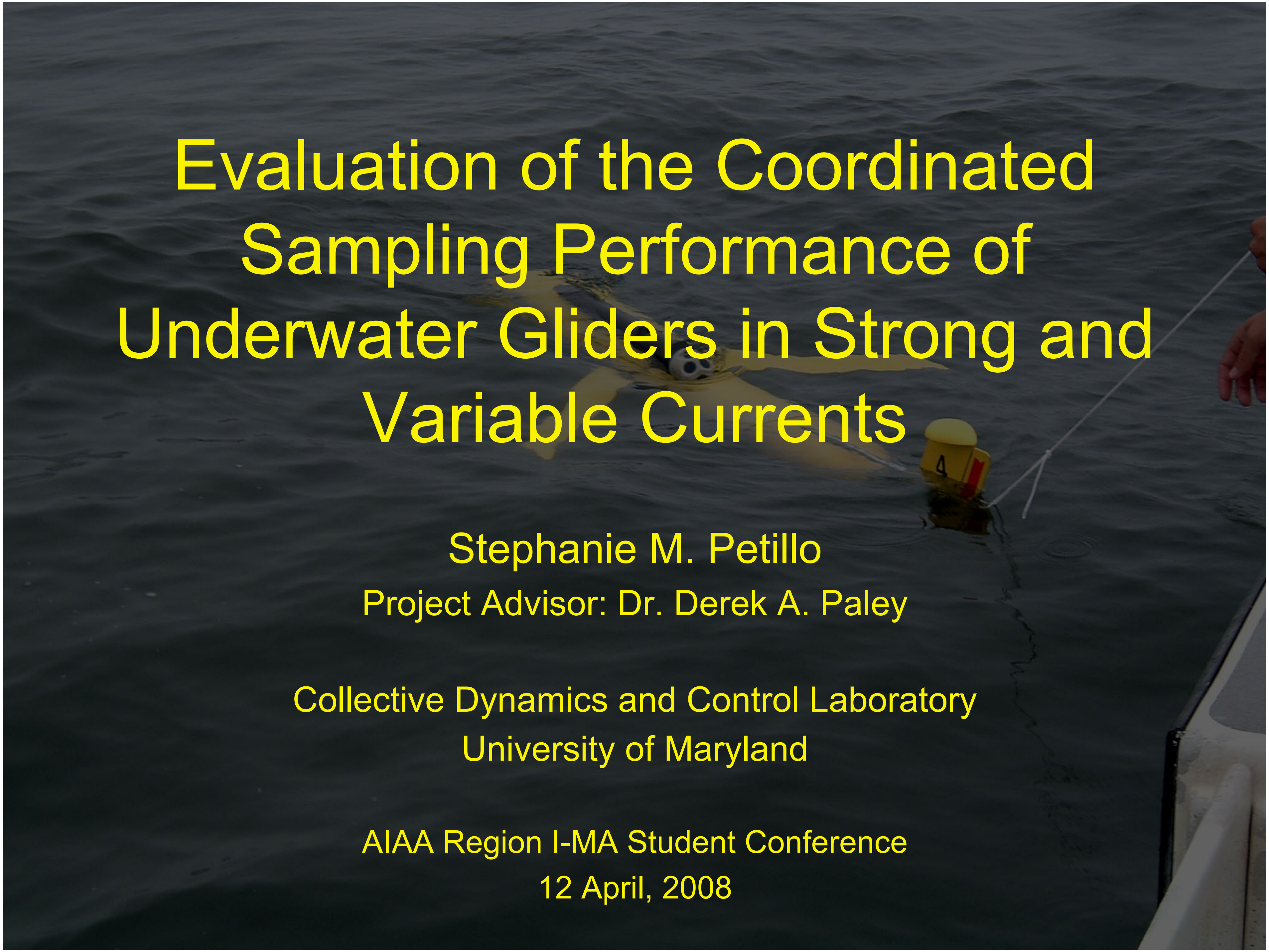

Evaluation of the Coordinated Sampling Performance of Underwater Gliders in Strong and Variable Currents

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AIAA Region I-MA Student Conference

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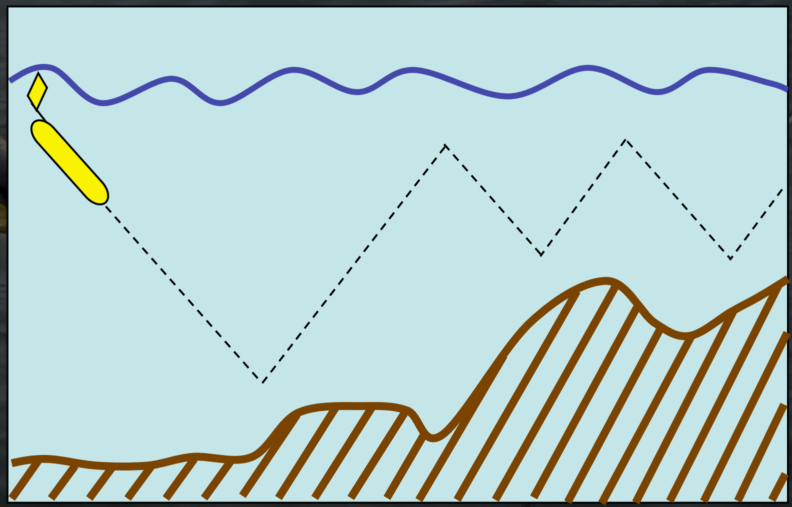
Outline

- Autonomous underwater gliders and control of a fleet
- Chesapeake Bay tidal flow
- What we learn from simulating tidal flows

Glider Background

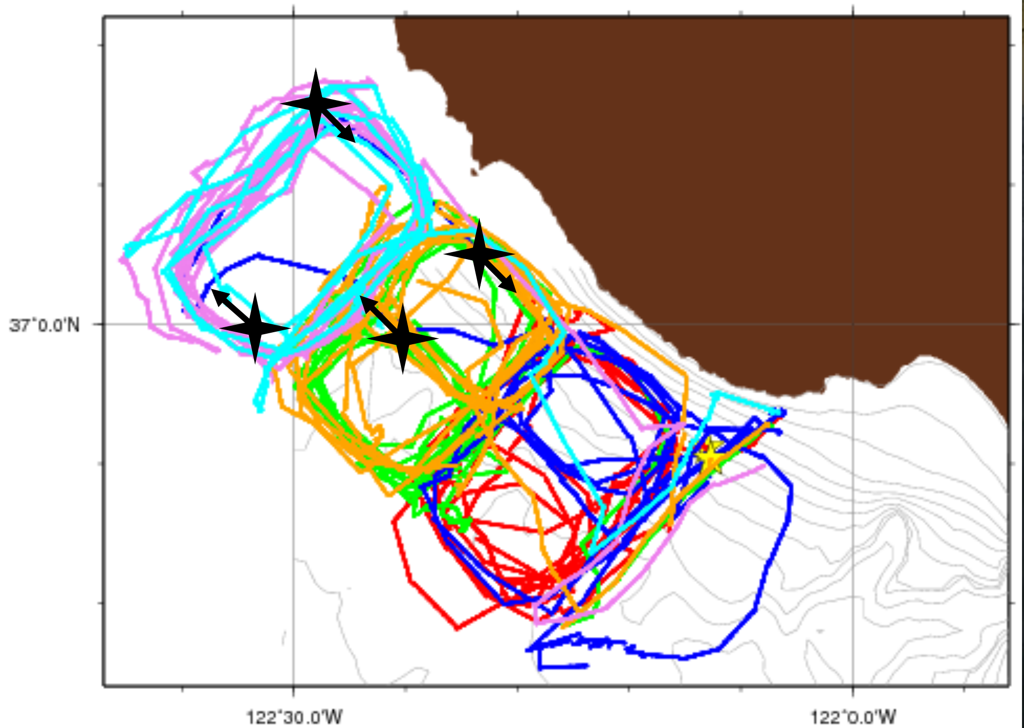
- Underwater gliders are unmanned submarines used for oceanographic data collection.
- They are propelled through the water using a buoyancy pump to descend and ascend in a vertical zigzag motion. (No propeller!)
- The high efficiency of the passive propulsion system allows for long-duration missions at an effective speed of 25 cm/s through the water.



- An onboard feedback control system is implemented to generate and follow a set of waypoint tracks that coordinate the motion of a fleet of gliders.

Glider Coordinated Control System (GCCS)

The GCCS is a detailed planning and prediction model, developed by Dr. Derek Paley, for the autonomous operation and control of a fleet of underwater gliders along a set of coordinated trajectories.

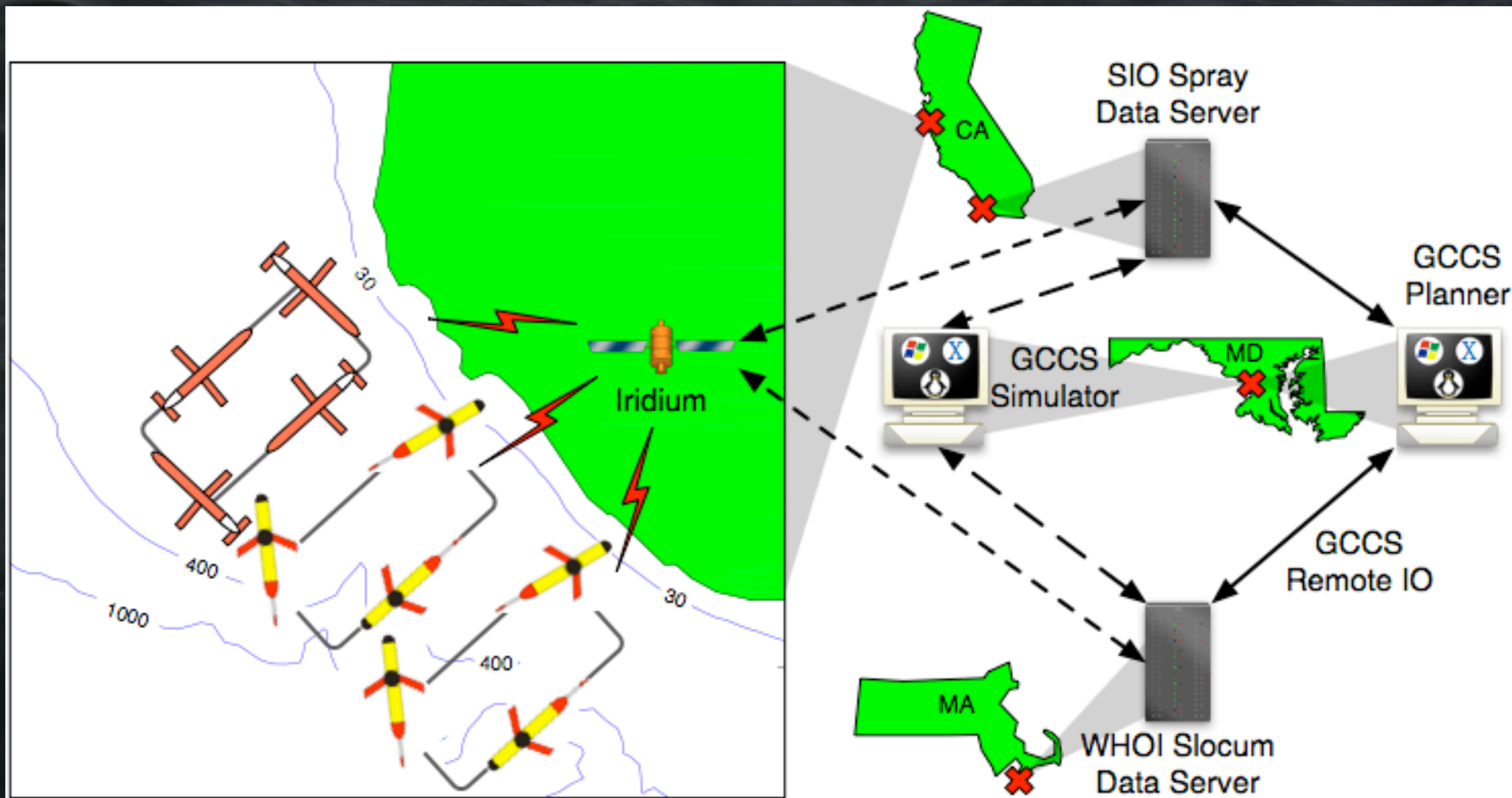


Coordinated glider trajectories from a 2006 glider deployment in Monterey Bay, CA. Led by Dr. David Fratantoni, Woods Hole Oceanographic Institution.

- Glider simulations
- Glider field deployments

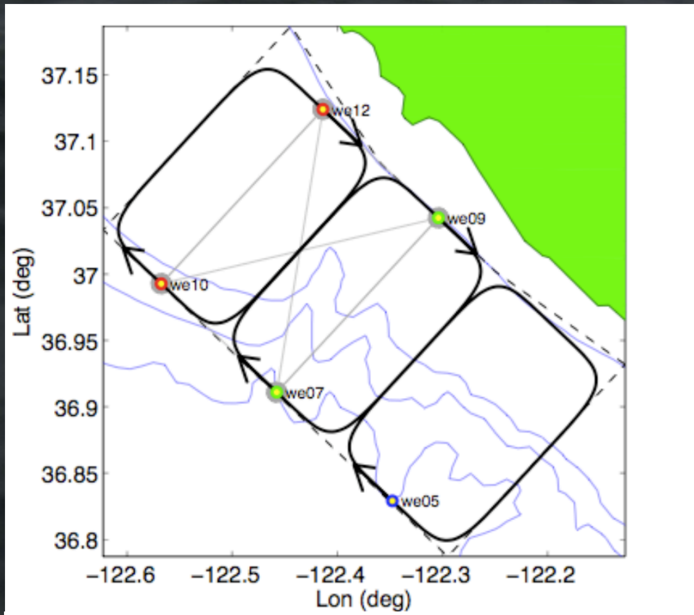
- Optimizes data collected by coordinating the trajectories and positions of multiple gliders in an area
  - Covers the greatest area
  - Avoids overlapping data that occurs when gliders cross paths

GCCS Network

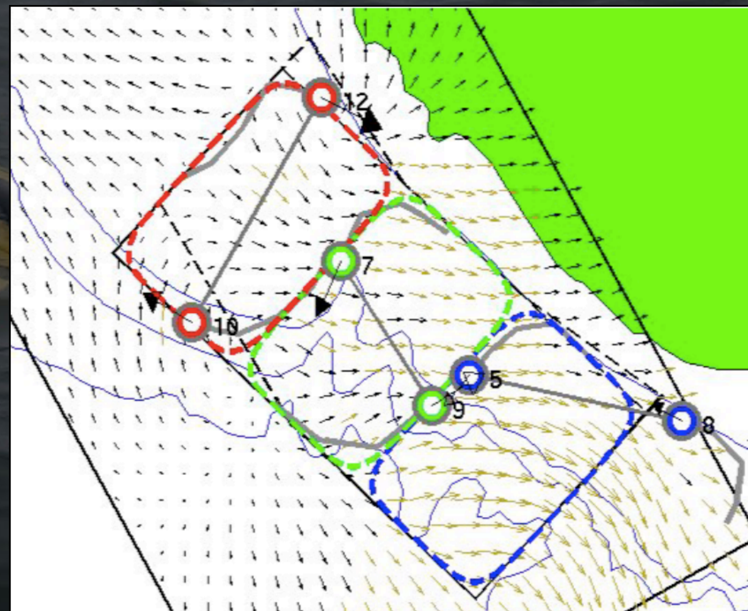


Credit: Dr. Derek Paley

Coordinated Glider Motion

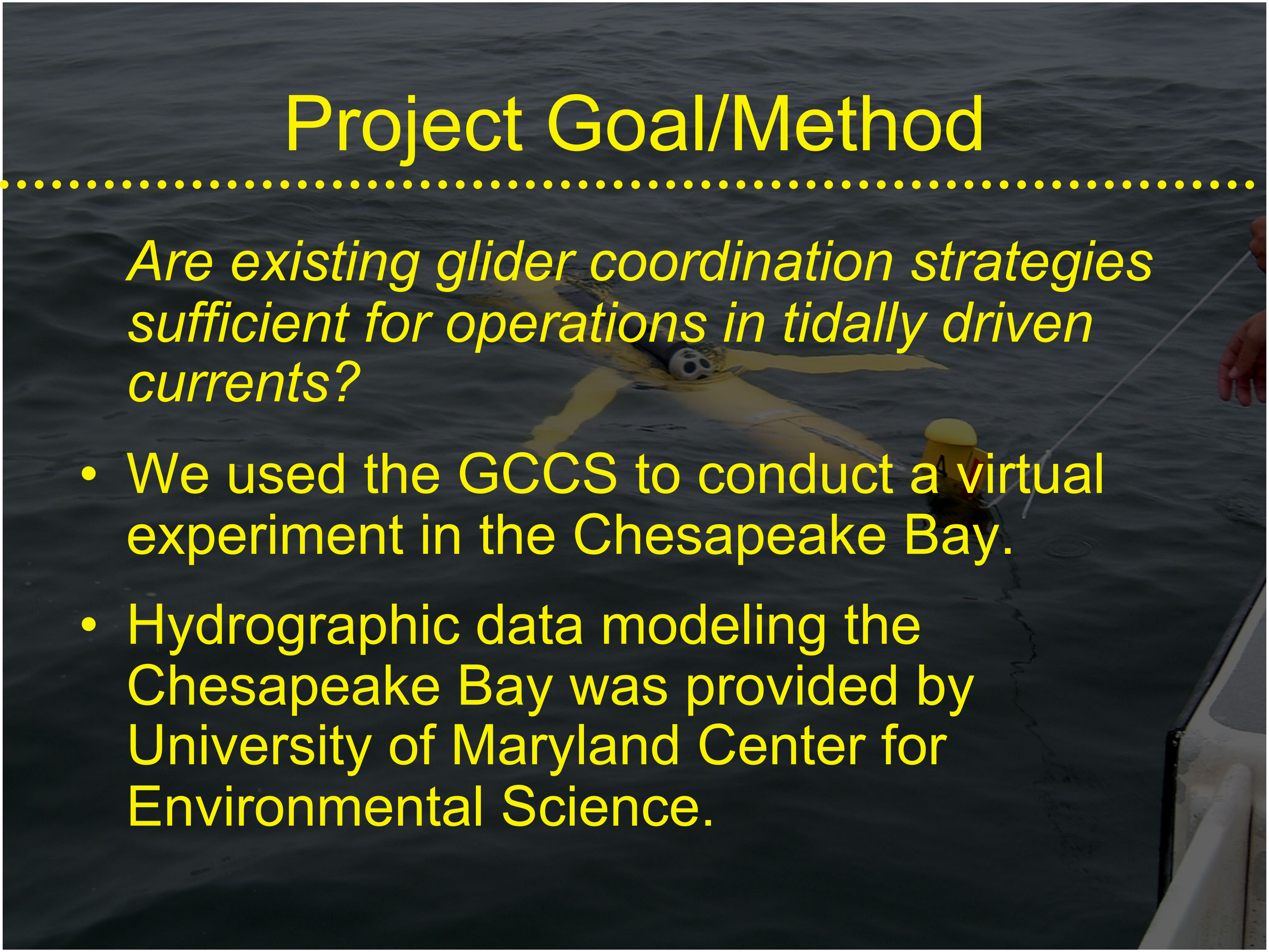


Fully coordinated gliders in benign flow. (Derek Paley)

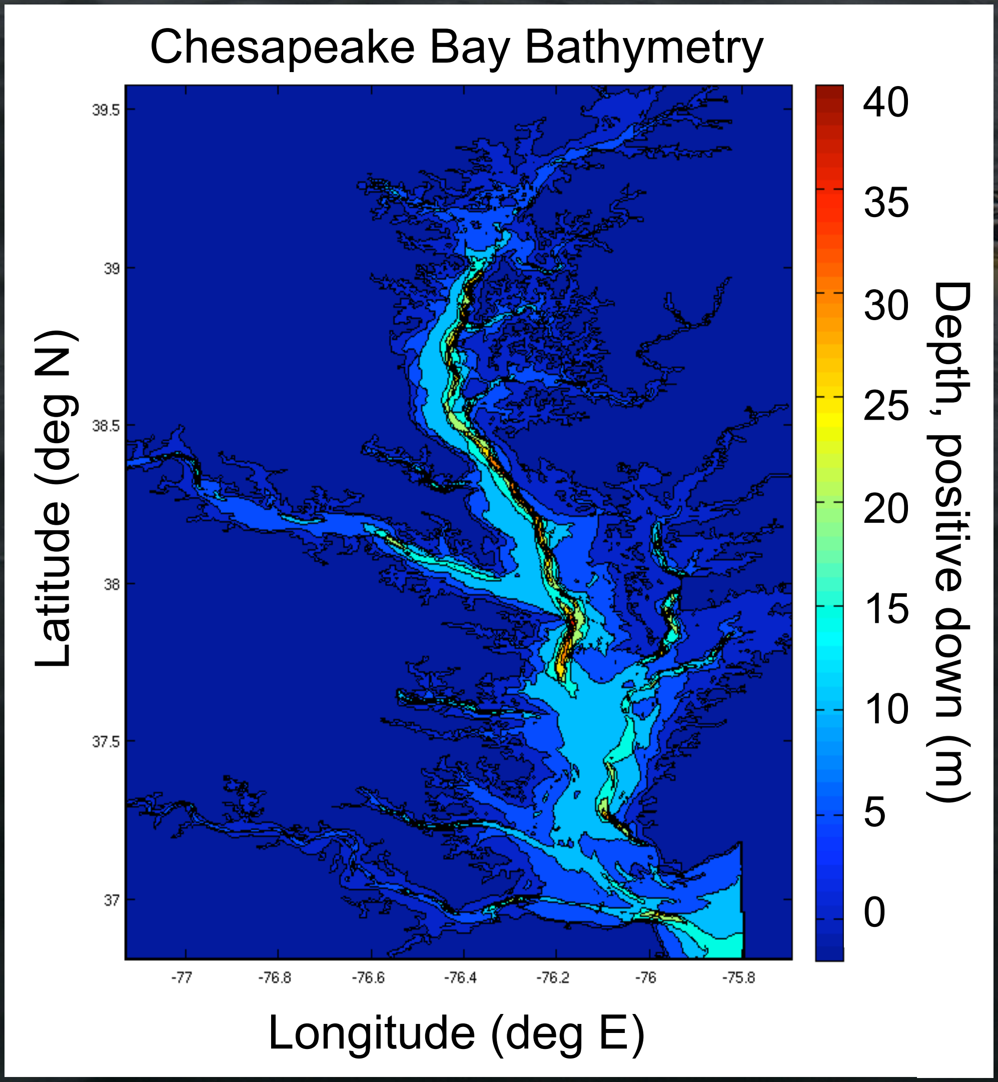


Degradation of glider coordination in the presence of currents. (Derek Paley)

- Existing glider coordination strategies work well in benign flows.
- However, glider coordination degrades in the presence of strong and variable currents.


Project Goal/Method
Are existing glider coordination strategies sufficient for operations in tidally driven currents?
• We used the GCCS to conduct a virtual experiment in the Chesapeake Bay.
• Hydrographic data modeling the Chesapeake Bay was provided by University of Maryland Center for Environmental Science.

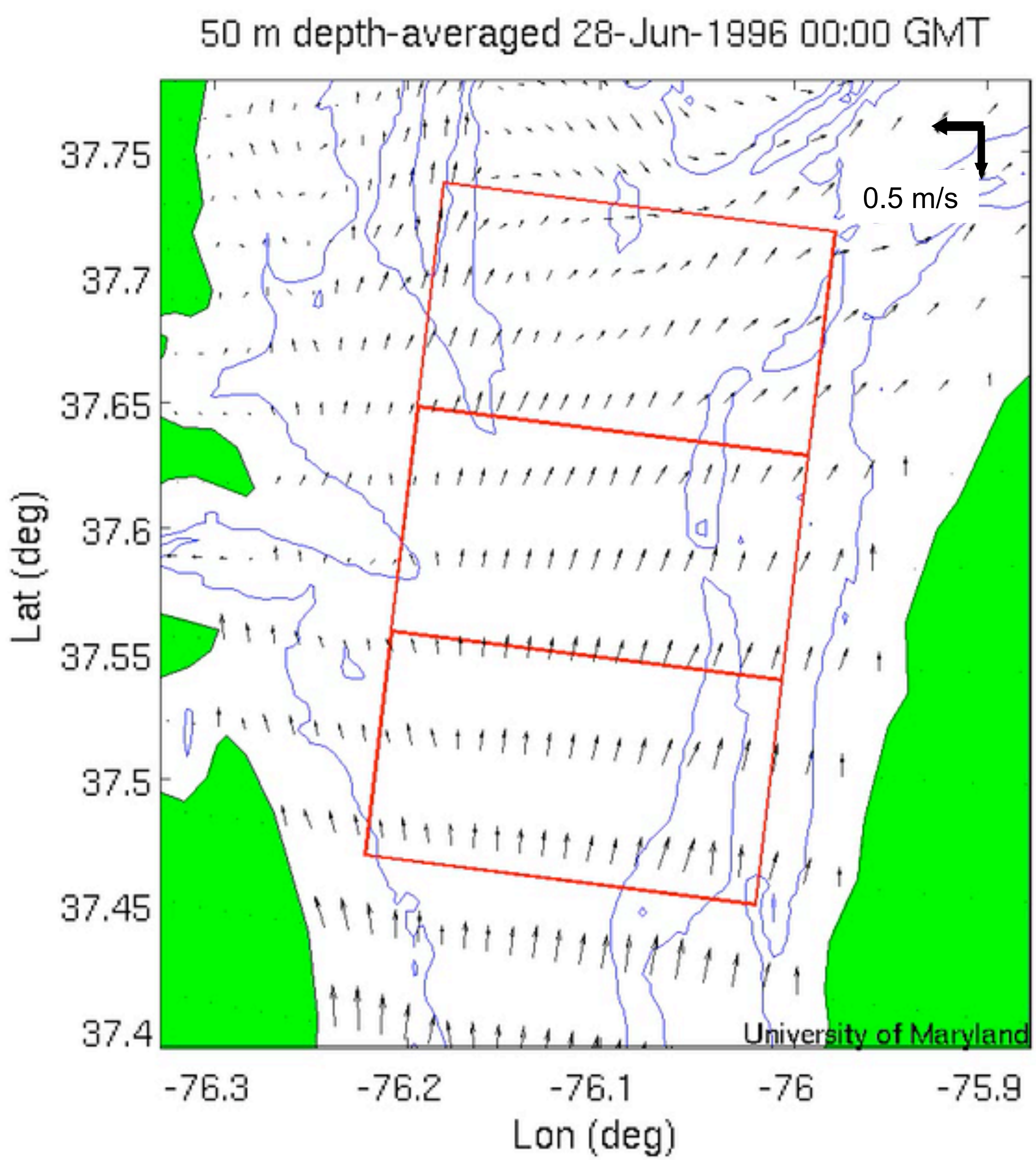
Chesapeake Bay (CB) Properties



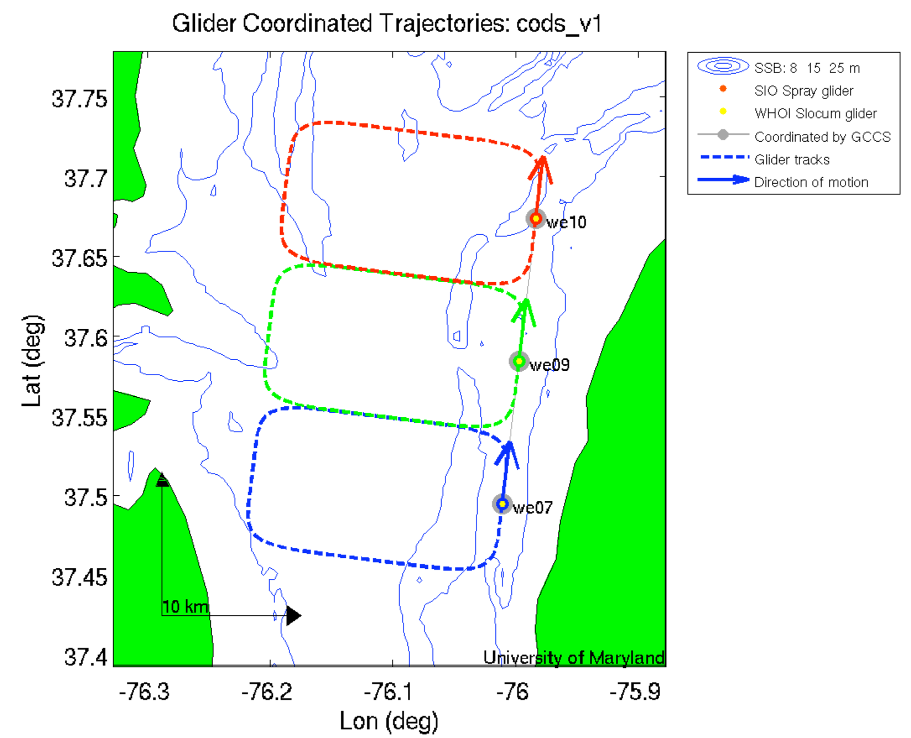
- Semidiurnal tidal flow
  - Period of approximately one-half of a tidal day (24 hours and 50 minutes)
  - Two high waters and two low waters each tidal day
- River tributaries feed the Bay, which empties into the Atlantic Ocean
- Long and narrow
- Shallow (mostly < 25 m deep, 50 m max depth)
- Strong tides up to about 77 cm/s (~2.5 ft/s)

CB Sampling Area

- Data gathered at UMCES using the Remote Ocean Monitoring System
- 28 June, 1996 - 7 July, 1996
- Southern region of CB
  - Larger area to sample
  - Much of the Bay is shallower than 25m deep
- Widely varying current speed and direction
  - High and low tides flow at over 50 cm/s (2x glider speed!)
- Simulating deployment of a 3-glider fleet
- Helpful for planning virtual experiments

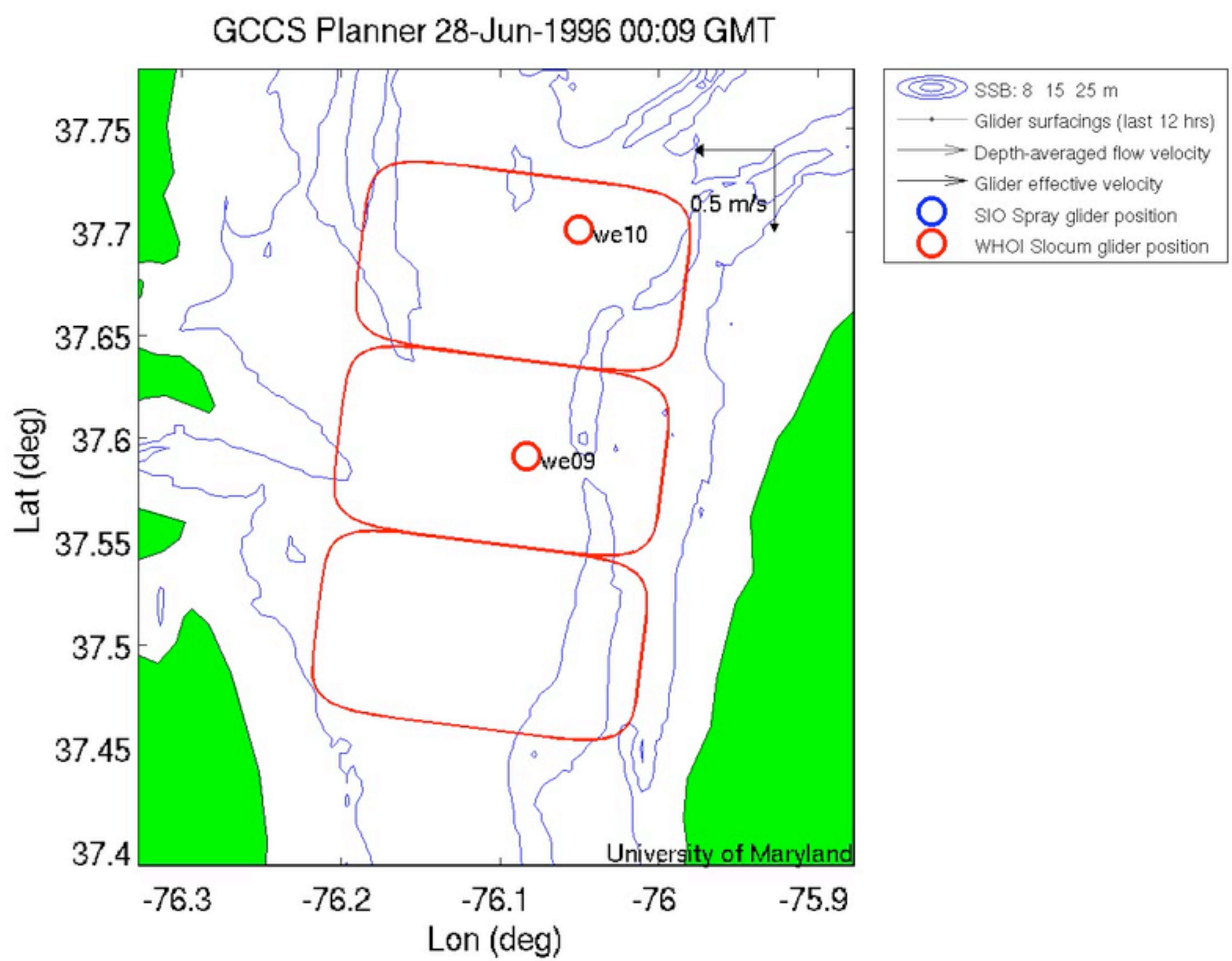

50 m depth-averaged 28-Jun-1996 00:00 GMT
0.5 m/s
Lat (deg)
37.75
37.7
37.65
37.6
37.55
37.5
37.45
37.4
Lon (deg)
-76.3
-76.2
-76.1
-76
-75.9
University of Maryland

Simulated Deployment



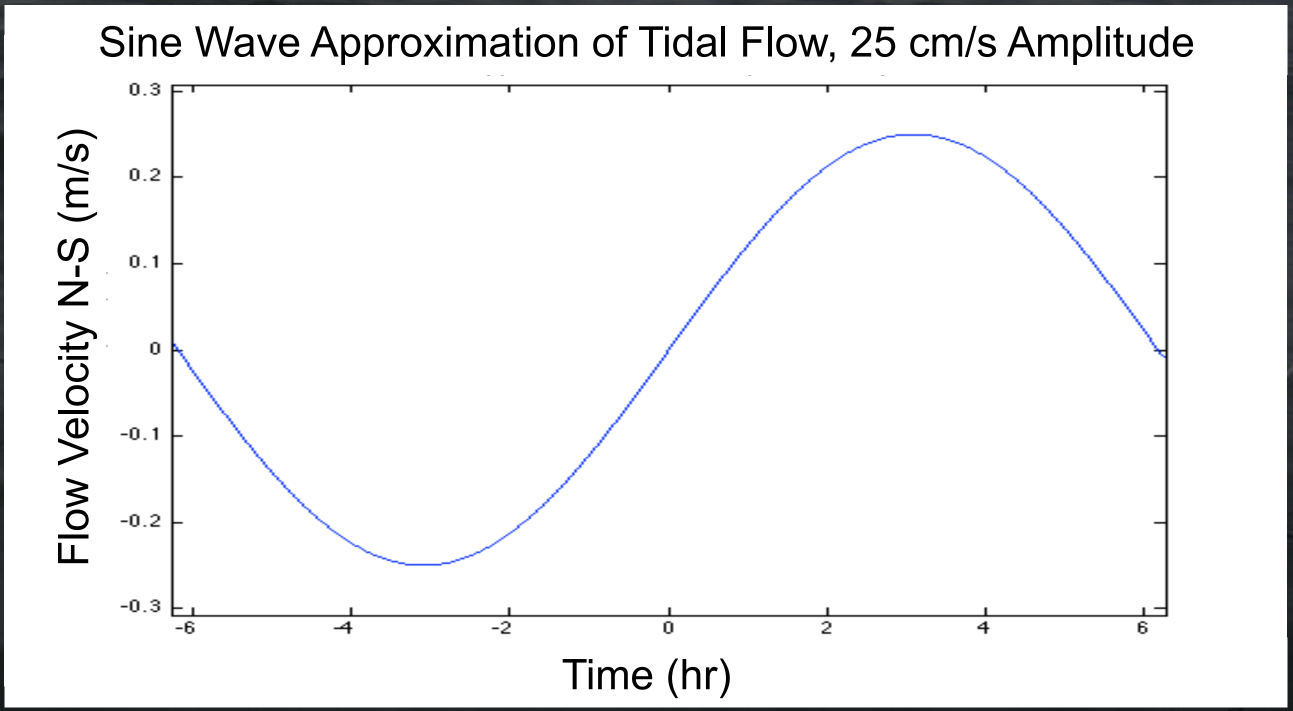
Three gliders coordinated along parallel tracks in the Chesapeake Bay.

- 10-day deployment in the Chesapeake Bay
- Incorporating actual tidal flow from the bay



GCCS Planner 28-Jun-1996 00:09 GMT
SSB: 8 15 25 m
Glider surfacings (last 12 hrs)
Depth-averaged flow velocity
Glider effective velocity
SIO Spray glider position
WHOI Slocum glider position
0.5 m/s
we10
we09
University of Maryland
Lat (deg)
Lon (deg)
37.75
37.7
37.65
37.6
37.55
37.5
37.45
37.4
-76.3
-76.2
-76.1
-76
-75.9

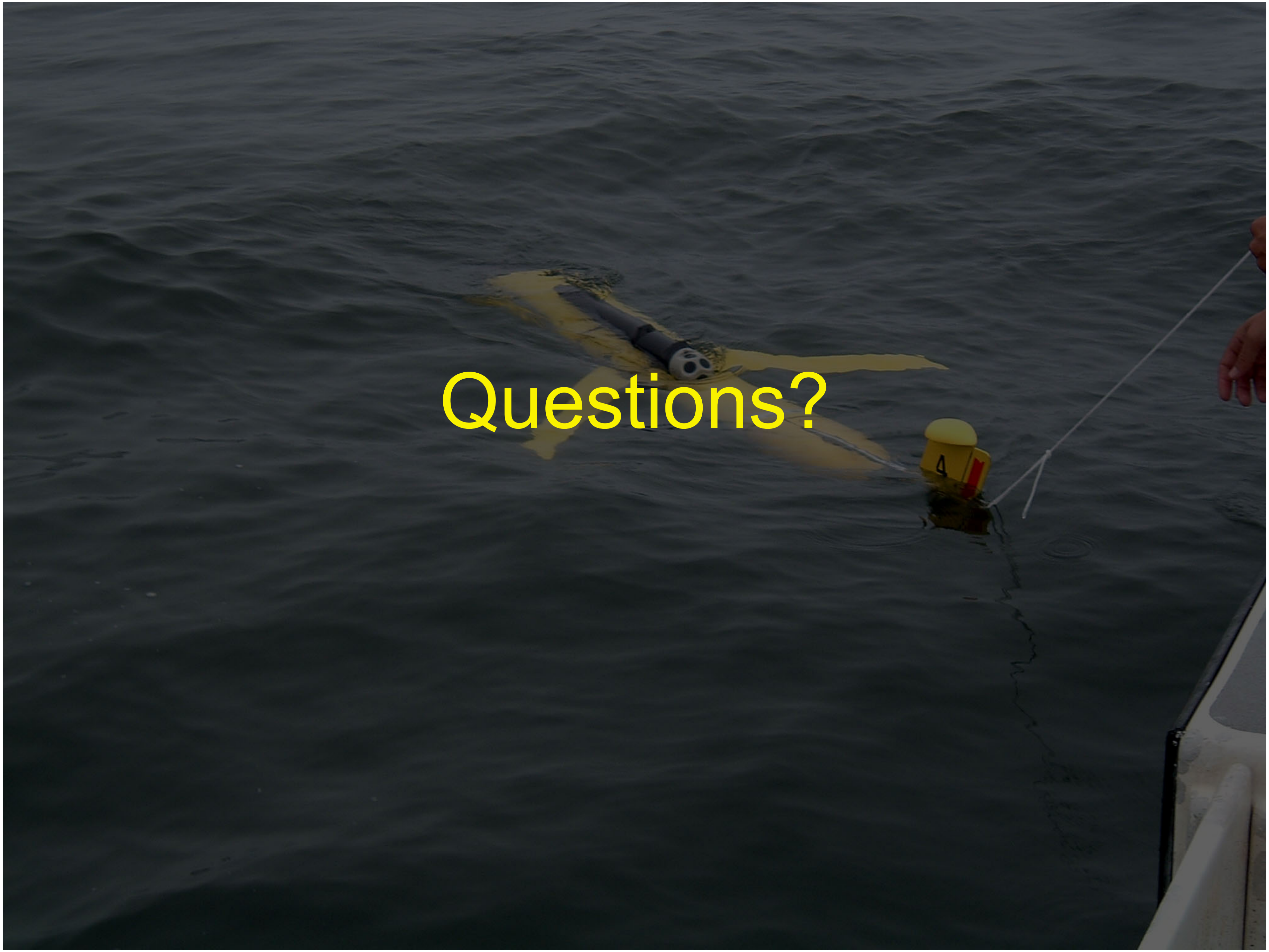
Perfect Sinusoidal Tidal Flow



- Constant-amplitude sinusoidal wave to approximate CB tides (not very accurate)
- Vary amplitudes

Results & Conclusions

- We cannot accurately simulate CB flow with a constant amplitude semidiurnal tidal flow due to wide variations in actual CB tide amplitudes.
- Tidal flows exceeding 50 cm/s push the gliders significantly off course and out of synchronization.
- This project illustrates a limitation of the glider coordination strategy.
- Also motivates the design of new strategies to handle strong and variable currents.


Questions?

References

- D. Paley. “Cooperative Control for Ocean Sampling: The Glider Coordinated Control System,” IEEE Transactions on Control Systems Technology. July 2007.
- D. Fratantoni. ASAP0806 Field Experiment in Monterey Bay, CA. Woods Hole Oceanographic Institution. August 2006. < http://asl.whoi.edu/research/gods/gods_index.html>