# Broadband acoustic scattering from nonlinear internal waves

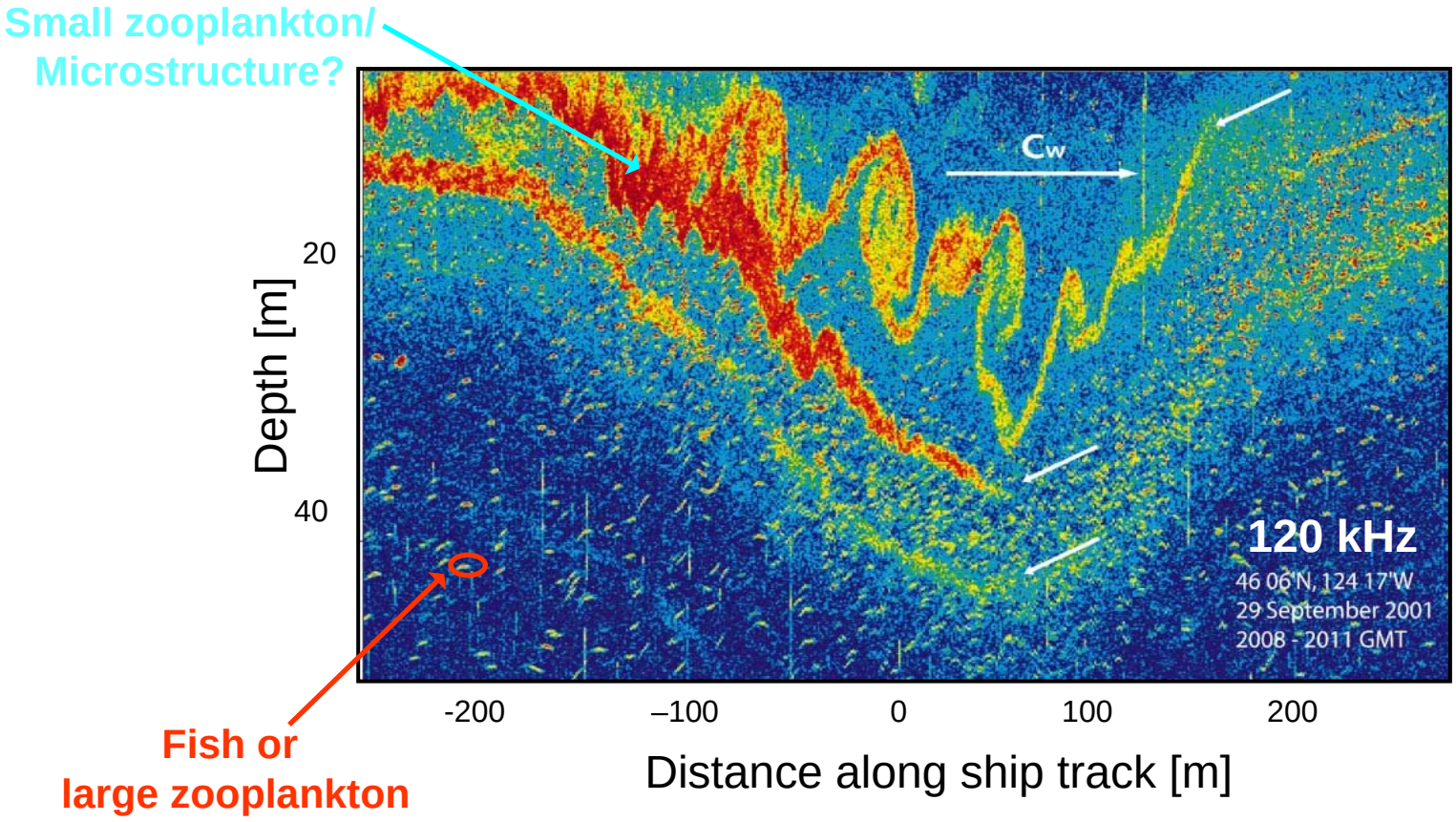
*Andone C. Lavery*
Woods Hole Oceanographic Institution

Presented by
*Timothy K. Stanton*
Woods Hole Oceanographic Institution

Acknowledgements:
Dezhang Chu (Northwest Fisheries Sciences Center)
Jim Moum and team (Oregon State University)
Karen Fisher (Los Alamos National Lab)
Doris Leong (Dalhousie University)
Paul Heslinga (Falmouth Academy)

Funding provided by ONR Ocean Acoustics and WHOI

# Why use acoustic scattering techniques for investigating physical processes?

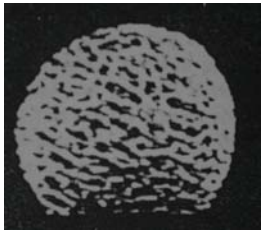



Moum *et. al*., *J. Phys. Oceanography* **33**, 2093-2112, 2003.

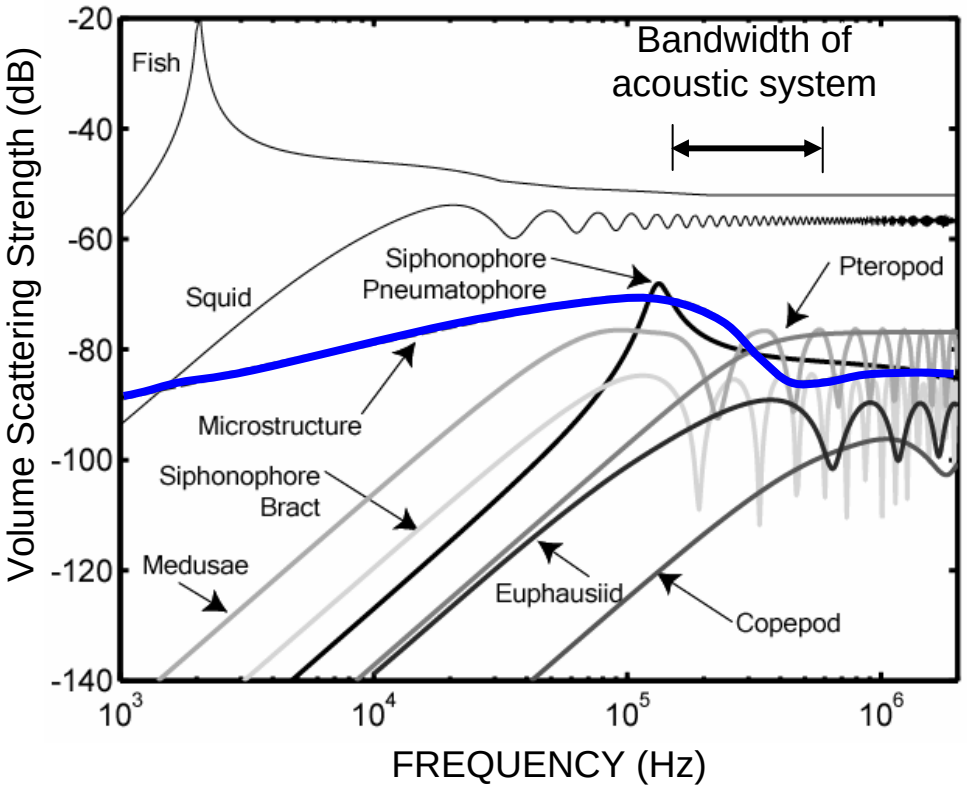
# Sources of scattering and scattering models

Fish
(Gas-bearing)

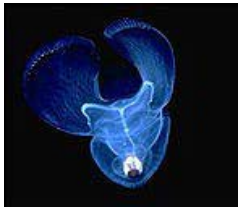
Squid (Fluid-like?)



Turbulent Microstructure



Siphonophores
(Gas-bearing)



Pteropods
(Elastic-shelled)

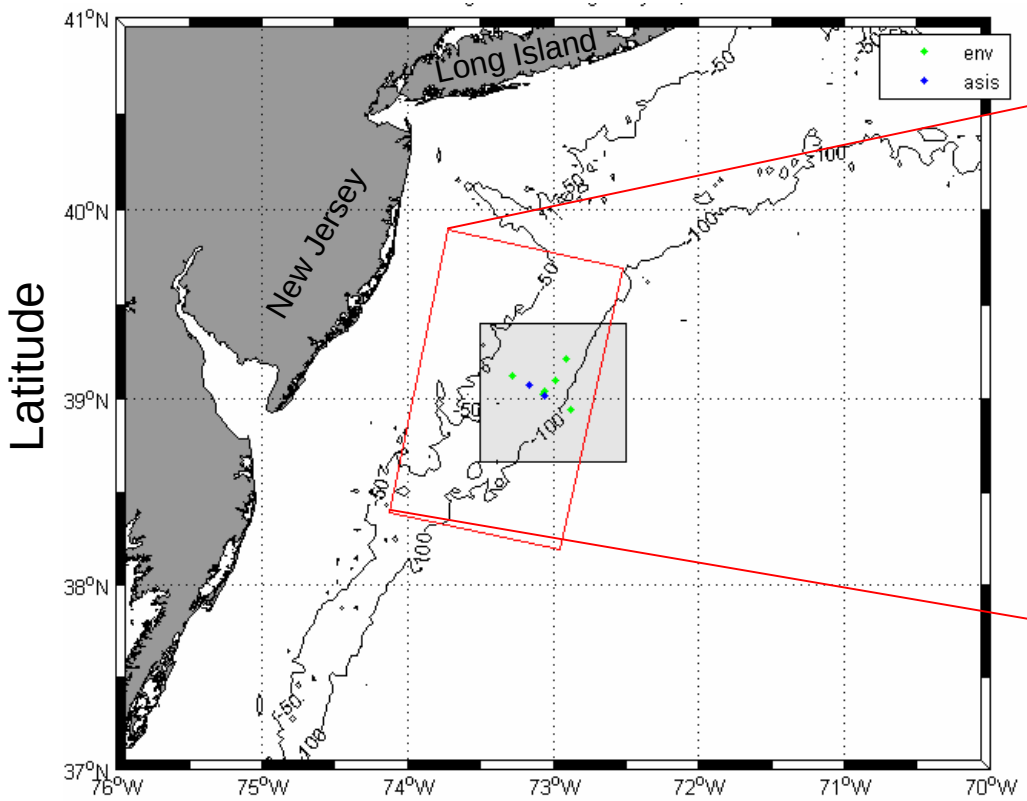
Copepods
(Fluid-like)

Medusae
(Fluid-like)

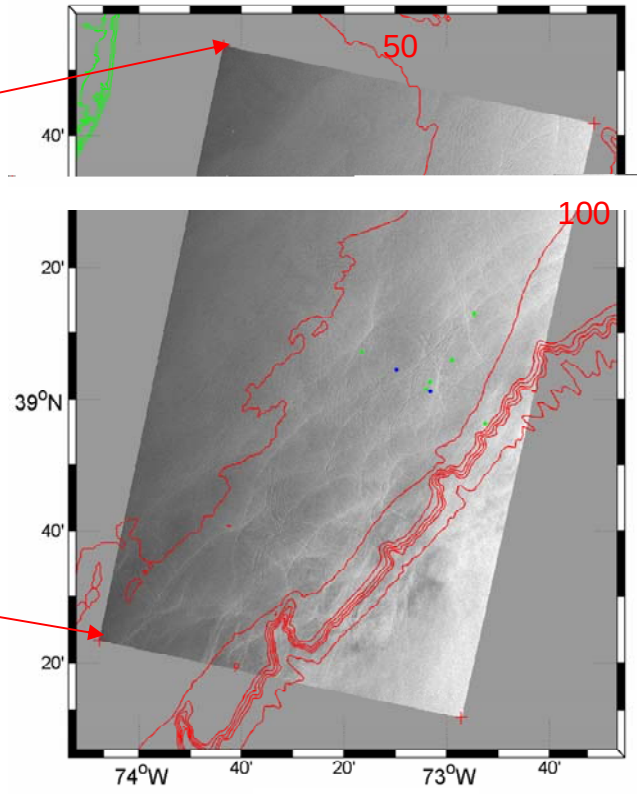
Euphausiids
(Fluid-like)

# SW06/NLIWI Experiment

Experiment duration:
July 31- August 27, 2006

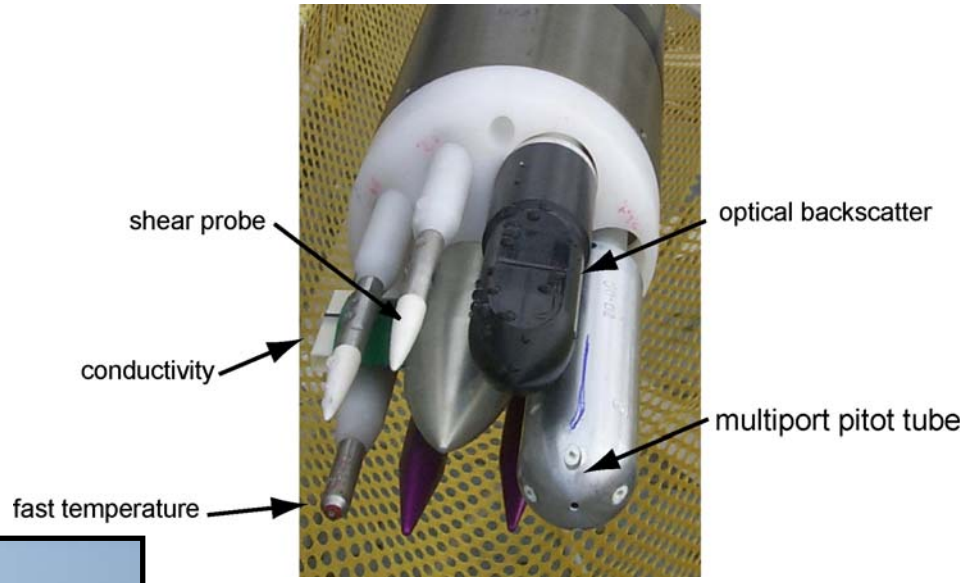


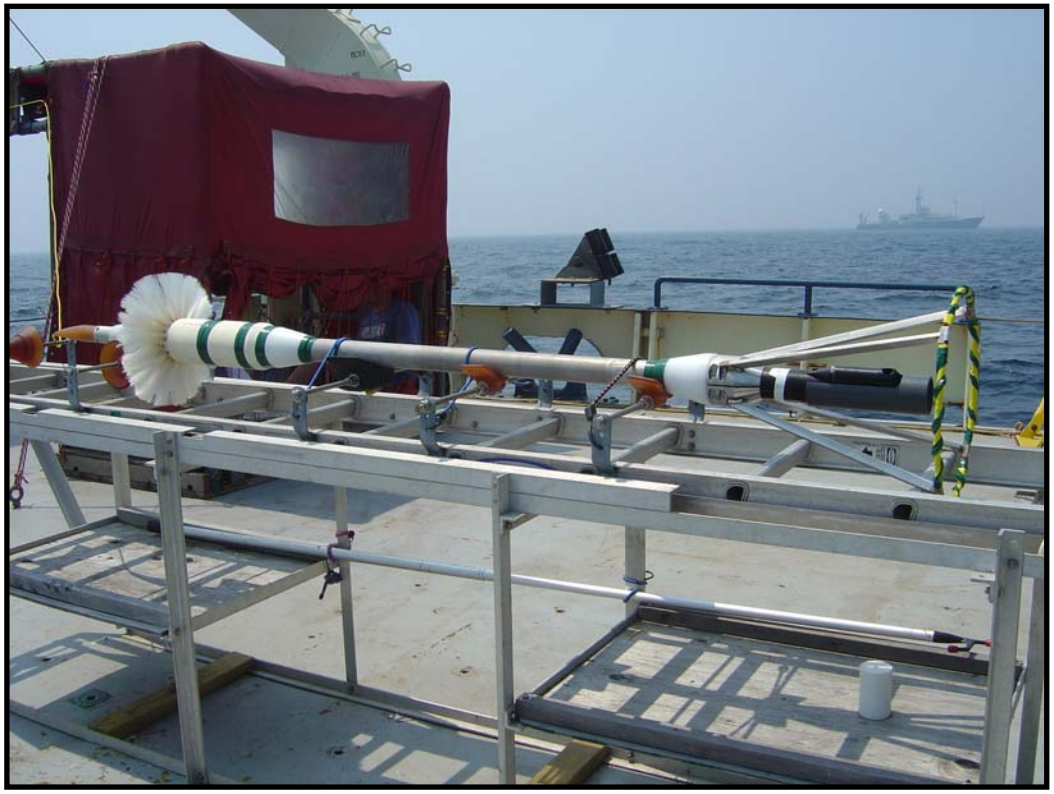

SARS Satellite Image
July 23, 2006




Complex IW field

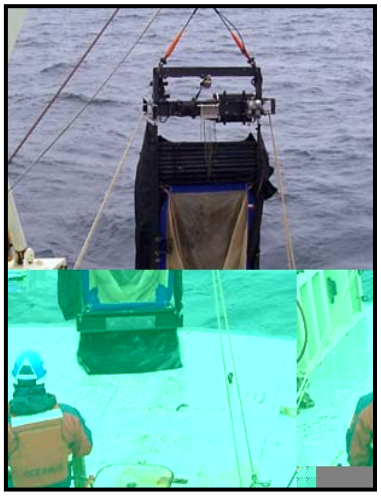
# Microstructure measurements (Jim Moum)



# Zooplankton net tows

MOCNESS:
Multiple Opening/Closing Net and Environmental Sampling System



MOCNESS track superimposed on 120 kHz echogram

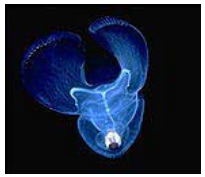
Depth (m)

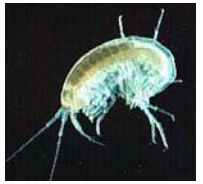
MOC 4: 24 August 2006

Local Time

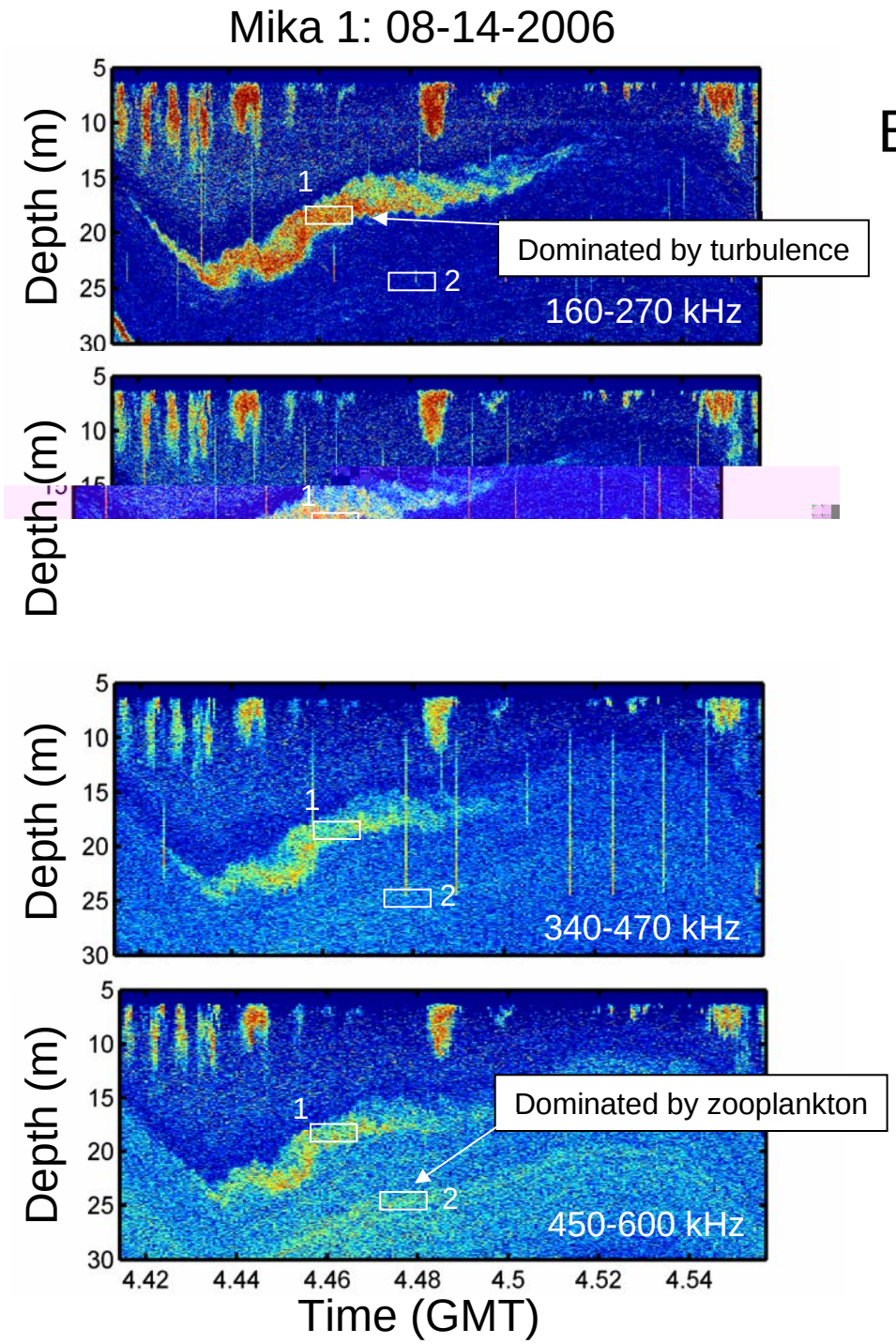
Conclusions:

1. Abundance and biomass dominated by small copepods (fluid-like)
2. Scattering dominated by small pteropods (elastic-shelled) and amphipods (fluid-like)

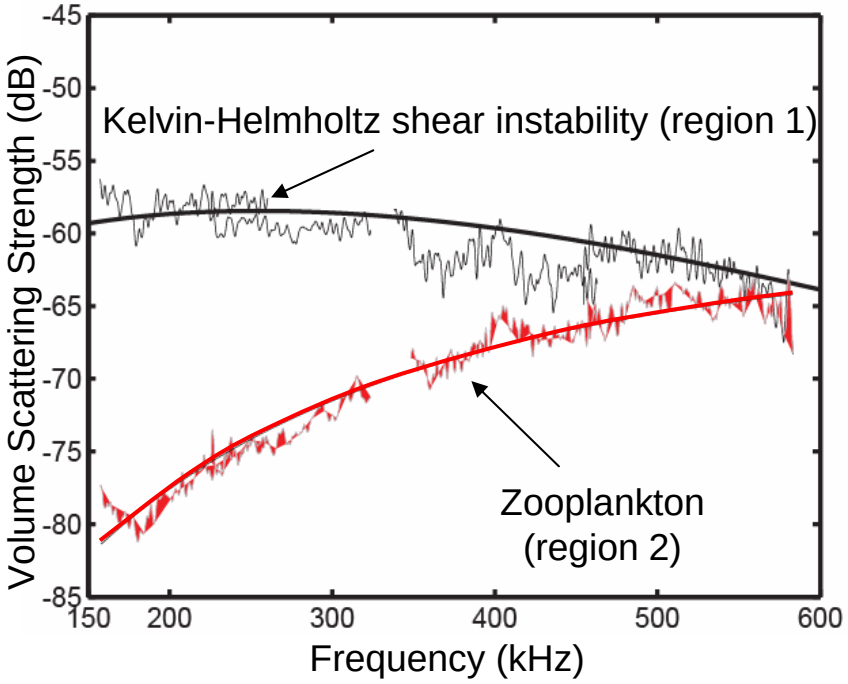




# Broadband spectra: example 1

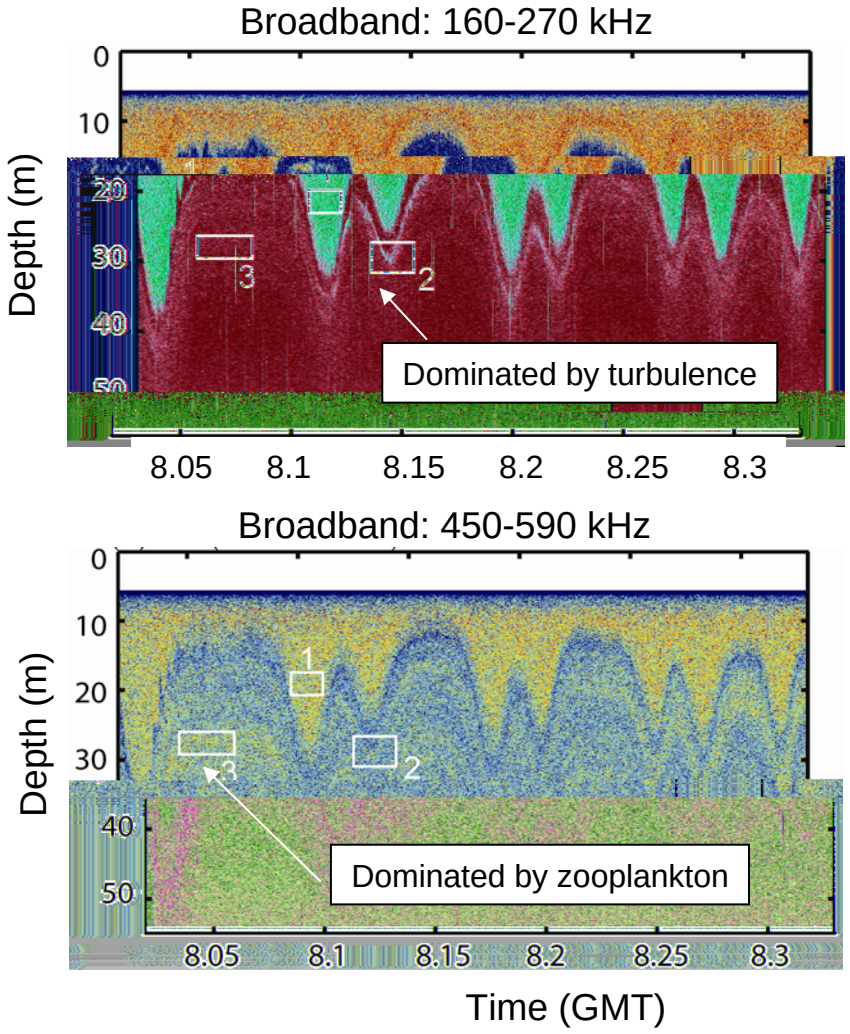


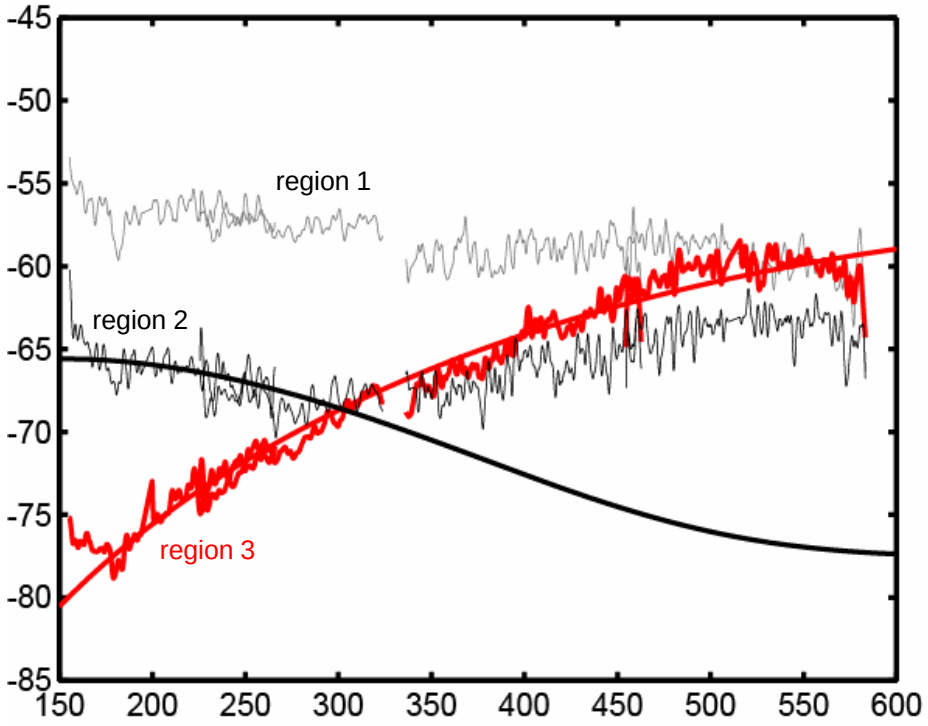

**Region 1**: Microstructure dominated.
Inferred dissipation: $\varepsilon = 8 \times 10^{-6}$ W/kg.




**Region 2**: Zooplankton dominated.
Inferred pteropod: diameter = 0.78 mm.

# Broadband spectra: example 2




**Region 2:** MIXED:

- Microstructure dominated at low frequencies.
  Inferred dissipation: $\varepsilon = 2.5 \times 10^{-6}$ W/kg.
- Zooplankton dominated at high frequencies.

**Region 3**: Zooplankton dominated at all frequencies.
Inferred: 960 pteropods/m$^3$ of diameter 0.53 mm.

# Summary/Conclusions

- First use of broadband acoustics to image microstructure.
  - Improved image resolution.
  - Improved discrimination from zooplankton.

- Scattered spectra often consistent with scattering from biology alone, particularly at depths below the thermocline.

- Scattered spectra consistent with scattering from turbulent oceanic microstructure alone only at a few locations, particularly in the vicinity of shear instabilities.