ECN
Your energy. Our passion.

Ring analysis floating LiDAR, static LiDAR and offshore meteorological mast

Dr. Jan Willem Wagenaar

EWEA Conference, Paris
Friday, 20th of November 2015

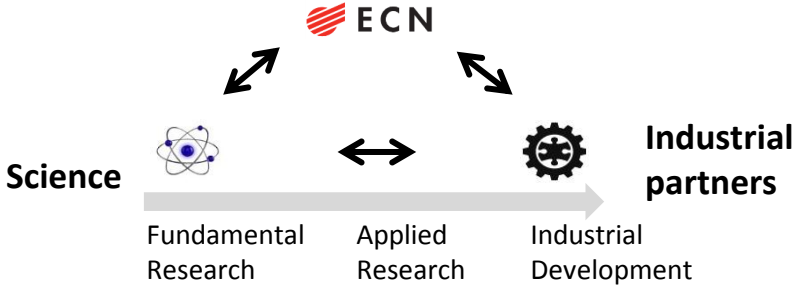
Content

- ECN at a glance
- Offshore wind and floating LiDAR
- Measurement approach
- Results
- Conclusions
- Takeaways

ECN at a glance

Mission:
…To develop with and for the market knowledge and technologies that enable a transition to more sustainable energy systems…

Operations:
Offices around the world and a global client and partner base.



ECN Focus Areas

Solar energy | Biomass | Policy studies | Energy efficiency | Wind energy | Environment & energy engineering

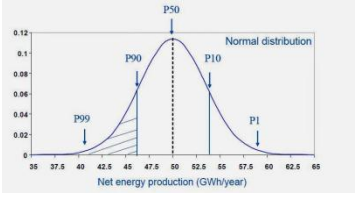
Offshore Wind Energy R&D & Services

ECN

Offshore Wind and Floating LiDAR

Offshore wind development

- Wind resource assessment for business case
- Project Finance: P50, P90, CAPEX, OPEX



The burning question

➢ Is floating LiDAR a cost effective and reliable alternative to a fixed offshore meteorological mast?

Addressed in this presentation:

- ✓ How does floating LiDAR perform?
- ✓ To what extent are deviations technology driven?
- ✓ What are the main drivers for deviations with the mast?
- ✓ To what extent can a static LiDAR be used as a reference?

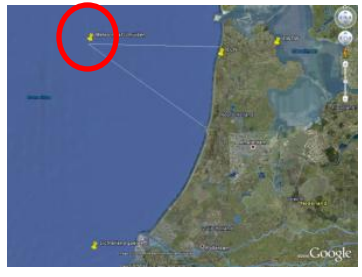
Used methodology

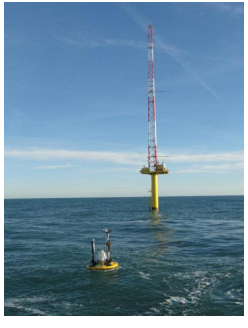
- CDV IEC 61400-12-1 Annex L (Feb 2013)
- OWA Roadmap commercial acceptance: KPIs

Measurement approach

Meteorological mast IJmuiden (RWE, ECN)

- Offshore, 80 km from IJmuiden
- Largest distance from coast in Europe
- 92m height, 26m water depth
- Measurements from 27m upto 92m at 4 heights
- Operational since November 2011



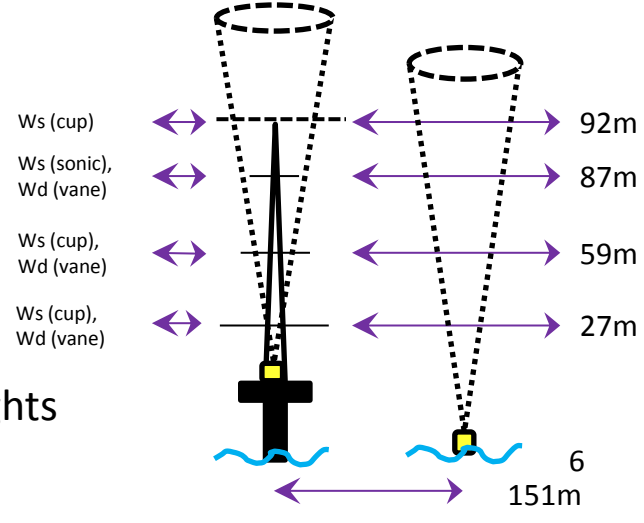


Zephir 300 static LiDAR

- Installed inside mast
- Measurements from 90m upto 315m at 10 heights

Fugro Seawatch floating LiDAR (RWE, Eneco)

- Deployed 151m from mast
- Measurements from 4m + 12m upto 190m at 10 heights
- Period: April 2014 until November 2014



Results

Floating LiDAR commercial maturity

Availability

- Pass. System out of water

Wind speed (FL=X * Ref)

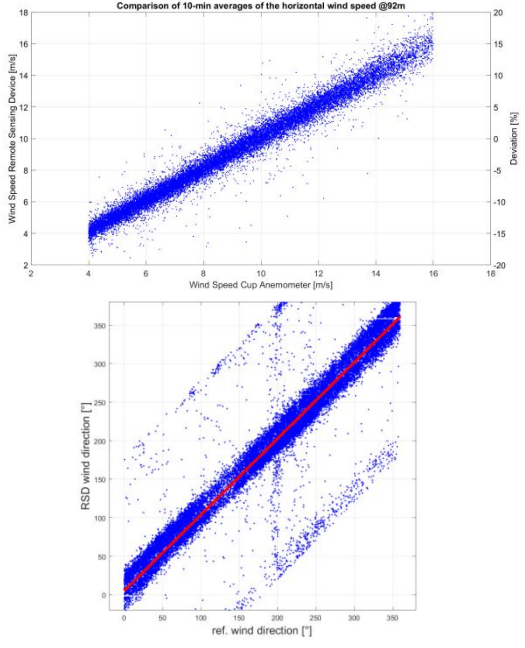
- X_mws: Pass
- R2: Minimal & Fail

Wind direction (FL=M * Ref + OFF)

- M_mwd: Pass in all cases
- OFF_mwd: Pass & Minimal
- R2: Fail. 180 degrees issue

TI and shear also assessed. No criteria

OWA roadmap KPIs



DNV GL report: ‘pre-commercial’. ECN agrees (rounding, 180 degrees issue)

Validation comparison

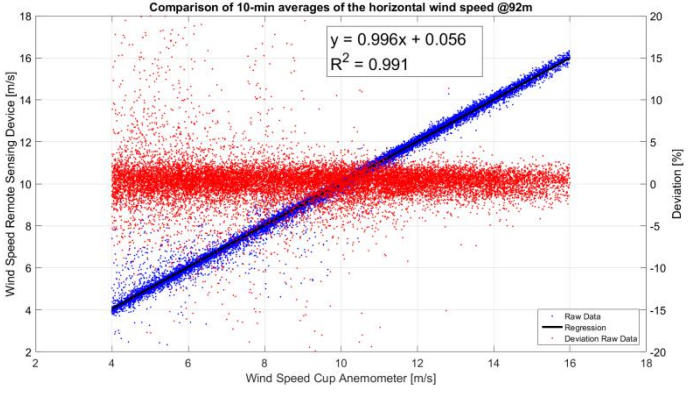
CDV IEC 61400-12-1 Annex L

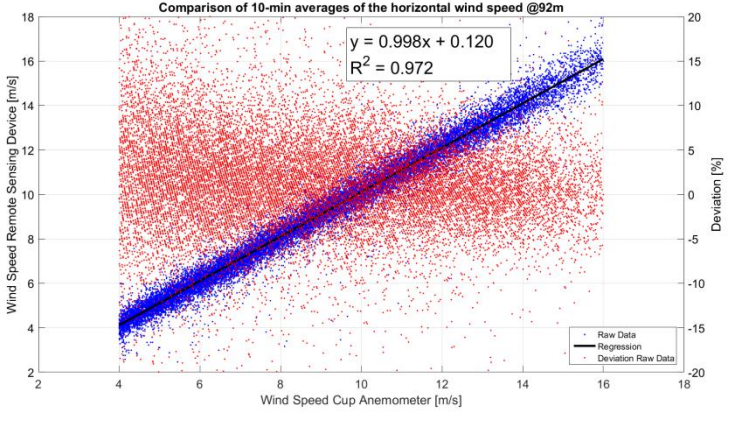
Static

- Ws: a=0.996, b=0.056m/s, R^2 =0.991
- Ws: Mean deviation 0.4%
- Ws: Spread deviation 4.8%

Floating

- Ws: a=0.998, b=0.120m/s, R^2 =0.972
- Ws: Mean deviation 1.3%
- Ws: Spread deviation 6.4%





Sensitivity analysis

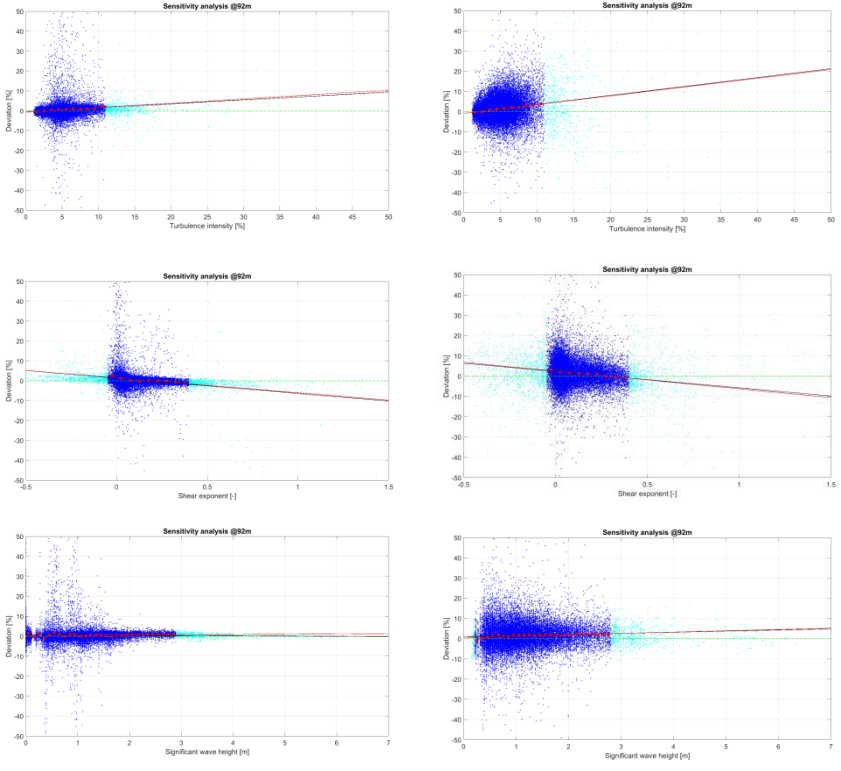
Addressed

- Atmospheric:
  - ρ, T, flow inclination, precipitation, TI, wd, ws, availability, shear, veer
- Metocean
  - Significant wave height, significant wave period, wave steepness, current speed, tilt

Key

- Atmospheric:
  - TI: Larger influence floating
  - Shear & Veer: About same influence
- Metocean
  - Wave height & Tilt: slight increase

Static | Floating

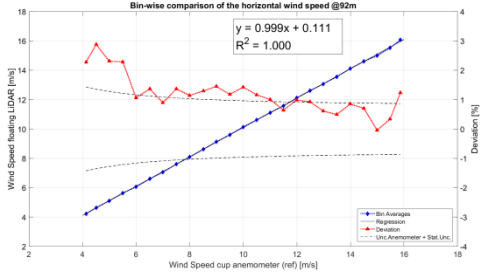


Static LiDAR reference

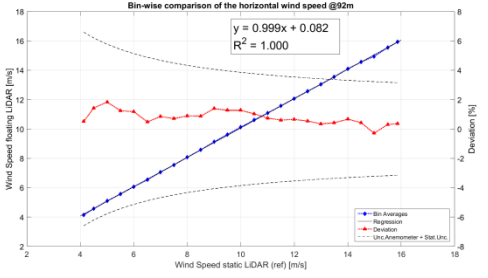
Validation

- Similar results in regression
- No calibration

Floating vs mast



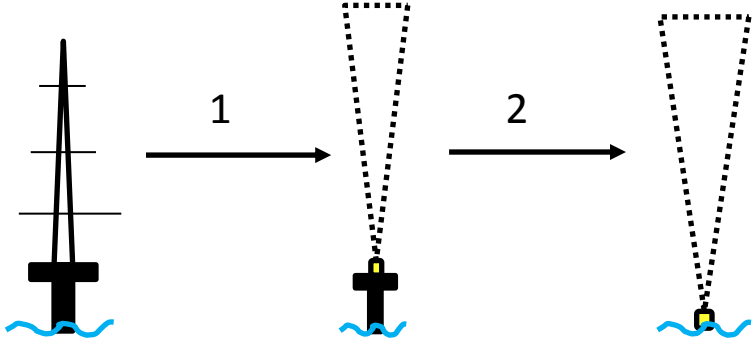
Floating vs static LiDAR



Uncertainty

- Slight increase ref ~0.2%
- Additional mounting ~0.5%

- Total floating LiDAR unc ~3.5%-6.8%
- Distance significant (both) ~1.6%
- Classification ~3%-6.5%



Conclusions and Takeaways

Conclusions

- **How does the floating LiDAR perform?**
  - Pre-commercial phase (DNV-GL)
  - Take into account: Rounding and 180 degree correction
- **To what extent are deviations technology driven?** (Static vs Floating)
  - Floating: increased spread in deviation of ws. 4.8% to 6.4%
- **What are the main drivers for deviations with the mast?**
  - Shear and veer: Same effect on static as on floating
  - Wave height and tilt: Slight increase in deviation for floating LiDAR
  - TI : Clear increase in deviation for floating LiDAR
- **To what extent can a static LiDAR be used as reference**
  - Validation results similar. No calibration
  - Increase of uncertainty. Total ~3.5%-6.8%
  - Distance significant (both) ~1.6% in this case
  - Classification ~3%-6.5%

Takeaways/Moving forward

- Turbulence intensity seems to be the largest influencer of deviations between the floating LiDAR and the mast. This was not anticipated and may be an indirect effect.

- Classification turned out the have the largest contribution to the uncertainty budget of the static LiDAR as reference for the floating LiDAR. Therefore, a decent classification scheme is essential.

- The commercial acceptance of floating LiDAR is guided by the OWA roadmap. Currently, recommended practices are being developed in the framework of IEA task 32 and Carbon Trust (ECN is involved in both).

- More and more floating LiDAR systems appear on the market, getting more and more mature. Validation tests are essential in the development.

Questions would be most welcome. Thank you!

Jan Willem Wagenaar
ECN Wind Energy
j.wagenaar@ecn.nl
+31 88 515 4909