Turbulent Exchange Processes between Forested Areas and the Atmosphere

TECHNISCHE UNIVERSITÄT DRESDEN

SPP 1276 C4

Numerical Simulation

Boundary Layer Model

Subject:

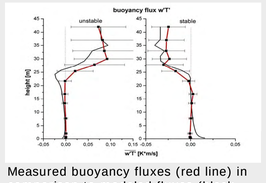
- 2D flow simulation to distinguish between advective and turbulent mass and heat transport
- Coupling between atmosphere, vegetation and soil

Current State:

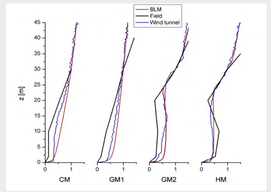
- Stable calculation method implemented
- Approximate pre-version of a vegetation model integrated
- First simulation results show good agreement to measured data

Further Steps:

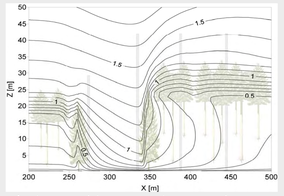
- Consideration of soil characteristics for adequate representation of heat fluxes
- Improvement of vegetation model by high spatial resolution
- Derivation of turbulence parameters inside the canopy



Measured buoyancy fluxes (red line) in comparison to modeled fluxes (black line) for stable and unstable stratification at the main tower



Measured and calculated wind profiles at tower locations normalized to 30 m



Isotaches of the calculated mean flow field in m/s (given 7 m/s at top of model)

Parameterization (Drag coefficients, pressure distribution, turbulence characteristics)

Initial and boundary conditions

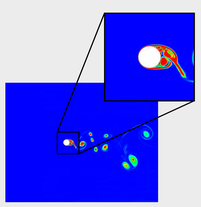
Large Scales

Sub-goals:

- Appropriate vegetation- and sub-grid scale models for LES with resolution about $\Delta x \sim$ trunk diameter
- LES of fluid flow and passive scalar transport at forest edges in comparison to field- and wind tunnel experiments

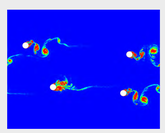
Current state:

- Implementation of a state-of-the-art vegetation model in FEM/SEM-solver
- Validation of SVV in Semtex: flow around single cylinder at $Re = 3300$ (figure: vorticity)



Methods:

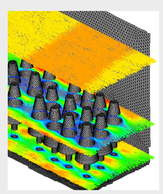
- SEM – Fourier-Spectral method



✓ SGS in Semtex: Spectral vanishing viscosity (SVV)

☞ Reference-DNS/LES for single trees and trunk zone (figure: vorticity at $Re = 3300$)

- FEM / SEM



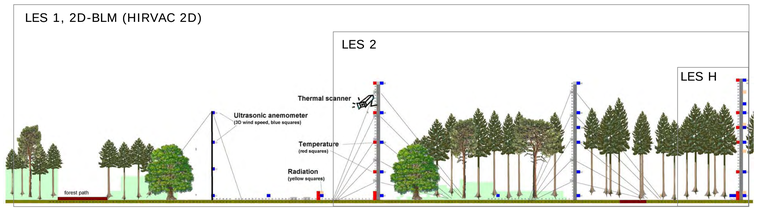
✓ Tetraeder elements, linear up to $P = 15$, parallel, h-adaptive

☞ Heterogeneous drag force from canopy elements

☞ SGS-energy transport with bypass effects and anisotropic sources

Current State

- Continuous measurements at four towers
- Tested wind tunnel model
- Established computational frame of the 2D boundary layer model
- LES for a representative trunk zone section as database for further improvements of a state-of-the-art vegetation model
- First results: Good agreement of modeled and measured profiles in the undisturbed canopy space, deviations near the forest clearing



Further Steps

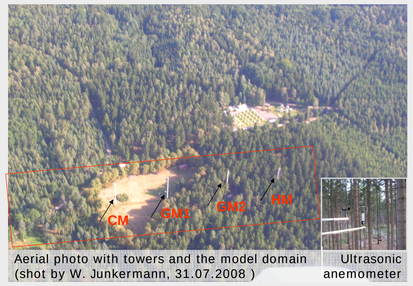
- Investigation of the fine structure of vegetation and its influence on the turbulent flow
- Improved parameterization of inhomogeneities in flows at forest edges
- Validation of measurements and numerical methods
- Quantification of measurement uncertainties under complex conditions

Measurements

Field Measurements

Experimental setup

- Towers: 4 positions on west-east transect (height 30, 40, 40, 42 m)
- Sensors: 25 ultrasonic anemometers (20 Hz), 20 thermocouples and 5 radiation sensors, plus thermal scanner
- Central data collecting system, WLAN (data stream 1000 MByte/d)

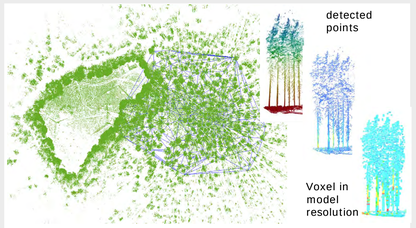


Aerial photo with towers and the model domain (shot by W. Junkermann, 31.07.2008)

Ultrasonic anemometer

Perspectives

- Detailed measuring of special features of the turbulent flow
- Analysis of measured data: time series analysis, investigation of gusts and frequency spectra applying quadrant and wavelet analysis



Detailed canopy structure by laser scanning:
Mean distance 9m, tree height < 30m and diameter 0.2-0.5 m.
Left site: Derivation of a measure for the plant area density

Further optimization of the setup after results of the wind tunnel

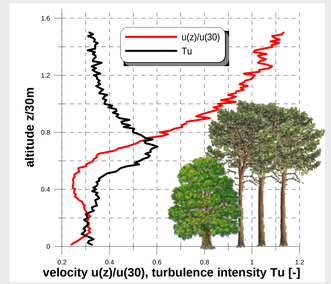
Vegetation structure, turbulence data (fluxes statistical parameter)

Wind Tunnel

Objectives

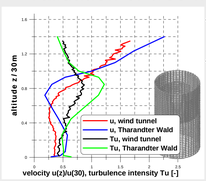
- Database for boundary conditions and for the verification of numerical models
- Experimental studies of different designs of trees and seasonal vegetation

- Verification of the entire section of the Tharandter Wald at a scale of 1:450
- Measurement of the profiles of velocity and turbulence at diverse positions
- Flow visualization at the clearing



velocity and turbulence intensity at the ASTW

Validation of tree models with field data



- Tree models out of metallic meshwork
- Comparison of the allocation of velocity and turbulence with the measured data of the outdoor experiments

Flow visualization

Flow visualization at the clearing

Further steps:

- Measurements of the concentration of volatile organic compounds in the considered area
- Simulation and verification of large-scale squalls above the canopy

Associated groups: Schatzmann/Leitl (Wind tunnel), Raasch (LES)

R. Grundmann, J. Stiller, V. Hildebrand
Technische Universität Dresden
Institute for Aerospace Engineering

C. Bernhofer, V. Goldberg
Technische Universität Dresden
Institute of Hydrology and Meteorology