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Floating Lidar: A Platform for Offshore Wind Resource Characterization and Marine Life Data Collection

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U.S. DEPARTMENT OF ENERGY

Attraction of Offshore Wind Energy in California

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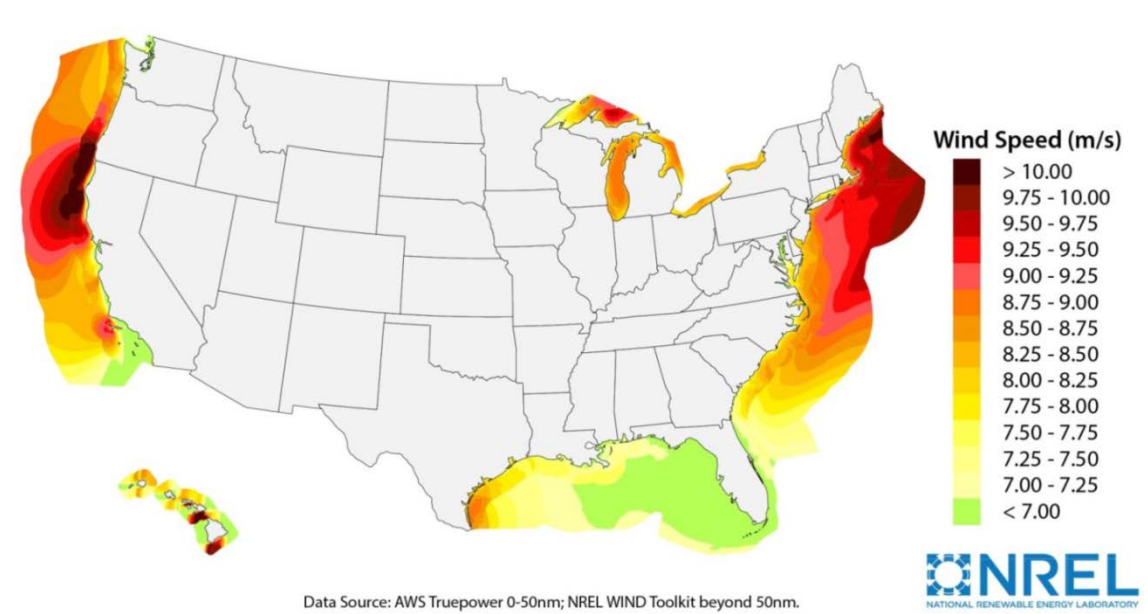
- Substantial Resource
  - Comparable to best terrestrial wind areas
- Near Load Centers
  - Reduced transmission distances
  - Steady, strong winds
- Larger Turbines
  - Greater efficiency



Modeled Offshore Mean Winds at 100m above MSL*

*Musial et al. 2016. *2016 Offshore Wind Energy Resource Assessment for the United States*. Tech. Rpt. NREL/TP-5000-66500.

Uncertainties in Offshore Wind

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- Model Validation
  - No long-term winds measured at hub heights
- Scaling Buoy Surface Winds to Hub Height
  - Power or log profiles
    - Non-equilibrium conditions
    - Effects of coastal circulations
    - Effects of MABL depth

Photos credit: NOAA

- Comprehensive Research Data
  - Includes MABL winds, turbulence above the surface
  - BUT, episodic: Does not sample full range of conditions

The Challenge of Offshore Wind Resource Characterization

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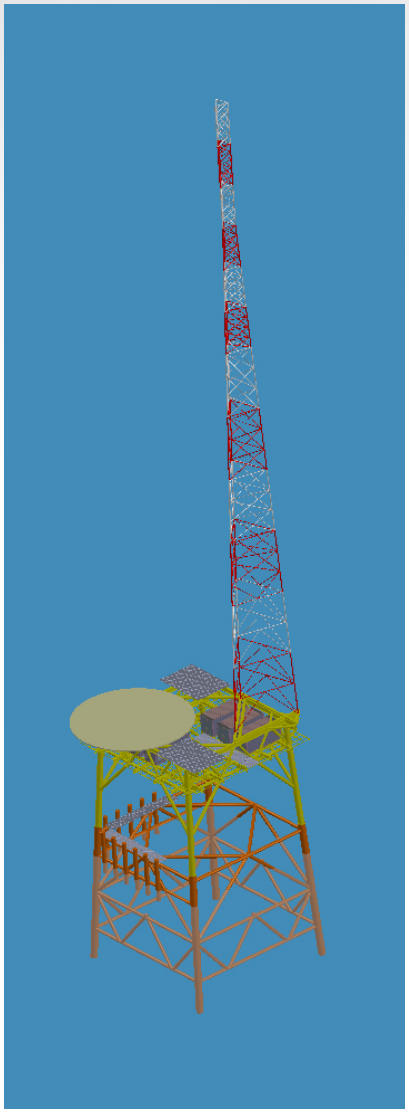
- Convention for Assessment—Fixed Tower
  - Costly at sea
  - Not feasible in deep water
  - Coastal towers potentially influenced by local atmospheric circulations

Photo by Rick Driscoll, NREL



Schematic: Rick Driscoll

Example Solution: DOE's WindSentinel® Lidar Buoy

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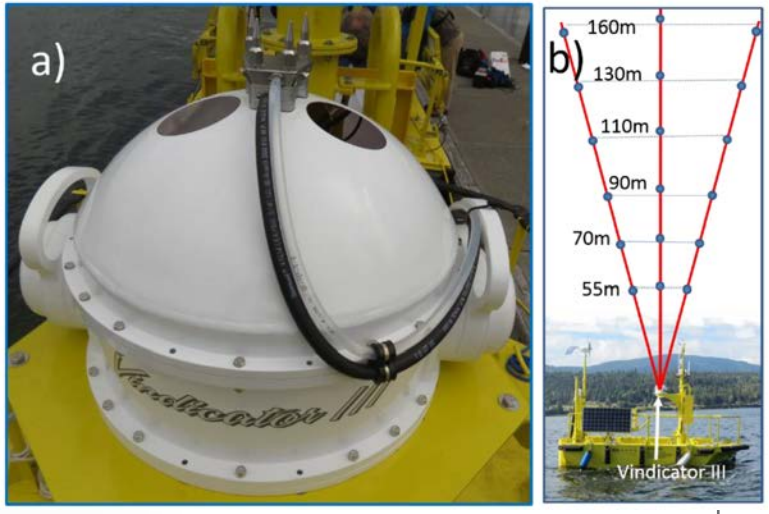
- Advantages
  - Far less costly than fixed tower
  - Deployable in depths >15 m
  - No wind distortion around a tower
  - Motion-corrected lidars can produce accurate winds
    - 2016 Carbon Trust best practices
  - Can be powered with renewable energy
- Challenges
  - Lidar returns somewhat weather-dependent
  - Weather windows for servicing and deployment

Example: One of DOE's two WindSentinel® buoys



Lidar and sampling geometry

DOE Buoy Deployments

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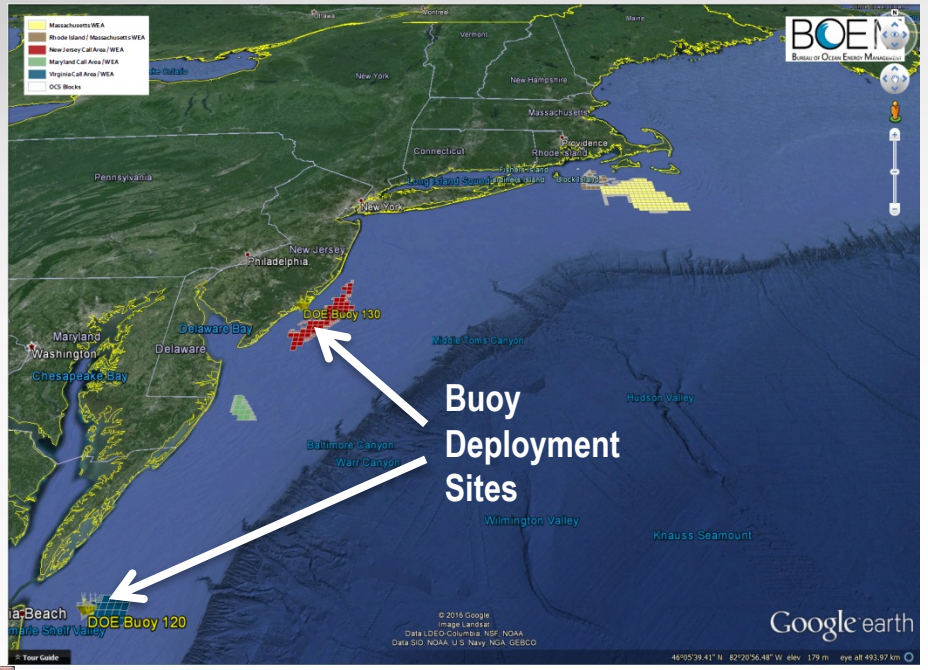
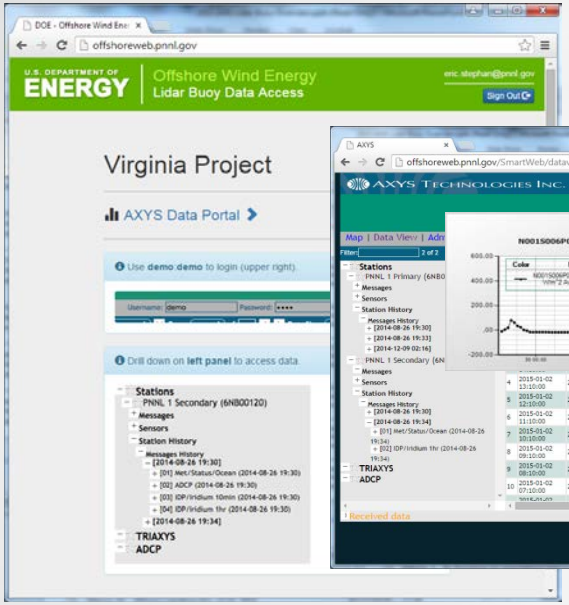
Virginia

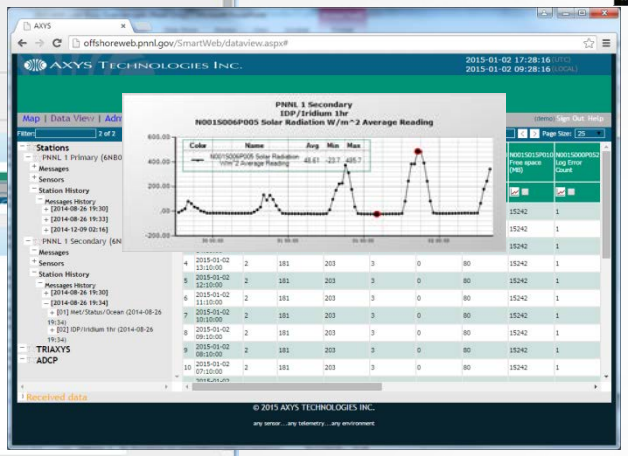
- Deployed 12 December 2014
- Recovered 15 June 2016
- 17 months of data delivered to archive

New Jersey

- Deployed 4 November 2015
- Recovery awaiting weather window







Buoy 120 42 km off Virginia shore

Example Sensors: WindSentinel

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Sensor Type	Manufacturer	Model
Wind Profile (6 range gates to ~200 m above MSL)	OADS	Vindicator III
Wind Speed (2)	Vector Instruments	A100R
Wind Direction	Vector Instruments	WP200
Temperature, Relative Humidity	Rotronic	MP101A
Barometer	RM Young	61302V
Pyranometer	Licor	LI-200
Water Temperature	AXYS	YSI
CTD	Seabird	SBE 37SMP-1j-2-3c
Wave	AXYS	TRIAXYS NW III
Current Profile (ADP)	Nortek	Aquadopp 400 kHz
Tilt/Compass	MicroStrain	3DM GX3 25

Wind Resource R&D Applications

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- Validation of Wind Resource Models
  - Full spectrum of synoptic forcing
  - Full range of thermodynamic stratification
  - Model reproduction of wind speed distributions
- Behavior of Wind Profile from Surface to Hub Height
  - Uncertainties associated with conventional profile forms
  - Effects of non-equilibrium wave states and strong atmospheric non-stationarity or inhomogeneity
  - Effects of local coastal circulations
- Wave Measurements for Load Modeling
- Subsurface Impacts of Air-Sea Interaction
  - Current structure, with implications for scour in shallow water

Lidar Buoys as Environmental Platforms

- Permitting Requires Species Information
  - Bird/bat presence and migration
    - Abundance and flight height
    - Flight response to turbine arrays
  - Marine mammals/sea turtles
    - Species abundance
    - Movement near wind plant areas
  - Threatened/endangered species
    - Presence and movement
    - Habitat impacts

Sooty shearwater—species of concern off California

Albatross—some species endangered; potentially at risk from turbine blades

Harbor Porpoise—not endangered, but protected marine mammal

Potential Environmental Instruments

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Instrument	Purpose	Special Considerations
Radar – upward facing and outward scanning	Detect bird and bat species and abundance, determine flight heights	Power requirements might be substantial. Data could be stored on board.
Bat detector – passive acoustic instrument	Detect presence and perhaps species of bats, particularly at night	Self contained for power and data.
Hydrophones (underwater)	Detect presence and species of vocalizing marine mammals	Small power draw, can be self contained for data.
Stereo cameras (video or still; optical or IR) can be triggered by radar	Identify species of birds and bats in daylight (optical) or night (IR)	Can be self contained for power and data.
* **Underwater stereo cameras** (video or still; optical or IR) be triggered by hydrophone	Identify species of vocalizing marine mammals, perhaps catch sea turtles	Can be self contained for power and data.
Oceanographic instrumentation, such as **CTD**, preferably profiling; **ADP**, etc.	Determine water column profile in vicinity of proposed wind farms, which partially determines animal movement	Requires onboard power, data could be wholly or partially stored onboard.

*Potentially challenging to deploy

Summary

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- Lidar buoys are a viable means for resource characterization, including assessment, in U.S. offshore waters, including California
  - Buoys are the only realistic platform for long-term measurements in deep water
  - Buoys also provide wave and current information for loads modeling
- R&D needs remain significant for offshore wind resource modeling
- Buoys have the capacity to carry environmental sensors for permitting and research