

Progress in Refreshing the Tropical Atmosphere Ocean (TAO) Array

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Outline

Background

Climate Principles

TAO Refresh Testing and Results

**Subsurface Temperature and Salinity
Calibration results**

Refresh Systems Deployed

Results



Background

Pacific Marine Environmental Laboratory (PMEL) built and serviced the TAO array (1984 – 2007), still provide sensors

PMEL transition TAO Array to NDBC (2004 – 2009)

NDBC Refresh testing began in 2006

Laboratory sensor testing (2007)

Field system testing (2006)

Comparison testing in the TAO array (2007 – 2011)

Deploy Refresh for Legacy beginning 2011



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**
- **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

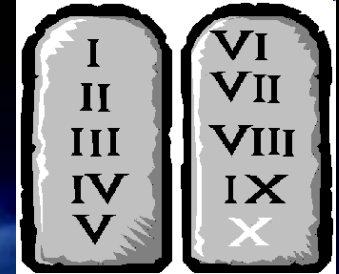
Seabird SBE 37-SM CT

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)

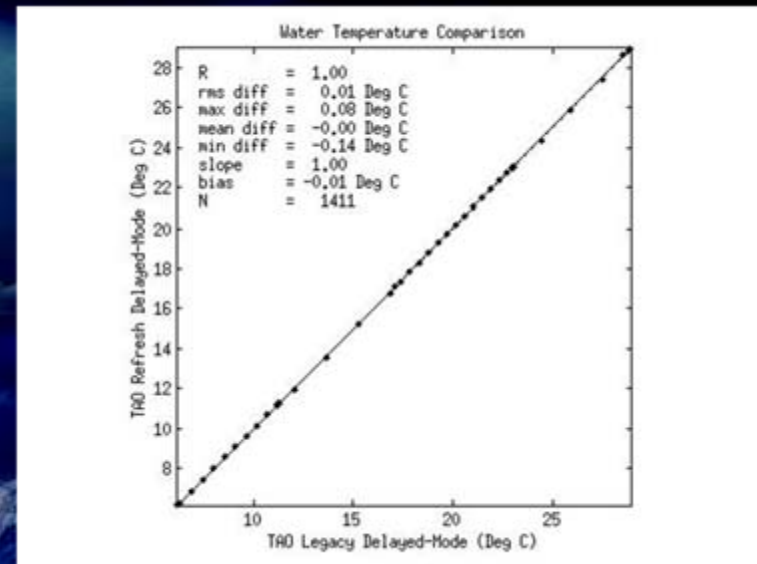
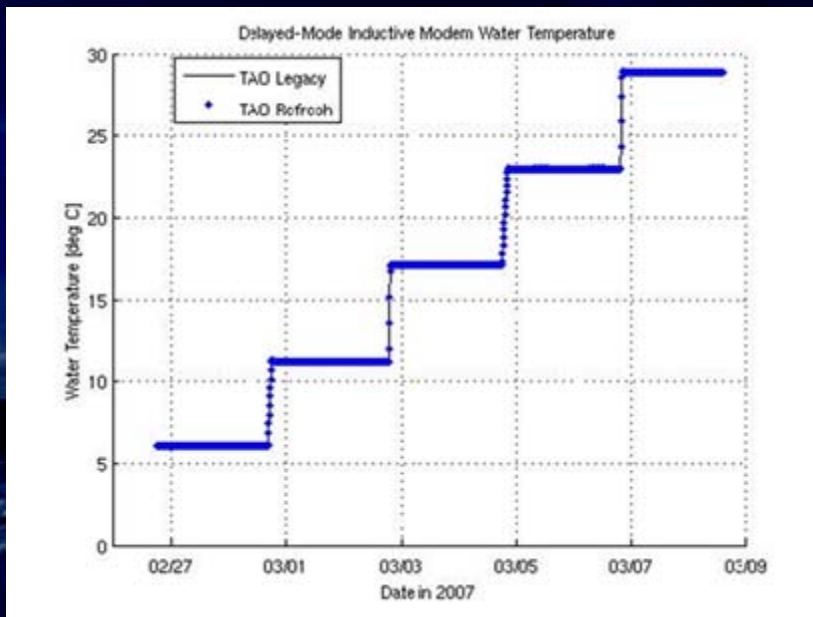


TAO Refresh Testing

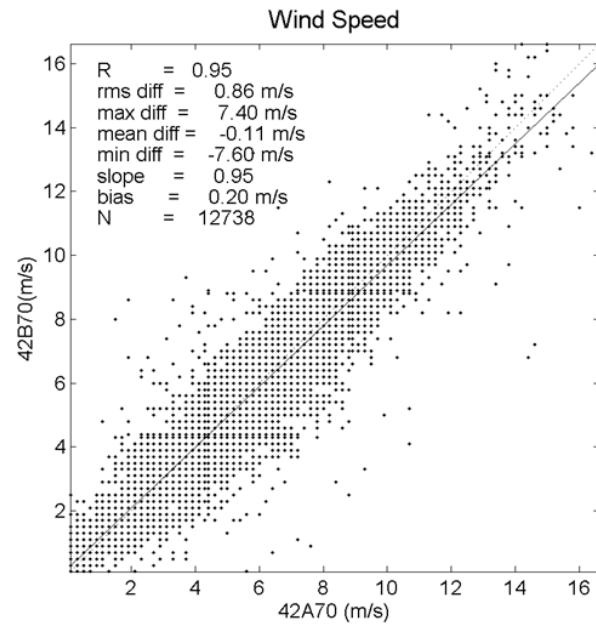
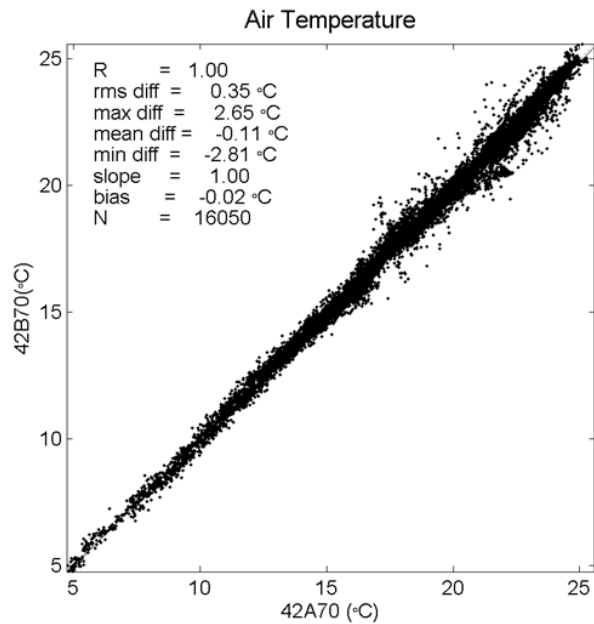
- **Laboratory Tests**
 - Ocean sensor/transmission test
- **Buoy System Tests**
 - Refresh buoy at 14N 46 W near PIRATA buoy
 - Two refresh buoys near Buoy 42040 in Gulf of Mexico
 - Two refresh buoys in western Gulf of Mexico
- **Field Comparisons**
 - Twenty-two co-located Refresh and Legacy buoys at fifteen mooring locations
 - Deployed throughout the TAO array, but concentrated in the western half due to vandalism



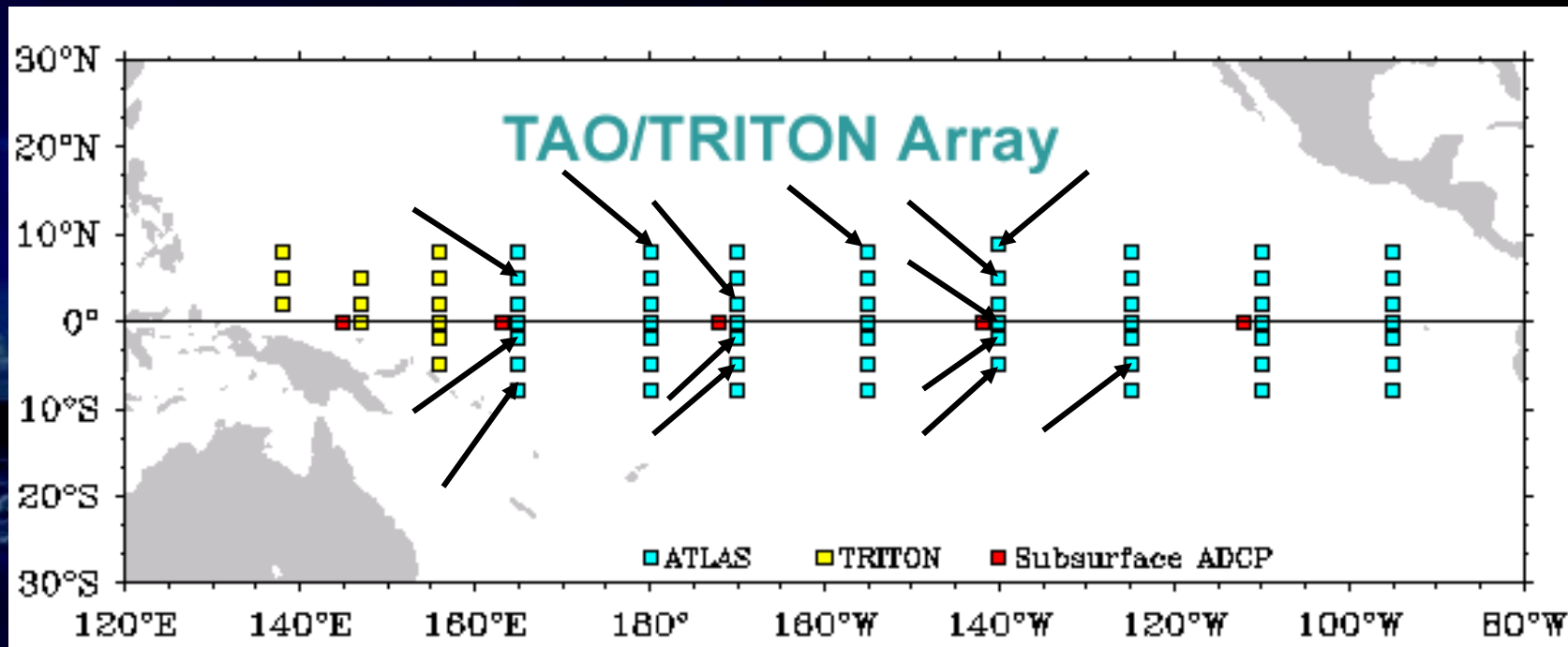
Laboratory Comparisons



System Comparisons



Field Side-by-Side Comparisons



2S 140W Deployment a Refresh-Legacy Comparison

	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

Refresh-Legacy Comparison

	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 Deployment b

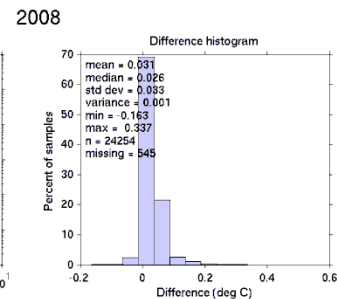
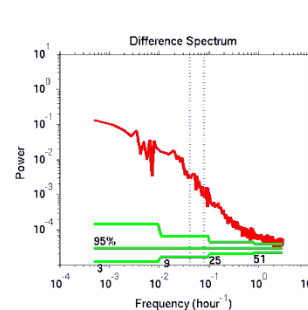
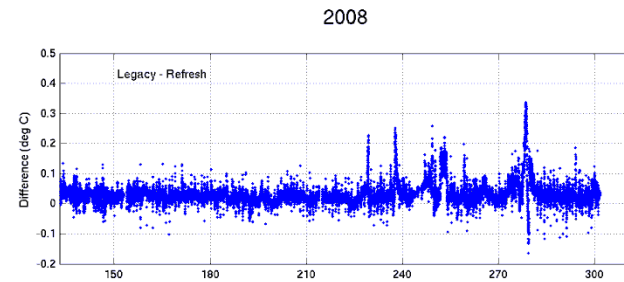
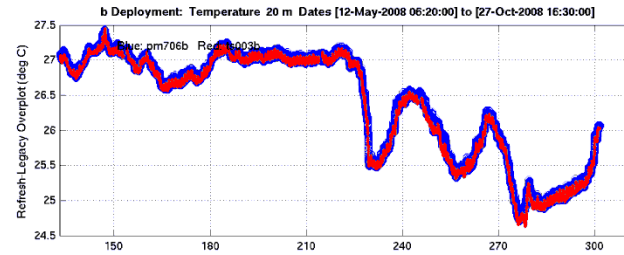
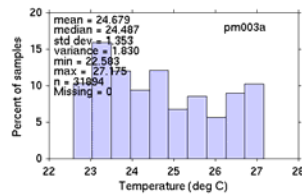
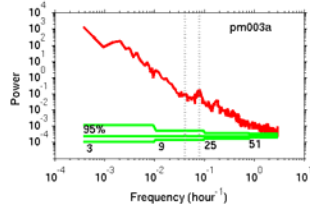
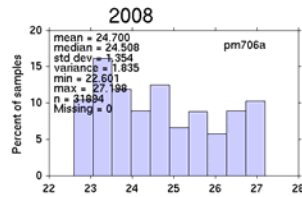
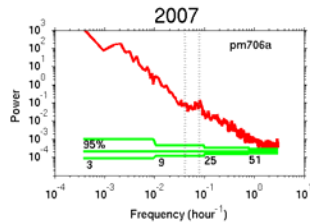
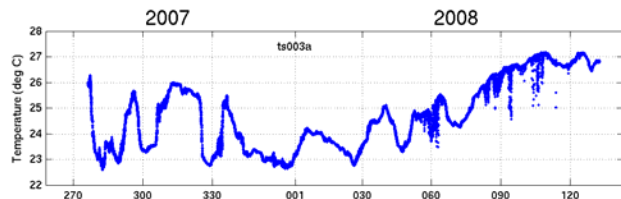
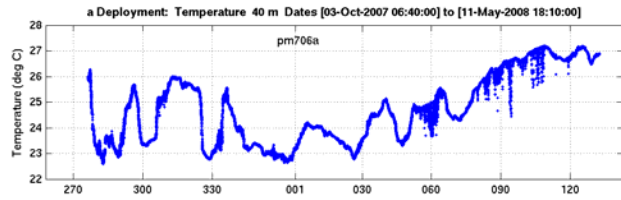
Refresh-Legacy Temp Comparison

Depth (m)	Mean	Standard Deviation	Variance
	Refresh/Legacy	Refresh/Legacy	
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

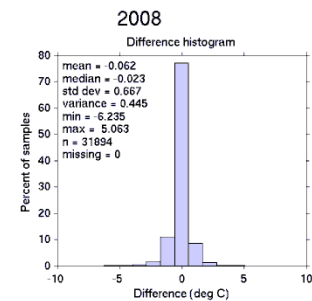
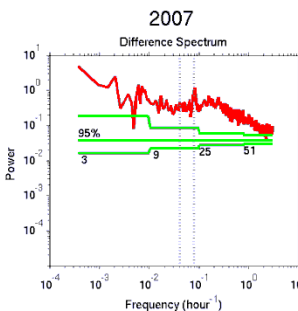
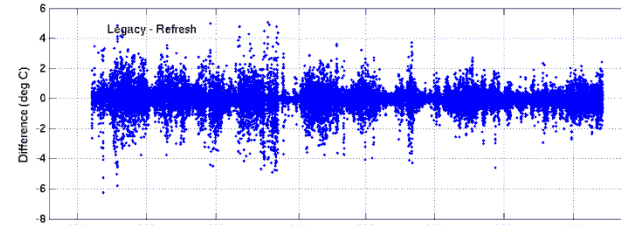
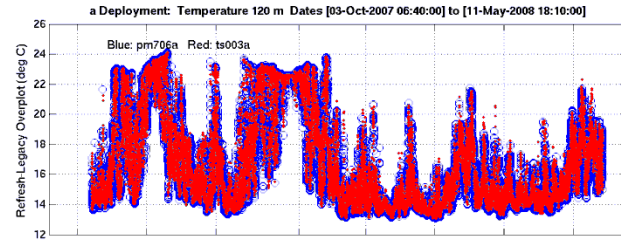
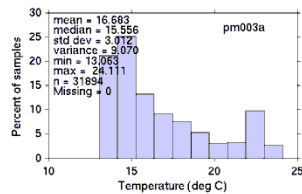
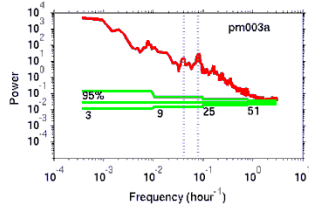
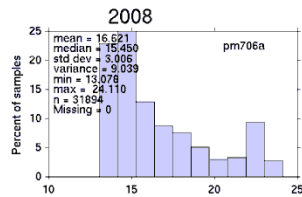
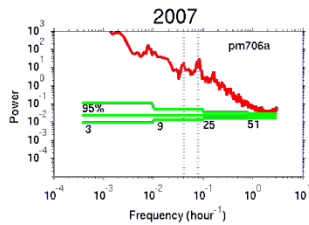
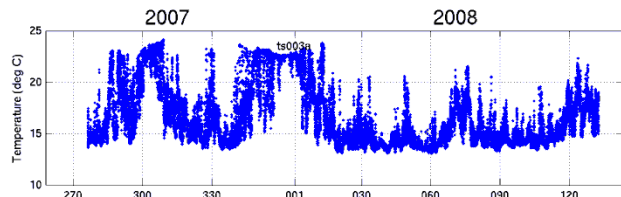
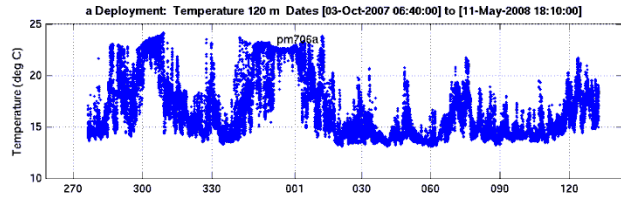


2S 140W Deployments

40 m Temperature



2S 140W Deployment a 120 m Temperature Excursions

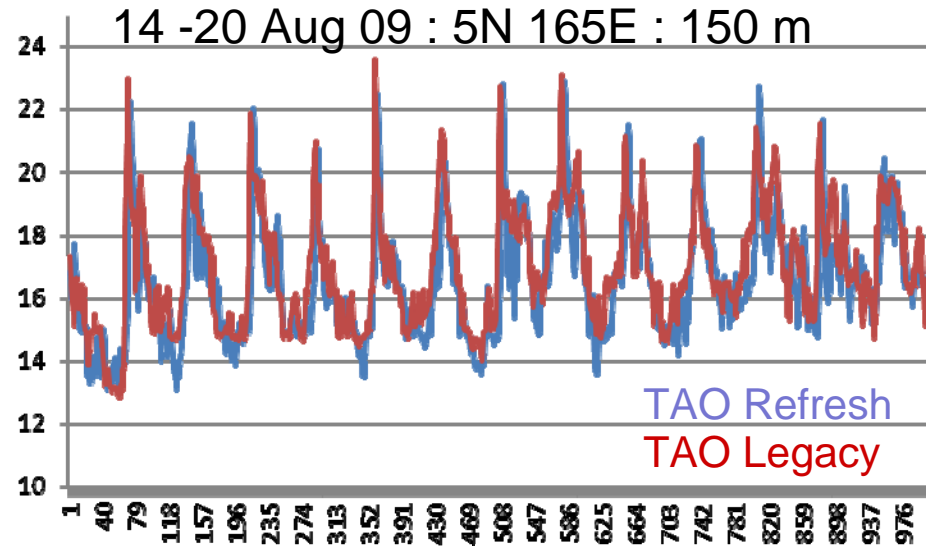
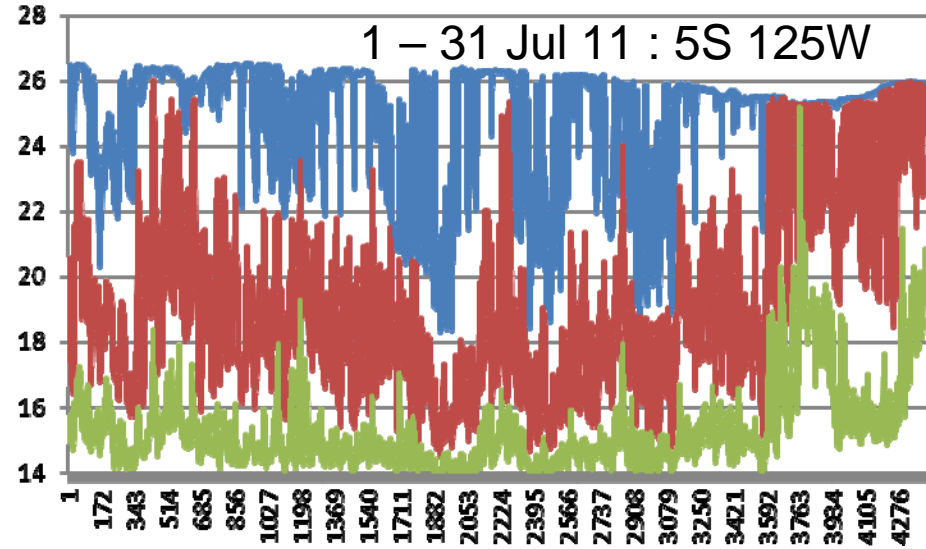


Depth Offset Error Magnitudes

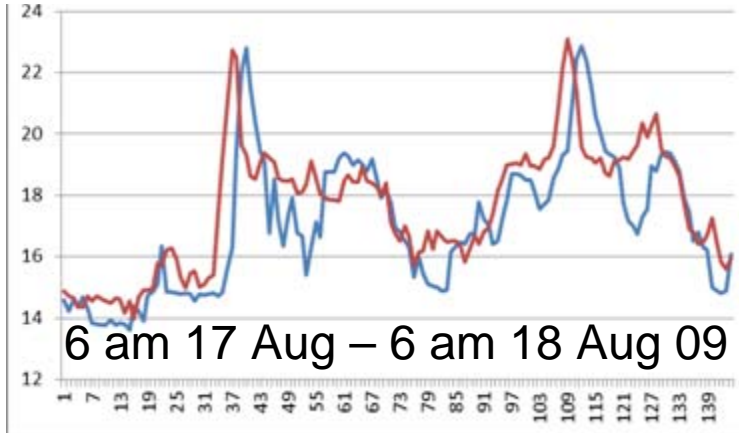
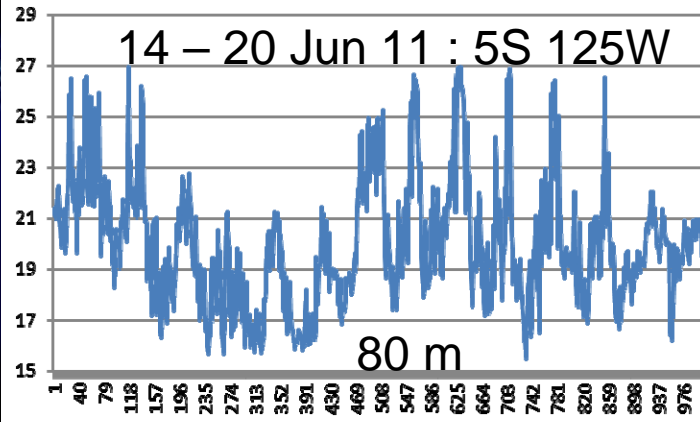
Depth	Average Depth	Legacy T	Refresh T	Delta T	Gradient T	New Delta
1	1.014	26.452	26.423	0.029		
20	20.285	26.385	26.346	0.039	0.003995	0.038
60	60.861	26.269	26.229	0.040	0.002884	0.037
80	81.148	25.397	25.182	0.215	0.051609	0.150
120	121.722	16.585	16.301	0.284	0.222025	-0.129
140	142.009	14.212	12.063	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



Internal Wave Examples



Blue = 60 m
Red = 80 m
Green = 100 m



Temperature and Salinity Calibration Drift Results

Parameter	Average of Abs Values	Average	Maximum	Minimum
Temperature (N=226)	0.000146	-0.000072	0.0008	-0.0009
SBE-39 (N=202)	0.000133	-0.000080	0.0008	-0.0009
SBE-37 (N=24)	0.000257	-0.000016	0.00053	-0.0008
Salinity (N=24)	0.001729	0.001646	0.0052	-0.0008

Temperature drift is °C per year
Temperature accuracy limit = 0.01°C
Salinity drift is psu/month
Salinity accuracy limit = 0.02 psu



Refresh System Testing

- Before incorporation into the TAO array to take the place of TAO Legacy buoys
- Refresh data were transmitted over the GTS under a different header than the Legacy data
- This allowed users to alter code to be able to calculate a daily average value, as averages are not included in the real-time data stream.
- Led to a smooth transition, when the Refresh system was deployed



Refresh Buoy Deployments

Lat/Lon	WMO ID	Deployment	Payload
2S165E	52002	2-3-11	dm019a
5S125W	51018	12-8-11	dm023a
8S155W	51302	13-10-11	dm025a
5N165E	52003	10-11-11	dm027a
8S165E	52007	16-11-11	dm029a
2S180	52312	24-11-11	dm030a
8S95W	32305	16-2-12	dm032a
2N125W	51016	31-3-12	dm033a
8S125W	51308	5-4-12	dm034a
5S140W	51004	9-4-12	dm035a
5N140W	51007	15-4-12	dm036a
9N140W	51006	17-4-12	dm037a

Lat/Lon	WMO ID	Deployment	Payload
8N170W	51308	13-5-12	dm038a
2N170W	51305	15-5-12	dm026b
001700W	51010	15-5-12	dm039a
2S170W	51306	18-5-12	dm040a
2N 180	52310	22-5-12	dm041a
00 180	52311	22-5-12	dm031b
8S 180	52316	26-5-12	dm042a
8S 170W	51310	5-6-12	dm043a
5S 155W	51019	10-6-12	dm044a
00 155W	51023	12-6-12	dm045a
5N 155W	51020	14-6-12	dm046a
8N 155W	41301	15-6-12	dm047a



Results

- Refresh systems are replacing Legacy systems in the TAO Array
 - Twenty-four locations are Refresh buoys as of Sep 2012
 - Climate principles governed the TAO Refresh Effort
 - Managing network change, parallel testing, data quality and data continuity
 - TAO Refresh system was tested
 - Comparison data supplied by Legacy System
 - Twenty-two Refresh systems have been deployed and eighteen tested against Legacy systems in the TAO Array
 - Both daily-averaged and 10-minute high resolution data compared
 - TAO Refresh data were transmitted through the GTS as development data for testing at Modeling Centers
 - Iridium communications continue to exceed 98%
- Plan to complete Refresh of the TAO array in 2015



Refresh Benefits

- Commercial Off-The-Shelf (COTS) components
 - SeaBird-39 and -37 systems use same “sensors” as Legacy
 - Electronics/Processing have been upgraded, standardized
 - PMEL no long has to provide systems
- Automated Modular Processing System (AMPS)
 - Used in other NDBC buoy systems
 - Stores all sensor data (including sub-surface) on-board
- Iridium satellite communications
 - Hourly data transmission
 - High resolution (10-minute) data available in near-real-time
 - If transmits are complete, no need to download sensor data
 - Currently, data may not be ready for upload to database for months after retrieval of moorings, due to cruise length, packing, transport, processing, and acquisition of calibration files



Thank You



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