Pacific Marine Environmental Laboratory

Marine Ecosystems

Acoustics Program

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PMEL ACOUSTICS PROGRAM

CIMRS

Mission:

Use underwater sound to assess the health of marine ecosystems

Ambient Ocean Sound:

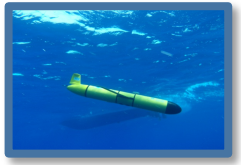
Evaluate the impacts of sound from human activities, and natural processes, on the marine environment

Bioacoustics:

Assess changes in abundance and distribution of marine mammals due to man-made noise and climate

Geophysics:

Quantify volcanic processes and develop methods to estimate CO_2 gas release from submarine volcanoes



New Technologies:

Develop innovative ocean sound sensing technologies

Relevance

NOAA's Missions:

- **Assessing health and productivity of marine ecosystems (Healthy Ocean Goal)**
- **Advance understanding of the oceans, manage marine ecosystems**

OAR/PMEL Science Goals and Objectives:

- Develop Next Generation tools and technology
- Monitor, understand and predict key aspects of the ocean environment
- Identify ocean issues of major consequence

National Acts:

Marine Mammal Protection and Endangered Species Acts:

- Provide acoustic information on presence, distribution of at risk cetaceans
- Our data used by NOAA/Navy to assess impacts on marine animals

Marine Sanctuary and Federal Power Acts:

- NOAA's responsibility to assess man-made noise impacts on marine sanctuaries
- Mitigate noise impacts from oil exploration and renewable energy development

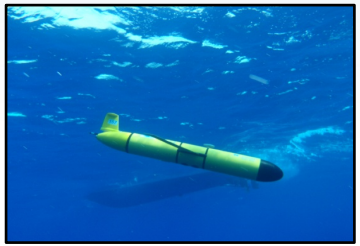
Quality

Leading NOAA program for acoustics technology development, data archiving, and analysis

Unique Acoustic Program Assets

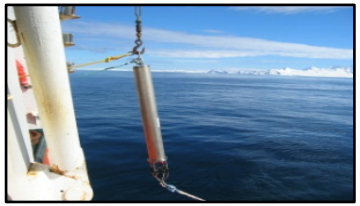
- 23-year archive of N. Pacific ocean sound (using U.S. Navy SOSUS hydrophone arrays)
- Global sound dataset (31 TB) from stationary and mobile hydrophone deployments
- Ishmael & Seas: In-house bio- and geo-acoustic analysis software (online free-ware)

Technology Transfer to Operations



- Passive acoustic recording module (WISPR Board), commercialized by EOS LLC
- Acoustic profiling float (QUEphone) available through Teledyne Webb, Inc.

Involvement in NOAA-wide Policy Initiatives



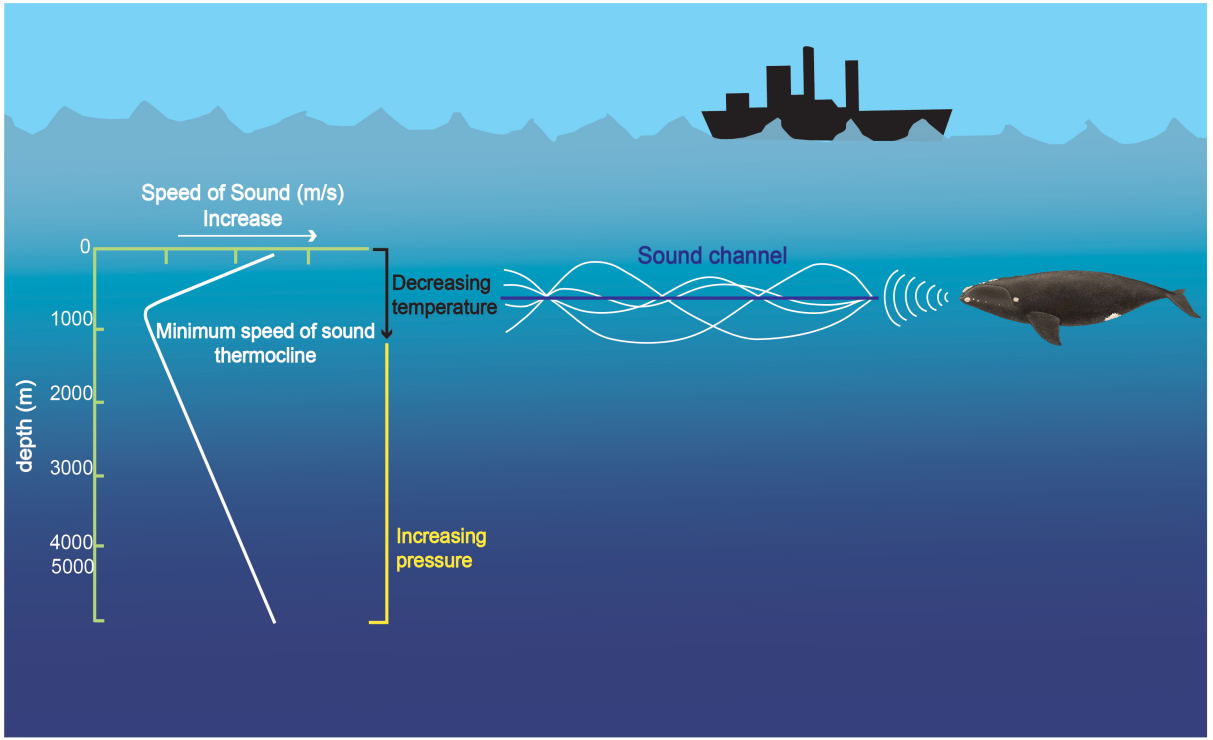
- Ocean Noise Strategy – assess affects of man-made noise on marine animals
- Team to evaluate NOAA echo-sounder impacts on marine mammals

Background

Why is passive acoustics ideal for ocean monitoring?

Physics of ocean sound propagation:

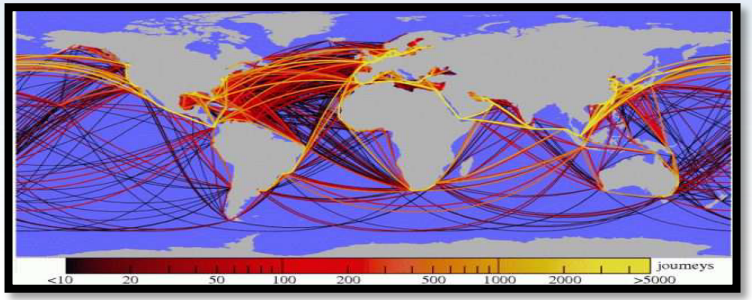
- Sound travels faster in water (1500 m/s) than in air (340 m/s)
- Existence of sound channel, low velocity zone (~ 1 km deep)
- Sound waves travel long distances with little energy loss
- Higher marine organisms are acoustically oriented



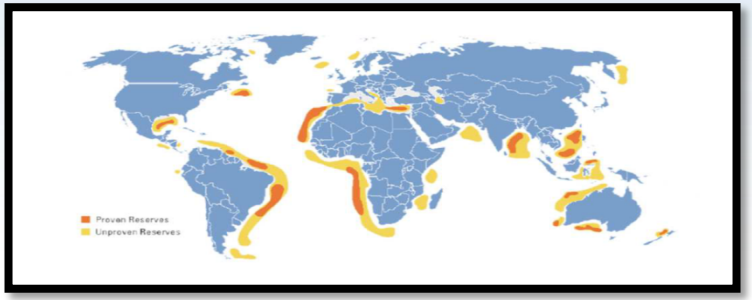
Background: Ambient Ocean Sound

- **Noise 3-4 times (12 dB) higher now in some regions than in 1960s**
- **Many marine animals use sound to communicate, navigate, find food**

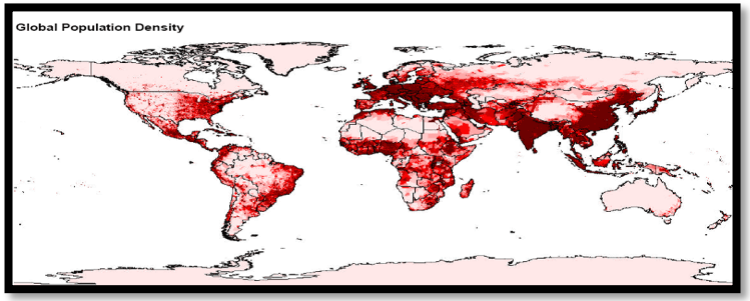
Global Shipping



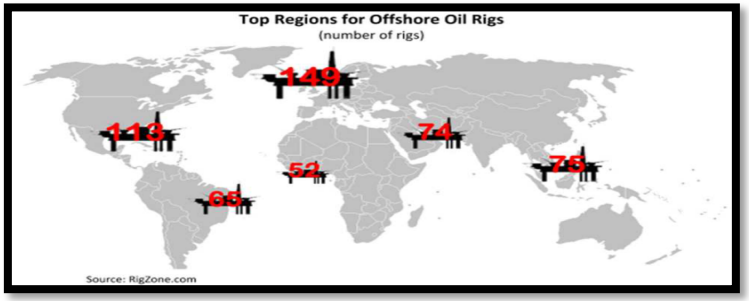
Global Oil and Gas Reserves



Coastal Populations



Offshore Oil Rigs



U.S. Navy Hydrophone Arrays

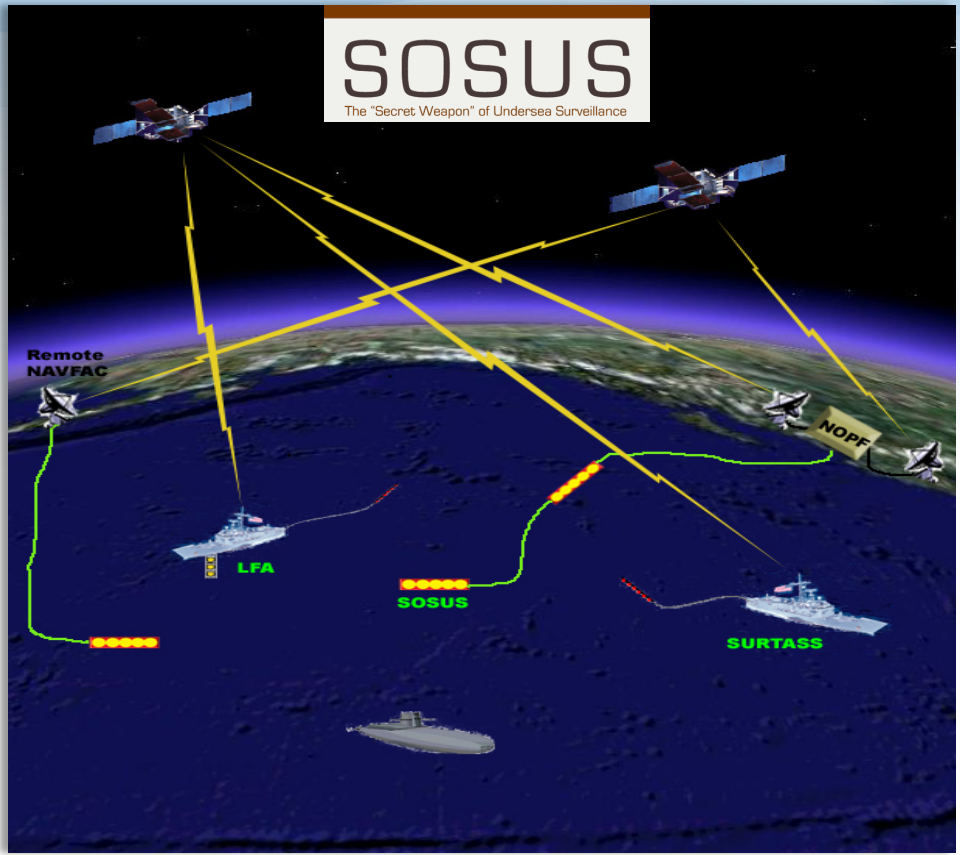
PMEL-Navy partnership to collect real-time hydrophone data in N. Pacific

SOSUS: a cold-war era cabled hydrophone network for anti-submarine warfare

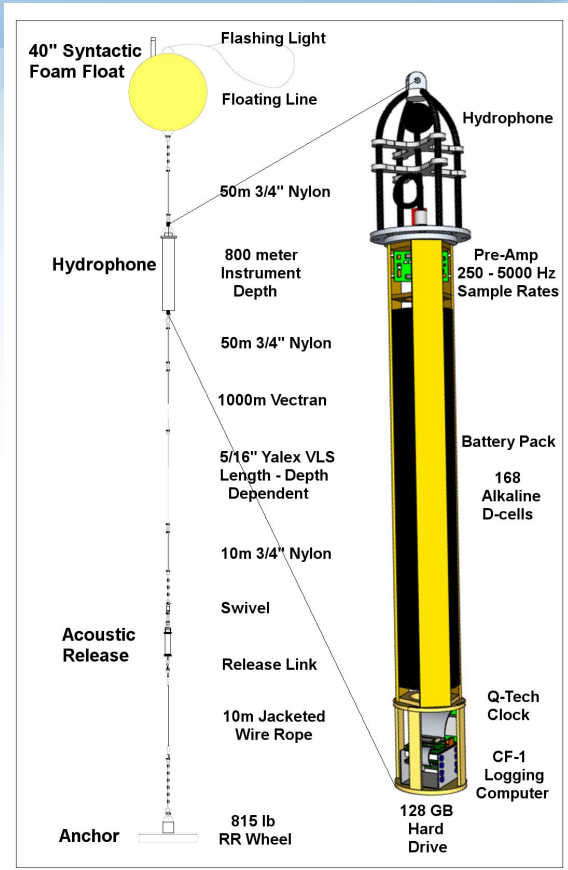
PMEL first accessed SOSUS in 1991, one of longest civilian archive of ocean sound

PMEL used the SOSUS sound archive to:

- Detect numerous submarine volcanic eruptions
- Track endangered blue and fin whales
- Evaluate long-term trends in ocean noise



Performance: PMEL Hydrophone Mooring



Following the success of SOSUS:

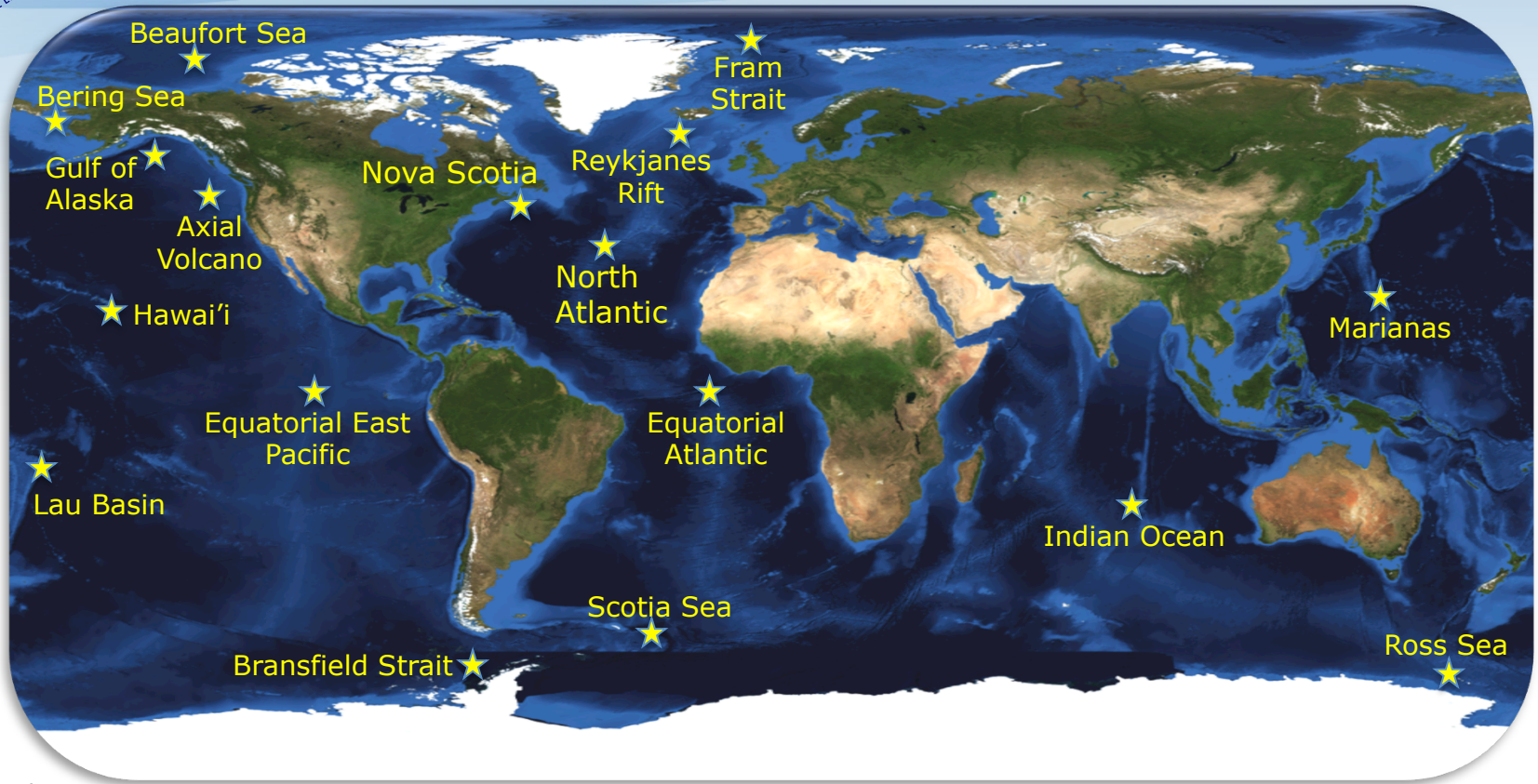
PMEL developed portable deep-ocean hydrophones

Current capacity:

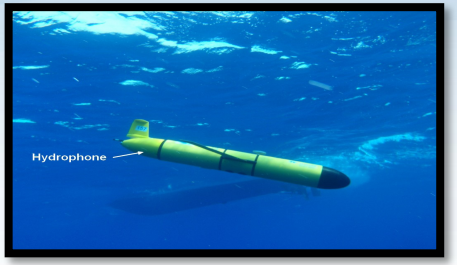
- 5 kHz sample rate
- Up to 2-3 year recording capability

Autonomous Hydrophones: Global Reach

17 Geographic Locations ~200 Individual Deployments and Recoveries



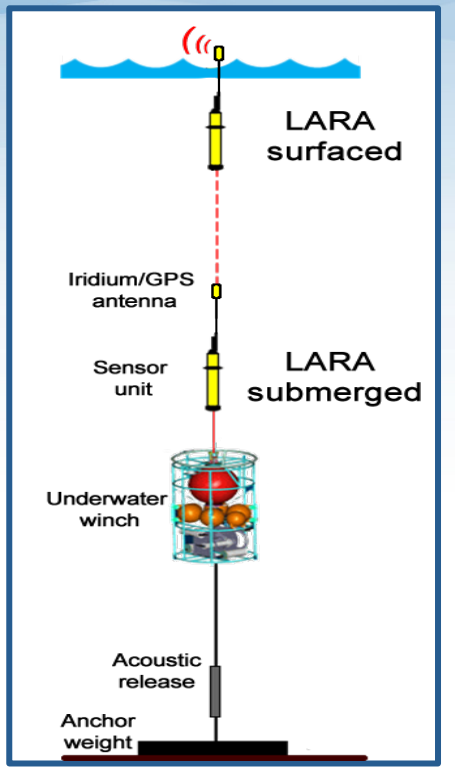
Mobile platforms and near-real-time communication



Slocum Glider

Seaglider

QUEphone
Quasi-Eulerian Float

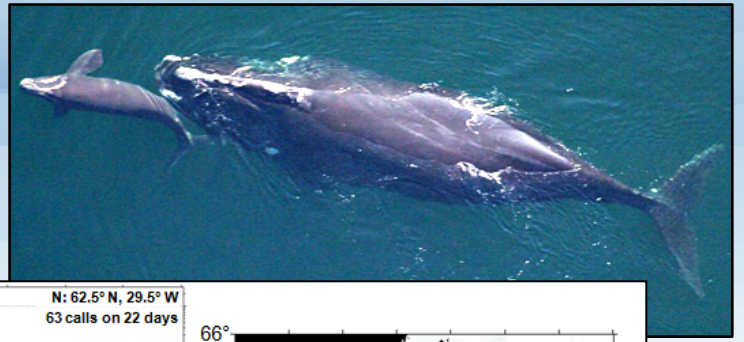


Winch Mooring:
under-ice recording

Roboat
Austrian Society for Innovative Computer Sciences

EMILY – Unmanned Surface Vehicle
NOAA – Weather Service

Performance



Acoustic Assessment of Marine Mammals

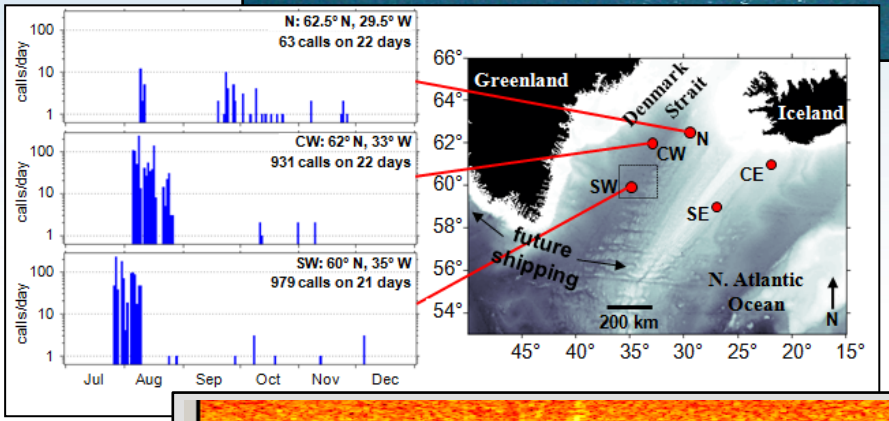
Why?

Basic research

- migration patterns
- feeding habitats
- trophic interactions

Find endangered species

- e.g., only ~500 right whales left in North Atlantic
- even fewer in N. Pacific
- finding seasonal distributions is critical



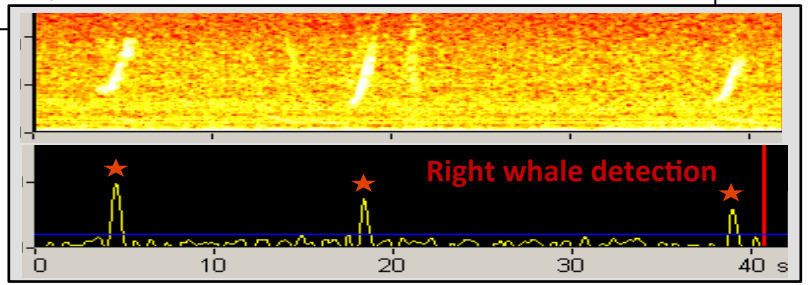
How?

Develop quality detection algorithms to find whale calls in acoustic data

- efficient
- robust to noise

For….

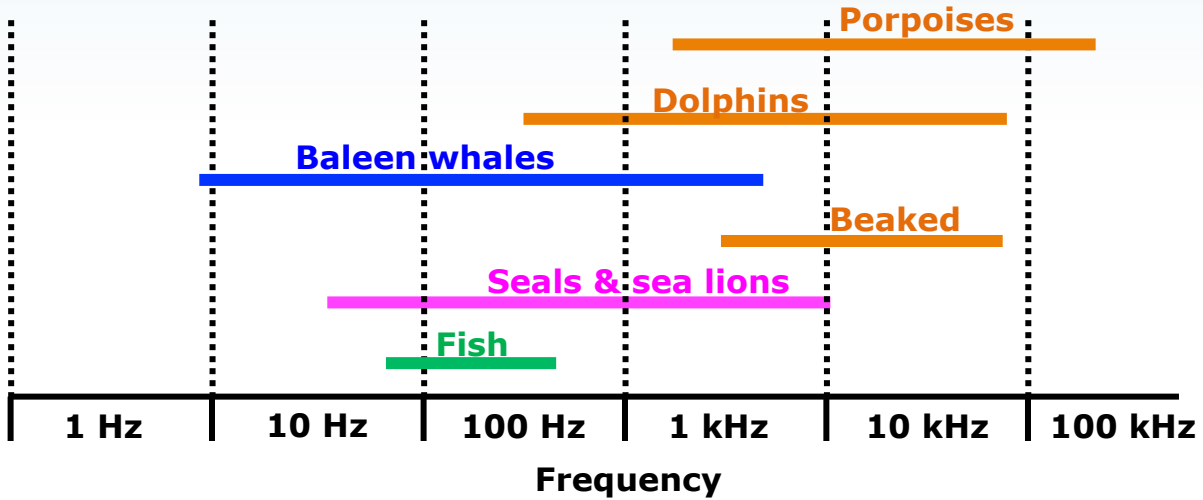
- Detecting baleen whale calls and toothed whale/dolphin clicks



Partners: ONR, NOAA-NMFS, Cornel U., U St. Andrews

Acoustic Identification of Marine Animal Species

Baleen Whales (9)	Toothed Whales (14)	Pinnipeds (5)	Fish
Blue	Sperm	Leopard seal	Rockfish
Fin	Beaked (5 species)	Weddell seal	
Bryde's	Dolphins (5 species)	Crabeater seal	
Sei	Killer whales	Harbor seal	
Humpback	Pilot whales	Walrus	
Right	Harbor porpoise		
Bowhead			
Gray			
Minke			



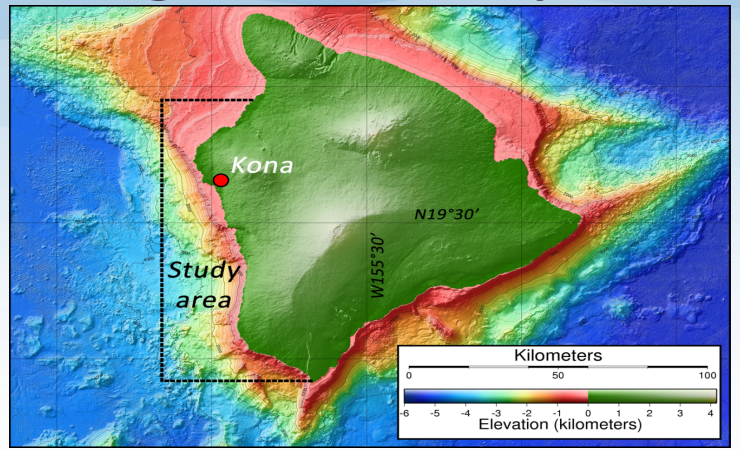
mobysound.org
Free online library of marine animal sounds to test detection & localization algorithms

Partner: Office of Naval Research

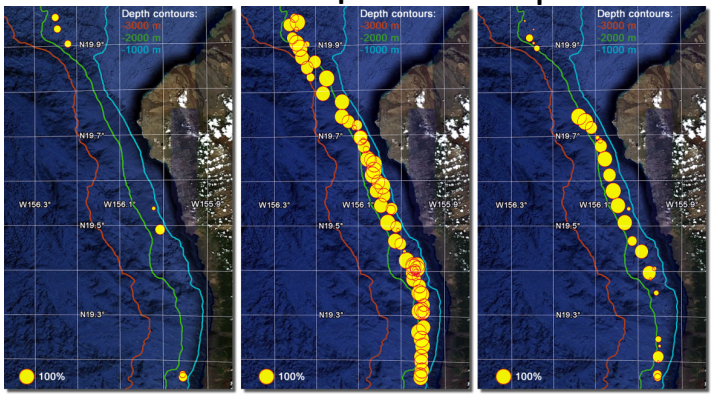
New Cetacean Tracking Techniques

Monitoring whales with ocean gliders

- Many cetacean species are thought to be sensitive to Navy sonar
- Deployed gliders in Navy test area off Hawai'i
- Detected Beaked whales, Dolphins, and Sperm whale calls
- All detections were reported to shore stations



Beaked Dolphins Sperm

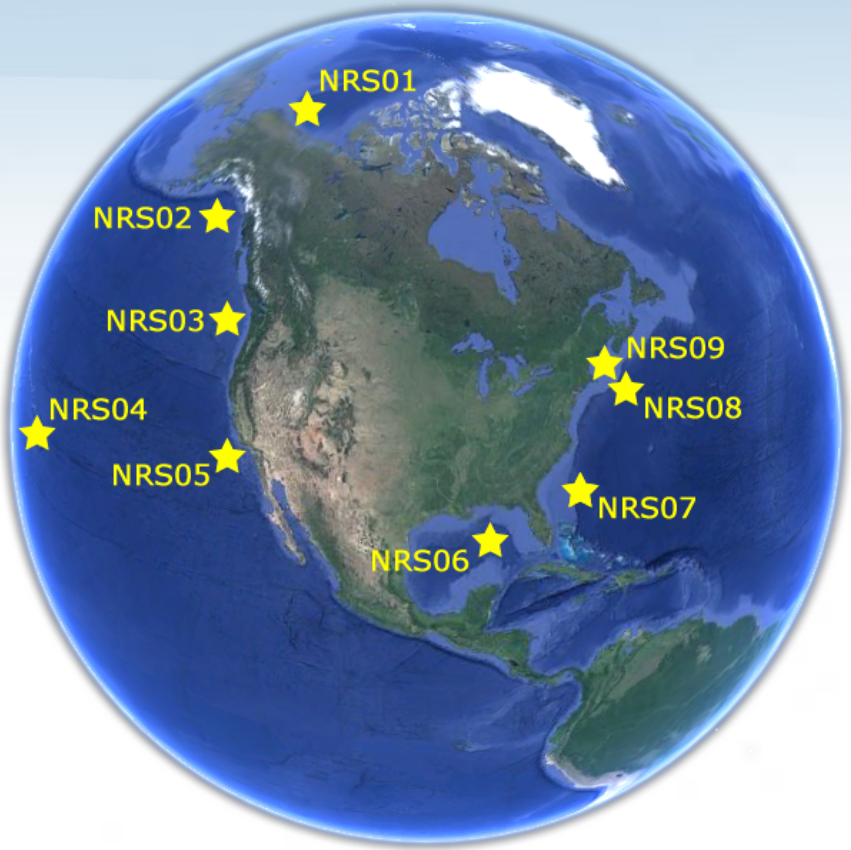


Partners: ONR, U. Washington-APL

Performance

Ambient Sound: OAR-NMFS Ocean Noise Reference Stations

- Establish a network of ten noise reference stations across the U.S. EEZ
  (3 Sanctuaries, 2 National Parks)
- Cooperative program between PMEL, Sanctuaries, all six NOAA Fisheries Science Centers, and Park Service
- Goal: Create first comprehensive network to study long-term noise in US waters
- Future: Expand coverage globally



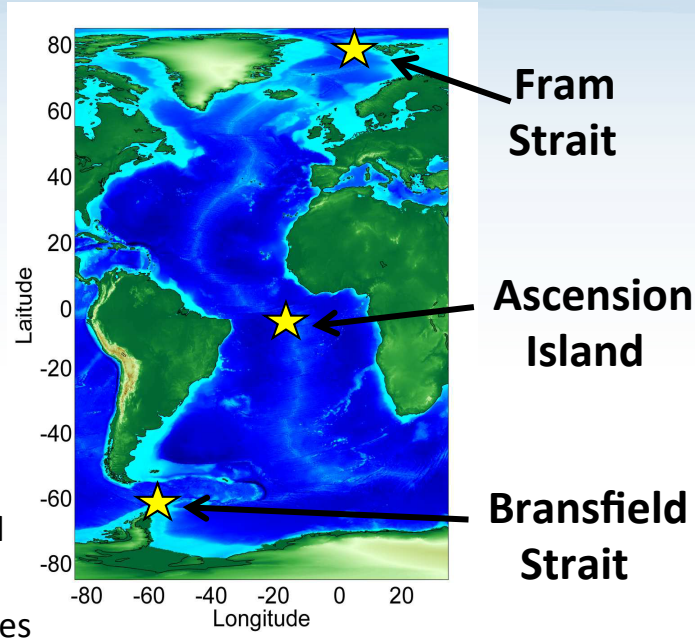
NOAA FISHERIES PMEL

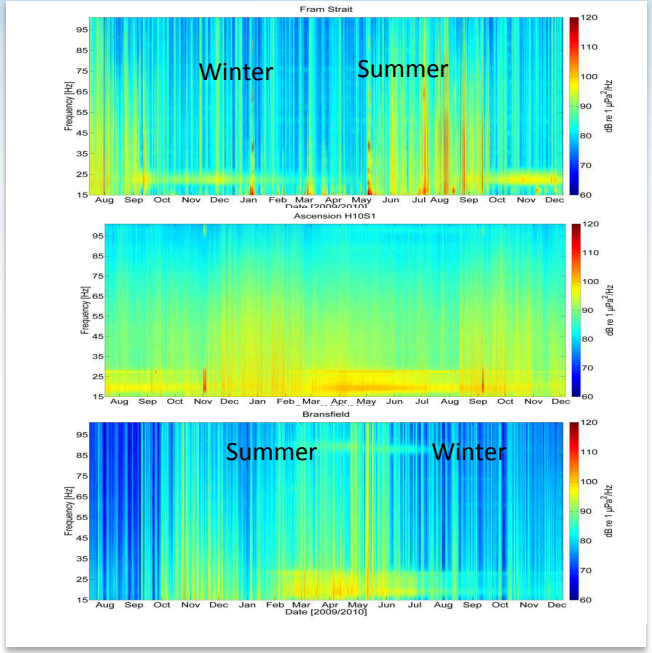
Ocean Scale Sound Comparisons: The Atlantic

Overall Sound Levels:
- Highest at Equator.
- Arctic higher than Antarctic
- Poles lowest in Winter due to sea-ice cover

Man-Made Noise:
- Airguns year-round at Equator
- Summer only in Arctic
- Very little in Antarctic

Marine Mammals:
- Blue-fin whales dominant sound in 15-30 Hz band (all locations)
- Leopard seals add 15 dB (~5 times ambient) over 300-350 Hz





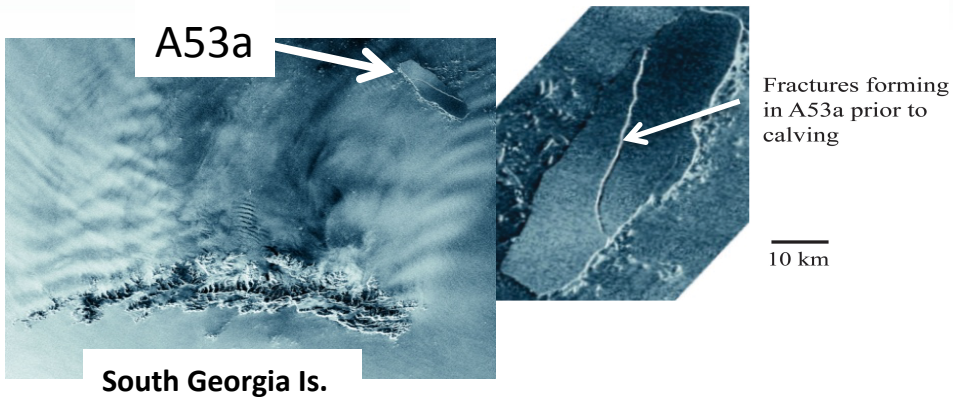
Partners: DOE-CTBTO, Penn State, Korean Polar Inst., Alfred Wegner Inst.

Polar Research

Sea-ice breakup contributes significantly to ambient noise

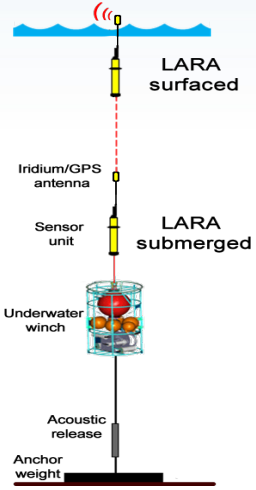
Antarctica

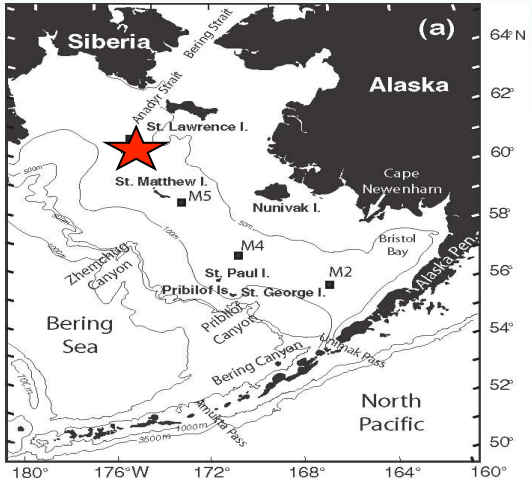
- Recorded sounds of iceberg breakup off Antarctica
- One fracturing event equal to the noise of several hundred super-tankers
- Ice sounds detected as far north as equator



Arctic

- Deploy winch mooring for under sea-ice recording
- Quantify variation in sound levels due to seasonal changes in sea-ice cover





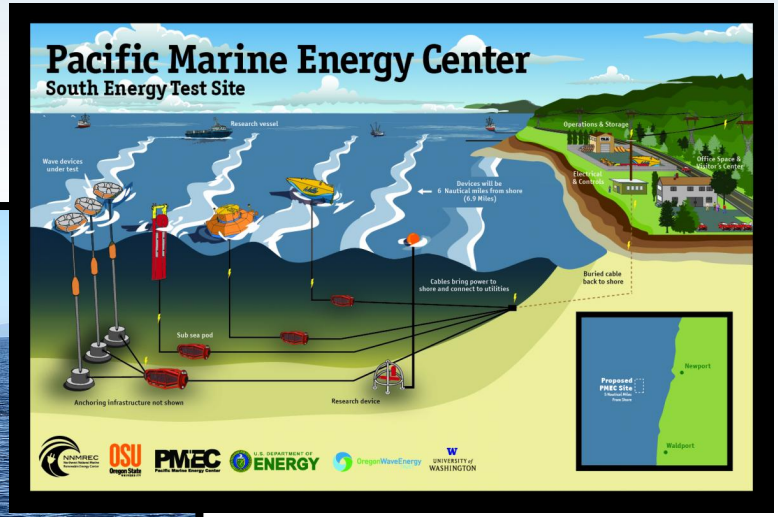
Partners: Korean Polar Inst.

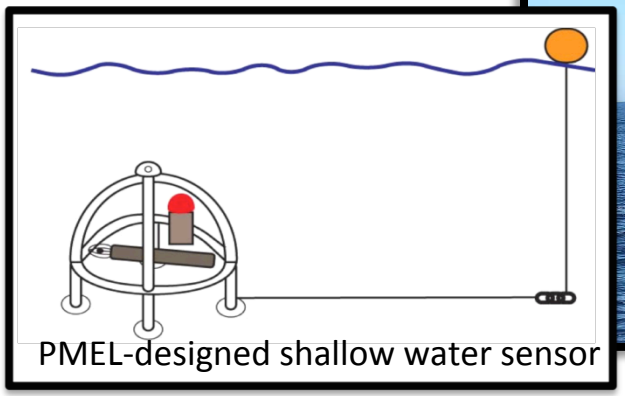
Partners: ONR, PMEL Eco-Foci

Supporting Renewable Energy:

PMEL/DOE/OSU partnership to study ambient sound at the wave-energy buoy test site

- Investigate noise produced by wave energy devices
- Understand impacts to marine mammals and fish
- Ambient noise dominated by surf, blue whales, ships

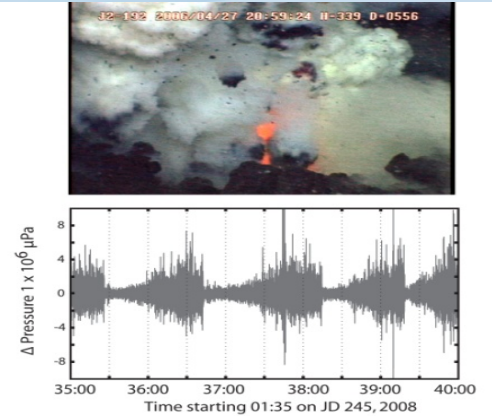



PMEL-designed shallow water sensor


Wave energy buoy

Geophysics:

Eruption Processes and Gas Flux from Submarine Volcanoes



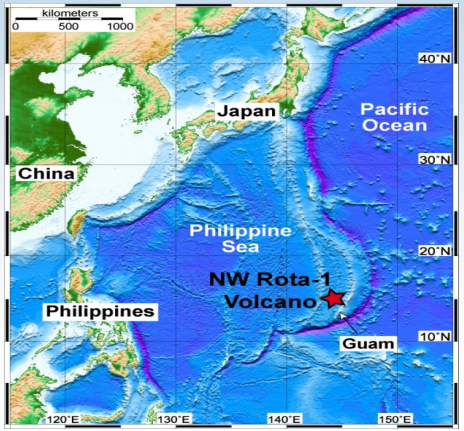
NW Rota-1 in the Mariana Isles

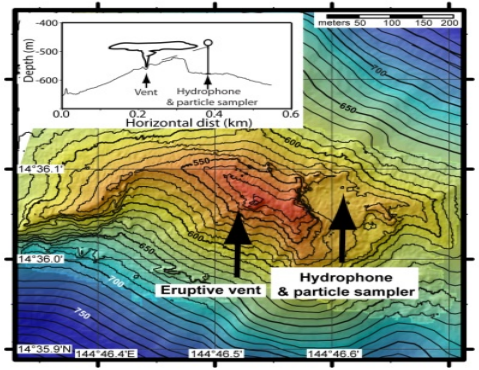
- First multi-year sound record of explosive deep-ocean eruption (512 m)
- Used sound to estimate flux of magmatic CO_2 gas into ocean
- Based on infrasound methods

Results

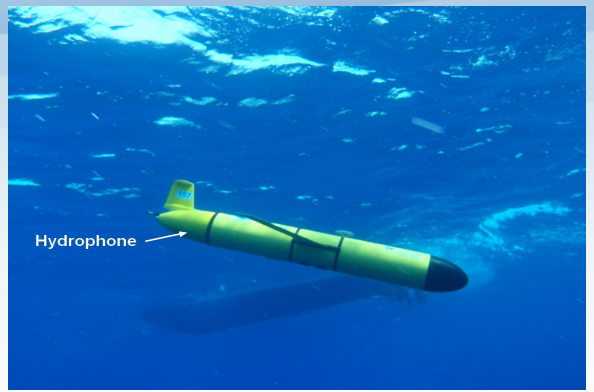
- CO_2 flux ≈ 0.4 ± 0.1 Tg per year
- This estimate is ~ 1% of global CO_2 flux from subaerial arc volcanoes

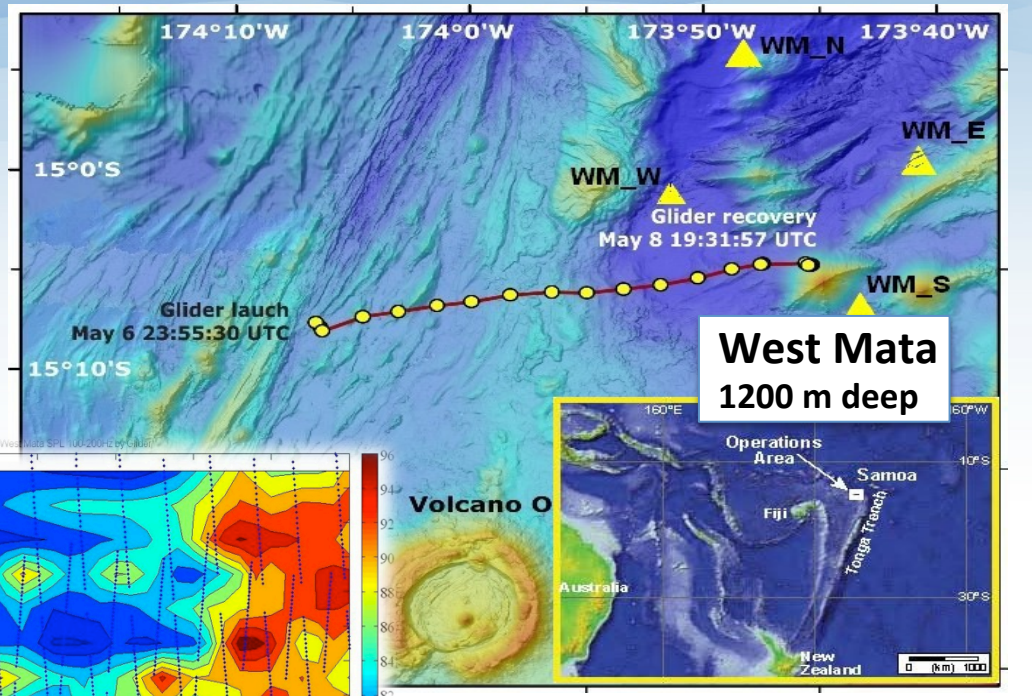
Partners:
NSF-Ocean Science Program, US Coast Guard, PMEL-EOI



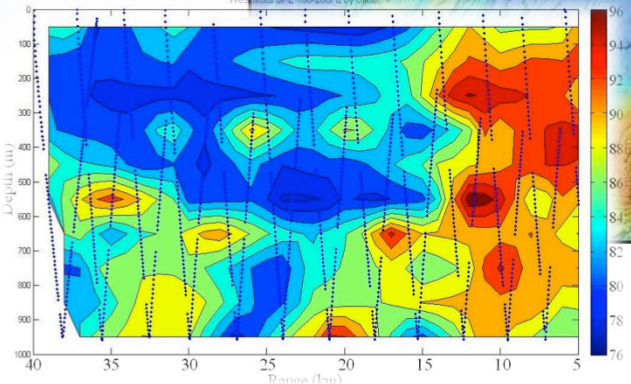


Using a Glider to Detect an Erupting Volcano





- First use of a glider to detect erupting volcano
- Mata volcano is dominant source of sound in the region (add 15 dB)
- Gliders effective means to map regional sound field



Cross section of ocean sound field

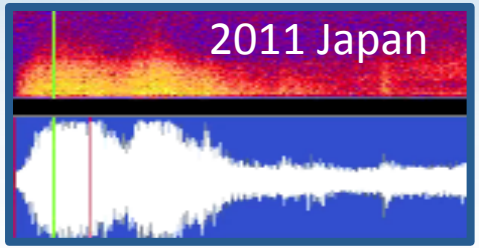
Glider purchased with a grant from OAR AA Fund

Partners: NSF – Ocean Sciences
PMEL- ED&D

Education and Outreach

Mission:

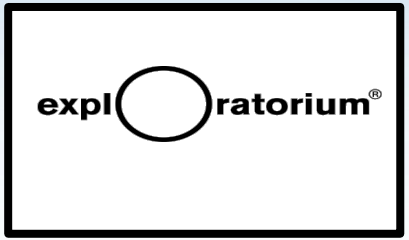
Provide accurate information about the science we conduct to educate the public and inform society



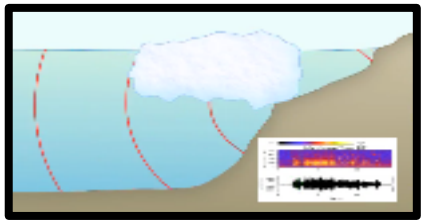
NOAA youtube:
600K views in 1 month

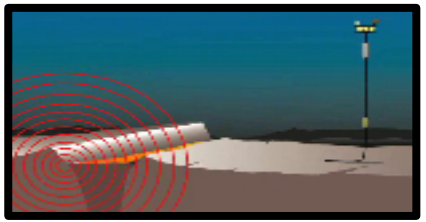
NOAA Ocean Today Kiosk video
At 40 sites worldwide

SeaGrant Saturday Academy:
Build a hydrophone



Scientist-in-Residence
Exploratorium - SFO

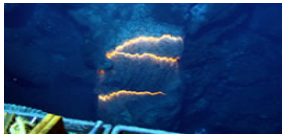
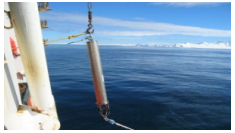


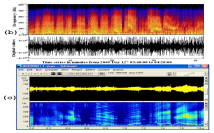


Sounds, videos and animations available at our poster and www.pmel.noaa.gov/acoustics

Future Directions

- Complete deployment of Noise Reference Station network, continue development of a NOAA-wide Ocean Noise Policy
- Expand hydrophone deployments for global coverage of ambient sound levels (e.g. Challenger Deep, Arctic and Antarctic)
- Continue analysis of SOSUS archive to evaluate 20+ year trends in ocean noise and cetacean populations
- Deploy winch mooring for baseline sound levels in the Arctic as ice-cap recedes (expand to deeper parts of Arctic Ocean)
- Continue development of near real-time, mobile hydrophone platforms


Thank You!