PERFORMANCE VERIFICATION STATEMENT
for the In-Situ Inc. Aqua TROLL 200 Sonde

TECHNOLOGY TYPE:	Coupled conductivity and temperature sensors with instrument based algorithms for estimation of salinity
APPLICATION:	In situ estimates of salinity for coastal moored and profiled deployments
PARAMETERS EVALUATED:	Response linearity, accuracy, precision and reliability
TYPE OF EVALUATION:	Laboratory and Field Performance Verification
DATE OF EVALUATION:	Testing conducted from May through October 2008
EVALUATION PERSONNEL:	S. Gilbert, K. Gundersen, T. Johengen, T. McKissack, M. McIntyre, A. Pinchuk, H. Purcell, C. Robertson, D. Schar, G.J. Smith, M. Tamburri and D. Wells.

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EXECUTIVE SUMMARY:

Instrument performance verification is necessary so that effective existing technologies can be recognized, and so that promising new technologies can become available to support coastal science, resource management, and ocean observing systems. The Alliance for Coastal Technologies (ACT) has therefore completed an evaluation of commercially available in situ salinity sensors. While the sensors evaluated have many potential applications, the focus of this Performance Verification was on nearshore moored and profiled deployments and at a performance resolution of between 0.1 – 0.01 salinity units.

In this Verification Statement, we present the performance results of the Aqua Troll 200 sonde conductivity sensor evaluated in the laboratory and under diverse environmental conditions in moored and profiling field tests. A total of one laboratory site and five different field sites were used for testing, including tropical coral reef, high turbidity estuary, sub-tropical and sub-arctic coastal ocean, and freshwater riverine environments. Quality assurance (QA) oversight of the verification was provided by an ACT QA specialist, who conducted technical systems audits and a data quality audit of the test data.

In the lab tests, the Aqua Troll 200 sonde exhibited a strong linear response when exposed to 15 different test conditions covering five salinities ranging from 7 – 34 psu, each at three temperatures ranging from 6 - 32 $^{\circ}$C (R^2 >0.9999, SE = 0.1013 and slope = 0.991). The overall mean and variance of the absolute difference between instrument measured salinity and reference sample salinity for all treatments was -0.7140 ±0.9885 psu. When examined independently, the relative accuracy of the conductivity and temperature sensors were -0.09093 ±2.4790 mS/cm and -0.0530 ±0.0331 $^{\circ}$C, respectively.

Across all five field deployments, the range of salinity tested against was 0.14 – 36.97. The corresponding conductivity and temperatures ranges for the tests were 0.27 – 61.69 mS cm^{-1} and 10.75 – 31.14 $^{\circ}$C, respectively. Extensive and rapid biofouling at the FL and GA test sites severely impacted instrument performance within approximately one week. In addition, there were calibration issues at some test sites as the initial relative accuracy of the instrument during the first few days of deployment period was 0.33, 0.43, -0.033, -0.005 and -0.32 psu for FL, GA, HI, MI, and AK, respectively. Essentially all of the variability and measurement error was traced to the performance of the conductivity cell. The temperature sensor was quite accurate and stable throughout all of the deployments. The average offset of the measured temperature relative to our calibrated reference temperature logger was -0.032, -0.038, -0.021, -0.038, and 0.008 $^{\circ}$C for FL, GA, HI, MI, and AK, respectively. When instrument response for the first 14 days of deployment was compared together for all five field sites, a fairly consistent and linear performance response was observed with R^2 = 0.995, SE = 0.954 and slope = 0.997.

Performance checks were completed prior to field deployment and again at the end of the deployment, after instruments were thoroughly cleaned of fouling, to evaluate potential calibration drift versus biofouling impacts. On several occasions results of these tests were compromised, most likely because of entrainment of air bubbles in the conductivity cell. The manufacturer had alerted us to this concern and we attempted to follow all handling recommendations, however, these results should be viewed as handling errors and not necessarily reflective of instrument performance. In general, there was no strong evidence for calibration drift during the period of deployment.

During this evaluation, no problems were encountered with the provided software, set-up functions, or data extraction at any of the test sites. One hundred percent of the data was recovered from the instrument and no outlier values were observed for all laboratory tests, all field deployment tests, and all tank exposure tests. Lastly, a check on the instruments time clocks at the beginning and end of field deployments showed differences of between minus 3 and plus 11 seconds among test sites.

We encourage readers to review the entire document for a comprehensive understanding of instrument performance.

BACKGROUND AND OBJECTIVES

Instrument performance verification is necessary so that effective existing technologies can be recognized and so that promising new technologies can be made available to support coastal science, resource management and ocean observing systems. To this end, the NOAA-funded Alliance for Coastal Technologies (ACT) serves as an unbiased, third party testbed for evaluating sensors and sensor platforms for use in coastal environments. ACT also serves as a comprehensive data and information clearinghouse on coastal technologies and a forum for capacity building through workshops on specific technology topics (visit www.act-us.info).

As part of our service to the coastal community, ACT conducted a performance verification of commercially available, in situ conductivity/temperature sensors that provide a derived measurement of salinity (hereafter referred to as salinity sensors). We focused on commonly used inductive and electrode cell based conductivity sensors with measuring ranges from 0 - 100 mS/cm. Salinity is a composite property of water, originally defined as the total mass of dissolved material in one kilogram of water. The consistency of the ratios of major constituent ions in seawater enabled the successive refinement of the original analytically untractable definition to correspond to the total chlorinity of water. In current use, the practical salinity scale is based on the analytically precise description of the relationship between the conductivity and chlorinity of water at defined temperature and pressure. As a unitless proxy, the practical salinity scale is used for the basic characterization of aquatic habitats, for tracing the mixing of water masses, and for understanding variability in density needed to accurately model physical processes such as sound propagation and geostrophic currents. Frequent short-term forcing or input events (e.g., vertical and horizontal mixing or runoff) are typical of many coastal environments leading to high temporal and spatial variability in salinity. In addition to hydrodynamic considerations, the capacity to acclimate to specific salinity levels is an important constraint of species distributions. Therefore, it is often critically important to be able to generate continuous and accurate in situ observations of salinity.

The basic parameters and application methods to be evaluated in the verification were determined by surveying users of in situ salinity sensors. The two most common applications for users of salinity sensors were moored deployments on remote platforms for continuous monitoring and vertical profiling using CTD/ rosette platforms. The use of salinity sensors among our survey respondents was evenly divided between freshwater, brackish water, and marine environments, but over 75% of the respondents indicated use within shallow, nearshore environments. The greatest use of salinity data was to provide a general description of the environment, followed by identification of water masses and making density calculations for stratification. Approximately 40% of the respondents stated an accuracy requirement of 0.1 salinity, while another 30% stated a requirement of 0.01 salinity. The performance characteristics that ranked highest included reliability, accuracy, precision, ease of calibration, and stability. The verification therefore focused on these types of applications and criteria utilizing a series of field tests at five of the ACT Partner Institution sites, representing marine, estuarine and freshwater environments. In addition, a laboratory component of the verification was performed at the Moss Landing Marine Laboratory Partner site.

The overall objectives of this performance verification were to: (1) highlight the potential capabilities of in situ salinity sensors by demonstrating their utility in a broad range of coastal environments with varying salinity, (2) verify manufacturer claims on the performance characteristics of commercially available salinity sensors when tested in a controlled laboratory

setting, and (3) verify performance characteristics of commercially available salinity sensors when applied in real world applications in a diverse range of coastal environments. This document summarizes the procedures and results of an ACT technology evaluation to verify manufacturer claims regarding the performance of the Aqua Troll 200 sonde. Appendix 2 is an interpretation of the performance verification results from the manufacturer's point of view.

TECHNOLOGY TESTED

The Aqua TROLL(r) 200 water quality instrument measures and records conductivity, water level, and temperature. It is also capable of calculating and recording derived parameters such as specific conductivity, salinity and water density. The instrument is housed in a titanium body and uses titanium pressure and temperature sensors, as well as titanium conductivity electrodes. The conductivity cell is comprised of six electrodes, three on each side of the cell. The two outer electrodes on each side are drive electrodes. The center electrodes on each side are sensing electrodes. The Aqua TROLL 200 measures actual conductivity by applying a controlled excitation voltage across electrodes in the solution and measuring the resulting electric current. An algorithm is then applied to convert the measured electric current into the actual conductivity of the solution. The conductivity cell leaves factory calibration with a Kcell of 1.0/cm. The conductivity measurement range is 5 to 100,000 µS/cm with an accuracy of 0.5% of reading +1 µS/cm from 5 to 80,000, and 1% of reading from 80,000 to 100,000 µS/cm.

SUMMARY OF VERIFICATION PROTOCOLS

The protocols used for this performance verification were developed in conference with ACT personnel, the participating instrument manufacturers and a technical advisory committee. The protocols were refined through direct discussions between all parties during a Salinity Sensor Performance Verification Protocol Workshop held on 26 -27 February, 2008 in St. Petersburg, FL. All ACT personnel involved in this Verification were trained on use of instruments by manufacturer representatives and on standardized water sampling, storage, analysis and shipping methods during a training workshop held on 12-16 May 2008 in Moss Landing, CA. During the instrument training workshop, ACT evaluated the current factory calibrations for each test instrument by exposing them to natural seawater in a well-mixed temperature controlled bath and making simultaneous laboratory measurements of triplicate reference samples. This calibration check was performed under the supervision of the manufacturer representatives and instruments were confirmed to be ready for testing. The manufacturer representative and the ACT Chief Scientist verified that all staff were trained in both instrument and sample collection protocols. Lastly, manufacturers worked with ACT to verify that the proposed instrument mounting configuration for the field tests would not produce a measureable effect on sensor performance due to electronic or structural interference.   The final mooring arrangement was approved by all parties.

This performance verification report presents instrument-measured conductivity, temperature and derived salinity values reported over time, position, or depth as directly downloaded from the test instruments. The report includes means, standard deviations, and

number of replicates of laboratory determined salinity values for corresponding reference samples at the same time, position, or depth of the instrument measurements. The report also includes an independently determined temperature record collected within the water column over corresponding time, position, or depth, by an RBR TR-1060 Temperature Logger which was used for all laboratory and field tests. A summary of the testing protocols is provided below. A complete description of the testing protocols is available in the report, *Protocols for the ACT Verification of In Situ Salinity Sensors* (ACT PV08-01) and can be downloaded from the ACT website (www.act-us.info/evaluation_reports.php).

Reference Standards and Analytical Procedures

State of the art, approved laboratory analytical methods and instrumentation were used to provide the best possible measure of 'true' conductivity and temperature values from laboratory and field reference samples. Reference samples served as the performance standards against which instrument conductivity, temperature and derived salinity estimates were compared. All reference and Quality Assurance and Quality Control (QA/QC) samples were analyzed on a Guildline 8410A Portasal salinometer, which has a reported accuracy of 0.003 and a resolution of 0.0003 equivalent psu. All reference samples for the verification were analyzed at Moss Landing Marine Laboratory (MLML) by the same technician using the same instrument. The Portasal was calibrated with IAPSO certified standard seawater (SSW) purchased from OSIL (Oceanic Scientific International Limited) at the beginning of each analytical batch and fresh SSW were analyzed as samples at the beginning and end of each analytical batch and randomly within the batch (approx. 10% of total volume) to characterize instrument drift. A linear drift correction, based on SSW sample performance, was applied to all reference samples within the SSW sample interval. Each salinity bottle sample generated 30 readings on the Portasal, collected as 3 consecutive readings on 10 aliquots drawn from the bottle. The 30 readings were averaged to a single salinity value per bottle. Variance estimates within our reference method come from replication across salinity bottles as well as a global mean variance for all reference samples collected for the laboratory test.

All reference samples were collected in standardized salinity bottles purchased from OSIL, made of type II borosilicate glass and sealed with polyethylene neck seals and screw caps. Sample collection bottles were preconditioned for at least one week with ambient water from each test site. All reference samples were collected, stored, and shipped according to approved protocols (see full document at www.act-us.info/evaluation_reports.php). In addition, an independent field reference standard set was made from a single batch collection of ambient water at each test site and immediately sub-sampled into conditioned sample bottles. Sets of three of these reference samples were shipped and analyzed with each batch of field sample bottles to account for any sample bias resulting from storage or shipping and as independent checks on the consistency of the analytical procedures.

Laboratory Tests

Laboratory tests focused on verifying the manufacturers' stated performance characteristics of accuracy and precision using controlled laboratory settings to obtain the highest degree of accuracy and precision for corresponding reference standards. The instrument package was tested at five different salinity levels including 35, 30, 25, 16 and 6 on the practical salinity scale (PSS-78; 60 to 6 mS/cm conductivity), each at three different temperatures including 32 $^{\circ}$C, 16 $^{\circ}$C and 6 $^{\circ}$C. The instrument was pre-equilibrated to the controlled bath test conditions for 60 minutes prior to the start of reference sampling. The instrument was set to measure in situ conductivity and temperature using its own algorithms to derive a practical salinity estimate from these values at 1-minute intervals. Ten reference water samples were collected at sensor depth into sealed pre-rinsed glass salinity bottles at 3 minute intervals over 30 minutes. Each reference sample set was stored at room temperature and analyzed after 24 hours on the Portasal 8410A (Fig. 1).

Figure 1. Analytical instrumentation (Portasal 8410A) used for laboratory analysis of salinity reference samples and one of the test baths and instrument racks used for the laboratory tests.
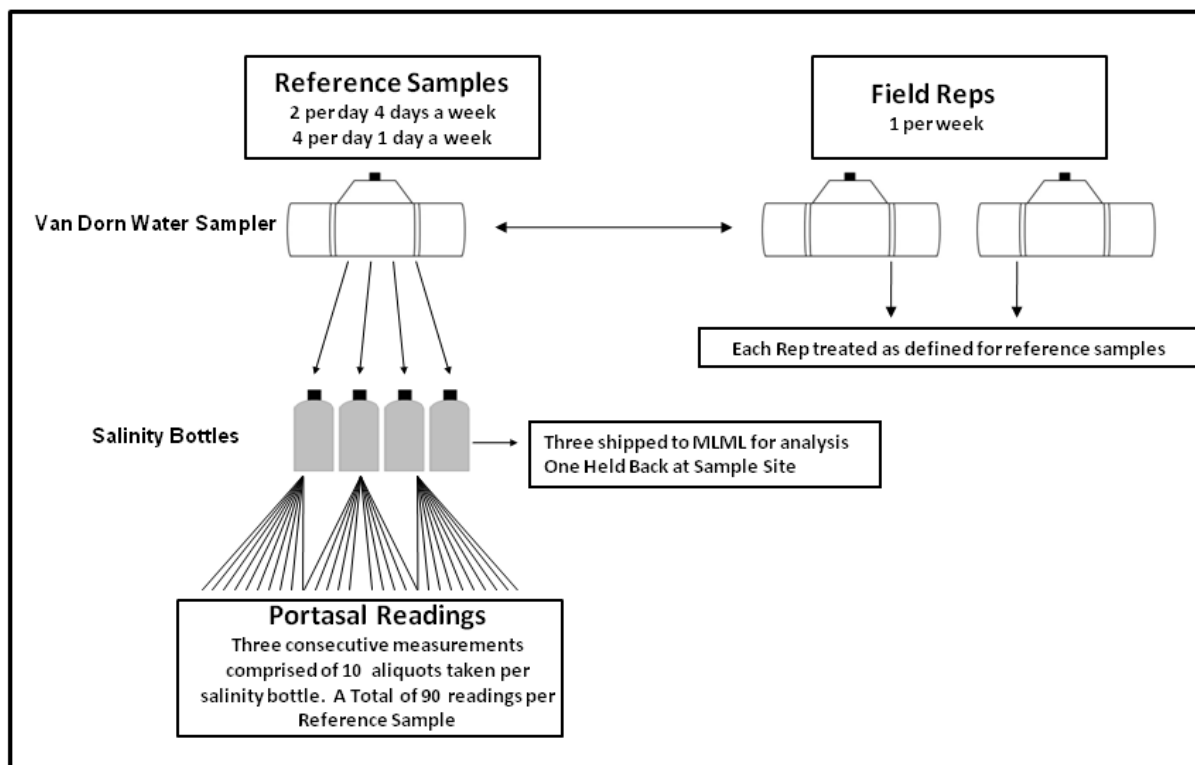
Moored Field Deployment Tests

Moored deployments were conducted at five ACT Partner sites covering a wide geographic distribution of coastal environments and a range of salinity and temperature conditions (see Table 1). Deployments were conducted over a 4-week duration at four of the test sites including Tampa Bay, FL, Skidaway Island, GA, Clinton River, MI and Resurrection Bay, AK. The deployment in Kaneohe Bay, HI was run over an 8-week duration to examine performance under an extended deployment. The test instrument was set to measure in situ conductivity and temperature using its own algorithms to derive a practical salinity estimate from these values at 15 minute intervals, except at HI where the measurement interval was increased to 30 minutes due to power constraints. Reference sampling for the 4-week test sites consisted of collecting 2 water samples per day on four days of the week and 4 samples per day once per week (Fig. 2). In addition, once each week we collected a replicate field sample by using two Van Dorn water samplers side by side in immediate vicinity of the mooring frame. For the longer deployment at the HI test site, the same pattern was used for the first two weeks, but then the sampling intensity was reduced to 3 collections per week and the intensive 4-per-day sampling every other week. For the Florida offshore site, the sampling schedule was somewhat modified due to vessel and weather constraints; however, all effort was made to produce a consistent number of reference samples as the other sites. Water samples were collected at the same depth and as close as physically possible to the instrument sensors and the water sampler was triggered to match the programmed sampling time of the instrument. Four replicate salinity samples were collected in pre-conditioned (with site water) 200 ml OSIL glass salinity bottles directly from the spigot of the sampler. Three of these salinity sample bottles were shipped to MLML for analysis and the fourth was held back at the collection site as a back up in case of a lost sample or if agreement among triplicates failed to meet a precision target of 0.005 psu. In that case, the remaining sample was also analyzed and the result was included in the final estimate of the reference salinity value. In situ temperature was recorded with an RBR TR-1060 Temperature Recorder which has a stated accuracy of 0.002 $^\circ$C and a resolution of < 0.0005 $^\circ$C. The calibration and temperature transfer standard of these sensors were independently verified in a NIST-certified laboratory.

As part of each field test, the instrument package was also tested in well-mixed tanks filled with ambient site water immediately before and after the moored deployment. The post-deployment tank test occurred after the instrument was thoroughly cleaned to remove all visible traces of biofouling. The purpose of the tank test was to help differentiate the effects of biofouling from those of instrument drift that may have occurred during the deployment. The instrument was equilibrated to the tank conditions for at least 30 minutes prior to sampling and programmed to sample at 1 minute intervals. Three reference samples were collected and each sub-sampled into triplicate salinity bottles during the instrument sampling interval for comparison.

Lastly, a series of PVC tiles were deployed adjacent to the mooring rack and used to photographically document the amount and rates of biofouling at the site. Each week one tile was retrieved and photographed to characterize the extent of fouling. The weekly photographs are displayed in the field results section of the report.

Figure 2. Schematic representation of the reference sampling process conducted during moored deployment field tests.

Veritcal Profiling Field Tests

A vertical profiling application was included at Resurrection Bay, AK for those instruments that are designed to sample at appropriate rates and with appropriate sensor response times. The test consisted of performing vertical profiling casts at 2 locations known to have well defined pycnoclines during a single 1 day cruise. One location was on the shelf just outside the Bay and the other was within the Bay in an area known to be influenced by coastal runoff. The profiling test involved the comparison of simultaneous instrument measurements and discrete samples collected at six discrete depths throughout the water column. Sampling depths were spaced to provide two reference samples in the surface mixed layer, two near or within the pycnocline, and two below the pycnocline in order to capture the maximum variation in salinity. One of the six discrete depths was sampled in replicate with two independent Niskin bottle collections. The Aqua Troll 200 sonde was not included in this portion of the evaluation.

Quality Assurance/Quality Control

This performance verification was implemented according to the QA test plans and technical documents prepared during planning workshops and approved by the manufacturer and the ACT salinity sensor advisory committee. Technical procedures included methods to assure proper handling and use of test instruments, laboratory analysis, reference sample collections, and data. Performance evaluation, technical system, and data quality audits were performed by

QA personnel independent of direct responsibility for the verification test. All implementation activities were documented and are traceable to the Test/QA plan and to test personnel.

The main component to the QA plan included technical systems audits (TSA) conducted by an ACT Quality Assurance Manager of the laboratory tests at MLML and of the field tests at two of the ACT Partner test sites (Florida and Alaska) to ensure that the verification tests were performed in accordance with the test protocols and the ACT *Quality Assurance Guidelines*. All analytical measurements were performed using materials and/or processes that are traceable to a Standard Reference Material. Standard Operating Procedures were utilized to trace all quantitative and qualitative determinations to certified reference materials. Lastly, ACT's QA Manager audited approximately 10% of the verification data acquired in the verification test to assure that the reported data and data reduction procedures accurately represented the data generated during the test.

RESULTS OF LABORATORY TEST

A series of laboratory tests were conducted at Moss Landing Marine Laboratories to examine the response linearity, operational precision and accuracy of the submitted test instruments. Three test baths were established and maintained at temperatures of ca. 6, 16, and 32 ^{o}C. In separate trials, instruments were exposed sequentially to salinity levels of approximately 35, 30, 25, 16, and 6 at each of these temperatures. The response linearity across the exposure trials was assessed by cross plotting average instrument measure against average reference measure obtained for each exposure level. The relative accuracy of the test instrument salinity measurements was assessed as the absolute differences between laboratory measurements of collected reference water samples and independent temperature records. Reference conductivities were derived from the Portasal salinity measurement and concurrent bath reference temperature measure at the time of sampling utilizing the algorithms provided in the 'Conductivity from Practical Salinity' module of Lab Assistant V2 (PDMS, Ltd). The accuracy of instrument temperature measurements was determined against a bath reference temperature recorded by calibrated and certified RBR TR-1060 logging thermometers. Two newly calibrated time-synchronized RBR TR-1060 loggers were placed at opposite ends of each laboratory bath at the depth of the instrument conductivity cell and temperature was monitored continuously at 5 second intervals from the top of the minute. For analysis of test results, temperature records were averaged to 1 minute intervals corresponding to the average sampling rate of the test instruments. Comparison of the two reference temperature logs revealed an average temperature difference of 0.005 (± 0.003) ^{o}C across the tank axis with a maximum difference of 0.019 ^{o}C during one of the 16 ^{o}C tests. Average stability of the bath temperatures across the 15 test runs was ± 0.0128 ^{o}C from the mean during reference sampling. Temperature drift associated with the time intervals of reference sampling averaged 0.0123 (± 0.0517) ^{o}C across all tests with a maximum drift of 0.116 ^{o}C encountered during one of the 16 ^{o}C test associated with a cooling line failure.

Analyzed across all five salinity levels and all three temperatures, the Aqua Troll 200 exhibited a strong linear response to the test solutions with $R^2 > 0.9999$, standard error = 0.1013 and a slope = 0.991 for measured salinity (Fig. 3). However, the relative accuracy of the conductivity sensor response, and corresponding derived salinity, was not consistent across all 3 temperatures. The performance is most likely a calibration or salinity algorithm issue as the temperature sensor response itself was very consistent across all temperature ranges. The variance in 30 repeated measurements taken at one minute intervals for each of the laboratory trials is shown in Figure 4. The plots are not a measure of engineering precision as environmental conditions within the test baths did change during the sampling process. The variation in instrument derived measurements is plotted relative to the average standard deviation and 3-times the standard deviation upper specification limit of reference salinity, conductivity, and temperature measurements taken over corresponding time intervals for all lab tests. An alternative version of this figure showing a direct comparison of instrument versus reference sample variance for each individual trial is given in Appendix 1. Instrument offsets in salinity, conductivity and temperature were computed for each test run as the difference in the mean instrument measure from the mean reference measure for that test bath condition (Fig. 5). The mean of the offset in measured salinity was -0.7140 ±0.9885 psu across all 15 exposure treatments. The mean offsets for the individual conductivity and temperature sensor measurements were -0.9093 ±2.4790 mS/cm and -0.0530 ±0.0331 ^{o}C, respectively.
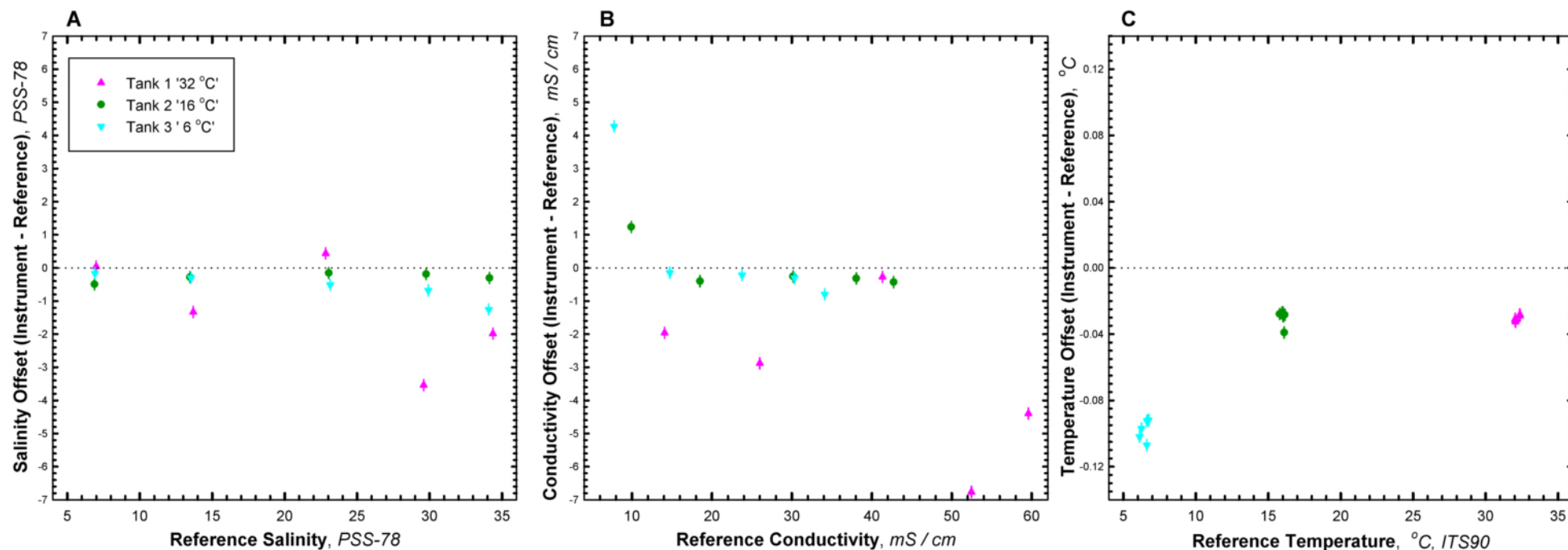
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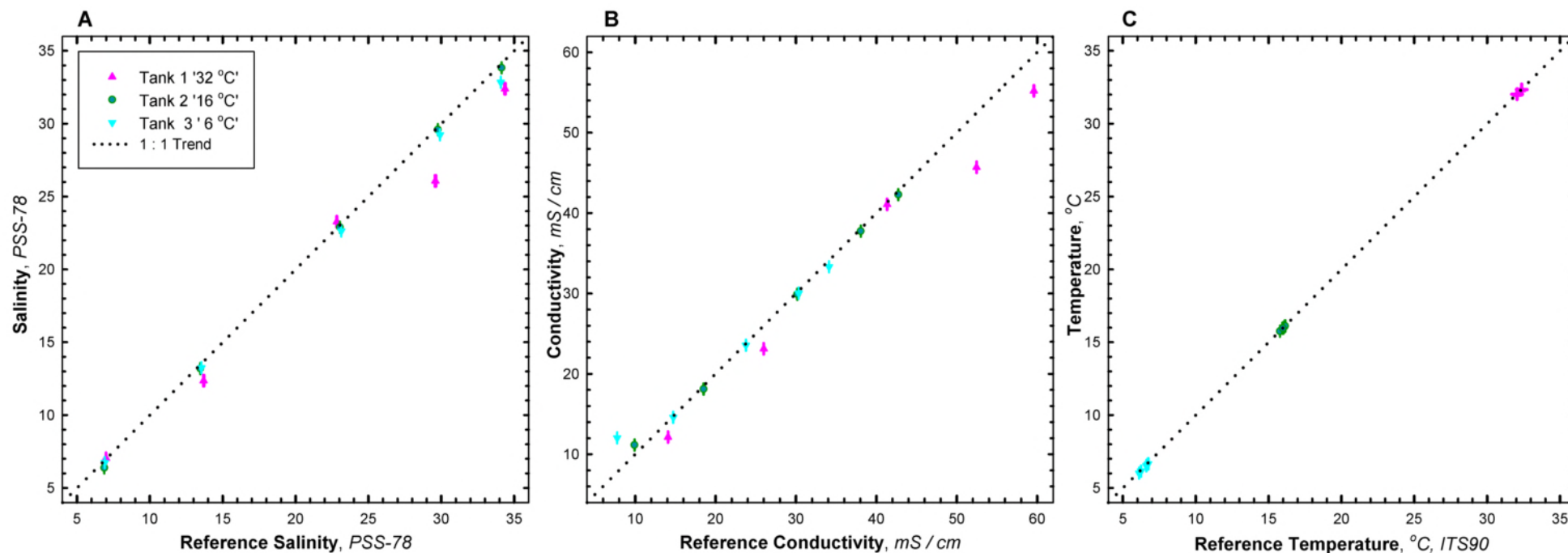
Figure 3. Evaluation of the response linearity for In-Situ's Aqua Troll 200 conductivity and temperature sensor package during controlled laboratory exposures to a combination of natural seawater dilutions and temperatures. Consecutive test exposures ranged between 35 to 6 on the practical salinity scale (PSS-78; 60 to 6 mS/cm conductivity) and 33 to 6 °C. [A]Correspondence of instrument derived salinity to Portasal reference measurements; [B] Correspondence of instrument in situ conductivity measurement to conductivity estimate derived from the Portasal salinity and reference temperature measurement by inversion of the seawater equations of state (IAPSO PSS-78); [C] Correspondence of instrument temperature measurement to bath reference temperature recorded by a calibrated RBR 1060 logging thermometer. Data points are represented as mean ± standard deviation of and 10 reference water samples. Dotted lines represent 1:1 ideal correlation of measures.

In Situ Aqua Troll 200
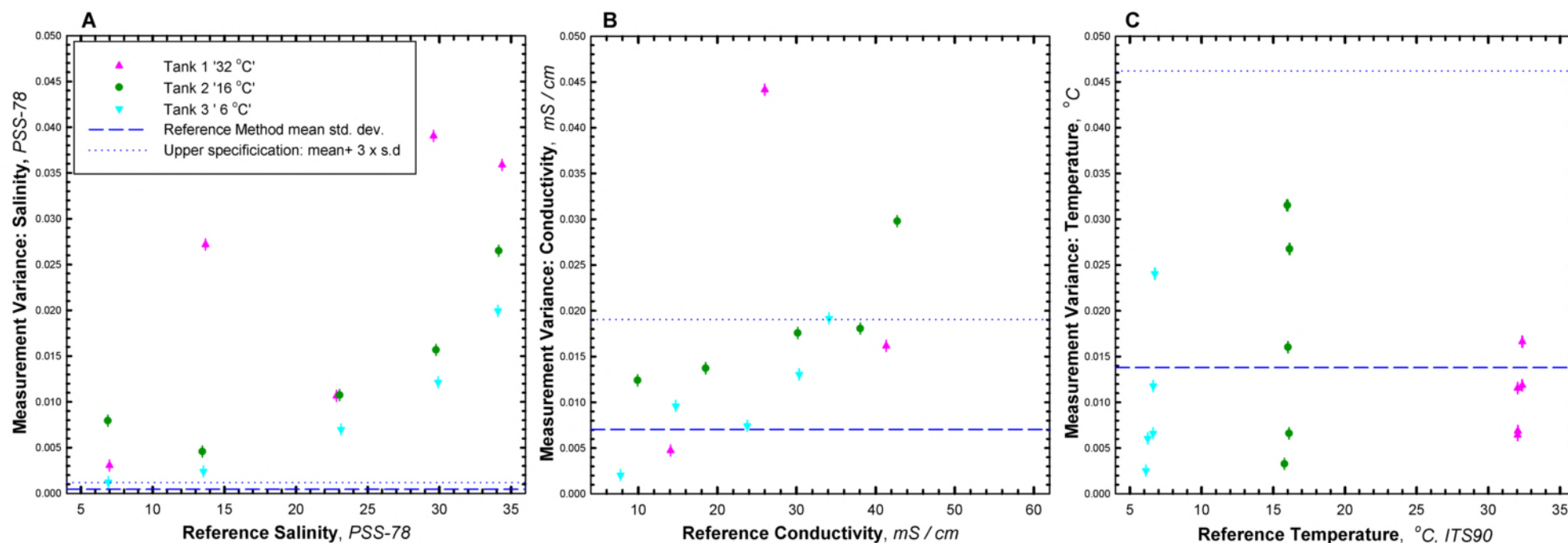
Figure 4. Evaluation of measurement variation of In-Situ's Aqua Troll 200 conductivity and temperature sensor package achieved during the laboratory exposure trials plotted in **Fig. 3**. Relative measurement variance is presented as the standard deviation from 30 consecutive instrument reads associated with each test exposure. The corresponding reference measurement variance range is provided in each plot as the mean standard deviation (dashed line) and 3x s.d. (dotted line) of consecutive reference samples, averaged across all trials. [*A*] Variance of derived salinity estimates; [*B*] Variance of in situ conductivity measurements; [*C*] Variance of instrument temperature measurements.

In Situ Aqua Troll 200

Figure 5. Evaluation of the relative accuracy of In Situ's Aqua Troll 200 conductivity and temperature sensor package achieved during the laboratory exposure tests plotted in **Fig. 3**. Relative accuracy is estimated as the difference or offset between the mean instrument reading and mean reference reading for each exposure test. [*A*] Relative accuracy of derived salinity estimate; [*B*] Relative accuracy of instrument's in situ conductivity measurement; [*C*] Relative accuracy of instrument's temperature measurements. Dotted horizontal line represents no difference between instrument and reference method measurement.

RESULTS OF MOORED FIELD TEST

Field Site Characterization

Field tests focused on the ability of the instrument to consistently track natural changes in salinity over extended deployment durations of 4-8 weeks. In addition, the field tests examined the reliability of the instrument, i.e., the ability to maintain integrity or stability of the instrument and data collections over time. Reliability of instruments was determined by quantifying the percent of expected data that was recovered and useable. In addition, instrument stability was determined by pre- and post-measures of reference samples in a well mixed test bath after removing any influence from accumulated biofouling.

The performance of the Aqua Troll 200 sonde was examined in field deployment tests at each of five ACT Partner test sites. The range and mean for temperature and salinity (or conductivity) for each test site is presented in Table 1. Across test sites, temperatures ranged from $10 - 31$ ^{o}C, salinity from $19.4 - 37.0$ at the coastal ocean test sites and conductivity ranged from $269 - 947$ μS cm^{-1} at the freshwater test site.

Table 1. Range and average for temperature, conductivity and derived salinity at each of the test sites during the sensor field deployment measured in situ by a SeaBird SBE 26 (or SBE26plus) mounted on the instrument rack and the duration of the deployment.

SITE (deployment period/duration)		Temperature (^{0}C)	Conductivity (mS cm^{-1})	Salinity
Off Tampa Bay, FL	Min.	27.84	58.45	36.01
02Jun – 01Jul	Max.	30.63	61.69	36.97
(n = 30 days)	Mean	29.54	60.17	36.59
Skidaway Island, GA	Min.	27.97	44.48	26.42
09Jun – 03Jul	Max.	31.14	53.88	32.62
(n = 24 days)	Mean	29.48	49.98	29.73
Kaneohe Bay, HI	Min.	26.13	52.73	33.03
10Jun – 19Aug	Max.	29.59	57.47	35.36
(n = 60 days)	Mean	27.51	55.67	35.08
Clinton River, MI	Min.	18.50	0.268	0.137
13Jun – 10Jul	Max.	25.98	0.947	0.505
(n = 28 days)	Mean	22.36	0.522	0.268
Resurrection Bay, AK	Min.	10.75	24.45	19.44
7Aug – 4Sep	Max.	14.69	32.99	28.10
(n = 29 days)	Mean	13.26	30.59	25.15

Moored Deployment in Tampa Bay, FL

The mooring test in Florida took place off a fixed mooring structure located offshore of Tampa Bay. The structure is located on Palatine Shoals at a depth of approximately 6.5m. The instrument rack was attached to the structure at 2.5m below mean sea level to minimize the chances of the instrumentation being exposed to the air during rough sea states. The site exhibited a high and consistent level of salinity, ranging from 36.01 – 36.97 and water temperature ranged between 27.8 – 30.6 ^{o}C.
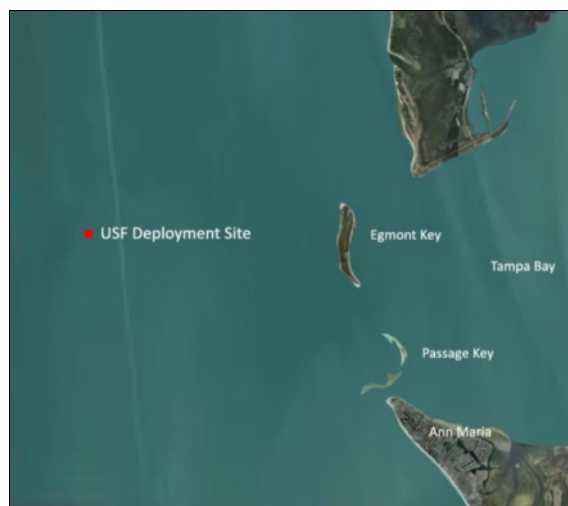
USF Deployment Site Location
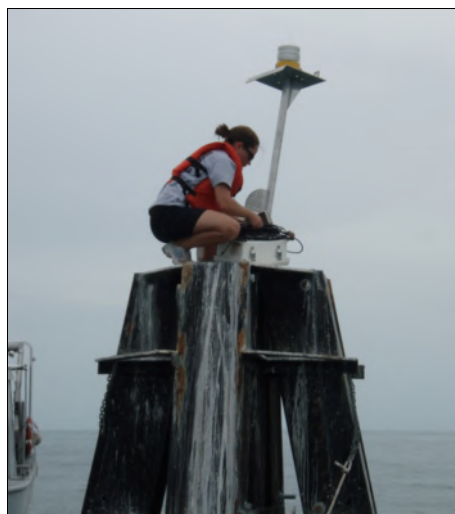
USF Deployment Site

Figure 6. Site map and photo of the field test site located outside of Tampa Bay, Florida.

Time series data of in situ measured conductivity and temperature, and derived salinity, for the FL field test were plotted against corresponding results from the laboratory analyzed reference samples and reference temperature logger (Fig. 7). The relative accuracy of the in situ measurements were depicted as numerical differences from the reference values and plotted over time (Fig. 8). The initial offset of instrument measured salinity for the first week was 0.33 psu above reference salinity, but then accuracy rapidly declined as biofouling became extensive. The data plotted were truncated as comparisons became meaningless. Despite heavy fouling the temperature sensor response was fairly stable and the average offset over the entire deployment was -0.0324 ± 0.1057 ^{o}C. To distinguish between biofouling impacts and potential instrument drift we compared measurement accuracy in pre- and post-exposure tests after the instrument was cleaned to remove any effects of biofouling using well mixed, reference sampled tanks (Fig 9). The agreement between instrument and reference sample actually improved slightly in the post-test indicating the performance in the field test were impacted by biofouling and not calibration drift. The amount of fouling that development on the instrument is shown in figure 10 and the rate of fouling was documented with a time-series of photographs showing the accumulation on PVC tiles (Fig. 11).
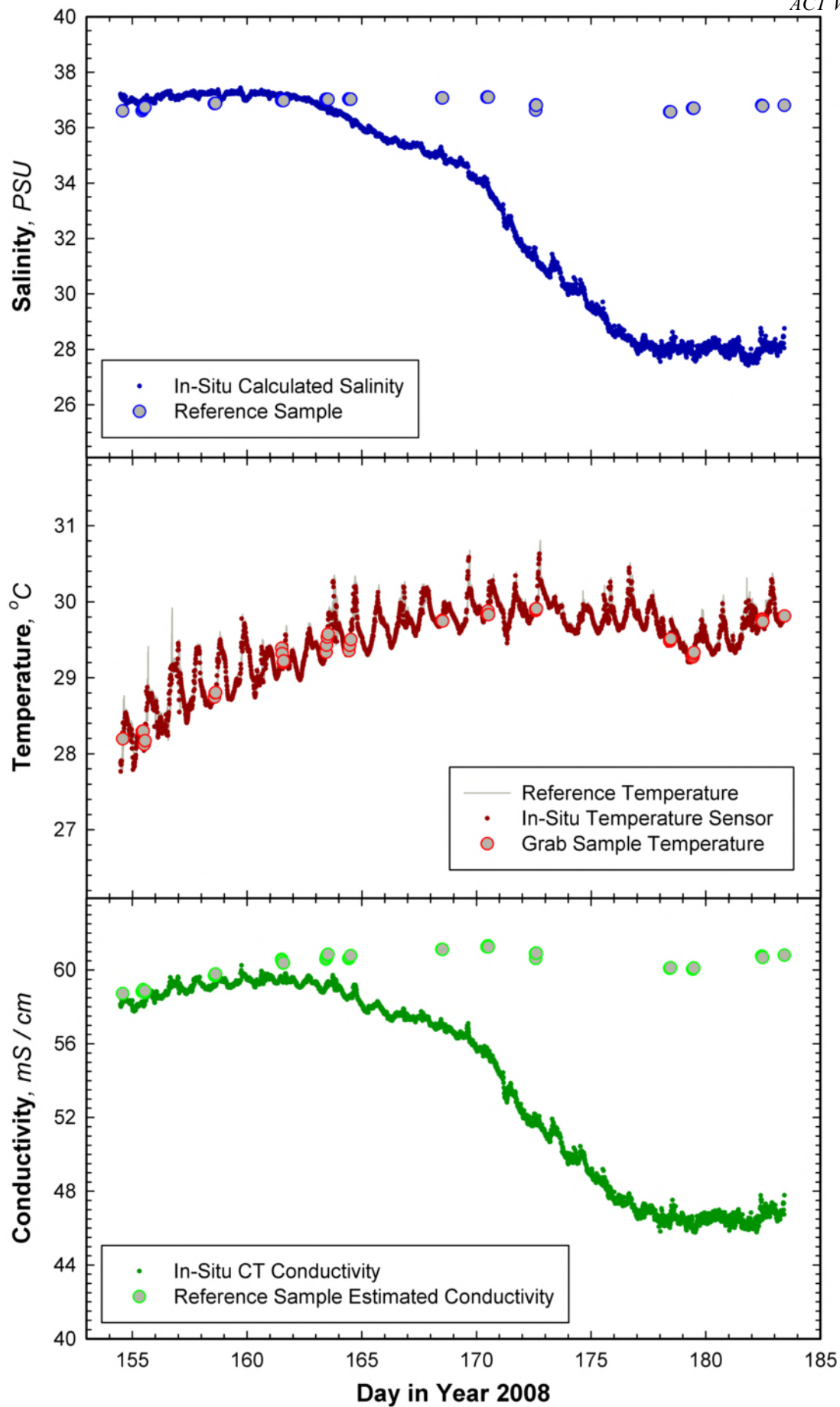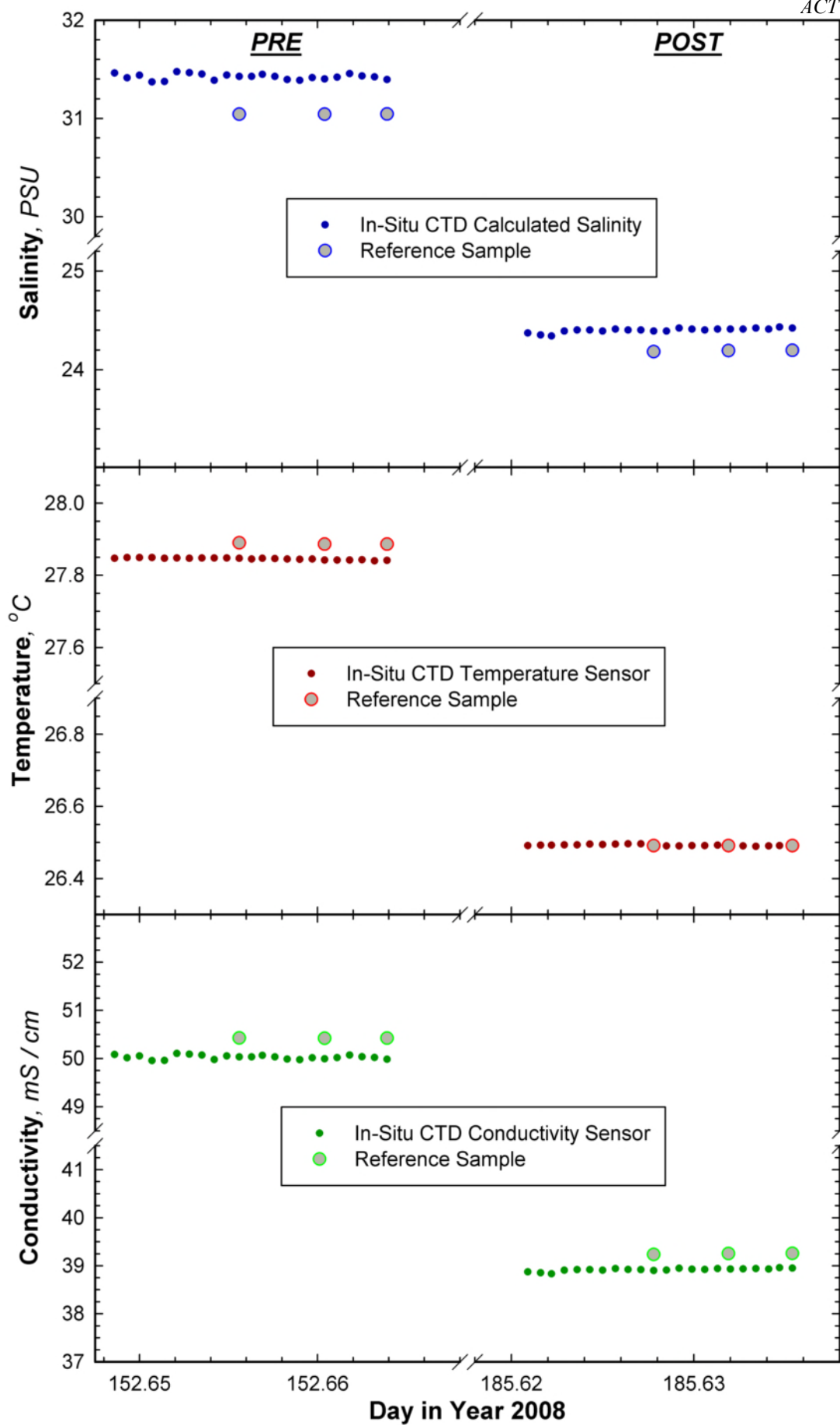
Figure 7. Time series of instrument measurements and corresponding reference samples acquired during USF field deployment.
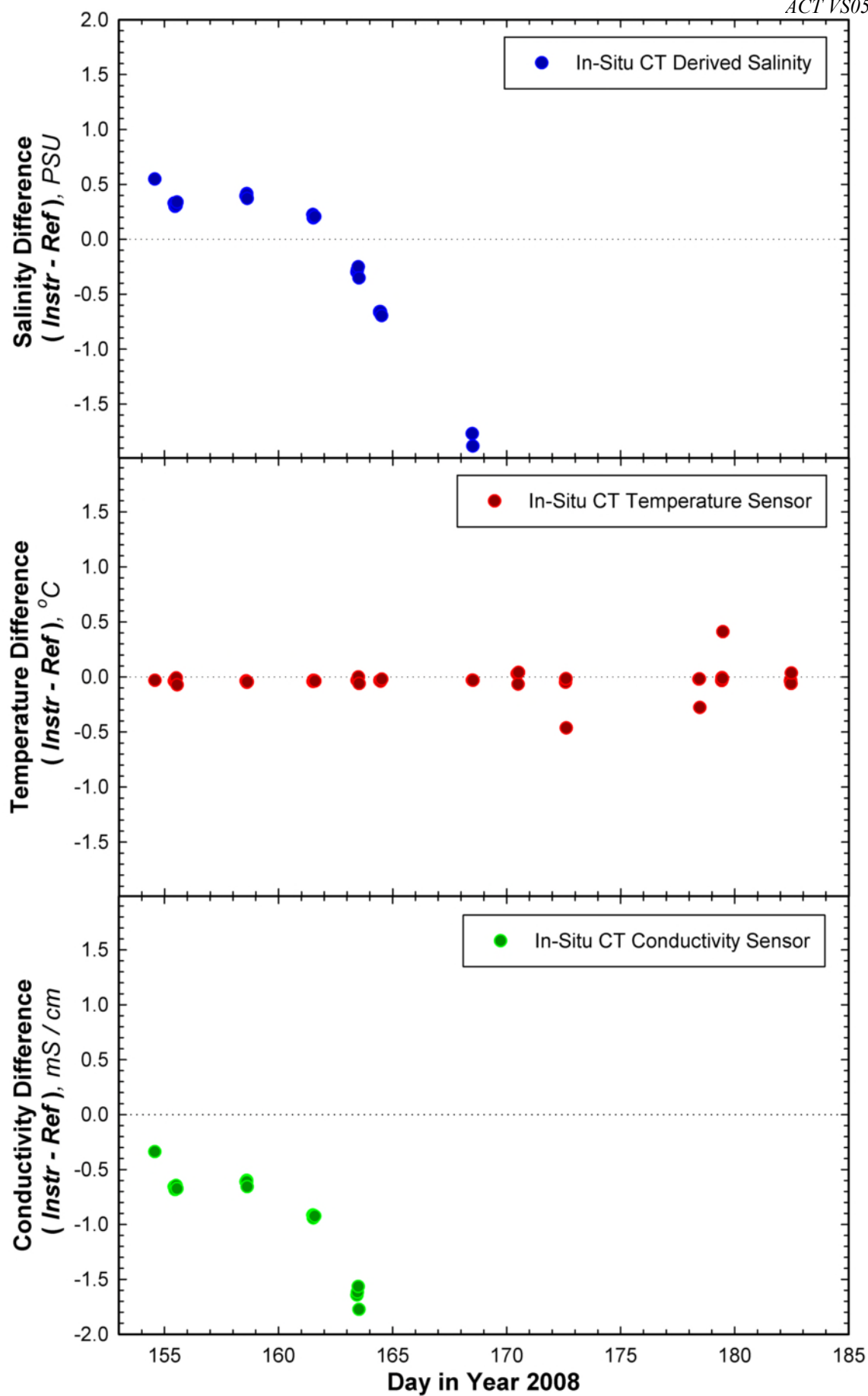
Figure 8. Assessment of relative accuracy of instrument time series measurements during USF field deployment.

Figure 9. Pre- and Post-deployment reference checks in tanks of natural seawater at USF. Post-deployment tests conducted after cleaning instrument of all fouling material according to manufacturer's recommendations.

Instrument Photographs

Before and after photos were taken of the instrument to examine the extent and possible impacts of bio-fouling (Fig. 10). A significant amount of hard, encrusting bio-fouling was evident across most of the instrument body by the end of the deployment and growth was even present directly within the conductivity cell.

Prior to Deployment (Close-up)

Prior to Deployment (Full View)

After Deployment (Close-up)

After Deployment (Full View)

Figure 10. Aqua TROLL 200 instrument photos from Tampa Bay, FL test site before and after deployment

Bio-Fouling Plate Photographs

Bio-fouling plates were retrieved and photographed once each week throughout the deployment to help define the rate and extent of biofouling within the test environment (Fig. 11). By the third week of deployment there was an extensive amount of hard, encrusting biofouling at the Florida test site.
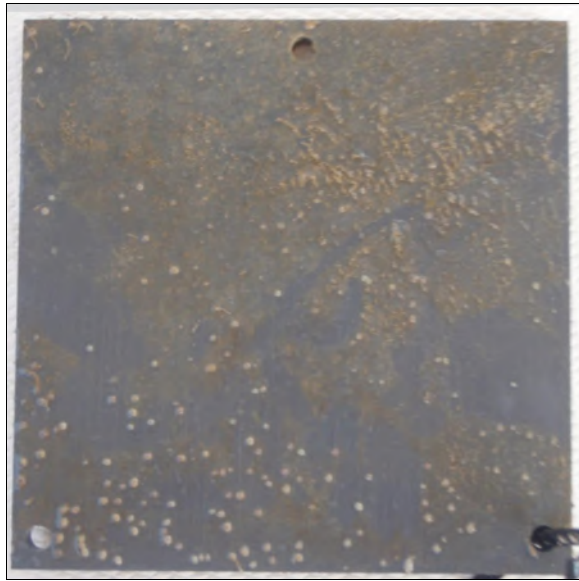
USF Site Week 1
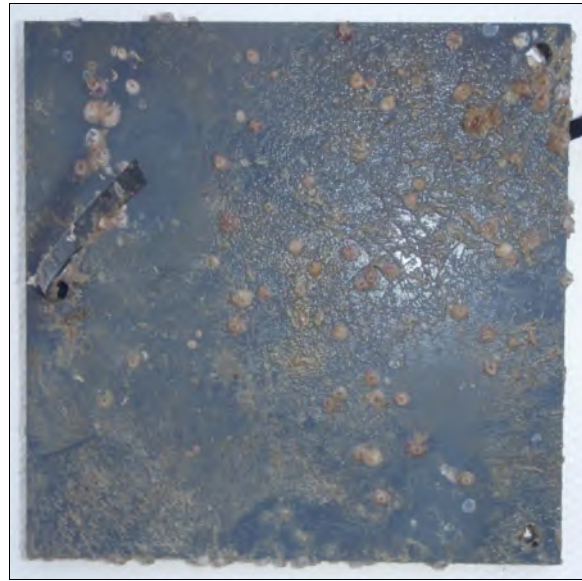
USF Site Week 2
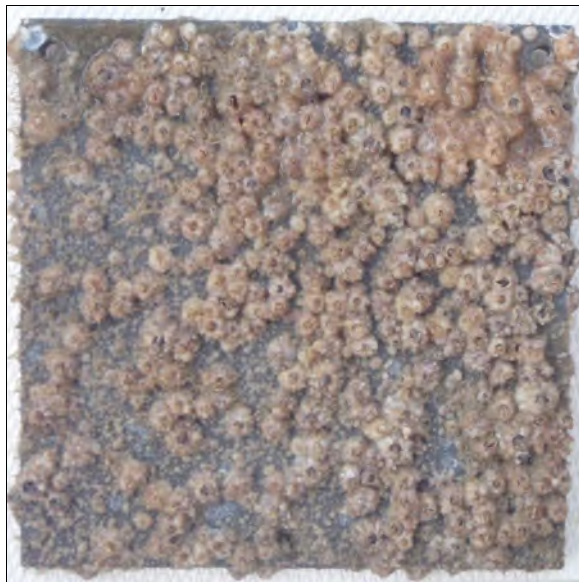
USF Site Week 3

USF Site Week 4

Figure 11. Weekly bio-fouling plates retrieved from the Tampa Bay, FL mooring test site.

Moored Deployment at Skidaway Island, GA

The mooring test in Georgia took place on a floating dock located on Skidaway Island on the Skidaway River (Fig. 12). The water depth of the test site was 2.3 m at minimum. The site exhibited a fairly large fluctuation in salinity, ranging from 26 – 33 PSU, and temperatures ranged from 28 – 31 ^{o}C.

SkIO Deployment Site off Skidaway Island   SkIO Easy Dock with Rack in Center

Figure 12. Site map and deployment arrangement for the field test conducted at Skidaway Island in Savannah, GA.

Time series data of in situ measured conductivity and temperature, and derived salinity, for the GA field test were plotted against corresponding results from the laboratory analyzed reference samples and reference temperature logger (Fig. 13). The initial offset of instrument measured salinity for the first week was 0.43 psu above reference salinity, but then accuracy rapidly declined as biofouling became extensive (Fig. 14). The data plotted were truncated as comparisons became meaningless. Despite heavy fouling the temperature sensor response was fairly stable and the average offset over the entire deployment was -0.0379 ± 0.0250 ^{o}C. Comparisons of the pre- and post-exposure tests show a significant improvement in accuracy for the post-test (Fig 15). The nearly 3.5 psu offset for the pre-test was most likely due to bubble entrainment in the conductivity cell, since the instrument's accuracy was much better when placed in the field. Again, the post-cleaned response indicates that instrument performance in the field test was impacted by biofouling and not calibration drift. The amount of fouling that development on the instrument is shown in figure 16 and the rate of fouling was documented with a time-series of photographs showing the accumulation on PVC tiles (Fig. 17).
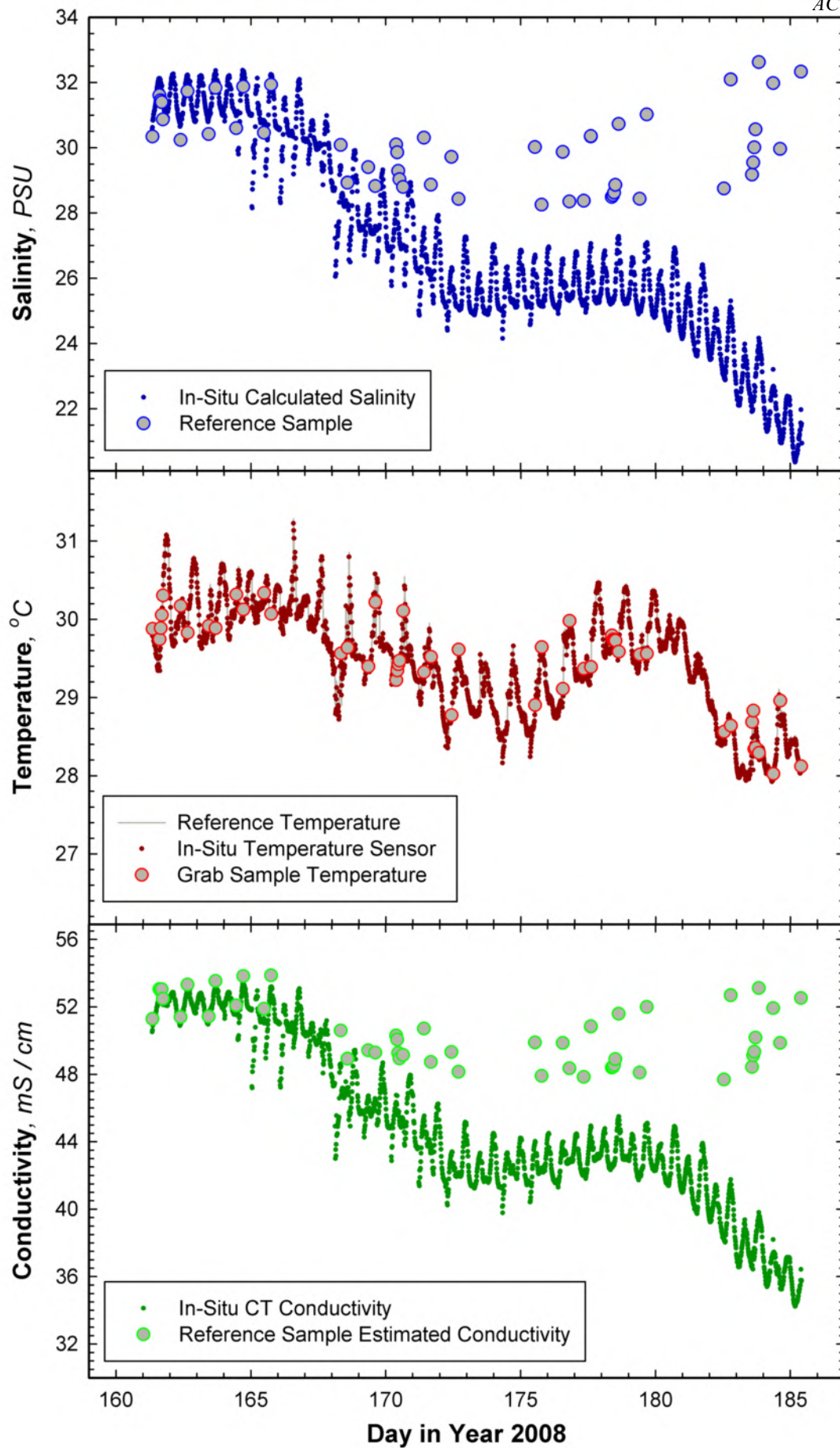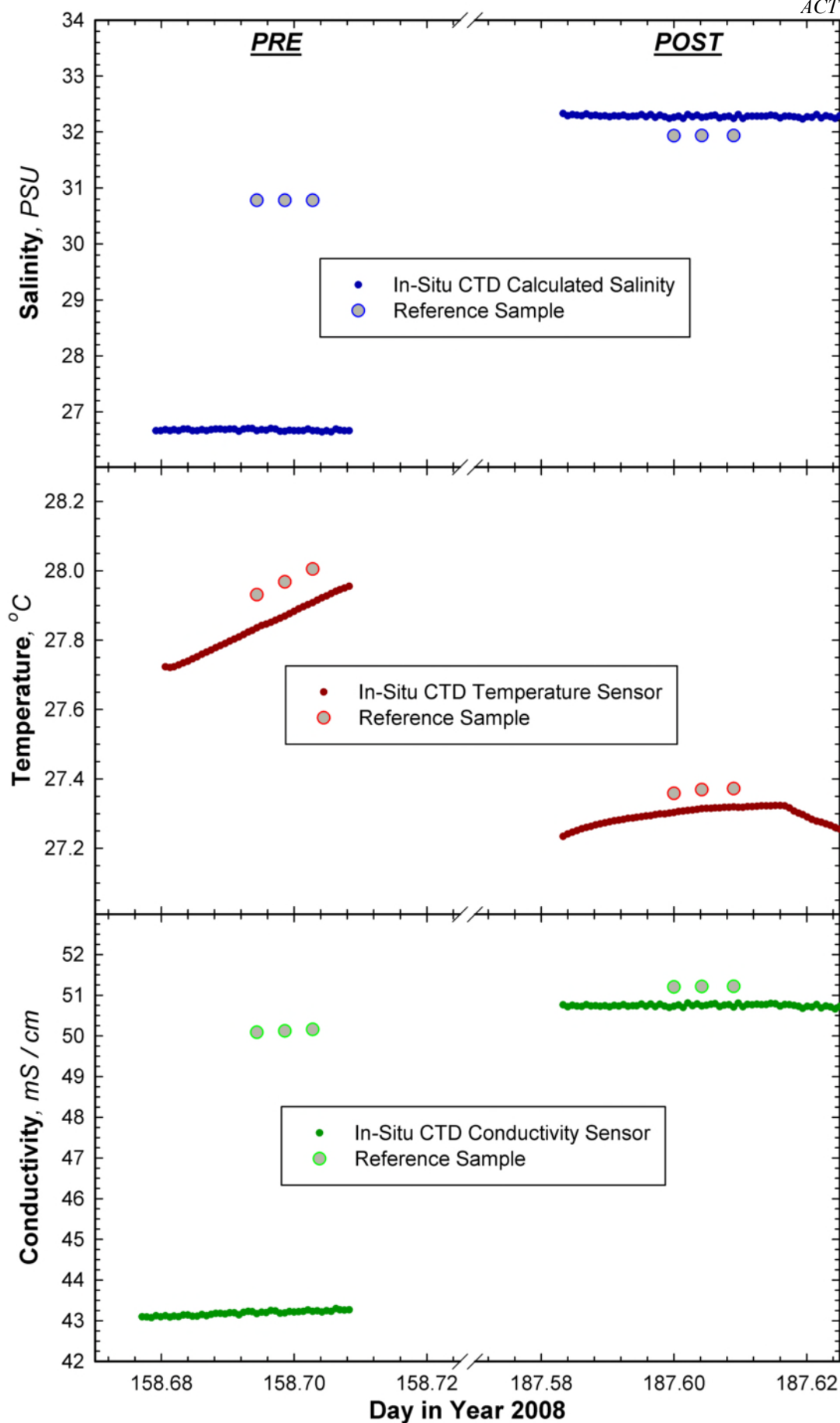
Figure 13. Time series of instrument measurements and corresponding reference samples acquired during the SkIO field deployment.
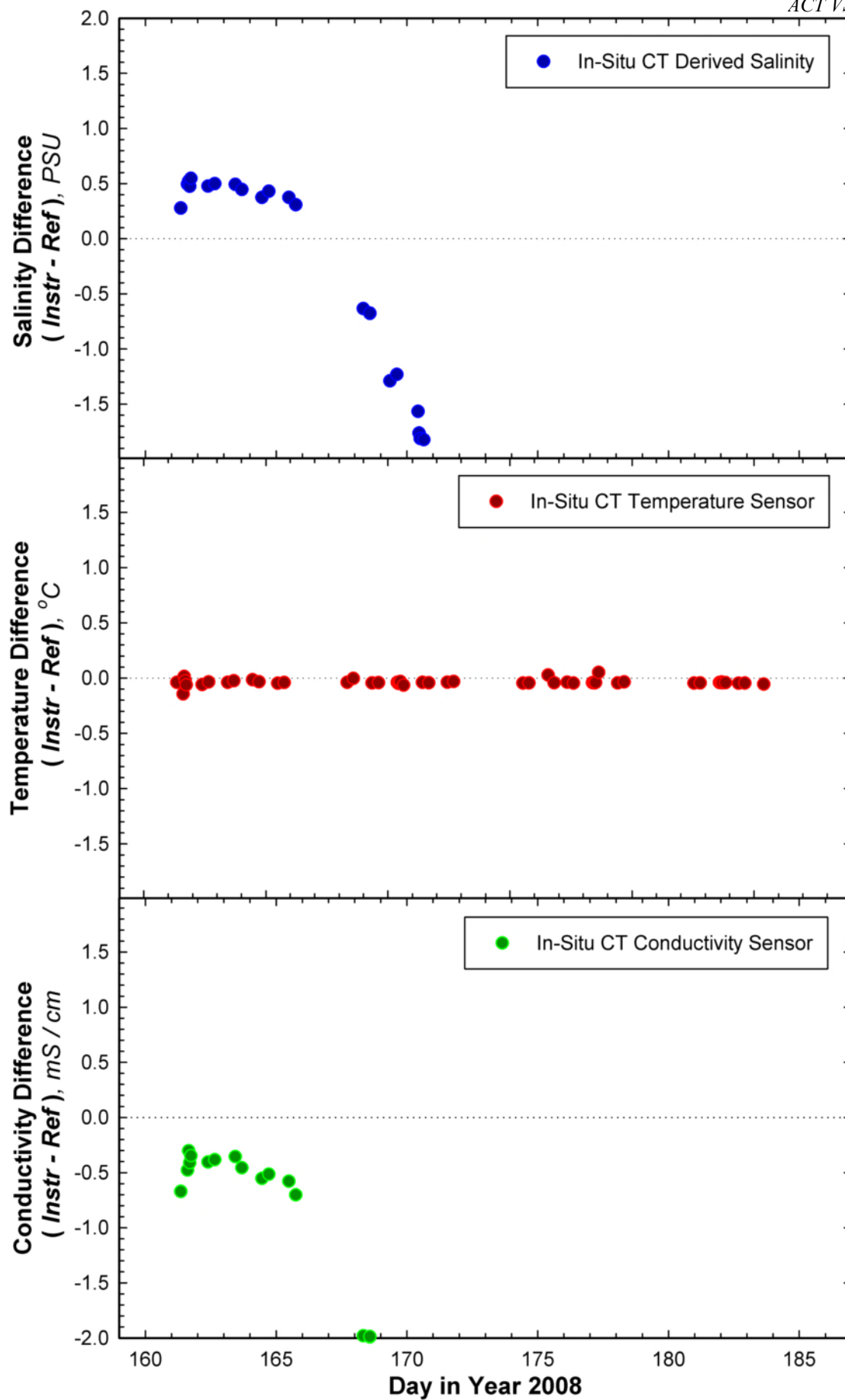
Figure 14. Assessment of relative accuracy of instrument time series measurements during the SkIO field deployment.

Figure 15. Pre- and Post-deployment reference checks in tanks of natural seawater at SkIO. Post-deployment tests conducted after cleaning instrument of all fouling material according to manufacturer's recommendations.

Instrument Photographs

Before and after photos were taken of the instrument to examine the extent and possible impacts of bio-fouling (Fig. 16). A significant amount of soft (plant material) and hard (calcified) bio-fouling was evident across most of the instrument body by the end of the deployment including fouling directly within the conductivity cell itself.

Prior to Deployment (Close-up)

Prior to Deployment (Full View)

After Deployment (Close-up)

After Deployment (Full View)

Figure 16. Aqua TROLL 200 instrument photos from Skidaway, GA test site before and after deployment

Bio-Fouling Plate Photographs

Bio-fouling plates were retrieved and photographed once each week throughout the deployment to help define the rate and extent of biofouling within the test environment (Fig. 17). Significant amounts of soft biofouling were evident by week 2 and progressed into heavy amounts of hard, encrusting biofouling at the Georgia test site.

SkIO Site Week 1
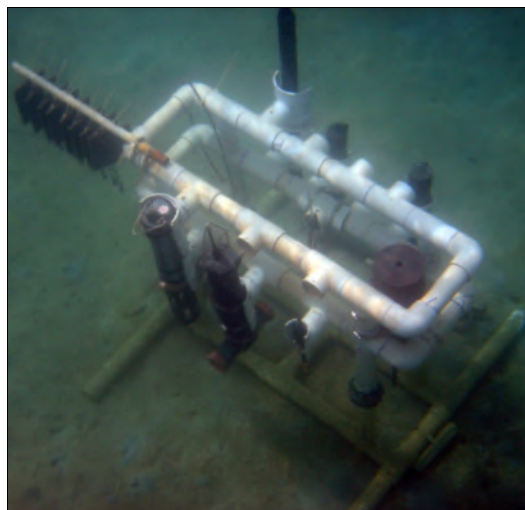
SkIO Site Week 2

SkIO Site Week 3

SkIO Site Week 4

Figure 17. Weekly bio-fouling plates retrieved from the Skidaway, GA test site.

Moored Deployment off Coconut Island in Kaneohe Bay, Hawaii

The mooring test in Kaneohe Bay took place on the fringing reef flat surrounding Coconut Island. The instruments were placed on a standing rack (Fig. 18) in a water depth of 3 meters with tidal variations typically less than 0.5 m at this site. During the deployment test, salinity values ranged from 33 to 35.5 and water temperatures from 26.1 to 29.6 ^{o}C.


Deployment Site on Coconut Island   Instruments in Deployment Rack

Figure 18. Site Photos from Field Deployment off Coconut Island, Kaneohe Bay, HI.

Time series data of in situ measured conductivity and temperature, and derived salinity, for the HI field test were plotted against corresponding results from the laboratory analyzed reference samples and reference temperature logger (Fig. 19). The relative accuracy of the in situ measurements were depicted as numerical differences from the reference values and plotted over time (Fig. 20). Biofouling at this test site was much less intense and the instrument performed fairly consistently throughout the deployment with an average offset of 0.3793 psu, -0.4304 mS/cm, and 0.0077 ^{o}C. Comparison of instrument accuracy and precision measured during pre- and post-deployment exposure tests, showed an increase in the amount of offset for measured salinity from approximately 0.35 to 0.75 psu (Fig 21). It is not possible to determine whether this increase is from instrument drift or from incomplete cleaning of the conductivity cell. The fact that the post-test offset is greater than what was observed in the field near the end of the deployment suggests that bubble entrainment may also be a factor. The amount of fouling that development on the instrument is shown in figure 22 and the rate of fouling was documented with a time-series of photographs showing the accumulation on PVC tiles (Fig. 23).
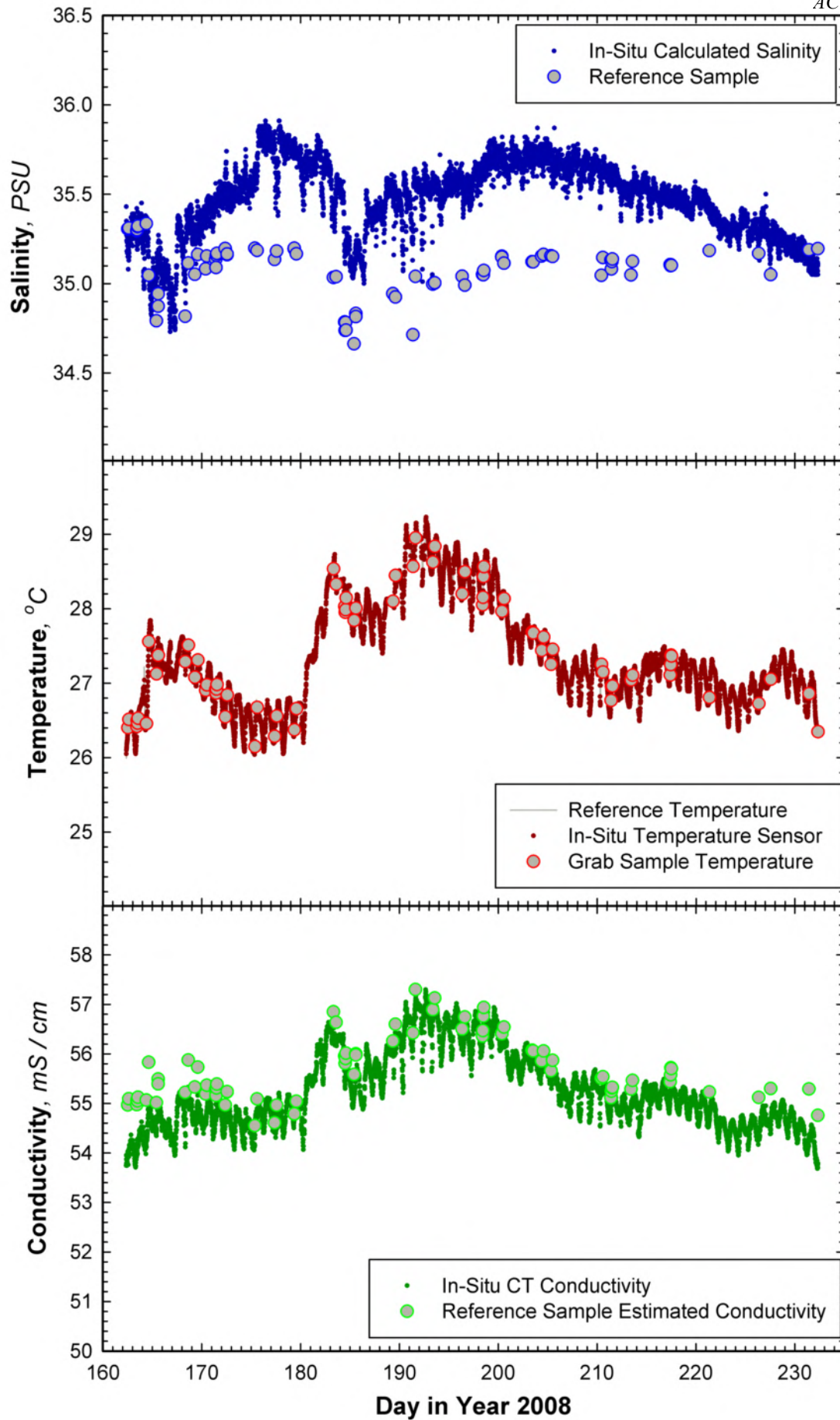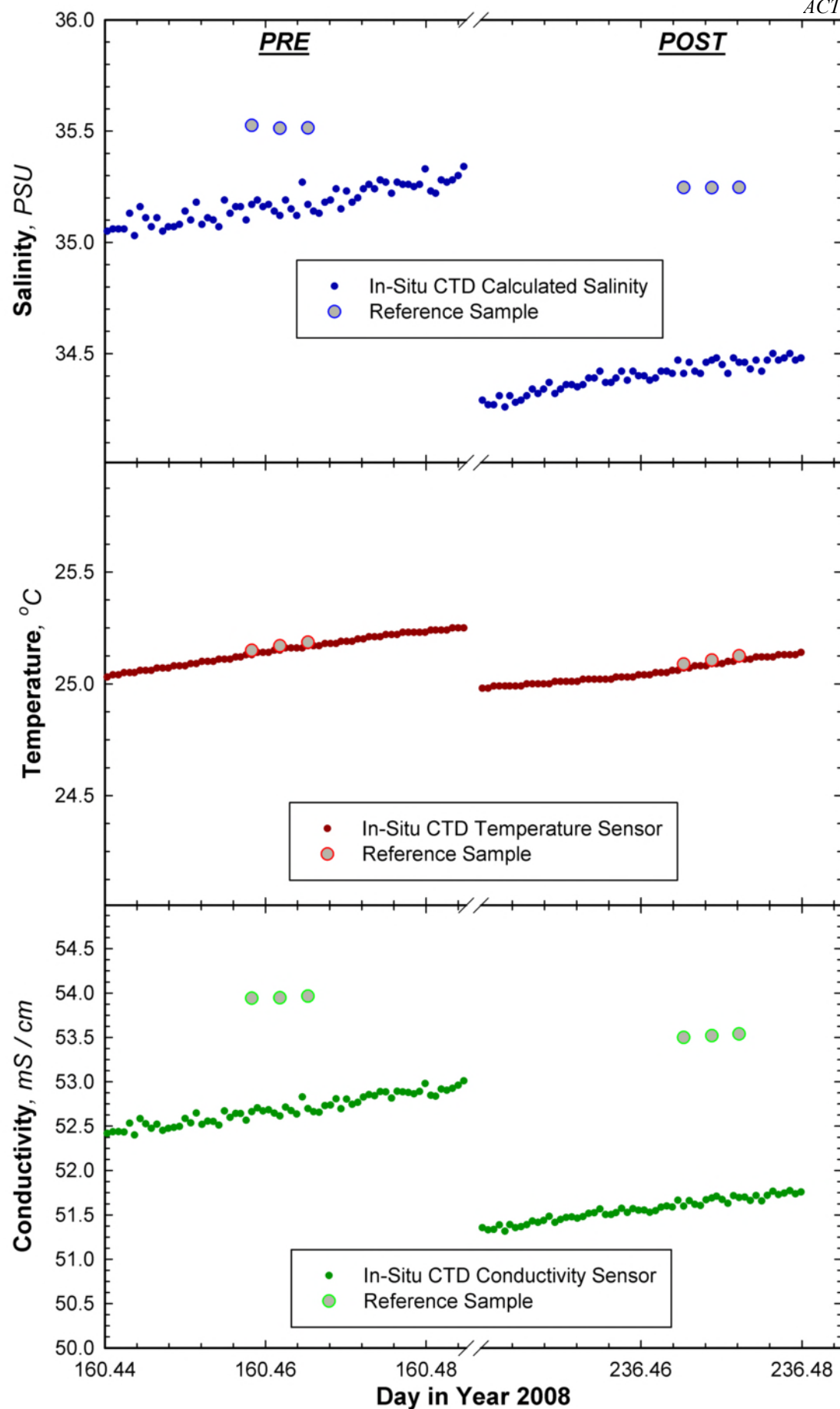
Figure 19. Time series of instrument measurements and corresponding reference samples acquired during the HI field deployment.
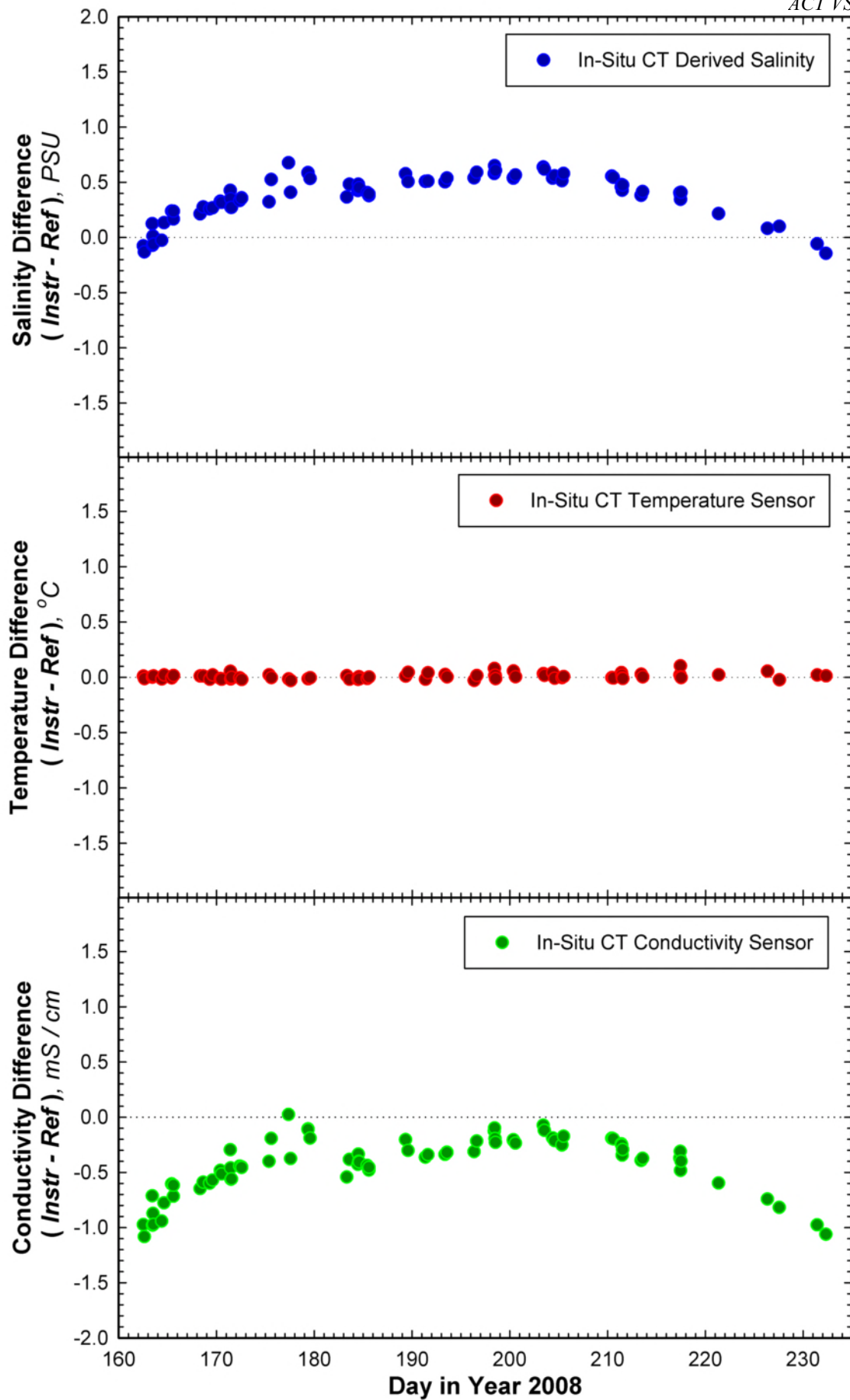
Figure20. Assessment of relative accuracy of instrument time series measurements during the HI field deployment.

Figure 21. Pre- and Post-deployment reference checks in tanks of natural seawater at HI. Post-deployment tests conducted after cleaning instrument of all fouling material according to manufacturer's recommendations.

Instrument Photographs

Before and after photos were taken of the instrument to examine the extent and possible impacts of bio-fouling (Fig. 22). The extent of bio-fouling was significantly less at this test site relative to FL or GA despite the longer deployment period and was mostly comprised of plant material and worm cases.

Prior to Deployment (Close-up)

Prior to Deployment (Full View)

After Deployment (Close-up)

After Deployment (Full View)

Figure 22. Aqua TROLL 200 instrument photos from Coconut Island, HI test site before and after deployment

Bio-Fouling Plates Photographs

      Bio-fouling plates were retrieved and photographed once each week throughout the deployment to help define the rate and extent of biofouling within the test environment. A sub-set of the plate photographs covering weeks 1, 2, 4, and 8 are shown in Figure 23. The extent of bio-fouling was significantly less at this test site relative to FL or GA despite the longer deployment period and was mostly comprised of plant material and worm cases.

HI Site Week 1

HI Site Week 2

HI Site Week 4

HI Site Week 8

Figure 23. Bio-fouling plates for weeks 1, 2, 4, and 8 for the field deployment test off Coconut Island, Kaneohe Bay, HI.

## Moored Deployment in Clinton River, MI

The mooring test in Michigan took place at the end of a fixed pier located at the mouth of the Clinton River which drains into Lake St. Clair (Fig. 24). The water depth of the test site was 2.2 m. The site exhibited a fairly large fluctuation in conductivity, ranging from 269 - 947 µS/cm as shifting winds produce a varying mixture of river water and lake water and water temperature ranged from 18.5 – 27 $^{\circ}$C.
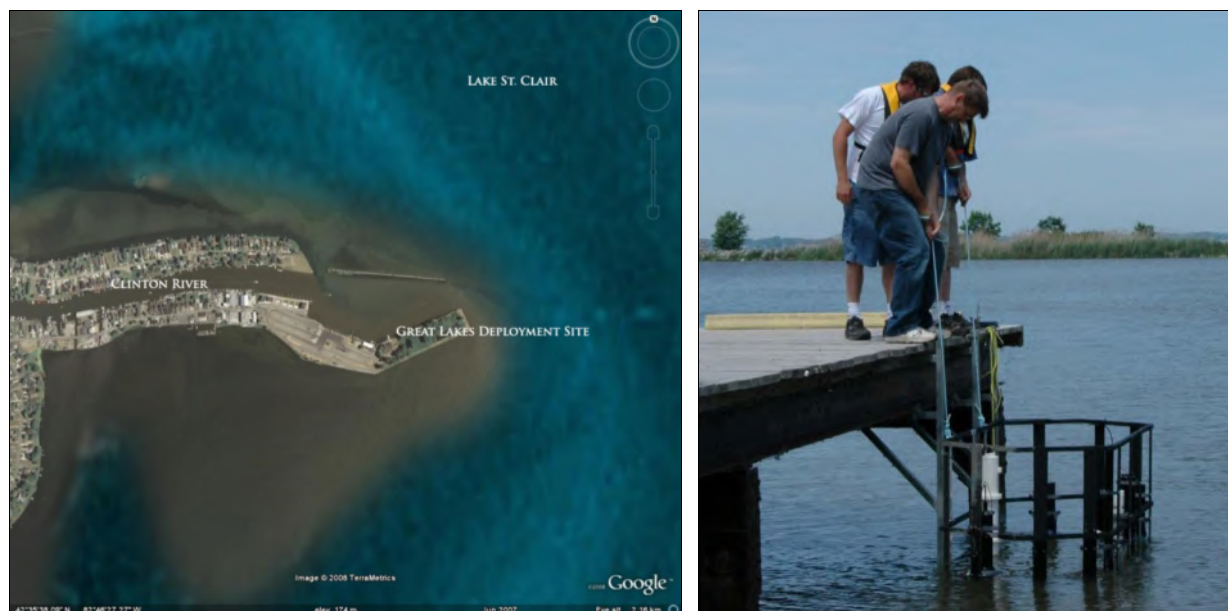

Figure 24. Site map and photo of the Great Lakes field test site located at the mouth of the Clinton River in Mt. Clemens, MI. The test instrument was deployed on a mooring frame attached to the end of a fixed pier.

Time series data of in situ measured conductivity and temperature, and derived salinity, for the MI field test were plotted against corresponding results from the laboratory analyzed reference samples and reference temperature logger (Fig. 25). Instrument measurements closely tracked large daily and weekly variations throughout the entire deployment period. The relative accuracy of the in situ measurements were depicted as numerical differences from the reference values and plotted over time (Fig. 26). The mean offset of instrument measured salinity, conductivity, and temperature over the entire deployment were -0.0024 psu, -0.0071 mS/cm, and -0.0211 $^{\circ}$C, respectively. Comparison of instrument accuracy and precision measured during pre- and post-deployment exposure tests, following instrument cleaning, revealed no measureable performance drift over the deployment period of 28 days (Fig 27). The amount of fouling that development on the instrument is shown in figure 28 and the rate of fouling was documented with a time-series of photographs showing the accumulation on PVC tiles (Fig. 29).
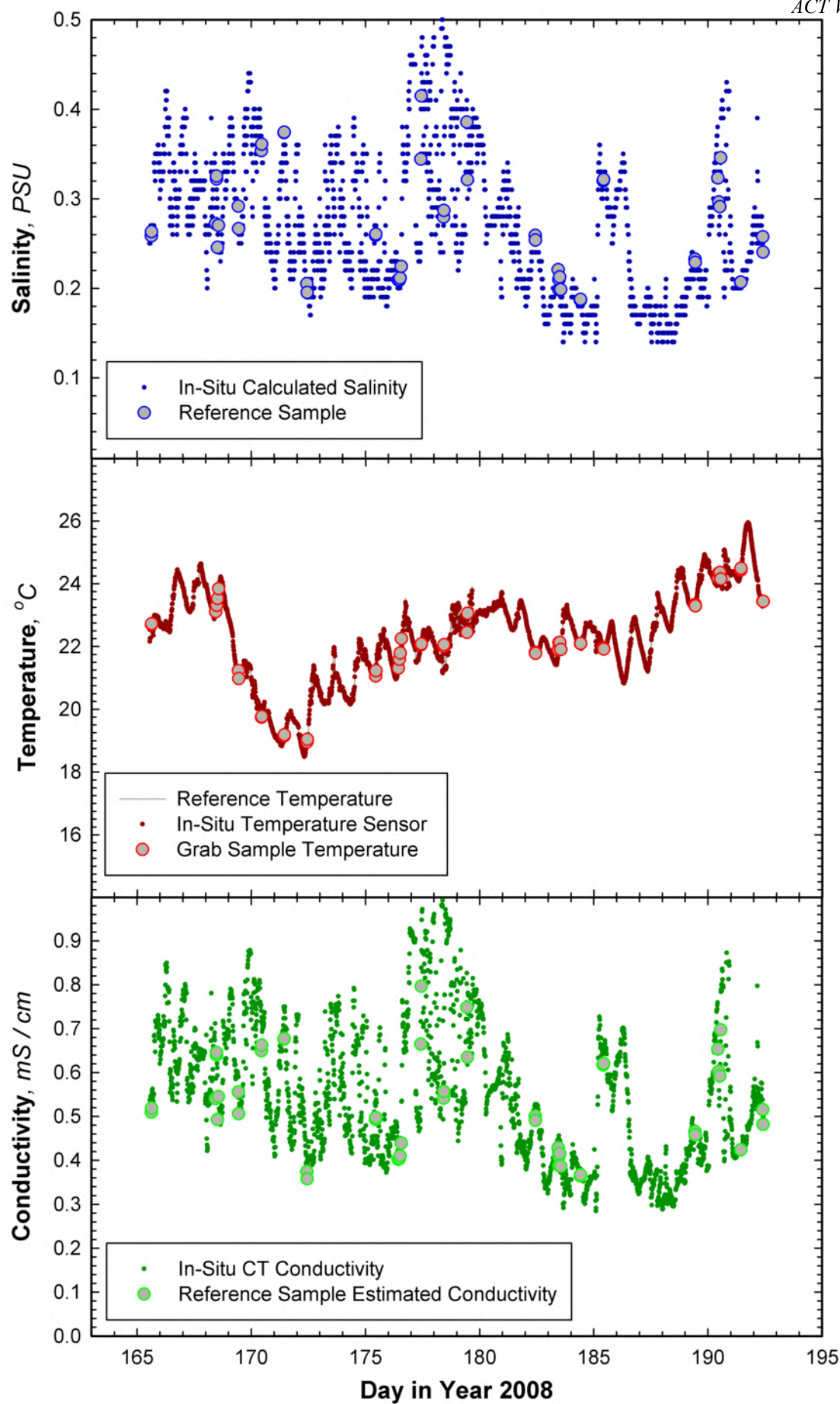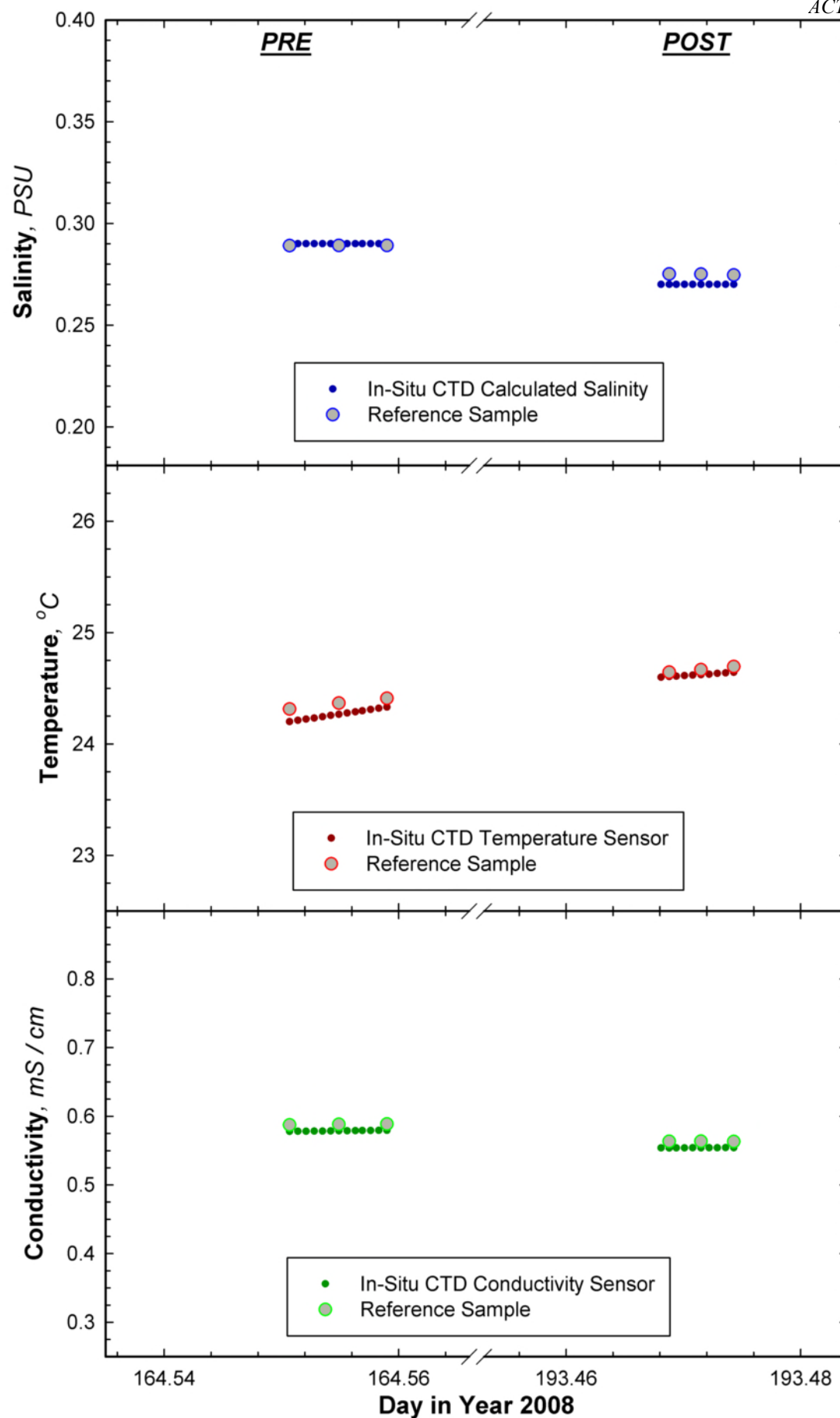
Figure 25 Time series of instrument measurements and corresponding reference samples acquired during the GL field deployment.
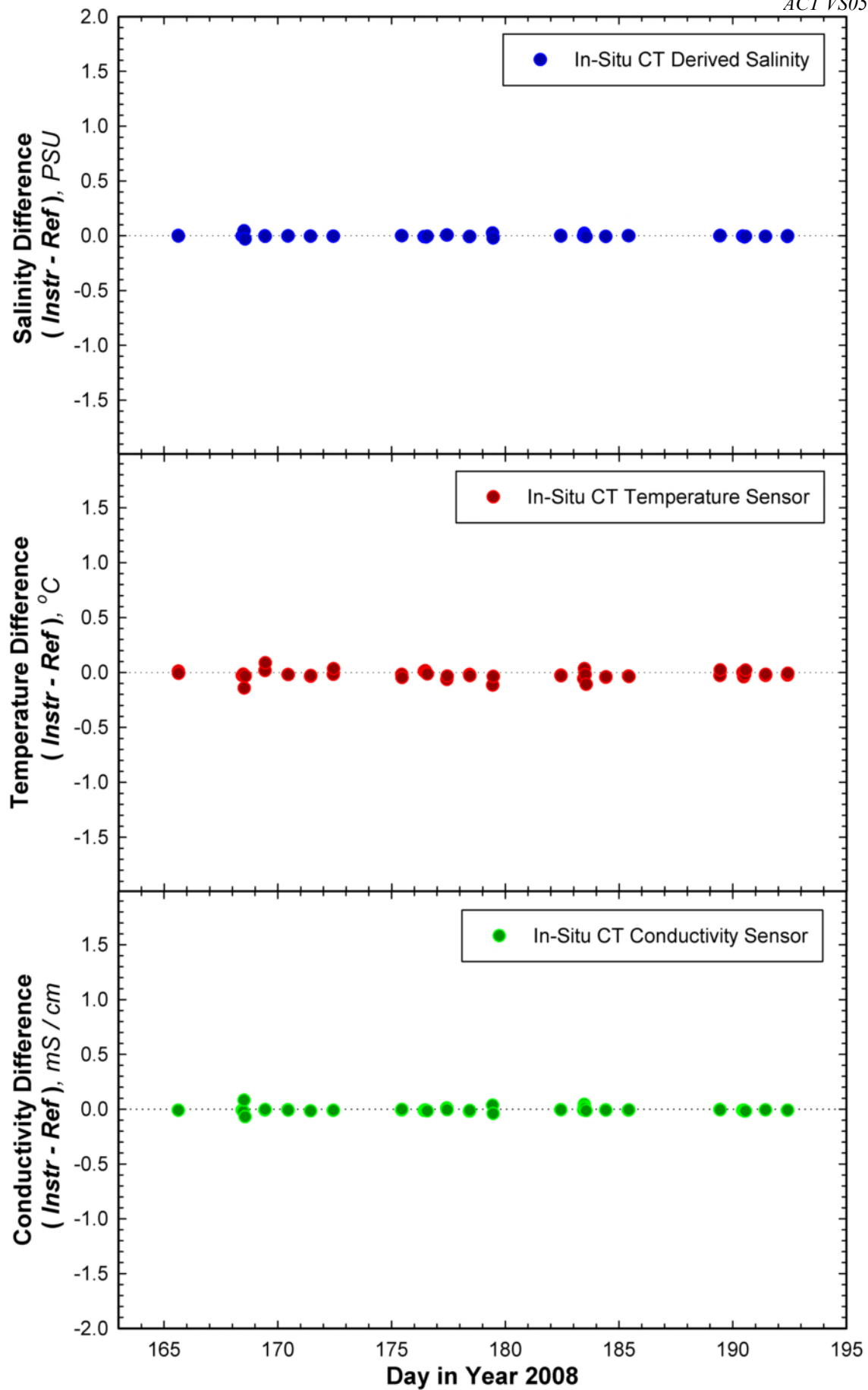
Figure 26. Assessment of relative accuracy of instrument time series measurements during the GL field deployment.

Figure27. Pre- and Post-deployment reference checks in tanks of river water at GL. Post-deployment tests conducted after cleaning instrument of all fouling material according to manufacturer's recommendations.

Instrument Photographs

Before and after photos were taken of the instrument to examine the extent and possible impacts of bio-fouling (Fig. 28). The extent of bio-fouling was quite low at the MI test site and consisted of only soft plant material.

| Prior to Deployment (Close-up) | Prior to Deployment (Full View) |

| After Deployment (Close-up) | After Deployment (Full View) |

**Figure 28.** Aqua TROLL 200 instrument photos from the Clinton River, MI test site before and after deployment

Bio-Fouling Plate Photographs

Bio-fouling plates were retrieved and photographed once each week throughout the deployment to help define the rate and extent of biofouling within the test environment (Fig. 29). Biofouling material was mostly comprised of plant material and developed rather quickly but did not appear to accumulate significantly once the original surface was covered.
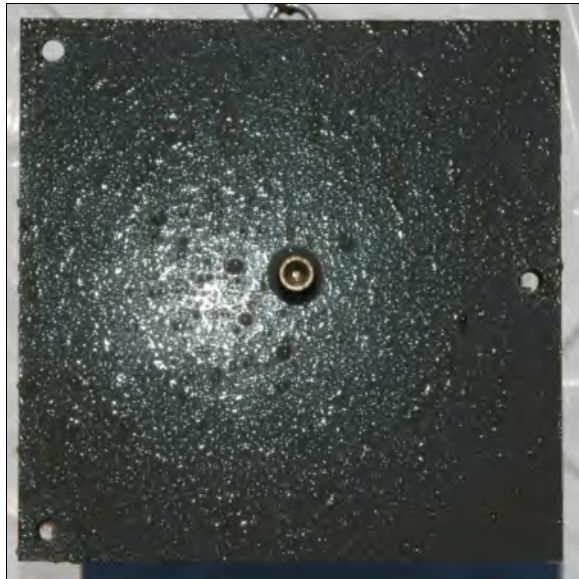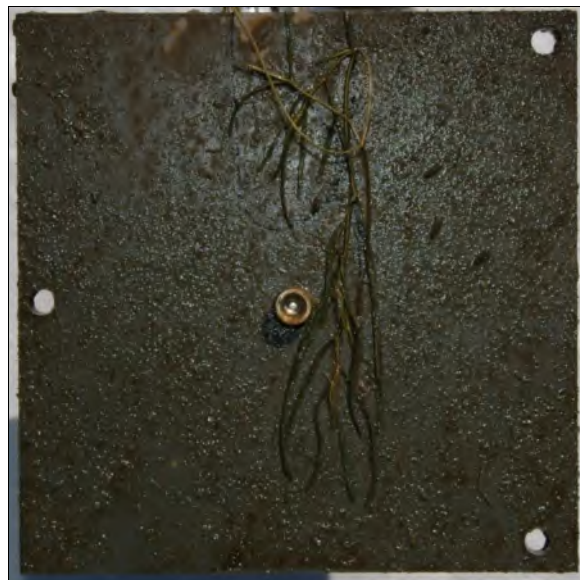

Great Lakes Site Week 1
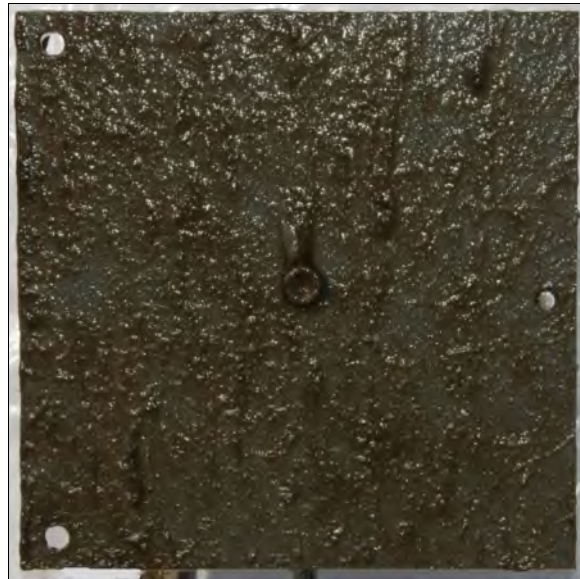
Great Lakes Site Week 2

Great Lakes Site Week 3

Great Lakes site Week 4

Figure 29. Weekly bio-fouling plates retrieved from the Great Lakes test site on the Clinton River, MI.

Moored Deployment in Humpy Cove, Resurrection Bay, AK

The mooring test in Resurrection Bay took place within the inlet of Humpy Cove on a floating dock attached to the end of a small fixed pier (Fig 30).   The water depth of the test site was 3 m.

Deployment Site in Ressurection Bay   Floating Dock location in Humpy Cove

Figure 30. Site map and photo of the Alaska field test site located in Humpy Cove of Resurrection Bay near Seward, AK. The test instrument was deployed on a mooring frame attached to a floating dock.

Time series data of in situ measured conductivity and temperature, and derived salinity, for the AK field test were plotted against corresponding results from the laboratory analyzed reference samples and reference temperature logger (Fig. 31). Instrument measurements tracked daily and weekly variations quite closely throughout the entire deployment which included frequent mixing events and sharp gradients. The relative accuracy of the in situ measurements were depicted as numerical differences from the reference values and plotted over time (Fig. 32). The pattern suggests a combination of calibration offset of approximately -0.3 to -0.4 psu followed by a further slight decline in accuracy over time. A possible explanation for the temporary excursions in accuracy day 222 and day 233 may be that sharp vertical gradients caused greater spatial heterogeneity in the water mass around the mooring which make it difficult to match instrument and reference measurements. Comparison of instrument accuracy for the pre- and post-deployment exposure tests are presented in figure 33. Bubble entrainment again likely affected results in the pre-test. The offset in the post-test was -0.3 psu and similar to the initial observed offset during the field test. The amount of fouling that development on the instrument is shown in figure 34 and the rate of fouling was documented with a time-series of photographs showing the accumulation on PVC tiles (Fig. 35).
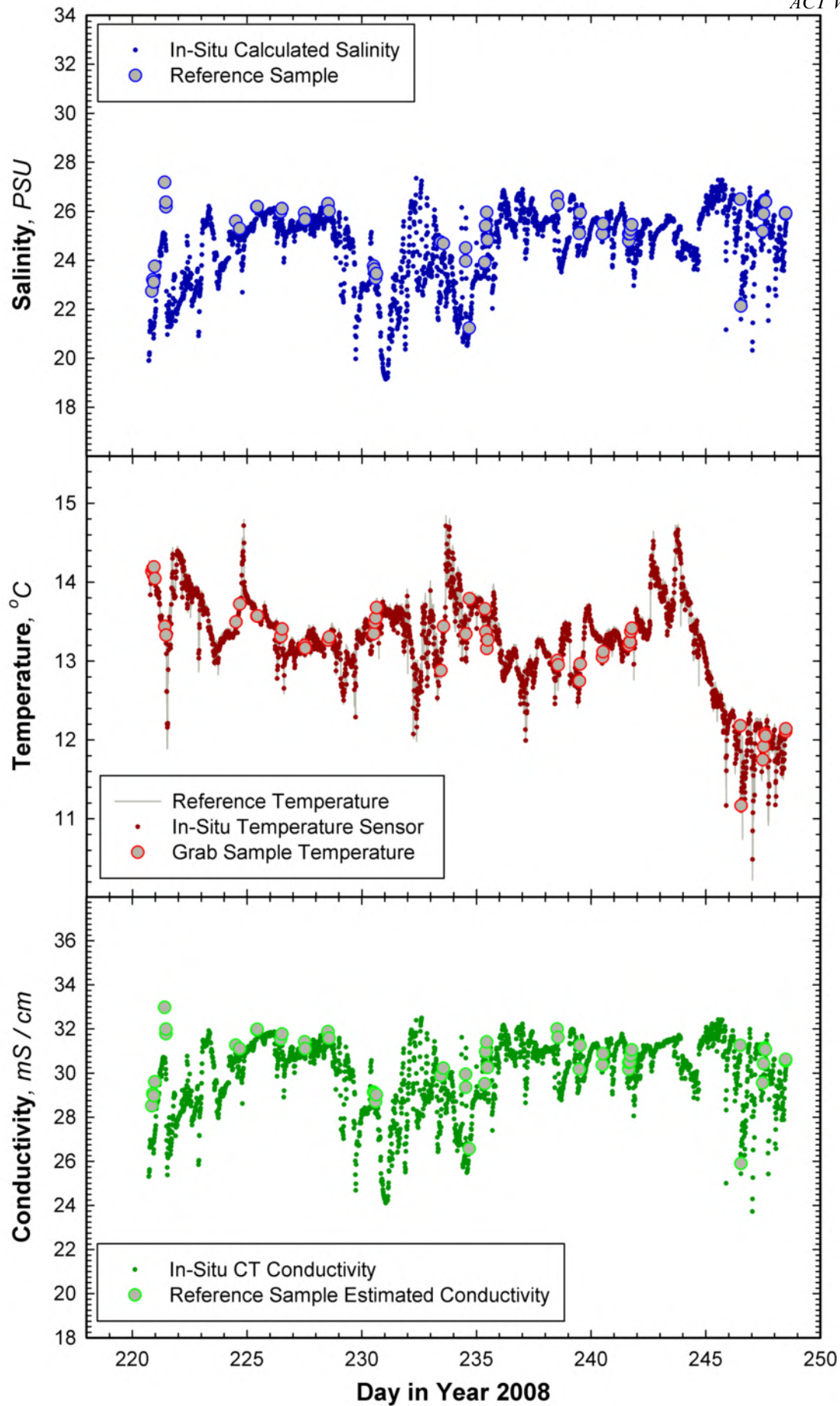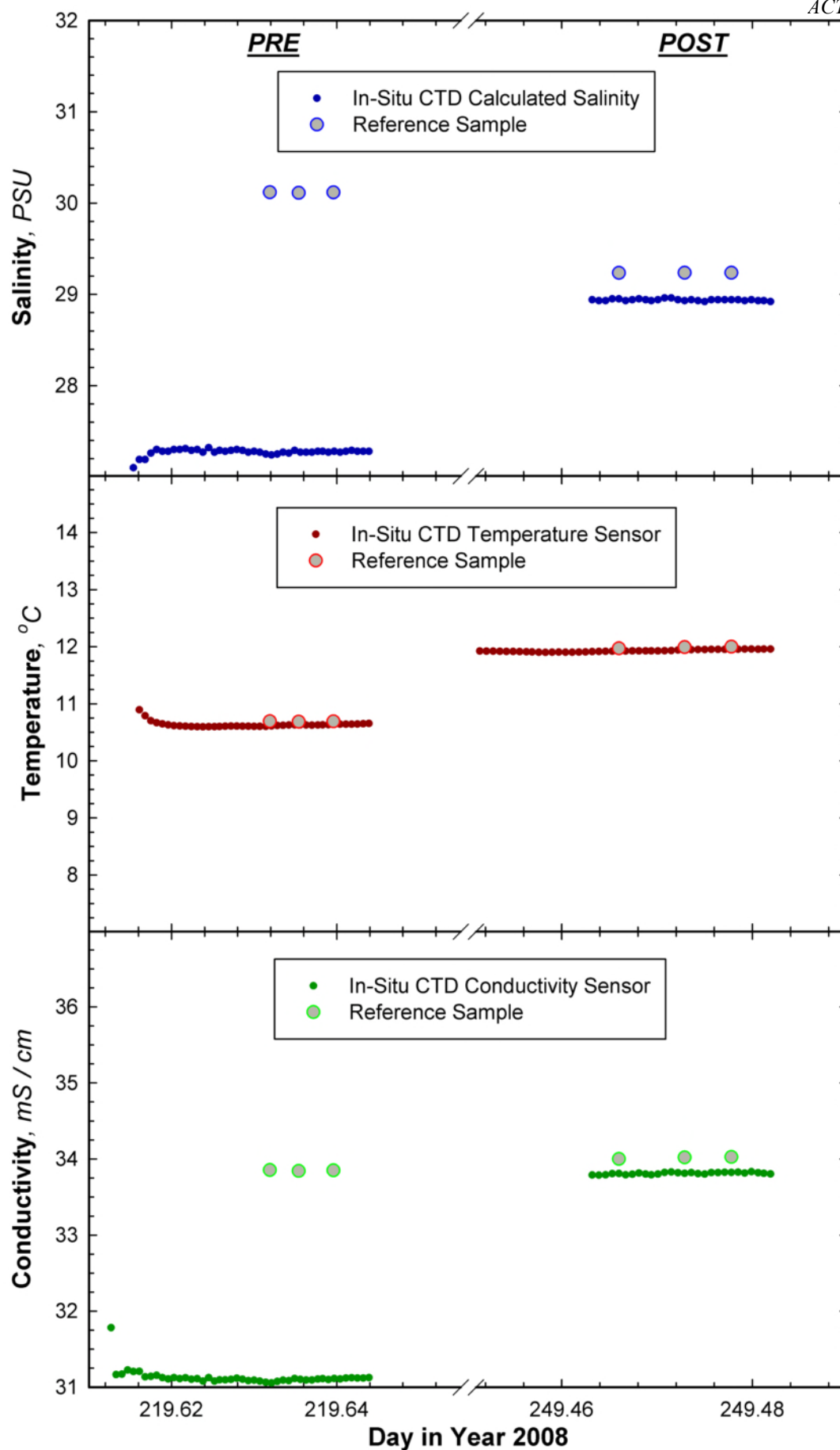
Figure 31. Time series of instrument measurements and corresponding reference samples acquired during the AK field deployment.
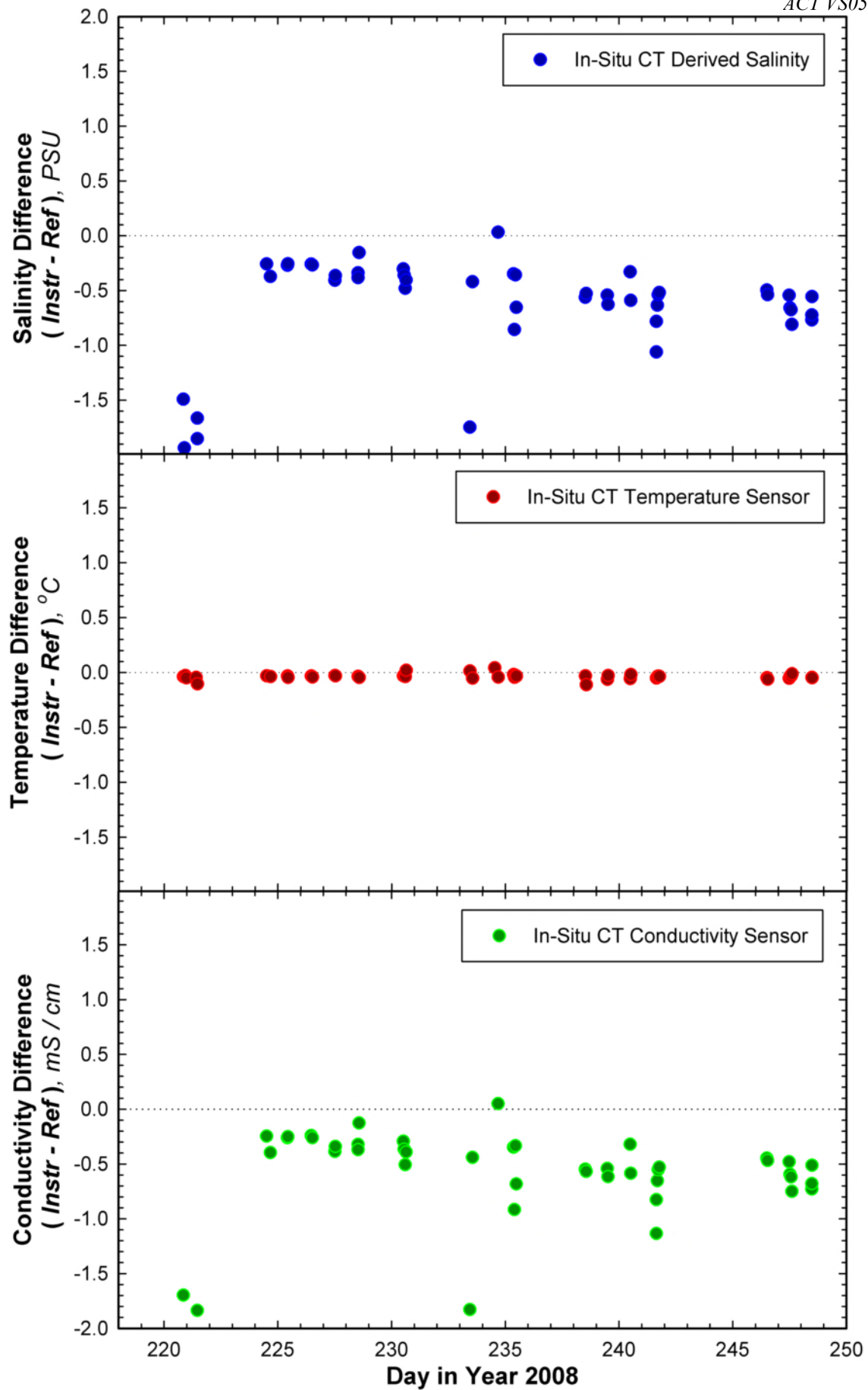
Figure 32. Assessment of relative accuracy of instrument time series measurements during the AK field deployment.

Figure 33. Pre- and Post-deployment reference checks in tanks of natural seawater at AK. Post-deployment tests conducted after cleaning instrument of all fouling material according to manufacturer's recommendations.

Instrument Photographs

Before and after photos were taken of the instrument to examine the extent and possible impacts of bio-fouling (Fig. 34). The extent of bio-fouling at the AK test site was very small and the lowest of any of the five test sites. No hard fouling was observed.

Prior to Deployment (Close-up)

Prior to Deployment (Full View)

After Deployment (Close-up)

After Deployment (Full View)

Figure 34. Aqua TROLL 200 instrument photos from the Resurrection Bay, AK test site before and after deployment.

Bio-Fouling Plate Photographs

Bio-fouling plates were retrieved and photographed once each week throughout the deployment to help define the rate and extent of biofouling within the test environment (Fig. 35). Biofouling material was mostly comprised of plant material and had a slower but consistent rate of fouling until the surface was completely covered.

AK Site Week 1

AK Site Week 2

AK Site Week 3

AK Site Week 4

Figure 35. Bio-fouling plates from the Humpy Cove test site in Seward, AK.

Composite Field Results

Field deployment results were composited for all five test sites to provide an overall comparison of instrument performance across the range of environmental conditions present at out test sites. Data were restricted to the first 14 days of the deployments at each site to minimize the effects of biofouling. The data are analyzed as in situ instrument measured plotted against reference sample measurements for salinity, conductivity, and temperature (Fig. 36). These results allow a general field-based performance assessment similar to the range of test conditions applied within the laboratory test. The effects of biofouling or calibration offsets can be viewed as the vertical deviations from the 1:1 data correspondence trend line. In general the response of instrument derived salinity was highly linear across the range of field test conditions with an $R^2 = 0.995$, a standard error of 0.954, and a slope of 0.997. As was noted individually at the test sites, the response of the temperature sensor was more stable than the conductivity sensor and appeared much less impacting by biofouling.

RELIABILITY

The Aqua TROLL 200 sonde was tested in a fixed mooring application at five different field sites including, estuary, coastal ocean, and riverine environments. Complete time series data were successfully retrieved at all five testing sites for the deployments. There were no problems encountered with the provided software, set-up functions, or data extraction at any of the test sites. Drift in instrument time clocks over the deployment intervals were examined and differences of 0, 11, -3 and 2 seconds were noted for the GA, AK, and HI test sites, respectively.
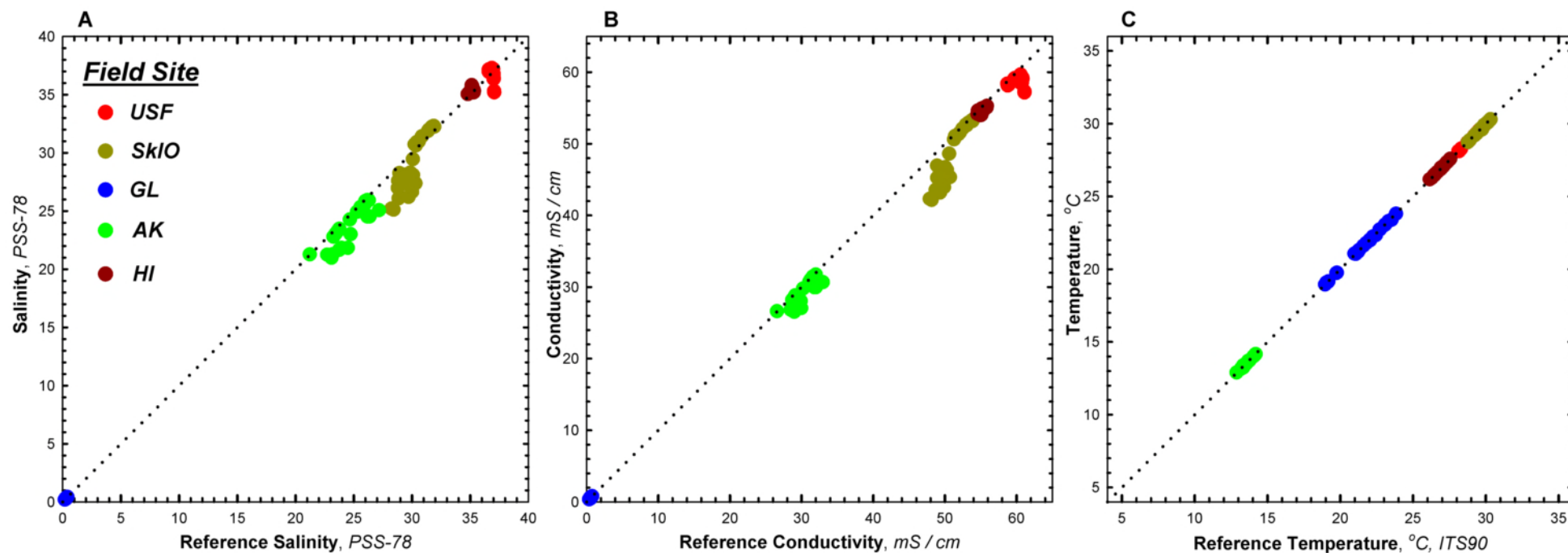
Figure 36. Composite summary of field performance over the first 14 days of deployment for the four In-Situ Aqua Troll 200 units tested during the five evaluation trials. Instrument output plotted against paired field reference sample assay and color indexed by field test site. Dotted line represents 1:1 data correspondence trend line. Scatter around trend line represents occurence of site-specific fouling effects on conductivity cell performance.

ANALYSIS OF QUALTIY CONTROL SAMPLES AND REFERENCE SAMPLE PRECISION

Instrument test results should be evaluated relative to the precision estimates of our analysis of laboratory and field reference samples. Precision analyses were performed on readings from individual salinity bottles, triplicate salinity samples drawn from a reference sample collection, globally across lab treatments, replicate field reference sample collections and reference samples stored and shipped over a 4-6 week time course.

Precision Estimates for Laboratory Test Reference Samples

Instrument performance for laboratory tests can be evaluated relative to the global precision estimates for our reference samples and the certified TR-1060 temperature data. We estimated the analytical precision of the Portasal salinity measurements of our reference samples by computing a mean variance for every salinity sample collected during the lab test as well as a mean for the variance obtained across each of the 15 salinity-temperature treatment conditions (Table 2). Our precision results (0.00023 and 0.00045, respectively) were well within the expected performance level of the laboratory instrumentation and confirmed that test protocols were appropriate for providing comparative reference standards.

Table 2. Precision of Portasal-derived reference salinity estimates (in PSS-78) associated with laboratory performance evaluation.

LEVEL	*Mean Variance*	*S.D.*	*n*
Bottle	0.00023	0.00013	150
Treatment	0.00045	0.00024	15

A reference method precision of the temperature control for our test baths was computed for each of the treatment conditions (Table 3). Temperature measurements were recorded at 1-minute intervals at 2 points within each test tank. The mean variance in temperature across the 15 treatment exposures was 0.0138 ^{o}C, indicating relatively well defined test conditions for comparing instrument performance. As the mean bath temperature and Portasal salinity measurements were independent of the test instrument records, the paired bath temperature and analytical salinity measured enabled computation of an independent estimate of in situ conductivity for each bath sample. These computations are based on the inversion of the equations of state for seawater and were performed with Lab Assistant V2 (PDMS, Ltd. 1995).

Table 3. Reference method precision levels obtained during laboratory performance evaluation tests.

LEVEL	*Mean Variance*	*S.D.*	*n*
RBR 1060, ^{o}C	0.0138	0.0108	15
Portasal, *mS/cm*	0.0070	0.0040	15

Precision Estimates for Field Test Reference Samples

The average analytical precision of salinity measurements taken from a single salinity bottle was 0.00022 for all field test sites with a range of 0.00009 – 0.00034 (Table 4). Similarly, the average analytical precision of salinity measurements taken from replicate (3-4) salinity bottles filled from a single Van Dorn sample collection was 0.00129 for all sites with a range of 0.00013 – 0.00249 (Table 5).

Table 4: Within bottle salinity measurement precision for field reference samples analyzed on a Portasal. S values in PSS-78 scale

Field Site	*Mean Variance*	*S.D.*	*n*
USF	0.00027	0.00016	198
SkIO	0.00018	0.00009	203
GL	0.00009	0.00006	203
HI	0.00034	0.00019	293
AK	0.00023	0.00014	255
Overall	*0.00022*	*0.00013*	*1150*

Table 5: Within Van Dorn sample bottle collection salinity measurement precision for field reference samples analyzed on a Portasal. Estimates derived from the average of 3-4 bottles analyzed for each reference sampling. S values in PSS-78 scale.

Field Site	*Mean Variance*	*S.D.*	*n*
USF	0.00178	0.00250	44
SkIO	0.00067	0.00101	53
GL	0.00013	0.00013	50
HI	0.00139	0.00331	81
AK	0.00249	0.00739	63
Overall	*0.00129*	*0.00287*	*291*

Precision Estimates for Replicate Field Reference Samples

Once per week (except at HI with 6 of 8 weeks) a replicated field reference sample was collected with a second Van Dorn bottle. The two Van Dorn bottles were positioned as close as physically possible to one another when sampling (Table 6). For USF and HI these replicates were collected by divers and were slightly more prone to slight offsets in space and time. At the other field sites bottles were fired by a messenger on a tethered line. The average precision obtained for the field replicates ranged from 0.0030 – 0.2612. The greater variability at the AK test site was likely due to persistent vertical variations in salinity at the test site that were confirmed by occasional vertical profiling. For the other four test sites the variability was less than 0.017 psu.

Table 6: Assessment of environmental heterogeneity based on comparison of simultaneous Van Dorn Bottle Snap samples at each field site. Replicate values represent mean of each Van Dorn Bottle Sample Salinity, comprised of 3 - 4 subsample bottles analyzed on a Portasal, with associated precisions provided in previous tables. Difference values in PSS-78.

Field Site	Year Day 2008	Van Dorn 1	Van Dorn 2	S Difference *absolute*	Overall Mean	s.d.
USF	158.615	36.86386	36.87139	0.00753		
	164.438	37.02441	37.030565	0.00616	0.00295	0.00317
	170.458	37.09299	37.09382	0.00082		
	178.448	36.57010	36.56747	0.00263		
SkIO	161.354	30.34166	30.34269	0.00103		
	168.583	28.92843	28.92578	0.00265	0.00416	0.00413
	177.604	30.34359	30.35383	0.01024		
	182.792	32.09234	32.08964	0.00270		
GL	168.479	0.32211	0.32530	0.00319		
	176.479	0.20867	0.20946	0.00079	0.00388	0.00511
	183.479	0.19835	0.20965	0.01130		
	190.479	0.29647	0.29624	0.00023		
HI	165.604	34.94302	34.87283	0.07019		
	172.583	35.16459	35.16526	0.00381		
	179.375	35.19322	35.19750	0.00428	0.01693	0.02666
	185.604	34.83228	34.81538	0.01690		
	193.583	35.00295	35.00425	0.00130		
	200.375	35.15303	35.14794	0.00509		
AK	221.469	26.17526	26.36265	0.18739		
	228.531	26.25852	26.30227	0.04375	0.26116	0.20593
	234.531	23.96403	24.49750	0.53347		
	241.645	24.79116	25.07116	0.28000		
All Test Sites					**0.0578**	**0.1138**

Reference Sample Storage and Shipping Test

Results of the reference sample storage and shipping test for each site are provided in figures 37 – 41. Values for stored bottles (between 20-80 days from collection) generally agreed with one standard deviation to the values determined for the first set of samples that were shipped and analyzed. There was a noticeable upward trend in salinity values for the storage time series at SkIO. This pattern may have resulted from the initial collection when all of the salinity bottles were being filled from an open bath that was subject to evaporation. The collected samples were numbered and analyzed sequentially instead of first being randomized, thereby allowing for the increasing trend. The other sites filled all bottles from a single well mixed carboy that likely minimized any variation among the storage bottle set.

TECHNICAL AUDITS

Technical Systems Audits

The ACT Quality Manager performed technical systems audits (TSA) of the performance of the laboratory tests conducted at MLML on May 21, 2008 and of the field tests conducted off Tampa Bay, FL, on June 16-18, and in Resurrection Bay, AK, on August 11, 2008. The purpose of the TSAs was to ensure that the verification test was being performed in accordance with the test plan and that all QA/QC procedures were implemented. As part of each audit, ACT's Quality Manager reviewed documentation including relevant standard operating procedures, logbooks tracking actual day-to-day operations, and records of quality control and maintenance checks; observed ACT personnel conduct all activities related to the reference sampling and analysis; compared actual test procedures to those specified in the test/QA plan; and reviewed data acquisition and handling procedures. Observations and findings from these audits were documented and submitted to the ACT Chief Scientist. In summary, there were no adverse findings or problems requiring corrective action in any of the audits. The laboratory and field tests for this verification met or exceeded ACT test requirements. The records concerning the TSAs are permanently stored with the ACT Chief Scientist and Quality Manager.

Data Handling Audits

ACT's Quality Manager audited approximately 10% of the data acquired during the verification test. The data were traced from the initial acquisition, through reduction and statistical analysis, to final reporting, to ensure the integrity of the reported results. All calculations performed on the data undergoing the audit were checked during the technical review process.
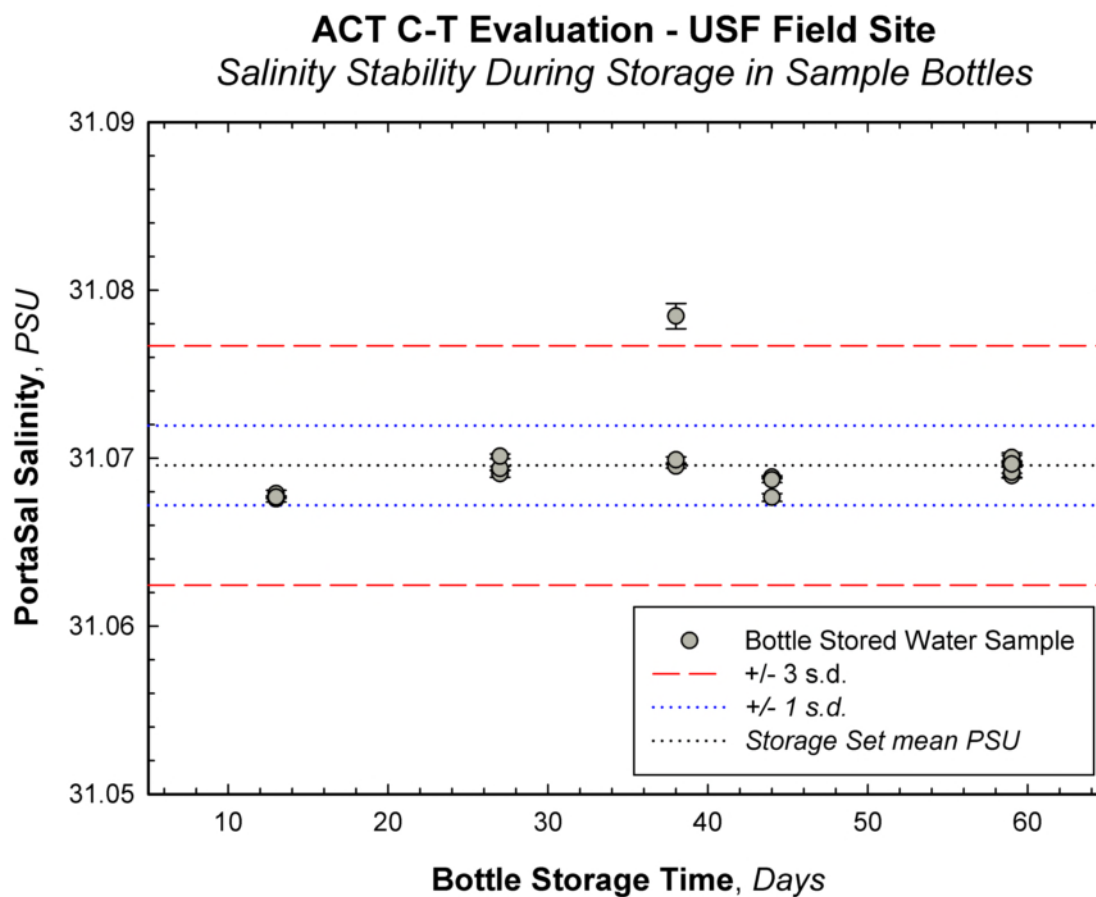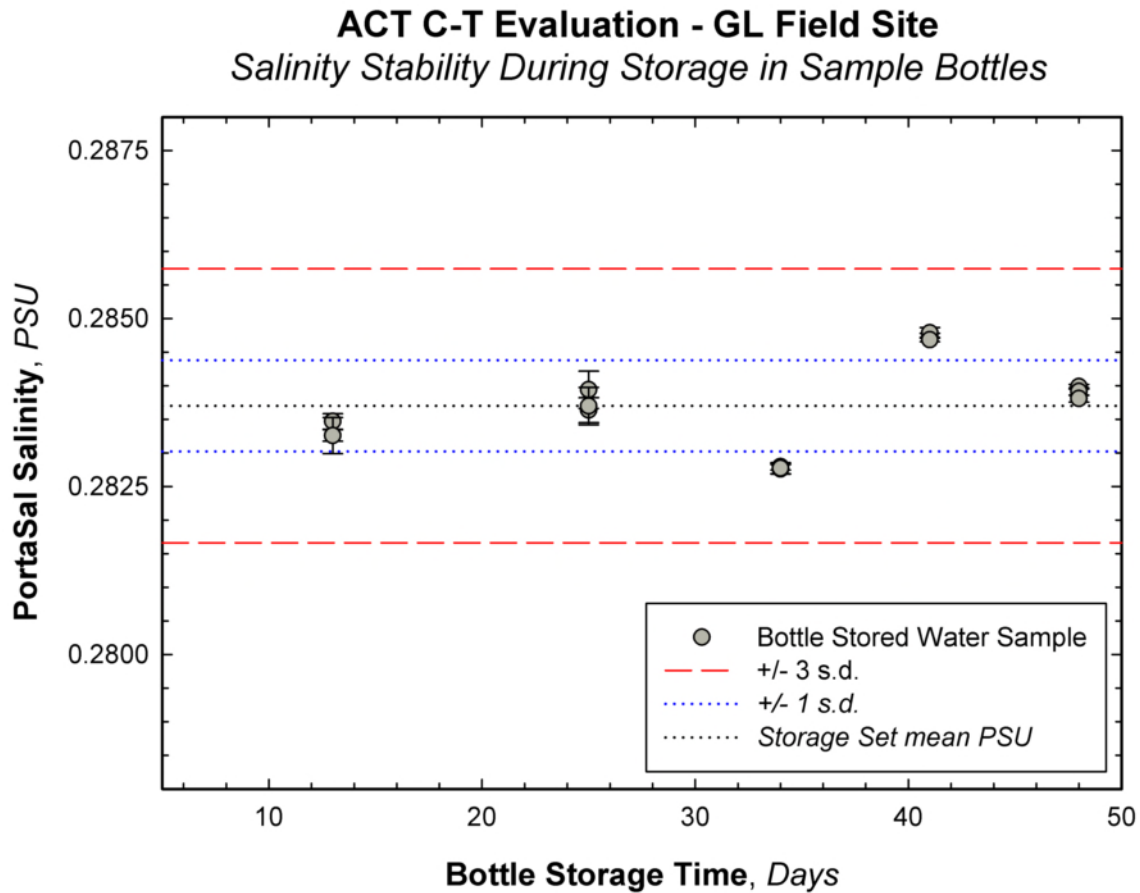
Figure 37. Assessment of drift in laboratory salinity measures associated with sample storage in field reference sample bottles. Sample bottles filled from single batch of test site surface water and subsets included in each sample shipment to MLML. Storage time reflects total time (days) since initial water collection.
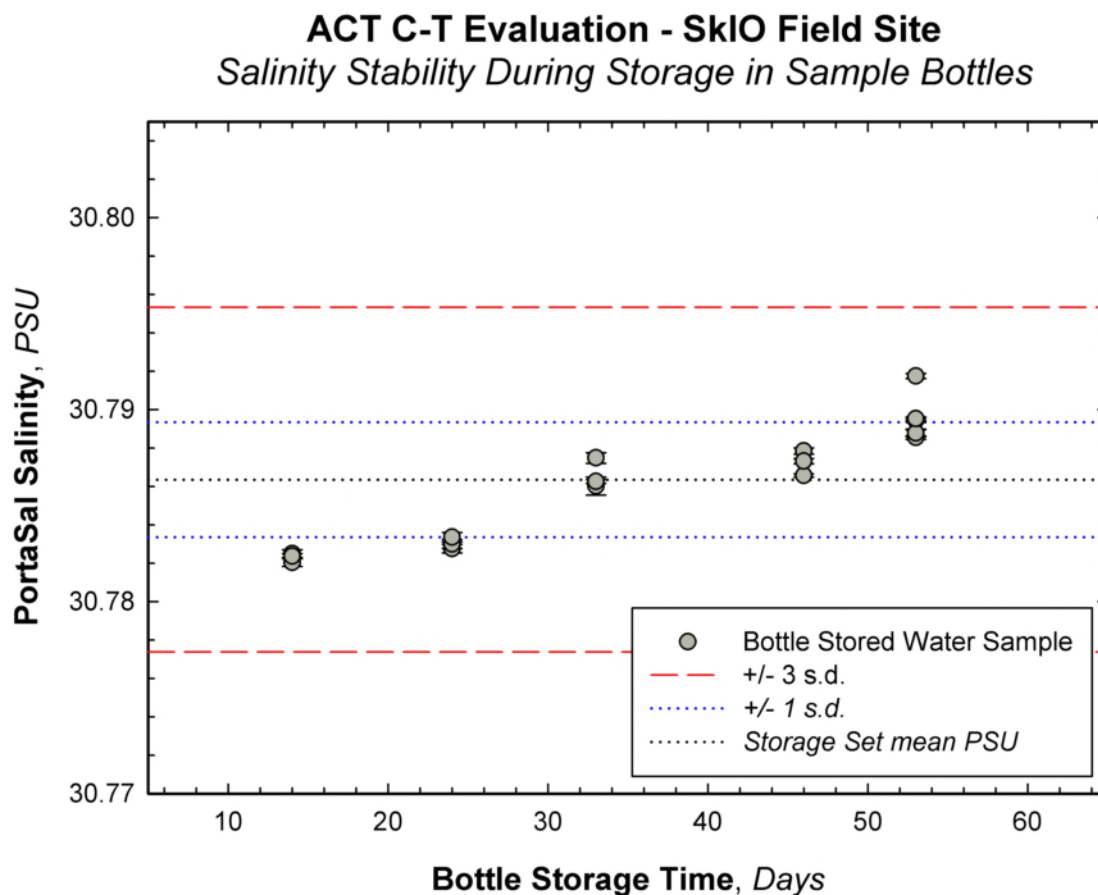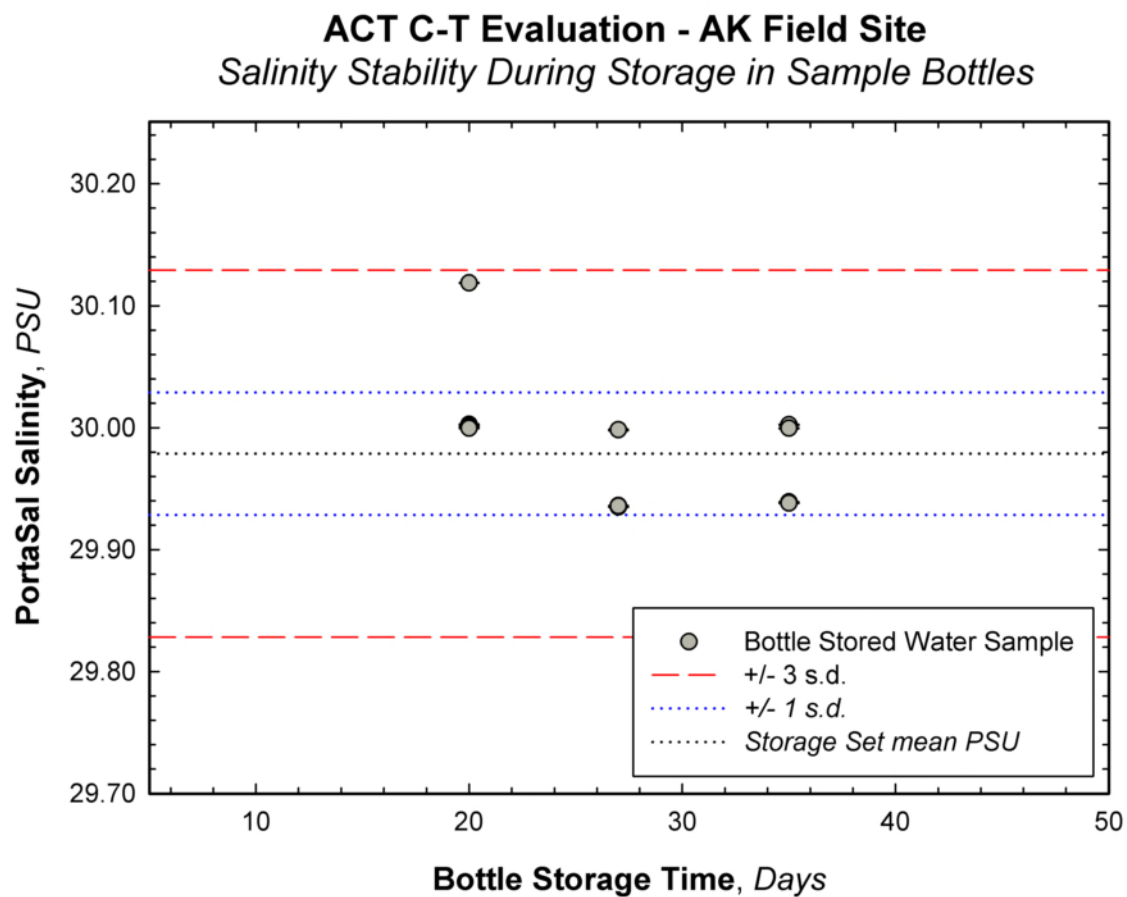
Figure 38. Assessment of drift in laboratory salinity measures associated with sample storage in field reference sample bottles. Sample bottles filled from single batch of test site surface water and subsets included in each sample shipment to MLML. Storage time reflects total time (days) since initial water collection.
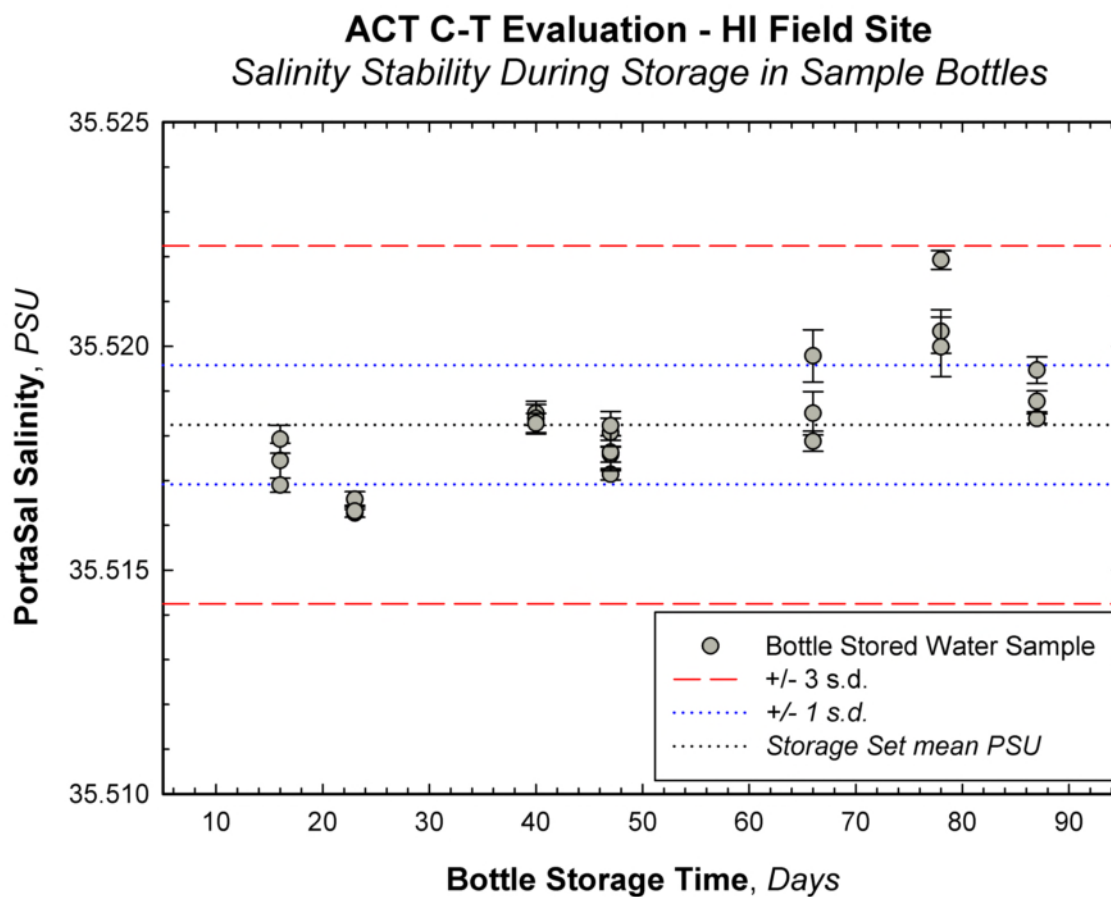
Figure 39. Assessment of drift in laboratory salinity measures associated with sample storage in field reference sample bottles. Sample bottles filled from single batch of test site surface water and subsets included in each sample shipment to MLML. Storage time reflects total time (days) since initial water collection.

ACT C-T Evaluation - GL Field Site
Salinity Stability During Storage in Sample Bottles

Figure 40. Assessment of drift in laboratory salinity measures associated with sample storage in field reference sample bottles. Sample bottles filled from single batch of test site surface water and subsets included in each sample shipment to MLML. Storage time reflects total time (days) since initial water collection.

Figure 41. Assessment of drift in laboratory salinity measures associated with sample storage in field reference sample bottles. Sample bottles filled from single batch of test site surface water and subsets included in each sample shipment to MLML. Storage time reflects total time (days) since initial water collection.

ACKNOWLEDGMENTS:
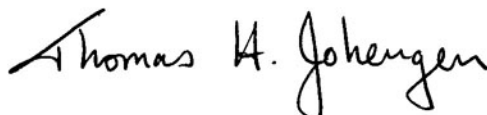
March 15, 2009
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Approved By: Dr. Mario Tamburri
ACT Executive Director
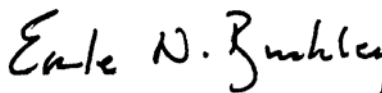
March 15, 2009
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Approved By: Dr. Tom Johengen
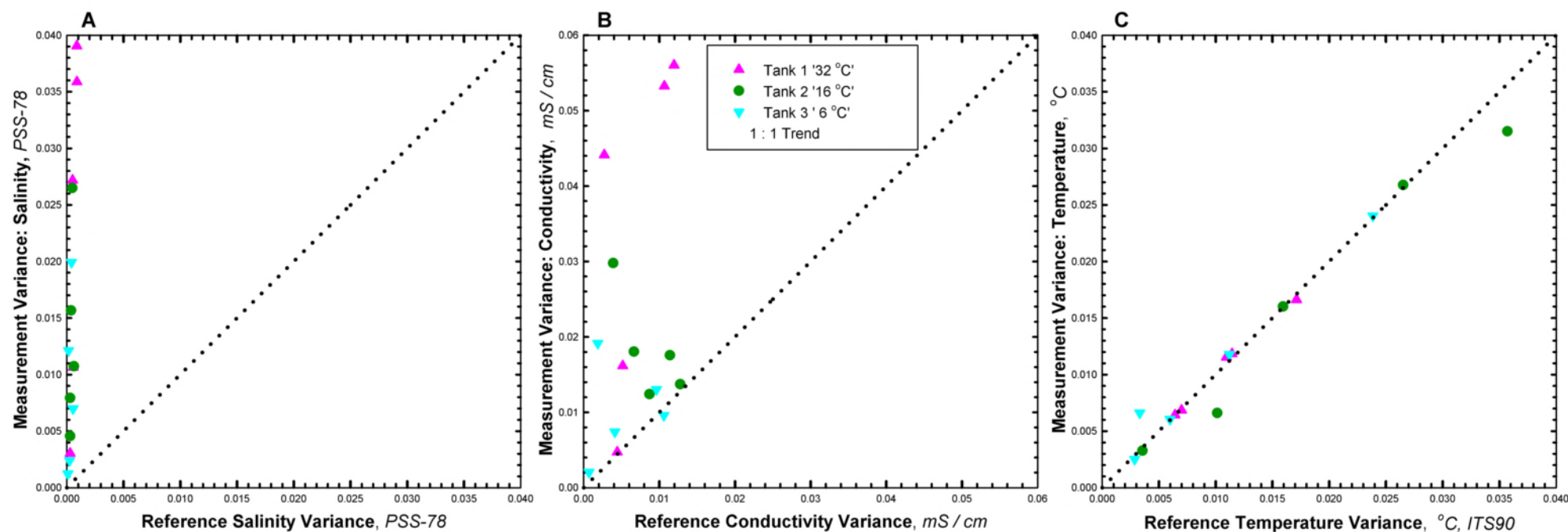**ACT Chief Scientist**

March 15, 2009
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  Date

Approved By: Dr. Earle Buckley
Quality Assurance Supervisor

APPENDIX 1

Alternative Presentation of Laboratory Test Results for Measurement of Instrument Variance Relative to Reference Sample Variance

Figure 4. Evaluation of measurement variation of In-Situ's Aqua Troll 200 conductivity and temperature sensor package achieved during the laboratory exposure trials plotted in **Fig. 3**. Instrument measurement variance is presented as the standard deviation from 30 consecutive instrument reads recorded during the 30 min reference sampling for each test exposure and plotted against the corresponding variation in the reference measure. The 1:1 correspondence line (dotted) is provided for comparison, with points below the line indicating lower and above higher-instrument measurement variation than obtained by our reference methods and test conditions. [*A*] Co-variation of derived salinity estimates; [*B*] Co-variation of in situ conductivity measurements; [*C*] Co-variation of instrument temperature measurements.

APPENDIX 2

Company Response Letter to Submitted Salinity Sensor Verification Report

March 17, 2009

Thomas Johengen, Ph.D.
Cooperative Institute for Limnology & Ecosystems Research
University of Michigan
4840 South State Rd
Ann Arbor, MI 48108

Dear Dr. Johengen,

Thank you for allowing us to participate in the Alliance for Coastal Technology (ACT) Salinity Sensor Performance Verification. We enjoyed working with you and your staff on this performance verification and appreciate your feedback on the Aqua TROLL® 200 instrument. We were pleased to see the strong linear performance of the instruments in both laboratory (R^2 >0.9999) and field conditions (R^2 = 0.995) over the first 14 days of deployment. We also agree with your conclusion that there was no strong evidence of calibration drift during the deployments, and that any offsets were due to either a calibration error or bubble entrainment. Additionally, all instruments performed as expected whereas the ACT team encountered no problems with the software, set-up functions, or data extraction; and that 100 percent of the data was recovered from all instruments. We would like to address certain points mentioned in the Verification Statement:

Fouling
During 2008, In-Situ Inc. developed and commercialized the TROLL® Shield antifouling system for use with the Aqua TROLL 200. This system was not available for the ACT evaluation. The TROLL Shield system includes a specially formulated copper alloy guard that protects the conductivity cell from fouling. During testing in high-fouling environments, instruments with the TROLL Shield system provided superior antifouling protection compared to instruments with copper tape (such as was used in the ACT study). In-Situ Inc. believes that instruments used in the ACT verification study would have benefited from the TROLL Shield antifouling system. It is surmised that biofouling would have been mitigated for 6 to 8 weeks beyond the systems used in the ACT study. Test data and a white paper on the TROLL Shield system are available upon request.

Temperature Affects on Conductivity
Conductivity offsets at higher temperatures were observed during testing at Moss Landing Marine Laboratories. Such offsets are common when measuring conductivity due to gas dissolution as solution temperatures increase. Gas bubbles can form inside the conductivity cell causing lower-than-expected conductivity readings. In addition, *Standard Methods for the Examination of Water and Wastewater* equations 2510 B and 2520 note other potential sources of error. These equations describe the temperature compensation used to convert actual conductivity values to specific conductivity and salinity. For the specific conductivity equation *Standard Methods* states, "The temperature coefficient of most waters is only approximately the same as that of standard KCl [potassium chloride] solution; the more the temperature of measurement deviates from 25.0˚C, the greater the uncertainty in applying the temperature correction."

Offsets
In-Situ Inc. agrees that the conductivity offsets seen at the Florida, Georgia, Hawaii, and Alaska sites may have been due to calibration errors or bubble entrainment in the conductivity cell. After the ACT evaluation, all instruments were returned to In-Situ Inc. These instruments were thoroughly cleaned, returned to factory settings, and checked for accuracy. Each instrument performed within stated factory accuracy specification of ±0.5% + 1 µS/cm (5-80,000 µS/cm), verifying these assumptions.

Any clock offsets observed during this evaluation fell within the accuracy specification of ±1 second/day drift.

If you have any questions or would like to request additional data, please contact me at (970) 498-1586.

Sincerely,

Cristina Windsor
In-Situ Inc., Technical Marketing Specialist