A System for Correcting ADCP Heading on Moorings at High Latitudes

Andreas Marouchos[1], Matthew Sherlock, Steve Rintoul, Lindsay Pender
CSIRO Marine and Atmospheric Research
Castray Esplanade
Hobart, Tasmania 7000, Australia
[1]andreas.marouchos@csiro.au
www.cmar.csiro.au

***Abstract-* CSIRO has deployed large oceanographic moorings near the South Pole to help scientists better understand ocean dynamics in the ice forming regions around Antarctica. A standard instrument on these moorings is an Acoustic Doppler Current Profiler (ADCP), which provides information on the direction and magnitude of ocean currents in the water column. These instruments use an integrated magnetic compass to alight current vector readings with compass points. Unfortunately, at high latitudes - such as those near the magnetic South Pole - those internal compasses are not able to produce a reliable heading. A system was needed to supplement the internal ADCP compass in order to properly align the current heading. A system using a fiber optic gyroscope was developed to provide corrected heading information for the instrument packages. This paper discusses the challenges of correcting for compass heading data at high latitudes. It discusses the design and development of a system for facilitating the correction of ADCP heading data on moorings deployed in the southern ocean. Results from ocean deployments in the Ross Sea are also presented. Finally, the paper disuses how the system can be modified to allow for deep operation, operation on larger moorings or integration with other ship deployed systems such as conductivity temperature and depth (CTD) systems.**

I. Introduction

Oceanographic moorings are heavily used by CSIRO and throughout the ocean science community as a way of measuring time varying water column and atmospheric conditions. In support of science in the southern ocean and waters in the sub-Antarctic zone, CSIRO operates a series of mooring arrays in the southern ocean [1,2]. At present there are a total of six moorings operated by CSIRO in the southern ocean, which is an increasingly important area of interest for the scientific community. These moorings are equipped with a range of instrument packages including temperature probes, current meters, and meteorological sensors.

A standard instrument on many of these moorings is an Acoustic Doppler Current Profiler (ADCP), which provides information on the direction and magnitude of ocean currents in the water column. This allows scientists to understand the direction and strength of ocean currents, as well as the mixing within the water column. To this end, CSIRO operates an array of three moorings in a polynya in the Ross Sea.

A. What's my heading?

Typically, instruments which require heading as part of their output parameters will include some method of heading measurement. In particular, ADCP's are equipped with an internal magnetic compass which can infer current heading by referencing measurements to the earth's magnetic field. At the poles however, the earth's magnetic field is weak, and as such the standard compasses contained in these instruments are not able to produce accurate or stable readings of heading.

In the past, CSIRO has used high sensitivity compasses (such as the Watson Compass) to help aid in the ADCP heading correction. These attempts proved unsuccessful in providing accurate or reliable heading corrections. Typical heading error for readings using magnetic field detection was found to be on the order of 10 to 20 degrees with quite a noisy signal. The error was especially poor close to the south magnetic pole where the moorings were regularly deployed. It was decided that a more accurate heading system was needed. A system was developed which uses an optical gyroscope to provide heading information.

Figure 1. The modified lander frame used in the polynya array.

978-0-933957-40-4 ©2013 MTS

II. System Design

In order to adequately correct the heading errors produced by the internal compass of the ADCP instruments, it was necessary to design a system that could produce an accurate heading with less than five degree error, which was stable and independent of magnetic field strength. The system should be flexible enough to operate in a range of latitudes, and be self contained. In order to contain costs, the system should also be designed in a way that allows it to be deployed on a series of moorings in succession with a quick turnaround at sea.

A. TOGS Pod

To best meet the requirements, a self contained system based around the use of a fiber optic gyro was developed. The system was designed around the use of a TOGS (Tiny Optical Gyro System) fiber optic gyro from CDL. The TOGS unit was found to be cost effective, small, and with low power use. This would allow for a compact system that did not require a large battery pack to operate. The TOGS unit would be housed in a self contained frame (TOGS Pod), which would be deployed in situ on moorings, allowing for redeployment on an entire mooring array. The system would be entirely self-contained with its own floatation, batteries, and logging system, and would be rigidly attached to the anchor mass of the moorings to record the final resting orientation of the anchor package.

This solution required some changes to the existing conventional mooring design. First, the ADCP frames needed to be rigidly attached to the landing anchor frames to prevent rotation while the moorings sat on the bottom. This would allow for stable heading readings from the ADCP throughout long deployments. The system can be used with any version of ADCPs, but in this instance the moorings were setup for use with the Long Ranger 75kHz ADCPs from Teledyne RDI. Second, as it was necessary to deploy this solution across multiple moorings, it was not cost effective to purchase optical gyros for each mooring. As such, a small docking platform was added to each of the anchors to allow the temporary attachment and subsequent release of the TOGS pod.

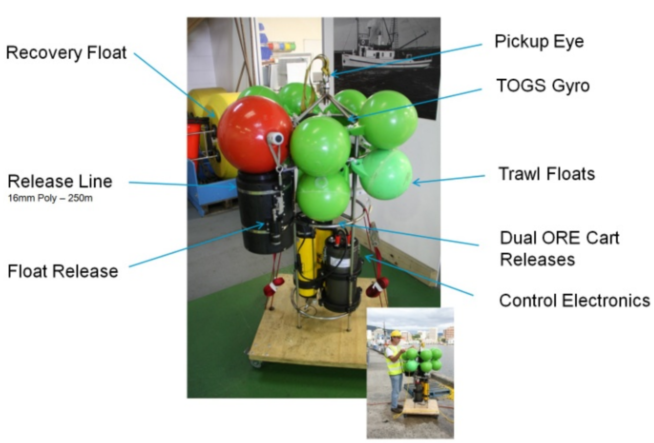

Figure 2. Labeled drawing of TOGS Pod fully assembled.

B. Mechanical Design

The TOGS pod is a self contained system which allows for the independent operation of the fiber optic gyro. The system consists of a small vertical stainless frame on which the components are mounted. It is equipped with a CDL TOGS unit, and custom made electronics housing containing batteries and control electronics. The TOGS gyro was precision fitted in the pod to locate accurately with the mooring lander, and subsequently, the ADCP. Floatation is provided through the use of twelve small trawl floats lashed to the upper section of the frame. A pair of ORE CART releases allow for release from the anchor when system logging is complete. The system is also equipped with a large surface recovery float connected to 250m of 16mm floating polyester recovery line. The line is roughly spooled in a small container with the float covering its opening. The float is held in place with a custom made depth rated solenoid which allows the float to be released (and hence the line spooled) on demand. At the surface, a custom made GPS transmitter and strobe beacon attached at the top of the unit aid in locating the system during recovery. In total, the system stands 1.2m tall and weighs around 94 kg in air. An overview of the system configuration can be seen in Figure 2. Nominally the system is rated for use to a depth of 1500m which is limited by the use of trawl floats for floatation. If deeper rated floats were used – such as glass or syntactic spheres - the system could operate to a depth of up to 3000m.

Upon completion it was necessary to mate the system to the mooring anchor base. At the base of the frame, four legs with receiving pegs allow for the system to be accurately aligned on a small platform welded to the side of the mooring anchor. Once the anchors were manufactured, each system was assembled in the CSIRO labs in order to accurately align the optical gyro to the ADCP unit attached to the pivoting frame directly above the system as shown in Figure 3.

Figure 3. Lander frame with TOGS Pod and ADCP frame.

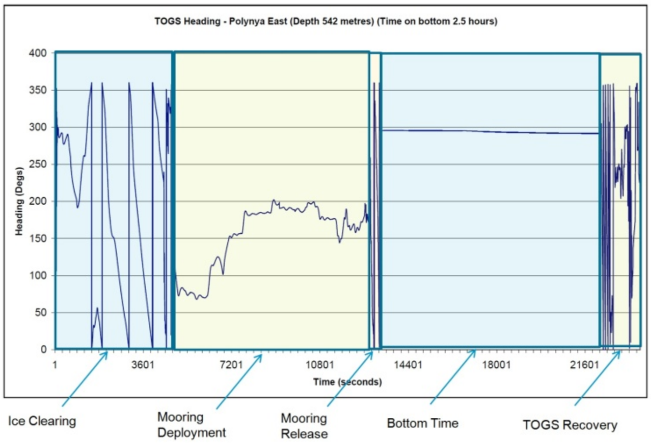

Figure 4. Sample heading data from single mooring deployment.

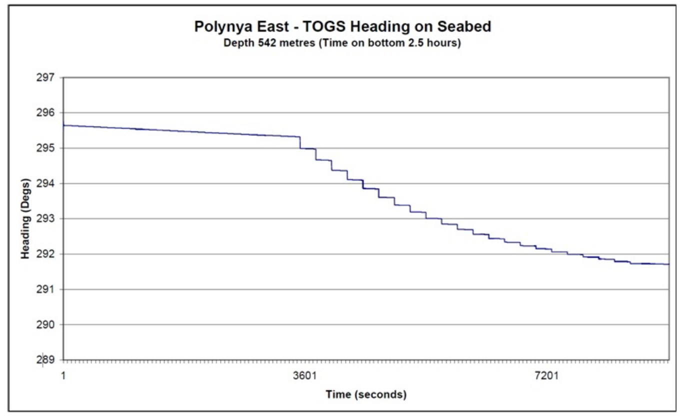

Figure 5. Heading data collected on landing.

C. *Power Electronics and Sensors*

Control, logging and power for the TOGS pod is all contained within a single aluminum housing. A set of two 18Ah alkaline battery packs, each running at 15V, are connected in series to provide power to the system. During operation, the system will draw nominally two amps allow for a run time of up to six hours. The system is also equipped with a Druck PMP1400 pressure transducer to monitor system depth, while a small set of external LEDs provide system status to outside users. A small custom made electronics board communicates with the TOGS unit while logging all relevant system information including depth, time and battery voltage. The system can be programmed to log at varying internals and has the ability to hibernate for extended periods. In addition, the system can also be operated manually using a laptop for control and logging over a serial RS232 connection.

III. System Operation

Although the system can be operated manually, it was designed to operate autonomously. Once aboard ship, the system is turned on approximately one to two hours prior to deployment. This allows the TOGS system to warm up to its required temperature, and acquire a steady location and heading fix. Although this can be done outside on the deck of a ship, it is typically performed indoors to keep the unit warm during position lock, and allow technicians to more readily monitor the state of the optical gyro. Just prior to deployment the system is then moved to the deck of the ship and attached onto the mooring anchor frame. Throughout this process the system is logging system data. The mooring and TOGS Pod are then deployed in tandem. During the descent, the system records depth, time and system heading.

Typically, the TOGS Pod will be left to sit on the bottom with the mooring for around two hours. When ready, the awaiting vessel would trigger the acoustic releases on the pod, sending it back to the surface for recovery. As the system is released from the mooring base and begins to ascend, the depth is monitored by the control software. At a predefined target depth - typically 200m below the surface - the system will fire the solenoid to release the large recovery float. The separation of the pickup float and TOGS pod during ascent allows an opportunity for the pickup line to stream out and separate from the system in advance of reaching the surface. This is important as surface conditions in the polynya are typically calm and there may be minimal wave action to separate the floats on the surface. Once at the surface, the system is recovered using a grappling hook and returned to the deck. Throughout the operation, all system parameters are being logged. On deck the system data is downloaded and batteries changed before the next deployment.

IV. Results and Discussion

The TOGS Pod was constructed and tested in the lab and from the CSIRO wharf allowing for the tuning of the data acquisition and heading correction software. The release and retrieval systems were also tested. Testing was successful and the resulting data proved valuable in tuning optical gyro for use in Antarctic waters. Three moorings were subsequently constructed using this design, and deployed in the Ross Sea off Antarctica. The moorings were deployed in depths of 1000m and left for two years to record data.

The initial deployments provided considerable information regarding the performance of the system in the field. Output heading data from one of the three mooring deployments can be seen in Figure 4. The various phases of the deployment can be clearly identified in the heading data. The process begins with ice clearing activities in which the ship moves in large circles to clear the deployment area of sea ice. This is followed by a steady heading during which the mooring is deployed. The mooring is then released and can be observed to rotate several times during its descent. Once on the bottom the heading begins to stabilize before recovery.

Overall the system performed as expected. Using the recorded depths it was found that the descent and ascent rates of the system were in line with expectations at 1.4m/s and 1.9m/s respectively. Closer inspection of the heading information however revealed that during the bottom interval, the fiber optic gyro did not operate as stable as expected. As seen in Figure 5, a close inspection of the heading while the system was on the seabed shows a stable reading followed by a rapid change to a new steady state value. This behavior was observed on all three deployments. Although the correction was consistently within a five degree band as required, it warranted further investigation.

A short series of tests were subsequently set up to evaluate and reproduce the phenomena observed during the bottom interval on the three moorings. There were three variables which were thought to contribute to the observed behavior; temperature, command sequencing, and platform stability. The system was exposed to large temperature fluctuations by repeated submersion into an ice bath after heating, sent various commands and GPS settings in varying orders, and set on a rotating platform to simulate heading changes aboard a vessel.

After some initial trials it became evident that the cause of the phenomena was platform stability during system initialization. Rotation of the platform during power up and initial heading fix was resulting in the system making an incorrect estimate of the rotation of the earth. This is a critical estimate used in computing the TOGS heading. Only once the system came to rest in a stationary position for some period did the system detect this error, and work to correct it. This can be seen in the stepwise change in heading to a new steady state value. It was found that although the system does eventually find the correct heading, it takes considerably longer than it would otherwise. Due to heavy ice conditions at the surface during the deployment of the three moorings, two of the three deployments were not given sufficient bottom time to correct the heading estimates.

As a result, it was decided that the systems operation would be changed to allow the TOGS unit to turn on only after reaching the bottom. This would remove the bias introduced by the rotating vessel at the surface, and provide a stable reading more quickly.

V. Conclusion and Future Work

This paper discusses the challenges of correcting for compass heading data at high latitudes. It discusses the design and development of a system for facilitating the correction of ADCP heading data on moorings deployed in the southern ocean. Preliminary results from ocean deployments in the Ross sea are also presented. Initial field deployments identified proved successful in providing heading data within a 5 degree margin of error. Subsequent analysis of the data however highlighted potential issues in the stability of the TOGS system which demands further investigation. Adjusted deployment procedures as well as a modified system boot up sequence would help combat the issues, and will be explored in subsequent trials. A further publication will look at the correction data in detail as well and recovered data from the ADCP, and subsequent deployments.

Overall the system was found to function as expected and proved a convenient and cost effective tool to correct heading information for instruments deployed at high latitudes. This method however is not limited to use on moorings. The system can be deployed on conventional shipboard CTD systems to correct heading on lowered ADCP's, aboard towed profilers, and on other ship deployed payloads.

Acknowledgments

The authors would like to thank all those that helped with the concept, design, manufacture and deployment of the TOGS system. Special thanks to Danny McLaughlan and Jamie Derrick in the Deepwater Moorings group, the CMAR mechanical workshop, and Mark Rosenberg at the University of Tasmania (UTAS) for his assistance in testing and deployment at sea. This work was made possible by funding from the CSIRO division of Marine and Atmospheric Research (CMAR), and the Integrated Marine Observing System (IMOS).

References

[1] Pender L., T. Trull, D. McLaughlan, T. Lynch. (2010). Pulse-a mooring for mixed layer measurements in the open ocean and extreme weather, In Proc. IEEE OCEANS'10, Sydney, pp. 1-6.

[2] Marouchos A., Pender L., Overview of CSIRO Deep Water Oceanographic Moorings (Indonesian Through Flow, East Australian Current and the Southern Ocean) – Designs and Challenges, WHOI Buoy Workshop Proc.; 2012 Mar 6-8; Victoria Canada.

[3] Rintoul, S.R., M.P. Meredith, O. Schofield, and L. Newman. 2012. The Southern Ocean Observing System. Oceanography 25(3):68–69, http://dx.doi.org/10.5670/oceanog.2012.76.