Exploring the Use of Multibeam Sonar Sound Speed Corrections to Map Water Column Variability

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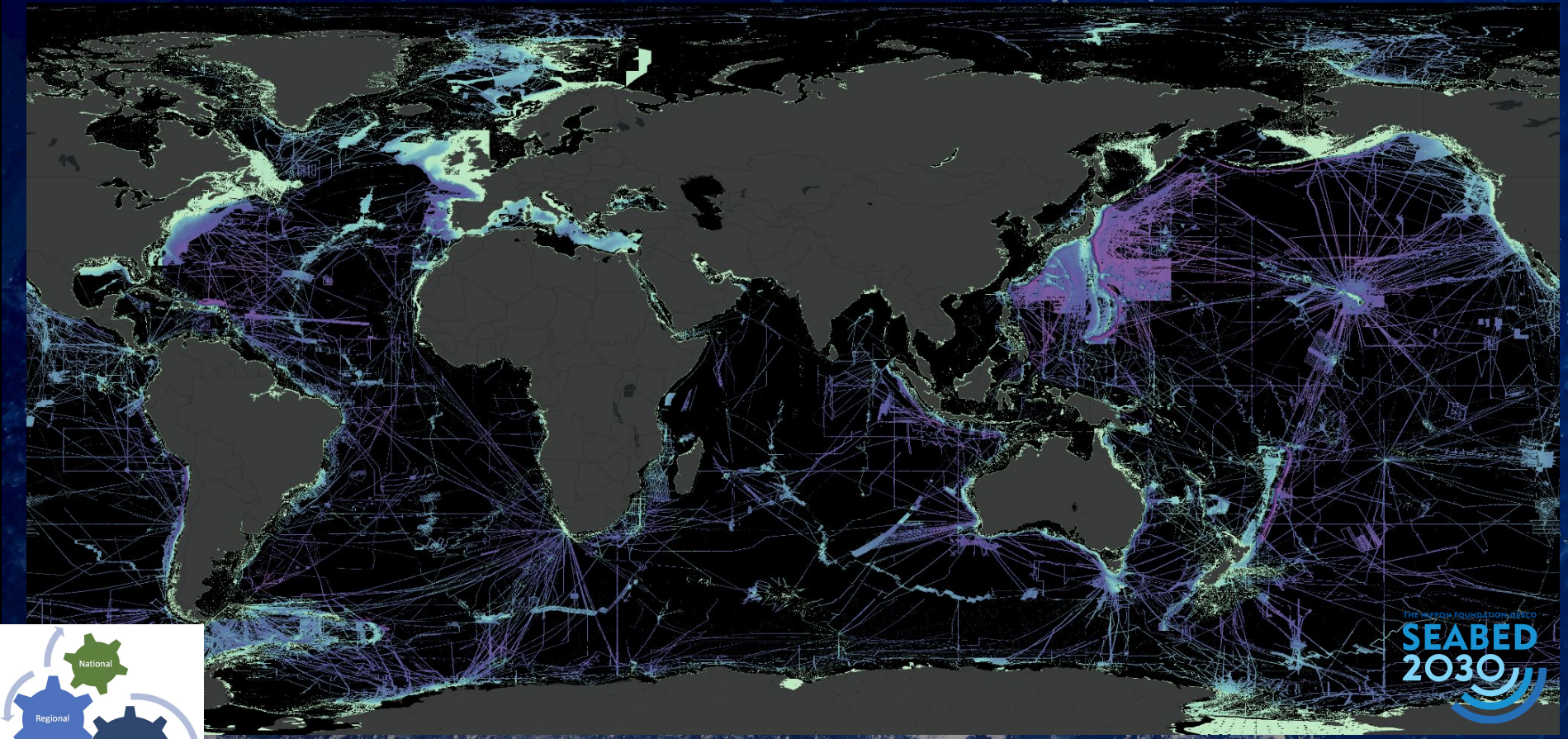
Columbia Climate School
Lamont-Doherty Earth Observatory

GMRT

Multibeam Advisory Committee

NSF

Only ~20% of the global ocean is mapped

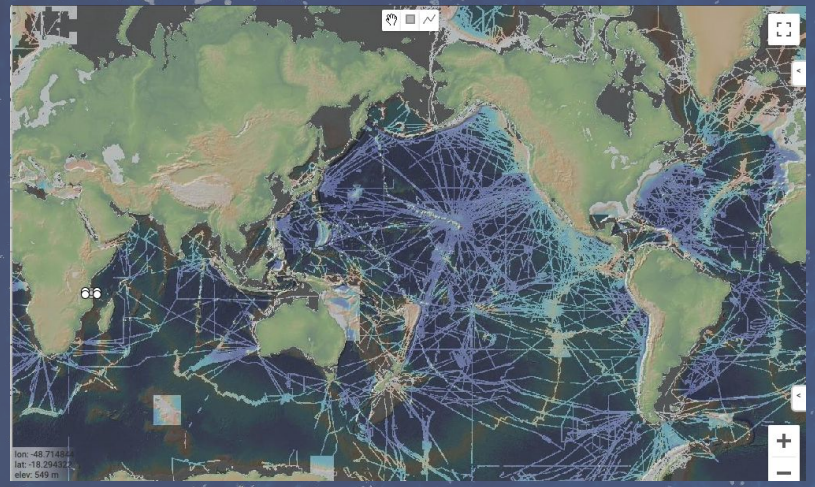


Only ~20% of the global ocean is mapped

Leveraging data processing efforts will help us build a complete map more quickly

GMRT (Global Multi-Resolution Topography)

- a multi-resolution **data synthesis**
- an **infrastructure for delivering elevation data** as grids, images, profiles and points at user-defined locations/elevations, with full attribution to sources & access to source data
- a **tiling scheme** for efficiently storing and delivering multi-resolution data, maintained simultaneously in 3 projections
- a **scalable methodology** for QA/QC'ing multibeam sonar data that is very well-suited for integrating multibeam data acquired during transits



GMRT Version 4.0 (January 2022)

- Curated MB Data from 1,326 cruises (10.5% global ocean)
- Contributed Grids
- GEBCO 2021 basemap

raw

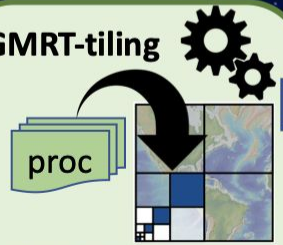
Ops Teams

Scientists

GMRT-team

Raw MB to NCEI via R2R

GMRT-tiling



QA/QC against GMRT 100-m compilation

proc swath to NCEI

Tiles and metadata to GMRT

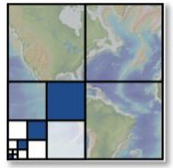
NOAA/NCEI MB Archive

raw

proc

Archived as received

GMRT.org

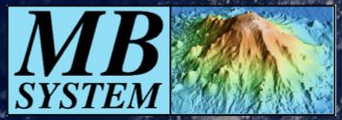


amazon web services

Broaden and accelerate QA/QC:
GMRT team + ops groups + science community + students + other partners

GitHub

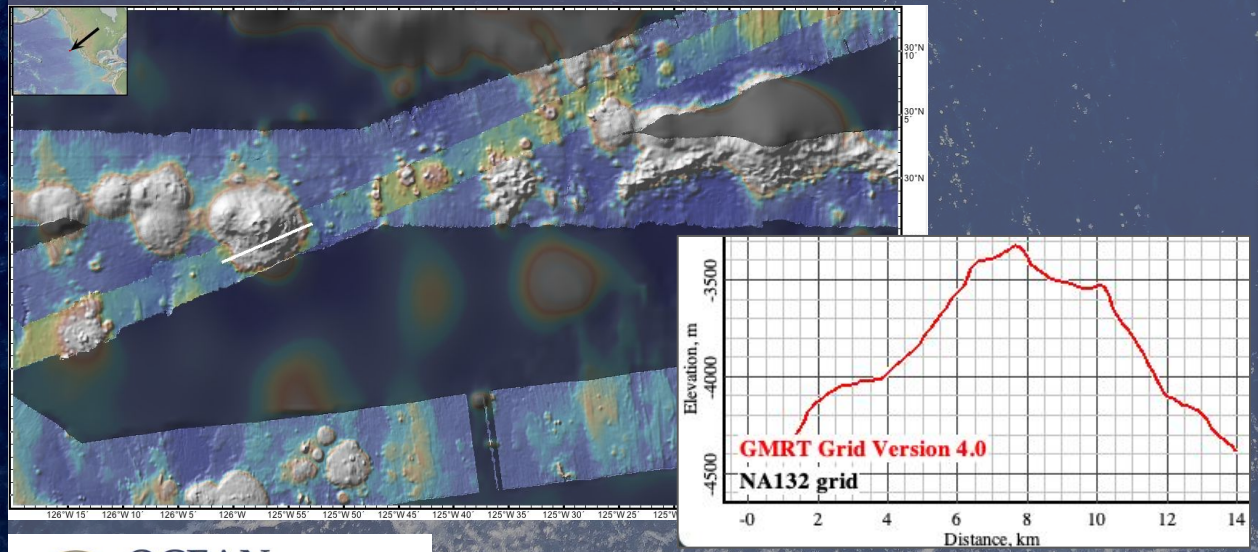
Java



- Accelerate creation of fit-for-purpose data products
- Optimize data in NCEI Multibeam Archive
- Minimize need to reprocess and version data in NCEI archive

GMRT Community

- At-sea use aboard *EV Nautilus*
- Comparison to existing publicly available data
- Easy QA/QC for rapid integration into GMRT



OCEAN EXPLORATION TRUST

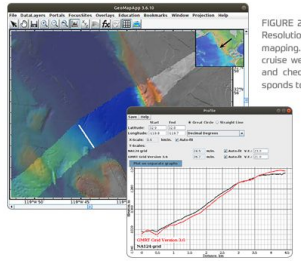


FIGURE 2. The image shows the use of Global Multi-Resolution Topography (GMRT) QA/QC tools for NA125 mapping. The new GMRT tiles generated during the cruise were compared to the current GMRT data set and checked for consistency. The white line corresponds to the profile image.

combined with filling further bathymetry gaps on transits across the Borderland between sites.

The final expedition of the season, NA125, was a mapping-only cruise that targeted gaps in NOAA's US bathymetry coverage and gap analysis (https://iocm.noaa.gov/seabed-2030-bathymetry.html) within the US Exclusive Economic Zone (EEZ). The primary mapping area was along the western boundary of the EEZ west of San Diego. A secondary mapping area located in the more protected regions in the California Borderland was completed when

been contributed directly to the Global Multi-Resolution Topography (GMRT) Synthesis. OET has worked with the GMRT team to improve workflows for processing and integration into GMRT, as well as to smooth the path for submission of data to the Seabed 2030 Regional Centers (Figure 2). In 2020, data collected on 28 *Nautilus* cruises from 2015 to 2019 were prepared for integration into GMRT, revealing some minor issues that were addressed prior to submission to NCEI. Combined, the submitted data cover more than 300,000 km² of seafloor in the Pacific Ocean.

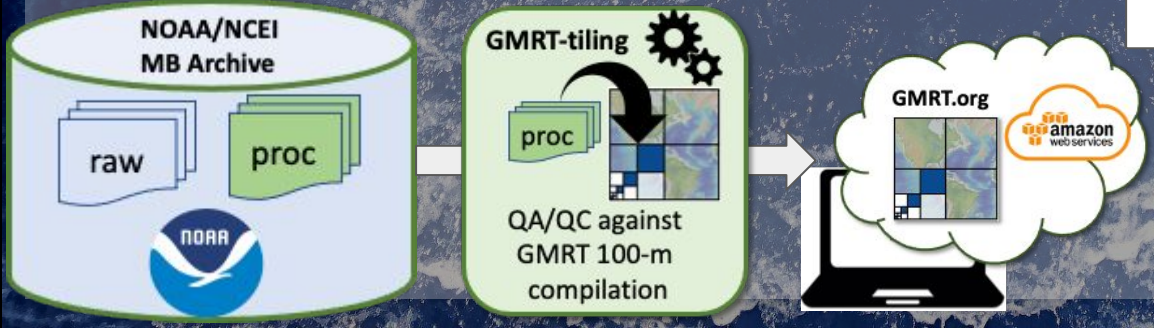
In order to accelerate the rate of data integration, not burden the GMRT team, leverage the skills of the *Nautilus* onboard mapping team, and contribute to the mapping community, GMRT tiling tools were adapted for use aboard *Nautilus* (Ferrini et al., 2020). OET prototyped the use of the tools on board in 2019, and in 2020, GMRT tiling tools were integrated into the standard operating procedures. These tools improve the data submission workflow and provide a testbed for tools that can benefit the broader seabed mapping community.

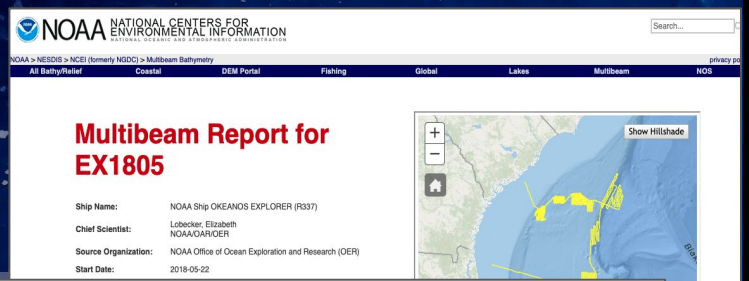
Since *Nautilus* exploration began in the area in 2015, OET

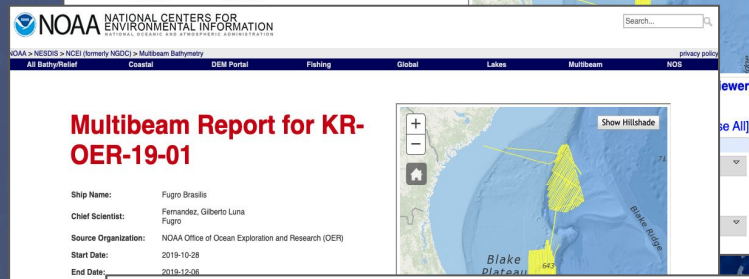
10.1002/essoar.10505639.1
10.5670/oceanog.2021.supplement.01

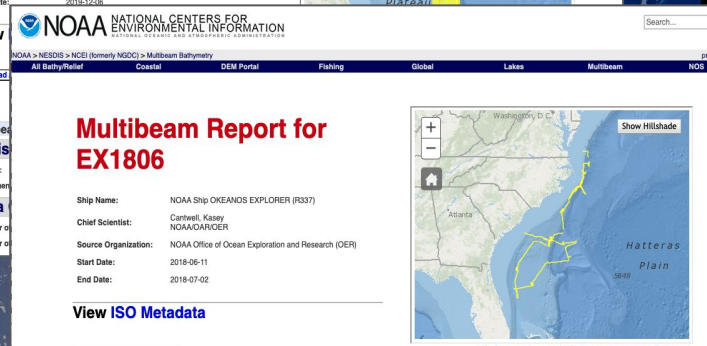
Review/Integrate: Processed Swath Data

- Download processed swath files from NCEI
- Grid into tiled rasters using GMRTTool
- QA/QC to ensure meets GMRT standard
- Explore/address problems
- Integrate into GMRT
- Contribute to GEBCO/Seabed 2030



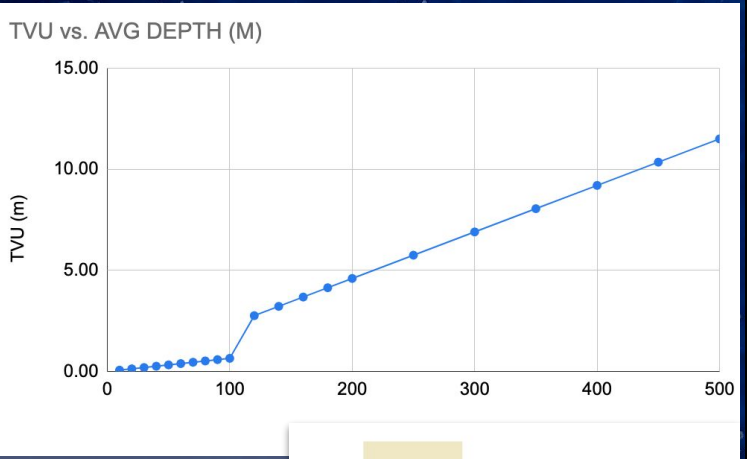


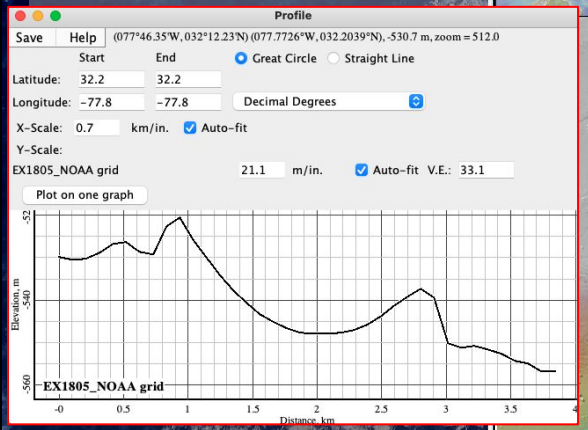


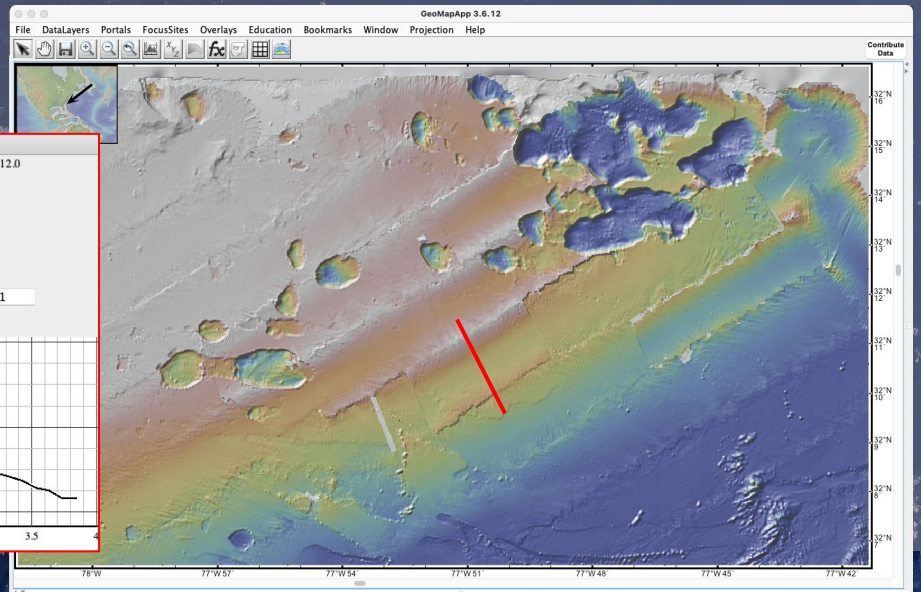


Examples of Sound Speed Problems

- Goal is fit for purpose
- IHO Spec provides useful guidelines but not always adequate in deeper water
- Discovered cruises from Blake Plateau with extensive artifacts due to sound speed-induced offsets

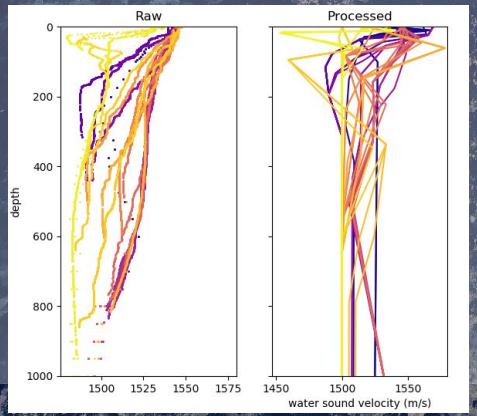


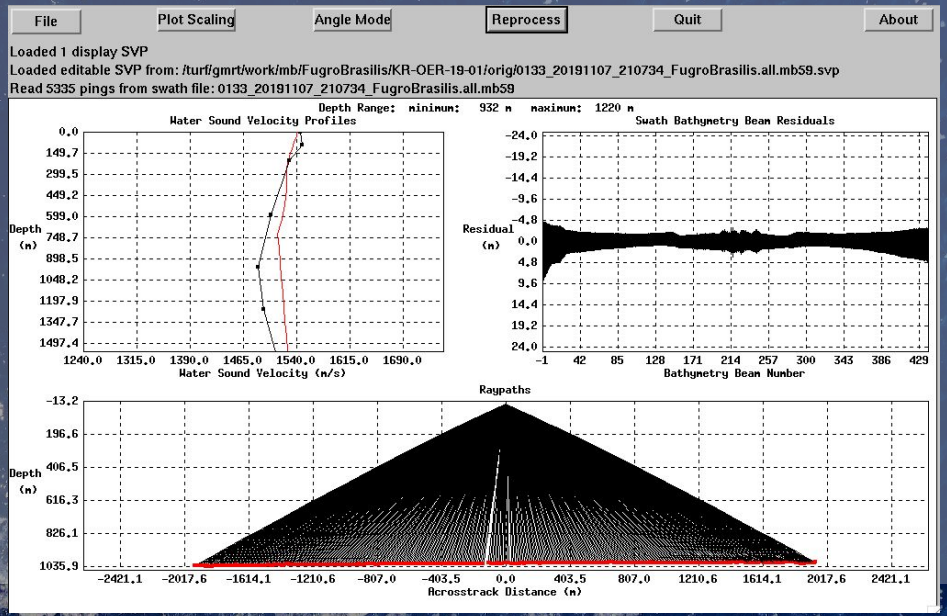


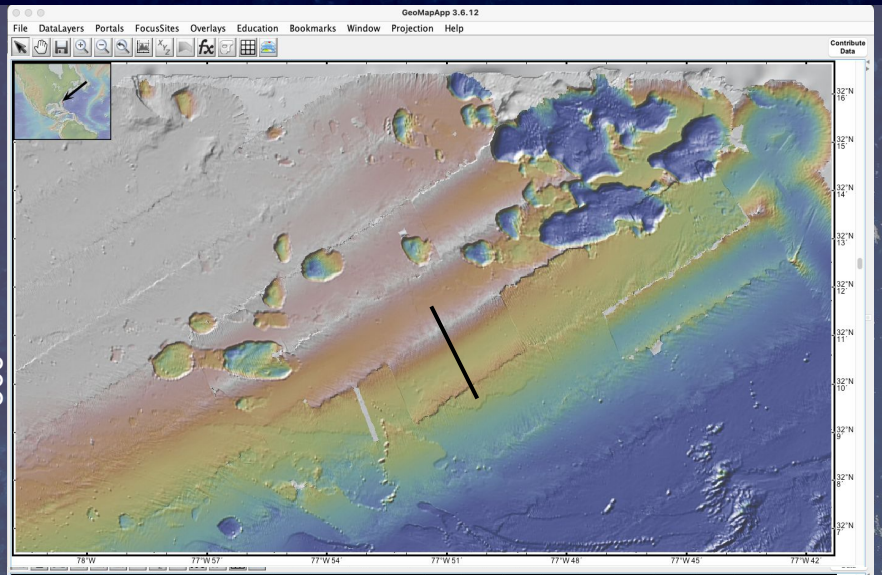


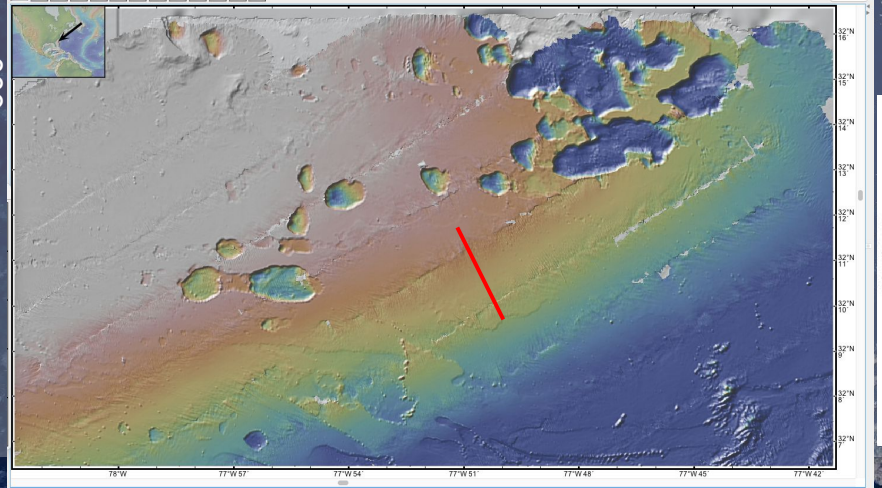
Fixing sound speed problems without starting from raw

- Extract edits from processed swath files (GSF) downloaded from NCEI
- Downloaded raw swath files (mb59) from NCEI and prepare them for processing with MB-System
- Apply extracted edits from GSF to raw data in MB-System
- Grid data with GMRT Tool
- Review data with GeoMapApp
- Apply sound speed corrections






GeoMapApp 3.6.12
File DataLayers Portals FocusSites Overlays Education Bookmarks Window Projection Help
Contribute Data
m
-500
-600
78°W
77°W 57'
77°W 54'
77°W 51'
77°W 48'
77°W 45'
77°W 42'


78°W
77°W 57'
77°W 54'
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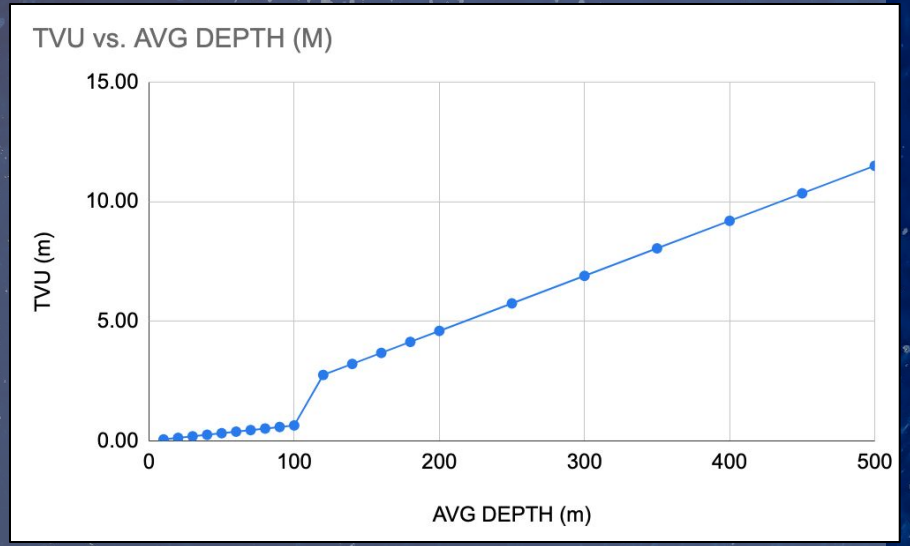
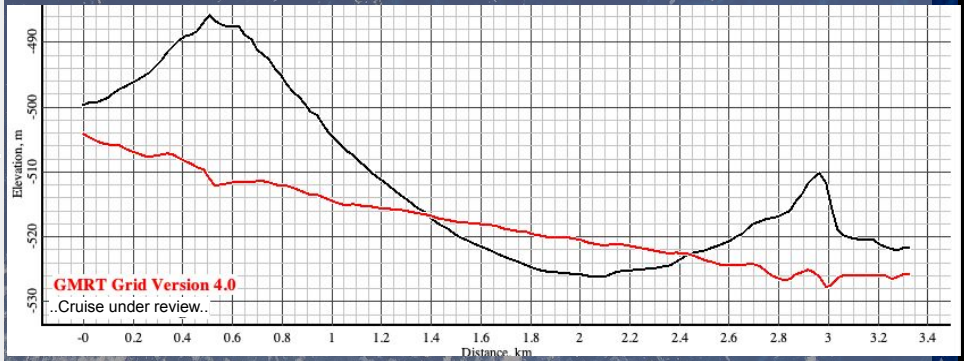
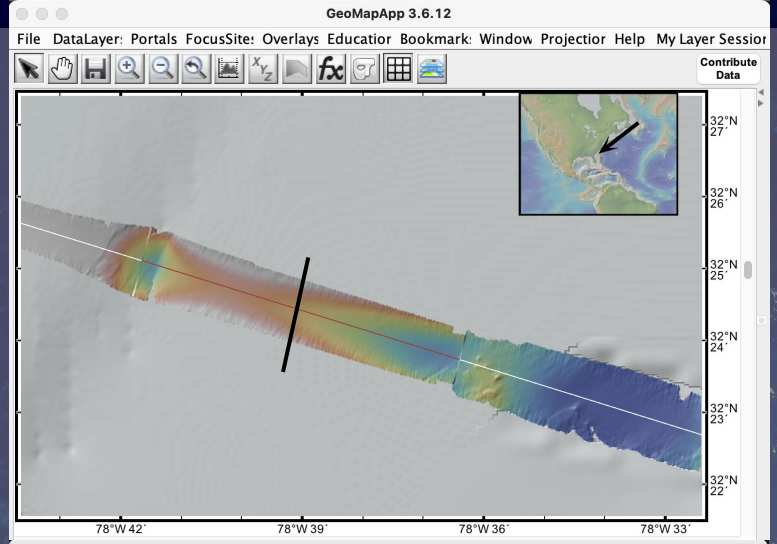
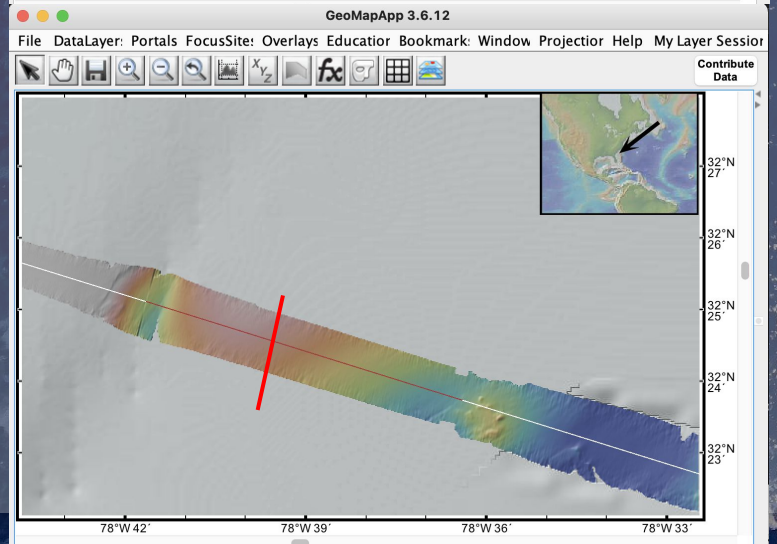

TVU vs. AVG DEPTH (M)
TVU (m)
15.00
10.00
5.00
0.00
0
100
200
300
400
500
AVG DEPTH (m)


Elevation, m
-490
-500
-510
-520
-530
GMRT Grid Version 4.0
..Cruise under review..
-0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
Distance, km


GeoMapApp 3.6.12
File DataLayer: Portals FocusSite: Overlays Educatior Bookmark: Window Projection Help My Layer Sessior
Contribute Data
32°N 27'
32°N 26'
32°N 25'
32°N 24'
32°N 23'
32°N 22'
78°W 42'
78°W 39'
78°W 36'
78°W 33'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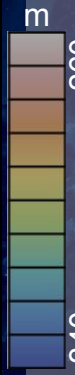
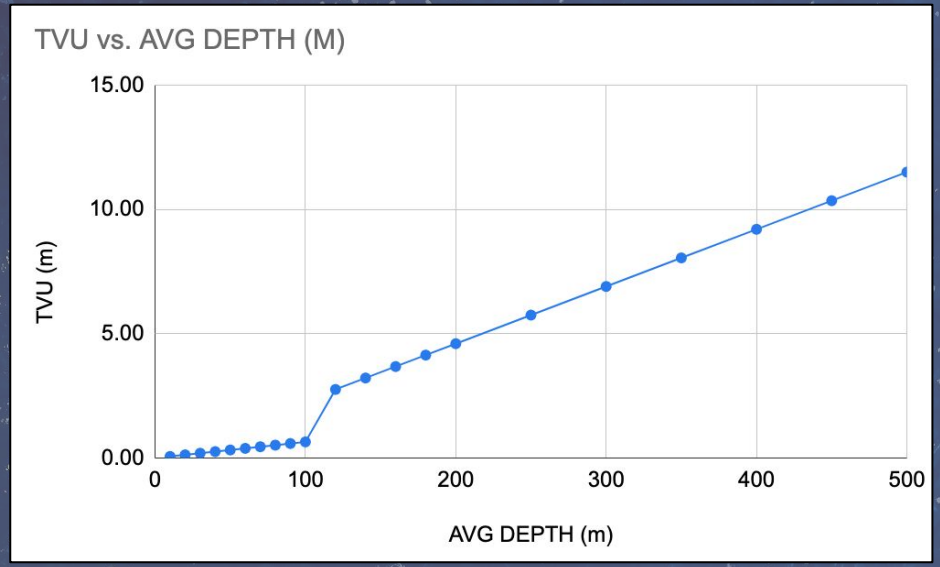
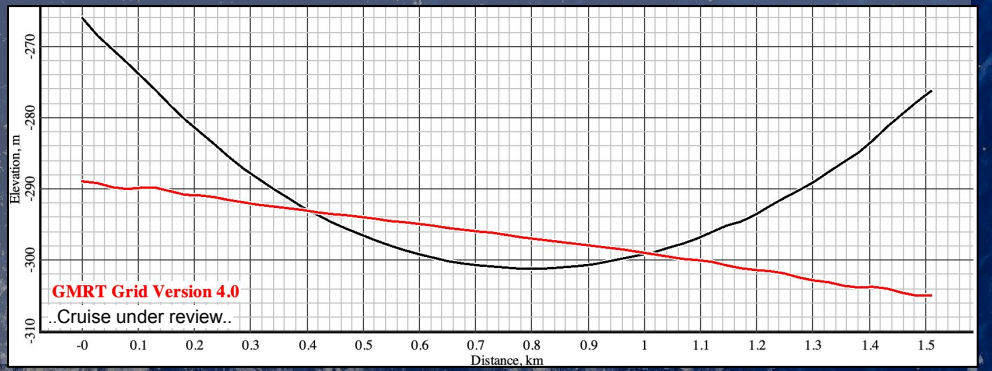
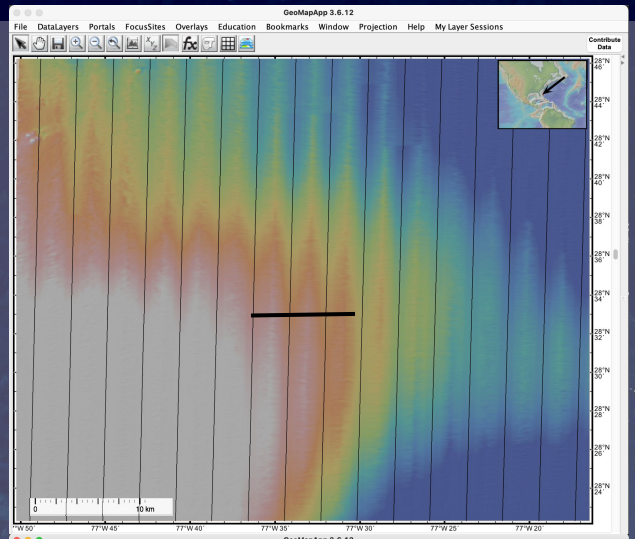
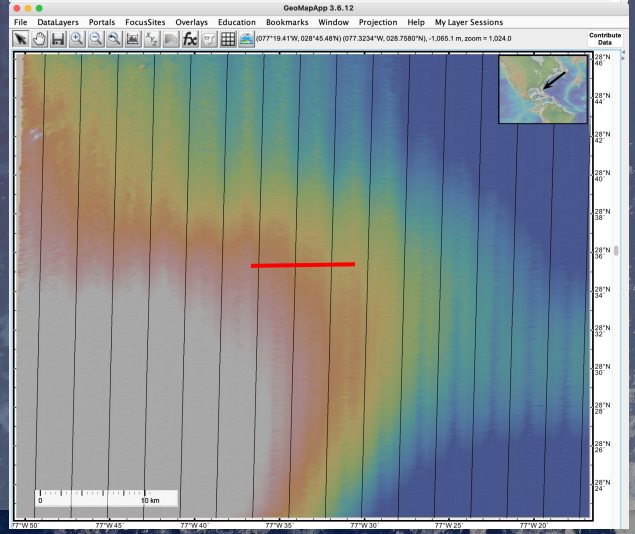
File DataLayer: Portals FocusSite: Overlays Educatior Bookmark: Window Projection Help My Layer Sessior
Contribute Data
32°N 27'
32°N 26'
32°N 25'
32°N 24'
32°N 23'
78°W 42'
78°W 39'
78°W 36'
78°W 33'


m
-260
-340


TVU vs. AVG DEPTH (M)
TVU (m)
15.00
10.00
5.00
0.00
0
100
200
300
400
500
AVG DEPTH (m)


Elevation, m
-270
-280
-290
-300
-310
-0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
Distance, km
GMRT Grid Version 4.0
..Cruise under review..


GeoMapApp 3.6.12
File DataLayers Portals FocusSites Overlays Education Bookmarks Window Projection Help My Layer Sessions
Contribute Data
10 km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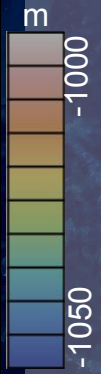
Contribute Data
10 km


m
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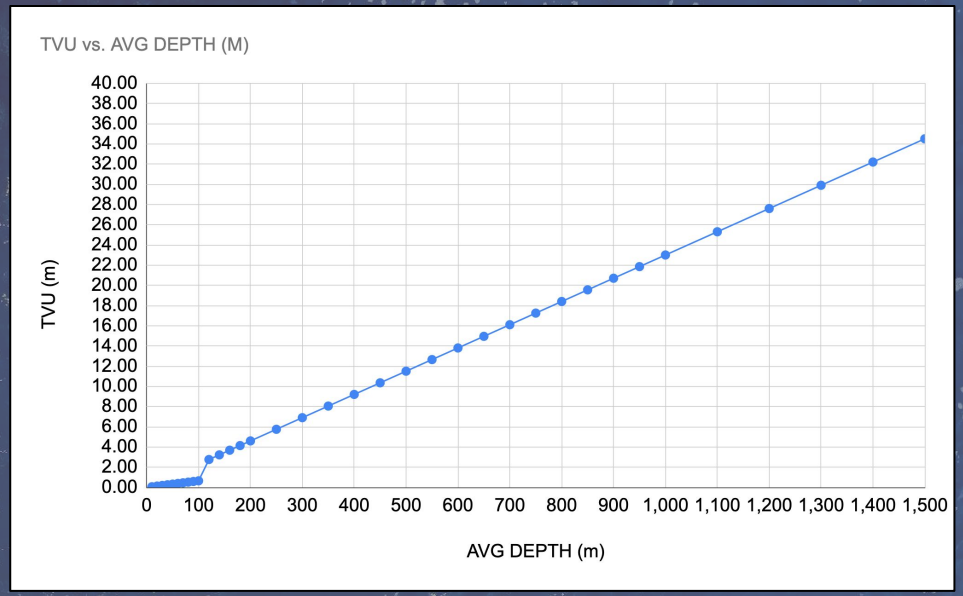
-1050


TVU vs. AVG DEPTH (M)
TVU (m)
AVG DEPTH (m)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
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36.00
38.00
40.00
0
100
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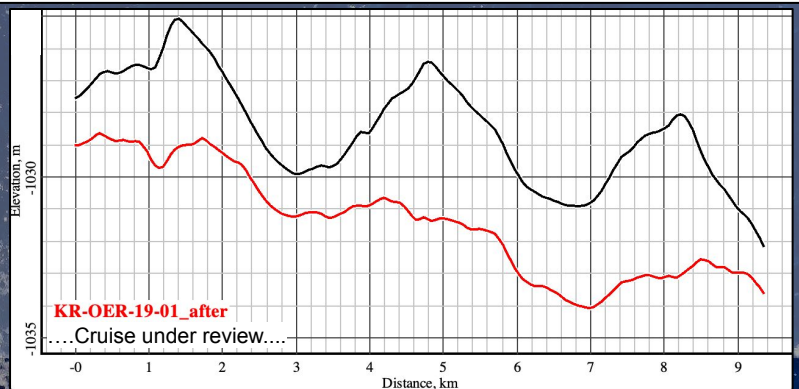
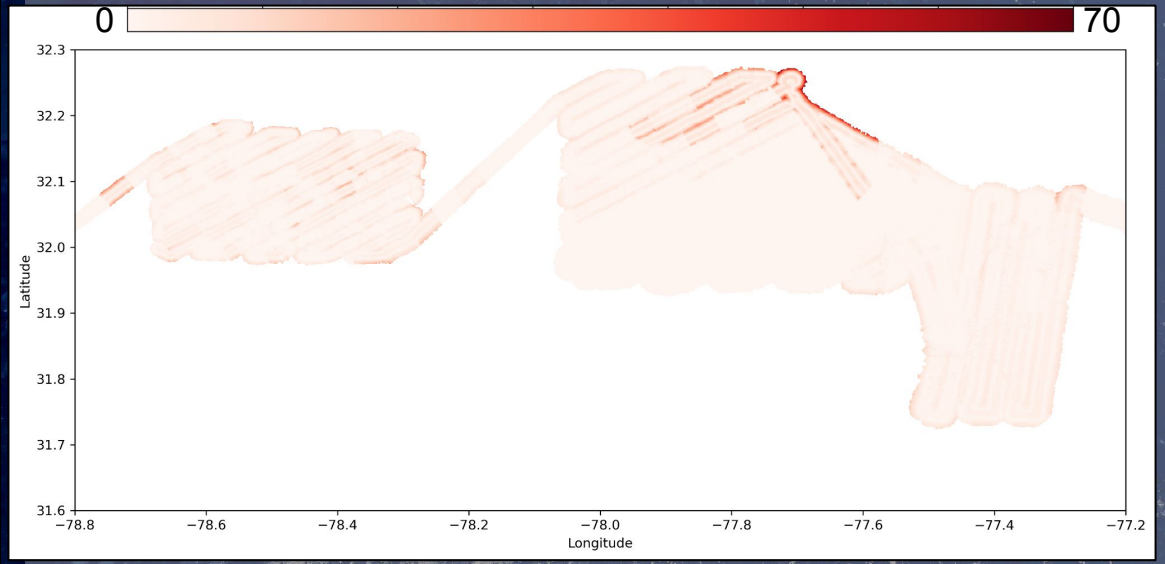
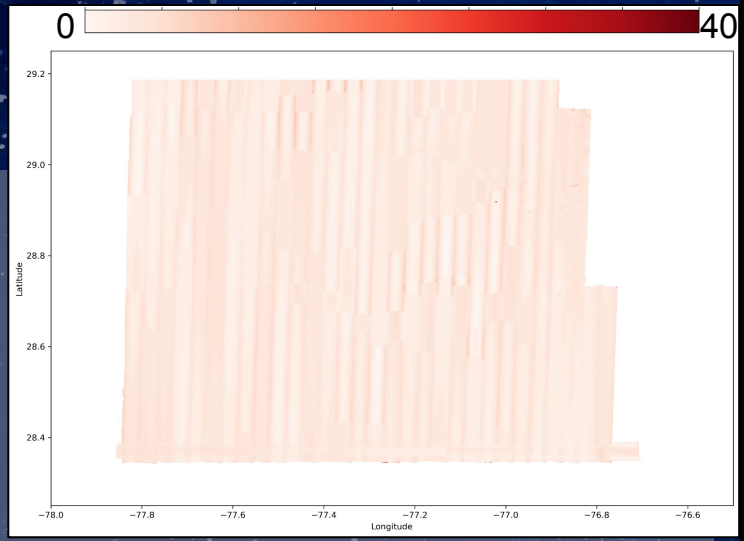
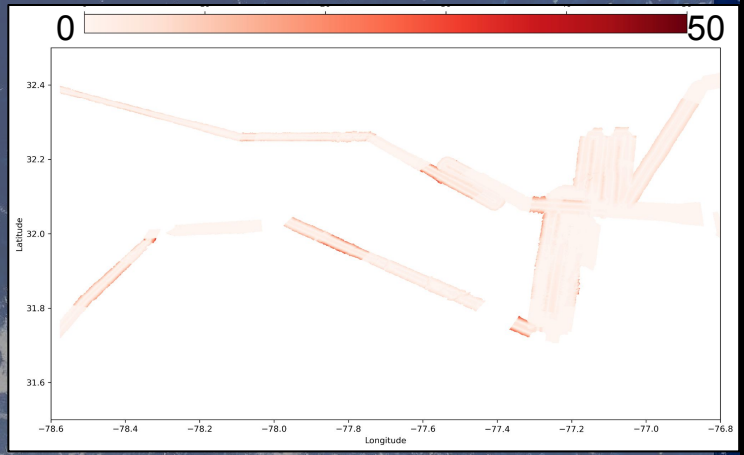
400
500
600
700
800
900
1,000
1,100
1,200
1,300
1,400
1,500


Elevation, m
-1030
-1035
KR-OER-19-01_after
....Cruise under review....
-0
1
2
3
4
5
6
7
8
9
Distance, km

Comparison of Gridded Data



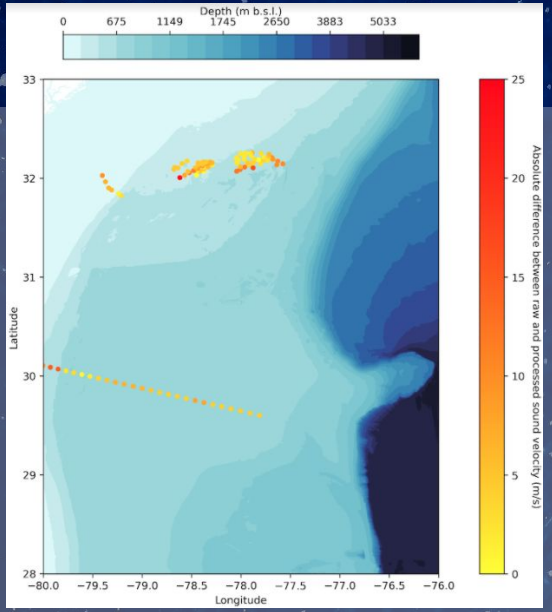


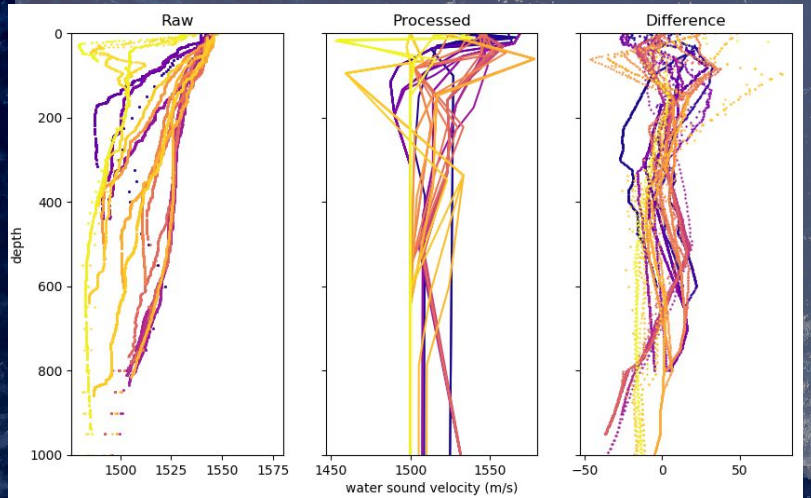


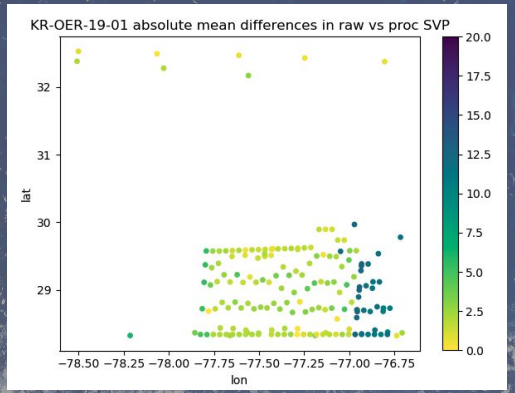
Difference between downloaded swath files and reprocessed swath files (m)

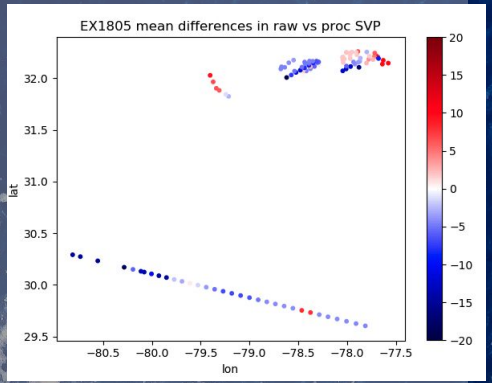
Sound Speed Variability

- Extremely frequent spatially & temporally
- How best to represent this structure on map to reveal patterns?
- What, if anything, does this tell us about water column?
  - Recognizing that sound speed profiles do not necessarily reflect Water column structure/layering but represent the solution that gave us the best bathymetric surface



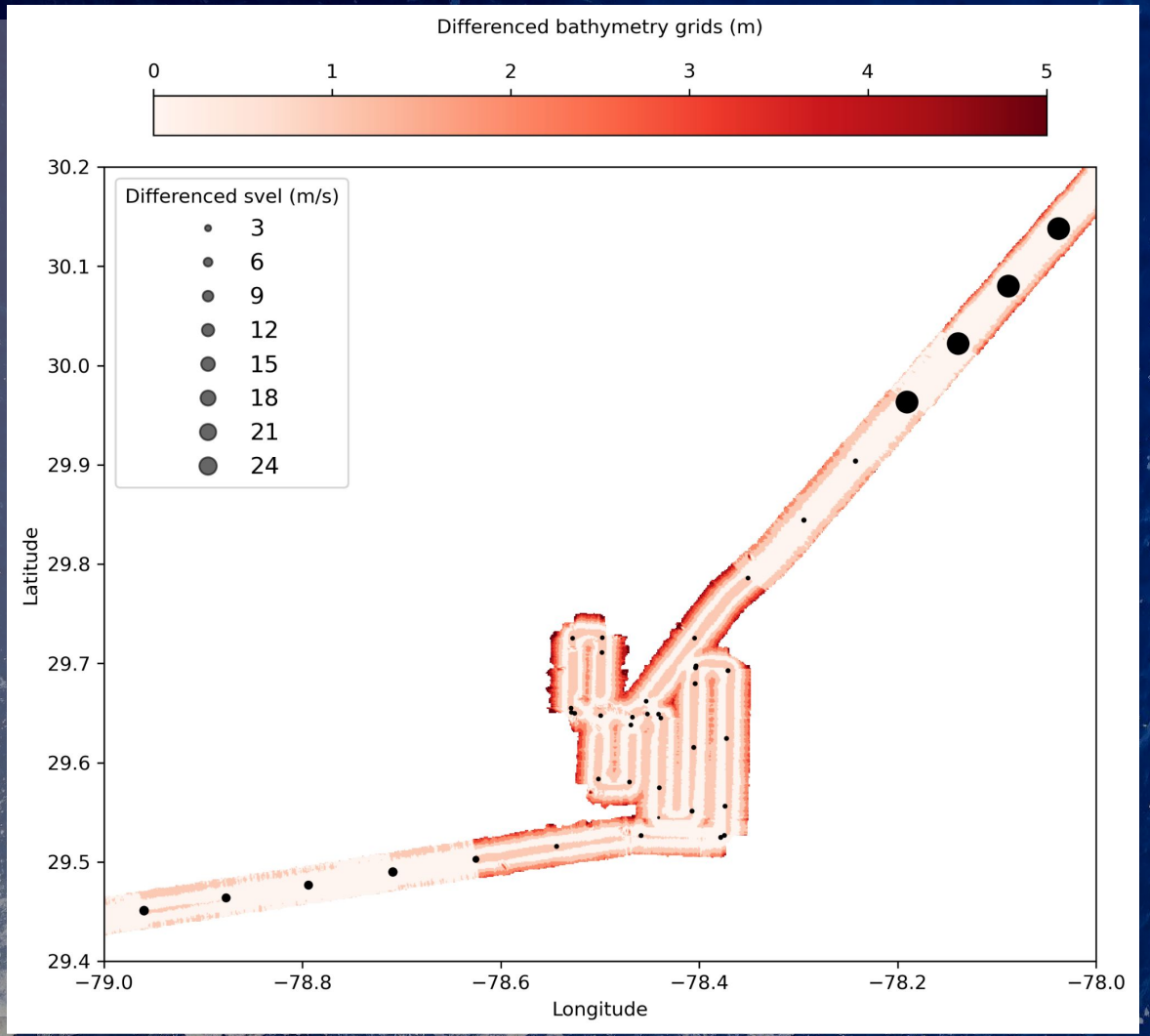






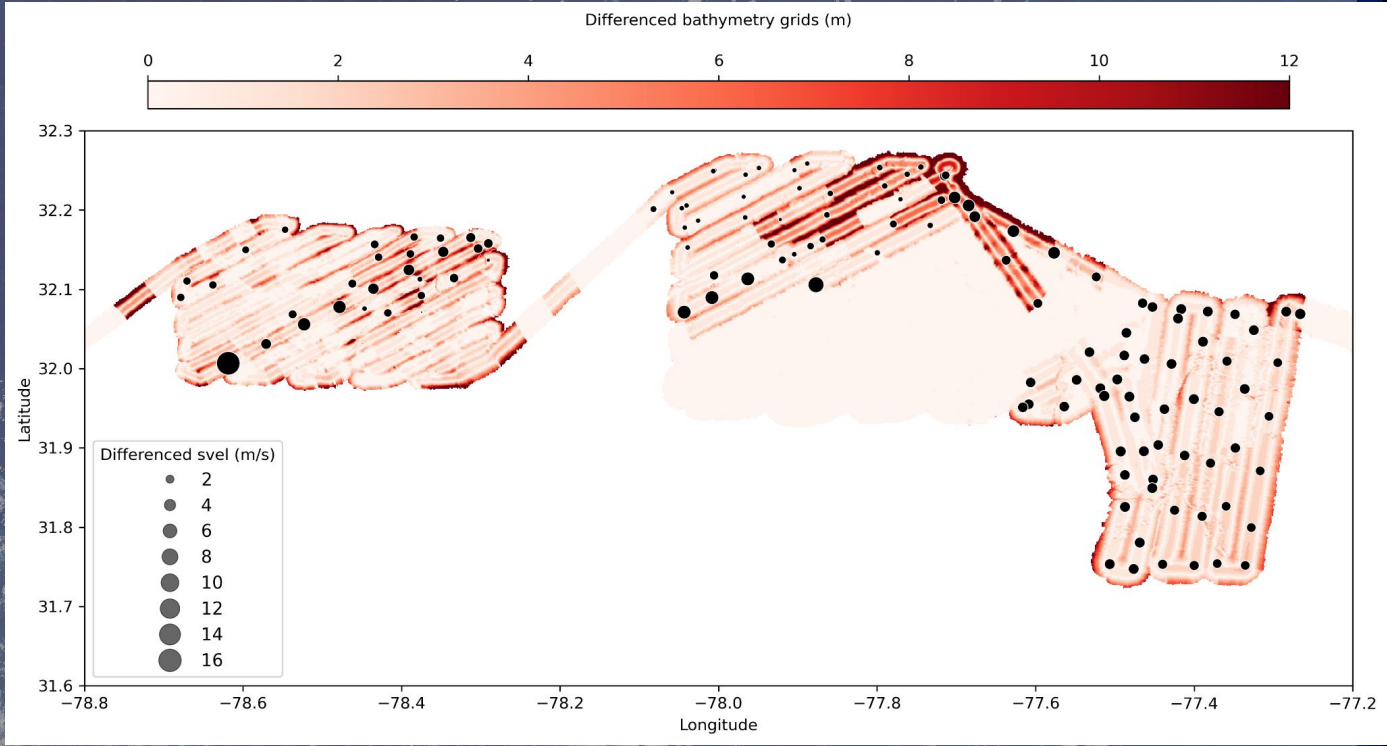
Comparison of Gridded Data

- Several areas throughout did not require sound speed corrections - these areas showed no vertical offset between grids
- Largest sound speed corrections are not necessarily associated with largest vertical differences
  - Could relate to ssp corrections made during initial processing?



Comparison of Gridded Data

- Sound speed corrections generally relate to areas with large vertical differences
- Areas with no vertical differences had no sound speed corrections
- Some areas with no sound speed corrections had large vertical differences - indicates sound speed corrections incorrectly applied in original processing



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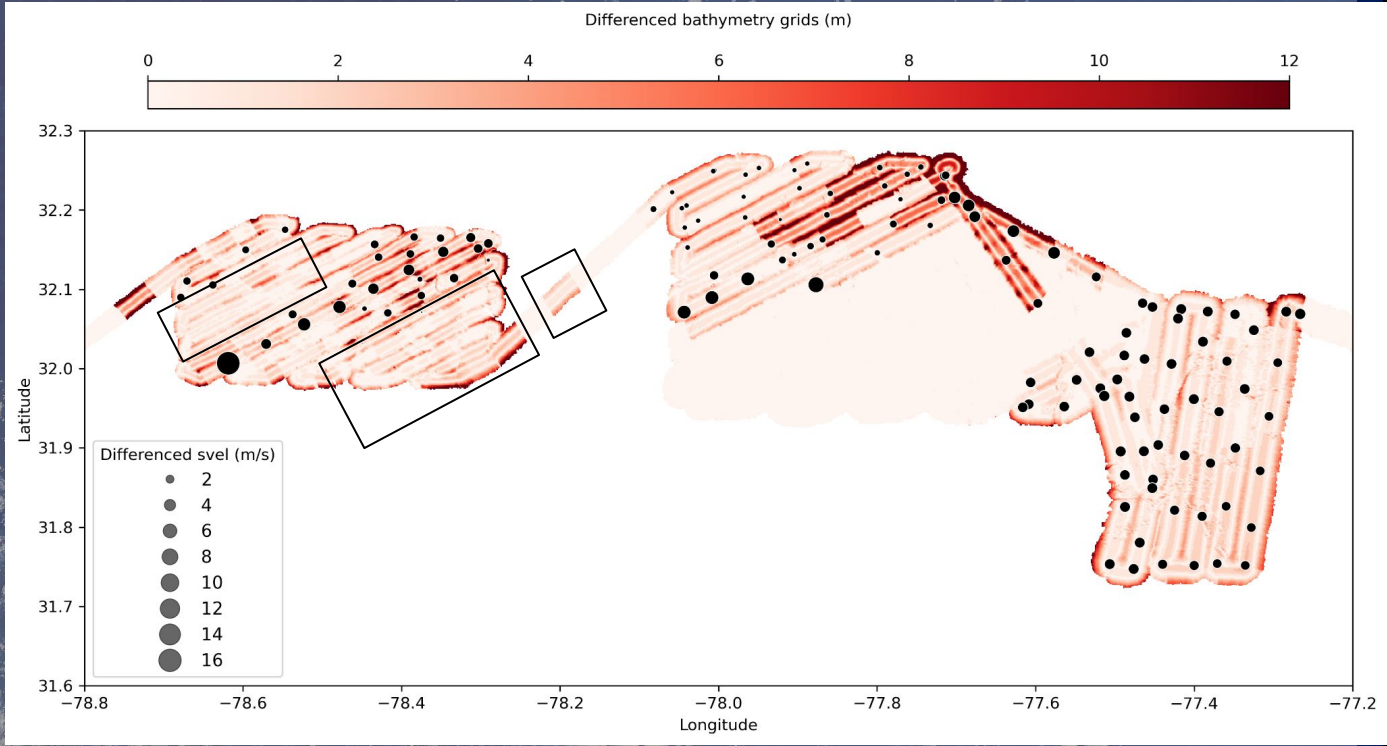
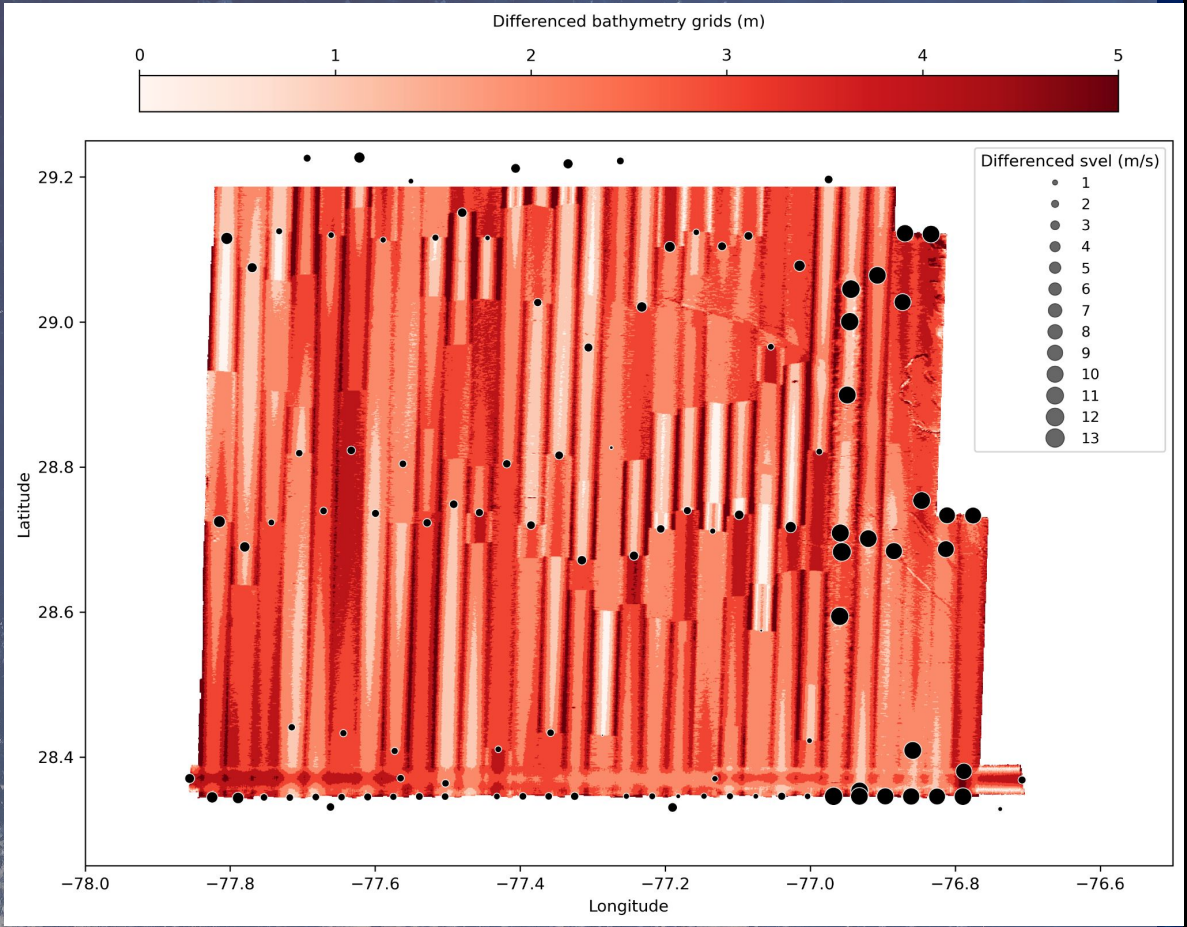


Comparison of Gridded Data

- Every swath file required fix
- Variability of sound speed (and water column characteristics) within a single file
- Spatial coherence of suggests coherent structure in water column
- Largest variability in svel profiles near shelf break



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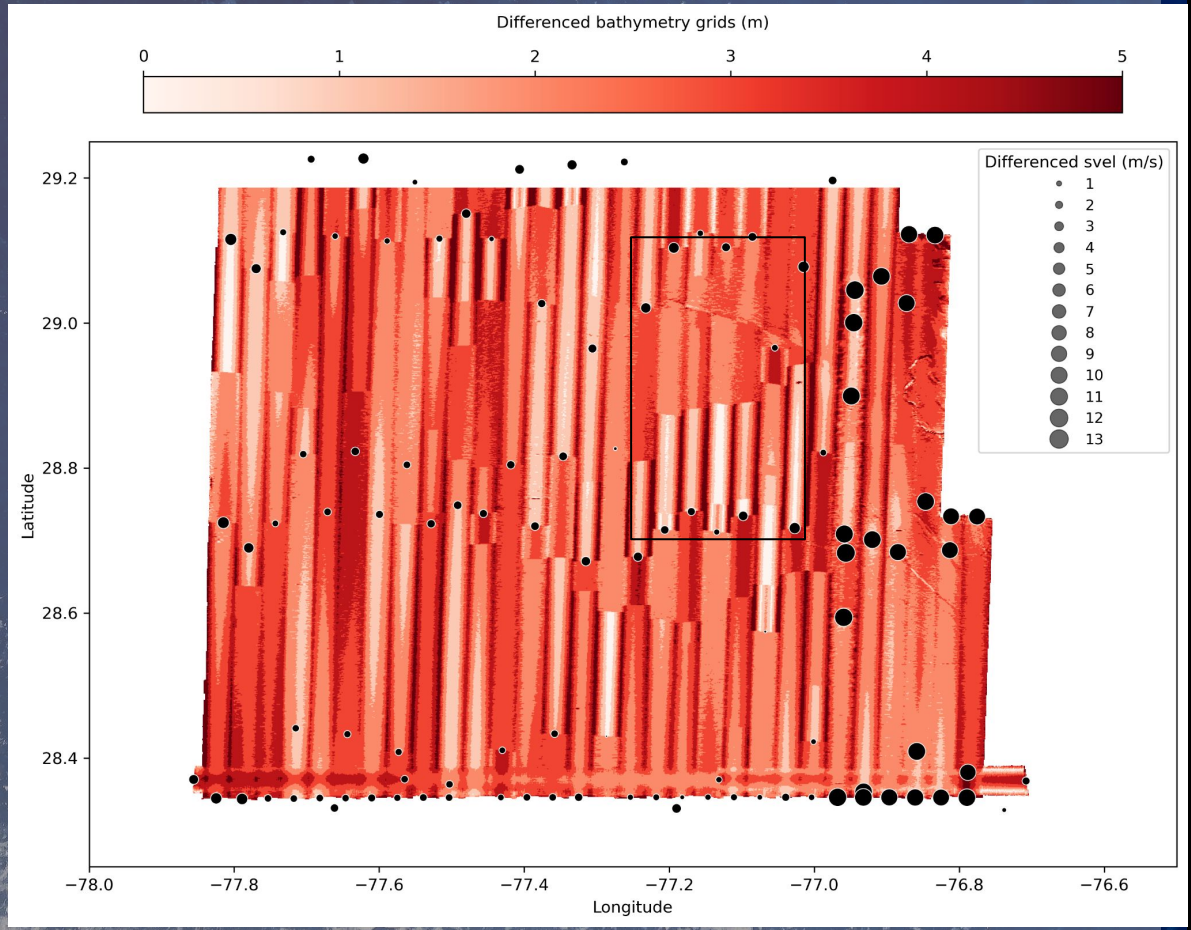
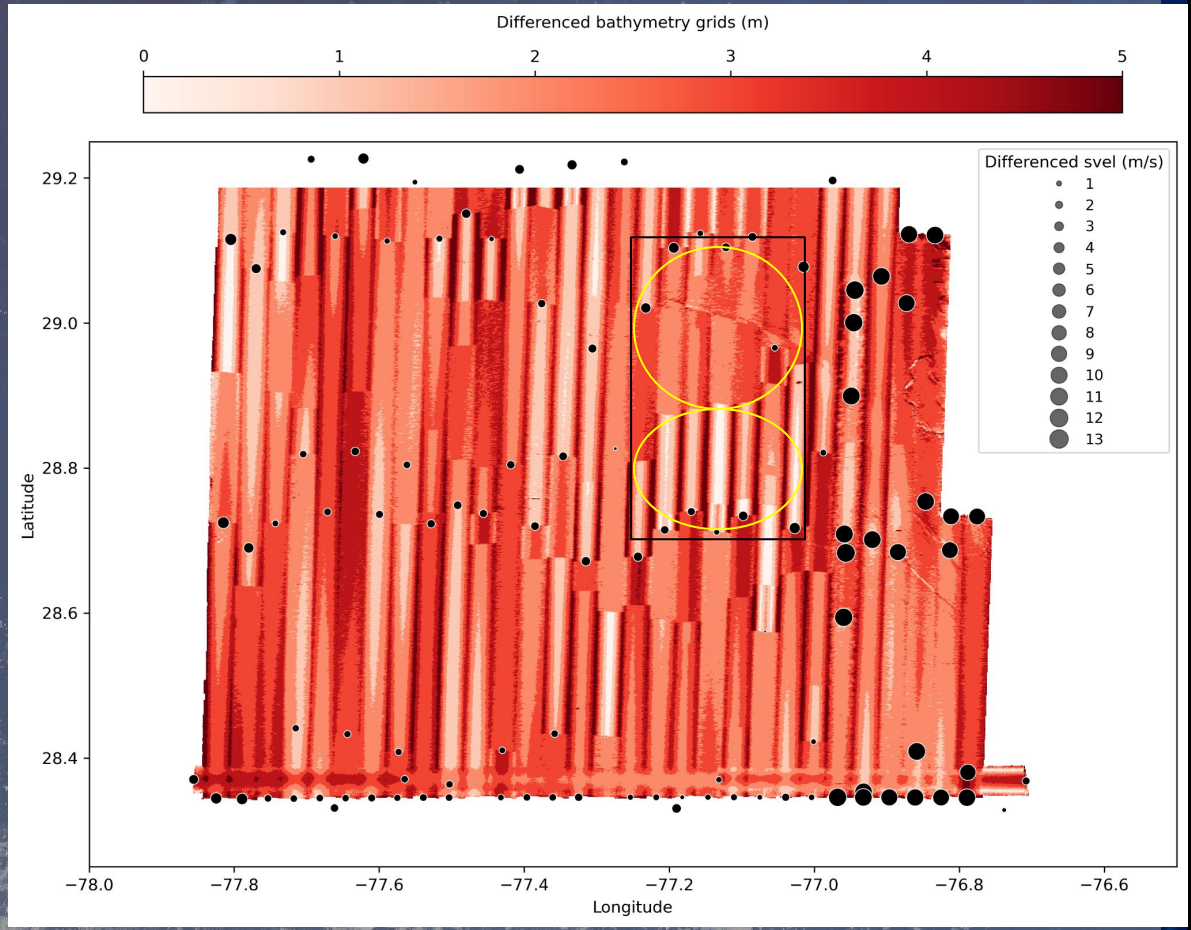
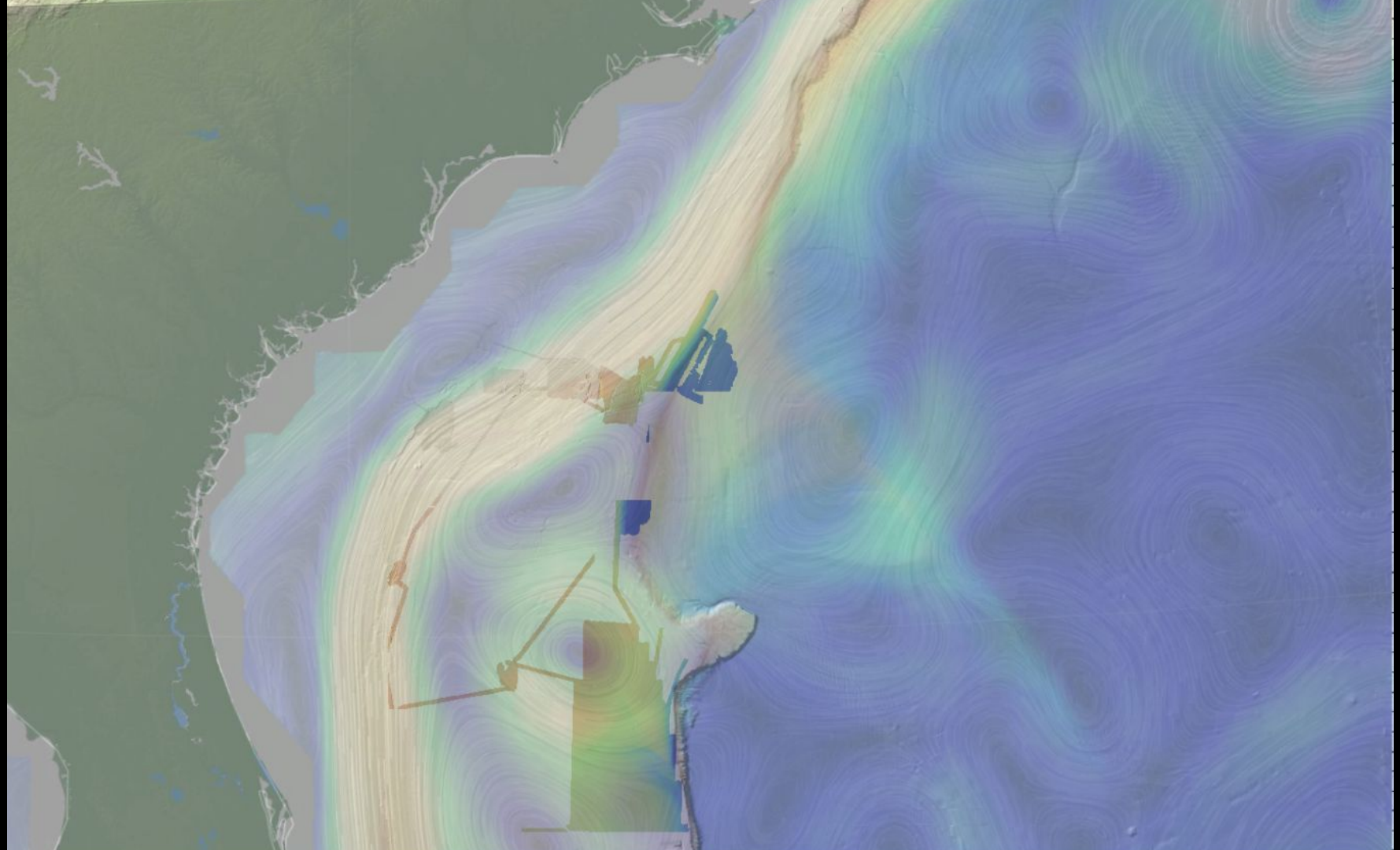
- Spatial coherence of suggests coherent structure in water column
- Largest variability in sound speed profiles near shelf break

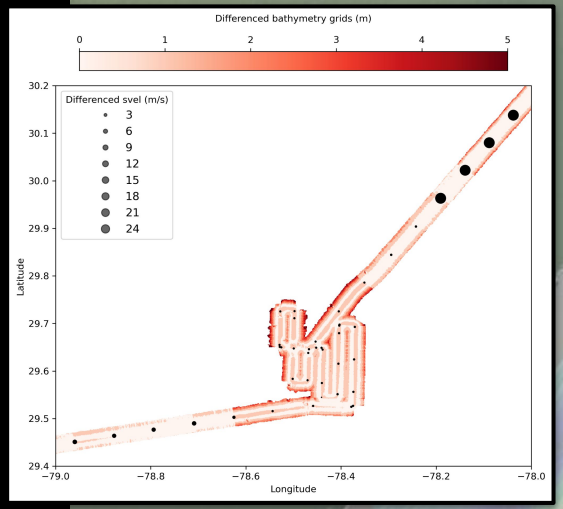


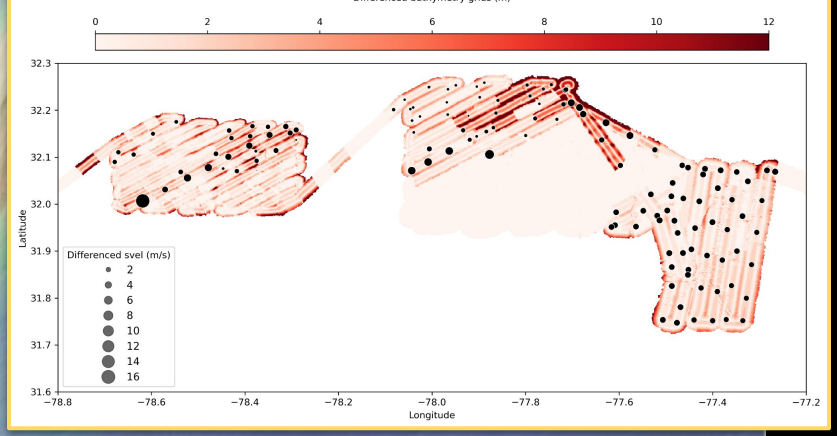
Comparison of Gridded Data

- Every swath file required fix
- Variability of sound speed (and water column characteristics) within a single file
- Spatial coherence of suggests coherent structure in water column
- Largest variability in sound speed profiles near shelf break






Differenced bathymetry grids (m)
0
1
2
3
4
5
Differenced svel (m/s)
3
6
9
12
15
18
21
24
Latitude
Longitude
30.2
30.1
30.0
29.9
29.8
29.7
29.6
29.5
29.4
−79.0
−78.8
−78.6
−78.4
−78.2
−78.0


0
2
4
6
8
10
12
Differenced svel (m/s)
2
4
6
8
10
12
14
16
Latitude
Longitude
32.3
32.2
32.1
32.0
31.9
31.8
31.7
31.6
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−78.6
−78.4
−78.2
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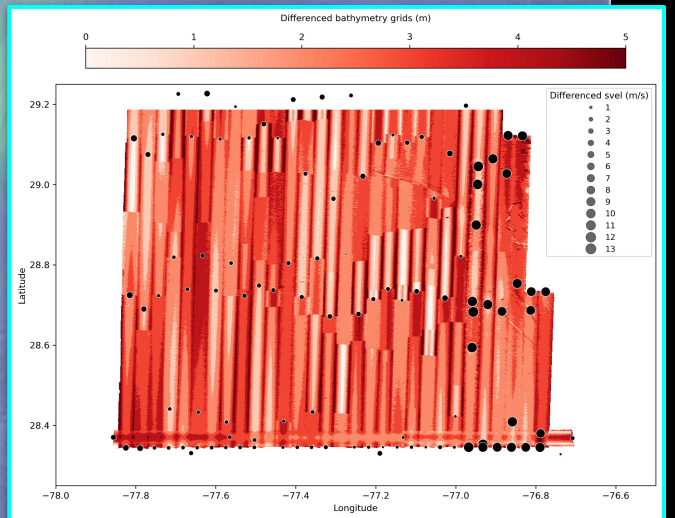
−77.8
−77.6
−77.4
−77.2


Differenced bathymetry grids (m)
0
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Differenced svel (m/s)
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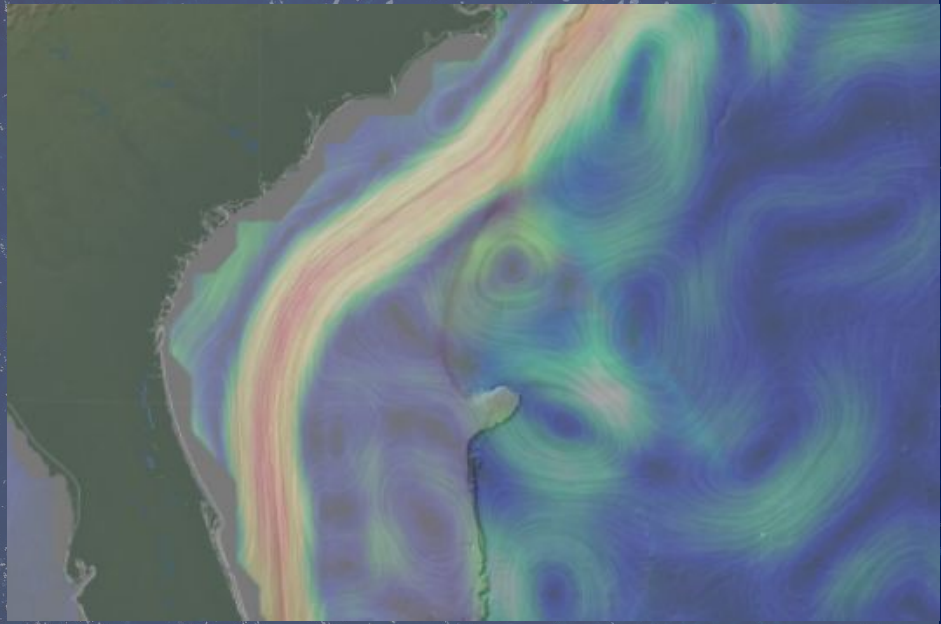
10
11
12
13
Latitude
Longitude
29.2
29.0
28.8
28.6
28.4
−78.0
−77.8
−77.6
−77.4
−77.2
−77.0
−76.8
−76.6

Conclusions

- Complex water column characteristics are challenging but with the right tools data quality can be improved
- Share processed multibeam data in a swath format (e.g. GSF)
  - Enable additional processing
- IHO specifications may/may not be adequate for deep water multibeam data -
  - Make data products fit for purpose !
  - Minimize artifacts that could easily be confused for seafloor morphology
- Common tools/standards should be used to ensure processed data meet a fit-for-purpose standard
  - Tools exist - let’s work together as a community!!
- Sound speed profiles from multibeam data can provide information about variable water column characteristics over short temporal and spatial scales

Next Steps

- Further explore sound speed corrections as a proxy for oceanographic conditions
- Establish common fit-for-purpose standards and guidelines for achieving them
  - Best-practice documents
  - Webinar?
- Maximize data acquisition and minimize redundant effort -



All ocean current overlays taken from OSCAR data displayed on earth.nullschool.net

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Thank you!

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