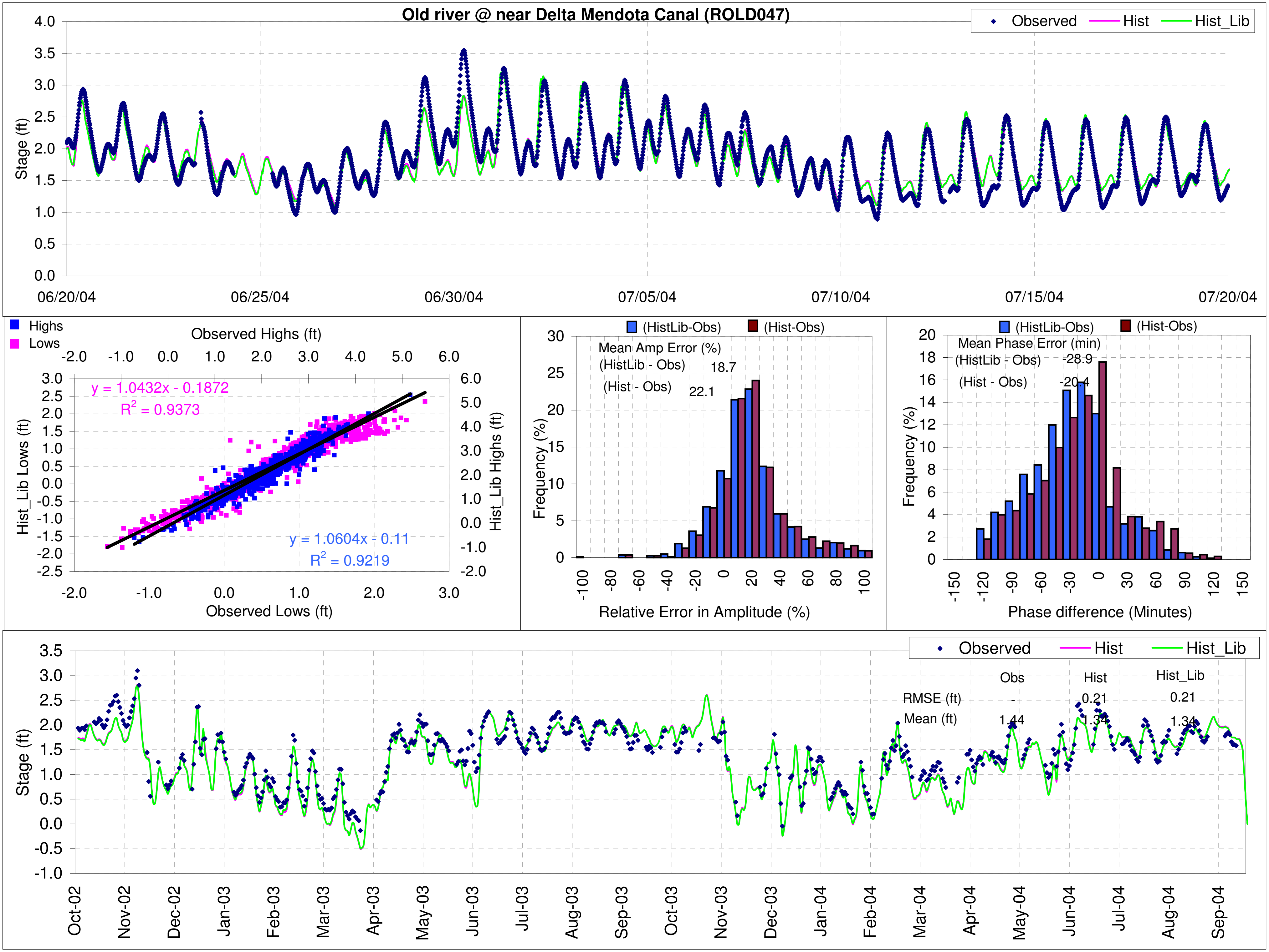


San Joaquin River at Antioch (RSAN007)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 1.064x - 0.0177
R^2 = 0.9825
y = 1.0601x + 0.1082
R^2 = 0.9714
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 12.1
(Hist - Obs) 36.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -10.1
(Hist - Obs) -6.
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.11 0.12
Mean (ft) 1.27 1.34 1.36
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

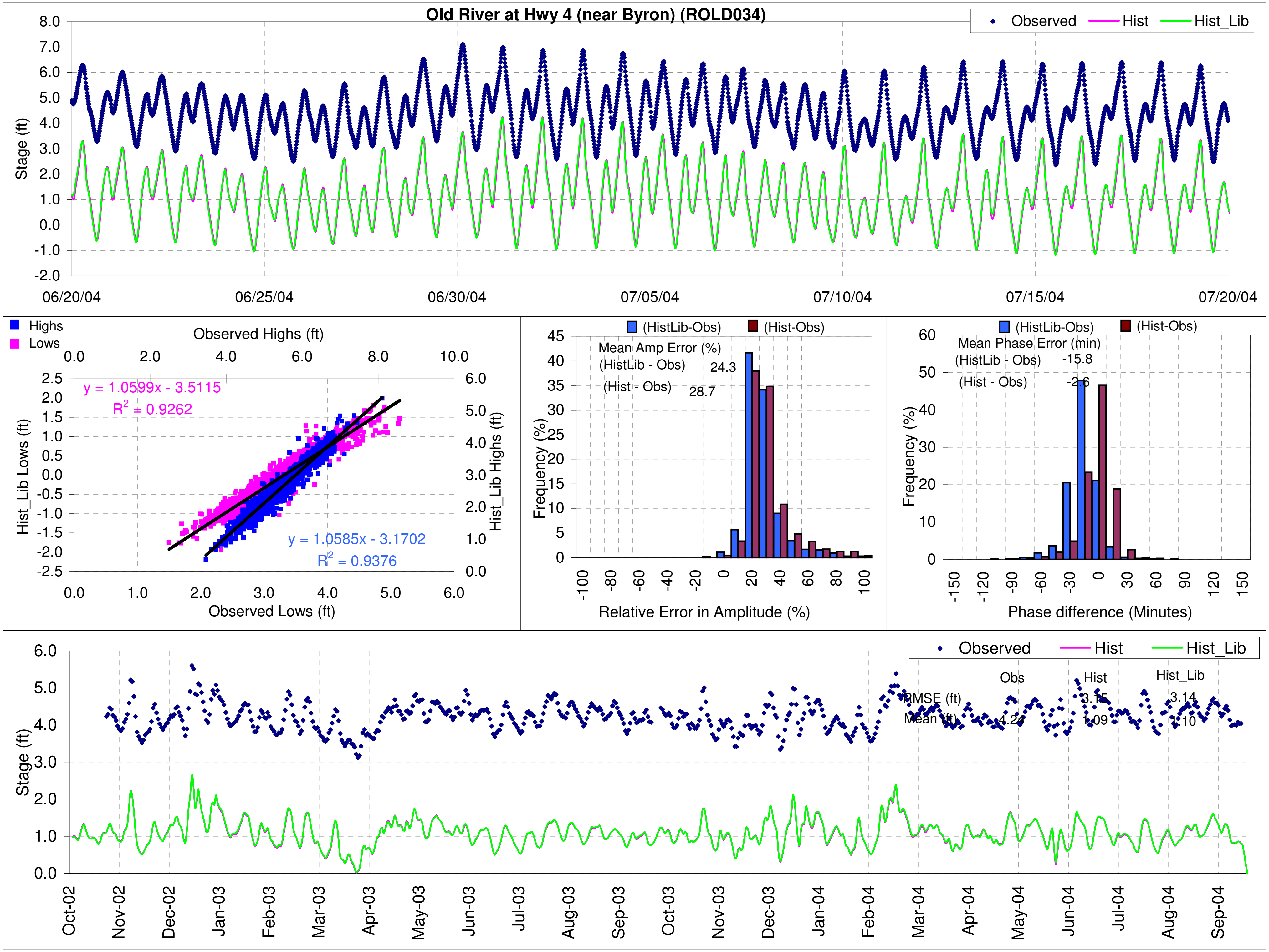


Old River at Head (ROLD074)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 0.8359x + 0.0061
R2 = 0.8609
y = 0.9614x - 0.1242
R2 = 0.8646
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 8.0
(Hist - Obs) 10.9
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -24.5
(Hist - Obs) -12.3
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.37 0.36
Mean (ft) 2.31 2.01 2.02
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

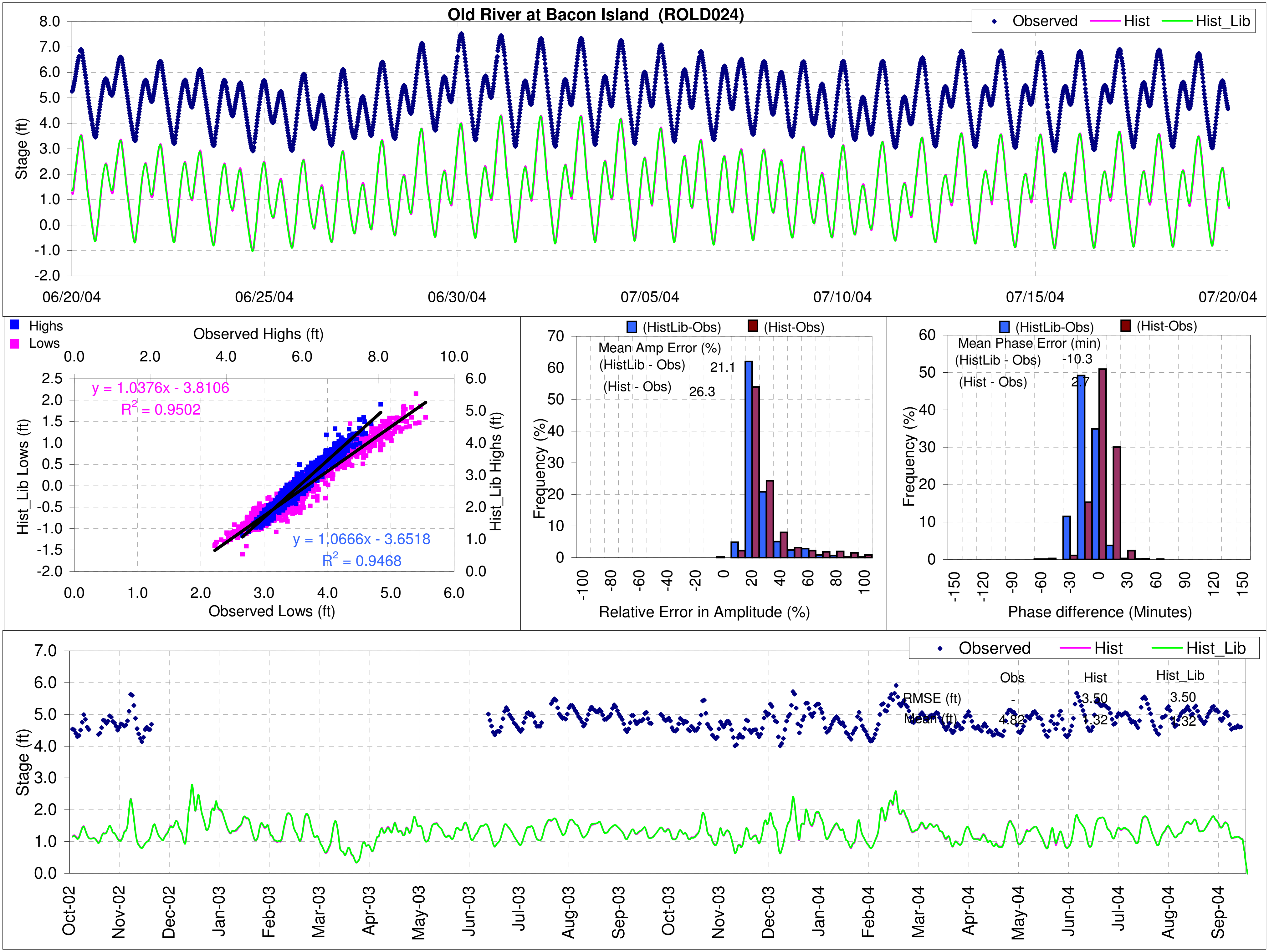

Old River at Tracy Blvd (ROLD059)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 0.4822x - 1.0109
R^2 = 0.5843
y = 1.0277x - 3.2187
R^2 = 0.9062
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 4.7
(Hist - Obs) 7.2
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -12.8
(Hist - Obs) -7.1
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 3.13 3.13
Mean (ft) 4.57 1.45 1.45
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04



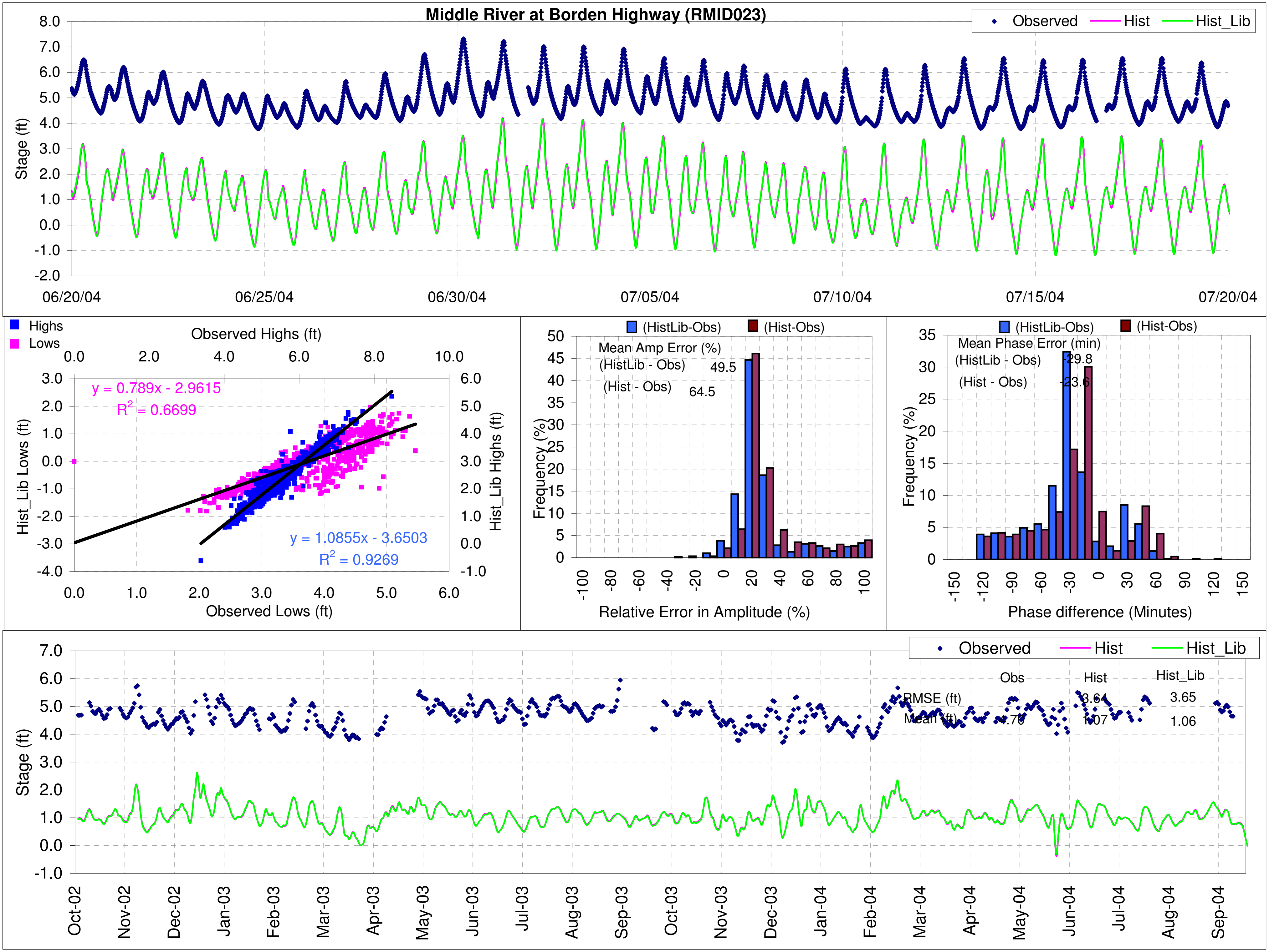
Old river @ near Delta Mendota Canal (ROLD047)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 1.0432x - 0.1872
R^2 = 0.9373
y = 1.0604x - 0.11
R^2 = 0.9219
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 18.7
(Hist - Obs) 22.1
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -28.9
(Hist - Obs) -20.4
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 0.21 0.21
Mean (ft) 1.44 1.34 1.34
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04



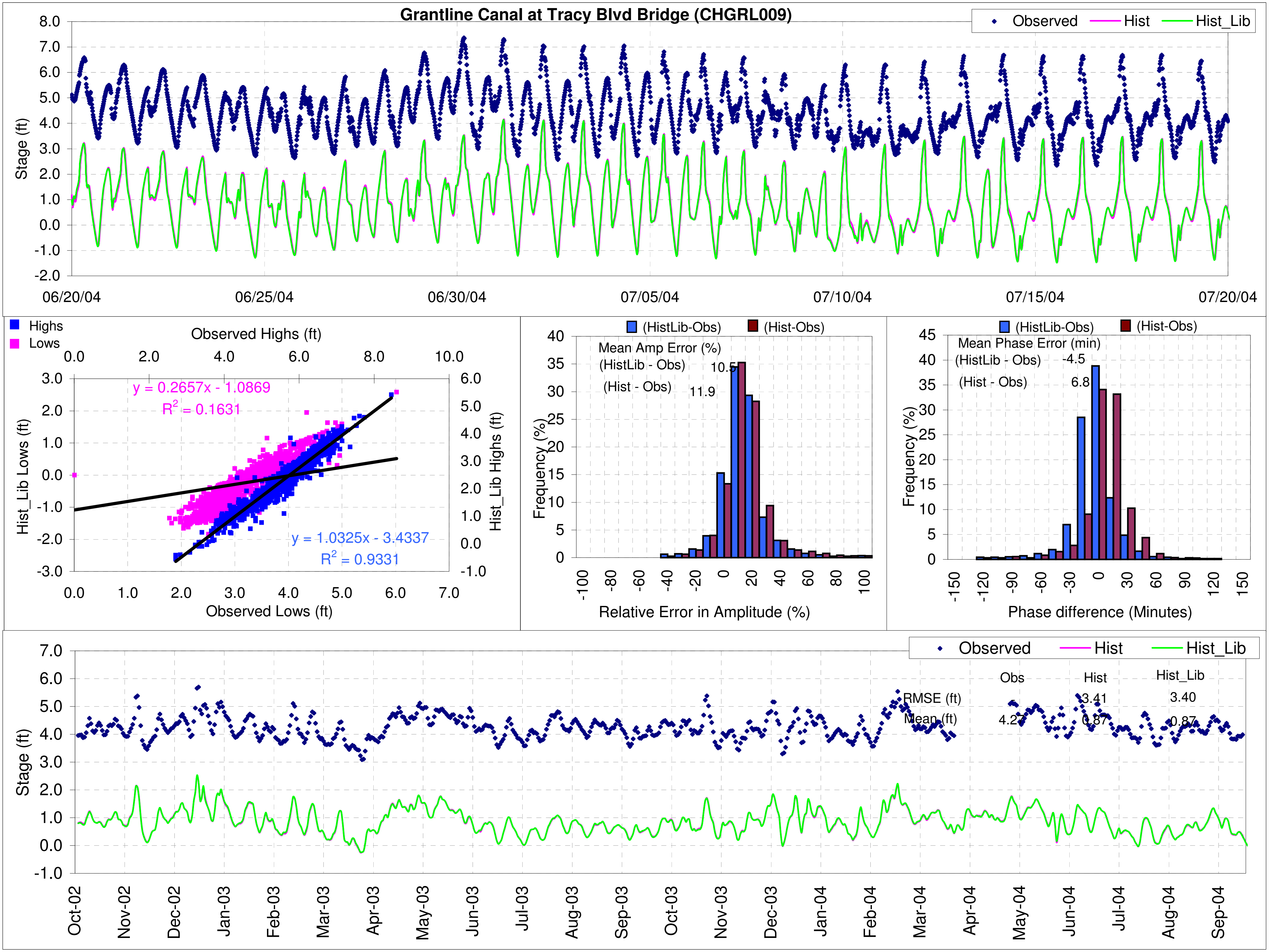
Old River at Hwy 4 (near Byron) (ROLD034)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 1.0599x - 3.5115
R2 = 0.9262
y = 1.0585x - 3.1702
R2 = 0.9376
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 24.3
(Hist - Obs) 28.7
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -15.8
(Hist - Obs) -2.6
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) 3.15 3.14
Mean (ft) 4.22 1.09 1.10



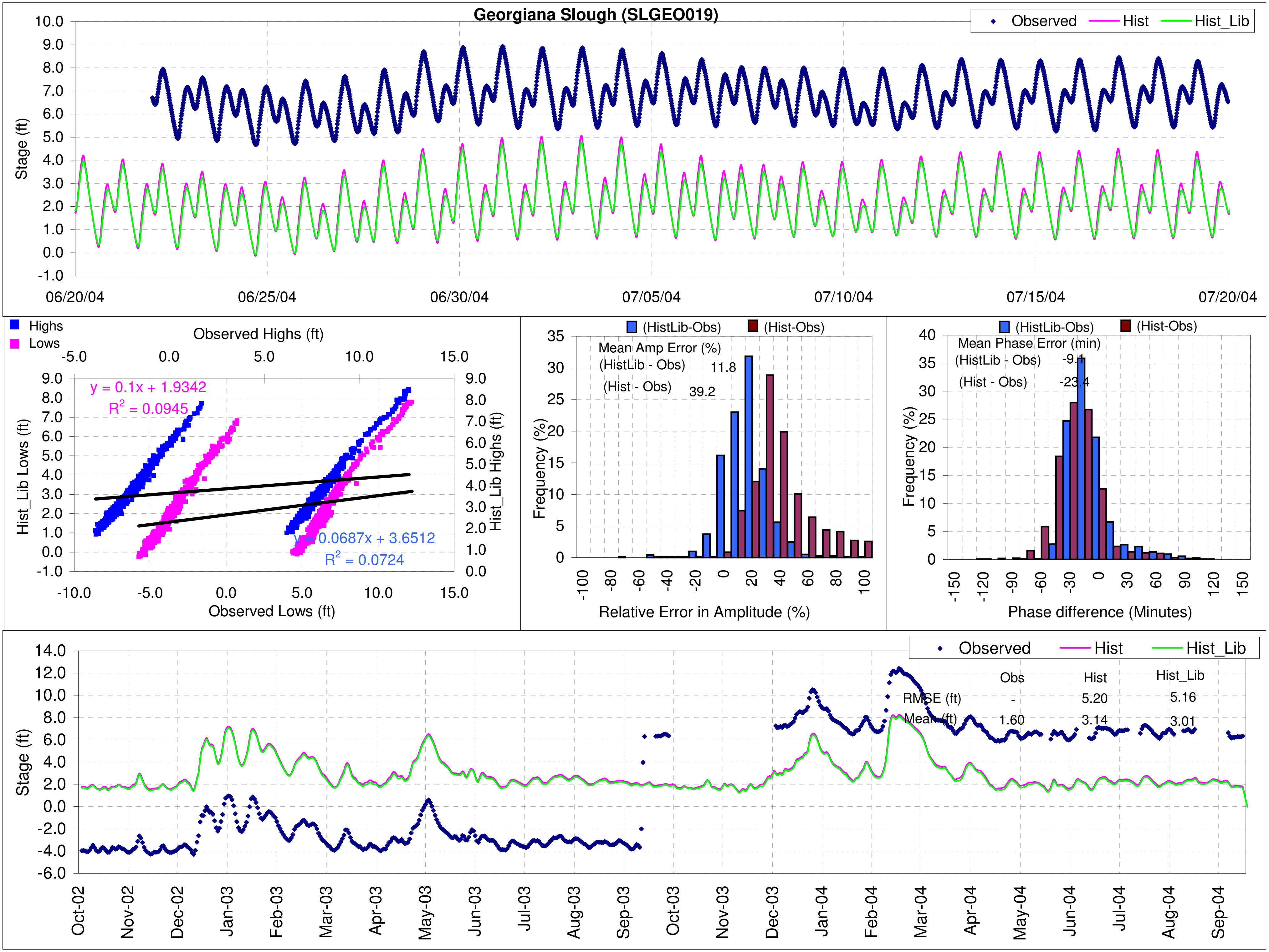
Old River at Bacon Island (ROLD024)
Observed
Hist
Hist_Lib
Stage (ft)
Highs
Lows
Observed Highs (ft)
Observed Lows (ft)
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
y = 1.0376x - 3.8106
R2 = 0.9502
y = 1.0666x - 3.6518
R2 = 0.9468
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 21.1
(Hist - Obs) 26.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -10.3
(Hist - Obs) 2.7
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 3.50 3.50
Mean (ft) 4.82 1.32 1.32

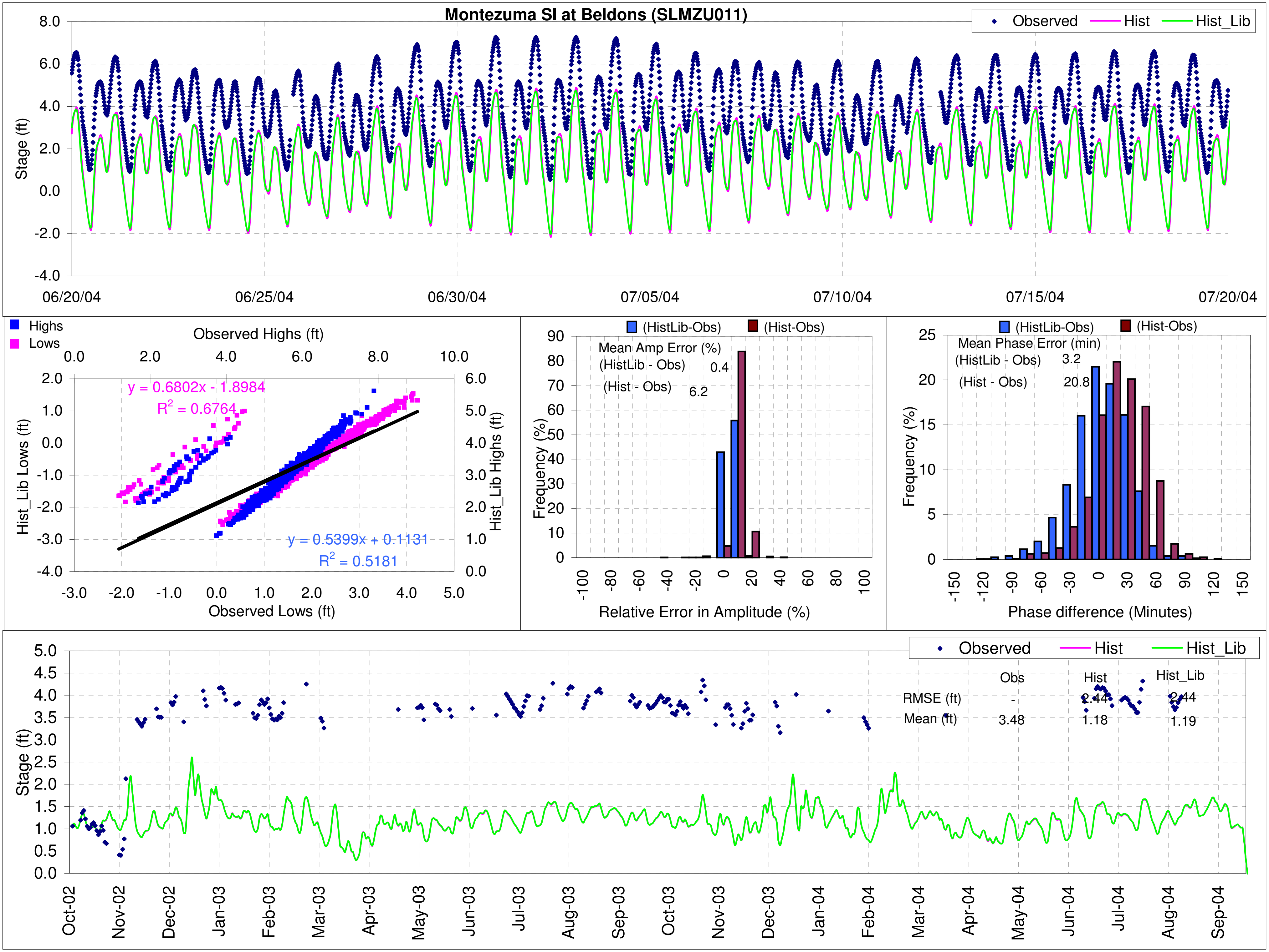


Middle River at Borden Highway (RMID023)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 0.789x - 2.9615
R2 = 0.6699
y = 1.0855x - 3.6503
R2 = 0.9269
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 49.5
(Hist - Obs) 64.5
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -29.8
(Hist - Obs) -23.6
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (ft) 3.64 3.65
Mean (ft) 4.70 1.07 1.06
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

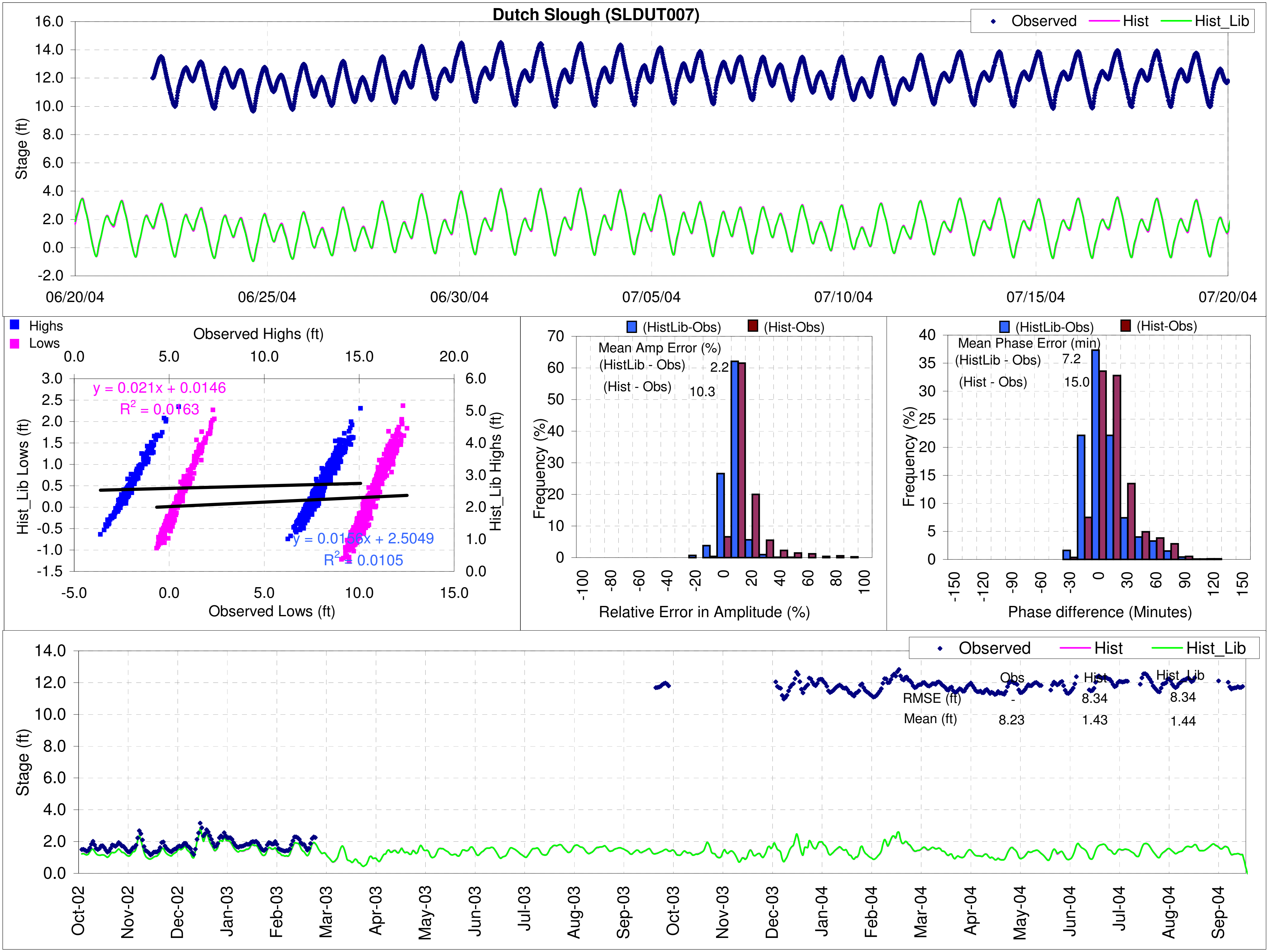


Grantline Canal at Tracy Blvd Bridge (CHGRL009)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
Observed Lows (ft)
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
y = 0.2657x - 1.0869
R2 = 0.1631
y = 1.0325x - 3.4337
R2 = 0.9331
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 10.5
(Hist - Obs) 11.9
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -4.5
(Hist - Obs) 6.8
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) 3.41 3.40
Mean (ft) 4.27 0.87 0.87
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04


Georgiana Slough (SLGEO019)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 0.1x + 1.9342
R2 = 0.0945
y = 0.0687x + 3.6512
R2 = 0.0724
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 11.8
(Hist - Obs) 39.2
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) -9.4
(Hist - Obs) -23.4
Frequency (%)
Phase difference (Minutes)
Observed
Hist
Hist_Lib
Obs
Hist
Hist_Lib
RMSE (ft) - 5.20 5.16
Mean (ft) 1.60 3.14 3.01
Stage (ft)
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

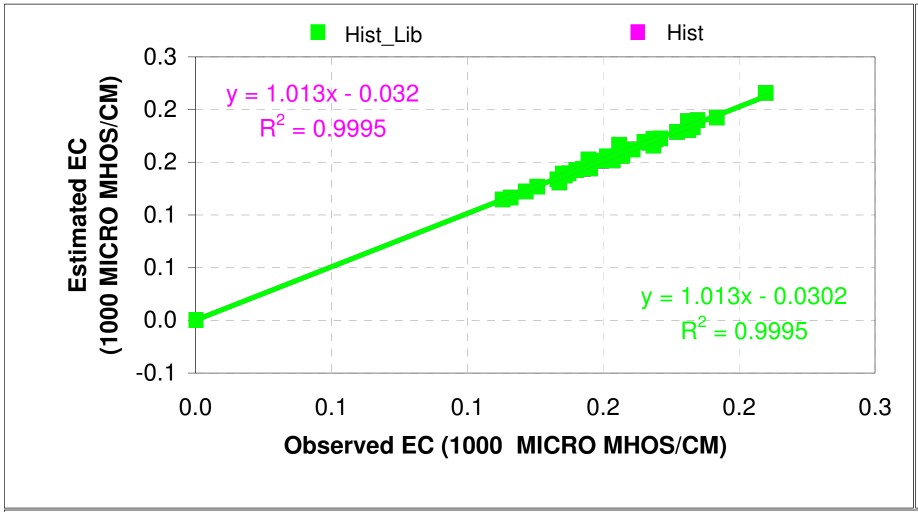


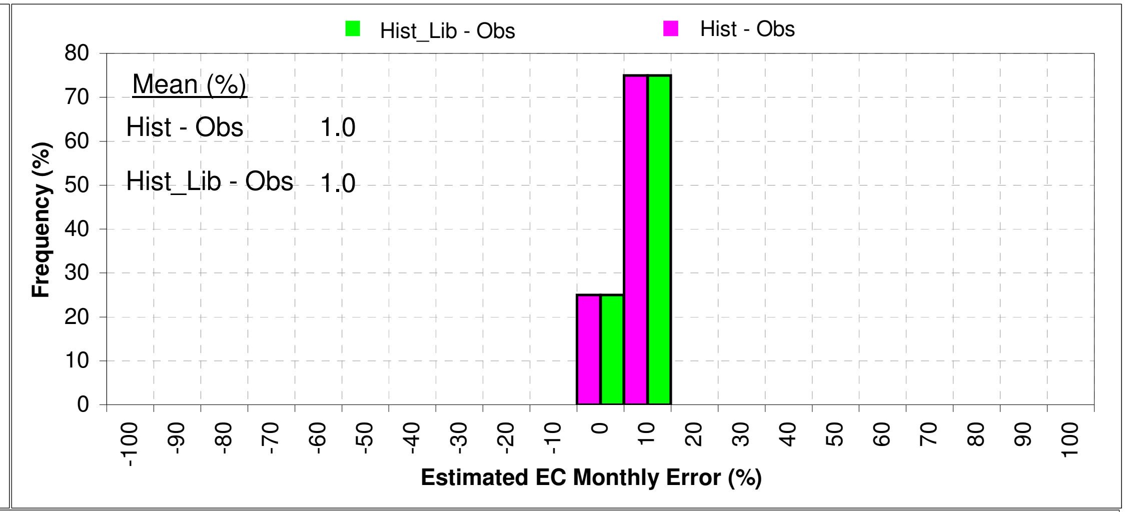
Montezuma Sl at Beldons (SLMZU011)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 0.6802x - 1.8984
R^2 = 0.6764
y = 0.5399x + 0.1131
R^2 = 0.5181
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 0.4
(Hist - Obs) 6.2
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 3.2
(Hist - Obs) 20.8
Phase difference (Minutes)
Obs
Hist
Hist_Lib
RMSE (ft) - 2.44 2.44
Mean (ft) 3.48 1.18 1.19
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

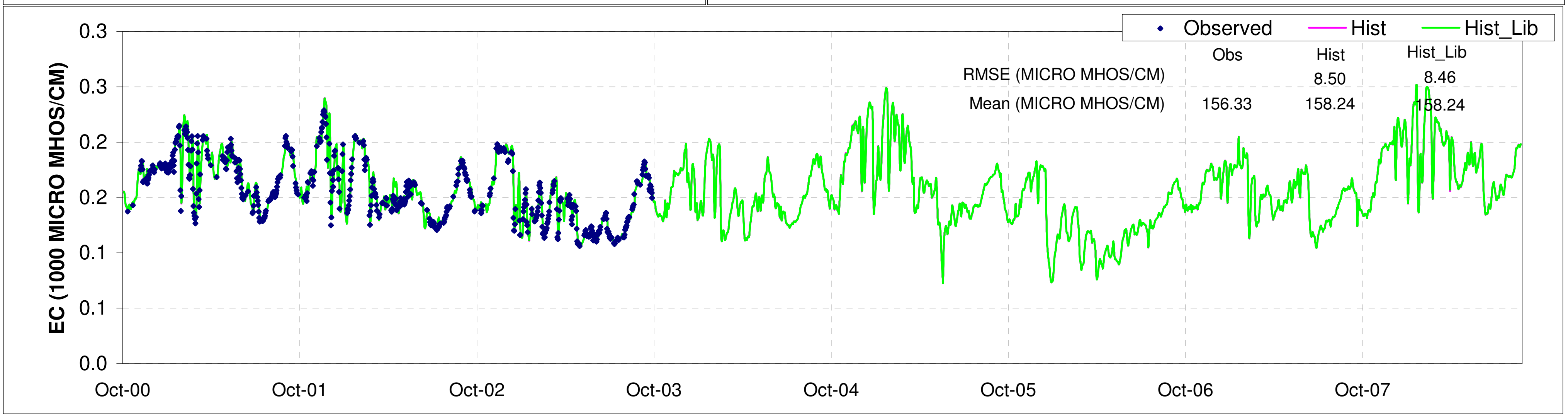

Dutch Slough (SLDUT007)
Observed
Hist
Hist_Lib
Stage (ft)
06/20/04
06/25/04
06/30/04
07/05/04
07/10/04
07/15/04
07/20/04
Highs
Lows
Observed Highs (ft)
y = 0.021x + 0.0146
R2 = 0.0163
y = 0.0156x + 2.5049
R2 = 0.0105
Hist_Lib Lows (ft)
Hist_Lib Highs (ft)
Observed Lows (ft)
(HistLib-Obs)
(Hist-Obs)
Mean Amp Error (%)
(HistLib - Obs) 2.2
(Hist - Obs) 10.3
Frequency (%)
Relative Error in Amplitude (%)
Mean Phase Error (min)
(HistLib - Obs) 7.2
(Hist - Obs) 15.0
Frequency (%)
Phase difference (Minutes)
Obs Hist Hist_Lib
RMSE (ft) - 8.34 8.34
Mean (ft) 8.23 1.43 1.44
Oct-02
Nov-02
Dec-02
Jan-03
Feb-03
Mar-03
Apr-03
May-03
Jun-03
Jul-03
Aug-03
Sep-03
Oct-03
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04

Appendix C
Detailed QUAL Calibration Results

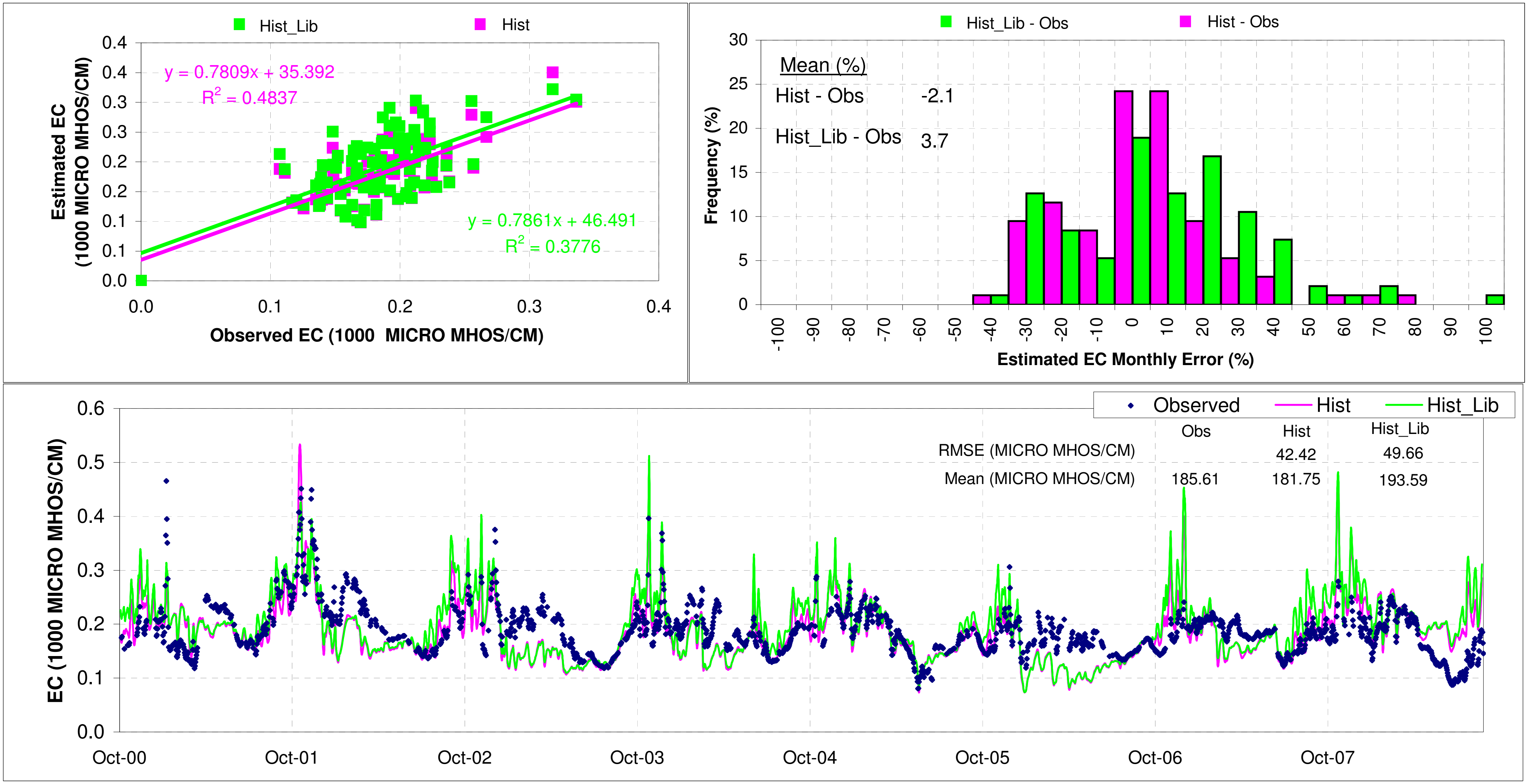
Sacramento River at Greens Landing (RSAC139)



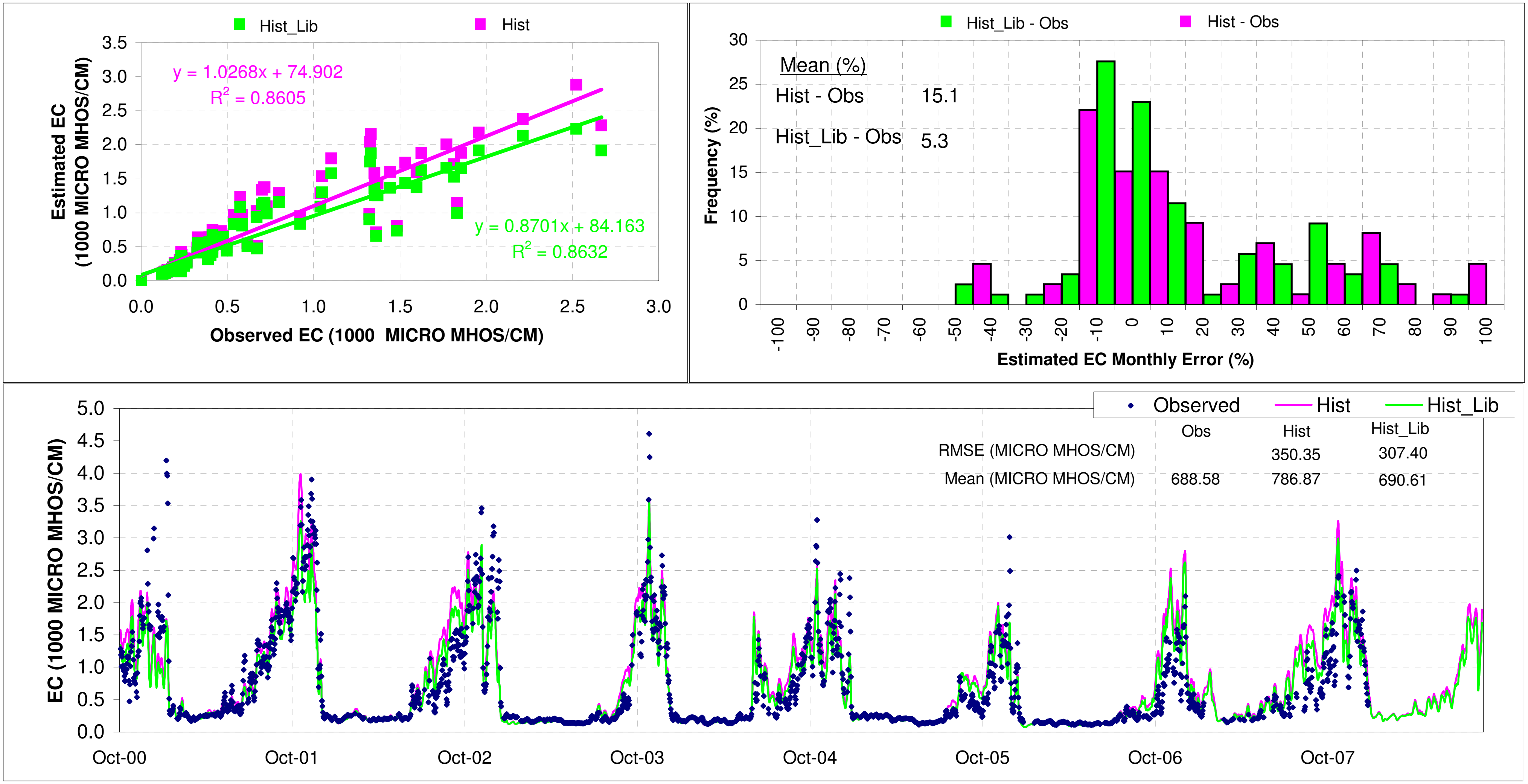




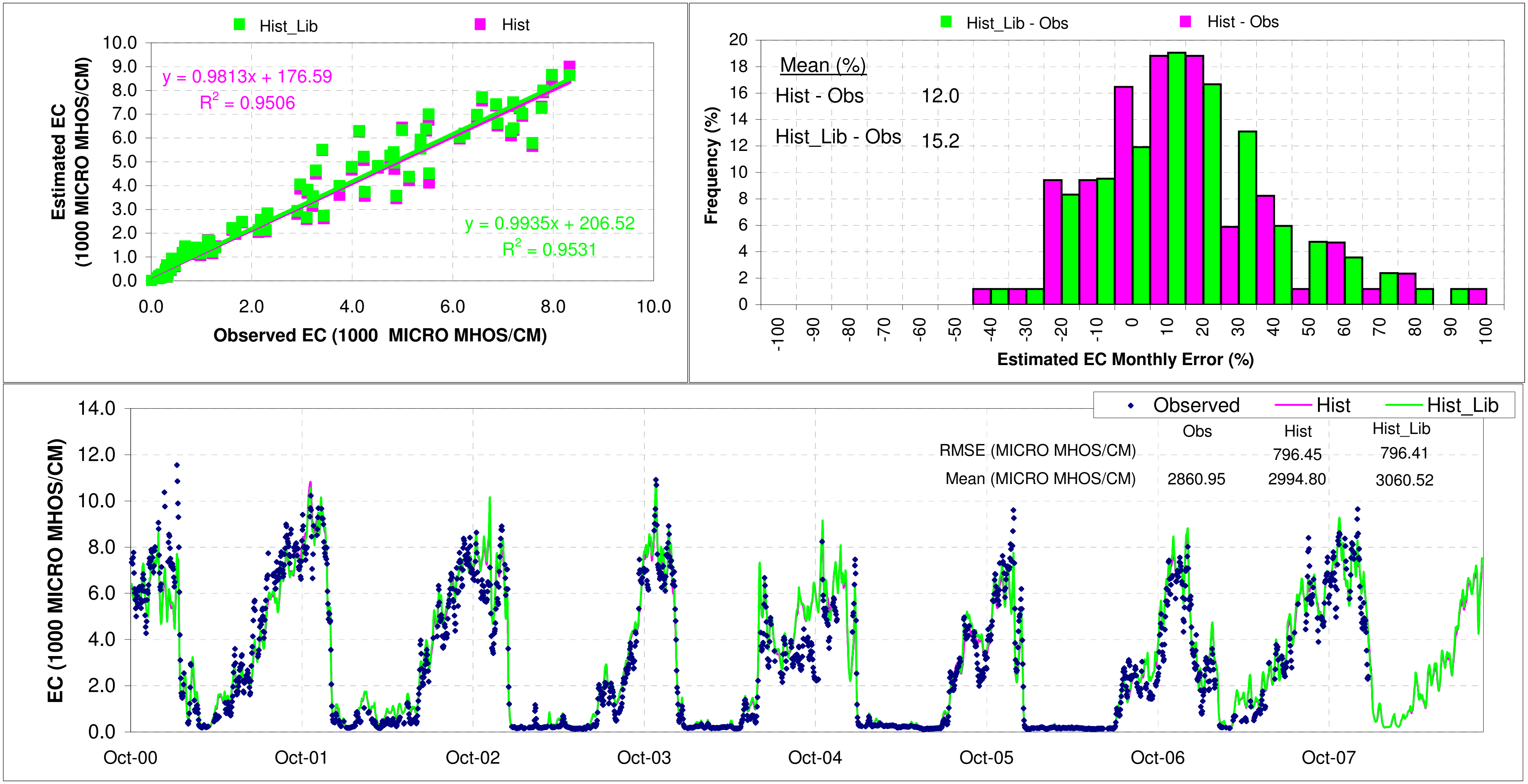
Sacramento River at Rio Vista (RSAC101)



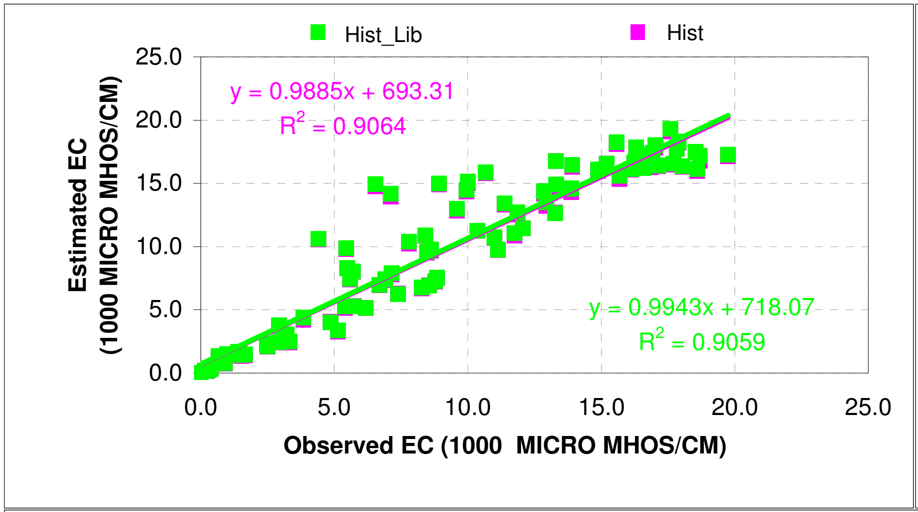
Sacramento River at Emmaton (RSAC092)

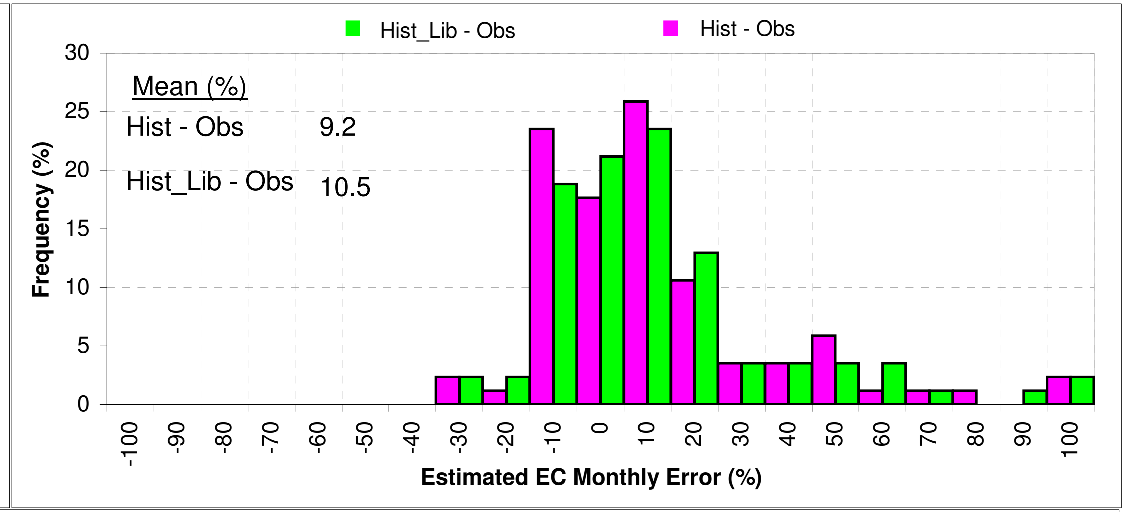


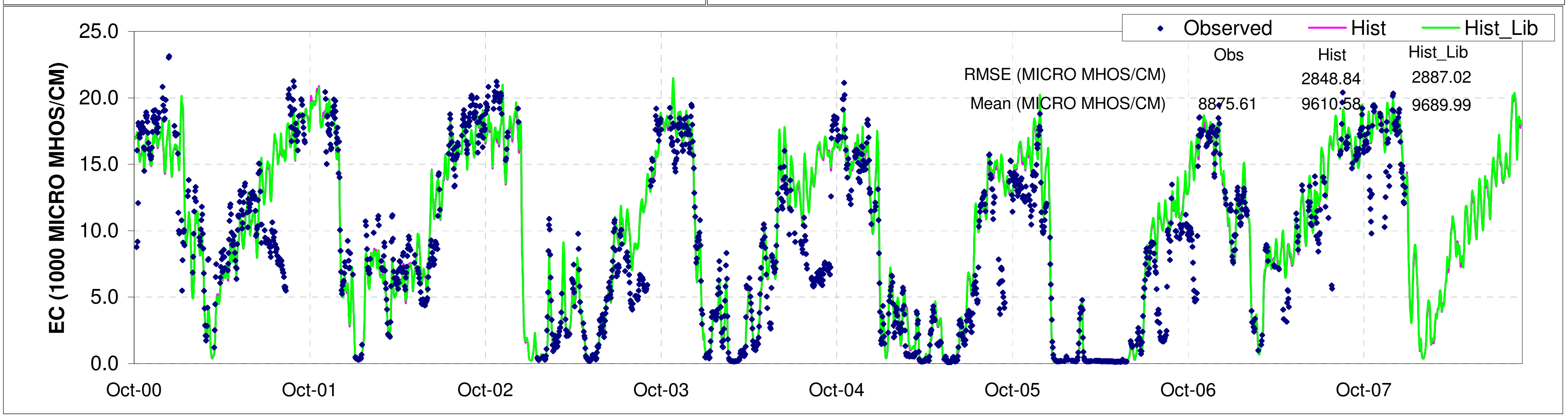
Sacramento River at Collinsville (RSAC081)



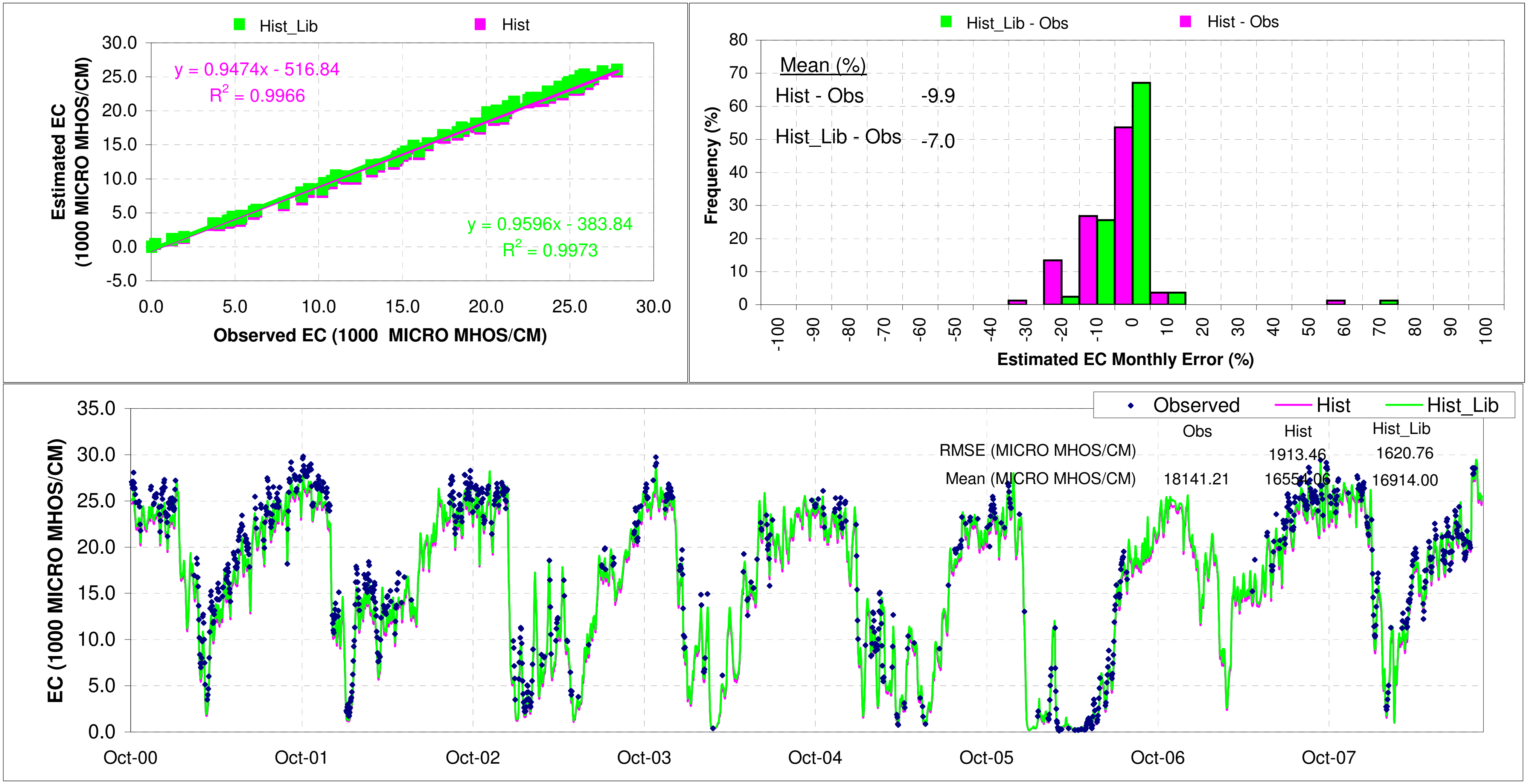
Sacramento River at Port Chicago (RSAC064)



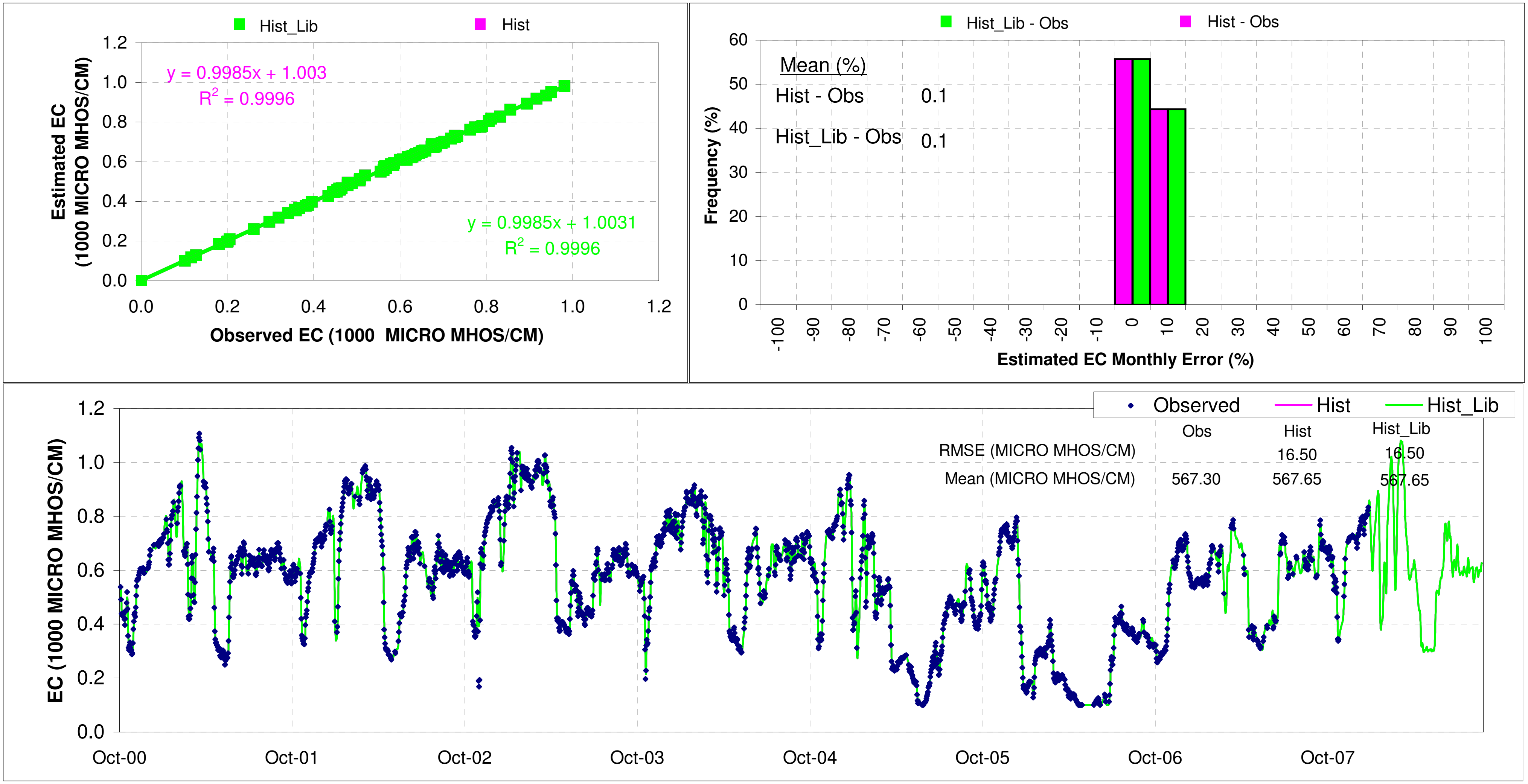




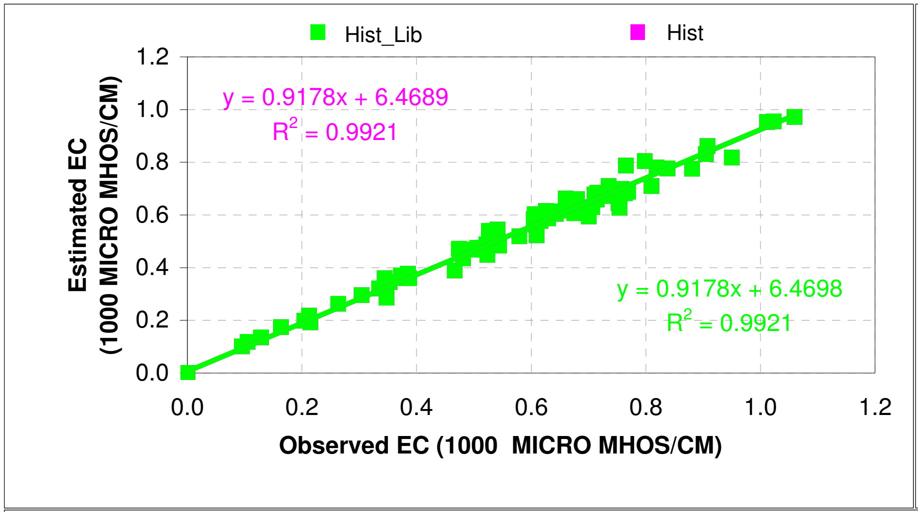
Sacramento River at Martinez (RSAC054)

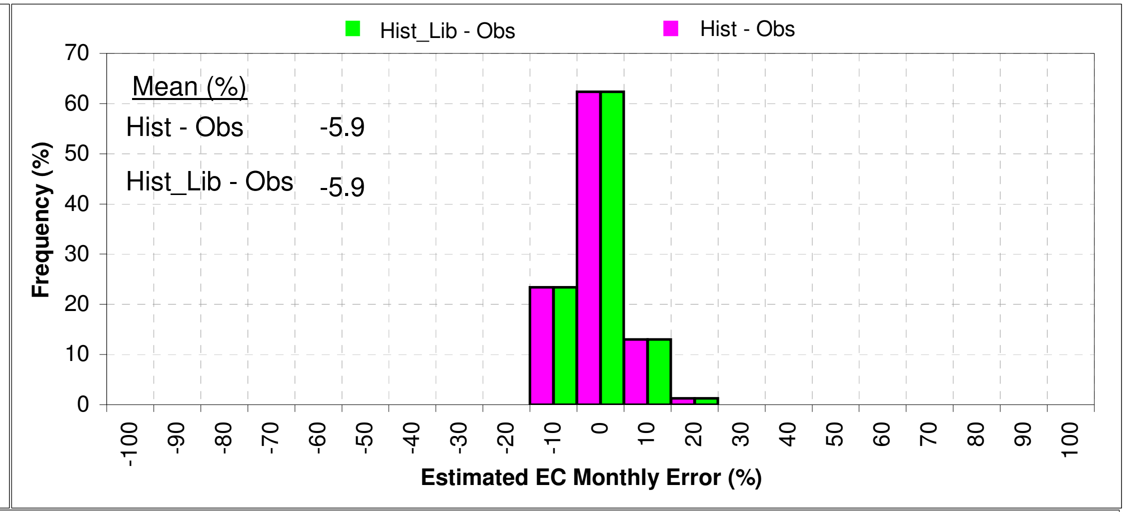


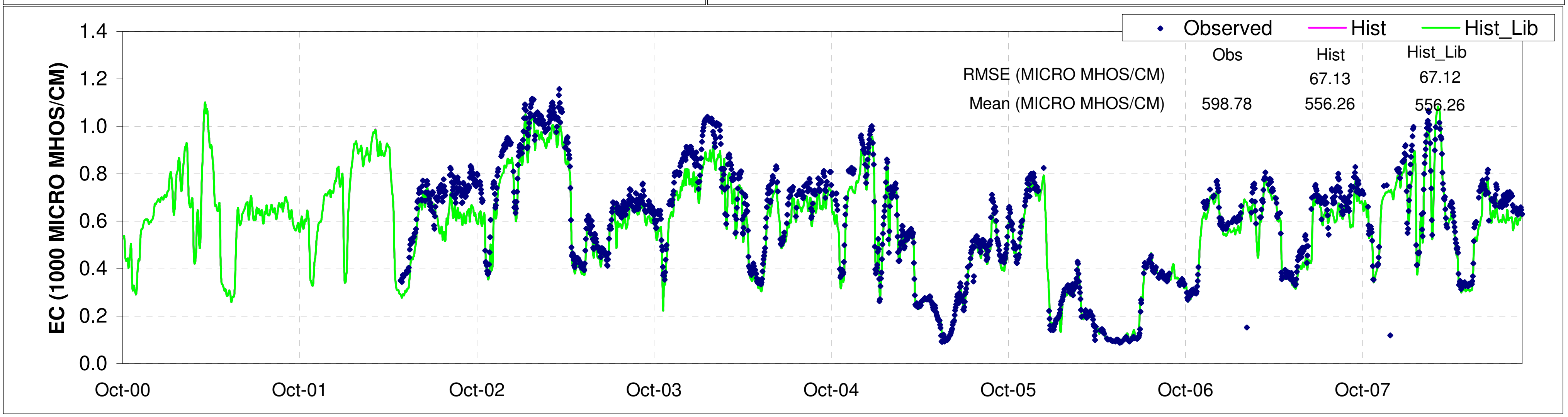
San Joaquin River at Vernalis (RSAN112)



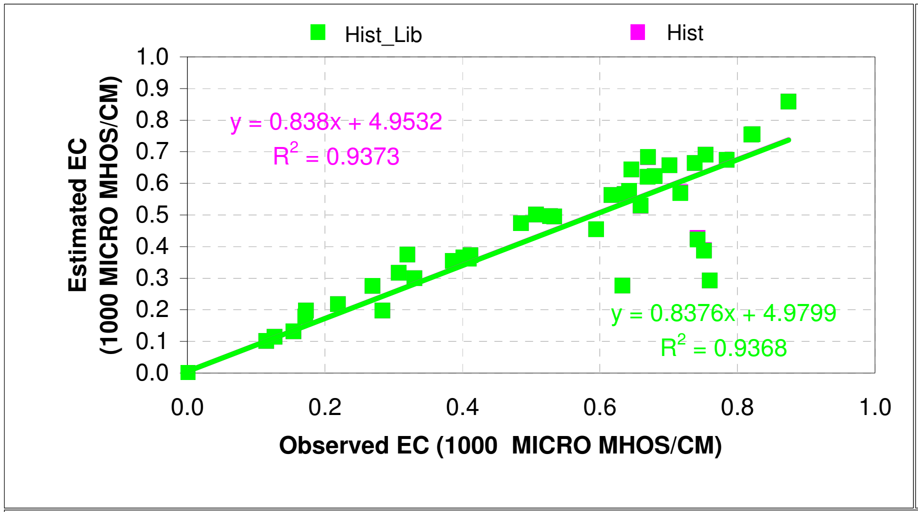
San Joaquin River at Mossdale (RSAN087)

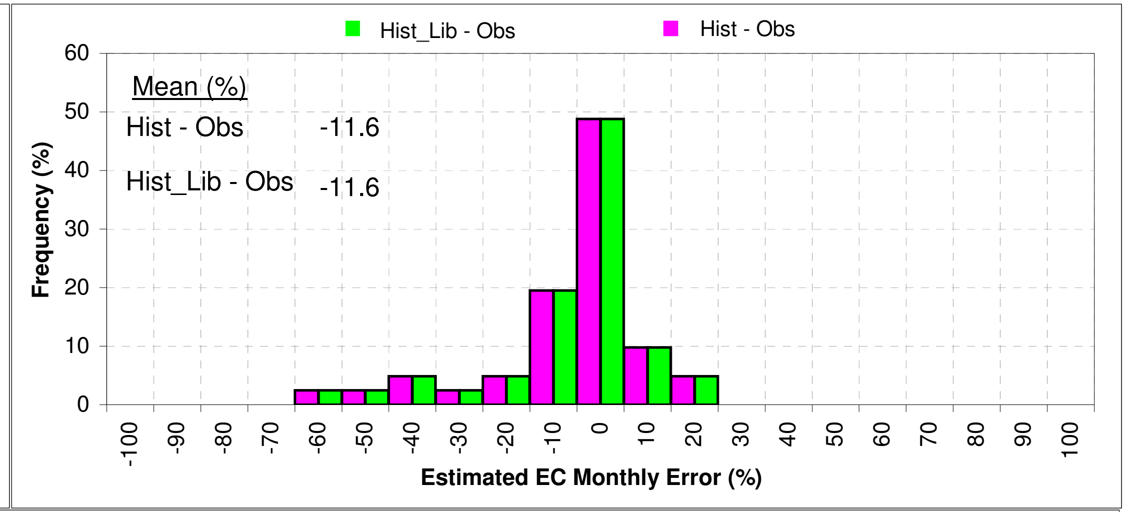


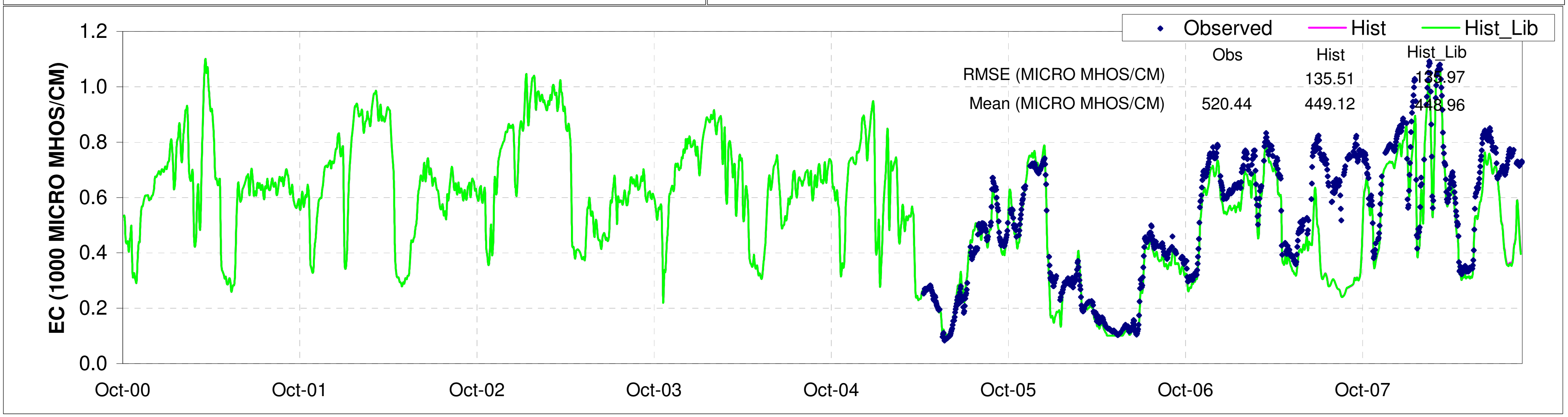




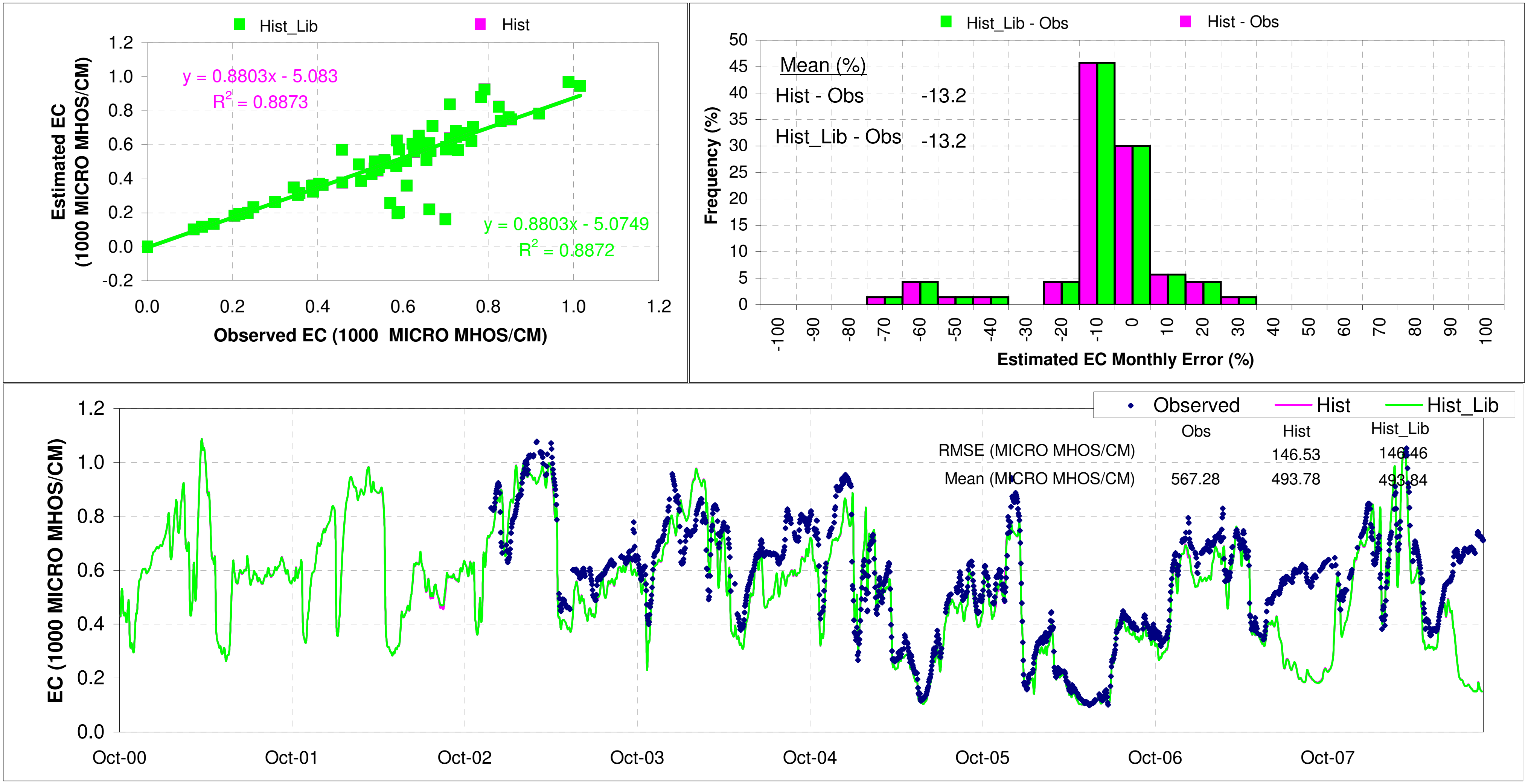
San Joaquin River at Brandt Bridge (RSAN072)



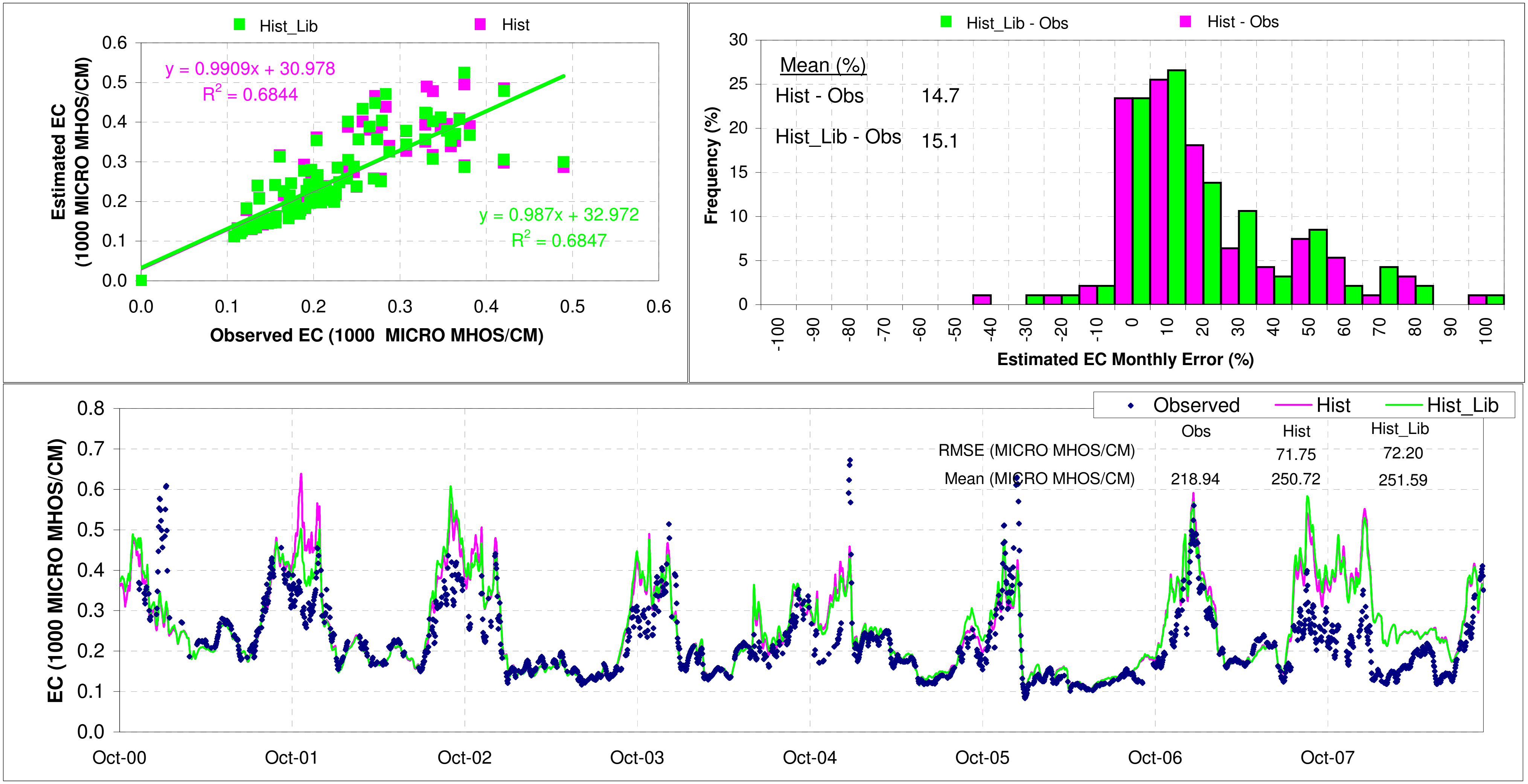




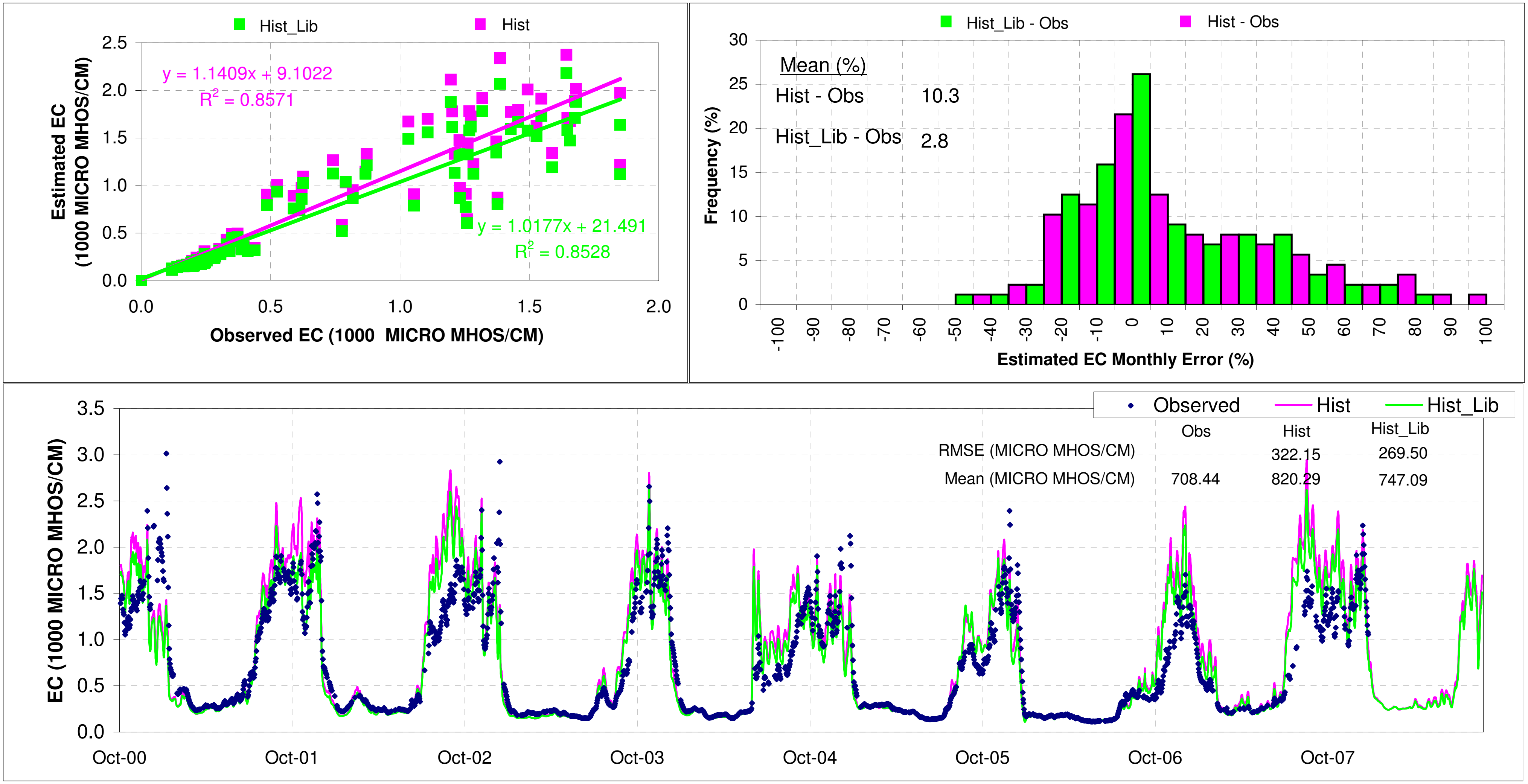
Stockton Ship Channel at Burns Cutoff (RSAN058)



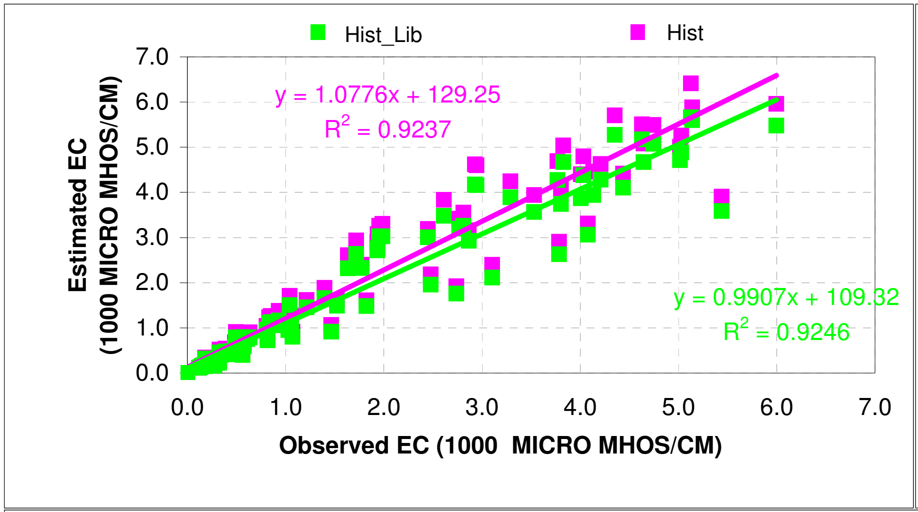
San Joaquin River at San Andreas Landing (RSAN032)

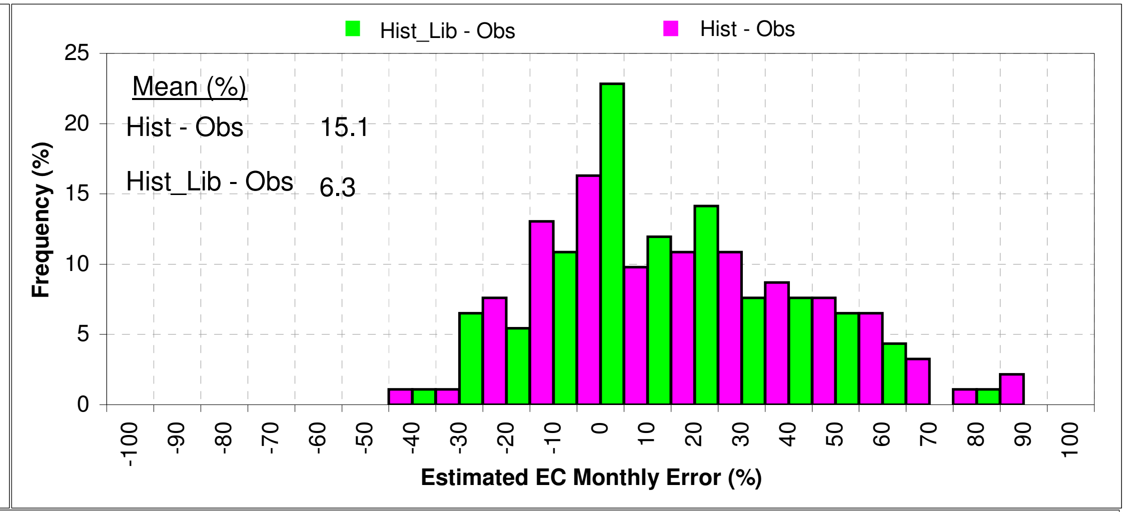


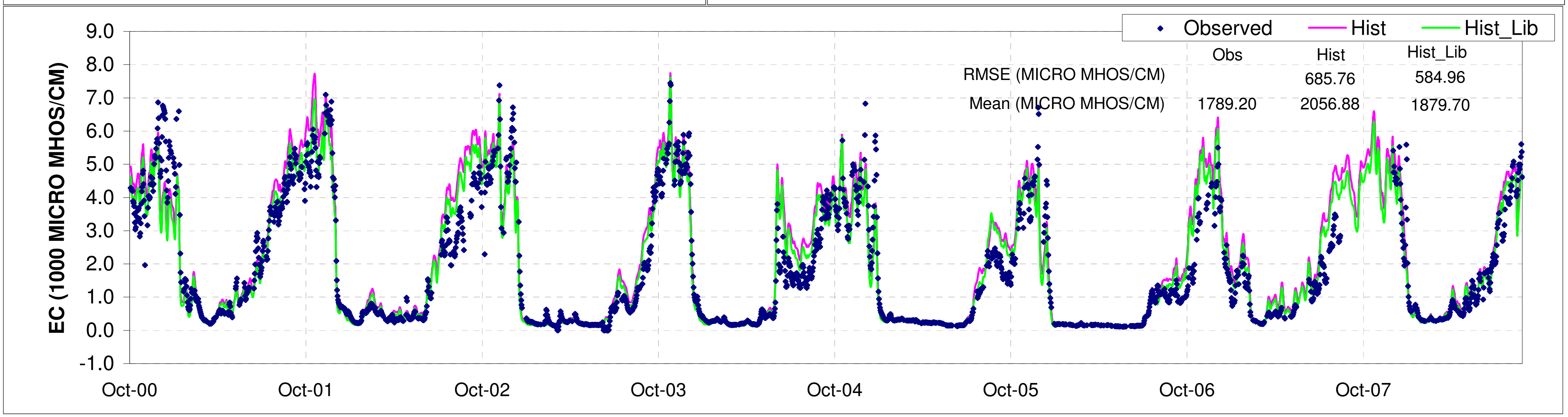
San Joaquin River at Jersey Point (RSAN018)



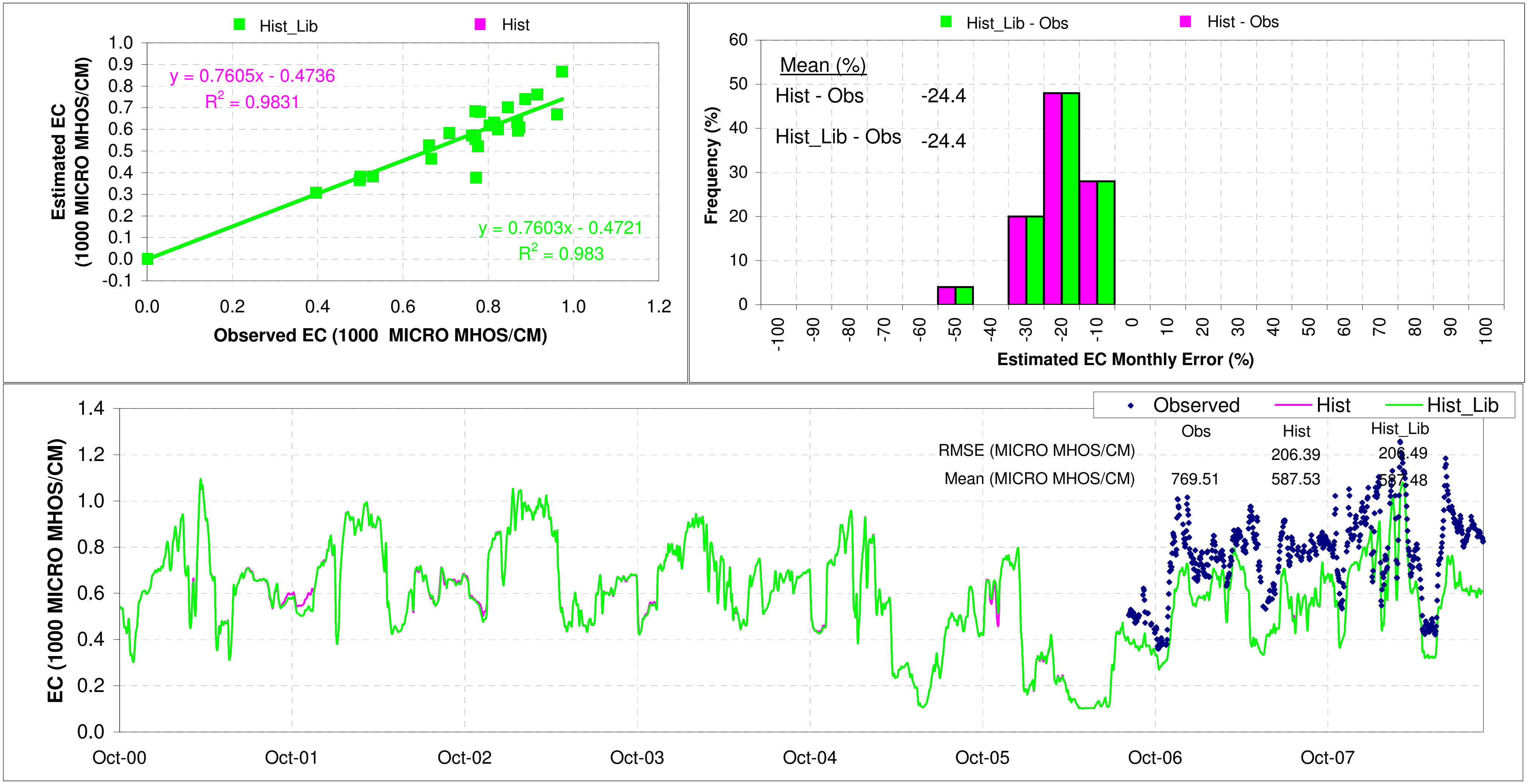
San Joaquin River at Antioch (RSAN007)



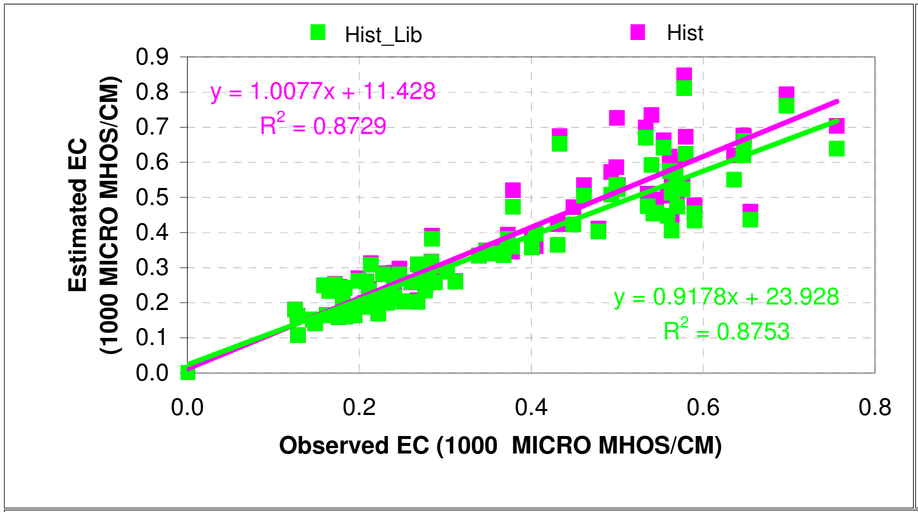


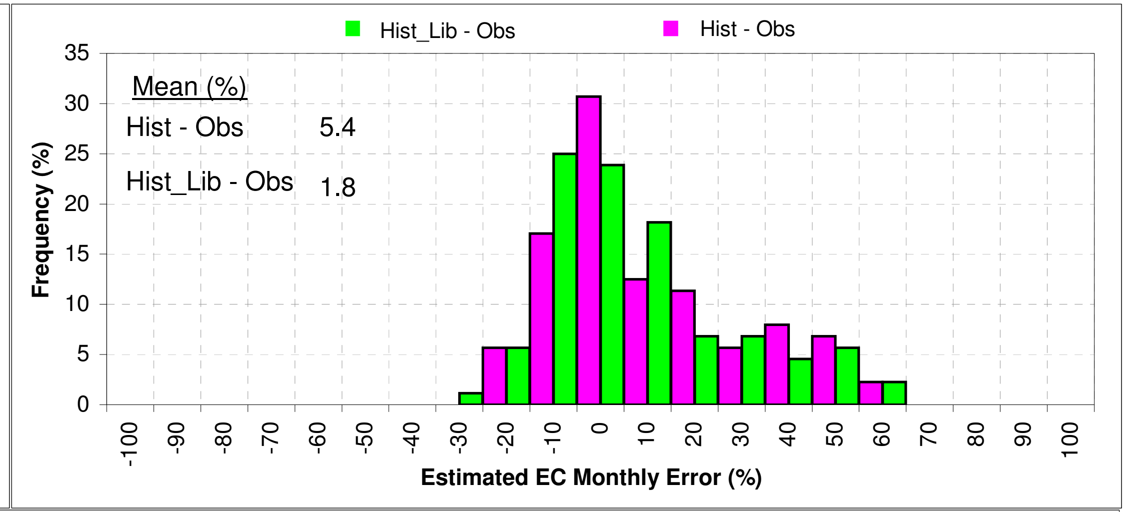


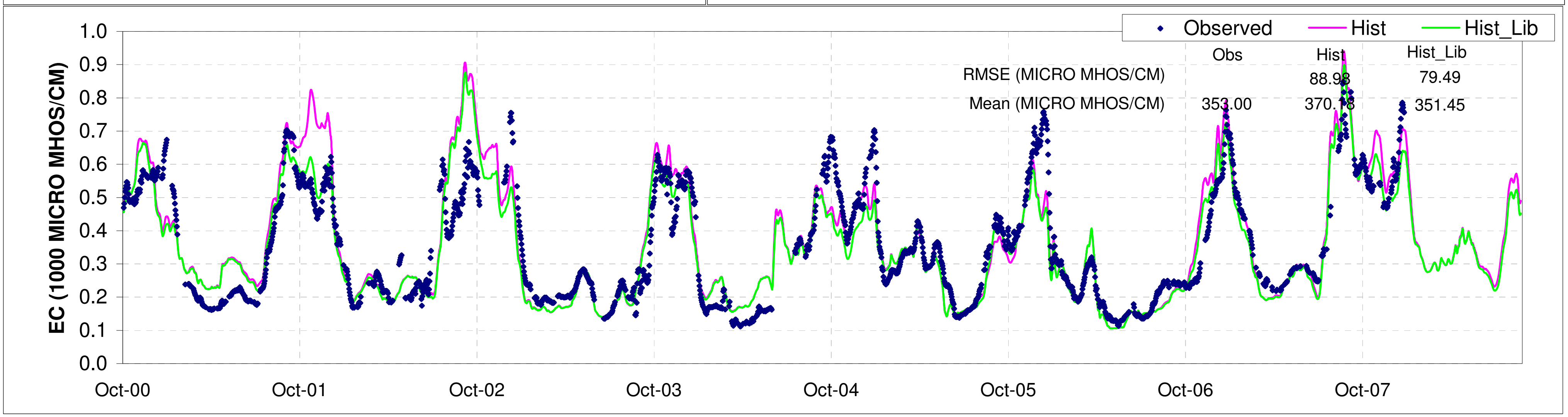
Old River at Tracy Road (ROLD059)



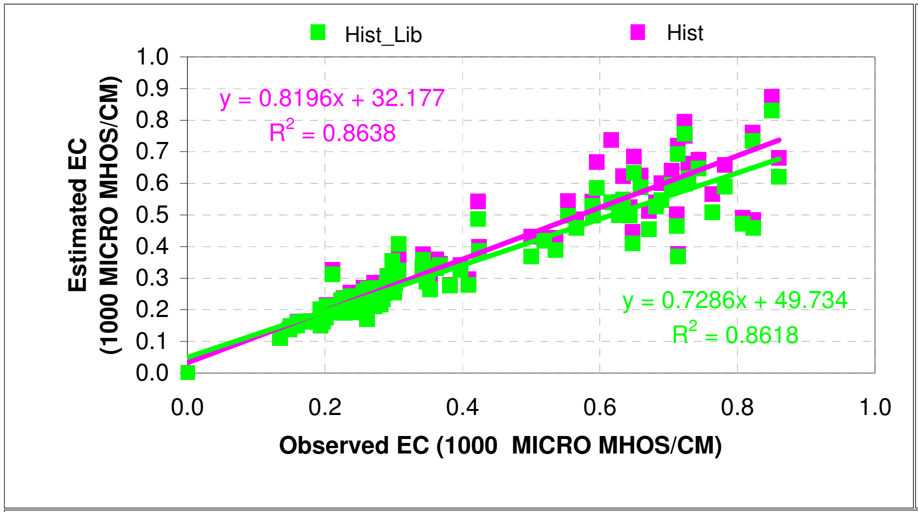
Old River at Bacon Island (ROLD024)

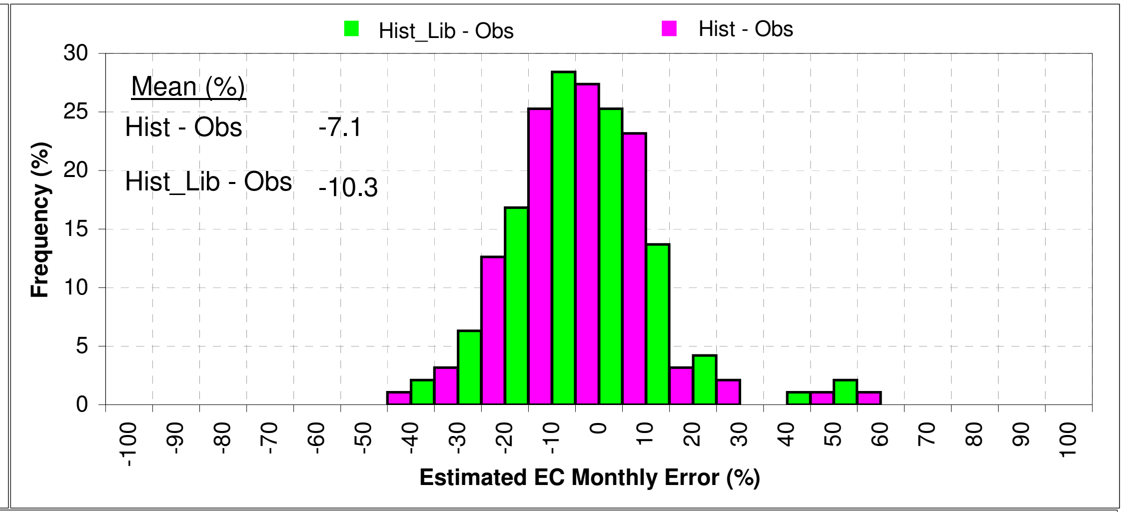


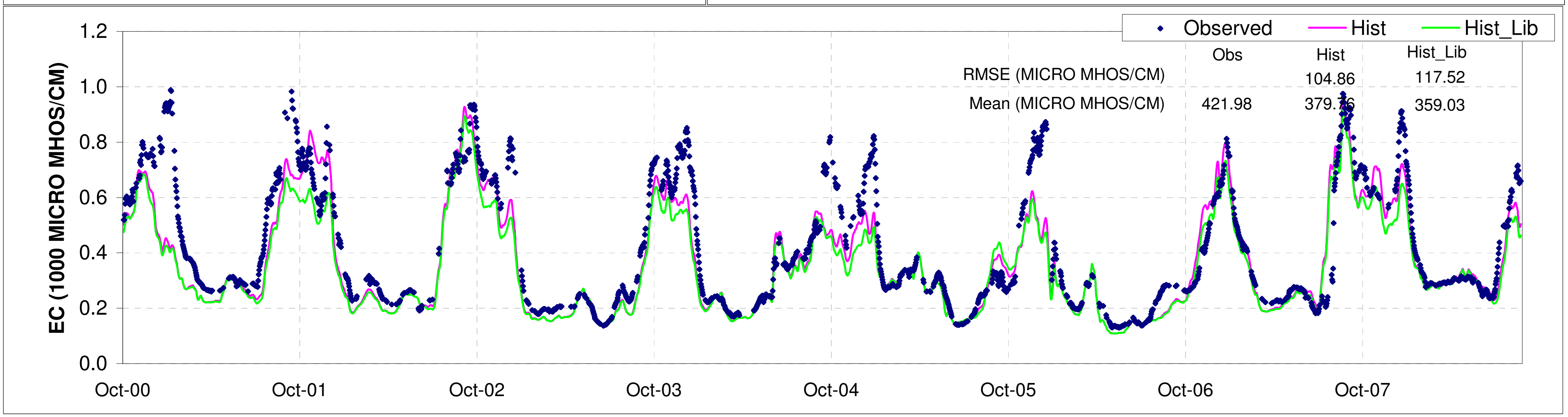




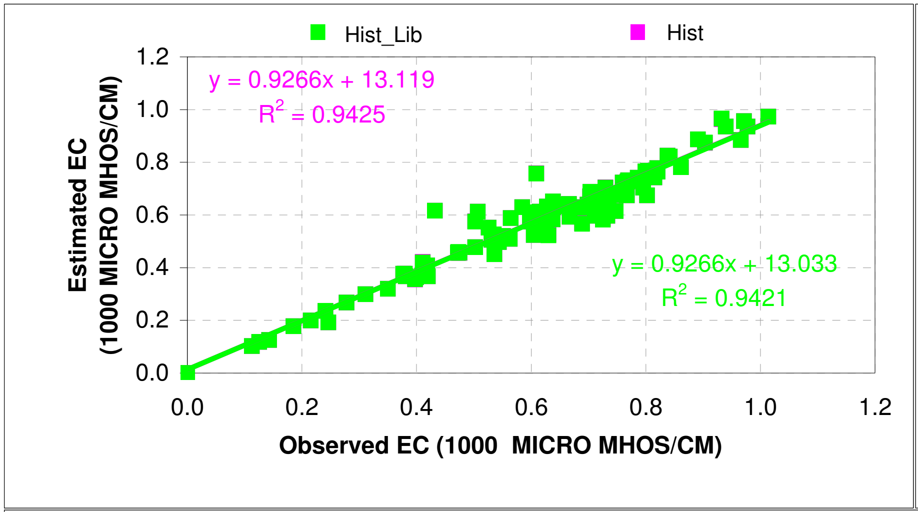
Old River at Holland Cut (ROLD014)

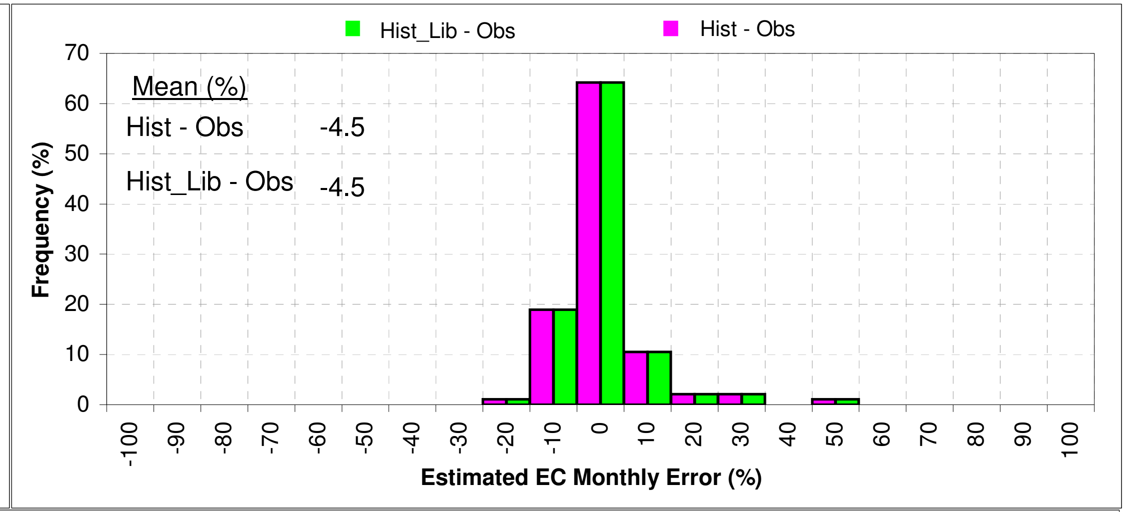


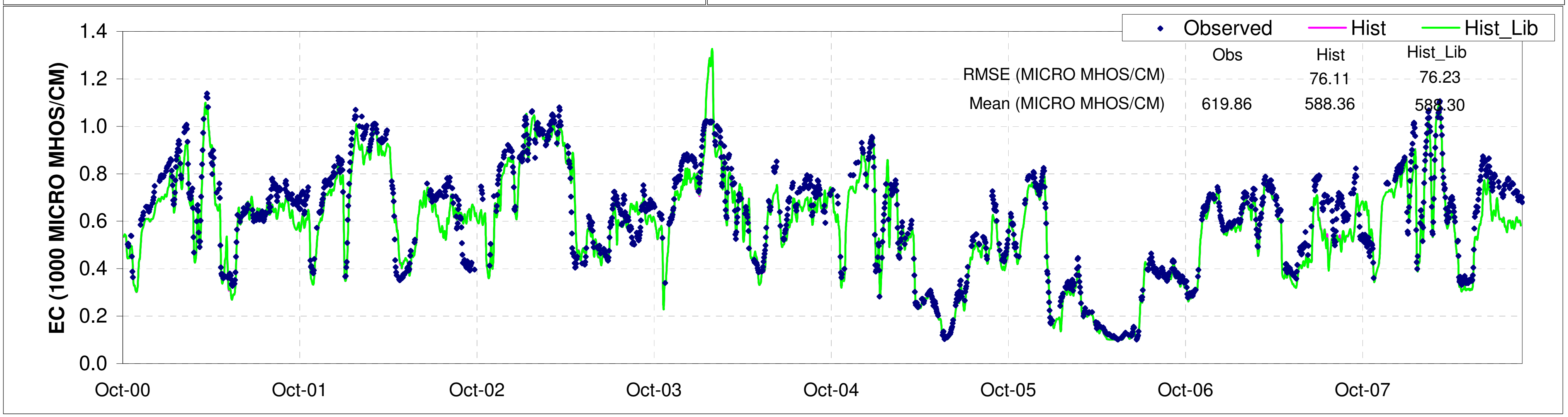




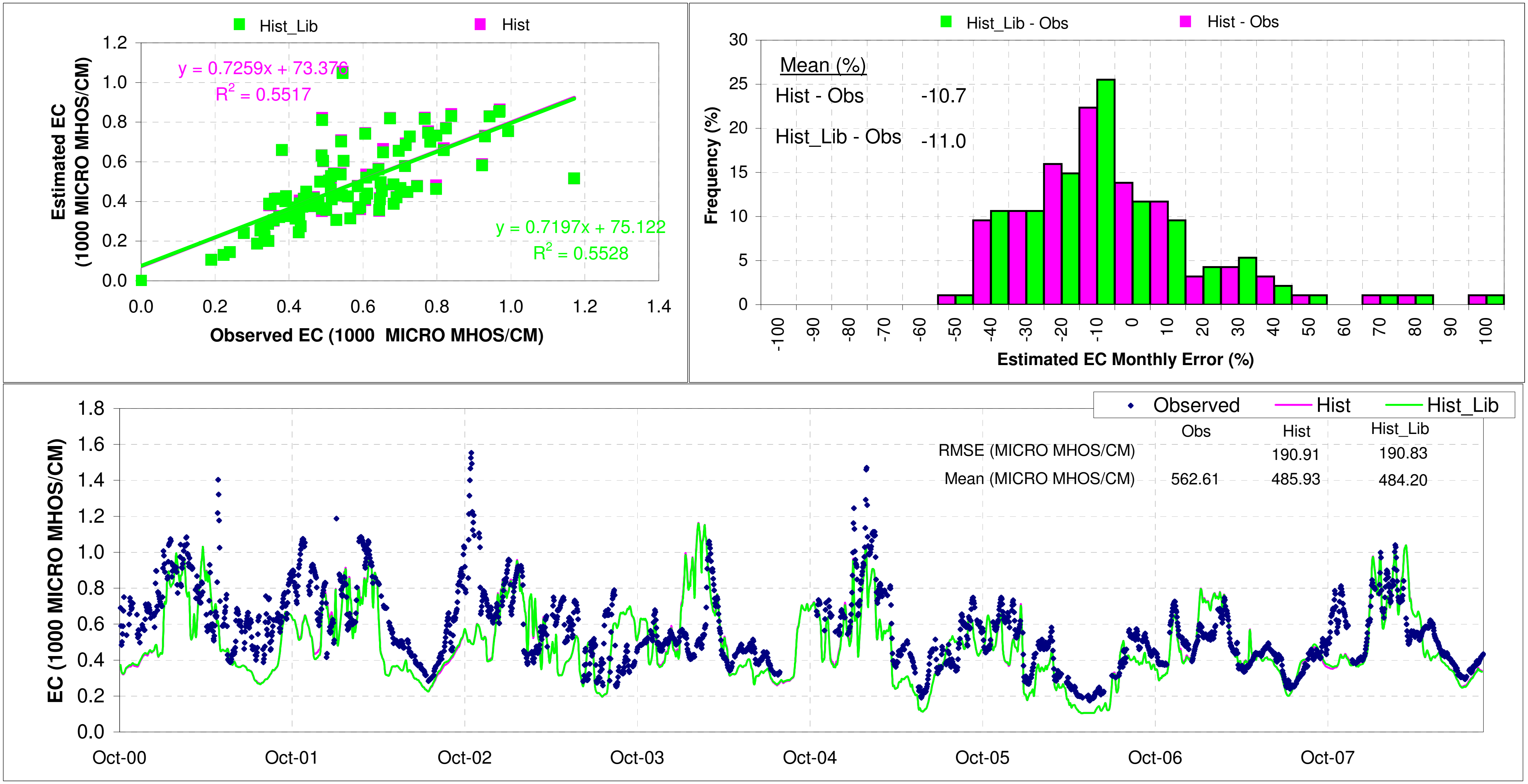
Middle River at Mowery Bridge (RMID040)



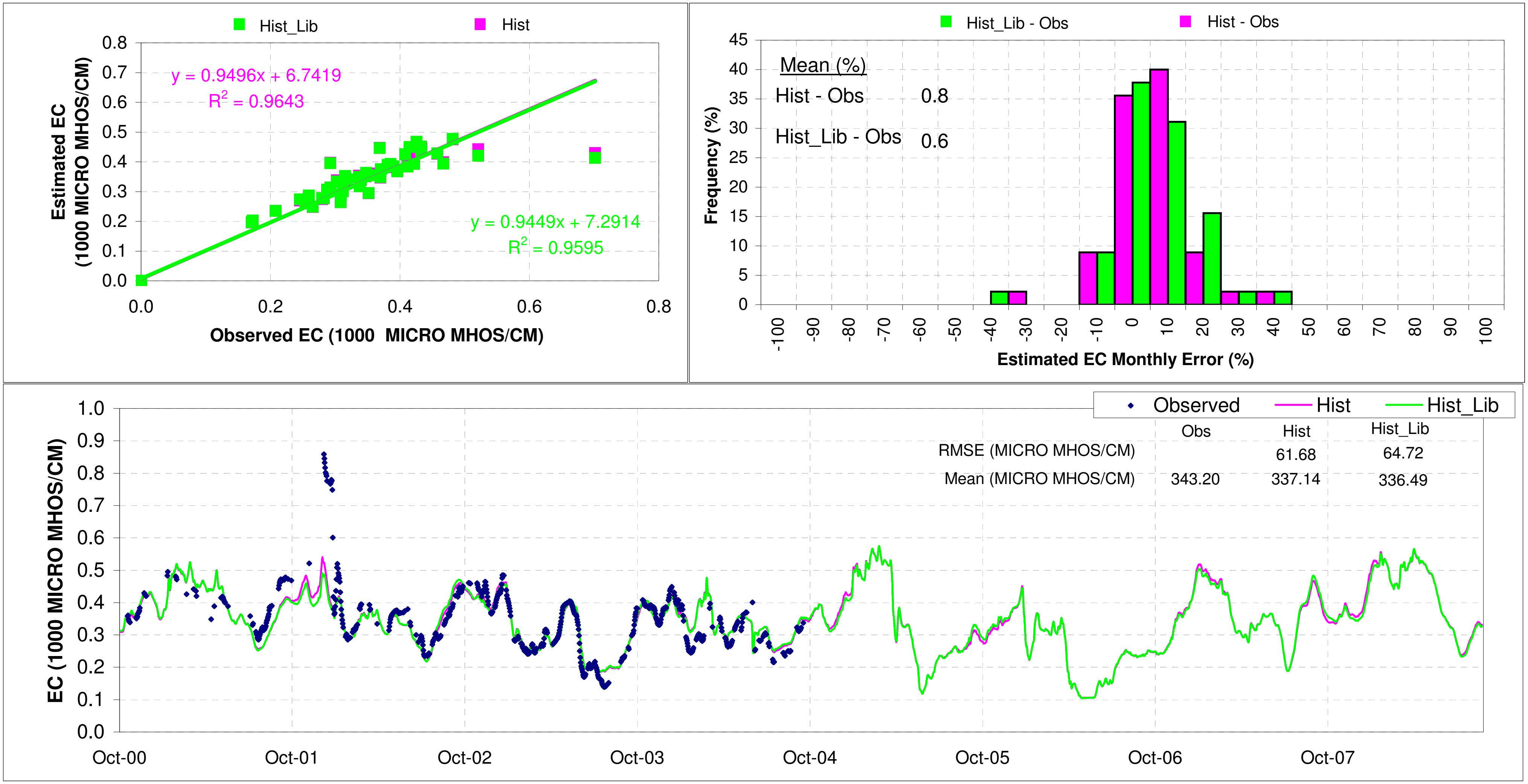




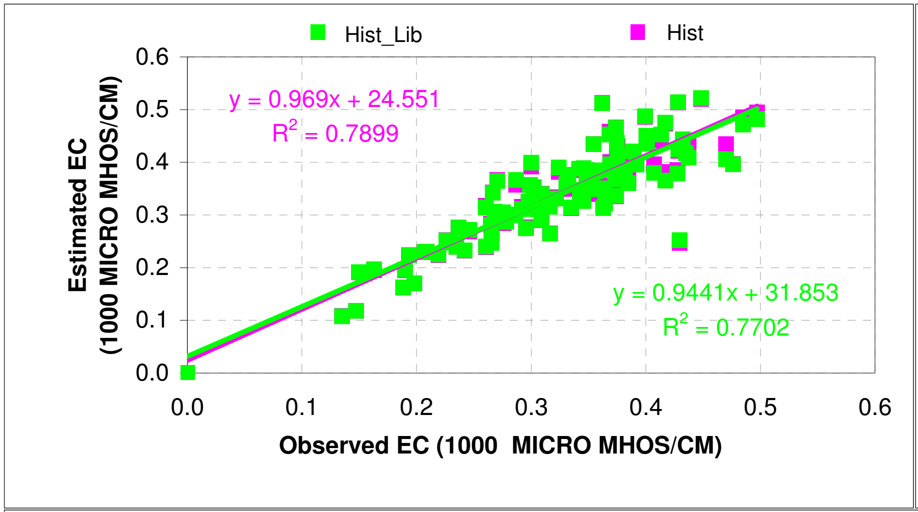
Middle River at Tracy Blvd (RMID027)

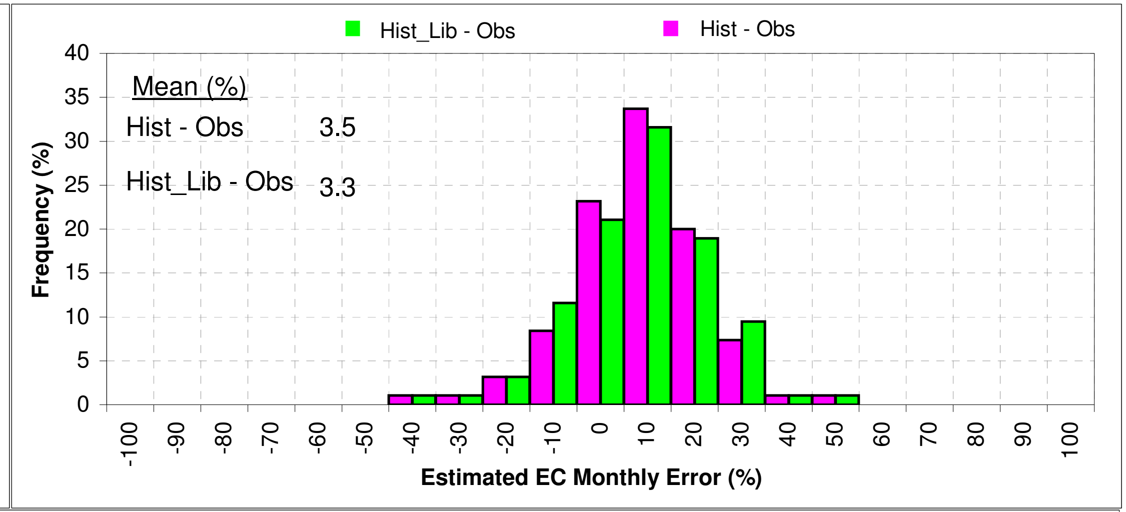


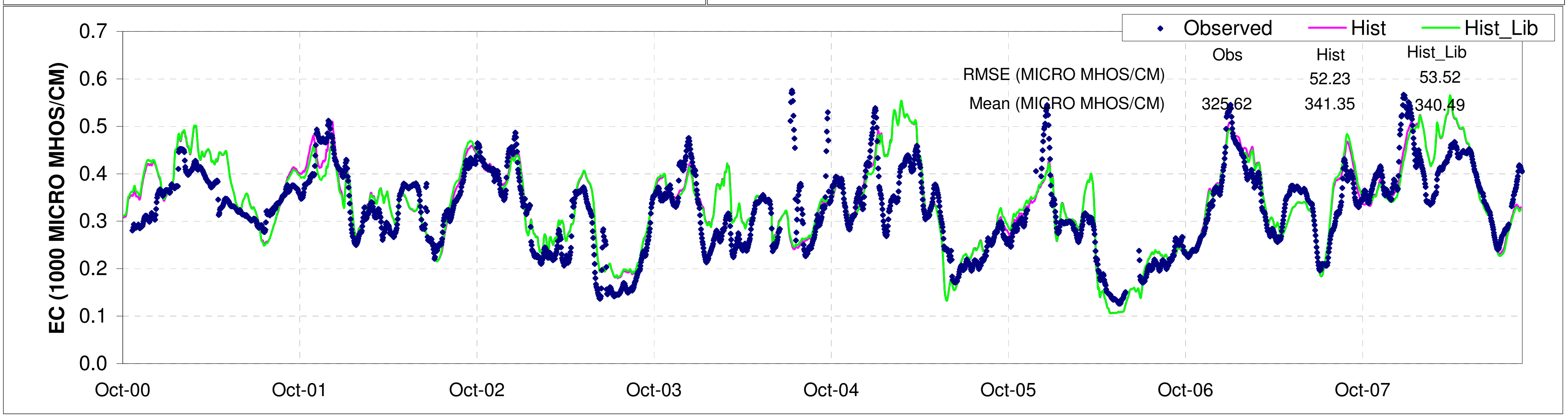
Middle River at Borden Highway (RMID023)



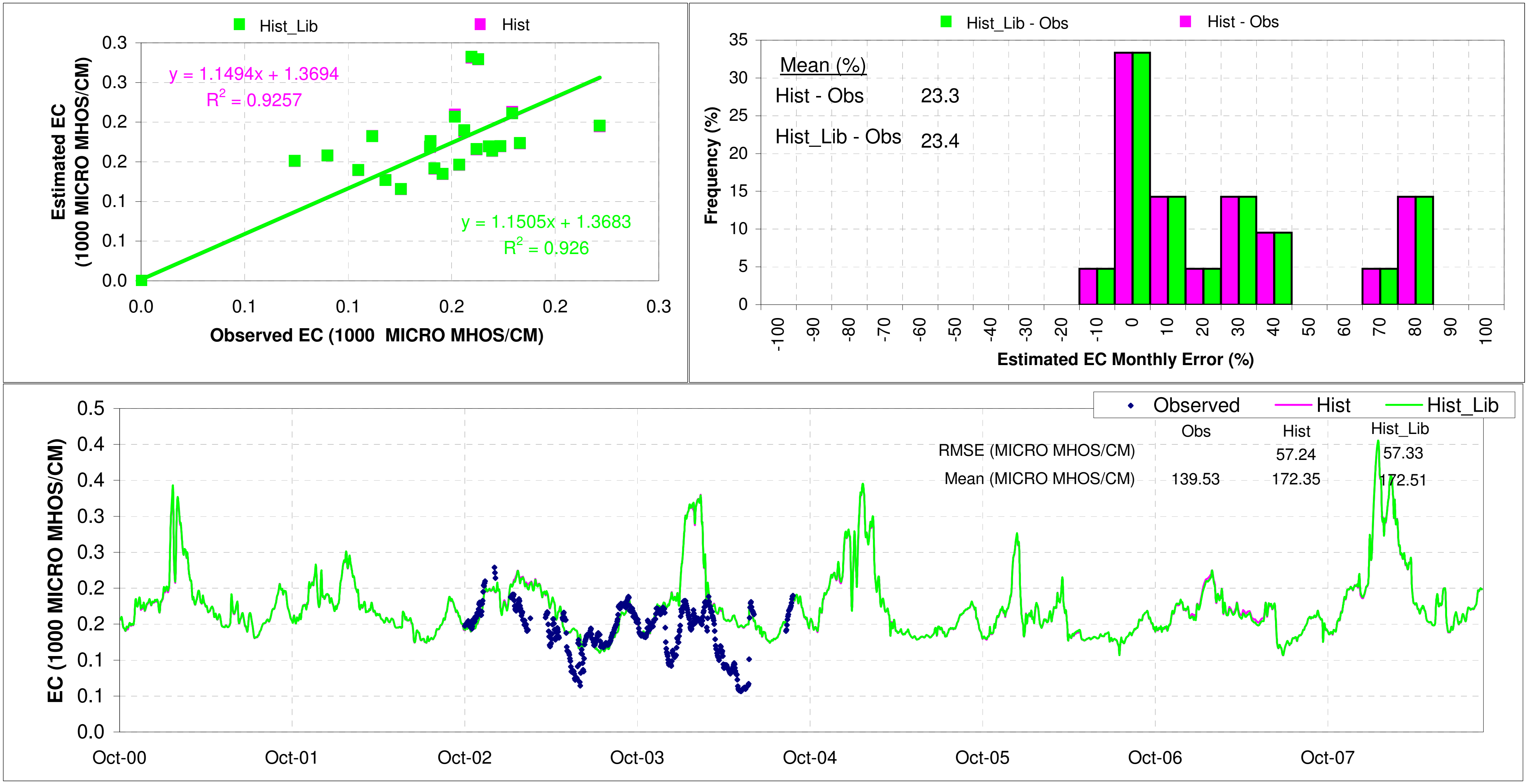
Middle River at Middle River (RMID015)



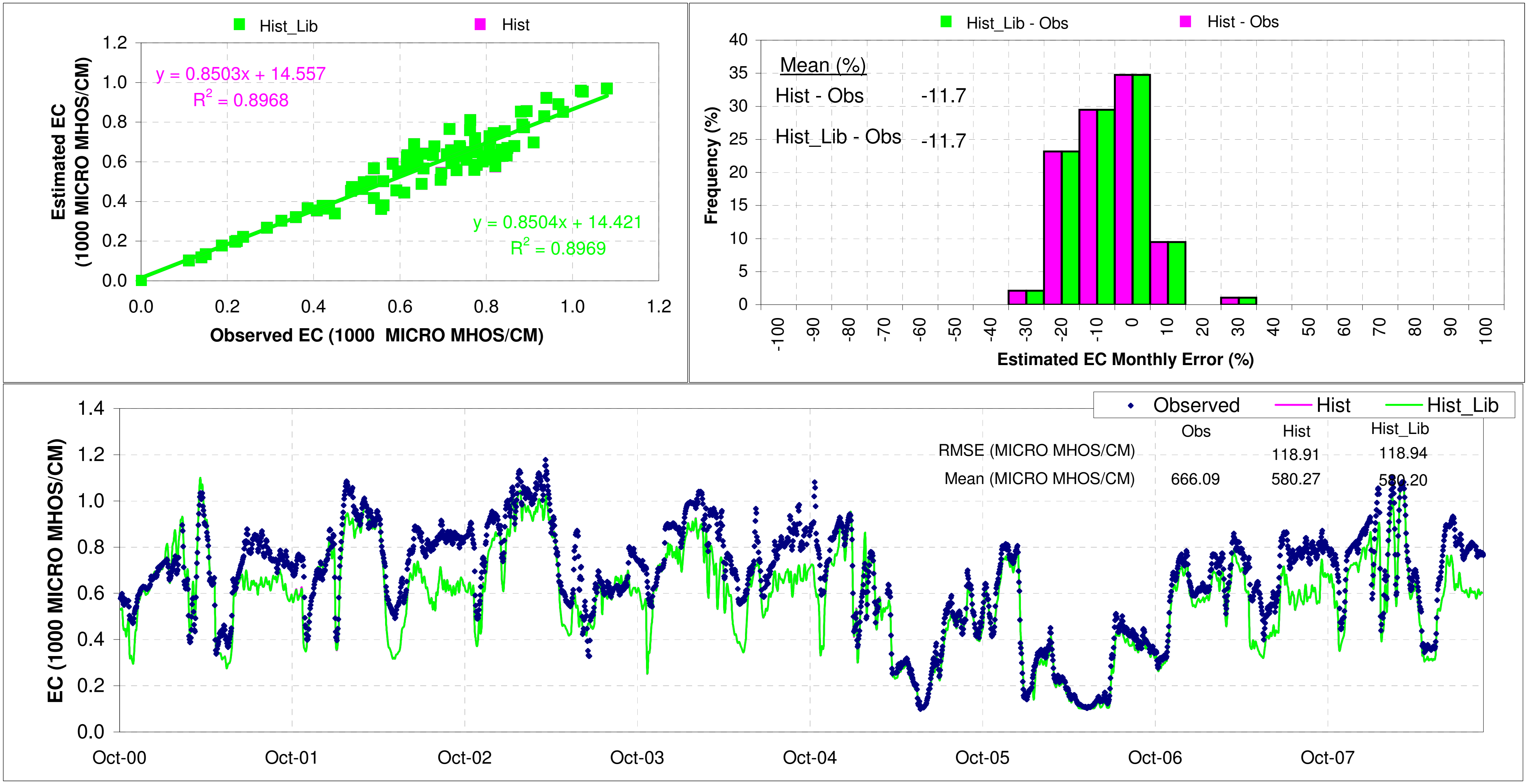




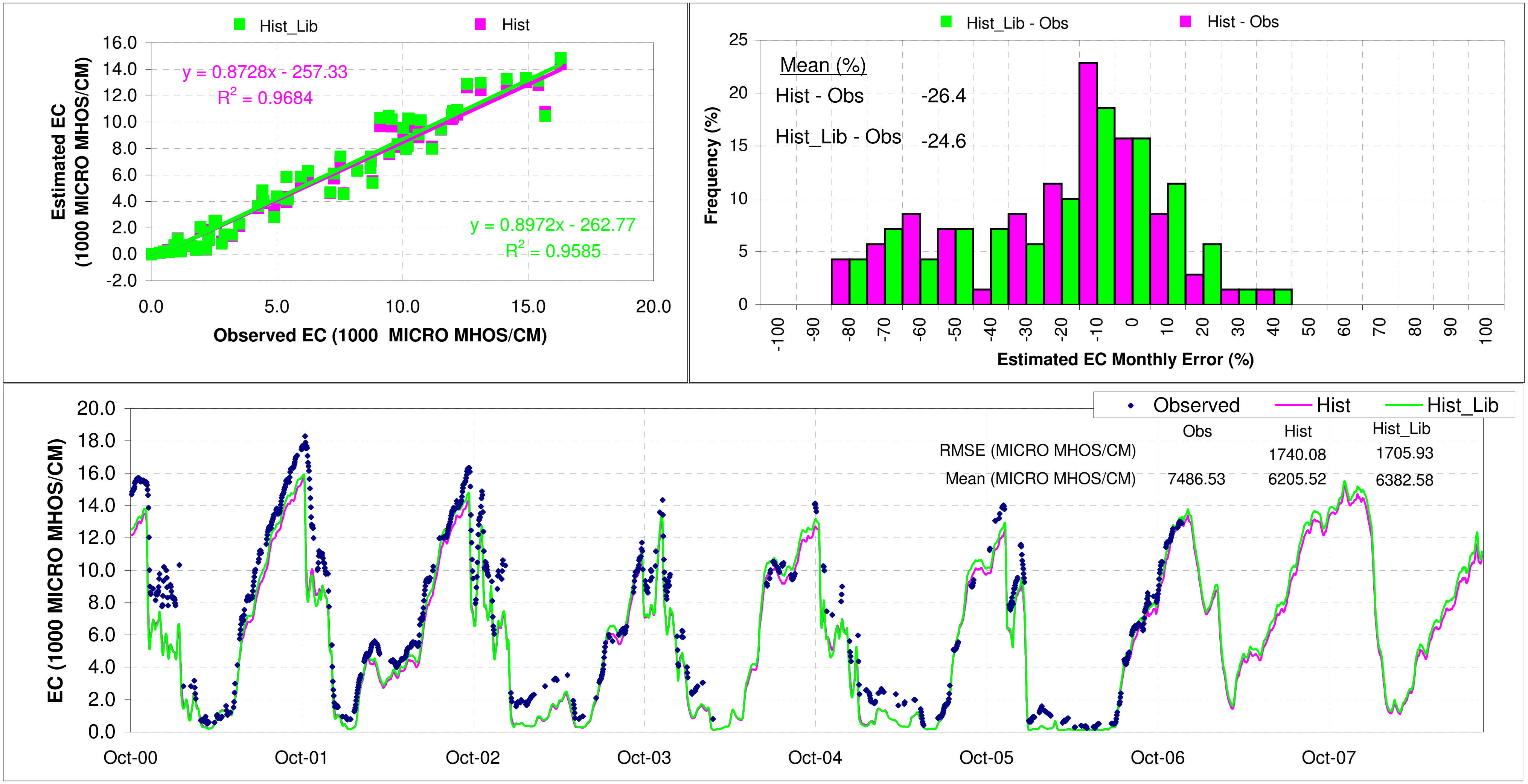
Mokelumne River at Snodgrass Sl (RMKL019)



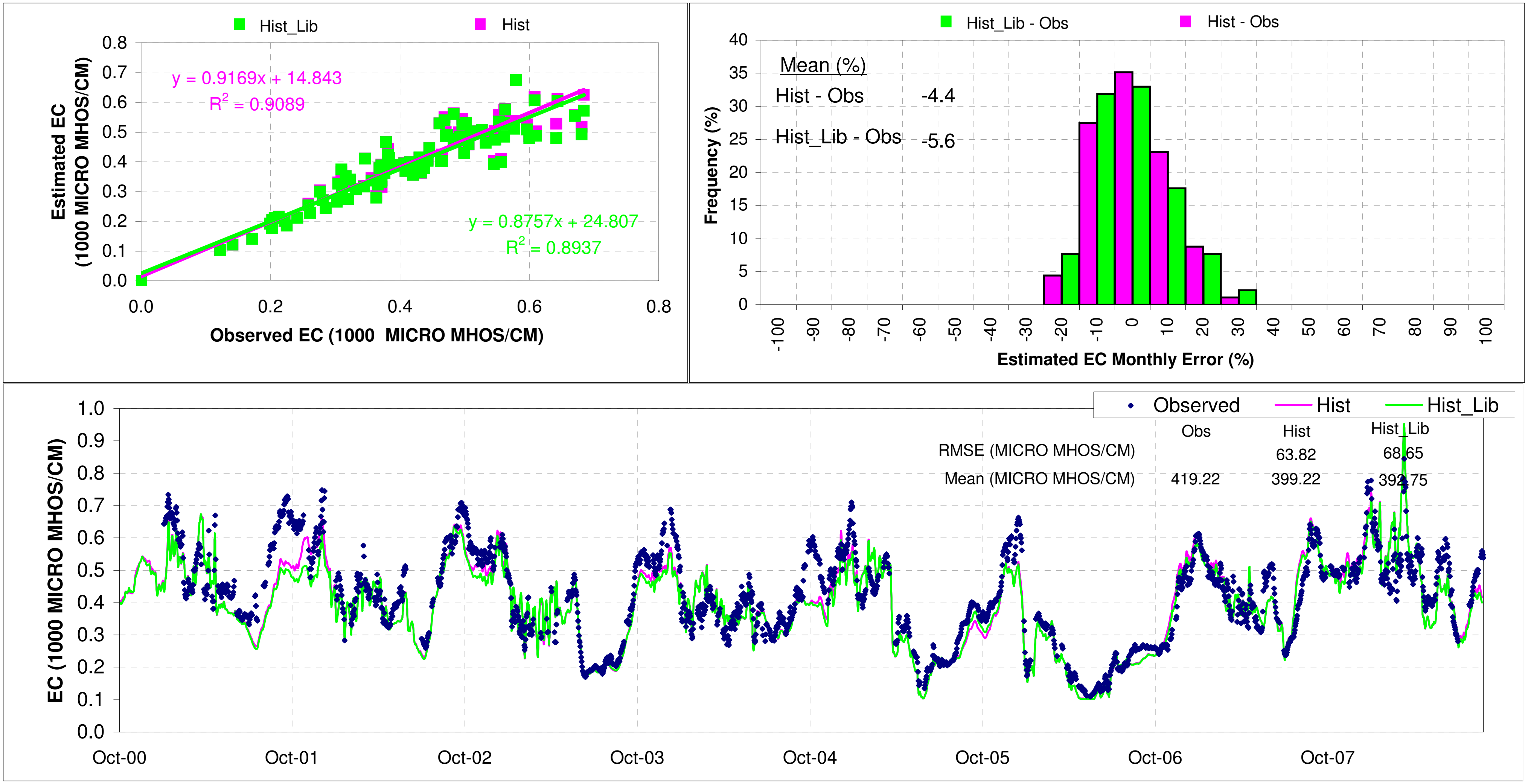
Grantline Canal at Tracy Blvd Bridge (CHGRL009)



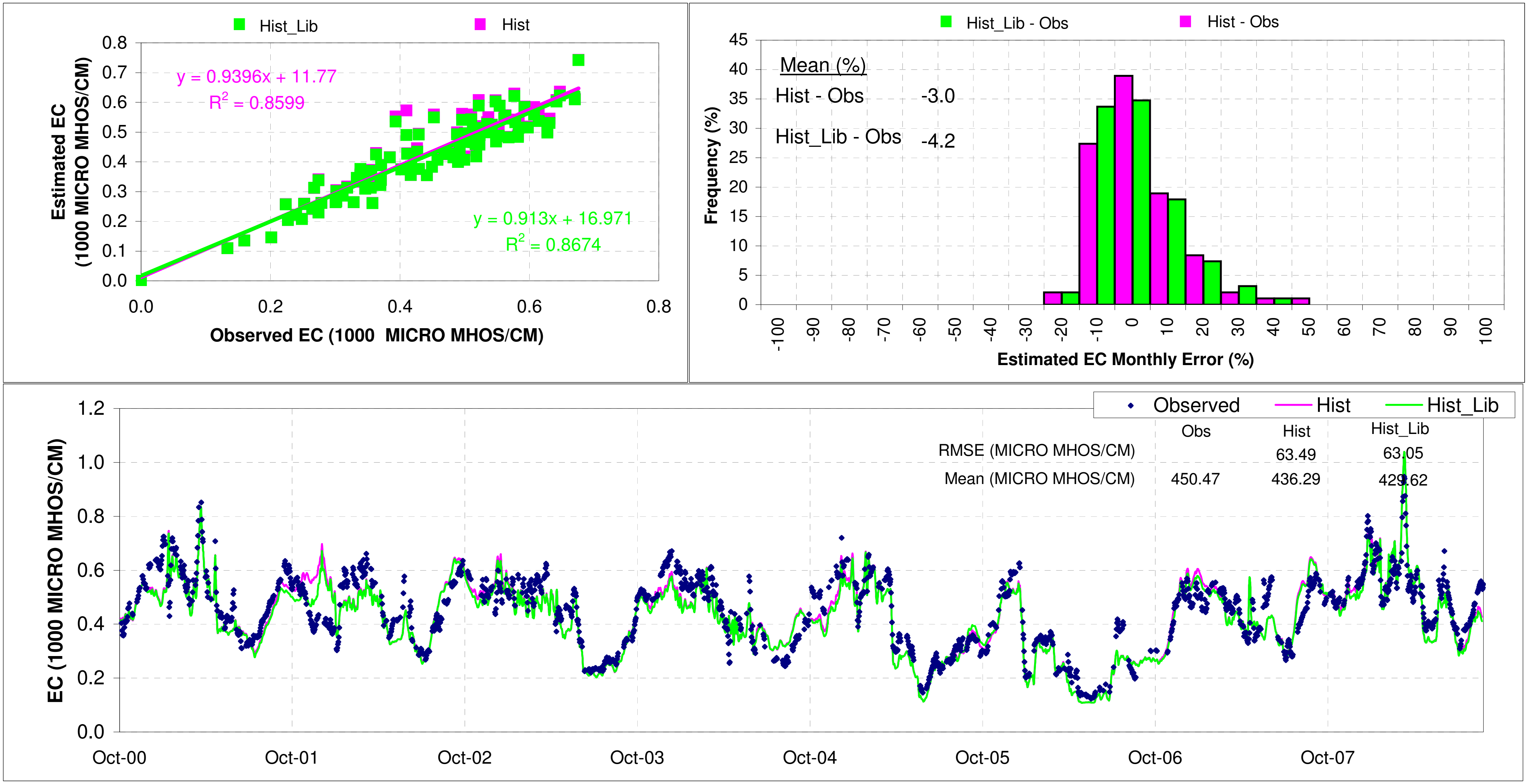
Montezuma Sl at Beldons (SLMZU011)



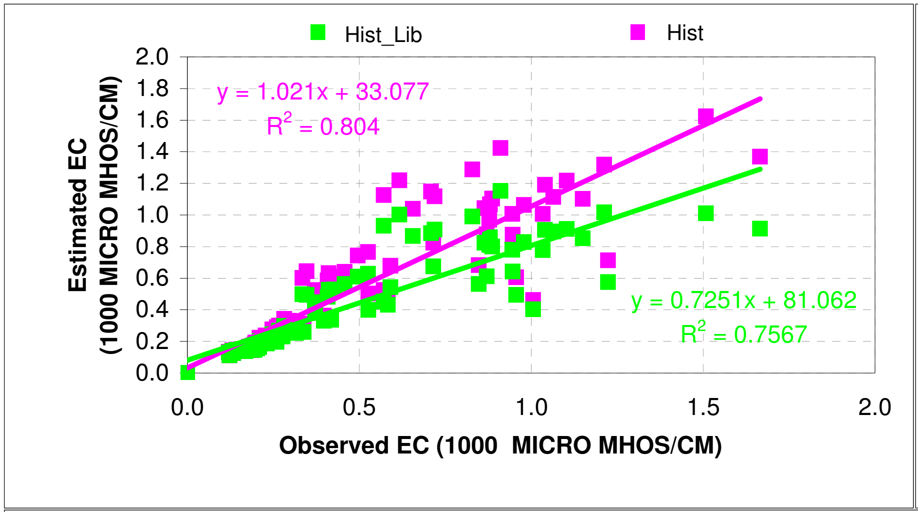
CliftonCourt Forebay (CHSWP003)

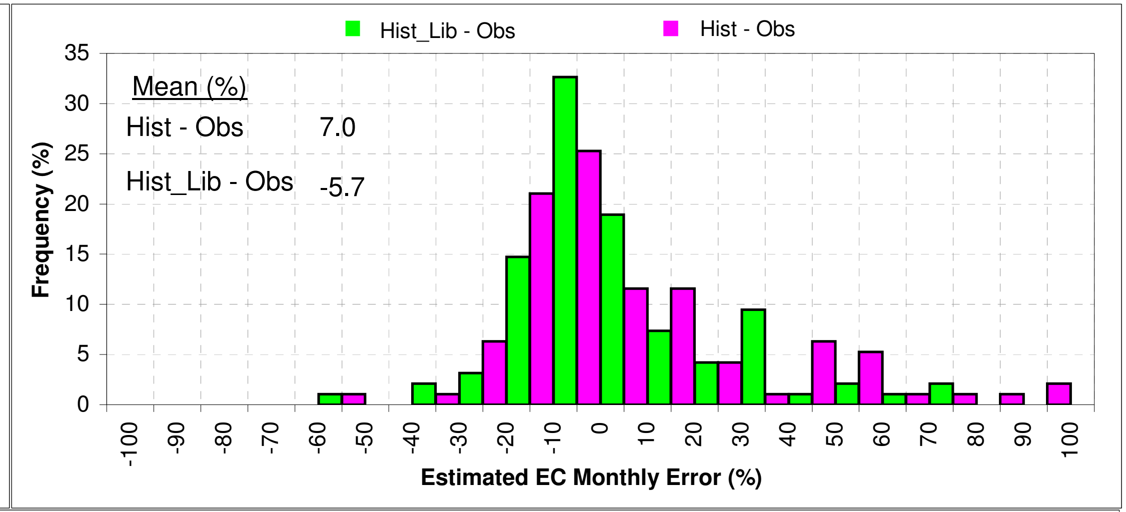


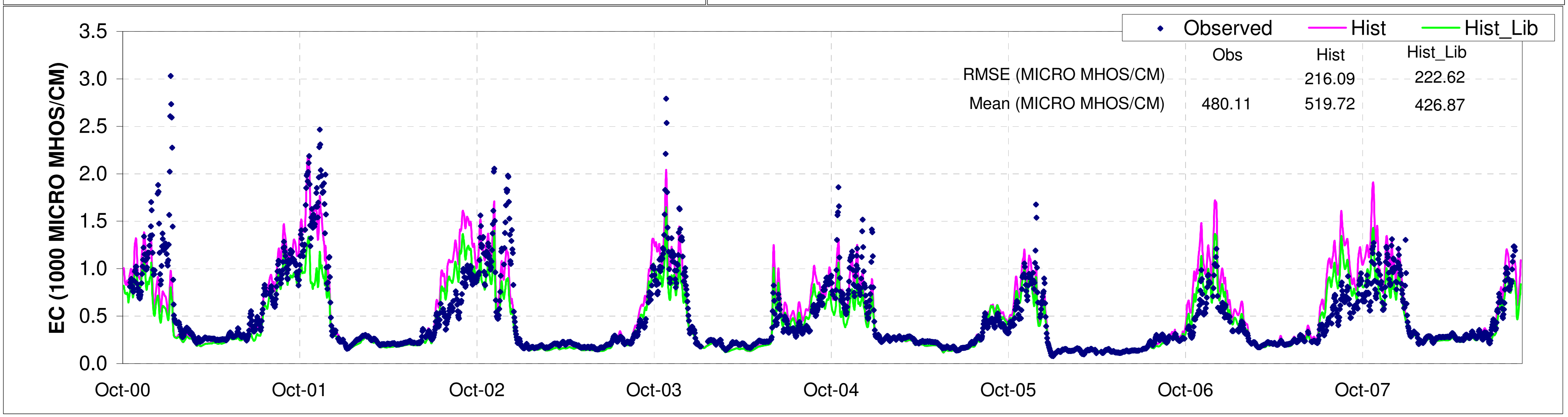
Delta Mendota Canal at Tracy Pumping Plant (CHDMC006)



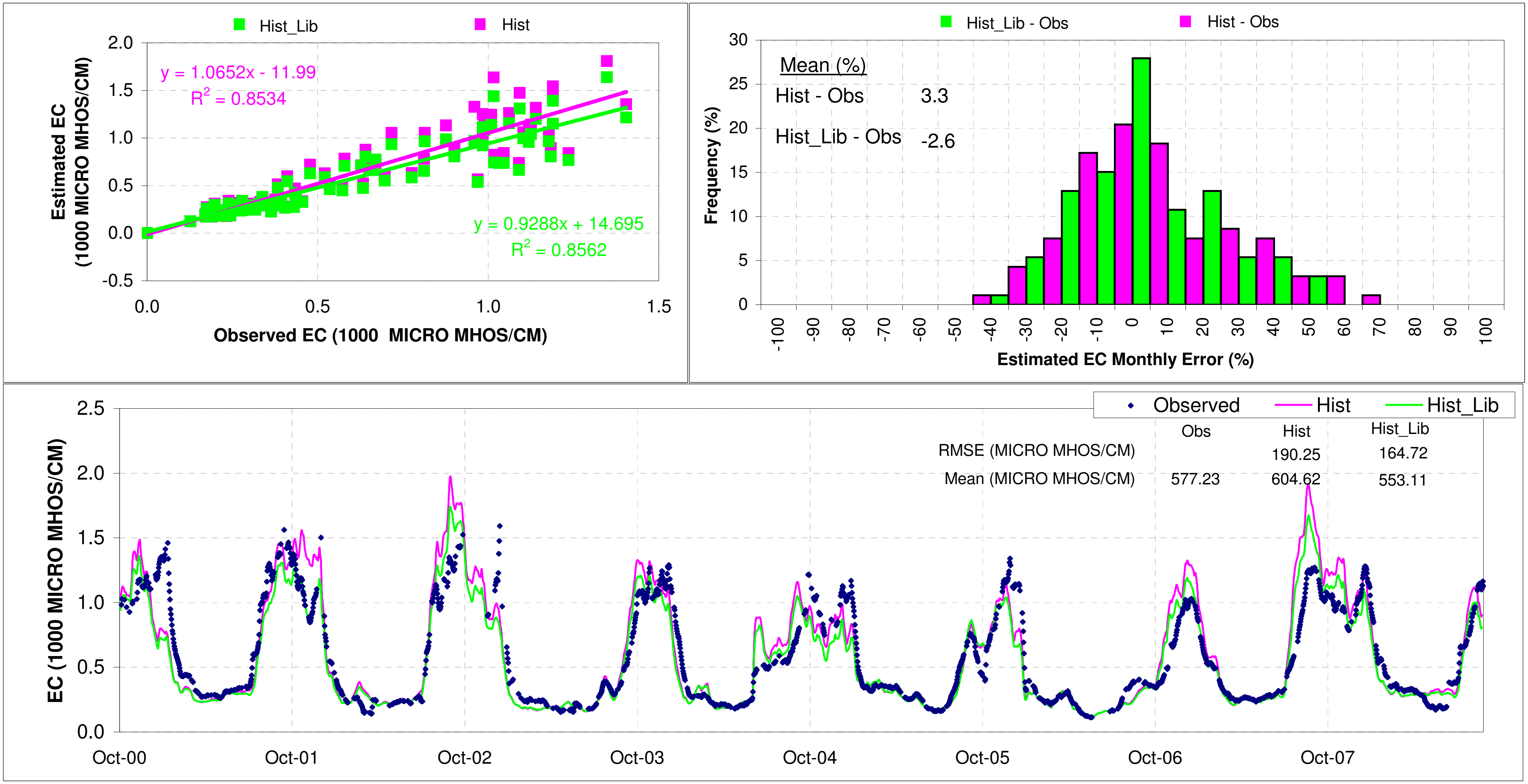
Three Mile Slough at San Joaquin River (SLTRM004)







Dutch Slough (SLDUT007)



Appendix D
DSM2 Output Location for EC at San Andreas Landing in the San Joaquin River

DSM2 Output Location for EC at San Andreas Landing in the San Joaquin River

PREPARED FOR: Parviz Nader/DWR

PREPARED BY: CH2M HILL

DATE: September 9, 2009

The salinity measurement gage at San Andreas Landing (CDEC SAL) in the San Joaquin River is located near the confluence of Mokelumne and San Joaquin Rivers as shown in the Figure D1. Even though the gage is located on the San Joaquin River, the salinity reading is likely from the Mokelumne plume. This plume separation is possible since the gage is very close to the confluence, as shown in the Figure D2. A 1-D model such as DSM2 cannot capture the plume separation along the channel. It assumes full mixing at any given location.

Figure D1: Location of the San Andreas Landing Salinity Gage in the San Joaquin River

During the DSM2 recalibration effort, the appropriate channel output location in DSM2 that would correspond to the observed salinity data at San Joaquin River at San Andreas Landing was determined. The observed EC was compared to various DSM2 locations on the San Joaquin River and on the Mokelumne River around San Andreas Landing.

Figure D2: Separation of the Mokelumne River Plume near the San Andreas Landing Salinity Gage in the San Joaquin River

The observed salinity data for San Andreas Landing was compared to the following output locations from DSM2. These locations are shown on the DSM2 grid in Figure D3.

- Channel 348 at upstream end (348_0) – Mokelumne River
- Channel 348 at downstream end (348_length) – Mokelumne River
- Channel 349 at upstream end (349_0) – Mokelumne River
- Channel 349 at downstream end (RSAN032) – Mokelumne River
- Channel 45 at downstream end (SJR_SAN_AND) – San Joaquin River

The observed and simulated 15 minute EC data were tidally filtered and daily averages were computed. Time series plots comparing the observed data to various DSM2 locations were prepared as shown in the Figures D4 and D5.

In Figure D4, the observed EC data is plotted along with the simulated EC at SJR_SAN_AND and RSAN032 locations. It is obvious that the simulated EC at the mouth of Mokelumne River (RSAN032) matches well with the observed data than that from the San Joaquin River (SJR_SAN_AND). The San Joaquin River values are too saline compared to the observed data.

Figure D5 compares the observed EC data at San Andreas Landing with simulated EC at various output locations on the Mokelumne River channels. Again, RSAN032 yields the best match with the observed data. Other locations are fresher than the observed data.

Therefore, simulated EC at the mouth of Mokelumne River (RSAN032) in DSM2 is the most appropriate output location corresponding to San Andreas Landing salinity gage in San Joaquin River.

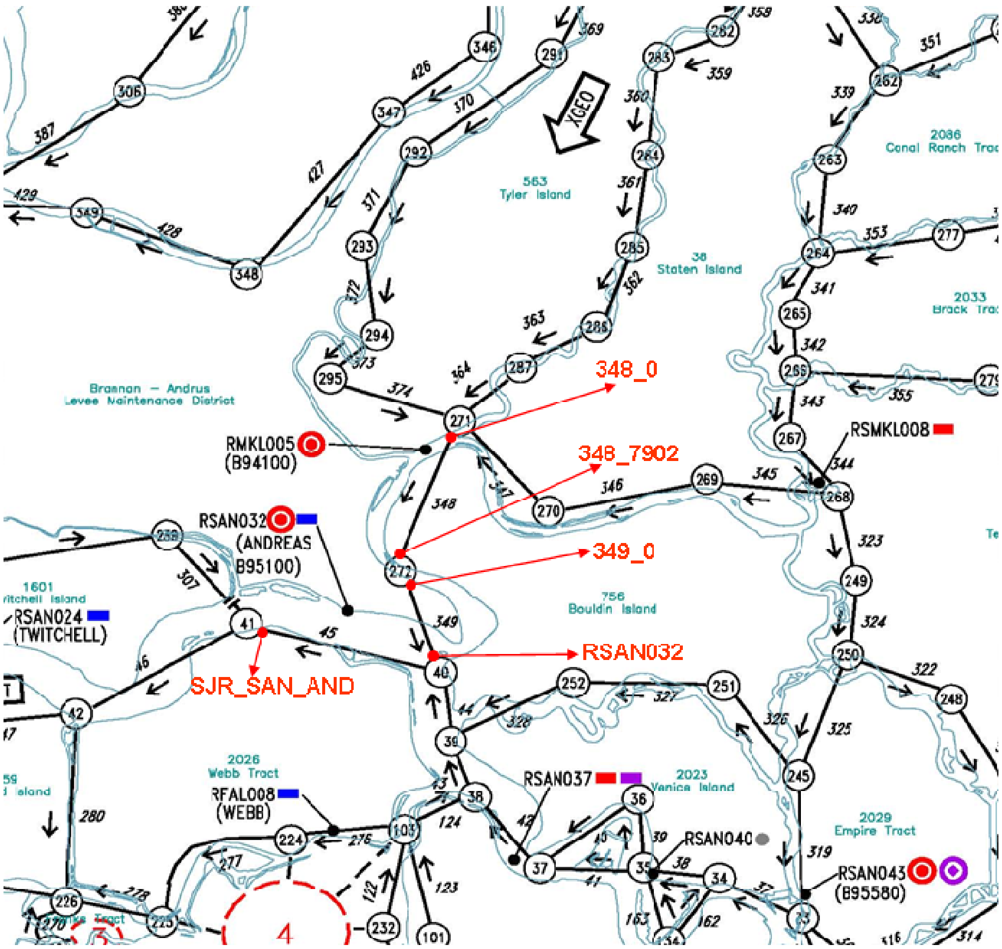


Figure D3: DSM2 Grid Showing the Channel Locations Used in the Comparison

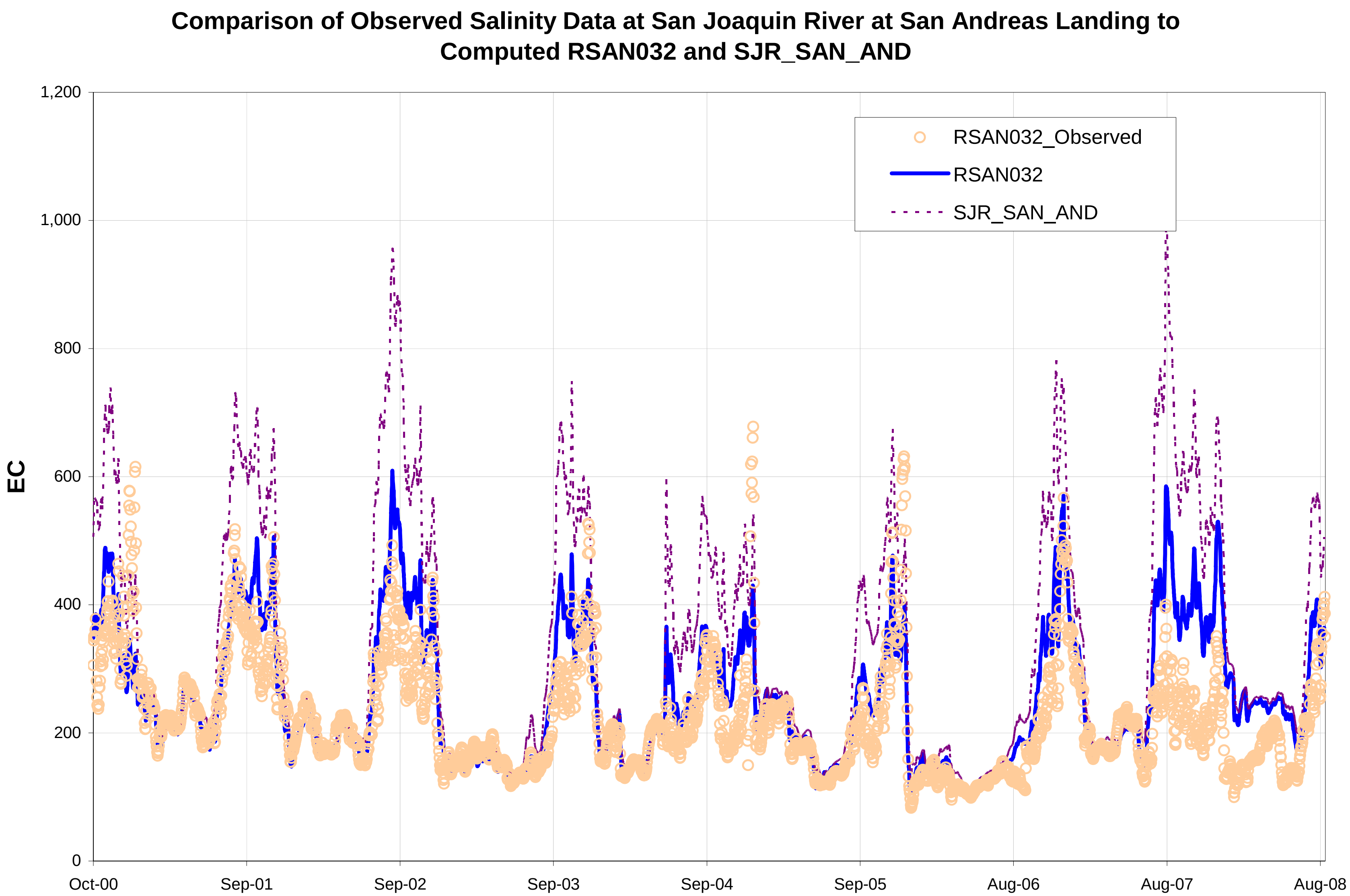


Figure D4: Comparison of RSAN032_Observed to RSAN032 computed and SJR_SAN_AND

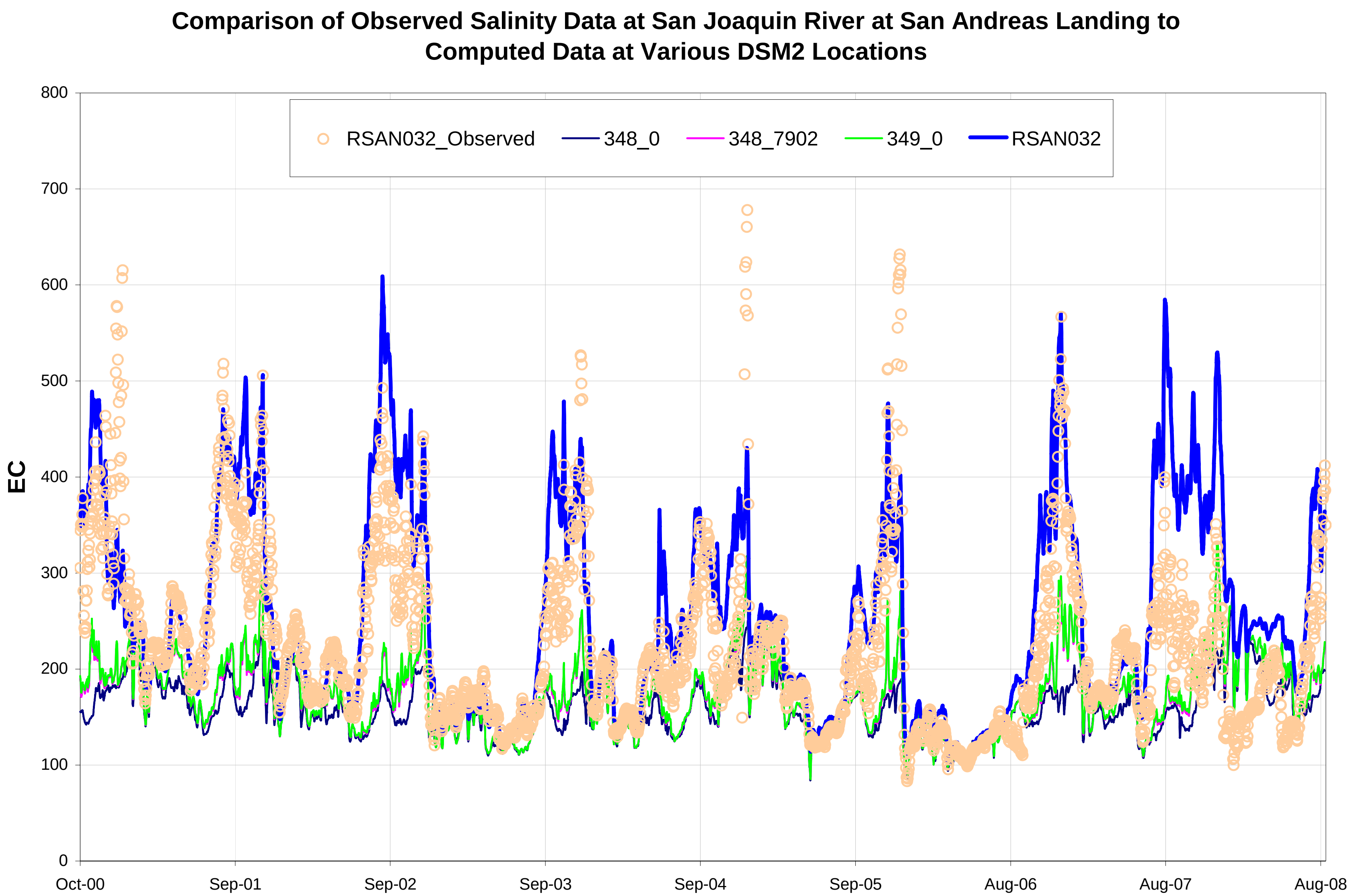


Figure D5: Comparison of RSAN032_Observed to RSAN032 computed, 348_0, 348_7902 and 349_0