16-2-2023 / IEA Wind Task 52 “lunch seminar” series
Day 4

Floating lidar within the IEA Wind ‘Lidar’ Task so far …

and what’s next

J. Gottschall

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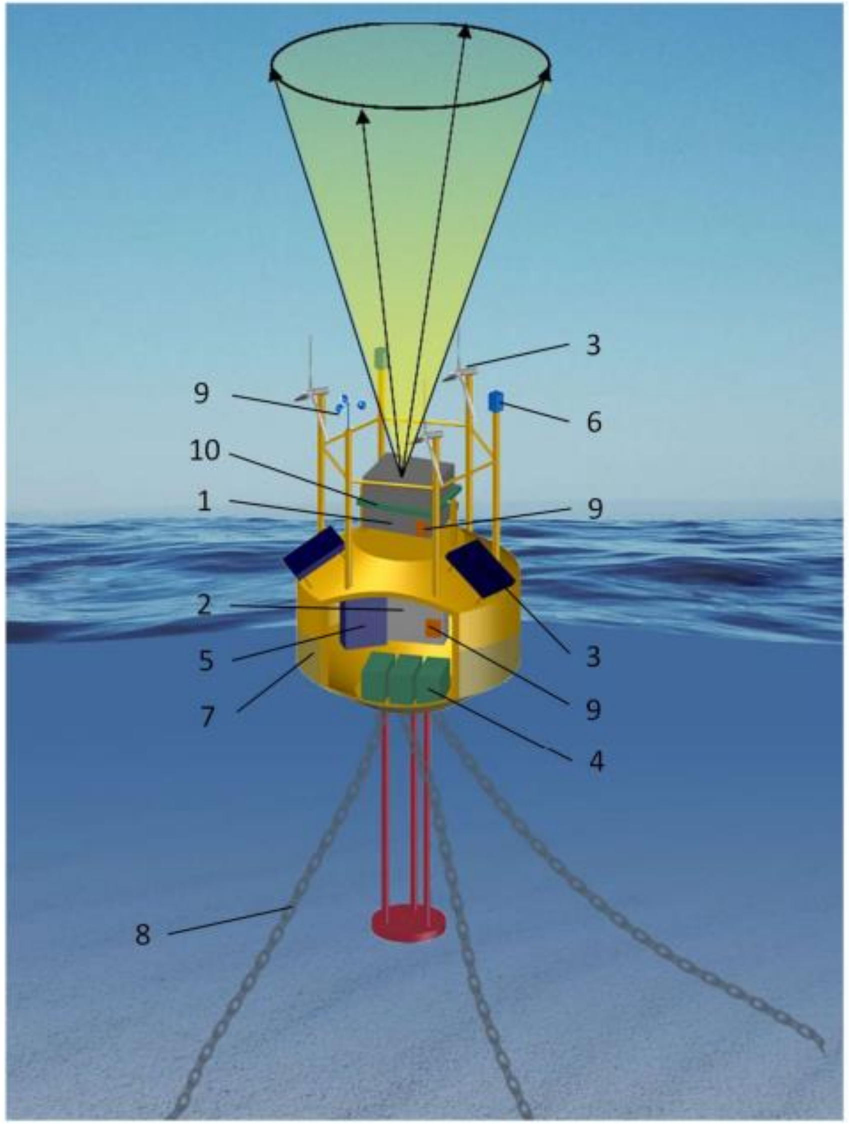
Floating lidar …



1 Lidar

2 FLS operating system

3 Energy generation system

4 Energy storage system

5 Data logging system

6 Communication system

7 Floating platform

8 Station-keeping system

9 Sensors

10 Motion compensation

Floating lidar system (FLS) deployments

… between 2009 and 2017

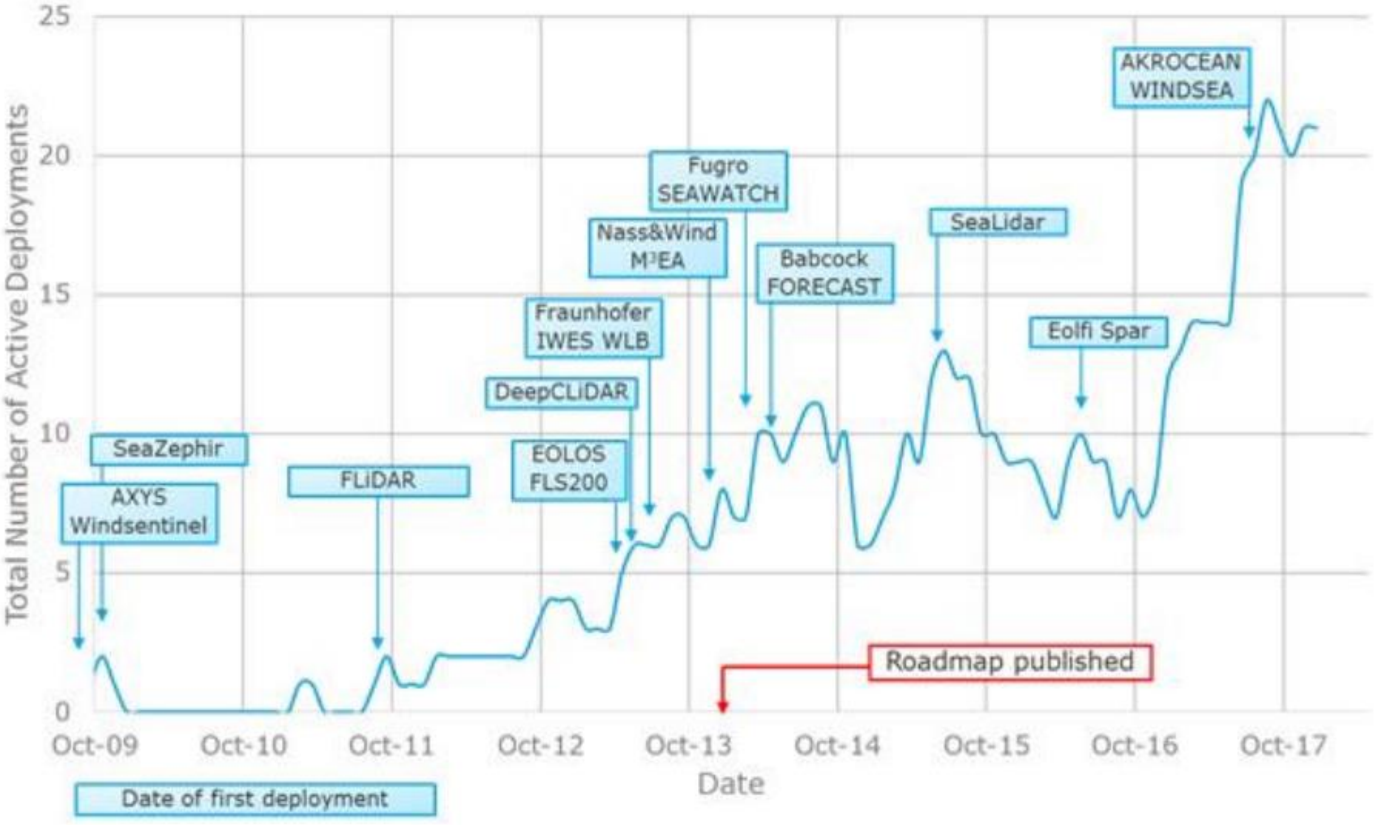
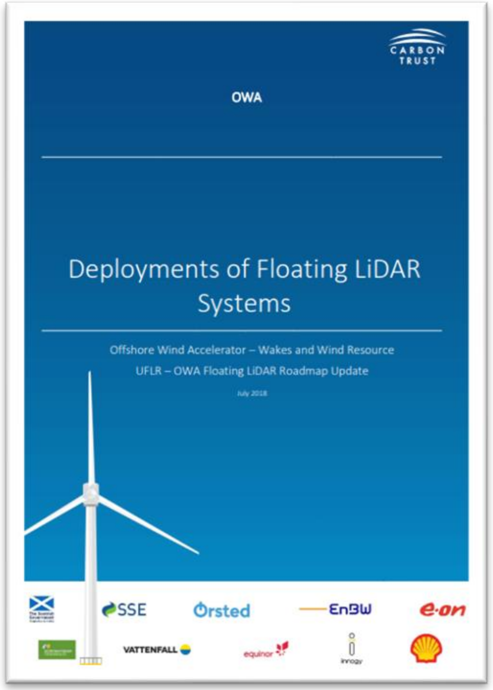


Figure 1: Indicative timeline showing number of deployed FLS systems. The date of the original OWA FLS Roadmap publication is shown in red.



CARBON TRUST

OWA

Deployments of Floating LiDAR Systems

Offshore Wind Accelerator – Wakes and Wind Resource

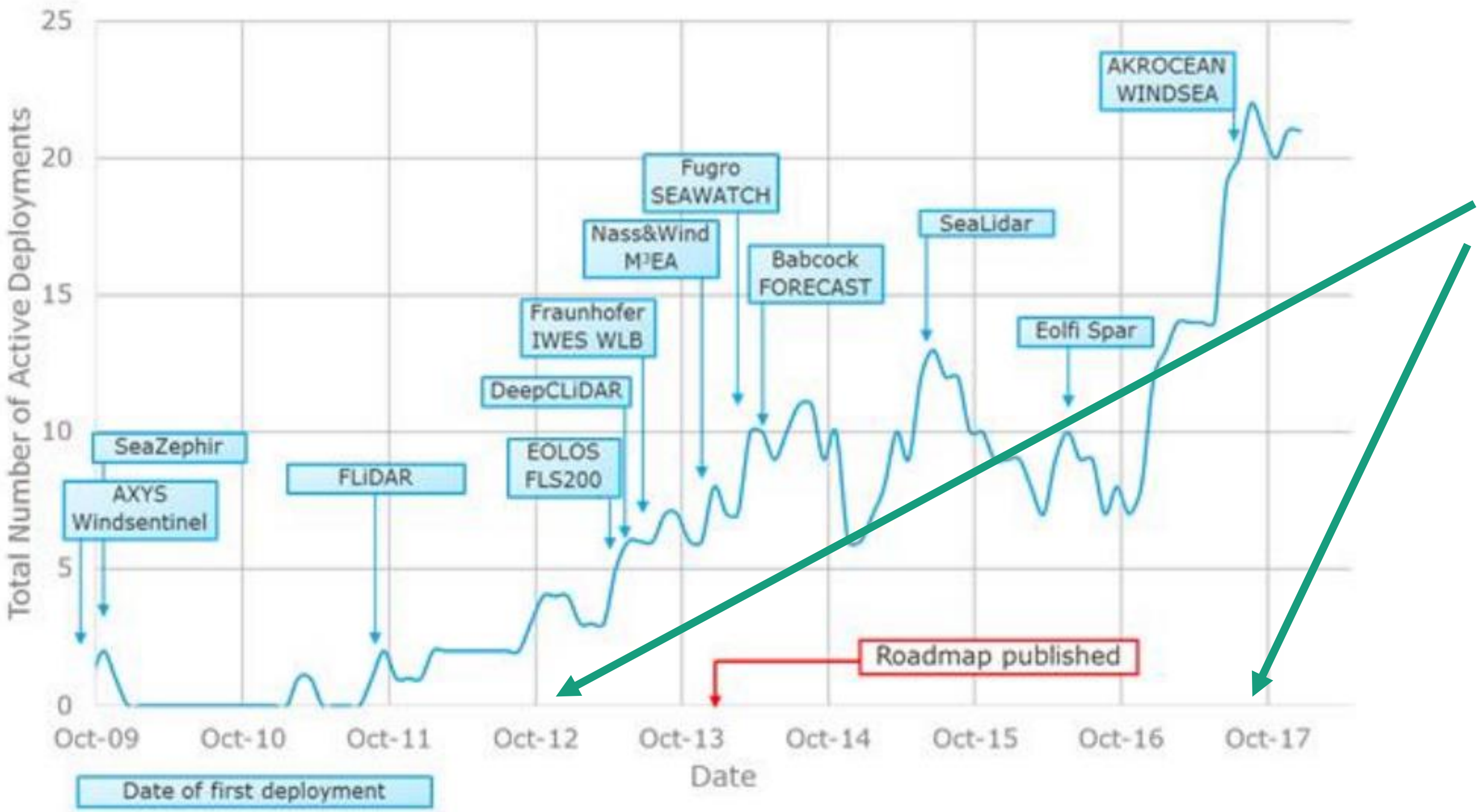
UFLR – OWA Floating LiDAR Roadmap Update

July 2018

https://www.carbontrust.com/our-work-and-impact/guides-reports-and-tools/deployments-of-floating-lidar-systems

Floating lidar system (FLS) deployments

… between 2009 and 2017



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IEA Wind [Task 32/52] perspective:

- First working group meeting on FLS
- Publication of 'RP18' (IEA Wind Recommended Practice 18 on Floating Lidar Systems)

iea wind

EXPERT GROUP REPORT ON RECOMMENDED PRACTICES

18. FLOATING LIDAR SYSTEMS

FIRST EDITION, 2017

Submitted to the Executive Committee of the International Energy Agency Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems

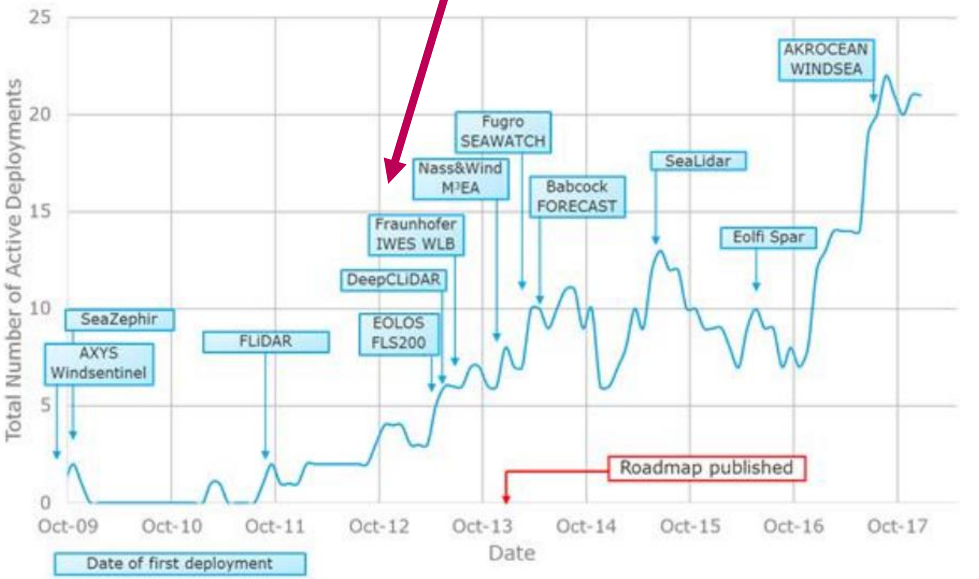
September 2017

https://iea-wind.org/wp-content/uploads/2020/12/IEA-Wind-RP-18-Floating-Lidar-Systems-fnl1.pdf

Floating lidar system (FLS) deployments

… between 2009 and 2017

Fraunhofer IWES perspective ☺



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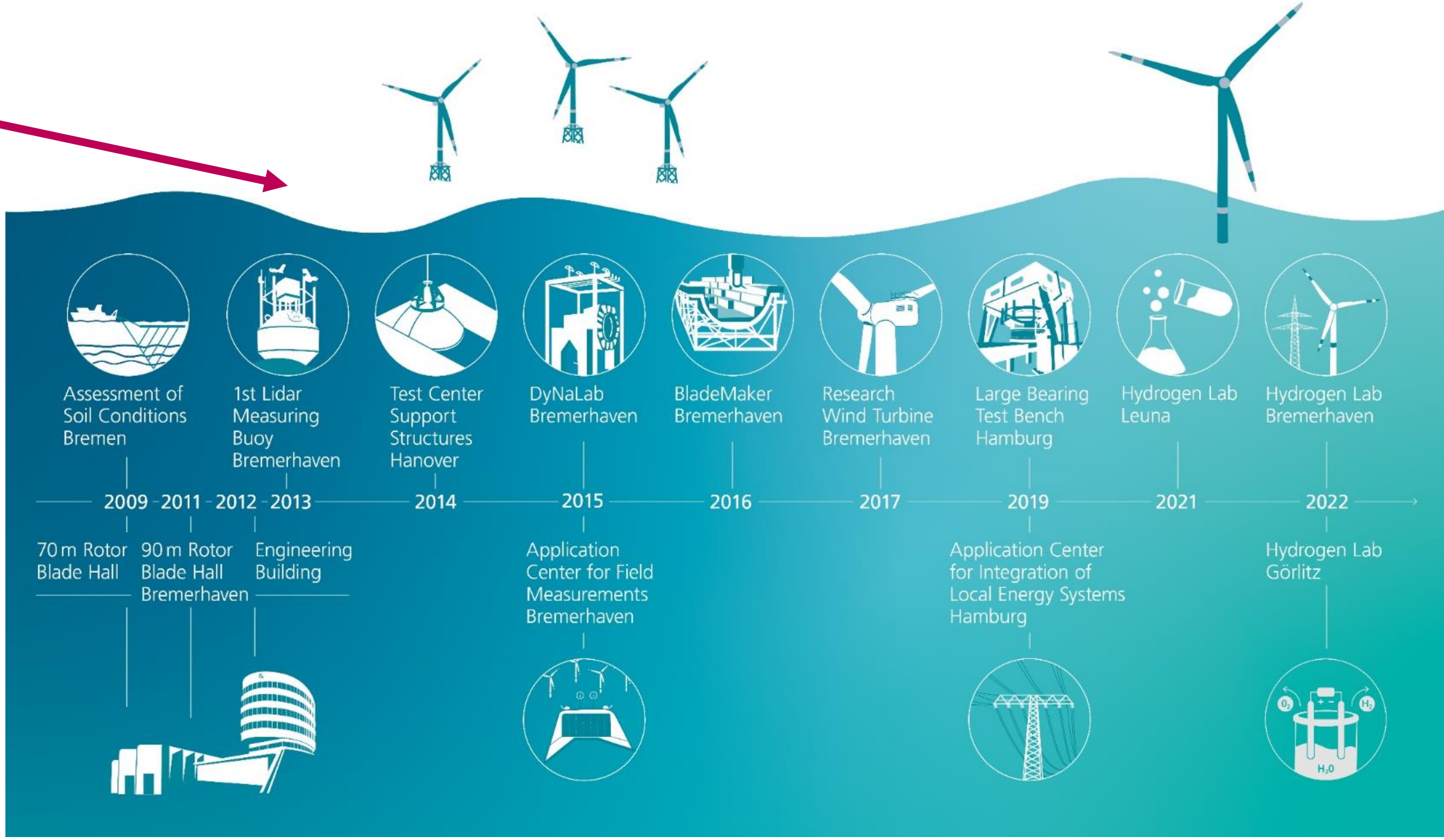
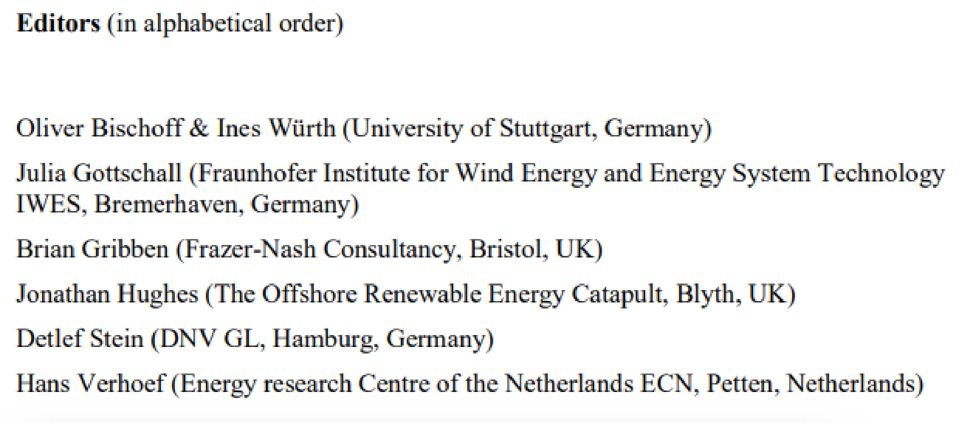


- 2009: Assessment of Soil Conditions Bremen; 70 m Rotor Blade Hall
- 2011: 90 m Rotor Blade Hall Bremerhaven
- 2012: Engineering Building
- 2013: 1st Lidar Measuring Buoy Bremerhaven
- 2014: Test Center Support Structures Hanover
- 2015: DyNaLab Bremerhaven; Application Center for Field Measurements Bremerhaven
- 2016: BladeMaker Bremerhaven
- 2017: Research Wind Turbine Bremerhaven
- 2019: Large Bearing Test Bench Hamburg; Application Center for Integration of Local Energy Systems Hamburg
- 2021: Hydrogen Lab Leuna
- 2022: Hydrogen Lab Bremerhaven; Hydrogen Lab Görlitz

IEA Wind RP 18

What it is about



Editors (in alphabetical order)

Oliver Bischoff & Ines Würth (University of Stuttgart, Germany)

Julia Gottschall (Fraunhofer Institute for Wind Energy and Energy System Technology IWES, Bremerhaven, Germany)

Brian Gribben (Frazer-Nash Consultancy, Bristol, UK)

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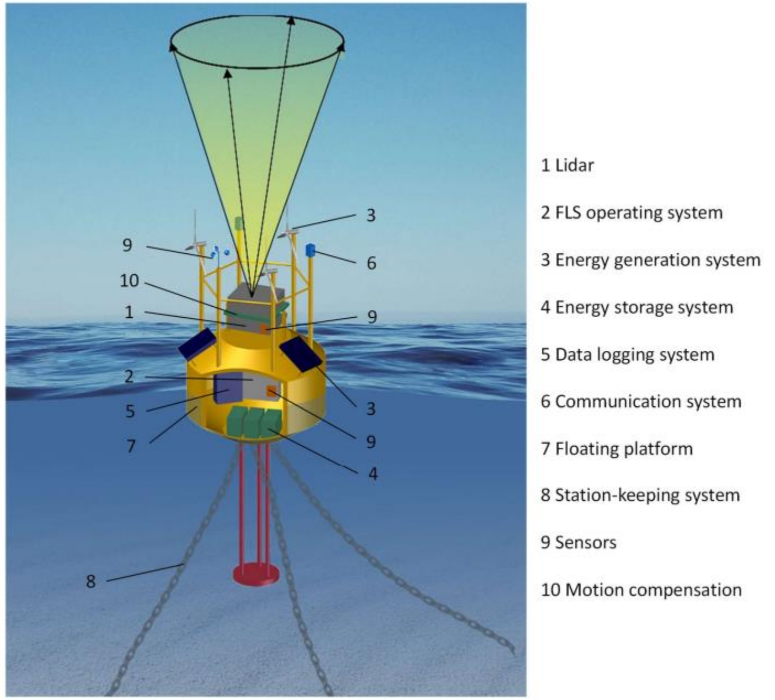

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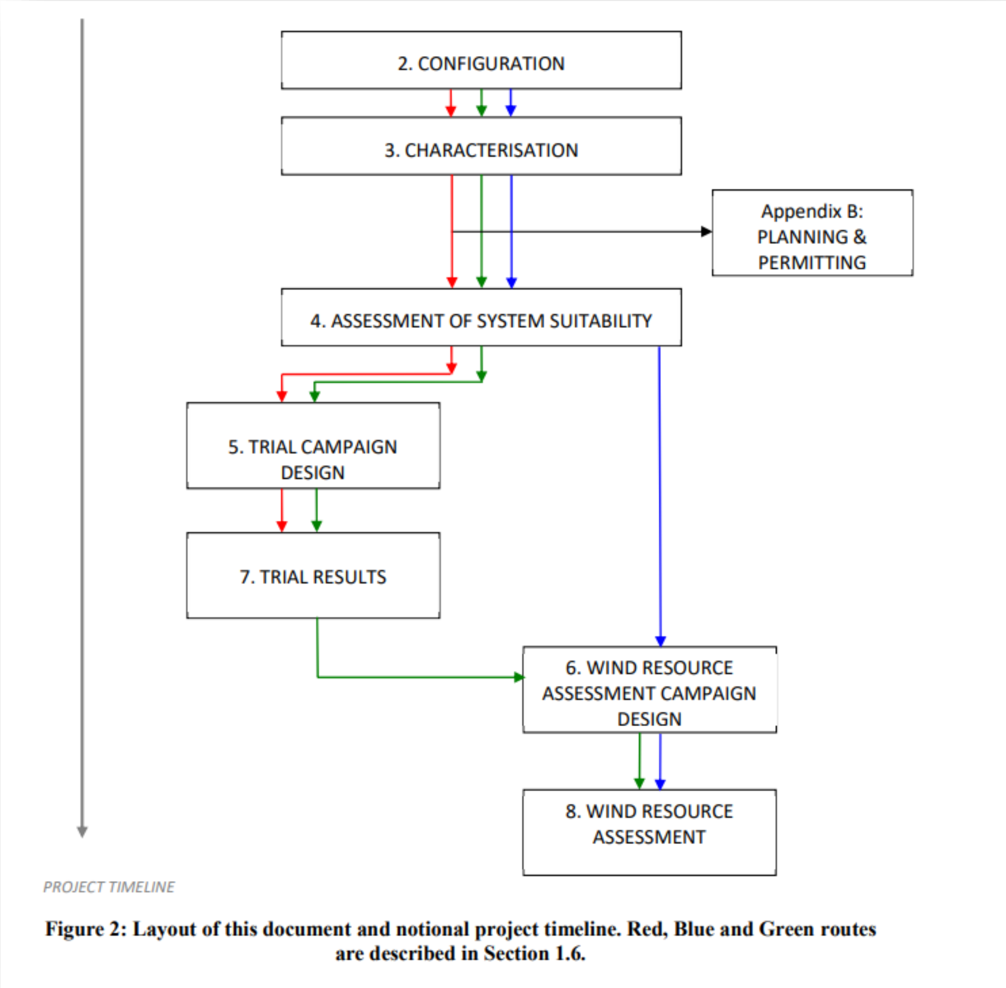
Figure 3: Schematic drawing of an FLS and its components. Note other buoy designs and mooring systems are possible.

IEA Wind RP 18

What it is about



2. CONFIGURATION

3. CHARACTERISATION

Appendix B: PLANNING & PERMITTING

4. ASSESSMENT OF SYSTEM SUITABILITY

5. TRIAL CAMPAIGN DESIGN

7. TRIAL RESULTS

6. WIND RESOURCE ASSESSMENT CAMPAIGN DESIGN

8. WIND RESOURCE ASSESSMENT

PROJECT TIMELINE

Figure 2: Layout of this document and notional project timeline. Red, Blue and Green routes are described in Section 1.6.

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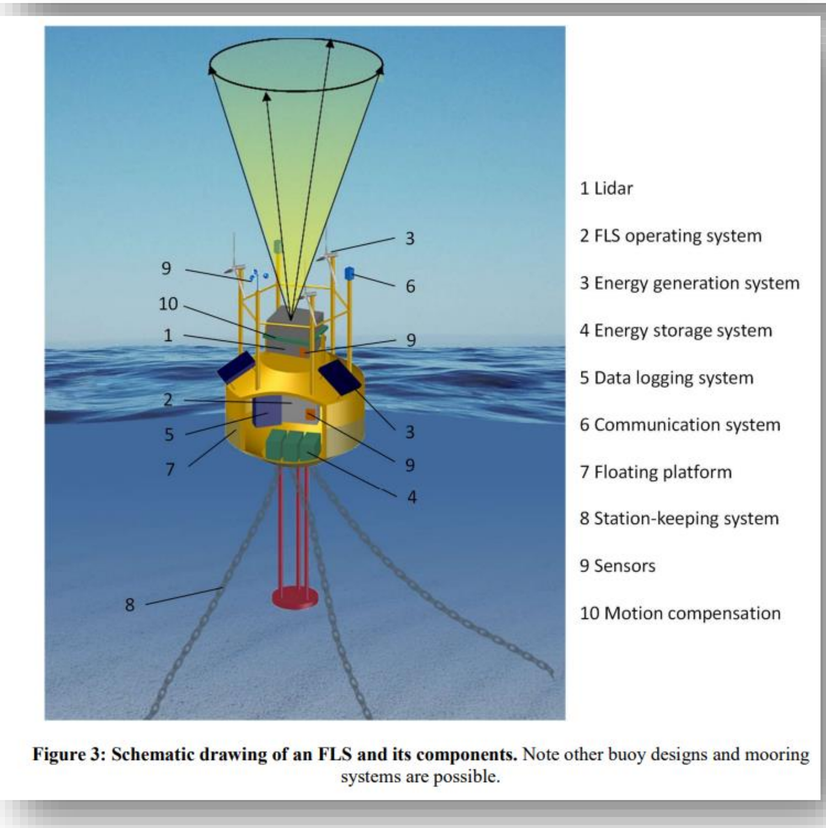

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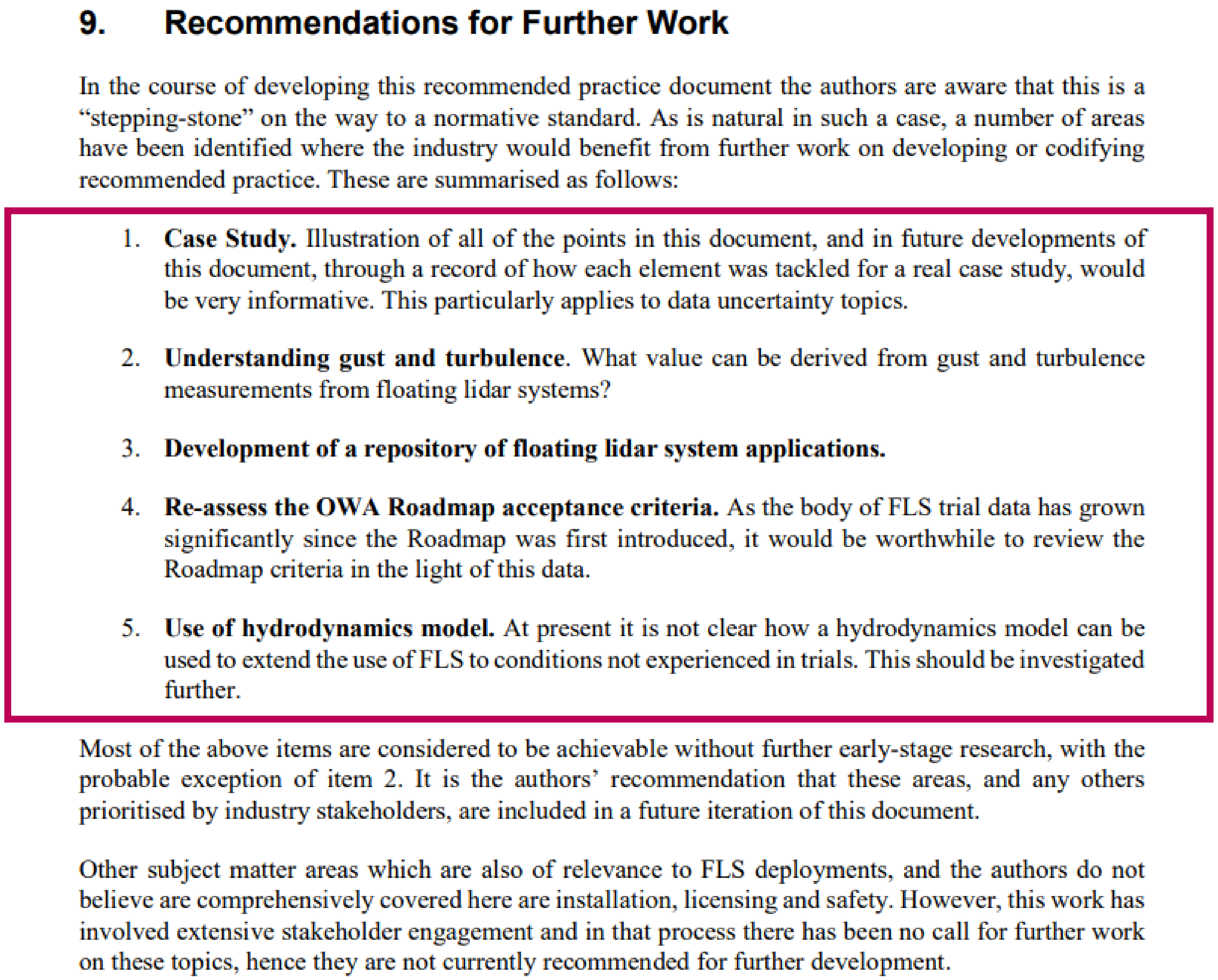
IEA Wind RP 18

What it is not about



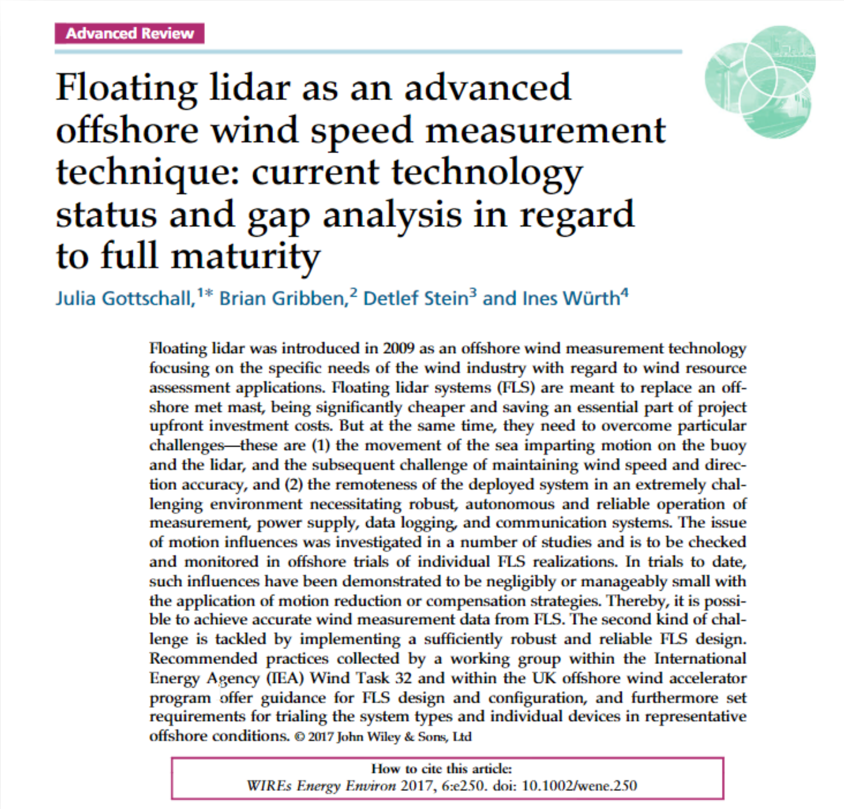
9. Recommendations for Further Work

In the course of developing this recommended practice document the authors are aware that this is a "stepping-stone" on the way to a normative standard. As is natural in such a case, a number of areas have been identified where the industry would benefit from further work on developing or codifying recommended practice. These are summarised as follows:

1. **Case Study.** Illustration of all of the points in this document, and in future developments of this document, through a record of how each element was tackled for a real case study, would be very informative. This particularly applies to data uncertainty topics.
2. **Understanding gust and turbulence**. What value can be derived from gust and turbulence measurements from floating lidar systems?
3. **Development of a repository of floating lidar system applications.**
4. **Re-assess the OWA Roadmap acceptance criteria.** As the body of FLS trial data has grown significantly since the Roadmap was first introduced, it would be worthwhile to review the Roadmap criteria in the light of this data.
5. **Use of hydrodynamics model.** At present it is not clear how a hydrodynamics model can be used to extend the use of FLS to conditions not experienced in trials. This should be investigated further.

Most of the above items are considered to be achievable without further early-stage research, with the probable exception of item 2. It is the authors' recommendation that these areas, and any others prioritised by industry stakeholders, are included in a future iteration of this document.

Other subject matter areas which are also of relevance to FLS deployments, and the authors do not believe are comprehensively covered here are installation, licensing and safety. However, this work has involved extensive stakeholder engagement and in that process there has been no call for further work on these topics, hence they are not currently recommended for further development.



Advanced Review

Floating lidar as an advanced offshore wind speed measurement technique: current technology status and gap analysis in regard to full maturity

Julia Gottschall,[1]* Brian Gribben,[2] Detlef Stein[3] and Ines Würth[4]

Floating lidar was introduced in 2009 as an offshore wind measurement technology focusing on the specific needs of the wind industry with regard to wind resource assessment applications. Floating lidar systems (FLS) are meant to replace an offshore met mast, being significantly cheaper and saving an essential part of project upfront investment costs. But at the same time, they need to overcome particular challenges—these are (1) the movement of the sea imparting motion on the buoy and the lidar, and the subsequent challenge of maintaining wind speed and direction accuracy, and (2) the remoteness of the deployed system in an extremely challenging environment necessitating robust, autonomous and reliable operation of measurement, power supply, data logging, and communication systems. The issue of motion influences was investigated in a number of studies and is to be checked and monitored in offshore trials of individual FLS realizations. In trials to date, such influences have been demonstrated to be negligibly or manageably small with the application of motion reduction or compensation strategies. Thereby, it is possible to achieve accurate wind measurement data from FLS. The second kind of challenge is tackled by implementing a sufficiently robust and reliable FLS design. Recommended practices collected by a working group within the International Energy Agency (IEA) Wind Task 32 and within the UK offshore wind accelerator program offer guidance for FLS design and configuration, and furthermore set requirements for trialing the system types and individual devices in representative offshore conditions.

How to cite this article:
WIREs Energy Environ 2017, 6:e250. doi: 10.1002/wene.250

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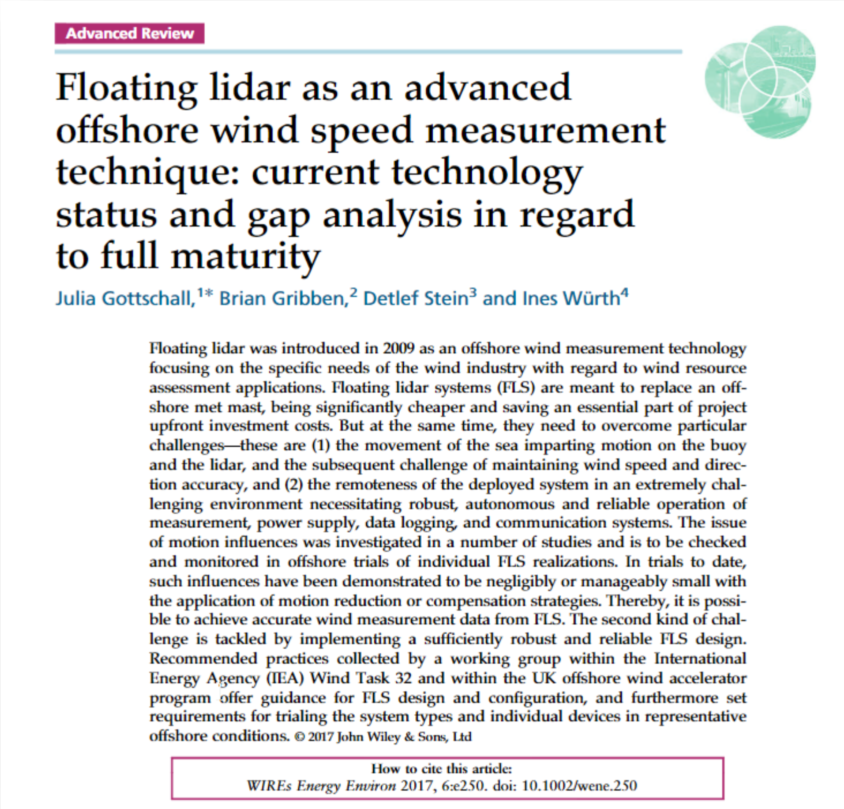

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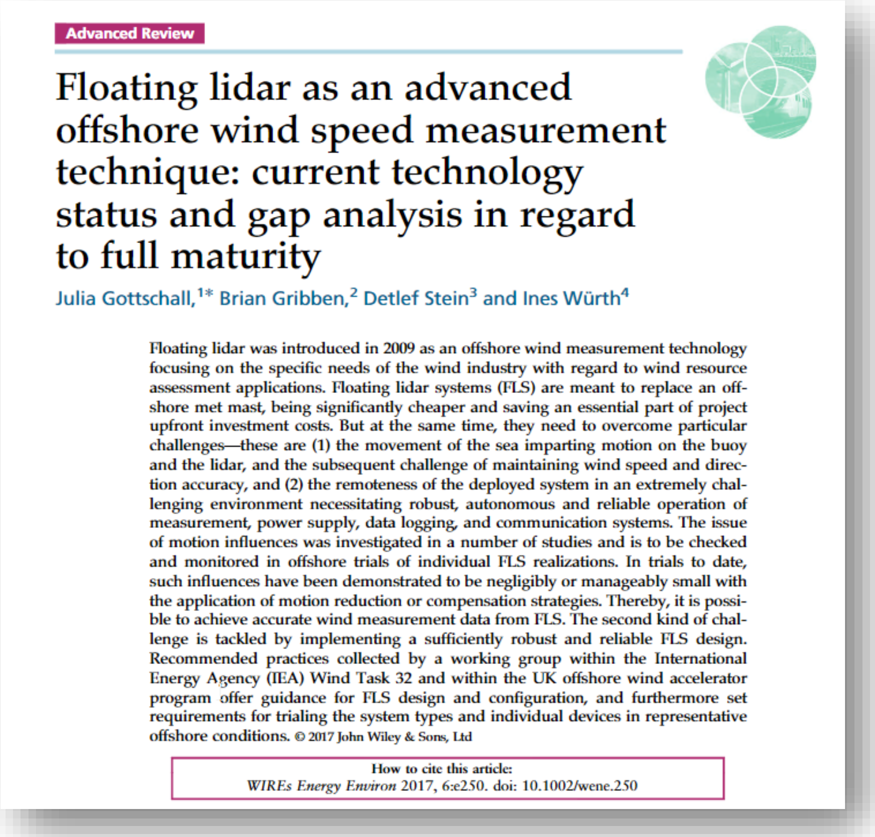
FIGURE 3 | Overview of known floating lidar system realizations—in rows from left to right and top down: (a, b) FLiDAR WindSentinel 6M, 4M, (c) SEAWATCH WindLiDAR Buoy, (d) SeaZephIR, (e) Fraunhofer IWES Wind Lidar Buoy, (f) EOLOS FLS200, (g) FORECAST, (h) DeepCLiDAR, (i) EOLFI BLIDAR, and (j) M^{3}EA project. (© figures by system providers as referred to in Table 1)



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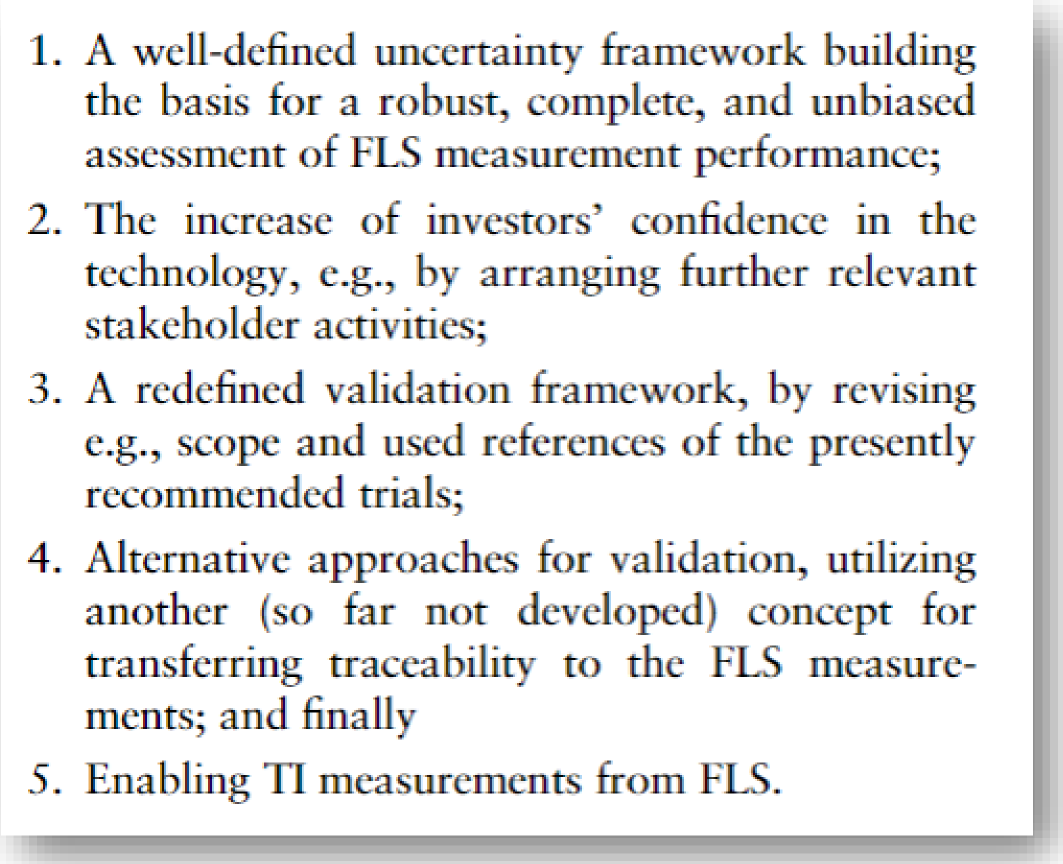
Conclusions from IEA Wind Task 32 Workshop #1 (Blyth, Feb 2016)

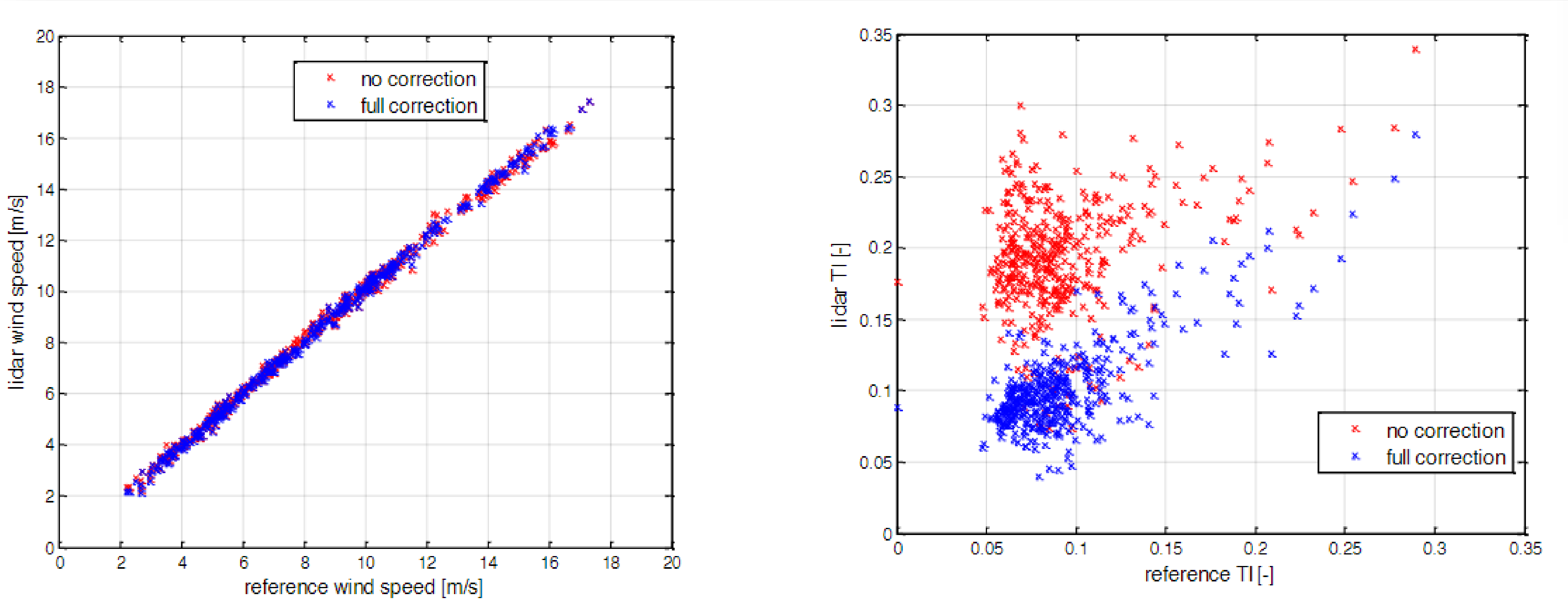
→ Five gaps:



1. A well-defined uncertainty framework building the basis for a robust, complete, and unbiased assessment of FLS measurement performance;
2. The increase of investors' confidence in the technology, e.g., by arranging further relevant stakeholder activities;
3. A redefined validation framework, by revising e.g., scope and used references of the presently recommended trials;
4. Alternative approaches for validation, utilizing another (so far not developed) concept for transferring traceability to the FLS measurements; and finally
5. Enabling TI measurements from FLS.

So, what about FLS Turbulence Intensity (TI) ?

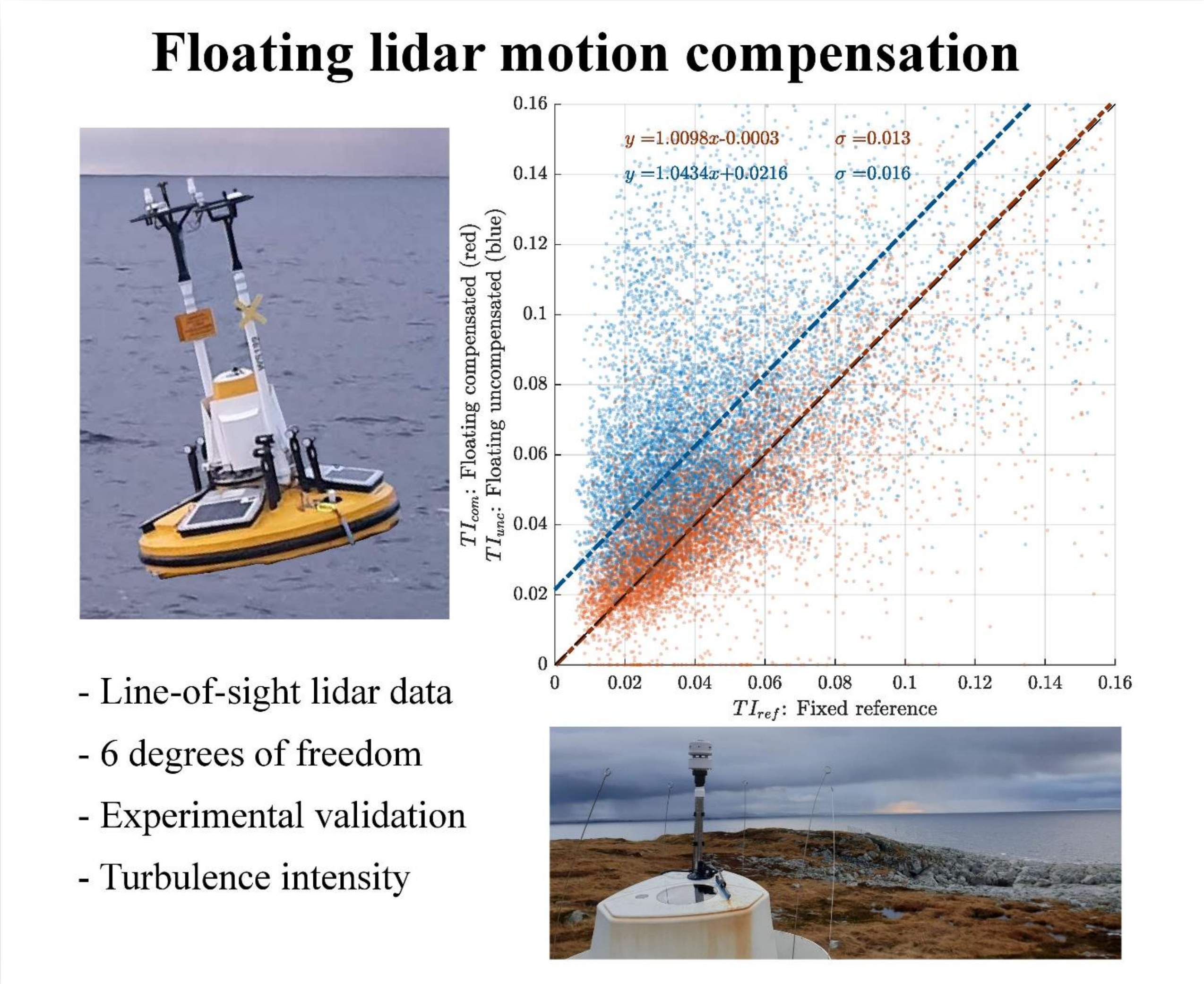
Some literature .. #1



J.G. et al. Energy Procedia 53 (2014) 156 – 161; doi: 10.1016/j.egypro.2014.07.224

So, what about FLS Turbulence Intensity (TI) ?

Some literature .. #2



Floating lidar motion compensation

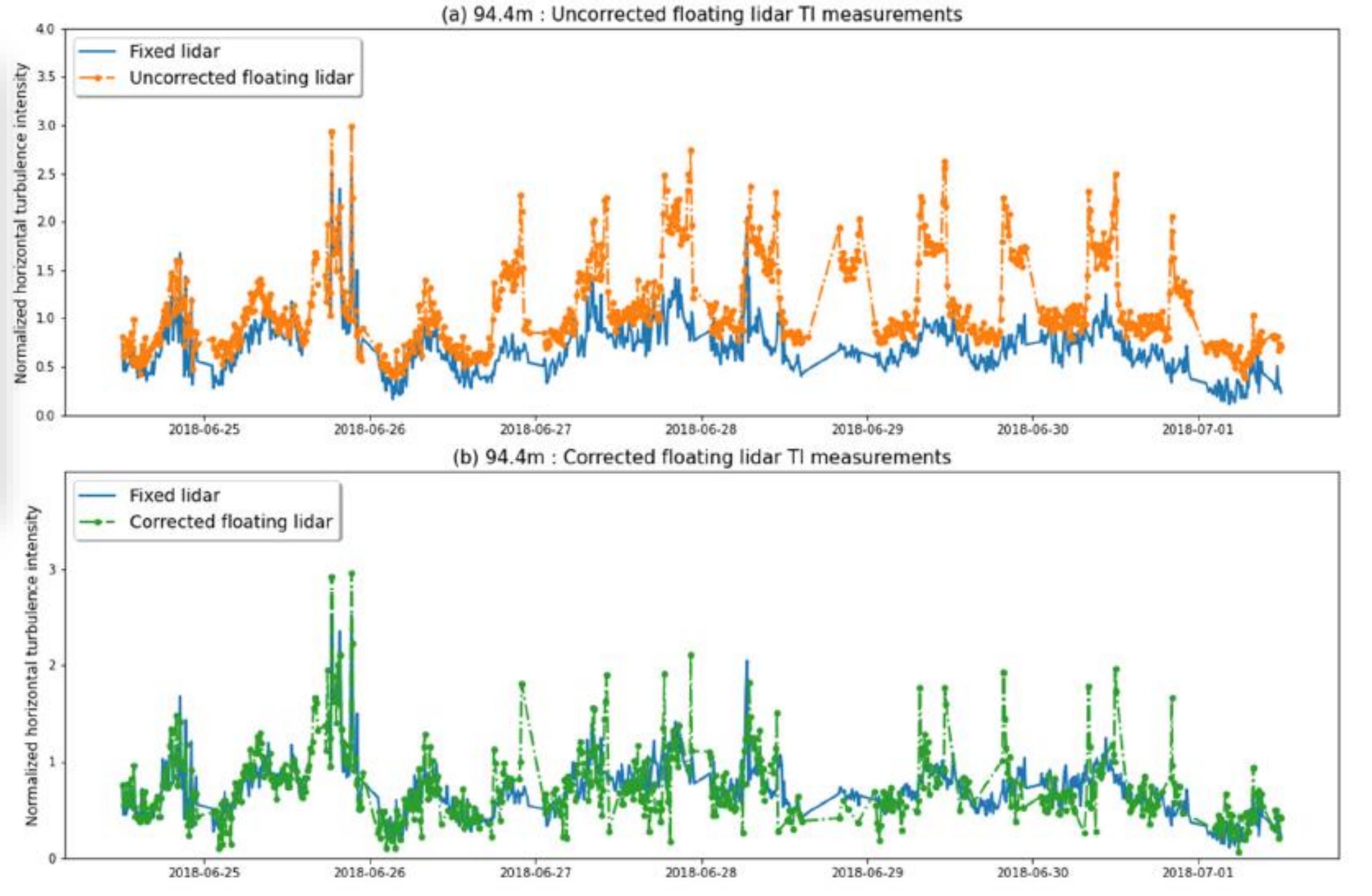
- Line-of-sight lidar data
- 6 degrees of freedom
- Experimental validation
- Turbulence intensity

F. Kelberlau et al. *Remote Sens.* 2020, *12*(5), 898; https://doi.org/10.3390/rs12050898

So, what about FLS Turbulence Intensity (TI) ?

Some literature .. #3

(a) WINDSEA_02 buoy and offshore plateform in Fécamp



T. Désert et al. *Remote Sens.* 2021, 13, 2973. https://doi.org/10.3390/rs13152973

So, what about FLS Turbulence Intensity (TI) ..

Is this solved now?

Not really .. We still don‘t know (sufficiently well) how to verify / calibrate FLS TI, i.e.

→ Which metric

→ Which reference

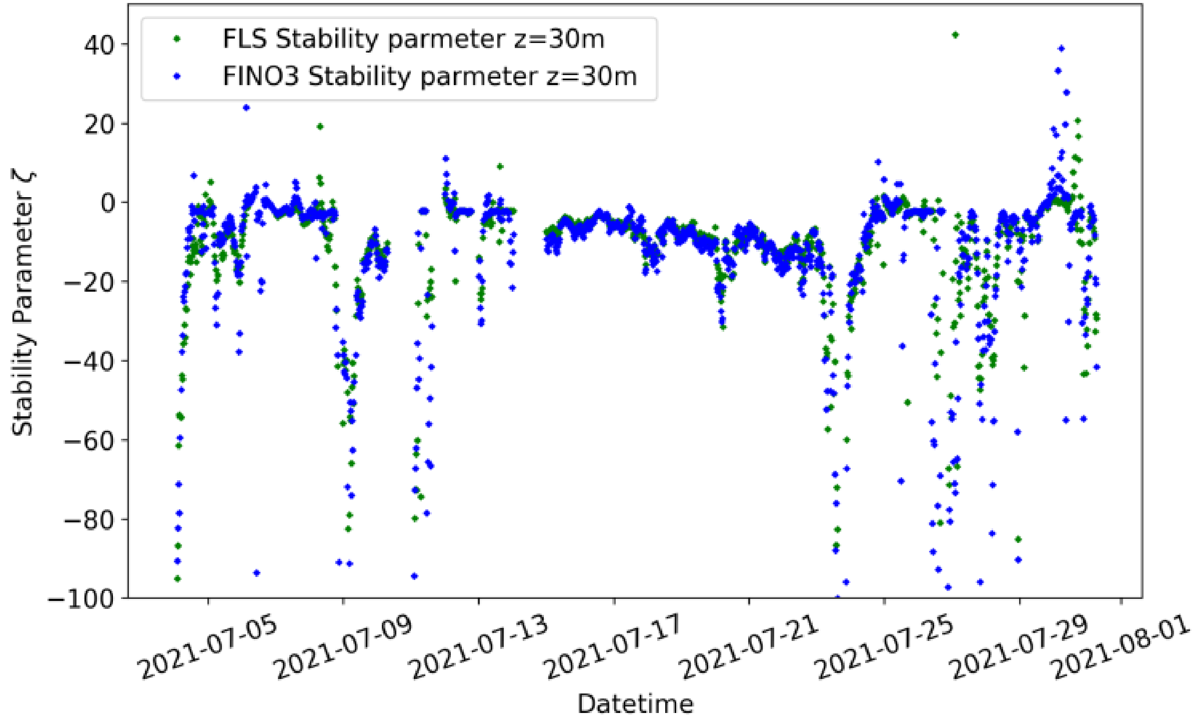
→ Which verification process

→ Which KPIs and respective acceptance criteria

→ → Scope of the Carbon Trust OWA ‘FTI’ Project [Oldbaum, Fraunhofer IWES, France Energies Marines – 2022/23]

Not only focus on TI ..

How about atmospheric stability?



(c) The time series of the calculated stability parameter of the FINO3 at 30-m with the FLS using $z = 30\,\mathrm{m}$ as well as the lidar mean wind speed at a height of 43-m

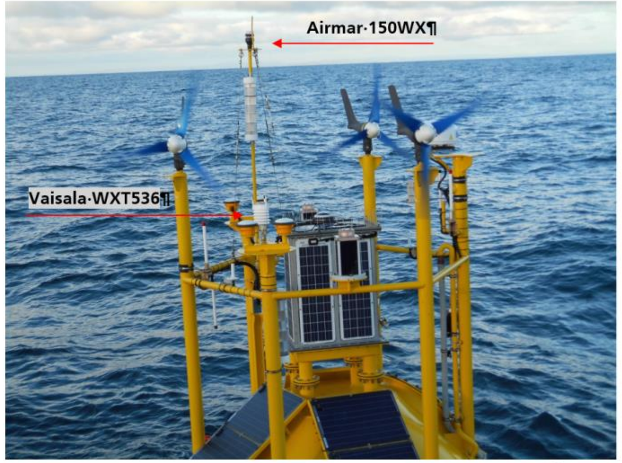
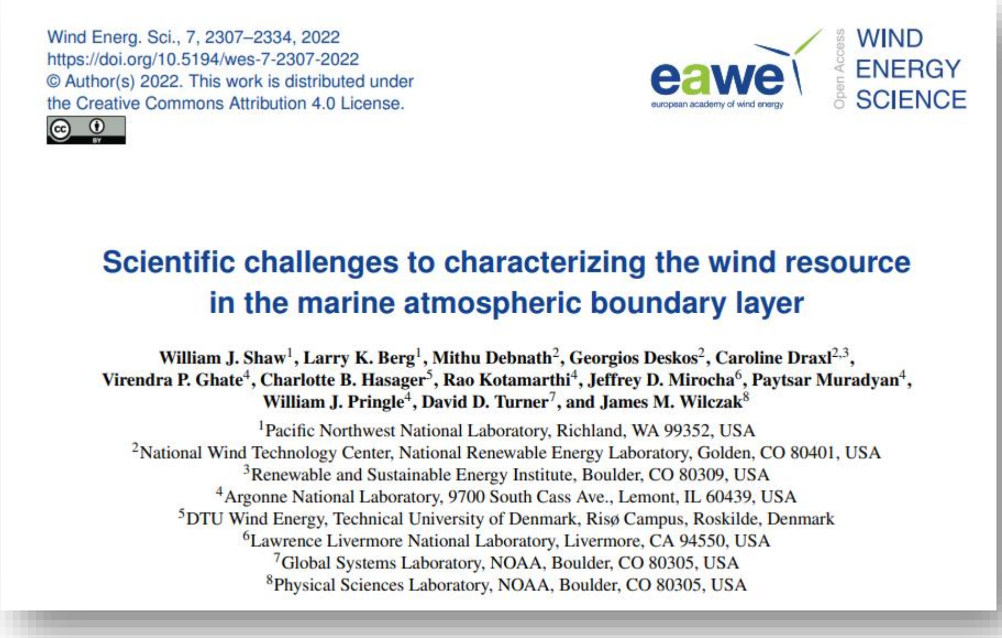


Figure (1) Placement of the atmospheric sensors on the FLS - © Fraunhofer IWES.

Daniel Hatfield et al 2022 J. Phys.: Conf. Ser. 2265 042024; doi:10.1088/1742-6596/2265/4/042024

Further challenges within atmospheric sciences

.. which may be solved by FLS



Wind Energ. Sci., 7, 2307–2334, 2022
https://doi.org/10.5194/wes-7-2307-2022

Scientific challenges to characterizing the wind resource in the marine atmospheric boundary layer

William J. Shaw[1], Larry K. Berg[1], Mithu Debnath[2], Georgios Deskos[2], Caroline Draxl[2,3], Virendra P. Ghate[4], Charlotte B. Hasager[5], Rao Kotamarthi[4], Jeffrey D. Mirocha[6], Paytsar Muradyan[4], William J. Pringle[4], David D. Turner[7], and James M. Wilczak[8]

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[2]National Wind Technology Center, National Renewable Energy Laboratory, Golden, CO 80401, USA
[3]Renewable and Sustainable Energy Institute, Boulder, CO 80309, USA
[4]Argonne National Laboratory, 9700 South Cass Ave., Lemont, IL 60439, USA
[5]DTU Wind Energy, Technical University of Denmark, Risø Campus, Roskilde, Denmark
[6]Lawrence Livermore National Laboratory, Livermore, CA 94550, USA
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Further challenges within atmospheric sciences

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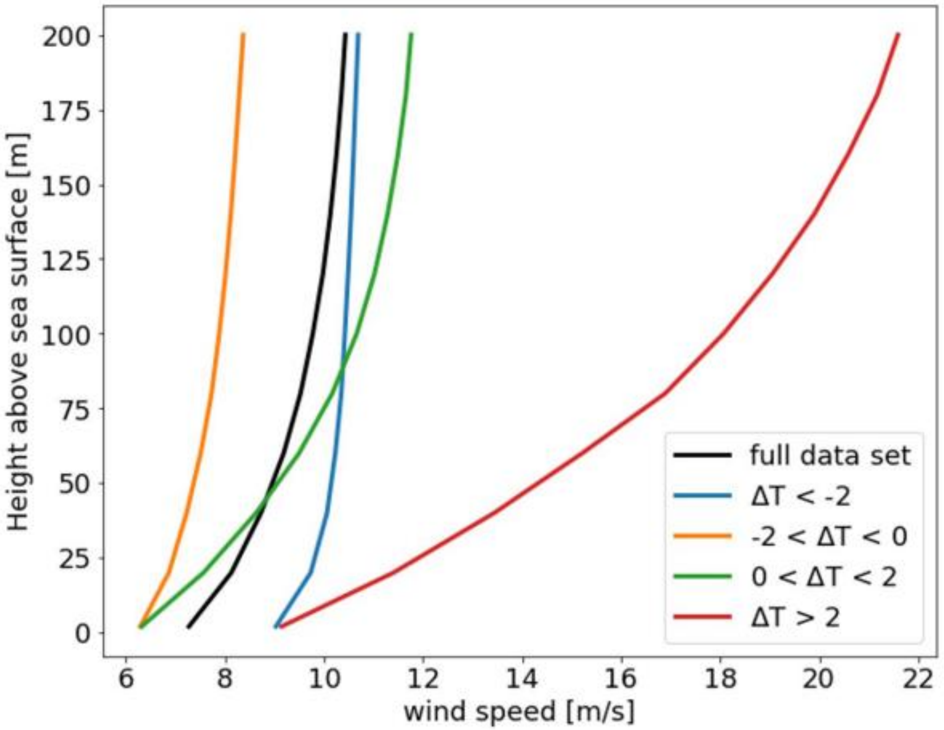
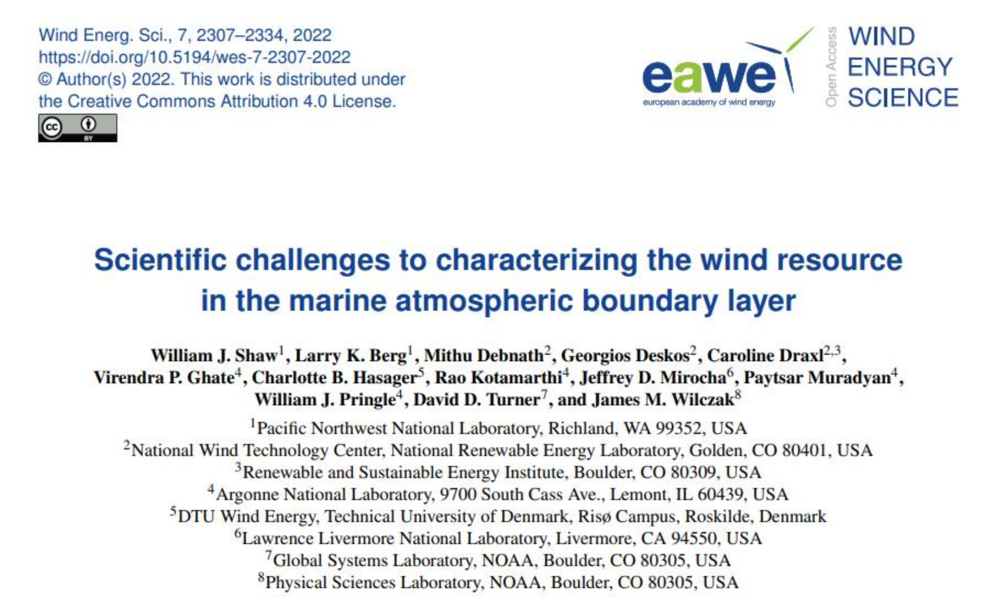


Figure 4. Vertical profiles of mean wind speed calculated from 12 months of buoy-based lidar observations, for four different categories of $\Delta T = T\,2\,\mathrm{m} - \mathrm{SST}$. Temperature differences are in K (DNV-GL, 2020).



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WIND
ENERGY
SCIENCE

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Further challenges within atmospheric sciences

.. which may be solved by FLS

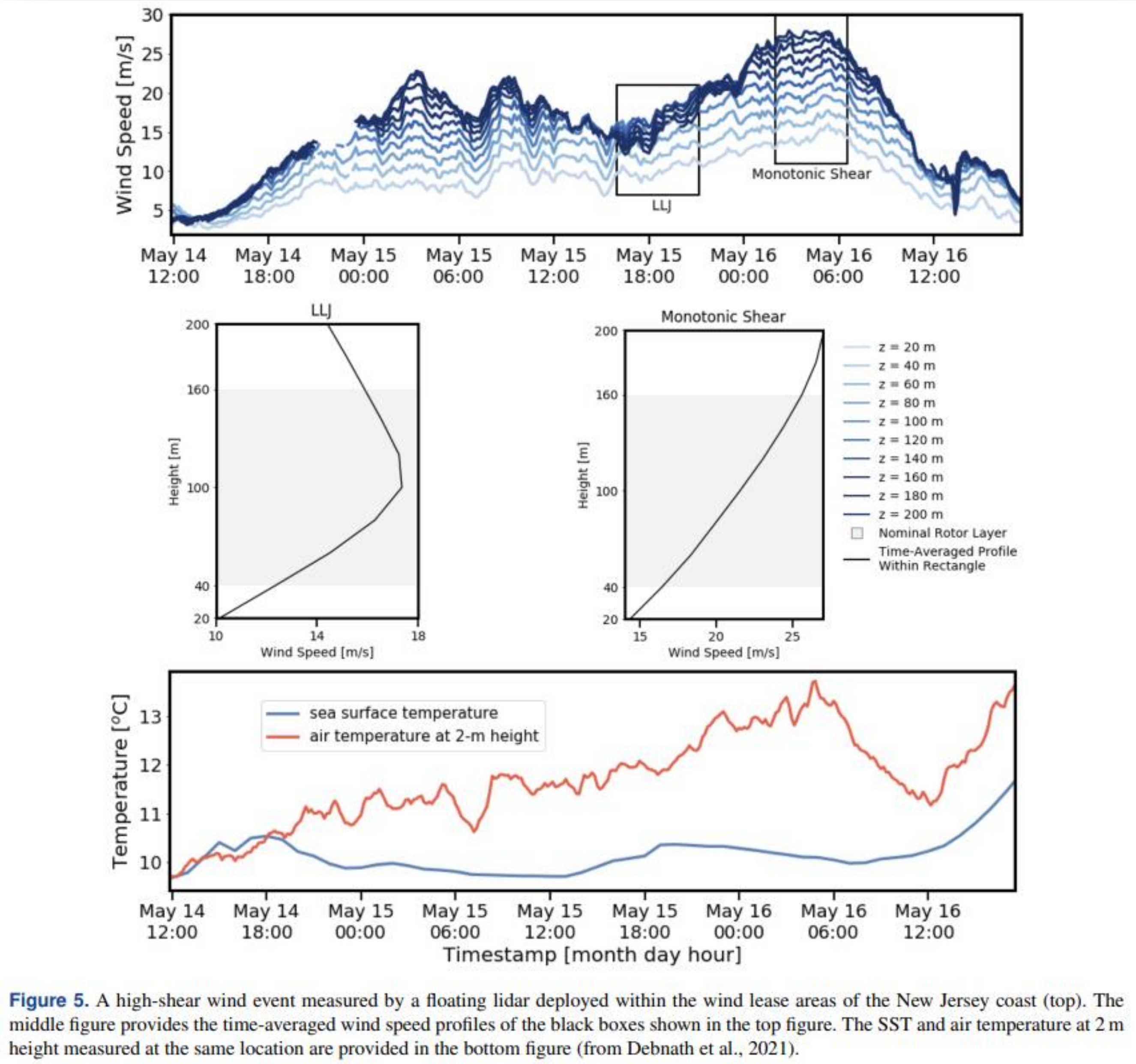
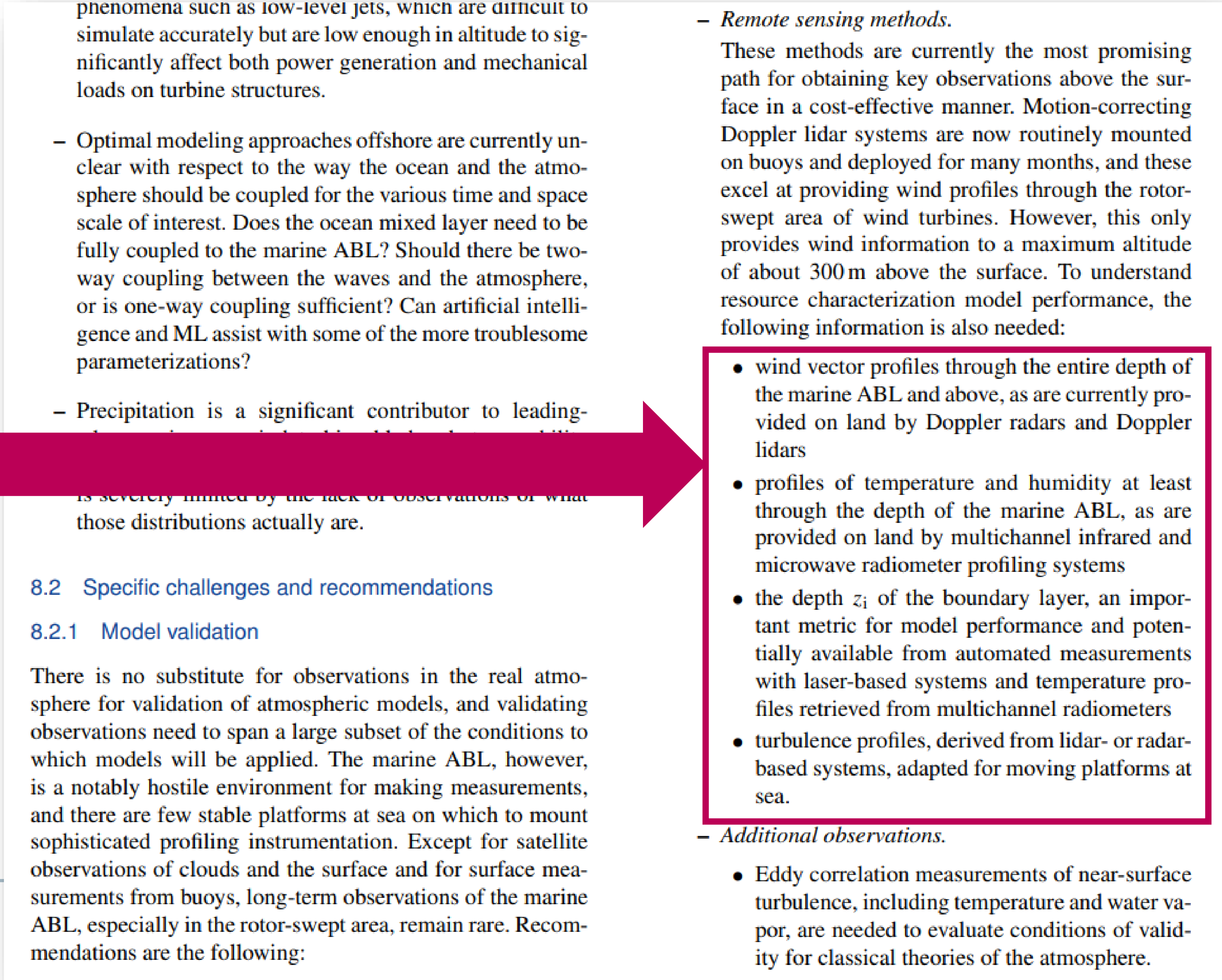


Figure 5. A high-shear wind event measured by a floating lidar deployed within the wind lease areas of the New Jersey coast (top). The middle figure provides the time-averaged wind speed profiles of the black boxes shown in the top figure. The SST and air temperature at 2 m height measured at the same location are provided in the bottom figure (from Debnath et al., 2021).

Further challenges within atmospheric sciences

.. which may be solved by FLS



phenomena such as low-level jets, which are difficult to simulate accurately but are low enough in altitude to significantly affect both power generation and mechanical loads on turbine structures.

- Optimal modeling approaches offshore are currently unclear with respect to the way the ocean and the atmosphere should be coupled for the various time and space scale of interest. Does the ocean mixed layer need to be fully coupled to the marine ABL? Should there be two-way coupling between the waves and the atmosphere, or is one-way coupling sufficient? Can artificial intelligence and ML assist with some of the more troublesome parameterizations?
- Precipitation is a significant contributor to leading- [illegible] is severely limited by the lack of observations of what those distributions actually are.

8.2 Specific challenges and recommendations

8.2.1 Model validation

There is no substitute for observations in the real atmosphere for validation of atmospheric models, and validating observations need to span a large subset of the conditions to which models will be applied. The marine ABL, however, is a notably hostile environment for making measurements, and there are few stable platforms at sea on which to mount sophisticated profiling instrumentation. Except for satellite observations of clouds and the surface and for surface measurements from buoys, long-term observations of the marine ABL, especially in the rotor-swept area, remain rare. Recommendations are the following:

- *Remote sensing methods.*

  These methods are currently the most promising path for obtaining key observations above the surface in a cost-effective manner. Motion-correcting Doppler lidar systems are now routinely mounted on buoys and deployed for many months, and these excel at providing wind profiles through the rotor-swept area of wind turbines. However, this only provides wind information to a maximum altitude of about 300 m above the surface. To understand resource characterization model performance, the following information is also needed:

  - wind vector profiles through the entire depth of the marine ABL and above, as are currently provided on land by Doppler radars and Doppler lidars
  - profiles of temperature and humidity at least through the depth of the marine ABL, as are provided on land by multichannel infrared and microwave radiometer profiling systems
  - the depth z_i of the boundary layer, an important metric for model performance and potentially available from automated measurements with laser-based systems and temperature profiles retrieved from multichannel radiometers
  - turbulence profiles, derived from lidar- or radar-based systems, adapted for moving platforms at sea.

- *Additional observations.*

  - Eddy correlation measurements of near-surface turbulence, including temperature and water vapor, are needed to evaluate conditions of validity for classical theories of the atmosphere.

So, what do we/you want to do in Task 52 on the topic of floating lidar?