(2.5 + 5.8) Years of successes and failures with long-range WindScanner system
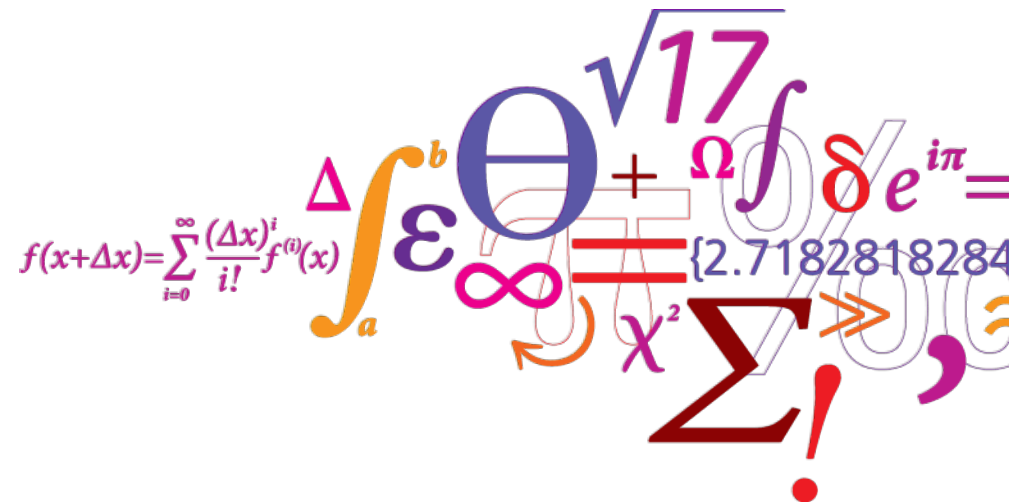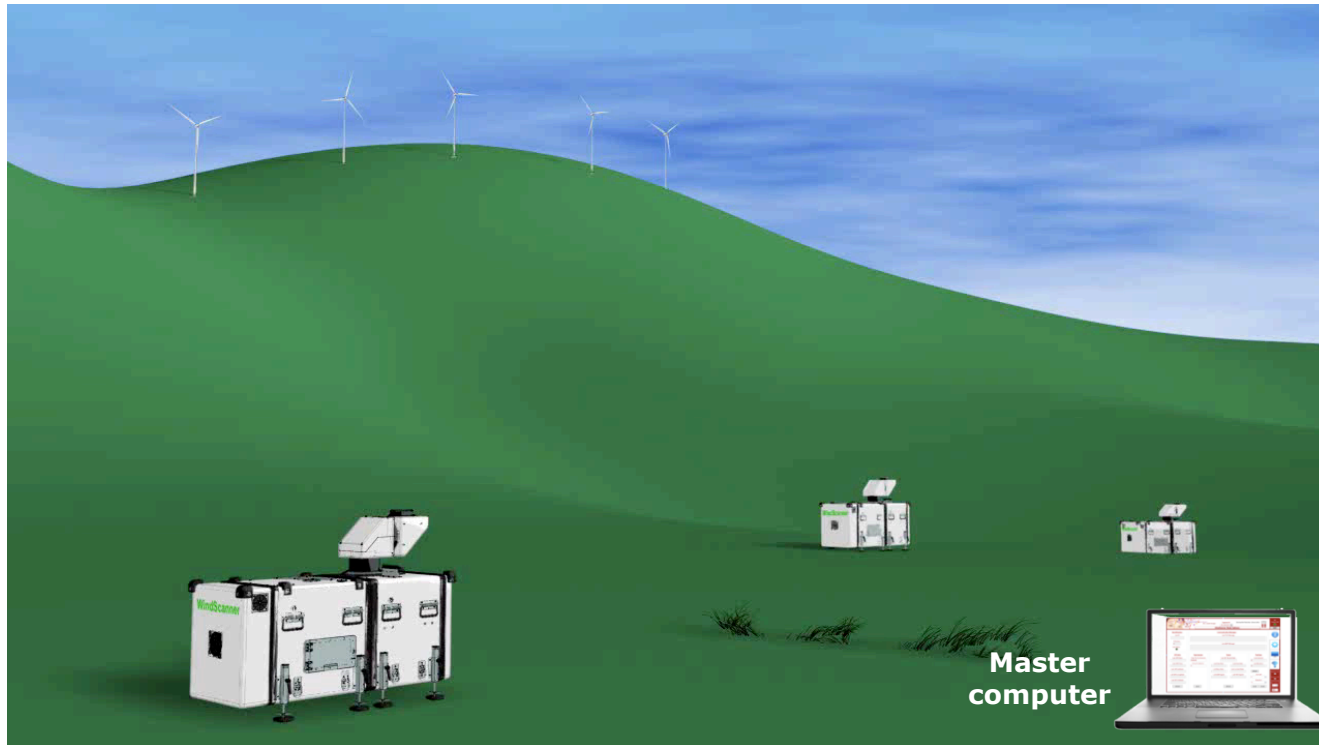
Nikola Vasiljević

RECAST Workshop
Risø, Denmark
October 2nd 2018

DTU Wind Energy
Department of Wind Energy

Long-range WindScanner (LRWS) system

https://doi.org/10.3390/rs8110896

Coordinated by a remote master computer using any type of network (3G, WiFi,…)

WindScanners are synchronized in time and space
Any scanning trajectory within mechanical limits

**Mean wind flow over
an entire wind farm**

History: Core development

06/2010 Development of LRWS initiated

12/2010 RSComPro developed

02/2011 First WindScanner assembled

03/2011 First trial outside lab failed

05/2011 Syncing motion, emission & acquisition

06/2011 WindScanner Client Software (WCS) Prototype

07/2011 First scanner head failed

04/2012 Prototype Master Computer Software

05/2012 Simple trajectory generator

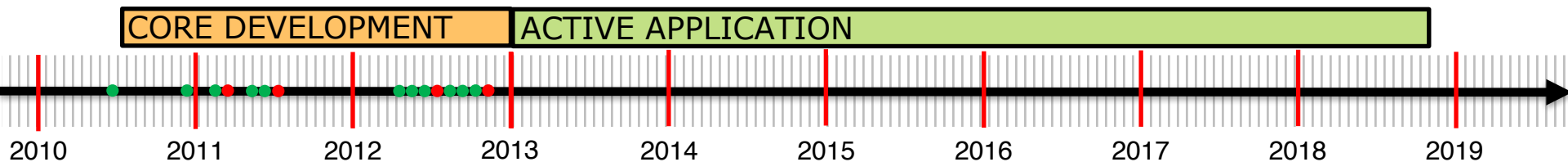**06/2012 Second WindScanner assembled**

07/2012 First sync test failed

08/2012 WindScanner team became team of two people

09/2012 Third WindScanner assembled

10/2012 First trial of WindScanner concept outside of lab

11/2012 Failure of the trial - two laser pumps destroyed

CORE DEVELOPMENT   ACTIVE APPLICATION

2010   2011   2012   2013   2014   2015   2016   2017   2018   2019

DTU Wind Energy, Technical University of Denmark

History: Active application

02/2013 Swinging musketeer

06/2013 IBL WiSH

07/2013 6-Beam experiment

10/2013 Site calibration

05/2014 Sector Scan vs Dual-Doppler

07/2014 Kassel-2014

09/2014 Epsilon

11/2014 Nordtank inflow measurements

05/2015 Perdigão-2015

07/2015 Perdigão After Party

09/2015 pre-RUNE campaign

10/2015 RUNE

03/2016 Balcony

04/2016 Björnafjord campaign

09/2016 Kassel-2016

02/2017 Perdigão-2017

03/2017 Waffle
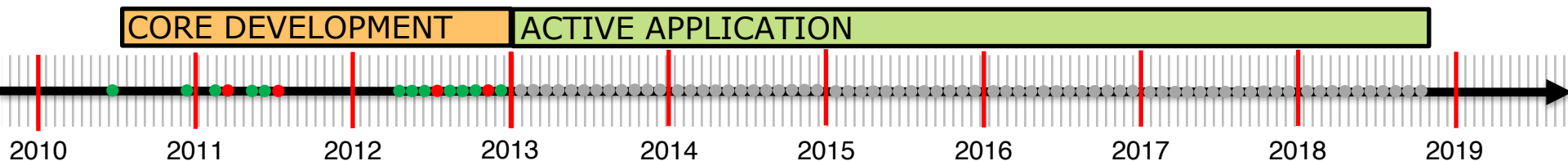
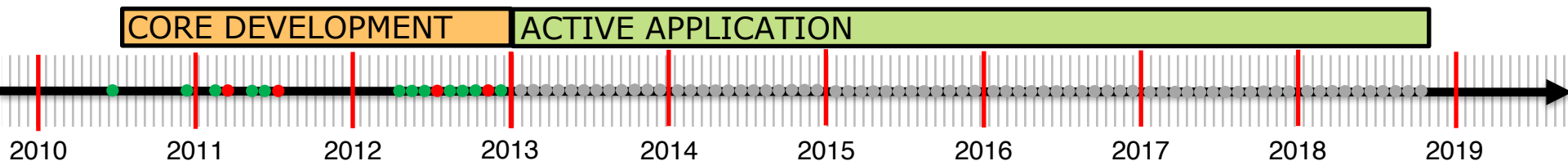04/2017 Beacon calibration

10/2017 Lascar

03/2018 Alex

08/2018 Multi-rotor wake

Some facts:
21 campaigns in 6 countries
- Denmark (14)
- Norway (1)
- Germany (2)
- Spain (1)
- Portugal (2)
- UK (1)

CORE DEVELOPMENT   ACTIVE APPLICATION

2010   2011   2012   2013   2014   2015   2016   2017   2018   2019

History: Active application

02/2013 **Swinging musketeer**

06/2013 **IBL WiSH**

07/2013 **6-Beam experiment**

10/2013 **Site calibration**

05/2014 **Sector Scan vs Dual-Doppler**

07/2014 **Kassel-2014**

09/2014 **Epsilon**

11/2014 **Nordtank inflow measurements**

05/2015 **Perdigão-2015**

07/2015 **Perdigão After Party**

09/2015 **pre-RUNE campaign**

10/2015 **RUNE**

03/2016 **Balcony**

04/2016 **Björnafjord campaign**

09/2016 **Kassel-2016**

02/2017 **Perdigão-2017**

03/2017 **Waffle**

04/2017 **Beacon calibration**

10/2017 **Lascar**

03/2018 **Alex**

08/2018 **Multi-rotor wake**

Some facts:
21 campaigns in 6 countries
- Denmark (14)
- Norway (1)
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- Spain (1)
- Portugal (2)
- UK (1)

CORE DEVELOPMENT   ACTIVE APPLICATION

2010   2011   2012   2013   2014   2015   2016   2017   2018   2019

Swinging musketeer

Date	February 2013
Location	Risø, Denmark
Aim	Test Multi-Lidar concept Validate measurements

118.0 m

DTU Wind Energy, Technical University of Denmark
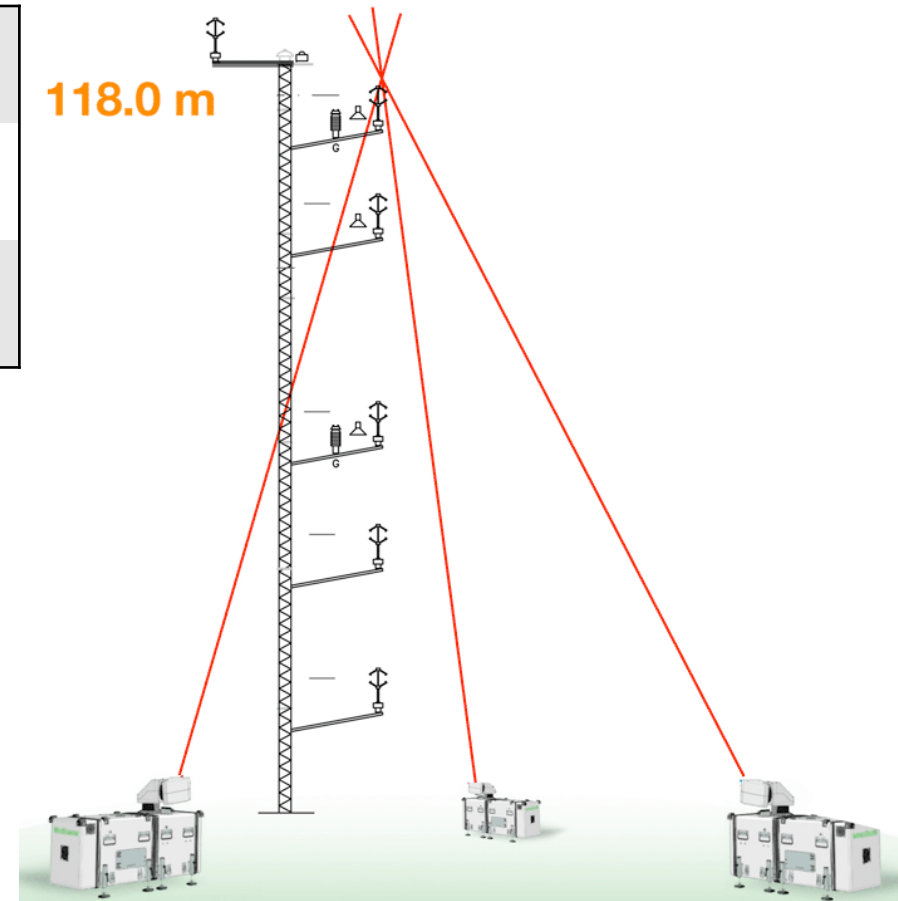
What went wrong

- Collected only 6 hours of good data (one WindScanner had hardware malfunction)

Malfunctioning WindScanner

Me running to save my PhD

IBL WiSH

Date	June-July 2013 (several weeks)
Location	Høvsøre, Denmark
Aim	Investigation of the sea-land Internal Boundary Layer development

DTU Wind Energy, Technical University of Denmark

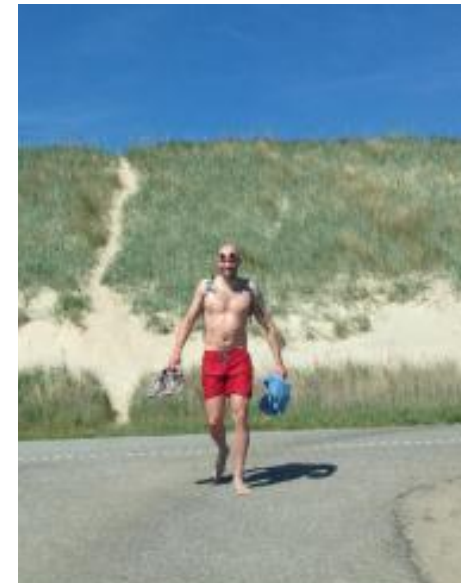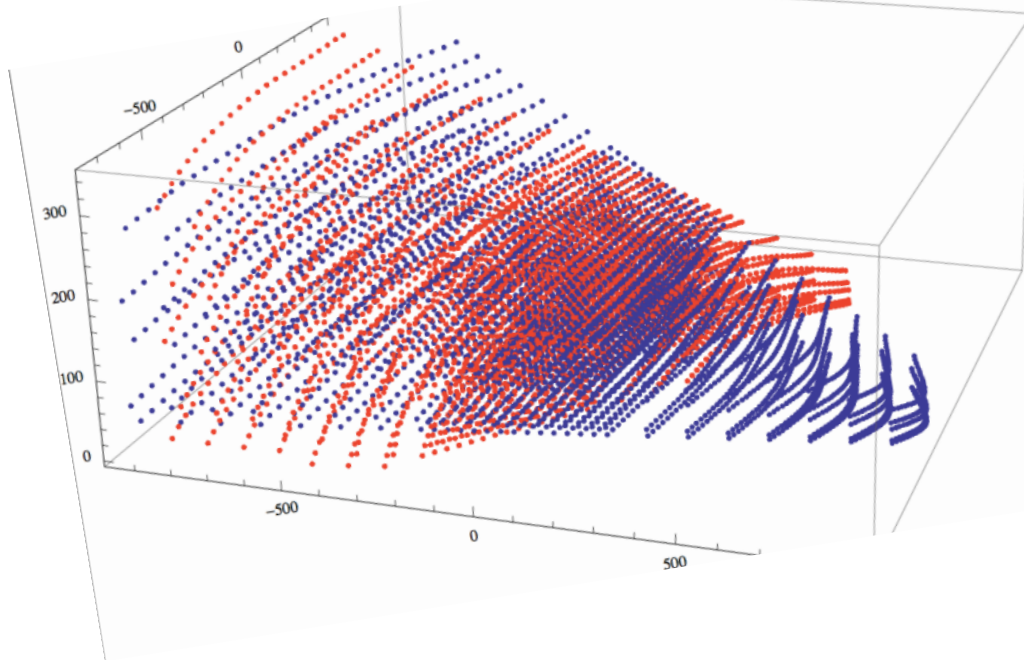⭕ WindScanner

Scanning strategies

0.3 km

1 km

1 km
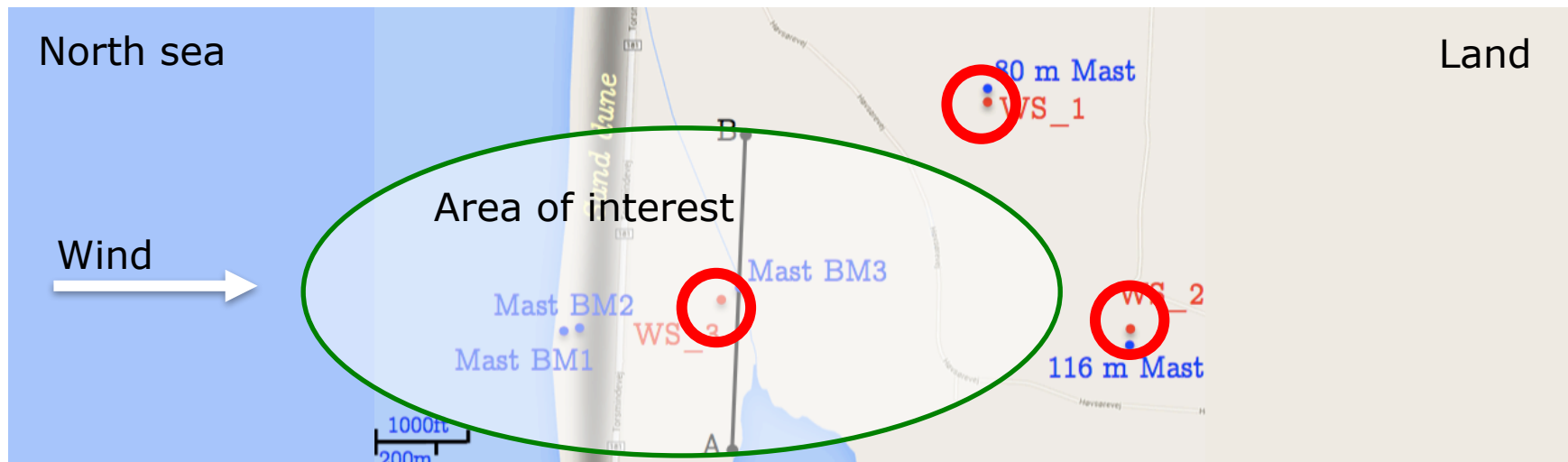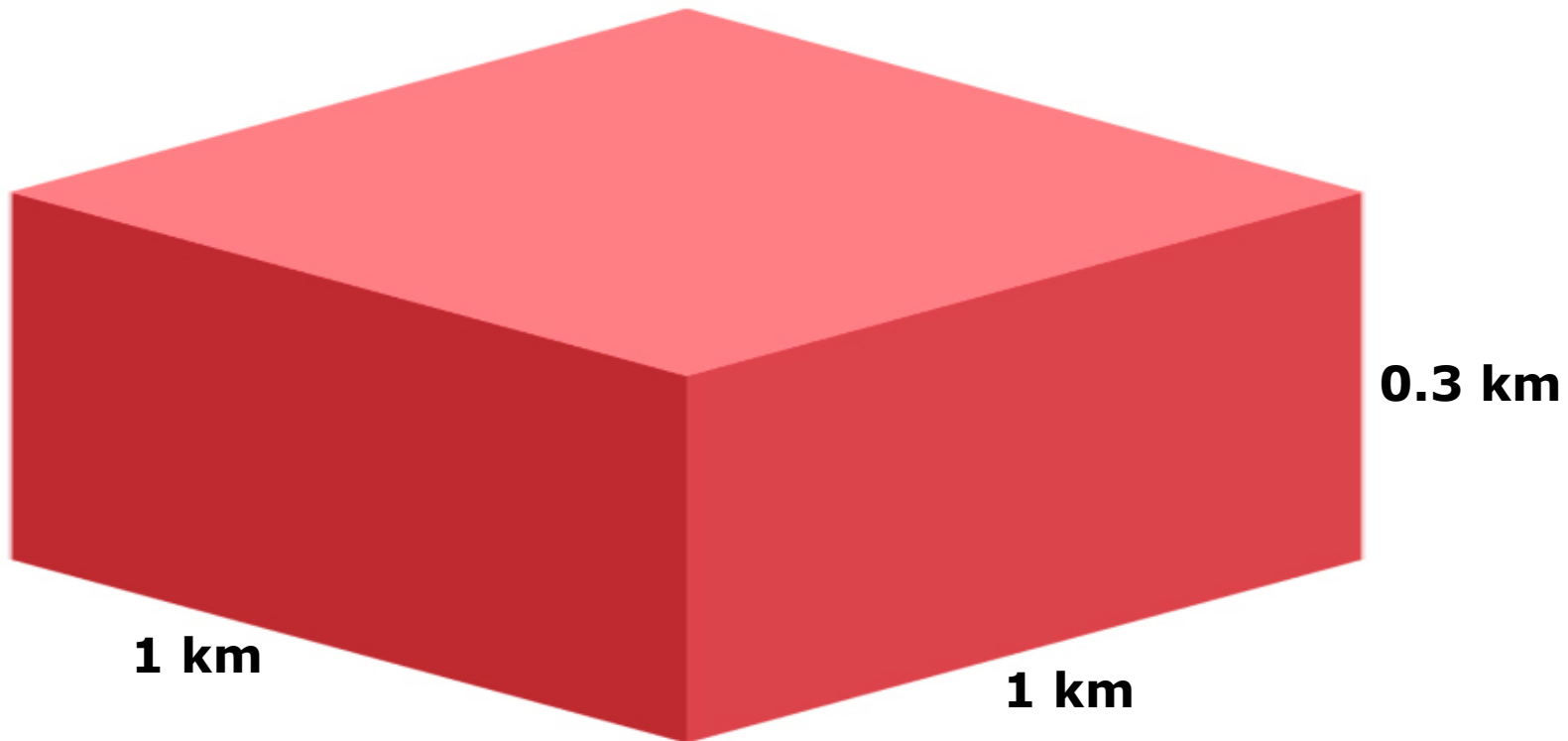
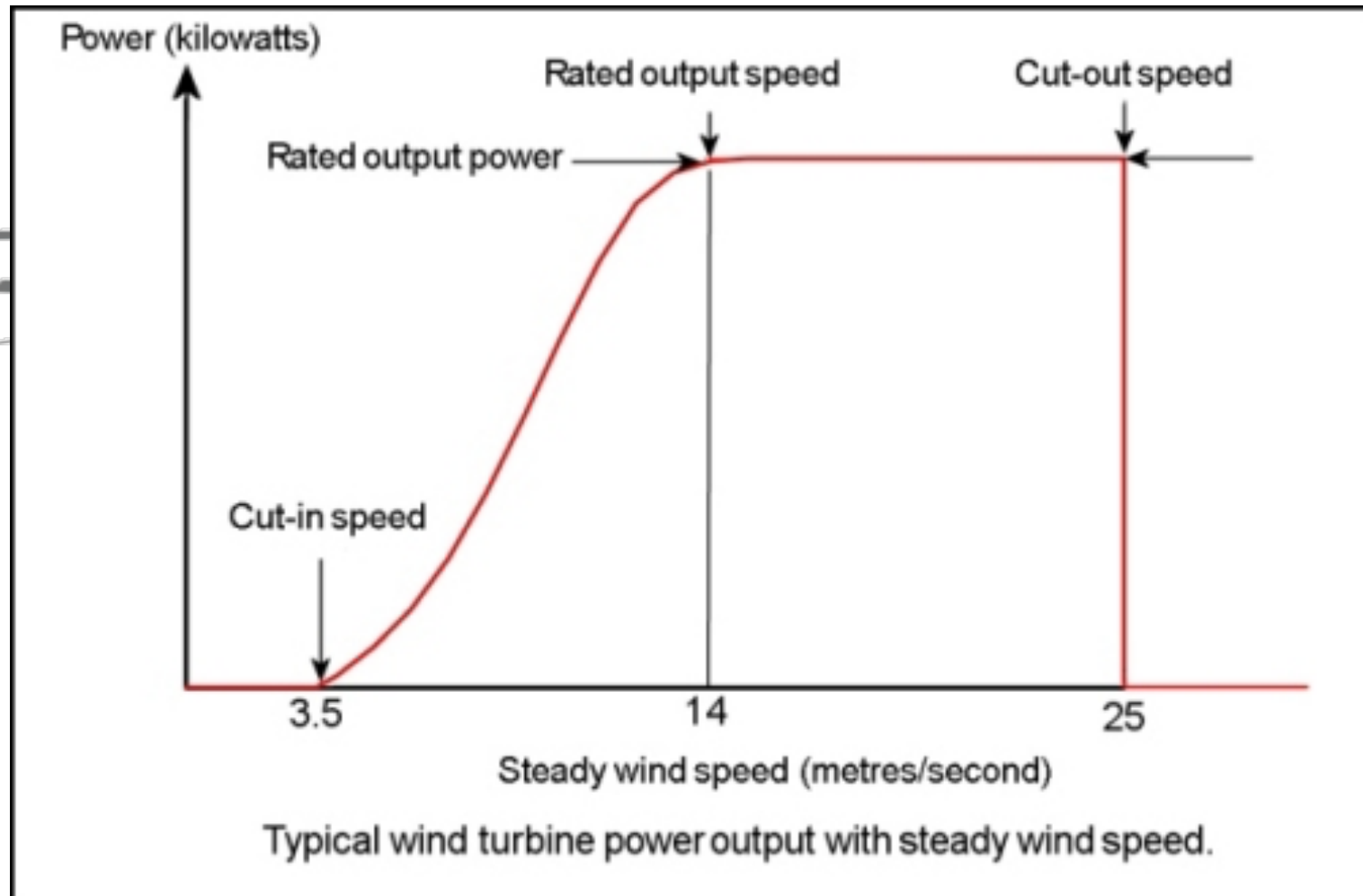**1 iteration of scan took 1 minute**

What went wrong

- Insufficient number of samples per averaging period

- We changed several times scanning strategies

- Complex scanning strategy = Complex data analysis

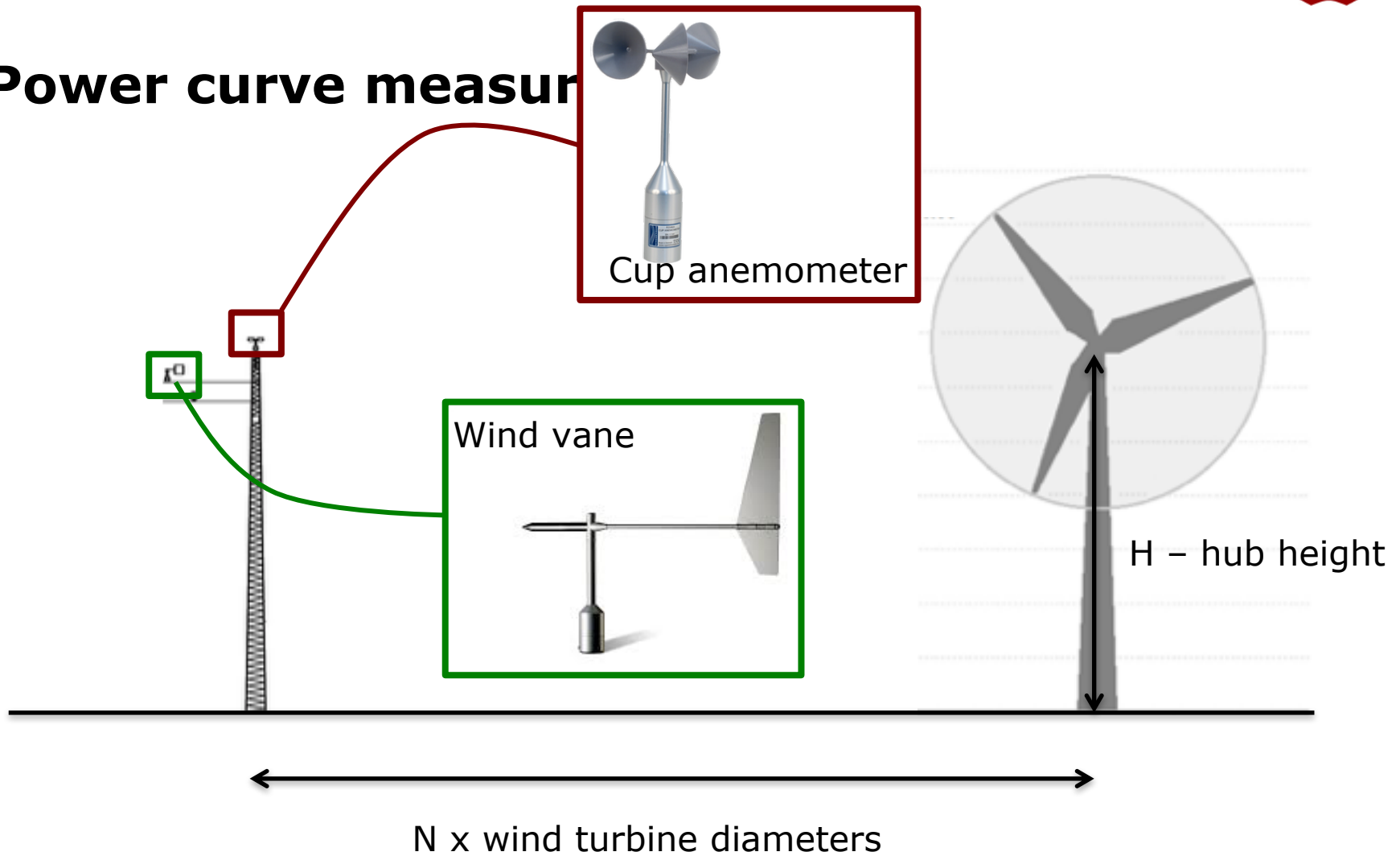- Data analysis was done once the experiment was over

Jacob Berg abandon **WindScanners** and moved to **LES**
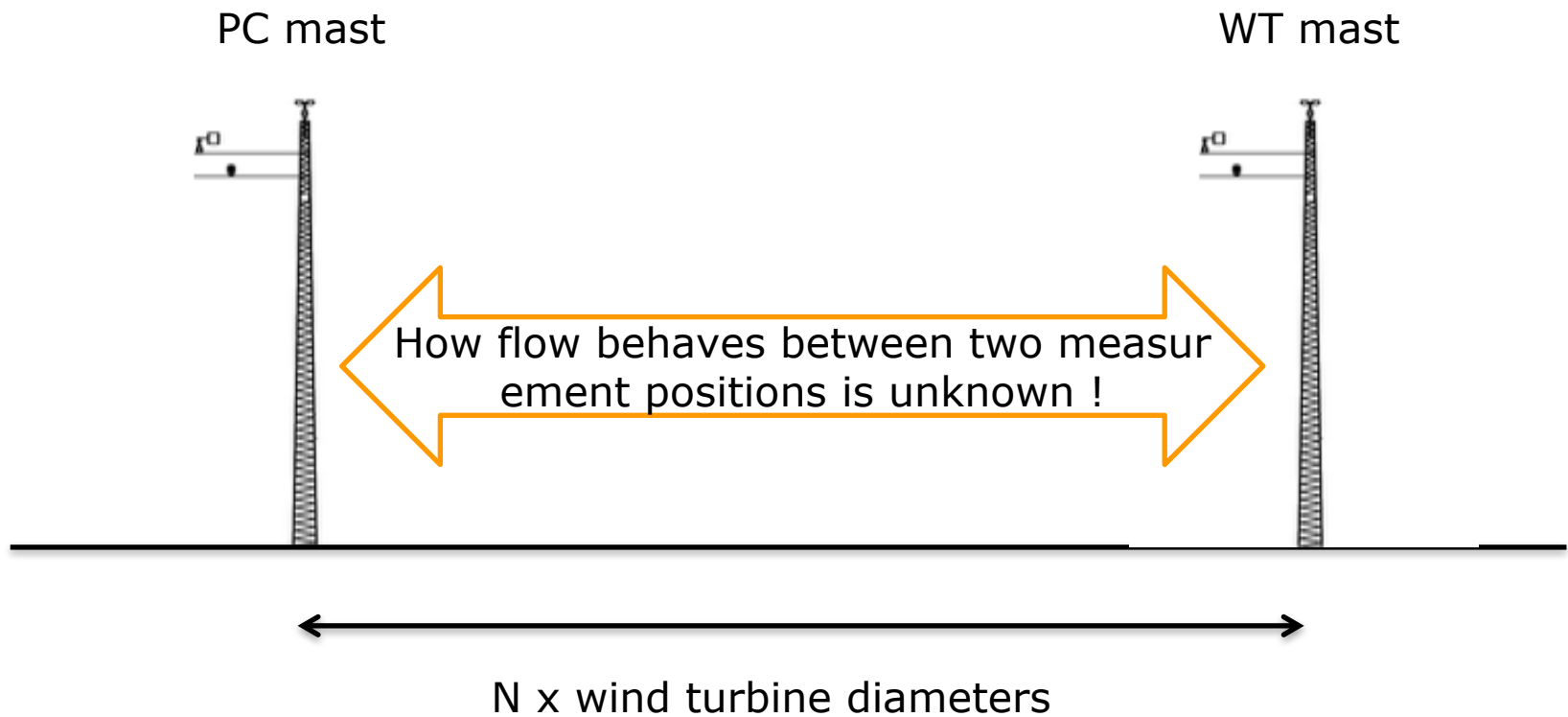
Wind turbine power curve

Typical wind turbine power output with steady wind speed.

DTU Wind Energy, Technical University of Denmark

Power curve measur

Cup anemometer

Wind vane

H – hub height

N x wind turbine diameters

Site calibration

PC mast   WT mast

How flow behaves between two measurement positions is unknown !

N x wind turbine diameters

Site calibration

Date	November 2013 – January 2014
Location	Høvsøre, Denmark
Aim	Spatial characterization of the wind field

○ WindScanner 1

PC mast

WT mast

Wind

~ 450 m ~ 300 m ~ 400 m

○ WindScanner 2

Site calibration

Date	November 2013 – January 2014
Location	Høvsøre, Denmark
Aim	Spatial characterization of the wind field

WindScanner 1

PC mast

WT mast

Wind

~ 450 m

~ 300 m

~ 400 m

WindScanner 2

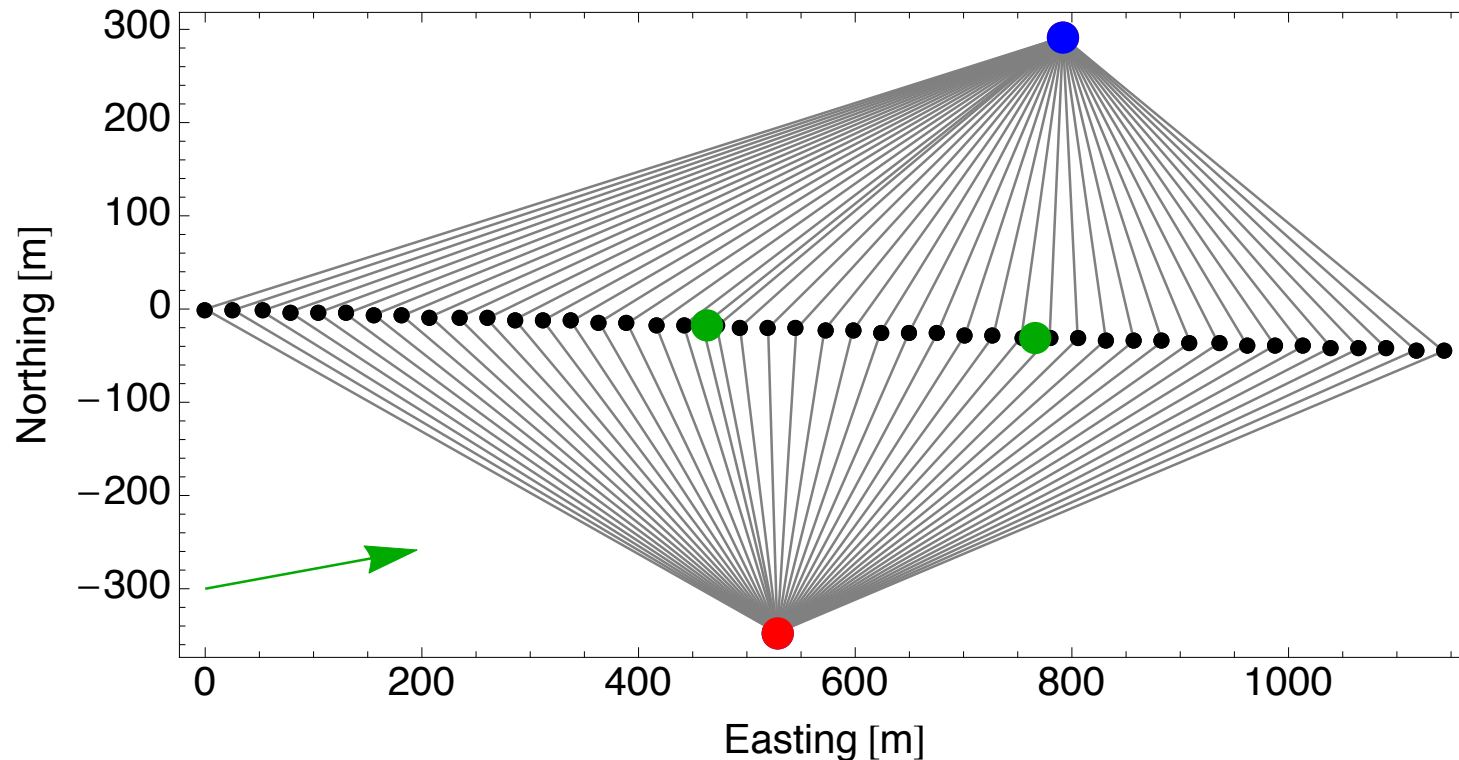# What went wrong

DTU Wind Energy, Technical University of Denmark
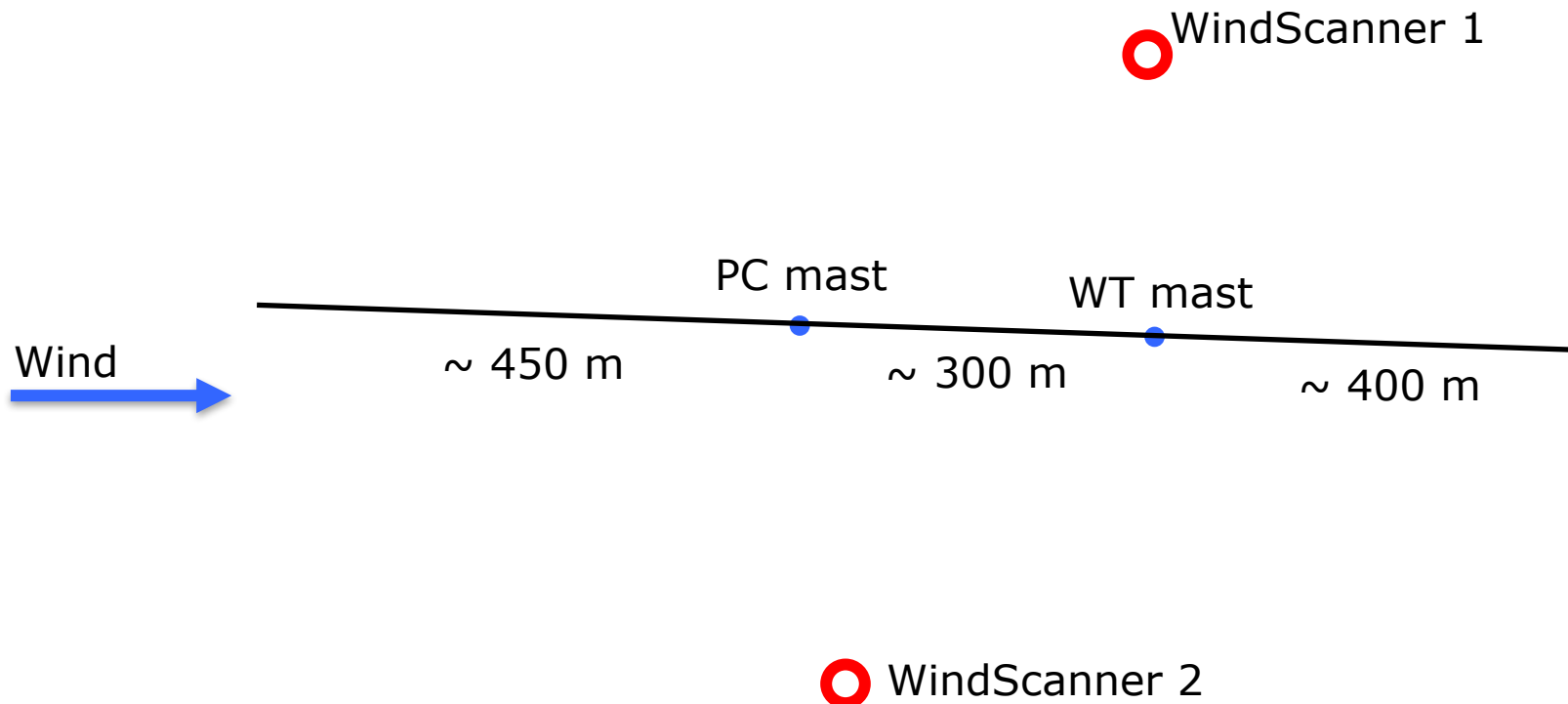
What went wrong

- Beams parallel to each other between two mast locations
- Erroneous reconstruction of horizontal wind speed and wind direction

DTU Wind Energy, Technical University of Denmark

History: Active application

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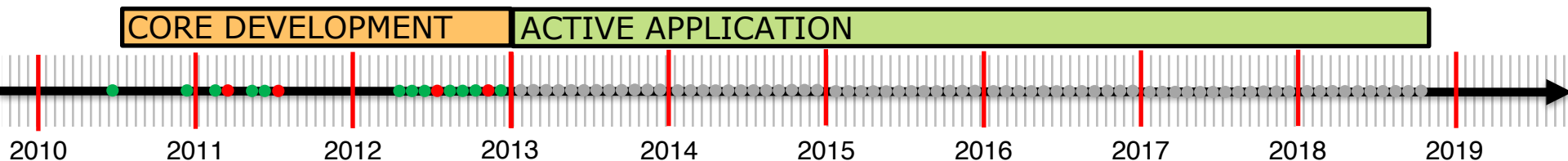
10/2017 Lascar

03/2018 Alex

08/2018 Multi-rotor wake

☺

Impressive pointing accuracy
Multi-lidar vs Mast fantastic comparison
Moved the whole lab from DK to DE
Running campaign via mobile network

☹

Low clouds = data availability
Low mobile coverage for some spots
Hitting hard targets (mast guidewires)

https://doi.org/10.3390/rs8090782

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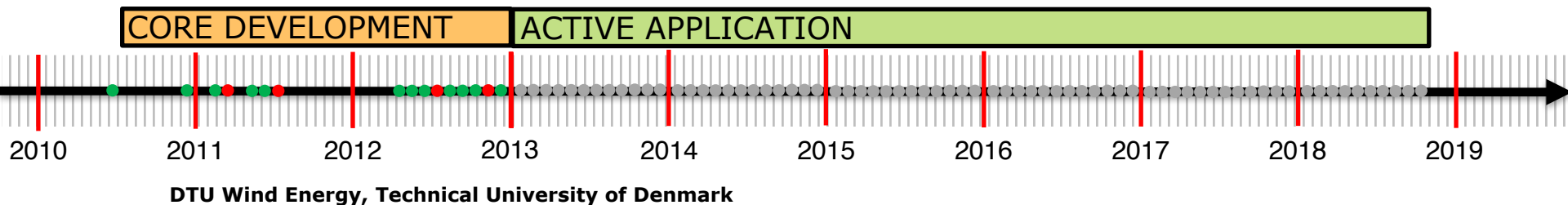
10/2017 Lascar

03/2018 Alex

08/2018 Multi-rotor wake

☺
First hard-core installation
Running WindScanners using generators
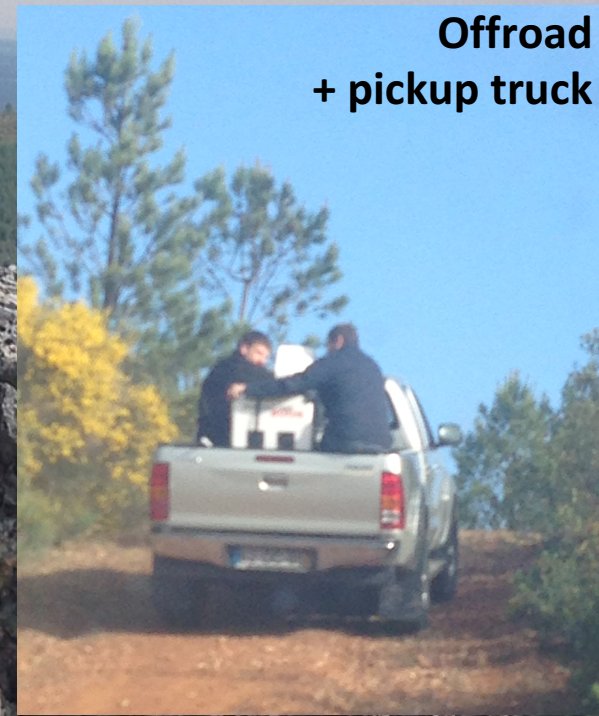Scanned wind resources along a ridge

☹
Air too clean = data availability?
Too hot = WindScanners needed siesta

https://doi.org/10.5194/amt-10-3463-2017

CORE DEVELOPMENT   ACTIVE APPLICATION

2010   2011   2012   2013   2014   2015   2016   2017   2018   2019

Installation of NW WindScanner

Hiking trail

Offroad
+ pickup truck

VILA VELHA DE RODÃO

Installation of NW WindScanner

Hiking trail

Offroad
+ pickup truck

"Don't go where the path may lead, go instead where there is no path…and leave a trail"
-Ralph Waldo Emerson

History: Active application

02/2013 Swinging musketeer

06/2013 IBL WiSH

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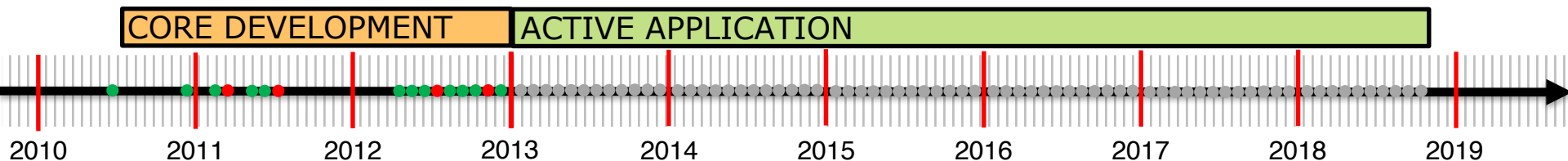
10/2017 Lascar

03/2018 Alex

08/2018 Multi-rotor wake

☺
Flow measurements in the coastal zone

☹
Too much aerosols (limited range)
Often needed cleaning of glass window
Too humid (desiccants 'roasted' often)

https://doi.org/10.3390/rs8110884

CORE DEVELOPMENT   ACTIVE APPLICATION

2010   2011   2012   2013   2014   2015   2016   2017   2018   2019

Beware!!!
We worked and
we are still working with prototype units!

RUNE campaign

More info: https://www.linkedin.com/pulse/seasons-greetings-nikola-vasiljevic/

DTU Wind Energy, Technical University of Denmark

What we learned

- Chose an adequate site

- Simple is sexy

- Look at data from day one

- If you need two lidars for experiments, then you actually need three lidars

- Don't do an experiment for the experiment sake

- Develop and use methodology for multi-lidar experiments:
  https://doi.org/10.5194/amt-10-3463-2017

- Make a simple uncertainty model use it to guide your lidar placement:
  https://doi.org/10.5281/zenodo.1441178

- **Scanning lidars / multi-lidars are complex to handle:**
  https://doi.org/10.5281/zenodo.1175211
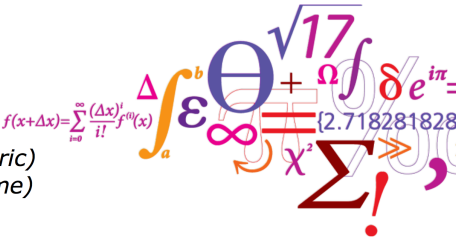
https://doi.org/10.5281/zenodo.1146326

New methods of measurements: where are we today, and where are we heading towards

Nikola Vasiljević

Contributors (in alphabetic order):
Alan Brewer (NOAA)
Jean-Pierre Cariou (Leosphere)
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Peter Clive (Wood Group)
Mike Hardesty (NOAA)
Mike Harris (Zephir)
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Raghu Krishnamurthy (UNI Notre Dame)
David Schlipf (UNI Stuttgart)
Elliot Simon (DTU)
Rozenn Wagner (DTU)

DTU Wind Energy
Department of Wind Energy

"There is a need to make the technology "dummy proof" for the larger audience, but also quite "open" for power users." – Lidar expert group

https://doi.org/10.3390/rs10030406

"Future challenges include the development of lidar uncertainty models, best practices for data management, and developing community-based tools for data analysis, planning of lidar measurements and lidar configuration. " – *IEA Wind Task 32*

"Future challenges include the development of lidar uncertainty models, best practices for data management, and developing community-based tools for data analysis, planning of lidar measurements and lidar configuration. " – *IEA Wind Task 32*

Tomorrow IEA Wind Task 32 Workshop:

"Future challenges include the development of lidar uncertainty models, **best practices for data management, and developing community-based tools for data analysis,** planning of lidar measurements and lidar configuration. " – *IEA Wind Task 32*

Thank you!

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https://www.youtube.com/user/cadenza83/videos