Atmospheric Transport and Chemistry in Forest Ecosystems
Thurnau, Germany, October 5th – 8th 2009

Turbulence parameter inside and above a tall spruce site

Tobias Biermann, Katharina Staudt, Andrei Serafimovich, Thomas Foken

University of Bayreuth, Department of Micrometeorology, Bayreuth

Profiles of integral turbulence characteristics

Integral turbulence characteristics (ITC), the normalized standard deviation of a turbulent quantity, were investigated to improve the quality control of flux data measured at the BayCEER research site Weidenbrunnen, a 25 m spruce stand, located in the Fichtelgebirge Mountains in North-Eastern Bavaria. The turbulence parameters were obtained in September and October 2007 in the framework of the EGER (ExchanGE processes in mountainous Regions) project. A comparison between profiles of ITC from different sites show a similar decrease inside the roughness sub layer and forest, but the profiles differ in the lower part depending on the stand structure (Figure 2).

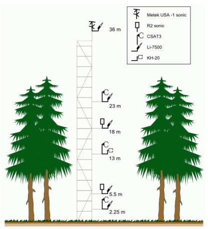

Figure 1: *Measurement setup from EGER IOP1 (Serafimovich et al. 2008).*

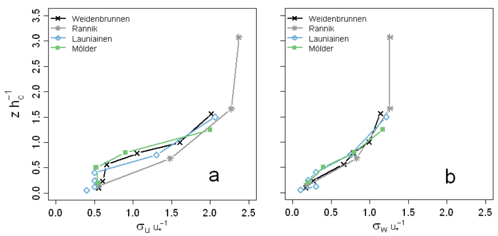

Figure 2: *Profiles of integral turbulence characteristics ($\sigma_x\, u_*^{-1}$) of u (a) and w (b) from different measurement sites during near neutral stratification. The stand at the Weidenbrunnen site (black cross) is spruce while the experiments by Rannik et al. (2003) (grey star) and Launiainen et al. (2007) (blue diamond) at Hyytiälä and from Mölder et al. (2004) (green square) are done in a pine stand. The measurement height z is normalized with the mean canopy height h_c.*

Parameterization of integral turbulence characteristics

In order to parameterize ITC of the wind components inside the roughness sub layer and a forest, which needs to be done for quality control, the dimensionless height $\zeta^* = h_c\, L^{-1}$ should be used instead of $\zeta = zL^{-1}$, which is used above short vegetation. Since ITC are influenced by stability and the structure of the stand it is useful for measurement heights inside the stand and lower roughness sub layer to combine for near neutral stratification Equation 1, representing the stand influence, and for stable and unstable stratification the parameterizations from Table 1 (Figure 3). As input for Equation 1, measurements in mean canopy height (h_c) should be used, if these are not available, literature values can be used instead. The coefficients α_i, β_i and γ_i are site specific and need to be adjusted to each stand structure. This parameterizations can be used for quality assessment routines but it is very site specific, therefore further investigation is necessary for a general application.

Near neutral stratification

$$\left(\frac{\sigma_i}{u_*}\right)_{(z)} = \left(\frac{\sigma_i}{u_*}\right)_{(h_c)} \left(\exp\left(-\alpha_i\left(1-\frac{z}{h_c}\right)^{\beta_i}\right)(1-\gamma_i)+\gamma_i\right)$$

Equation1: Parameterization to account for influence of the stand structure on integral turbulence characteristics, modified after Rannik et al. (2003).

Influence of stand structure

+

Table1: Parameterizations for integral turbulence characteristics under stable and unstable conditions. As input measured near neutral values should be taken or the ITC for the desired height can be parameterized by the Equation above

	0.01 < ζ < 1	**-1 < ζ < - 0.032**
σ_u/u_*	$\left(\frac{\sigma_u}{u_*}\right)_{(z)} (1+0.48\,\varsigma^*)$	$\left(\frac{\sigma_u}{u_*}\right)_{(z)} (1-0.22\,\varsigma^*)^{7/8}$
σ_v/u_*	$\left(\frac{\sigma_v}{u_*}\right)_{(z)} (1+1.11\,\varsigma^*)$	$\left(\frac{\sigma_v}{u_*}\right)_{(z)} (1-1.44\,\varsigma^*)^{7/8}$
σ_w/u_*	$\left(\frac{\sigma_w}{u_*}\right)_{(z)} (1+0.39\,\varsigma^*)$	$\left(\frac{\sigma_w}{u_*}\right)_{(z)} (1-1.82\,\varsigma^*)^{1/3}$

Influence of stratification

Stable stratification

Unstable stratification

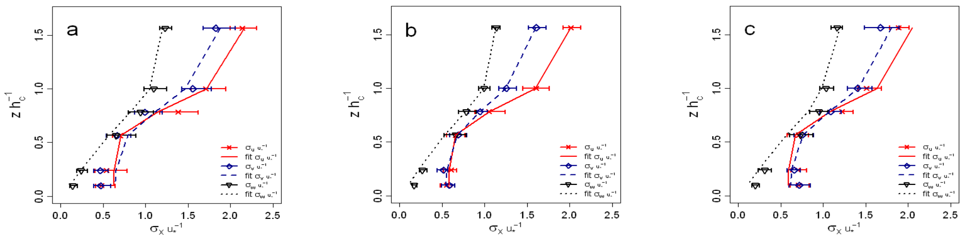

Figure 3: *Profiles of integral turbulence characteristics of the three wind components u (red), v (blue), w (black). Measured (symbols) and parameterized values (lines), under stable (a), near neutral (b), and unstable (c) stratification.*

Comparison of measured profiles with modeled profiles by the ACASA model

A comparison between measured values and ACASA (Advanced Canopy-Atmosphere-Soil Algorithm, Pyles et al. 2000) model results showed a good agreement for the normalized wind speed under near neutral and unstable but not for stable conditions. The ITC of the wind components u and w are usually overestimated above and inside the canopy regardless of the stratification. The ITC of w is also overestimated in the trunk space. The ITC of v is underestimated above the canopy during stable and unstable conditions and inside the trunk space for all conditions (Figure 4).

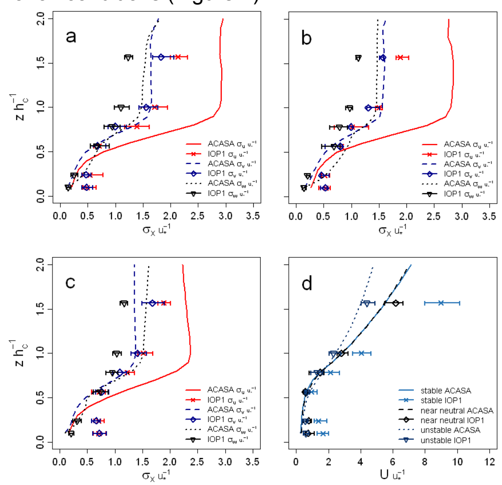

Figure 4: *Profiles of integral turbulence characteristics of the three wind components (red), v (blue), w (black). Median values of measurements (symbols) and values modeled by ACASA (lines) under stable (a), near neutral (b), and unstable (c) stratification. Subfigure (d) shows the measured (symbols) and modeled (lines) normalized wind speed, under stable (light blue), near neutral (black), and unstable (dark blue) stratification.*

Contact: tobias.biermann@uni-bayreuth.de
www.bayceer.uni-bayreuth.de/mm

References:
Launiainen. S. et al. (2007) Vertical variability and effect of stability on turbulence characteristics down to the forest floor of a pine forest, Tellus 59B, 916-936.
Pyles, R. D. et al. (2000) The UCD Advanced Canopy-Atmosphere-Soil Algorithm: comparisons with observations from different climate and vegetation regimes. Quarterly Journal of the Royal Meteorological Society, 126, 2951-2980.
Mölder, M. et al. (2004) Turbulence characteristics and dispersion in a forest: Tests of Thomson's random-flight model. Agric. For. Meteorol., 127, 203–222.
Rannik Ü. et al. (2003) Turbulence statistics in side and over forest: Influence on footprint predictions. Boundary-Layer Meteotol. 109: 163–189.
Serafimovich, A. et al. (2008) Exchange processes in mountainous Regions (EGER) Documentation of the Intensive Observation Period (IOP1) September 6th to October 7th 2007. Arbeitsergebnisse, 36, Universität Bayreuth, Abt. Mikrometeorologie, Bayreuth, Germany, 147 pp., Print ISSN 1614-8916.