PMEL/Vents Ocean Acoustics

Bob Dziak, Presenter
PMEL Laboratory Review, August 2008

- Three Main Acoustic Themes

  - Detection of seafloor earthquake & volcanic activity for discovery of new hydrothermal vent ecosystems

  - Marine mammal identification

  - Ambient sound measurements

Relevance of Ocean Acoustics

Acoustic monitoring can contribute in a significant way to numerous NOAA and other U.S. government agency missions including:

- Seafloor earthquake and volcano detection and monitoring
- Marine mammal assessment (for threatened and endangered species under MMPA and ESA)
- Ocean exploration
- Seismic, volcano and tsunami hazard research
- Ocean ambient noise assessment (ecosystem characterization)
- Meteorological monitoring (e.g. hurricanes, rainfall, windspeeds)
- Iceberg tracking (effects shipping, possibly related to climate change)
- Nuclear Test Ban Treaty verification (Dept of Energy)
- Identification of illegal fishing-trawler activity

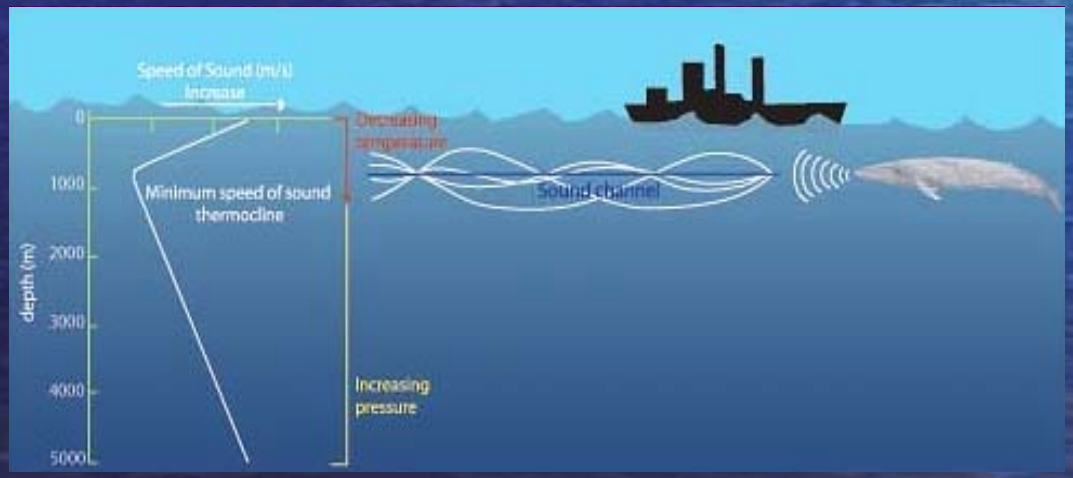
Why is passive acoustics ideal for ocean monitoring?

Physics of sound propagation in ocean:

- **Sound travels faster in water (1500 m/s) than in air (340 m/s)**
- **Existence of an ocean sound channel (SOFAR channel):**

  - Low sound velocity zone (typically 1 km deep), refracts sound waves toward minimum speed, acts as a wave guide

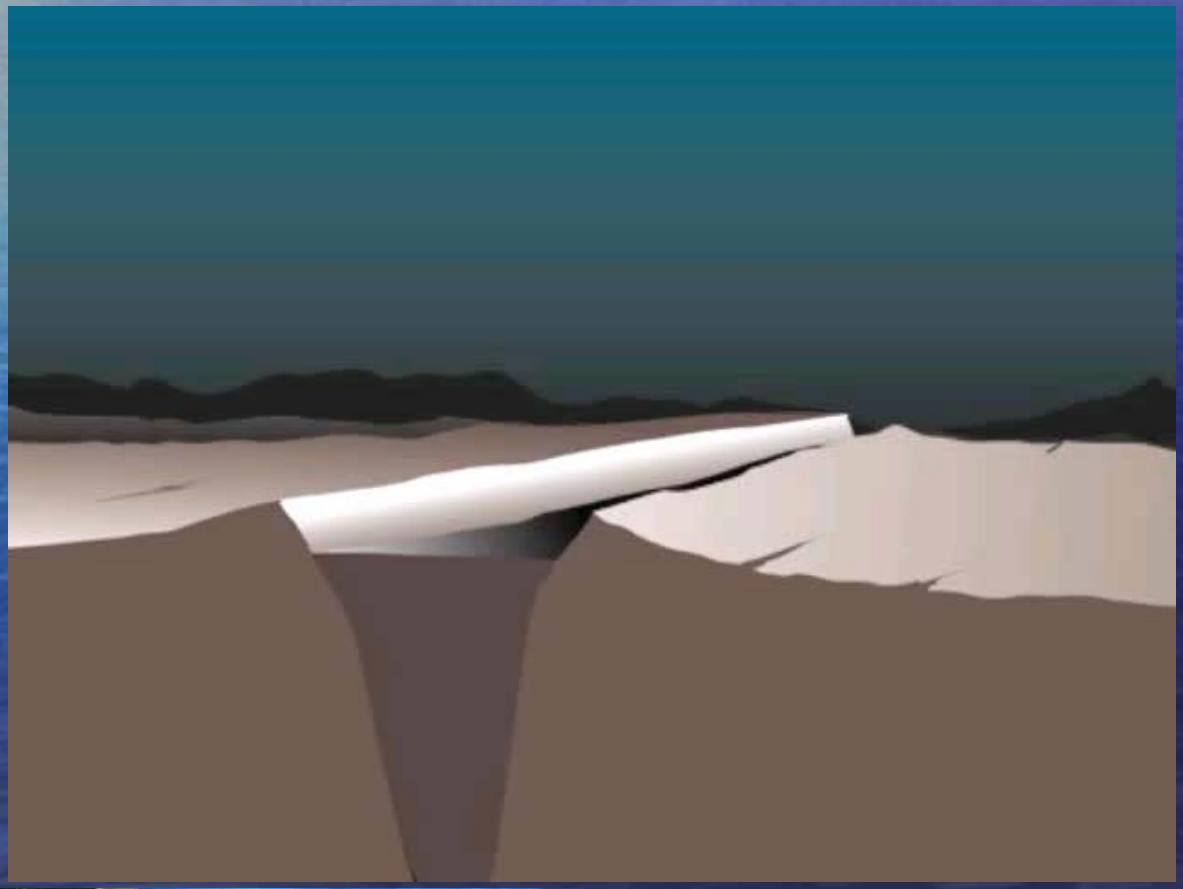
- **Sound waves travel long distances underwater with little energy loss**

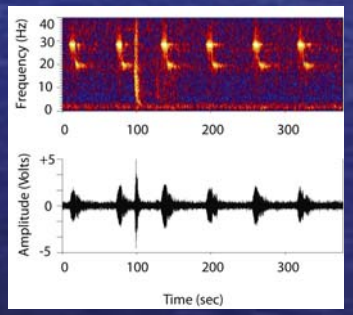


How Does PMEL Use Ocean Acoustics?

- Use special underwater microphone, called hydrophone, deployed in sound channel

- Record ocean sound to study geophysical and biological phenomena.





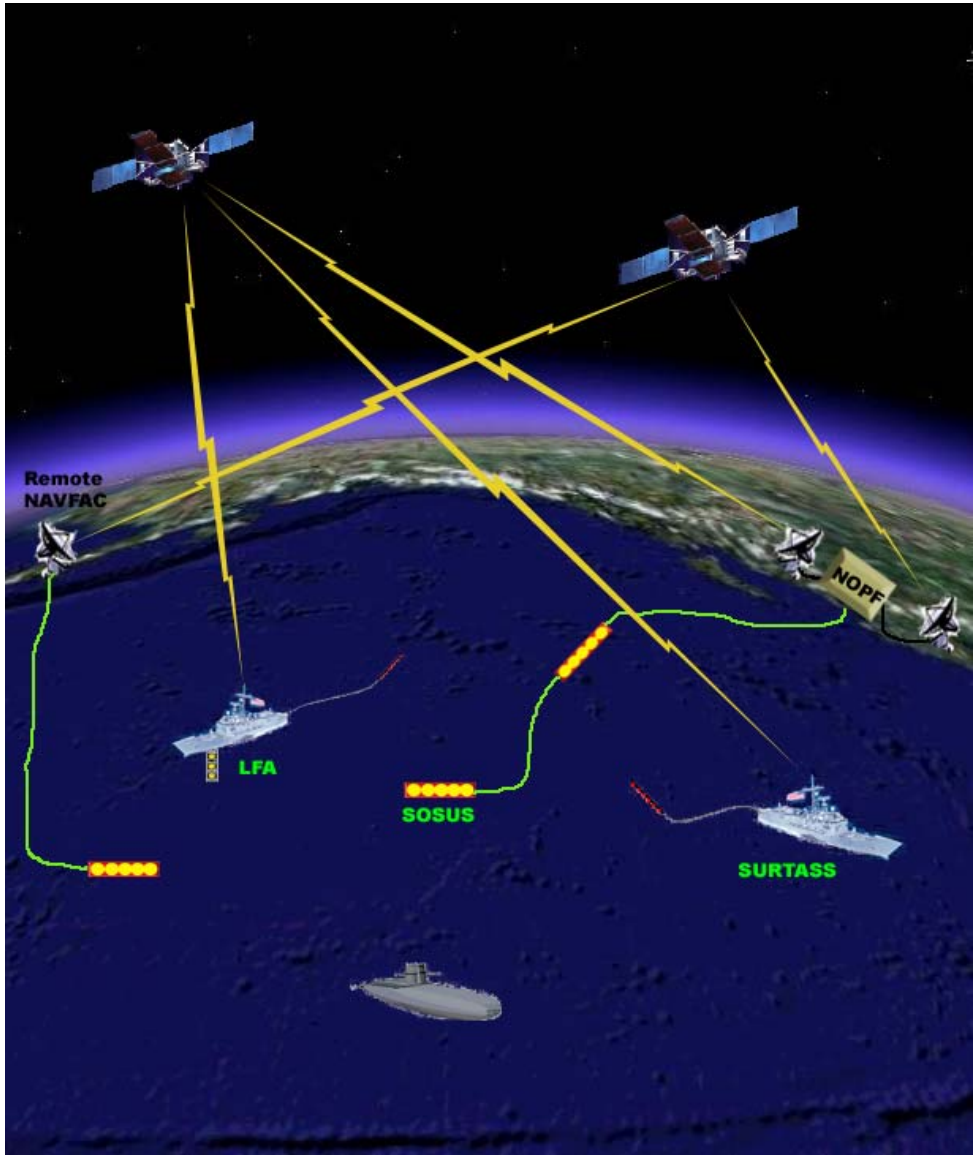
U. S. Navy SOund SUrveillance System: SOSUS Hydrophone Arrays

- **Billion $ cold-war era hydrophone system:**
  - *Bottom-mounted hydrophones*
  - *Deployed in sound channel throughout north Pacific Ocean*
  - *Used in anti-submarine warfare*

- **PMEL Acoustics Project accessed hydrophone data in 1991:**

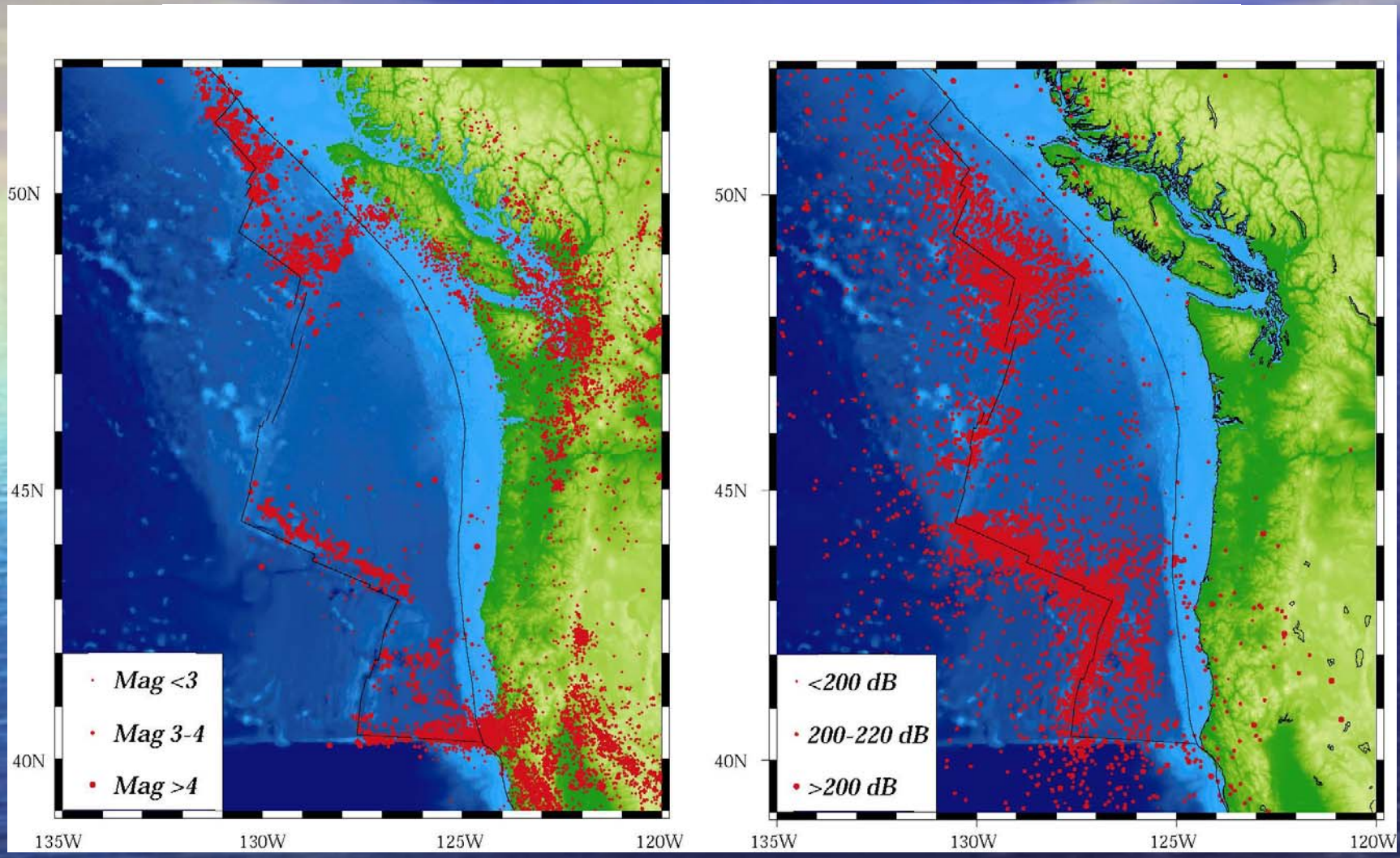
  - *Navy looking for environmental applications for their assets*
  - *Only civilian research group with access to SOSUS real-time data*
  - *Data sent via encrypted phone line from Whidbey Island NAS to Newport*

- **Vast improvement for ocean seismic detection over land-based networks:**
  - *Detect magnitude ~2 compared to ~4*
  - *Much more accurate event locations*



Land Seismic Networks (1991-2007)

SOSUS (1991-2007)



10 times more offshore earthquakes detected by SOSUS, located more accurately due to better sound-speed models and station coverage.

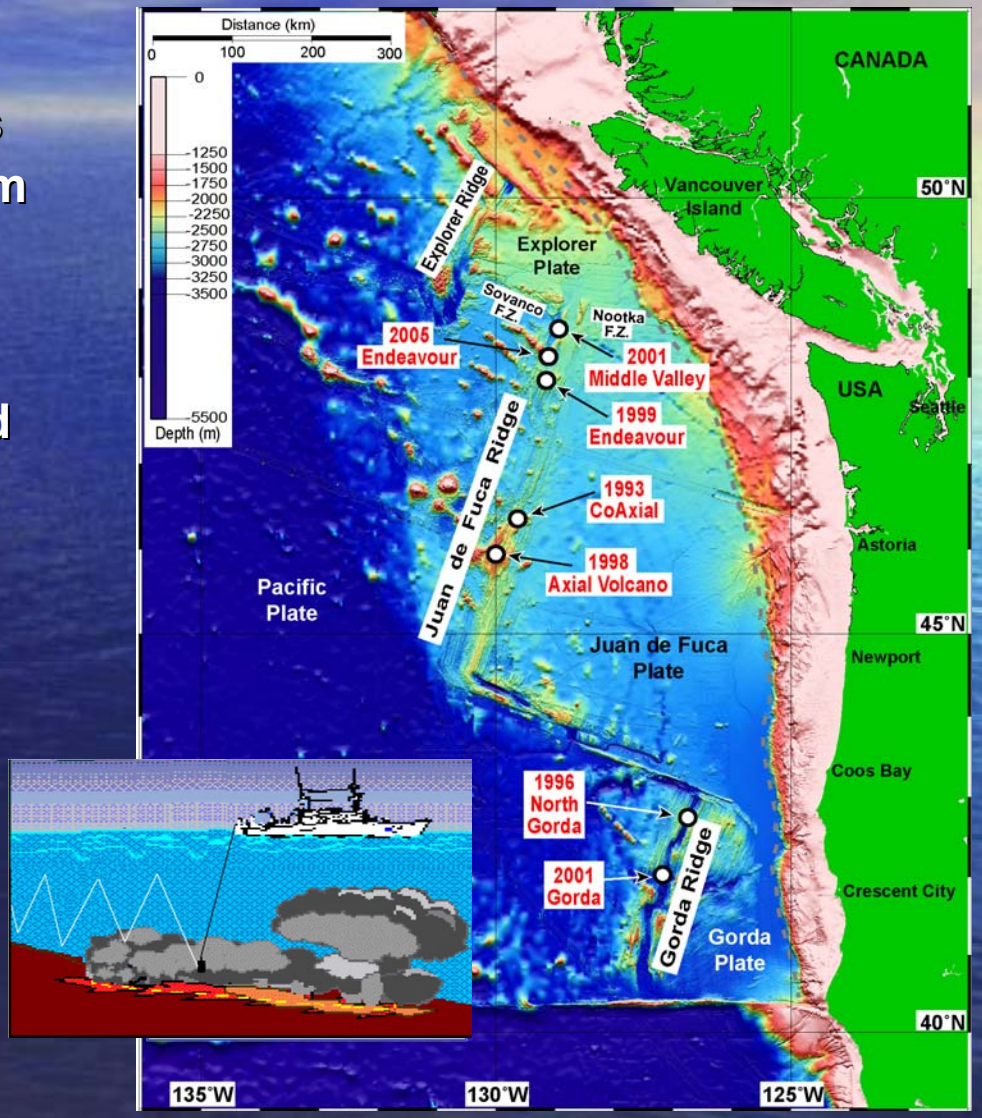
PMEL SOSUS Project: Volcanic event detection

- **Since Project began in 1991 –**
  - SOSUS detected 7 major seafloor spreading & magmatic events on Juan de Fuca Ridge system

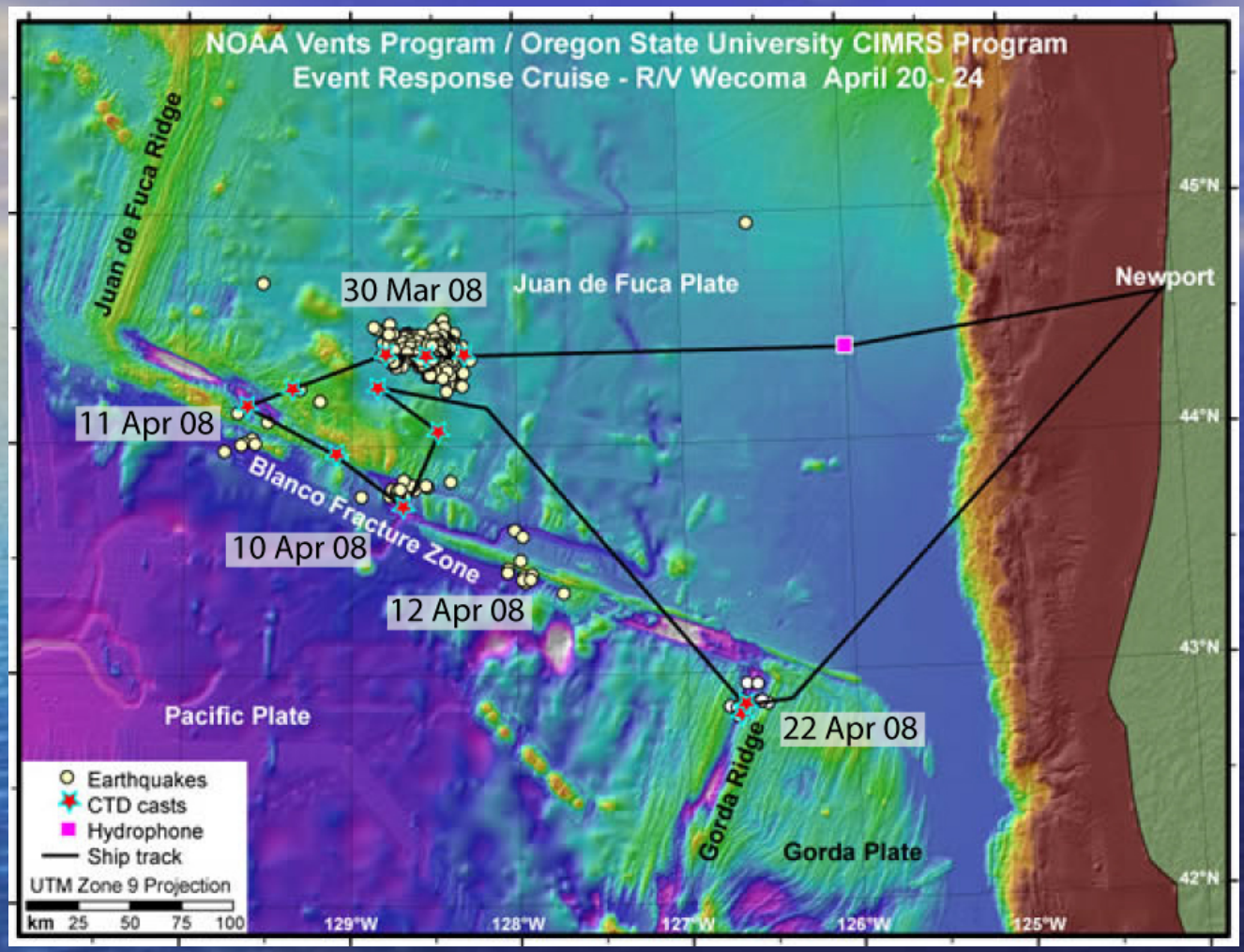
- **During events, research vessels:**
  - Observed release of massive volumes of hydrothermal fluid into ocean
  - Eruption of lava onto seafloor

- **Partner with NSF ocean science community**
  - Mobilize vessels to investigate sites

- **Use past observations:**
  - To better forecast future seafloor spreading events

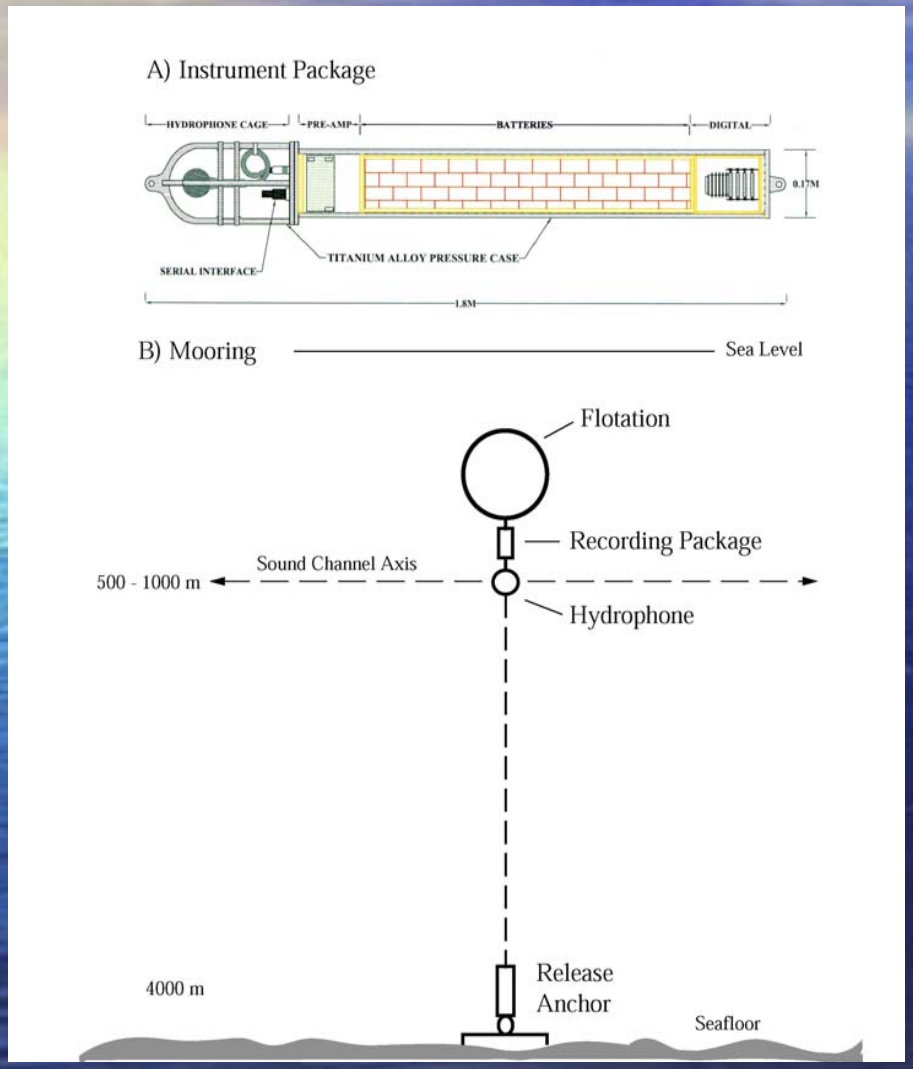


Recent earthquake swarm (April 2008) detected in Juan de Fuca plate by SOSUS



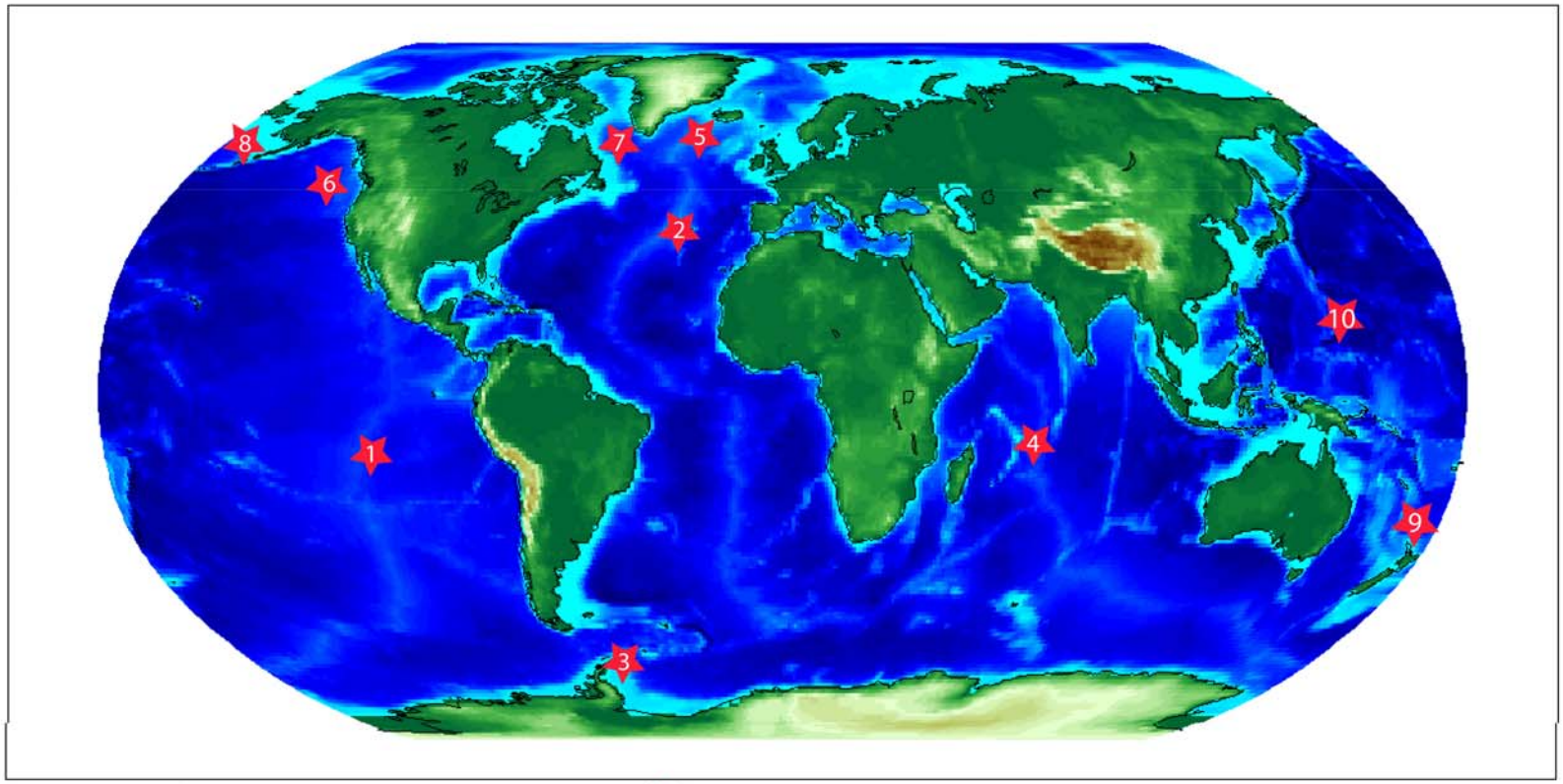
- More than 3000 earthquakes detected (10x more than land-based seismic nets)
- Progression of seismicity from midplate, to transform, to magma intrusion at ridge
- Water samples (stars) analysis consistent with tectonic event within intraplate, possible hydrothermal fluid release at ridge
- Press release carried by >200 media outlets worldwide, 3rd highest hits on Google News.

Hydrophone Mooring



With success of SOSUS, PMEL developed portable hydrophone

PMEL Autonomous Hydrophones: Global Reach

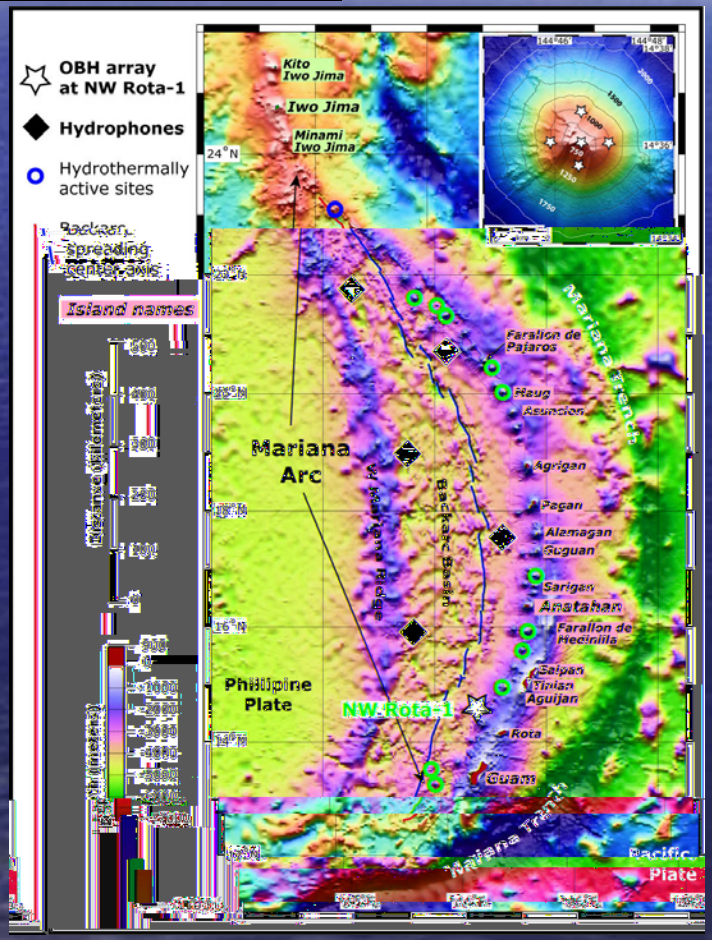


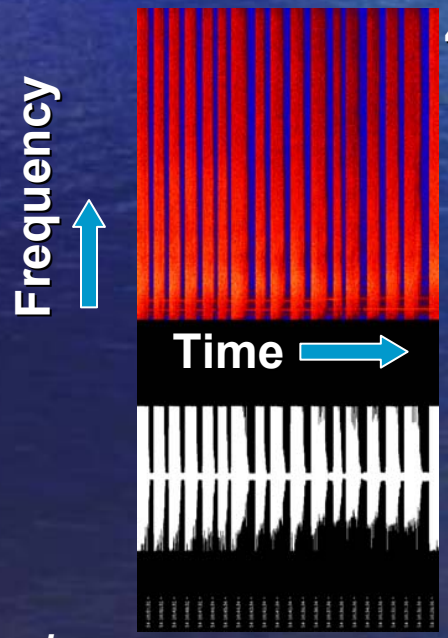
1. EPR: 5HIII's, 250Hz
2. MAR: 4 HIII's, 250Hz
3. Antarctica: 5 HIII's, 250Hz
4. IO: 3 HIII's, 250Hz
5. ICE: 5 HIII's, 250Hz
6. Axial OBH: 4 OBH, 250Hz
7. Davis Strait: 4 HIII's, 2KHz
8. Bering Sea: 2 HIII's, 2KHz
9. Brothers Volcano 3 OBH's, 250Hz
10. NW Rota Volcano 1 HIII, 250Hz

Mariana Islands:

NW Rota submarine volcano explosive eruption

First video and sound of deep ocean eruption





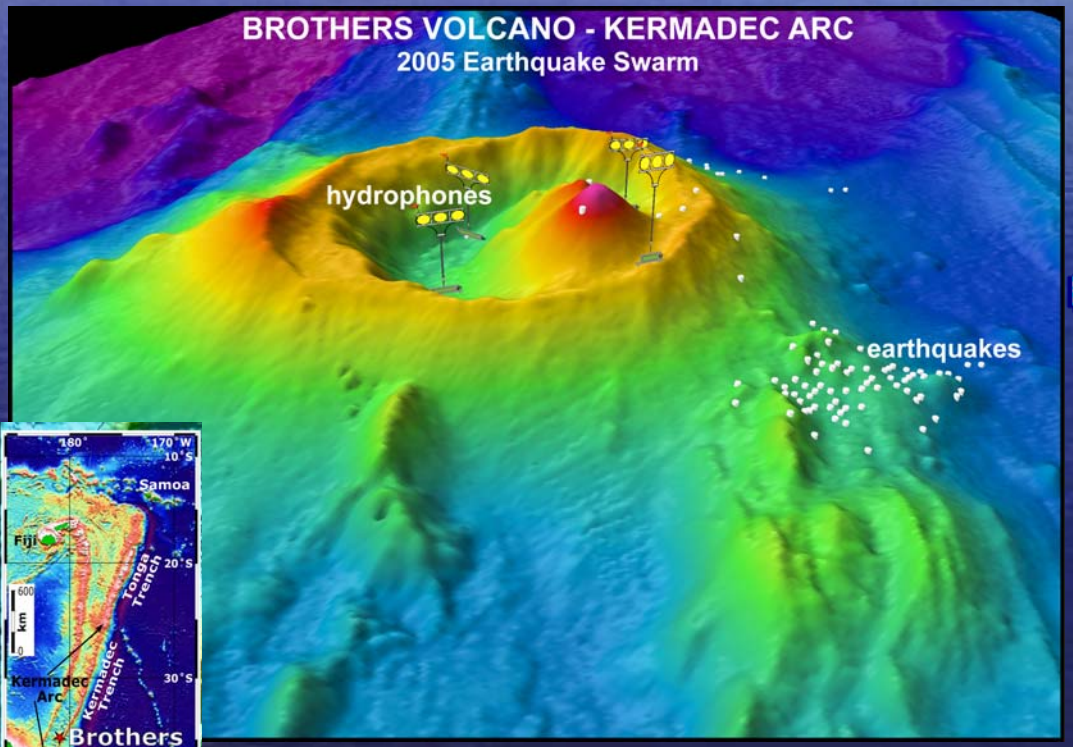
Hydrophone ~100 m from eruption vent

Sponsors: NOAA OE Program and US Coast Guard

Kermadec Arc - New Zealand:

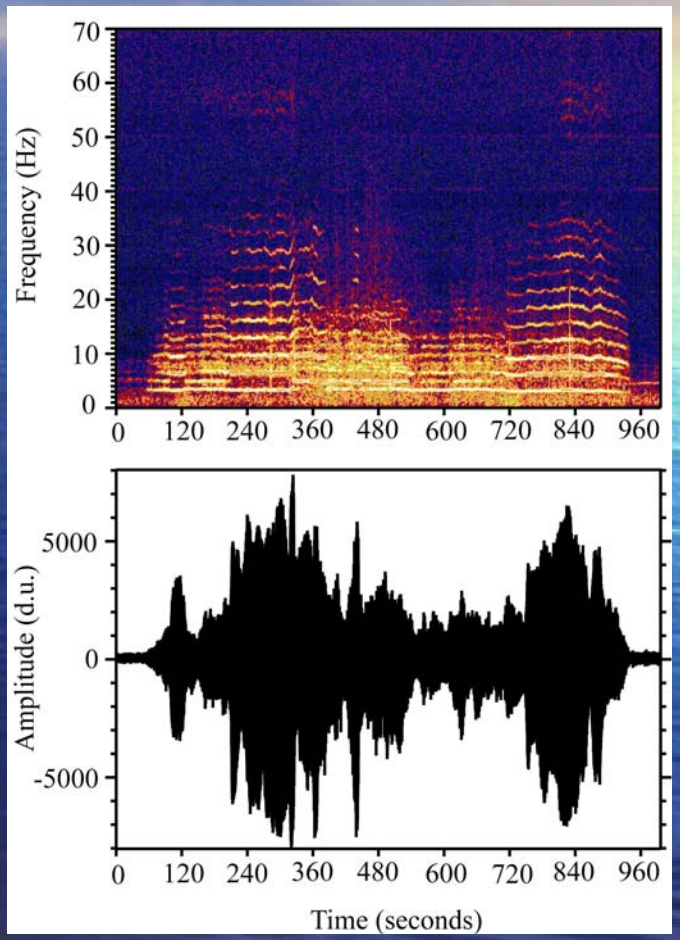
Brothers volcano - A volcano that resonates

Harmonic resonance from movement of fluid/magma inside volcano



3x

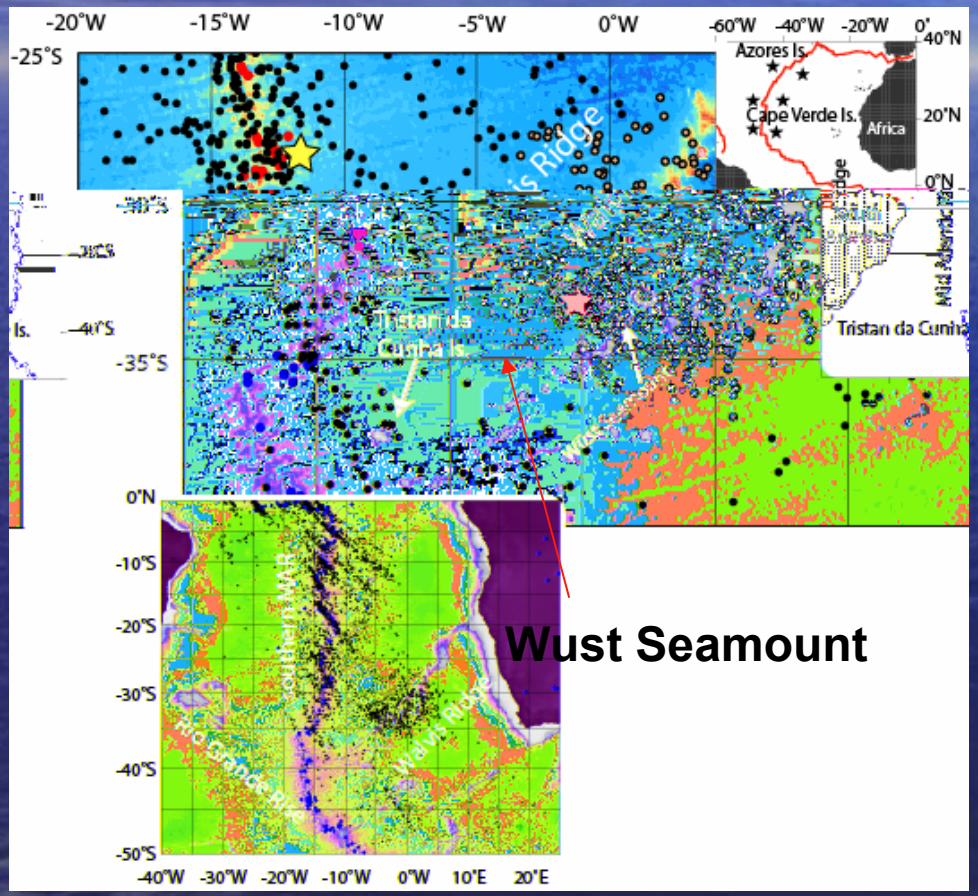
3 Hz fundamental – up to 18 overtones

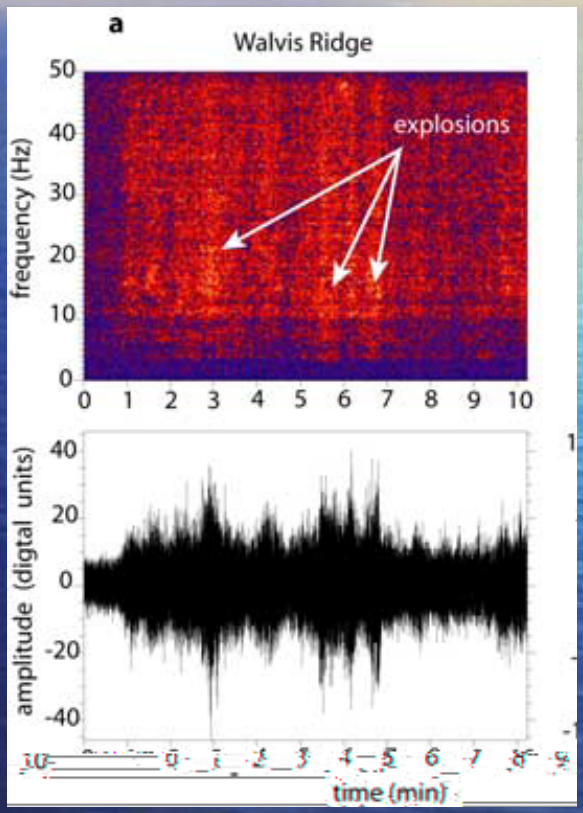


Sponsors: NOAA Ocean Exploration Program and GNS New Zealand

Walvis Ridge – South Atlantic:

- Far-field records of explosive volcanic activity
- Detected across the Atlantic Ocean basin, range of ~5,200 km



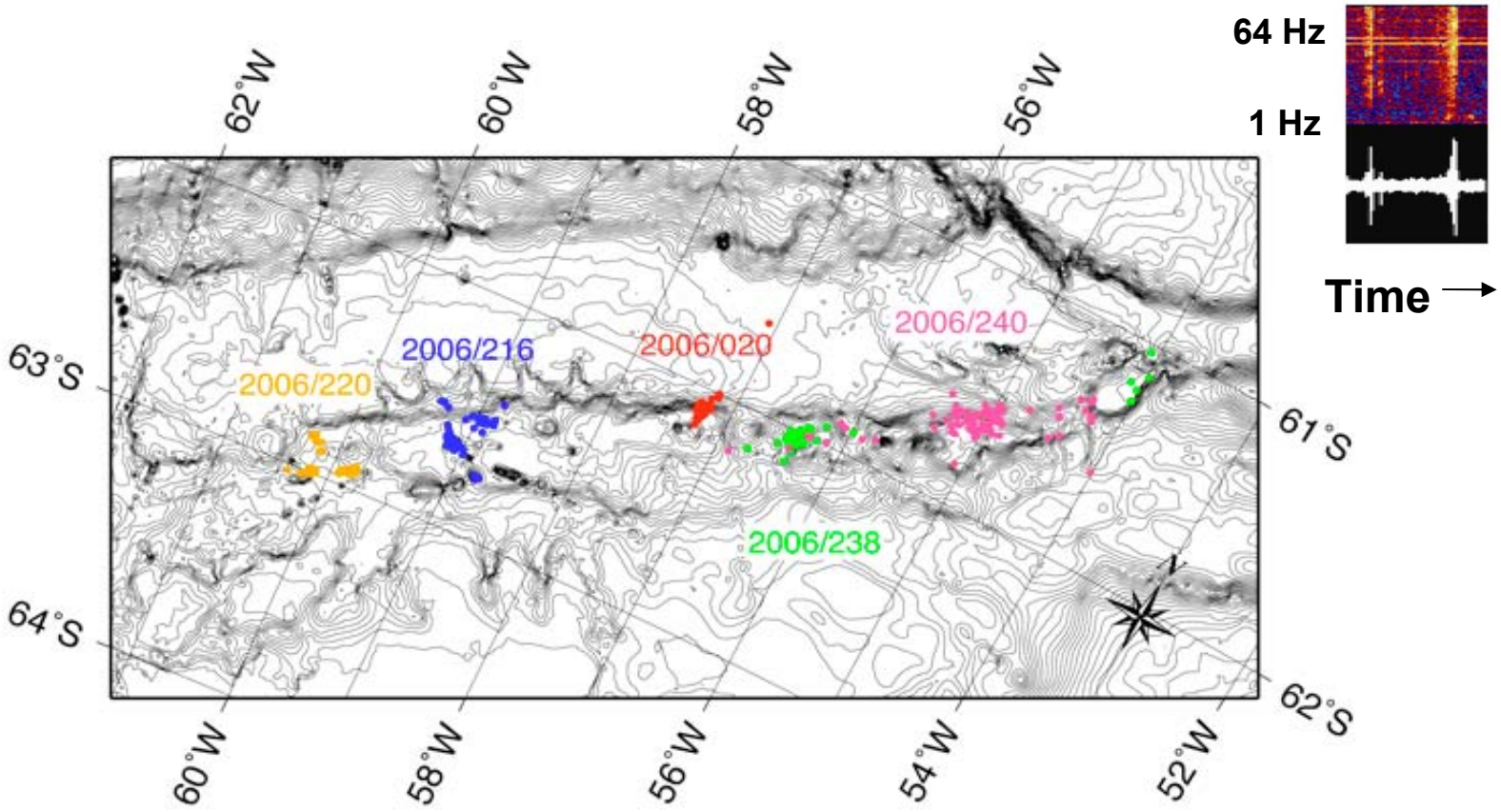


Sponsors: National Science Foundation and CNRS, France

Hydroacoustic Observations, Antarctica

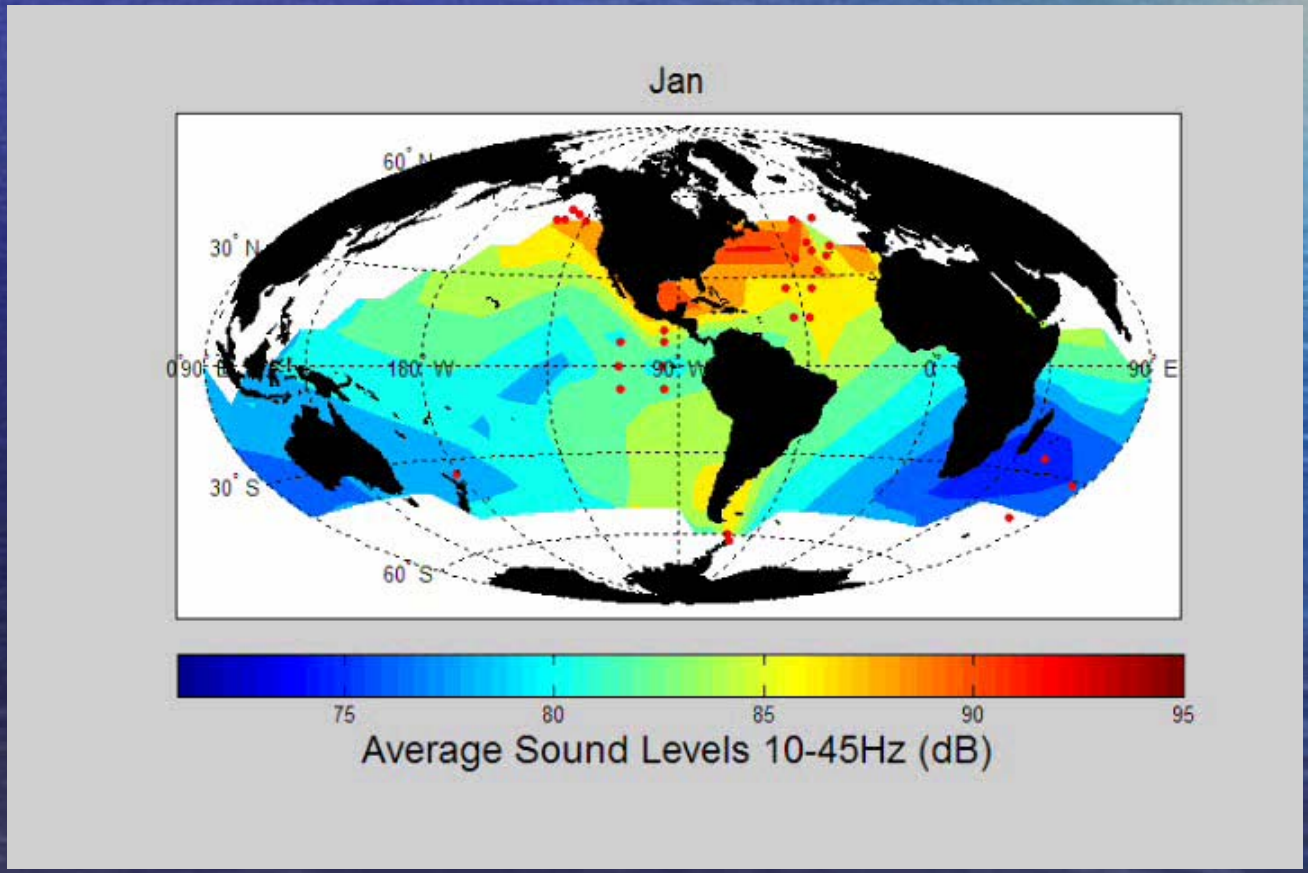
Volcanic Seismicity and Ice-quakes in Bransfield Strait, Antarctica

Volcanic Earthquake Swarms – planned ROV investigations in 2011



Global Map of Ambient Sound

- Global ocean ambient noise has increased 10 dB in the past 30 yrs, mainly from anthropogenic sources (e.g. increased container shipping).
- Antarctica and New Zealand volcano have highest noise levels, higher than mid-Atlantic shipping lanes, influenced by wind, ice, tectonic activity.
- No other lab is monitoring this issue globally, may have profound effects on marine animals and ecosystems that use sound for navigation/communication.



Acoustic Marine Mammal Detection

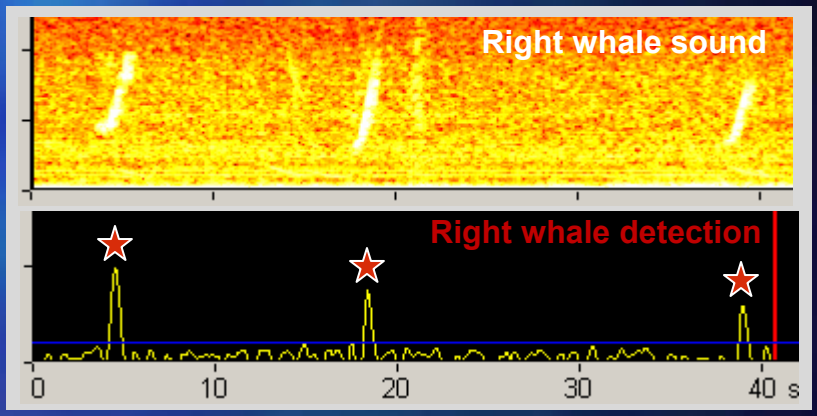
Why?

Basic research

- migration patterns
- feeding habitats
- trophic interactions

Find endangered species

- e.g., only ~350 right whales left in North Atlantic
- even fewer in N. Pacific
- finding seasonal distributions is critical



How?

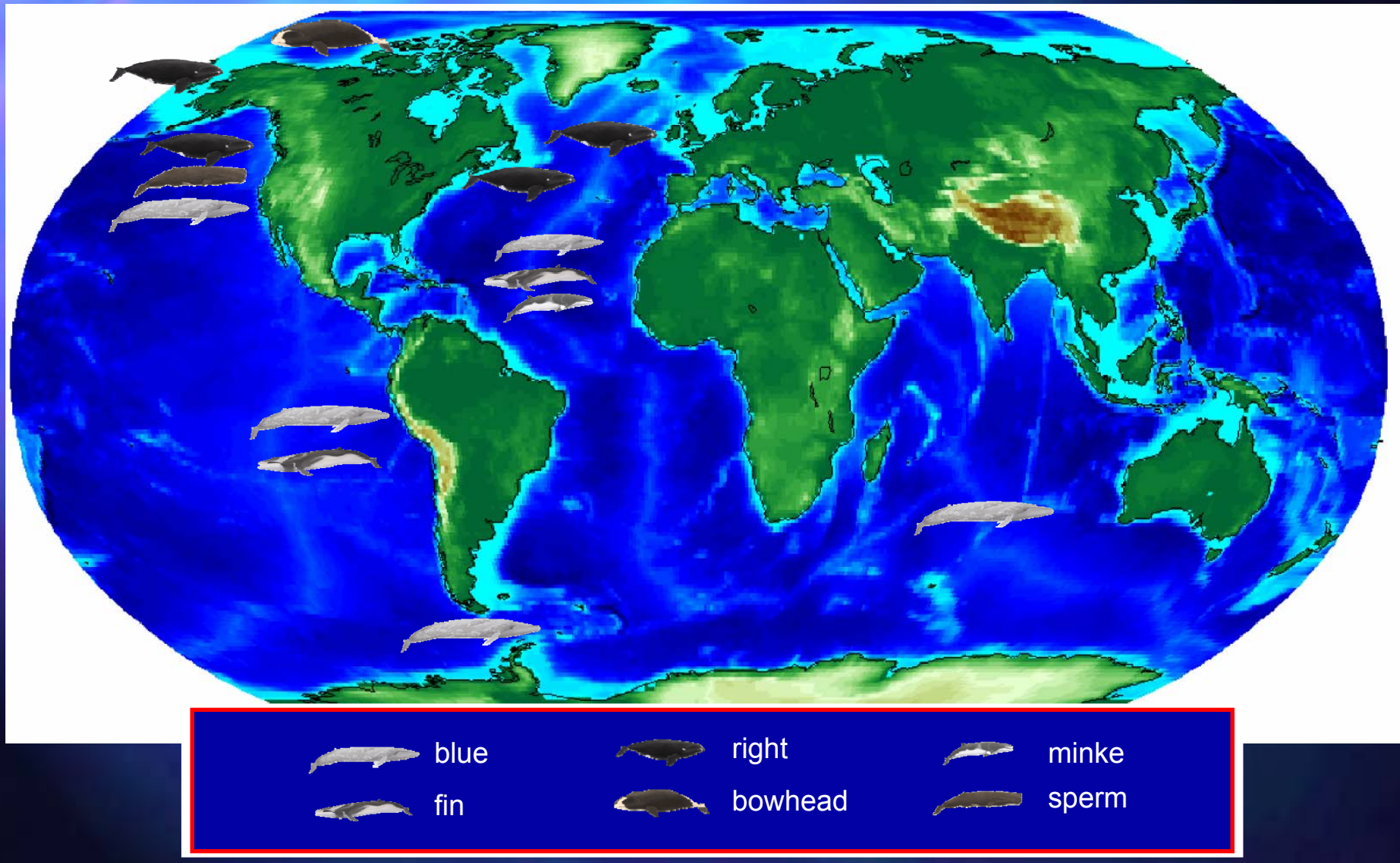
Develop quality detection algorithms to find whale vocalizations in hydrophone data

- efficient
- robust to noise

…for

- baleen whale moans (15 species)
- toothed whale/dolphin clicks (70 species)

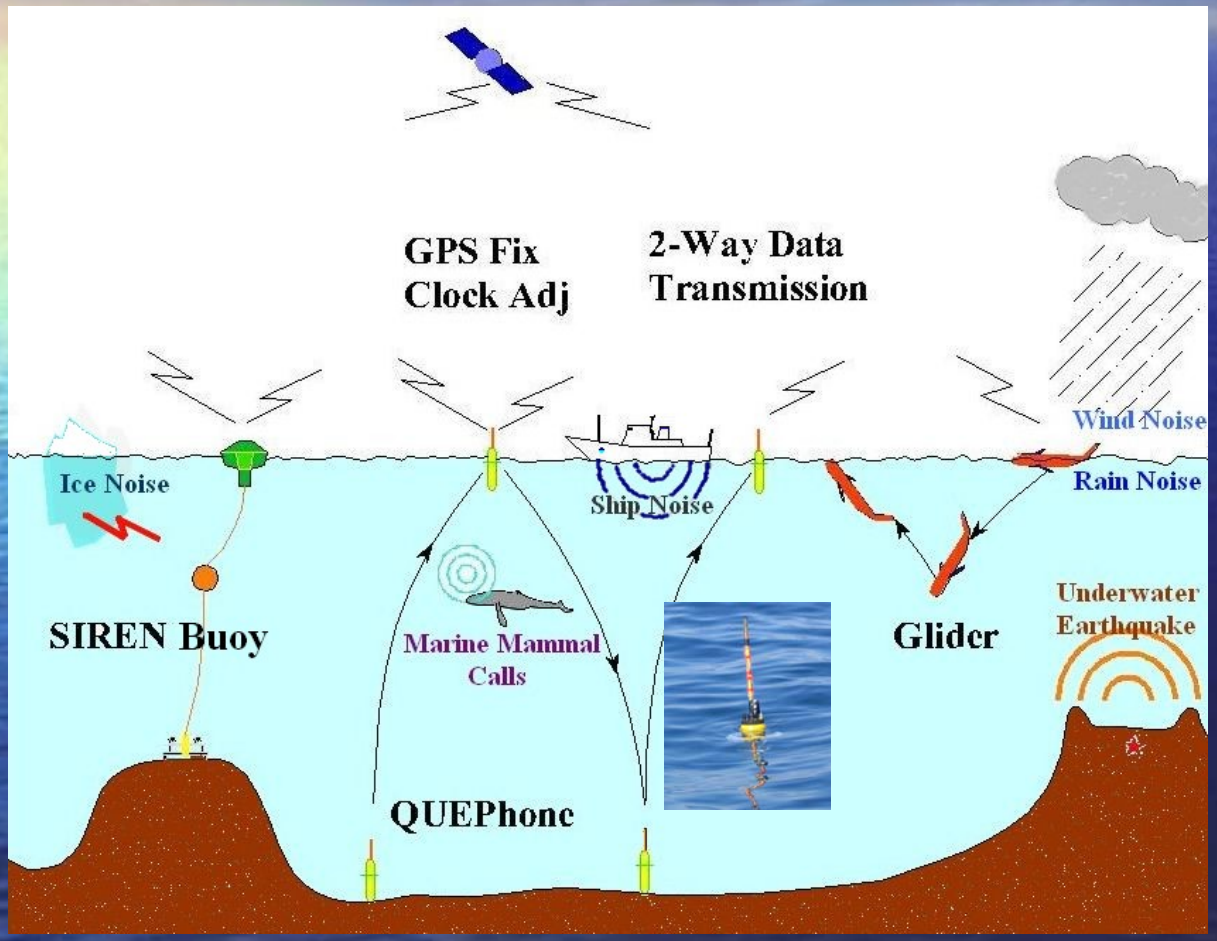
Whale Endangered Species Identification



Established presence of 6 endangered species

Developing New Acoustic Technologies

SIREN: Seafloor Incident Reporting and Evaluation Network



New strategy for acoustic monitoring of marine ecosystems

Combine hydrophones on:
- Satellite mooring
- autonomous vehicles (vertical profiler & sea-glider)

Provide near-real-time acoustic monitoring network

Sponsors: NOAA/PMEL and ONR

Future Goals of Acoustic Program Research:

- **Acoustics Provides insights into wide variety of topics:**
  - Destruction/creation of seafloor hydrothermal ecosystems
  - Seismic/volcanic hazard for coastal communities
  - Distribution of endangered marine mammals species
  - Increase in global ocean noise due to anthropogenic and climate change effects

- **Future project goals:**
  - Develop PMEL hydrophone assets into an integrated, global observing system

    Applied to various ocean research issues (ocean noise, fisheries, marine mammals and climate change).

  - Cultivate alternative acoustic monitoring technologies

    real-time hydrophone communication (autonomous floats, buoys or cabled hydrophone arrays)

  - Continue current and develop new international collaborations (e.g. France, South Korea, Iceland, New Zealand, South Africa)

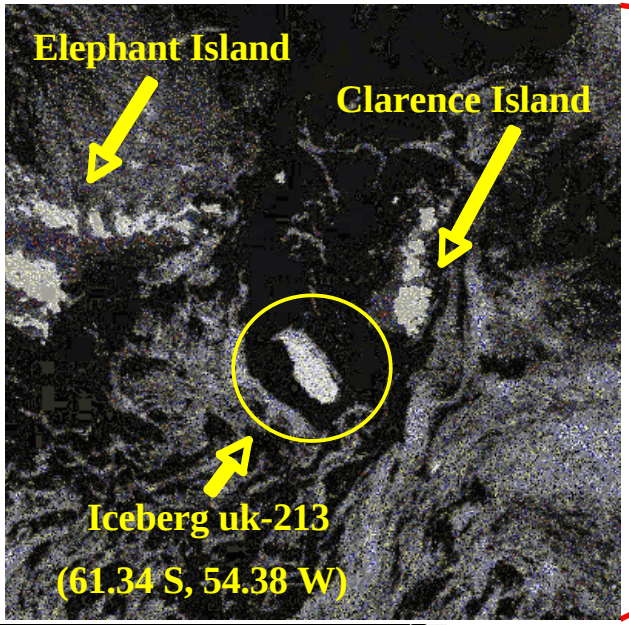

Thank you

Resonating Icebergs

Recorded unique harmonic signals off Antarctica

Satellite confirmed iceberg signal source location

Iceberg ~5x10 km



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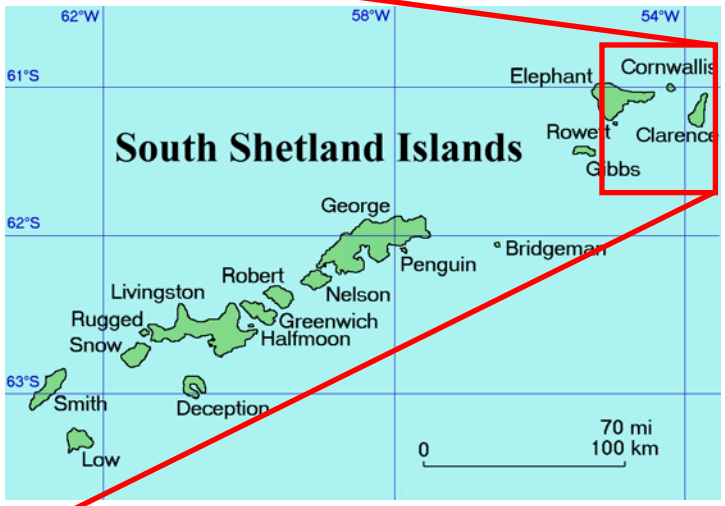
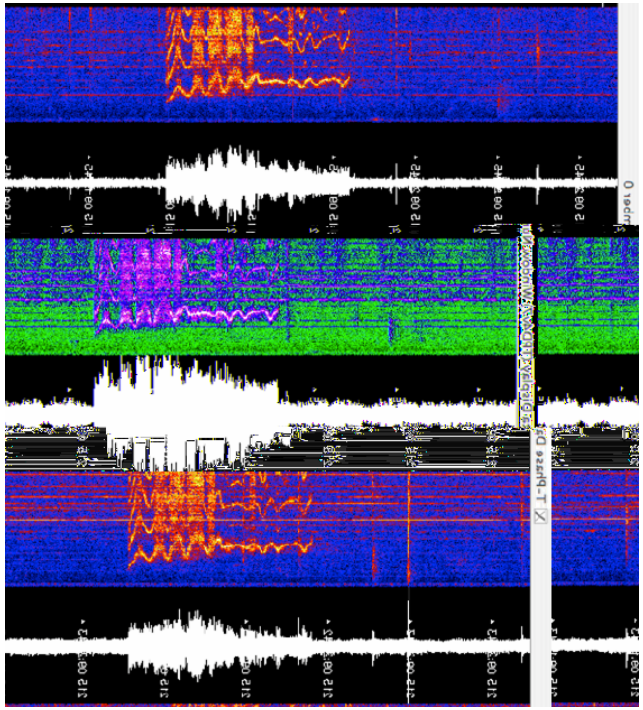




Hydroacoustic Observation, Icemicity

Ecosystem Research Program 5-year Goal to:

"Study ocean phenomena to ascertain the potential for generating coastal earthquakes and tsunamis and the extent to which these phenomena alter existing and create new and/or unique ecosystems."

Ecosystems Observations Program Goal of:

"Assessment of living marine resources (i.e. marine mammals under ESA and MMPA)."

PMEL/Vents Ecosystem Research: Linkages to NOAA Research Plan and Strategic Plan

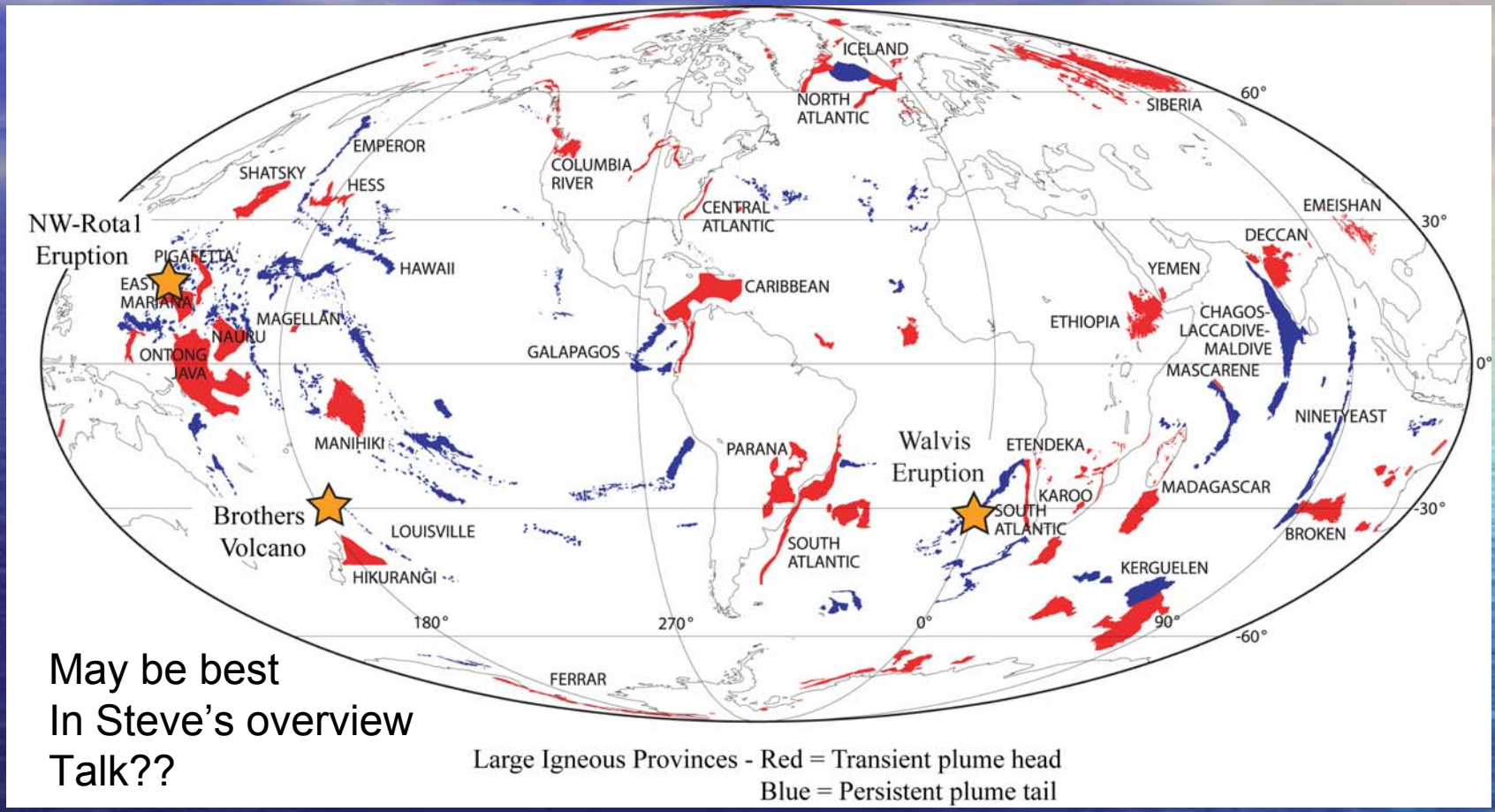
NOAA **Strategic** Plan - Performance

Objective: 3-5 year milestone to estimate ambient noise budgets in at least one regional ecosystem by characterizing the nominal acoustic environments

NOAA **Research** Plan - Research Area:

Advancing Understanding of Ecosystems to Improve Resource Management

Long-term volcanic eruptions



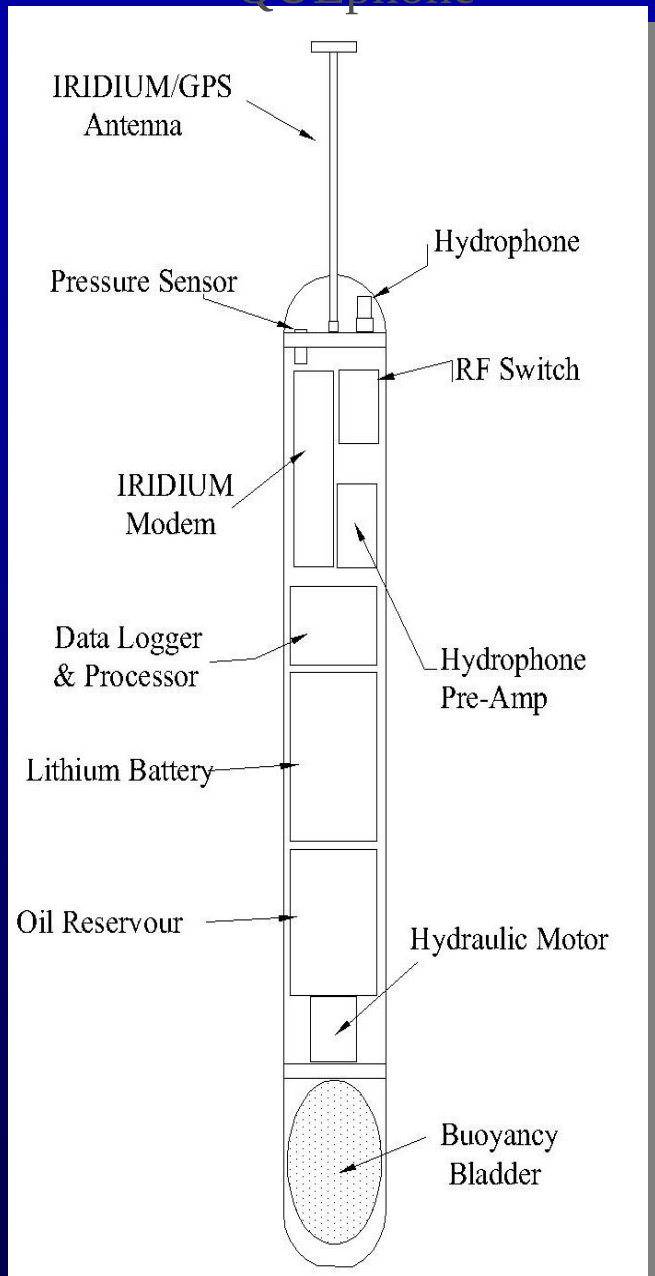
May be best
In Steve's overview
Talk??

Large Igneous Provinces - Red = Transient plume head
Blue = Persistent plume tail

Massive, long-term seafloor eruptions have occurred many times in Earth's history, and will occur again.

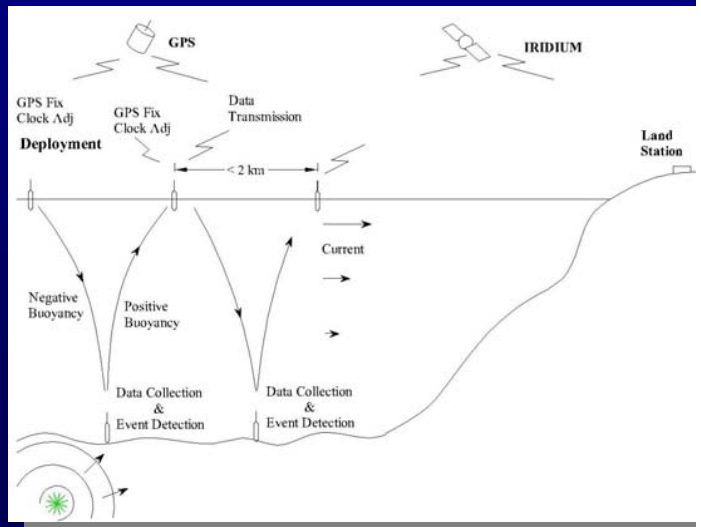
May play major role in volatile flux in ocean, and volcano/tsunami hazard.

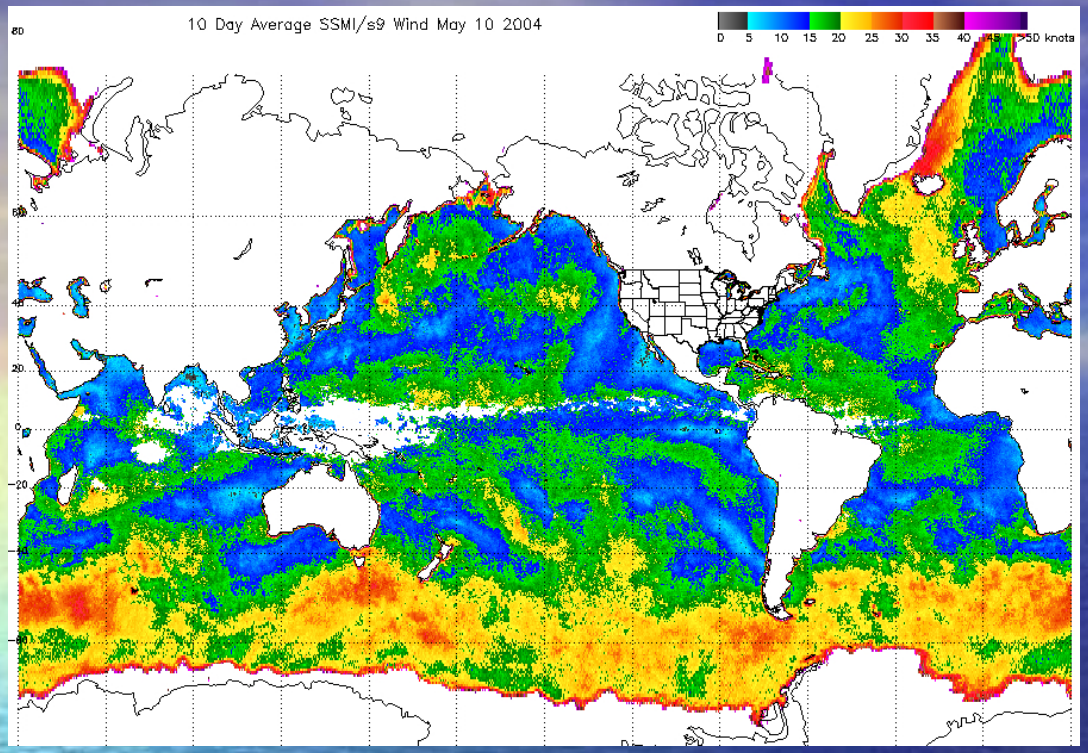
QUEphone



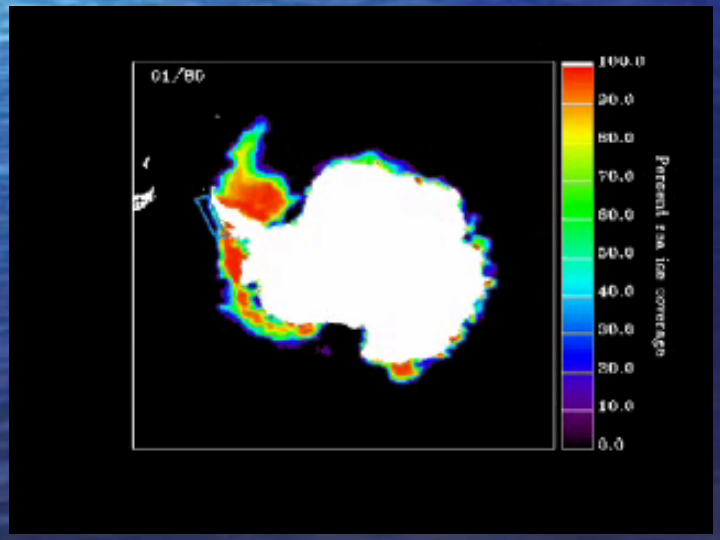
Developing (near) Real-time Hydrophone Technologies:

- Tether-free QUasi-Eulerian float
- Remains on seafloor for long-term monitoring
- Detects event, makes multiple trips seafloor to surface
- Near real-time, short satellite data transmission
- Portable, expendable, low power
- 1-year life time (up to 12 ascent/descent cycles)
- Minimum drift from rapid ascent/descent
- Modified for chemical or water-column measurements

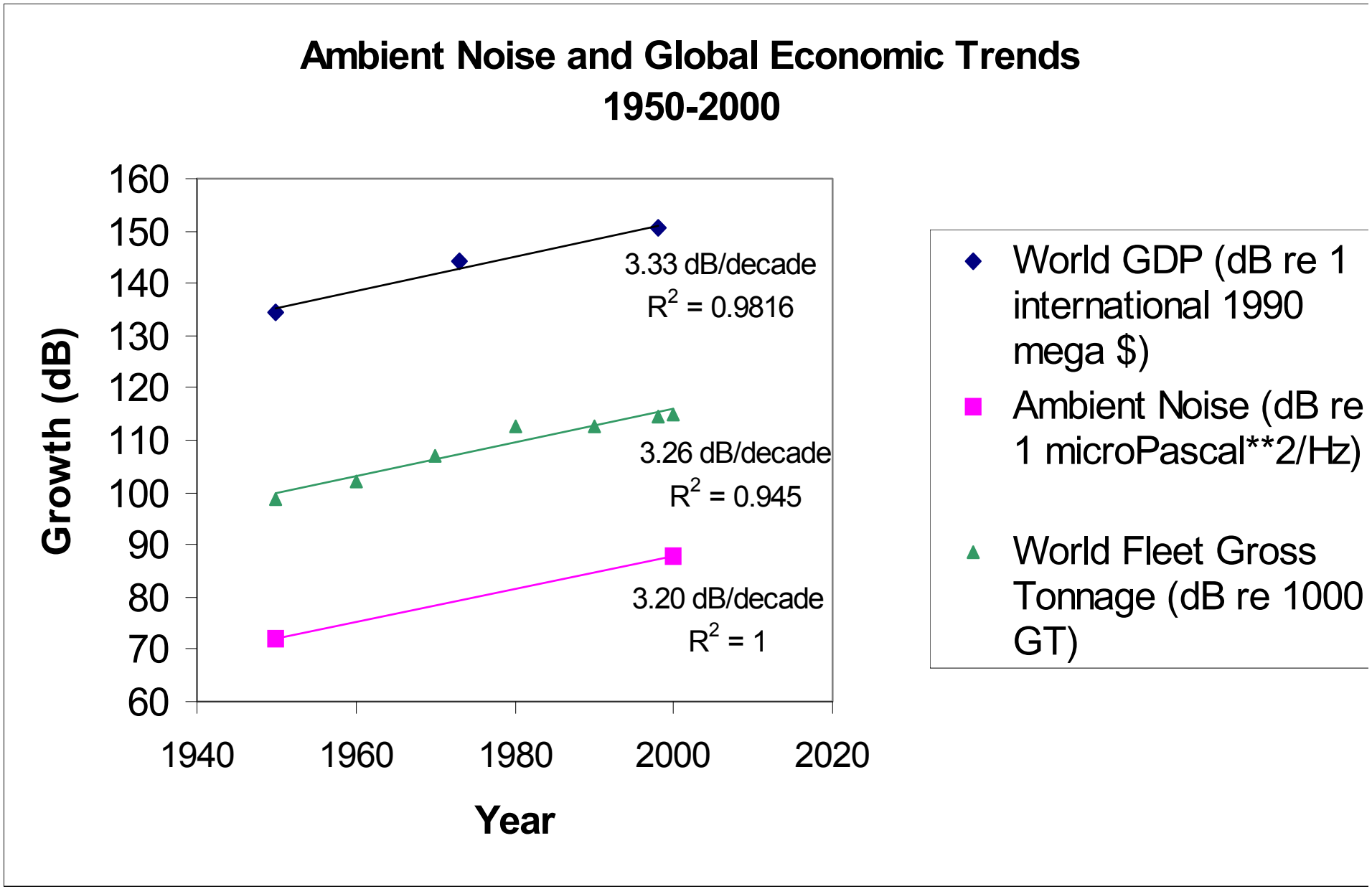




Ambient sound correlated with global wind field



Freeze and thaw of pack ice contributes to Antarctic noise.


Ambient Noise and Global Economic Trends
1950-2000
Growth (dB)
160
150
140
130
120
110
100
90
80
70
60
1940
1960
1980
2000
2020
Year
3.33 dB/decade
R2 = 0.9816
3.26 dB/decade
R2 = 0.945
3.20 dB/decade
R2 = 1
World GDP (dB re 1 international 1990 mega $)
Ambient Noise (dB re 1 microPascal**2/Hz)
World Fleet Gross Tonnage (dB re 1000 GT)

Example earthquake swarm: Axial Volcano, Juan de Fuca Ridge, January 1998

Earthquakes begin in summit caldera, migrate 60 km down rift-zone over a 2 day period.

In situ instruments detect water-temperature anomalies, seafloor subsidence, and are buried in lava!

Evidence of eruption at summit and injection of magma down the volcano at speeds of 0.2 - 1.0 m s^{-1}