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Development of a low cost, self-configuring ADCP and integrated deployment and recovery system

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***Abstract* – Here we present the development of a short range (0.5 to 20 m), low cost (< USD 5,000), three-beam, 1 MHz acoustic Doppler current profiler called the Nortek ECO. The system employs a robust wideband velocity measurement technique where the only required user inputs are: 1) when deployment should start, 2) how often to sample, and 3) what is the water type. The hardware is highly portable, measuring only 130 mm tall by 85 mm in diameter and weighing 1.0 kg in air. It communicates externally with Bluetooth Low Energy technology and is powered by an embedded smart Li-Ion battery that is charged by induction. Three independent activation methods are implemented, including Near-Field Communication, and all communication controlled via a platform-independent Progressive Web App. Coupled with the ADCP is a deployment and recovery system allowing for single person operation at depths up to 50 m. Discussion of the system concept and design are presented, including sample data. This is an example for preparing the full paper that is identical with the extended summaries format. It must be written in Times New Roman.**

Keywords - Portable ADCP, Shallow Water, Low Cost.

I. INTRODUCTION

Since its commercial inception in the early 1980s, theAcoustic Doppler Current Profiler (ADCP) has been expanding our knowledge of the world's water bodies, from small streams to the open ocean. For the oceanographic community, having a single instrument capable of collecting three-dimensional current profiles that were accurate, precise and with no drift was revolutionary. Here we present a newly developed ADCP, called the Nortek ECO (Fig. 1) that will continue this tradition, being designed to be highly portable, low cost, and yet require no prior experience to successfully collect high quality current profile data.Body paragraphs (like this one) should be set in Times New Roman 10pt, full justification, in two column format. Line spacing is single-spacing [1].

Fig. 1. ECO ADCP shown next to a standard size soda can for scale.

Additionally, it has been recognized that one of the job functions of any Oceanographic Instrumentation Technician (OIT) is the actual deployment of instruments in various ocean environments [1]. For many technicians, designing, deploying, recovering and maintaining an ADCP deployment apparatus is almost as complex as (and as costly as) the instrument itself. With this in mind, we also report on the ECO's integrated deployment and recovery system, which is made up of a ready-to-deploy subsurface buoy and a timed release.

II. DESIGN CONCEPT AND IMPLEMENTATION

The system's design concept was purposely constrained by seven factors as presented, all the while maintaining a target Manufacturer Suggested Retail Price of under USD 5,000 for the ADCP itself (under USD 7,000 inclusive of deployment/recovery system).

A. Small size

The first objective was to make the ADCP about the size of a soda can (Fig. 1), which had direct implications to most subsequent requirements. This process focused primarily on the design of a new electronics platform. We started by implementing a transducer multiplexing (sequential pinging) architecture that significantly reduced the transmit/receive circuitry size. The electronics platform also uses a single wireless communication method (Bluetooth Low Energy) that eliminated the need for multiple interface circuitry such as Serial and Ethernet, as well as external connectors (see section II.E. for details). We then established an internal battery as the single power source, which eliminated the need for input power line protection and filtering, further reducing the electronics size. Moreover, the system's Digital Signal Processor (DSP) was optimized to minimize standby current consumption, reducing the required battery size. Finally, the minimal transducer set required for three-dimensional currents (3) was used, minimizing the head's diameter. The resulting electronics platform allowed for a highly portable system only 130 mm tall by 85 mm in diameter, with in air weight of 1.0 kg and in water weight of 280 kg and total volume of 693 cm2.

B. Self-configuring

The second objective was to reduce the required user input to the absolute minimal for complete system configuration:

1)when deployment should start

2) How often to sample, and

3) Approximate water salinity.

In contrast, to configure a traditional ADCP for current profiling in an up-looking, autonomous deployment, users must also provide additional information on 1) available power and memory, 2) required deployment duration, 3) estimated depth range, and 4) desired spatial resolution. Next, we describe how each of these were addressed so the ECO can self-configure.

We start by discussing available power, which has historically been a difficult parameter to determine automatically. This is primarily due to ADCPs having traditionally used alkaline batteries as power source, whose voltage seldom is representative of available capacity, especially when not measured under a load or when a fresh battery is not used or both. Furthermore, user-supplied batteries rarely meet the same specifications of their manufacturer-supplied counterparts. However, with recent advancements in smart Lithium-Ion batteries, accurate power capacity can be easily determined. In the ECO implementation, a 7.2 VDC, 10.5 Ah smart Li-Ion battery was chosen, with embedded electronics capable of accurately reporting its capacity level and charge state. Lithium-Ion technology was chosen mostly due to it being long lasting and efficient at charging and energy transfer.

Available memory capacity has expanded significantly in recent years, and the ECO employs a micro-SD 16 GB card for data storage. At maximum number of cells (30) and shortest measurement interval (2 minutes), the ECO uses less than 1 MB/day. If a lunar cycle deployment is considered—a typical coastal oceanography deployment duration—at this acquisition rate the ECO has enough memory for almost 50 years of back-to-back monthly deployments, making storage a non-limiting factor. Directly connected to available power and memory is the required deployment duration.

TABLE I. SAMPLE ECO DEPLOYMENT DURATION (DAYS)

		Deployment Depth			
		4 m	**8 m**	**12 m**	**20 m**
Meas. Interval	**2 min.**	12	27	25	33
	5 min.	11	55	63	78
	10 min.	20	108	122	151
	30 min.	41	208	232	285

This has traditionally been an important input so that ADCP configuration software can compute whether the available power and memory are sufficient to meet the user requested duration. In the ECO implementation, rather than requesting a deployment duration from the user, the user is given the maximum duration based on a dynamic calculation of the available battery capacity and the instrument's configuration. This calculation is conservatively weighted to account for factors such as temperature and large depth range fluctuations (which impact transmit pulse power). An internal model is then consulted, and the maximum number of days automatically displayed. As an example, Table 1 shows a small subset of the model's output relating the user requested measurement interval (in minutes) and deployment depth, returning the duration, in days, of the deployment.

Depth range and spatial resolution are connected parameters that together define where in the water column velocity measurements will take place. In practice these define the cell size and their quantity. The choice of cell size is always a tradeoff between the user's desired spatial resolution and the acceptable velocity precision, which is generally given by:

$$\sigma = \frac{C}{F\ D\sqrt{N}}$$

where C is a configuration specific constant, F is the carrier frequency, D is the cell size, and N is number of pings within the measurement interval. The ECO self-configures the number of cells and their size to cover the entire water column, adjusting the number of pings aiming to return a horizontal velocity precision of 1 cm/s or better within the user requested measurement interval. The choice of depth range and spatial resolution traditionally required advance knowledge of the site's depth, including tidal variations and is traditionally set beyond the maximum expected value for uplooking systems as a safety margin. In the ECO implementation, the height of the water column is regularly determined using pressure sensor data. These data are then used for continual range and resolution configuration adjustments Further processing is done with acoustic ranging during the automated quality control step (see section II.C.).

C. Three-dimensional currents from 0.5 to 20 m

Given that Doppler shift can only be detected along an ADCP beam's radial axis, linear algebra dictates that it must have at the very least three beams if three-dimensional current measurement is intended. Therefore, the ECO employs three wideband capable transducers of 1 MHz carrier frequency. The choice of frequency was based on: 1) Nortek's extensive experience with this frequency, and 2) this frequency's improved transducer construction through optimizing the tradeoff between ceramic diameter (25 mm), profiling range and bandwidth.

Secondly, the low end of the profiling range requirement (0.5 m), coupled with the self-configuring requirement and minimal user input, presents the most challenging of the ECO's development processes. For short ranges (< 2 m), profiling techniques such as pulse-to-pulse coherent have been successfully used [2-4]. However, even with advanced implementations such as Nortek's Multi Correlation Pulse Coherent (MCPC) method [5,6], the inherent range-velocity tradeoff still exists. This demands significant user intervention at both system configuration and data analysis stages in order to obtain consistently robust results. And, even then, conditions such as high turbulent flows still exist that prevent successful data collection with a pulse-to-pulse coherent method. With these limitations in mind and the desire for minimal user input, we have opted for an implementation of the wideband processing technique used in Nortek's AD2CP platform (U.S. Patent 7,911,880), with modifications for a wider bandwidth and pulse lag settings optimized for short range performance.

D. Automated Data Quality Control

As data are collected, the ECO's firmware automatically performs data quality control of both acoustic and ancillary sensor data. Below we list the filters applied, which are done in a sequential order as listed below.

1) Fish Detection Filter – Following the algorithm first described in [5], data is flagged where an improbably high echo intensity for the local (profile) statistics exists, as opposed to a fixed, pre-defined value as is commonly implemented.

2) Low Correlation Filter – Masks data where the complex correlation score between the two pulse echoes in the wideband processing is below 50%.

3) Bin Mapping – Maps depth cells to the vertical orientation based on tilt data.

4) Data Transformation – Applies mask to all beams forrespective cells where at least one beam has already been masked.

5) Percent Good: Filter – Divides number of cells that have passed previous filters by total number of available cells, and masks those < 50%.

6) Sidelobe Filter – Masks cells contaminated by surface sidelobe by comparing the minimum absolute pressure during averaging interval to a conservative cutoff value of 1050 hPa for the corresponding surface pressure.

7) Out of Water Filter – Masks cells above surface in similar fashion as sidelobe filter, but using along-beam projected distances.

8) High Tilt Filter – Masks entire profile where either pitch or roll is > 40°.

9) High Acceleration Filter – Computes standard deviation of pitch and roll over ensemble interval and masks entire profile where this exceeds 5°.

Once all filters are performed, the data remaining are ensemble-averaged over the measurement interval and are stored to memory.

E. No External Connectors

Lack of physical connections demands, explicitly, wireless communication and, implicitly, both an induction charged power source as well as an activation (wake-up) mechanism. As a consequence, the implementation also fully removed the need for the user to open up the instrument at all, for the life of the device.

Bluetooth Low Energy (BLE) was chosen as the communication technology as it offers flexibility and capability in a low energy framework that is widely used in most devices today. Additionally, BLE allows for significantly faster scan and connection sequence when compared to classic Bluetooth and Wi-Fi.

As far as an activation mechanism, although magnetic switches and other similar hardware have been used in underwater systems lacking outside connectors, we have opted for three independent activation means: 1) induction charging, 2) Near-Field Communication (NFC), and 3) vertical acceleration (termed “Shake & Wake”). For the first, once placed on the induction charging plate, battery charging is initiated, the main processor is awaken and the BLE processor starts broadcasting the ECO’s identification continuously while on the charging plate. The second alternate activation method, NFC, uses a chipset inside the ECO as a target device. Once the initiator device (normally a smartphone) scans the NFC tag it creates an interrupt to the BLE processor, which then wakes up the ECO’s main processor. The last activation alternative, Shake & Wake, uses a dedicated accelerometer to wake up the instrument upon sensing a vertical acceleration in excess of 1 g above background, at which point an interrupt to the BLE processor is created in the same fashion as the NFC. Although false triggering (e.g. during transport) may occur under some conditions, broadcasting has minimal impact on battery capacity. But to minimize false triggering, three limitations are placed: 1) only vertical accelerations are considered, 2) accelerations must be both positive and negative, and 3) single-cycle accelerations are not considered. Finally, the ECO shuts off the battery at a minimally safe capacity such that it will always store enough energy to wake up the main processor. Long term drawdown is only a few mW, allowing for multi-year storage.

F. Complete Package

By “complete package” we mean that the user, upon instrument delivery, has everything needed for a successful deployment in water depths up to 50 m. Exempt from this requirement is the vessel to arrive at the desired site (if one is needed), anchor weights and a device for configuration, such as a smartphone. To meet this requirement and address common challenges related to deploying and retrieving an ADCP, including manufacturing a deployment frame, the ECO implementation provides an integrated deployment and recovery system comprised of two sub-surface buoys and a time-release device, (Fig. 2 and Fig. 3). With this system, both deployment and recovery of the ECO can be easily performed by a single-person with minimal vessel support (e.g. only a kayak).

The main components of the deployment and recovery system are shown in Fig. 2. The top buoy houses the ECO ADCP itself, which is secured to the buoy via a locking ring. A timed-release device is housed in the bottom buoy. Both buoys are connected by a supplied rope loop, about 30 cm long. Inside the bottom buoy is a supplied coil of 60 m, 4 mm diameter, Polyester rope. The rope is kept in place by a lid. The Release has holes for shackles at both its top and bottom. One end of the rope is attached to the top shackle while the other end to the bottom shackle. The top buoy is also attached to the top shackle and the anchor weight is attached to the bottom shackle. Once the release is activated, the top cap of the release (with shackle attached) is freed, floating to the surface pulled by the buoyancy of the top buoy, and at the same time bringing up with it the rope coiled inside the bottom buoy. As all components are attached together, the entire mooring inclusive of anchor can be retrieved. The ECO ADCP and Release are both rated to 50 m.

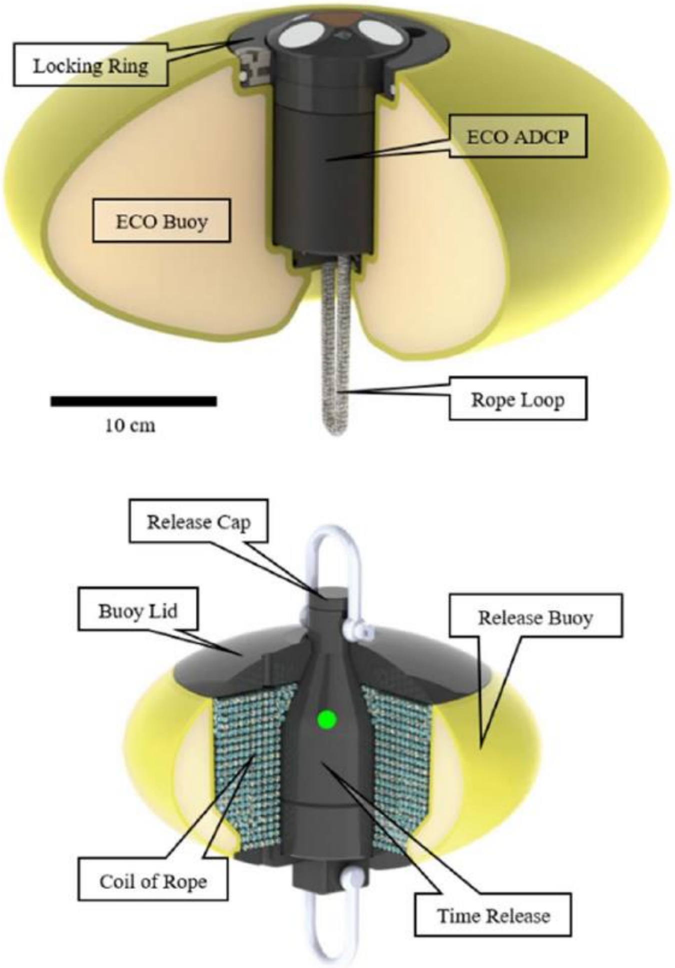

Fig 2. ECO buoy (top) and Release buoy (bottom) cutaway view showing main components. With the ECO ADCP installed, the top buoy has 11 kg of buoyancy and with the Release installed, the bottom buoy has 3 kg of buoyancy. Drawings are to scale and a 10 cm marker is shown for reference. All exposed materials are non-corrosive.

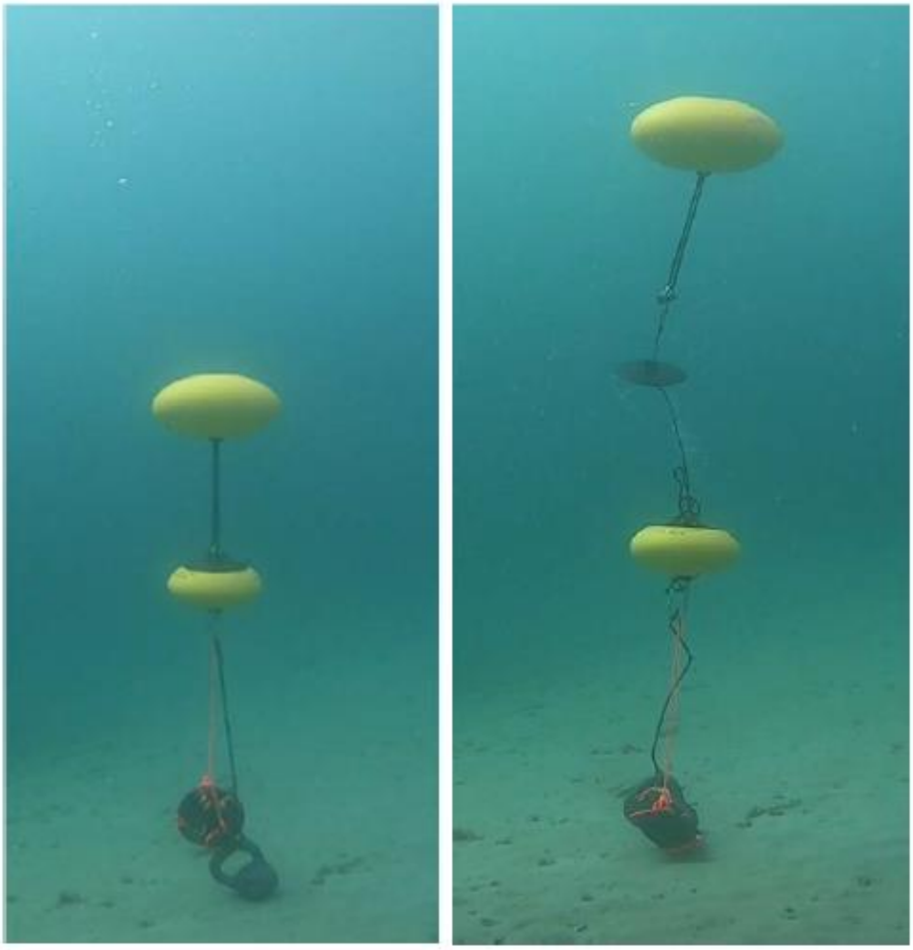

Fig 3. Complete mooring line as deployed (left). Once released (right), the ECO buoy (top buoy) floats toward the surface pulling the Release buoy lid along with the coil of rope housed inside it, allowing for retrieval of entire mooring, inclusive of anchor weight.

The ECO Release is a time-release mechanism comprised of a high-torque motor powered by four user-replaceable AA batteries (Fig. 4). The device is programed to activate at a user-defined date and time. Once activated, the release's motor drives a low-friction titanium screw which holds the release's top cap. The ECO Release has a Safe Working Load of 200 kg, which is a factor of 8 greater than the typical load with the ECO buoy. The motor also provides > 25 kg of lifting force thus capable of dislodging potential biofouling between the cap and its female socket.

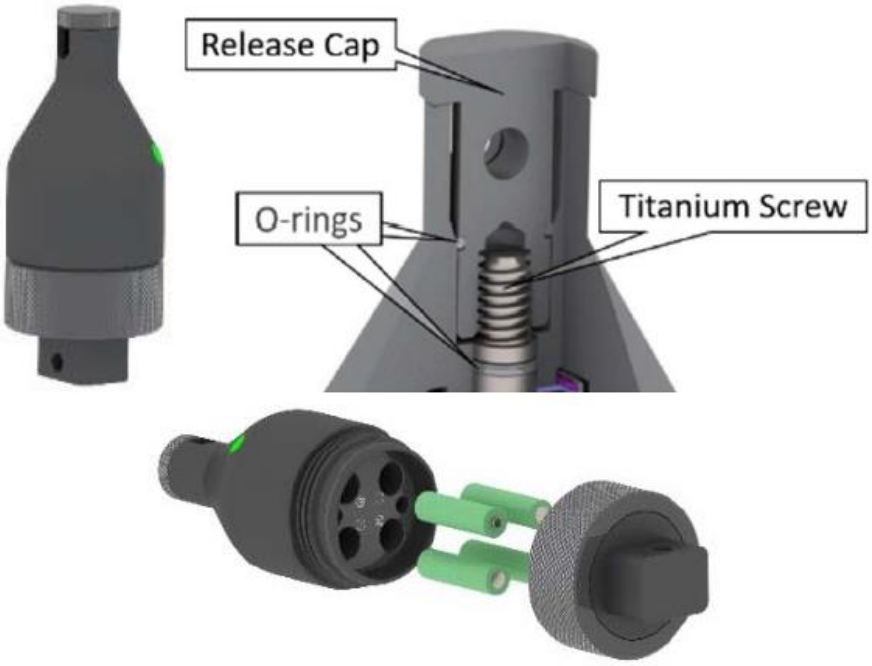

Fig. 4. ECO timed-release device (top-left). Cutaway of release’s top showing titanium screw and removable top cap with hole for shackle (top right). O-ring seals help minimize sediment intrusion and biofouling around the titanium screw. Bottom image shows AA-size battery compartment with screw-on lid.

A mooring analysis was performed with Dynamic Systems Analysis’ (DSA) *ProteusDS* software, which is an ocean engineering program used to simulate the dynamic mooring response in wind, waves, and currents. The mooring was resolved with a finite element model and the top buoy with a rigid body model. The hydrodynamic drag, buoyancy, and added mass effects were accounted for and the result shows that tilts remain under 8° under steady-current cases up to 1 m/s (Fig. 5). Although the ECO’s tilt data are averaged over the ensemble and not stored for every ping, visual observations of tilt during test deployments compare well with the modelled results. With respect to waves, dynamic loads were also modelled at 10 m mean depth (no mean currents) and showed that mean tension on the anchor remains consistently around 140 N under various conditions (Fig. 6), matching the static floatation of the combined ECO buoy (11kg) and Release buoy (3 kg).

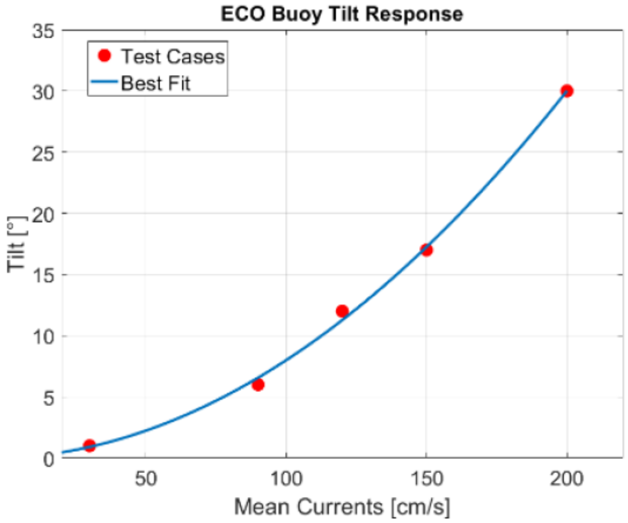

Fig. 5. Modelled ECO buoy tilt response to mean currents. Tilt remains under 8° for currents up to 1 m/s.

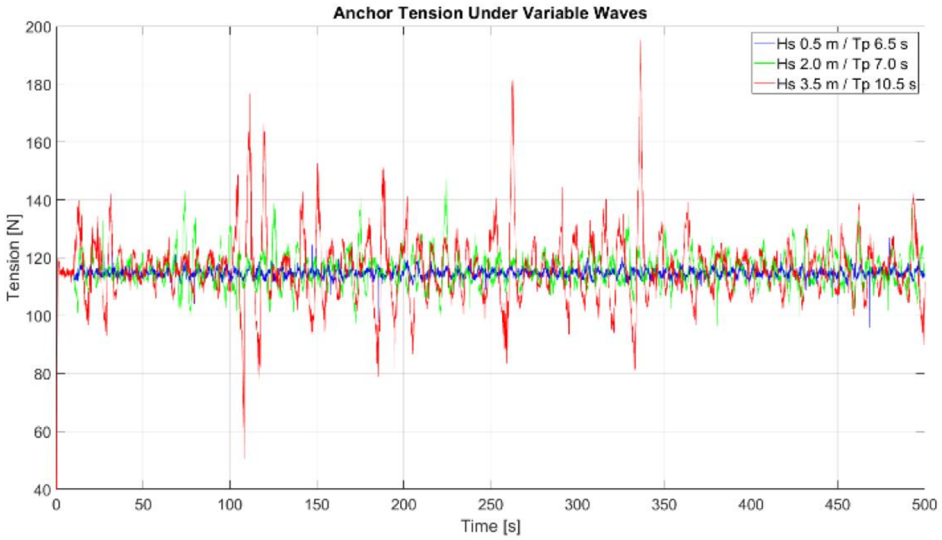

Fig. 6. Modelled anchor tension for three separate cases. Water depth used was 10 m and no mean currents were assumed.

Finally, for deployments in shallow water where the height of the mooring line may limit the useable profiling range, a bottom mount is also available as an option for the ECO. It is easily carried by one person, foldable for easy packing and transport, made of non-corrosive material, and low profile for operation in shallow water.

G. Multi-platform, cloud-based operation with geolocation

The seventh and last requirement envisioned: 1) maximizing usability across multiple devices (from mobile phones to desktop computers) and operating system; and 2) delivering a ready-to-use data report with minimal user interaction required. Furthermore, cloud-based data storage also opens up data sharing capability, allowing greater interdisciplinary collaboration among users as well as faster system enhancements.

Unlike platform-specific software, which must be developed independently and installed by the user on individual machines, the ECO software is implemented as a Progressive Web Application (WebApp) accessed online at eco.nortekgroup.com (Fig. 7) and utilizing the browser’s Web Bluetooth interface for communication. WebApps offer a consistent user interface through a web browser, without needto install in a local machine. Although ECO data files inside the instrument’s memory are stored in a proprietary binary format, once transferred to the WebApp data are converted to the human-readable JavaScript Object Notation (JSON) format, which is both open-source and self-describing. Additionally, data sharing has been implemented both internally and externally in both JSON and ASCII formats, allowing users to quickly share ECO deployments with anyone with an ECO account, thus facility interdisciplinary collaboration,

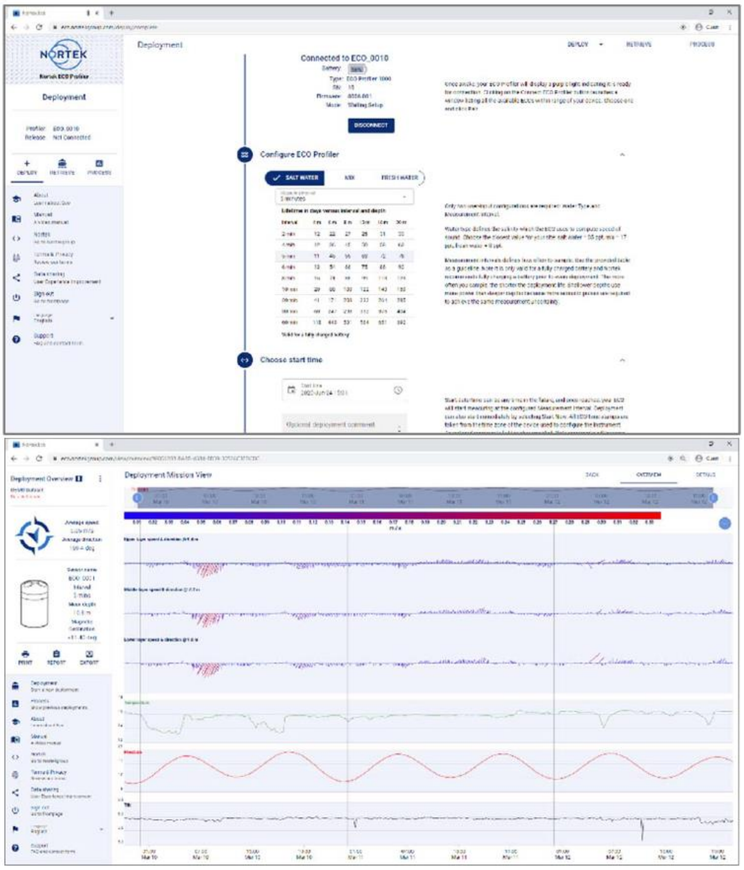

Fig. 7. Screenshot of ECO WebApp main page showing the main setup steps (top) and sample data display (bottom). Note the easy-to-read approach with three layers shown.

As data download and display is performed on a WebApp, it is also inherently cloud-based. We have opted for Microsoft’s Azure cloud computing platform for this service. User access is controlled with password-protected credentials to an individual ECO account. The built-in GNSS receiver allows ECO deployment data location to be easily mapped within the WebApp. Geolocation also provides automatic magnetic declination compensation through a NOAA/NCEI API.

Finally, although data from all depth cells are recorded by the ECO, in the interest of user accessibility, especially having in mind the before mentioned requirement of no prior experience needed, data display on the WebApp is limited to three layers at a time, and their position within the water column may be user defined, or automatically set.

III. SAMPLE DATA

Extensive field tests have been conducted with the ECO ADCP, both in shallow water (< 2 m) as well as deeper water (> 10 m). As of submission deadline for this paper, more than 45 in-water deployments have been performed in six countries with more than 12 separate instruments, and more than 2500 hours of data have been collected. In this section we highlight one such deployment showing performance of the ECO ADCP in comparison with a reference system.

A five day deployment east of Toulon, France, was conducted between 03/JUN/2020 and 08/JUN/2020. The site location is shown on Fig. 8, at a mean depth of 13 m and about 400 m from shore. The ECO was deployed by divers on a fixed bottom frame (Fig. 9). About 60 m to the west of the ECO was a Signature1000 reference ADCP, which was deployed along the same isobath. Oceanographic engineering firm Nortek Méditerranée operates a MetOcean buoy at this site, and wind speed and direction data were also collected.

The ECO was configured for a measurement interval of 10 minutes and it self-configured for 16 depth cells of 1 m each, a 0.1 m blanking distance (default) and 35 pings evenly spread over 105 s (0.33 Hz effective sampling rate), bringing the predicted horizontal precision to 0.99 cm/s. The Signature1000 was set for two concurrent measurements: Average and Burst/Waves, both using wideband pulses. In the Average Mode, it was configured for a measurement interval of 5 minutes sampled over 20 depth cells of 1 m each, a 0.1 m blanking distance and 105 pings over 105 s (1 Hz effective sampling rate). This had a predicted horizontal precision of 0.34 cm/s, a factor of almost 3 improvement over the ECO. Data from the Signature was further averaged to 10 minutes to match the ECO's interval. In the Burst/Wave Mode, the Signature1000 was configured for a continuous internal sampling rate of 8 Hz, internally averaging every two pings, for an effective sampling rate of 4 Hz throughout the five day deployment. A total of 20 depth cells of 1 m each were used, and blanking was 0.1 m, all set to match the ECO. The sampling rate used allowed for directional waves computation with the Signature1000 and these data are shown on the bottom of Fig. 11.

Fig. 8. Location of ECO/Signature1000 comparison deployment within the Golfe de Giens east of Toulon, France. ECO Location: 43.0838 N, 6.0879 E. Signature1000 was about 60 m to the west of the ECO along the same isobath. Mean water depth approximately 13 m. Nortek Med MetOcean buoy was about 70 m to the east of the ECO.

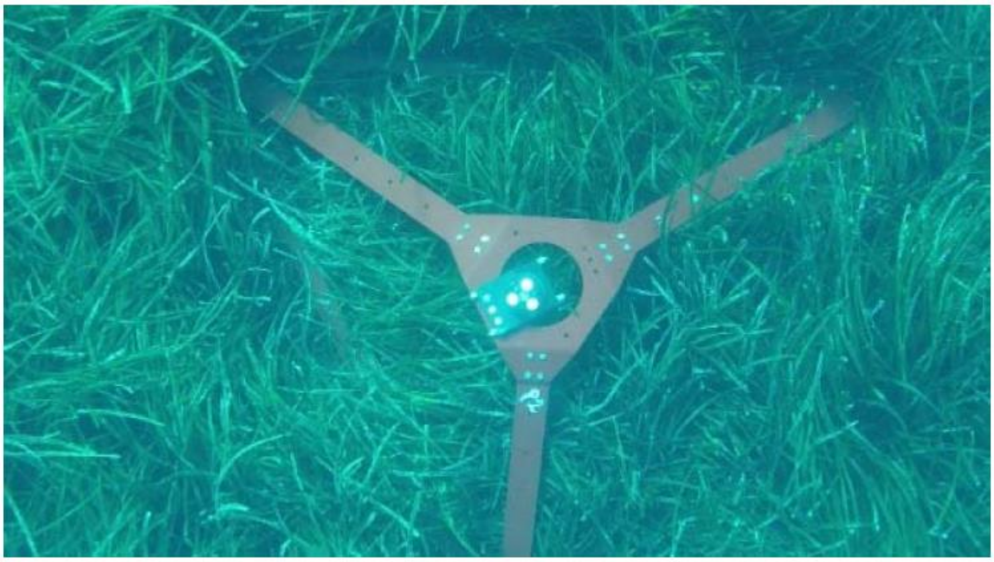

Fig. 9. ECO as installed in a bottom frame in the northern Golfe de Giens east of Toulon, France.

In evaluating the comparison deployment data quality, we start with the ancillary sensor data. As shown in Fig. 10 (a. and b.), both systems captured the small tidal and temperature variations at the site, showing nearly identical data. Compass heading (not shown) for both systems was steady at 264° for the Signature1000 and 117° for the ECO. Tilt data not shown), showed the ECO had less than 2° total tilt (with 0.4° standard deviation) while the Signature1000 showed larger tilt of approximately 9° (with 0.4° standard deviation). Although this tilt is higher than normally recommended (±5°), the shallow depth at the site meant negligible impact due to tilt.

Two acoustic parameters must be checked: correlation score and Signal-to-Noise Ratio (SNR) data. For wideband ADCPs, correlation describes how similar a returned echo is to itself at a delayed time, and its magnitude is a key quality measure of the velocity data. Acceptable correlation values vary between system hardware design and firmware implementation. A commonly used threshold is 50% [7]; data below this value is considered suspect. It is important to note that the impact of lower correlation values is a worsening of velocity precision and not of velocity accuracy

Signal-to-Noise Ratio (SNR) refers to the energy of the acoustic signal in relation to the energy of the system’s noise. Data where the SNR is less than 3 dB above the noise floor are considered invalid. Both the ECO and Signature1000 systems used in this deployment had a noise level of approximately 26 dB and minimal SNR of 40 dB, even at the top of the water column (i.e. farthest range from instrument) as shown in Fig. 10.

Signal-to-Noise data (Fig. 10, e. and f.) show very similar patterns between the two instruments and a typical decay with range is observed. SNR values for both the ECO and the Signature1000 tend to be slightly lower for the second half of the deployment indicating water with fewer particles moved into the site. This also matches the noticeable drop in water temperature observed during this time. Review of correlation data (Fig. 10, c. and d.) shows both systems had values well in excess of 90% for the entire deployment and most of the water column, giving further assurance of data quality.

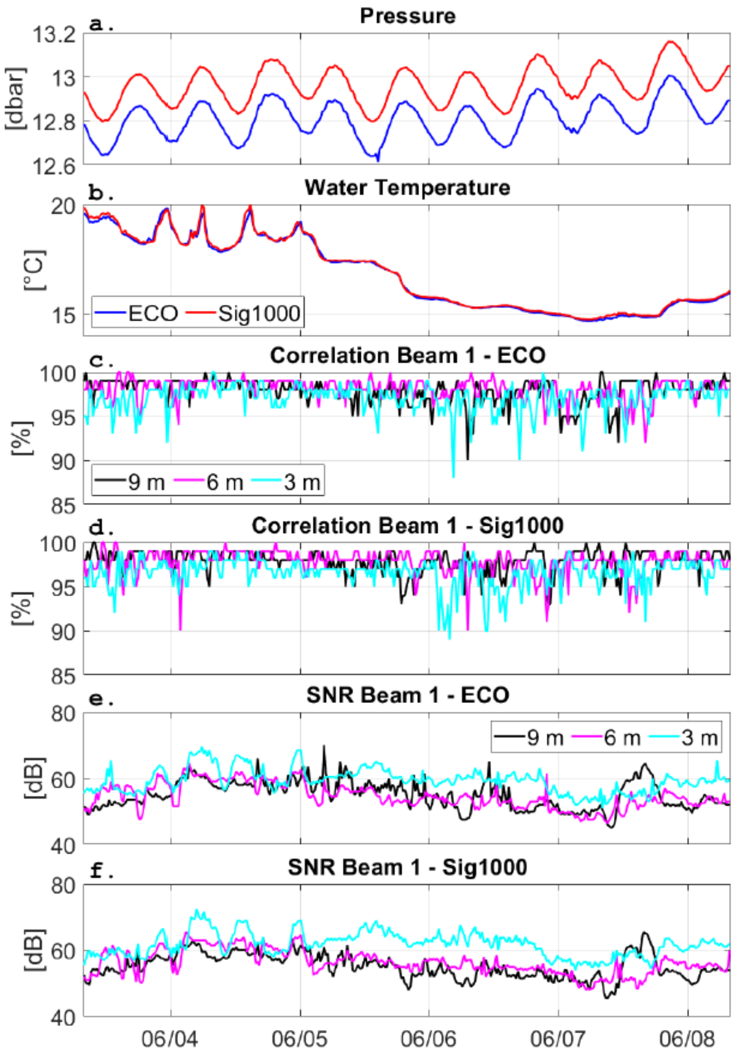

Fig. 10. ECO and Signature1000 environmental sensor and acoustic data. Panel a. shows pressure, b. water temperature, c. and d. are acoustic correlation score, and e. and f. are Signal-to-Noise Ratio (SNR) for the ECO and Signature1000, respectively. Panels c.-f. are for the three range layers normally used in the ECO's WebApp display and represent the top/middle/bottom of the water column. Distances are ranges above the top of the instrument. All times UTC.

Once satisfied with the overall data quality, we can proceed to review the current data (Fig. 11, a.) for the three range layers used. For the most part, the data compares very well, with the ECO data generally being slightly noisier when compared to the reference Signature1000 ADCP due to the coarser precision owed to the lesser number of pings accumulated over the 10 minute averaged interval (210 pings for the Signature1000 versus 35 pings for the ECO).

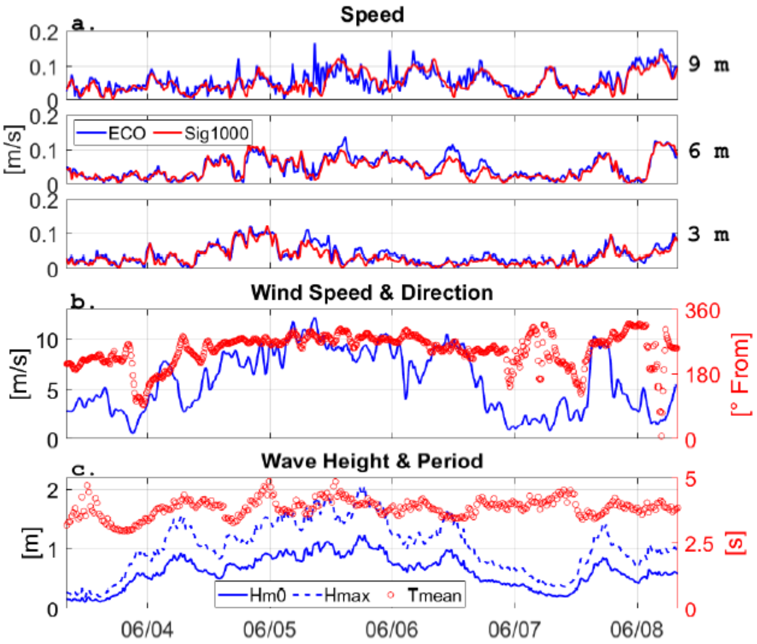

Fig. 11. ECO and Signature1000 horizontal current speed and direction, wind speed and direction, and basic wave statistics. Wind data are from a surface MetOcean buoy about 70 m away from the site. Wave data computed from Signature1000. All times UTC.

A linear regression of the horizontal current speed, $\sqrt{U^2 + V^2}$., between the two instruments for the three layers is shown in Fig. 12. A regression score (R2) of 0.73 was obtained which is significant given the number of points used (1080) and the inherent lower noise of the reference system in relation to the ECO, as evidenced by the scatter in the plot. Most of the outliers, especially those above the 1:1 line, are from the topmost range layer. The potential wind-induced shear within the top of the water column, in addition to undoubtedly higher near surface turbulence due to the wave conditions, poses a challenge for Doppler systems unless they provide both the spatial and temporal resolution to resolve these velocities. This is further complicated the farther away an up-looking ADCP is from the surface due to sidelobe interference, and the slanted beam separation distance as they intersect the surface. These effects contribute to the scatter observed in the regression, so in an effort to validate the regression model and better quantify any potential bias in the ECO velocities, we also produced a histogram of the difference in horizontal current speed between the two instruments (taking the Signature1000 as the independent variable) and fitted a Gaussian distribution function centered on the mean of the data (Fig. 13). From this we observe a bias of only +0.0049 m/s, which is less than the constant of the regression model (0.0089 m/s). Considering the test site produced very low mean currents of less than 10 cm/s, the resulting bias falls well within the 1% ± 0.5 cm/s accuracy specification for the ECO.

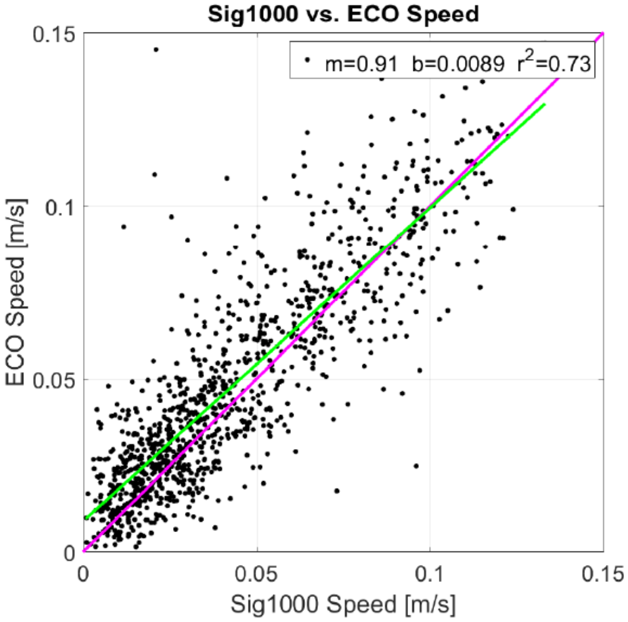

Fig. 12. Linear regression model of horizontal speed data from both instruments for the three layers used (3 m, 6 m, 9 m above instrument). R2 value of least-squares fit line (green) given on graph as well as y-interceptand slope. The 1:1 line (magenta) is also shown.

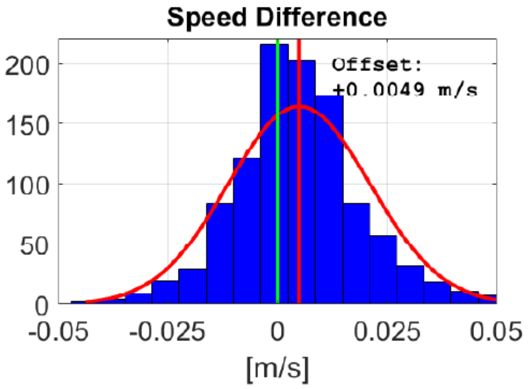

Fig. 13. Histogram of velocity residuals (ECO minus Signature1000) for the horizontal speed for the three layers used. A Gaussian distribution function was fitted to the data. Green vertical line represents 0 m/s difference while red vertical line is center of distribution. Offset from 0 m/s given.

IV. CONCLUSIONS

We have presented the design concept and development of a short range, low cost ADCP called the Nortek ECO. The system is based on a completely new electronics platform and designed to be self-configuring such that only three user inputs are needed: 1) when deployment should start, 2) how often to sample, and 3) what is the water type it will measure. It uses an implementation of Nortek's AD2CP technology to profile currents over a maximum range of 20 m and in water depths as shallow as 0.5 m. The hardware is complemented by an integrated deployment and retrieval system comprised of a subsurface buoy and time-release mechanism. The instrument contains no moving parts and no external connectors. Power is supplied by an inductively charged battery and all communications performed via a Bluetooth Low Energy link.

Data is visualized in a cloud-based Progressive WebApplication (WebApp), thus not requiring native software installation and being able to run on most smart devices. Datafrom a test deployment were presented where a bias of only +0.0049 m/s was observed against a reference system.

V. ACKNOWLEDGEMENTS

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