

APPLICATION OF GAUSSIAN PROCESSES TO SCANNING LIDAR MEASUREMENTS

NASSIR CASSAMO, MARCO TURRINI, JAN WILLEM WAGENAAR
WIND TECHNOLOGY WORKSHOP | 24TH JUNE | BRUSSELS

› AGENDA

WHAT'S ON THE MENU TODAY ?

0. BACKGROUND INFORMATION
1. APPLICATION OF GAUSSIAN PROCESSES
2. GAUSSIAN PROCESS BASED MULTI LIDAR
3. CONCLUSIONS

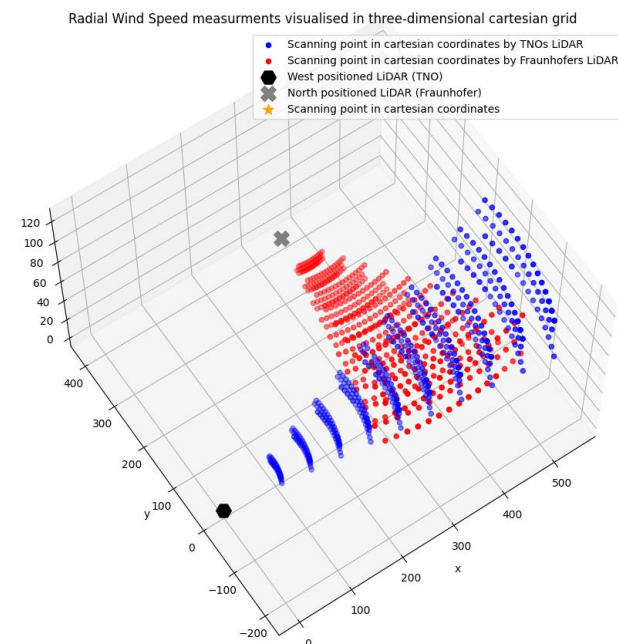
APPLICATION OF GAUSSIAN PROCESSES TO SCANNING LIDARS

(0/3) BACKGROUND INFORMATION

- › **Aim:** Test Gaussian Processes suitability and data driven wind field reconstruction algorithm with 2 scanning Lidars. Relevant setup/instrumentation:
 - › TNO **scanning** Lidar (WindCube 200s) at **SL1**; ~283m from Met Mast.
 - › Fraunhofer **scanning** Lidar (WindCube 200s) at **turbine location**; ~388m from meteorological mast.
 - › 115m IEC conform Met Mast with cup anemometer and sonic anemometer at the level of interest (55 meters).



Onshore campaign at Bremerhaven: LiDARs positioning with relation to met mast.
Source: AFFABLE

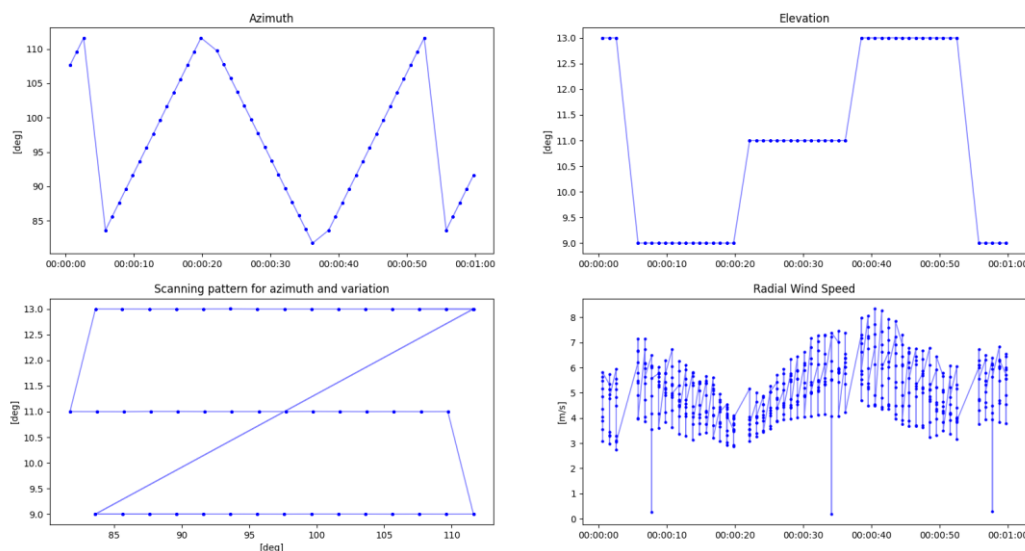


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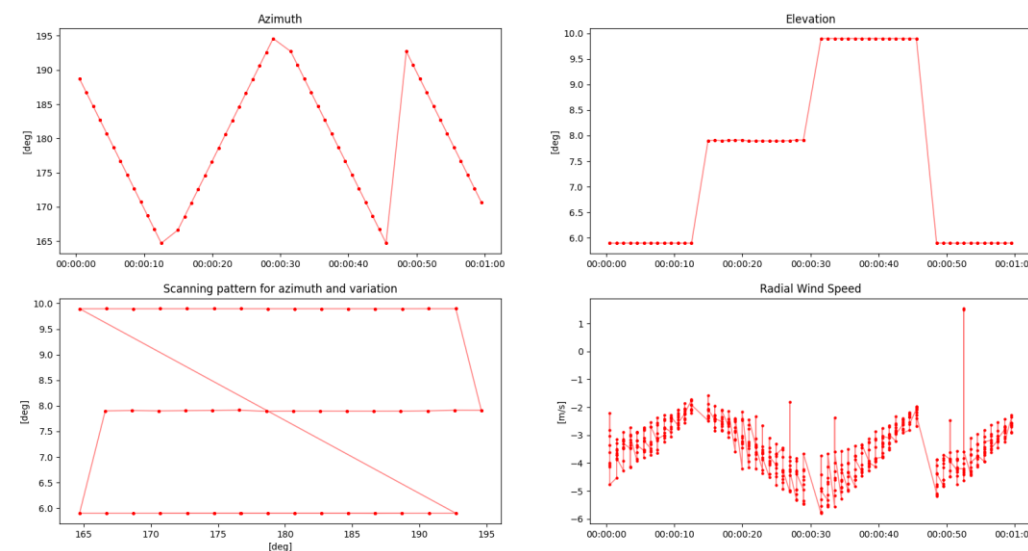
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Time window analysis. Total number of points of 526



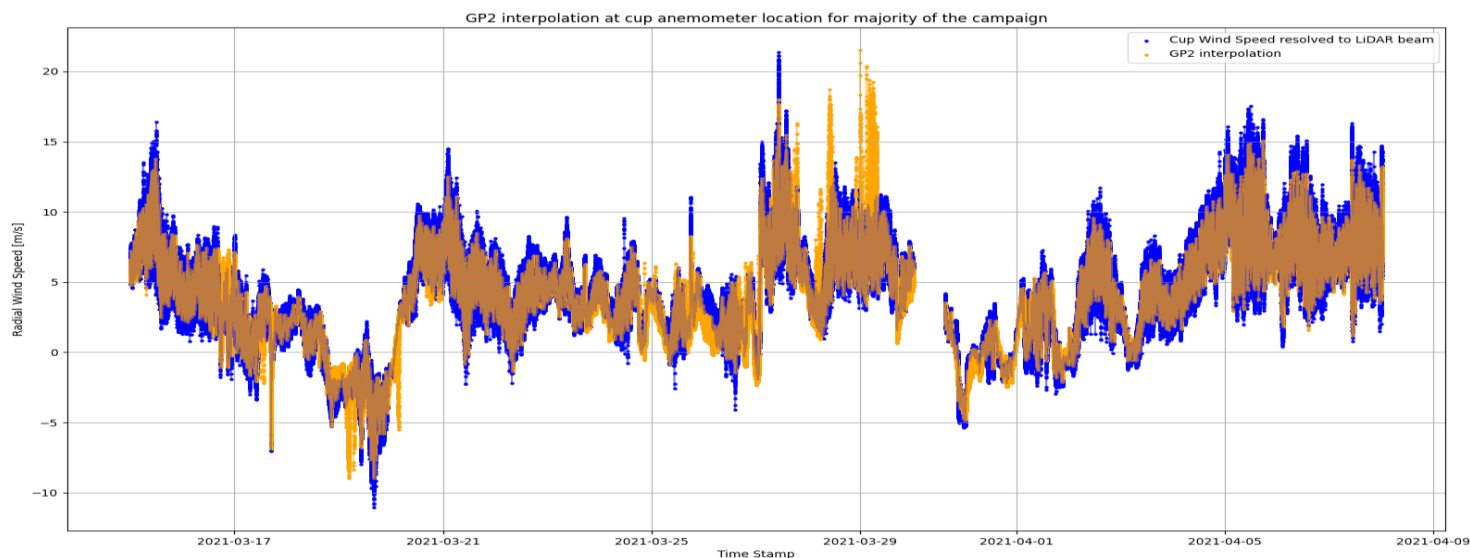
Time window analysis. Total number of points of 546



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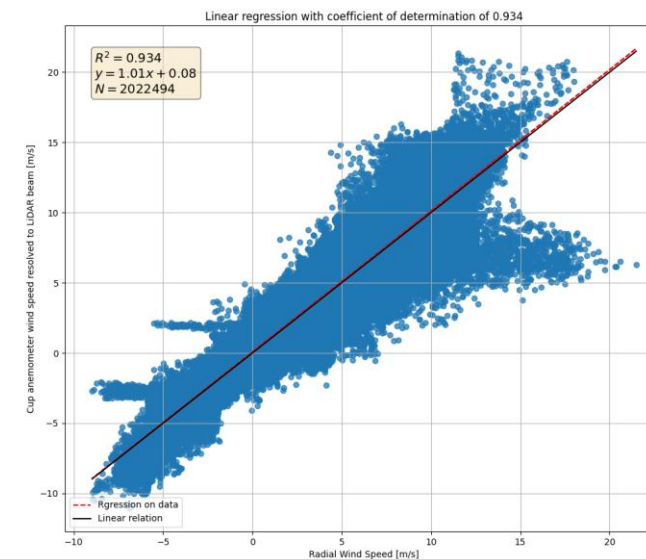
(1/3) APPLICATION OF GAUSSIAN PROCESSES

- How suitable are Gaussian Processes, a machine learning technique, to perform radial wind speed predictions?
- Comparison between the prediction of the Gaussian Process model at the cup location for all time instants and the 1Hz cup anemometer horizontal win speed projected onto the LiDAR LOS for the complete onshore campaign of approximately 3 weeks.
- Good matching between the two, with an **R2 value of 0.934** and linear relation of **$1.01x+0.08$** . 2 million data points used for this regression.



Comparison of cup anemometer wind speed resolved to LiDAR beam (blue) and Gaussian Process interpolation (orange) for the majority of the onshore campaign. Gap in data is due to inexistence of data from the LiDAR at a short time window, which difficults the application of the GPs.

Source: AFFABLE



Regression analysis between cup resolved to LiDAR LOS (disregarding vertical wind component, vertical axis) and Gaussian Process prediction (horizontal axis). 15th of March to 7th of April.

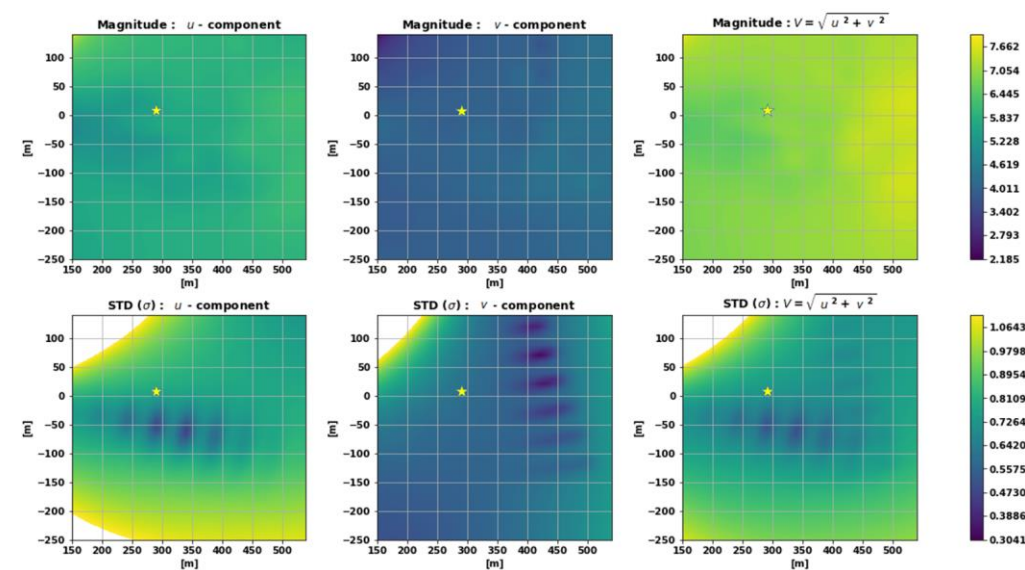
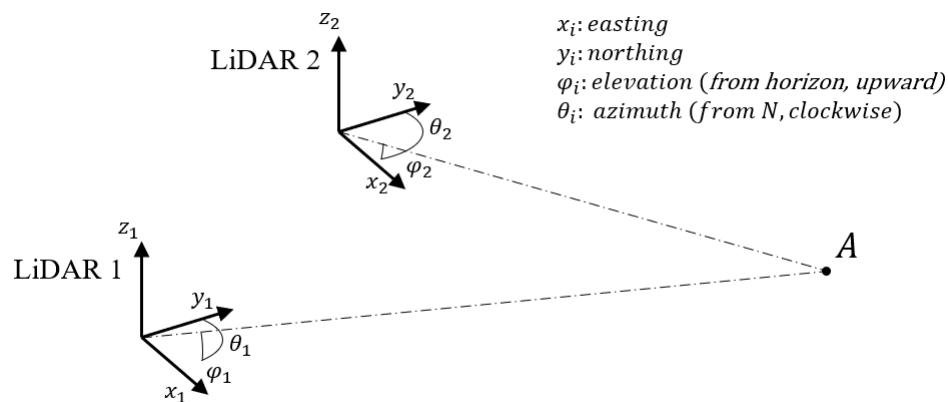
Source: AFFABLE



APPLICATION OF GAUSSIAN PROCESSES TO SCANNING LIDARS

(2/3) GAUSSIAN PROCESS BASED MULTI LIDAR

- How can we leverage the two LiDARs and the Gaussian Process Model to perform high frequency two dimensional wind field reconstructions?
- By fitting one Gaussian Process model to each one of the scanning LiDARs, it is possible to **predict radial wind speeds at the same point in space and time**. Those predictions can be used to reverse engineer the horizontal wind speed components.
- The uncertainty related to the horizontal wind speed components can be estimated by propagating the uncertainty from the radial wind speed prediction.



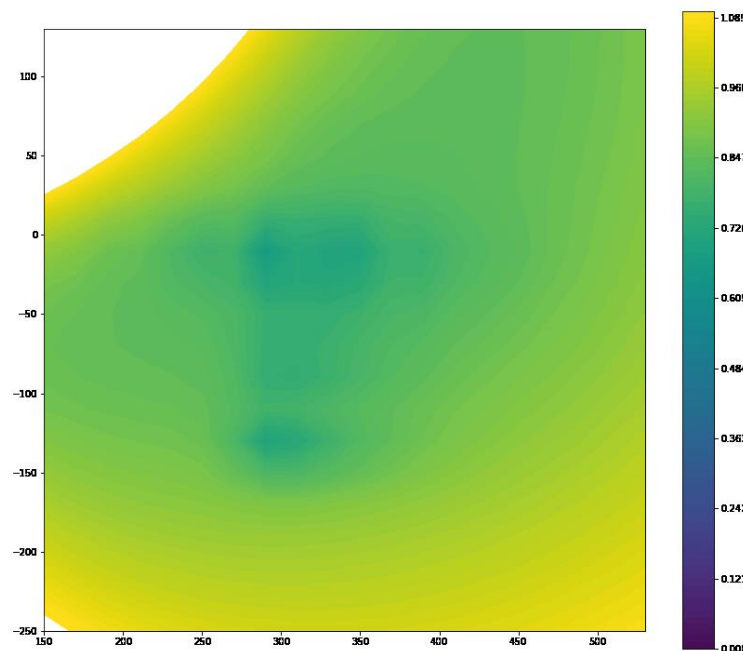
Wind Field Reconstruction (u , v and resulting magnitude) and associated standard deviation (proxy for uncertainty)



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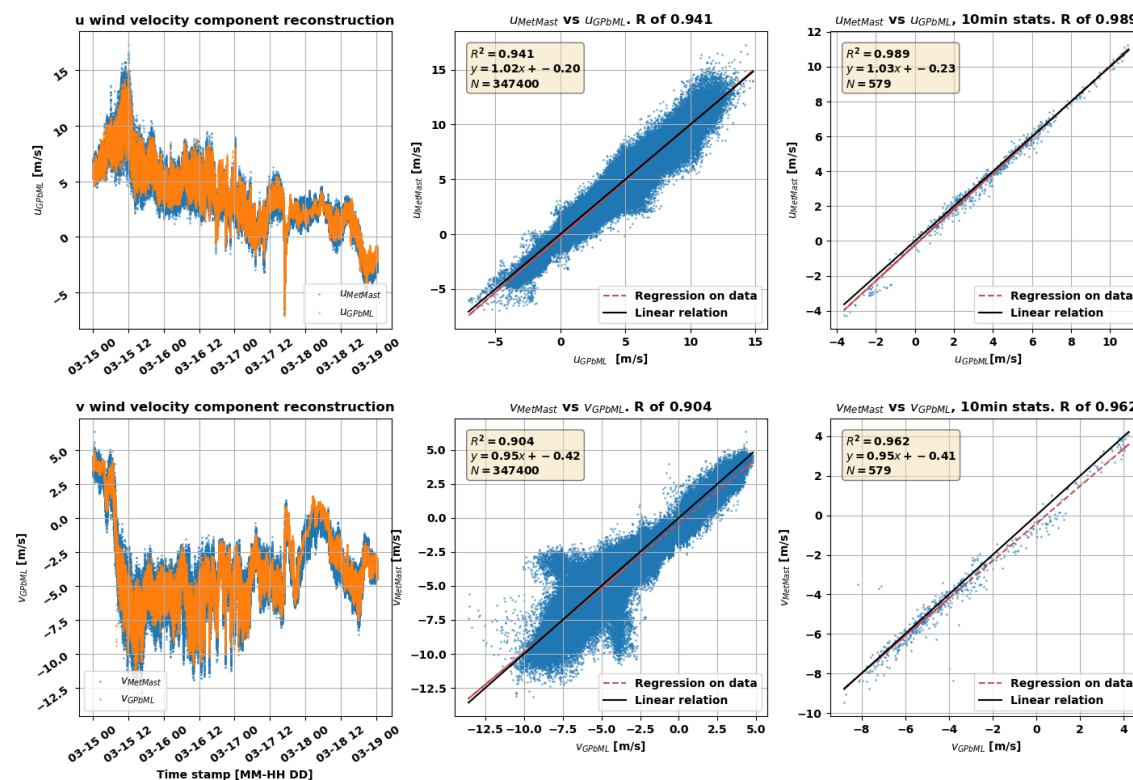
- › How can we leverage the two LiDARs and the Gaussian Process Model to perform high frequency two dimensional wind field reconstructions?
- › By fitting one Gaussian Process model to each one of the scanning LiDARs, it is possible to **predict radial wind speeds at the same point in space and time**. Those predictions can be used to reverse engineer the horizontal wind speed components.
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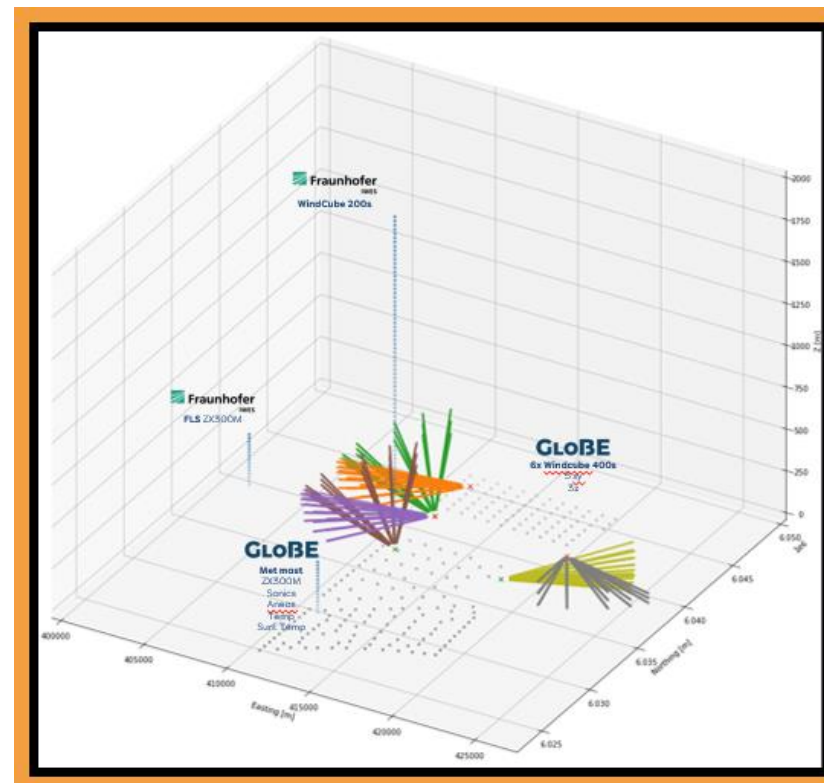
- How can we leverage the two LiDARs and the Gaussian Process Model to perform high frequency two dimensional wind field reconstructions?
- Using a time window of 4 days, the comparison of measured and estimated for the u components yields a R^2 of 0.937 and linear fit of $y=1.02x-0.19$. For the v the comparison yields a R^2 value of 0.892 and a linear fit of $y= 0.96x-0.45$.



APPLICATION OF GAUSSIAN PROCESSES TO SCANNING LIDARS

(3/3) KEY TAKEAWAYS AND FUTURE WORK

- › Gaussian processes are a **suitable technique** to interpolate radial wind speed measurements from scanning LiDARs. This campaign further strengthens the evidence we gathered in previous campaigns towards these conclusions.
- › The developed methodology to reconstruct two dimensional wind speeds **has been successful as a proof of concept**. This methodology where two independent Gaussian Processes are computed with data from 2 distinct LiDARS are going to be used to extract more value from an offshore campaign aiming at identifying global blockage effects.



"Schematic of GloBE measurement equipment. Solid colored lines represent the scanning patterns of the WindCube 400s", by Christopher Rodaway, Kester Gunn and Sam Williams (RWE).

Source: [Sam William's article on LinkedIn](#)





› **THANK YOU FOR YOUR TIME**
QUESTIONS AND DISCUSSION

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This project is co-financed by TKI-Energy from the 'Toeslag' for Topconsortia for Knowledge and Innovation (TKI's) from the Ministry of Economic Affairs and Climate