Investigation of vertical wind profiles formulations for initialisation of atmospheric dispersion models
Towards a pre-processor for CFD code

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Context and objective

Many applications such as wind energy estimations or pollutant dispersion studies need finely resolved 3D meteorological fields that take into account topography, buildings, roughness variations, etc. To get these, nowadays, we often use CFD models such as Code_Saturne. To run the simulations we need to know the vertical profiles of wind and turbulence at the boundaries of the domain and we need to construct them in a consistent manner on the basis of a few measurements

Input and validation data

In order to evaluate the different formulations we used measurements from the SIRTA site (http://sirta.ipsl.polytechnique.fr/) which is located in Palaiseau near Paris. Among the many routine measurements available we used here sonic anemometers data to determine 10 m wind speed and other near ground parameters and Remtech PA2 SODAR data between 100 and 600m averaged over 20 minutes.

I - Classical Similarity method for the surface layer (MOST)

We start from classical similarity profiles such as those proposed by COST 710 working group. The function Φ depends on the stability classification that is here based on the value of *Lmo* (Monin-Obukhov length).To be noted also that u_* do not varies with z in this formulation. This formulation is supposed to be valid only for the surface layer.

$$\frac{du}{dz} = \frac{u_*}{kz}\Phi\left(\frac{z}{Lmo}\right)$$

II - VDI 3783-part 8

Also based on the similarity theory, some improvements are proposed. The functions are defined in more detailed regions of *z/Lmo.* With these improvements, the profiles are expected to be valid also above the surface layer (see reference)

III - Gryning & al (2007) proposed extension

This formulation is an attempt to find a formulation for the whole boundary layer. Here, u_* is supposed to vanish with altitude. The length scale is the the sum of three terms: one for the surface layer, one for the middle of the boundary layer and a last one for the upper part of the boundary layer.

$$\frac{du}{dz} = \frac{u_*}{kl} \qquad \frac{1}{l} = f\left(\frac{1}{z}, Lmo\right) + \frac{1}{Lmbl} + \frac{1}{z_i - z}$$

$$u_* = u_{*0}\left(1 - z/z_i\right)^{\alpha}$$

For neutral & unstable : z_i=1100

For stable conditions :

$$z_i = \max\left(250, \min\left(800, 0.7\frac{u_* Lmo}{f}\right)\right)$$

Comparison of Gryning with SIRTA data

The comparison of the normalized wind speed with SODAR measurements averaged over 1 year show a good agreement for neutral and weakly to moderately stable or unstable situations. A strong improvement is noticed compared to classical MOST approach for *Lmo* between 50 and 200 m. For strongly stable situations, there is still an over estimation of the model.

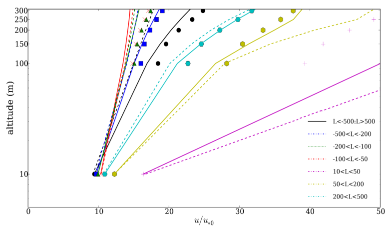

Figure 1: Mean normalized vertical profiles of wind speed over one year – points SODAR data – straight lines Gryning & al formulation – dotted lines MOST approach.

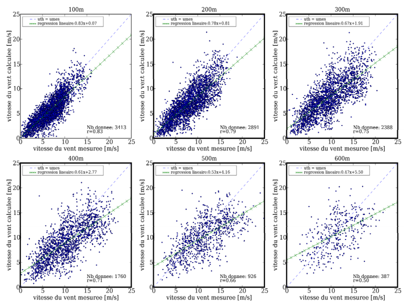

Figure 2: Scatter plots of wind speed for a 3 months sample period between SODAR measurements and Gryning & al theoretical profiles for different altitude and all stability conditions.

Comparisons of MOST / Gryning / VDI

The correlations shown on Figure 3 decrease with altitude for neutral and unstable situations but keep reasonable values. For stable cases, the two evolutions of the MOST do improve the correlation. Some sensibility tests (not shown here) demonstrate that the boundary layer height is very important for Gryning & al formulation.

One must keep in mind that this are mean comparisons and as shown on the Figure 2 particular situations can have quite large discrepancies.

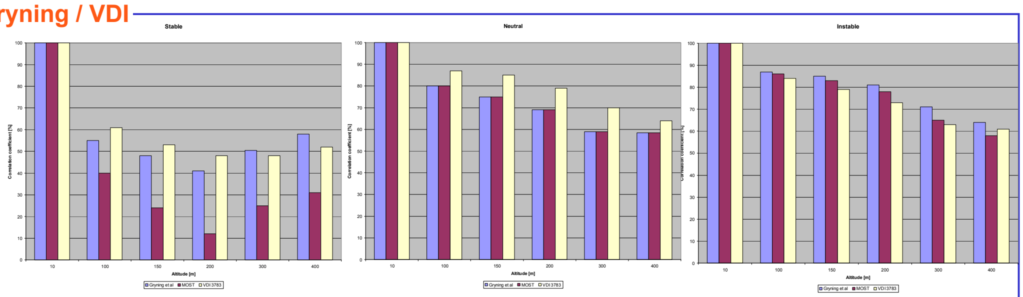

Figure 3: Evolution with the altitude of the correlation coefficients for wind speed between theoretical profiles and SODAR measurements – Gryning & al in blue – MOST in red – VDI in yellow for stable (left), neutral (middle) and unstable (right) situations.

Conclusions

- ✓The profiles determined with the Gryning & al proposition do better than classical similarity theory especially in stable situations;
- ✓The profiles determined from VDI-3783 do as well as the Gryning et al proposition ;
- ✓Simples tests with Code_Saturne show a good adaptation of these profiles to this CFD code
- ✓More tests and comparisons have to be done
- ✓To be noted, the boundary layer height is a very important but badly known parameter, especially in stable situations

References

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