U N I V E R S I T E T E T   I   B E R G E N

Geophysical Institute, Faculty of Mathematics and Natural Sciences

SUMO and SAMURAI – GFI/UiB drones for wind energy reserach

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Science meets Industry, Bergen

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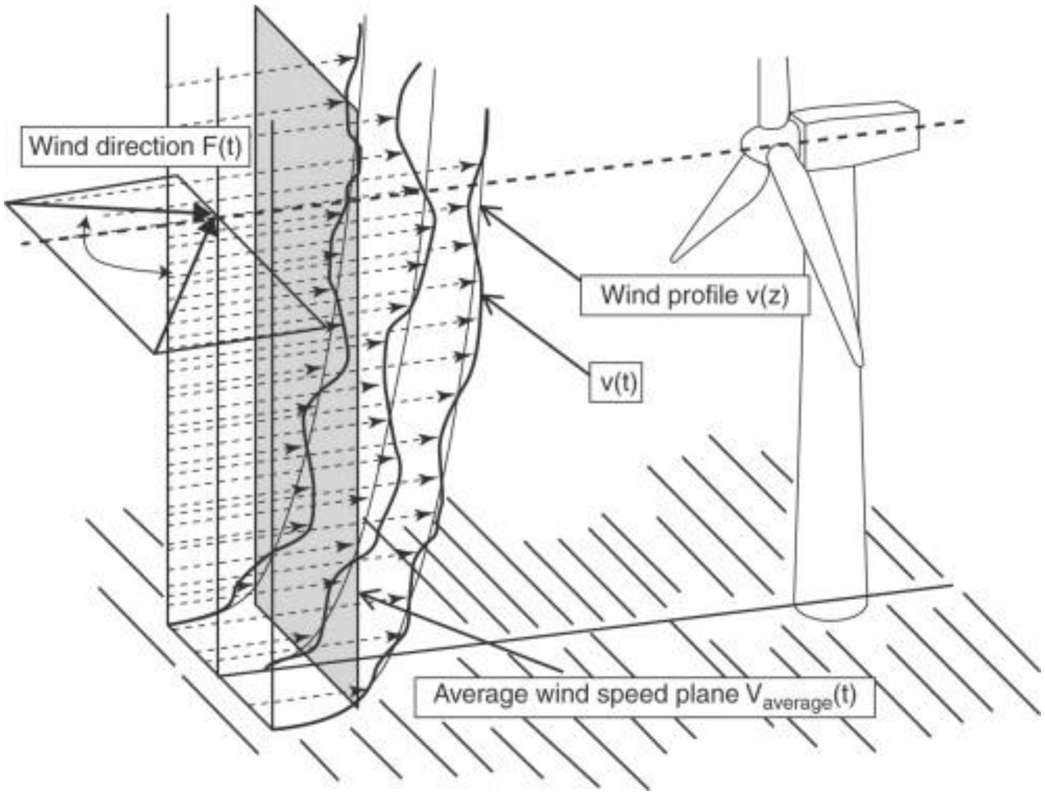
What do we need to estimate power and loads?

- Average wind speed
- Wind shear over the rotor disk
- Turbulence intensity and turbulence structure (coherence)

Two main problems:

- Massive lack of observational data offshore
- Questionable applicability of our boundary layer theories
    - based on measurements over homogeneous surfaces over land
    - Increasing size of modern wind turbines



Source: H. Söker, Loads on wind turbine blades, In: Woodhead Publishing Series in Energy,Advances in Wind Turbine Blade Design and Materials, Woodhead Publishing, 2013, 29-58, ISBN 9780857094261, https://doi.org/10.1533/9780857097286.1.29.

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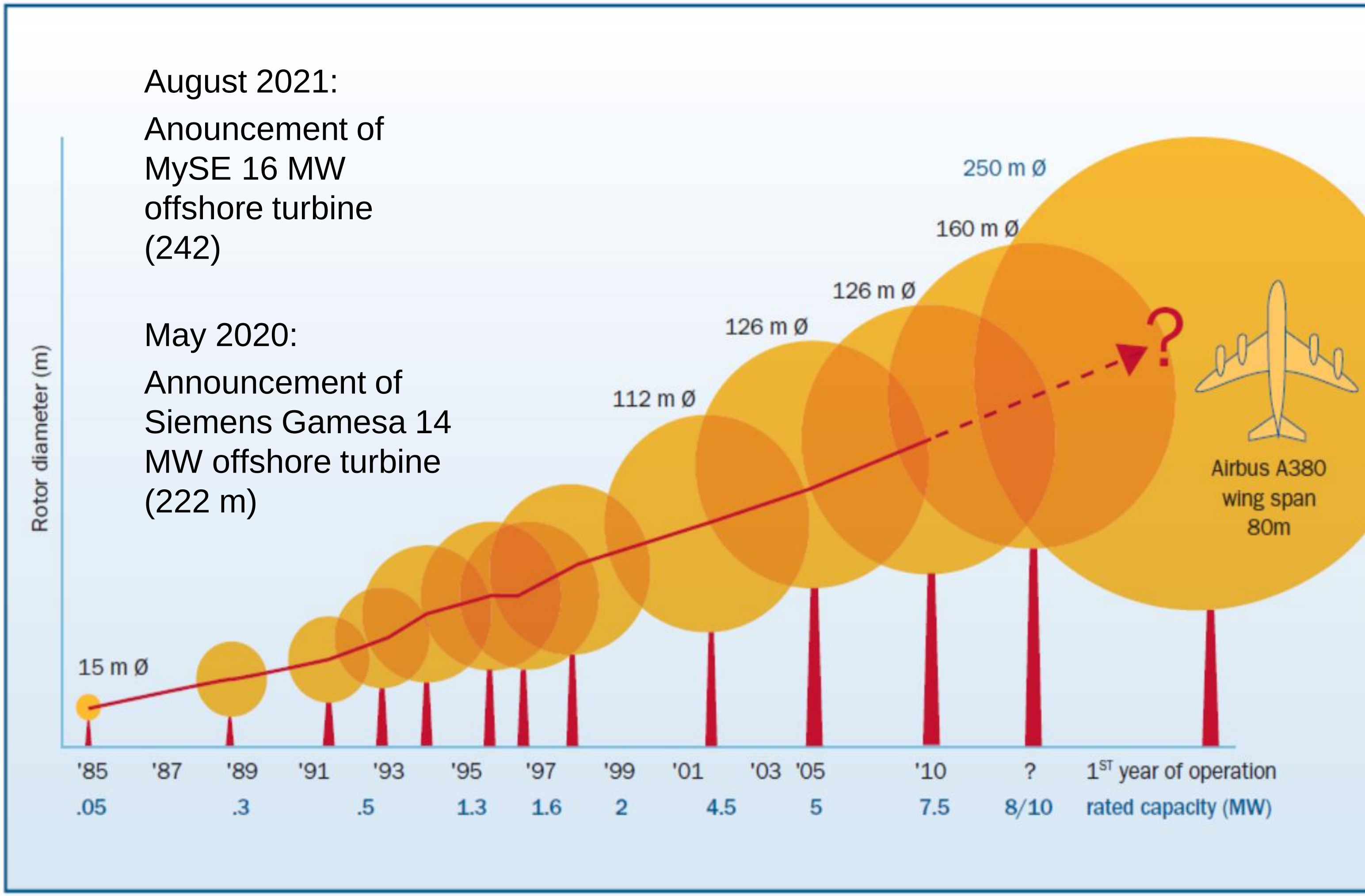
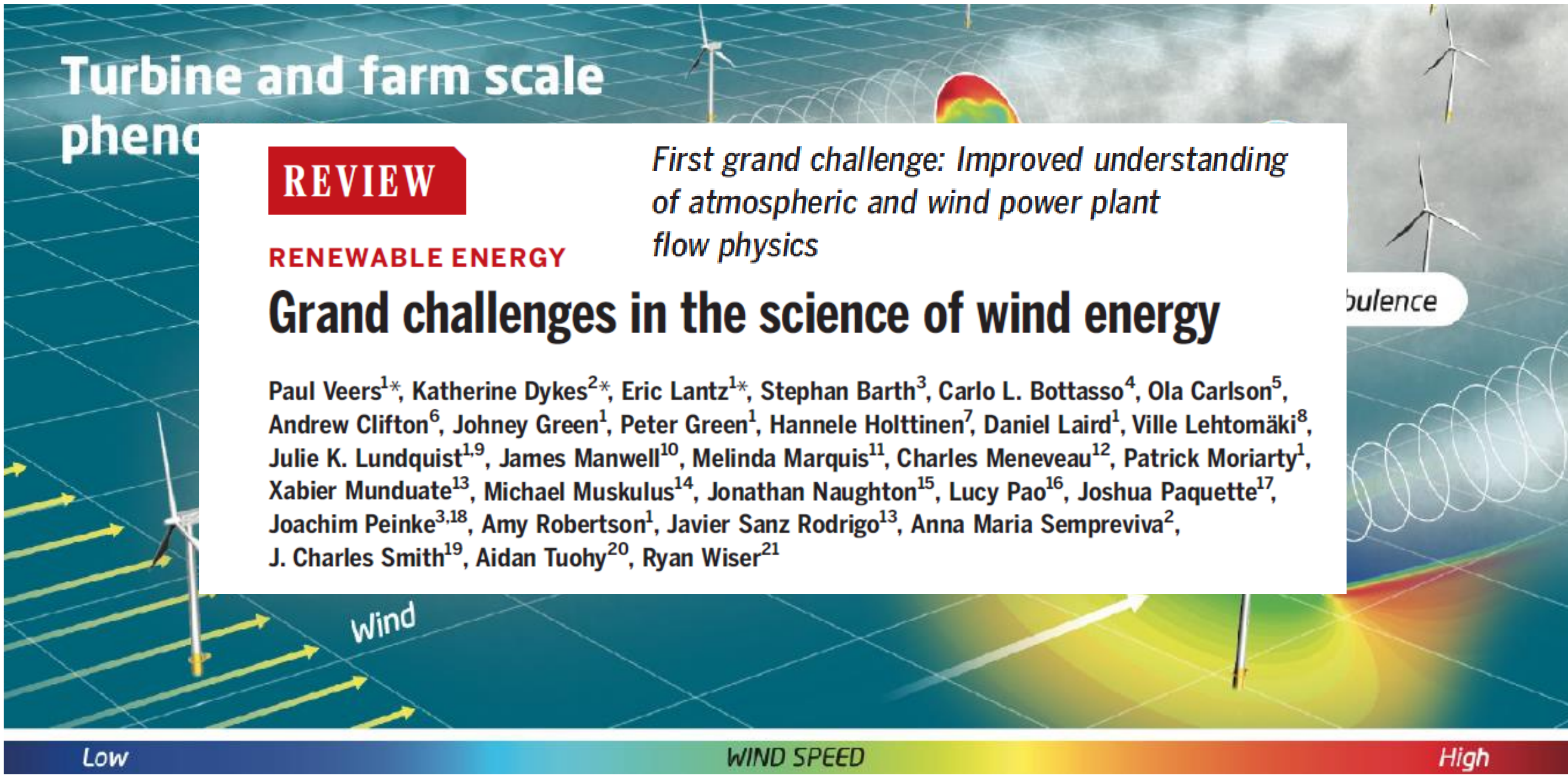
Continuous increase in wind turbine size



Source: http://nextbigfuture.com/2012/06/800-foot-tall-wind-turbines-are.html

Flow characterization is essential for wind energy



REVIEW

RENEWABLE ENERGY

First grand challenge: Improved understanding of atmospheric and wind power plant flow physics

Grand challenges in the science of wind energy

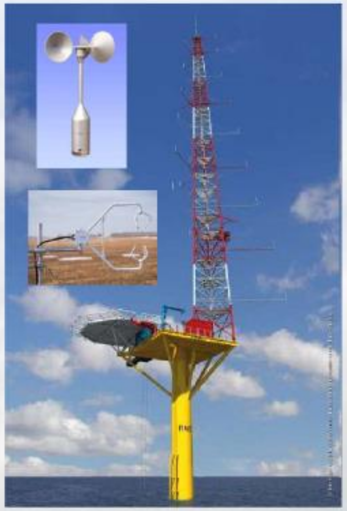
Paul Veers[1]*, Katherine Dykes[2]*, Eric Lantz[1]*, Stephan Barth[3], Carlo L. Bottasso[4], Ola Carlson[5], Andrew Clifton[6], Johney Green[1], Peter Green[1], Hannele Holttinen[7], Daniel Laird[1], Ville Lehtomäki[8], Julie K. Lundquist[1,9], James Manwell[10], Melinda Marquis[11], Charles Meneveau[12], Patrick Moriarty[1], Xabier Munduate[13], Michael Muskulus[14], Jonathan Naughton[15], Lucy Pao[16], Joshua Paquette[17], Joachim Peinke[3,18], Amy Robertson[1], Javier Sanz Rodrigo[13], Anna Maria Sempreviva[2], J. Charles Smith[19], Aidan Tuohy[20], Ryan Wiser[21]

Courtesy: Jakob Mann, DTU.

Potential measurement systems

(floating) lidar

offshore masts



drones ?

moderate flexibility

expensive

Beam average (20 m, 1Hz)

no flexibility

very expensive

in-situ (20-100 Hz)

high flexibility

not so expensive

in-situ (20-100 Hz)

SUMO

https://www.reddit.com/r/funny/comments/oy4qq/sumo_ski_jump/

SUMO – Small Unmanned Meteorological Observer

Technical data:

wingspan: 80 cm
length: 75 cm
weight: 600 g

electric powered, motor time per flight: ≈25 min

maximum ascent rate: 15 m/s
average ascent rate: 7-10 m/s

maximum air speed: 35 m/s
average air speed: 12-18 m/s

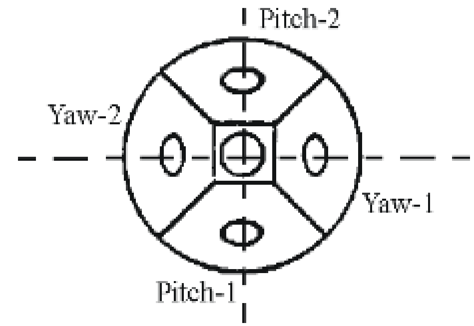
maximum altitude above ground: 3.5-(6) km

SUMO – Small Unmanned Meteorological Observer

miniaturized 5-hole probe from Aeroprobe Inc., USA (3 mm diameter)

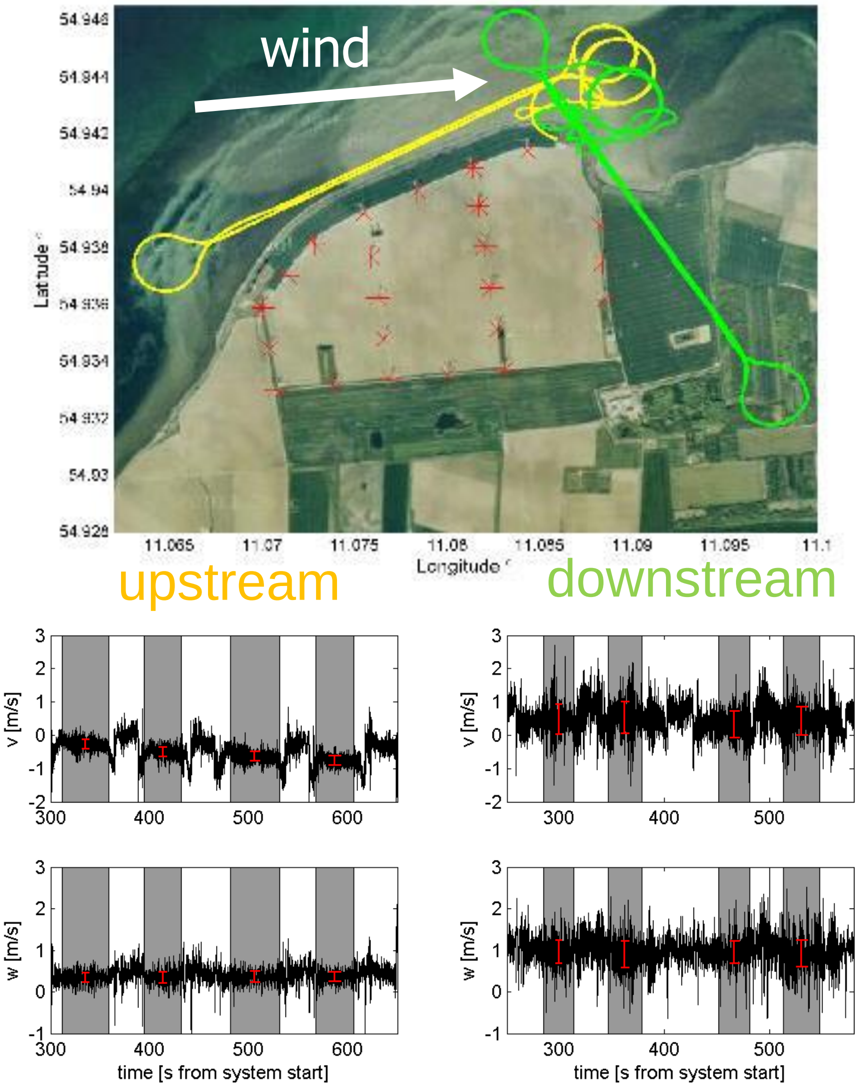
differential pressure measurements (static-dynamic, left right, up-down)

provides flow velocity and angles of sideslip and attack with 100 Hz resolution



Reuder, J., M. Jonassen, and H. Olafsson, The Small Unmanned Meteorological Observer SUMO: Recent developments and applications of a micro-UAS for atmospheric boundary layer research. Acta Geophysica, DOI: 10.2478/s11600-012-0042-8, 2012

SUMO turbulence measurements around a wind farm



SUMO – Investigation of wind turbine wakes

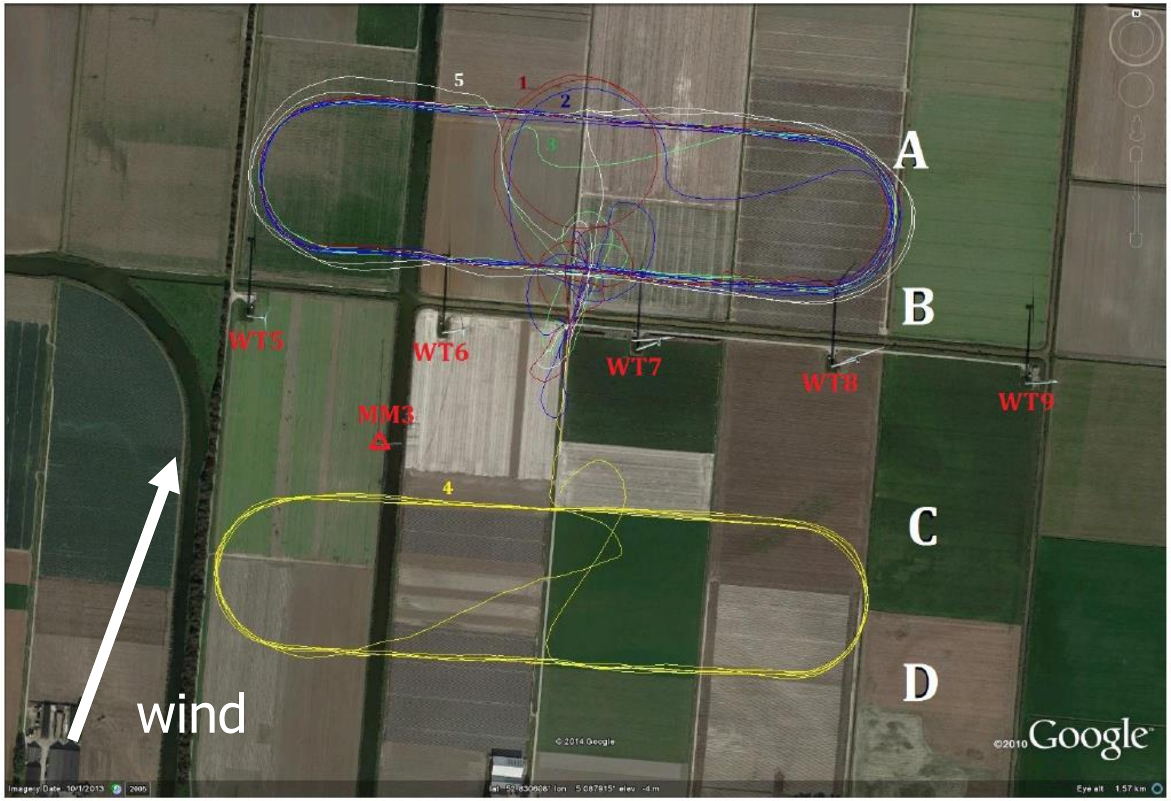


Fig. 2. Location of the 5 NORDEX N80 2.5 MW turbines (WT5-WT9) and the meteorological mast at the ECN test site Wieringermeer, together with the flight tracks of the 5 SUMO flights performed on May 10, 2014. The wind was coming from Southwest, placing the flights # 1-3 and 5 downstream and the flight # 4 upstream the row of wind turbines.

Reuder, J., Båserud, L., Kral, S. T., Kumer, V., Wagenaar, J.-W., and Knauer, A. : Proof of concept for wind turbine wake investigations with the RPAS SUMO. Energy Procedia, 94, 452-461, doi:10.1016/j.egypro.2016.09.215., 2016.

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SUMO – Investigation of wind turbine wakes

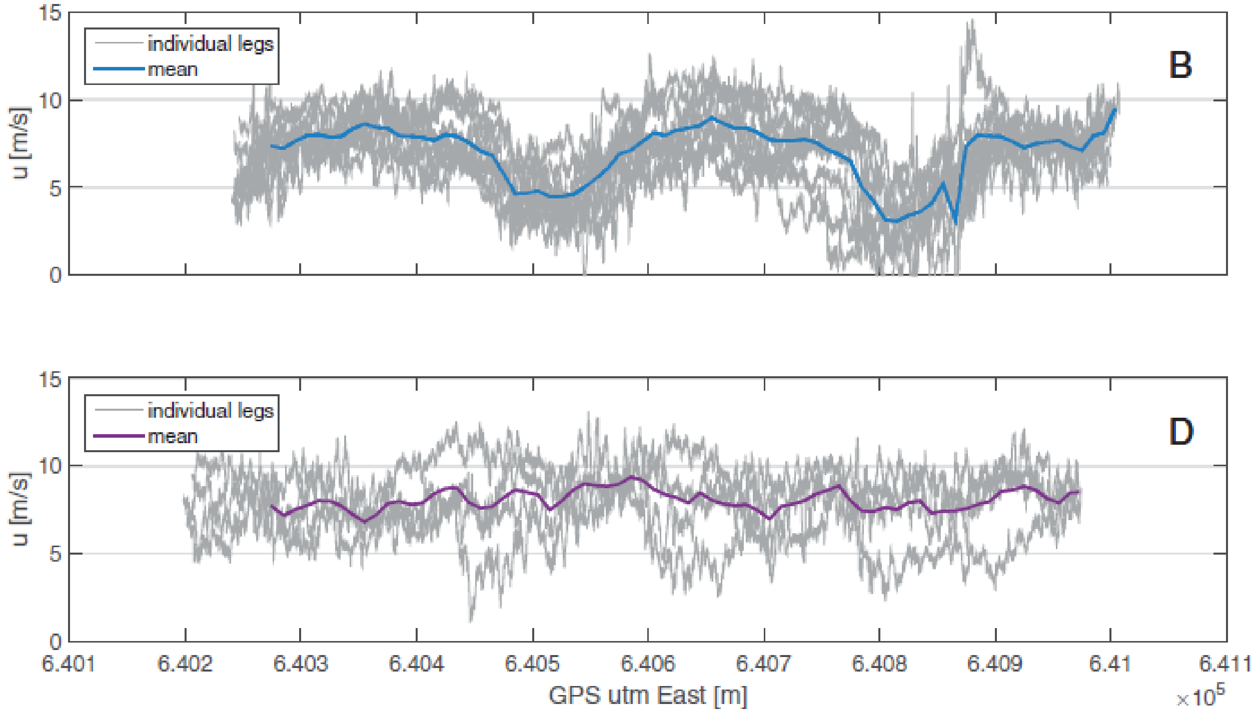

Fig. 6. East-West wind speed component u measured by SUMO on track B (ca. 1.5 rotor diameter downstream the row of wind turbines) and track D (upstream). The thin gray lines show the data from the individual flight legs, the thick colored line in each plot indicates the average over all corresponding flight legs. The average curve is based on 10 individual legs for track B and 4 individual legs for track D.

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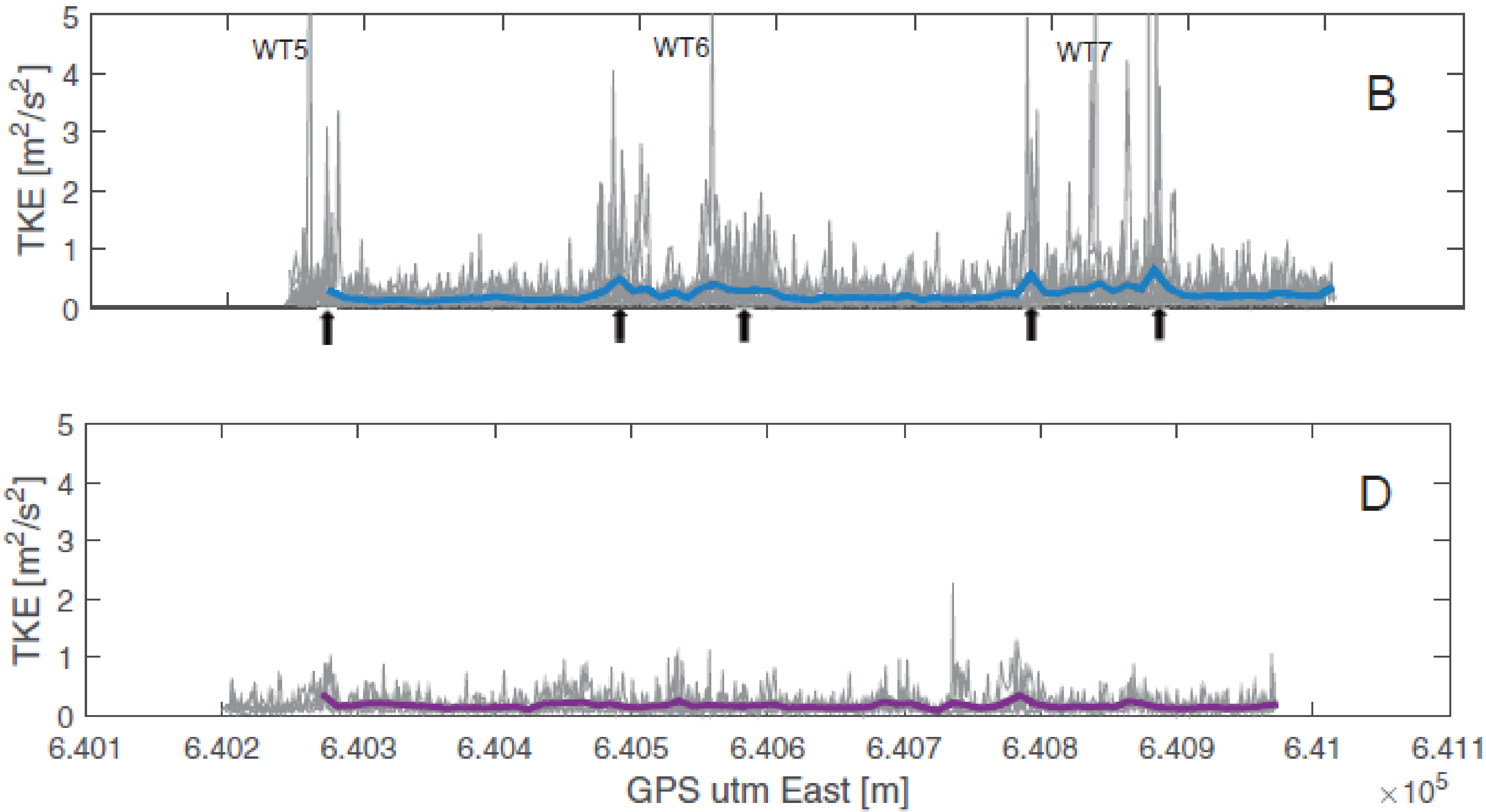

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Sonic anemometer on drones

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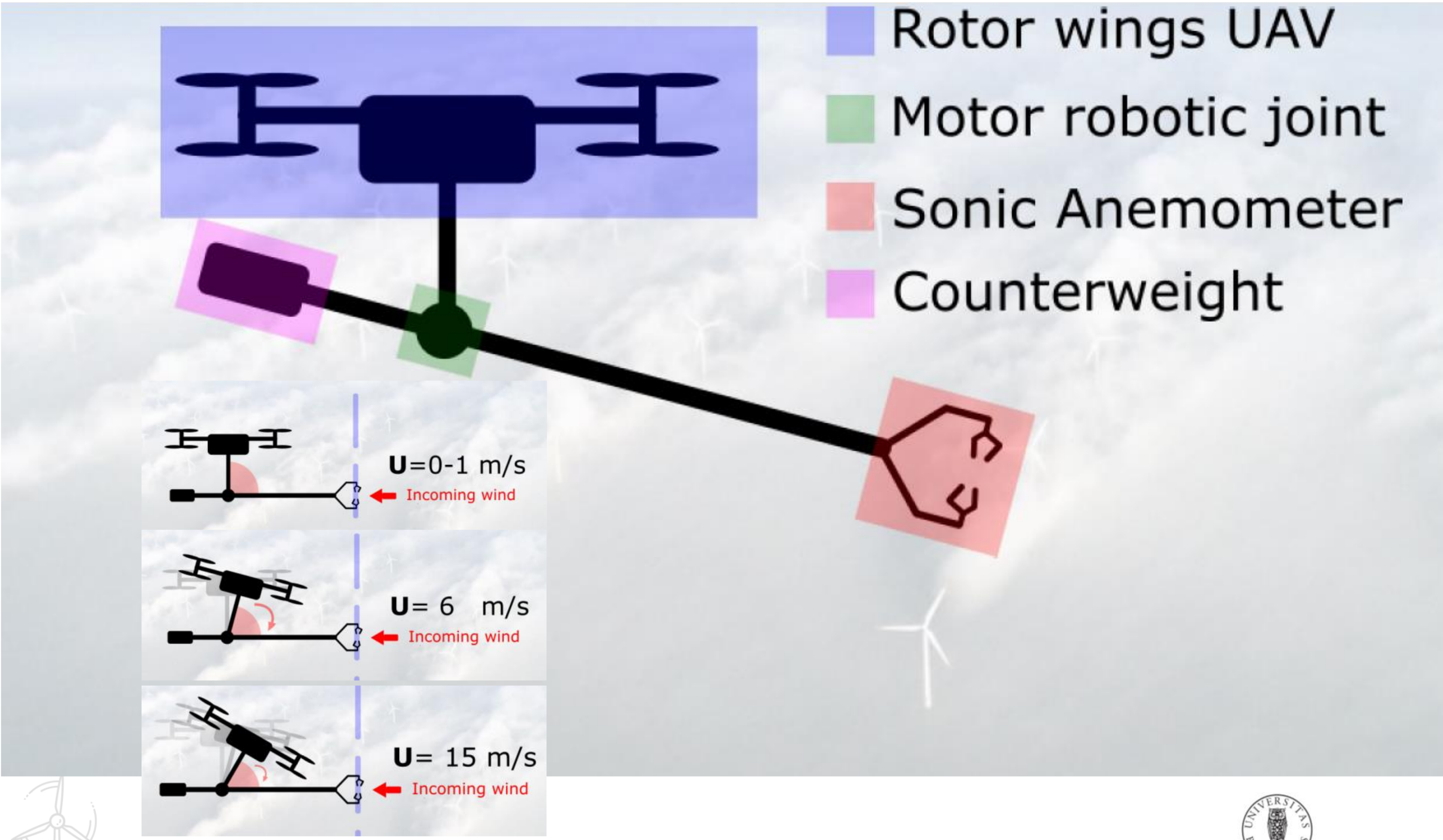
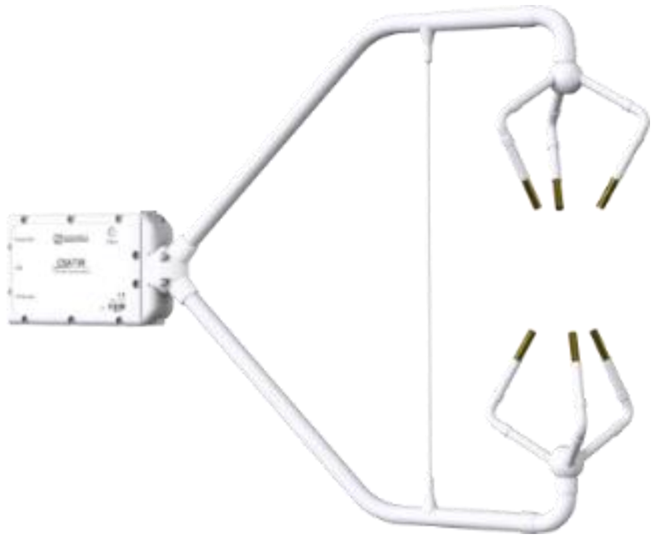
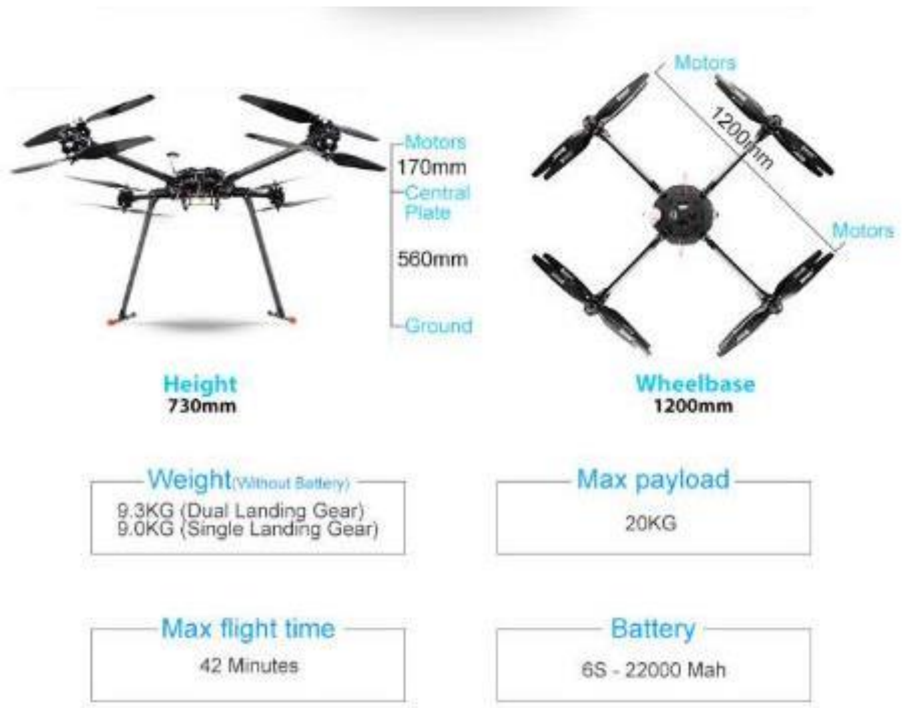
SAMURAI concept



SAMURAI – main components





Sonic anemometer:
Campbell CSAT-3B

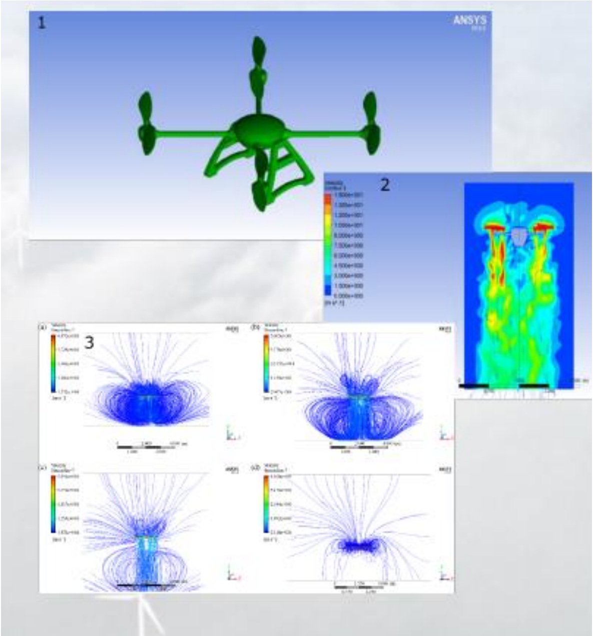
Octocopter:
FoxTech D130 X8

SAMURAI – work plan

- Meteorological sensor integration:
  - sonic anemometer + IMU/GPS + data logging

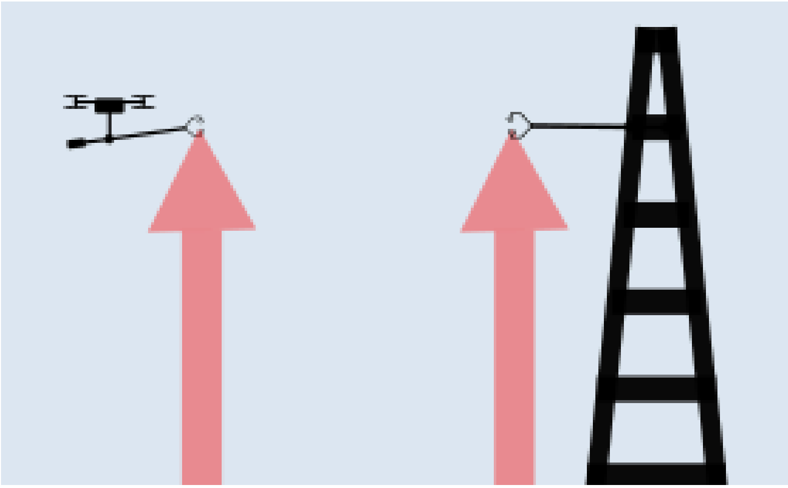
- Development of a dummy sensor arm for basic tests of quadcopter stability and flight control

- CFD simulations to find the required minimum length of the extension arm for a placement of the sonic anemometer outside the rotor downwash



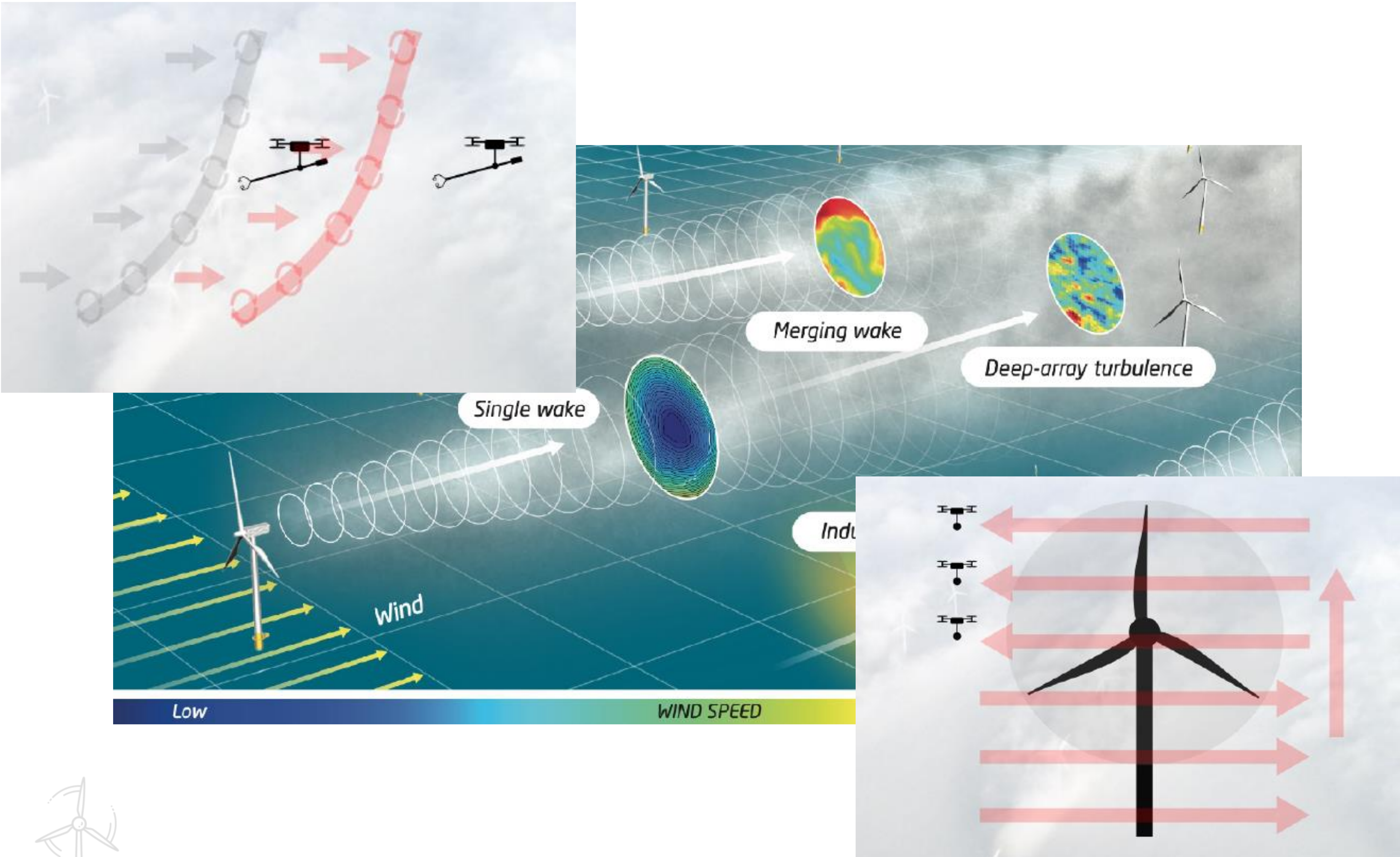
SAMURAI – work plan

- Comparison/validation against a sonic anemometer on a mast



- Field measurements

SAMURAI – planned measurement strategies



The Acronym solution

Sonic **A**nemometer on a **MU**lti-**R**otor drone for **A**tmospheric turbulence **I**nvestigations

https://www.japantrends.com/watch-two-samurai-warriors-jet-packs-fight-midair-japan/

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