NDBC Ocean Observations

and the Potential Mission Applications for Unmanned Systems

Presented at NOAA Sponsored Workshop at IEEE/MTS OCEANS 2012

On

Integrating Autonomous Technologies in Ocean Observations

15 October 2012

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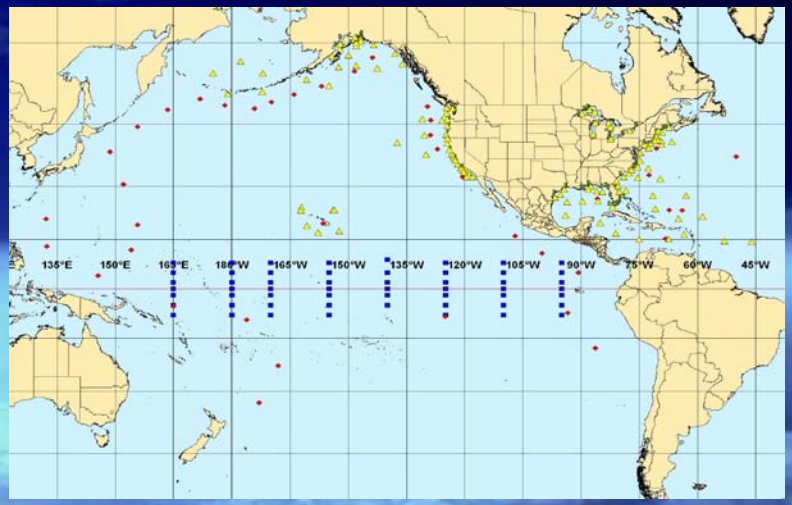
36°09'12.12" N 88°43'00.39" W elev 443 ft Eye alt 5926.67 mi

NDBC General Ocean Observation Requirements



- Operate in any Ocean Area Around the World (Equator to Arctic)
- Operate in all Seasons and Survive Extreme Weather (Hurricanes, etc…)
- Operate Continuously for a Minimum 1 Year Without Intervention
- Report 24/7/365 with Minimum 80% System and Data Availability
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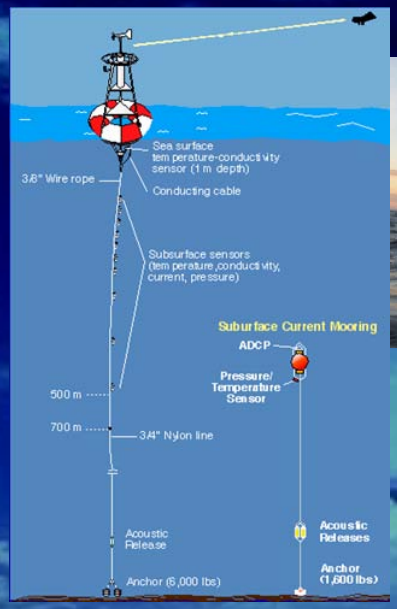
- Deployable with Reduced or Avoided Reliance on Large Ships with Cranes

NDBC TAO-Specific Additional Ocean Observation Requirements



Tropical Atmosphere Ocean Array (TAO) Required Accuracies and Sampling Resolutions

Parameter	Accuracy	Resolution	Range	Freq/Day	Max Delay (hours)	Averaging	Notes
Temperature (Ocean)	0.01°C	0.001°C	0 - 40°C	12	6	10 min	surface and 10 depths
Sea Surface Temperature	0.01°C	0.001°C	0 - 40°C	12	6	N/A	
Salinity	0.02 psu	0.002 psu	0 - 40 psu	12	6	10 min	surface and 7 depths[1]
Current Velocity				12	6	10 min	
Speed	5 cm s^{-1}	0.1 cm s^{-1}	0-250 cm s^{-1}				2
Direction	5°	0.1°	0-359°				2
Pressure (hydrostatic)	0.3 psi	±0.25% full scale	0-1000 psi				
Wind direction	5°	1.4°	0-359°	4	3	2 min	
Wind speed	0.3 m s^{-1} or 3%	0.2 m s^{-1}	0-35 m s^{-1}	4	3	2 min	
Air Temperature	0.2°	0.01°C	0.01°C	4	3	2 min	
Rel humidity	2%	0.4%	0-100%	4	3	2 min	3
Precipitation	0.4 mm hr^{-1}	0.2 mm hr^{-1}	0-500 mm hr^{-1}	1	3	3 hr	3,4
S/W radiation	± 1%	0.4 W m^{-2}	0-1600 W m^{-2}	12	6	1 hr	3
L/W radiation (down welling)	± 1%	0.1 W m^{-2}	0-500 W m^{-2}	12	6	1 hr	3,4
Surface Air Pressure	0.1 hPa or 0.01%	0.1 hPa	800-1100 hPa	4	6	2 min	3

[1] Surface salinity should be measured at all sites. Subsurface salinity at all flux reference sites and at selected additional sites. Subsurface salinity at 6 depths below surface: 10, 20, 40, 60, 80, and 120m or 10, 25, 50, 75, 100, and 125 m.
[2] For ADCP measurements, profiles shall span 20-250 m with 8 m vertical resolution. For point velocity measurements, current meters shall be placed at 1 to 5 depths in the upper 200 m, with at least one within 10 m of the surface. Current should be measured at all flux reference sites and at other selected sites.
[3] At flux reference sites only.
[4] Required only if an outside agneyc provides LWR and a rain sensor

- **All Observation Measurements must be Climate Principles Compliant**
- **Real-Time Surface MET, Sea T & C, and Profile T, & P to ~ 500m Depth**
- **Survive Increasingly Prevalent Vandalism**
- **New Requirement – Real-Time Cameras on all Platforms**

NDBC WX-Specific Additional Ocean Observation Requirements

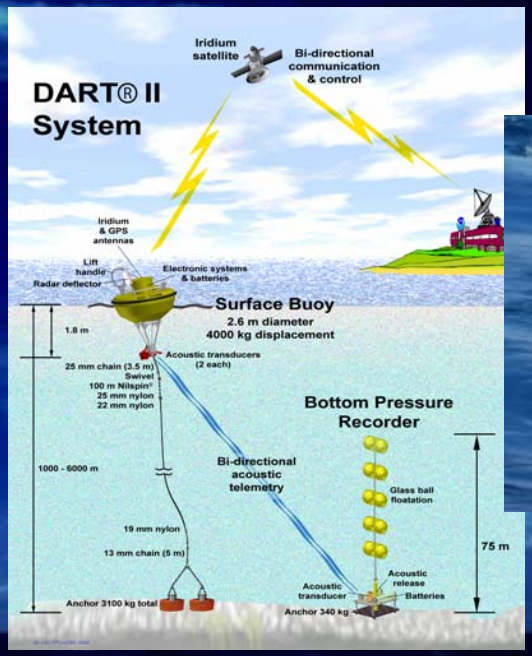
Meteorological and Ocean Platform (MOP) Required Accuracies

Parameter	Reporting Range	Reporting Resolution	Sample Interval (s)	Sample Period	Total System Accuracy
Wind Speed[2]	0 - 62 m/s	0.1 m/s	1	8 min [2]	± 1 m/s OR 10%
Wind Direction [2]	0 - 360°	1°	1	8 min [2]	± 10°
Peak Wind	0 - 82 m/s	1 m/s	1	5s	± 1 m/s OR 10%
Air Temperature	-40 to 50 °C	0.1 °C	90	8 min	± 1°C
Barometric Pressure[1]	800-1100 hPa	0.1 hPa	4	8 min	± hPa
Solar Radiation[4]	0-2150 W/m^2	0.5 W/m^2	1	8 min	± 5%
Dew Point Temperature	-35 to 30 °C	0.1 °C	1	8 min	± 1°C
Precipitation Rate (ORG)[4]	1-1600 mm/hr	1 mm	1	15 min	± 5%
Sea Surface Temperature	-7 to 41 °C	0.1 °C	1	8 min	± 1°C
Significant Wave Height	0 - 35 m	0.1 m	<0.6	20 min	± 0.2 m or 5%
Wave Period	3 - 30 s	0.1 s	<0.6	20 min	± 1 s
Non Directional Wave Spectra	0.03 - 0.40 Hz	0.01 Hz	<0.6	20 min	--
Directional Waves[3,4]	0 - 360°	1°	<0.6	20 min	± 5°
	0.03 - 0.35 Hz	0.01 - 0.2 Hz	<0.6	20 min	± 5%
Conductivity[4]	0-70 µS/cm	0.0001 µS/cm	1s	8 min	± 0.001µS/cm
Sea Level[4]	0 - 99.99 ft	.01 ft	1s	3 min	± 1 ft
Ocean Current Profile - Relative Velocity[4]	0 - 1000 cm/s	1 mm/s	1s	5 min	± 5 mm/s or 1%V
Ocean Current Profile - Direction[4]	0 - 360 deg	0.1 deg	1s	5 min	± 2°

[1] Extended range of 600 - 1100 hPa reported on select stations; else 900 - 1100 hPa
[2] For continuous winds, reported on select stations, successive 10-min samples.
[3] Wave sampling period 40 min on some systems
[4] Parameter reported on selected MOP stations
[5] Parameter reported on tsunami buoys

- **Stringent MET and Ocean Platform (MOP) Required Accuracies**
- **Standard MET Measurement Height = 4m/5m ; some IOOS Partners = 3m**
- **Move Away from Reliance on USCG for Deployment and O&M**
- **Future Requirement – Real-Time Cameras on all Platforms**

NDBC DART-Specific Additional Ocean Observation Requirements



Deep ocean Assessment and Reporting of Tsunamis (DART) Required Accuracies and Sensitivities

Parameter	Requirement
Pressure Measurement sensitivity	1 millimeter in 6000 meters ($2x10^{-7}$)
Sampling interval, internal record	15 seconds
Sampling interval, event reports	15 and 60 seconds
Sampling interval, tidal reports	15 minutes
Two-way end-to-end communications	On demand, tsunami warning center (TWC) trigger
Tsunami data report trigger	Automatically by tsunami detection algorithm
Data flow, BPR to TWC	Less than 3 minutes after triggered event

- **Bottom Pressure Sensor Survivable to ~ 6000m & Meet TWC Standards**
- **Sea Surface C2 Relay Platform must hold Station within ~ 3nm Watch Circle**
- **Future Requirement – MET sensors and Real-Time Cameras on all Platforms**

Where Unmanned Systems can fit into NDBC Operations

- **NDBC Procures COTS Platforms & Modifies & Integrates its own Systems**
  - Potentially Affords Most Control and Lowest Market Risk to Government
  - This is how NDBC has Historically Operated

- **NDBC Leases Platforms & Vendor Integrates NDBC Systems & Sensors**
  - Vendor could Prepare, Deploy, Retrieve, and conduct O&M of Platform
  - GOVT-Owned Sensors & Payload Systems would Return to NDBC for Refurb/Cal
  - Liability Issue on Platform Damage while under NDBC MCC Command & Control

- **NDBC Buys Ocean Observations and lets Vendor Define Platform Solution**
  - GOVT Needs to be Protected from Disruption or Loss or Services
  - GOVT Needs to Retain Command & Control of Data Availability & Quality

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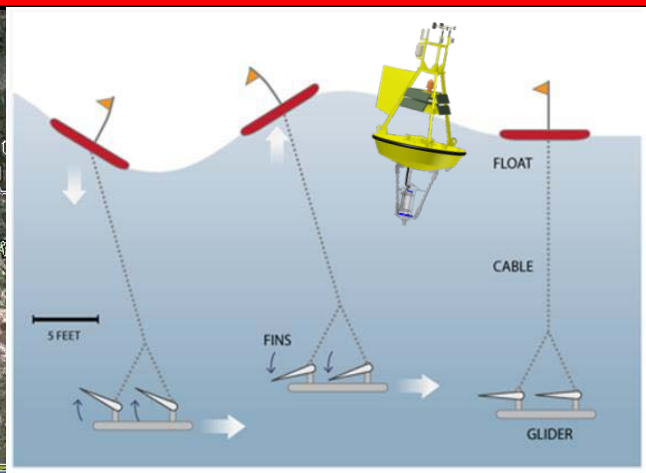
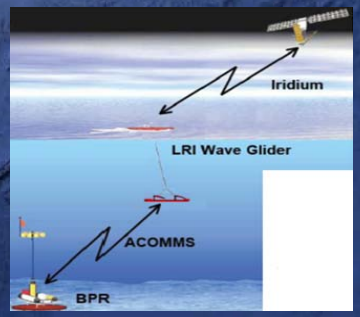
- **Common Denominator**
  - Pre & Post Mission Sensor Testing & Calibration Controlled/Managed by NDBC
  - Procured & Leased Platforms Command & Controlled by NDBC MCC
  - All Data Quality-Controlled and Released by NDBC MCC

NDBC Operational T&E Experience and Lessons Learned

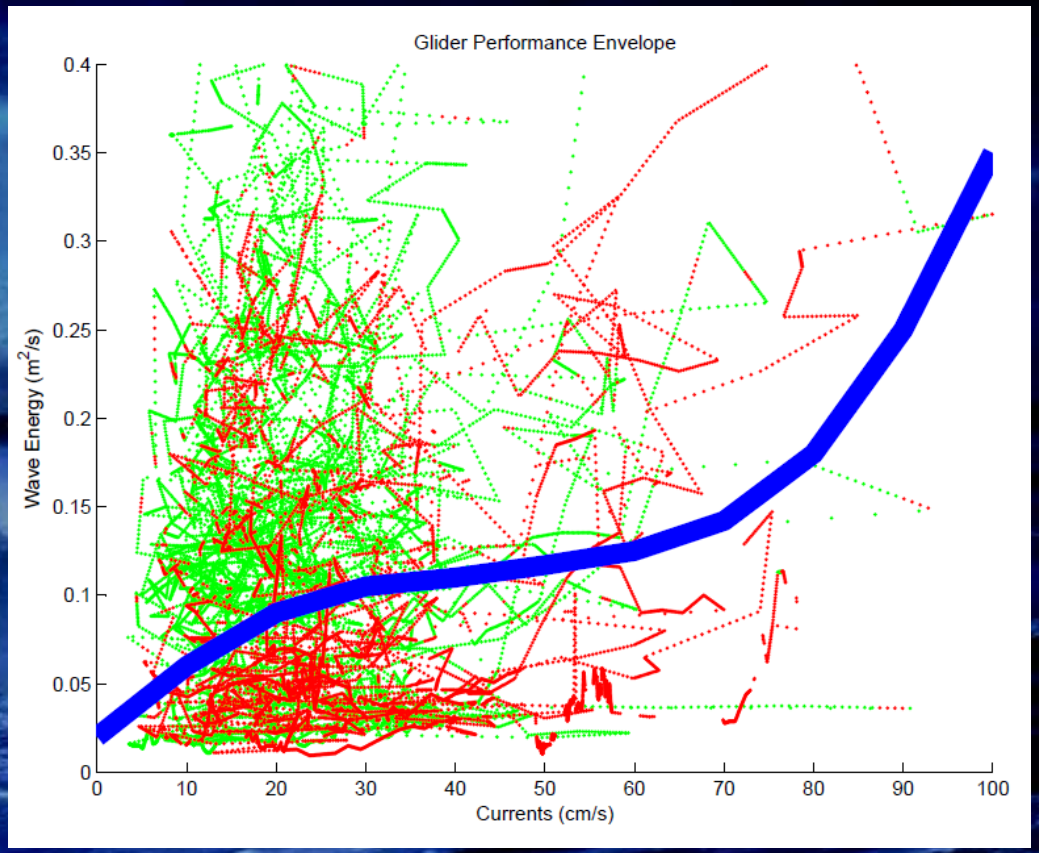




NDBC Wave Glider Test and Evaluation

Test Results – Station Keeping Data

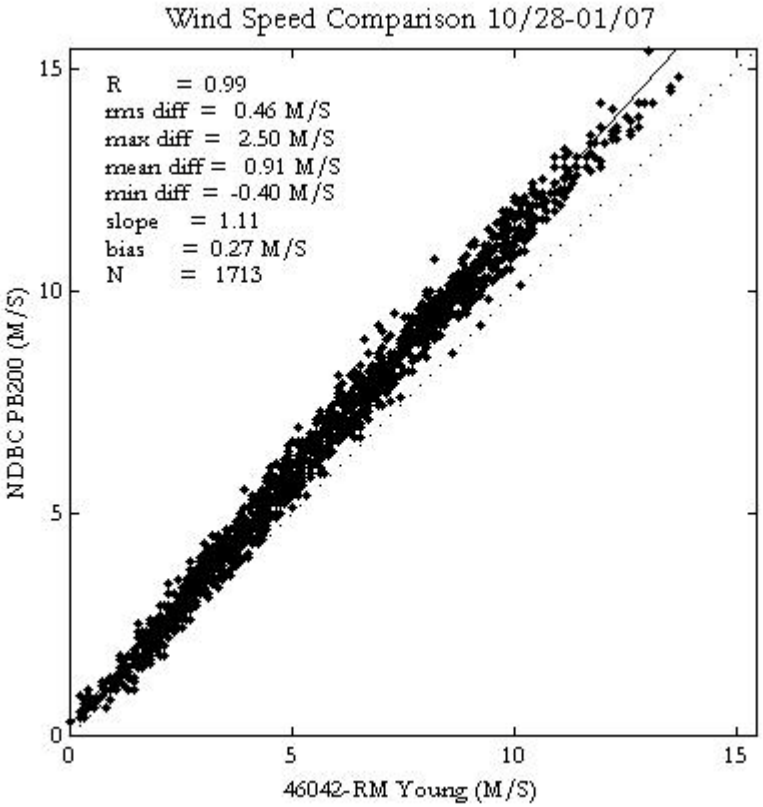
Watch Circle Radius (m)	Percentage in Circle
700	64.9
1500	70.2
3000	77.6
6000	83.7

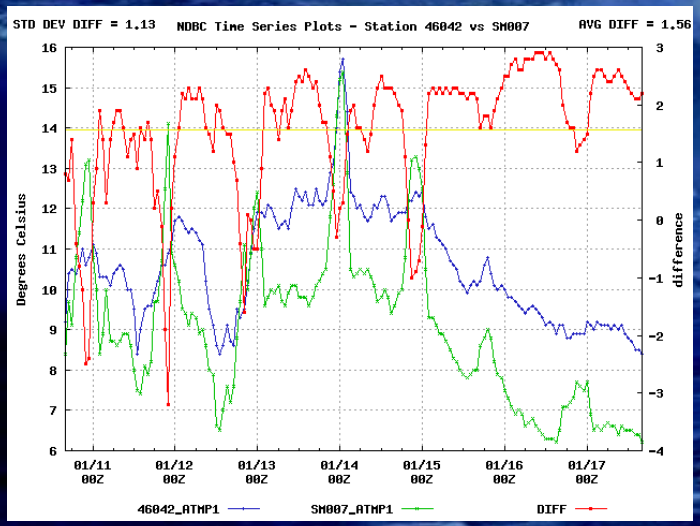


AIRMAR Sensors vs Wx Sensors – both on Buoy (5m)

Table 2

Measurement	80% tolerance
Wind Speed	1.2 m/s
Sea Level Pressure	.87 mb

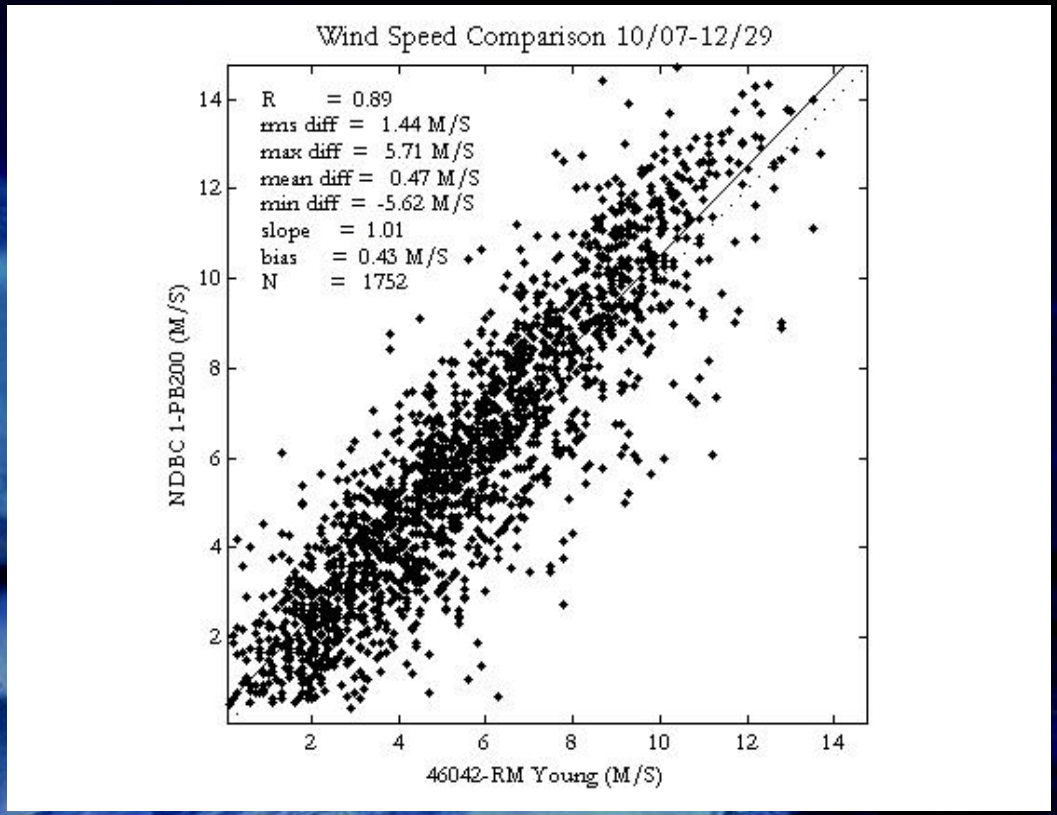


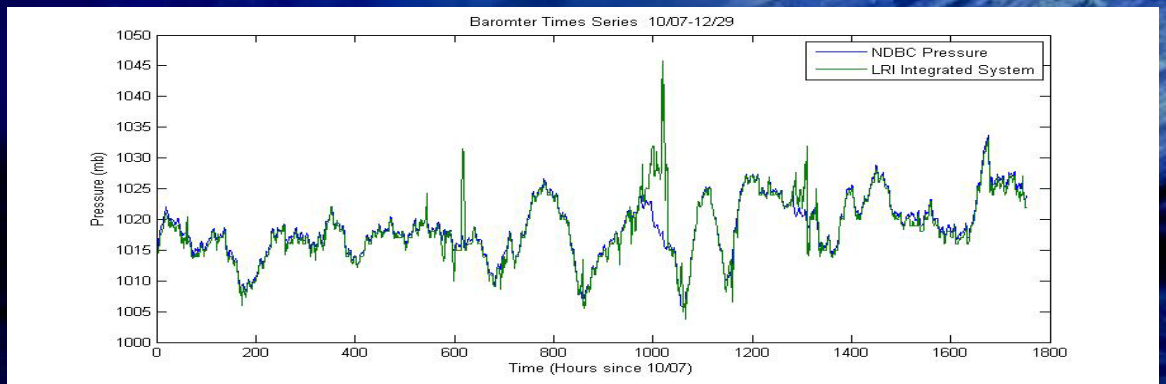


AIRMAR Sensors on Glider (1m) vs Wx Sensors on Buoy (5m) Performance

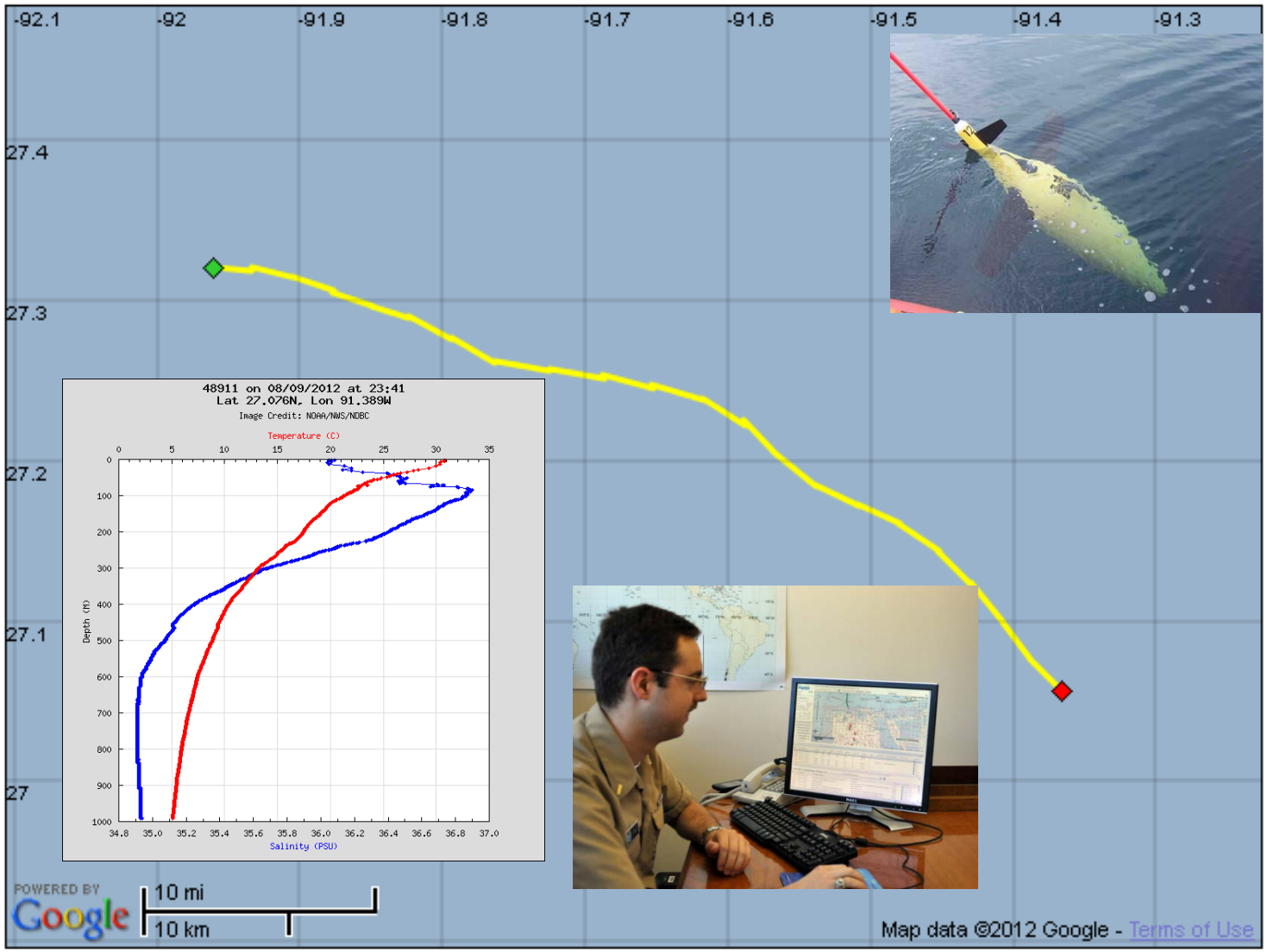
Table 1

Measurement	80% tolerance
Wind Speed	1.6 m/s
Sea Level Pressure	.91 mb
Air Temperature	6.2 ºC





Shell SeaGlider



◆ = start position

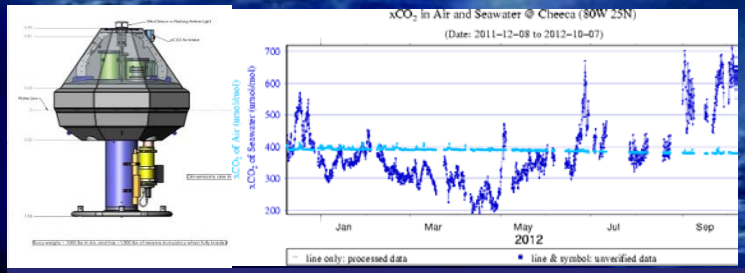
◆ = last reported position

NOAA Ocean Acidification Program Emerging Observing Requirements

Federal Ocean Acidification and Monitoring Act (2009)….

he FOARAM ACT calls for the establishment of a long-term monitoring program of ocean acidification utilizing existing global and national ocean observing assets, and adding instrumentation and sampling stations as appropriate to the aims.

• What are the rates and magnitude of OA and how does vary across time, space, and depth as a consequence of local and regional geochemical, hydrological, and biological mechanisms?



PMEL carbon group operates dozens of $MAPCO_2$ systems in the Pacific, Atlantic, and Indian oceans in collaboration with a wide range of partners. (T,S,pCO_2, pH)

International OA Observing Network Minimum* Requirements demand measure of T, S, Oxygen, and full Carbonate-system Constraint.

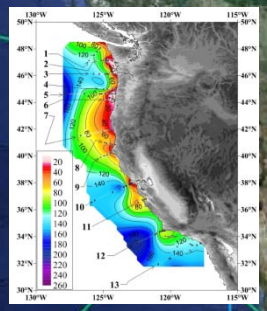
**Where feasible and appropriate* fluorescence and Irradiance should also be included.

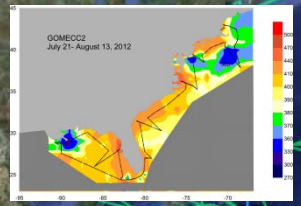
Carbonate-system constraint can be achieved in a number of ways, including combinations of measurements and synthetic, non-collocated estimates of other parameters.

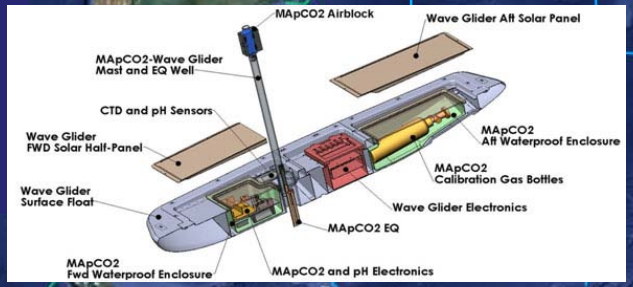
Critical Needs Include:

- *Enhanced monitoring in coastal/estuarine environments*
- *Autonomous measure of TCO_2 and/or TA*
- *Near-real-time may not be paramount in many applications*
- *Fixed subsurface measurements (e.g. benthic boundary within coral reefs) needed.*
- *Improved tech for measuring ecosystem response*

Current OA Observing Network







The current OA observing network is comprised of a suite of fixed stations, SOOP/VOS operations including autonomous underway systems and geochemical survey cruises in oceanic, coastal , and coral reef environments. (T,S, pCO_2, TCO_2, Alkalinity, nutrients, chlorophyll, etc.). New technologies are being evaluated including the a Carbon Wave Glider.

Image courtesy NOAA PMEL
http://www.pmel.noaa.gov/co2/story/Ocean+Acidification


Questions / Discussion