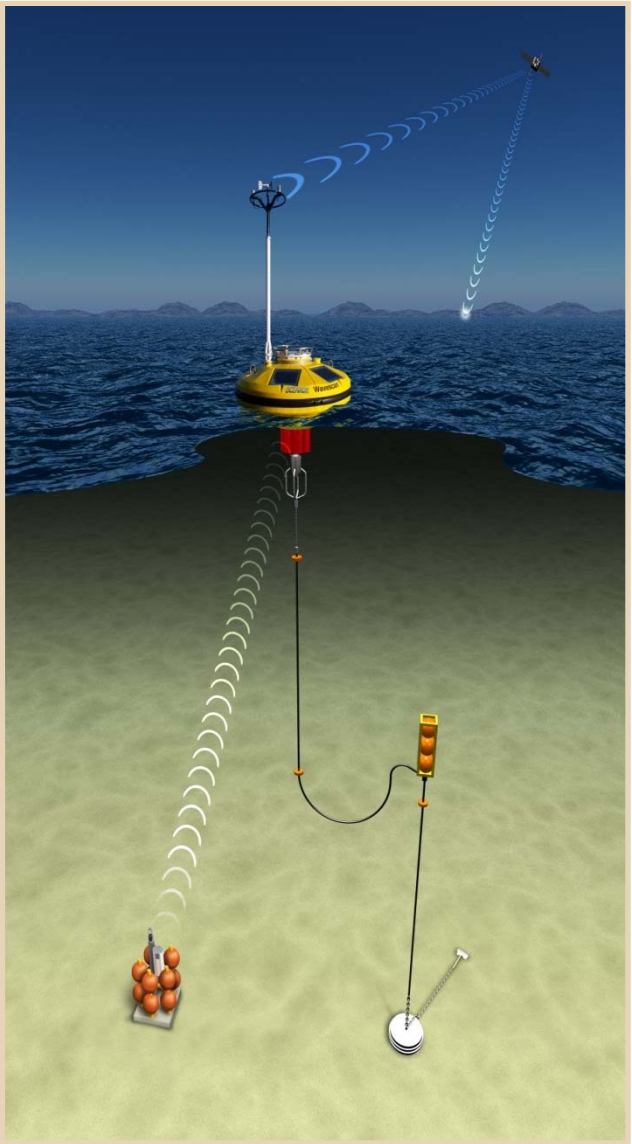
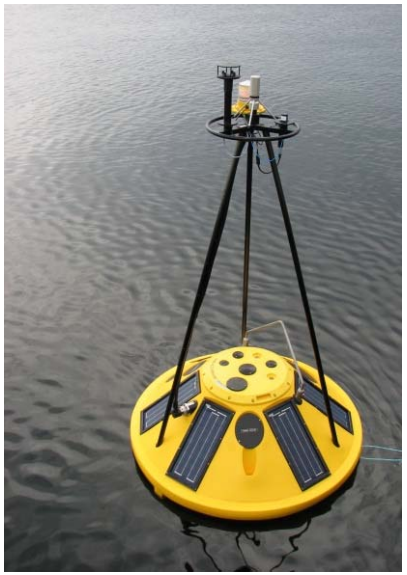
Fugro OCEANOR SEAWATCH Wind LiDAR BUOY

Type validation of a compact, proven measurement buoy that includes waves, current profile and wind profile

Seawatch Real-time Monitoring Buoys





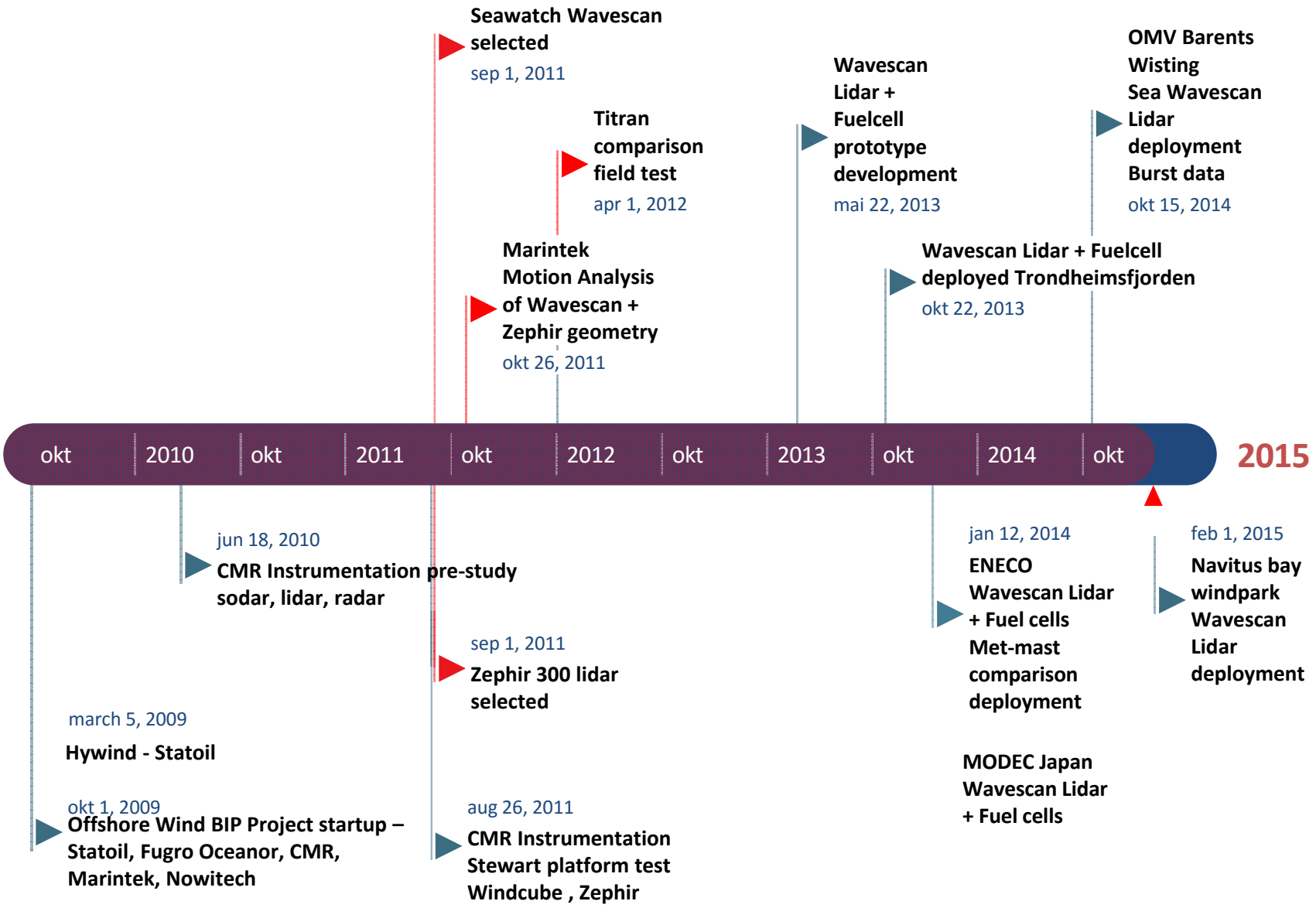
Validation of SEAWATCH Wind LiDAR

A roadmap towards commercial acceptance of the floating LiDAR technology has been generated and adapted to the SEAWATCH Wind LiDAR buoy specified by DNV-GL.

The Roadmap defines three stages:

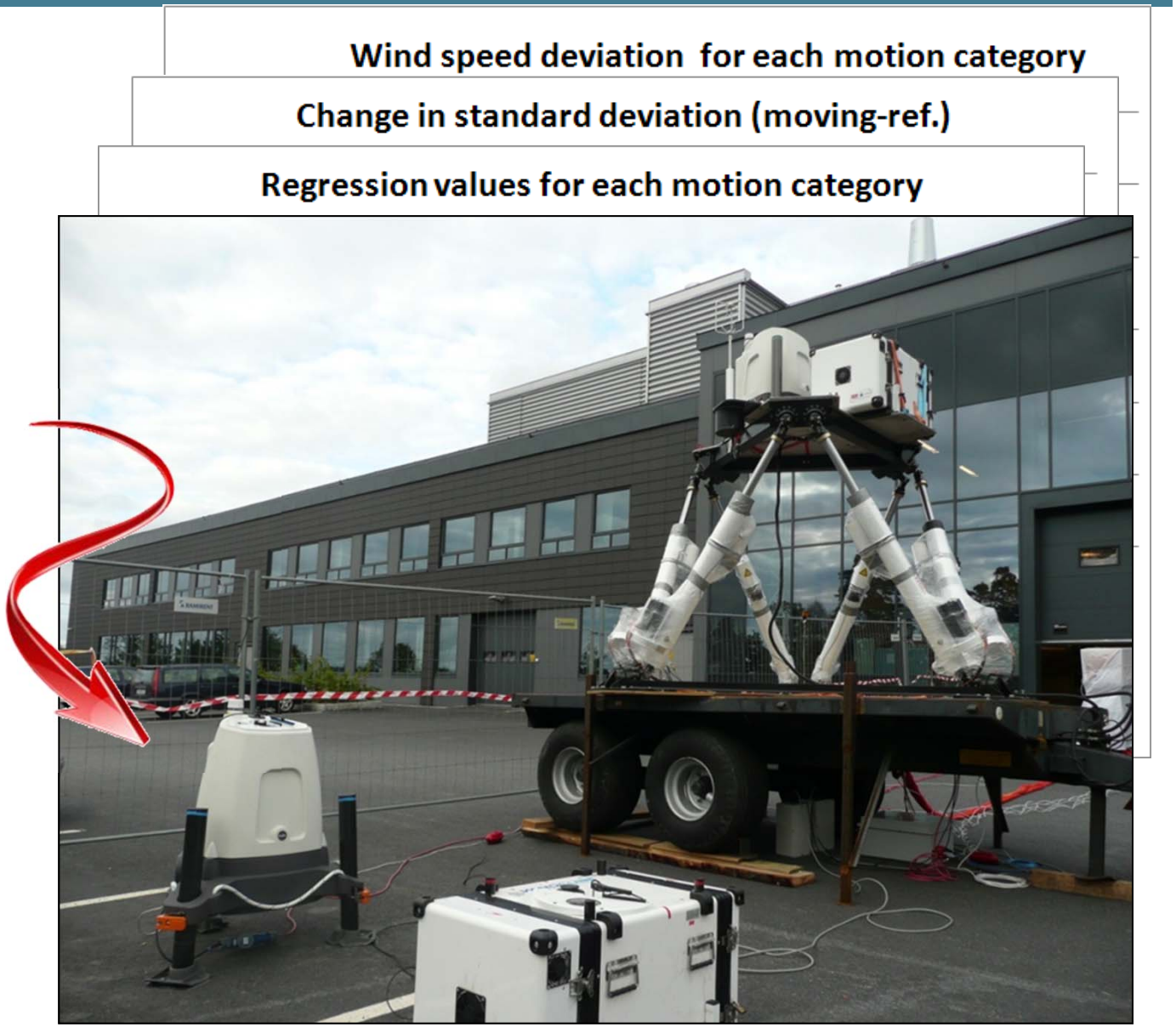
- Baseline: As a pre-requisite, the LiDAR measurement unit should have achieved wide-spread acceptance.
- Pre-commercial: Following a successful pilot validation trial, the floating LiDAR technology may be used commercially (‘well defined’ according to roadmap)
- Commercial: Following successful further trials and early commercial deployments covering a range of site conditions, a sufficient body of evidence is accumulated to relax the elevated uncertainty assumptions (‘moving target’).

Seawatch Wind LiDAR Buoy Timeline

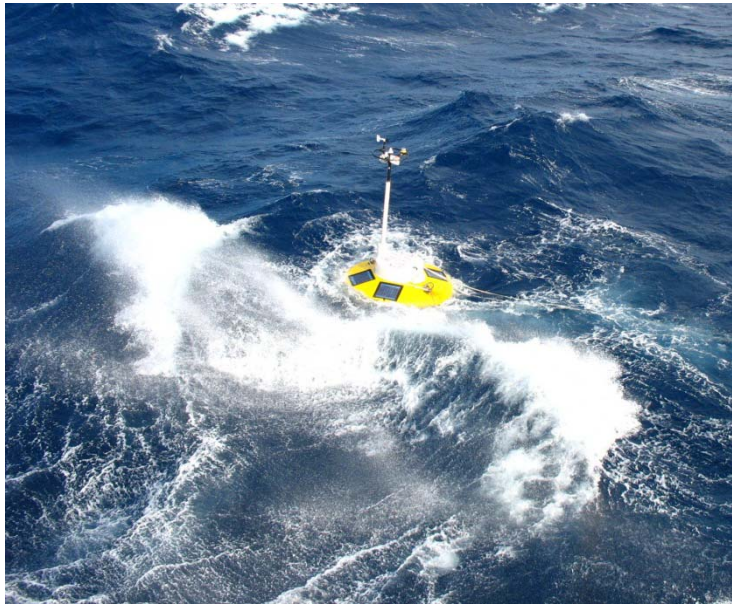


Motion analysis – UiA Grimstad

- 2011 Motion test Stewart platform
  - WindCUBE
  - ZephIR
- 2011 ZephIR 300 selected



Seawatch design



SEAWATCH Wavescan

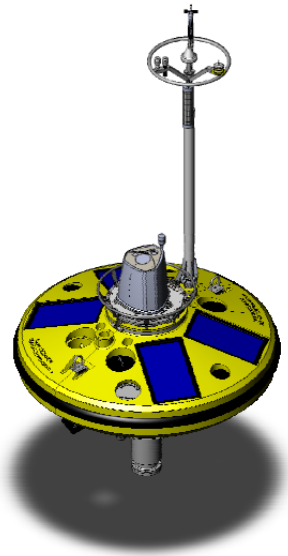
- Successful track record world-wide since 1985
- Uniquely designed to optimise wave direction measurements
- Full on-board processing of all measured data
- Two-way communication link for data transfer and control
- Robust and reliable in temperature extremes and harsh environments

The Seawatch Wind LiDAR Buoy

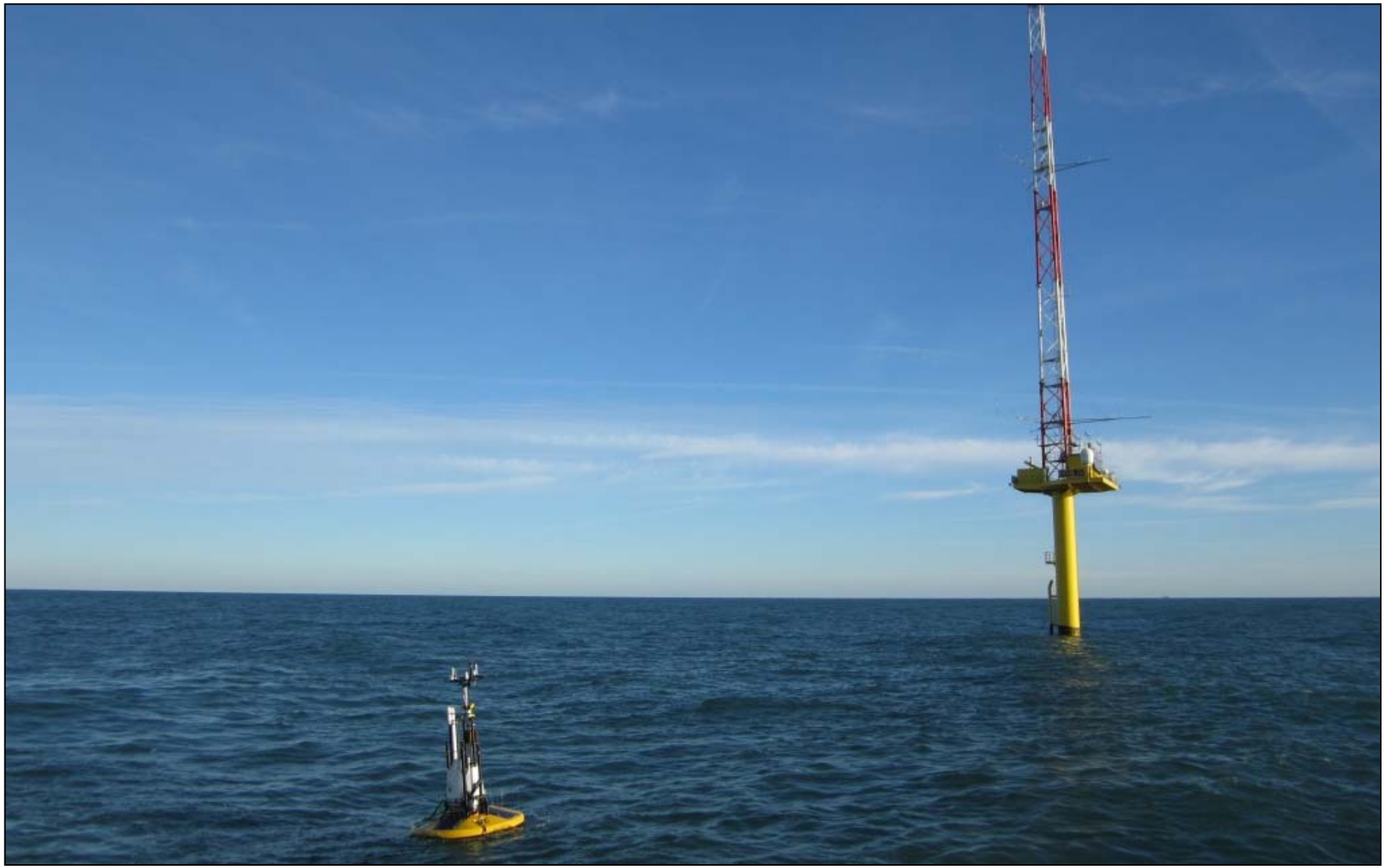
Use a proven oceanographic measurement buoy that has withstood extreme environmental conditions.

Add a proven LiDAR Wind Profiler.

Prototype version.



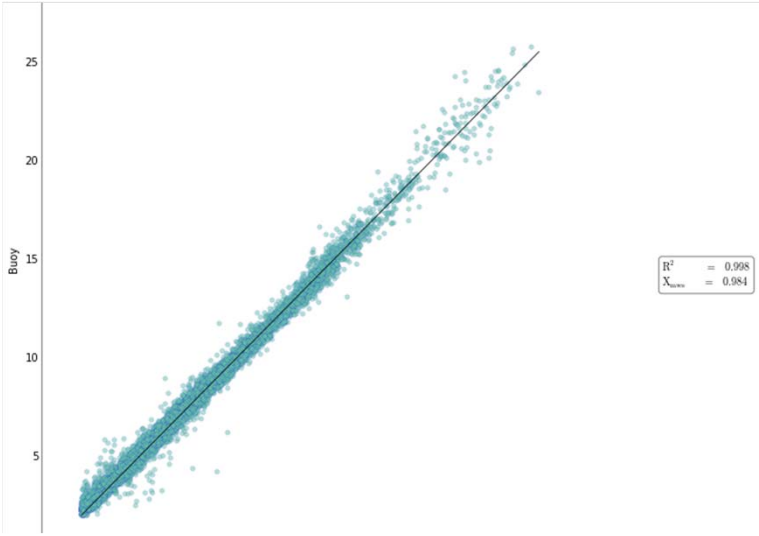
ENECO Met-mast validation



Wind Profile Data

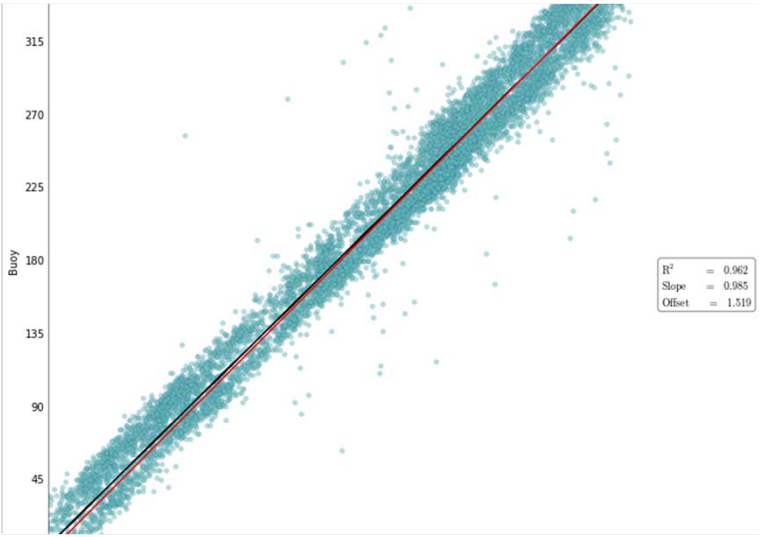
Wind Speed

- R^2 = 0.99 (Best practice criteria >0.98, minimum 0.97)
- Slope = 0.98 (Best practice criteria 0.98-1.02, minimum 0.97-1.03)
- Mean offset between 0.11 and 0.15 m/s

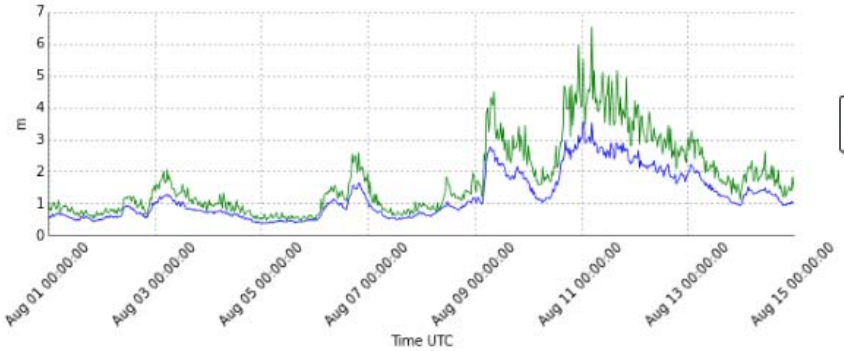


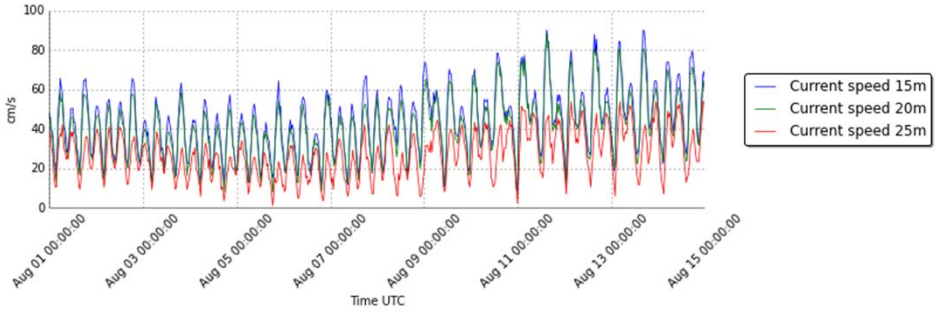
Wind Direction

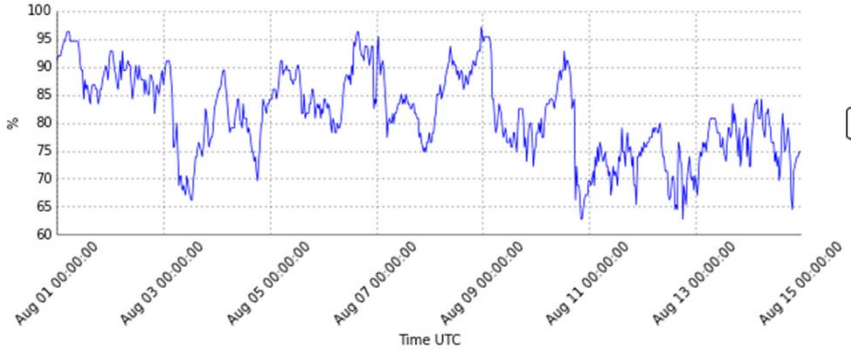
- R^2 = 0.96 - 0.97. (Best practice criteria >0.97, minimum >0.95)
- Slope = 0.97 - 0.99 (Best practice criteria 0.97-1.03, minimum 0.95-1.05)
- Mean offset between 1.5 and 5.8 degrees (Best practice criteria <5 degrees, minimum <10 degrees)

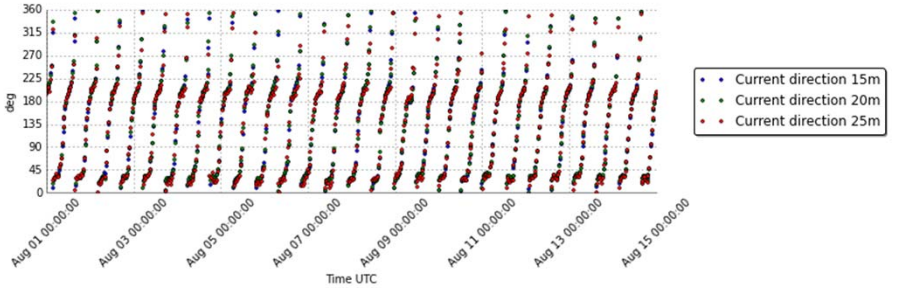


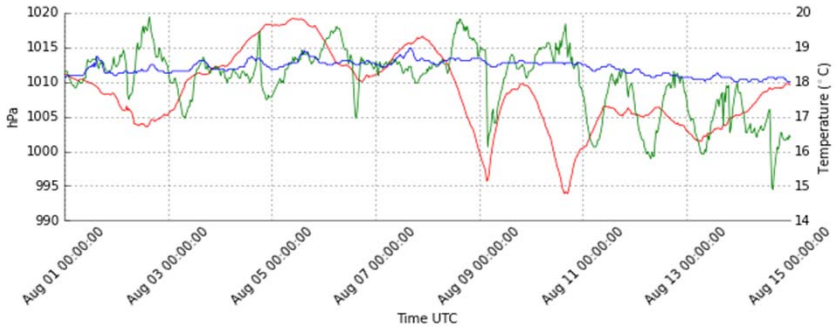
Met-Ocean Data



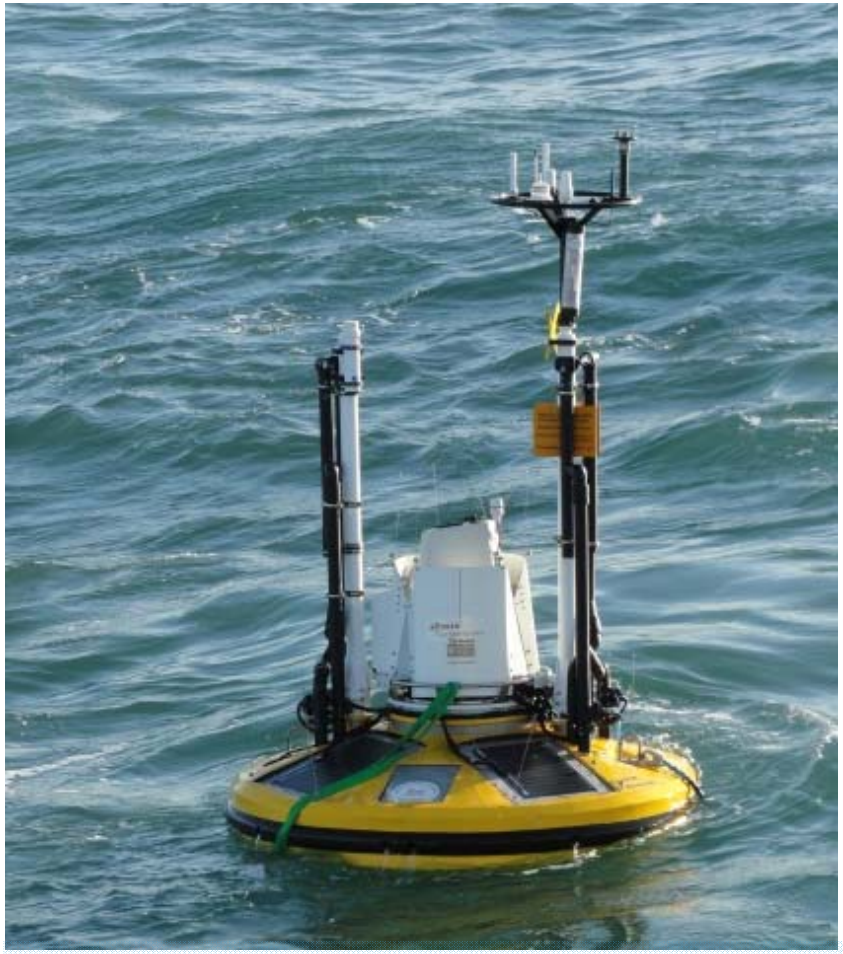








SEAWATCH Wind LiDAR Buoy approval – pre-commercial



Project name:	Fugro/Oceanor Seawatch Wind LiDAR Buoy	DNV GL / GL Garrad Hassan
Report title:	ASSESSMENT OF THE FUGRO/OCEANOR SEAWATCH FLOATING LIDAR VERIFICATION AT RWE IJMUIDEN MET MAST	Deutschland GmbH Section Offshore Germany Brooktorkai 18
Customer:	Fugro/OCEANOR AS, Trondheim, Norway	20457 Hamburg
Contact person:	Lasse Lonseth, Olaf Sveggen	Germany
Date of issue:	2015-01-30	Tel: +49 40 36149 2748
Project No.:	4257 13 10378	DE 118 606 038
Report No.:	GLGH-4257 13 10378-R-0003, Rev. B	

Task and objective: 3rd Party Assessment of an Offshore Performance Verificaton of the Fugro/Oceanor SEAWATCH Wind LiDAR Buoy at RWE IJmuiden Met Mast in the Dutch Northsea Sector

Prepared by:	Verified by:	Approved by:
A. D.Stein Deputy Head of Section Offshore, Hamburg	D. Fugro, A. Beeken, P. Schwenk Senior and Project Engineers	A. D. Stein Deputy Head of Section Offshore, Hamburg

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☐ Commercial in Confidence
☐ DNV GL only
☒ Client's Discretion
☐ Published

Keywords:
LiDAR, Floating Lidar Device,

Reference to part of this report which may lead to misinterpretation is not permissible.

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	2014-12-19	Draft issue, for clients comments, only	DeSte	AnBee	DeSte
B	2015-01-30	Final isue (electronic only)	DeSte	DariF, AnBee, Pasch	DeSte

"An evaluation of the Fugro/Oceanor SWL Buoy floating LiDAR system was completed by comparing its measurements against data from the IEC-compliant IJmuiden met mast. Sufficient data were collected to allow an assessment in line with the Roadmap. In the IJmuiden offshore trial very encouraging results were indeed obtained. DNV GL concludes that the FO SWL Buoy system has demonstrated its capability to produce accurate wind speed and direction data across the range of sea states and meteorological conditions experienced in this trial (i.e. up to about 5.8 m significant wave height and 9.8 m maximum wave height and 10 min averaged wind speeds up to 26 m/s). Furthermore, it has recorded excellent availability throughout the 6 month period and demonstrated structural survivability in the met-ocean conditions present from early spring."

Pre- commercial stage achieved . Conclusions from DnV-GL

Date : 2015-01-30

“An evaluation of the Fugro/Oceanor SWL Buoy floating LiDAR system was completed by comparing its measurements against data from the IEC-compliant IJmuiden met mast. Sufficient data were collected to allow an assessment in line with the Roadmap.

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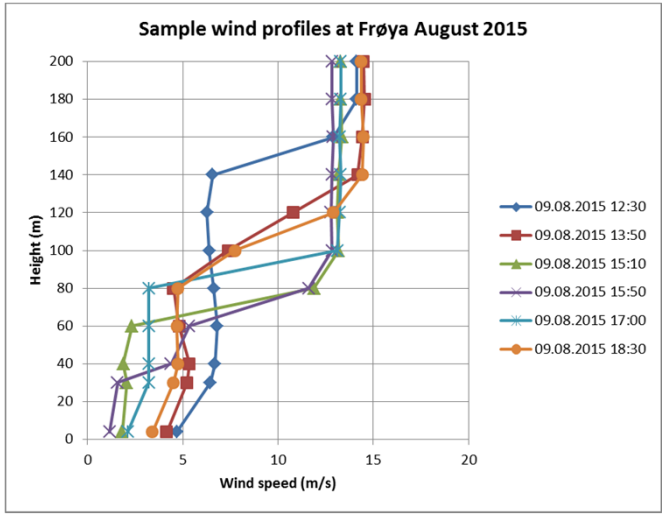
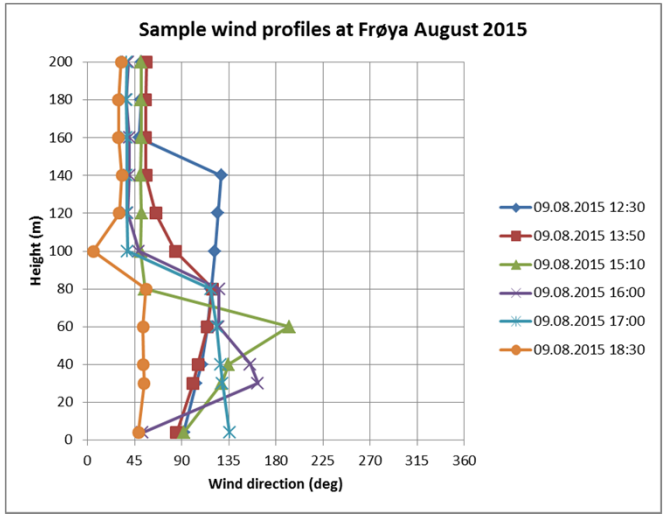
Furthermore, it has recorded excellent availability throughout the 6 month period and demonstrated structural survivability in the met-ocean conditions present from early spring.”

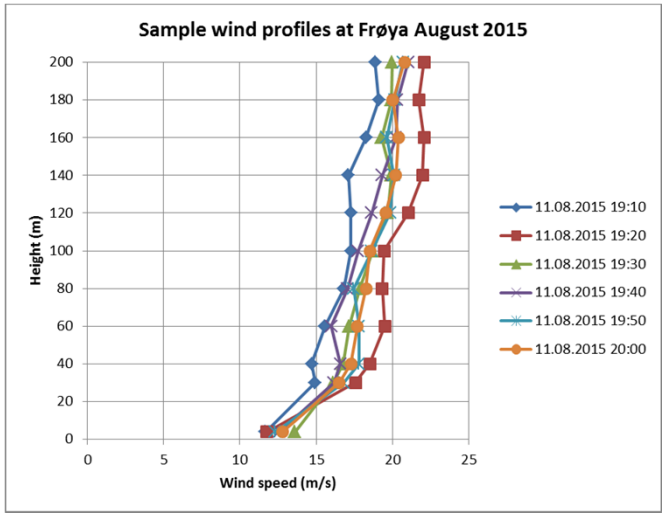
Fugro Lidar Buoy validation site – Titran, Frøya

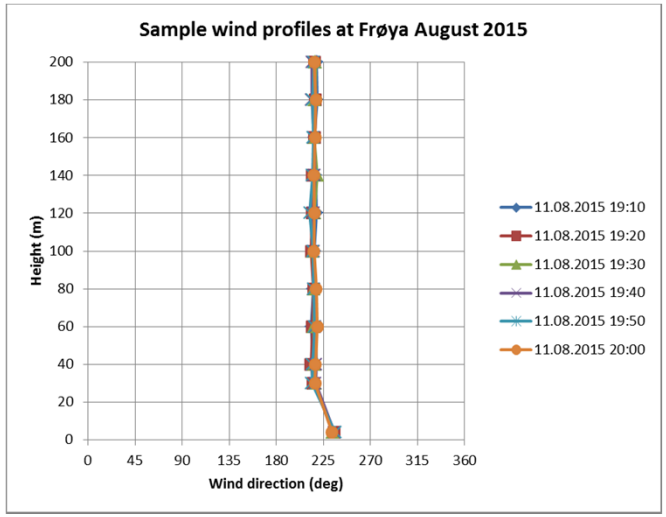
- Pre- and post validation site approved by DNVGL
- On-shore Lidar reference at Stabben Fort is established, and standard anemometry reference masts (NTNU/ University) are available
- So far: Three SWLB successfully validated at site since start of 2015

SEAWATCH Wind LiDAR Buoy – Wind shear at Titran, Frøya



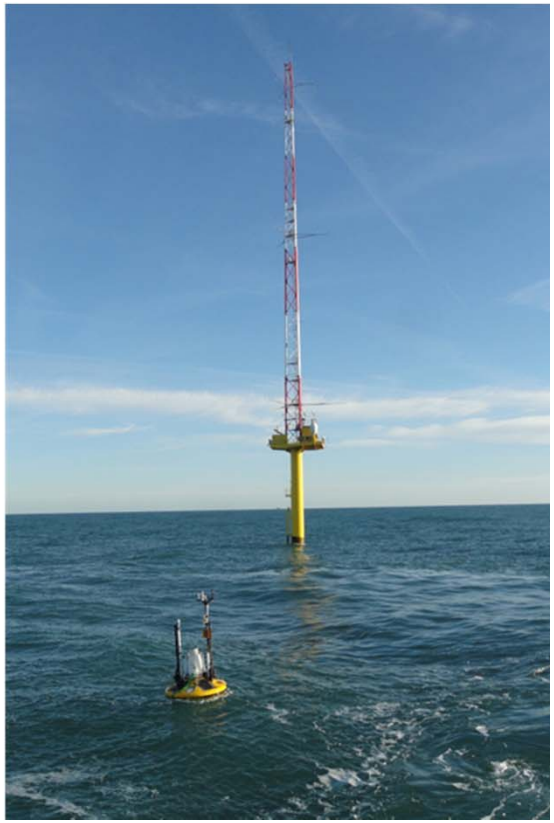






Seawatch Wind Lidar buoy - applications

Bottom fixed wind farms:	Eneco, edf, rvo
Floating wind turbines :	Statoil, Modec
Offshore Oil&Gas:	OMV (Barents Sea)



SEAWATCH Wind LiDAR Buoy – Navitus Bay, English Channel

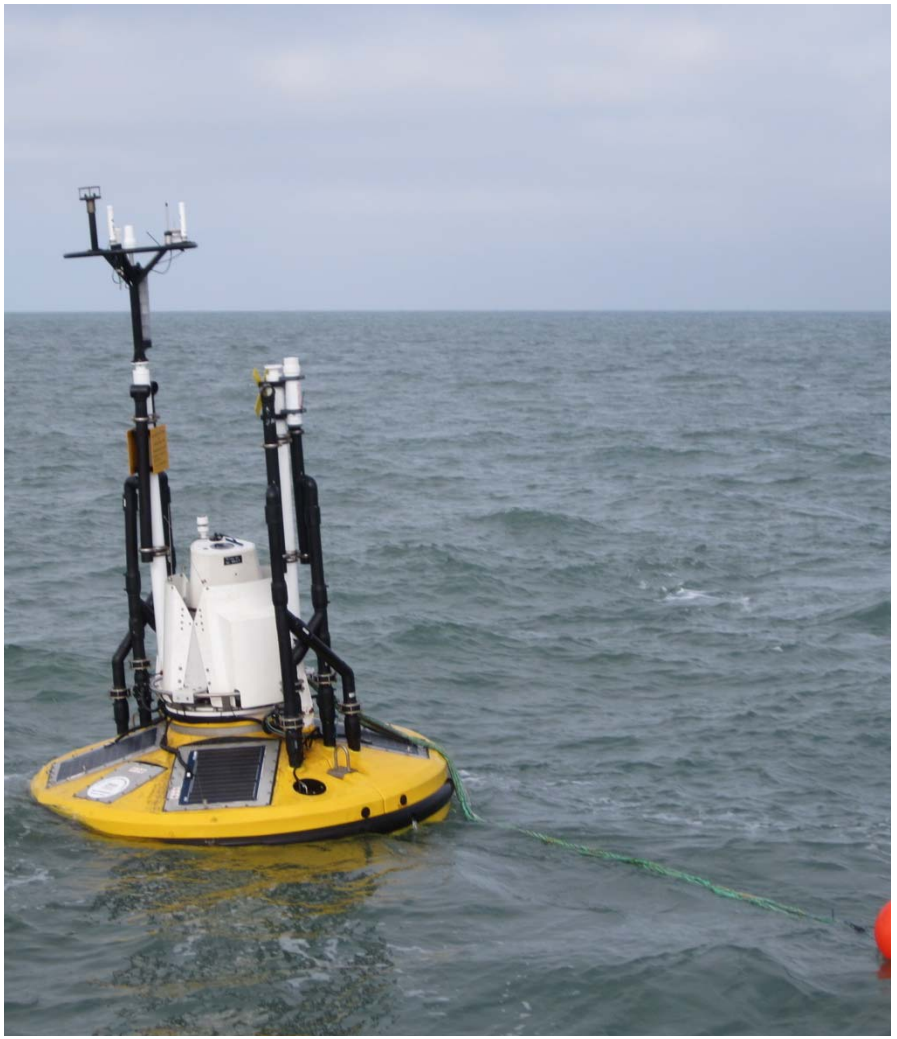
Applications: Offshore Wind

Parameters:

- Mooring at 35m water depth
- Wave height, period and direction
- Near surface current profile and water temperature
- Wind speed and direction from 4m to 190m
- Air pressure
- Air humidity
- Air temperature

Observations

The highest recorded significant wave height exceeded 4 m, the highest wind speed was 25 m/s, and currents regularly peaked at 120 – 170 cm/s.



SEAWATCH Wind LiDAR Buoy – Wisting Field, Barents Sea

Application: Oil&Gas industry

Parameters:

- Mooring at 400m water depth
- Wave height, period and direction
- Near surface current profile and water temperature

- Wind speed and direction profile from 4 to 200m
- Air pressure
- Air humidity and temperature
- Near surface water temperature and conductivity

- Near bottom current profile and water temperature using seabed observatory and acoustic transmission

Observations:

Remotely scheduled by operators based on storm forecasting

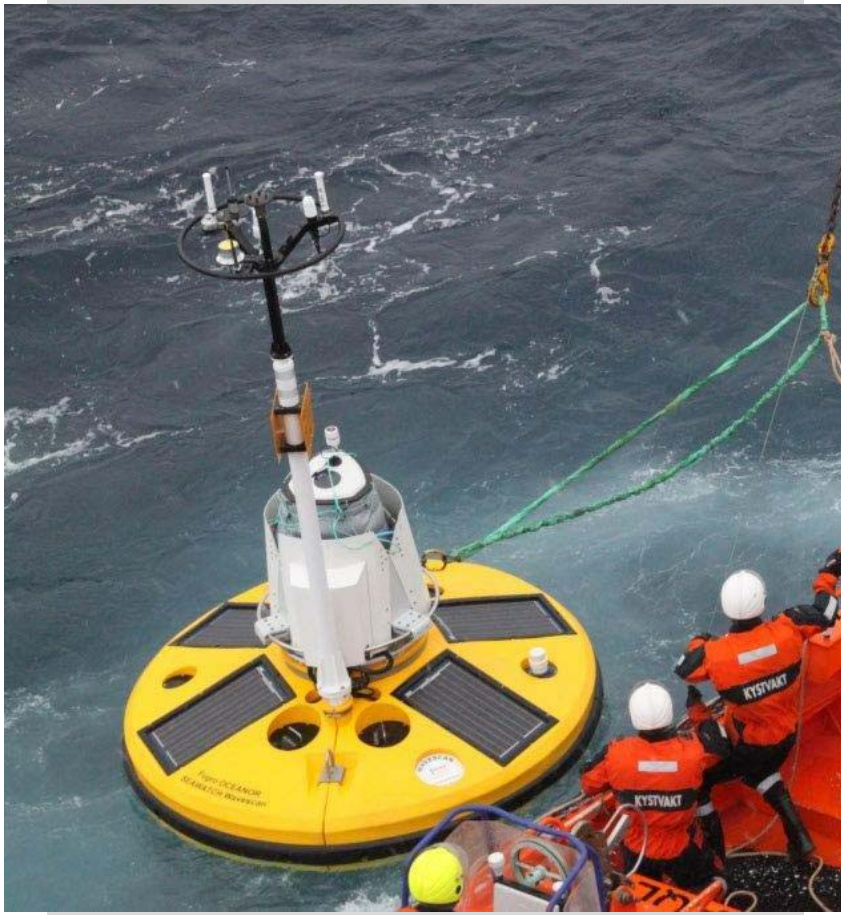
15th October 2014 to 31 January 2015 - 2402 wind profiles – data recovery 100%

Recorded 8 storms with significant wave height exceeding 6m

Max wind speed 28.6 m/s

Max wave height 13.4m

Max current 60cm/s in upper 40m



SeaWatch Wind Lidar Buoy – Modec Japan

- **Application**: Originally purchased by Modec to be used with SKWID floating vertical wind turbine and tidal current generator.
- Now owned by Saga Prefecture.
- **Current application**: Research and industry for offshore wind development in Kyushu, Japan

SEAWATCH Wind LiDAR Buoy – RVO Borssele - *Ongoing*

Borssele Wind farm survey and Northwind wake effects study

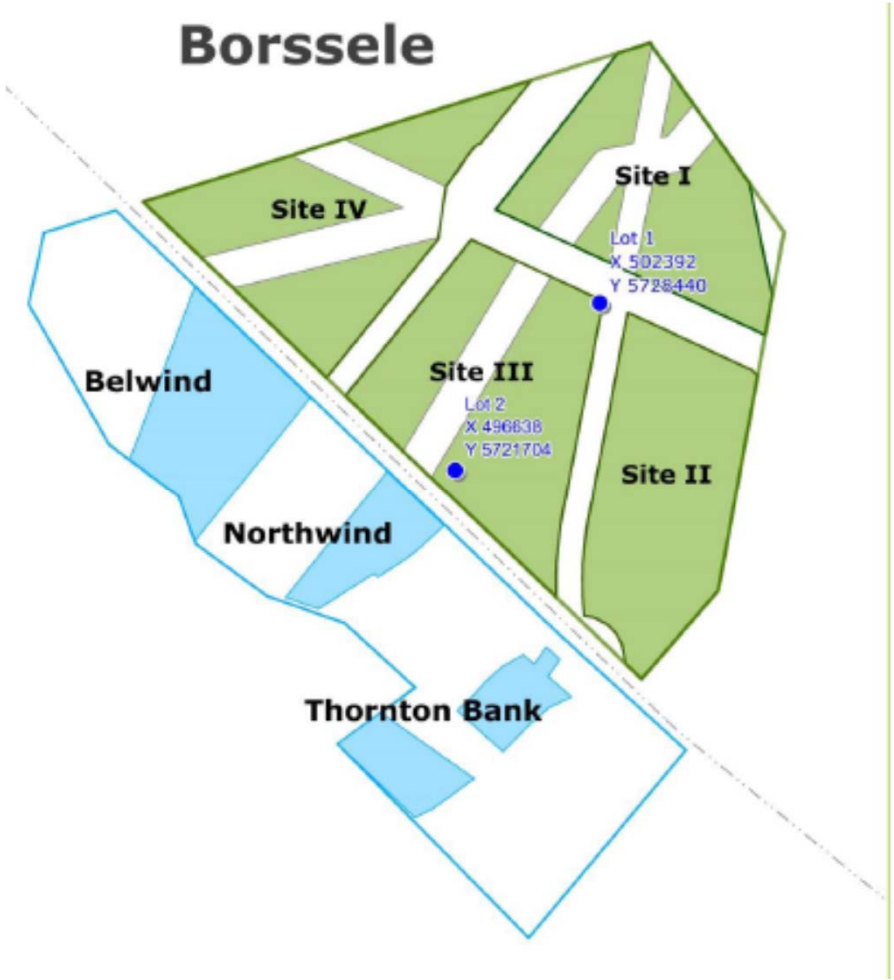
Application: Offshore Wind Industry

Parameters:

- Mooring at 30m water depth
- Wave height, period and direction
- Near surface current profile(35m) and water temperature
- Wind speed and direction
- Wind speed and direction profile
- Air pressure
- Air humidity and temperature

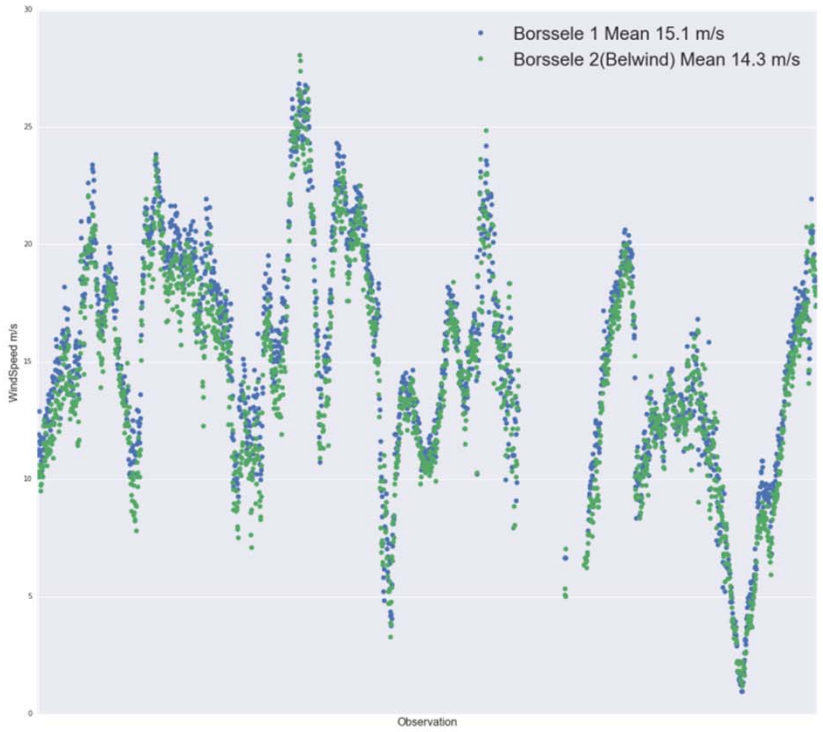
Observations

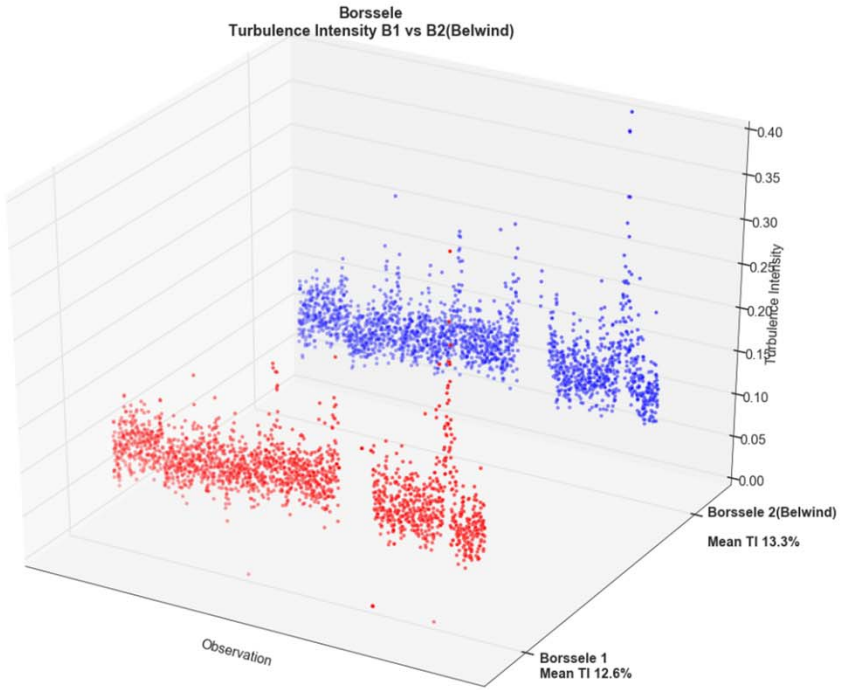
Turbulence intensity, inflow angle and wind shear/veer



SWLB - Borssele Wake Effects – Observations (Unofficial)

Parameter	B2(Wake Effects)
Mean Wind Speed@200m	94,7% of B1
Turbulence Intensity@200m	0,7% higher than B1

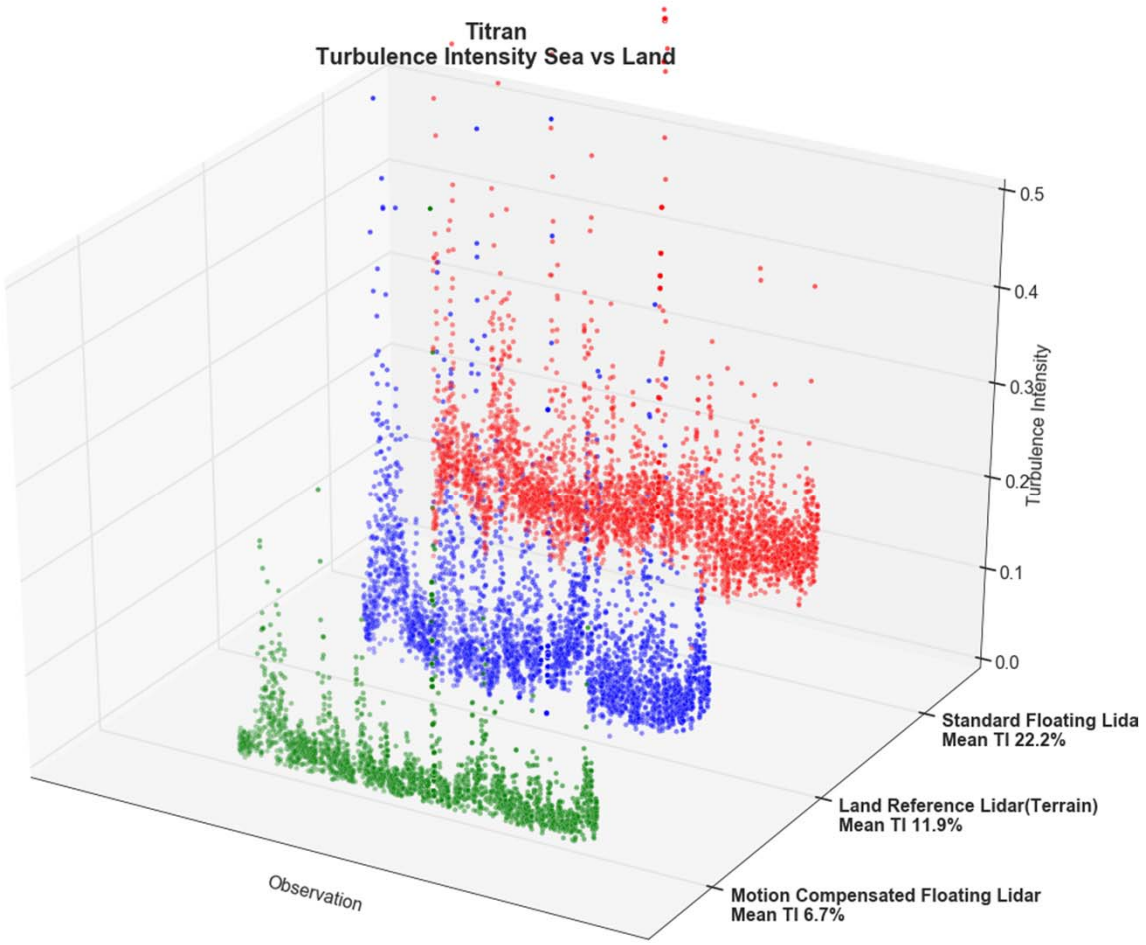




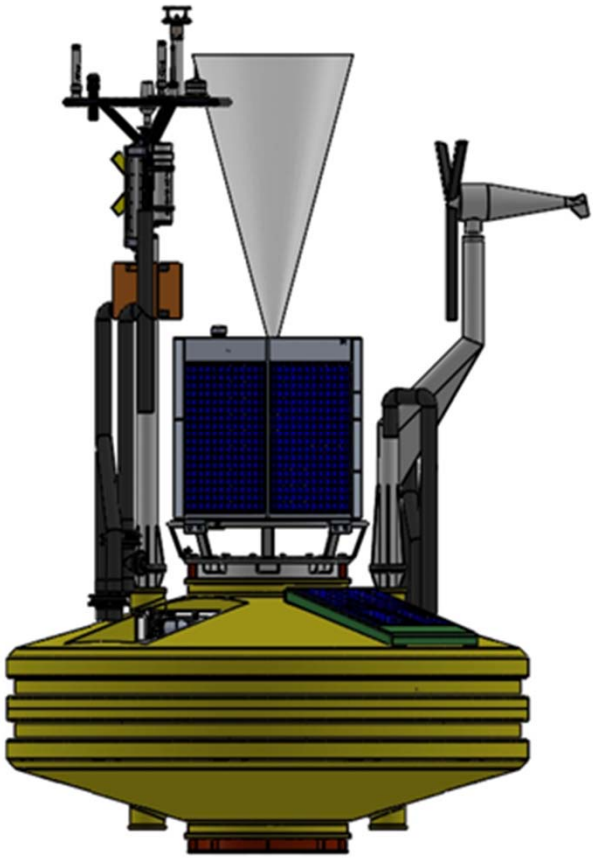
SEAWATCH Wind LiDAR Buoy - Turbulence Intensity

Turbulence

- Applications in wind resource assessment and structural engineering
- Current parameter available is Turbulence Intensity
- Validation challenging criteria not well defined



SEAWATCH Wind LiDar Buoy – next generation



Full power system redundancy
- Increased solar
- adding wind turbine(s)
- fuel cells as back-up

Increased volume
- increased buoyancy
- increased carrying capacity

Achievement
- Twelve months service intervals

New parameters
- turbulence intensity
- Inflow angle, shear and veer
- 1Hz motion corrected raw data

Sensor Combinations
- bird counter
- hydrophone – mammals
- eccosounder
- temperature profile

The Seawatch Wind LiDAR Buoy

The result

- A robust proven multi-parameter Meteorological and Oceanographic Measurement Platform
- Wind profiling capability up to 300m
- Current profiling capability down to 1000m
- Directional wave measurements
- Measurement of a wide range of met-ocean parameters
- Flexible energy system
- A fraction of the cost of a traditional met-mast and mobile

Floating Lidar buoys - Business Model has changed

From ‘Sale of Floating Lidar buoys’ to ‘Sales of Data’

Sales of Lidar buoy(s)

- S&M
- Data analysis and presentation
- Paid for delivery of buoy, for the agreed S&M cruises, and for delivered data reports
- Penalties related to late start of project and lack of data.

Sale of collected wind profile data (and other parameters as requested by clients)

- Total responsibility
- Paid according to data recovery percentage
- Measurements have to continue until agreed amount of data is collected
- Data analysis and presentation

Thank you for your time

Fugro OCEANOR
SEAWATCH Wind LiDAR
BUOY

Frode S. Berge

EERA DeepWind 2016