Conference Paper SNMREC/CP-10-125

May, 2010

Ocean Energy: Challenges and Opportunities

Susan H. Skemp

Offshore Technology Conference, 2010
Houston, TX

Southeast National Marine Renewable Energy Center

College of Engineering and Computer Science / Florida Atlantic University

Ocean Energy –

Challenges and Opportunities

Susan H. Skemp
Executive Director
Center for Ocean Energy Technology

Offshore Technology Conference
4 May 2010

http://coet.fau.edu
sskemp@fau.edu

FAU
FLORIDA ATLANTIC UNIVERSITY

Ocean Energy

Kinetic sources: tides waves currents

Thermal sources:
thermocline ΔT

FAU/COET Focus

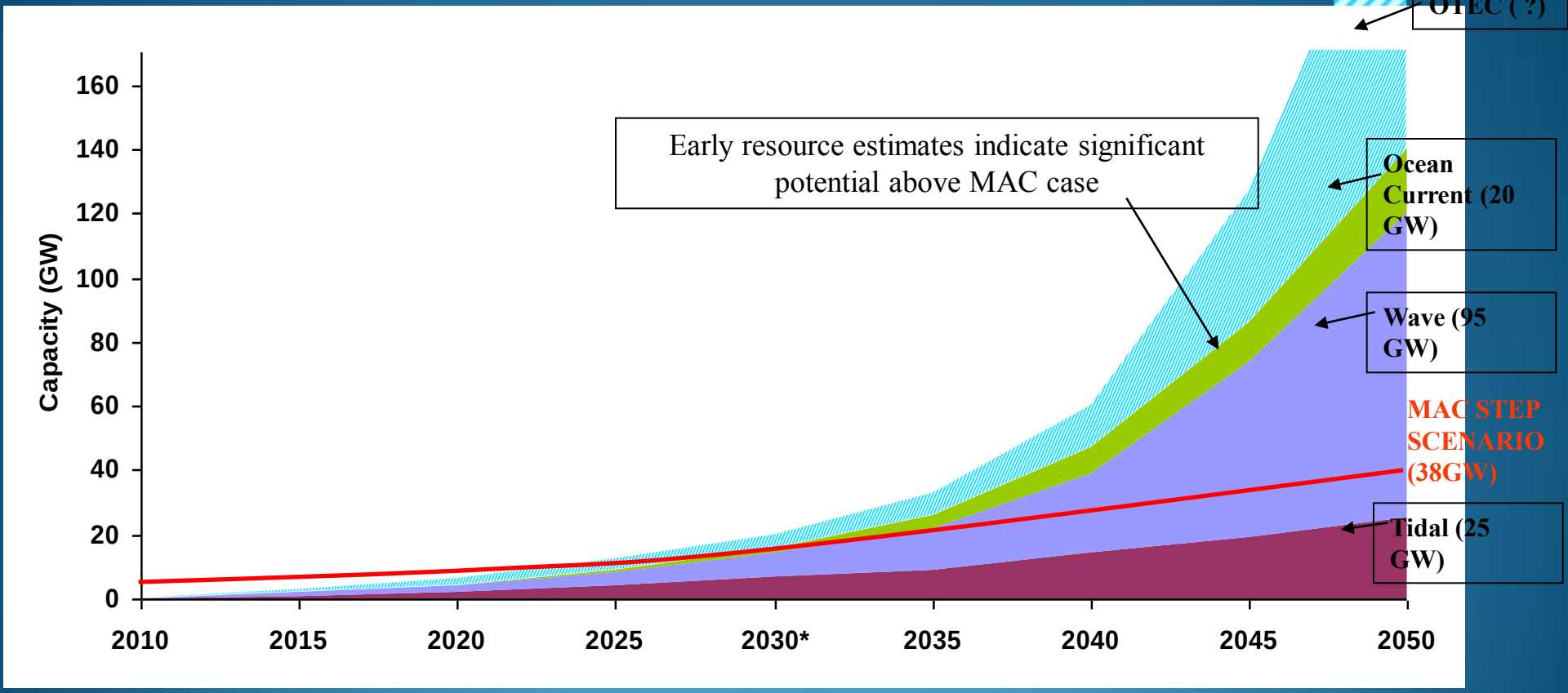
World-wide...

...interest, and R&D, is governed largely by available (oceanic) resources, not all of which have been fully assessed. The tides and waves of the North Sea, for example, have stimulated considerable effort in the nearby EU countries.

Operational deployments will also be governed by the locally available resource.

Early Estimates of Potential Marine & Hydrokinetic Resource Penetration (GW)

Potential MHK Resource



More detailed resource assessments and validation for wave, current, tidal and OTEC to be completed by 2012

Major Challenges to Renewable Ocean Energy Development

- Regulatory and Institutional
- Technology Readiness
- Testing Capability
- Global Standards
- Renewable Energy Policy and Legislation
- Cost-competitive systems

The Ocean as a System

Ownership – No one; Everyone!

- Interdependencies between: *environment, ecology, resource, and power extraction systems*

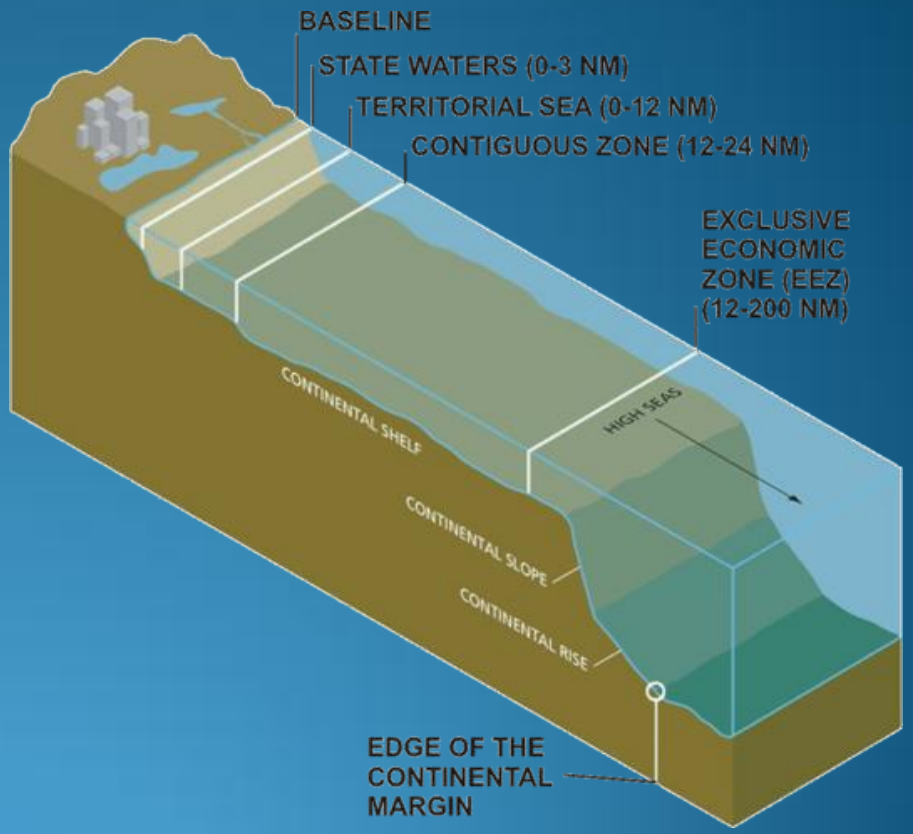
AND

- Owners / Users (Stakeholders): *Public, Government, Private Industry*

Meeting this challenge will require engaging the large stakeholder community in the public policy debate

Challenges-Jurisdictional

- **Ocean Jurisdictions**
  - Many projects will span both state and federal waters via
    - Location of machinery
    - Transmission Cable
    - Connection to Land-based Grid
    - Staging Area for Construction
  - Siting of Projects includes, but is not limited to:
    - Marine Spatial Planning
    - Public Attitudes/Engagement
    - Optimal Resources



Source: US Ocean Commission

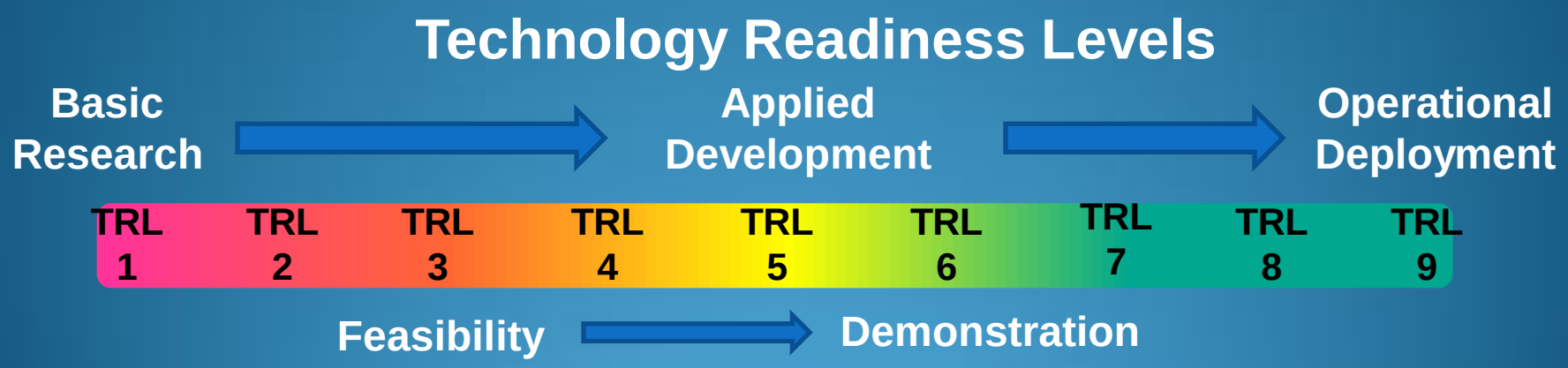
Federal-State-Local Compliance

Permitting Process Complex

- ***At Federal Level-***
  - Compliance with multiple federal statutes including NEPA
  - MMS lead permitting agency for OCS
  - USACOE likely lead permitting agency for Great Lakes
- ***At State Level-***
  - Environmental Quality Review Boards
  - Coastal Zone Management Programs
  - Siting Boards for Energy Facilities and Transmission Lines
- ***At Local Level-***
  - Town Planning and zoning Boards
  - By-laws (e.g., setbacks)

Maturing Research – Advancing Technology

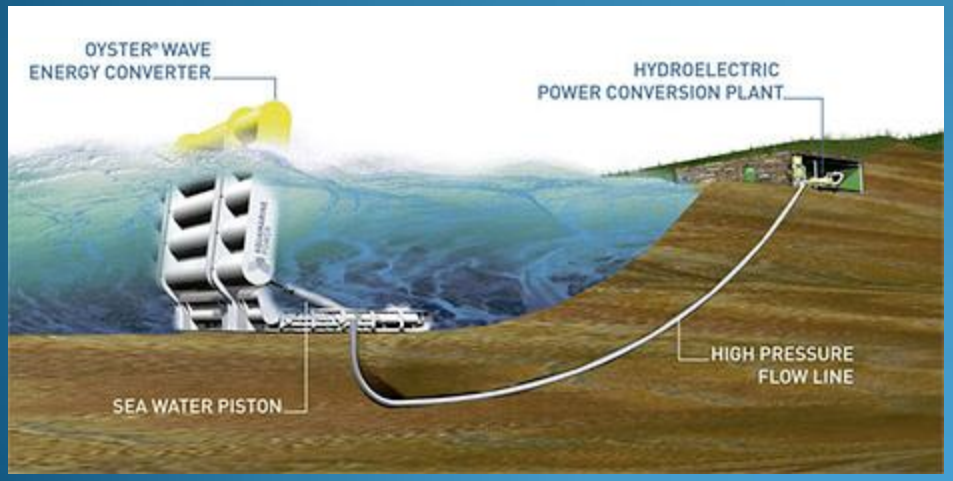
Building upon a framework from NASA and DOD:



Wave Technologies

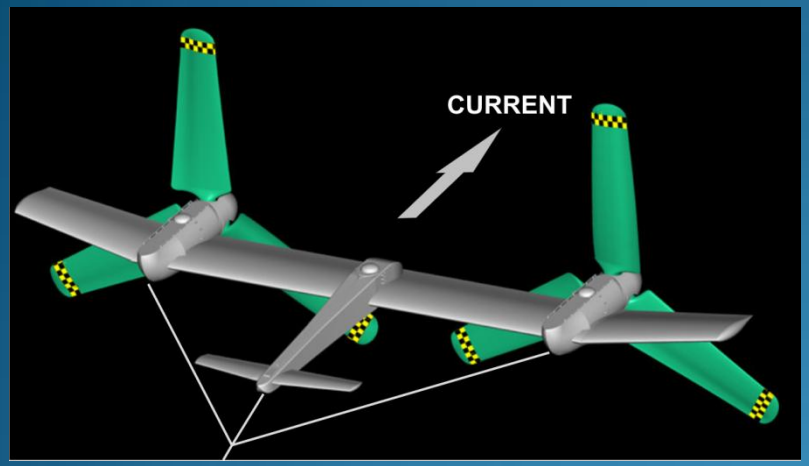
Devices convert wave displacement into another form of energy (e.g., hydraulic);

Production depends on wave height and frequency.



Continental west coasts are best locations.

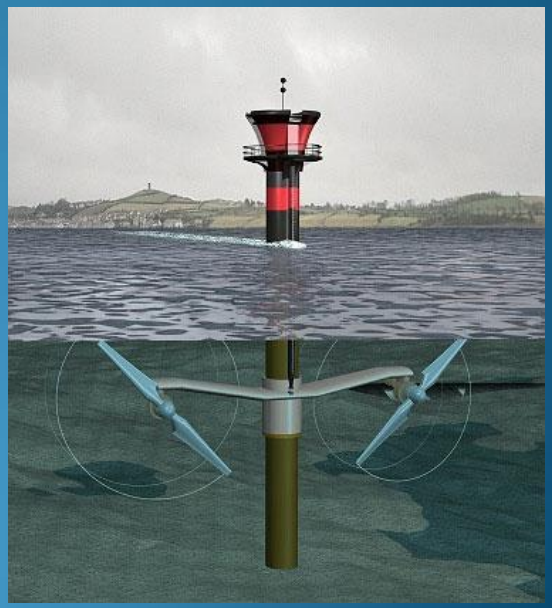
Current Technologies



Work like wind turbines underwater; apply to both tidal and open-ocean currents

Tidal channels: shallow, but flows change direction;

Open-ocean: unidirectional, but water is deep.



Global Research Focus

Not Inclusive:

- Resource assessment and flow characterization
- Prognostics and health monitoring
- Turbine performance and fluid/rotor interaction
- System dynamics and stability
- Ecosystem interactions
- Materials, Corrosion, and Bio-fouling
- Data management, analysis and visualization
- Integrated modeling and simulation
- Energy transmission & grid integration
- Alternative uses for energy generated
- Standards development

Limited Global Testing Capability

Open Water Test Centers – Marine Hydrokinetic Devices

- UK / EU: Pre-permitted, open-water facility
  - EMEC, Wavehub and Galway Bay

    - But

- No existing facility in US to test Marine HydroKinetic devices at advanced TRLs
  - All projects must be deployed on public lands (waters)
  - Existing licensing process based on large-scale hydro and fossil fuel projects

Tested at EMEC

OPT

Tested at EMEC

OpenHydro
(Snohomish PUD)

In the US…

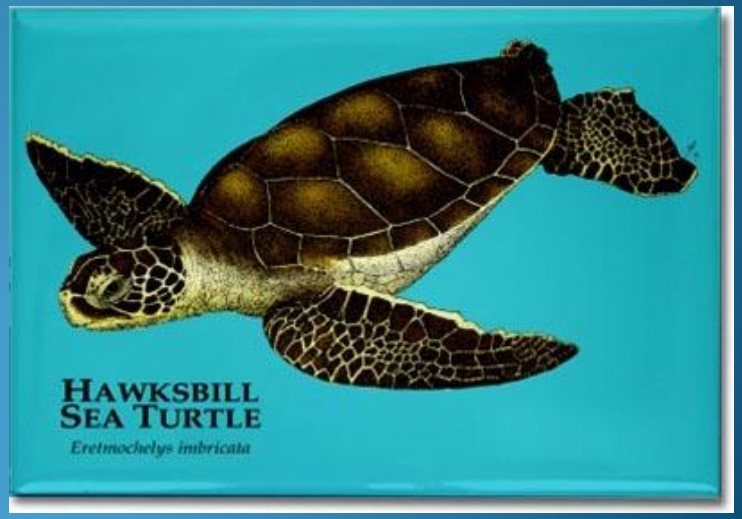
…the Department of Energy's Wind and Hydropower Technologies Program is attempting to stimulate R&D leading toward commercialization here. Two official centers have been established:

- Northwest National Marine Renewable Energy Center
  (waves/tides: nnmrec.oregonstate.edu)
- Hawaii National Marine Renewable Energy Center
  (waves/OTEC: hinmrec.hnei.hawaii.edu)

FAU's COET is the only center working open-ocean currents.

Potential Effects

- Quantifying environmental baselines and risks on a industry-wide basis is critical to securing permits for demonstration projects in the short term and ultimately reducing licensing costs across project types
  - Wakes and their influences (alteration of currents and waves)
  - Alteration of bottom substrates, sediment transport and deposition
  - Alteration of benthic habitats
  - Interference with animal movements and migrations
  - Strikes and entanglement
  - Inadvertent FADs issues
  - User conflicts (shipping; fisheries)
  - Noise & Electromagnetic fields
  - Chemical toxicity



Addressing Global Standards

- TC 114 was created in 2007 – *Marine Energy: Wave, tidal and other water current converters*
- Secretariat held by the British Standards Institute (BSI), United Kingdom
- 15 Member Countries with participating status (P-member), 4 Countries as observers (O-member)
- Two plenary meetings held
  - Inaugural meeting in Ottawa, Canada, May 2008
  - 2nd plenary meeting in Seoul, South Korea, May 2009
- Formal Liaisons established
  - TC 4 – Hydraulic Turbines
  - TC 88 – Wind Turbines
  - IEA – OES
  - EquiMAR

IEC TC 114 Scope

- To prepare international standards for marine energy conversion systems.
- The primary focus will be on conversion of wave, tidal and other water current energy into electrical energy, although other conversion methods, systems and products are included.
- Tidal barrage and dam installations, as covered by TC 4, are excluded.

Standards will Address

- System definition
- Performance measurement of wave, tidal and water current energy converters
- Resource assessment requirements
- Design and safety requirements
- Power quality
- Manufacturing and factory testing
- Evaluation and mitigation of environmental impacts

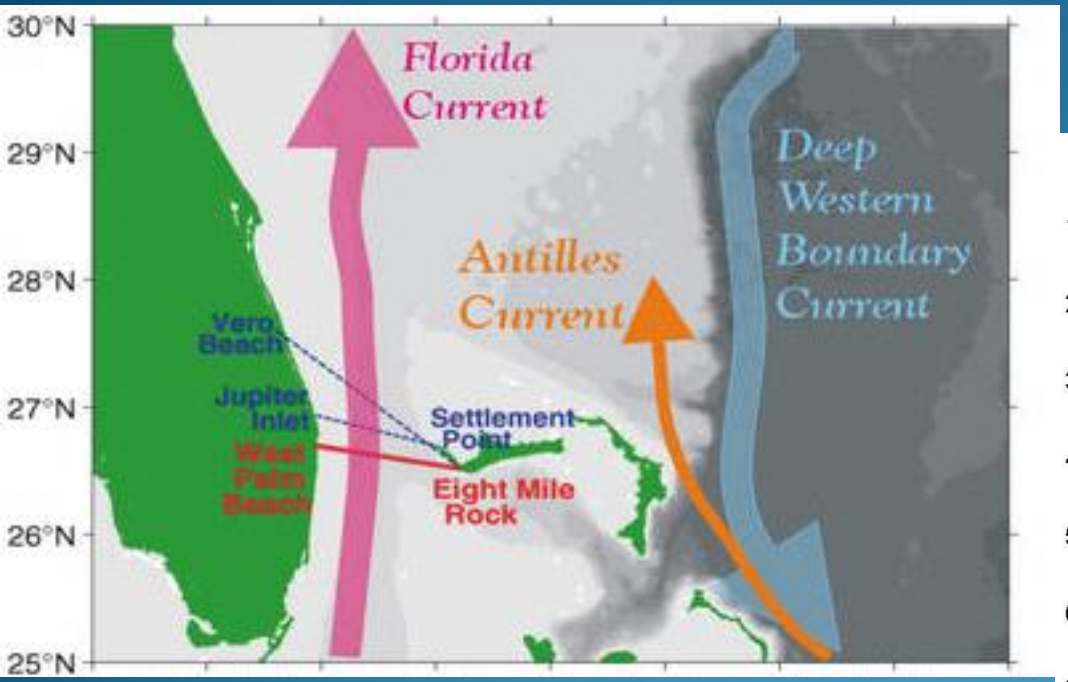
Key Technologies – not yet cost competitive

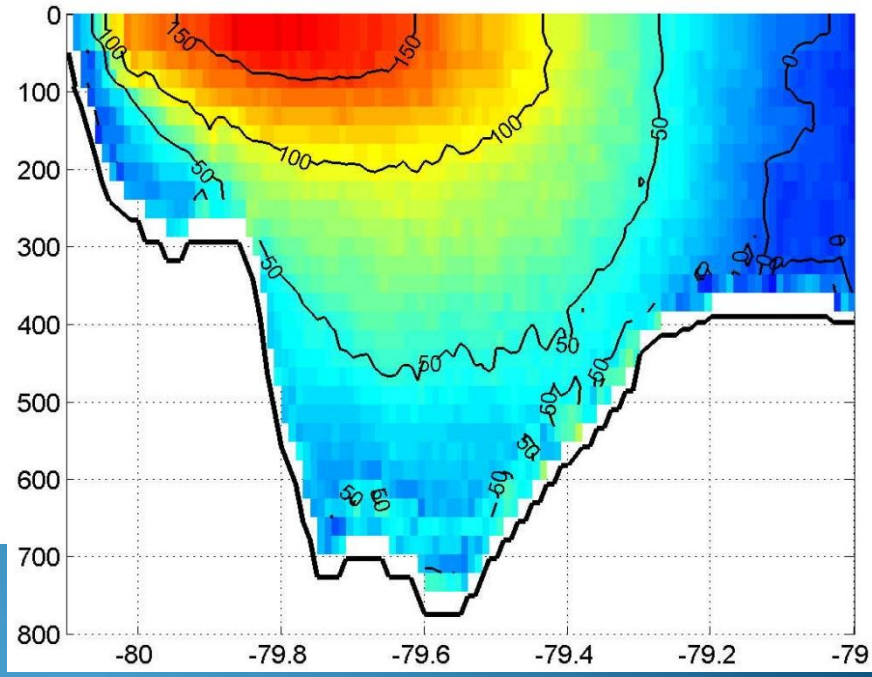
Cost Reduction

- *Actions Needed:*
  - Develop a Research and Development agenda to advance components and systems to demonstration phase
  - Identify, assess and minimize key environmental impacts to facilitate demonstration permits
  - Establish comprehensive testing strategy at progressive technology stages
    - Evaluate performance drivers
    - Quantify costs
  - Develop tools, models, and materials to ensure system survivability
  - Integrate resource assessments, technology cost and performance data
  - Establish advanced cost/performance models to identify critical drivers in overall cost reduction

In Florida -

...the waves are tame;
...the tides are weak;



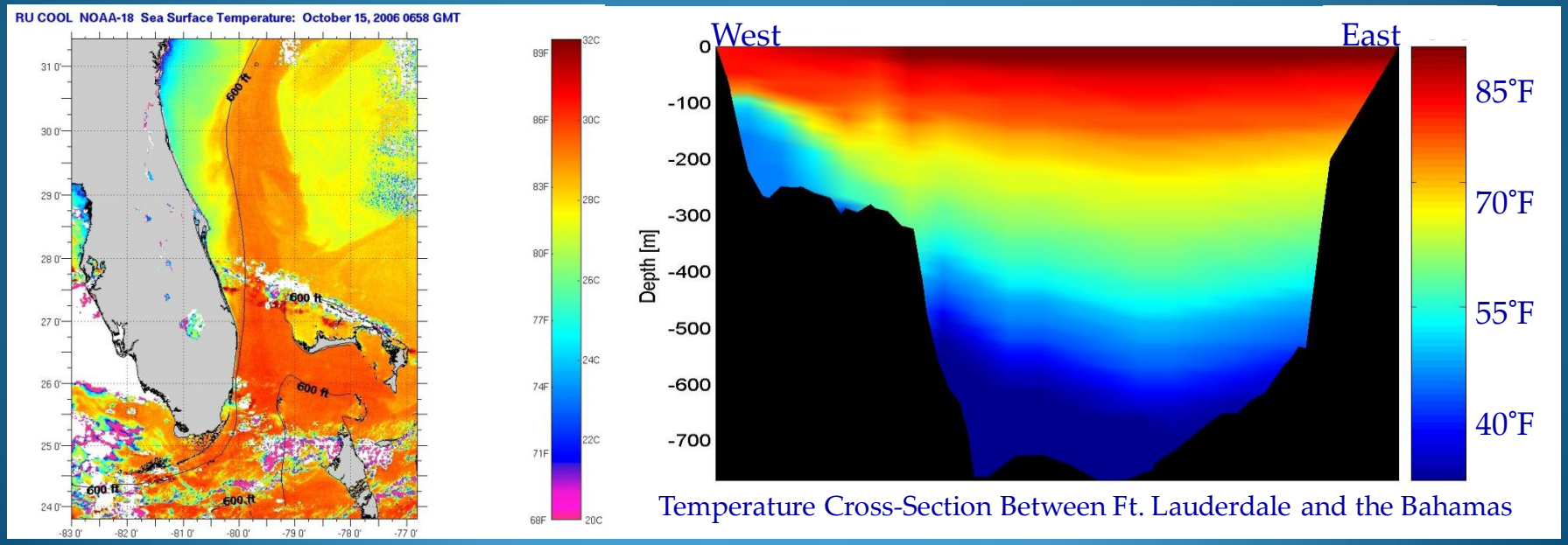


...but we've sure got current.

Moreover, we have a significant thermal potential as well.

Ocean Thermal Energy Conversion

- Ocean thermal energy has the greatest potential
- A pilot plant is being developed in Hawaii
- Florida is also a prime location (water is renewed by Gulf Stream flow)



FAU's COET

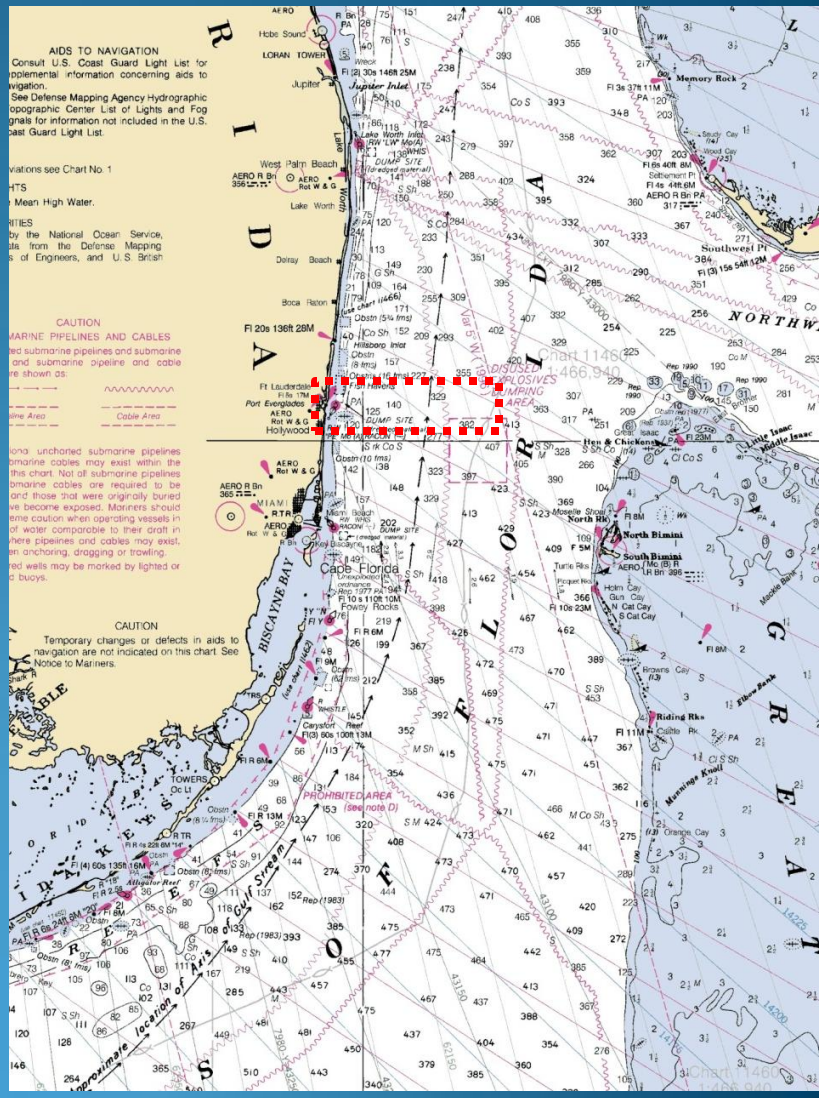
FAU's Center for Ocean Energy Technology, embedded in the College of Engineering and Computer Science, was founded with an award from the Florida Center of Excellence Program in 2007.

Additional funding from the State of Florida and from the US Department of Energy is underwriting our efforts to advance the science and technology of oceanic energy extraction.

We're starting with the Florida Current and progressing toward OTEC implementation.

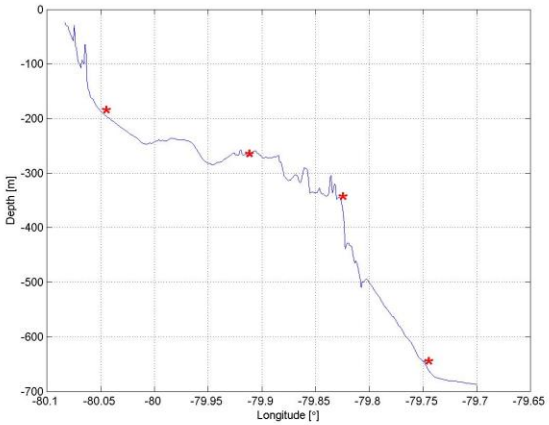
Regulatory Framework

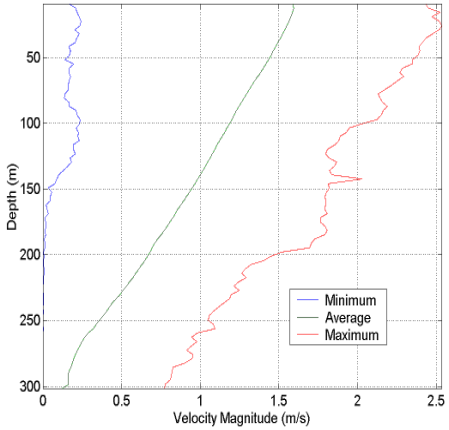
- U.S. Army Corps of Engineers
- U.S. Coast Guard
- U.S. Navy
- Federal Communication Commission
- U.S. Environmental Protection Agency
- Federal Energy Regulatory Commission
- U.S. Department of Interior – Minerals Management Service
- National Oceanic and Atmosphereic Administration, NOAA Fisheries
- U.S. Fish and Wildlife Service
- Florida Dept. of Environmental Protection
- Florida Fish and Wildlife Commission

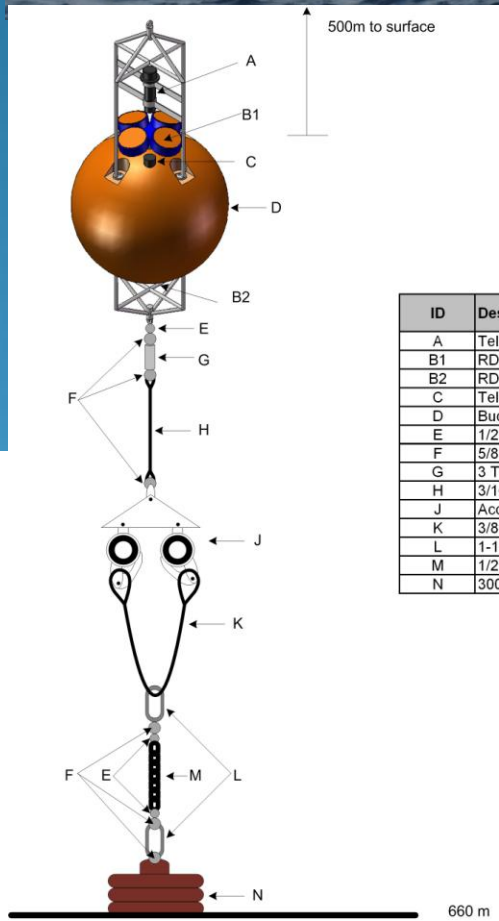


Current Profiling Measurement

- 4 bottom mounted ADCP buoys measuring the water profiles every 30 minutes with bin sizes from 2–8 meters
- These buoys are located approximately 5, 10, 15, and 20 miles off shore
- 2 buoys have both upward and downward looking ADCPs
- 2 buoys have only upward looking ADCPs
- Two additional buoys are scheduled to be deployed this year
- Ship mounted ADCPs will allow us to make transects across the Gulf Stream



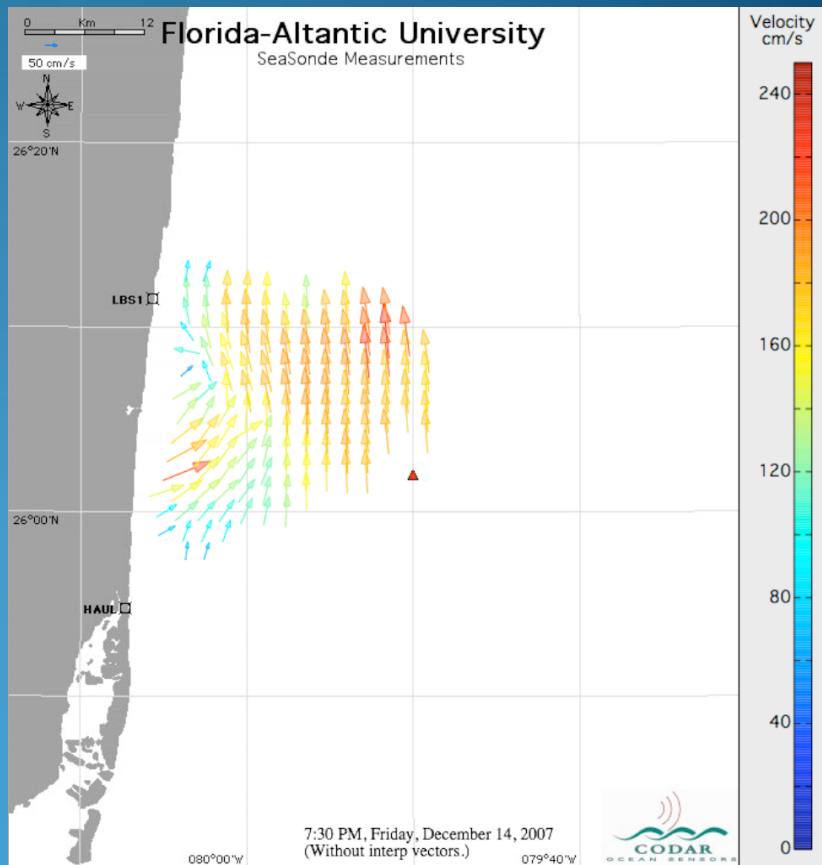




ID	Description
A	Teledyne Benthos Acoustic Transducer
B1	RDI 75 kHz ADCP (looking up)
B2	RDI 300 kHz ADCP (looking down)
C	Teledyne Benthos Acoustic Modem
D	Buoy (1250 lb in air), (890 lb buoyant in SW)
E	1/2" Galvanized Safety Anchor Shackle
F	5/8" Galvanized Safety Anchor Shackle
G	3 Ton Stainless Steel Swivel
H	3/16" SS Cable, 150m
J	Acoustic Release
K	3/8" SS Cable, 6m
L	1-1/4" Galvanized Ring
M	1/2" Galvanized Chain, 5m
N	3000 lb Anchor (railroad wheels)

Ocean Current Surface Measurement

- Two surface current radar stations have been installed
- These measure an approximately 40 x 40 mile area off our coast
- Measurements are made every 30 minutes
- Resolution is approximately 2 miles
- Two more stations may be added



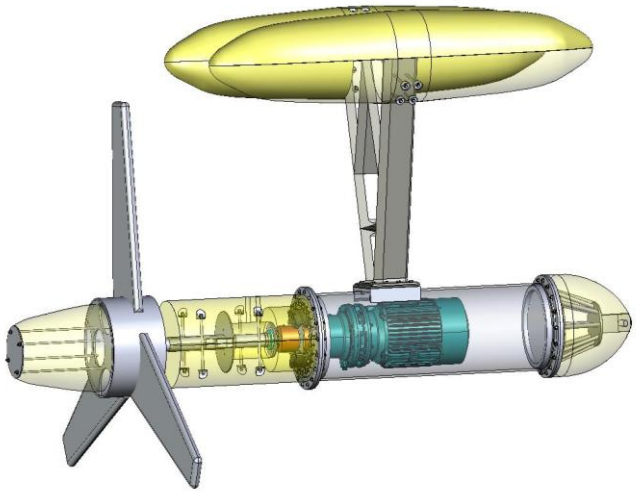
Water Property Measurement

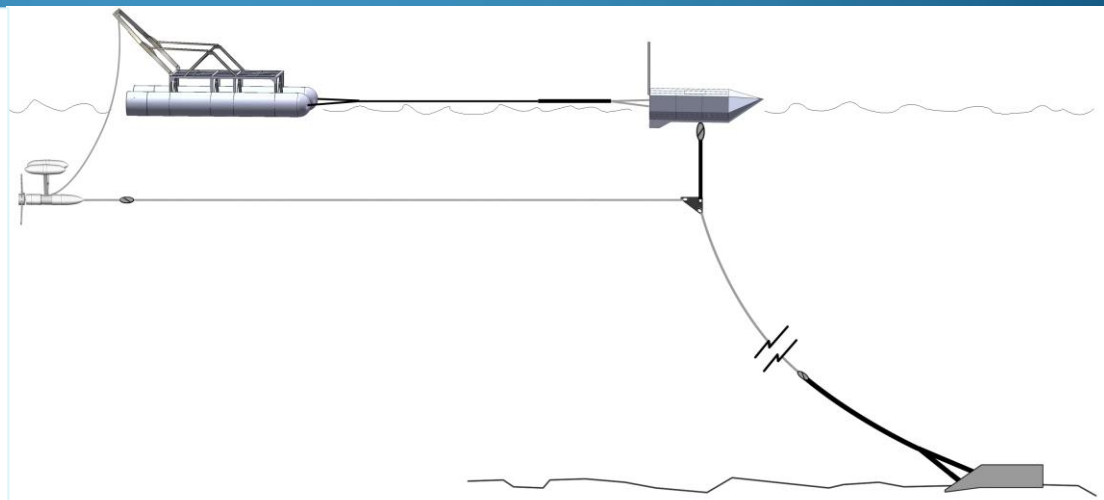
- Water property profiles are made from near the surface to 10 meters from the bottom
- Measurements are made along four 25-30 mile long transect lines along a constant latitude separated by 33 miles with 9-11 profiles made along each transect
- Conductivity, temperature, pressure, salinity, PH, and dissolved oxygen are simultaneously measured at 24 Hz
- 48 transects have been made off our coast (See Table) and 8 at the other locations

Distance from shore (km)	Mean Δt (°C)	Min Δt (°C)	Max Δt (°C)	Std Δt (°C)
3	9.88	2.68	18.39	3.11
4	16.60	11.65	21.62	2.64
7	17.59	12.94	22.23	2.65
8	18.07	13.36	22.30	2.43
13	18.00	13.25	22.38	2.46
18	18.07	13.76	21.46	2.20
23	18.35	13.67	21.32	2.13
28	19.44	15.79	22.53	1.90
33	21.18	18.43	23.89	1.71
38	21.36	18.37	24.09	1.70
43	21.58	18.38	23.96	1.66

Ocean Current Prototypes and Testing

- Demonstrate feasibility of extracting ocean current energy
- Investigate technology gaps and hurdles
- Study environmental and ecological interactions
- Develop a platform to support ocean energy technology development
- Initial turbine has a 3 m diameter rotor, 20 kW generator, and 1500 kg dry weight
- Prognostics and health monitoring systems to ensure assessment, avoidance, and risk mitigation





Summary

- Renewable energy – in all cases some form of solar power that has been processed by various components of the Earth System – represents an alternative to the “ancient” sunlight locked up in fossil fuels.
- The oceans, an important component of the Earth System, are finally being tapped for their renewable potential.
- Like the atmosphere’s winds, the oceans’ large-scale current systems offer significant potential for electrical power generation be it hydrokinetic or ocean thermal.
- The challenges are significant, but not insurmountable
- We must work together on global renewable energy solutions