MODELLED AGGREGATED TURBULENT FLUXES COMPARED TO URBAN TURBULENCE MEASUREMENTS AT DIFFERENT HEIGHTS

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OUTLINE

- Understanding through scales
- The Sofia Experiment
- Aggregation of fluxes over heterogeneous area
- Results

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Understanding through scales

Street scale, 100-200 m
Flows around buildings and in street canyons
(Sperstrasse, Basel BUBBLE experiment June/July 2002)

The neighborhood scale,1-2 km

(Salt Lake City experiment, BUBBLE TRACER)

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Understanding through scales

The City scale,

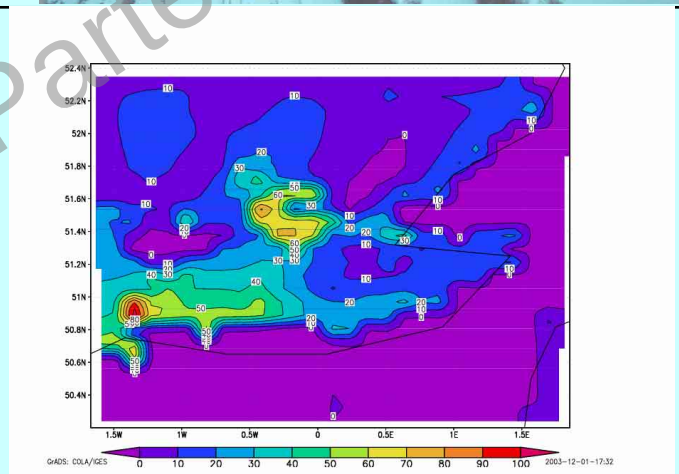
10-20 km

(ESCOMPTE, Copenhagen tracer experiment)

The Meso-meteorological or regional scale,

100-200 km

(London, MM5, 9km, 28x28 grid p)



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Understanding through scales

Red - urban internal boundary layers where advection is important

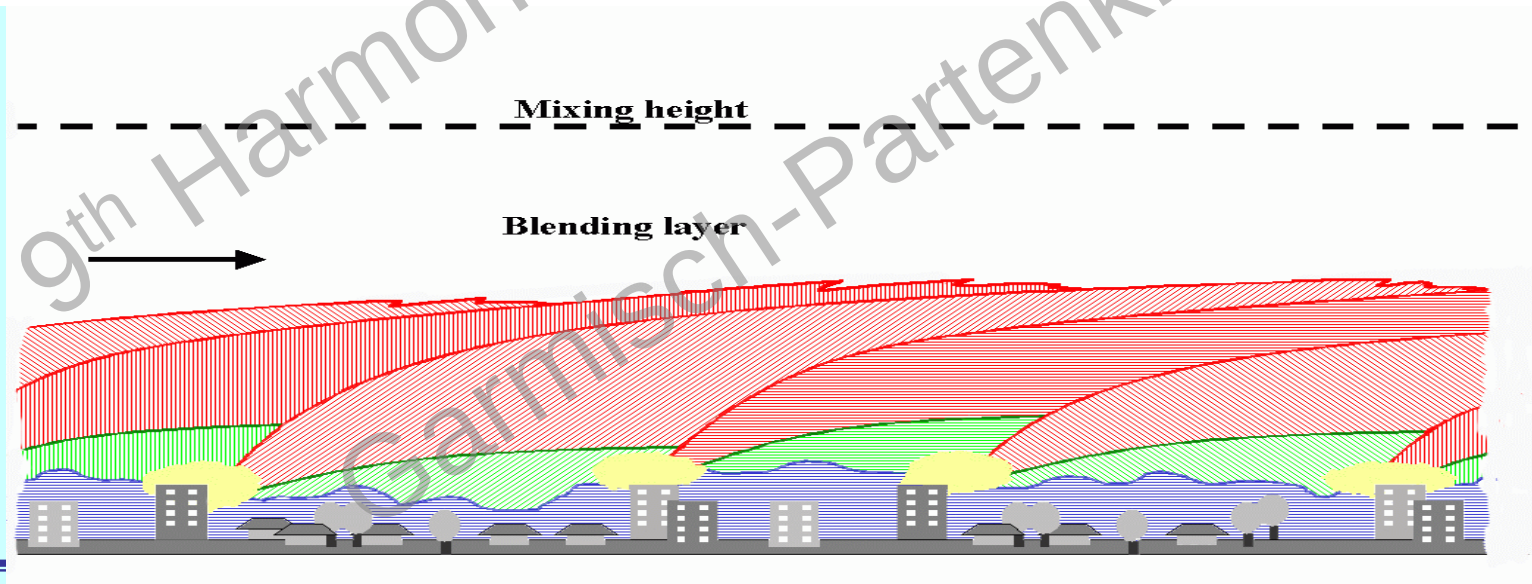
Green - inertial layers, in equilibrium with the underlying surface and M-O scaling valid

Blue - roughness layer, highly inhomogeneous both in its vertical and horizontal structure

Yellow - adjustment between neighbourhoods with large accelerations and shear in the flow near the top of the canopy.

Different hatchings for the underlying surface of the neighbourhoods.

Blending - the internal boundary layers are intermixed the effects of the individual neighbourhoods cannot be distinguished any more



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Different cities

FIG. 1. Aerial view of downtown SLC looking toward the northeast into City Creek Canyon. (Photograph from Don Green Photography, Salt Lake City, Utah.)

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Eastern European cities' suburban areas

Sofia experiment 2003

Swiss-Bulgarian Partnership 7IP 065650 initiated through COST715

Measurements

- 20 m and 40 m agl METEK ultrasonic anemometres
- 40 m fast Krypton Hygrometer
- High resolution radiosoundings

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Eastern European cities' suburban areas

Is the area urban? The vast spaces between high buildings should create deep surface layer and its constitutes - roughness sub-layer and inertial layer

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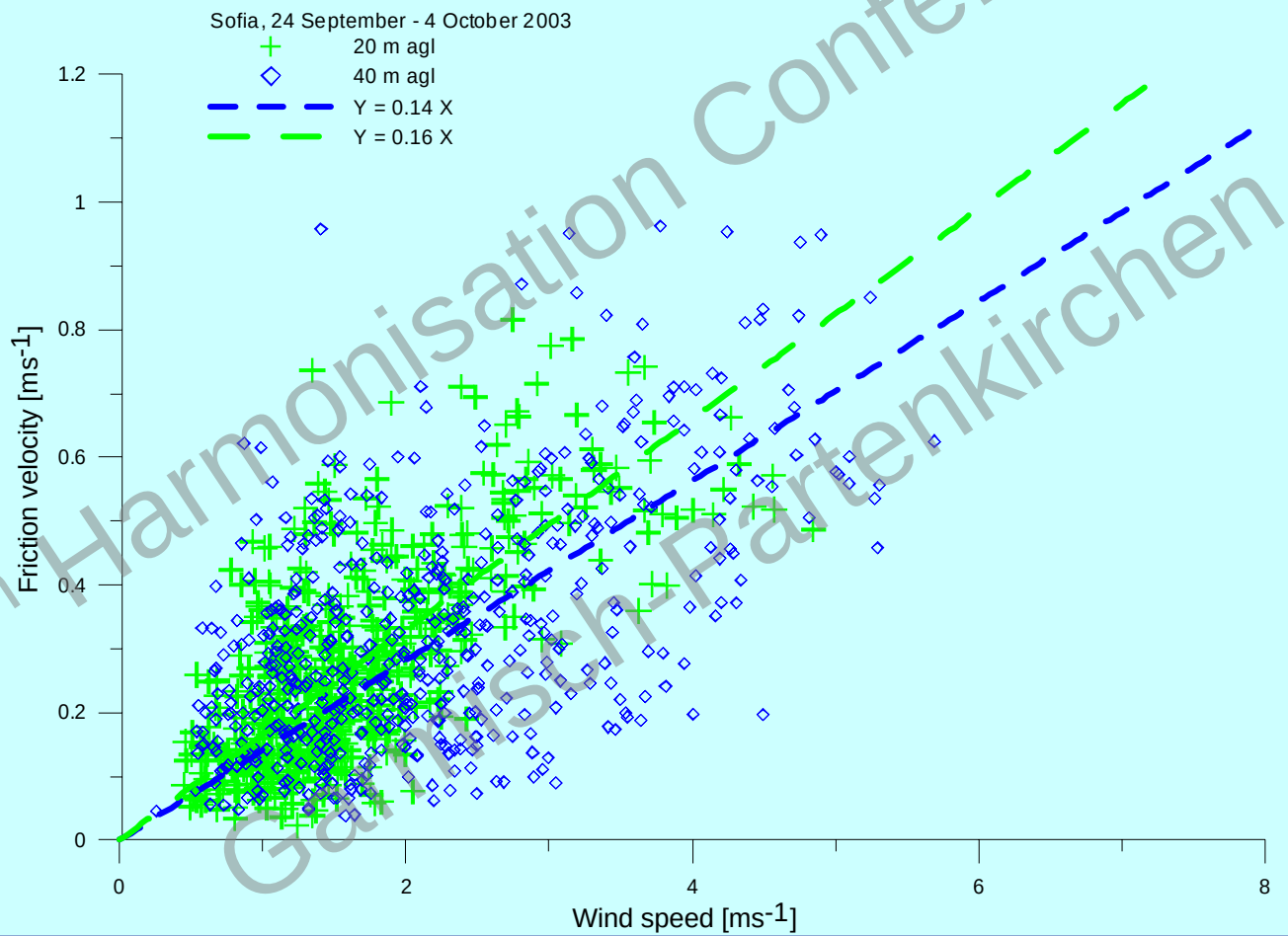
$U_*/U = ?$



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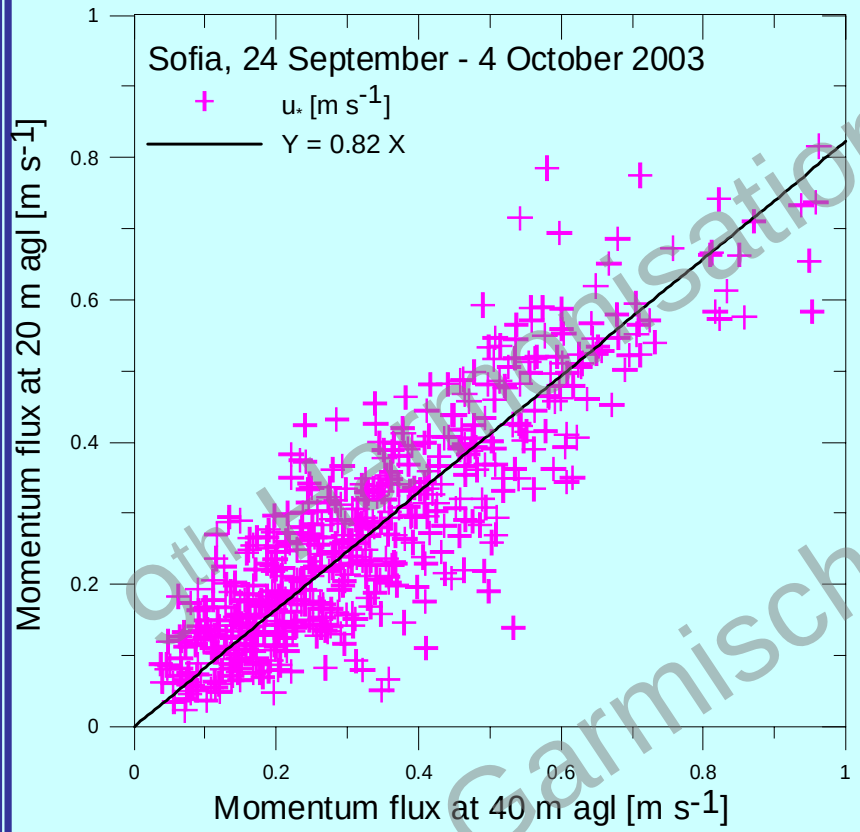
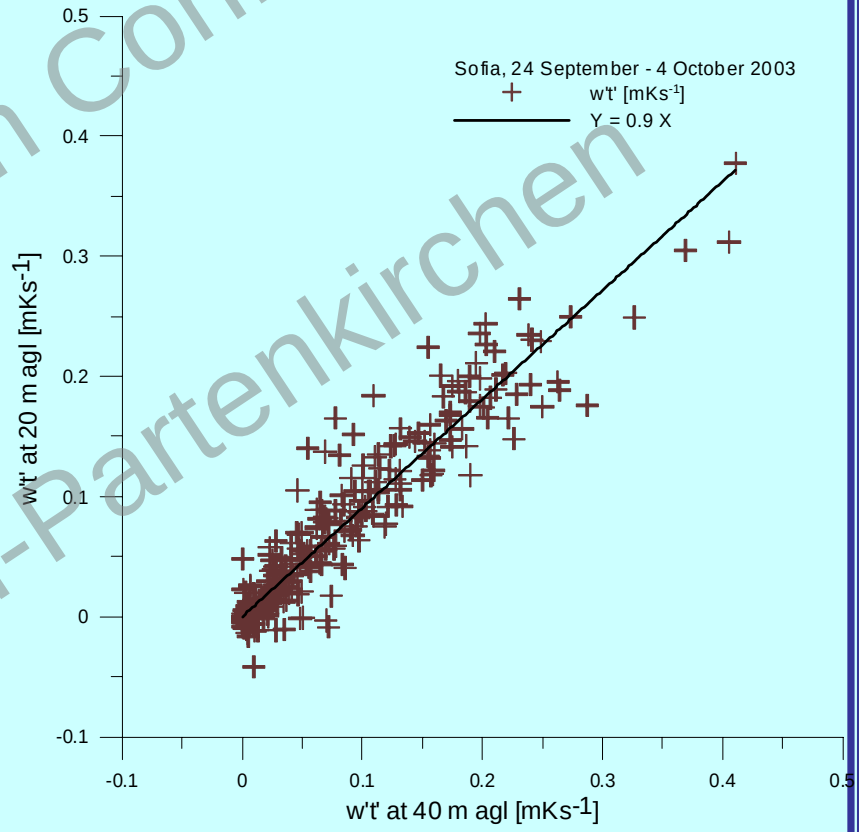
Momentum and sensible heat fluxes





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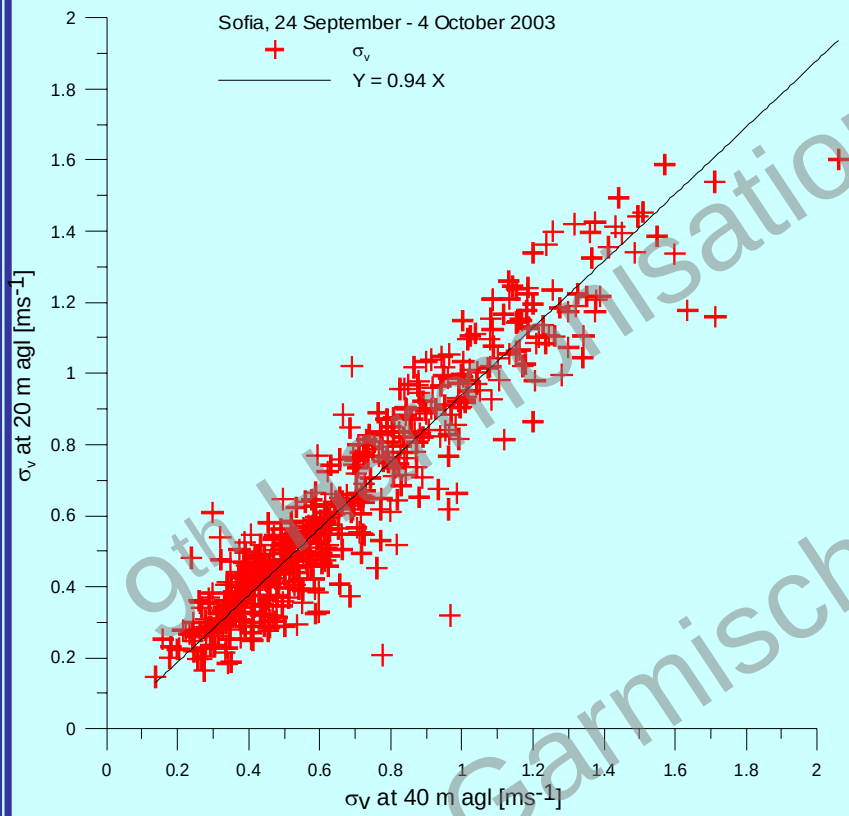
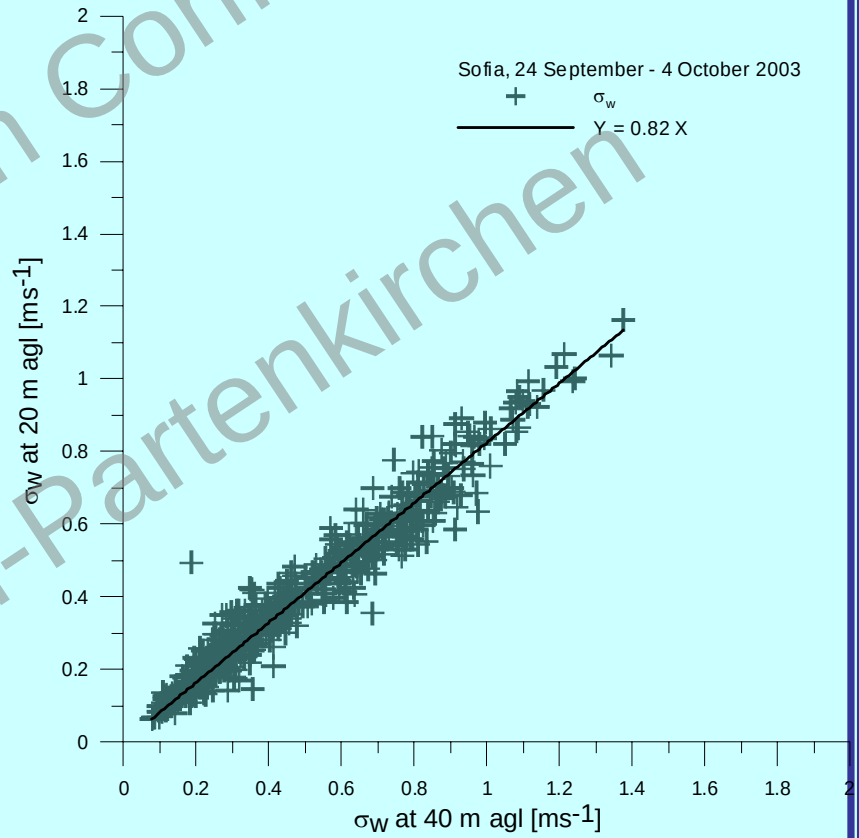
Standard deviations of the lateral and vertical wind speed components





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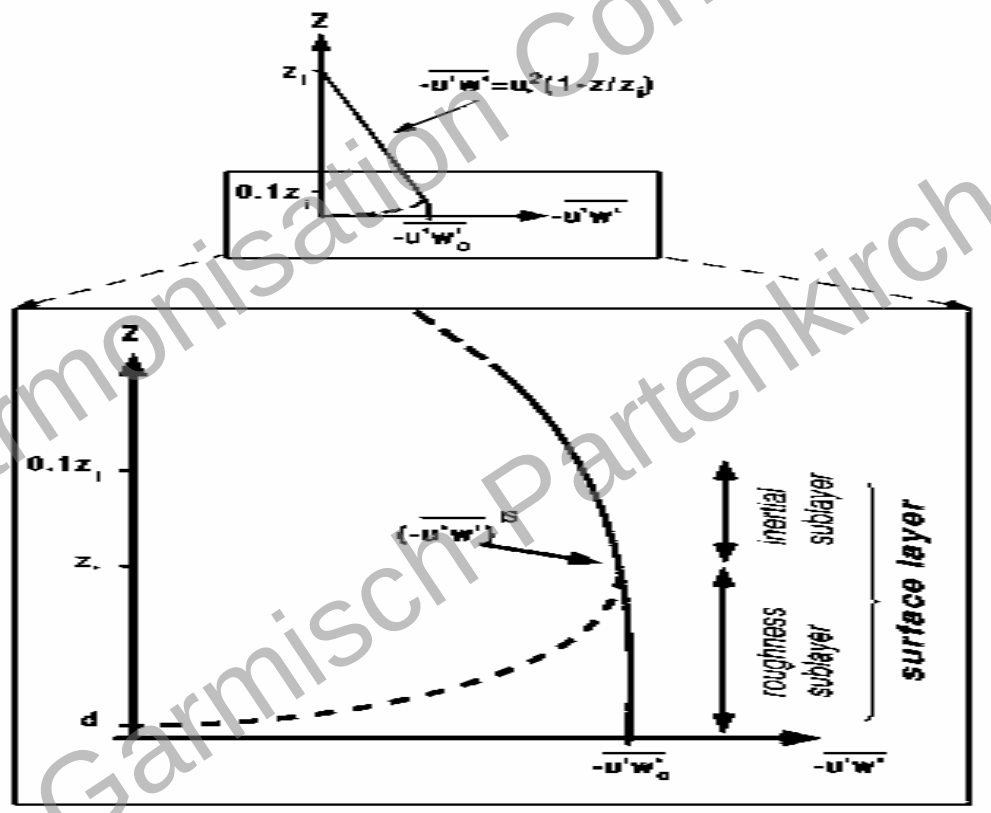
Surface layer in urban areas



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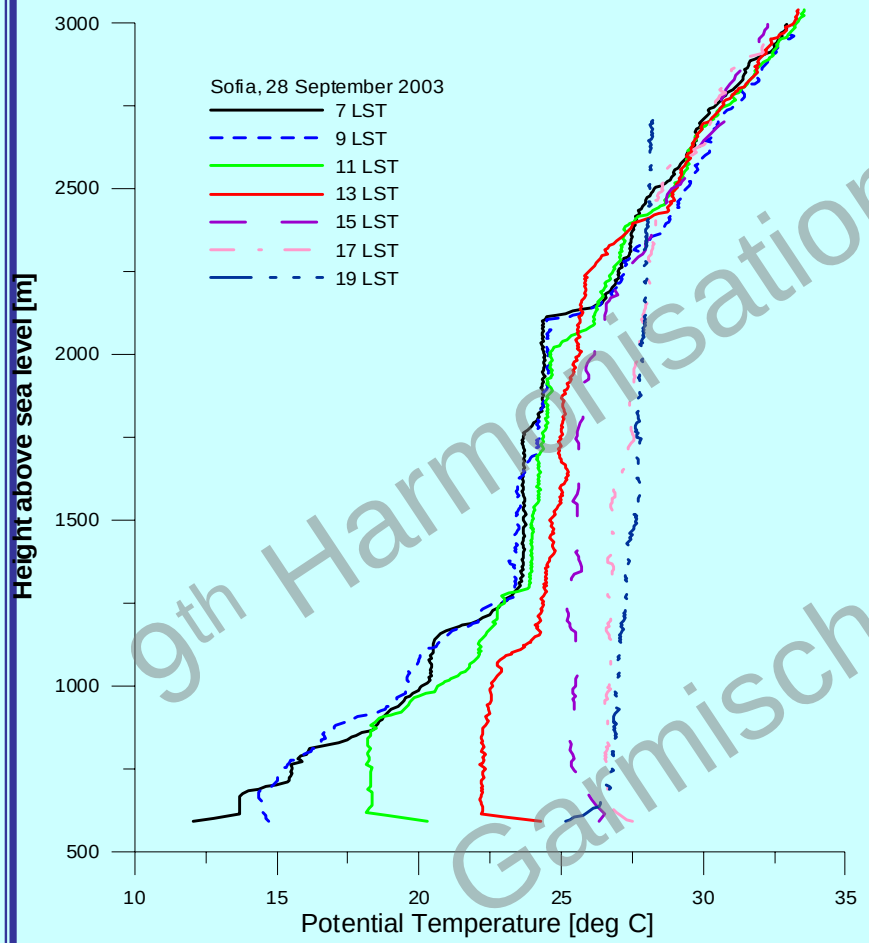
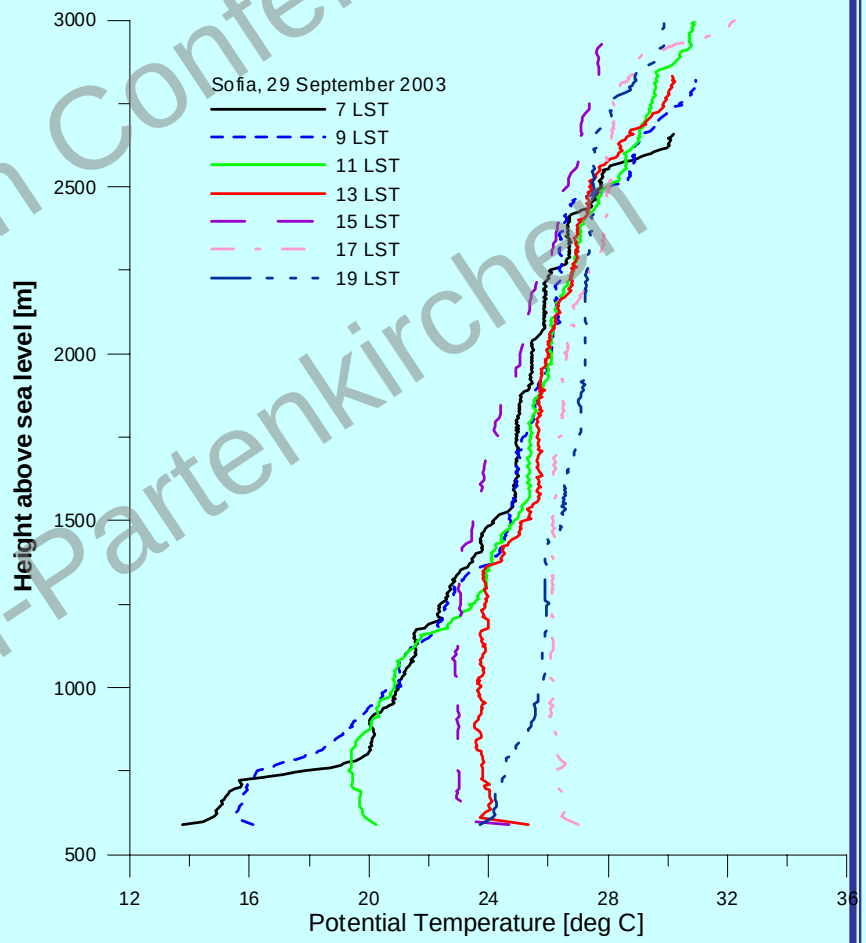
Mixed layer development -1





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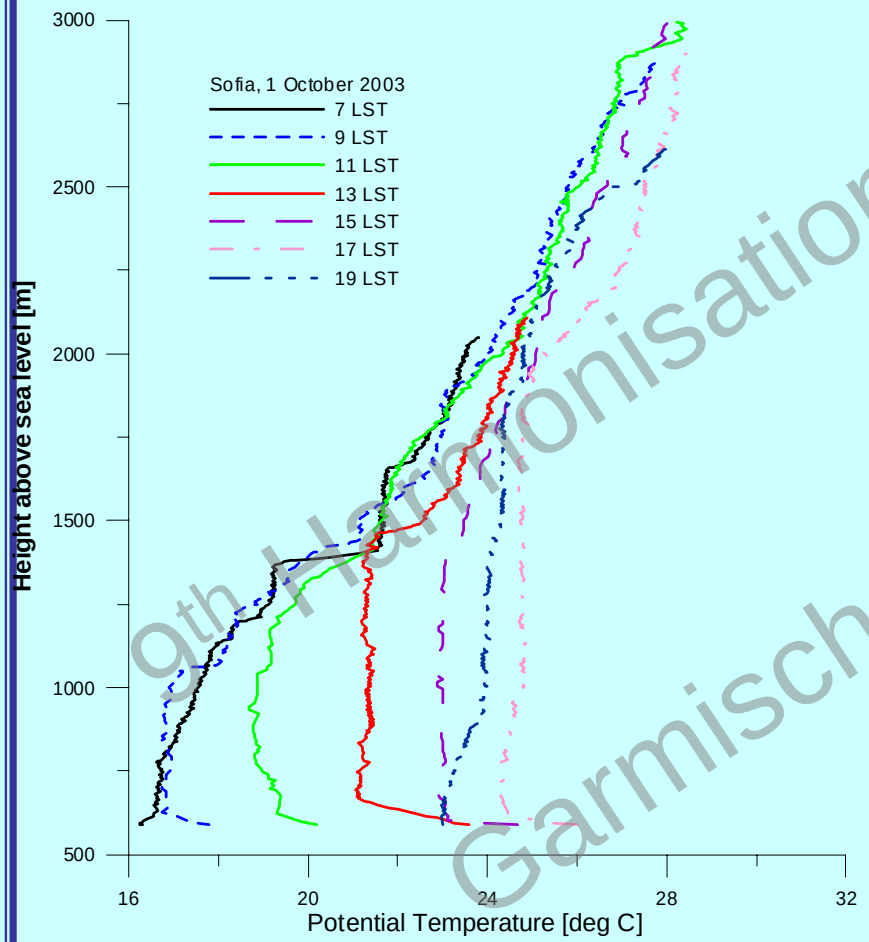
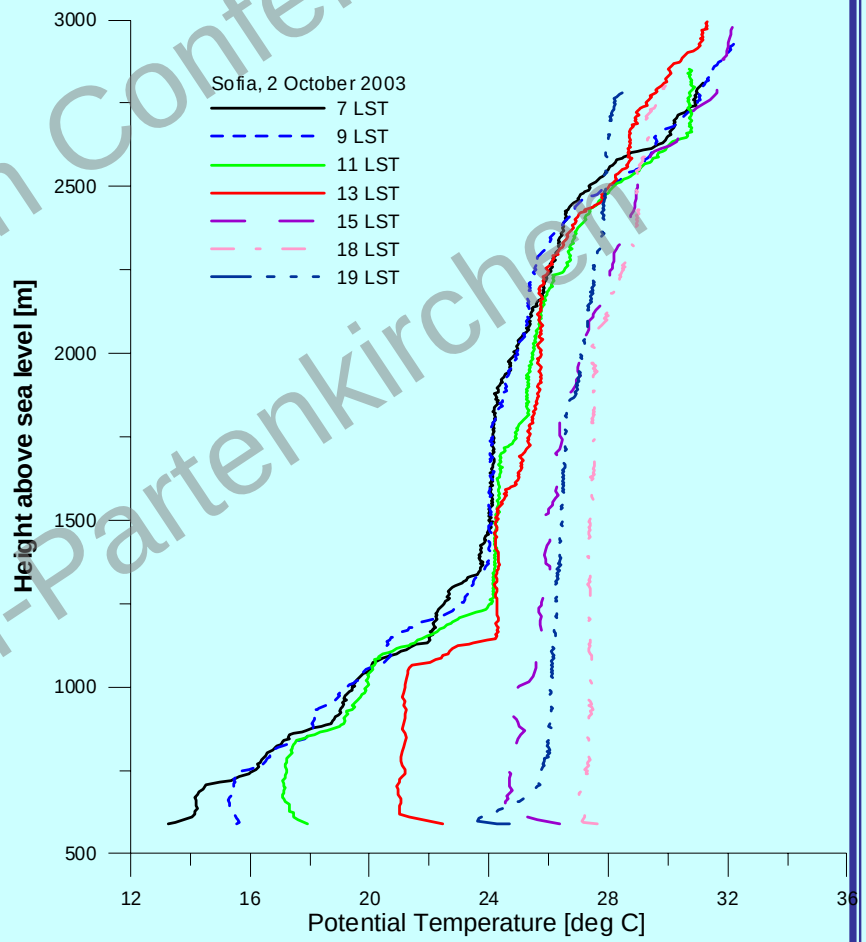
Mixed layer development -2





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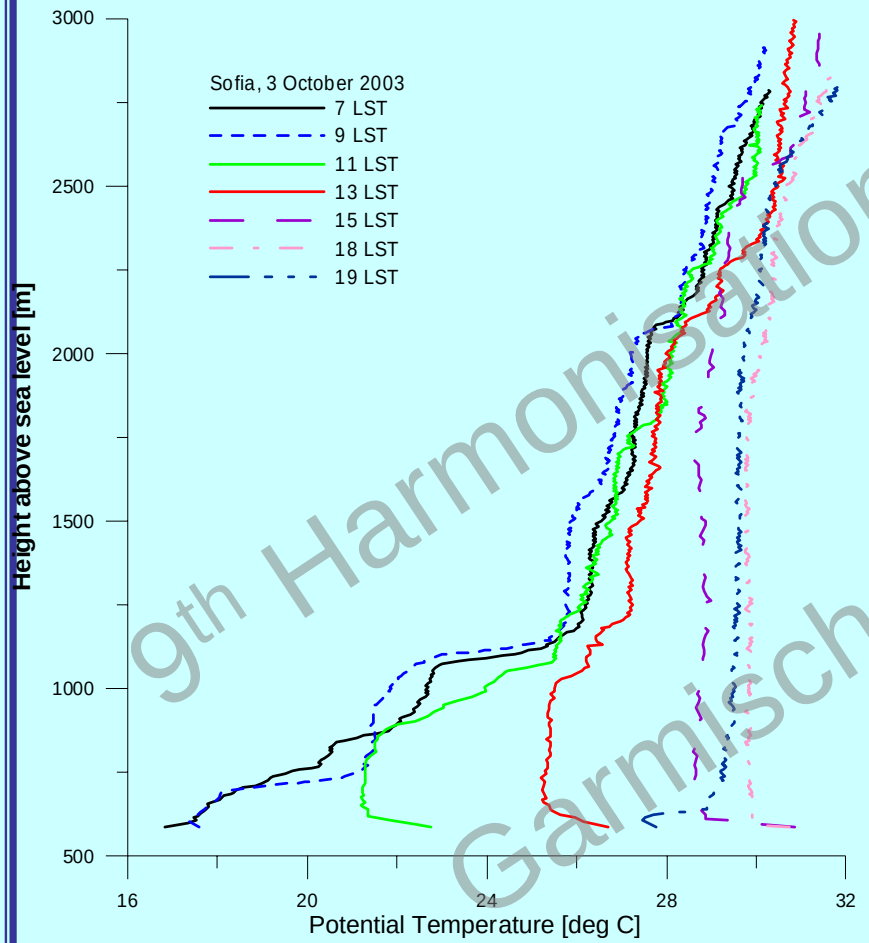
Mixed layer development - 3



- During 5 days with sunshine
- 7 successive high-resolution radiosoundings were performed starting at 7 a.m. and ending at 7 p.m. Local Summer Time

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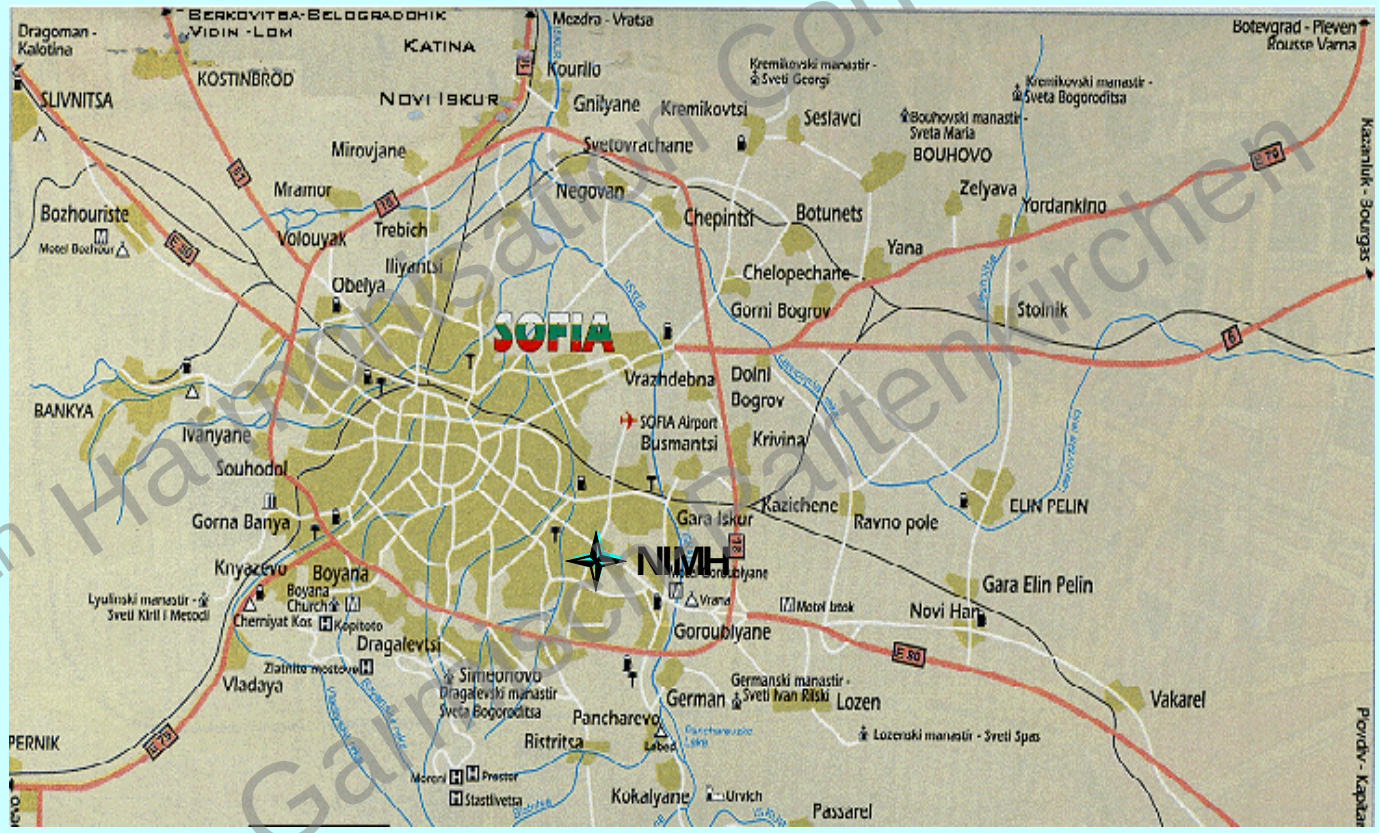
Map of Sofia and close rural areas (56 by 28 km approximately)



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Aggregation of sensible heat flux

Gryning and Batchvarova, 1999, Agric. And forest meteorol.

$$\left\{\frac{h^2}{(1+2A)h-2B\kappa L}+\frac{Cu_*^2T}{\gamma g[(1+A)h-B\kappa L]}\right\}\left(\frac{\mathrm{d}h}{\mathrm{d}t}-w_s\right)=\frac{(\overline{w'\theta'})_s}{\gamma} \quad (1)$$

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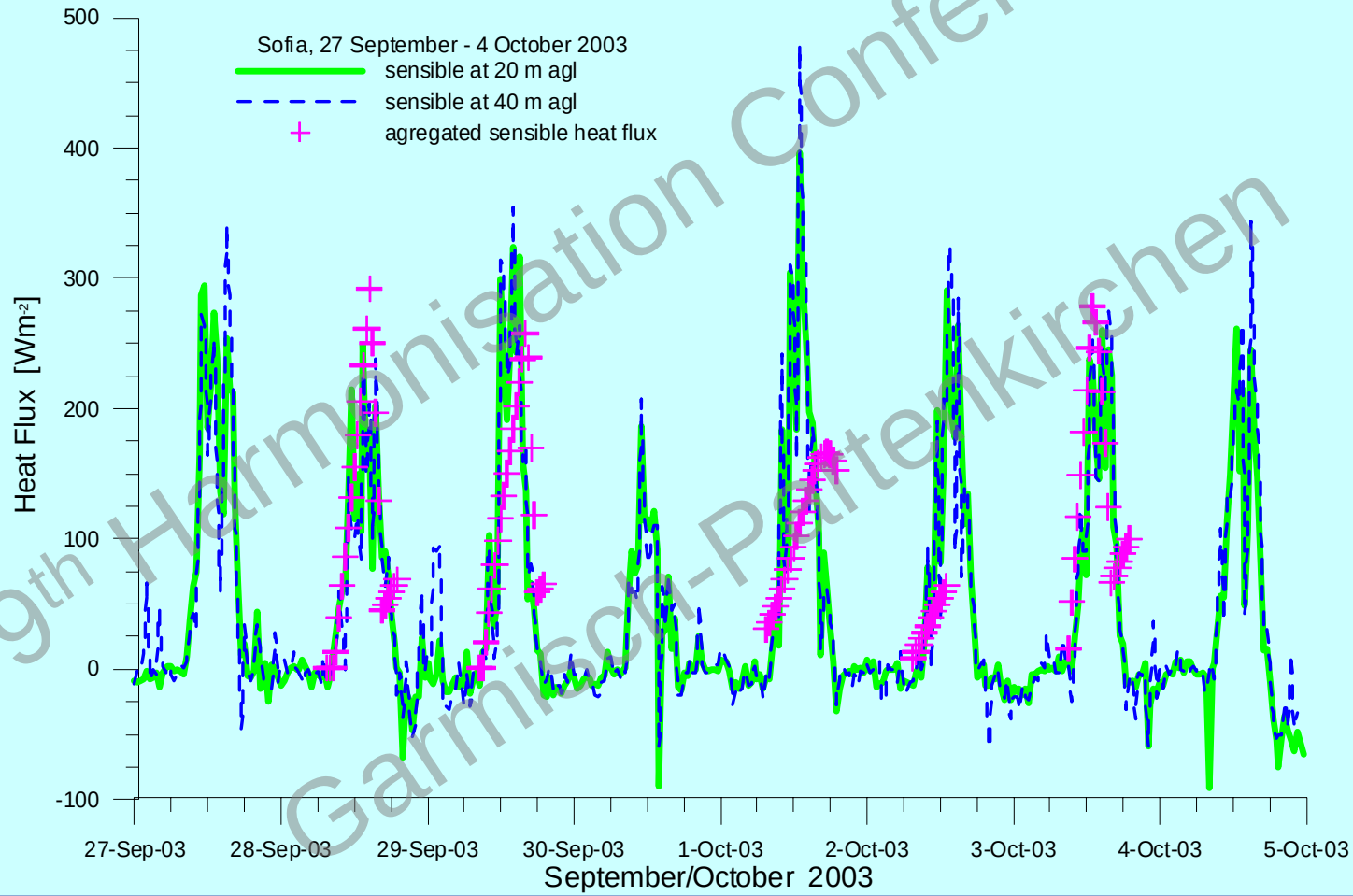
Aggregated vs measured kinematic heat flux



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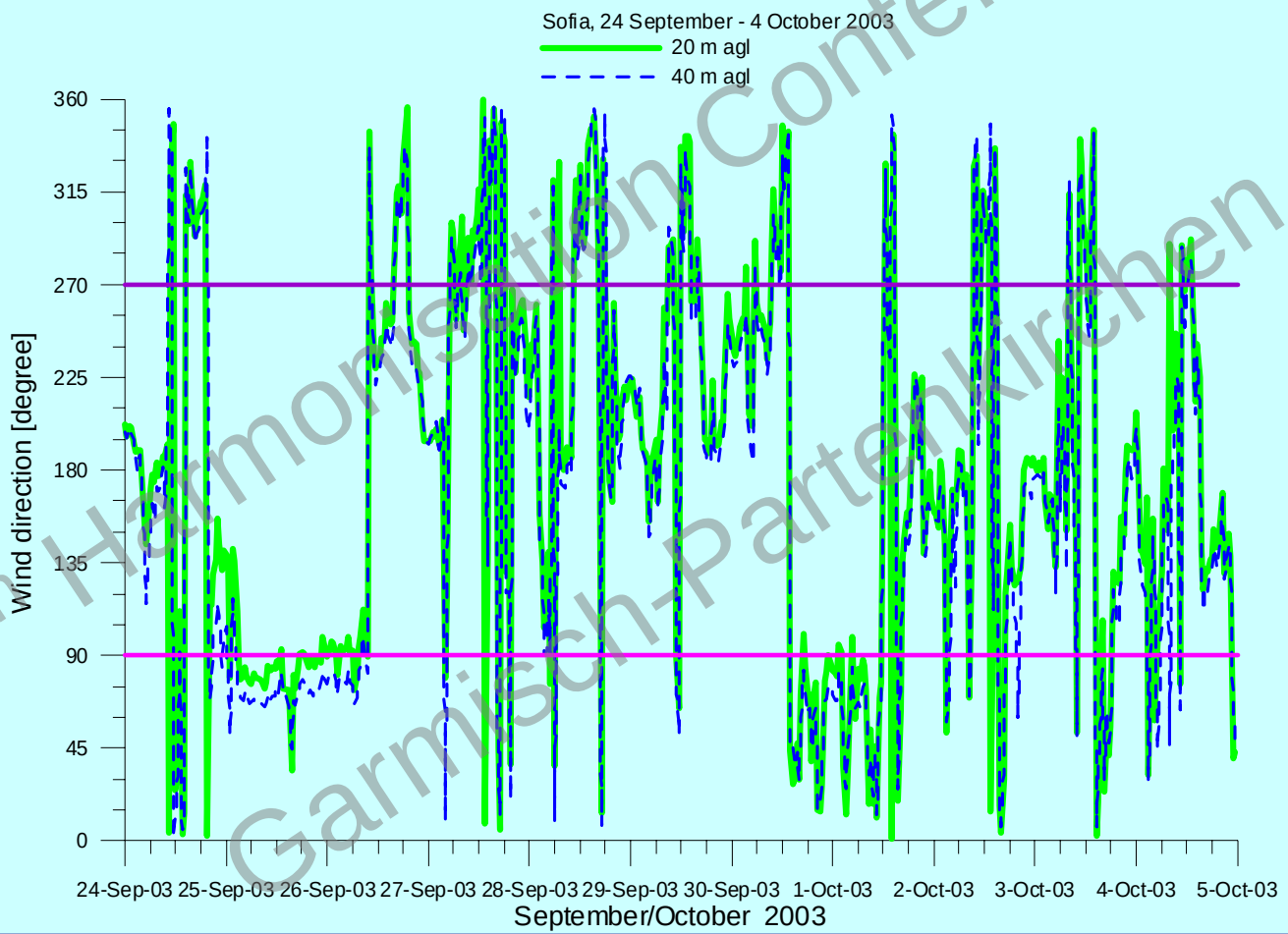
Wind direction from sonics



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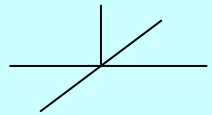
To consider

Footprint of measurements – mast (neighborhood), PBL – 20 km

Grid averaged values from models –



comparison of model results with monitoring data depends on wind direction (hourly values)

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Conclusions

- Analogy between urban and plant canopies is sound:
- The roughness sub-layer is 3-5 times the canopy height
- Over 50-100 km domain cities with their internal heterogeneity over 25-30 km are part of the larger heterogeneous area and form the aggregated turbulent fluxes that define the mixed layer growth
- Blending of flow features can be considered depending on the size of patches of different geometrical or physical surface characteristics

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