



Webinar - Optimising design of offshore wind turbines by characterising turbulence

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Measurement and modelling of offshore turbulence (POWSEIDOM & DRACCAR-NEMO JIP)



Vaisala key figures

Customers in over

150

countries

540

MEUR

in net sales

2,300+

experts



59

nationalities

300+

product families

1,400+

shipments weekly

4.1/5

Employee
engagement index

28%

of our people work
in R&D

The widest, most flexible suite of lidars in the industry

INSTRUMENTS



WindCube®



WindCube®
Offshore



WindCube®
Scan



WindCube®
Nacelle

- Ground-based vertical profiling lidar for bankable Energy Yield Assessment
- IEC-grade Power Performance Testing (PPT)

- WindCube for harsh offshore conditions
- Used as fixed installation nearshore or mounted on several validated Floating Lidar Systems (buoys)

- Long-range, 3D scanning lidar for offshore WRA (single or dual lidar)
- R&D studies onshore and offshore

- Nacelle-mounted lidar for IEC-grade PPT, onshore and offshore
- Turbine Control version for load reduction and production optimization.

SOFTWARE



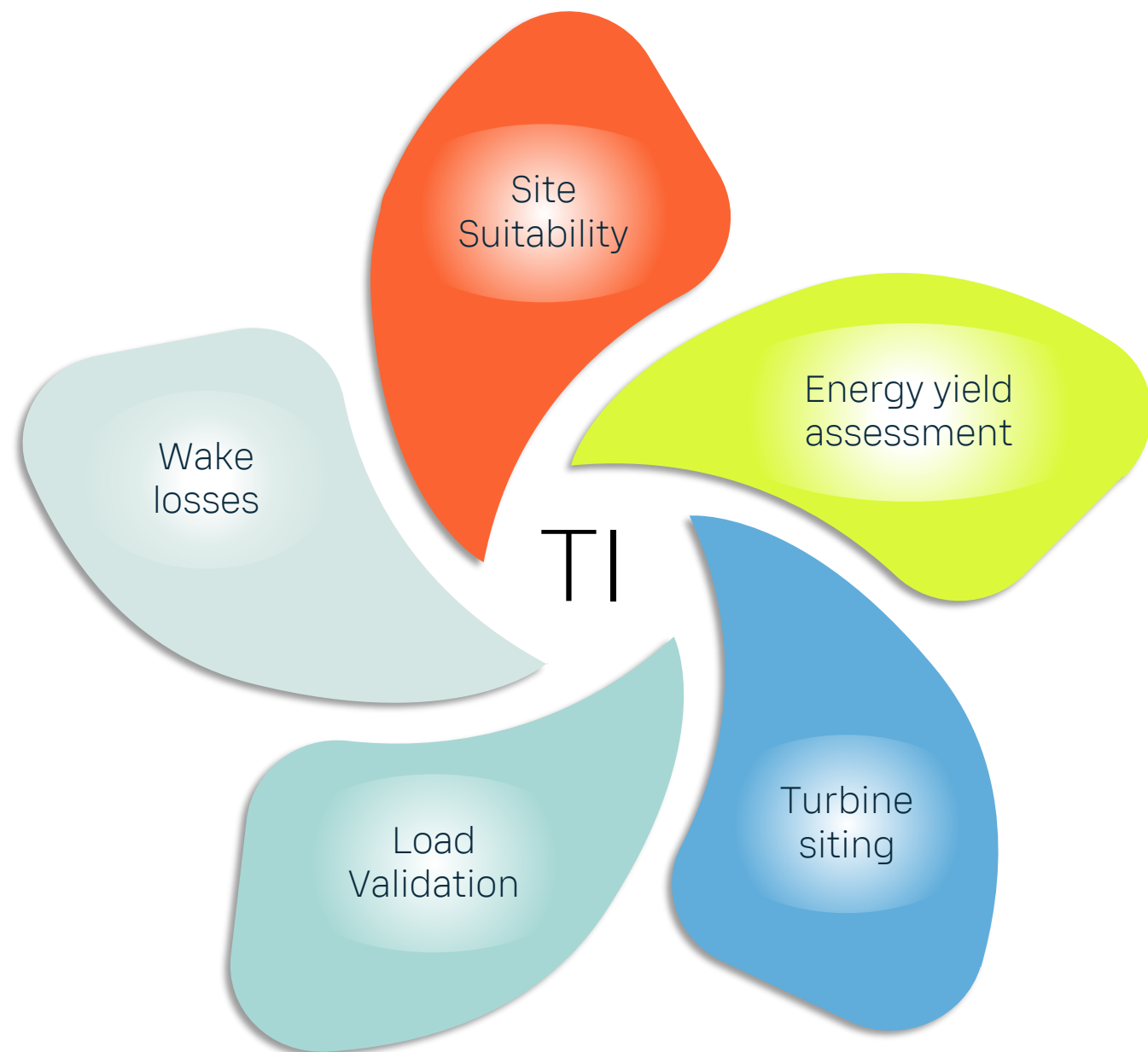
WindCube®
Insights

- Fleet: web-based platform for single unit and fleet management
- Analytics: simple and transparent, IEC-based PPT calculation



Compass

- Web-based platform for single unit and fleet management for wind/solar campaigns
- Weather intelligence and historical data for campaign optimization
- Only available for WindCube and AWS



CHALLENGES

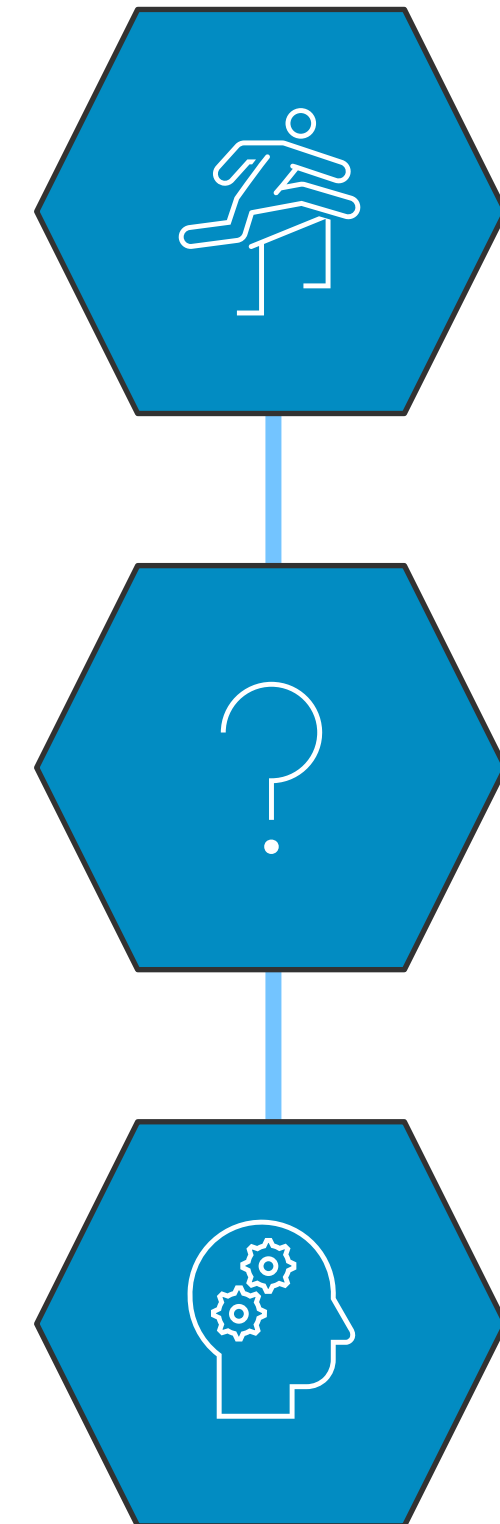
LiDARs underestimate or overestimate the turbulence intensity

WHY?

Inter-beam contamination
Intra-beam averaging
Terrain conditions
Sampling rate

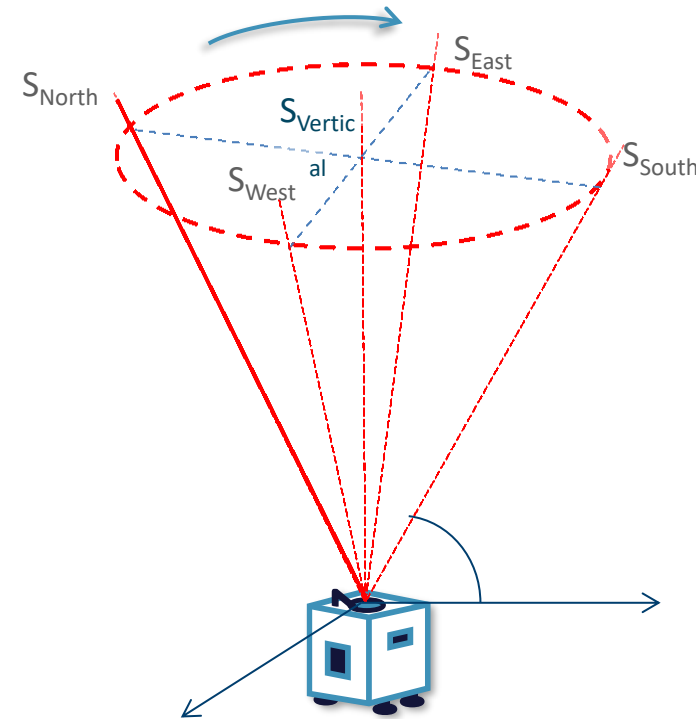
OBJECTIVES

Demonstrate accuracy of new strategies to improve turbulence intensity accuracy



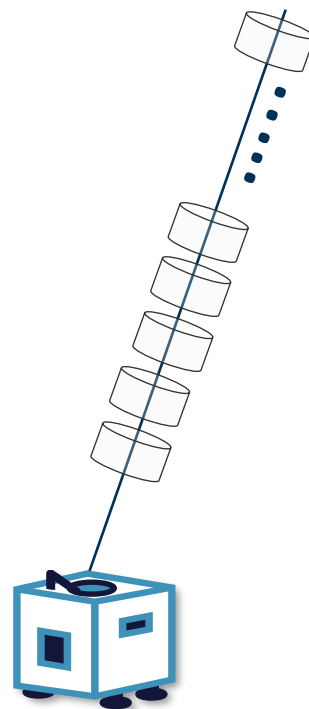
How WindCube works?

Measurement frequency



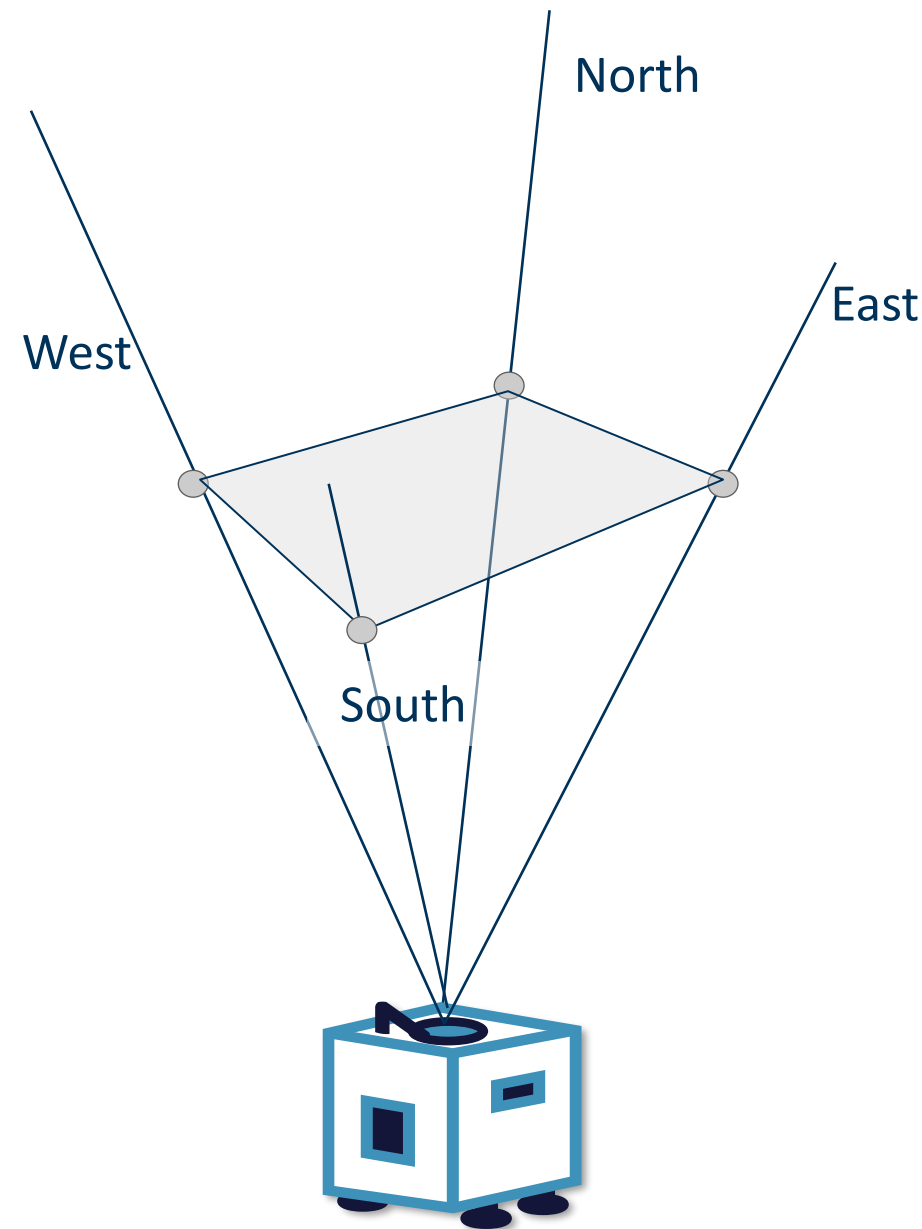
- 1Hz wind field reconstruction
- 5 LoS are measured $S_{\text{North}}, S_{\text{East}}, S_{\text{West}}, S_{\text{South}}, S_{\text{Vertical}}$

Measurement volume



- WindCube is a pulsed LiDAR.
- The volume of measurement remains constant regardless of the height.
- Spatial accuracy remains the same for all heights.

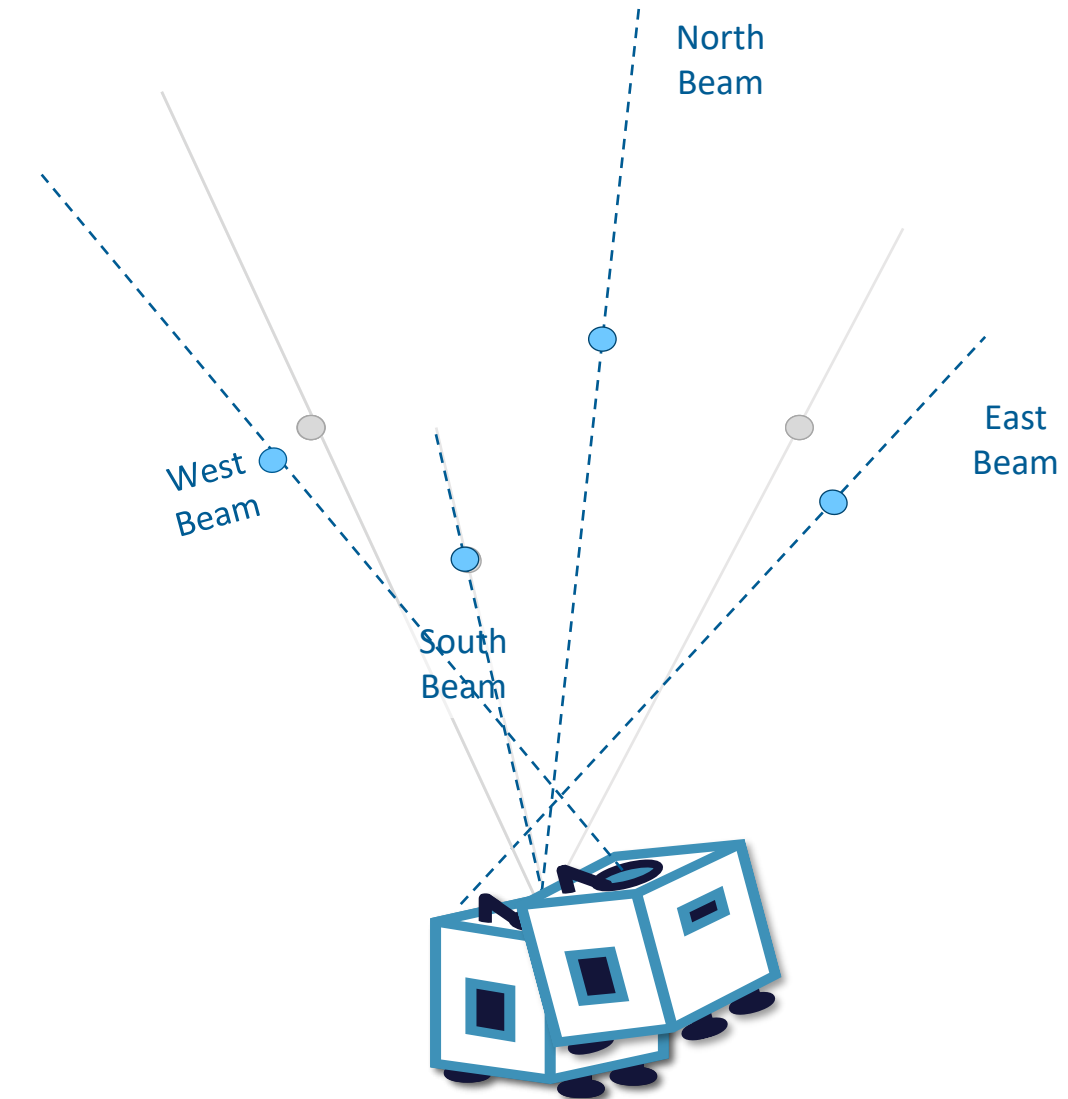
Source of error in the turbulence intensity #1: Inter Beam Averaging



WindCube in
fixed position

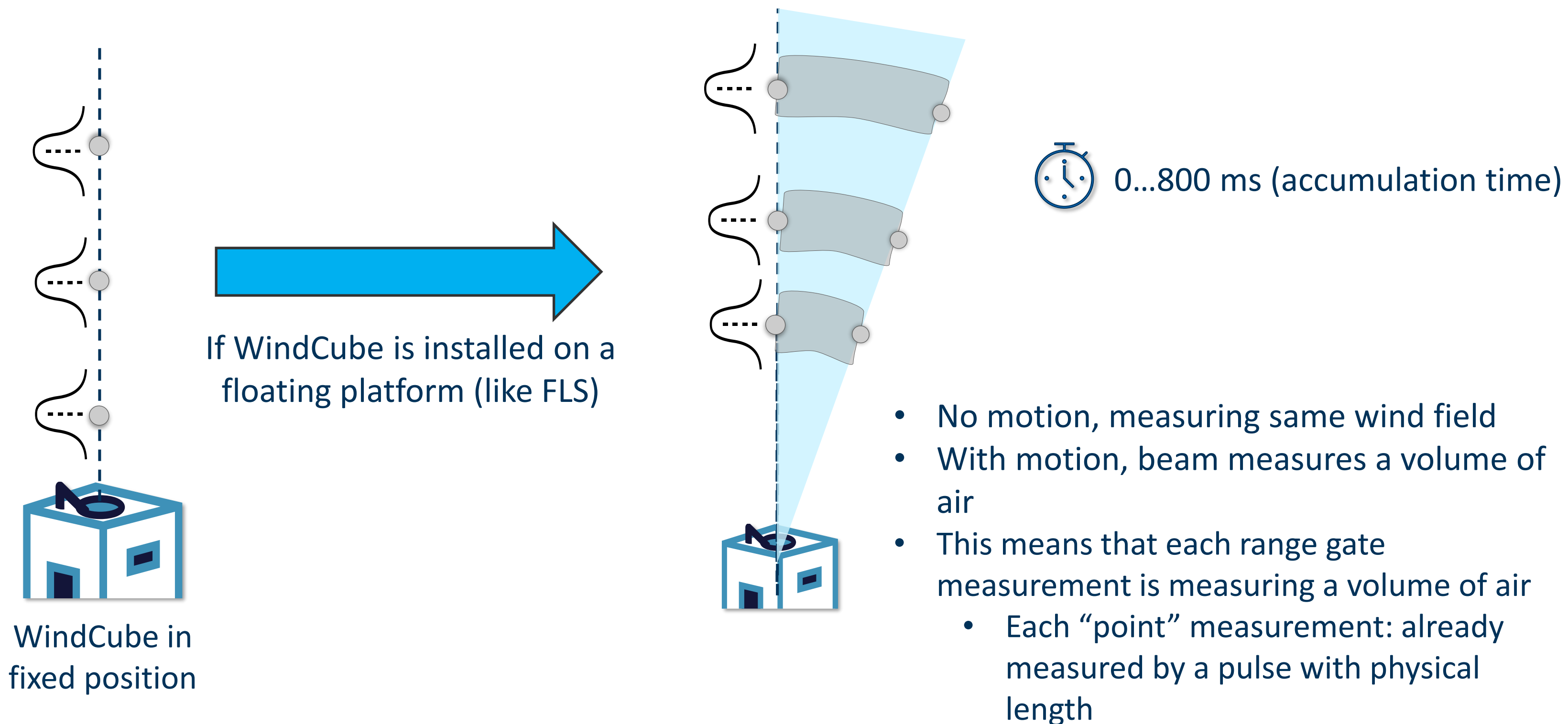


If WindCube is installed on a
floating platform (like FLS)



- Motion of the WindCube on the FLS causes a change in the measurement height.
- High impact on the measurement in motion frequency of FLS is high.

Source of error in the turbulence intensity #2: Intra Beam Filtering

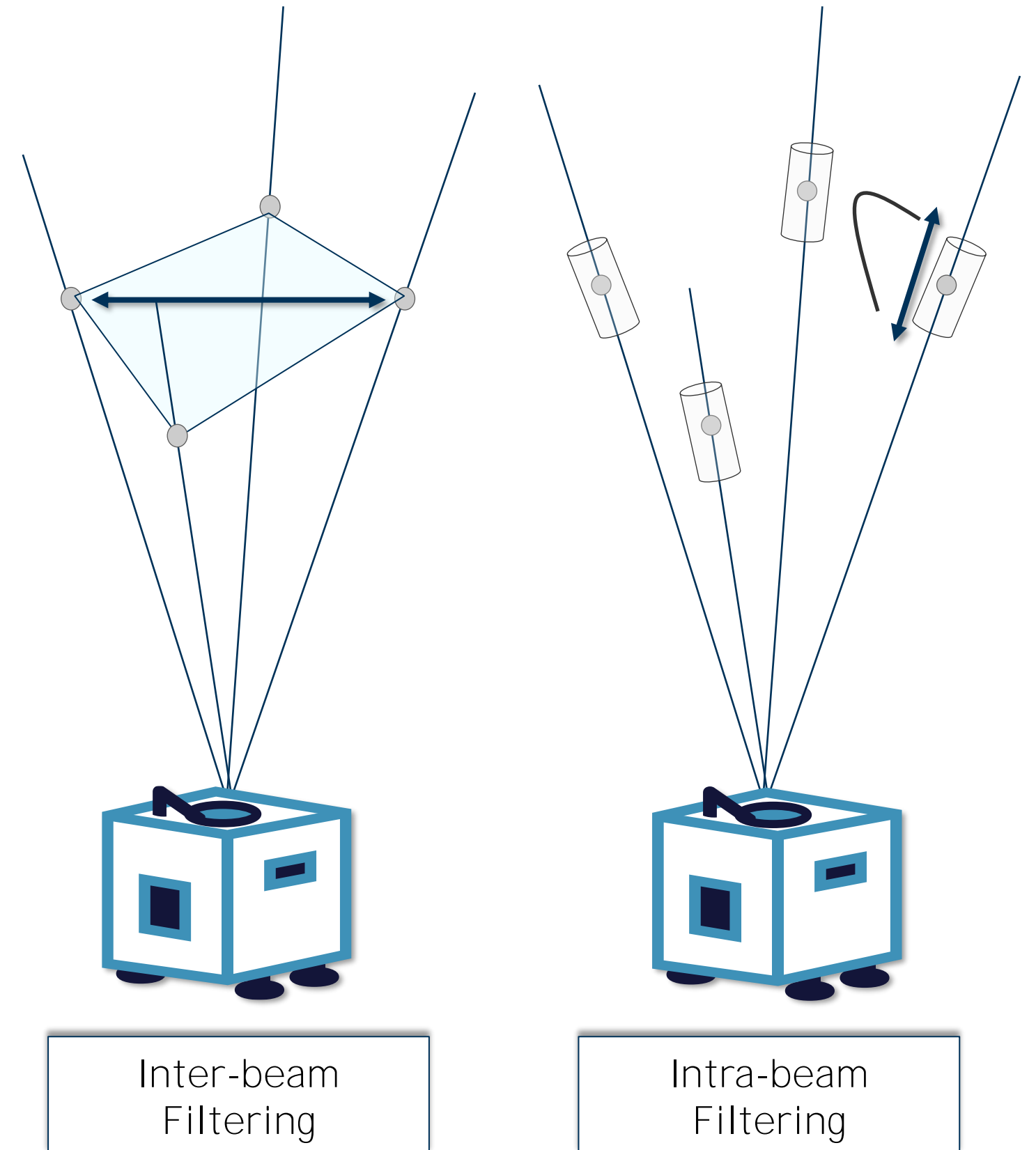


Solution for inter-beam: increase sampling rate

- The wind reconstruction (without motion compensation) is less accurate if LoS are not well aligned due to motion of the buoy.
- Increasing sampling rate reduces this effect:
Standard configuration for WindCube: 1 LOS every 0.8s
Proposed configuration for WindCube: 1 LOS every 0.2s

Solution for intra-beam: reduce length of pulses

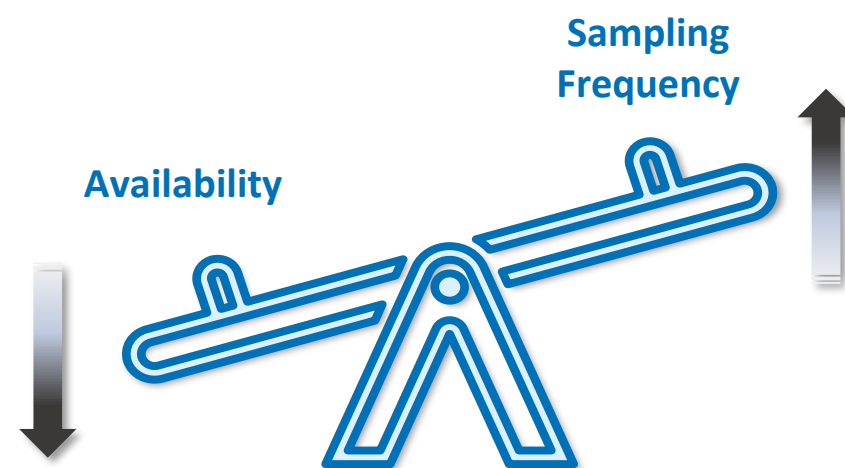
- Propose method was to reduce probe length by 30%.
- Tested and show low improvement on the measurements.



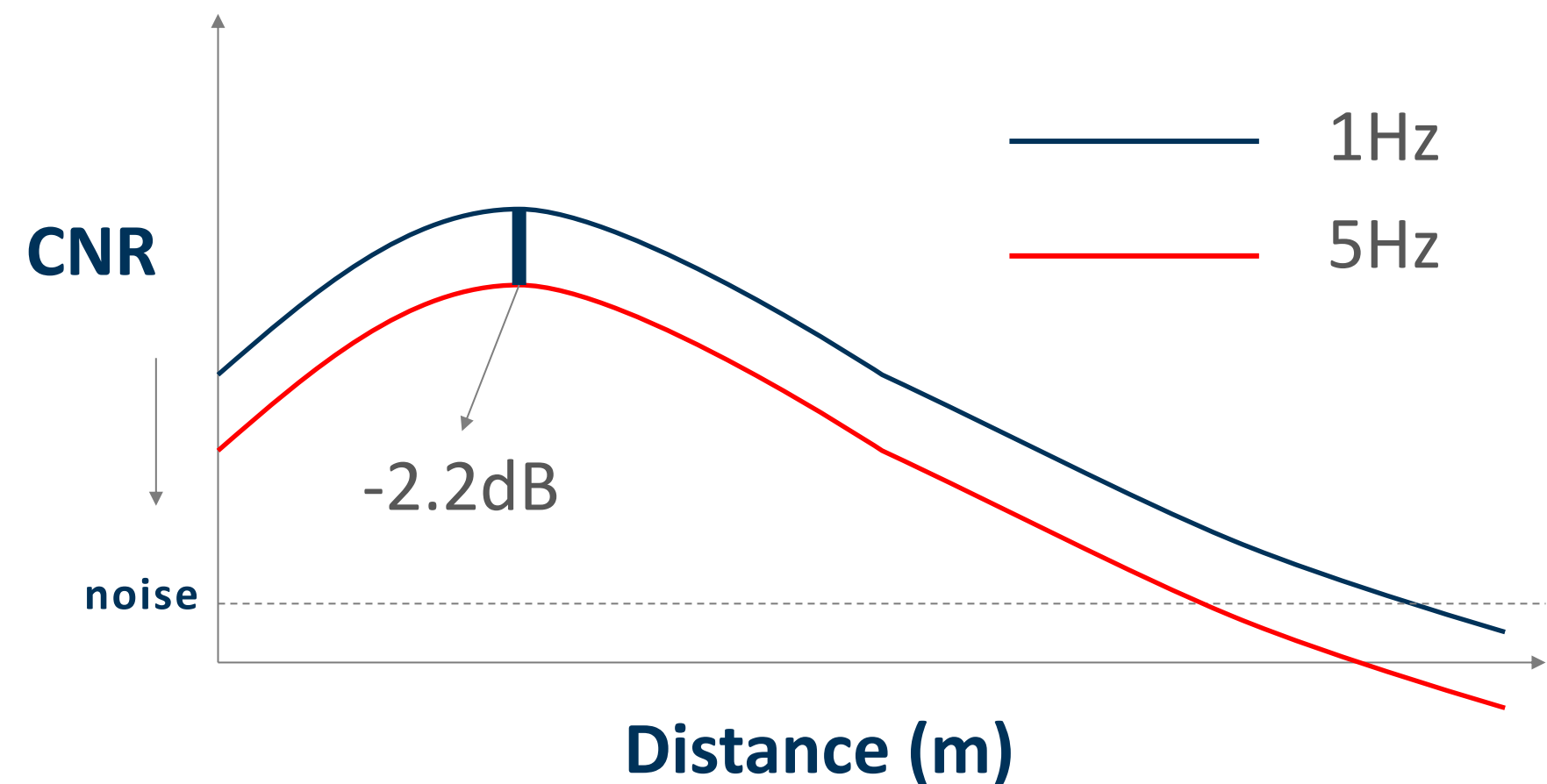
Increasing sampling rate doesn't come for free....there's no free lunch

Data availability depends on:

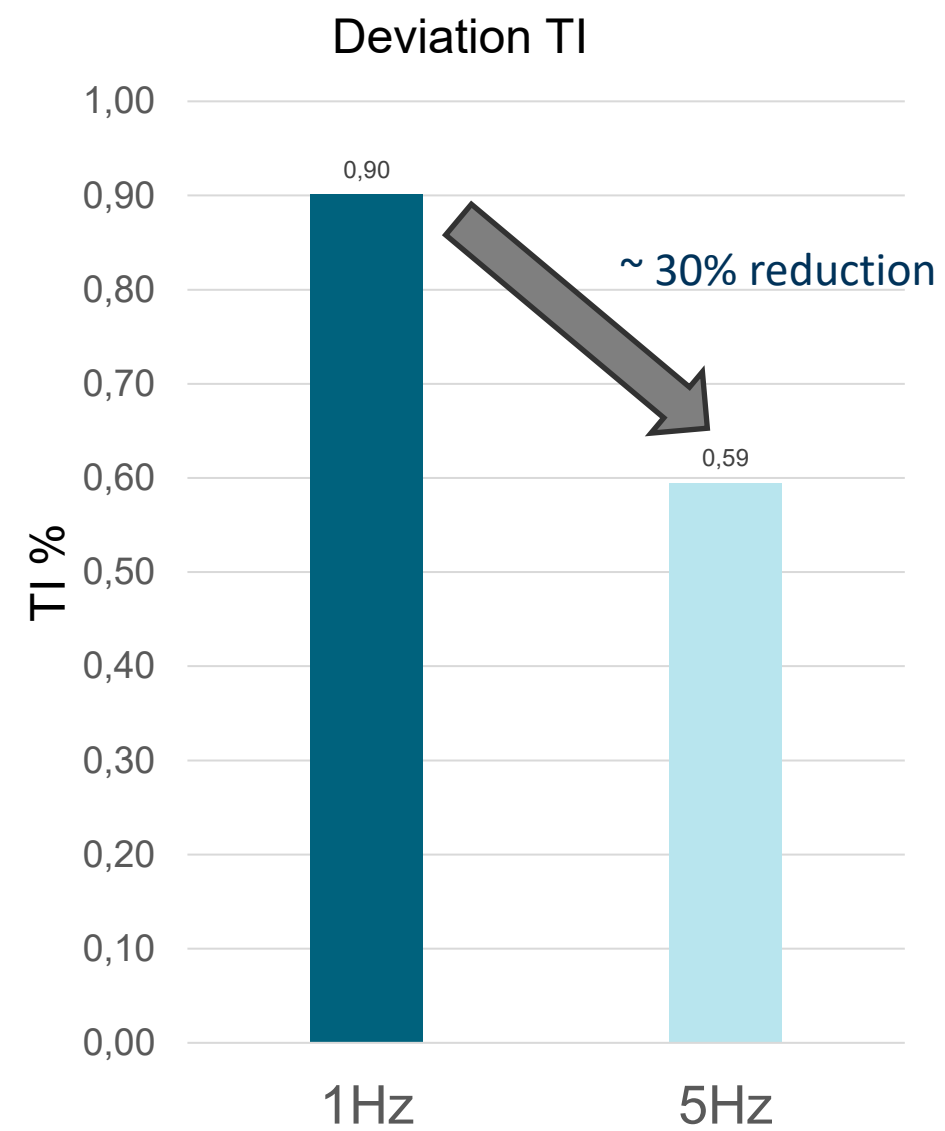
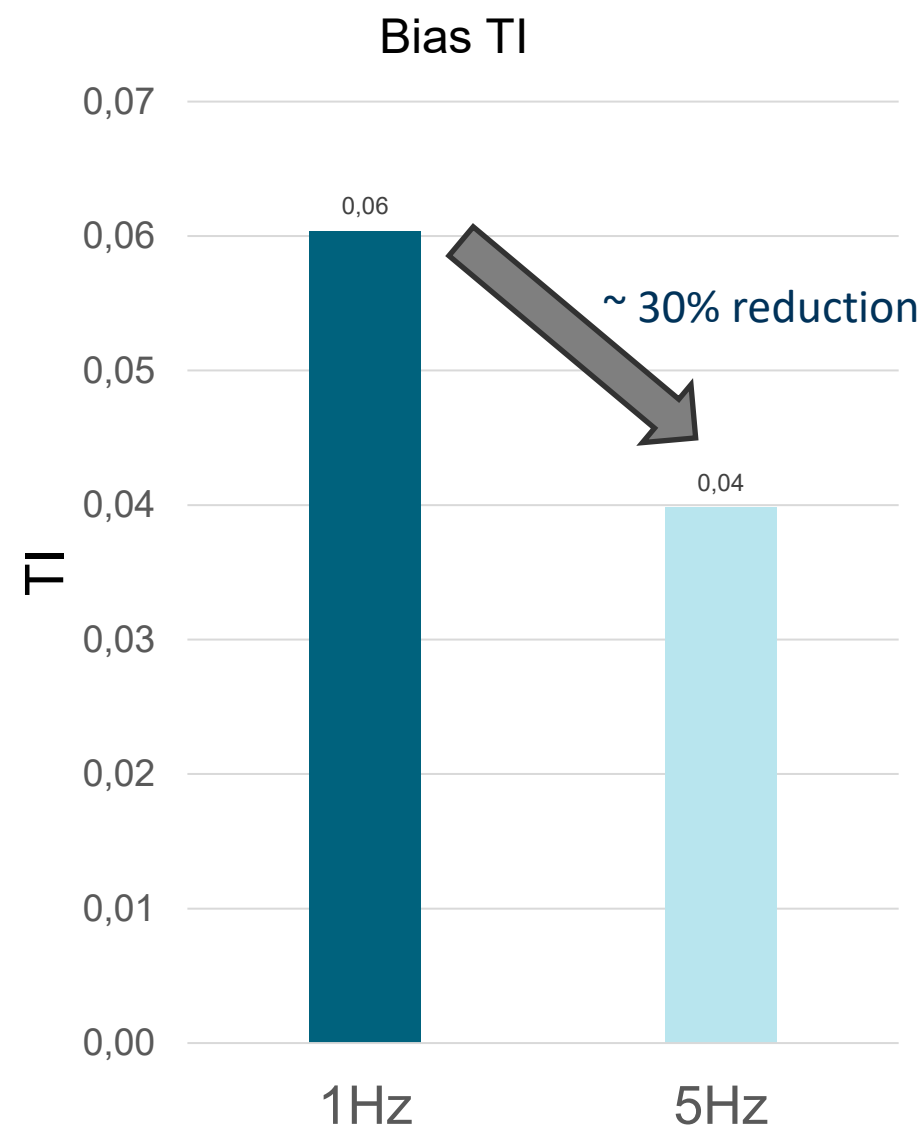
- Atmospheric parameters
- Lidar parameters (hardware)
- Lidar settings (signal processing)



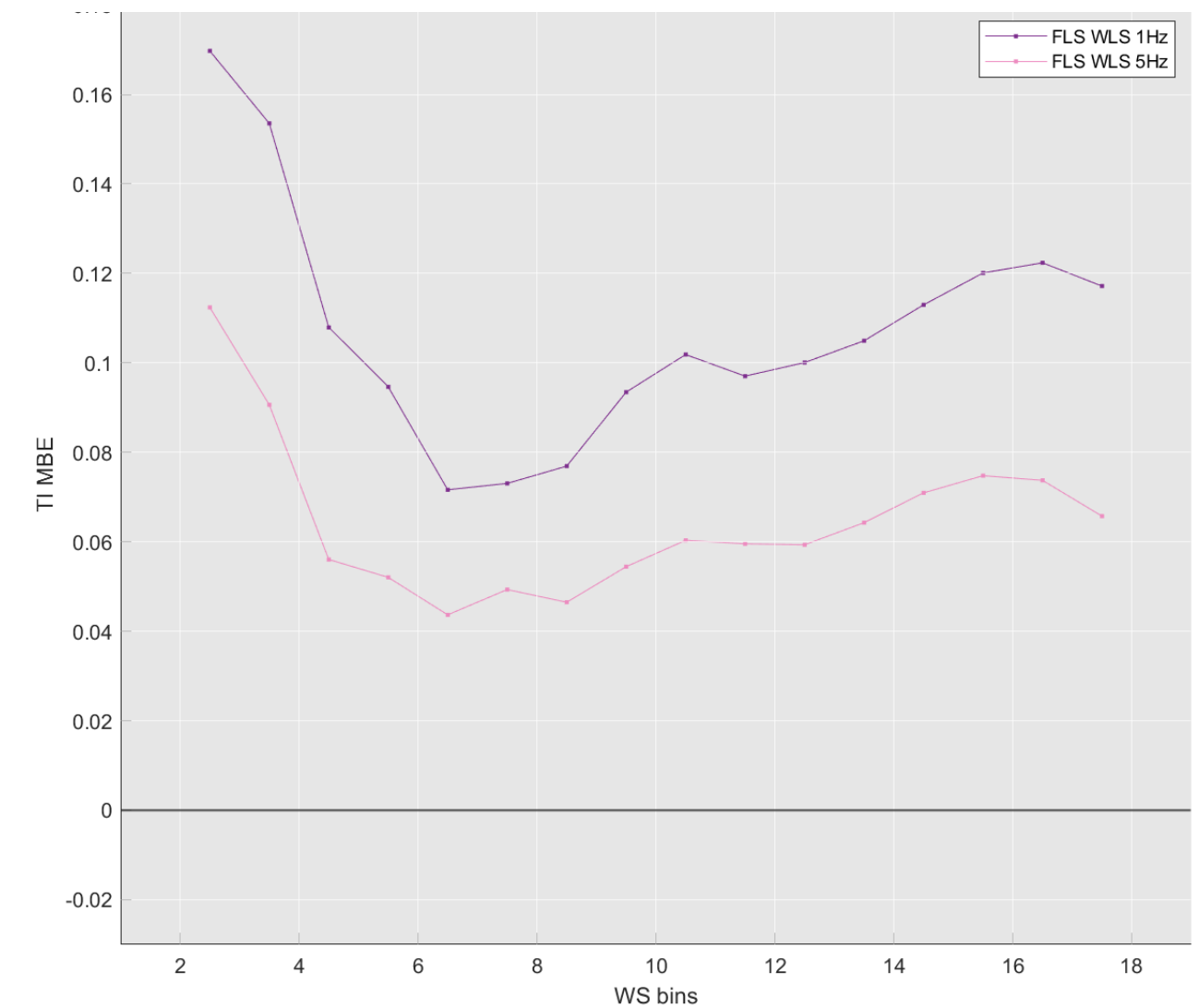
New accumulation time = 0.25 x current accumulation time



- 30% improvement in the bias of the turbulence intensity and the deviation was found when using the higher rate configuration.
- The improvement in the bias can be also seen as a function of the wind speed bins.

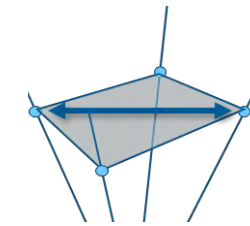
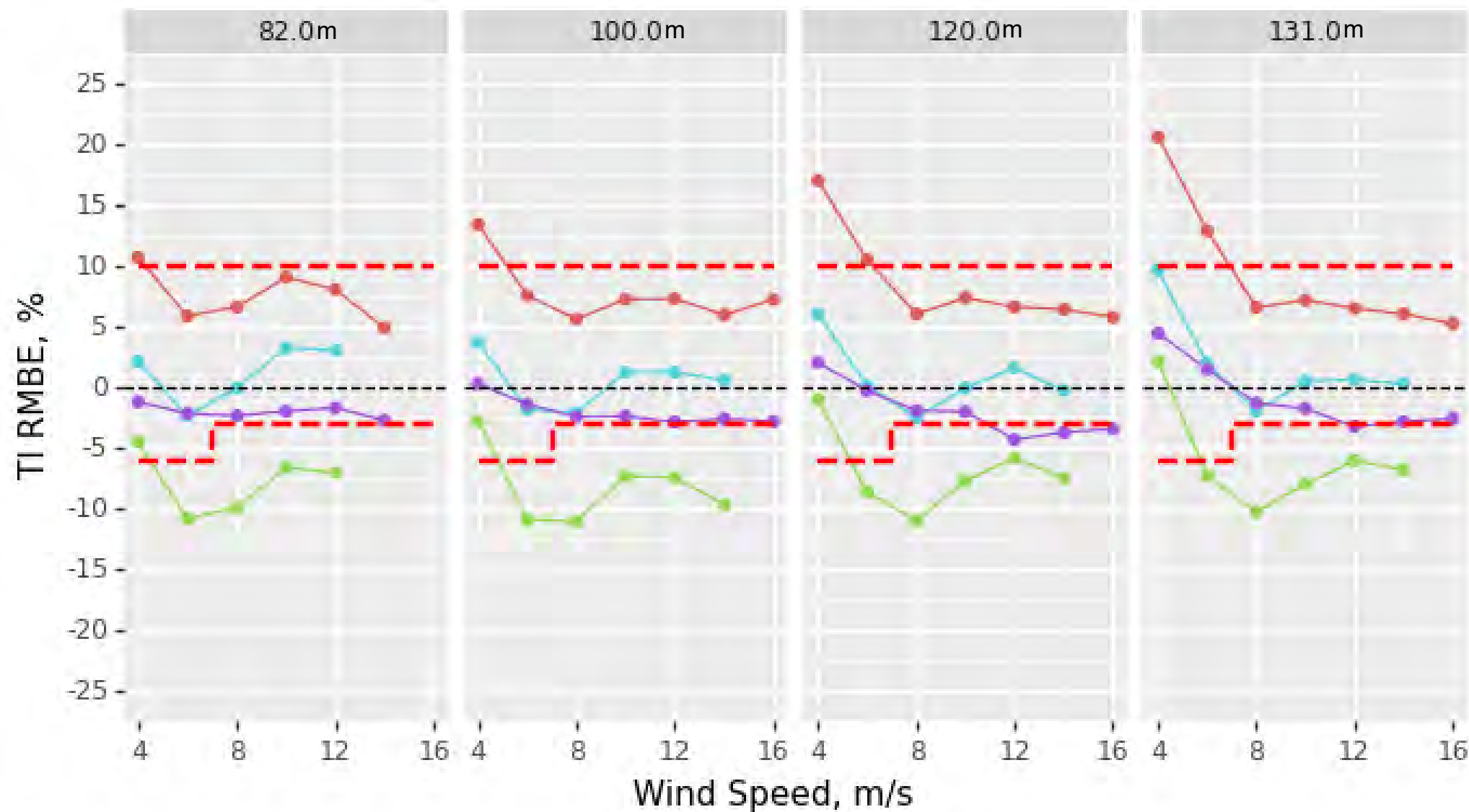


Turbulence intensity mean bias error by wind speed bins

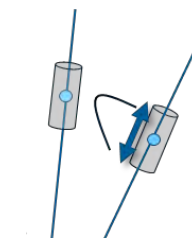


- Vaisala is currently working on an algorithm to improve the turbulence intensity (see Javelina below).
- This has been tested onshore with quite impressive results. It could be adapted for offshore (FLS) in the future.

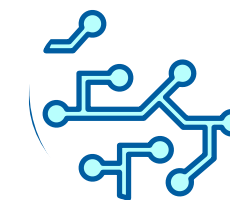
DNV RP 0661: Site Suitability



- **Interbeam (Javelina)**
 - Best agreement with met mast
 - Meets all Site Suitability KPIs



- **Intrabeam (Saguarro)**
 - underpredicts mast by ~10%
 - Does not meet RP 0661 KPIs



- **MLTI**
 - slightly underpredicts at this site
 - Meets all Loads Validation KPIs

- Source of errors in the turbulence intensity are well understood.
- Increasing the repetition rate improves the turbulence intensity measurement in floating Lidars.
- We are currently working on new algorithms to improve the turbulence intensity, showing already a good prospect.
- Our experience shows that motion compensation algorithms are important for buoys with high amplitude motion. Synchronization with IMU is one of the main challenges and something super important to properly manage.

Thank you for your attention!

