NOAA Approach to Testing New Water Level Sensors

- **When introducing new technology into pre-existing observatory, critical to conduct rigorous testing to fully understand sensor functions and performance**.
  - ➢ *provide extensive evidence to confirm sensor accuracy*
  - ➢ *quantify impact of environmental variability*
  - ➢ *design optimal processing techniques*

- **Test plan driven by NWLON's multiple applications and stringent requirements**
  - ➢ *Stations located in many different types of coastal environments*
  - ➢ *Data used to monitor many different processes, with range of time scales*

- **Previous testing throughout sea level community also taken into account**

- **Series of laboratory tests and long term field testing currently underway**

  - ➢ *Lab tests: basic target range, wave tank, environmental chamber*

  - ➢ *Field tests – Collect long term measurements in multiple locations near NWLON reference stations to capture broad range of environmental variability*

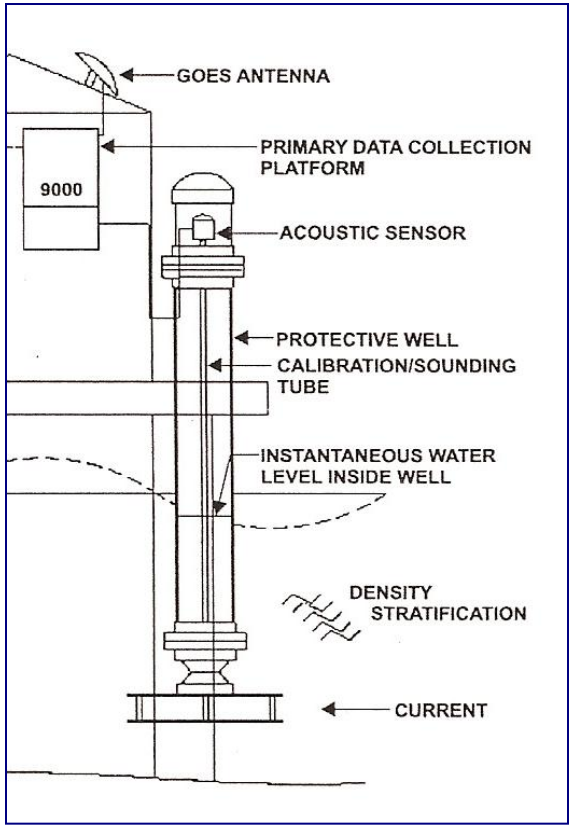
NOAA Microwave Sensor Performance Criteria

Table 1. Aspects of WaterLog® sensor that influenced selection for use at Port Townsend and similar environments.

Sensor Characteristic	Resulting Advantages
Smaller signal spreading angle (10 degrees)	Narrow footprint, high spatial measurement resolution, and decreased likelihood of false echoes when transmitting in enclosed well/sump (required in Great Lakes applications).
Required input voltage of 10-16 Volts DC	Low enough power requirement to operate in system consisting of DCP with just one 12-volt battery and one solar panel.
SDI 12 interface	Three-wire interface easily connects to Xpert DCP used by NOAA; sensor can be powered directly from DCP, eliminating need for additional power source.
Time of Flight (TOF) Tool Windows-based software - configuring sensor parameters	Sensor configuration parameters can be set very easily via laptop and RS232 connection. Software setup with graphics makes most parameters easy to understand.
TOF – automated plotting of return signals	A plot of sensor return signal, intensity versus range, is easily generated.
TOF – preventing detection of return signals from obstructions	TOF software can be used to easily eliminate return signals from obstructions in sensor field of view (in scenario where sensor still has a clear view of water surface).
TOF – enabling fast time response	Sensor time response can be easily adjusted to be very short (5 seconds) via TOF software.
1-Hz sampling	Sensor comes from the factory capable of logging range data to DCP at 1-Hz rate.
26 -GHz pulse signal	Addresses NTIA concerns about the possibility of sensor transmissions causing harmful interference.
Consistent, reliable, long-term performance	No signs of system reboots, sensor failures, or power downs. Minimal dropouts/gaps in 1-Hz record.

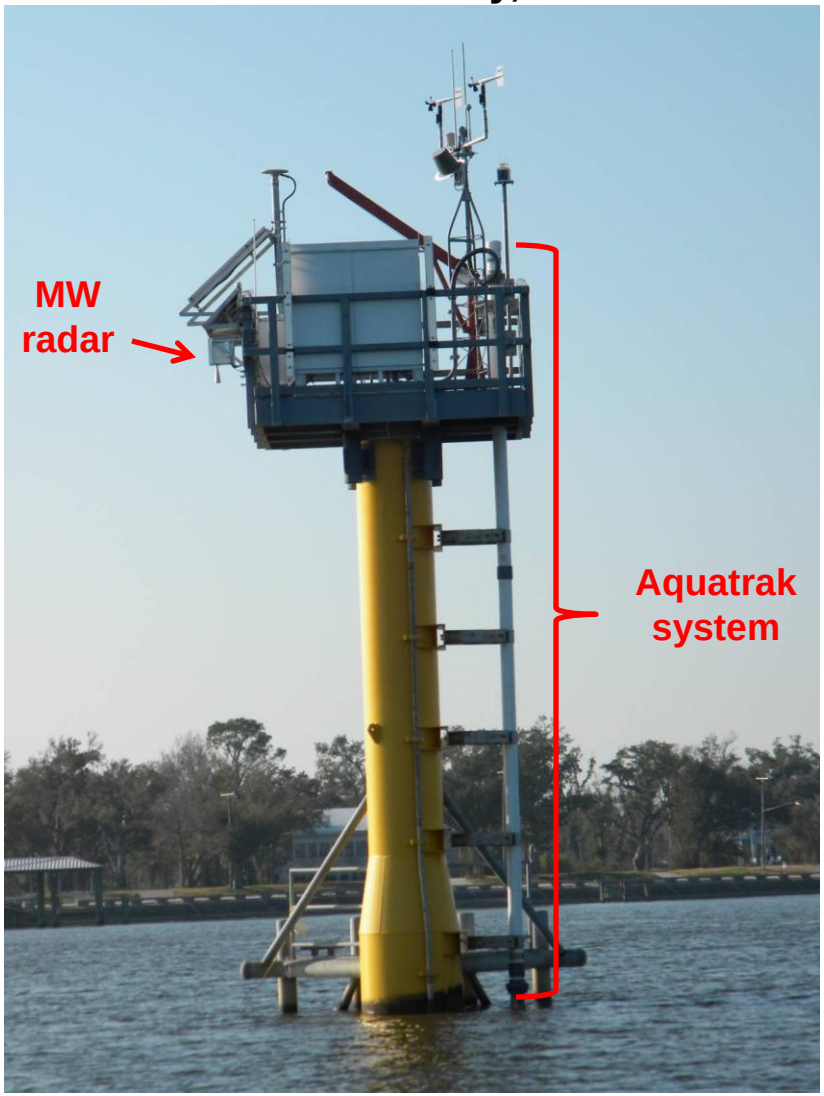
Water Level Sensor Characteristics

Aquatrak ®
acoustic sensor



Waterlog ®
microwave radar

NWLON 'Sentinel' station, St. Louis Bay, MS



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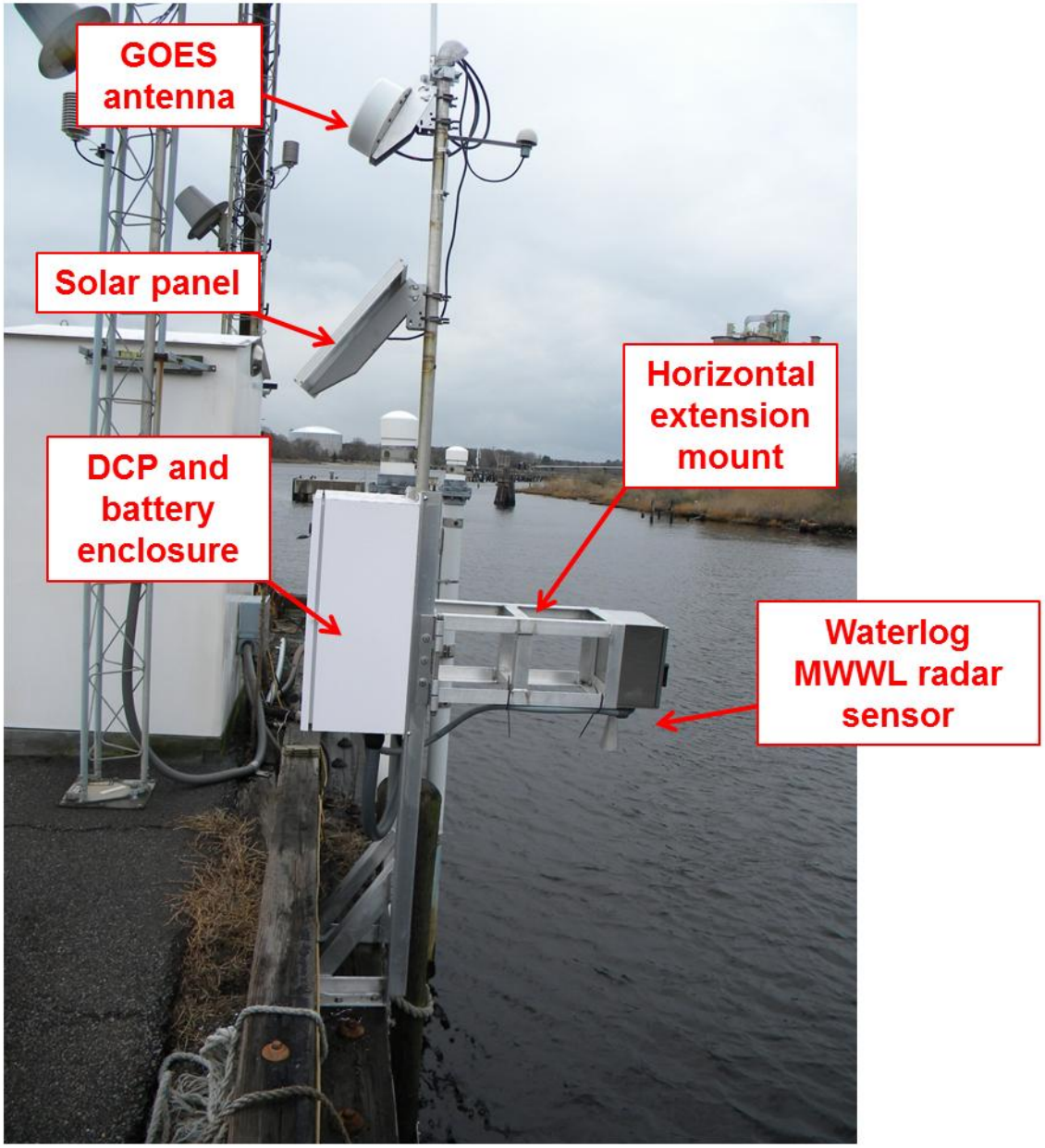
Transition to Operations Plan

NOAA effort to transition radar water level sensors to operations involve three different categories of applications:

1. Introducing WaterLog® sensors to a subset of existing NWLON stations.
2. Enabling use of WaterLog® sensors in hydrographic survey applications.
3. New water level stations where WaterLog® sensors can be introduced from start.


GOES antenna
Solar panel
Horizontal extension mount
DCP and battery enclosure
Waterlog MWWL radar sensor

MWWL Water Level Measurement

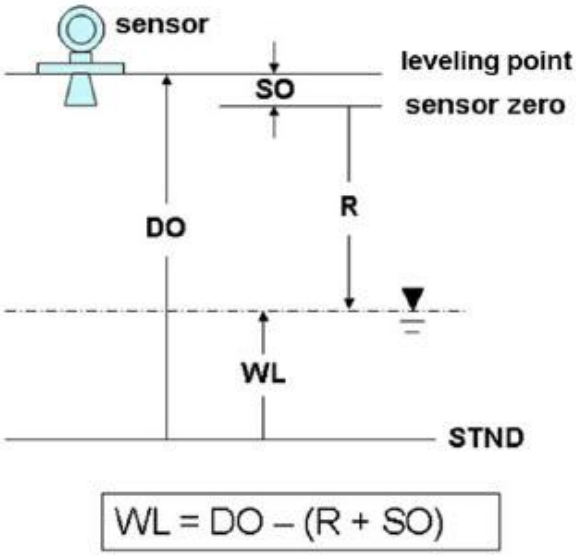


Figure 3. Depiction and expression for water level (WL) derivation *(taken from J. Boon 2011 MSEA test report).*

MWWL Water Level Testing and Calibration

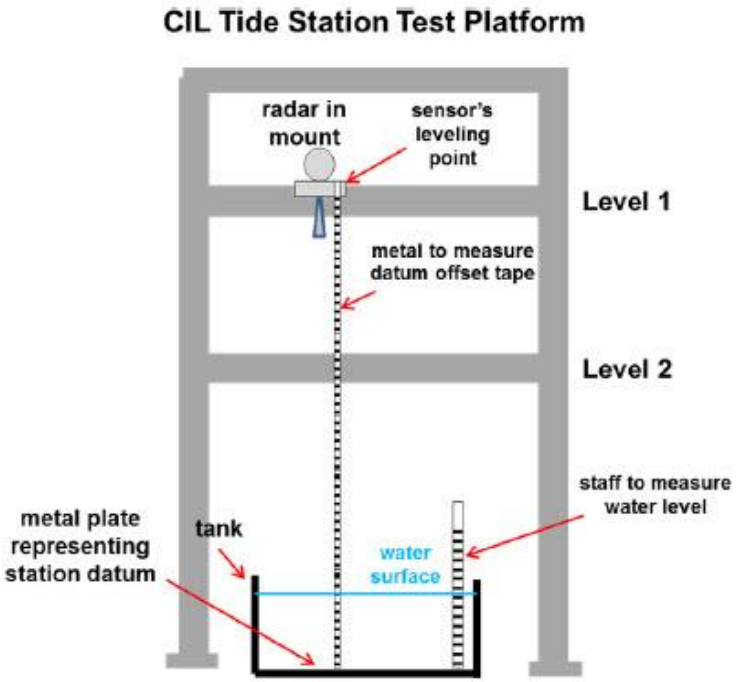
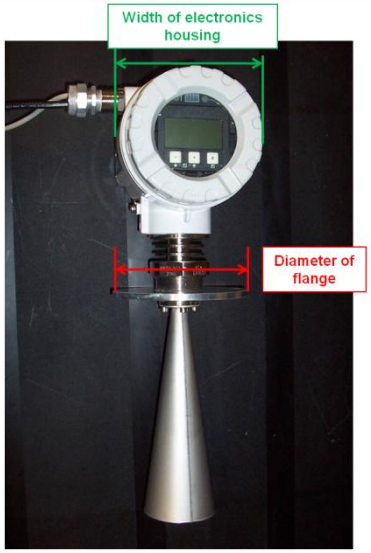
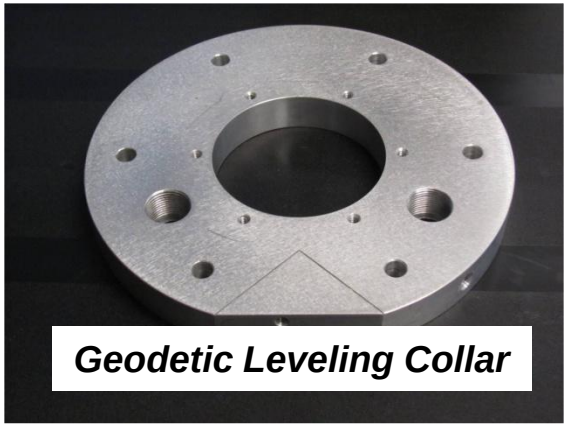


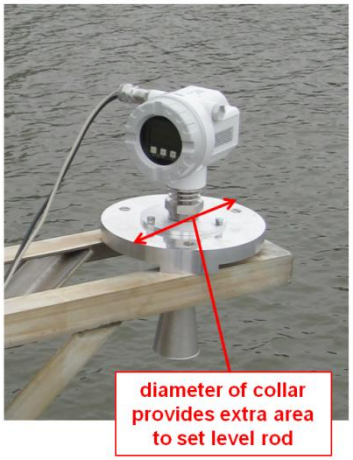
Figure 5. Diagram of radar offset verification test setup using the test platform shown in fig 4.

Transition to Operations

Mount Designs

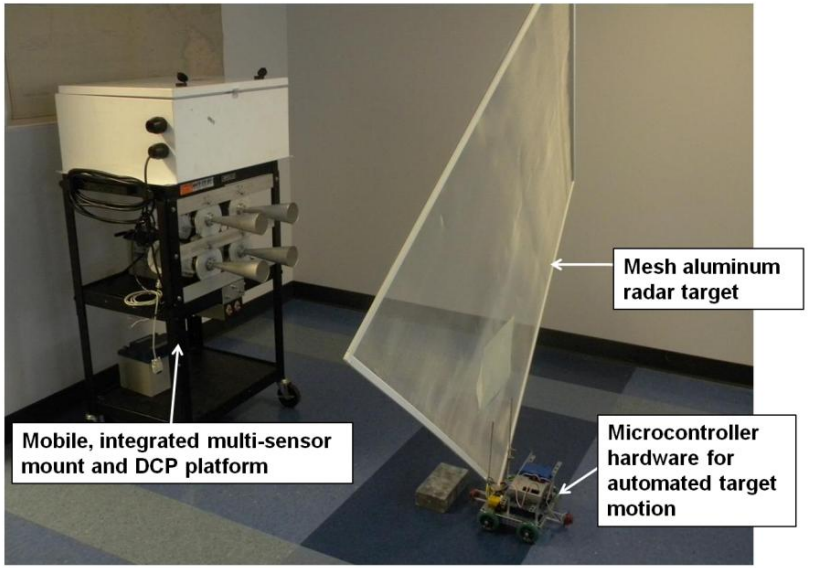






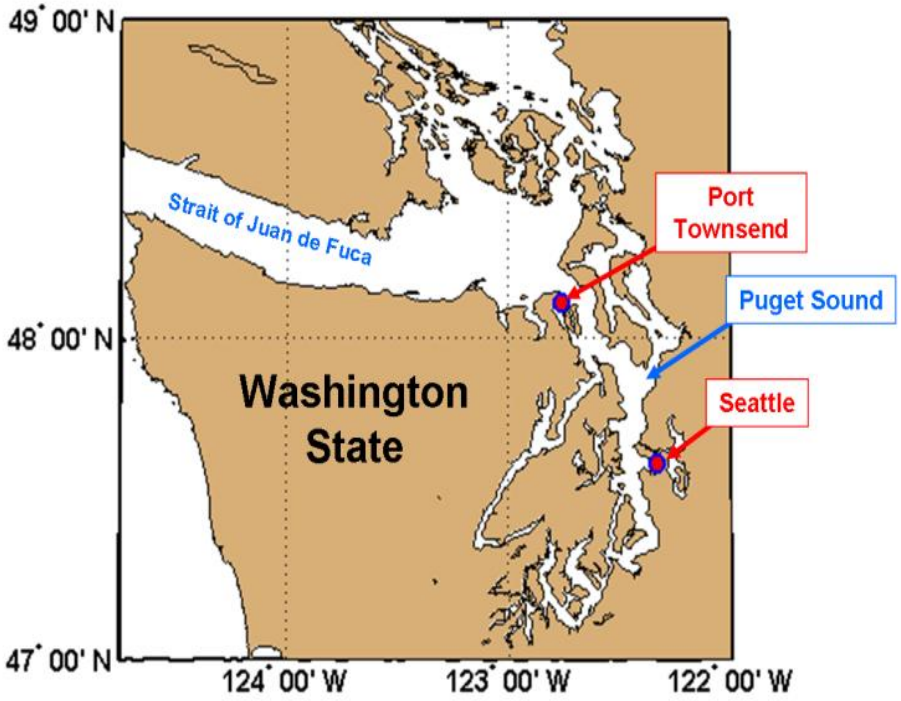
Laboratory Test Procedure and Facility

1) Fixed Target - Resolution Verification
2) Time Response Verification
3) Sensor Offset Derivation
4) Dynamic Liquid Tare test
5) Range Accuracy Verification

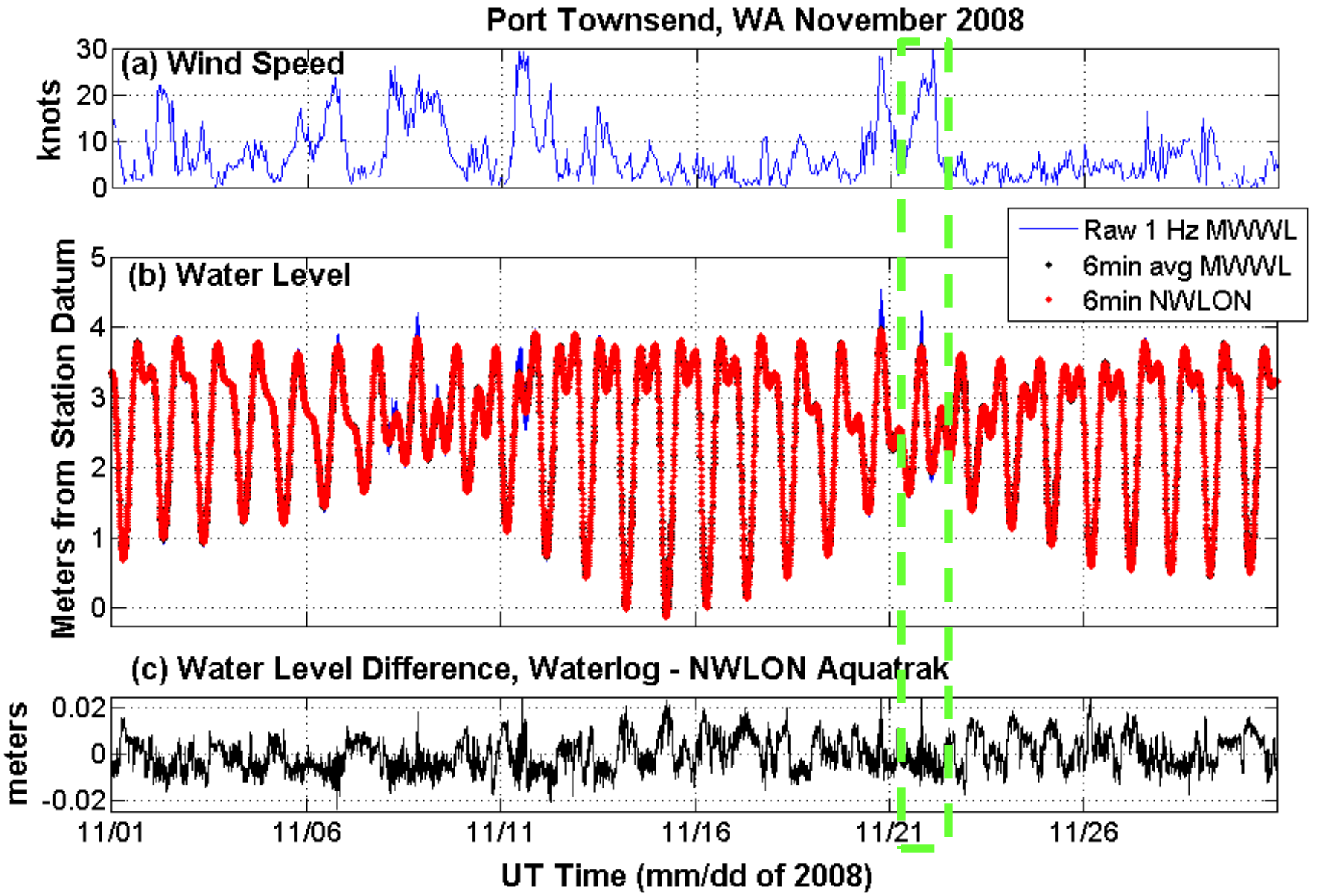


Long-Term Field Testing - Example

Port Townsend, WA



Field Test Data Analysis Results



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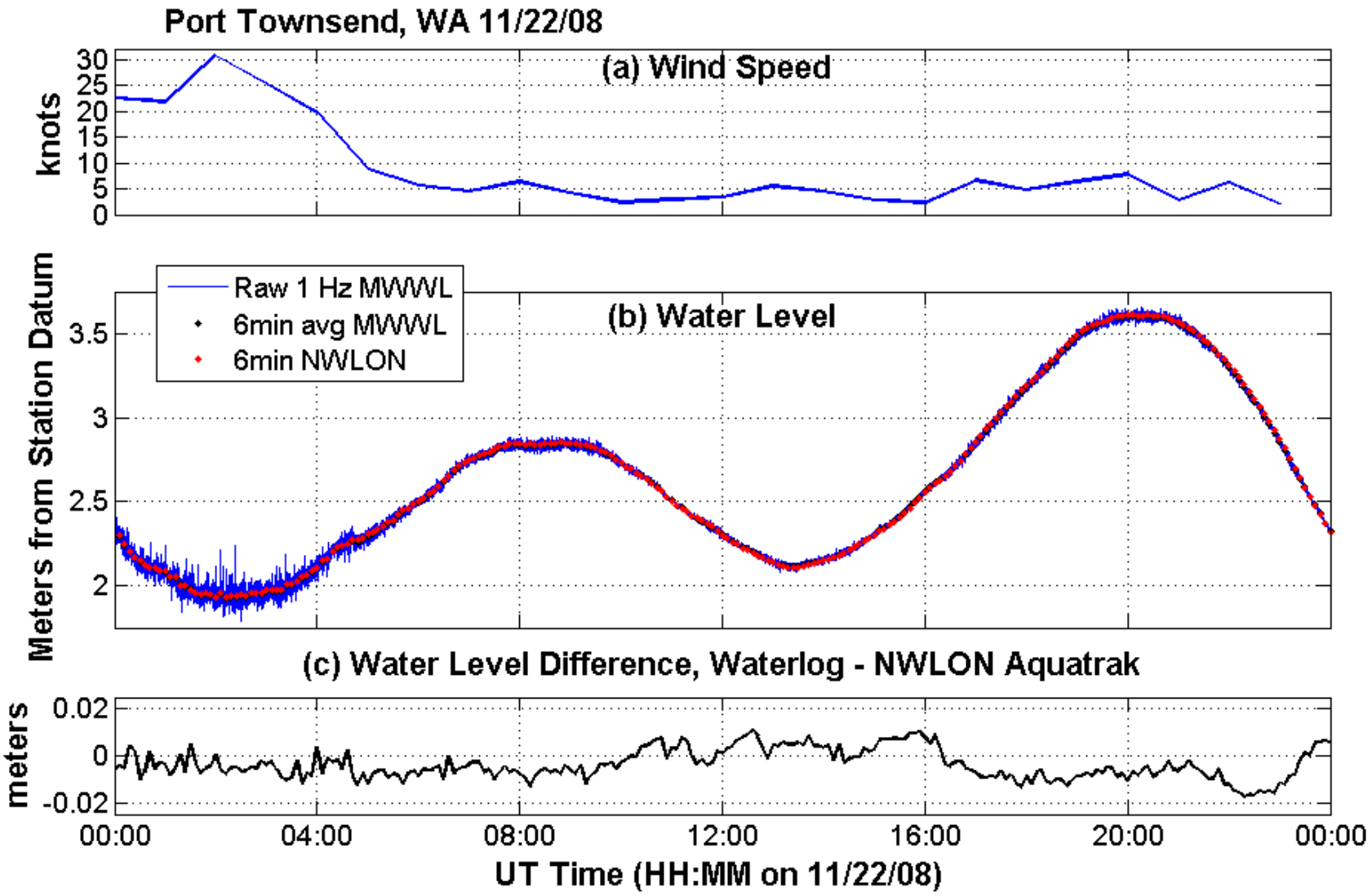
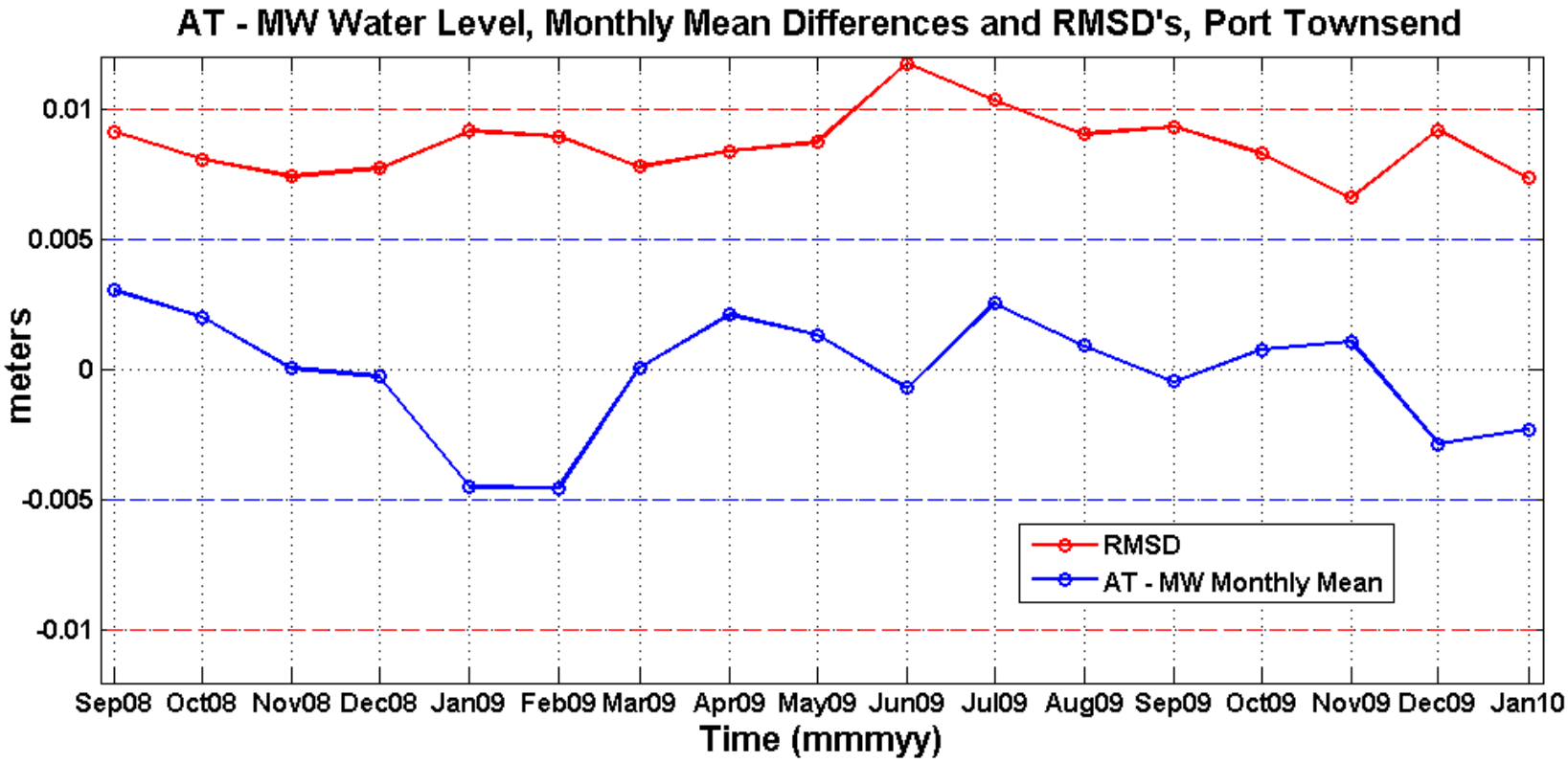
Field Test Data Analysis Results



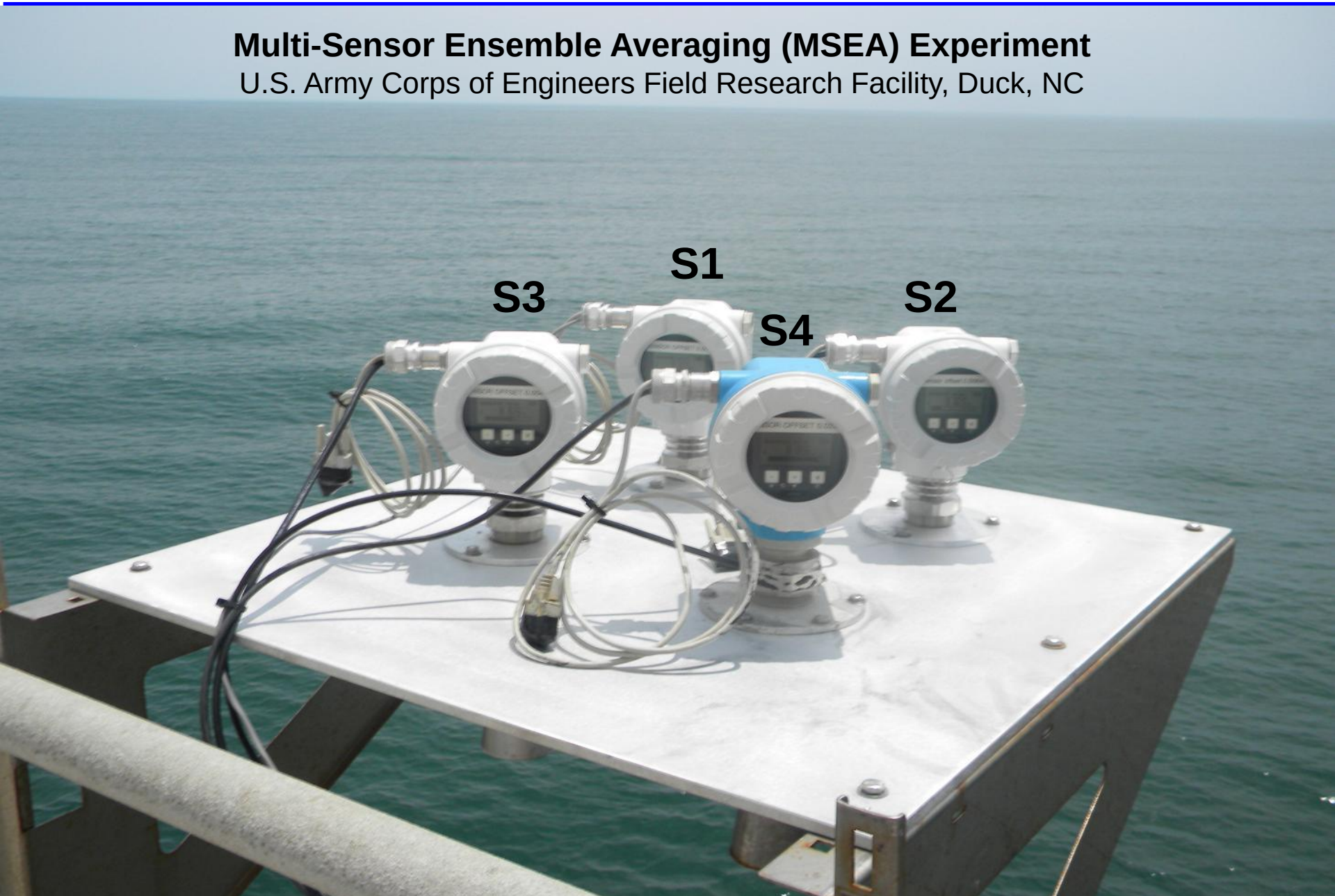
Field Test Data Analysis Results



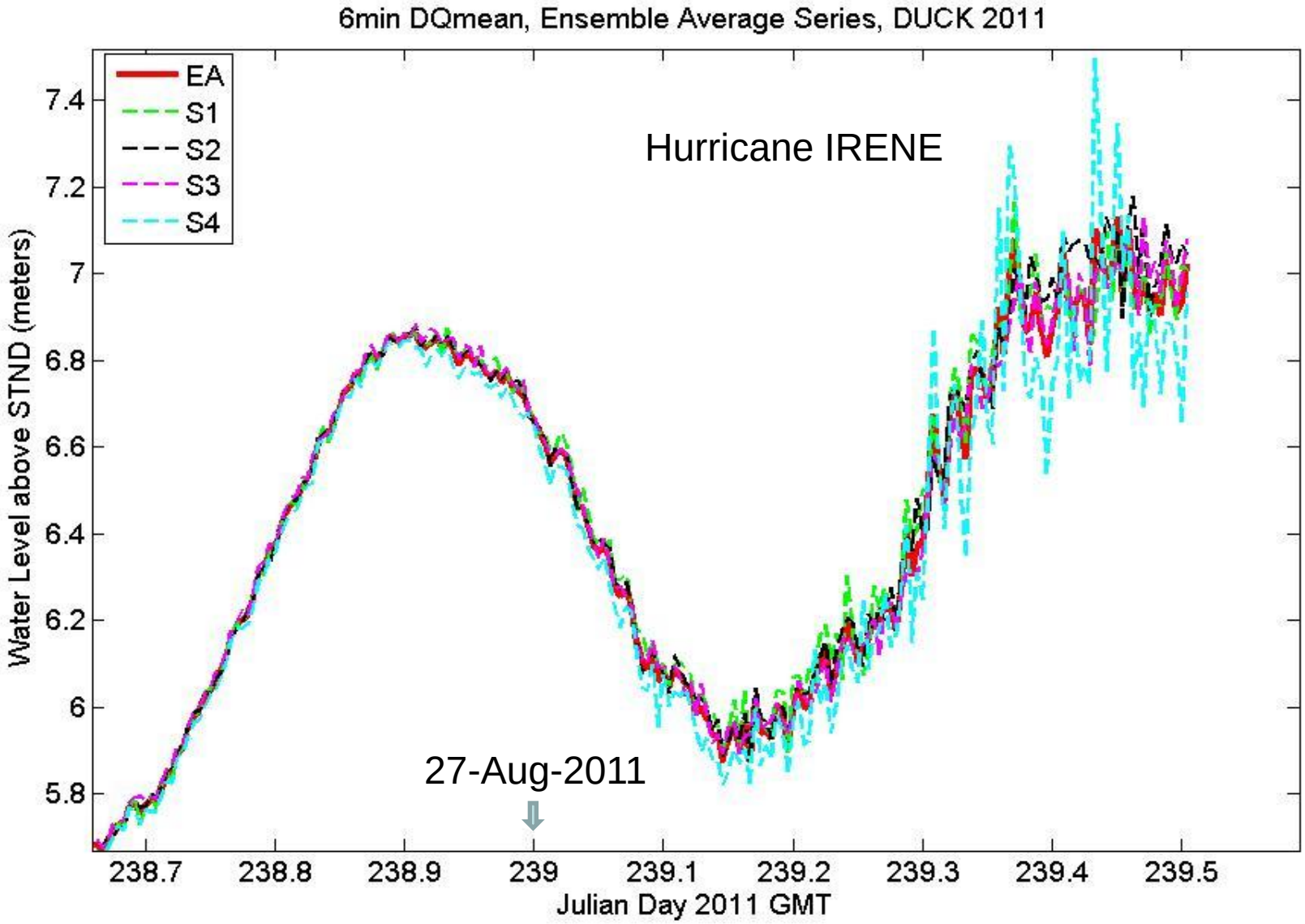
Additional Field Testing

Multi-Sensor Ensemble Averaging (MSEA) Experiment

U.S. Army Corps of Engineers Field Research Facility, Duck, NC



Additional Field Testing



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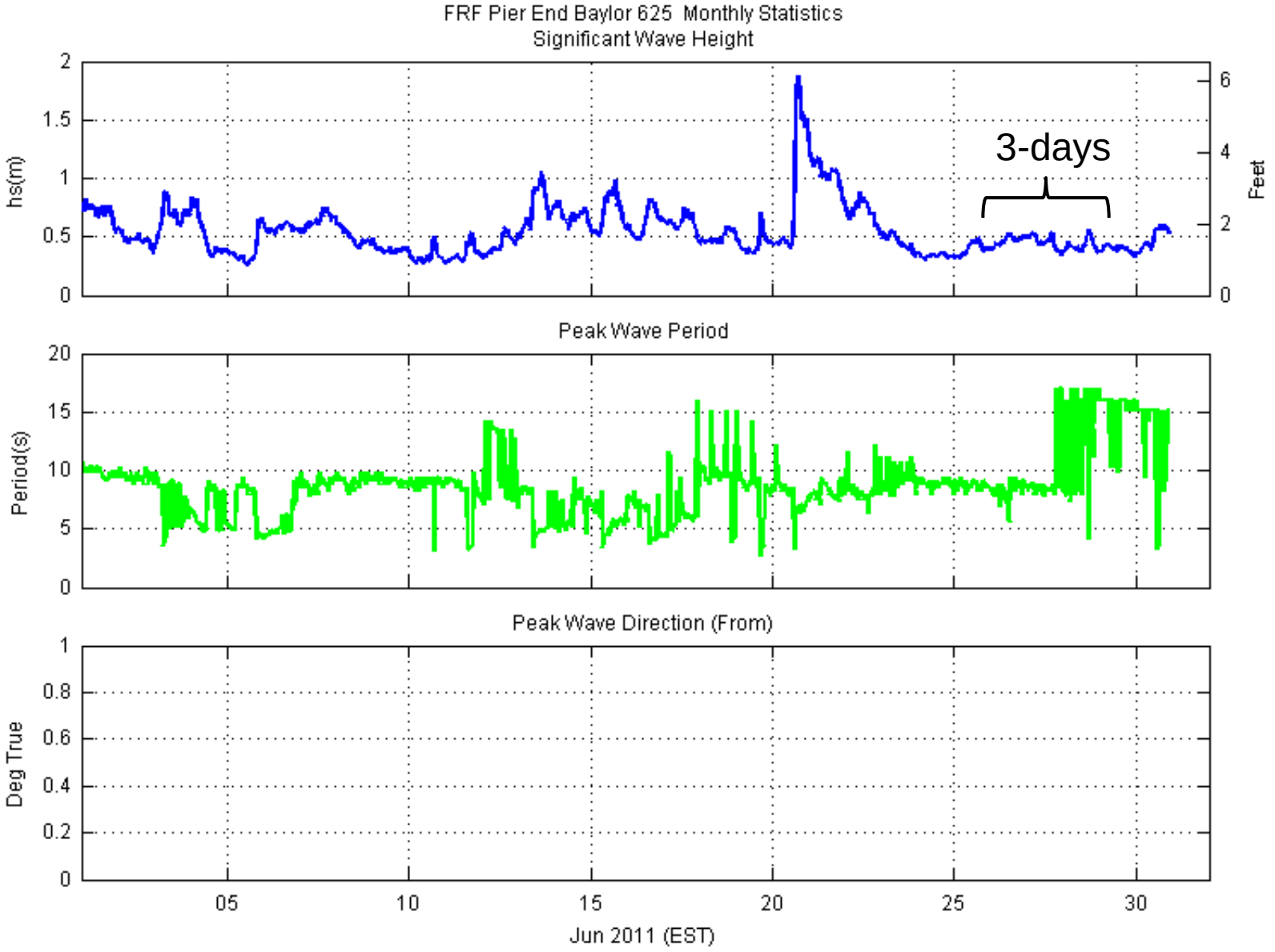
Multi-Sensor Ensemble Averaging (MSEA) Experiment – Duck FRF

- Six-minute data computed using 360 1-Hz water levels centered on the hour and tenth hour
- Arithmetic mean, DQ mean and Trimean computed
- Error analysis conducted using four model H-3611i microwave water level sensors (M=4) to obtain ensemble average (EA) at six-minute intervals
- Estimated sensor measurement error for jth sensor:

  $S_j = k\, S_{j\text{-}EA}$ where $k = (M/M\text{-}1)^{1/2}$ and $S_{j\text{-}EA}$ = RMS deviation between sensor j and the EA



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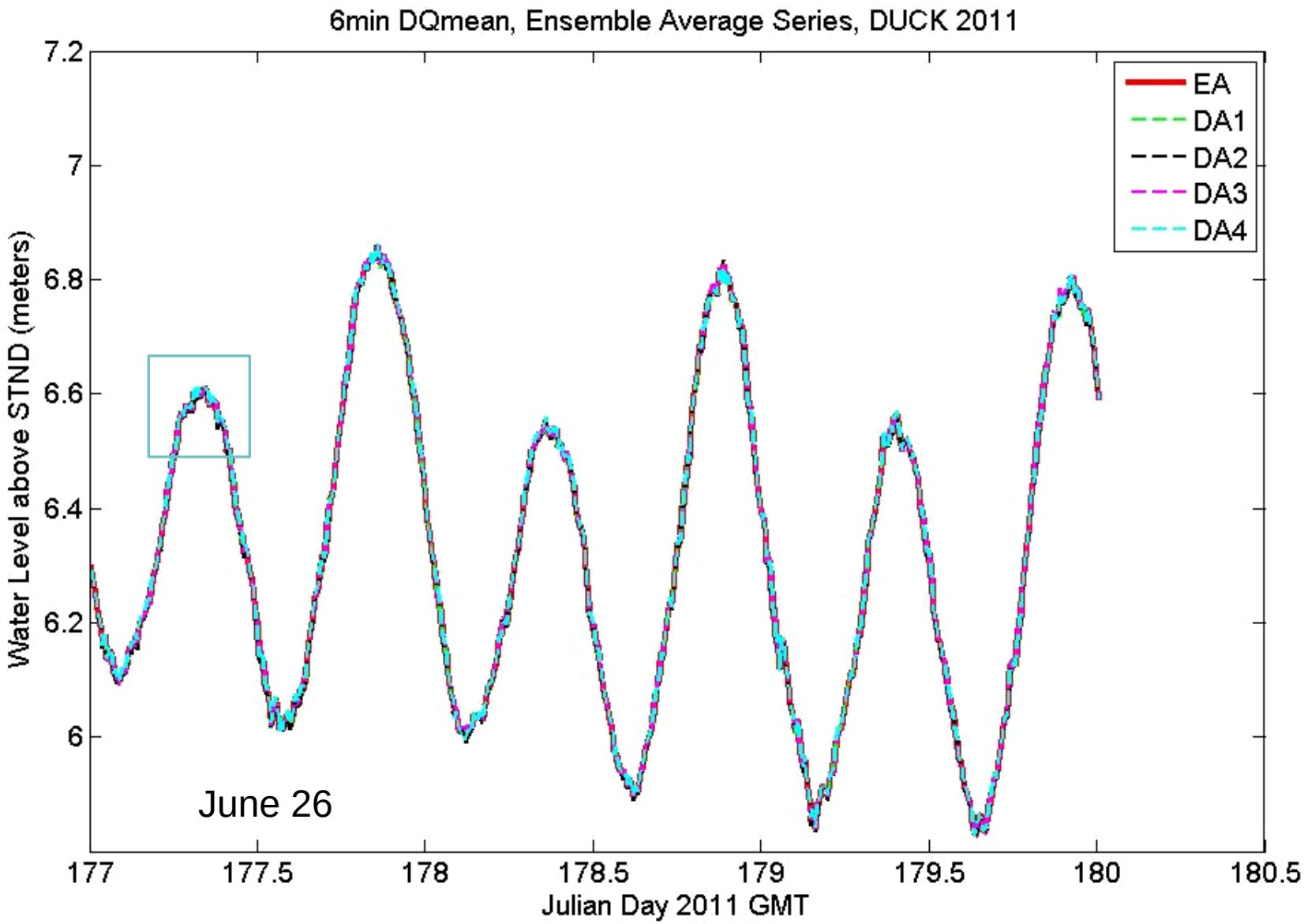

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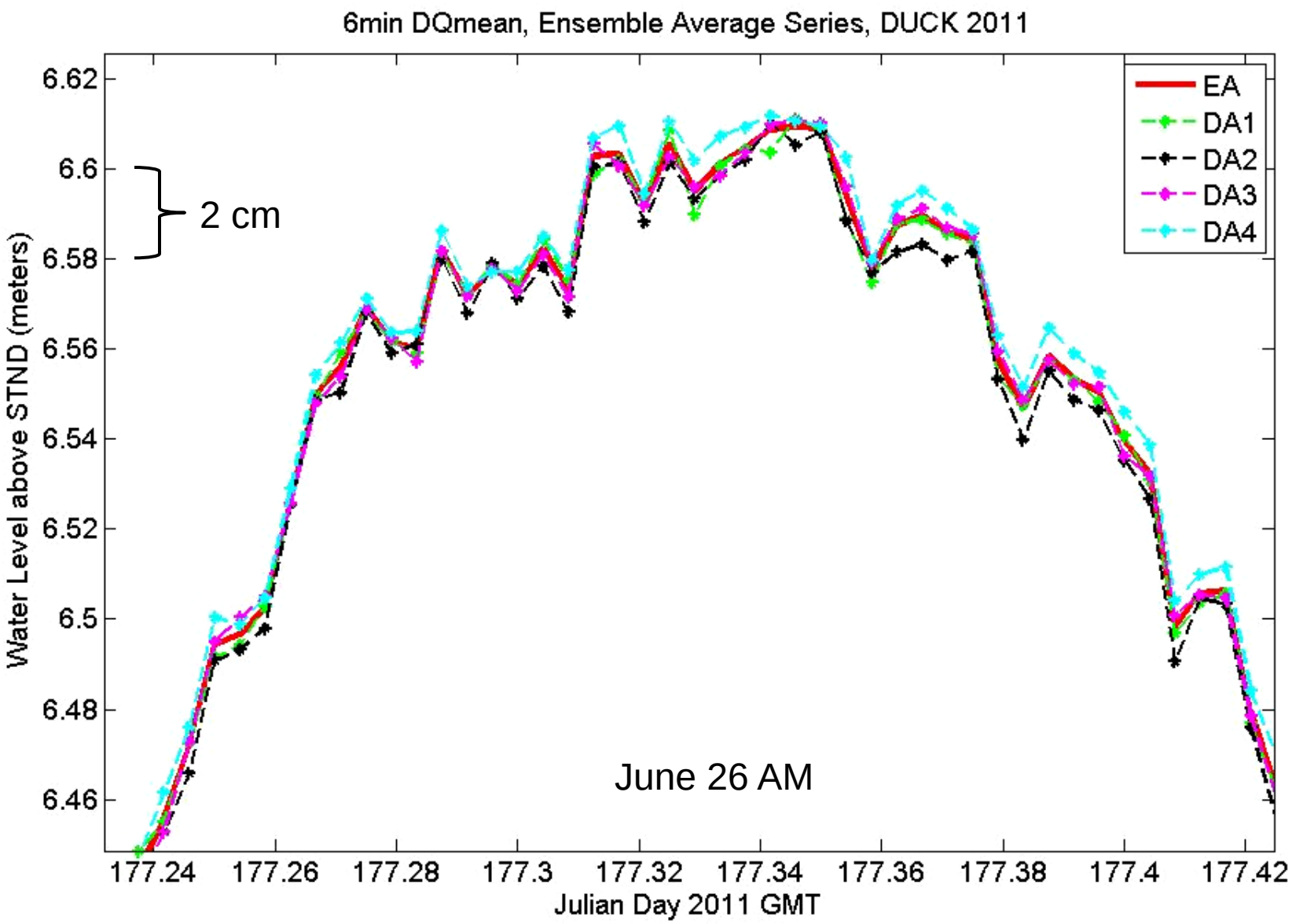

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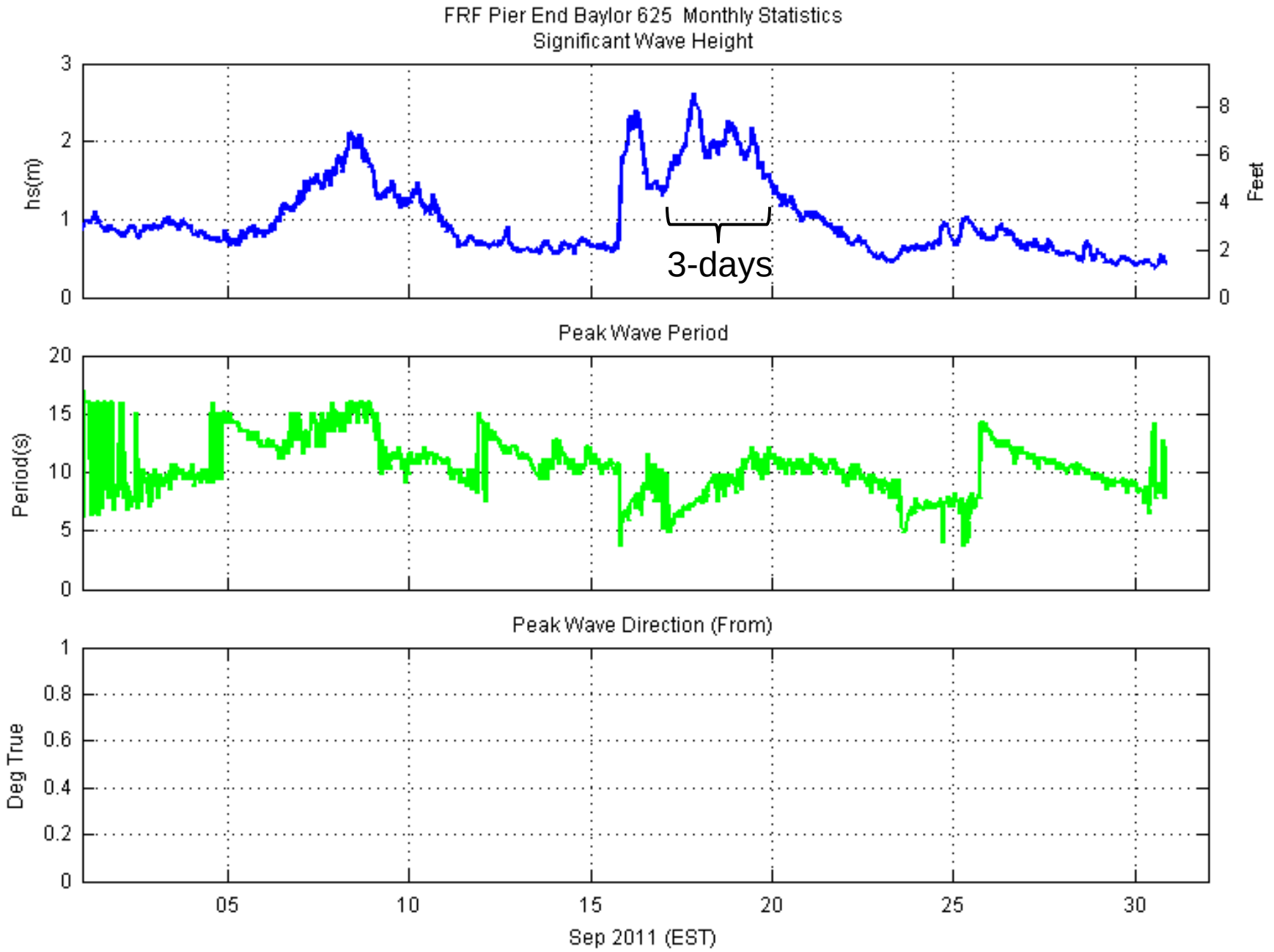

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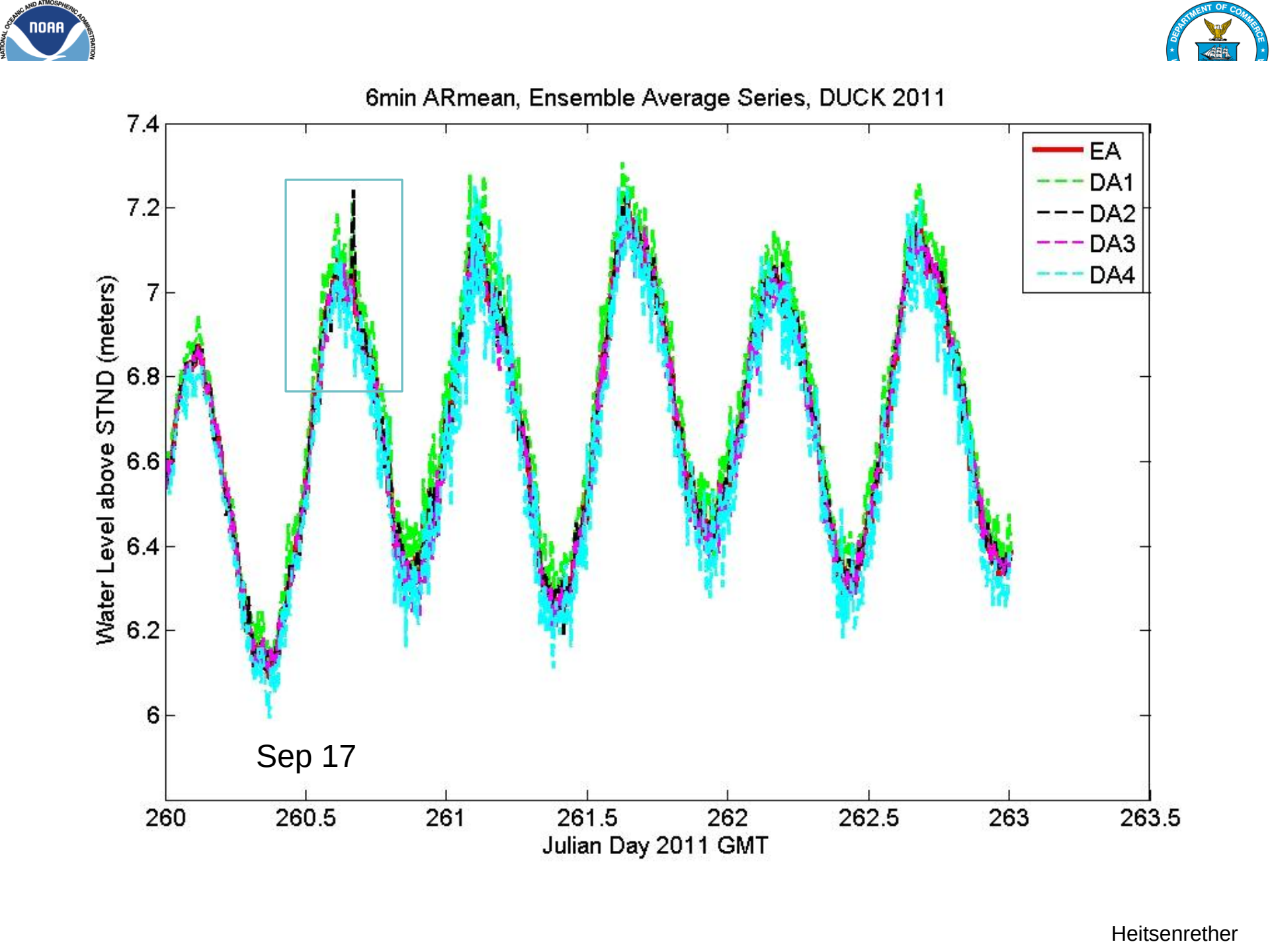

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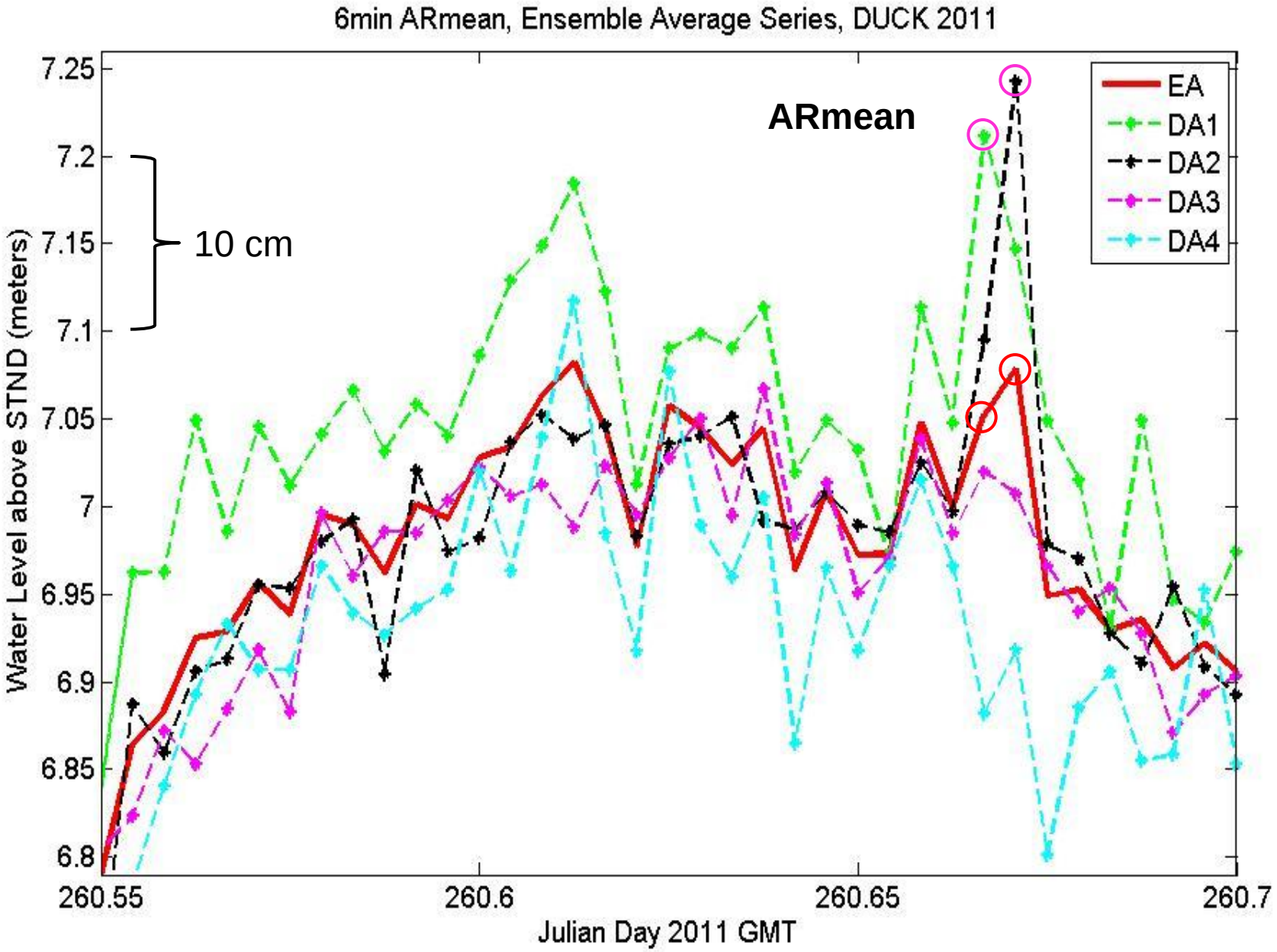

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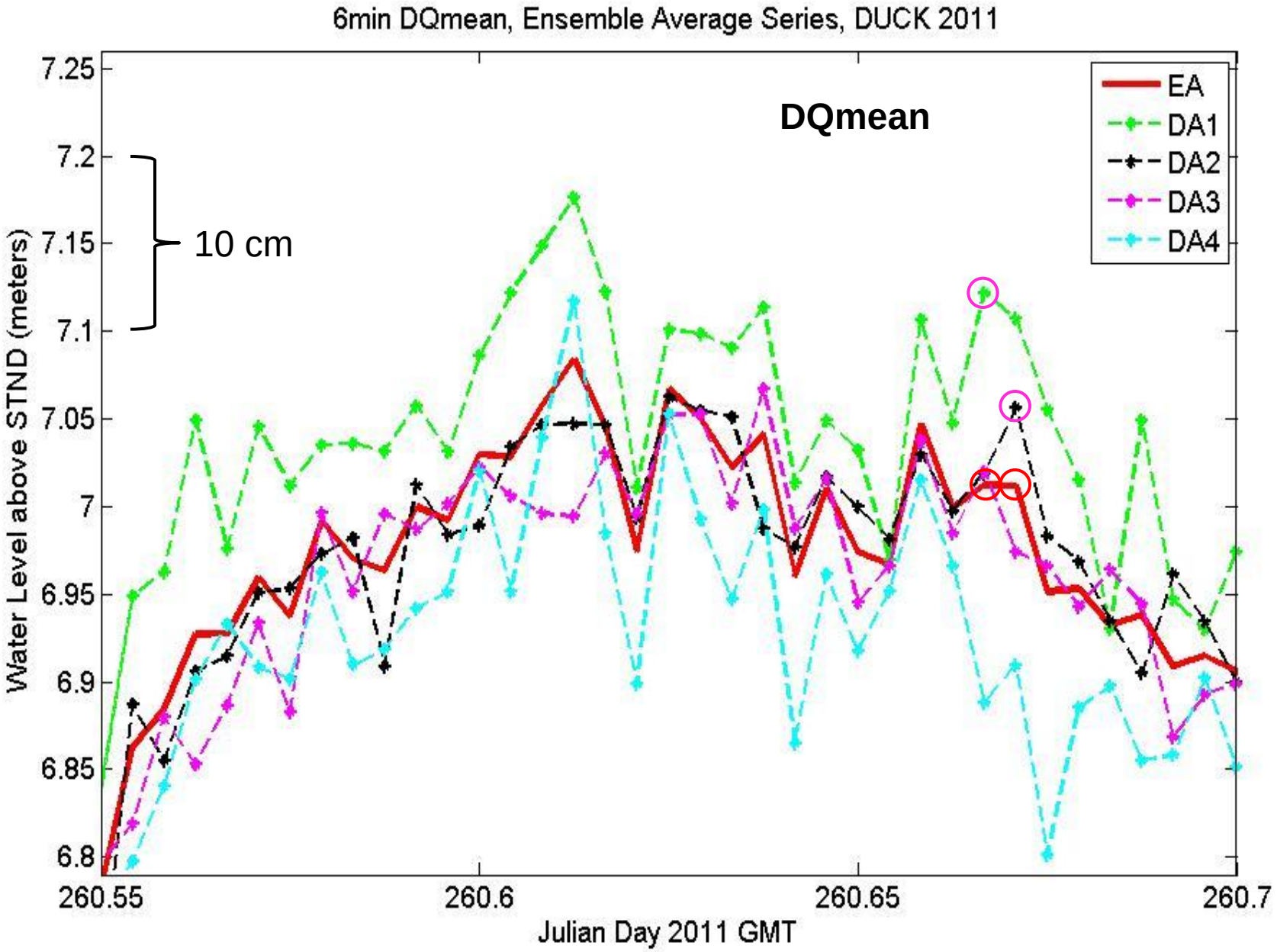

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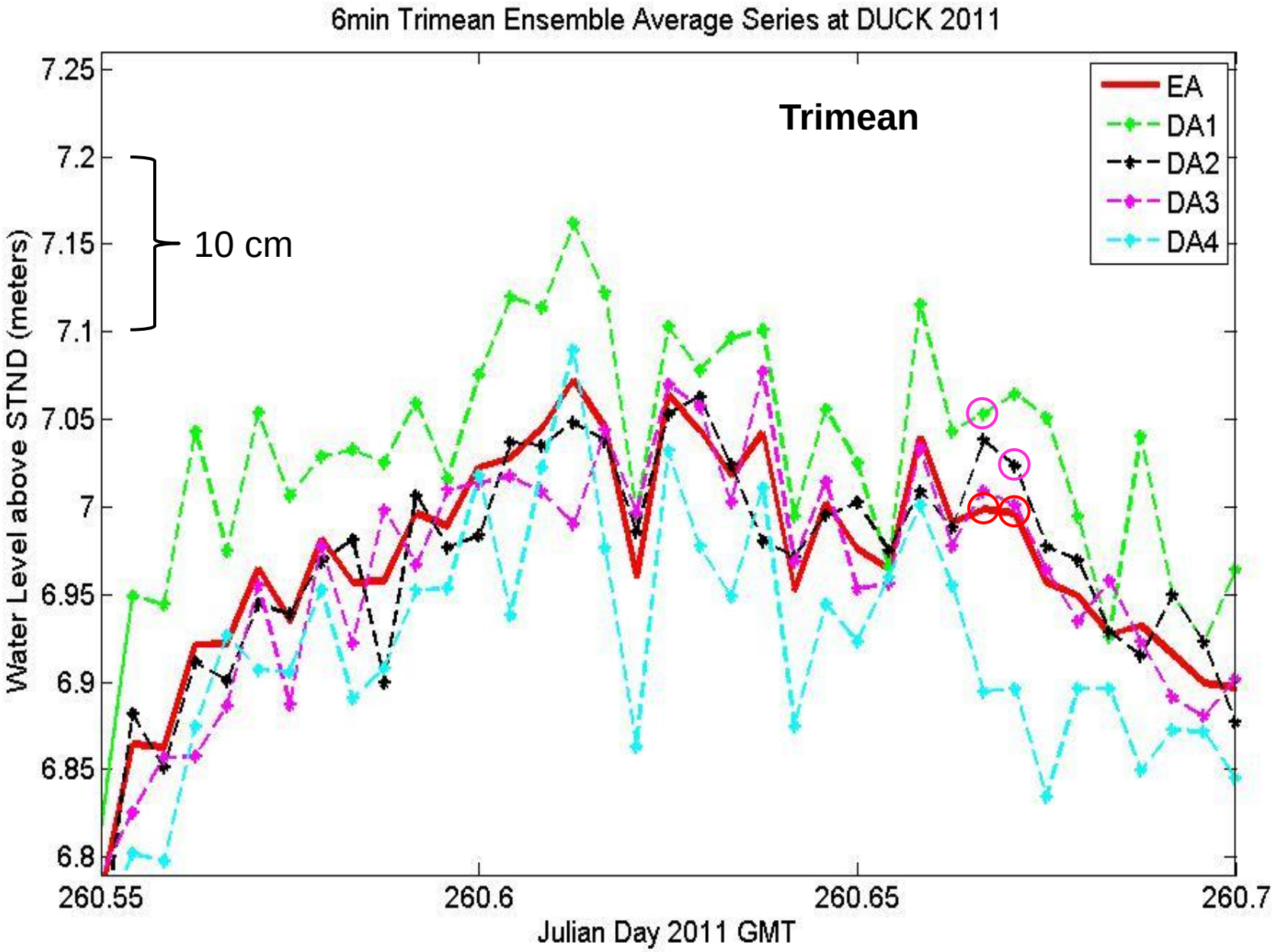

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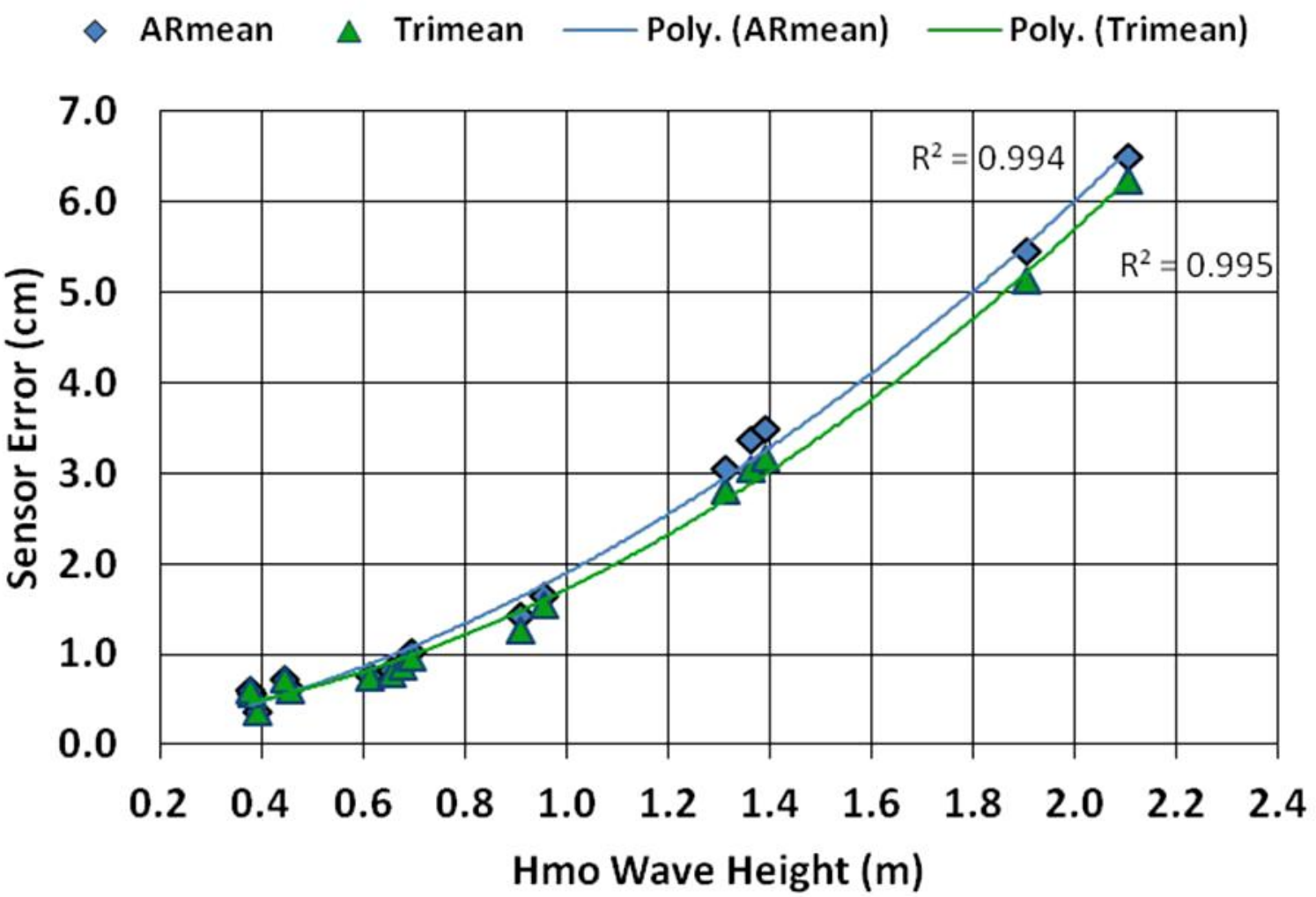
Sensor Error vs. Average Wave Height for selected 3-day periods

Fitted using degree 2 Polynomial



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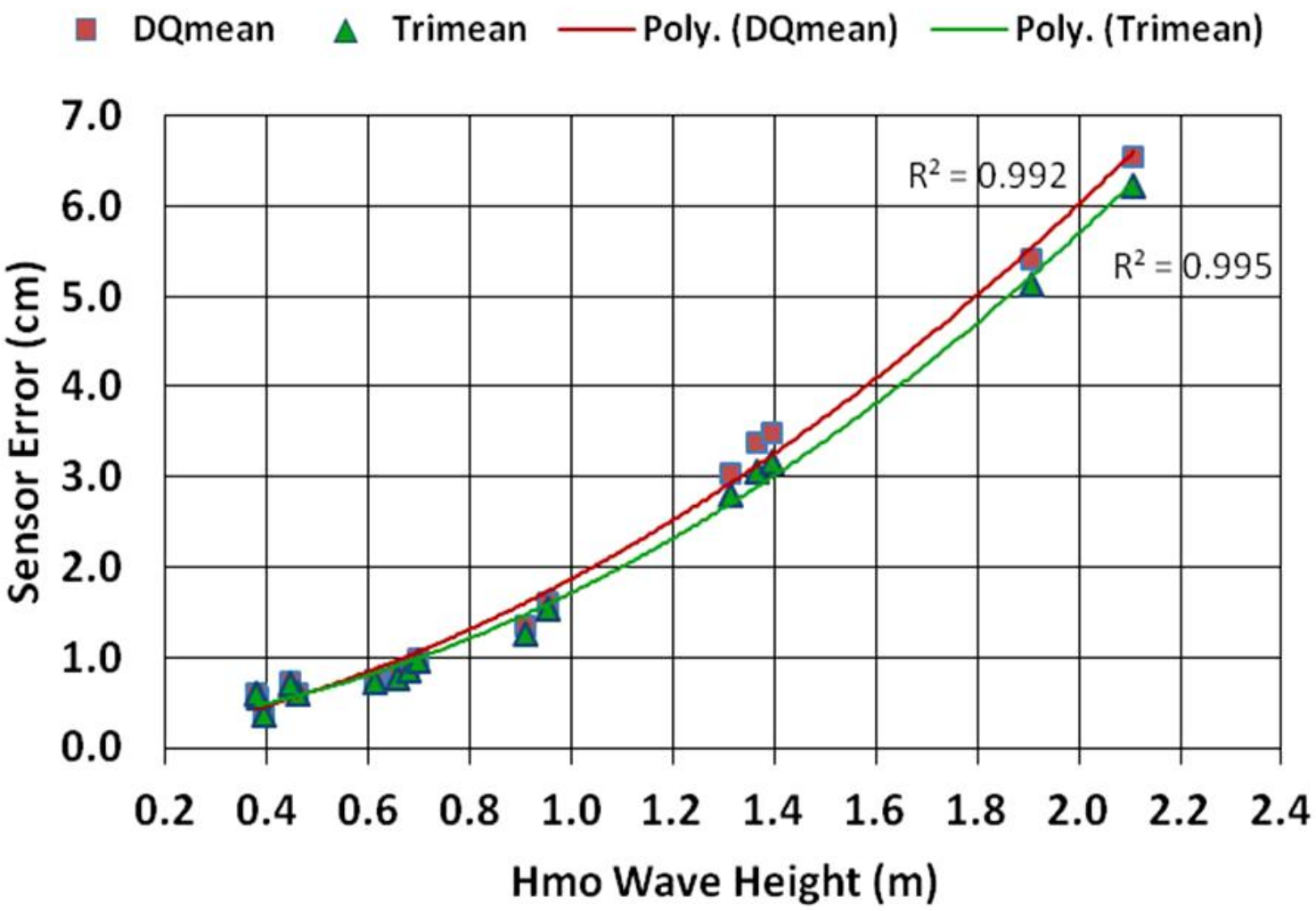
DQmean
Trimean
Poly. (DQmean)
Poly. (Trimean)
R² = 0.992
R² = 0.995
Sensor Error (cm)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
Hmo Wave Height (m)

Summary

Over the past 3 years, significant progress has been made on NOAA's MW radar test effort; a unique and valuable set of field and lab test data have been collected

DAA WaterLog® sensor has been recommended for use in CO-OPS applications at this time.

Field test results show MW vs NWLON data compare well at Pt Townsend, Ft Gratiot, and Money Point; **NWLON vs MW monthly RMSDs generally < 1 cm, monthly mean differences are within ± 5 mm**

Test and evaluation program has proposed 'Limited Acceptance' for use WaterLog sensors at NWLON sites located in semi-enclosed, fetch-limited, small surface gravity wave environments.

NOAA effort to transition to operations underway for NWLON and PORTS; 1st operational deployments completed in Mobile Bay, AL.

Preliminary MSEA open coast results - Likely MW sensor measurement error: less than ±1 cm 95% of the time with minimal wave activity (H_s<1m), increasing to ± 2 cm 95% of the time under moderate wave conditions (H_s =1-2 m) inshore at Duck, NC.