Comparison and Validation of GNSS vs Accelerometer Wave Sensors

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Abstract

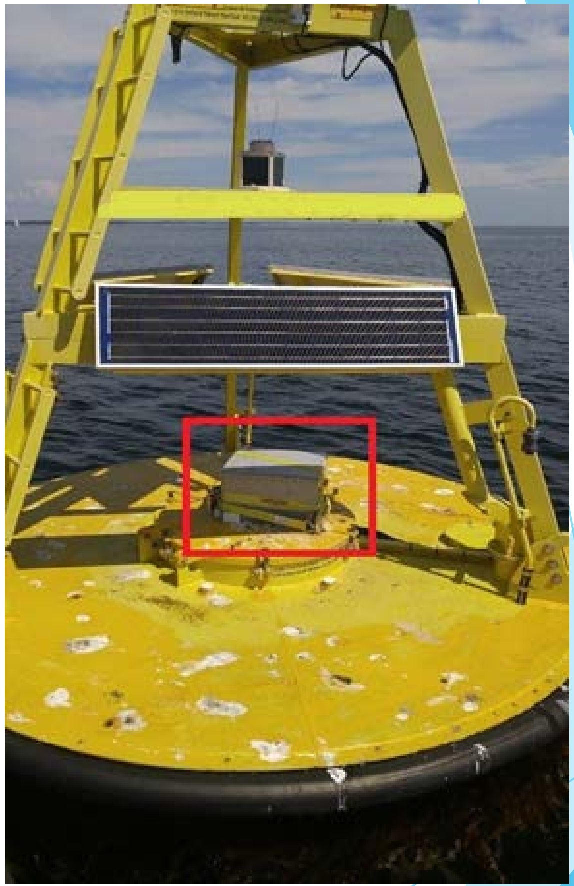
- Standalone, OEM (Original Equipment Manufacturer), GNSS (Global Navigation Satellite System) wave sensor module
- Co-located on 3 m accelerometer-based disc wave buoy
- Also deployed on pre-existing, already deployed navigation buoy 700 m away
- Both in 30 m of water
- Located in Herring Cove, NS, Canada
- Statistical validation of GNSS sensor ‘Brizo’ vs accelerometer based wave sensor (Sensor A)

Background

- Doppler profilers, pressure-based sensors, accelerometers, GPS/GNSS based solutions
- Accelerometer and force-feedback have been traditional choice
- GNSS sensors are more robust due to lack of moving parts, lower cost, less maintenance, easy to deploy on existing offshore infrastructure
- Not limited to center of gravity of buoy, closer to Z-axis decreases bias in directional measurements
- Errors of rotational acceleration removed because GNSS receivers are measuring velocity
- Highly accurate OEM unit with integrated cellular and Iridium telemetry, datalogger options

Test Platforms and Equipment

- Brizo1 mounted on 3 m disc buoy alongside industry standard accelerometer-based sensor (Sensor A)
- Deployed on access hatch, accelerometer inside buoy
- GNSS antenna, Brizo and batteries all inside grey waterproof box
- Should be noted that positioning of antenna was suboptimal, metal superstructure above causes loss of lock and multipath



Test Platforms and Equipment

- Brizo2 deployed in similar fashion on existing navigational bell buoy (HM1)
- Placed in waterproof box with batteries and embedded cell modem
- External antenna placed above buoy structure
- Bias from horizontal offset is reduced as vertical offset increases
- Locations determined by existing buoy infrastructure

Tested Parameters

- 5 major wave parameters

1. Significant Wave Height (m)
2. Maximum Wave Height (m)
3. Peak Wave Period (sec)
4. Average Wave Direction (deg)
5. Average Wave Spread (deg)

Statistic	Minimum	Maximum
Significant Wave Height (m)	0.10	2.43
Maximum Wave Height (m)	0.37	4.96
Peak Wave Period (sec)	2.66	12.80
Peak Wave Direction (deg)	46	158
Peak Wave Spread (deg)	33	49

- Significant wave height varied between 0.10 m and 2.43 m

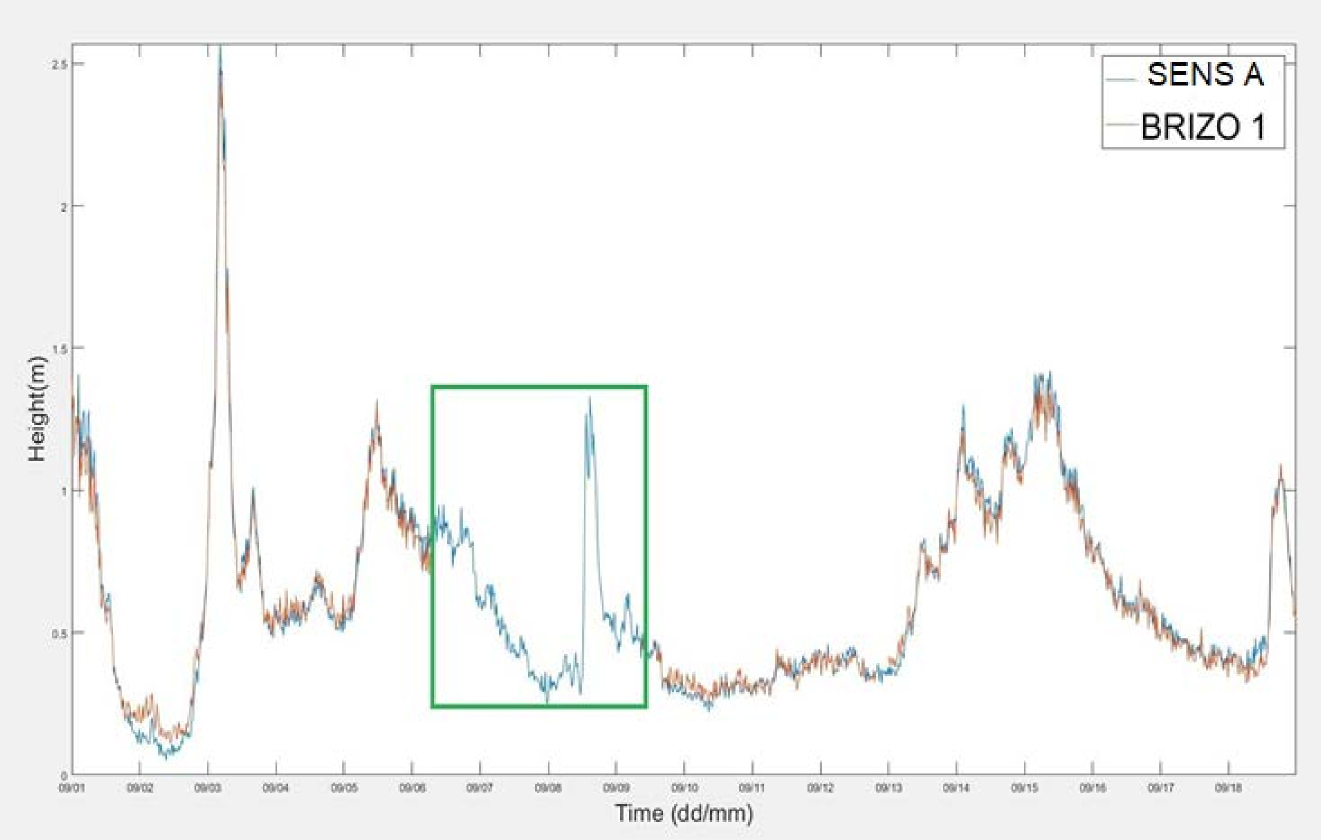
Field Data

- Installed on already developed buoys without removing them from the water
- Data was output at the rate of 2 measurements / hour
- Only measurements that were temporally aligned from all 3 sensors were included in statistics
- 1052 data points for Brizo1, 1201 data points for Brizo2
- Reduced data points due to use for RTK (Real-Time-Kinematic) system used for future tide gauge application

Oceanographic Buoy: Brizo1

- Deployment was designed to closely mimic traditional positioning of GNSS or accelerometer based sensor
- This test confirms validity of using GNSS – based wave height sensors agreeing with previous findings (Herbers et. Al 2012)
- In graph below, Brizo1 trends closely with Sensor A for reasonable wave signal (sig. wave height above 0.25 m)

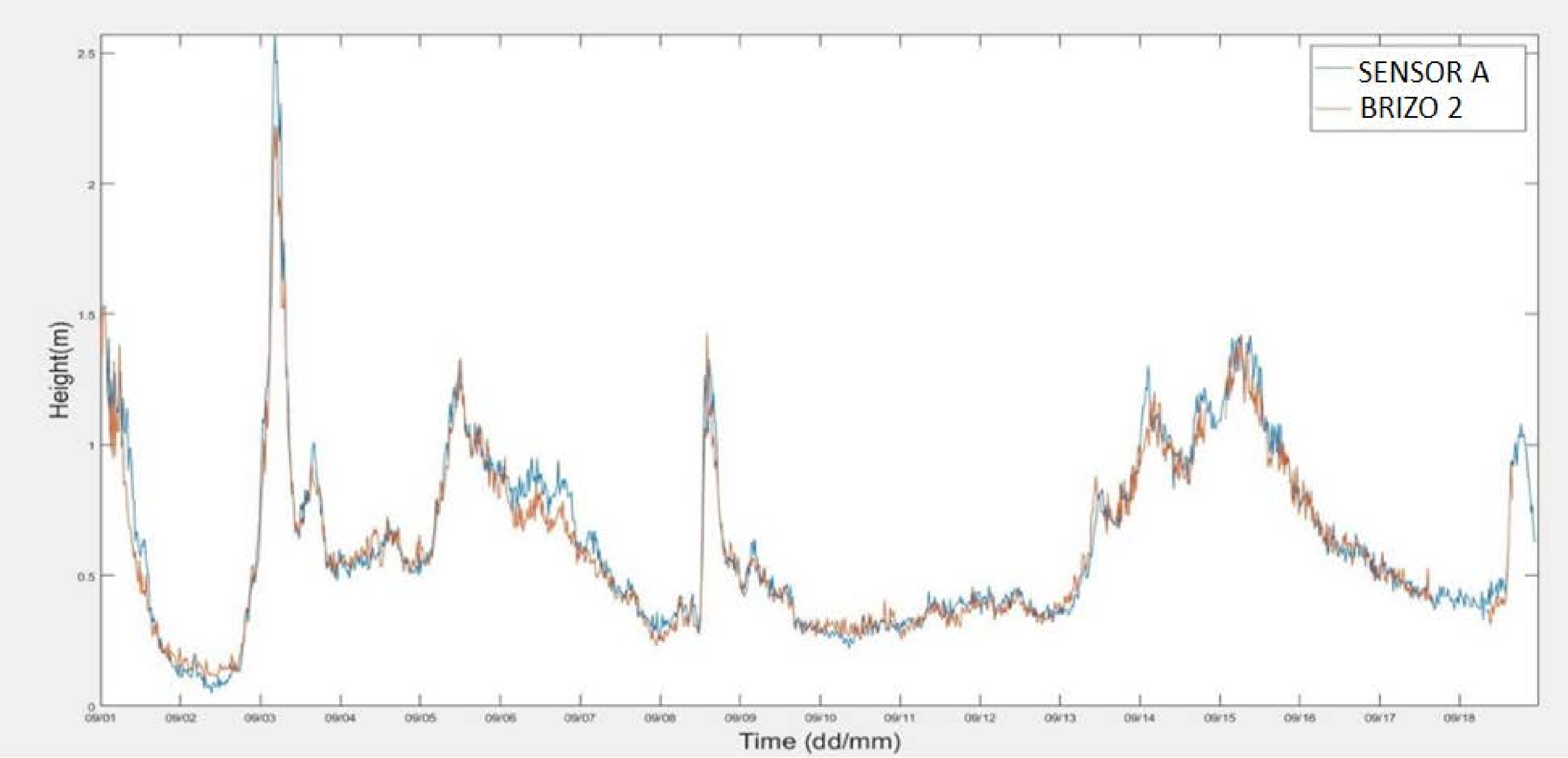
Oceanographic Buoy: Brizo1



Navigation Buoy: Brizo2

- Deployed 700 m away on different type of buoy
- Distance, buoy shape, weight had minimal effect on data
- Significant wave height trends very closely with accelerometer sensor, seen below
- Brizo2 peak wave direction shows small bias compared to Brizo1 graph, can be attributed to antenna offset from centre of buoy

Navigation Buoy: Brizo2



Statistical Analysis

- The following are statistical analysis tables between Brizo1 and Brizo2 vs Sensor A, respectively
- Included is Bias, MAE (Mean Absolute Error), RMSE (Root-Mean-Square Error), and MPE (Mean Percentage Error)
- Varying results for Brizo1 vs Sensor A for period of non-significant (sig ht <.25m) wave signal over 2 days. Brizo measured more signal from long period waves
- MPE increased for all Brizo2 stats, accounted for by differences in buoy dynamics, wave fields, depth, proximity to shore and antenna offset

Statistical Analysis

Table 3: Statistical Analysis of Parameters, Brizo1 vs Sensor A

	Significant Wave Height (m)	Maximum Wave Height (m)	Peak Wave Period (sec)	Peak Wave Direction (deg)	Peak Wave Spread (deg)
Bias	-0.01	0.01	0.03	+7.4	-1.2
MAE	0.03	0.08	0.623	9.34	2.4
RMSE	0.035	0.11	1.21	11.43	3.14
MPE	1.01%	0.67%	0.37%	5.28%*	3.48%

Table 4: Statistical Analysis of Parameters, Brizo2 vs Sensor A

	Significant Wave Height (m)	Maximum Wave Height (m)	Peak Wave Period (sec)	Peak Wave Direction (deg)	Peak Wave Spread (deg)
Bias	-0.01	0.00	-0.075	7.0	-0.197
MAE	0.04	0.11	0.98	13.2	2.84
RMSE	0.06	0.15	1.55	16.92	3.6
MPE	2.07%	1.35%	2.82%	4.16%	4.36%

Current and Future Development

- Brizo sensor has finished its initial development cycle
- Available on the market to output "First Five" wave parameters
- Further research will look at use of additional sensors to augment performance when offset from centre
- Also use of external sensors as a data source is of interest
- We would like to thank the Halifax Harbour Pilotage Authority and Environment Canada for their assistance during this testing

Conclusion

- Comparison of GNSS wave height and direction sensor vs accelerometer wave height buoy showed a high level of agreement
- Held true for second deployment 700 m away on a different, non-purpose buoy style
- Worked better in scenarios of long peak periods, low height values
- Findings leverage advantages of GNSS sensors over accelerometer-based systems in modifying buoys for the addition of OEM wave height sensors