Mixing height studies

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The mixing height

Atmospheric boundary layer height, or the mixing height determine the volume available for pollutant dispersion.

It depends on basic meteorological parameters, surface turbulent fluxes and physical parameters, and follows a diurnal cycle.

The mixing height cannot be observed directly by standard measurements, so that it must be parameterised or indirectly estimated from profile measurements or simulations.
Meteorological measurements

**NOT directly applicable**

- **CAR-FMI**, traffic
- **UDM-FMI**, urban
- **OSPM (NERI)**, street canyon
- **ESCAPE**, chem. accidents
- **BUOYANT** buoyant gases, fires
- **EXPAND (+ YTV)** exposure
Ceilometer locations
Reference mixing height

- In convective situations the Holzworth method used
- In stable situations the Richardson number $Ri$ method used ($Ri_{crit} = 1$)

\[
Ri(z+1) = \frac{g}{T_s} \frac{(\theta_{i+2} - \theta_i)(z_{i+2} - z_i)}{(V_{i+2} - V_i)^2}
\]

(Joffre et al., 2001)
Ceilometer: Clear sky situations

- MH estimated by fitting an idealized profile to the measured backscattering profile by the formula

\[ B(z) = \frac{B_m + B_u}{2} - \frac{B_m - B_u}{2} \text{erf} \left( \frac{z - MH}{\Delta h} \right) \]

(Steyn et al., 1999)

- \( B_m \) is the mean mixing layer backscatter and \( B_u \) is the mean backscatter in the air above the mixing layer; \( \Delta h \) is related to the thickness of the entrainment zone

An idealized backscattering profile.
Results: Clear sky situations

Comparison between mixing heights determined by the ceilometer and radiosoundings in convective situations. The regression line is

\[ h_{\text{ceilometer}} = (0.80 \pm 0.10) h_{\text{sounding}} + (47 \pm 89) \]

The correlation coefficient \( r = 0.90 \)

Comparison between mixing heights determined by the ceilometer and radiosoundings in stable situations. The regression line is

\[ h_{\text{ceilometer}} = (0.62 \pm 0.16) h_{\text{sounding}} + (120 \pm 34) \]

The correlation coefficient \( r = 0.80 \)
Examples of longer observation periods

A 24-h period of ceilometer echo intensity observations at Vantaa, 29 May 2002

Mixing height as determined by different methods or schemes during a surface temperature inversion (2-3 January 2002)
Vallila, 21 August 2006: The height of the MHs determined by the ceilometer and radiosounding are superimposed on the ceilometer raw echo data.
Further developments

- The 2 & 3-step algorithms:

\[
B(z) = \frac{B_{SL} - B_{ML}}{2} - \frac{B_{SL} - B_{ML}}{2} \cdot \text{erf} \left( \frac{z - MH_{SL}}{\Delta h_{SL}} \right) \\
+ \frac{B_{ML} + B_U}{2} - \frac{B_{ML} - B_U}{2} \cdot \text{erf} \left( \frac{z - MH_{ML}}{\Delta h_{ML}} \right)
\]

\( MH_{SL} \) corresponds to the lower gradient (Step1); \( MH_{ML} \) to the upper one (Step2).

The new algorithms have been tested with a very limited number of observations – so far…

An idealized backscattering profile (2-step algorithm) => 3-step
20/5/2005 Kumpula

Cloud off 200505

measured profile

model -profile

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Cloudy situations

- observations divided into foggy and cloudy (types 1 and 2) situations:
  - Fog - Backscatter maximum on the ground.
  - Cloud type 1 - No local minimum below the cloud
  - Cloud type 2 - A local minimum below the cloud

Examples of the cloud types 1 (upper figure) and 2 (lower figure)
Cloudy situations – methods

- Fog: the idealized profile method
- Cloud type 1: The critical value (25% of the maximum value)
- Cloud type 2:
  - Minimum well-defined: the cloud removed and the idealized profile method used
  - Otherwise the minimum or the critical value (10% of the maximum value) used

Example of the removed cloud at Vantaa, 3 April 2002 9:40 UTC
Results: Cloudy situations

Figure 7. Comparison between mixing heights determined by the ceilometer and radiosoundings in cloudy situations.
Doppler lidar at Malmi (http://www.ties.salford.ac.uk/people/keb/ufamlidar.html)

Most promising method for Doppler lidar seems to be the "fixed threshold" method – NOTE! Vertical wind speed information not yet utilized
Status/conclusions/further work

The most promising instruments in mixing height determination – identified so far - are ceilometers and Doppler lidar.

Both systems still face some problems. The biggest problem for ceilometer are the clouds, as the biggest problem for the Doppler lidar is the range of the data.

Further work: assessing the usefulness of several other promising (“MH-wise”) HTB-instruments (wind profilers, sodar, RASS)
References