

Update on Analysis of Refresh Data from the Tropical Atmosphere Ocean (TAO) Array

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Background

**Pacific Marine Environmental Laboratory
(PMEL) built and serviced the TAO array**

**PMEL directed to transition TAO Array to
NDBC**

NDBC Refresh testing began in 2007

Laboratory sensor testing

Field system testing

Comparison testing in the TAO array



TAO System Components

- **Wind Sensor**
- **Compass**
- **Air Temperature/Relative Humidity Sensor**
- **Sea Surface Conductivity and Temperature**
- **Subsurface Temperature and Temperature/Pressure Sensors**
- **Acoustic Release**
- **CPU/Datalogger**
- **Communications: Iridium Short Burst in place of ARGOS transmissions (10 minute data every hour)**
- **Shore side IT/Data System**



Sensors

TAO Legacy

RM Young 05103

Anemometer

EG&G 64764 Compass

Rotronic MP-101 Air
Temperature/Relative
Humidity

NX ATLAS SSC Module

NX ATLAS TP Module

TAO Refresh

RM Young 05103

Anemometer

Sparton SP3003D

Compass

Rotronic MP-101A Air
Temperature/Relative
Humidity

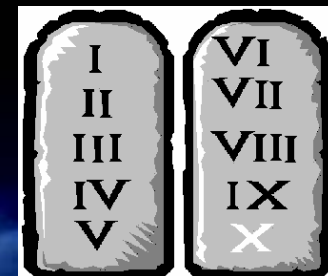
Seabird SBE 37-SM CT

Seabird SBE 39-IM T/TP



Climate Principles

1. Management of Network Change
2. Parallel Testing
3. **Meta Data**
4. Data Quality and Continuity
5. **Integrated Environmental Assessment**
6. **Historical Significance**
7. **Complementary Data**
8. **Climate Requirements**
9. **Continuity of Purpose**
10. **Data and Meta Data Access**



NRC (1999) recommended principles proposed by Karl, et al. (1995)

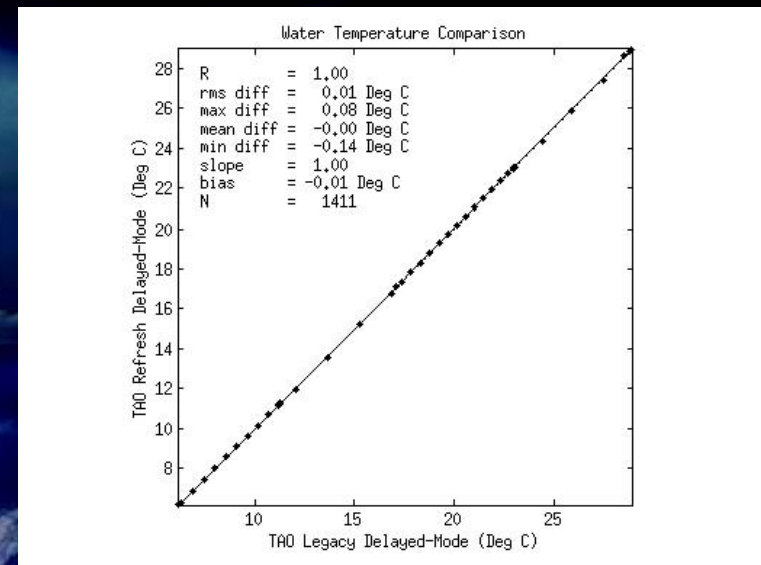
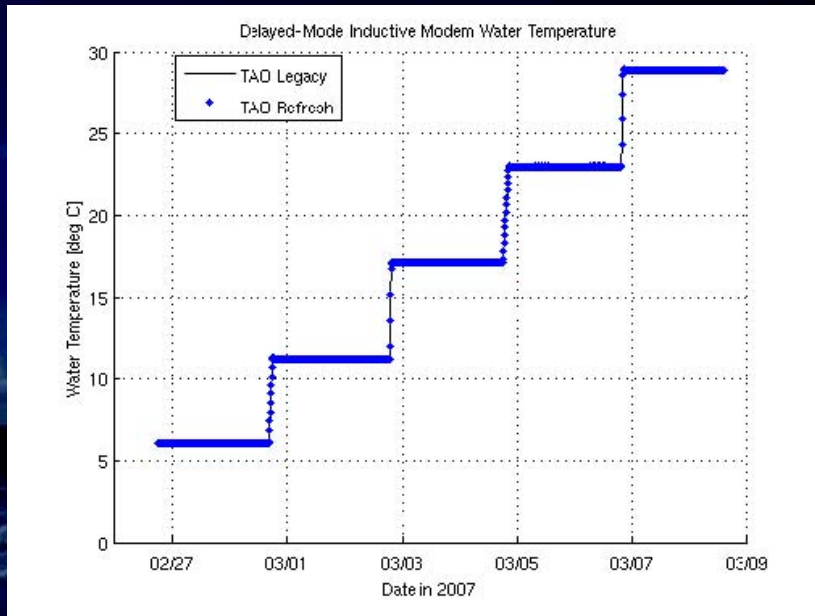


Comparison Tests

- **Laboratory Tests**
 - Ocean sensor/transmission test
- **Buoy System Tests**
 - Refresh buoy at 14N 46 W near PIRATA buoy
 - Two refresh buoys near Buoy 42040 in Gulf of Mexico
 - Two refresh buoys in western Gulf of Mexico
- **Comparisons – Field side-by-side tests**
 - Refresh buoy co-located with 9N 140W (P)
 - Refresh buoy co-located with 2S 140W (P)
 - 7 refresh buoys co-located at 5N 165E; 2S 165E; 8S 165E; 8N 180; 2S 180; 5S 170W; 2S 170W; 2N 170W; 8N 155W; 5S 140W; 5N 140W; and 00 140W (flux site)

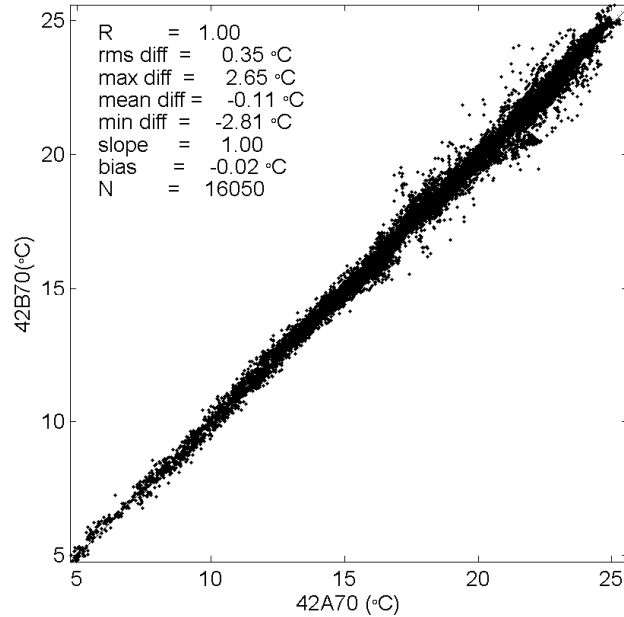


Sensor Laboratory Tests (T)

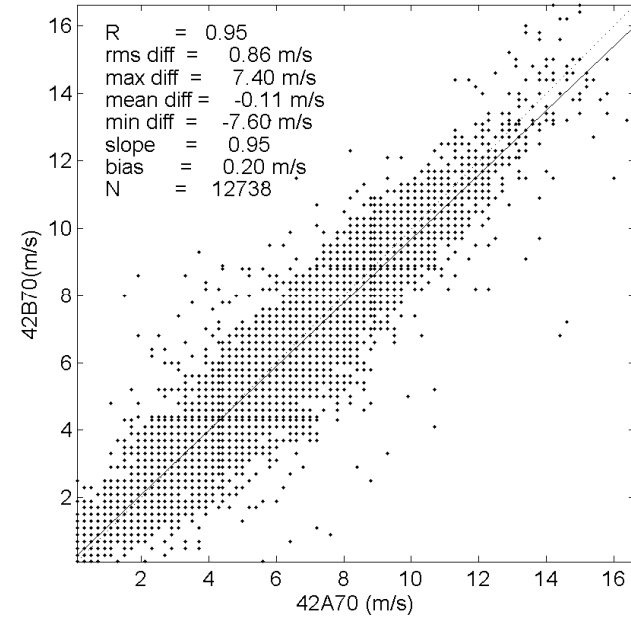


Buoy System Test

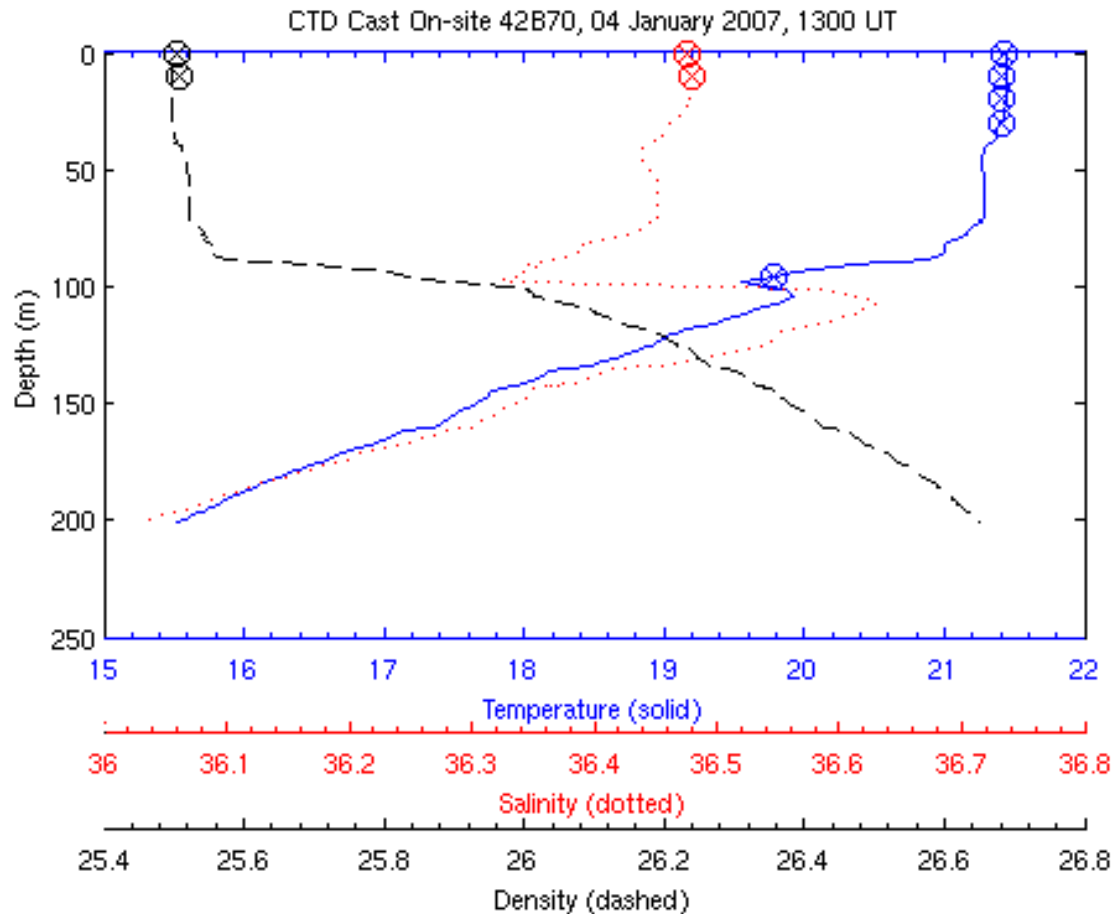
Air Temperature



Wind Speed



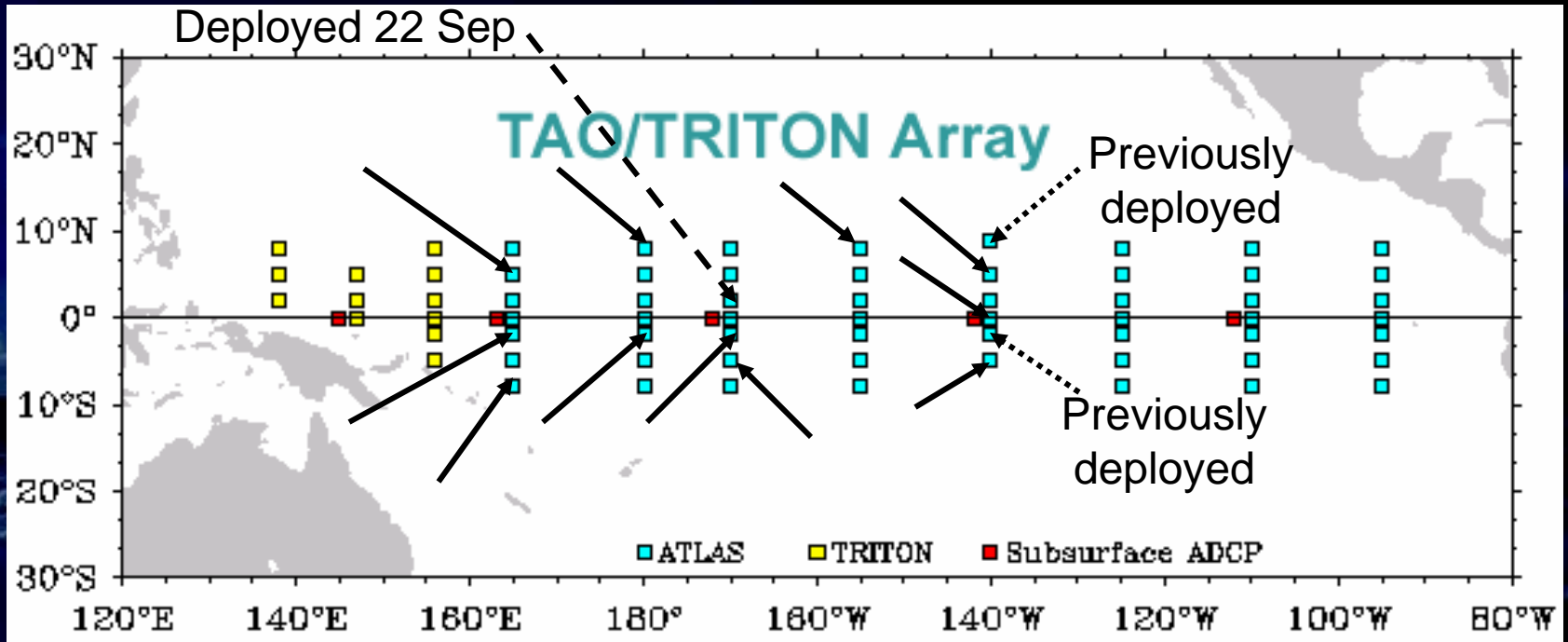
Buoy System Test



Gulf of Mexico Refresh Buoy comparison to adjacent CTD



Field Side-by-Side Tests



Currently Deployed Refresh Buoy Daily-Averaged Data Comparison



TAO Refresh Deployments

Buoy	Successful Transmissions
5N 140W	99.6%
00 140W	98.9%
5S 140W	99.2%
8N 155W	99.2%
2S 170W	99.5%
5S 170W	99.1%
8N 180	98.7%
2S 180	99.8%
5N 165E	98.1%
2S 165E	99.3%
8S 165E	99.1%

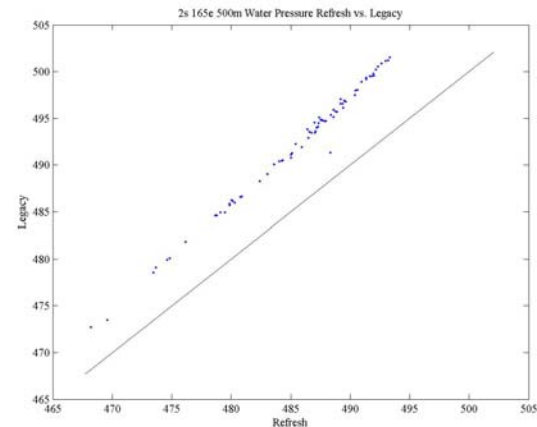
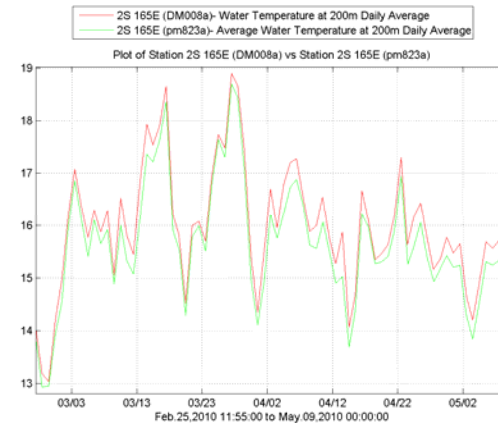
From deployment date through 9 May 2010.

Real-Time Mean Differences Daily-Averaged Data

Station	WSPD	WDIR	ATMP	REL HUM	SST
5N 140W	0.75	-0.13	-0.02	-3.07	0.00
00 140W	-0.04	7.50	0.61	-2.26	-0.01
5S 140W	0.00	-11.21	0.05	0.35	0.00
8N 155W	0.70	-2.05	-0.06	2.71	0.01
2S 170W	0.49	24.33	0.04	-0.11	0.00
5S 170W	0.61	3.17	0.05	-4.51	0.05
8N 180	-0.05	-24.56	-0.13	-5.08	0.00
2S 180	0.54	5.77	0.24	-1.85	0.00
5N 165E	0.39	-3.27	0.26	2.17	0.00
2S 165E	0.30	9.96	0.11	-2.39	-0.02
8S 165E	0.29	-13.58	0.31	-0.68	-0.02

Daily Averaged, Sub-Surface Temperature Data (20-500 m)

- A warm bias appears for most of the Refresh buoy stations
- Pressure sensors at 300 and 500 meters indicate that the temperature sensors are not at the correct depths
- When corrected, sub-surface Refresh temperatures align with Legacy sub-surface temperatures, except in the thermocline
- Internal waves impact the water column within the thermocline region.



2S 140W Meteorological Parameters Daily-averaged Data



2S 140W

Meteorology Parameters

Parameter	Mean Refresh/Legacy	Standard Deviation Refresh/Legacy	Variance
Wind Speed (a)	6.69 / 6.70	1.54 / 1.52	0.227
Wind Direction (a)	266.96 / 266.21	19.78 / 16.13	104.42
Air Temperature (a)	24.059 / 24.219	0.98 / 0.98	0.020
Wind Speed (b)	6.27 / 6.38	1.60 / 1.56	0.351
Wind Direction (b)	268.14 / 274.29	32.52 / 36.56	182.17
Air Temperature (b)	26.721 / 26.579	0.62 / 0.55	0.380

2S 140W

Meteorology Parameters

Parameter	Mean Difference	Slope/Intercept	Regression
Wind Speed (a)	0.042	0.9141 / 0.2477	0.95
Wind Direction (a)	-0.754	1.0509 / -12.7877	0.86
Air Temperature (a)	0.141	1.0013 / -0.1739	0.99
Wind Speed (b)	0.129	0.9534 / 0.1932	0.93
Wind Direction (b)	7.984	0.8284 / 39.8069	0.80
Air Temperature (b)	-0.142	1.0679 / -1.6626	0.95

Statistics for 2S 140W Field Test

Daily Averaged Data

	Mean Difference	Linear Regression (slope/intercept)	Regression Coefficient
1 Conductivity	0.0115 mS/cm	0.980 / 0.062	> 0.99
1 Temperature	-0.019 C	0.999 / 0.006	> 0.99
40	-0.024 C	0.999 / 0.001	> 0.99
60	-0.289 C	0.991 / 0.184	0.96
100	-0.005 C	0.993 / 0.144	0.70
120	0.071 C	0.996 / 0.239	0.82
180	0.014 C	1.005 / -0.089	0.80
300	0.003 C	0.984 / 0.220	0.91
500	0.004 C	0.987 / 0.155	0.88

2S 140W Meteorological Parameters “Delayed-Mode” Data



2S 140W Deployment a

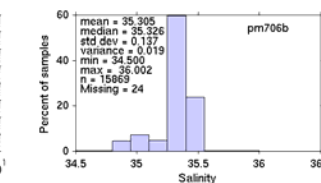
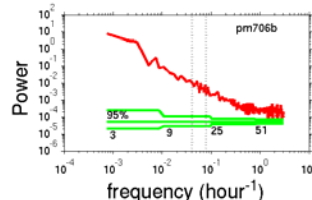
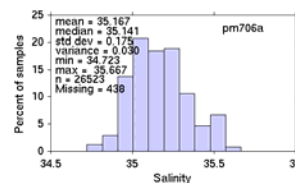
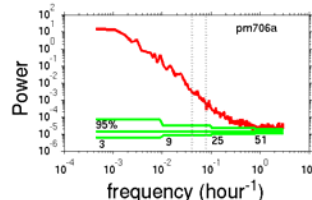
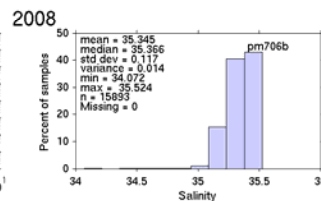
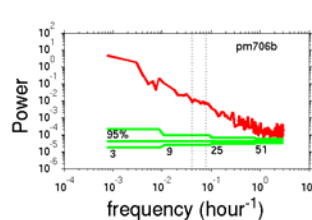
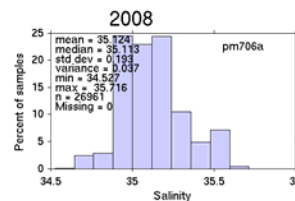
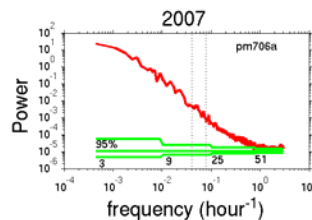
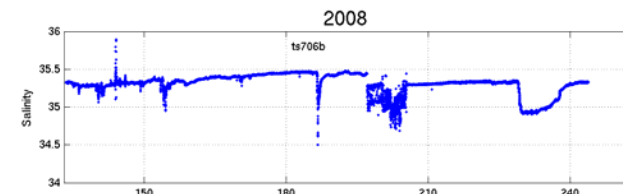
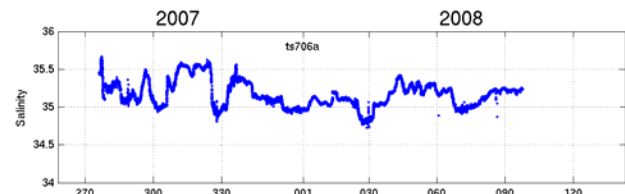
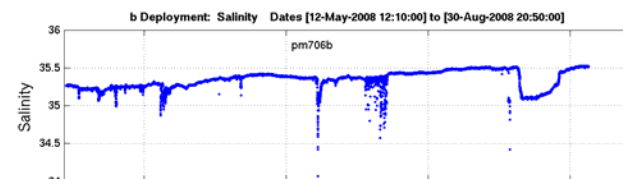
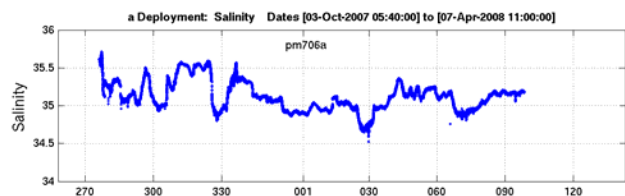
	Mean Difference	Linear Regression (slope/intercept)	Regression Coefficient
Salinity 1	-0.043 PSU	0.882 / 4.200	0.98
Temperature 1	0.016C	0.998 / -0.011	> 0.99
40	0.021 C	0.997 / 0.065	> 0.99
60	0.027 C	0.965 / 0.830	0.97
120	-0.062 C	0.977 / 0.442	0.98
140	0.015 C	0.969 / 0.428	0.97
180	0.006 C	0.979 / 0.269	0.96
300	0.003 C	0.965 / 0.396	0.97
500	-0.005 C	0.992 / 0.070	0.96

2S 140W Deployment b

	Mean Difference	Linear Regression (slope/intercept)	Regression Coefficient
Salinity 1	0.040 PSU	0.472 / 18.640	0.40
Temperature 1	0.028C	1.008 / -0.223	>0.99
20	0.031C	1.009 / -0.264	> 0.99
60	0.040 C	0.989 / 0.246	0.98
80	0.208 C	0.931 / 1.549	0.85
120	0.277 C	0.851 / 2.190	0.91
140	0.147 C	0.794 / 2.780	0.88
180	0.099 C	0.915 / 0.976	0.895
300	0.045 C	0.981 / 0.167	0.96
500	0.108 C	0.880 / 0.921	0.94

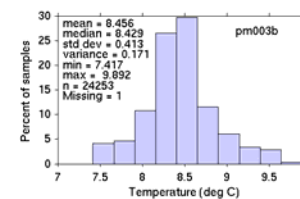
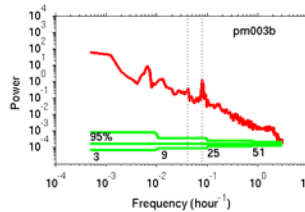
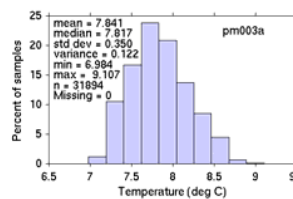
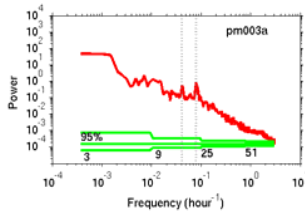
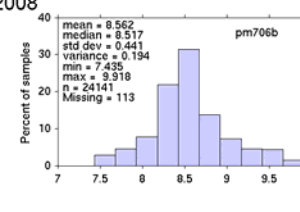
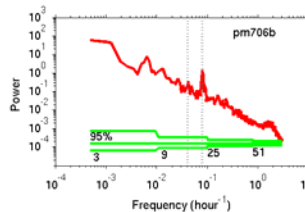
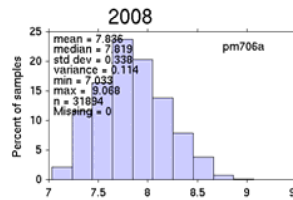
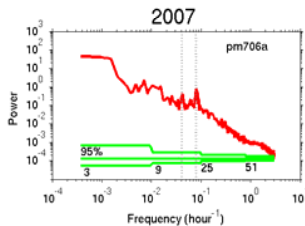
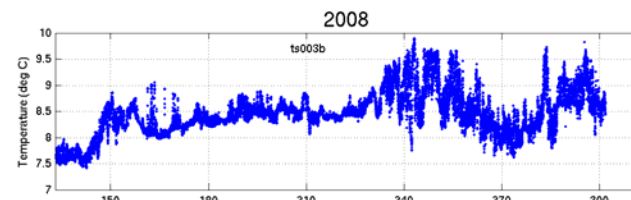
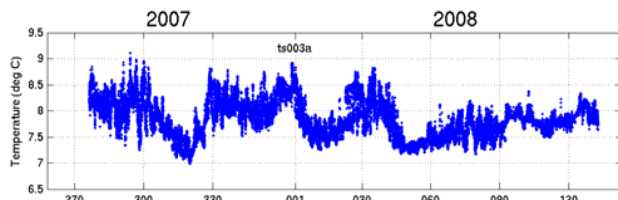
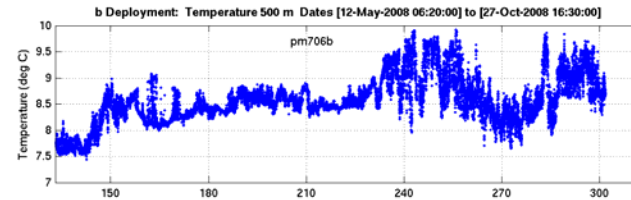
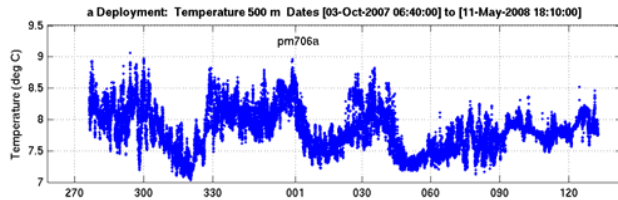
2S 140W Deployments a & b

1 m Salinity



2S 140W Deployment b

500 m Temperature



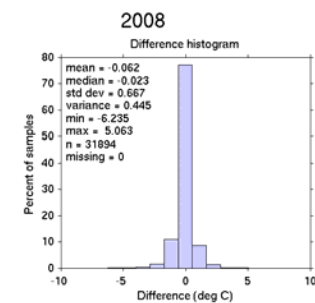
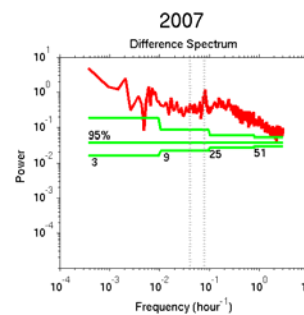
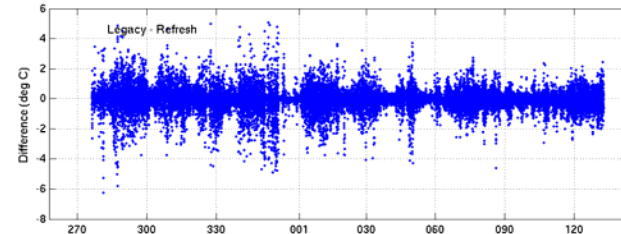
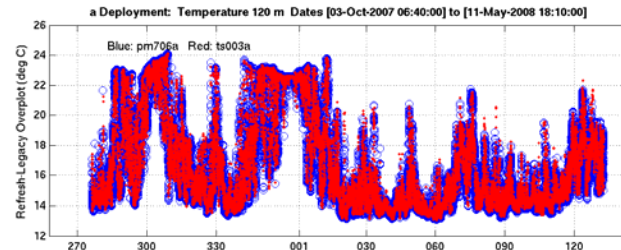
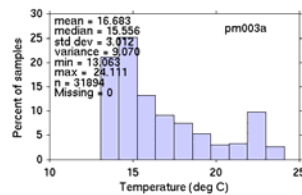
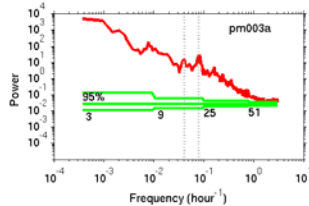
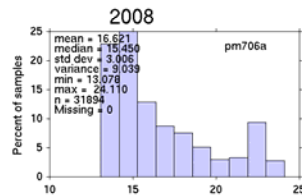
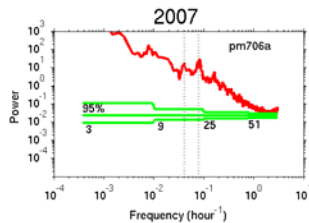
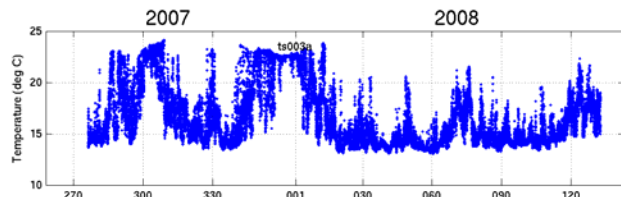
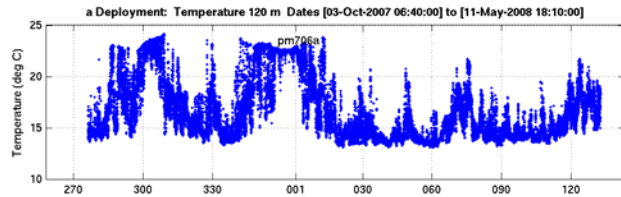
Statistics for 2S 140W Field Test Deployment a - 10 Minute Data

Depth (m)	Mean Refresh/Legacy	Standard Deviation Refresh/Legacy	Variance
1	24.569 / 24.599	1.030 / 0.943	0.002
40	24.679 / 24.700	1.357 / 1.354	0.008
60	24.214 / 24.241	1.194 / 1.196	0.097
120	16.683 / 16.621	3.012 / 3.006	0.445
140	14.378 / 14.393	1.687 / 1.693	0.155
180	13.002 / 13.008	0.371 / 0.365	0.010
300	11.448 / 11.451	0.388 / 0.390	0.009
500	7.841 / 7.836	0.350 / 0.338	0.010

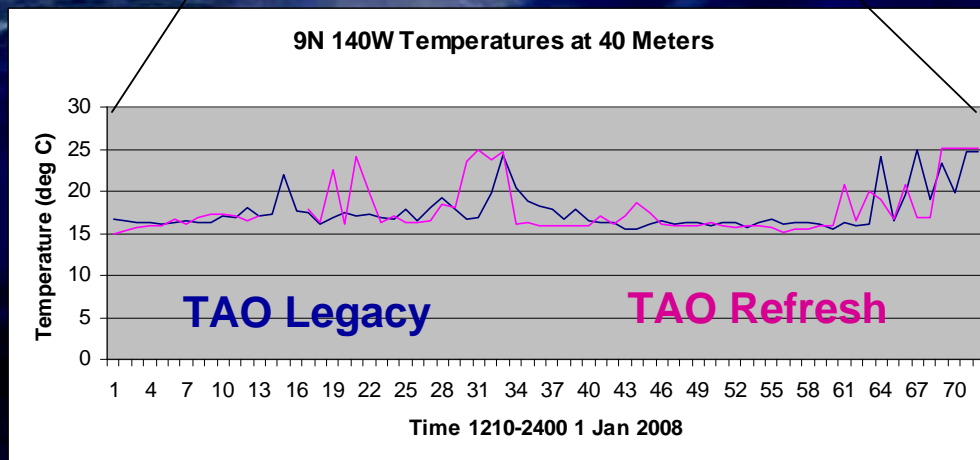
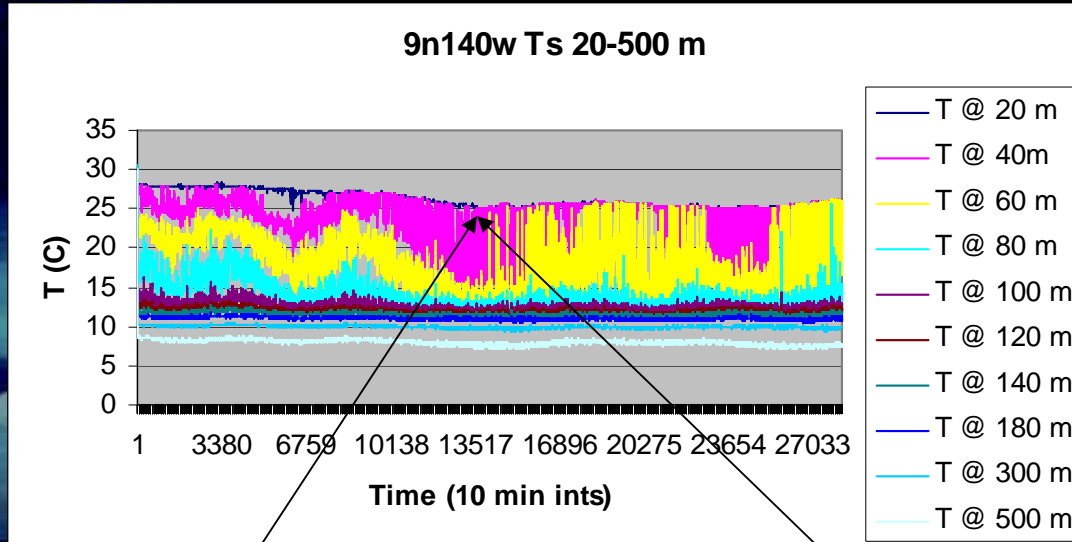
Statistics for 2S 140W Field Test Deployment b - 10 Minute Data

Depth (m)	Mean	Standard Deviation	Variance
1	26.423 / 26.452	0.769 / 0.759	0.002
20	26.346 / 26.385	0.772 / 0.763	0.001
60	26.229 / 26.269	0.773 / 0.769	0.021
80	25.182 / 25.397	1.534 / 1.395	0.672
120	16.310 / 16.585	1.920 / 2.045	0.757
140	14.063 / 14.212	0.792 / 0.773	0.174
180	12.523 / 12.623	0.418 / 0.409	0.036
300	11.067 / 11.112	0.294 / 0.287	0.008
500	8.456 / 8.562	0.413 / 0.441	0.023

2S 140W Deployment a 120 m Temperature Excursions



Internal Wave Example



SeaBird Sensor Calibrations

Depth	2S 140W	Drift (yr)	9N 140W	Drift (yr)
S 1m	SN 4754	0.00180		
T 1m	SN 4754	-0.00009	SN 4751	-0.00032
T 20m	SN 3181	-0.00010	SN 3188	-0.00026
T 40m	SN 3162	-0.00016	SN 3512	0.00008
T 60m	SN 3201	-0.00014	SN 3194	-0.00010
T 80m	SN 3166	-0.00020	SN 3513	0.00009
T 100m	SN 3172	-0.00020	SN 3514	0.00003
T 120m	SN 3208	-0.00007	SN 3510	0.00016
T 140m	SN 3205	-0.00010	SN 3511	0.00008
T 180m	SN 3147	-0.00023	SN 3189	0.00011
TP 300m	SN 3523	0.00010	SN 3602	0.00029
TP 500m	SN 3226	-0.00023	SN 3601	0.00001

Depth Offset Error Magnitudes

Depth	Average Depth	Legacy T	Refresh T	Delta T	Gradient T	New Delta
1	1.014	26.452	26.423	0.029		
20	20.285	26.385	26.346	0.039	0.003995	0.038
60	60.861	26.269	26.229	0.040	0.002884	0.037
80	81.148	25.397	25.182	0.215	0.051609	0.150
120	121.722	16.585	16.301	0.284	0.222025	-0.129
140	142.009	14.212	12.063	0.149	0.11190	-0.094
180	182.583	12.623	12.523	0.100	0.03850	-0.008
300	304.305	11.112	11.067	0.045	0.011962	-0.011
500	507.175	8.562	8.456	0.106	0.013055	0.005



Preliminary Results

- TAO Refresh system is being tested
 - Operational data supplied by Legacy System
 - Fourteen Refresh system and sensors have been deployed and tested against Legacy system in the TAO Array
 - Time delay between a fix and deployment and testing
- Climate principles are being observed
 - Managing network change
 - Parallel testing
 - Data quality and continuity
- Comparisons are reasonable
 - Both systems exhibit the same daily characteristics
 - Variability in oceanography over 5 km and 10 minutes is challenging, but quiescent times indicate correlation
- Testing collaboration between NDBC and PMEL
 - Measures to insure that data being compared are the “same” (calibrations, age, etc.)



Conclusions

- Real-Time Refresh data
 - Being disseminated over the GTS
 - Not as primary TAO data, for investigation only
 - Available on NDBC DODS server
 - Iridium communications > 98%
 - Real-time data *are* Delayed-Mode data
- Refresh System improving and nearing acceptance to replace Legacy System



Thank You



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