U.S. NAVAL RESEARCH LABORATORY

US Navy Automated Glider Guidance: NRL Glider Optimization Strategies Overview (GOST)

Charlie N. Barron and Lucy F. Smedstad
Naval Research Laboratory

NRL 7320 Ocean Dynamics and Prediction
Stennis Space Center, MS
18 January 2017

U.S. NAVAL RESEARCH LABORATORY

Glider Observation Strategies (GOST)

Challenge: Workload for glider pilots

Solution: Automate glider guidance

Purpose of GOST:
Generate an automated Glider Observation Strategy plan using cost functions to identify regions of higher interest, using forecast currents to determine viable paths, and identifying from among these preferred paths that maximize mission-relevant value of glider observations.

U.S. NAVAL RESEARCH LABORATORY

Glider Observation Strategies (GOST)

Challenge: Workload for glider pilots

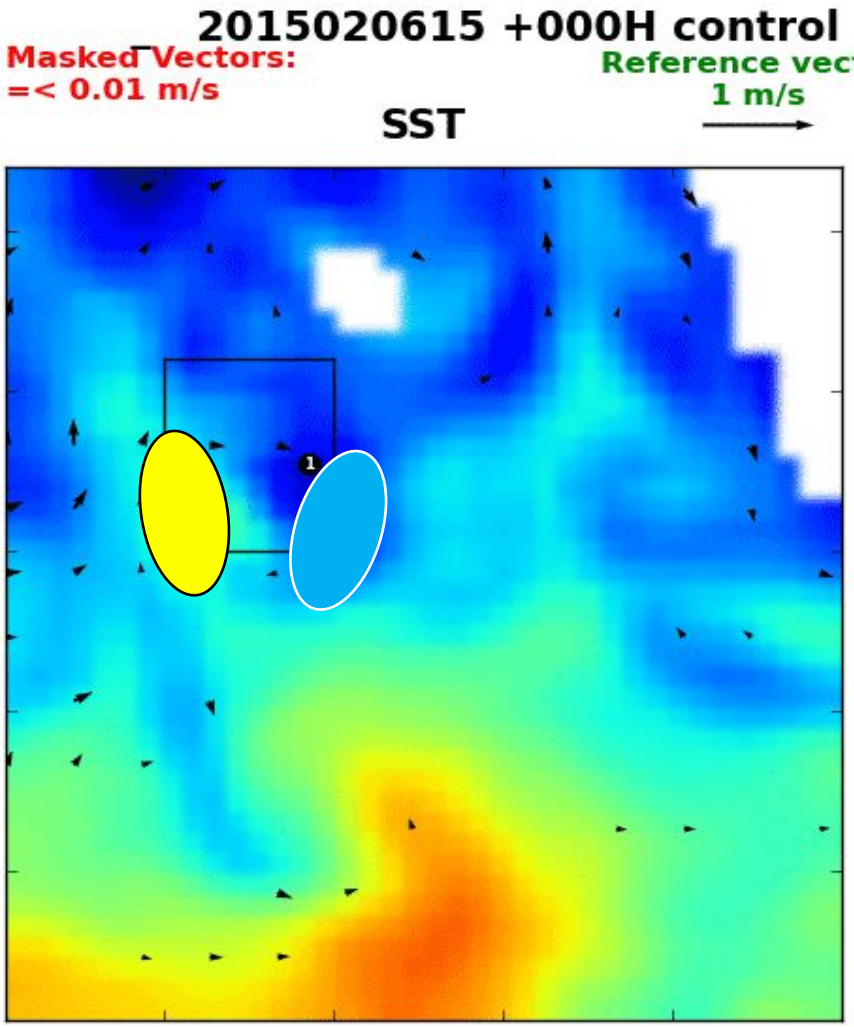
Solution: Automate glider guidance

Purpose of GOST:

- **Where do I want to go?**
- **Where can I go?**
- **What combination is best?**

U.S. NAVAL RESEARCH LABORATORY

Example of active glider observations in the right place: tactically relevant features



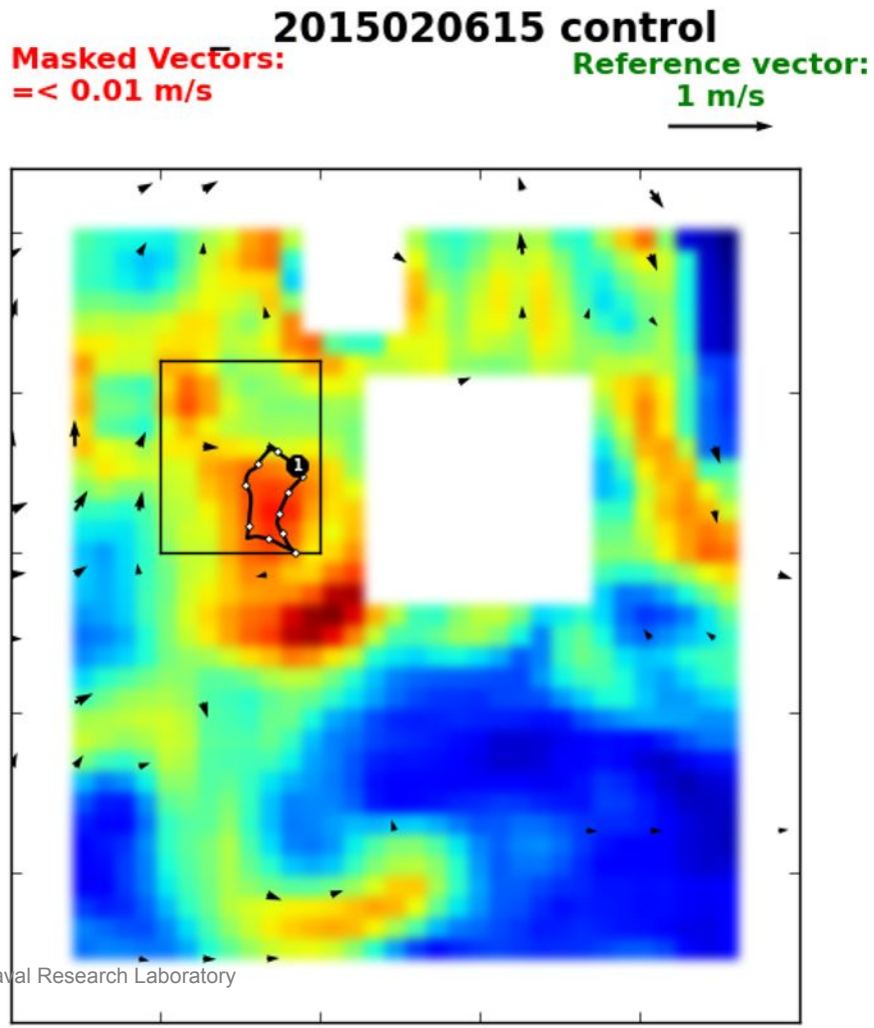
Glider defines boundary between warm and cold eddies

Assimilate glider observations into forecast models

Inform tactical decisions regarding:

- **Acoustic transmission**
- **Mine drift**
- **Special warfare**
- **Small boat operations**
- **Search and recovery**

GOST: Cost function defines relative mission value among different locations



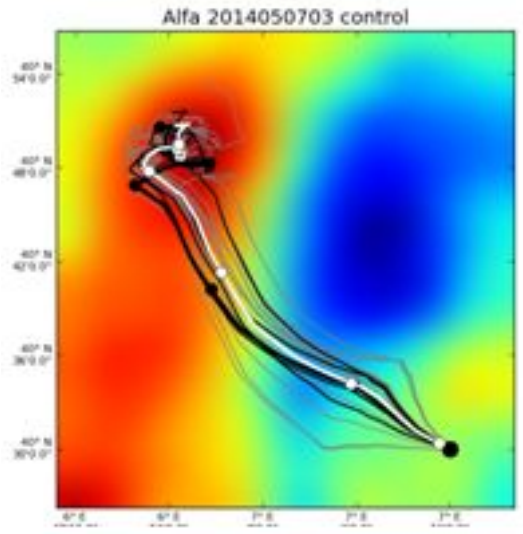
The cost function is a means translate the manual judgment of a subject matter expert into a field used in an automated optimization

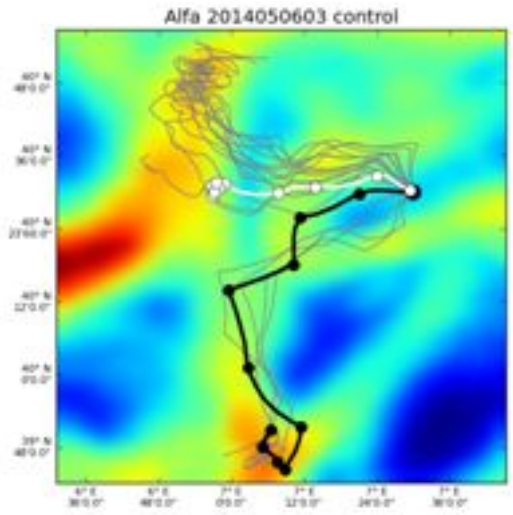
Specific cost functions are designed to quantify preferences relevant for typical Navy missions.

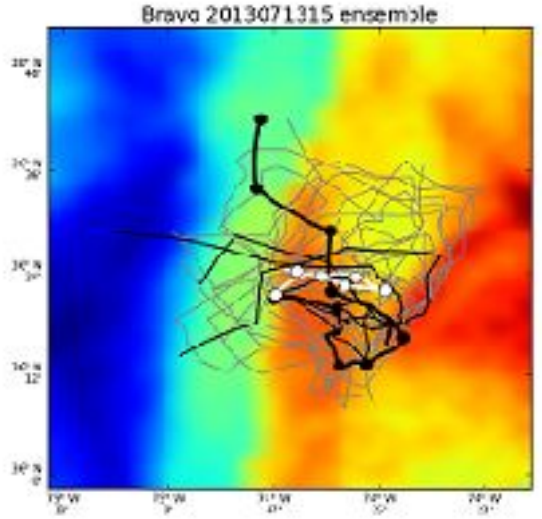
red = more valuable
blue = less valuable

U.S. NAVAL RESEARCH LABORATORY

GOST Cost Functions: Of many possible paths, which one is best?





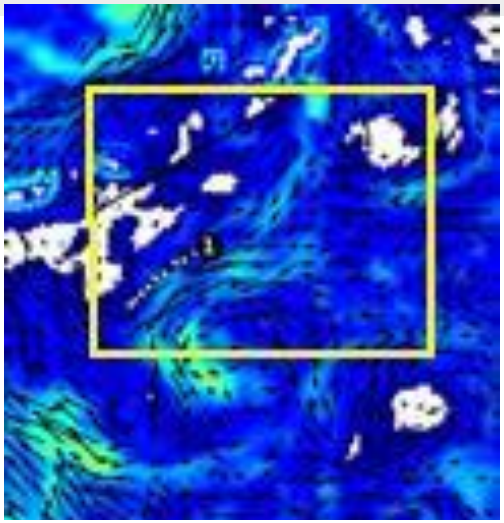


Potential (gray) glider trajectories superimposed on mission cost functions. The preferred waypoints (black) compared with the mean (white) of possible solutions. GOST uses a genetic algorithm to find the preferred path (Heaney et al., 2007)

U.S. NAVAL RESEARCH LABORATORY

GOST uses forecast currents to determine waypoints that fulfill assigned glider missions

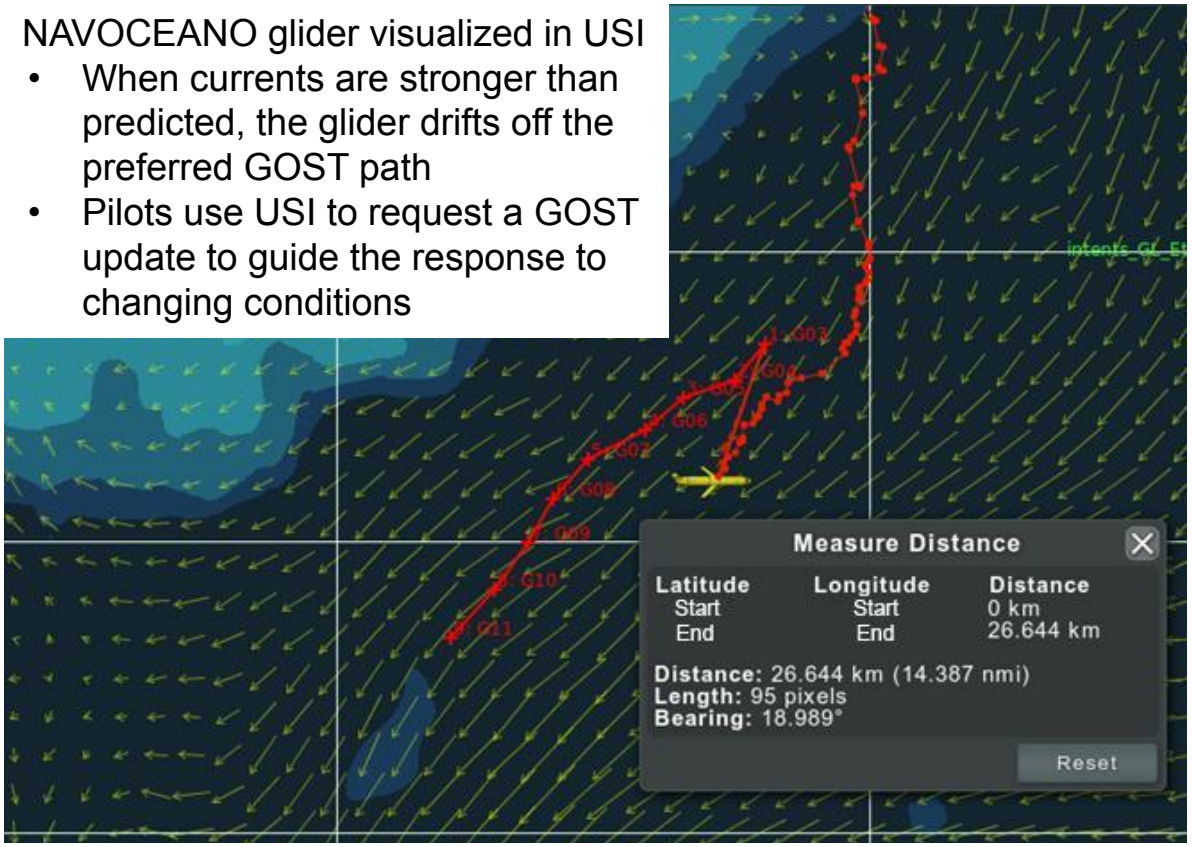
GOST support for UUV operations at NAVOCEANO, developed by NRL 7320



local forecast currents and Glider Optimization Strategies (GOST) mission cost function

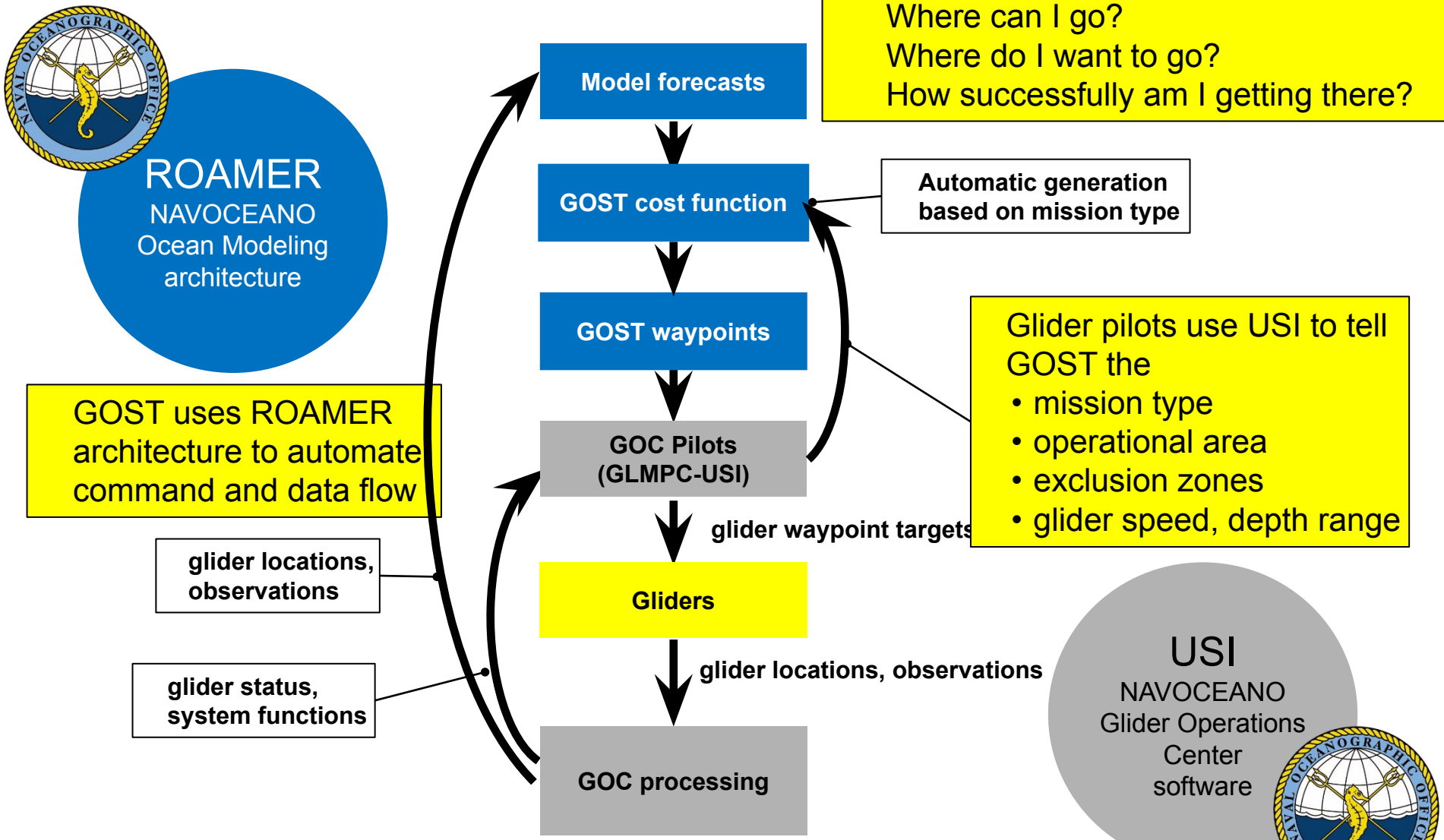
NAVOCEANO glider visualized in USI

- When currents are stronger than predicted, the glider drifts off the preferred GOST path
- Pilots use USI to request a GOST update to guide the response to changing conditions



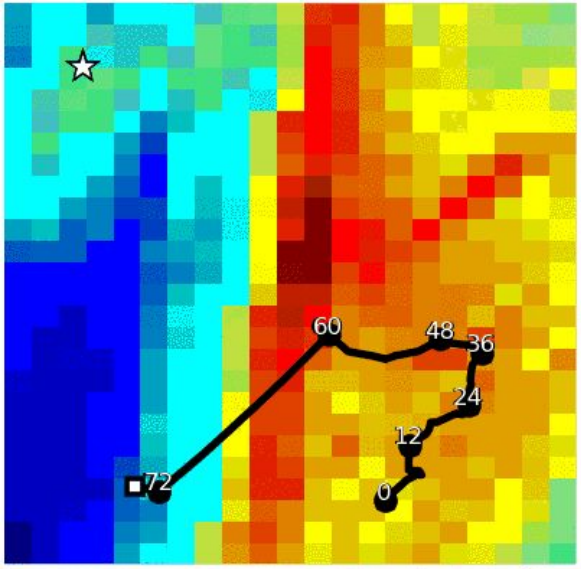
GOST generates an automated glider observation strategy, providing paths to achieve present and future mission goals.

GOST automated commands, data flow, and pilot interaction

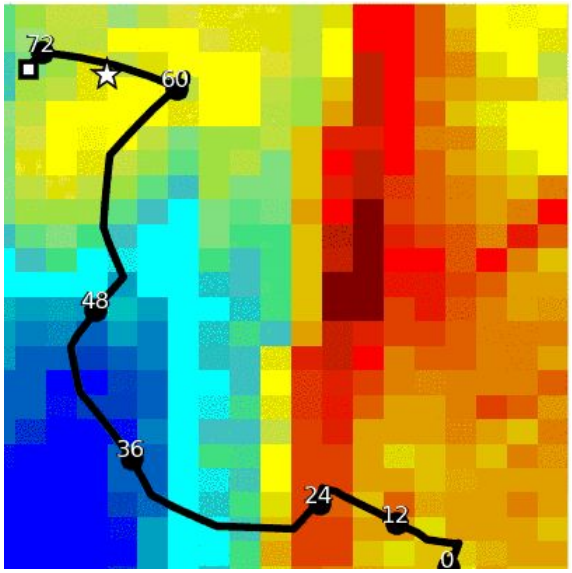


GOST Cost Functions: Finding the right balance between glider observations and recovery

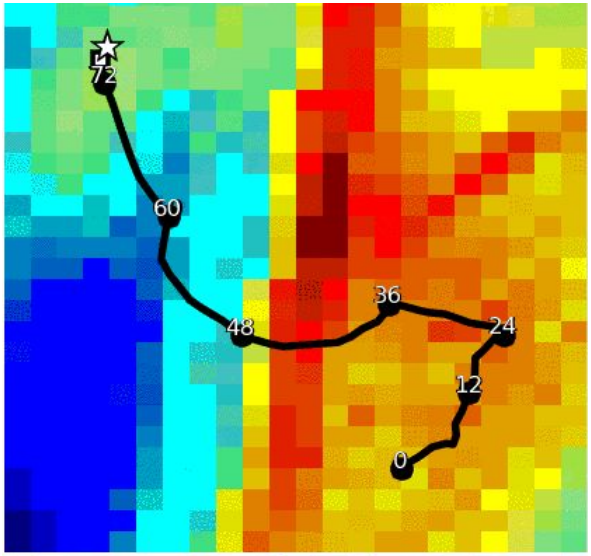
Overemphasize sampling: route fails by missing recovery (☆) location/time



Overemphasize recovery: route fails by missing valuable (red) observations



A successful glider mission finds a path that seeks needed observations and reaches its recovery ☆ location on time



Mission success!

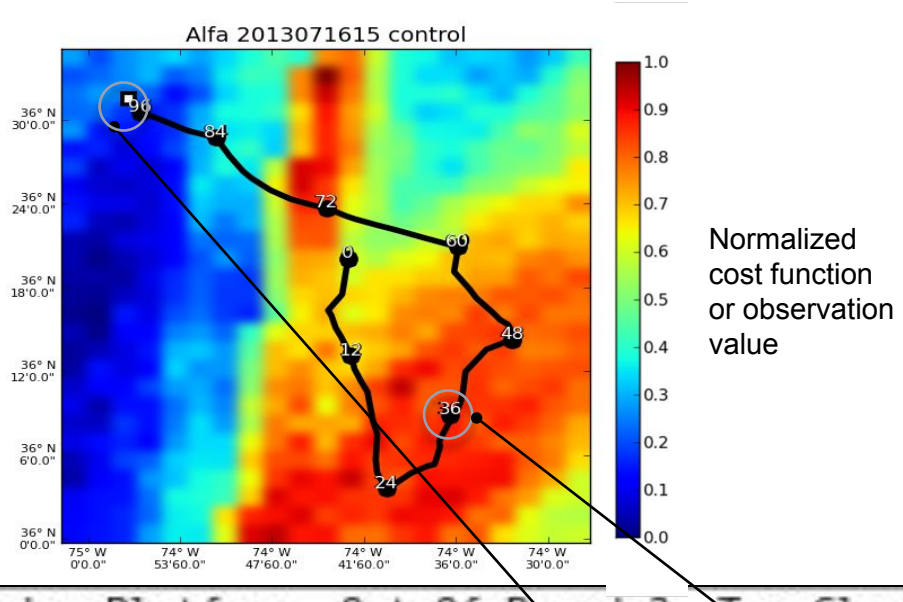
Measurements are more valued in warmer (redder) areas, but glider must reach recovery in 72 hours.

Waypoints from GOST are guidance for glider pilots

GOST conveys normalized value of observations at different waypoints

Pilot can prioritize more valuable waypoints

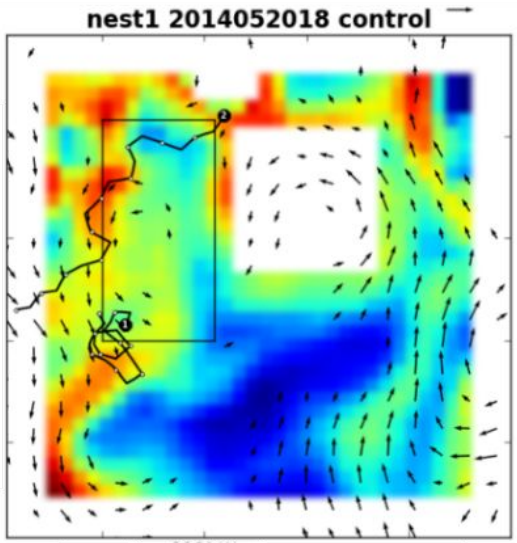
More flexible vs less flexible

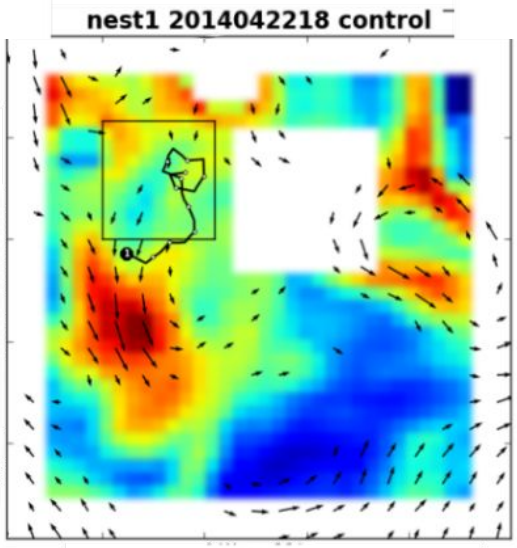


Normalized cost function or observation value

Time,	Latitude,	Longitude,	Platform,	Out Of Bounds?,	Too Close?,	Weight
000,	36 N 20'03.840",	74 W 43'01.920",	Alfa,	Clear,	Clear,	0.6130
012,	36 N 13'06.960",	74 W 42'50.760",	Alfa,	Clear,	Clear,	0.6566
024,	36 N 03'36.000",	74 W 40'29.280",	Alfa,	Clear,	Clear,	0.8428
036,	36 N 08'51.000",	74 W 36'21.240",	Alfa,	Clear,	Clear,	0.8720
048,	36 N 14'15.720",	74 W 32'20.760",	Alfa,	Clear,	Clear,	0.8563
060,	36 N 20'53.880",	74 W 35'52.800",	Alfa,	Clear,	Clear,	0.5604
072,	36 N 23'40.560",	74 W 44'25.080",	Alfa,	Clear,	Clear,	0.8669
084,	36 N 28'42.600",	74 W 51'38.160",	Alfa,	Clear,	Clear,	0.3714
096,	36 N 30'32.760",	74 W 56'33.720",	Alfa,	Clear,	Clear,	0.1499
098,	36 N 31'33.600",	74 W 57'21.240",	Alfa,	Clear,	Clear,	0.1499

How is GOST guidance used by pilots?



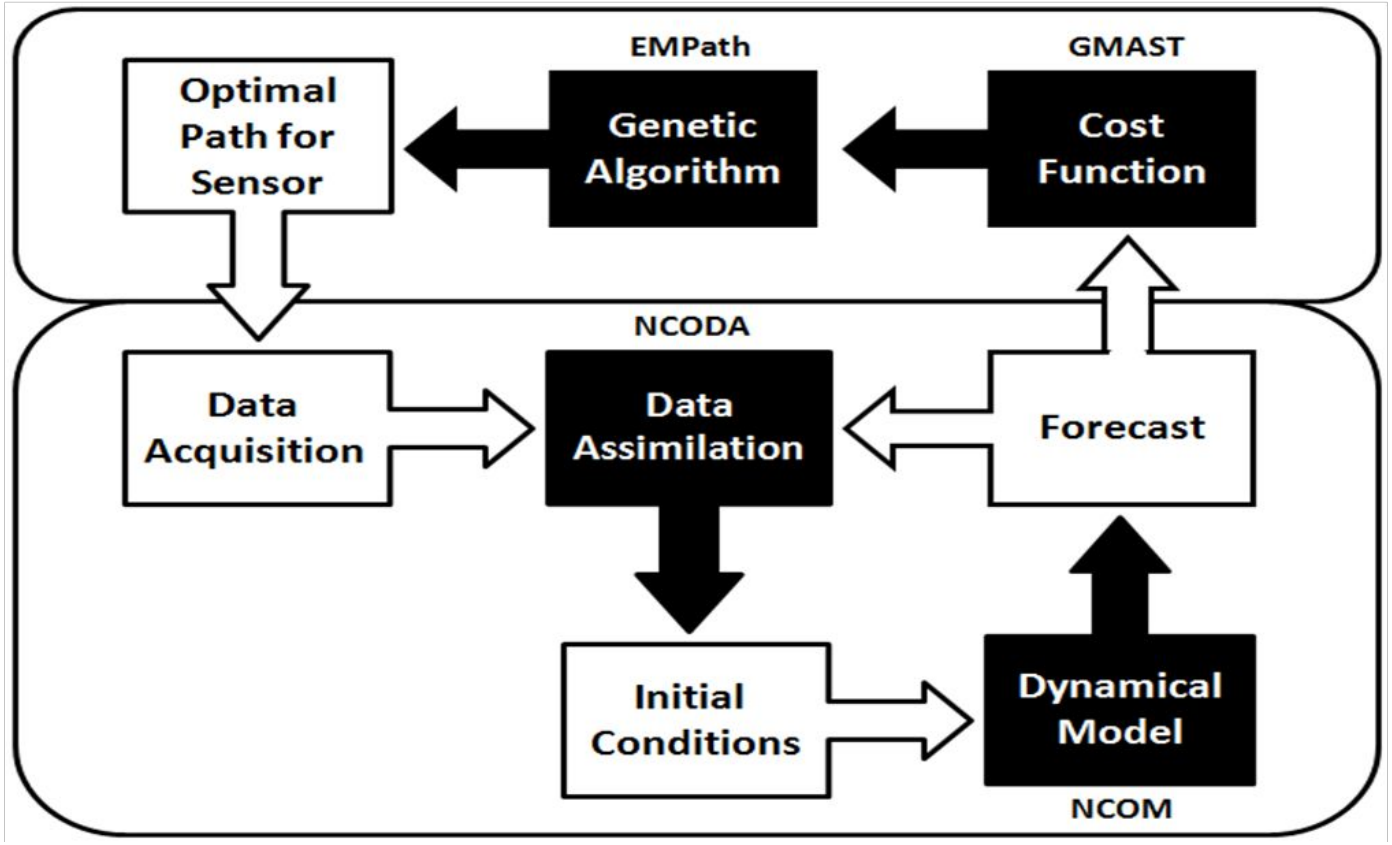


How are GOST waypoints typically used?
(evaluation over 10 months)

41.9% Used As Is	**39.8% Adjusted (change a few points near boundaries or to accommodate how a glider identifies its next waypoint)**
9.7% Not used (manual control just before recovery, points outside of OpArea)	**8.8% non-guidance issues (Hardware Issues, file transfer issues, format issues)**

GOST as part of Ocean Forecast System

Involvement in Forecasting



GOST

OCEAN FORECAST SYSTEM

U.S. NAVAL RESEARCH LABORATORY

Glider Observation Strategies (GOST)

Result: Glider pilots have increased efficiency

Solution: Automated glider guidance

Purpose of GOST:
Generate an automated Glider Observation Strategy plan using cost functions to identify regions of higher interest, using forecast currents to determine viable paths, and identifying from among these preferred paths that maximize mission-relevant value of glider observations.