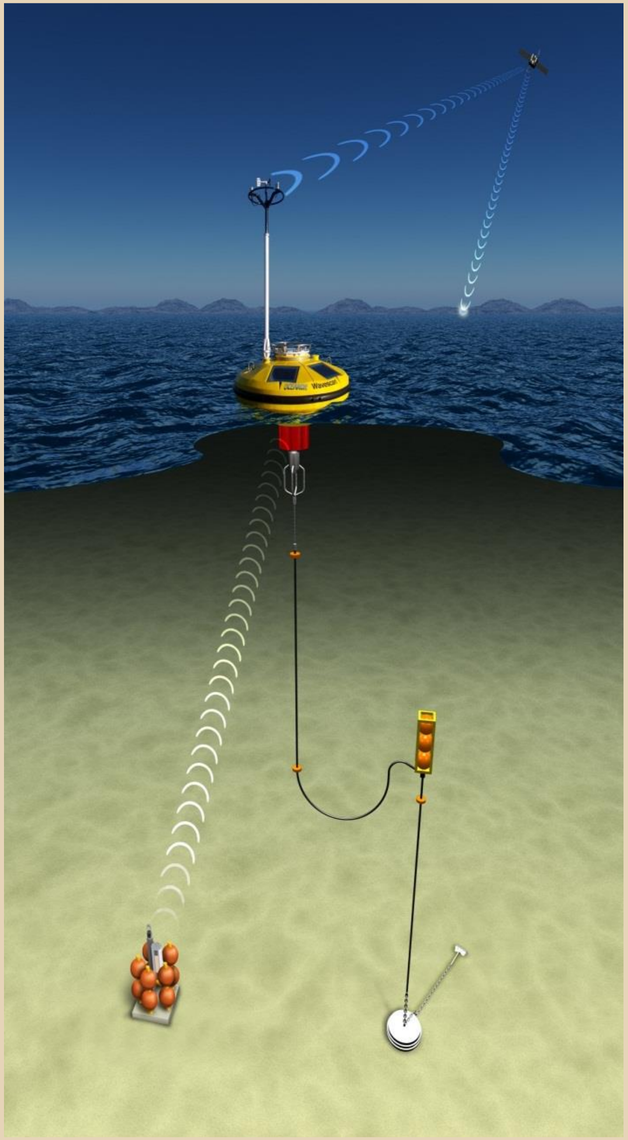
Fugro OCEANOR SEAWATCH Wind LiDAR BUOY

A compact, proven measurement buoy that includes waves, current profile and wind profile

Seawatch Real-time Monitoring Buoys



Seawatch Wind LiDAR Buoy Timeline

okt | 2010 | okt | 2011 | okt | 2012 | okt | 2013 | okt | 2014 | okt | **2015**

march 5, 2009
Hywind - Statoil

okt 1, 2009
Offshore Wind BIP Project startup – Statoil, Fugro Oceanor, CMR, Marintek , Nowitech

jun 18, 2010
CMR Instrumentation pre-study sodar, lidar, radar

aug 26, 2011
CMR Instrumentation Stewart platform test Windcube , Zephir

sep 1, 2011
Seawatch Wavescan selected

sep 1, 2011
Zephir 300 lidar selected

okt 26, 2011
Marintek Motion Analysis of Wavescan + Zephir geometry

apr 1, 2012
Titran comparison field test

mai 22, 2013
Wavescan Lidar + Fuelcell prototype development

okt 22, 2013
Wavescan Lidar + Fuelcell deployed Trondheimsfjorden

jan 12, 2014
ENECO Wavescan Lidar + Fuel cells Met-mast comparison deployment

MODEC Japan Wavescan Lidar + Fuel cells

okt 15, 2014
OMV Barents Wisting Sea Wavescan Lidar deployment Burst data

feb 1, 2015
Navitus bay windpark Wavescan Lidar deployment

Motion analysis – UiA Grimstad

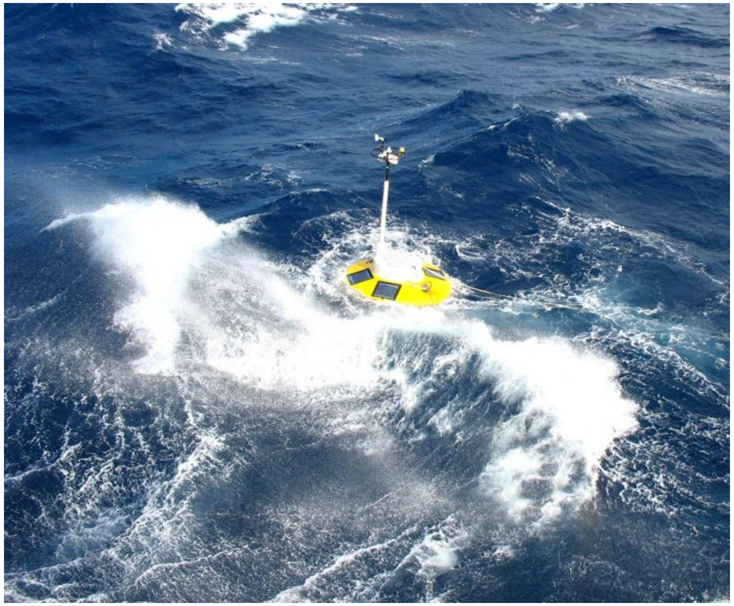
Wind speed deviation for each motion category

Change in standard deviation (moving-ref.)

Regression values for each motion category

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

Seawatch design



SEAWATCH Wavescan

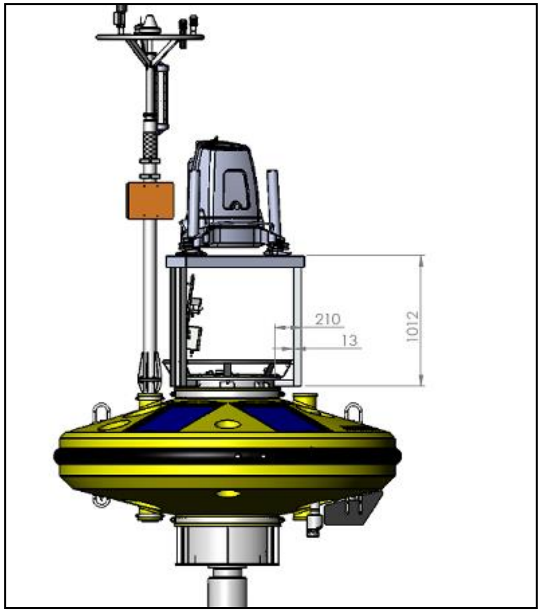
- Successful track record world-wide since 1985
- Uniquely designed to optimise wave direction measurements
- Full on-board processing of all measured data
- Two-way communication link for data transfer and control
- Robust and reliable in temperature extremes and harsh environments

The Seawatch Wind LiDAR Buoy – A single solution possible?

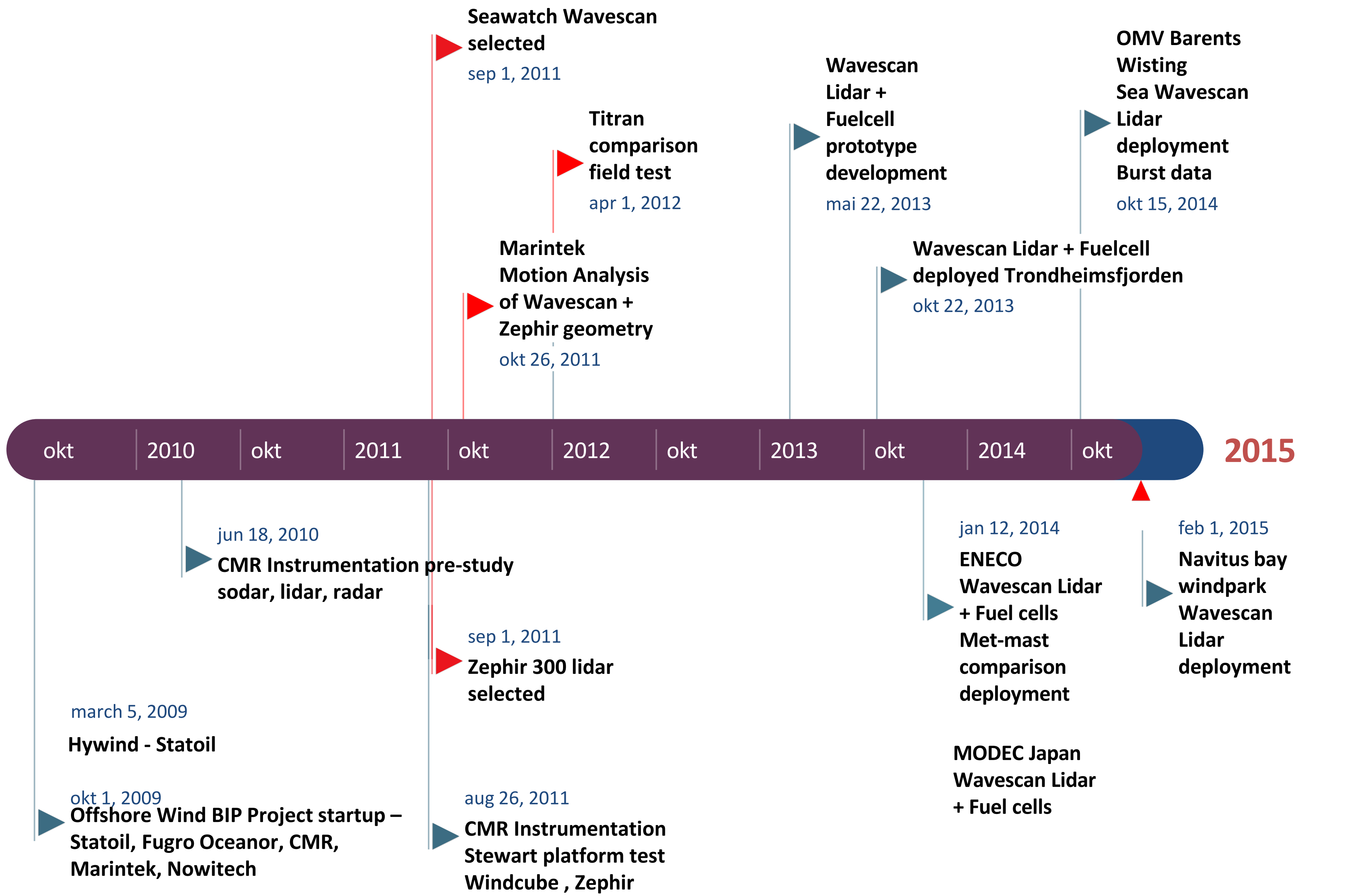
Use a proven oceanographic measurement buoy that has withstood extreme environmental conditions.

Add a proven LiDAR Wind Profiler.

Early design sketch.

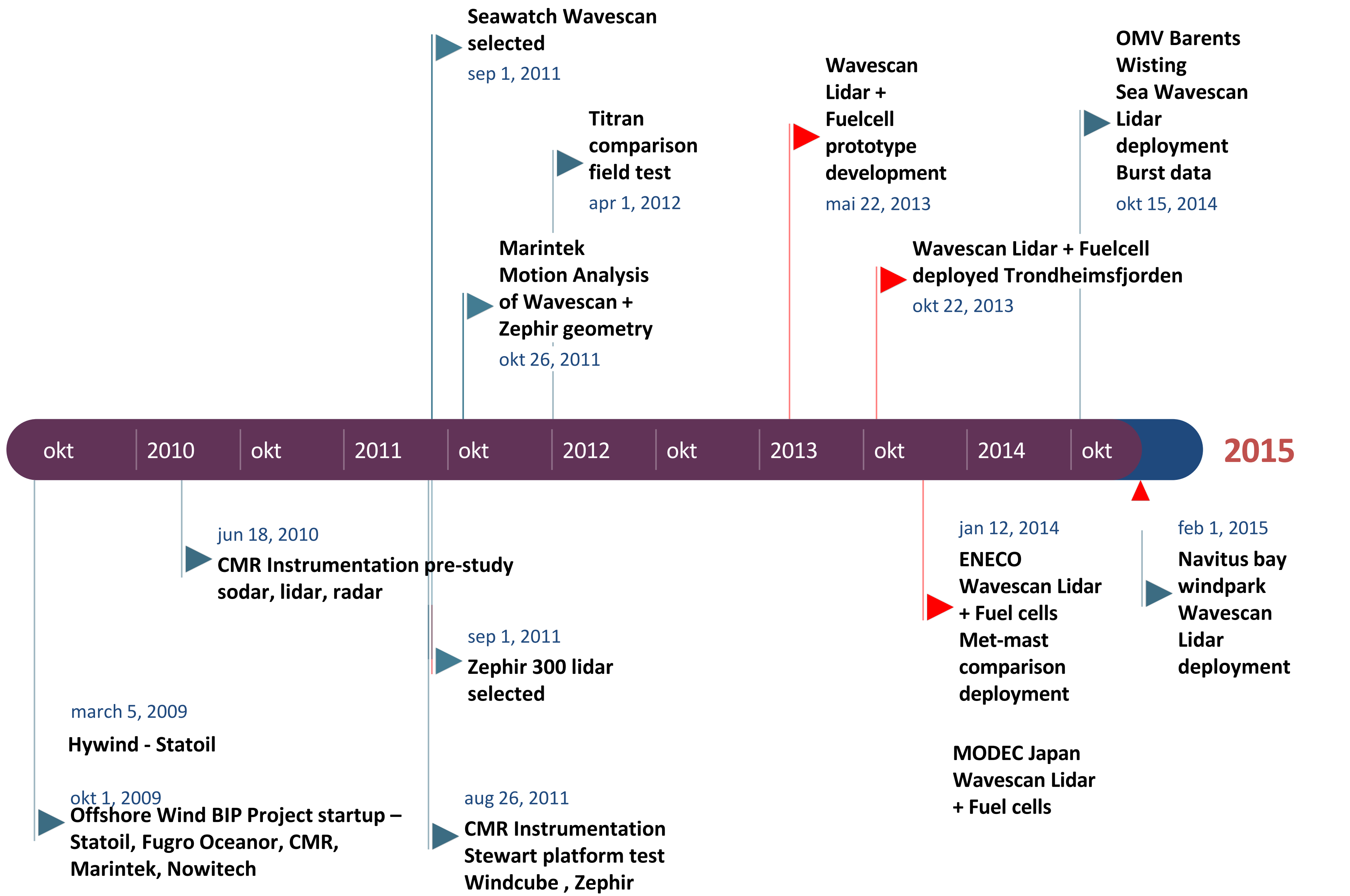


Seawatch Wind LiDAR Buoy Timeline



Titran comparison field test 2012

Seawatch Wind LiDAR Buoy Timeline



ENECO Met-mast validation

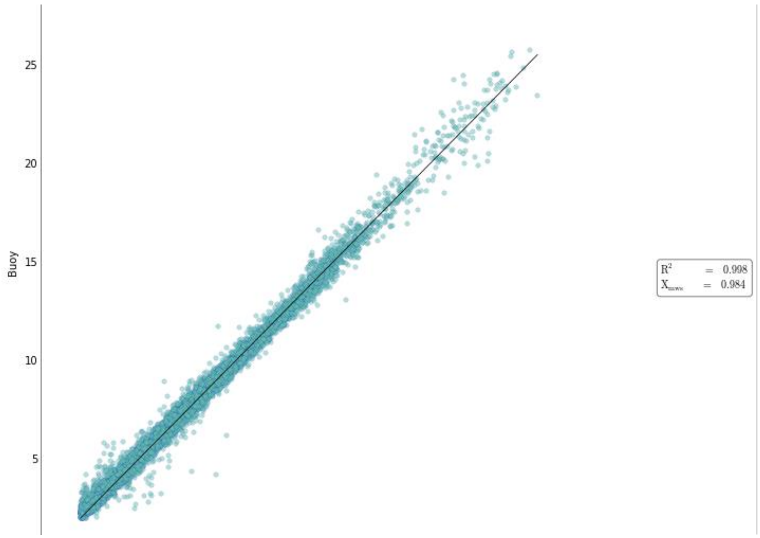
Evaluation of SEAWATCH Wind LiDAR performance

A roadmap towards commercial acceptance of the floating LiDAR technology has been generated and adapted to the SEAWATCH Wind LiDAR buoy specifics by DNV-GL. It defines three stages of technical maturity for the system

- Baseline: As a pre-requisite, the LiDAR measurement unit should have achieved wide-spread acceptance within the offshore wind industry as “proven” in the field of wind resource characterization for non-complex terrain types at least.
- Pre-commercial: Following a successful pilot validation trial, the floating LiDAR technology may be used commercially in limited circumstances – specifically in conditions similar to the ones experienced during the trial. Elevated measurement uncertainty assumptions may be expected for such application, when benchmarked against the deployment of a conventional fixed offshore meteorological mast.
- 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.

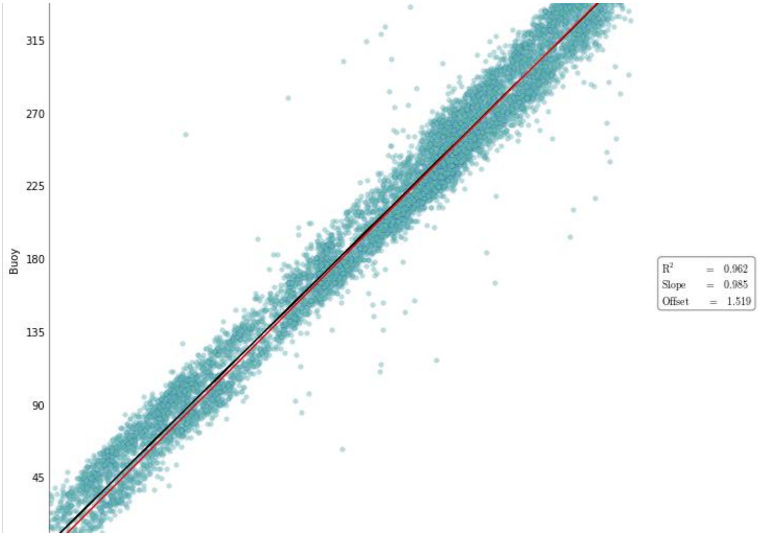
Wind Speed

- 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

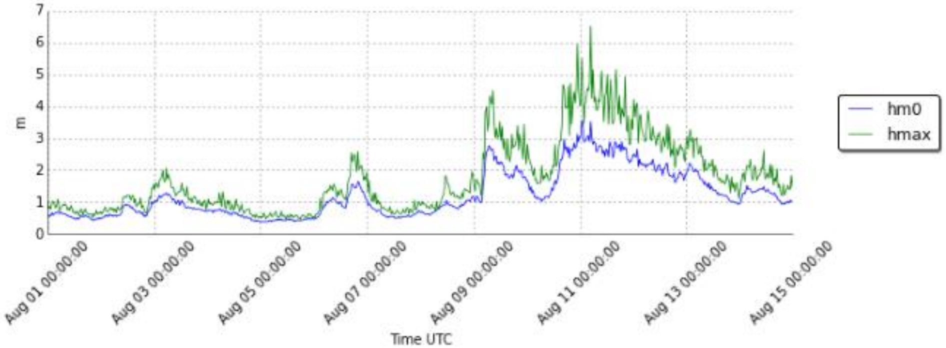


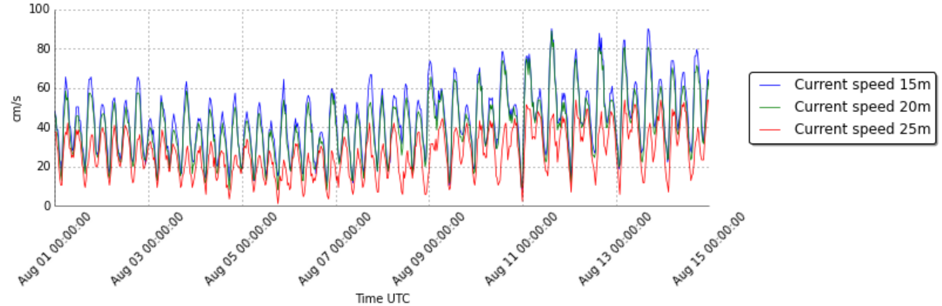
Wind Direction

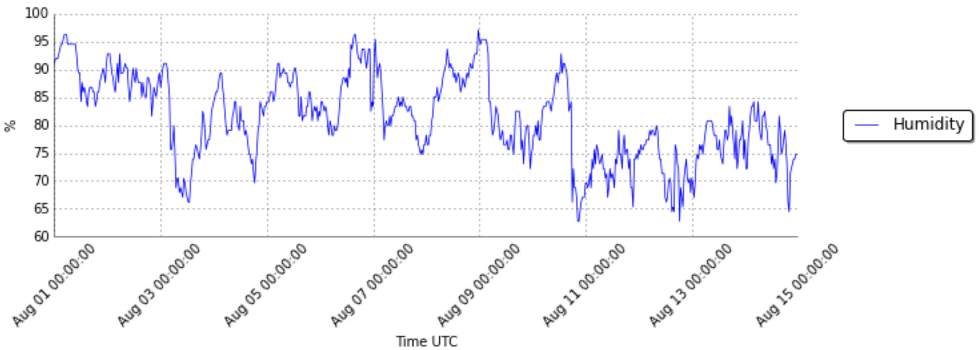
- R^2 between 0.96 and 0.97. (Best practice criteria >0.97, minimum >0.95)
- Slope between 0.97 and 0.99 (Best practice criteria 0.97-1.03, minimum 0.95-1.05)
- Mean offset between 1.5 and 5.8 degrees (Best practice criteria <5 degrees, minimum <10 degrees)

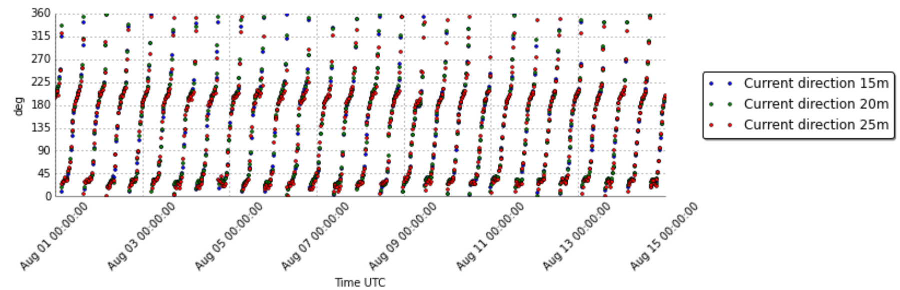


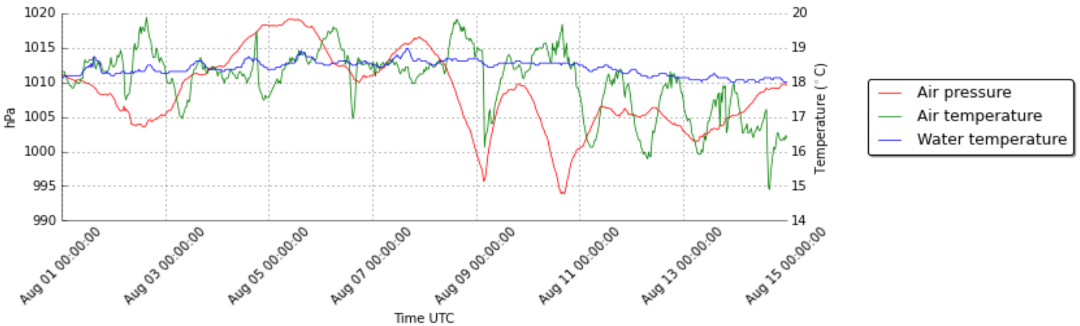
Met-Ocean Data



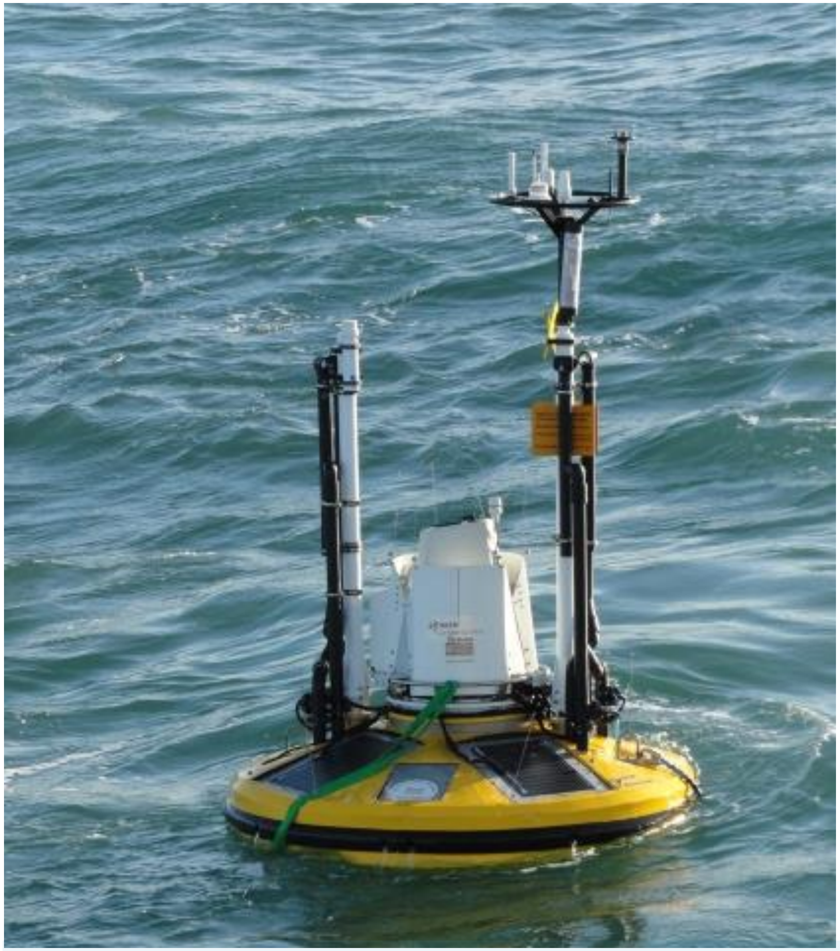








SEAWATCH Wind LiDAR Buoy approval – pre-commercial



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:
I.A. D.Stein Deputy Head of Section Offshore, Hamburg	D. [illegible], A. Beeken, P. Schwenk Senior and Project Engineers	I. A. D. Stein Deputy Head of Section Offshore, Hamburg

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☐ 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."

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

Fugro Lidar Buoy validation site – Titran, Frøya

- Pre- and post validation site approved by DNVGL
- On-shore Lidar reference Stabben Fort
- Standard anemometry reference NTNU mast

Seawatch Wind Lidar buoy - applications

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

Thank you for your time

Fugro OCEANOR
SEAWATCH Wind LiDAR
BUOY

Vegar Neshaug

Industry Meets Science
2015

Parameters

Mooring at 35m water depth

Wave height, period and direction

3-axis buoy motion and rotation

Near surface current profile and water temperature

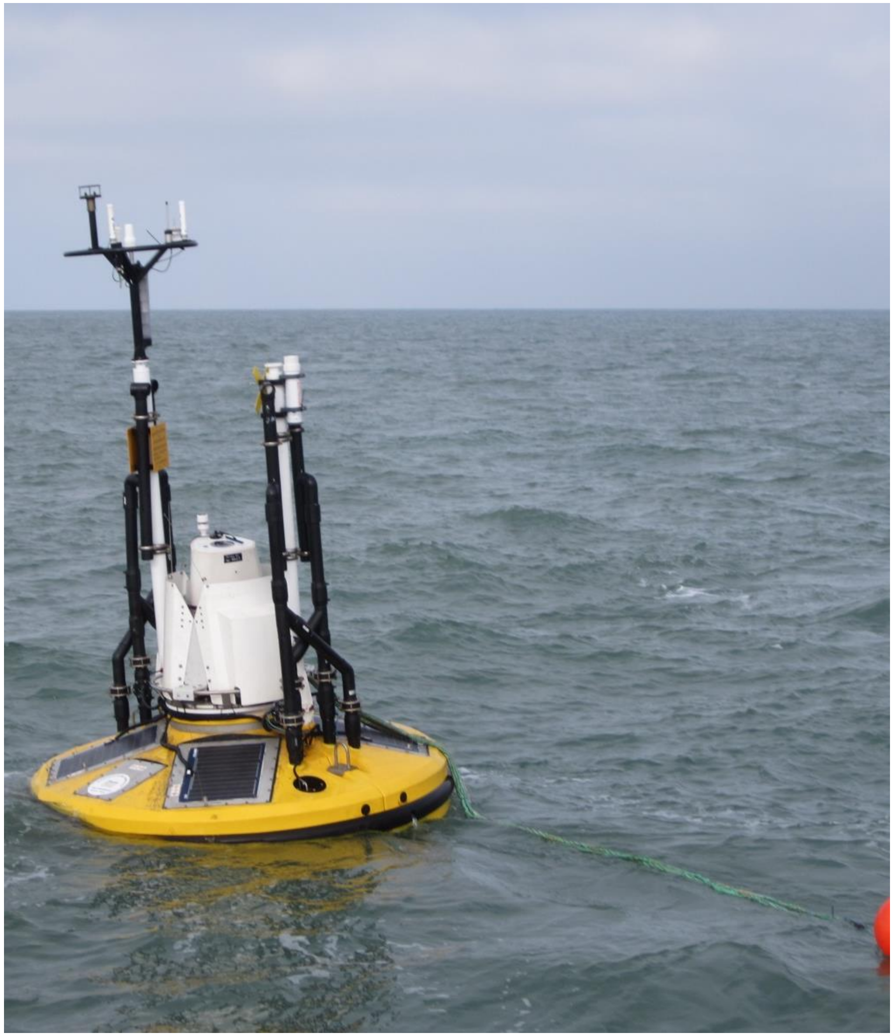
Wind speed and direction from 4m to 190m

Air pressure

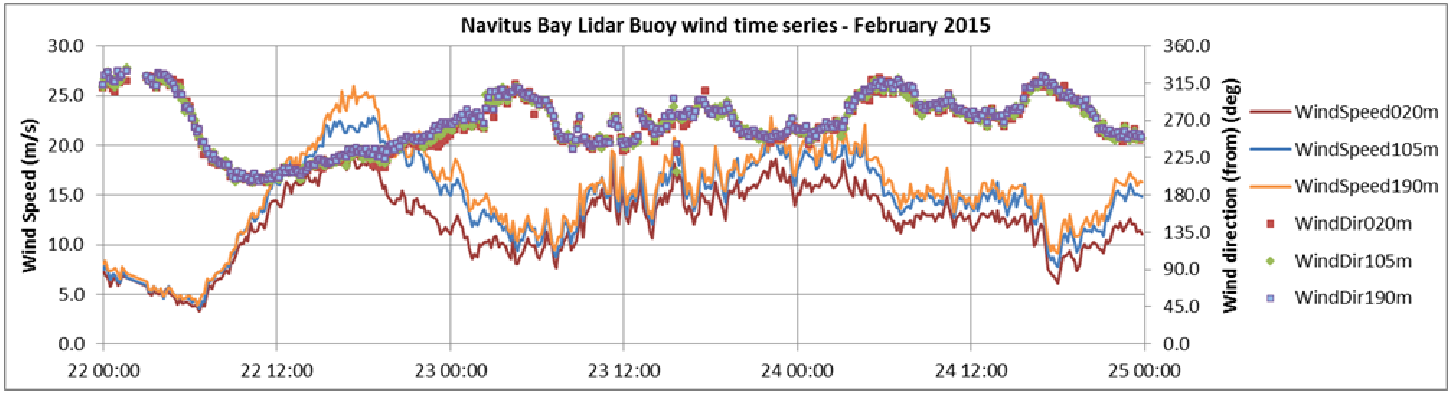
Air humidity and temperature

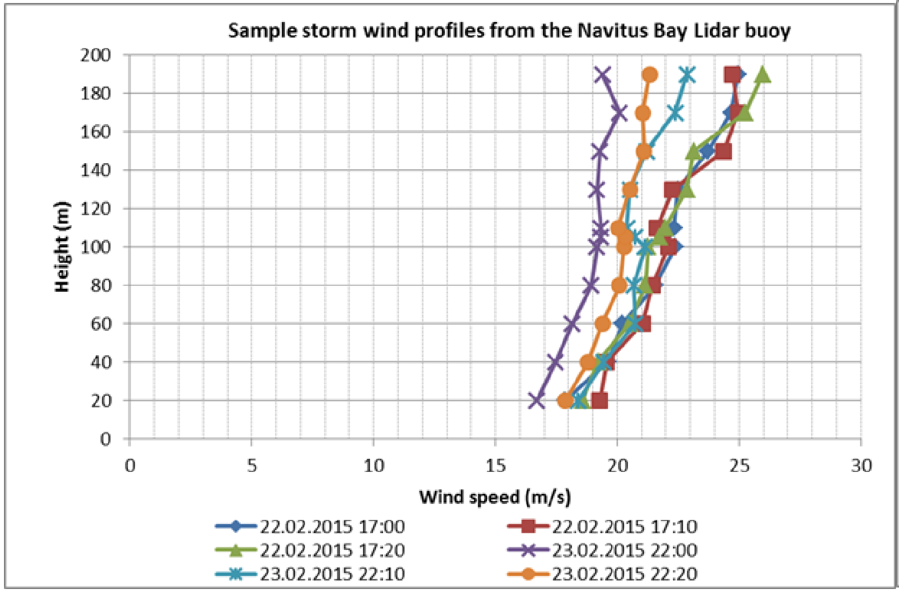
Observations

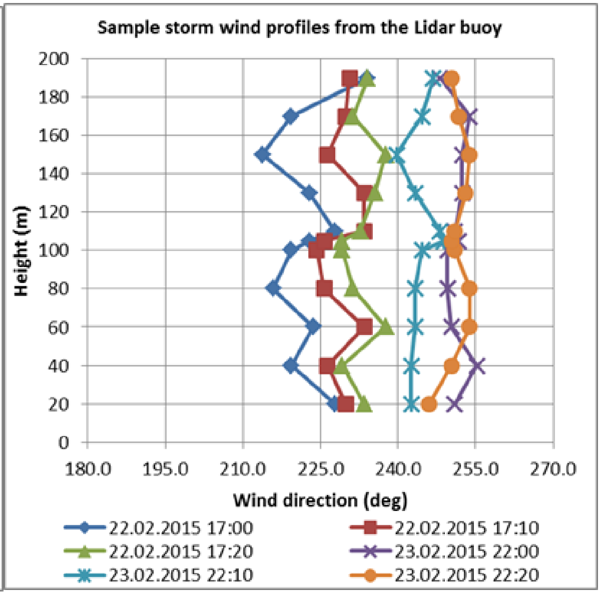
The highest recorded significant wave height exceeded 4 m, the highest wind speed was 25 m/s, and currents regularly peaked at 120 – 170 cm/s.



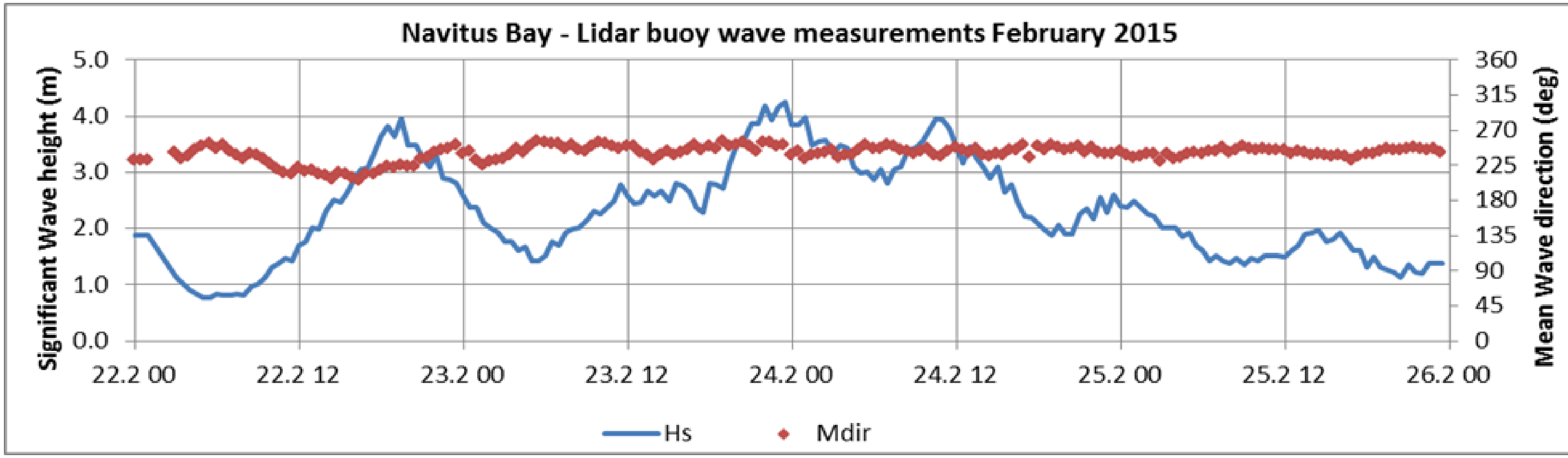
SEAWATCH Wind LiDAR Buoy – Navitus Bay

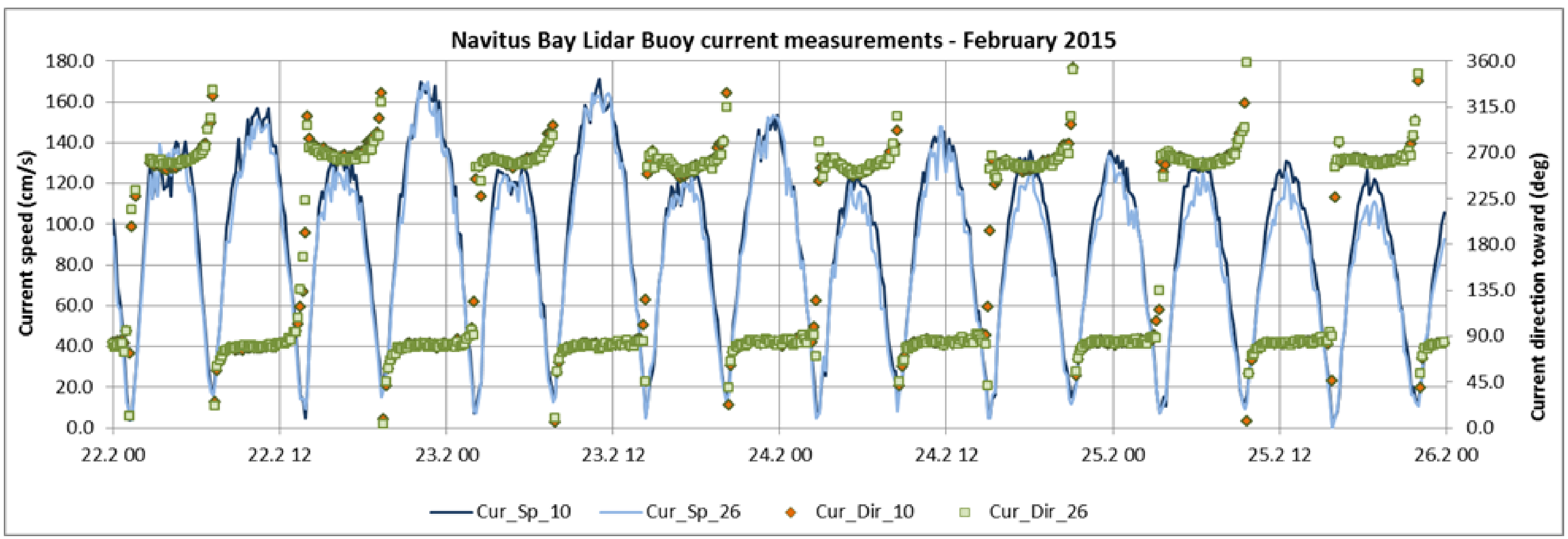






SEAWATCH Wind LiDAR Buoy – Navitus Bay





SEAWATCH Wind LiDAR Buoy – Wisting Field, Barents Sea

Parameter s

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

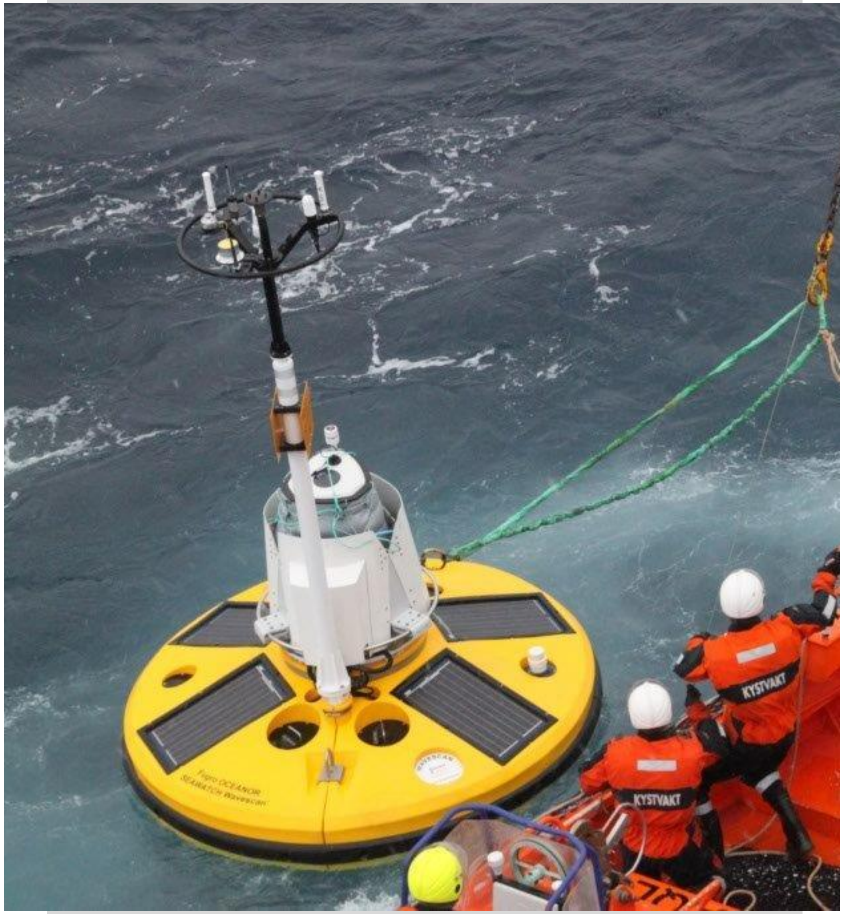
15th October 2014 to 31 January 2015 - 2402 wind profiles – data recovery 100%

Recorded 8 storms with significant wave height exceeding 6m

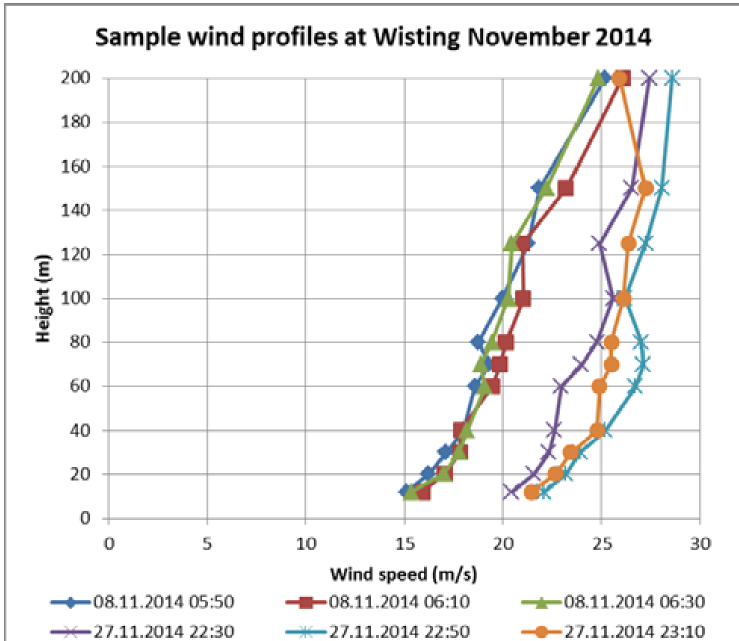
Max wind speed 28.6 m/s

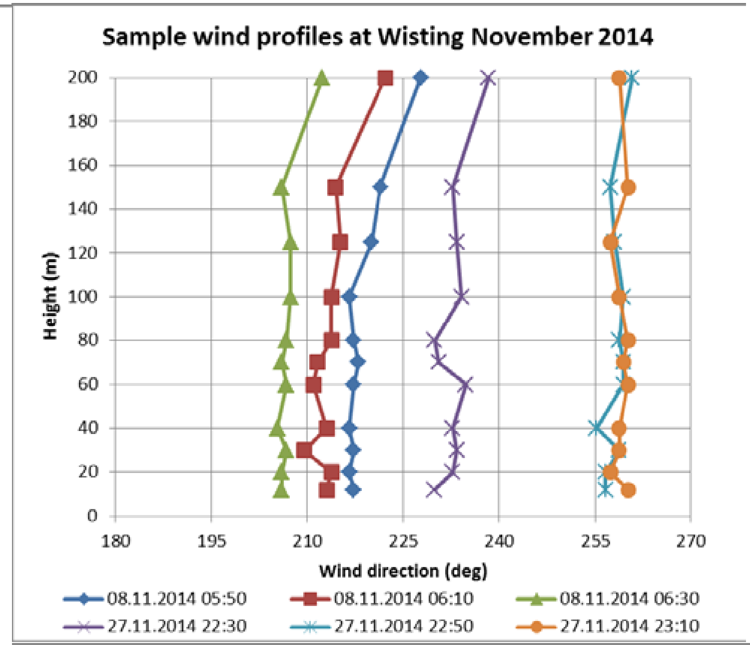
Max wave height 13.4m

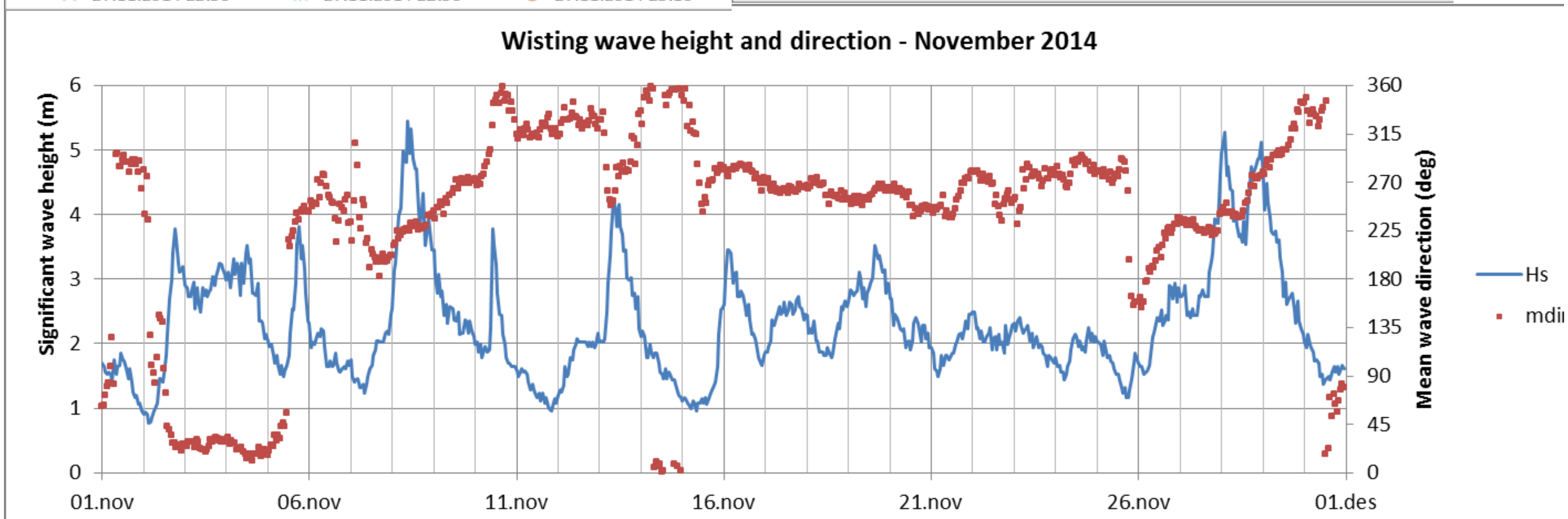
Max current 60cm/s in upper 40m



SEAWATCH Wind LiDAR Buoy – Wisting Field, Barents Sea







SEAWATCH Wind LiDAR Buoy – RVO Borssele - *Ongoing*

Borssele Wind farm survey and Belwind wake effects study

Parameters

Mooring at 30m water depth

Wave height, period and direction

3-axis buoy motion and rotation

Near surface current profile(35m) and water temperature

Wind speed and direction

Wind speed and direction profile

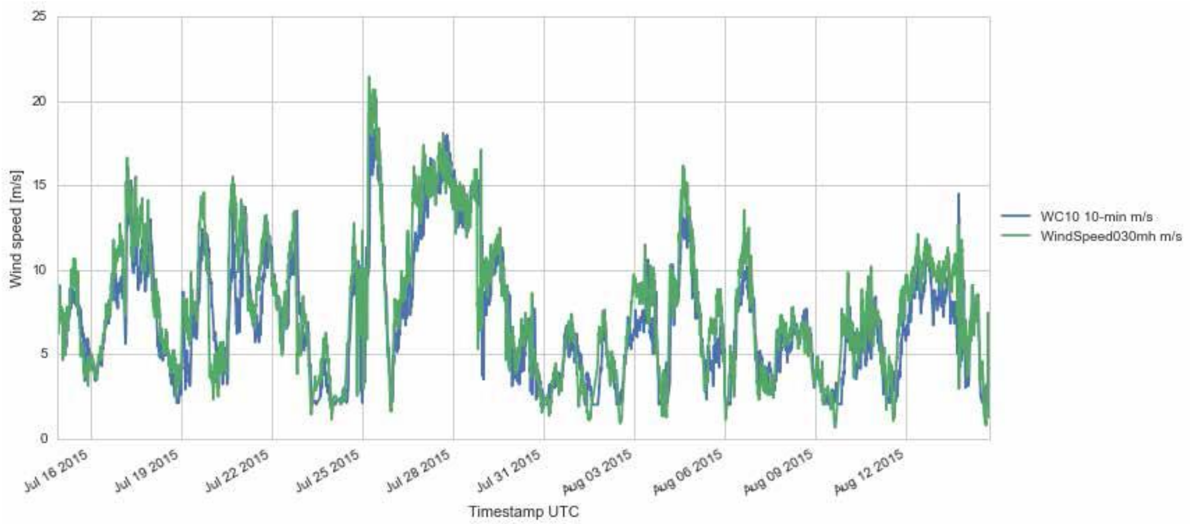
Air pressure

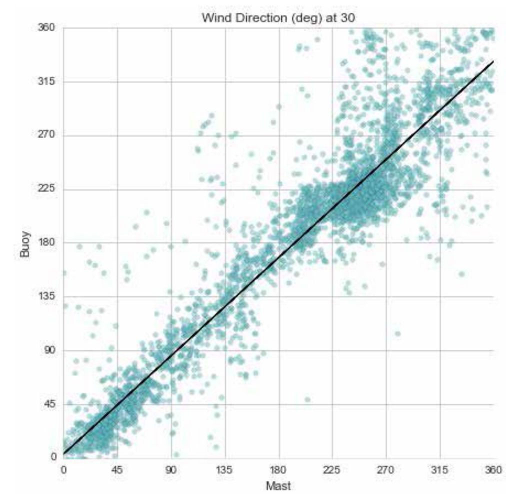
Air humidity and temperature

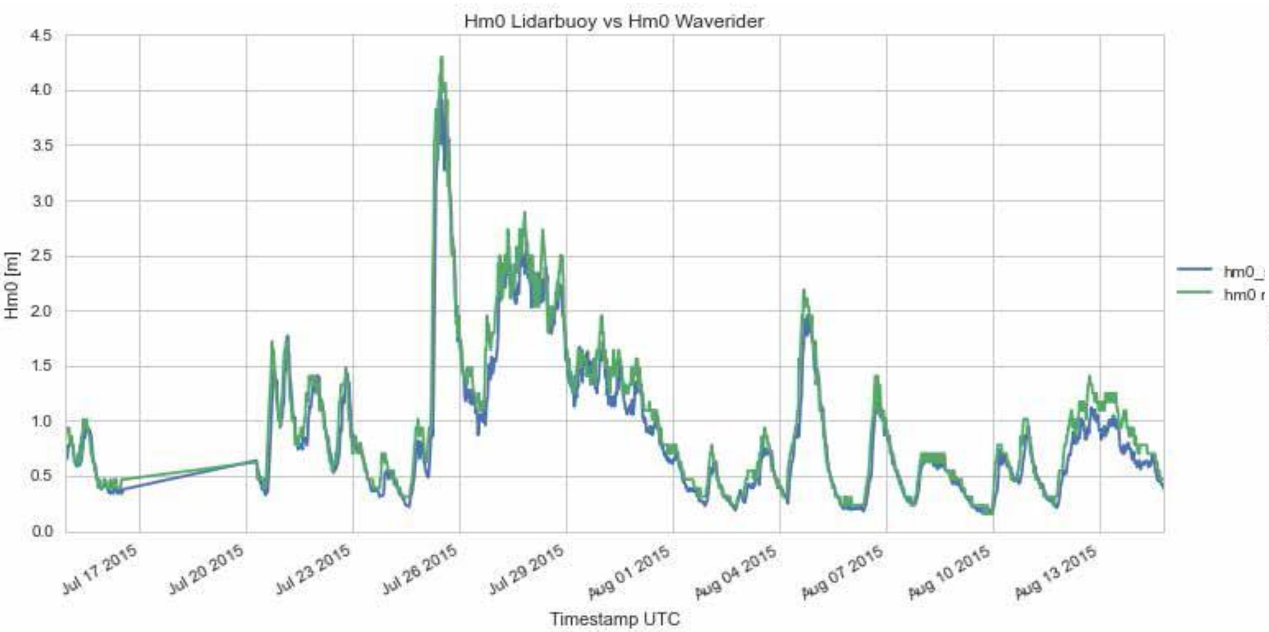
Observations

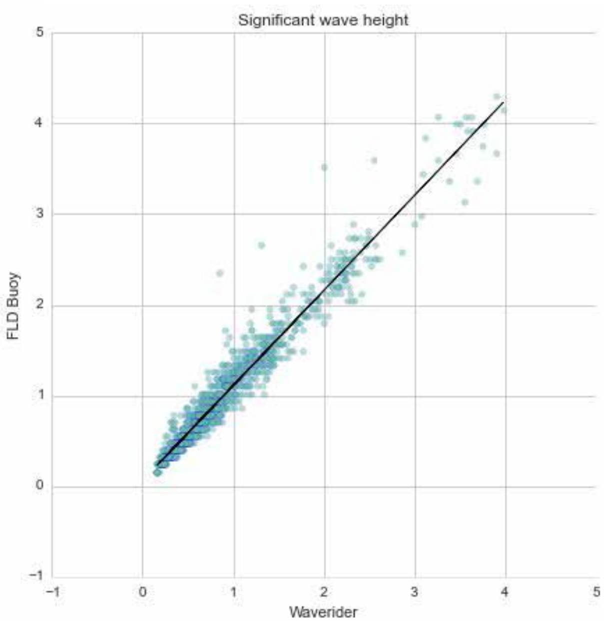
Turbulence intensity, inflow angle and wind shear/veer

Schouwenbank and Vlakte van Raan Reference

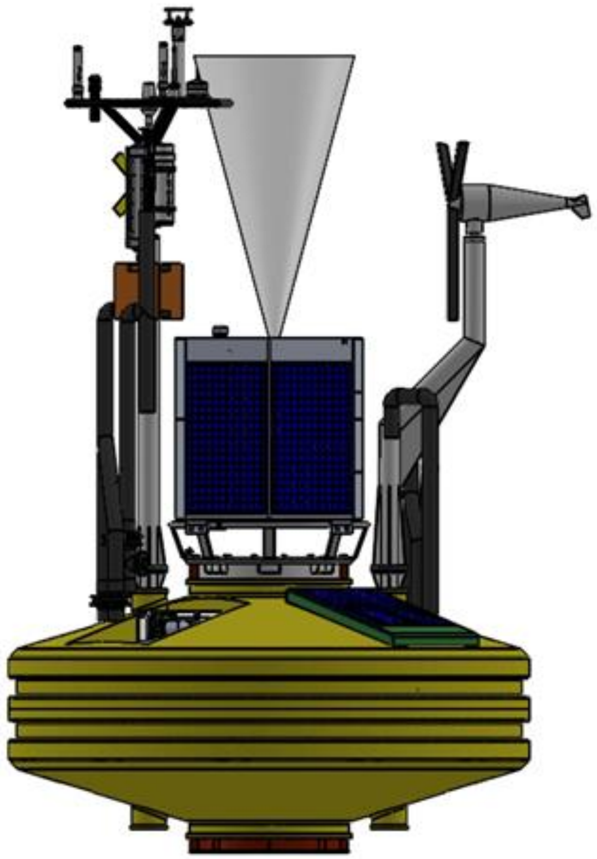








SEAWATCH Wind LiDar Buoy – next generation



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