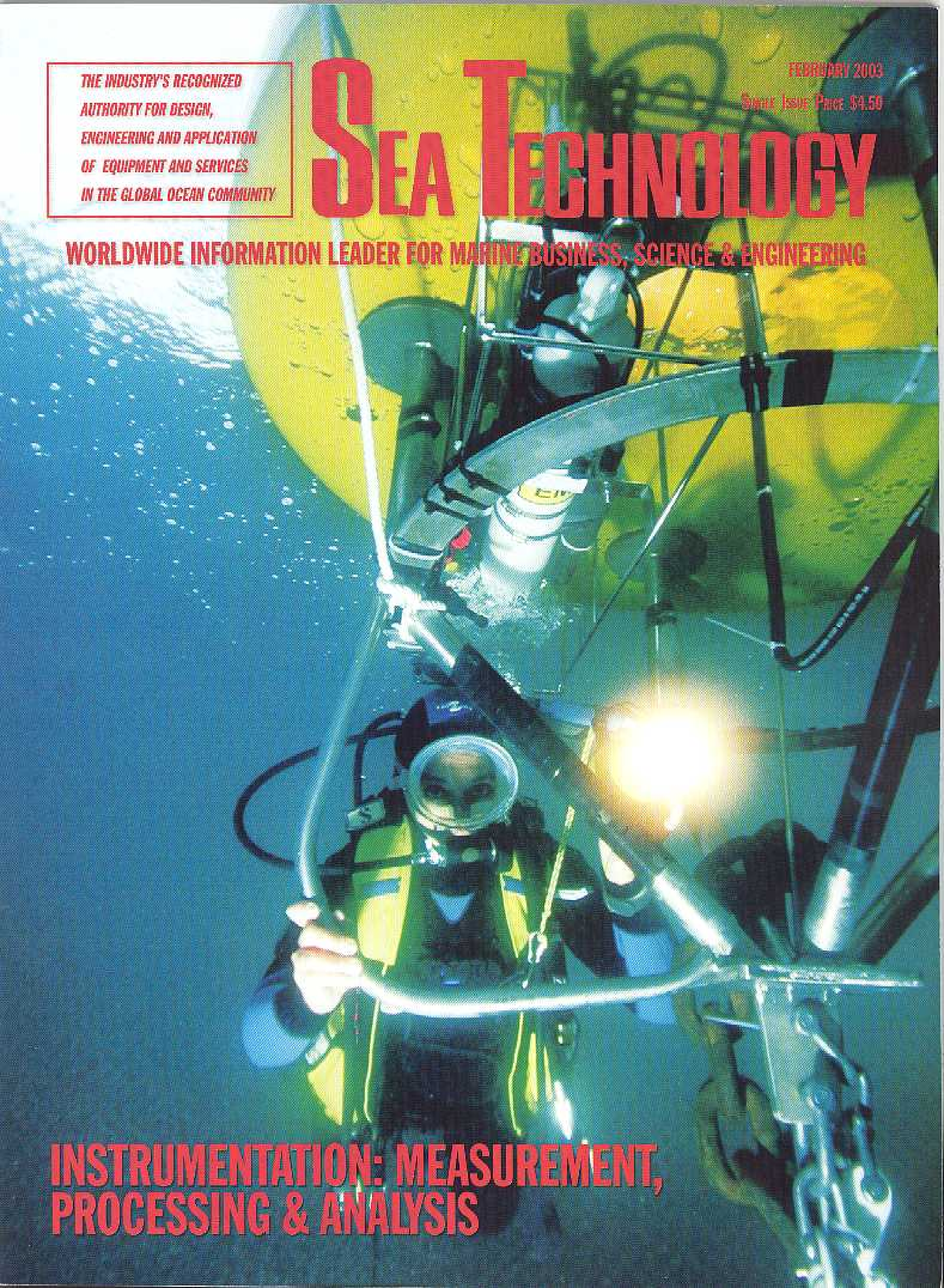

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INSTRUMENTATION: MEASUREMENT, PROCESSING & ANALYSIS

The Evolution of a Coastal Mooring System

A Simple Current Meter Mooring is Transformed into a Complete 'Air-Sea Interaction' Monitoring System in the Gulf of Mexico

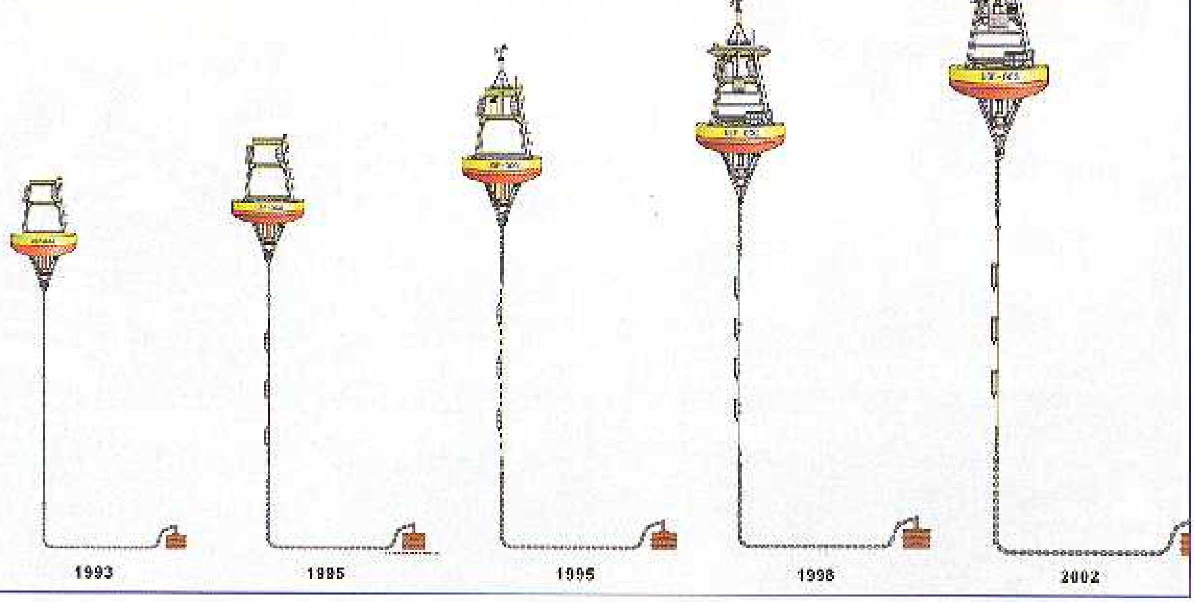
By R. Cole
Oceanographic/Diving Operations Manager, OCG
Dr. R. Weisberg
Professor, OCG
J. Donovan
Programmer/Analyst, OCG
C. Merz
Program Director, COMPS
R. Russell
Electronics Engineer, COT
V. Subramanian
Data Manager, COMPS
and
Dr. M. Luther
Associate Professor, OMPL
College of Marine Science
University of South Florida
St. Petersburg, Florida

The University of South Florida (USF), College of Marine Science (CMS), Ocean Circulation Group's (OCG) coastal mooring program is a component of an evolving coastal ocean observing system for the West Florida Continental Shelf (WFS). CMS-OCG buoys, along with other platforms, provide meteorological and oceanographic observations in support of a variety of coastal ocean programs. Data acquisition has migrated from internally recording instruments for currents, temperature and conductivity to more complete, real-time, air-sea interaction data streams using the National Oceanic and Atmospheric Administration's (NOAA) Geostationary Operational Environmental Satellite (GOES) system.

Data from these coastal moorings are available on the Internet for use by local and state emergency managers and federal agencies for marine weather forecasts, search and rescue operations, and emergency planning. These data also support scientific investigations, including WFS physical and biological models, and they also serve the recreational boating community. The overall scientific goal is to improve our understanding of how physical processes affect property distributions on the WFS.

The USF-CMS-OCG, under the direction of Robert Weisberg, professor of physical oceanography, started as a predominately blue-water group that employed both subsurface and surface moorings in scientific studies

OCG Coastal Mooring Systems, 1993-2002. 1993: Pilot ADCP surface buoy with an all-chain mooring; 1995: Middle mooring of wire rope added with self-recording temperature and conductivity instruments attached; 1995: Meteorological sensors added to the tower to measure atmospheric conditions; 1998: Incorporating the broadband Workhorse ADCP; 2002: Complete air-sea interaction mooring system with near-real time telemetry.



of the equatorial Atlantic and Pacific oceans. Our WFS applications began in the early 1990s in cooperation with the newly established United States Geological Survey (USGS) Center for Coastal Geology in St. Petersburg, Florida.

A pilot mooring was deployed in October 1993 consisting of a foam buoy for surface flotation secured by chain to an anchor composed of railroad wheels. Deployment was on the 50-meter isobath for a duration of 16 months. Instrumentation consisted of an RD Instruments acoustic Doppler current profiler (ADCP) for currents and a SeaBird Electronics SBE-16 SeaCat for temperature and conductivity.

Lacking prior experience in shallow water mooring design, we benefited from a trip to NOAA's National Data Buoy Center (NDBC), whose personnel kindly provided design assistance for this first application.

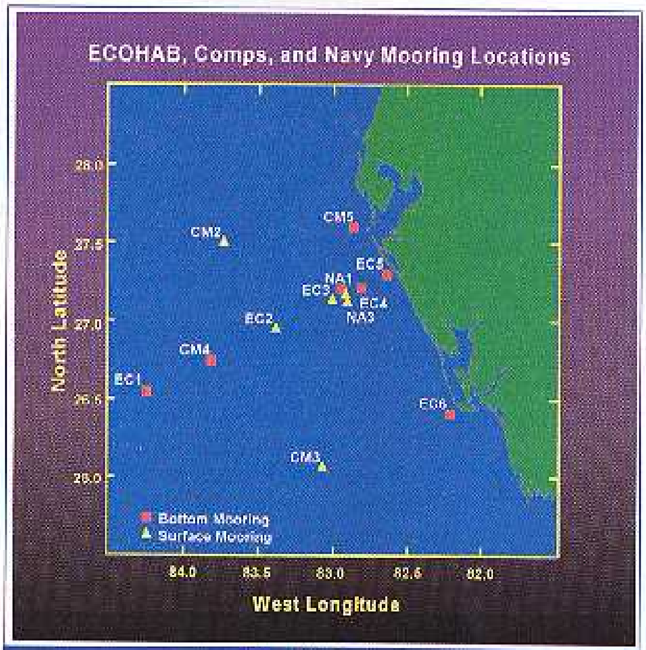
Our USGS cooperative study was expanded upon in 1995 with support from the Office of Naval Research (ONR), which allowed us to deploy a trans-shelf array of five surface or subsurface moorings between the 30-meter and 300-meter isobaths for approximately one year. This was followed by a Minerals Management Service (MMS)-sponsored mooring at mid-shelf for an additional two years. With the exception of the second year of the MMS mooring, our data returns were nearly 100 percent.

Motivated by coastal flooding due to an extra-tropical storm in 1993 and tropical storm Josephine in 1995, USF initiated a Coastal Ocean Modeling and Prediction System (COMPS) with added state of Florida support. COMPS consists of a real-time array of both offshore buoy and coastal stations, the responsibility of which is shared between Dr. Weisberg and Dr. Mark Luther, respectively. COMPS also imports all other available real-time data from systems maintained by federal, state and local agencies, and provides these on the Internet at http://comps.marine.usf.edu.

Despite its oligotrophic description, the WFS ecology is diverse and productive, supporting strong recreational and commercial fisheries and subject to disruptive blooms of *K. brevis* red tide. Given these scientifically interesting phenomena and the backbone of measurements provided by COMPS, we were successful in establishing multidisciplinary programs of study for the WFS under the NOAA Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) and the ONR Hyperspectral Color Ocean Dynamics Experiment (HyCODE) programs. The combined ECOHAB-HyCODE-COMPS (EHC) array was implemented beginning in July 1998, and several elements are being maintained presently.

Our most recently added element came through a cooperative effort with the Pasco County Office of Emergency Preparedness through the Florida Department of Community Affairs (DCA). The Florida Fish and Wildlife Commission has also played a part in our evolving support.

At its peak, the EHC array consisted of six surface and eight subsurface moorings with downward- or upward-looking ADCPs, respectively. Each mooring also contained some instrumentation for temperature and conductivity, and several of the surface buoys were equipped with meteorological sensors.



The EHC array.

Buoy Design

Surface buoys for oceanographic applications exist with many designs and materials. We needed a cost-effective, relatively small structure sufficient to house oceanographic as well as meteorological instruments. We opted for a Surlyn® foam modified discus float manufactured by the Gilman Corp. Buoys originally put in use a decade ago still remain serviceable.

The buoys are fashioned after the 2.4-meter discus buoys used by NDBC. The hull is approximately three meters in diameter and is referred to as a three-meter discus with a bottom chine cut for reduced wave response. The structural hardware design had to accommodate the ADCP transducer configuration in the bridle below and a tower with enough space to accommodate meteorological instrumentation above.

The four-legged bridle is constructed of 316 non-magnetic stainless steel, and the tower (also four-legged) is constructed of 6061-T6 aluminum. The tower and bridle are connected through four penetration points symmetrically located in the foam that is sandwiched between 1/4-inch stainless steel sheeting and held together by 3/4-inch all-thread rods. The top sheet serves as the buoy deck and provides an excellent work platform. All dissimilar metals are isolated using Delrin bushings. Brackets were designed for simple deployment/recovery of the ADCPs without having to retrieve the mooring. Aloft on the tower are shelves for instrumentation, data loggers, antennas, batteries, radar reflectors and navigation beacons.

Mooring Design

NDBC established three basic mooring designs in the 1970s: all-chain for depths of up to 90 meters, semi-taut for depths of 60 to 600 meters and inverse catenary for deep ocean and Great Lakes depths of 600 to 6,000 meters. Additionally, each mooring design is divided into three sections: upper, middle and lower.

Our applications started with the all-chain design. With the help of NDBC engineers, we used their mooring design software with environmental conditions specified for the WFS. On this basis we used one-inch open link carbon steel chain for the upper mooring and 1.5-inch open link chain for the lower mooring. A middle mooring consisting of 7/16-inch jacketed wire rope was later added to accommodate temperature and conductivity sensors as the system evolved. The upper mooring then became a two-meter section of chain serving as a bridge between the buoy and the instrumented middle mooring. Middle mooring wire rope also allows for the use of inductive modems for real-time telemetry of temperature and salinity.

> *"The overall scientific goal is to improve our understanding of how physical processes affect property distributions on the WFS."*

Coupling hardware consists of safety anchor shackles with a cotter pin and a swivel to decouple potential buoy spin from the wire rope (in practice the buoy does not spin). For anchoring there is the combined effect of 1.5-inch chain on the bottom (of length approximately equal to the water depth for a 2:1 scope mooring) and a stack of railroad wheels. They are cost-effective, readily available and easy to handle aboard ship.

Instrumentation

Depending on application, we use ADCPs at four different frequencies or types. Initial surface buoy applications were with 600 kHz narrowband ADCPs mounted downward-looking. While we continue to use these older instruments, subsequent deployments were made with either 300 kHz or 600 kHz broadband ADCPs. We have also employed 150 kHz narrowband ADCPs on subsurface moorings in deeper water along the shelf-break.

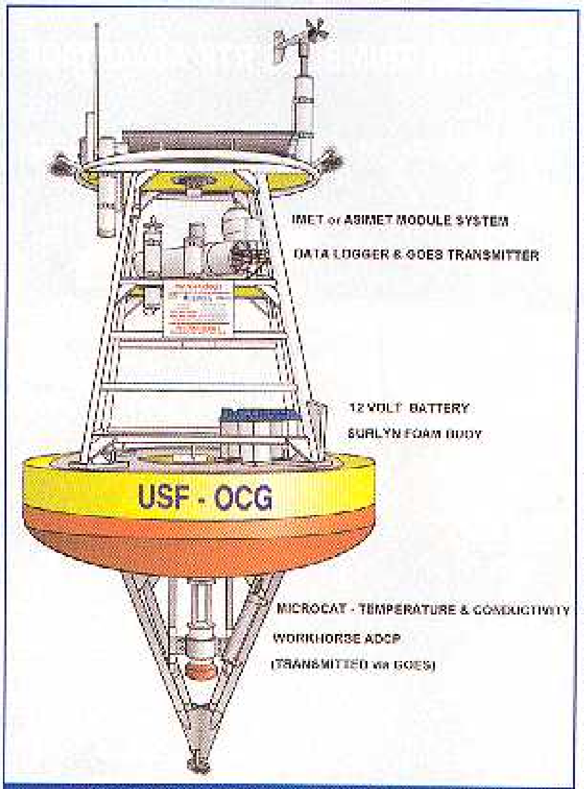
Older style SeaBird Electronics SBE-16 SeaCat temperature and conductivity recorders are gradually being replaced by SBE-37 MicroCats with inductive coupling.

Our buoy-mounted meteorological sensors consist of either the Coastal Environmental Systems Weatherpak 2000 system, modified to accommodate GOES telemetry, or the Woods Hole Oceanographic Institution (WHOI)-designed Improved Meteorology (IMET) system, which has now evolved into the Air-Sea Interaction Meteorology (ASIMET) system presently being manufactured by Star Engineering. With the Weatherpaks, we measure wind, air and sea temperature, relative humidity and barometric pressure. With IMET or ASIMET we add incoming short- and long-wave radiation and precipitation.

Given the modular design of IMET, we added a new module to incorporate the ADCP data into the telemetry stream.

This ADCP module was initially designed at WHOI and then modified by the USF Center for Ocean Technology (COT) for integration with both ASIMET and a USF-COT-designed data logger and telemetry system.

This logging and telemetry system also handles the temperature and salinity provided by the inductively coupled MicroCat sensors. We use a conducting cable to transfer these data from the inductive coupler located on the mooring wire to a modem located in the data logger on the buoy.



Complete air-sea interaction buoy system.

Data Acquisition System

The data logger and telemetry system developed by USF-COT in conjunction with the OCG is based on a Motorola 68HC16 microcontroller with 128 kilobytes of flash memory and 128 kilobytes of RAM for program use. A multiplexed serial communications I/O allows for RS485 and RS232 devices to be interfaced. The controller accesses the suite of IMET or ASIMET sensors, plus either narrowband or broadband ADCPs via an RS485 bus. MicroCat data, depending upon whether inductively coupled or direct, are accessed through either RS485 or RS232. All data are both locally stored and telemetered hourly via GOES satellite. The logger-transmitter also has radio communications. This allows for remote communications with the controller for the purposes of setup, data download and troubleshooting, without having to board the buoy. We have successfully utilized this feature from both research vessels and aircraft.

Processing and Disseminating Data

USF has two downlink systems to acquire the data via GOES: a Digital Direct Reading Ground Station (DDRGS) and a domestic satellite rebroadcast receiving system (DOMSAT). Once received, the data are processed using decoder scripts written in C and Perl programming languages. Observations are then served to the public via the Internet at http://comps.marine.usf.edu. These data are also available via the NDBC, which has direct access for input to the National Center for Environmental Prediction for improved marine weather forecasts at www.ndbc.noaa.gov/Maps/Florida.shtml. Development of a web-based data management system is in progress. This will further facilitate the ease of use by a broader community.

Conclusion

Moored observations by the USF-OCG on the WFS have evolved from an initial pilot study in 1993 to a practical applications-oriented component of a larger scale coastal ocean observing system. This system is part of the COMPS program for the WFS and the recently initiated Southeast Atlantic

Coastal Ocean Observing System (SEACOOS) for the coastal states from North Carolina to Florida. Our buoys, combined with surface radars, profiling floats and other vehicles, and coastal stations, all linked through physical and biological models, will assist in determining the state of the coastal ocean and its coupling with the atmosphere.

Acknowledgments

We acknowledge support from several federal agencies including the USGS, ONR, MMS, NOAA and the state of Florida and its agencies, including the FFWC and the DCA. The authors thank all OCG staff past and present and graduate students, NOAA's NDBC, NESDIS and PMEL, the USF-CMS COT, Machine Shop and Graphics Dept., the officers and crew of the Florida Institute of Oceanography's R/V *Suncoaster* and R/V *Bellows*, the crews of R/V *Price* and R/V *Gilbert*, the Dept. of Physical Oceanography and rigging shop at WHOI, and the countless number of graduate students and divers involved in all OCG research on the WFS. /st/

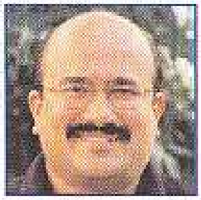
Rick Cole received his B.S. in oceanographic and marine technology from Florida Institute of Technology. With nearly 30 years of sea-going and diving experience, he has been involved in a variety of mooring designs and applications in the Gulf of Mexico, Atlantic and Pacific oceans. His current focus is on the telemetry of ADCP/Waves data via acoustic modems.

Dr. Robert Weisberg heads the USF Ocean Circulation Group and is responsible for monitoring and modeling ocean circulation-related ocean-atmosphere properties on the WFS with applications of societal importance. Weisberg holds a B.S. in materials science and engineering and an M.S. and a Ph.D. in physical oceanography.

Jeff Donovan has worked as a programmer/analyst and computer system administrator within the College of Marine Science at USF since 1986. He holds a B.S. in computer engineering from the University of Florida. While at USF he has been involved in all aspects of oceanographic data collection and analysis. His current focus is the collection, archival and dissemination of real-time oceanographic data.

Clifford Merz is the program director and systems engineer for the COMPS program. He holds a Bachelor of Science degree in ocean engineering and a Master of Science degree in water resource engineering from Florida Atlantic University. Merz also has a Master of Science degree in ocean engineering from the University of Connecticut. His 20-year professional career encompasses marine vehicle and buoy hydrodynamics, structural dynamics, underwater acoustics and electronics.

Randy Russell develops both electronics hardware and software for data acquisition and control systems utilized in marine research. Primary research efforts center around embedded controller designs for buoys, ROVs, AUVs and towed platforms. He holds an M.S. and a B.S. in electrical engineering and has been working with the University of South Florida since 1995.



Vembu Subramanian is the data manager for COMPS. He is also the computer system administrator and data manager for the USF Ocean Modeling and Prediction Laboratory. He holds an M.S. in oceanography and an M.S. in environmental science. He is responsible for data processing, archival and dissemination of real-time data collected by USF-operated weather stations located both along the shore and offshore of the WFS.

Mark E. Luther directs the OMPL. He received a B.S. in physics and mathematics and an M.S. and a Ph.D. in physical oceanography from the University of North Carolina at Chapel Hill. Luther's research involves the development of numerical models of ocean currents and processes and their application to various problems.