Measurements of turbulence and vegetation structure across a forest clearing

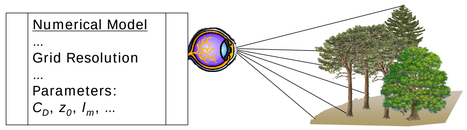
TECHNISCHE UNIVERSITÄT DRESDEN

Ronald Queck
Christian Bernhofer
Anne Bienert
Hans-Gerd Maas

Faculty Forest-, Geo- and Hydro Sciences – Institute of Hydrology and Meteorology & Institute of Photogrammetry and Remote Sensing

Challenge

The turbulent flow around flux measurement sites and thus the exchange of energy and mass between atmosphere and land surface are affected by vegetation structure. The vegetation layers of forests act as storage for energy, and advective fluxes cause remarkable uncertainties in the measured fluxes. Calculating reliable fluxes depends on realistic wind fields and thus on the parameterisation of the vegetation in numerical models.

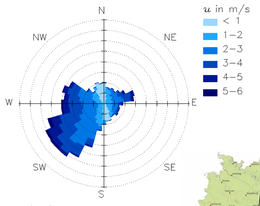


Site & Setup

Ultrasonic measurements at 32 sensor positions in total placed on four towers and five 2 m stands, 16 thermocouples, radiation balance, thermal camera, 15 laser scanner recordings.

Fluxnet Station Tharandt

Spruce stand: 120 years, 30 m
Clearing: 50 m × 90 m



Wind distribution 2008-2009

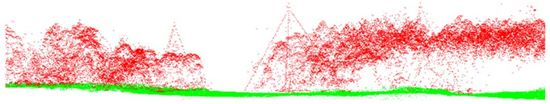
Aerial photograph: Staatsbetrieb Geobasisinformation und Vermessung Sachsen 2009

German map: http://www.stepmap.de

Right Fig.: Laser scanner "Riegl LMS-Z 420i" at the top of the flux tower

Left Fig.: Ultrasonic anemometer, synchronous registration, storage of 20 Hz raw data from 5/2008 to 5/2009

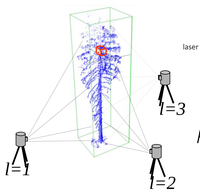
Fig. below: Point cloud of ≈ 50×10⁶ surface points combined from 15 scan positions, including 2 positions from the top of the towers



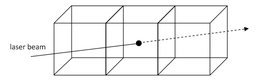
Vegetation Model

Method: Registration of the different scans in a single coordinate system and generation of a multi-scale voxel structure with attributes to derive the plant area density

Measured points



$$N_{max} = N_{Miss} + N_{Hit} + N_{Occlusion}$$

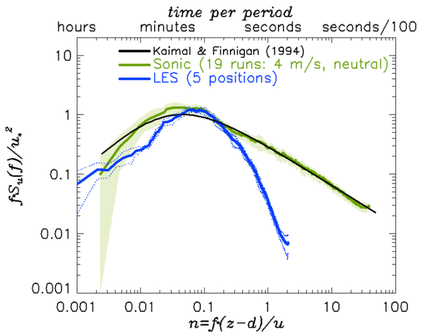


$$PAD = F_{clump} \frac{\sum_{l=1}^{n} N_{Hit,l} / N_{max,l}}{\sum_{l=1}^{n} \frac{N_{Hit,l} + N_{Miss,l}}{N_{max,l}}}$$

Voxel space: grid of cubic volumes V(x,y,z) with attributes of the point distribution

Observation / Validation

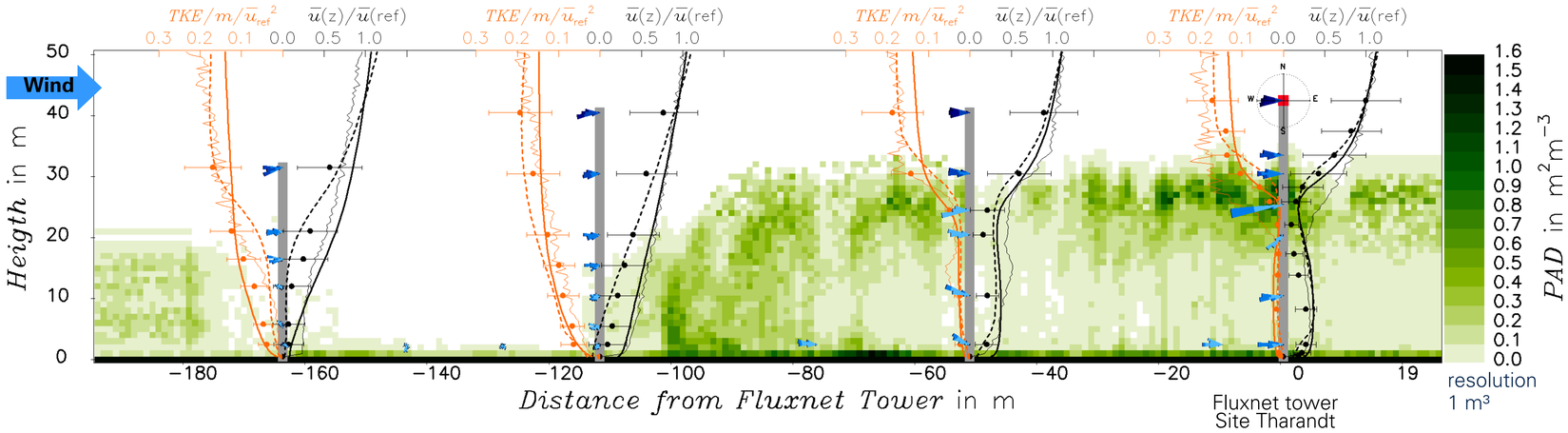
Comparison of measurements and model results is only possible in very clear defined conditions. The figures in this box show the "Neutral case": stability: -0.1< z/L < 0.1, wind speed: 3.9 m/s < u < 4.1 m/s, wind direction: 255° < WD < 285°, no surface wetness.



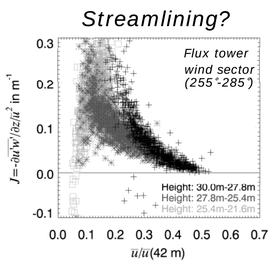
Left Fig.: Power spectra of the horizontal wind speed from selected measurement intervals (19 half hourly runs) made at reference point (42 m, red dot in the figure on the right) and results from a Large Eddy Simulation (LES, Schlegel et al. 2012) from the corresponding grid point (plus 5 grid points transversal to the wind direction).

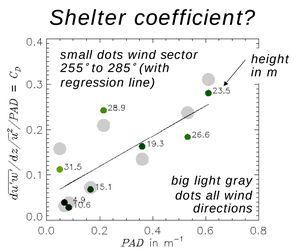
Right Fig.: Profiles of turbulent kinetic energy (TKE/m) and wind speed (u), both normalised by the wind speed at the reference point. Results are from the TurbEFA project, see references below

straight thin l.: wind tunnel measurement
straight thick l.: boundary layer model
dashed thick l.: large eddy simulation
dots with whiskers: measurements
background: plant area distribution
blue flags: wind distribution for the selected situations in 10° sectors



Parameterisation





Figs.: Measurements of impulse absorption within the canopy indicate a variable drag coefficient

$$C_{D,eff} = C_{D0} \cdot PAD^{n} \cdot \bar{u}^{m}$$

Plant specific exponents for Surface density and Streamlining

$n = 0.6$ $m = -0.8$

Application (next steps)

Calculation of complete balances requires knowledge of advective fluxes over the boundaries of the control volume. Measurements within tall vegetation can provide few vertical profiles only and must be complemented by numerical models considering the canopy architecture.

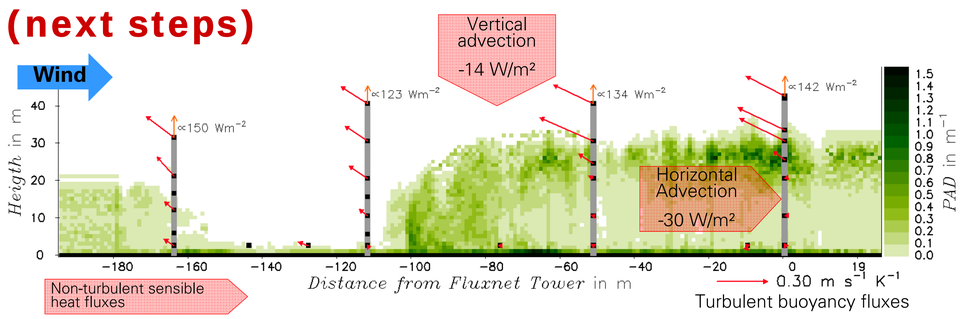


Fig. above: Measured mean buoyancy fluxes (red arrows) under **unstable conditions** (note: only the divergence within the control volume contributes to the heat balance) and Non-turbulent sensible heat fluxes calculated from mean temperatures and wind speeds.

Expected Outcome

Combining meteorological measurements (wind, temperature etc.) with measurements of plant area density this study aims at the following:

- investigation of the effect of inhomogeneities in canopy structure on exchange processes and quantification of the resulting uncertainties of flux measurements,
- derivation of effective parameters for numerical models like drag coefficient, mixing length, displacement height and roughness length from the canopy structure,
- validation of results from numerical models.

This presentation aspires to make the dataset public and to invite modellers to further data analysis.

IHM METEOROLOGIE

Ronald Queck
Institute of Hydrology and Meteorology
queck@forst.tu-dresden.de
http://tu-dresden.de/turbefa.

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