Sensor Network Infrastructure for Ocean Observatories

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Outline

- Overview
- Mobile platforms – acoustic Seaglider
- Mooring sensor network
- Fixed nodes
- Acoustics
- Concluding remarks

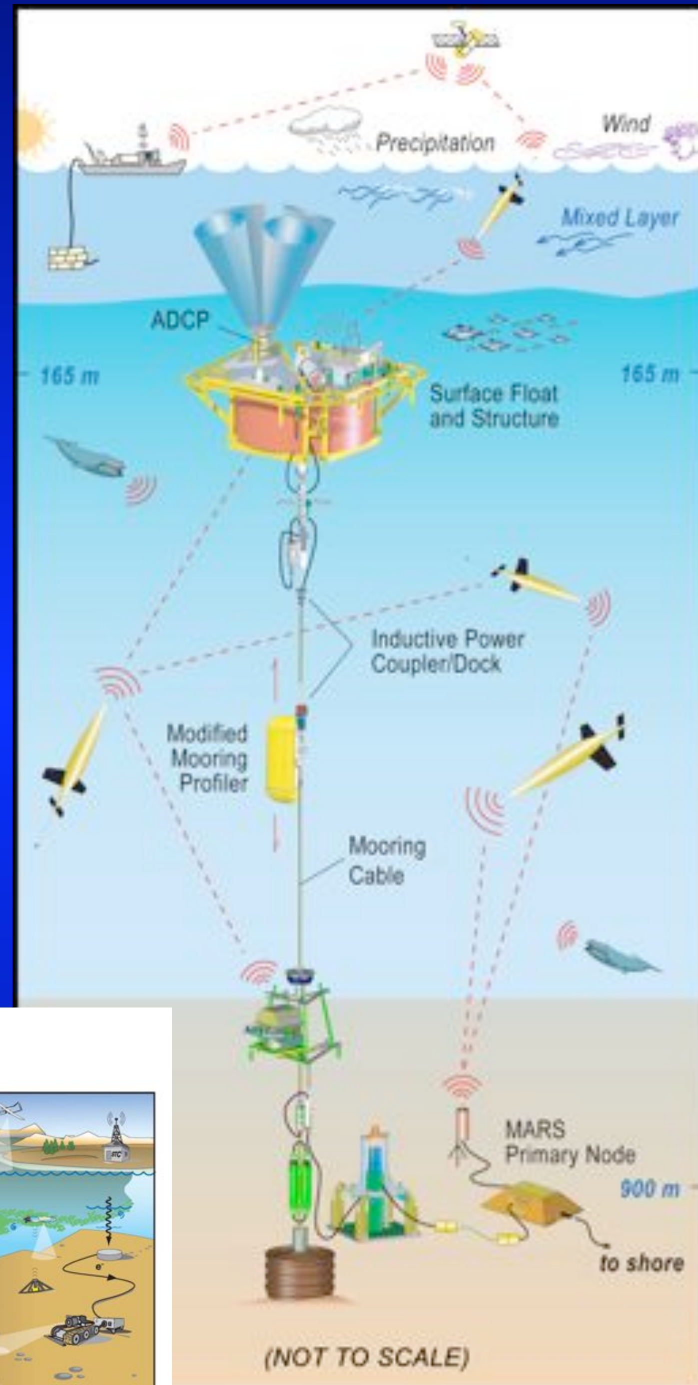
Background

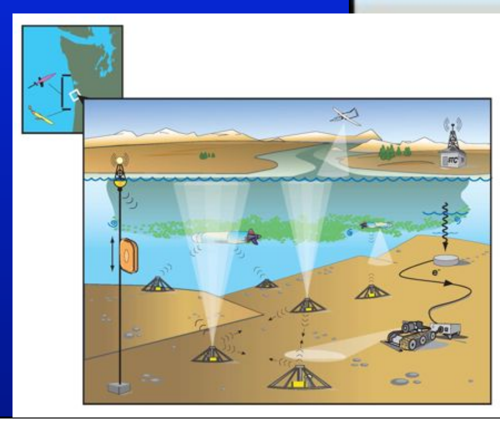
- Many "ocean observatories" being installed or under development
  - e.g., VENUS, NEPTUNE Canada, NSF OOI Regional scale observatory (aka NEPTUNE), ALOHA, and global and coastal scale components
- Over the long term
  - The reliable backbone will be transparent (we hope!)
  - The sensor network infrastructure will be "closest" to the user/scientist, and will be the largest cost over the lifetime
- Sensor network infrastructure needs development

Goals: Ocean Observatories

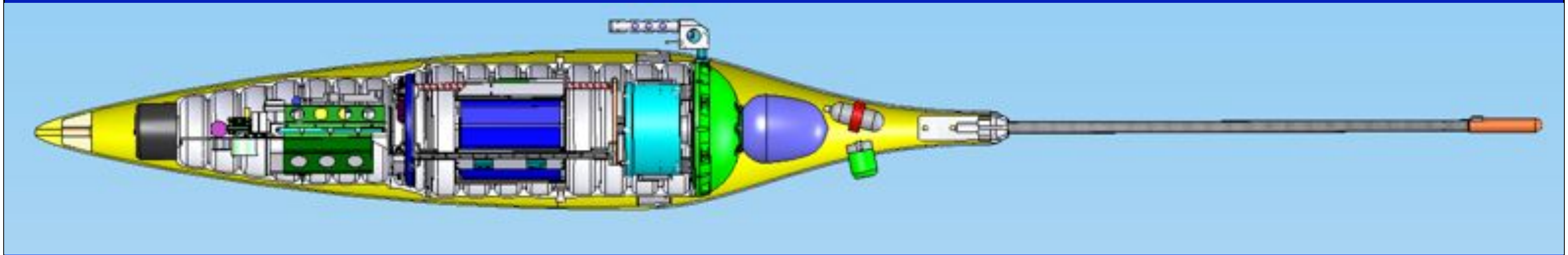
Example:

- Power, timing, navigation, comms: f(**x**,t)
- Fixed cabled nodes with high power and bandwidth
- Mobile/fixed hybrids – profiler, ROVs, docking, etc
- Mobile autonomous
- Fixed autonomous
- Role of acoustics





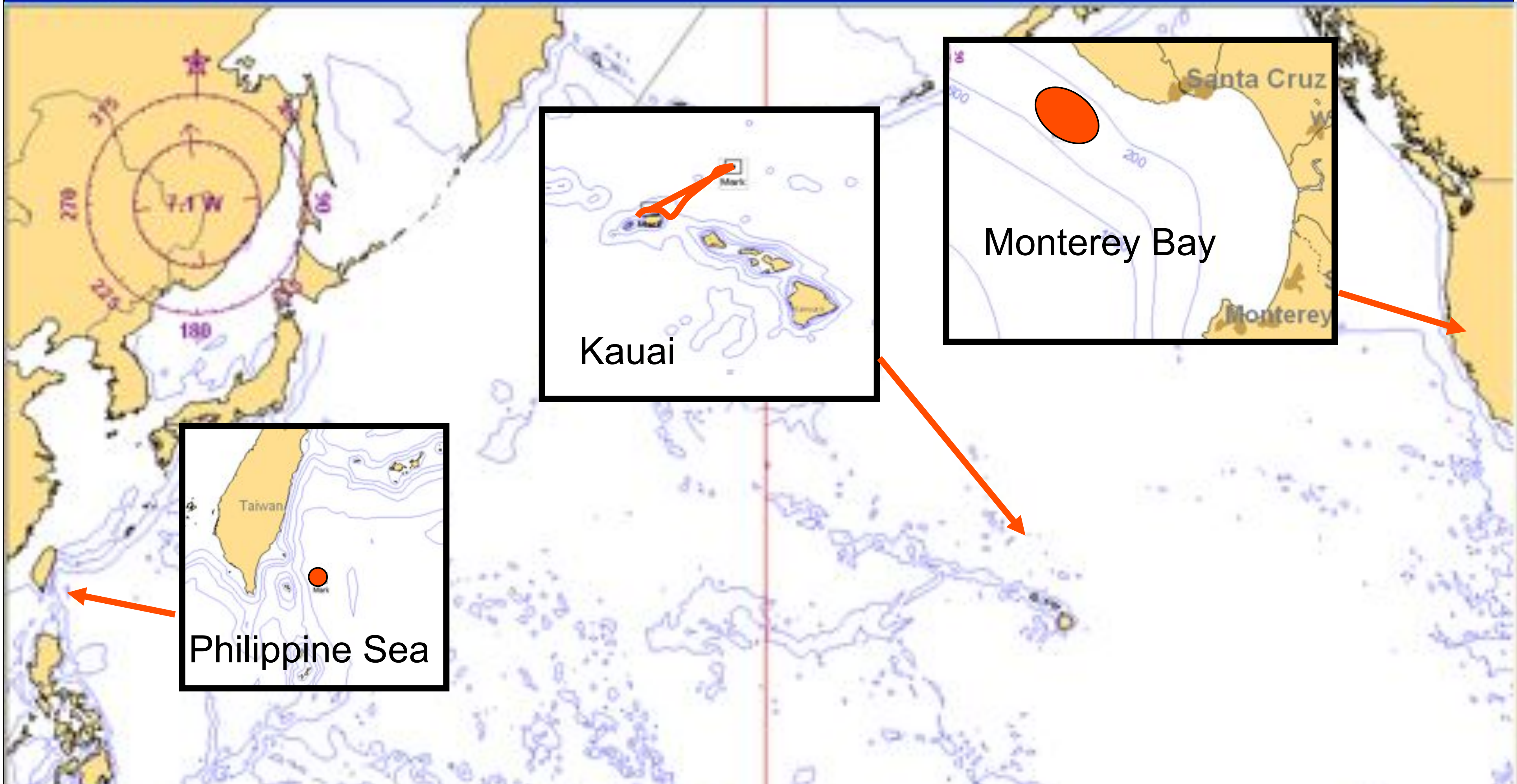
Acoustic Seaglider



- ½ knot at ½ W
- Up to 1000 m dives
- > 6 months, 3000 km, 600 dives
- Temperature, salinity and others
- **Now with hydrophone and acoustic modem**

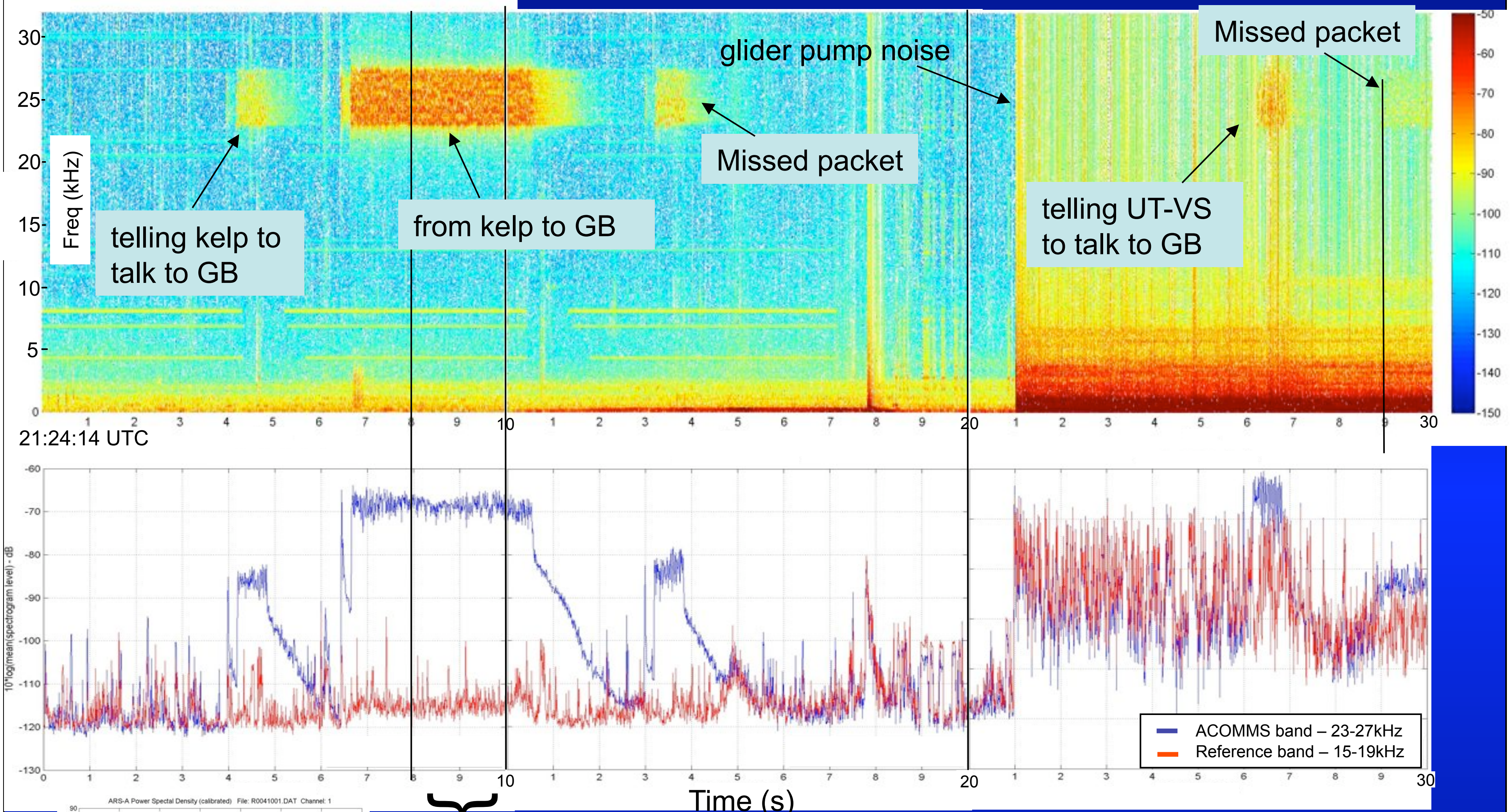
Fumin Zhang

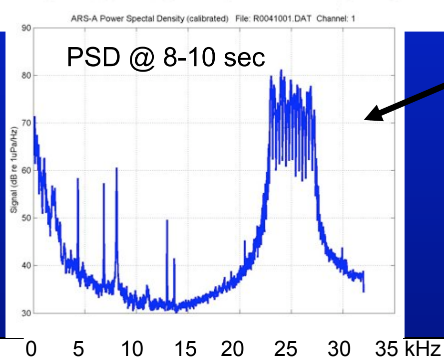
Acoustic Seaglider Operations – Summer 2006



Philippine Sea –	SG022, 7/29/06-7/30/06,	1 day,	15 dives,	low ARS band,CTD	
Monterey Bay –	SG022, 8/15/06-8/21/06,	6 days,	61 dives,	low ARS band,CTD	
	SG023, 8/18/06-8/23/06,	5 days,	83 dives,	low ARS band, CTD	
	SG106, 8/12/06-8/18/06,	6 days,	131 dives,	high + low ARS bands,CTD,mmodem	
Kauai -	SG023, 8/31/06-10/8/06,	39 days,	143 dives,	low ARS band, CTD	

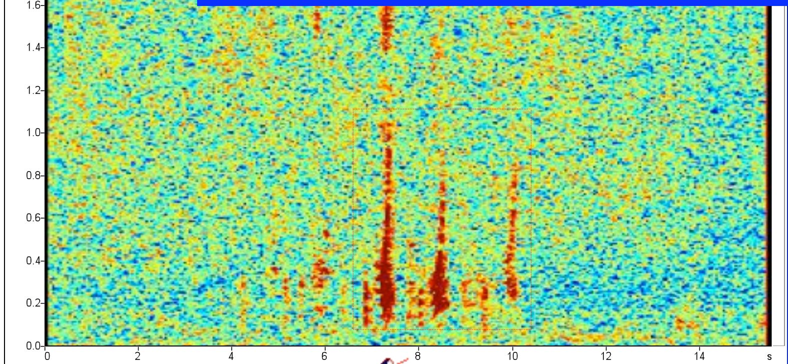
Modem performance: 1st 30 sec of dive 41



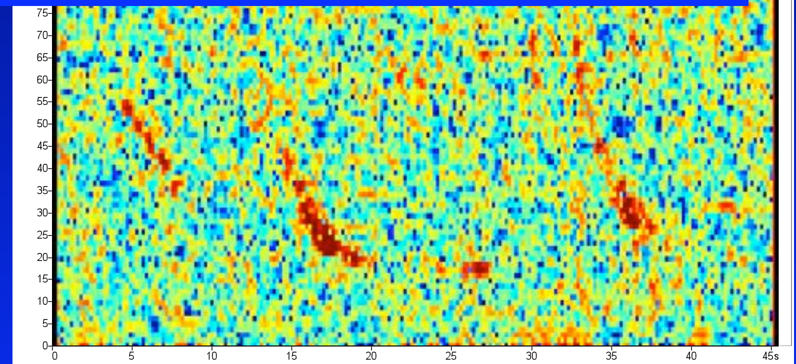


Simple ACOMMS detector: ratio of energy in 23-27 kHz band to energy in 15-19 kHz band

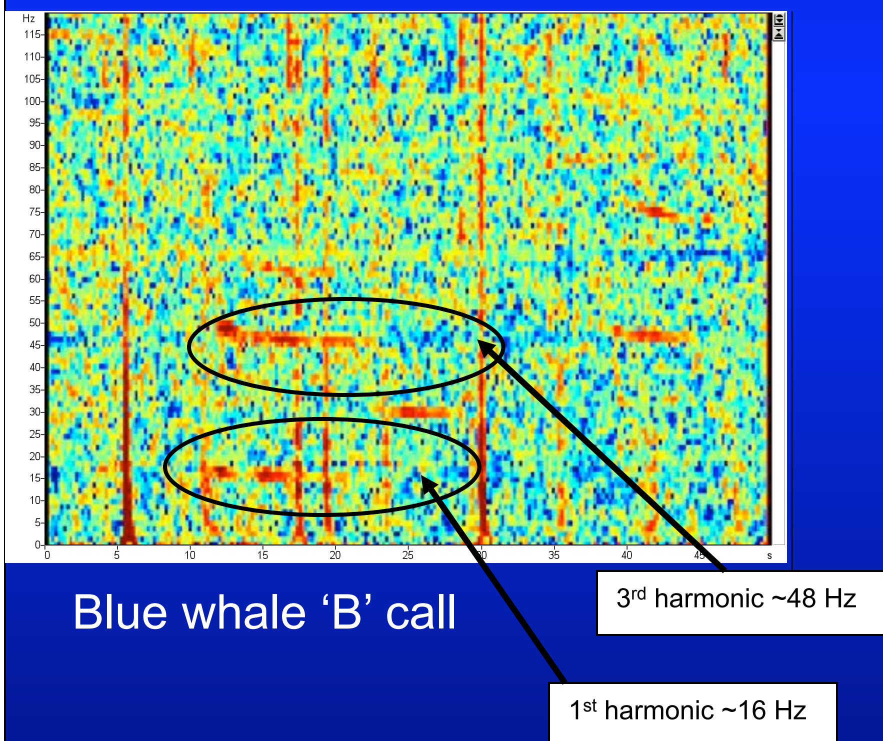
Animal sounds recorded on Seaglider ARS Monterey Bay, MB06



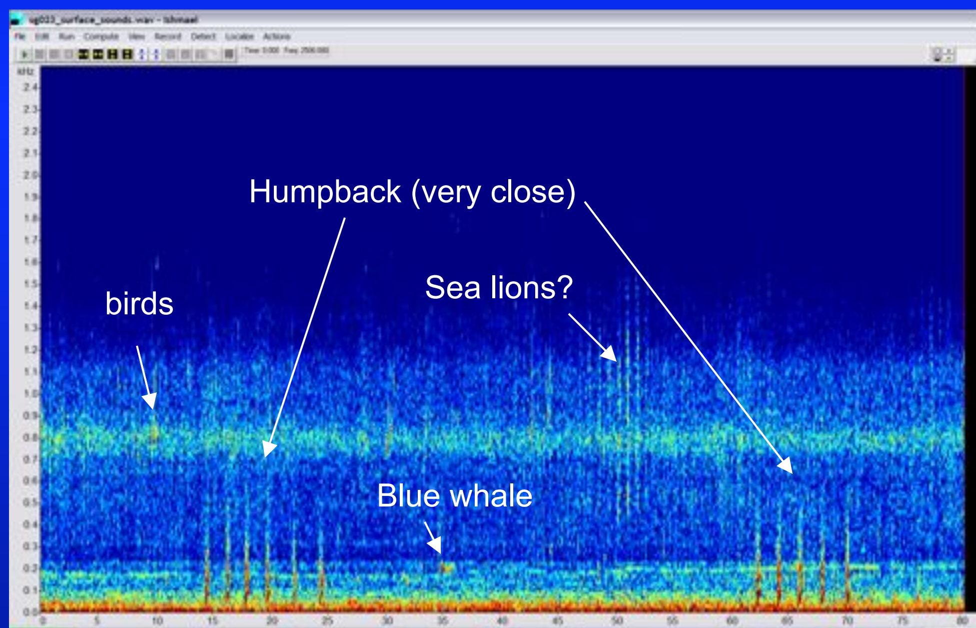
humpback



Blue whale 'D' call

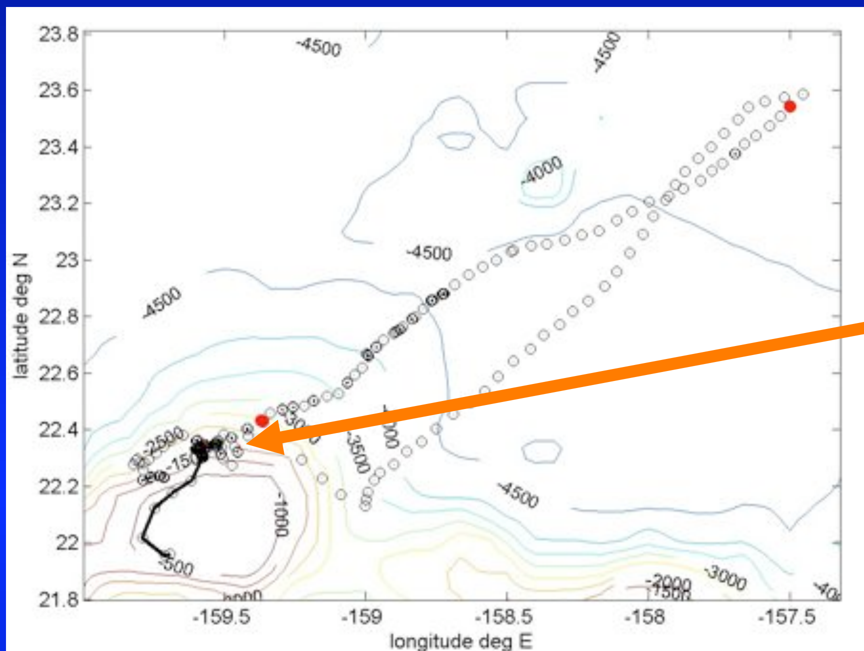


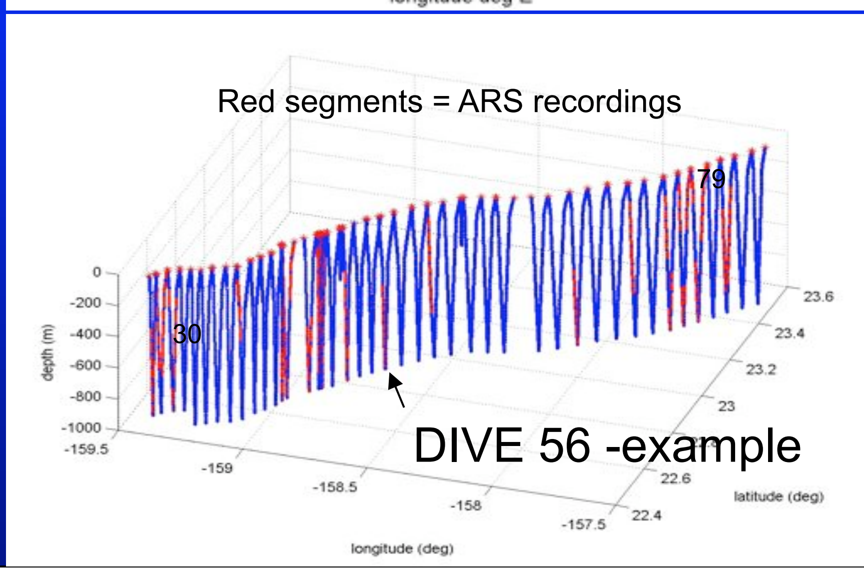
Blue whale 'B' call



Humpback @ 15 and 65 sec
Blue @ 35 sec
Sea Lions? @ 50 sec

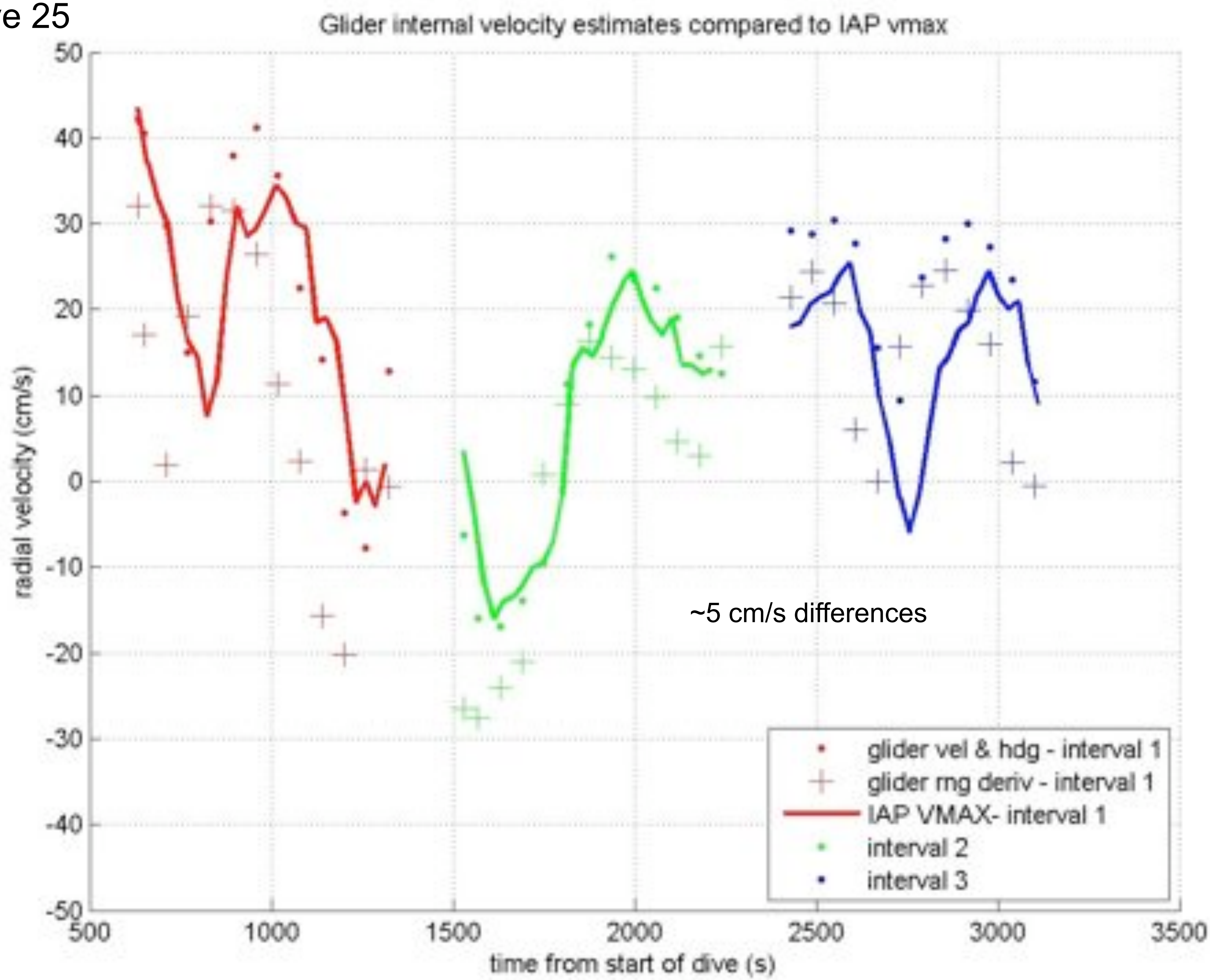
NPAL / ATOC Kauai source





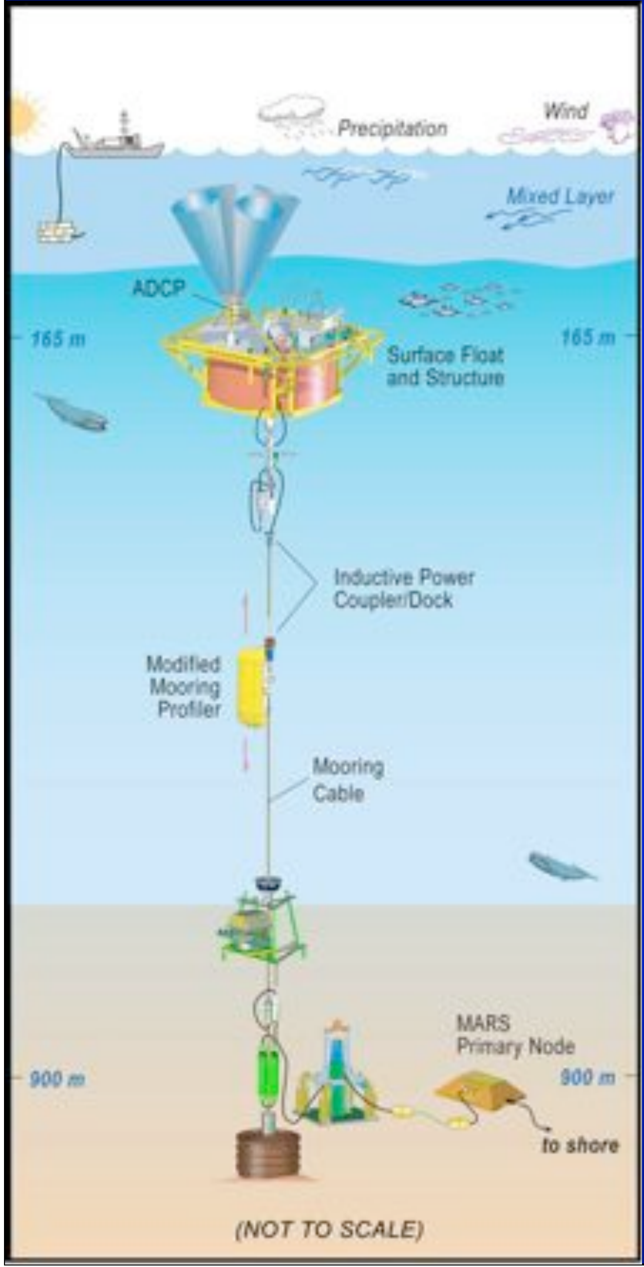
- 260 W
- M-sequence coded signals
- 75 Hz, 35 Hz bandwidth
- 28 ms peak
- 27.28 s period
- 2 hour transmissions, 1 per day

Dive 25



Glider internal velocity estimates compared to IAP vmax
radial velocity (cm/s)
time from start of dive (s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
500
1000
1500
2000
2500
3000
3500
~5 cm/s differences
glider vel & hdg - interval 1
glider rng deriv - interval 1
IAP VMAX- interval 1
interval 2
interval 3

ALOHA-MARS Mooring (AMM)



- Moorings called for in many NSF OOI plans
- Features
  - Enables adaptive sampling
  - Distributes power and communications capability throughout the water column
  - ROV servicing
- Major Components
  - Subsurface float at ~165 m depth with sensor suite and junction box
  - Profiler with sensor suite that can "dock" for battery charging, continuous two-way communications via inductive modem
  - Electro-optical-mechanical mooring cable
  - Seafloor sensor suite and junction box
- Deployments
  - 2007 – 2008 on Seahurst Observatory in Puget Sound, 30 m depth
  - Proposed 2010 – 2011 MARS Monterey
  - Planning 2012 – ALOHA Cabled Observatory

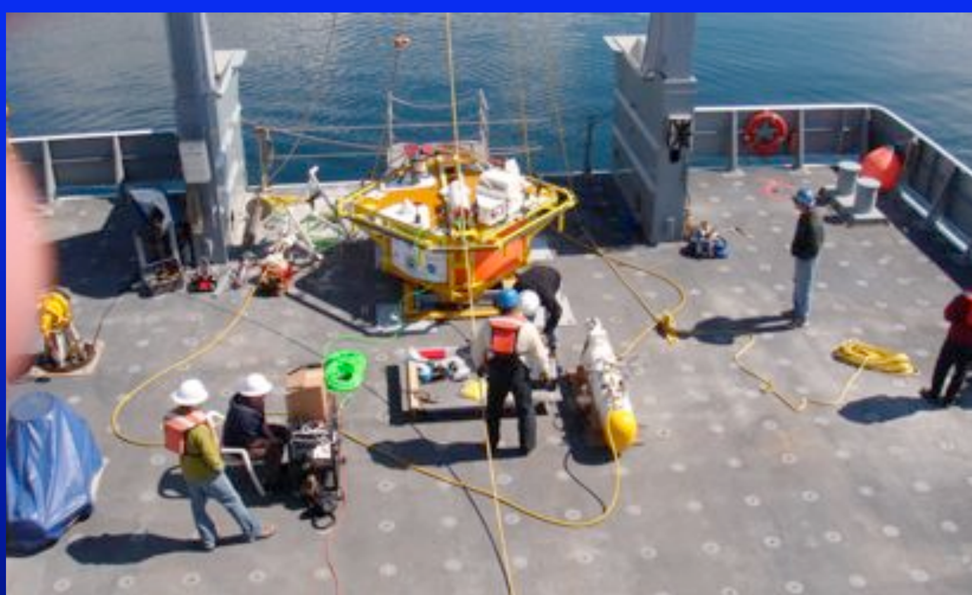
NSF funded – OTIC - Lukas and Boss co-PIs

Profiler with inductive power docking station

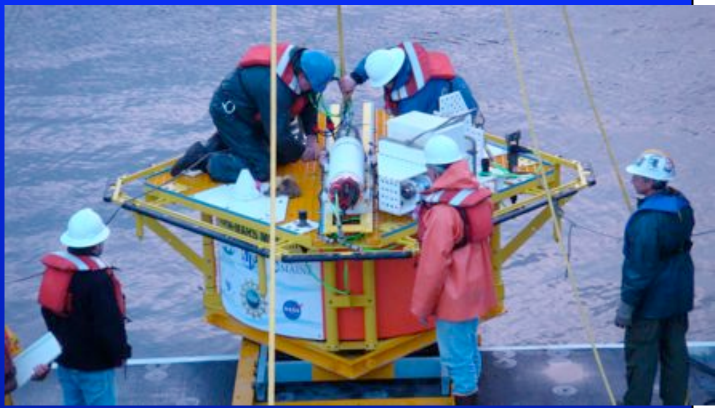
- Concentrated on Inductive power coupler
  - S&K Engineering
  - Efficiency ~70%
  - 200 W transfer
  - 50 kHz
- Tested on the APL barge in June 2006

Subsurface Float assembly

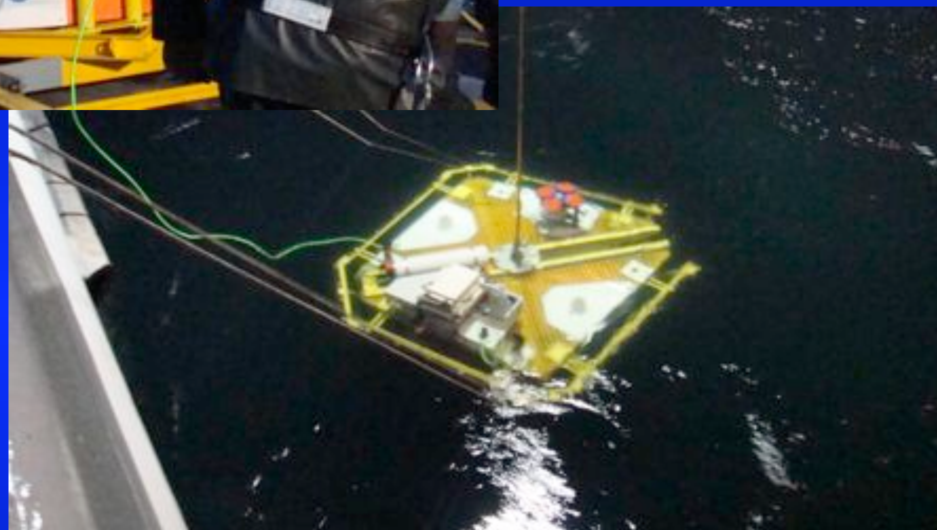
Deploying AMM

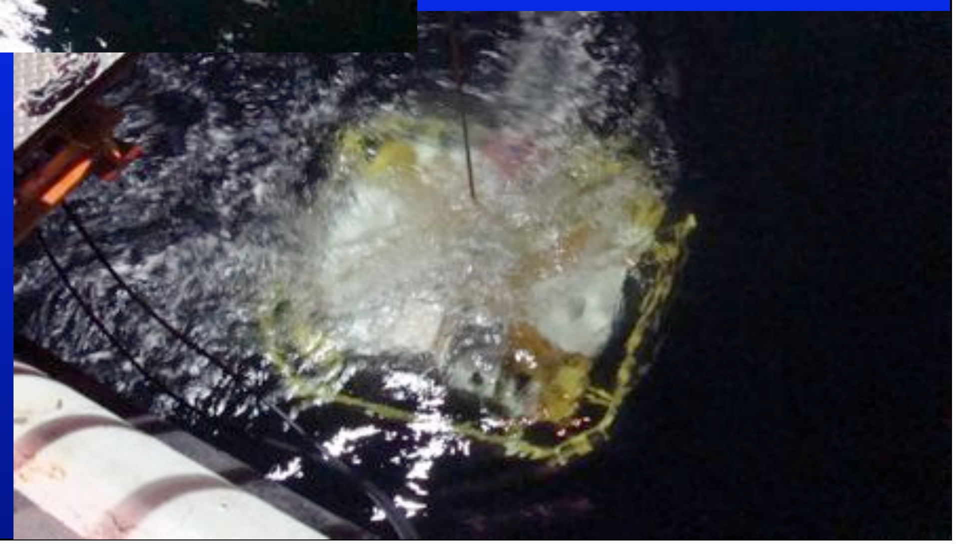


Deploying AMM



Deploying AMM

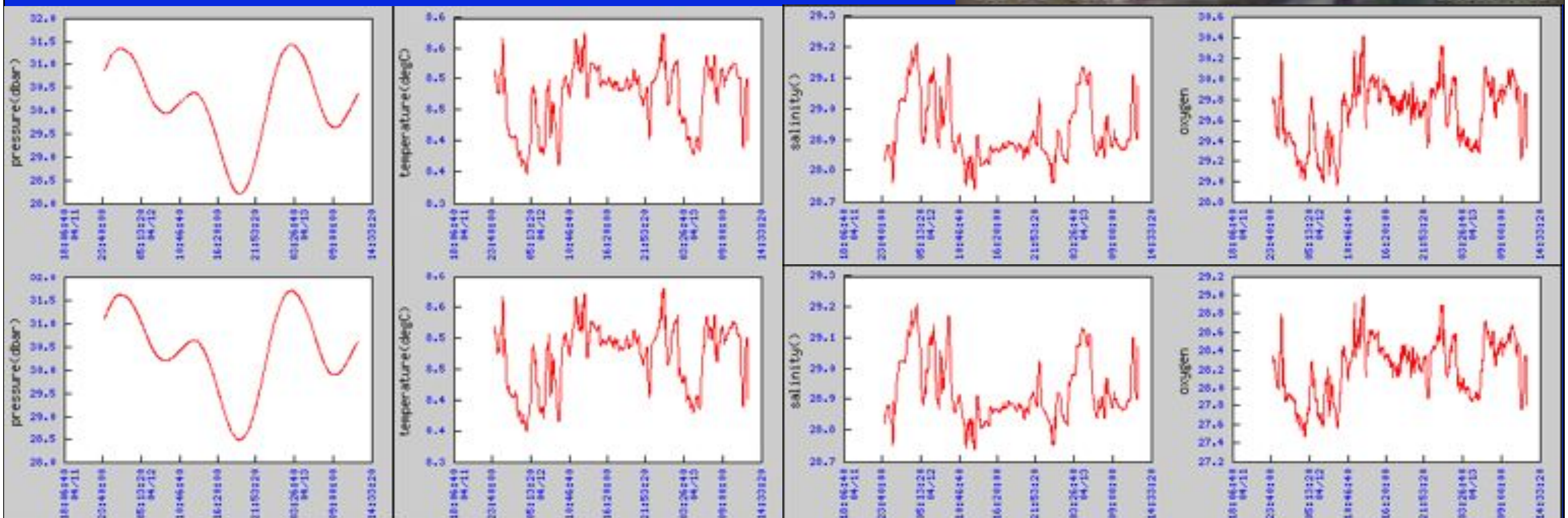




Seahurst data

CTD data:

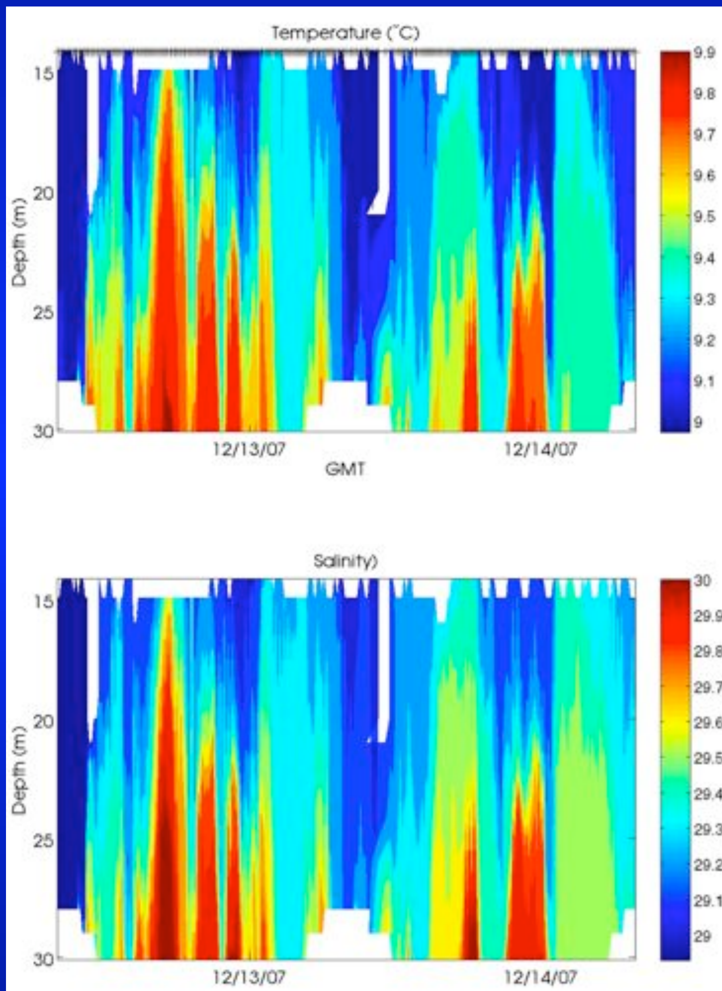
Harbor seal

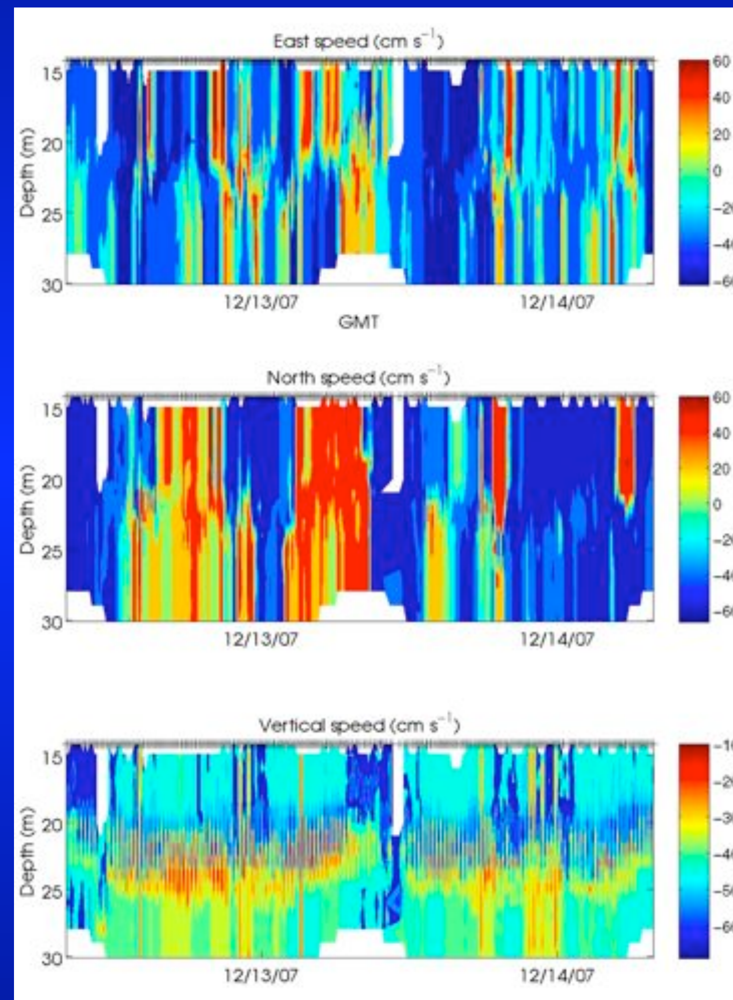


Pressure Temperature Salinity Oxygen

2 units provide redundant data – improves scientific value and reliability
Salinity inversely proportional to temperature
From 12 April 2007

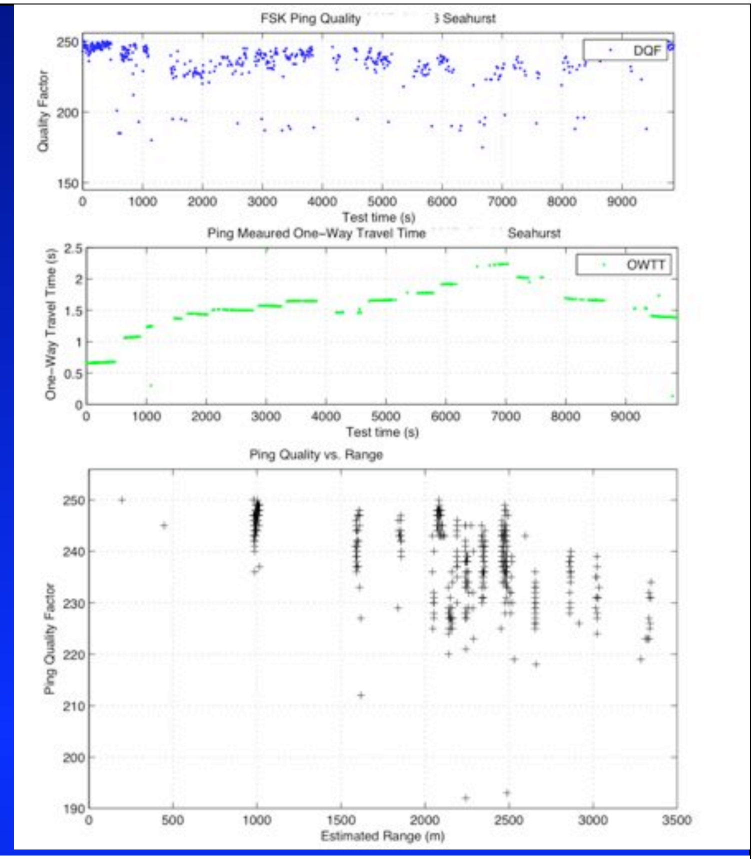
MMP profile data T,S and **u**

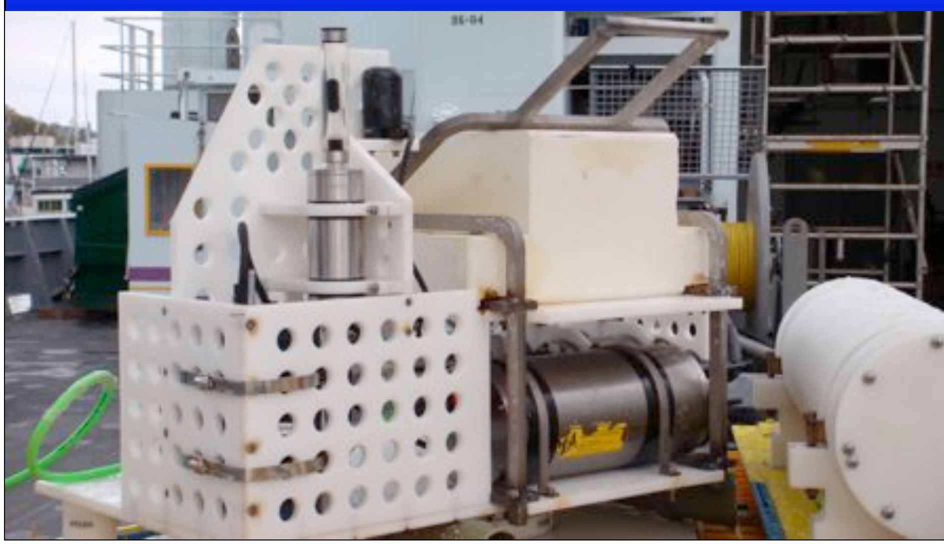


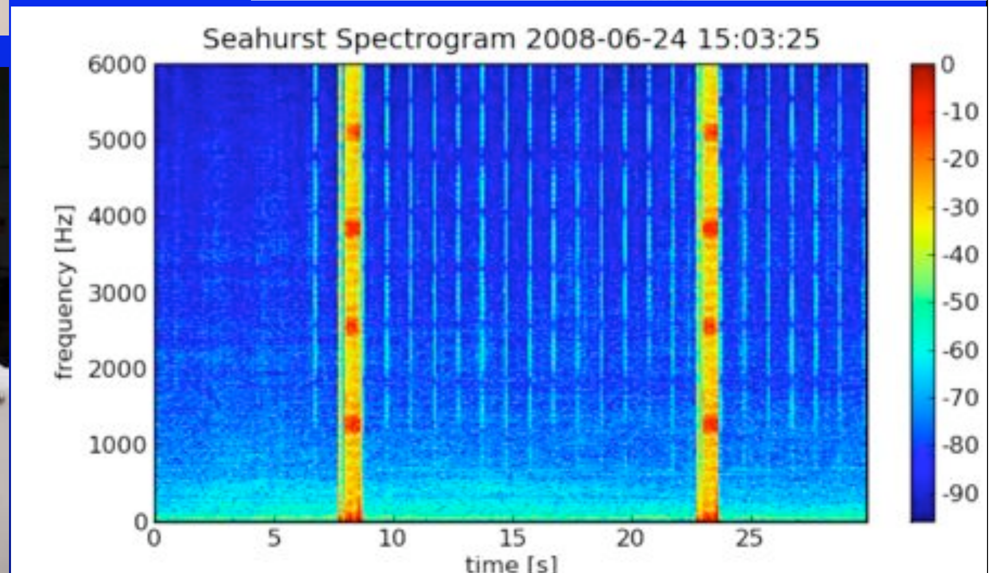


- T and S vs depth
- U, v, w, vs depth

AMM Modem and hydrophone

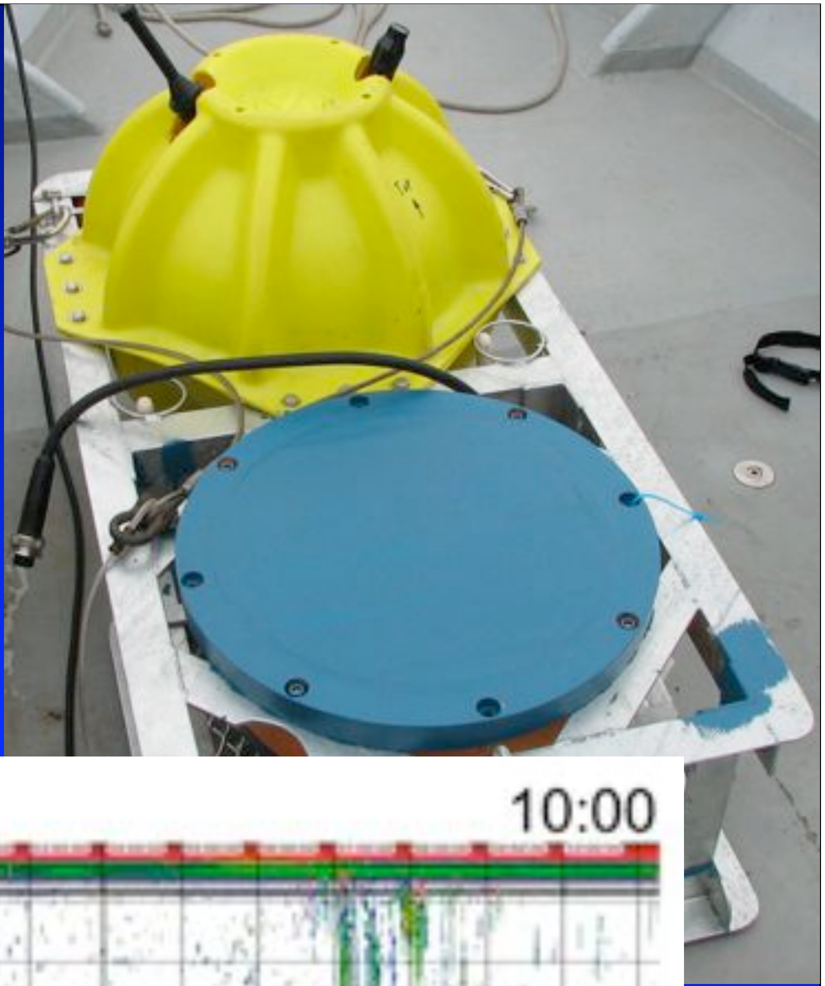


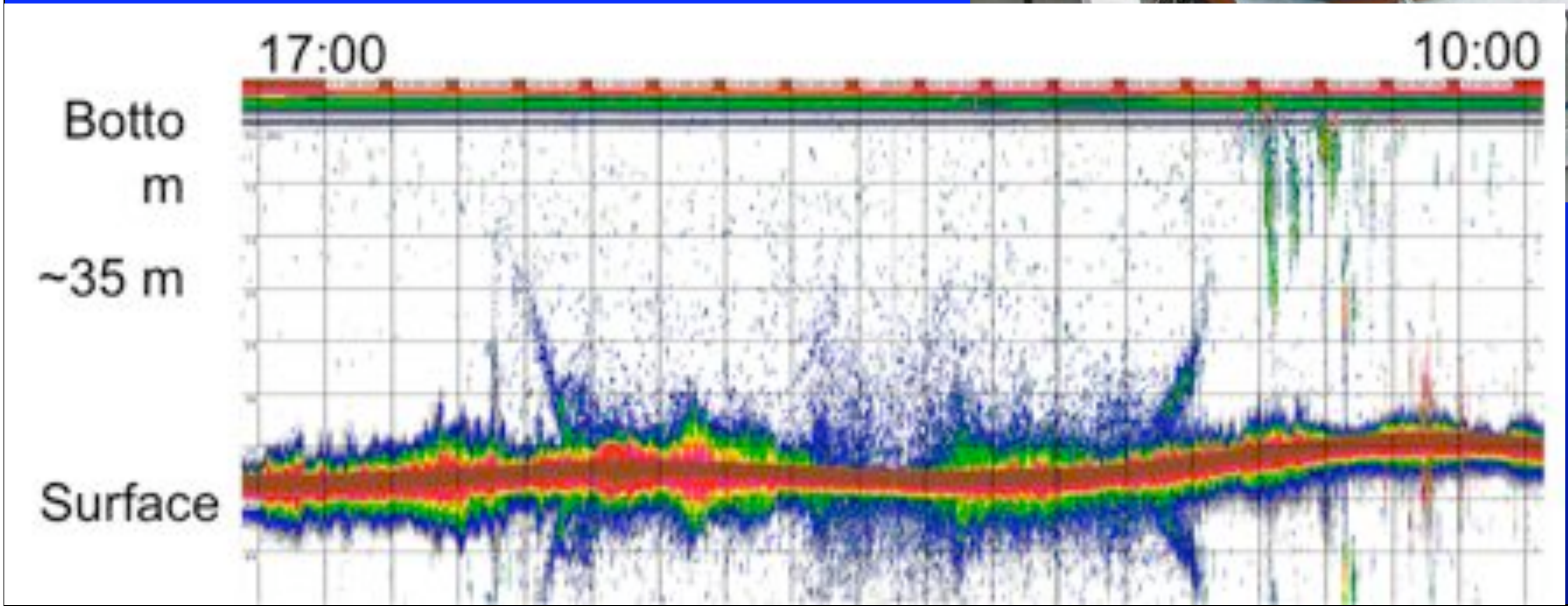




Simrad EK-60 fish sonar

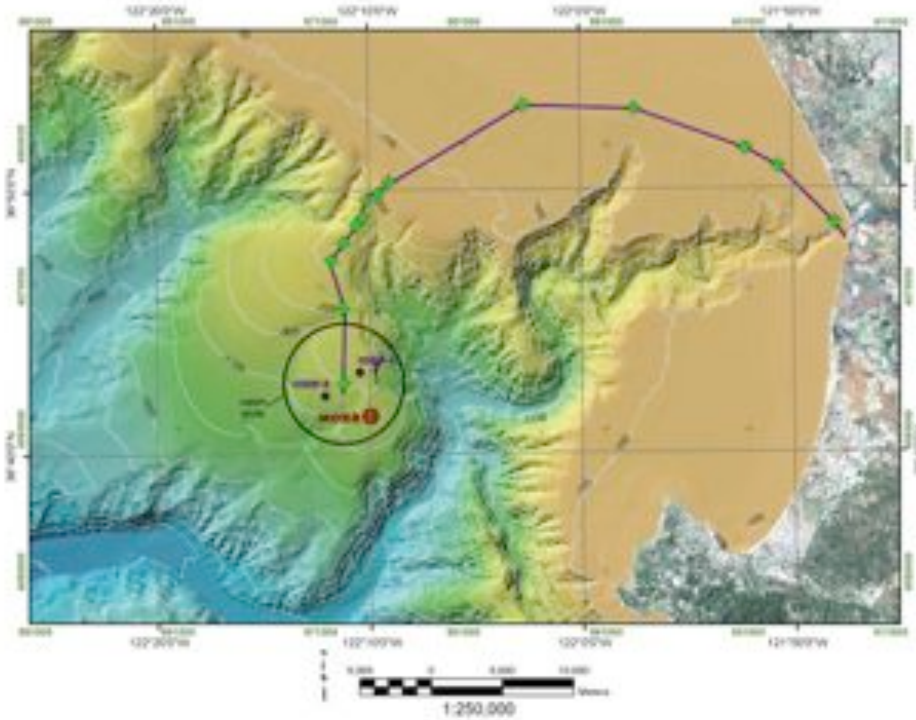
- John Horne, UW
- Now on MARS

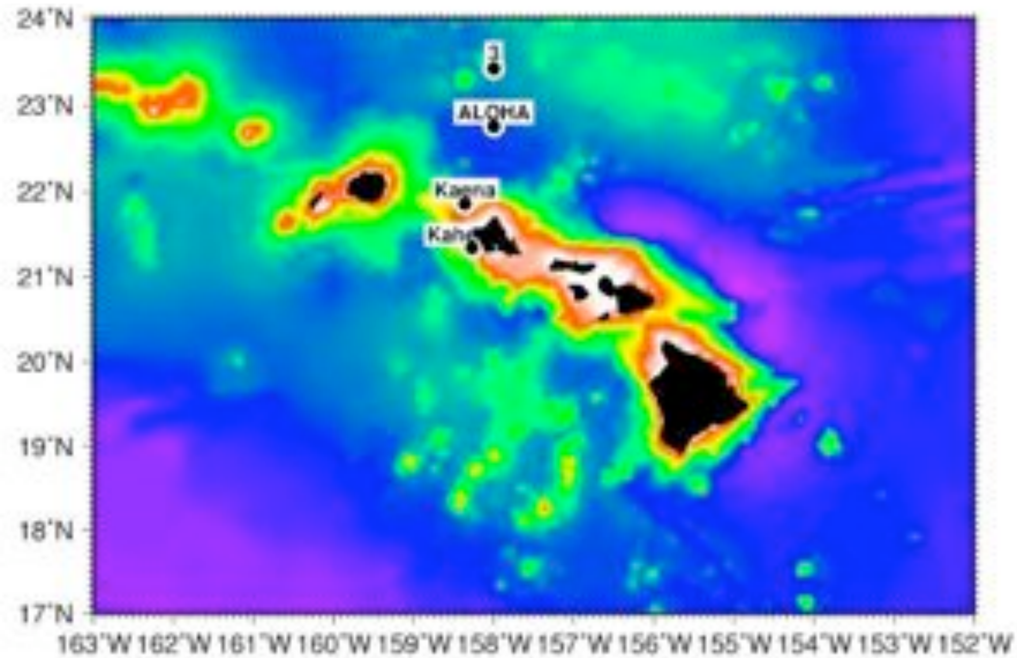




AMM mooring: Next deployments

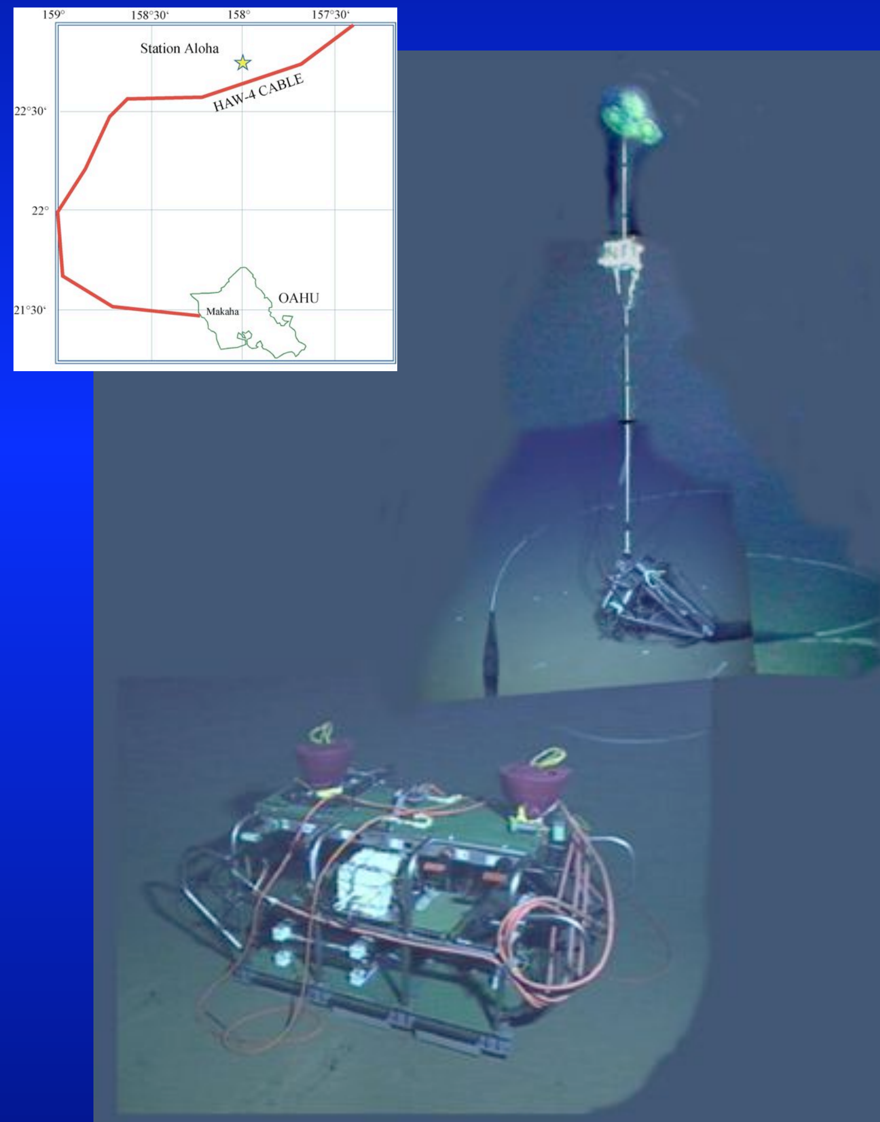
- MARS Location
  - 920 m water depth
  - Proposed - deploy summer 2010
- ALOHA Cabled Observatory
  - 100 km N of Oahu
  - 4750 m
  - 2012?





ALOHA Cabled Observatory

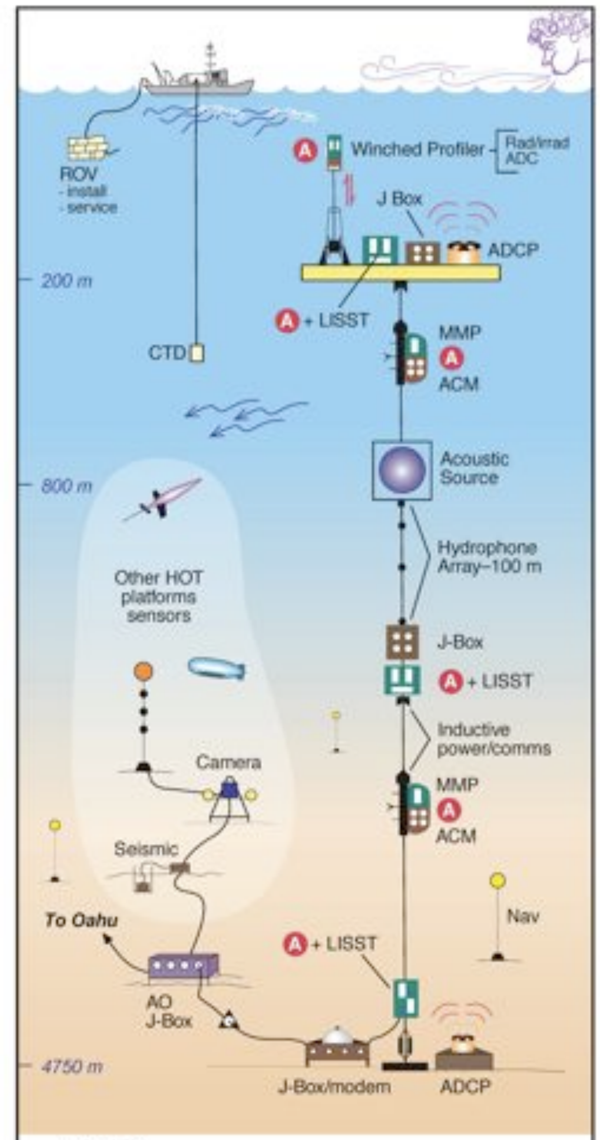
- Fred Duennebier (PI), Roger Lukas, David Karl
- 100 km north of Oahu 4750 m water depth
- hydrophone+pressure data, 3/2007-10/2008
- October 2008 failed attempt to install node – connector problems
- Proposing again, hope to deploy July 2010

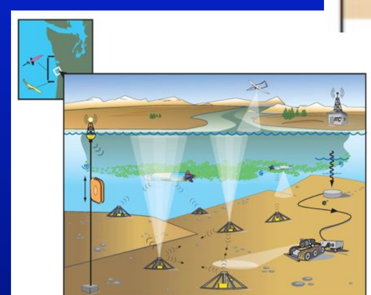


Acoustics

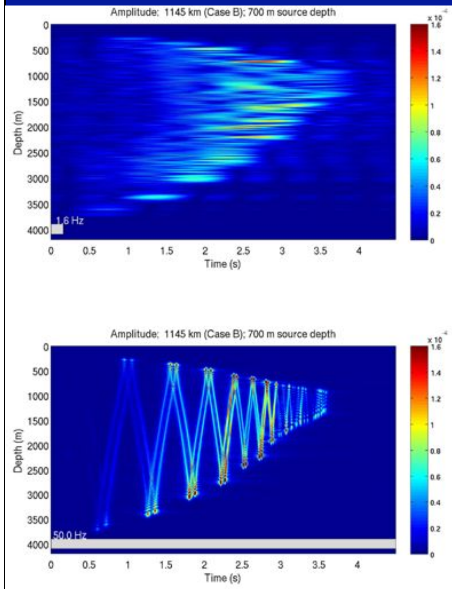
Example:

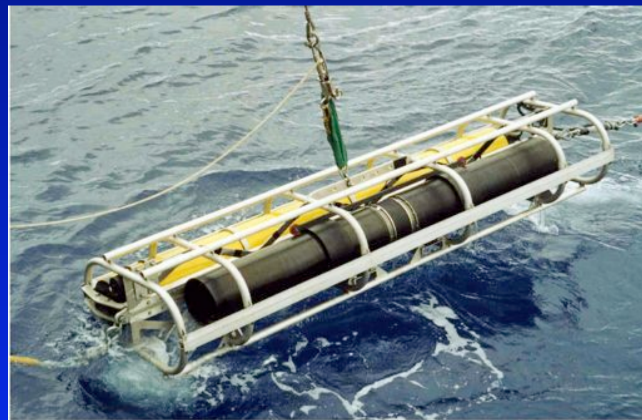
- Extend the spatial footprint of a fixed sensor system
- Add modems, fixed and mobile
- Integrated precise time, navigation, communications
- Work on network protocols
- AND Science
  - Geodesy,
  - Ultimately tomography:
    - short range tomography around node
    - Long range source / receiver
  - Ambient sound

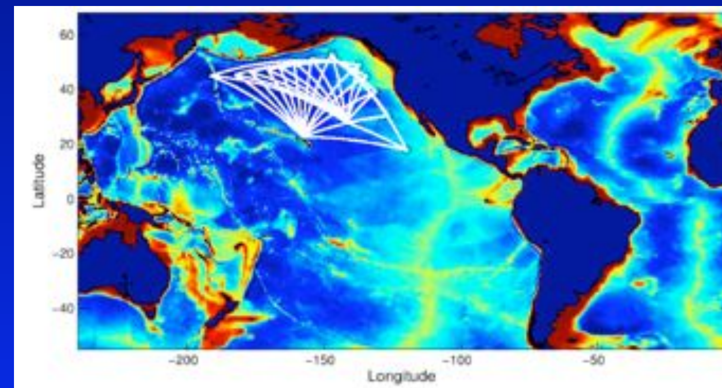




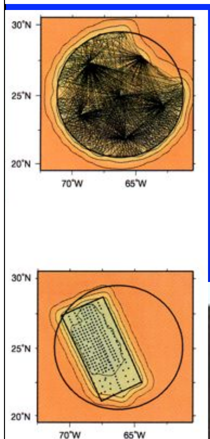
Long-range Tomography + navigation, fixed and mobile

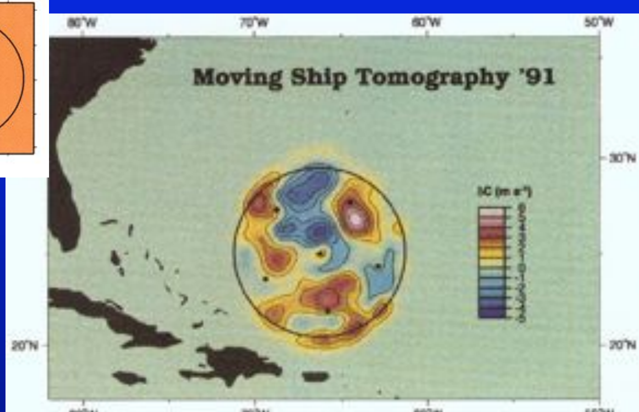


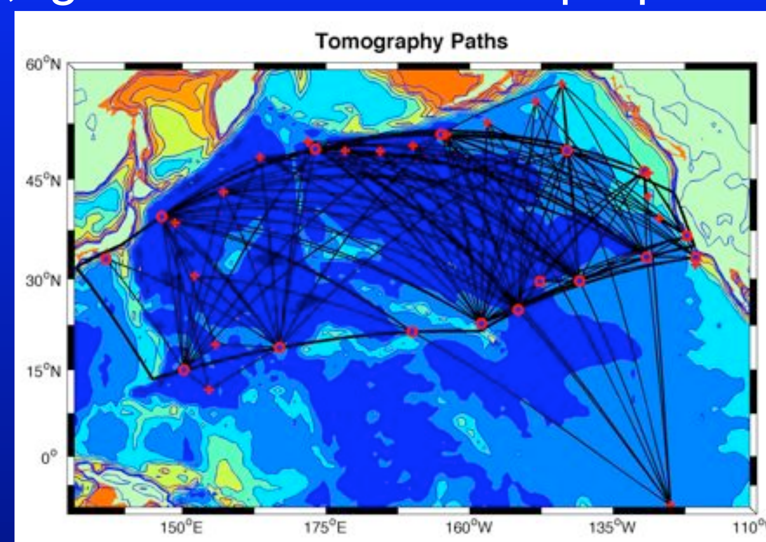




- Broadband precision, Improve 1-2 s to 1-10 ms
- Webb sweeper, <200-300 Hz, efficient
- Acoustic mooring at ALOHA
- DART buoys, TPC-5 cable
- Mobile receivers – floats, gliders. AUVs – multi-purpose







Concluding Remarks

- Acoustics on Seagliders demonstrated:
  - Communications and navigation gateway – data mule, timing
  - Acoustic receiver – marine mammals, tomography
- Mooring – distributing power and comms vertically
  - Demonstrated in Puget Sound, proposed Monterey Bay
  - Autonomous version with buoyancy driven profiler (Alford et al.)
  - Include acoustic transceiver, cabled and autonomous
- Fixed cabled nodes coming on-line
  - ALOHA, Kilo Nalu, OOI/RSN/VENUS/Canada, TPC-5, …

- Integrating acoustics + navigation into data assimilation – mobile + fixed acoustic tomography sources/receivers

More remarks

- The moorings, gliders, and acoustics are just some of many possible ways to extend the spatial sampling in ocean observatories
- Fixed, hybrid, mobile and direct, remote, autonomous control all have roles
- Improving reliability at this cutting edge and reducing cost are crucial to success
- More than enough problems!

Thanks to many!

Questions?

Chris Siani, APL engineer

Sponsors:
- •NSF - National Science Foundation
- •ONR - Office of Naval Research
- •NASA – National Aeronautics and Space Administration