

Marine and Hydrokinetic Energy Metocean Data-use, Sources, and Instrumentation

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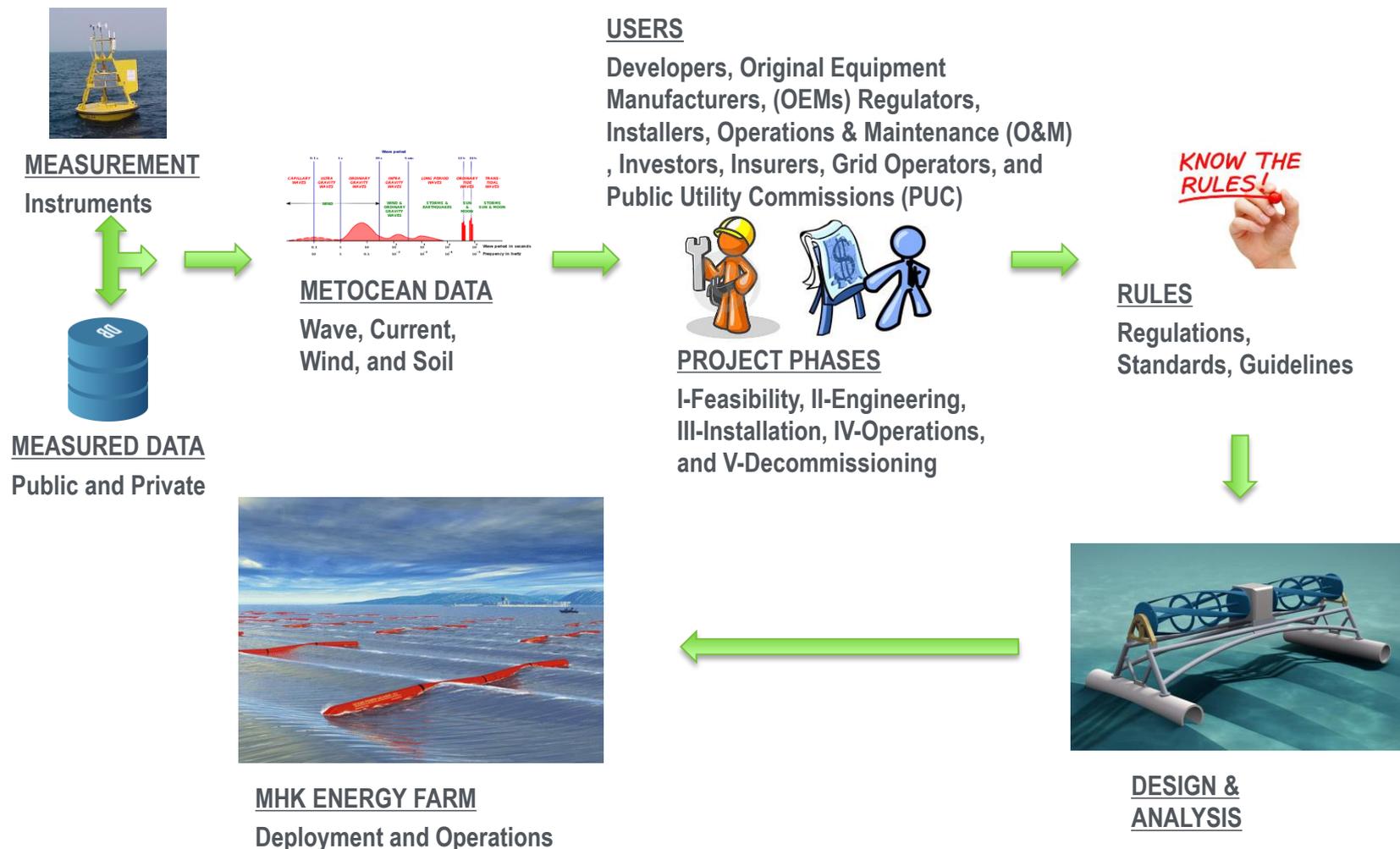
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Metocean Data Flow Throughout Project Lifecycle



- This project aims to accelerate deployment of marine and hydrokinetic (MHK) technology by establishing:
 - relevant existing and evolving standards and guidelines
 - meteorological and oceanic (metocean) data use
 - data sources
 - instrumentation guidance

for siting, design, and operation of MHK devices along the U.S coastline

- The purpose is to improve the process of exploration of potential development sites, which involves design, deployment, operation, decommissioning, and cost and revenue studies
- Draft report under review prior to publication

Technology Maturity

- Test and demonstrate prototypes
- Develop cost-effective approaches for installation, grid integration, and operations and maintenance
- Conduct R&D for innovative MHK systems & components
- Develop tools to optimize device and array performance and reliability
- Develop and apply quantitative metrics to advance MHK technologies

Deployment Barriers

- Identify potential improvements to regulatory processes and requirements
- Support research focused on retiring or mitigating environmental risks and reducing costs
- Build awareness of MHK technologies
- Ensure MHK interests are considered in coastal and marine planning processes
- Evaluate deployment infrastructure needs and possible approaches to bridge gaps

Market Development

- Support project demonstrations to reduce risk and build investor confidence
- Assess and communicate potential MHK market opportunities, including off-grid and non-electric
- Inform incentives and policy measures
- Develop, maintain, and communicate our national strategy
- Support development of standards
- Expand MHK technical and research community

Crosscutting Approaches

- Enable access to testing facilities that help accelerate the pace of technology development
- Improve resource characterization to optimize technologies, reduce deployment risks, and identify promising markets
- **Exchange of data information and expertise**

Crosscutting Approaches

- Exchange of data information and expertise

The Impact

- De-risk projects for stakeholders by:
 1. Providing data for guidance to applicable regulations, standards, guidelines, and certification processes
 2. Providing guidance and outlining the required metocean data for evaluating project feasibility
 3. Providing metocean data sets available by state and gaps in areas of coverage
 4. Gathering the required metocean data for instrumentation requirements
- Draft report under review prior to publication

- Leverage existing knowledge from:
 - MHK industry
 - Offshore wind industry
 - Offshore oil and gas industry
 - Instrumentation experts
 - Universities
 - Resource centers
- Regulations, standards, guidelines, and certification
 - Investigate gaps existing for MHK development and supplement the gaps from other offshore-related industries
- Metocean users
 - Identify MHK project life cycle data users and data needs
- Metocean data
 - Identify metocean parameters needed for MHK project life cycle and relevant instrumentation to measure such data
 - Identify sources for instrumentation
- Metocean data sets (private and public)
 - Mine sites with metocean data (not clearing houses) relevant for MHK development
 - Provide a list filtered by states
- Metocean data set gaps
 - Identify stations collecting some kind of metocean data to highlight the areas that are not being covered
 - Bridge gaps in metocean data sets

Regulations, standards, guidelines, and certification applicable to the MHK industry:

Regulations	Standards	Guidelines	Certification
<ul style="list-style-type: none">• Code of Federal Regulations (CFR)• Federal Aviation Administration (FAA)• U.S. Coast Guard (USCG)	<ul style="list-style-type: none">• American Institute of Steel Construction (AISC)• American National Standards Institute (ANSI)• American Petroleum Institute (API)• International Electrotechnical Commission (IEC)• International Standards Organization (ISO)	<ul style="list-style-type: none">• American Bureau of Shipping (ABS)• Det Norske Veritas - Germanischer Lloyd (DNVGL)	<ul style="list-style-type: none">• Type Certification Modules (adapted from IEC 61400-22 type certification)• Project Certification Modules (adapted from IEC 61400-22 type certification)

Project life cycle users of metocean data and the level of data uncertainty:

Entity	Phase I Feasibility	Phase II Engineering	Phase III Installation	Phase IV Operations	Phase V Decommissioning
Developer	✓	✓	✓	✓	✓
OEM	✓	✓	✓	✓	✓
Regulators		✓	✓	✓	✓
Installers		✓	✓		✓
O&M		✓		✓	
Certified Verification Agent		✓			
Investors	✓	✓			
Insurers		✓			
Grid Operators		✓		✓	
PUC		✓		✓	
Metocean Data	Measured or Modeled	Measured (1-year min)	Measured	Continued Measurement (3-year min)	Measured
Uncertainty	Medium to High	Low	Low	Low	Low

Metocean data needed for both wave and current devices:

WAVE DEVICE	Phase I Feasibility	Phase II Engineering	Phase III Installation	Phase IV Operation	Phase V Decommissioning
WAVE					
Significant Height [Hs]	✓	✓	✓	✓	✓
Peak Period [Tp]	✓	✓	✓	✓	✓
Direction	✓	✓	✓	✓	✓
Annual Hs/Tp Occurrence Probability	✓	✓			
Directional Spectrum	✓	✓			
CURRENT					
Speed [U]	✓	✓	✓	✓	✓
Direction	✓	✓	✓	✓	✓
Depth		✓	✓	✓	✓
Annual Speed Occurrence Probability		✓			
OCEAN/RIVER					
Depth (MWL)	✓	✓	✓	✓	✓
Salinity		✓			
WIND					
Speed		✓	✓	✓	✓
Direction		✓	✓	✓	✓
SOIL					
Bathymetry		✓	✓		✓
Soil Type	✓	✓	✓		✓

CURRENT DEVICE	Phase I Feasibility	Phase II Engineering	Phase III Installation	Phase IV Operation	Phase V Decommissioning
WAVE					
Significant Height [Hs]		✓	✓	✓	✓
Peak Period [Tp]		✓	✓	✓	✓
Direction		✓	✓	✓	✓
CURRENT					
Speed [U]	✓	✓	✓	✓	✓
Direction	✓	✓	✓	✓	✓
Depth	✓	✓	✓	✓	✓
Annual Speed Occurrence Probability	✓	✓			
Turbulence	✓	✓			
OCEAN/RIVER					
Depth (MWL)	✓	✓	✓	✓	✓
Density	✓	✓			
Salinity		✓			
WIND					
Speed			✓	✓	✓
Direction			✓	✓	✓
SOIL					
Bathymetry		✓	✓		✓
Soil Type	✓	✓	✓		✓

Instrumentation needed to measure metocean data:

	ATMOSPHERIC					WIND		OCEAN & RIVERS					WAVE					CURRENT			SOIL							
	AT-D	AT-P	AT-T	AT-L	AT-PR	AT-I	WN-S	WN-DR	WA-D	WA-SL	WA-MG	WA-I	WA-T	WA-MWL	WA-SS	WV-H	WV-DR	WV-HS	WV-TP	WV-DS	WV-FS	CR-S	CR-DR	CR-DP	SL-BY	SL-TY	SL-SC	
Air Properties																												
Air temperature, pressure, and relative humidity sensors	X	X	X																									
Lightning detector				X																								
Pressure					X																							
Freezing rain and ice detectors						X																						
Wind Speed and Direction																												
Cup and vane anemometers						X	X																					
Ultrasonic anemometers						X	X																					
Acoustic resonance anemometers						X	X																					
Acoustic Current and Wave																												
Doppler current meter – Single point																						X	X	X				
Doppler current profilers											X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Velocimeters																							X	X				
Single beam (vertical)												X	X	X		X	X			X								
Mechanical/Other Current																												
Vane current meters																						X	X	X				
Electromagnetic																						X	X	X				
Laser Doppler velocimeters																						X	X	X				
Radar																						X	X					
Mechanical/Other Wave																												
Wave-following buoys															X	X	X	X	X	X								
Pressure/tide gauge															X		X	X		X								
Radar																	X	X	X									
Water Properties																												
Stationary conductivity and temperature (CT)								X	X		X											X						
Profiling conductivity, temperature, and depth (CTD)								X	X		X																	
Sampling rosette									X																			

Examples of Metocean Data Set (report includes world, United States, and U.S. states)

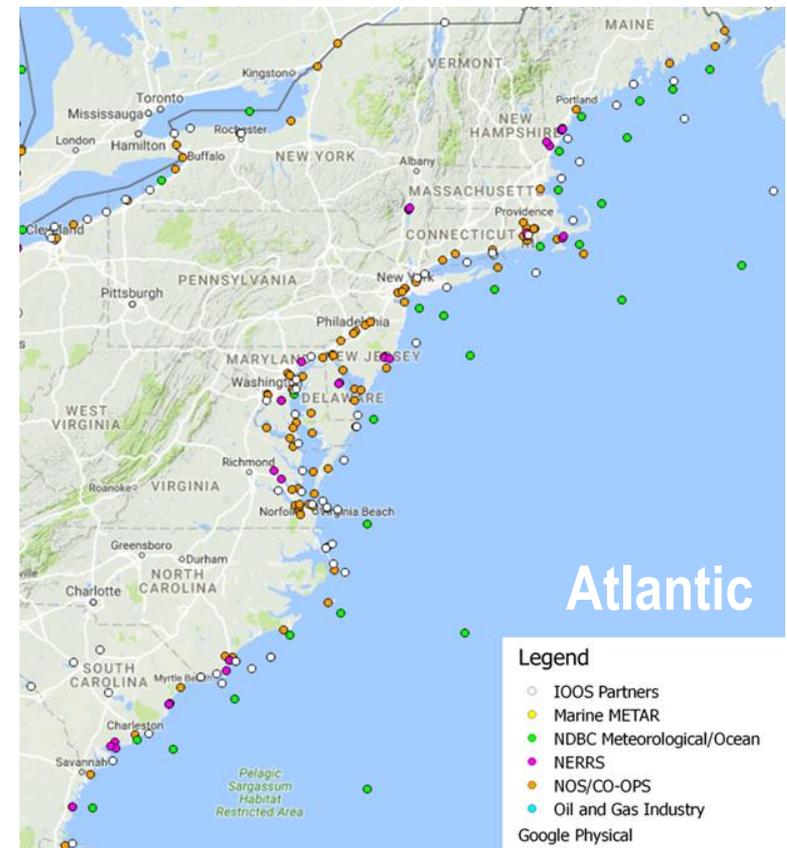
United States

Entity	Link	Air	Water	Soil
Public				
National Oceanic & Atmospheric Administration, National Data Buoy Center (NOAA-NDBC)	http://www.ndbc.noaa.gov/	WN-S, WN-SD (AT-P, AT-T)	WV-DR, WV-HS, WV-TP, WV-DS (OR-T, WV-H, WV-FS)	
National Oceanic & Atmospheric Administration (NOAA-TC)	http://tidesandcurrents.noaa.gov/products.html		CR-S, CR-DP, CR-DR, CR-PO (OR-T, OR-MWL, OR-SS, OR-TD)	
U.S. Army Corps of Engineers (WIS)	http://wis.usace.army.mil/	WN-S, WN-SD	WV-DR, WV-HS, WV-TP, WV-DS (WV-H, WV-FS)	
NOAA Integrated Ocean Observing System (NOAA-IOOS)	http://www.ioos.noaa.gov/catalog/welcome.html	WN-S, WN-SD (AT-P, AT-T)	OR-SL, WV-DR, WV-HS, WV-TP, CR-S (OR-T, WV-H)	
Physical Oceanographic Real-Time System (NOAA-PORTS)	http://tidesandcurrents.noaa.gov/ports.html	WN-S (AT-P, AT-T)	(OR-T, OR-MWL, OR-TD)	
Coastal Data Information Program (CDIP)	http://cdip.ucsd.edu/themes/cdip	WN-S	OR-SL, WV-DR, WV-HS, WV-TP, WV-DS, WV-PO, CR-S (OR-T, WV-H, WV-FS, WV-SM)	
Private				
AWS Truepower: Mesoscale Modeling and Wind Trends Database (AWS)	http://www.awstruepower.com/	WN-S, WN-SD, WN-DR (WN-DD)		

California

Entity	Link	Air	Water	Soil
Public				
Central & Northern California Ocean Observing System (CenCOOS)	http://www.cencoos.org/	WN-S, WN-SD (AT-P, AT-T)	OR-SL, WV-HS, WV-TP (OR-T, OR-MWL, WV-H)	
Southern California Coastal Ocean Observing System (SCCOOS)	http://www.sccoos.org/	(AT-P)	OR-SL (OR-T)	
Bodega Marine Laboratory Bodega Ocean Observing Node, UC Davis (BOON)	http://bml.ucdavis.edu/boon/index.html	WN-S, WN-SD (AT-P, AT-T, AT-PR)	OR-SL, WV-DR, CR-S, CR-DP (OR-T, WV-H)	
Monterey Bay Research Institute Ocean Observatories (MBARI)	http://www.mbari.org/	(AT-T)	CR-S, CR-DP, CR-DR (OR-TD)	(SL-BY)
Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)	http://www.piscoweb.org/		CR-S, CR-DP, CR-DR (OR-T, OR-MWL)	
Shore Station Program (SCRIPPS-SSP)	http://shorestations.ucsd.edu/shore-stations-data/	WN-S	OR-SL, CR-S (OR-T)	

Examples of Metocean Data Collection Stations to Identify Lack of Coverage (Report includes the United States, Alaska, Atlantic Coast, Great Lakes, Gulf of Mexico, Hawaii, and Pacific Coast)



Example of NDBC and Partner Stations with Applicable Metocean Data for MHK Development

Station	Site	Barometric Pressure (AT-P)	Atmospheric Temperature (AT-T)	Wind Direction (WN-DR)	Wind Speed (WN-S)	Wave Height (WV-H)	Dominant Wave Period (WV-DP)	Water Temperature (OR-T)	Water Tide (OR-TD)	Water Salinity (OR-SL)	Current Speed (CR-S)	Current Direction (CR-DR)	Current Depth (CR-DP)
41001	2.3D04 (SC) East Hatteras	x	x	x	x	x	x	x					
41002	3D50 (AR) South Hatteras	x	x	x	x	x	x	x					
41004	3D58 (AR) Edisto	x	x	x	x	x	x	x					
41008	3D36 (AM) Grays Reef	x	x	x	x	x	x	x					
41009	3D86 (AM) Canaveral	x	x	x	x	x	x	x					
41010	3D26 (AR) Canaveral East	x	x	x	x	x	x	x					
41013	2.3D01 (SC) Frying Pan Shoals, NC (buoy)	x	x	x	x	x	x	x					
41025	3DV09 (AR) Diamond Shoals	x	x	x	x	x	x	x					
41040	3D56 (AR) North Equatorial One	x	x	x	x	x	x	x					
41041	3D72 (AM) North Equatorial Two	x	x	x	x	x	x	x					
41043	2.3D08 (SC) NE Puerto Rico	x	x	x	x	x	x	x					
41044	3DV49 (SC) NE St. Martin	x	x	x	x	x	x	x					
41046	2.3D07 (SC) East Bahamas	x	x	x	x	x	x	x					
41047	3DV42 (SC) NE Bahamas	x	x	x	x	x	x	x					
41048	3DV02 (AR) West Bermuda	x	x	x	x	x	x	x					
41049	3DV31 (AR) South Bermuda	x	x	x	x	x	x	x					
42001	3D30 (AR) Mid Gulf	x	x	x	x	x	x	x					
42002	3D74 (AR) West Gulf	x	x	x	x	x	x	x					
42003	3D20 (AR) East Gulf	x	x	x	x	x	x	x					
42012	3DV11 (AR) Orange Beach, AL	x	x	x	x	x	x	x					
42019	3DV14 (AR) Freeport, TX	x	x	x	x	x	x	x					
42020	3DV26 (AR) Corpus Christi, TX	x	x	x	x	x	x	x					
42035	3DV17 (AR) Galveston, TX	x	x	x	x	x	x	x					
42036	3D37 (AR) West Tampa	x	x	x	x	x	x	x					
42039	3D55 (SM) Pensacola	x	x	x	x	x	x	x					
42040	2.4D05 (SC) Luke Offshore Test Platform	x	x	x	x	x	x	x					
42055	3D49 (AR) Bay Of Campeche	x	x	x	x	x	x	x					
42056	3DV46 (SC) Yucatan Basin	x	x	x	x	x	x	x					
42057	3D57 (AR) Western Caribbean	x	x	x	x	x	x	x					
42058	3DV27 (AR) Central Caribbean	x	x	x	x	x	x	x					
42059	3DV38 (SC) Eastern Caribbean Sea	x	x	x	x	x	x	x					
42060	2.3D10 (SC) Caribbean Valley	x	x	x	x	x	x	x					
44005	3DV16 (AM) Gulf Of Maine	x	x	x	x	x	x	x					

- Project schedule
 - October 2015 initiation date
 - September 2016 completion date

- Milestones

FY16	Milestone	Percent Complete
Q1	Compile list of existing MHK metocean measurement data sets identified (both public and private)	100%
Q2	Establish list of MHK metocean data needs from site identification through decommissioning	100%
Q3	Complete draft MHK metocean gaps analysis (geographic, data types, data attributes)	100%
Q4	Provide summary of MHK metocean data use guidelines to DOE HQ and schedule call to walk through	100%

- Go/No-Go decision
 - None

Budget History

FY2014		FY2015		FY2016	
DOE	Cost Share	DOE	Cost Share	DOE	Cost Share
\$0	\$0	\$200k	\$0	\$0	\$0

- There has been no variance from planned budget or project plan
- Project was executed as budgeted and fully costed
- Additional funding necessary for publication and dissemination of the work's usefulness for the MHK industry at MHK conferences

Partners, Subcontractors, and Collaborators

- None

Communications and Technology Transfer

- The report will be distributed to the Marine Energy Council Resource Assessment Subcommittee for comments.
- Additional funds are needed to get the report ready for public distribution.

FY17/Current Research

- Project completed

Proposed Future Research

- There is a need for joint probability distributions (JPDFs) of wave height, wave period, and wind speed to provide design parameters for MHK devices, as well as give better estimates of the expected energy production at a site
- Include hourly values of significant wave height, wave period, and 10-m wind speed on a 4-ft (1/15-degree) grid for the U.S. coastal waters which will be available from the 30 years of hind-cast data from NOAA's WaveWatch III model
- The hind-cast data can be processed to create JPDFs of wave and wind conditions at each point to be displayed on NREL's MHK Atlas

MHK Atlas

