Lessons learned in the practical application of glider quality control tests in an ocean observing system

Laura Palamara Nazzaro
nazzaro@marine.rutgers.edu

Center for Ocean Observing Leadership
Rutgers University
rucool.marine.rutgers.edu

RUTGERS UNIVERSITY

IOOS | Integrated Ocean Observing System

MARACOOS Ocean Information for a Changing World

Rutgers Glider Deployments & Sensors

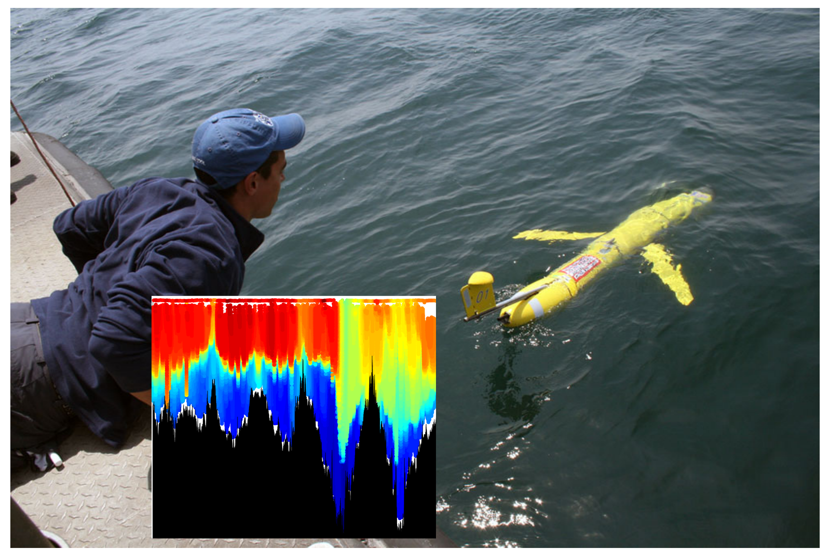
Rutgers has flown nearly 500 Slocum glider deployments all over the world.

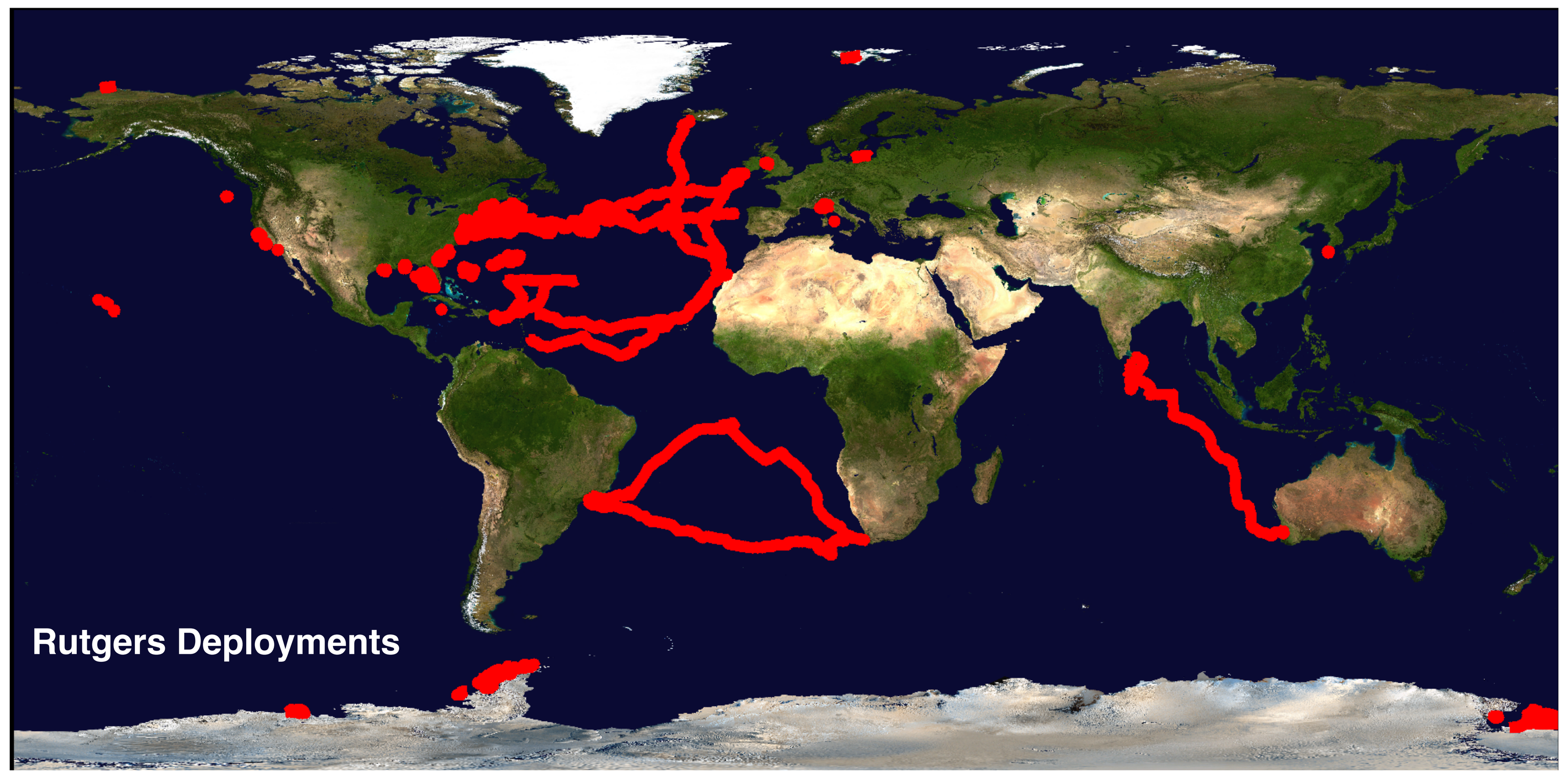
- Highest data density in the Mid-Atlantic Bight
- Significant coverage in Antarctica
- Some deployments span entire ocean basins

All include CTD data (conductivity, temperature, depth/pressure, and derived salinity) and many of the deployments also had additional sensors on board, including but not limited to:

- Dissolved oxygen
- Ocean currents
- Backscatter
- Fluorescence
- pH

Much of this data (especially CTD) is shared with various user groups, and often assimilated into hydrodynamic models and forecasts that don't have alternative vertical water column data sources available at comparable resolution and spatial coverage, so it is important to ensure that we are providing the best data possible.





Quality Control & QARTOD

The Integrated Ocean Observing System Quality Assurance/Quality Control of Real-Time Oceanographic Data program (IOOS QARTOD) has several well-defined tests for quality control of glider CTD data (right).

- Rutgers is implementing all nine required (Group 1) and strongly recommended (Group 2) tests
- Some are better achieved than others due to a lack of available data to develop suitable thresholds (particularly Group 2)
- Suggested tests (Group 3) are potentially feasible for post-deployment full datasets but more difficult to implement well in real-time

These tests were originally written for CTD data but can easily be applied to at least some other sensors often on board gliders. Even though QARTOD can help flag some questionable data there are still other common data quality issues in CTD data that need to be addressed (thermal lag), and other corrections that frequently need to be made to non-CTD data (time offsets).

Group 1 *Required*	Test 1)	Timing/Gap Test ✓
	Test 2)	Syntax Test ✓
	Test 3)	Location Test ✓
	Test 4)	Gross Range Test ✓
	Test 5)	Pressure Test ✓
Group 2 *Strongly Recommended*	Test 6)	Climatological Test ✓
	Test 7)	Spike Test ✓
	Test 8)	Rate of Change Test ✓
	Test 9)	Flat Line Test ✓
Group 3 *Suggested*	Test 10)	Multi-Variate Test
	Test 11)	Attenuated Signal Test
	Test 12)	Previous Profile Test
	Test 13)	TS Curve/Space Test
	Test 14)	Density Inversion Test

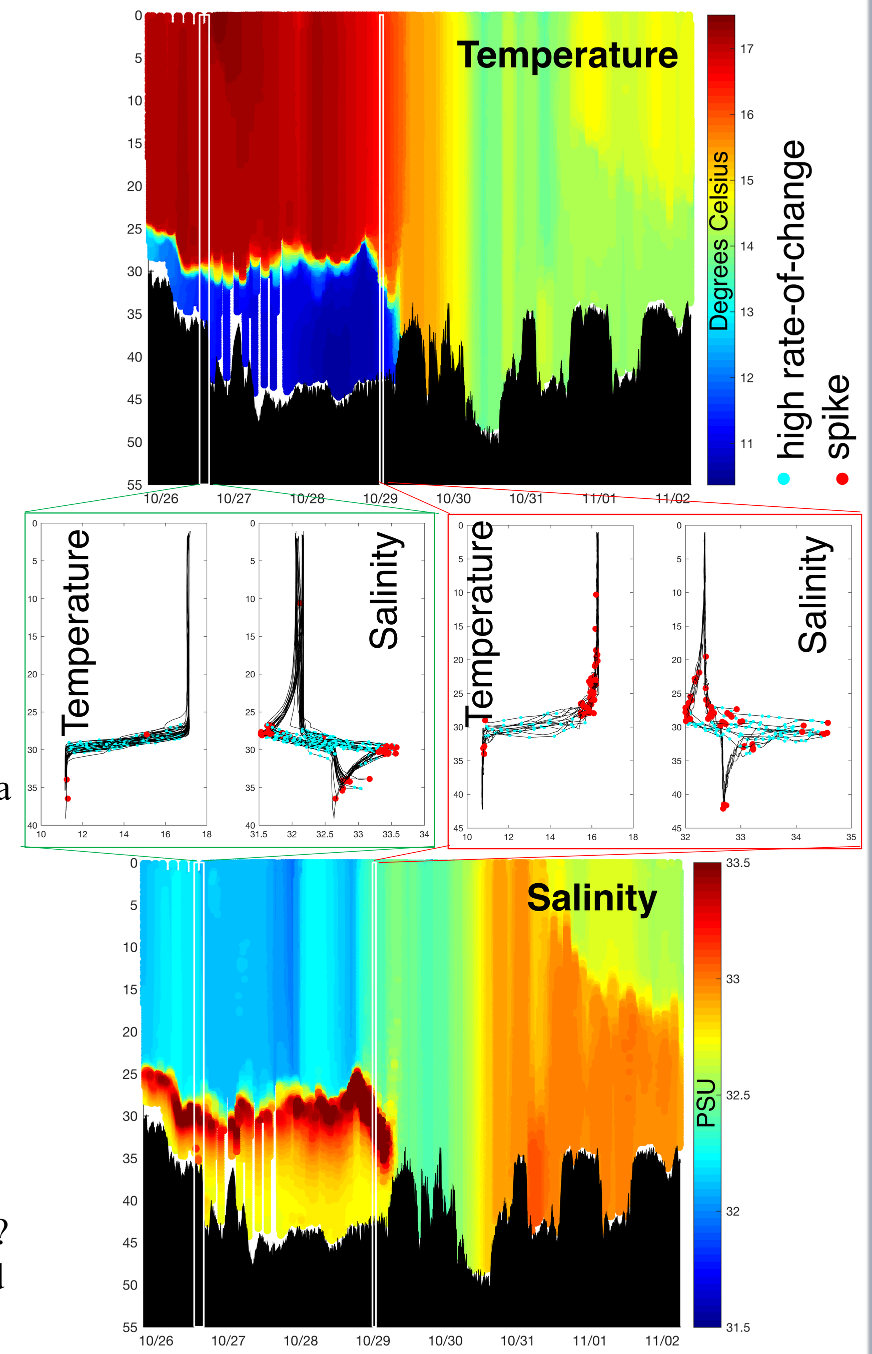
Acknowledgements

Thanks to past and present members of RUCOOL who have contributed to this work, especially John Kerfoot, Josh Kohut, Filipa Carvalho, and Liza Wright-Fairbanks.

CTD Data

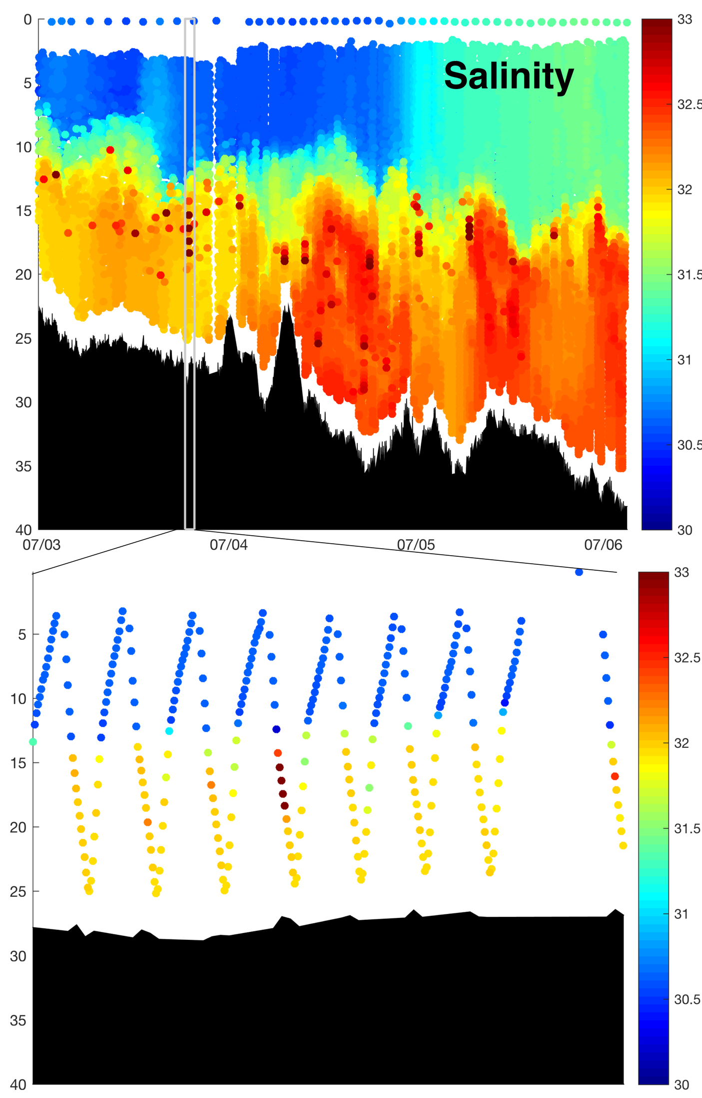
QARTOD tests we are running:

1. **Timing/Gap** (did data arrive in a reasonable amount of time?)
2. **Syntax** (is data file formatted correctly?)
3. **Location** (did glider report from a reasonable location?)
4. **Gross Range** (is data within a range that the sensor can measure?)
5. **Pressure** (does profile go continuously up or down?)
6. **Climatological** (is data reasonable for the region, season, depth, etc.)
7. **Rate of Change** (does data change too quickly between measurements?)
8. **Spike** (is a measurement too much higher or lower than those immediately before and after?)
9. **Flat Line** (is the sensor stuck?)



Challenges:

- How do we define **climatological thresholds** in a region with high intra- and inter-annual variability? Need lots of data! We have an abundance for some regions at certain times of year, but full water-column data is scarce for other regions and/or seasons.
- How do we best define and apply **depth-dependent** thresholds?
- How do we define and apply rate of change and spike thresholds that effectively flag bad data **without flagging the entire thermocline** (right)?
- How do we acknowledge the fact that flags could identify good **data of interest**, such as storms that quickly change environmental features (ie Hurricane Sandy, right), in addition to data of poor quality?



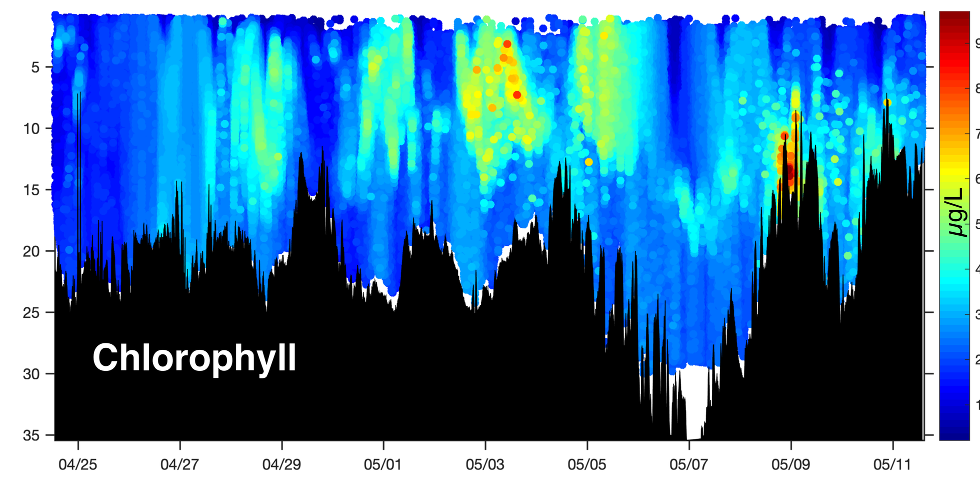
Future Work:

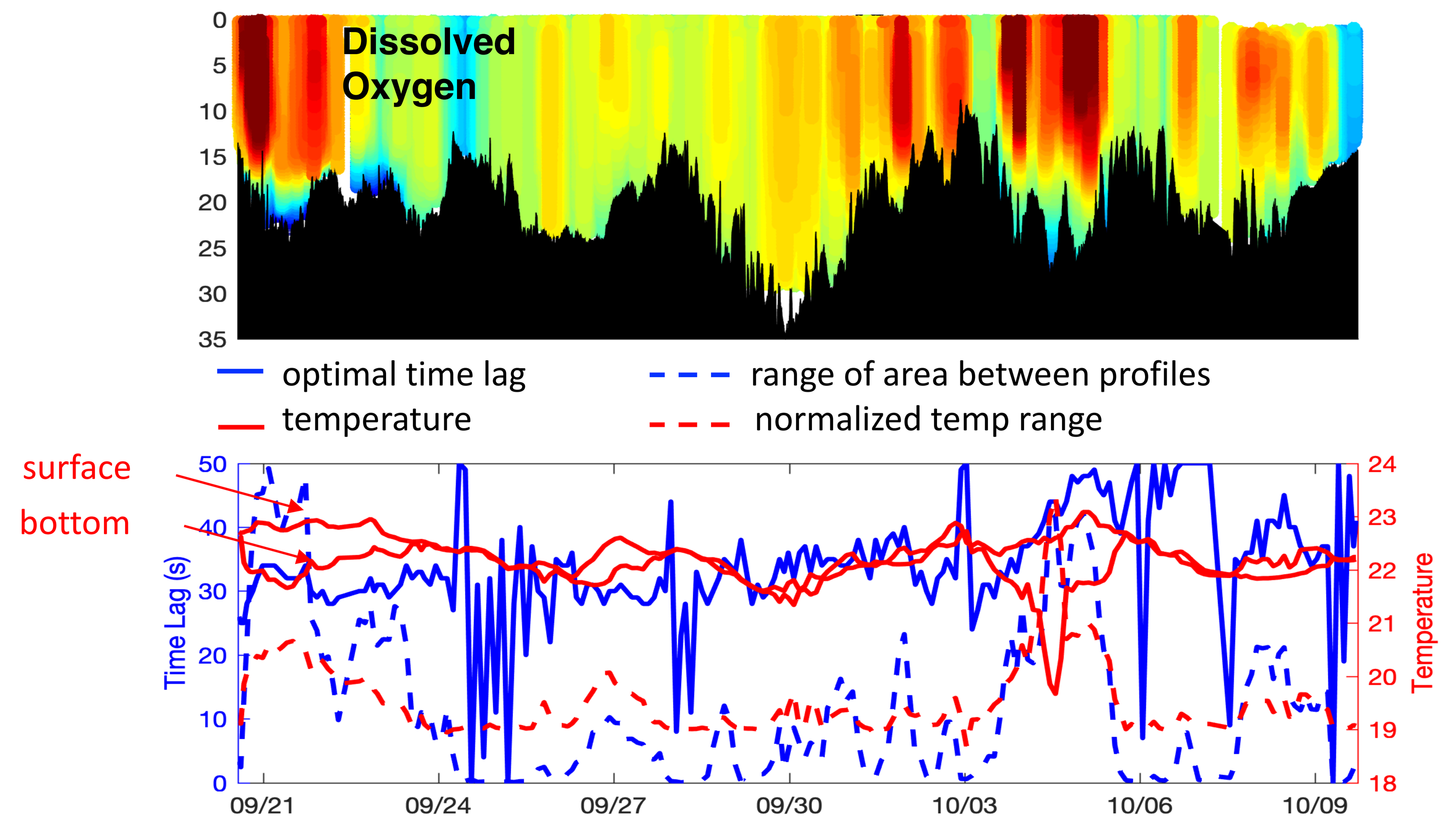
- Development of QARTOD suggested tests
  - Some may perform better as post-recovery tests instead of real-time
- Development of a method to address thermal lag errors in CTD data
- Development of non-QARTOD QC tests
  - A spatial spike test, similar to the QARTOD previous profile test, might identify clear spikes in Hurricane Arthur data (left) that are not identified by the temporal spike test.

Other Sensors

QARTOD

- Manuals exist for certain other frequently used sensors, but tests are not as well-developed
- Tests already in place for CTD data can be applied
  - Occasionally difficult for certain types of data (ie chlorophyll can be naturally spiky)

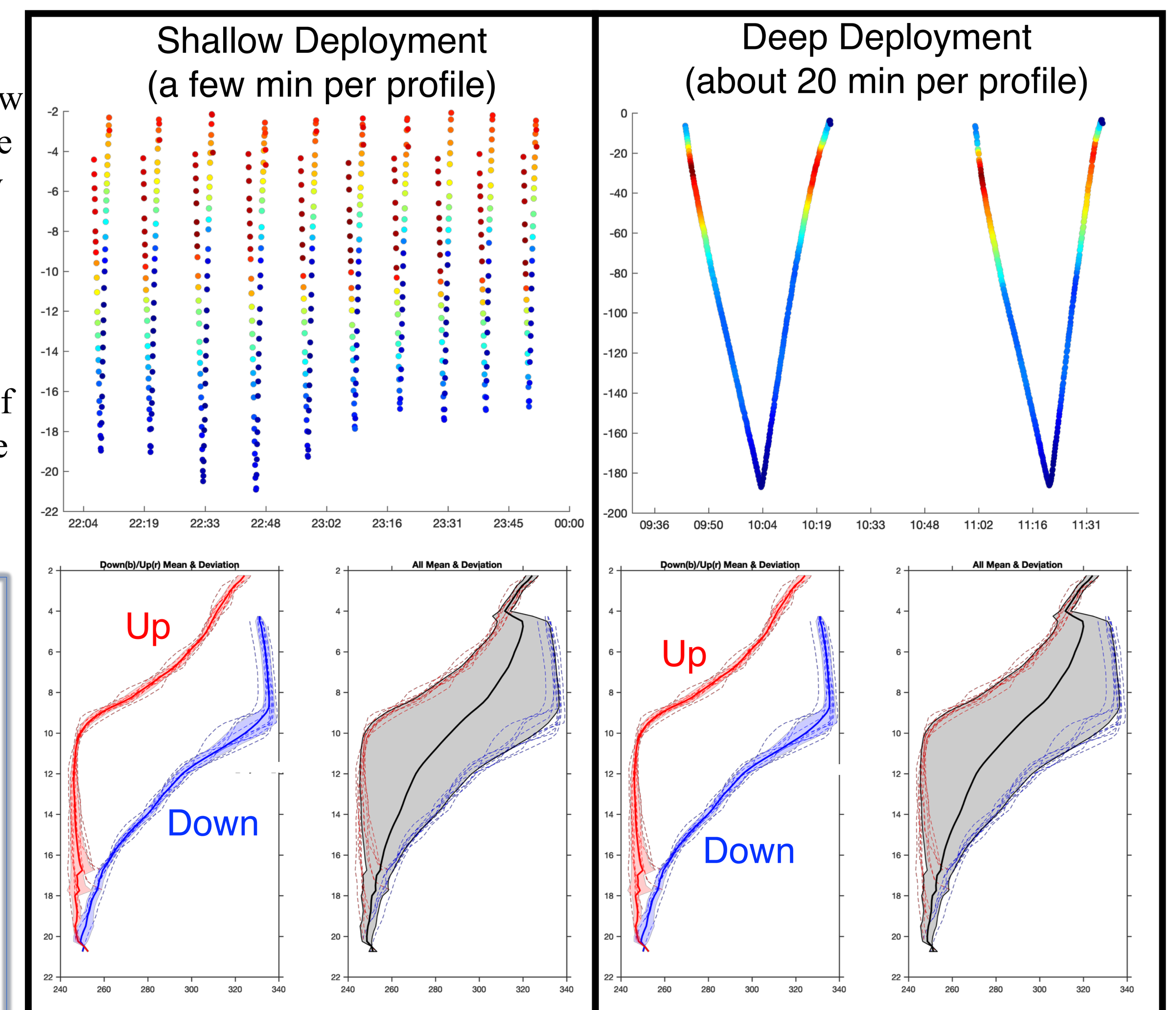




Other QC: Sensor Time Lag

One of the more common data adjustments is a shift backwards in time to account for a significant sensor time lag, used for both dissolved oxygen (DO) and pH sensors. An optimal shift is determined by iterating across multiple times and checking which best minimizes the area between neighboring profiles (below). The majority of Rutgers DO data has come from shallow summer deployments in stratified water, with a strong thermocline to highlight differences between profiles. Recent deployments in well-mixed (above) or deep (below) water has revealed unexpected difficulties in determining appropriate time-lag.

- **Well-mixed water** (above) displays less of a difference between neighboring profiles. Area between profiles has minimal difference regardless of time-lag, and "optimal" time shift can be erratic and unreliable.
- In **deep water** (right) data sent back in real-time often only has a few profiles with a long time between them, typically only down-up pairs. If the thermocline is close to the surface, there could be a long time between thermoclines of each profile, making the pair comparison questionable.



Conclusions

- Data from gliders are assimilated into several regional and global nowcast and forecast models, and both the raw data and and model output is used by a wide array of user groups, so it is important to make sure that the data provided is high quality.
- The storms and strong thermoclines that play a large role in characterizing the MAB can provide key examples of QC success stories, but also highlight the need for further work and the potential for certain tests to identify data of interest in addition to poor quality data.
- Methods of applying QC can vary significantly depending on several characteristics of the water being sampled, as well as the sampling methods utilized by the glider.