Measurements of atmosphere-surface interactions at SMEAR III site, Helsinki

Timo Vesala
Dept. Physical Sciences
Univ. Helsinki

• Thanks for Leena Järvi (M.Sc. thesis ” Alustan rosoisuus ja turbulenssin ominaisuudet kaupunkiympäristössä ” (”Surface roughness and properties of turbulence for urban environment”)

SMEAR III station and measuring tower

- **Since autumn 2004**

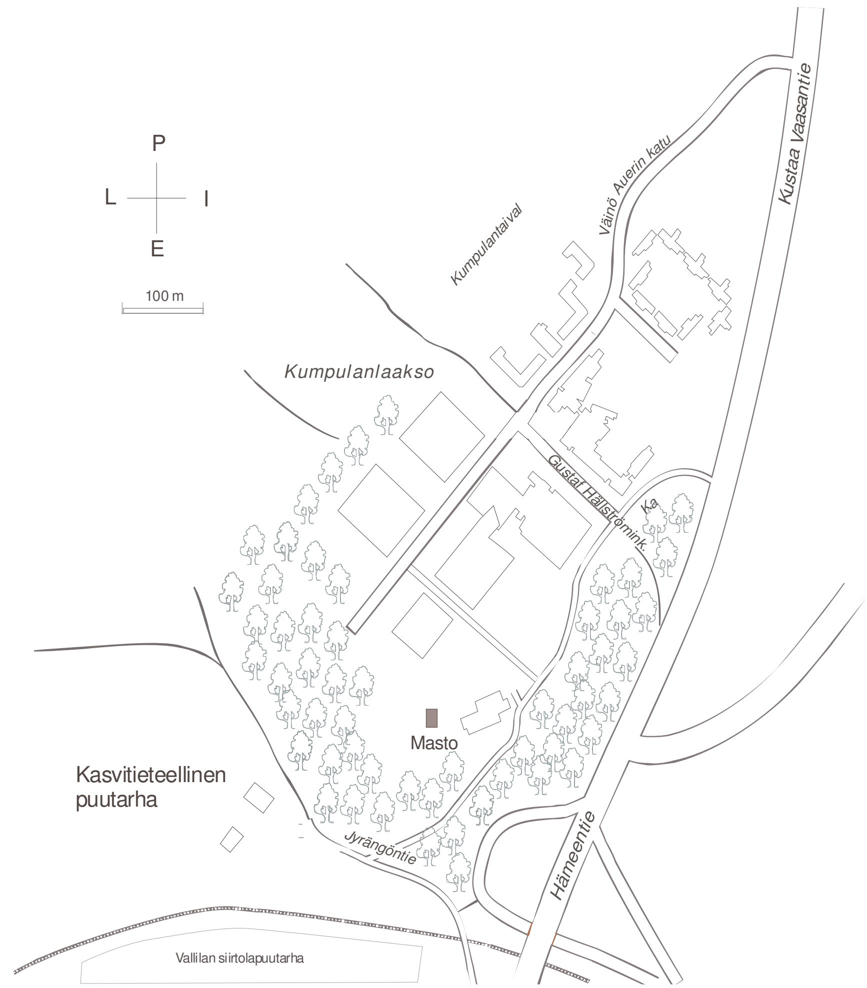
Measuring tower

Picture: Leena Järvi

- Basic measurements are done in four levels 4, 8, 16 and 31 m
- Measured quantities are wind + wind direction (2-D), temperature, global radiation, PAR radiation, long wave
- Sensible and latent heat, momentum and CO_2 fluxes by eddy covariance, i.e
  by direct technique (top)
- 3 m: O_3, NO_x concentrations

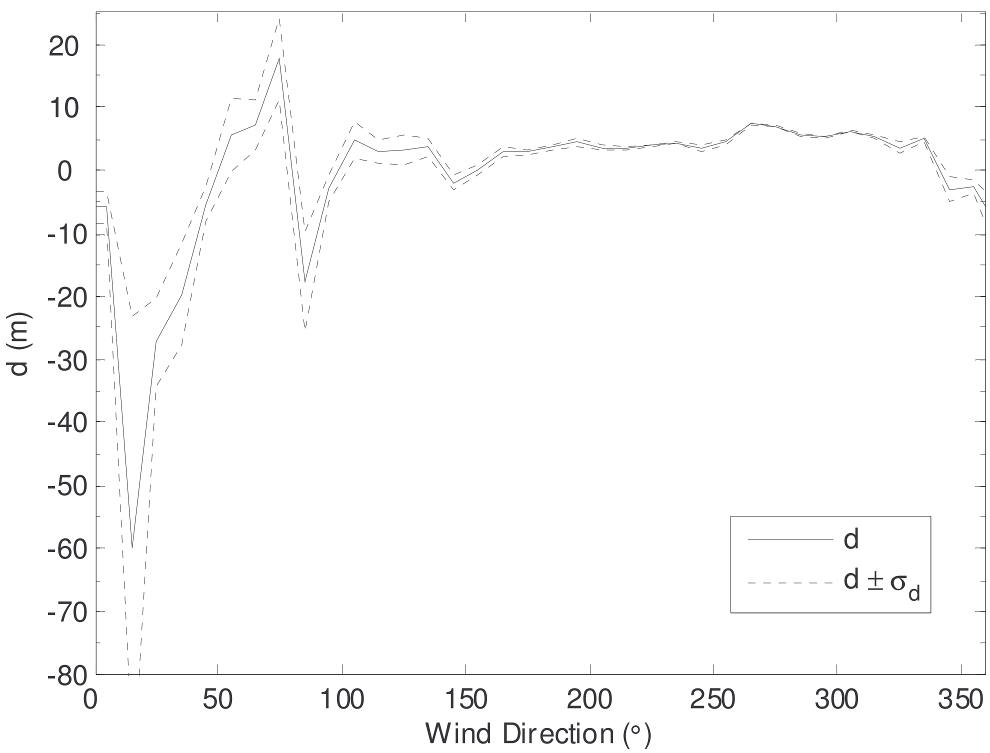
Map of Kumpula campus

Land use	Direction (°)
High buildings	0 - 35
Parking lot	35 - 55
Buildings	55 - 105
Forest	105 - 320
High buildings	320 - 0



Some micromet results

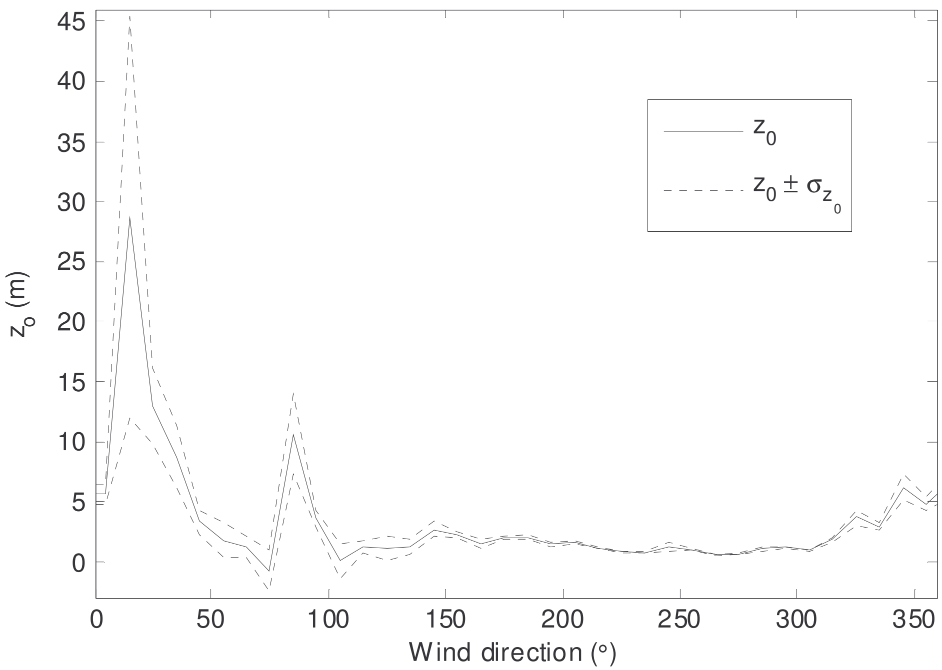
Displacement height *d*



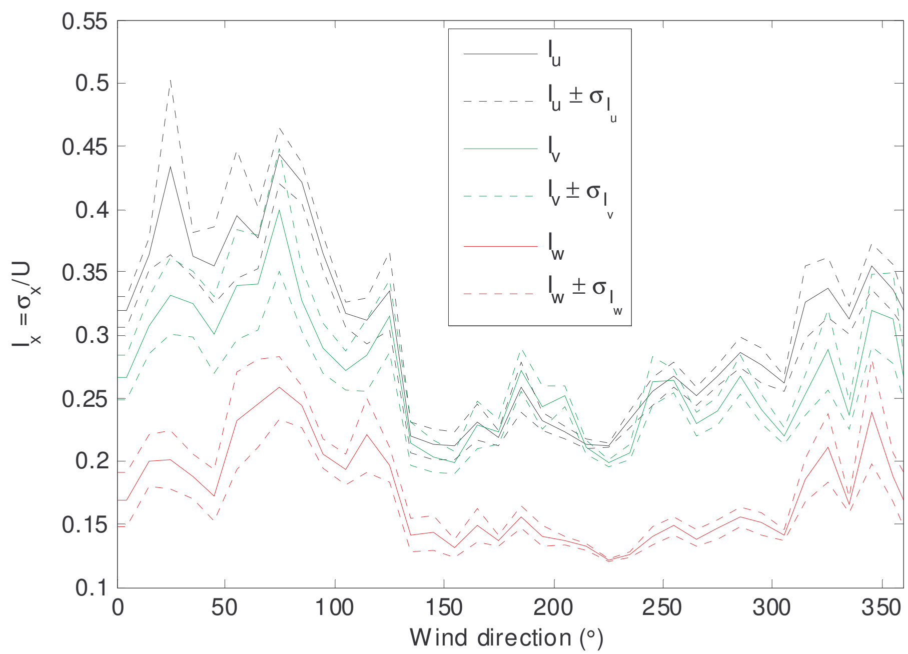
- It gets negative values in directions 340 – 50°, 80 – 100° and 140 – 150°
- Logarithmic wind law doesn't apply in these directions because
  - ➢Measurements are made in the RSL
  - ➢Tower disturbances in direction 0 – 60°
- In other directions we got values between 3 – 6 m

Roughness parameter z_0

- Directions where *d* got negative values, z_0 gets too large values, which corresponds values in mountain areas (e.g. Stull, 1988)
- Elsewhere values are about 2 m, which corresponds values in other urban areas



Turbulence intensity *I*



$$I_s = \frac{\sigma_s}{\overline{U}} \quad , s = u, v \text{ or } w$$

- Turbulence intensity is acting same in the case of all wind components
- Smaller values it gets in directions 130 - 310º
- This is direction where also roughness parameter gets smaller values
- Directions where I gets higher values mechanical turbulence production is larger
- Smaller changes tells about the heterogeneity of the surroundings

Normalized standard deviations

- According to MOS-theory normalized standard deviations of rotated wind-components, temperature and other scalars, can be expressed through equation (Monin and Yaglom, 1971)

$$\frac{\sigma_x}{x_*} = f(\zeta)$$

  where x_* is corresponding scaling measure
- Function f gets in unstable cases form

$$f(\zeta) = C_1(1 - C_2\zeta)^{\pm 1/3}$$

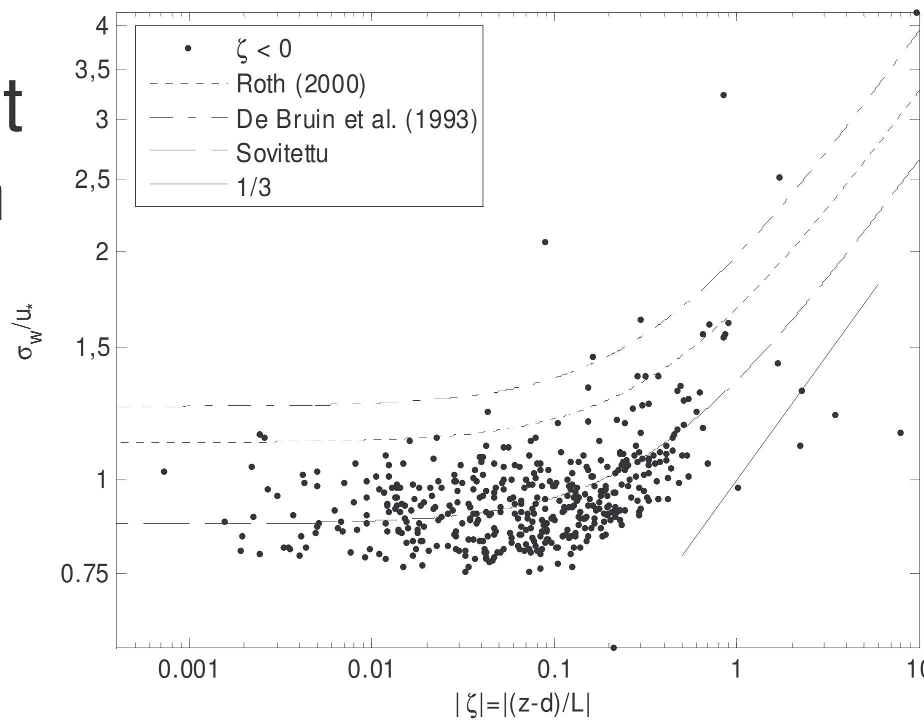
  where C_1 and C_2 are experimentally defined constants
- These were determined for wind direction 330–70°

w-component

- Curve fitting to the data points gives an equation

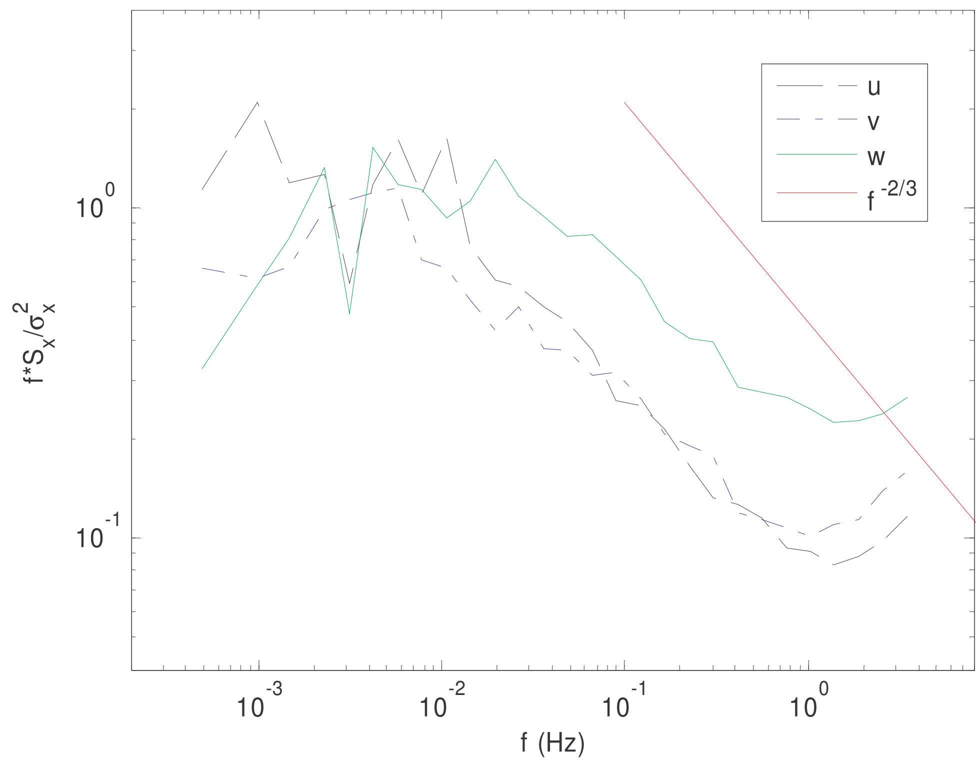
$$\sigma_w / u_* = 0.87 \cdot (1 - 2.80\zeta)^{1/3}$$

- This correspond well whit the fitting over flat terrain (De Bruin et al., 1993) and over other urban area (Roth, 2000)
- *w*-component follows MOS-theory well
- Urban values are again lower than rural values



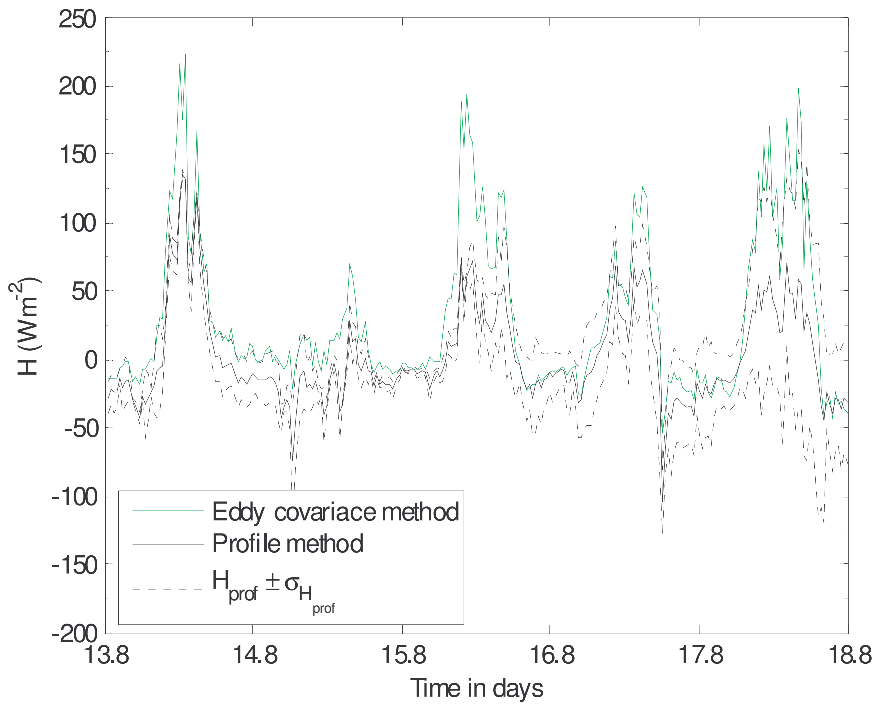
- In other studies has been similar results that vertical wind component and temperature obey well whit the MOS-theory but horizontal wind components don’t (e.g. De Bruin et al., 1993)
- This is because large eddies affect to horizontal wind components disturbances (e.g. Van Den Hurk)
- In the case of all wind components the urban values were smaller than over flat terrain and the reason is larger friction velocity values due to mechanical turbulence production (e.g. Roth and Oke, 1995)

Velocity spectra



- *u*-components peak appears at frequency interval 0.001 - 0.01 Hz (2-16 min)
- *v*-components peak appears at 0.002 - 0.006 Hz (3-8 min)
- *w*-components peak appears at 0.004 – 0.02 Hz (20-50 s)

Sensible heat flux



- Was calculated over five days using two methods: Eddy covariance and profile method
- Both gave similar results but profile method slightly underestimates fluxes
- Lower the atmospheric stability is, the larger are differences between these methods
- Diurnal cycle can clearly been seen in both fluxes

Other measurements at SMEAR III:

Container: particle number size distribution, aerosol light scattering, particle mass concentration, inorganic ion content of fine particles and fine particle carbon

Physicum roof: wind speed and direction, T and humidity, pressure, global radiation, PAR, longwave rad, precipitation and cloud base

Campaigns: VOC and neutral airborne ions (down to 0.5 nm)

Viikki: PAR, T, tree stem variation (1 micron and 1 min), sap flow, soil T and soil humidity

Dynamicum roof ?

Chemicum ?

Future:

- All mentioned continue
- footprint analyses by BL model
- particle number flux
- VOC, N_2O and CH_4 flux campaigns
- etc.