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Let's Solve Water

June, 2022

Wave and Current measurements
Select the right methods

DR. ANDERS TENGBERG, SCIENTIFIC ADVISOR, PRODUCT MANAGER

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Dr. Anders Tengberg

BACKGROUND

- Since 1997, Product Manager for water quality sensors & scientific advisor at Aanderaa/Xylem, Bergen, Norway
- 30 years experience in development and use of underwater technology: sensors & autonomous platforms
- Part time oceanographic research at the Chalmers University of Technology & University of Gothenburg, Sweden
- Research work reflected in +50 scientific publications

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Agenda

- Acoustic Currents: downward/upward facing, broadband or narrow band?
- Acoustic Currents: importance of movement compensation for every ping
- Current measurements from autonomous vehicles: Sailbuoy in the North Sea
- Waves: 3 technologies developed by Aanderaa
- Acoustic Wave: Adaptive broadband/narrow band pulse technology
- Waves: Comparing 4 technologies for 3 years in the field
- Waves & Currents combined: optimize power use of ADCP deployments
- Waves, Currents & Water Quality combined: understand the environment
- Summary & Questions

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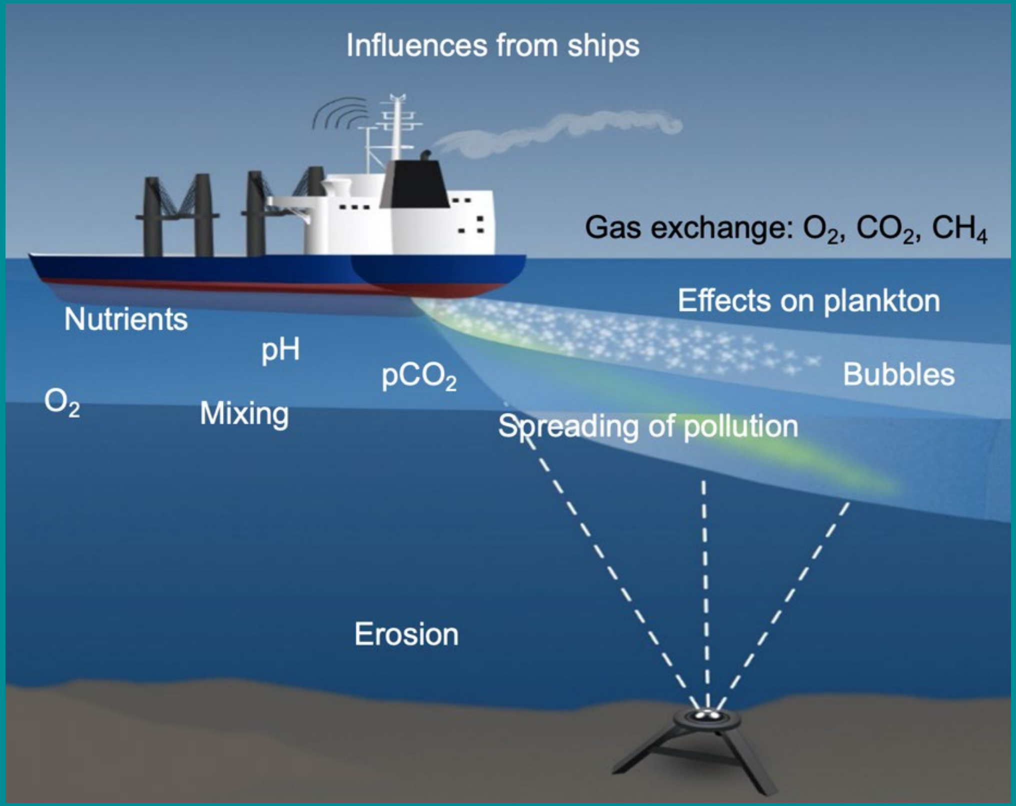
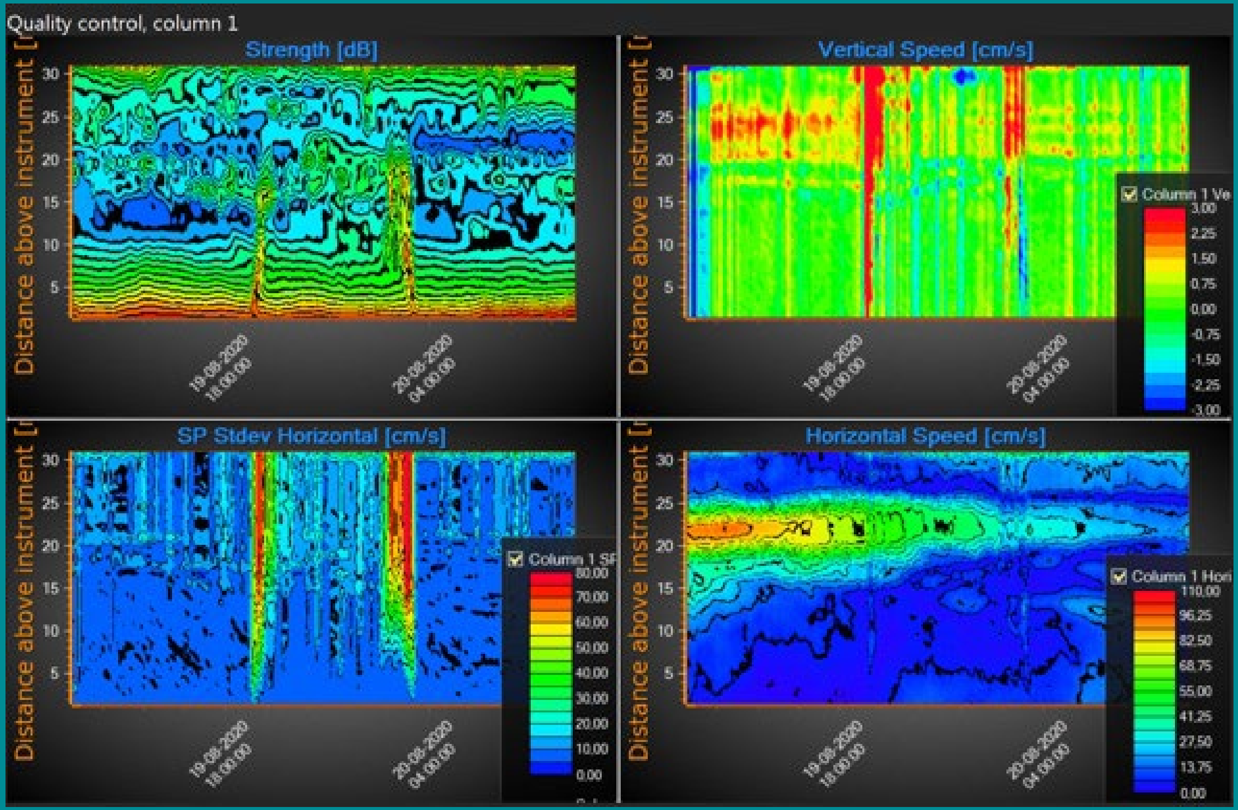
Project to study environmental effects of shipping





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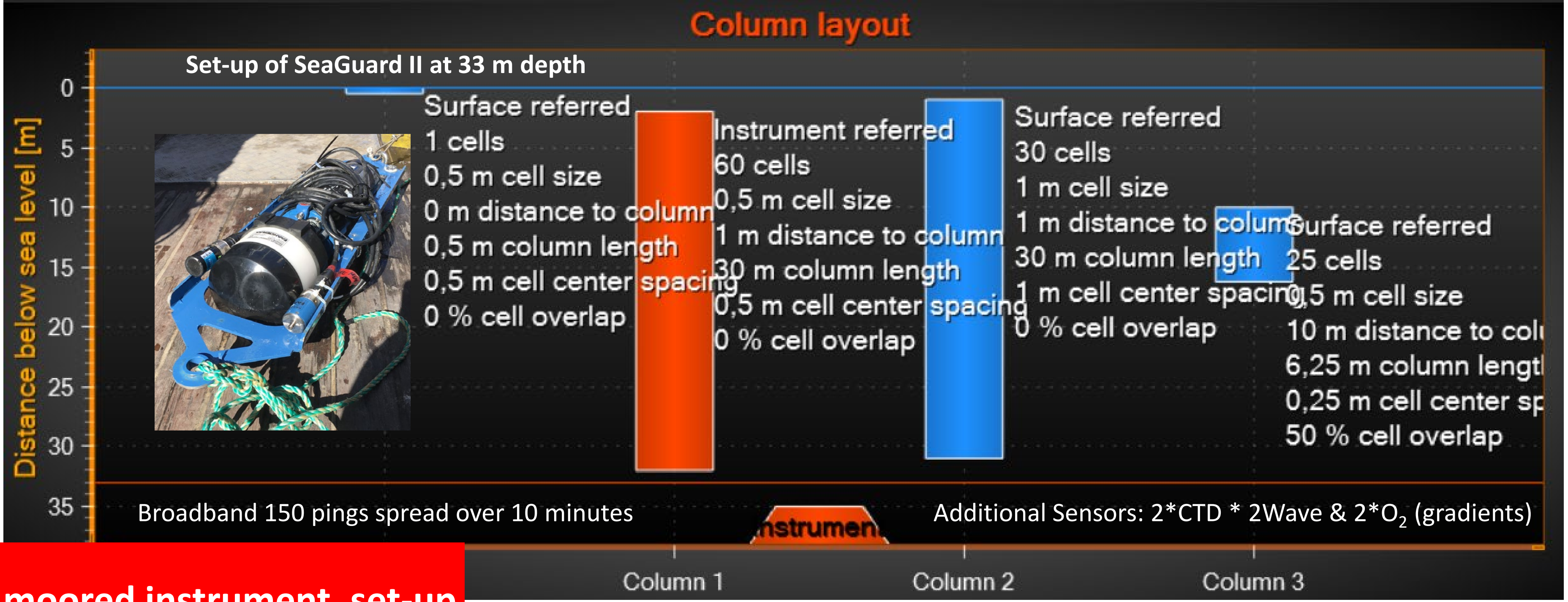
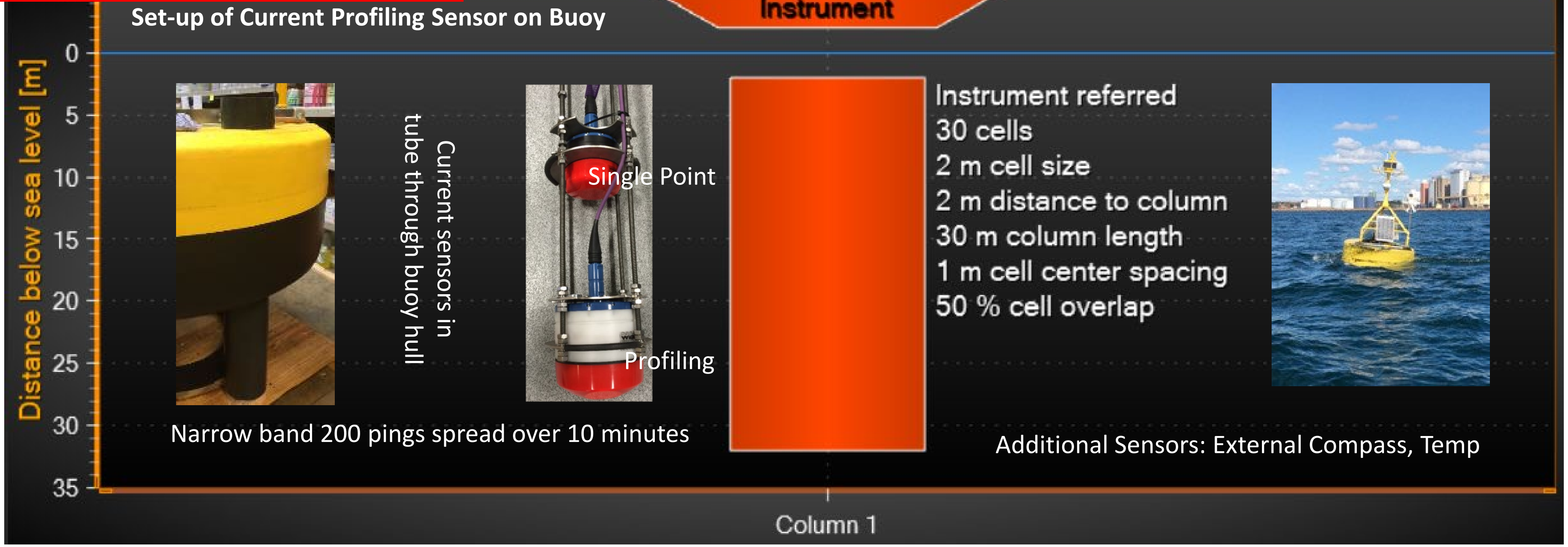
Deployments below ship lanes

SeaGuardII in mooring frame close to bottom
Sensors: DCPS, 2*O_2+2*Sal/Temp+2*Wave/Tide

Check out the free cell phone app, search for “*viva-vind & vatten*”

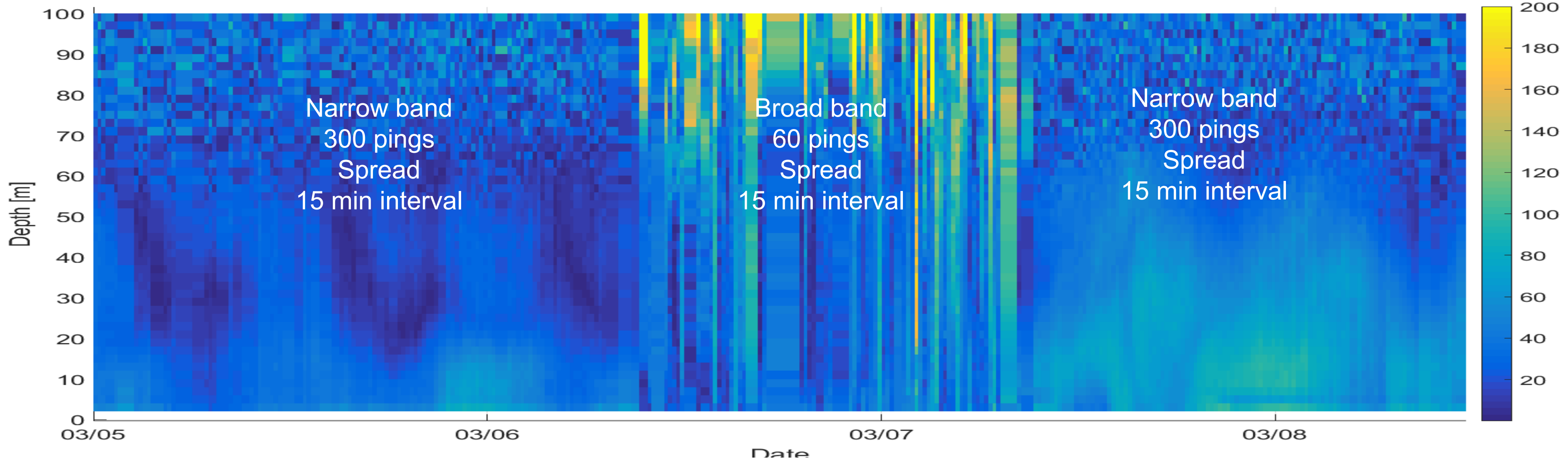
DCPS on buoy & moored instrument, set-up

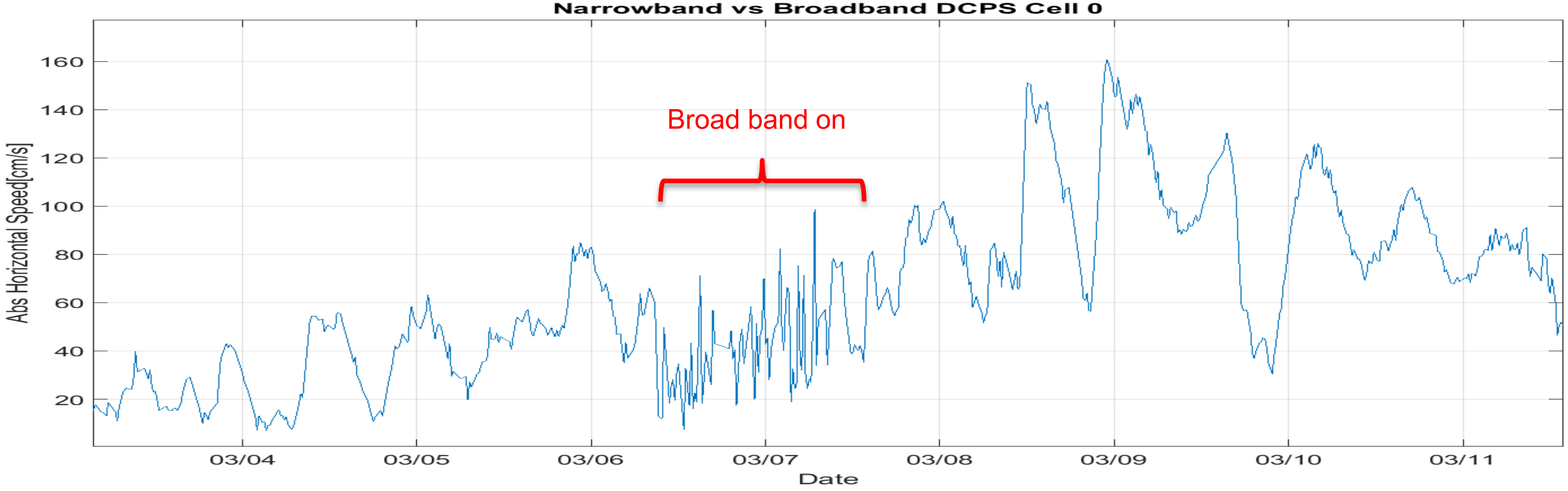




Broad band or Narrow band?

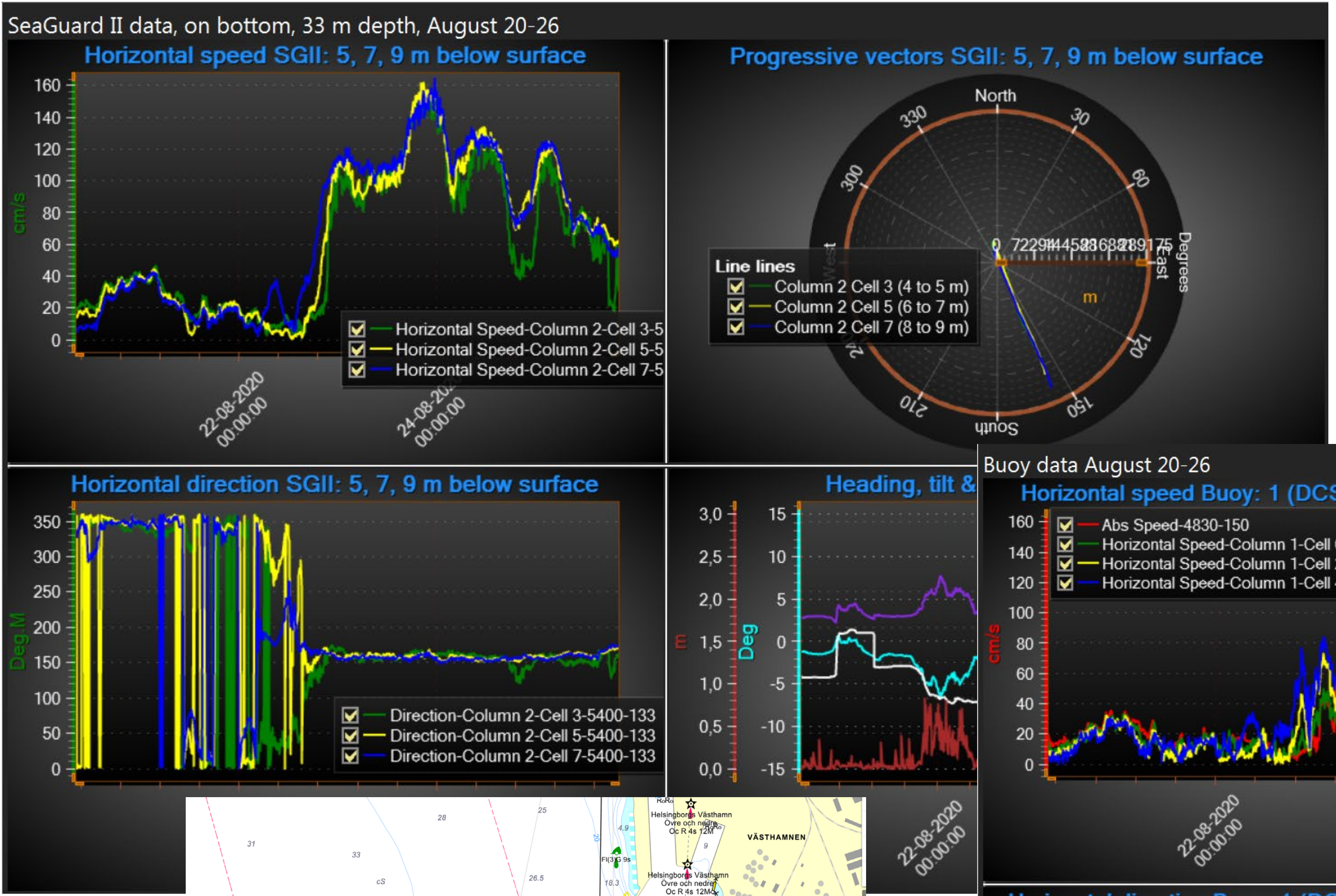
Broad band unsuitable for current measurements from rocking platforms: ambiguity issues because of movements

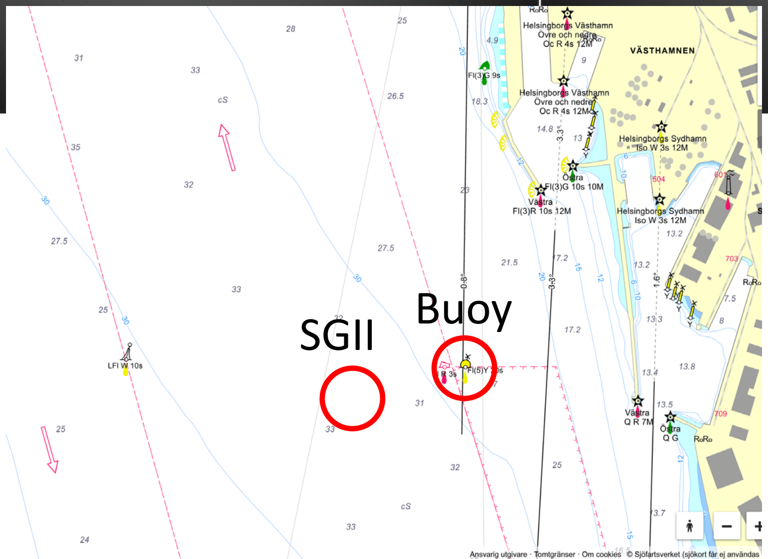


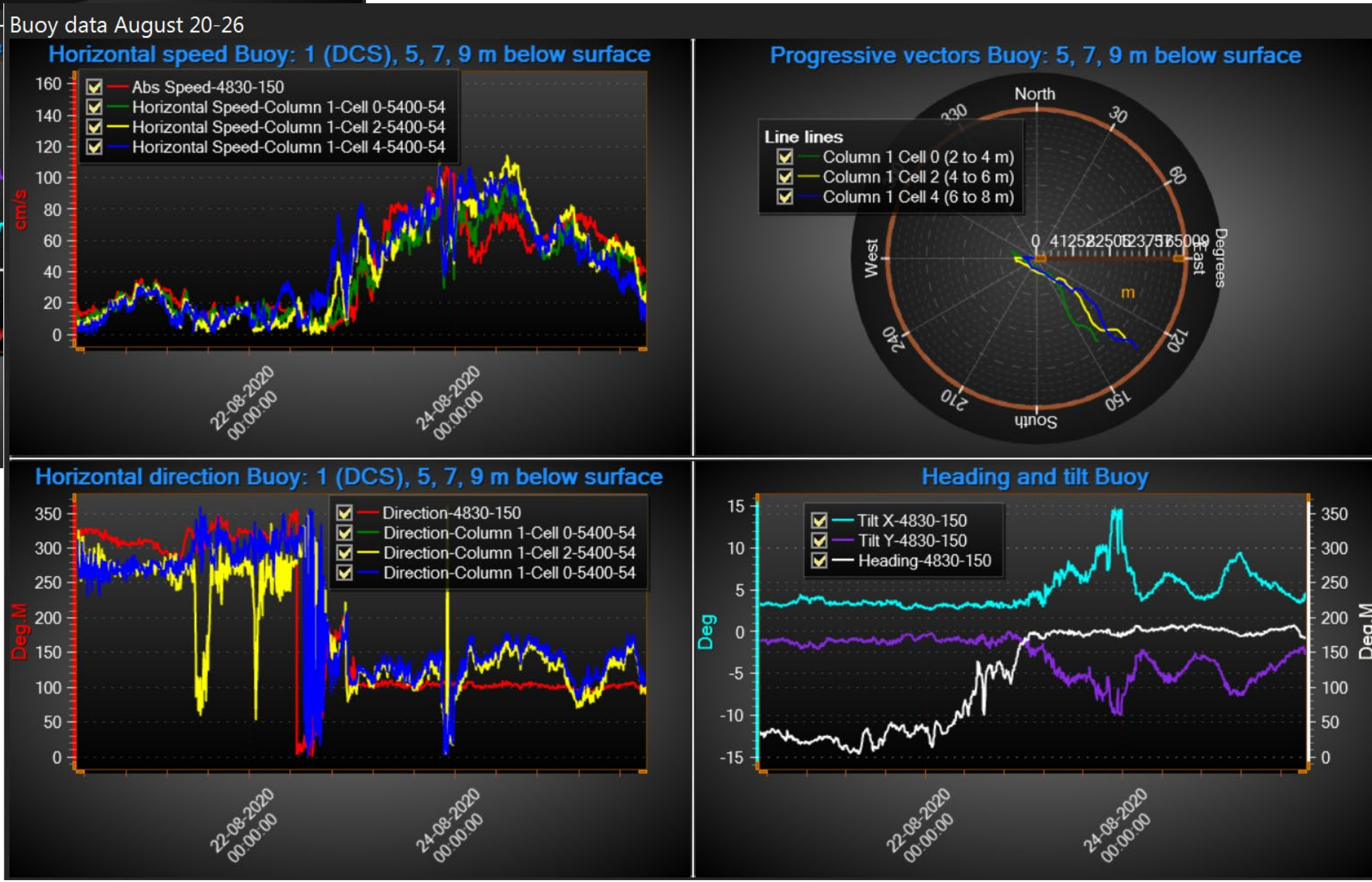


DCPS on buoy & moored instrument, results

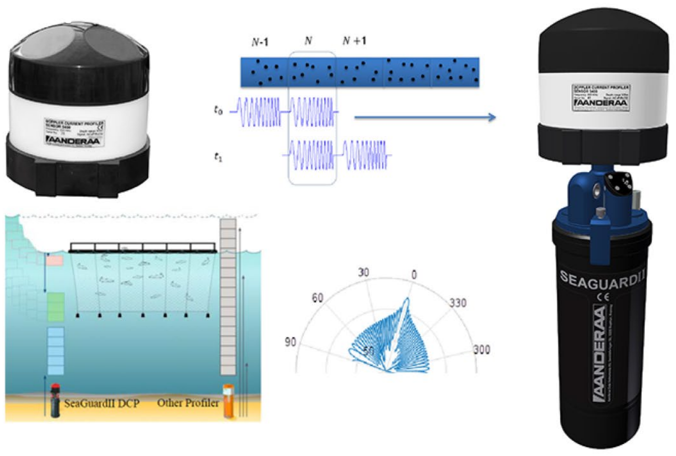
Two platforms are constantly moving, crucial with tilt & heading compensation for every acoustic ping.
In DCPS sensors this is done automatically on the fly







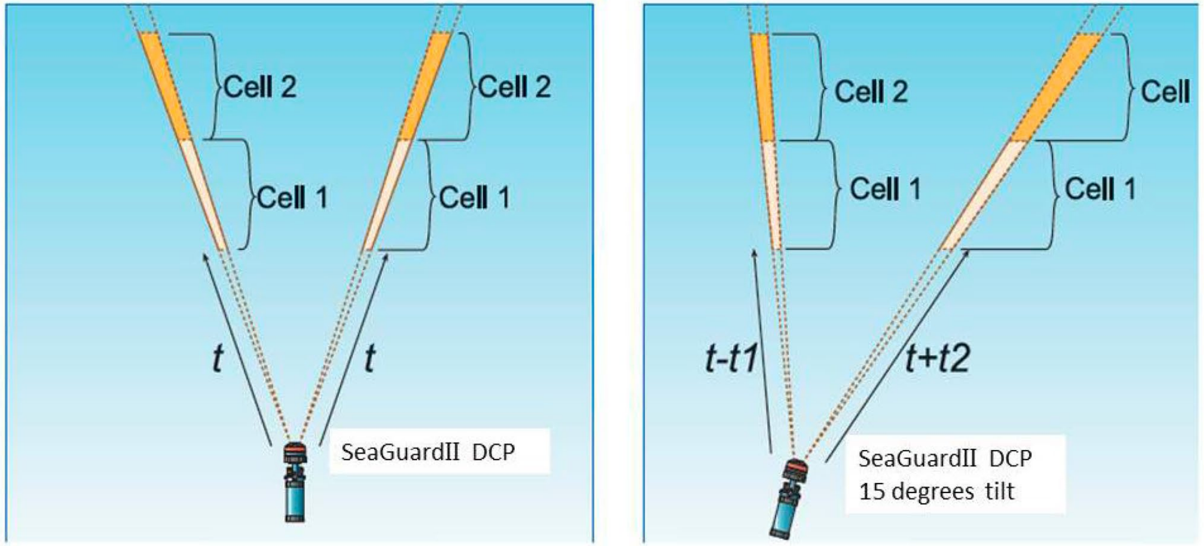
TD 310 DCPS Primer
April 2019



DCPS Theoretical Primer
Current and Wave

3.2 Compensation for tilt and rotation in each measurement (ping)

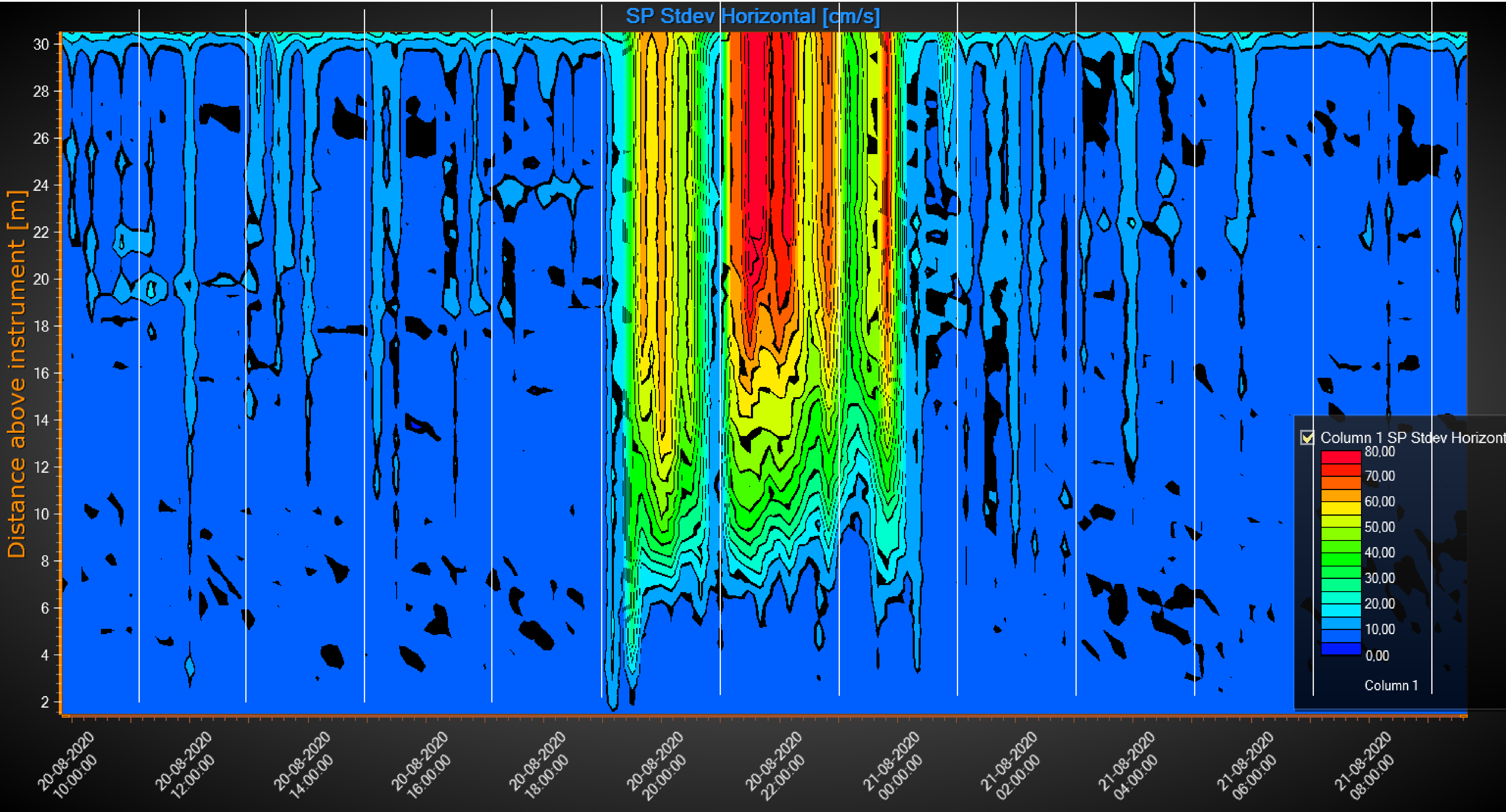
With the inbuilt 3-axes compass (gives heading) and an accelerometer (gives tilt) each single is compensated for tilt and rotation of the sensor.



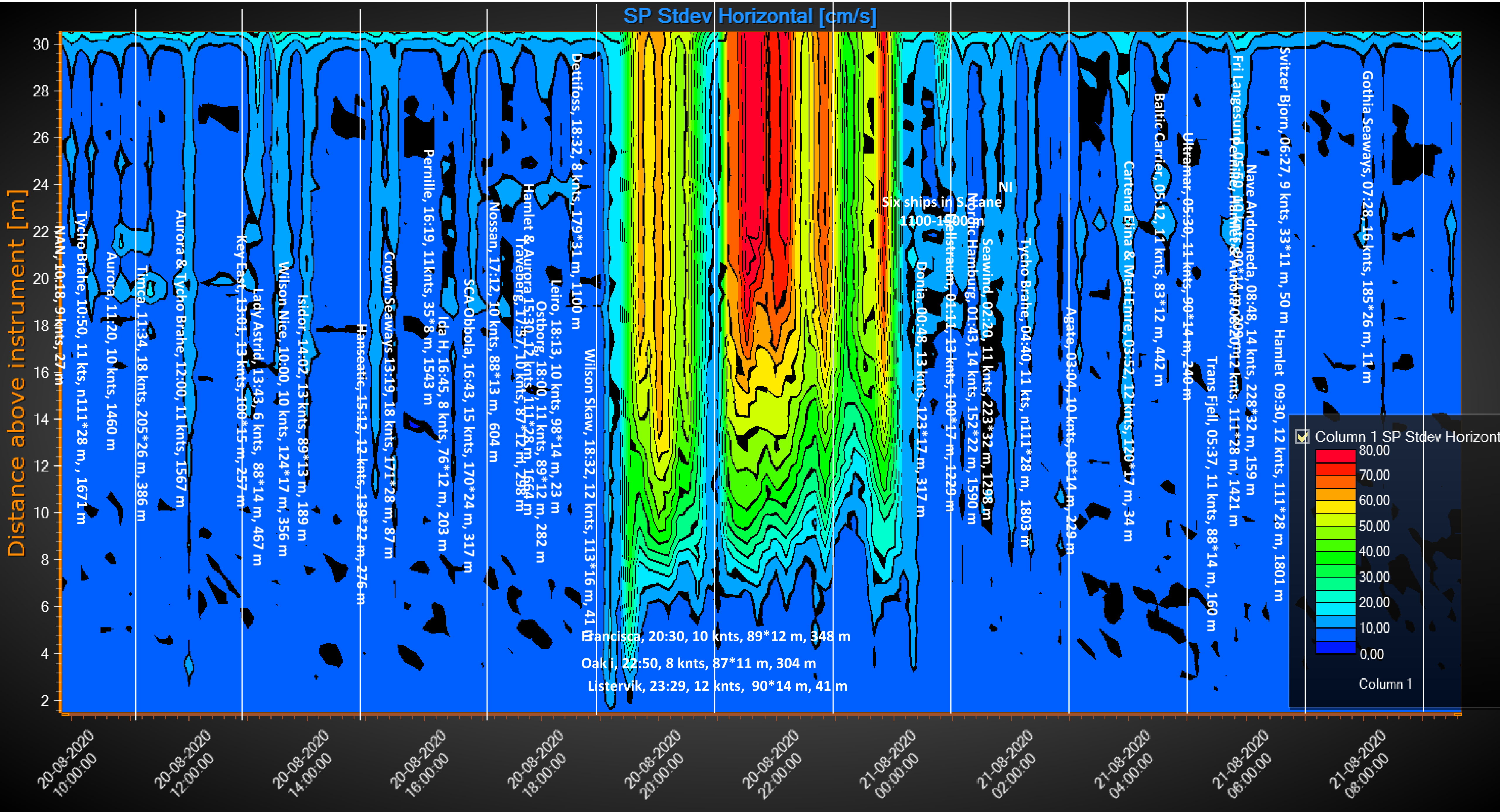
Repositioning of beams and tilt compensation of the beams in up to 35 deg tilt, this is done automatically on the fly.
This feature was first implemented on the RDCP-600 in 2003

Single point Doppler Current Sensor (DCS) measures horisontal currents correctly in up to 50 deg tilt. Verified at DT-INSU CNRS, Brest, France

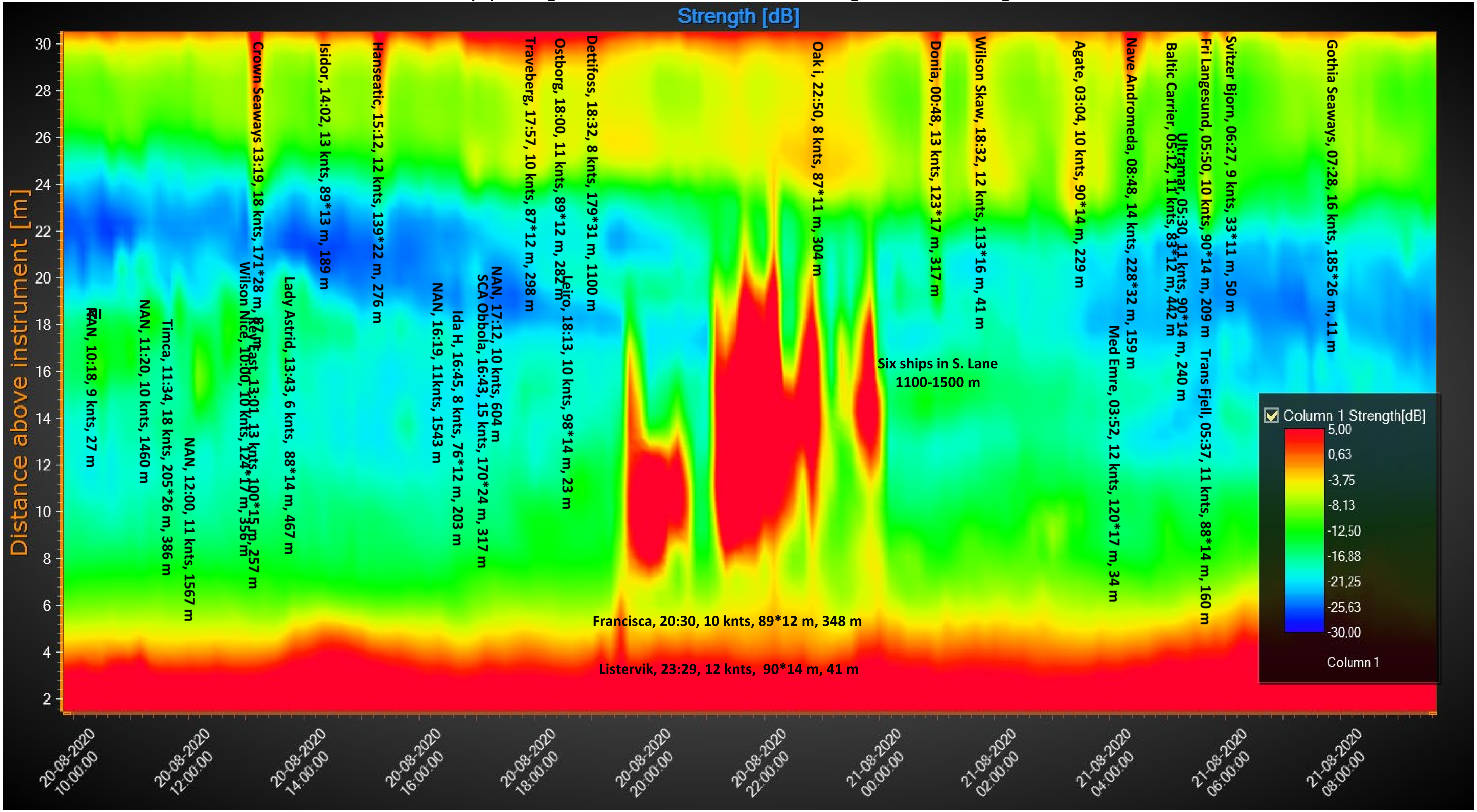
SeaGuard II, detection of ship passages, standard deviation horizontal currents, Aug 20@10 to Aug 21@10



SeaGuard II, detection of ship passages, standard deviation horizontal currents, Aug 20@10 to Aug 21@10



SeaGuard II, detection of ship passages, accoustic backscatter, Aug 20@10 to Aug 21@10



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Sailbuoy Ocean Currents

Low-Cost Upper Layer Ocean Current Measurements in a Large Geographical Area

NEWSFLASH

Aanderaa, Offshore Sensing, Akvaplan NIVA, and the Norwegian Meteorological Institute recently completed a joint project to develop a low-cost solution to measure upper ocean currents in a large geographical area. Over a three-year period, these institutions have conducted local and offshore experiments with an autonomous solution, the Sailbuoy, to measure currents from surface to 85m. Supported by ConocoPhillips and the Research Council in Norway, Vestland, the consortium collaborated to arrive at a fully functional, correlated solution for ocean current measurements.

Only a tiny portion of the ocean is monitored today, and some studies refer to as little as 5%. Many areas are hard to reach. Traditional methods requiring research vessels to deploy moorings or to monitor currents directly are expensive and limited by the cost of the ship and crew. Observatories have been established in many areas and can include ocean current profilers. These can provide good ocean current data at specific depths, but the upper 6-15% of the water column is not adequately covered due to sidelobe interference.

Only a tiny portion of the ocean is monitored today, and some studies refer to as little as 5%

Current profilers are getting more advanced and able to compensate for instrument movements during operation in real-time. The Aanderaa Doppler Current Profiler Sensor has successfully been installed on many buoys worldwide and has a good track record for providing quality data. Many of the same features that have been successful in the buoy application could be extended to a moving surface platform like the Sailbuoy.

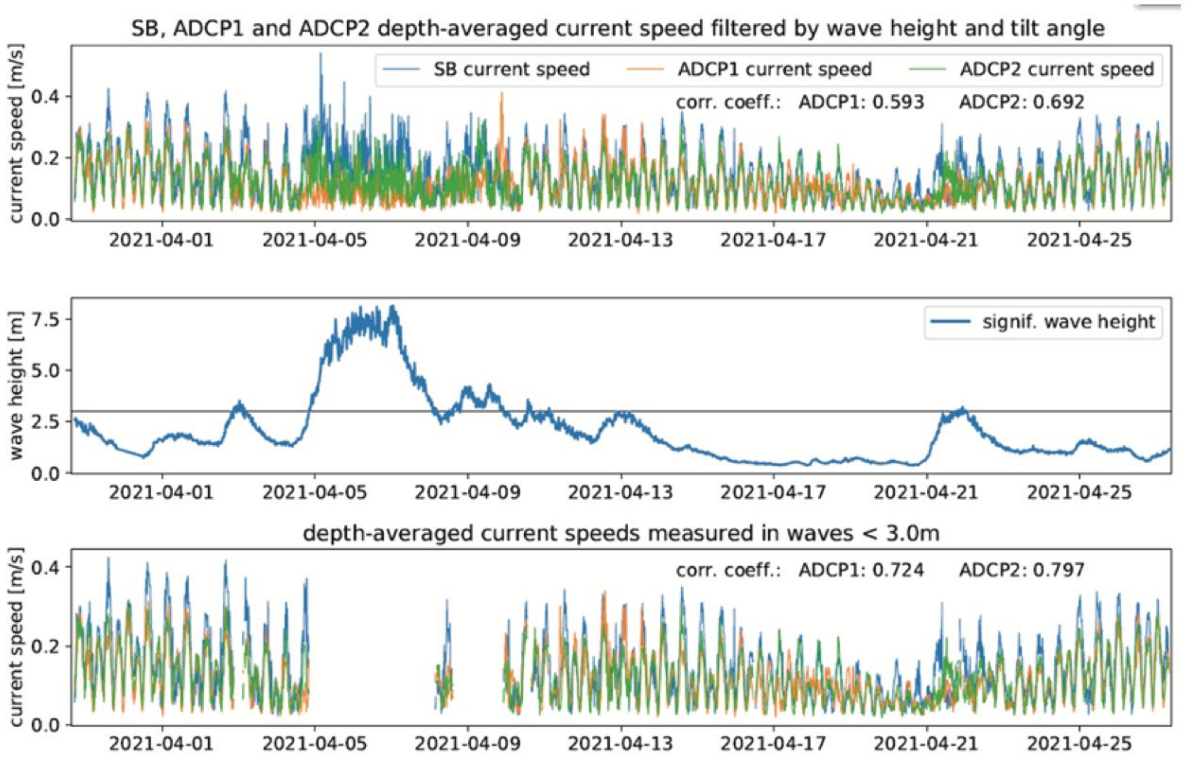
The Sailbuoy had already proven itself as a sea-worthy vessel and had successfully navigated from Canada to Norway via the Irish coast as the first unmanned surface vessel ever. It is competitively priced and has been used for various environmental studies. The central technical challenge when using a small surface vessel to measure currents is compensating for the motion due to waves and the vessel's movement through the water. For the ocean currents to be accurate, these effects must be characterized.

Current profilers mounted on small ocean-going vessels can measure currents in the upper ocean due to integrated motion compensation algorithms.

The first surface autonomous vessel to make the journey across the Atlantic

The first surface autonomous vessel to make the journey across the Atlantic

Current measurements from autonomous vehicles: Sailbuoy



During high wave conditions, there is a lower correlation vs. in calmer weather.

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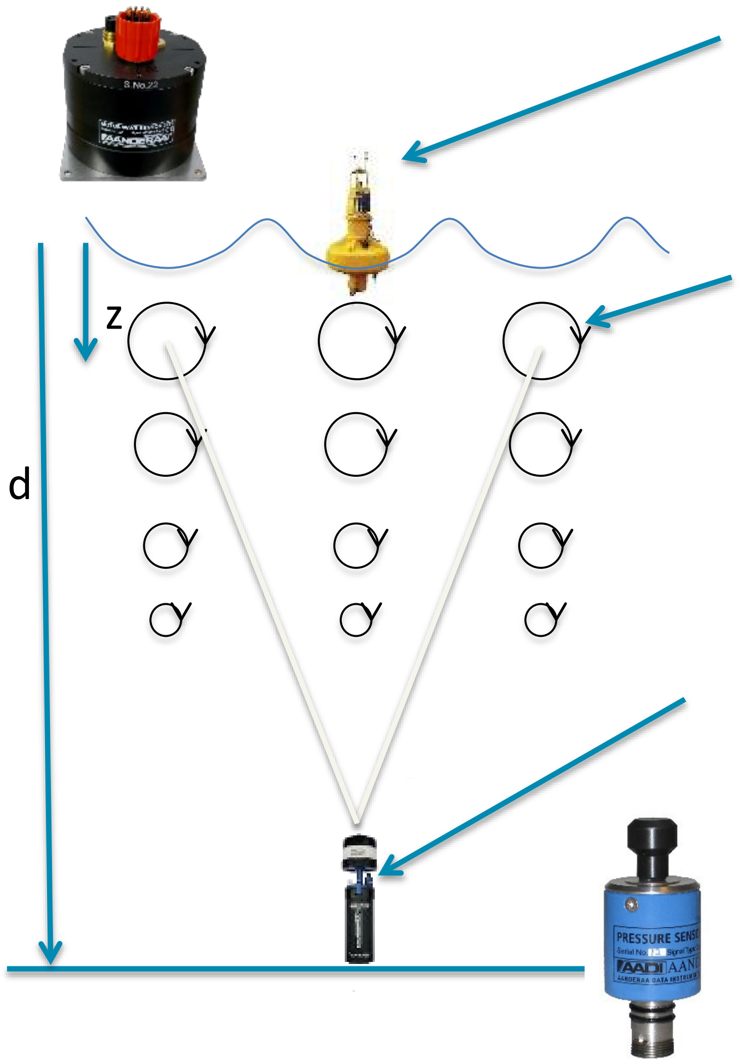
Poll Question #1

?

Do you measure water currents today.
If yes what technology/technologies do you use?

- No
- Acoustic profilers, ADCPs
- Single point instruments, acoustic
- Single point instruments, other type
- Other type of current measurements

Different wave measuring methods all rely on low noise
Aanderaa offers three methods to measure waves

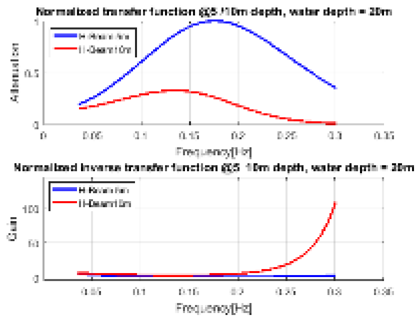


Accelerometer (AHRS) on a buoy at the surface to calculate wave height

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

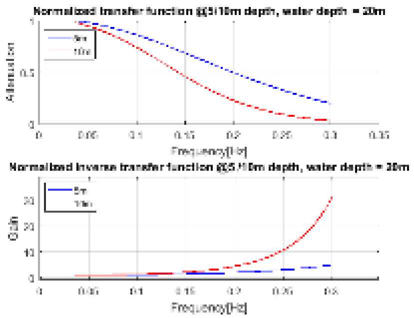
Measuring orbital movement at a given water depth to calculate wave height

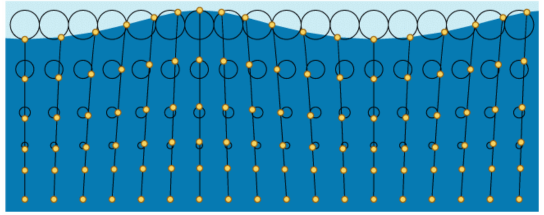
$$v_z(f) \sim H_z(f) \cdot \omega \cdot \frac{\sinh\big(k \cdot (d - z)\big)}{\sinh(k \cdot d)}$$



Measuring pressure fluctuation at a given depth to calculate wave height

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





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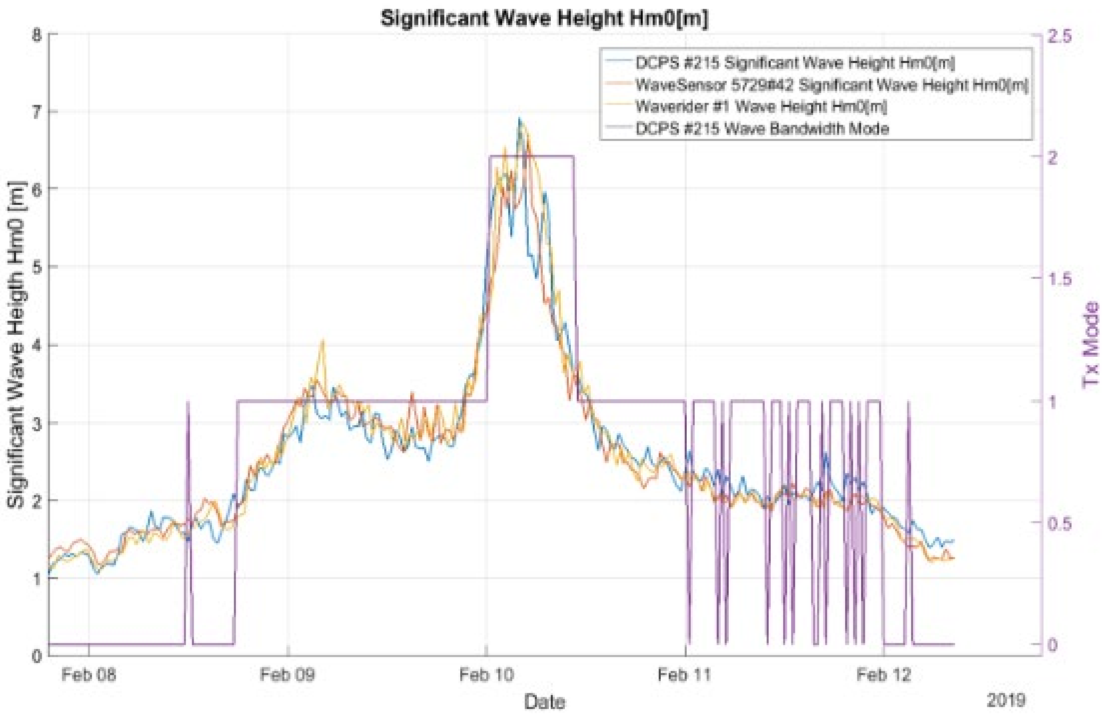
Adaptive BB pulse (570 – 630kHz) & NB pulse

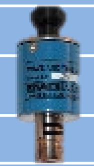
- The SGII DCP Wave samples wave data @ 4Hz.
- Automatically switches between a highly accurate BB mode limited to Hm0 up to about 2.2 m, a medium accurate BB mode limited to Hm0 up to about 4m, and a robust NB mode with no practical speed limitations.
- The automatic Tx pulse – sea state dependent selection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

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_{mo}	Significant Wave Height/Swell/Wind H_{mo}	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 zerocrossing 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 Tmax	
	Wave Height Max Crest C_{max}	
	Wave Height Max Trough Tr_{max}	
	Heave TimeseriesH(t) + Horizontal Timeseries(t) E/N	



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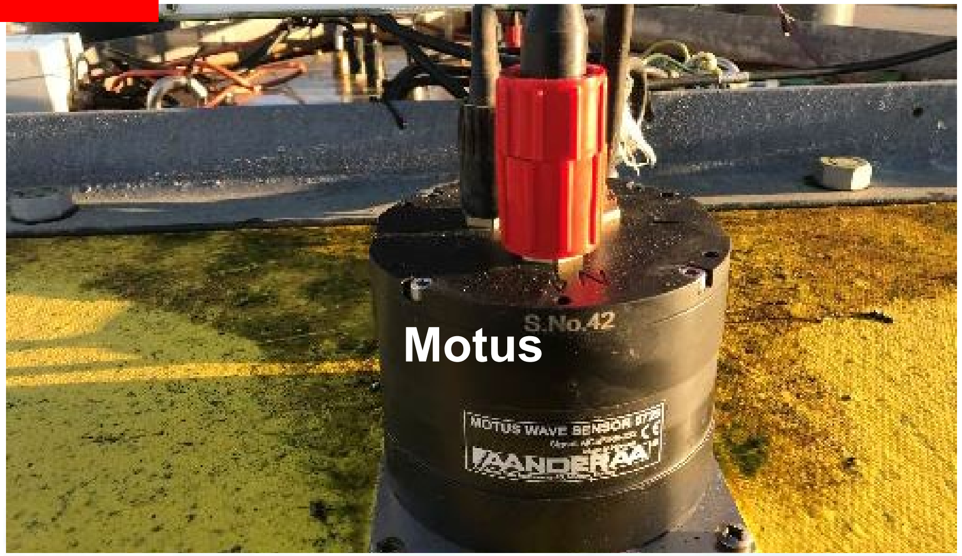
Comparing 4 wave measuring technologies off the coast of Norway for 3 years

Acoustic Directional Wave & Pressure Based Non Directional Wave



Wave rider buoy, Directional Wave (reference)

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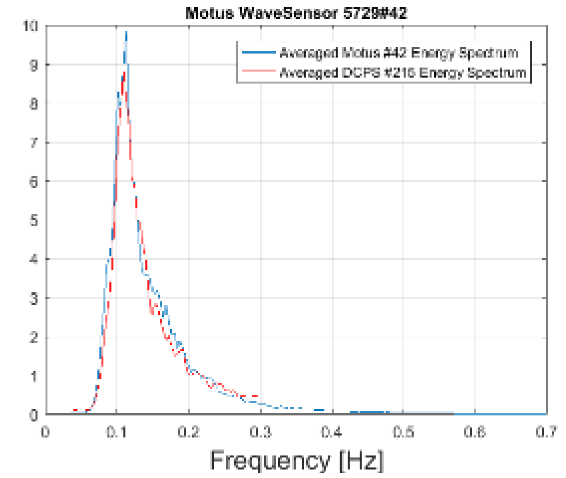
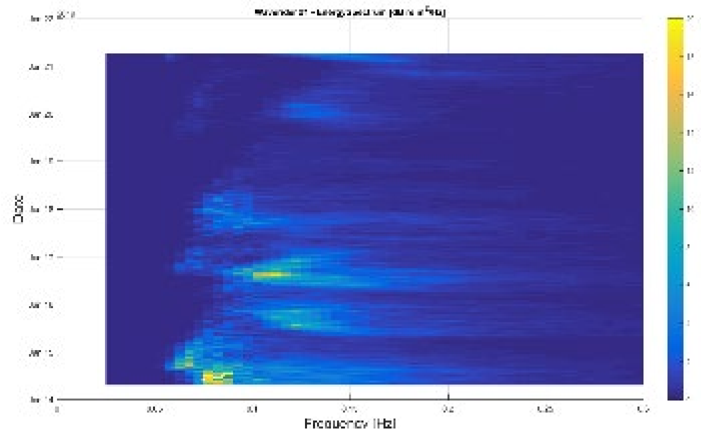
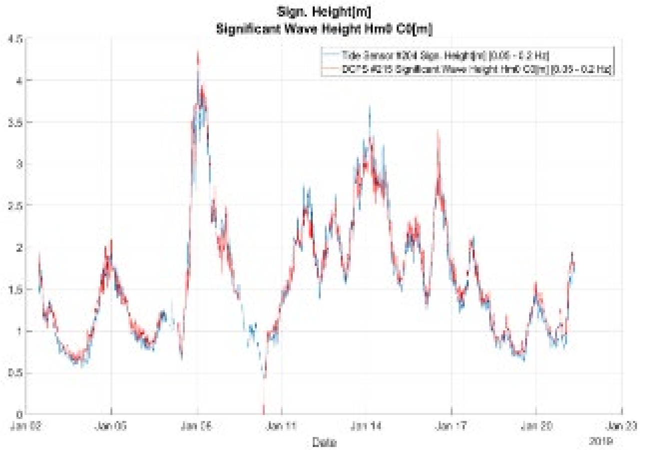
Result highlights



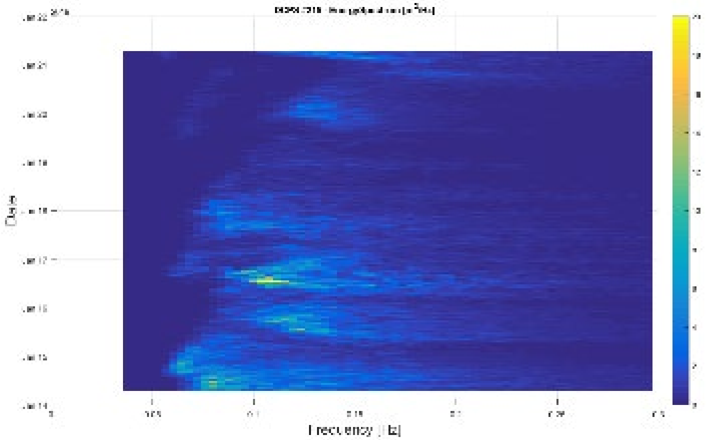
Averaged Energy Spectrum Motus – SGII DCP Wave



Energy spectrum from Waverider. January 14 – January 22

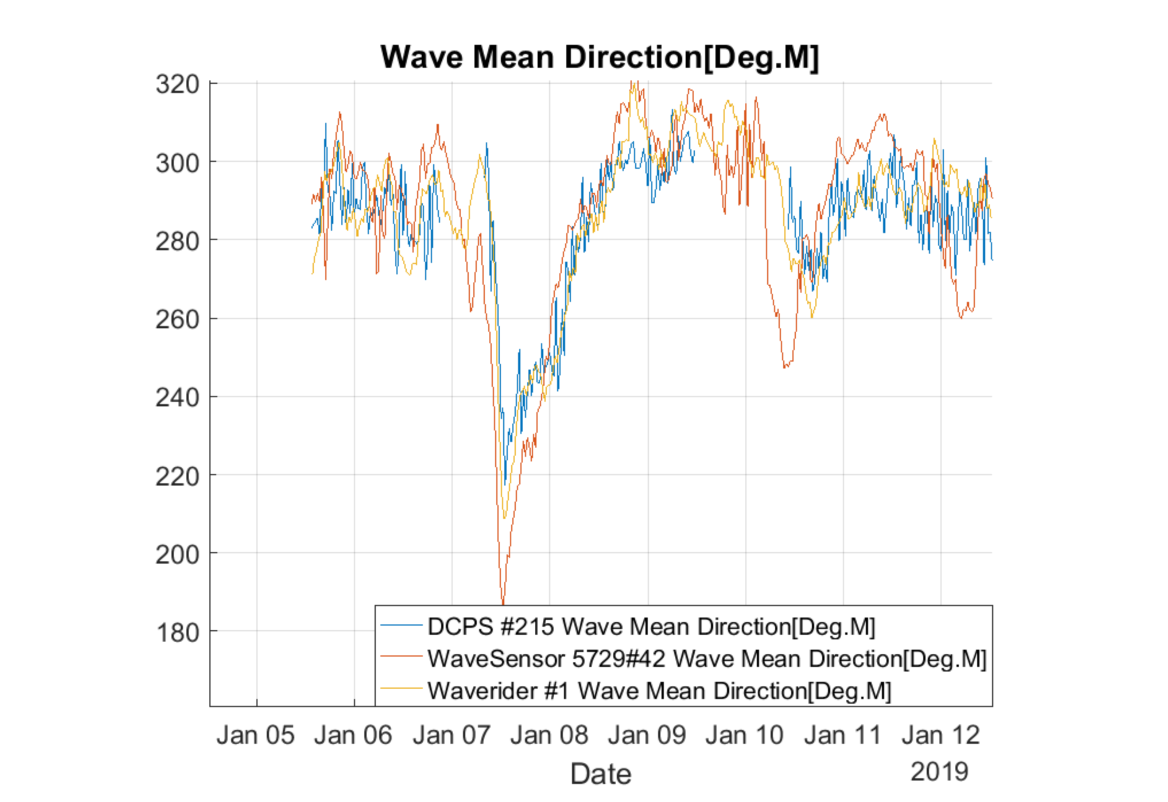


Hm0 comparison Wave and Tide sensor versus SGII DCP Wave



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

Wave direction comparison



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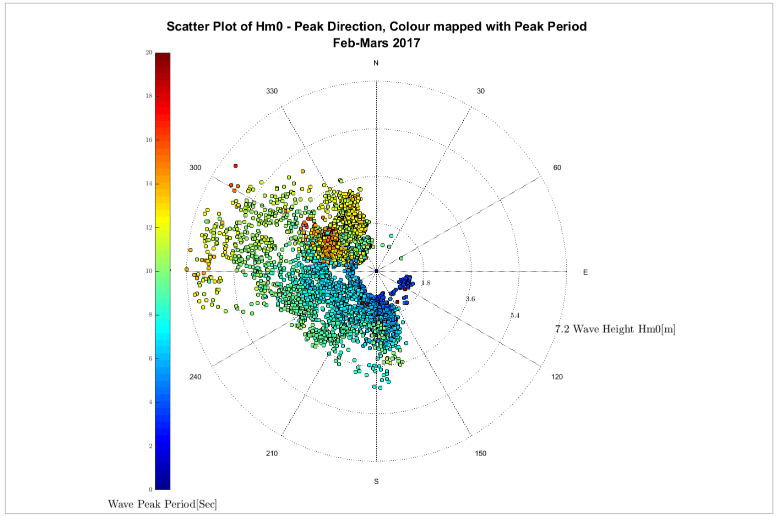
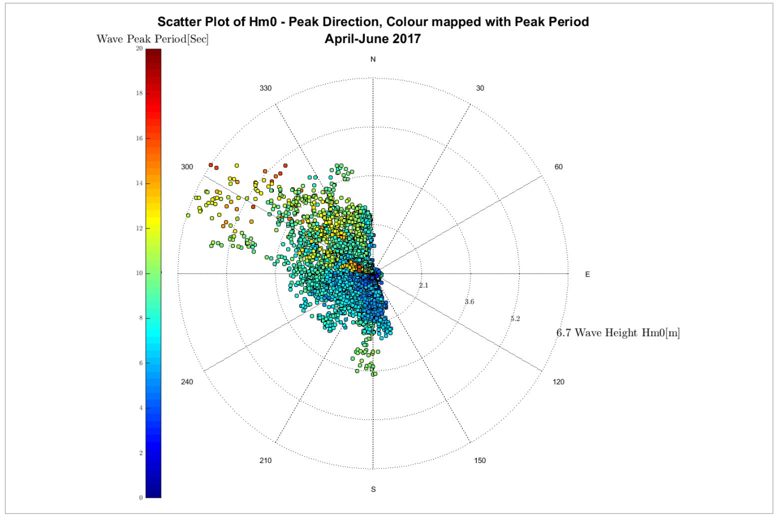
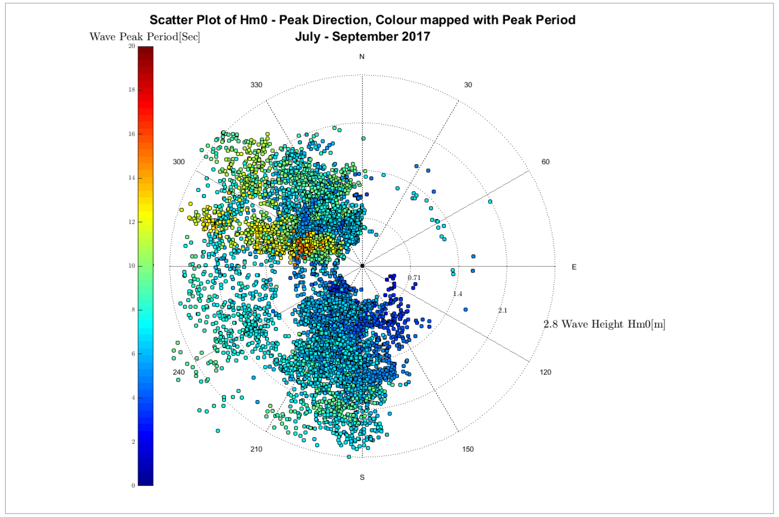
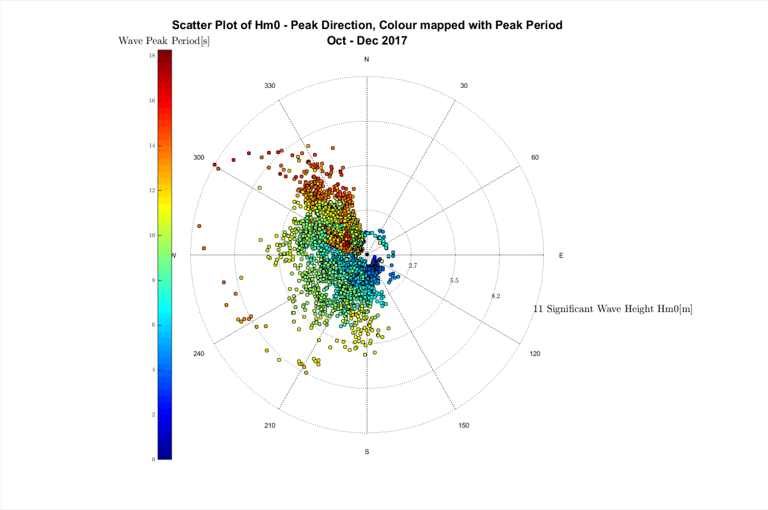
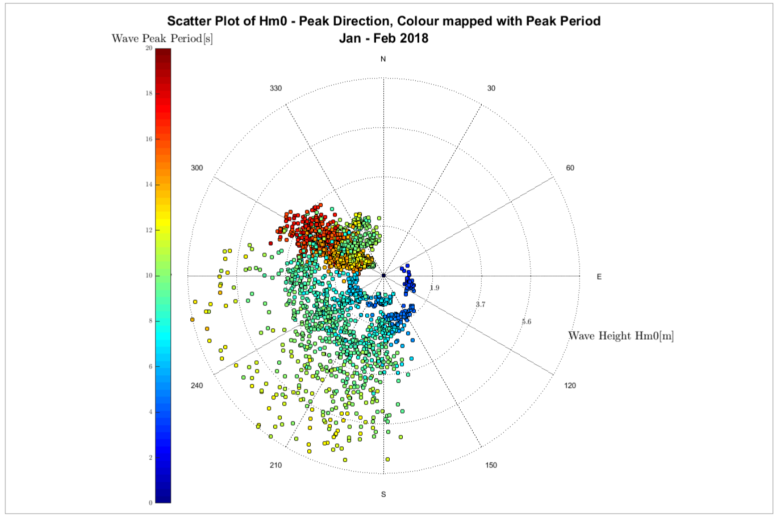
Wave Peak direction vs Hm0 and Peak Period – One year of wave data











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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

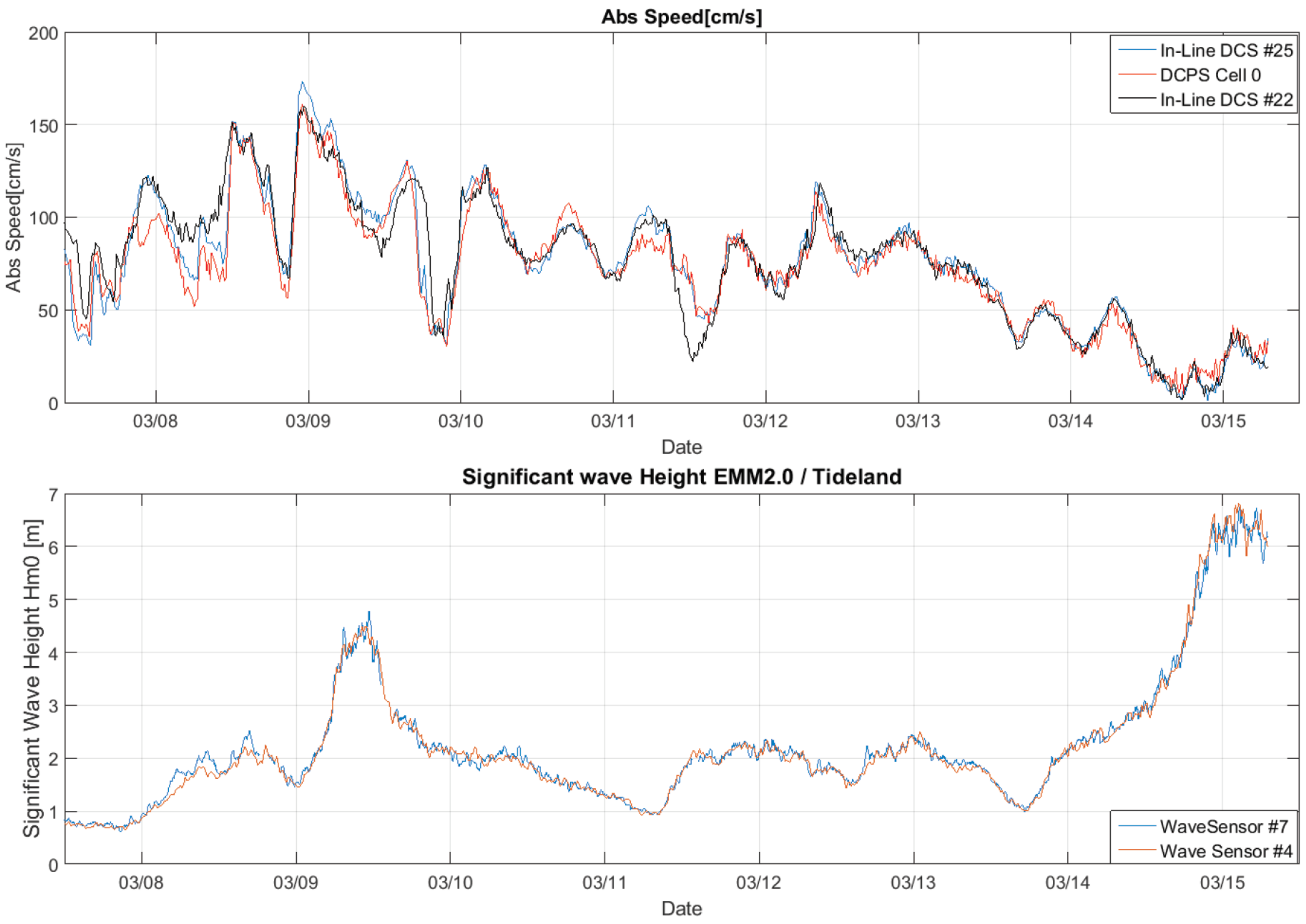
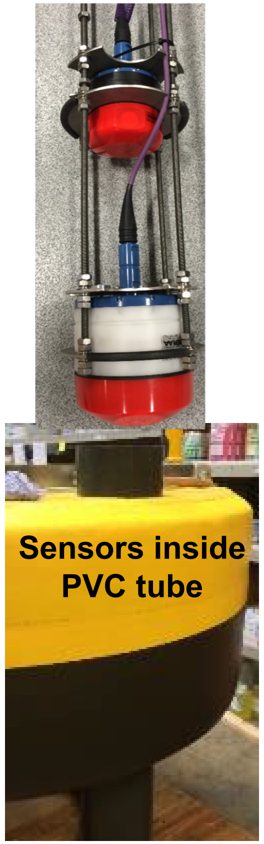


Figure 13: Current speed from DCS #25 (blue) on navigational buoy and #22 (black) and DCPS first cell (red) on Hydrographic buoy. The DCPS first cell is located about 2.5m below the two DCS sensors.

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



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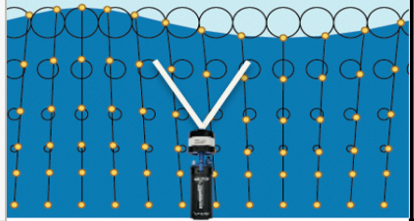
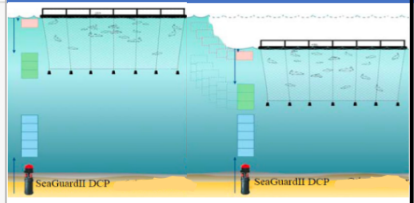
Optimize autonomous ADCP deployments

SeaGuardII DCPS-Directional Wave Power Calculator

Fill out white boxes, grey boxes are calculated

	Interval [min]	Mode	Frequency (2 or 4 Hz)	Wave calc period (min)	Pings per hour	Energy per ping (mA)	Energy per h (mA)
Dir Wave + Currents in 3 top cells	120	Broad Band	2	10	600	0,05	30,0
	Interval [min]	Mode	Pings for currents (spread/burst)	Current period (min)	Pings per hour	Energy per ping (mA)	Energy per h (mA)
Currents & Surface Currents	120	Broad Band	60	110	30	0,15	4,5
	Interval [min]	Frequency (Hz)	Tidal average period (min)	Wave samples	Active per hour	Energy per period	Energy per h (mA)
Wave/Tide & Temp sensor	10	4	5	512	0,5	8	4,0
	Interval [min]	Oxygen/Temp	Cond/Sal/Temp	Turbidity/Temp	Pressure/Temp	Temperature	Energy per h (mA)
Auxilary sensors (number)	10	1	1	1	0	0	0,8
	Type	Intern 1	Intern 2	External	Capacity (Ah)	Consum (mA)	Autonomy (d)
Battery capacity (Ah)	Alkaline	15	15		30	39,3	31,8
Battery capacity (Ah)	Lithium	35	35		70	39,3	74,2

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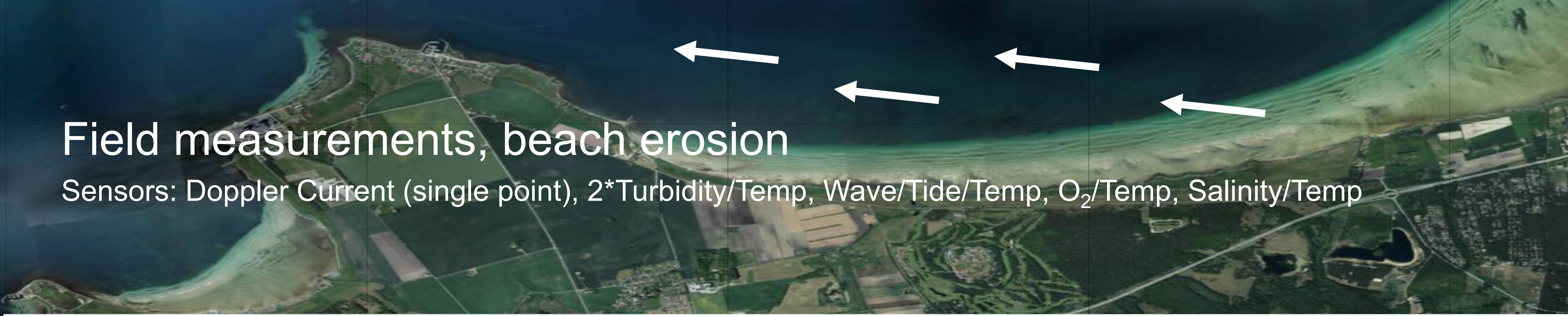
Poll Question #2

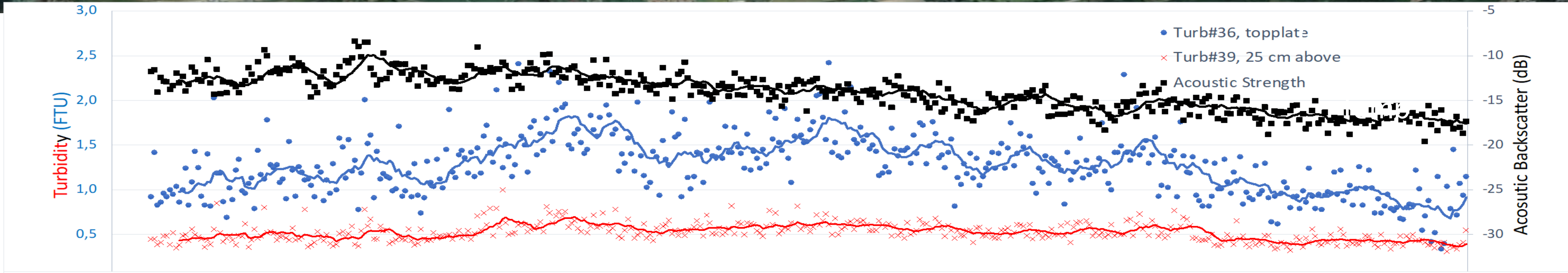
Do you measure water waves today.
If yes what technology/technologies do you use?

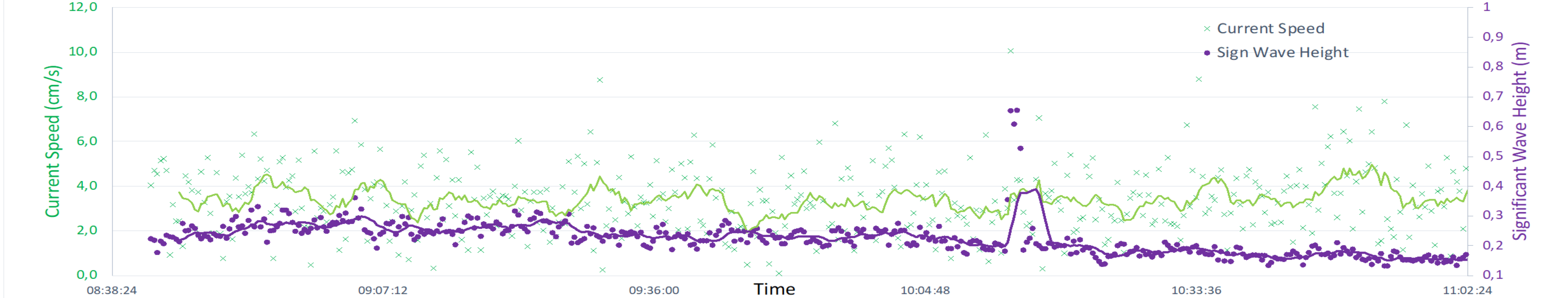
- No
- Wave buoys
- Acoustic profilers, ADCPs
- Pressure based
- Radar
- Other technique

Field measurements, beach erosion

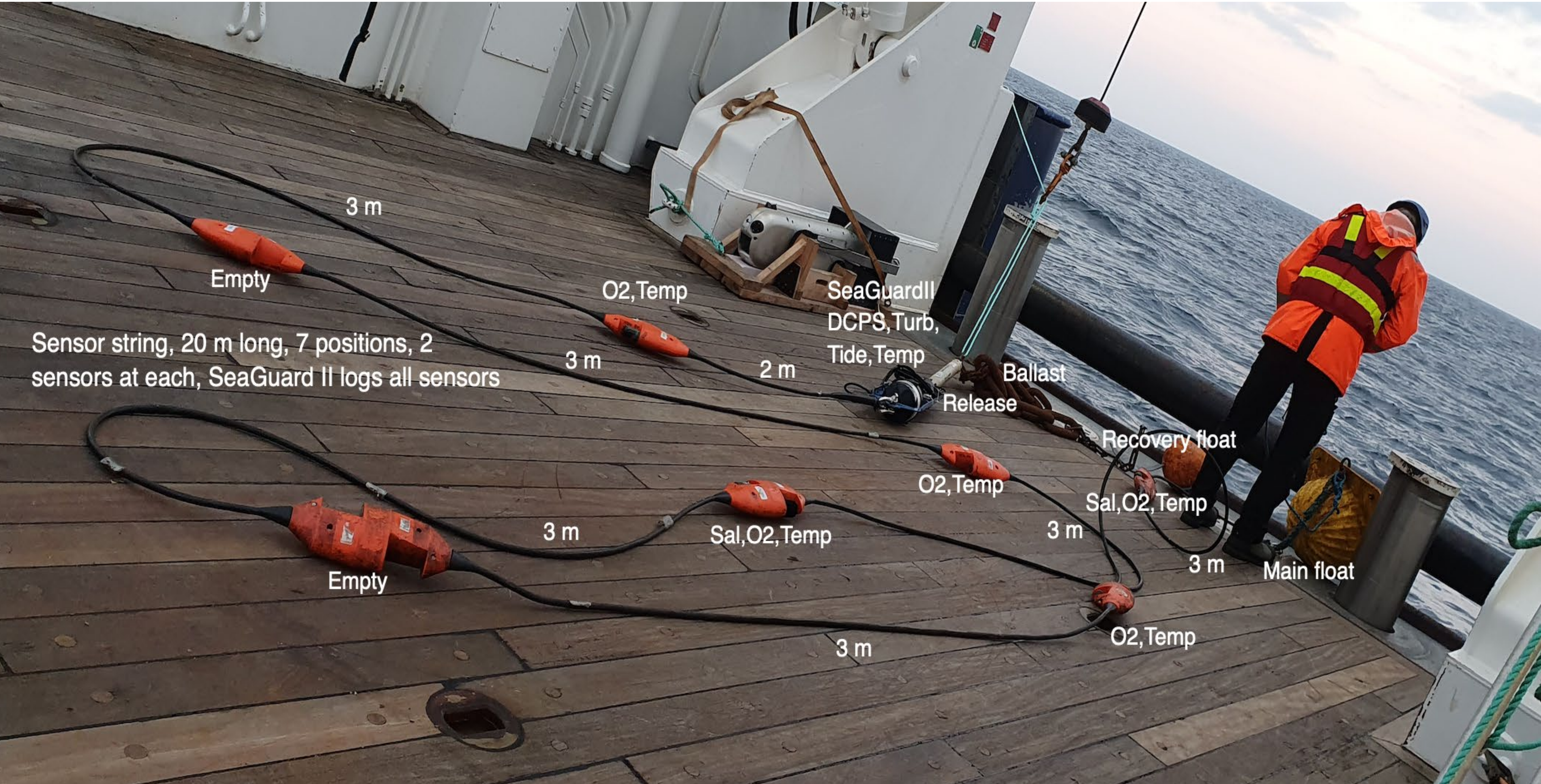
Sensors: Doppler Current (single point), 2*Turbidity/Temp, Wave/Tide/Temp, O_2/Temp, Salinity/Temp



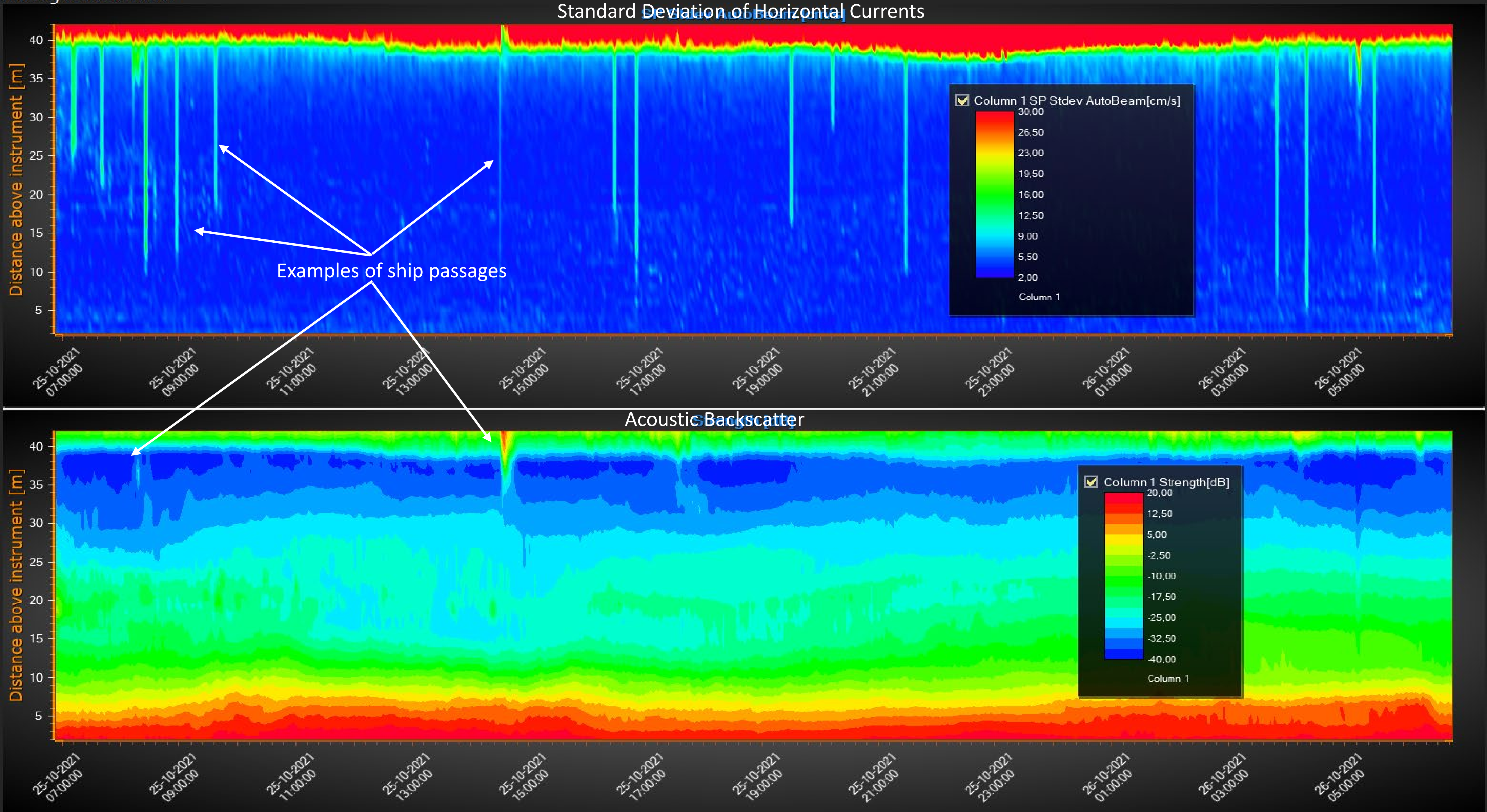




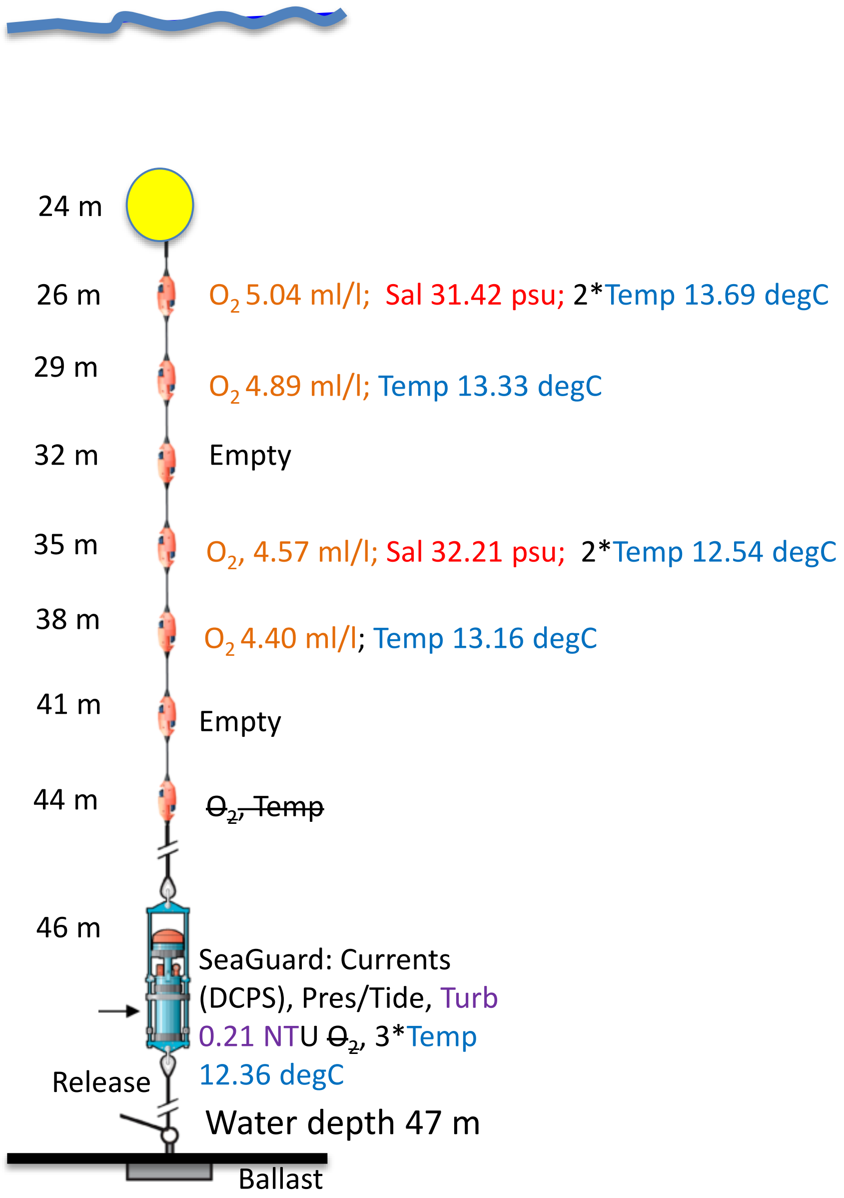
SeaGuardII string, Measurements under ship lanes, Svea expedition, October 25-28, 2021

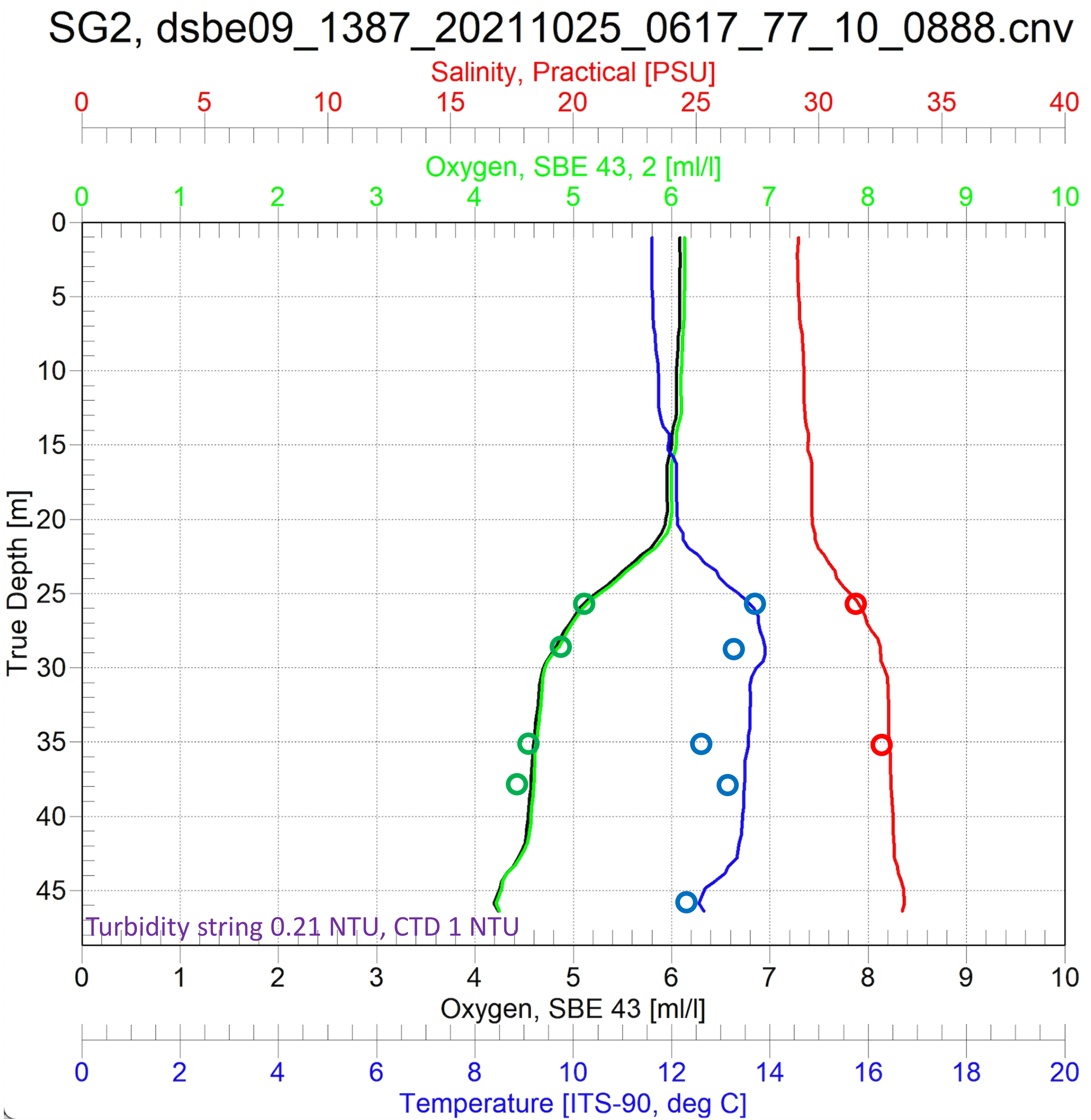


Mixing & Backscatter

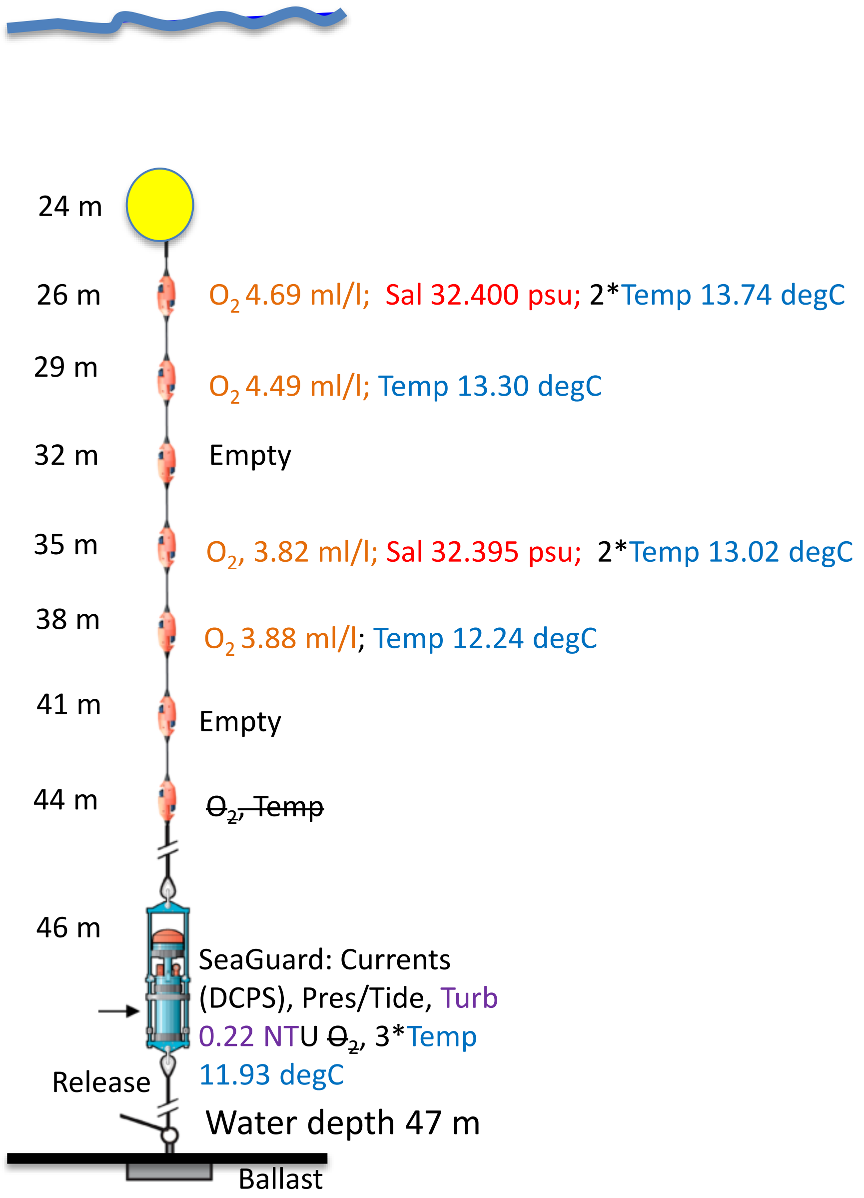


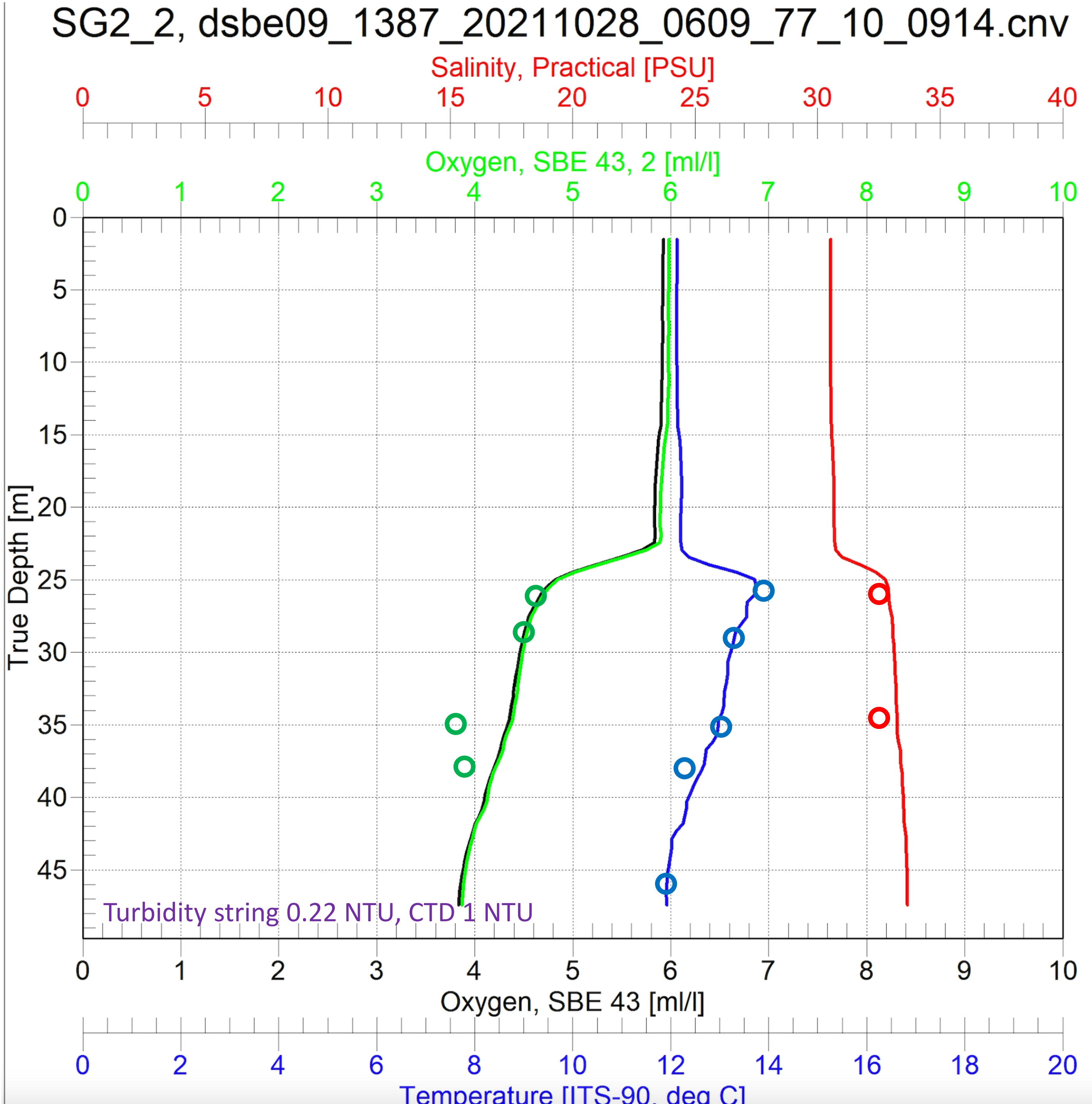
Correlation of CTD profile and String, October 25, CTD @ 06:17 and String @ 07:00 (deployed at 06:40)

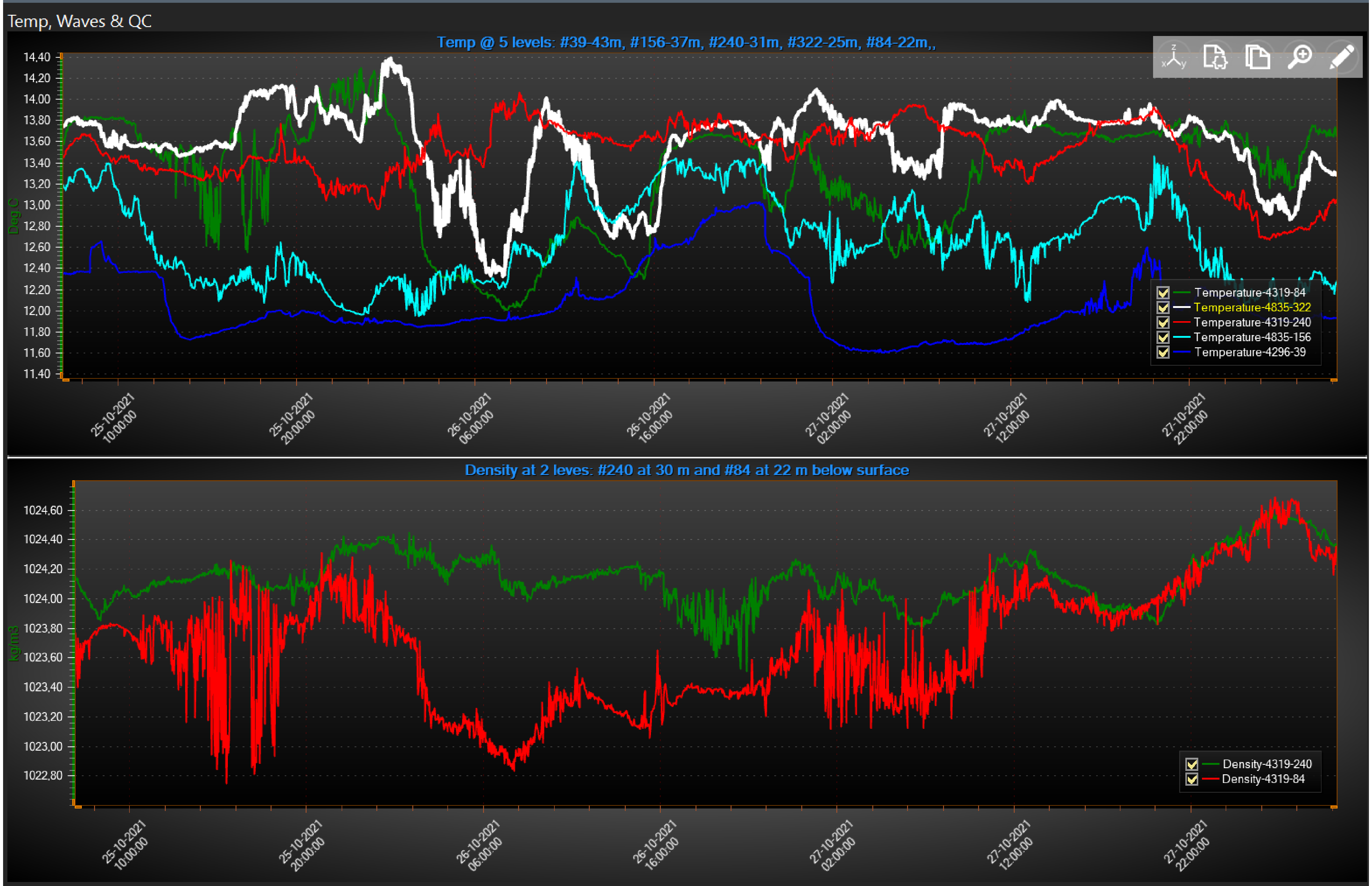




Correlation of CTD profile and String, October 28, 06:10







Temp, Waves & QC
Temp @ 5 levels: #39-43m, #156-37m, #240-31m, #322-25m, #84-22m,,
Deg C
14,40
14,20
14,00
13,80
13,60
13,40
13,20
13,00
12,80
12,60
12,40
12,20
12,00
11,80
11,60
11,40
Temperature-4319-84
Temperature-4835-322
Temperature-4319-240
Temperature-4835-156
Temperature-4296-39
25-10-2021 10:00:00
25-10-2021 20:00:00
26-10-2021 06:00:00
26-10-2021 16:00:00
27-10-2021 02:00:00
27-10-2021 12:00:00
27-10-2021 22:00:00
Density at 2 leves: #240 at 30 m and #84 at 22 m below surface
kg/m3
1024,60
1024,40
1024,20
1024,00
1023,80
1023,60
1023,40
1023,20
1023,00
1022,80
Density-4319-240
Density-4319-84
25-10-2021 10:00:00
25-10-2021 20:00:00
26-10-2021 06:00:00
26-10-2021 16:00:00
27-10-2021 02:00:00
27-10-2021 12:00:00
27-10-2021 22:00:00

Poll Question #3

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Do you combine current, wave and water quality measurements in your projects?
If yes for what type of application(s)

- No
- Environmental monitoring
- Aquaculture
- Off-shore energy
- Costal constructions
- Dredging
- Marine Transport

Summary

- Broadband gives lower noise & saves power but not suitable if platform is moving in the waves. Use narrowband from buoys and autonomous vehicles

- For high quality current data crucial to compensate every acoustic ping for movements. Aanderaa DCPS handles 35 deg & DCS 50 deg tilt. Compensation automatic on the fly, no postprocessing needed

- Comparing 4 wave technologies in the field for 3 years. Overall good agreement but limitations in Acoustic & Pressure based wave measurements to detect very short and long waves & to separate between wind driven waves & swell. Buoy based measurements provides most information

- Combining Acoustic & Pressure based wave measurements on SeaGuardII instruments increase the autonomy and provides additional information

- Waves & Current measurements easily combined with water quality parameters on the SeaGuard multiparameter platforms to collect the information needed in many projects

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Hand outs

and this presentation in pdf and the webinar recording

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Poll Question #4

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Would you like an Aanderaa Product Specialist to contact you with more current and wave monitoring information?

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Questions?

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