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Taking the motion out of floating lidar: A method for correcting estimates of turbulence intensity

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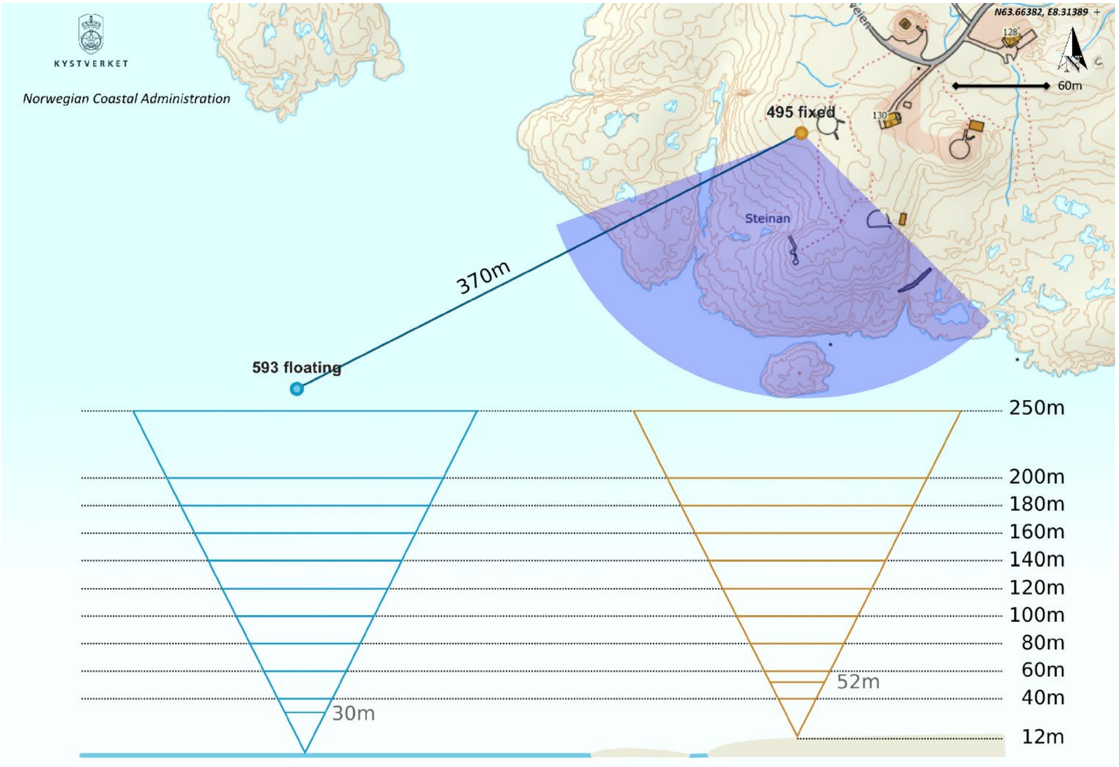
Setup (1/2): SEAWATCH wind lidar buoy

- ZX300M wind lidar (ZX Lidars)
  - Doppler spectra, 49Hz
- MRU 6000 IMU (Norwegian Subsea)
  - 6 DOF motion, 50Hz
- Embedded PC
- GPS time server

Setup (2/2): Land based reference lidar

- Onshore reference lidar (ZX300)
- Frøya, Norway
- One month of data: April/May 2019
- 11 heights
  - 10 comparable: 30-250m a.s.l.
- Offshore sector



Objective: Removing motion induced turbulence

Buoy motion increases estimates of turbulence intensity (TI)

- Compensate for the motion induced TI

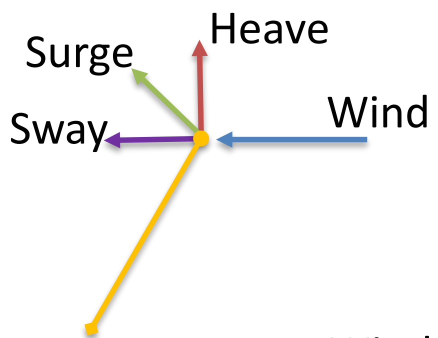
$$TI_{lidar,floating} = TI_{lidar,fixed}$$

- ~~Improve lidar estimated TI values~~

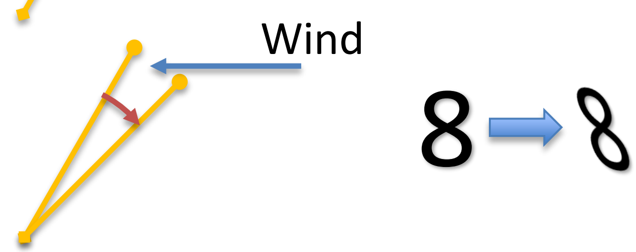
Approach

Compensation for **every single line-of-sight** measurement

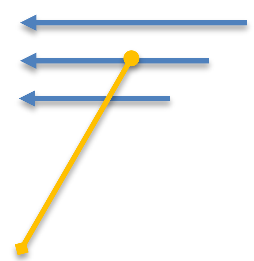
1. Translatory motion
   (Changed radial velocities)



2. Changing scanning geometry
   (Figure-of-eight fitting)

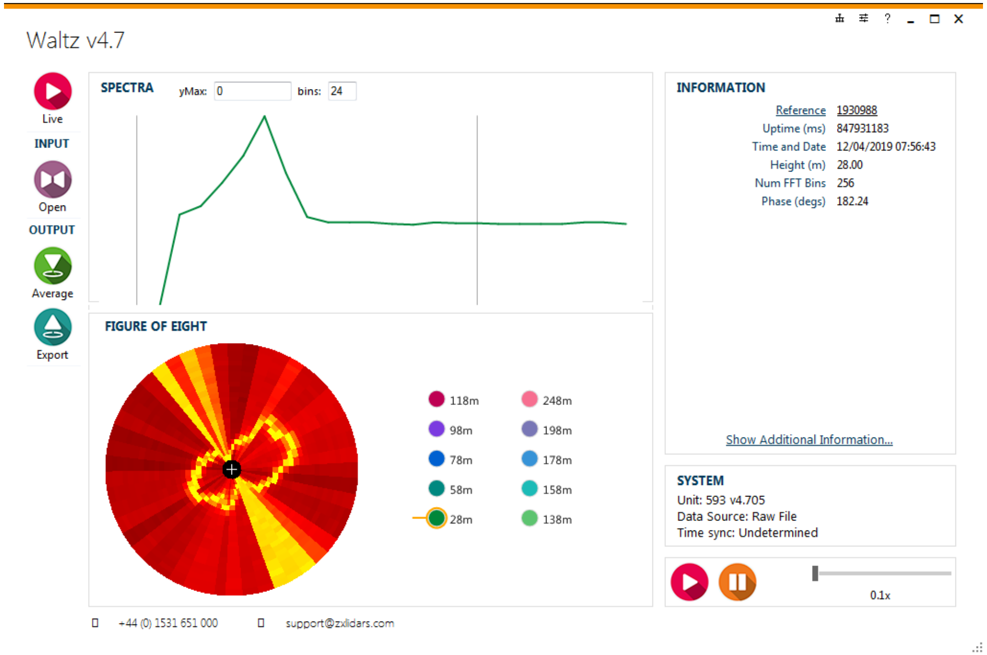


3. Wind shear and veer
   (Changing measurement height)



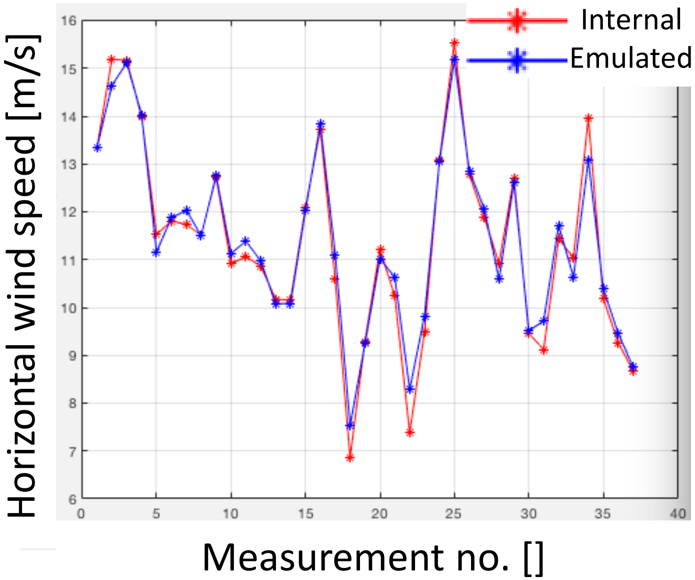
Challenge 1: Access to line-of-sight data

- Embedded PC onboard
- Remote connection
- Waltz stream to file
- Files contain Doppler spectra but no radial velocities
- Determine radial velocities from Doppler spectra

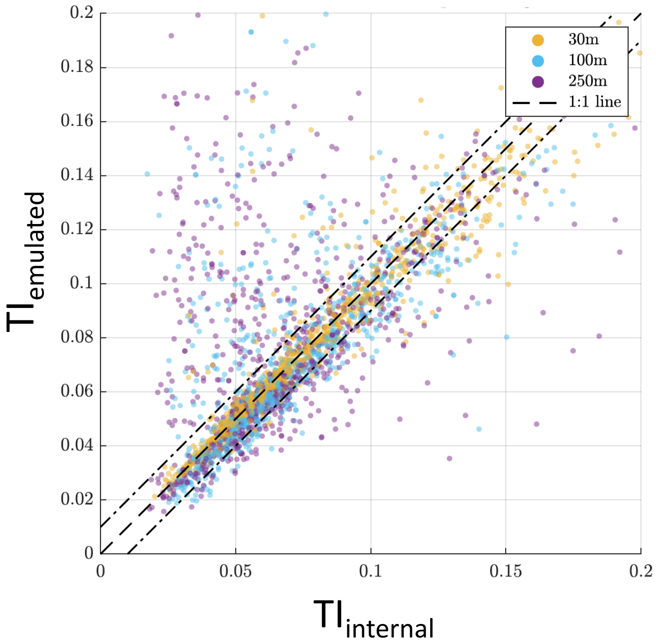


Challenge 2: Emulate data processing (1/2)

- Wind vectors reconstructed by the unit's internal and my emulated processing are similar but **not identical**:



TI: emulated vs. internal processing



Height	$\lvert TI_{emu} - TI_{int} \rvert > 0.01$
30 m	18.8%
100 m	33.4%
250 m	49.5%

- The effect is stronger for **higher elevations**
- Potential reasons:
  - Advanced **radial velocity determination** from Doppler spectra (Cloud detection)
  - Filtering of certain "bad" radial velocities

➢ We **cannot imitate the ZX300** processing exactly

Challenge 2: Emulate data processing (2/2)

- As a consequence we will use three different datasets:

1. **Land reference**: Data as it comes out of fixed unit 495
2. **Floating uncompensated**: Data as it comes out of floating unit 593
    I. **Emulated uncompensated**: Data of unit 593 processed in a conventional way by my *own code*
    II. **Emulated compensated**: Data of unit 593 processed in a conventional way by my *own code with motion compensation*
3. **Floating compensated**:

$$\text{Floating uncompensated} - \underbrace{(\text{Emulated uncompensated} - \text{Emulated compensated})}_{\text{Motion compensation}}$$

➢ The aim is to see the **same results** between 1. & 3.

Challenge 3: Time synchronization (1/2)

	Date	Time	IMUTimestamp_[-]_[-]
1	Date	Time	IMUTimestamp_[-]_[-]
2	03/04/2019	53:01.7	2597921063

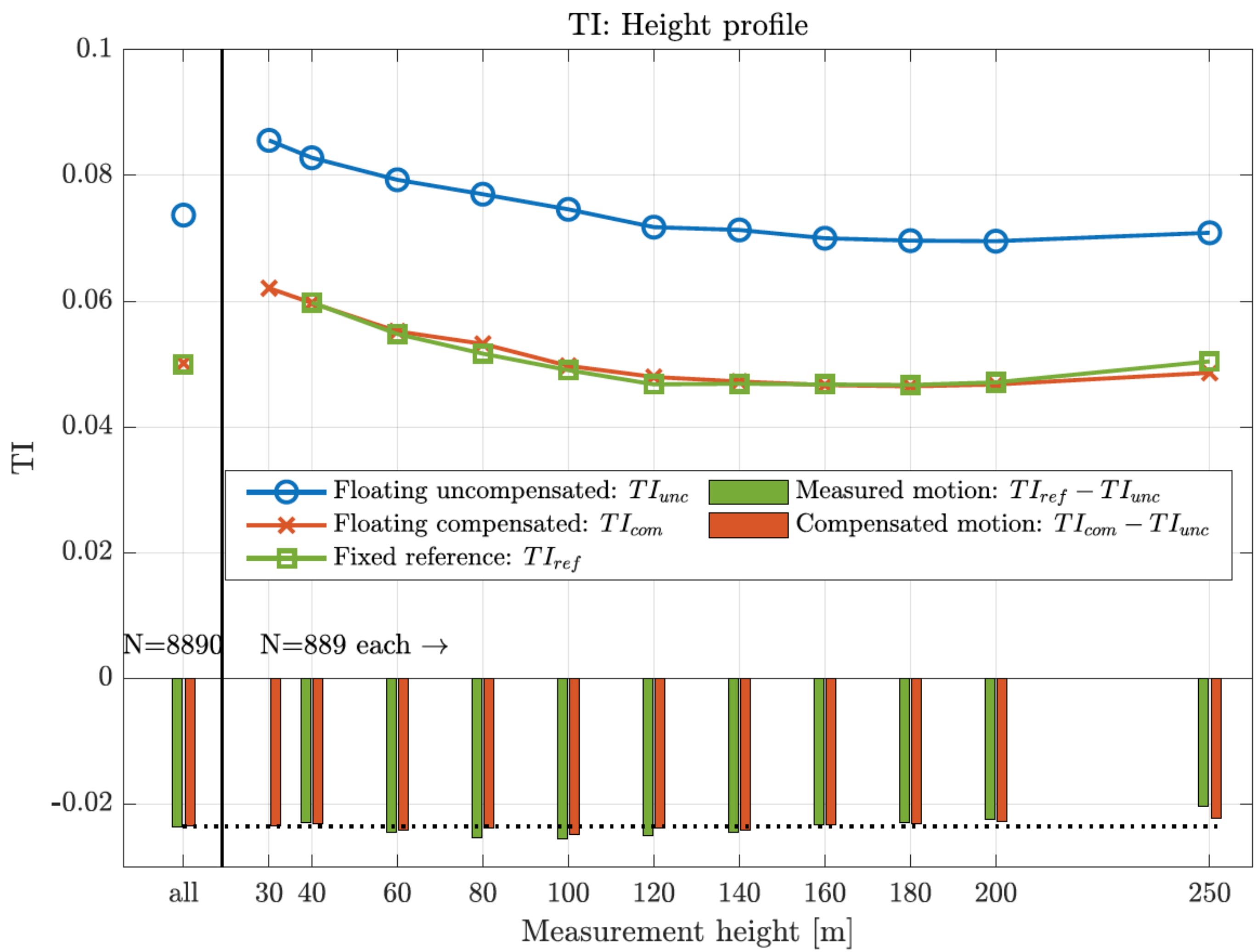
- **MRU** timestamp can be used directly (hh:mm:ss.xxxx)

	Time and Date	Timestamp (s)	Uptime (ms)
1	Time and Date	Timestamp (s)	Uptime (ms)
2	04.04.2019 20.52.57	621809577	203314069

- **Lidar** Timestamp (hh:mm:ss) and Uptime value (ms) are independent
  - Uptime values are slower than Timestamp. Approx. 1.2s shift per day -> Reset once per day

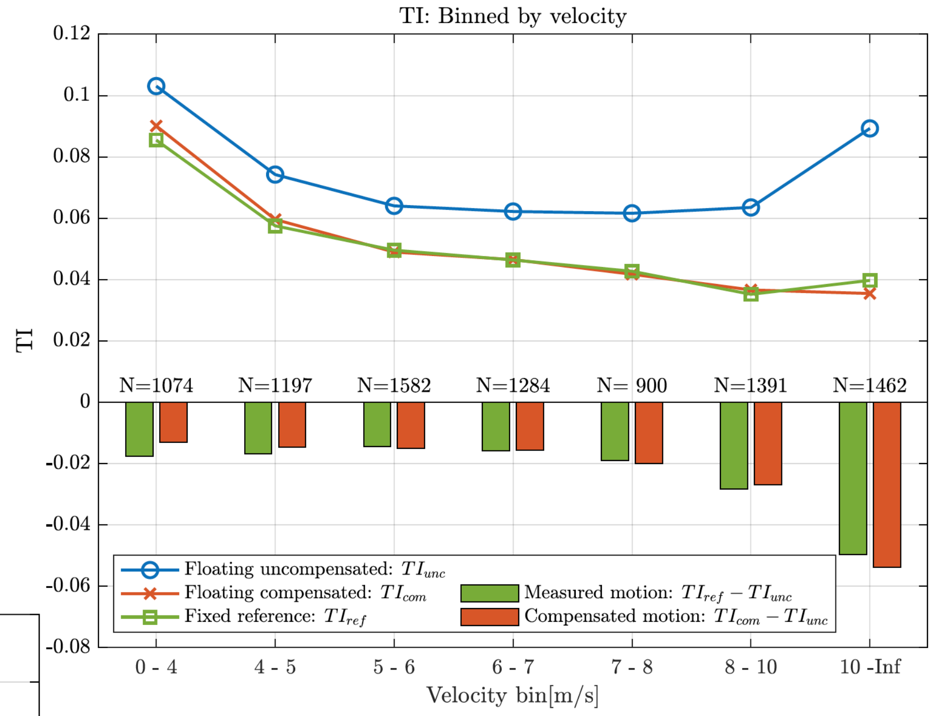
➢ Motion and wind data must be synchronized

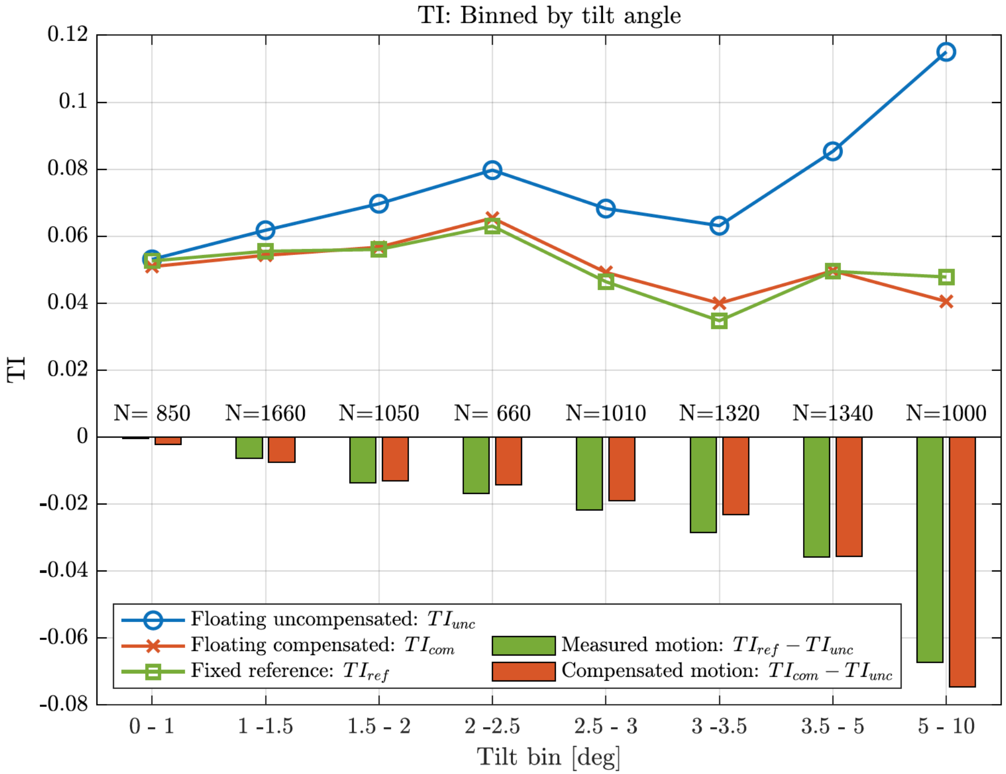
Results (1/4): TI vertical profile



Results (2/4)

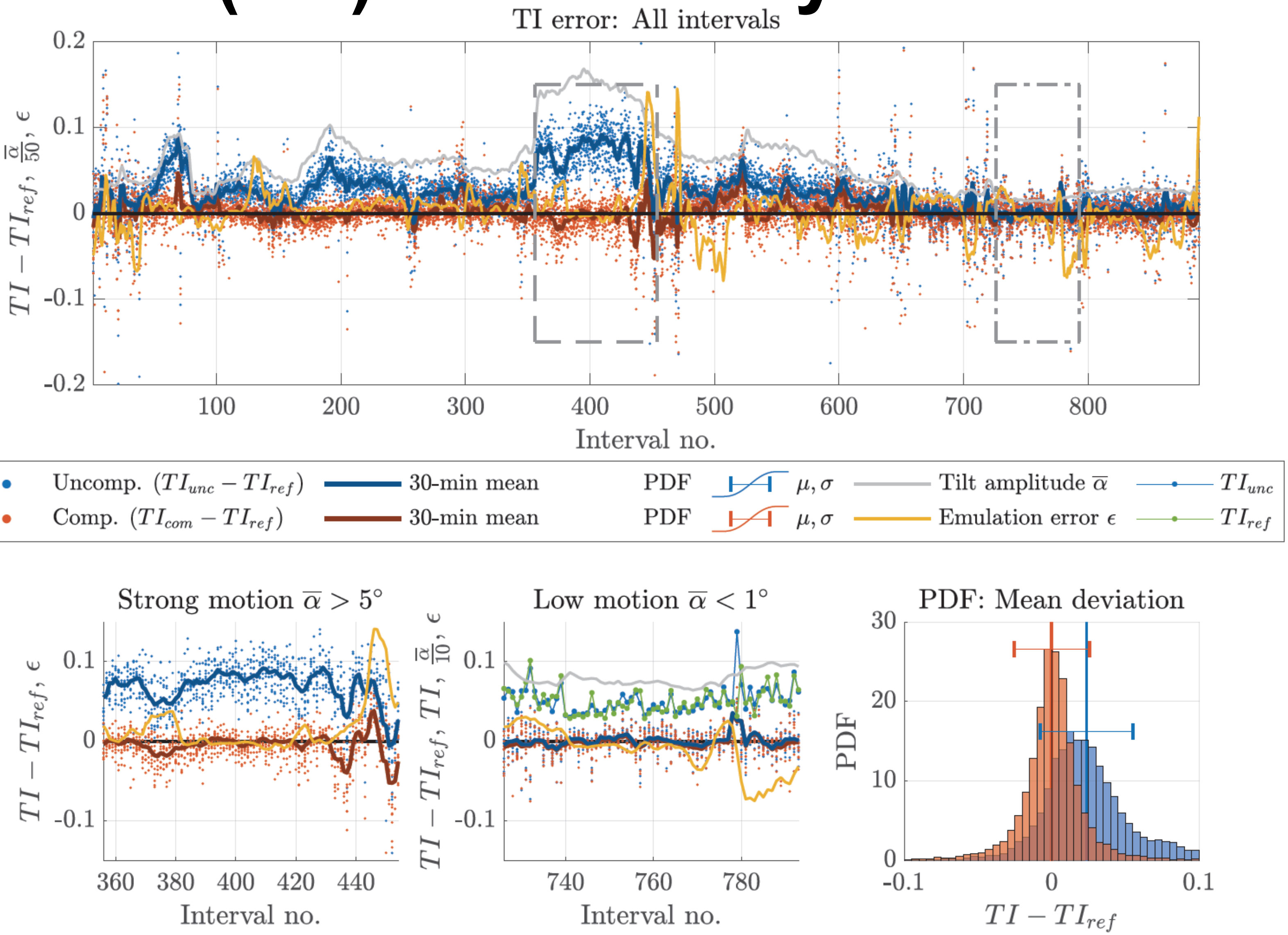
TI binned by wind velocities



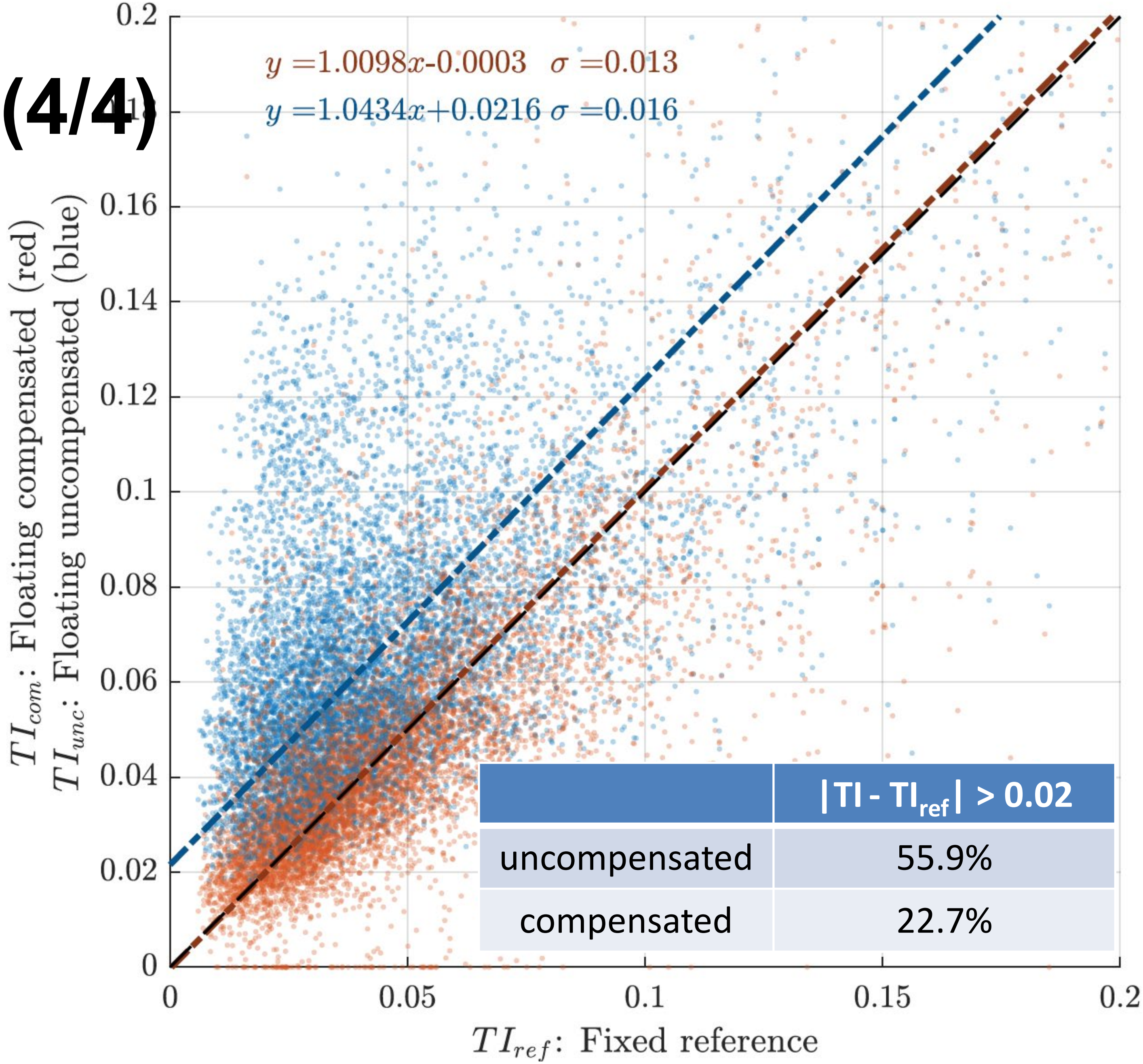


TI binned by buoy tilt angle

Results (3/4): Error analysis



Results (4/4)



	$\lvert TI - TI_{ref} \rvert > 0.02$
uncompensated	55.9%
compensated	22.7%

Conclusions

Motion compensation on line-of-sight level works very well!

- Drawbacks:
  - Cumbersome acquisition of line-of-sight velocities
  - No knowledge about filter on line-of-sight level
  - No direct time synchronization
  - Not many samples per 10min per height
  - Large distance between the two lidar units

When time series of wind data are not required there might be a simpler solution

BTW: Horizontal mean wind speeds are also corrected

Thank…

… you for your attention and…

Statens vegvesen

ENERSENSE

…for funding this project.