Atmospheric stability characterization for CFD modelling of the stable Boundary layer

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Abstract

The impact of atmospheric stratification on the wind profile attracts more and more attention [1]. CFD modelling for wind resource assessment generally uses standard turbulence models that are not suitable for strong stability cases, especially when the wind turbine hub height is greater than the Stable Boundary Layer height.

The 3-L (three layer) model of Meteodyn [2][3] considers a classical MOST layer where the gradient Richardson number is inferior to a value of about 0.2 [4][5], a transitional layer where the fluxes decrease with height according to a "z-less scaling" or a local MOST theory and the outside layer, where the turbulent fluxes depend on large scale turbulence generated at the mesoscale level [6]. The stability classes are defined according to the Obukhov length.

The research has been focused on relating the stability classes with the Obukhov length deduced from masts measurements. The studies have been conducted for Cabauw (NL), Röderesberg (D) and an Indian site, where very strong stabilities are observed.

Objectives

This paper proposes a methodology to estimate statistically WT stability classes through the routine mast measurements, the wind velocity vertical profile and the air temperature vertical profile.

Diurnal variations of the Obukhov length and turbulence intensity are observed. The comparison between computed and measured vertical wind profiles will give the « best-fitting » stability class that has to be linked to the Obukhov length deduced from mast measurement.

Methods

The methodology for assessing WT stability class has followed several steps:

- Classifying the data according to chosen bulk Richardson number (RIB) ranges;
- Averaging profiles of wind speed and turbulence in each RIB range;
- Best-fitting average profiles with WT stability class;
- Computing the Obukhov length from temperature and wind speed in the RIB range as:

\[ L = \frac{1}{R_i} \frac{\Delta T}{\Delta z} \left[ \frac{\ln(z_f^2/z_i^2) - \ln(z_f^2/z_i^2)}{\Delta z} \right] \]

- When the measured wind speed vertical profile is accelerated locally, transferring wind measurements to a more representative location usually at the domain inlet.

- Associating WT Class and the Obukhov length according to the correspondence table listed in the conclusions.

Results

The 3-L model for strong stability classes, implemented in Meteodyn WT has been validated at three sites prone to strong stability situations. A methodology has been developed in order to establish statistics of the Obukhov length or bulk Richardson number using on-site measurements of temperature and wind speed gradients.

We demonstrate, for strong stability cases, the coherence of the Meteodyn WT stability classes with the Obukhov length deduced from measured vertical gradients of wind speed and temperature (see the correspondence table of 3-L model).

Conclusions

<table>
<thead>
<tr>
<th>WT stability class</th>
<th>RIB range (m/s)</th>
<th>L median (m)</th>
<th>L average (m)</th>
<th>Turbulence Intensity (80 m a.g.l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.004 / 0.007</td>
<td>3334</td>
<td>3574</td>
<td>0.137</td>
</tr>
<tr>
<td>4</td>
<td>0.007 / 0.010</td>
<td>2535</td>
<td>2533</td>
<td>0.123</td>
</tr>
<tr>
<td>5</td>
<td>0.010 / 0.020</td>
<td>1311</td>
<td>1415</td>
<td>0.123</td>
</tr>
<tr>
<td>6</td>
<td>0.020 / 0.030</td>
<td>755</td>
<td>796</td>
<td>0.118</td>
</tr>
<tr>
<td>7</td>
<td>0.030 / 0.050</td>
<td>456</td>
<td>454</td>
<td>0.110</td>
</tr>
<tr>
<td>8</td>
<td>0.050 / 0.100</td>
<td>145</td>
<td>112</td>
<td>0.096</td>
</tr>
<tr>
<td>9</td>
<td>0.150 / 0.300</td>
<td>31</td>
<td>30</td>
<td>0.084</td>
</tr>
<tr>
<td>10</td>
<td>0.300 / 0.500</td>
<td>21</td>
<td>20</td>
<td>0.078</td>
</tr>
</tbody>
</table>

RIB range and calculated the Obukhov length in each RIB range for each WT stability class (Validation of Cabauw).

References


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