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DETERMINATION OF BOUNDARY LAYER DEPTH IN URBAN ENVIRONMENT

ABL 17 JUNE 2008

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Backgrounds of the current work

- **Data from Helsinki Testbed measurement campaign (Jan 2005 – Sep 2007) is used**
- **UbiCasting project (Sep 2007 – Jan 2009) serves as a development platform for the Testbed campaign**
- **Our principal aim is to estimate the mixing height (MH) from the monitored data, so that we**
    - study fitting methods applicable to ceilometer and lidar data for the estimation of the urban or suburban boundary layer (UBL) height
    - compare the planetary boundary layer (PBL) based on RS measurements with UBL
    - compare fitted MHs with estimates of numerical models

Testbed data is monitored by

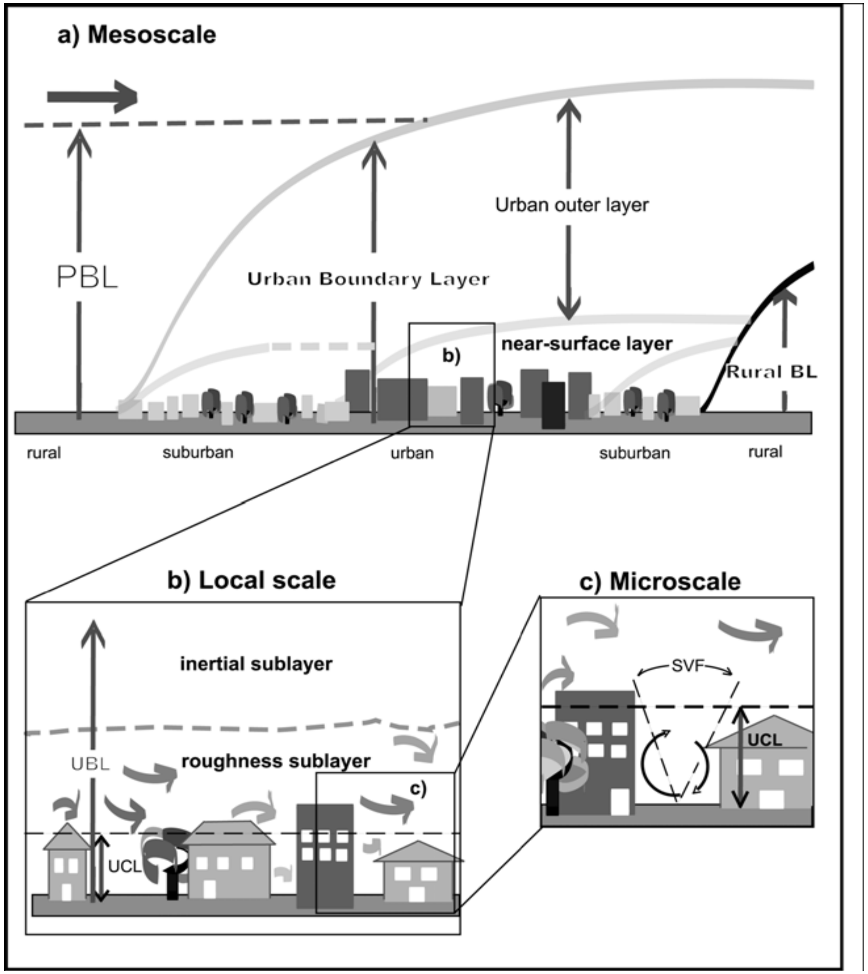
- **6 ceilometers**
- **A radio acoustic sounding system (RASS)**
- **Radiosoundings**
- **A Doppler lidar**
- **5 measurement spots: 2 urban, 1 suburban and 2 rural sites**
- **2 observation periods used in preliminary tests:**
  - 22nd November 2005 (surface inversion)
  - 9.-28. August 2006 (regional range transport)

Figure 1. The monitoring sites of Testbed measurements.

Expexted differences between UBL and PBL

Figure 2. Schematic diagram showing processes, flow and scale lengths within an urban boundary layer, UBL. This is set in the context of the planetary boundary layer, PBL, the urban canopy layer, UCL, and the sky view factor, SVF, a measure of the degree to which the sky is obscured by surrounding buildings at a given point which characterises the geometry of the urban canopy.

www.atmos-chem-phys.net/6/555/2006/



Methods – PBL by radiosoundings (RS)

- **Methods of determining Planetary Boundary Layer (PBL) and Urban Boundary Layer (UBL) heights are different**
- **Moreover, methods are sensitive to stability**
- **The bulk Richardson number is used in stable stratified PBL when the critical number equals 1 (figure A)**
- **In unstable PBL the Holzworth method used (figure B)**

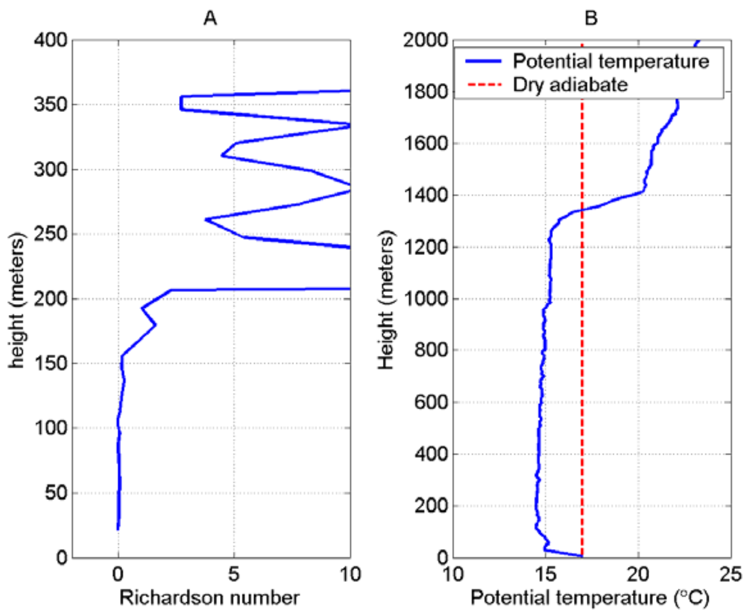


Figure 3. MH of PBL is estimated using bulk Richardson number (left) and Holzworth method (right).

Mixing height from fitted ceilometer or lidar profiles in UBL

- **1-step fitting method (Steyn et al, 1999) based on aged aerosols is enlargened to 3-step procedure including fresh particulates from urban environment**
- **3-step fitting allows backscattering from three aerosol levels**

$$B(z) = \underbrace{\frac{B_1 - B_{ML}}{2} - \frac{B_1 - B_{ML}}{2} erf\left(\frac{z - MH_1}{\Delta h_1}\right)}_{STEP1}$$
$$+ \underbrace{\frac{B_{ML} - B_2}{2} - \frac{B_{ML} - B_2}{2} erf\left(\frac{z - MH_{ML}}{\Delta h_{ML}}\right)}_{STEP2}$$
$$+ \underbrace{\frac{B_2 + B_U}{2} - \frac{B_2 - B_U}{2} erf\left(\frac{z - MH_2}{\Delta h_2}\right)}_{STEP3}$$

- **B_i, MH_i and Δh_i represent values of backscattering, mixing height and entrainment depth of the steps**

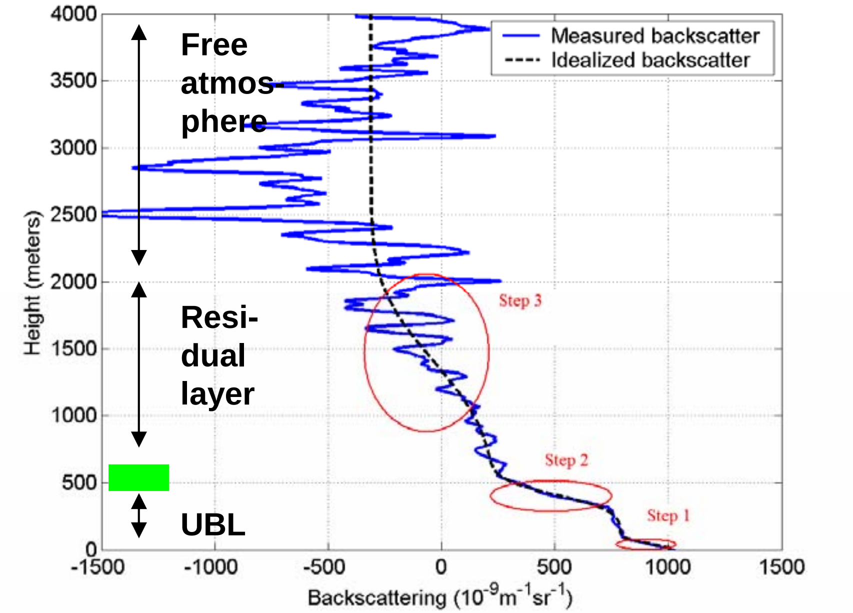


Figure 4. An example of the fitted ceilometer bakscattering profile (Vallila, 21 August 2006 at 11 UTC). The green slab denotes the entraiment layer.

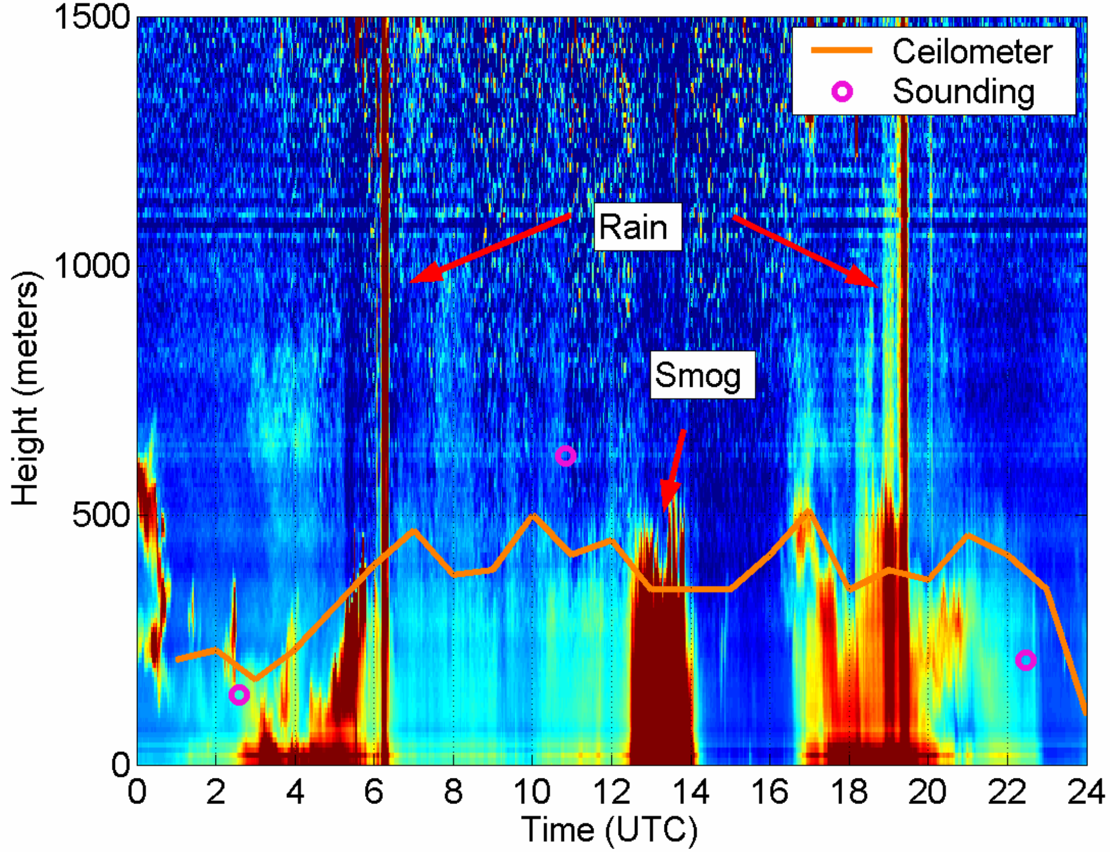
Classification of aerosols from the fitted profiles - identification of residual layers?

- Table 1. Step height h(m), depth Δh(m), backscattering ΔBS($10^{-9}m^{-1}sr^{-1}$) from the step, ratio of backscattering to the depth ΔBS/Δh($10^{-9}m^{-2}sr^{-1}$), aerosol source scale and age.

STEP	h (m)	Δh(m)	ΔBS($10^{-9}m^{-1}sr^{-1}$)	ΔBS / Δh	Scale / aerosols
STEP1	0-100	100	200	2	Local / fresh
STEP2	300-500	200	500	2.5	Urban / ~ fresh
STEP3	1000-2000	1000	500	0.5	LRT / aged

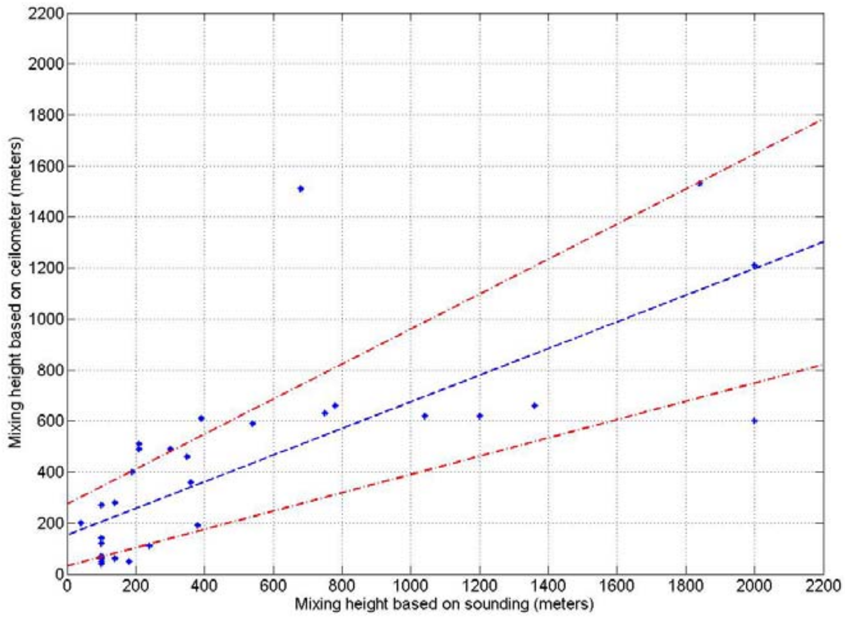
- **The slope of the step (Δh/ΔBS) may include inherent knowledge of the age of aerosols in statistical sense.**
- **Statistical methods, as autocorrelation between the properties of the layers, will be applied to the time series.**

Figure 6. A 24-h period of ceilometer echo intensity observations in Vallila, Helsinki, 21 August 2006. Comparable with Figure 4 at 11 UTC.



Preliminary results of linear regression

Figure 5. Linear regression of MHs estimated by ceilometer (vertical) and radiosoundings (horizontal) with 95 % confidence limits.



- **The correlation between MHs estimated by radiosoundings (PBL) and ceilometer (UBL) is 0.75**

$$h_{ceilometer} = (0.52 \pm 0.16) h_{sounding} + (150 \pm 120)$$

- **A moderate consistency between the estimates of stable and neutral conditions is expected, while ceilometer estimates are strongly negatively biased in convective atmosphere.**

To do in the near future

- **To get Noora back from her maternity leave**
- **Development of algorithm includes**
  - the treatment of convective cases and separation of a possible residual layer from the boundary layer
  - the treatment of cloudy conditions (ceilometer uses Vaisala's method for cloud elimination)
  - using the modeled MH values, based on observed meteorological parameters on the ground surface, as the initial guesses for the optimization
- **When the algorithm is satisfactory, the monitored MHs are compared with the results of numerical models (e.g. SCADIS (HU) and LAPS (FMI))**