AWS TRUEPOWER

OFFSHORE WIND MEASUREMENT TECHNOLOGY

Advanced Energy Conference | 28 March 2018 | New York, NY | Version 1

OUTLINE

UL Introduction

Background on Metocean Data

Classical Measurement Approach

New Measurement Technology

UL INTRODUCTION

UL DRIVES TRUST IN RENEWABLES

140+

Country locations of UL renewable energy customers

55+

Years of combined experience in the renewable energy industry

Independent / Owner's Engineer on

450+

wind & solar projects*

*since 2012

ADVISED

90%

of the wind and solar industry's top **PROJECT DEVELOPERS** and **PLANT OWNERS**

500+ UL Renewable Energy Experts

200,000+ MW

Total renewable energy megawatts (MW) assessed

FORECAST PROVIDER for

60+ GW

of installed renewable energy projects

METOCEAN DATA NEEDS

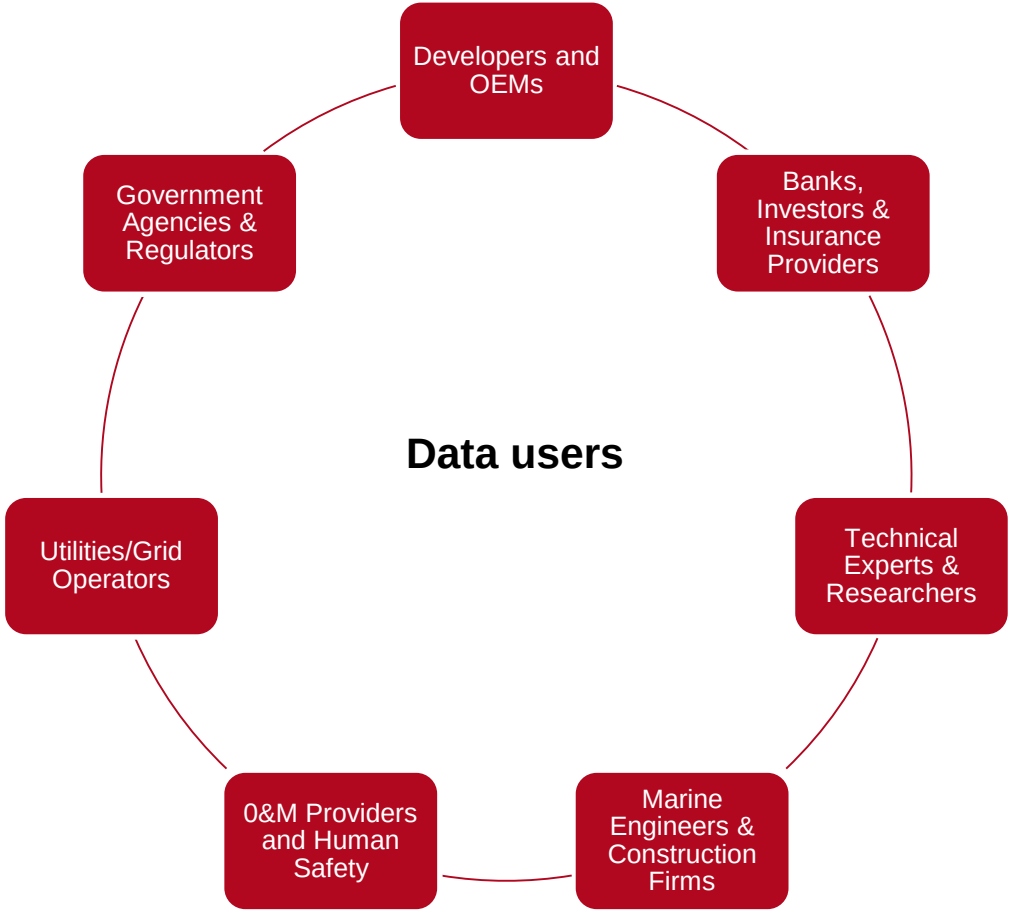
BACKGROUND

- High-quality meteorological and ocean (metocean) data are essential to successful offshore wind project initiation and development.
- There is a scarcity of key atmospheric/ocean measurements in US waters that adds both uncertainty and cost to the wind development process.
- Classical approaches to onsite and regional measurement present significant time and cost hurdles.
- New measurement technology application is accelerating schedules and is expected to help lower costs.

METOCEAN DATA

Applications

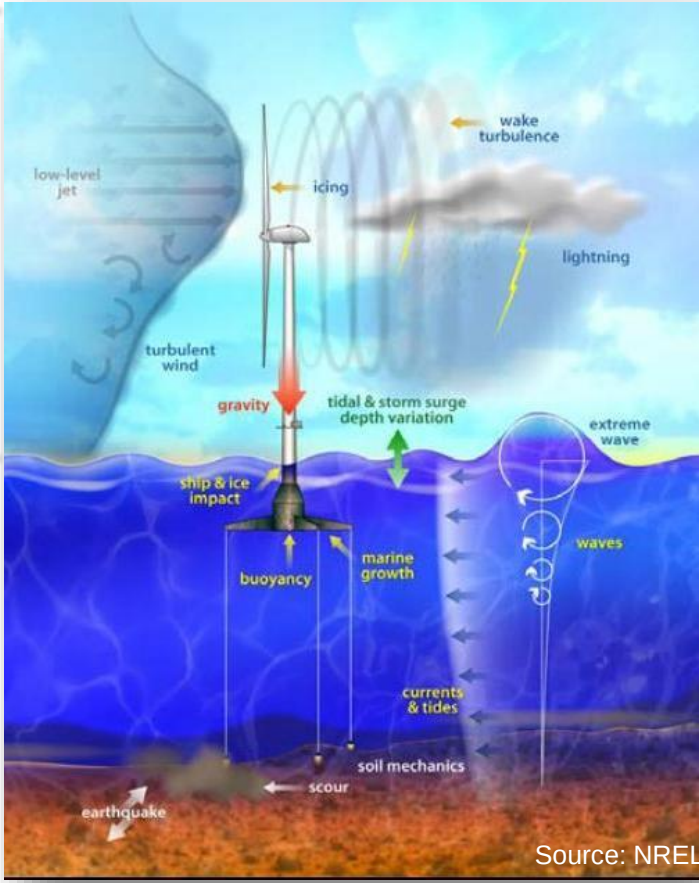
- Project Siting & Permitting
- Energy Projections
- Technology Design & Validation
- Facility Design
- Financing
- Construction
- Operations & Site Safety
- Forecasting



PRIMARY DATA PARAMETERS

Atmosphere

- Wind: ⇧ 200m MSL
- Atmosphere State:
  - ✥ MABL Characterization
  - Temp., Press., RH, Stability, Transient events
- Climatology
  - Means, Distribution, Extremes
  - Time Series
  - Hurricanes, Icing, Lightning

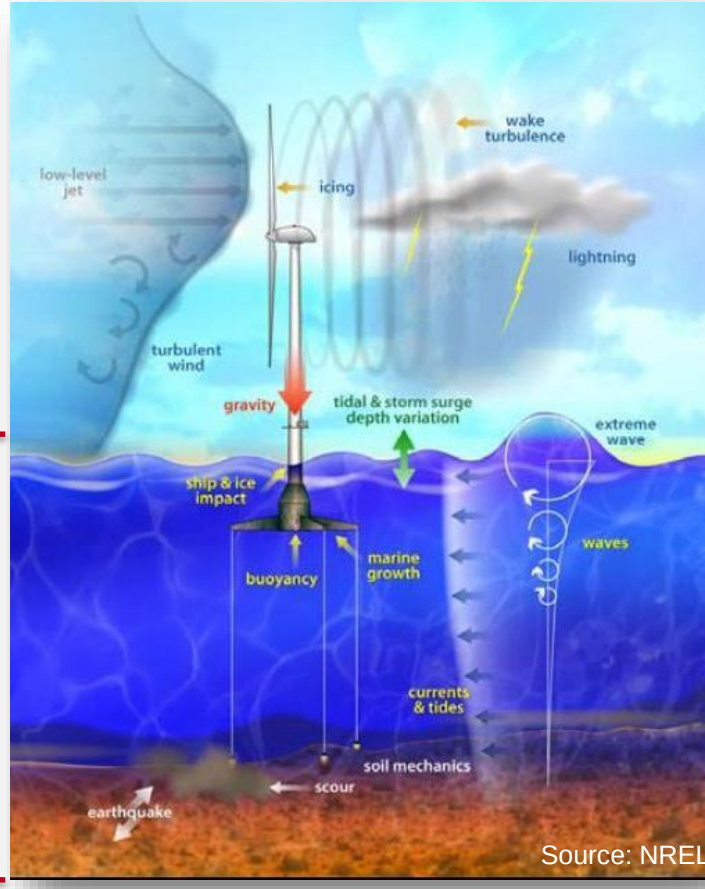


Source: NREL

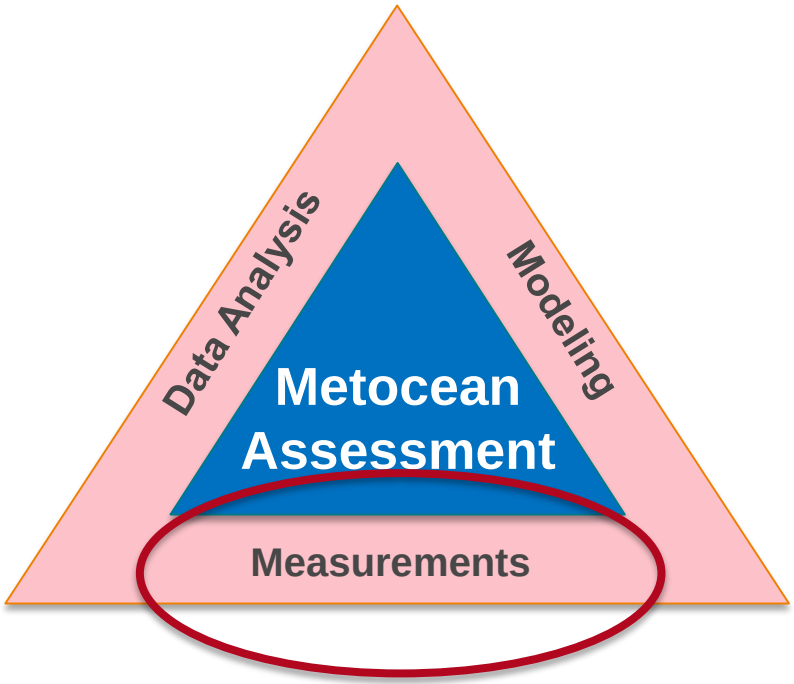
PRIMARY DATA PARAMETERS

Water Surface and Subsurface

- Hydrographic:
  - Wave height, direction, freq., spectra
  - Surface currents and profiles
- Water State:
  - Surface temperature and profile
  - Salinity, chemistry and Ice
- Biologic and Bottom:
  - Marine growth rates
  - Bottom soil types and dynamics



DATA ANALYSIS AND INTEGRATION



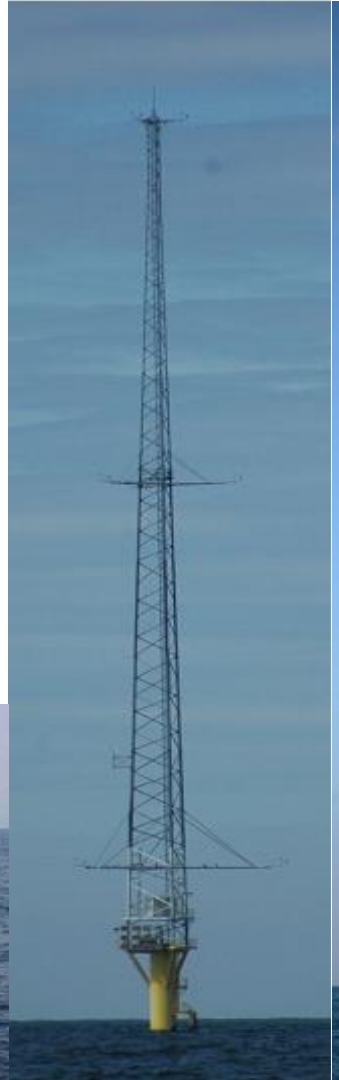
Characterizing these key parameters for long-term energy yield analyses and design basis information requires a robust analytical approach with three primary components.

This presentation focuses on measurements since they commonly represent the most significant investment and schedule driver.

CLASSICAL MEASUREMENT APPROACH

MAST-BASED APPROACH

- Bottom-fixed, tall mast with multiple monitoring levels and ancillary measurements
- Project-specific and regional installations – hub height winds, atmospheric stability and turbulence, ocean conditions
- Benefits:
  - Low uncertainty
  - Large regional coverage



MAST-BASED APPROACH

- Challenges:
  - Very Expensive
  - Long timeline to design, permit and deploy
- Relatively few (<20%) European offshore developers opted to deploy onsite masts
- Efforts to deploy regionally representative masts in the US have not succeeded.
- Almost no developers US or European developers are planning to deploy new offshore masts

NEW MEASUREMENT TECHNOLOGY

FLOATING LIDAR APPROACH

Is this really new? Not new in concept; still new in commercial practice

ESTABLISHED

- Technically sound and defensible approach
- Roadmap and Guidance documents in 2013, 2016, 2017
- >15 Project campaigns in Europe, 5 in US; numerous validation campaigns

NOVEL

- Performance and reliability of new platforms
- Bringing a new project through financing using only floating lidar
- Developing design basis for a project using only a floating lidar

FLOATING LIDAR APPROACH

- One or two accepted profiling lidars deployed on a floating platform with ancillary measurement systems
- Several platforms available, at various stages of commercial maturity
- Benefits:
  - Faster to specify, permit and deploy
  - Less expensive overall, with buy & lease programs

FLOATING LIDAR APPROACH

- Challenges
  - Potentially higher measurement uncertainty & campaign risk
  - Limitations on certain measurement parameters
- Finance and design communities still assessing how data and resulting reports are to be interpreted
- Validation facilities in the US still limited

SUMMARY

- Offshore wind resource assessment has moved beyond requiring a classical mast-based campaign to allowing floating lidar as the primary measurements.
- Floating lidar systems have demonstrated faster deployment schedules than bottom-fixed structures, and significantly lower costs for the resulting data.
- Well-characterized units have demonstrated operational reliability and excellent measurement precision.
- Uncertainties and acceptance of the floating lidar data are both improving with more public and private campaigns underway.

THANK YOU

Matthew V. Filippelli Director Offshore Services - North America
Matthew.Filippelli@UL.com | +1 518 213 0044 x 1015