

› **DUTCH OFFSHORE WIND ATLAS**

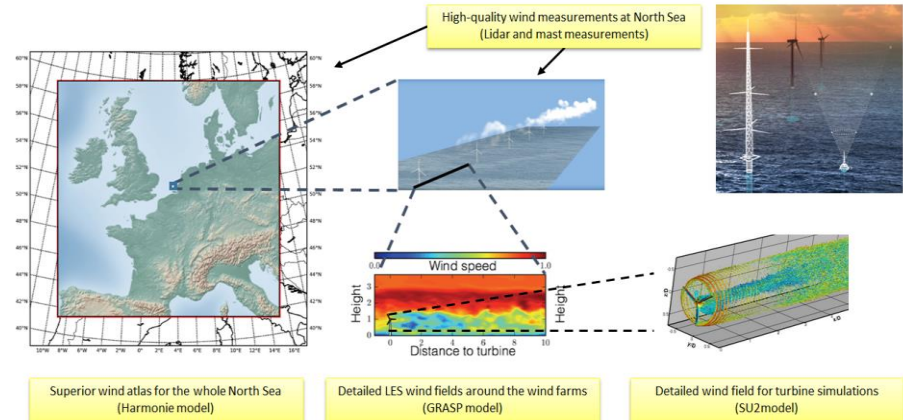
WindDays, Rotterdam, 14 June 2018

Dr. J.W. Wagenaar (ECN part of TNO)
Ir. P.A. van Dorp (Whiffle)



CONTENT

- › Background & Objectives
- › Approach
- › Results so far
- › Take away messages



› **BACKGROUND AND OBJECTIVES**

BACKGROUND

› Operational (957MW)

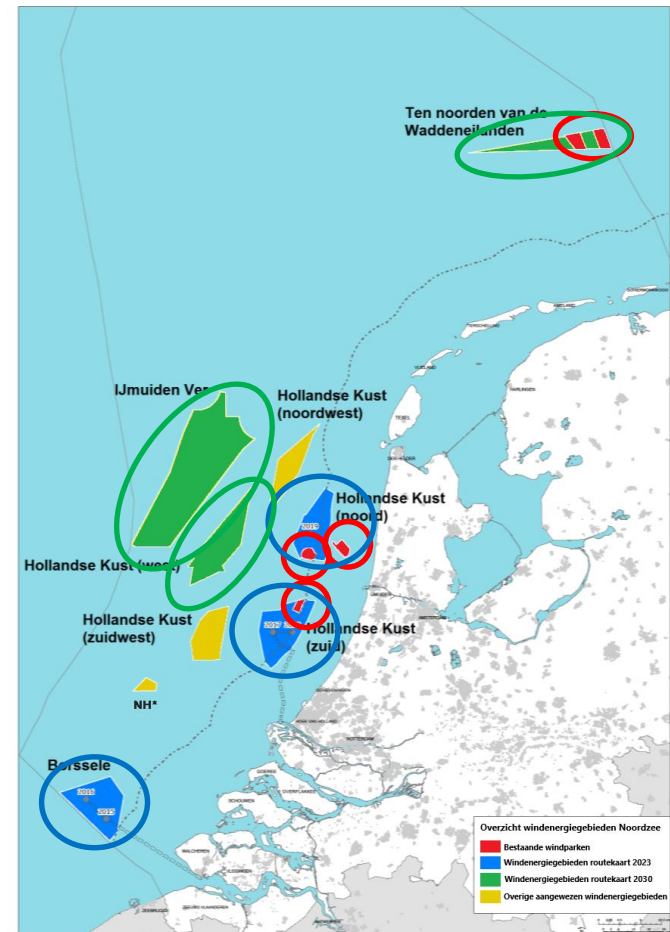
- › OWEZ 2006 108MW
- › Amalia 2008 120MW
- › Luchterduinen 2015 129MW
- › Gemini 2017 600MW

› Tender (3.5GW)

- › Borssele 2016 1400MW
- › HKZ 2017/18 1400MW
- › HKN 2019 700MW

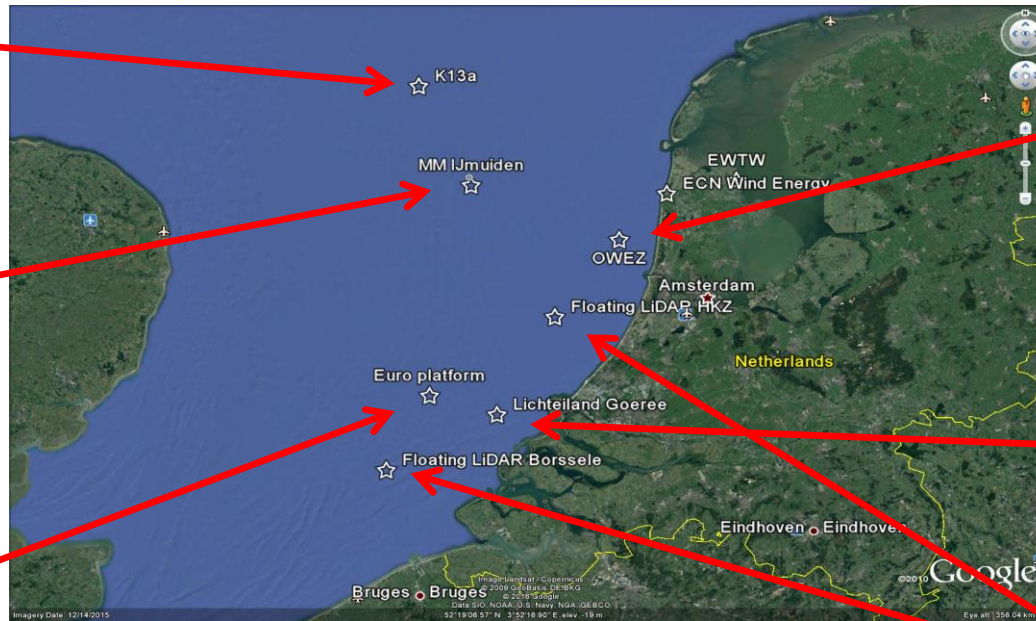
› Roadmap 2030 (6.1GW)

- › HKW 1400MW
- › Fryslan Islands 700MW
- › IJmuiden ver 4000MW



Source: Letter of minister to House of Representatives

OFFSHORE MEASUREMENT PLATFORMS



All data publicly available at www.windopzee.net

LONG TERM MODELLING

- › **From available mesoscale models KNW shows best quality**
 - › From first principles as compared to EMD-ConWx
 - › Validation study Ecofys (Borssele OWFZ WRA, 2015)

- › **However, ...**
 - › KNW only up to 2013
 - › Daily cycle not included (MCP)
 - › KNW only to 200m, no information at higher altitude for
 - › Larger wind turbines, airborne wind power, large wind farm
 - › Wake effects of existing wind farms not included

- › **... DOWA project**



OBJECTIVES



- › Make available the Dutch Offshore Wind Atlas (DOWA)
 - › *Including long term climatology and wind field information aiming specifically at the wind energy industry*
- › Understanding of offshore wind conditions up to large heights
 - › *Wind profile up to 600m height*
 - › *Extreme events (low-level jets) and understanding of occurrence*
- › Development of detailed wind fields for more accurate wind resource and wind load assessments
 - › *LES models are nested within weather models*
- › Include offshore wind farms (and their wakes) in the wind field modelling
 - › *Development and demonstration only*

Lower the levelized costs of offshore wind energy

› **APPROACH**

APPROACH

Update existing KNW

- › Update for the recent years
- › Total period of 40 years

Create new DOWA

- › Up to a height of 600m
- › Better correlation, e.g. daily cycle

Wind turbine and farm effects

- › Accurate wind field modelling:
1h/2.5km -> 10s/100m
- › Wake effects of wind farm clusters

› **RESULTS SO FAR**

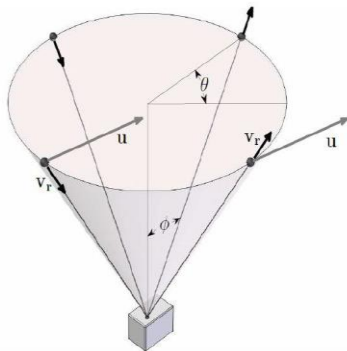
RESULTS SO FAR

- › KNW atlas updated until March 2018
 - › <https://data.knmi.nl/datasets>
- › Scanning LiDAR measurements completed
 - › *Comparison with KNW work in progress*
- › First analyses offshore wind measurements
 - › *Profiles, distributions and low level jets*
- › DOWA validation started
- › First LES turbine parametrization and runs
 - › *Validation with measurements*



LEOSPHERE WINDCUBE 200S SCANNING LIDAR

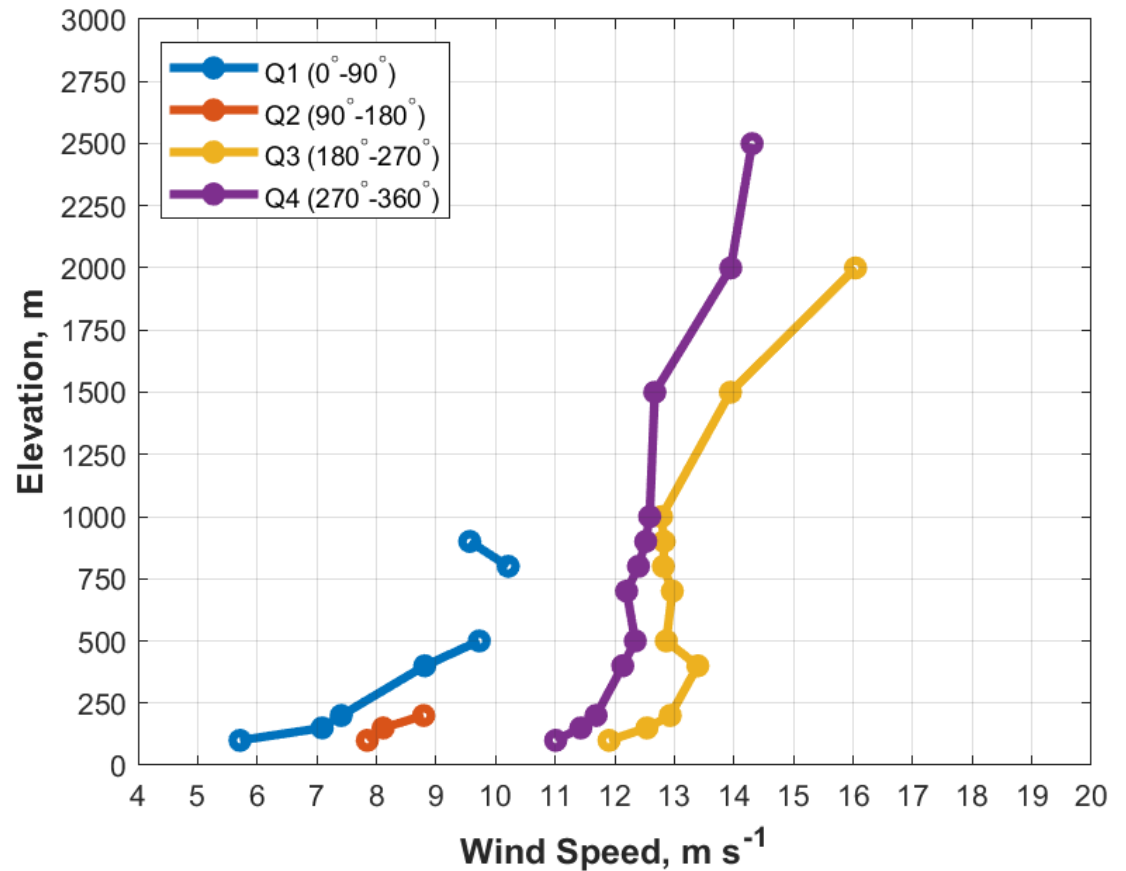
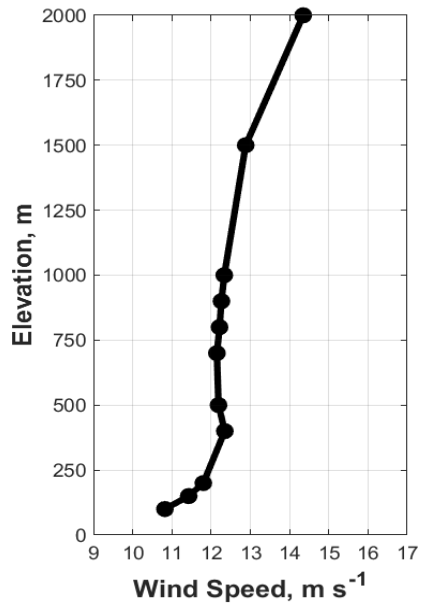
Doppler Beam Swinging (DBS) scanning techniques were used to measure the vertical wind profile



- Data collected between: *03-Nov-2017 and 01-Jan-2018 (1404 Possible Wind Profiles)*
 - 100 m and 7050 m at 50-m intervals
- Data thresholded using CNR (<-22) and LiDAR Confidence Index (=100)

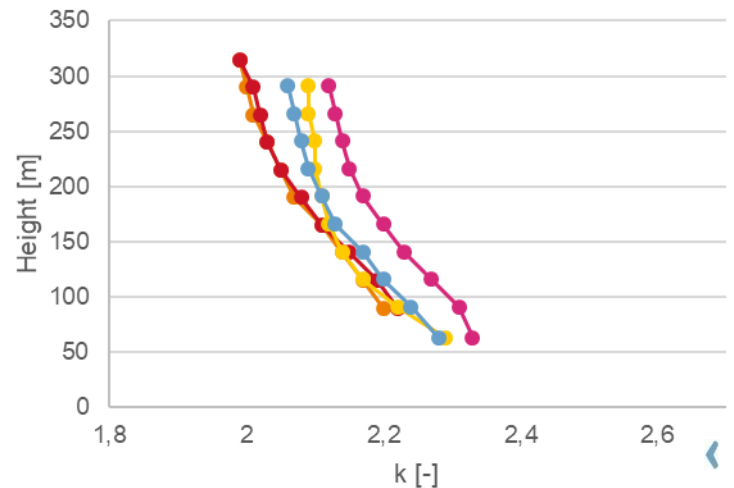
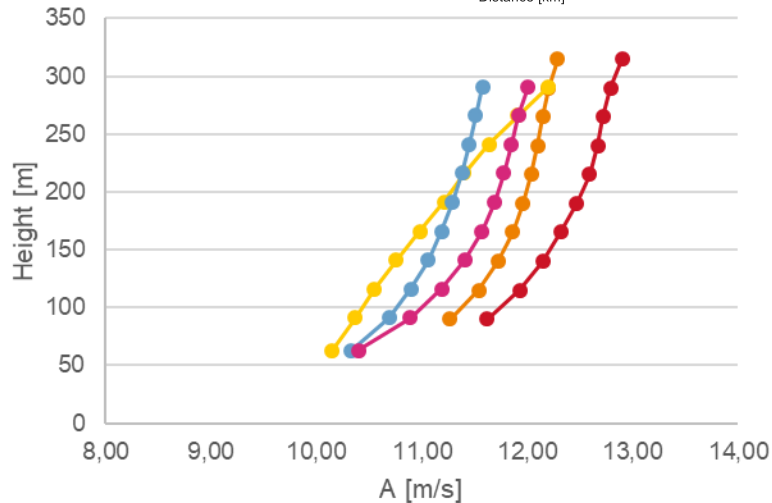
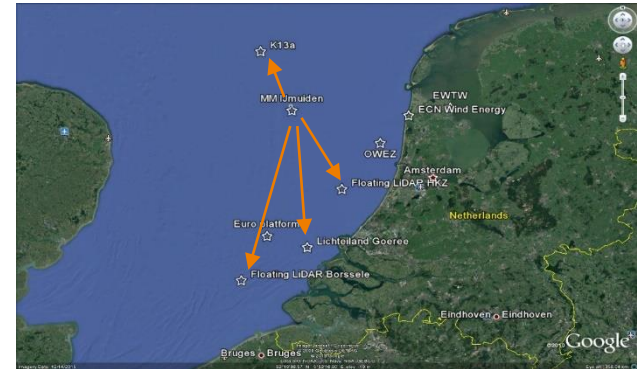
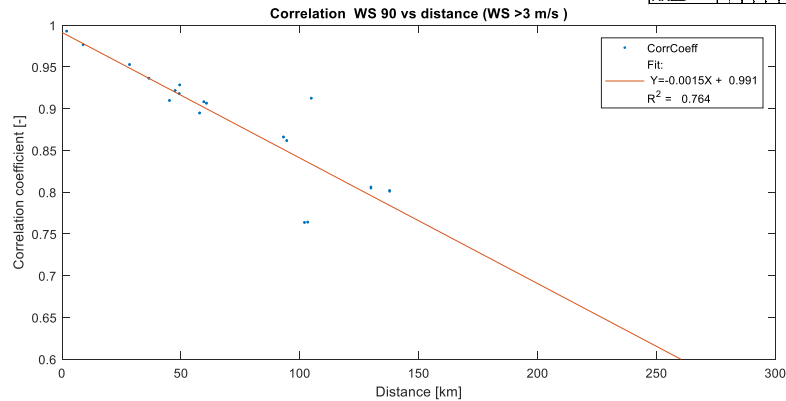
PROFILE + SEGMENTED BY WD

› Comparison with KNW WIP

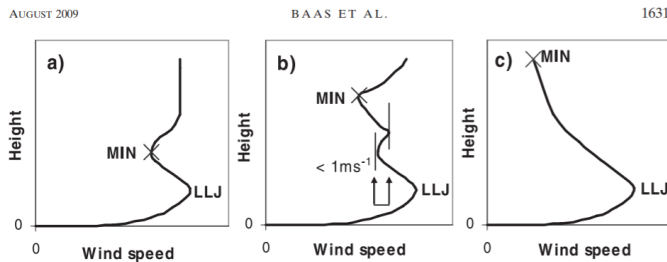


OFFSHORE WIND CONDITIONS

	2012			2013			2014			2015			2016			2017			2018																	
	F	M	A	M	J	J	A	S	O	N	D	F	M	A	M	J	J	A	S	O	N	D	F	M	A	M	J	J	A	S	O	N	D			
MMIJ																																				
LEG																																				
EPL																																				
K13																																				
BWZ L1																																				
BWZ L2																																				
HKZA																																				
HKZB																																				



LOW LEVEL JET IDENTIFICATION AND CHARACTERISTICS

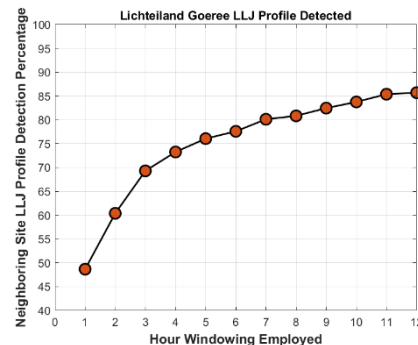
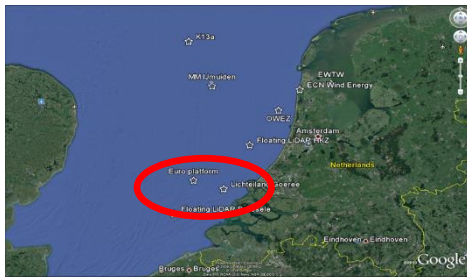


Measurement Heights Between 90 m and 291 m

- MMIJ ~ 2,55 % – 9,76 m/s at 117,62 m
- LEG ~ 2,37 % – 8,04 m/s at 118,26 m
- EPL ~ 3,13 % – 8,91 m/s at 113,45 m

Measurement Heights Between 27 m and 215 m

- MMIJ (Tower and LiDAR Data Coupled)
 - 1,72 % – 8,70 m/s at 83,03 m
- Hollandse Kust Noord
 - HKN A ~ 1,40 % – 6,93 m/s at 58,36 m
 - HKN B ~ 1,40 % – 6,85 m/s at 53,59 m
- Hollandse Kust Zuid
 - HKZ A ~ 1,37 % – 7,23 m/s at 63,60 m
 - HKZ B ~ 1,36 % – 7,16 m/s at 61,12 m
- Borssele Wind Zone
 - Lot One ~ 1,80 % – 8,23 m/s at 67,40 m
 - Lot Two ~ 2,76 % – 8,70 m/s at 68,17 m



Note: Statistics depend on

- › definitions and choices
- › seasonal availability of LiDAR data

WHIFFLE

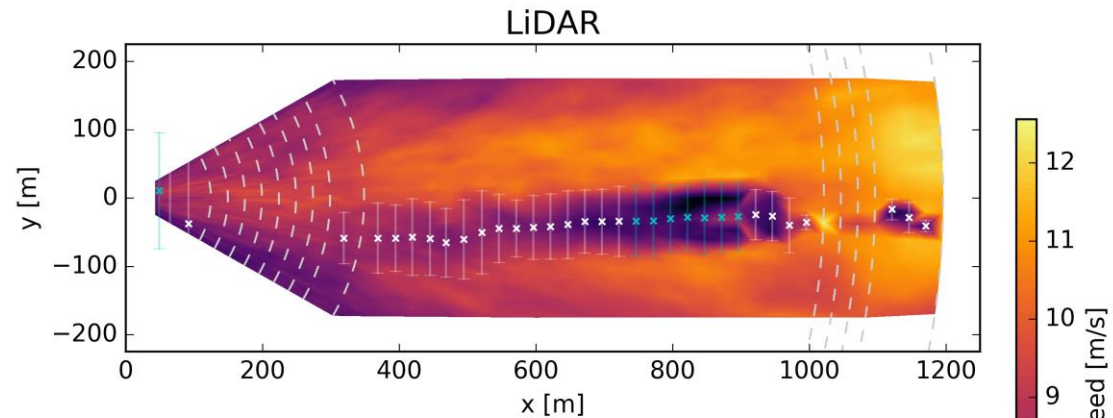
WEATHER FINECASTING

- GRASP:
 - Turbulence-resolving weather model
 - Runs operationally with ECMWF boundary conditions
- DOWA project:
 1. High spatial (10-100 m) and temporal (1-10 sec) representation of atmosphere for long time periods (10+ year) using ERA5 and HARMONIE reanalysis boundary conditions
 2. Effect of wind farm wakes on local wind climatology

2013-11-01 06:50:00, 10-min average

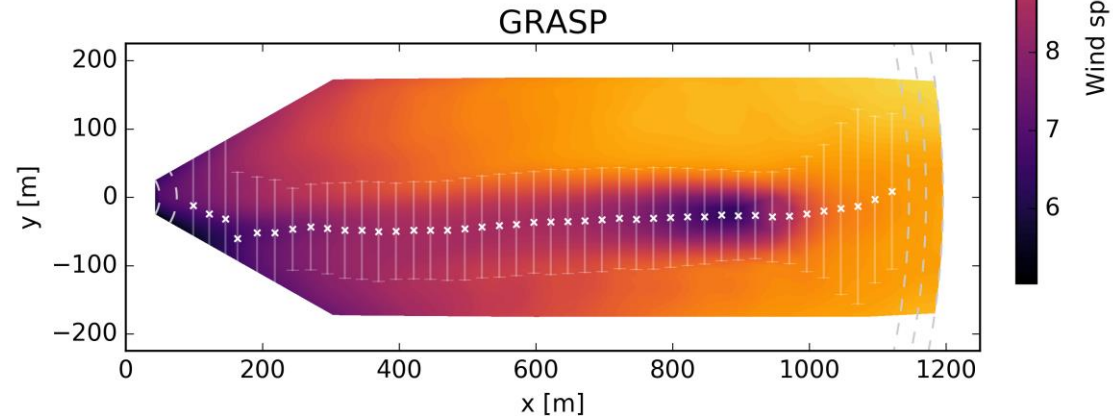
Wind turbine model:

- Actuator disk parametrisation (Meyers & Meneveau, 2010)



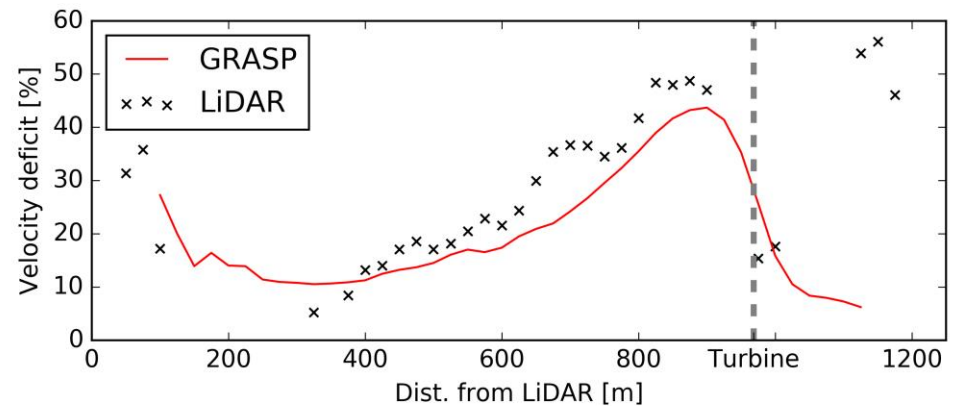
Validation:

- LiDAR observations at ECN wind turbine test site
- Emulate LiDAR in GRASP
- Wake detection algorithm (Aitken et al., 2014)
- Validation of wake depth and width



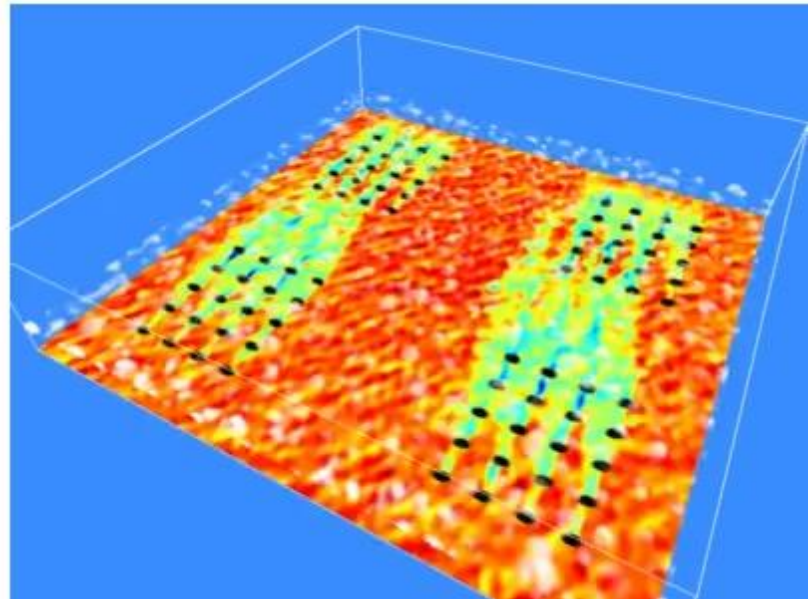
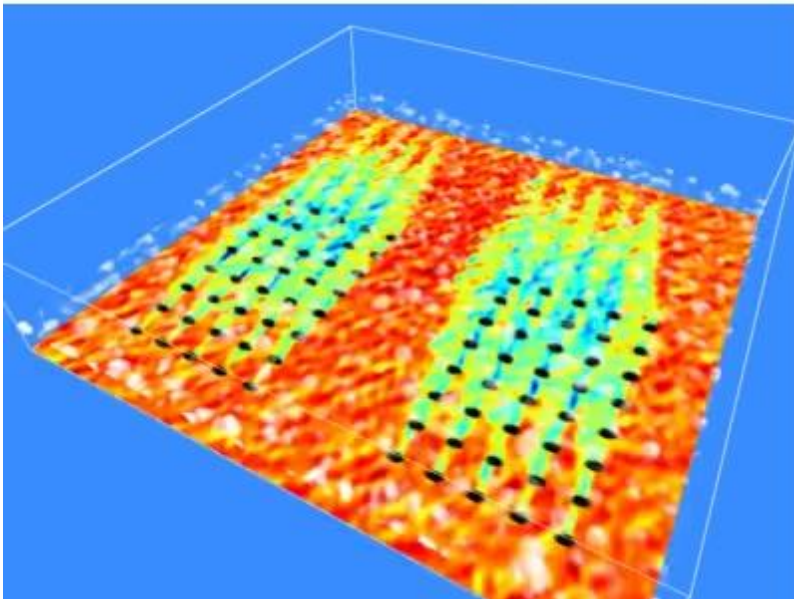
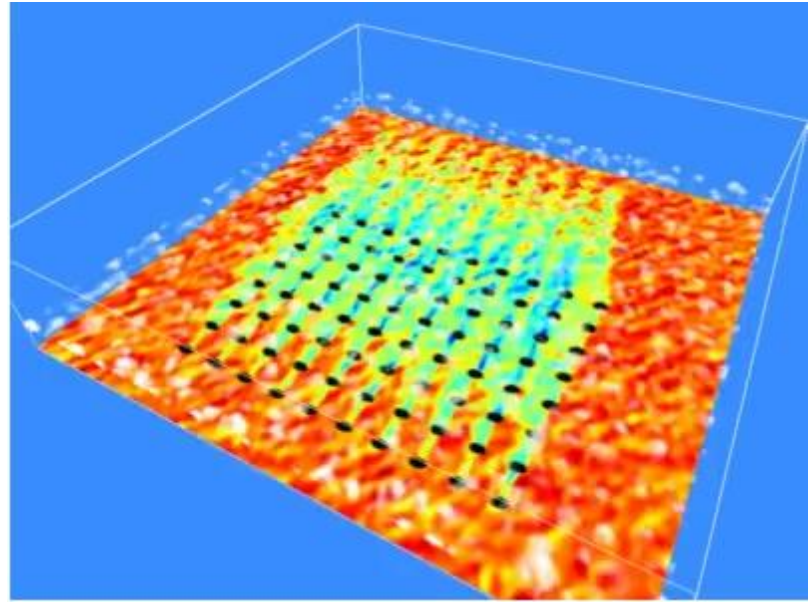
Ongoing research:

- GRASP resolution sensitivity
- Further optimisation of wind turbine parametrisation



Next step: generate wind farm wake climatology

- 800 MW of wind power on 25 x 25 km site
 - Intra- and inter-wind farm wake effects
1. Single wind farm (80 x 10 MW)
 2. Two wind farms (2 x 40 x 10 MW)
 3. Four wind farms (4 x 20 x 10 MW)
 4. ...



› **TAKE AWAY MESSAGES**

TAKE AWAY MESSAGES

Summary

- › Important project for WRA
- › Support from leading companies
- › Higher accuracy
 - › Day-night
 - › Higher altitude
 - › Wind farm effects
- › Strong consortium
- › DOWA will become available end of 2019

DOWA specs

- › Wind speed and direction
- › 2008-2017
- › 2.5km x 2.5km grid
- › 10m to 600m height



Available data

- › KNW updates until March 2018 available at <https://data.knmi.nl/datasets>
- › Offshore measurement data available at www.windopzee.net

› **THANK YOU FOR YOUR ATTENTION**

TNO.NL/ECNPARTOFTNO



ECN

TNO

innovation
for life