Exocetus Coastal (Littoral) Glider

Application to Hypoxia Research

Important Factors for Hypoxia

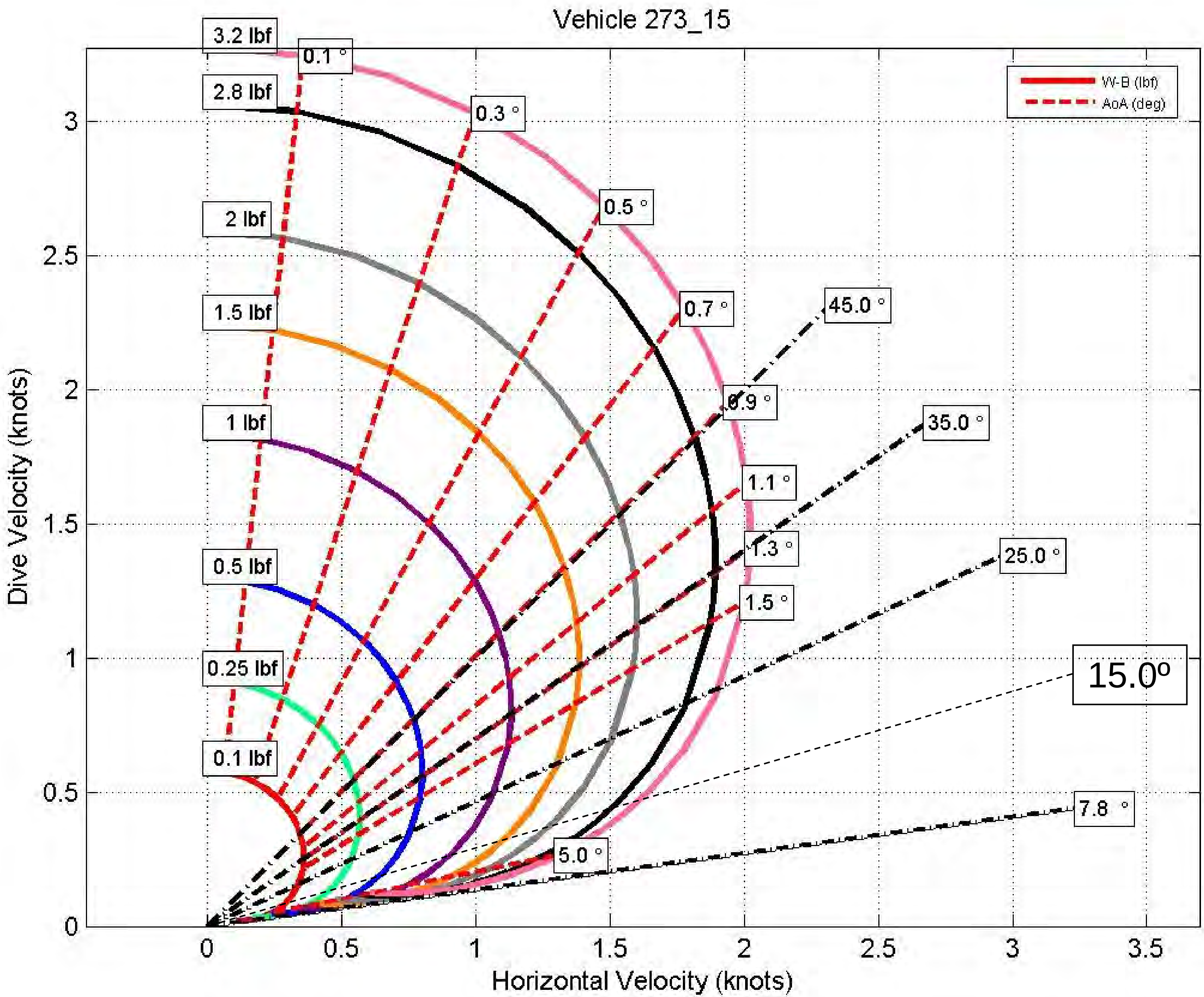
- High salinity Gradients
  - ~ 15 kg/m^3
  - ~ 1.5% (15 / 1027)
- Shallow Waters
  - 5 – 60 m range
  - 10 – 30 m target
- Near Bottom
  - < 1.0 m target

➢ Buoyancy Engine Design is Critical

- Needs to be large, fast, and predictive

CG Buoyancy Engine Specs

- Total Volume: 5 L (4.7% of Vehicle)
- Total Buoyancy Variation: +/- 5.5 lbs (24.4 N)
- Buoyancy Variation Rate: ~ 0.1 lb/sec (.097 lb/sec; .43 N/sec)
- Specific Buoyancy Variation: ~ 2 lbs/in (1.83 lb/in; 8.13 N/in)



Vehicle 273_15
W-B (lbf)
AoA (deg)
3.2 lbf
2.8 lbf
2 lbf
1.5 lbf
1 lbf
0.5 lbf
0.25 lbf
0.1 lbf
0.1 °
0.3 °
0.5 °
0.7 °
0.9 °
1.1 °
1.3 °
1.5 °
5.0 °
45.0 °
35.0 °
25.0 °
15.0º
7.8 °
Dive Velocity (knots)
Horizontal Velocity (knots)
0
0.5
1
1.5
2
2.5
3
3.5

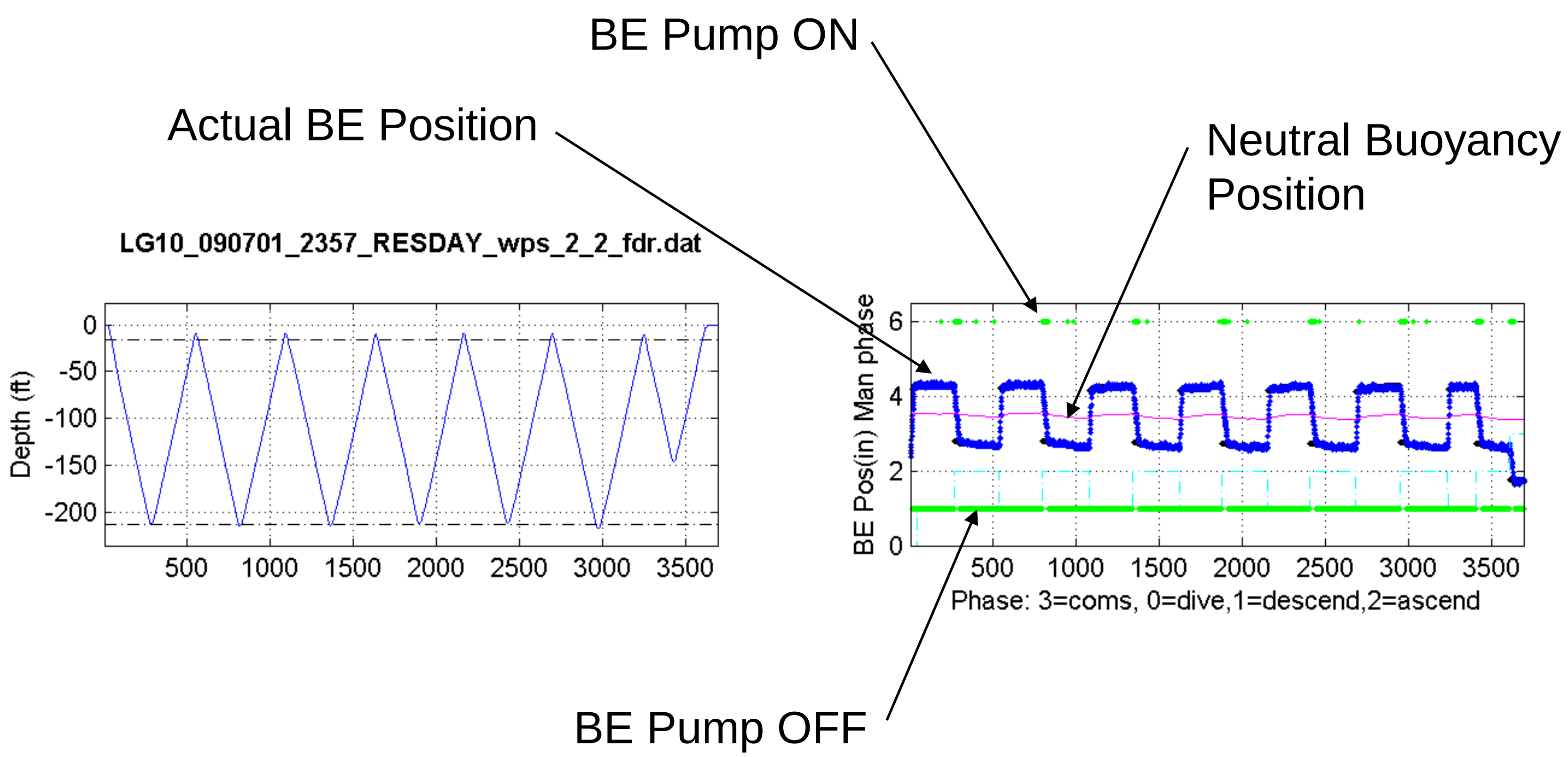
CG BE Design

- BE designed to have a range of 0 to 6.25 inches of travel (approx. 5 L; 11.7 lbs)
- Designed maximum speed requires +/- 3.2 lbs (6.4 lbs total) and a glide slope of 35 degrees
- Remaining 5.3 lbs ‘reserved’ for adaptive ballasting (range of 27 ppt)
- Reserve can be used for speed if full adaptive ballasting is not necessary

CG BE Overview

- The CG BE is both Variable and Adaptive:
- Variable aspects allows for variable speed:
  - The amount the glider ingests and expels at each inflection is determined by the commanded speed
  - Larger commanded speeds result in larger BE displacements and therefore larger changes to the net buoyancy
  - Larger displacement require the BE to run longer and result in higher BE duty cycles
- Adaptive aspect allows the CG to self-ballast:
  - As water density changes, the glider adjusts the ‘Neutral Buoyancy Position’ (NBP) of the BE
  - This is done continuously
  - The result is a low duty cycle adjustment to the BE during ascent/descent
  - Added drag on the glider (e.g. from a tethered modem) ‘looks like’ density variations and result in BE adjustments during ascent/descent

Glider BE Operation



BE Adaptive Speed

0.0 inch — BE Range — 6.25 inch

1 knt @ 1019 kg/m^3

1.8 in — 3.9 in

2 knt @ 1019 kg/m^3

1.1 in — 4.6 in

BE Adaptive Ballasting

0.0 inch BE Range 6.25 inch

1 knt @ 1027 kg/m^3

0.7 in 2.8 in

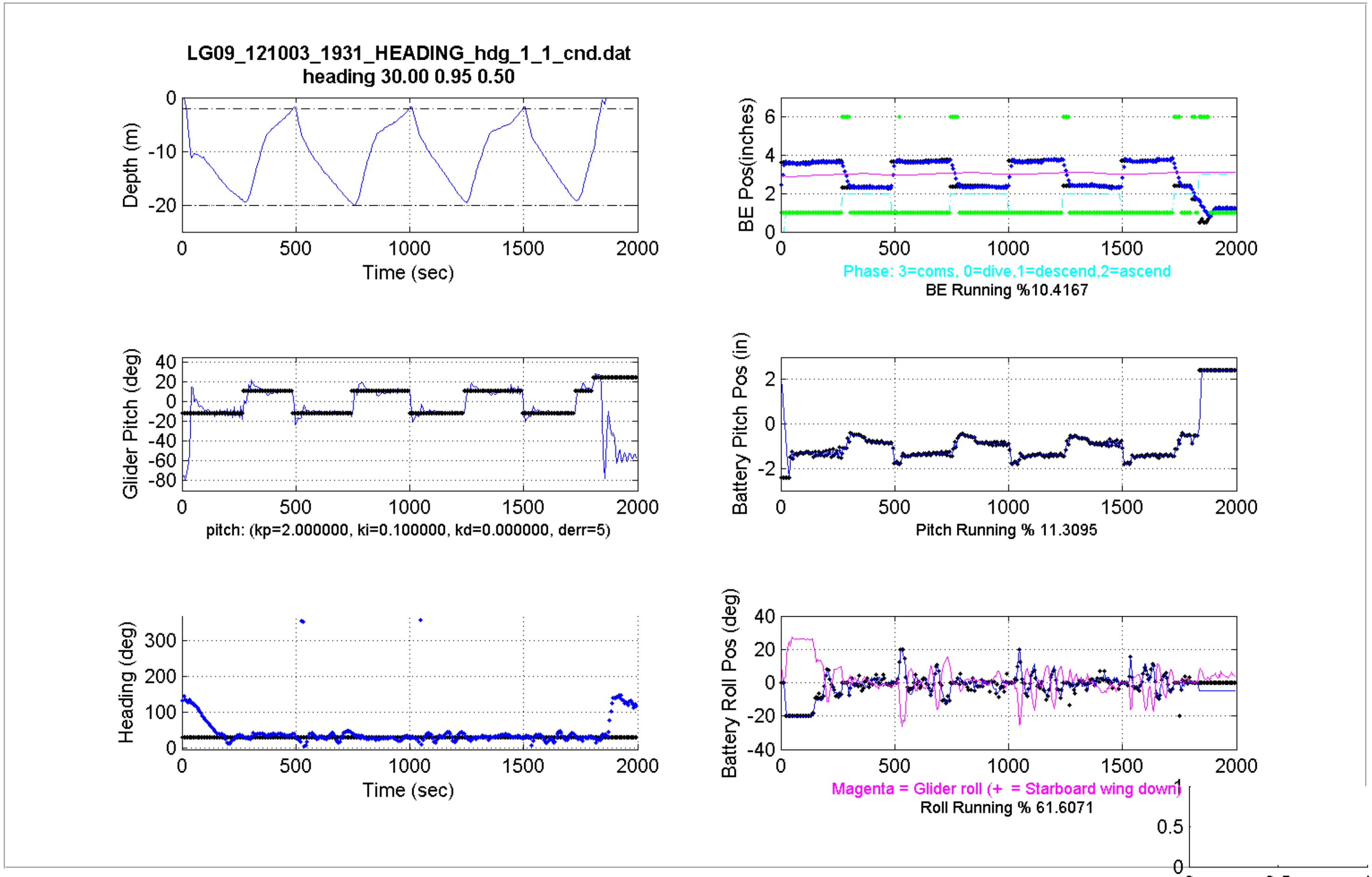
1 knt @ 1010 kg/m^3

3.0 in 5.1 in

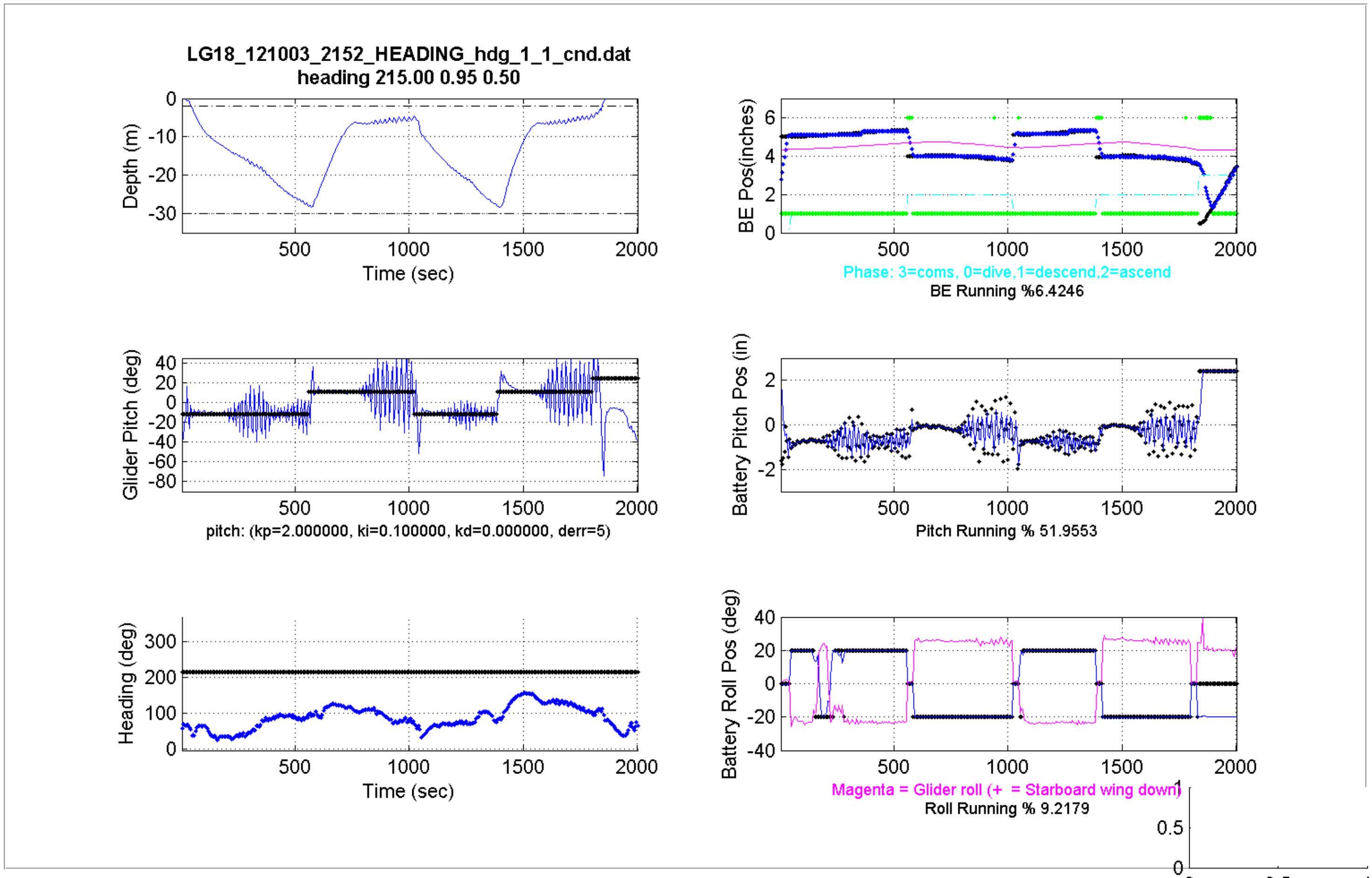
Current USM Hypoxia CG

- RINKO DO Sensor
- WET Labs ECO FLNTU Sensor
- AML Micro CTD
- Note: Other current project (UAF) has Sea Bird GPCTD Integrated)
- All Sensors at 1 Hz

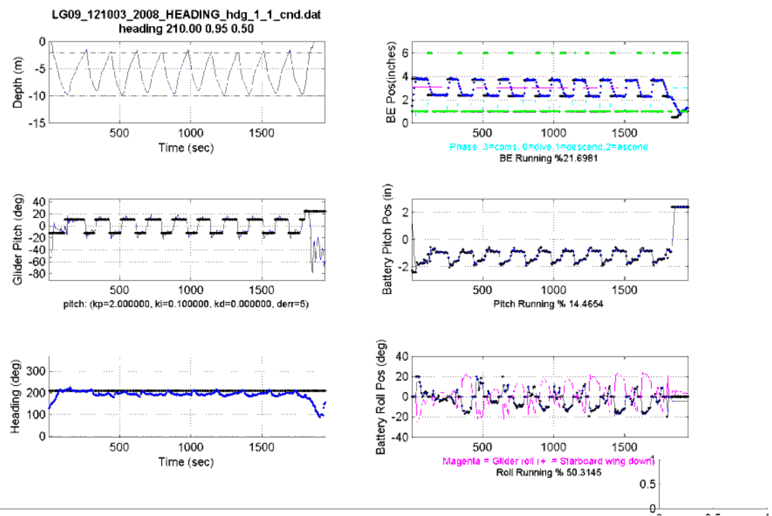
Salinity Variation

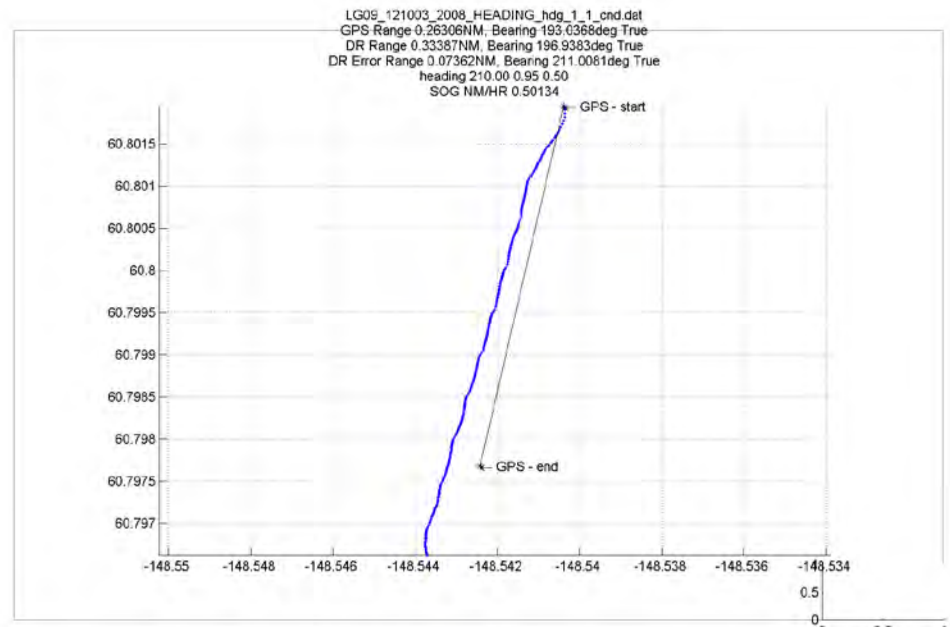


Salinity Variation



Shallow Water Navigation





Note:

- Top and bottom of yo’s are predicted
- SOG < Commanded speed

CG Behaviors

1. Heading Maneuver (*Heading, Speed, Time*)
2. Waypoint Maneuver (*Waypoint, Speed*)
3. Communications Maneuver (*Surface, Nose Down*)
4. Station-Keeping Maneuver (Waypoint, Radius)
5. Drift/Re-locate Maneuver (Waypoint, Radius)
6. Surface Maneuver (*Recovery Mode*)
7. Hover Maneuver (*Depth, Depth Tolerance, Time*)
8. Sleep Maneuver (*Time*)
9. Emergency Rise Maneuver (*Depth, Heading*)
10. Emergency Dive Maneuver (*Depth, Heading*)

BE Limitations

- Note that glider commanded speed is used as a guideline. It is based on steady state analysis of the glider model. Actual speed over ground will vary with:
  - Differences in drag from the model;
  - Currents;
  - Yo profiles.

Navigational Limitations

- Shallow water increases BE duty cycle; decreases efficiency
- Turning in shallow water presents difficulties:
  - Depth rate = turn rate
  - Altimeter not downward looking during turns
- Salinity layers lead to skewed yo profiles

Summary

- Accomplishments:
  - Navigation w/ 8 m yo differential
  - Operation in high salinity gradient
  - Data collection at 1 Hz continuous
- To Do:
  - Demonstrate altimeter functionality (to within 1 m of bottom)
  - Improve speed of adaptive ballasting