Australian Forum for Operational Oceanography

Ryan Carlon

Oct 15, 2019

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The Wave Glider

Unmanned Surface Vehicle

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PO'OKELA

Our Markets

Defense and Security

Environmental Assessment

Offshore Energy

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Science & Research

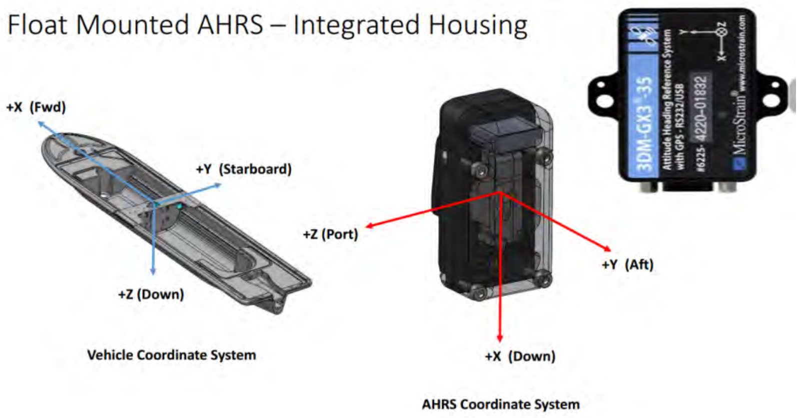
Less risk, less cost, more actionable data

- Increase accuracy for weather forecasting models
- Measure changes in climate (sea levels, CO_2, temp.)
- Monitor the health and biology of the environment
- Detect deep-sea earthquakes & tsunamis
- Measure waves and currents in high latitudes
- Track migrations of great white sharks and fish

GPSwaves Sensor

- Float mounted AHRS
  - Microstrain GPS + IMU – 4Hz
  - Outputs >2kB/sec of raw data
- SW computation algorithm developed by Dr. Jim Thomson
  - Wave height, direction, period and spectrum
  - Report summary generated every 30 min
  - Wave spectrum data saved every 30 min

Float Mounted AHRS – Integrated Housing



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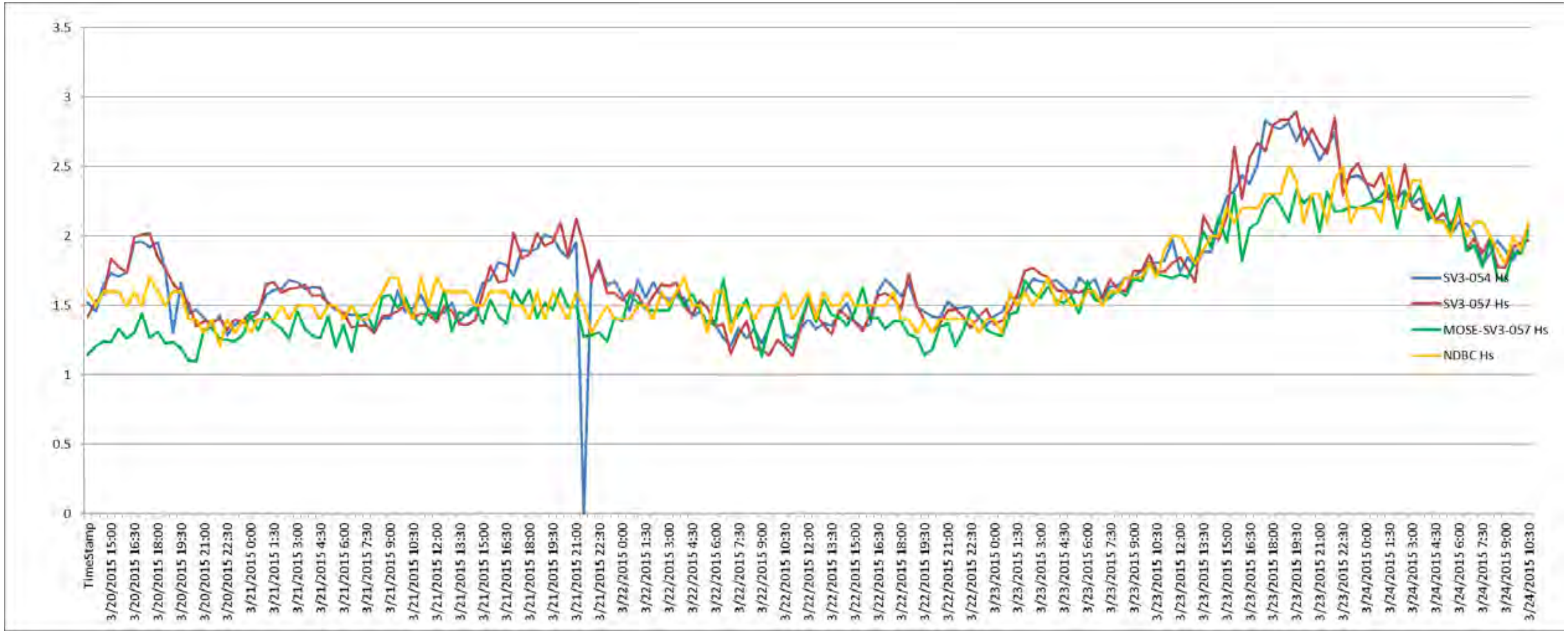
Wave Height: GPSwaves Sensor (GX3-35) vs Datawell



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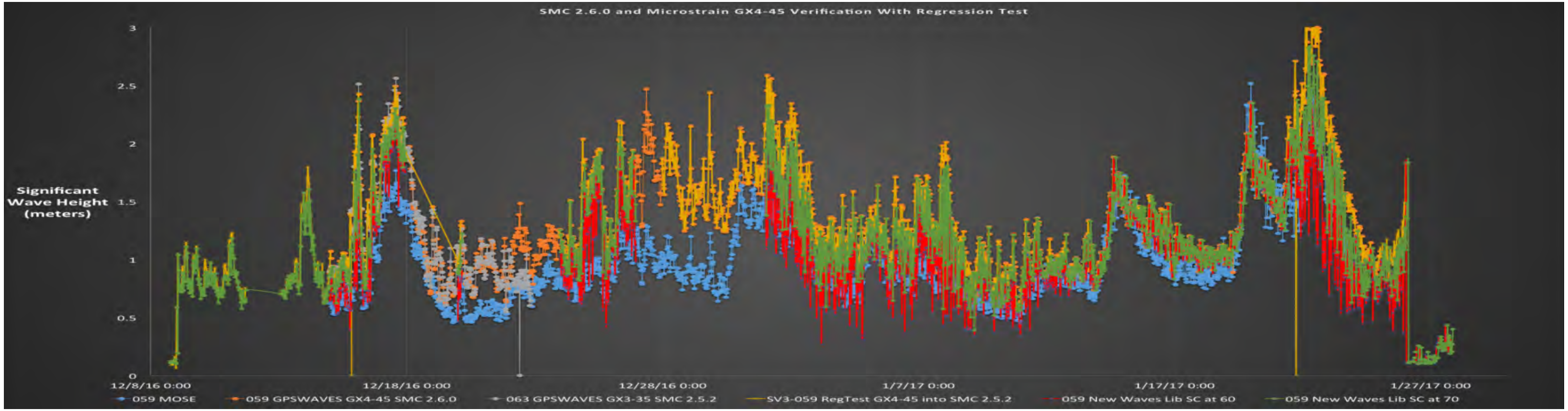
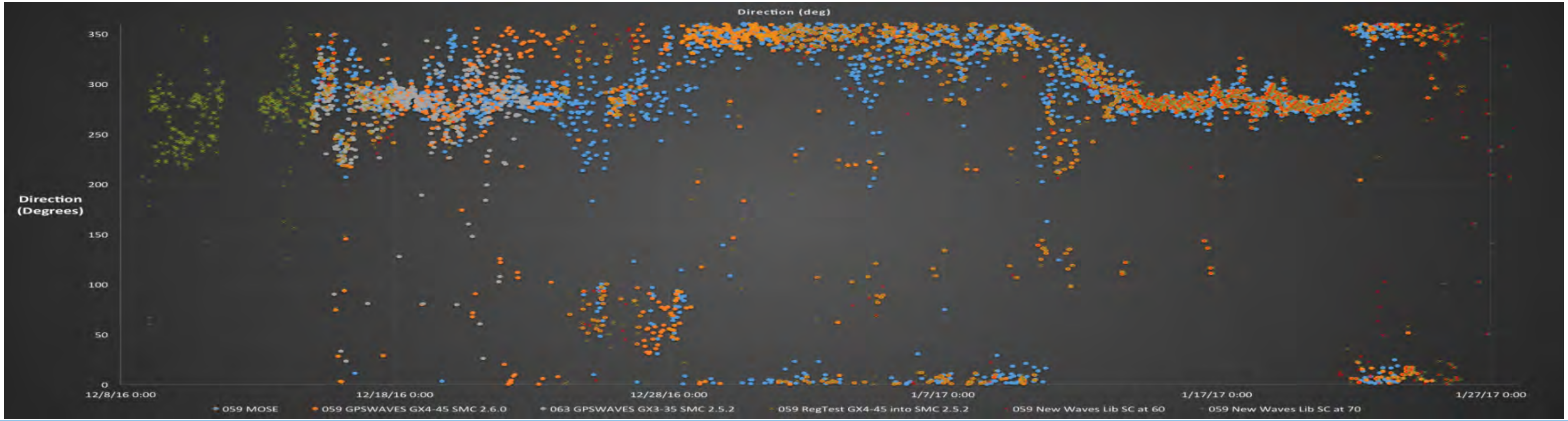
GPSwaves Sensor with new Microstrain GX4-45





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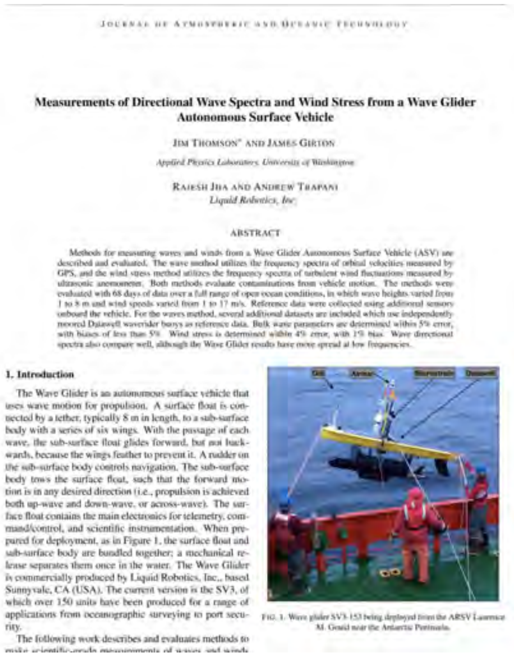
Measurements of Directional Wave Spectra and Wind Stress from a Wave Glider Autonomous Surface Vehicle

Journal of Atmospheric and Oceanic Technology



Measurements of Directional Wave Spectra and Wind Stress from a Wave Glider Autonomous Surface Vehicle

JIM THOMSON* AND JAMES GIRTON
Applied Physics Laboratory, University of Washington

RAJESH JHA AND ANDREW TRAPANI
Liquid Robotics, Inc

ABSTRACT

Methods for measuring waves and winds from a Wave Glider Autonomous Surface Vehicle (ASV) are described and evaluated. The wave method utilizes the frequency spectra of orbital velocities measured by GPS, and the wind stress method utilizes the frequency spectra of turbulent wind fluctuations measured by ultrasonic anemometer. Both methods evaluate contaminations from vehicle motion. The methods were evaluated with 68 days of data over a full range of open ocean conditions, in which wave heights varied from 1 to 8 m and wind speeds varied from 1 to 17 m/s. Reference data were collected using additional sensors onboard the vehicle. For the waves method, several additional datasets are included which use independently moored Datawell waverider buoys as reference data. Bulk wave parameters are determined within 5% error, with biases of less than 5%. Wind stress is determined within 4% error, with 1% bias. Wave directional spectra also compare well, although the Wave Glider results have more spread at low frequencies.

1. Introduction

The Wave Glider is an autonomous surface vehicle that uses wave motion for propulsion. A surface float is connected by a tether, typically 8 m in length, to a sub-surface body with a series of six wings. With the passage of each wave, the sub-surface float glides forward, but not backwards, because the wings feather to prevent it. A rudder on the sub-surface body controls navigation. The sub-surface body tows the surface float, such that the forward motion is in any desired direction (i.e., propulsion is achieved both up-wave and down-wave, or across-wave). The surface float contains the main electronics for telemetry, command/control, and scientific instrumentation. When prepared for deployment, as in Figure 1, the surface float and sub-surface body are bundled together; a mechanical release separates them once in the water. The Wave Glider is commercially produced by Liquid Robotics, Inc., based Sunnyvale, CA (USA). The current version is the SV3, of which over 150 units have been produced for a range of applications from oceanographic surveying to port security.

The following work describes and evaluates methods to make scientific-grade measurements of waves and winds

FIG. 1. Wave glider SV3-153 being deployed from the ARSV Laurence M. Gould near the Antarctic Peninsula.

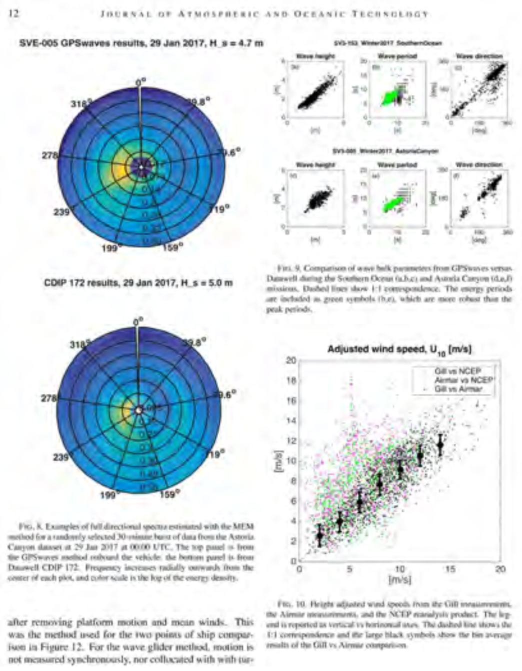


FIG. 8. Examples of full directional spectra estimated with the MEM method for a randomly selected 30-minute burst of data from the Astoria Canyon dataset at 29 Jan 2017 at 00:00 UTC. The top panel is from the GPSwaves method onboard the vehicle; the bottom panel is from Datawell CDIP 172. Frequency increases radially outwards from the center of each plot, and color scale is the log of the energy density.

FIG. 9. Comparison of wave bulk parameters from GPSwaves versus Datawell during the Southern Ocean (a,b,c) and Astoria Canyon (d,e,f) missions. Dashed lines show 1:1 correspondence. The energy periods are included as green symbols (b,e), which are more robust than the peak periods.

FIG. 10. Height adjusted wind speeds from the Gill measurements, the Airmar measurements, and the NCEP reanalysis product. The legend is reported as vertical vs horizontal axes. The dashed line shows the 1:1 correspondence and the large black symbols show the bin average results of the Gill vs Airmar comparison.

after removing platform motion and mean winds. This was the method used for the two points of ship comparison in Figure 12. For the wave glider method, motion is not measured synchronously, nor collocated with with tur-

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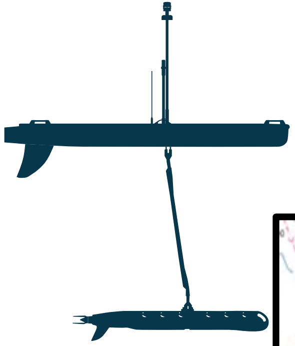
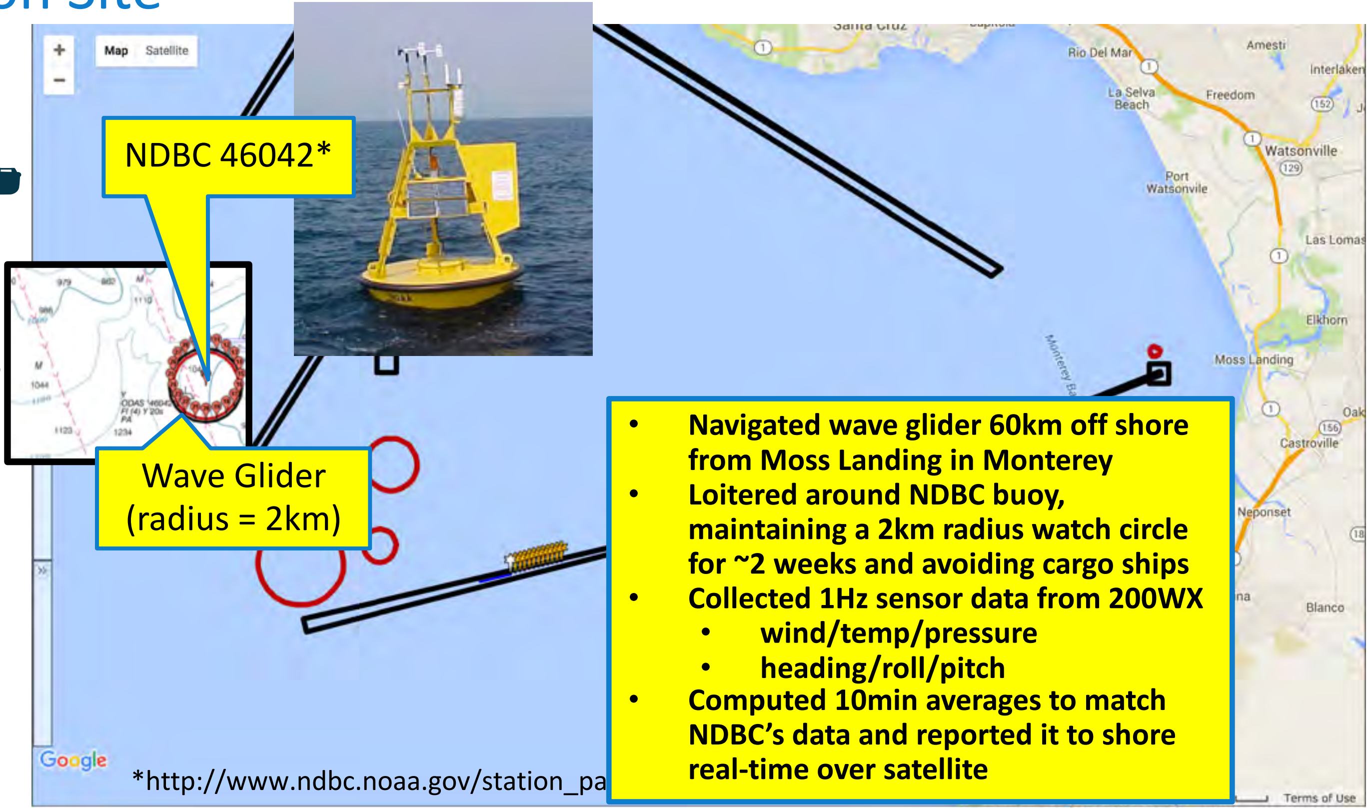
Validation Site





- Navigated wave glider 60km off shore from Moss Landing in Monterey
- Loitered around NDBC buoy, maintaining a 2km radius watch circle for ~2 weeks and avoiding cargo ships
- Collected 1Hz sensor data from 200WX
  - wind/temp/pressure
  - heading/roll/pitch
- Computed 10min averages to match NDBC's data and reported it to shore real-time over satellite

*http://www.ndbc.noaa.gov/station_pa

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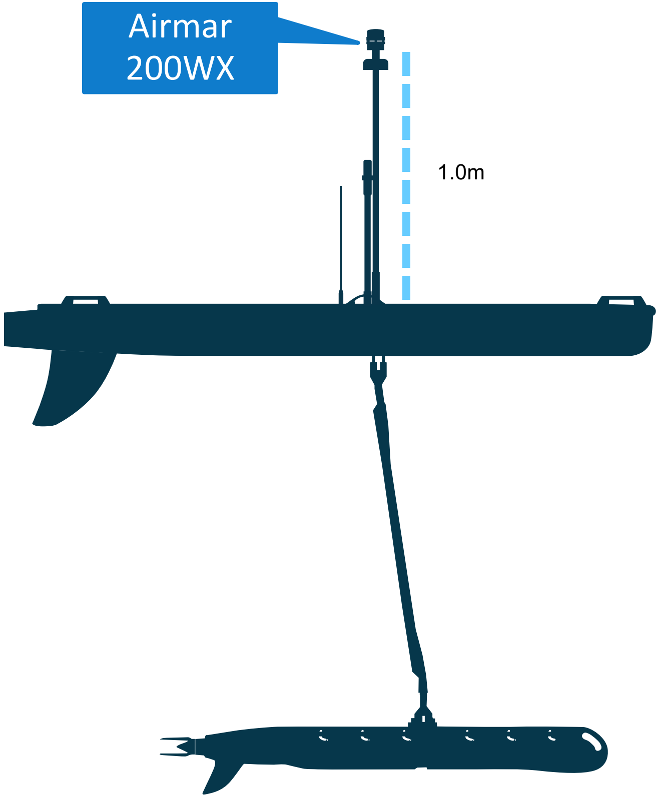
Payload Comparison

	NDBC ARES Payload*	Wave Glider Payload
Anemometer Technology	4-blade, impeller-driven, wind-vane sensors	Ultrasonic, transducers
Anemometer Height	5m	1m
Air Temp Height	4m	1m
Barometer Elevation	Sea Level	1m



*http://www.ndbc.noaa.gov/station_page.php?station=46042

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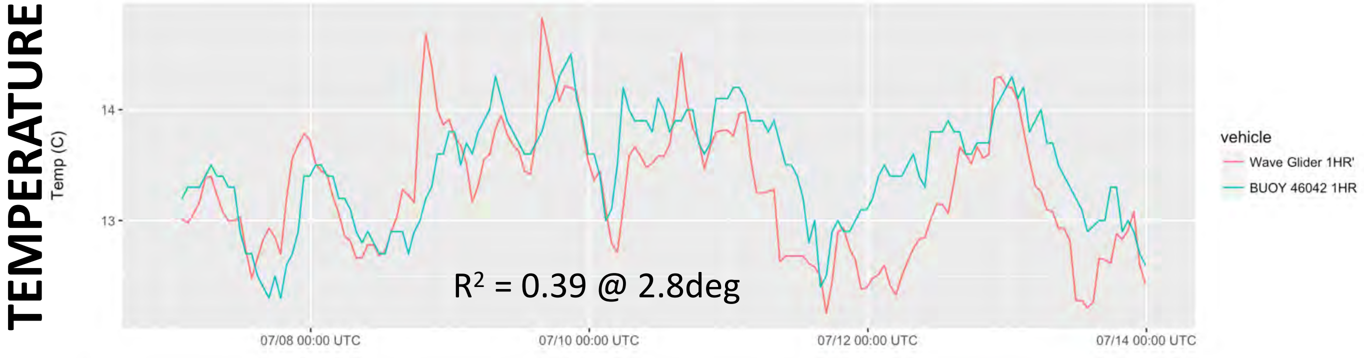
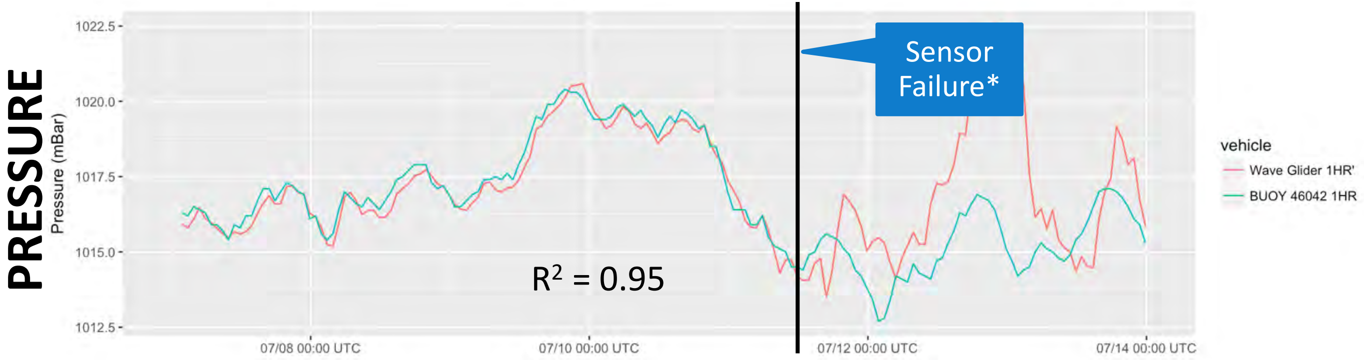
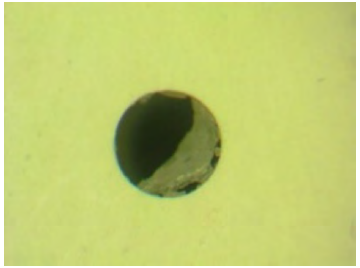
Comparison: Temp & Pressure



Thermistor cap to prevent sea water contamination



*Post mission analysis shows salt build up in the pressure vent



Salt build-up in barometric pressure vent

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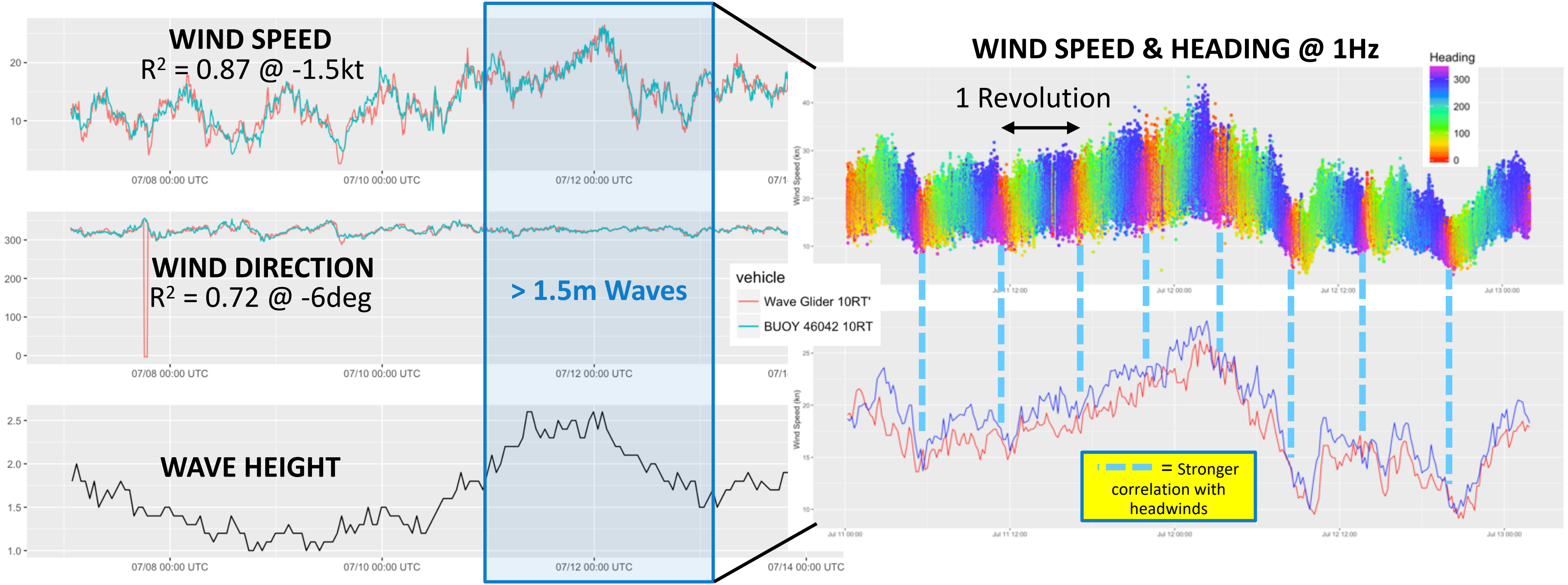
Comparison: Wind Data



Observed strong correlation between the glider and buoy data with some adjustments within instrument's margin of error

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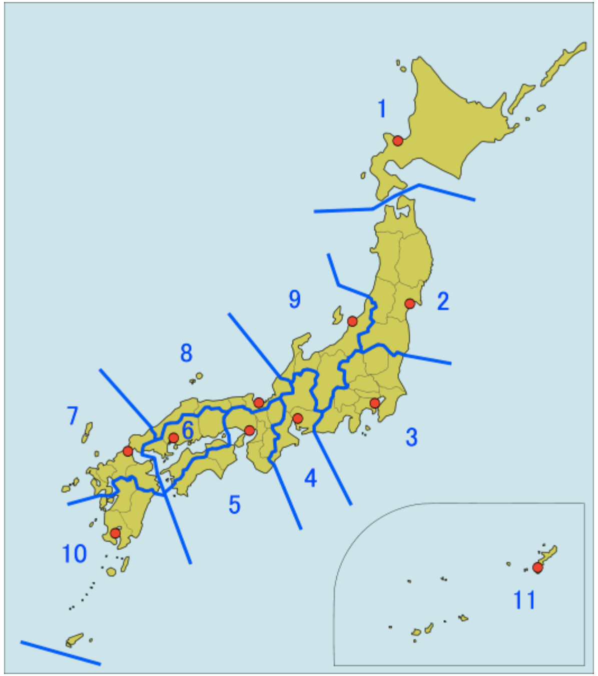
Japan Coast Guard

Japan's First Long-Term Ocean Observation Network

- Deployed fleets of Wave Gliders to four regions in 2016 to provide real-time situational awareness of ocean currents, wave activity, and weather along Japan's coastlines
- Expanded ocean observation network to the 9th Regional District in 2018
- 24/7 year-round continuous operations
- Real-time environmental data published for Japan's commercial fisheries and tourism industries
- Total of 20 Wave Gliders in the JCG fleet, active in Regions 7, 8, 9, 10, 11



The 11 regions of the Japan Coast Guard operations.
Image by Los688 via Wikimedia Commons.

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JCG Real-Time Data

- Example data published by JCG in real-time
- Data Published:
  - > Surface T, P, and Wind Speed/Direction
  - > Wave Height, Direction, frequency
  - > Ocean Surface Current magnitude and direction
  - > SST at 8m depth
- Next steps: sea testing of a higher threshold wind speed sensor

西日本海域の海象・気象リアルタイム観測情報

海上保安庁の自律型海洋観測装置（AOV）のリアルタイムデータ

風向・風速

下図の表示地点をクリックすると過去の気象観測値が表示されます。

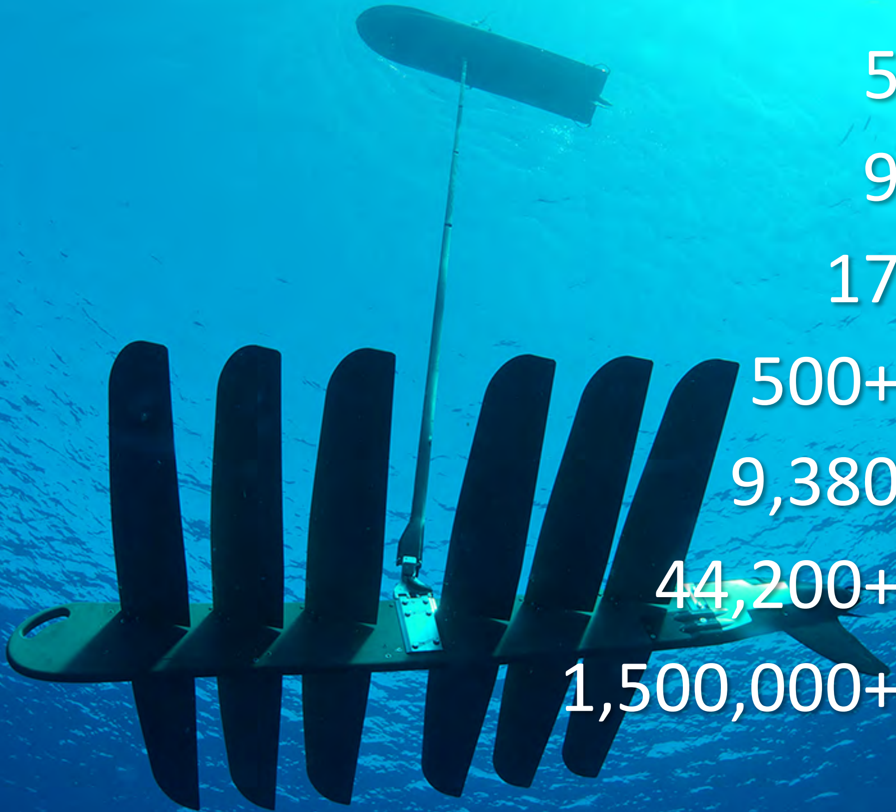
表示する日時の選択≫ 2019/05/26 23:00 ▼

★のみ表示されている場合は最新データ未受信または欠測です。

2019/05/26、 23時51分(JST)現在、稼働中の各AOVの位置

AOV	運用管区	年月日 (JST)	時刻	緯度 度	経度 度	備考
とらふく04号	(七管区)	2019/05/26	23:10	33.0578	128.7876	
きびなご01号	(十管区)	2019/05/26	23:03	28.6776	129.5140	
がまー	(十一管区)	2019/05/26	23:10	24.1051	123.5464	

Wave Glider Accomplishments



5	World's major oceans traveled
9	Technology Readiness Level
17	Hurricanes navigated
500+	Vehicles manufactured
9,380	Longest single mission (NM)
44,200+	Total days at sea
1,500,000+	Nautical miles traveled (69x around the globe)

Thank you.
Questions?