Expanding autonomy: Integrating data streams to optimize glider sampling

Catherine R. Edwards

Skidaway Institute of Oceanography,
University of Georgia

Dongsik Chang, Klimka Szwaykowska
Mengxue Hou, Qiuyang Tao, Tony Lin, Fumin Zhang
Georgia Institute of Technology

Collaborators at NRL, SeaTrec/UCLA,
MBARI, Rutgers, others

SECOORA
Southeast Coastal Ocean Observing Regional Association

IOOS

Strategies for optimized sampling

Reduce operational burden

Enable longer/multi-platform studies

Increases value of observations

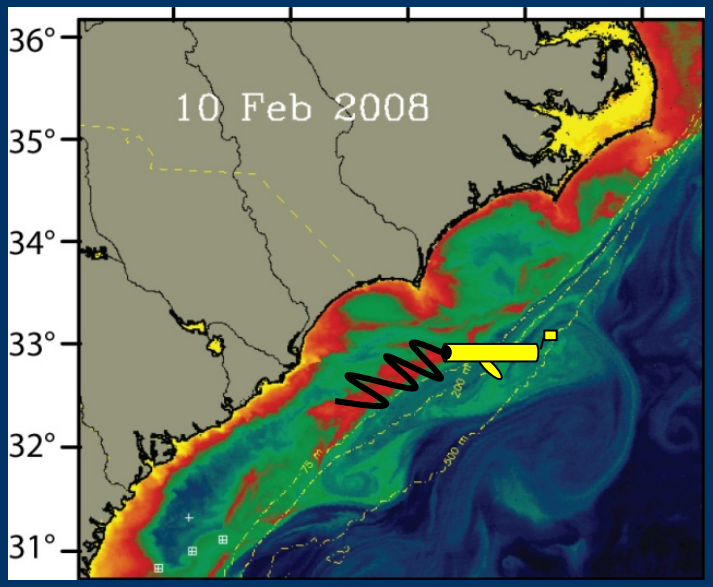
General model for adaptive AUV control

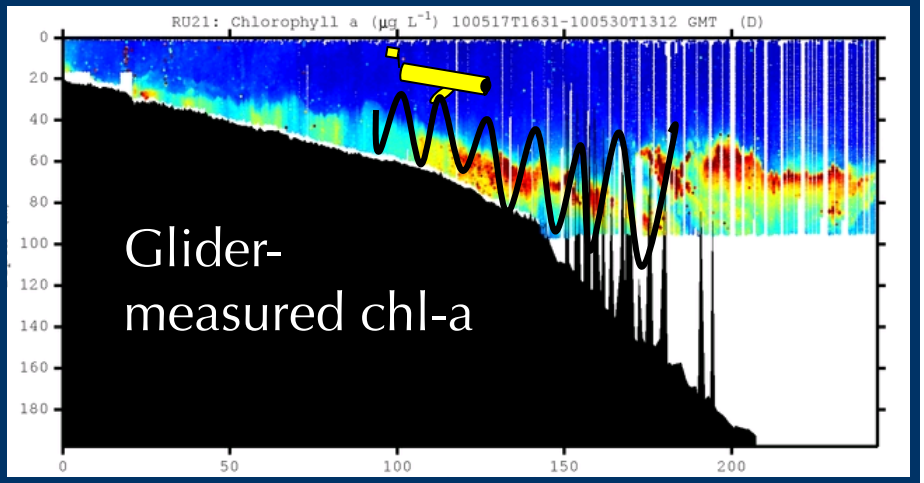
Decision-making based on:

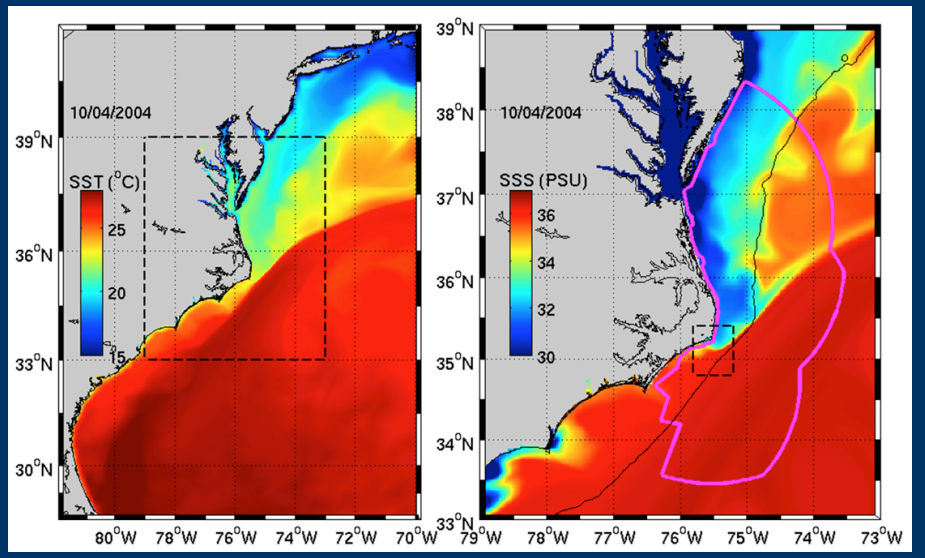
Predictive model (operational physics-based or empirical)

Build cost function using avoidance, mapping, tracking strategies, rules to follow

Instrument information



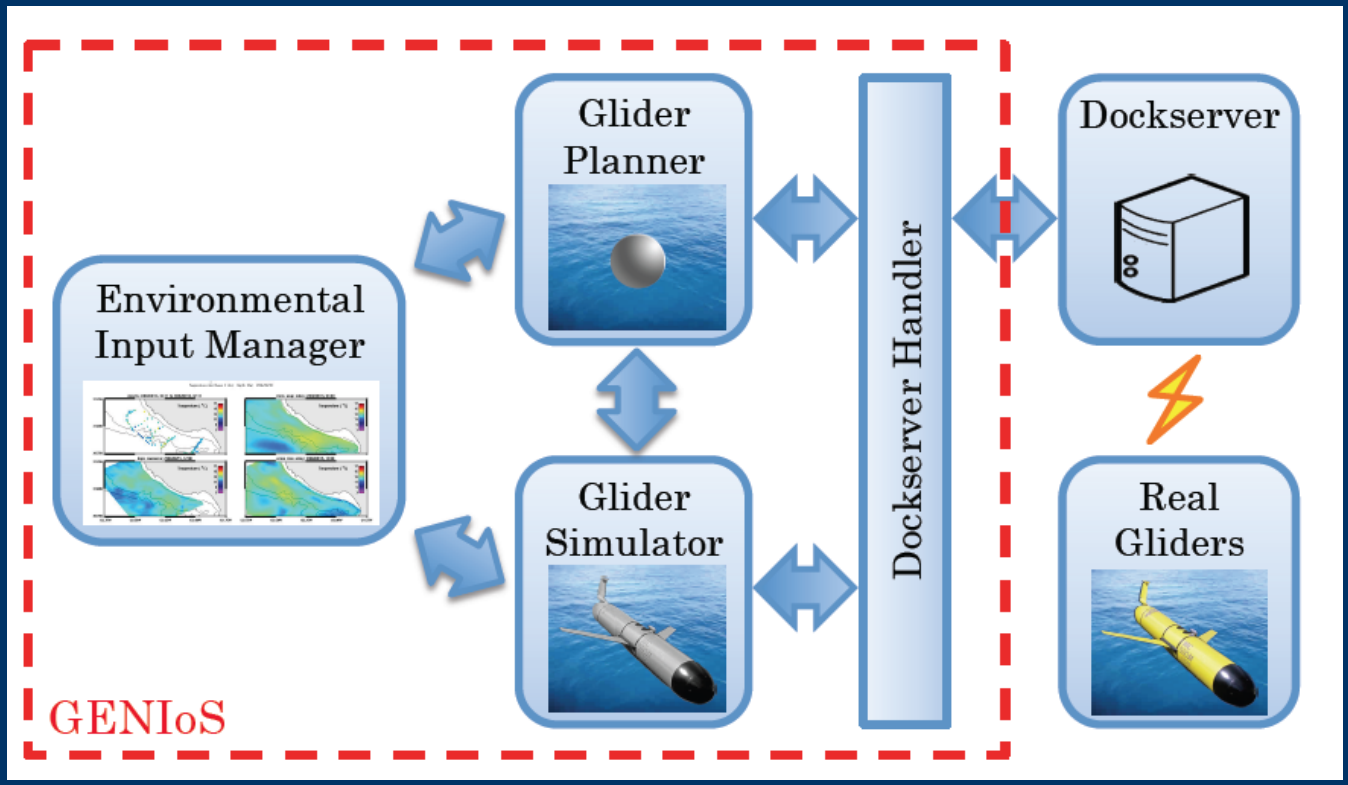




Glider Environment Network Information System (GENIoS)

Adaptive control optimizes glider's path given:

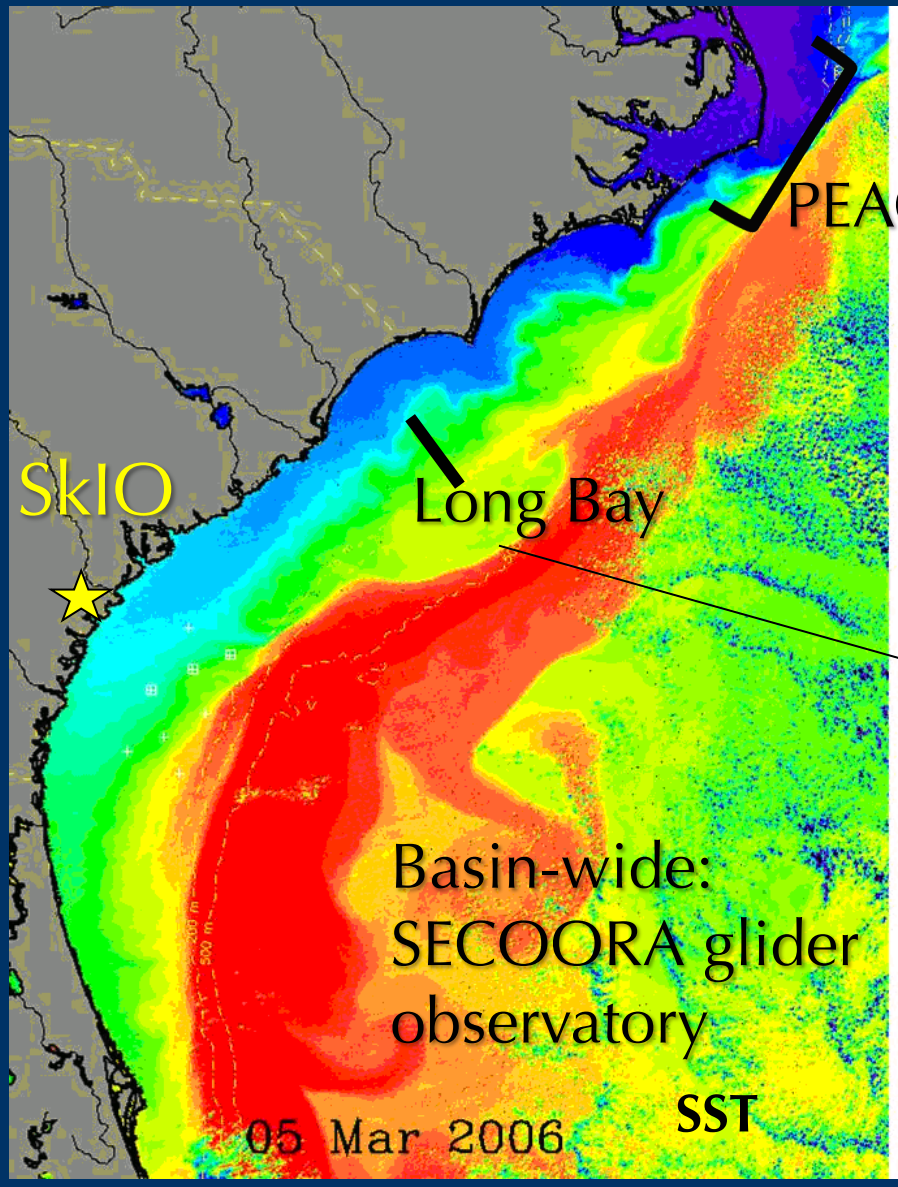
- Initial position
- Desired location
- Glider mission, goals
- Forecasts from operational ocean models
- Real-time data
- 300+ glider-days

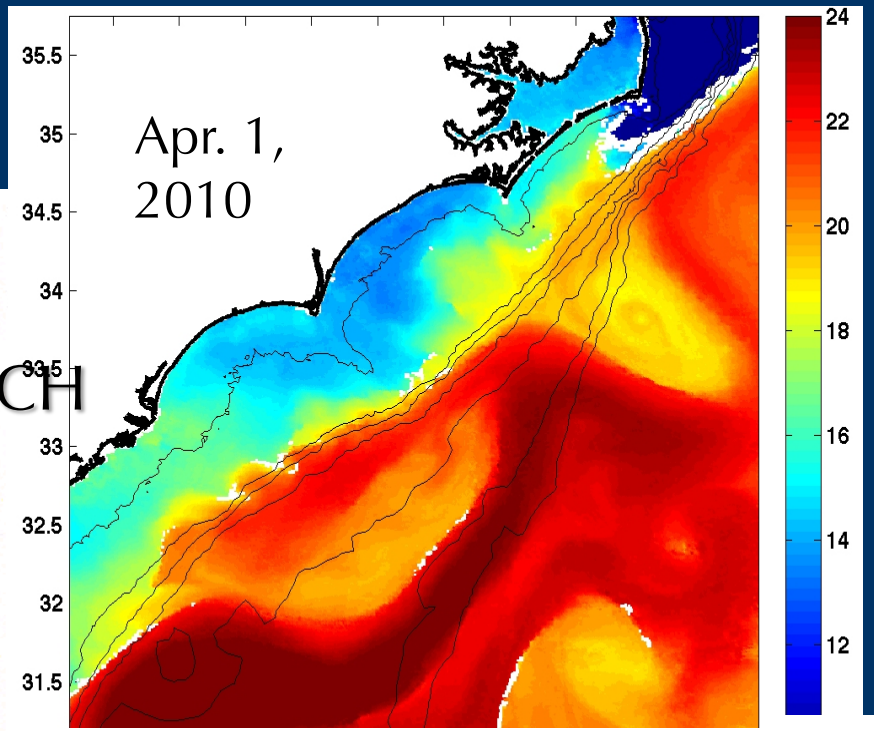


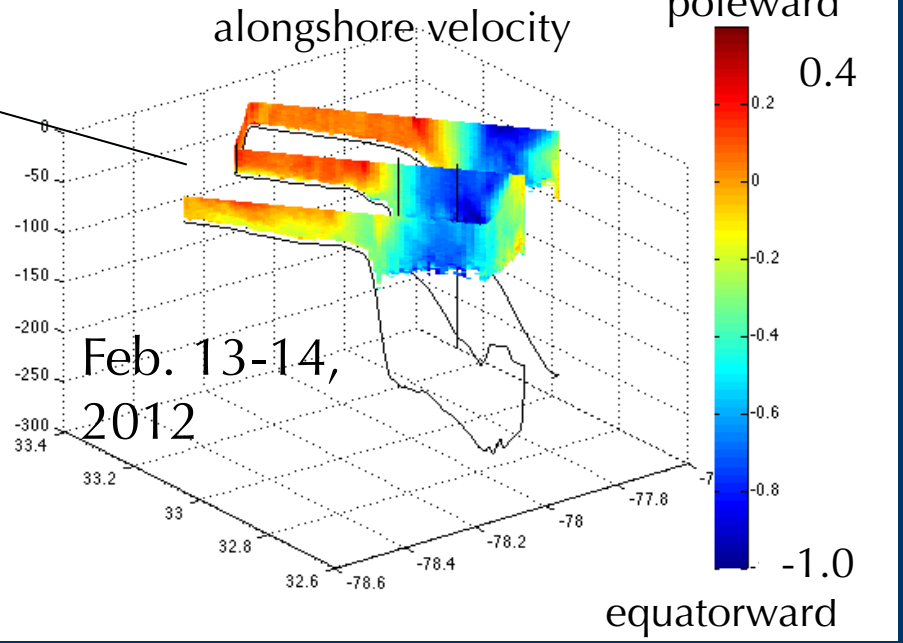
Challenge: error highly dependent on model resolution

Chang, Zhang, and Edwards, J Tech, 2015

Spatial variability







Seim and Edwards, 2019

Strong currents, temporal variability

Reply Forward

From root@dockserver.marine.unc.edu <root@dockserver.marine.unc.edu>

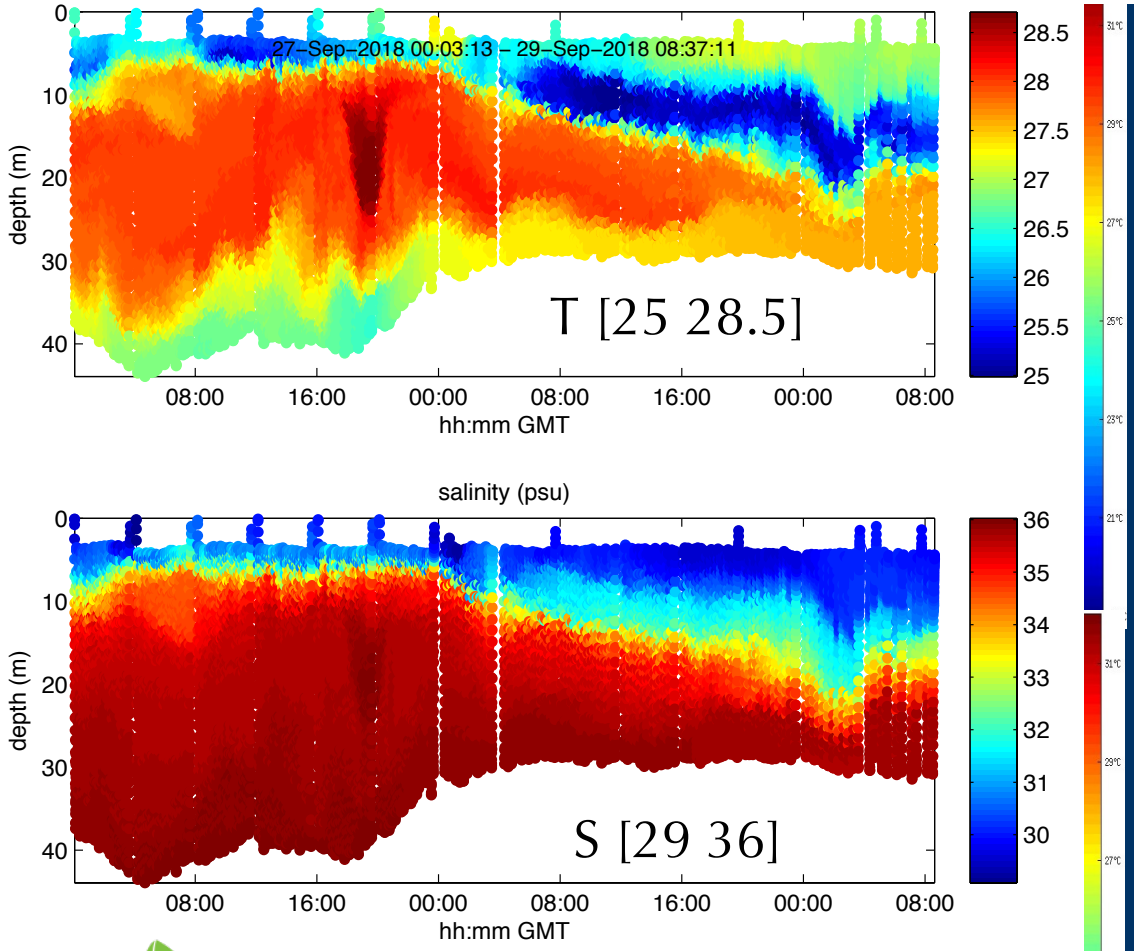
Subject **Glider: pelagia Event: Glider connects to dock server Reason: timeout expired**

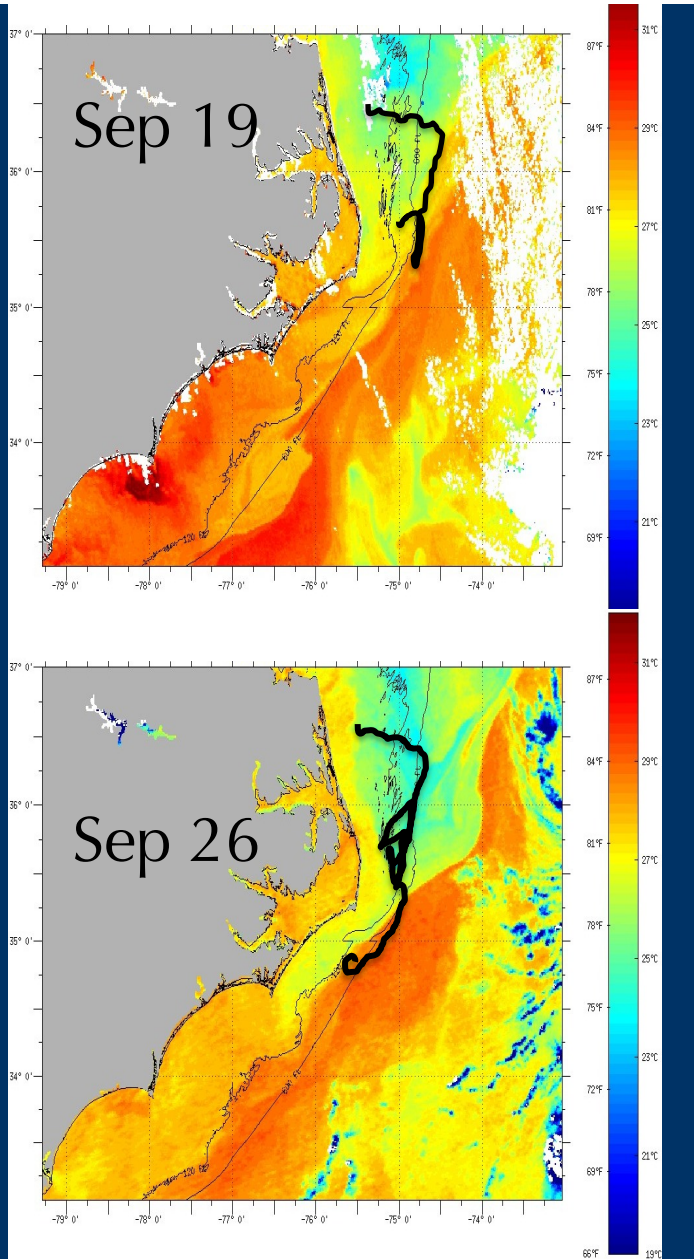
To Catherine R. Edwards

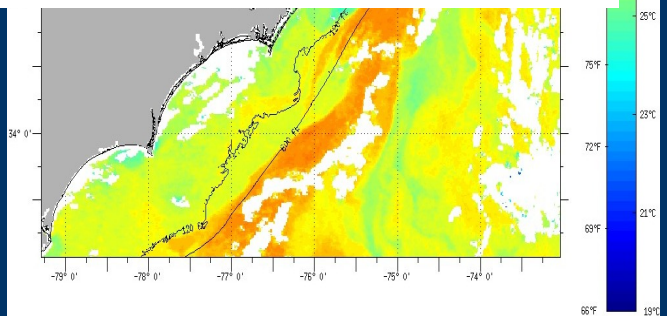
```
  2199    Iridium console active and ready...
Vehicle Name: pelagia
Curr Time: Thu Mar  8 12:39:29 2012 MT:    2199
DR  Location:  3417.640 N -7602.684 E measured     46.804 secs ago
GPS TooFar:    3412.167 N -7607.295 E measured     1e+308 secs ago
GPS Invalid :  3417.457 N -7602.891 E measured    148.804 secs ago
GPS Location:  3417.640 N -7602.684 E measured     49.228 secs ago
   sensor:m_battery(volts)=10.2791328821168        58.757 secs ago
   sensor:m_dr_time(sec)=-1                         3.453 secs ago
   sensor:m_gps_lat(lat)=3417.6401                 49.601 secs ago
   sensor:m_gps_lon(lon)=-7602.684                 49.676 secs ago
   sensor:m_iridium_signal_strength(nodim)=5       15.246 secs ago
   sensor:m_lat(lat)=3417.64010004661               47.41 secs ago
   sensor:m_leakdetect_voltage(volts)=2.4956043956044     59.069 secs ago
   sensor:m_lon(lon)=-7602.68400000071             47.528 secs ago
   sensor:m_mission_start_time(timestamp)=1331208169     1e+308 secs ago
   sensor:m_present_time(timestamp)=1331210368.00839      1.825 secs ago
   sensor:m_water_vx(m/s)=1.70833264681386          52.88 secs ago
   sensor:m_water_vy(m/s)=1.15173575306477         52.937 secs ago
```

Chang, Edwards, and Zhang, 2015

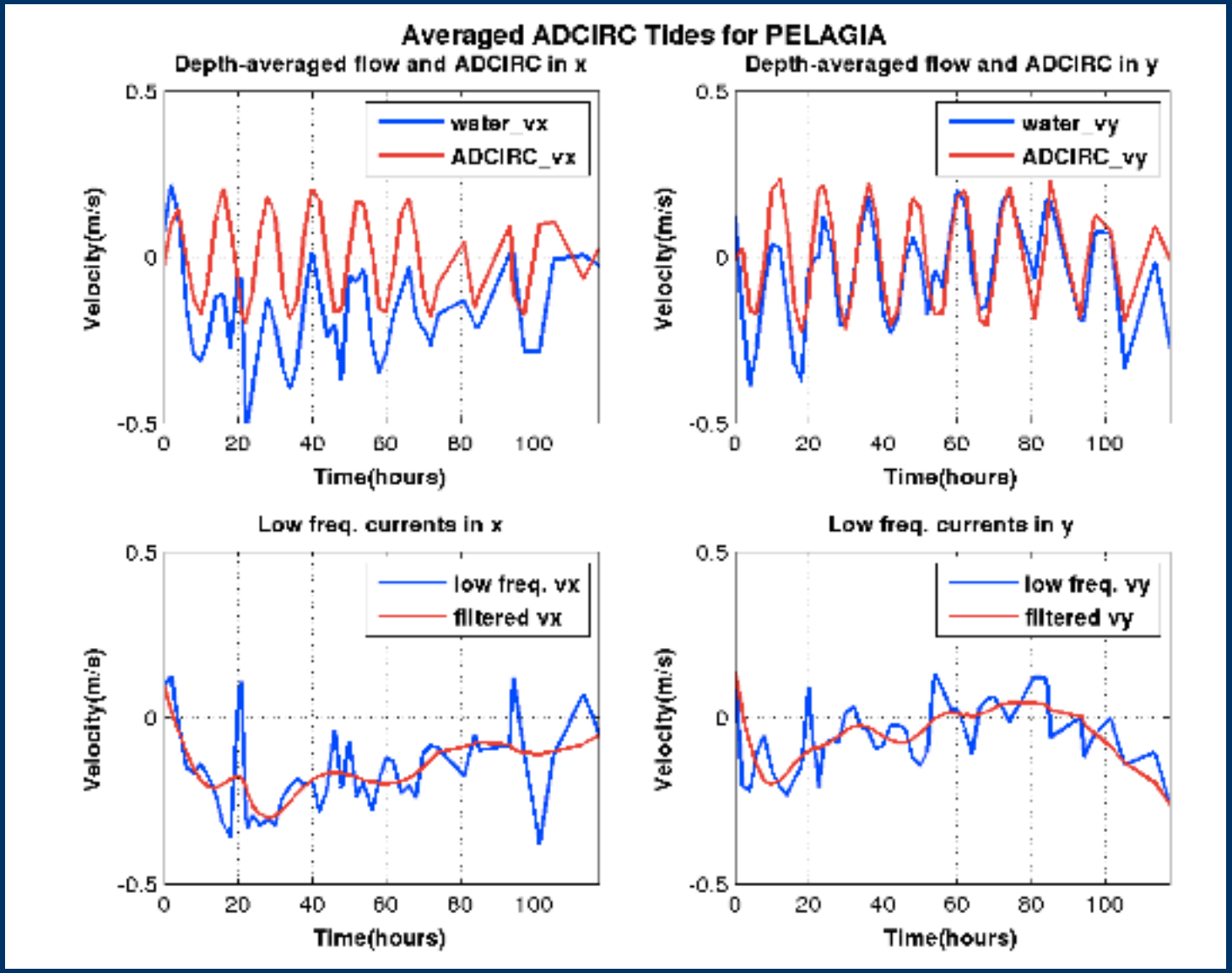
Strong gradients = features of interest





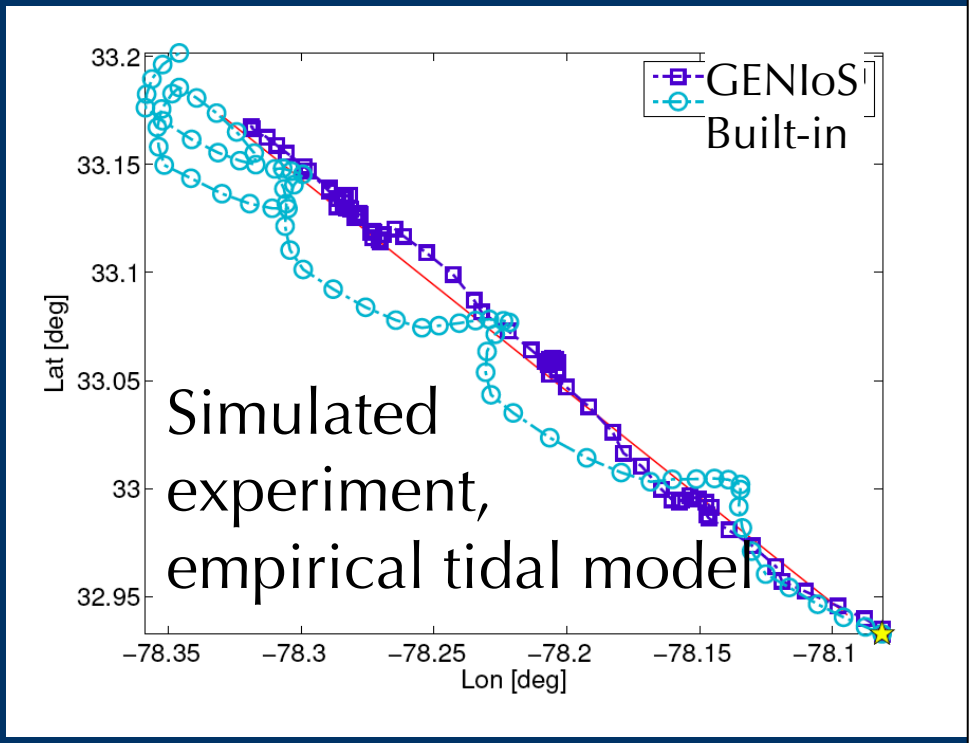


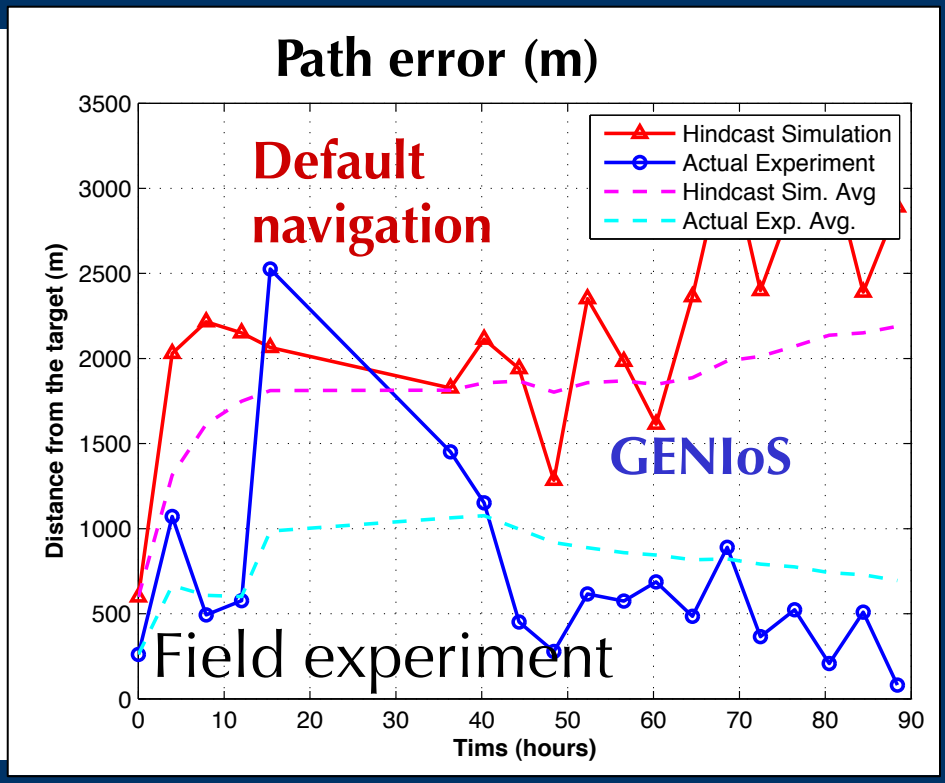
ADCIRC feedback control



ADCIRC: 2d-depth integrated finite element barotropic tidal model

GENIoS + 1D empirical model





ADCIRC feedback control in SAB:
even 1-D empirical model >> available regional models

Chang, Zhang, and Edwards, J Tech, 2015

Challenge: lightweight 2-D model

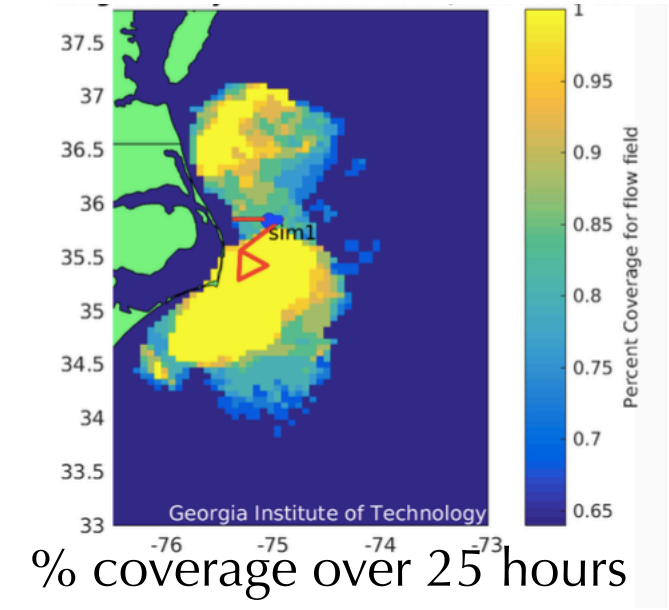
HF radar

QA/QC, data stream delays

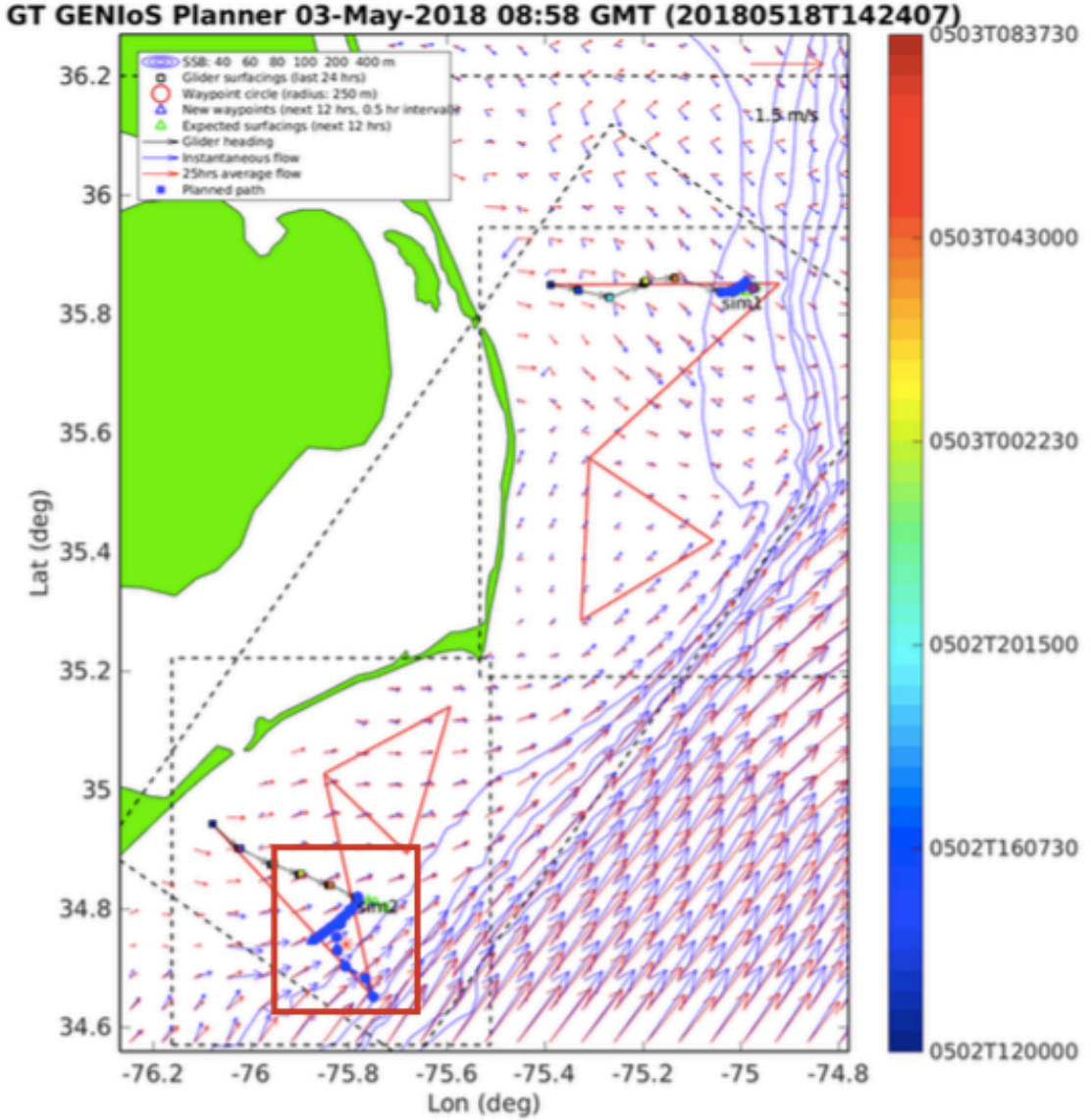
Forecasting $\bar{u}$ from maps of u_{surf}

Variable coverage

More complexity, more time



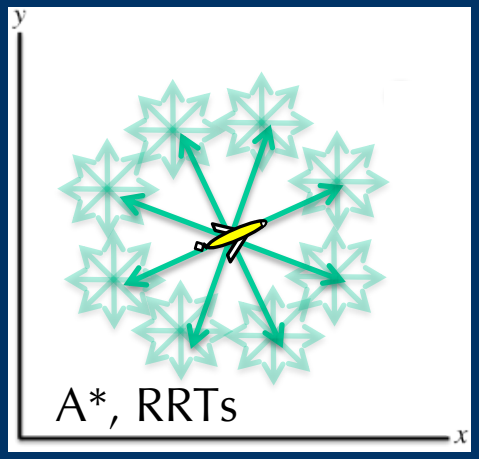
% coverage over 25 hours

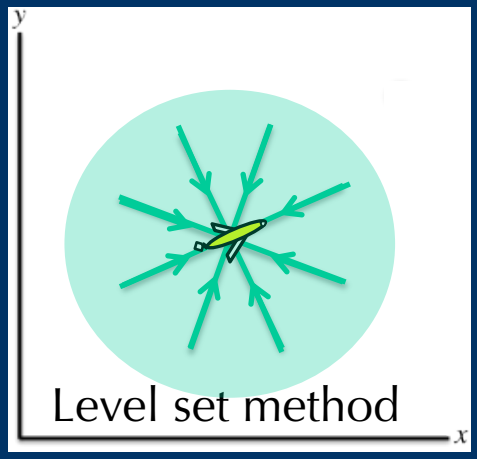


Challenge: reducing computational time

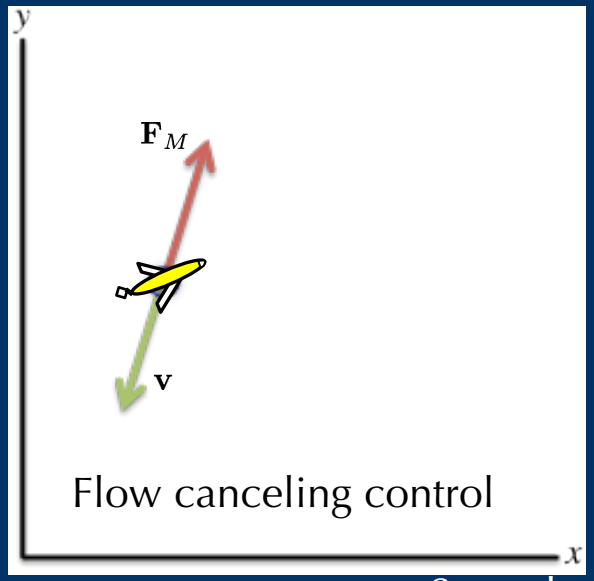
Under flow $F_M(x,y,z,t)$

Path planning chooses optimal path on $\overline{F}(x,y,z)$

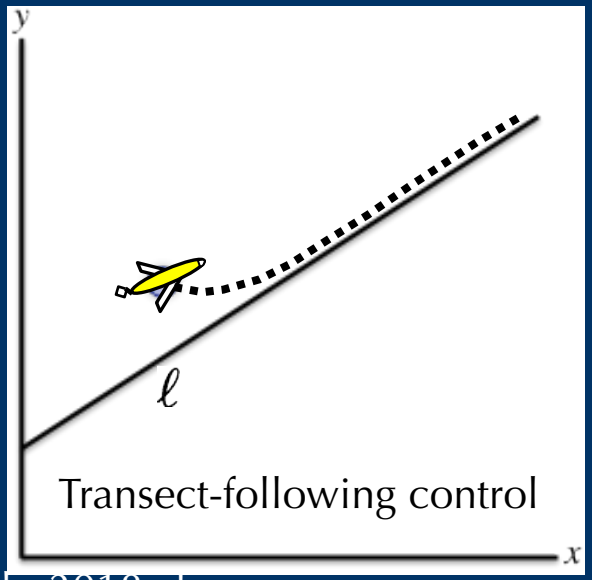




Can add obstacles



Path-following control navigates in time

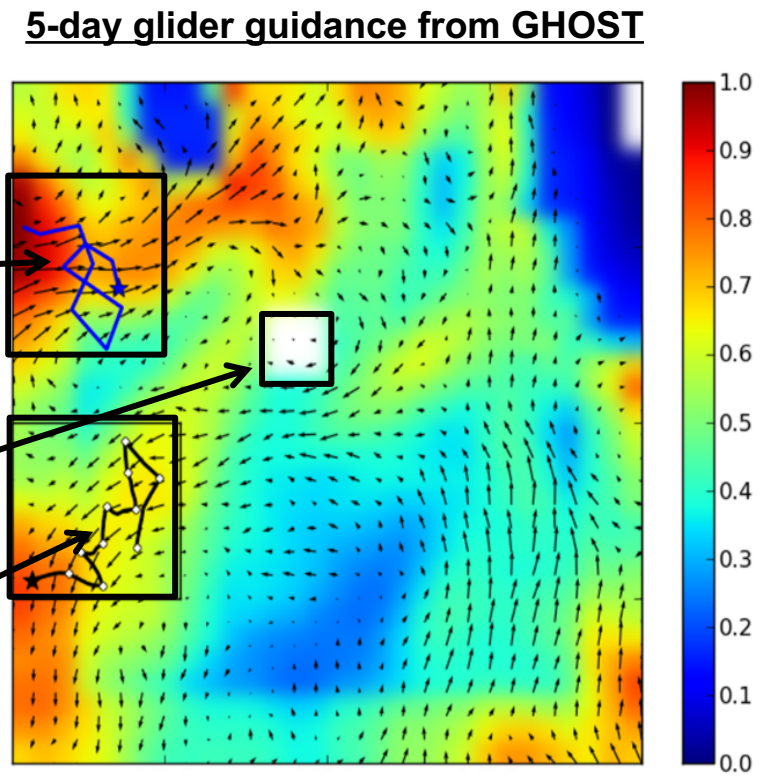


Szwaykowska et al., 2014; Hou et al., 2018a,b

GHOST: Guidance for Heterogeneous Observation Systems

L. Smedstad, C. Barron, U.S. Naval Research Laboratory

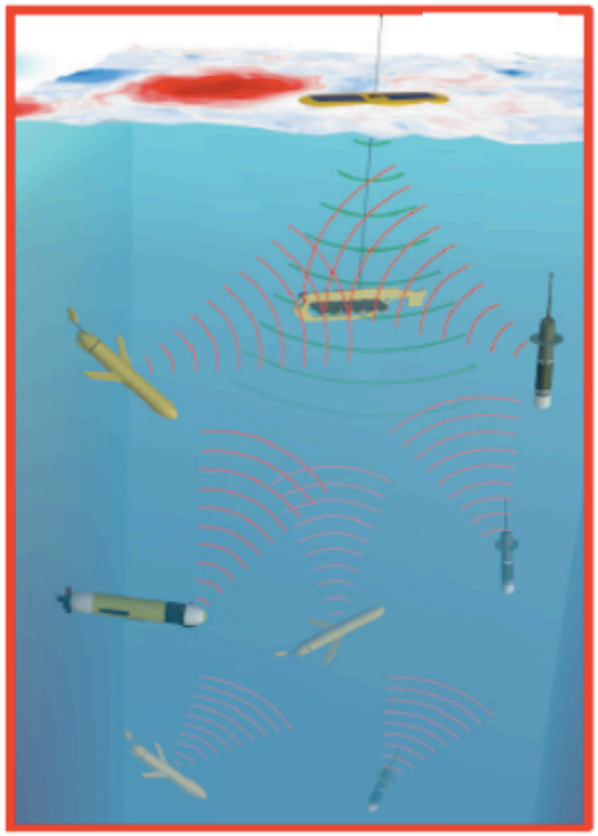
- Purpose of GHOST: To generate an automated glider observation strate that:
  - Maximizes the value of observations
  - Avoids areas where gliders are excluded
  - Provides reasonable paths to achieve present and future goals



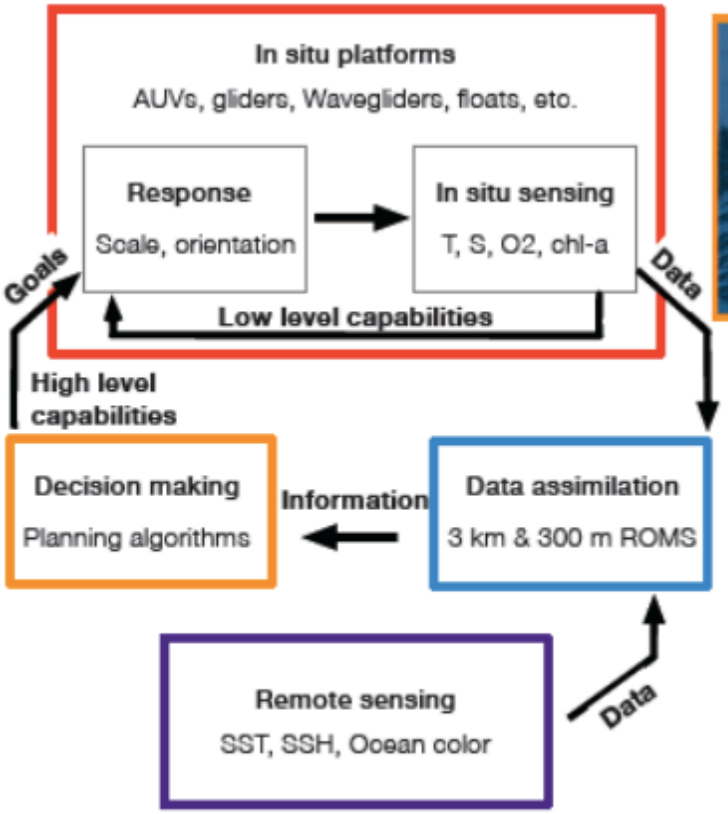
Courtesy L. Smedstad, J. Book, NRL

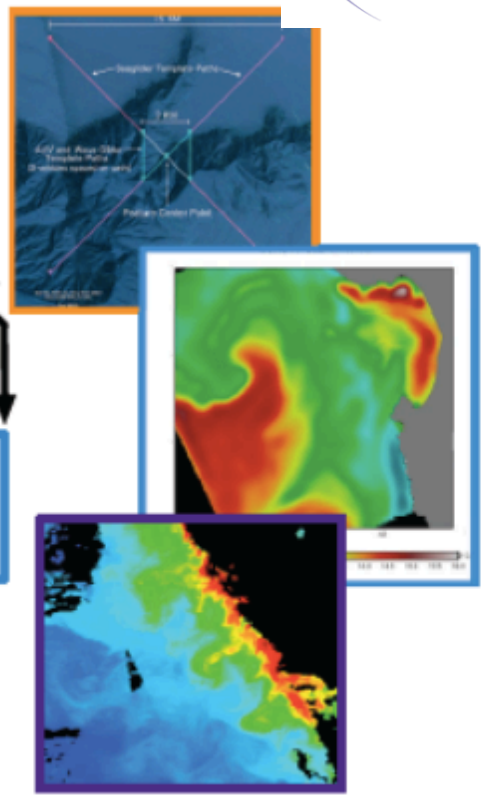
Sampling strategies: integrated data/modeling

D. Fratantoni, others at CalTech/JPL/RSS, MBARI, WHOI



Courtesy Yi Chao



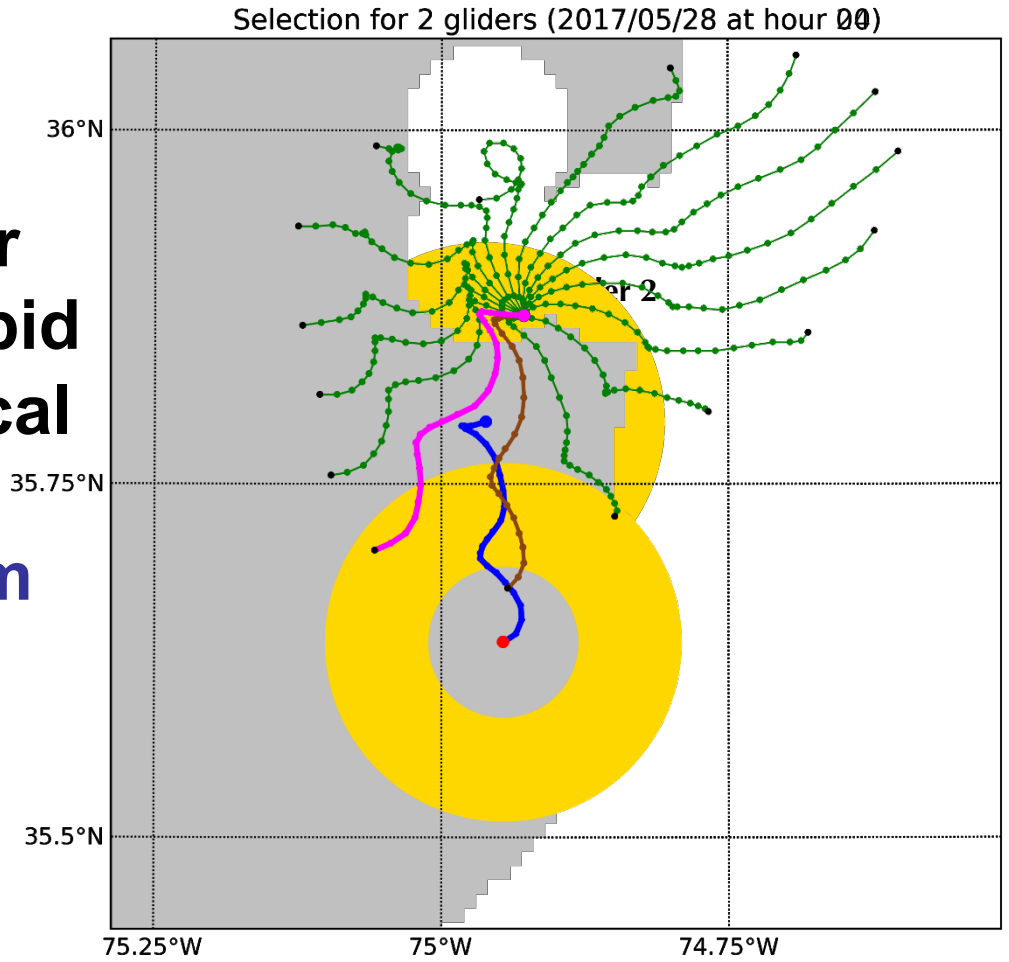


Thompson et al. 2015, 2017

Sampling strategies: Team control

Smart Glider Teams for Rapid Update of Local Analysis

GHOST Team Planning

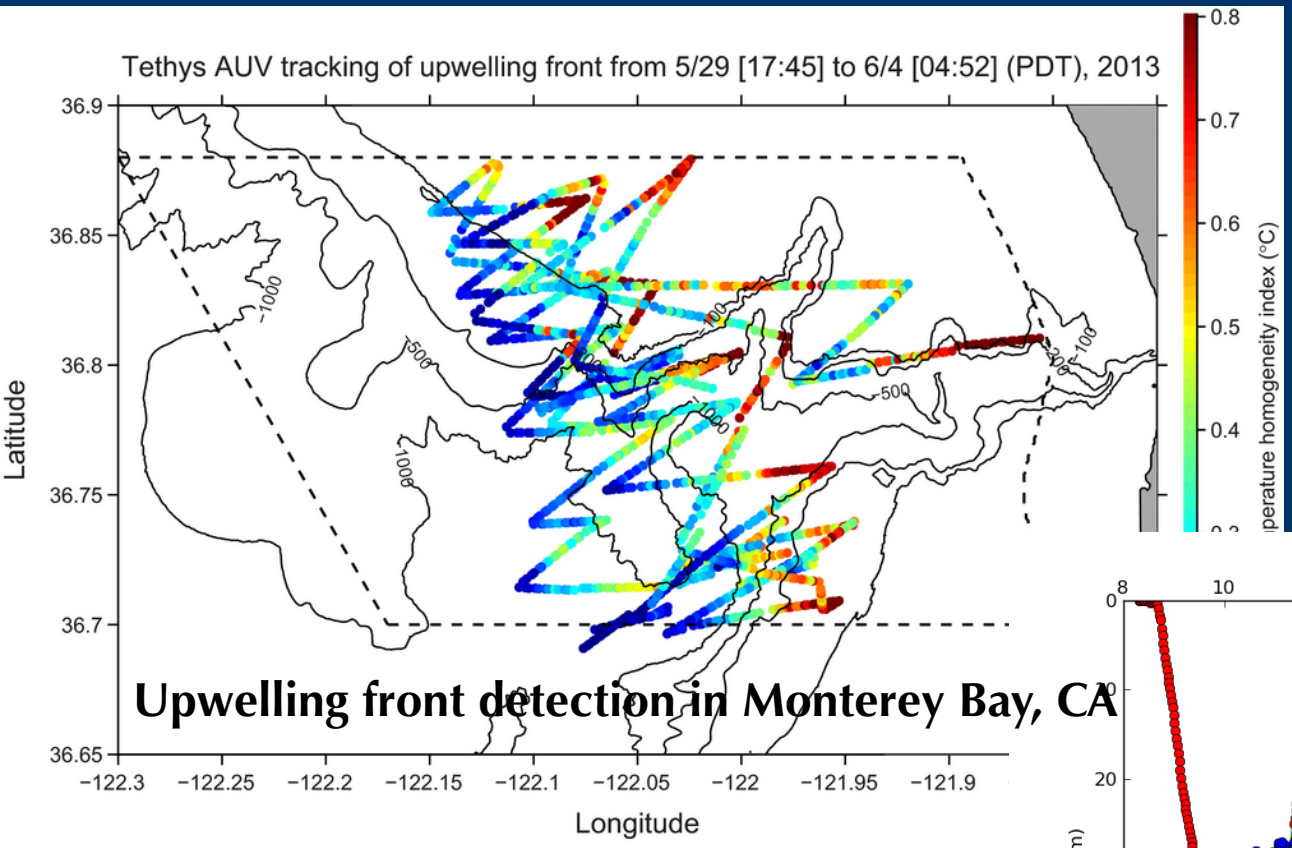


J. Book, A. Rice, J. Osborne, L. Smedstad, C. Barron, and others, NRL

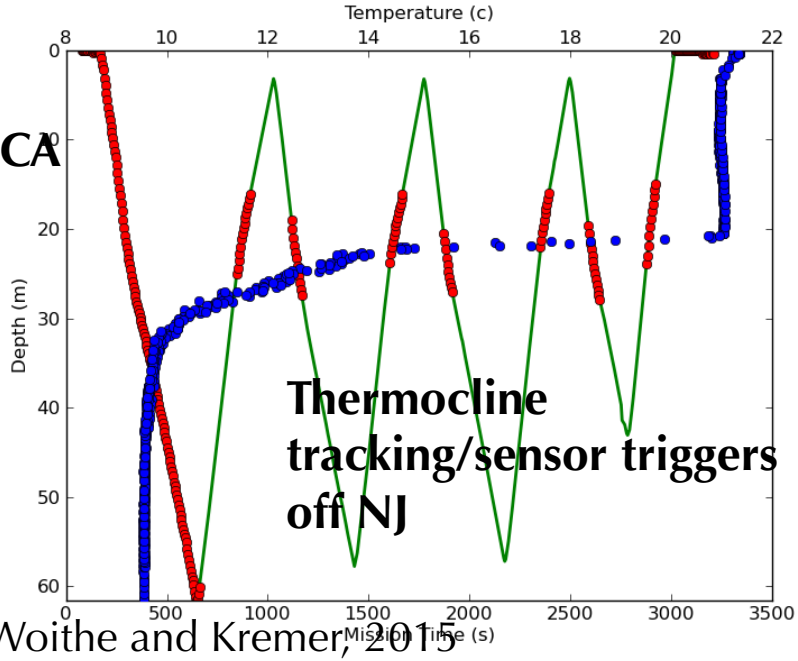
Courtesy Jeff Book, NRL

- Gliders can now be **controlled as teams** within GHOST
- Donut reward function only rewards gliders that stay with a certain radius of team members
- Optimizes team behavior while allowing team structure and shape to adapt to conditions

Sampling strategies: feature tracking …



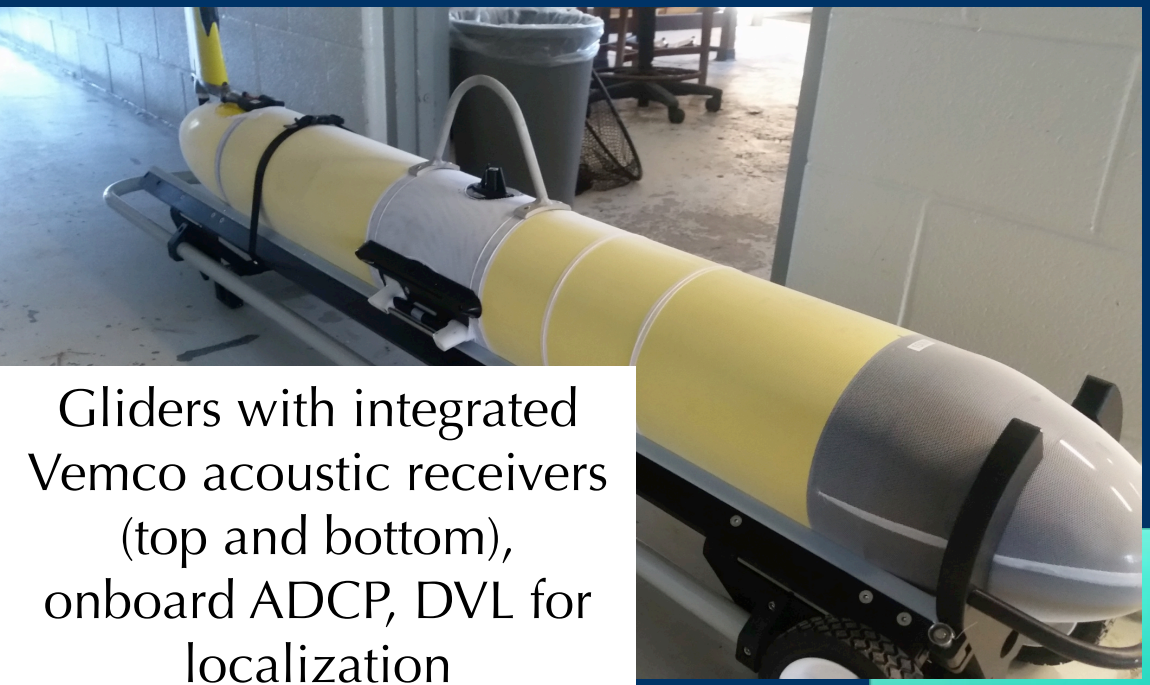
… and triggering



Zhang et al., 2015; Branch et al., 2019

Woithe and Kremer, 2015

Integrating autonomous systems



Gliders with integrated Vemco acoustic receivers (top and bottom), onboard ADCP, DVL for localization

Collaborative fleet of robots for fisheries management at Gray's Reef NMS

Fleet of robotic fish with receivers, gliding and bio-inspired motion

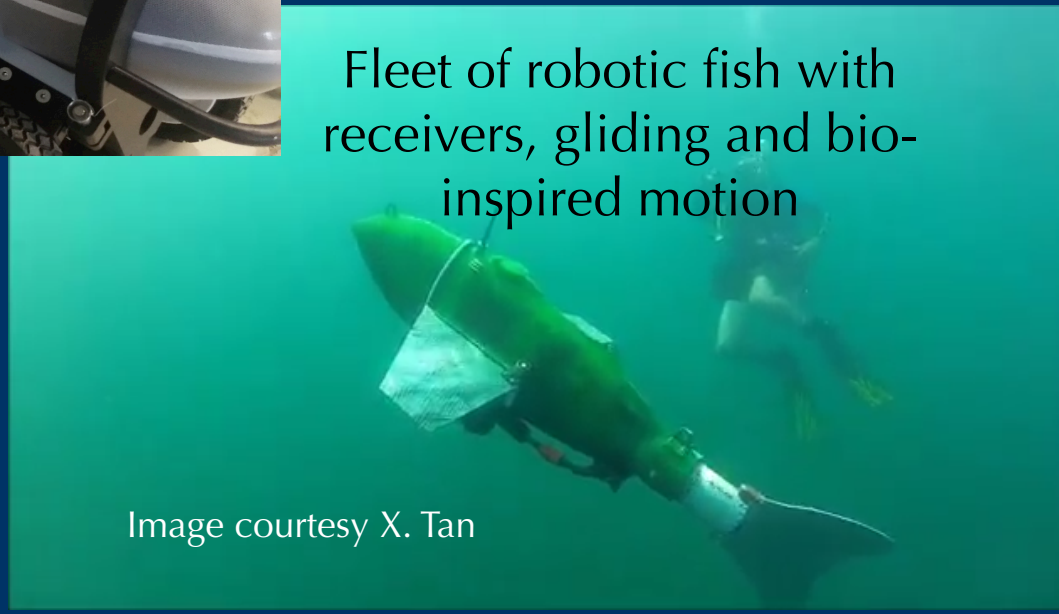


Image courtesy X. Tan

Multi-level planning tool developed through AI

Zhang, Edwards, Tan, and Cox, NSF-SAS, 2019-2022

Discussion

Goal/mission-driven

Resources

Tradeoffs in risk/reward, computational expense/speed, error (how to eval??)

Integrating systems

Emerging/maturing technologies


Thank you!
Topic #8 next meeting Nov. 2020:
Autonomy and sampling strategies??