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UNITED STATES DEPARTMENT OF COMMERCE
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Office of Marine Pollution Assessment
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Contents

Abstract

A quality analysis of data collected on water sampling cruises in the New York Bight, 1973-1979, indicates that the data reported are generally good. The Inter-Ocean CSTD sensors showed improvement but were sometimes challenged by the considerable variability of this coastal environment. Other inaccurate data were the result of faulty equipment. Dissolved oxygen continues to be a difficult parameter to measure electronically.

1. Introduction

An investigation of the environmental systems of the New York Bight began in 1973 under the direction of the National Oceanic and Atmospheric Administration/Marine Ecosystems Analysis Program (NOAA/MESA). Hydrographic and chemical parameters were observed in a total of 35 water sampling cruises conducted by the Atlantic Oceanographic and Meteorological Laboratories (AOML) on NOAA Ships Ferrel, George B. Kelez, and Researcher. Four additional cruises were conducted in 1980 by the National Ocean Survey (NOS) (Table 1).

The primary instrument used aboard the Ferrel and Kelez was the Inter-Ocean Model 513-10 CSTD, with added sensors to measure turbidity, dissolved oxygen, pH, and Redox (Eh). The system monitored the sensors' functions during the cast as data were logged on magnetic tape, one set per second. The ship was equipped with bottles and a wet lab to collect and process water samples. The manufacturer's specifications on the sensors are as follows:

(a) Depth, 0 to 300 m, ± 1 m

(b) Temperature, -5° to 45°C, ± 0.02°C

(c) Conductivity, 0 to 65 m mhos, ± 0.05 m mhos

(d) Salinity, 0 to 40°/oo, ± 0.05°/oo

(e) Turbidity, 0 to 100%, ± 3% transmission

Table 1

Water Sampling Cruises in the New York Bight

Cruise	Dates	Ship
WCC-1	8/27/73 - 8/29/73	Ferrel
WCC-2	9/16/73 - 9/20/73	Ferrel
WCC-3	10/ 1/73 - 10/ 4/73	Ferrel
WCC-4	11/ 5/73 - 11/ 9/73	Ferrel
WCC-5	11/26/73 - 11/29/73	Ferrel
WCC-6	4/16/74 - 4/20/74	Ferrel
WCC-7	5/ 6/74 - 5/ 9/74	Ferrel
WCC-8	6/10/74 - 6/13/74	Ferrel
WCC-9	7/16/74 - 7/19/74	Ferrel
WCC-10	8/21/74 - 8/24/74	Ferrel
WCC-11	9/29/74 - 10/ 2/74	Ferrel
WCC-12	11/ 4/74 - 11/ 7/74	Ferrel
XWCC-2	2/22/75 - 3/ 5/75	Researcher
XWCC-3	4/ 9/75 - 4/12/75	Researcher
XWCC-4	5/ 5/75 - 5/ 9/75	Kelez
XWCC-5	6/ 9/75 - 6/14/75	Kelez
XWCC-6	9/29/75 - 10/ 4/75	Kelez
XWCC-7	12/ 3/75 - 12/ 8/75	Kelez
XWCC-8	4/12/76 - 4/16/76	Kelez
XWCC-9	5/17/76 - 5/23/76	Kelez
XWCC-10	6/28/76 - 7/ 1/76	Kelez
XWCC-11	9/12/76 - 9/17/76	Researcher
XWCC-12	4/28/77 - 5/ 6/77	Kelez
XWCC-13	5/31/77 - 6/ 7/77	Kelez
XWCC-14	6/27/77 - 7/ 1/77	Kelez
XWCC-15	8/ 1/77 - 8/ 9/77	Kelez
XWCC-16	10/11/77 - 10/19/77	Kelez
XWCC-17	4/10/78 - 4/18/78	Kelez
XWCC-18	5/30/78 - 6/ 9/78	Kelez
XWCC-19	7/ 5/78 - 7/15/78	Kelez
XWCC-20	7/31/78 - 8/ 9/78	Kelez
XWCC-21	4/ 9/79 - 4/18/79	Kelez
XWCC-22	5/29/79 - 6/ 7/79	Kelez
XWCC-23	7/16/79 - 7/27/79	Kelez
XWCC-24	8/13/79 - 8/23/79	Kelez
WMC-1	4/21/80 - 4/26/80	Kelez
WMC-2	6/ 2/80 - 6/ 6/80	Kelez
WMC-3	7/14/80 - 7/18/80	Kelez
WMC-4	9/ 2/80 - 9/ 6/80	Kelez

(f) Dissolved oxygen, 0 to 20 ppm, ± 0.2 ppm

(g) pH, 2 to 12 pH, ± 0.1 pH

(h) Redox (Eh), -2 to +2 V, ± 5 mv

Time constants for most of the sensors are relatively short, varying between 10 and 400 ms. Exceptions are oxygen, which has a time constant of 10 s, and salinity, which has a time constant of 1.4 s, caused by the use of slow-response thermistors.

The sensor package was calibrated by the National Oceanographic Instrumentation Center (NOIC) in August 1973. Calibration checks and equipment repair were made between cruises.

After each cruise the recorded sensor data were processed and published in a series of reports. Reports were published by Charnell et al. (1976); Starr et al. (1976, 1977 a,b); Hazelworth and Darnell (1976); Kolitz et al. (1976 a,b); Hazelworth et al. (1977 a,b,c, 1978 a,b,c,d,e, 1981 a,b,c,d,e,f); and Hazelworth and Berberian (1981 a,b). All reported data have been sent to the National Oceanographic Data Center.

This report describes the experiences with the various sensors and summarizes the accuracy of the data collected.

2. Performance of Sensors

A. Depth

The depth sensor was checked in the field by lowering the Inter-Ocean CSTD to the bottom and checking the reported depth against a calibrated lead line. The reported depth was also checked against the ship's fathometer. The depth sensor was reliable and always reported the correct depth within manufacturer's specifications.

B. Redox (Eh)

The redox sensor was unreliable. Attempts to calibrate the recorded data were unsatisfactory. Redox data were reported during WCC 7 and 8 only. After the 1974 season, this sensor was replaced by a second dissolved oxygen sensor.

C. Turbidity

The turbidity sensor was operational and values were reported for each cruise. Before each cruise, the sensor was calibrated at 0 and 100 percent of transmission. No post cruise transmissivity correction factor was calculated. Accuracy of data is unknown.

D. Conductivity and Salinity

These sensors were operational throughout. Salinity was determined by two independent sensors. The conductivity and temperature sensor measurements were used to compute salinity values. Accuracy tests comparing the salinity sensor and the computed salinity values were run. These tests indicated that the computed salinity values were more accurate. No salinity sensor values were reported. The following salinity accuracy analysis refers to the computed salinity values.

E. pH

The pH sensor was not operational until WCC-5. pH was recorded and reported for cruises WCC-5 through WCC-12, and XWCC-4 through XWCC-16. These recorded data were processed by a standard method used for all sensors. The processing method and accuracy of the recorded pH data are included in several reports. After XWCC-16, questions arose as to the accuracy of the pH standard water measurements. It was decided to discontinue publishing these values. The pH sensor continued to be operational through XWCC-24. All published values are believed to be accurate within manufacturer's specifications.

F. Temperature

The temperature sensor performed reliably throughout all cruises. It was always accurate within manufacturer's specifications. A detailed accuracy analysis follows in another section.

G. Dissolved Oxygen

Dissolved oxygen is a difficult parameter to measure electronically. Dissolved oxygen was measured and reported for WCC-5, and WCC-8 through WCC-10. Then it was not reported until XWCC-9, and continued to be reported through XWCC-24. More details on the accuracy are discussed later.

3. Sensor Accuracy Analysis

The calibration procedure for all the sensors was similar. For any calibration procedure there must be a standard. The data collected with the Inter-Ocean CSTD were calibrated by water samples collected simultaneously with a rosette sampler. Sampling at two depths provided an adequate standard. Protected reversing thermometers were attached to the Niskin water sample bottles. The salinity of the water samples was determined using a conductivity salinometer. Disolved oxygen was determined via the Winkler method. The reversing thermometers are accurate to $\pm 0.05^{o}C$, the salinometer to $\pm 0.02^{o}/oo$, and the Winkler oxygen to ± 0.02 ml/l.

A computer program was developed to compare all individual standard measurements within a cruise with corresponding uncalibrated electronic sensor values. The mean and standard deviation of the differences between the corresponding values were computed. Standard measurements with differences greater than two standard deviations from the mean were eliminated. The remaining measurements were used to compute a calibration formula. The calibration formula was a multiple linear equation that allowed for differences relating to change in depth and drift with time.

The standard deviation technique was designed as a quality control method to eliminate bad standard measurements. For example, some reversing thermometers were found to be of poor quality, resulting in a large number of inaccurate readings. During three cruises in 1980, duplicate Winkler oxygen measurements were made (Table 2). The mean differences between the two samples is within 0.01 ml/l of the accepted accuracy, ±0.02 ml/l, for all three cruises. A large root mean square (RMS) value for WMC-3, however, indicates some variability in the differences. A closer inspection of the individual differences showed that most values were within accepted accuracy, with a few differences contributing to the high RMS.

After eliminating bad standard measurements and applying the calibration formula to the electronic sensor values, a new mean and standard deviation of the differences between the corrected electronic sensor values and the corresponding water sample values were computed for each cruise (Table 3). Some of the standard deviations are larger than those previously reported due to a larger sample used for the computations in the table. The table shows a yearly improvement in the accuracy of the sensors. For 1978, 1979, and 1980 the electronic temperature and salinity are as accurate as their non-electronic counterparts. The calibrated electronic oxygen values still are not as accurate as those determined by the Winkler method, but steady improvement is evident.

Table 2

Water Monitoring Cruises 1-3, 1980 - Duplicate Winkler Oxygen Values (ml/l)

Cruise	Station	Depth	Sample #1	Sample #2	(#1 - #2) W	RMS	Mean
WMC-1	205	53	6.55	6.48	.07		
	33	27	7.37	7.44	- .07		
	3	13	7.06	6.98	.08	.07	.03
WMC-2	1	1	7.10	7.09	- .01		
	131	9	7.46	7.44	.02		
	124	9	8.38	8.34	.04		
	34	9	6.91	6.87	.04		
	201	9	7.71	7.70	.01		
	202	53	6.08	6.05	.03		
	203	10	7.57	7.54	.03		
	15	17	6.80	6.81	- .01	.02	.02
WMC-3	1	1	4.99	4.98	.01		
	1	15	4.58	4.55	.03		
	7	20	4.27	4.29	- .02		
	13	35	3.94	3.85	.09		
	19	24	5.47	5.46	.01		
	25	30	5.06	4.97	.09		
	77	33	4.81	4.81	.00		
	33	62	4.78	4.77	.01		
	23	43	4.60	4.59	.01		
	17	23	3.99	3.97	.01		
	16	16	3.66	3.64	.02		
	21	17	4.52	4.52	.00		
	119	16	3.37	3.38	.01		
	129	15	3.54	3.54	.00		
	141	26	7.02	7.05	- .03		
	139	13	5.77	5.79	- .02		
	151	23	6.54	6.56	- .02		
	153	32	5.30	5.35	.05		
	133	42	5.36	5.35	.01		
	124	36	5.62	7.72	-2.10		
	37	70	6.42	4.50	1.92		
	82	42	5.06	5.06	.00		
	83	38	4.86	4.89	- .03		
	35	70	4.89	5.63	.73		
	27	31	4.46	4.47	- .01		
	28	40	4.50	4.48	.02		
	201	55	5.31	5.31	.00		
	70	46	5.76	5.75	.01	.19	.03

Table 3

Calibration Analysis By Cruise
Standard Deviation (STD) of the Mean Difference Between Corrected CTD and the Standard

		Temperature		Salinity		Oxygen #1		Oxygen #2	
Cruise	Year	STD	Average For Year	STD	Average For Year	STD	Average For Year	STD	Average For Year
XWCC-4	1975	.06		.04		No data			
XWCC-5	1975	.02		.05		No data			
XWCC-7	1975	.03	.04	.02	.04	No data			
XWCC-8	1976	.02		.02		No data			
XWCC-9	1976	.04		.06		.10			
XWCC-10	1976	.07	.04	.03	.04	.26	.18	.33	
XWCC-12	1977	.06		.07		.09			
XWCC-13	1977	.04		.04		.12			
XWCC-14	1977	.06		.05		.15			
XWCC-15	1977	.10		.03		.11			
XWCC-16	1977	.02	.06	.02	.04	.09	.12		
XWCC-17	1978	.02		.03		.07			
XWCC-18	1978	.02		.03		.07			
XWCC-19	1978	.03		.02		.06		.10	
XWCC-20	1978	.02	.02	.03	.03	.08	.07	.15	.13
XWCC-21	1979	.01		.01		.04		.08	
XWCC-22	1979	.01		.01		.10		.09	
XWCC-23	1979	.01		.01		.10		.10	
XWCC-24	1979	.03	.02	.06	.02	.07	.08	.10	.09
WMC-1	1980	.02		.02		.07		.06	
WMC-2	1980	.02		.04		.11		.09	
WMC-3	1980	.02	.02	.02	.03	.12	.10	.08	.08

Plots of electronic values versus standard values for the XWCC cruises on the *Kelez* are presented in Section 4 and further illustrate the validity of the data. Generally, the fit is tight and there are no systematic variations from cruise to cruise.

There are, however, as the table of standard deviations and plots point out, isolated cases of cruises characterized by large standard deviations. The large temperature standard deviation for XWCC-15 resulted from using poor quality reversing thermometers. The salinometer malfunctioned and resulted in a large salinity standard deviation for XWCC-24. The most pronounced variation in the standard deviation for dissolved oxygen occurred during XWCC-10 and is also evident in the scatter of the plot (Section 4, Fig. 7C). This large variation is a function of the electronic dissolved oxygen sensor and water conditions.

As mentioned before, the electronic dissolved oxygen sensor has shown improvement, but the standard deviations remain large. The oxygen sensor has a large time lag (a slow response time) and often fails to report true conditions of the water. The plots of the electronic data versus the Winkler oxygen values show scatter in most cruises. This scatter is larger during summer cruises because the sensor does not accurately describe the large vertical gradients of dissolved oxygen associated with strong stratification typical for the season. XWCC-10 (June-July 1976) was during a period of low dissolved oxygen, but the sensor values were not adequately indicative of the anoxic condition. Therefore, the dissolved oxygen values reported for XWCC-10 were in error. The Winkler oxygen values continue to be a more accurate indicator of true conditions and a good standard to use for the electronic sensor calibration.

Overall, the New York Bight cruise data are good. There are some questionable data, as stated previously, resulting sometimes from faulty equipment and sometimes from particularly challenging environmental conditions. Data users are cautioned to take these problems into account. Except in the case of dissolved oxygen, the reported electronic values are believed to be more reliable than individual bottle-sample results. Preponderately, the data meet standards of accuracy required for this highly variable coastal environment.

4. Figures

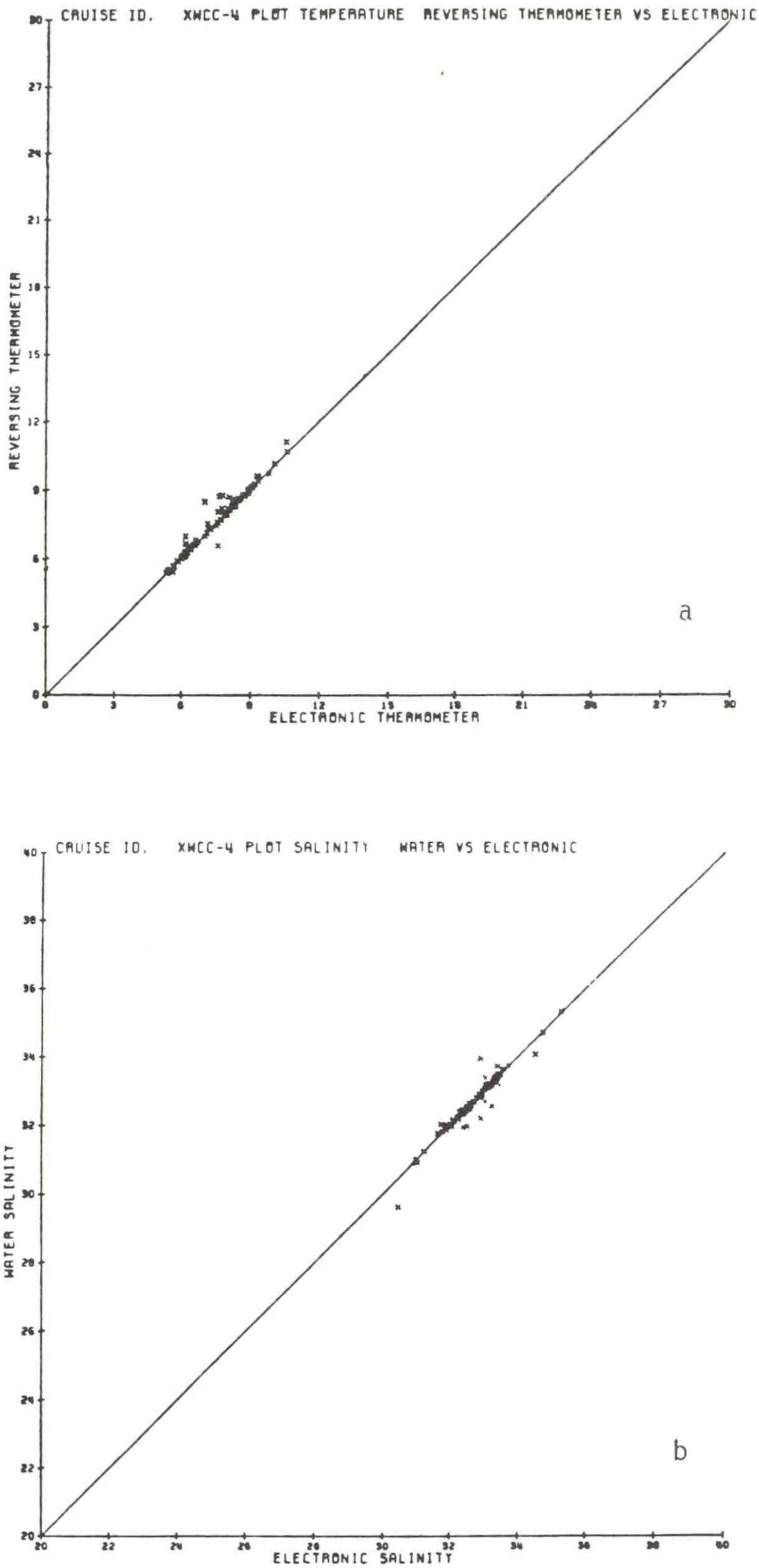


Figure 1 a,b: XWCC-4 standard temperature and salinity values versus corresponding electronic sensor data.

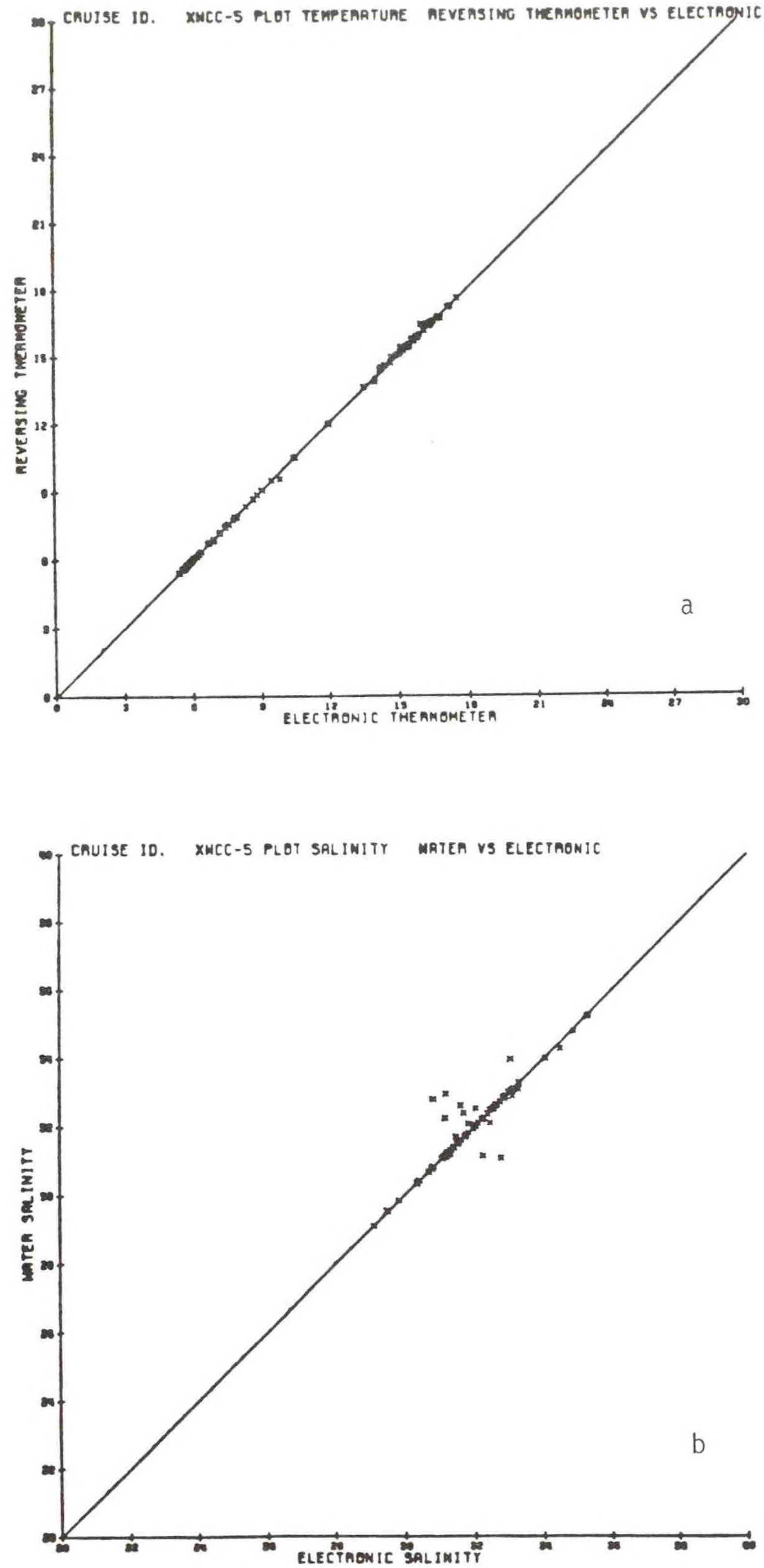


Figure 2 a,b: XWCC-5 standard temperature and salinity values versus corresponding electronic sensor data.

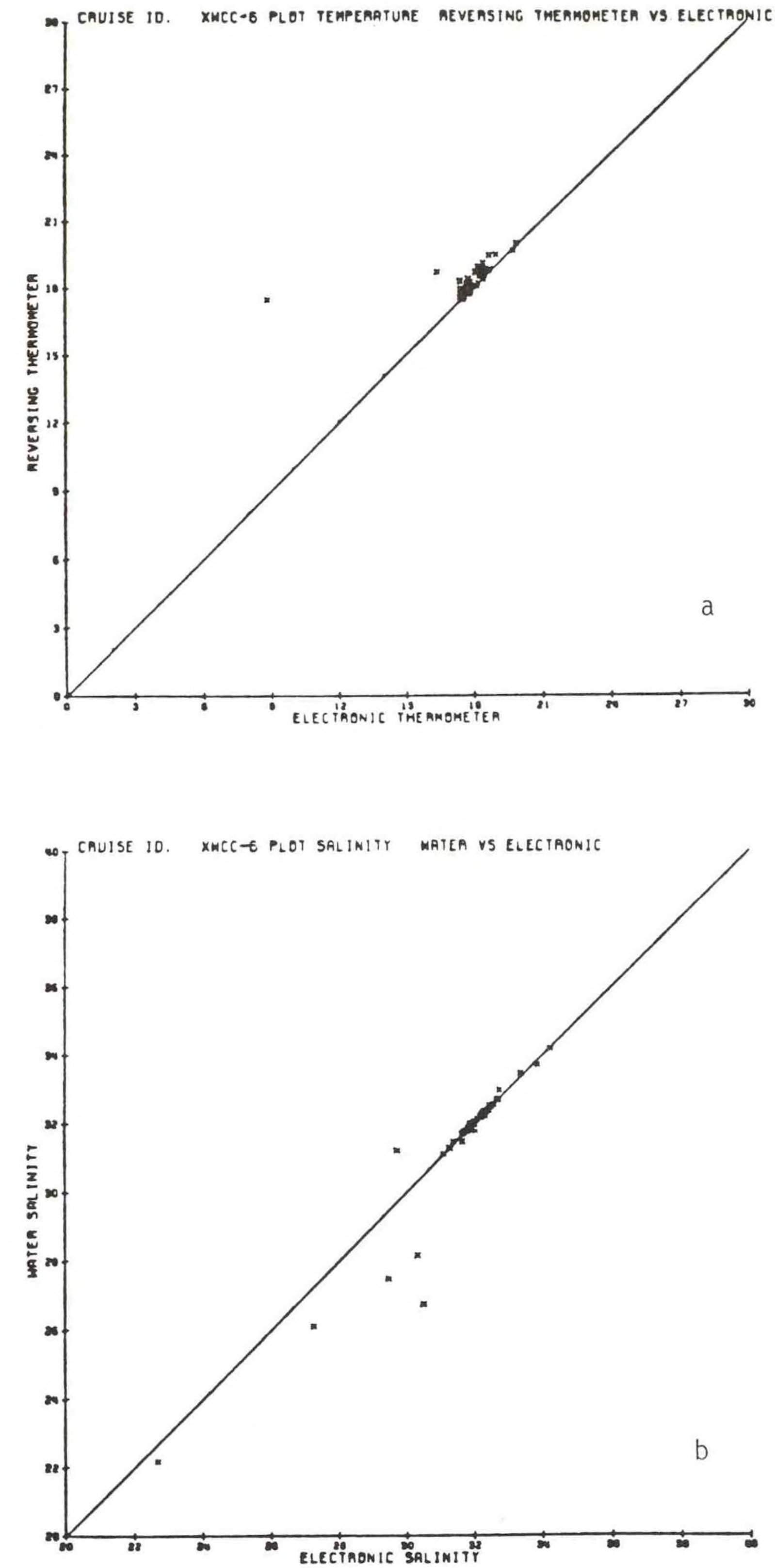
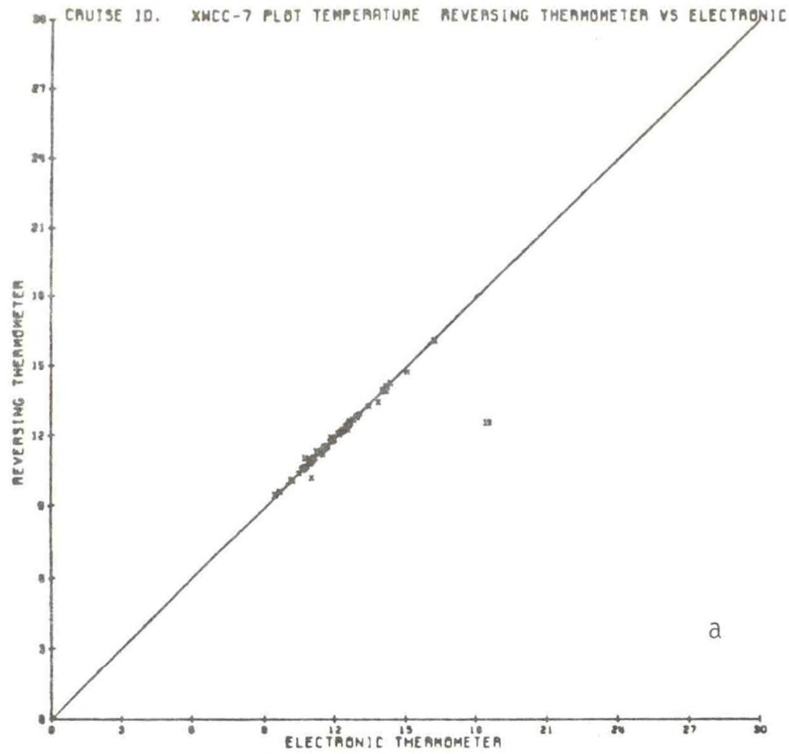


Figure 3 a,b: XWCC-6 standard temperature and salinity values versus corresponding electronic sensor data.



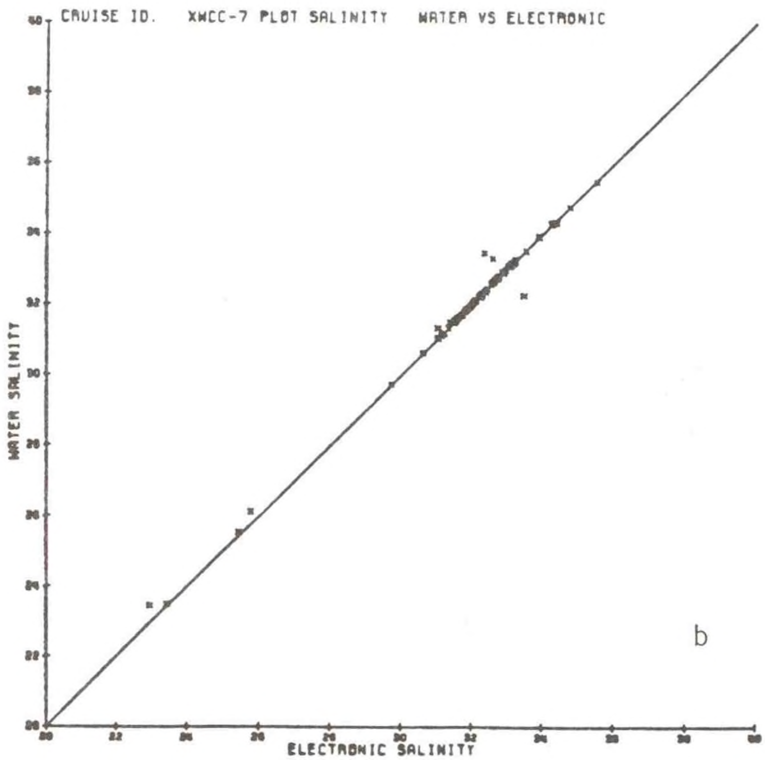
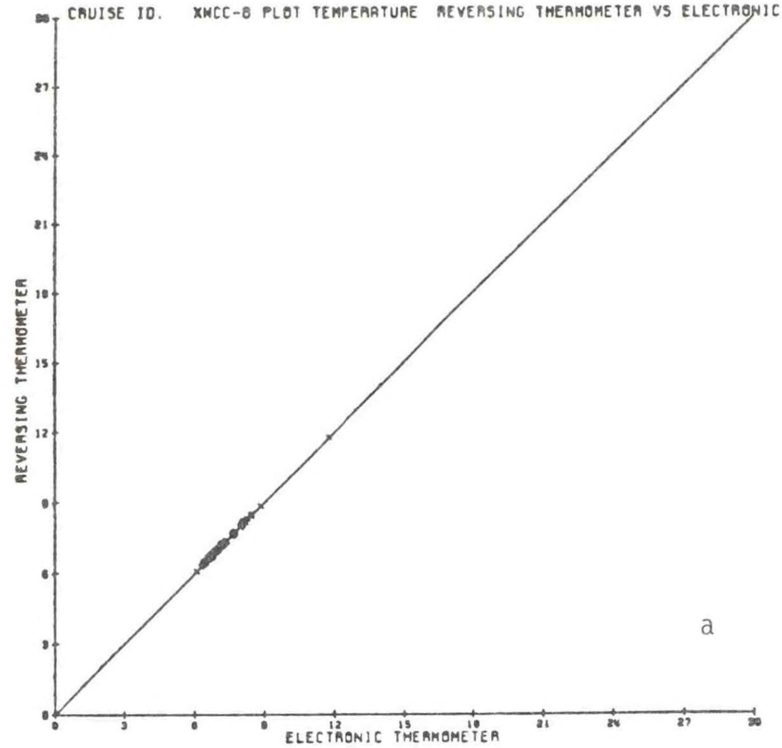


Figure 4 a,b: XWCC-7 standard temperature and salinity values versus corresponding electronic sensor data.



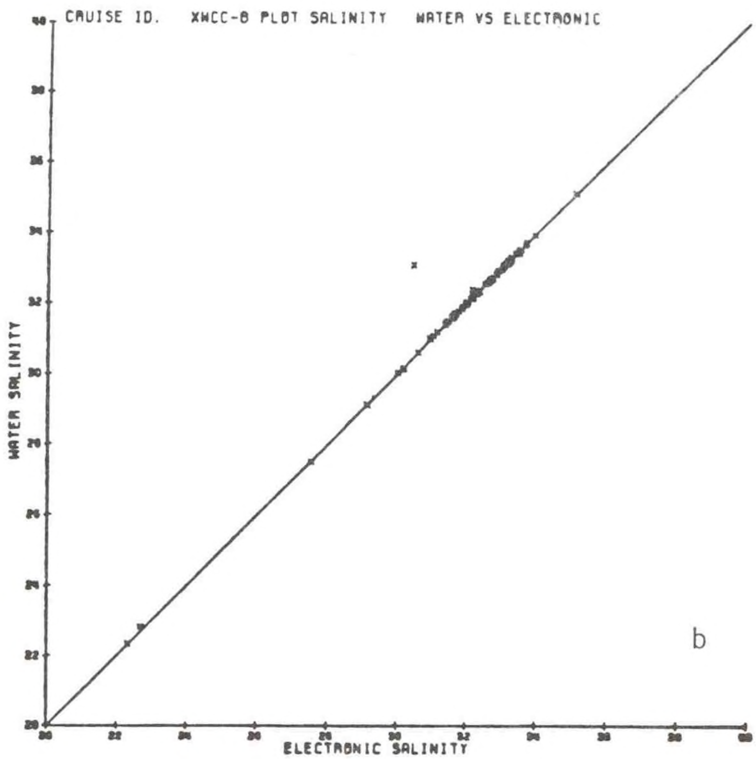


Figure 5 a,b: XWCC-8 standard temperature and salinity values versus corresponding electronic sensor data.

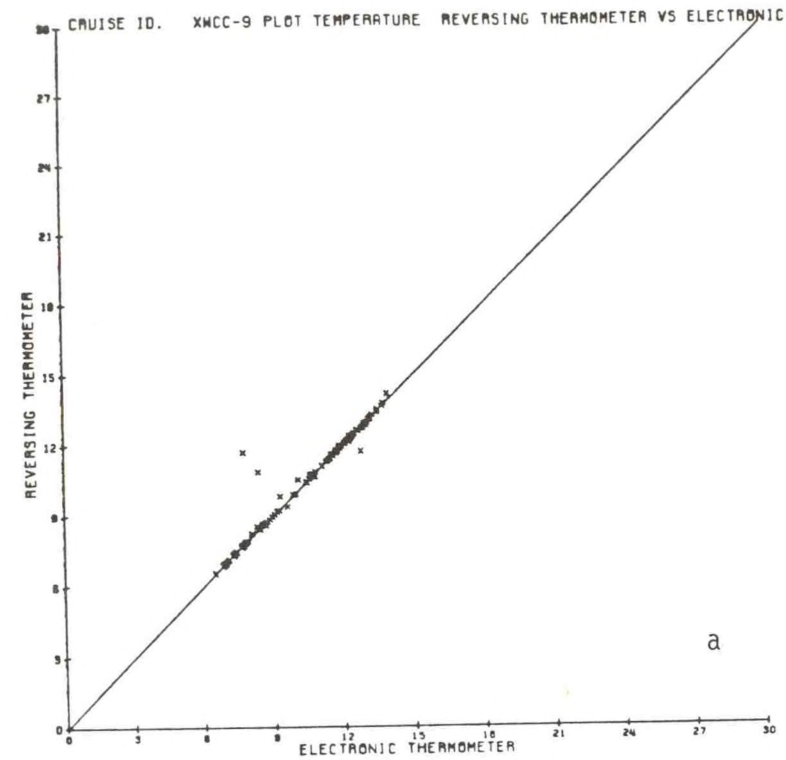
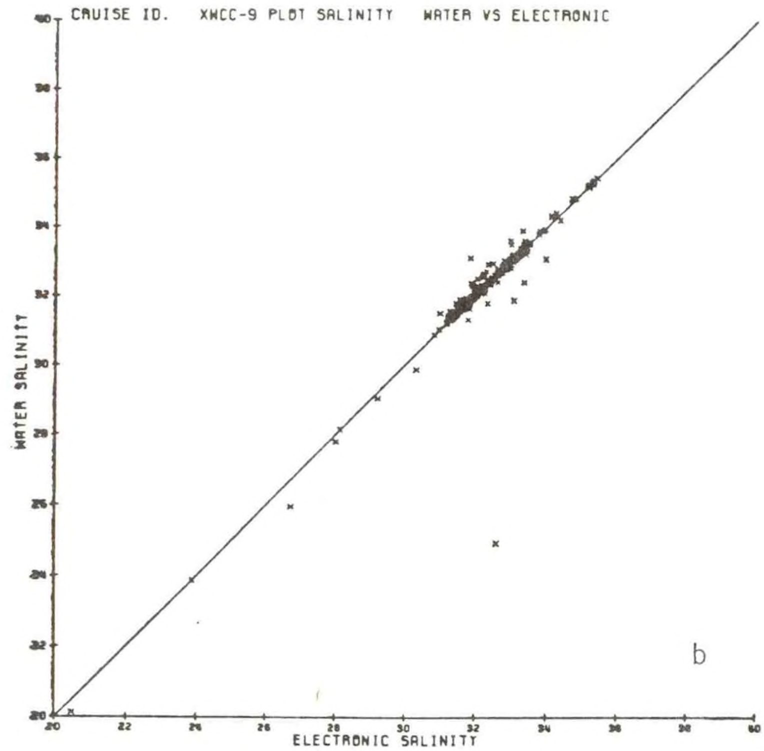


Figure 6 a,b,c: XWCC-9 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.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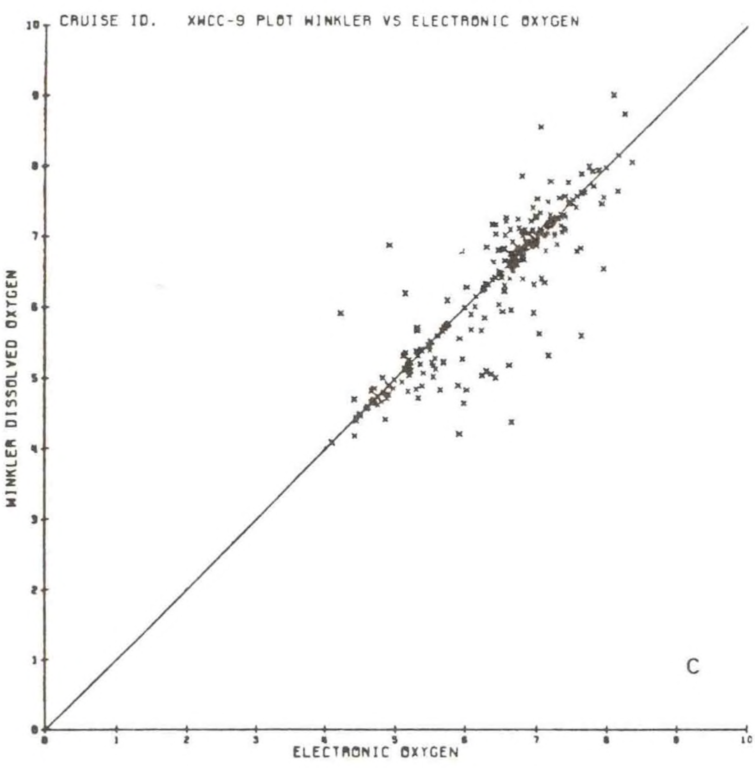
WATER SALINITY
ELECTRONIC SALINITY
b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WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

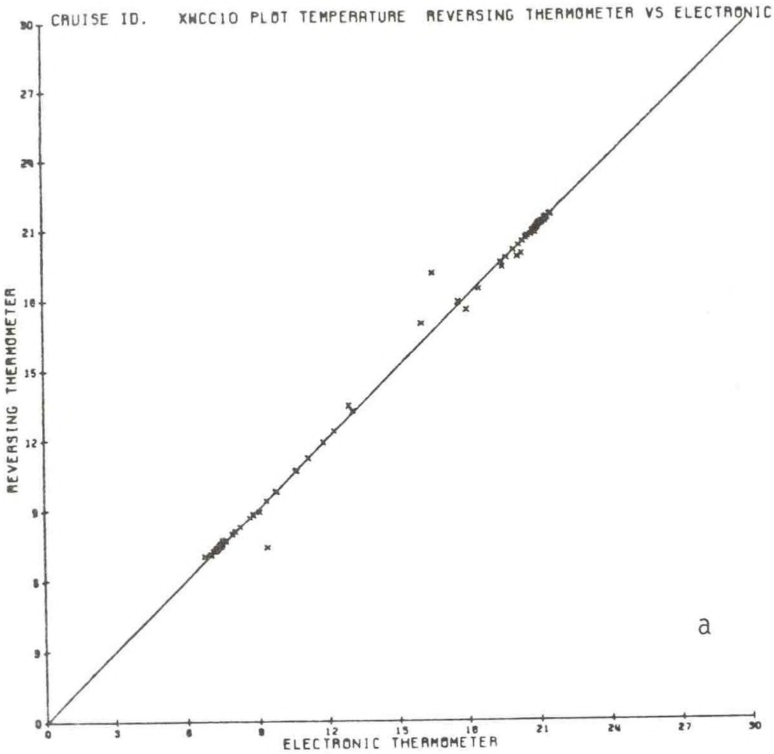
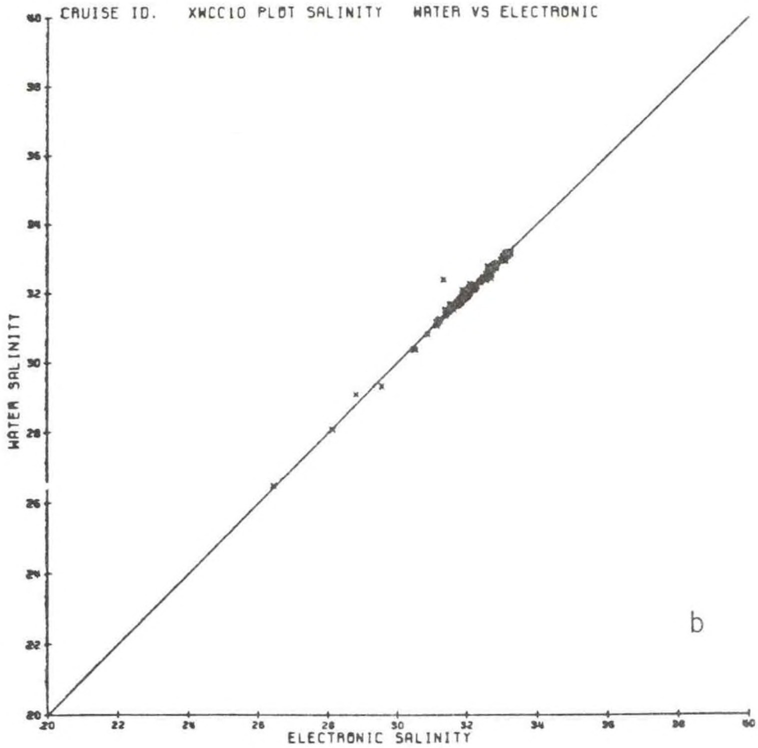


Figure 7 a,b,c: XWCC-10 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.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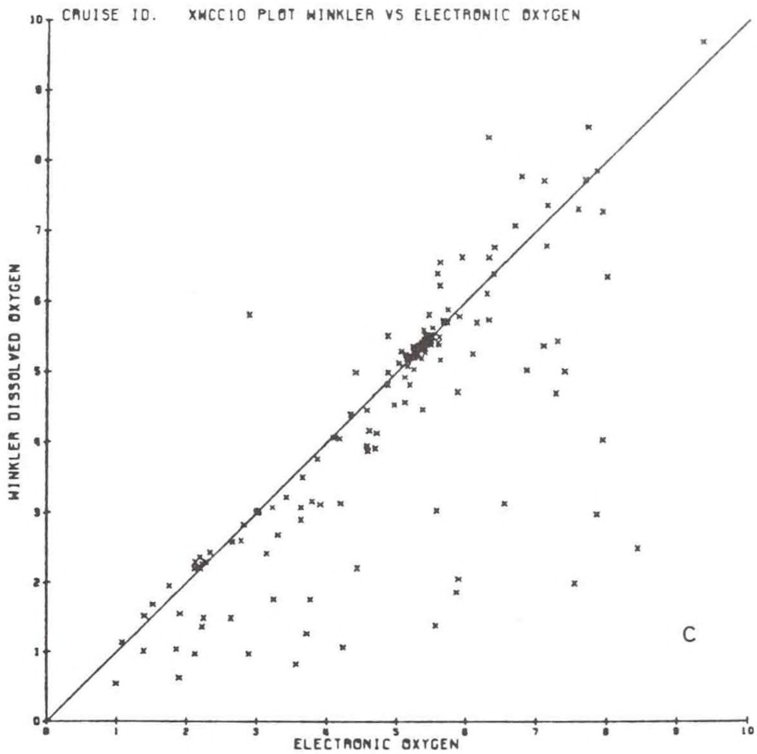
WATER SALINITY
ELECTRONIC SALINITY
b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WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

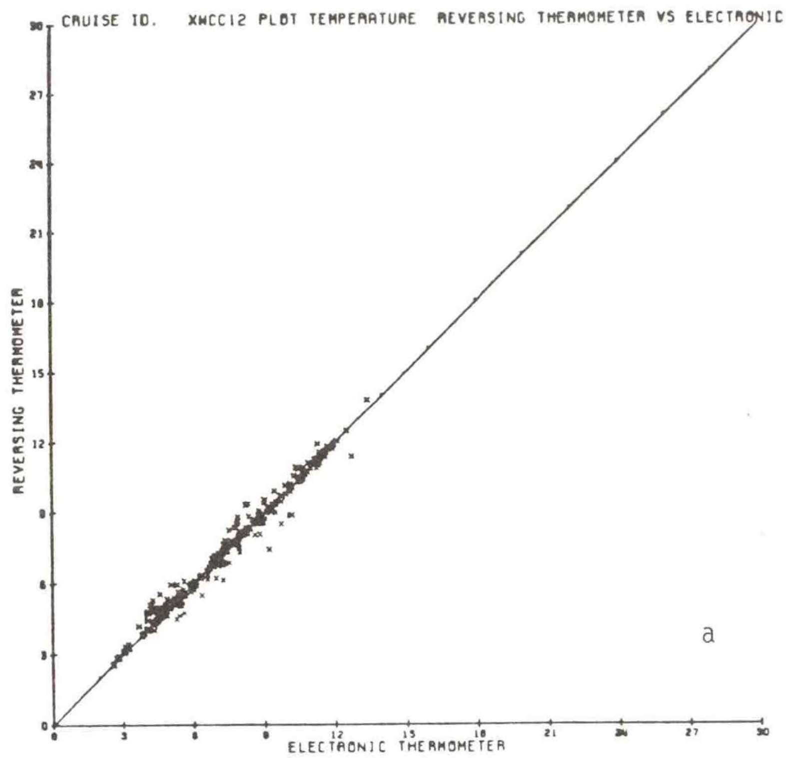
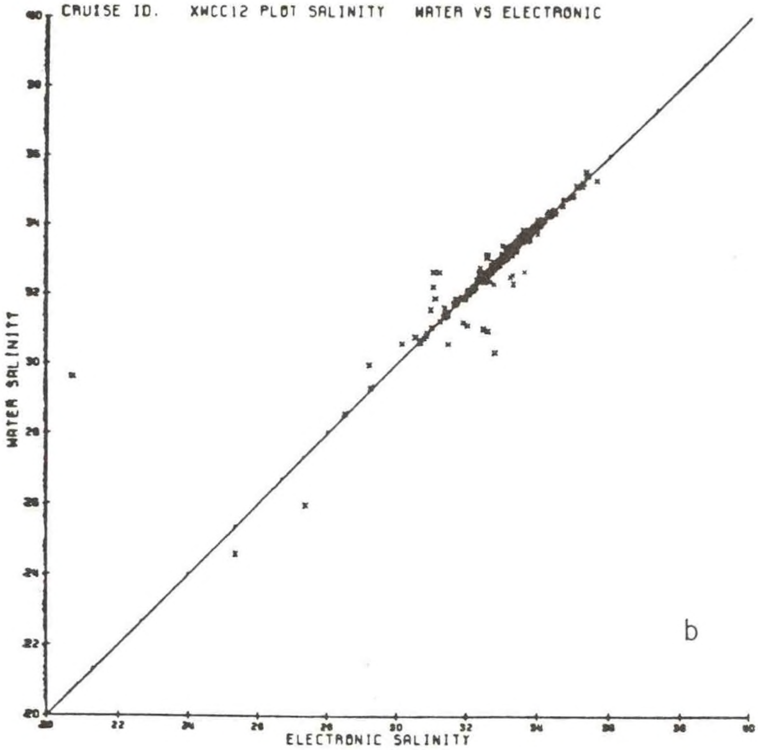


Figure 8 a,b,c: XWCC-12 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.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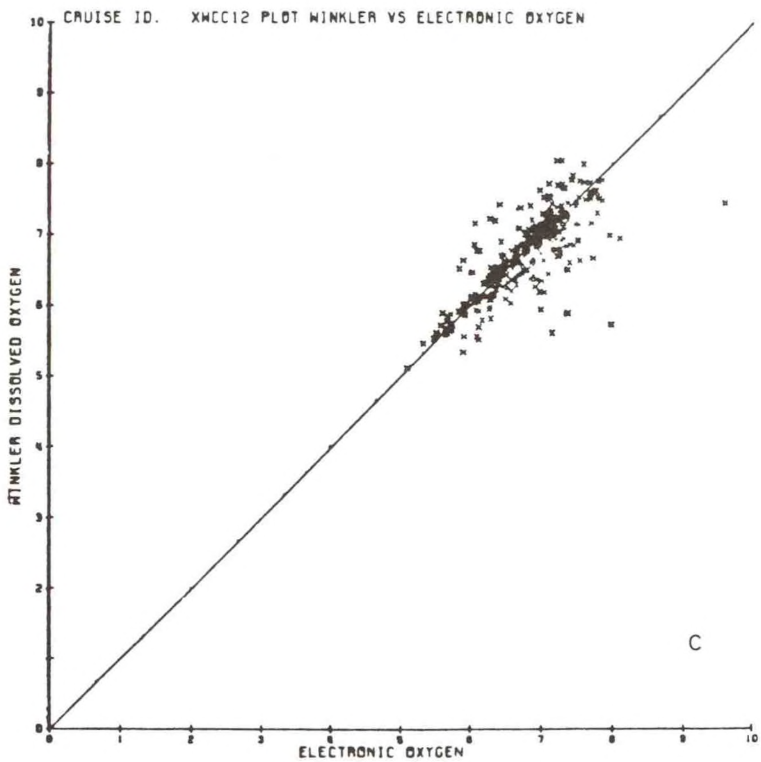
WATER SALINITY
ELECTRONIC SALINITY
b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WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

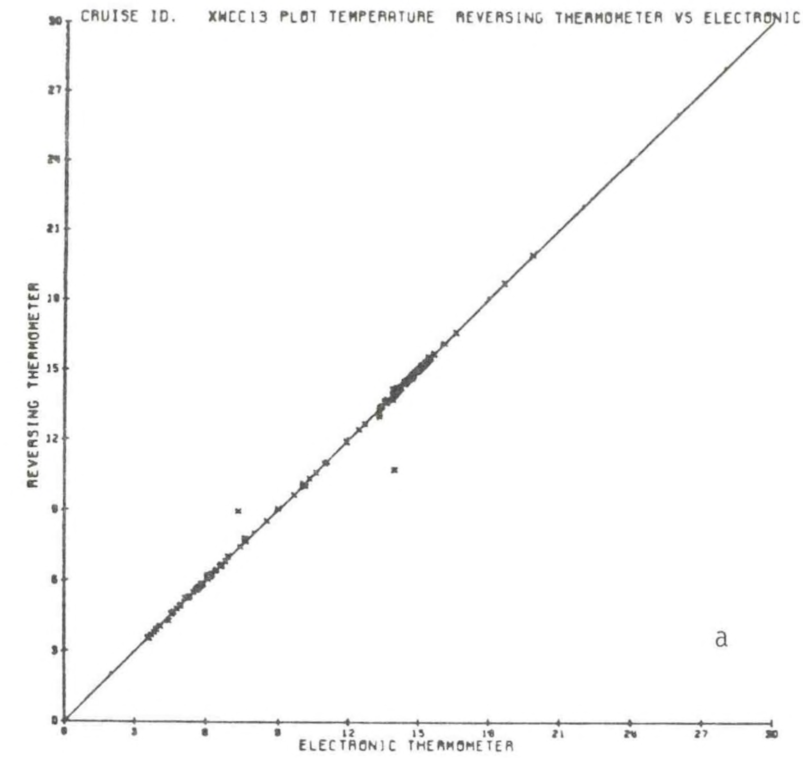
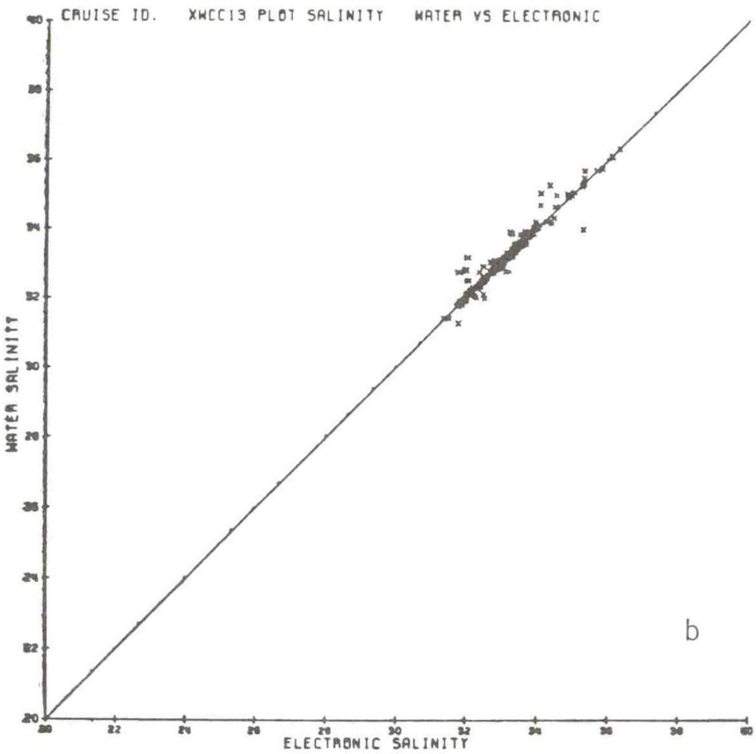


Figure 9 a,b,c: XWCC-13 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.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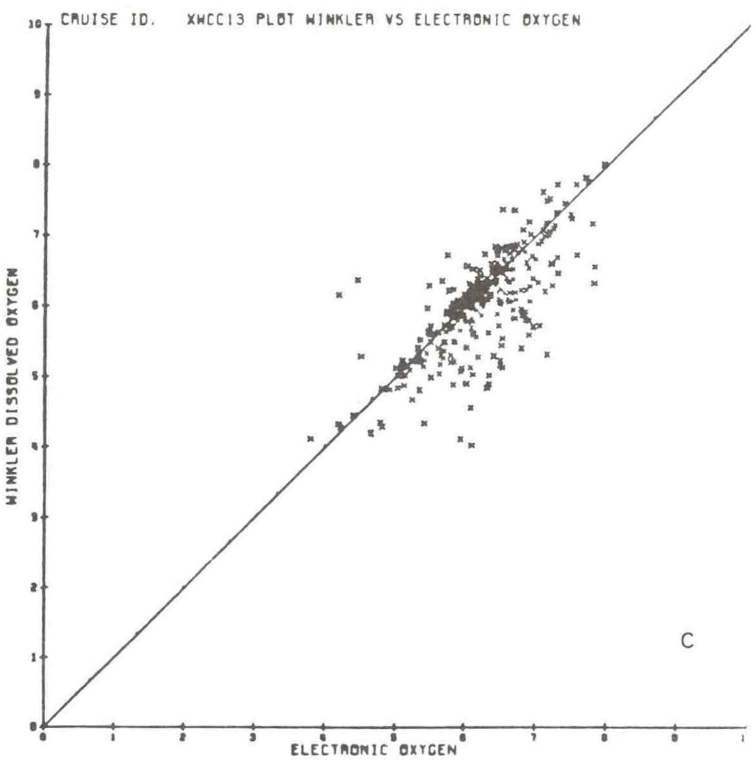
WATER SALINITY
ELECTRONIC SALINITY
b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WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

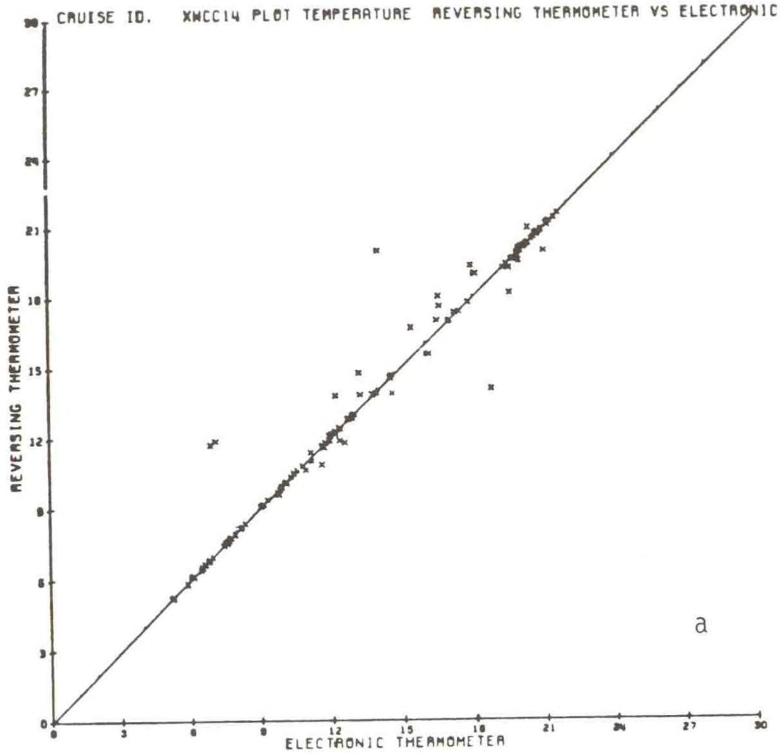
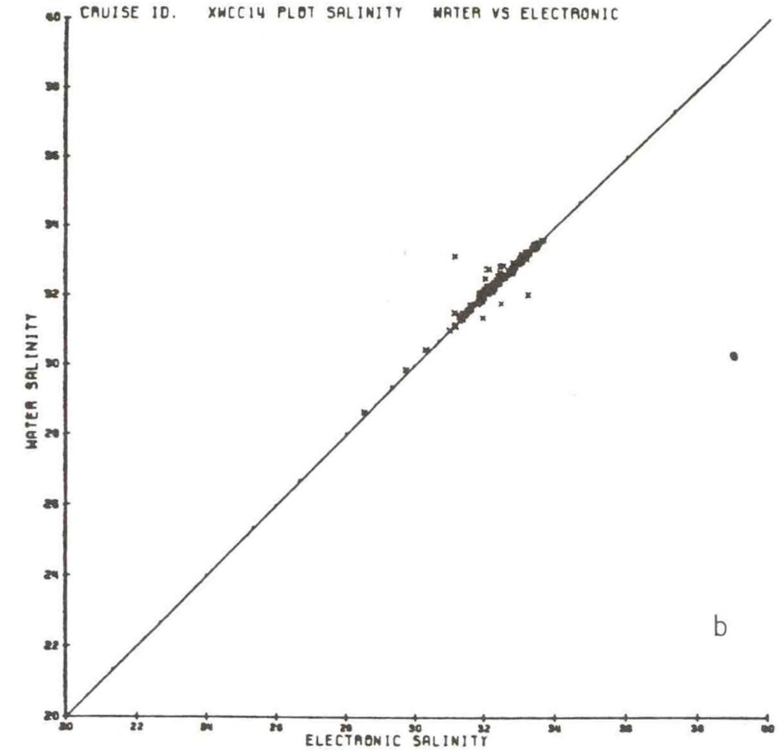


Figure 10 a,b,c: XWCC-14 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.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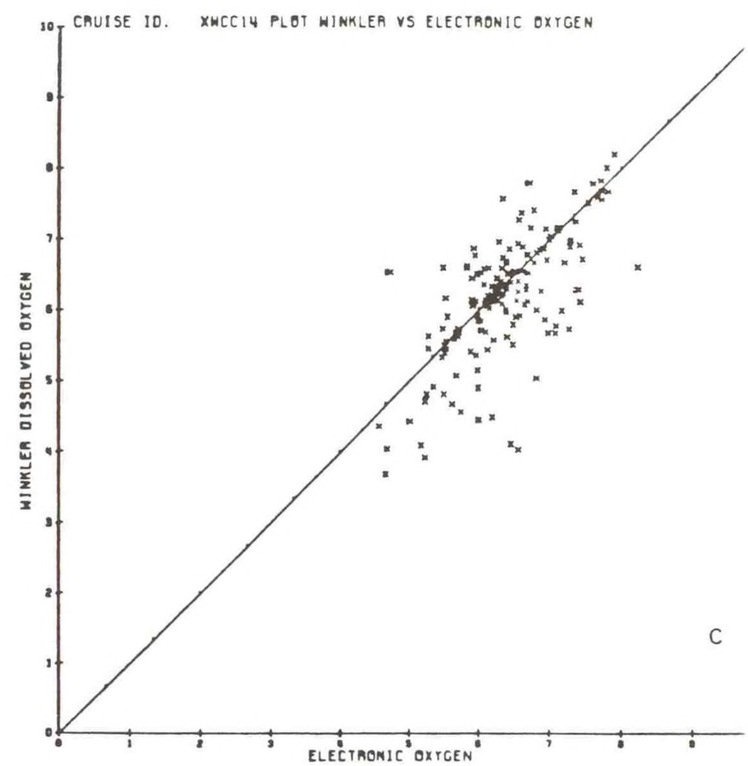
ELECTRONIC SALINITY
b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ELECTRONIC OXYGEN
c

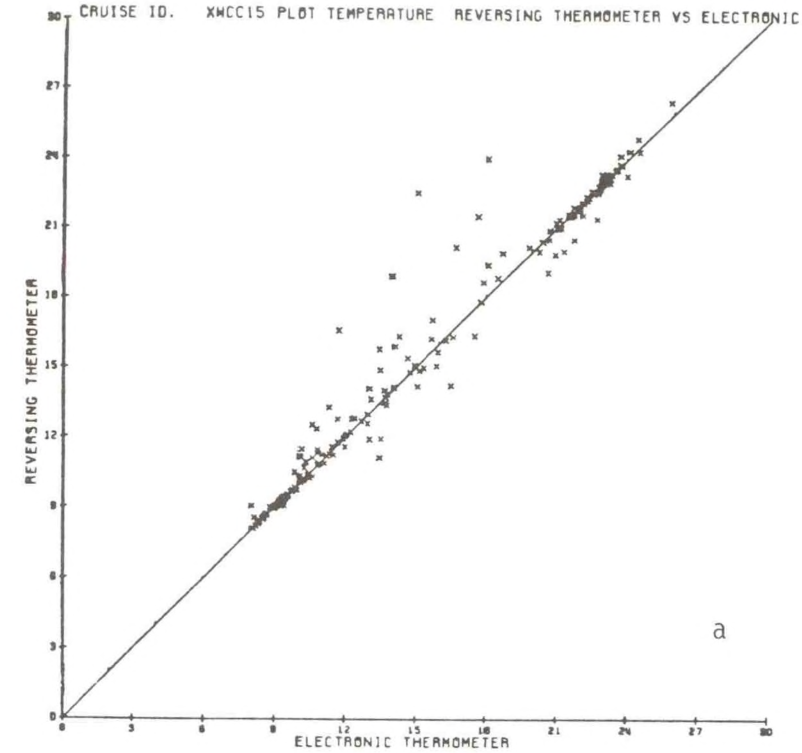
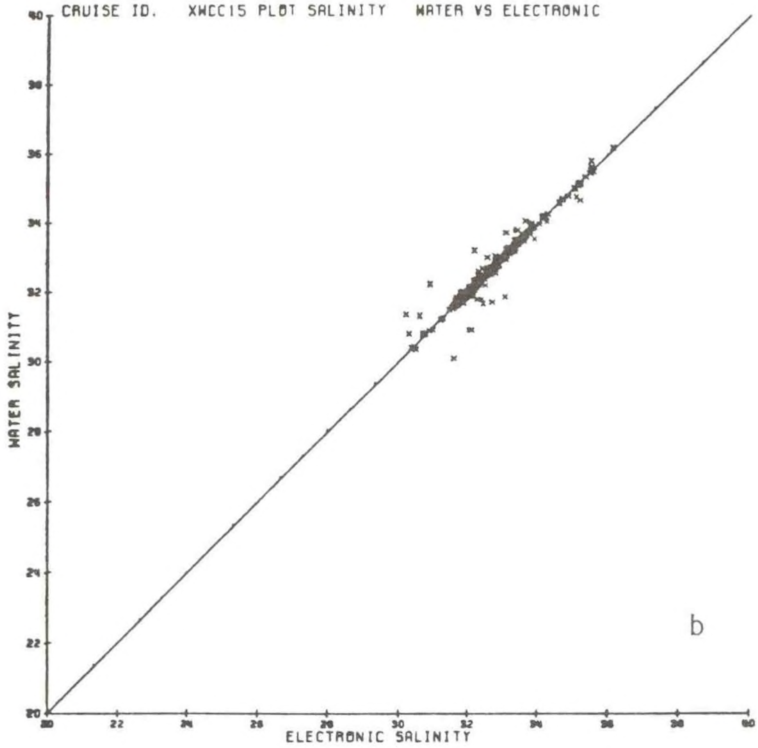
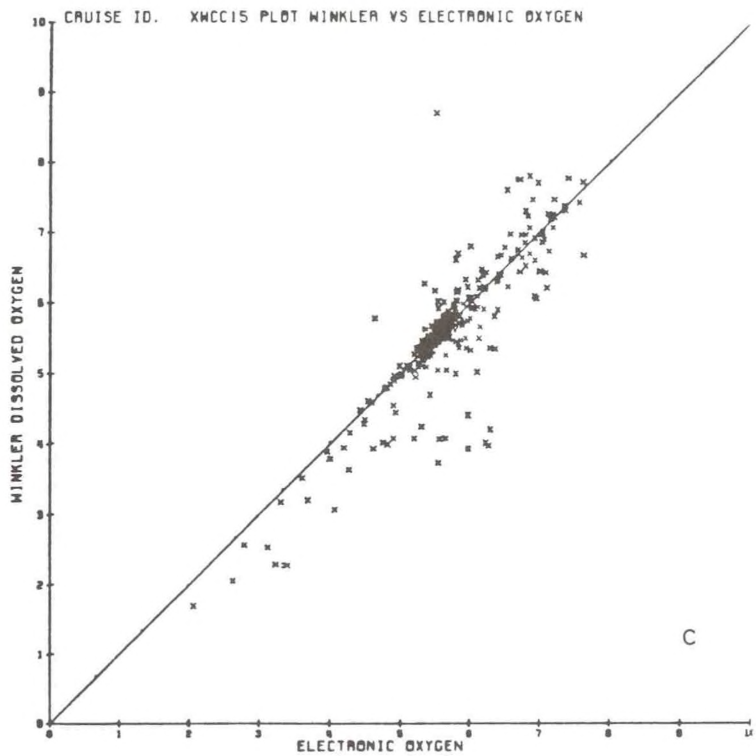


Figure 11 a,b,c: XWCC-15 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.


CRUISE ID. XWCC15 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b


CRUISE ID. XWCC15 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

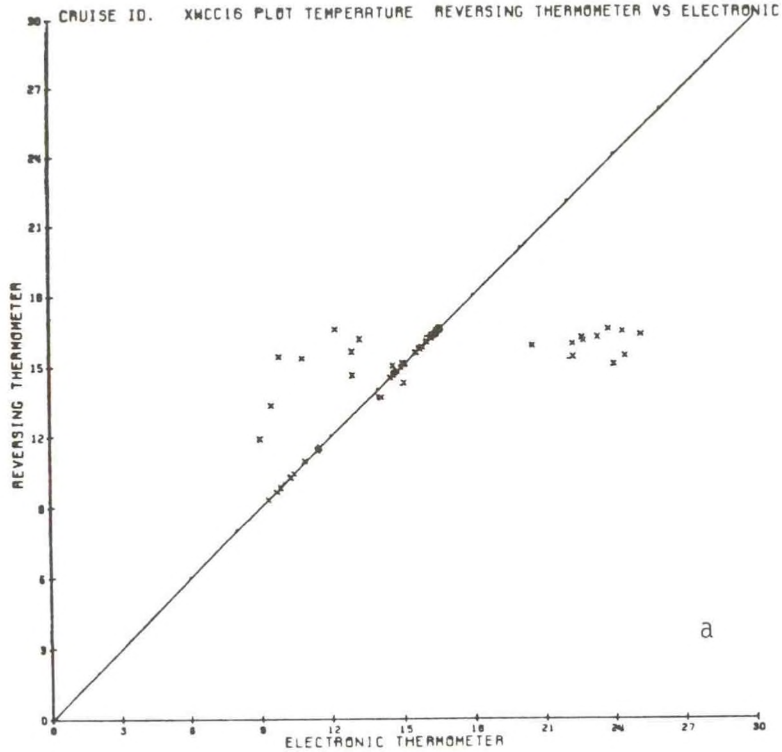
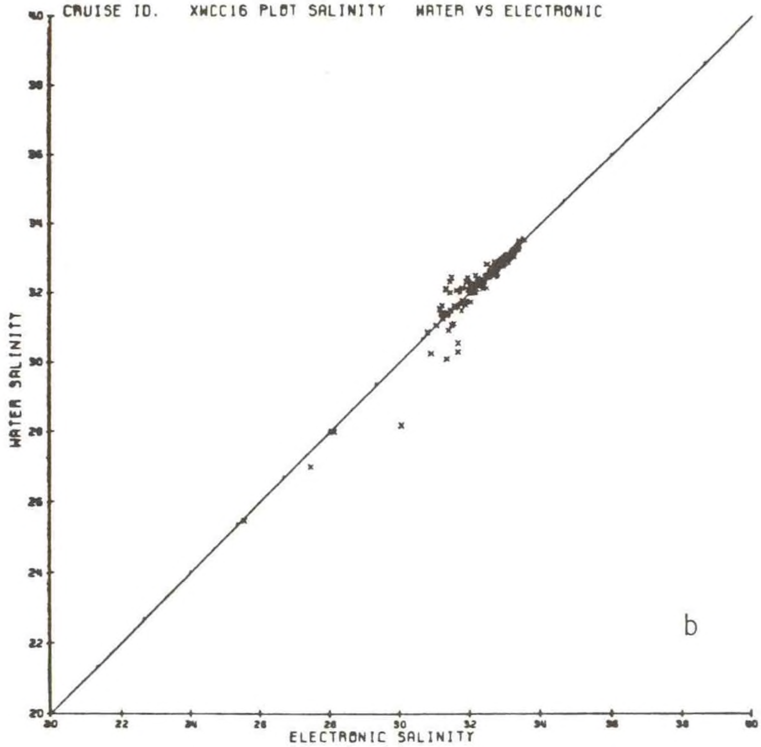
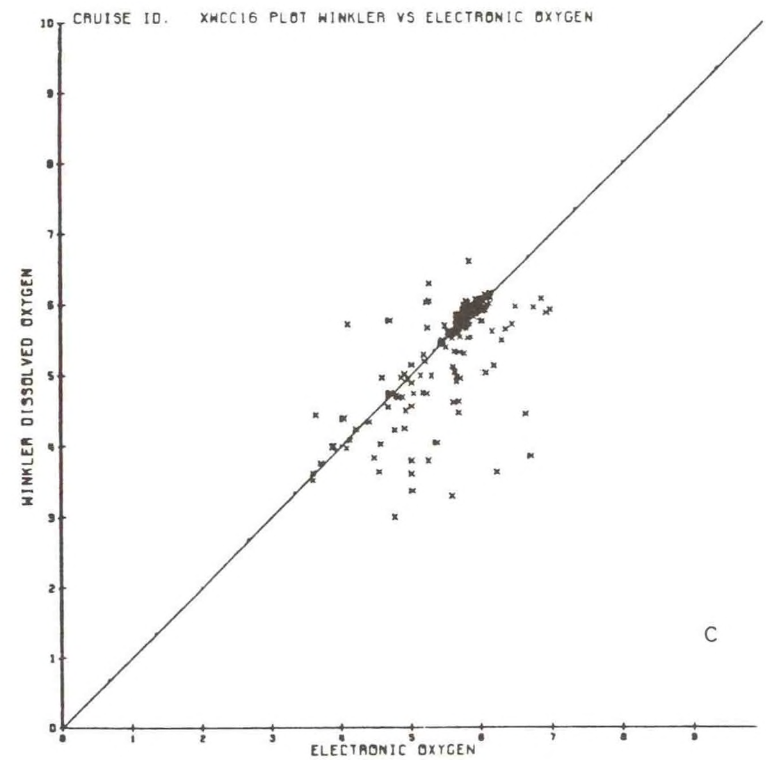


Figure 12 a,b,c: XWCC-16 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.


CRUISE ID. XWCC16 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b


CRUISE ID. XWCC16 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

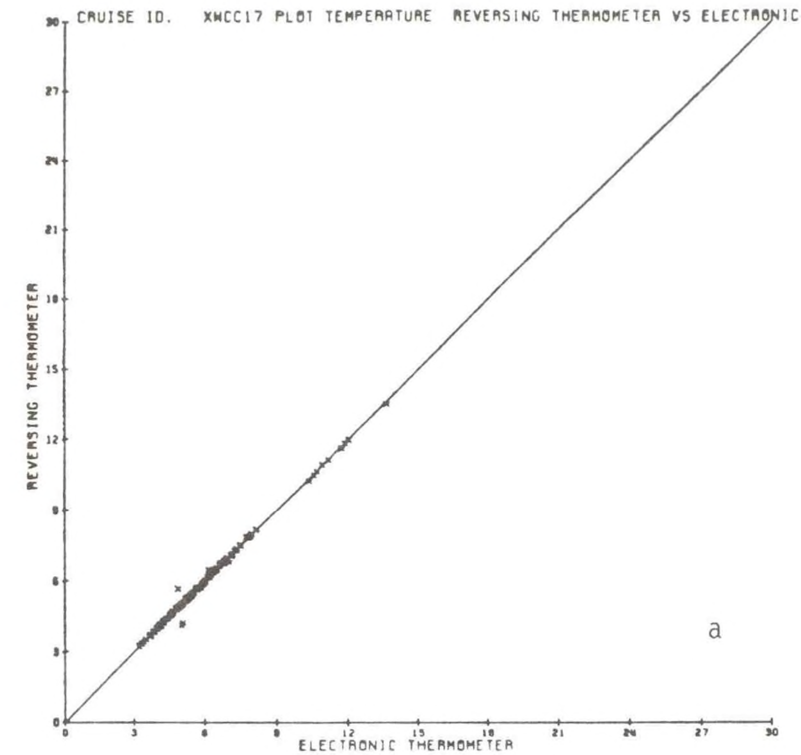
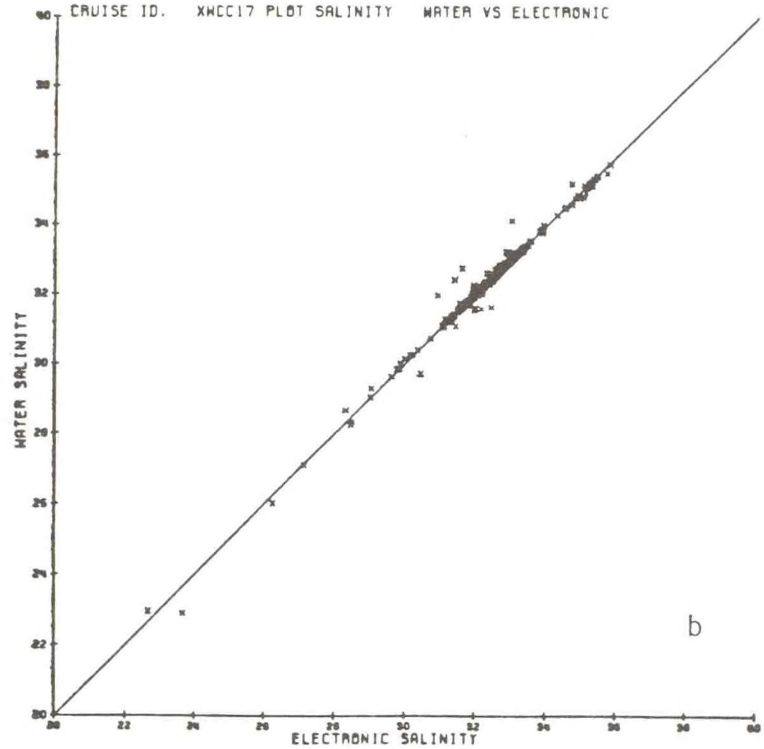
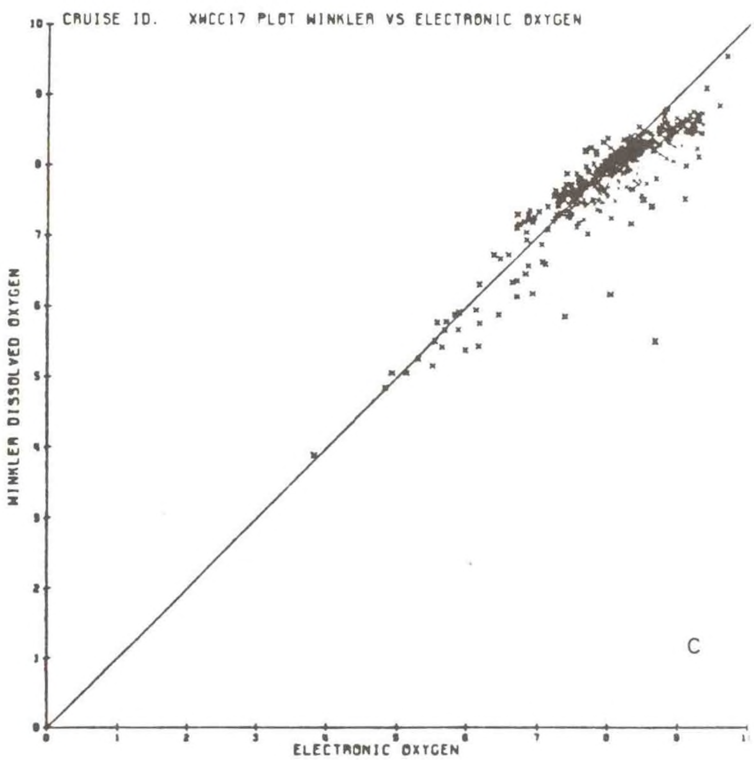


Figure 13 a,b,c: XWCC-17 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.


CRUISE ID. XWCC17 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b


CRUISE ID. XWCC17 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

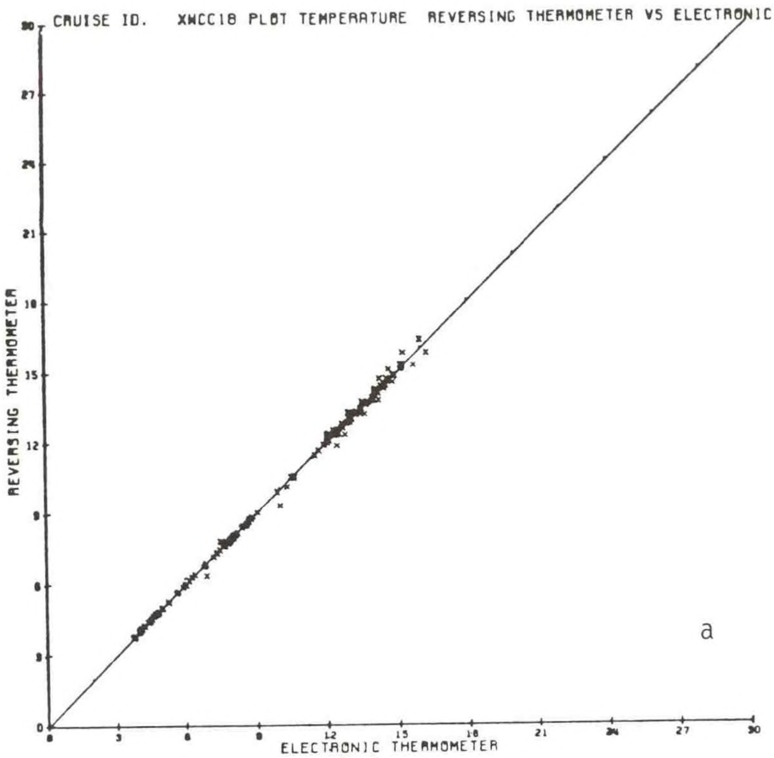
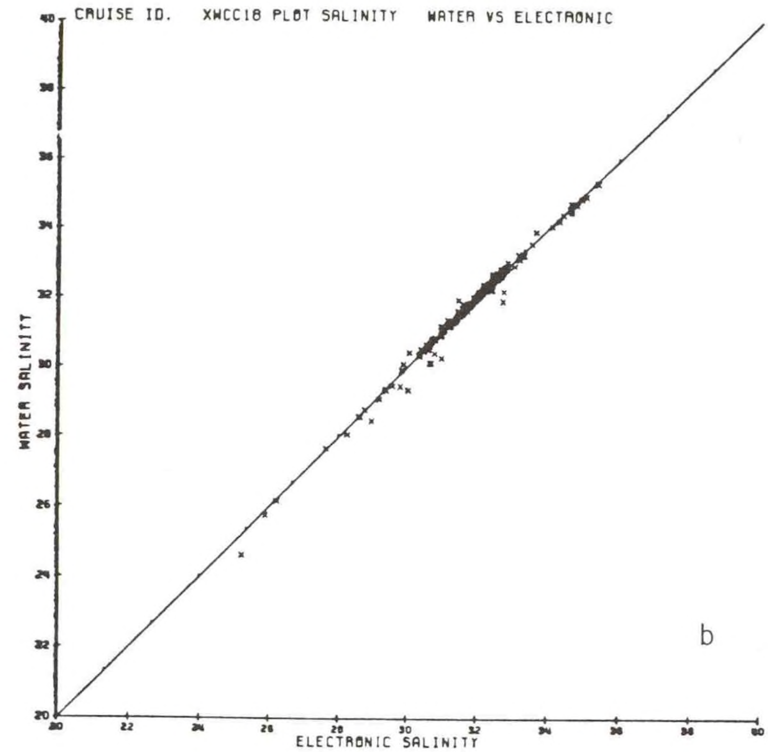
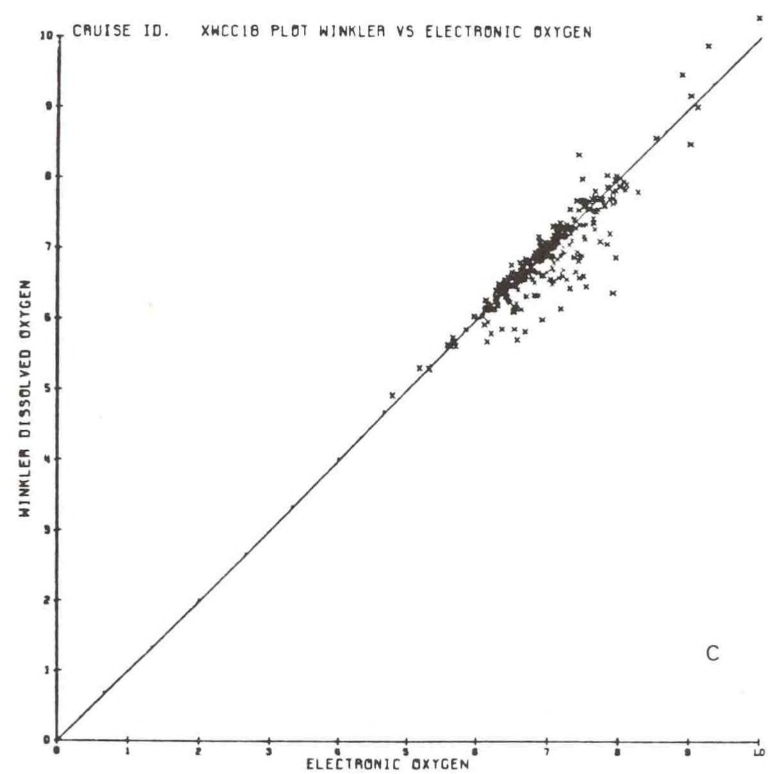


Figure 14 a,b,c: XWCC-18 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.


CRUISE ID. XWCC18 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b


CRUISE ID. XWCC18 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

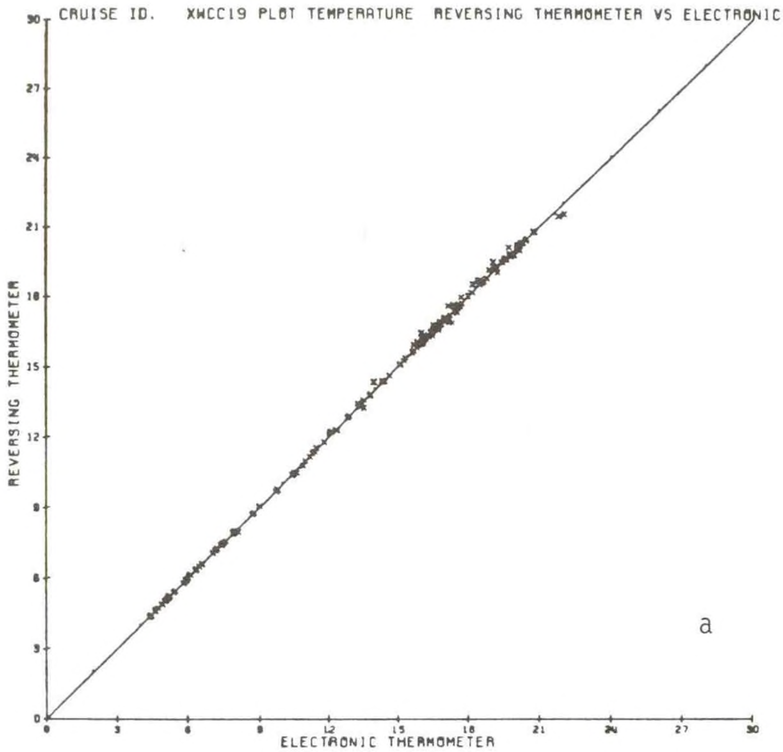
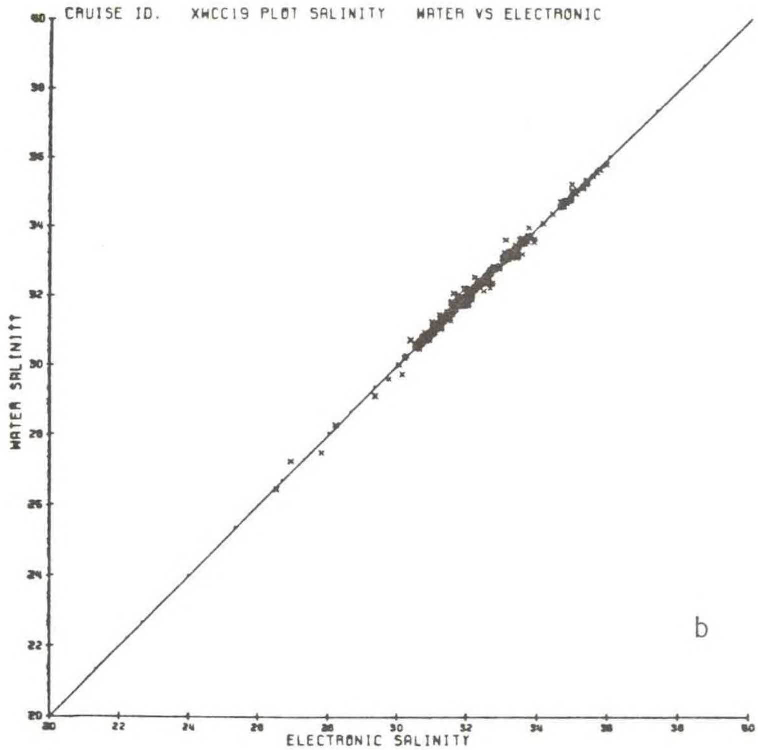
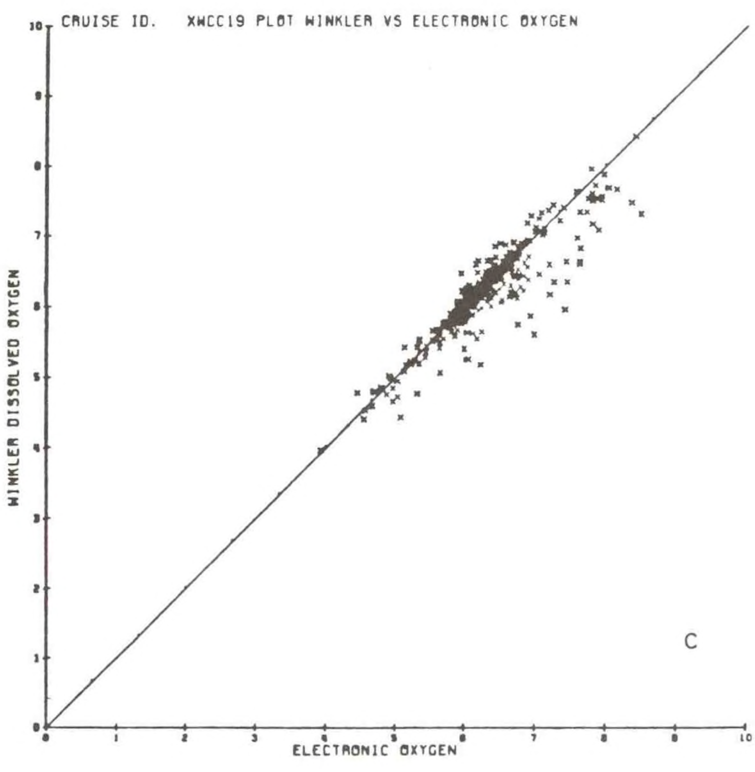


Figure 15 a,b,c: XWCC-19 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.



CRUISE ID. XWCC19 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b



CRUISE ID. XWCC19 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

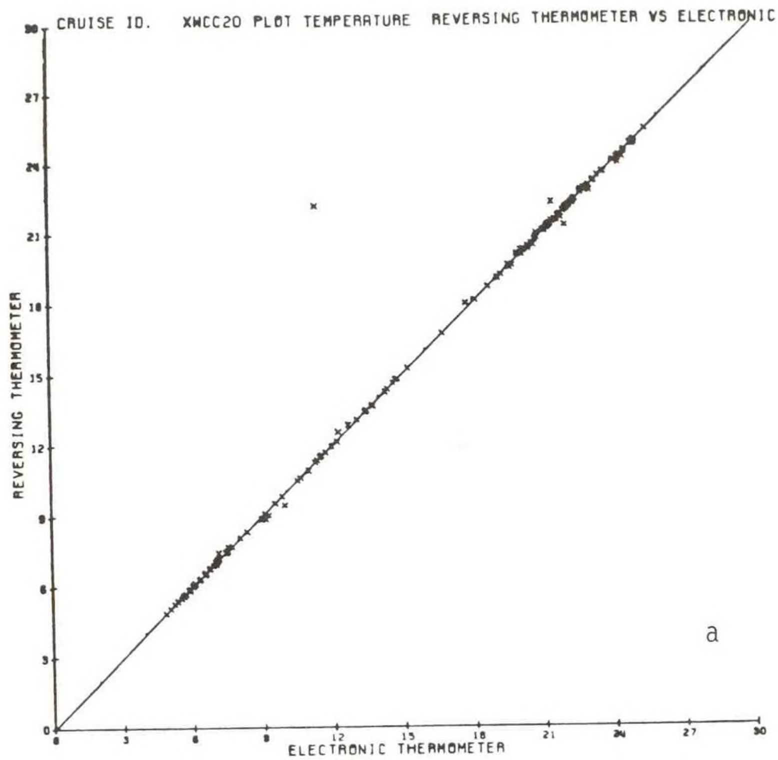
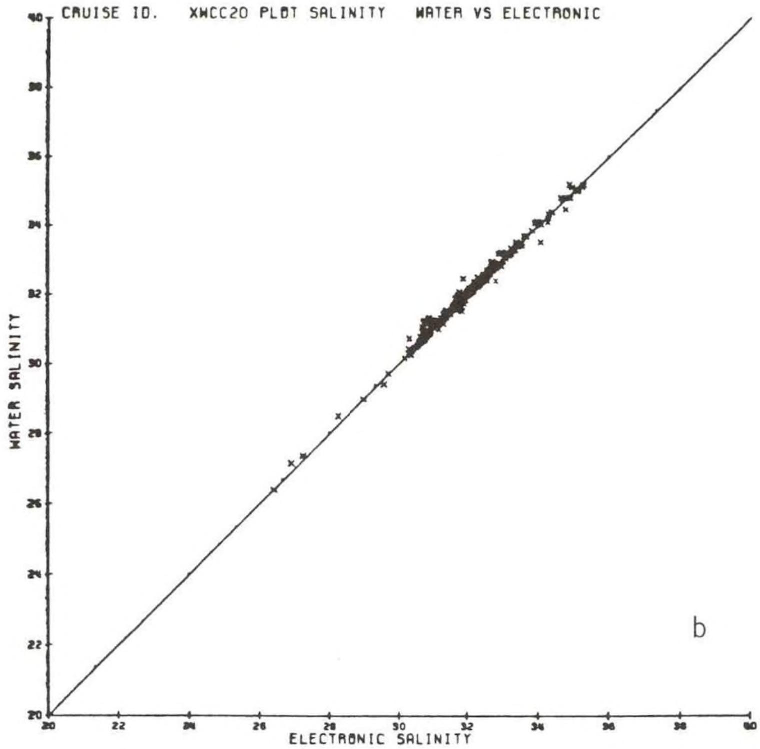
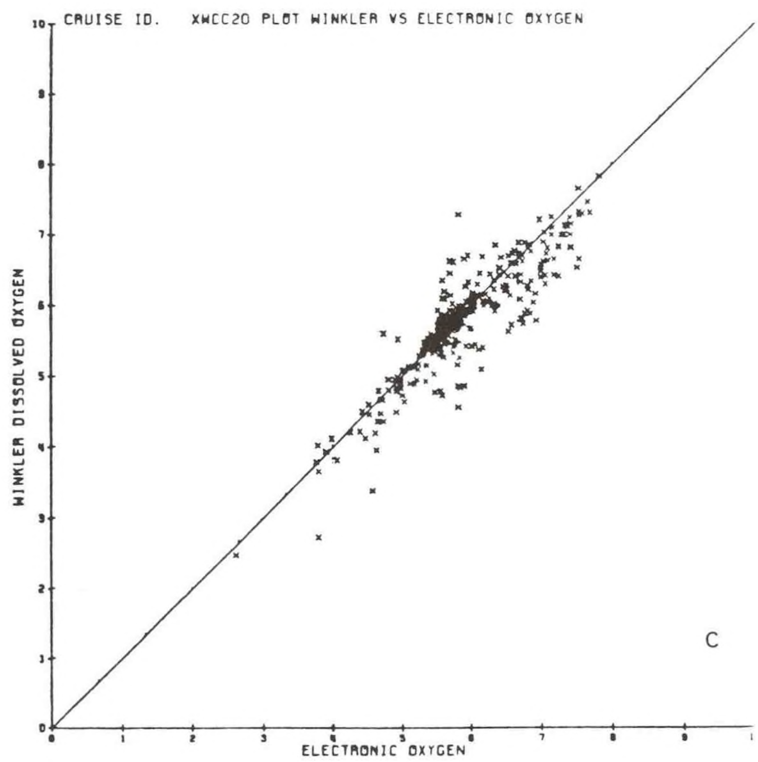


Figure 16 a,b,c: XWCC-20 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.


CRUISE ID. XWCC20 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b


CRUISE ID. XWCC20 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

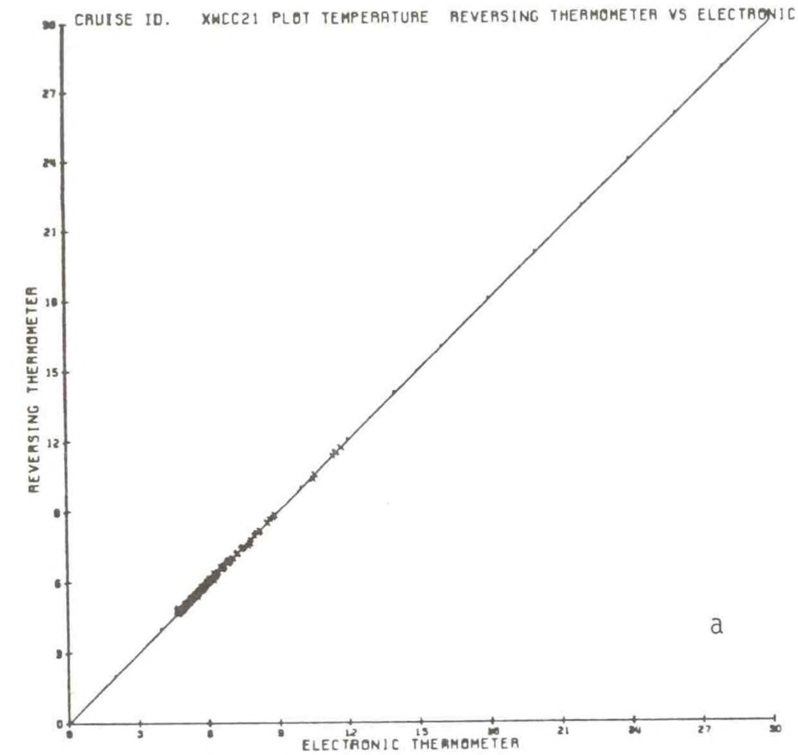
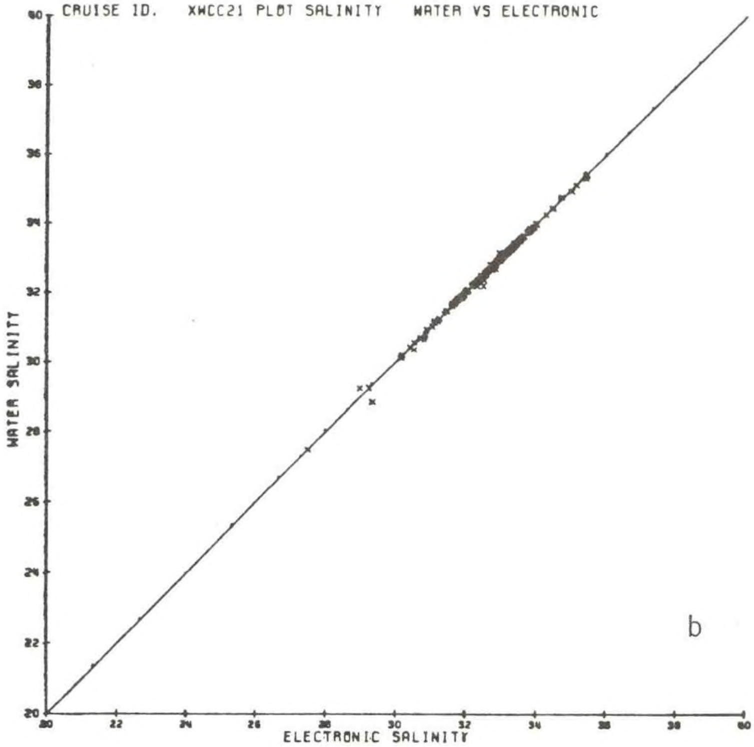
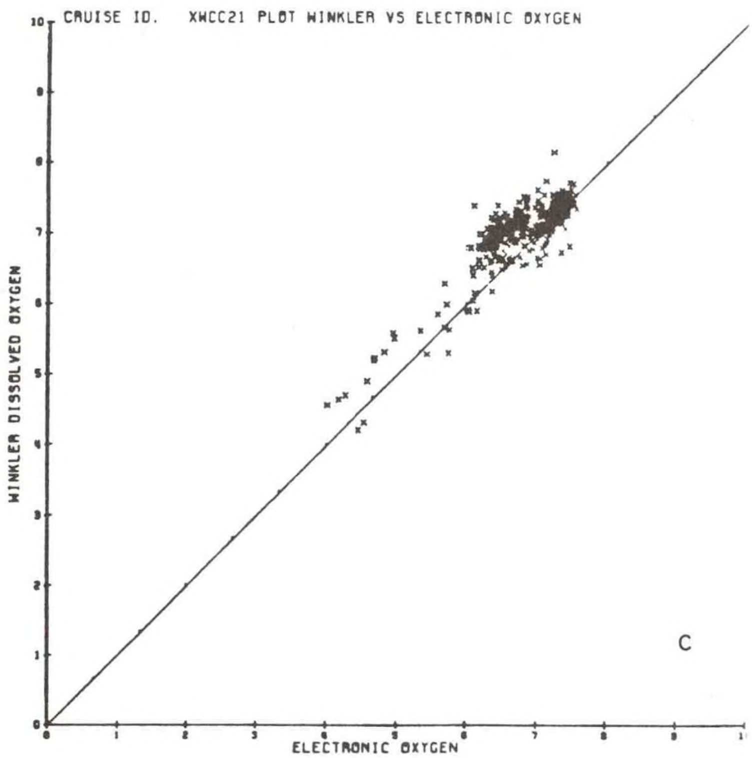


Figure 17 a,b,c: XWCC-21 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.


CRUISE ID. XWCC21 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b


CRUISE ID. XWCC21 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

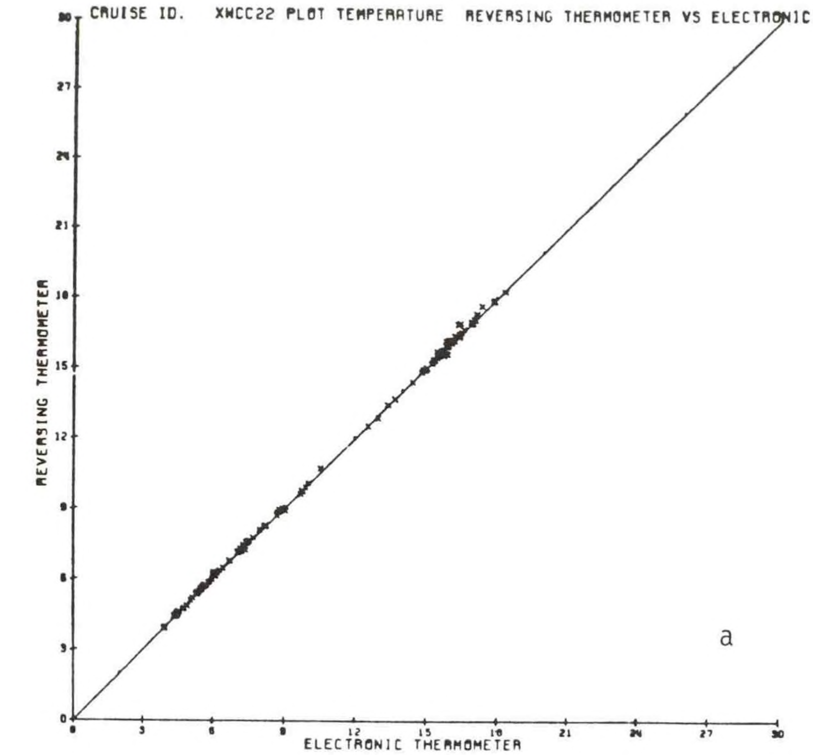
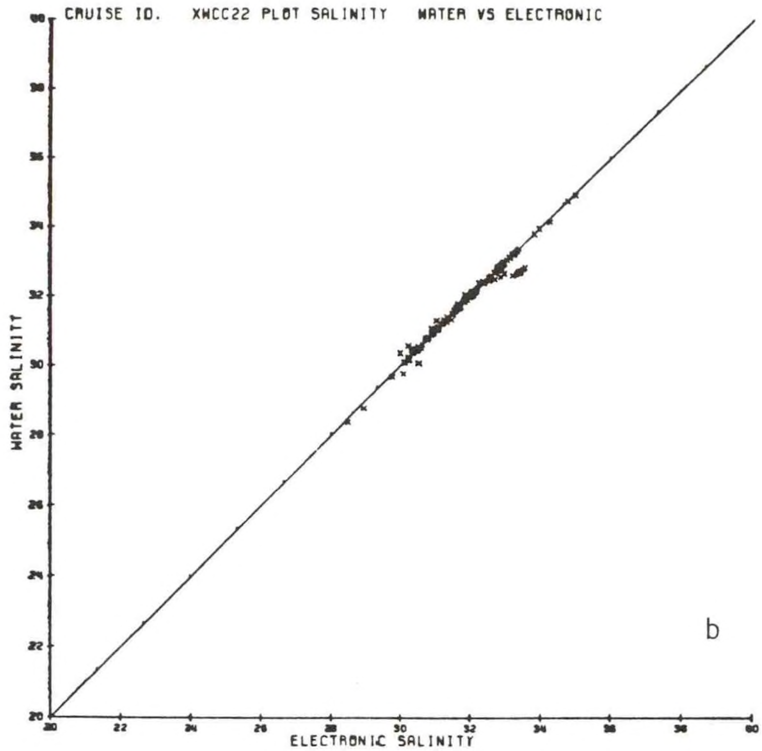
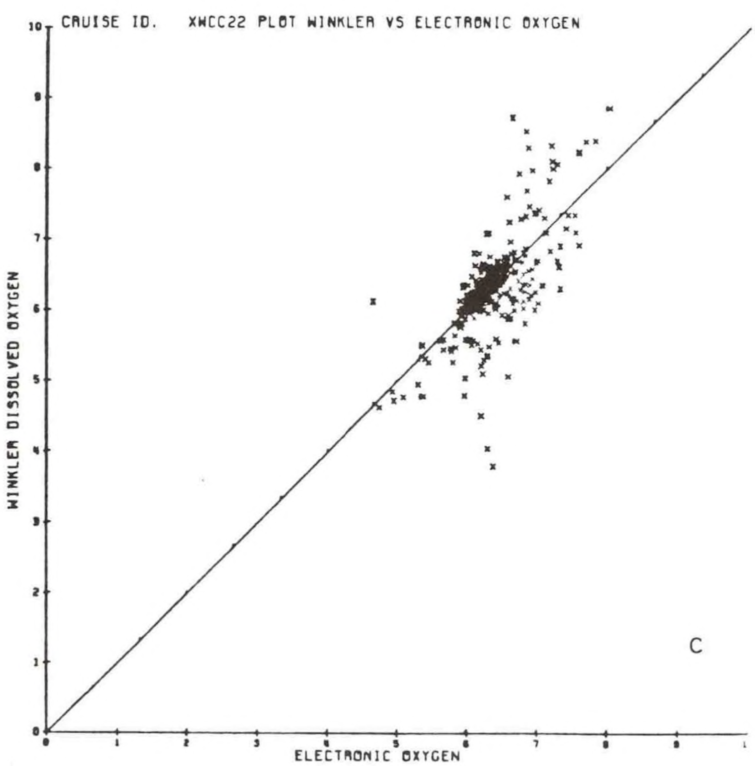


Figure 18 a,b,c: XWCC-22 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.


CRUISE ID. XWCC22 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b


CRUISE ID. XWCC22 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

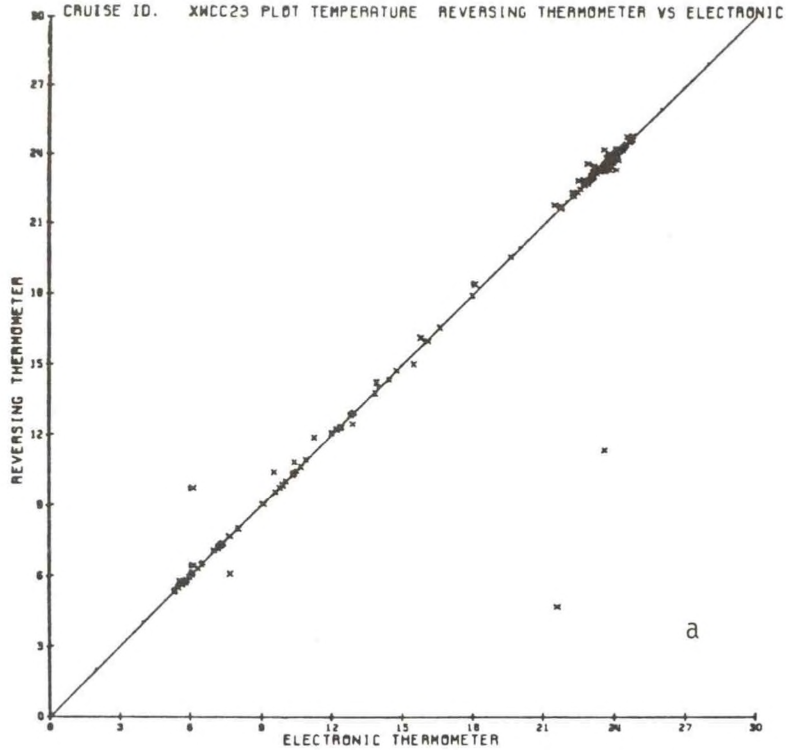
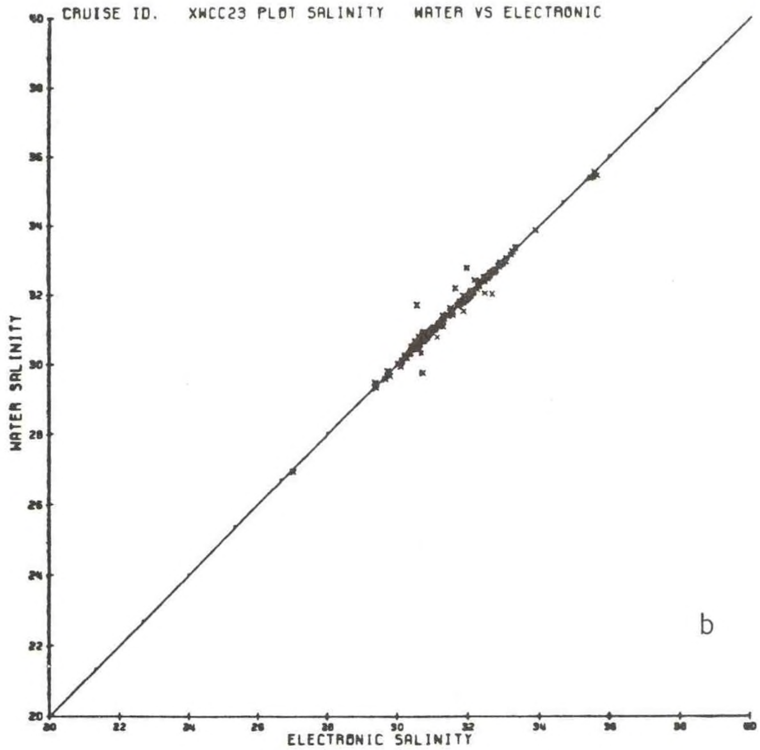
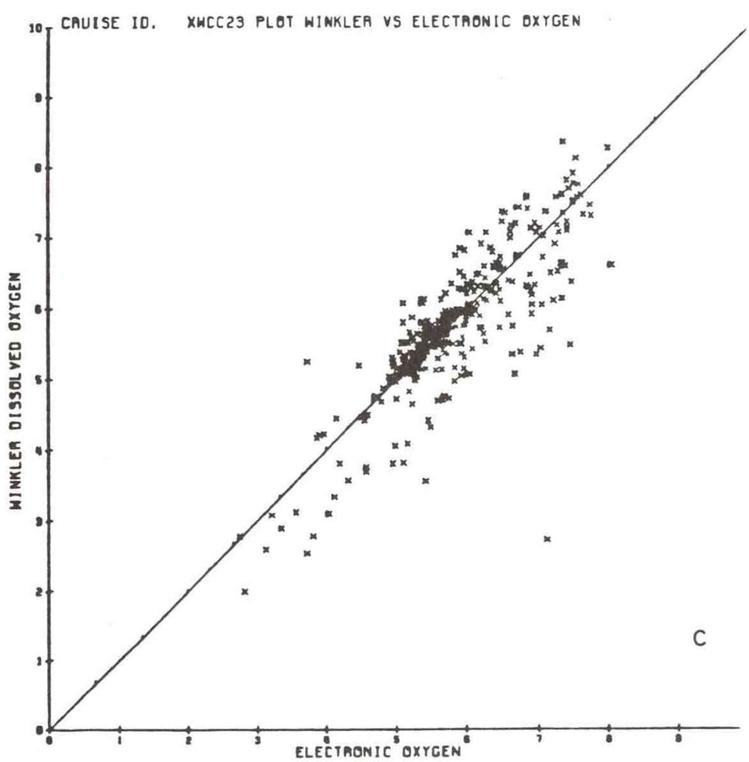


Figure 19 a,b,c: XWCC-23 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.


CRUISE ID. XWCC23 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b


CRUISE ID. XWCC23 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

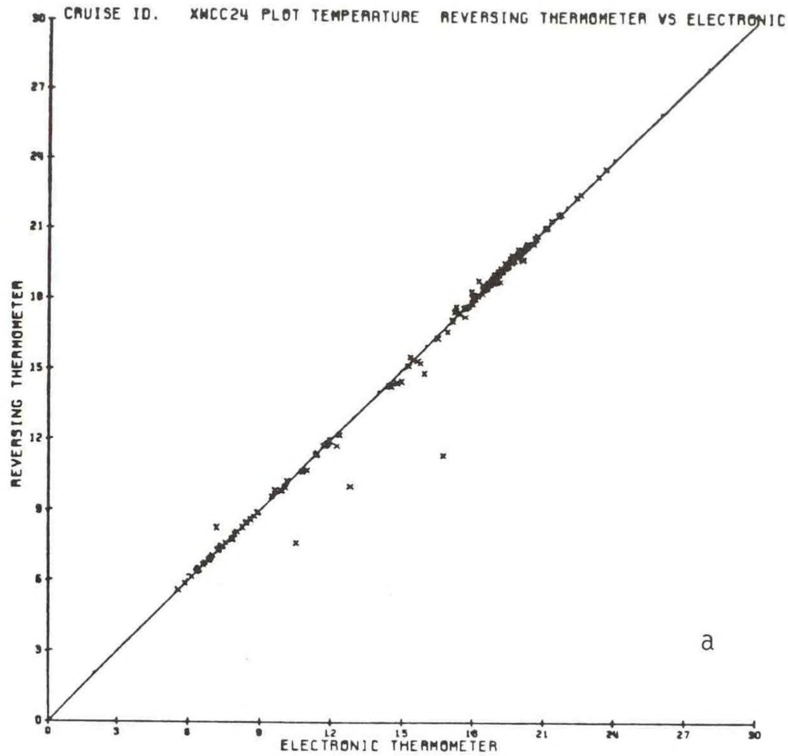
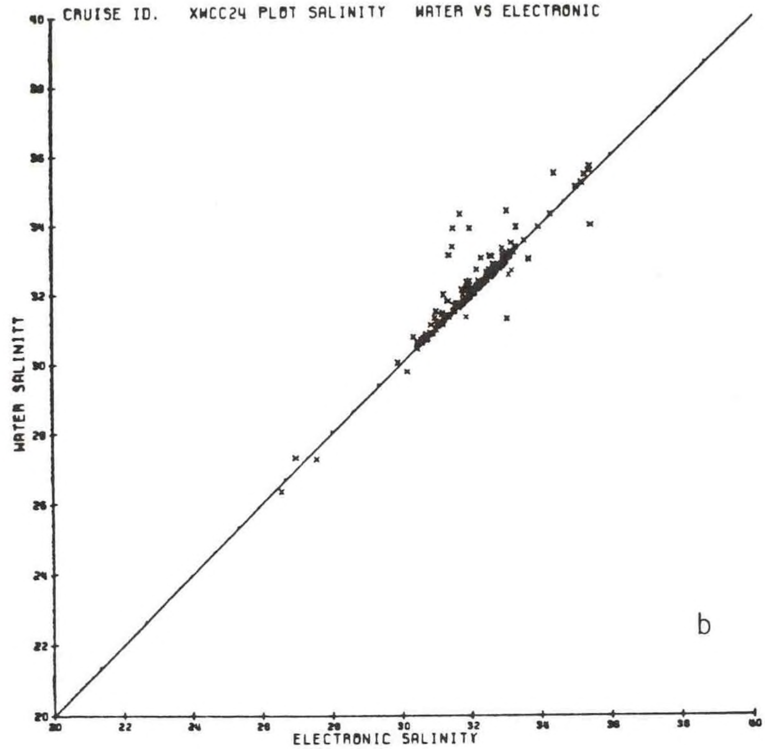
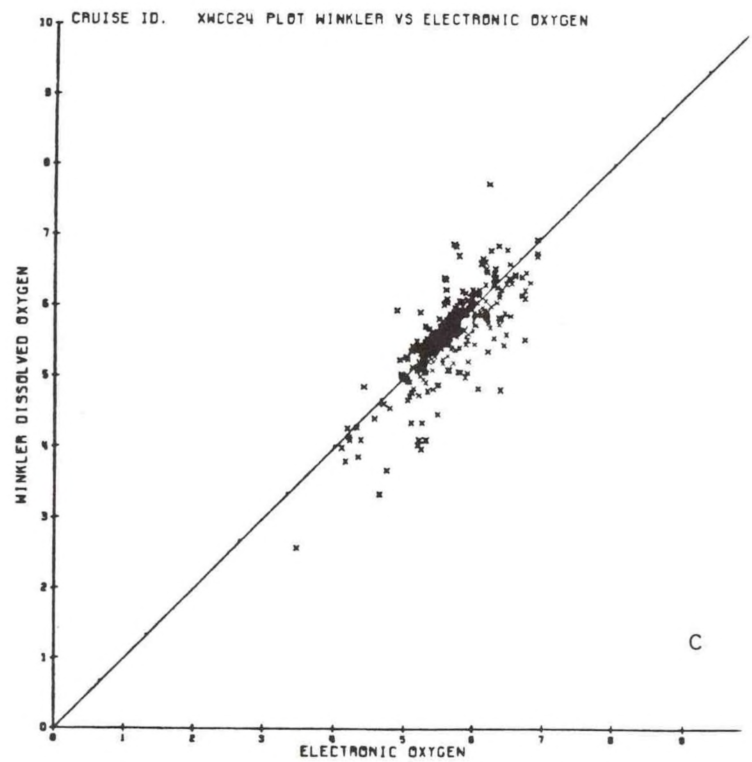


Figure 20 a,b,c: XWCC-24 temperature, salinity and dissolved oxygen standard values versus corresponding electronic sensor data.


CRUISE ID. XWCC24 PLOT SALINITY WATER VS ELECTRONIC
WATER SALINITY
ELECTRONIC SALINITY
b


CRUISE ID. XWCC24 PLOT WINKLER VS ELECTRONIC OXYGEN
WINKLER DISSOLVED OXYGEN
ELECTRONIC OXYGEN
c

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