SeaGuardII DCP: innovation in Doppler Current Profiling and Observatory Technology

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Abstract: *The SeaGuardII DCP is a recent multi-parameter data collection platform that offers new and innovative capabilities. Featuring advanced tilt compensation, autobeam functionality, broadband / narrowband selection, surface current, ocean observatory expansion, low power consumption, the SeaGuardII DCP opens new possibilities for multi-parameter monitoring of the marine environment. This conference paper will describe the instrument functionalities and illustrate some of its capabilities by giving different examples from field applications.*

Keywords*: Multi-parameter observatory, real-time monitoring, current profiling, pCO2, pH*

INTRODUCTION

More than two decades of technical development in electronics, optics and acoustics measuring techniques have opened new possibilities for on-line monitoring of the marine environment. Increasing computing and filtering capacity of instruments and sensors have increased the measurement accuracy at the same time as the equipment has been made smaller, smarter, long-term stable and consume less energy.

The SeaGuardII DCP is a medium range 600kHz current profiler designed to measure current profiles with a 40m to 100m range. It is configured to measure currents at different levels in the water column with a cell size selectable from 0,5m to 5m either surface referred (the column will follow the surface as the water level changes) or instrument referred. It offers configuration flexibility to address different applications scenarios (multiple sensor groups with individual recording, multiple columns, burst/spread mode with the same low power consumption, narrowband/broadband). Available as self-recording, it also implements enhanced real time capabilities to simplify system integration and easy access to data.

With the multiple sensor capability, it is possible to extend to ocean observatory by hosting multiple sensors; 6 sensors on the end plate of the instrument, up to 20 AiCaP Aanderaa smart plug-and-play sensors, 4 analog inputs and 2 serial ports with power control and full resolution of the integrated sensors. Furthermore two acoustic profiling sensors (DCPS) can be plug-and–play connected to the same instrument making it possible to profile upwards and downwards simultaneously, reaching the double range with the same moored instrument.

This instrument offers powerful functionalities to address most of the oceanographic monitoring applications of today.

CURRENT PROFILING IN DYNAMIC WATERS

The SeaGuardII DCP combines advanced technology to work on moving and tilting moorings in dynamic environment and correct data for each acoustic ping using magnetometer and tilt sensors to compensate for 3D orientation. It also features an advanced tilt compensation algorithm with cell position adjustment to achieve the true horizontal current measurements up to 50deg tilt. It is possible to either work in broadband to save power and get current profiles with reduced variation or in narrowband to get profiles with longer range.

When deployed upward looking the instrument can measure the current at the surface boundary based on data input from a pressure sensor connected to the SeaGuardII. This is a useful feature when looking at spreading and transportation of e.g. an oil spill.

The power consumption of the instrument and most of the sensors used on it is particularly low. In a configuration focusing on studying the carbonate systems with sensors to measure currents, salinity, wave/tide/pressure, temperature, turbidity, chlorophyll-A, oxygen, pH (optode) and pCO_2 (optode) the instrument is capable of logging data for more than one year at 30 minutes interval using internal batteries.

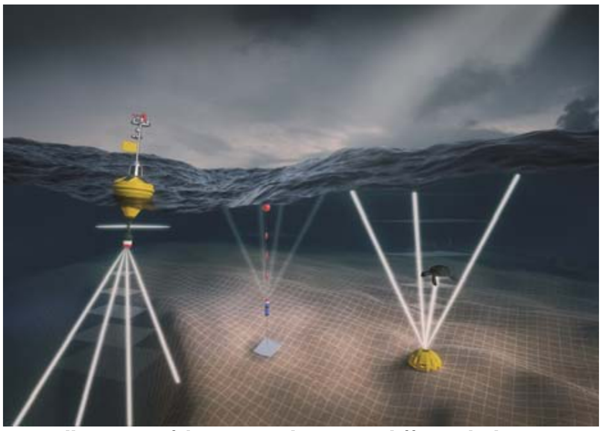

Fig 1. Illustration of the SeaGuardII DCP in different deployment configurations. To the left the Doppler Current Profiling Sensor (DCPS) is deployed downward looking on a buoy and combined with a single point current sensors (DCS) measuring close to the surface. In the middle the instrument is used with a string of sensors above. To the right is an example of when one of the beams is disturbed by an object. The instrument then suggests the best 3-beam solution to calculate currents.

For on-line two-way communication the instrument has serial (RS232, RS422) capabilities and support operation of various modems (Radio, GPRS, GOES, Iridium, AIS).

The Doppler Current Profiler Sensor can also be used as stand-alone in third party system as it can also output data in RS232 or RS422.

DATA QUALITY CONTROL

A SeaGuardII DCP was deployed in Raunefjorden in the middle of the fjord, South West of Bergen, Norway from 3rd of July to 3rd of August 2014. The instrument was set up with a recording interval of 10 minutes with an average of 20 pings in broadband mode. The orientation of the fjord gives a current in the north/north west direction for the incoming tide, and south/south east for the outgoing tide. The peak current during the deployment was around 60 cm/s at the maximum.
The signal strength (Fig.2) indicates tide related scattering conditions. Reflections from the surface can be observed at approximately 93meters. The side lobes reflection from the surface impacts cells close to the surface corresponding to about 10% of the range.

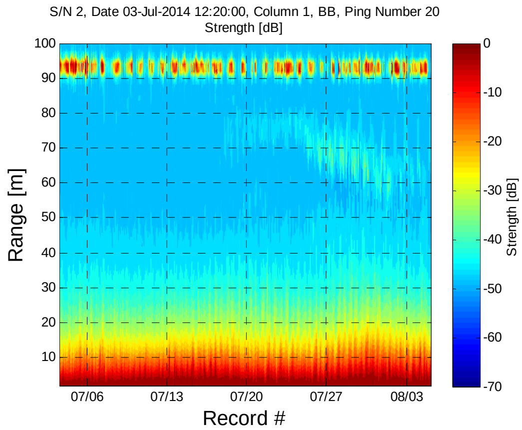

Fig.2: Signal strength, instrument deployed in the Raunefjorden, Broadband. Surface reflection is observed around range 93m.

One interesting quality parameter to look at is the cross difference; the cross difference is the sum of the opposite transducers; (Beam 1 +Beam 3) - (Beam 2 +Beam 4), the value will normally be close to zero indicated homogeneity in the measured current values.

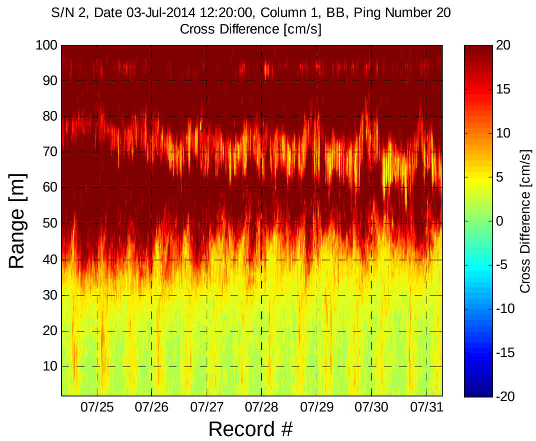

Fig.3; From 40m and over, cross difference is increasing indicated some noise in the data, to quality check, the standard speed deviation should be analyzed. Under 40m, there is higher cross difference (stripes) indicating non homogenous current across the beams.

Fig.3 indicates some inhomogeneous currents when the tide current is flowing north.

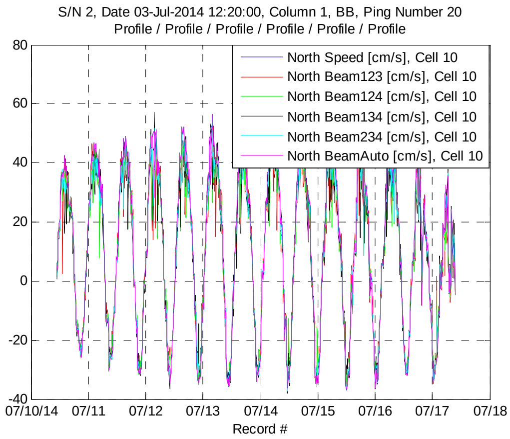

Fig.4 Slightly diverging currents for four beam and three beam solutions.

The system does a real time quality check on the datasets and selects the best of all available solutions for the *Auto Beam solution*. If the user has selected all *Three Beam solution*, the instrument will provide data from 4 combinations of three different beams.
By looking at the currents from the 4 three beam solutions and the Autobeam (fig.4), it is clear that there is some turbulence effects giving non-homogeneous currents when flowing north and the 5 solutions agree when the current is flowing south. This is due to the location and vicinity of an island creating some turbulence when the current is flowing north.
The currents data indicate mainly currents related to tide along the fjord mainly in the north/south direction (fig.5/6).

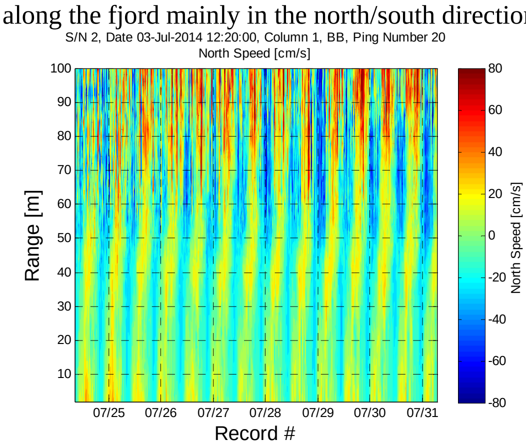

Fig.5; Contour plot for North speed current from the 25th to the 31st July

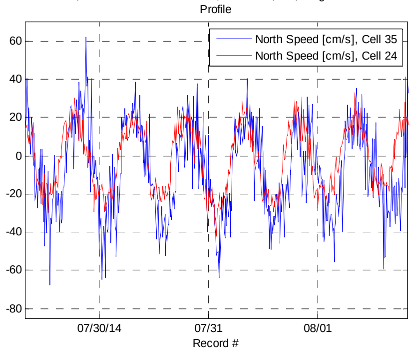

Fig.6: North speed at individual cells at 50m - cell 24 and 72m - cell 35

DETECTION OF OBJECT IN THE WATER COLUMN

In case one or more beams hits an object with strong reflections at a certain cell, the correlation factor will be influenced by a low correlation factor on both the cell before and after the influenced cell (Fig.7). The influenced cell will have an increased correlation factor. In order to avoid processing these influenced cells a three beam solution omitting this beam should be selected. If the user has selected all *Three Beam solution*, the selection of the best solution can even be evaluated in post processing.

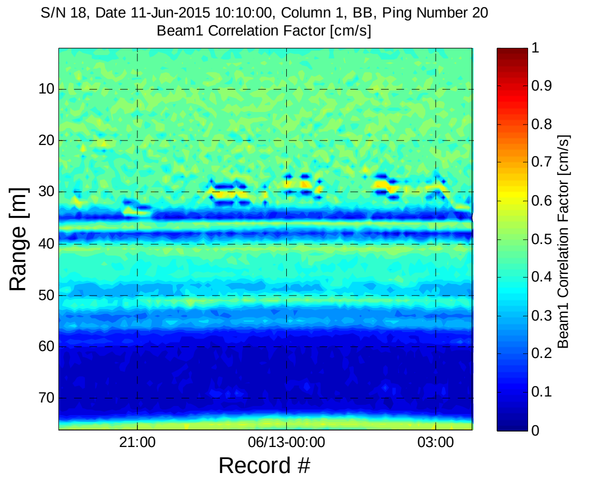

Fig. 7. Correlation factor indicates mooring line passing in front of beam 1 at around 30m. The cell will be contaminated, and a three beam solution omitting this beam should be selected.

EXAMPLE OF USE: THE BLUE CARBON PROJECT

Since the beginning of the industrial revolution, the release of carbon dioxide (CO_2) from human activities has increased the amount of CO_2 in the atmosphere. A possible solution to slow down atmospheric CO_2 increase is to use the potential of carbon storage from natural resources. The School of Geographical and Earth Sciences at the University of Glasgow, Scotland is studying the carbon storage capacity of red coralline algae beds. In contrast to other well-studied natural carbon sequestration systems, red coralline algal beds sequestrate CO_2 via both community photosynthesis and calcification. Additionally, the CO_2 released by coralline algae during respiration can also be 'locked up' by organisms associated with the algal ecosystem for long term storage. This sequestration of atmospheric carbon dioxide by marine ecosystems is known as "Blue carbon".

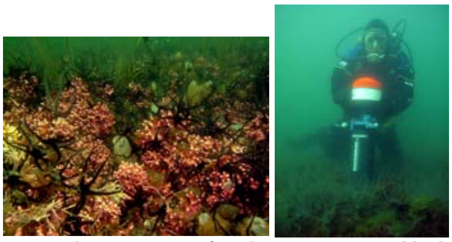

Fig. 9. Photo courtesy of Nick Kamenos. Maerl bed in the Loch Sween, Nick Kamenos deploying the SeaGuardII DCP at 4,5m depth

Given its global distribution, red coralline algae are likely to be promising carbon stores in coastal regions. The understanding of blue carbon storage is still limited by the lack of knowledge regarding the natural variability. This project aims to refine the understanding of blue carbon storage by red coralline algae over multiple timescales using a combination of field and laboratory techniques. The SeaGuardII DCP is a key component providing a unique opportunity to collect high resolution in-situ multi-parameter data (current profiles, pH, pCO_2, oxygen, conductivity, temperature and tide). The instrument has been configured to collect data at 15 minutes sampling interval in a 4,5m water depth, buried in the sediment measuring currents with a 0,2m cell spacing from a surface referred column (the column is moving up and down with the water level changes always referring to the surface), an instrument referred column and collecting current data from the surface using the surface cell functionality. See data examples in Fig.10, 11 and 12.

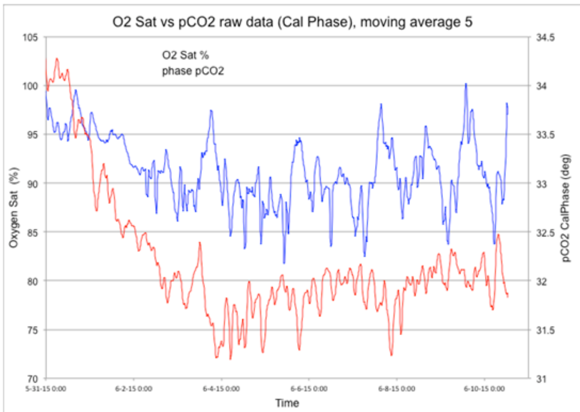

Fig. 10. Oxygen and pCO2 data from a 10 days deployment in June 2015

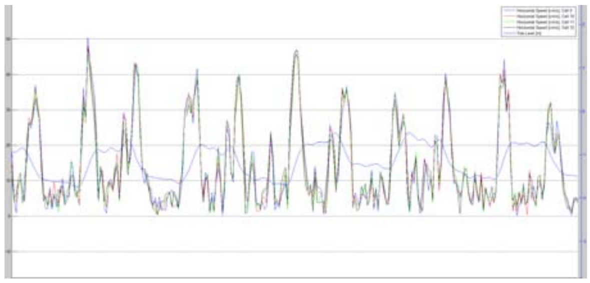

Fig. 11. Tide data and horizontal current amplitude at about 2m depth from 4 different cells with 0,2m spacing

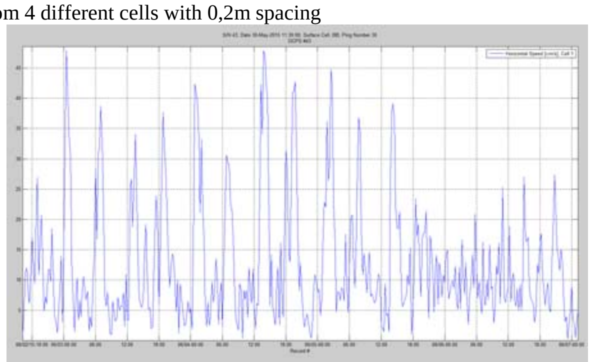

Fig. 12. Current measured at the surface by using the surface cell functionality

IMPACT OF AQUACULTURE ON THE MARINE ENVIRONMENT

Aquaculture uses natural resources and interacts with the environment. In Norway the intention to use resources more efficiently is resulting in intensification of aquaculture production. There is an increased risk that such trends will increase the environmental impact. Major environmental impacts of aquaculture include discharge of suspended solids, nutrients (eutrophication) and organic enrichment of recipient waters resulting in build-up of anoxic sediments and changes in bottom (benthic) communities. In order to understand this impact, the Institute of Marine Research in Bergen has started a long-term international project; ERA, Ecosystem Responses to Aquaculture induced stress funded by the research council of Norway.
The project will therefore combine in situ data collection using SeaGuardII DCP instruments; current profiles, conductivity, tide and pressure, multi-point calibrated oxygen, turbidity and chlorophyll together with benthic biological data and environmental models. A high temporal resolution on the biological parameters is a key component of the project and the ability of the SeaGuardII DCP to define a group for the sensors to sample every minute and every 10 minutes for currents makes it unique to explore the impact of aquaculture on the benthic ecosystems (Fig.13 showing current profiles data obtained with a 10minutes sampling interval).

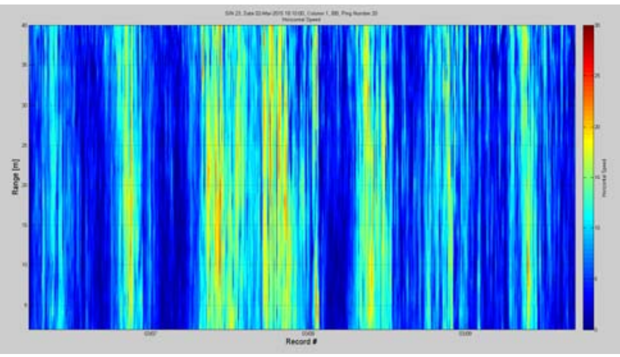

Fig. 13. Current profile data using Broadband, 20 pings, cells with 2m spacing over a 4 days period (6th to 10th of March 2015), 10 minutes while other parameters output data every minute.

PORT OF DOVER

The Port of Dover is approximately 120 ferry movements a day, 140 cruise ships and 160 cargo ships a year making it the second busiest cruise port in the UK. From June 2015, Dover starts to receive large cruise ships in addition to the cross channel ferries they already handle. The cruise ships are much wider than the ferries and the entrance to the harbour is quite narrow. It is therefore needed to provide accurate real time current information to incoming and outgoing vessels as to the speed and direction of the flow immediately outside the harbour wall.
A system based on the use of a EMM 2.0 buoy (Fig.14) was installed combining a single point current meter to measure the surface current combined with a downward looking Doppler Current Profiler Sensor and an external compass to compensate for the buoy magnetism connected to SmartGuard datahub sending data in real time using a radio communication and Geoview for real time web based display of the paramount data for navigation safety (Fig.15)

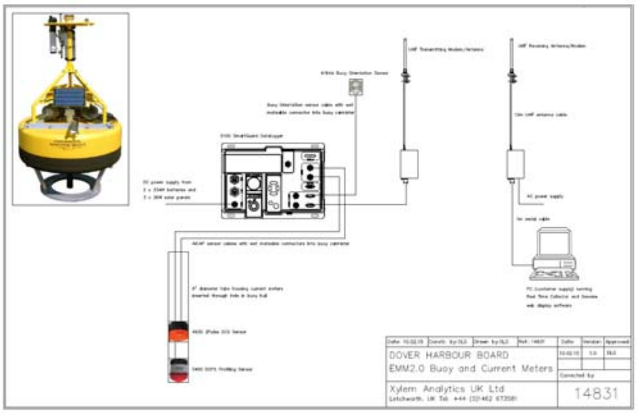

Fig. 14. System drawing of the solution used in the Port of Dover to provide real time current data

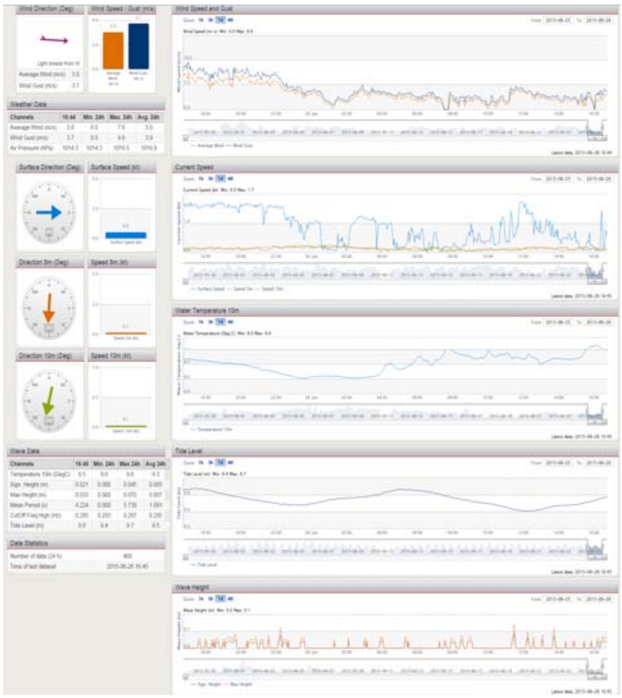

Fig. 15. Geoview real time data vizualisation web-based display

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