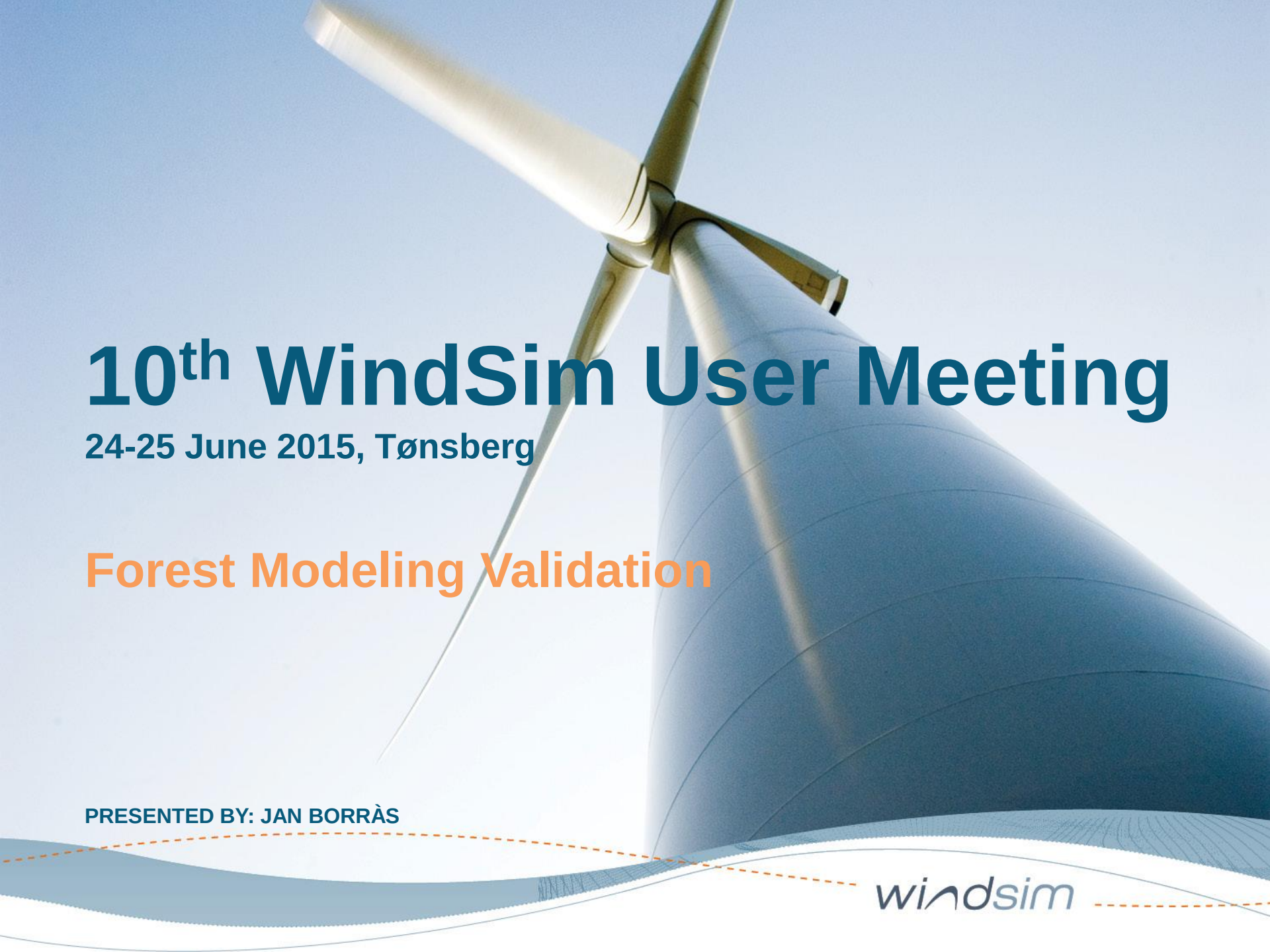


10th WindSim User Meeting

24-25 June 2015, Tønsberg

Forest Modeling Validation

PRESENTED BY: JAN BORRÀS

windsim

Content

- Forest validation: Collaboration with Iberdrola
- Atmospheric Stability Assessment
- Forest modeling:
    - Grid Sensitivity study
    - Sensitivity study regarding Roughness classification
    - Sensitivity study regarding Drag coefficient C_2
    - Sensitivity study regarding Forest Height
- Turbulence Intensity Vertical profiles
- Conclusions

Forest validation: Collaboration with Iberdrola

- During last year's user meeting, WindSim announced that we are looking for good quality measurements of wind speed and turbulence in forested areas

- Iberdrola has offered data from one forested site with several met masts, several sodar measurements, and a virtual met mast

- Data used in this study:
  - 5 Met Mast dataset: period 2 – 4 years
  - 3 Sodar dataset: period 3 – 8 months
  - 1 Long-term Virtual Met Mast with stability classification

Atmospheric Stability Assessment

- Provided Virtual met mast:
  - 22-year period, records every 1h
  - CFSR mesoscale model
  - Wind Speed and Direction. Reference height 70 m
  - Bulk Richardson Number

- How the provided Bulk Richardson Number was calculated:

$$R_B = \frac{g \cdot (T_{h+10} - T_{h-10}) \cdot (h_{+10} - h_{-10})}{T_h \cdot \{(u_{h+10} - u_{h-10})^2 + (v_{h+10} - v_{h-10})^2\}}$$

T: Potential temperature
u, v: horizontal components wind speed
h: reference height

  - Unfortunately, virtual potential temperature was not used
  - Unrealistic values may occur with vertical wind gradients very close to zero
  - Monin-Obukhov Length would be a more precise approach

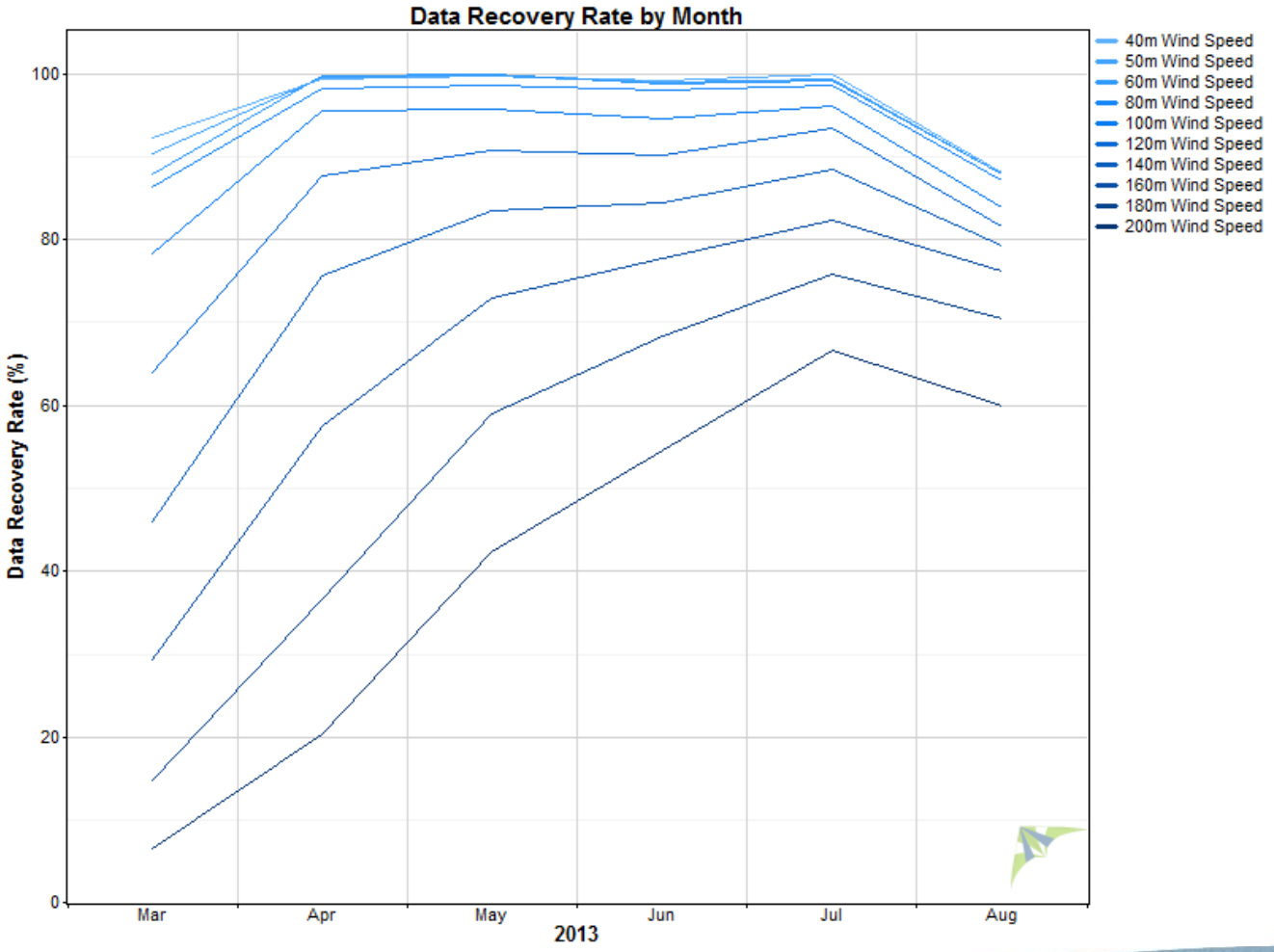
Atmospheric Stability Assessment

- Assessing stability with Bulk Richardson Number:

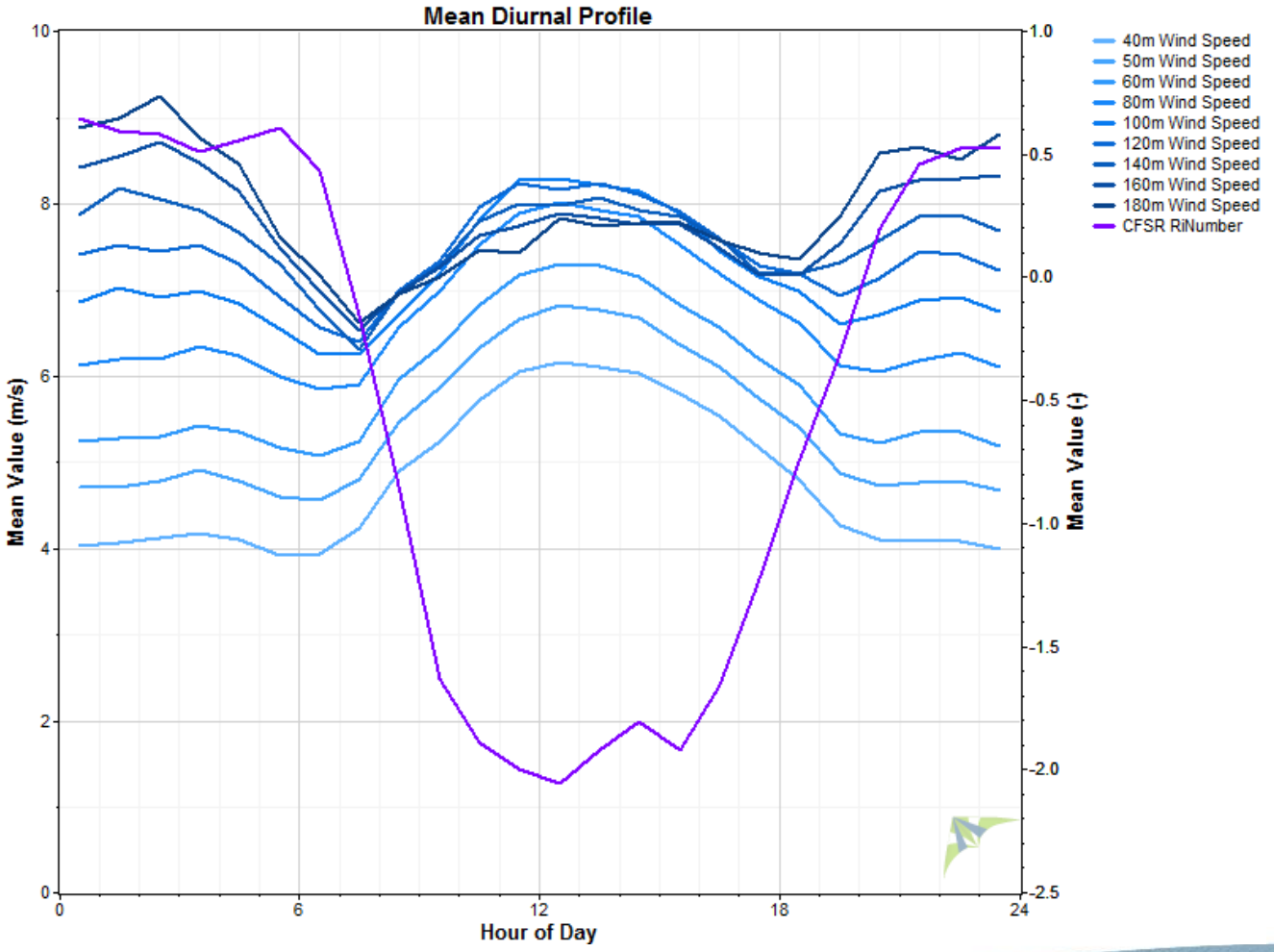
Atm. Stability	Bulk Ri Number
Unstable	$-10 < Ri_B < 0$
Neutral	$0 < Ri_B < 0.25$
Stable	$0.25 < Ri_B < 1$
Very Stable	$1 < Ri_B < 10$

Values $|Ri_B| > 10$ are disregarded.

Atmospheric Stability: Sodar 2

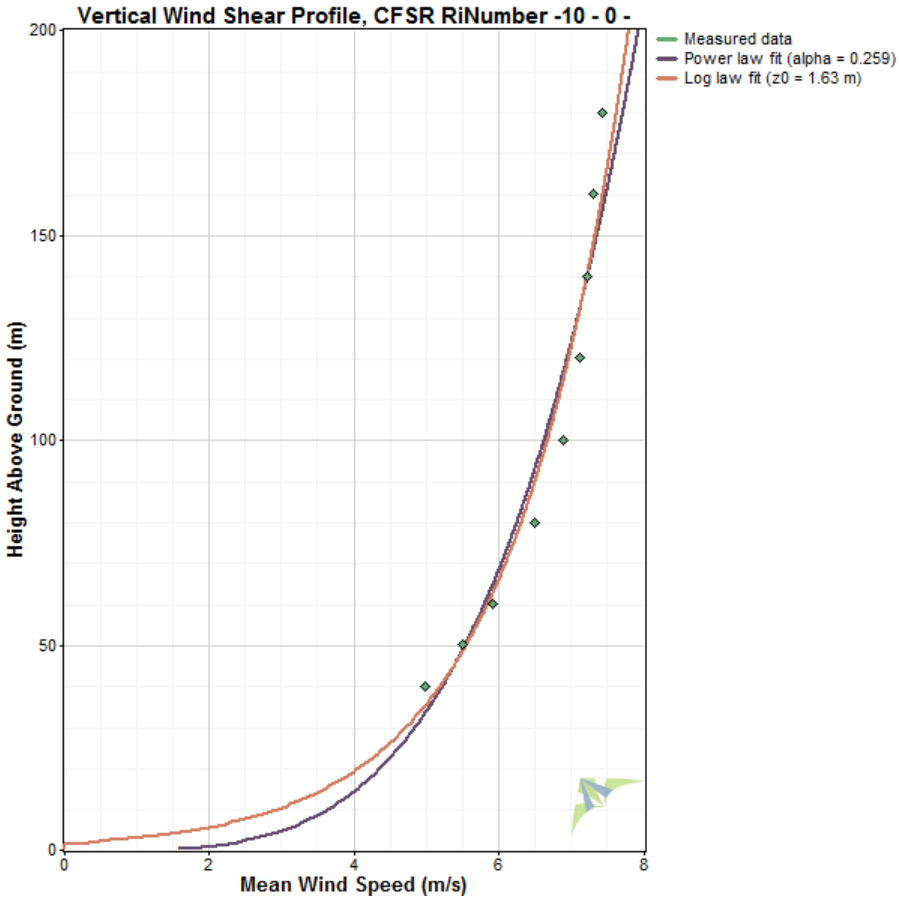


Atmospheric Stability: Sodar 2

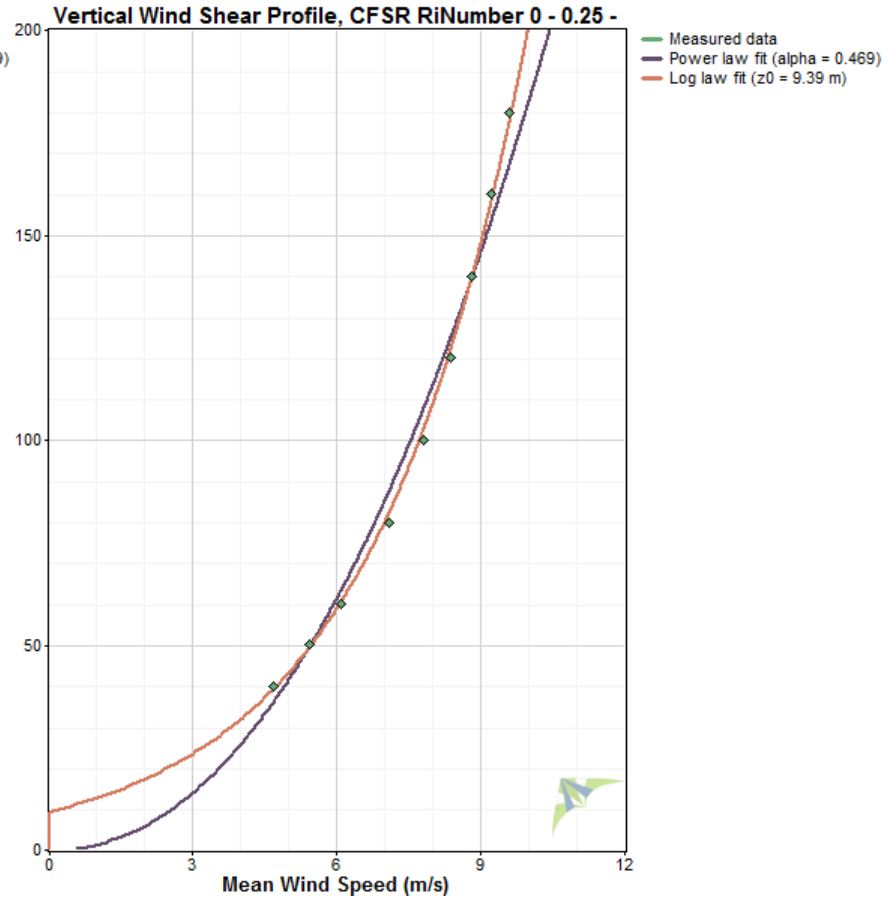


Atmospheric Stability: Sodar 2

Unstable

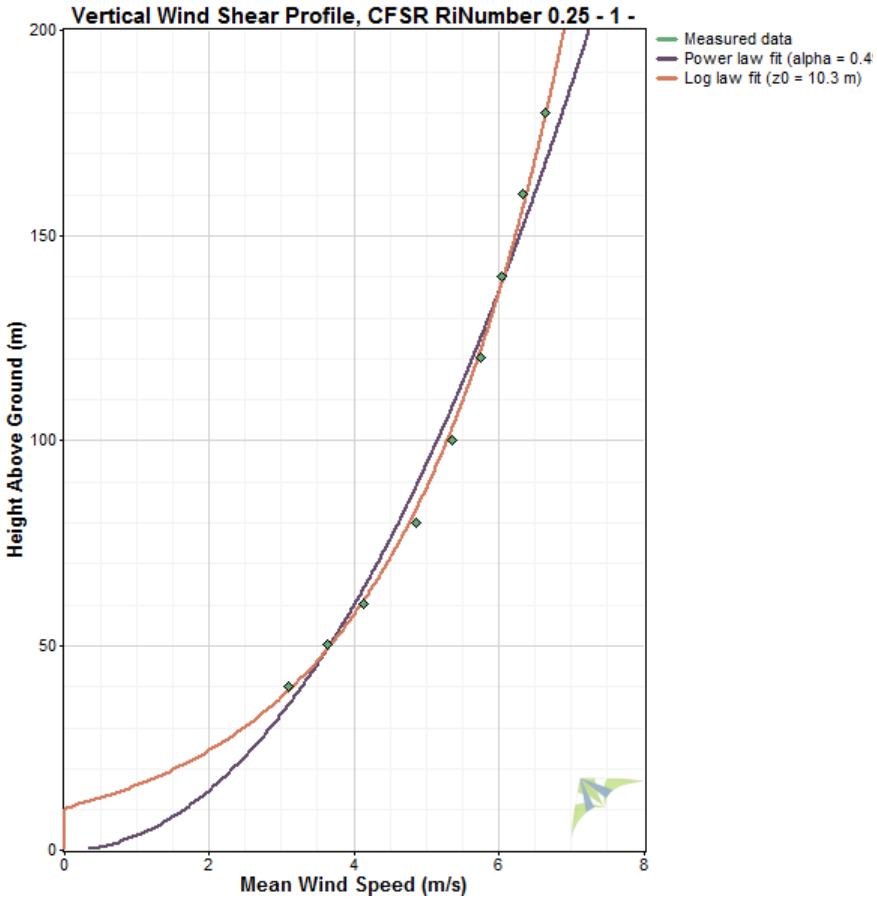


Neutral

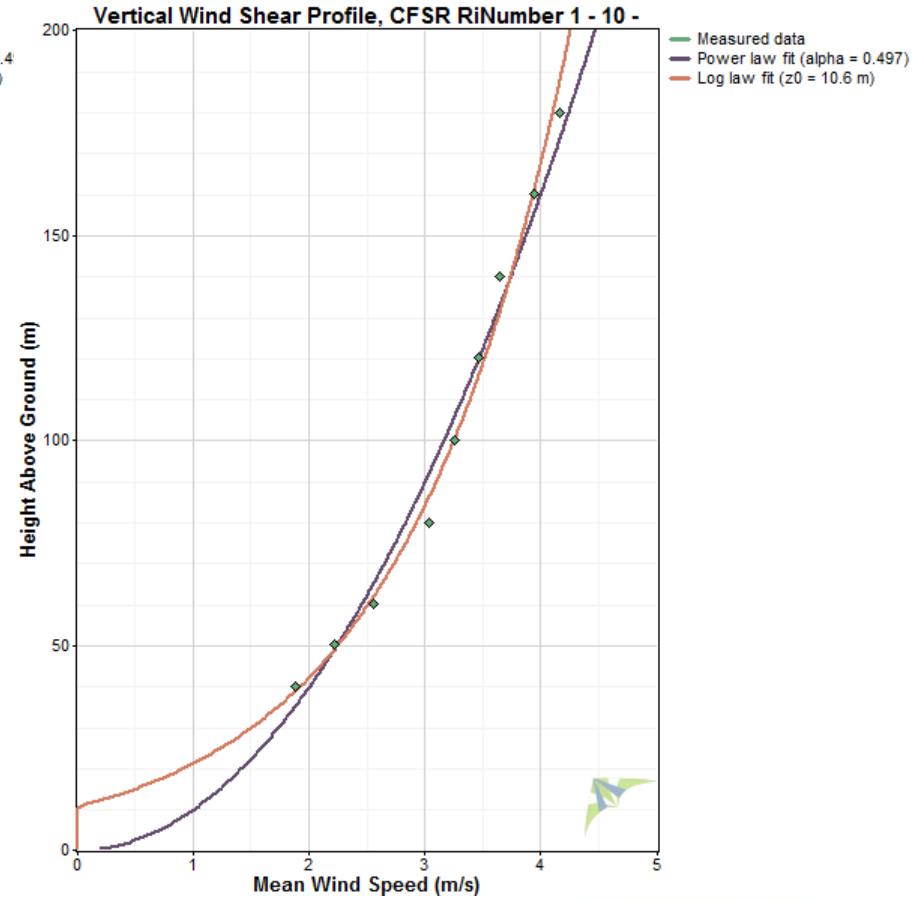


Atmospheric Stability: Sodar 2

Stable

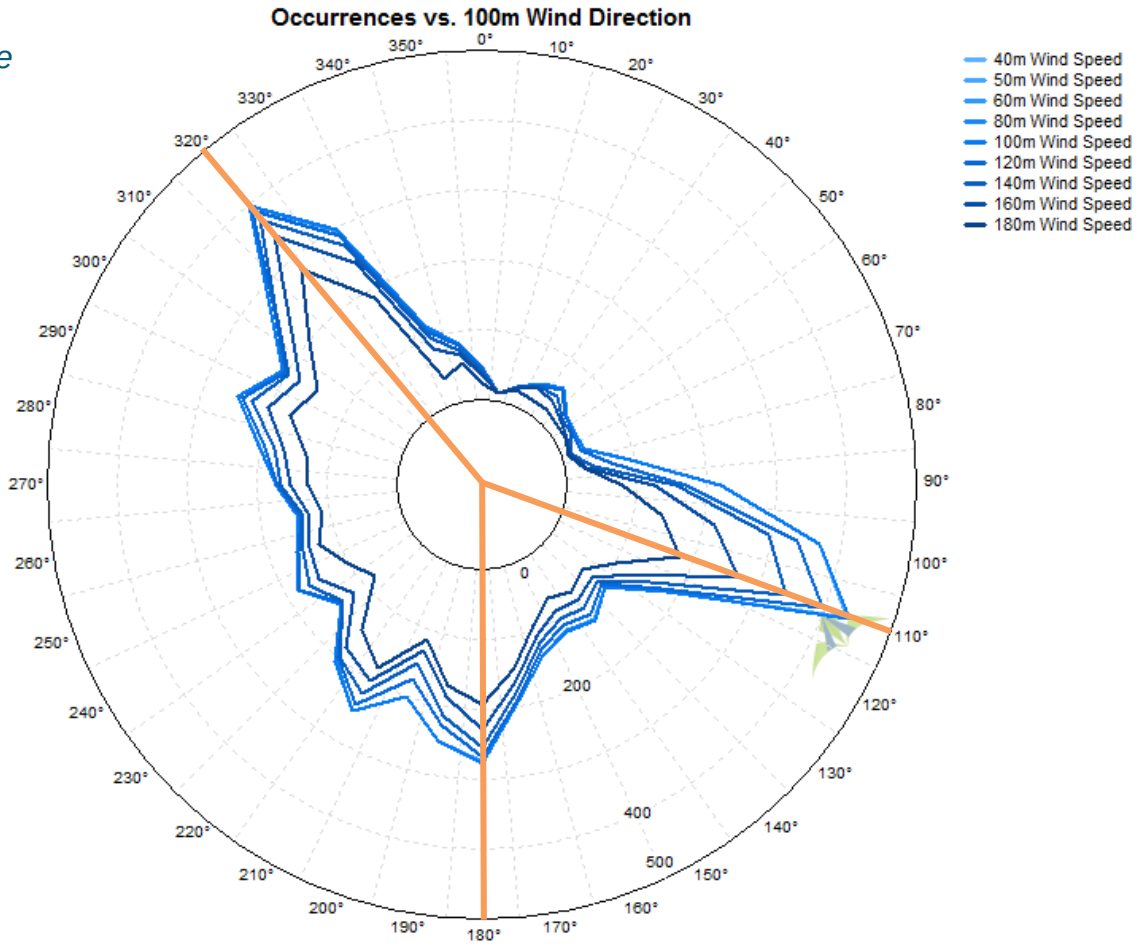


Very Stable

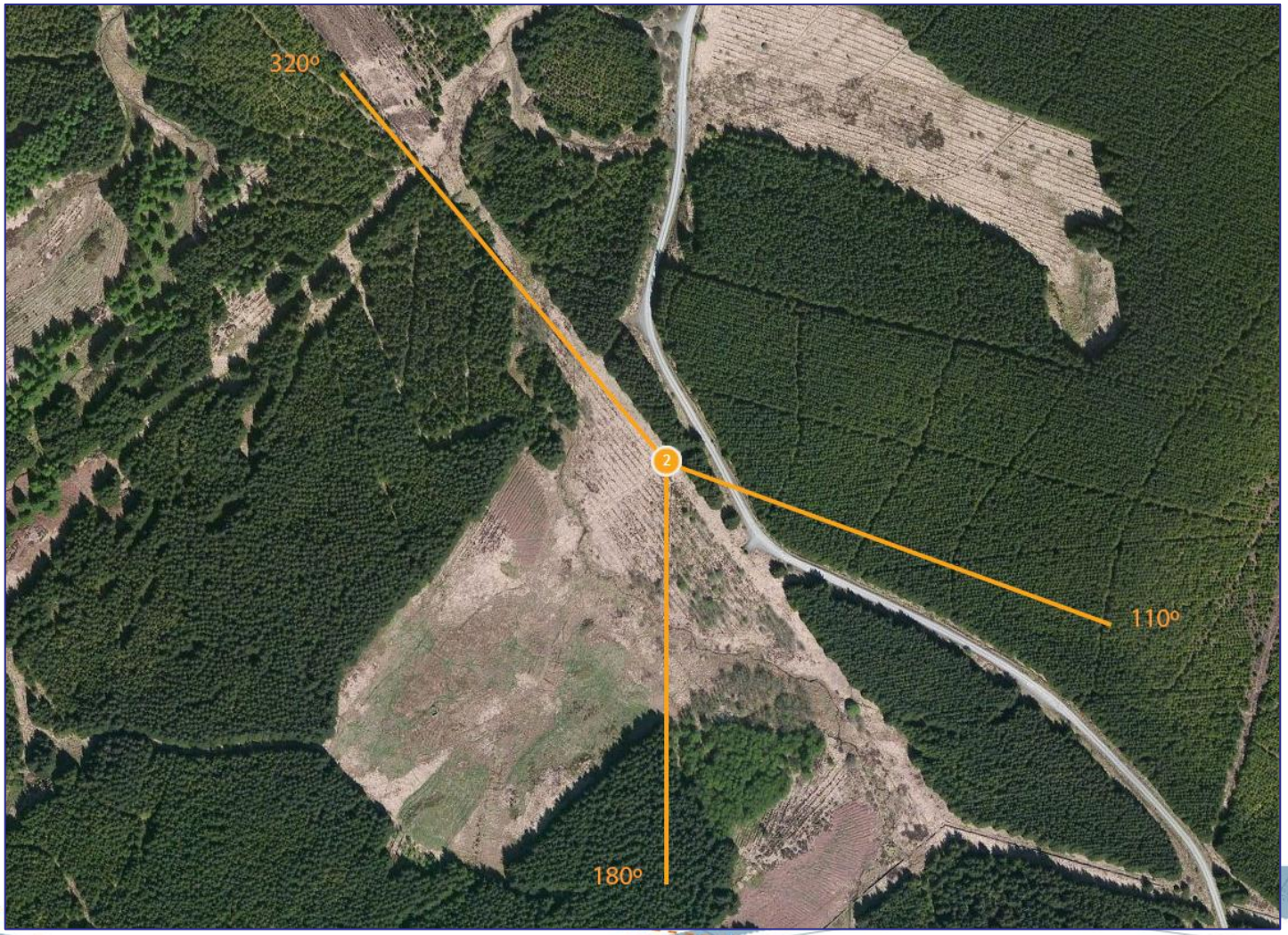


Atmospheric Stability: Sodar 2

- *Records under neutal atmosphere*
- *Only concurrent measurements for 40 to 180 m*
- *Three main flow cases:*
  - *110º ±10º*
  - *180º ±10º*
  - *320º ±10º*



Atmospheric Stability: Sodar 2



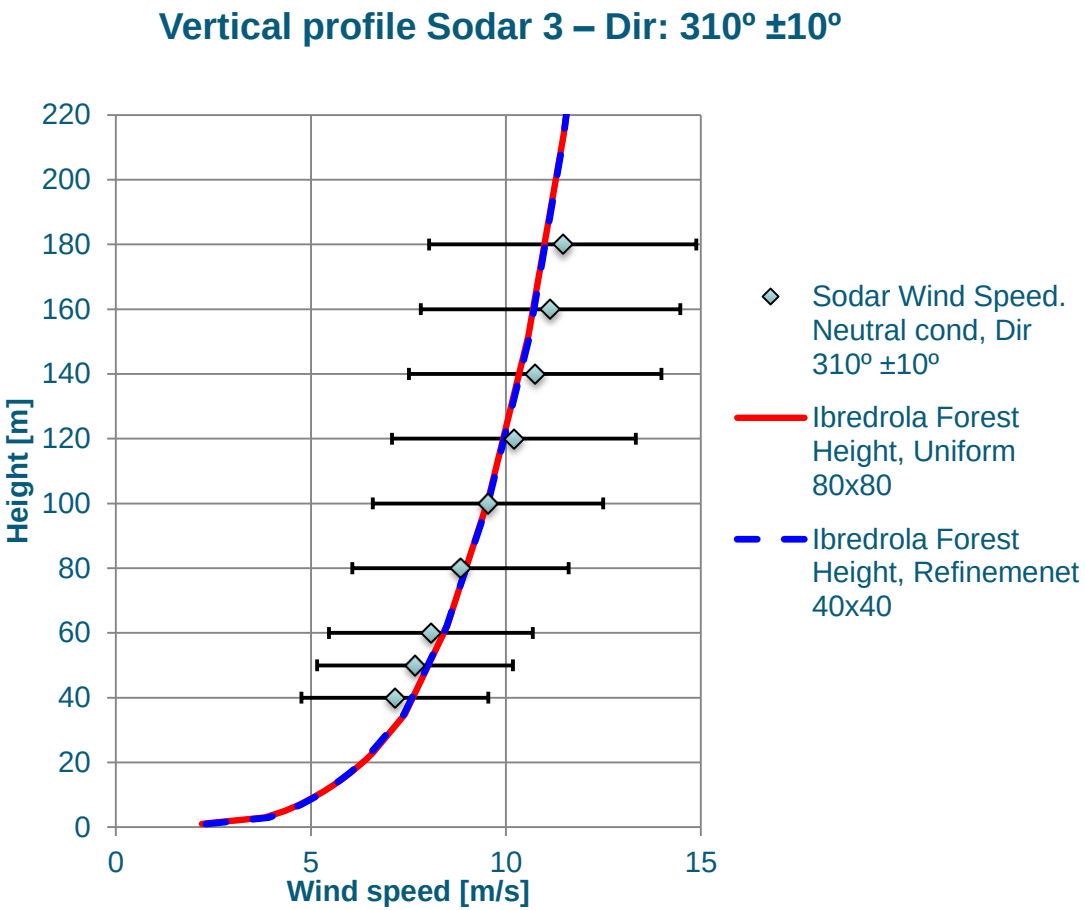
Atmospheric Stability: Sodar 1

Atmospheric Stability: Sodar 3

Forest modeling

- Grid Sensitivity study
- Sensitivity study regarding Roughness classification
- Sensitivity study regarding Drag coefficient C_2
- Sensitivity study regarding Forest Height

Grid Sensitivity study

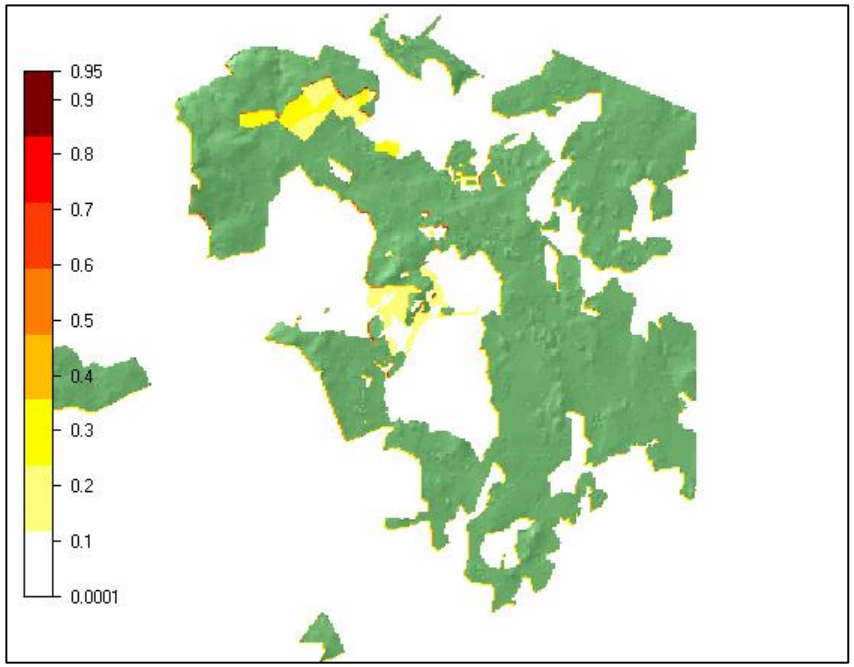


Forest modeling

- Grid Sensitivity study
- Sensitivity study regarding Roughness classification
- Sensitivity study regarding Drag coefficient C_2
- Sensitivity study regarding Forest Height

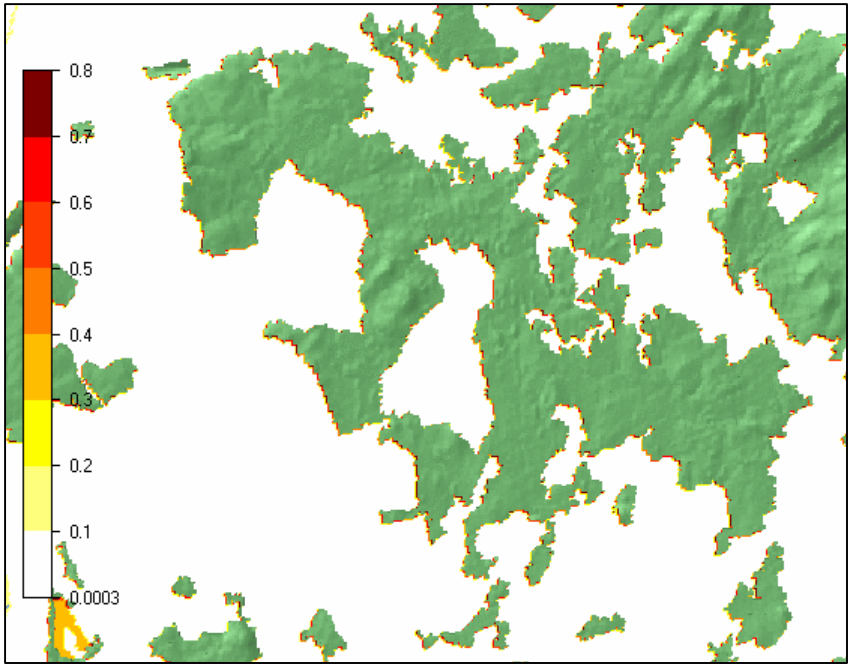
Sensitivity study regarding Roughness classification

Iberdrola Forest Assessment



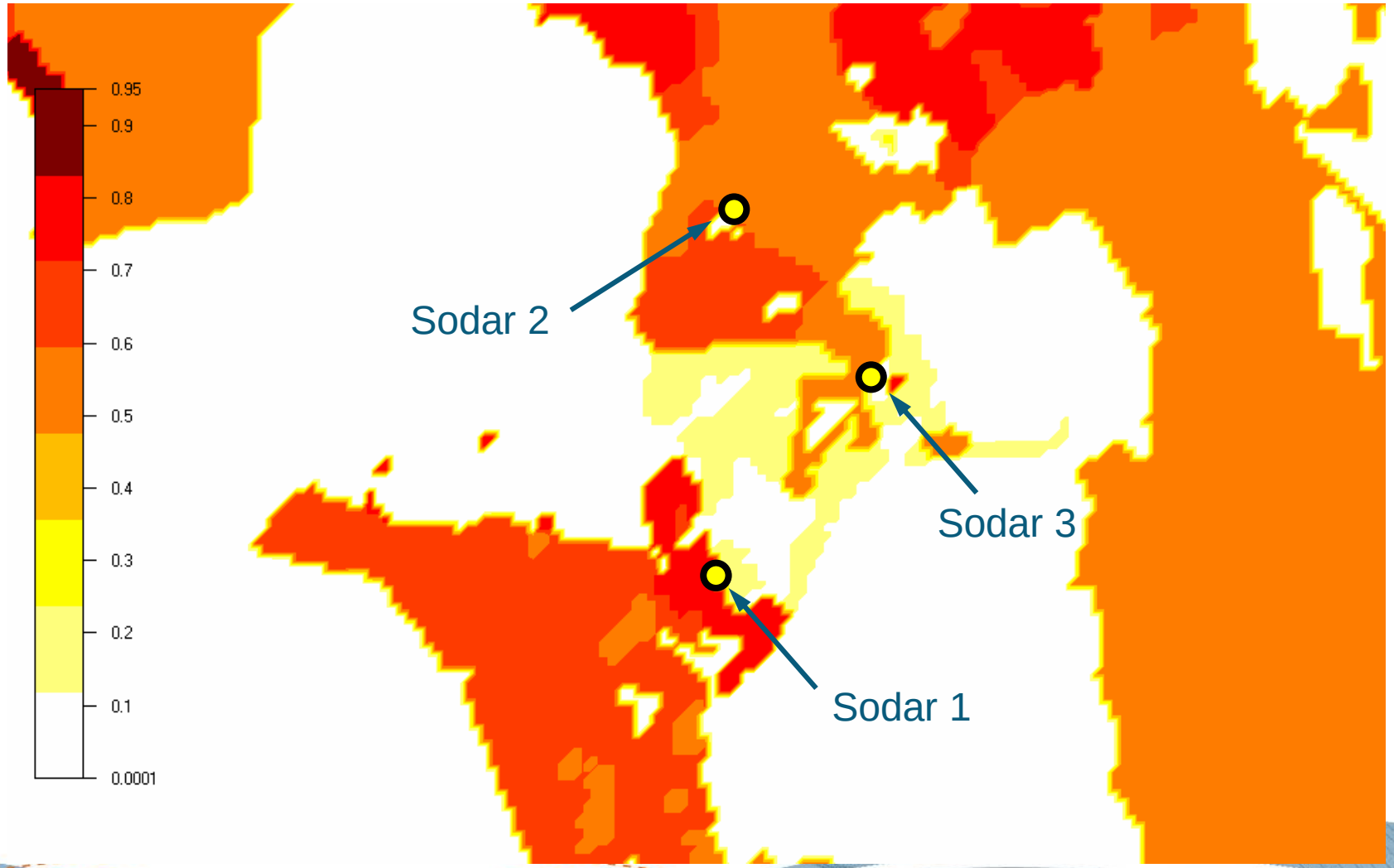
- Detailed map with forest height every 1 m
- Modelled with cells 2 m high
- Background roughness 0.04m

Corine Roughness Database

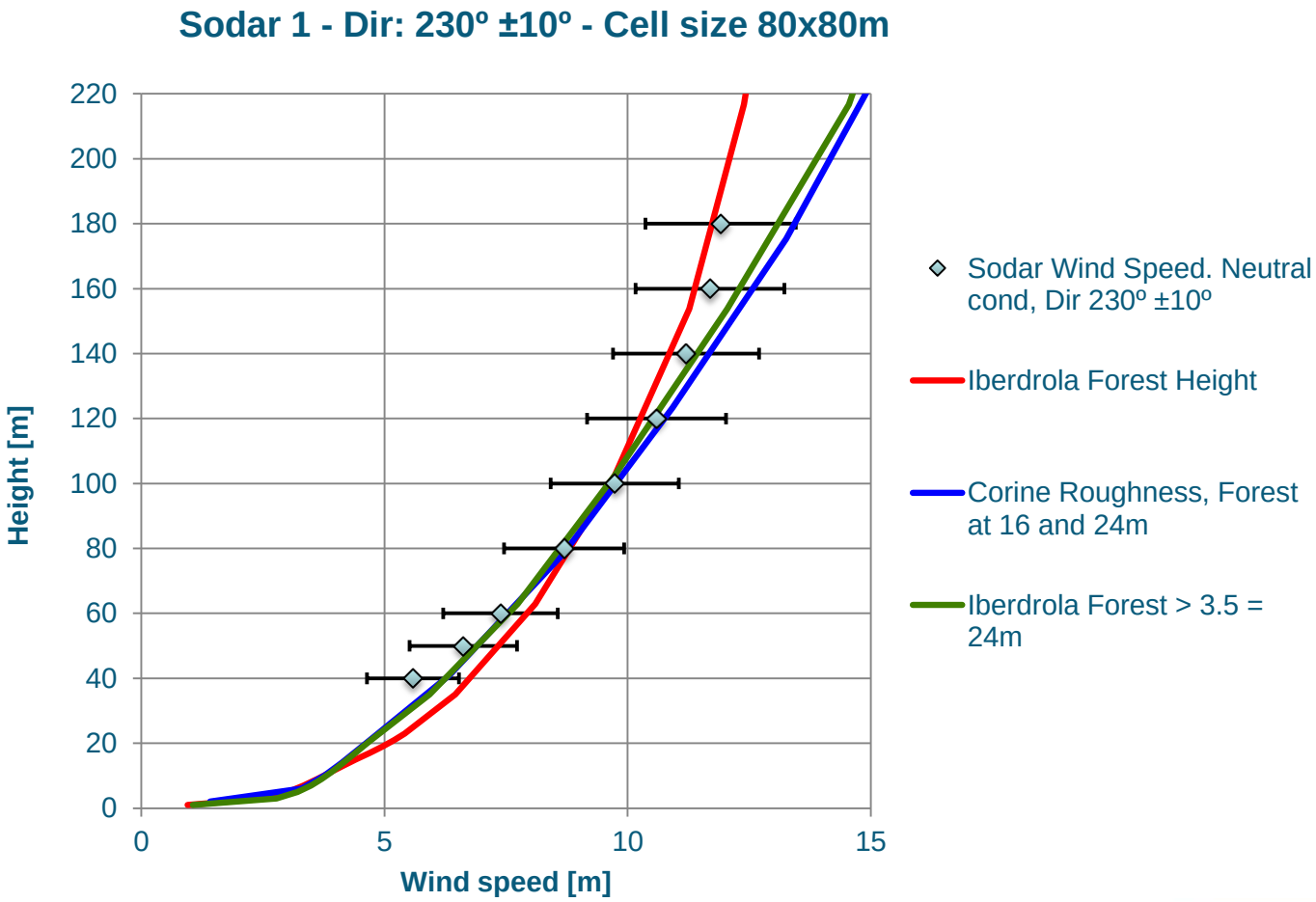


- Forest from roughness classification.
- 0.5 = 16 m and 0.8 = 24 m
- Modelled with 6 cells 4 m high
- Background roughness 0.03 – 0.05m

Sodar location relative to Iberdrola Roughness classification



Sensitivity study regarding Roughness classification



Forest modeling

- Grid Sensitivity study
- Sensitivity study regarding Roughness classification
- Sensitivity study regarding Drag coefficient C_2
- Sensitivity study regarding Forest Height

Sensitivity study regarding Drag coefficient C_2

- Study using only GCV solver (no porous cells available)
- Additional Source of turbulence is introduced in the KE and EP transport equations:

$$S_k = C_2 \left(|U|^3 - 6.51 \cdot |U| \cdot k\right)$$
$$S_\varepsilon = C_2 \left(1.24 \cdot (\varepsilon/k) \cdot |U|^3 - 8.072 \cdot |U| \cdot \varepsilon\right)$$

- Drag coefficient Cd obtained from Huang et al. (2008) [1]:

Vegetation type	Cd
Single deciduous	0.15
Mixed forest	0.2
Row of deciduous	0.5
Conifers	1.0

[1] Huang, J., Cassiani, M. & Albertson, J., "*The effects of vegetation density on turbulent structures within canopy sublayer*", AMS, Paper 2.2, (2008).

Sensitivity study regarding Drag coefficient C_2

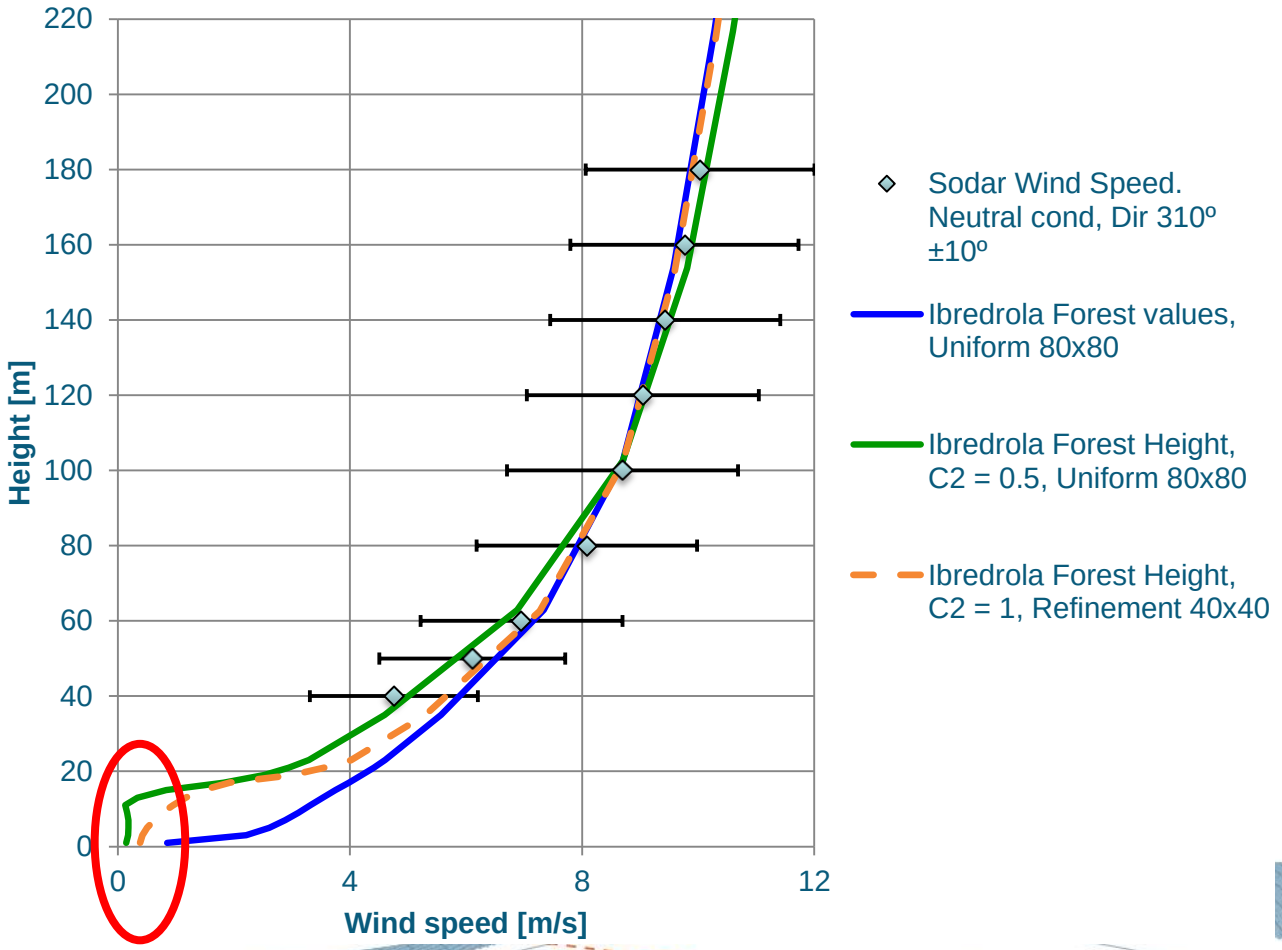
Tested C_2 values:
0.5
1.0

Location Sodar 2

Location Sodar 1

Sensitivity study regarding Drag coefficient C_2

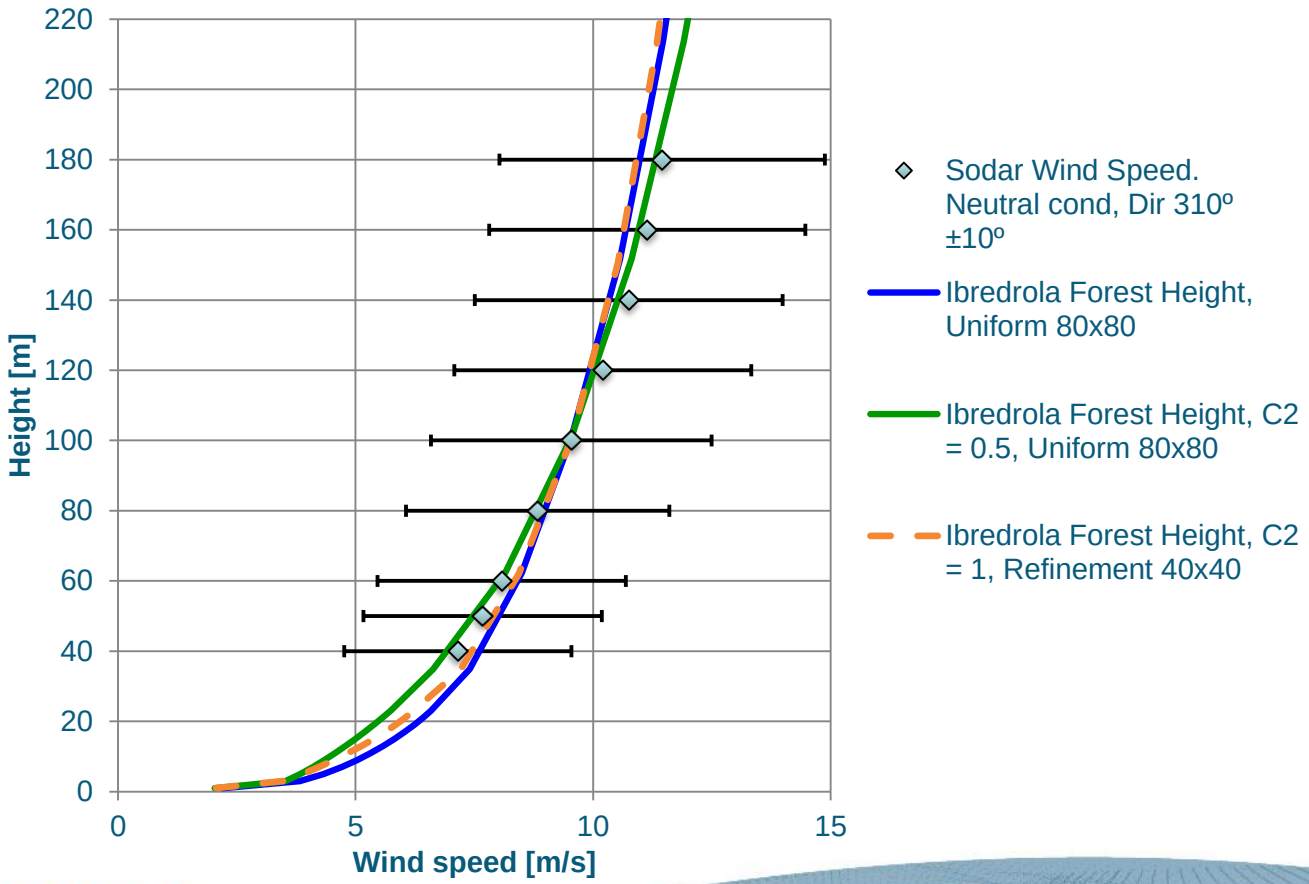
Sodar 1 – Dir: 310º ±10º



- C_2 = 0.5
- Displ. height = 13 m
- Modeled forest:
  18 m high
- d ≈ 0.75 H
- Forest distance ~120 m
- Distance in model: 0 m
- Meas. Wind speed:
  8.7 m/s

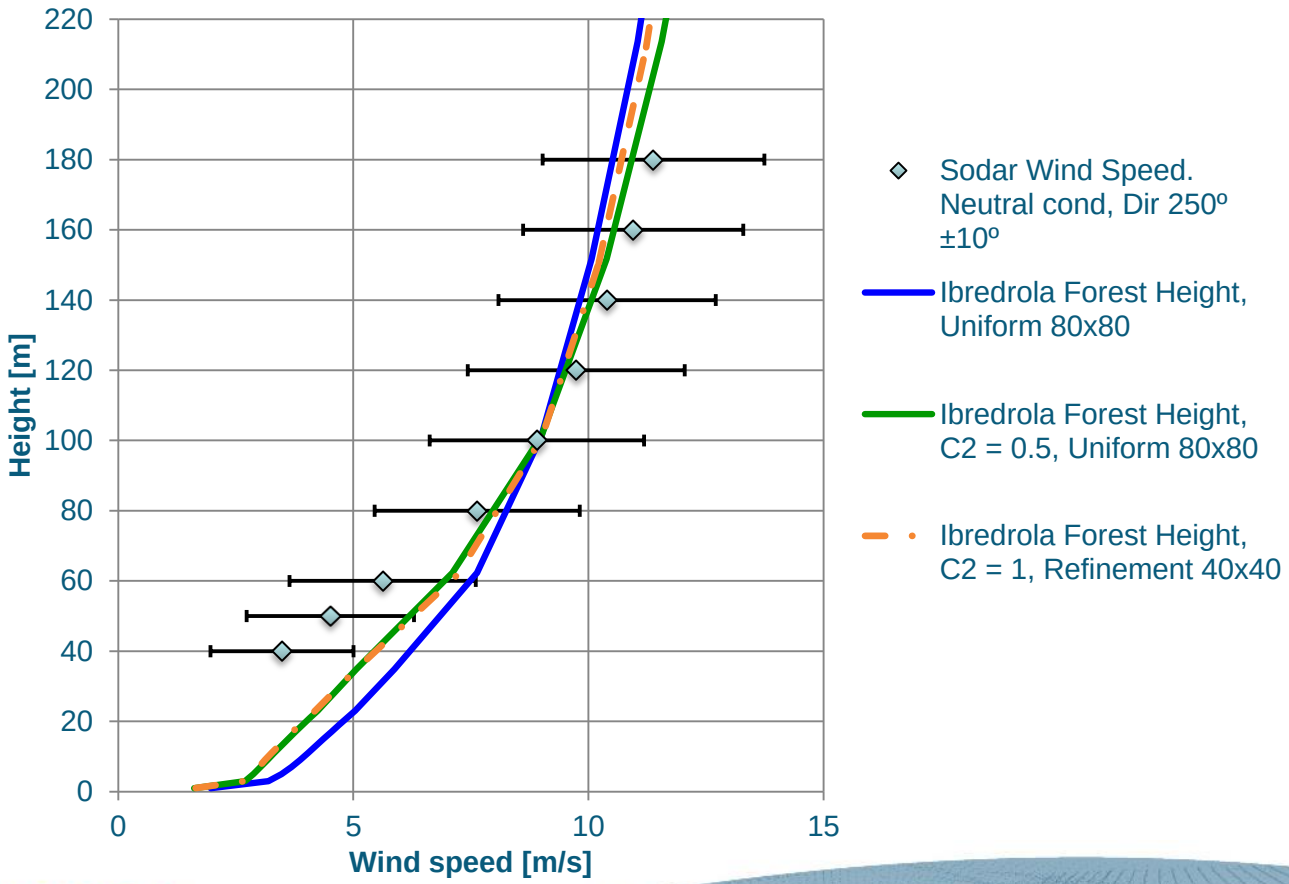
Sensitivity study regarding Drag coefficient C_2

- C_2 = 0.5
- Modeled forest:
  6 m high
- Forest distance ~150 m
- Distance in model:
  140 m
- Meas. Wind speed:
  9.5 m/s



Sensitivity study regarding Drag coefficient C_2

- C_2 = 0.5
- Modeled forest:
  6 m high
- Forest distance ~120 m
- Distance in model:
  120 m
- Meas. Wind speed:
  8.9 m/s



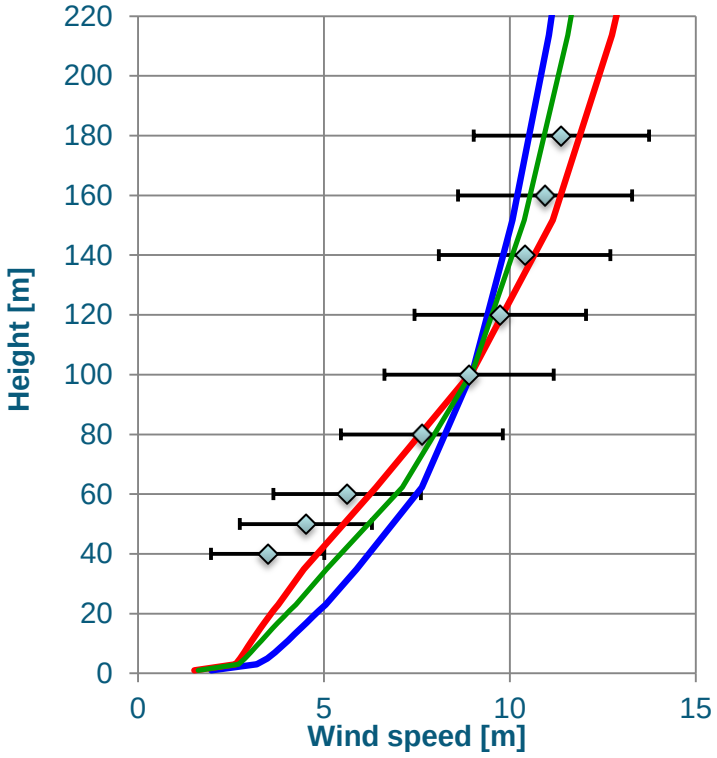
Forest modeling

- Grid Sensitivity study
- Sensitivity study regarding Roughness classification
- Sensitivity study regarding Drag coefficient C_2
- Sensitivity study regarding Forest Height

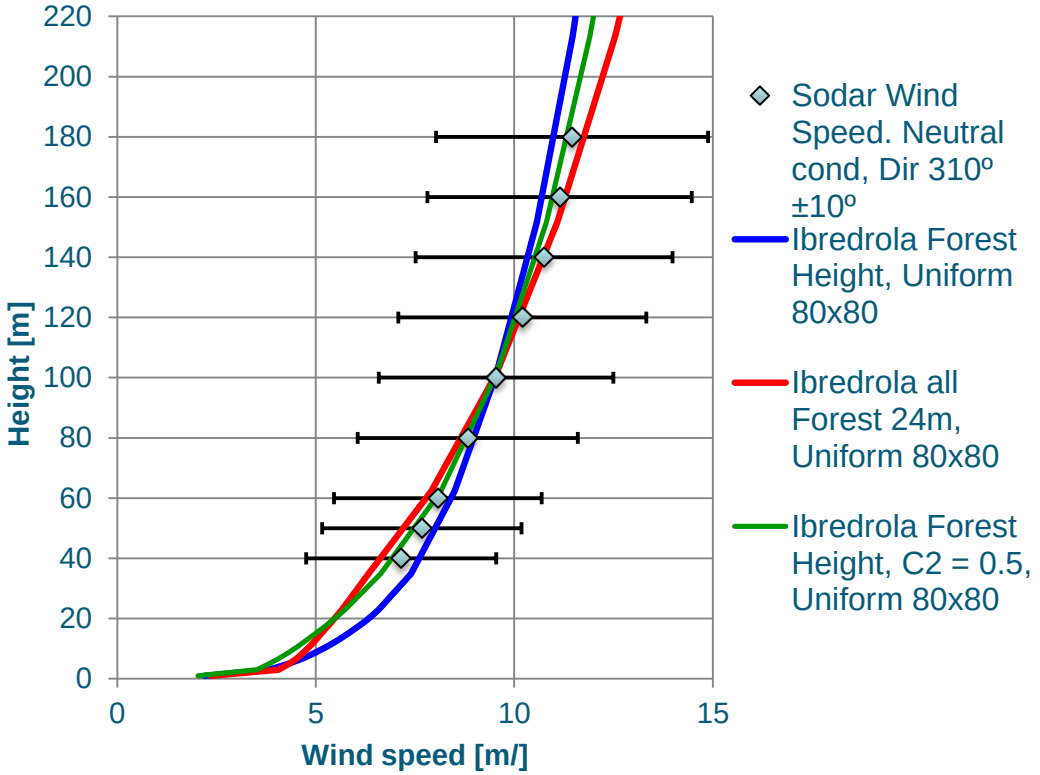
Sensitivity study regarding Forest Height

- Modeling a forest height of 24 m, C_2 = 0.05, improves results in most of the cases:

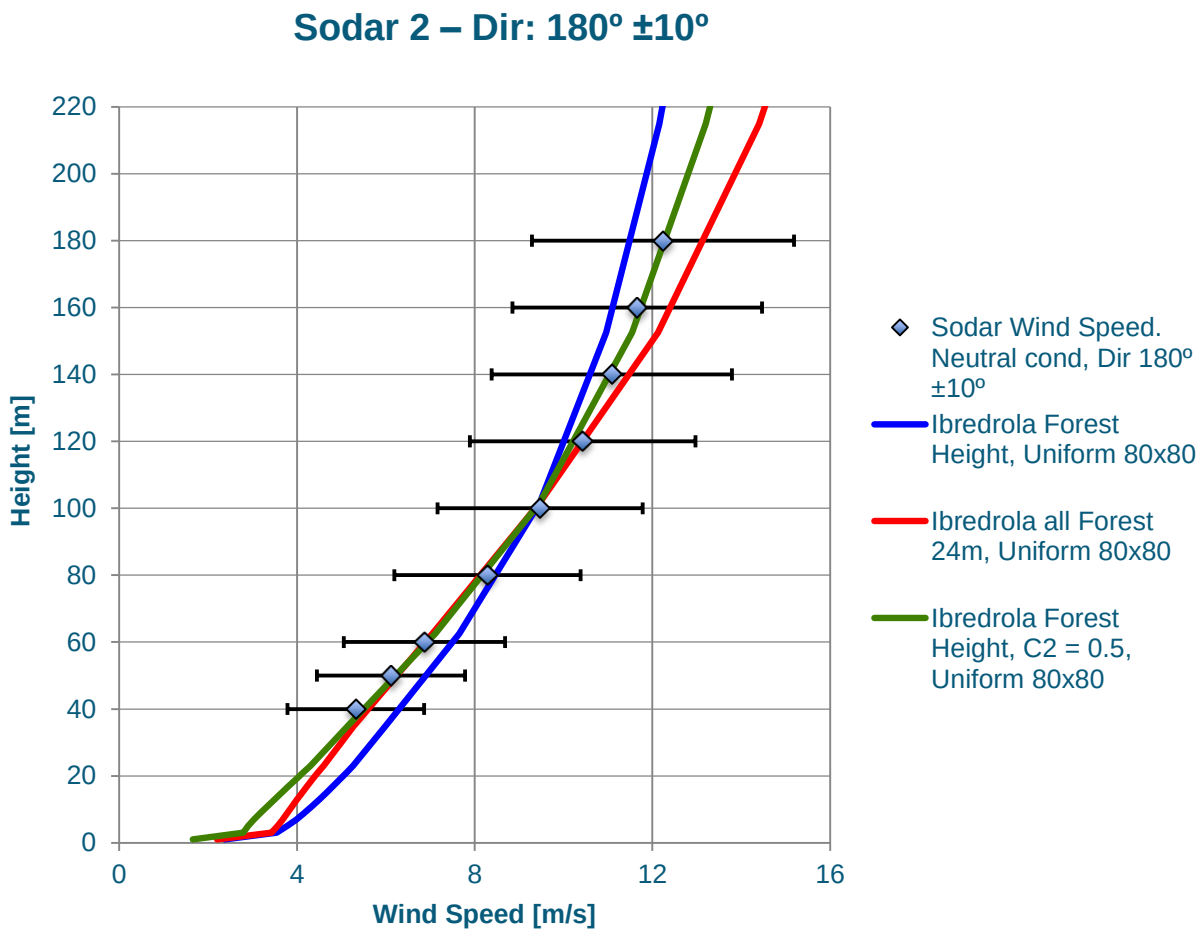
Sodar 3 – Dir: 250º ±10º



Sodar 3 – Dir: 310º ±10º



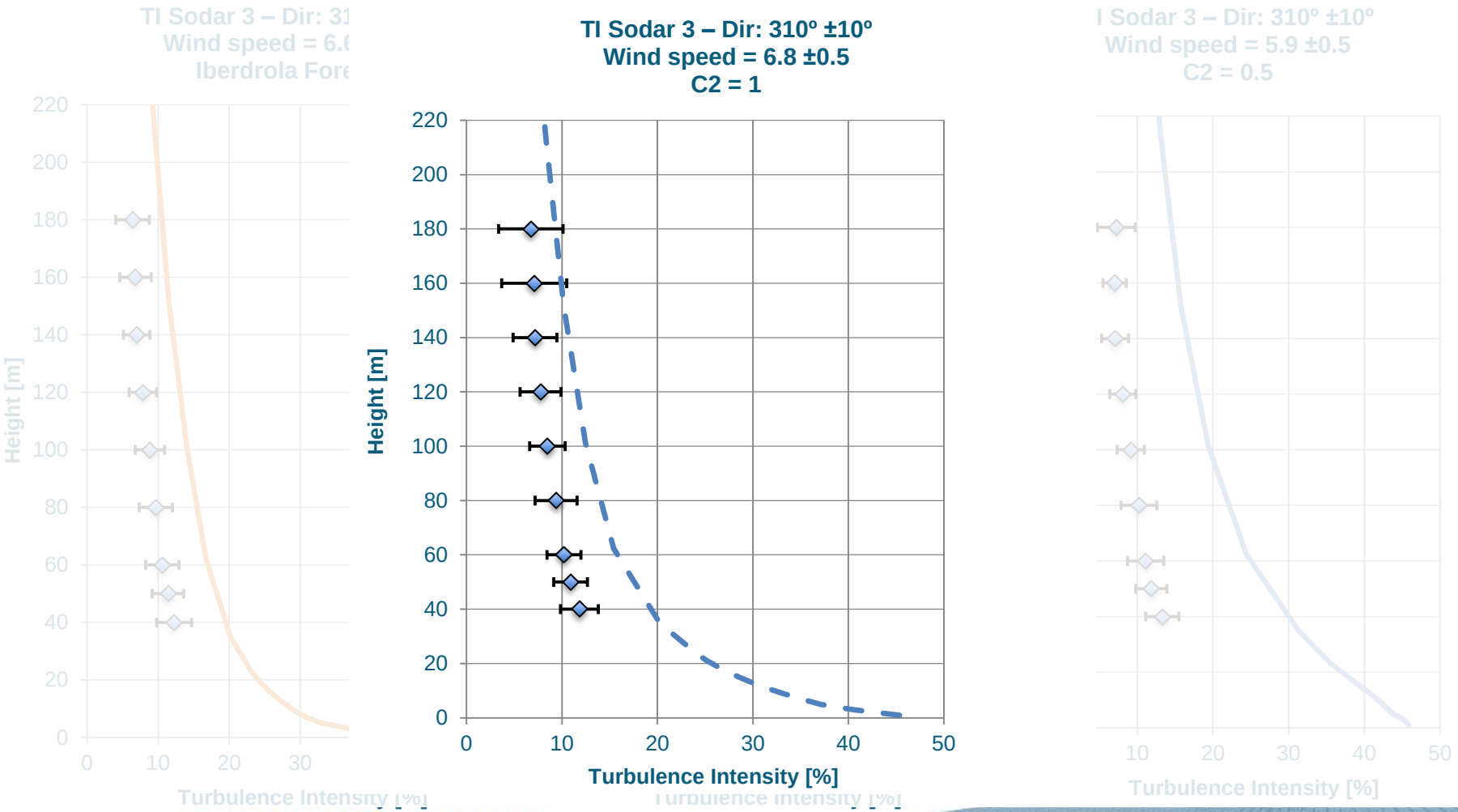
Sensitivity study regarding Forest Height



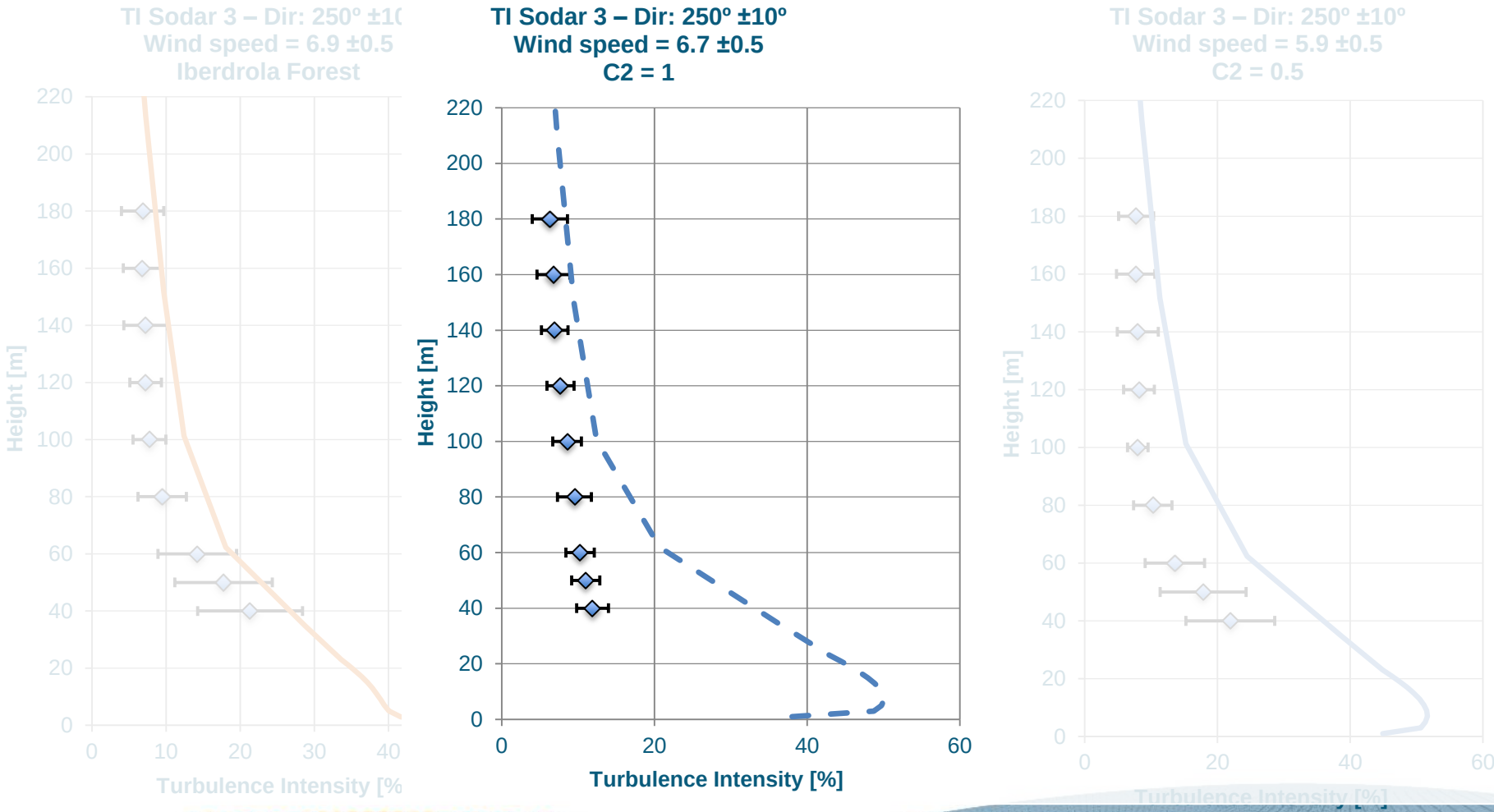
Turbulence Intensity Vertical profiles

- Grid Sensitivity study
- Sensitivity study regarding Roughness classification
- Sensitivity study regarding Drag coefficient C_2
- Sensitivity study regarding Forest Height

Turbulence Intensity Vertical profiles – Sodar 3 Dir: 310º



Turbulence Intensity Vertical profiles – Sodar 3 Dir: 250º



Conclusions

- Vertical Wind profiles:
  - C_2 = 0.5 provides the best fit in most of locations and sectors, but further validation and has to be undertaken.
  - Using a too large C_2 parameter does not incur major errors.
  - Height of the forest has a large impact. Accurate forest classification is needed.
  - Modeling higher forest could be helpful if low quality data is used.

- Turbulence intensity:
  - C_2 = 0.05 – Bad fit to the Wind Profile but excellent trend of TI.
  - C_2 = 0.5 and 1 – Better fit in Wind Profile but capture TI trend correctly only for some sectors.
  - Test impact of other turbulence models (Modified, K-Omega, etc.).

- Verification:
  - Distance to forest and forest height accurately assessed.
  - Provided values for forested areas and forest height do not completely coincide with Sodar installation reports.

Thank you for your attention!