FESC
Florida Energy Systems Consortium

Florida Agricultural and Mechanical University

Fusion Energy Spheromak Turbulent Plasma Experiment-STPX

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Description: The Florida A&M University's Center for Plasma Science and Technology (CePaST) has nearly completed the construction of a spheromak fusion reactor. A spheromak is one of a general class of experiments used to investigate key plasma physics principles relevant for the development of magnetically confined, controlled thermonuclear fusion as a source of electrical power. This project involves collaboration between Florida A&M University CePaST, West Virginia University, and Auburn University. The spheromak turbulent plasma physics experiment (STPX) is being constructed at FAMU in a facility especially built for the STPX experiment. Fusion research is a key element in the nation's long term energy supply strategy, The spheromak concept may be a possible alternative to the tokamak concept (deployed at ITER) which affords access to fundamental fusion science issues supportive of fusion while allowing us to maintain and nurture an American fusion scientific workforce. This project will determine, using a fast duty cycle between theory, experiment, and simulation, the essential elements required for full kinetic modeling of an entire spheromak plasma using *ab initio* MHD with direct modifications from new turbulence physics. The project will focus on the management of fluctuations and transport in a spheromak plasma using new turbulence physics models and comprehensive helicity control. We will employ high time- and spatial- resolution measurements of electron temperatures, ion temperatures, and magnetic field fluctuations to investigate, understand, and eventually control reconnection driven heating as a means of increasing the plasma temperature of spheromak plasmas. We will use divertor diagnostics of radiation and particle transport along with edge biasing for electric field control to explore the effects of driven flows on confinement and heating in spheromak plasmas with microparticles and will investigate the effects of MW pulses coupled to protons on the plasma current and confinement.

Budget: $950,000
Universities: FAMU
Universities and External Collaborators:
Dr. Earl Scime, West Virginia University
Dr. Ed Thomas, Auburn University
Dr. Simon Woodruff, Woodruff Scientific, Inc

Florida Atlantic University

Southeast National Marine Renewable Energy Center (SNMREC)

PI: Susan H. Skemp **Co-PIs (at FAU):** Howard P. Hanson, James VanZwieten

Description: The Southeast National Marine Renewable Energy Center (SNMREC) at Florida Atlantic University (FAU) was established by an award from the US Department of Energy in 2010 as an extension of FAU's Center for Ocean Energy Technology, which was originally founded in 2007 by the 2006 Florida State University System Center of Excellence Program. The Center's mission is to investigate ocean-based solutions to the nation's energy challenges, specifically open-ocean current energy conversion and ocean thermal energy conversion in the Florida straits. Key drivers for investigation are determined by the regulatory process at State and Federal levels and by market and technology gaps needed to commercialize MRE. The SNMREC's role is to bridge the gap between concept and commercial deployment of ocean energy technologies by providing at-sea testing facilities and technology development for both ocean current and thermal energy systems. Research areas span environmental, resource, economic, education, and technology topics.

Budget: $8,750,000

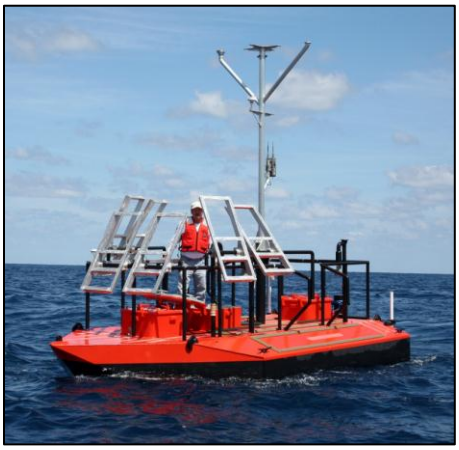
Universities: FAU**,** collaborating with UCF, FSU, USF, Embry-Riddle Aeronautical University, University of Miami, Oregon State University, University of Washington, Pennsylvania State University, University of New Hampshire, University of Hawaii, University of Edinburgh, Heriot-Watt University, Nova Southeastern University, Virginia Polytechnic Institute and State University, and FIT

External Collaborators: Numerous industry partners, state and federal government agencies, FFRDCs such as the National Renewable Energy Laboratory, Oak Ridge National Laboratory, Woods Hole Oceanographic Institution, U.S. Department of Energy (Office of Energy Efficiency and Renewable Energy), U.S. Department of Interior (Bureau of Ocean Energy Management, Regulation, and Enforcement), U.S. Department of Commerce (National Oceanic and Atmospheric Administration), the Florida Fish and Wildlife Commission, and Florida Departments of Agriculture and Environmental Protection.

Progress Summary

The Southeast National Marine Renewable Energy Center is developing an open-ocean energy laboratory and test capability to advance research on *marine and hydrokinetic* (MHK) ocean current energy and thermal potential energy. The SNMREC is moving forward with strategically selected research, developing and testing key technology, infrastructure and systems as well as standards criteria to meet this need. The SNMREC's technology and industry support efforts are underway in three distinct but inter-related tracks. First, the Center is actively engaged in sensor and instrument acquisition, deployment, and analysis to more fully characterize offshore energy resources, and the benthic and pelagic environment. Second, in support of ongoing research and to further an operational and technical understanding of offshore energy systems and challenges, a small-scale hydrokinetic turbine system has been designed and partially fabricated. Testing is ongoing for components, sub-systems, and major systems of the turbine. Full system testing will be a phased, risk-reduced approach. Discussions are ongoing in individual meetings with over 30 companies to determine testing/validation requirements for open-ocean testing of their proposed experimental devices at the SNMREC's test facility. The SNMREC will provide a centralized, standardized testing capability for current energy conversion prototypes; initially, scaled versions and eventually full-scale devices will be tested. In addition, critical environmental measurements will be obtained from the observational platform.

Program Status: An MHK lease application on the outer continental shelf (OCS) was submitted to the US Department of Interior, Bureau of Ocean Energy Management (BOEM). This is the first national application submitted which will influence the model for future lease applications. BOEM is funding an Environmental Assessment, a precursor to approving the lease. Two sea trials were successfully conducted of a mooring and telemetry buoy to ready it for at-sea deployment. In-lab technology testing is underway with a scaled generator dynamometer which provides a platform to test offshore electrical systems before use and simulate offshore grids. Aerial surveys are being conducted to determine offshore turtle and marine mammal distribution and activity prior to install/test of MHK devices. Sub-sea surveys of installation sites are helping to identify deep water coral distribution and determine appropriate anchor areas. The SNMREC hosted an industry / government / academe conference on *"Renewable Ocean Energy & the Marine Environment: Responsible Stewardship for a Sustainable Future".* The Center developed a curriculum for upper-division high-school students to introduce the topic within secondary education. Five workshops have been held reaching more than 80 science teachers in 11th and 12th grades. In addition, over three-dozen upper-division graduates have been trained with specializations in MRE areas.



Mooring and Telemetry Buoy Sea-trial

20kw Dynamometer for Generator Testing

2011 Annual Report

Introduction: SNMREC is developing and installing the first open-ocean current energy conversion test facility in the U.S. consisting of at-sea equipment for the purpose of investigating current energy conversion devices in the Florida Current, approximately 12 miles offshore Fort Lauderdale, Florida. Initially, the capability will be limited to scaled devices (⅛ – ¼ scale, or up to 7 meter diameter rotors or 100kW instantaneous maximum power production). The SNMREC facility will provide a centralized, standardized approach to testing for current energy conversion prototypes. In addition, the facility will serve as an observational platform from which critical environmental measurements can be obtained. A generically designed and fabricated experimental research turbine will provide a non-proprietary platform for component development at small scales. The test procedure/plan is laid out to incorporate monitoring and failure prediction systems, to gain experience in at-sea operations of this nature, and to support standards and protocol development. Industrial beneficiaries will be able to use the results of testing to enhance and accelerate prototype development. The major initial challenge, obtaining an outer continental shelf lease, is nearly met.

Resource Assessment

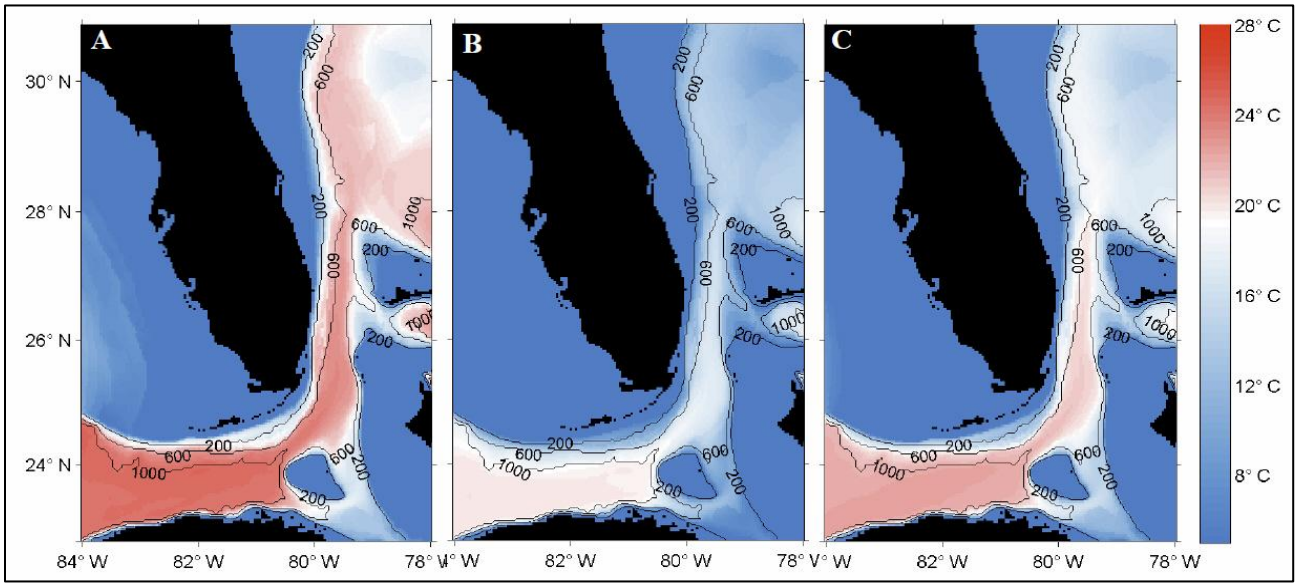


Figure 1: Thermal Energy Resource For (A) Summer, (B) Winter, (C) Annual Average.

The global analysis of ocean thermal energy conversion (OTEC) potential, a DOE-funded project undertaken jointly with the Lockheed-Martin Marine Systems and Sensors Division, has produced results pertinent to the thermal resource in the Florida Straits (Fig. 1). Using the Hybrid Coordinate Ocean Model (HYCOM) results produced in data-assimilation mode by the Naval Research Laboratory and new analytic processes reveals that the resource offshore Southeast Florida described previously from conductivity, temperature, and depth (CTD) instrument surveys extends throughout the Straits of Florida. Figure 1 shows the commonly-used resource parameter ΔT, the temperature difference between the near-surface water and that at depth, which depths are shown in Figure 1 with contours. A threshold for the resource, above which OTEC becomes technologically effective, is 20°C, and it can be seen that even in winter there is potential in the Straits. The summertime potential is quite significant, and it occurs at depths far more shallow than the 1000 m generally used for OTEC potential assessments.

It is instructive to compare the HYCOM results to the SNMREC CTD measurements. Figure 2 shows near-surface (top) and 200-m temperatures about 16 km east of Ft. Lauderdale from SNMREC CTD casts and the nearest HYCOM grid point. HYCOM captures the 20-m temperatures quite well, reproducing the annual cycle faithfully. This is to be expected, as most of the assimilated data in the HYCOM integrations pertain to the sea surface (in particular, satellite observations). On the other hand, at 200 m HYCOM temperatures tend to be too warm by 1-3°C, which implies an underestimation of the thermal resource by the same amount. These CTD measurements, on the Miami Terrace near the bottom, reveal a (relatively) near-shore and shallow cold water pool, and the relatively coarse resolution of the model—with only a few grid points to resolve the terrace—may alias the dynamical processes that move that water out of the main trench of the Straits up onto the terrace. This is under investigation in the HYCOM community.

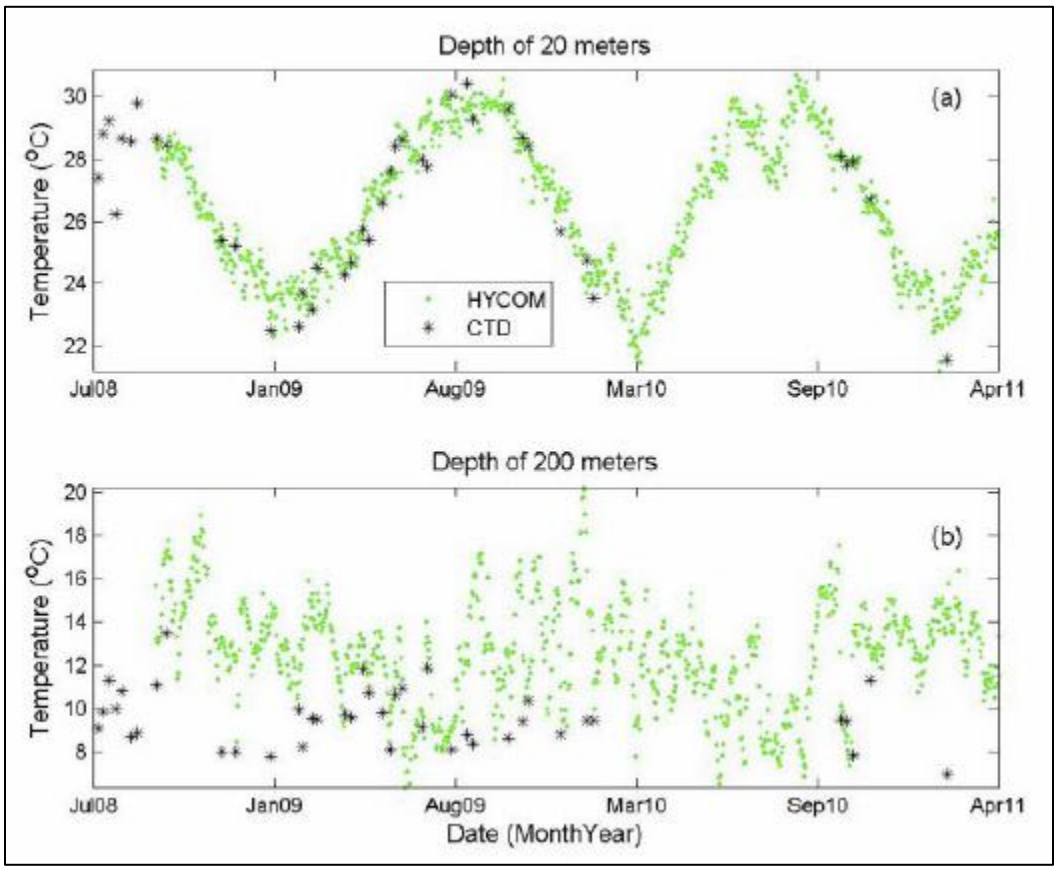


Figure 2: Comparison Of HYCOM Results (Green) With CTD Measurements of Temperature Near the Surface and At 200 M Offshore Fort Lauderdale.

Because HYCOM also presents a potentially useful tool for estimation of the hydrokinetic resource, it is also instructive to compare the model's currents with those measured by SNMREC acoustic instruments. The 13-month deployment reported previously, in particular, provides an especially rich comparison.

Figure 3 compares the vertical structure of averaged currents from the model and the instrument. The model is seen to under-predict the current throughout much of the water column. Within the HYCOM user community, it is a well-known model deficiency, one under active investigation, that the depth-averaged currents in the Straits of Florida are low by about 10%. In Figure 3, this low bias means that the black curve is displaced to the left by about 0.1 m/s (or half a tick mark on the horizontal axis). Correcting the HYCOM curve in Figure 3 for this issue improves the comparison. As with the thermal resource, the model under-predicts the hydrokinetic resource, making its use as a resource assessment tool conservative.

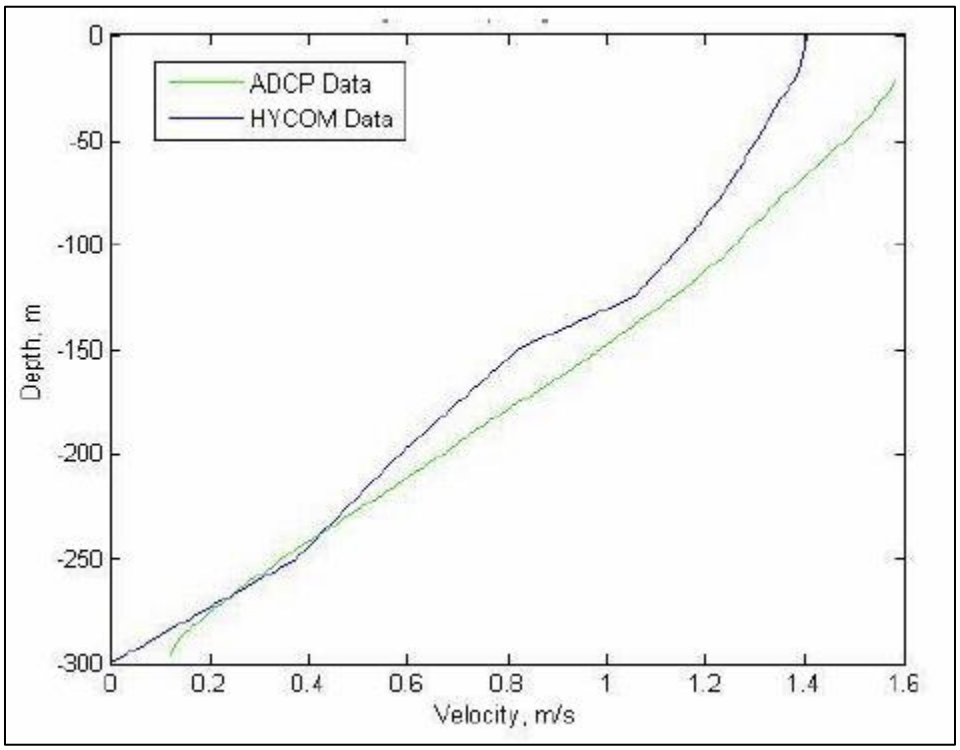


Figure 3: Comparison of 13-Month Averages of Northward Velocities from HYCOM and The SNMREC ADCP.

Finally, during the past year, a short-term ADCP has been deployed, and a longer-term redeployment of SNMREC ADCP buoys is planned for October to enhance the ongoing monitoring of Florida Current hydrokinetic resources.

Regulatory Environment: Continual evolution of (both state and federal) agency requirements has resulted in a challenge obtaining permits for open-ocean deployment of even experimental test systems. Pursuing any research and development in renewable energy on the Outer Continental Shelf (OCS) must comply with the federal Outer Continental Shelf Lands Act. With respect to the SNMREC deployments of prototype devices/systems, the major permits, approvals, and authorized actions necessary to construct, operate, maintain, and decommission project facilities while falling outside of State of Florida waters (i.e., the deployment and operations will be more than 3 miles offshore), will involve interaction with the Florida Fish and Wildlife Commission due to its agreements with the U.S. Fish and Wildlife Service. In addition, shore-side activities in support of the offshore deployment will be conducted within State waters, at a commercial marina under the purview of the Florida Department of Environmental Protection. These activities will also engage agencies such as the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration's Marine and Fisheries Service, the U.S. Coast Guard, the U.S. Navy, etc. SNMREC submitted the first lease application in the nation to the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) to deploy equipment related to hydrokinetic energy conversion device on the outer continental shelf (OCS). As the lead agency, BOEM filed a Notice of Intent (NOI) to prepare an Environmental Assessment Marine Hydrokinetic Technology Testing Offshore Florida in the Federal Register on 23 May 2011 (see http://www.boemre.gov/ooc/press/2011/press0523.htm).

Based on a draft schedule, BOEM anticipates it will complete the draft EA and consultations in the October/November 2011 timeframe, and they should be in a position to begin lease negotiations (assuming a FONSI) before the end of the calendar year. BOEM is also planning to conduct a public stakeholder forum in South Florida during the next quarter to review the SNMREC's proposed activities. Barring any complications with the lease negotiations, we anticipate issuance of a lease by the beginning of 2012.

Progress on the EA has moved the Center closer to deployment of the first U.S. testing capability for open-ocean current MRE prototypes. The three-block area of interest requested in the application includes BOEM defined blocks 7003, 7053 and 7054, as shown with red outlines in Figure 4. Numerous discussions were held with stakeholders sharing mutual interests in these area(s) to determine the best approach to select sites with the least impact. These discussions included state and federal agencies as well as other public interested parties such as commercial and recreational ship and vessel operators. Figure 4 is a compilation of many of the other identified primary interests and potential user conflicts that were considered during selection of the final BOEMRE blocks.

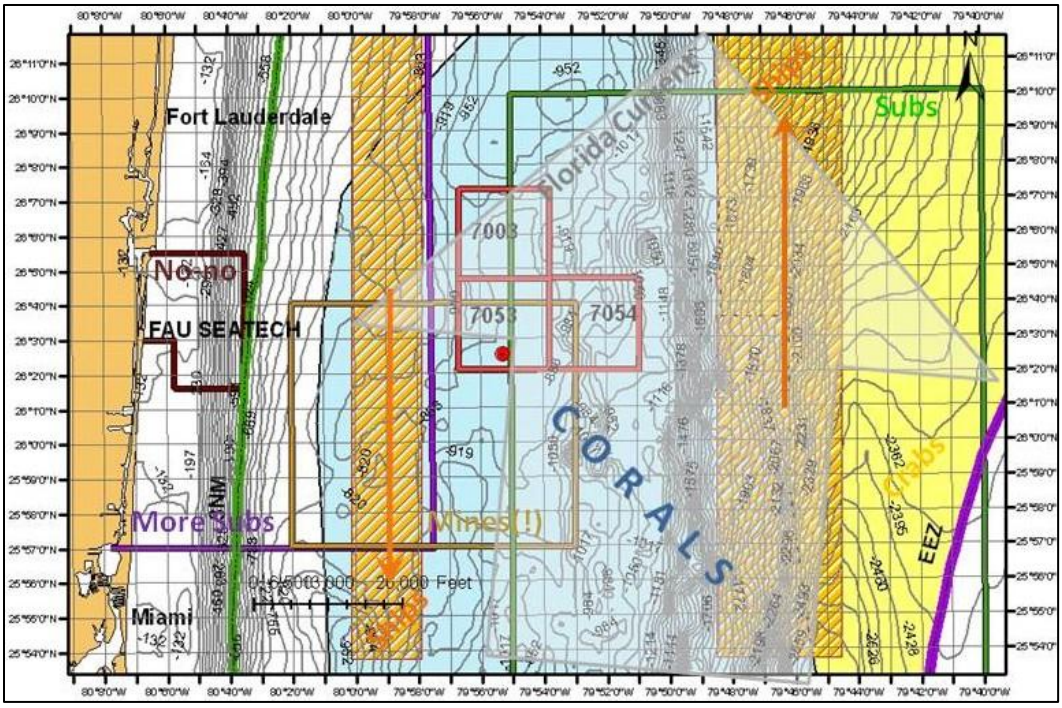


Figure 4: Map Of SNMREC Requested OCS Lease BOEM Blocks (7003, 7053 And 7054).

In addition, recent research results, some of which were supported by the SNMREC, have provided additional information about a newly discovered genus of corals that inhabit the outer parts of the Miami Terrace in the Florida Straits. The vulnerability of these corals to deep-trawl commercial fishing has led the National Oceanic and Atmospheric Administration to designate a large part of the sea-bed offshore of Florida and Georgia as a Coral Habitat Area of Particular Concern. While this designation will result in relatively little disruption of the SNMREC's operations – the Center's two or three anchor systems can easily be deployed on the large, sandy patches that exist between coral beds – there will likely be significant challenges for commercial-scale deployments in the future.

Infrastructure:

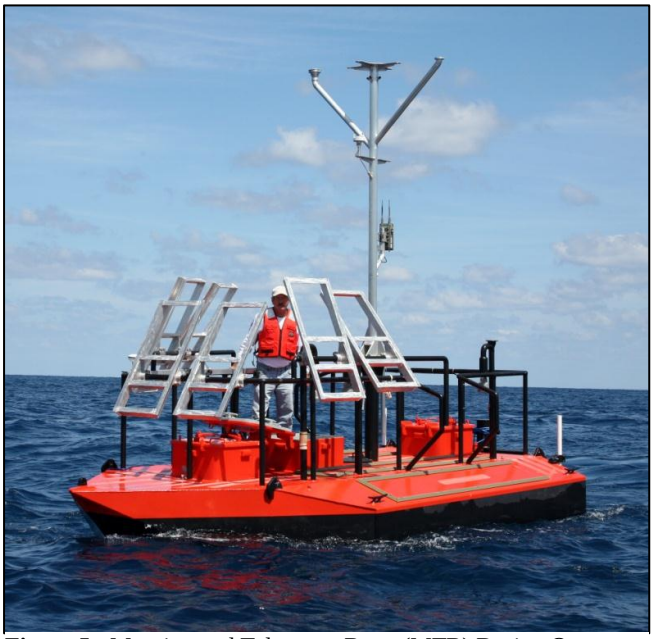


Figure 5: Mooring and Telemetry Buoy (MTB) During Open-Ocean Sea Trials.

The SNMREC's proposed initial deployment, approximately 12 miles offshore Fort Lauderdale, Florida which regularly experiences 3-4 kt of current, will consist of an anchored mooring and telemetry buoy (Figure 5), to be used as an attachment point for work boats to deploy prototype systems for testing, and as an observational platform for a variety of environmental and met-ocean studies. The SNMREC's buoy, a design based on the familiar NOMAD weather buoys originally developed by the U.S. Navy in the 1940s, is undergoing final tune-up modifications following a series of successful sea trials earlier this summer. The initial deployment will provide testing capabilities for devices in the 100kW class and smaller.

One of the biggest unknowns in the operations of OCT systems concerns the behavior of the generator sub-system as it experiences both variable loads and the torque differentials associated with changing currents acting on the rotor. In order to provide a capability to test generators under conditions as realistic as possible without actually having to go to sea, SNMREC has developed a computer-controlled dynamometer system, located at the FAU SeaTech facility in Dania Beach. This capability is further being developed in conjunction with oceanographic measurements and modeling to simulate rotor behavior as it would behave in the current.

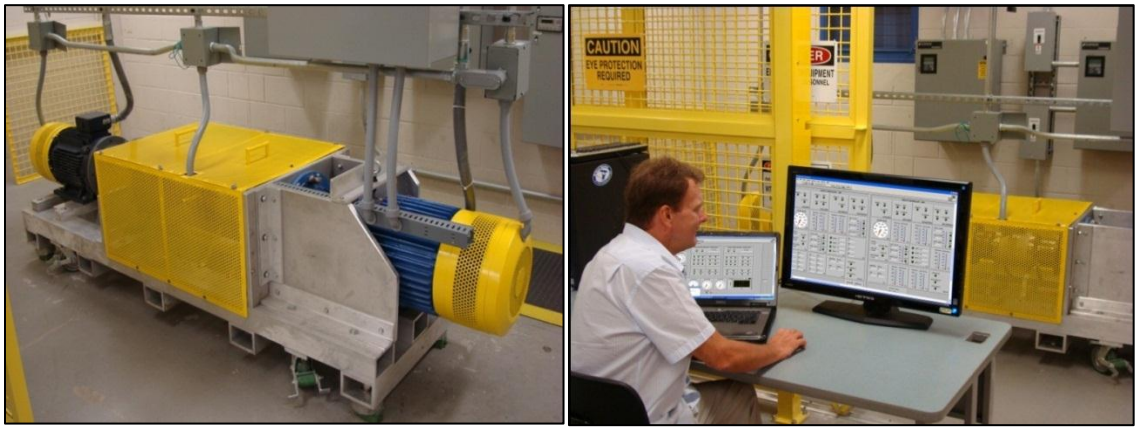


Figure 6: The SNMREC's dynamometer for generator testing. Unit on left (much of which in hidden by the computer display in the right-hand photograph) is ~3 m long.

The dynamometer system, which uses a 20 kW electric motor to drive generators to be installed in turbines, is shown in Figure 6. The dynamometer is operational, but undergoing system testing and windowing of its capabilities. The preliminary work is underway to program the drive to simulate the ocean current's effects on a rotor, and sensor data is already being collected. The SNMREC's experimental turbine's electric and power systems have been installed to begin component and subsystem

testing before integration with the body of the turbine. The Prognostics and Health Monitoring (PHM) research is collecting basic vibration data which is training the custom data fusion and data mining algorithms that make assessments about component health and reliability.

Environmental Monitoring / Demonstration: Monthly aerial diversity and distribution surveys are being conducted to assess sea turtle and marine mammal populations. The surveys employ the currently accepted protocol – human observers viewing transect areas from a plane flying approximately 500 ft. from the ocean surface. However, other researchers are developing a technology package to provide high resolution video recording and post-processing capability for future surveys which aim to be more accurate and thorough, and would not require observer passengers. The research team is working with the National Oceanic and Atmospheric Administration's, National Marine Fisheries Service to evaluate the SNMREC's enhanced approach as an expansion of currently accepted methods. The survey areas currently being assessed are depicted in Figure 7.

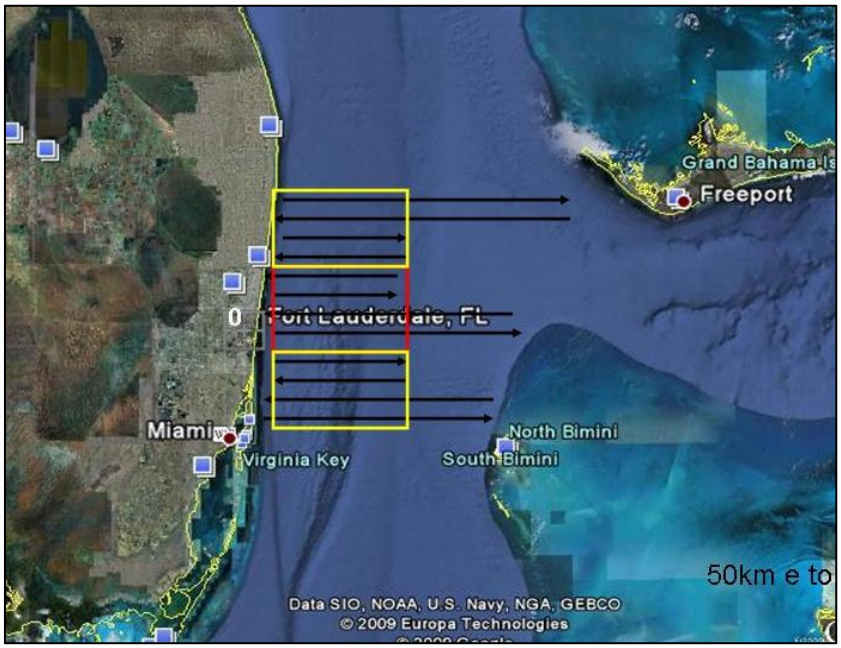


Figure 7: Map Of Aerial Survey Areas Offshore Ft. Lauderdale, Florida To Determine Sea Turtle And Marine Mammal Population Information.

Education and Outreach

- *Professional Community:* SNMREC sponsored a three-day event focused on "*Renewable Ocean Energy & the Marine Environment: Responsible Stewardship for a Sustainable Future"*. The conference was well attended with 163 participants from government, industry, academe, and laboratories. Panel and workshop presentations are available at http://www.ces.fau.edu/coet/agenda.php

- *Education:* The SNMREC has developed an Educational Curriculum to enhance interest in science, mathematics, engineering, and technology which supports improvements in education for students from K-12 with original curricula and teacher workshops. *Energy from Ocean Currents: the New Renewable* is an ocean-energy curriculum developed for 11th and 12th grade students with funding from an award by the US Department of Energy's Office of Energy Efficiency and Renewable Energy. The curriculum is based on the "5 E's", an innovative instructional-based model used for teaching that fosters inquiry-based thinking by *engagement, exploration, explanation, elaboration,* and *evaluation.*

There are six comprehensive lessons built around the scientific basis of the SNMREC's research, each aligned with the Florida Sunshine State Standards benchmarks, with hands-on activities reinforcing each lesson. One such activity is building an electric generator from a soda can to demonstrate an induction coil alternating current generator. The lessons also include "Meet the Scientist" segments that feature a SNMREC engineer or scientist.

To date, six teacher trainer workshops have been held for more than seventy 11th and 12th grade science teachers. The curriculum is undergoing revisions based on teacher feedback and overall lesson improvements. The CRT (curriculum revision team) is made up of the original curriculum writers with the addition of 4 participating teacher facilitators. Of particular note, two of the teachers have submitted a proposal in response to FOA 10-023 from the Office of Naval Research (ONR) to create a STEM Maritime program for females and minorities based on the SNMREC's curriculum. Continued educational assessment of the curriculum and its successes are being examined with emphasis on future applications to middle and elementary levels.

Figure 8: Teachers at a Snmrec Teacher Training Workshop Becoming More Familiar with the Activities Suggested in the Developed Curriculum.

Allegro Productions "Science Screen Report for Kids" has highlighted the SNMREC's research as a DVD that will be distributed to high schools on a national level. In addition, other SNMREC educational outreach includes numerous presentations at K-12 educational venues as well community outreach such as museums.