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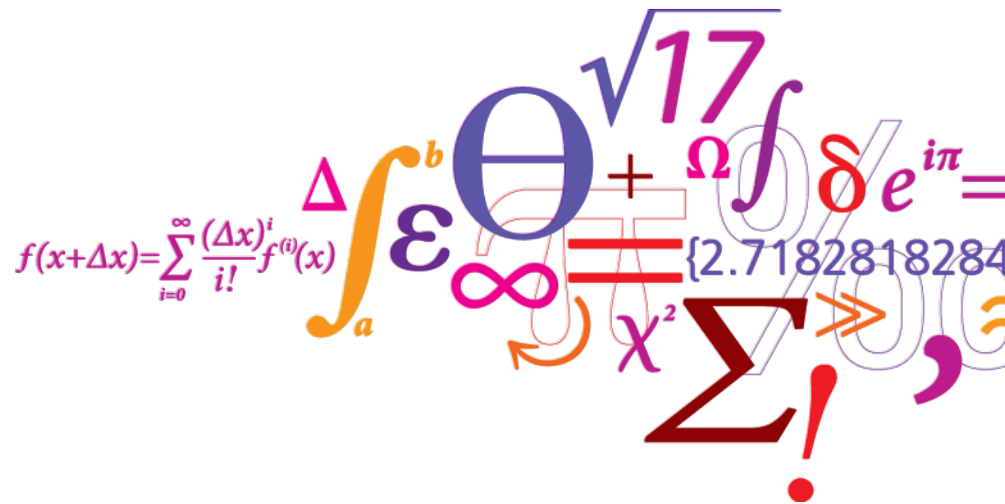
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Measuring offshore winds from onshore – *one lidar or two?*

Nikola Vasiljević, Michael Courtney, Alfredo Peña,
Guillaume Lea and Andrea Vignaroli

11/03/2015

EWEA Offshore 2015, Copenhagen

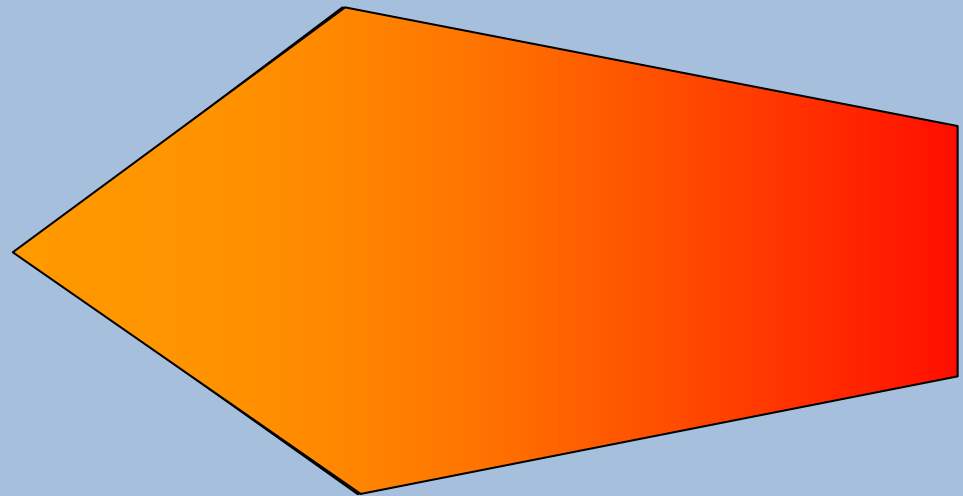


Estimation of near-shore wind resource

Land

Sea

Area of future wind farm

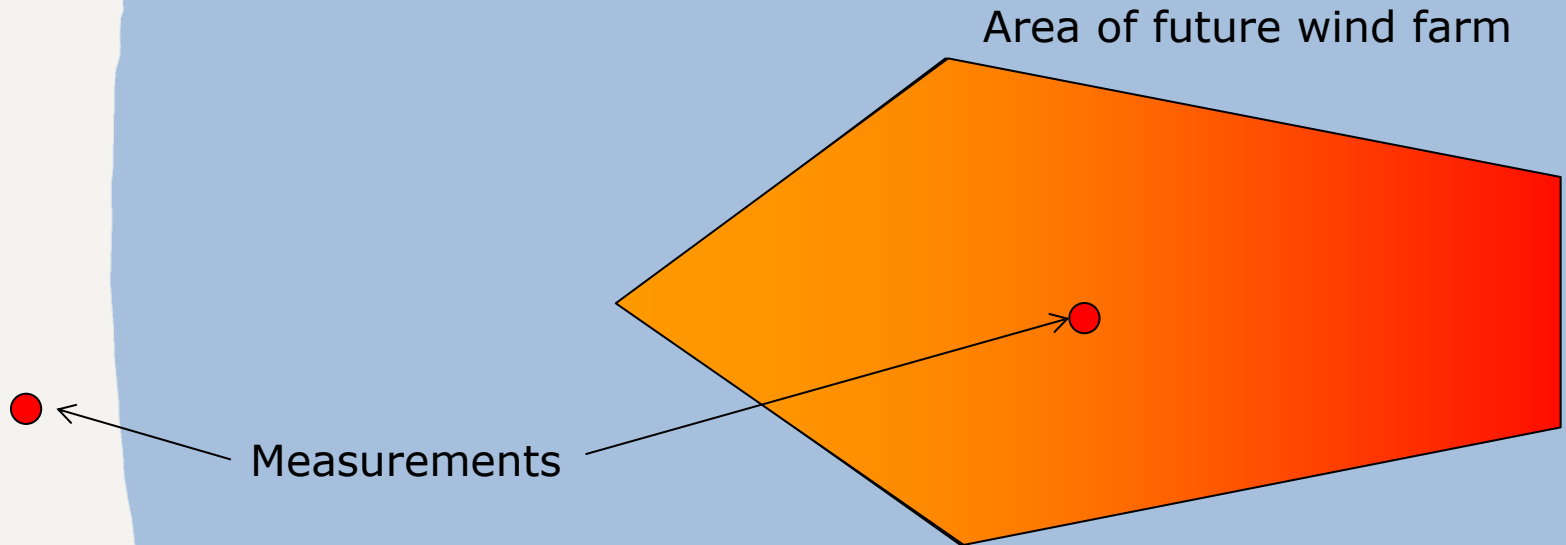


Technique	Pros	Cons
Mesoscale models	Cheap	Uncertainty of prediction up to 10%

Estimation of near-shore wind resource

Land

Sea



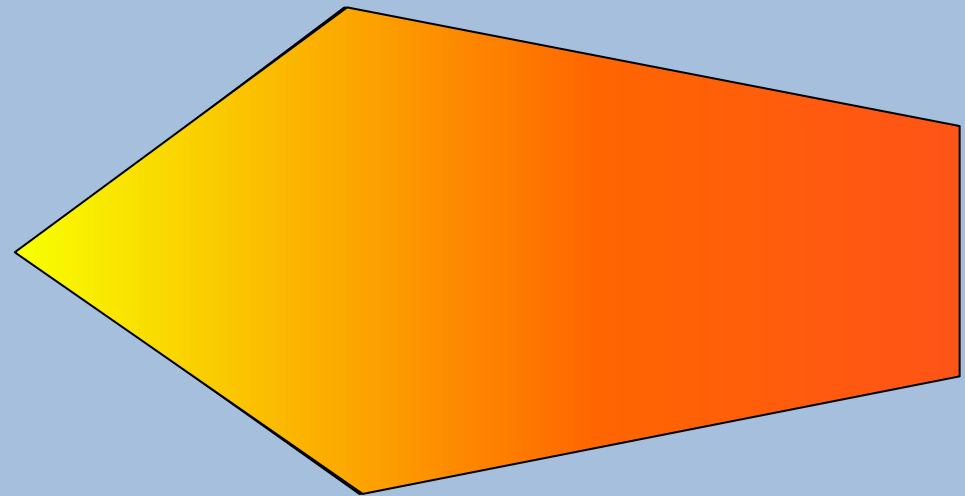
Technique	Pros	Cons
Mesoscale models	Cheap	Uncertainty of prediction up to 10%
Mesoscale models + local measurements		

Estimation of near-shore wind resource

Land

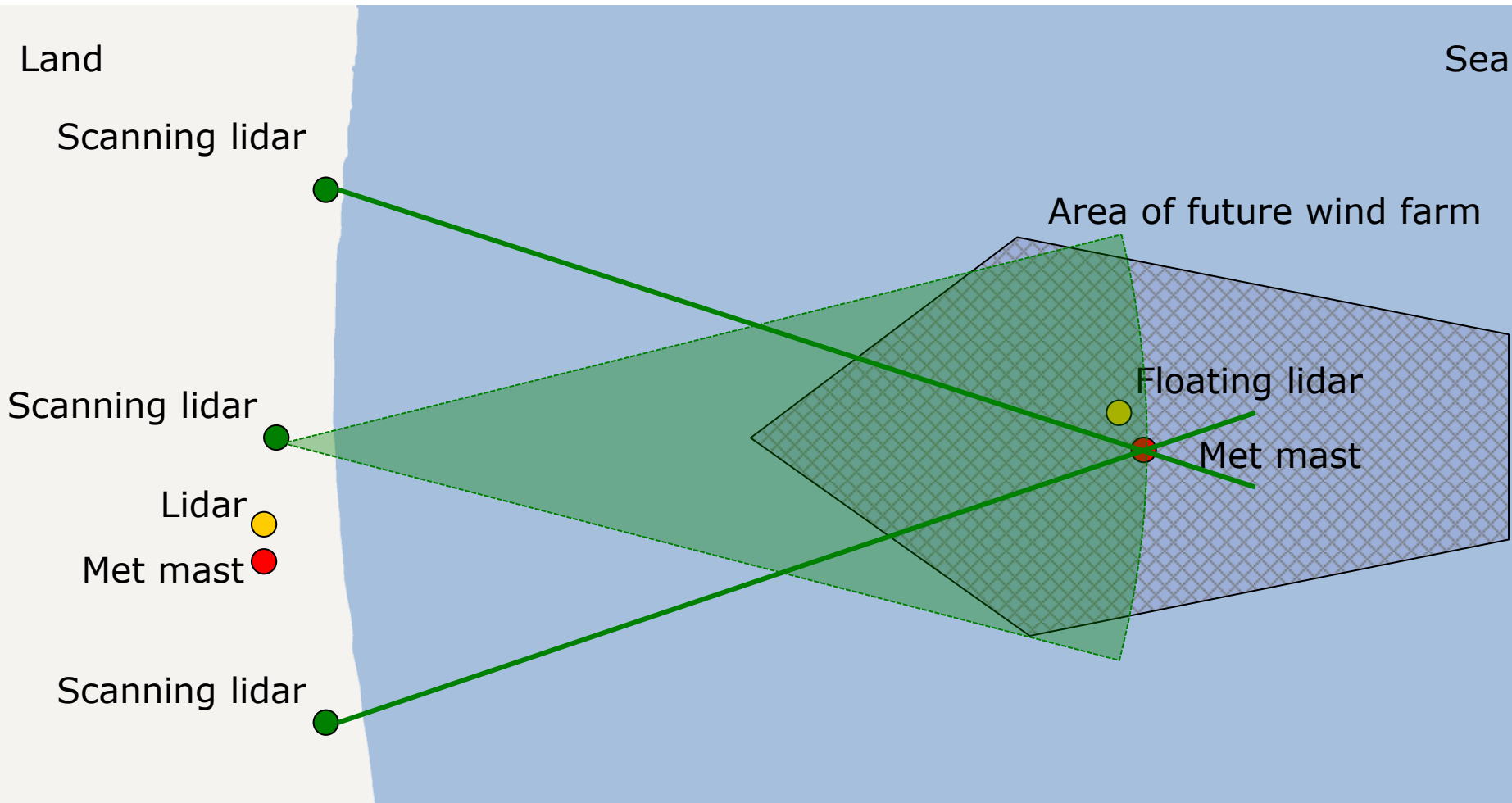
Sea

Area of future wind farm



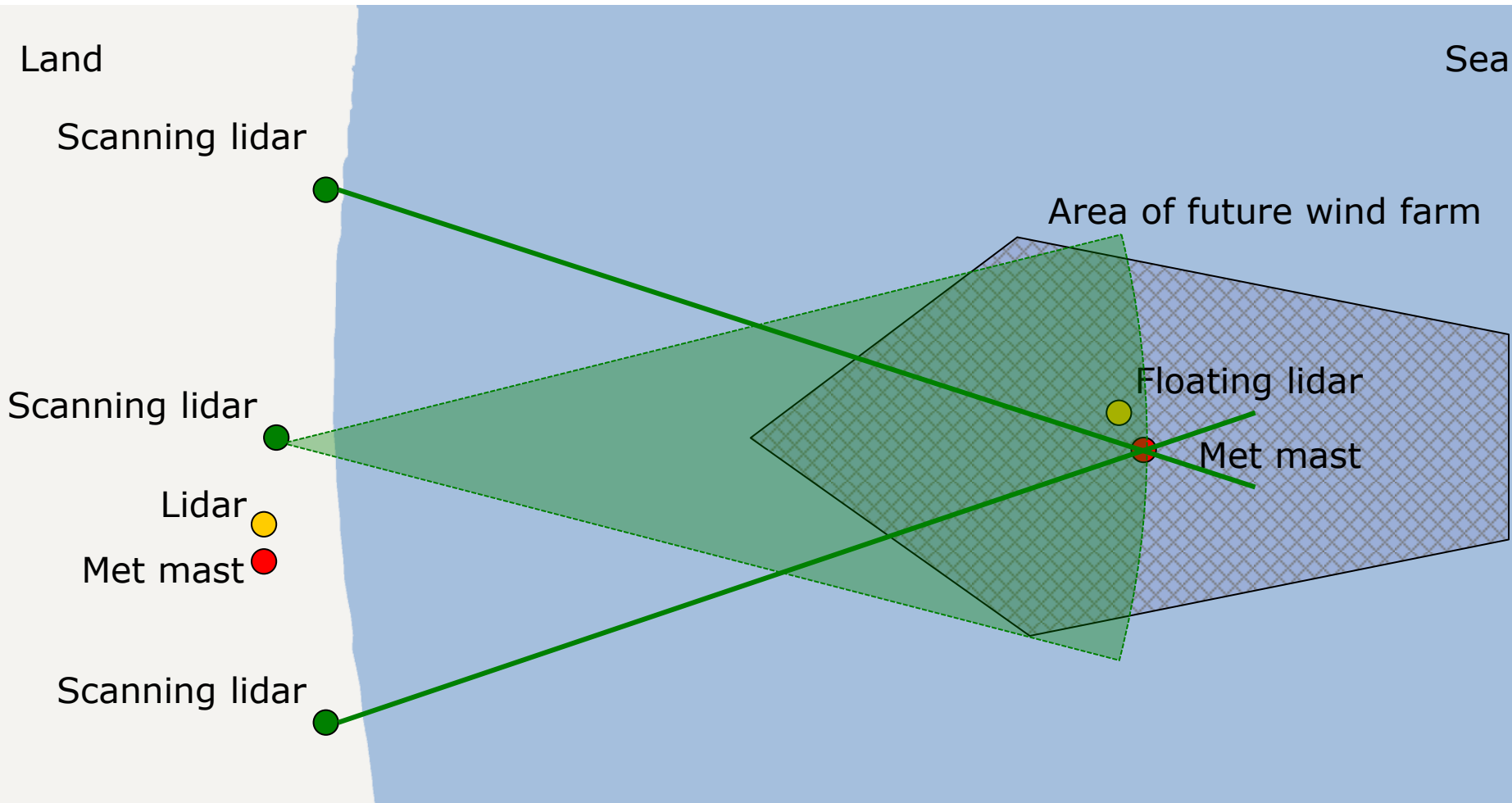
Technique	Pros	Cons
Mesoscale models	Cheap	Uncertainty of prediction up to 10%
Mesoscale models + local measurements	Uncertainty reduced to 3%	

Options for local measurements



Technique	Pros	Cons
Mesoscale models	Cheap	Uncertainty of prediction up to 10%
Mesoscale models + local measurements	Uncertainty reduced to 3%	

Which measurement solution is most cost-effective (cost vs. accuracy)?



Technique	Pros	Cons
Mesoscale models	Cheap	Uncertainty of prediction up to 10%
Mesoscale models + local measurements	Uncertainty reduced to 3%	\$\$\$?

Which measurement solution is most cost-effective?

- The **RUNE** project is designed to investigate cost-effective measurement solutions for improving wind resource modeling of coastal areas.



Offshore mast



Floating lidar



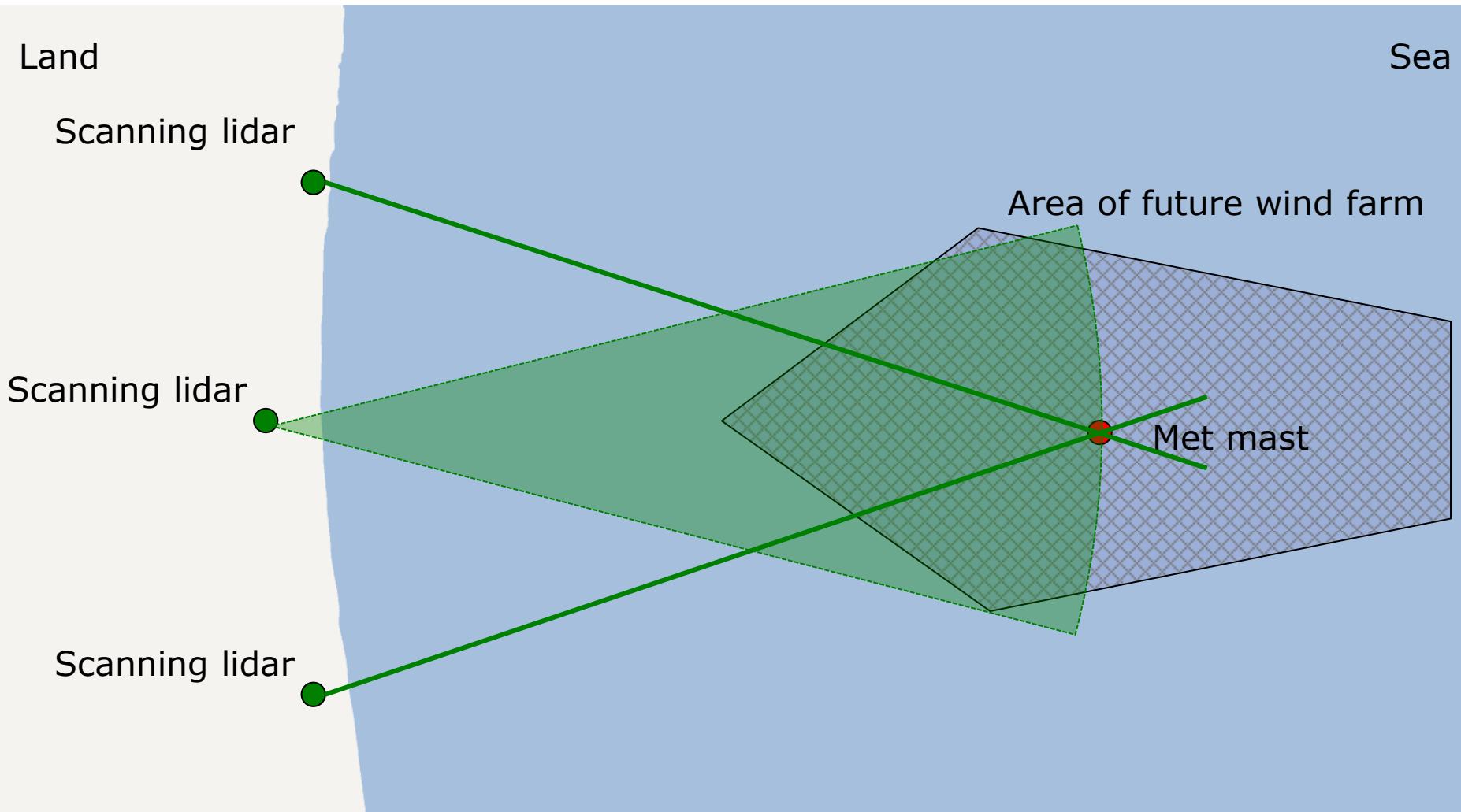
Onshore lidar

Comparison with mast mounted cup anemometer and wind vane

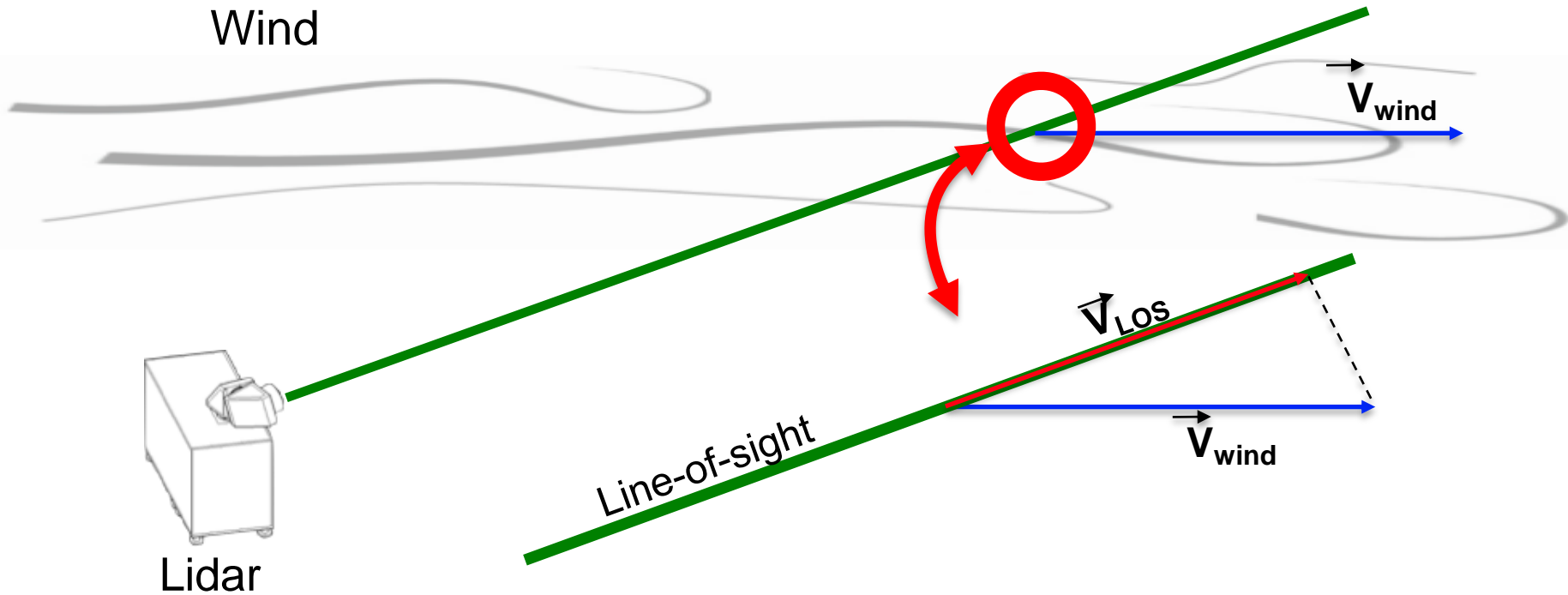


Onshore scanning lidar(s)

First attempt to answer the question: One or two lidars?

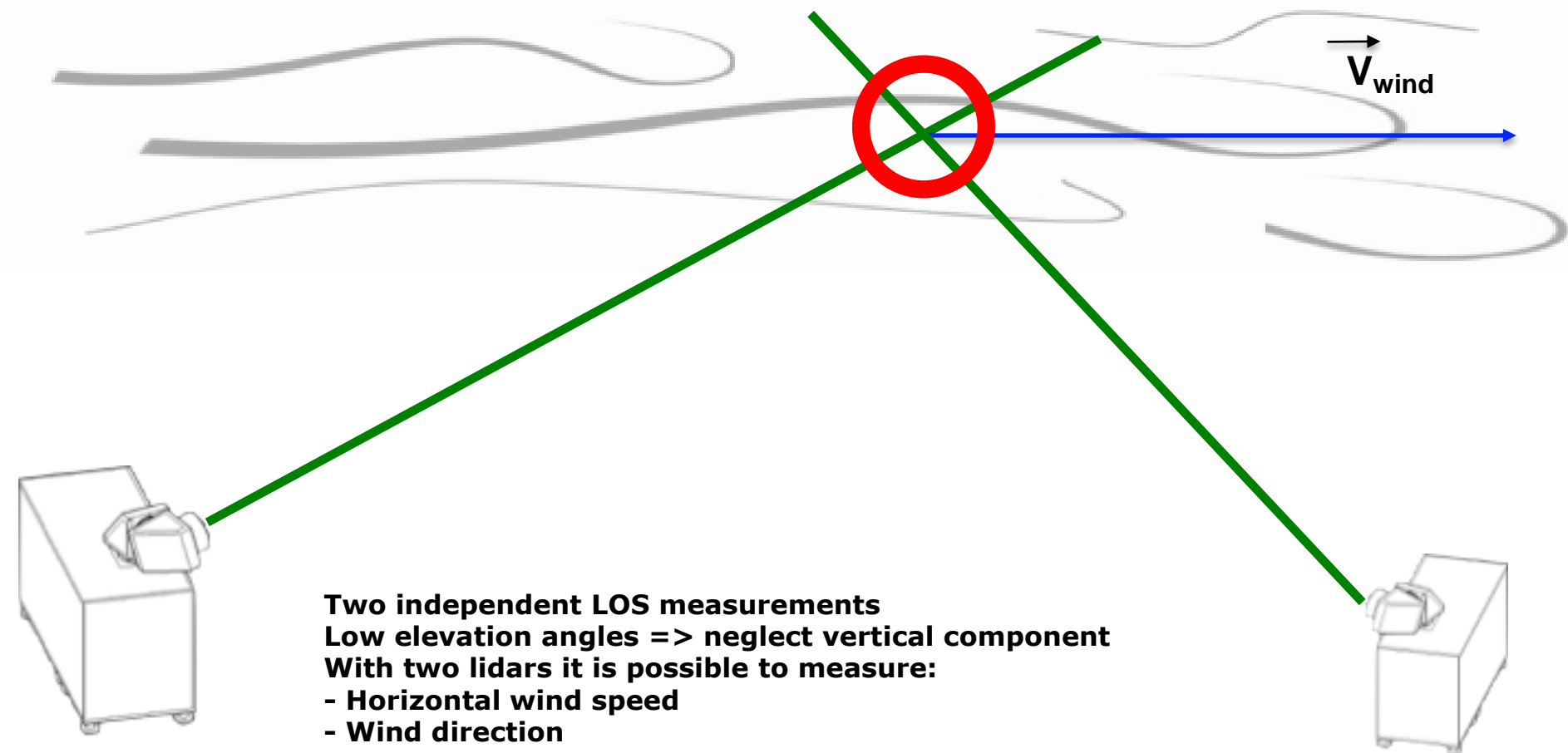


Lidar measurement background

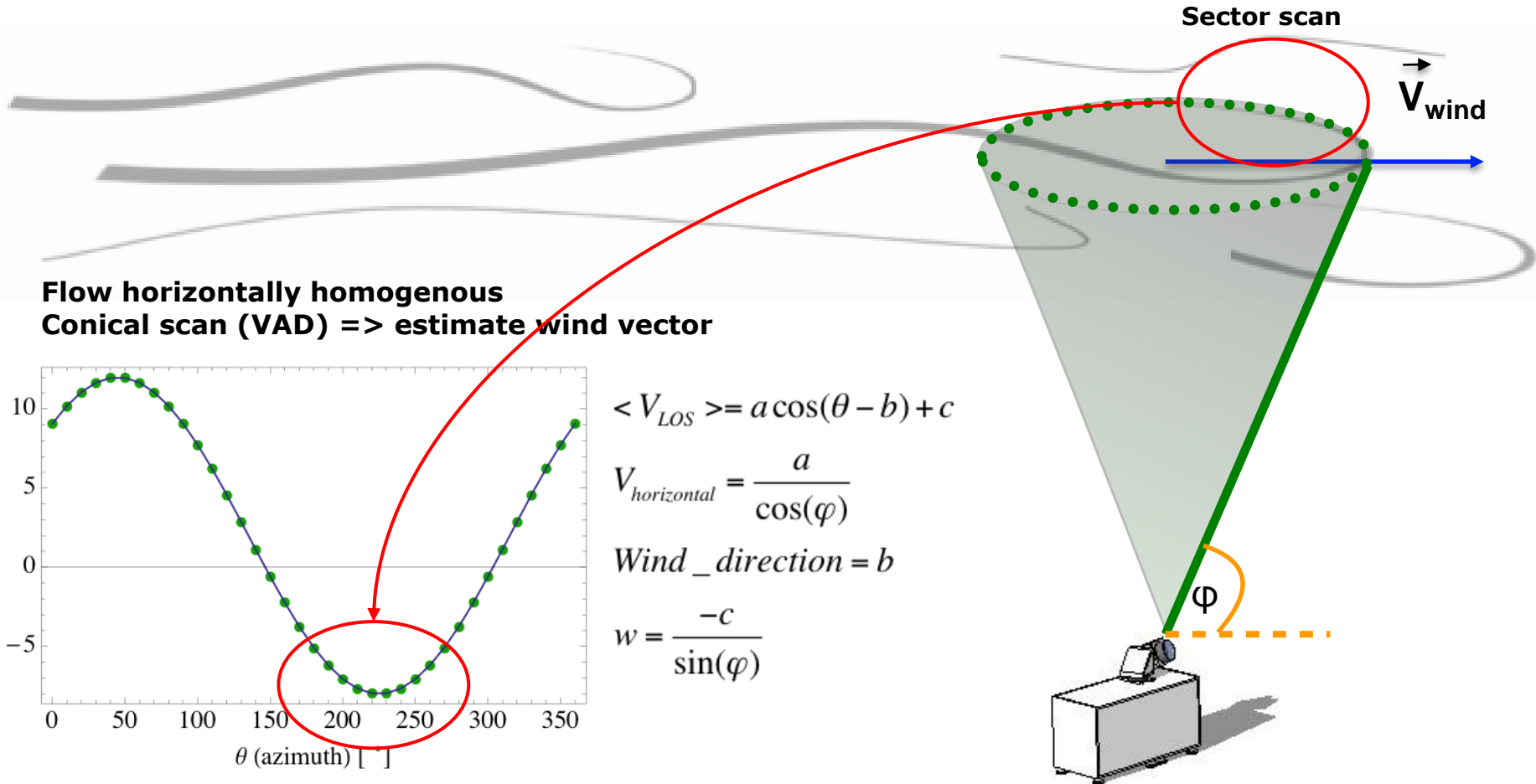


A lidar can only measure a portion of the wind vector!!!

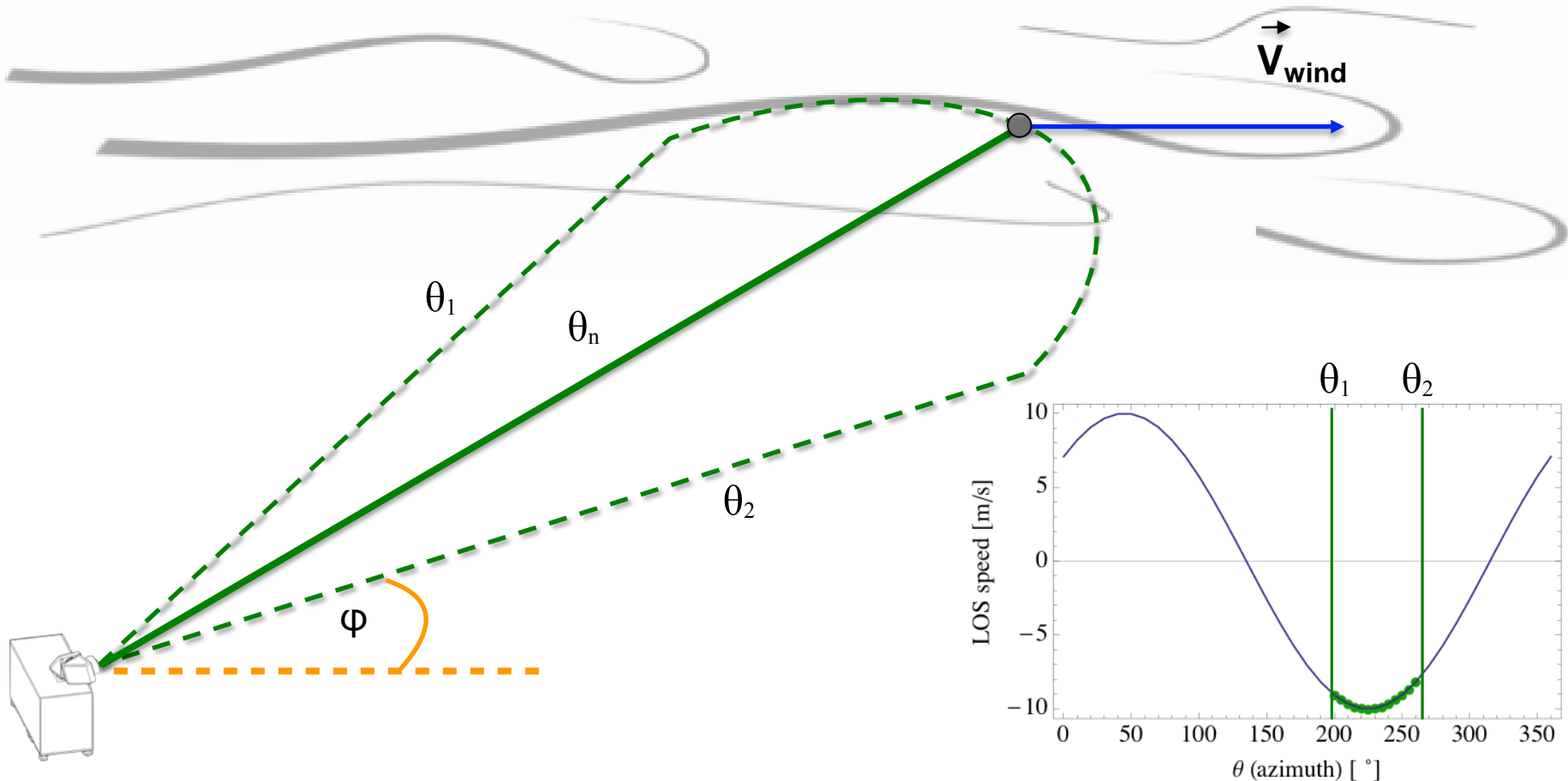
Dual-Doppler



Conical scan



Sector scan



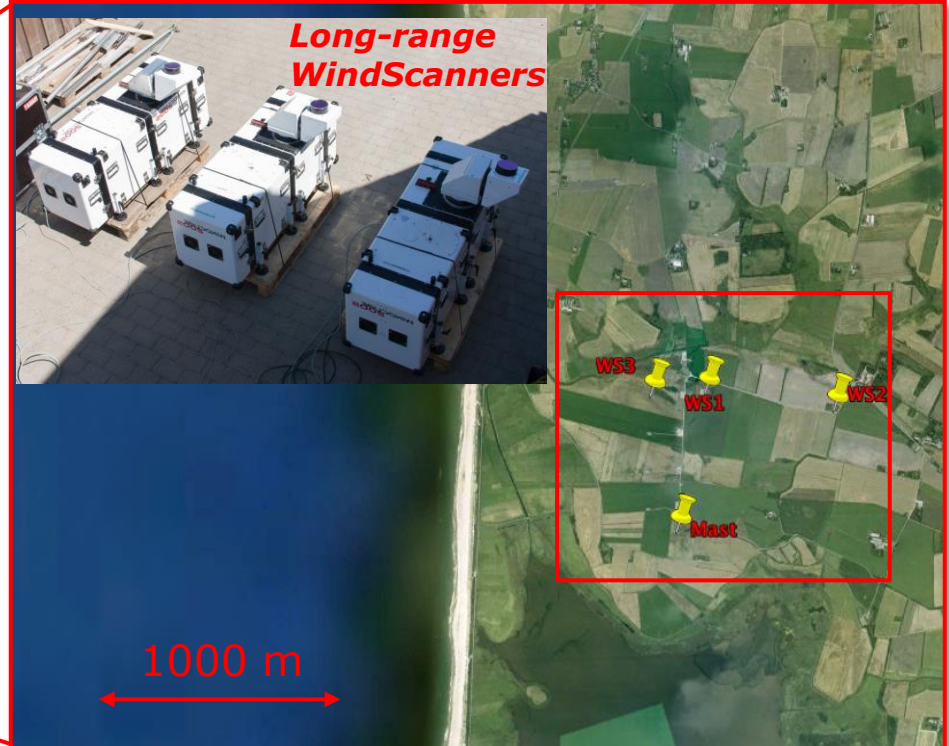
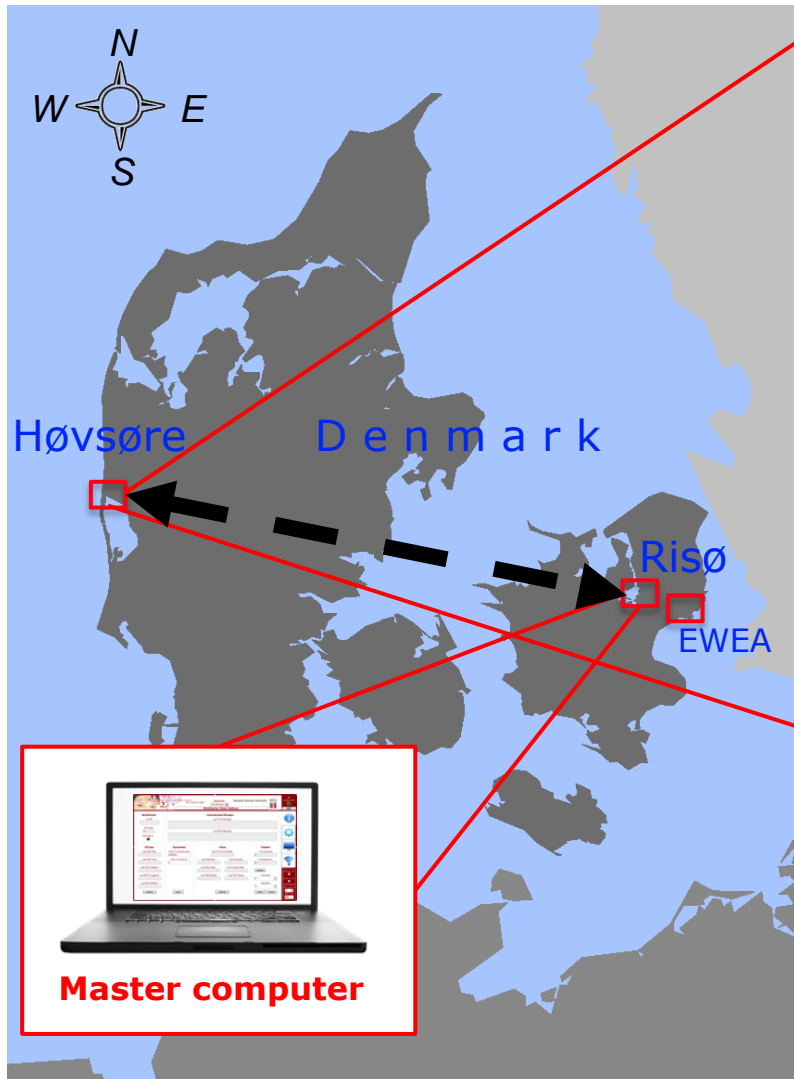
Flow horizontally homogenous
Vertical component low
Low elevation angle } Neglect vertical component
Sector scan => estimate horizontal wind speed and wind direction

$$\langle V_{LOS} \rangle = a \cos(\theta - b)$$

$$V_{horizontal} = a$$

$$Wind_direction = b$$

Pre-RUNE experiment, April-May 2014



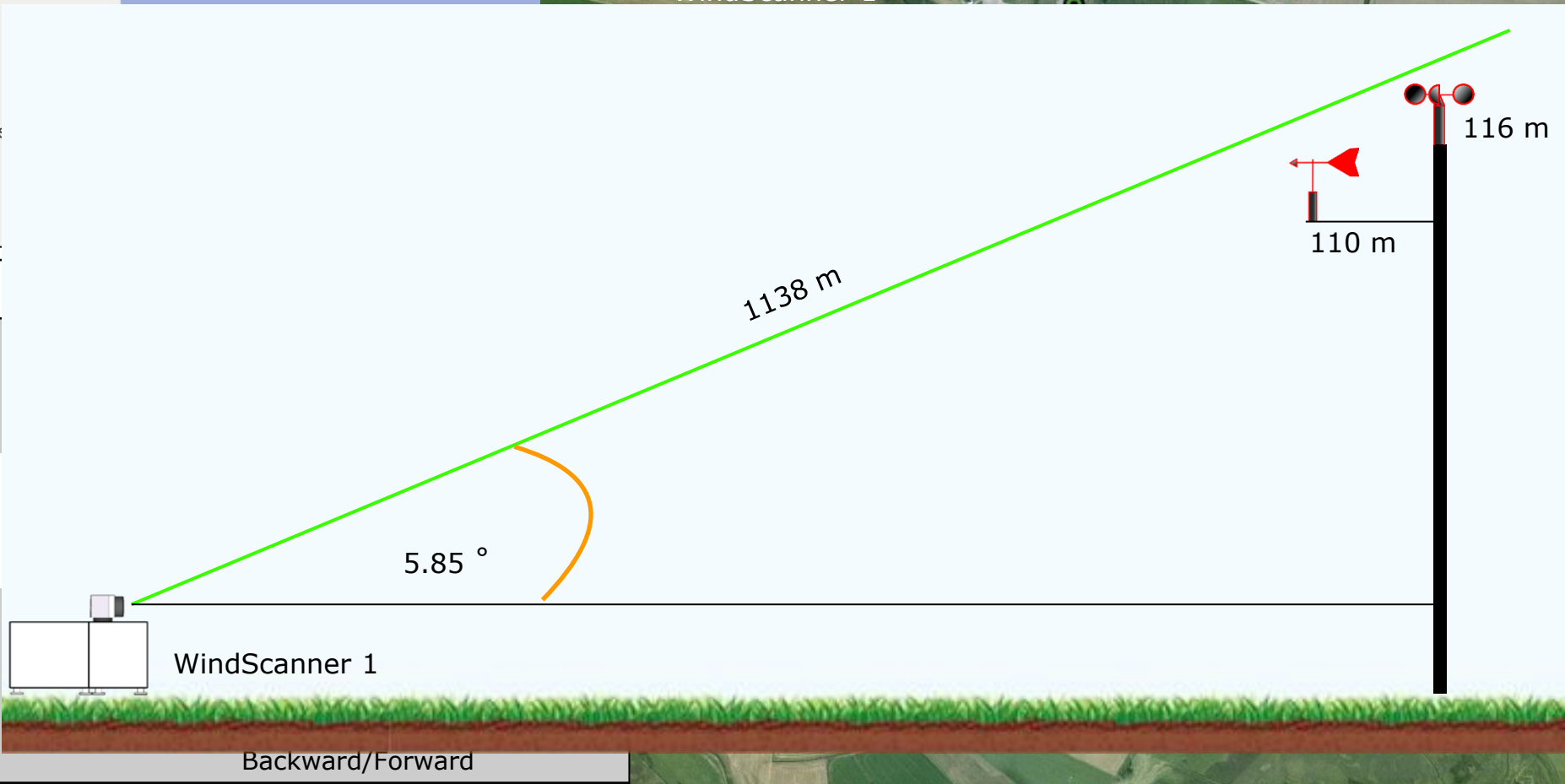
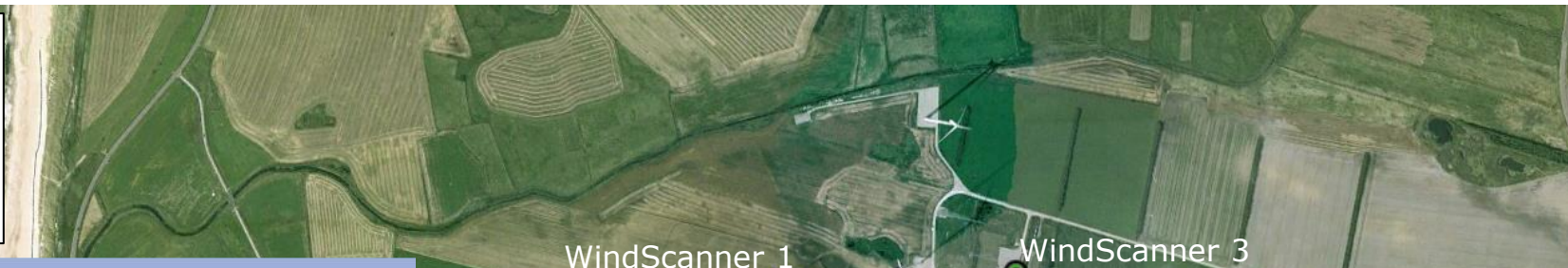
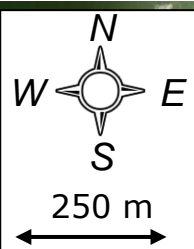
A detailed description of the long-range WindScanners:

Nikola Vasiljevic. *A time-space synchronization of coherent Doppler scanning lidars for 3D measurements of wind fields.* PhD thesis, Technical University of Denmark (DTU), 2014. PhD-0027

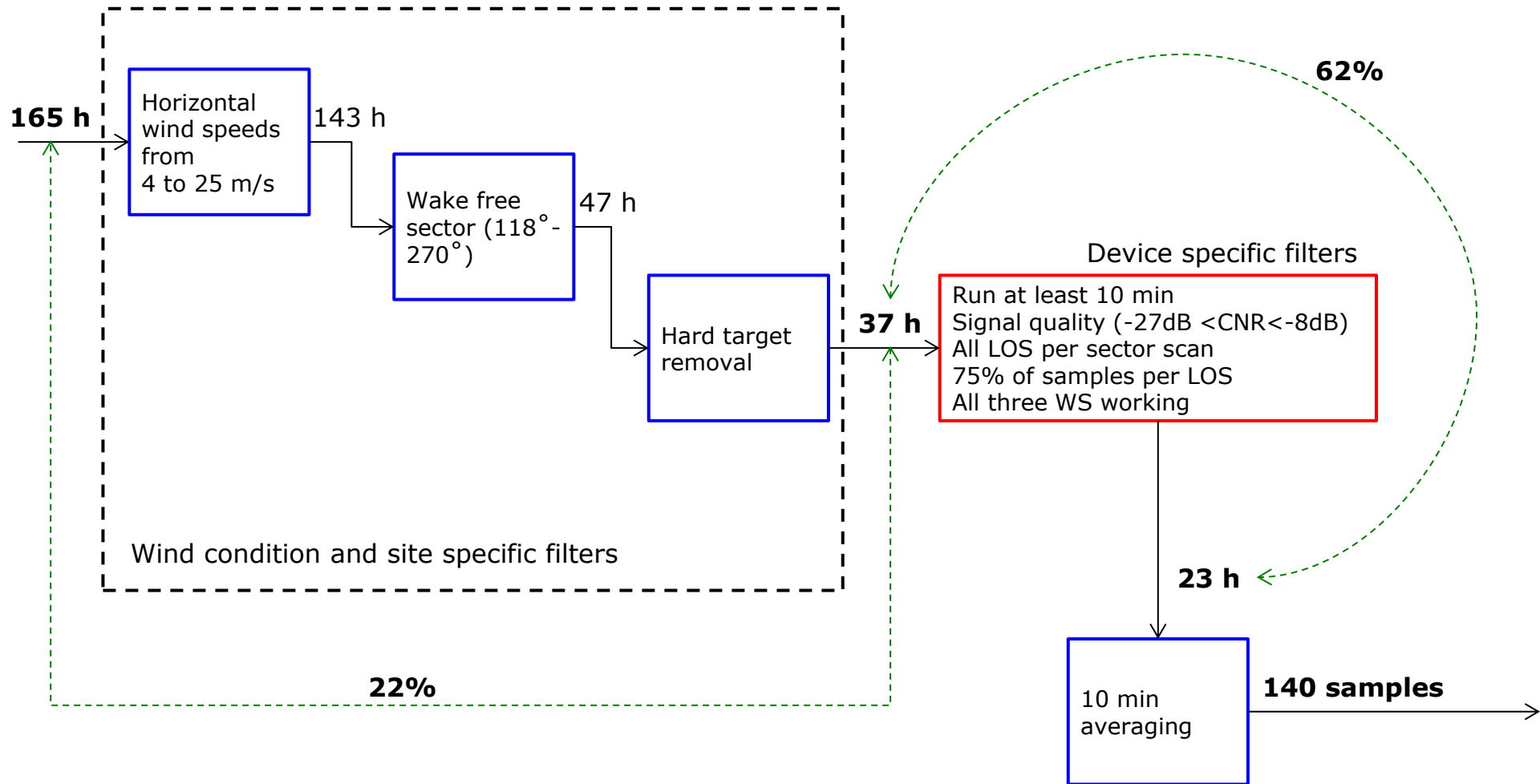
Link: <http://bit.ly/1K82w0G>



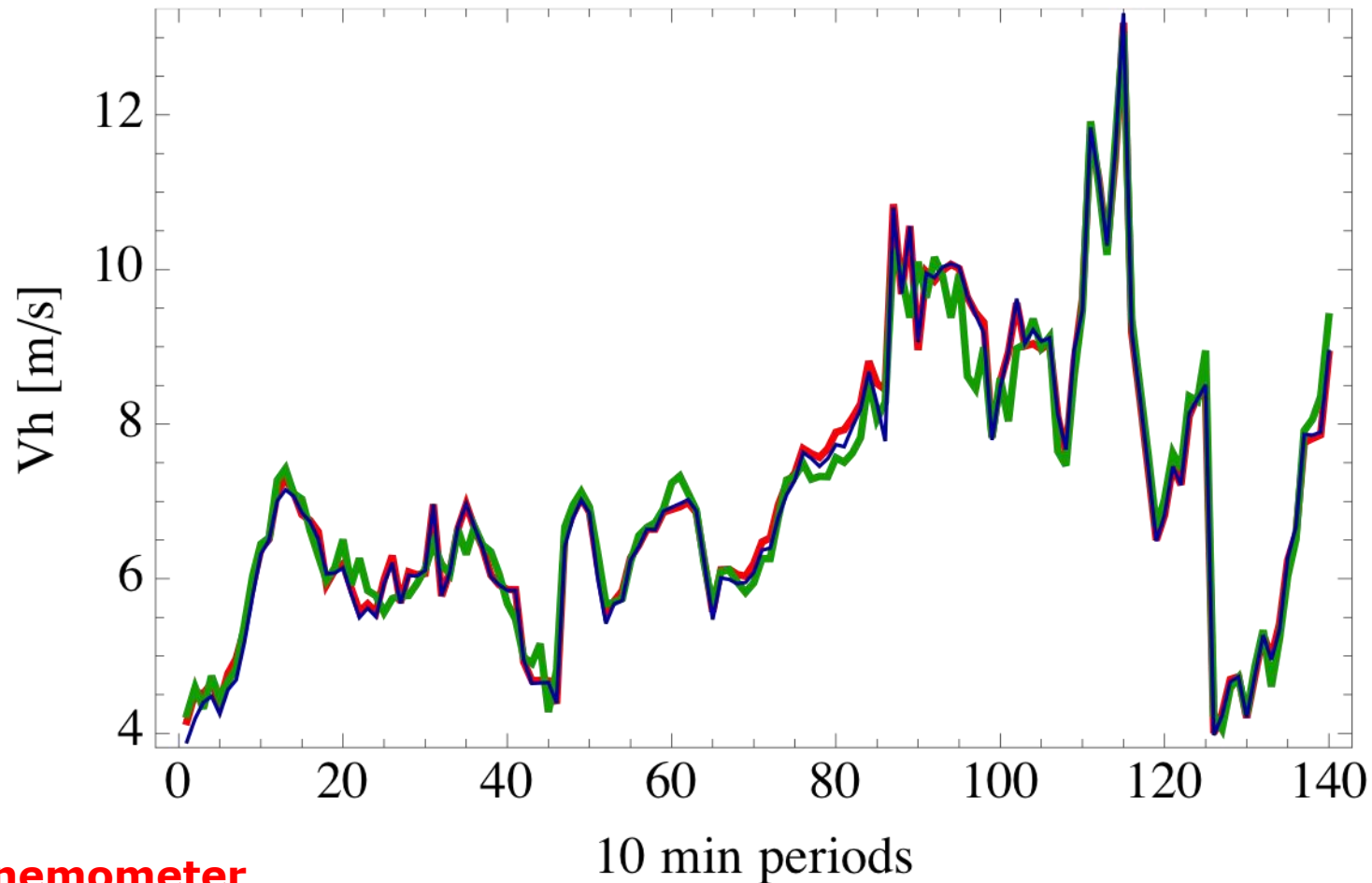
Experimental layout



Data processing



Horizontal wind speed



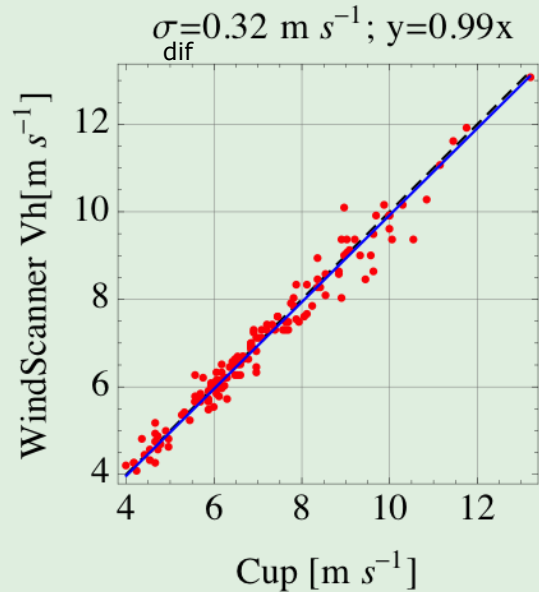
Cup anemometer

Two lidars (Dual-Doppler)

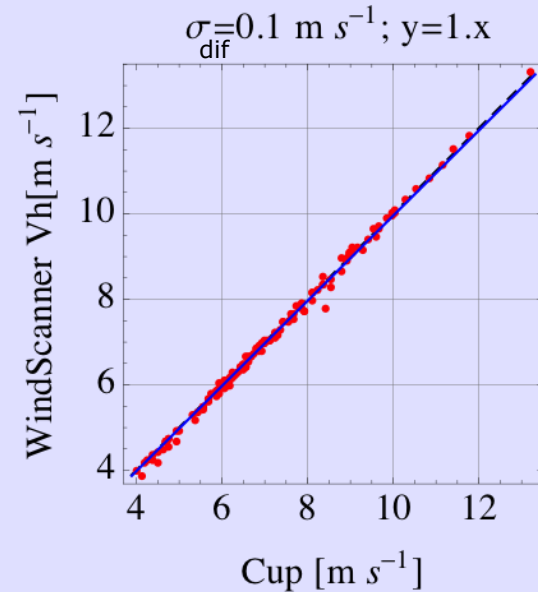
One lidar (Sector Scan 60°)

Horizontal wind speed

One lidar (Sector Scan 60°)

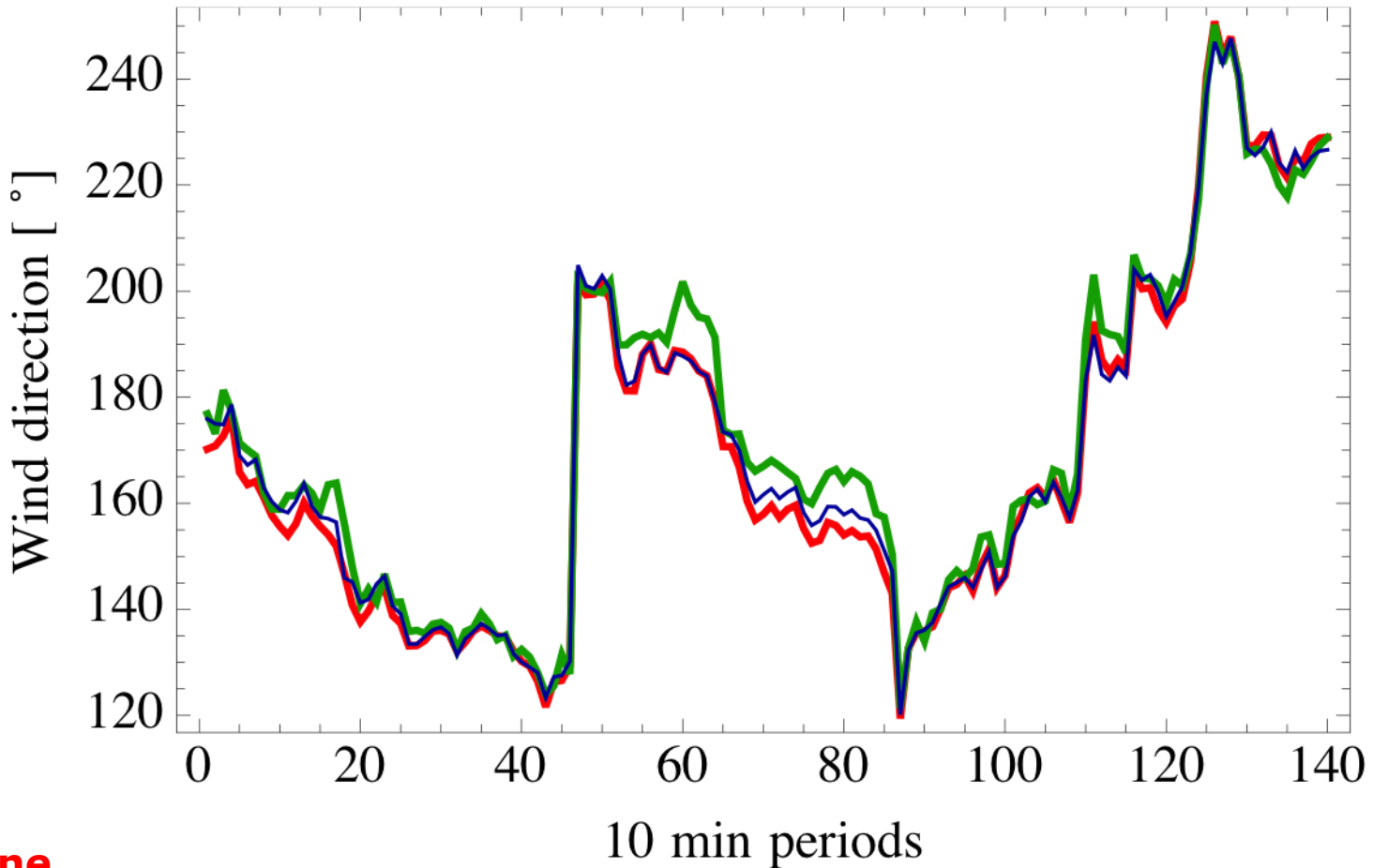


Two lidars (Dual-Doppler)



	Cup	One lidar	Two lidars
Number of samples	140	140	140
Mean wind speed [m/s]	<u>7.07</u>	<u>7.04</u>	<u>7.04</u>
R ²	/	0.98	0.99
Difference [m/s]	/	0.03	0.03
Difference [%]	/	<1	<1
Standard deviation of the difference [m/s]	/	0.32	0.10

Wind direction



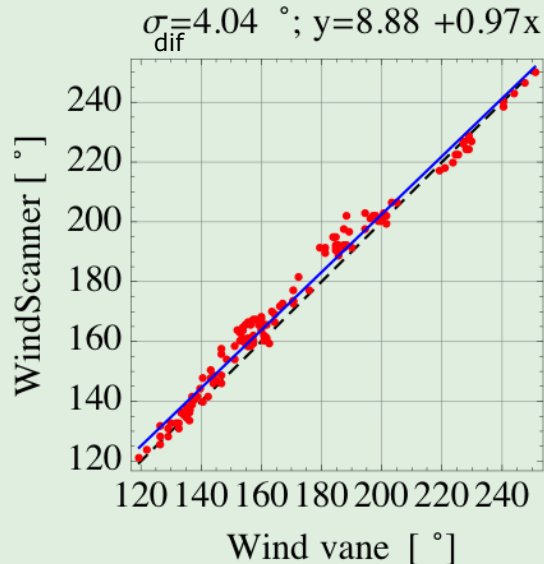
Wind vane

Two lidars (Dual-Doppler)

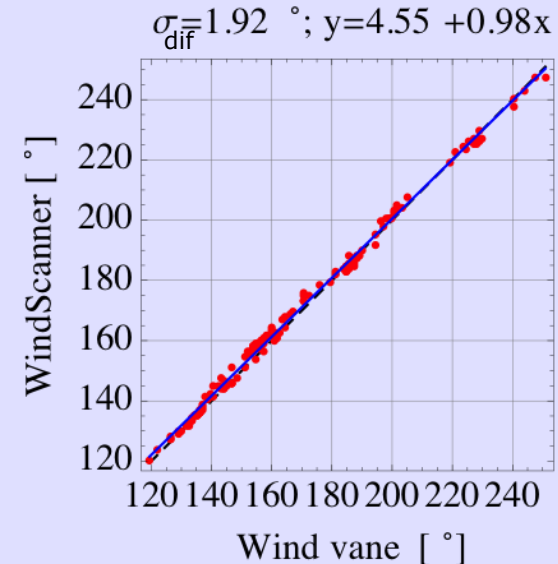
One lidar (Sector Scan 60°)

Wind direction

One lidar (Sector Scan 60°)



Two lidars (Dual-Doppler)



	Cup	One lidar	Two lidars
Number of samples	140	140	140
Mean wind direction [°]	<u>168.40</u>	<u>171.75</u>	<u>169.50</u>
R ²	/	0.97	0.99
Difference [°]	/	-2.11	-1.11
Difference [%]	/	1.98	0.65
Standard deviation of the difference [°]	/	4.04	1.92

One lidar or two?

- One lidar will provide necessary local measurements
- If you have sufficient funds there are merits of using two lidars:
 - Higher measurement rate
 - Small portion of area sampled
 - More measurement points
 - If the flow is not horizontally homogeneous
- Be careful with the installation!
A high pointing accuracy is crucial in achieving reliable measurements!!!

Future work

- Derive a parameter that indicates if the estimated values of the horizontal wind speed and direction from the sector scan are trustworthy
- Relating the theoretical calculation of the minimum sector scan to the experimental results
- Perform a similar experiment in real offshore conditions while going for a longer range and adding:
 - floating lidar
 - onshore lidar
 - ...
- **Test pointing accuracy**

**For a live demonstration of the long-range WindScanner system
visit the DTU WIND ENERGY stand in front of the Bella Center!**



Thank you!

