Buoyancy glider observations for modeling distinct water quality zones in Lake Ontario

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2018 CSMI Glider 'Nokomis' sampling plan

- Each deployment started on the western end
- Completed a series of cross shore transects to ~20 km from shore at selected geographic landmarks
- Cross shore out-back pairs take ~1.5 days to complete
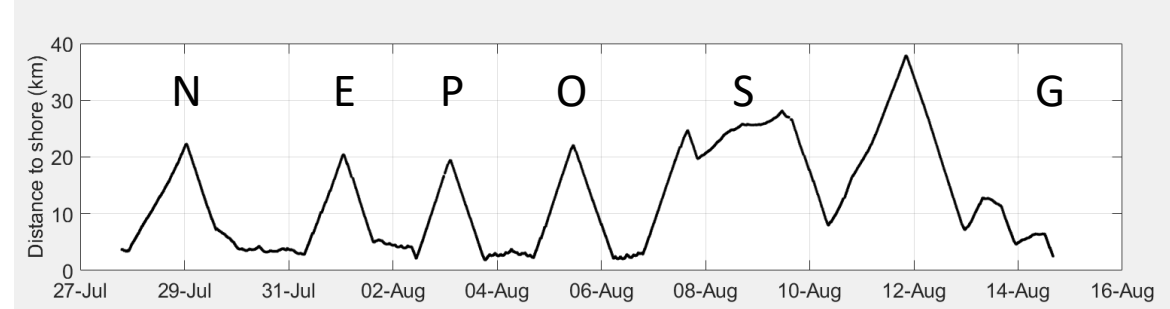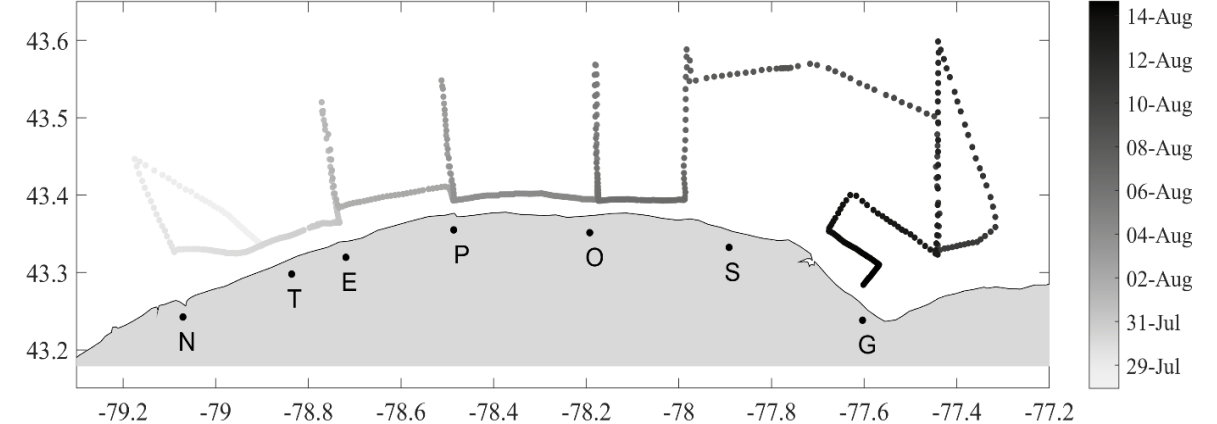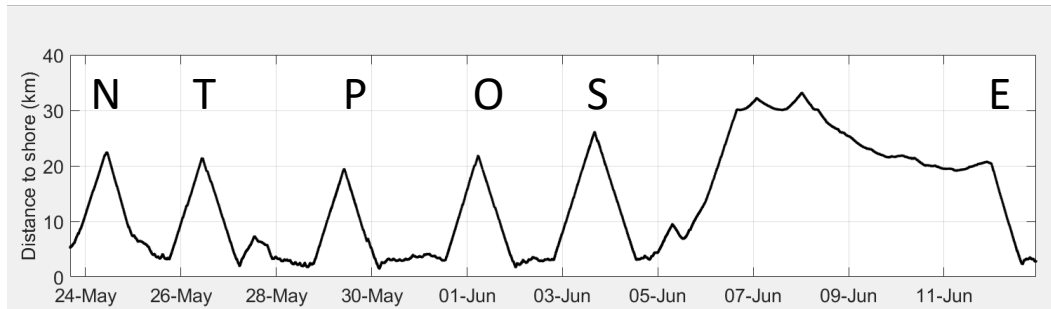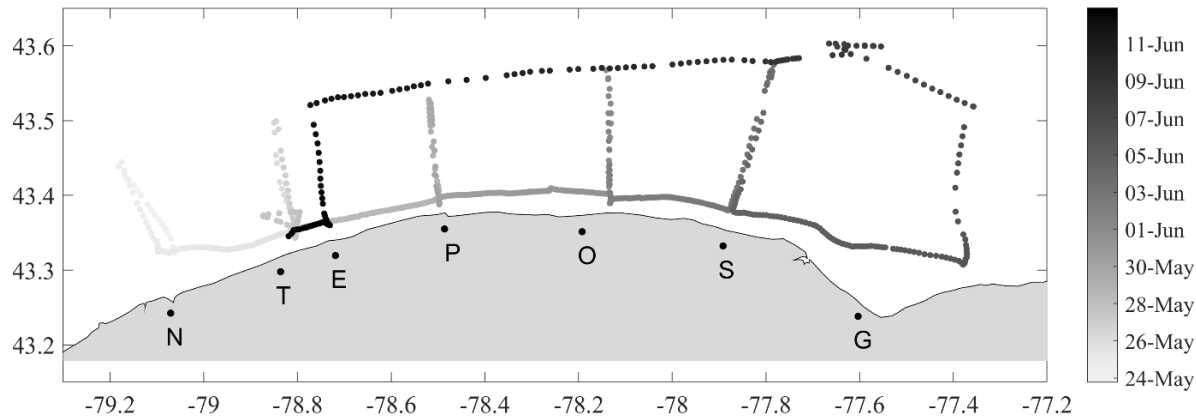

N=Niagara River   T= Twelve Mile Creek   E = Eighteen Mile Creek   P=Thirty Mile Point lighthouse   O=Oak Creek   S = Sandy Creek   G = Genessee River

Example for upcast vs downcast
1. Raw temperature/depth data (below, left) is fit to uniform vertical spacing with layers 0.5 meters (below, center)
2. Surface mixed layer (SML) depth = depth layer above which dt/dz< -1 °C m^{-1}
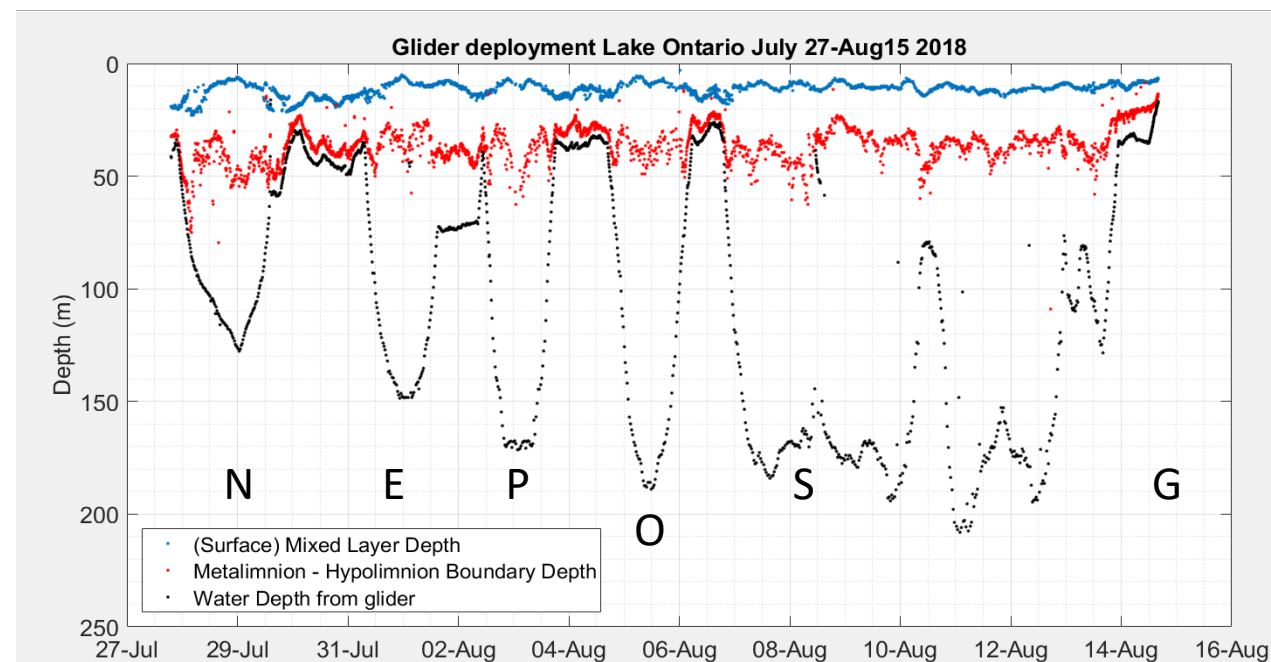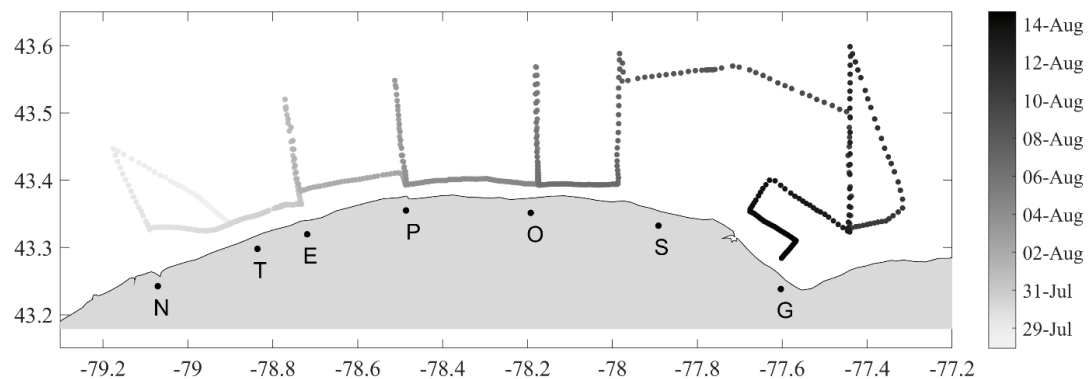3. Meta-Hypolimnion depth = depth layer below which dt/dz < 0.1 C/m
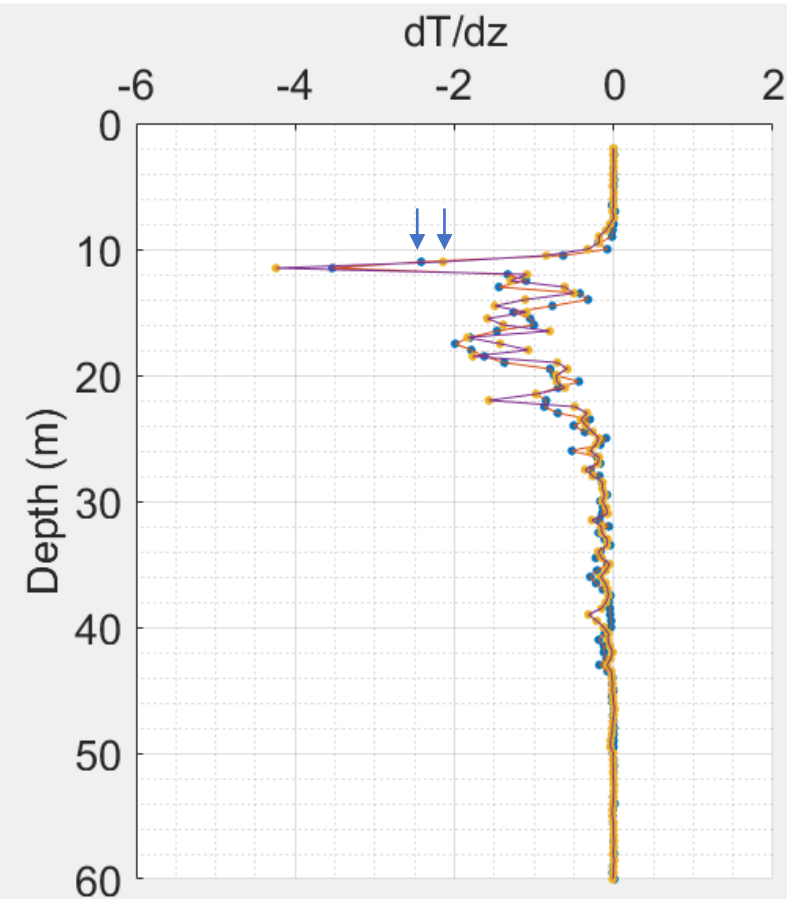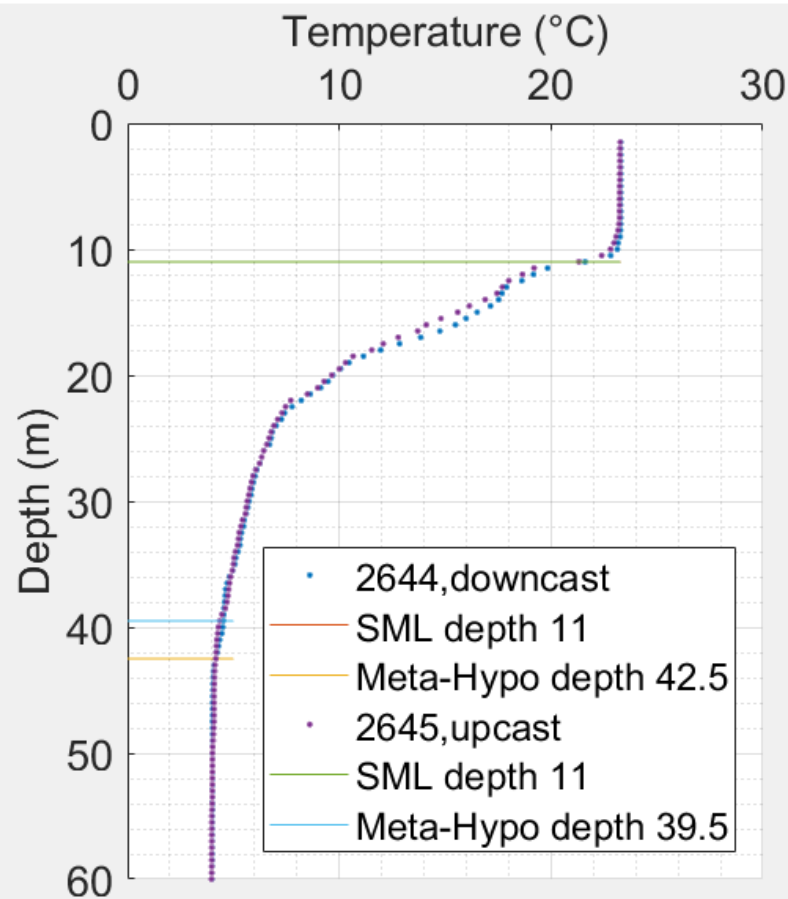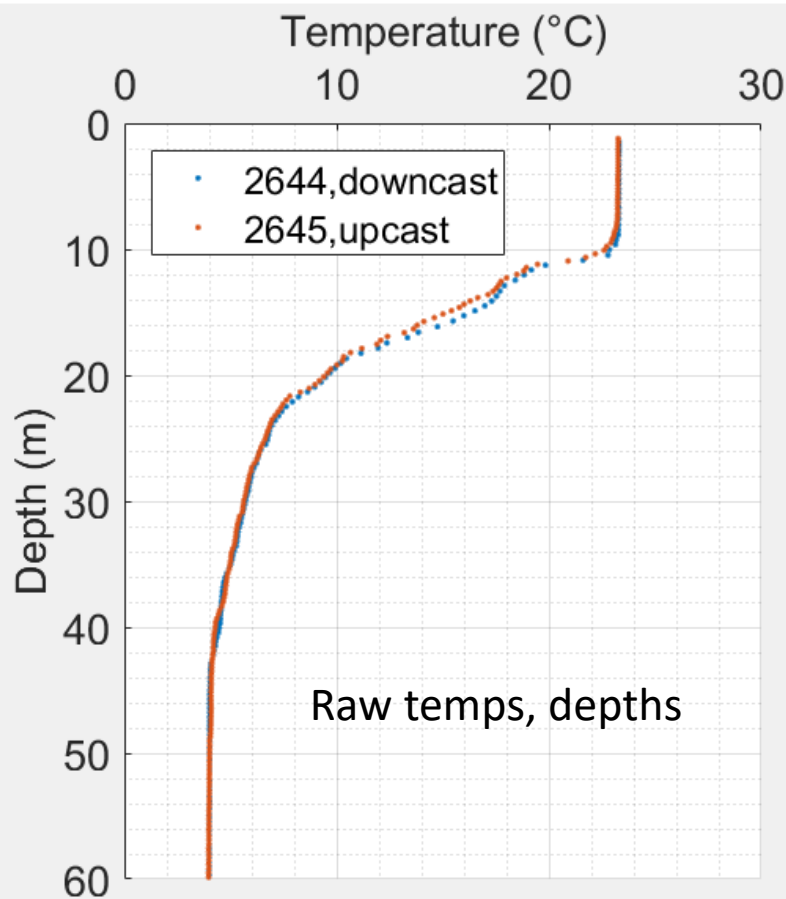
. Upcast vs downcast difference not affect SML
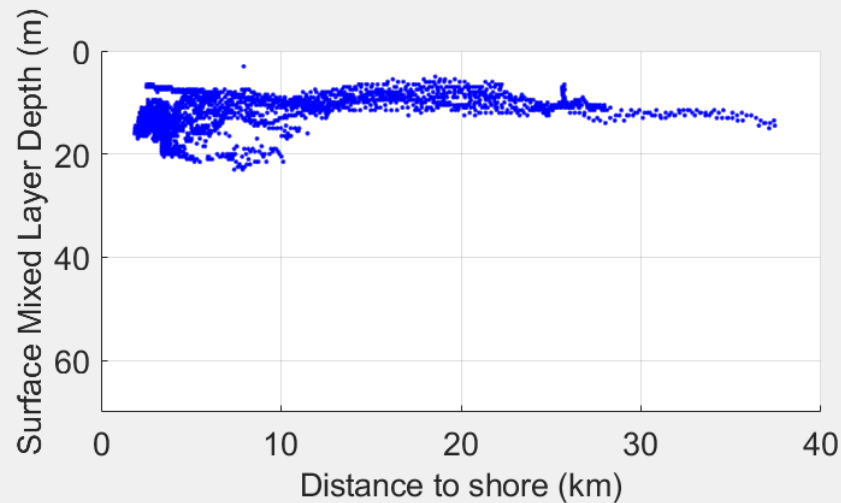
Early summer condition.
Deeper offshore areas have not yet stratified.
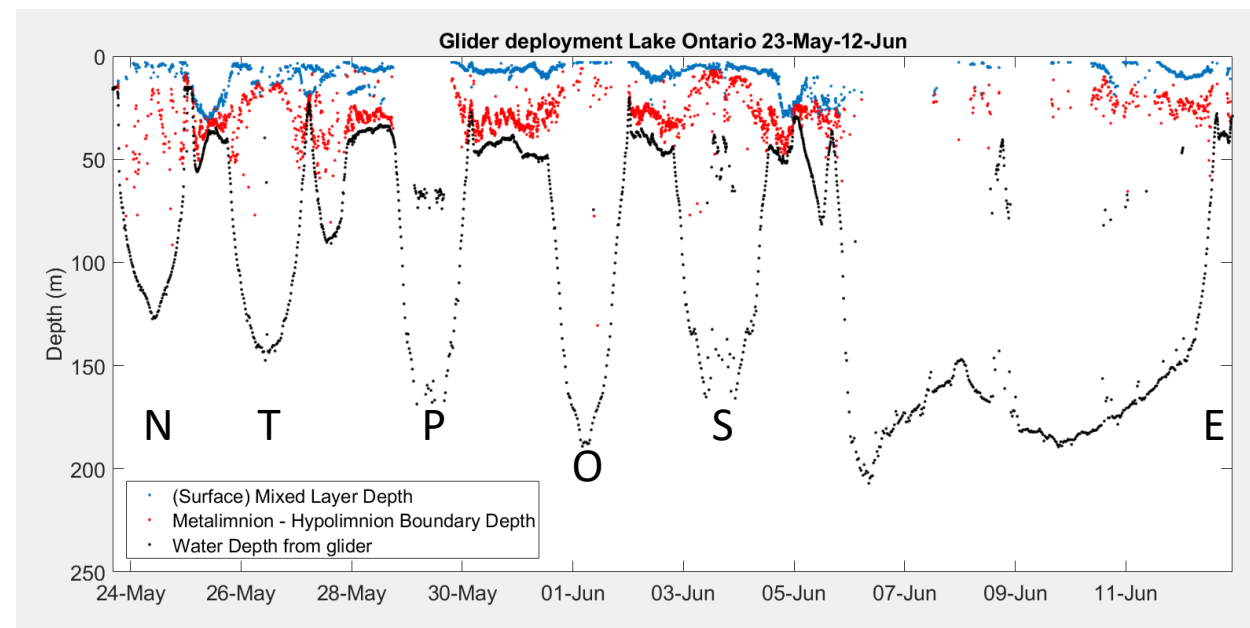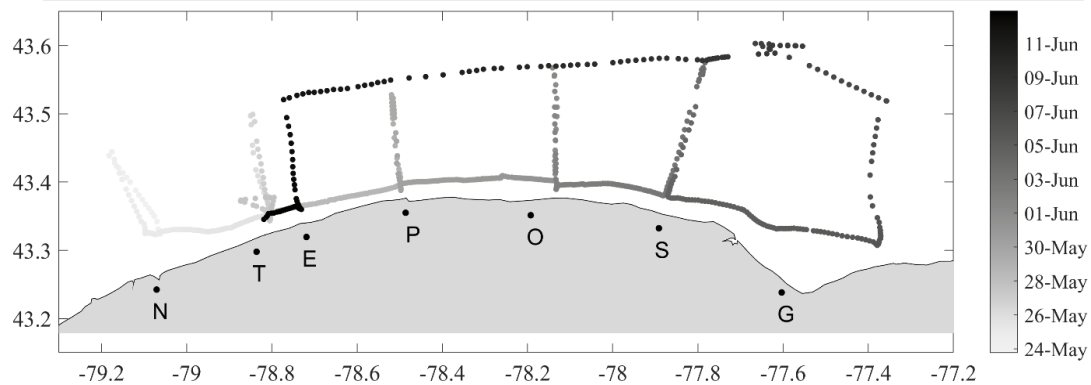
Late summer condition. Lake is stratified.

Distance from shore for glider temperature profiles from late summer (top)
Surface mixed layer depth (blue, lower left) variable <10 to >20m within ~10km of shore.
Metalimnion-hypolimnion boundary depth (red, lower right) variable 20 – 50m within 10km shore
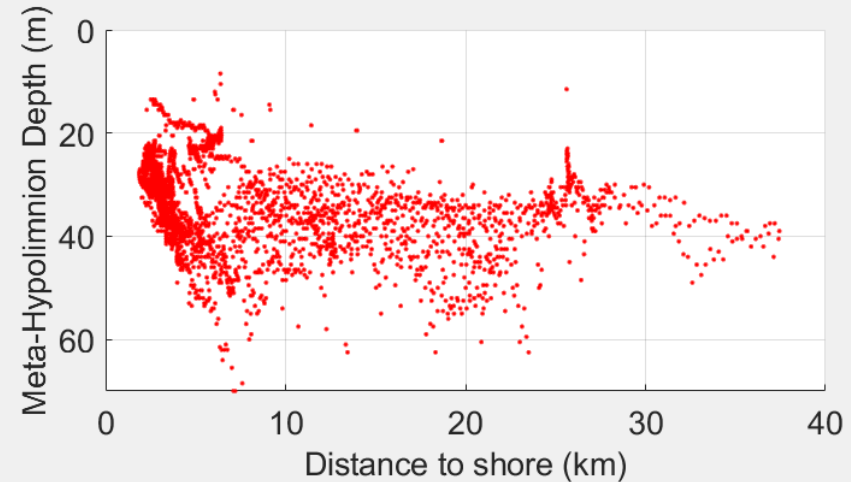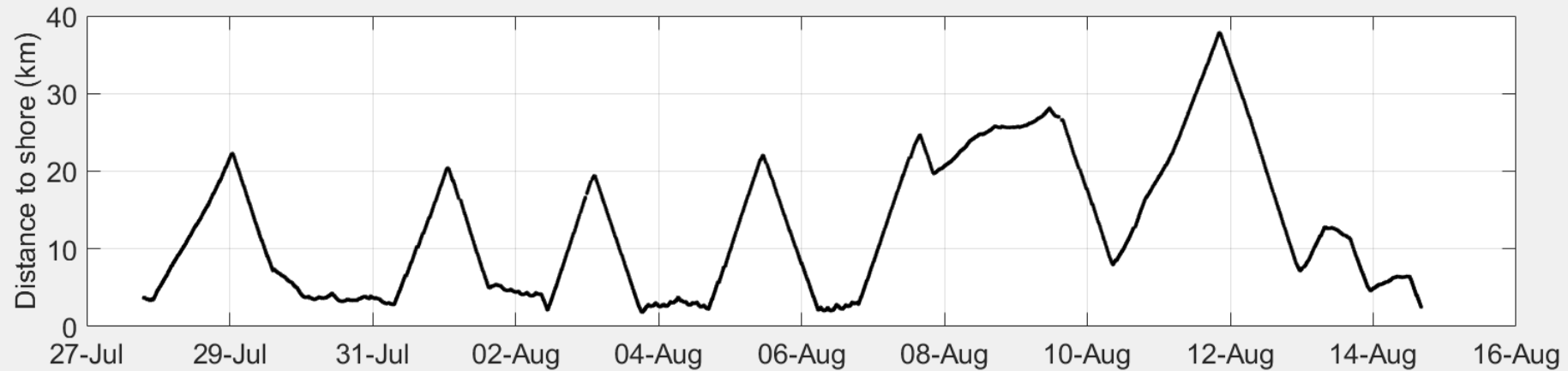
Autonomous Glider results from 2018 Lake Ontario – variability in depth of surface mixed layer
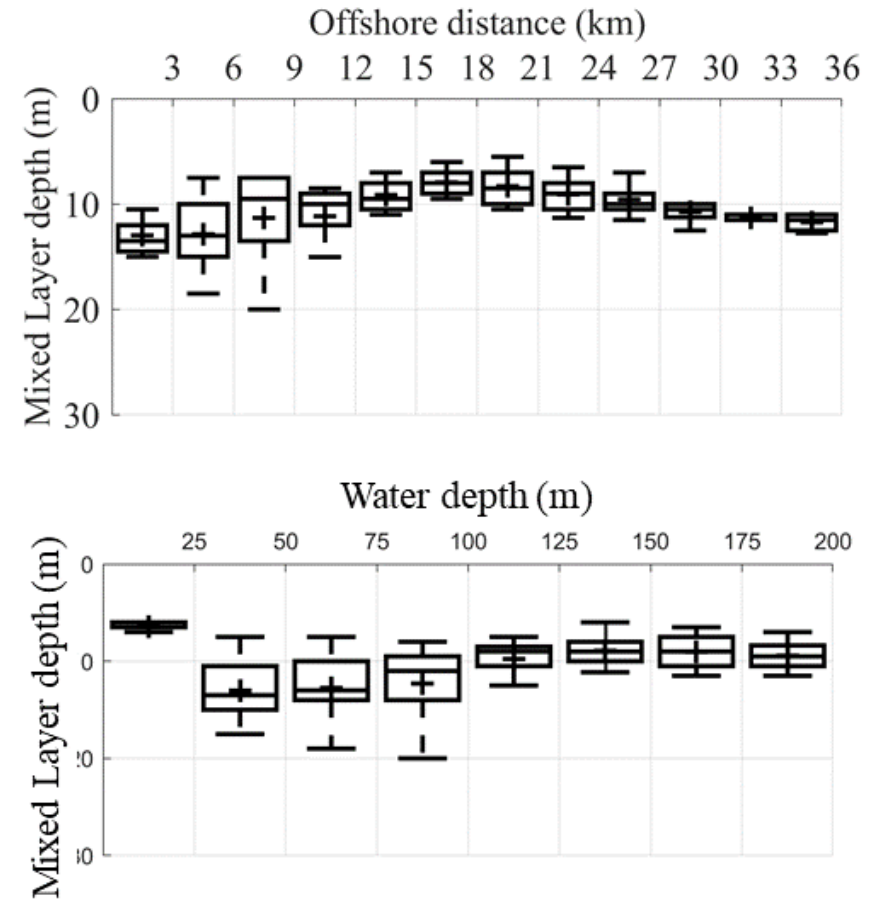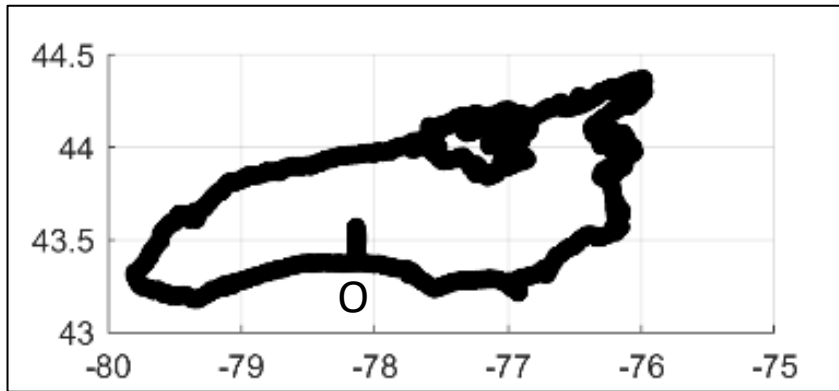
- Detail of cross – shore segment near Oak Creek (O)
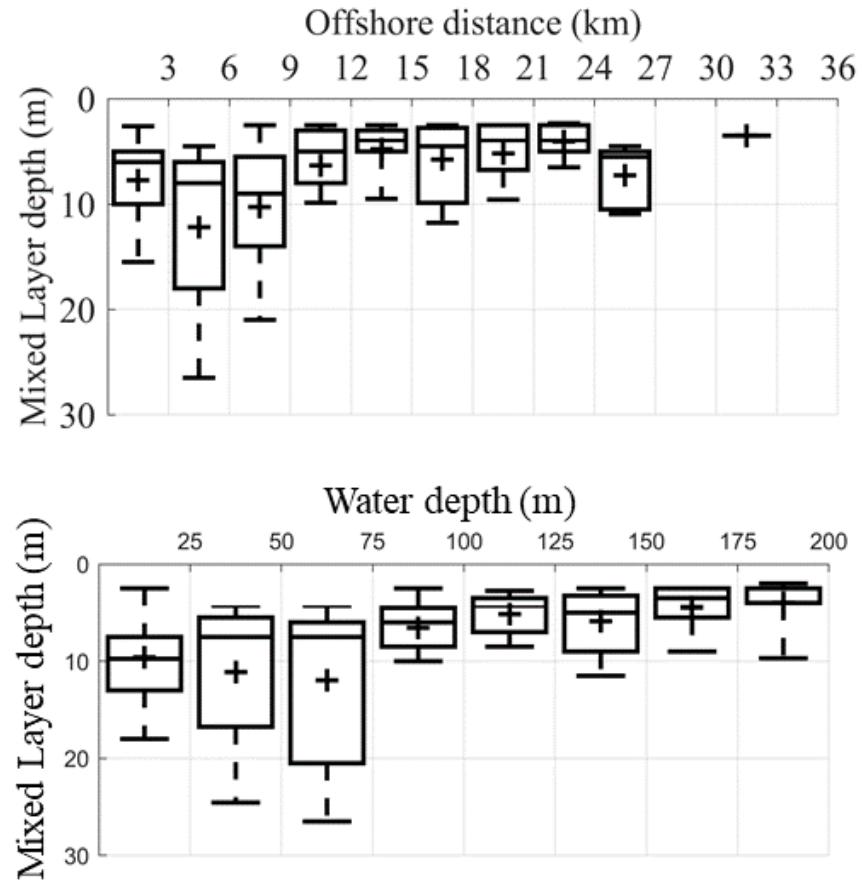- Early season (left) and late season (right)
- Conductance (top) and Chlor (bottom)
- Surface mixed layer depth (upper dotted line)
- Meta-Hypolimnion boundary depth (lower dotted line)
- Structure at ~10-15 km from shore suggests vertical mixing

June 1- June 3

Aug 1- Aug 3

Glider travel direction
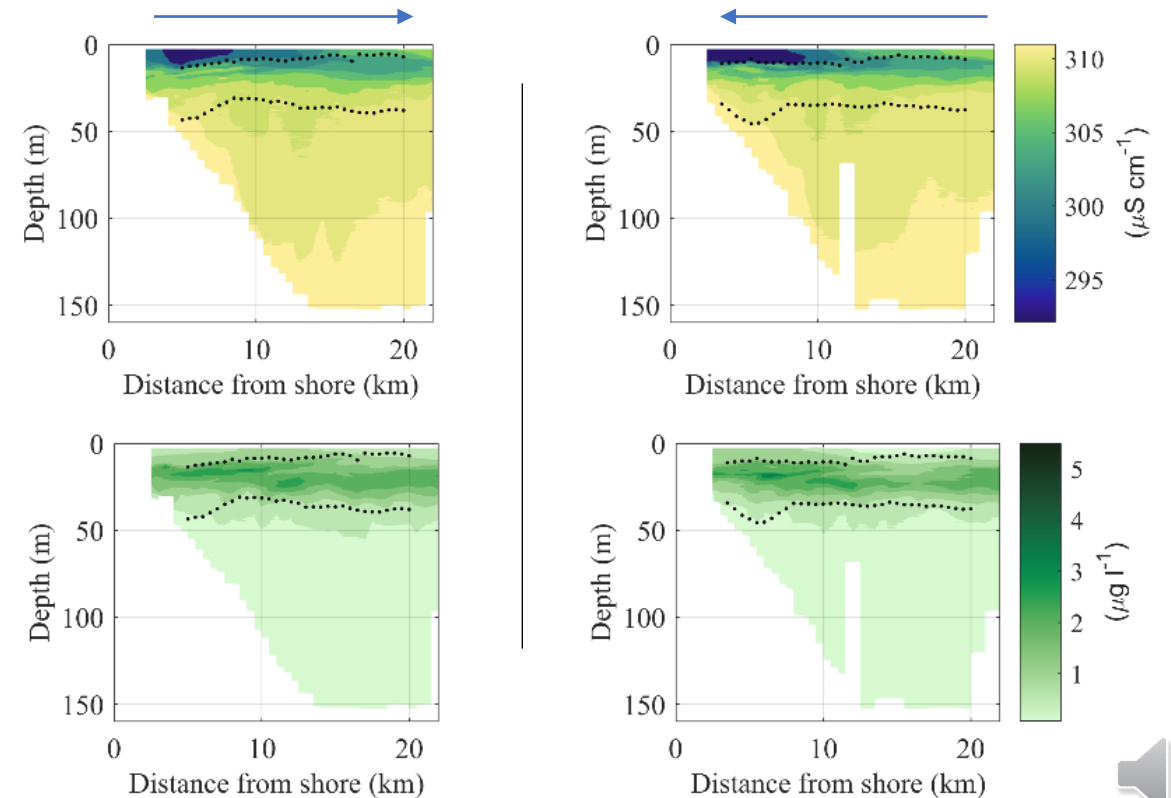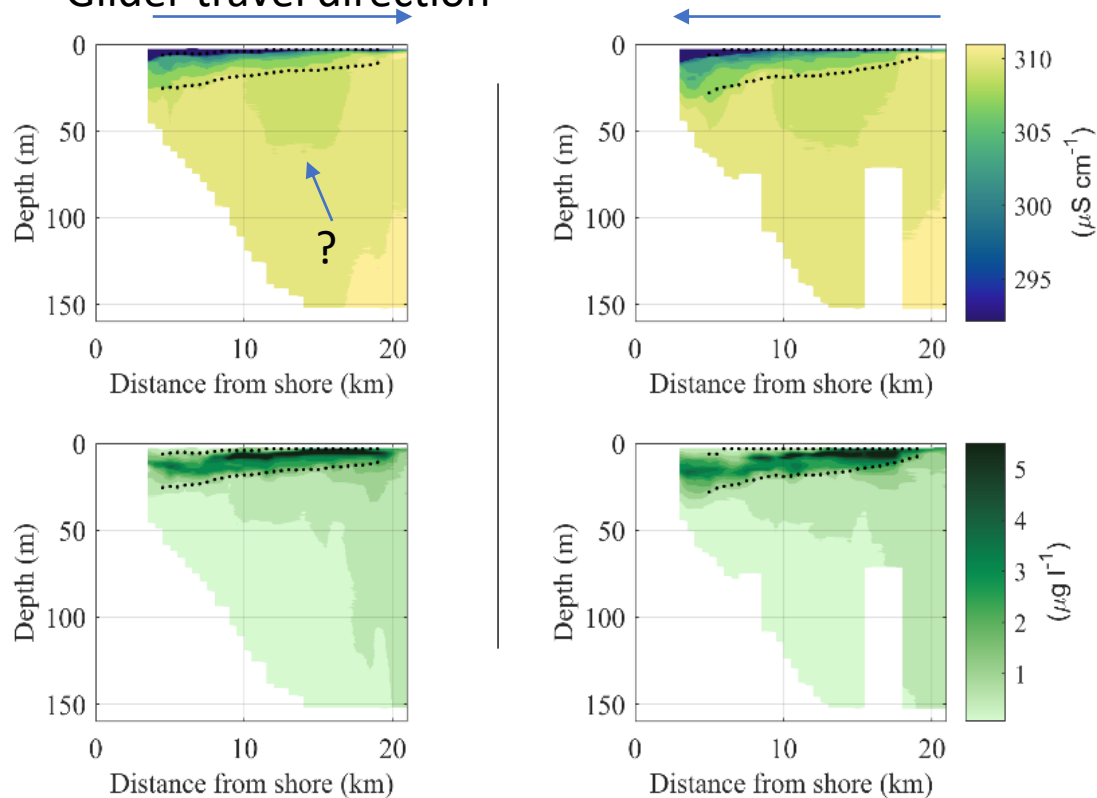
- Model comparison 1
- GLCFS Lake Ontario
- Freely available GLCFS archive
- Model grid 2km orthogonal
- 19 vertical levels, with variable thickness. Higher resolution near surface and bottom.
- Updated every 3 hours
- Output downloaded from website
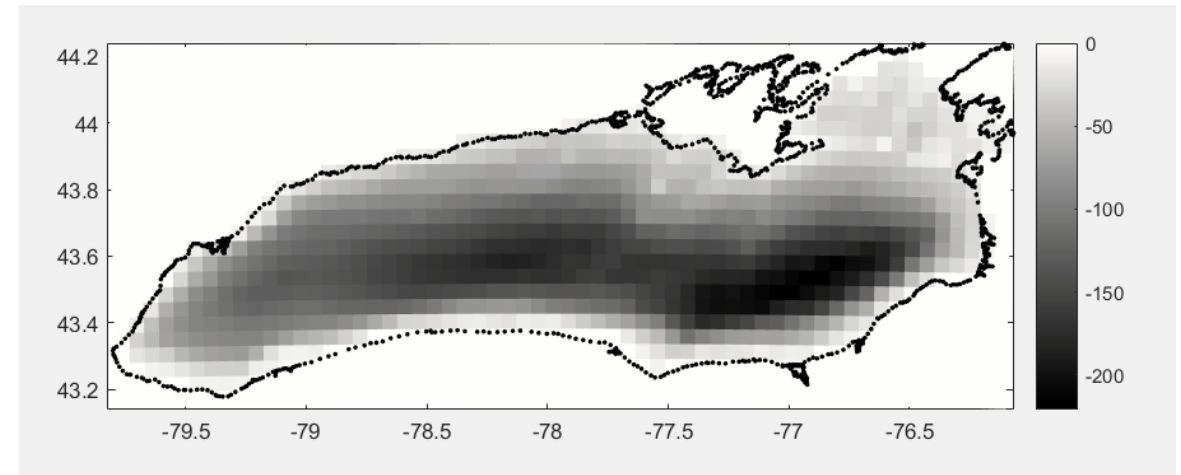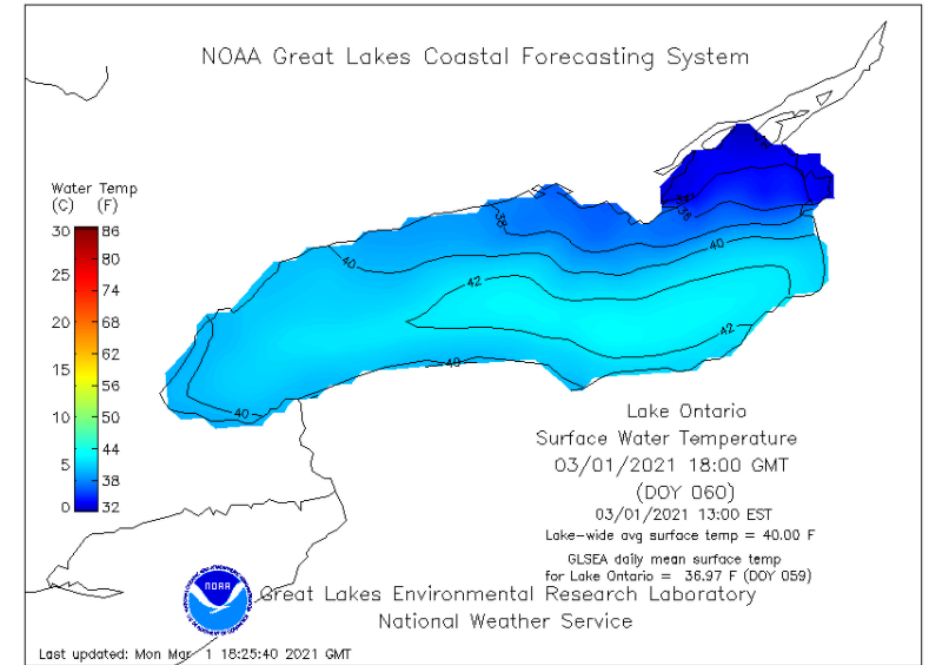
Comparison of temperature profiles from late summer glider deployment and GLCFS model.
Glider raw data (red) is fit to the 19 model depths (green) for comparison.
Offshore profiles appear to match fairly well. Closer to shore, not so well.
Some profiles, the glider did not sample the full water column.
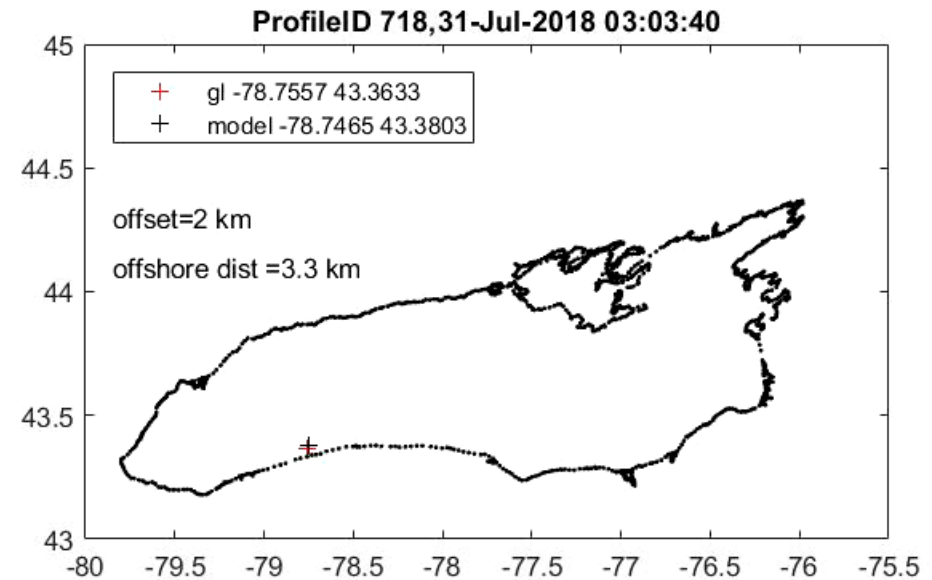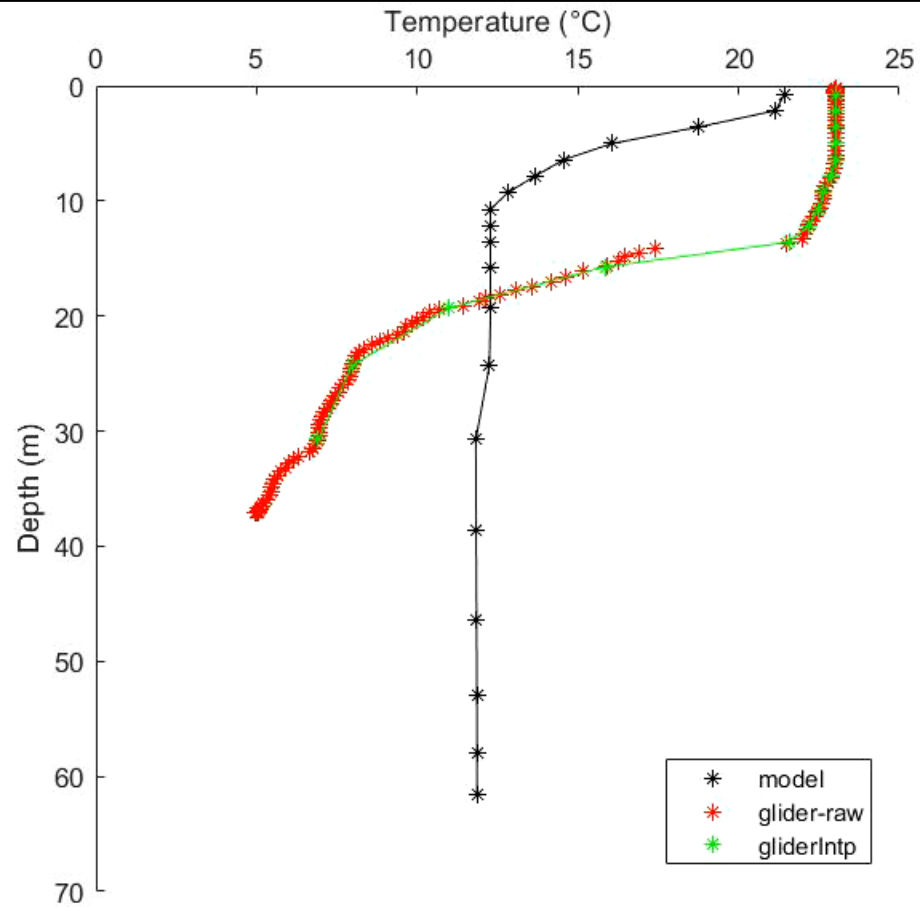
Glider - Model temperature profile matchups for May23-Jun12
Glider temp data was fit to the model depths.
Based on frequency of model updates , there were 140 potential.
Not many matchups because the lake was only partially stratified.
Model warm bias. No evidence that model performs better further from shore.
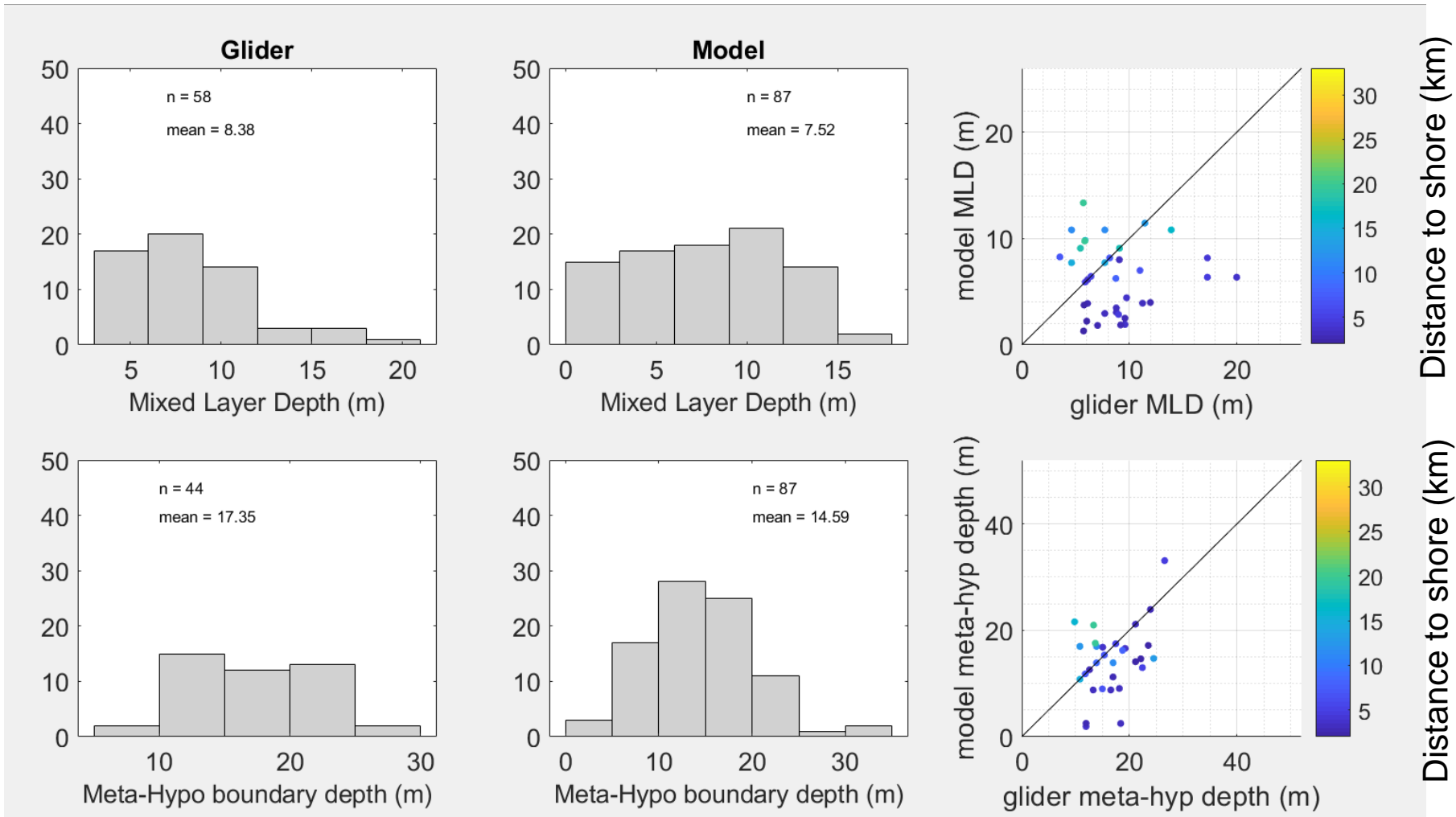
Glider - Model temperature profile matchups ; July27-Aug15 deployment.
Glider temp data shown was fit to the model depths.
There were 143/143 potential matchups due to widespread stratification.
Model shows shallow bias for surface Mixed Layer Depth.
Not conclusive that model performs better further from shore.
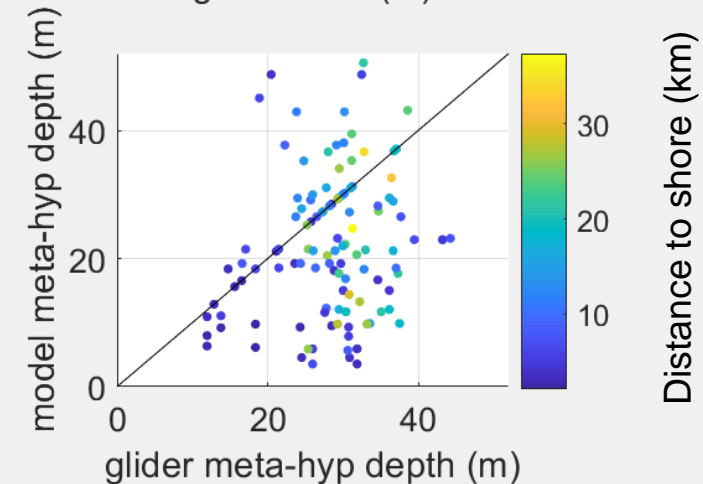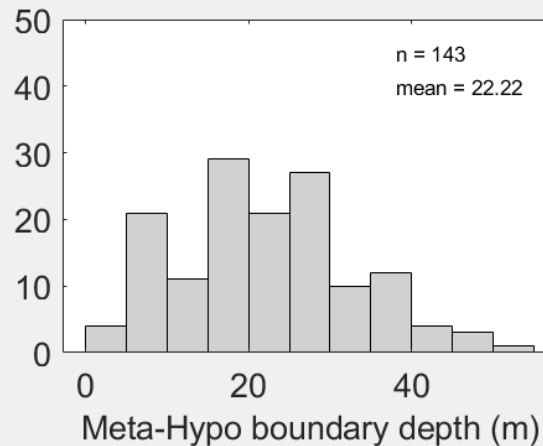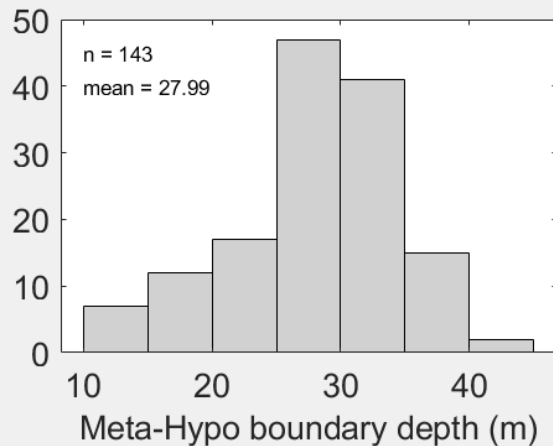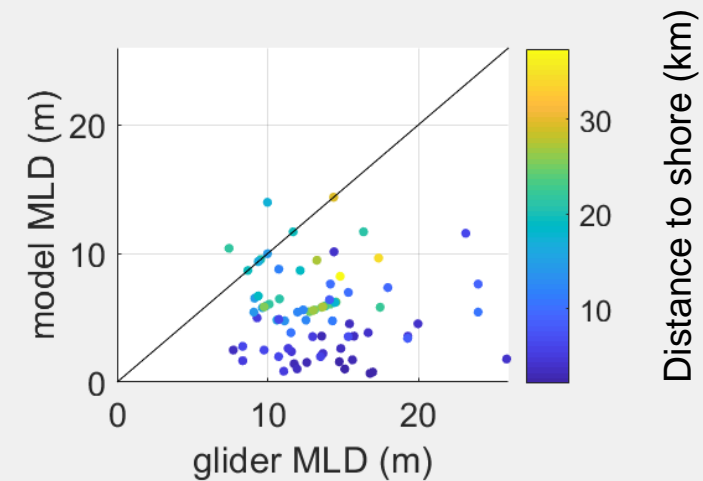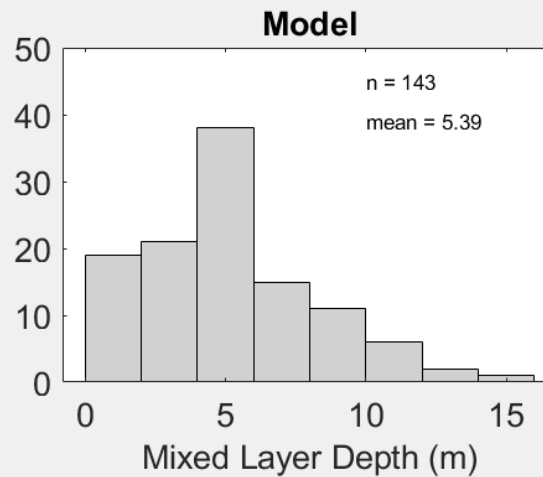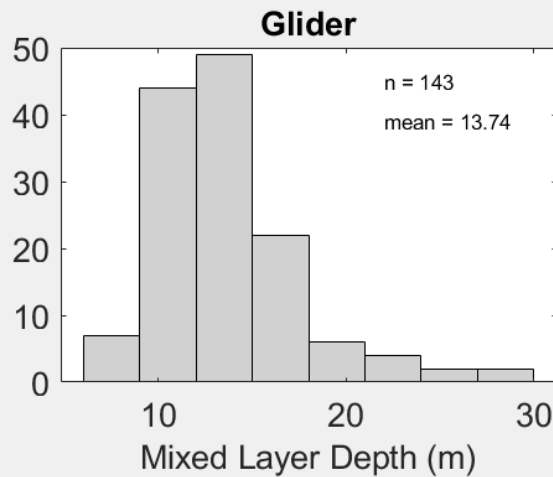
Alternative method for defining surface mixed layer depth and meta-hypolimnion boundary depth
(Use the depth of the 13 °C and 5 °C isotherms)
Glider - Model temperature profile matchups ; July27-Aug15 deployment.
Glider temp data shown was fit to the model depths.
Model shows shallow bias for depth of 13C, deep bias for depth of 5C. ie, model warm bias
Not conclusive that model performs better further from shore.

Summary
glider : model 1 comparison
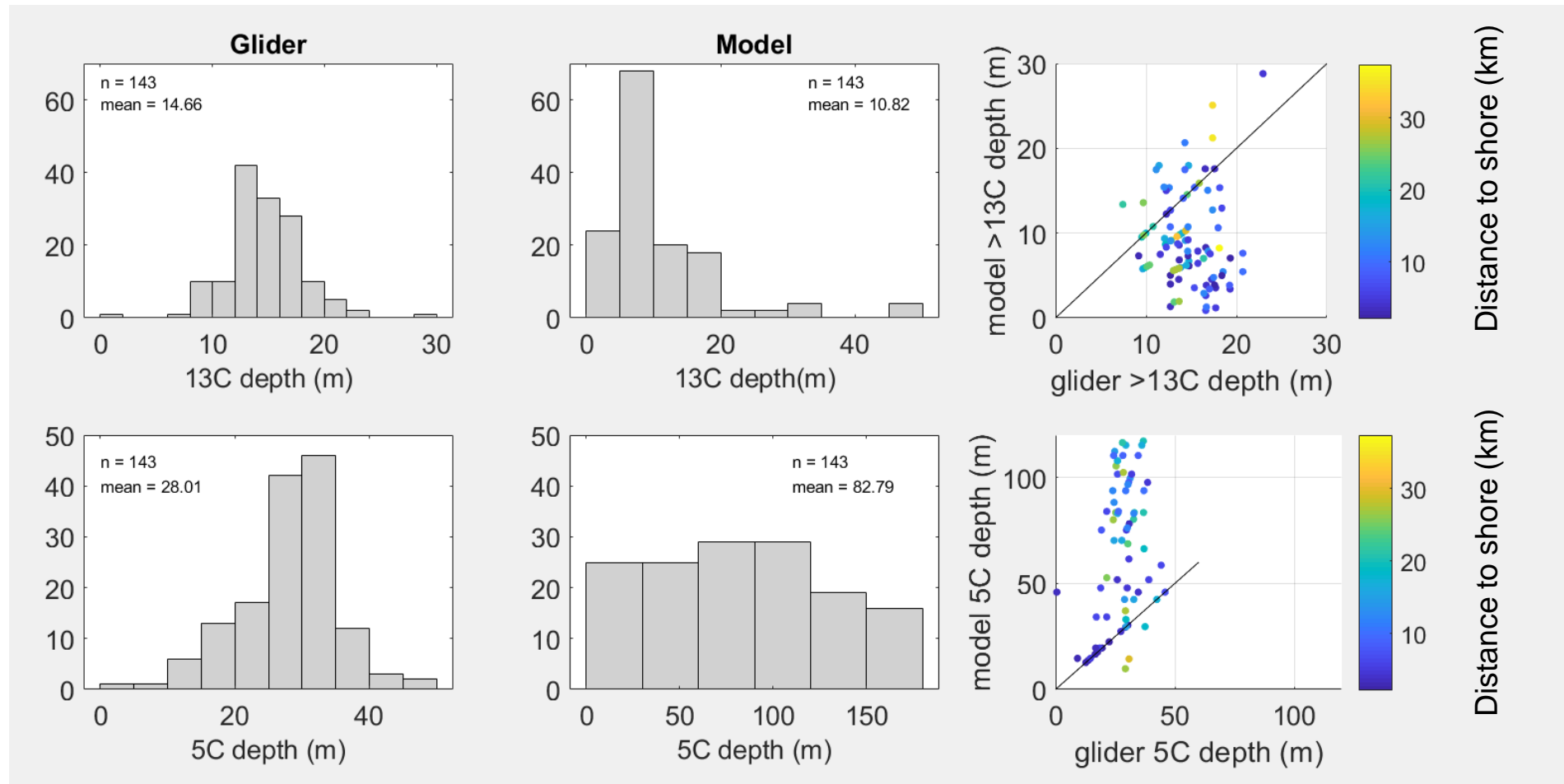
Early summer
- model had greater number of stratified profiles
- model mean mixed layer depth and meta-hypo boundaries were both shallower than glider observed.

Late summer
- mean mixed layer depth and meta-hypo boundaries were both shallower than glider observed.

Both: No evidence that model better further from shore

Additional comment: Surface temperature comparison (right) showed glider observed steady increase in second deployment. The model showed similar pattern for the first half. Suspect the model forcing, and particularly the satellite sea-surface temperature used to tune the model was affected by cloud cover or other, which affected model performance.
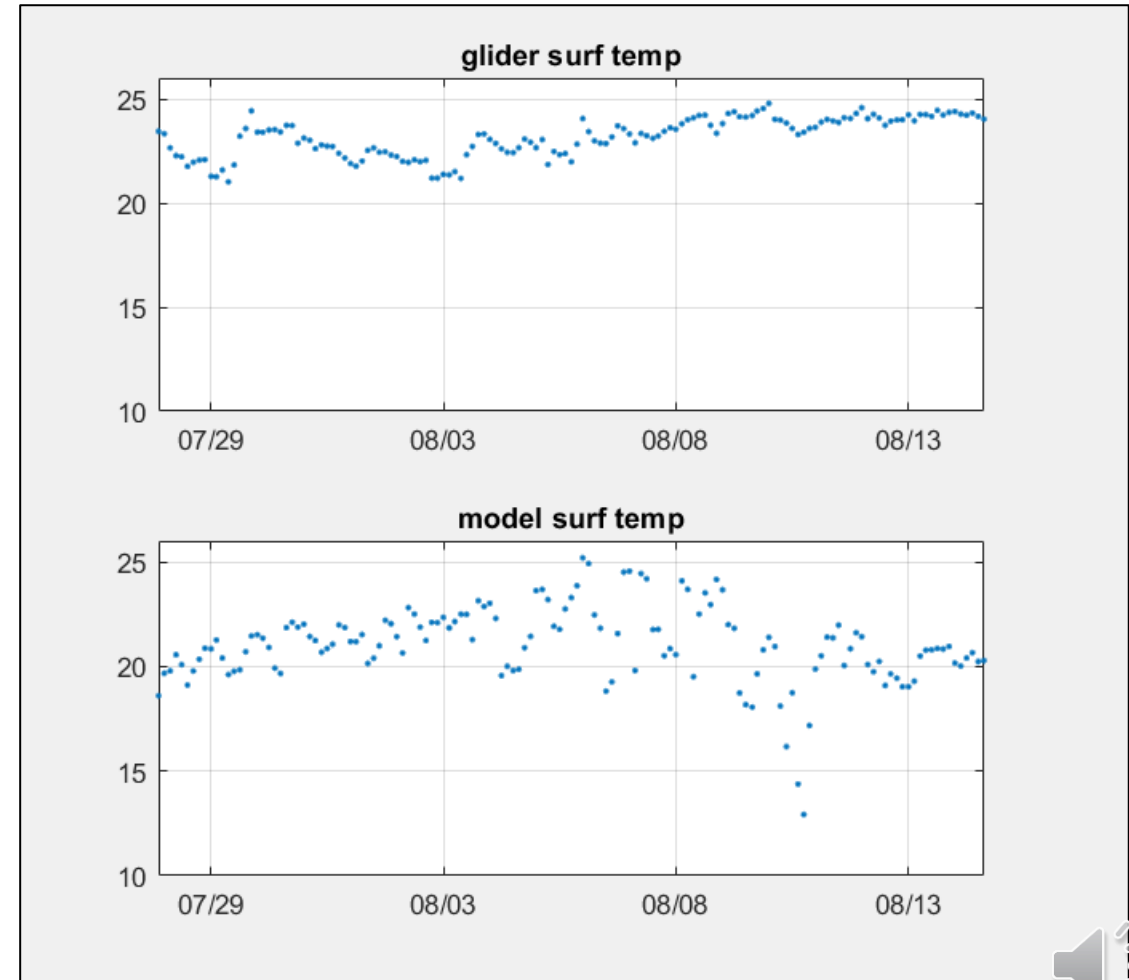
Glider / Model2 comparison

- The computational grid 13,778 surface cells

- Variable vertical layers depends on local water depth.

- Open-water cells have 10 vertical layers. (local water depth divided into 10 equal layers)
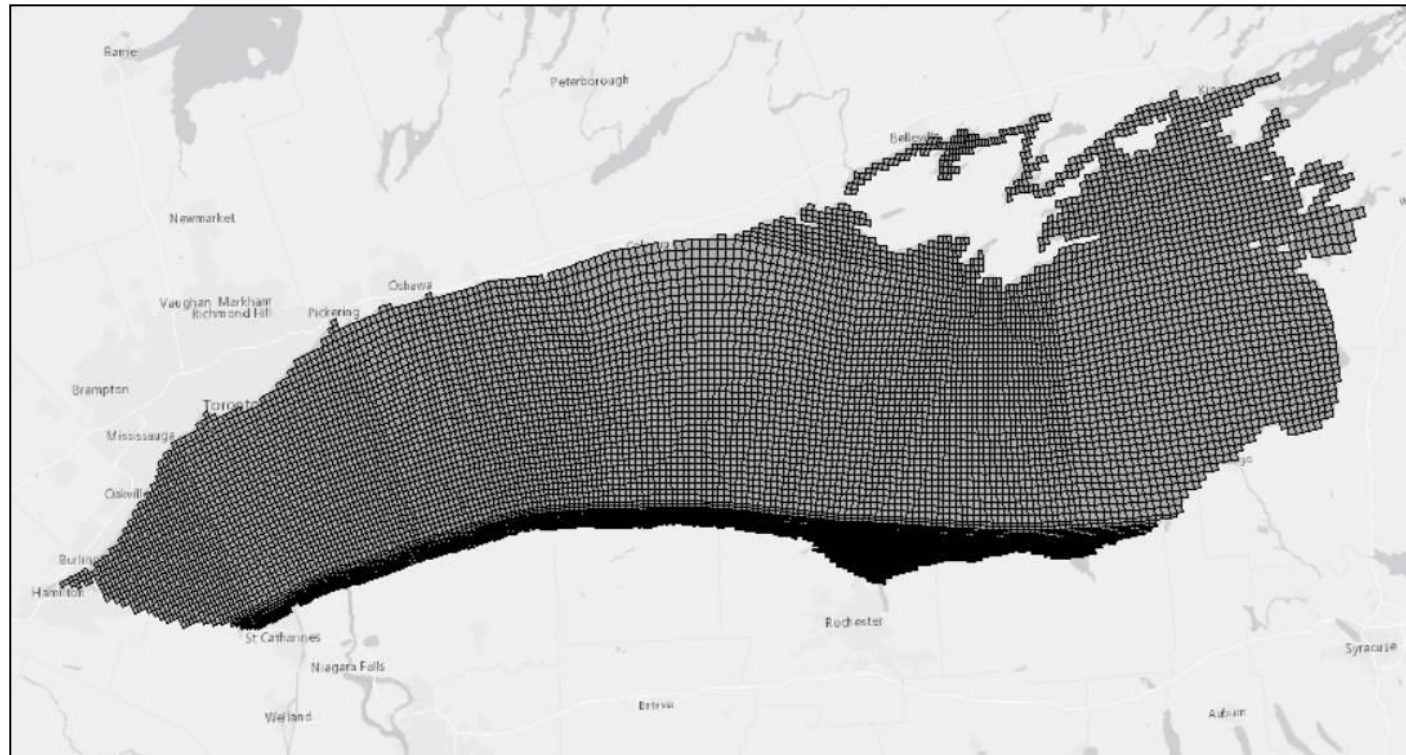
- Cell length in the along-shore direction ranges from around 678 m to 2 km.

- Cell length in cross shore direction ranges from around 100 m to 2.4 km.

- Output courtesy of Wilson Menendez, USEPA contractor.

Glider / Model2 comparison

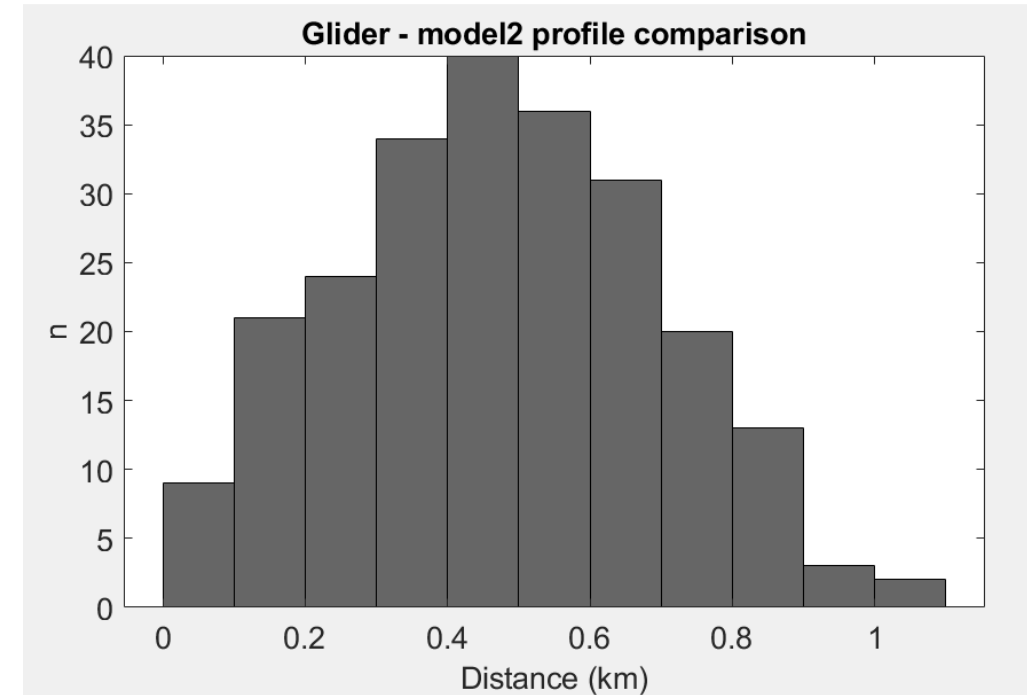234 potential comparisons from the late summer glider deployment

Distance between profiles (Glider/Model)

Glider - **Model2** temperature profile matchups ; July27-Aug15 deployment.
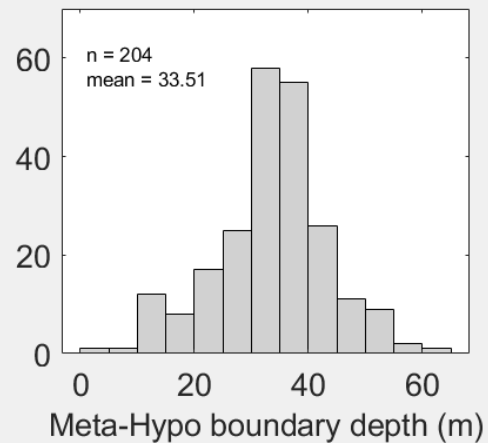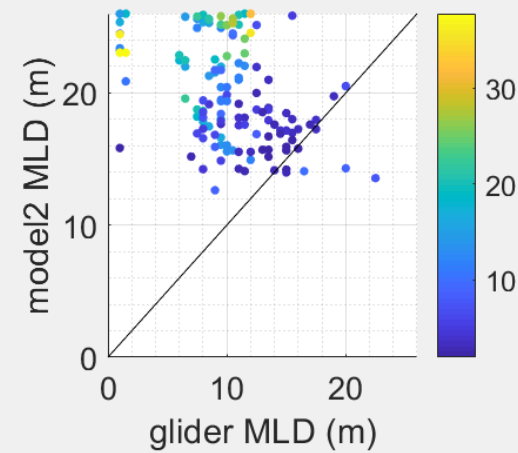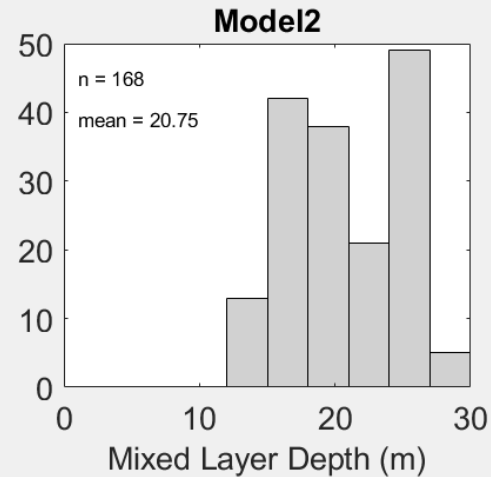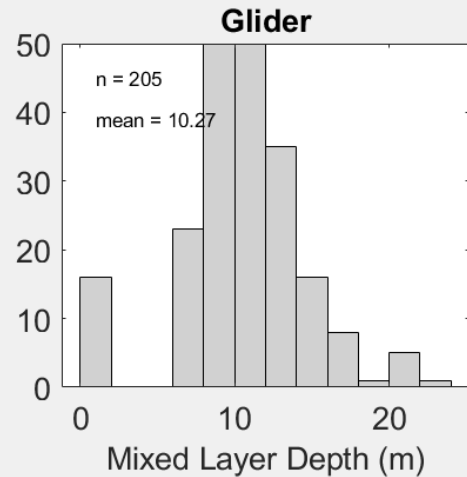Potential 234 matchups.
Glider temp data shown was fit to 0.5 m vertical bins for this comparison.
Model shows deep bias for both surface mixed layer depth and depth of meta-hypolimnion boundary.
ie, model warm bias
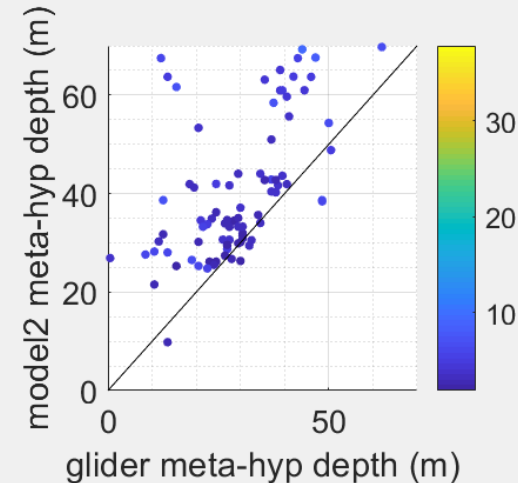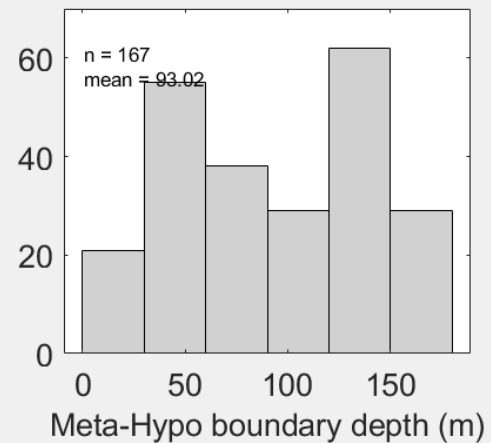
Summary
glider : model 2 comparison

Late summer :
- Only considered late summer due to low number of stratified profiles in early summer deep areas.

- mean mixed layer depth and meta-hypo boundaries were both deeper than glider observed.

Both: No evidence that model better further from shore

Additional comment: The model vertical component was quite coarse in deeper areas (bottom depth divided into 10 equal compartments), which resulted in low number of profiles meeting the original stratification metrics. Comparison with glider profiles fit to uniform 0.5m vertical spacing showed model deep bias for both surface mixed layer depth and depth of meta-hypolimnion boundary.

Conclusions

Autonomous glider completed two deployments in southern Lake Ontario summer 2018 including several cross-shore transects between Niagara and Rochester, NY.

Mid-depth region to ~10km from shore and water depths ~100 was characterized by variability of surface mixed layer depth and depth of the metalimnion-hypolimnion boundary.

This variability may explain cross shore variability of conductance and other parameters in hypolimnion, and suggests physical processes operating within or at the boundary of the coastal boundary layer (Csanady, 1973) that may play important role in cross-shelf exchange and coastal benthos ecosystem functioning.

Comparison of depth of surface mixed layer and depth of metalimnion-hypolimnion from the glider deployments to archived hydrodynamic model output indicates these models as configured did not capture the variability of the mid-shelf density structure.

The models were used as convenient demonstration, and were not necessarily designed to resolve processes at these spatial and temporal scales.