4DVAR Assimilation of Glider Teams on the North Carolina Shelf

U.S. NAVAL RESEARCH LABORATORY

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NRL Postdoctoral Fellowship Program

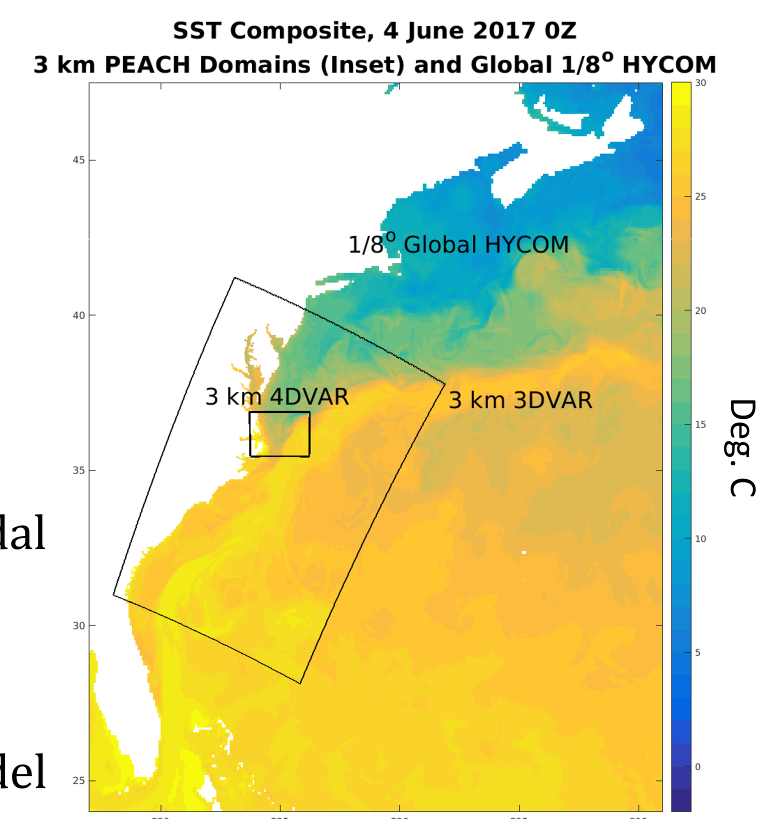
NG31A-0165

ABSTRACT

We demonstrate a new method to assimilate glider profile data from multiple gliders in close proximity (~10 km or less). Previous work shows assimilating glider data in close proximity (e.g., 1 profile every 10 km or less) super-imposes assimilation updates and over-corrects the background state. The new “boundary control” method was developed using gliders deployed in a field experiment from 17 May until 4 June 2017 near Cape Hatteras (US East Coast), co-incident with the NSF-funded PEACH experiment (Processes driving Exchange At Cape Hatteras). Increasing the number of glider profiles can improve the hindcast/re-analysis of the ocean state.

RELOCATABLE NAVY COASTAL OCEAN MODEL

- Spin-up
  - 1 March – 17 April: 3DVAR
  - 18 April – 17 May: 4DVAR
- Baroclinic, Boussinesq, free-surface, and hydrostatic forward model
- 3 km horizontal resolution (74 x 53)
- σ-z vertical coordinate (25 σ-levels above 125 m)
- Tidal forcing (8 constituents, OSU Tidal Inversion Software)
- COAMPS atmospheric forcing
- Boundary conditions from a 3 km model nested in a global HYCOM model (experiment 92.8)



4DVAR ASSIMILATION

NCOM-4DVAR

- Weak-constraint indirect representer approach
- Gulf Stream is non-linear: two “outer loops” are used, model background re-computed after each loop

Assimilated Data

- Glider temperature and salinity profile data
- Sea surface temperature
- Sea surface height (using synthetic temperature and salinity profiles from the Modular Ocean Data Assimilation System)

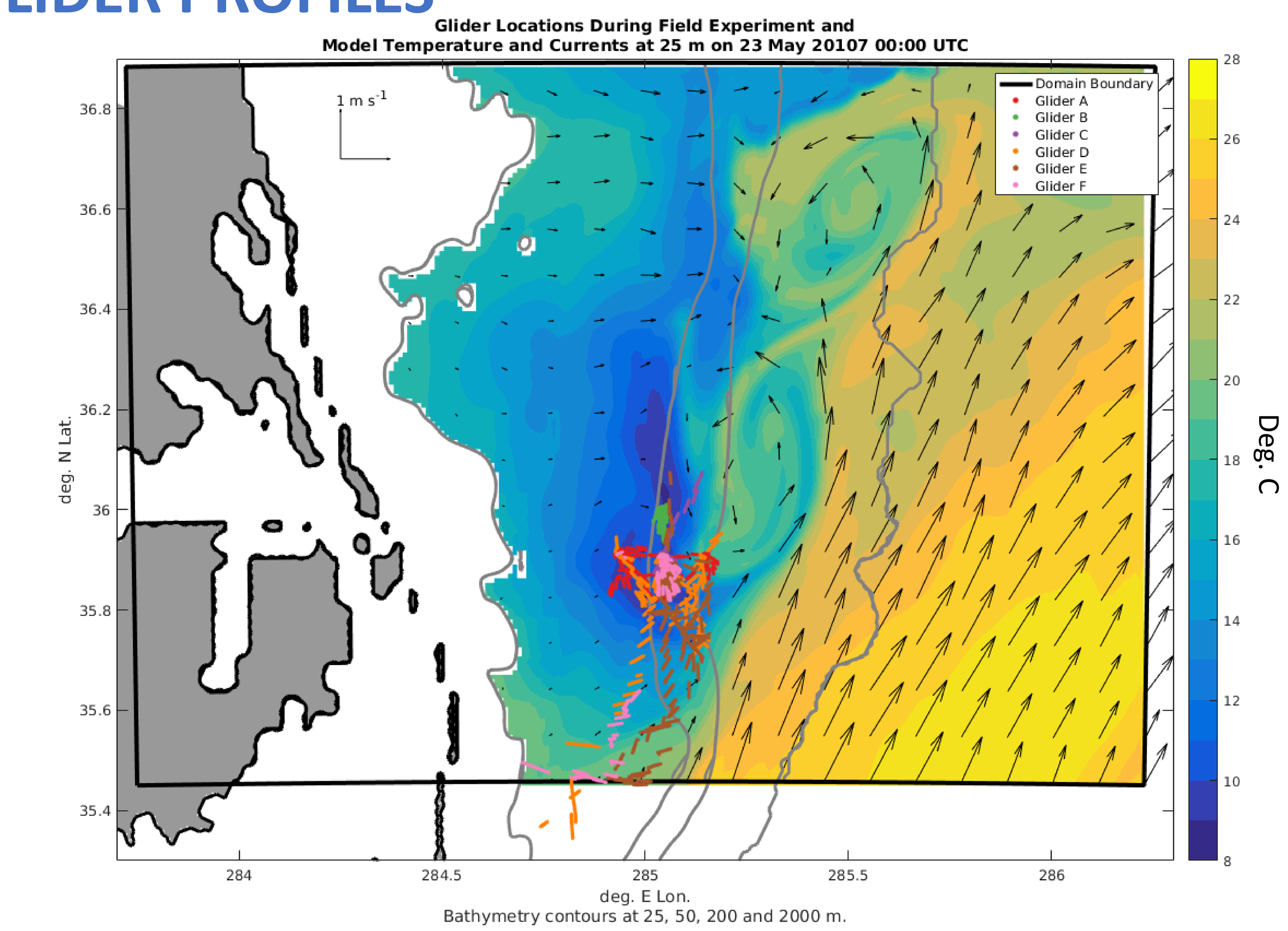
“Standard” Experiment

- Glider data “thinned” with 20 km decorrelation length scale/3 hourly time scale in both loops (e.g., one glider profile per 20 km every 3 hours).

“Boundary Control” Experiment

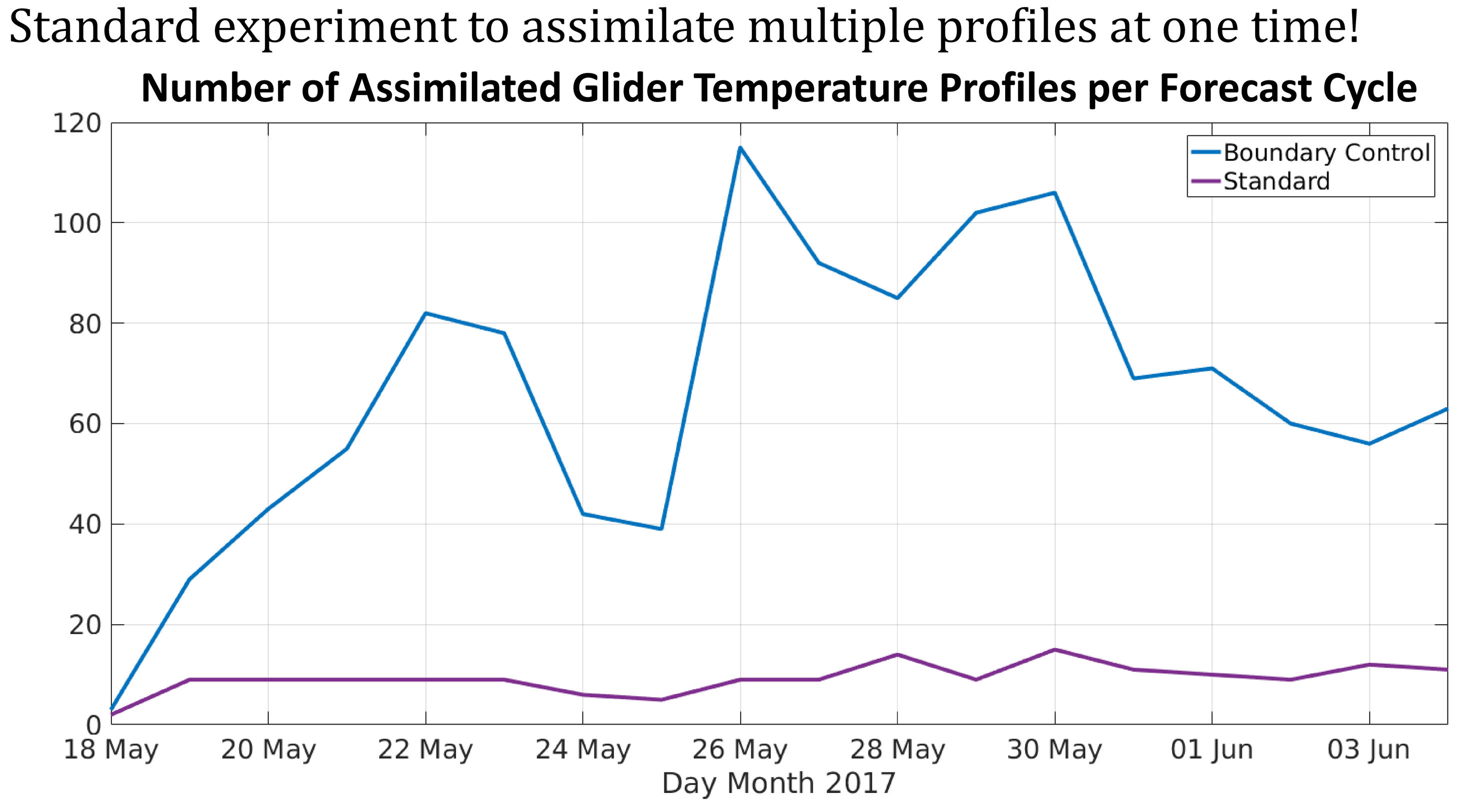
- NCOM-4DVAR tangent linear model initialized only at boundaries (i.e., interior adjoint forcing is discarded)
- Glider data thinned at 6 km/hourly in both loops – much finer than Standard!

GLIDER PROFILES



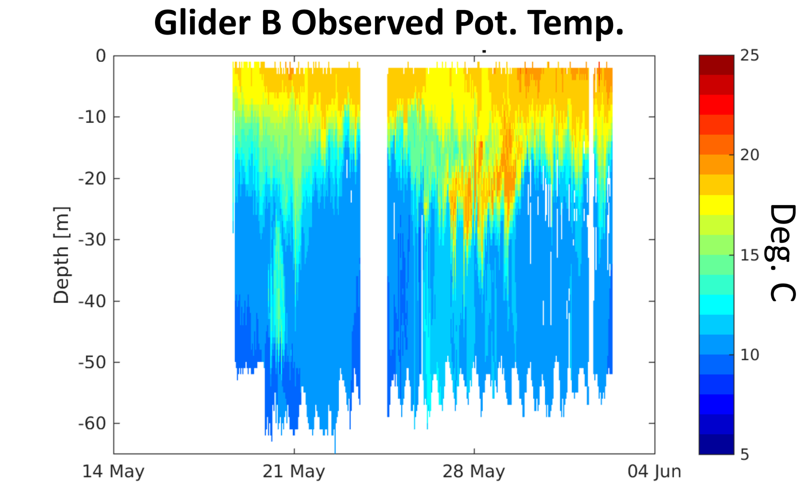
Glider profiles are very close - each “line” is a number of overlapping dots!

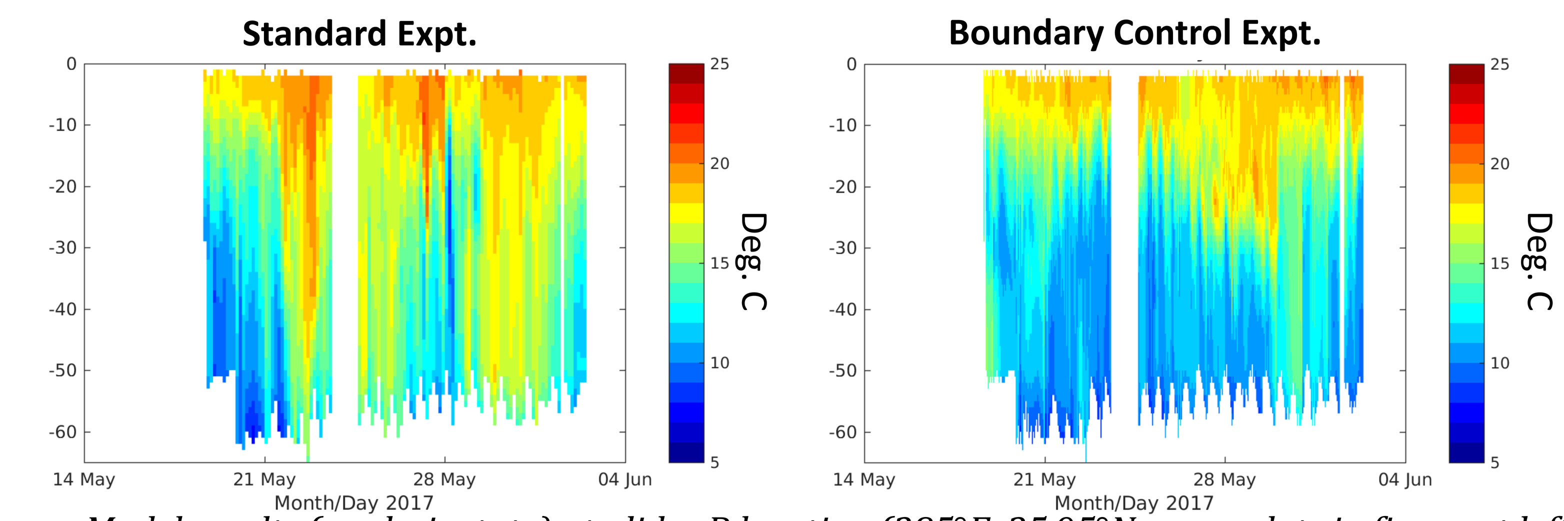
- 14682 profiles over 19 days
- 1-6 gliders deployed each day, usually 5 or 6
- Most profiles in water 50 m to 200 m deep
- All gliders typically within a 40 km by 40 km region – difficult for Standard experiment to assimilate multiple profiles at one time!



- **Standard Experiment:** Uses roughly one profile every 20 km every 3 hours. With most gliders often within a 20 km x 20 km area, roughly 10 profiles are assimilated each day (167 during the 19 day study period).
- **Boundary Control Experiment:** With “finer” thinning of glider profiles (roughly one profile every 6 km per 1 hour), many more profiles are assimilated (1190 during the study period).

GLIDER TEMPERATURE OBSERVATIONS



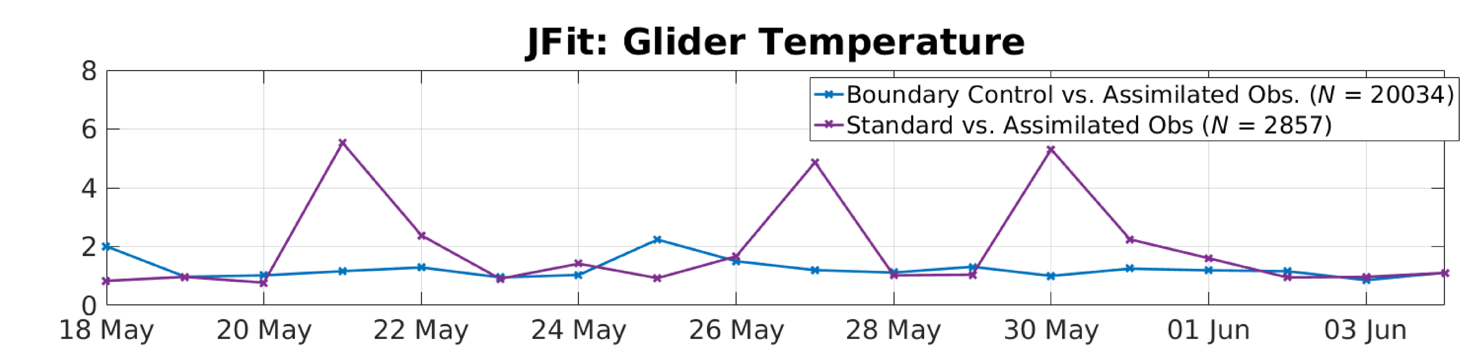


Model results (analysis state) at glider B location (285°E, 35.95°N; green dots in figure at left), representative of model performance

The vertical stratification is weak in the Standard Experiment, which is too warm below the surface layer. The cool interior and 26-29 May temperature inversion are better resolved by the Boundary Control Experiment.

MODEL SKILL AT FITTING GLIDER TEMPERATURE

Do the analysis solutions fit their assimilated observations within “observation” error, the sum of instrument (~0.002°C) and representativeness (~1°C) errors?



JFit = 1 ⇒ Model error against observation averages 1 standard deviation of observation error

Experiments are evaluated against their assimilated observations using JFit (average normalized error). JFit ≤ 1for the analysis solution indicates assimilation scheme is accurately fitting observations. The Boundary Control Experiment performs much better than Standard Experiment against glider temperature, with RMSE around 1°C (not shown).

$$J_{Fit} = \frac{1}{N}\sum_{i=1}^{N}\frac{|y_i - Hx_i|}{\sigma_i}$$

N: Number of observations
y_i: Observation value
H: Observation operator
x_i: Model analysis state
σ_i: Observation error

This work supported by the Naval Research Laboratory-American Society for Engineering Education Postdoctoral Fellowship Program and the Naval Research Laboratory and Office of Naval Research under the Smart Glider Teams for Rapid Update of Local Analysis project.