GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines

IOCCP Report No. 14

ICPO Publication Series No. 134

Version 1, 2010

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ACKNOWLEDGEMENTS

Support for GO-SHIP is provided by the IOC-SCOR International Ocean Carbon Coordination Project (IOCCP) and the WCRP Climate Variability and Predictability Project (CLIVAR). Major financial support for this project is provided by the U.S. National Science Foundation through a grant to UNESCO - IOC (OCE - 0715161) and to the Scientific Committee on Oceanic Research (OCE – 0608600 and OCE - 0938349) for the IOCCP.

For bibliographic purposes, this collection that should be cited as:

> Hood, E.M., C.L. Sabine, and B.M. Sloyan, eds. 2010. *The GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines*. IOCCP Report Number 14, ICPO Publication Series Number 134. Available online at *http://www.go-ship.org/HydroMan.html*.

Individual chapters written for this collection should be cited as:

> Lastname1, A., B. Lastname2, C. Lastname3. 2010. Chapter Title. In *The GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines*. Hood, E.M., C.L. Sabine, and B.M. Sloyan, eds. IOCCP Report Number 14, ICPO Publication Series Number 134. Available online at: *http://www.go-ship.org/HydroMan.html*.

Individual chapters previously published elsewhere should use the original citation accompanying the chapter.

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PREFACE

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Global hydrographic surveys have been carried out approximately every decade since the 1970s through research programs such as GEOSECS, TTO/SAVE, WOCE / JGOFS, and CLIVAR. However, global repeat hydrography has lacked formal global organization since the end of WOCE and this has led to a lack of visibility for hydrography in the global observing system as well as a significant decrease in the number of trans-basin sections carried out by some countries. More importantly, the lack of international agreements for implementation of hydrographic sections has led to duplication of some sections, cruises being carried out without a consistent suite of core variables, inconsistencies in data analysis procedures leading to variable data quality, and disparate data sharing policies.

Acknowledging the lack of coordination, the initiative to establish the Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP) was supported by the 3rd session (November 2009) of the IOC-WMO Joint Technical Commission on Oceanography and Marine Meteorology (JCOMM). GO-SHIP will provide international scientific and technical coordination for the sustained global network of hydrographic sections that are an integral component of the Global Ocean / Climate Observing System.

One priority for the new GO-SHIP program was to revise the 1994 WOCE Hydrographic Programme manual. In the 15 years since the original publication of the manual, many methods and techniques have changed and new sensors have been developed. The GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines provides detailed instructions for the high quality collection and analysis techniques of numerous ocean parameters. The manual addresses both physical and biogeochemical parameters. Sixteen chapters covering CTD methods, discrete samples, and underway measurements have been reviewed and revised by more than 50 experts in field oceanography. Chapters have been through a period of open community review and comment and have also been reviewed through an informal peer-review process.

While most chapters were written specifically for this new version of the manual, several chapters are recently published guides that have been adopted as the GO-SHIP reference for specific variables. These chapters include the Calculation of the Thermophysical Properties of Seawater (McDougall et al., 2010), The Guide to Best Practices for Ocean CO_2 Measurement (Dickson et al., 2008), A Guide to Making Climate Quality Meteorological and Flux Measurements at Sea (Bradley and Fairall, 2006), and the IHO Standards for Hydrographic Surveys (2008). A new guide for thermosalinograph installation and operation is being developed and will be added to this collection when it is published.

The goal of this effort is to promote standardized methods for a core set of parameters measured on the GO-SHIP hydrographic reference sections, although the hope is that the

techniques described in this manual will be adopted by others wishing to make high quality measurements. The JCOMM has highlighted the importance of the GO-SHIP revision of the 1994 WOCE hydrographic Programme Manual.

We gratefully acknowledge the efforts of expert authors and reviewers in producing this manual.

Bernadette M. Sloyan and Christopher L. Sabine, GO-SHIP Co-Chairs.

INTRODUCTION TO THE COLLECTION OF EXPERT REPORTS AND GUIDELINES

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The GO-SHIP program was developed to provide a sustained coordination mechanism for global repeat hydrography as outlined in the GO-SHIP strategy published in 2009 (available online at: http://www.go-ship.org/Docs/IOCTS89_GOSHIP.pdf). Central to this coordination is ensuring that measurements made by different groups are comparable, compatible, and of the highest quality possible. Under the guidance of the GO-SHIP committee and following the original work of Joyce (1991), the following measurement standards, or expectations, have been developed as goals for the data quality desired from GO-SHIP reference sections.

1. STANDARDS FOR CTD SENSORS

Temperature	Accuracy = 0.002°C. Precision = 0.0005°C (ITS90).
Salinity	Accuracy = 0.002 g kg^{-1} (TEOS-10) depending on frequency and technique of calibration. Precision = 0.001 g kg^{-1} (TEOS-10), depending on processing techniques. [1]
Pressure	Accuracy = 3 decibar (dbar) with careful laboratory calibration. Precision = 0.5 dbar, dependent on processing.[2]
O_2	Accuracy [†] = 1%. Same for precision.
Notes:	[†] If no absolute standards are available for a measurement then accuracy should be taken to mean the reproducibility presently obtainable in the better laboratories. [1] Although conductivity is measured, data analyses require it to be expressed as salinity. Conversion and calibration techniques from conductivity to salinity should be stated. [2] Difficulties in CTD salinity data processing occasionally attributed to conductivity sensor problems or shortcomings in processing may actually be due to difficulties in accounting for pressure sensor limitations.

2. STANDARDS FOR WATER SAMPLES

Salinity	Accuracy of 0.001 is possible with Autosal™ salinometers and concomitant attention to methodology, *e.g.*, monitoring Standard Sea Water. Accuracy with respect to one particular batch of Standard Sea Water can be achieved at better than 0.001 PSS-78. Autosal precision is better than 0.001 PSS-78. High precision of approximately 0.0002 PSS-78 is possible following the methods of Kawano (this manual) with great care and experience. Air temperature

	stability of ± 1°C is very important and should be recorded.[1]
O_2	Target accuracy is that 2 sigma should be less than 0.5% of the highest concentration found in the ocean. Precision or reproducibility (2 sigma) is 0.08% of the highest concentration found in the ocean.
NO_3	approximately 1% accuracy†, [2] and 0.2% precision, full scale.
PO_4	approximately 1-2% accuracy†, [2] and 0.4% precision, full scale.
SiO_2	approximately 1-3% accuracy†, [2] and 0.2% precision, full-scale.
DIC	Accuracy† = 1-2 μmol kg^{-1}
Alkalinity	Accuracy† = 2-3 μmol kg^{-1}
pCO_2	Accuracy† = 3 μatm; optimal 1 μatm
pH	Accuracy† = 0.005 pH units.
^3H	Accuracy† 1%; precision 0.5% with a detection limit of 0.05 tritium unit (TU) in the upper ocean of the northern hemisphere and 0.005 TU elsewhere.
δ ^3He	accuracy† /precision = 1.5 ‰ in isotopic ratio; absolute total He of 0.5% with less stringent requirements for use as a tracer (e.g., He plume near East Pacific Rise).
CFCs	Approximately 1-2% accuracy† and 1% precision, blanks at 0.005 pmol kg^{-1} with best technique.
SF6	Target precision for SF_6 = 1.5% or 0.02 fmol kg^{-1} (1 fmol = 10^{-15} mole), whichever is greater, with overall accuracies of about 3% or 0.04 fmol kg^{-1}.
Carbon Isotopes	^{14}C: Accuracy† = 4-5 ‰; ^{13}C : Accuracy† = 0.03-0.04 ‰.
Notes:	† If no absolute standards are available for a measurement then *accuracy* should be taken to mean the *reproducibility* presently obtainable in the better laboratories. [1] Keeping constant temperature in the room where salinities are determined greatly increases their quality. Also, room temperature during the salinity measurement should be noted for later interpretation, if queries occur. Additionally, monitoring and recording the bath temperature is also recommended. The frequent use of IAPSO Standard Seawater is endorsed. To avoid the changes that occur in Standard Seawater, the use of the most recent batches is recommended. The bottles should also be used in an interleaving fashion as a consistency check within a batch and between batches. [2] Developments of reference materials for nutrients are underway that will enable improvements in the relative accuracy of measurements and clearer definition of the performance of laboratories when used appropriately and the results are reported with the appropriate meta data.

T. Joyce. 1991. *Introduction to the collection of expert reports compiled for the WHP programme*. WHP Operations and Methods, WOCE Operations Manual, WHP 91-1. Available online at: http://cchdo.ucsd.edu/manuals/pdf/91_1/introjoy.pdf