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IFYGL PHYSICAL DATA COLLECTION SYSTEM: INTERCOMPARISON DATA

Jack Foreman

Center for Experiment Design
and Data Analysis
Washington, D.C.
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IFYGL PHYSICAL DATA COLLECTION SYSTEM: INTERCOMPARISON DATA

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ABSTRACT. During the International Field Year for the Great Lakes (IFYGL) 1972-73, 14 buoys and towers (equipped with automatic recording devices) were deployed in Lake Ontario as the major segment of the Physical Data Collection System (PDCS). Data from buoy intercomparisons before deployment indicate that measurements by the PDCS sensors were accurate. During the field year, the buoy system was compared with sensors aboard the U.S. S/V (survey vessel) *Johnson*, and the data obtained confirmed the reliability of the air- and water-temperature sensors. The wind-speed and wind-direction sensors apparently functioned properly throughout the field year, but the quality of current speed, current direction, and dew-point data deteriorated after deployment.

I. INTRODUCTION

Final data obtained from the Physical Data Collection System (PDCS) during the International Field Year for the Great Lakes (IFYGL) have been edited and placed in the IFYGL Archive at the National Climatic Center at Ashville, N.C. This final data-set consists of several million measurements of 14 limnological and meteorological parameters recorded on 20 IFYGL platforms between May 1972 and March 1973. Fourteen of these platforms were automatic remote buoys and towers. To evaluate the validity of these measurements (prior to an extensive analysis of the entire data set) is advantageous.

Two system intercomparisons of the remote towers and buoys were conducted by the IFYGL-PDCS team: (1) Buoy Predeployment Intercomparison and (2) U.S. S/V (survey vessel) *Johnson* Intercomparison. The first of these evaluated the PDCS sensors in a sheltered environment prior to deployment. The second was conducted on site (Lake Ontario) after the sensors had been deployed for extended periods. Results of the S/V *Johnson* Intercomparison should indicate the quality of the data available to the investigator.

II. BUOY PREDEPLOYMENT INTERCOMPARISON

Prior to deployment, each buoy was compared to IFYGL buoy 15. This buoy had frequent maintenance done during the intercomparison period. Each comparison took place in a shallow protected boat slip, with the buoys separated by 5 to 10 m. Individual comparisons lasted from 1 to 40 hr. The sample rate of one instantaneous observation every 6 min was the same as that used throughout the field year. All of the meteorological sensors, one current meter, and (at least) one water-temperature sensor were tested. A complete discussion of the PDCS buoys can be found in Foreman (1975).

The intercomparison was designed to check out the complete buoy system prior to deployment. Unfortunately, these data were not processed until after the field year was completed--hence, deploying buoys with faulty sensors was possible.

Differences between the buoy being tested and the standard are defined as

$$\Delta X_i = X_{\tau i} - X_{ci}$$

where $X_{\tau i}$ is the observation from the test buoy and X_{ci} is the corresponding standard buoy observation.

The mean difference $\overline{\Delta X}$ for each observation set was computed as

$$\overline{\Delta X} = \frac{\sum_{i=1}^{n} \Delta X_i}{n}$$

where n is the size of the observation set.

The sample standard deviation, skewness, and kurtosis were computed in the usual manner. The intercomparison results were not considered as "corrections" to be applied to the PDCS data-set. When evaluating the test results, the system design accuracies (table 1) must be considered.

A sensor's measurements were considered valid if the computed mean difference $(\overline{\Delta X})$

Table 1.--PDCS parameter design accuracies

Parameter	Design accuracy
Air temperature	0.5°C
Atmospheric pressure	0.5 mb
Dew point	1.0°C
Wind speed	1.0 m/s
Wind direction	5.0°
Water temperature	0.2°C
Current speed	2.0 cm/s
Current direction	5.0°

was within the limits of ±1.5 times the sensor design accuracy (σ_{DA}). This limit can be written as

$$-1.5\ \sigma_{DA} < \overline{\Delta X} < 1.5\ \sigma_{DA}.$$

A. Wind Speed

In table 2, stations 14 and 20 indicate a possible bias in the data. The other stations are within the system design limits.

Table 2.--Wind speed comparison results*

Sta.	*n*	Mean dif. (m/s)	S.D.	Skew.	Kurt.
12	252	0.3	±0.6	0.1	3.0
13	353	.0	.5	.0	2.8
14	307	-2.4	1.1	- .1	2.3
16	228	0.2	0.4	.2	2.8
17	317	.1	.6	.1	2.6
18	12	.1	.6	- .2	1.6
19	182	-1.3	1.0	- .1	1.7
20	82	-2.0	0.6	.0	2.5
21	150	0.0	.3	- .1	2.9

*Sta. is station; dif., difference; S.D., standard deviation; Skew., skewness; and Kurt., kurtosis.

B. Current Speed

In table 3, all of the current speed results are within the system design limits.

Table 3.--Current speed comparison results*

Sta.	*n*	Mean dif. (cm/s)	S.D.	Skew.	Kurt.
12	238	-0.1	±0.0	0.6	1.3
13	341	- .1	.0	.5	1.3
14	304	.0	.0	- .4	1.1
16	216	.0	.0	.0	1.0
17	319	.0	.0	- .4	1.1
18	11	.0	.1	.0	1.0
19	172	.0	.0	- .5	1.2
20	75	.0	.0	-1.2	2.5
21	146	.0	.0	-0.2	1.0

*See table 2 for abbreviations.

C. Air Temperature

In table 4, the sensor on station 20 was known to be defective and was replaced prior to deployment.

Table 4.--Air temperature comparison results

Sta.*	*n*	Mean dif. (°C)	S.D.	Skew.	Kurt.
12	224	0.06	±0.12	-0.42	2.68
13	333	- .02	.98	.20	2.96
14	291	.04	.09	- .18	2.84
16	209	- .04	.07	- .07	2.53
17	297	- .02	.19	- .29	3.04
18	12	- .20	.29	.55	1.64
19	159	.17	.21	.15	3.21
20	76	-37.27	1.36	.41	1.76
21	145	0.13	0.18	.02	3.40

*See table 2 for abbreviations.

D. Dew Point

In table 5, all of the sensors were recording valid data at deployment.

Table 5.--Dew point comparison results

Sta.*	*n*	Mean dif. (°C)	S.D.	Skew.	Kurt.
12	198	0.08	±0.16	-0.60	2.57
13	319	- .29	.86	- .21	2.83
14	278	.50	.16	- .15	2.94
16	194	- .46	.12	.31	3.00
17	312	.27	.43	.24	3.06
18	12	1.14	.59	-1.29	4.47
19	164	0.72	.18	-0.16	2.69
20	70	.63	.11	- .29	2.54
21	135	- .06	.15	.20	2.92

*See table 2 for abbreviations.

E. Atmospheric Pressure

In table 6, only three sensors fall within the system design limit. All of the test measurements were lower than the standard. The standard being faulty throughout the intercomparison is possible. The atmospheric pressure data should be used with caution.

Table 6.--Atmospheric pressure comparison results

Sta.*	*n*	Mean dif. (mb)	S.D.	Skew.	Kurt.
12	253	-1.82	±0.27	-0.02	2.03
13	353	-0.69	.35	.19	1.97
14	300	-1.61	.57	.07	1.65
16	235	-0.45	.42	- .06	1.61
17	330	-1.32	.37	.10	1.56
18	12	-1.14	.42	3.58	15.24
19	177	-1.49	.17	-0.88	3.64
20	82	-1.33	.16	.52	2.12
21	155	-0.07	.27	- .35	1.91

*See table 2 for abbreviations.

F. Water Temperature

In table 7, the sensor position indicates the sensor depth at deployment. All of the thermistors were at approximately the same depth (plus or minus a few inches) and in close proximity during the intercomparison test. All sensors, except those for station 18, meet the design specifications. Unfortunately, station 18 was the only one that had the entire thermistor array tested.

The results for station 18 must be evaluated in detail. The 75-m sensor should be ignored since the test sensor was faulty and was replaced. The 25- and 60-m results fell outside the design limits. Data from these sensors should be used with some caution.

The Buoy Predeployment Intercomparison indicates possible PDCS buoy data quality. These tests, however, were made in a sheltered boat slip. To detect changes that may have occurred in the open lakes after deployment, one must evaluate the S/V *Johnson* Intercomparison data.

Table 7.--Water temperature comparison results

Sta.*	*n*	Mean dif. (°C)	S.D.	Skew.	Kurt.	S.P.
12	230	-0.02	±0.00	-0.05	2.32	5
13	259	- .01	.03	.20	2.64	5
14	293	- .05	.04	.26	2.71	5
16	216	- .02	.05	- .48	2.59	5
17	305	- .03	.04	.09	2.90	5
18	12	.30	.80	.12	3.38	Sfc.
	12	.16	1.18	.97	4.54	5
	12	.25	0.34	- .39	2.41	10
	12	- .20	.28	.11	1.73	15
	12	- .08	.34	- .03	1.78	20
	12	- .98	.44	2.09	7.18	25
	12	- .27	.38	0.13	1.68	30
	12	- .01	.30	.05	2.27	35
	12	- .27	.32	- .14	1.82	40
	11	- .13	.35	- .33	1.88	50
	12	.38	.27	- .88	2.72	60
	12	22.04	6.65	-6.61	32.87	75
	12	0.29	0.35	0.06	1.93	100

*Sta. is station; dif., difference; S.D., standard deviation; Skew., skewness; Kurt., kurtosis; S.P., sensor position; and Sfc., surface.

III. S/V JOHNSON INTERCOMPARISON

Early in the field year, a decision was made whereby onsite intercomparisons would be valuable in monitoring sensor operation and in establishing confidence levels for the data. For various reasons, the intercomparison did not begin until the middle of the field year, after the platforms had been deployed for 2 to 4 mo.

A sensor system, identical to a standard IFYGL buoy, was mounted on S/V *Johnson*. Thus the sensors aboard the vessel simulated those of the buoys as to height or depth. This system and the detailed intercomparison procedures are described in Foreman (1975). No effort was made to evaluate the PDCS sensors by comparing them with different sensors.

The S/V *Johnson* Intercomparison suffered from several major problems. One was the different motion characteristics of the vessel and the buoys. The vessel's engines were used for station keeping during the comparisons, adding to the sensor motion problem.

This motion affected the wind and current speed and direction measurements and possibly the water-temperature data. In addition, S/V *Johnson* did not go to all of the towers and buoys. Individual intercomparisons were run for no more than 2 hr, and no station was visited more than once. Hence, any conclusions must be drawn from 20 or fewer samples. The entire S/V *Johnson* dataset must be viewed with this in mind. Very little, if any, hard statistical inference can be drawn from such a small number of samples on such dissimilar platforms. Intercomparison data do not exist for all sensors on each of the visited stations.

In table 8, notice that at least 2 to 4 mo elapsed between station deployment and S/V *Johnson* going to the station.

The S/V *Johnson* Intercomparison data were reduced in the same manner as the Buoy Predeployment Intercomparison data.

Table 8.--Platform deployment and intercomparison dates

IFYGL no.	Platform type	Deployment date	Intercomparison date
12	Buoy	June 13	Aug. 30
13	"	May 26	Aug. 25
14	"	June 14	Oct. 13
15	"	July 18	Not visited
16	"	May 23	Aug. 22
17	"	June 15	Aug. 23
18	"	July 19	Not visited
19	"	June 6	Sept. 27
20	"	May 31	Sept. 25
21	"	June 7	Sept. 26
23	Deep tower	June 29	Oct. 20
26	" "	May 16	Oct. 5
24	Shallow tower	June 16	Oct. 24
27	" "	June 5	Oct. 6

A. Air Temperature

In table 9, all of the results are with the design limits.

Table 9.--Results of S/V *Johnson* comparisons

Sta.*	*n*	Mean dif. (°C)	S.D.	Skew.	Kurt.
12	7	0.04	0.05	0.61	2.09
13	7	.11	.05	-2.43	7.53
16	20	.07	.05	0.19	1.95
19	13	.04	.10	.36	2.13
20	4	.01	.04	- .24	1.00
21	18	.03	.06	- .32	2.64
23	20	- .13	.13	.17	2.32
24	13	.23	.26	.56	3.05
26	24	- .06	.06	.03	3.25
27	21	.05	.06	- .20	3.21

*See table 7 for abbreviations.

B. Atmospheric Pressure

In table 10, the mean differences for stations 14, 16, 21, 26, and 27 meet the system design specifications. The large mean differences and high moments of the mean for stations 23 and 24 indicate that data from the sensors may be doubtful.

Table 10.-Results of S/V *Johnson* comparisons

Sta.*	*n*	Mean dif. (mb)	S.D.	Skew.	Kurt.
14	13	0.62	0.20	-4.76	22.11
16	20	.02	.15	0.01	3.86
20	4	1.15	.68	-3.15	7.96
21	20	0.63	.47	-0.05	2.06
23	20	-2.55	.86	2.52	7.68
24	13	-2.79	.81	6.75	34.77
26	11	0.30	.20	-0.51	2.65
27	21	- .60	.40	.00	1.96

*See table 7 for abbreviations.

C. Current Speed and Direction

Tables 11 and 12 indicate that the quality of the current speed and direction data degraded dramatically after deployment. This reduction in data quality probably was due to sensor fouling and breakage. The S/V *Johnson* sensors were given frequent routine maintenance, while those on the towers and buoys had no maintenance between deployment and retrieval. Future intercomparisons should be run frequently for longer periods, and frequent onsite sensor maintenance should be carried out.

Table 11.--Results of the S/V *Johnson* current direction comparisons

Sta.*	*n*	Mean dif. (cm/s)	S.D.	Skew.	Kurt.	Depth (m)
14	5	- 21.1	56.4	-1.0	2.2	5
	5	36.1	23.6	-1.8	4.3	15
16	6	- 13.8	38.6	0.4	1.7	30
	7	24.3	78.1	- .2	1.7	15
20	4	29.4	18.7	-2.6	6.1	30
21	7	- 21.4	32.5	0.9	2.5	15
	6	-125.4	70.9	2.1	6.1	5
23	5	- 11.1	146.3	-0.1	1.3	5
	2	-222.8	229.2	1.8	2.7	10
	5	-134.0	123.3	1.4	2.3	15
27	4	-197.1	119.3	3.0	7.5	4

*See table 7 for abbreviations.

Table 12.--Results of the S/V *Johnson* current speed comparisons

Sta.	*n*	Mean dif. (*)	S.D.	Skew.	Kurt.	Depth (m)
14	5	-7.3	6.4	0.5	2.2	5
	5	-7.7	4.9	1.9	4.8	15
16	6	-1.9	3.2	-0.7	1.6	30
	20	7.9	27.3	- .8	3.4	5
21	6	1.9	1.5	- .6	2.1	5
	7	7.1	7.3	-1.0	2.1	15
24	6	-8.0	5.5	1.8	3.6	2
	7	-5.8	3.2	2.4	6.0	4
26	4	42.6	24.6	-3.4	8.9	5
	6	40.5	18.1	-4.7	15.0	10
	5	15.8	23.9	0.2	0.9	15
	5	40.4	20.2	-4.0	11.9	19
27	4	-5.8	3.9	2.2	4.8	2

*Degree of arc

D. Dew Point

In table 13, only stations 20, 23, and 24 meet the system design specifications.

Table 13.-Results of S/V *Johnson* comparisons

Sta.	*n*	Mean dif. (°C)	S.D.	Skew.	Kurt.
13	7	15.69	6.41	-4.90	17.99
16	20	14.35	4.79	-2.66	8.11
19	13	15.62	6.51	-3.44	11.05
20	4	0.39	0.24	-2.74	6.56
21	18	9.22	8.46	-0.30	1.19
23	20	-0.56	0.65	.21	3.46
24	13	- .90	.27	6.34	32.05
27	21	13.86	5.66	-2.04	5.16

E. Water Temperature

Table 14 is a listing of S/V *Johnson* water temperature comparisons. Station evaluations appear after the table.

Table 14.--Results of S/V *Johnson* water temperature comparisons

Sta.	*n*	Mean dif. (°C)	S.D.	Skew.	Kurt.	Depth (m)
12	7	1.11	0.61	2.16	5.88	Sfc.
	7	0.04	.03	-0.93	3.40	5
	7	.05	.05	- .52	2.17	10
	7	.08	.12	- .03	1.34	15
	7	.15	.14	.05	1.66	20
13	7	.07	.14	1.65	3.89	Sfc.
	4	- .66	1.13	-0.04	1.14	5
	4	-1.19	1.26	.04	1.62	10
14	7	0.01	0.05	-1.68	3.98	Sfc.
	7	- .09	.00	1.53	3.56	5
	10	.09	.03	-3.53	13.54	10
	10	.00	.04	-0.77	1.56	15
	12	.04	.00	-1.27	4.04	20
	5	- .49	.33	1.72	3.98	25
	5	- .11	.24	-0.89	1.96	30
	2	1.86	3.15	- .42	0.58	35
	2	0.80	1.59	- .26	.47	40
16	8	.01	0.00	.57	3.00	Sfc.
	8	- .04	.08	-1.76	4.54	5
	18	.06	.06	0.66	3.00	10
	18	.06	.07	- .05	1.49	15
	18	.39	.77	.08	2.10	20
	9	.23	.18	- .67	1.74	25
	9	.15	.13	- .48	1.52	30
19	5	.03	.00	-1.67	3.72	Sfc.
	5	.05	.03	-2.75	7.22	5
	10	.10	.10	-0.18	1.06	10
	10	.10	.06	- .66	1.96	15
	11	.10	.04	-2.34	7.02	20
	6	7.04	4.70	-1.98	4.05	25
	6	9.68	6.42	-2.03	4.14	30
20	4	0.04	0.04	-0.15	1.64	Sfc.
	4	- .01	.00	.67	1.67	5
	4	.03	.00	-3.46	9.00	10
	4	.01	.00	-0.97	1.68	15
	4	.03	.00	-2.56	6.07	20
	4	.46	.27	-3.26	8.30	25
	4	.36	.22	-2.89	7.03	30
	4	.09	.08	-0.90	2.34	35
	4	.10	.08	-1.02	2.88	40
21	8	.46	.16	-5.52	24.14	Sfc.
	9	.54	.19	-5.19	21.45	5
	18	.58	.14	-8.10	49.78	10
	18	- .20	1.24	-1.08	2.96	15
	8	7.60	2.89	-5.20	20.52	20
	8	6.64	2.62	-4.68	17.78	25
	8	1.81	0.69	-5.14	20.18	30
23	6	-0.03	.03	0.90	1.79	2
	6	- .02	.00	.96	3.07	3
	6	.04	.00	-1.87	5.59	4
	6	- .04	.00	-2.56	7.31	5
	8	.04	.03	-0.73	1.83	7

Table 14.--Concluded

Sta.	*n*	Mean dif.. (°C))	S.D.	Skew.	Kurt.	Depth (m)
23	9	0.02	0.03	0.80	1.83	9
	6	.02	.00	-1.60	2.87	11
	6	- .01	.00	0.67	1.15	13
24	13	- .01	.00	6.93	36.00	1
	13	- .01	.00	-0.72	2.13	2
	13	.06	.00	-3.85	17.88	3
	13	.02	.00	-0.80	2.35	4
26	6	.07	.03	-2.78	8.76	1
	6	1.38	1.24	-1.11	2.01	2
	6	0.01	0.00	-0.51	1.49	3
	6	- .06	.04	1.06	2.86	4
	6	.01	.00	0.20	2.44	5
	7	- .14	.47	-1.83	4.29	7
	7	- .24	.61	-1.79	4.20	9
	9	- .17	.18	-0.77	2.62	11
	9	- .33	.15	2.68	9.23	13
	9	- .16	.14	0.61	1.59	15
27	21	.10	.06	- .06	2.65	1
	21	.16	.15	.88	2.90	2
	21	.07	.48	.73	2.29	3
	14	- .44	.45	- .56	2.25	4

For station 12, the surface sensor data may be valid. The large difference probably is due to one of the sensors breaking the water.

For station 13, both the 5- and 10-m sensors have large residuals; however, only four observations are available for each.

For station 14, the 25-, 35-, and 40-m sensors indicate large discrepancies. The results for the 35- and 40-m sensors should not be weighted heavily because of the very small sample size.

For station 16, the 20-m sensor does not meet the system design limits.

For station 19, data from the 25- and 30-m sensors may be questionable.

For station 20, the 25- and 30-m sensors indicate large residuals; however, the sample size is very small.

For station 21, only the 15-m sensor is within the system design limits. Considering the large higher moments of the mean for the other sensors, one has doubts that any of the sensors were functioning properly at the time of the intercomparison.

For station 23, all sensors are within the design limits.

For station 24, all sensors are within the design limits.

For station 26, the 2-m sensor does not meet the sensor specification.

For station 27, the 4-m sensor appears to be doubtful.

F. Wind Direction

In table 15, none of the wind direction sensors (except for stations 14 and 21) meet the system design specifications. These results probably are due to the intercomparison technique. The wind direction data should be used with caution. The wind direction is defined as from true north.

Table 15.--Results of the S/V *Johnson* comparison

Sta.	*n*	Mean dif. (*)	S.D.	Skew.	Kurt.
13	7	-47.3	113.8	-1.3	3.3
14	13	2.3	14.1	0.7	2.4
19	13	-25.4	12.7	1.8	5.7
20	4	-13.2	12.3	0.5	1.9
21	11	- 4.5	36.9	- .7	2.7
24	14	118.7	35.9	-5.5	27.8
27	21	-20.4	12.7	0.3	1.9

*Degree of arc

G. Wind Speed

In table 16, all of the sensors meet the design specifications.

Table 16.--Results of S/V *Johnson* wind speed comparison

Sta.	*n*	Mean dif. (m/s)	S.D.	Skew.	Kurt.
13	7	-0.2	0.6	0.8	2.2
14	13	.2	.7	- .5	2.0
16	20	.5	.3	- .3	2.2
19	13	.4	.5	- .5	2.5
20	4	- .1	.3	.2	1.4
21	18	1.1	1.9	1.4	3.3
23	13	0.5	0.8	0.3	1.8
24	13	-1.5	.8	1.4	3.9
26	24	1.1	.4	-0.5	2.6
27	24	1.2	.9	.5	2.8

IV. CONCLUSIONS

The Buoy Predeployment Intercomparison results indicate that the IFYGL-PDCS sensors agreed with each other prior to deployment. There is no reason to doubt that measurements from these sensors correctly represent the environment when the sensors are maintained well. The S/V *Johnson* Intercomparison results indicate that the air and water temperature sensors functioned properly after deployment; however, it appears as if the dew-point sensor degenerated after deployment. This may be due to system design and placement on the measurement platform. The current speed and direction sensor data quality degenerated completely, primarily because of instrument fouling, breakage, and a lack of maintenance. Thirty-three out of 47 current meters deployed were either inoperative when recovered or were lost during the operations. The S/V *Johnson* Intercomparison results for the wind-speed sensors show they functioned properly throughout the deployment period. The wind-direction data from the S/V *Johnson* is useless, except to point out that the intercomparison design was faulty.

REFERENCE

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