SeaExplorer Underwater Glider: A New Tool to Measure Water Velocity; Glider-based ADCPs yielding promising results for measuring depth-resolved currents profiles in open-waters.

By Orens Pasqueron de Fommervault, Florent Besson & Philippe Lattes

Autonomous underwater gliders are beginning to prove their large potential in modern oceanography and have an increasingly important place in ocean monitoring studies. The SeaExplorer glider, developed and commercialized by Alseamar, is a buoyancy-controlled UUV. By changing its buoyancy, it moves through the water column down to a depth of 1000m, coming periodically to the surface for data transmission. Over the past 10 years, the SeaExplorer has been used to make a variety of measurements in both coastal and deep-sea environments. It has been deployed to characterize water masses properties, to study biological processes and to track dissolved hydrocarbons through the water column.

In 2017 a new sensor dedicated to water velocity measurements was integrated to the platform in the framework of a research project conducted by Alseamar together with the entity in charge of metocean discipline in TOTAL SA. The sensor is a 1 megahertz Acoustic Doppler Current Profiler (ADCP) commercialized by Nortek AS. This ADCP was a good match for the SeaExplorer glider due to its low power consumption, and for its ability to let users create and transmit telemetry files, small subsets of the data, in real time when the glider surfaces and transmits via Iridium. The full data remains on board and can be retrieved when the glider is recovered. With this ADCP, users are able to run long glider missions and transmit data in real time.

Figure 1. Deployment of a SeaExplorer glider equipped with a Nortek ADCP.

Water velocity observations are of great interest in oceanography. They provide valuable information on ocean mixing and dispersion, processes that control the distribution of many parameters (e.g. phytoplankton and nutrients concentrations, suspended matter, pollutants). Currents also transfer significant amounts of heat and thus play important roles in determining the climate of various regions. In that sense, there is also a need for in situ ocean currents measurements for modelling and weather forecast purposes. Water velocity observations are also critical to better characterize metocean conditions for new assets of the oil & gas industry or directly in support of their offshore activities.

In this short overview we present water velocity measurements acquired in deep waters by the SeaExplorer. This opens new perspectives in ocean research and monitoring.

A CHALLENGING MEASUREMENT

ADCPs determine water velocity by transmitting a sound pulse and measuring the acoustic Doppler shift signal returning from scattering material in the water column. Raw velocity measurements are thus relative to ADCP transducers and differ from absolute water velocities by including vehicle displacement. Consequently, to determine absolute water velocity, one theoretically needs to know the underwater motion of the platform. For gliders operating in shallow water with downward-looking ADCPs, bottom tracking can be used to obtain this information, by referencing ADCP data with the bottom. If bottom tracking is unavailable, i.e. in open ocean or if the ADCP is in upward-looking configuration, other methods must be used and the measurement is much more challenging.

DATA PROCESSING

The Nortek AD2CP was specifically developed for glider applications. In particular, the instrument uses a four-beam transducers head compensated for pitch angle of the glider. This way velocity data can be acquired during both the descent and the ascent which yields a complete dataset for post-processing. The ADCP was programmed to emit an acoustic signal (4 averaged pings) every ten seconds. For each averaged ping, data were recorded by the ADCP at discrete depth intervals (30 cells) of 1m resolution (cell size). This leads to a usable range of 15 to 30 m, depending on water masses properties. Raw along-beam velocities were converted into an earth-based reference system using rotation matrices and compass angles measurements (heading, pitch and roll).

The underlying assumption in using an ADCP mounted on a glider is that one can use successive overlapping velocity profiles to obtain a full ocean depth velocity pro-

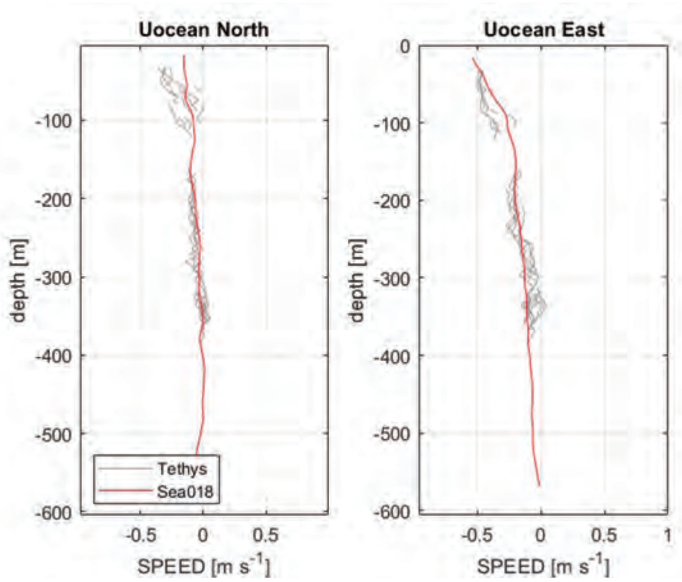

Figure 2. Comparison between R/V Tethys II ADCP measurements and Glider ADCP profile.

file. One method to remove unknown glider motions is the "shear method". Taking the vertical difference of raw water velocities for each ensemble provides the shear values between cells and removes glider motion and the depth average (barotropic) constant. Overlapping shear values were averaged over a given interval, set at 2 m in our processing, to determine a mean shear profile for a dive. This profile was then vertically integrated to obtain a baroclinic velocity profile. During our missions, most of the time, bottom-tracking data were not available because gliders were operating in deep-waters (bottom depth > 1000 m). Hence, the baroclinic profile was referenced using the displacement of the glider between two surfacing, known through GPS position, to obtain the barotropic profile. Finally, the absolute water velocity profile was obtained by summing the baroclinic and the barotropic profile.

CASE STUDY: THE MEDITERRANEAN SEA

Five ADCP-glider missions were conducted by Alseamar in the Northwestern Mediterranean Sea, off the French coast, in the last eight months. We present the results of two of them. The first one took place in February 2018, and the second one in July 2018. To improve the profiling rate, gliders were programmed to dive to 700 m depth. In this configuration, two consecutive surfacings were separated by around three hours, and were around three kilometers apart. The area where gliders were deployed is widely studied as part of the Mediterranean Observing System (MOOSE, www.moose-network.fr). In particular, Alseamar's gliders performed transects between the time-series station Boussole and Nice harbor which is a reference line, monthly monitored by the R/V Tethys II equipped with a 75 kHz ADCP. Since 2007, the transect is also regularly occupied by gliders but it is the first time one of them was deployed with an ADCP.

The first objective of the missions was to validate our processing of glider-mounted ADCP data. To this end, glider measurements were compared with in situ ship-ADCP data from the R/V Tethys II, kindly processed and provided by the DT-INSU data center (http://www.dt.insu.cnrs.fr/spip.php?article35). A profile-to-profile comparison showed a very good accordance between glider and ship-data. The mean difference was found to be 1.5 cm.s-1, which is very satisfactory.

Data also showed that gliders were perfectly capable of catching interesting and known features of the Northwestern Mediterranean Sea. For example, the Northern current, a permanent flow that results from the large-scale thermohaline circulation of the Mediterranean Sea, was regularly sampled. In the transect presented here, the flow had a westward direction and reached a maximum velocity of 60 cm.s-1, which agrees with model simulations. The Northern current was located at around 30 km distance from the coast and had a maximum vertical extend of 300 m depth on the North edge. At 40 km, the current dropped below 10 cm.s-1. The comparison between ADCP data and other conventional measurements, concomitantly acquired by the glider (temperature, salinity, dissolved oxygen, chlorophyll), also highlights the predominant impact of the current on the vertical distribution of physical and biological parameters. In particular, a coherence between the vertical distribution of current velocity and the density field was observed. The Northern current separates the area into light coastal waters and an open-water with higher surface densities.

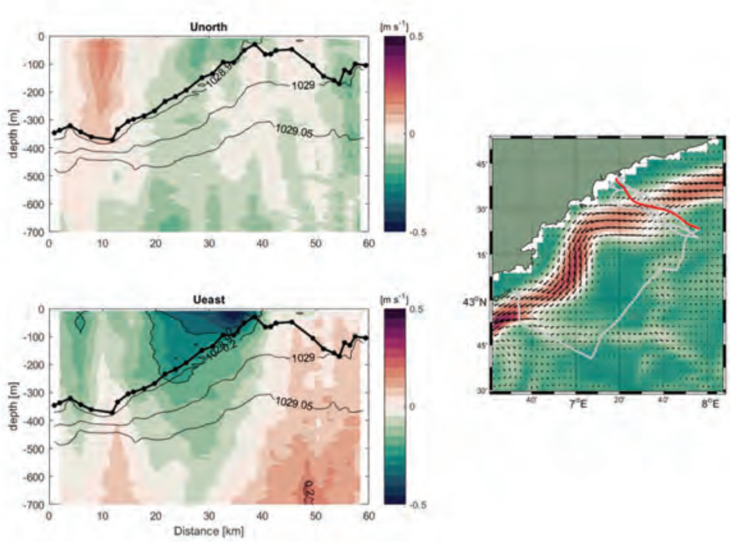

Figure 3. Glider-ADCP data acquired during the mission conducted in February 2018. The trajectory is superimposed on surface currents estimated by the NEMO v3.6 model (data downloaded on www.marine.copernicus.eu).

Another interesting feature was a cyclonic-like structure observed at the margin of the Northern current, which results from current instabilities. Such structures of few kilometers and short duration are hardly detectable from other means (e.g. ship, satellite) and almost impossible to forecast with numerical simulations.

CONCLUSION

The success of these missions highlights the reliability of measuring accurate depth-resolved water velocity profiles with SeaExplorer gliders. Measuring water currents from a glider has many benefits. Data can be obtained in near-real-time, with a high vertical resolution (in the order of 1 m) and up to 1000 m depth (unlike a ship-mounted ADCP which has a depth range of around 400 m). Velocity profiles may also be very useful to interpret other variables measured by gliders and to study physical-biological interaction at unexplored scales. This also opens new perspectives for metocean applications and can help for characterization of conditions in support of offshore operations.

Other deployments are planned to start soon, in various area around the globe.

ACKNOWLEDGMENTS

The authors acknowledge the financial support from TOTAL and Naval Group. We are also grateful to Céline Heyndrickx (DT-INSU, CNRS) for providing processed ship-ADCP data and to Vincent Taillandier (LOV-CNRS), Louis Prieur (LOV-CNRS), Fréderic Marin (IRD), Yann Le Page (Alseamar) and Laurent Beguery (Alseamar) for their scientific assistance.

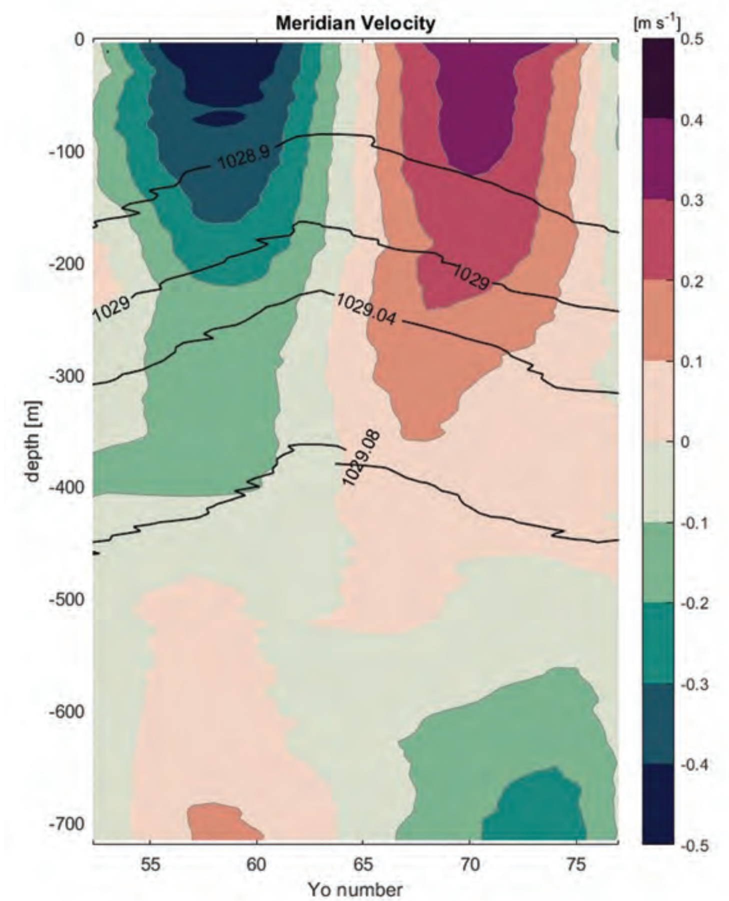

Figure 4. Glider-ADCP data acquired during the mission conducted in July 2018. Only data acquired during the period when the glider was sampling the cyclonic structure are plotted.