Towards bankable lidars - how stable are lidars over time?

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TOWARDS BANKABLE LIDARS

- HOW STABLE ARE LIDARS OVER TIME?

BY

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Overview

- What is needed for bankability
- What is temporal uncertainty
- Comparing old and new calibrations
- Assessing our repeatability
- Can we do better?
- Conclusions and outlook

What is needed for bankability?

We see four fundamental elements to reach bankability of lidars in wind resource assessment:

- **Accredited lidar calibration.** (DTU DANAK) 
- **Best practices.** (IEA Recommended Practices coming soon) 
- **Understanding of temporal uncertainty.**
  - Not really investigated yet
- **Understanding of site sensitivity.**
  - The draft IEC 61400-12-1 Annex L includes lidar classification to tackle this as one approach
  - More fundamental understanding is another, complementary approach

What is the aim of this project?

- **Accredited lidar calibration.** (DTU DANAK)
- **Best practices.** (IEA Recommended Practices coming soon)
- **Understanding of temporal uncertainty.**
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- **Understanding of site sensitivity.**
  - The draft IEC 61400-12-1 Annex L includes lidar classification to tackle this as one approach
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What is this presentation about?

- **Accredited lidar calibration.** (DTU DANAK)
- **Best practices.** (IEA Recommended Practices coming soon)
- **Understanding of temporal uncertainty.**
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Temporal uncertainty – our plan

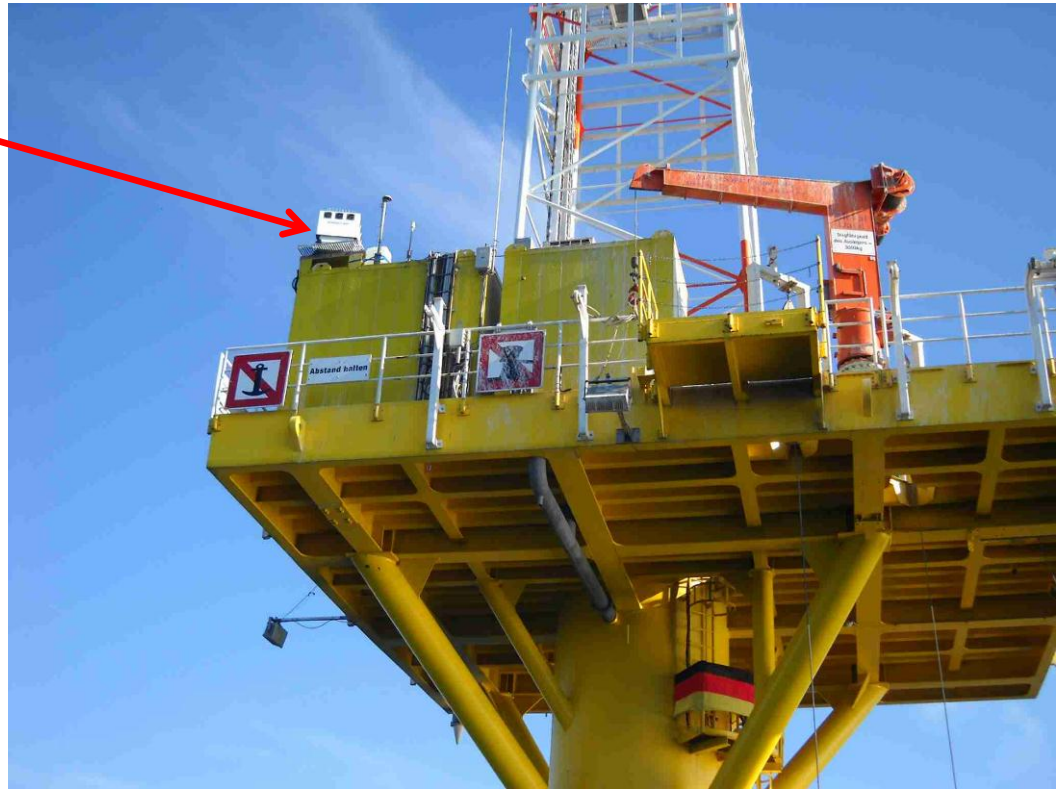
- Temporal uncertainty = Do lidars drift?

To answer this question we will:

1. Look at a number of old calibration results and compare with more recent results

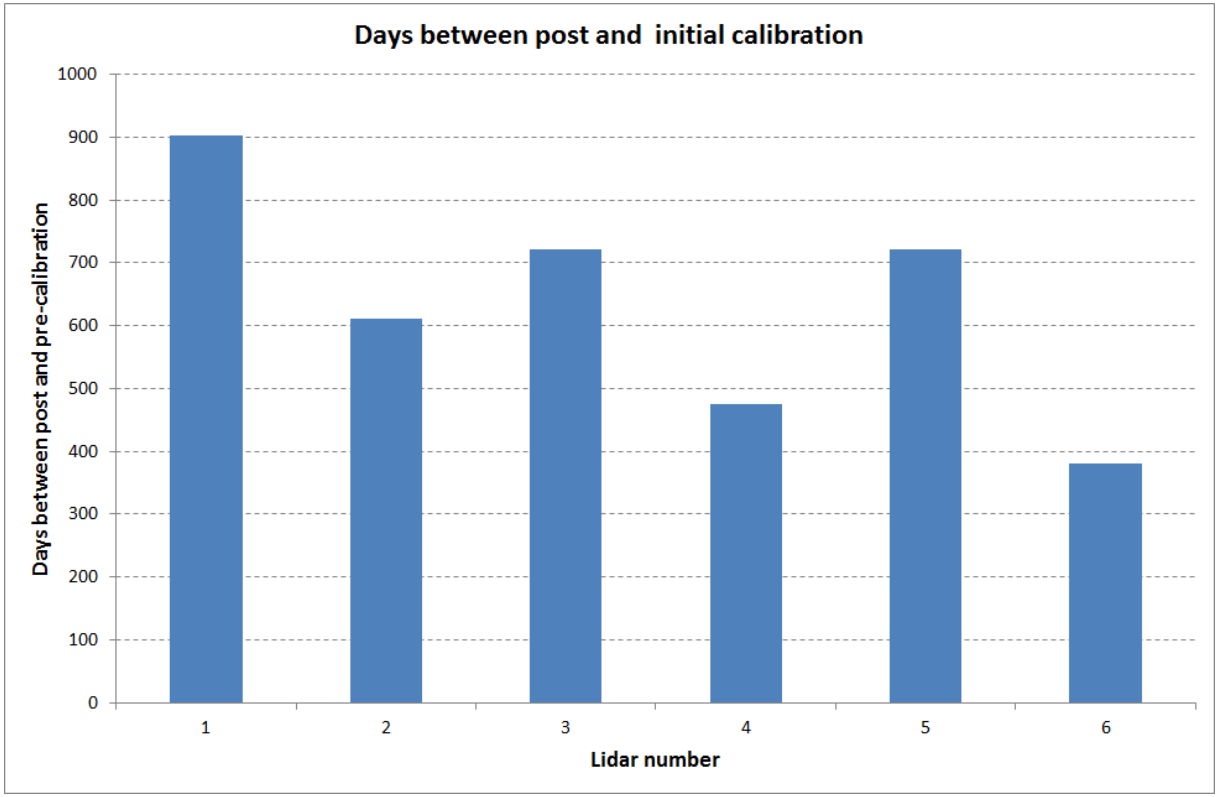
2. Run 2 calibrated lidars offshore for a year each and then post calibrate them.

Lidars on FINO2

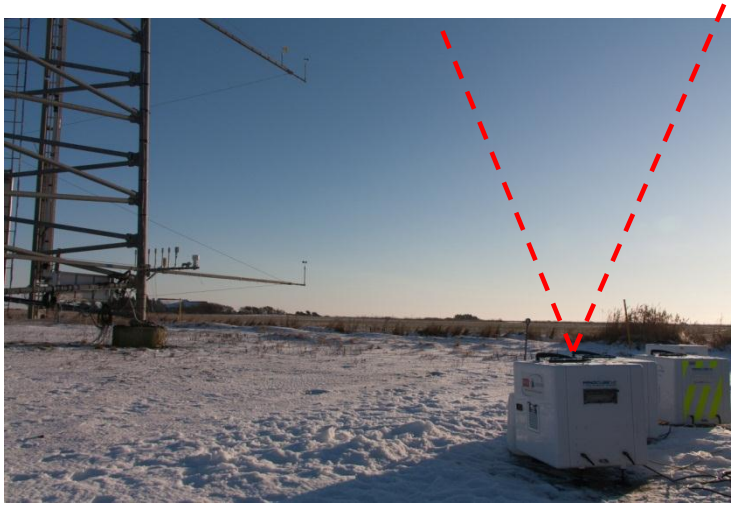


Our method

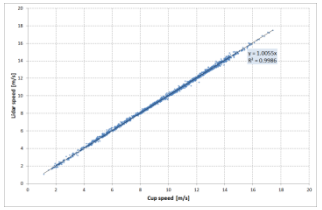
- Study lidar calibrations made for 6 different lidars before and after field operation
- All were pulsed lidars, most "first generation"
- Time in field varies between 390 and 900 days
- 2 were offshore deployments, 4 were onshore



What is a lidar calibration?



116m



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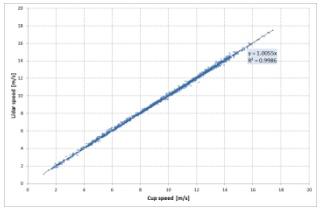
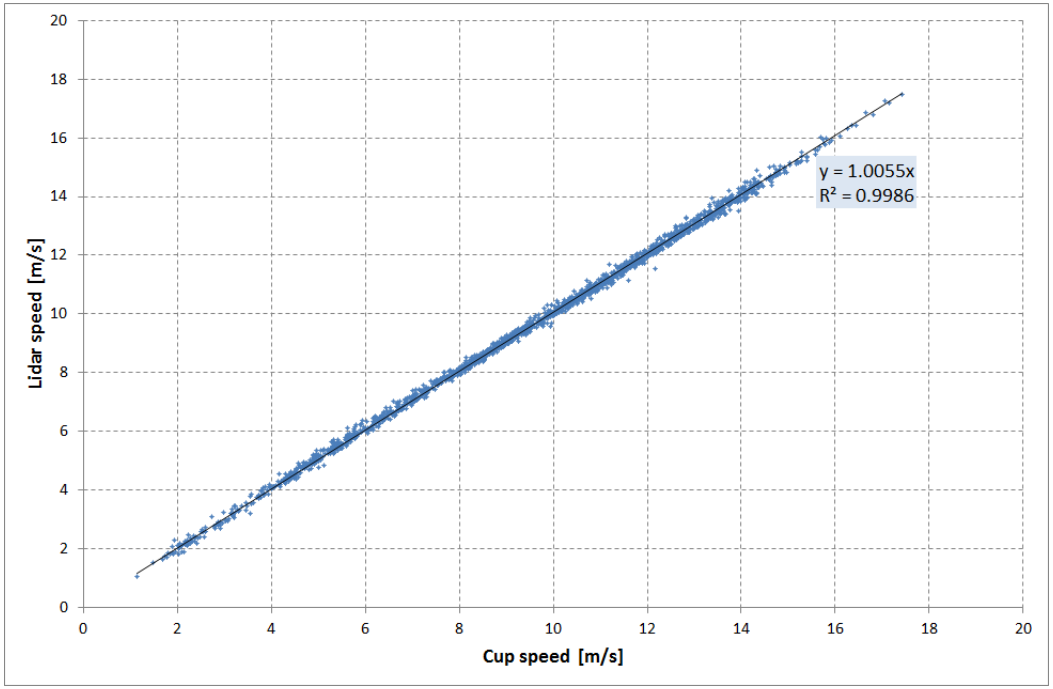
60m



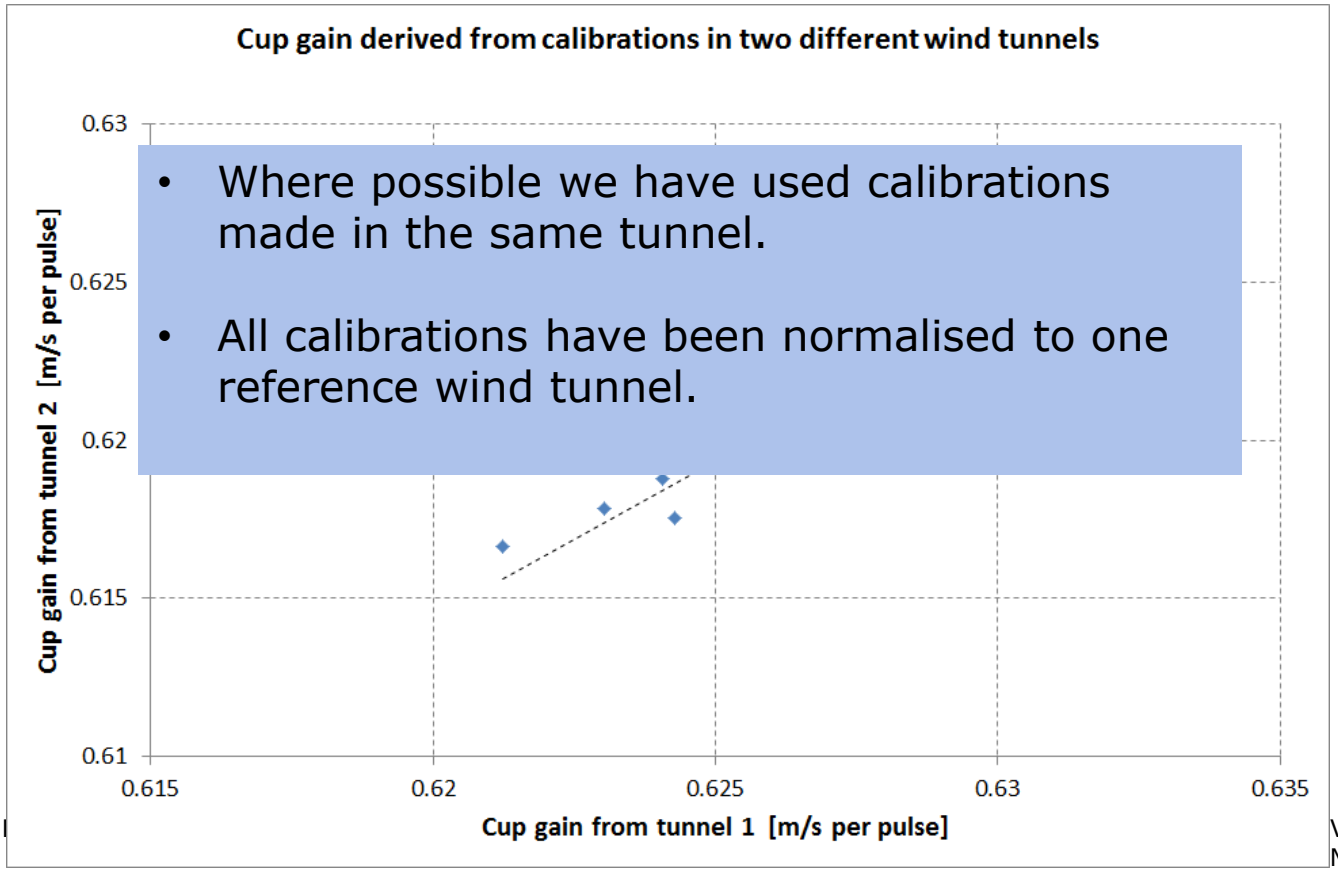
40m



Things to be careful about

- Avoid changes in the calibration procedure (data analysis)
  - Use the same procedure for the old and new calibrations
  - Use the accredited DTU DANAK procedure

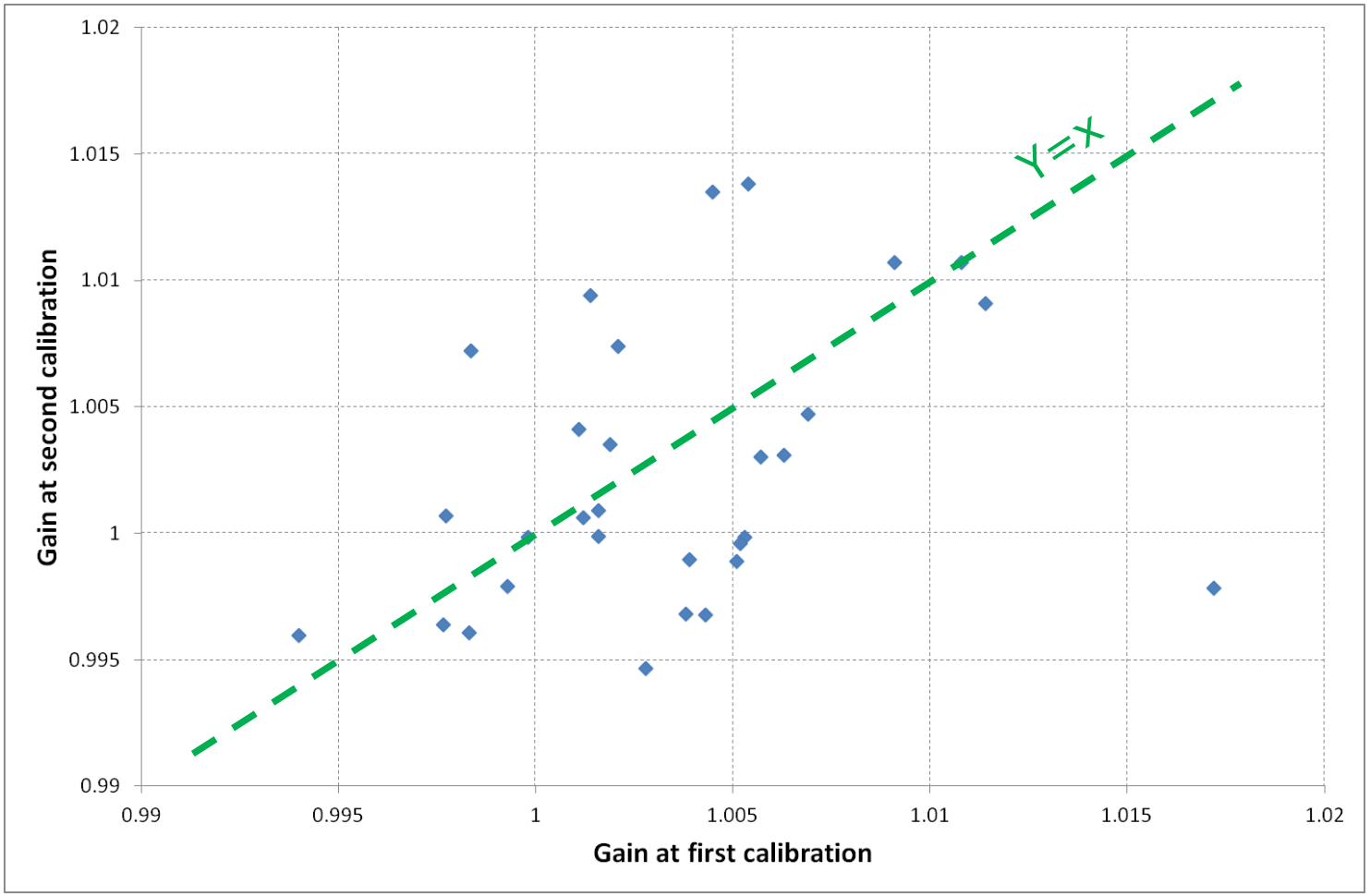
- Cup anemometer calibrations



Results

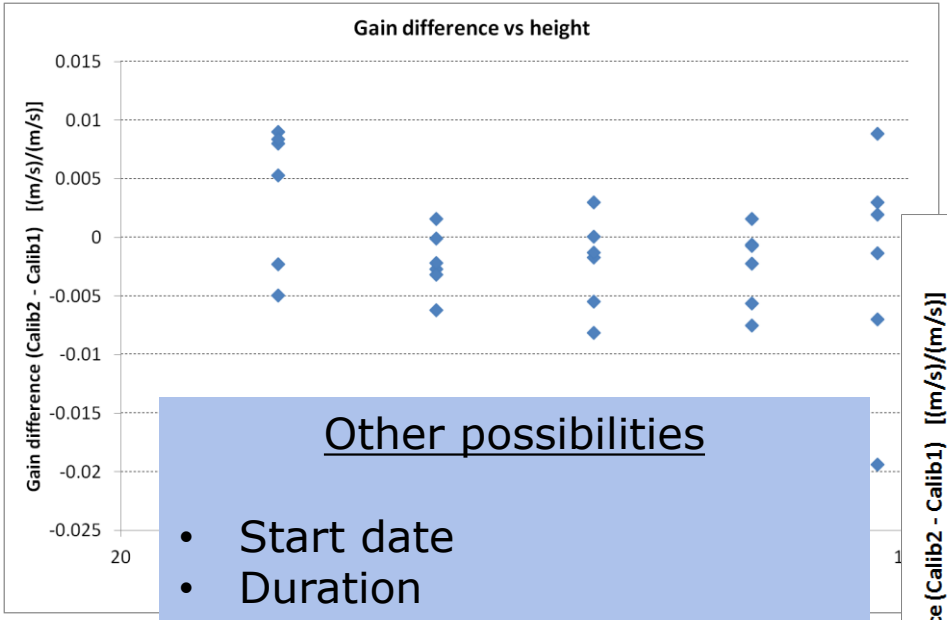
The simplest result is for the 'forced' linear regression $U_{lidar} = M \cdot U_{cup}$

We can compare values of M obtained for the different calibrations. In the plot there are 6 lidars x 5 heights = 30 different data pairs.

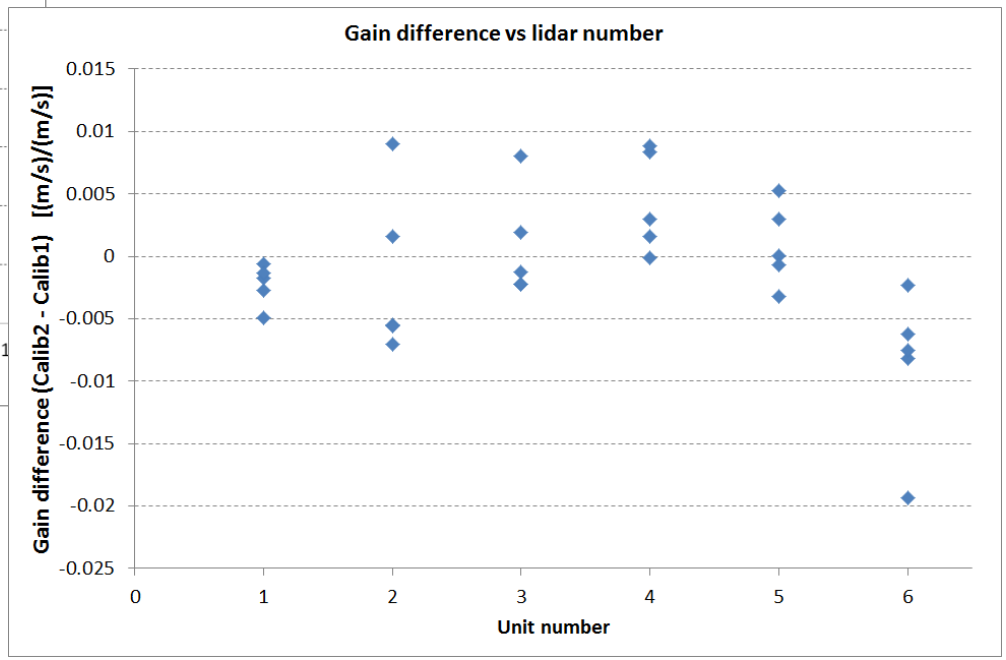


Grouping gain differences

Height



Individual lidar



Other possibilities

- Start date
- Duration
- Mean speed
- Mean direction
- Mean shear
- Mean turbulence intensity
- ……..

What does this tell us?

- Gain is reasonably well correlated between the two calibrations.

But

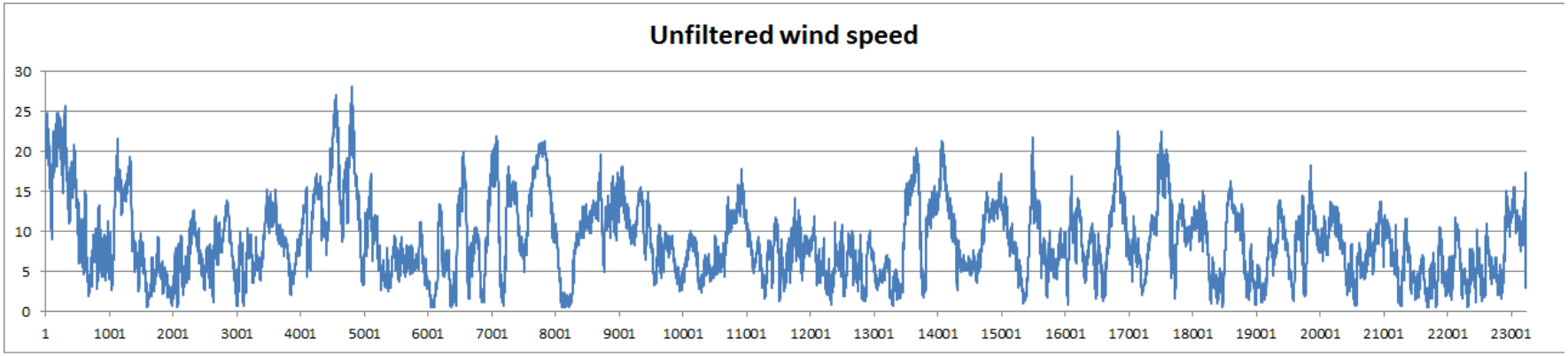
- There is also quite significant variation.
- Are these differences real changes in the lidar characteristics?

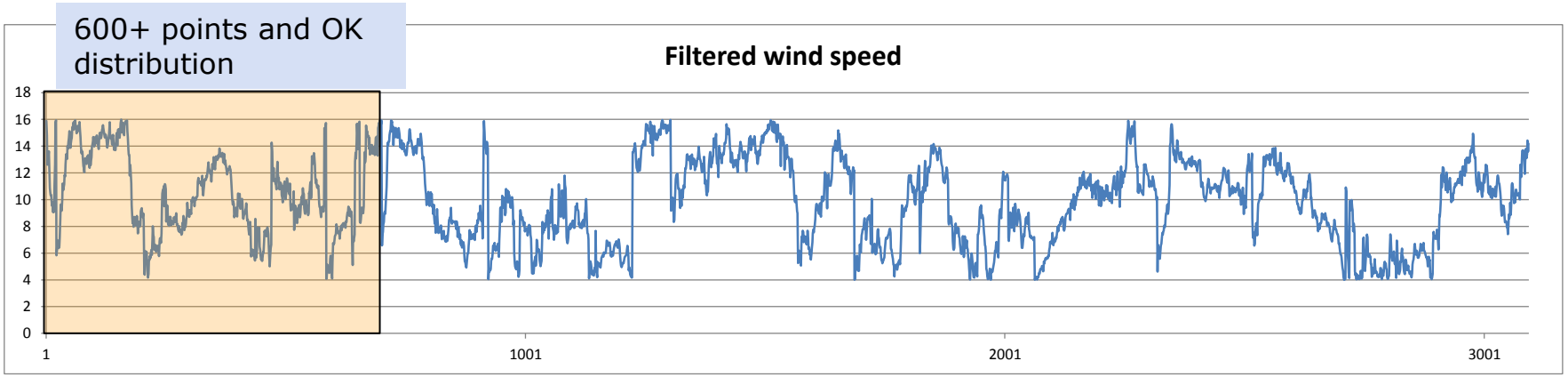
Or

- Can they be at least partly explained by the 'natural variation' in calibration results?
- What we really need to assess is the **repeatability** of our lidar calibrations

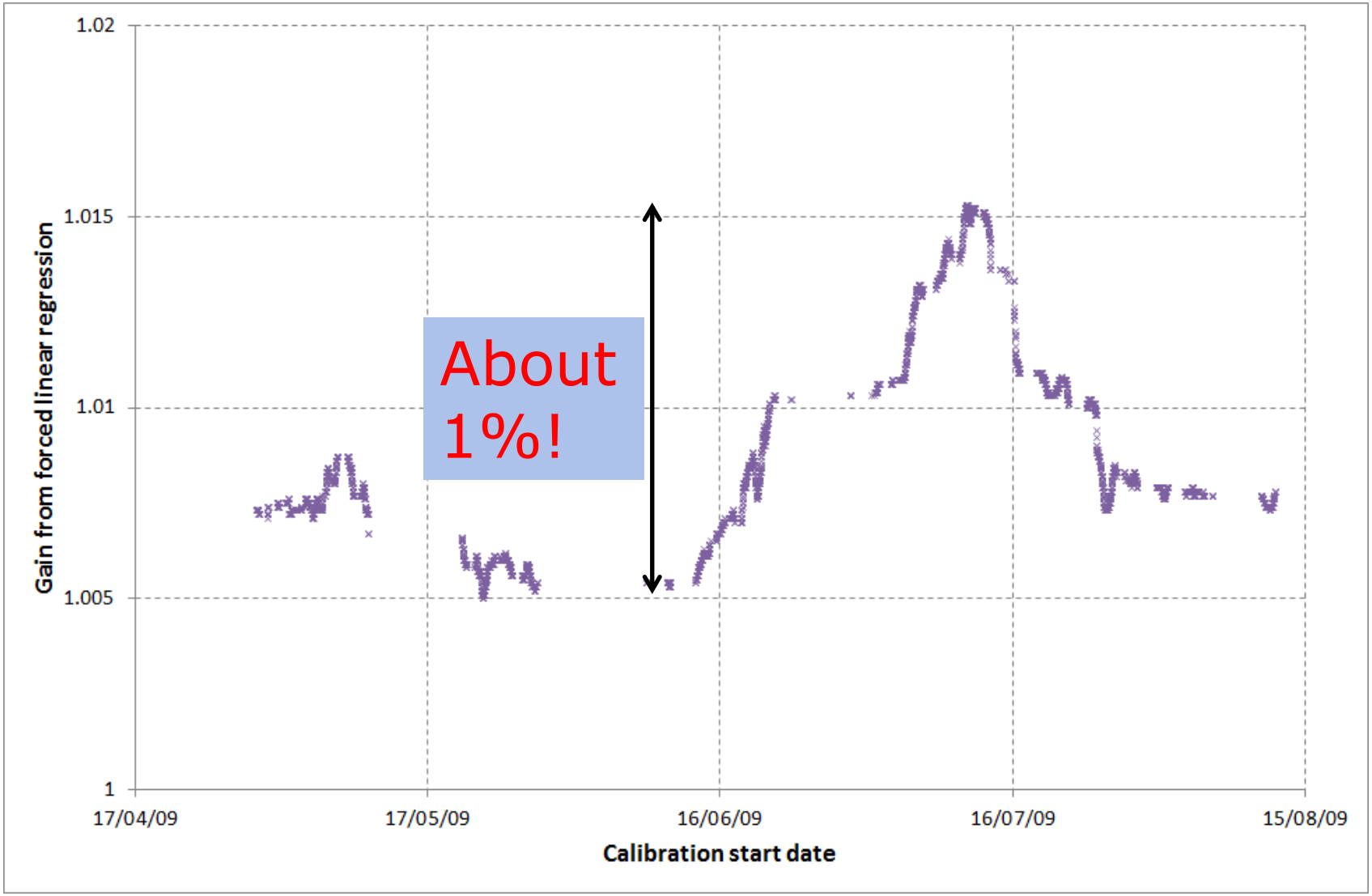
One lidar in one place – how much can the calibration change?

The sliding window technique

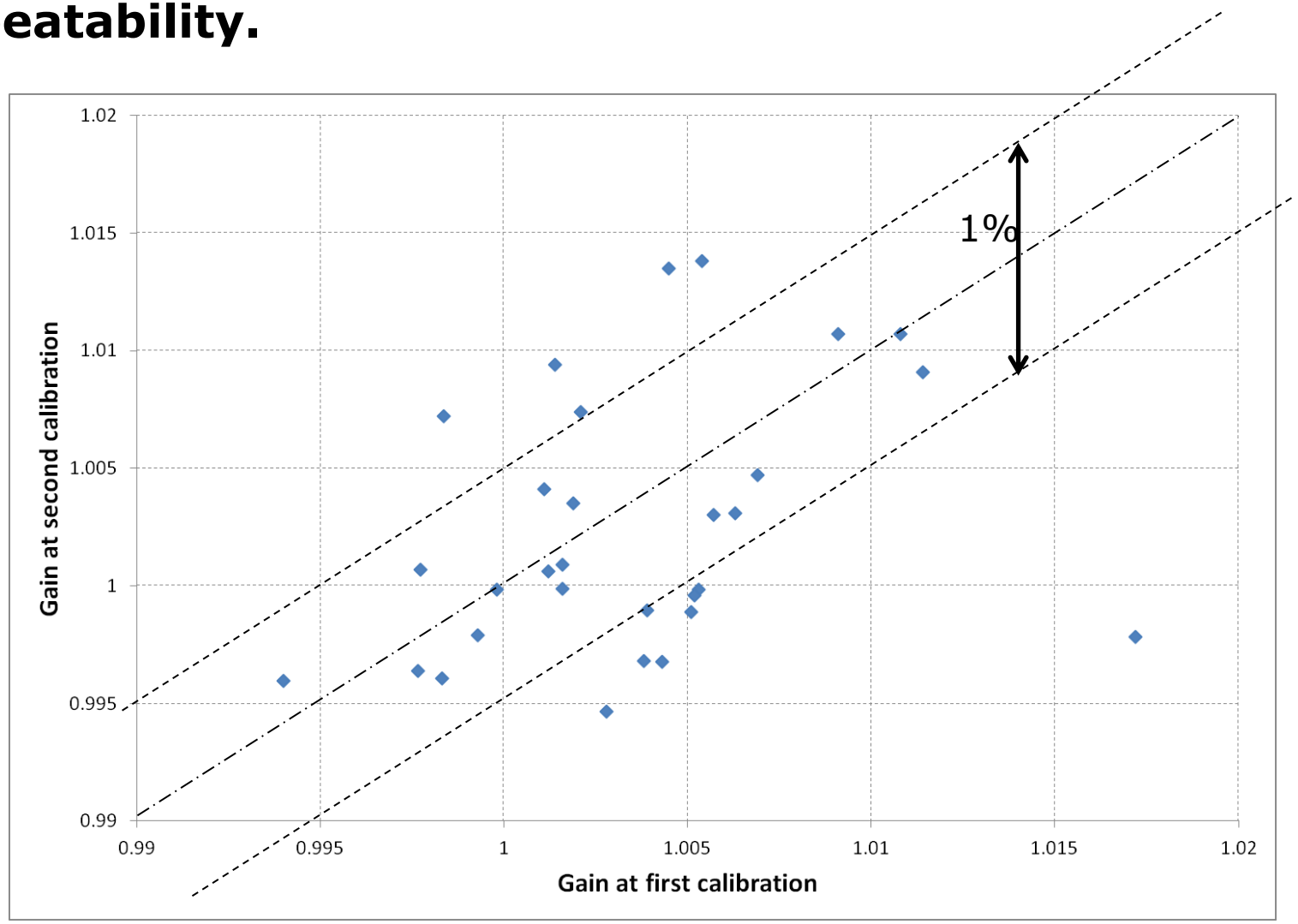




How much the calibration can change just by starting in a different month?

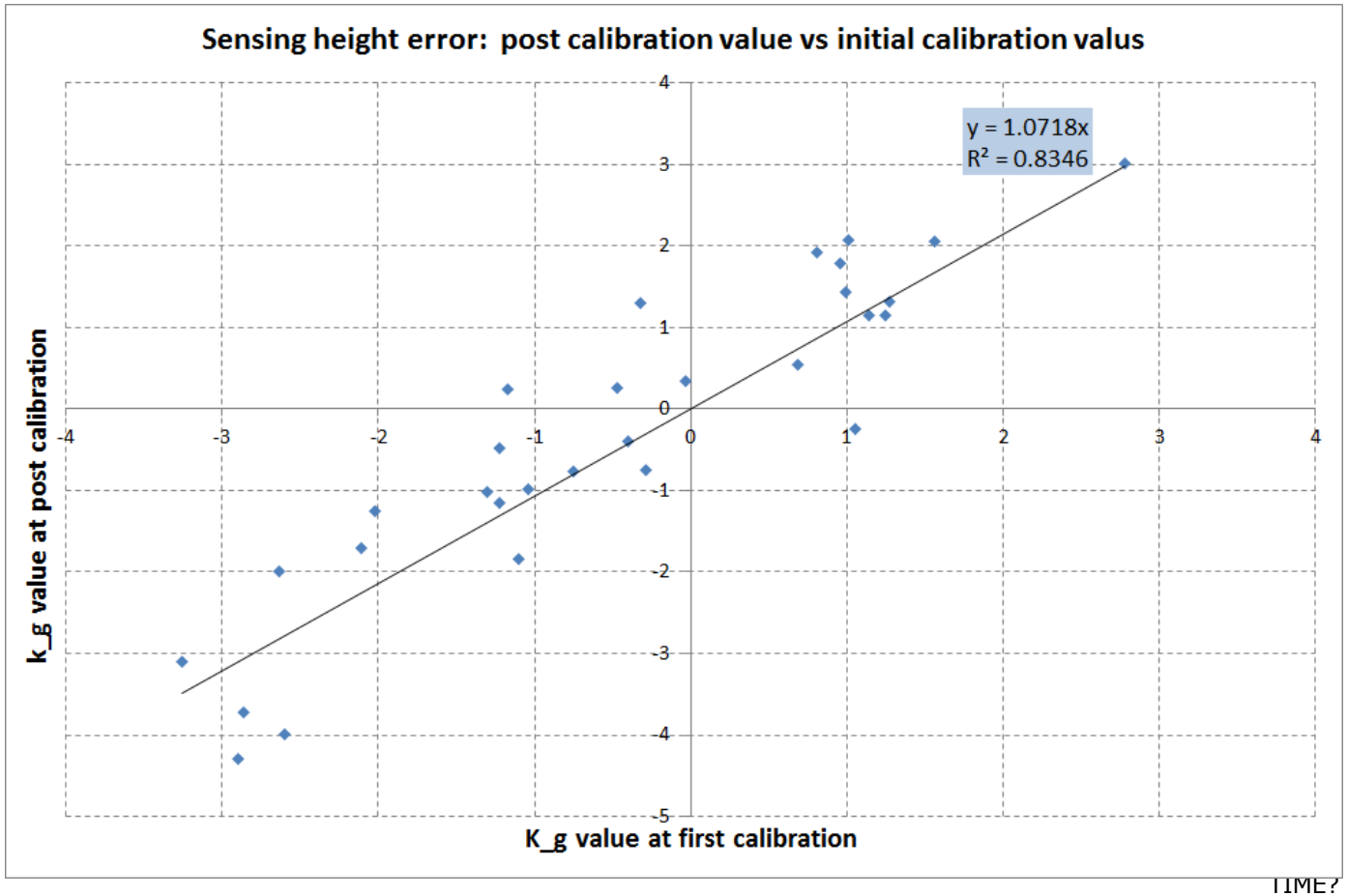


Most of the scatter between the first and second calibrations can be explained by this limited repeatability.



Reasons for the poor repeatability -1

- Shear effects on the regression results
  - Sensing height errors are consistently reported between the initial and post calibrations and can explain some of the calibration variability.



TIME?

Reasons for the poor repeatability - 2

- Shear effects on the regression results
  - Need more rigorous analysis of sensing height error and correction for this in the data (or a modified procedure)

- Turbulence effects on the regression results
  - Can be reduced by using and comparing vector means instead of scalar means

- Mast effects on the regression results
  - More careful attention needed here

- Lidar performance changes ? ?

Conclusions and outlook

- There is quite good correlation between old and new lidar calibration results with most differences contained within the limits of the repeatability.
- There is no evidence of significant long term drift.
- Calibration repeatability needs to be improved by better understanding of the shear and turbulence effects.
- This improved understanding will also reduce the differences in lidar performance between different sites. This will further decrease the uncertainties in lidar wind speed measurements.
- We are working on these issues in the Bankable Lidar project and also under the IEA Annex32.

Acknowledgments to my co-authors