Moorings for Ocean Observatories: Continuous, Adaptive Profiling

Bruce M. Howe, Tim McGinnis, and Jason Gobat

Applied Physics Laboratory, University of Washington, Seattle, WA 98105-6698 USA

www.apl.washington.edu | howe, tmcginnis, jgobat@apl.washington.edu

http://alohamooring.apl.washington.edu

ABSTRACT

Present autonomous moored profilers often undersample the ocean and alias "high" frequency processes such as tides and internal waves because they are slow and have short missions and/or intermittent sampling schedules. To improve this situation, we are developing a mooring-profiler system to be attached to a cabled observatory node, thereby removing power as the major constraining factor. A profiler docking station with an inductive coupler will transfer power from the cabled node to a modified McLane moored profiler (MMP). This will permit near-continuous profiling (>90 % duty cycle) at 0.25 m s^{-1}. Further, two-way inductive communications will be used to offload profiler data at modest rates in real-time as well as transfer adaptive sampling commands. With sensors on the profiler and with dual sensors at fixed points top and bottom on the mooring, cross-calibration and overall robustness will be improved.

Secondary junction boxes on the subsurface float and on the seafloor will be ROV-serviceable. Arbitrary instrument packages can be added on the subsurface floats, such as acoustic instrumentation to remotely sense the ocean to the surface, and a winched profiling system to carry in-situ point sensors through the mixed layer to the surface. These secondary junction boxes will provide several hundred watts and 100 Mb/s Ethernet.

This mooring will be tested in late 2005 in Puget Sound and deployed on the MARS cabled observatory system in Monterey Bay, California in 900 m of water in late summer 2006 for 1 year. Input from potential users is welcome. These developments enable a wide range of new sensing modalities with moored profiler systems, one essential element (hybrid fixed-mobile sensor platform) of ocean observatory sensor network infrastructure.

OVERVIEW

Need for profiling moorings in ORION and ocean observatories

- Reduce temporal and spatial aliasing in the vertical sampling of the ocean (e.g., at tide and internal wave frequencies and space scales).
- Deliberately intensive sampling of fine vertical structure — Meddies/coherent eddies, biological thin layers, overflows, etc.
- Sampling of episodic or otherwise non-stationary flow
- Less expensive than many fixed instruments

User Requirements

- Current profiling for entire water column
- Real-time adaptive sampling capability
- Near continuous in-situ profiling from near surface to seafloor with $CTDO_2$, Acoustic Current Meter (ACM), bio-optics
  - 1 cycle per tidal half cycle
  - Non-stop run time > 3 days
  - Duty cycle > 90%
  - Depth range controllable
- Provide extra ROV-mateable Science User Connectors with "standard" power and data interface on float and seafloor

System Requirements

- Compatible with MARS/NEPTUNE/VENUS/ORION global buoys (and others) power and data interfaces
- Provide 48Vdc and 400Vdc power and 100BaseT communications at Science User Connectors; provide interface for RS-232 sensors at 12 V and 48V
- Timing (~ 1 ms)
- ROV-serviceable secondary junction boxes and connections
- Operational life of > 2 years
- Located 1.5 km from MARS node to allow ROV access to MARS node and other instruments

Software

- Build on a simplified version of NEPTUNE/MARS power management and control system (PMACS)
- Will interface with University of Hawaii live action server
- While on MARS will contribute to LOOKING prototype ocean observatory cyberinfrastructure development
- Will use ROADNET DMAS services

Mooring Deployment

- Use dynamically positioned ship and ROV, 2 days
- Special winch
- Anchor first
- Attach titanium post at mooring top, above swivel
- Slide slotted buoy onto post, fasten, test, lower
- Connect mooring to seafloor secondary junction box with ROV
- Connect sensor package at base of mooring

Operations and Maintenance

- Expect two 2-day visits per year with ROV for instrument calibration/change-out (assuming ROV replaceable profiler);
- Basic mooring should last 10 years
- Learn to use real-time data and adaptive sampling capability (science part of project)

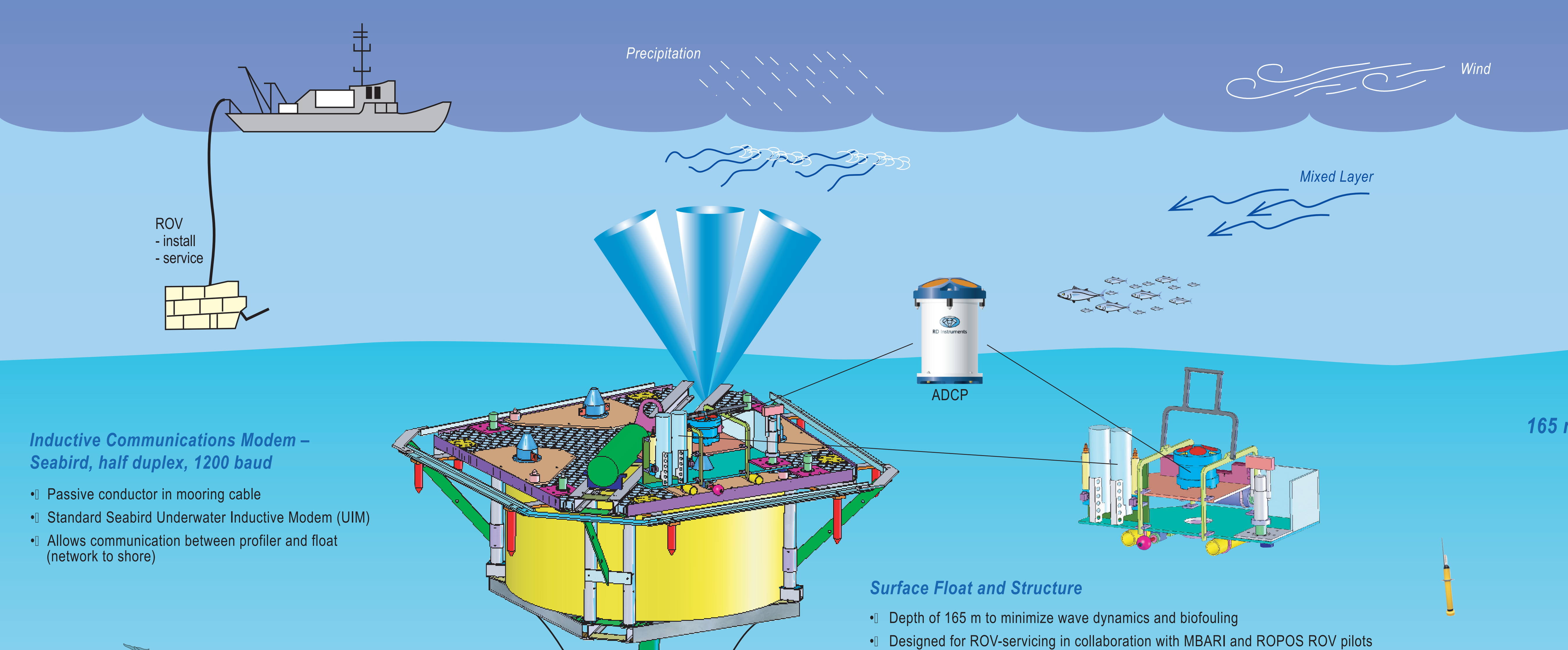
FUTURE DEVELOPMENTS

- Increase real-time inductive modem data rate; make full duplex
- High(er) rate inductive (or other) communications at every docking
- Make all active components ROV serviceable, especially the profiler
- Increase profiler speed to > 0.4 m s^{-1} to reduce tidal aliasing over full ocean depth
- Increase the profiler payload capacity — weight, volume, energy storage
- Improve inductive power coupler efficiency and robustness
- Modify profiler so it can dock top and bottom and have multiple profilers on a mooring
- Interface shallow winch systems on the subsurface float, extending the observatory infrastructure to the surface
- Develop energy storage capability on mooring/seafloor to accommodate high peak loads (or autonomous operation)
- Add an acoustic modem to profiler and/or float; use for local communications, mooring and mobile platform navigation, and tomography with bottom transponders and remote sources
- Interface many others sensors, including video
- Deal with biofouling issues
- Conduct extensive testing to improve survivability and reliability, while reducing cost
- Improve energy efficiency of profiler (include buoyancy engine, streamlining, etc.)
- Extend 1μs precise timing to subsurface float (presently limited by single fiber swivel, lack of CWDM in-line package)

Acknowledgments

This work is funded by the National Science Foundation Grant OCE-0330082 "Sensors: Collaborative Research: ALOHA Mooring Sensor Network and Adaptive Sampling", with co-PIs Emmanuel Boss and Roger Lukas.

The on-going interaction with engineers from the Monterey Bay Aquarium Research Institute (MBARI), the Canadian Scientific Submersible Facility (CSSF, ROPOS), and the Woods Hole Oceanographic Institution is greatly appreciated.



Inductive Communications Modem – Seabird, half duplex, 1200 baud

- Passive conductor in mooring cable
- Standard Seabird Underwater Inductive Modem (UIM)
- Allows communication between profiler and float (network to shore)

Surface Float and Structure

- Depth of 165 m to minimize wave dynamics and biofouling
- Designed for ROV-servicing in collaboration with MBARI and ROPOS ROV pilots
- Non-corrosive materials (plastic, titanium; easily made with water jet cutting)
- Secondary junction box, 2 extra guest ports
- Standard Seabird Surface Inductive Modem (SIM)
- SIIM with sensors (dual $CTDO_2$, 1 BBF2, ADCP)
- Float structure slotted to engage titanium post at top of mooring cable
- Swivel/slip rings beneath float (single fiber, 12 conductor)
- ROV-mountable instrument module allows MBARI ROV ro easily carry, attach and connect sensor package

Modified Mooring Profiler

- Add inductive power transfer
- Rechargeable Smart-Li-Ion batteries, 90% duty cycle (4 days on, 4 hr charge)
- Add inductive communications
- Add controller
- New drive wheel for larger EOM cable (~21 mm), keep 0.25 m s^{-1} speed
- Sensors: Seabird $CTDO_2$, FSI Acoustic Current Meter (ACM), WetLabs Red/Blue Backscatter and Fluorometer (BB2F)

Inductive Power Coupler/Dock

- S&K Engineering
- 300 W (75% efficient with 2 mm gap)
- Operates at 10 kHz
- Docking has proximity switch, compliance

Mooring Cable

- 21-mm diameter cross section
- Kevlar (24,000 lb breaking strength, peak load 4000 lb, elongation < 0.5% at peak load)
- Braid fishbite protection, 70% coverge, 0.25 mm 304 SS wire
- 4 optical fibers in 2 mm steel tube (use 1)
- 4 power conductors each (18 AWG)
- 450 W available at float (325 W charging, 60 W hotel, 15 W sensors, 50 W guests)
- 2 passive conductors (18 AWG) for inductive modem, cable voltage measurement/spare (sea grounds at each end)
- 330 lb/1000ft in air, 92 lb/1000 ft in water

ACM

Science Instrument Interface Module (SIIM) / Multiplexer

- On subsurface float and seafloor/mooring base
- Connects all instruments together (dry mate), then 1 wet-mate connector to 2ndary junction box
- Simplified versions of secondary node, no controller
- Uses small industrial 100 Mb/s 8-port Ethernet switch
- Uses serial/Ethernet device server hardwired to ports as needed
- Switched power through device server using Web interface
- 48 – 12 V conversion
- Video server (Web cam)

Sensors

- Seabird 52MP/43F pumped $CTDO_2$ (2 each on subsurface float and base of mooring, 1 on MMP)
- WetLabs BB2F optical backscattering at 470 nm and 700 nm, and chlorophyll fluorescence within the same volume (1 each location)
- Falmouth Scientific 2-axis Acoustic Current Meter (1 on MMP)
- RD Instruments Workhorse Sentinel 150 kHz ADCP on subsurface float
- Color camera (with video server to make it a web cam), on subsurface float looking at MMP docking

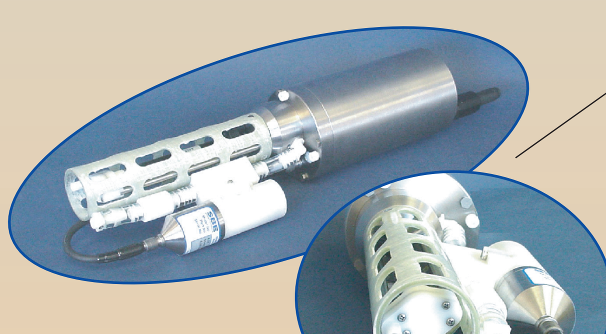
BB2F

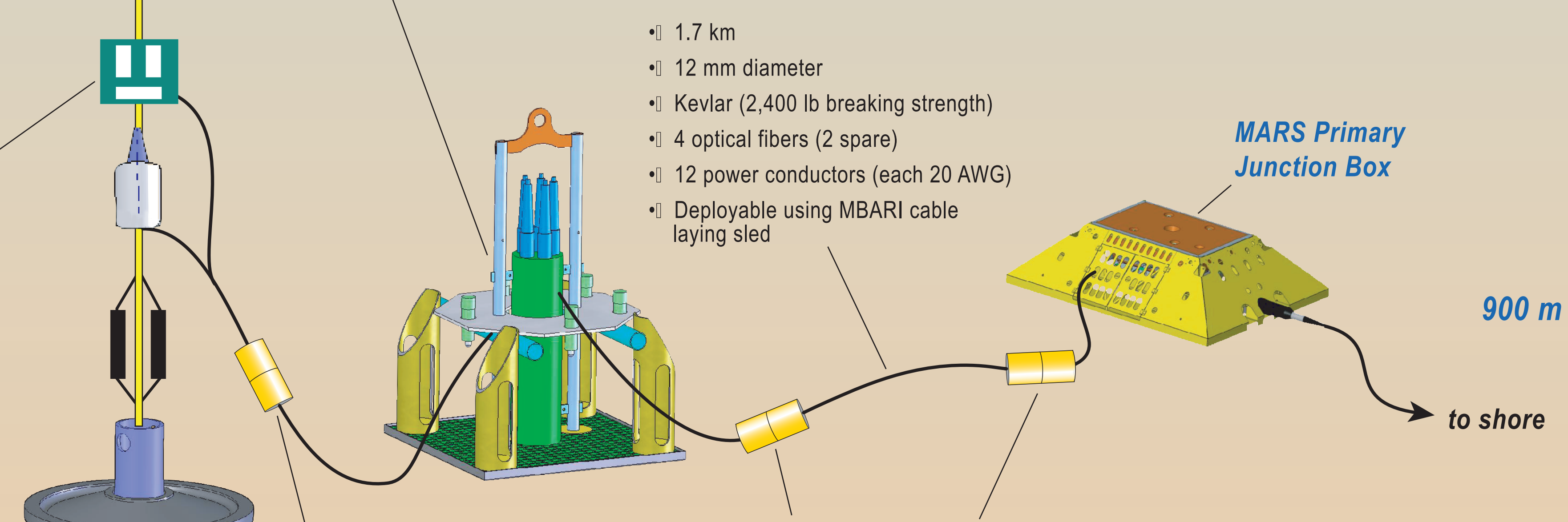
Secondary Junction Boxes (on subsurface float and seafloor)

- Simplified versions of primary nodes – same nominal interface, reduced capability
- Uses small industrial 100 Mb/s 8-port Ethernet switch
- Load control – switching, current monitoring, ground fault
- Will provide 400 – 48 V conversion (several hundred watts)
- 400 V can be fed in from any port (to facilitate testing on shore, deployment, using supplemental energy storage, mesh structure, etc)
- 4 ROV-mateable connectors ports
- Pressure case – titanium
- 200 W available at seafloor (60 W hotel, 15 W sensors, 125 W guests)

Seafloor Cable

- 1.7 km
- 12 mm diameter
- Kevlar (2,400 lb breaking strength)
- 4 optical fibers (2 spare)
- 12 power conductors (each 20 AWG)
- Deployable using MBARI cable laying sled





In-Line Media Converters

- Use for seafloor cable and mooring cable
- Ethernet to optical, uses bi-directional 1310 and 1550 nm wavelengths on single fiber
- Use second fiber for precise timing signal (seafloor only)