

Wave and Current measurements

Select the right methods

DR. ANDERS TENGBERG, SCIENTIFIC ADVISOR, PRODUCT MANAGER

House Keeping

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Ask Questions

We'll try to answer as many as we can during the presentation

Chat

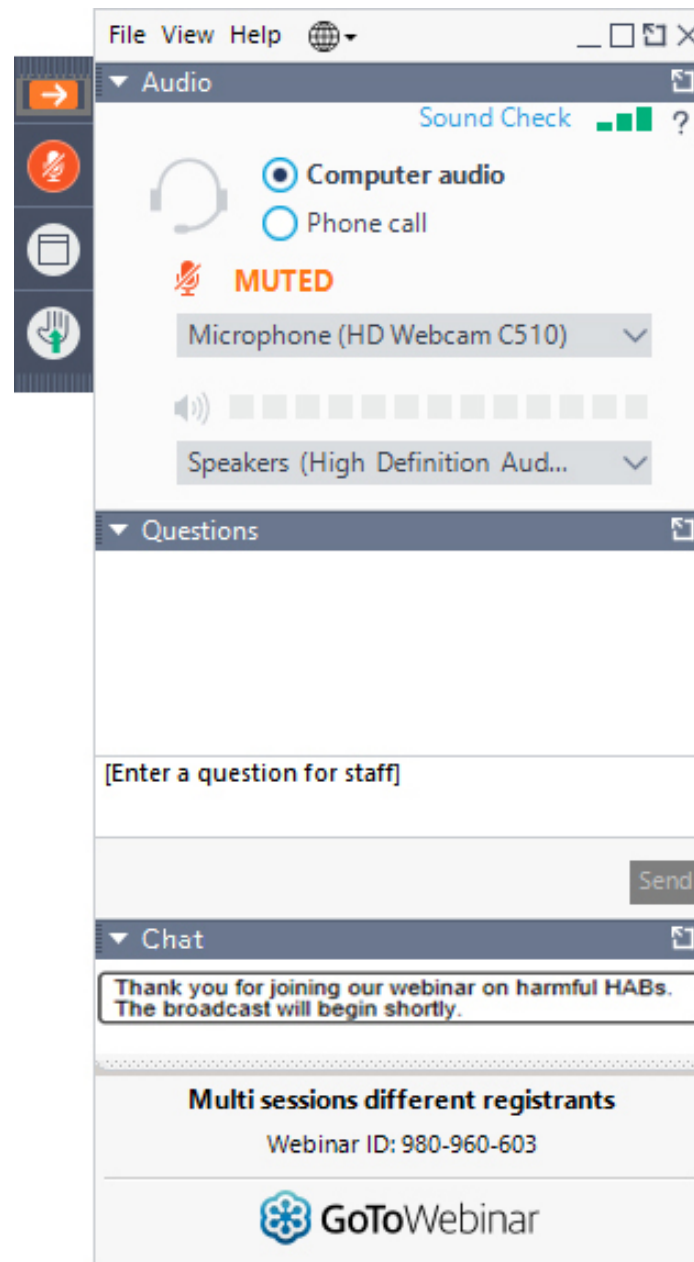
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Dr. Anders Tengberg



BACKGROUND

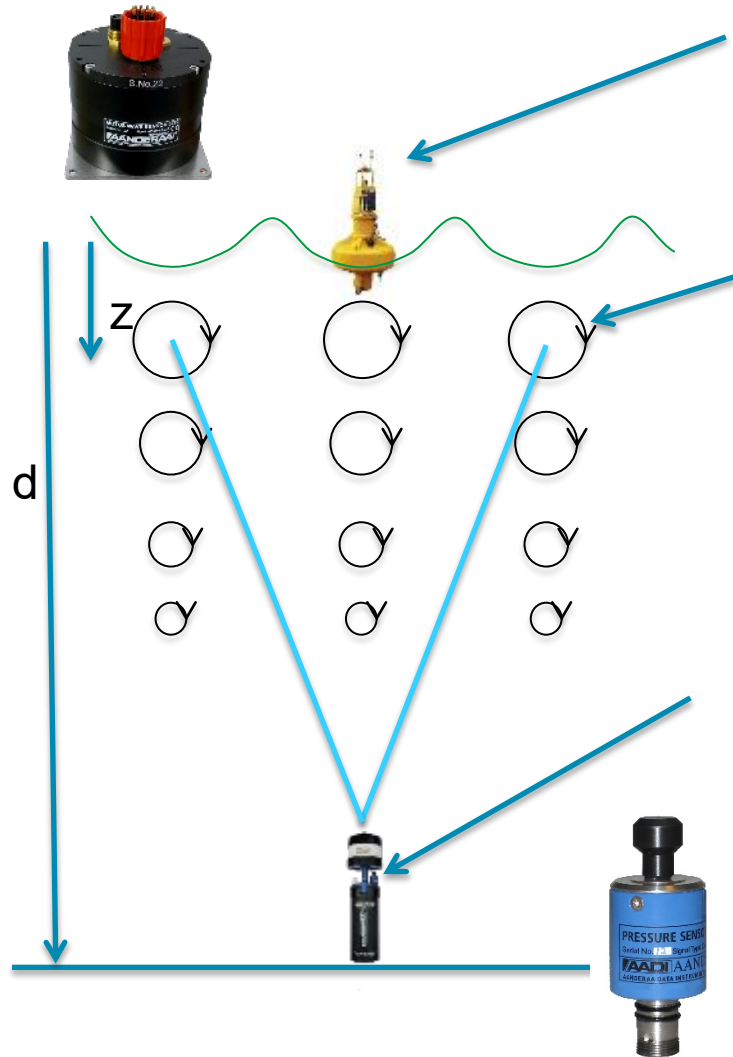
- Aanderaa Product Manager for water quality sensors
- 25 years experience in development and use of underwater technology.
- His work is reflected in ~50 scientific publications.
- Since 1997 product manager for water quality sensors at Aanderaa/Xylem in Norway and part time with oceanographic research at the University of Gothenburg, Sweden

AGENDA

- TRANSFER FUNCTIONS FOR DIFFERENT WAVE SENSORS, MEASURING PRINCIPLES
- MOTUS NOISE REDUCTION & APPLICATIONS
- ACOUSTIC WAVE- ADAPTIVE BROADBAND/NARROW BAND PULSE TECHNOLOGY
- PRESSURE BASED WAVE SENSORS & APPLICATIONS
- INTERCOMPARISON OF FOUR WAVE SENSORS
- MEASURING CURRENTS FROM BUOYS AND MOORED PLATFORMS
- MEASURING CURRENTS IN HIGH SEA-STATE
- NEW SENSORS FROM AANDERAA IN 2021
- SUMMARY & QUESTIONS

Different wave measuring methods all rely on low noise

Aanderaa offers three methods to measure waves



Accelerometer (AHRS) on a buoy at the surface to calculate wave height

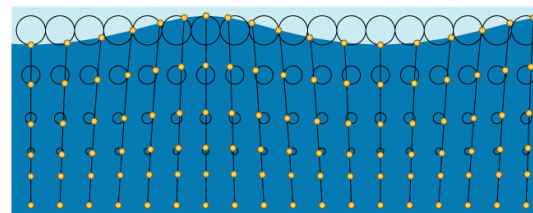
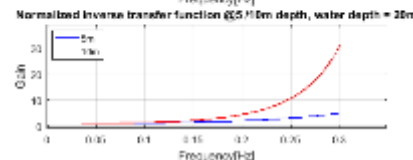
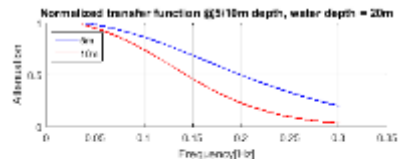
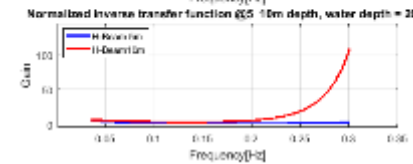
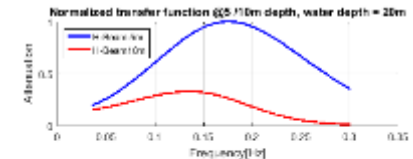
$$a_z(f) \sim H_z(f) \cdot \omega^2 \leftrightarrow H_z(f) \sim \frac{a_z(f)}{\omega^2}$$

Measuring orbital movement at a given water depth to calculate wave height

$$v_z(f) \sim H_z(f) \cdot \omega \cdot \frac{\sinh(k \cdot (d - z))}{\sinh(k \cdot d)}$$

Measuring pressure fluctuation at a given depth to calculate wave height

$$p(f) \sim H_z(f) \cdot \rho \cdot g \cdot \frac{\cosh(k \cdot (d - z))}{\cosh(k \cdot d)}$$



Poll Question #1

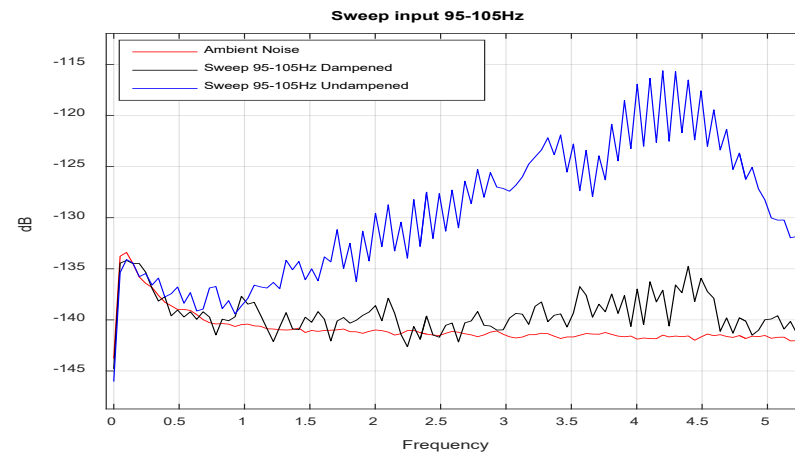
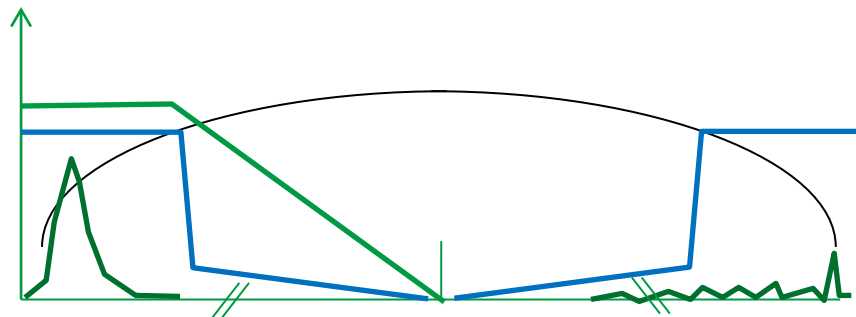


What is your preferred device
for measuring waves?

Motion based wave measurement

How to reduce noise from an accelerometer based wave sensor

- When measuring long wavelengths up to 30 seconds, it is required that the accelerometers have low noise. (Acceleration attenuation at low frequencies $\sim \omega^2$)
 - Low Noise Accelerometer
 - Mechanical filter (vibration isolation) implemented.
- Digital filtering FIR/FFT take care of noise with frequency up to $f_s/2$ (50Hz).
- Wind and current can induce high frequency vibration on the buoy.
- Performance of mechanical filter verified at lab.



Motus directional wave sensor



Gill or Vaisala wind and weather sensors



The Norwegian Coastal Administration ensures safe navigation

MEASURING ENVIRONMENTAL DATA WITH THE AANDERAA MOTUS WAVE BUOY

Safe navigation and up to date weather information from the MOTUS Wave Buoy

The Norwegian Coastal Administration (NCA) ensures safe navigation in the fairways along the coast and in the entry to ports. Their responsibilities include aids to navigation services, AIS network, vessel traffic services (VTS) and reporting services. As part of this, the NCA deploys and maintains the lights and marker buoys along the Norwegian coast and provide reporting services for wave and currents.



MOTUS Wave Buoy on the West Shores of Norway

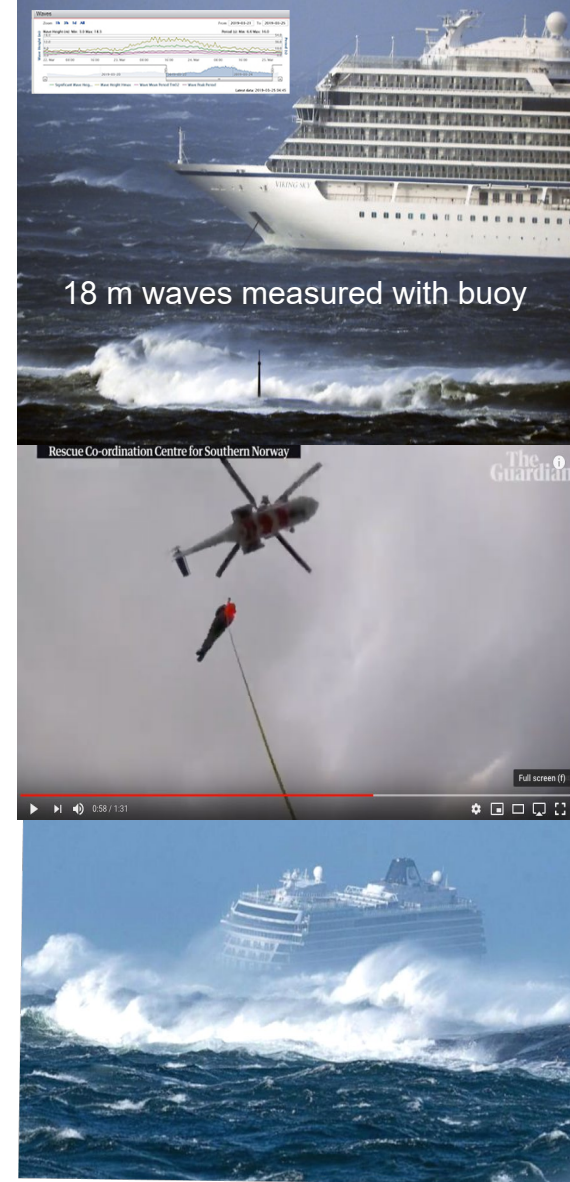


BarentsWatch service providing data for the coastal industries

"The Aanderaa MOTUS Wave Buoy is particularly important for measuring the waves and currents in the area"

In 2017, the NCA wanted to replace one of their standard Cardinal West marker at a challenging location on the Western Shores of Norway. They also needed to measure the waves and currents in the area, especially to give the fishermen information on the conditions, but also for all other ships in that area. Large waves are common and several earlier marker buoys had drifted during winter storms. They approached Aanderaa to see if the MOTUS Buoy equipped with wave, current and met sensors from Aanderaa could possibly do the job of both the marker buoy and provide data from the area. The challenge posed by the NCA was on several fronts:

- 1) Providing a reliable marker buoy in a challenging location with IALA certified nav aids
- 2) Providing quality wave, met and current data consistently from this location
- 3) Minimizing the need for boat operations of the combined solution
- 4) Seamlessly provide data to their existing BarentsWatch wave and current service
- 5) Providing data via AIS to users in the region



18 m waves measured with buoy

Rescue Co-ordination Centre for Southern Norway

The Guardian

Full screen (f)

0:58 / 1:31

Surface currents (single point DCS) + Current Profile (DCPS)



Sensors inside PVC tube

Motus directional wave sensor



Gill or Vaisala wind and weather sensors



xylem
Let's Solve Water



Fig. 1: Deployed SB-138 P buoy equipped with MOTUS wave sensor, DCPS, GMX200 weather sensor, and ATON AIS Type 3

First MOTUS Wave Buoy deployment in the Mediterranean Sea

Xylem and their Spanish partner SIDMAR, have just deployed a **MOTUS Wave Buoy** in the Mediterranean sea, in front of the Cartagena Port, Spain (fig. 1).

Inhabited for over two millennia and founded by the Fenicians, the city of Cartagena has always been a crucial base for commerce from the West to the East of the Mediterranean. It is a major naval station and a commercial harbour in the South East Coast of Spain.

The Cartagena Port Authority is a member agency of **Puertos del Estado** (Spanish Port Authorities) which operates two networks of oceanographic buoys: coastal and deepwater. The buoys are equipped with meteorological (MET) and current wave sensors that provide real-time data to help navigation. They also produce weather forecast that are made available to vessel traffic, Spanish MET agencies, universities, etc.

The Cartagena Port Authority chose Xylem to provide them with a new buoy equipped with directional wave sensors. With the support of our Spanish partner SIDMAR, Xylem delivered a Tideland SB-138P buoy



Fig. 2: Site of deployment, Cartagena, Mediterranean Sea



Fig. 3: MOTUS Wave Buoy

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App note 108 February 2019
Marine Transport • MOTUS WAVE BUOYS

Brazilian Port chooses MOTUS Wave Buoy

THE MOTUS WAVE BUOYS IMPROVE NAVIGATION TO PARANAGUA PORT

SISMO PARANAGUA

Paranáguá Port - Background

Located in the Southern region of Brazil, Paranáguá port is one of the three most important ports in the country.

The region is affected by strong winds, waves, frequent fog, intense tide currents, and river discharge. There are sand banks around the estuary's inlet due to the high sediment input in the area, narrowing the access channel and causing refraction of incident waves. These factors provoke changes in the local hydrodynamic conditions and create complex and challenging navigation.

The port's navigation channel extends to a long-unprotected area off the coast, which is affected by the incidences of waves from all directions.

SISMO® is the information system used to improve navigation safety with real-time monitoring of meteorological and oceanographic parameters. It provides a better understanding of hydrodynamical variables that can affect ships when entering or leaving the port's complex.

"The Aanderaa MOTUS Wave Buoy is particularly important for the Paranáguá port with regards to the wave current fluctuations."

Client: Paranáguá Pilots

The Pilots' association is strong in Brazil and around the world, providing safe navigation and maneuvers inside port areas. With real-time monitoring, pilots are more confident in making important decisions during critical situations.

System Configuration

SISMO® is the Real Time Met-Ocean Information System developed by HidroMares, the representative of Aanderaa in Brazil. The **MOTUS Wave Buoy** is a crucial component of the Paranáguá project. The solution is made of a Tideland SB-138P Buoy equipped with Aanderaa sensors to provide real-time measurement of wave height, period and direction, current speed and direction as well as weather parameters, such as visibility and wind speed.

The real-time directional wave spectrum data obtained with the Aanderaa MOTUS Wave Buoy is particularly important for the Paranáguá port because of the wave current fluctuations.

HidroMares provides a turnkey solution with system integration, sensors maintenance, data transmission and quality analysis, together with Aanderaa's experience and support.



Figure 1. Location of Paranáguá Port, Brazil



Figure 2. MOTUS Wave Buoy at Paranáguá Port

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Surface currents (single point DCS) + Current Profile (DCPS)



Sensors inside PVC tube

Motus directional wave sensor



Gill or Vaisala wind and weather sensors



YSI EXO water quality sensors w antifouling



Flexible MOTUS Buoys chosen by major dredging operator

Dredging, breakwater building, and coastal construction, all depend on up-to-date information about the sea state and environmental conditions on site. However, each job has slightly different needs for monitoring.

Major dredging companies have long used different buoys for measuring directional waves, currents and environmental data such as turbidity and oxygen. With the new MOTUS Wave Buoy, dredgers are finding their monitoring needs covered by one buoy solution. Designed to vary the payload while compensating the buoy motion with built-in parameters, the MOTUS Buoys, can be configured with different sensor packages without jeopardizing the accuracy of the wave and current measurements. We are happy to announce that a major dredging company now has chosen the MOTUS Wave Buoy Solution for their dredging operations.



MOTUS Wave Buoy Solution

Emilie Dorgeville, Product Manager for the MOTUS Wave Direction Sensor, explains more about what the MOTUS Wave Buoy Solution has to offer: "A focus for our development has been to measure accurate currents and waves from a navigational buoy. The MOTUS Wave Direction Sensor packages have been tested for over a year to ensure the accuracy and robustness of the solution. The result is better than anticipated, and we are now able to measure research grade results for both wave height and direction as well as currents from our 1.75m buoy."

Versatile Platform Tailored to any Project

Aanderaa has developed a buoy concept in collaboration with their Xylem Analytics (XA) sister companies Tideland and YSI to offer a complete package for measuring currents, waves and environmental parameters from the same buoy with all major products from XA. These

products have individually strong track records, but are now also part of the [MOTUS Wave Buoy solution](#). Included are market leading products such as the YSI EXO2/EXO3 Multiparameter Sonde, the Doppler Current Profiler Sensor 600kHz, the MOTUS Wave Direction Sensor from Aanderaa and the Tideland buoy SB 138P.

MOTUS for Dredging Operations

The MOTUS solution solves a number of challenges for the dredging industry. Waves limit the type of operations that can be executed during building of breakwater constructions. When large rocks are positioned to form the breakwater, vessels depend on calm sea with limited wave activity. Both the wave height and the wave direction will play a role in planning the daily operations in the field.

Aquaculture Pens, Tasmania, Australia SEASTATE CONDITION MONITORING

Background

Salmon farming commenced in Tasmania in the mid-1980s after a report to the Tasmanian Fisheries Development Authority concluded that a salmon farming industry could be successfully developed in Tasmania. Fertilised Atlantic salmon eggs were purchased in 1984 from stock originally imported in the 1960s from Nova Scotia, Canada. A sea farm was established at Dover in the south of Tasmania and a hatchery was developed at Wayatinah in the central highlands.

The first commercial harvest of 53 tonnes was in the summer of 1986/87 with the Tasmanian industry now producing almost 55,000 tonnes per annum. Tasmania prides itself on its clean, green environment, and it is in the crystal clear waters which has Tasmanian Salmon synonymous with fine seafood around the world.

System Solution

With increasing production comes increasing pressure to manage the stock and the surrounding environment for continuing sustainable production. Xylem Analytics was engaged to provide a monitoring solution that provided a comprehensive measurement of:

- Seastate conditions
- Health of the production waters
- A better understanding of weather and ocean influences
- A survey marker for the production lease.

Xylem Analytics solution was a complete in-house turnkey configuration drawn from our Tideland, Aanderaa and YSI manufacturing facilities and integrated at our Brisbane Regional Integration Centre.

Key components were as follows:

- Tideland SB138-P Buoy
- YSI EXO Water Quality Sonde
- Aanderaa MOTUS sensor (Wave Profiler)
- Aanderaa DCP55400 (Current Profiler)



Client: Huon Aquaculture
Completion: 2017

Xylem's role: Integrator
Xylem scope: Design, manufacture, delivery, installation and commissioning of the MOTUS Buoy that incorporates the real-time measurement of Wave Height and Direction, Current Speed and Direction, Water Quality and Weather parameters.

Xylem also provided the Web Based portal for viewing and management of the collected data that allows planning and management of the Lease operations.



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Surface currents (single point DCS) + Current Profile (DCPS)





NEWSFLASH

Successful MOTUS Wave Sensor integration on larger buoy platform

Installations in harsh environments increase the need for information on Metocean parameters. Operators in these environments want to benefit from fewer installed sensor platforms.

A major manufacturer of larger sensor platforms in Europe has chosen the Aanderaa MOTUS Wave Sensor combined with the Aanderaa Doppler Current Profiler to monitor Ocean Waves and Ocean Currents. In partnership with LiDAR and other sensors, we provide the end-users with a complete solution for Metocean monitoring with high-quality data

MOTUS Wave Sensor

Stig B. Øen, Product Manager for the MOTUS Wave Direction Sensor, explains more about the MOTUS Sensor's latest news:

– Our continued effort in listening to the users of **MOTUS Sensors** and **MOTUS Buoys** have resulted in an upgrade of the sensor to provide some additional wave parameters based on the vertical time series displacement in addition to an NMEA AIS mode. The new parameters in the MOTUS sensor are Wave Mean Period T1/3, Significant Wave Height H1/10, Wave Mean Period T1/10, Wave Height H1/1, Wave Mean Period T1/1 and the earth referred East and North Horizontal time series that is configurable for sampling at 2Hz or 4 Hz. Parameters provided by MOTUS Wave Sensor can be found in the **datasheet**.

MOTUS sensor New parameters

- Wave Mean Period T1/3,
- Significant Wave Height H1/10,
- Wave Mean Period T1/10,
- Wave Height H1/1,
- Wave Mean Period T1/1
- East and North Horizontal time series, configurable for sampling at 2Hz or 4 Hz.



10 m diameter buoy with:
Motus, DCPS, GPS compass



3.5 m long autonomous, wave driven



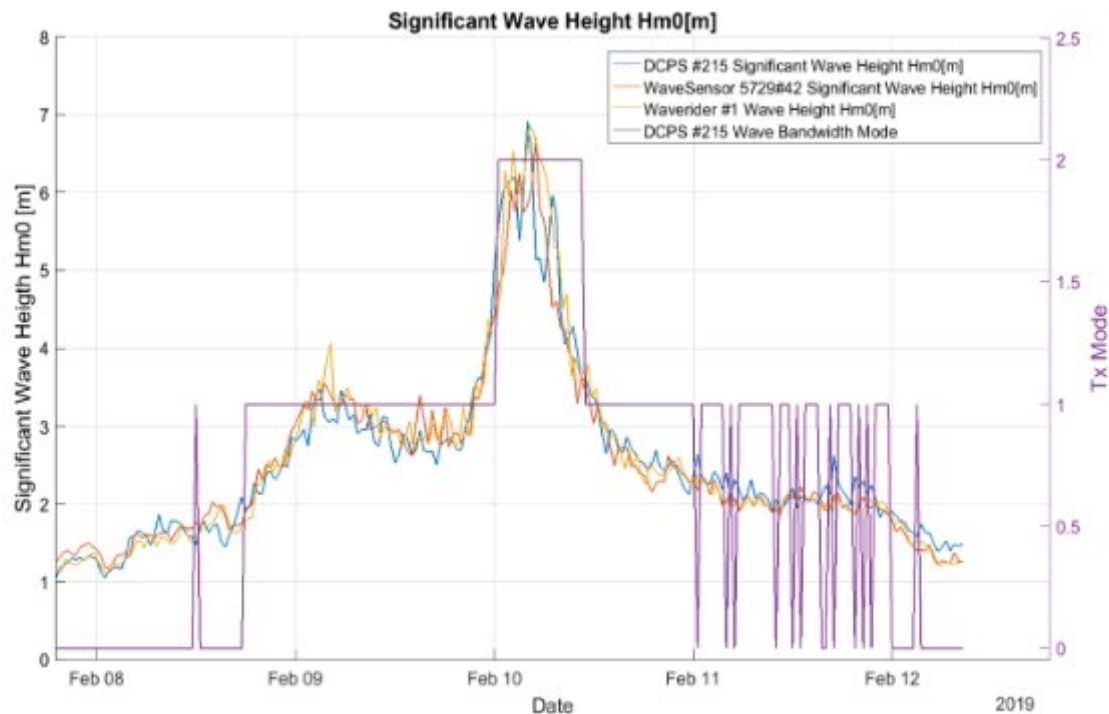
0.6 m long autonomous, wind driven

<https://autonautusv.com>

<http://www.sailbuoy.no>

Adaptive BB pulse (570 – 630kHz) & NB pulse

- The SGII DCP Wave samples wave data @ 4Hz.
- Automatically switches between a highly accurate BB mode limited to Hm0 up to about 2.2 m, a medium accurate BB mode limited to Hm0 up to about 4m, and a robust NB mode with no practical speed limitations.
- The automatic Tx pulse – sea state dependent selection ensures a accurate low noise wave measurement.



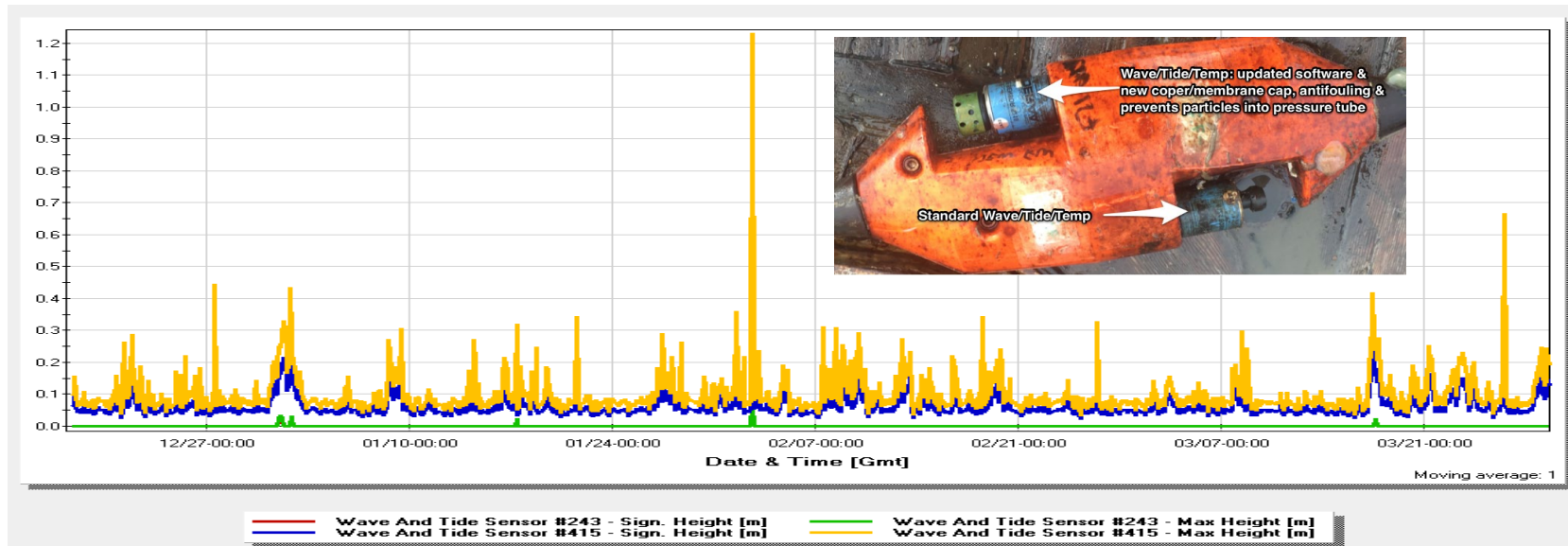
- The DCPS uses wave samples to measure current simultaneously for three cells.
- Full current profile is measured in between each wave measurement.

Pressure based Wave and Tide sensor

- Utilize 24bit low noise A/D converter.
- Gives both time series output at 4 or 2Hz along with Energy spectrum for post processing purpose (see datasheet for all parameters available (https://www.aanderaa.com/media/pdfs/d407_aanderaa_wave_and_tide_sensor_5218_5218r.pdf))
- By evaluating the energy spectrum, the original cut-off frequency was found to be too conservative.
- New! The wave bandwidth used for significant wave height can be extended by user settings.
- Sensor has been revalidated together with SGII DCP Wave



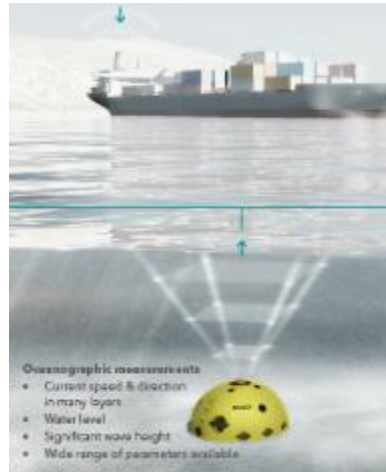
Wave height new (#415) and old software



Ultra Sensitive Wave/Tide/Depth sensor have a wide use

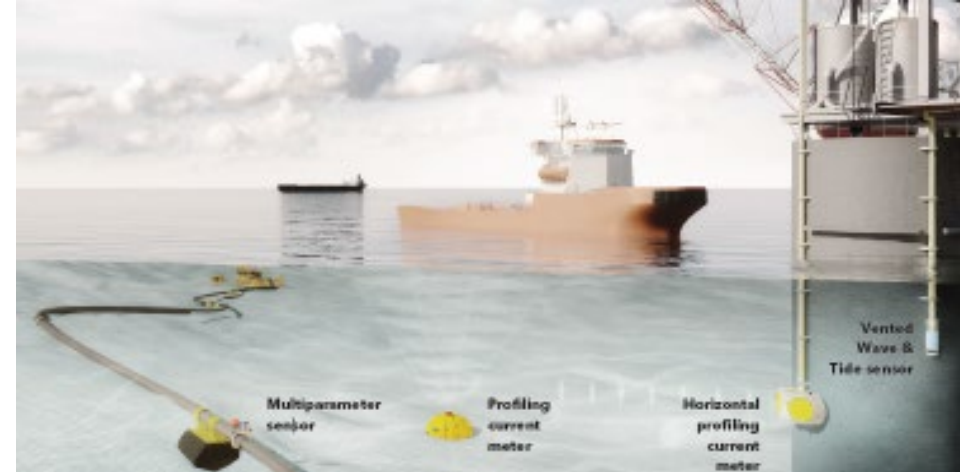


Barrier and Dam operations

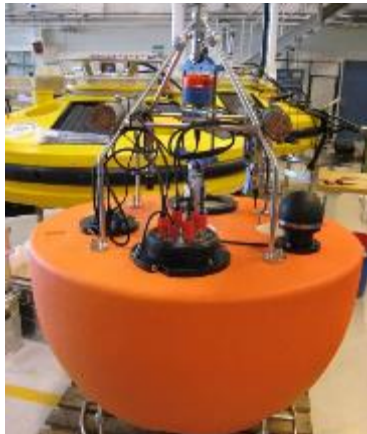


- Oceanographic measurements
- Current speed & direction in many layers
 - Water level
 - Significant wave height
 - Wide range of parameters available

Port Operations



Off shore including slope stability and oil well monitoring



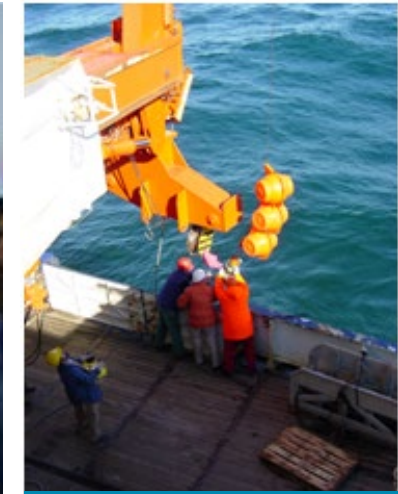
Tsunami and flood warning systems



Cabled Observatories






Autonomous Platform



Moorings

Overview of provided wave parameters

Parameters provided by the SeaGuardII DCP Wave	Parameters provided by The Aanderaa MOTUS sensor	Parameters provided by the wave and tide sensor 5218	
Significant Wave Height H_{m0}	Significant Wave Height/Swell/Wind H_{m0}	Significant wave height	
Peak Wave direction θ	Peak Wave Direction Height/Swell/Wind θ	Max wave height	
Wave Peak Period T_p	First Order Spread σ	Mean period	
Wave Mean Period T_{m02}	Mean Spreading Angle	Peak period	
Wave Energy Period T_{m-10}	Peak Wave Period T_p	Mean zero-crossing period	
Mean Spreading Angle θ_K	Mean Wave Period T_{m02}	Energy period	
First Order Spread σ	Long Crestedness Parameter	Steepness	
Energy Spectrum $E(f)$	Mean Wave Direction	Irregularity of sea-state	
Directional Spectrum $DWS_m(f)$	Wave Energy Spectrum $E(f)$	Cut-off frequency	
Orbital Ratio Spectrum $K(f)$	Directional Wave Spectrum $DWS_m(f)$	Pressure and tide series, raw data	
Fourier Coefficients Spectrum $A1(f), A2(f), B1(f), B2(f)$	Principal Wave Directional Spectrum $DWS_p(f)$	Last pressure sample index	
	Orbital Ratio Spectrum $K(f)$	Wave spectrum	
	Fourier Coefficients Spectra $A1(f), B1(f), A2(f), B2(f)$		
	Significant Wave Height $H_{1/3}, H_{1/10}$		
	Mean Wave Period $T_z, T_{1/3}, T_{1/10}$		
	Maximum Wave Height H_{Max}		
	Wave Period T_{max}		
	Wave Height Max Crest C_{max}		
	Wave Height Max Trough Tr_{max}		
		Heave Timeseries $H(t)$ + Horizontal Timeseries (t) E/N	
			

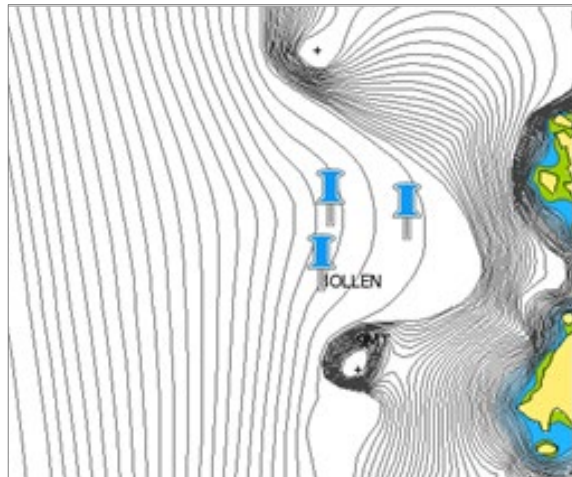
Poll Question #2



Why do you want to measure waves?

Comparing different systems to measure waves

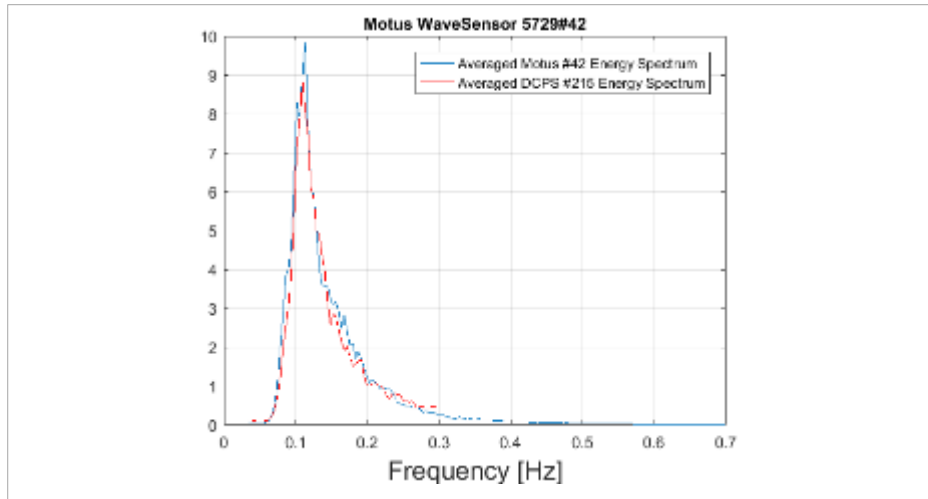
- Four different wave measurements systems are deployed close to the shoreline off the south west coast of Norway at approximately 20m depth.
- One Waverider is located in South West.
- One EMM2.0 Buoy with Aanderaa MOTUS wave sensor, Aanderaa DCS single point current meter and Aanderaa SeaGuardII DCP (ADCP) profiler in North West.
- One Aanderaa submerged bottom frame equipped with a SeaGuardII DCP Wave and a Aanderaa pressure based Wave and Tide Sensor in East.
- Depending on wave direction some discrepancies in the wave field is expected to be observed between the different locations.



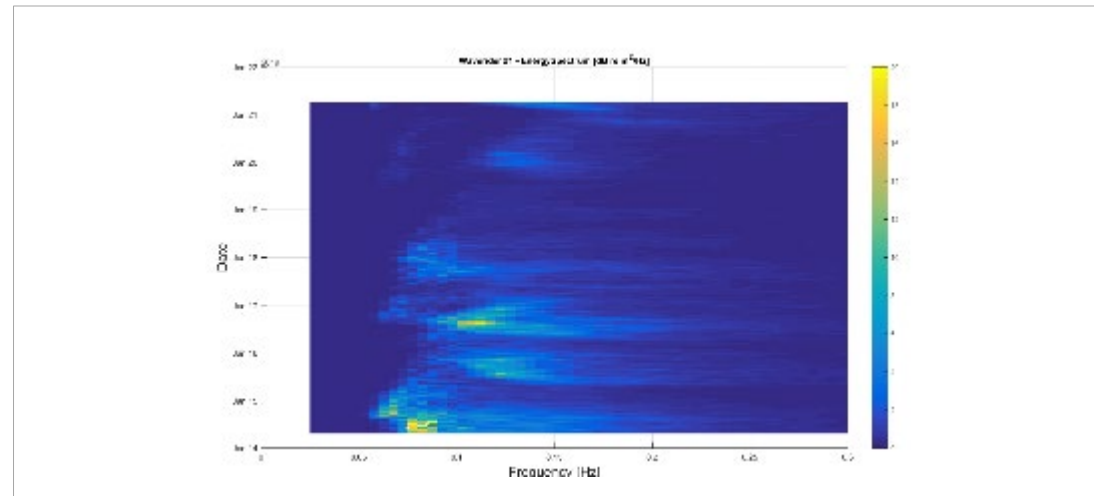
Test equipment



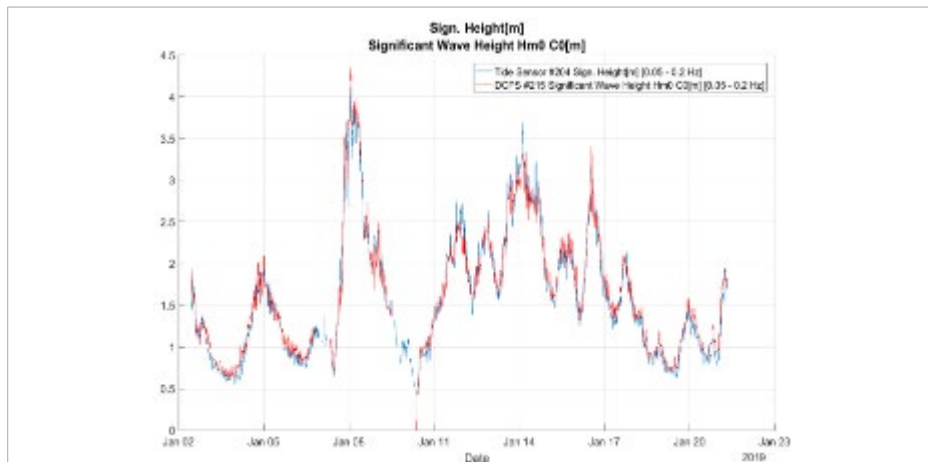
Result highlights



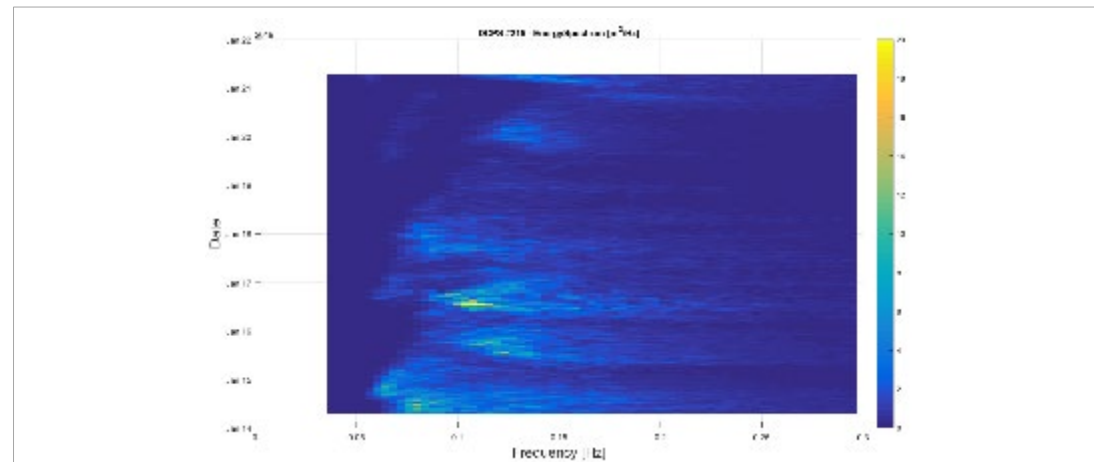
Averaged Energy Spectrum Motus – SGII DCP Wave



Energy spectrum from Waverider. January 14 – January 22

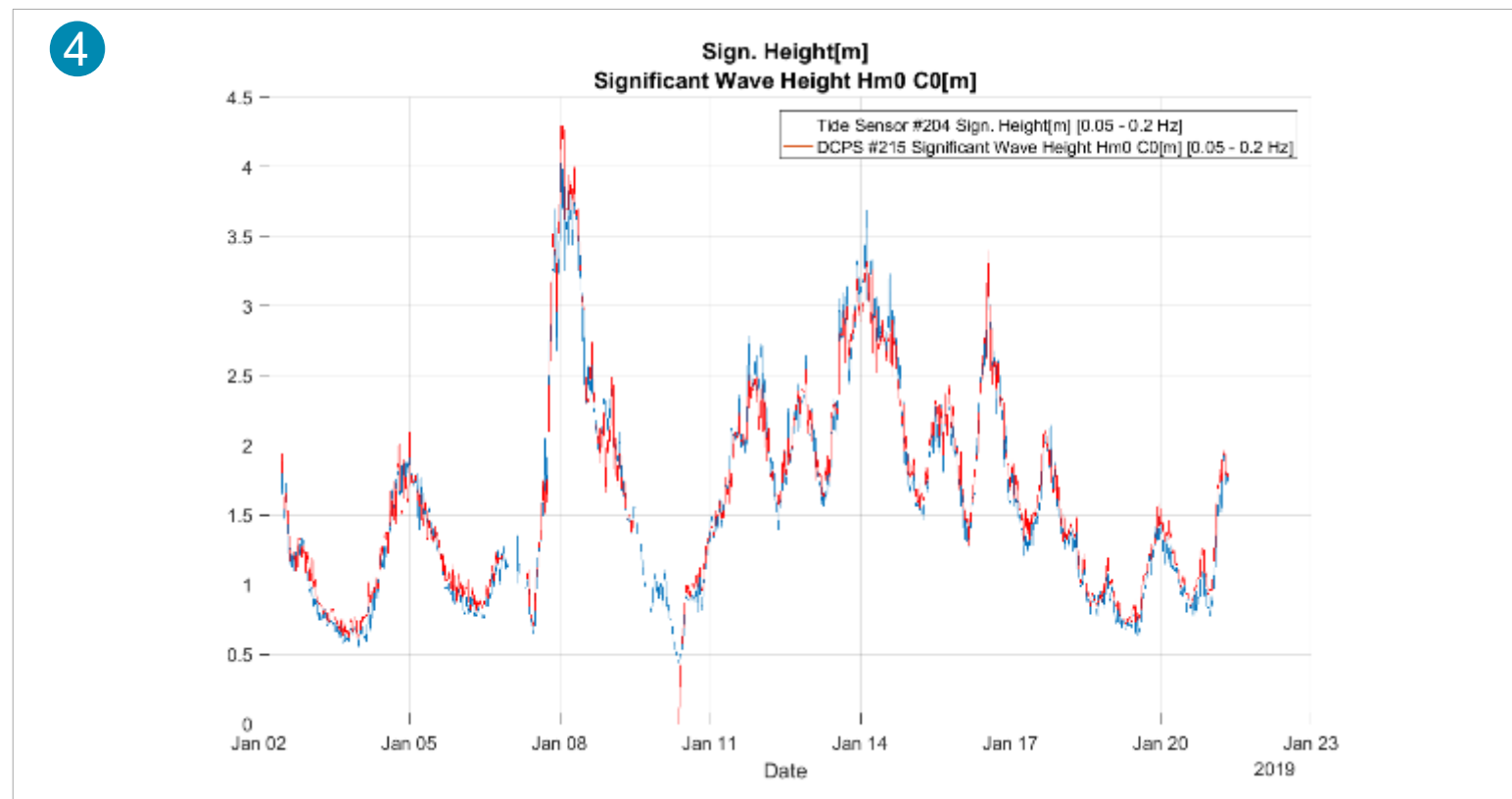
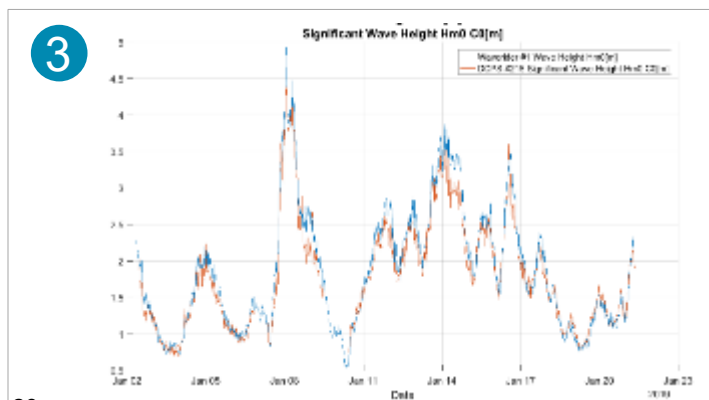
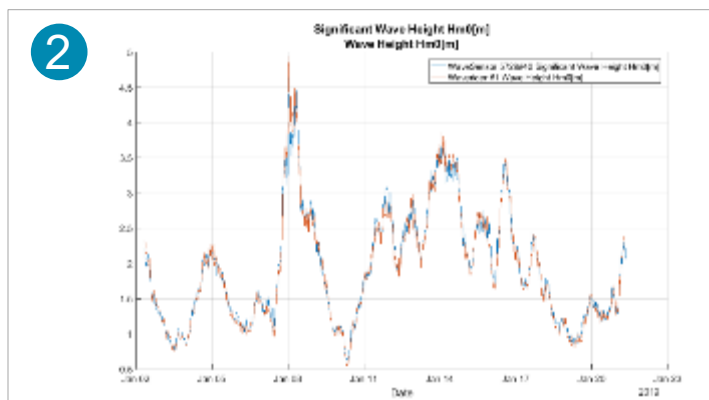
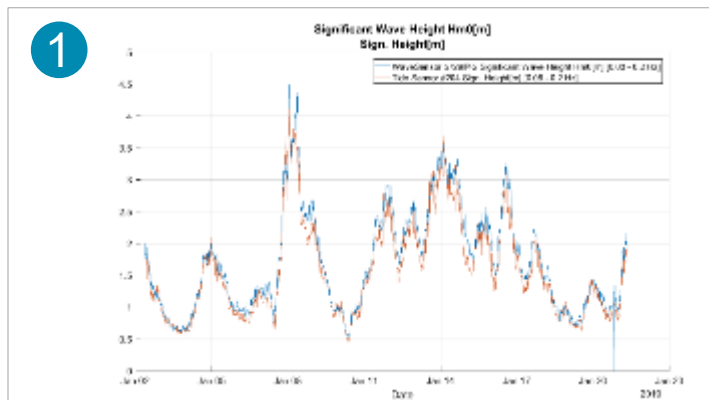


Hm0 comparison Wave and Tide sensor versus SGII DCP Wave



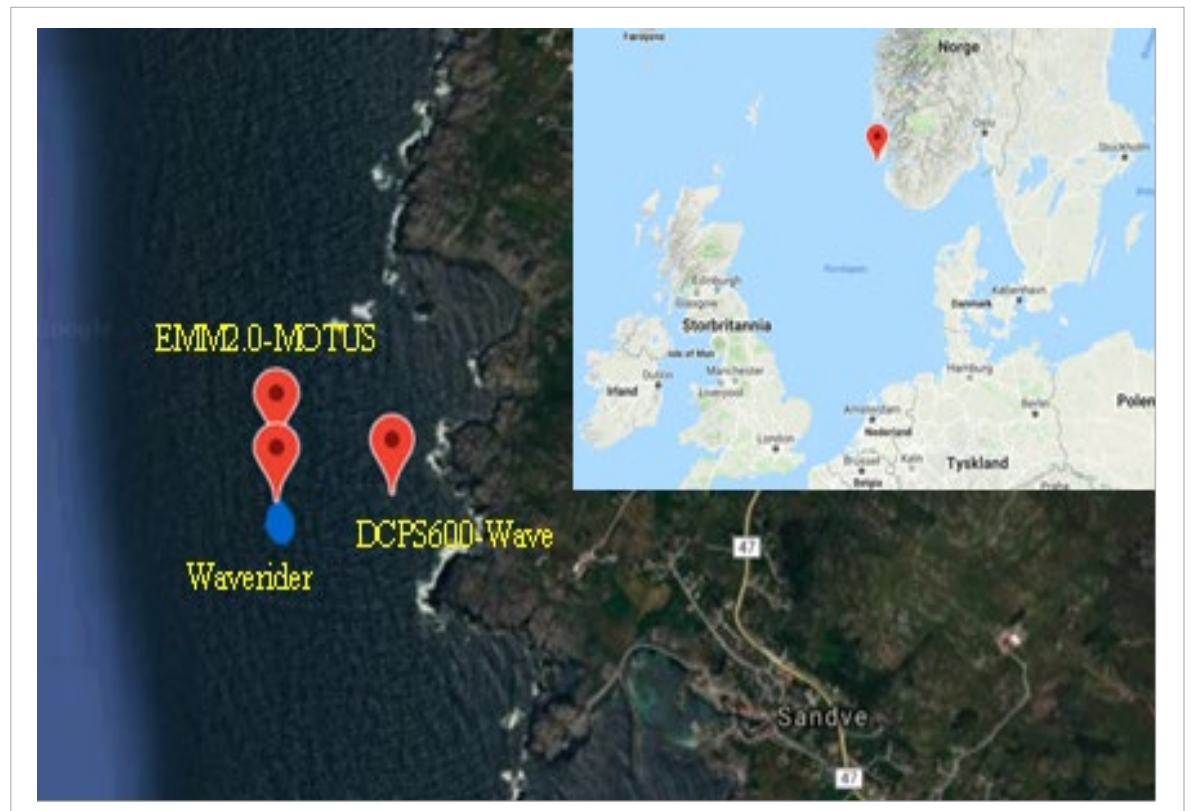
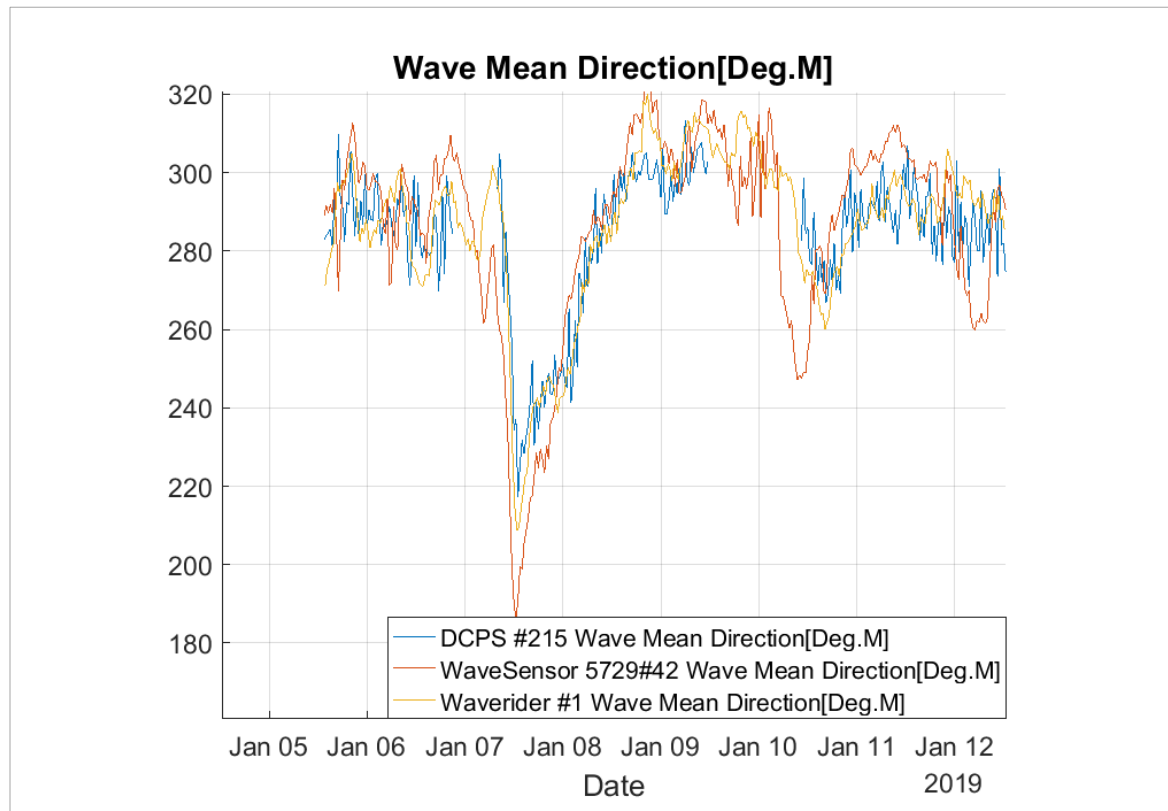
Energy spectrum from SGII DCP Wave January 14 – January 22.

Hm0 comparison at Karmøy

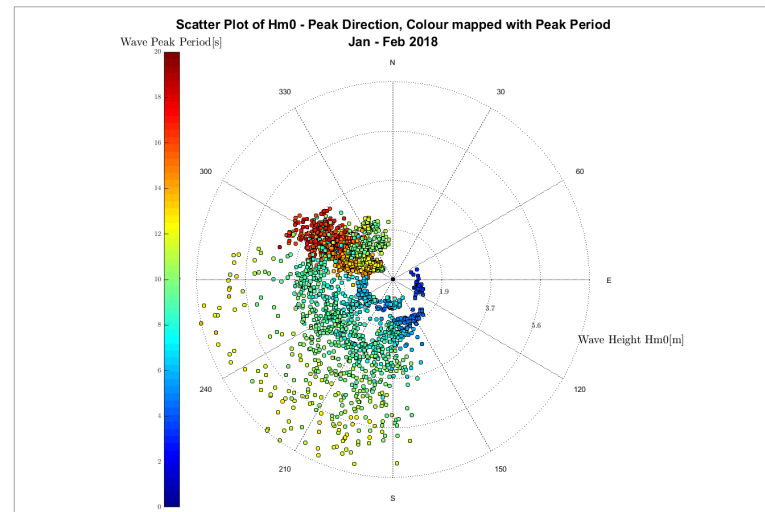
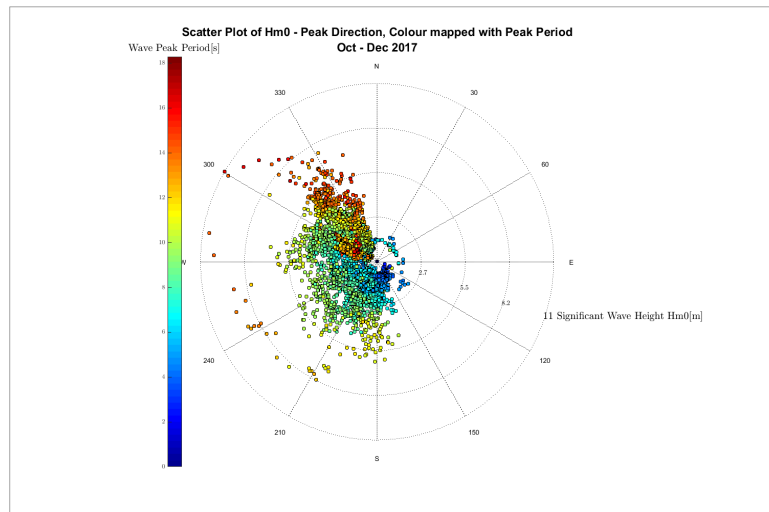
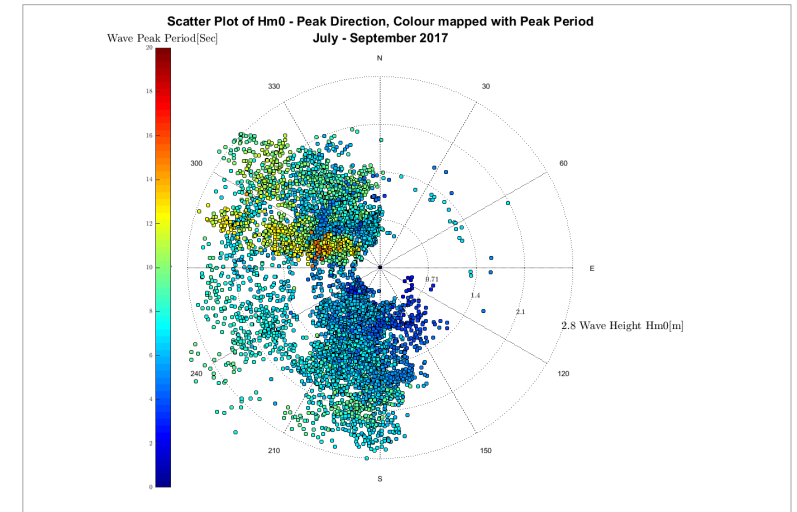
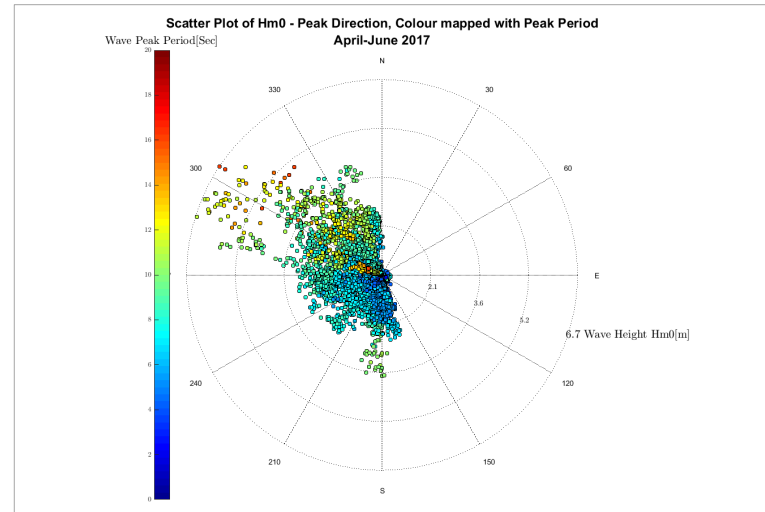
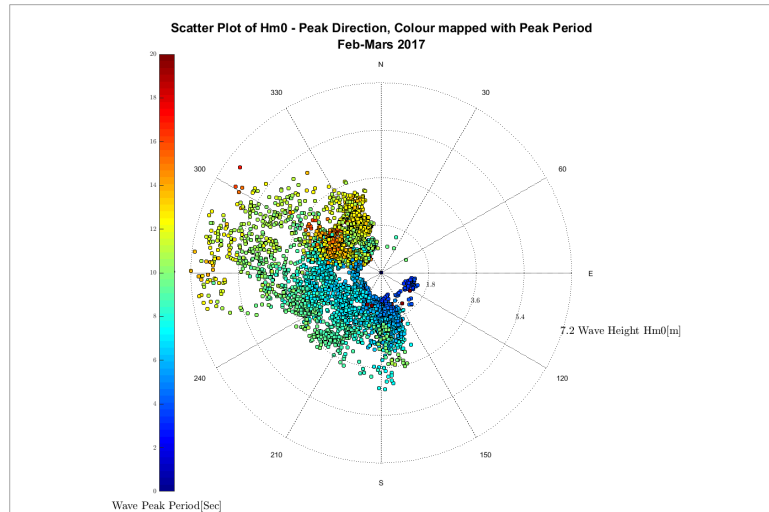


- 1) Comparison Motus swell (0.03 – 0.2 Hz) Hm0 versus Tide (0.05 – 0.2Hz)
- 2) Comparison Motus Hm0 versus Waverider Hm0
- 3) Comparison Motus Swell Hm0 versus AWS (0.03 - 0.3 Hz)
- 4) ASW (0.03 – 0.2Hz) versus Tide Wave (0.05 – 0.2Hz)

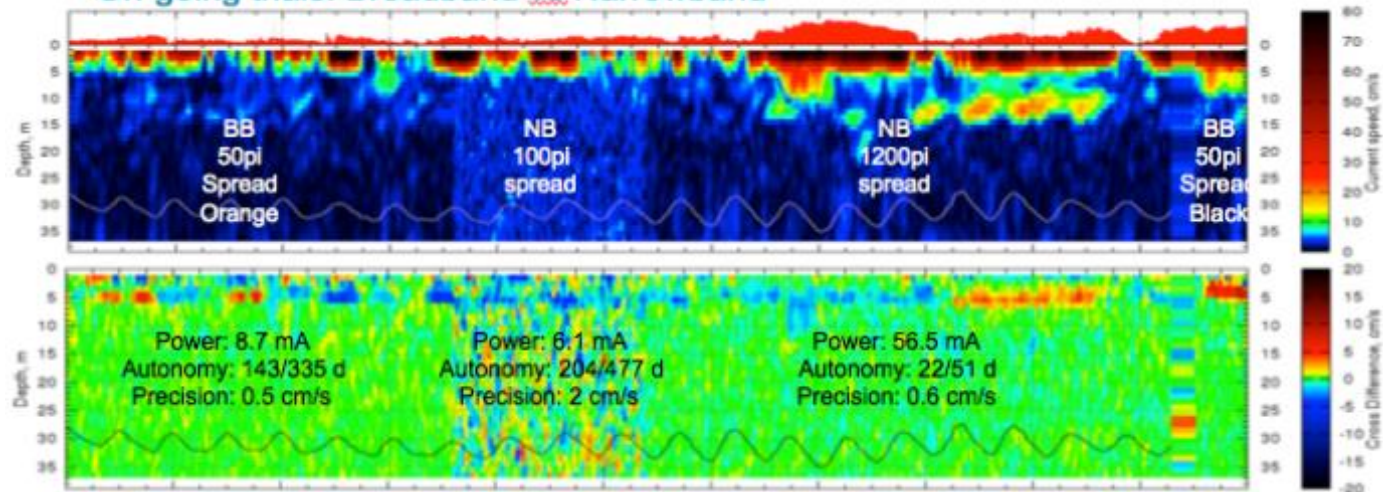
Wave direction comparison



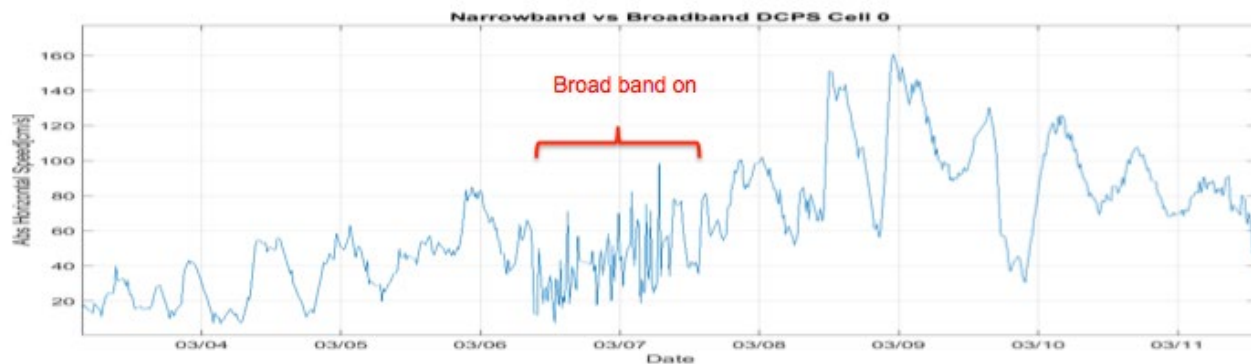
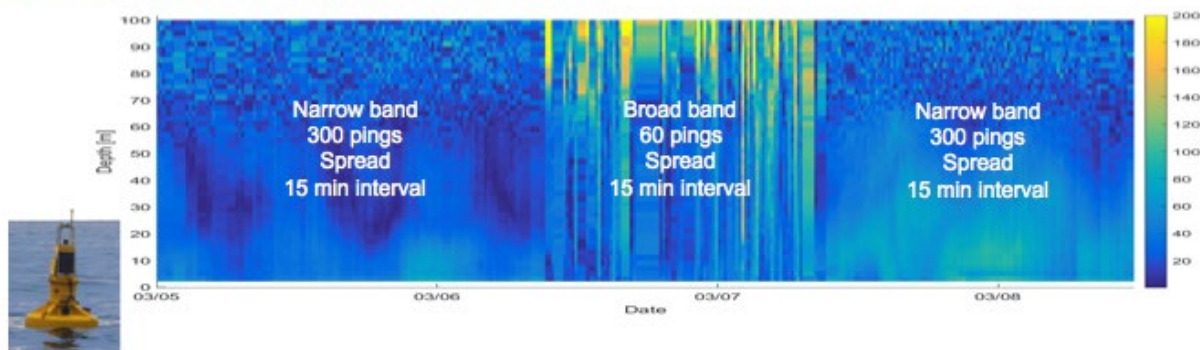
Wave Peak direction vs Hm0 and Peak Period – One year of wave data



On-going trials: Broadband vs Narrowband



Broad band unsuitable for current measurements from rocking platforms: ambiguity issues because of movements



Poll Question #3



What is the water depth that you will be carrying out **current measurements**?

Current measurements in high sea state

- Current measurements correlate well between buoys even in high waves
- Wave measurements correlate well even in high current conditions

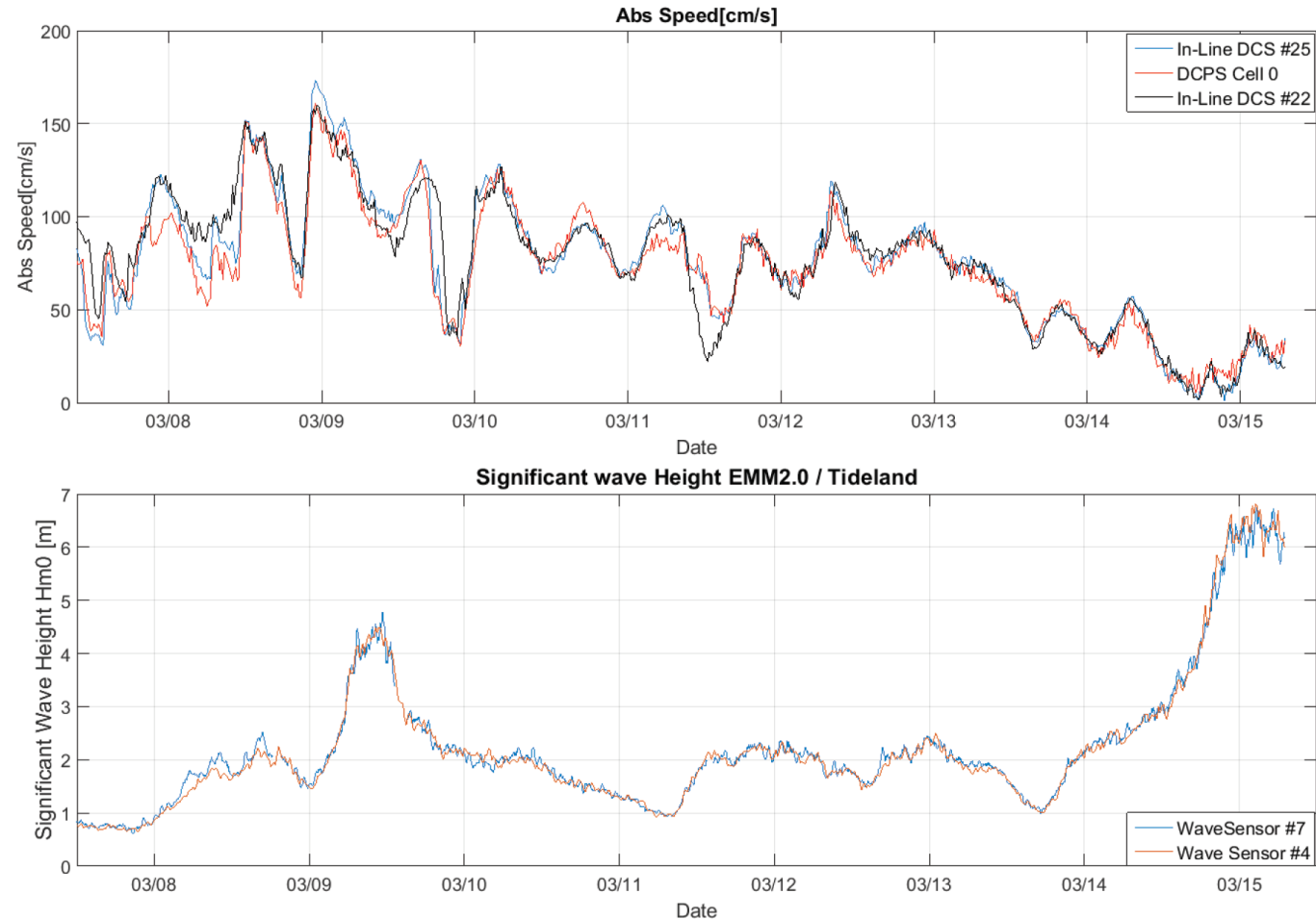
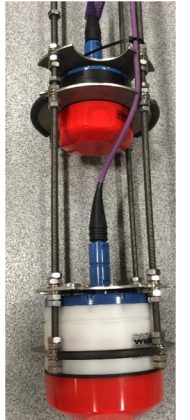


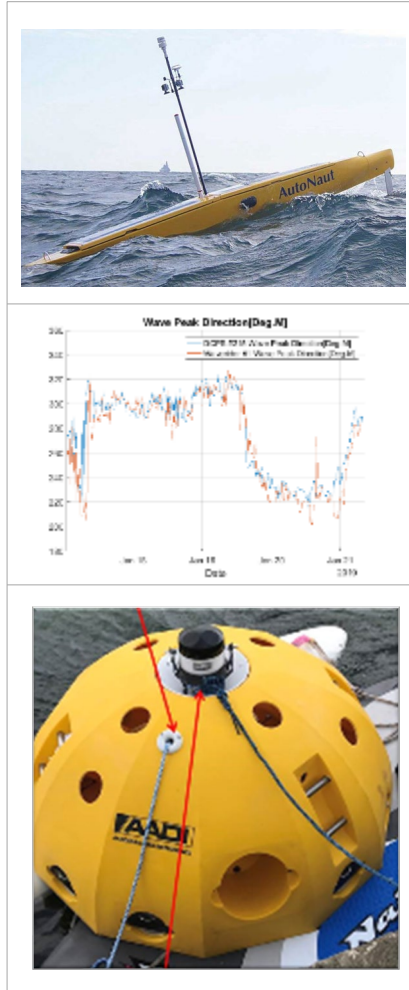
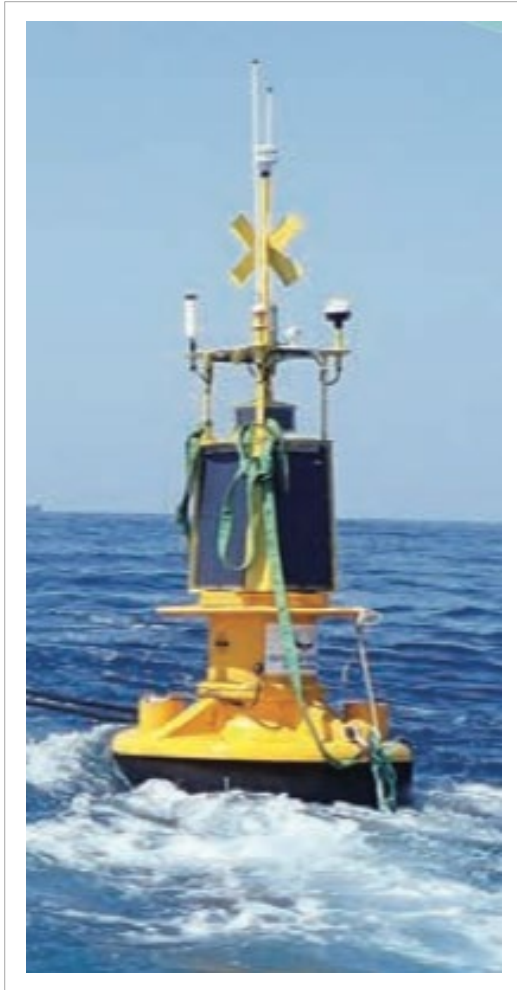
Figure 13: Current speed from DCS #25 (blue) on navigational buoy and #22 (black) and DCPS first cell (red) on Hydrographic buoy. The DCPS first cell is located about 2.5m below the two DCS sensors.

**Surface currents
(single point DCS)
+ Current Profile
(DCPS)**



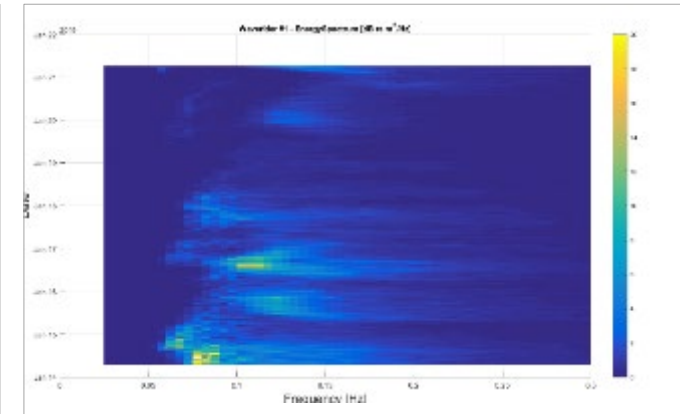
**Sensors inside
PVC tube**

Three ways to measure waves: Theory, Solutions and Applications



SUMMARY

- Aanderaa/Xylem offers 3 different ways to measure waves: Motus (accelerometer), SeaGuardII (acoustic) and Pressure based (5218)
- Innovative solutions like Adaptive Tx pulse (SGII DCP Wave) and mechanical anti vibration filter (MOTUS) have been implemented Aanderaa wave sensors. This give high quality data
- Wave data from different platforms using different technologies agree well
- Current measurements from different sensors and platforms agree well
- From platforms that are moving in the waves/vibrating Narrow Band gives much better current measurements than Broad Band. Every acoustic ping has to be compensated for movements (Accelerometer & 3D compass)



New technology from Aanderaa in 2021

5730 optode
Open sales

Q2



All optodes
40 p calibrated

Q3



Turbidity
0-2500 NTU
6000 m

Q3



Cond/Sal
0.002 mS/cm

Q3



Ultrastable O2
WTW foils, deep
0.2 % drift/year

Q3



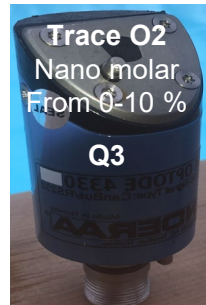
Wave/Tide
cm waves
from 40 m

Q1



Cond with
antifouling

Q4



Trace O2
Nano molar
From 0-10 %

Q3



UV
Anti-fouling
Sensor

Q4

Optode

AANDERAA
a xylem brand

Poll Question #4



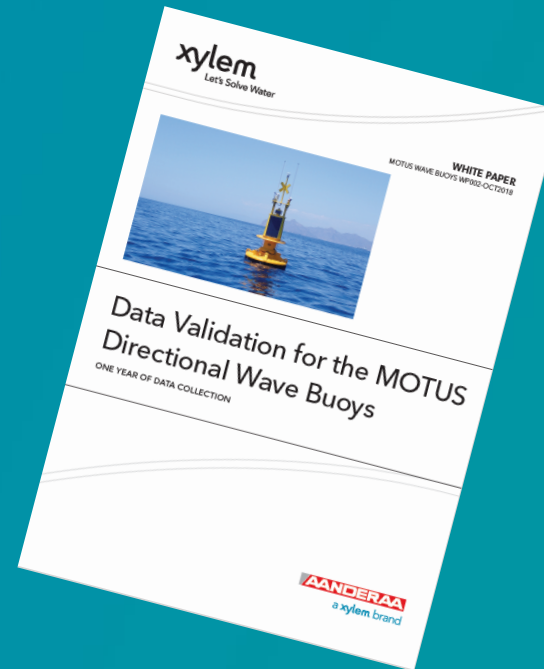
Would you like an Aanderaa product specialist to contact you with more information?

Questions?

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[Data Validation for the MOTUS Directional Wave Buoys](#)



[SeaGuard II DCP Wave](#)

Thank you.

