cmr Instrumentation

Effect of wave motion on wind lidar measurements - Comparison testing with controlled motion applied

DeepWind 2013 – 10th Deep Sea Offshore Wind R&D Conferance
24-25 Janyary 2013, Trondheim, NORWAY

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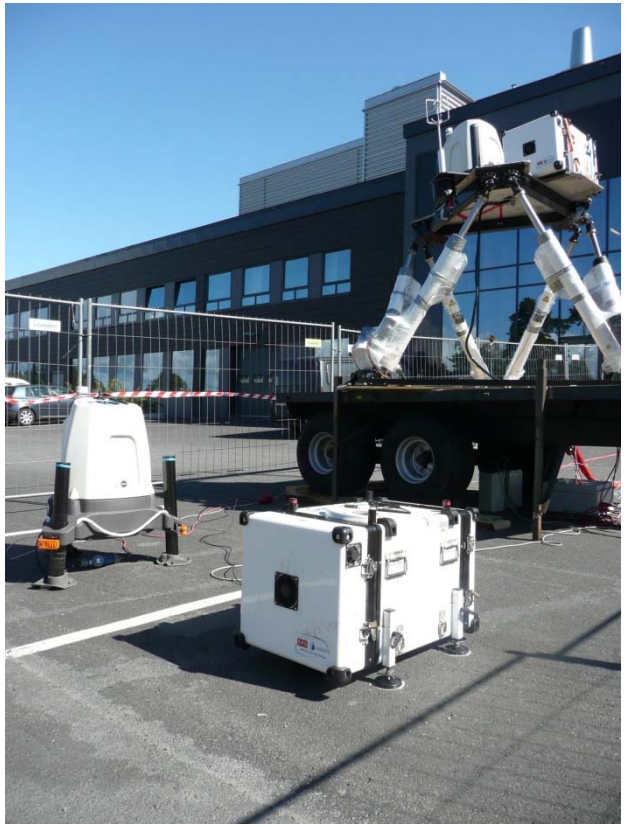
Presented by: Joachim Reuder (UiB)

Outline of presentation

- We will presented the key results from a comparison test between a pulsed and continuous wave (CW) lidar systems subject to controlled wave motion
  - Background/aim
  - Test site/setup
  - **Results**
  - Summary
- *Note: Results from offshore field test will be given by Jan-Petter Mathisen, Fugro OCEANOR at 16:15 "Measurement of wind profile with a buoy mounted lidar".*



[Picture from lidar comparison test (CMR)]

Background

- Mapping of offshore wind potential is of high economic importance for the power companies with respect to bankability and profitability of the investments
- Building, installing and operating offshore wind mast is very expensive
- Using autonomous measurement system on floating buoy could be a very cost efficient solutions if found sufficient accurate and reliable

[Picture of FINO 1, Courtesy of Bilfinger]

[Picture of lidar buoy, Courtesy of Fugro OCEANOR]

Project aim/organisation

- **Aim:** Demonstrate autonomous measurement system using floating buoy
- Part of the project: "**Autonomous measurement** of wind profile, current profile and waves for mapping of offshore wind potential, design and operation of offshore wind turbines".
- Comparison test presented here is part of WP2: **Concept for wind profiling** (with CMR as work package coordinator)
- Financed by the Research council of Norway (NRC) and Statoil (in addition to in-kind from Fugro OCEANOR, CMR and UiB)
- Fugro OCEANOR as project owner

Test Site / Setup

- University in Agder, Grimstad capus
- Reasonable flat within a radius of 1km
- Sea to the south and east, while there are hills further to the west
- Motion platform placed 10 meter west of a 9 meters tall building
- Motion platform: Bosch Rexroth Boxtel 6-DOF E-motion 1500 Motion System
- Lidars compared during test:
  - Wind Cube V.1 (pulsed)
  - ZephIR 300 (CW)
- Two similar lidars fixed on the ground used as reference measurement

[Map test site: www.gulesider.no Picture: Test setup Grimstad (CMR)]

Motions applied

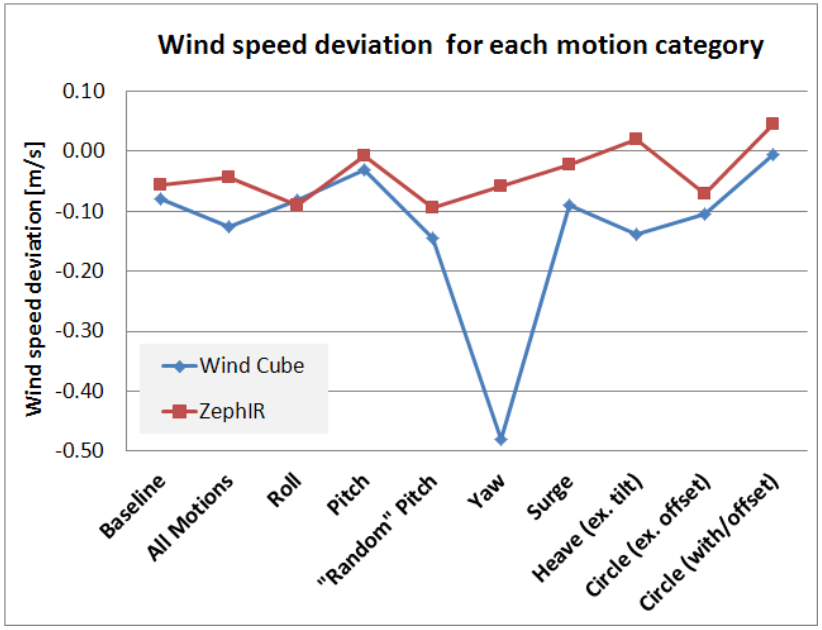
Play video

(*YouTube link*)

- 55 motions tested:
  - 9 baseline (no motion through the night)
  - 9 roll; A=3, 5, 10 and 15° | f=0.1 and 0.2Hz (tilt east-west)
  - 6 pitch; A=3, 5, 10, 15 and 20° | f=0.1 and 0.2Hz (tilt north-south)
  - 6 «random» pitch (based on Pierson-Moskowitz spectrum)
  - 5 yaw; A=39° | f=0.025, 0.005, 0.1, 0.15 and 0.2Hz
  - 3 surge; A=40cm | f=0.1 and 0.2Hz
  - 5 heave; A=20 and 40cm | f=0.1, 0.15, 0.2 and 0.4Hz
  - 11 vertical circle; r=30cm | A=3, 5, 10 and 12.5°, 3 and 5° offset
- Approximately 3 hours for each motion (total of 10 days)
- Pure sine-wave, except “random” motions
- Results presented are horisontal wind speed at 85 meter based on 10 minute average data (NB: No motion compenstaion applied)

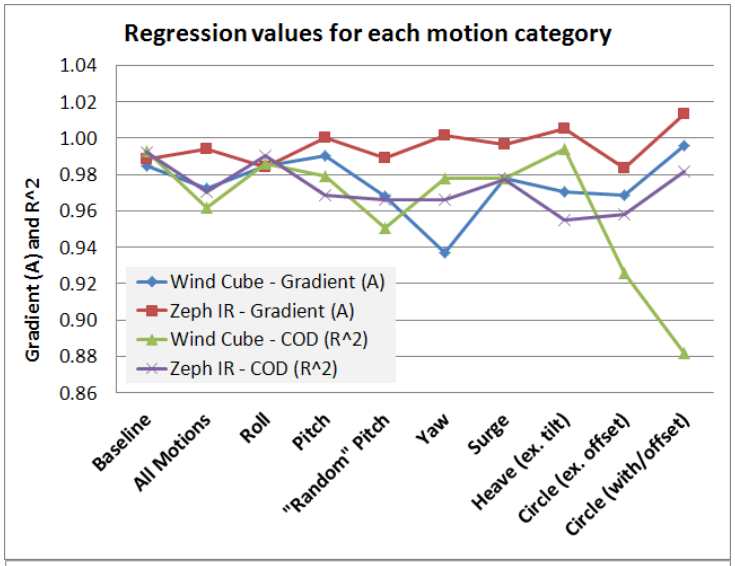
Results - Horizontal wind speed

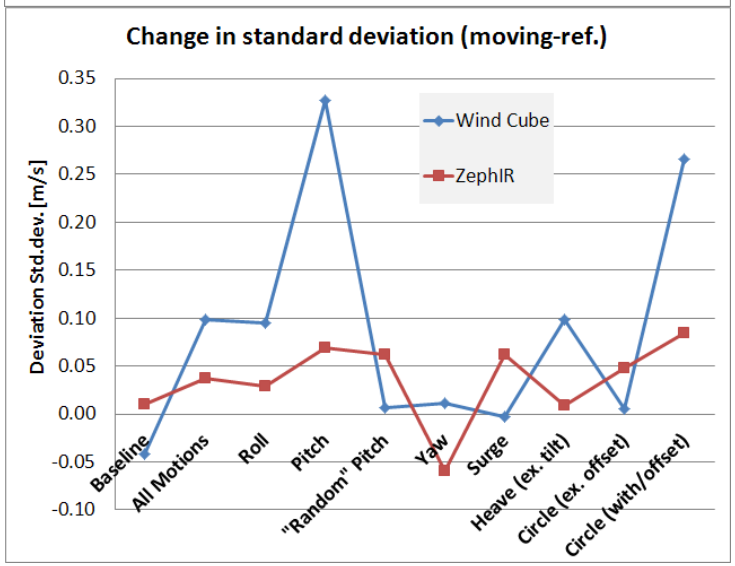
- Slight bias observed during baseline measurements
- Average of all tests with motion show very small deviation between reference and moving units
- Only yaw motion with Wind Cube shows significant deviation
- Note the higher reading with circle motion with offset pitch angle compared to the one without any offset in pitch angle
- The average wind speed is about 5m/s
- Next slides show more details



Results – Std. dev and regression

- Gradients (A) and coefficient of deterministic (R^2) are quite good for all tests
- High increase in standard deviation for Wind Cube during circle w/offset and pitch might be related to lower average wind speed (3.6m/s) compared to the other tests (5.4m/s)
- Note: The regression is forced through origin (Y=Ax), reference lidar on x-axis and moving lidar on y-axis. Based on 10 minute data obtained during each test

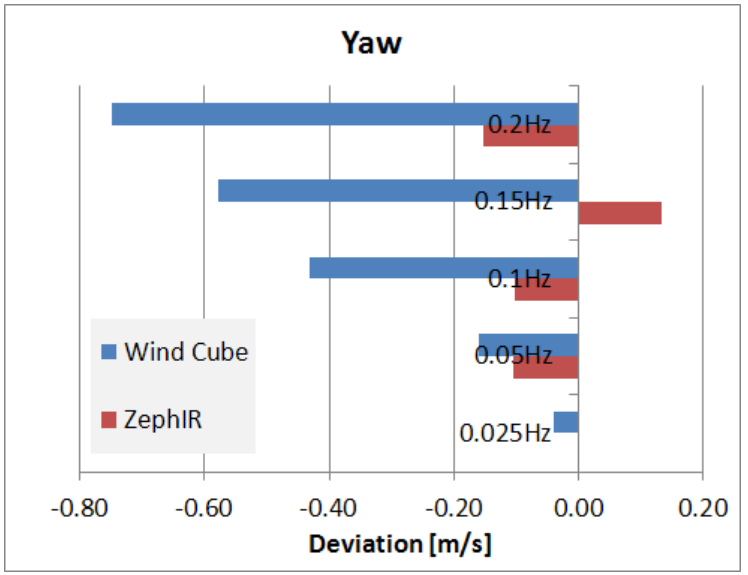


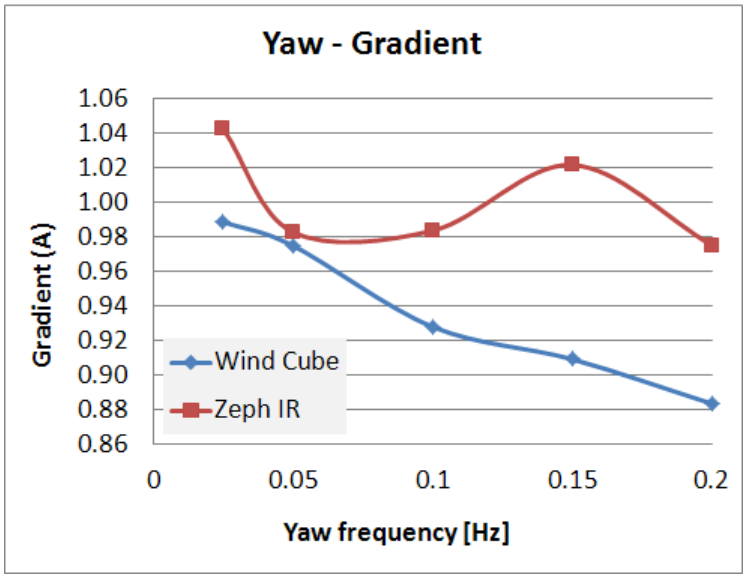


Results – Yaw motion

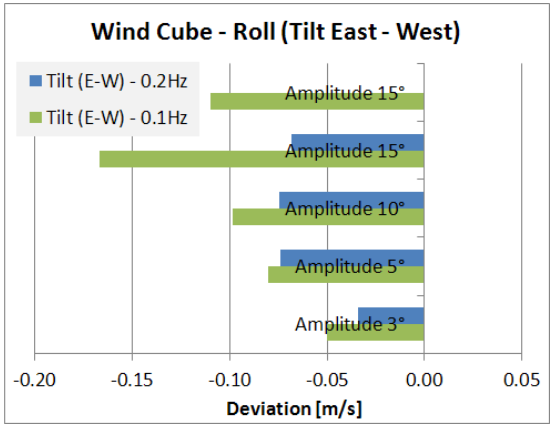
- Increasingly underestimation of the wind speed with yaw frequency for Wind Cube (A=39° for all tests)
- We believe that the Wind Cube wind speed calculation algorithm is somehow failing when subjected to such fast yaw motion, as the lidar only measure four points in about four seconds (ZephIR measure 50 points in one second)
- R^2 is very good throughout all tests

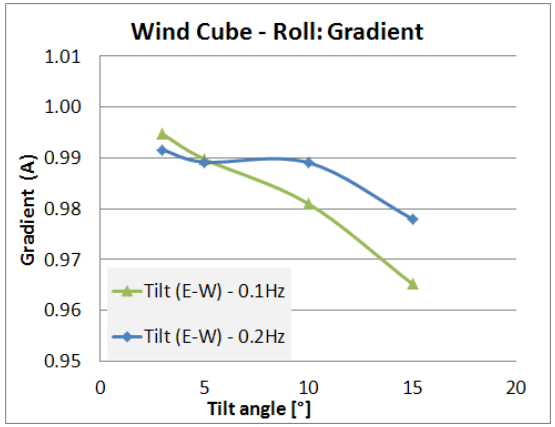
- Note: Such fast yaw motion might not be realistic during operation

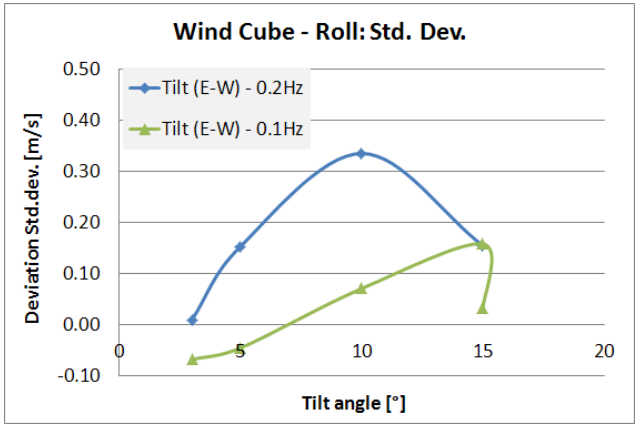


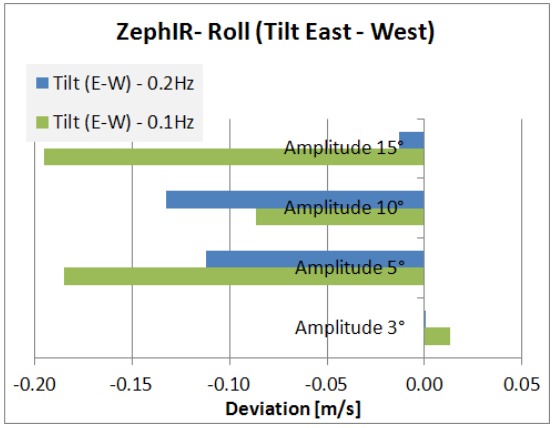


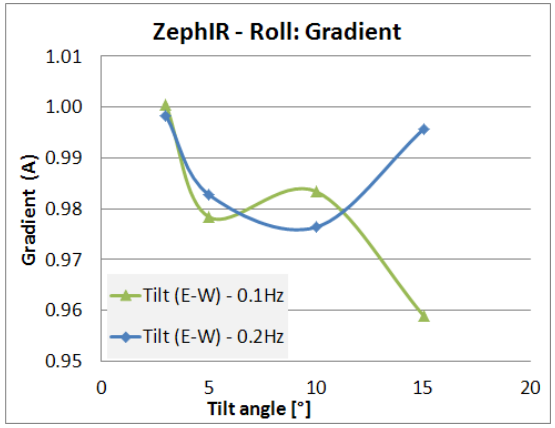
Results – Roll motion

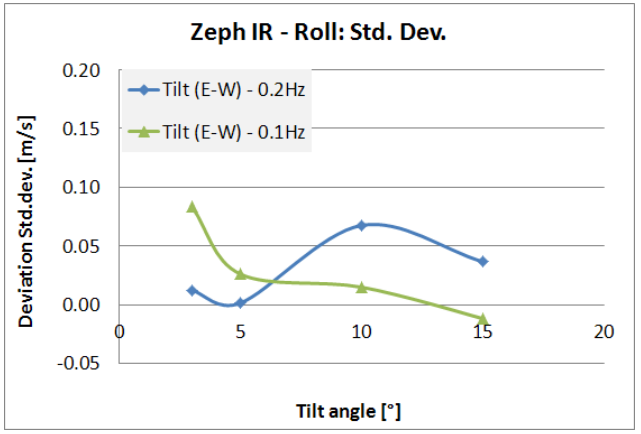






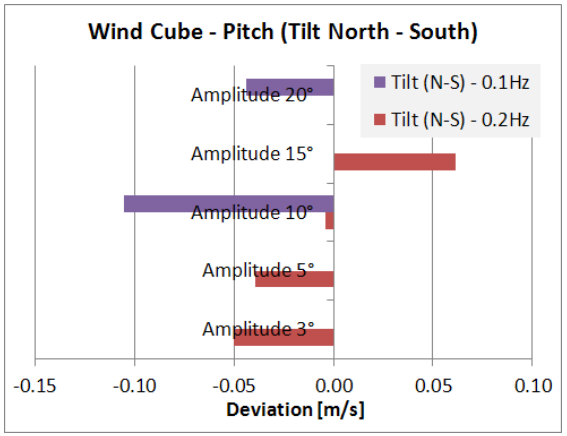


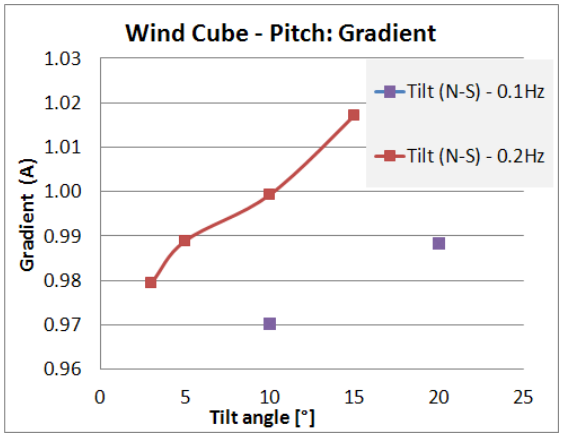


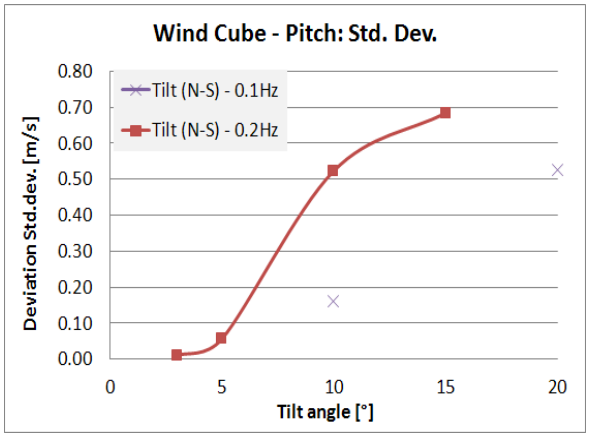


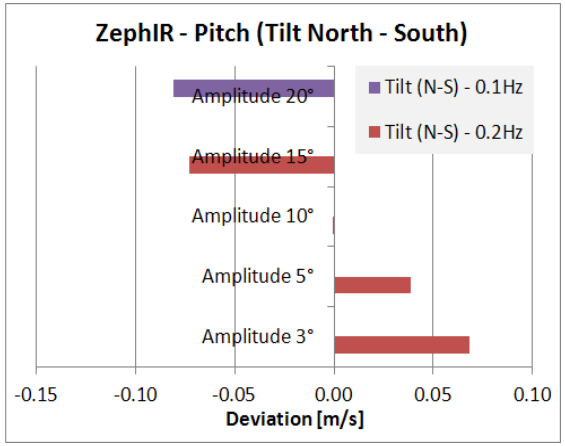
- The results indicate an decrease in horizontal wind speed and increase in standard deviation with increasing roll angle

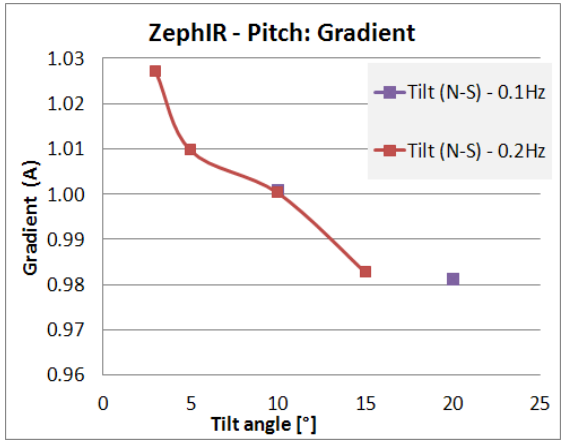
Results – Pitch motion

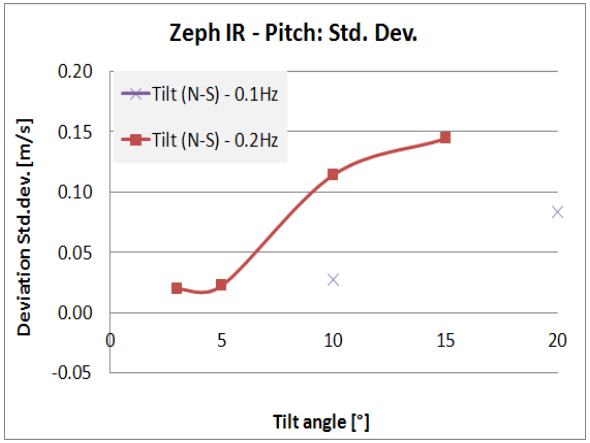








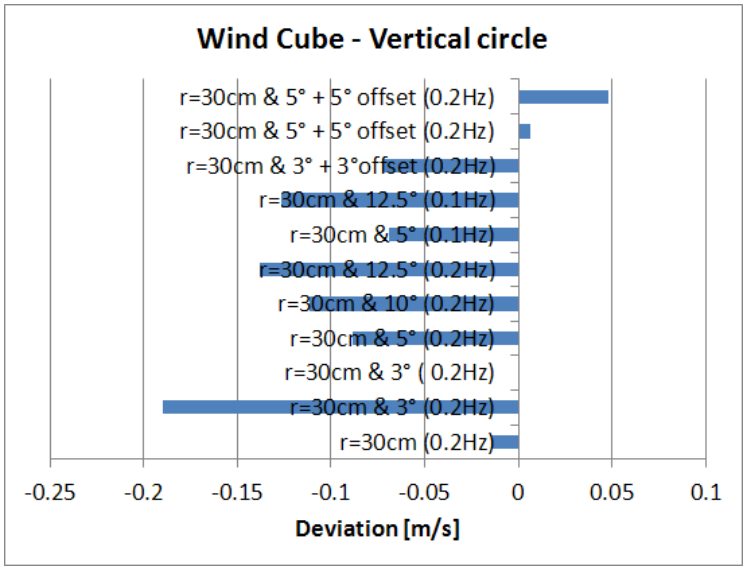


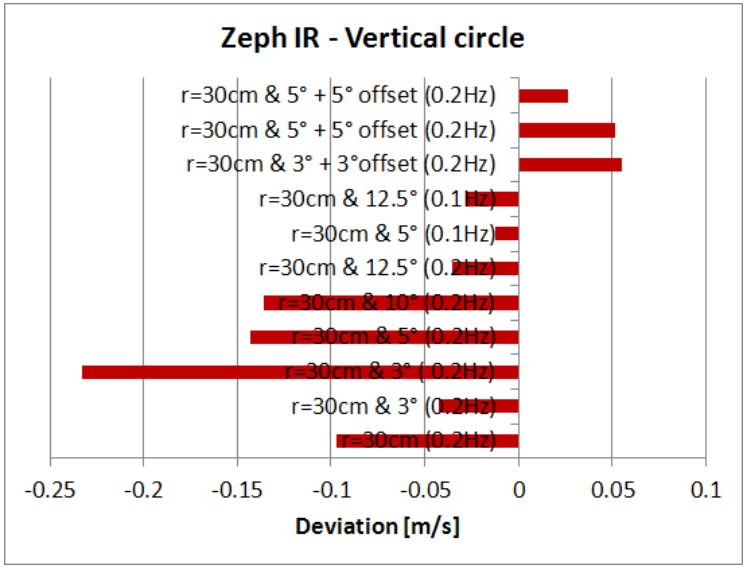


- We observe increase in standard deviation with increasing roll angle
- Average wind speed and gradient indicate different trend for the two lidar systems

Results – Vertical Circle

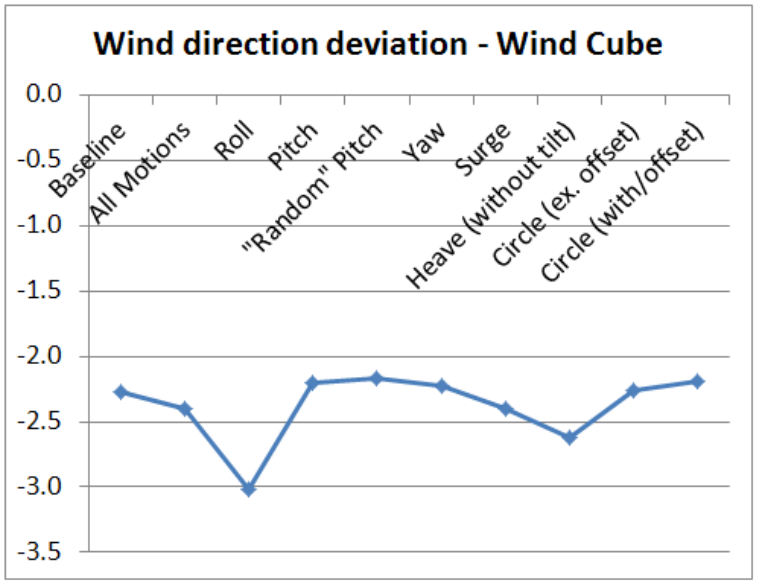
- It seems as the test with offset angle has higher reading compared to the other tests, especially for the Zeph IR lidar (we expect an opposite trend)
- Possible explanations might be:
  - Measurement with an offset angle has in general lower wind speed (3.3m/s) compared to the tests without any offset (4.8m/s)
  - Higher standard deviation and poorer R^2 during testing with offset angle
  - Somewhat different wind direction during the two types of motion (130-180° vs. 206-328°)
  - Different wind profile





Results – Wind direction

- Very small impact of motion on wind direction measured
- Bias can be explained by offset during setup
- We observe that the ZephIR lidars shows a 180° deviation compared to Wind Cube during many of the tests
- ZephIR has a 180° wind direction unambiguity, which is solved using a local met station on the lider



- Structural disturbance at the ground level where ZephIR has the local met station can explain the errors with ZephIR
- This might also be a problem in open areas if the buoy is rotating

Summary

- Relatively small deviation between moving and reference lidars
- Most measurements are with the measurement uncertainty

- Increasingly underestimation of the wind speed with yaw frequency for Wind Cube
- The standard deviation is increasing with tilt angle
- In general the deviation seems to increase somewhat with tilt angle (as expected by theory)
- ZephIR measure 180° wrong wind direction during many of the test (probably due to nearby structures and setup)

- *Note: Results from offshore field test with ZephIR lidar will be given by Jan-Petter Mathisen, Fugro OCEANOR at 16:15 "Measurement of wind profile with a buoy mounted lidar"*

Acknowledgment

- University of Agder, campus Grimstad, especially Eivind Arne Johansen and Geir Hovland, for helping out with the practicalities of setting up this test
- Martin Flügge (UiB) and Stiand H. Stavland (CMR) for assisting with running the test
- Joakim Reuder (UiB) and Ivar Øyvind Sand (CMR) for valuable input to the test
- NORCOWE and NOWITECH for renting us the Wind Cube lidars and NORCOWE for renting us the motion platform used
- The project owner Fugro OCEANOR for allowing the results to be published
- The Reseach Council of Norway and Statoil as exernal funder of the project

- For more information: jono@cmr.no

[Picture: Lidar comparison test Grimstad (CMR)]