Research Supporting Offshore Wind Energy at PNNL

William J. Shaw
Pacific Northwest National Laboratory

Ocean Renewable Energy Conference
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poet
PACIFIC OCEAN ENERGY TRUST

Knowledge Gaps for Offshore Wind Energy

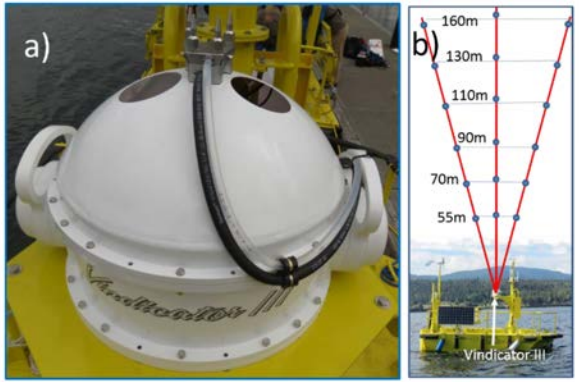
- Validation of Wind Resource Models
  - Full spectrum of synoptic forcing
  - Full range of thermodynamic stratification
  - Model reproduction of wind speed distributions
- Behavior of Wind Profile from Surface to Hub Height
  - Uncertainties associated with conventional profile forms
  - Effects of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

Photo credit: Dennis Schroeder, NREL

DOE Lidar Buoys for Long-Term Wind Resource Characterization

- Advantages
  - Far less costly than fixed tower
  - Deployable in depths >15 m
  - No flow distortion as around a tower
  - Motion-corrected lidars can produce accurate winds
    - 2016 Carbon Trust best practices
  - Can be powered with renewable energy
- PNNL Management
  - Procurement in 2014
  - Acceptance testing at PNNL's Marine Sciences Laboratory
  - Deployments off Virginia, New Jersey

One of DOE's two WindSentinel® buoys



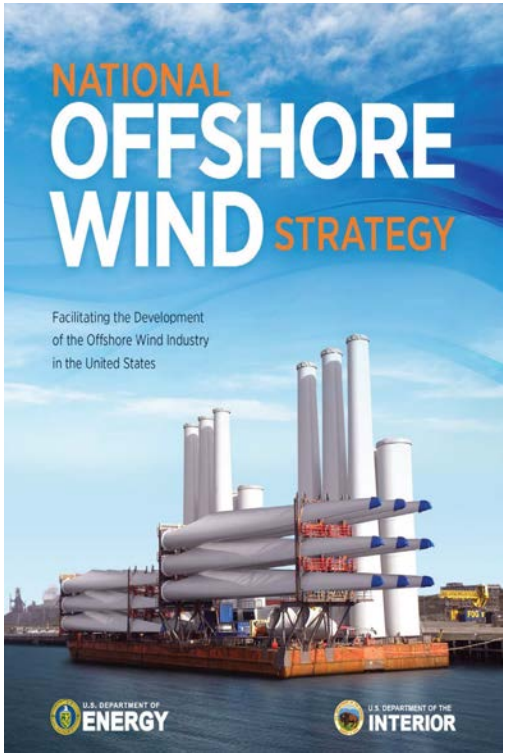
Lidar and sampling geometry (Rob Newson, PNNL)

WindSentinel Observations

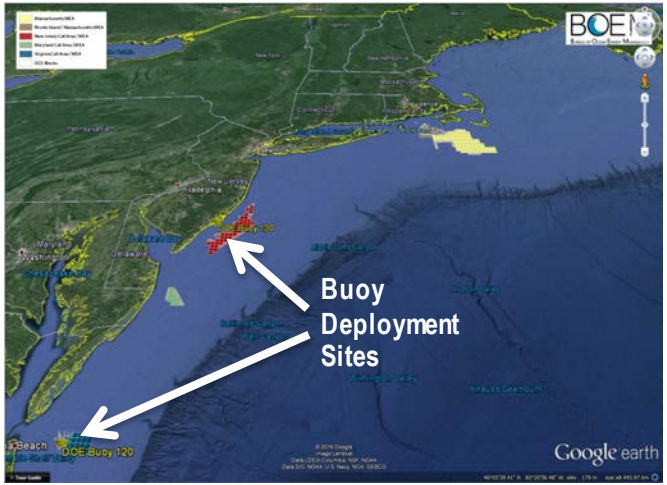
Sensor Type	Manufacturer	Model
Wind Profile (6 range gates to ~200 m above MSL)	OADS	Vindicator III
Wind Speed (2)	Vector Instruments	A100R
Wind Direction	Vector Instruments	WP200
Temperature, Relative Humidity	Rotronic	MP101A
Barometer	RM Young	61302V
Pyranometer	Licor	LI-200
Water Temperature	AXYS	YSI
CTD	Seabird	SBE 37SMP-1j-2-3c
Wave	AXYS	TRIAXYS NW III
Current Profile (depths to 90 m)	Nortek	Aquadopp 400 kHz
Tilt/Compass	MicroStrain	3DM GX3 25

Buoy Context: National Offshore Wind Strategy

- Action Area: Offshore Wind Power Resource and Site Characterization
  - Current Baseline
    - "without…towers similar to…German FINO metocean research stations…difficult to validate wind observation and model data."
    - Mesoscale models not validated offshore for U.S.-specific conditions
    - No consensus standards for site-specific data collection
  - Gaps
    - Continuing need for accepted U.S. reference facility
    - Lidar buoys, if accepted, could help fill data gaps
      - IEA Task 32 released "Recommended Practices" based on Carbon Trust's "OWA Floating LiDAR Best Practices"
  - Need for DOE expand resource characterization
    - Lidar buoys procured 2014
    - Deployed 2014–2017



Buoy Deployments—First Sampling of Full Annual Cycle in the U.S.



Buoy 120 42 km off Virginia shore

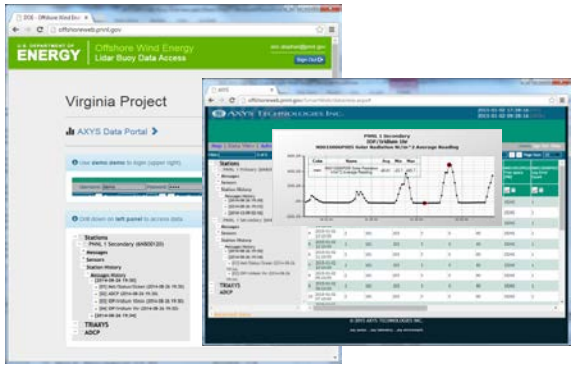
Photo: Mikhail Pekour, PNNL

Virginia

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

New Jersey

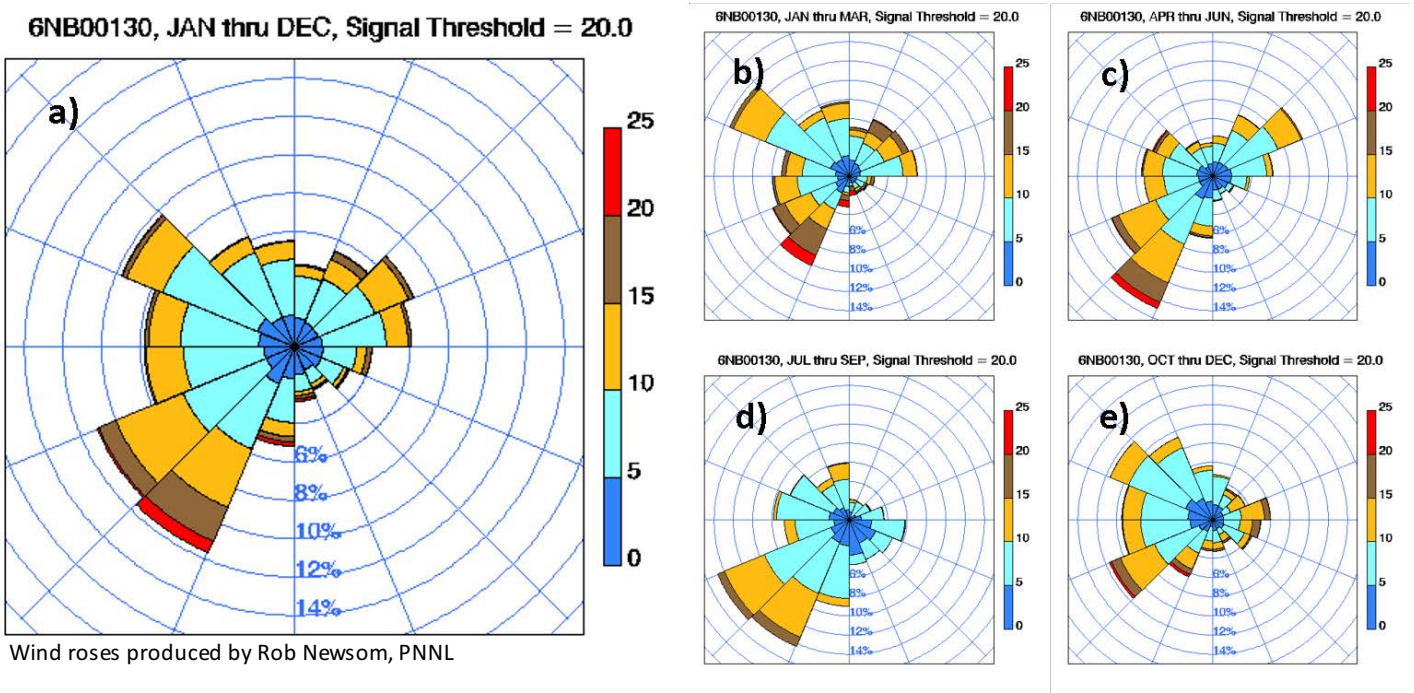
- Deployed 4 November 2015
- Recovered 03 February 2017
- 15 months of data delivered to archive



Data available from
http://offshoreweb.pnnl.gov or

http://a2e.energy.gov/data#buoy

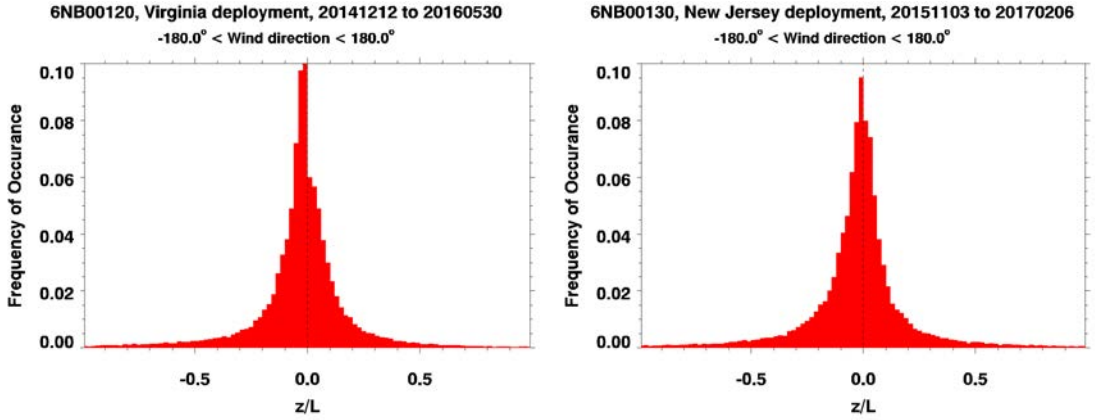
Hub-Height Winds: New Jersey



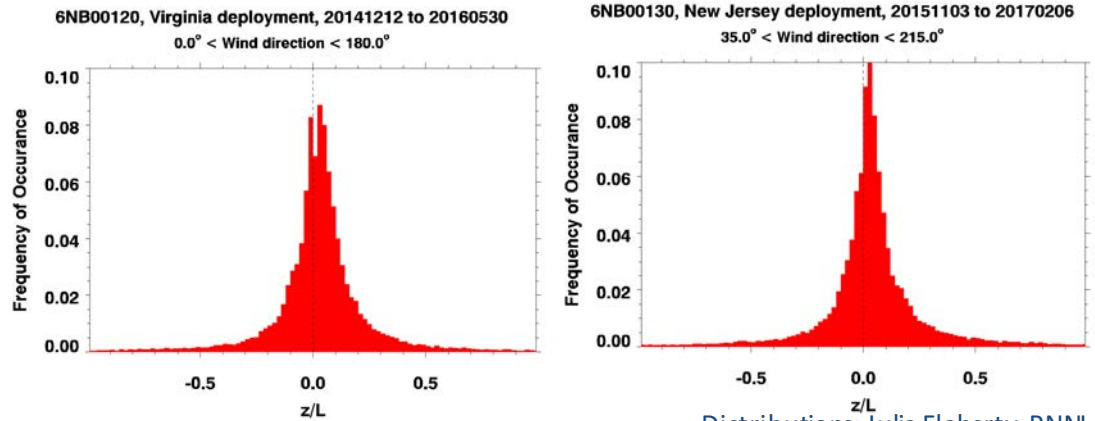
Wind roses produced by Rob Newsom, PNNL

Wind roses at 90 m MSL from the buoy lidar for (a) all of 2016; (b) winter; (c) spring; (d) summer; (e) fall.

Stability Parameter Distributions



All Wind Directions

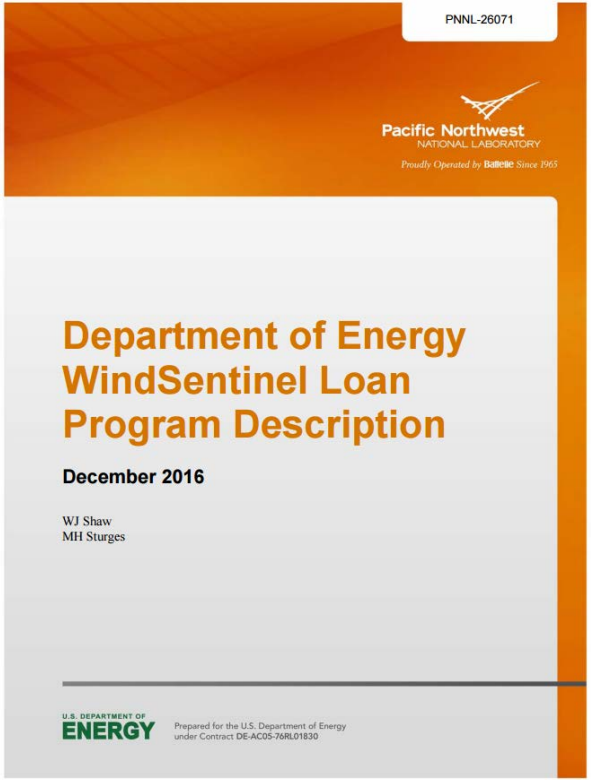


Onshore Wind Directions

Distributions: Julia Flaherty, PNNL

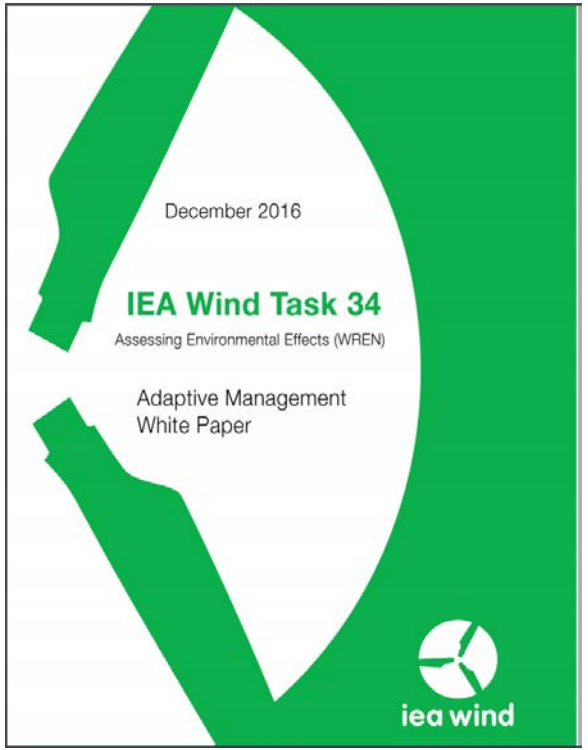
Buoy Plans

- Lidar Upgrades
  - Lidars to be replaced with more powerful units by March, 2019
- Next Planned Deployment
  - Summer, 2019 off California
  - BOEM, DOE collaboration
- Also available to Non-DOE Organizations
  - Includes other agencies, industry, and academia
  - Buoy use to be consistent with the mission of DOE's Wind Energy Technologies Office
  - Borrowers to manage all aspects and costs of deployment
  - All data to be publicly available through A2e Data Archive and Portal
  - More info: http://wind.pnnl.gov
- Extended Analysis of Buoy Data and Offshore Models



Environmental Contributions to Offshore Wind Energy

- Current Work
  - Tethys (https://tethys.pnnl.gov)
    - Curated collection of documents on environmental effects of wind energy
  - IEA Task 34—WREN
  - Whale-strike modeling (BOEM)
  - ThermalTracker
  - RF Tags

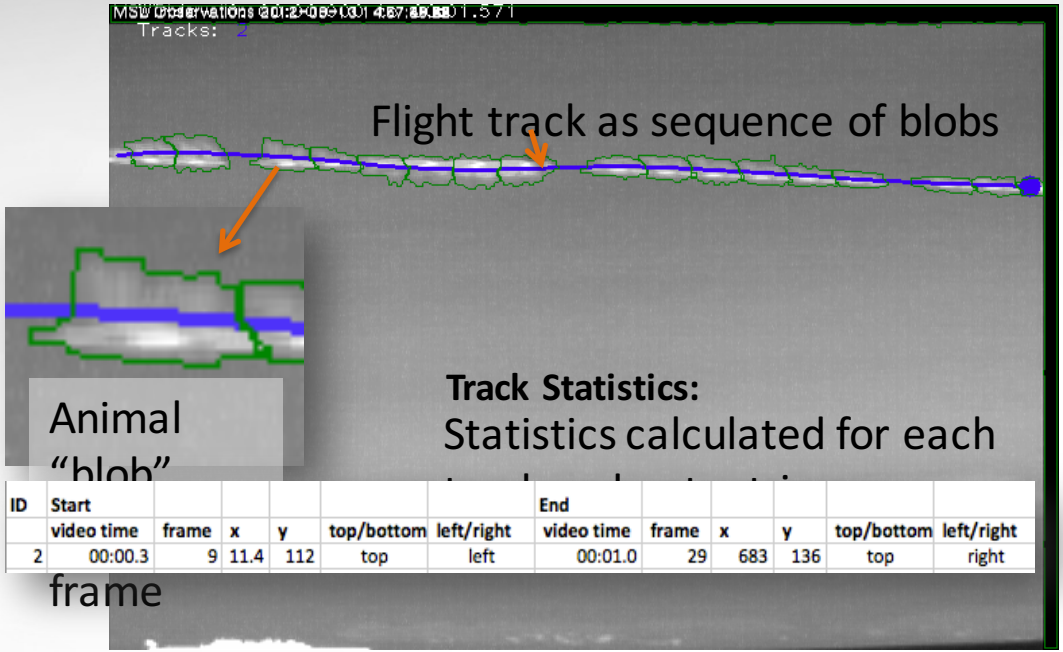


ThermalTracker Project Overview

- Goal: Develop technology for studying bird and bat occurrence and behavior at offshore wind energy sites.
  - Funded by DOE EERE Wind Energy Technology Office
- Phase 1 (2014-2016)
  - Developed offline tool to process thermal video.
  - Open source available on github.
- Phase 2 (2017-2019)
  - Transition to real-time operation.
  - Integrate stereo vision.

ThermalTracker software extracts flight tracks.

A composite image of 300 frames (10 seconds of video at 30 frames per second) makes entire flight track visible.



ID	Start						End					
	video time	frame	x	y	top/bottom	left/right	video time	frame	x	y	top/bottom	left/right
2	00:00.3	9	11.4	112	top	left	00:01.0	29	683	136	top	right

Image: Shari Matzner, PNNL

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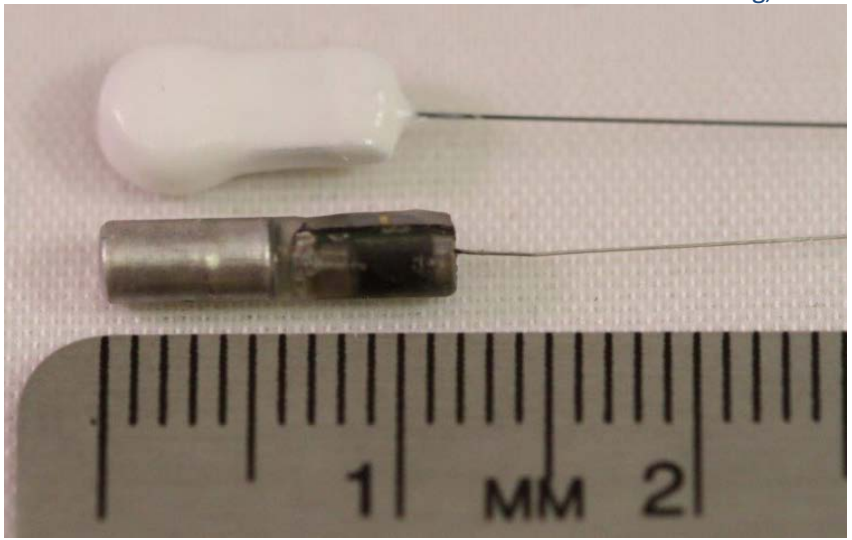
A Miniature Injectable Radio-Frequency Transmitter*: Overview

- Two coding schemes:
  - coded signals (courtesy of Lotek via NDA)
  - un-coded signals
- Two configurations:
  - high signal strength
  - low signal strength
- Bio-effects evaluation using three tagging methods on hatchery-reared spring Chinook salmon
  - Surgical incision with catheter
  - 9-gauge needle injection
  - 9-gauge needle with catheter

Photo: Daniel Deng, PNNL



Technical contact: Daniel Deng, (509) 372-6120, zhiqun.deng@pnnl.gov
Commercialization contact: Sara Hunt, (509) 375-6555, sara.hunt@pnnl.gov
*Patented

- Also demonstrated the self-powered option using the circuit design used for the self-powered acoustic transmitter

A Miniature Injectable Radio-Frequency Transmitter: Performance

	Size	Dry Weight	Calculated Life (days)			
Transmitter	w x h x l (mm)	(g)	2s PRI	5s PRI	10s PRI	60s PRI
Lotek NTQ-1 (commercially available)	5*3*10	0.26	10	21	33	59
Lotek NTQ-2 (commercially available)	5*3*10	0.31	16	33	52	94
Uncoded low signal strength	2.95*11.22	**0.15**	15	37	69	245
Uncoded high signal strength	2.95*11.22	**0.15**	12	30	56	217
Coded low signal strength	2.95*11.85	**0.16**	11	27	52	206
Coded high signal strength	2.95*11.85	**0.16**	9	21	41	176

- Both coded and uncoded options are >10 dB stronger than the Lotek NTQ-2's.
- The actual service life was verified using coded option at a 3-s PRI .
- The American Society of Mammalogists recommended transmitter weight should be less than 5% of the bats' body weight. Many endangered birds and bats weigh only about 4 g and thus a transmitter is required to weigh less than 0.2 g to meet the tag burden requirement.

Thank you