

Experimental Evaluation of Wind Field Reconstruction Techniques Using a Novel Buoy-Based Scanning Lidar

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- **Demonstration of a modular, mobile test platform for controlled FLS validation.**
- **Validation of a buoy-optimized scanning lidar system with configurable scan geometries.**
- **Buoy-based scanning lidar is a promising solution for offshore wind measurements.**

Abstract

Accurate reconstruction of wind fields is a prerequisite for offshore wind energy development, where floating lidar systems (FLS) are increasingly considered as cost-effective alternatives to conventional meteorological masts. While floating platforms offer flexibility and reduced deployment costs, motion-induced effects present significant challenges for the reliability of wind measurements. This study reports on an experimental investigation of wind field reconstruction methods for a novel buoy-based scanning lidar concept.

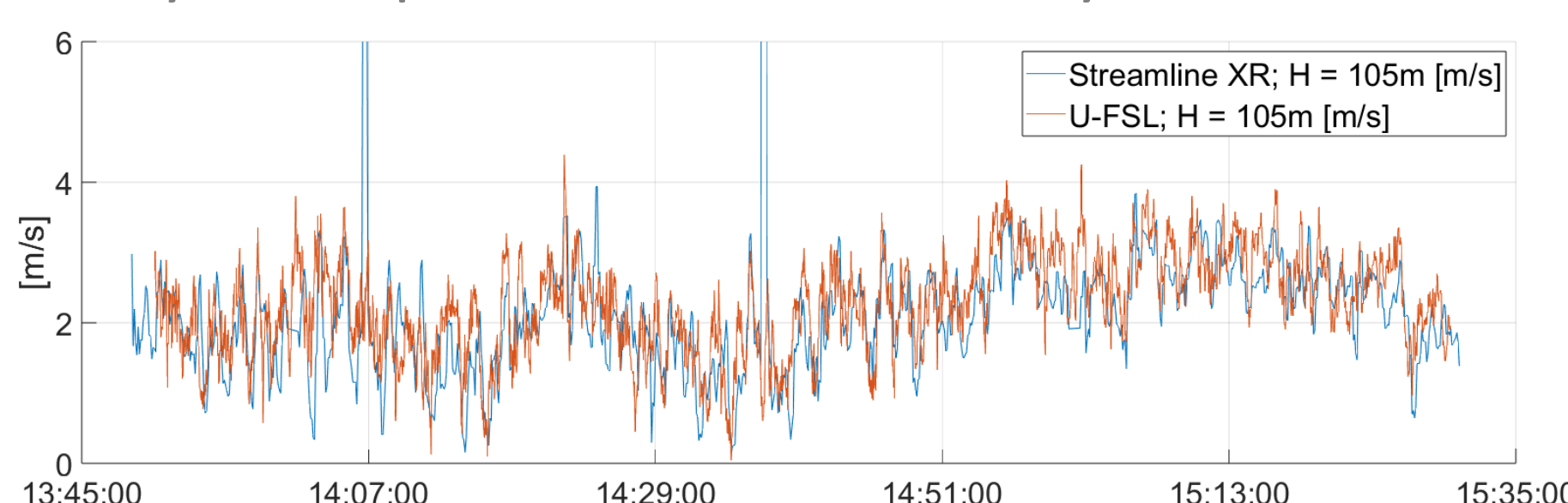
Experimental setup

- **6-DOF motion platform**
 - Test stand for floating lidar systems (pitch, roll, heave) providing the possibility to simulate sea states from calm to rough sea within system limits (synthetic or measured time series).
 - Modular and mobile design for deployment outside laboratory buildings.
- **USTUTT Floating Scanning Lidar (U-FSL)**
 - U-FSL mounted on motion platform. Developed specifically for buoy deployment with integrated IMU/GNSS and designed for long-term autonomous offshore operation.
 - Freely configurable scanning patterns
 - See also: [PO411: The USTUTT-FSL: Development and Validation of an Offshore-Ready Scanning LiDAR for Marine Atmospheric Wind Field Measurements](#)
- **Additional static Streamline XR lidar**



Experimental procedure

- The experimental campaign was conducted onshore with two scanning lidar systems: the U-FSL mounted on a motion platform to emulate buoy dynamics and the other a Streamline XR lidar installed in a fixed position to serve as a reference.
- Before each new experiment,
 - timestamp verification is performed to ensure correct time synchronization.
 - the measurement trajectory is verified to confirm proper scanning geometry.
 - directional alignment is checked to ensure accurate orientation.
 - overall system functionality is verified via e.g. time series comparison (U-FSL in VAD scanning mode in fixed position) to confirm proper system operation of both lidar systems.



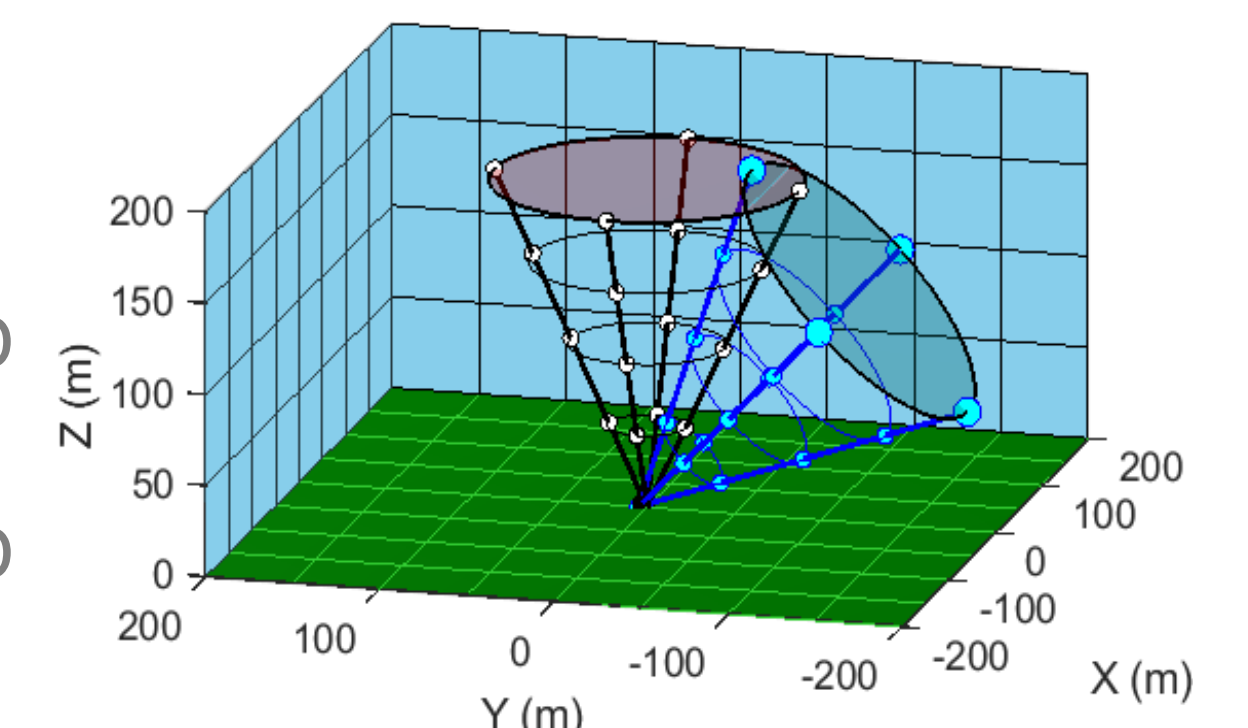
- Wind speed estimates for horizontal wind speed from the moving U-FSL are then systematically compared against the stationary reference to quantify deviations introduced by motion.

Measurement trajectories

To systematically compare velocity–azimuth display (VAD) methods with different scanning strategies under motion conditions, three dedicated experiments have been designed and implemented.

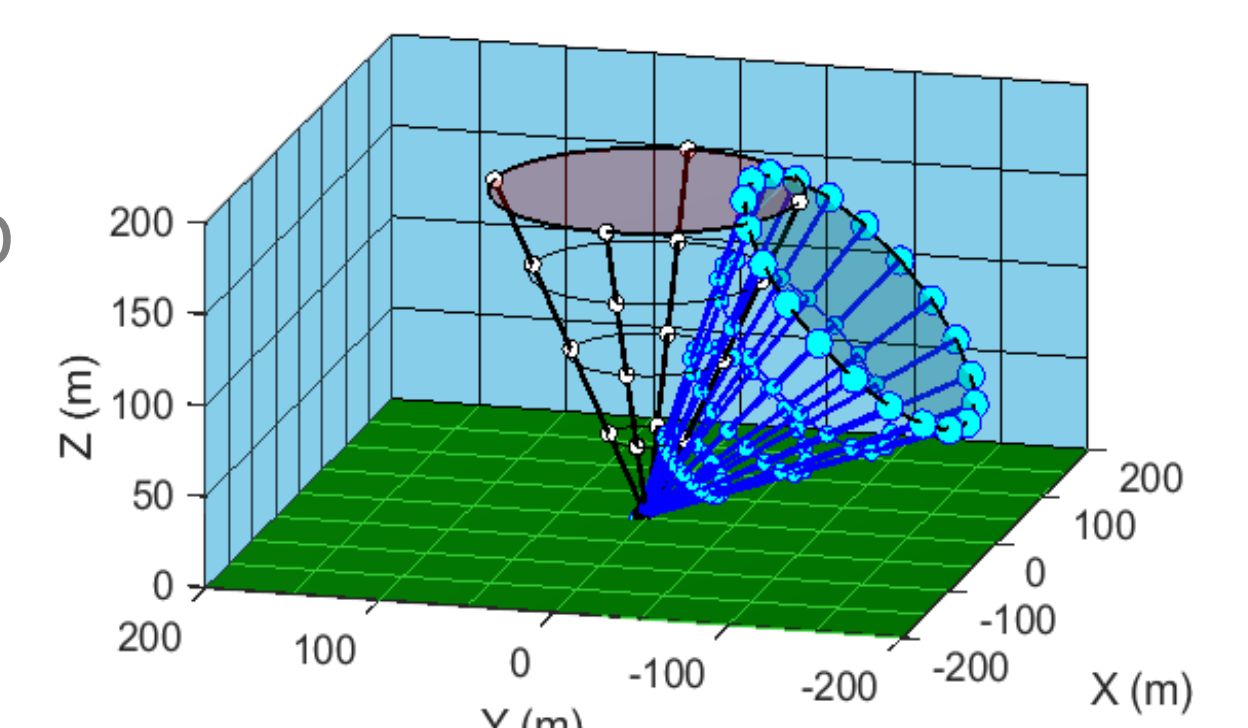
Experiment 1

- Fixed Device with 4-point VAD
- Tilted Scanner with 4-point VAD



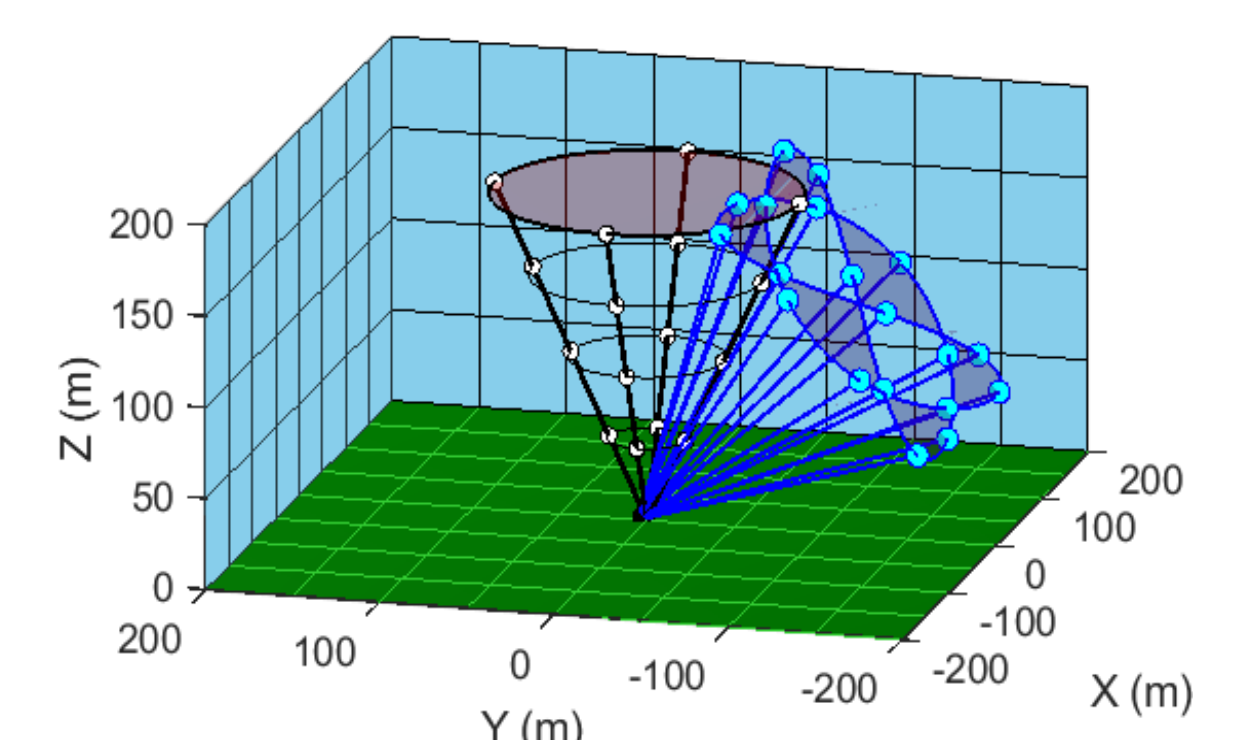
Experiment 2

- Fixed Device with 4-point VAD
- Tilted Scanner with 20-point circle



Experiment 3

- Fixed Device with 4-point VAD
- Tilted Scanner with Lissajous scanning figure



Results

- The experimental setup has been successfully established and validated, providing a controlled basis for FLS motion-impact studies.
- The system is now ready for a range of experiments to evaluate reconstruction techniques under varying motion conditions.
- This framework enables systematic investigation of scanning lidar integration on floating platforms.

Conclusions & Outlook

- This experimental test platform can be valuable in regions without offshore met masts supporting uncertainty assessment of motion affected lidar systems.
- The U-FSL enables the investigation of motion-adapted scanning trajectories, allowing the evaluation specific scanning algorithms.
- The U-FSL also provides the potential to maintain a stationary VAD configuration despite buoy motion.

Acknowledgment

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