Field Evaluation of the Wave Module for NDBC's New Self-Contained Ocean Observing Payload (SCOOP) on Modified NDBC Hulls

Richard H. Bouchard[1], Rodney R. Riley[1], Lex A. LeBlanc[1], Michael Vasquez[1], Michael Robbie[1], Robert E. Jensen[2], Mary A. Bryant[2], and Laura A. Fiorentino[3]

[1]NOAA National Data Buoy Center (NDBC)
[2]US Army Corps of Engineers, Coastal and Hydraulics Laboratory
[3]NOAA National Ocean Service, Center for Operational Oceanographic Products and Services

What Are We Doing?

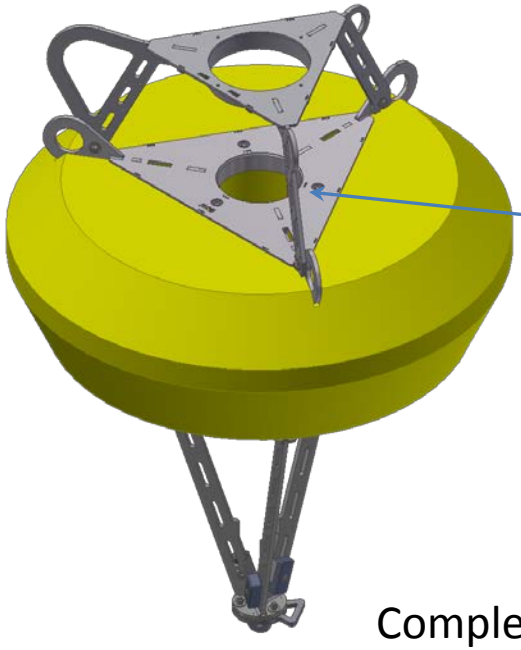
- Field Evaluation to determine how well new hull types and wave processing compare to the operational systems
- Two candidate systems located near deployed operational 3-m aluminum buoys
- Candidate systems use existing NDBC hulls modified to accommodate SCOOP payload.
  - Reduced superstructure area
  - Wave sensors elevated above the waterline

Motivation

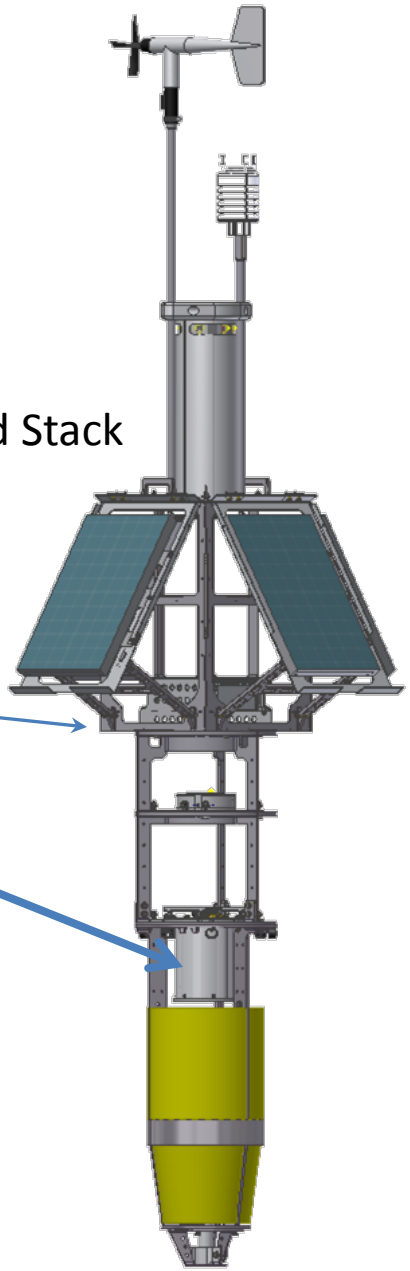
- Field Evaluation comparison to existing operational NDBC systems is one part of the process to bring a candidate system to full operational status
- Intercomparison between NDBC systems forms the basis of NDBC published accuracy standards: http://www.ndbc.noaa.gov/rsa.shtml
- Meet GCOS Climate Monitoring Principles:
  1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
  2. A suitable period of overlap for new and old observing systems is required.

SCOOP:

Increased reliability, Lower costs
More Met Obs: 1hr -> 10 minutes



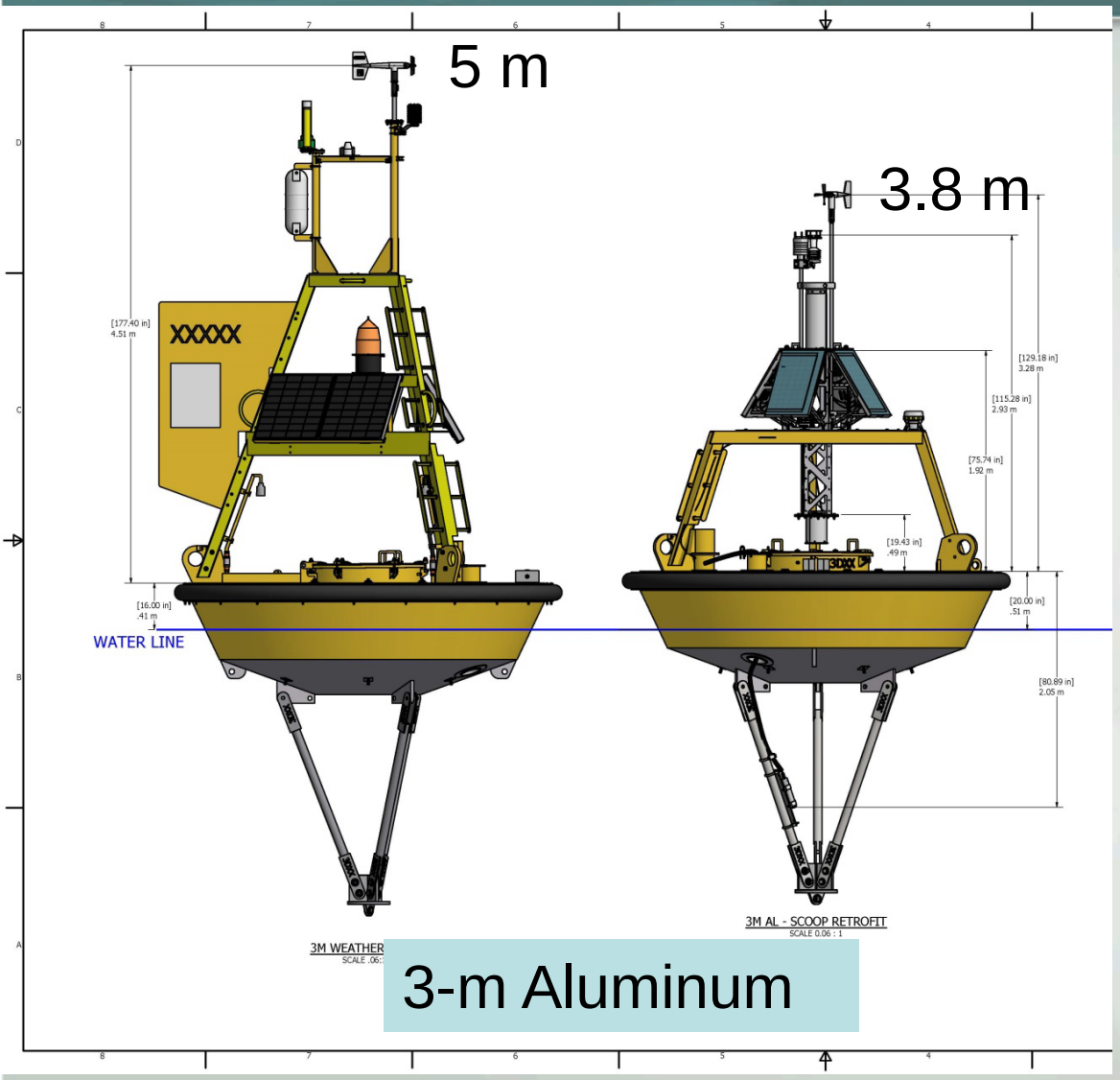
Payload Stack



Wave/Ocean Module

Complete payload stack is installed by lowering into the buoy receptacle and fastening in place at the top of the tower and at the deck level (optional)

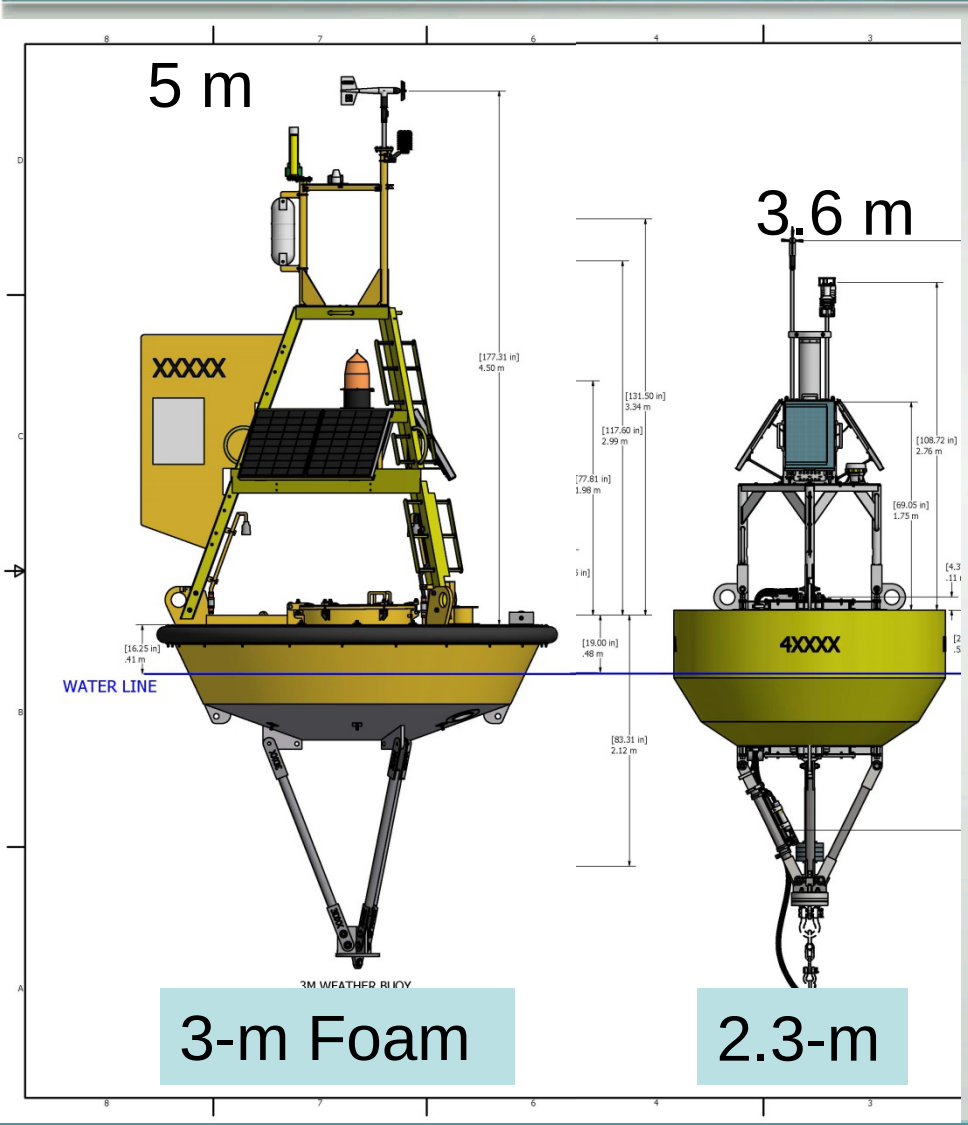
SCOOP: Modified 3-m aluminum hull



3-m Aluminum

- Deployed in northern Gulf of Mexico, 42039
- 6 km separation
- SCOOP Wave Sensor: +0.84 m above the waterline
- Operational buoy at the waterline
- Dataset:
  Nov 2014 – Mar 2017
  N = 19,409

SCOOP: 2.3-m Foam



- Central Caribbean, 42058
- 11 km separation
- Depth 4136 m
- Thermistor string attached to mooring
- Wave Sensor:
  SCOOP: +0.46 m
- Operational buoy at the waterline

- Dataset:
  May 2015 – Mar 2017
  N = 15,046 records

Encounters MH Matthew

DDWM (Digital Directional Wave Module)

- Samples at 1.7066 Hz for 20 minutes/2048 samples
- Fast Fourier Transform (FFT)
- 1024 Fourier frequencies boiled down to 47 by averaging adjacent frequencies
  - Overlapping averaging < 0.1 Hz to preserve 24 degrees of freedom
- Full 20 minutes used for spectra 0.02 to 0.35 Hz
  - 0.02 Hz is a noise band
  - Low-frequency noise correction < 0.18 Hz
- Last 10 minutes used for 0.365 Hz to 0.485 Hz
  - Hull/Mooring Response Function
- Tilt correction to vertical acceleration to mitigate *Bender Effect*
- Wave Directions from Longuet-Higgins *et al*., 1963
  - Pitch and Roll from integration of Angular Rate Sensors

DDWM Versions

Operational: DDWM Ver. 2.03

- Logarithmic-encoding of spectra ~ 1.9% loss in fidelity
- On-board low-frequency noise correction to spectra

SCOOP: DDWM Ver 3.04

- No log-encoding, full fidelity spectra
- No on-board low-frequency noise correction spectra

Apply shoreside low-frequency noise correction to both

See: Riley, R., C-C. Teng, R. Bouchard, R. Dinoso, and T. Mettlach, 2011: Enhancements to NDBC's Digital Directional Wave Module, *Proc. MTS/IEEE OCEANS 2011*

Lang, N., 1987: The Empirical Determination of a Noise Function for NDBC Buoys with Strapped-Down Accelerometers, *Proc. IEEE Oceans '87*

Primary Products

- Significant Wave Height
- Peak Period (Dominant Wave Period)
- Mean Wave Direction (at the Peak Period)

$$(3\pi/2) - ATAN2(b1,a1)$$

- Encode in WMO FM-13 SHIP Report distributed via the Global Telecommunication System
  - Peak Period will appear as Period for either Wind Wave or Swell Wave Group
  - Mean Wave Direction only appears in Swell Wave Group

Significant Wave Height (m)

Error = SCOOP – Operational; Standard = +/- 0.2 m or 10%

Loc/ Hull	Max Ob	Mean Error	MAE	RMSE	LSQ Fit Slope
GoM/ 3.0	6.1	-0.003	0.06	0.084	+0.98
Carib /2.3	10.3	-0.009	0.11	0.157	+0.98

RMSE/Mean Hs:
GoM/3.0 = 0.08
Carib/2.3 = 0.08

For **L**east-**SQ**uares Fit Slope:
Y = SCOOP
X = Operational

Peak Period (s)

Error = SCOOP- Operational; Standard = +/- 1.0 s

Loc/ Hull	Max/ OB	Mean Error	MAE	RMSE	LSQ Fit Slope
GoM 3.0	11.3	~0.00	0.40	0.71	+0.88
Carib 2.3	15.0	+0.20	0.41	0.70	+0.81

For **L**east-**SQ**uares Fit Slope:
Y = SCOOP
X = Operational

Mean Wave Direction (deg)

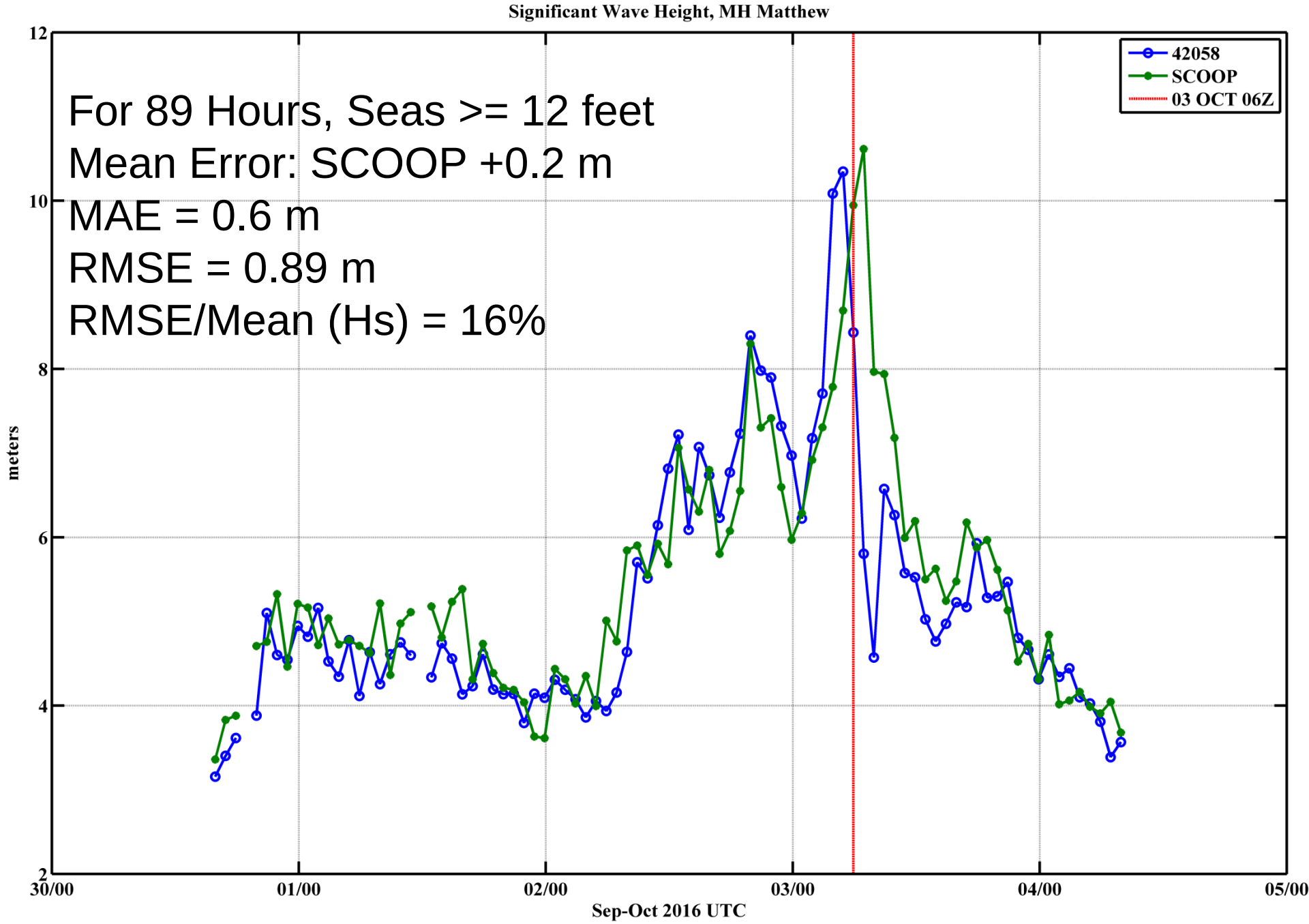
Error = SCOOP- Operational; Standard = +/- 10 degrees

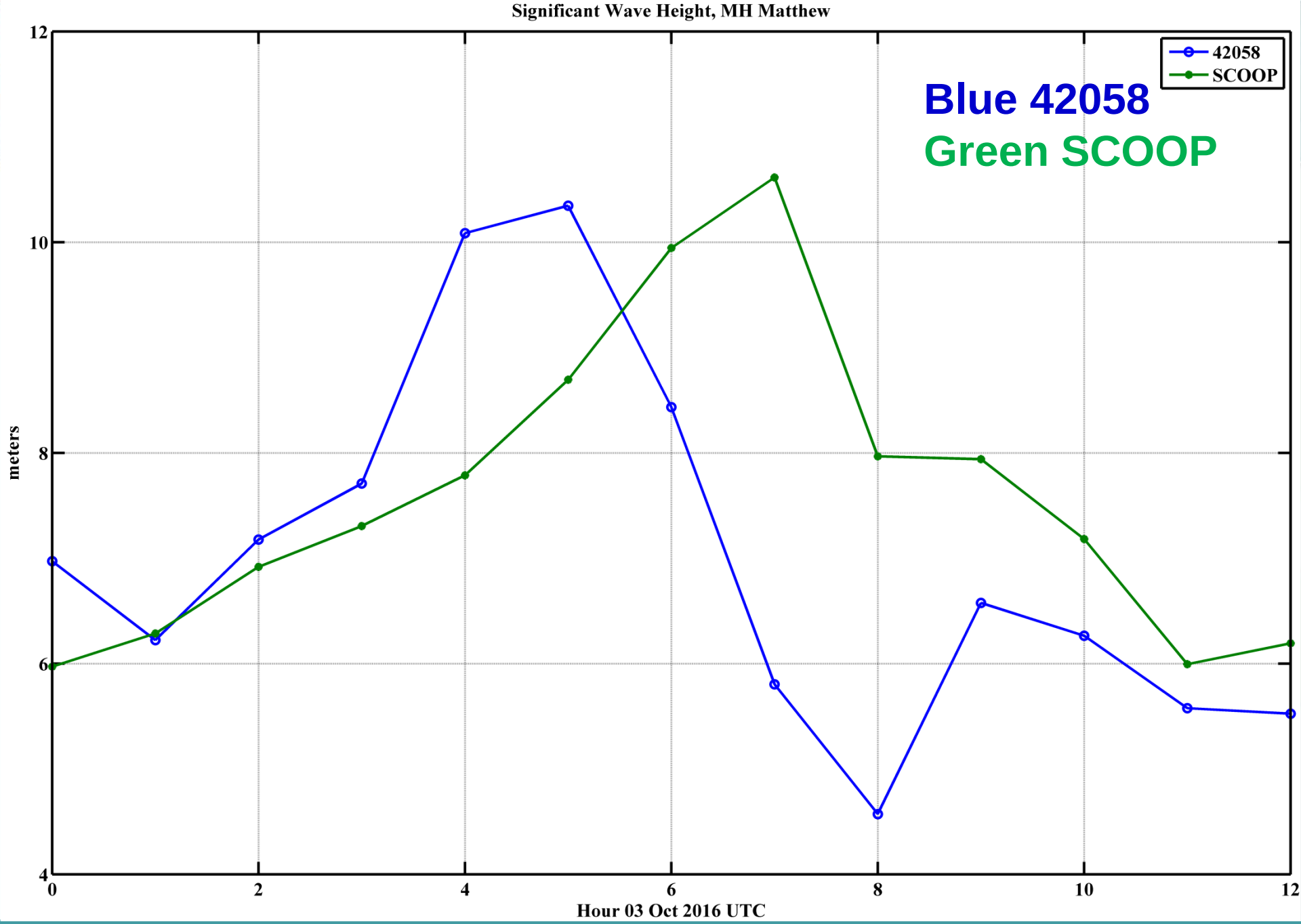
PP = Peak Period

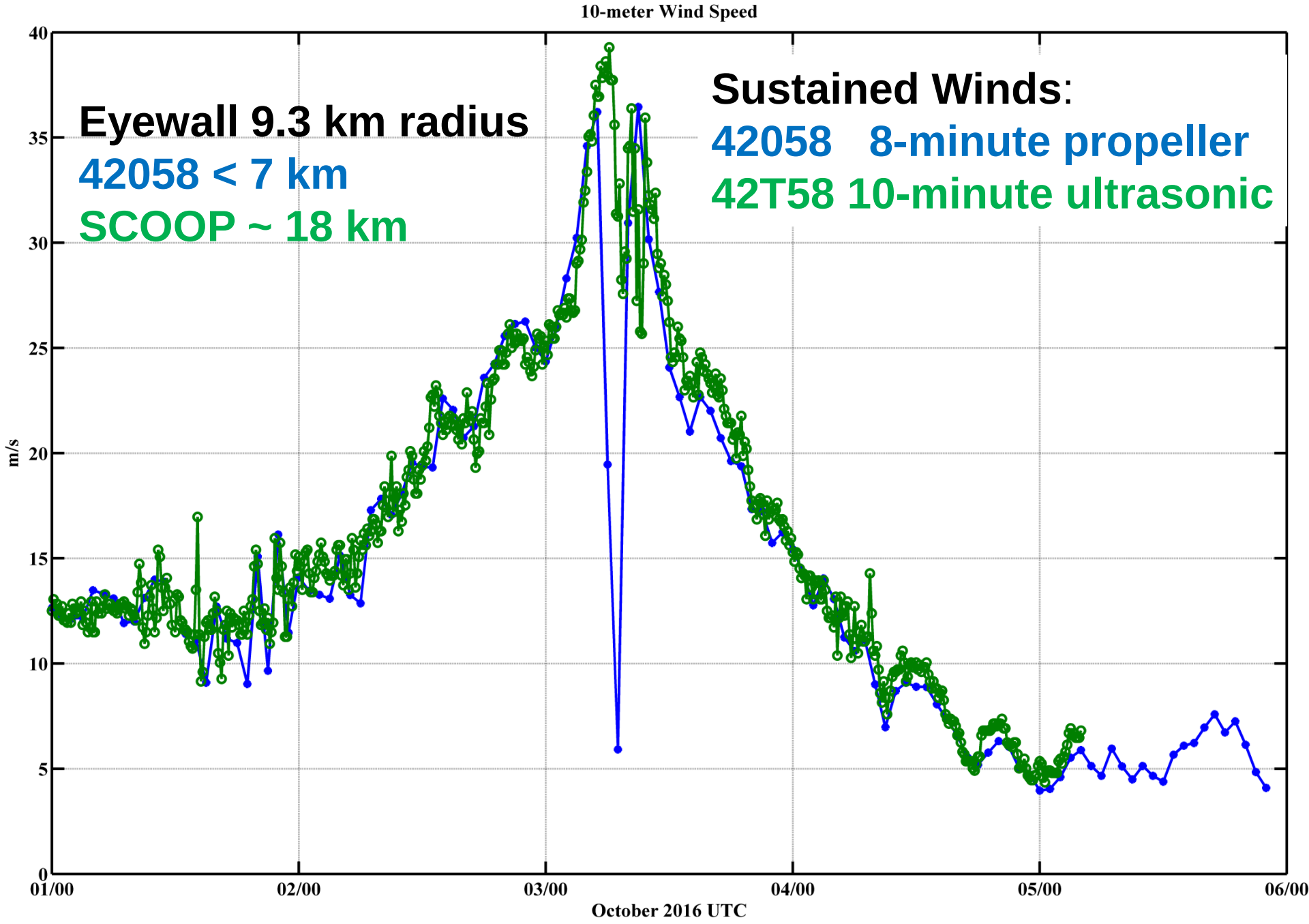
Location Hull	Mean Error	RMSE All	RMSE ΔPP = 0	RMSE |ΔPP| > 0 & <= 1 s
GoM 3.0	+0.6	22	11	16
Carib 2.3	+0.7	14	10	13

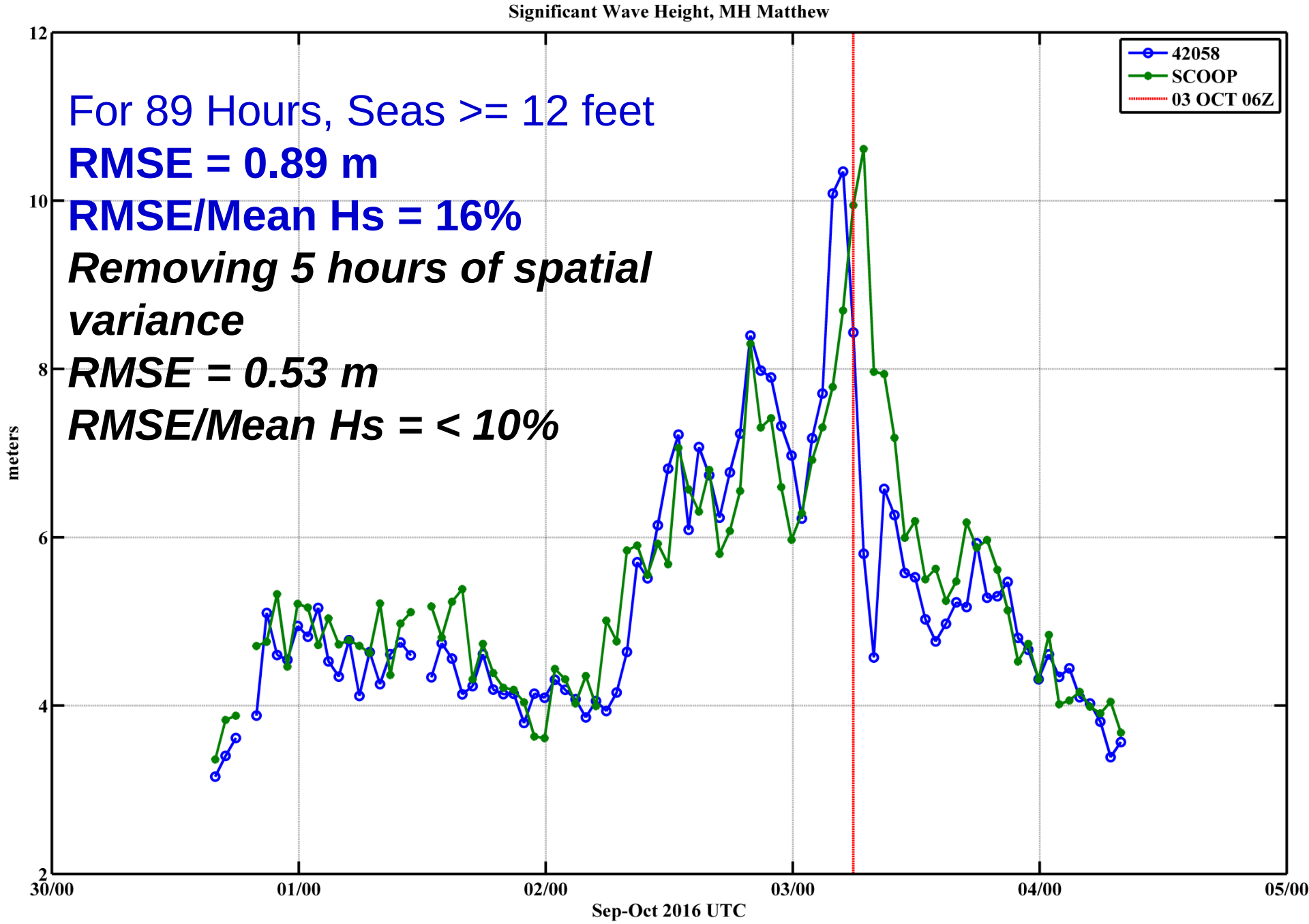
MH Matthew

On 03 Oct 2016, MH Matthew passes:
< 7 km west of 42058
at 0600 UTC; then
~18 km west of SCOOP (42T58) at 0700 UTC
Moving North 5-7 km/hour
Wind Speed 125 kt (64 m/s)


Significant Wave Height, MH Matthew
For 89 Hours, Seas >= 12 feet
Mean Error: SCOOP +0.2 m
MAE = 0.6 m
RMSE = 0.89 m
RMSE/Mean (Hs) = 16%
42058
SCOOP
03 OCT 06Z
meters
12
10
8
6
4
2
30/00
01/00
02/00
03/00
04/00
05/00
Sep-Oct 2016 UTC


Significant Wave Height, MH Matthew
42058
SCOOP
Blue 42058
Green SCOOP
meters
12
10
8
6
4
0
2
4
6
8
10
12
Hour 03 Oct 2016 UTC


10-meter Wind Speed
Eyewall 9.3 km radius
42058 < 7 km
SCOOP ~ 18 km
Sustained Winds:
42058 8-minute propeller
42T58 10-minute ultrasonic
m/s
40
35
30
25
20
15
10
5
0
01/00
02/00
03/00
04/00
05/00
06/00
October 2016 UTC


Significant Wave Height, MH Matthew
42058
SCOOP
03 OCT 06Z
For 89 Hours, Seas >= 12 feet
RMSE = 0.89 m
RMSE/Mean Hs = 16%
Removing 5 hours of spatial variance
RMSE = 0.53 m
RMSE/Mean Hs = < 10%
meters
12
10
8
6
4
2
30/00
01/00
02/00
03/00
04/00
05/00
Sep-Oct 2016 UTC

In Summary

- Small Biases
- Generally meet NDBC Standards
- Some variance due to spatial effects
- Further work will focus on spectra and improving directions
  - MoU with Naval Research Laboratory
- Info on hull type and payload:

  http://www.ndbc.noaa.gov/wstat.shtml

  http://www.ndbc.noaa.gov/stndesc.shtml

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