Towards a Synergistic Ocean Observing System in Monterey Bay

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Monterey Bay Aquarium Research Institute

MBARI

March 2011

Monterey Bay Aquarium Research Institute (MBARI)

MBARI founder David Packard:

"Send instruments to sea, not people.

Return information to shore, not samples"

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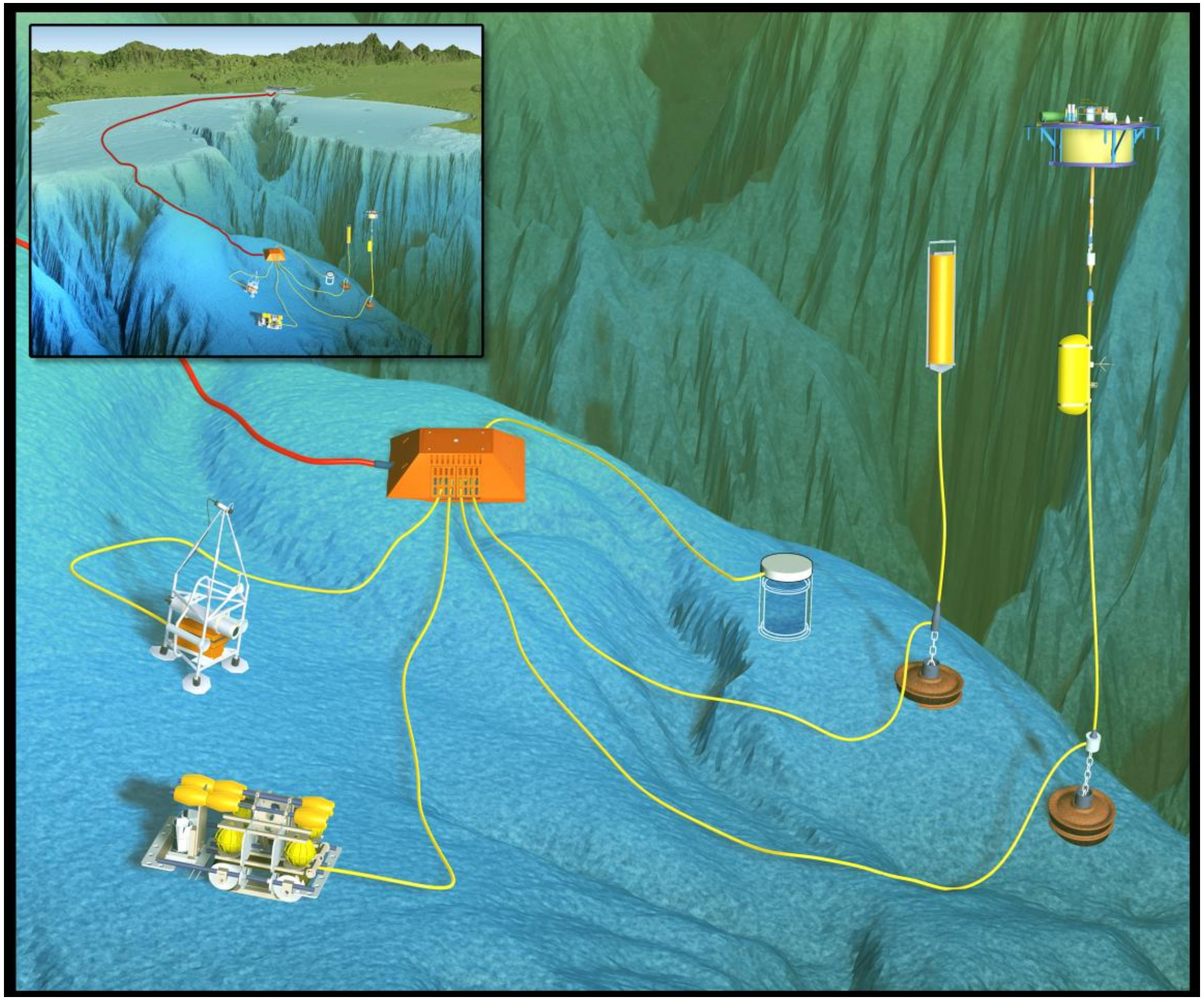
Outline

- Overview of the Monterey Accelerated Research System (MARS) ocean observatory
- Four representative science experiments on the MARS observatory
  - Monterey Ocean-Bottom Broadband (MOBB) Seismometer
  - Free-Ocean Carbon Dioxide Enrichment (FOCE) Experiment
  - Benthic Rover
  - Deep-Sea Environmental Sample Processor (ESP)
- Towards a synergistic ocean observing system
  - State-of-the-art of autonomous underwater vehicles (AUVs)
  - AUV docking
  - Adaptive sampling by an AUV
- Interoperability between U.S. and Chinese Ocean Observatories
- Conclusions and discussions

The Monterey Accelerated Research System (MARS) Ocean Observatory

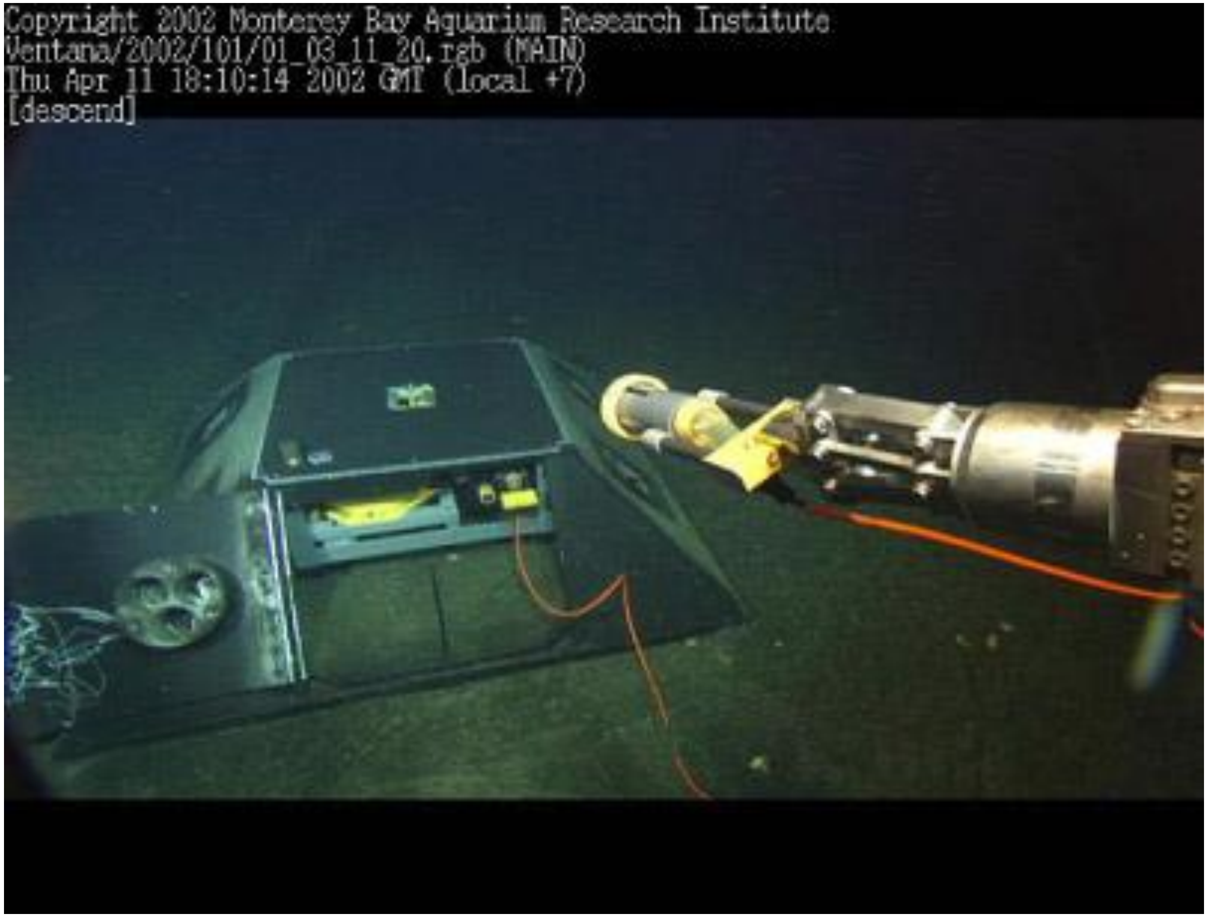


- Depth: 890 m. 52-km undersea cable.
- 37 km from MBARI.
- 8 ports: 9 kW power and 100 Mbps x 8 ethernet communications.
- Development cost:
  6 years (2002-2008), $13.5M.

MARS Workflow Process

- Proposal
- Design, test, re-design, re-test in lab
- Stage for pre-deployment test
- Test, modify as necessary, in MBARI's test tank
- Stage for deployment
- Deploy
- Operation
- Recover

Monterey Ocean-Bottom Broadband (MOBB) Seismometer
(installed in February 2009)



Chief Engineer: Paul McGill

- Monitoring seismicity in real time. No need to recover the seismometer. (*Traditionally, data can only be accessed when the seismometer has been recovered --- have to wait for several months.*)

- No longer limited by battery and hard drive capacities.

- Can easily reprogram the seismometer when needed.

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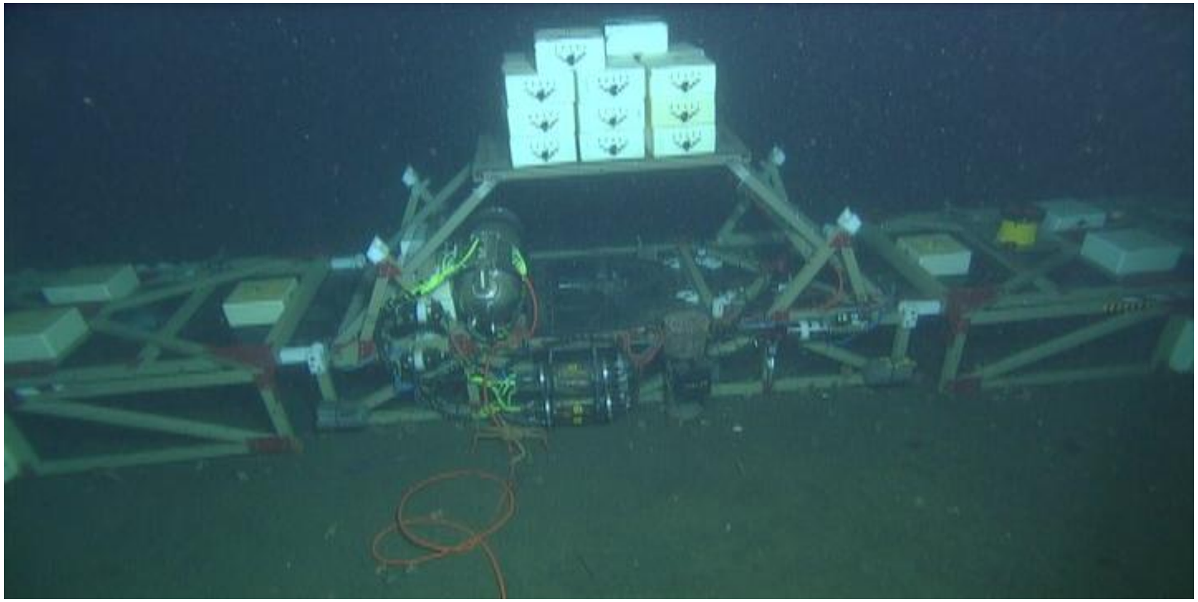
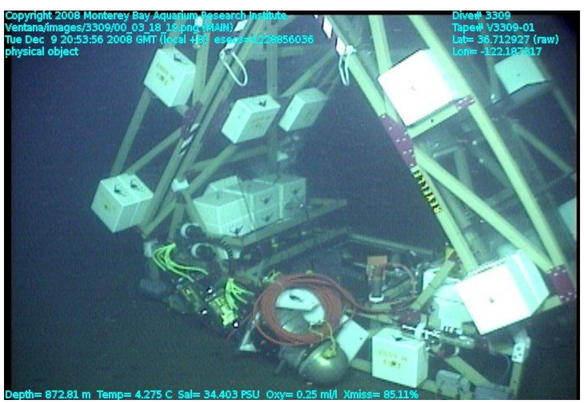
Free-Ocean Carbon Dioxide Enrichment (FOCE) Experiment

(installed in December 2008)



- Oceans absorb roughly 1/3 of all the CO_2 that humans release into the atmosphere, and thus become more acidic. This has significant effects on marine plants and animals.



Principal Investigator:
Dr. Peter Brewer

- FOCE on MARS is the first carefully controlled study of ocean acidification on deep-sea animals in their native habitat.

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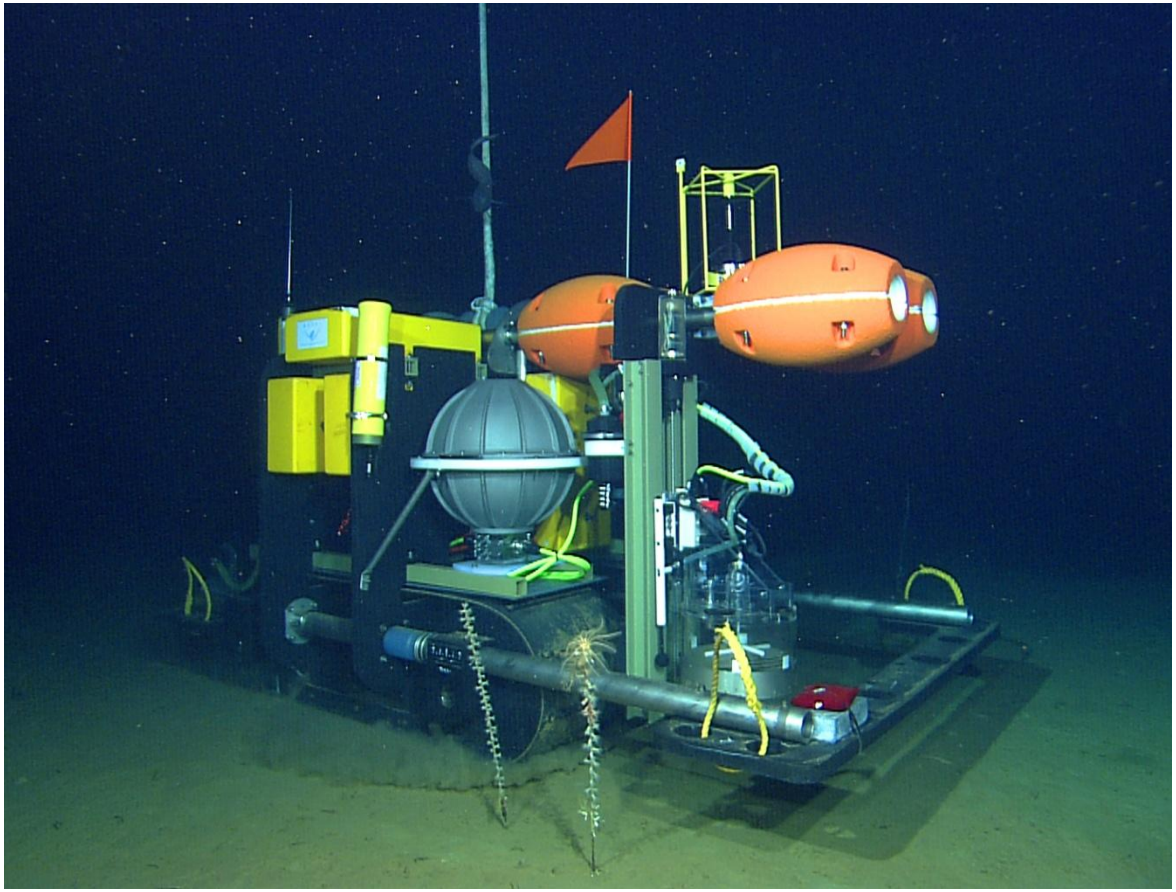
Benthic Rover
(installed in July 2009)



Principal Investigator: Dr. Ken Smith

- A mobile physiology lab for studying carbon cycling in the deep ocean.
- Performs long time series of measurements (e.g., oxygen) at the sediment interface at different locations, thus avoiding numerous separate expeditions and ROV dives.
- MARS' constant data link to shore greatly facilitates testing and refinement of the benthic rover.

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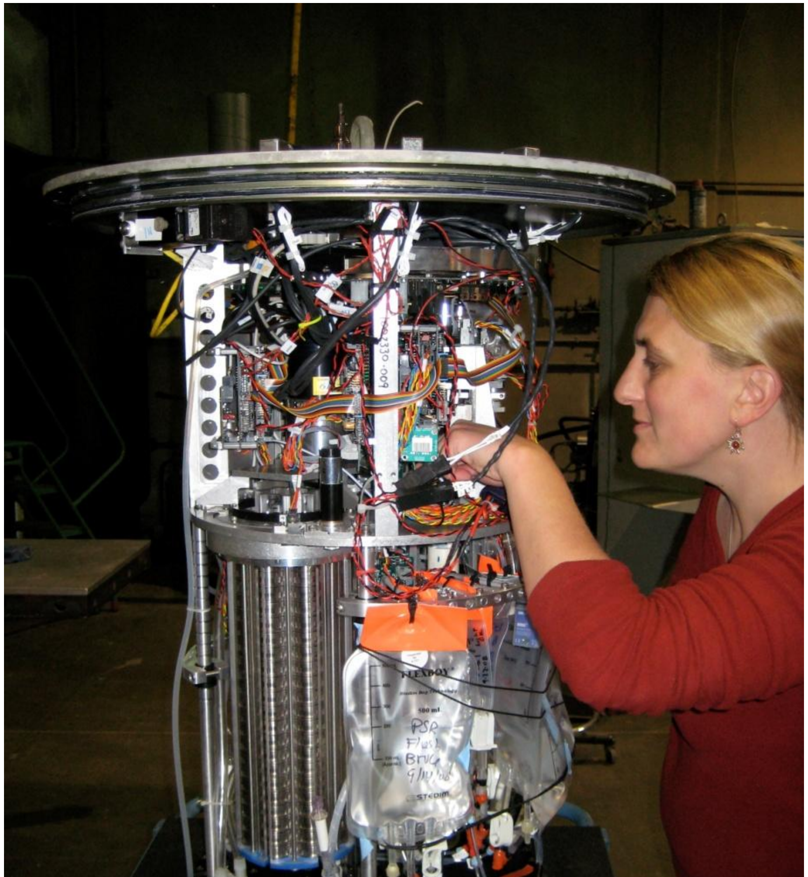
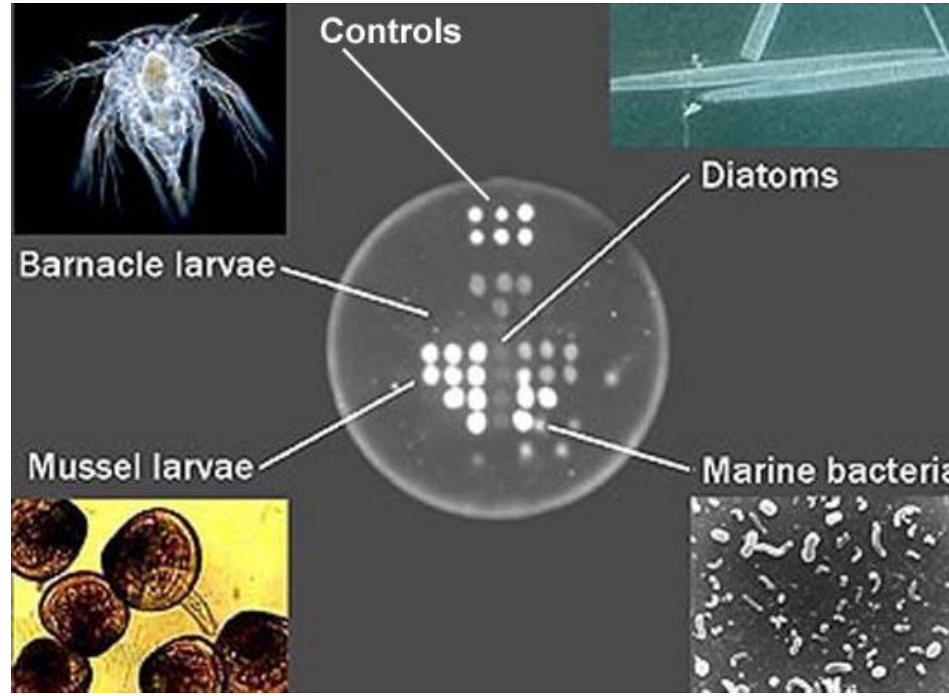
Deep-Sea Environmental Sample Processor (ESP)
(installed in September 2009)



Principal Investigator:
Dr. Christopher Scholin



- An automated molecular biology lab.
- ESP on MARS analyzes the sample as soon as it is collected and transmits the results back home without delay.
- Scientists can use other MARS sensors to decide when the ESP should take samples: adaptive sampling.

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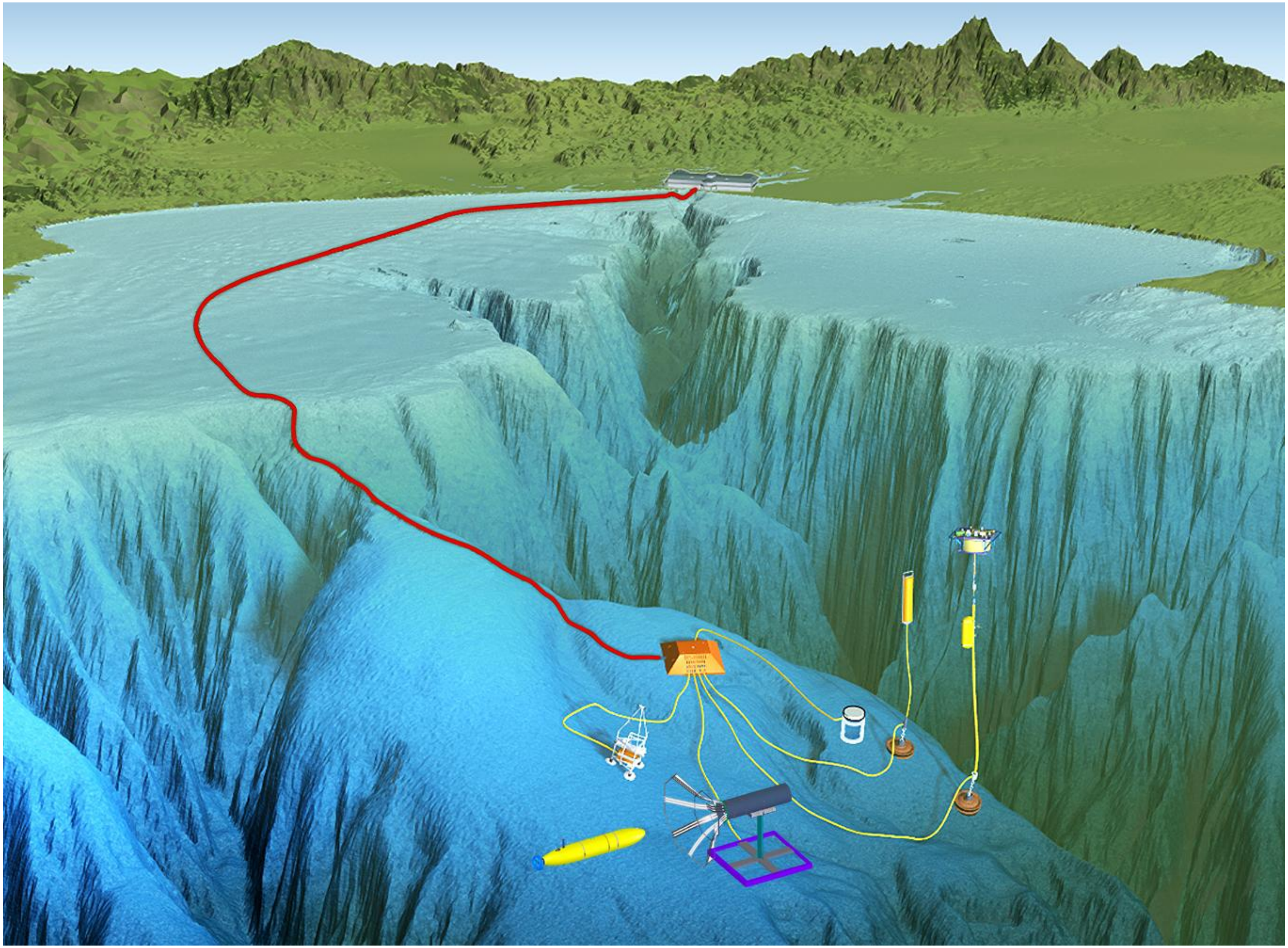
Towards Synergistic Ocean Observation: Observatory + AUVs



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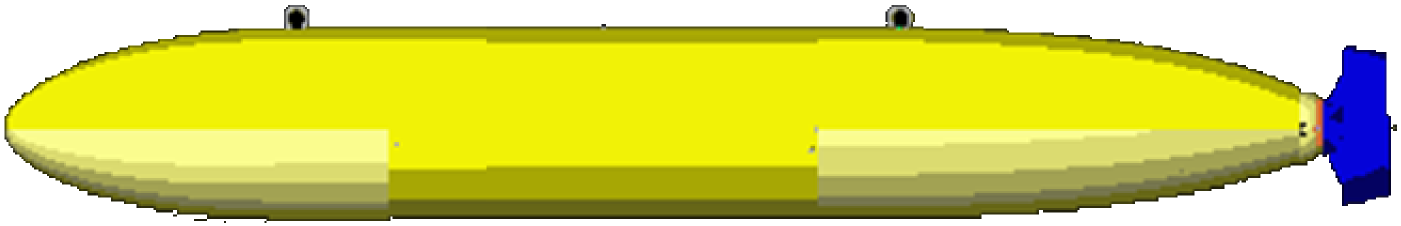
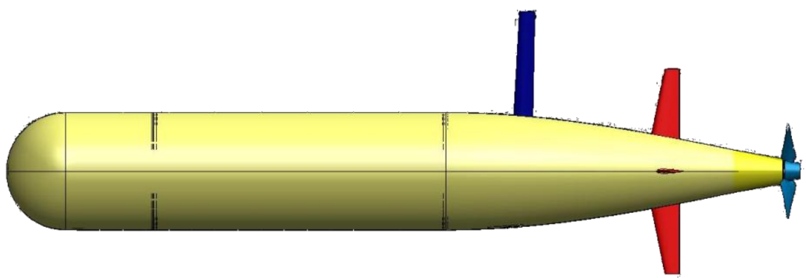
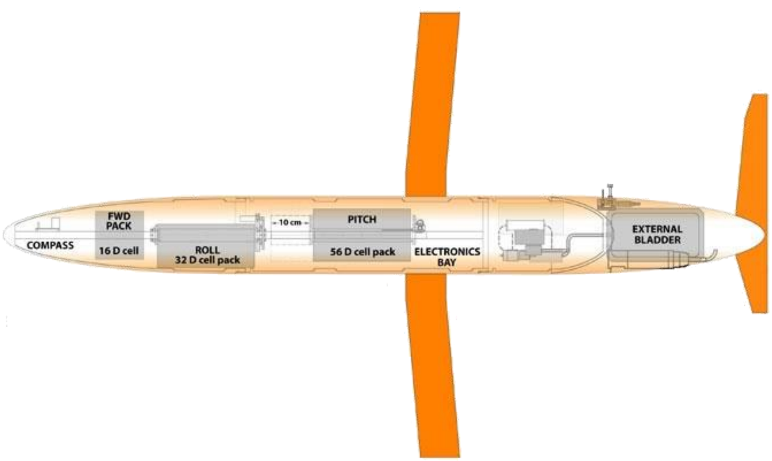
State-of-the-art of AUVs



MBARI Dorado
500 kg. 1.5 m/s.
Carries many sensors, but only lasts a day.



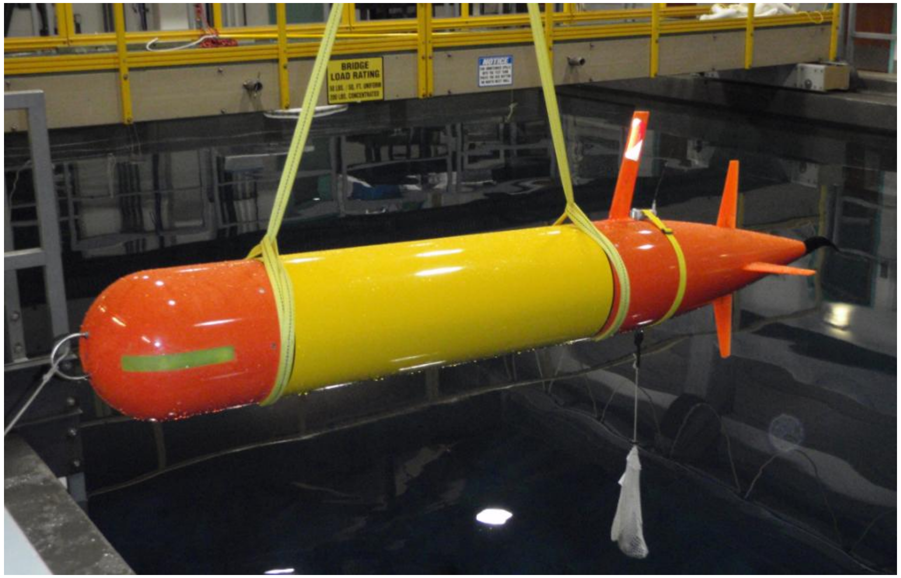
MBARI Tethys
110 kg. 0.5 m/s and 1 m/s.
Can run slowly for a long distance or faster for a shorter distance. Can wait in drifting mode until something interesting happens.



Scripps Spray (Russ Davis)
48 kg. 0.27 m/s.
Can run for months, but can only carry a few sensors, and goes quite slowly.

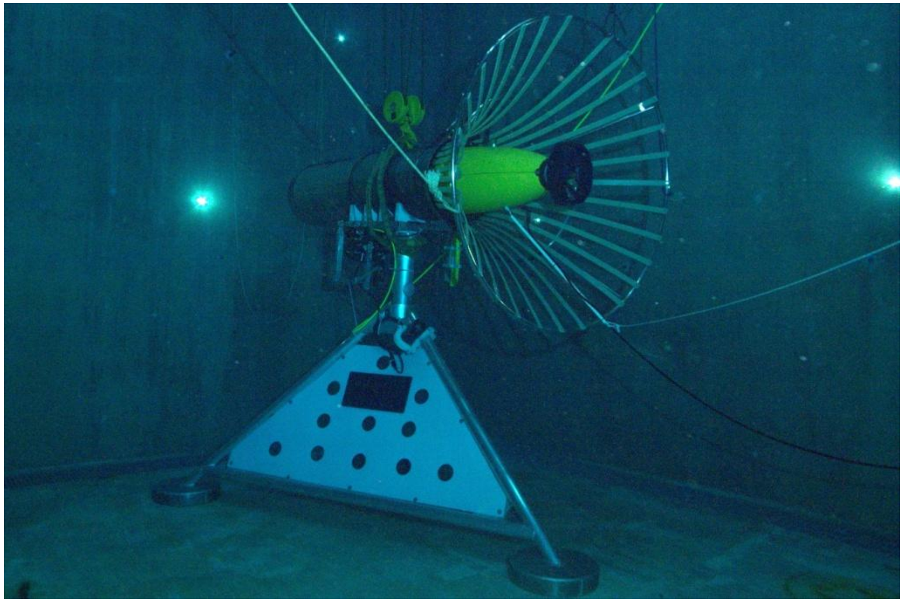
Bellingham

MBARI Tethys AUV



- Carrying 8 W sensors, at speed 1 m/s: range > 1000 km.
- With minimal sensors, at speed 0.5 m/s: range > 4000 km.
- Ability to trim to neutral buoyancy and drift.

AUV Docking



- Autonomous homing and docking
- Batteries recharge
- Data download
- Mission upload
- Vehicle sleep/wakeup
- Code modification & recompile

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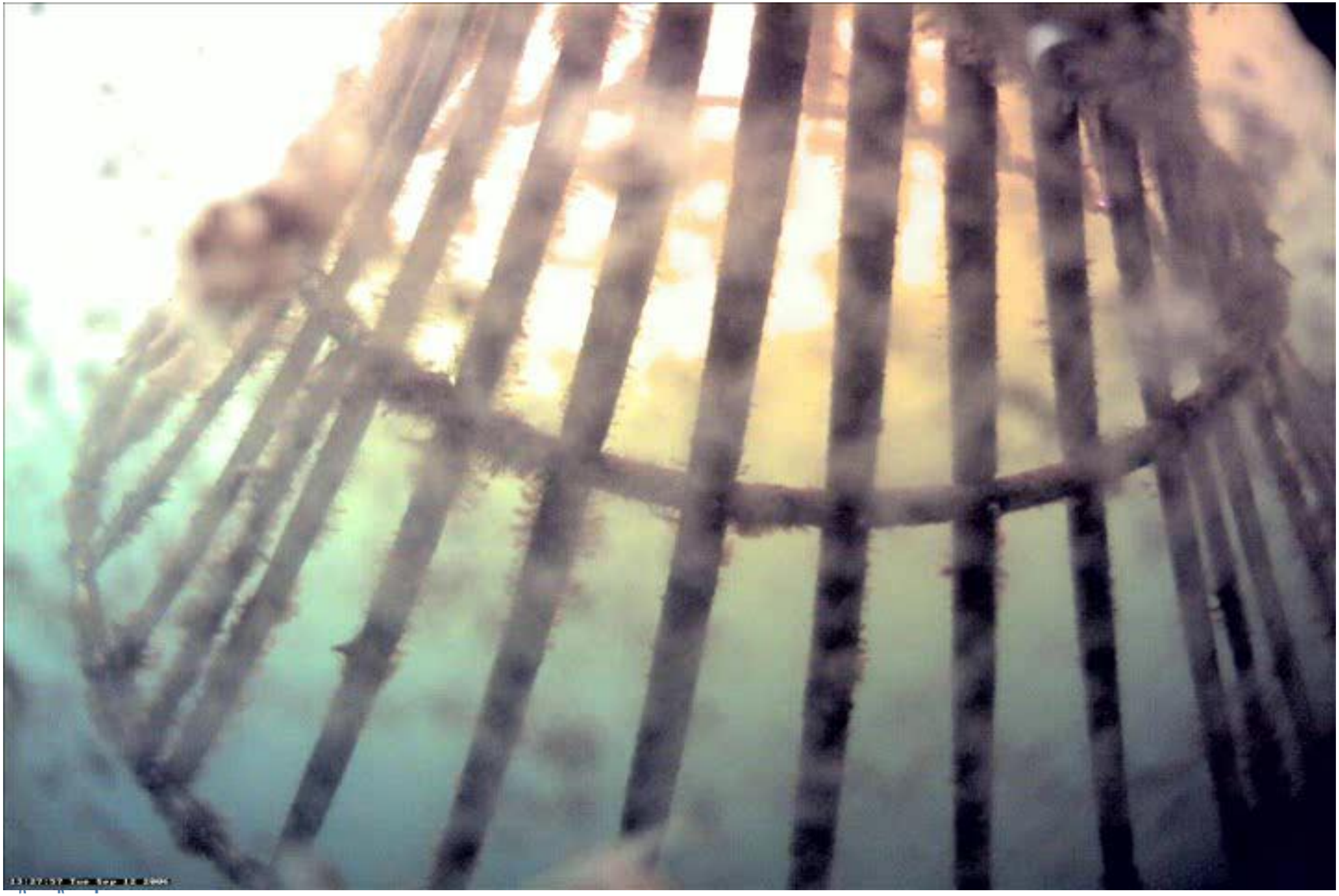
AUV Docking

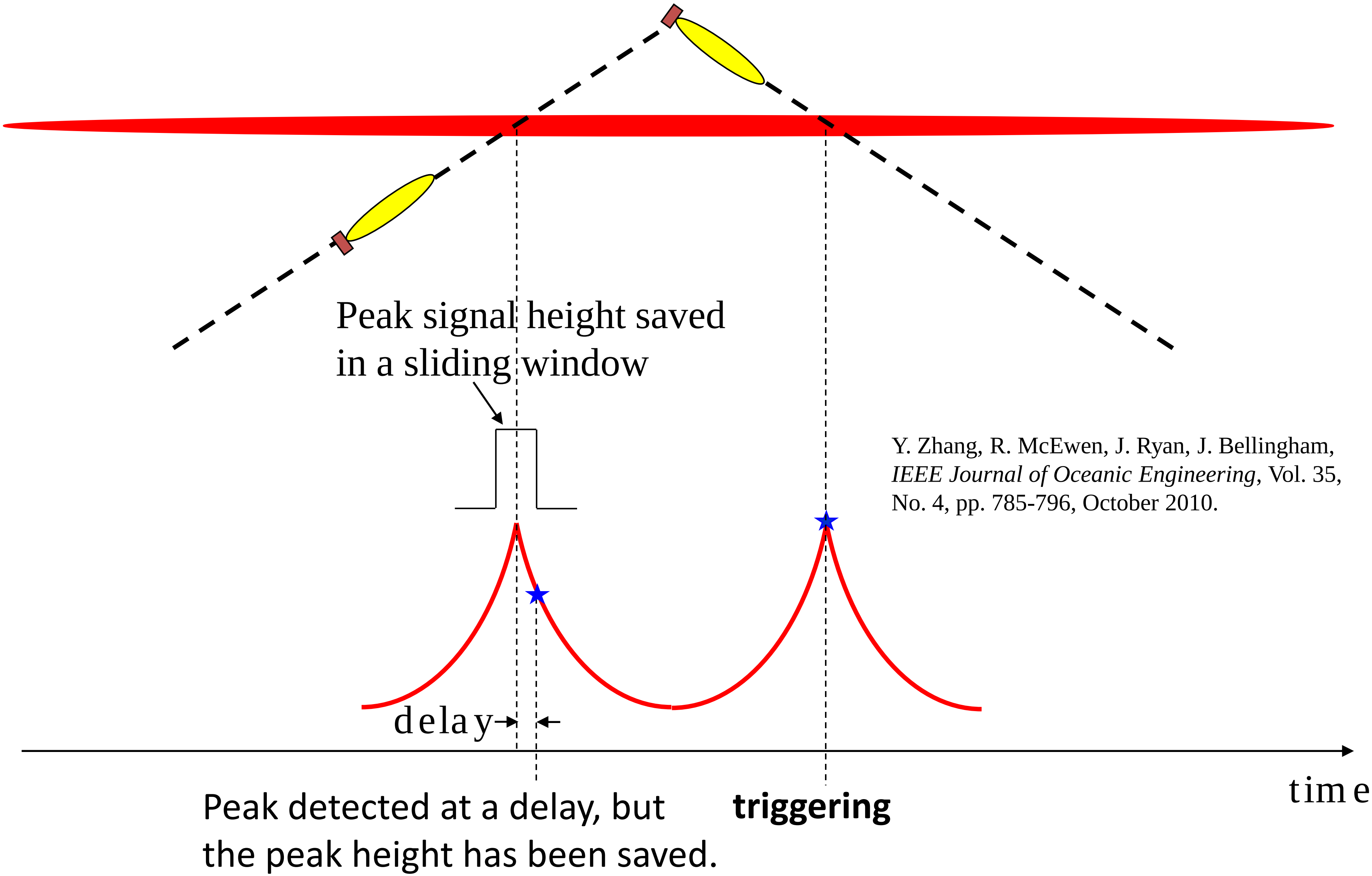


Bellingham, Hobson, McEwen, and McBride

Adaptive Sampling by an AUV

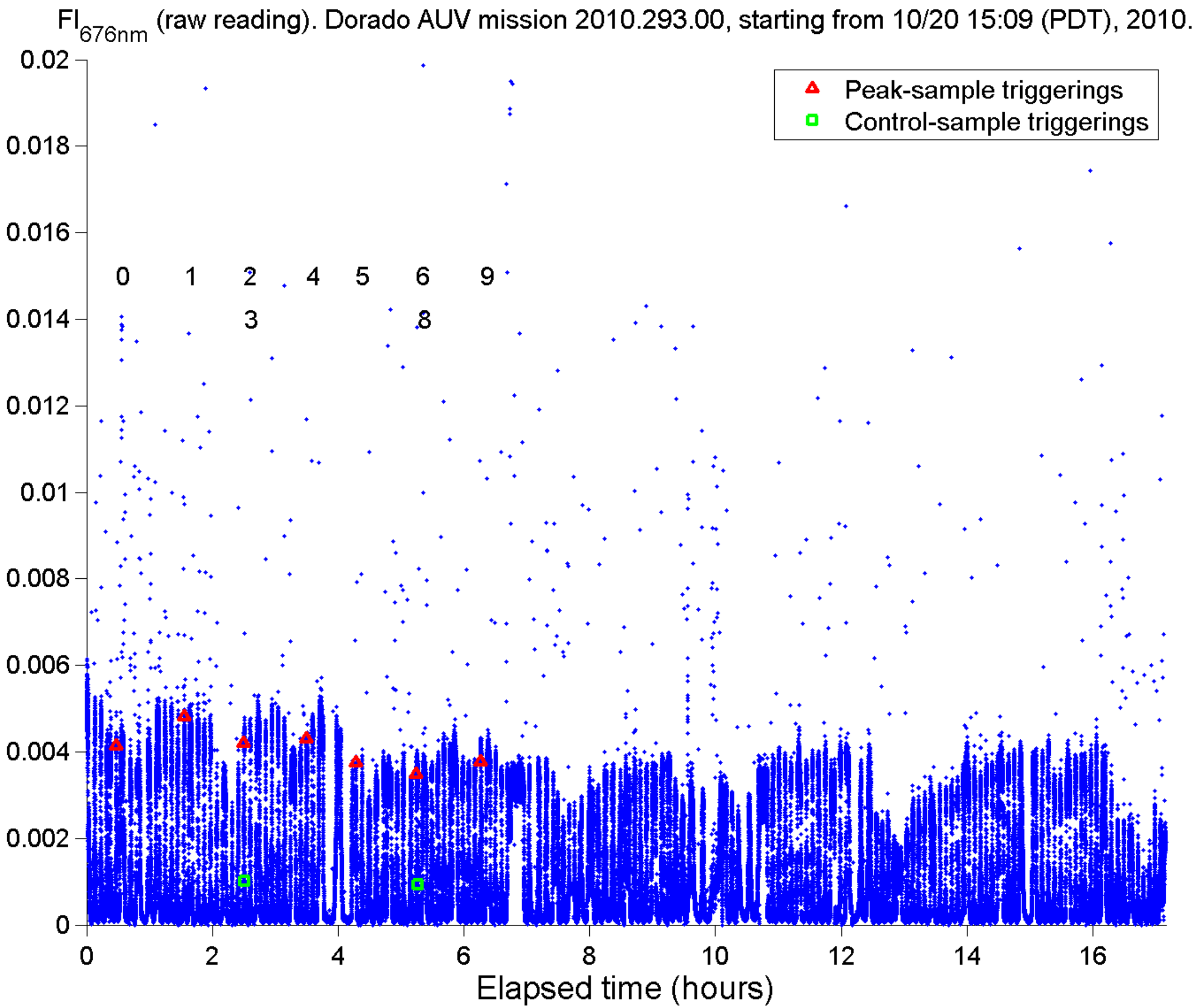
Courtesy of Larry Bird and Alana Sherman

An Adaptive Triggering Method for Capturing Peak Samples in a Thin Phytoplankton Layer by an AUV

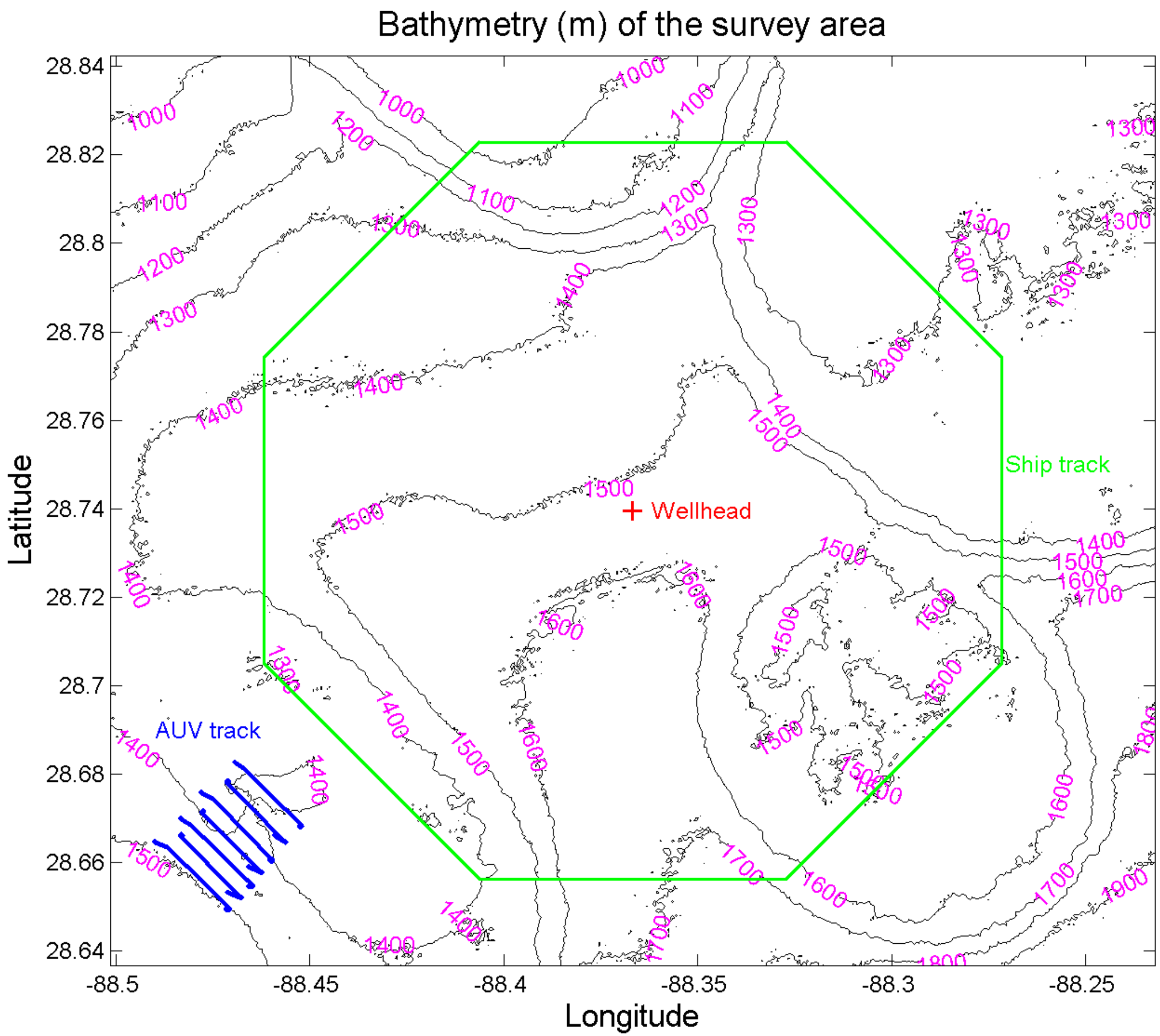


Y. Zhang, R. McEwen, J. Ryan, J. Bellingham,
IEEE Journal of Oceanic Engineering, Vol. 35,
No. 4, pp. 785-796, October 2010.

Peak-Capture Performance in an AUV Mission in BloomEx in October 2010



Gulf of Mexico Oil Spill Response Scientific Survey in 2010



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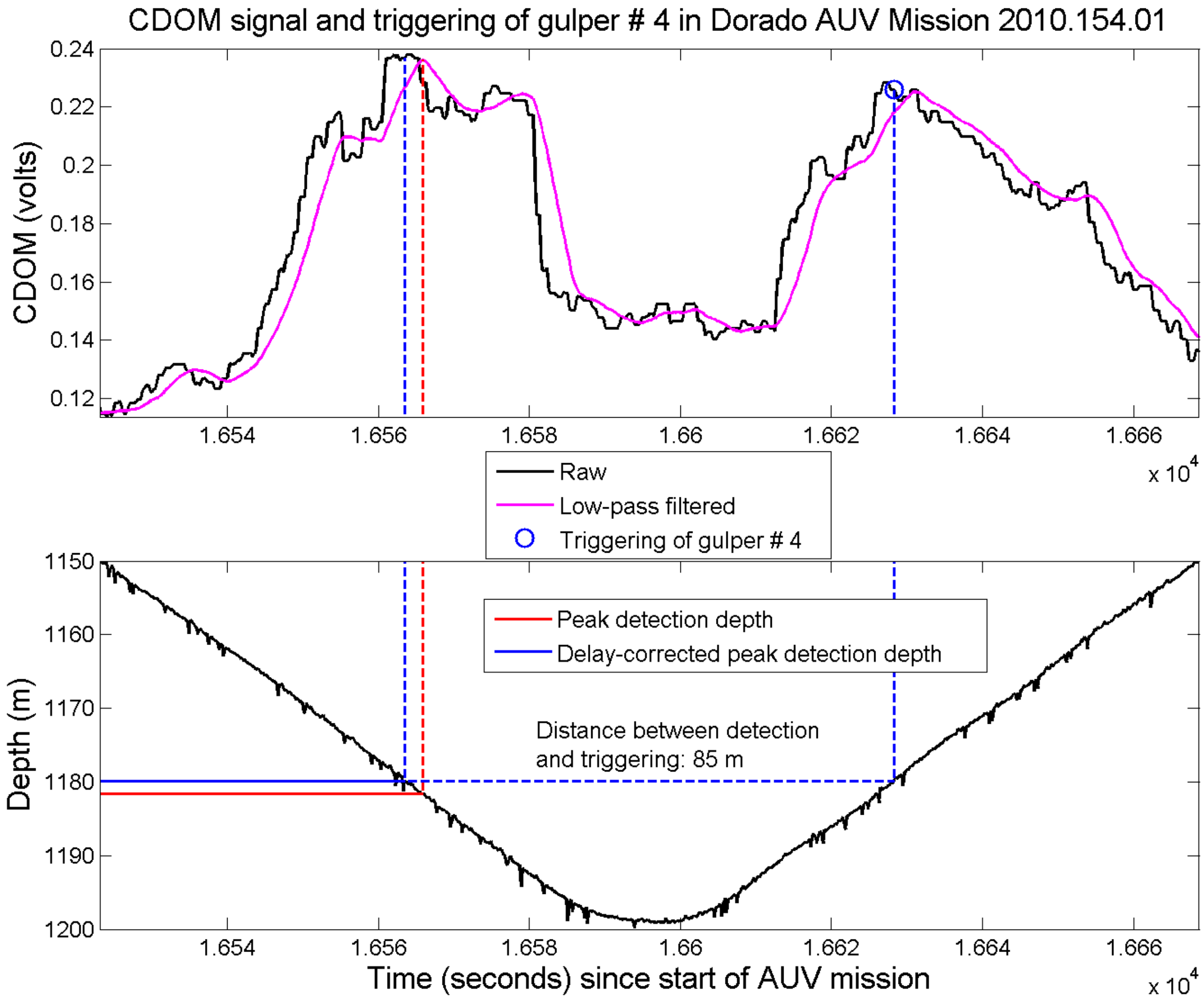
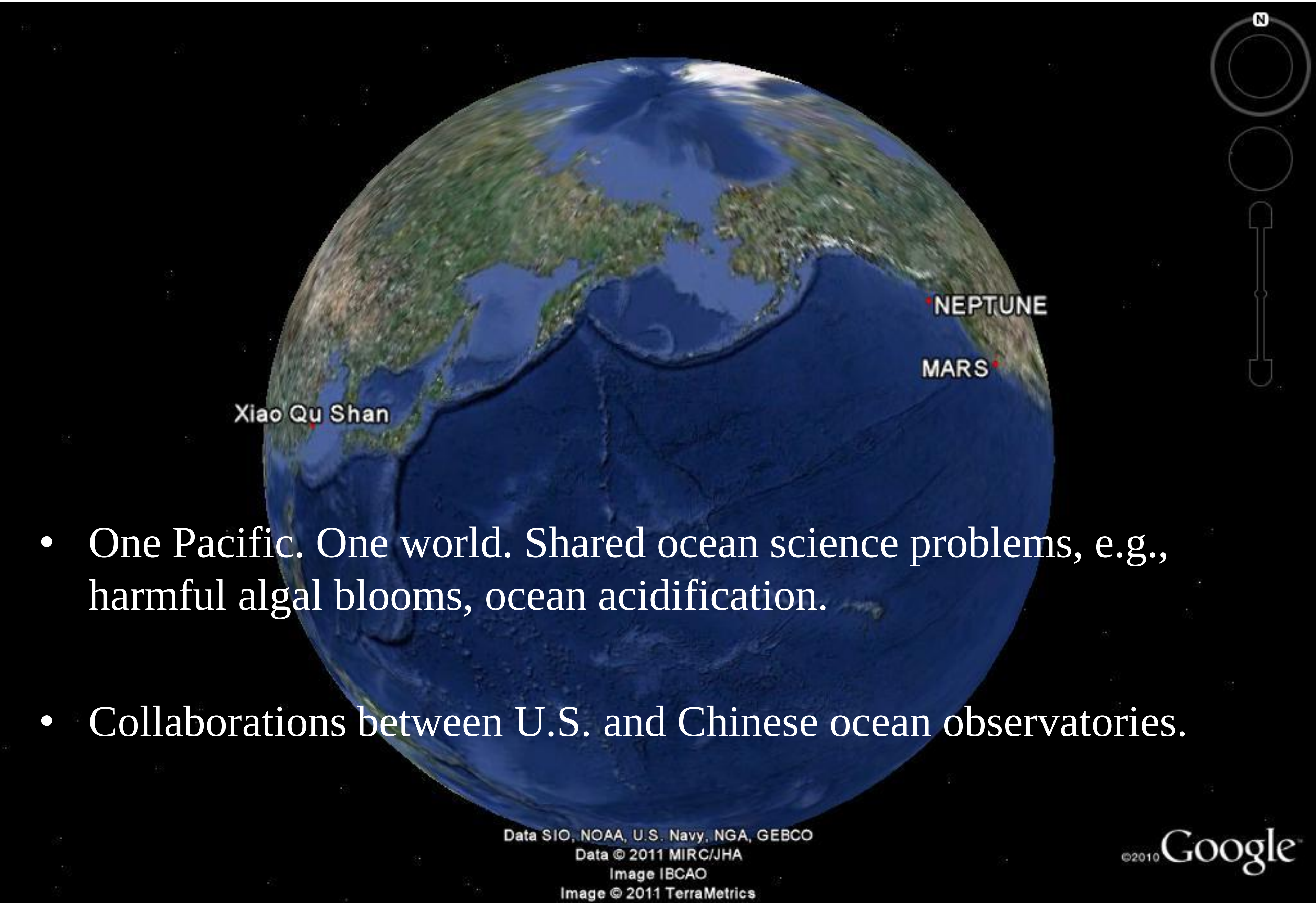


Y. Zhang, R. S. McEwen, J. P. Ryan, J. G. Bellingham, H. Thomas, C. H. Thompson, and E. Rienecker "A Peak-Capture Algorithm Used on an Autonomous Underwater Vehicle in the Gulf of Mexico Oil Spill Response Scientific Survey," *Journal of Field Robotics*, under review.

Interoperability between U.S. and Chinese Ocean Observatories



- One Pacific. One world. Shared ocean science problems, e.g., harmful algal blooms, ocean acidification.
- Collaborations between U.S. and Chinese ocean observatories.

Interoperability between U.S. and Chinese Ocean Observatories

- Compatibilities
  - Electrical, mechanical, communications, and data and meta data.
  - ROV tools, deployment, and recovery techniques.
  - Science and engineering workflow process.

- Chinese ocean science instruments to be installed on MARS in April 2011.

- Will U.S. instruments be installed on Chinese ocean observatories in East China Sea and South China Sea?

Conclusions and Discussions

- The MARS ocean observatory has so far hosted 11 science experiments (some completed and removed), and more coming …
- Key considerations in selecting the location of an ocean observatory:
  - Science value: what are the ocean features or events to observe or capture?
  - Logistic support: how far is it from shore base?
  - Risk from fishing activities.
- Synergistic ocean observation calls for collaborative use of fixed and moving platforms.
- Cultivating collaborative opportunities between U.S. and Chinese ocean observatories.