



# Uncrewed Systems and the Naval Research Laboratory

Controlled by: Department of Navy  
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Distribution: A  
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# **Naval Research Laboratory**

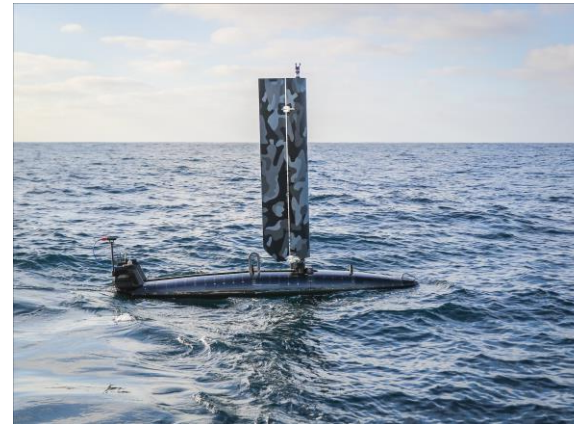
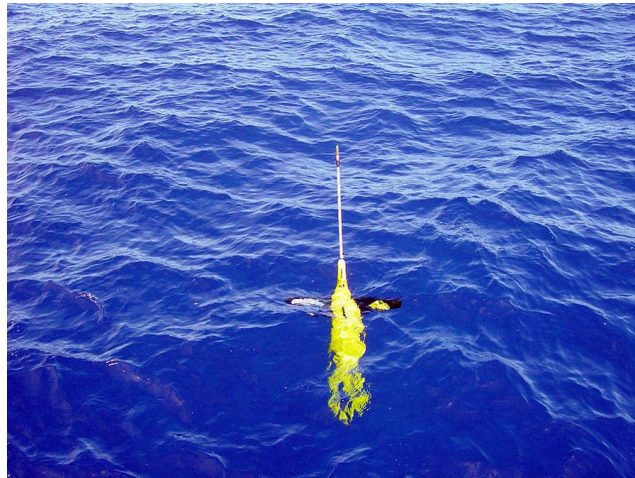
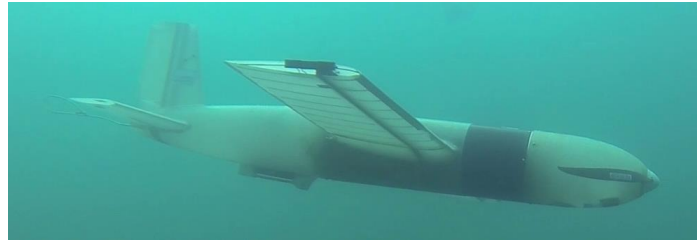
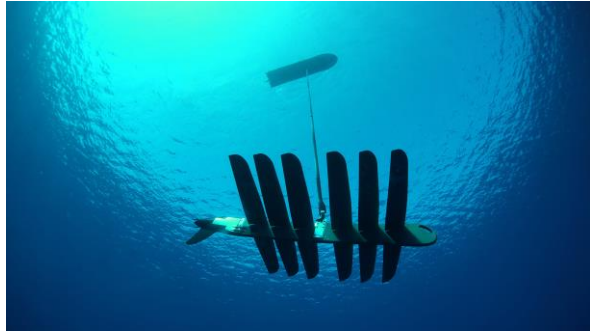
## **7300 Ocean Sciences Division**

**Mission - The Ocean Science Division conducts a RDT&E program in biological, chemical, dynamical, and physical processes of the open ocean, coastal and littoral areas, marine boundary layers as well as marine geology, geophysics, geoacoustics, and mapping, charting and geodesy.**

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## Uncrewed Vehicles

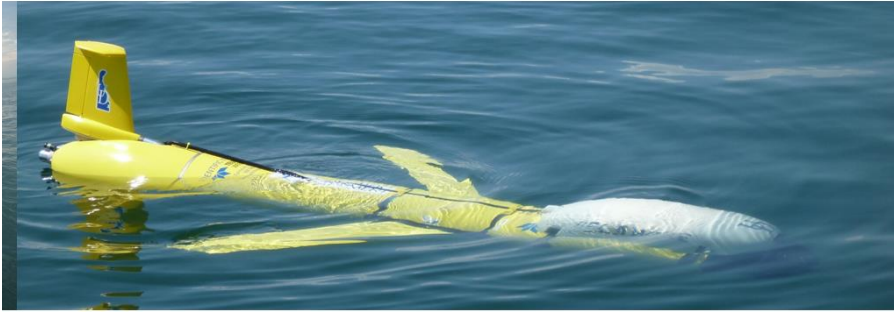
### UxS Platforms



## Glider with bioluminescence (BL) sensor (Blglider).

Glider with BL sensor provides sustained presence and sampling of BL potential (especially in access denied areas).

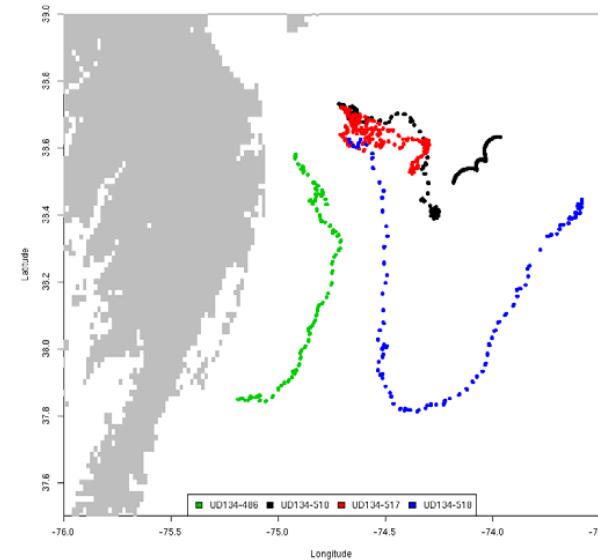
The BL sensor (bathyphotometer UBAT) was installed on the Slocum glider as a plug-and-play, and was demonstrated on 4 missions in the Delaware Bay area.



The glider with BL sensor demonstrated operational success, good data quality, and a number of behaviors important for sampling of BL potential:

- depth holding to target particular layers of BL organisms;
- slow ascents/descents to examine the entire community structure;
- various navigational challenges to adapt to the changing environment (i.e. station-keeping).

The glider was able to operate through a hurricane in 2016.



2016 (green, blue)  
2017 (black)  
2018 (red)



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## Previous experience with new sensors/data

### 1980s-90s Satellite Altimetry

Sea surface height representing upper 1000 m of the ocean

Along track spacing: 7-10 km

Across track spacing: 100s-1000s km, depending on repeat track (10, 17, 21 days)

We were rubber sheeting fronts and eddies into models that were based on sparse in situ and voluminous satellite sea surface temperature data.

Assimilative techniques were built that bring the sea surface heights into the ocean model(s) as temperature salinity profiles.

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## Assimilation of Uncrewed Data

### 2020s Uncrewed Vehicles

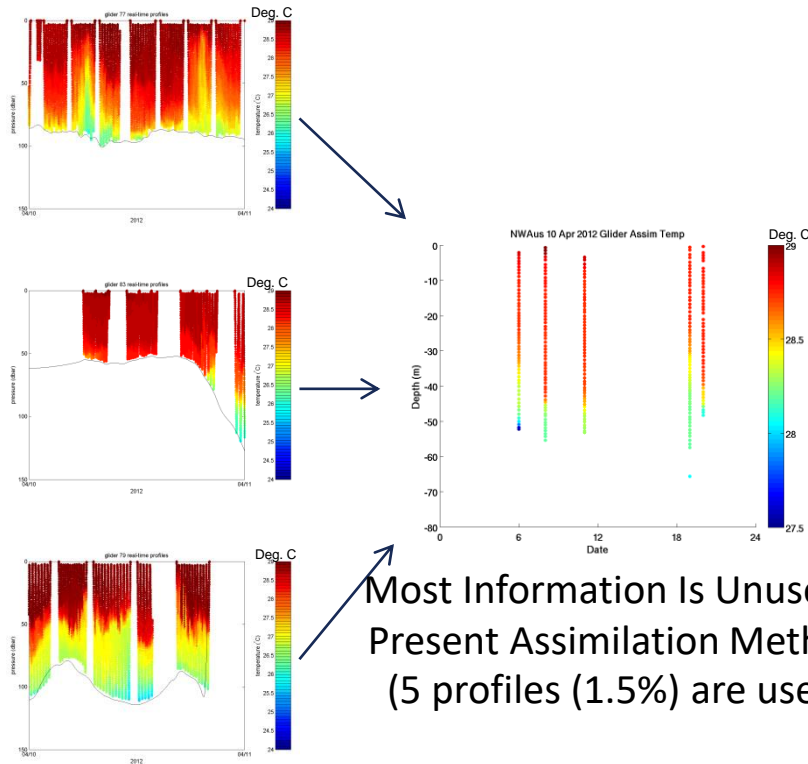
200-1000 m depth range

Uncrewed vehicles that can ply the surface or depths and provide data in real-time provides a new challenge. Now we have dives that can occur several times each day. These vehicles are slow.

### Assimilation into Ocean Models

Covariance matrices for each data type (temperature, sea surface height, etc.) Sets spatial and temporal resolutions for assimilation.

# Glider Assimilation

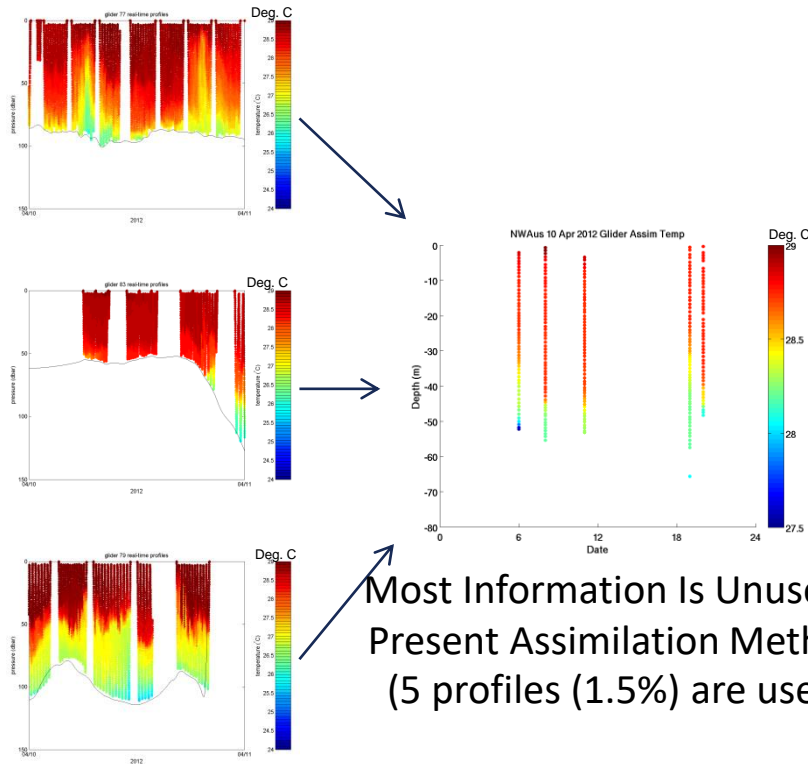


3 gliders sampling for  
1 day (330 profiles)

Glider are not very efficient at measuring mesoscale circulation for daily assimilation

- Present Navy data assimilation is designed to correct operational ocean model's mesoscale circulation at 24 hour intervals
  - Data are averaged to 20-50 km scales, therefore **each glider contributes ~1 CTD profile per day**
  - Satellite altimeter contributes ~1000 data points per day in a regional model, **overwhelming the glider data**

# Glider Assimilation



Most Information Is Unused in Present Assimilation Methods (5 profiles (1.5%) are used)

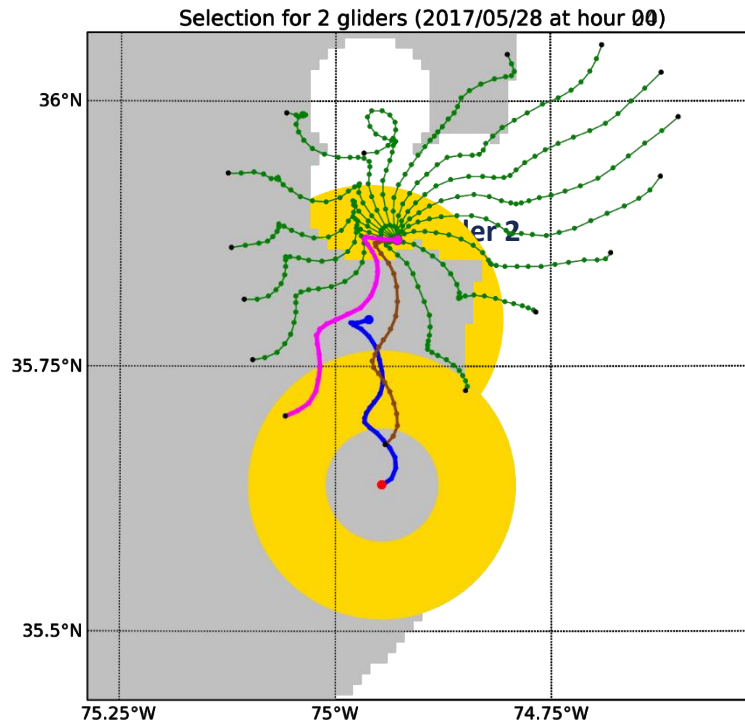
3 gliders sampling for  
1 day (330 profiles)

Glider are efficient at measuring the local battlespace time variability.

- New data assimilation methods
  - Multi-scale data assimilation (4D-VAR) utilizes the high temporal sampling of the glider
- Local Analysis
  - Preserve data fidelity within the local area
- Glider Teams
  - Multiple gliders resolve spatial scales



# Smart Glider Teams for Rapid Update of Local Analysis I Results



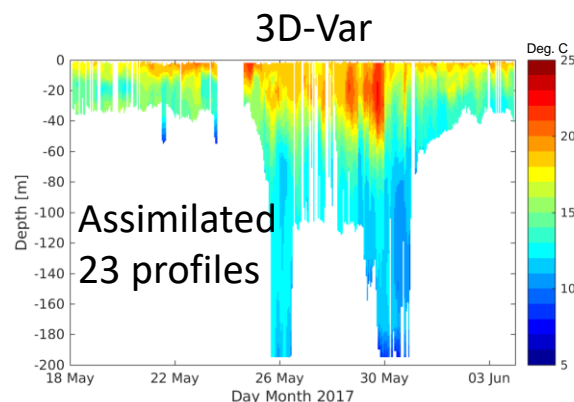
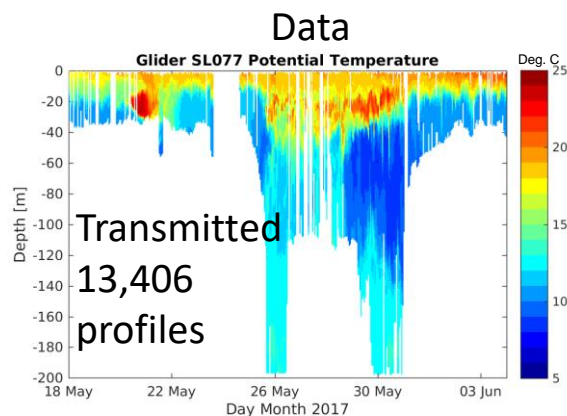
## Previous 6.2 effort

- Challenged the paradigm of using widely separated gliders
- Additions to software used by NAVOCEANO's Glider Operations Center (Guidance for Heterogeneous Observation Strategies - GHOST)
  - Station keeping behavior
  - Optimize team behavior while allowing team movement to adapt to conditions
  - Simulated glider behavior more realistically

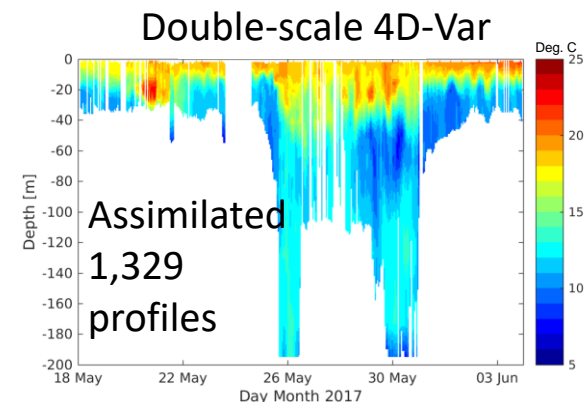
# Smart Glider Teams for Rapid Update of Local Analysis I Results

## Local Analysis Impact

- Double-scale 4D-Var tremendously increased usage of glider data (> 500%)
- Use of Glider Teams reduced error versus using individual gliders
- Solutions are starting to look more like the glider data they are assimilating
- Big Improvements, but also identified the need for more work (e.g. 3.1°C rms error, 10% profile usage)



baseline

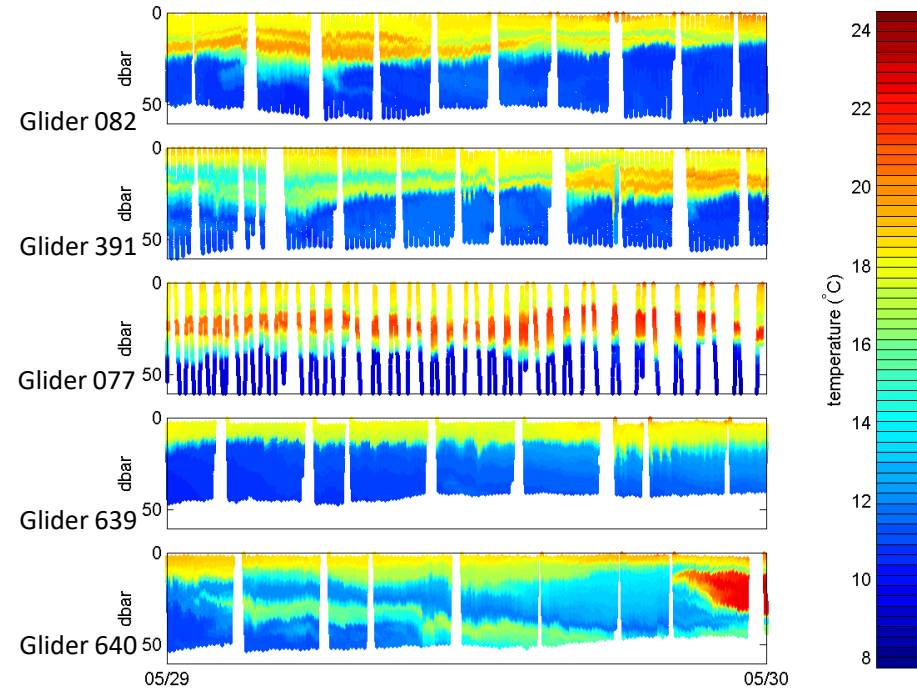
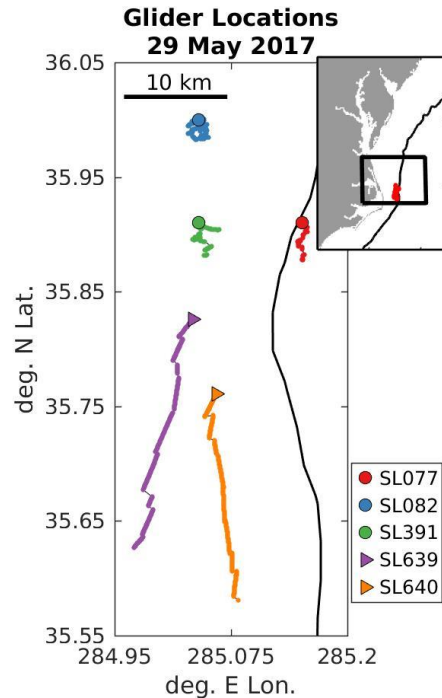


18% lower error than 3D-Var  
vs. withheld CTD data;  
23% lower error than  
standard 4D-Var (not shown)

### Variational Data Assimilation (Var)

- 3-Dimensional Var (3D-Var) adjusts model in 3D space around observation
- 4-Dimensional Var (4D-Var) adjusts model in 3D space and in time
- Double-scale 4D-Var uses two different scales in 3D space for adjustment

# Smarter Use of Glider Team Data: Assimilate Glider Team Variables



Glider teams were controlled in the PEACH field experiment so that they could stay close enough together to resolve ocean fronts and eddy features. Assimilation of calculated glider team variables could be a valuable model constraint for the features that are being resolved.

# Conclusions

The US Navy is very interested in UxS.

Interoperability will be necessary.

Maintenance will be an issue.

Data as a service is being investigated.

Ancillary sensors will increase the utility of the UxS.

## Disclaimer:

The US Naval Research Laboratory is a working capital fund organization. Principal Investigators are funded through internal and external proposals. We are open to collaborations, but we do not have the resources to fund other research or purchase large quantities of equipment.