Reply to the Reviewers comments

We thank the reviewer for his/her review and constructive feedback. We have therefore revised and modified the original manuscript as to take into account the raised comments. A point to point response to the reviewer's comments follows.

1 Specific comments

1. [*Reviewer*]: The study offers little new content. The Lillgrund data has been used as validation data for wake models already in e.g. Gaumond et al, 2012: "Benchmarking of wind turbine wake models in large offshore wind farms" (also with Larsen and Jensen model) and Keck et al, 2014 "Validation of the standalone implementation of the dynamic wake meandering model for power production".

   [*Authors*]: Gaumond et al. (2012) indeed used data from the Lillgrund wind farm for validation purposes of the Larsen (2009); Jensen (1983); Ott et al. (2011) wake models. The dataset used in their investigation was for the main wind direction of $221.8°$ at a wind velocity of 8 ± 0.5 m s^{-1} and they focused on the wind turbines positioned in Column C. They found that the three models perform similarly for the Lillgrund case. We have likewise used the Lillgrund wind farm for our comparative analysis, but our dataset comprised of data for the main wind directions of $120°$ (Row 3 and 5) and $222°$ (Column B and D) at a wind velocity of 9 ± 0.5 m s^{-1}. We have found that the Larsen (1988) wake model in general outperforms the Jensen wake model. One may argue that it should not be expected that similar conclusions would be found when investigating different columns/rows (with or without the gap in between in this case) of wind turbines, wind velocities and slightly different wake models. In that sense our investigation can be seen as complementary to the one of Gaumond et al. (2012).

   Other authors e.g. Rolf-Erik (2015), used the standalone DWM model and the actuator line method in OpenFOAM® provided by Churchfield et al. (2012). We, on the other hand, used two different actuator discs methods and two analytical wake models.

   The Lillgrund data have indeed been used by many researchers for different validation purposes e.g. Nilsson et al. (2015); Pena et al. (2013); Creech et al. (2013); van der Laan et al. (2015); Churchfield et al. (2012); Rolf-Erik (2015); Gaumond et al. (2012). These studies reveal the complexity of this type of analysis and often complement each other. In addition, they highlight the strengths and limitations of each model/method and offer to researchers better possibilities to gain a deeper and more integrated insight of the particular usefulness of every model/method under different circumstances and cases. Author's changes in manuscript (Page 2, lines 7-11) and (Page 12, lines 3-14).

2. [*Reviewer*]: The authors compare their "new" actuator disc approach with a very simplified version of an actuator disc method. The simplification of using only hub height wind speed is not the current standard. E.g. van der Laan et al, 2015 "The k-epsilon-fp model applied to double wind turbine wakes using different actuator disk force methods" or Wu and Porte-Agel, 2011: "Large-eddy simulation of wind-turbine wakes: evaluation of turbine parametrisations" use at least an average of the wind speed over the rotor to calculate the free-stream velocity.

   [*Authors*]: We acknowledge the reviewer's comment that the old ACD method uses a simplified way to calculate the power production of the wind turbine i.e the wind velocity at hub height and not at least an averaged wind velocity over the ACD. In our paper, however, the main goal is to compare the new ACD method implemented in WindSim with the previous method used within WindSim and two widely used analytical wake models in the industry. Nevertheless, we agree that it would be interesting to include the ACD method presented in Laan et al. (2015) in comparison studies. We are actually investigating now a kind of continuation of our paper where the focus would be a comparison of the ACD from Laan et al. (2015) and the new ACD presented within this manuscript. We are happy that the reviewer already sees some value in this possibility.

The methods presented in Wu and Porté-Agel (2011) require airfoil data (typically not available to industrial users) or are applicable only in a single wind turbine case. On the other hand, our method aims to be used by industrial users and for power production assessment of layouts consisting of multiple wind turbines in a row. Author's changes in manuscript (Page 13, lines 18-23)

3. $[Reviewer]$:The authors use the standard k-epsilon model for the turbulence closure in RANS. Van der Laan et al, 2015 "An improved k-epsilon model applied to wind turbine wake in atmospheric turbulence "and Rethoré, 2009 "Wind turbine wake in atmospheric turbulence" have shown with wind measurements and LES that this model is not capable of replicating wakes of isolated wind turbines. The change of the thrust coefficient does not change this behavior.

   $[Authors]$: We thank the reviewer for his/her comment. We agree that investigating in more detail the impact of using different turbulence closer models on the results will prove beneficial. This point was already identified in the manuscript at Page 12, lines 15-16. We further agree with the reviewer that the turbulence closer model has an impact on the results, especially for the first three wind turbines of the row, as shown in van der Laan et al. (2015). Furthermore, Réthoré (2009) did indeed discuss the limitation of the $k-\varepsilon$ turbulence closure model, i.e. it's under–prediction of wake effects due to it being too diffusive. In our paper the goal is not to investigate the influence of the effect of using different turbulence closer models, rather we are interested in a comparative analysis of two actuator disc methods and two analytical wake models for a wind farm configuration.

   It is apparent, though, as the reviewer pointed out, that it would be interesting to investigate the use of different turbine closure models in wind farm resource assessment and wake modelling. This has come to our attention through this interactive commentary procedure employed by the Wind Energy Science Journal and we therefore would like to acknowledge the value of such an open peer review process. Author's changes in manuscript (Page 12, lines 16-21)

4. $[Reviewer]$: I could see a value in the contribution, if the authors focus on the RANS calculation and do more literature research on the state of art of actuator disc and turbulence modeling and use these approaches as comparison.

   $[Authors]$: Following the reviewer's proposal in the new version of the manuscript we have now focused more on the set-up of the RANS calculations. To this end we have included new material where we better describe the grid set-up used in the RANS calculations (Page 7, lines 25-31 and Page 8, Figure 3 and Table 2). Furthermore, we have now included a wider literature review and discussion on the state of the art regarding ACD methods and turbulence modelling (Page2, lines 8-11, Page 12, lines 3-14 and Page 12, lines 16-21) that now entails more recent advances in the field and can facilitate future researchers in performing similar comparative analysis.

2 Further comments

1. $[Reviewer]$: The description of the methods is incomplete. The coefficients used for the analytical models are missing. There is no information about the mesh of the RANS calculations.

   $[Authors]$: In accordance to the reviewer's comment, the following points have been introduced in the manuscript for the Jensen and Larsen models:

   Jensen: "The wake expansion coefficient k is found by $k = A_j ln(z_h/z_0)$. Where A_j is a constant equal to $A_j = 0.5$, z_h the wind turbine hub height and z_0 is the effective roughness height. " Author's changes in manuscript (Page 5, lines 13-14).

   Larsen: The parameter c_1 is found by

$$c_1 = \left(\frac{D}{2}\right)^{5/2} (C_T A x_0)^{5/6} \tag{1}$$

where:

$$x_0 = \frac{9.5D}{(2R_{95}/D)^3} - 1, \tag{2}$$

$$R_{95} = 0.5\left(Rnb - \min(z_h, Rnb)\right), \tag{3}$$

$$Rnb = \max\left(1.08D, 1.08D + 21.7D(TI_h - 0.05)\right). \tag{4}$$

TI_h is the ambient turbulence intensity at hub height (z_h). Author's changes in manuscript (Page 6, lines 1-8).

A description of the mesh is now included as following: "In Fig. 1 a top view of the grid at ground level is presented. The domain used for the simulation has dimensions of (x,y,z)= (86R, 86R, 11R). An inner equidistant area (within the dashed box Fig. 1) of cell size R/6 is defined for the domain containing the actuator discs, while outside this equidistant region the resolution expands. The equidistant region is automatically defined by the software after the wind turbine locations are selected. The total number of cells is approximately 3.8 million. Table 1 presents the main parameters of the domain, R is the rotor radius and (Lx,Ly,Lz), (lx,ly,lz) are respectively the length of the domain and inner equidistant region." Author's changes in manuscript (Page 7, lines 25-31 and Page 8, Figure 3 and Table 2)

Table 1. Domain set-up.

Domain			Inner equidistant region				Total number of cells
Lx	Ly	Lz	lx	ly	lz	cell size	
$86R$	$86R$	$11R$	$54R$	$60R$	$5R$	R/6	3.4×10^6

2. $[Reviewer]$: The figures should be readable in grey-scale.

$[Authors]$: The figures have been revised to be readable in grey-scale.

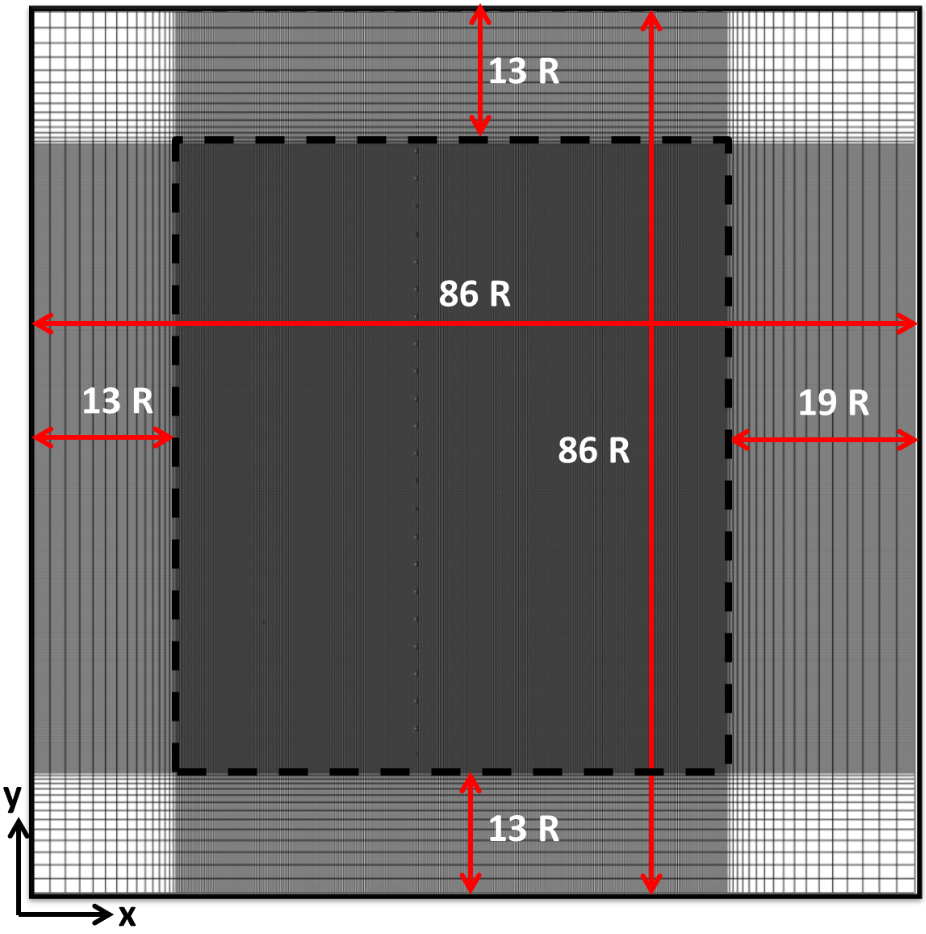

Figure 1. Top view of WindSim generated mesh. The figure displays the grid resolution at ground level, R is the wind turbine radius.

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