

Microstructure turbulence, ADCP, and passive acoustic observations in the Nordic Seas using underwater gliders



Donglai Gong Ph.D., Laur Ferris Ph.D., Ricardo Bourdon, Jack Slater, Nicole Trenholm

Virginia Institute of Marine Science - William & Mary

Three-part mission

- Research
- Education
- Advisory Service

Science for the Bay— Impact for the World

- Coastal & Ocean Processes
- Ecosystem Health
- Natural Resources



Coastal & Polar Physical Oceanography (C2PO) Lab

Research Interests:

- Coastal Ocean Dynamics
- Shelf-Basin Interaction
- Boundary Currents
- Submarine Canyons
- Flow-bathymetry interactions
- Frontal dynamics
- Submesoscale processes
- Upper ocean turbulence



Coastal & Polar Physical Oceanography (C2PO) Lab

Lab Members (past & present)

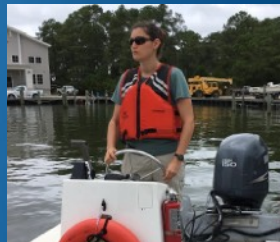
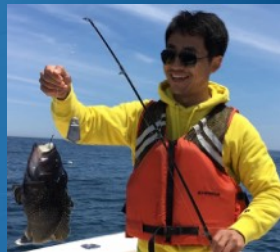
Students:

- Ricardo Bourdon, doctoral
- Laur N. Ferris, Ph.D (2022)
- Haixing (Daniel) Wang, Ph.D. (2021)
- >20 undergraduates over the years

Technical Staff:

- Jack Slater (Glider Engineering Lead)
- Fiona Gordon (W&M Undergrad Intern)
- Anthea Empson (former W&M Undergrad Intern)
- Jeanna Hudson (former Lab Manager)

2012—present

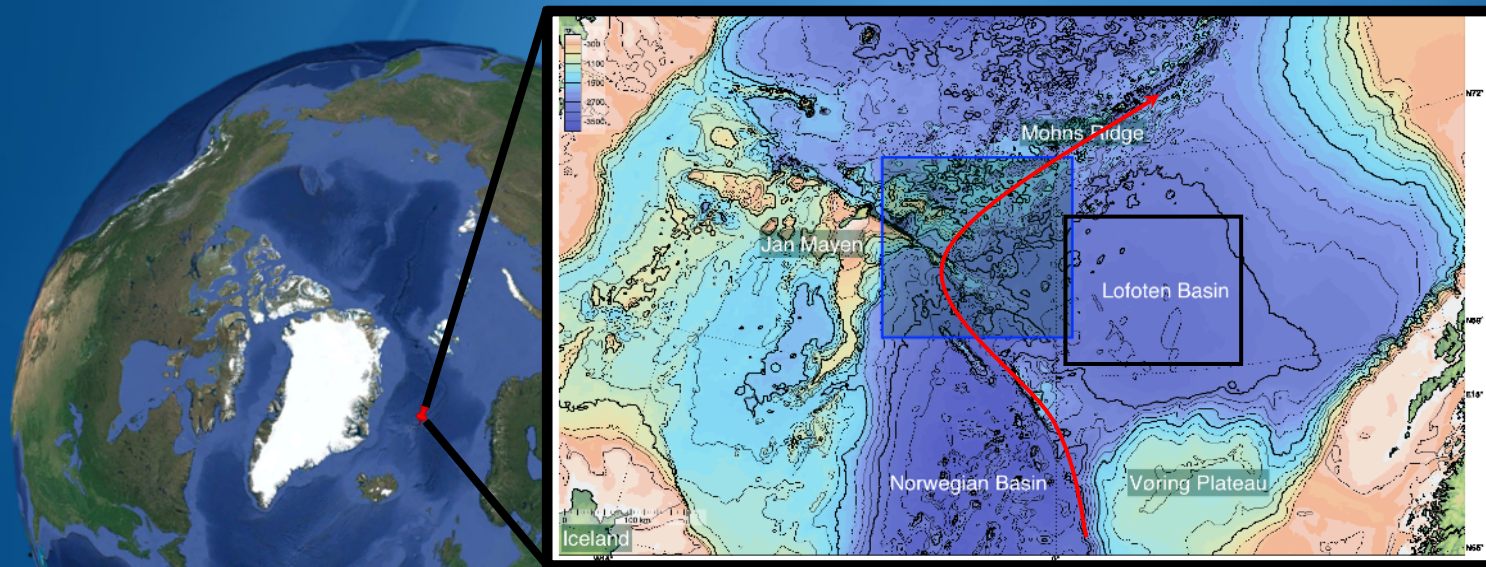


Northern Ocean Rapid Surface Evolution (NORSE) DRI

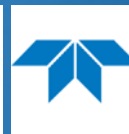
Program goals

- Improve physical and acoustic predictive capability for the upper ocean.
- Improved physical and acoustic data collection methodologies for autonomy-based sampling of the ice-free high latitudes.
- Improved predictive capability for sound propagation, transmission loss, and surface duct formation.

Northern Ocean Rapid Surface Evolution (NORSE) DRI



NORSE DRI



RBR



NORSE Science Objectives

- Characterize the water mass exchange and mixing between Arctic water and Atlantic water across the Arctic Front in the Norwegian Sea.
- Characterize the flow structure and the turbulent mixing around Mayen and inside the Lofoten Basin Eddy.
- Quantify the impact of strong wind events on the mesoscale and submesoscale oceanography.
- Assess the impact of the physical oceanography on acoustic propagation and scattering.
- Develop/test new ocean sensing techniques and methodologies.

NORSE Gliders: MARACOOS03 (French Lady/SEA064) & Electa



SeaExplorer X2
(MARACOOS03):
CTD+ADCP+MR1000G
Realtime processing

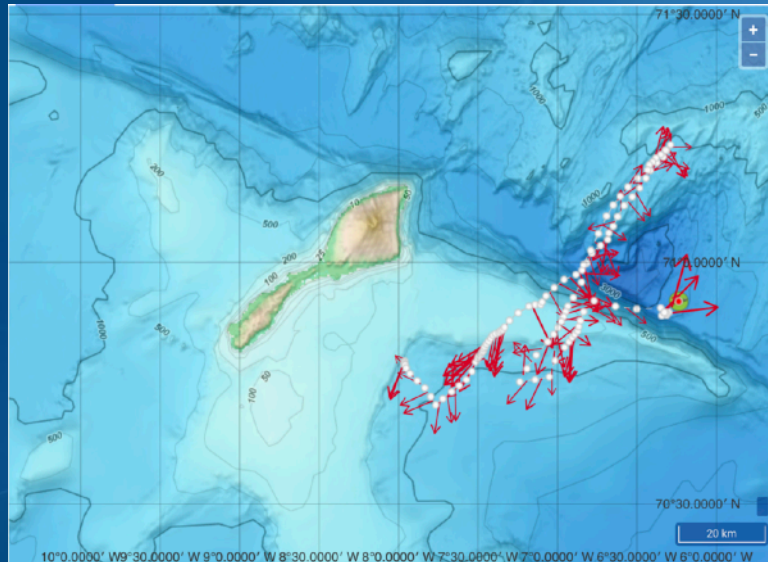
Slocum G3S (Electa):
CTD+PAR+FLBBBCD+
Passive Acoustic



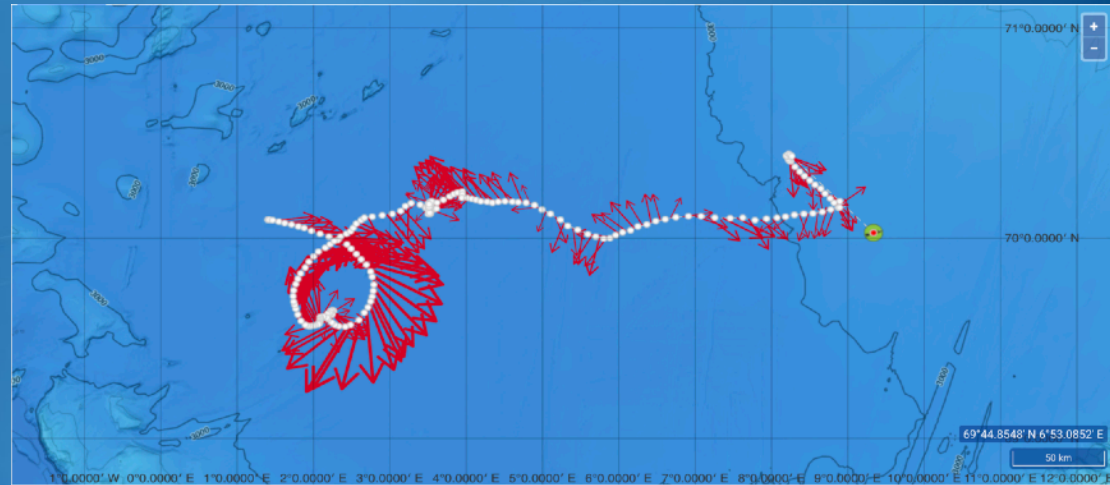
Ships:
2022: NRV Alliance (NATO)
2023: R/V Kronprins Haakon
(Norway)

NORSE Field Campaign (Jan Mayen & Lofoten Basin Eddy 2022)

2022 October (SeaExplorer)

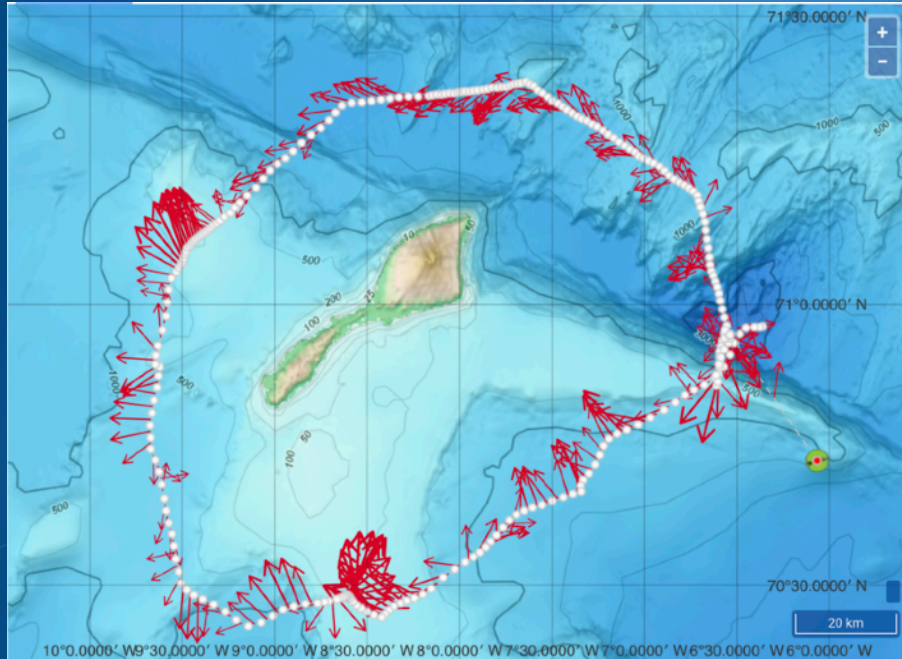


2022 November (SeaExplorer)

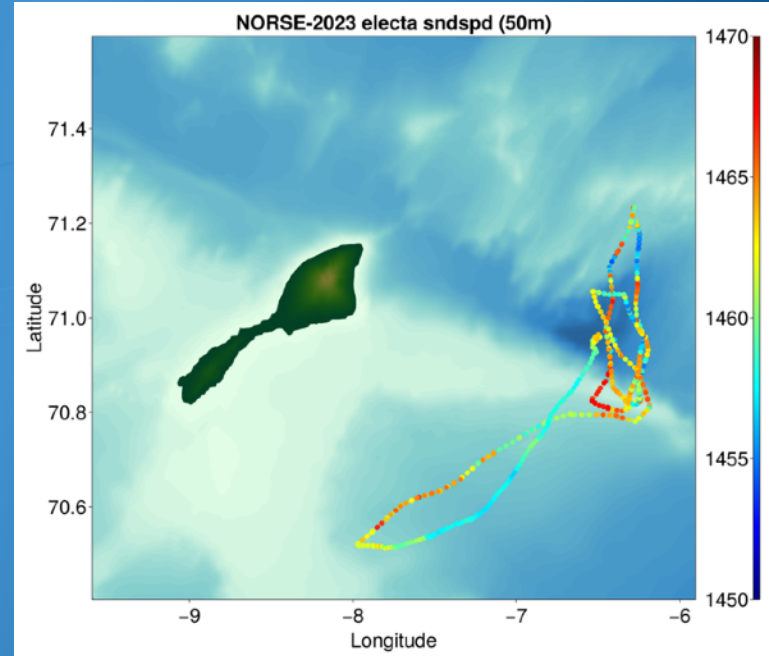


NORSE Field Campaign (Jan Mayen 2023)

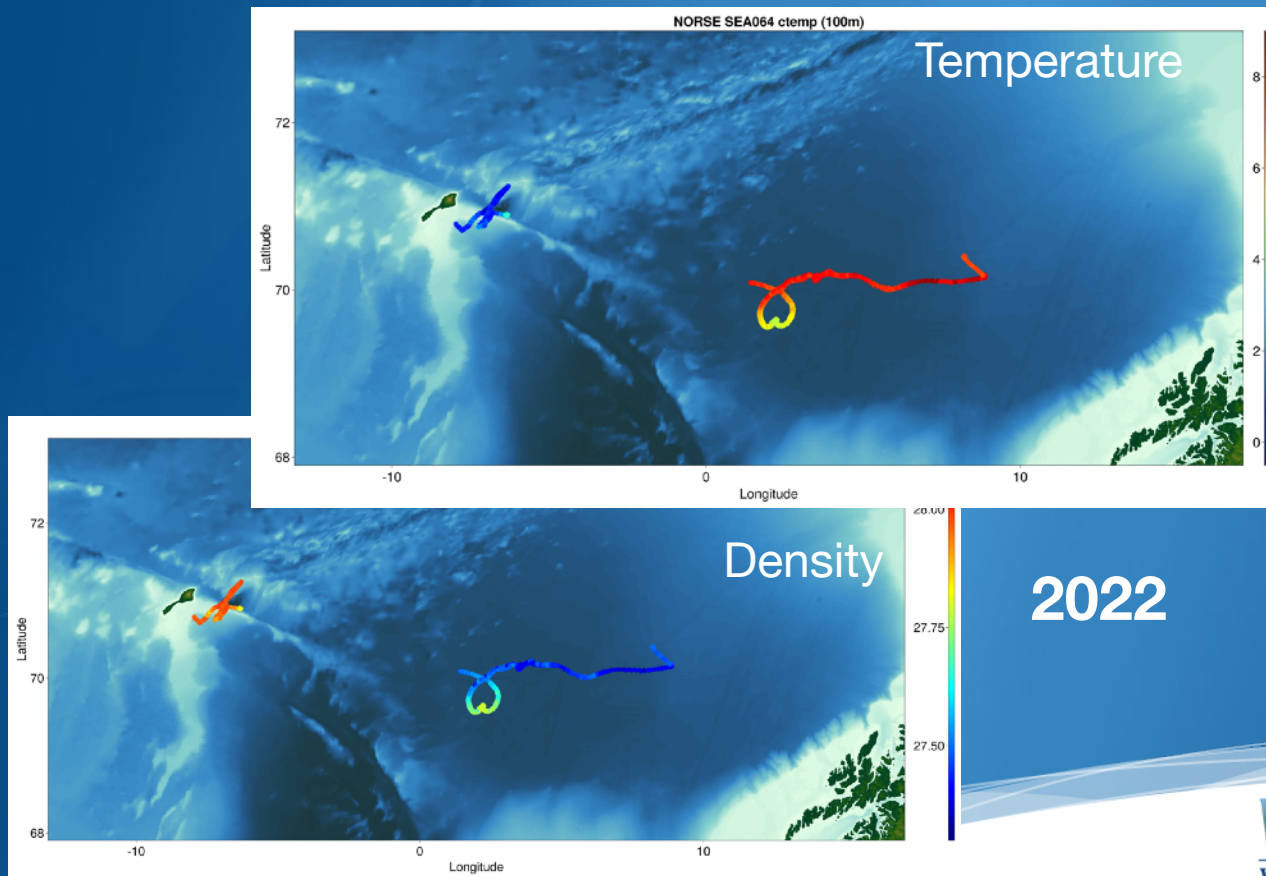
2023 November (SeaExplorer MARACOOS03)



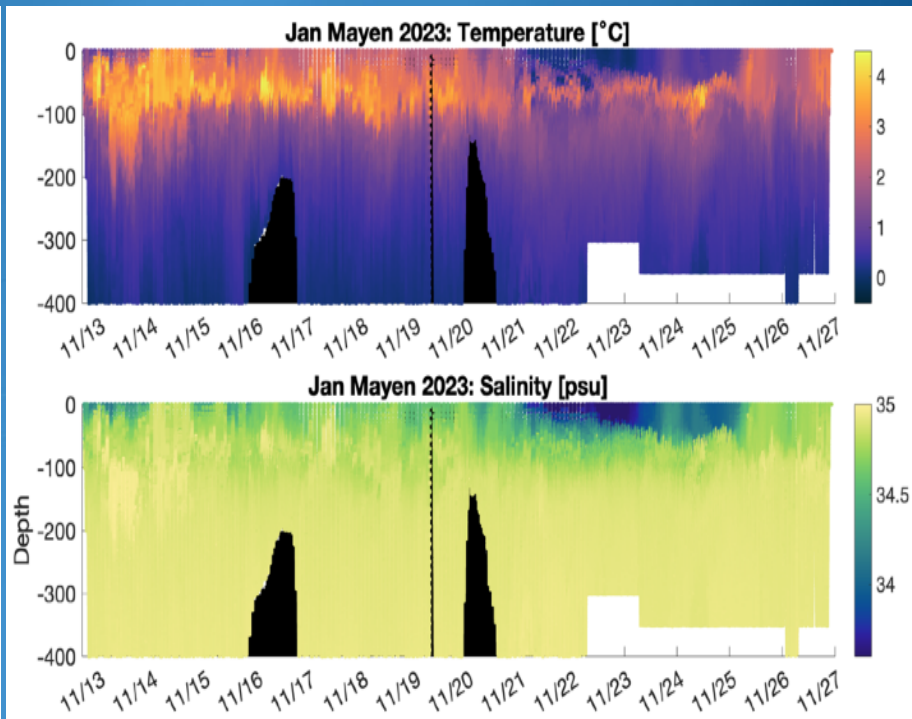
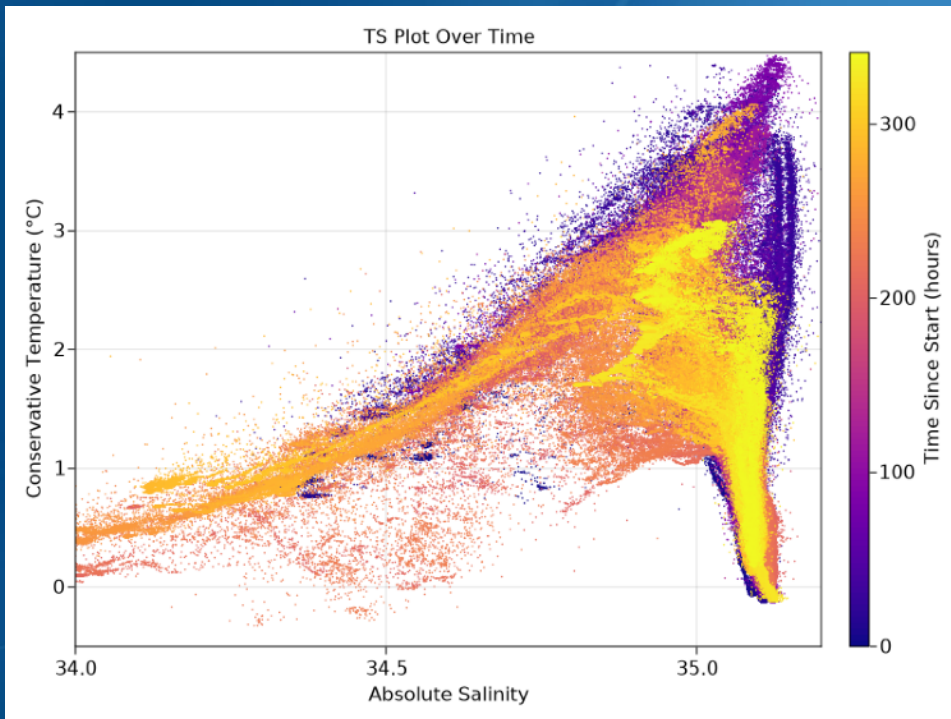
2023 November (Slocum Electa)



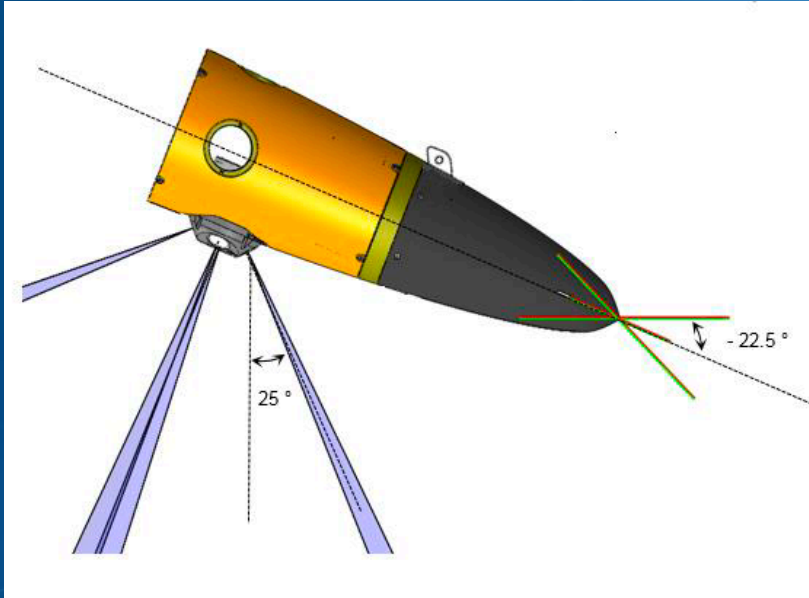
NORSE: Water masses in the Norwegian Sea



NORSE: Water masses around Jan Mayen (MARACOOSS03)



NORSE: Nortek ADCP System on SeaExplorer X2



Shear-based velocity estimate:

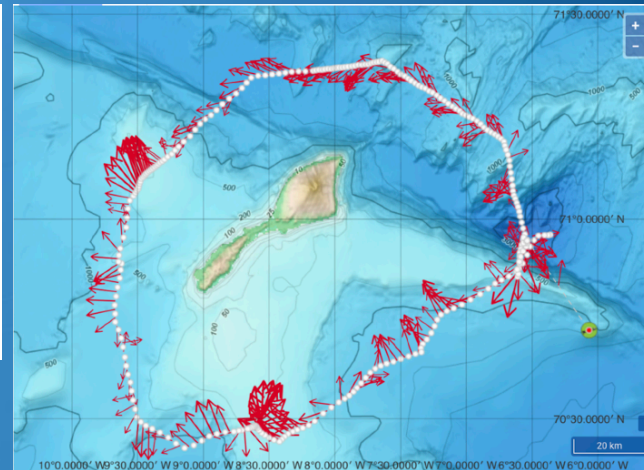
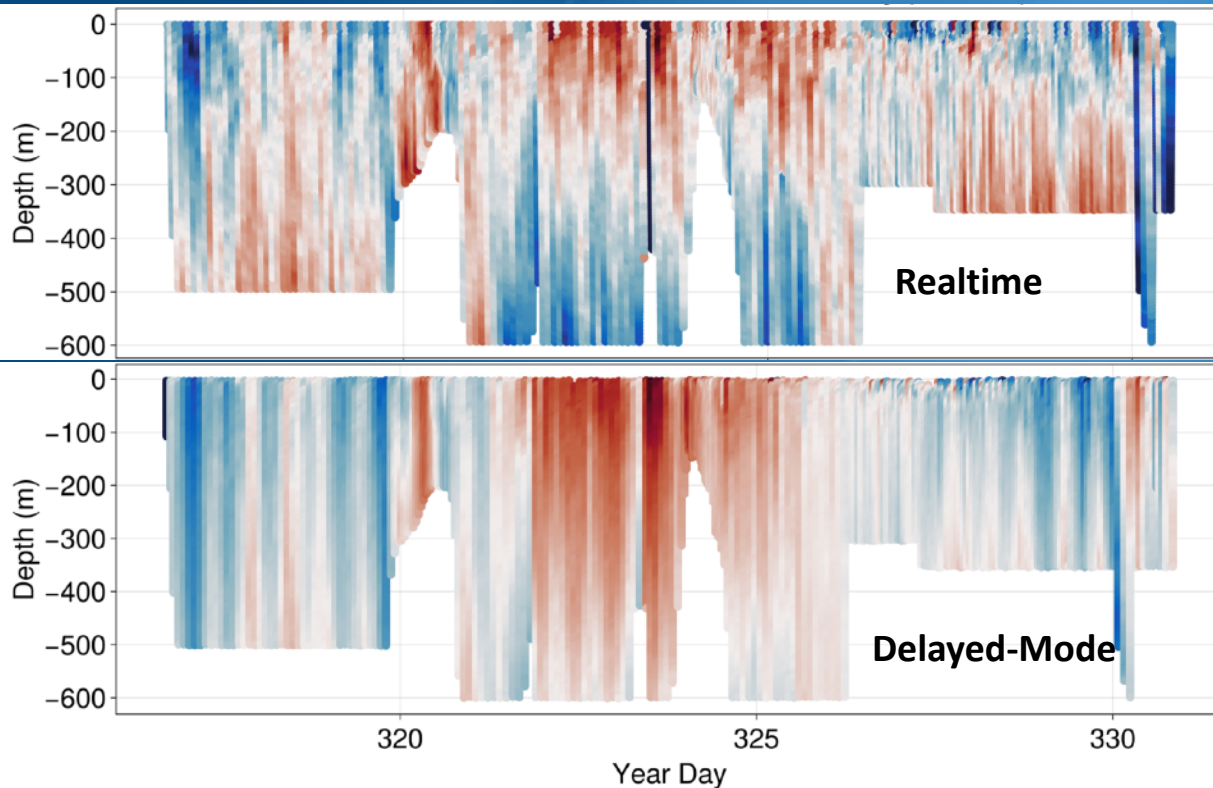
1. Obtain shear (du/dz) from ADCP velocity.
2. Integrate shear to obtain baroclinic velocity.
3. Estimate barotropic velocity.

$$u_{barotropic} = \int (u_{ADCP} - u_{baroclinic} + u_{glider}) dt / t_{profile}$$

4. Calculate total velocity by summing barotropic and baroclinic components.

NORSE: Flow around Jan Mayen (Realtime vs Delayed)

North - South Velocity (2023 November)



360 KM in 14 days = 29 cm/s
SOG average

NORSE: SeaExplorer Microstructure Measurements

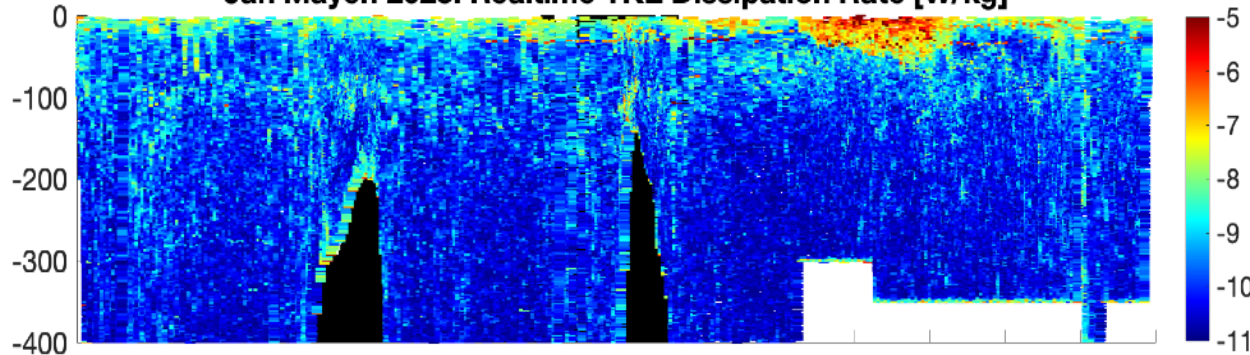


Rockland Scientific MR1000G + RDL

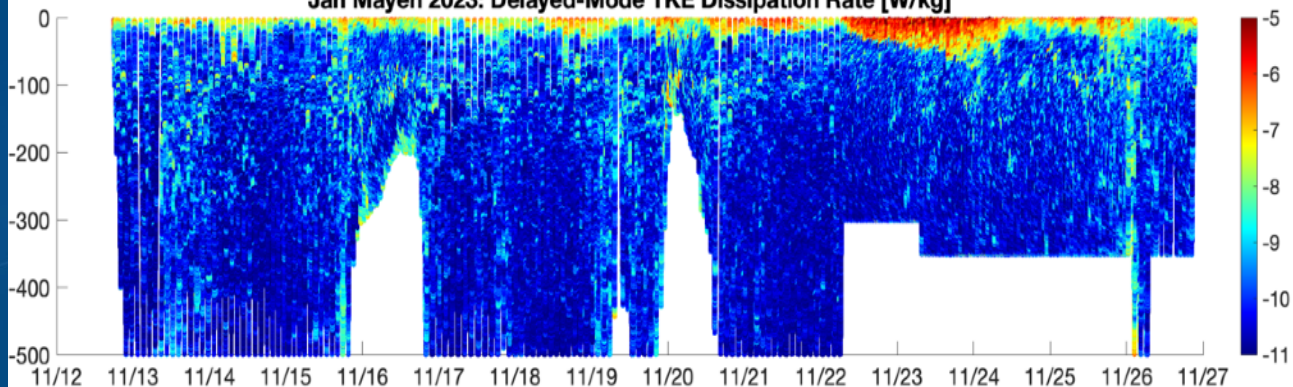
- TKE dissipation rate calculated onboard and telemetered via iridium
- First SeaExplorer glider with ADCP + MicroRider & realtime processing

NORSE: TKE Dissipation around Jan Mayen (Realtime vs Delayed)

Jan Mayen 2023: Realtime TKE Dissipation Rate [W/kg]



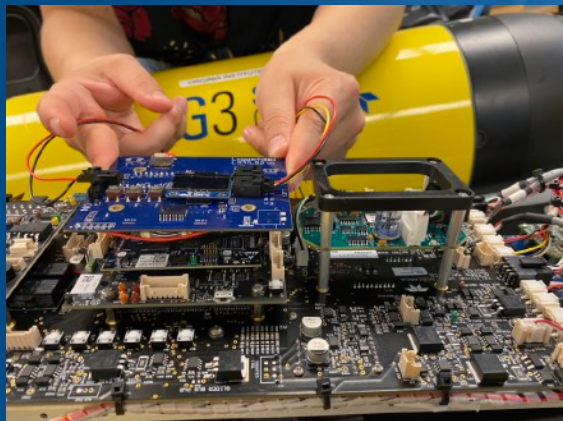
Jan Mayen 2023: Delayed-Mode TKE Dissipation Rate [W/kg]



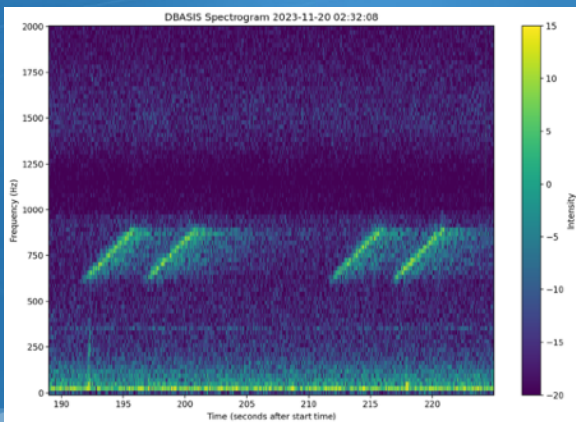
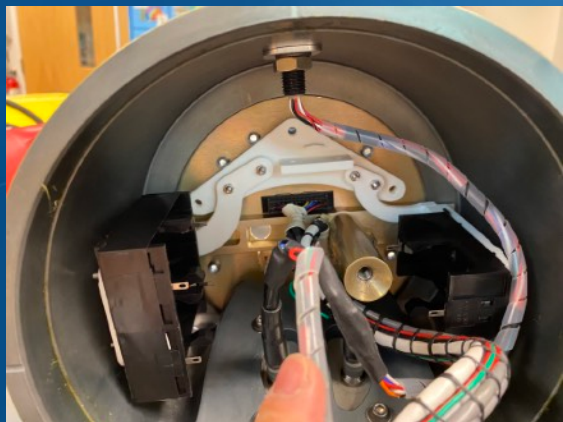
Realtime and delayed mode turbulence processing are largely consistent with each other despite varying glider behaviors.

SeaExplorer + MR1000G is an effective combo for studying ocean turbulence.

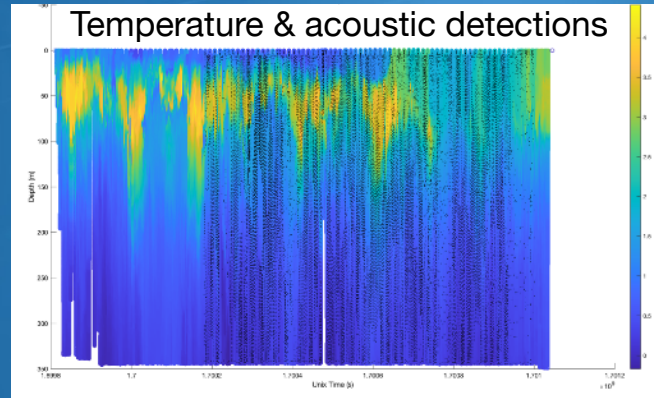
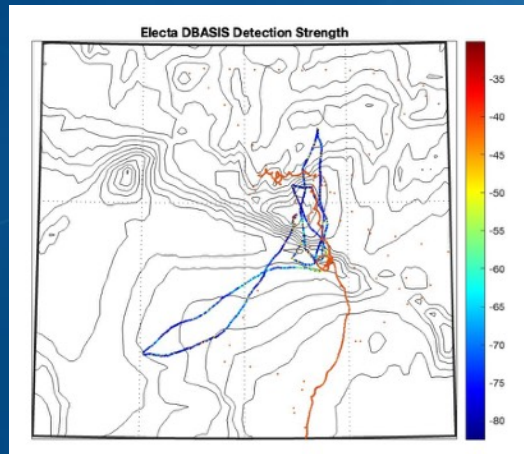
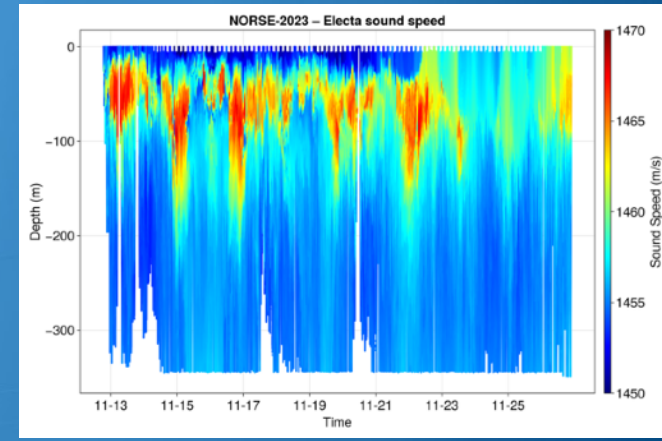
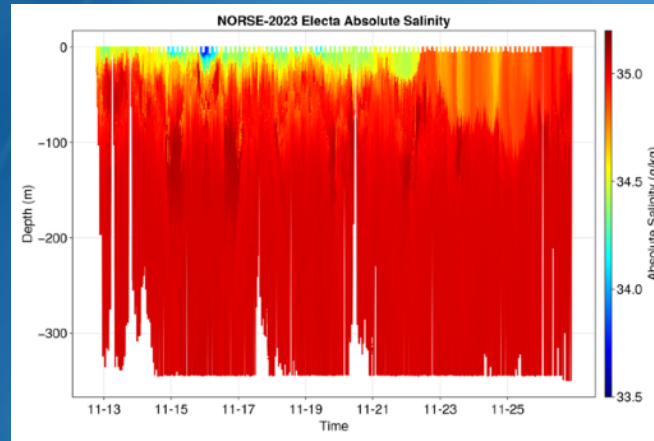
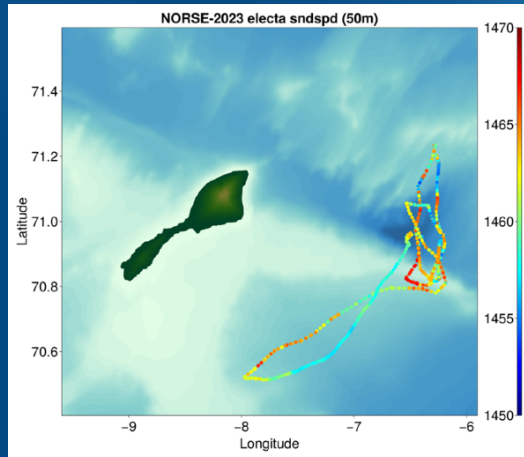
NORSE: Slocum Passive Acoustic (Loggerhead) Integration



- Custom integrated Loggerhead LS1 with HTI-96 hydrophone into Slocum gliders utilizing DO port
- Delayed-mode only currently
- 3 D-cell lithium batteries can last 30 days
- Low-cost



NORSE: Slocum Passive Acoustic Data

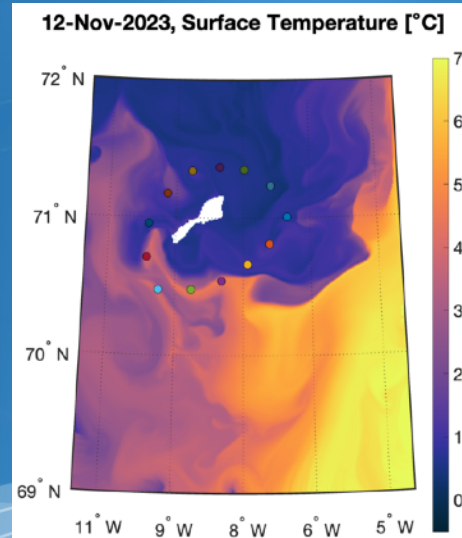
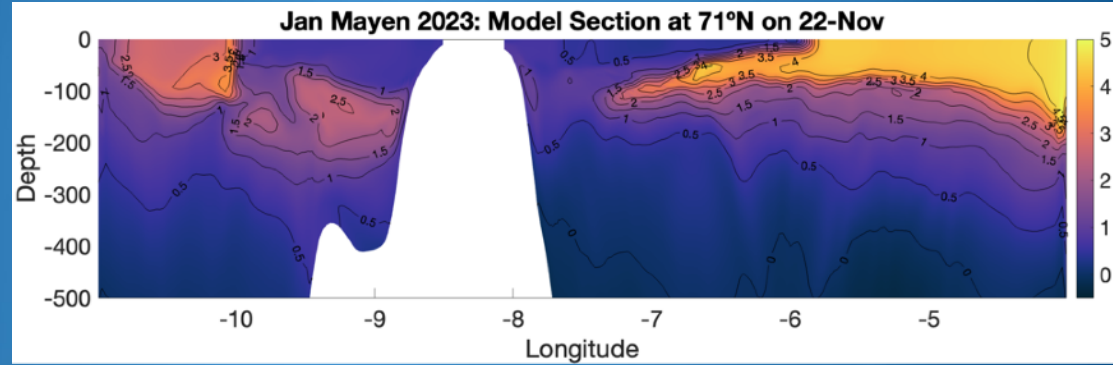
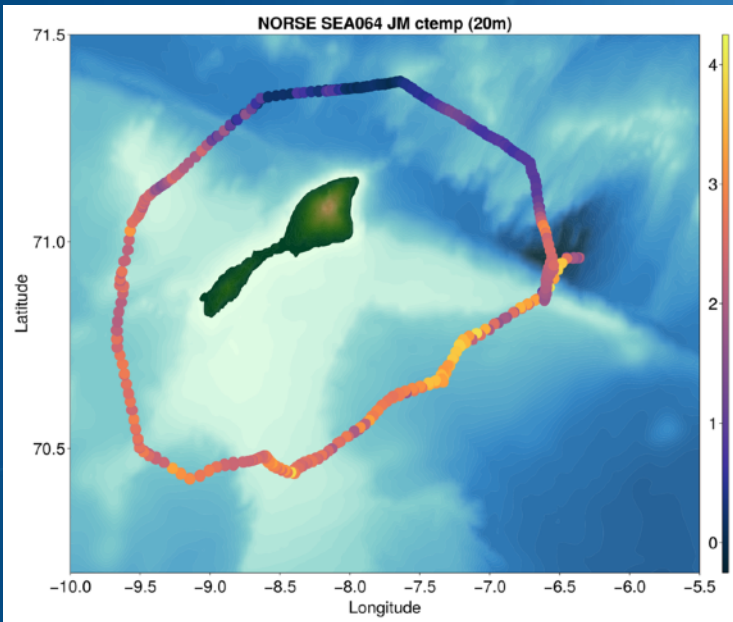


Single channel hydrophone system on Slocum detected near surface drifting source (~60 km).

Potential for studying multi-path transmission.

NORSE: Data—Model Comparison (ROMS)

Glider Temperature at 20 m

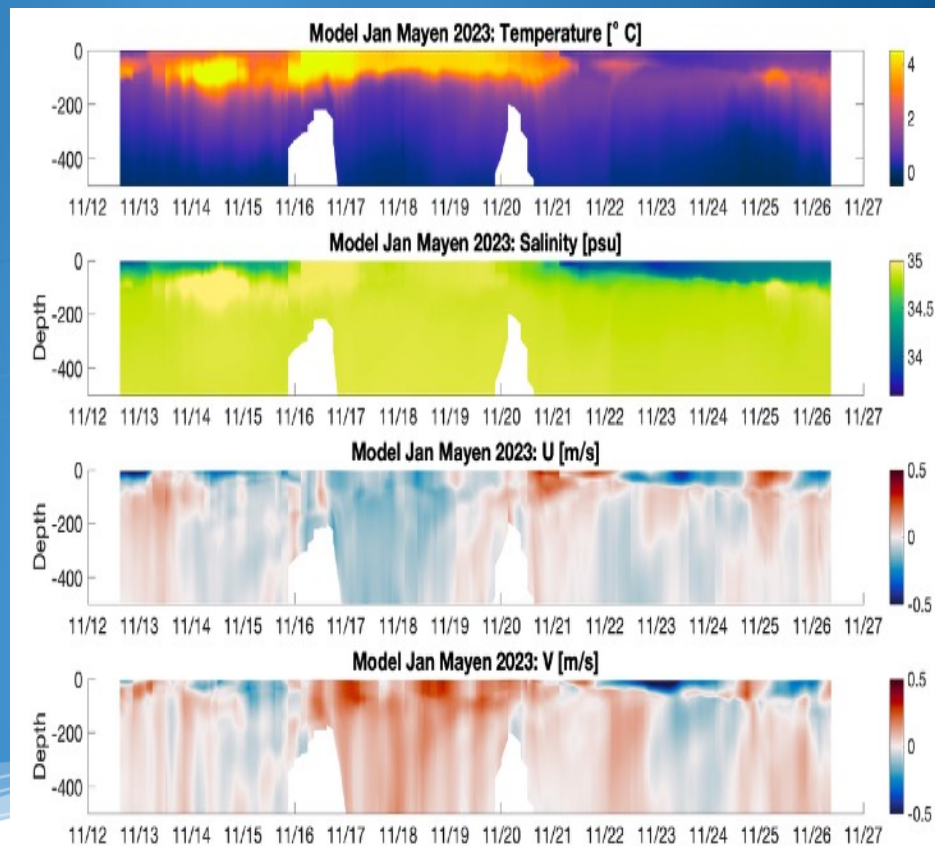
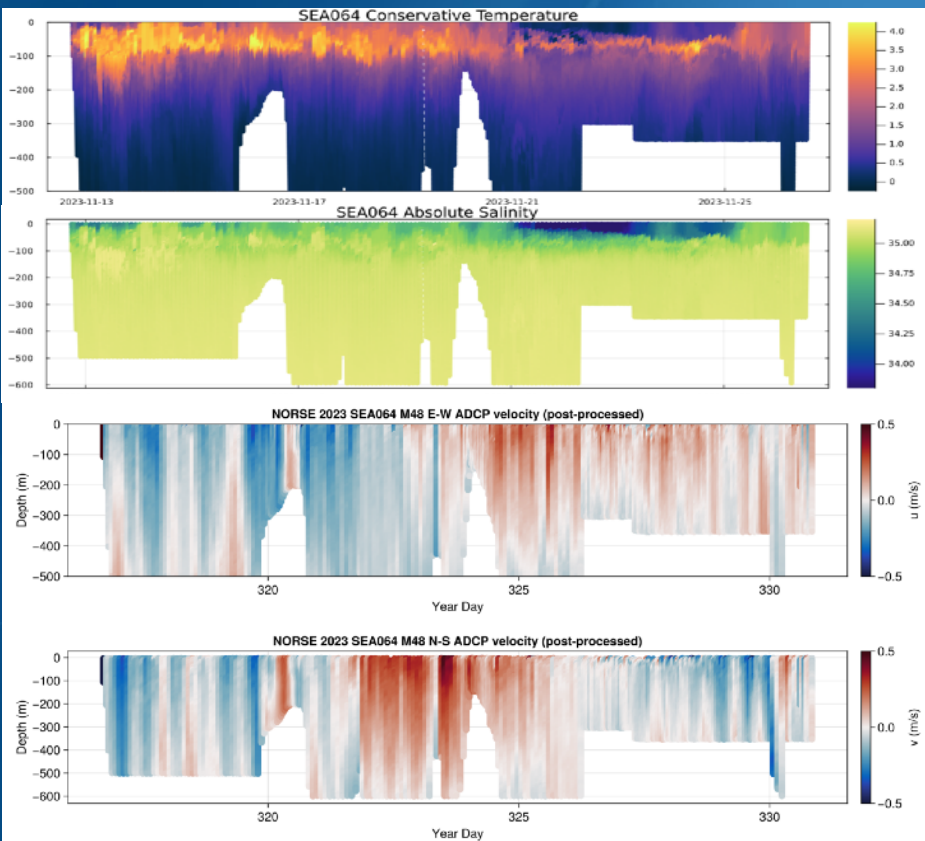


ROMS Surface Temperature

NORSE: Data—Model Comparison (ROMS)

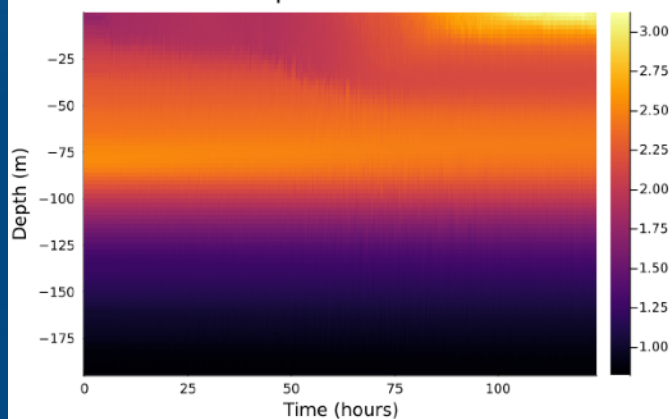
Glider @ Jan Mayen 2023

ROMS @ Jan Mayen 2023

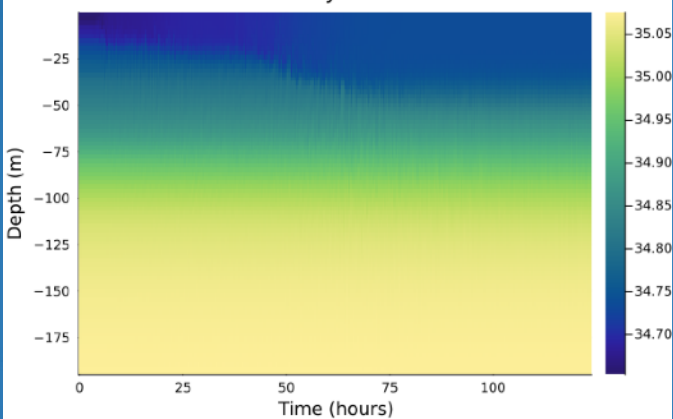


NORSE: Data—Model Comparison (LES)

Temperature Profile

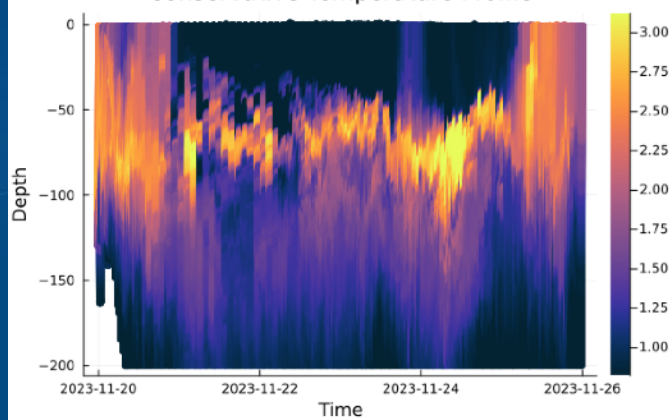


Salinity Profile

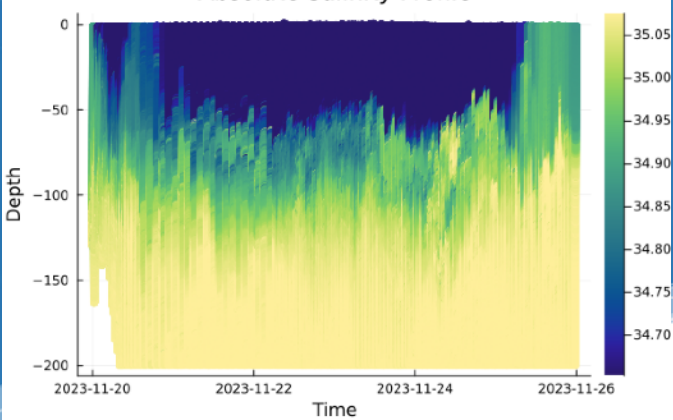


Model variability is driven by 1D processes, mainly limited to the upper 60 m.

Conservative Temperature Profile

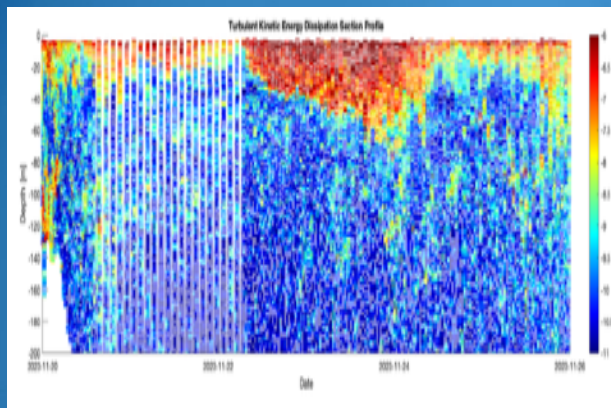
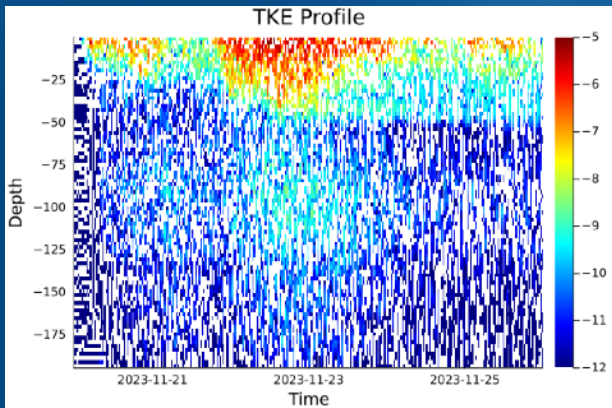


Absolute Salinity Profile



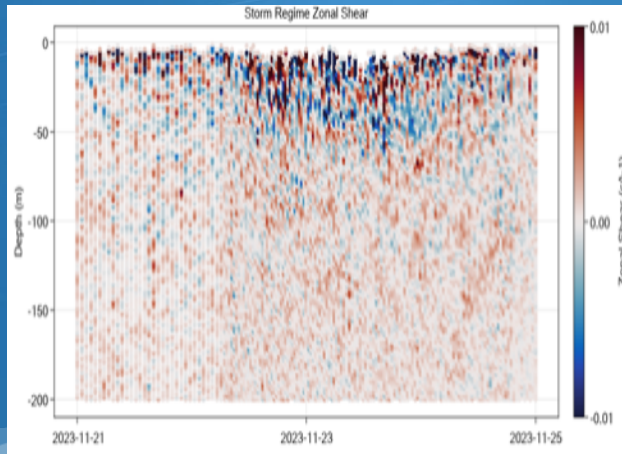
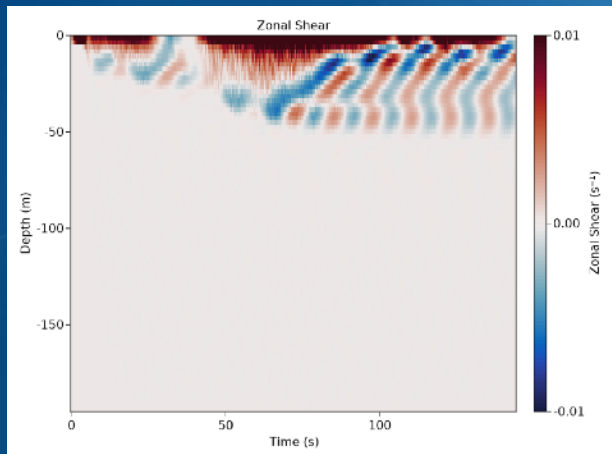
Glider observation suggests 3D advection of cold and fresh water into the study region

NORSE: Data—Model Comparison (LES)



2023/11/20 - 2023/11/29

TKE dissipation at surface is stronger in glider data, subsurface signal is less coherent in data



Velocity shear data indicate NIW generation due to storm in LES model. The signal is less clear in data, but still consistent with model.

NORSE: Physical Oceanographic Findings

- There are strong hydrographic and flow variabilities in the Norwegian Sea on a range of time scales.
- Water mass transformation processes around Jan Mayen is three dimensional modulated by complex flow pattern.
- A subsurface warm layer that was not present in October 2022 but present in November 2023 is likely sustained by frontal subduction.
- Strong surface forcing limits the Active Mixing Layer mainly to the upper 75m of the water column near Jan Mayen.
- Enhanced sub-surface turbulence likely due to energetic flow over shallow banks and boundary currents around Jan Mayen.

NORSE: Technology Development/Testing

- SeaExplorer + MR1000G is an effective ocean turbulence measurement system, fast vehicle (>35 cm/s) and high quality data
- Rockland realtime turbulence processing works well, access to Q-file would provide more realtime processing flexibility (not available on SeaExplorer)
- Realtime ADCP processing (server-side) works, but algorithm is proprietary for SeaExplorer. Multiple delayed-mode algorithms are now available.
- Custom Loggerhead PAM works well on the Slocum glider and was able to pick up drifting source 100 km away.
- New measurement technologies and methodologies are being developed using the NORSE dataset.
- Very successful partnership of government, academia, and industry.

Acknowledgements

Organizations:

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Illker Fer
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Harper Simmons
Lou St. Laurent
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Dan Vient
Anthea Empson
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