FLOWSTAR-Energy Validation
Nysted Wind Farm

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FLOWSTAR-Energy 5.1

1 Introduction

Nysted is an offshore wind farm in Denmark. A FLOWSTAR-Energy model of the wind farm was compared with measurements of the power deficit for each turbine.

2 Input Data

2.1 Study Area

Nysted wind farm consists of 72 turbines arranged in a parallelogram grid with 8 columns and 9 rows, with the rows at an angle of 8º to the W-E direction. The layout of the turbines is shown in Figure 2, along with the 7 wind direction cases for which measurements are available: 263, 268, 273, 278, 283, 288 and 293 degrees. There are 3 wind speed cases: 6, 8 and 10 m/s.

Each turbine is a Bonus 2.3 MW turbine, with diameter 82.4 m and height 69 m. The measurements available are normalised power at every turbine for each wind speed and direction case, with reference to the power generated at turbine A05, in the middle of the upstream column.

Figure 1 Map showing the location of the Nysted wind farm off the coast of Denmark

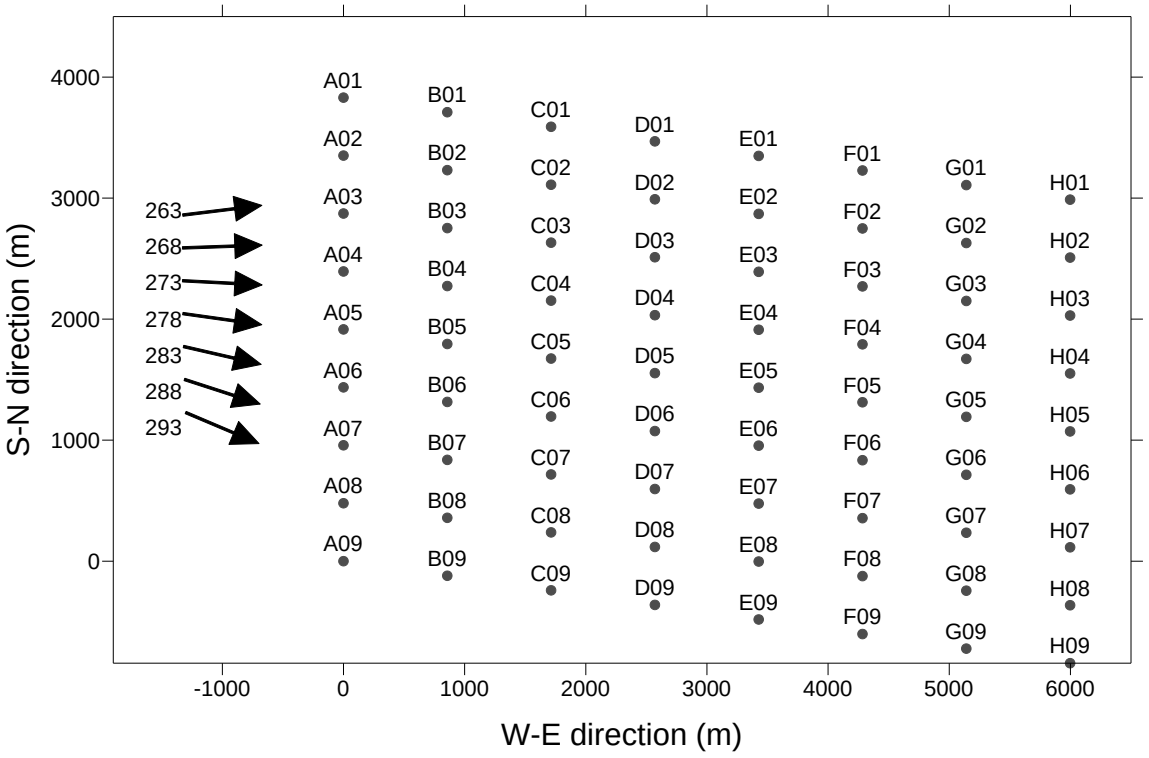

Figure 2 Layout of turbines in the Nysted wind farm

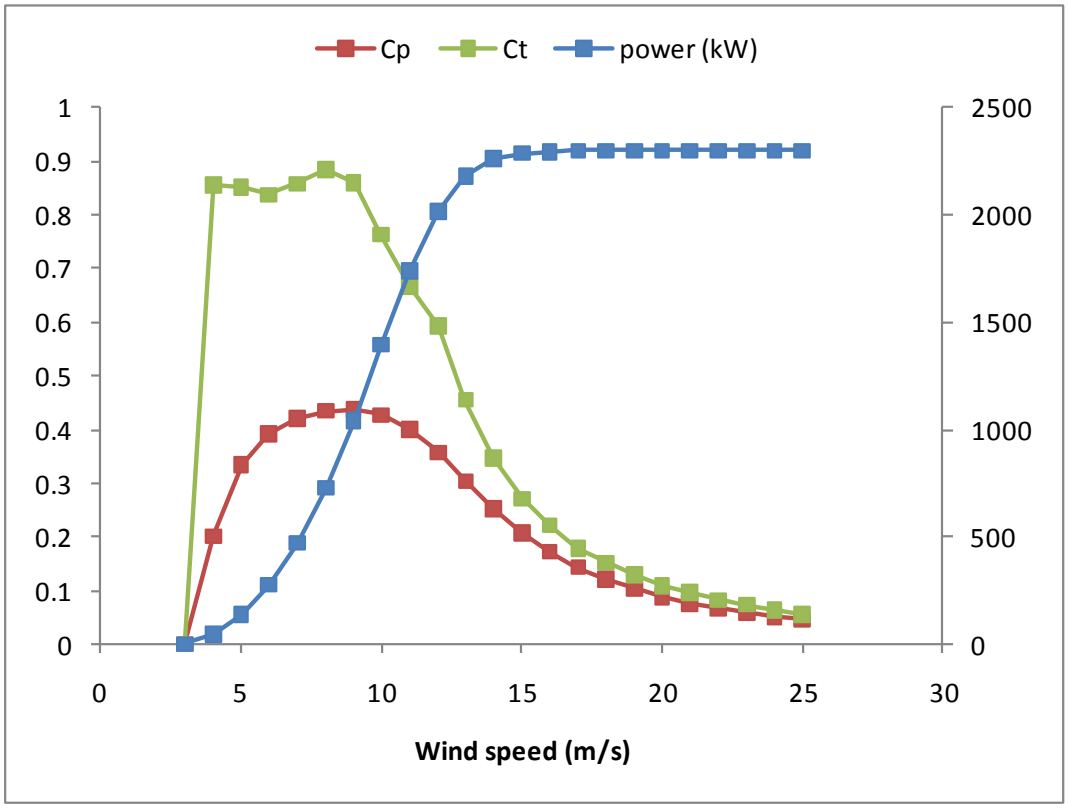

Figure 3 Power output (kW), power coefficient C_p and thrust coefficient C_T as a function of inflow wind speed for the Bonus 2.3MW turbines installed at the Nysted wind farm.

2.2 Model setup

The inputs to FLOWSTAR-Energy were as follows:

- Offshore site, constant surface roughness 0.01 m
- 3 flow cases: U = 6, 8, and 10 m/s (at turbine hub height)
- 7 wind direction cases: 263, 268, 273, 278, 283, 288 and 293 degrees
- Results are the average of 5 modelled wind directions within a 5-degree wind direction sector
- Boundary layer height 800m, ground heat flux 0 W/m^2, i.e. neutral conditions
- Turbine hub height 69 m
- Turbine diameter 82.4 m
- Power (kW) as a function of wind speed (see Figure 3)
- C_T as a function of wind speed (see Figure 3)
- 72 turbine sources (9 rows, 8 columns), locations as shown in Figure 2

Output is the normalised power deficit at each wind turbine for each flow case, with reference to the power output available from the upstream flow (calculated from FLOWSTAR-Energy 'wind farm output').

3 Results

The results presented in Figure 4, Figure 5 and Figure 6 show, for each flow case respectively, graphs of the observed and modelled normalised power output for each turbine column for each wind direction, averaged over the inner 7 turbines in each column. The results presented in Figure 7, Figure 8, Figure 9 show, for each flow case respectively, graphs of the observed and modelled normalised power output for each turbine for each row for wind directions 263, 278 and 293 degrees.

4 Discussion

The model results show generally good agreement with measurements. In many cases, the measurements show a lateral gradient in power production along the upstream column, which is not due to wake effects and is therefore not simulated by the model. This gradient could be caused by the non-uniform fetch along the upstream edge of the wind farm for some wind directions due to the location of the wind farm near to the coast of Denmark (see Figure 1).

5 Acknowledgements

CERC is very grateful to Kurt Schaldemose Hansen of DTU's Wind Energy department for providing the measured data and wind farm specification presented in this report during the course of the EU's FP6 TOPFARM project, in which CERC and DTU were both partners.

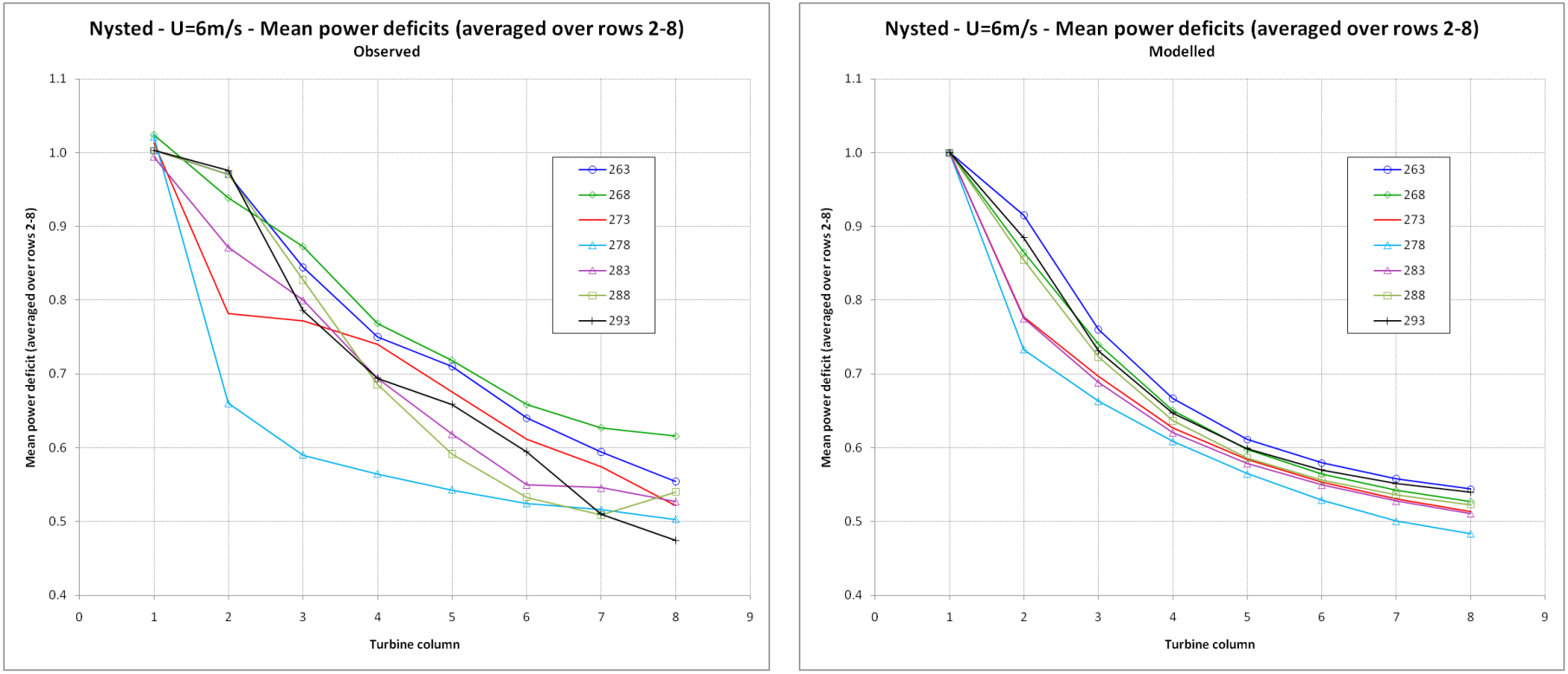

Figure 4 U = 6 m/s: Row averaged normalised power; observed (left) and modelled (right)

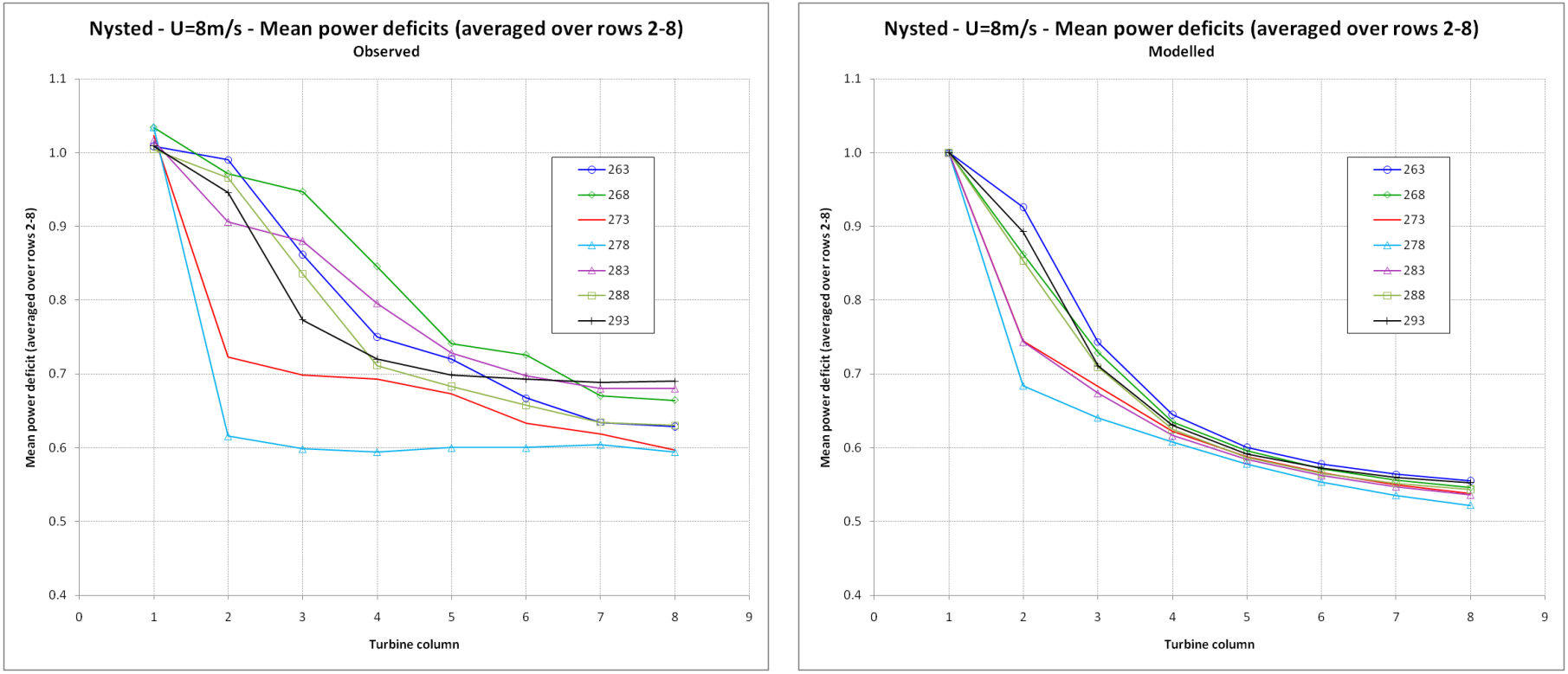

Figure 5 U = 8 m/s: Row-averaged normalised power; observed (left) and modelled (right)

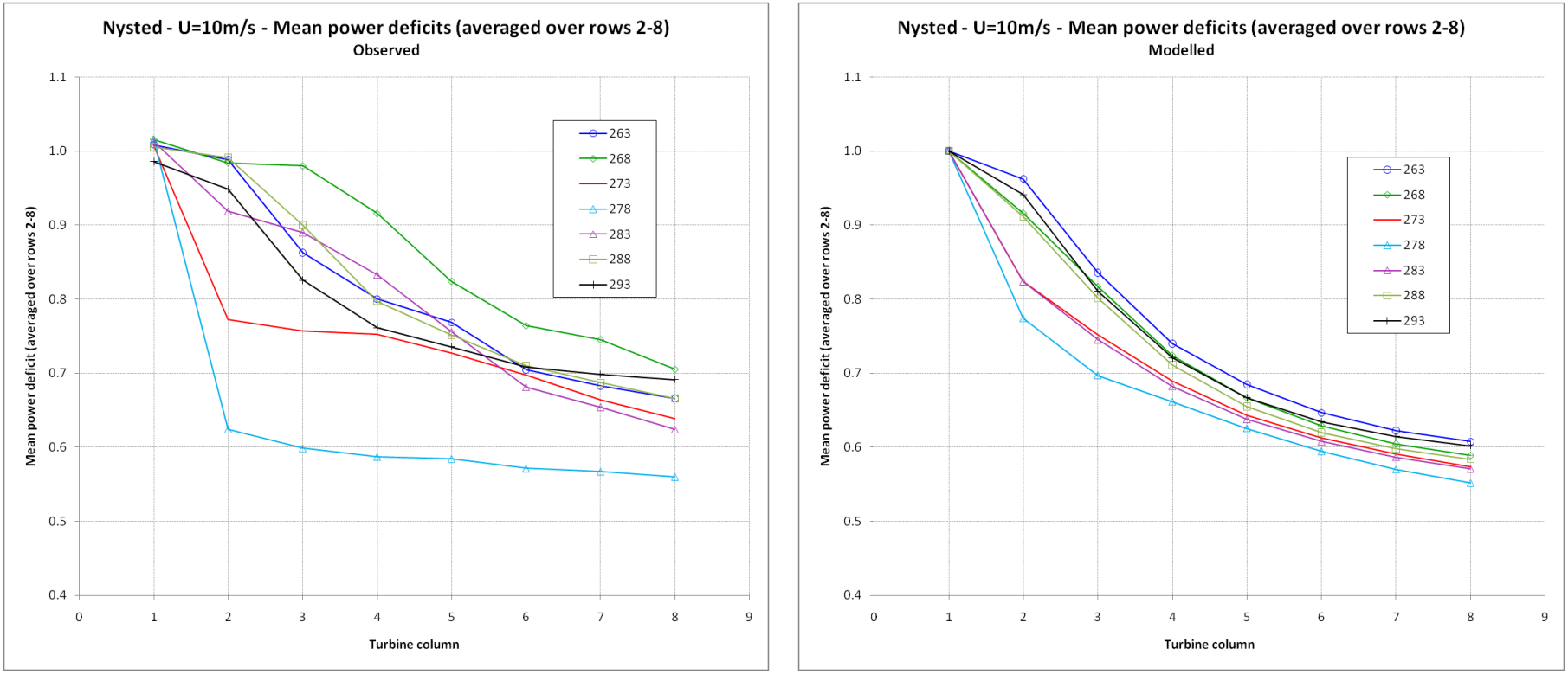

Figure 6 U = 10 m/s: Row-averaged normalised power; observed (left) and modelled (right)

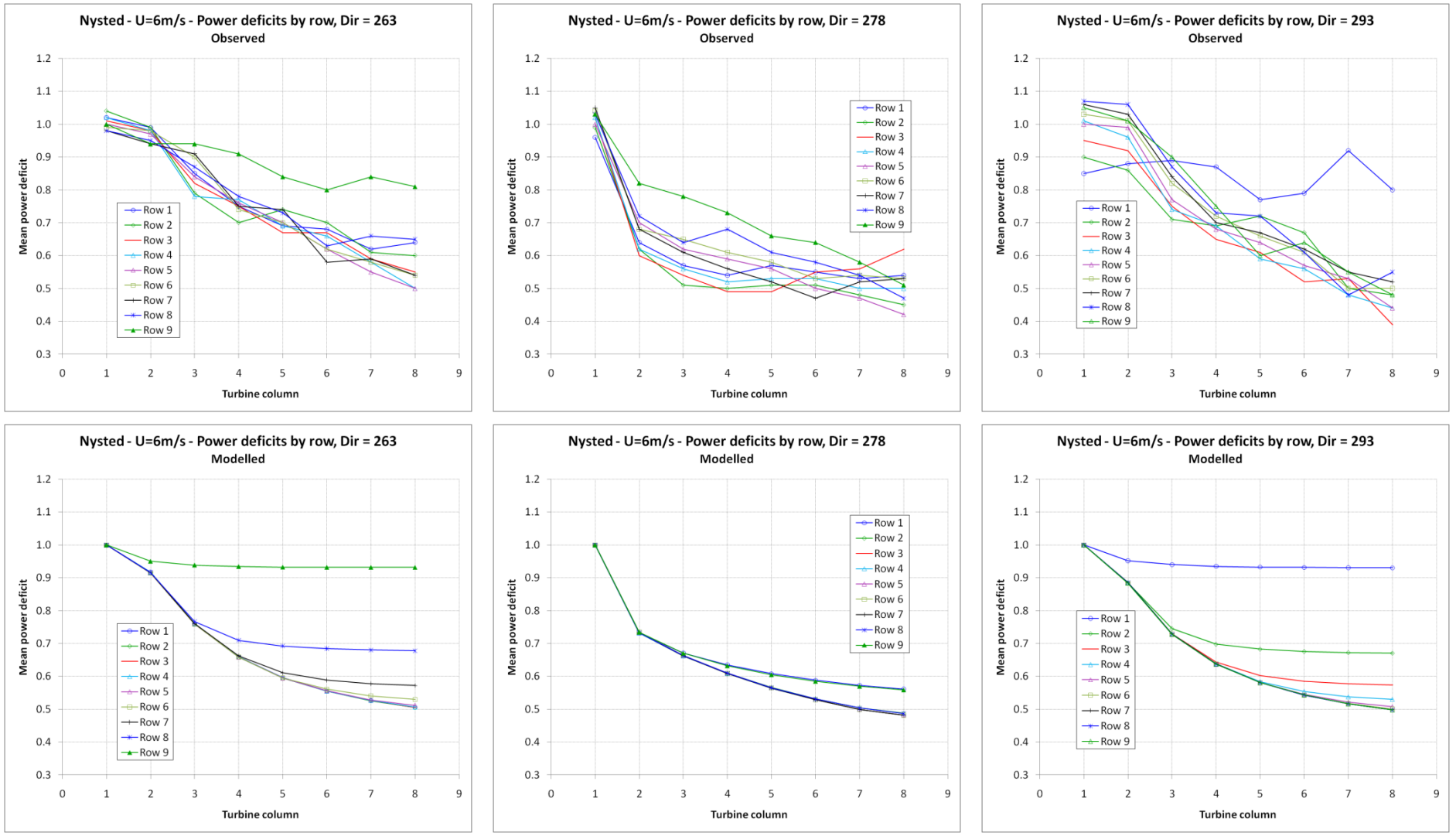

Figure 7 U = 6 m/s: Normalised power by row for wind directions 263, 278 and 293 degrees; observed (top) and modelled (bottom)

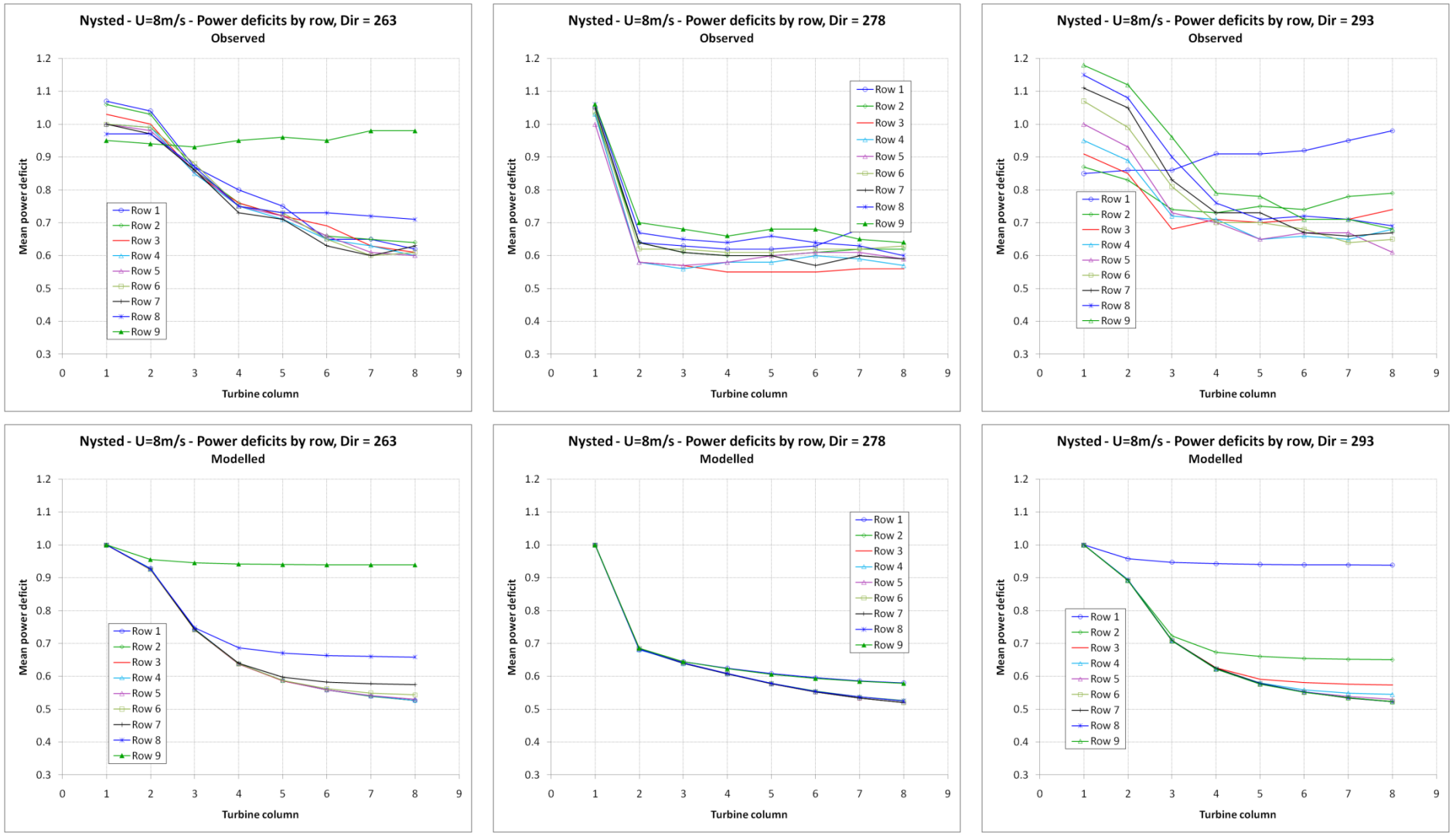

Figure 8 U = 8m/s: Normalised power by row for wind directions 263, 278 and 293 degrees; observed (top) and modelled (bottom)

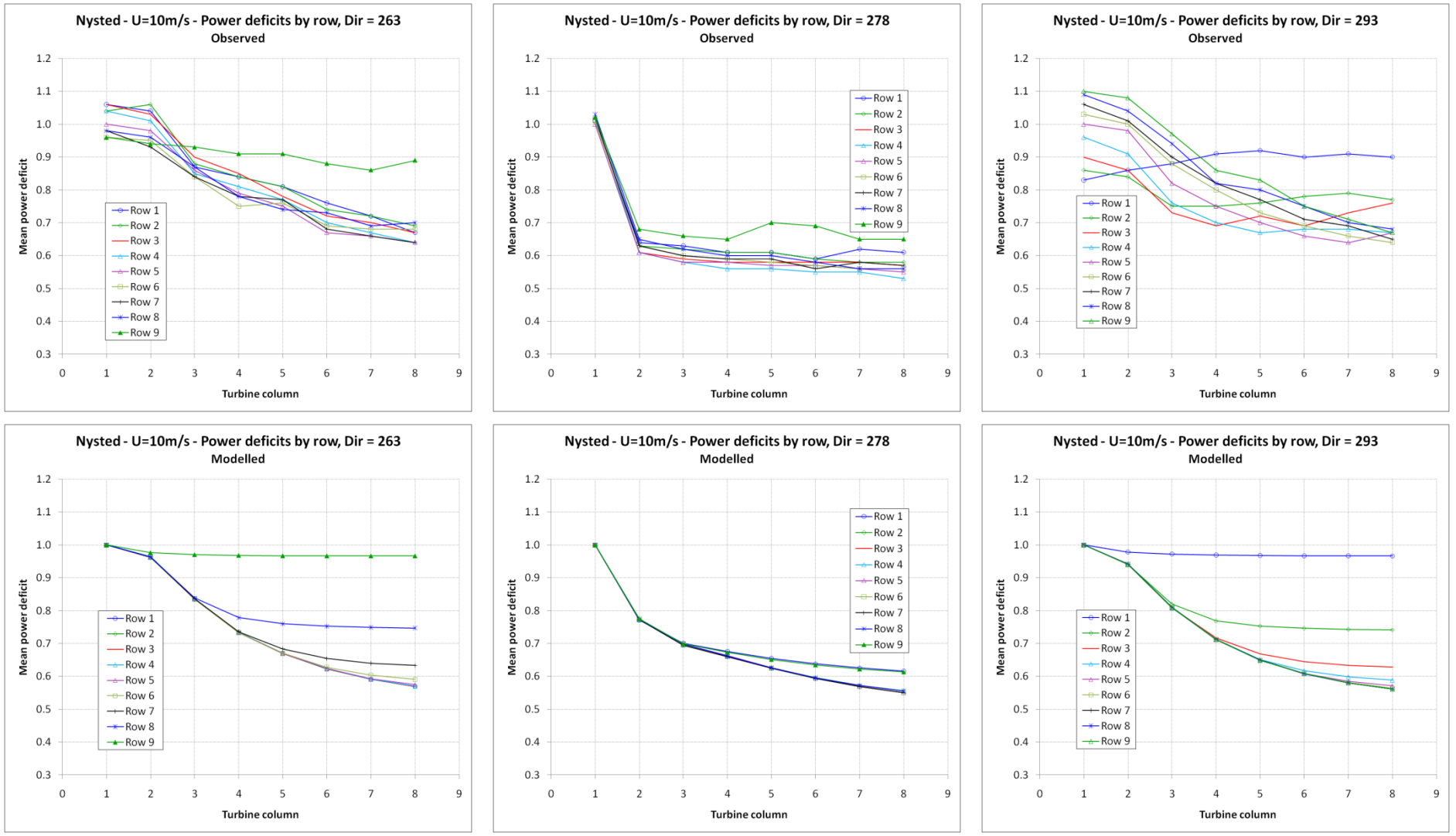

Figure 9 U = 10 m/s: Normalised power by row for wind directions 263, 278 and 293 degrees; observed (top) and modelled (bottom)