Spatial and Temporal Monitoring of Dissolved Oxygen (DO) in New Jersey Coastal Waters Using AUVS

Data Quality Assurance Project Plan

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Approved by: ____________________ 7/12/2011
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Revision Log

Revision Date	Reason for Revision

2.0 Table of Contents:

Appendix

3.0 Distribution List:

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4.0 Project Organization:

Josh Kohut – Rutgers University: Josh Kohut will serve as the lead manager of the Rutgers component of the project. He will serve as the Rutgers point of contact and ensure that all objectives as outlined in the contract are met. Josh Kohut will also be responsible for overall project QA.

John Kerfoot – Rutgers University: John Kerfoot will be responsible for the data management and quality control for each glider deployment.

Chip Haldeman - Rutgers University: Chip Haldeman will direct all logistics related to glider deployment and recovery.

Michael Borst – EPA ORD: Michael Borst will serve as the EPA project officer. He is a member of the project team and will act as the primary point of contact for EPA, oversee operations.

Darvene Adams – EPA Region 2: Darvene Adams will serve as the EPA Region 2 project technical lead.

Robert Schuster – NJDEP: Will serve as the technical point of contact for the New Jersey Department of Environmental Protection.

All individuals listed above are part the project team.

5.0 Special Training Needs/Certification

All glider related tasks and data management will be carried out by the experienced team at Rutgers. As of the award of this contract from EPA to Rutgers University, the Rutgers AUV team has completed 259 deployments and delivered quality data to local, state, research and federal agencies. Each member of the Rutgers team has been trained both in the lab and in the field. At sea experience specific to glider operation will be required for each deployment and recovery. At least one individual on the vessel must be certified by the lead PI to complete the deployment/recovery as described in appendix C and D. This certification will be documented in the deployment checklist. Additionally experience with oceanographic sensors and sensor care of at least one year or equivalent manufacturer training is required. Operation of the glider and all calibration procedures require no specific certification beyond the experience described here.

6.0 Problem Definition/Background

6.1 Problem Definition

The coastal ocean is a highly variable system with processes that have significant implications on the hydrographic and oxygen characteristics of the water column. The spatial and temporal variability of these fields can cause dramatic changes to water quality and in turn the health of the entire ecosystem. Both the New Jersey Department of Environmental Protection (NJDEP) and the Environmental Protection Agency (EPA) – Region II have prioritized monitoring the coastal waters off New Jersey in their long-term strategic plans as an essential component of the decision-making process. Of particular interest are the spatial and temporal characteristics of dissolved oxygen (DO). Hypoxic and anoxic conditions ripple through the entire ecosystem causing fish kills and potentially large disruptions to local and remote food webs. In response to this need, we have put together a program to augment existing monitoring with targeted deployments of glider Autonomous Underwater Vehicles (AUVS) equipped with sensors to map coastal hydrography and dissolved oxygen conditions in near-real time along the New Jersey inner-shelf.

The study area for this project will be the coastal waters off the New Jersey coast between Sandy Hook and Cape May. The glider will be tasked on a zig-zag pattern to cover the waters within the 3 nm NJ jurisdiction (Figure 1). The objectives of this project are to monitor the hydrography and dissolved oxygen of these coastal waters. We will deploy a Slocum-electric glider 6 times (three per year) during the stratified summer season. The primary users for the data generated by this project will be the EPA and the water monitoring division of the NJDEP. During each mission the real-time data will be used to map dissolved oxygen and water column stratification along the New Jersey coast. Following each deployment the full quality controlled dataset will be delivered to the EPA for inclusion in their coastal data archive.

Dissolved oxygen thresholds developed by EPA, NJDEP and Rutgers are based on the state standard of 5.0 mg/l and the EPA criteria of 2.3 mg/l and 4.8 mg/l (U.S. EPA, 2000). These thresholds will guide the use of the data throughout the project. If the glider observes values below the state standard of 5.0 mg/l, the EPA and NJDEP will determine the course of action including possible re-task of the glider and deployment of additional assets to sample the region. In addition NJDEP will use these data to evaluate the adoption of the EPA criteria of 4.8 mg/l and 2.3 mg/l as a state standard. The high-resolution sampling approach of the glider will also be able to bound these areas of low oxygen in time and space to guide both the response to significant events and the adoption of potential new standards.

Based on these thresholds, a healthy marine environment will be defined as having dissolved oxygen values higher than the State standard and EPA criteria (>5 mg/l). Conditions become hypoxic when these levels decrease below the 5.0 mg/l limit (State) and 4.8 mg/l limit (EPA). More extreme events defined by dissolved oxygen values below 2.3 mg/l (EPA) fall below the limit of juvenile and adult survival (U.S. EPA, 2000). For this project and fact sheet describing these conditions in more detail will be developed and made available to those interested in accessing the data.

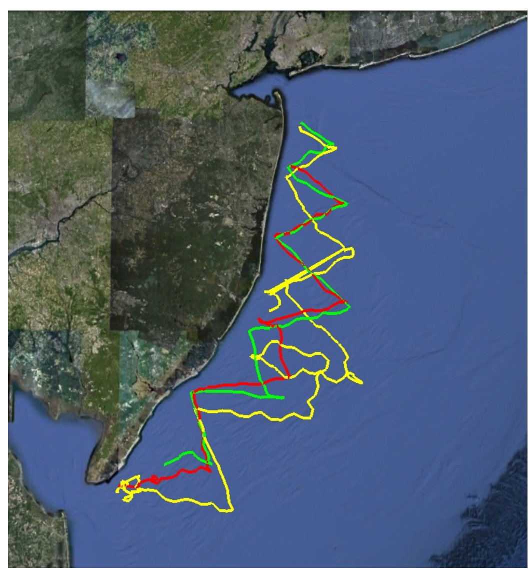

Figure 1: Glider tracks for the three coastal runs completed in 2010.

6.2 Background

The Rutgers University Institute of Marine and Coastal Sciences (RU/IMCS) in collaboration with the NJDEP Division of Water Monitoring and Standards and the EPA Region II demonstrated the use of the IMCS Slocum glider to observe temperature, salinity, and dissolved oxygen concentrations off the coast of New Jersey. These near-shore missions provide continuous measures of ocean temperature, salinity, and dissolved oxygen. In the summer of 2009, a single deployment was completed to serve as a pilot. A glider was deployed on August 20, 2009 for 20 days covering 316 kilometers and generating 5,100 water-column profiles from the surface to near the ocean floor. This deployment provided an increased horizontal, vertical, and temporal resolution for dissolved oxygen in coastal ocean water conditions previously unavailable. We tracked the evolving fields of dissolved oxygen and hydrography through upwelling and coastal storm events (Ragsdale et al., 2011). In 2010, three missions were run from late summer into fall. From late August through mid-November over 1,200 km of data were collected in the waters just off the New Jersey coast (Figure 1). Procedures were implemented to service the glider so that it could be redeployed in Sandy Hook, NJ within one week of recovery in Cape May, NJ. Real-time hydrographic and oxygen data was collected and posted to our public website and shared with Stevens Institute of Technology for assimilation into their operational ocean forecast model. The experience gained during these series of deployments has enabled us to customize glider hardware and mission planning to operate in this challenging region of our coastal ocean.

7.0 Project/Task Description:

Glider AUVs: The research will use continuous ocean observations from a series of glider deployments along the inner-shelf of the waters off the New Jersey coast. The buoyancy-driven propulsion of these vehicles affords high efficiency and deployment endurance approaching 30 days with alkaline batteries (Schofield et al., 2007). These particular gliders have been operated jointly by Rutgers University Coastal Ocean Observation Lab (RU COOL) scientists and Teledyne Webb Research Corporation engineers in science experiments since 1999, transitioning to sustained deployments by the COOL Operations Center in 2003.

The vehicle preparation and deployments will leverage the significant federal investment in the Rutgers University glider center. Initial glider preparation and ballasting will be completed at the Rutgers center before each deployment. Throughout the missions, the gliders will surface and connect via an onboard satellite modem to the

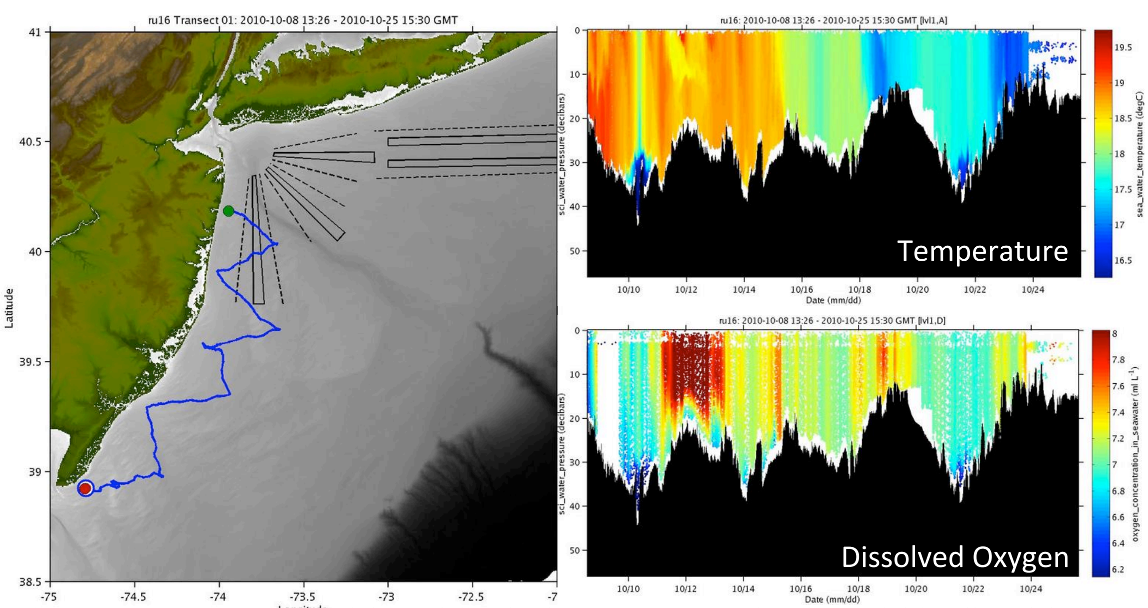

Figure 2: Temperature (upper right) and dissolved oxygen concentration (lower right) collected during a coastal run along the New Jersey coast from October 8, 2010 through October 25, 2010

glider center at regular intervals, typically 3 hours. These surfacings provide an opportunity to download the most recent data segment from the glider and send new mission commands as needed to the glider. The most recent data transferred back from the gliders will be automatically processed in real-time and visualized on the lab website (http://rucool.marine.rutgers.edu/).

Through this work we will run three (3) deployments per year between July and September (inclusive) in both 2011 and 2012. Based on prior experience it is anticipated that each deployment will take about 21 days to complete. For each coastal run, the glider will be deployed off Sandy Hook, NJ and run a zigzag track down the coast toward Cape May, NJ (Figure 1). The precise location of the track will be dependent on environmental conditions and accessible water depths. Prior to each deployment we will meet with NJDEP and EPA to ensure that the planned mission path meets their monitoring interests. Along this track the glider will sample temperature, salinity, and density from the CTD and dissolved oxygen concentration and percent saturation from the optode (Figure 2). Data will be stored locally on the glider and a subset of science data will be sent back to Rutgers in real-time via the satellite link. The subset will consist of every third data point within every third up and down profile. The resulting resolution of this subset will be approximately 0.9m in the vertical and 110m in the horizontal. After recovery of the glider, all data will be run through sensor specific QA/QC verifications outlined in sections 10, 13-16 of this document before delivery to NJDEP and EPA.

For each deployment the glider will be equipped with two main sensors, a pumped Sea-Bird CTD (Model GPCTD_and an Aanderraa Optode (Model 3835/5014W). The CTD will sample conductivity, temperature and pressure a rate of 0.5 Hz throughout the mission. The pressure will be used to calculate depth. These data will be used to map ocean temperature, salinity and density along the track. The optode will measure raw phase shifts across a calibrated foil that when combined with measured temperature from the CTD will give measures of dissolved oxygen concentration and percent saturation at a rate of 1 Hz.

Project Timeline

	June 2011	**July through October 2011**	**November 2011 thru May 2012**	**July through October 2012**	**April 2013**
Glider Delivery	X				
Glider Deployments (6)		XX XX XX		XX XX XX	
Factory Calibration: CTD and Optode			XX XX		
Deployment Reports (6)		X X X		X X X	
Final Report					X

8.0 Quality Objectives and Criteria for Measurement Data

The quality objectives for this project will be categorized as real-time and post processed. The real-time data are those subset of data that are sent back to Rutgers during the mission via the satellite link. The transmission is a data subset to reduce file size that will 1) reduce time on the surface when the glider is most vulnerable to damage and 2) reduce the airtime on the expensive satellite link. During each deployment the data will be logged locally on the glider with the glider manufacturer software on 2 Silicon Systems 2.0 GB flash drives powered by the glider batteries. The glider engineering data will be logged every 4 seconds and the science data will be logged at the sample rate for each sensor (CTD: 2 seconds, Optode: 1 second). Following recovery of the glider the entire dataset logged locally on the glider will be recovered and used to construct the post-processed dataset.

Geo-location for all glider collected data will be determined with an on board GPS, three-dimensional attitude sensor (heading, pitch, and roll), two pressure sensors (redundant depth) and an altimeter (height above the seabed). All sensors will be checked for accuracy prior to and following each deployment as described and documented in the pre- and post-deployment worksheets (Appendix A and E). If any values are found out of the acceptable range reported by the component manufacturers, they will be recalibrated and documented in the worksheets.

	CTD Real Time	**CTD Post Processed**	**Optode Real-Time**	**Optode Post Processed**
Precision *based on manufacturer claims*	Temp.: ±0.05 °C Cond.: ±0.0001 S/M Pres.: ±0.03 dbar	Temp.: ±0.05 °C Cond.: ±0.0001 S/M Pres.: ±0.03 dbar	Conc.: ±8μM Sat: ±1%	Conc.: ±8μM Sat: ±1%
Bias	Bias will be determined through the direct comparisons with simultaneous in situ CTD data.	Bias will be determined through the direct comparisons with simultaneous in situ CTD data.	Bias will be determined through the two-point calibration described in this document.	Bias will be determined through the two-point calibration described in this document.
Representativeness	Data will represent the vertical and horizontal structure with resolution of 0.9 m and 120m in the vertical and horizontal, respectively	Data will represent the vertical and horizontal structure with resolution of 0.5 m and 120m in the vertical and horizontal, respectively	Data will represent the vertical and horizontal structure with resolution of 0.9 m and 120m in the vertical and horizontal, respectively	Data will represent the vertical and horizontal structure with resolution of 0.5 m and 120m in the vertical and horizontal, respectively
Comparability *based on manufacturer claims*	Temp.: ±0.05 °C Cond.: ±0.005 S/M Pres: ±0.1 dbar	Temp.: ±0.05 °C Cond.: ±0.005 S/M Pres: ±0.1dbar	Sat.: ±5%	Sat.: ±5%
Completeness*	70% for all measurements	95% for all measurements	70% for all measurements	95% for all measurements
Sensitivity *based on manufacturer claims*	Temp.: 0.001 °C Cond.: 0.00001 S/M Pres.: 0.001 dbar	Temp.: 0.001 °C Cond.: 0.00001 S/M Pres.: 0.001 dbar	Conc.: <1μM Sat: 0.4%	Conc.: <1μM Sat: 0.4%
*100 % completeness is based on user specification of a measurement resolution of 0.5 m in the vertical and 120 m in the horizontal.				

9.0 Non-Direct Measurements

Secondary data will provide context for data collected and be used to guide the mission planning for each deployment. These data include satellite and HF radar measurements from the Mid-Atlantic Regional Coastal Ocean Observing System (MARCOOS) and aircraft remote sensing from the the NJDEP. Both the MARACOOS and

NJDEP data are hosted on local machines at Rutgers as part of other projects. These data will be accessed directly from these machines using OPeNDAP protocols. The remote sensed data will provide maps of currents and other sea-surface conditions to guide the specific piloting decisions related to these missions. These data meet the quality criteria required to guide the glider missions along the New Jersey coast based on assessments generated by the data providers.

10.0 Field Monitoring Requirements

10.1 Monitoring Process Design

This plan is based on manufacturers recommendations, the scientific literature, and our own experience collecting data from autonomous gliders off the coast of New Jersey since 2003.

Deployment description: We will focus these sections on the coastal waters from Sandy Hook to Cape May between the 5 and 30 meter isobaths. The Slocum glider that we will use in this project transfers vertical motion generated by changing buoyancy into horizontal motion on the order of 20-30 cm/s. The result is a saw-toothed pattern that allows the vehicle to sample the water column from the surface to the bottom along its glide path with high spatial resolution (on the order of 100m). This particular glider has the shallow water capabilities and sensor payload required for this work. It is equipped with a pumped Sea-bird CTD for hydrographic measurements and an Aanderraa Optode for dissolved oxygen measurements. In addition to this sensor payload, the glider will be a next generation G2 model from Teledyne Webb Research with significant durability upgrades. The buoyancy drive configuration for this vehicle will allow it to operate in waters from 5 to 30 meters deep. This shallower operating range will allow us to extend the glider lines closer to the coast than in previous missions. The location and time of the data collected by the glider will be recorded on board and transmitted periodically to shore via the satellite link at each surfacing. The geo-location of these data will be determined based on an on board GPS, attitude sensor (compass, pitch and roll), pressure (depth) and altimeter (height above the bottom). Horizontal location will be determined through a linear interpolation based on time of the data points between the known GPS positions recorded at each surfacing event. GPS locations will be determined with an onboard Garmin GPS (model: GPS15L-W) with a standard accuracy of <15m. This unit has been flown on glider missions around the world including those operated by Rutgers and The U.S. Navy. Time will be recorded on two separate onboard processors and maintained through automatic synchronization with the GPS clock at each surfacing. The pressure sensor incorporated into the pumped CTD will be used to determine the depth of the measurement. These methods reduce the uncertainty on the sub-surface data location and are consistent with those carried out on the previous 259 deployments completed by the Rutgers glider team.

10.2 Monitoring Methods

All data related to this project will be collected using a G2 glider purchased from Teledyne Webb Research customized for shallow water application. This glider will be equipped with a Sea-Bird pumped CTD and Aanderra Optode. Prior to each deployment the preferred path will be determined through a meeting between Rutgers, EPA, and NJDEP.

The glider will be tasked along this path and programmed to sample the CTD at 0.5 Hz and the optode at 1.0 Hz throughout the mission. A detailed description of the deployment and recovery procedures and required equipment can be found in Appendix H, I, and J of this document.

The primary mission of each deployment will be to sample the coastal waters between Sandy Hook and Cape May. Two possible scenarios could modify this initial plan.

1) Weather-related mission modifications: In the event of a significant coastal storm or high current event, the experienced Rutgers pilots will make modifications to the path to ensure that the glider will not be put in danger and can continue its primary mission to monitor the waters between Cape May and Sandy Hook. In each case, Rutgers will forward mission changes to the EPA project officer via email with copies to the project team.
2) Significant Hypoxic Event: If the glider identifies a region of low oxygen (concentration < 2ppm), it could be retasked to temporarily suspend the mission and survey the low oxygen area. Based on battery estimates this sampling could be carried out for approximately 3 to 4 days without affecting the mission duration. In this case, EPA will notify Josh Kohut at Rutgers of the interest to suspend the primary mission and modify the mission waypoints. Rutgers will then respond with an email to the EPA Project Officer with copies to the project team outlining the details on the new mission path.

In the event of equipment malfunction or damage that will not allow the glider to continue its mission, it will be tasked to remain at the surface until a vessel can be arranged for recovery. Depending on the severity of the issue, the glider will be repaired and returned to operation starting at either the recovery location to continue its previous mission or at Sandy Hook to start a new mission. The starting location will be determined through a meeting between Rutgers, EPA, and NJDEP and will be dependent on the length of the time the glider is under repair.

Throughout the missions glider engineering and science data will be logged on two 2.0 GB flash drives. These data will be stored locally until the conclusion of the mission. During the mission a subset of these data will be downloaded to a server on the Rutgers network every 3 hours coinciding with a surface event. These data will be subset to meet the criteria outlined in the table in section 8.0.

10.3 Field Quality Control

Before and after a given deployment:

Sea-bird CTD: The CTD will be referenced to a second, factory calibrated CTD in a seawater tank before each deployment as part of the ballasting procedure. A second reference will be generated with a full water column cast using the same calibrated CTD at the deployment and recovery location. These reference profiles will be compared with CTD profiles recorded by the glider. Using the satellite link, data collected on the glider will be uploaded to the lab and compared with the in situ data. If the data comparisons fall within the comparability criteria outlined in section 8 of this document, the glider data will be distributed to project partners and users identified above. Following each mission the glider

CTD will be cleaned as recommended from the manufacturer. Reference CTD profiles taken at the recovery site will be compared to glider profiles recorded just before recovery to ensure data consistency. All steps will be documented as shown in Appendix (A and B).

Aanderraa Optode: Before each deployment the we will confirm the DO sensor factory calibration with the two point test (0% and 100% saturation) described in the owners manual. The results of these tests will confirm the most recent factory calibration. Any drift observed between the pre- and post-deployment tests will be used to linearly correct the data in time throughout the mission. All steps will be documented in pre- and post-deployment sheets as shown in Appendix B.

Analyte	DQI	Field QC Check	Frequency of Collection	Acceptance Criteria	Corrective Actions
CTD	Comparability and bias	In tank CTD	Before and After each deployment	Within range listed in table in Section 8	Suspect values are flagged as described in section 16.2 of this document.
CTD	Comparability and bias	SBE-19 CTD cast	Before and after each deployment	Within range listed in table in Section 8	Suspect values are flagged as described in section 16.2 of this document.
CTD	All	Manufacturer Factory Calibration	Annually	Within range listed in table in Section 8	Recalibrate until data quality meets criteria listed in table in Section 8.
Optode	Comparability and bias	Manufacturer defined 2-point test	Before and After each deployment	Within range listed in table in Section 8	Correct data based on test results.
Optode	All	Manufacturer Factory Calibration	Annually	Within range listed in table in Section 8	Recalibrate until data quality meets criteria listed in table in Section 8.

Data post-processing following each deployment:

Prior to data delivery to NJDEP and EPA, all sensor specific QA/QC will be applied including time offsets and thermal corrections. These techniques will be followed based on the scientific literature and manufacturer recommendations. All processing will be based on the extensive infrastructure already in place at Rutgers to support the 259 missions already flown from the command center.

Sea-bird CTD: During the mission, 2 corrections will be applied to the real-time CTD dataset: 1) The temperature and conductivity sensors on the instrument have different measurement response times, thus the 2 independent measurements are aligned with respect to time so that each CTD record represents a measurement on a single parcel of water. This time shift is accounted for by the known flow rate of the pump on the CTD. 2) The second correction results from the thermal mass of the conductivity cell and this effect on the resulting salinity calculation. The CTD temperature is measured outside of the conductivity cell while the conductivity is measured inside the cell. In addition, the conductivity cell is made of borosilicate glass and is capable of storing heat from the surrounding water inside the wall of the cell, resulting in a heating or cooling of new water parcels as they pass through the cell. The result of this configuration is that the measured conductivity and temperature used to calculate salinity will result in erroneous salinity values, especially across strong thermoclines. A method has been developed which allows us to correct for this heating inside the cell, resulting in more accurate salinity profiles (Morison, J.R., et. al., 1994). A description of the method with glider specific examples can be found in Garau, B., et. al., 2011).

Aanderraa Optode: The calculation of oxygen concentration and saturation is based on the measured phase shifts from optode and the concurrent temperature values from the CTD. We will align these two measurements based on manufacturer suggestions and combine them to get the observed dissolved oxygen data. This will be done in accordance with the manufacturers manual section titled : 'External calculation of Oxygen'. The description is attached as appendix G.

11.0 Analytical Requirements

The analytical requirements for this project are restricted to the Winkler titrations used in the 2-point oxygen tests to confirm the calibration of the optode. The analytical methods and quality control for these titrations will be carried out as described in EPA Method 360.2 attached as Appendix F.

12.0 Sample Handling and Custody Requirements

The samples collected in the lab as part of the optode two point tests will be immediately transferred for the titration method described in EPA method 360.2 (Appendix F).

13.0 Testing, Inspection, Maintenance, and Calibration Requirements

13.1 Instrument/Equipment Testing, Inspection and Maintenance

Sea-bird CTD: The CTD will be inspected and tested as outlined in Appendix A. This includes a visual inspection, instrument cleaning before and after each deployment and comparisons with additional CTD data both in the tank and in situ during deployment and recovery. These procedures as followed are outlined in the manual drafted by the manufacturer.

Aanderaa Optode: The Aanderra Optode will be inspected and tested before and after the deployment as described in Appendix B. This includes visual inspection of the membrane to detect degradation, and 2 point calibration testing before and after each deployment. These procedures will be conducted in accordance with those outlined in the manufacturers manual.

Glider Vehicle: The glider itself will be inspected and tested before and after each deployment as described in Appendix A and E. This includes confirmation of proper operation of the gliders position (GPS), time of measurement (onboard processors), heading (Compass), and depth (pressure).

13.2 Instrument/Equipment Calibration and Frequency

Sea-bird CTD: The CTD will be calibrated by the factory annually prior to each set of summer deployments. This is in accordance with recommended annual factory calibrations from the manufacturer. In addition to these factory calibrations, comparisons will be made with in situ CTD measurements from another Sea-Bird CTD in the ballast tank and with a concurrent profile in the field both before and following each deployment. These will be used to confirm the factory calibration.

Aanderaa Optode: The optode will be calibrated by the factory prior to each set of summer deployments. This is in accordance with recommended annual factory calibrations from the manufacturer. In addition to these factory calibrations, a 2 point calibration will be conducted at Rutgers both before and after each deployment. This test will be conducted as outlined in the manufactures manual. These will be used to confirm the factory calibration.

Glider Vehicle: The three-dimensional attitude sensor will be calibrated as required to ensure accurate measures of heading, pitch, and roll. These calibrations will be no more than one year apart.

13.3 Inspection/Acceptance of Supplies and Consumables

Reagents used for the dissolved oxygen titrations will be purchased for each test. All reagents will be purchased and utilized as prescribed in the test-kit manufacturer manual.

14.0 Data Management

The data management for this project will be based on the considerable infrastructure already in place at Rutgers to support glider operations. For each deployment the complete dataset will be stored locally on the glider. In addition a subset of the data files recorded by the glider in real-time is transferred back to shore via the satellite communication system. Once the binary encoded files arrive on shore, they are converted to ascii text using a set of unix utilities. These files are then archived to a fileserver at the Institute of Marine and Coastal Sciences, where they are backed up daily.

The Matlab programming language will be used to process the raw data stream. Scientific (i.e., temperature, conductivity, depth) parameters are merged with the glider navigational parameters (i.e., GPS, timestamps) and are stored in organized data structures, which are saved to the IMCS fileserver in near real-time. The following quality control checks are then performed:

1. Duplicate timestamps are removed.
2. Invalid GPS fixes are removed using an algorithm that eliminates fixes that result in impossible surface drift velocities (>10 m/s).
3. Invalid temperature and salinity values are removed based upon expected hydrographic values that occur at the time of deployment (summer conditions). Values more than 2 standard deviations outside these ranges will be removed.
4. Differences in the temperature and conductivity sampling are corrected by aligning the measurements in the time domain based on successive profiles.
5. The aligned temperature and conductivity values are used to calculate ocean salinity values and these values are then corrected for thermal inertia to get rid of artificial salinity spiking (Garau, B., et. al., 2011; Morison, J.R., et. al., 1994).
6. Oxygen values from the optode are aligned by shifting them in the time domain by a pre-determined number of seconds based on manufacturer recommendations and confirmed by comparing successive profiles.

Real-time glider health and deployment status will also be available on the internet at:

http://marine.rutgers.edu/cool/auvs

This webpage will include plots of relevant scientific parameters (temperature, salinity, density, oxygen concentration, etc.) and maps showing the gliders path and intended waypoints. These processed datasets will be made available in near real-time in the NetCDF file format via the Thematic Real-time Environmental Data Distribution System (**THREDDS**). While the glider is in its mission the real-time distributed data will be considered provisional until the complete dataset is quality controlled after recovery. During the deployment, if any of these provisional data fall outside the criteria listed in section 8 of this document under 'real-time', they will be flagged and removed from the data stream.

Once the glider has been recovered, files containing the full datasets are downloaded and the previous steps are repeated, providing the end user with the complete scientific and navigational data streams. All levels of these processing will be stored on the file server and backed-up daily throughout the project. Upon completion of a given deployment a copy of all data will be delivered to the EPA project officer with the documentation described in section 15 of this document.

15.0 Assessments/Oversight

The calibration, testing, maintenance for each deployment will be documented. This documentation includes:

1) a pre-deployment check out (Appendix A)
2) a pre-deployment check out for the optode (Appendix B)
3) a deployment checklist (Appendix C)
4) a recovery checklist (Appendix D)
5) a post-deployment checklist (Appendix E)
6) manufacturer calibration documentation

A deployment packet will be made up of all the above documents and a hardcopy of the data. For each deployment the Rutgers team will ensure that all are filled out completely and accurately. Throughout the deployments, EPA will be permitted to field audit the project.

16.0 Data Review, Verification, and Usability

16.1 Data Review, Verification, and Validation

Josh Kohut and Chip Haldeman will ensure that all testing, maintenance and inspection is completed before and after each deployment. These steps will be documented and complied in the deployment reports described in section 15 of this document. The checkout and checklist documents listed in the appendix of this document will ensure that all steps are included. Josh Kohut and John Kerfoot will ensure that all quality control processing and assessment is carried out on all real-time and post-processed data prior to delivery to EPA. Any deviations from the QAPP/SOPs will be documented.

16.2 Reconciliation with User Requirements

Following each deployment, the final quality controlled data will be within the criteria described in section 8 of this document. If a value is found outside these criteria, it will be flagged in the final dataset. Each data point will be treated independently so that any one point flagged will not restrict use of the other quality data from the same deployment.

17.0 Reporting, Documents, and Records

The project will generate deployment reports and a final report. The deployment report will document all glider and sensor preparation, maintenance, calibration, and inspection. These reports will be labeled with glider name, deployment number, and deployments dates. These reports will include all components described in section 15 of this document. Two copies will be generated for each of the 6 deployments. The first copy will be sent to the EPA project officer in both hard copy and PDF forms. The second copy will remain at Rutgers with Josh Kohut the Rutgers project lead.

Rutgers will also prepare and submit a final report to the EPA project officer documenting the results of the data collection, the validation/verification of the results, and the final standard operating procedures conducted for all 6 deployments. This report will summarize the information contained in the deployment reports described above. Additional documents resulting from this work could include public and scientific presentations and articles submitted to the peer review literature. The real-time and post processed data for each mission will be maintained on the Rutgers file server described in Section 14.0 of this document for at least 7 years following the conclusion of each deployment. The documentation will also be retained in electronic and hardcopy forms for at least 7 years following the each deployment. The 7 year time horizon in consistent with NJDEP standards.

References

Garau, B., Ruiz, S., Zhang, W.G., Pascual, A., Heslop, E., Kerfoot, J., Tintore, J., 2011: Thermal Lag Correction on Slocum CTD Glider Data. *J., Atmos. Ocean. Technol.,* in press.

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U.S. EPA, 2000. *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras.* EPA-822-R-00-012.

GLIDER	
PREPARER	
PREP DATE	
LOCATION	

PRE-SEAL

FORE CHECK

Check pump threaded rod (grease) __________

Check pitch battery threaded rod (grease) __________

Leak detect in place, batteries secure, white guides free, no metal shavings, bottles installed, grounded? __________

PAYLOAD CHECK

Science Bay Instrument Serial Numbers

1 ____________________

2 ____________________

3 ____________________

4 ____________________

5 ____________________

CTD cable clear, no leak at CTD joint, no leak at pucks
Grounded? __________

Science Bay Weight Configuration

____

AFT CHECK

Iridium Card Installed (SIM #)

1 _______________

Flash card old files removed?

Inspect strain on connectors (damaged connectors as well), Persistor power supply cable secure, battery secured, ballast bottle in place, aft cap clear of leak, grounded? __________

Battery check (using load?)

1. Attach aft battery pack, verify voltage at J13 __________
2. Disconnect aft battery
3. Screw in aft connector
4. Connect pitch battery, verify voltage at J13 __________
5. Disconnect pitch battery
6. Screw in fore connector, verify voltage at J13 __________
7. Attach pitch battery
8. Attach aft battery
9. Verify voltage at J31 (simple probe)

____

POST-SEAL

GENERAL

Pick Point Present? ____________
Special Instruments Present? ____________

HARDWARE

Nose Cone and pump bladder inspection ______
put c_alt_time 0, verify alt chirping ____________
Corrosion Prevention & Anode Check
- Anode Style/Weight ________________
- Glider Parts Grounded (stickers) ______

Ejection weight assembly OK and unseized? ______
Pressure Sensor Check (corrosion, clear) ______
- Aft sensor ____________
- Payload sensor ____________

POWERED

Verify Argos ping ____________
Wiggle for 5 minutes ____________
Record m_battery once stabilized ____________
Record m_vacuum @ temperature @ ballast ____________

OUTSIDE

Record compass reading ________________
GPS check? (40 28.75, 74 26.25) ________________
Iridium connect ____________
zero_ocean_pressure, get m_pressure ______
let air bladder inflate, does it shut off? ______

SOFTWARE

GENERAL

Version ____________
Date ok, delete old logs ______
Re-burn latest software image
mdblist.dat, mi, ma, science! ____________

\CONFIG

simul.sim deleted ____________
if ver < 7.0 configure sbdlist.dat ____________

\MAFILES

____
goto_l10.ma (set x_last_...) ____________

AUTOEXEC.MI

Phone Number
Main is RUDIC, alt is TWR ____________
u_iridium_failover_retries = 10 ____________
c_ctd41cp_num_fields_to_send 4 ____________
Calibration coefficients ____________

In Gliderdos, reset glider to test settings
get f_max_working_depth (102 m) ______
f_ballast_pumped_deadz_width = 30? ______

CACHE MANAGEMENT (DONE ON DOCKSERVER!)
(this step is very important!)

del ..\state\cache*.*
after *bdlist.dat are set (exit reset):
logging on; logging off
send ..\state\cache*.cac ____________

send *.mbd *.sbd *.tbd ____________

* **Software Burning Tips :** if using Procomm or local folder, copy all the files from the software image locally. Then proceed to edit them for the glider and do a mass freewave transfer of the files. Save these files or prepare the to-glider with these f

SCIENCE

SENSOR RETURN

put c_science_send_all 1
put c_science_all_on 8
put c_science_on 3
All sensors reporting values? ____________

CTD

Tank static comparison OK? ____________

OPTODE

Check in completed? ____________
Remove any shielding ____________

PUCK 1

Puck Type ____________

Verify Darkcounts ____________________

PUCK 2

Puck Type ____________

Verify Darkcounts ____________________

PUCK 3

Puck Type ____________

Verify Darkcounts ____________________

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Slocum Glider Aanderaa Optode Check IN/OUT
2 Point Calibration & Calibration Coeffcient Record

OPTODE MODEL, SN: ____________ **IN / OUT** ____________

Calibration Record **PERFORMED BY:** ____________

CALIBRATION DATE: ____________

Previous: / *Current:*

C0Coef	5.3E+03	-1.9E+02	4.1E+00	-3.8E-02	**C0Coef**	5.3E+03	-1.9E+02	4.1E+00	-3.8E-02
C1Coef	-2.9E+02	9.7E+00	-2.1E-01	2.0E-03	**C1Coef**	-2.9E+02	9.7E+00	-2.1E-01	2.0E-03
C2Coef	6.5E+00	-2.0E-01	4.5E-03	-4.3E-05	**C2Coef**	6.5E+00	-2.0E-01	4.5E-03	-4.3E-05
C3Coef	-6.7E-02	1.9E-03	-4.4E-05	4.3E-07	**C3Coef**	-6.7E-02	1.9E-03	-4.4E-05	4.3E-07
C4Coef	2.7E-04	-6.8E-06	1.7E-07	-1.6E-09	**C4Coef**	2.7E-04	-6.8E-06	1.7E-07	-1.6E-09

Delta: 0.0

2 point Calibration

0% Point	*100% Point*
Solution: ____ **Na_2SO_3**	*Solution:* ____ **Na_2SO_3**
____ **H_2O**	____ **H_2O**
____ **Temperature**	____ **Temperature**
____ **Air Pressure**	____ **Air Pressure**
____ **Winkler Label**	____ **Winkler Label**
____ **Winkler Source**	____ **Winkler Source**
Results:	*Results:*
OPTODE: ____ **Wphase**	**OPTODE:** ____ **Wphase**
____ **% Saturation**	____ **% Saturation**
____ **Temperature**	____ **Temperature**
____ **Calculated Concentration**	____ **Calculated Concentration**
____ **Calculated % Saturation**	____ **Calculated % Saturation**
WINKLER: ____ **% Saturation**	**WINKLER:** ____ **% Saturation**
____ **Concentration**	____ **Concentration**

In-Air Saturation Check

SATURATION: ____ **@ TEMP** ____ **@ PRESS** ____

Paste Sample Report

Rutgers COOL Optode Check IN/OUT 4/15/11 3:07 PM

Protect	3830	1024	0			
PhaseCoef	3830	1024	1.915733	1.090776	0	0
TempCoef	3830	1024	21.16457	-0.030634	2.89E-06	-4.18E-09
FoilNo	3830	1024	1707			
C0Coef	3830	1024	5326.502	-192.1173	4.143571	-0.037869
C1Coef	3830	1024	-292.0675	9.719927	-0.214295	0.0020078
C2Coef	3830	1024	6.475949	-0.19808	0.0044994	-4.31E-05
C3Coef	3830	1024	-0.066929	0.0018807	-4.42E-05	4.284E-07
C4Coef	3830	1024	0.000265	-6.83E-06	1.671E-07	-1.62E-09
Salinity	3830	1024	35			
CalAirPhase	3830	1024	31.09332			
CalAirTemp	3830	1024	9.937991			
CalAirPress	3830	1024	1005.22			
CalZeroPha	3830	1024	65.60457			
CalZeroTen	3830	1024	19.1812			
Interval	3830	1024	2			
AnCoef	3830	1024	0	1		
Output	3830	1024	100			
SR10Delay	3830	1024	-1			
SoftwareVe	3830	1024	3			
SoftwareBu	3830	1024	11			

Glider ______________ Date ______________

Pilots ______________ Where ______________

Laptop ______________ Vehicle Powerup: **CTRL ^ C (until you get to prompt)!!!**

On boat (Remember after 10 min glider will go into mission, as well as on powerup!)	Battery Voltage	______	get m_battery
	Vacuum Pressure	______	get m_vacuum, should be > 7 for bladder inflation
	Iridium Connection	______	look for connect dialog & surface dialog, let it dial at prompt
	boot app	☐	boot app
	boot (should report application)	☐	reports boot application
	run status.mi	☐	mission completed normally?
			(this can be run the night before or at dock)
In Water	zero_ocean_pressure	☐	while glider in water
	run odctd.mi (with or without float, ask RU)	☐	glider should dive and surface, type why? Should say overdepth, if not call (would say don't need float for ru06, ru07 use it the first deployment) (can skip want for multiple deployments)
	send *.dbd *.mlg *.sbd	☐	"send *.sbd" is most important
			(this applies moreso to when handoff'ed to iridium)
	run 100_tn.mi	☐	sequence 100_tn.mi(5)
	Verify dive; **disconnect freewave** Report to Rutgers		
	Perform CTD Comparison CAST	☐	typically done with RU provided SB19 or Cast Away CTD
	LAT: **LON**		

Glider ______________ Date ______________

Pilots ______________ Where ______________

Laptop ______________

Recovery	get Lat/Lon from email or shore support	☐
	obtain freewave comms obtain lat/lon with where command	☐
	Perform CTD Comparison CAST	☐
	LAT: **LON:**	
	(note instrument type!)	

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Slocum Glider Check-IN

DATE: ___________

GLIDER: ___________ **SB:** ____________

Power on vehicle in order to fully retract pump, and/or to deflate air bladder.

Vehicle Cleaning (hose down with pressure)

Nose cone

1. Remove nose cone
2. Loosen altimeter screws, and remove altimeter or leave temporarily attached
3. Retract pump
4. Remove altimeter and hose diaphragm removing all sand, sediment, bio oils
5. Clean nose cone and altimeter

Tail cone

1. Remove tail cone
2. Hose and clean anode and air bladder making sure air bladder is completely clean
3. Clean cowling

Wing rails

1. Remove wing rails and hose down

Tail plug cleaning

1. Dip red plug in alcohol and clean plug if especially dirty
2. Re-dip red plug and repeatedly insert and remove to clean the glider plug
3. Compress air glider female connector
4. Lightly silicon red plug and replace in glider once silicon has been dispersed evenly in the plugs.

CTD Comparison Check

1. Inspect CTD sensor for any sediment buildup, take pictures of anything suspicious or make note.

Static Tank Test

SB19
Temperature: _________________

Conductivity: _________________

Glider (SB41CP or pumped unit)
Temperature: _________________

Conductivity: _________________

CTD Maintenance (reference SeaBird Application Note 2D)

1. Perform CTD backward/forward flush with 1% Triton X-100 solution
2. Perform CTD backward/forward flush with 500 – 1000 ppm bleach solution
3. Perform the same on a pumped unit, just different approach
4. Repeat comparison test if results not within T < .01 C, C < .005 S/m

Static Tank Test

SB19
Temperature: _________________

Conductivity: _________________

Glider (SB41CP or pumped unit)
Temperature: _________________

Conductivity: _________________

METHOD #: 360.2 Approved for NPDES (Issued 1971)

TITLE: Oxygen, Dissolved (Modified Winkler, Full-Bottle Technique)

ANALYTE: CAS # O Oxygen 7782-44-7

INSTRUMENTATION: Titration, Probe

STORET No. 00300

1.0 Scope and Application

1.1 This method is applicable for use with most wastewaters and streams that contain nitrate nitrogen and not more than 1 mg/L of ferrous iron. Other reducing or oxidizing materials should be absent. If 1 mL of fluoride solution is added before acidifying the sample and there is no delay in titration, the method is also applicable in the presence of 100 200 mg/L ferric iron.

1.2 The Dissolved Oxygen (DO) Probe technique gives comparable results on all samples types.

1.3 The azide modification is not applicable under the following conditions: (a) samples containing sulfite, thiosulfate, polythionate, appreciable quantities of free chlorine or hypochlorite; (b) samples high in suspended solids; (c) samples containing organic substances which are readily oxidized in a highly alkaline solution, or which are oxidized by free iodine in an acid solution; (d) untreated domestic sewage; (e) biological flocs; and (f) where sample color interferes with endpoint detection. In instances where the azide modification is not applicable, the DO probe should be used.

2.0 Summary of Method

2.1 The sample is treated with manganous sulfate, potassium hydroxide, and potassium iodide (the latter two reagents combined in one solution) and finally sulfuric acid. The initial precipitate of manganous hydroxide, $Mn(OH)_2$, combines with the dissolved oxygen in the sample to form a brown precipitate, manganic hydroxide, $MnO(OH)_2$,. Upon acidification, the manganic hydroxide forms manganic sulfate which acts as an oxidizing agent to release free iodine from the potassium iodide. The iodine, which is stoichiometrically equivalent to the dissolved oxygen in the sample is then titrated with sodium thiosulfate or phenylarsine oxide (PAO).

3.0 Interferences

3.1 There are a number of interferences to the dissolved oxygen test, including oxidizing and reducing agents, nitrate ion, ferrous iron, and organic matter.

3.2 Various modifications of the original Winkler procedure for dissolved oxygen have been developed to compensate for or eliminate interferences. The Alsterberg modification is commonly used to successfully eliminate the nitrite interference, the Rideal-Stewart modification is designed to eliminate ferrous iron interference, and the Theriault procedure is used to compensate for high concentration of organic materials.

3.3 Most of the common interferences in the Winkler procedure may be overcome by use of the dissolved oxygen probe.

4.0 Sample Handling and Preservation

4.1 Where possible, collect the sample in a 300 mL BOD incubation bottle. Special precautions are required to avoid entertainment or solution of atmospheric oxygen or loss of dissolved oxygen.

4.2 Where samples are collected from shallow depths (less than 5 feet), use of an APHA-type sampler is recommended. Use of a Kemmerer type sampler is recommended for samples collected from depths of greater than 5 feet.

4.3 When a Kemmerer sampler is used, the BOD sample bottle should be filled to overflowing. (overflow for approximately 10 seconds). Outlet tube of Kemmerer should be inserted to bottom of BOD bottle. Care must be taken to prevent turbulence and the formation of bubbles when filling bottle.

4.4 At time of sampling, the sample temperature should be recorded as precisely as required.

4.5 Do not delay the determination of dissolved oxygen in samples having an appreciable iodine demand or containing ferrous iron. If samples must be preserved either method (4.5.1) or (4.5.2) below, may be employed.

4.5.1 Add 2 mL of manganous sulfate solution (6.1) and then 2 mL of alkaline iodide-azide solution (6.2) to the sample contained in the BOD bottle. Both reagents must be added well below the surface of the liquid. Stopper the bottle immediately and mix the contents thoroughly. The sample should be stored at the temperature of the collection water, or water sealed and kept at a temperature of 10 to 20°C, in the dark. Complete the procedure by adding 2 mL H_2SO_4 (see 7.1) at time of analysis.

4.5.2 Add 0.7 mL of conc. H_2SO_4 (6.3) and 1 mL sodium azide solution (2 g NaN3 in 100 mL distilled water) to sample in the BOD bottle. Store sample as in (4.5.1). Complete the procedure using 2 mL of manganous sulfate solution (6.1), 3 mL alkaline iodide-azide solution (6.2), and 2 mL of conc. H_2SO_4 (6.3) at time of analysis.

4.6 If either preservation technique is employed, complete the analysis within 4-8 hours after sampling.

5.0 Apparatus

5.1 Sample bottles-300 mL ±3 mL capacity BOD incubation bottles with tapered ground glass pointed stoppers and flared mouths.

5.2 Pipets-with elongated tips capable of delivering 2.0 mL ±0.10 mL of reagent.

6.0 Reagents

6.1 Manganous sulfate solution: Dissolve 480 g manganous sulfate ($MnSO_4$•$4H_2O$) in distilled water and dilute to 1 liter.

6.1.1 Alternatively, use 400 g of $MnSO_4$•$4H_2O$ or 364 g of $MnSO_4$ •$4H_2O$ per liter. When uncertainty exists regarding the water of crystallization, a solution of equivalent strength may be obtained by adjusting the specific gravity of the solution to 1.270 at 20°C.

6.2 Alkaline iodide-azide solution: Dissolve 500 g of sodium hydroxide (NaOH) or 700 g of potassium hydroxide (KOH) and 135 g of sodium iodide (Nai) or 150 g of potassium iodide (KI) in distilled water and dilute to 1 liter. To this solution add 10 g of solution azide (NaN3) dissolved in 40 mL of distilled water.

6.3 Sulfuric acid: concentrated.

6.4 Starch solution: Prepare an emulsion of 10 g soluble starch in a mortar or beaker with a small quantity of distilled water. Pour this emulsion into 1 liter of boiling water, allow to boil a few minutes, and let settle overnight. Use the clear supernate. This solution may be preserved by the addition of 5 mL per liter of chloroform and storage in a 10°C refrigerator.

6.4.1 Dry, powdered starch indicators such as "thyodene" may be used in place of starch solution.

6.5 Potassium fluoride solution: Dissolve 40 g KF $2H_2O$ in distilled water and dilute to 100 mL.

6.6 Sodium thiosulfate, stock solution, 0.75 N: Dissolve 186.15 g $Na_2S_2O_3 \bullet 5H_2O$ in boiled and cooled distilled water and dilute to 1 liter. Preserve by adding 5 mL chloroform.

6.7 Sodium thiosulfate standard titrant, 0.0375 N: Prepare by diluting 50.0 mL of stock solution to 1 liter. Preserve by adding 5 mL of chloroform. Standard sodium thiosulfate, exactly 0.0375 N is equivalent to 0.300 mg of DO per 1.00 mL. Standardize with 0.0375 N potassium biiodate.

6.8 Potassium biiodate standard, 0.0375 N: For stock solution, dissolve 4.873 g of potassium, biiodate, previously dried 2 hours at 103°C, in 1000 mL of distilled water. To prepare working standard, dilute 250 mL to 1000 mL for 0.0375 N biiodate solution.

6.9 Standardization of 0.0375 N sodium thiosulfate: Dissolve approximately 2 g (±1.0 g) KI in 100 to 150 mL distilled water; add 10 mL of 10% H_2SO_4 followed by 20.0 mL standard potassium biiodate (6.8). Place in dark for 5 minutes, dilute to 300 ml, and titrate with the standard sodium thiosulfate (6.7) to a pale straw color. Add 1-2 mL starch solution and continue the titration drop by drop until the blue color disappears. Run in duplicate. Duplicate determinations should agree within ± 0.05 mL.

6.10 As an alternative to the sodium thiosulfate, phenylarsine oxide (PAO) may be used. This is available, already standardized, from commercial sources.

7.0 Procedure

7.1 To the sample collected in the BOD incubation bottle, add 2 mL of the manganous sulfate solution (6.1) followed by 2 mL of the alkaline iodide-azide solution (6.2), well below the surface of the liquid; stopper with care to exclude air bubbles, and mix well by inverting the bottle several times. When the precipitate settles, leaving a clear supernatant above the manganese hydroxide floc, shake again. When settling has produced at least 200 mL of clear supernatant, carefully remove the stopper and immediately add 2 mL of conc. H_2SO_4 (6.3) (sulfamic acid packets, 3 g may be substituted for H_2SO_4) [1] by allowing the acid to run down the neck of the bottle, re-stopper, and mix by gentle inversion until the iodine is uniformly distributed throughout the bottle. Complete the analysis within 45 minutes.

7.2 Transfer the entire bottle contents by inversion into a 500 mL wide mouth flask and titrate with 0.0375 N thiosulfate solution (6.7) (0.0375 N phenyarsine oxide (PAO) may be substituted as titrant) to pale straw color. Add 1-2 mL of starch solution (6.4) or 0.1 g of powdered indicator and continue to titrate to the first disappearance of the blue color.

7.3 If ferric iron is present (100 to 200 mg/L), add 1.0 mL of KF (6.5) solution before acidification.

7.4 Occasionally, a dark brown or black precipitate persists in the bottle after acidification. This precipitate will dissolve if the solution is kept for a few minutes longer than usual or, if particularly persistent, a few more drops of H_2SO_4 will effect dissolution.

8.0 Calculation

8.1 Each mL of 0.0375N sodium thiosulfate (or PAO) titrant is equivalent to 1 mg DO when the entire bottle contents are titrated.

8.2 If the results are desired in milliliters of oxygen gas per liter at 0°C and 760 mm pressure multiply mg/L DO by 0.698.

8.3 To express the results as percent saturation at 760 mm atmospheric pressure, the solubility data in Table 422:1 (Whipple & Whipple, p 446-447, Standard Methods, 14th Edition) may be used. Equations for correcting the solubilities to barometric pressures other than mean sea level are given below the table.

8.4 The solubility of DO in distilled water at any barometric pressure, p (mm Hg), temperature, T °C, and saturated vapor pressure, μ (mm Hg), for the given T, may be calculated between the temperature of 0° and 30°C by:

$$\text{ml/L DO} = \frac{(P - \mu) \times 0.678}{35 + T}$$

and between 30° and 50°C by:

$$\text{ml/L DO} = \frac{(P - \mu) \times 0.827}{49 + T}$$

9.0 Precision and Accuracy

9.1 Exact data are unavailable on the precision and accuracy of this technique; however, reproducibility is approximately 0.2 mg/L of DO at the 7.5 mg/L level due to equipment tolerances and uncompensated displacement errors.

Bibliography

1. Kroner, R. C., Longbottom, J. E., Gorman, R.A., "A Comparison of Various Reagents Proposed for Use in the Winkler Procedure for Dissolved Oxygen", PHS Water

Pollution Surveillance System Applications and Development, Report #12, Water Quality Section, Basic Data Branch, July 1964.
2. Annual Book of ASTM Standards, Part 31, "Water", Standard D1589-60, Method A, p 373 (1976).
3. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 443, method 422 B (1975).

Appendix 8 Calculate the Oxygen Externally

If the Optode is mounted on a CTD and the CTD is equipped with a fast responding temperature sensor it might be desirable to do the temperature compensation externally. This will improve the accuracy when subjected to fast temperature changes (when going through a gradient). The Optode must then be configured to output differential phase shift information (DPhase). Based on this data and the temperature data from the CTD, the oxygen concentration can be calculated by use of the following formula:

$$[\mathrm{O_2}] = C0Coef + C1Coef \cdot P + C2Coef \cdot P^2 + C3Coef \cdot P^3 + C4Coef \cdot P^4$$

P is the measured phase shift (DPhase) and the *C0Coef* to *C4Coef* are temperature dependent coefficients calculated as:

$$CxCoef = CxCoef_0 + CxCoef_1 \cdot t + CxCoef_2 \cdot t^2 + CxCoef_3 \cdot t^3$$

The $CxCoef_{0\text{-}3}$ are the foil characterizing coefficients found in the Calibration Certificate for the Sensing Foil 3853, and *t* is external temperature in °C.

An Excel sheet that includes these calculations is available by contacting the factory.

If the CTD is not able to receive the RS232 output, the Oxygen Optode 3975 with analogue output can be used. The two channel "intelligent" digital to analogue converter supplied with this sensor is able to output two channels of your selection (including DPhase). By setting the Output property to –103 the Optode 3975 will output phase (10 to 70°) at analogue output 1 (refer to Table 3-4 at page 23).

Rutgers Coastal Ocean Observation Lab

Glider Deployment

- Make sure you have Glider Deployment Checklist
- Glider equipment
- Spare wings!

THIS GUIDE FOLLOWS THE GLIDER DEPLOYMENT CHECKLIST AND SHOULD BE USED AS A 2ND HAND REFERENCE WHEN DEPLOYING

1. **Obtain control of the glider** – do as so in class and the general communications sheet. The *enter* button pressed repeatedly will let you know if you are at a prompt.
2. **Allow glider to call Rutgers** – Once you have the following dialog, it is OK to type *callback xx* to obtain better control of the glider.

```
18631    Iridium modem matched: CONNECT 4800
18631    Iridium connected...
18631    Iridium console active and ready...
Vehicle Name: ru16
```

3. ***boot app*** – this is a crucial double check, entering the command should report (if the vehicle resets, it was NOT in *boot app* mode, obtain control after reset and continue):
   `Boots Application at 0xE40000`
4. **confirm boot app** – type *boot*
5. ***consci*** – This should switch the terminal control over to the science computer, your prompt will change to sci_dos. If this does not occur, call Rutgers or supervisor for further instruction.
6. **on boat – *run status.mi***:
   a. **What is this mission doing?**
      i. This mission is checking general mission parsing, input sensors, and GPS position.
   b. **What is end result of mission?**
      i. Glider should attempt GPS hits:

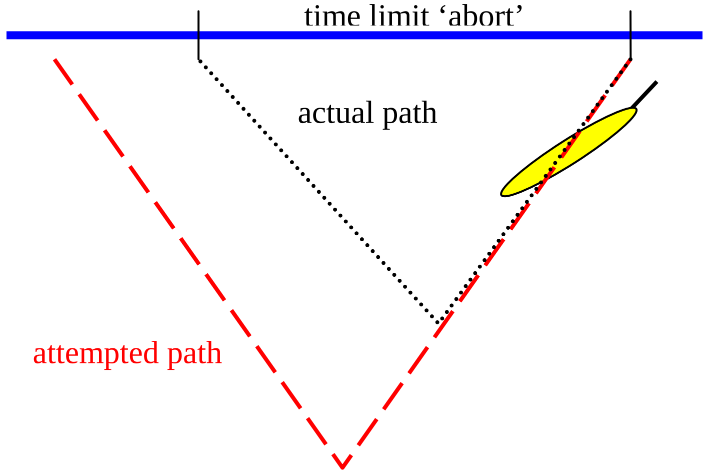
```
185.76 14 behavior surface_2: SUBSTATE 2 ->3 : waiting for GPS fix
185.84    init_gps_input()
186.15    sensor: m_gps_lat = 1754.2646 lat
186.21    sensor: m_gps_lon = -6701.6409 lon
186.31    sensor: m_gps_status = 0 enum
```

      ii. Mission should complete with following information:

```
201.29 16 behavior surface_2: STATE Active -> Mission Complete
201.39    behavior ?_-1: layered_control(): Mission completed normally
201.46    behavior ?_-1: run_mission(): Mission completed:
MS_COMPLETED_NORMALLY(-1)
```


REMINDER : GLIDER'S WILL SIT IDLE 1O MINUTES BY DEFAULT, ISSUE A CARRIAGE RETURN TO KEEP CONTROL WHILE YOU DEPLOY

7. **Place glider in water**
8. **zero_ocean_pressure**
   a. glider should report that the pressure sensor has been re-calibrated. This step is very important, and could be a solution to problems down the line with pressure sensors being out of calibration. This must be done with glider in the water.
9. **run overtime.mi: (SEE DEPLOYMENT CHECKLIST IF NECESSARY TO RUN!) (Rutgers no longer runs this mission during deployments)**
   a. **What is mission doing?**
      i. This mission tests an abort capability of glider detecting time, and responding to a time limit.
      ii. Tests buoyancy of vehicle, because it will dive



   b. **What is end result of mission?**
      i. Glider will dive but a time limit will expire and glider will 'abort' the overtime mission.
      ii. Glider will submerge for several minutes, witness it surface by monitoring Freewave or computer terminal.
      iii. Mission will end with an abort, if you have glider on terminal, hit enter to see if you are at a command line. You should either witness the following:

```
233.32    ERROR behavior ?_-1: we_are_done(): At the surface, return (-
2)MS_COMPLETED_ABNORMALLY

233.40    behavior ?_-1: we_are_done(): Restoring U_CYCLE_TIME from
15.000000 to 4.000000
233.50    restore_sensors()....
          Restored u_depth_rate_filter_factor from -1 to 4
233.59    behavior ?_-1:    ABOVE WORKING DEPTH
233.64    behavior ?_-1:    drop_the_weight = 0
234.87    behavior ?_-1: run_mission(): Mission completed:
MS_COMPLETED_ABNORMALLY(-2)
```

      iv. ***why?*** – That should indicate the reason for abort, in this case, ms_abort_overtime in case you missed the above messages.

```
ABORT HISTORY: total since reset: 1
ABORT HISTORY: last abort cause: MS_ABORT_OVERDEPTH
ABORT HISTORY: last abort time: 1987-09-16T12:27:14
ABORT HISTORY: last abort segment: ru17_ghost_deep-
1987-258-0-0 (0150.0000)
ABORT HISTORY: last abort mission: ODCTD7.MI
```

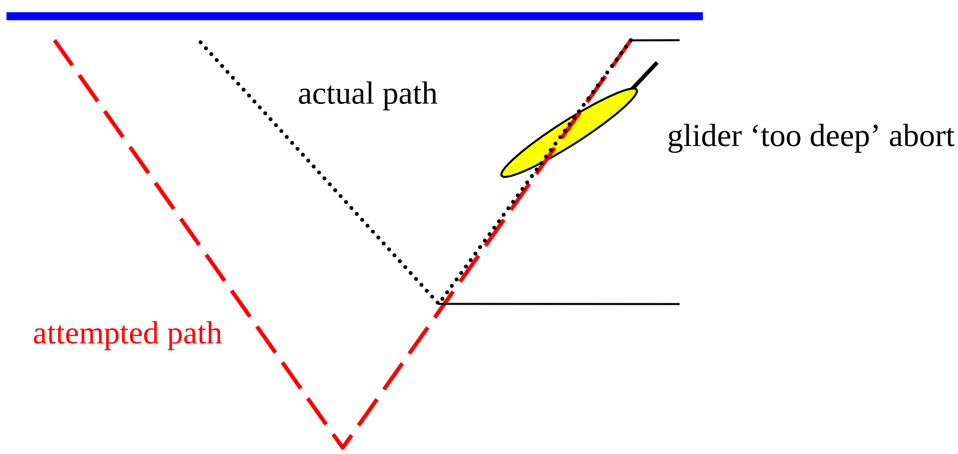
10. **run odctd.mi:**

a. **What is this mission testing?**

i. This mission tests the ability of the glider to detect depth and abort for being in water deeper than it thinks it should be in. The operator's task is to witness the glider submerge and surface. This verifies proper ballast of the vehicle. Occasionally for certain deployments a float will be used on the tail until ballast is confirmed.

b. **What is end result of this mission?**

i. Glider should dive and surface, this time aborting just as in overtime.mi but for overdepth.



ii. Attempt to witness the following at mission completion:

```
172.03    ERROR behavior ?_-1: we_are_done(): At the surface, return (-
2)MS_COMPLETED_ABNORMALLY

172.09    behavior ?_-1: we_are_done(): Restoring U_CYCLE_TIME from
15.000000 to 4.000000
172.16    restore_sensors()....
          Restored u_depth_rate_filter_factor from -1 to 4
172.23    behavior ?_-1:    ABOVE WORKING DEPTH
172.27    behavior ?_-1:    drop_the_weight = 0
173.46    behavior ?_-1: run_mission(): Mission completed:
MS_COMPLETED_ABNORMALLY(-2)
```

iii. If you do not see above, type ***why?*** and this should indicate reason for aborting, overdepth. Note abort count is now at 1-2 aborts.

11. **Receiving data files from test missions:**

a. If you are on a terminal equipped with Z-modem protocol you can transfer the files from the test missions to the laptop.
b. **send *.sbd *.mlg** *.**dbd *.tbd**

12. Run the following missions:
    a. **sequence 100_tn.mi(5)**
    b. **Ctrl-P** – will hasten the process of running the mission.

ONCE THE GLIDER DIVES FROM THIS MISSION, RUTGERS WILL OBTAIN CONTROL FROM THE NEXT SURFACING. DO THE FOLLOWING ITEMS:

1. ONCE GLIDER DIVES, UNPLUG FREEWAVE MODEM POWER
2. NOTIFY/CALL RUTGERS ALERTING THEM YOU PLACED THE GLIDER ON A 15 MINUTE MISSION
3. WEATHER CONDITIONS PENDING, TAKE A CTD CAST
4. WEATHER CONDITIONS PENDING, SLOWLY START STEAMING HOME
5. CONTACT RUTGERS IN 20-30 MINUTES FOR A STATUS, RUTGERS WILL CONTACT YOU EARLIER IF A SITUATION ARISES

RUTGERS UNIVERSITY
COASTAL OCEAN OBSERVATION LAB
OPERATIONS CENTER

Glider Recovery

IMPORTANT NOTE:
GPS and Iridium antennas are shared. You must issue a **callback xx** command to insure a timely GPS once glider communications are established.

1. Glider will call Dockserver and issue its GPS location. These should be used prior to leaving dock. Communication from Rutgers personnel or an email/text message to Sat phone from a Dockserver email can facilitate this.
2. Setup equipment, notably an antenna as high as possible on boat.
3. Standby equipment waiting for connection as you proceed to given GPS location. Shore-side personnel can be called for latest GPS locations as well if need be.
4. Once glider is within range of the Freewave modem, issue immediately a ***callback xx*** command.
5. type ***where***, glider will respond with the following:

```
GliderLAB I -3 >where
Vehicle Name: ru01
Curr Time: Tue Jan  8 20:48:17 2008 MT:   13931
DR  Location:  3928.824 N -7412.074 E measured    13930.6 secs ago
GPS TooFar:   69697000.000 N 69697000.000 E measured     1e+308 secs
ago
GPS Invalid :  3929.233 N -7418.050 E measured      1.667 secs ago
GPS Location: 69697000.000 N 69697000.000 E measured     1e+308 secs
ago
   sensor:m_final_water_vx(m/s)=0                     1e+308 secs ago
   sensor:m_final_water_vy(m/s)=0                     1e+308 secs ago
   sensor:c_wpt_lat(lat)=0                            1e+308 secs ago
   sensor:c_wpt_lon(lon)=0                            1e+308 secs ago
   sensor:x_last_wpt_lat(lat)=3927.492                 13931 secs ago
   sensor:x_last_wpt_lon(lon)=-7413.635                13931 secs ago
   sensor:m_battery(volts)=11.5033497532925            1.933 secs ago
   sensor:m_vacuum(inHg)=0.0990272592008097            2.014 secs ago
   sensor:m_leakdetect_voltage(volts)=2.49575702100992      1.886 secs
ago
   sensor:sci_water_cond(S/m)=3                       1e+308 secs ago
   sensor:sci_water_temp(degC)=10                     1e+308 secs ago
```

   a. Note the highlighted region, this is the glider's GPS location

IMPORTANT: note seconds at end of line, this is the age of the GPS hit. It is important this be something reasonable, on the order of minutes or seconds. OR ELSE YOU ARE USING AN OLD HIT OR A NON-EXISTENT ONE. If there is no new hit, try issuing a ***callback 5*** command, and repeat the ***where*** command until a hit is received.
Proceed to wrangle glider, report 'The bear is in the igloo…' to shore.

Glider Equipment Checklist

General (ALWAYS):

1.  Freewave modem configured for that glider (see Freewave modem configuration guide)
2.  Serial DB-9 Cable
3.  12 V DC power supply for Freewave (or battery for freewave with proper connector)
4. Computer with terminal software
5. DC → AC converter (if needed/available)?

Recovery:

1.  N-terminated coax cable for Freewave modem
2.  900 MHz antenna for quick-securing to boat
3. Satellite Phone
4. Animal control pole, boat hook, or some controlling device (most boats possess a boat hook for worst case scenarios)
5. Empty glider cart
6. Recent email or phone call to someone with access for GPS location
7. Red plug for glider power-down

Deployment:

1. Glider Deployment Checklist
2.  N-terminated coax cable for Freewave modem
3.  900 MHz antenna for quick-securing to boat
4. Satellite Phone
5. Glider Toolbox(s) (if available)
6. Animal control pole, boat hook, or some controlling device (most boats possess a boat hook for worst case scenarios)
7. Designated glider wings + spares!
8. Buoy with line (if Rutgers/operators feel is necessary)
9. SeaBird 19 for comparison cast at deploy location (along with SeaBird software)

Amendment 1: Use of YSI CastAway CTD

The YSI CastAway CTD is a small self-contained lightweight CTD that is GPS enabled. The flow through cell houses a suite of instruments that measure water temperature, conductivity and pressure. The manufacturer specifications for each parameter are listed in the table below. For more detailed information on the CastAway please visit the YSI website at: www.ysi.com.

	Range	Accuracy	Resolution
Conductivity	0 – 100,000 µS/cm	0.25% ±5 µS/cm	1 µS/cm
Temperature	-5° - 45° C	0.05° C	0.01° C
Pressure	0 – 100 dBar	0.25% of FS	0.01 dBar
Salinity (Derived)	Up to 42 (PSS-78)	0.1 (PSS-78)	0.01 (PSS-78)
Sound Speed (Derived)	1400 – 1730 m/s	0.15 m/s	0.01 m/s
GPS		10m	

The purpose of this amendment is to authorize the substitution of the SBE-19 described in the QAPP with the CastAway. Both CTDs will be used for side-by-side comparison profiles with the glider at the deployment and recovery of the vehicle. The small size of the CastAway permits a safer deployment/recovery in rough weather or from a small vessel. In addition, the self-contained data collection eliminates the need for a laptop and the required external power.

It will be the judgment of Josh Kohut the Rutgers lead on this project to determine weather conditions require the use of the CastAway instead of the SBE-19. The decision will be based on forecasted sea-state and vessel characteristics at the time of recovery or deployment. The decision will be communicated to each signatory of the QAPP in via email.

Amendment 2: Use of non-factory calibrated Glider CTD

The purpose of this amendment is to authorize the use of a glider installed SeaBird CTD that has not met the annual factory calibration criteria. In the case that equipment loss and project deployment timeline does not permit the delay of a lengthy factory calibration, a CTD that has not been calibrated within the last year could be substituted given the following:

1) The substituted CTD was factory calibrated no more than five years prior to deployment.

2) The substituted CTD meets the requirements outlined in the table listed in Section 8 of this QAPP relative to the SeaBird-19 (calibrated within the last year).

If a CTD meeting these requirements is used in a given deployment, a statement will be included with the deployment documentation. The statement will specify that the CTD was not factory calibrated in the last year, calibration checks were preformed, and the data meets the QC criteria specified in the QAPP.

Amendment 3: Use of manufacturer-suggested replacement for dissolved oxygen field titration kit

Verification of AAnderaa oxygen optode calibration is conducted via the azide modification of the Winkler titration method, pursuant to EPA method # 360.2. This test involved the usage of EPA compliant field kits manufactured by Lamotte Company, purchased from Fisher Scientific. This kit (item # S45088) has been discontinued, but the manufacturer has issued a replacement kit (item # S94979) that uses a liquid sulfamic acid instead of a powdered version. This kit will be used to verify oxygen optode calibrations for the remainder of this project. Methodology will remain the same.

Amendment 4: Use of multiple gliders to complete remaining coastal glider flights

Losses incurred throughout the duration of this project have led to the usage of Slocum gliders other than the glider initially purchased by the NJ DEP. The glider used for the second coastal monitoring run, RU07, will be used again for this project, starting with a coastal flight in June 2012. The glider purchased by the NJ DEP, RU28, was struck and sunk by a cargo ship and later recovered. This glider has been rebuilt by the manufacturer and is scheduled to be delivered to Rutgers by the end of May 2012. The ability to use these two gliders interchangeably provides some flexibility in the project while adhering to the standards in the QAPP. Glider RU07 can carry one of 3 payload bays that will meet the standards set forth in this document for CTD calibration criteria. Bay 1 is CTD and oxygen only. In addition to these sensors, Bay 2 carries one optical puck (Wetlabs EcoPuck BBFL2-599, calibration date 29Jan2009), with two channels of fluorometry (chl a and CDOM) and one channel of backscatter at 470 nm. Bay 3 carries CTD, oxygen, and two optical pucks (BB3-796, calibration date 16Dec2010; BBFL2-338, calibration date 11May2011) measuring backscatter at 470, 532, 650, and 880 nm and fluorescence for chl a and CDOM. Data from the EcoPucks would be provisional as calibration dates fall outside of the limits set forth in this document, but can provide a qualitative understanding of the physical and biological coupling present during the coastal monitoring flights.

Amendment 5: Updated glider check-out lists

As the Rutgers glider program continues to expand, best practices and procedures are often refined, pursuant to operational experience. As such, preparatory checklists are updated to include new or more thorough procedures, as well as accounting for changes from the manufacturer, such as software updates internal to the glider.

Attached are three documents that have been updated since the fall coastal monitoring run has been completed. They are:

1.) Pre-deployment check-out (Appendix A)
2.) Deployment checklist (Appendix C)
3.) Post-Deployment checklist (Appendix E)

Appendix A has been updated with checks to avoid issues that we have recently seen in the field, including uncalibrated compasses resulting in the inability to attain specified headings and therefore necessitating recovery vs. continuing flight.

Appendix C has been modified slightly to include new preliminary test mission names, aimed at reducing confusion on the part of the deployment technician, which can often be students or those otherwise unfamiliar with the intricacies of glider operations.

Appendix D has been modified with the intent of streamlining the data backup process, thereby removing single point failures.

GLIDER	
PREPARER	
PREP DATE	
LOCATION	

SCIENCE BAY SERIAL NUMBERS

1) ____
2) ____
3) ____
4) ____

PRE-SEAL

FORE CHECK

Check pump & pitch threaded rod (grease & clean if necessary) ____

Grounded Nose? ____

Leak detect in place, batteries secure, white guides free, no metal shavings, bottles installed ____

PAYLOAD CHECK

Special Sensors / Additional Sensors

1) ____

2) ____

CTD cable clear, no leak at CTD joint, no leak at pucks ____

Grounded Parts: Fore Sci Ring ____ Aft Sci Ring ____

CTD ____

Other? ____

Science Bay Weight Configuration ____

AFT CHECK

Iridium Card Installed (SIM #) (if not standard) ____

Flash Card: old data removed? ____

Inspect strain on connectors (worn connectors), battery secured, ballast bottle present, aft cap clean/clear of leak ____

Aft cap grounded? ____

Battery check

Aft Pack - J13 Voltage ____

Pitch Pack - J13 Voltage ____

Nose Packs - J13 Voltage ____

Aft Emer - J31 Voltage ____

POST-SEAL

GENERAL

Pick Point Present? ____

Special Instruments? ____

HARDWARE

put c_alt_time 0, verify alt chirp ____

Anode grounded? ____

Pressure Sensor Check (corrosion, clear)

Aft sensor ____

Payload sensor ____

Nose Cone and pump bladder inspection ____

Anode size / remainder (est) ____

Ejection weight assembly OK and unseized? ____

POWERED

Verify Argos ping ____

Wiggle for 5 minutes ____

Stabilized m_battery ____

m_vacuum @ T @ ballast ____

OUTSIDE

Compass Check (reading @ compass)

1) ____
2) ____
3) ____
4) ____

logging on; rotate slowly 360, logging off, plot data: 360 test ____

GPS check

(lat) ____ (lon) ____

Iridium connect ____ Alt ____

zero_ocean_pressure, get m_pressure ____

let air bladder inflate, does it shut off? ____

SOFTWARE

GENERAL

Version	________	Re-burn latest software image	________
Date OK?	________	configure TBDlist	________
delete old logs	________	NBDlist	________

\CONFIG

simul.sim deleted ________

\MAFILES

goto_l10.ma (set x_last_...) ________

AUTOEXEC.MI

Irid Main: 88160000592	________	c_ctd41cp_num_fields_to_send 4	________
Irid Alt: 15085482446	________	Calibration coefficients	________
u_iridium_failover_retries = 10	________	f_ballast_pumped_deadz_width = 30?	________
Reset the glider, observe any errors		get f_max_working_depth (102 m)	________

CACHE MANAGEMENT

del ..\state\cache*.*
after *bdlist.dat are set (exit reset):
logging on; logging off
send ..\state\cache*.cac ________
send *.mbd *.sbd *.tbd ________

*** Software Burning Tips :** if using Procomm or local folder, copy all the files from the software image locally. Then proceed to edit them for the glider and do a mass freewave transfer of the files. Save these files or prepare the to-glider with these files

SCIENCE

SENSOR RETURN

put c_science_send_all 1
put c_science_all_on 8
put c_science_on 3
All sensors reporting values? ________

CTD

Tank static comparison OK? ________

OPTODE

Check in completed? ________

Glider ____________ Date ____________

Pilots ____________ Where ____________

Laptop ____________ Vehicle Powerup: CTRL ^ C (until you get to prompt)!!!

<table>
<tr><td rowspan="6">On boat
(Remember after 10 min glider will go into mission, as well as on powerup!)</td><td>Battery Voltage</td><td>____</td><td>get m_battery</td></tr>
<tr><td>Vacuum Pressure</td><td>____</td><td>get m_vacuum, should be > 7 for bladder inflation</td></tr>
<tr><td>Iridium Connection</td><td>____</td><td>look for connect dialog & surface dialog, let it dial at prompt</td></tr>
<tr><td>boot app</td><td>☐</td><td>boot app</td></tr>
<tr><td>boot (should report application)</td><td>☐</td><td>reports boot application</td></tr>
<tr><td>run status.mi</td><td>☐</td><td>mission completed normally?</td></tr>
<tr><td rowspan="8">In Water</td><td>zero_ocean_pressure</td><td>☐</td><td>while glider in water</td></tr>
<tr><td>run od.mi (with or without float, ask RU)</td><td>☐</td><td>glider should dive and surface, type why? Should say overdepth, if not call</td></tr>
<tr><td>send *.dbd *.mlg *.sbd</td><td>☐</td><td>"send *.sbd" is most important
(this applies moreso to when handed off to iridium)</td></tr>
<tr><td>run shallow.mi
or deep.mi</td><td>☐</td><td>(glider should dive and not reappear) (report to Rutgers or steam out slowly once it dives)</td></tr>
<tr><td>Verify dive; disconnect freewave</td><td></td><td></td></tr>
<tr><td>Report to Rutgers</td><td></td><td></td></tr>
<tr><td>Perform CTD Comparison CAST</td><td>☐</td><td>typically done with RU provided SBE19 or Cast Away CTD</td></tr>
<tr><td>LAT: LON</td><td></td><td></td></tr>
</table>

Slocum Glider Check-IN

DATE: ____________

GLIDER: ____________ **SB:** _____________

Vehicle Powered

Power on vehicle in order to fully retract pump, and/or to deflate air bladder.

Vehicle Cleaning (hose down with pressure)

Nose cone

1. Remove nose cone
2. Loosen altimeter screws, and remove altimeter or leave temporarily attached
3. Retract pump
4. Remove altimeter and hose diaphragm removing all sand, sediment, bio oils
5. Clean nose cone and altimeter

Tail cone

1. Remove tail cone
2. Hose and clean anode and air bladder making sure air bladder is completely clean
3. Clean cowling

Wing rails

1. Remove wing rails and hose down

Tail plug cleaning

1. Dip red plug in alcohol and clean plug if especially dirty
2. Re-dip red plug and repeatedly insert and remove to clean the glider plug
3. Compress air glider female connector
4. Lightly silicon red plug and replace in glider once silicon has been dispersed evenly in the plugs

CTD Comparison Check

1. Inspect CTD sensor for any sediment buildup, take pictures of anything suspicious or make note.

Static Tank Test

SBE19
Temperature: ________________

Conductivity: ________________

Glider (SBE41CP or pumped unit)
Temperature: ________________

Conductivity: ________________

CTD Maintenance if comparison is not acceptable (reference SeaBird Application Note 2D)

1. Perform CTD backward/forward flush with 1% Triton X-100 solution
2. Perform CTD backward/forward flush with 500 – 1000 ppm bleach solution
3. Perform the same on a pumped unit, just different approach
4. Repeat comparison test if above results not within T < .01 C, C < .005 S/m

SB19
Temperature: ________________

Conductivity: ________________

Glider (SB41CP or pumped unit)
Temperature: ________________

Conductivity: ________________

Vehicle Disassembled

1. Check leak points for water or salt buildup
2. **BACKUP FLASH CARDS** in /coolgroup/gliderData/glider_OS_backups/<glider>/<glider-deploymentID>/<from glider>,<from sb_0xxx>

   ____

   DO NOT DELETE DATA OFF CARDS
3. Change permissions on <glider-deploymentID> folder to read, write, execute for owner and group, and read, execute for everyone
4. Remove used batteries and place in return crate

   ____
5. Re-assemble glider with a vacuum