

Ocean Applications of AUVs off FL: Corals to Currents

SEFCRI Land-Based Sources of
Pollution TAC

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SEFCRI/LBSP Action Plan

<http://www.southeastfloridareefs.net/lbsp.aspx>

- ◆ Develop specific projects (engineering/management actions) for designated hot spots
- ◆ Quantify amount and flow rate (flux) of pollution transported by groundwater to the coastal waters
- ◆ Determine flux of pollutants exiting offshore wastewater outfall pipes and net flux to reef communities
- ◆ Determine flux of pollutants exiting ocean inlets and net flux to reef communities
- ◆ Determine flux of pollutants from oceanic sources to coastal waters
- ◆ Determine flux of pollutants from atmospheric sources to coastal waters

Indicators and Pollutants

http://www.dep.state.fl.us/coastal/programs/coral/documents/2006/LBSP/17Jan_Summary.pdf

“minimum set of indicators to be monitored would be those in the FKNMS program:”

- ◆ Salinity, Temperature
- ◆ Dissolved oxygen (DO)
- ◆ Turbidity (NTU)
- ◆ Relative fluorescence
- ◆ Light attenuation
- ◆ N-- Dissolved nitrate & nitrite, Ammonium, Dissolved inorganic nitrogen (DIN), Total unfiltered nitrogen (TN), Organic nitrogen (TON)
- ◆ P-- Phosphorus (TP), Soluble reactive phosphate (SRP)
- ◆ Organic carbon (TOC)
- ◆ Silicate
- ◆ Chlorophyll *a*

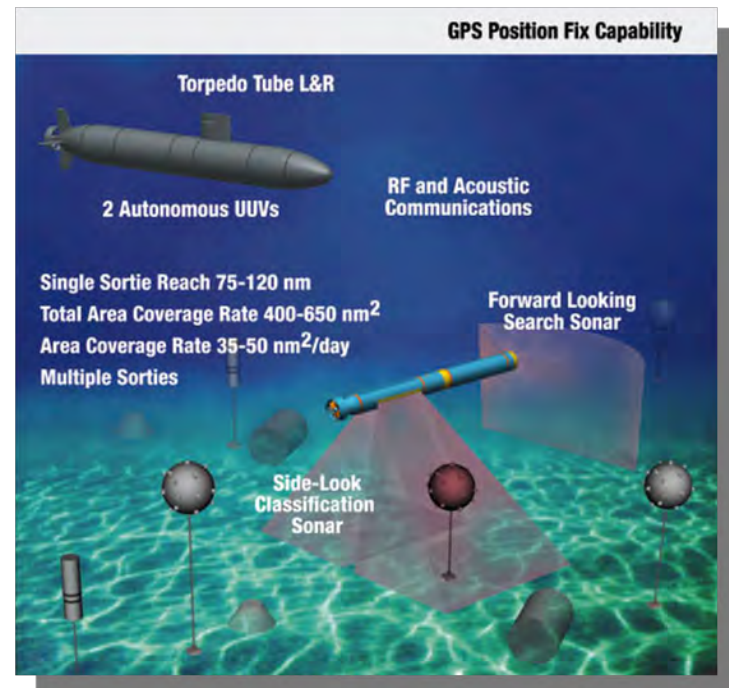
Other indicators (chemical tracers):

- Estrogen
- Caffeine
- Tricolosan
- chemical lawn fertilizers used for suburban lawn maintenance
- nutrient color to identify land sources of turbidity
- Sewage tracers
- remote sensing tracers

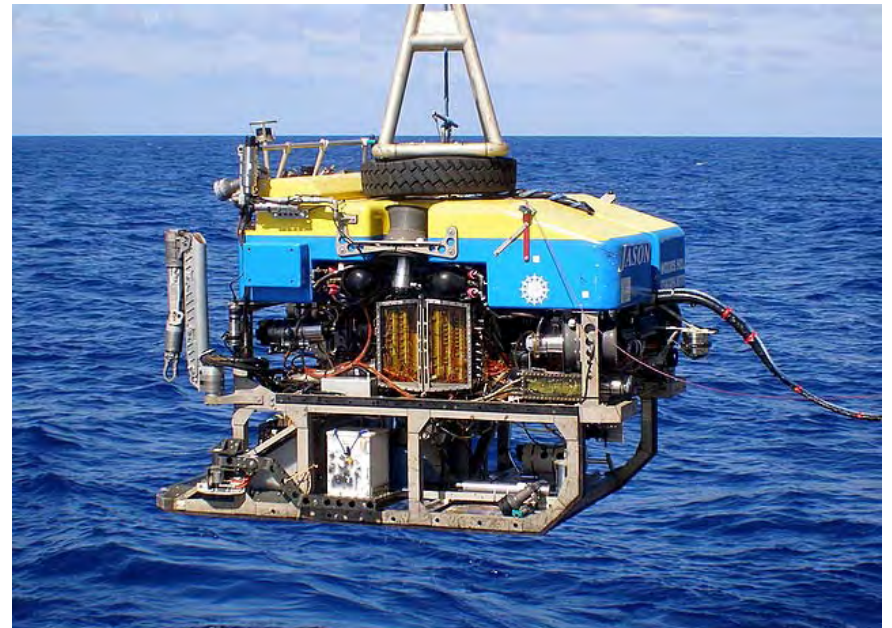
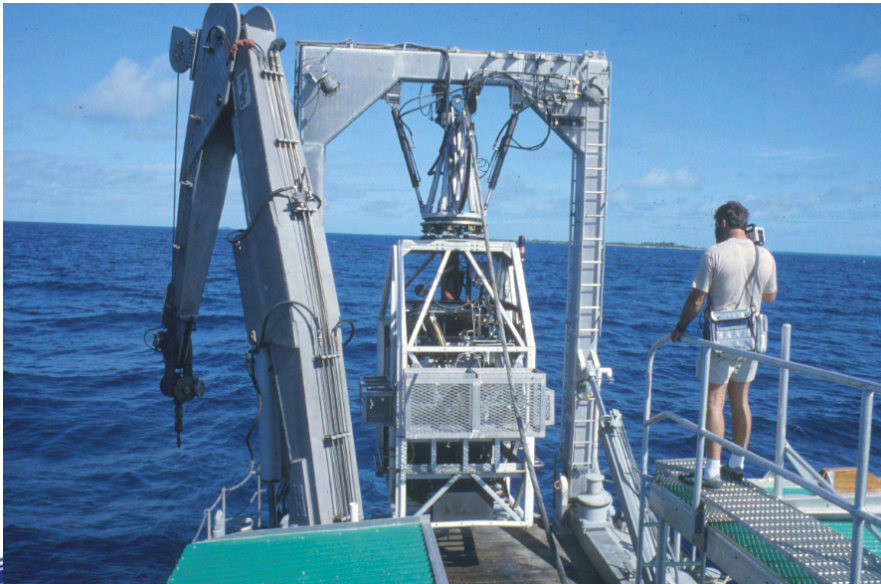
🟢 AUV Types

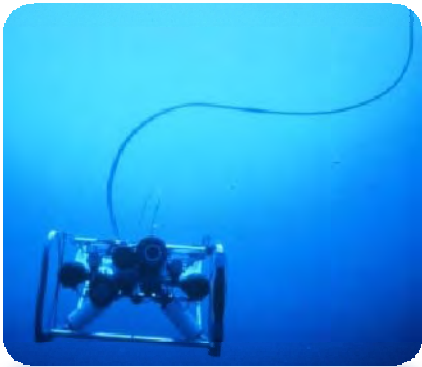
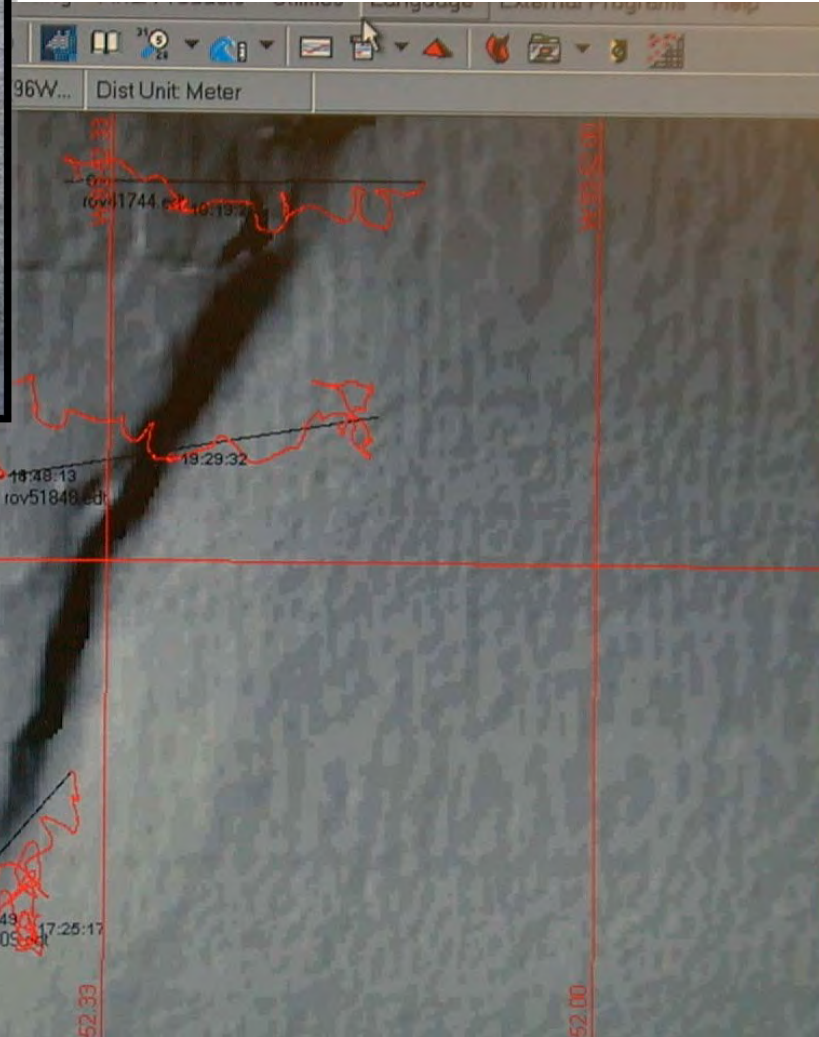
🟢 Applications

🟢 FL Resources



Remotely Operated Vehicles





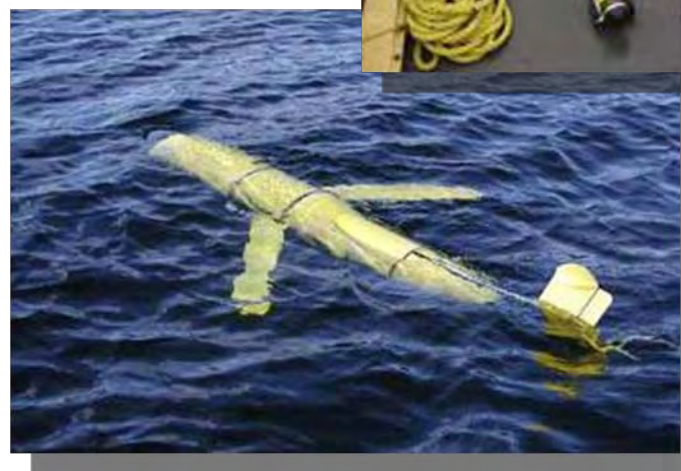
AUV

- Autonomous Undersea Vehicle, aka Unmanned Undersea Vehicle, Unmanned Maritime Vehicle
- Autonomy from surface control = no tether



Pelagia Webb Glider

- ◆ **Weight:** 52 Kg
- ◆ **Hull Diameter:** 21.3 cm
- ◆ **Vehicle Length:** 1.5 meters
- ◆ **Depth Range:** 200 meters
- ◆ **Speed:** 0.4 m/sec horizontal
- ◆ **Endurance:** < 30 days
- ◆ **Range:** ~1500 km
- ◆ **Navigation:** GPS, internal dead reckoning, altimeter
- ◆ **Communications:** RF modem, Iridium satellite, ARGOS, Telesonar modem
- ◆ **Sensor Package:** Conductivity, Temperature, Depth, Oxygen; optics--
fluorescence (CDOM, Chla),
OBS particles, light level



Recent Applications: water mass mapping, ocean color ground-truth, particle loads, calibrate/validate mooring networks

REMUS 6000



- 6000 m
- 12 ft long x 28 inches max D
- 1900 lbs
- 0.5 to 5 kts
- Up to 22 Hour missions
- Payloads: vary by customer



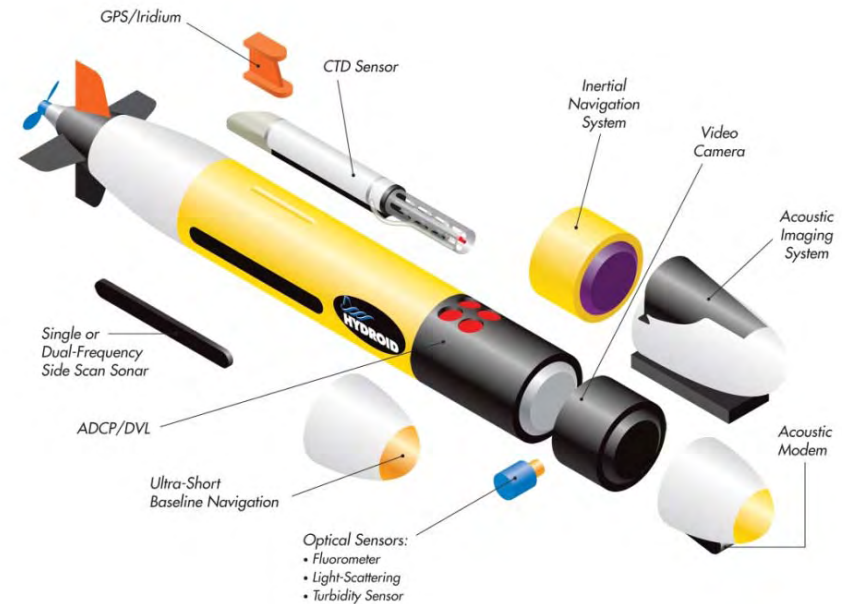
www.hydroid.com

Typical AUV Sub-Systems

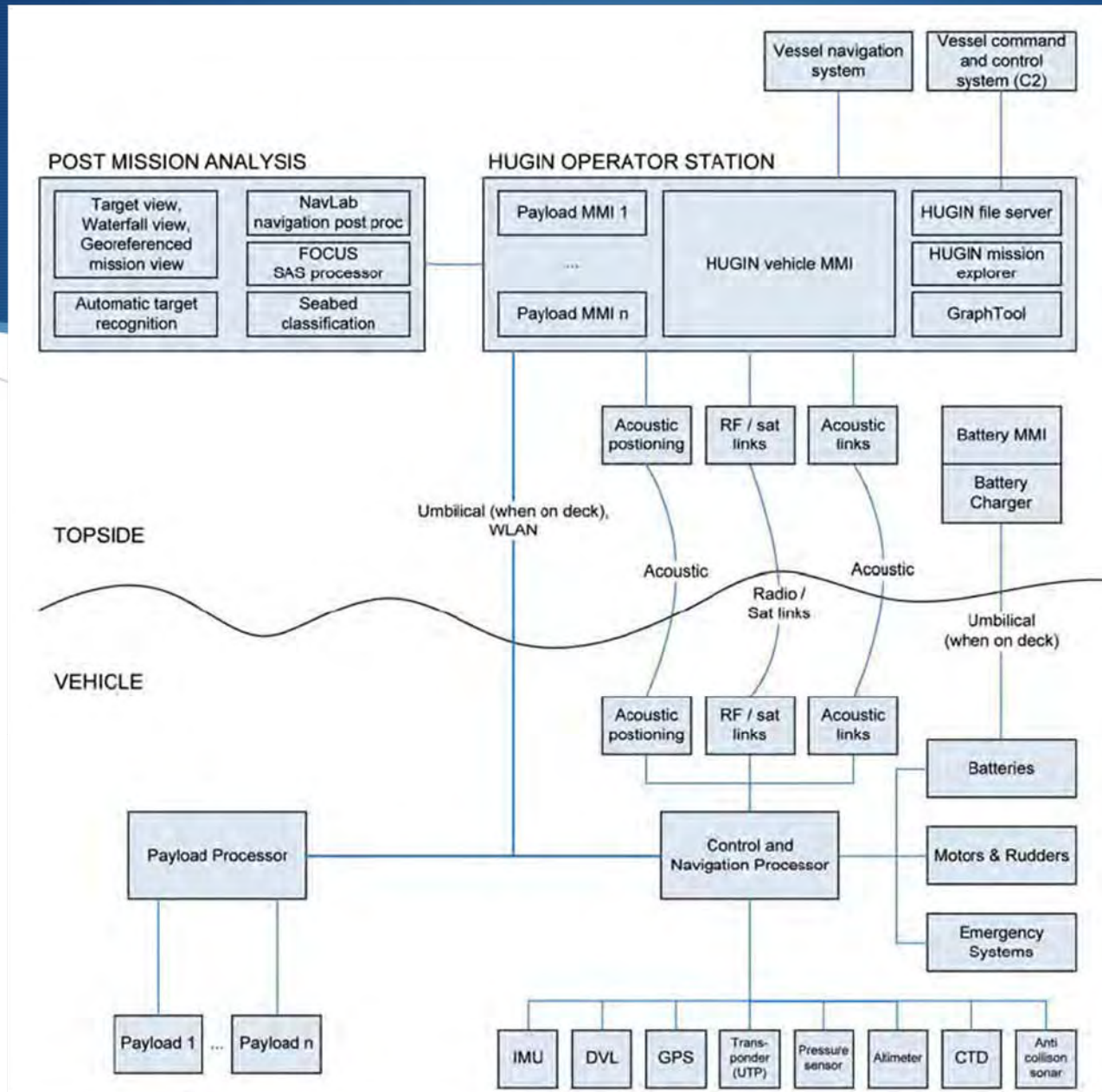
- 💧 Mission Planning Software
- 💧 Communications
- 💧 Power (batteries)
- 💧 Payloads, e.g.:
 - 💧 Sonar – Side Scan, Multi-Beam, Synthetic Aperture
 - 💧 Sub-Bottom Profiler
 - 💧 ADCP, CTD
 - 💧 Camera (Video, Still, Film)
 - 💧 Water Quality



<http://www.iver-auv.com/>



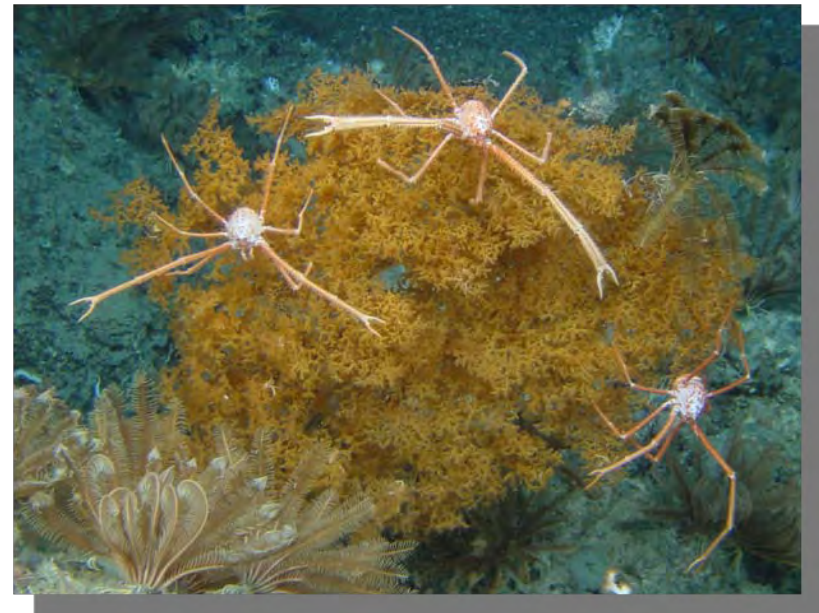
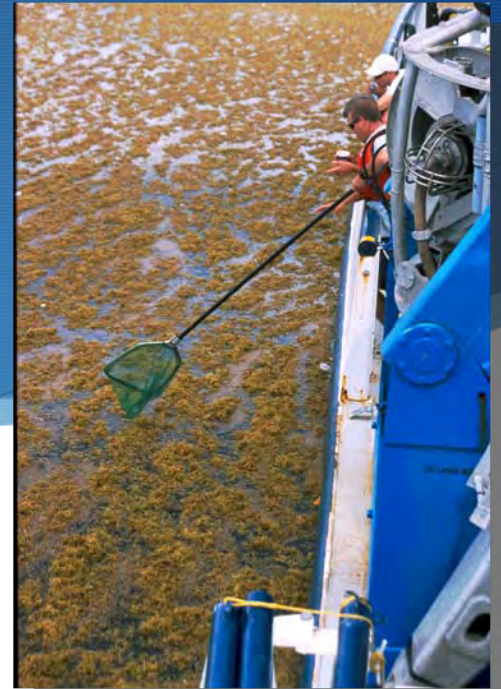
www.hydroid.com



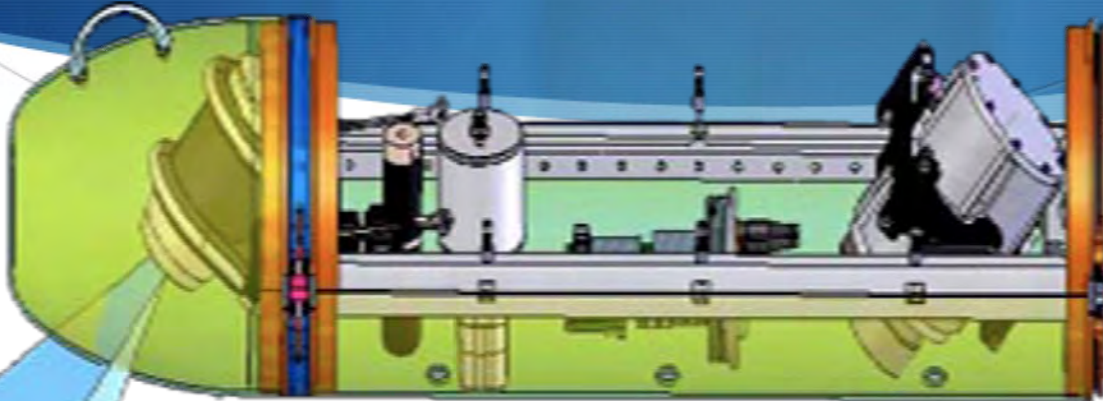
<http://www.km.kongsberg.com>

Habitat Mapping

- ◆ Habitat = physical, chemical, biological elements
- ◆ Sea surface to seafloor
- ◆ Resolution- generally $<1\text{m}$

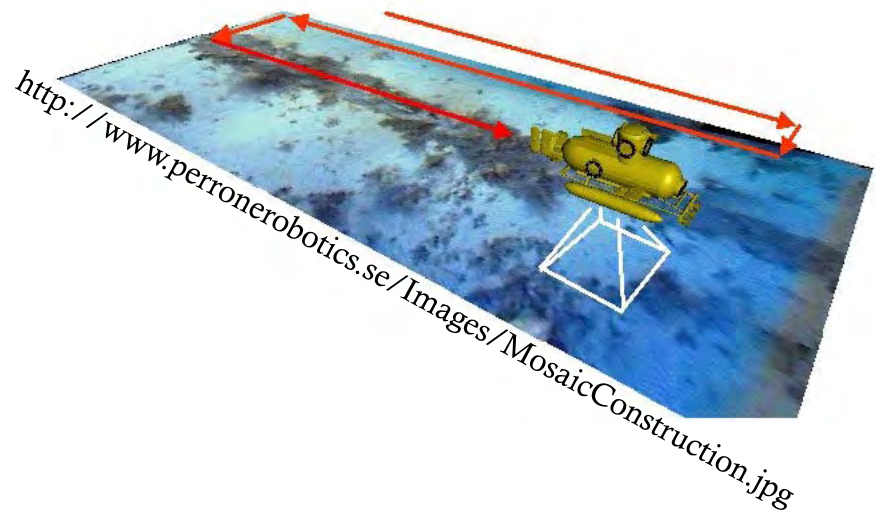


Optical Mapping



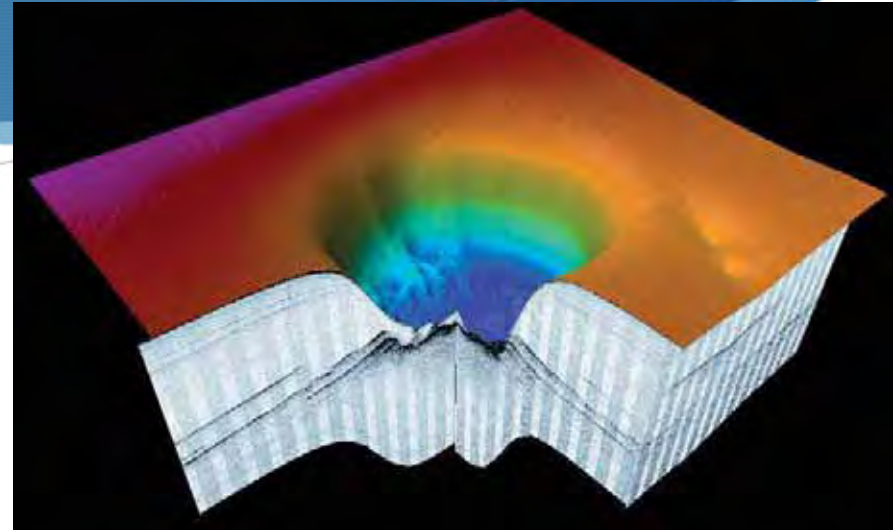
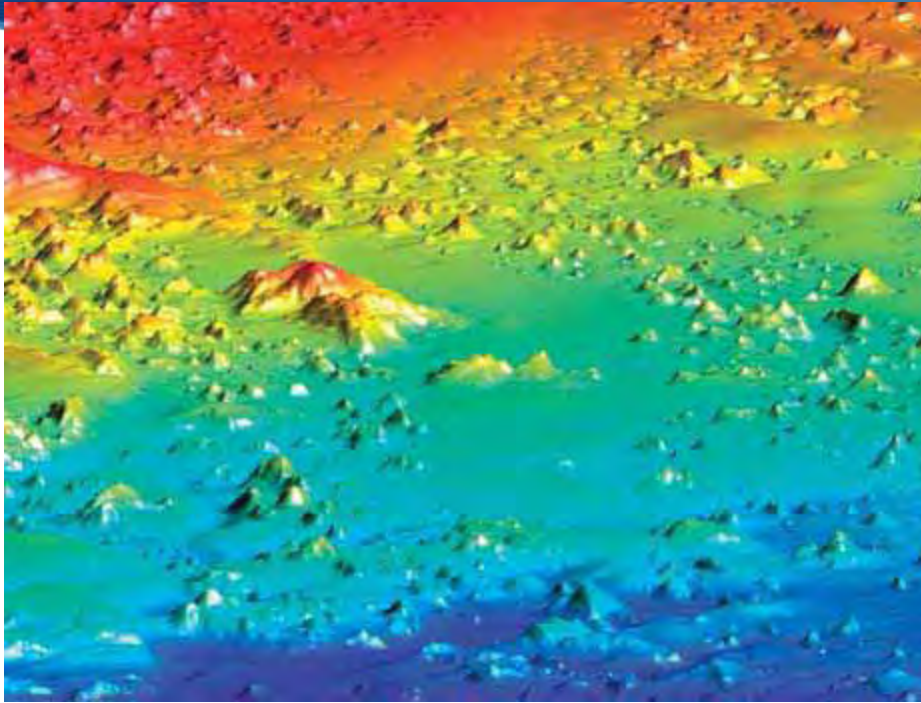
<http://www.dep.state.fl.us/marinemapping/workshops/2007/Feb07/J-Kloske-AUV.pdf>

- ◆ Cameras-- mosaics
- ◆ Laser-line Scanning



<http://www.perronerobotics.se/Images/MosaicConstruction.jpg>

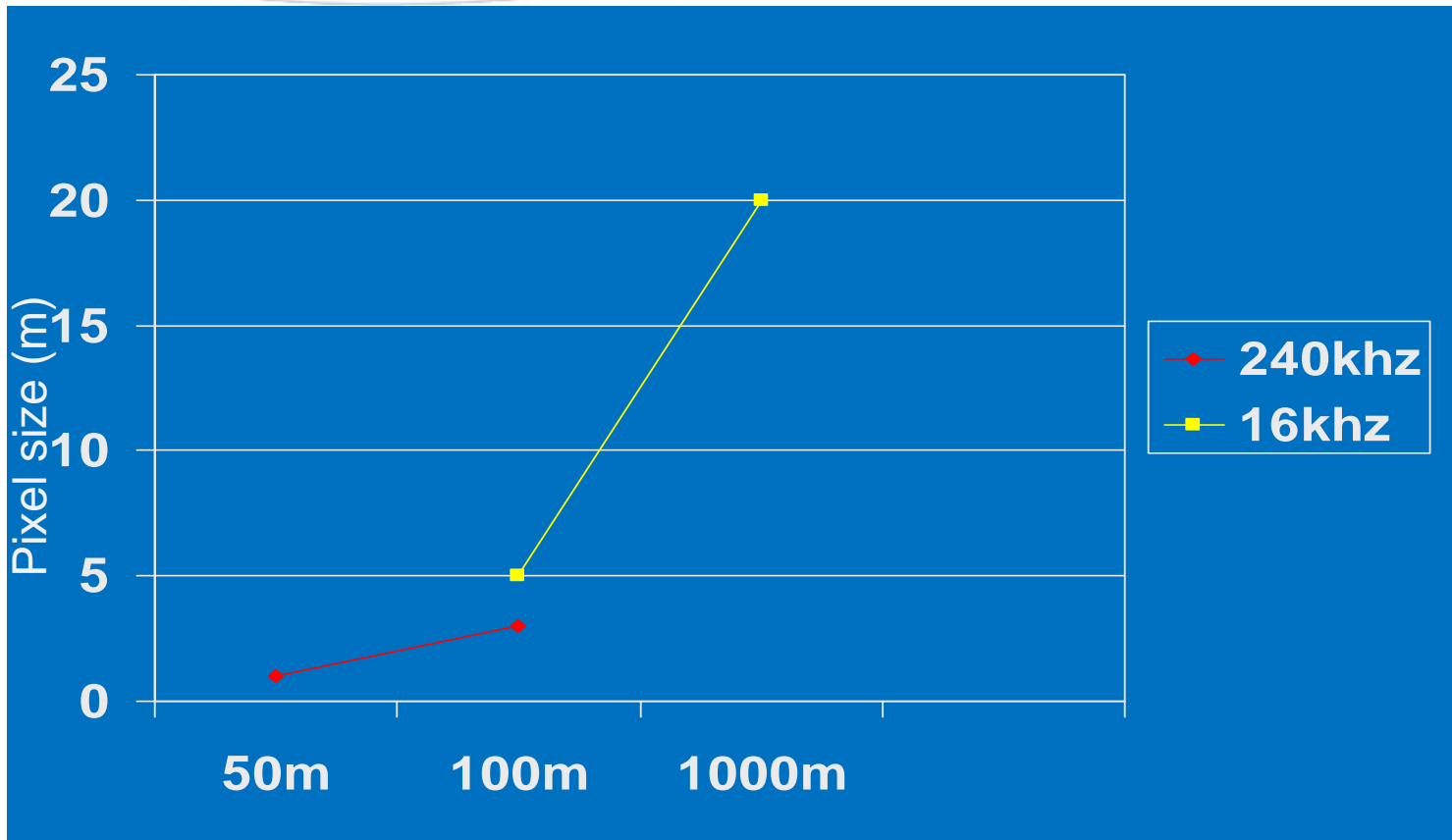
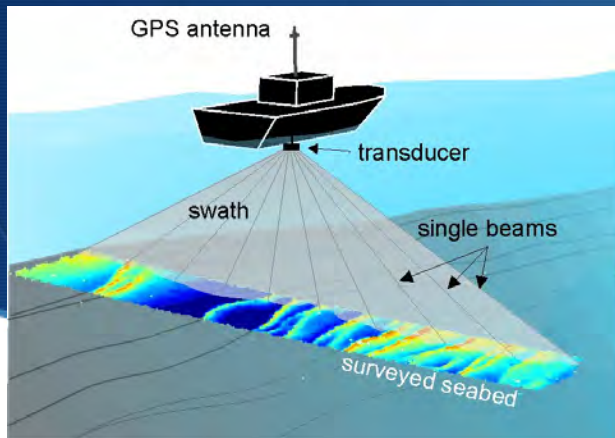
Acoustic Seafloor Mapping

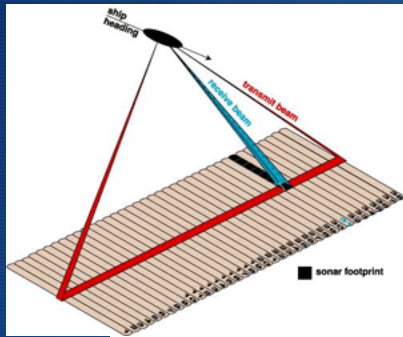


Overlay of MBE and SBP data.
(<http://www.km.kongsberg.com>)

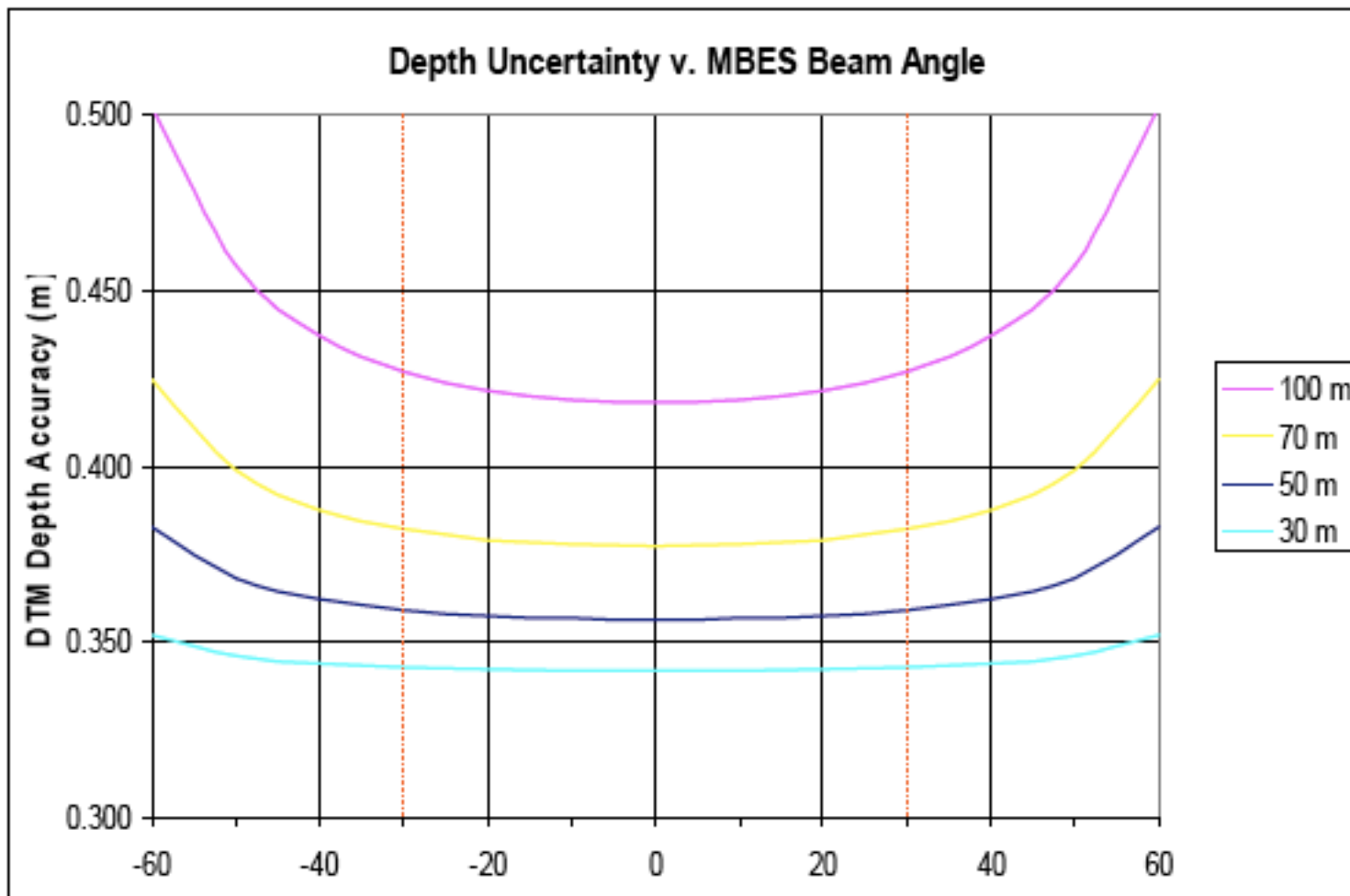
2002 HUGIN bathymetry from the
Ormen Lange field.

Mapped with HUGIN II and EM 3000
multibeam echosounder.
(<http://www.cctechnol.com>)



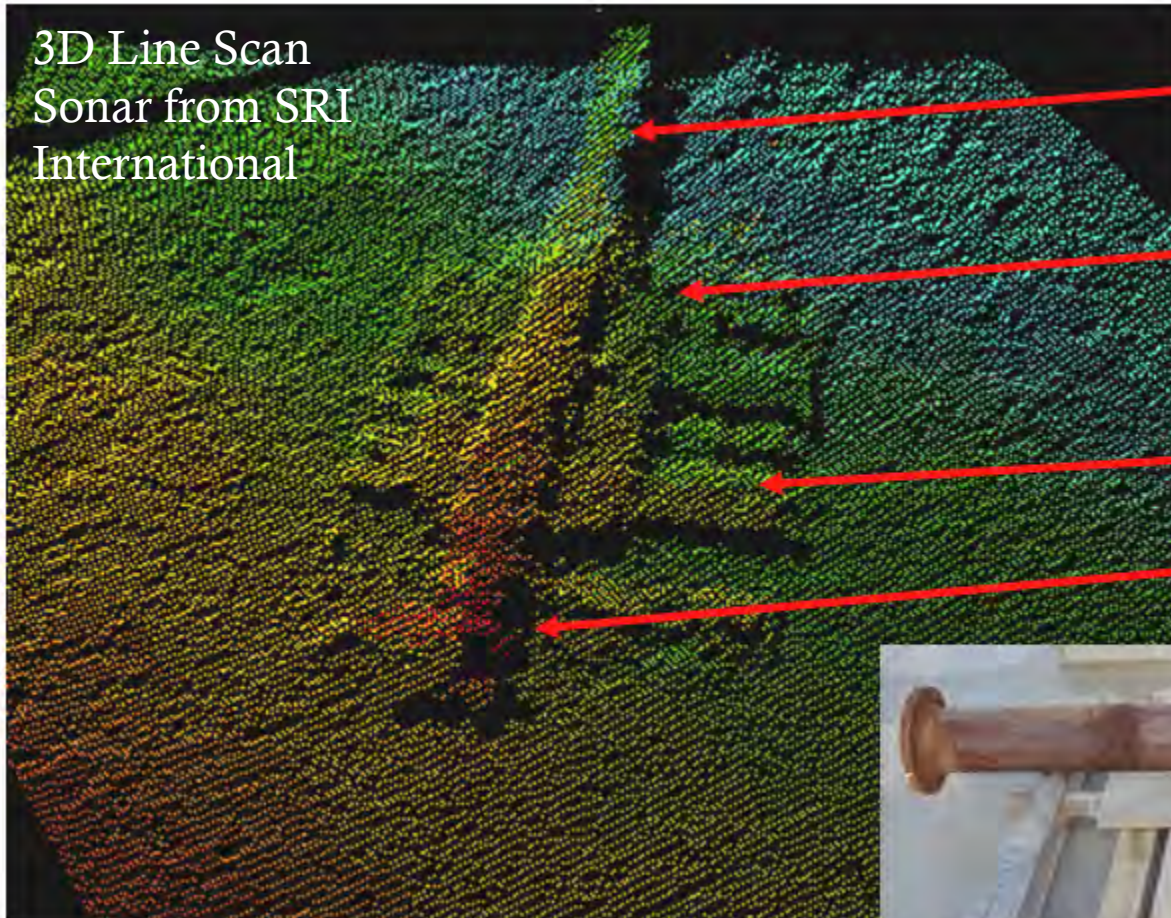


Total Depth Error Budget



Acoustic Seafloor Mapping

3D Line Scan
Sonar from SRI
International



6" D X 7' L Steel Pipe

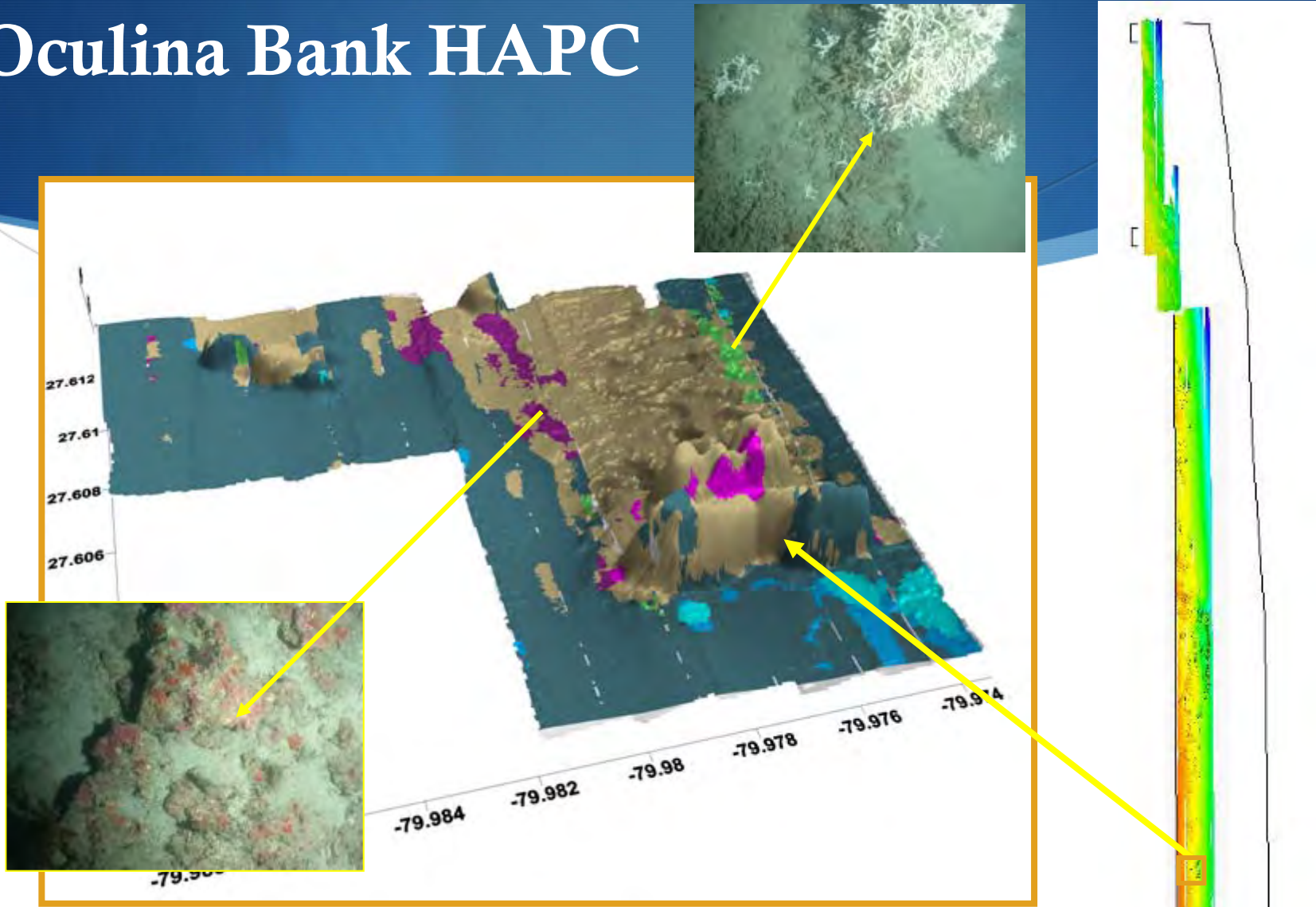
Two 2"x6" wooden
planks on each side
of the pipe

Wooden pallet

11" Dia. flange



Oculina Bank HAPC



QTC MultiView habitat map using XYZ/XYA data from ship-board EM-3002 (Maness et al. 2009, in prep.)

Mapping 4-D Oceanographic Events

- LBSP oceanographic indicators vary mm-km and sec to decadal!
- Need to measure/model such events using “*non-uniform sampling topologies*”¹:
 - Topology-- mathematical study of properties that are preserved through deformations, twistings, and stretchings of objects
 - Non-uniform sampling-- randomized or pseudo-randomized
- Typical sampling effort = high temporal rez, low spatial rez (buoys/moorings, satellites), augmented with periodic samples with high spatial rez & low temporal rez (ship samples, towed sensors, AUV dives)
- Challenge-- achieve both high spatial and temporal rez as needed for event/parameters!

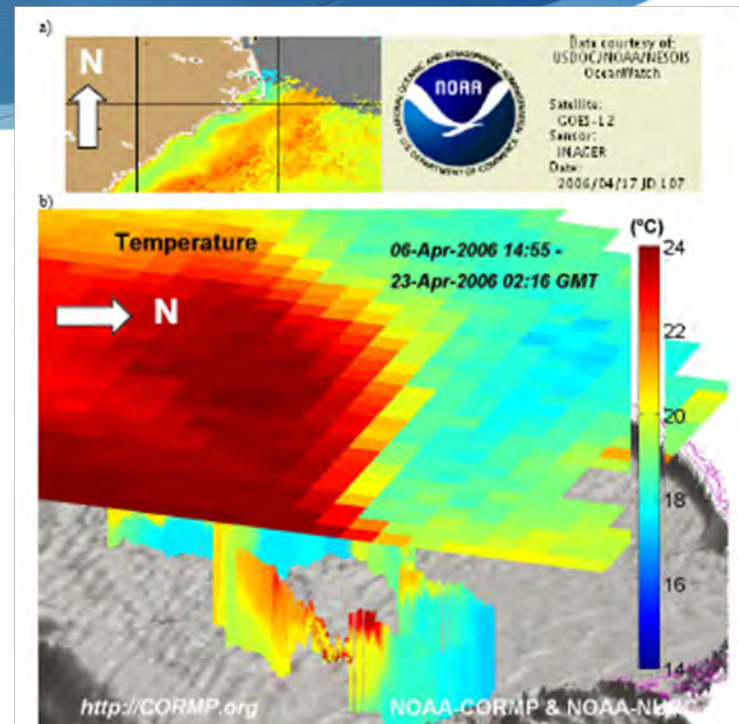
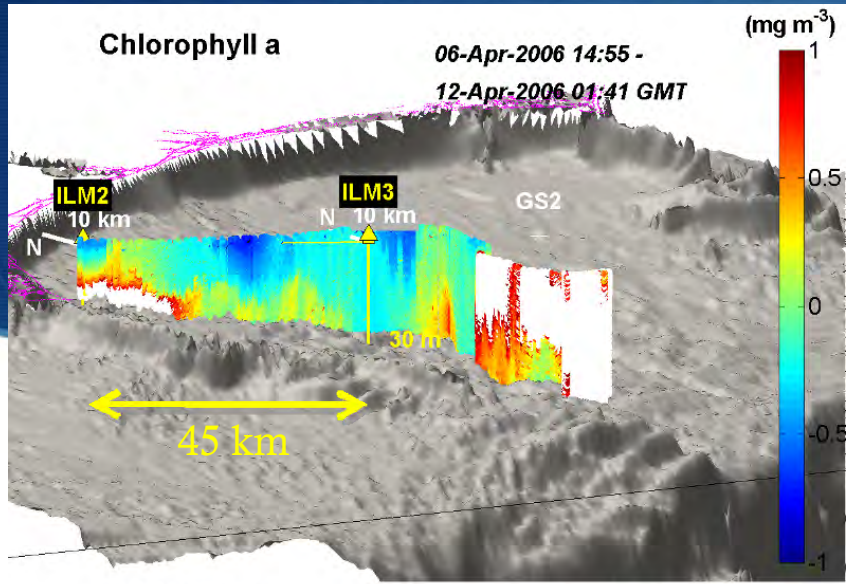
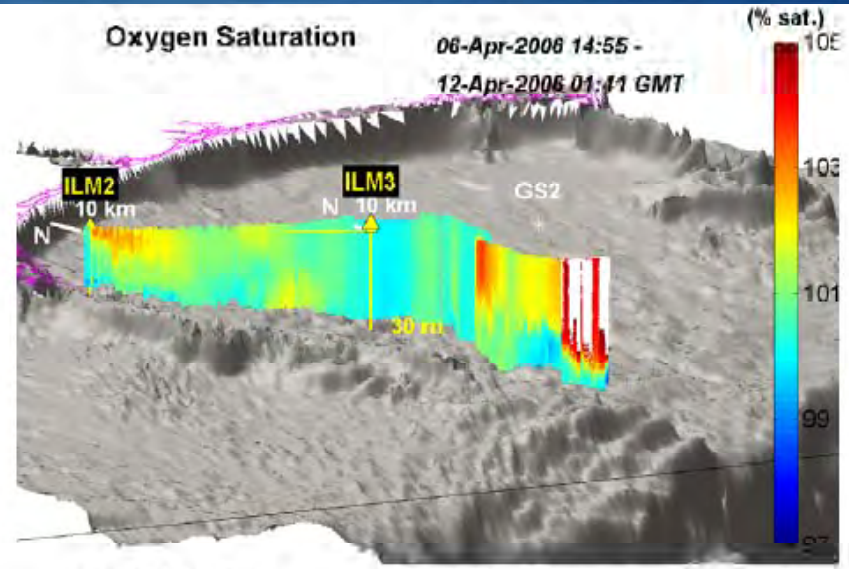


Figure 6. a) The passage of a Gulf Stream eddy over Easter weekend (Apr 17, 2006) was seen in GOES 12 sea surface temperature data and b) coincident glider data. Glider Pelagia (maximum operating speed 0.25 m/s) was entrained in northeastward-moving warm waters with velocities up to 0.7 m/s. Pelagia was able to escape the current after a few days, coinciding with passage of the eddy out of the region. Rapid (1 week) thermal stratification of Onslow Bay waters developed during this event, although seasonal stratification was not maintained until the following month.



<http://CORMP.org>

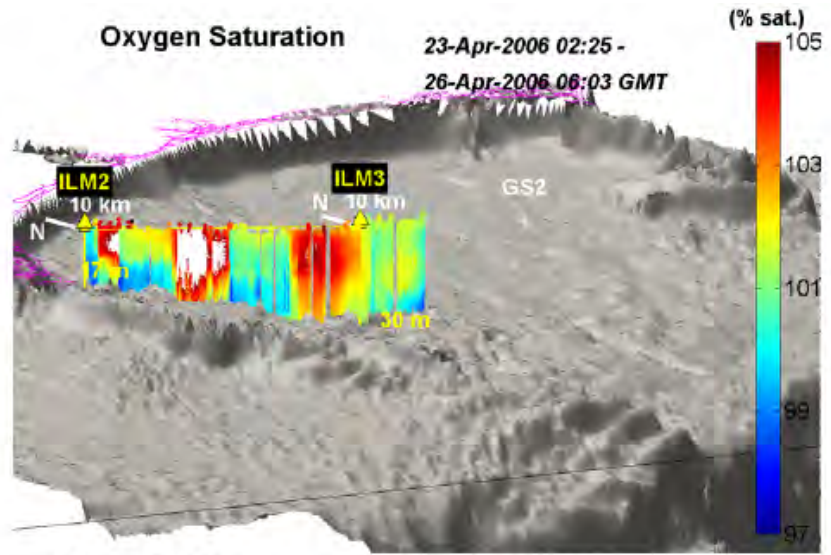
NOAA-CORMP & NOAA-NURC



<http://CORMP.org>

NOAA-CORMP & NOAA-NURC

● Pelagia glider transects off NC, Apr 2006

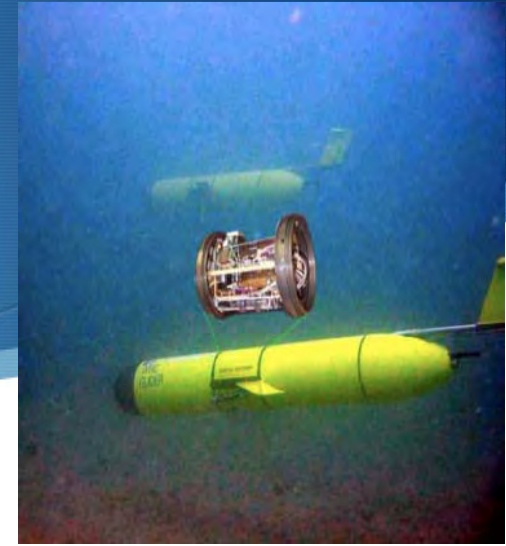
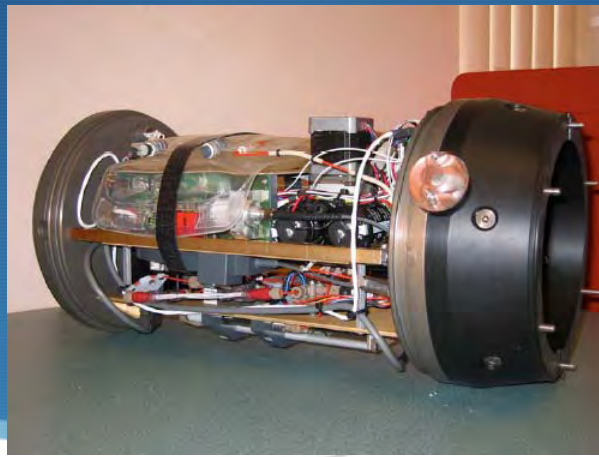


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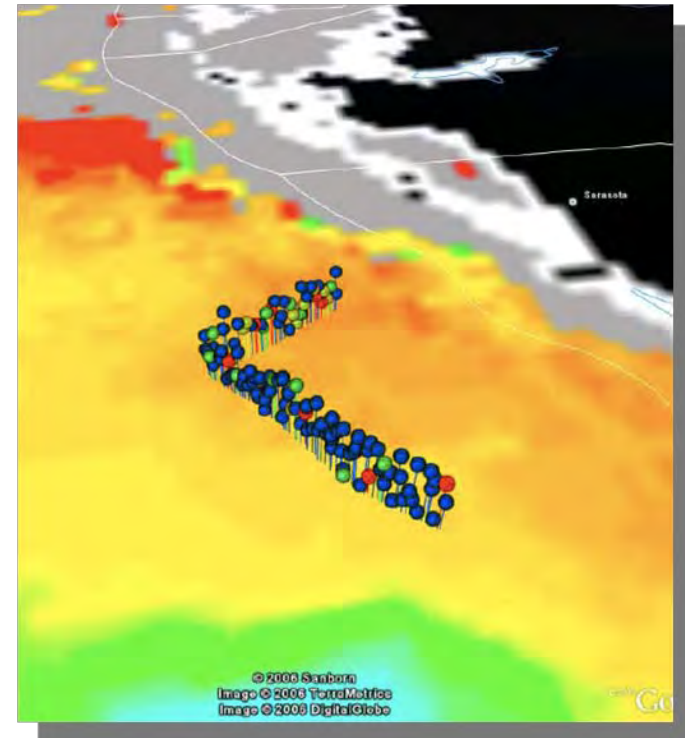
NOAA-CORMP & NOAA-NURC

Figure 7. Dissolved oxygen concentrations in Onslow Bay a) prior to and b) after the rapid thermal stratification event of Apr 17, 2006 associated with the passage of a Gulf Stream eddy.

HABs

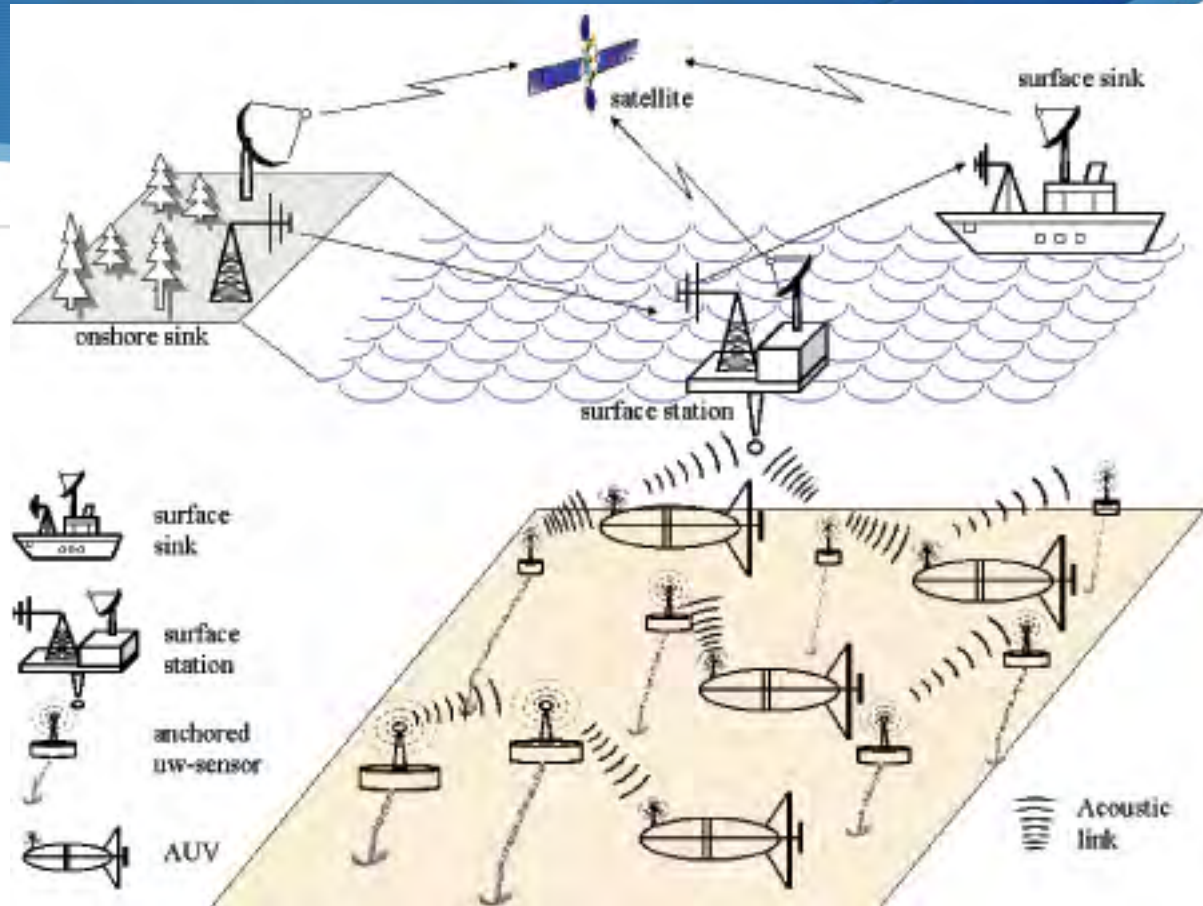


- ◆ FRCOOS glider experiment: develop methods to monitor and predict *K. brevis* bloom formation and transport
- ◆ BreveBuster (Kirkpatrick et al. 2008)—optical phytoplankton discriminator (OPD)
- ◆ Similar *Remus* study “provides evidence that a *nested array of AUVs and moorings equipped with new sensors*, combined with remote sensing, can provide an early warning and monitoring system to reduce the impact of HABs.” --
<http://www.marine.calpoly.edu/community/staff/MasterthesisIanRobbins.pdf>



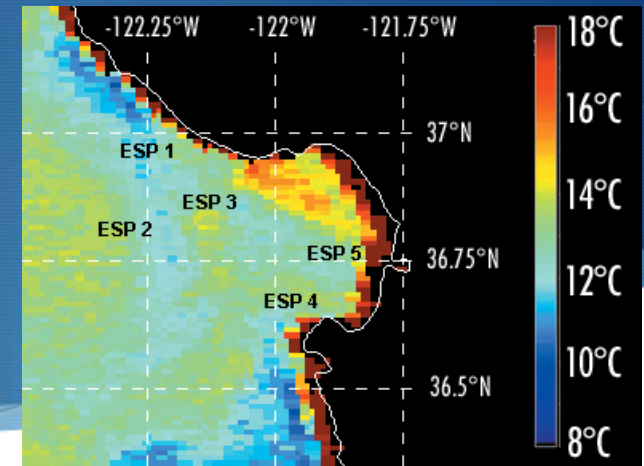
OOS Networks

- ◆ Acoustic comms
- ◆ Sensor nodes
- ◆ Data Management
- ◆ Uplink options

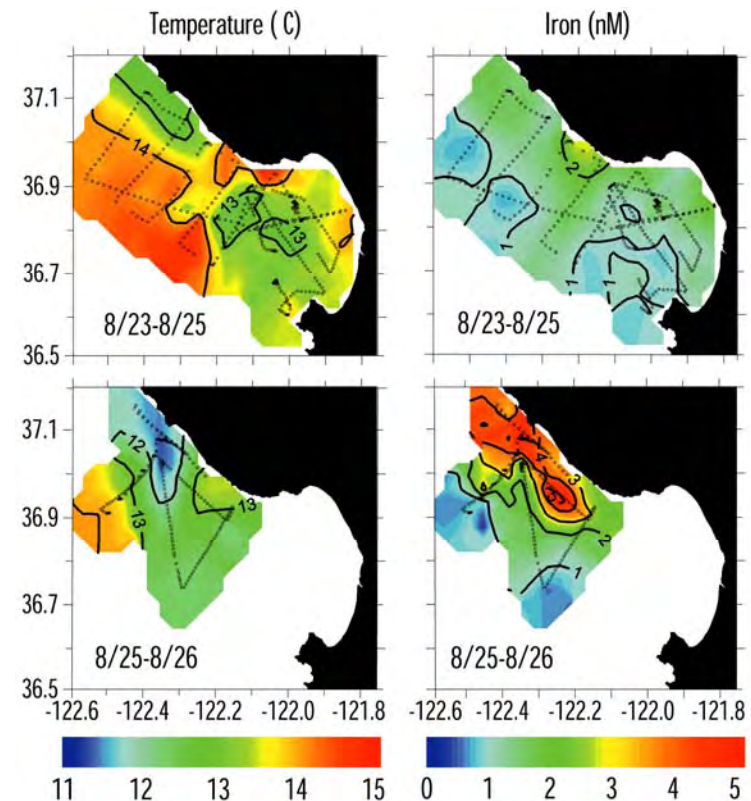


http://www.ece.gatech.edu/research/labs/bwn/Underwater/AUV3D_arch.jpg

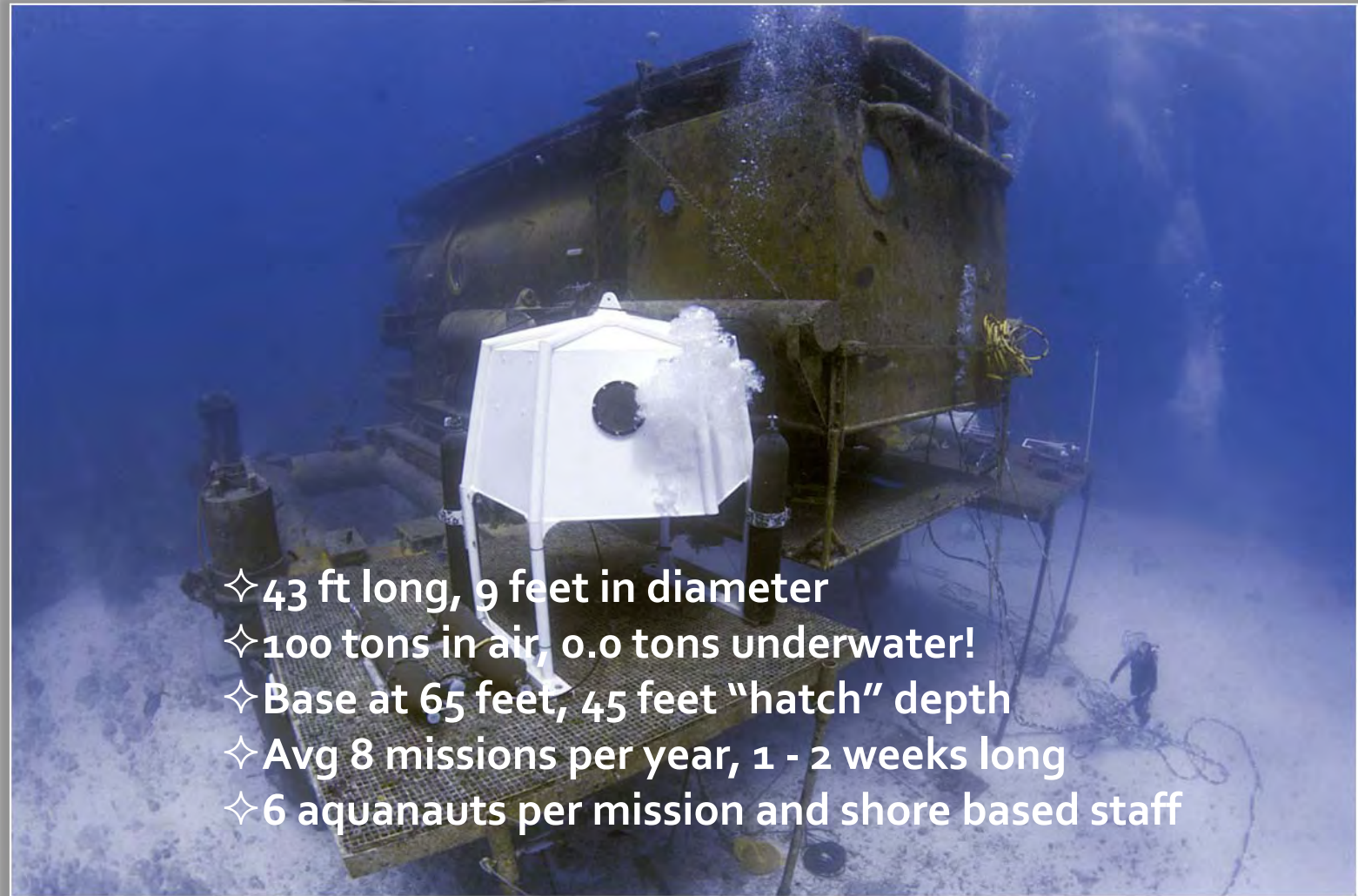
Upwelling



- Monterey Bay Autonomous Ocean Sampling Network--
<http://www.mbari.org/aosn/>
- MUSE-- <http://www.mbari.org/muse/>:
“surveys with AUVs and gliders revealed previously unnoticed details of the complex coastal circulation system during the fertilization event”; Iron concentrations increased from ambient values while the system was in relaxed state (upper panels), prior to onset of upwelling favorable winds, to values six times higher in core of upwelled plume.



NOAA's Aquarius Reef Base



- ✧ 43 ft long, 9 feet in diameter
- ✧ 100 tons in air, 0.0 tons underwater!
- ✧ Base at 65 feet, 45 feet "hatch" depth
- ✧ Avg 8 missions per year, 1 - 2 weeks long
- ✧ 6 aquanauts per mission and shore based staff

ARB Technology Testbed

- Exploration and Research
- Communications
- Robotic Technology
- Ocean Observing
- Energy
- Marine Operations

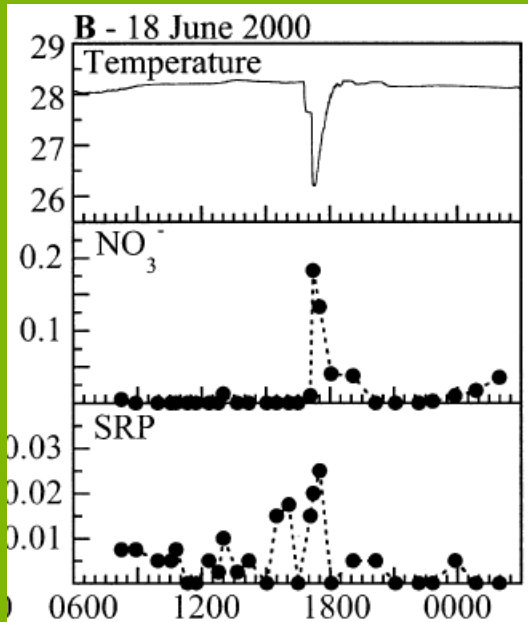


Nutrients & Internal Waves

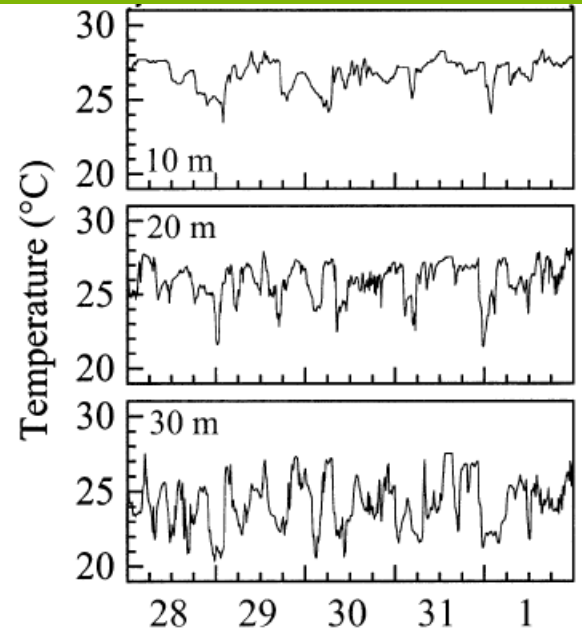
- ◆ Nutrients important factor for coral, algae, disease
- ◆ Conch Reef Breaking Wave (Leichter et al. 2003. L&O)
- ◆ Deliver nutrients and change microscale temperature



Water Temperature - 4 meter grid spacing



nitrate (NO_3^-) and soluble reactive phosphate (SRP) from sample collected at irregular intervals, 1 m above the bottom on Conch Reef at 32-m depth

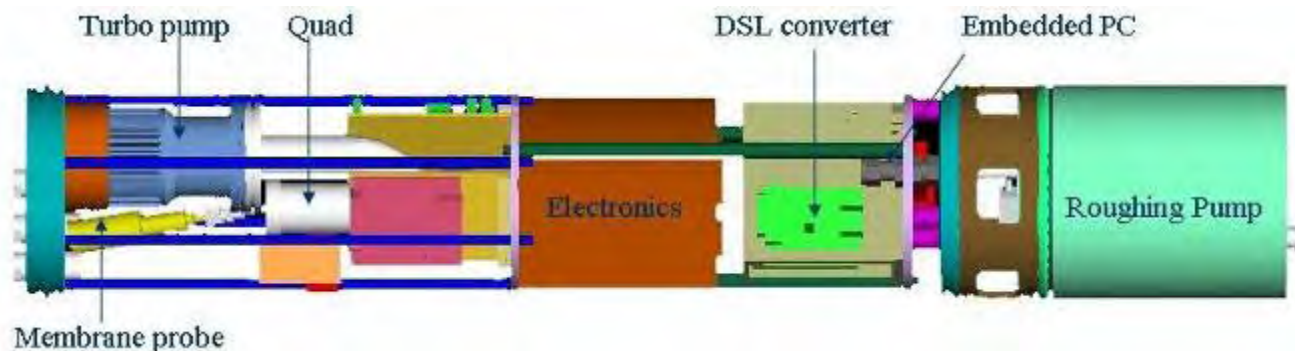


10-min T aver., 1-m above reef, 28 May–1 June 2000

SRI Underwater Mass Spectrometry

- AUV & ROV Configurations
- Dissolved Gases
- VOC
- Larger MW Compounds (PCBs, Pesticides, Drugs, Toxins)

Type	Linear quadrupole mass spectrometer
Mass range	200 amu
Inlet System	Membrane introduction system
Power consumption	85-90 Watts
Voltage of operation	24 VDC or 110 VAC
Deployment time	Configuration Dependent
Dimensions	∅ 19 cm (7.5")
	L 114 cm (45")
Weight	33 kg (72.7 Lb)
Depth	500 m
DSL tether range	1609 m (1 mile)



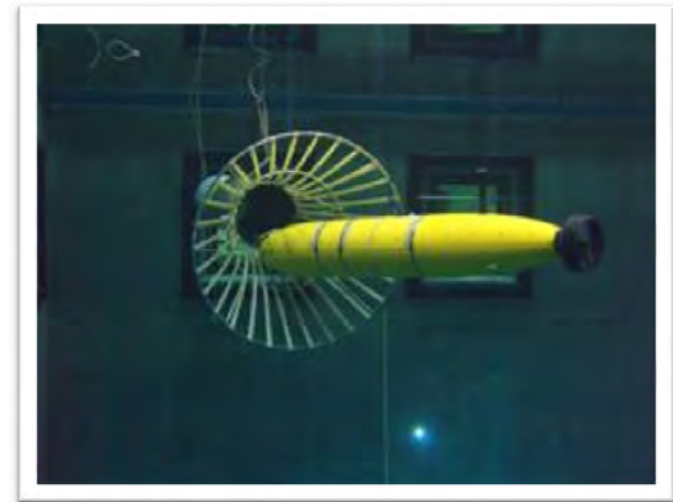
Assets & Costs

FL:

- ◆ USF/SRI Gliders (\$\$?)
- ◆ SRI MIPs-- AUV and ROV (\$\$?)
- ◆ FAU AUVs; docking station? (\$\$?)

Other:

- ◆ NURC/UNCW glider (\$2800/d)
- ◆ Coastal AUVs (>\$1000/d)
- ◆ C&C Tech- Hugin (\$95k/d)
- ◆ NIUST- Eagle Ray AUV, SeaBed AUV (\$10k/d)
- ◆ MARS (MBARI) docking station (n/a)
- ◆ Martha's Vineyard Coastal Observatory (MVCO) docking station (n/a)
- ◆ Hydroid's Remus-100m AUV/DS (\$370k)



Other AUV Resources

- ◆ <http://auvac.org>-- UW APL
- ◆ <http://ausi.org/>-- UNH
- ◆ <http://auvlab.mit.edu>
- ◆ https://oceanography.navy.mil/legacy/web/auv/auv_main.html
- ◆ <http://www.auvsi.org/>-- Assoc. for Unmanned Vehicles
- ◆ <http://rucool.marine.rutgers.edu/>