WIND KNOWLEDGE

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Two methods to improve turbulence estimates above a forest in a CFD model

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windsim

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Motivation

- WindSim users are satisfied with the wind speed and turbulence intensity (TI) calculations of the WindSim CFD software over forested areas (Envision/Siemens presentation today, EON presentation at WindEurope conference last year).

- The absolute cross-prediction error at 80-100 m above ground is below 5% for wind speed and around 10% for TI for most of the sites shown in these validations.

- WindSim simulates the relative change of TI above the forest very well.

Motivation

But there is always room for improvement:

- Wind Speed profiles inside the forest can be different from observations
- Absolute TI values inside and right above the forest can be too high

New forest data sets are available which give information about the vertical density distribution inside the forest => should we use them?

Seeking new parameterization to limit TI values and create a more realistic profile inside and right above the forest

Wind tunnel

- Recreated wind tunnel from Meroney experiment (1968)
- Selected for its use of zero-pressure-gradient ceiling and the inlet wind speed and TI profile which is the same as the WindSim standard set-up
- Wind speed and turbulence intensity data was collected at many locations downstream the forest edge
- Wind tunnel dimensions 2x2x26 m

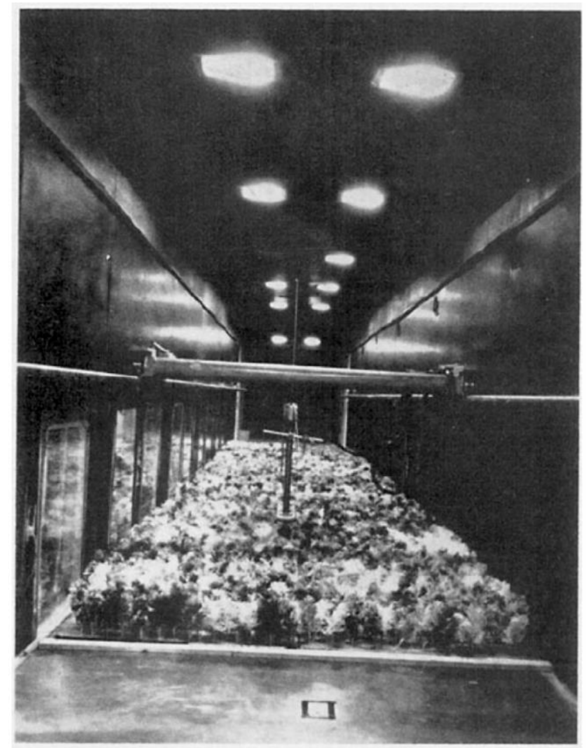
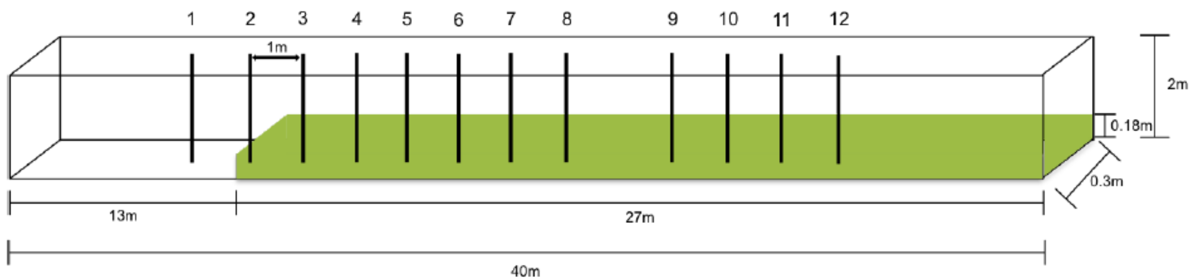


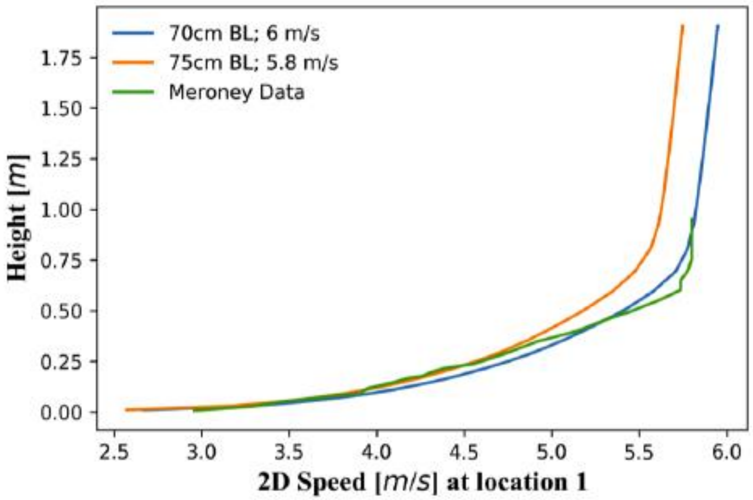
FIG. 3. Meteorological wind tunne and artificial tree canopy.

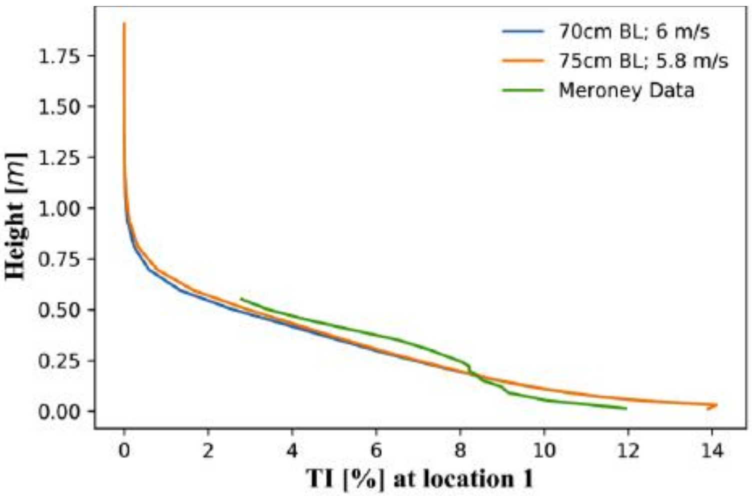
CFD model

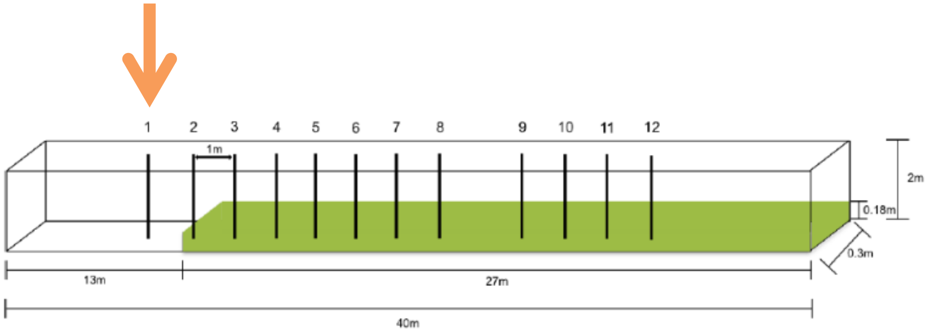


Wind tunnel

- Inlet wind conditions very similar between measurements and CFD model



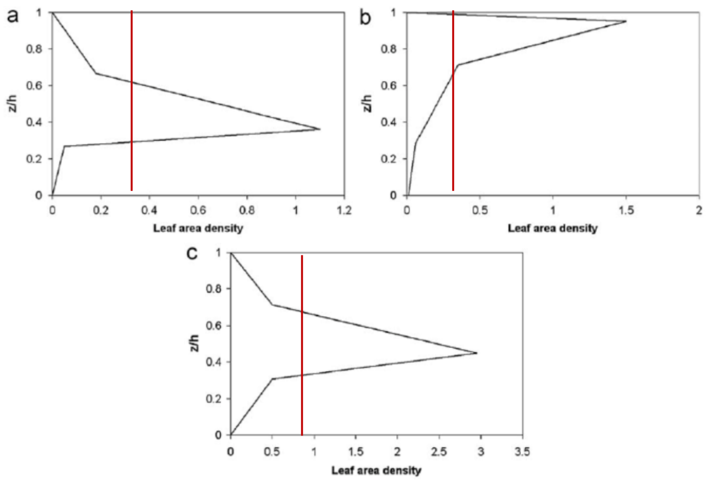




New methods

We can try to produce a more reasonable wind profile and to reduce the TI inside and near the forest by two methods:

Use a variable leaf area density instead of a constant one



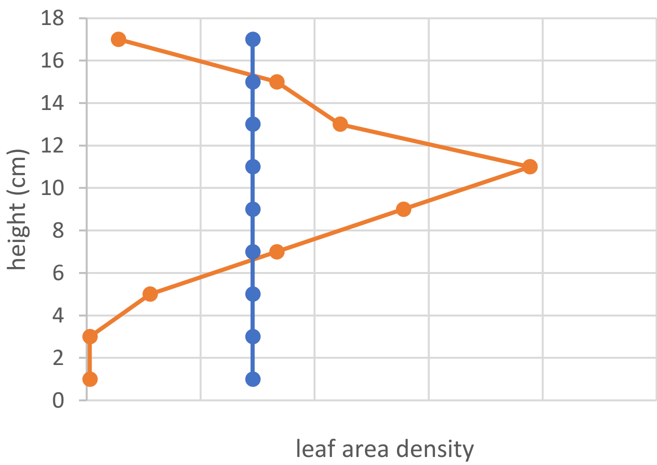
Closure coefficient modification

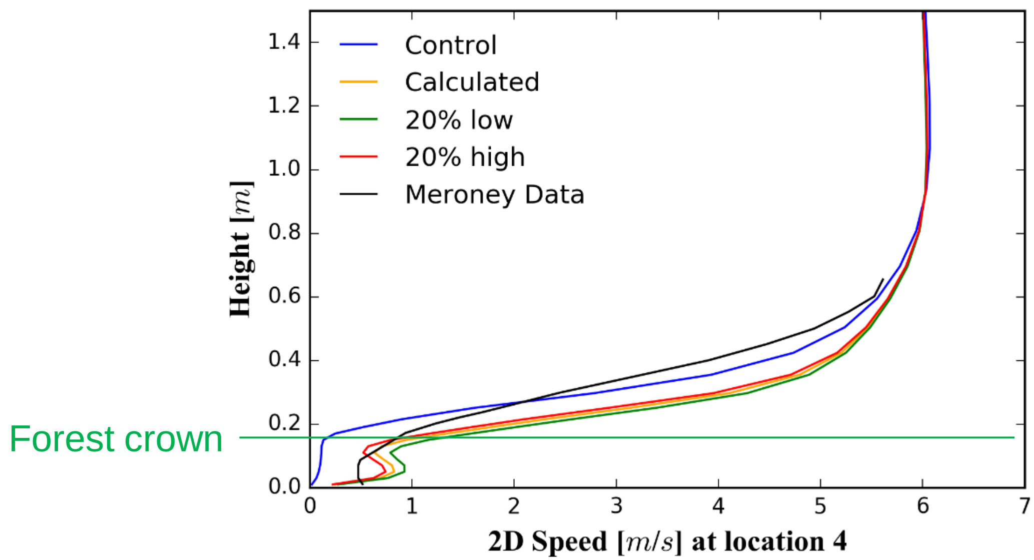
$$S_k = C_2(\beta_p|U|^3 - \beta_d|U|k)$$

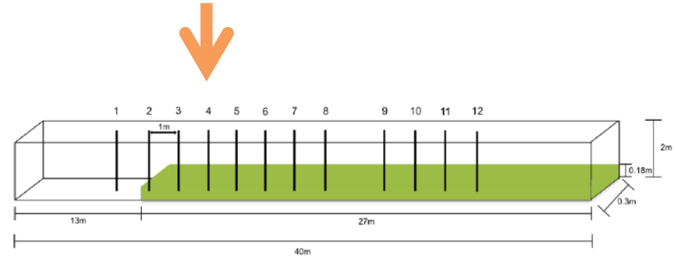
$$S_\epsilon = C_2\left[C_{\epsilon 4}\beta_p\left(\frac{\epsilon}{k}\right)|U|^3 - C_{\epsilon 5}\beta_d|U|\epsilon\right]$$

Method 1: Variable leaf area density

Generated LAD profile based on the tree geometry and varied it by ±20% to test sensitivity







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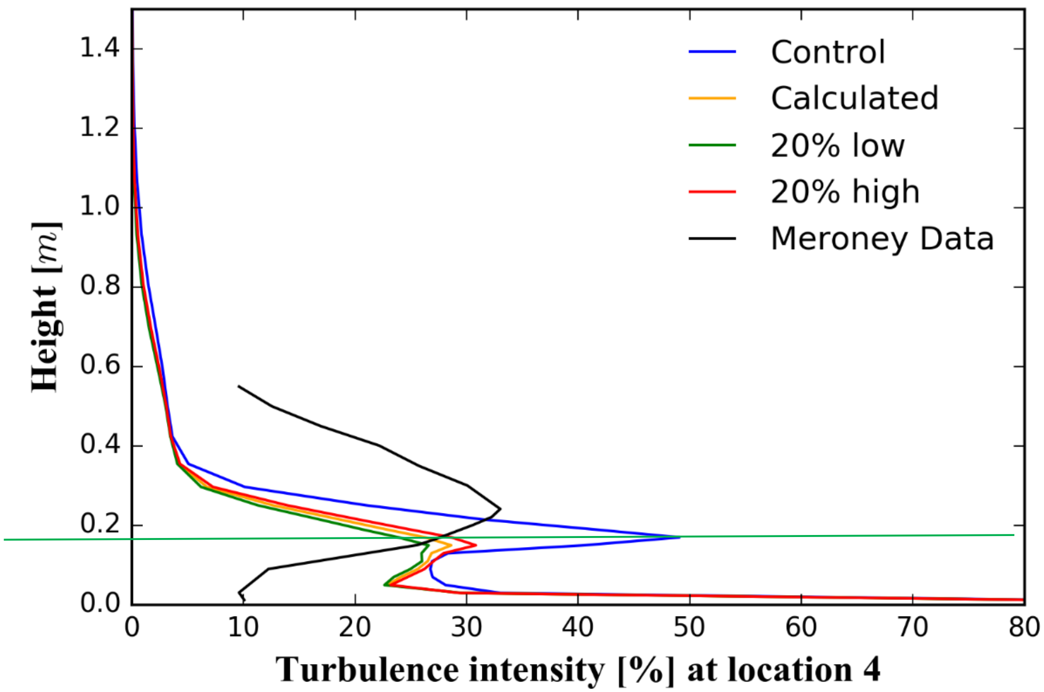
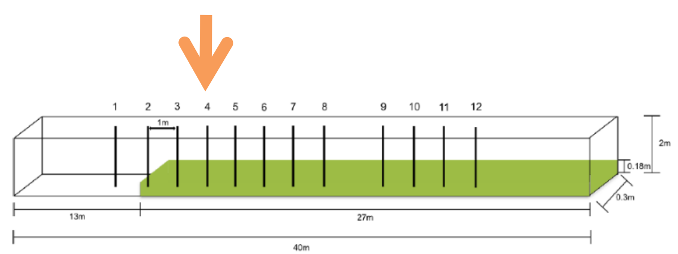
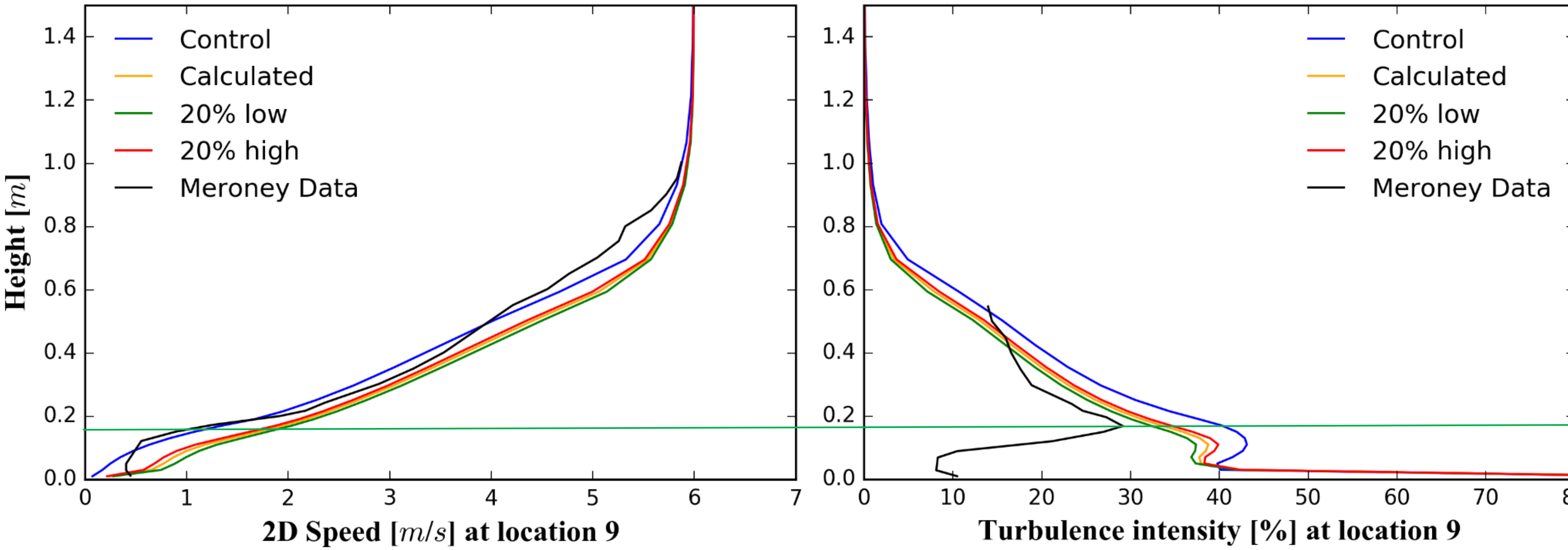
Method 1: Variable leaf area density

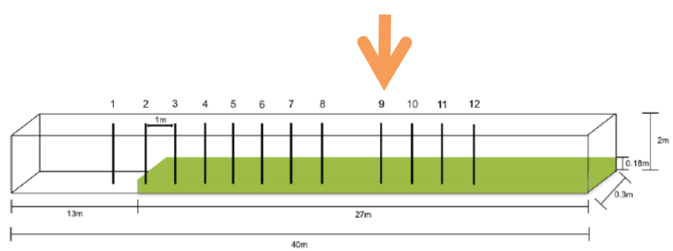
Forest crown





Method 1: Variable leaf area density





Method 2: Closure coefficient modification

- Closure coefficients

$$S_k = C_2(\beta_p|U|^3 - \beta_d|U|k)$$

$$S_\epsilon = C_2\left[C_{\epsilon 4}\beta_p\left(\frac{\epsilon}{k}\right)|U|^3 - C_{\epsilon 5}\beta_d|U|\epsilon\right]$$

β_p = TKE production

β_d = TKE destruction

$C_{\varepsilon 4}$ = EP production

$C_{\varepsilon 5}$ = EP destruction

- Lopes hypothesis

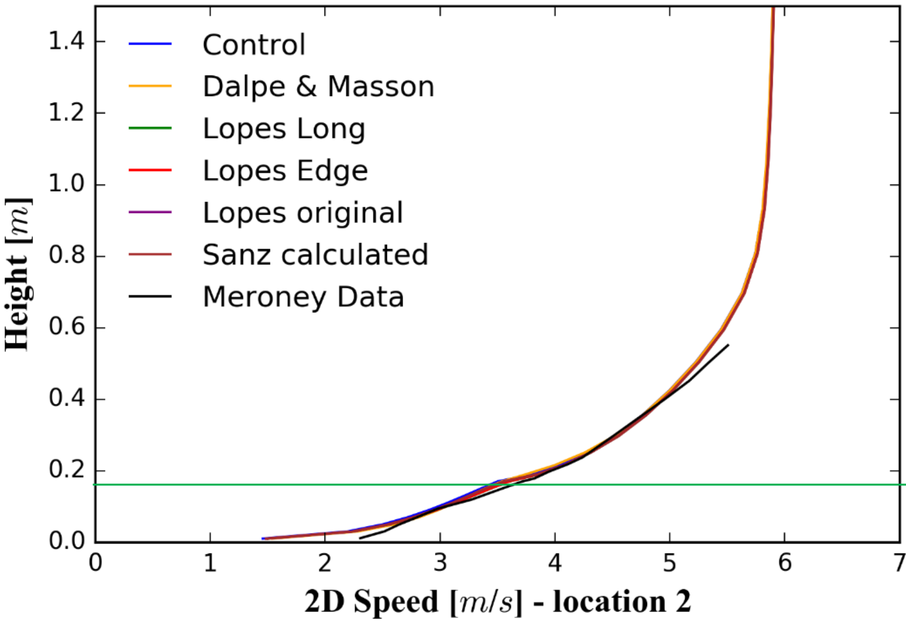
Lopes (2011) used LES to show that forest only acted as sink => β_p was unnecessary (and thus also $C_{\varepsilon 4}$)

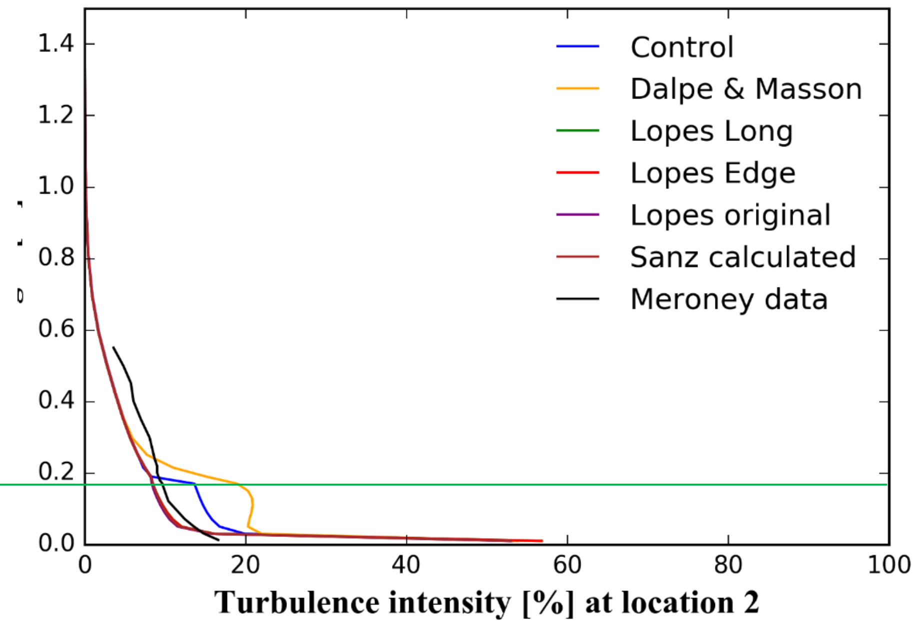
Method 2: Closure coefficient modification

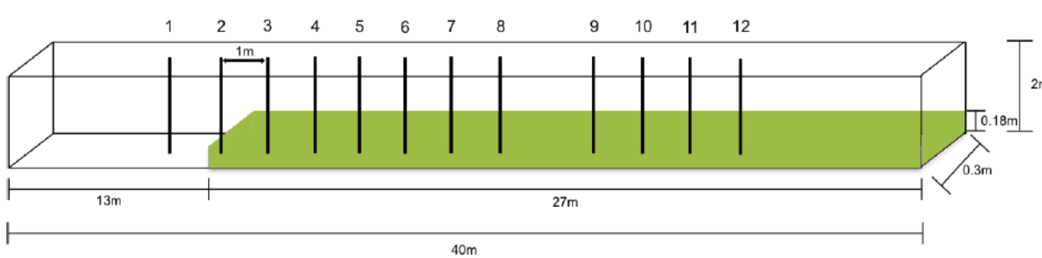
Coefficient combinations which have been tested:

Source	β_p	β_d	$C_{\varepsilon 4}$	$C_{\varepsilon 5}$
Standard	1.00	6.51	1.24	1.24
Dalpé & Masson	1.00	5.03	0.79	0.79
Lopes Long	0	3.80	0	0.79
Lopes Edge	0	4.11	0	0.68
Lopes Original	0	4.00	0	0.90
Sanz calc'd	0	3.00	0	0.83

Method 2: Closure coefficient modification







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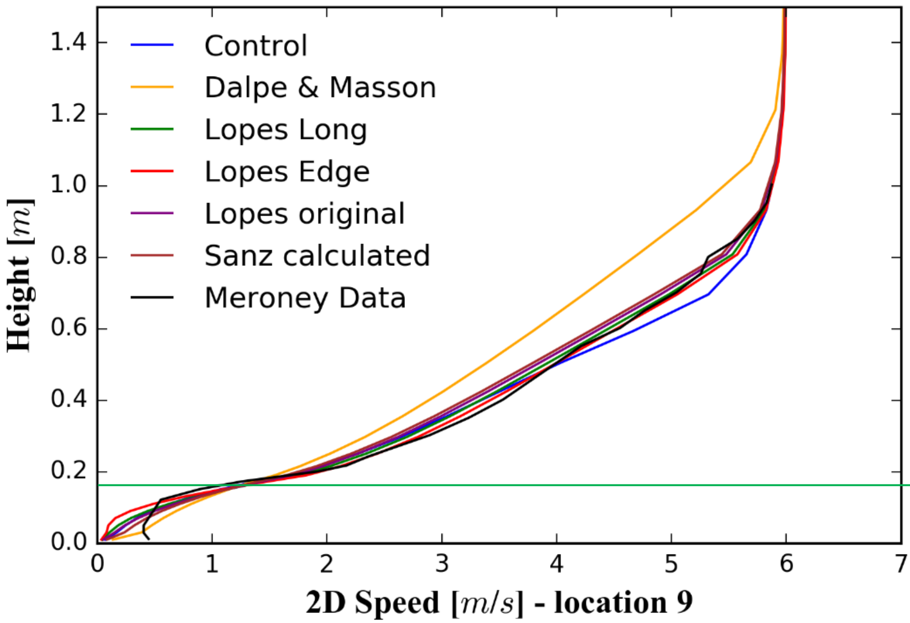
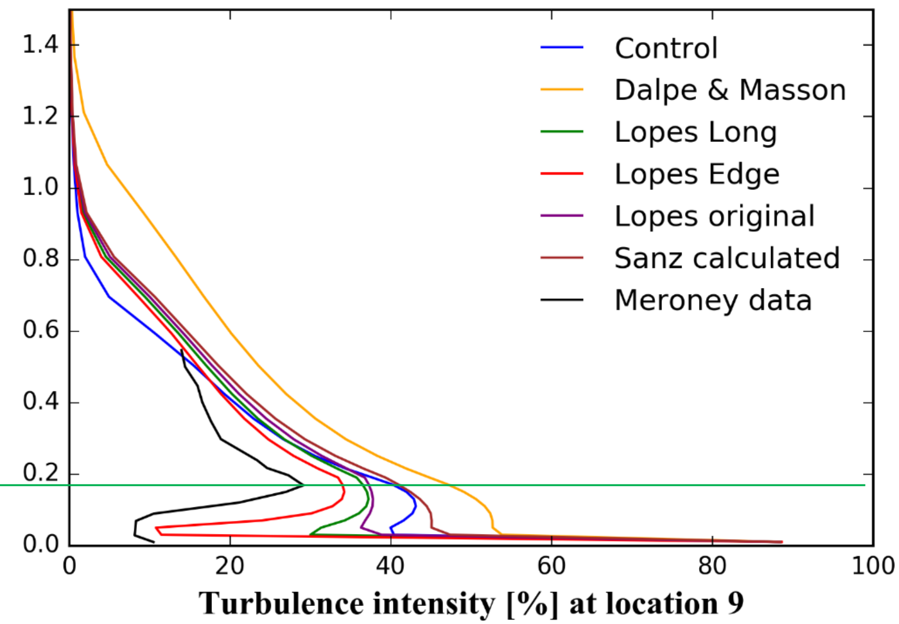
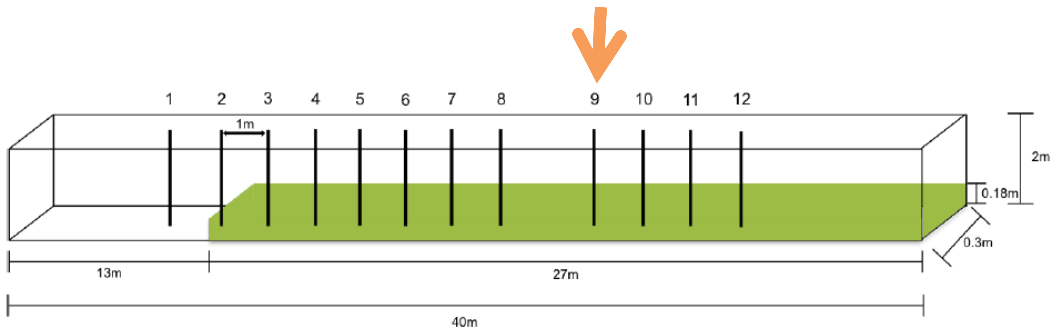
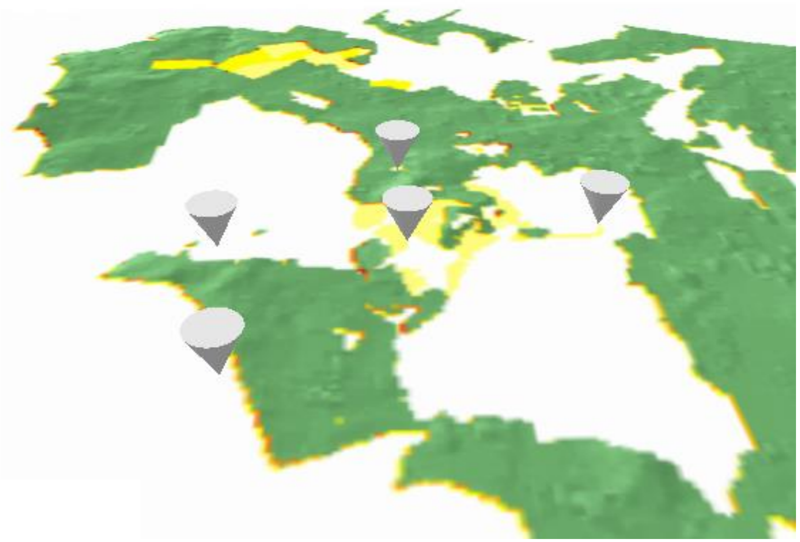






Application to a real wind farm



TI cross-checking results

Reference mast	Standard Forest	Lopes Forest
Mast 1	19.27%	9.67%
Mast 2	12.54%	4.78%
Mast 3	11.54%	6.60%
Mast 4	23.25%	6.91%
Mast 5	12.51%	9.04%

Conclusion

- Using variable leaf area density instead of a constant value does improve the TI simulation results. If such data is available for a site it might be worth using it
- Lopes modification for turbulence coefficients seems to improve the TI simulation
- More wind tunnel validations and validations at real sites will follow

Thank you

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