# TURBULENCE PARAMETERIZATION FOR DISPERSION IN URBAN AREAS

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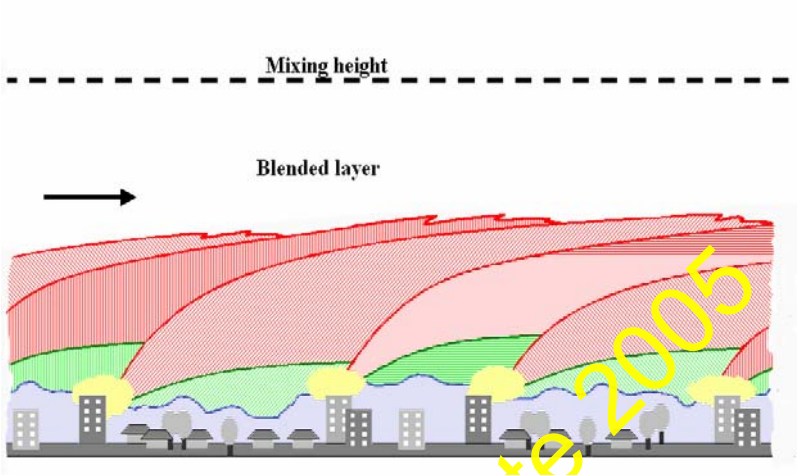
## Outline of presentation

- The urban boundary layer structure
- Parametrisation of turbulence characteristics
- Experiments
  - The BUBBLE experiment
  - The Copenhagen experiment
  - The Sofia experiment
- Results and discussion

*Schematic illustration of the formation and layering of the urban boundary layer, simplified according to neighbourhoods (Batchvarova and Gryning, 2005, TAC)*






## Surface boundary layer structure

- Consensus is slowly being reached that the roughness sublayer height is about 3-5 times the average building height.
- The implication – measurements of turbulence characteristics within the inertial sublayer can be used directly in dispersion calculations.
- Urban measurements at 3-5 times the average building height are needed?!

## Crosswind and vertical fluctuations of the wind velocity

Gryning et al., 1987

$$\sigma_v^2 = 0.35 w_*^2 + (2 - z/z_i) u_*^2$$

$$\sigma_w^2 = u_*^2 \left[ 1.5 \left( \frac{z}{z_i} \right)^{2/3} \left( \frac{w_*}{u_*} \right)^2 \exp\left( -2 \left( \frac{z}{z_i} \right) \right) + \left( 1.7 - \left( \frac{z}{z_i} \right) \right) \right]$$

$$w_* = \left( (g/T) \overline{w'T'} z_i \right)^{1/3}$$

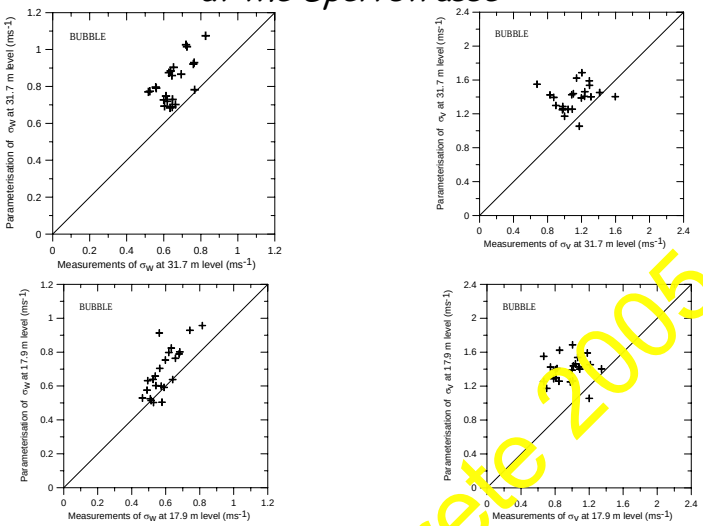


## The BUBBLE experiment

Intensive campaign June-July 2002

Turbulence measurements at about 18 and 32 m are used and Mixed layer height extracted from LIDAR backscatter signal.

*Parametrised versus observed half-hourly averaged values of sigma-w (left) and sigma-v (right) at a height of 31.7 m (upper) and 17.9 m (lower panels) at the Sperrstrasse*






- At both heights the parameterization gave higher values than actually measured.
- The agreement between parameterised and measured values improved with height for sigma-v and remained about the same for sigma-w.
- At the level of 17.9 m the parameterised values were 40% (sigma-v) and 18% (sigma-w) larger than the measured ones.
- At 31.7 m the difference was reduced to 20% and 25% correspondingly.

The strong vertical variability of sigma-v and sigma-w indicates that the layer of measurements is not part of the inertial sublayer. In the inertial sublayer sigma-v should be constant and sigma-w slightly increasing as function of height.

The layer of measurements belongs to the roughness sublayer, where the flow has a considerable spatial and vertical variability.

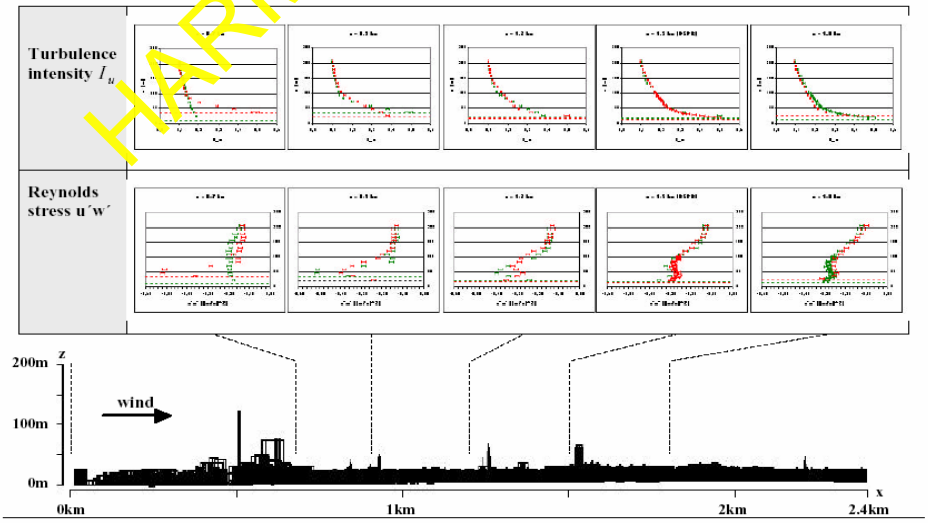
The transition is at 3-5 times the average building height.

This is in agreement with Feddersen (2005) based on laboratory simulation of the DUBBLE experiment.



Feddersen B., Leitl B., Rotach M.W., Schatzmann M. (2003): Wind tunnel investigation of the spatial variability of turbulence characteristics in the urban area of Basel City, Switzerland,

*Workshop Proceedings PHYSMOD2003, September 3-5, 2003, Prato, Italy*, pp.23-25, Firenze



# The Sofia experiment

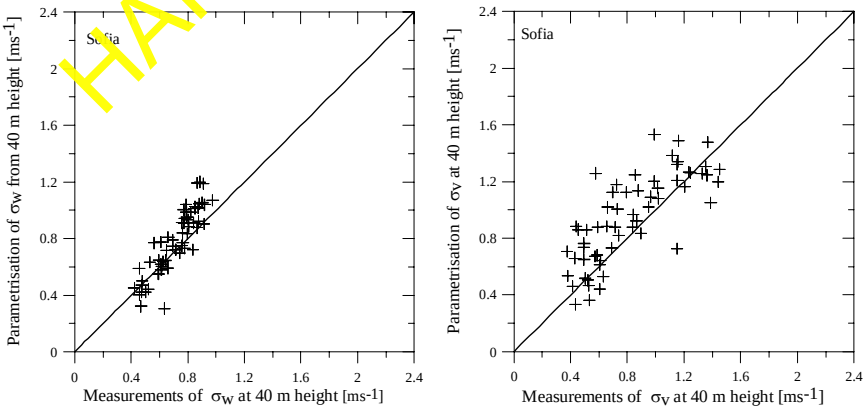
September-October 2003

Turbulence at 20 and 40 m

High resolution (in space and time) boundary layer radiosoundings



*Parameterised versus observed half-hourly averaged values of sigma-w (left panel) and sigma-v (right panel) at 40 m*



- The agreement suggests that at 40 m the transition between the roughness sublayer and the inertial sublayer has occurred.
- The mixed layer height was provided by high resolution (2 hours in time and about 10 m in height) radiosoundings performed at the same site.

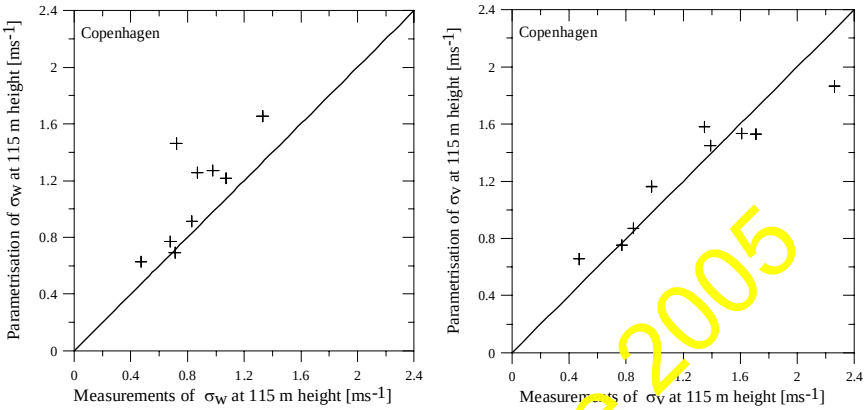


## The Copenhagen experiment

In winter 1979

- Measurements of turbulence variances - at 115 m.
- Atmospheric stability - from temperature and wind profile measurements.
- The mixing height - from standard radiosoundings

## *Parametrised versus observed half-hourly averaged values sigma-w of (left) and sigma-v (right panel) at 115 m at the Gladsaxe tower*






Good agreement for sigma-v
And fair for sigma-w

## Results and discussion - 1

The use of the parameterisations for the standard deviations is feasible within the urban inertial sublayer.

This is of considerable interest for dispersion modelling in the urban boundary layer, because sigma-w and sigma-v are controlling parameters for spreading of plumes in vertical and lateral directions, respectively.



## Results and discussion - 2

Gryning and Batchvarova (2005) applied simple models for the lateral and vertical atmospheric dispersion for the BUBBLE and Copenhagen experiments and found an agreement of about a factor of two between model results and measurements.

Similarly, the maximum observed half-hourly tracer concentration during the BUBBLE tracer experiment on 26 June compared with the maximum of the ground level concentration at the centreline from the Gaussian plume formula within a factor of 2.

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