

› **FARMFLOW**
A WAKE MODEL FOR OFFSHORE WIND FARMS AND ITS VALIDATION
E.T.G. BOT

› INDEX

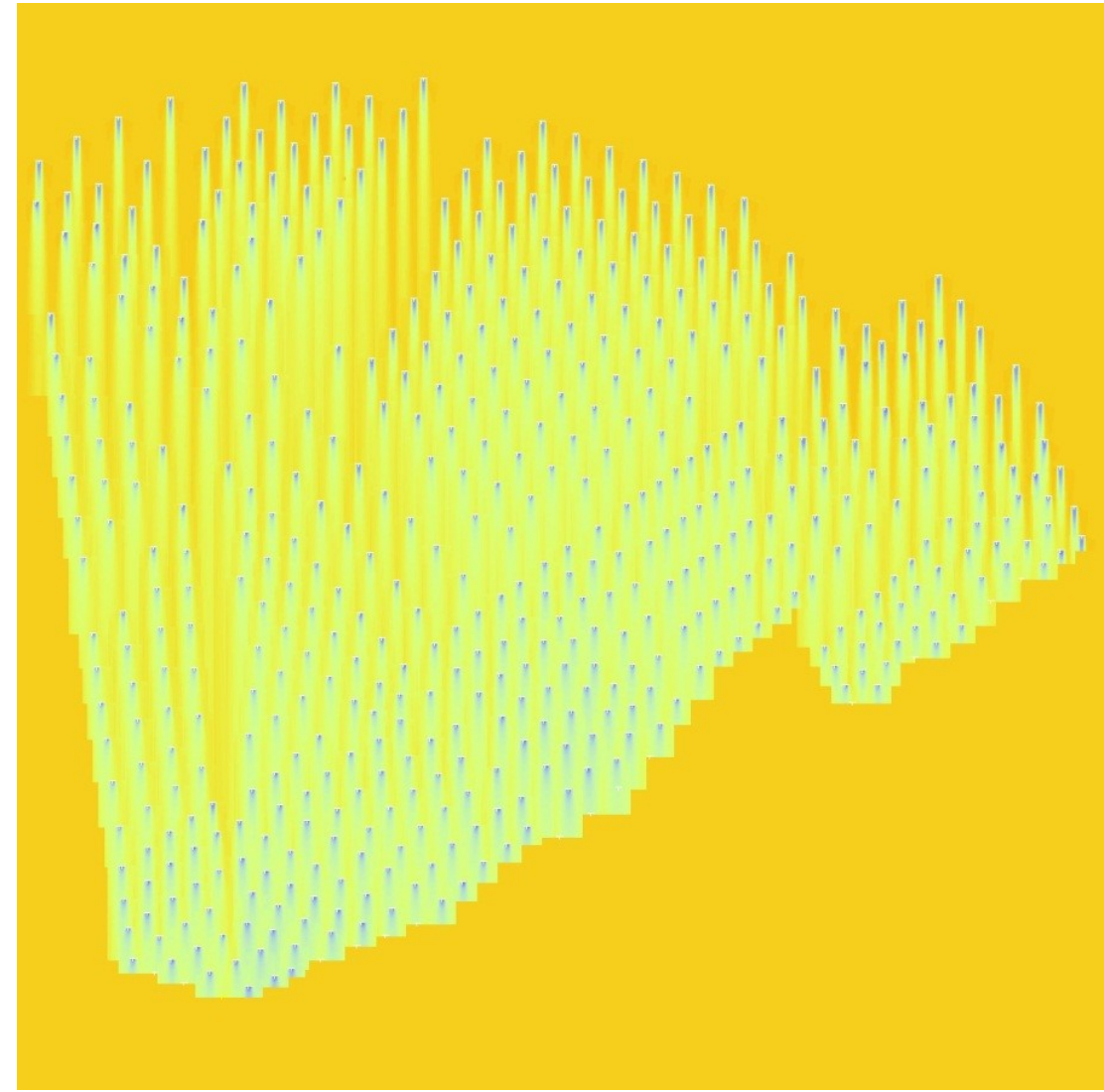
FARMFLOW

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› WAKE MODEL

3D PARABOLIZED RANS WITH $k-\varepsilon$ TURBULENCE MODEL

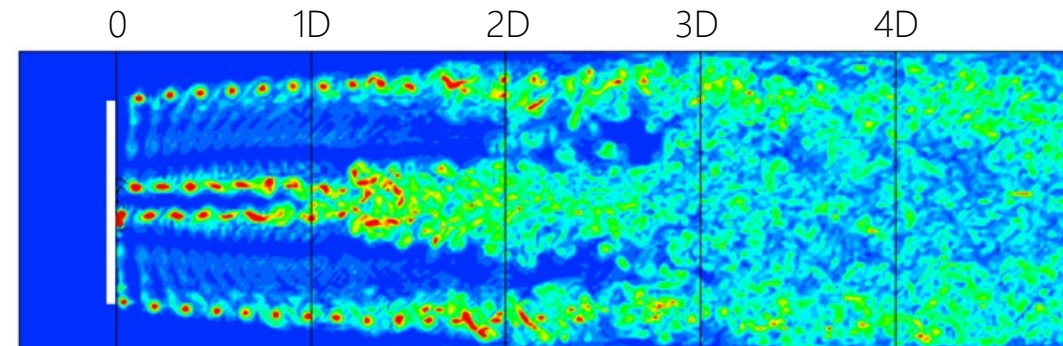
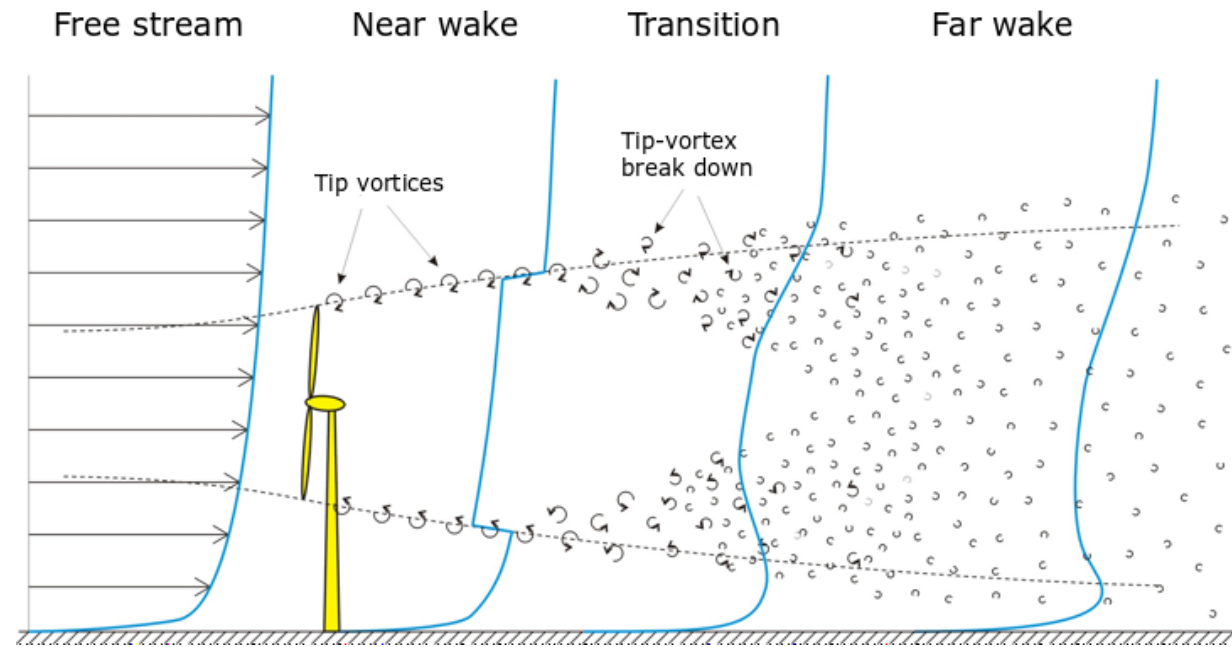
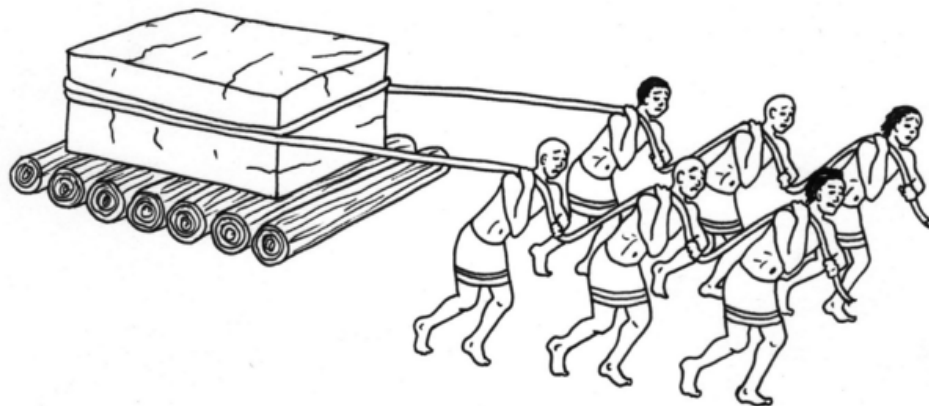
- › RANS equations parabolized in flow direction
- › Pre-calculated pressure gradients prescribed as source term, obtained from a panel method with an actuator disk model
- › Atmospheric surface layer model based on Monin-Obukhov similarity theory
- › Grid resolution: $1/9$ x rotor diameter
- › Grid height: 5.33 x rotor diameter
- › Computational time: 3s per wake in single thread
- › Parallelization up to 16 threads in a single process (3 wakes per second)
- › True multiple wakes (no superposition of single wakes)
- › No correction needed for large wind farms



› TURBULENCE MODEL

NEAR WAKE CALIBRATION

- › Standard $k-\epsilon$ turbulence model parameters are derived for isotropic turbulence.
- › Near wake and transition region are strongly anisotropic.
- › RANS model with actuator disk overestimates shear stresses in the near wake region
 - › FarmFlow solution: turbulence production in the near wake region based on shear stress in front of rotor
 - › Near wake length depends on inflow conditions

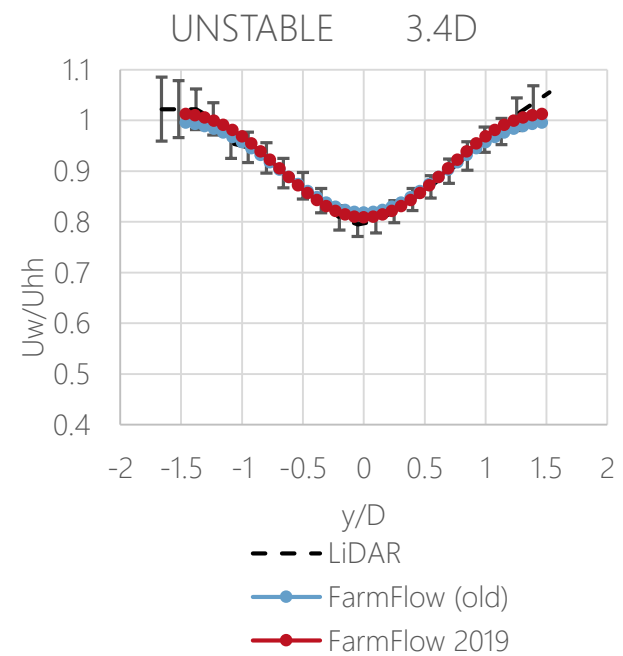
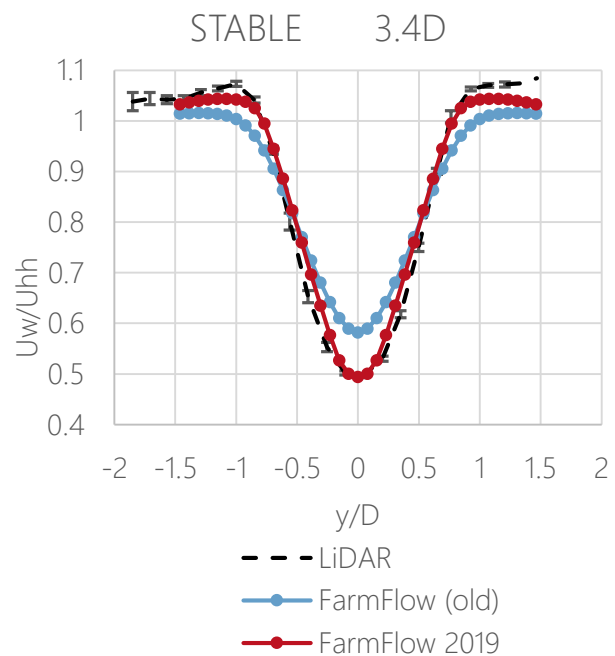
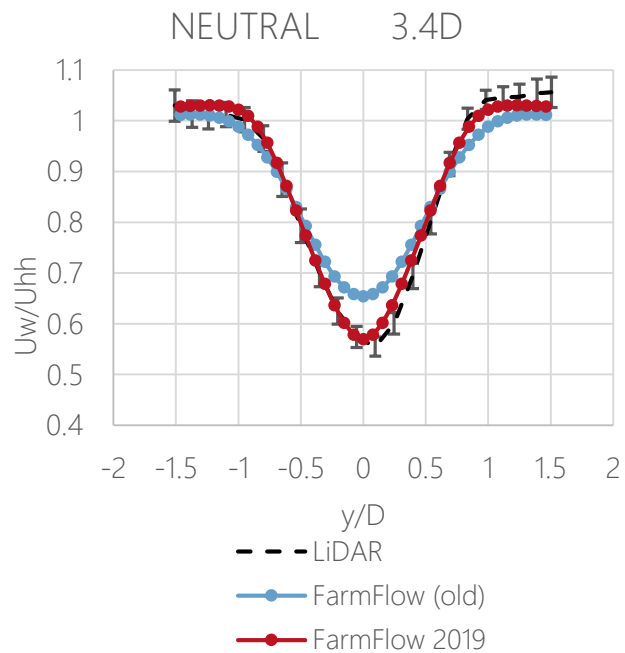


JAXA Supercomputer System Annual Report, April 2016-March 2017

TEXAS

LIDAR - SINGLE WAKE

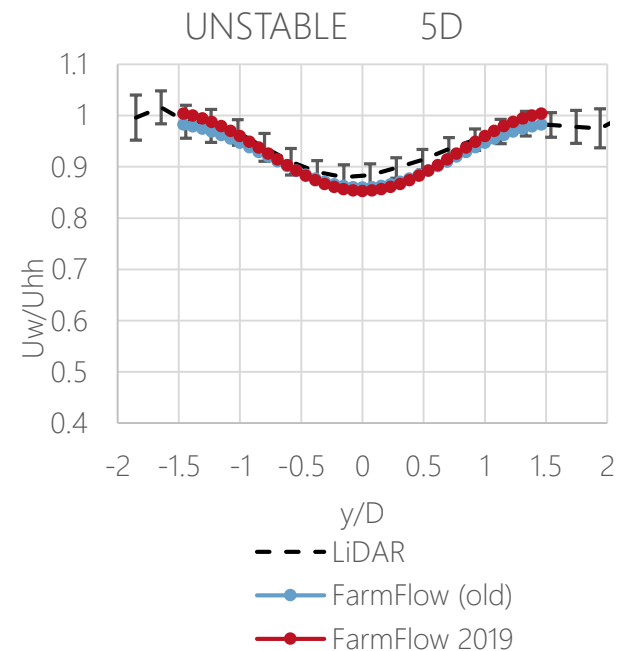
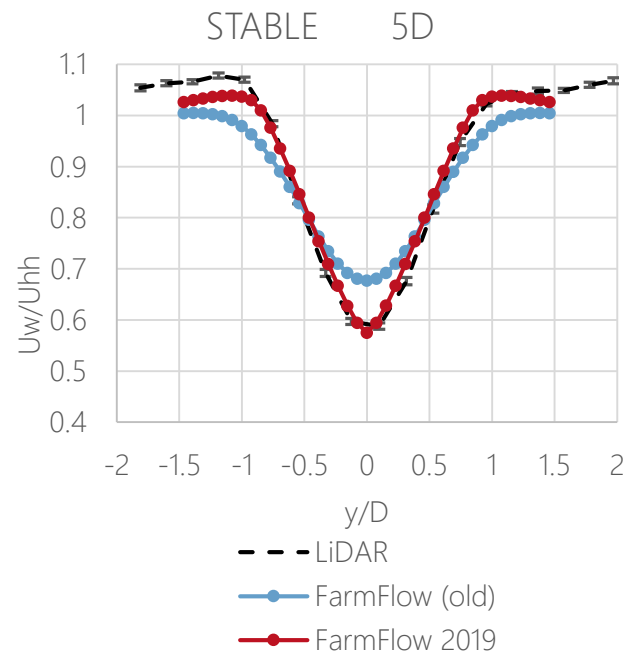
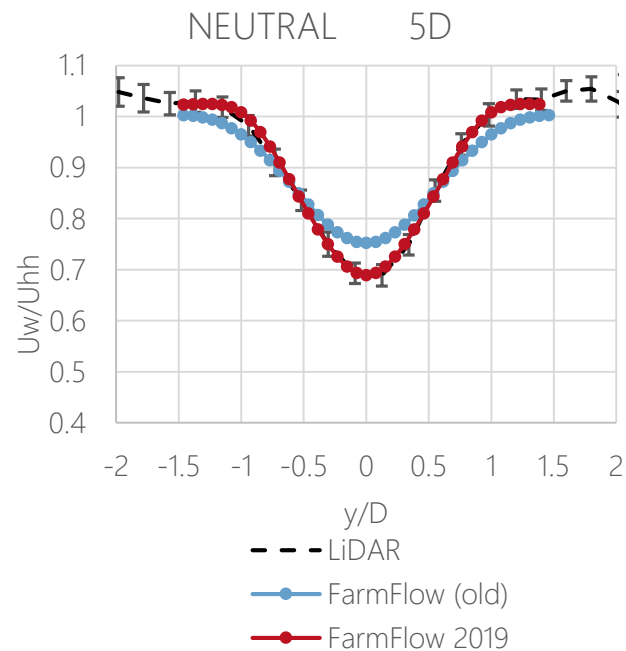
3.4D DOWNSTREAM



TEXAS

LIDAR - SINGLE WAKE

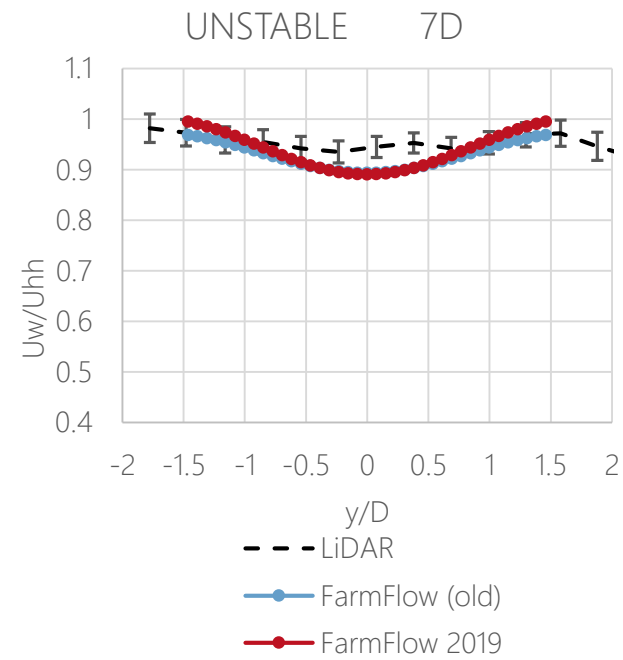
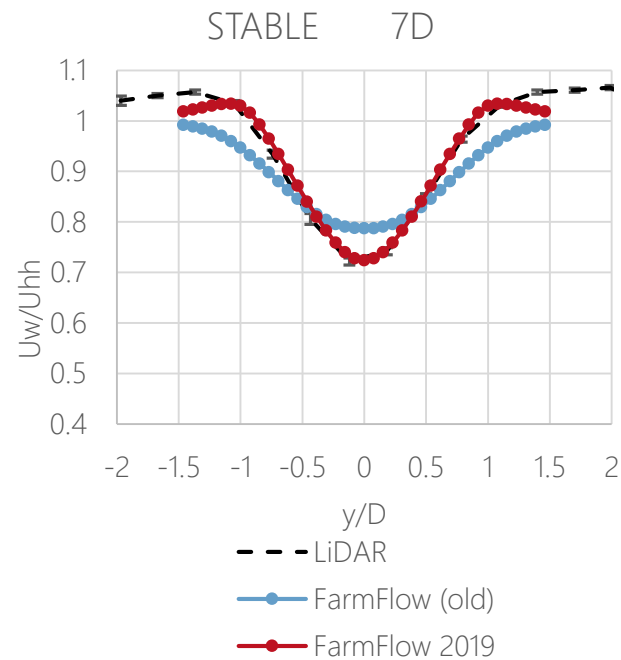
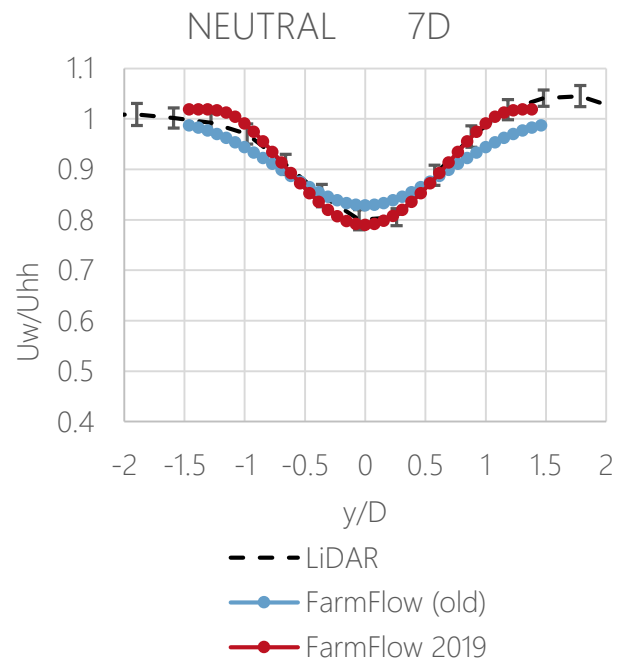
5.0D DOWNSTREAM



TEXAS

LIDAR - SINGLE WAKE

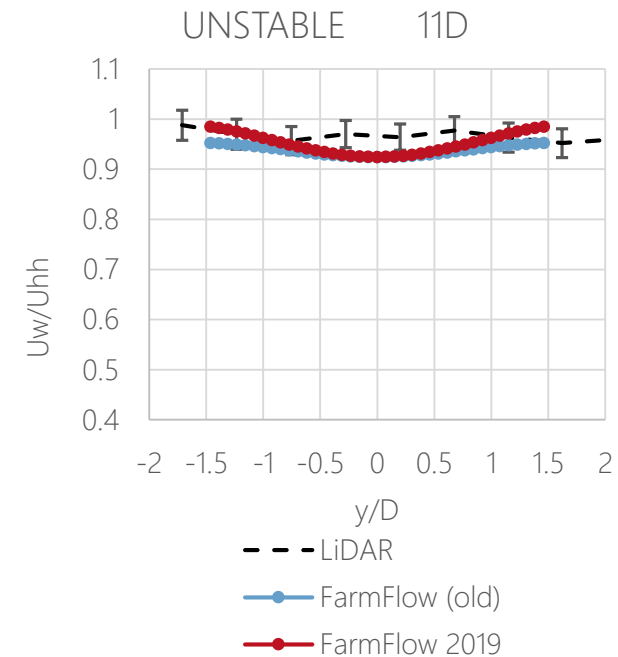
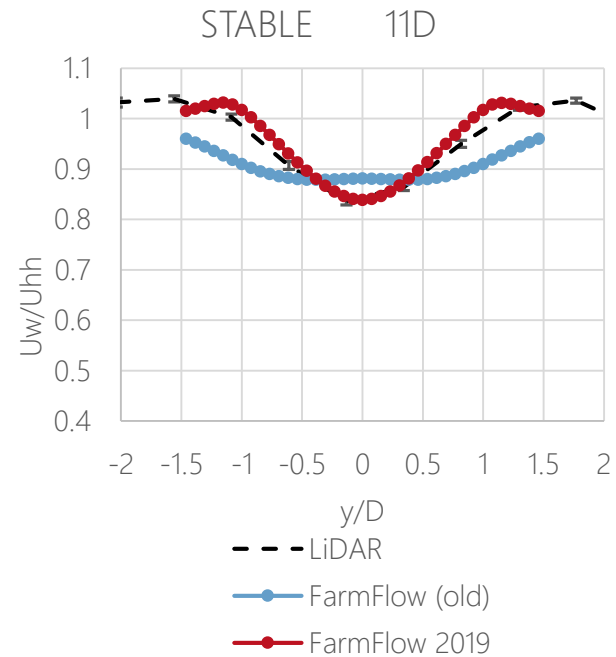
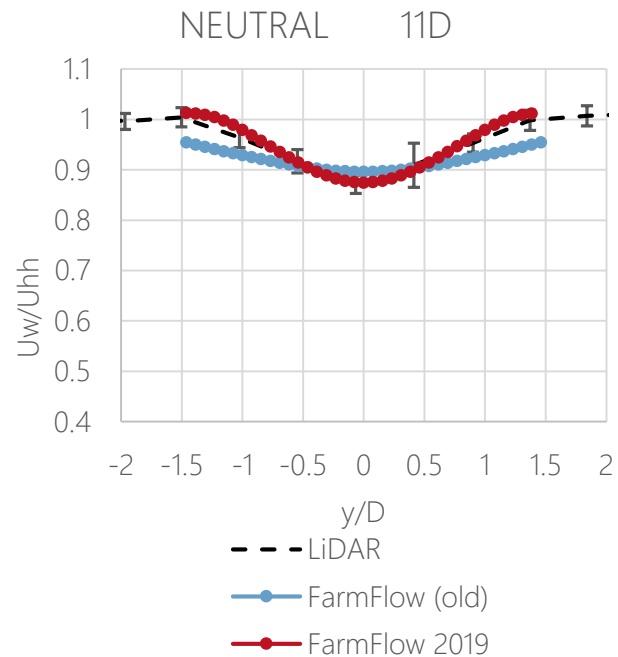
7.0D DOWNSTREAM



› TEXAS

LIDAR – SINGLE WAKE

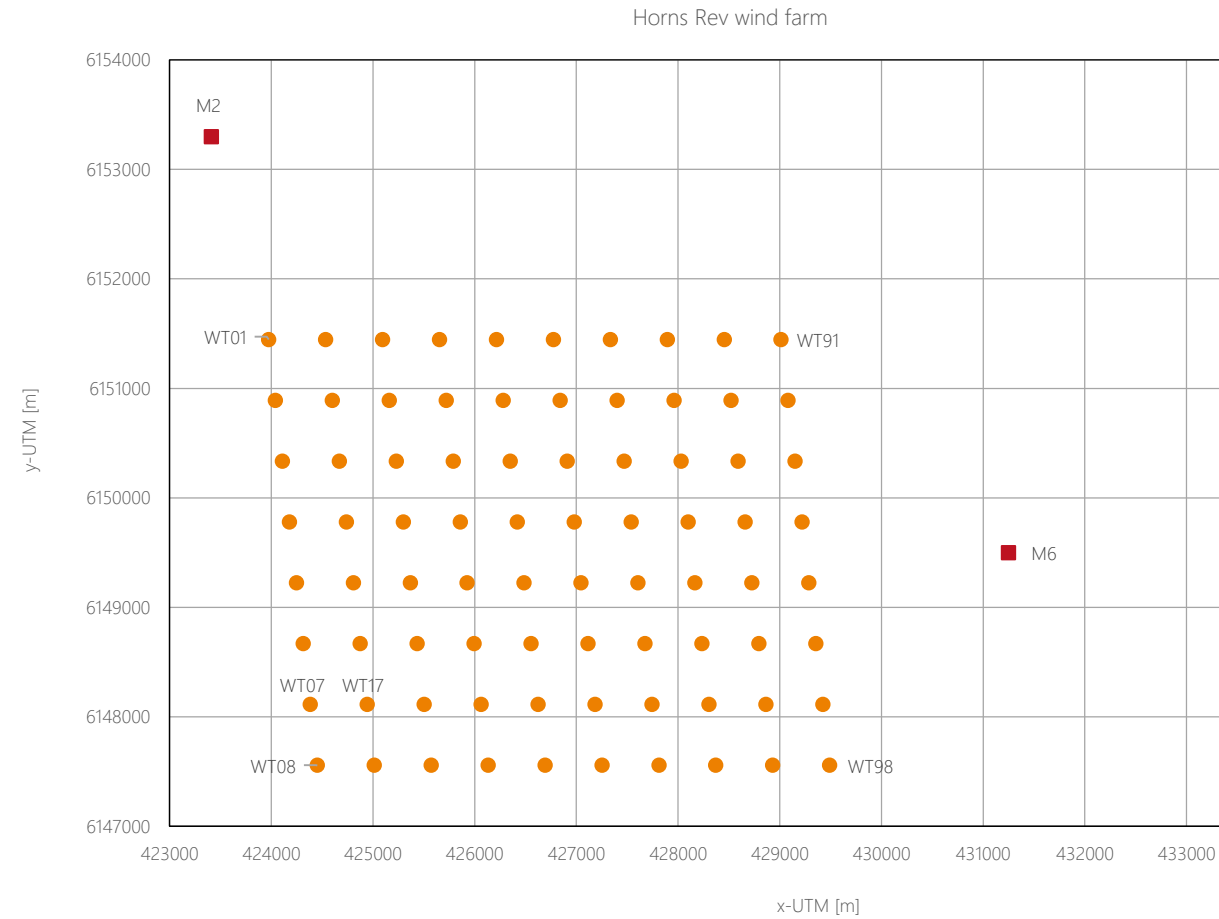
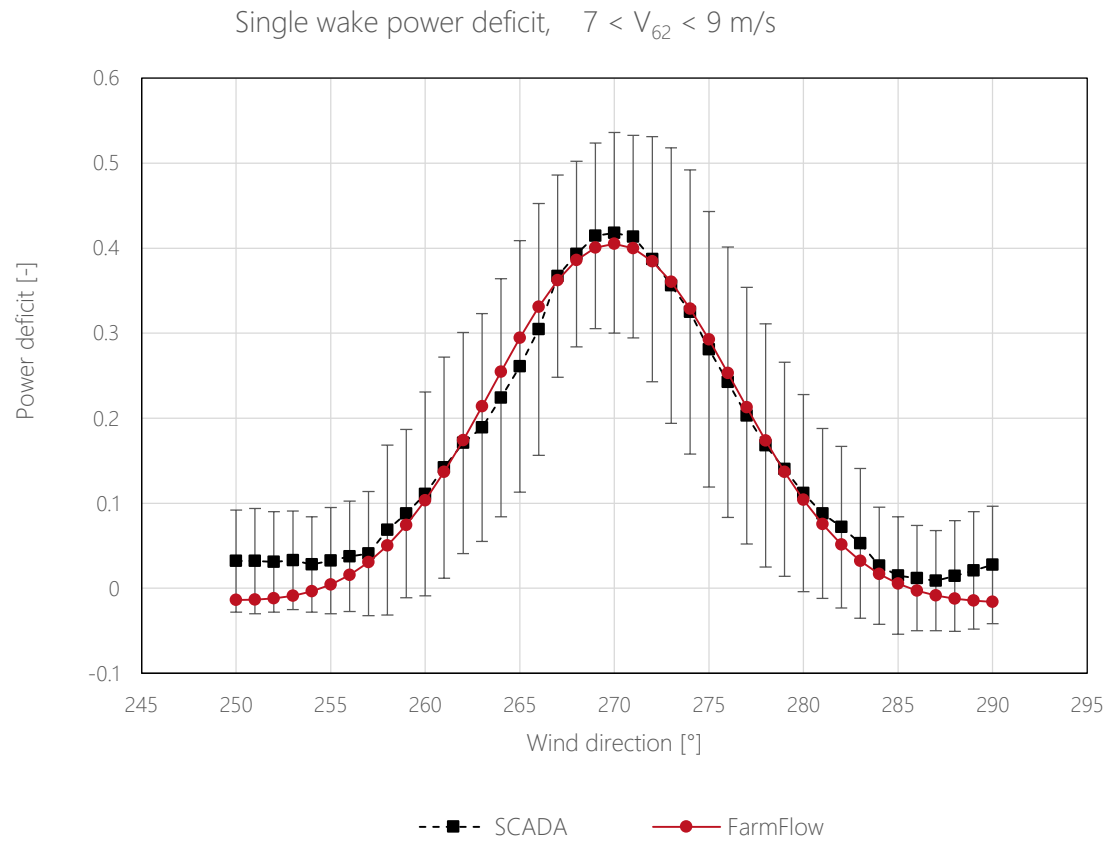
11.0D DOWNSTREAM



HORNS REV

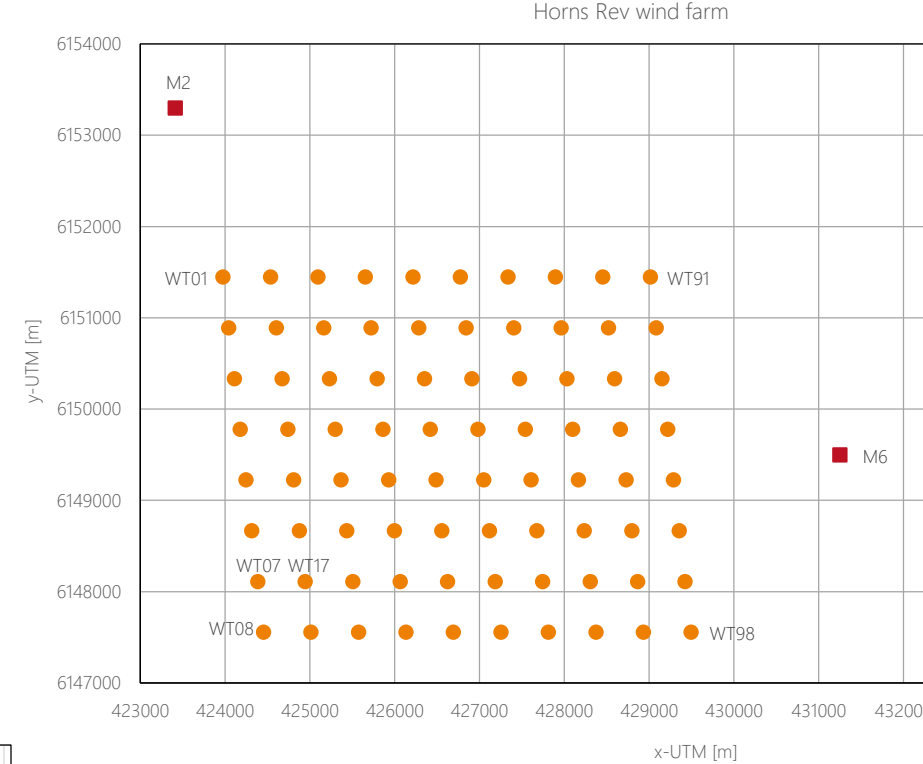
SINGLE WAKE

270° WIND DIRECTION SECTOR

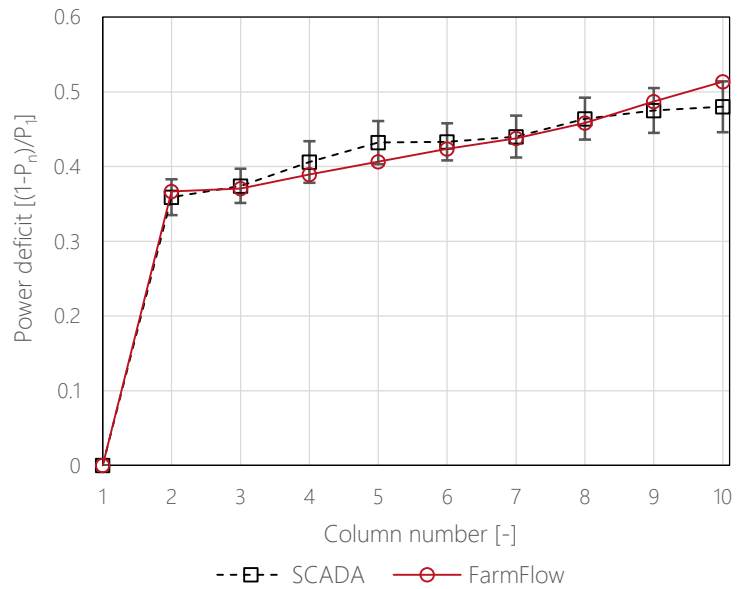


HORNS REV ARRAYS

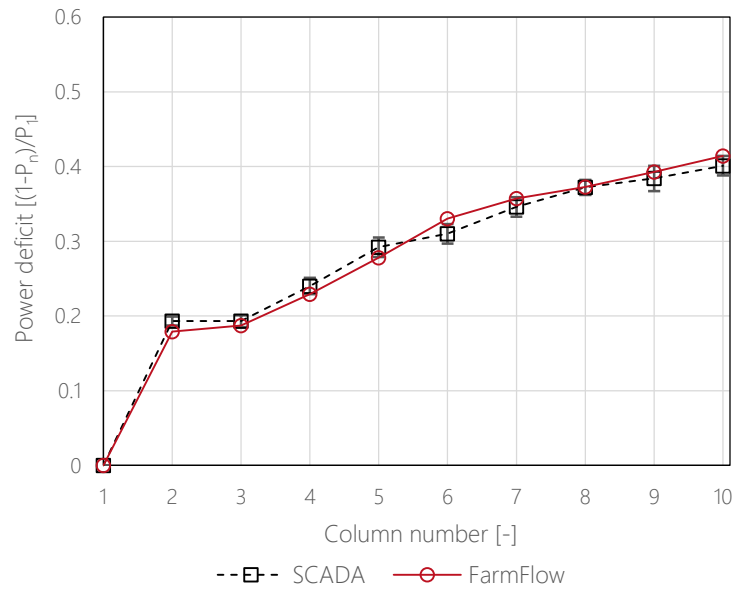
270° WIND DIRECTION SECTOR



Horns Rev, row 7, $270 \pm 2.5^\circ$, 8 ± 0.5 m/s



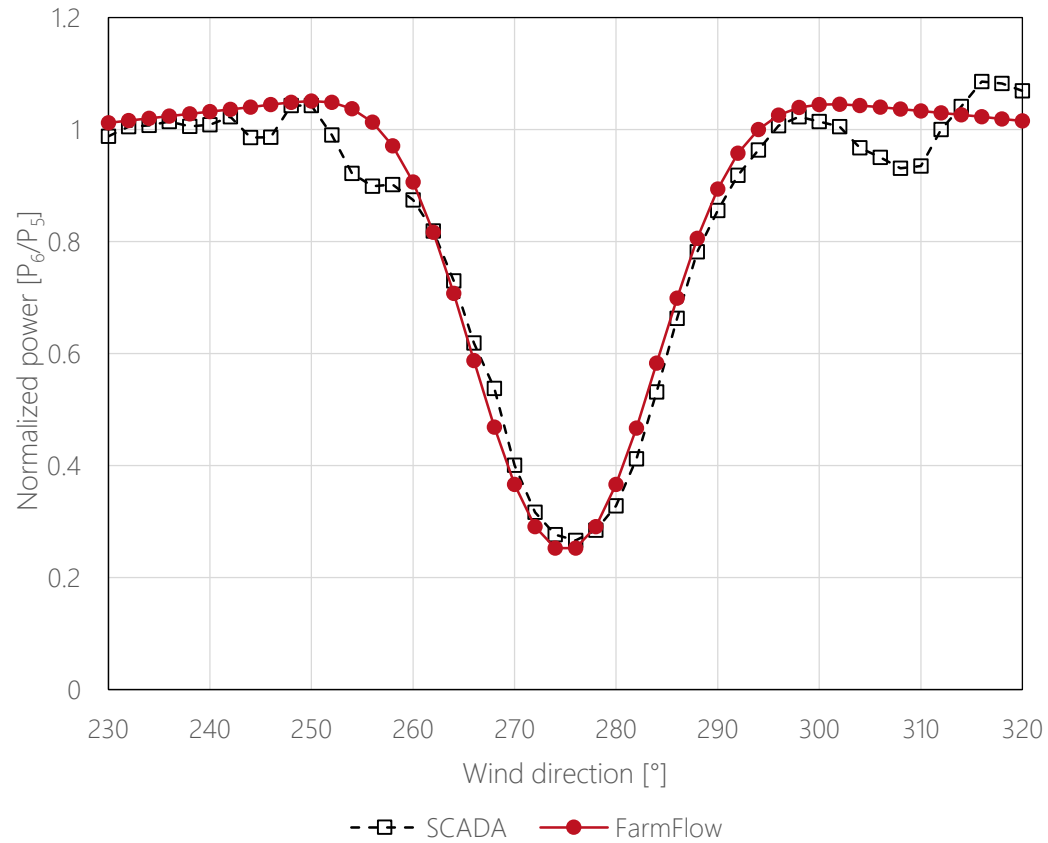
Horns Rev, row 7, $270 \pm 15^\circ$, 8 ± 0.5 m/s



EWTW

SINGLE WAKE

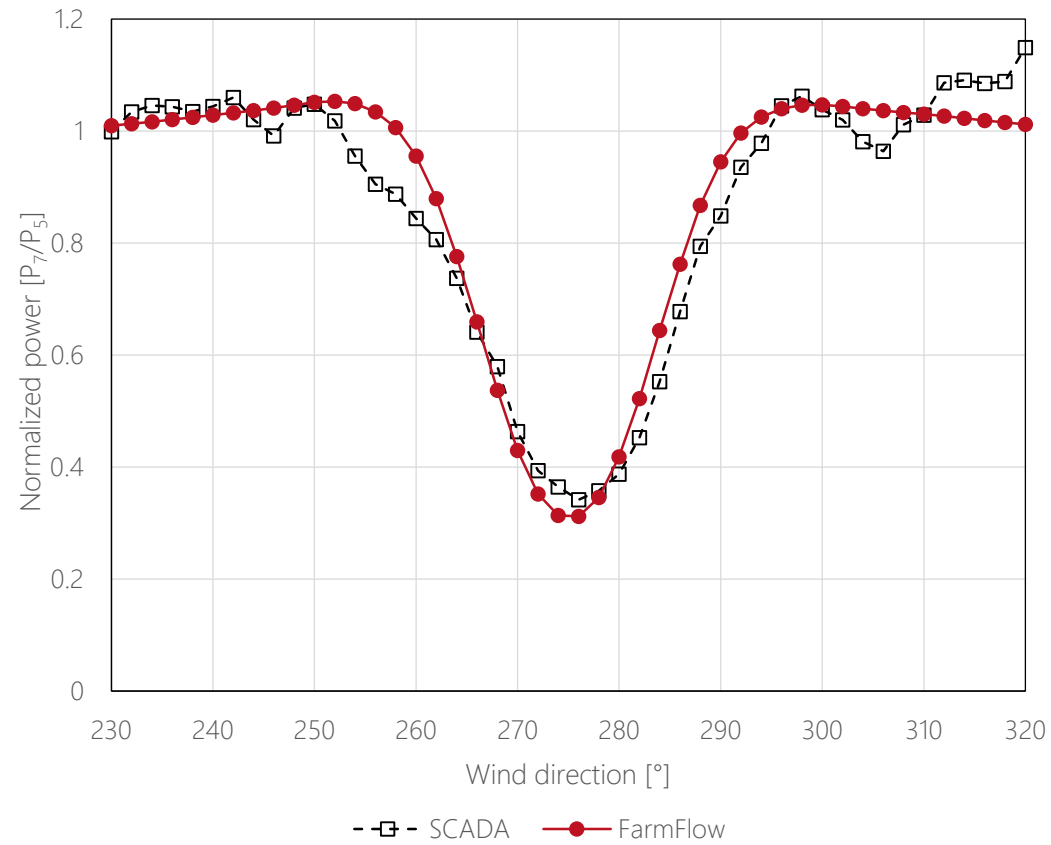
Single wake, 6-8 m/s



› EWTW

DOUBLE WAKE

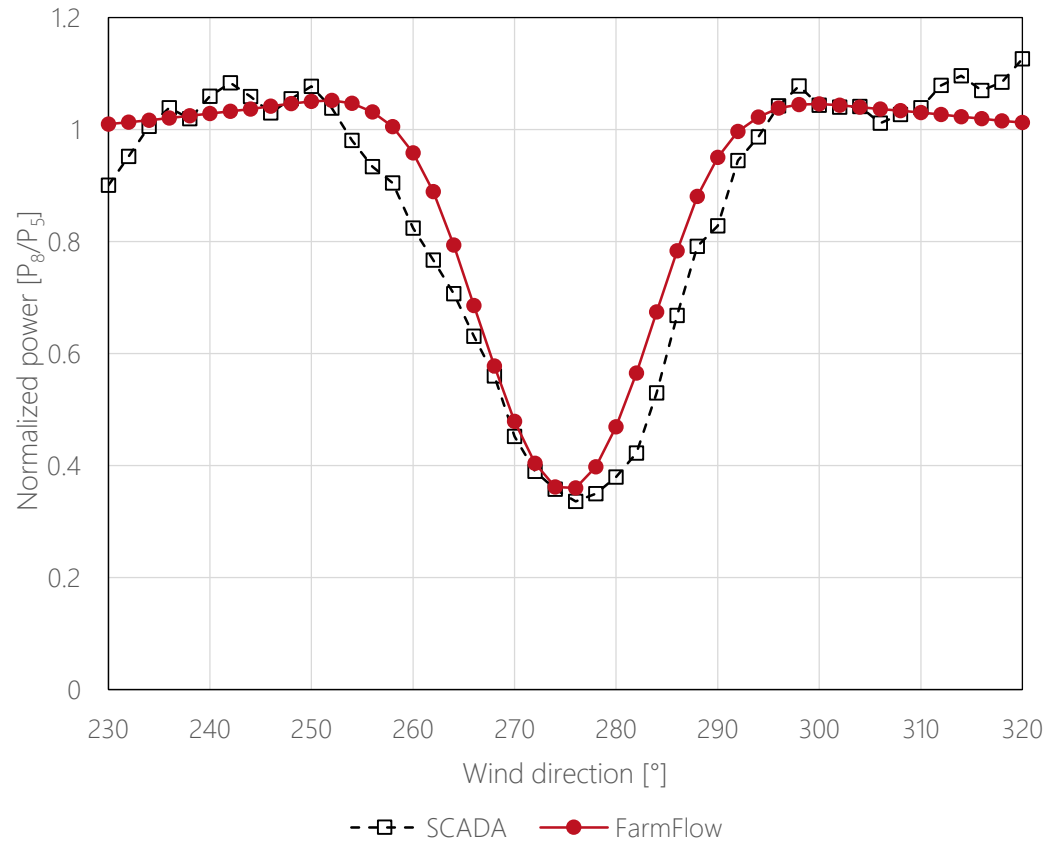
Double wake, 6-8 m/s



EWTW

TRIPLE WAKE

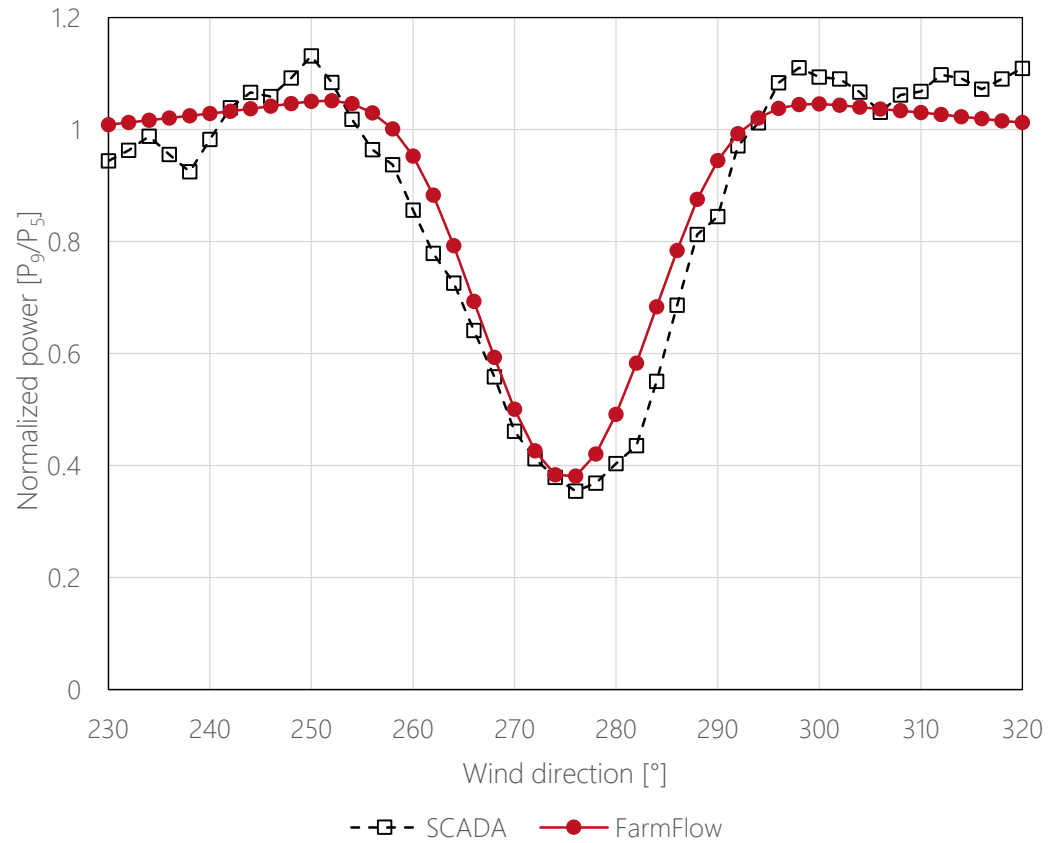
Triple wake, 6-8 m/s



EWTW

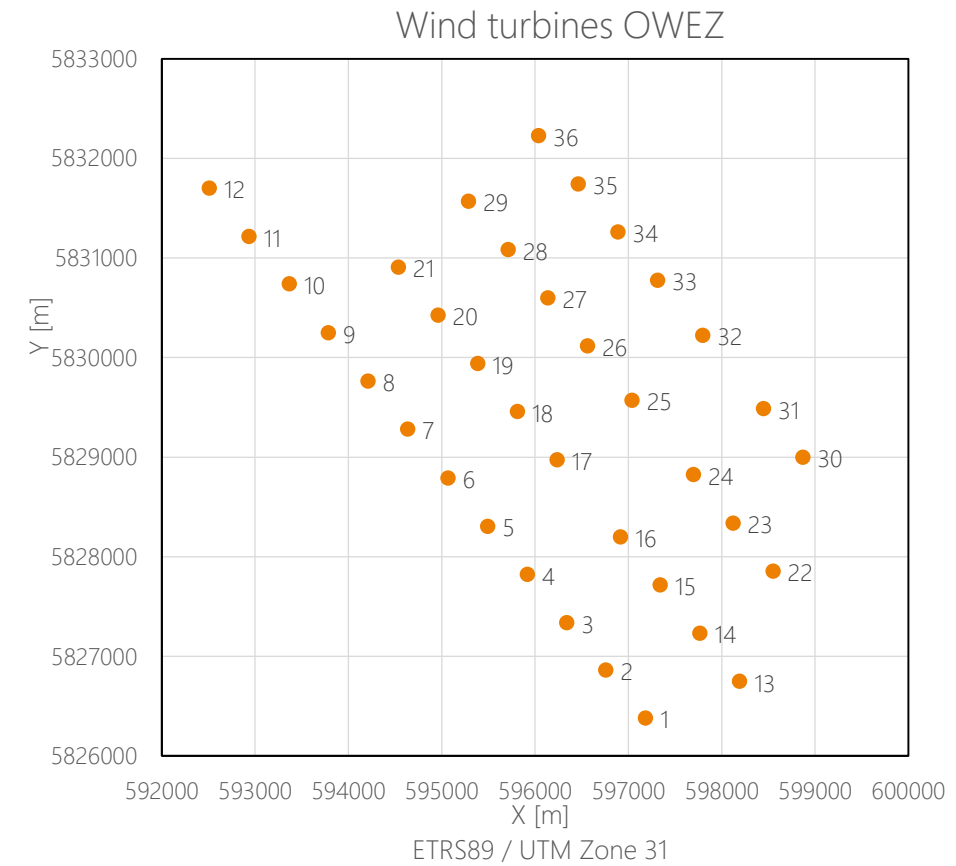
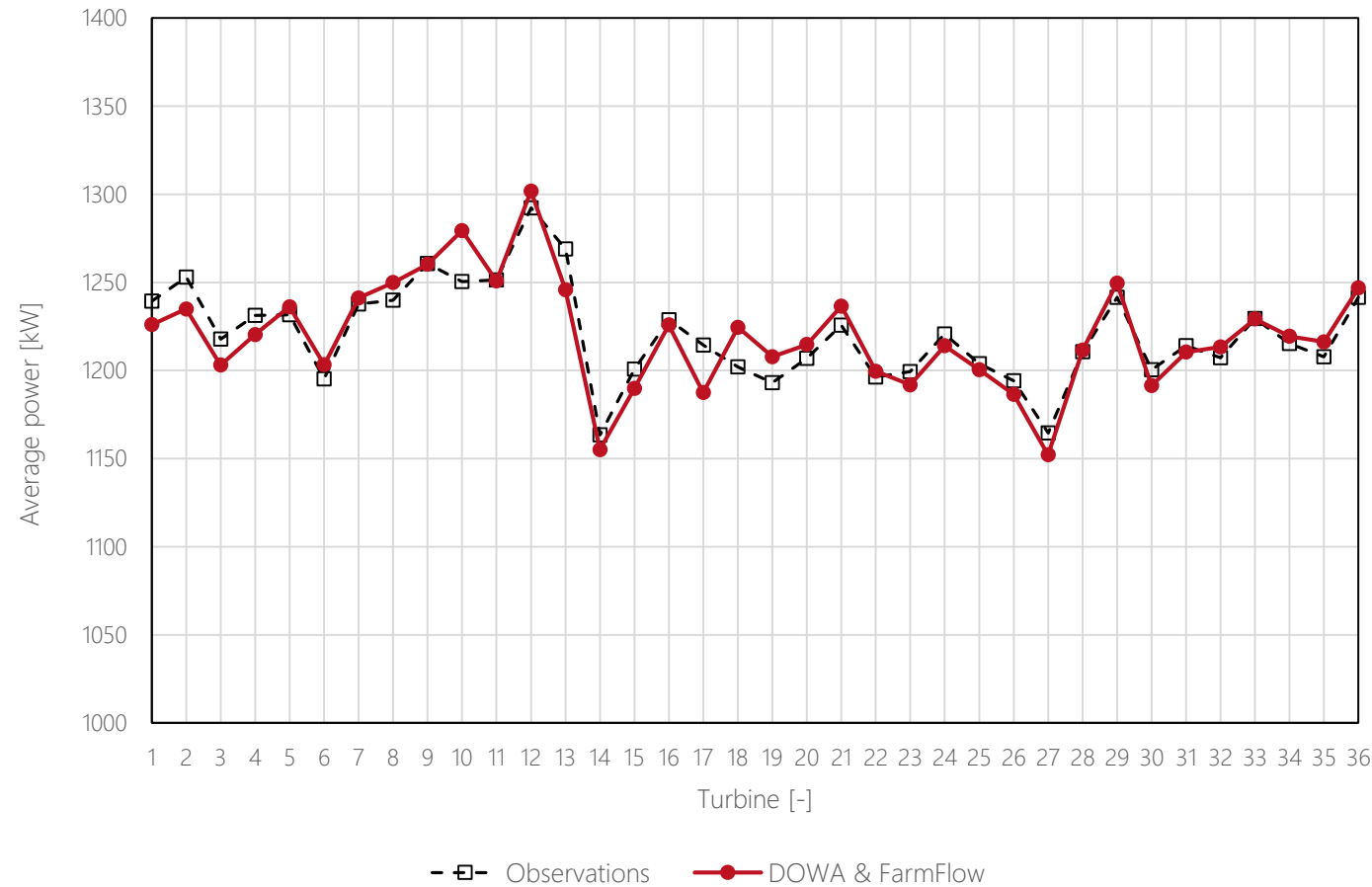
QUADRUPLE WAKE

Quadruple wake, 6-8 m/s



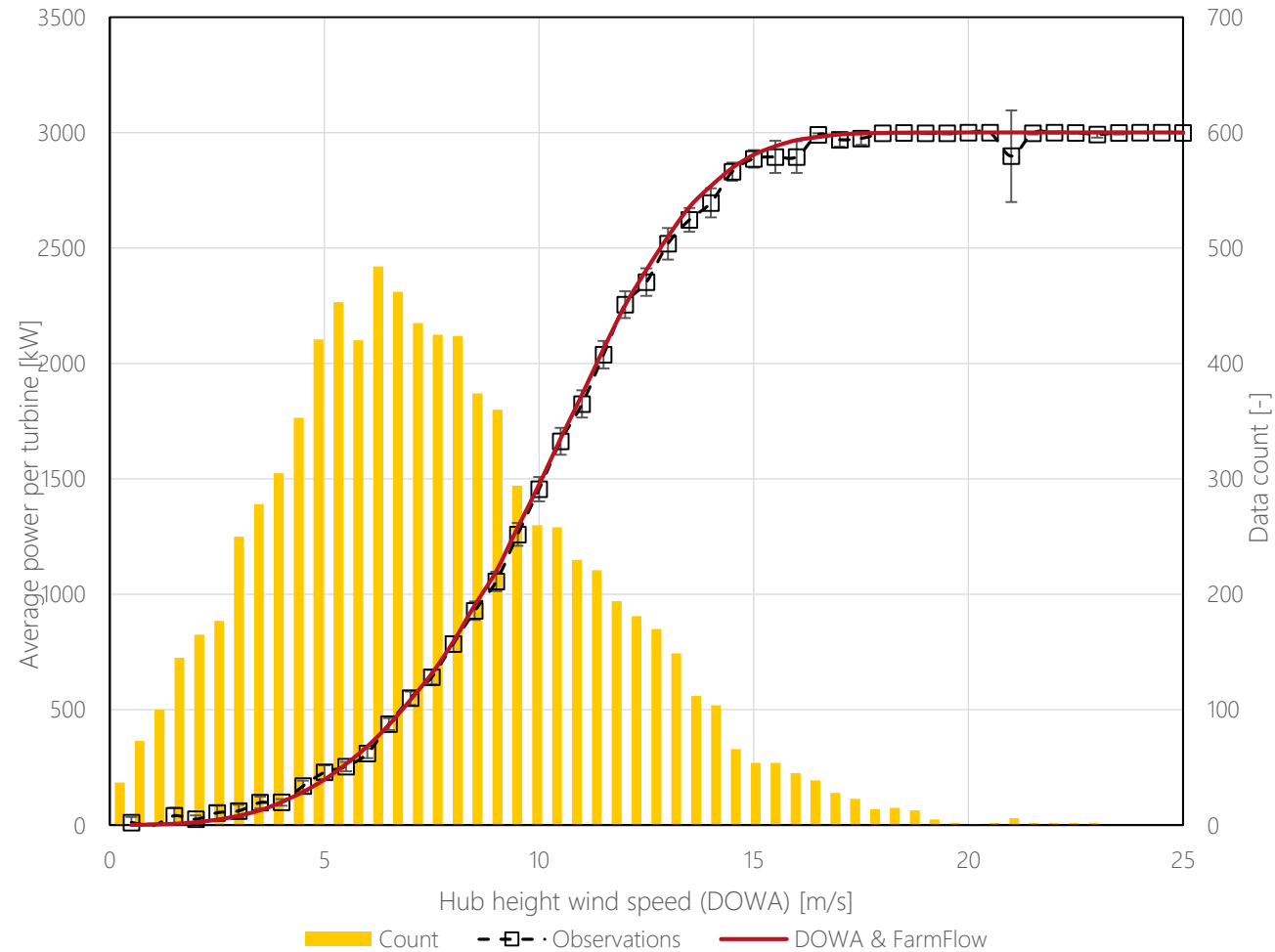
OWEZ

ANNUAL ENERGY PRODUCTION



OWEZ

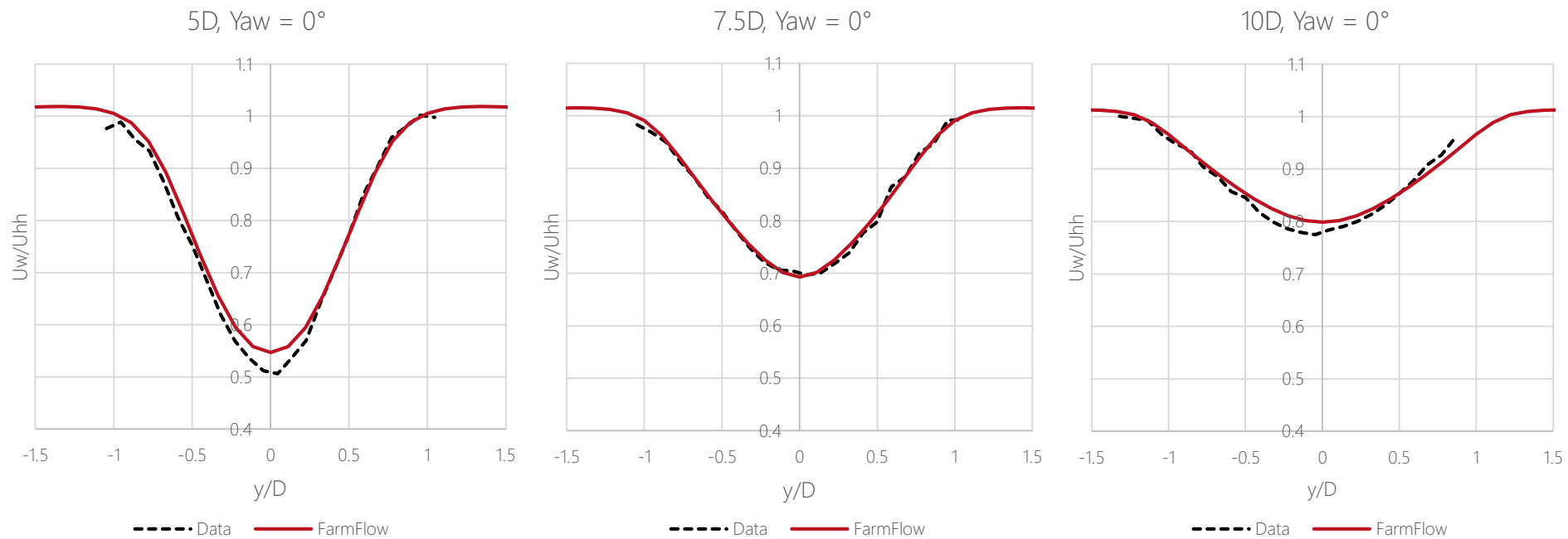
AVERAGE POWER PRODUCTION PER TURBINE



ACTIVE WAKE CONTROL

WIND TUNNEL MILAN

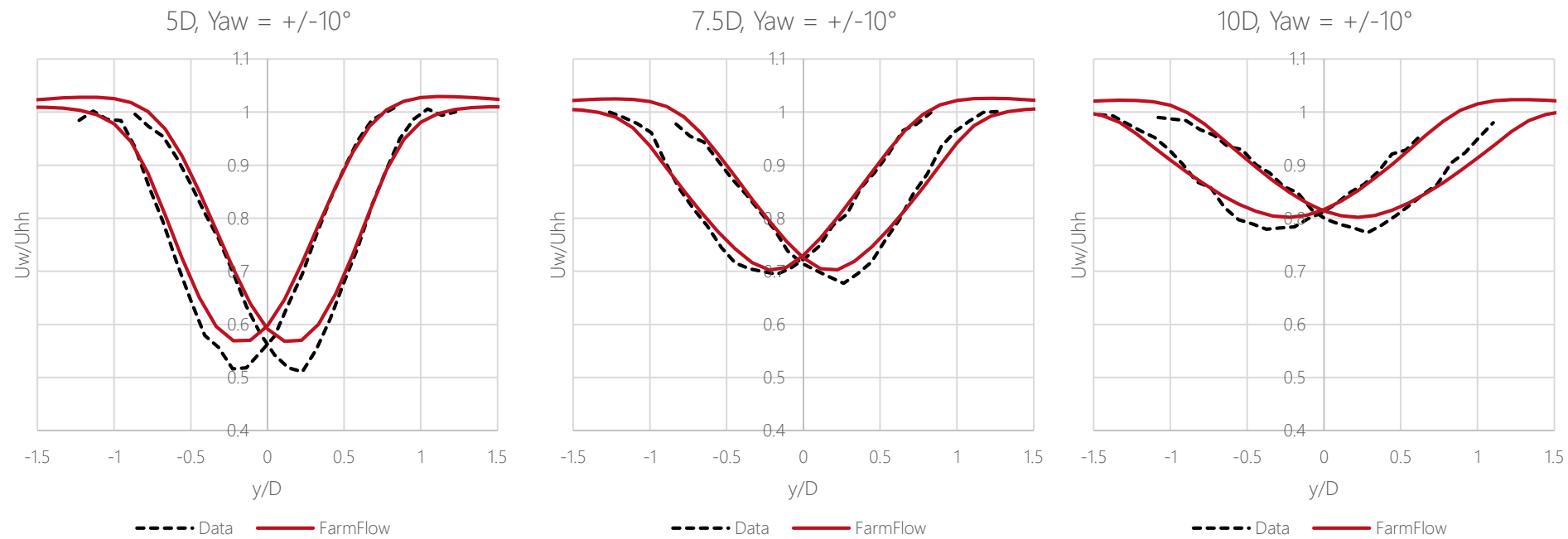
0° YAW MISALIGNMENT



ACTIVE WAKE CONTROL

WIND TUNNEL MILAN

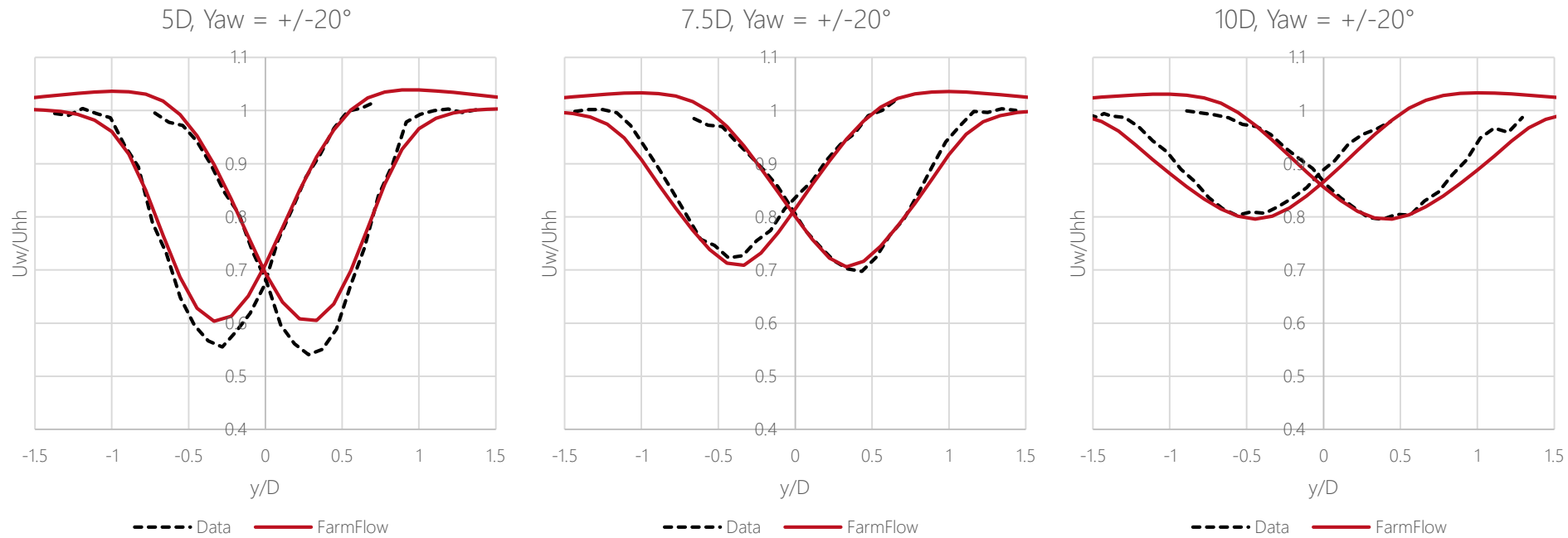
$\pm 10^\circ$ YAW MISALIGNMENT



ACTIVE WAKE CONTROL

WIND TUNNEL MILAN

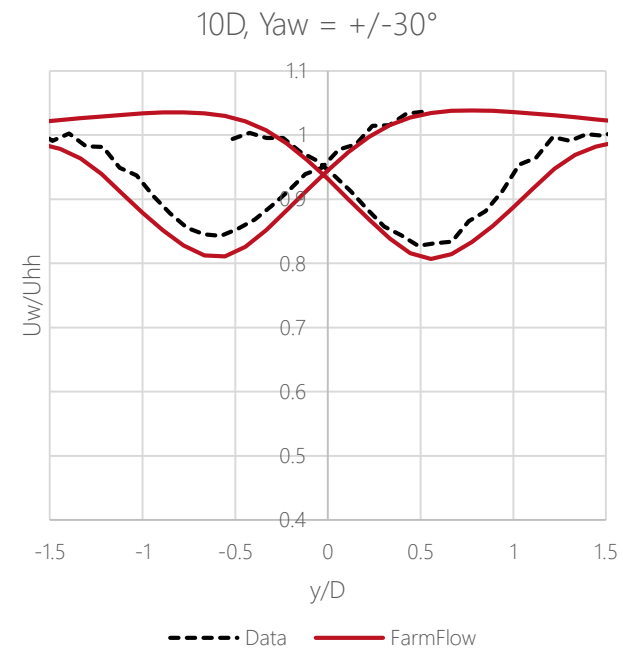
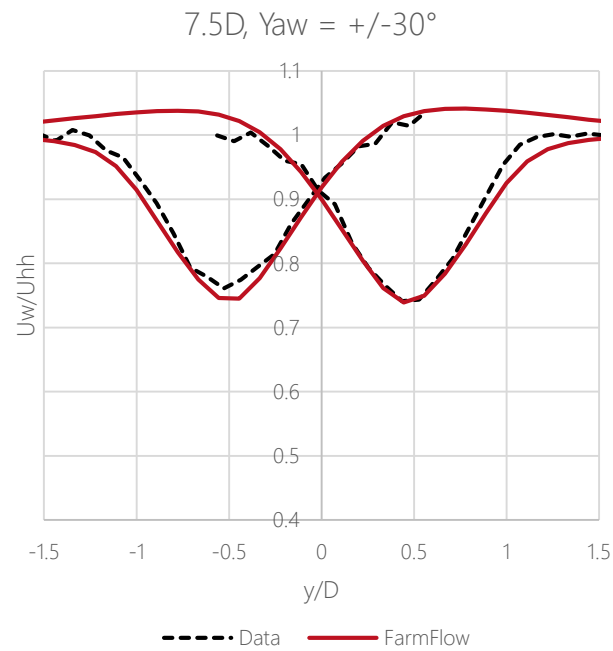
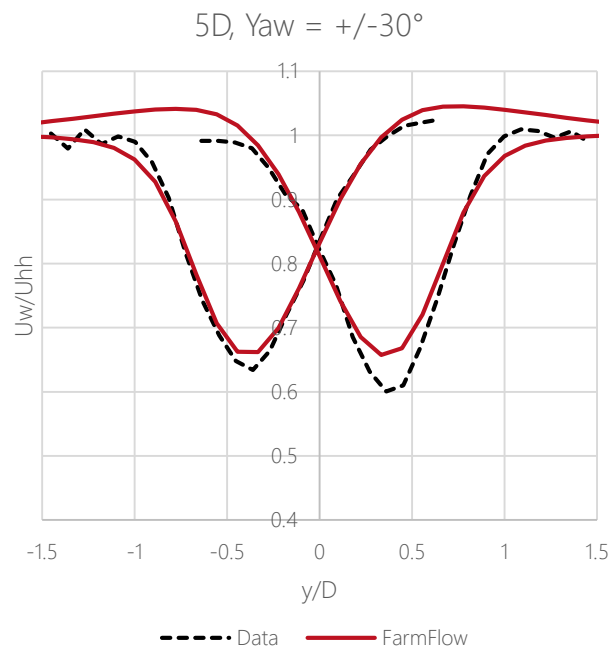
±20° YAW MISALIGNMENT



ACTIVE WAKE CONTROL

WIND TUNNEL MILAN

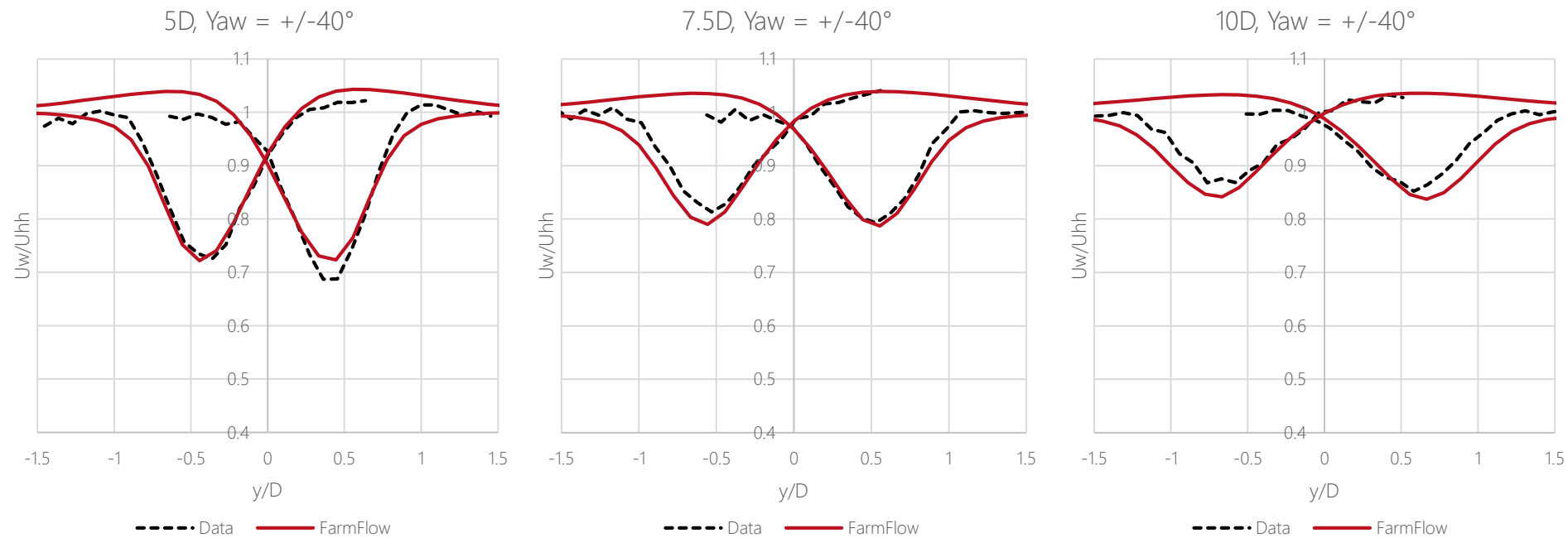
±30° YAW MISALIGNMENT



ACTIVE WAKE CONTROL

WIND TUNNEL MILAN

$\pm 40^\circ$ YAW MISALIGNMENT





› **THANK YOU FOR**
YOUR TIME

TNO innovation
for life