

April 2023 - WindEurope - Copenhagen

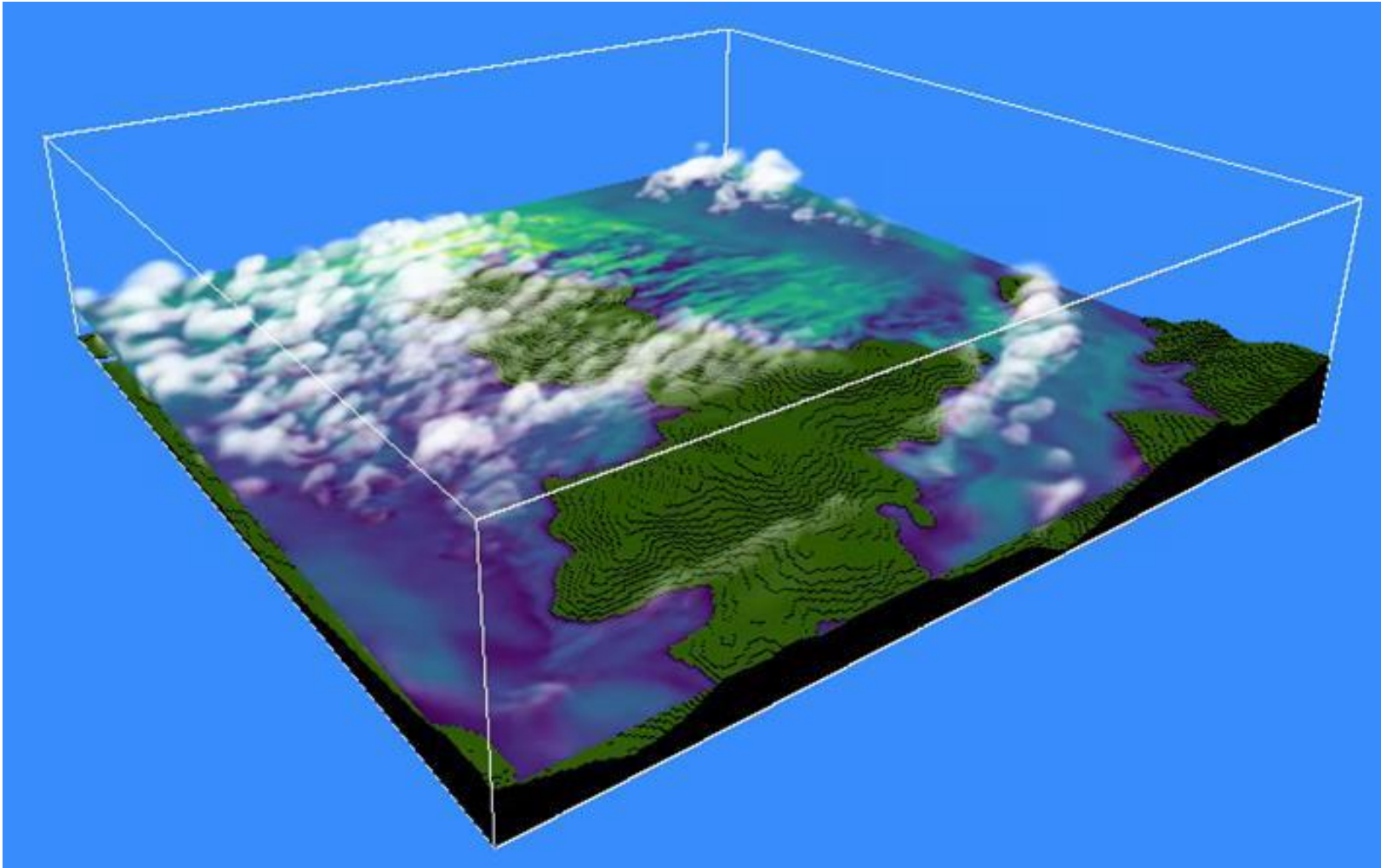
# Wind resource modelling of entire sites using Large Eddy Simulation

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**Why? → The Model → Validation → Results**

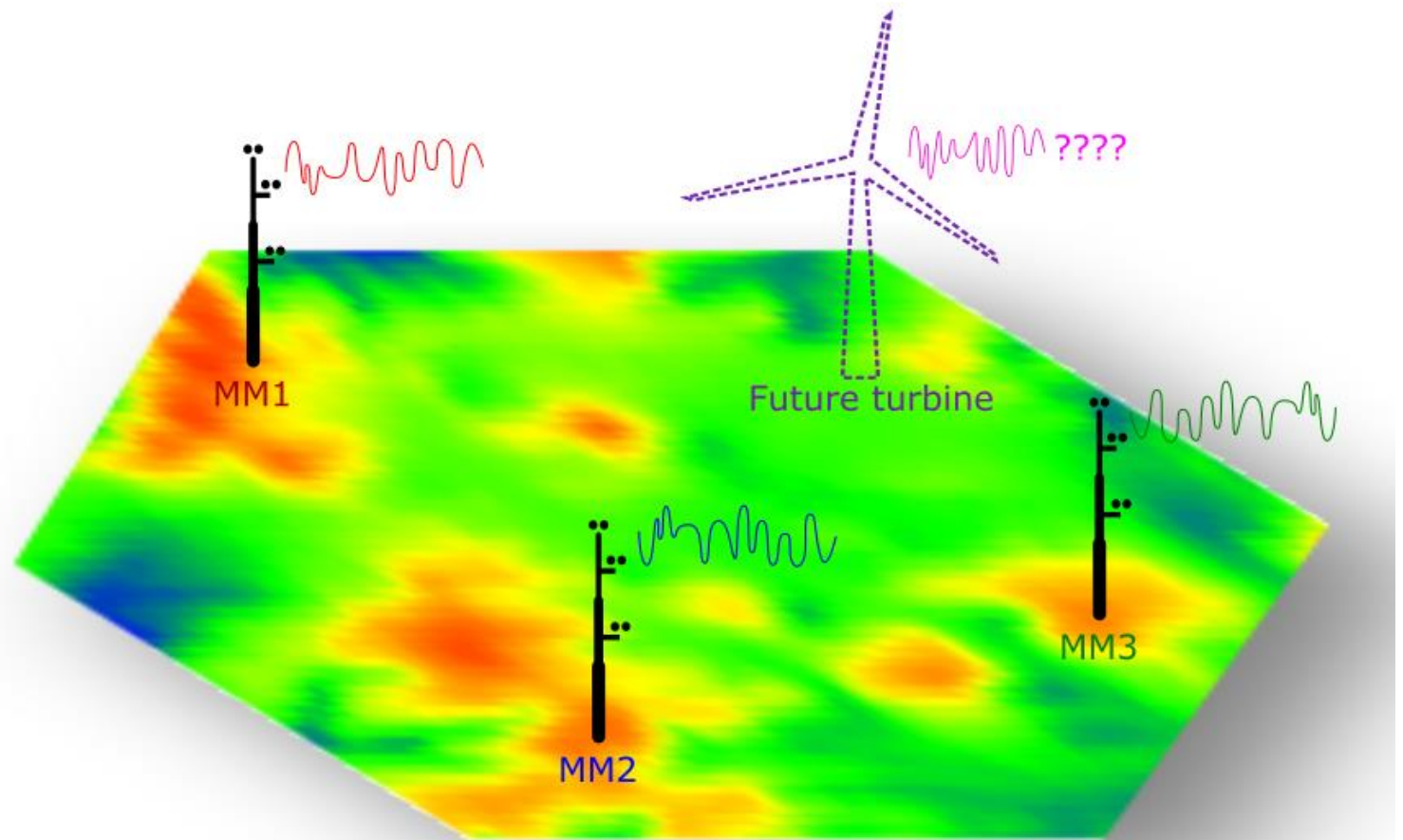
# Why?

***Met-masts are limited***

***Time dimension***

***Better physics***

***Accuracy***





# The Model

**Full atmospheric LES**

**GPU Resident**

**Coupled to large scale  
weather data**

***Developed by Whiffle*** in  
the Netherlands

# The Model

## Boundary conditions

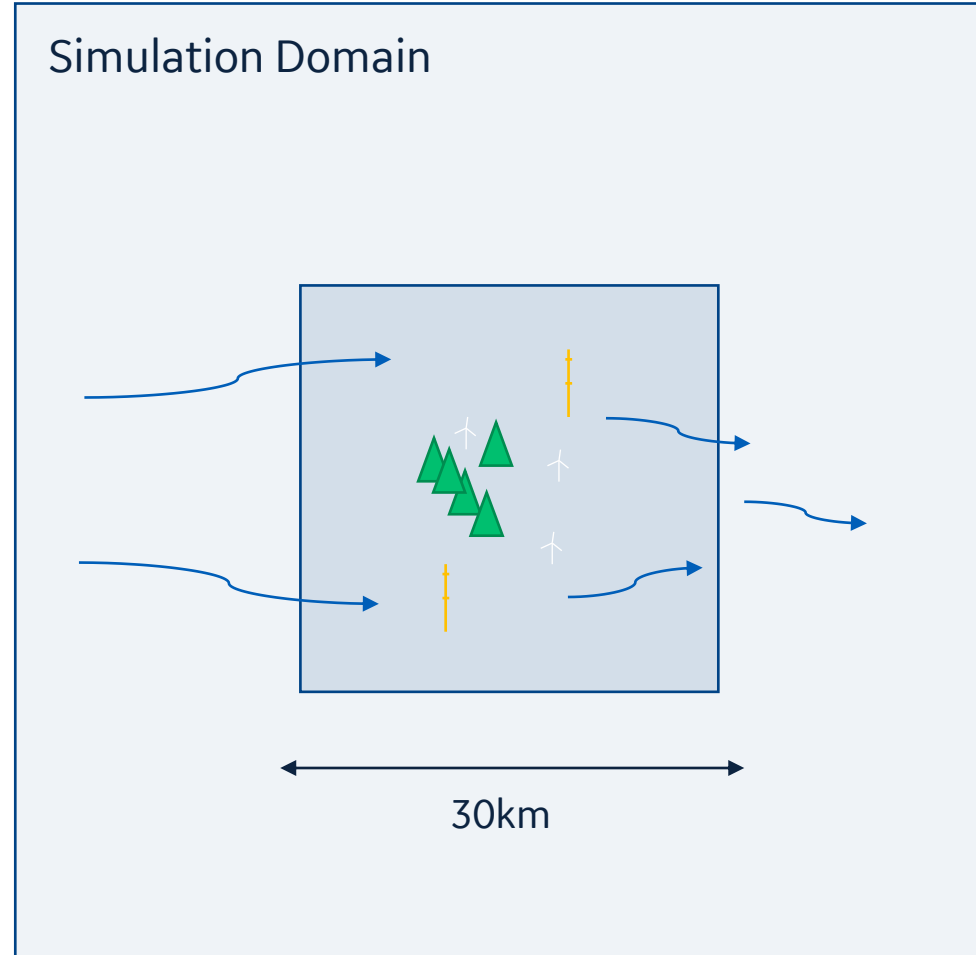
Driven by reanalysis data  
+ terrain + land-use

## Domain configuration

Downscale and refine  
Inner resolution: 50 – 100m

## Model Settings

Surface-air interaction  
SGS etc.



Site-wide 4D  
flow field

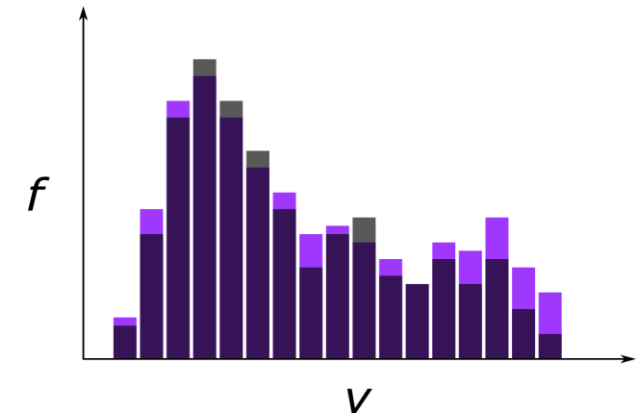
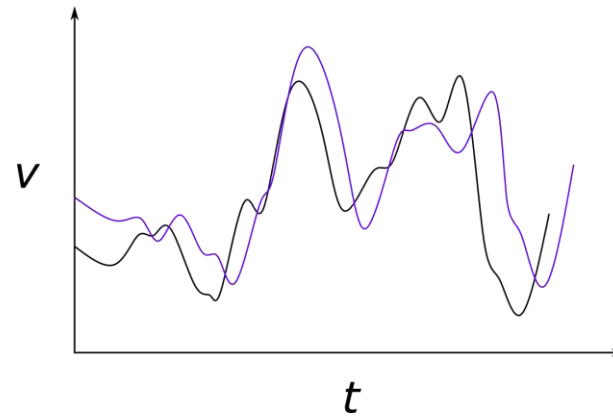
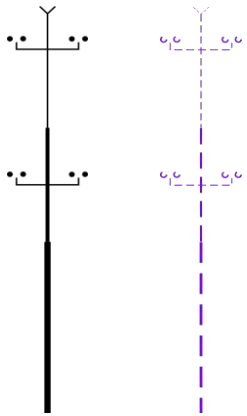
For WRA:

Simulate 365 days  
in parallel

Average compute  
time ~4 hrs per day

Record 10-  
min time-series  
of vel, std & dir

# Continuous Validation Approach



Simulate representative days  
from met-mast data

14 diverse sites  
~900km<sup>2</sup> each  
50+ masts

**Directly** compare  
10-minute time-  
series:  
vel, TI, dir.



MAE, diurnal cycles,  
correlations, spectra

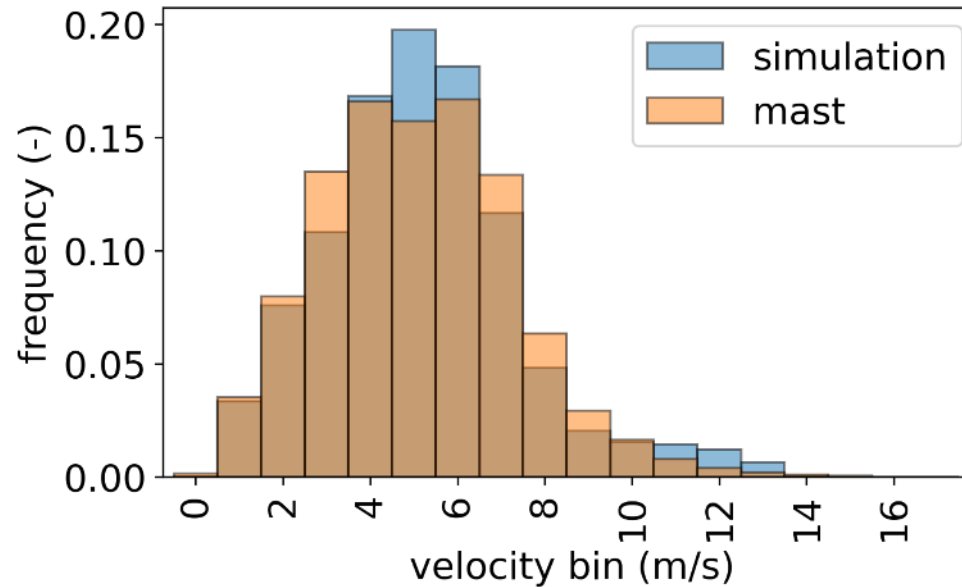
Compare aggregated  
distributions:  
vel, TI, dir.



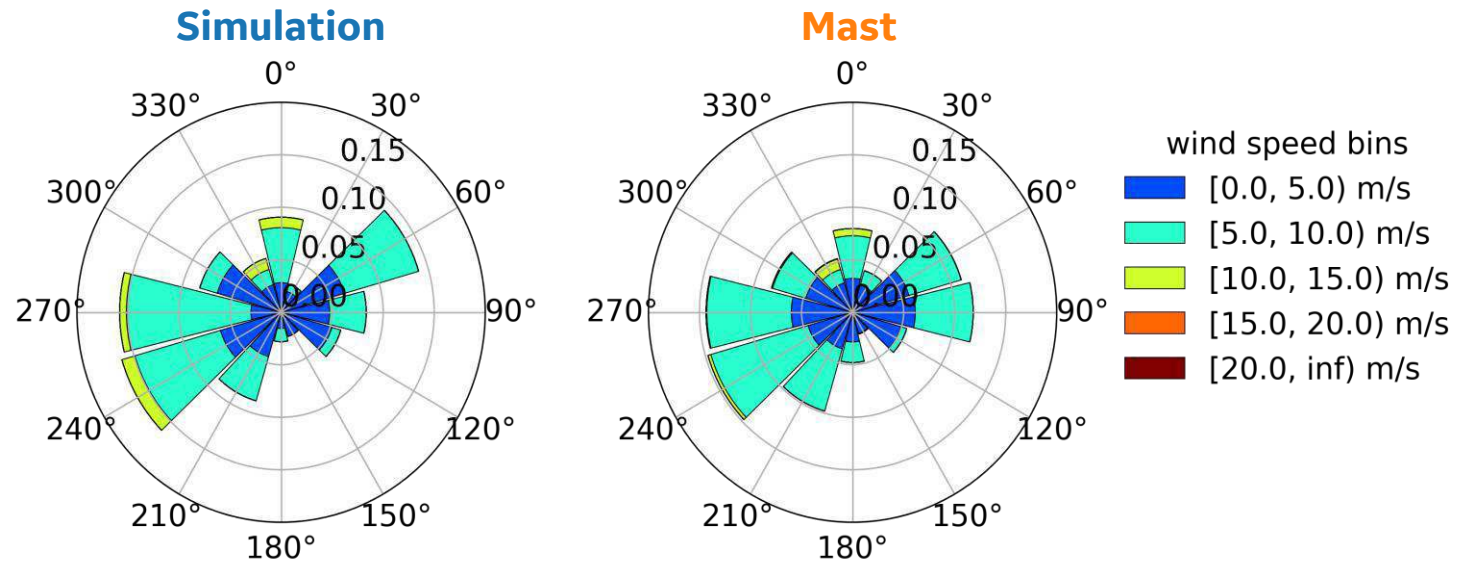
Biases,  
distribution errors

# Sample results: Wind speed & direction

American Site 1  
(a flat site)



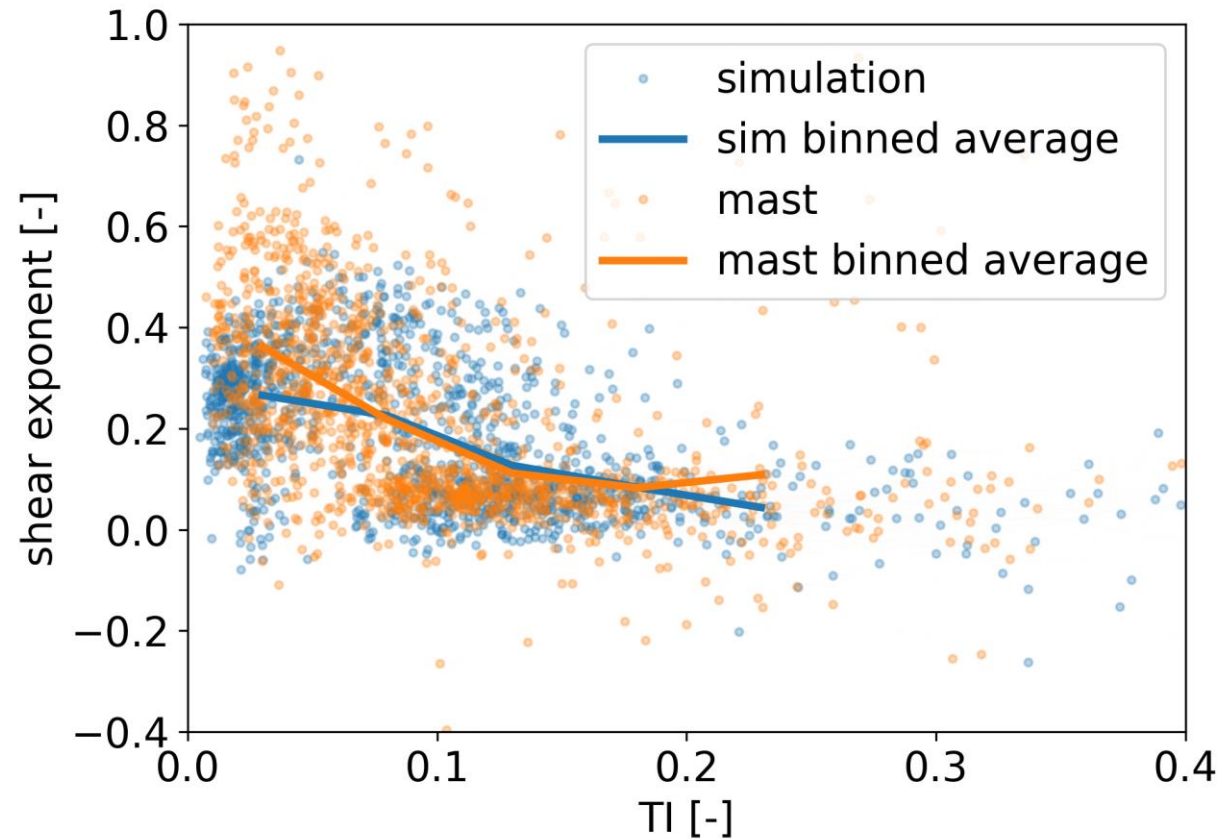
## Simulation vs Mast



# Sample results: Turbulence & Shear

American Site 2  
(a site with low level jets)

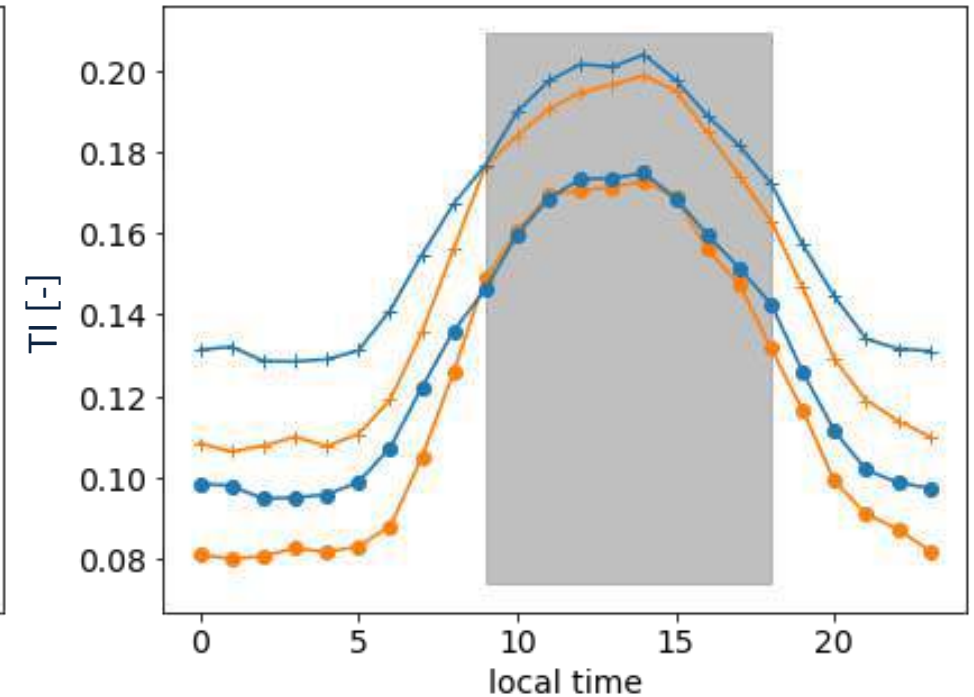
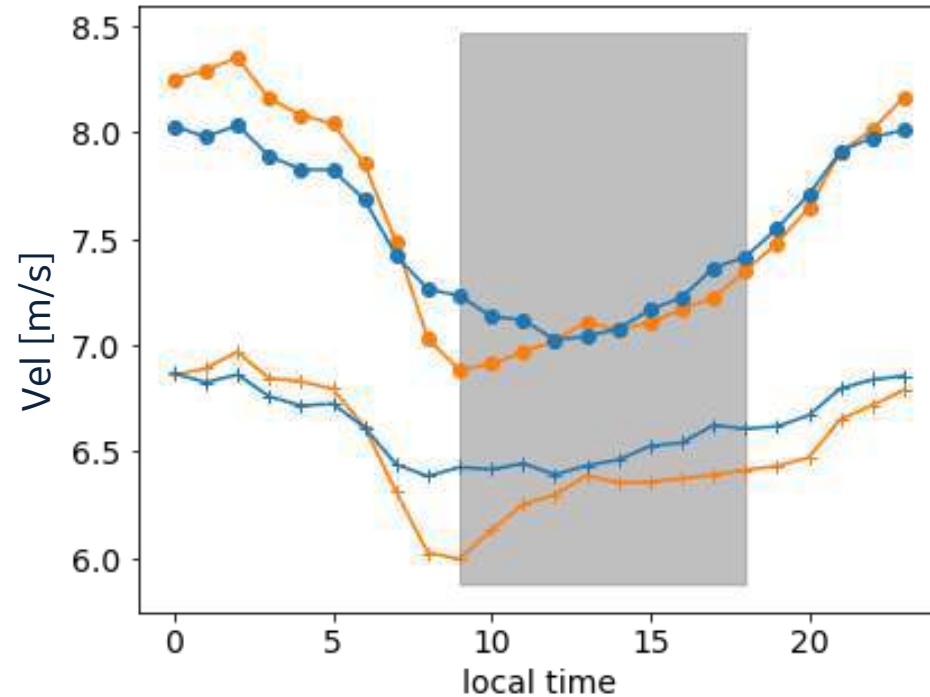
**Simulation vs Mast**



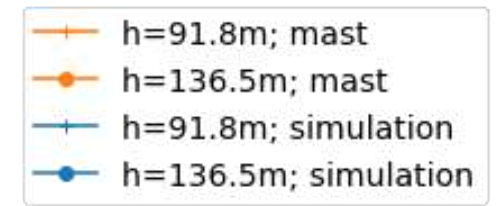


# Sample results: Temporal Information

Swedish Site  
(a moderately forested site)

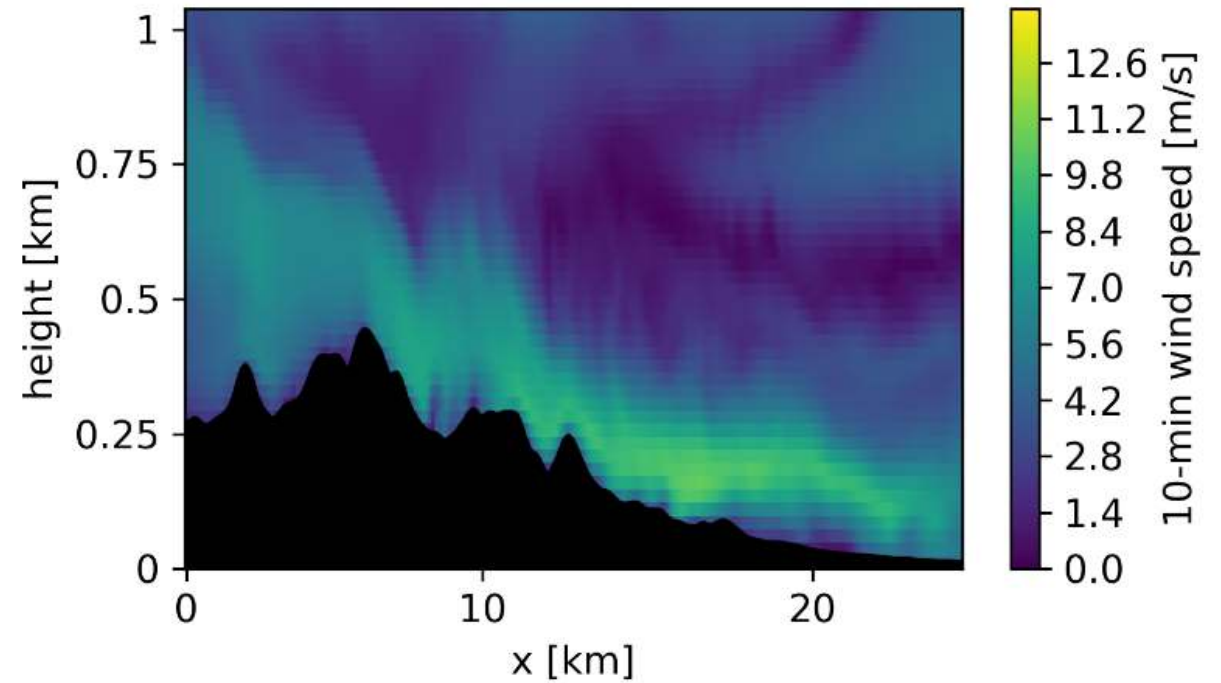
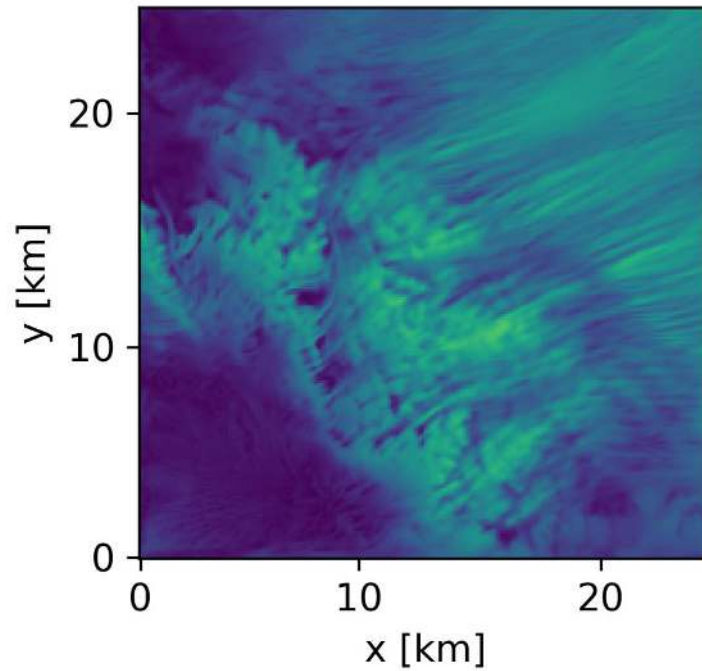


## Simulation vs Mast



# Sample results: Spatial Information

Complex Site  
(a site with  
mountain ridges)



# Overall results: Quantitative Metrics

Metric	Channel	Mean value over all sites
Mean Bias (Mast - Simulation)	velocity	0.4 m/s
	std(vel.)	0.004 m/s
Mean Absolute Error (distributions)	velocity	2.7%
	wind rose	2.9%
	TI mean curve	3%

# Takeaways

**LES is feasible for full-site WRA with GPUs**

**Enables resolution of time-series and turbulence which are key for WRA**

**Validation demonstrates good accuracy for a diverse set of sites**

**Opens the door to improved turbine siting and design**

# What Next?

**Turbine wake modelling**

**Forecasting?**

# Questions?

**Please get in touch!**

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Whiffle booth in the Dutch Village in hall C1 - B12

More details of this work can be found in our upcoming scientific paper on IOP Journal of Physics Conference Series