An updated method for estimating of surface-layer scaling parameters from routine ground-based meteorological data

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Why a new method?

Due to lack of meteorological and emission data in most of practical cases, the numerical models don't perform in local and urban scale significantly better than advanced numerical ones, but consume much more computer resources (Air4EU, 2005). Often the entire condition of surface layer must be still estimated from the surface-based mean flow wind and other routine meteorological station data, as neither flux- nor gradient-based micrometeorological measurements are available.

There is presented a technically new method for rough estimation of surface-layer scaling parameters from wind velocity and cloud amount measured in meteorological stations, and regarding the solar elevation. Practical need for that method appeared due to preprocessing of meteorological data series for a bi-Gaussian model AERMOD (Cimorelli *et al.*, 2005), version 6, for environmental impact assessment purposes.

The algorithm

The algorithm is based on two classical relationships:

(i) definition of Pasquill stability classes through wind speed and net radiation index (Turner 1964);

(ii) Pasquill classes as a discrete empirical function of surface roughness z_o and Monin-Obukhov length L (Myrup & Ranzieri, 1976).

Based on these relationships, it is possible to estimate the surface layer key parameter L from routine meteorological measurement data. In an automatic procedure it is desirable to have the continuous functions instead of discrete insolation index and Turner classes. Thus, these quantities are interpolated as following.

Net radiation index

Clear-sky NRI, originally ranging from 0 to 4, is approximated as a function of solar elevation h_o:

$$\mathrm{NRI}_o = 0.0914 h_o - 0.0005 h_o^2$$

Corrected NRI for cloud amount C (tenths) is

$$\mathrm{NRI} = \mathrm{NRI}_o / \left(1 + 0.01 C^2\right) \qquad \text{(daytime)}$$

$$\mathrm{NRI} = 0.02 C^2 - 2 \qquad \text{(nighttime)}$$

Pasquill stability function

We derived a continous counterpart of Pasquill stability classes, here denounced as X, depending on NRI and 10 meter wind velocity u (m/s),. A polynomial fit according to discrete presentation by Turner (1964):

$$P = B_{00} + B_{01}\, u + B_{02}\, u^2 + B_{03}\, u^2 + B_{10}\mathrm{NRI} + B_{20}\mathrm{NRI}^2 + B_{30}\mathrm{NRI}^3 + B_{11}\mathrm{NRI}\, u + B_{12}\mathrm{NRI}\, u^2 + B_{21}\mathrm{NRI}^2\, u \qquad (1)$$

values -3, -2, -1, 0, 1, 2 of P correspond respectively to discrete classes A, B, C, D, E and F; P=-2.5 corresponds to transition between classes A and B etc. Regression coefficients in eq. (1) are given in Table 1.

Table 1. Regression coefficients in equation (1).

Coefficient	Value	Coefficient	Value
B_{00}	0.444109	B_{20}	0.095300
B_{01}	-0.177258	B_{30}	-0.008333
B_{02}	0.019689	B_{11}	0.266387
B_{03}	-0.000486	B_{12}	-0.011147
B_{10}	-1.343386	B_{21}	-0.014444

To avoid inconsistent and too extreme unstability, the stability function P is set zero, if u>7 m/s and values higher than 2.5 (appearing at low wind and negative NRI) are set to 2.5. Results see Fig. 1.

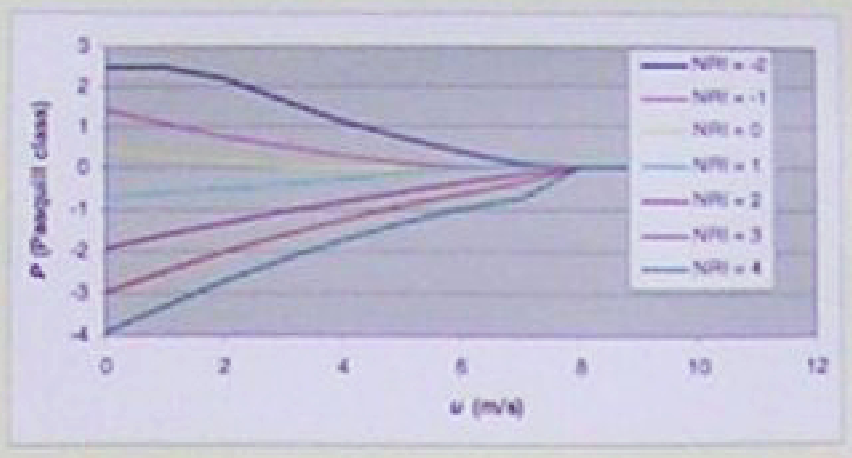

Figure 1. Derived "continuous Pasquill class" values *P*, depending on 10 m wind speed *u* and NRI. .

Derivation of Monin-Obukhov length

From graphical representation by Myrup & Ranzieri (1976) we derive the polynomial fit for Monin-Obukhov length L:

$$L^{-1} = A_{00} + A_{01} Z + A_{02} Z^2 + A_{10} Z + A_{11} PZ + A_{12} PZ^2 + + A_{20} Z^2 + A_{21} P^2 Z + A_{22} P^2 Z^2, \qquad (1)$$

where Z = -log z_o (m). There regression coefficients are given separately for unstable (P<0, L<0) and stable stratification (P>0, L>0) in Table 2.

Polynomial fit (1) produces an artefact maximum of L^{-1} in unstable stratification and minimum in stable stratification for z_o>0.5 m and Pasquill stability close to neutral. These false extremums are removed, using linear interpolation for L^{-1} between values 0 and -0.0015 for unstable stratification and between values 0 and 0.001 for stable stratification. Finally, we get the dependence $L^{-1}(P, z_o)$ given in Figure 1.

Table 1. Regression coefficients in equation (2).

Coefficient	Unstable stratification	Stable stratification
A_{00}	-0.002107	0.002309
A_{01}	0.001128	-0.001385
A_{02}	-0.000379	0.000166
A_{10}	-0.014491	-0.022966
A_{11}	0.011234	0.006258
A_{12}	0.004600	0.009098
A_{20}	-0.015660	0.023065
A_{21}	-0.001540	0.004786
A_{22}	0.002279	-0.004117

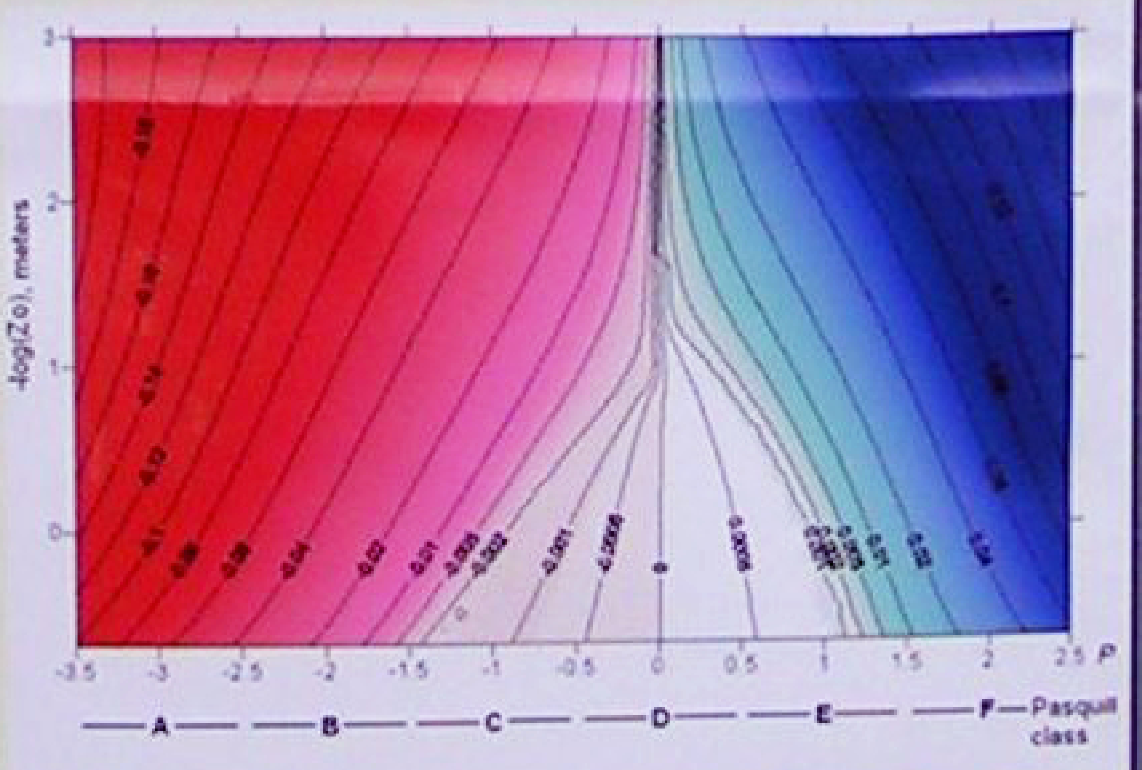

Figure 2. Dependence of inverse Monin-Obukhov length L^{-1} (isolines, colors) on Pasquill stability and surface roughness z_o (meters).

Derived scaling parameters

After the Monin-Obukhov length is determined, it is straightforward to evaluate the friction velocity u_* from the modified-logartithmic wind profile, e.g. (Högström, 1988). Then, applying the definition of Monin-Obukhov length, we estimate the surface heat flux.

Relying on calculated parameters, it is possible to estimate even the mixing height (based on e.g. Deardorff, 1972). However, such an estimation has to be considered as a rough one – for the case, if sounding profile or numerical model output is not available.

Validation: a case [illegible]dy

As for environmental impact assesment ta[illegible]s the long-term statistics is most i[illegible], a corresponding test case was pr[illegible] The frequency of stable atmospheric co[illegible] was studied for Tallinn, Estonia:

1. based on this method: (a) P>0.5, (b) L<100 m;
2. from radio sounding profile, 00 GMT;
3. from a meteorological mast – measured potential temperatures Θ at 8 m and 22 m.

The study is based on meteorological data from 2005 – 2007 (sounding 2002 – 2006). For Tallinn meteorological station (measurement sets 1, 2) z_o was estimated as 0.3 for Nov. – Apr. and 0.4 for May – Oct (fairly level wooded outskirts, Stull, 1988), for mast site in Tallinn zoo, 5 km away, z_o=1±0.3 m was calculated from two-level wind profiles.

The comparison of monthly average frequencies of night-time stable conditions are given in Fig. 3.

Figure 3. Frequencies of stable meteorological conditions estimated by different methods.

Conclusions

Although the statistics presented in Fig. 3 are neither strictly comparable nor comprehensive, they constitute a rough proof that the developed method is applicable in practice for diagnosing the night-time stagnating conditions in surface layer.

Hovever, due to surface-based initial data and definition of NRI, this method is in principle not able to predict neither elevated inversions nor relatively infrequent daytime inversions.

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