Urban workshop (Mon-14-May-2012 Brainstorm)

10:00	**Coffee and snacks reception**
10:15	Opening words (Curtis Wood & Jaakko Kukkonen)
10:20	Keynote speaker (Sue Grimmond)
11:10	Helsinki's Urban Boundary-layer Observation Network (Curtis Wood)
11:30	Scintillometer and sodar in HKI and some applications (Rostislav Kouznetsov)
11:45	Local winds in a valley city (Hannu Savijärvi)
12:00	**Break for lunch**
13:00	Helsinki's Urban Heat Island, and mobile measurements (Achim Drebs)
13:15	Eddy-covariance methods in Helsinki (Annika Nordbo)
13:30	Modelling and Observations of Helsinki fluxes of CO_2 (Leena Järvi)
13:45	Towards urban weather prediction at FMI (Carl Fortelius)
14:00	**Break (coffee provided)**
14:15	Investigation of ABL structures with ceilometer using a novel robust algorithm (Reijo Roininen)
14:30	Some aspects of LES and the potential for Helsinki (Antti Helsten)
14:45	Polar ABL studies in FMI and their relevance for wintertime UBL over Helsinki (Timo Vihma)
15:00	Valuation of ecosystem services in urban areas (Adriaan Perrels)
15:15	**Discussion/end**

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”Urban Boundary-layer Atmosphere Network”

Curtis Wood, Leena Järvi, Rostislav Kouznetsov, Ari Karppinen, Jaakko Kukkonen, Annika Nordbo, Timo Vesala, Achim Drebs, Anne Hirsikko, Sylvain Joffre, Timo Vihma, Irene Suomi, Carl Fortelius, Ewan O’Connor, Dmitri Moisseev, Markku Kangas

Thanks to co-authors and the help from many support/technical/admin staff (and many research grants including EC, Finnish Academy)

Helsinki

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Some Questions:

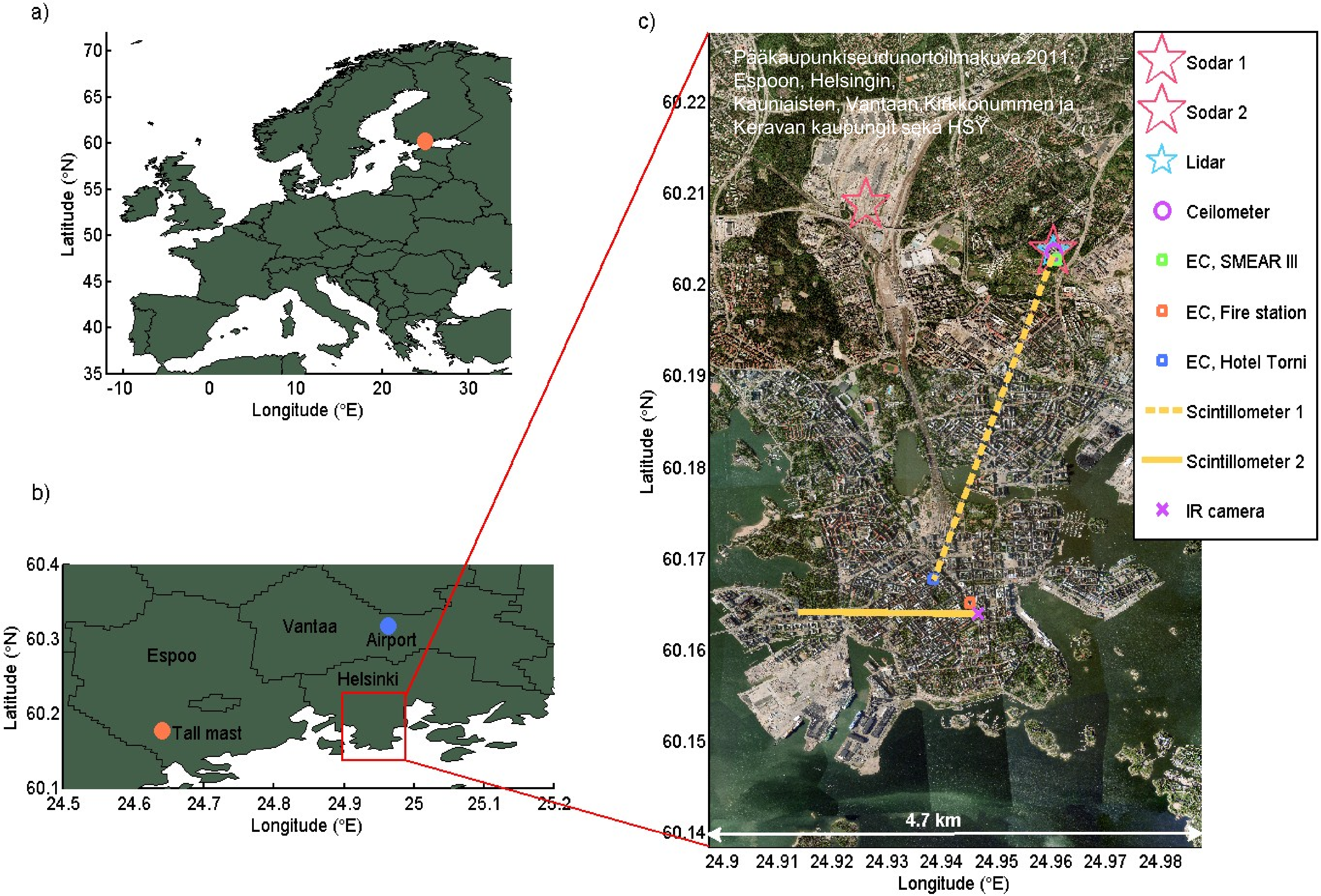
General research-grade data collection for NWP/AQ validation, improvement

Science

- 3-4D structure of Helsinki's ABL
- Effects of urban snow
- Anthropogenic heating

Technology

- Area-average heat flux
- Morphology datasets



Map made by Annika Nordbo, from HSY data

Key instrumentation:

Instrument/set	Raw information	Science output
Eddy covariance	20Hz u,v,w,Ts, concentration	**Fluxes** (heat, moisture, momentum, etc); **Turbulence statistics**
SODAR	Profile of acoustic backscatter	Temperature gradient variations with height – hence **ABL depth (+ profile of vertical velocity)**
Lidar (/ceilometer)	Doppler backscatter profile of concentration	**Profiles** of aerosol, wind speed and direction, turbulence
Thermal camera	Longwave emission from pixels	Temporal and spatial variation of **emission temperature**
Scintillometer	Temporal variation in backscatter intensity	Temperature structure parameter - possibly **flux of heat**

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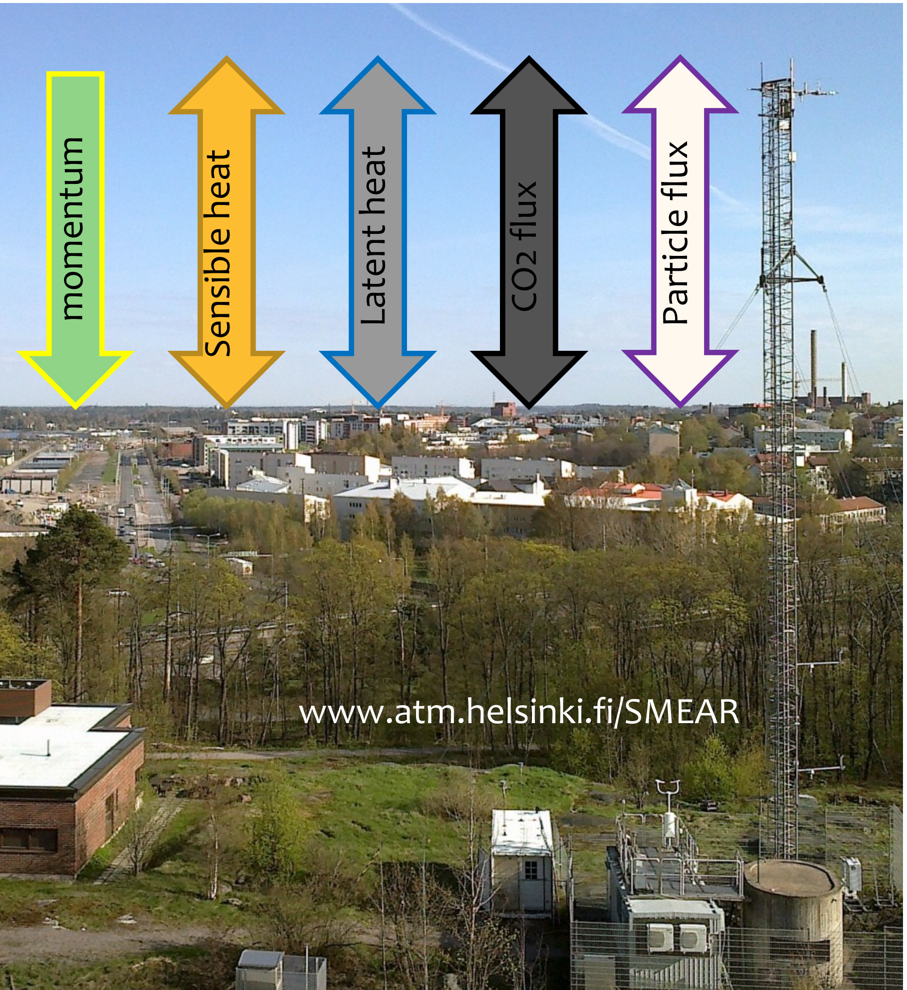
Flux stations

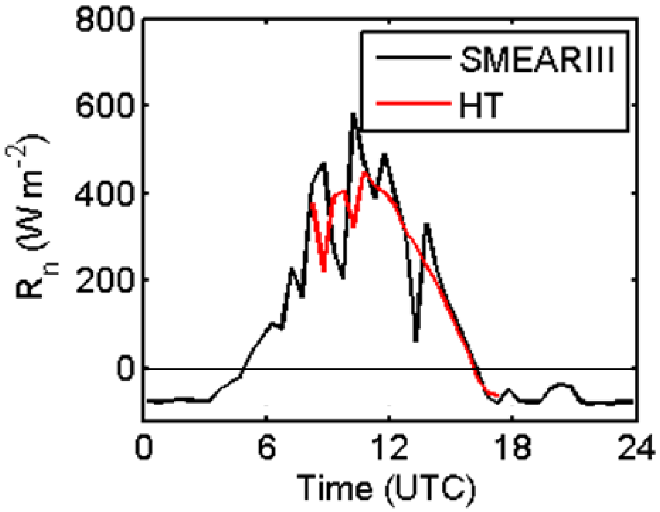
- Eddy-covariance method
- Tower-based measurement
- SMEAR-III, Torni (+more)



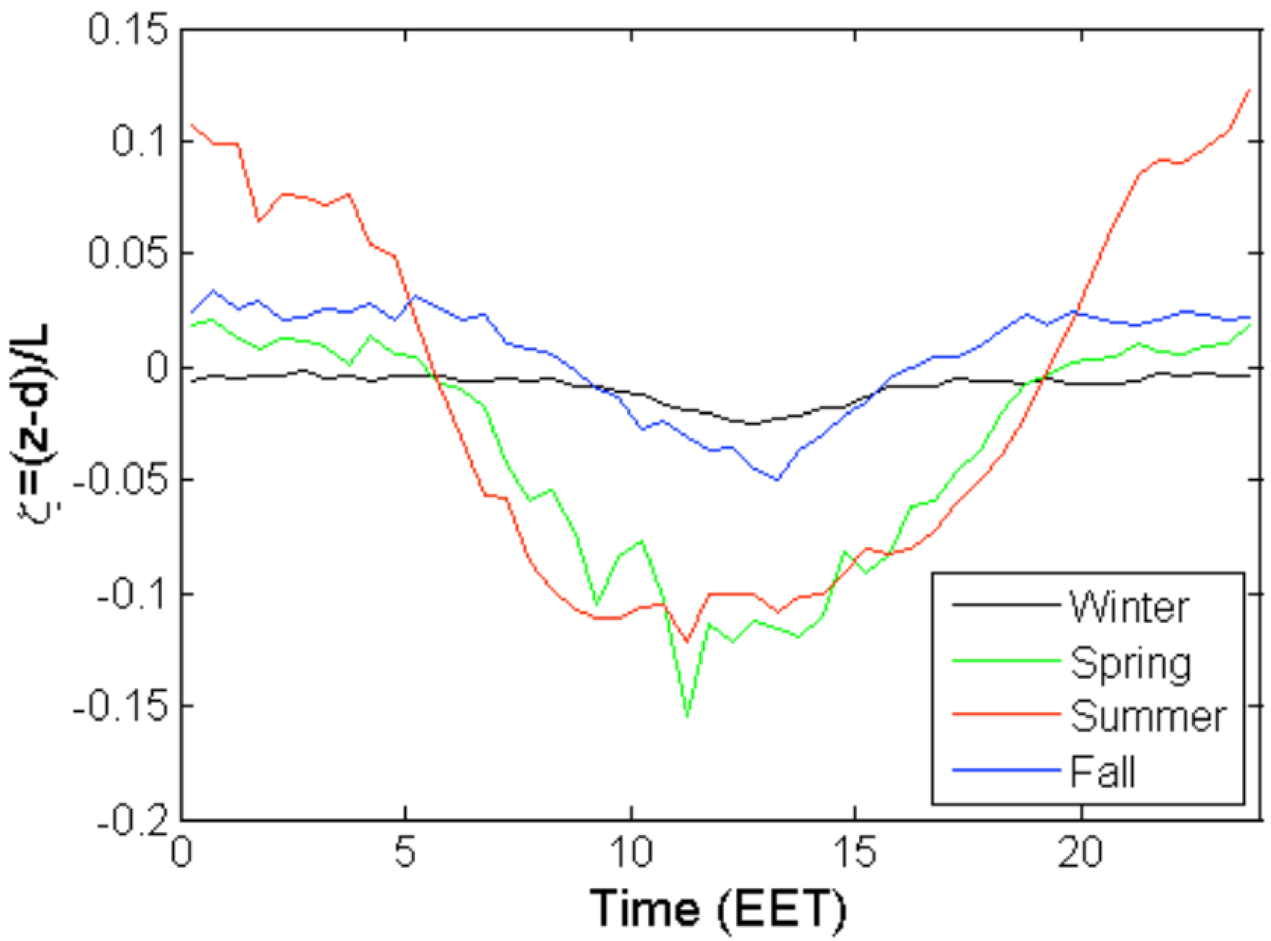
1st case-study in this presentation:

✓ 4th September 2011

✓ Mostly clear skies (cumulus)



SMEAR-III



Strong seasonality

Stable nights in spring/summer

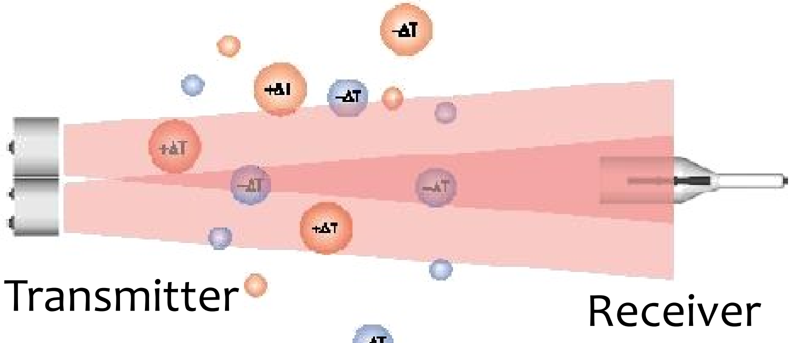
Cloudy winter

Koskiken et al. 2011 (TestBed)

Scintillometer

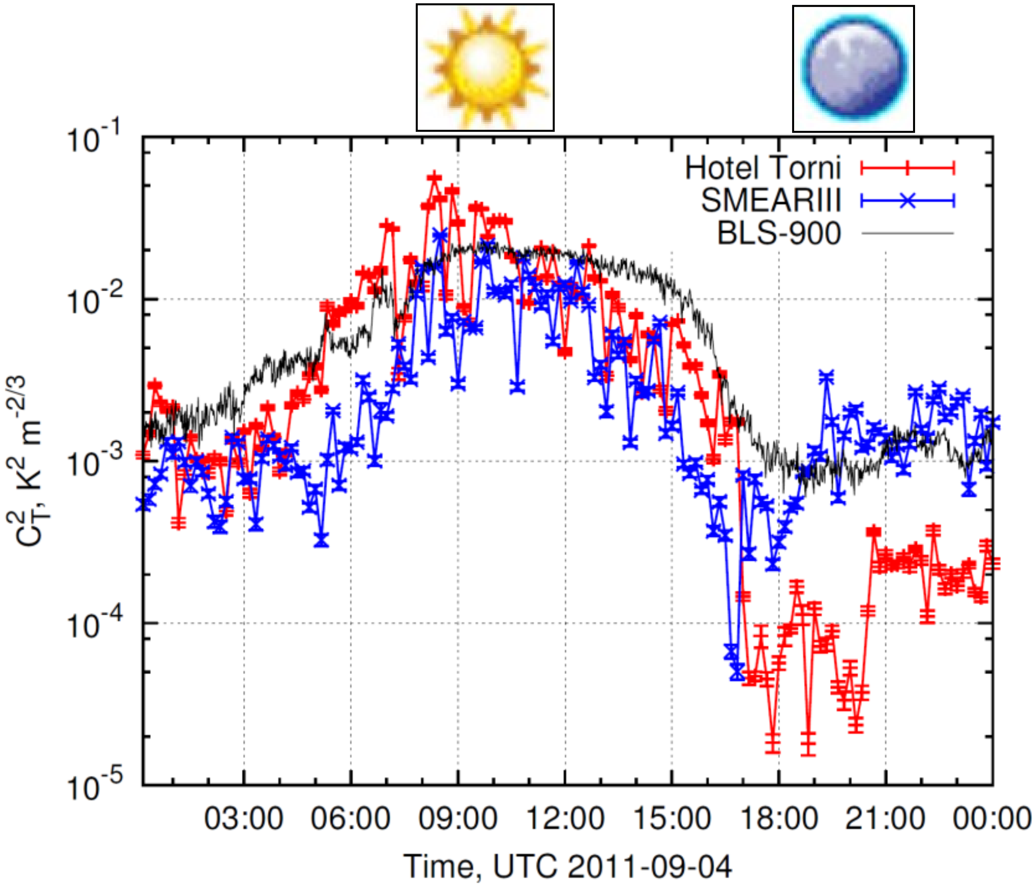
- ✓ Scintillations (twinkling)
- ✓ Related to vertical temperature gradient

4.3km path Kumpula-Torni



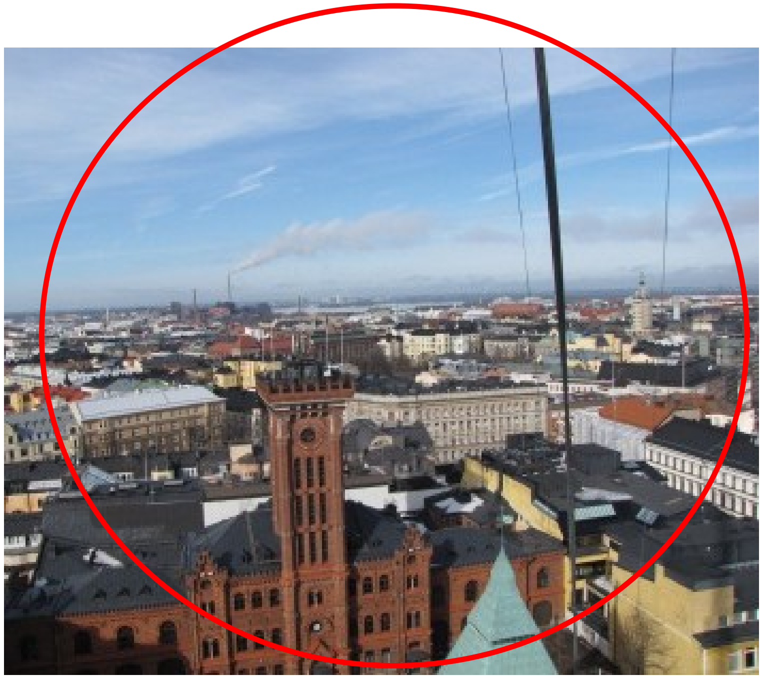
Structure parameter:

(think of the sign of H)

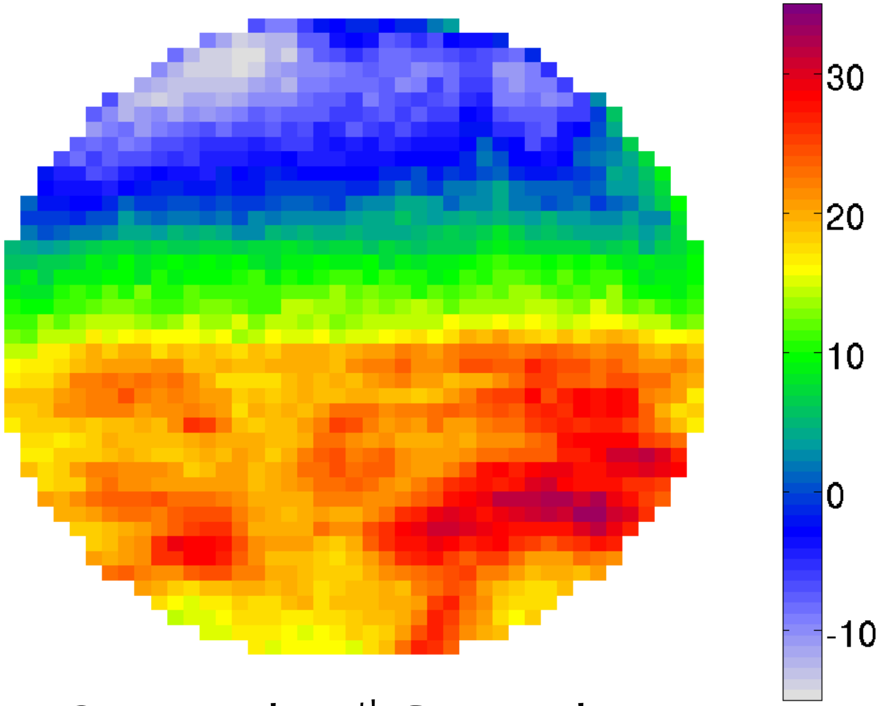


Infra-red camera

- ✓ Brightness temperature (longwave emission)
- ✓ Somewhat coincident with flux-tower footprint
- ✓ Needs development of science usefulness



Looking west from Elisa tower



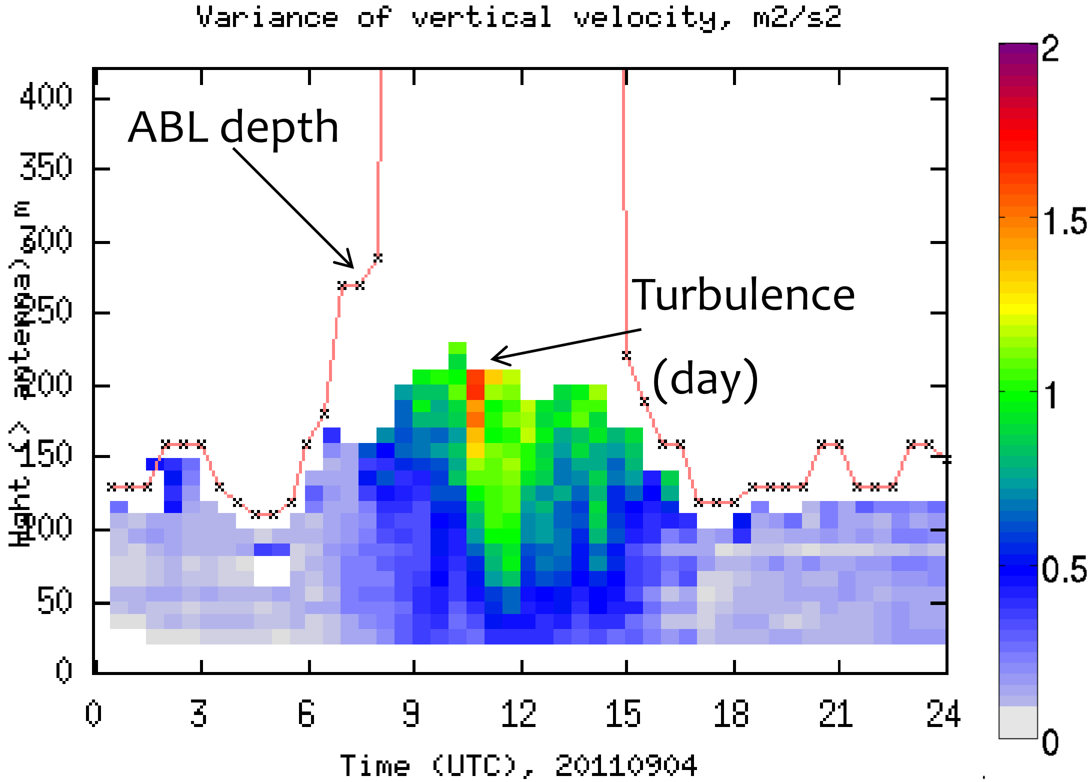
Case-study: 4th September 2011

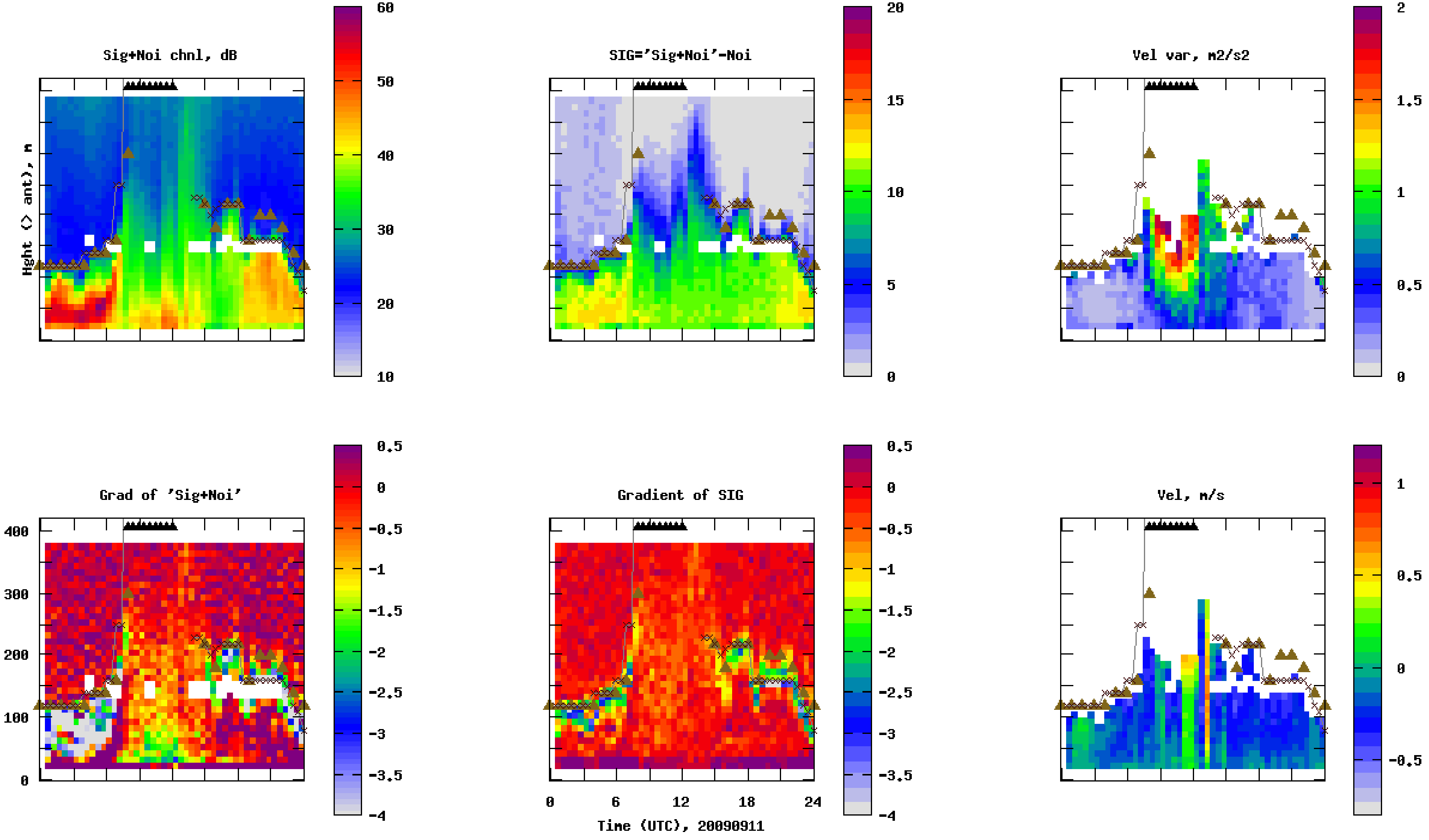
Sodar

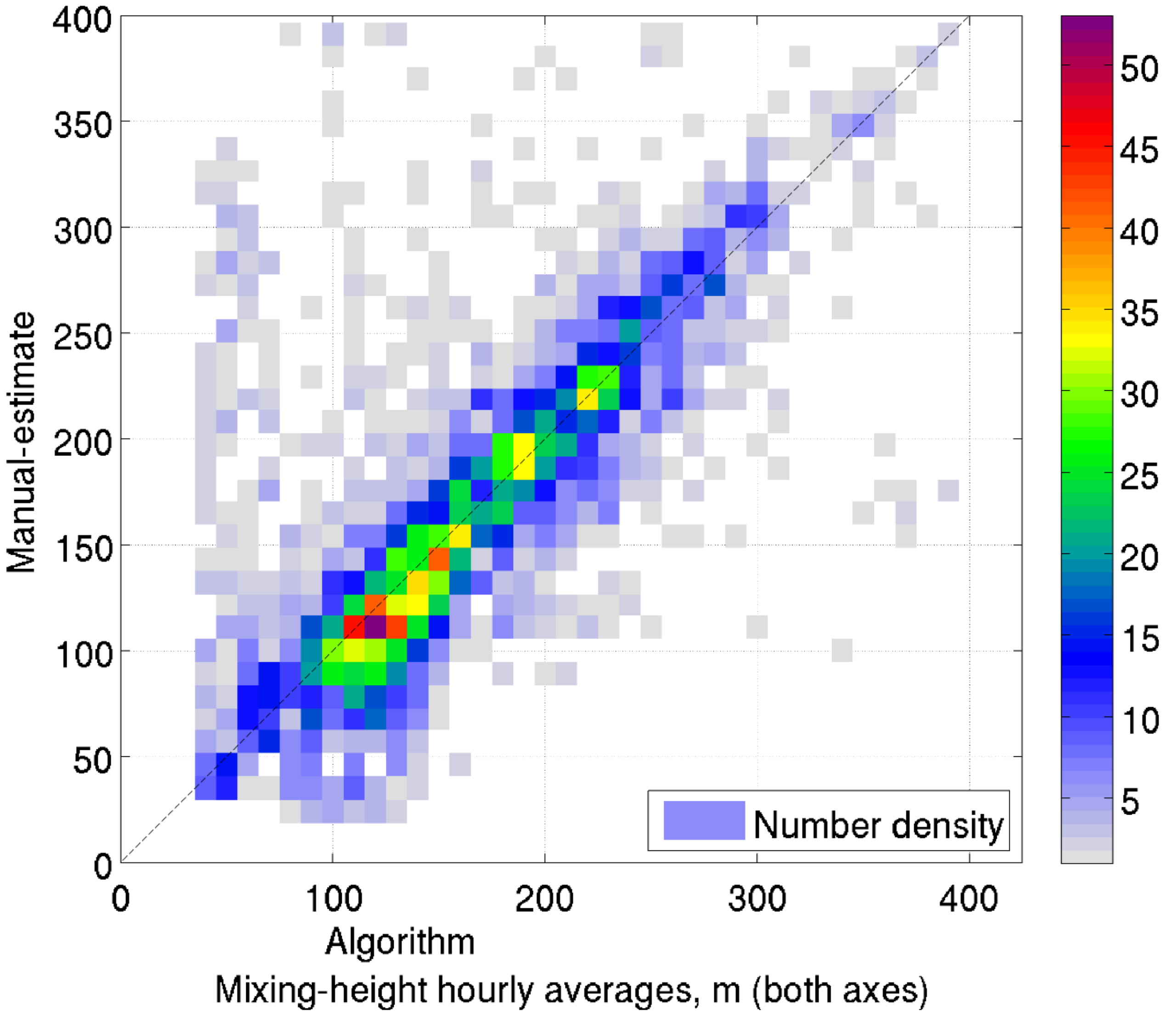
- Single vertically-pointing antenna (1D)
- 5 s sounding interval
- 20-400m range; with 10-m resolution
- Kumpula, then Pasila

Variables:

- Profile of vertical velocity
- Atmospheric boundary-layer depth (based on backscatter gradient)

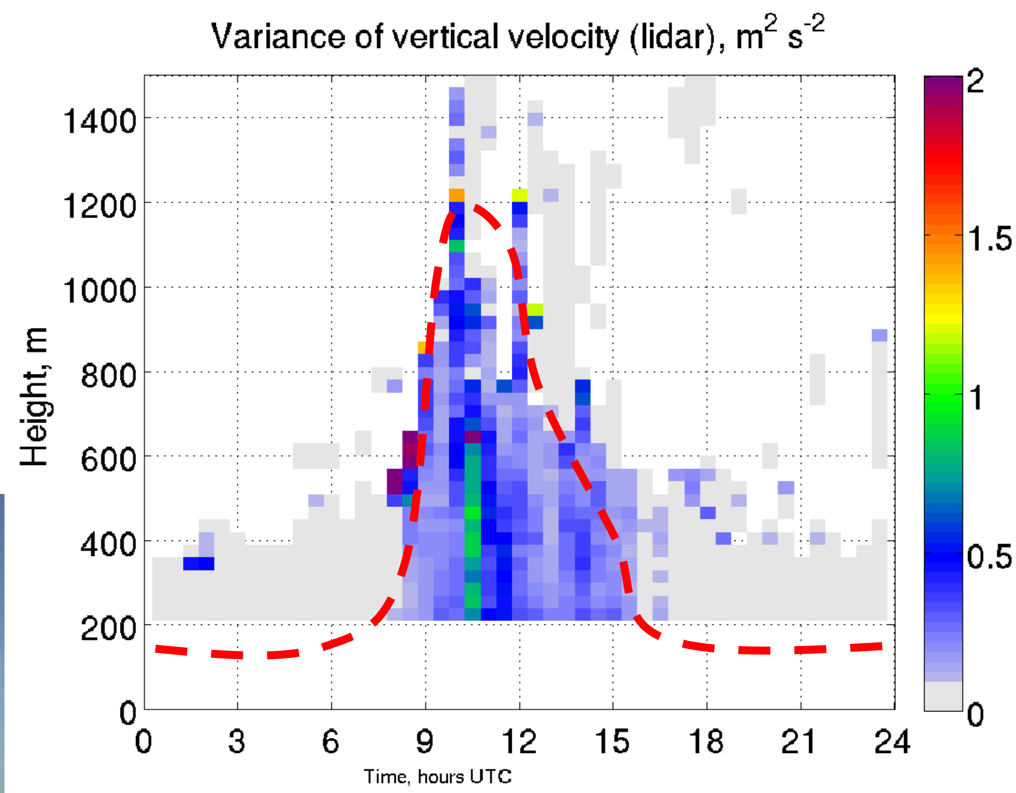



Sig+Noi chnl, dB
SIG='Sig+Noi'-Noi
Vel var, m2/s2
Hght (> ant), m
Grad of 'Sig+Noi'
Gradient of SIG
Vel, m/s
400
300
200
100
0
0
6
12
18
24
Time (UTC), 20090911
60
50
40
30
20
10
20
15
10
5
0
2
1.5
1
0.5
0
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1
0.5
0
-0.5


400
350
300
250
200
150
100
50
0
Manual-estimate
0
100
200
300
400
Algorithm
Mixing-height hourly averages, m (both axes)
Number density
50
45
40
35
30
25
20
15
10
5

Lidar

- HALO Photonics Streamline
- Several km range (~30m resolution)
- Vertical profiles: turbulence, wind, aerosol (e.g. pollution or volcanic ash)
    - Boundary-layer depth
- Custom scans (any angle)



- Deep ABL seen by lidar
- Shallow ABL seen by sodar

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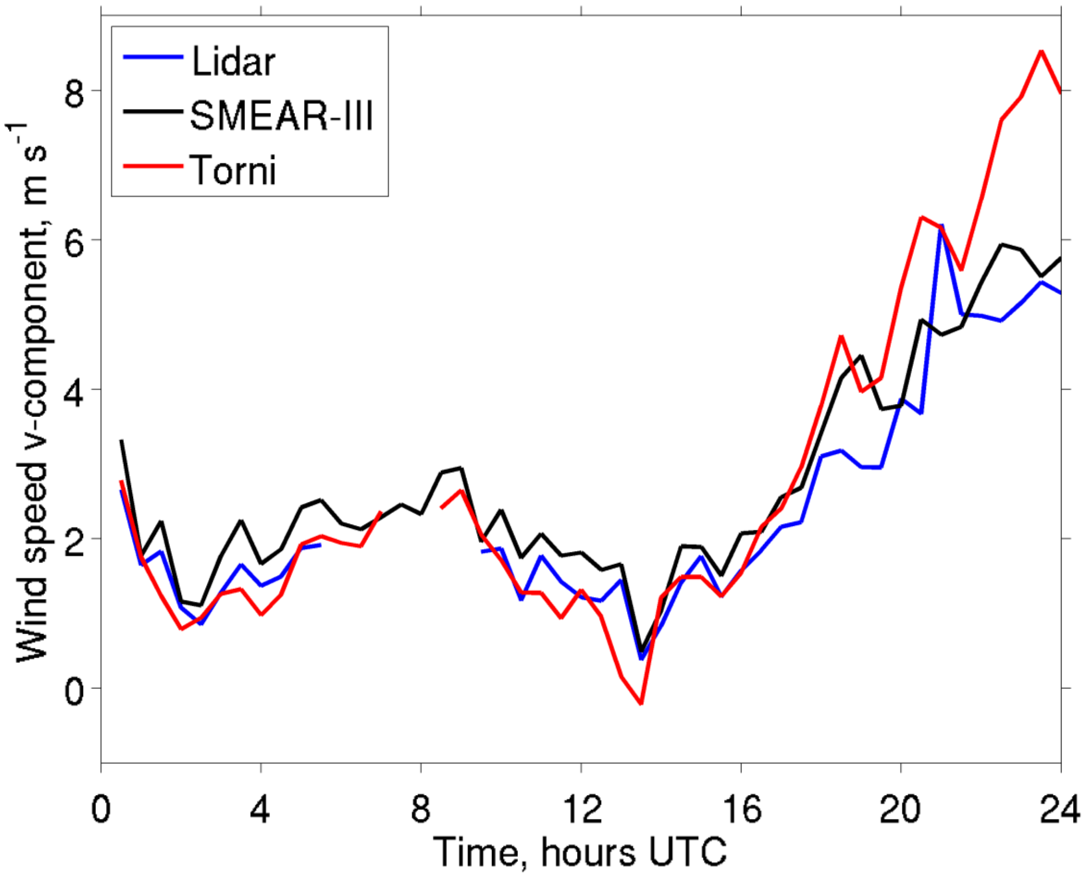
Intercomparison

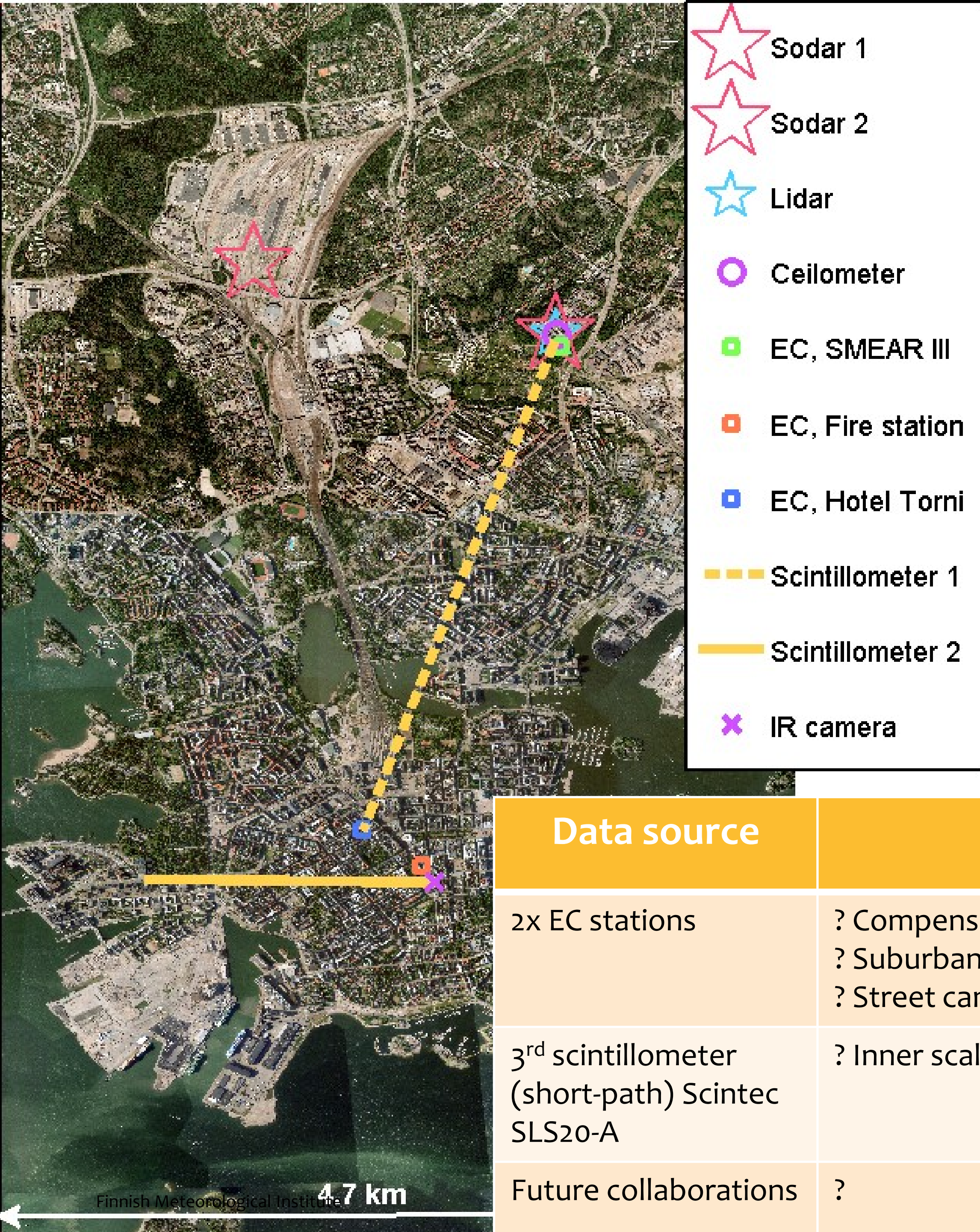
Case-study 2:
03 January 2012



r = 0.96
rmse = 0.48 m/s
bias= –0.23 m/s (SMEAR-III greater than lidar)

Auxiliary measurements:

Data source	Science output
Doppler radars	2D meso-scale flow field
Soundings (AMDAR, radiosonde)	Vertical profiles of T, U, dd, RH
Tall masts (Espoo, Isosaari)	Vertical profiles of T, U, dd, RH
Satellite analyses	Surface temperature, gas concentrations
Building and traffic data	Building morphology (relate to fluxes of momentum, heat), also anthropogenic flux



New/planned measurements:

Data source	Science output
2x EC stations	? Compensate for tower flow distortion missing sectors ? Suburban ? Street canyon
3rd scintillometer (short-path) Scintec SLS20-A	? Inner scale of turbulence
Future collaborations	?

SWOT analysis for the observation network

Strengths:

- ✓ Growing observational network
- ✓ Some high-quality local expertise in both modelling and observations (e.g. Zilitinkevitch & ERC grant)
- ✓ Some collaboration with corresponding UK studies
- ✓ Helsinki TestBed
- ✓ Unique site (strong seasonality, high-latitude)

Weaknesses:

- ✓ No tall tower
- ✓ Moderate current funding
- ✓ Not lots of long-term expertise
- ✓ No street canyon work

Opportunities:

- ✓ Write proposals
- ✓ Bring together many people/skills (e.g. workshops)
- ✓ Connect with companies and customers (e.g. Vaisala, HSY)

Threats:

- ✓ Skills too varied?
- ✓ Not many people’s priority
- ✓ No external future funding?

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Conclusion: we have a growing basket of fruit. We've eaten some individual fruits, but now we need to make a fruit salad ☺

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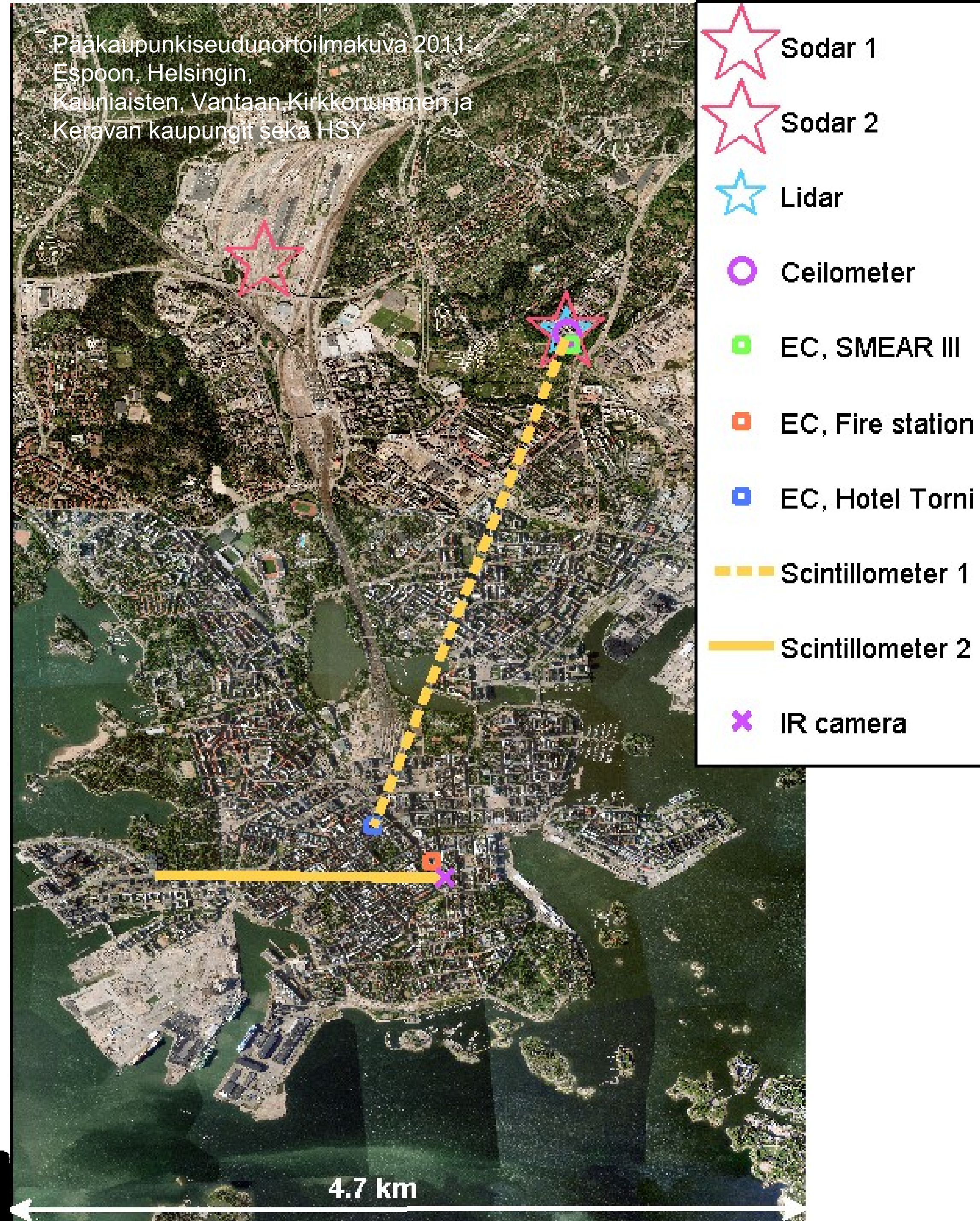

Scintillometer and sodar in HKI and some applications

- Scintillometer:
- setup
- CT2 example
- Sodar
- setup
- PBL verification for NWP

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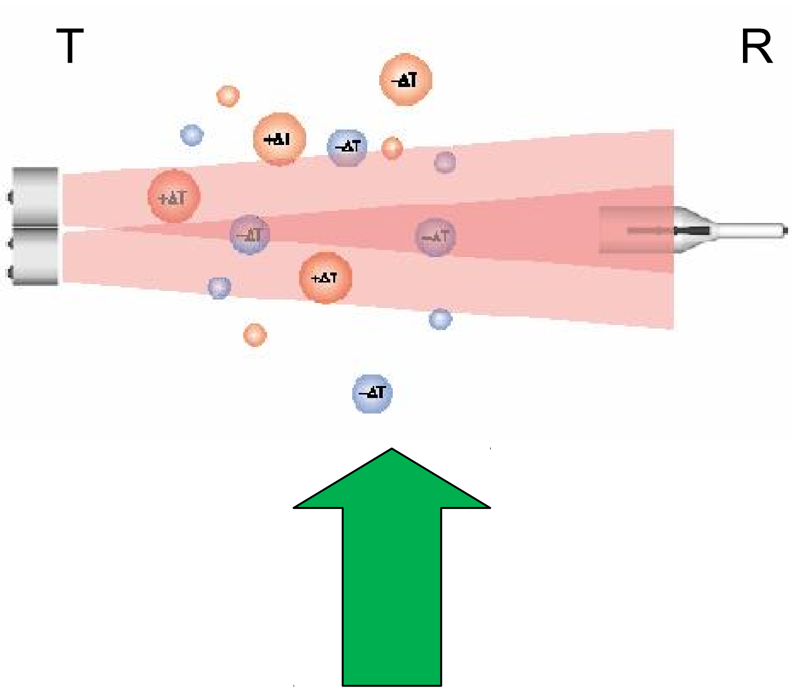
Scintillometer (background)

Scintillation – twinkling

T R



Measures **path-averaged** Cn2, Cross-wind

The "2/3" law:

$$(X(\vec{r}_1) - X(\vec{r}_2))^2 = C_X^2 r_{12}^{2/3}$$

Function of dissipation rates

$$C_T^2 = C_\theta \frac{\varepsilon_T}{\varepsilon^{1/3}}$$

Monin-Obukhov similarity (surface layer)

$$\frac{z^{2/3} C_T^2}{T_*^2} = g_t(z/L)$$

Free-convection limit

$$\langle wt \rangle = 1.16 \kappa z \cdot (C_T^2)^{3/4} (g/T)^{1/2}$$

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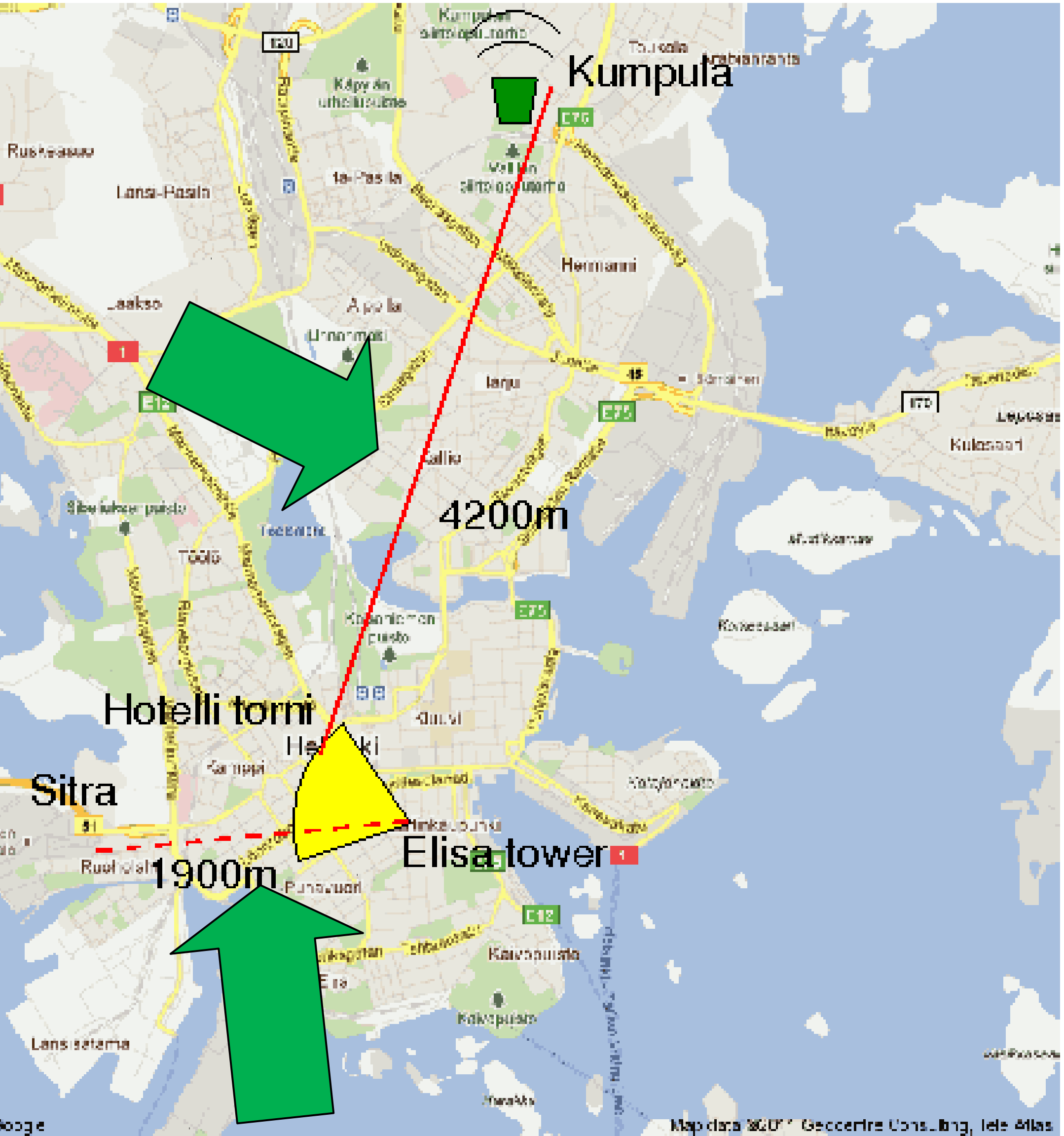
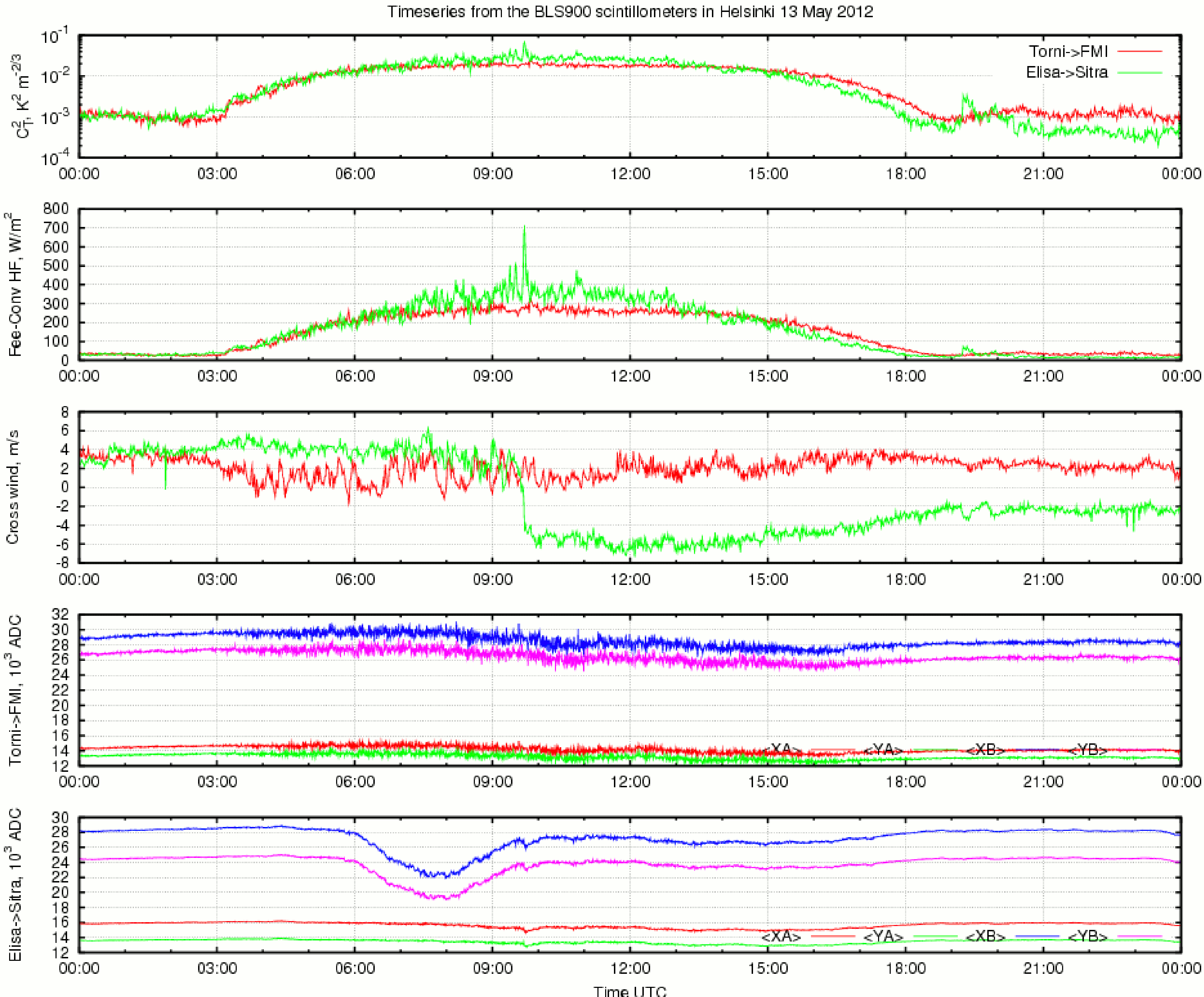
Scintillometer setup



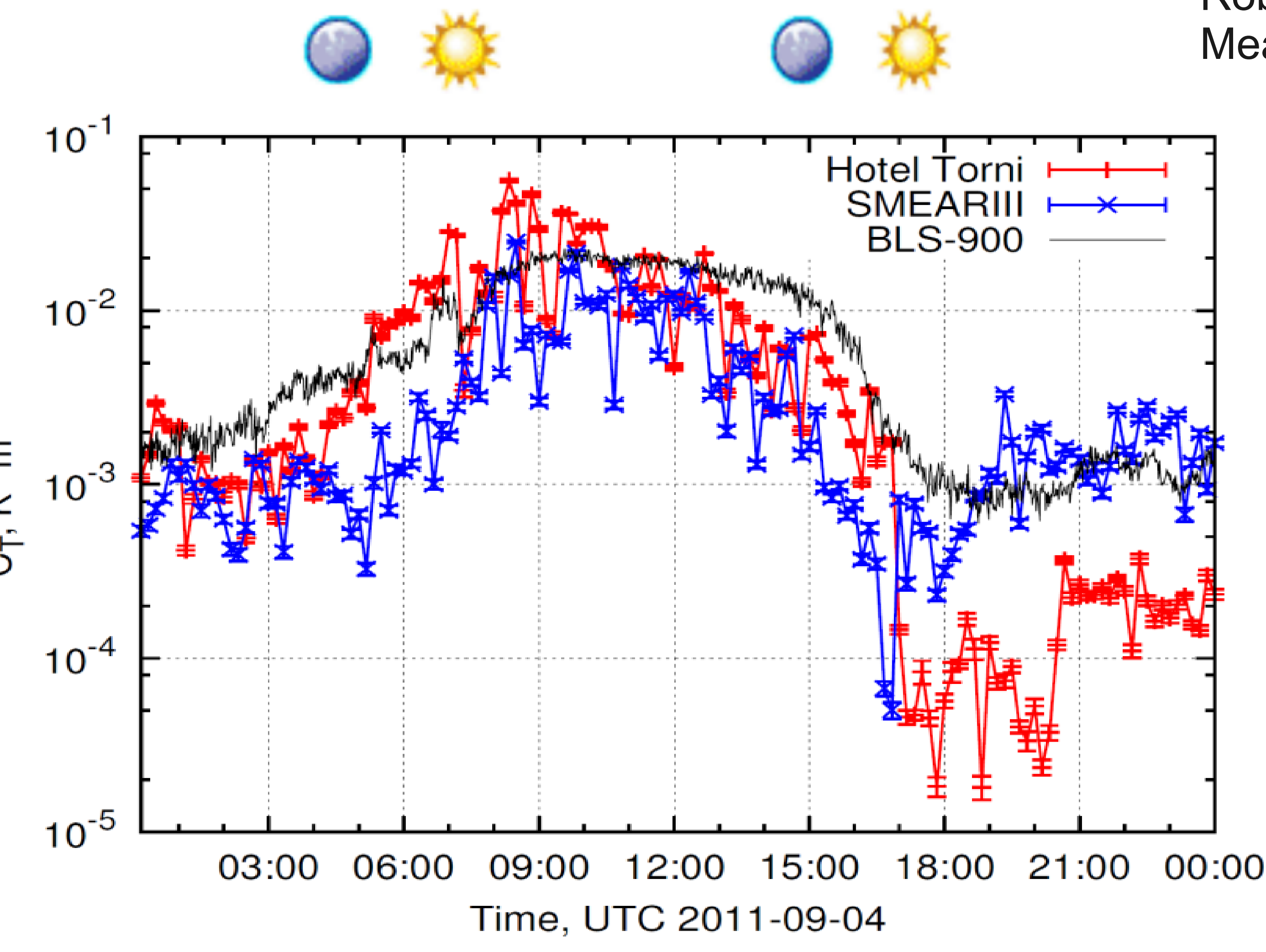
- 2 wind components
- CT2 over 2 paths
- ~50 m a.g.l



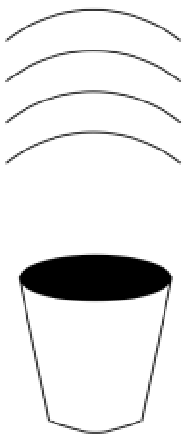
Timeseries from the BLS900 scintillometers in Helsinki 13 May 2012
C_T^2, K^2 $m^{-2/3}$
Torni->FMI
Elisa->Sitra
Fee-Conv HF, W/m^2
Cross wind, m/s
Torni->FMI, 10^3 ADC
Elisa->Sitra, 10^3 ADC
<XA>
<YA>
<XB>
<YB>
Time UTC

Sci vs. sonic

Path-averaged
High temporal resolution
Robust
Measure of turbulence



SODAR



Single antenna:

- Delay – distance. $z = ct/2$
- Frequency shift – radial velocity. $v_r = c\Delta f/(2f)$
- Intensity – intensity of temperature fluctuations.. $R \propto C_T^2$

Three antennae:

- Wind speed profile
- Variances of radial components.

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Sodar in HKI

- Single vertically-pointing antenna (1D)
- 5 s sounding interval
- 20-400m range; with 10-m resolution
- Kumpula (2009-2011,single freq)
- Pasila (2012- , multiple frequency)

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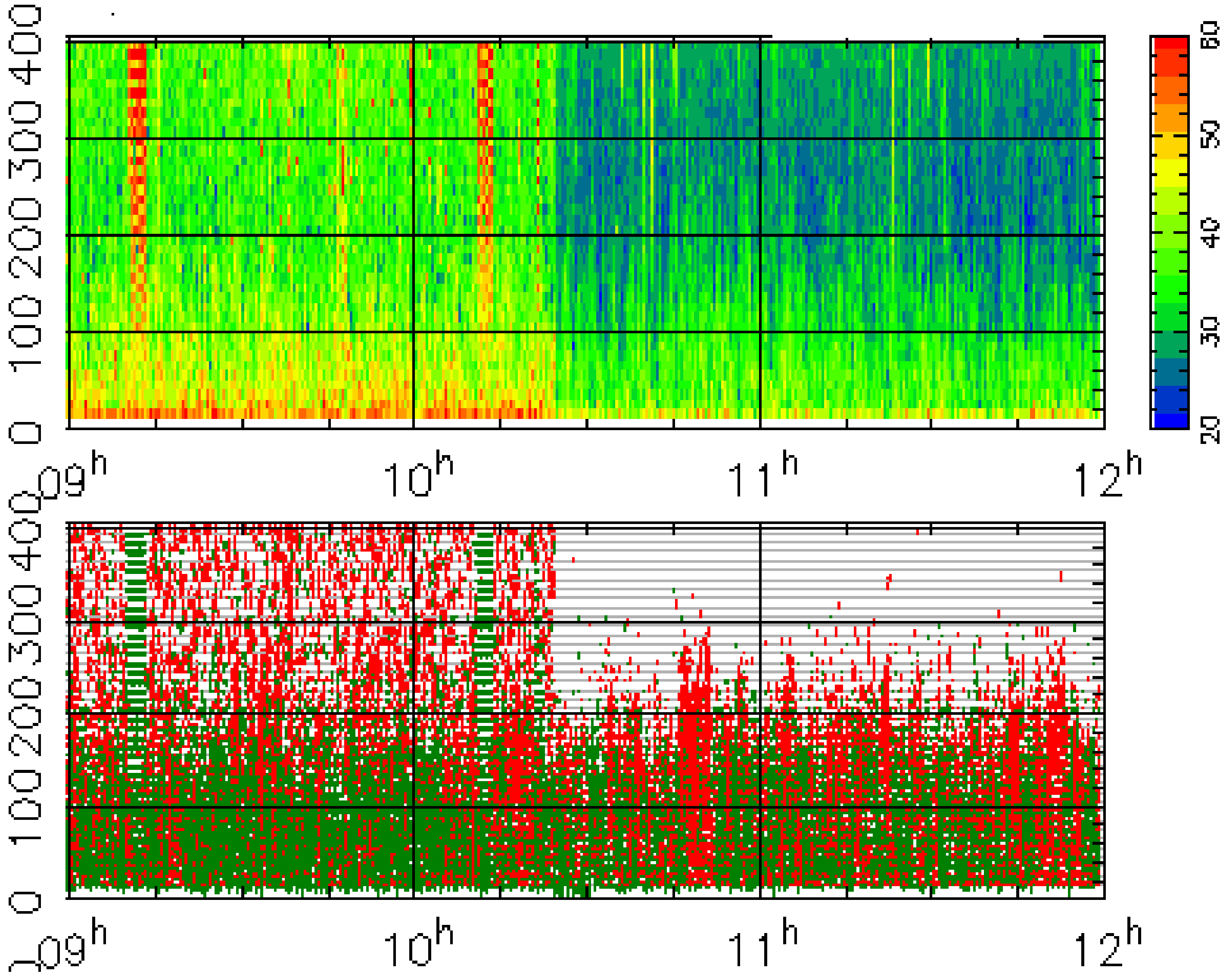
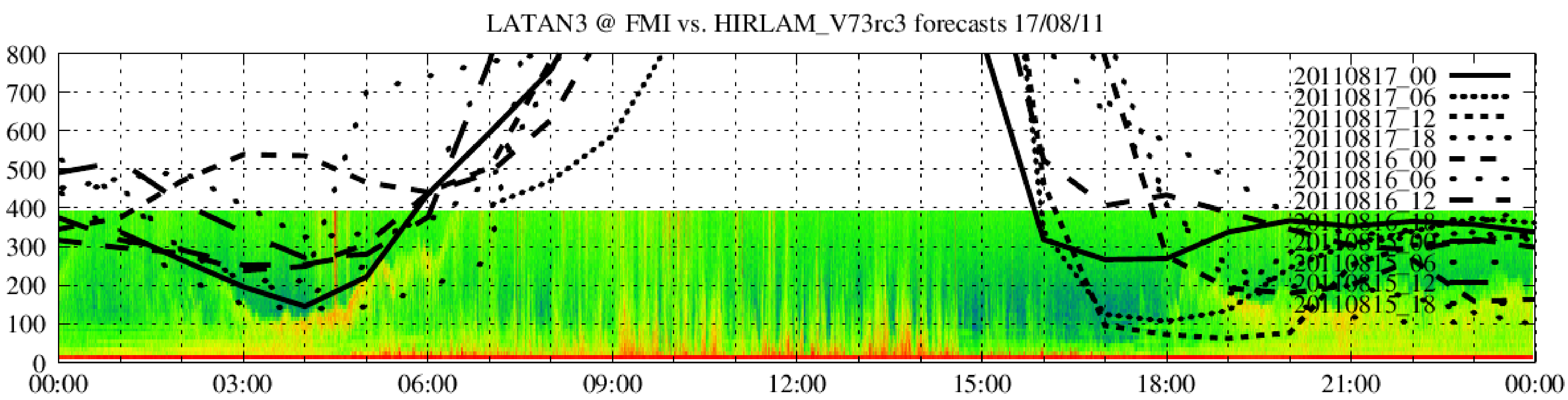
One vs. six frequencies

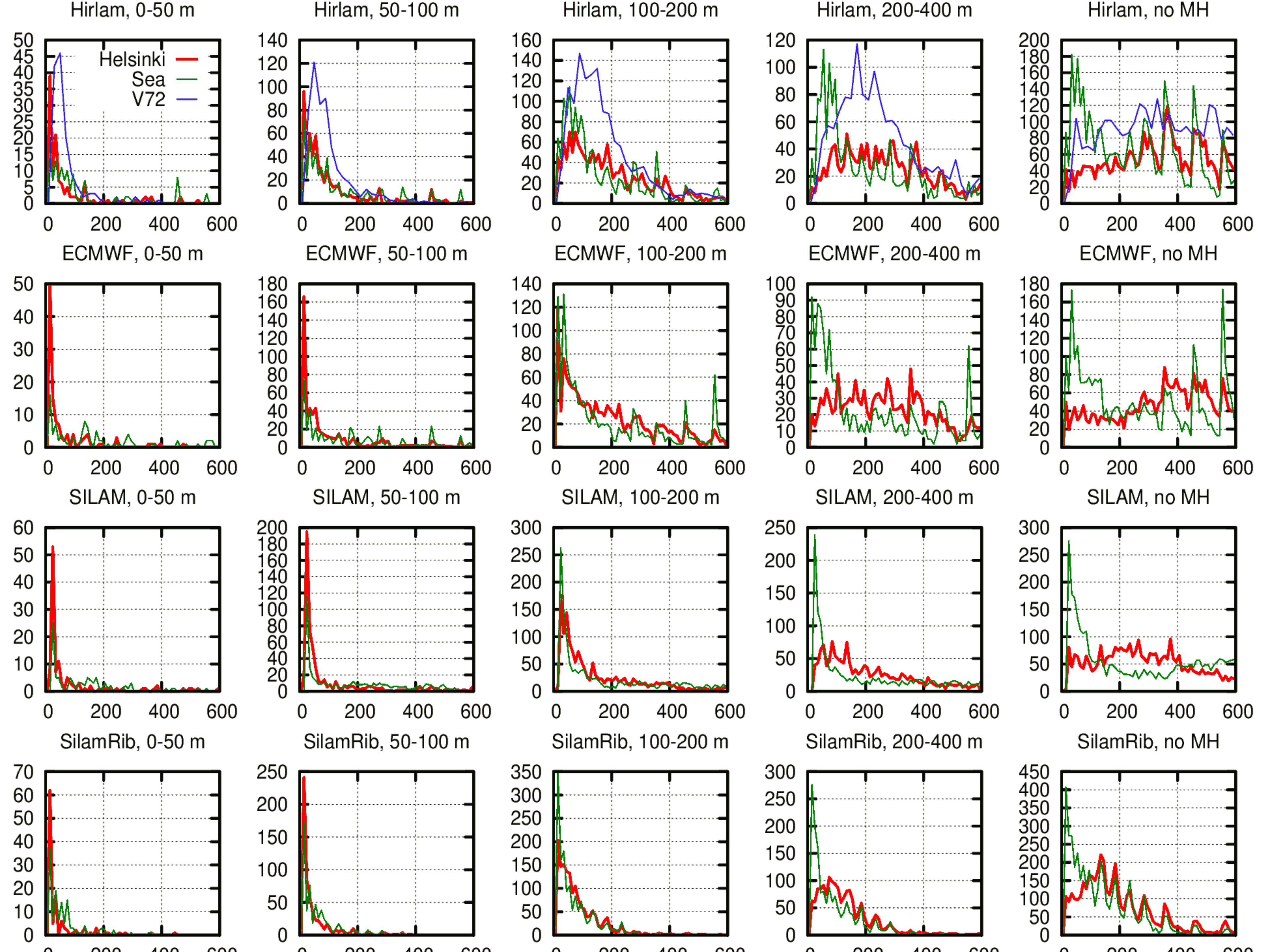


Verification of BLH in NWP models

- BLH is not directly used in NWP
- Poorly verified
- Of critical importance for AQ



- Measurements classified in 5 ranges
- For each range the distribution of model PBL height and hit-rate evaluated


Hirlam, 0-50 m
Hirlam, 50-100 m
Hirlam, 100-200 m
Hirlam, 200-400 m
Hirlam, no MH
Helsinki
Sea
V72
ECMWF, 0-50 m
ECMWF, 50-100 m
ECMWF, 100-200 m
ECMWF, 200-400 m
ECMWF, no MH
SILAM, 0-50 m
SILAM, 50-100 m
SILAM, 100-200 m
SILAM, 200-400 m
SILAM, no MH
SilamRib, 0-50 m
SilamRib, 50-100 m
SilamRib, 100-200 m
SilamRib, 200-400 m
SilamRib, no MH

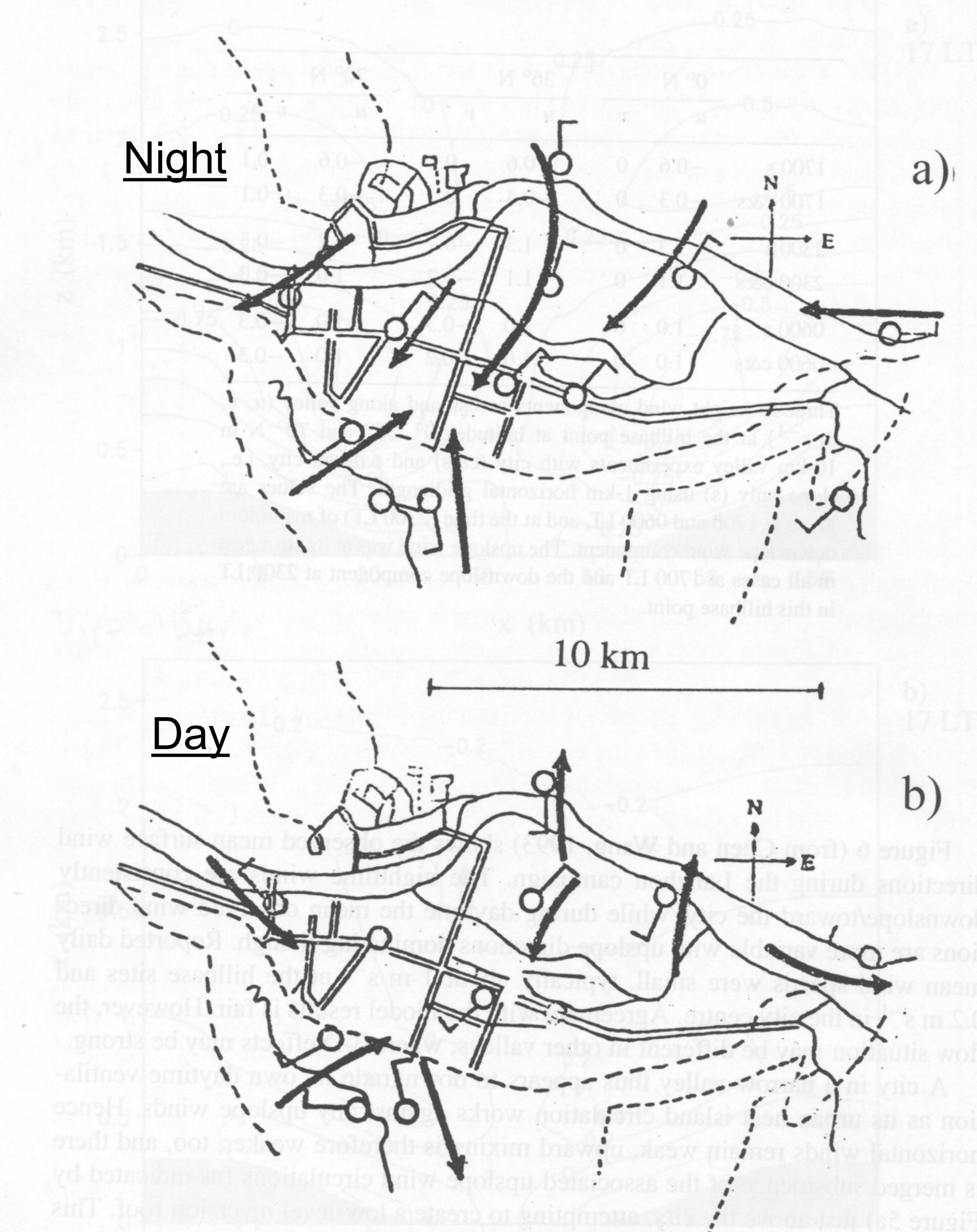
Final remarks

- Scintillometer
  - Robust, spatially averaged
  - Turbulence in urban PBL
  - Can't be directly used for fluxes
- Sodar
  - PBL vertical structure, incl. PBL height
  - Used for verification of PBL in NWP models

Local winds in a (valley) city

Hannu Savijärvi, University of Helsinki
Jin Li-Ya, University of Lanzhou

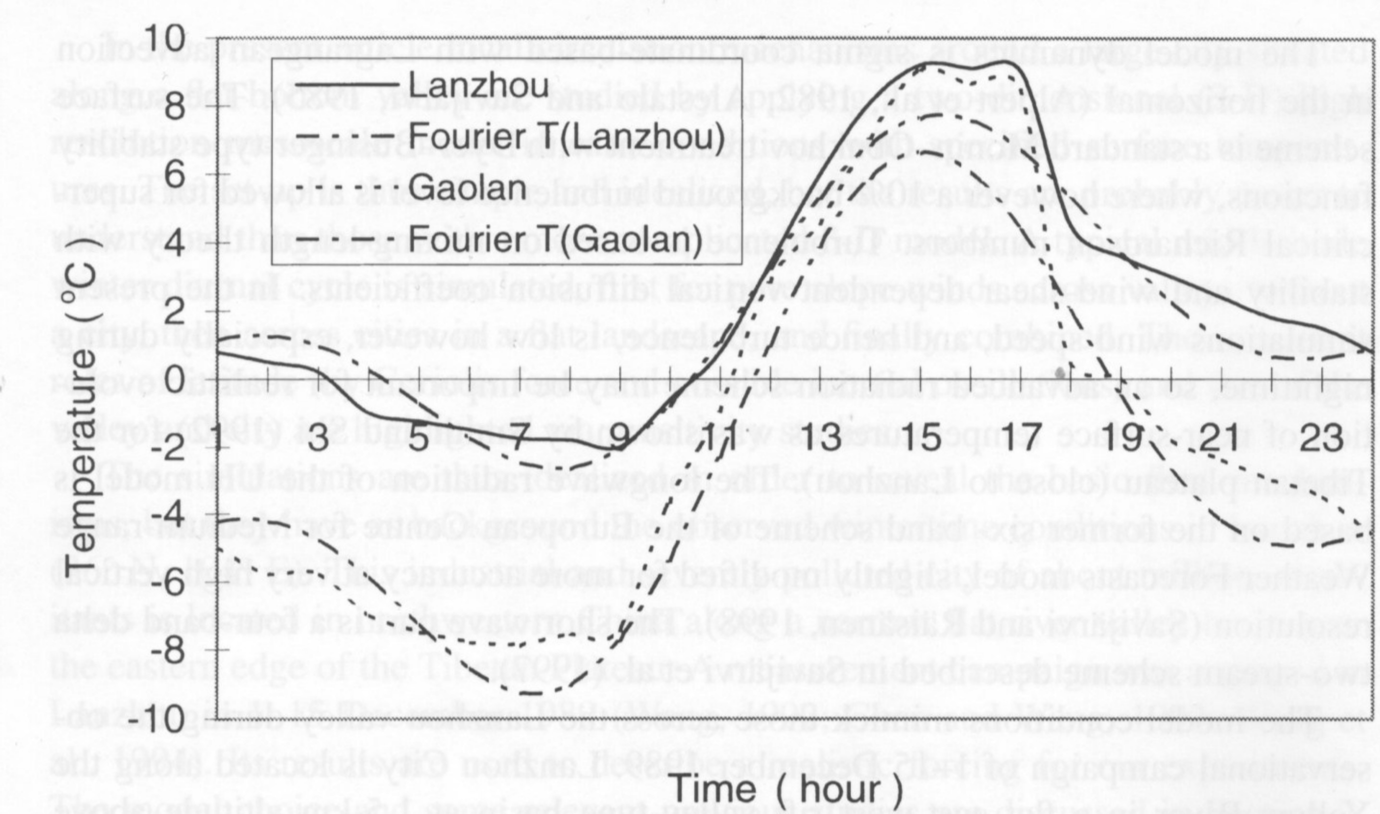
(Boundary-Layer Meteorology 100: 301-319, 2001)



Measurement campaign 1-15 Dec 1989, a clear, calm period in Lanzhou, a city of 1M in NW China located in the Yellow River valley. Air quality problems.

a) Observed mean nighttime surface winds around Lanzhou. Winds 2-3 m/s into the city.

b) Observed mean daytime winds. Winds are weak, 0-1 m/s, directions are variable but mostly out of the city near the boundaries.



Mean T2m in the city and 50 km out of the city (Gaolan).

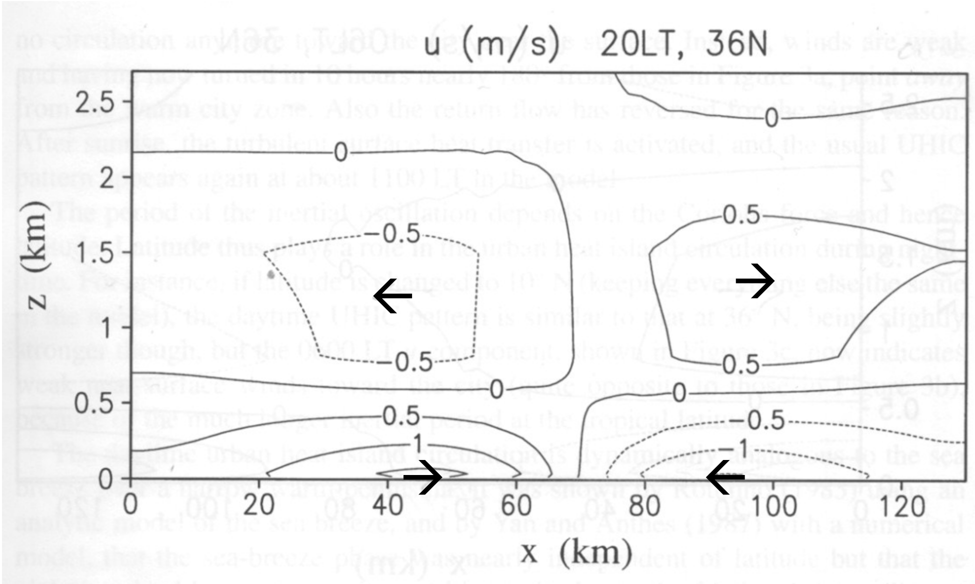
and Fourier 3-term fits for T(t):

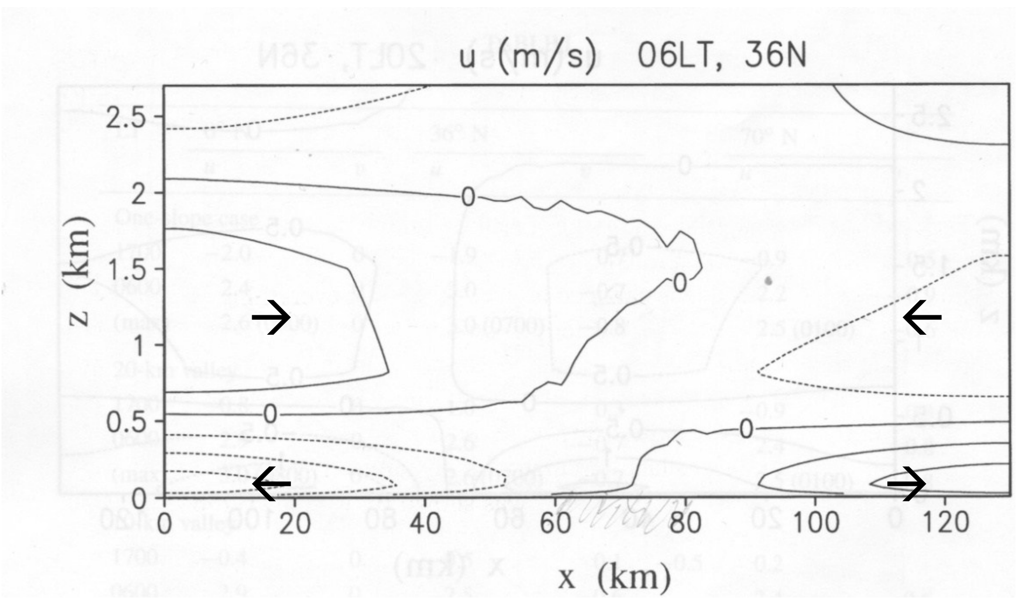
Urban heat island.

The UH 2-D sigma coordinate model (grid length 1 km) was set across the river valley and run

1) with the 20 km wide city in flat terrain
2) with valley topography but no city
3) both valley and the city at the valley base.

City temperatures: by the Fourier fits.
Countryside: by the model (T2m stayed within 1K to the Gaolan mean obs).





City (at 60-80 km) in flat terrain, Lanzhou campaign conditions:

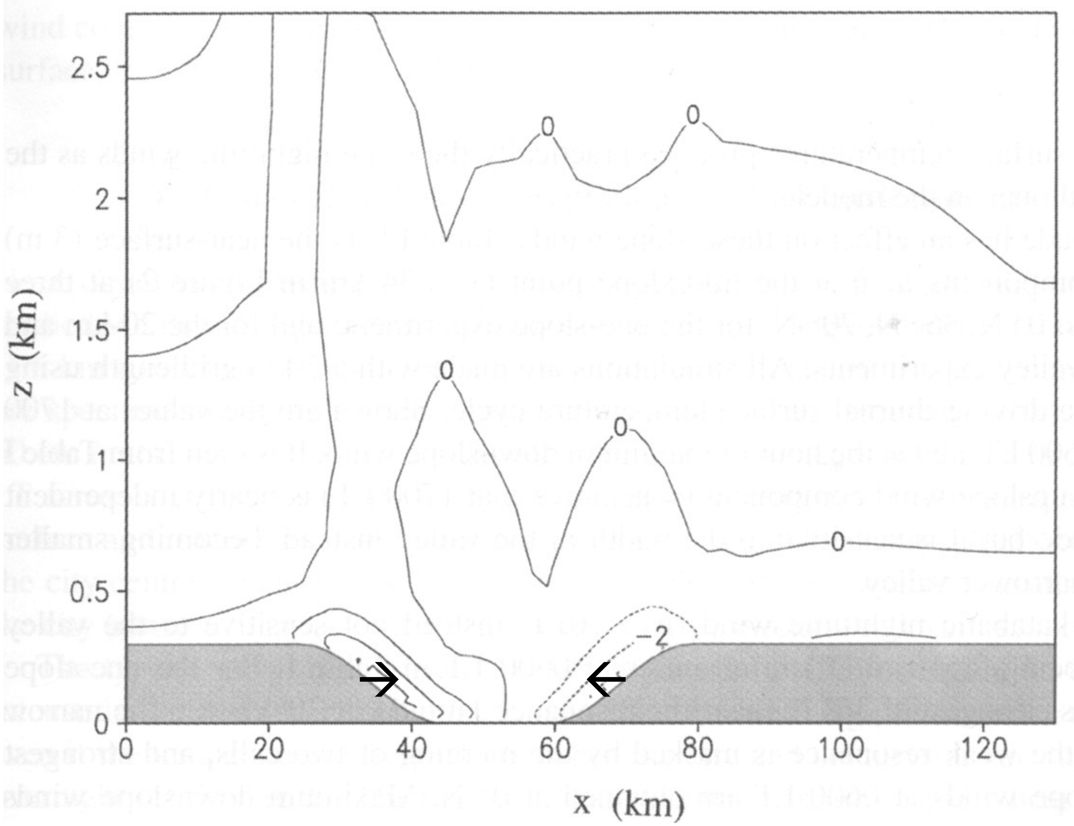
<u>Afternoon, evening</u>: <u>Urban heat island circulation (UHIC)</u>: (near-surface winds 1-1.5 m/s into the city, return flow at about 1 km, convective heat transfer.)

<u>Night</u>: the city is 5-6K warmer than the countryside, but the strong nighttime stability

a) decouples heat transfer to the air, and
b) decouples momentum transfer → inertial oscillation: UHIC turns opposite in 10 hours (i-period=20h at 36N)

→ <u>No UHIC during the night</u>, despite the large ΔT.

u (m/s) at 06 local time



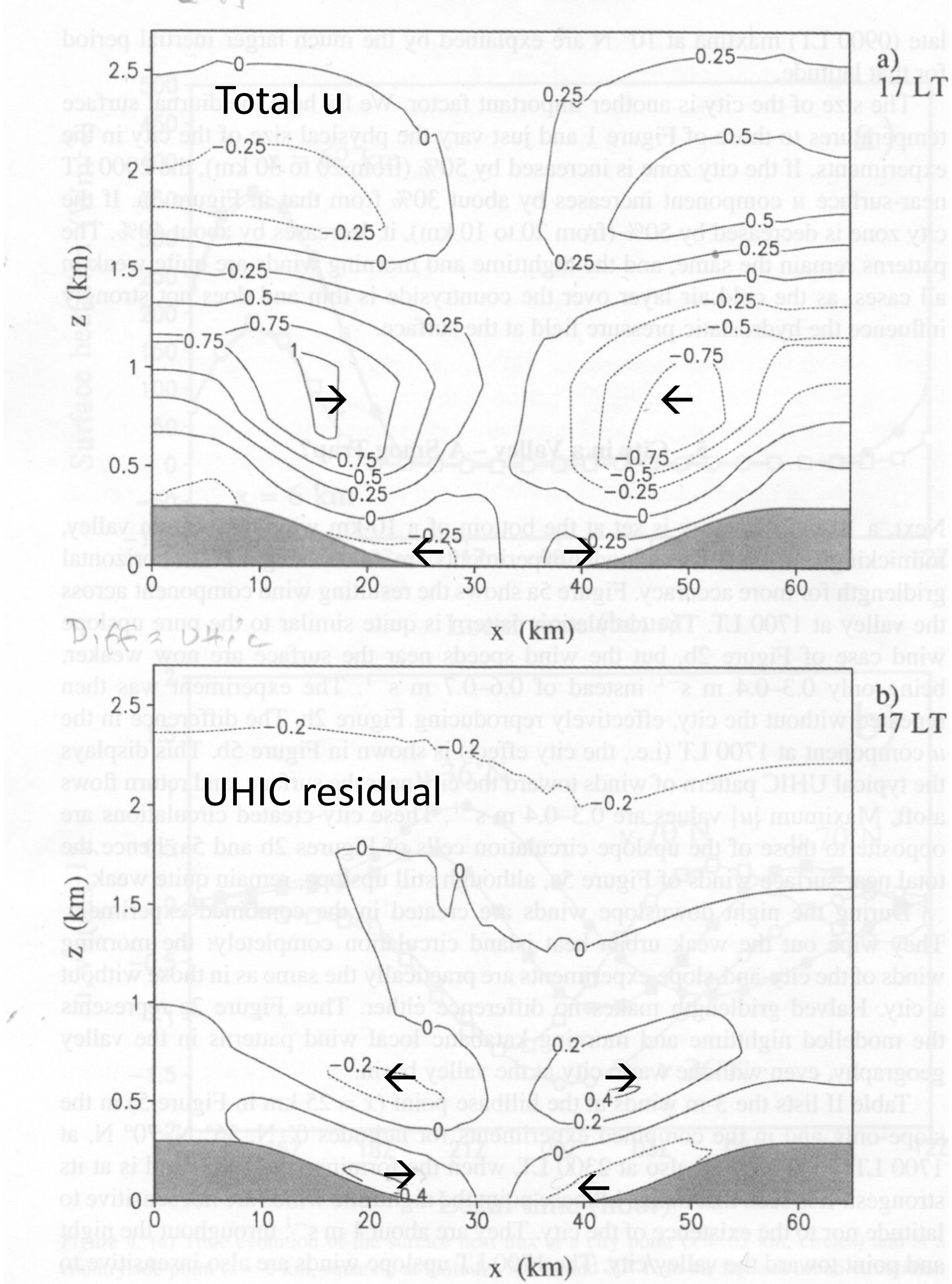
River valley:
Night-time cross-valley winds

Without city:
Katabatic drainage winds down the cold slopes, 2-3 m/s, inversion at the valley base.

With the city: Practically the same result; i.e. no UHIC.

Drainage winds dominate at night: sfc winds into the city (as observed in Lanzhou)

(winds converge pollutants to the city centre to be trapped in the inversion: *a night-time "smog trap"*)



a) <u>Afternoon cross-valley winds</u> with the city (calm Lanzhou conditions):

Weak upslope sfc winds + return flows

= Upslope anabatic winds resisted by the opposite UHIC winds

→ <u>Weak daytime winds</u>, <u>out-of-town in the borders</u> (as observed).

(No wind transport + subsidence: city pollution cumulates: *a daytime smog trap*.)

b) Difference in u between a) and the experiment without the city: UHIC

Conclusion:

- Calm clear days: The local urban heat island circulation UHIC is strongest in late afternoon with surface winds into the city about 0.5-1 m/s

- but UHIC is weak or nonexistent during the night, as strong stability inhibits the surface heat transfer to the air.

- The weak UHIC is easily dominated by large-scale and meso-scale flows, e.g. slope winds in valley cities during large-scale calms.

- Helsinki does not accommodate slope winds, but the coastal sea and land breezes can probably interfere with the Helsinki UHIC (similarly to the slope winds) during large-scale calms.

- UHIC in Helsinki might be detectable from observations, as in Lanzhou.

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Helsinki urban heat island

as a local and a temporal phenomena

Achim J. Drebs

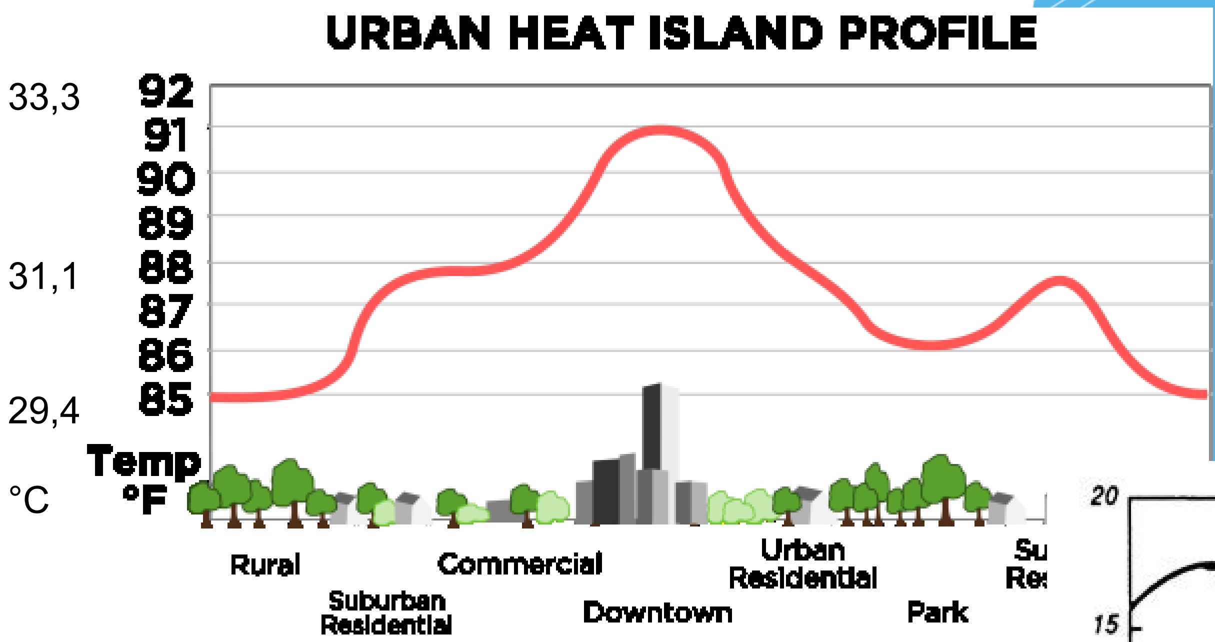
FMI research project July 2009 – June 2010

14.5. 2012

Content:

- Definition, history, objectives
- Geographical Helsinki centre
- Instrumentation
- Traverse routes
- Background materials
- Results
- Trivia and varia

Urban heat island phenomena



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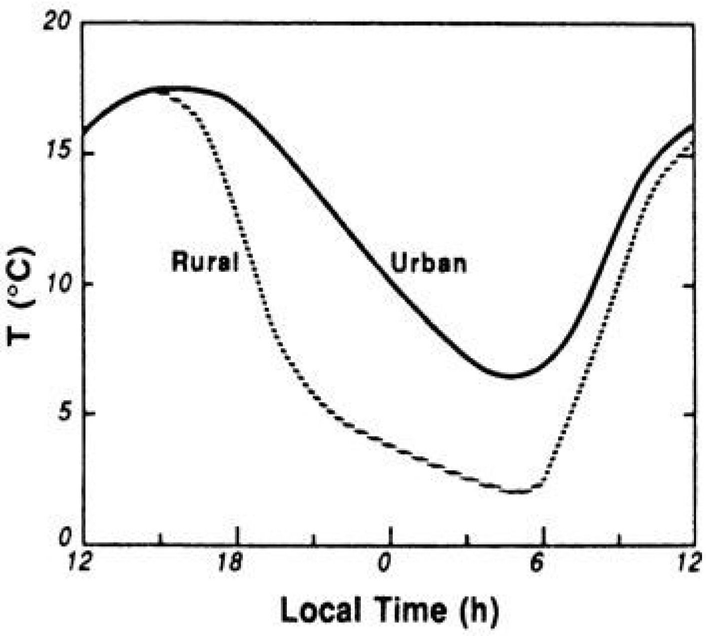
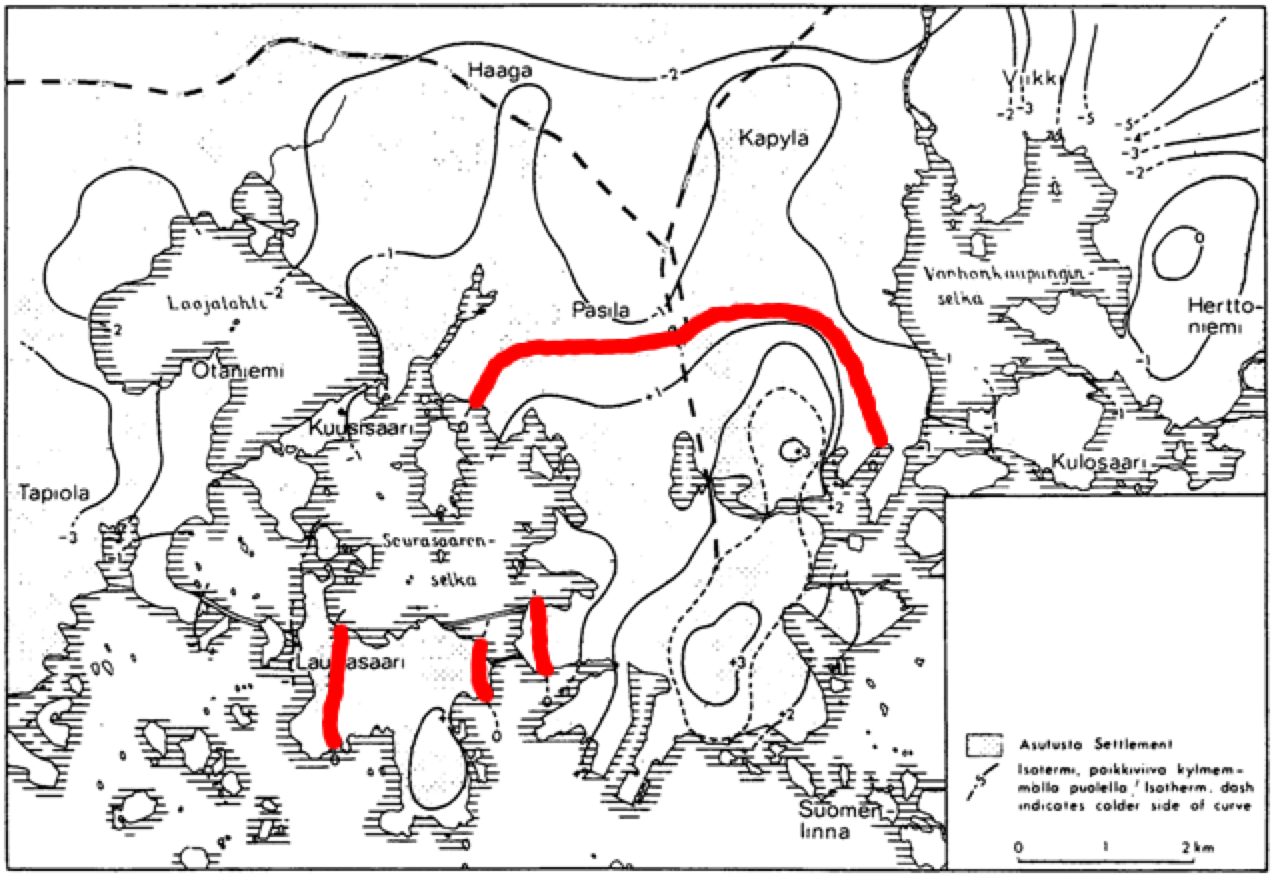


Oke, T.R. 1987: Boundary Layer Climates.
2nd edition. Routledge

Helsinki urban heat island Februar 1973



Map based on 3 nights in February 1973 (Fogelberg et al. 1973).

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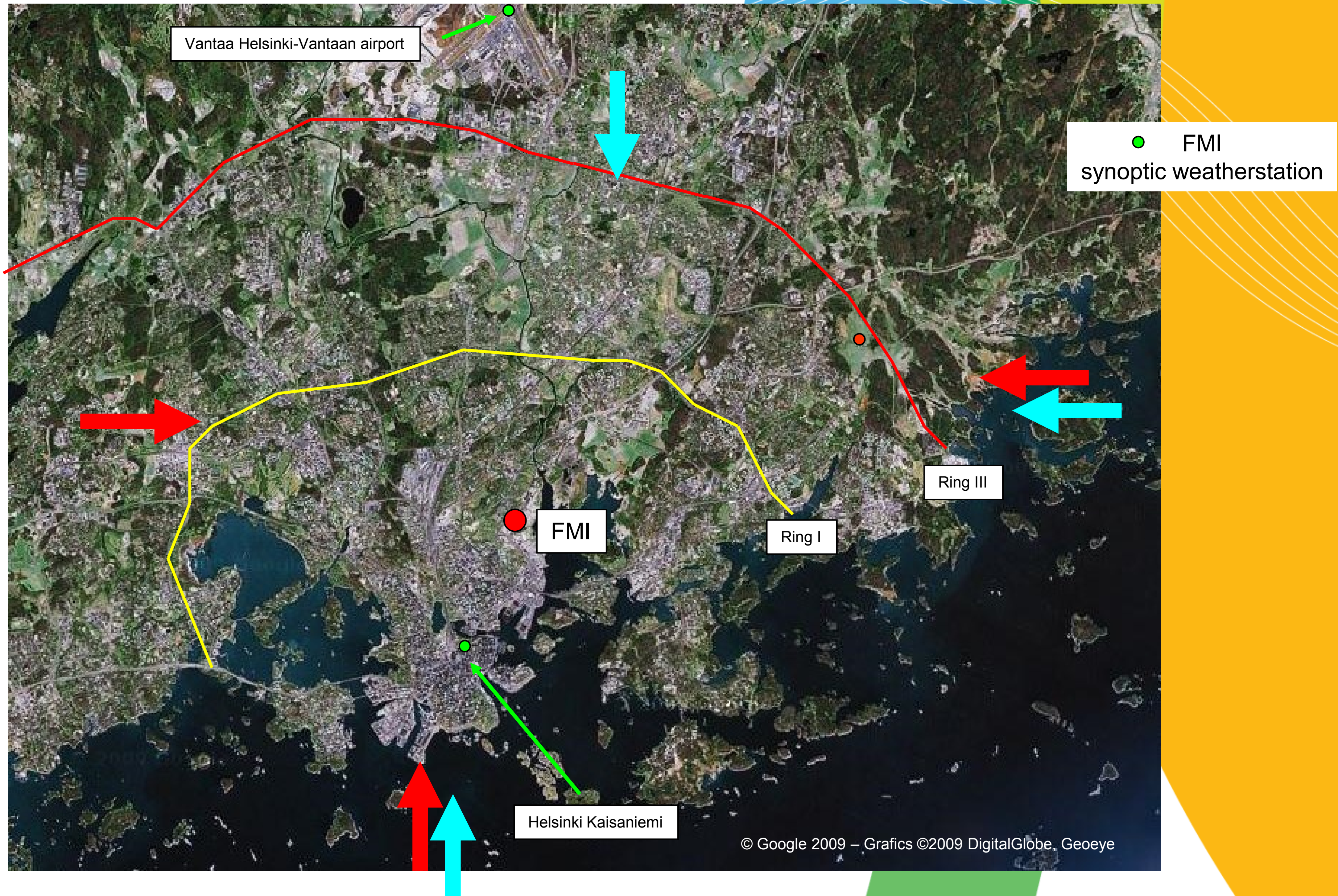
Air masses influencing the metropolitan area



Instrumentation …

air temperatur
relative humidity
dewpoint
….

…mounted on the car.

…. solar radiation components

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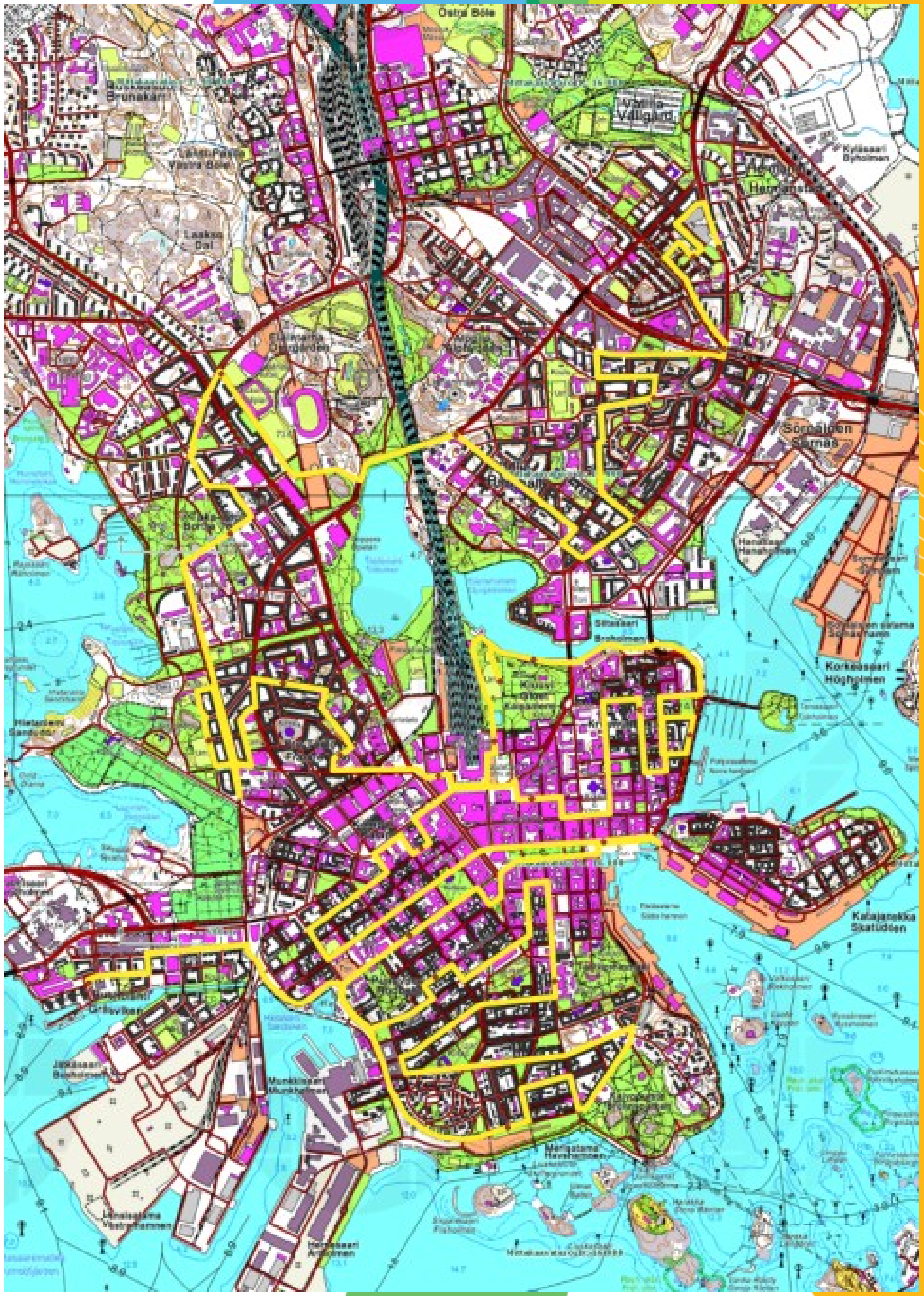
Traverse route

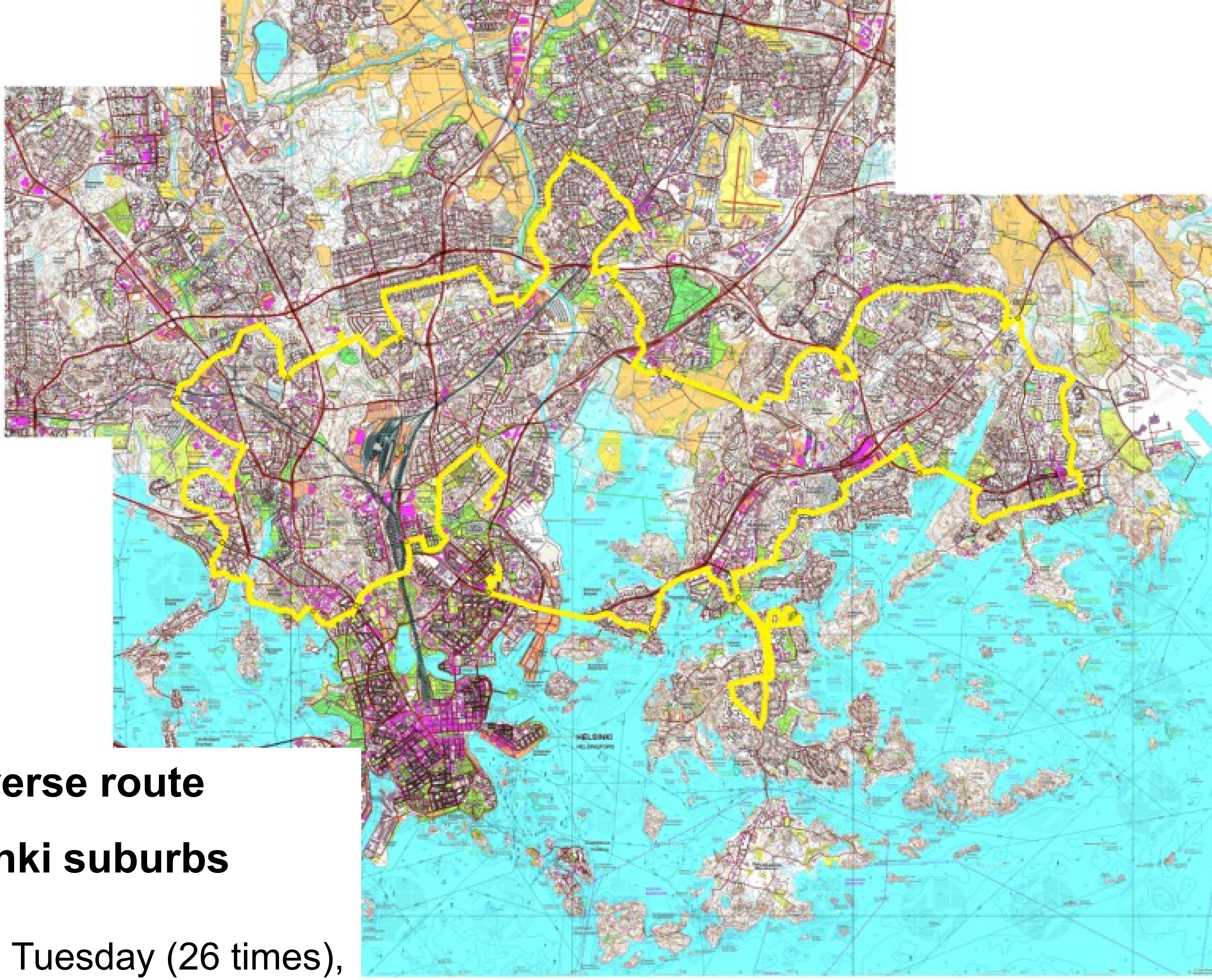
Helsinki centre

every Tuesday (52 times),

July 2009 – June 2010,

7:45 – 9:45 and
19:45 – 21:45 UTC





Traverse route

Helsinki suburbs

every second Tuesday (26 times),
July 2009 – June 2010,
9:45 – 12:15 and
21:45 – 00:15 UTC

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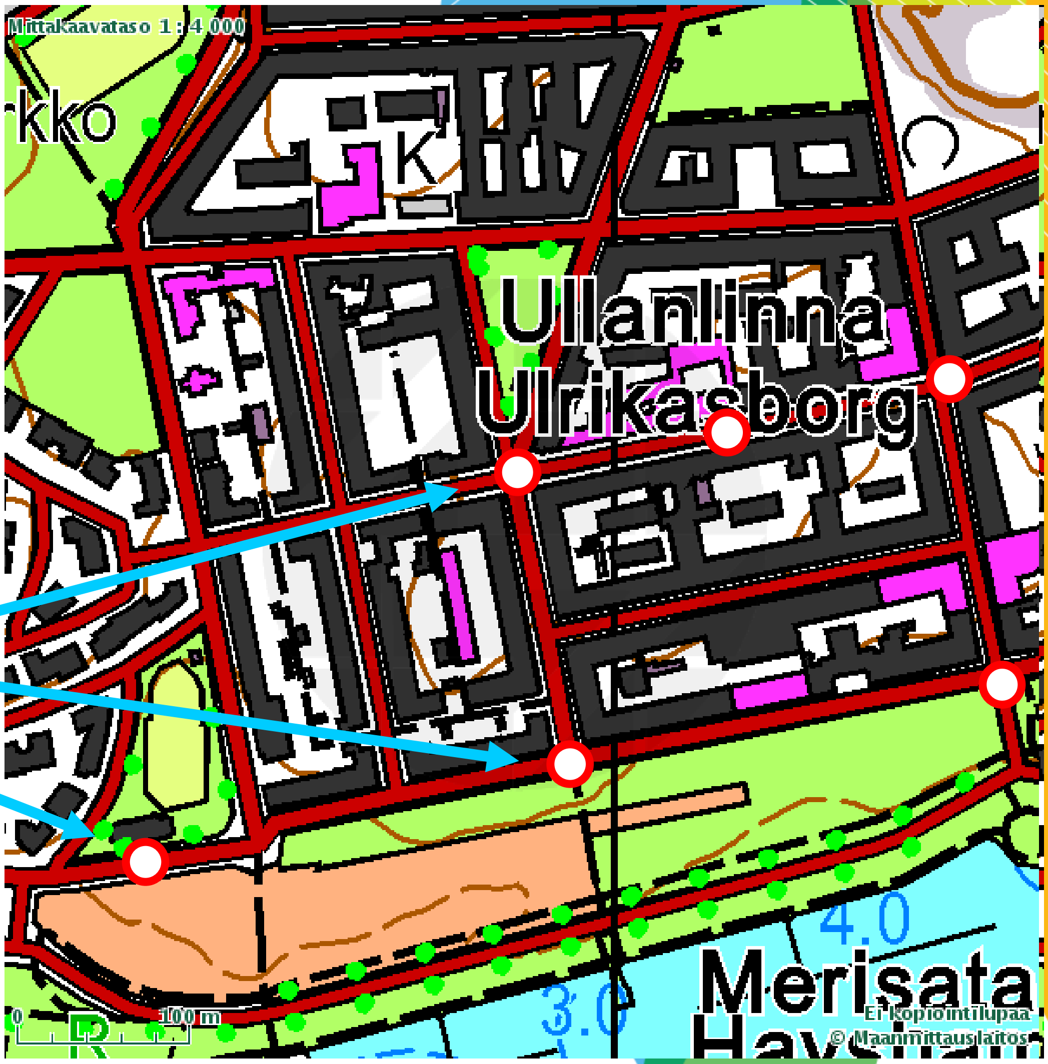
135 fixed way points
city centre

200 fixed way points
sub-urban area

fixed way point



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Data used in the project …

25 meter digital elevation model (DEM)

Population density, 100 m grid

Land use, 100 m grid, CORINE

Helsinki municipality real estate register, 100 m grid

Helsinki Kaisaniemi climatological data 1971 – 2000

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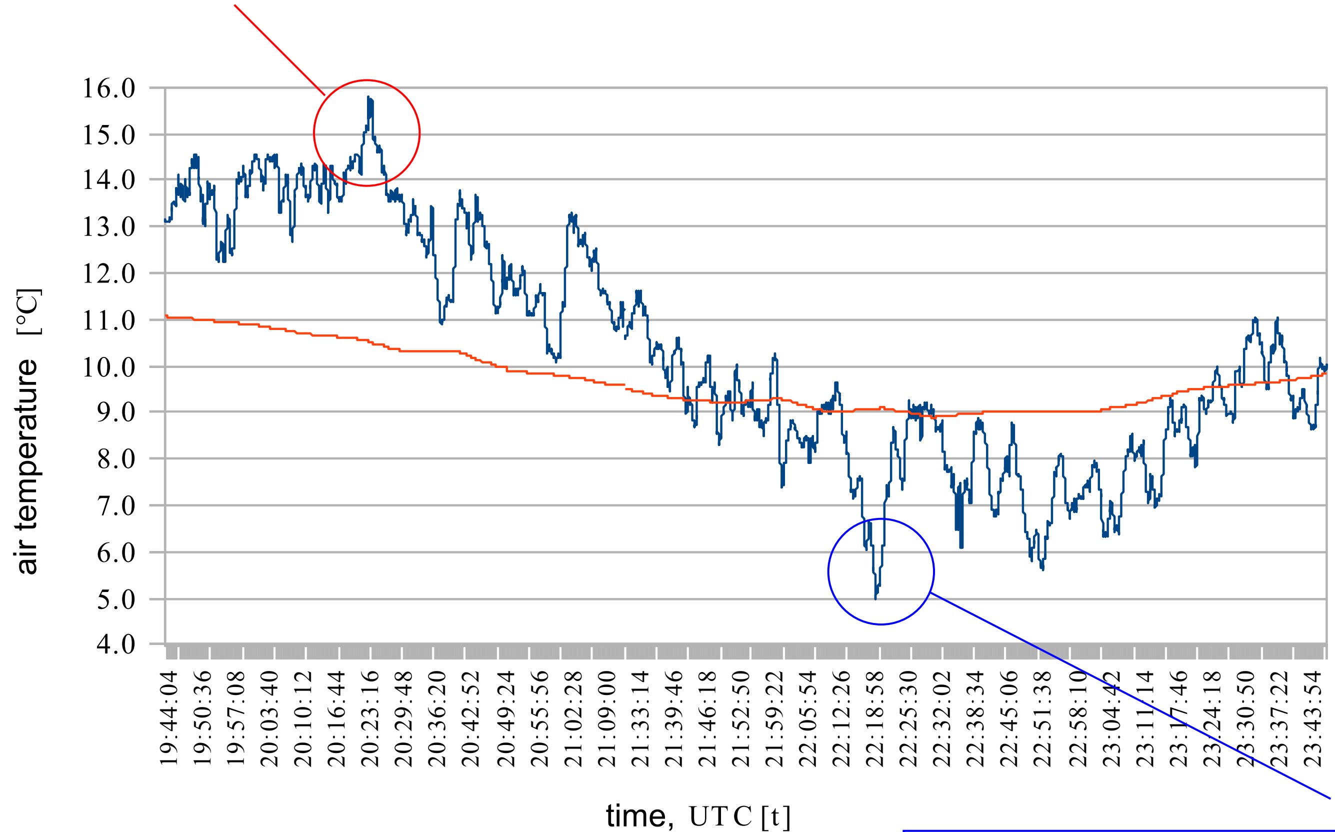
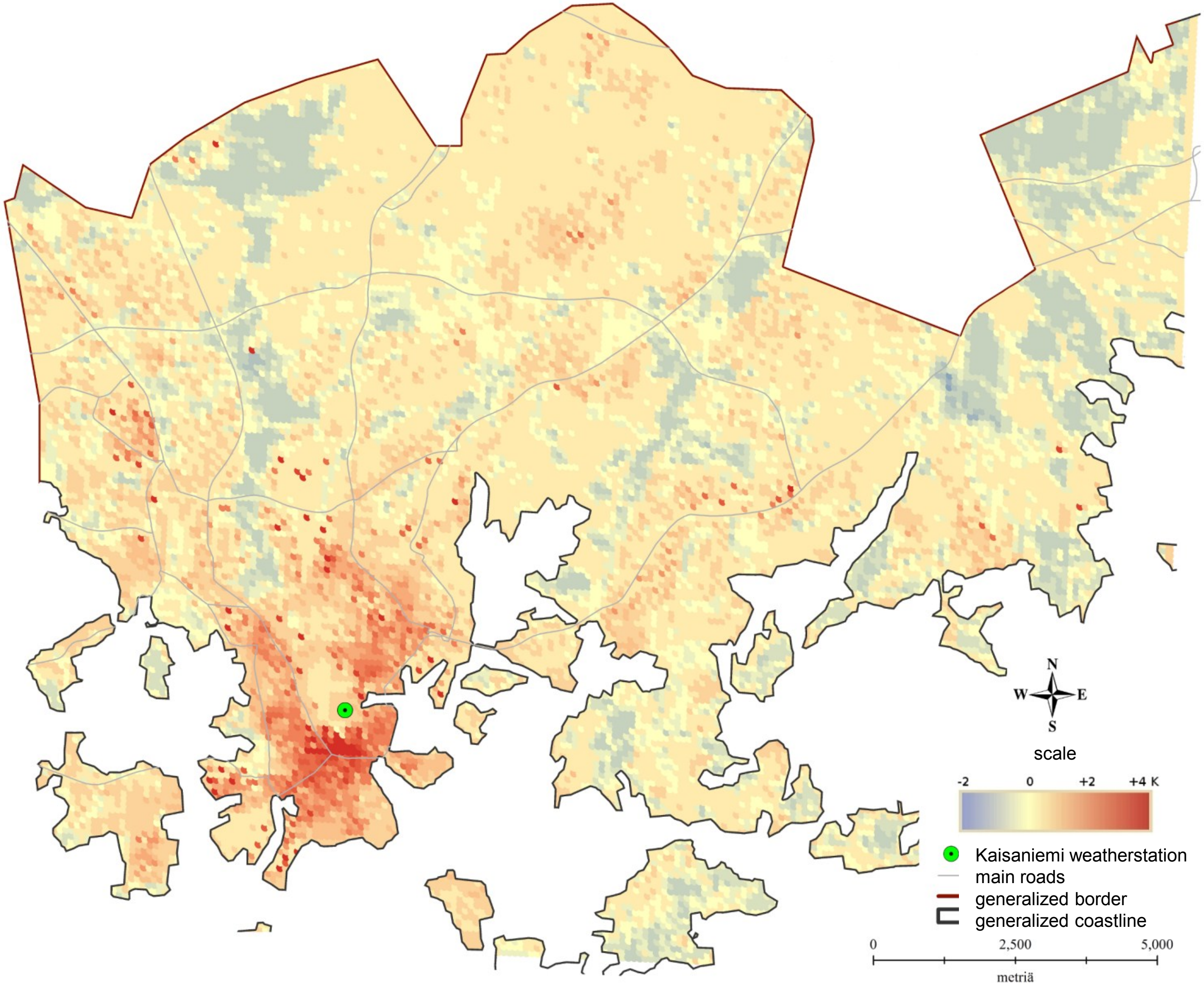
Helsinki central railwaystation

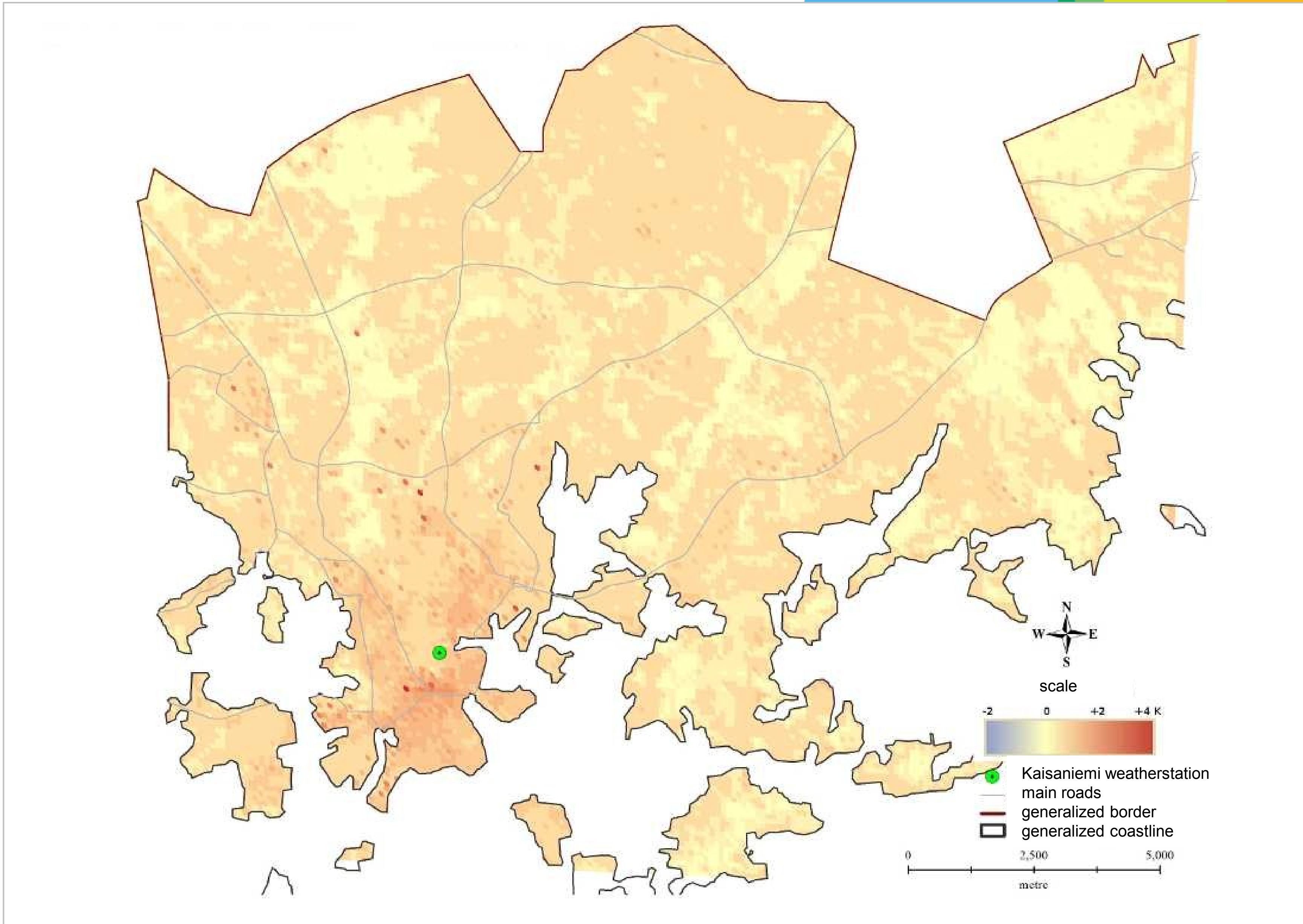


Eastern-Helsinki topografically influence area

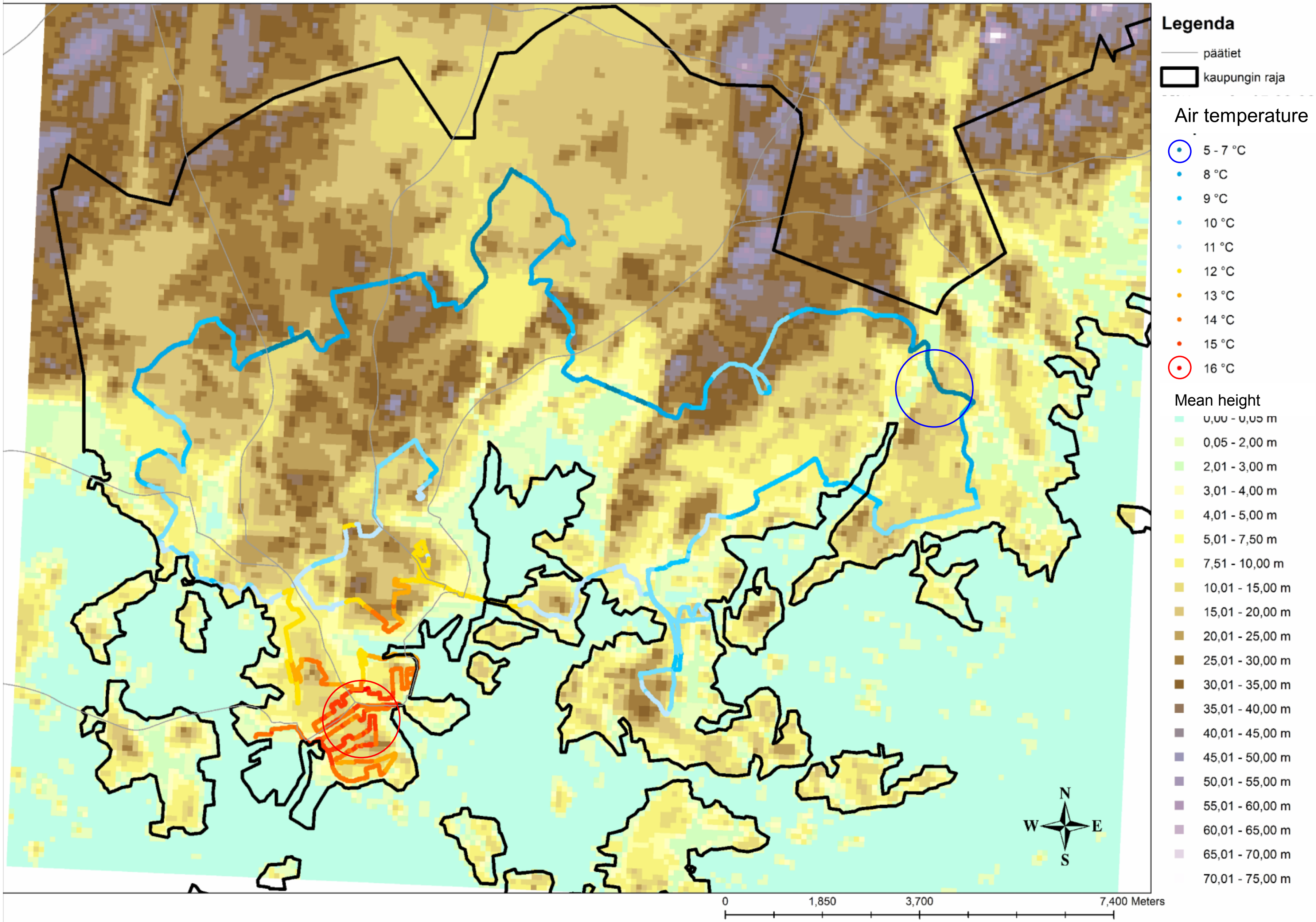
15./16. 9. 2009 night-drive observations and Helsinki Kaisaniemi weatherstation 10 min observation.



Air temperature difference map, July 2009 – June 2010, reference station Kaisaniemi, air temperatur average +5,2 °C



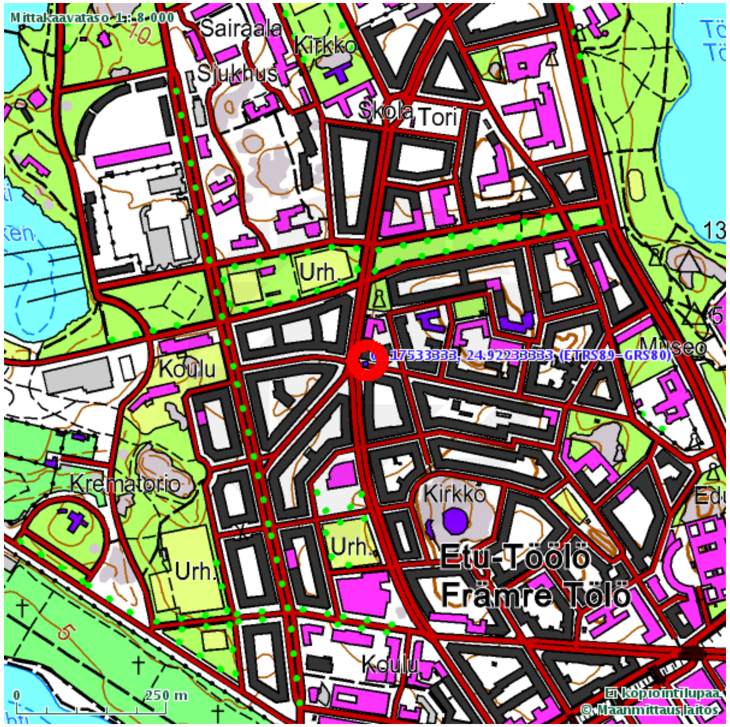
Air temperature difference map, July 2009 – June 2010, reference station Helsinki-Vantaa airport, air temperatur average +4,7 °C

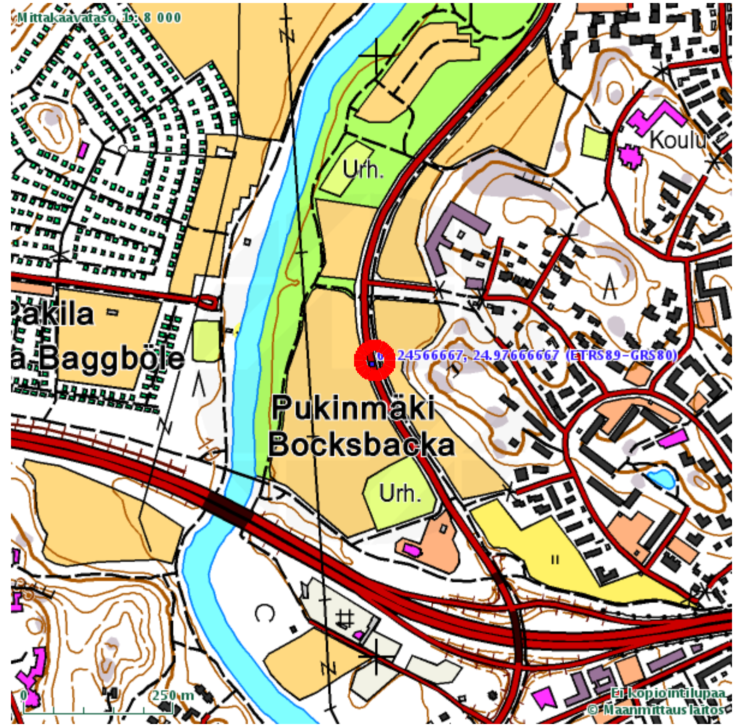


15./16. 9. 2009 night-drive observations

Topografical influence on air temperature

Some extreme results, measuring night 16.3.2010



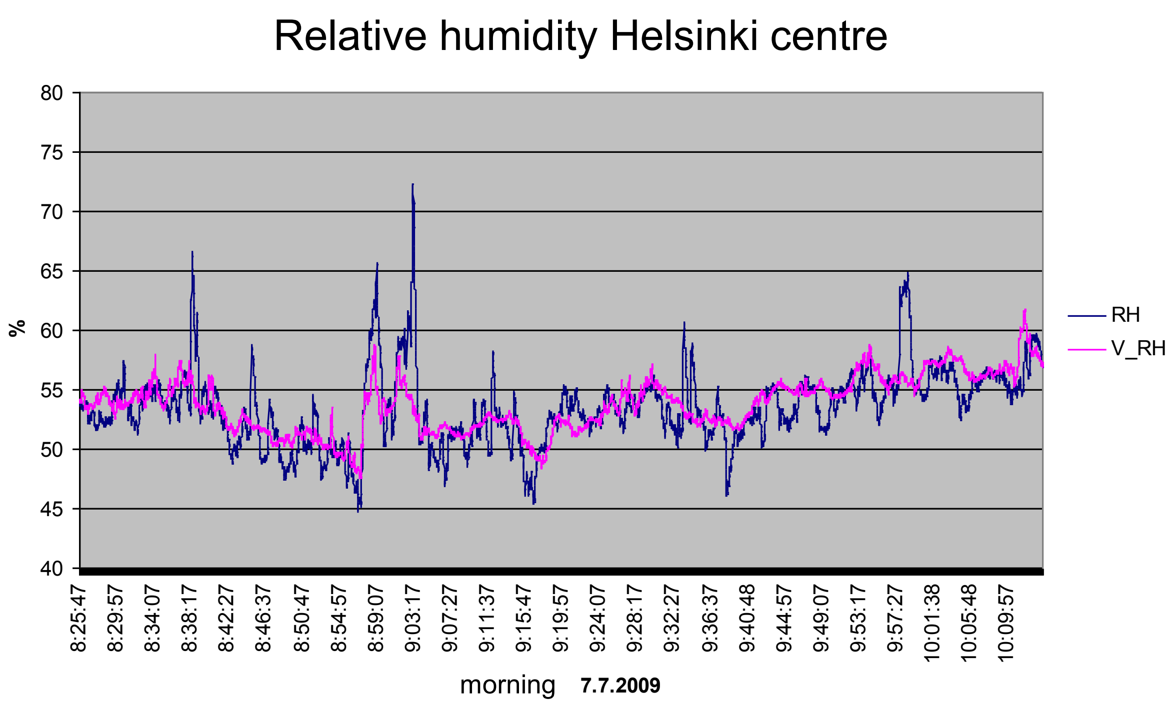


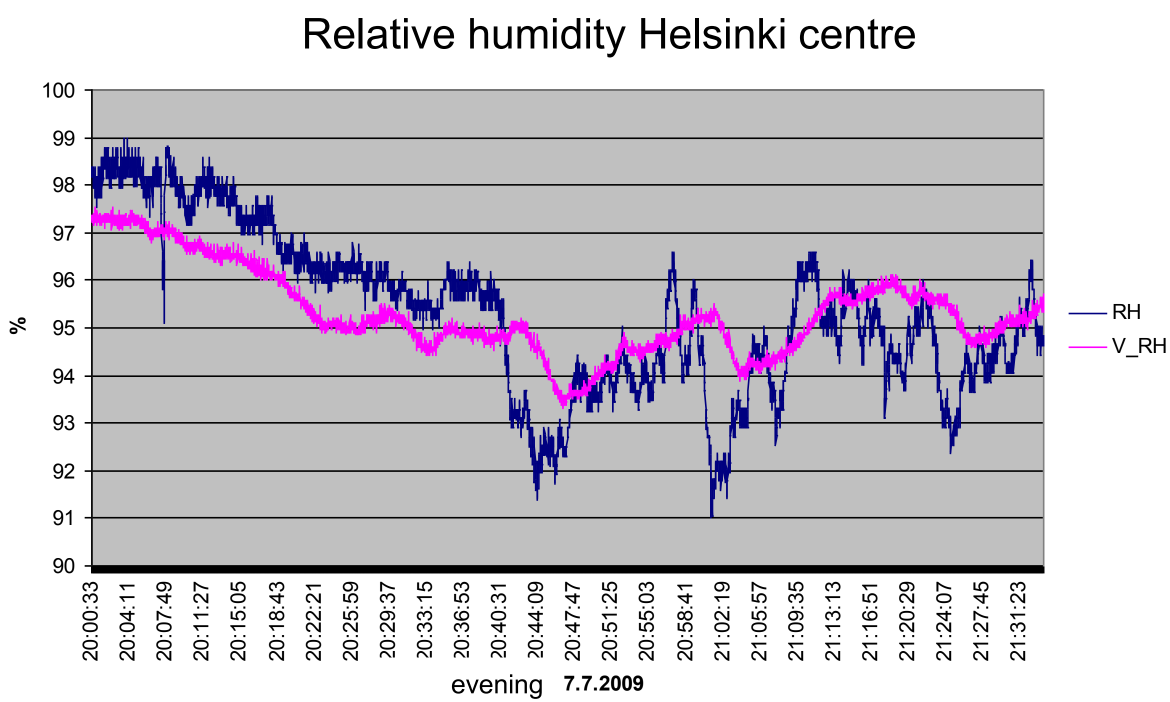
Tmax, -5,56 °C, 21:41 UTC

Kaisaniemi, -7,0 °C, 21:40 UTC

Tmin, -14,64 °C, 22:45 UTC

Kaisaniemi, -8,8 °C, 22:50 UTC


Relative humidity Helsinki centre
80
75
70
65
60
55
50
45
40
%
RH
V_RH
8:25:47
8:29:57
8:34:07
8:38:17
8:42:27
8:46:37
8:50:47
8:54:57
8:59:07
9:03:17
9:07:27
9:11:37
9:15:47
9:19:57
9:24:07
9:28:17
9:32:27
9:36:37
9:40:48
9:44:57
9:49:07
9:53:17
9:57:27
10:01:38
10:05:48
10:09:57
morning 7.7.2009


Relative humidity Helsinki centre
100
99
98
97
96
95
94
93
92
91
90
%
RH
V_RH
20:00:33
20:04:11
20:07:49
20:11:27
20:15:05
20:18:43
20:22:21
20:25:59
20:29:37
20:33:15
20:36:53
20:40:31
20:44:09
20:47:47
20:51:25
20:55:03
20:58:41
21:02:19
21:05:57
21:09:35
21:13:13
21:16:51
21:20:29
21:24:07
21:27:45
21:31:23
evening 7.7.2009

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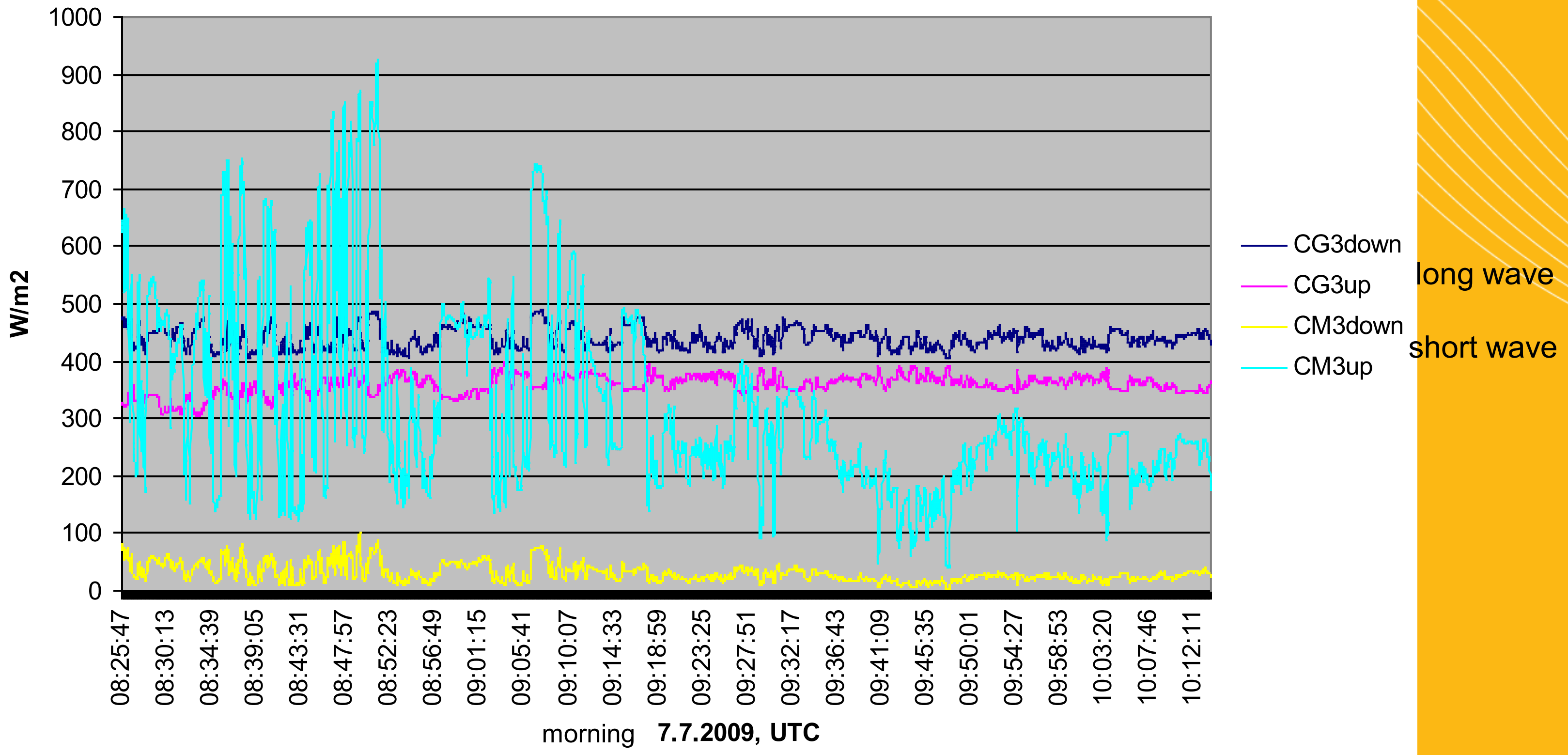
Energy radiation components Helsinki centre



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Summary

a) The city centre of Helsinki is warmer than its surroundings, both on a monthly main basis, and for the annual mean.

46 out of 38 191 grid points displays a temperature difference of more than 1K.

b) Isolated large buildings and suburban centres create their own individual heat island.

c) The topographical influence on air temperature can generally be neglected for the monthly mean, but can be strong under certain weather conditions.

d) No humidity and radiation data analysis yet

Trivia and varia

Measurements:	8 parameters, 982800 each
Traverse drives duration:	273 hours, 38 working days
Traverse drives length:	6981,8 km

Number of traffic lights in Helsinki centre: 85 kpl

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Thank you for your attention!

Eddy-covariance methods in Helsinki

Urban symposium

May 14 2012, University of Helsinki, Finland

Annika Nordbo,

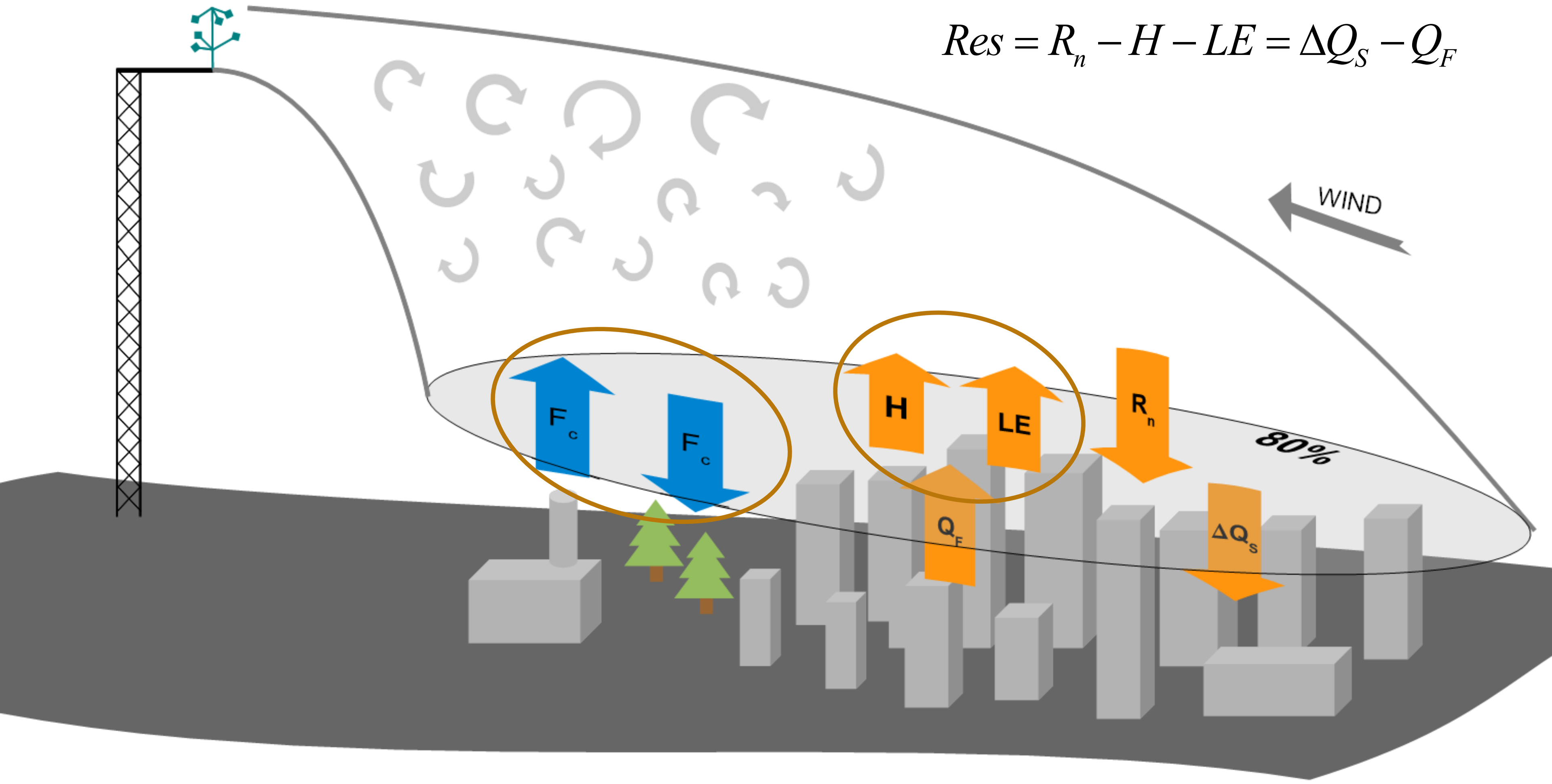
Leena Järvi, Sami Haapanala, Joonas Moilanen, Timo Vesala, Gaby Katul, Pekka Kekäläinen, Jussi Timonen …

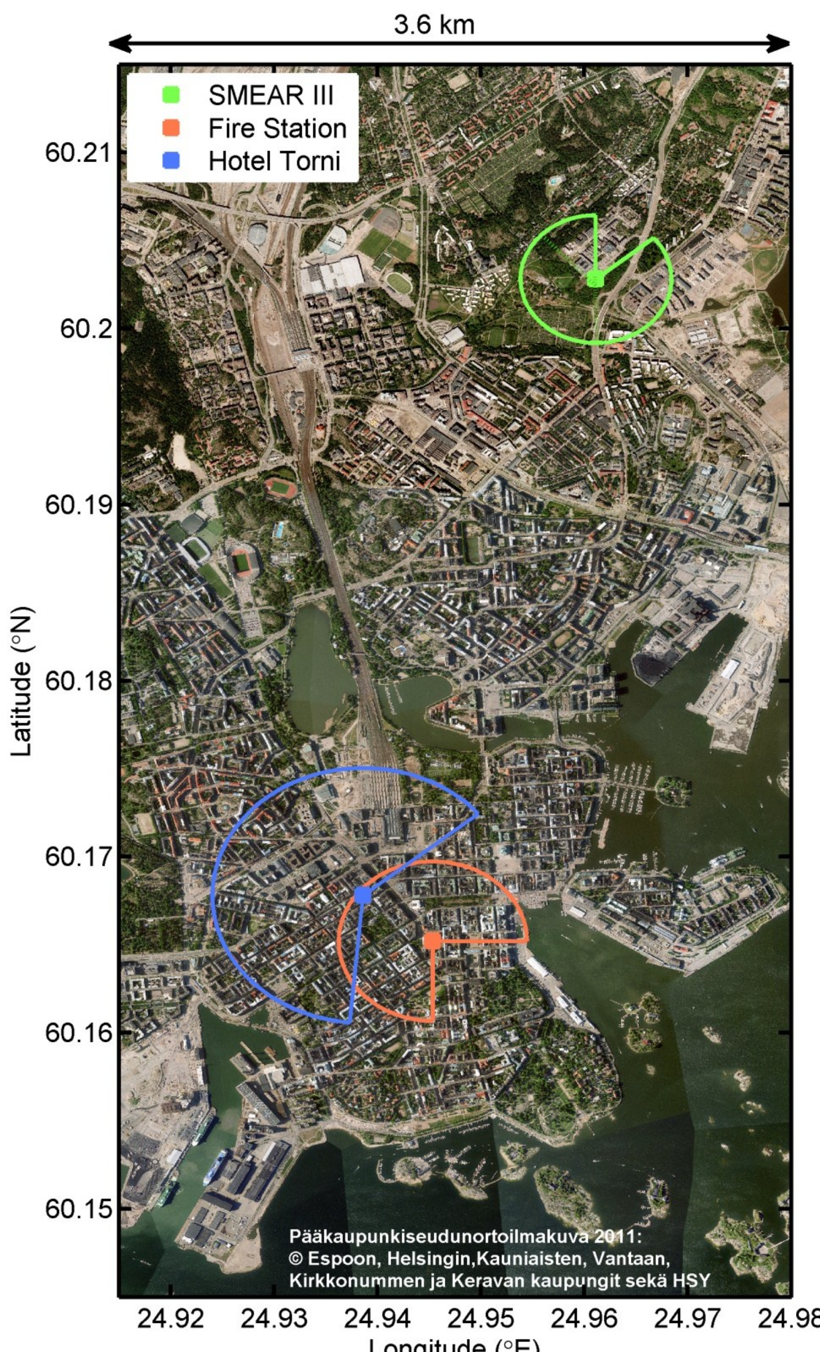
The eddy-covariance method

Energy balance

$$R_n + Q_F - \Delta Q_S = H + LE + Q_A + \varepsilon_{EB}$$

$$Res = R_n - H - LE = \Delta Q_S - Q_F$$





SMEAR III

- Dec 2005 →
- 31 m
- EC (τ, H, LE, F_c , F_p)
- Basic meteorology
- T & U profiles
- Gases, particles

Fire Station

- Jul2010–Jan2011
- 42 m
- EC (τ, H, LE, F_c , F_p)

Hotel Torni

- Oct 2010 →
- 60 m
- EC (τ, H, LE, F_c , F_p)

Median diurnal cycles Oct 2010 – Jan 2011

Nordbo et al. 2012, Submitted to BLMet

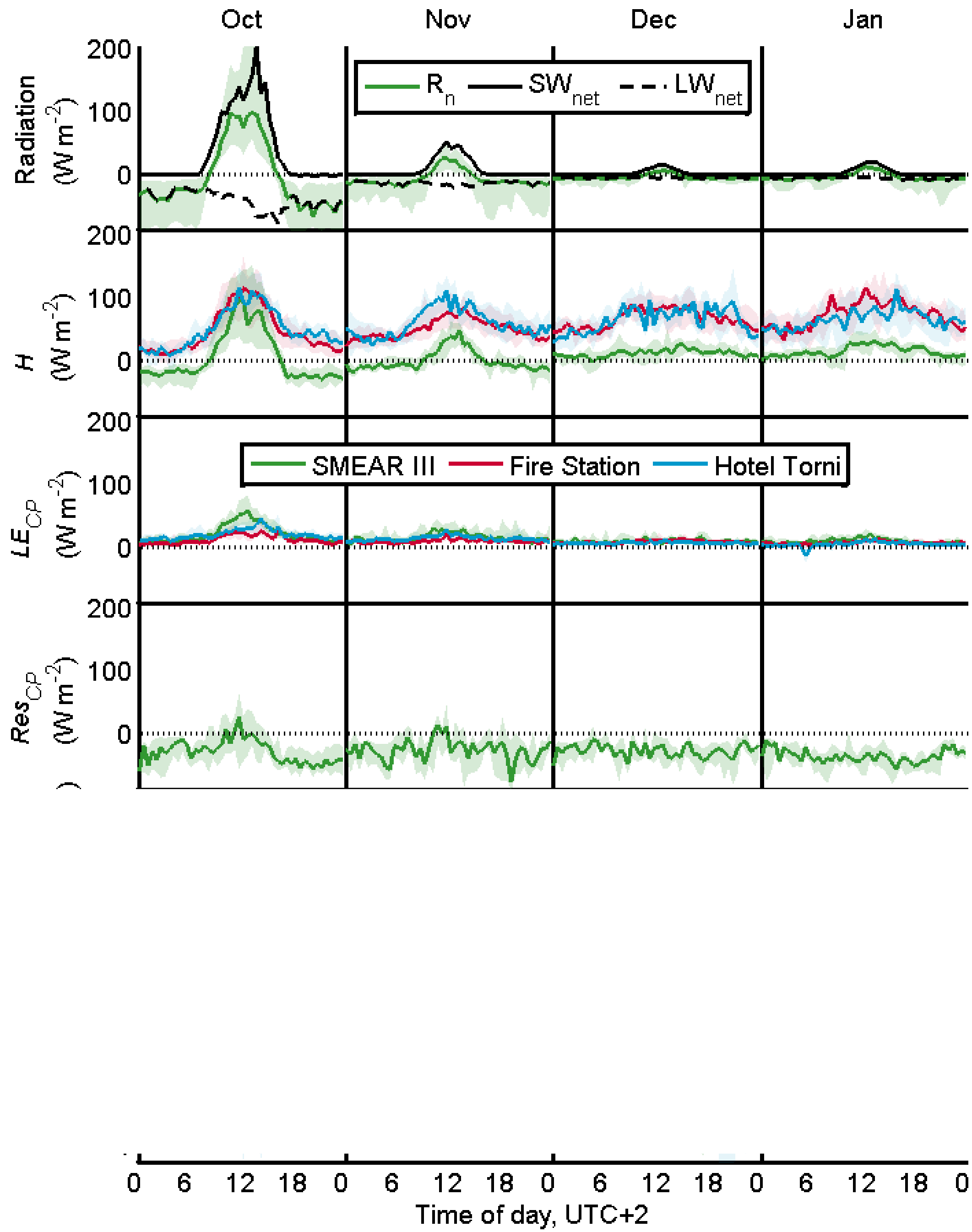
Energy balance

$$R_n + Q_F - \Delta Q_S = H + LE + Q_A + \varepsilon_{EB}$$

$$Res = R_n - H - LE = \Delta Q_S - Q_F$$

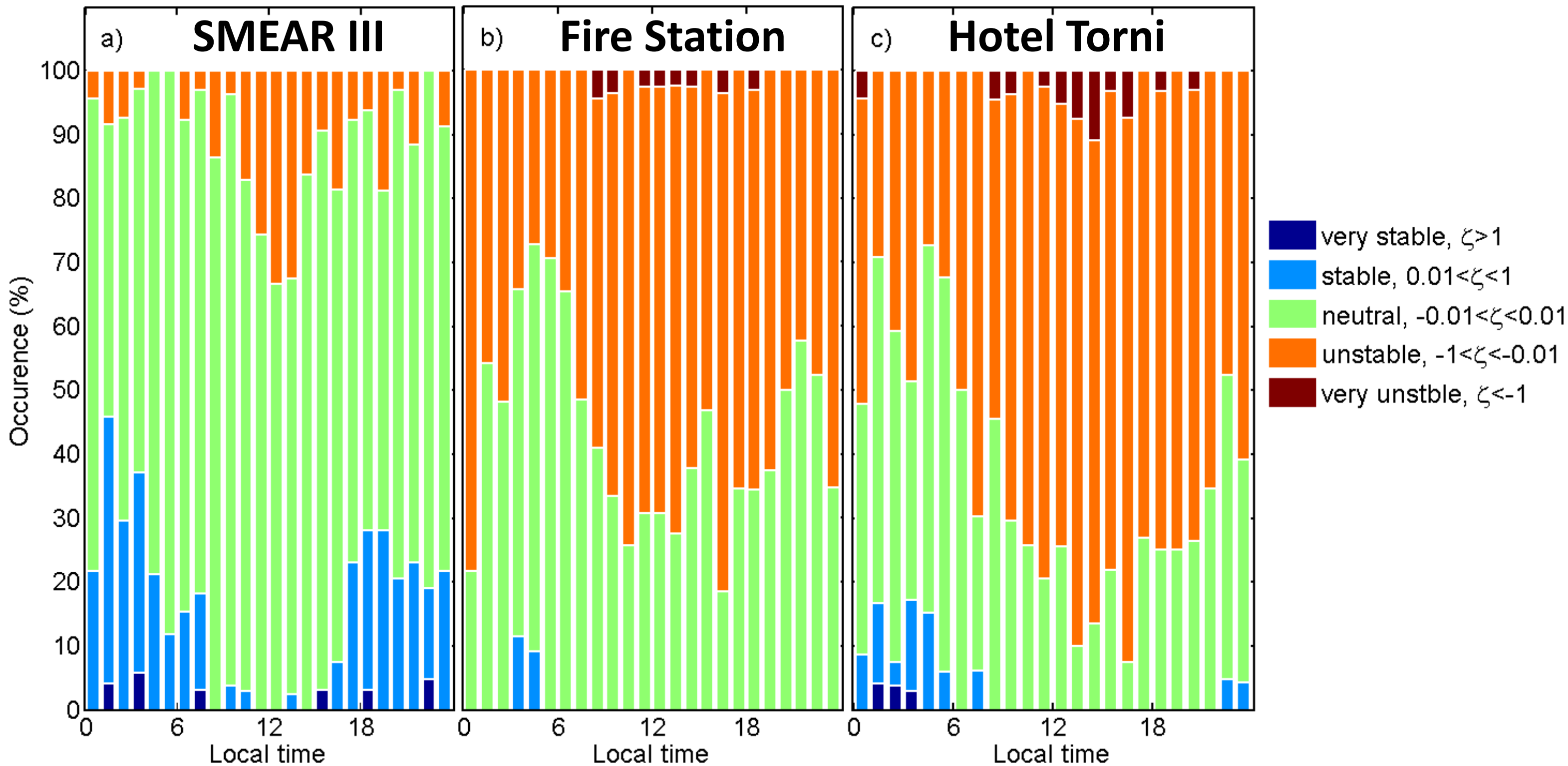
H ~50 W m^{-2} larger downtown
Res ~40 W m^{-2} in winter
(Annual *Res* ~13 W m^{-2})

F_c largest at Hotel Torni, followed by Fire Station and sectors at SMEAR III



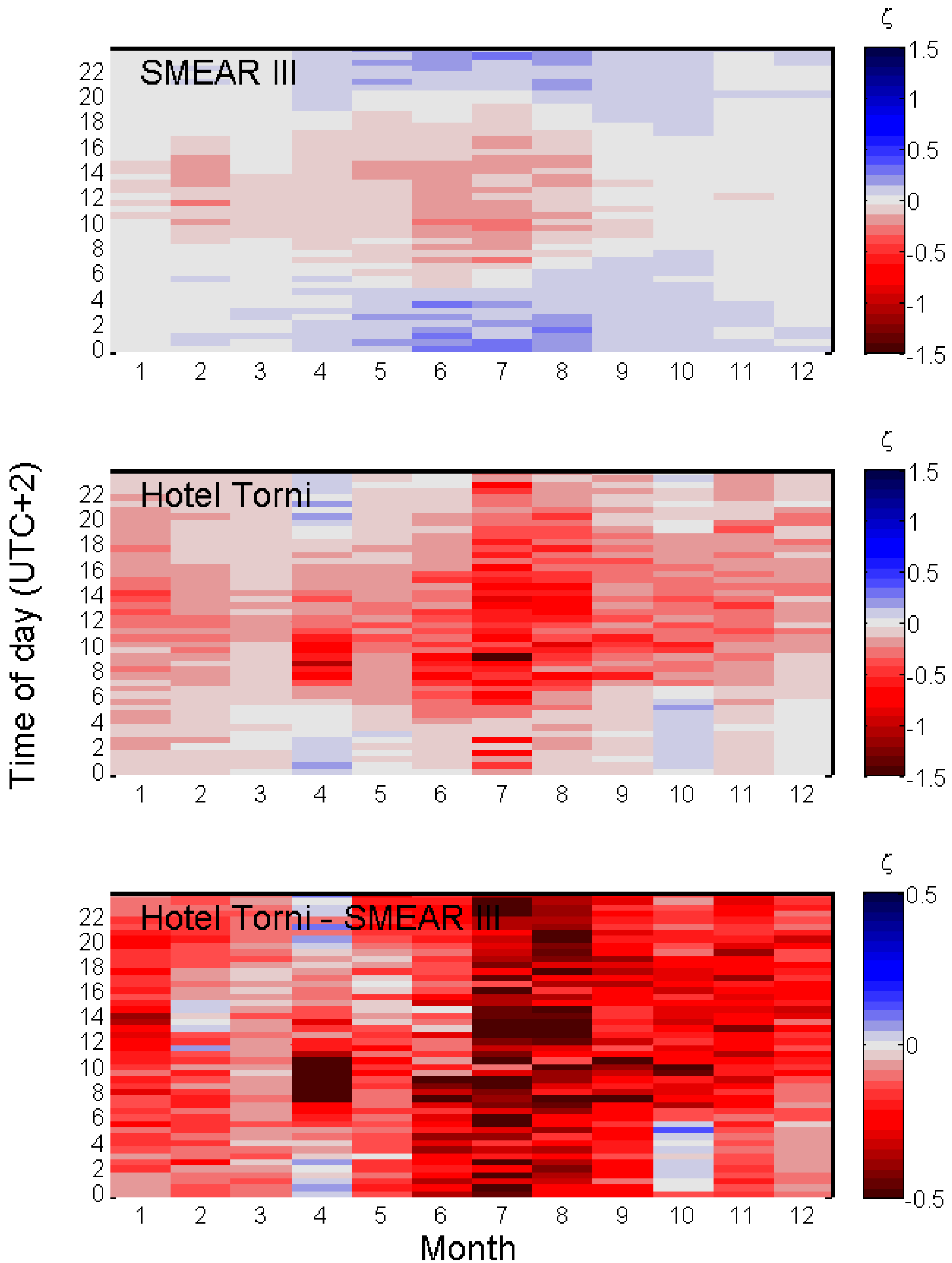
Diurnal cycle of stability histograms

Oct 2010 – Jan 2011



Monthly median diurnal cycles of stability for 2011

Heat island effect seen as substantial differences in atmospheric stability throughout the year



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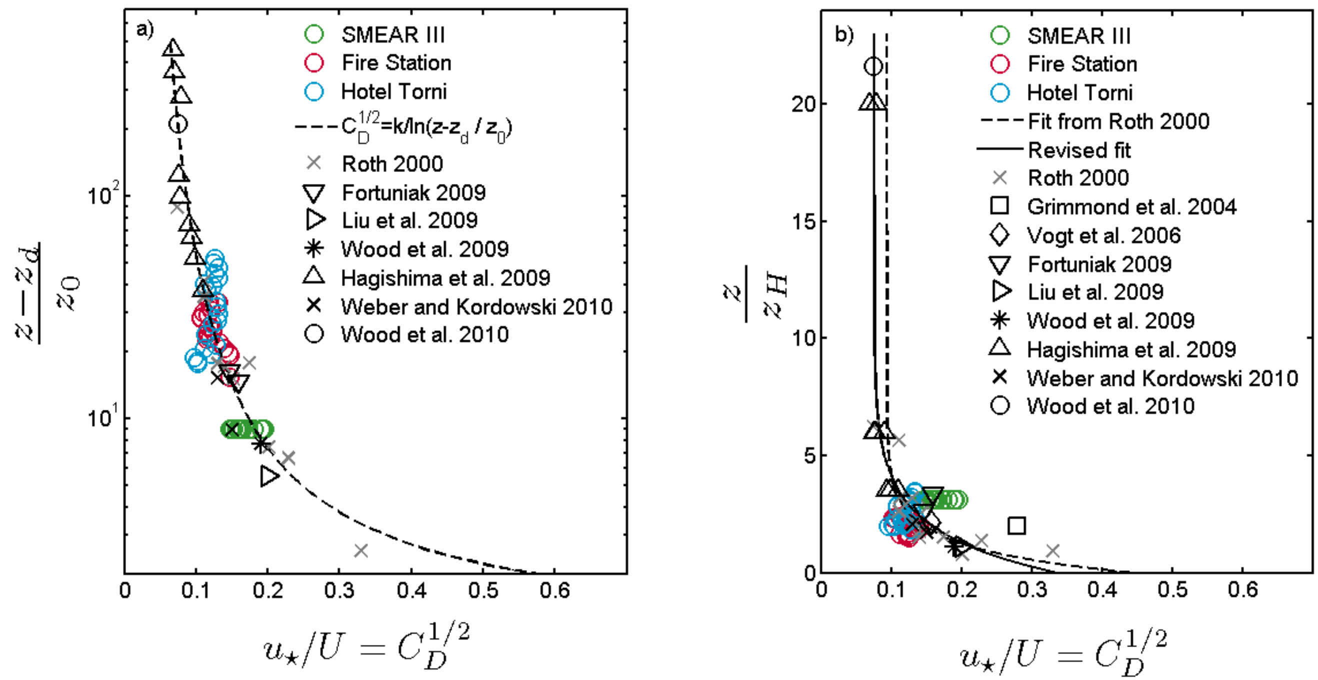
Morphological determination of z_0 and z_d in central Helsinki

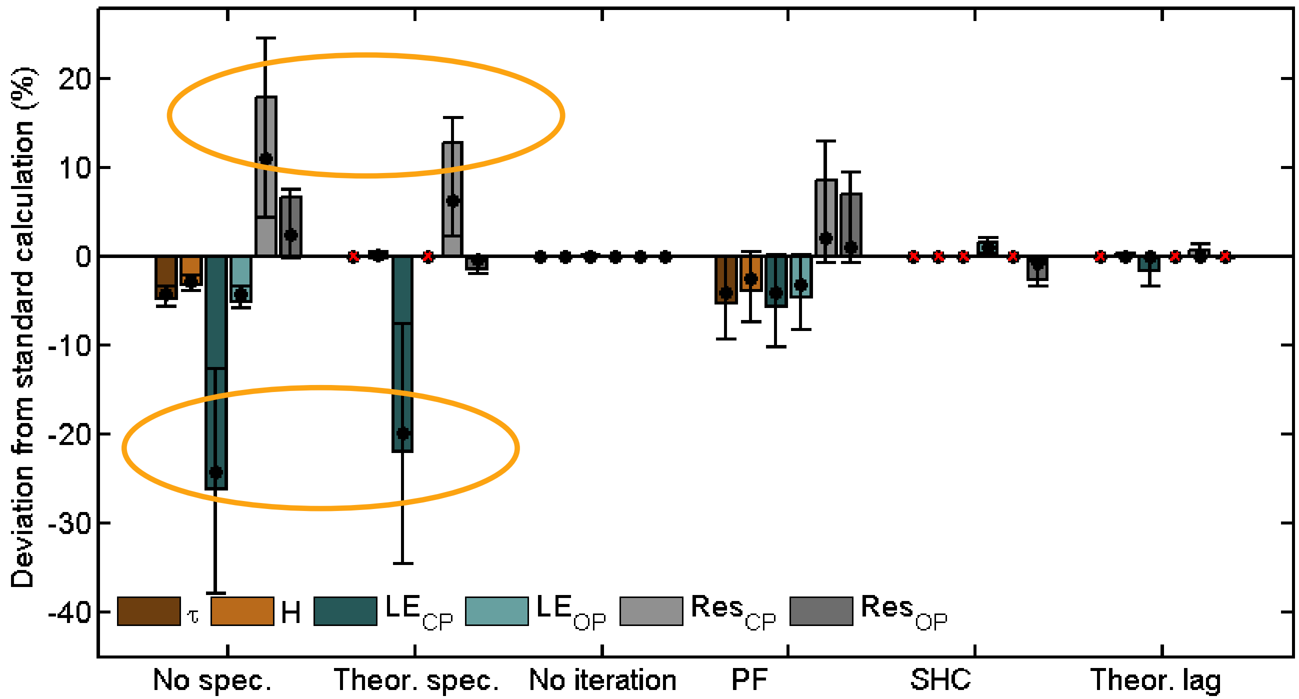
Updated C_D parameterization with over 20 sites and some wind tunnel data

Morphological determination of z_0 and z_d ~30% better than rule-of-thumb estimates



Measurement height and building height are rough estimates for the drag coefficient

Effect of eddy-covariance calculation procedures on final flux values

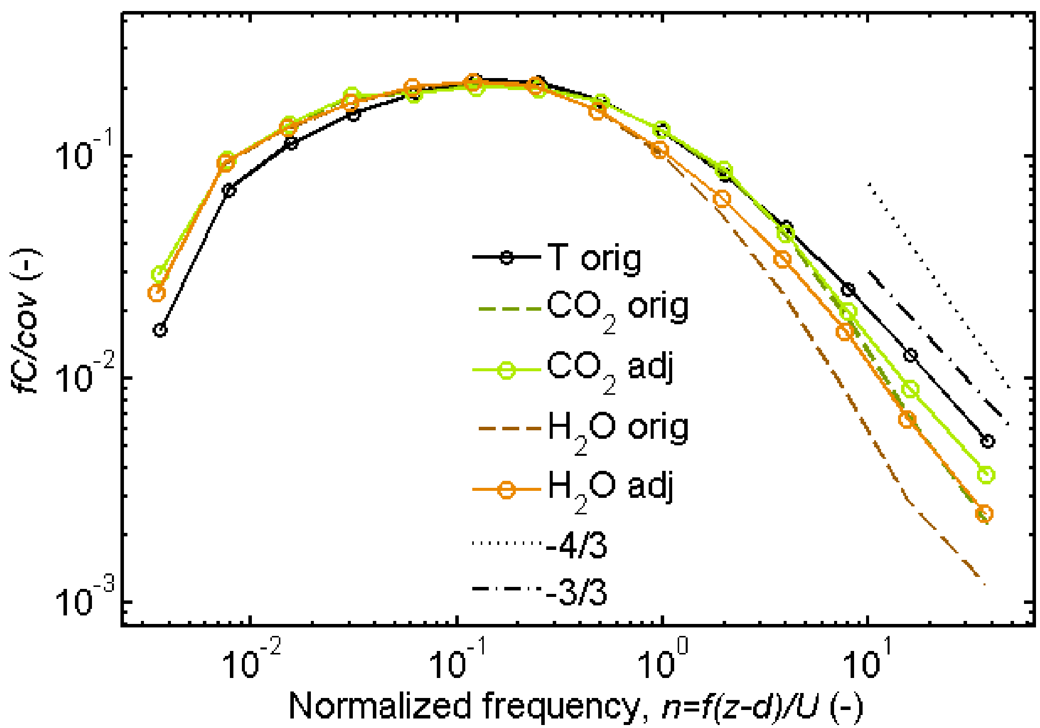


Different calculation procedures can affect the energy balance residual by an amount comparable to its magnitude

A new method for correcting for loss of flux transported by small eddies

- Totally independent of previous methods
- Automatic (not laborious)
- Based on forward and backward wavelet transforms
- Recreates lost variation in scalar time series (T, CO_2, H_2O, CH_4…)
- Result is increased fluxes, variances….

Mean co-spectra in May - July 2011



Water vapor suffers from more flux loss due to sorption (depends on tube dirtyness)

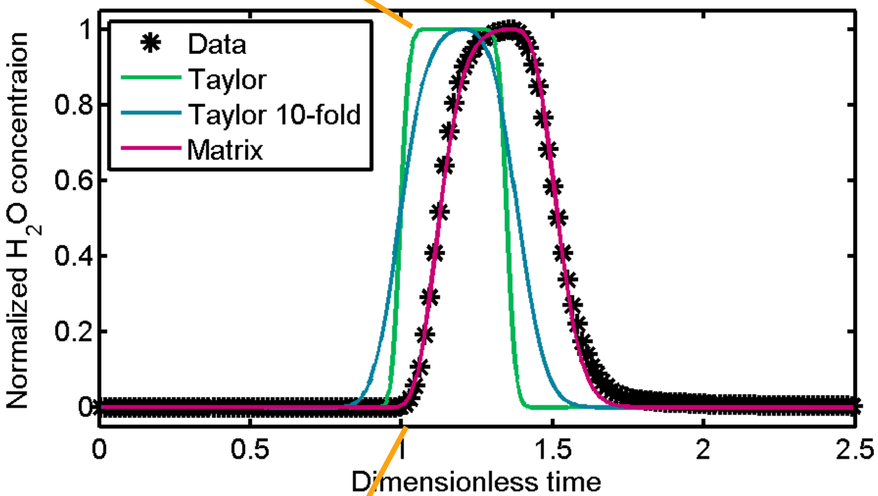
Nordbo et al., in preparation

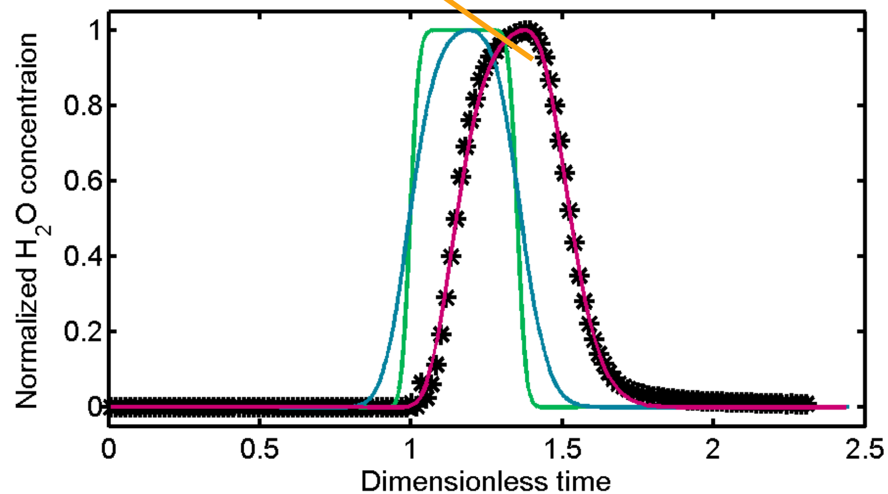
Lab measurements of water vapor flow in tubes

→ new theories using Matrix-diffusion modeling

Taylor's dispersion cannot explain

Data pulse not symmetrical anymore





Pulse arrives at time = 1

Tube length 14.2 m
flow rate 17 lpm
tube diameter 8 mm
RH = 30 %

The dirtiness of the tube appears as a change in a parameter in the matrix-diffusion solution
→ sopriton effects can be modeled!

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Technical staff of UHEL

Fire Station

Hotel Torni

ACCC PhD funding

....

www.tinyurl.com/HelsinkiMicromet

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Nordbo A., L. Järvi and T. Vesala (2012). Revised eddy covariance flux methodologies – effect on urban energy balance. *Tellus B,* 64, 18184, doi: dx.doi.org/10.3402/tellusb.v64i0.18184

Nordbo A. and G. Katul (2012). A wavelet-based correction method for eddy-covariance high-frequency losses in scalar concentration measurements. *In Review in BLMet.*

Nordbo A., L. Järvi, S. Haapanala, J. Moilanen and T. Vesala (2012). Intra-city variation in urban morphology and turbulence structure in Helsinki, Finland. *Submitted to BLMet.*

Nordbo A., P. Kekäläinen J. Timonen and T. Vesala. Explaining with matrix diffusion the lag time and flux loss of water vapour in closed-path measurements. *In preparation.*

5-years of CO_2 flux measurements in SMEAR III station

Leena Järvi, Annika Nordbo, Heikki Junninen, Joonas Moilanen, and Timo Vesala

Department of Physics, UHEL

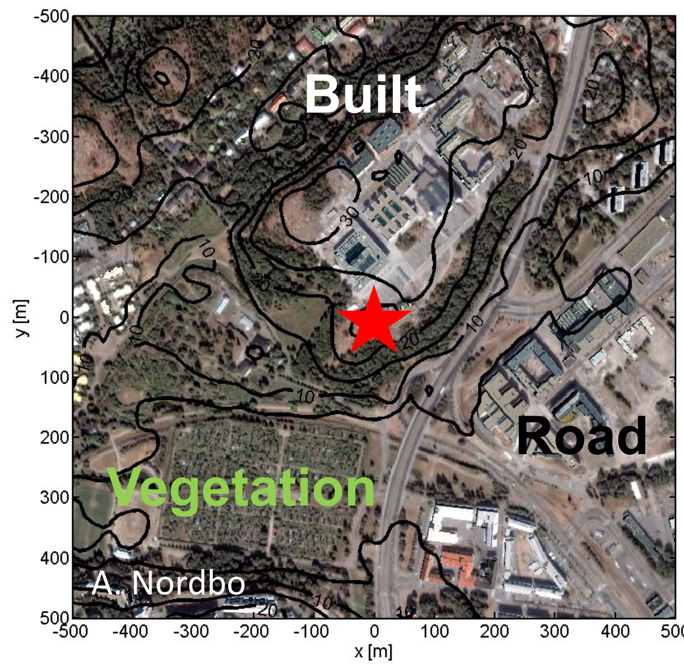
Anu Riikonen and Eero Nikinmaa

Department of Forest Ecology, UHEL

SMEAR III station

- Part of the SMEAR network covering different land uses
- Covers meteorology, turbulent measurements and urban trees
- Measurements carried out in Kumpula and in Viikki

Measurements and site characteristics of SMEAR III station



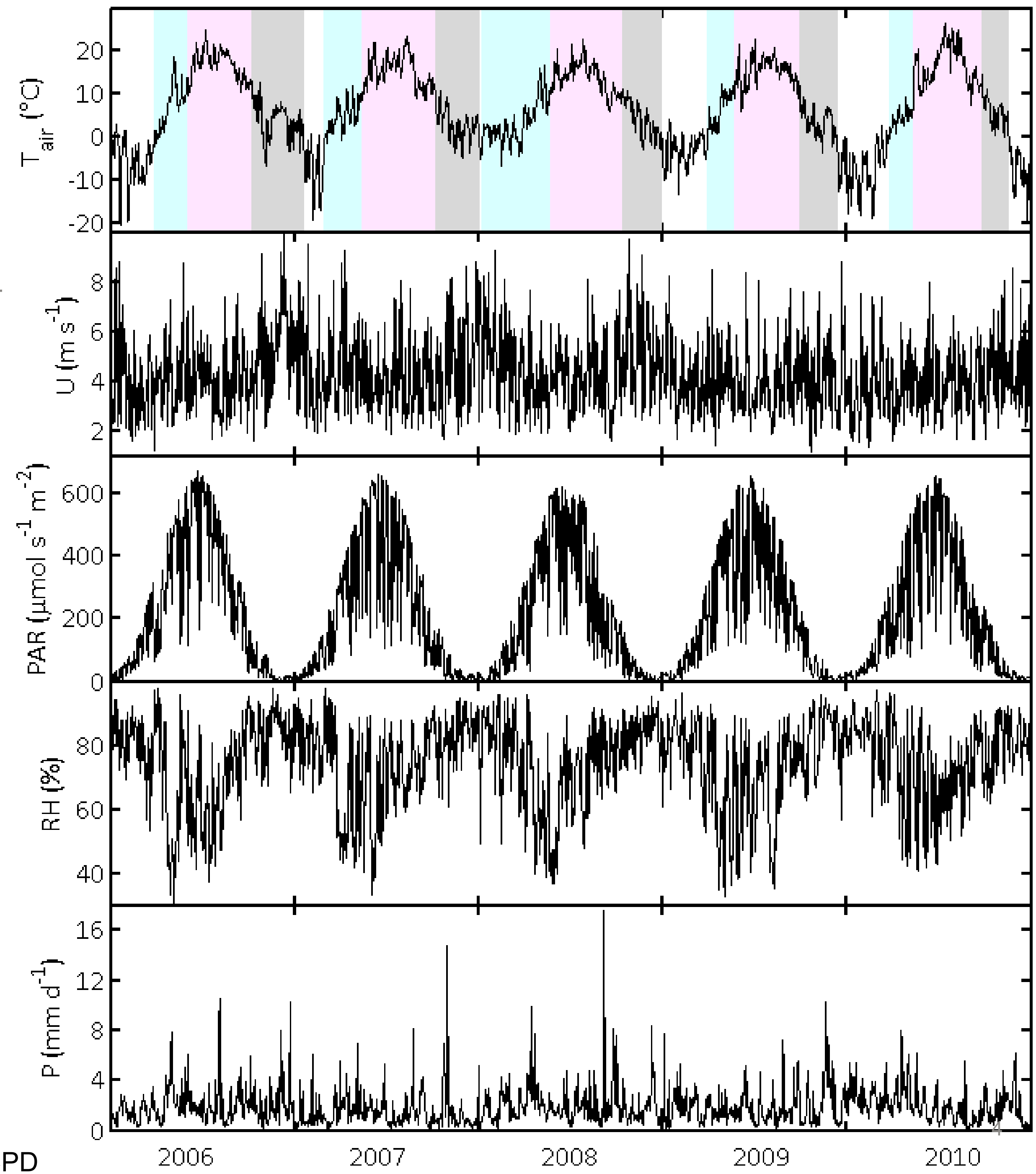
All	f_p	f_b	f_v
All	0.22	0.34	0.44
Build	0.18	0.39	0.43
Road	0.30	0.29	0.41
Vegetation	0.15	0.35	0.50

CO_2 flux with eddy covariance (EC) technique

Dec 2005 Metek USA-1+LI7500

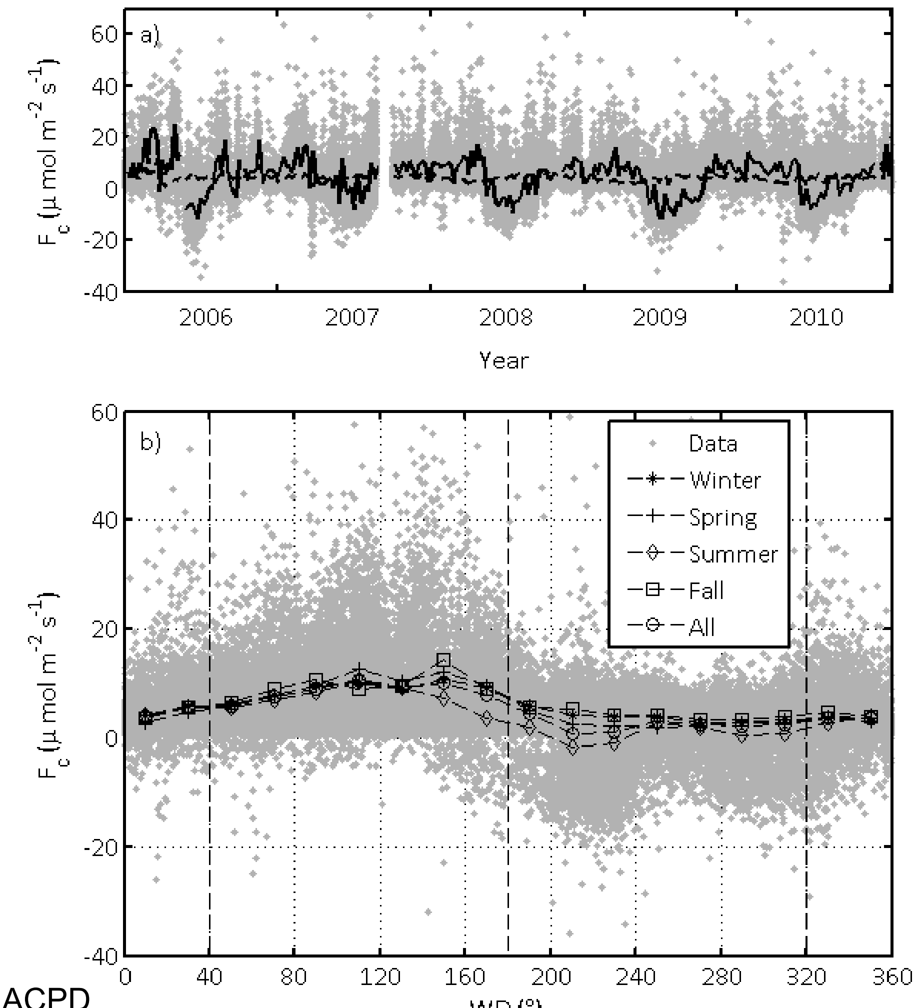
Jul 2007 Metek USA-1+LI7000

High latitude location creates strong annual behaviour in radiation and air temperature



Järvi et al., ACPD

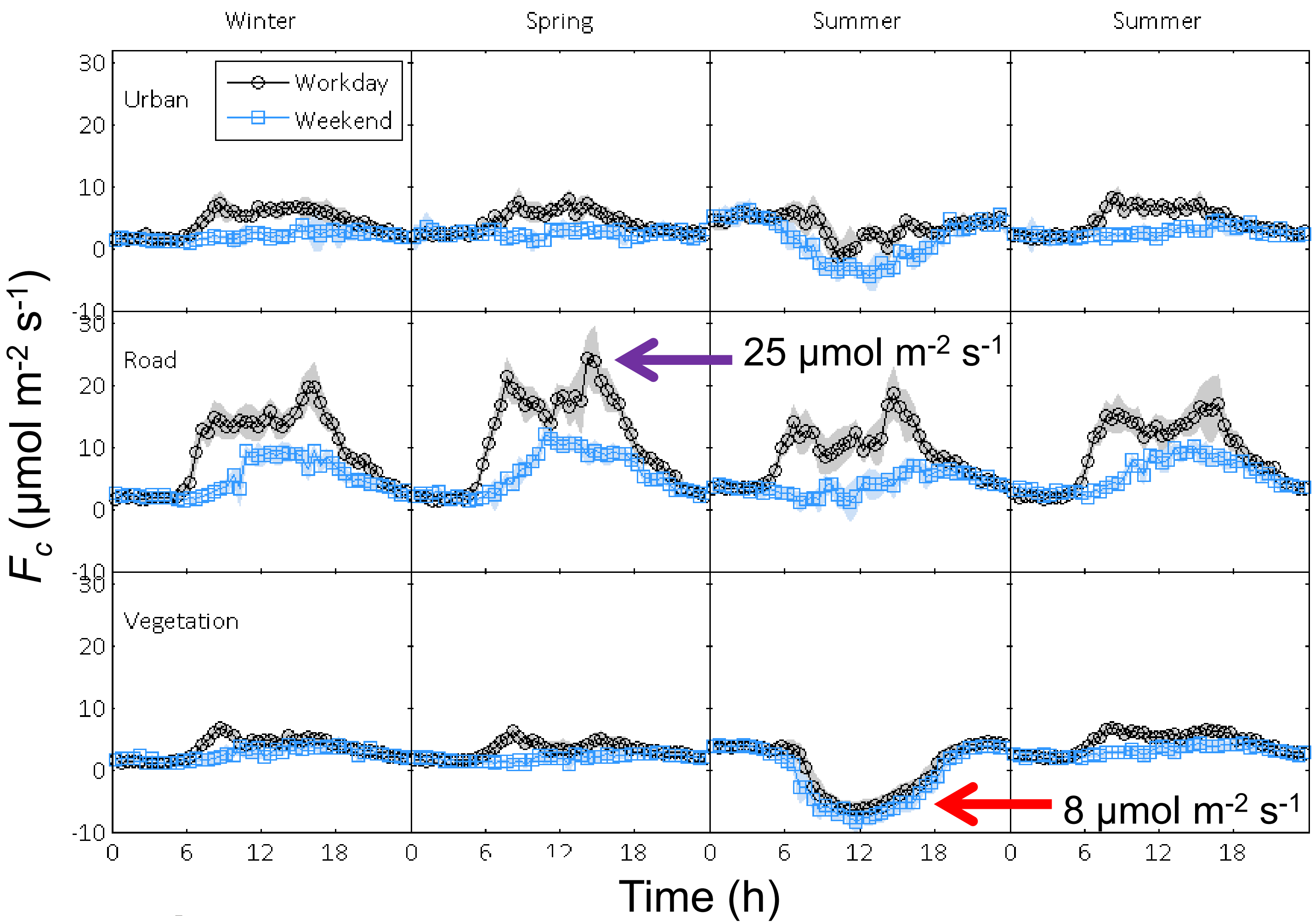
CO_2 exchange has strong annual behaviour and dependence of surface cover



First 18 months
From OP → corrected for instrument heating

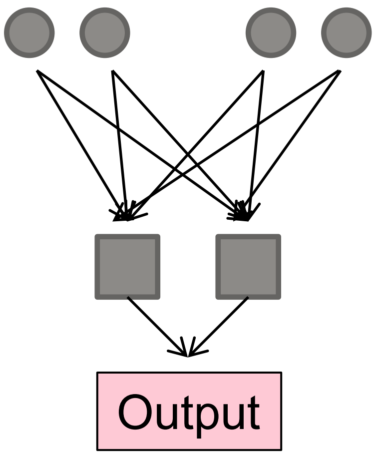
Järvi et al., ACPD

Diurnal variation of F_c varies strongly according to season and surface cover sector



Järvi et al., ACPD

For comparisons between different years, proper gap filling needs to be made



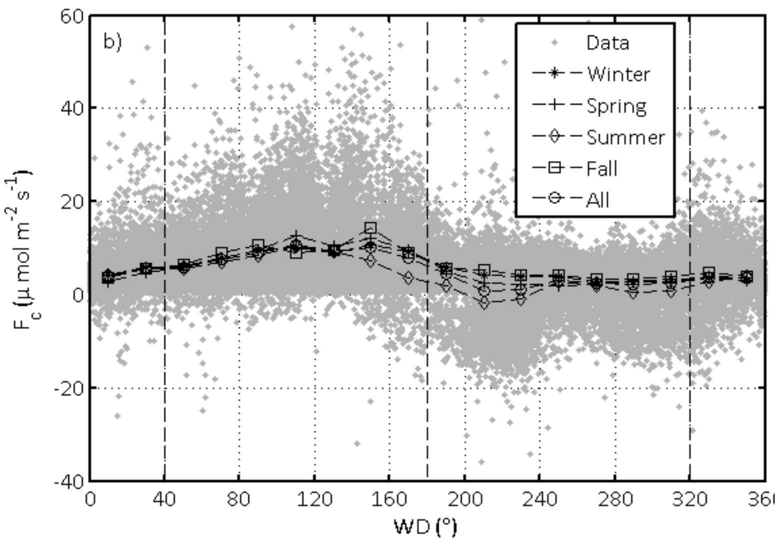
(Traffic)
Air temperature
PAR
RH
Wind speed
WD *(*WD1,…,WD9*)*
Month of year
Hour of day

Promising results using artificial neural networks

An adaptive system that has the capability of **learning** without knowledge on actual processes

We use a multilayer perceptron feed-forward network consisting of three layers

Optimized network:
21 – 5 – 1 with traffic
20 – 7 – 1 without traffic

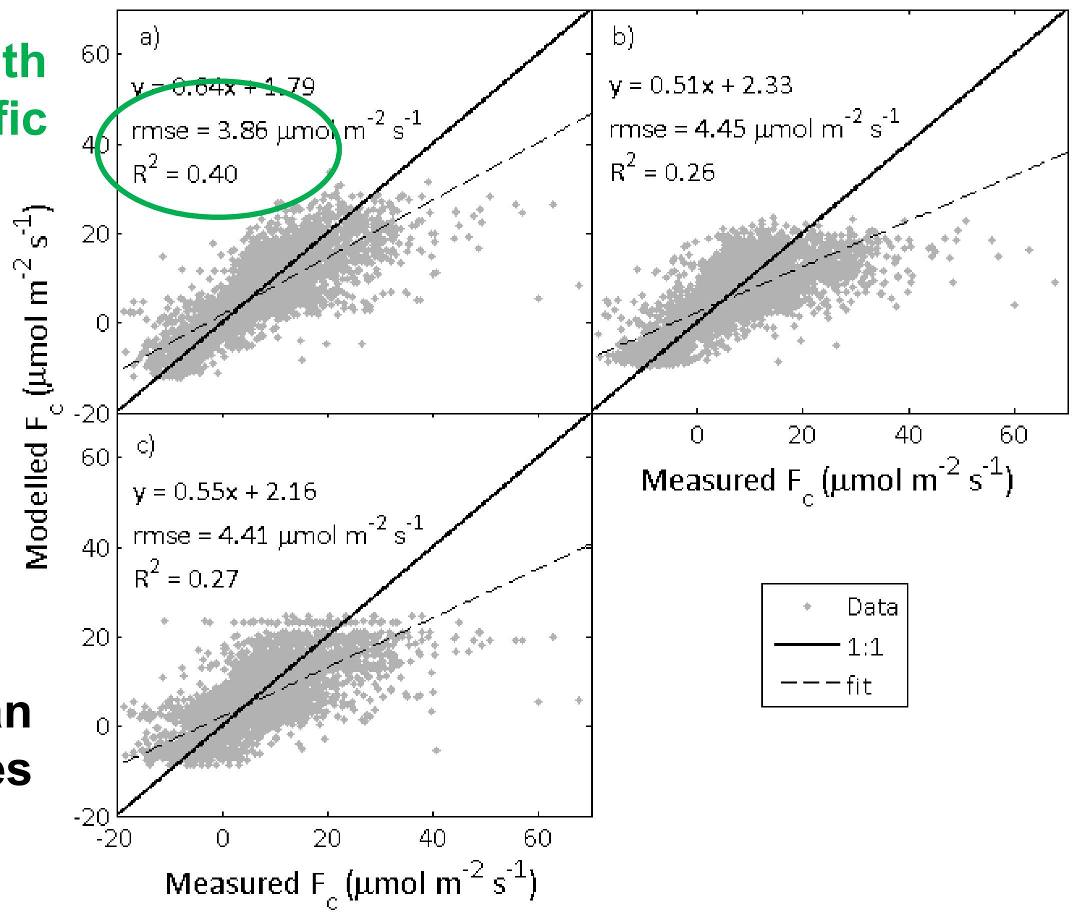


The performance of the final networks with and without traffic rates for the independent dataset

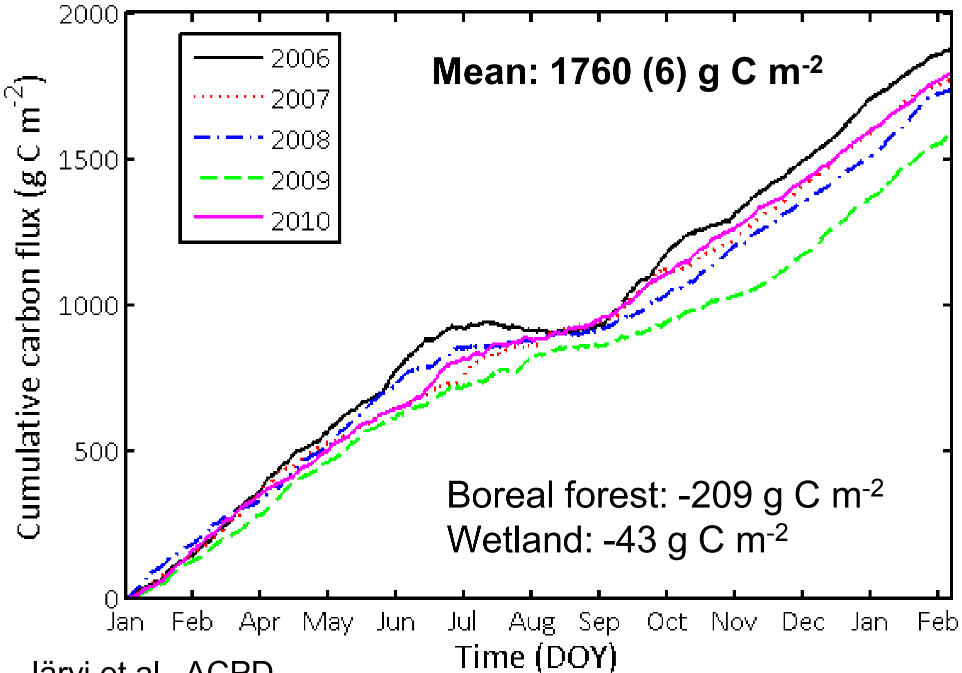
ANN with traffic

ANN without traffic

Median diurnal cycles

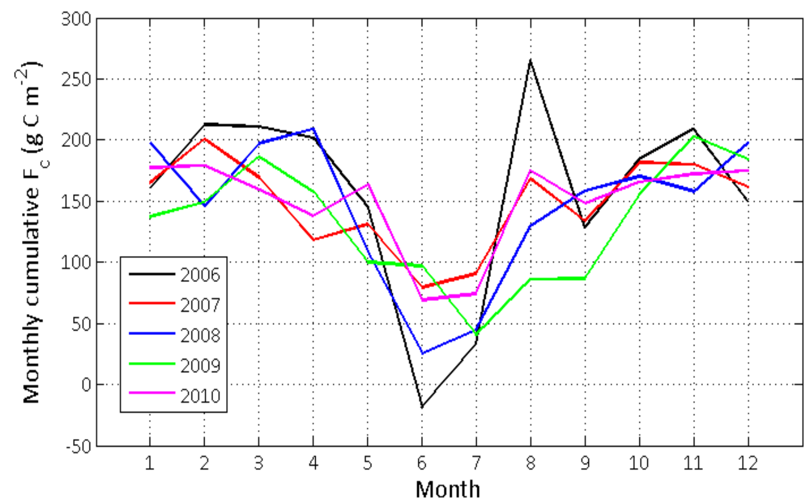


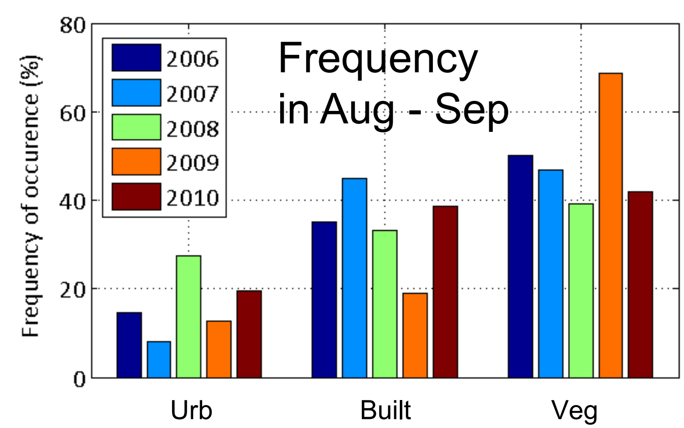
Differences in annual emissions around 10%



Järvi et al., ACPD

Why less CO_2 in 2009?





70% downwind from veg,
Other years less than 50%

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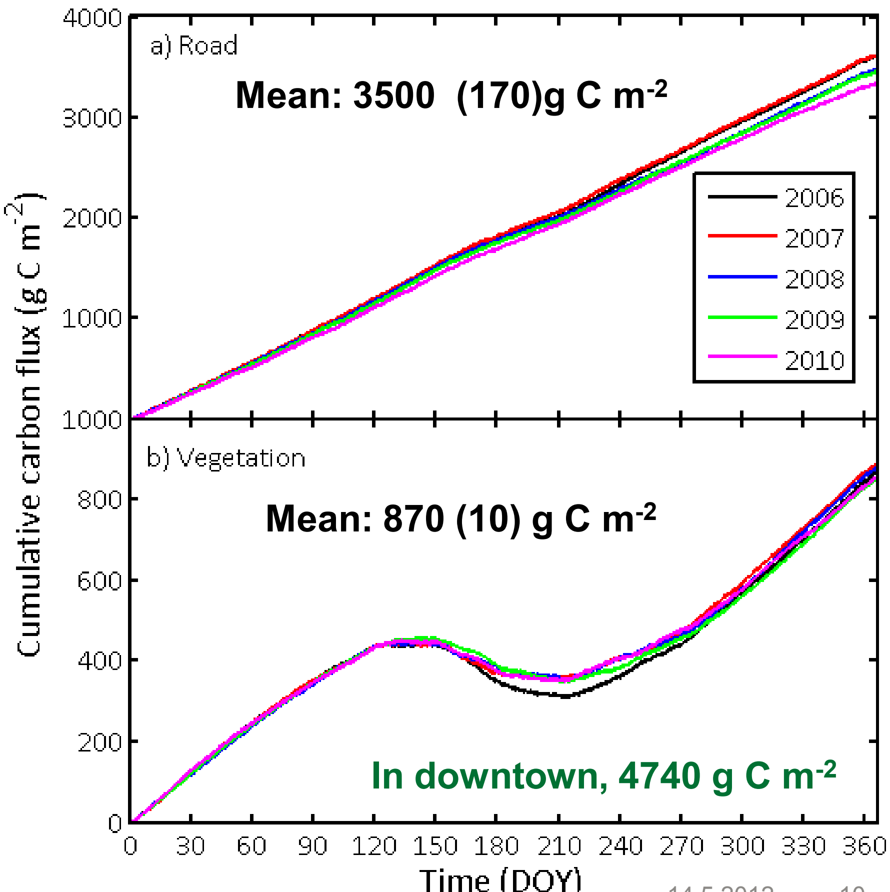
ANN can be used to create artificial time series for different surface cover areas

Inside a city, difference of 80% observed!

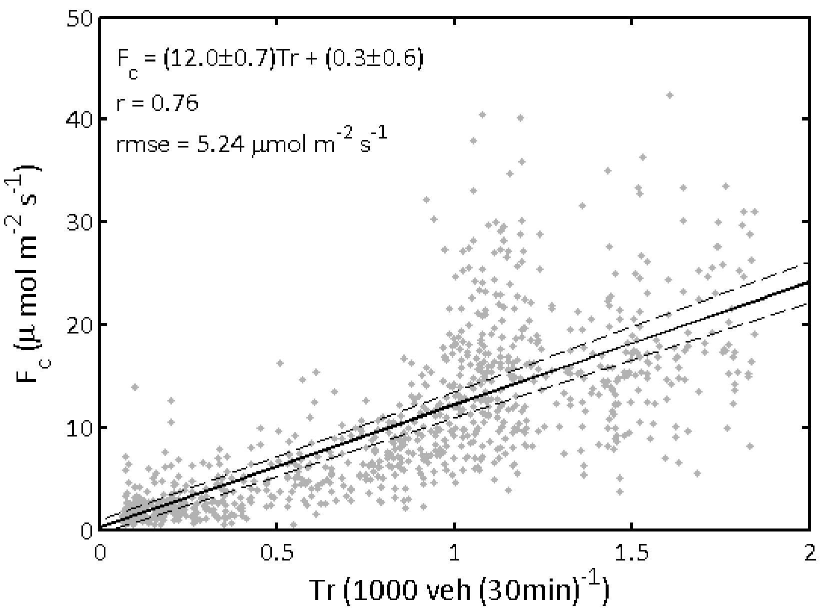
Traffic
T_{air}
PAR
RH
U
WD3=1/WD6=1
Month of year
Hour of day

The exceptionally warm summer in 2006 is seen as increased vegetation uptake

8% increase from the road sector from 2006 to 2010



The increase in CO_2 emissions from road is caused by increased traffic rates



Winter time EC measurements can be used to get emission factors for mixing fleet traffic

In five years:

502 g km^{-1} → 361 g km^{-1}

From inventories for mixed fleet traffic (2010&2011):

285 g km^{-1}

Conclusions

Long-term CO_2 flux measurements show clear dependence from season and surface cover type

In SMEARIII, 49% difference observed in different directions → Inside a city scale 80% difference

Observed trends:

- 2006 heat wave seen as increased uptake
- emissions from road have slightly increased likely due to increased traffic

EC measurements can be used to get realistic emission factors for mixed fleet traffic

Thank you!

Acknowledgements

For financial support we thank Finnish Academy and EU-funded projects BRIDGE and ICOS.

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Towards urban weather prediction

Carl Fortelius
Helsinki Urban symposium, 14 May 2012

Outline

- Downscaling urban forecasts by a stand-alone surface simulator
- Proof of concept: Simulating the SMEARIII site
  - The site and the measurements
  - The simulations
  - Results
- Conclusions, questions, comments,...
- Acknowledgements

Motivation

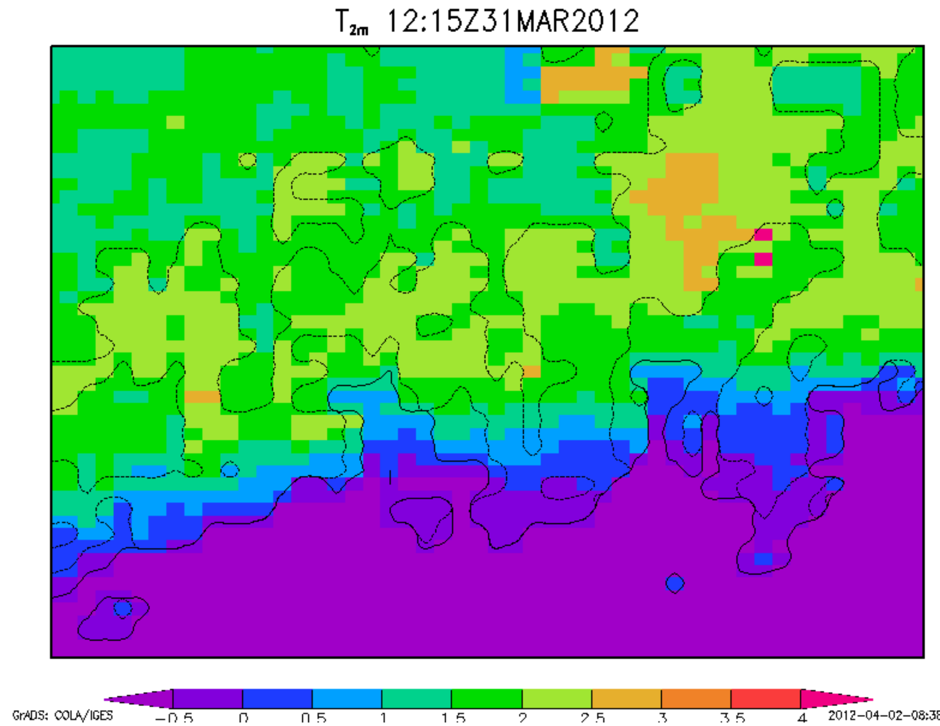
Growing importance of urban forecasting: perceived weather, air quality, road maintenance, energy demand.

Required high resolution is still an obstacle to urban NWP

Can we rely on a stand-alone surface simulator as a low-cost downscaling tool for numerical forecasts?

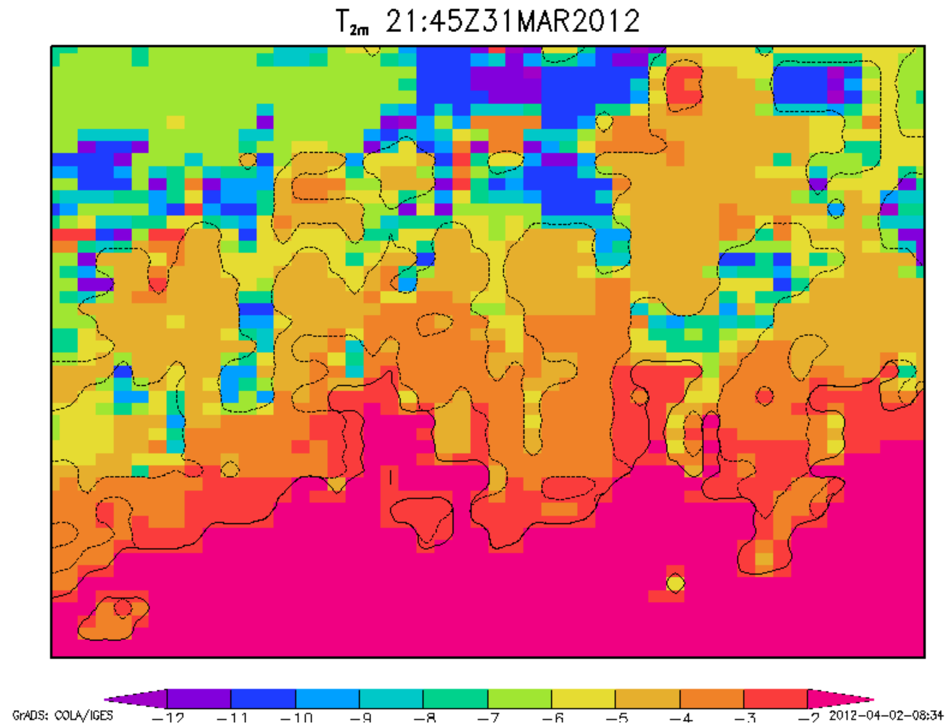
Example: 31st of March 2012, Afternoon

- A chilly, overcast spring day followed by a cold clear night
- SURFEX running off-line on a 500 by 500 m grid
- Physiographic data base: ECOCLIMAP II, gtopo30
- Atmospheric forcing and initial state from HARMONIE 06 UTC run on 2012-03-31 (2500 m by 2500 m)
- Solid line: frac. of sea=0.5
- Dashed line: frac of town=0.5
- Cool sea - warm land
- Cool fields and forests - warm town



Example: 31st of March 2012, Midnight

- A chilly, overcast spring day followed by a cold clear night
- SURFEX running off-line on a 500 by 500 m grid
- Physiographic data base: ECOCLIMAP II, gtopo30
- Atmospheric forcing and initial state from HARMONIE 06 UTC run on 2012-03-31 (2500 m by 2500 m)
- Solid line: frac. of sea=0.5
- Dashed line: frac of town=0.5
- Warm sea - cold land
- Cold fields and forests - warm town



SURFEX Overview

SURFEX (Surface Externalisée, in French) is a surface modelling platform developed by Météo-France in cooperation with the scientific community.

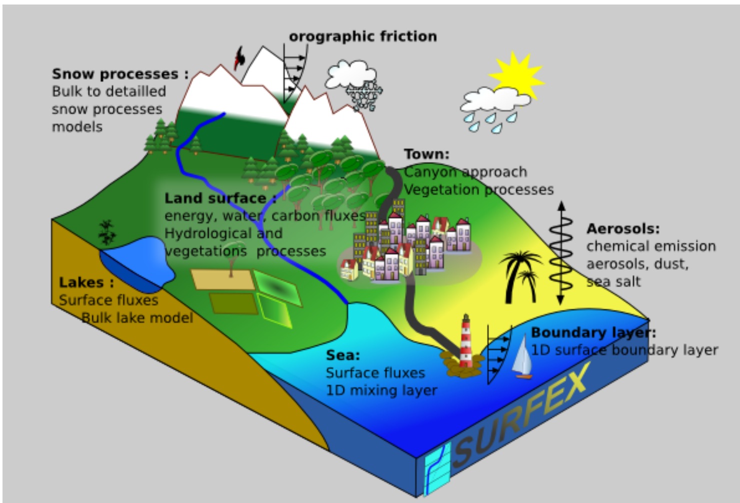
SURFEX is composed of various physical models for natural land surface, urbanized areas, lakes and oceans. It also simulates chemistry and aerosols surface processes and can be used for assimilation of surface and near surface variables.

SURFEX has its own initialisation procedures.

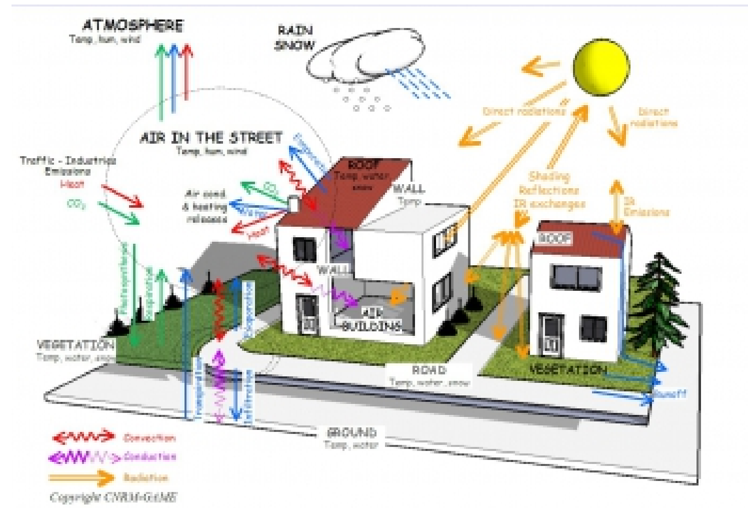
SURFEX can be used in a stand alone mode or coupled to an atmospheric model.

SURFEX is in daily use at FMI in the HARMONIE forecasting system

SURFEX Overview



The surface is treated as a mosaic of tiles



Built-up surfaces are handled by the Town Energy Balance model TEB, describing:
Radiative trapping, shadows
Conduction in roofs, roads and walls separately
Water interception and evaporation, snow mantel evolution on roads and roofs
Turbulent exchanges
Heating of building space, heating due to traffic and industry may be prescribed

The SMEARIII site in Kumpula

operated by University of Helsinki and the Finnish Meteorological Institute

4 kilometres from down town Helsinki.

31 m tower, standing on a small hill, 26 m above sea level

instrumented at several heights, yielding profiles of temperature, wind, radiation components.

fluxes of sensible heat, momentum, carbon dioxide and water vapour by eddy covariance technique.

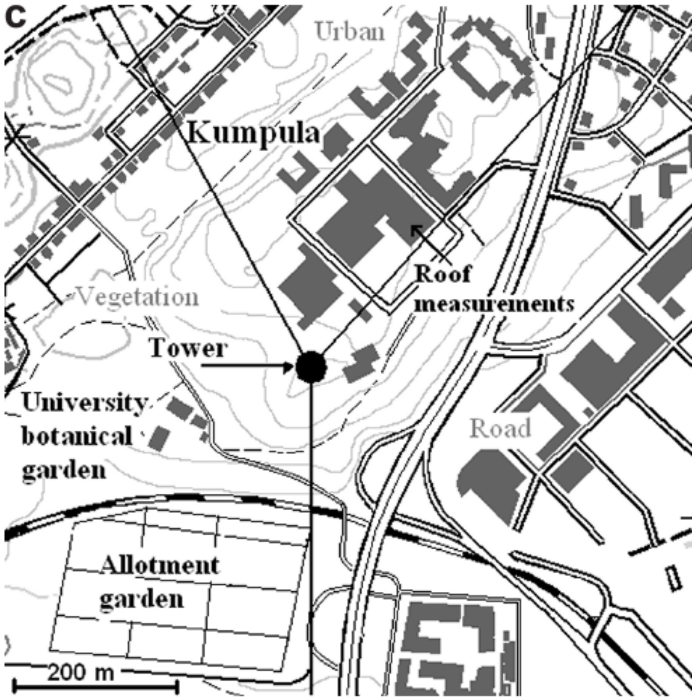
large diversity of aerosol particle and gas concentration instrumentation

All about SMEAR: http://www.atm.helsinki.fi/SMEAR/

The SMEARIII site in Kumpula

The SMEARIII measuring tower seen from the roof of the U. Helsinki physics building. FMI building to the right.

The SMEARIII site in Kumpula



The tower is located in a heterogeneous environment: Large buildings and a busy road to the north and east, nature to the west and south-west.

Modelling

SURFEX v 7.1 was configured corresponding to the three different sectors: *"urban"*, *"road"*, *"veg"*, and according to local characteristics in the *ECOCLIMAP II* data base

Experiments were carried out for all configurations, using identical meteorological forcing (Wind speed, temperature, humidity, downwelling solar and atmospheric radiation, precipitation and snow fall) measured at a the top of the tower, with a time resolution of 30 minutes

Integration period: November 2009 – December 2010

Analysis presented for January 2010 – December 2010

Modelling

Model settings and fractional coverage of different surface types coresponding to different sectors.

	“Urban“ 320°..40°	“Road” 40°..180°	”Vegetation“ 180°..320°	”Ecoclimap” 0..360°
Natural	**0.41**	**0.37**	**0.50**	**0.44**
Parks	0.04	0.26	0.35	0.1
Forest	0.36	0.05	0.14	0.34
Unmanaged	0.05	0.05	0.01	-
Built-up	**0.59**	**0.63**	**0.50**	**0.56**
Buildings	0.41	0.33	0.35	0.28
Paved	0.18	0.30	0.15	0.28
Bld. hgt	8.4 m	9.9 m	8.5 m	10 m
Forcing hgt	5 m	32 m	32 m	22 m
$\frac{WALL}{HOR.}$	0.29	0.32	0.1	0.28
Irrigation param.	no	no	yes	no

Analysis

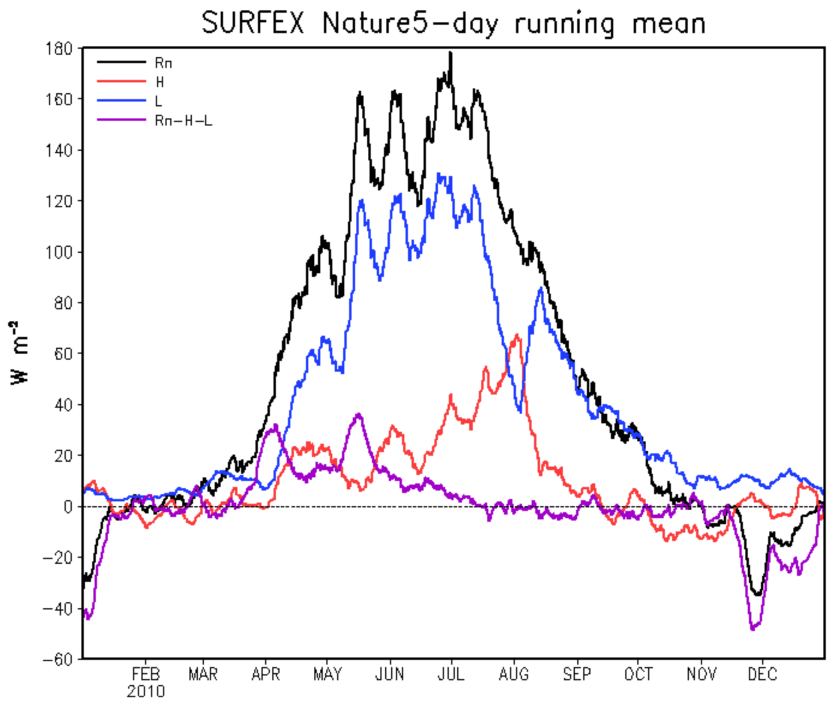
Model results were compared to observations in terms of a model output composite, X_m:

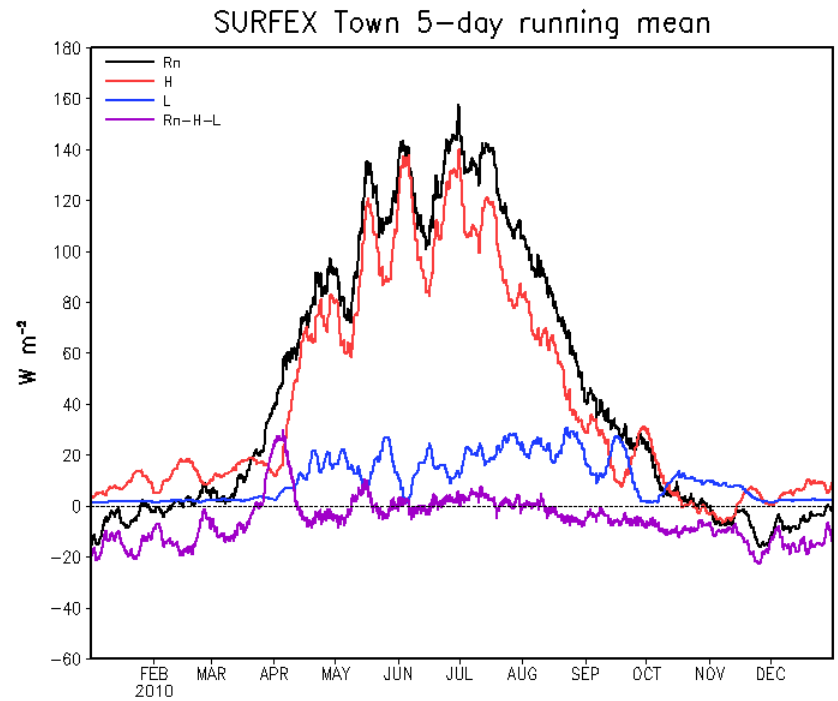
$$X_m = (\delta_{urban} X_{urban} + \delta_{road} X_{road} + \delta_{veg} X_{veg})\Psi_o$$

$$\delta_i = \begin{cases} 1, \text{ if the wind blows from the i:th sector} \\ 0, \text{ otherwise} \end{cases}$$

$$\Psi_o = \begin{cases} 1, \text{ if the measurement is present} \\ undefined, \text{ otherwise} \end{cases}$$

Results: Simulated nature vs. town





Annual course surface energy budget components (net radiation Rn, sensible heat flux H, latent heat flux L, and storage flux (Rn-H-L) in the nature tile (left) and town tile (right). Differences between natural and built-up surfaces are large, so a correct specification of the scene is essential.

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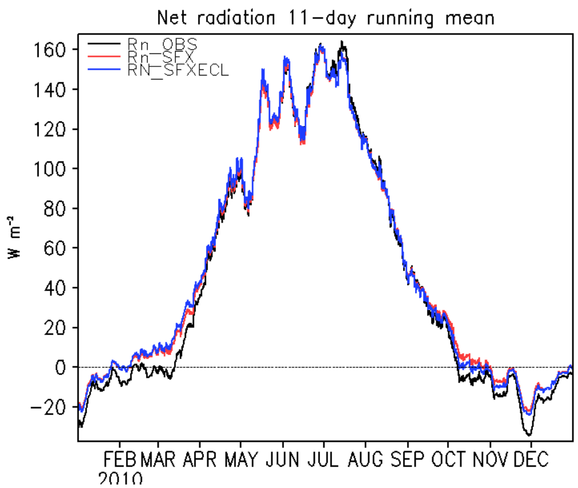
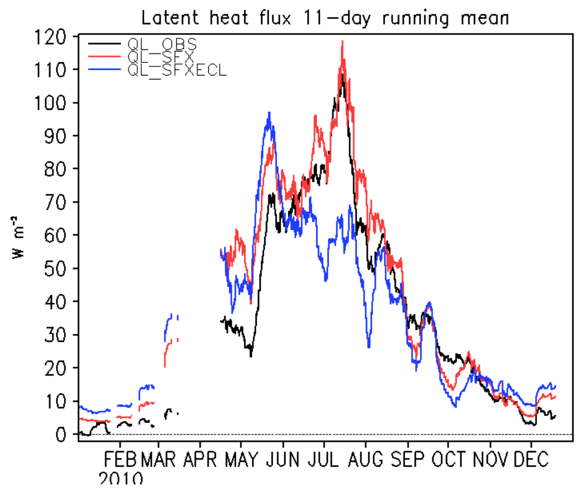
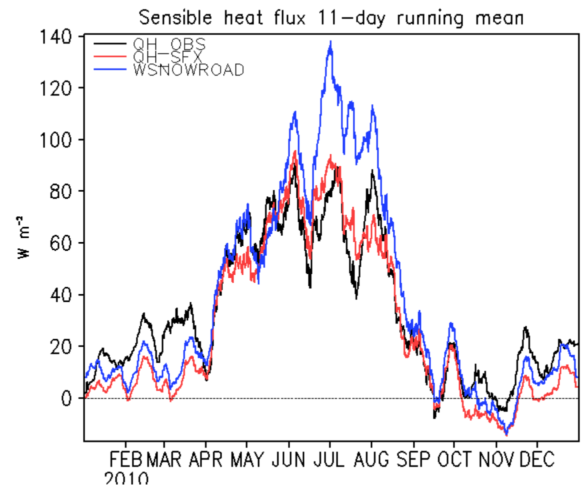
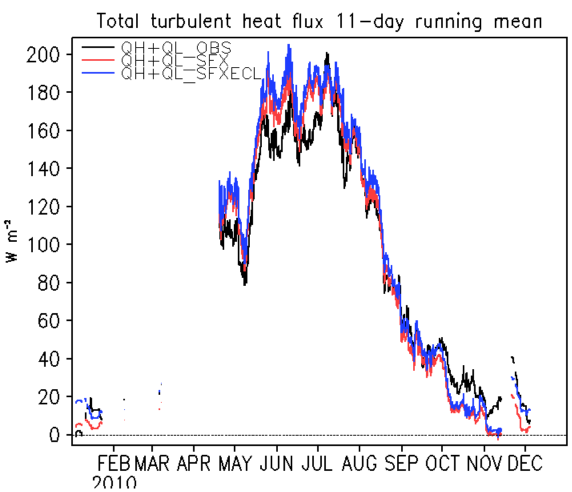
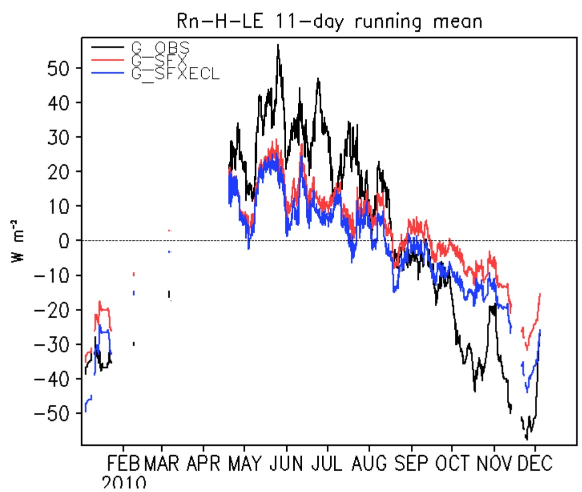
Results: Annual cycles











Annual course of observed (black) and simulated surface energy budget components at Kumpula. Red lines: 3-sector composite, Blue lines: ECOCLIMAP II data base

Results: Irrigation

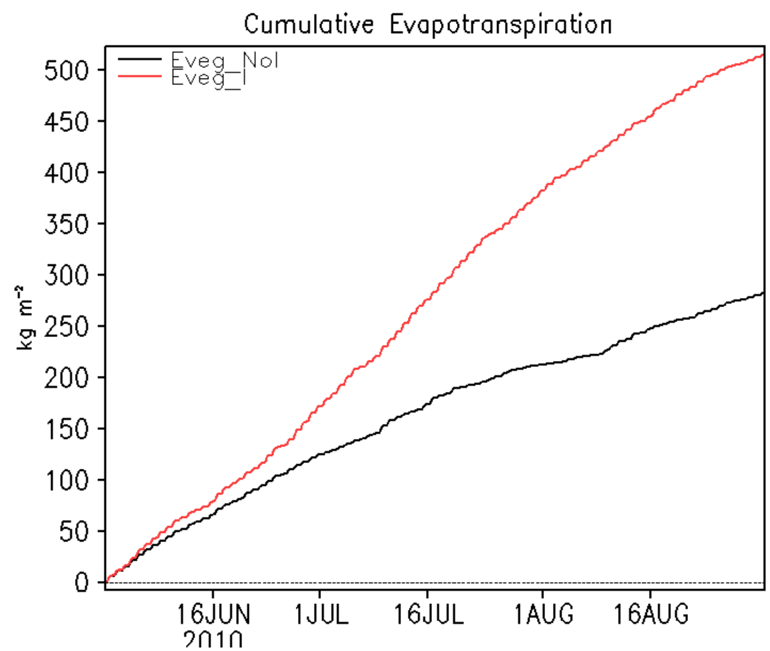
Irrigation is parameterized by maintainting the soil moisture content at least at half way between the field capacity and the wilting point

Applied only in the sector "veg"

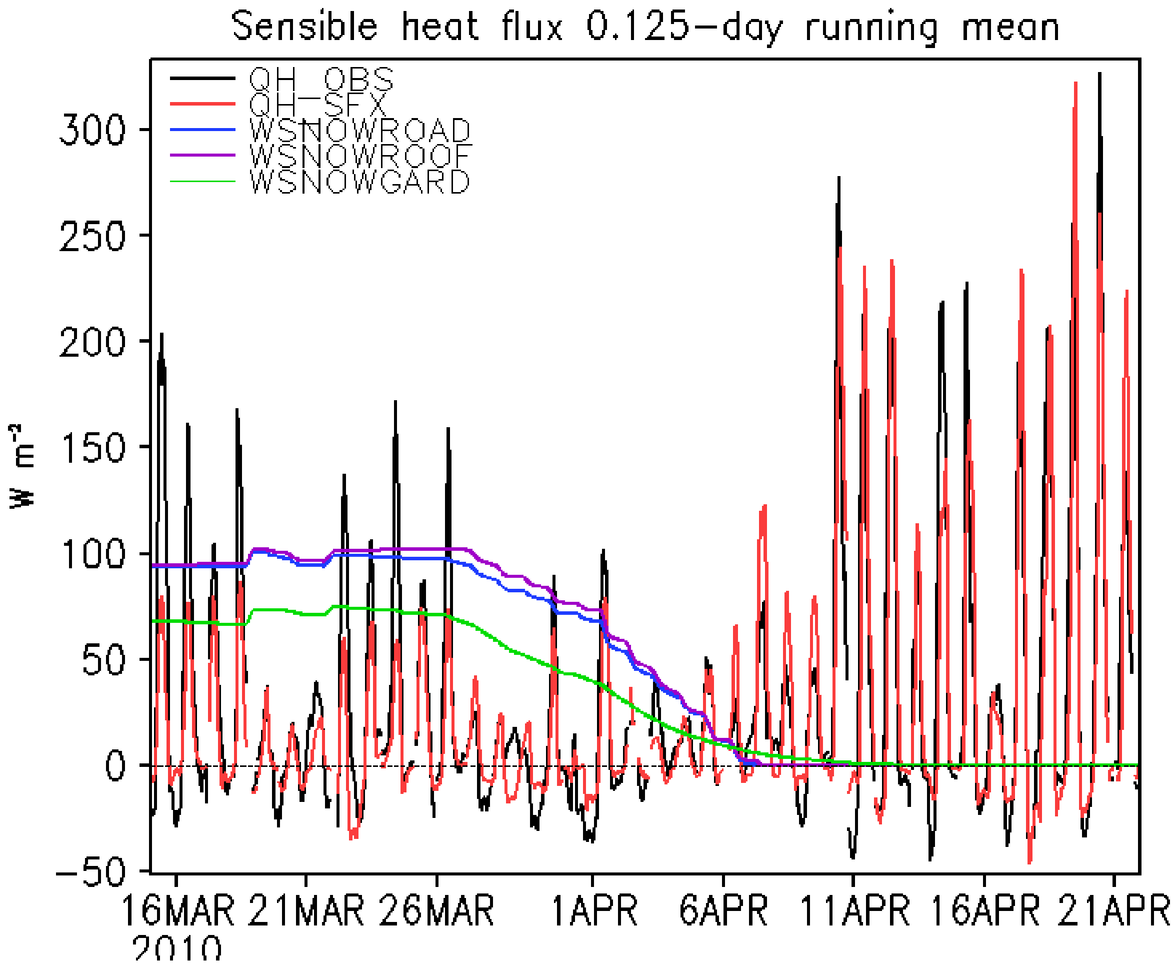
Applying the irrigation parameterization doubles the evapotranspiration from the vegetated tile in June..August.

The daily average June..August increase amounts to some 2.7 mm

The average sensible heat flux changes from 27 to -40 W m^{-2}

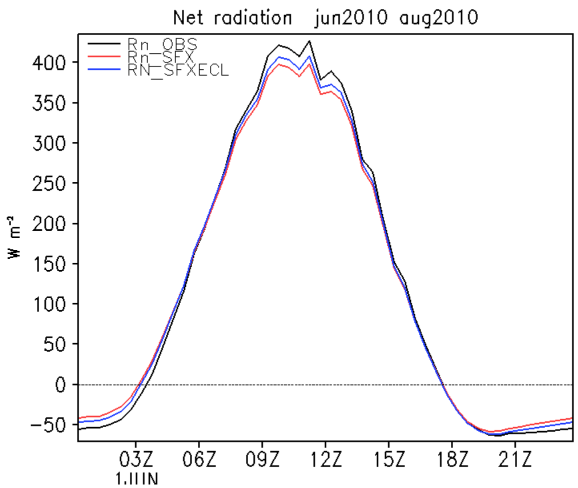


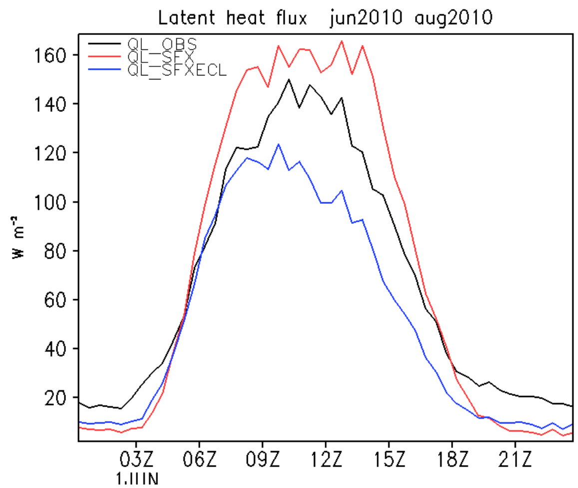
Results: The snow melt

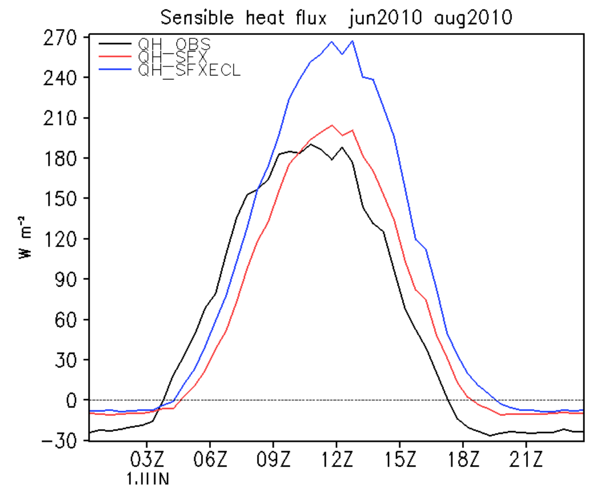


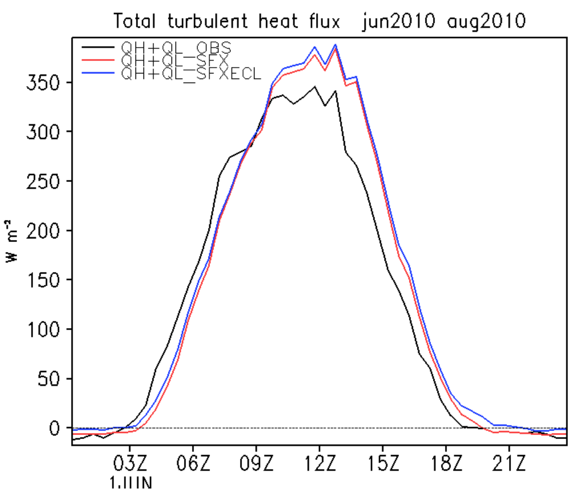
When the snow cover disappears, the sensible heat flux increases dramatically. The increase is well simulated.

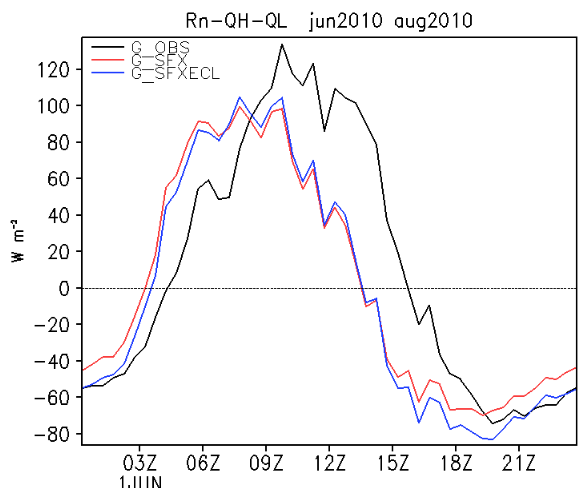
Results: Summer time diurnal cycles











Summer time mean daily course of observed (black) and simulated surface energy budget components at Kumpula. Red lines: 3-sector composite, Blue lines: ECOCLIMAP II data base

Conclusions

- SURFEX is able to reproduce the essential features of the observed annual and diurnal cycles of the surface energy budget components for the heterogeneous landscape of Kumpula hill.
- A good description of the scene is important in the model
- Anthropogenic influences, like heating and/or irrigation, are important and should therfore be realistic.
- Thermal properties of buildings may need some adjustment

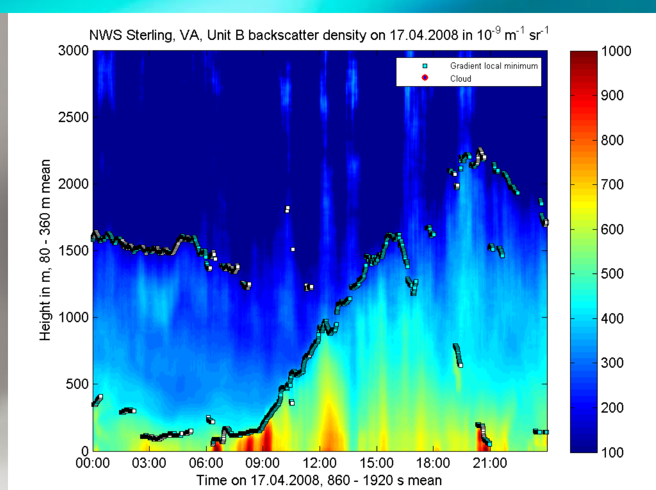
Acknowledgements

The SMEARIII data were provided by Dr. Leena Järvi, University of Helsinki, Department of Physics.

The research leading to these results has received funding from the European Research Council under the European Community's 7 th Framework Programme (FP7/2007-2013) / ERC grant agreement number 227915, project PBL-PMES

Investigation of ABL structures with ceilometer using a novel robust algorithm

Reijo Roininen — Vaisala Oyj, Helsinki, Finland
Christoph Münkel — Vaisala GmbH, Hamburg, Germany



VAISALA

Contents

- Vaisala Ceilometers
- Boundary layer height investigation – basics
  - A day from the boundary layer textbook
    - good result with simple algorithm
  - A common day with clouds and rain
    - more sophisticated algorithm required
- Steps towards an automatic stable algorithm
  - Cloud and precipitation filter
  - Height dependant averaging
  - Signal noise dependant time averaging
  - Variable detection threshold
  - Outlier removal
- PBL Reporting and Analysis Tool Vaisala BL-VIEW

Vaisala Ceilometers

CT25K

- First generation of single lens Ceilometers
- Based on LIDAR technology
- Range 25 000 ft
- Main applications: Aviation, general MET
- Terminated from production 2005

CL31

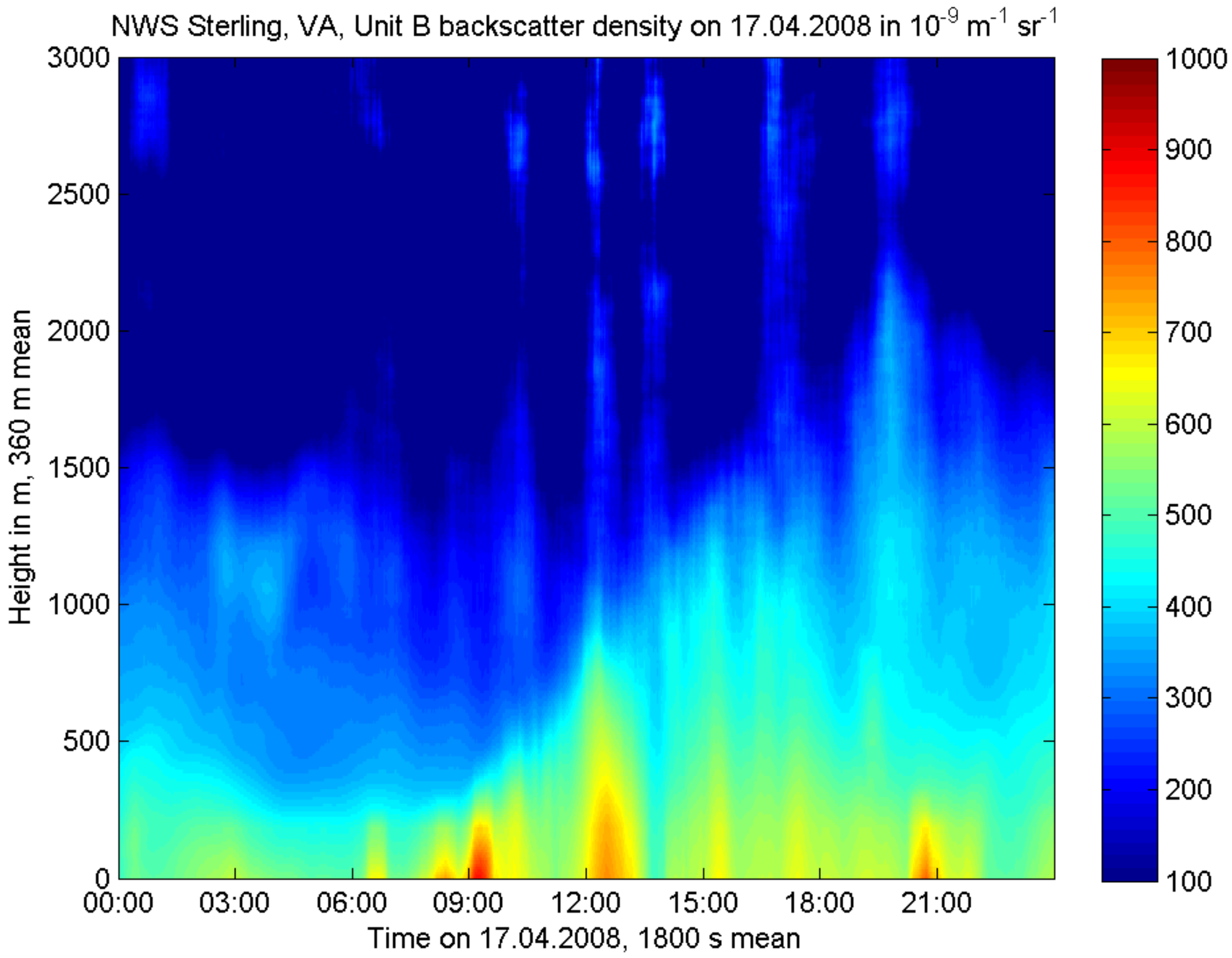
- Based on LIDAR technology
- Range 25 000 ft
- Advanced single lens technology
- Main applications: aviation, general MET, air quality

CL51

- Based on LIDAR technology
- High Range 43 000 ft (50 000 ft)
- Advanced single lens technology
- Main applications: advanced MET, air quality, climatology

- **Boundary layer height investigation – basics**
  - A day from the boundary layer textbook
    - good result with simple algorithm
  - A common day with clouds and rain
    - more sophisticated algorithm required

A day from the boundary layer textbook



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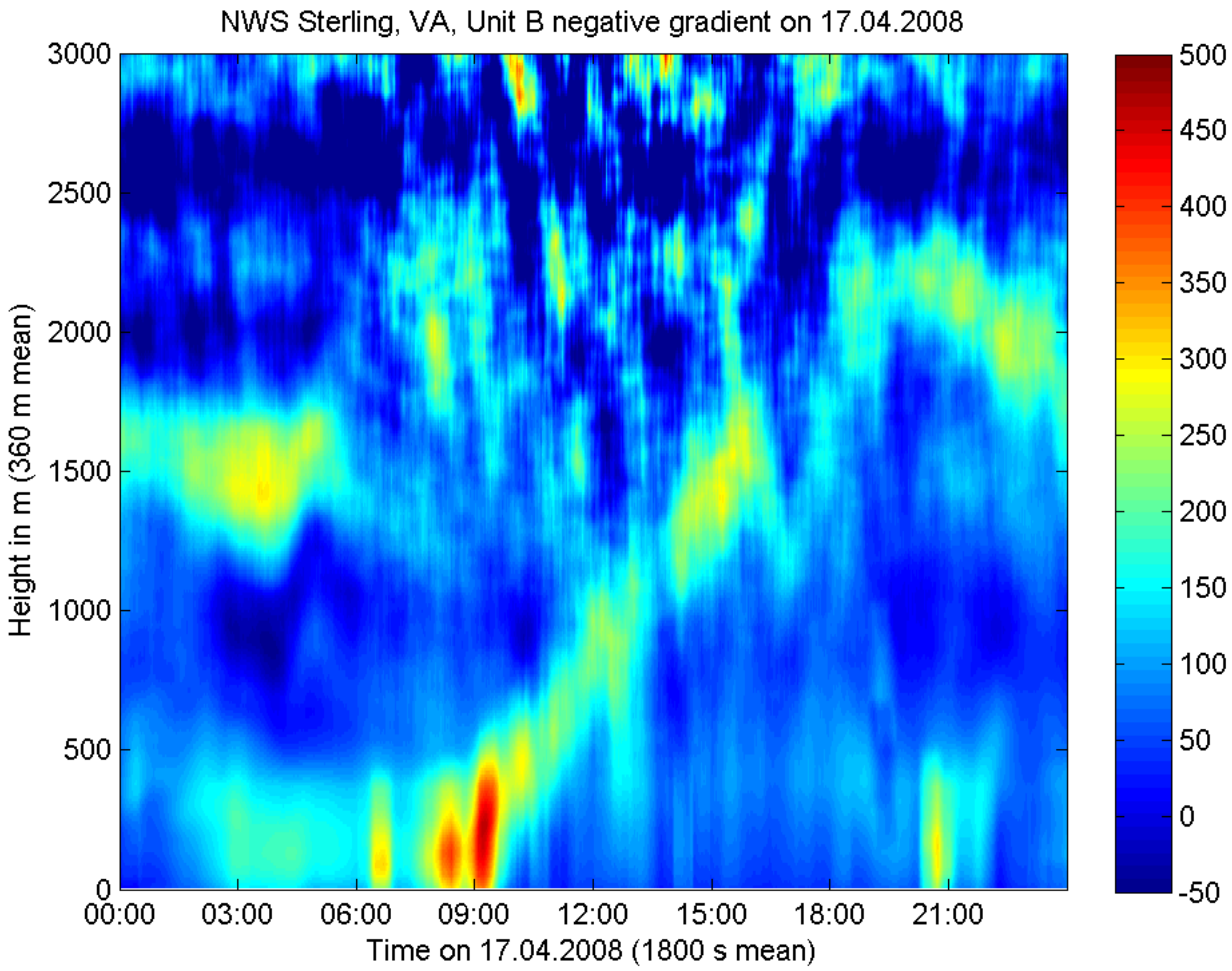
Negative gradient plot



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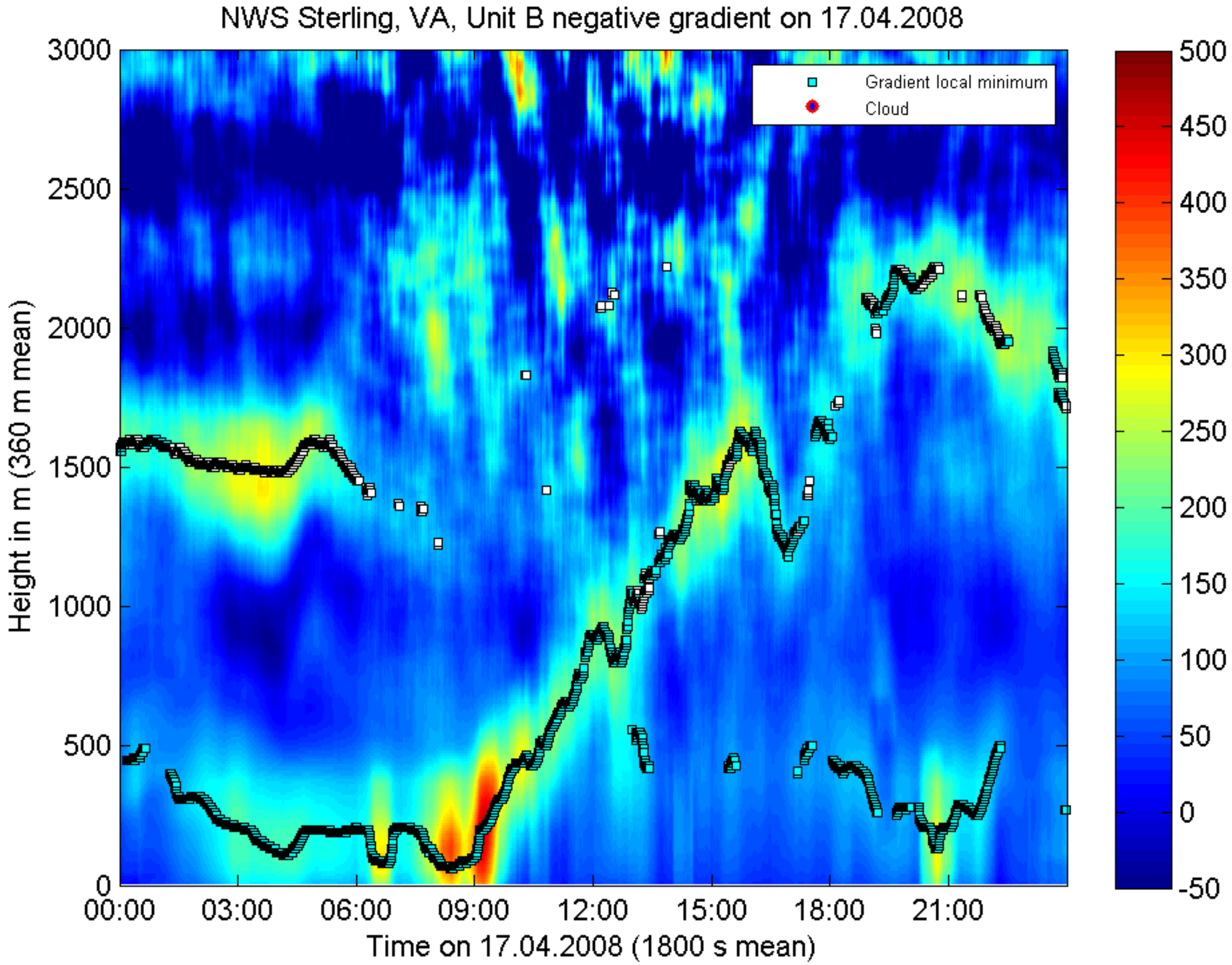
Up to two gradient local minima



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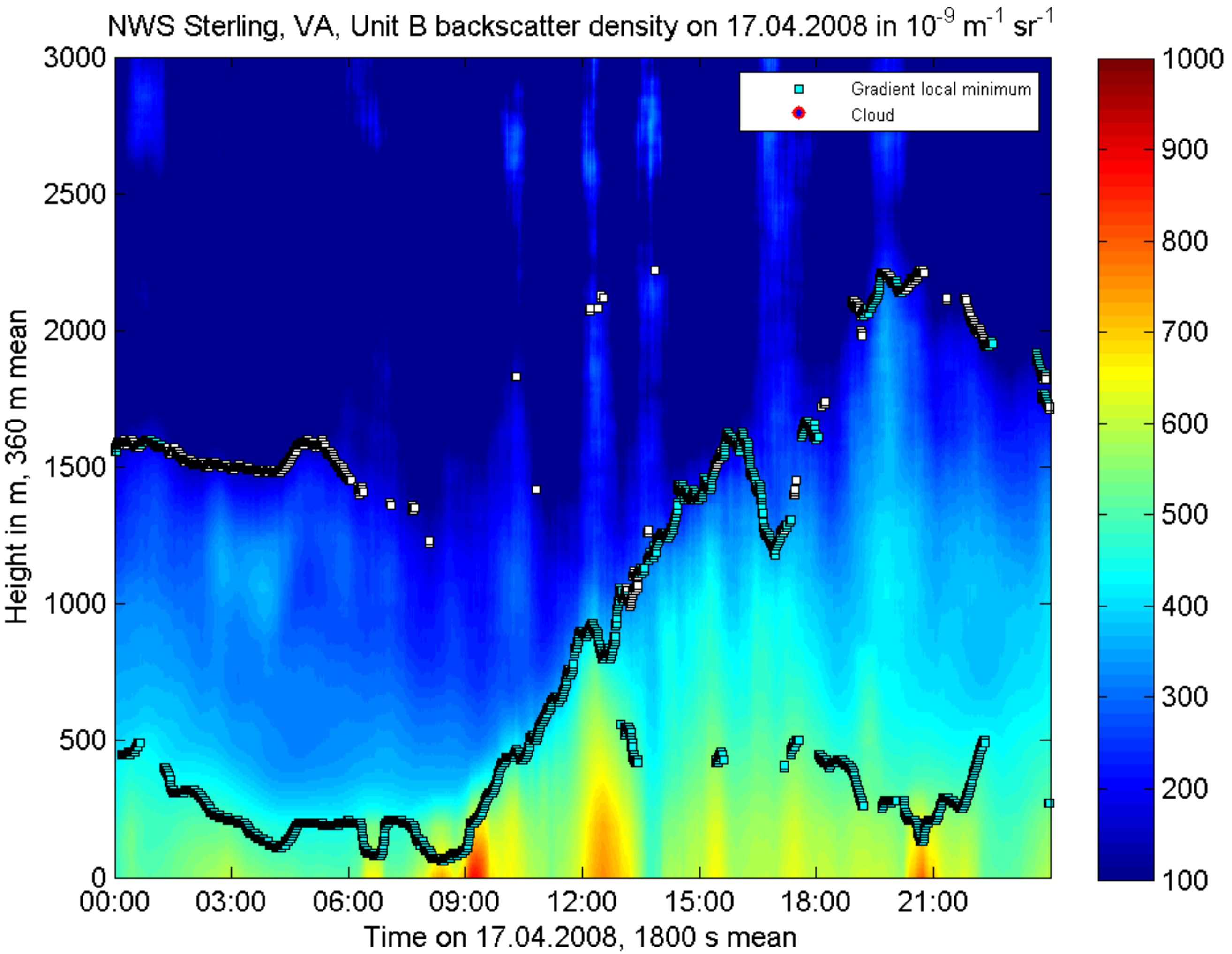
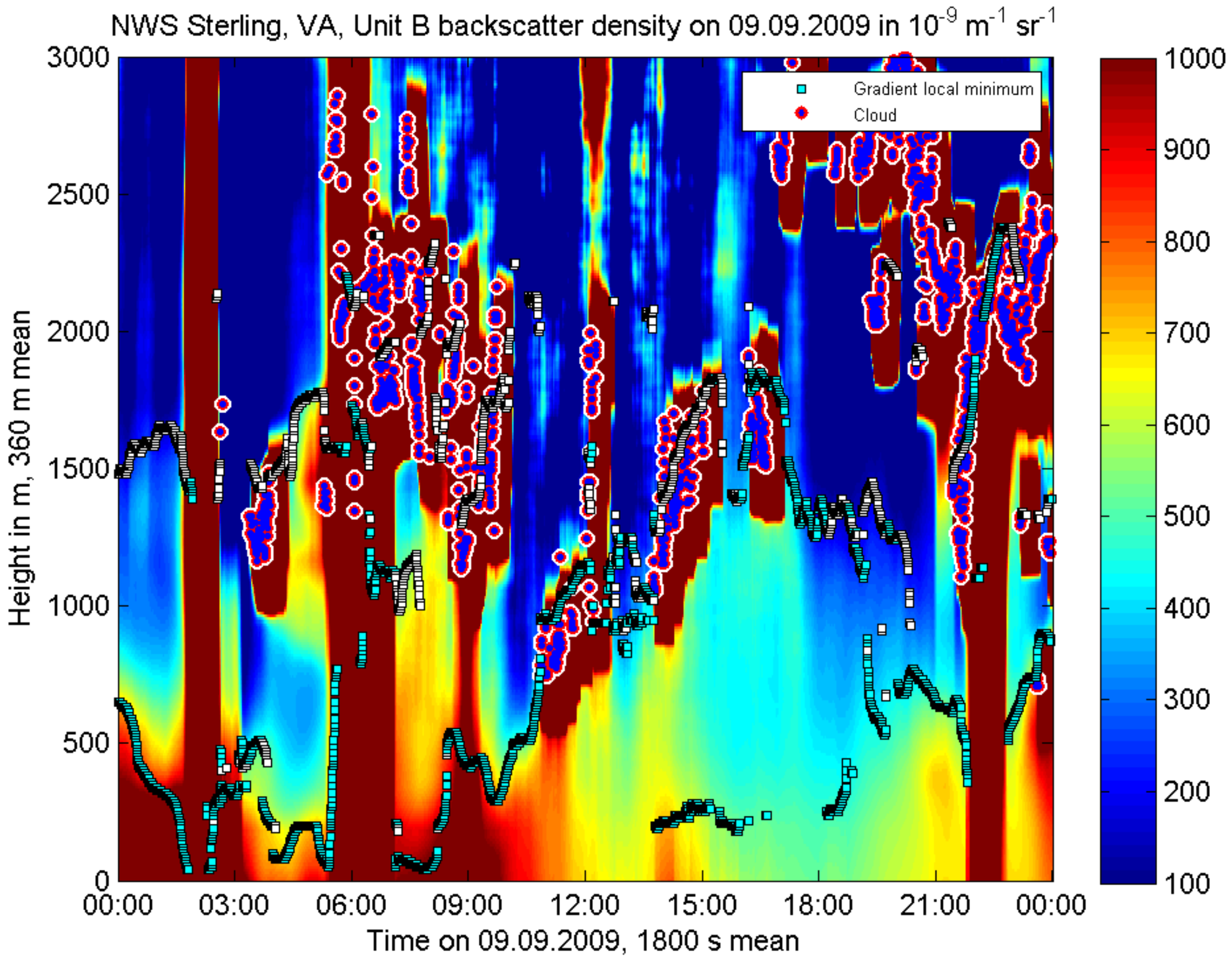
A day from the boundary layer textbook

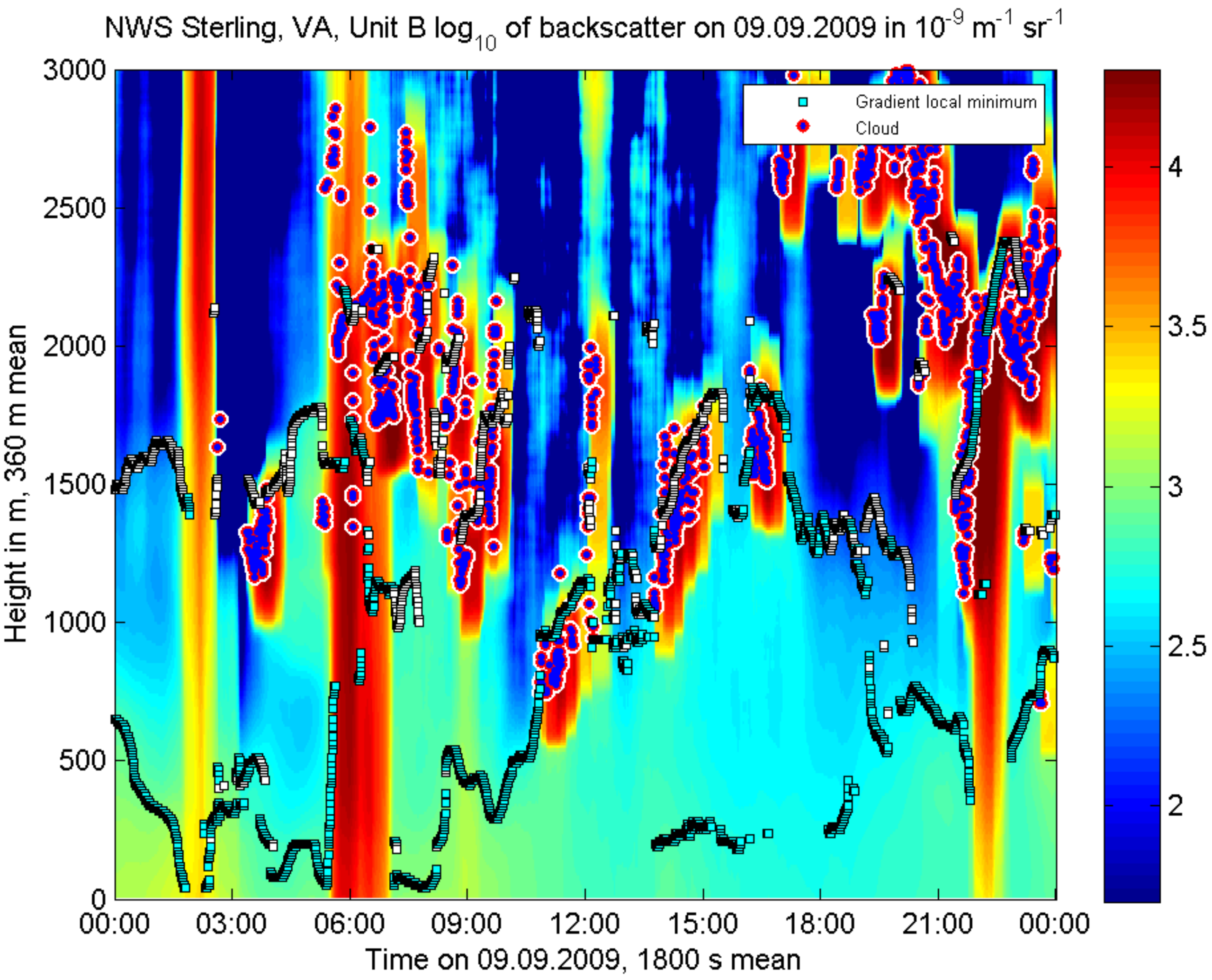


VAISALA

A common day with clouds and rain

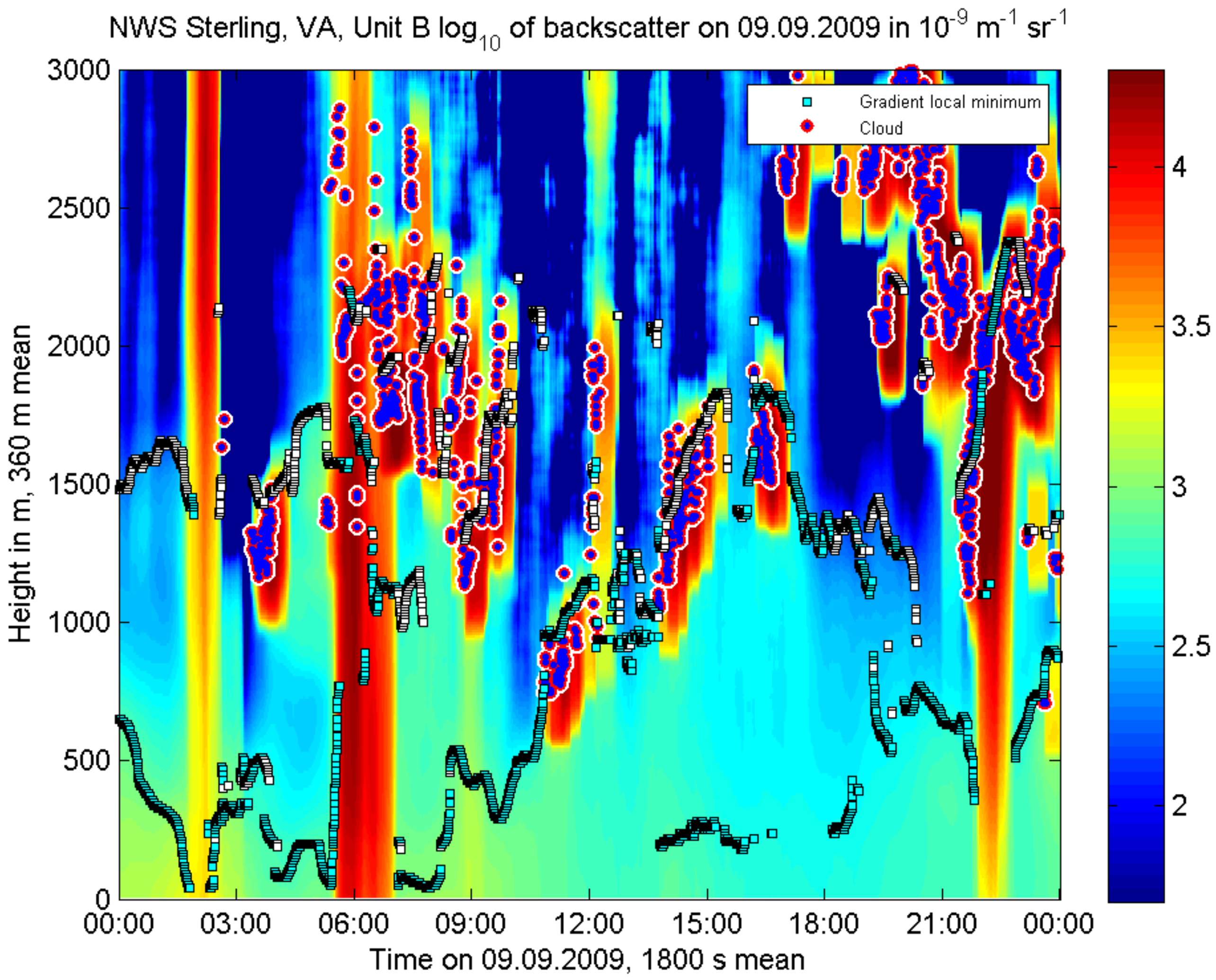


A common day – logarithmic scaling



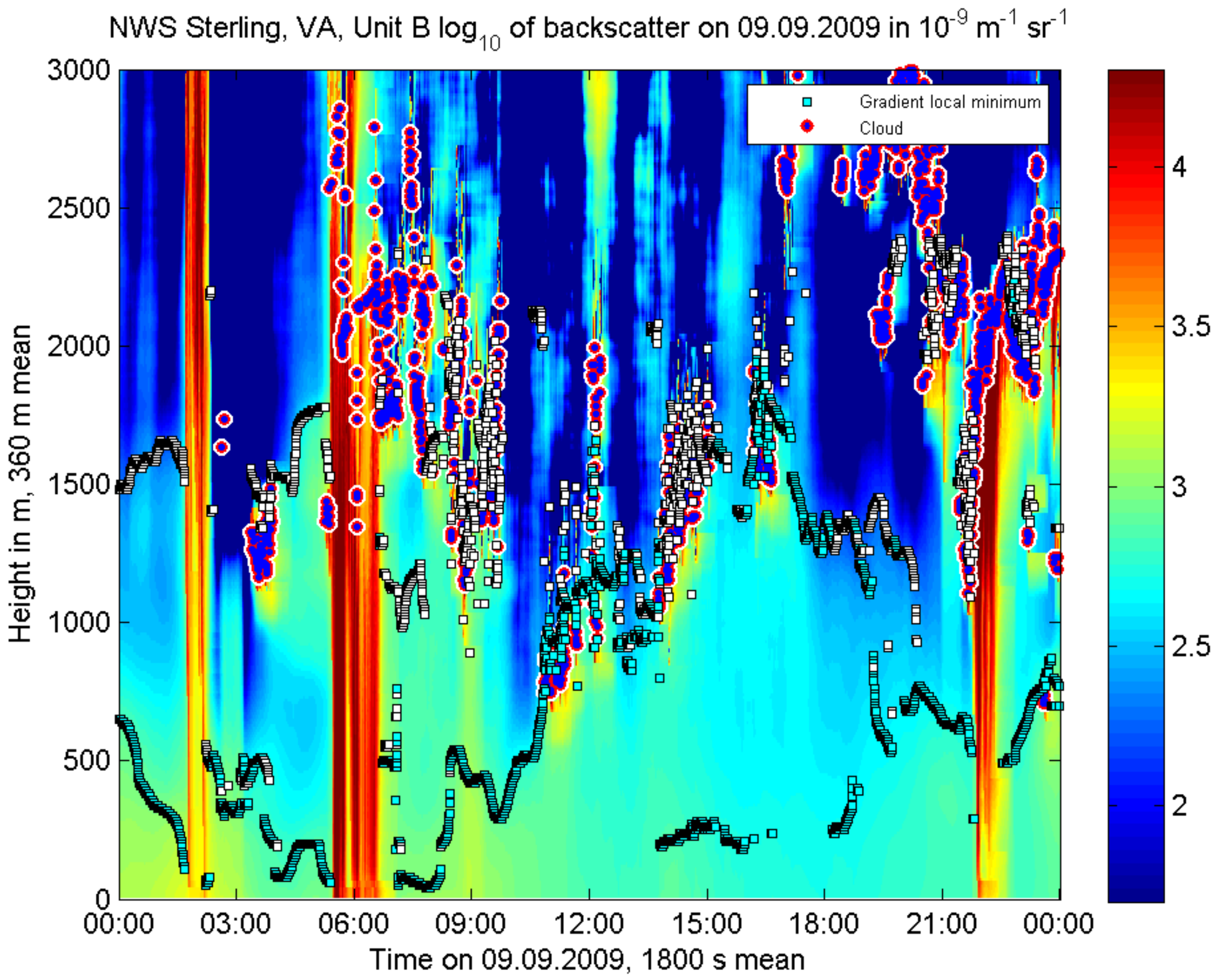
- **Steps towards an automatic stable algorithm**
  - Cloud and precipitation filter
  - Height dependant averaging
  - Signal noise dependant time averaging
  - Variable detection threshold
  - Outlier removal

A common day – logarithmic scaling



VAISALA

Cloud and precipitation filter



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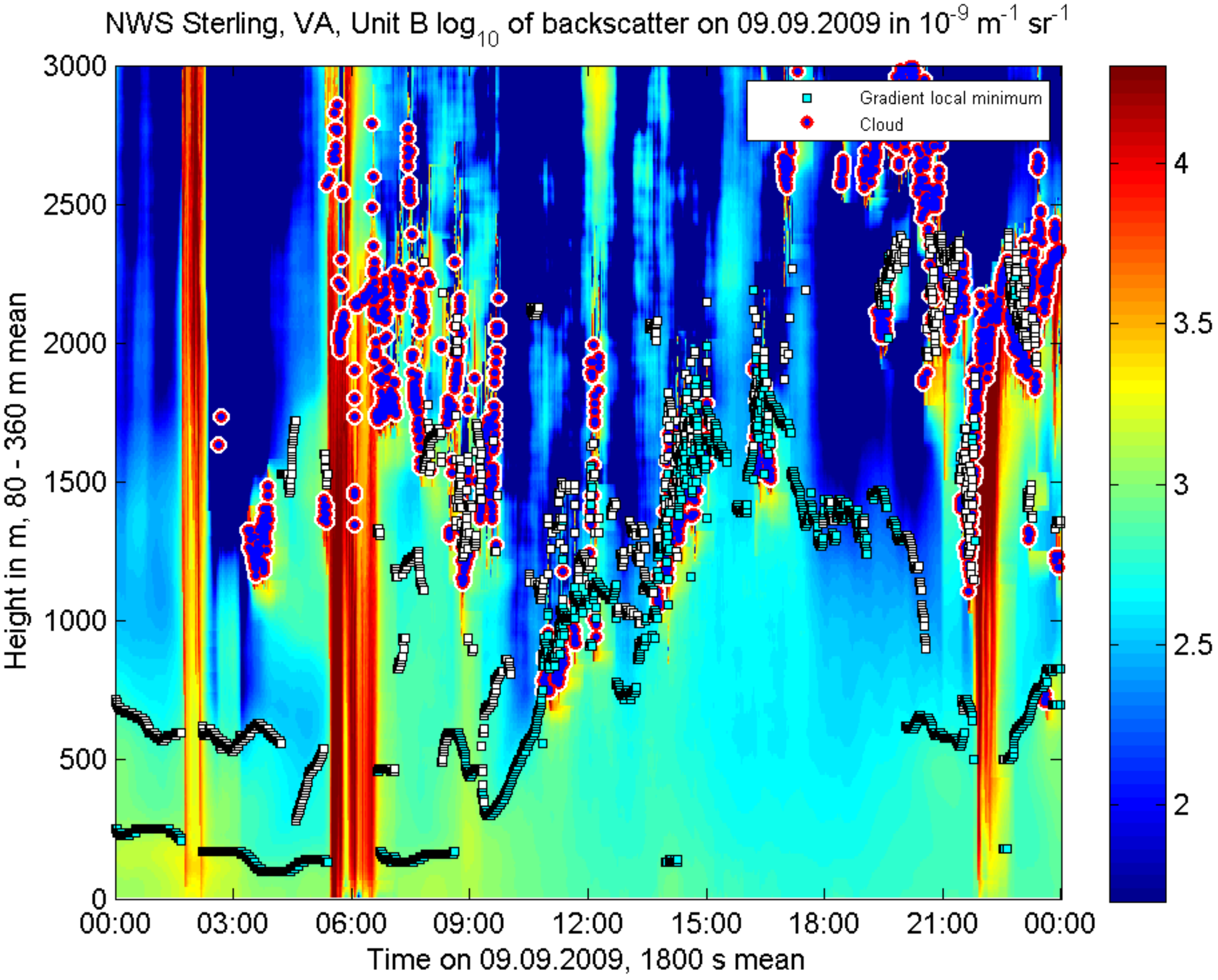
Height dependant averaging



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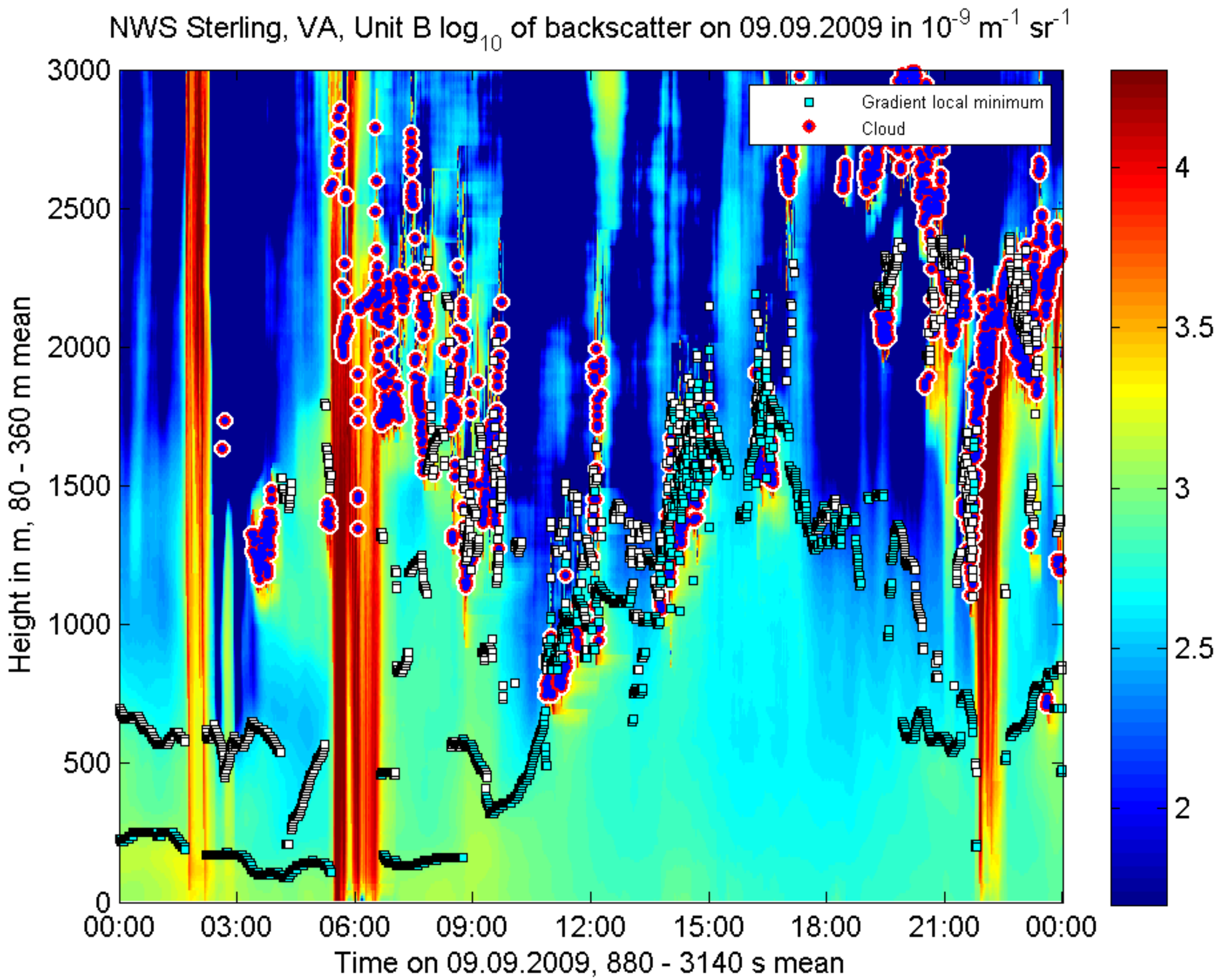
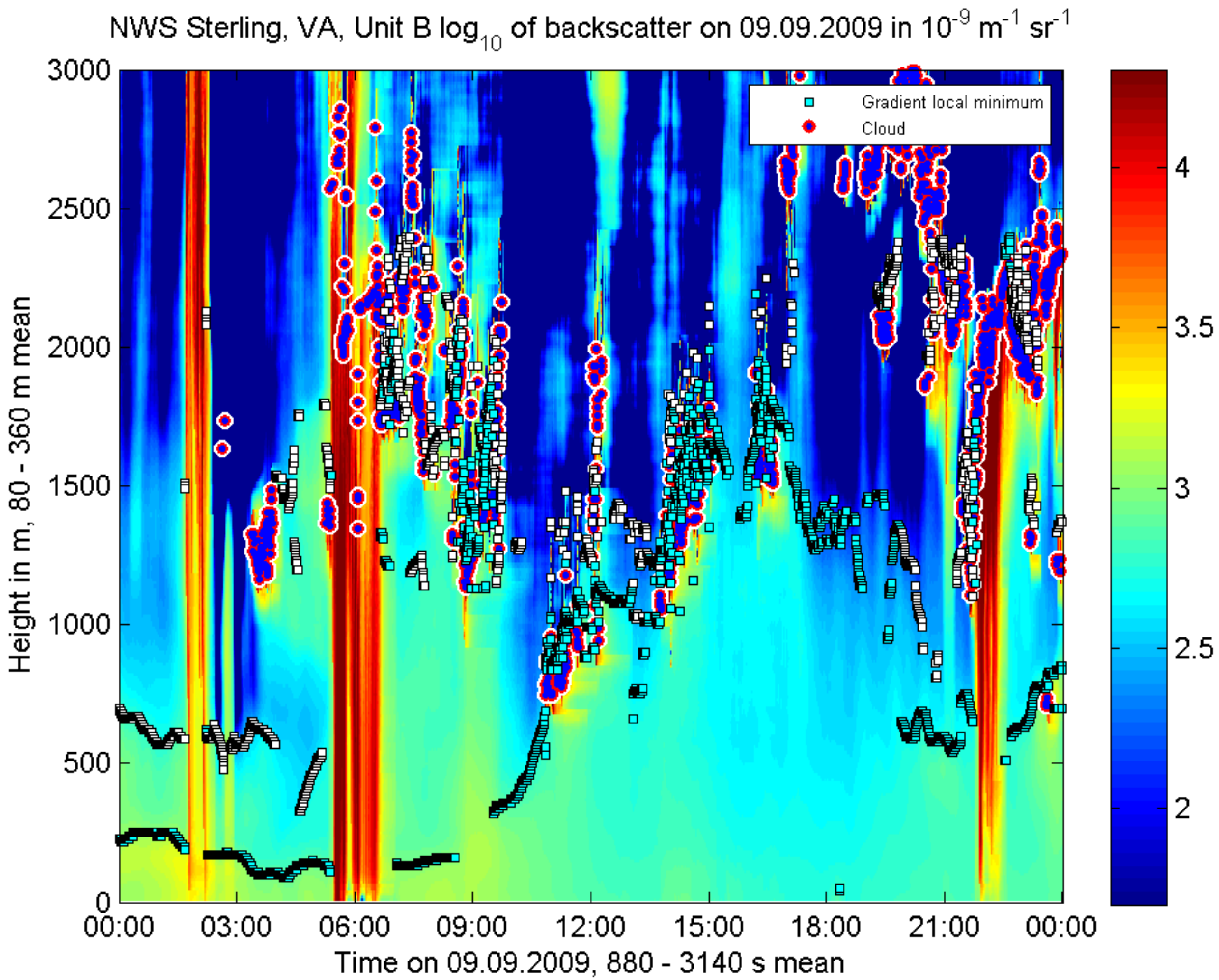
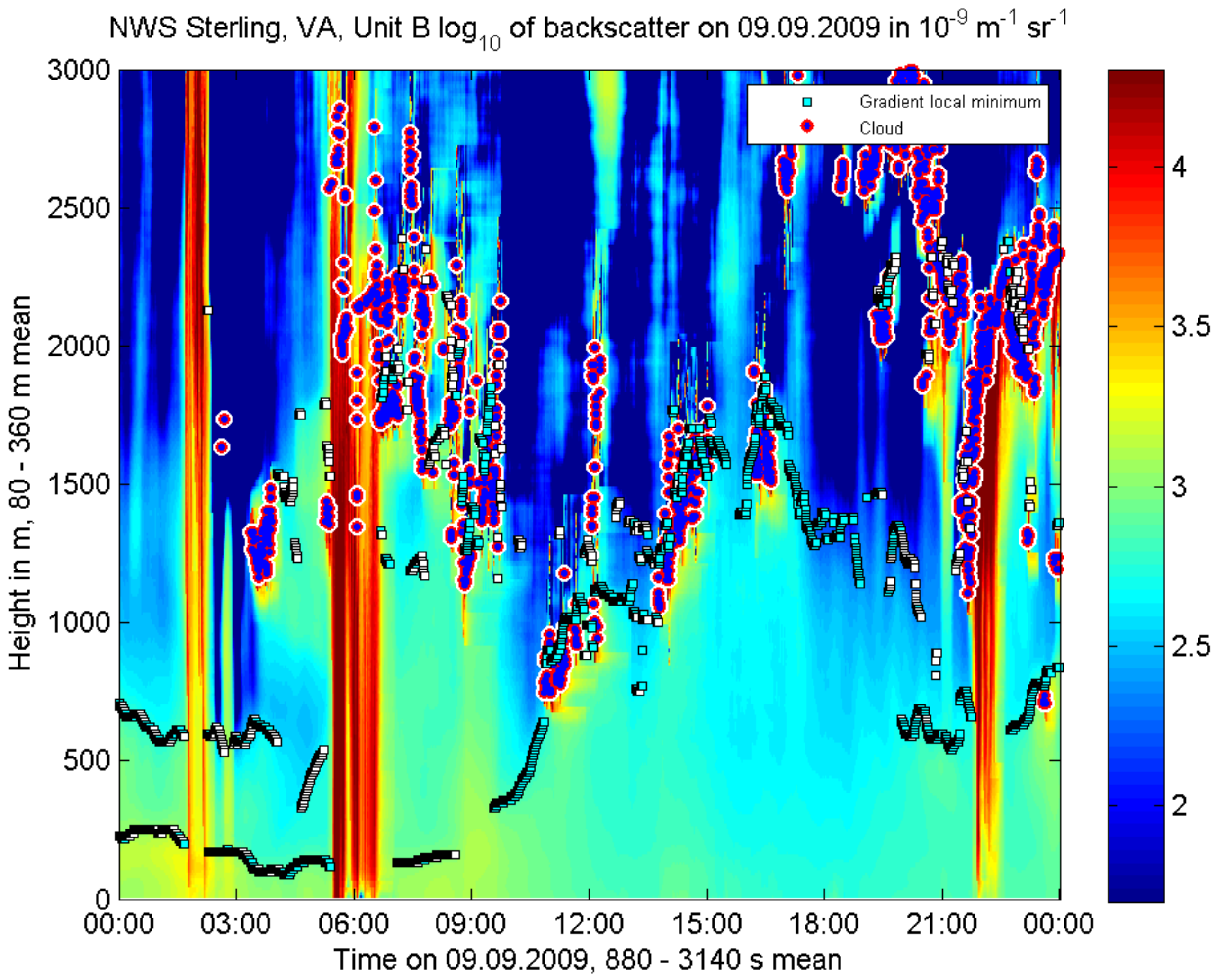
Signal noise dependant averaging



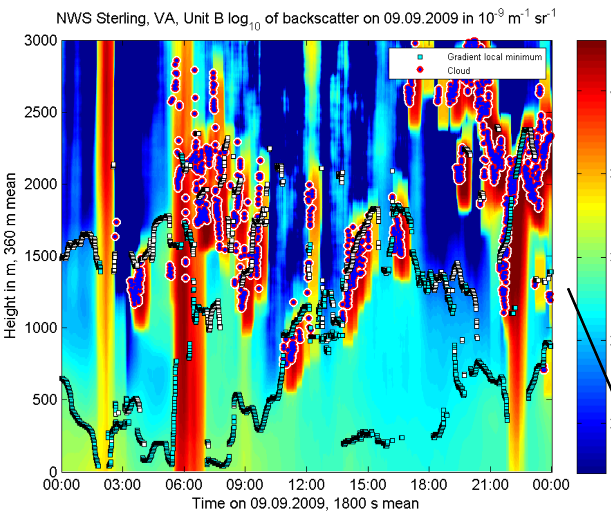
Variable detection threshold

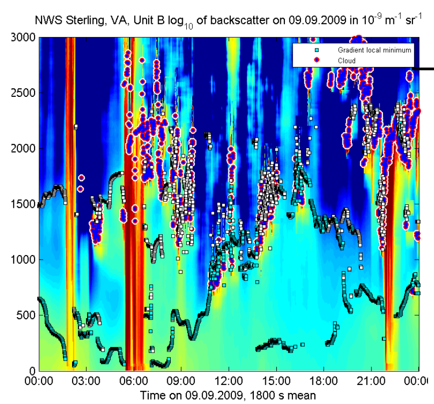


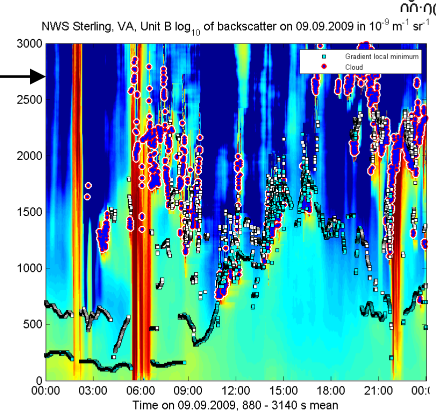
Finally – outlier removal

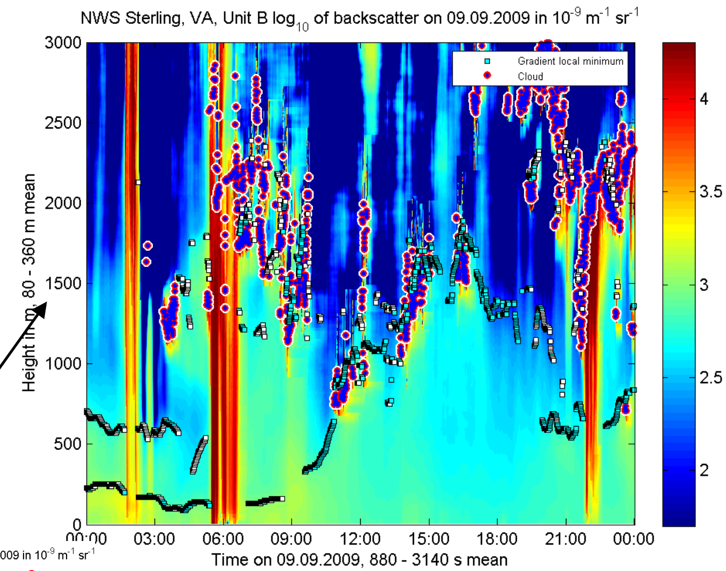


Summary of the steps towards an automatic stable BLH algorithm









3. Variable thresholds, outlier removal

1. Cloud and precipitation filter
2. Variable averaging

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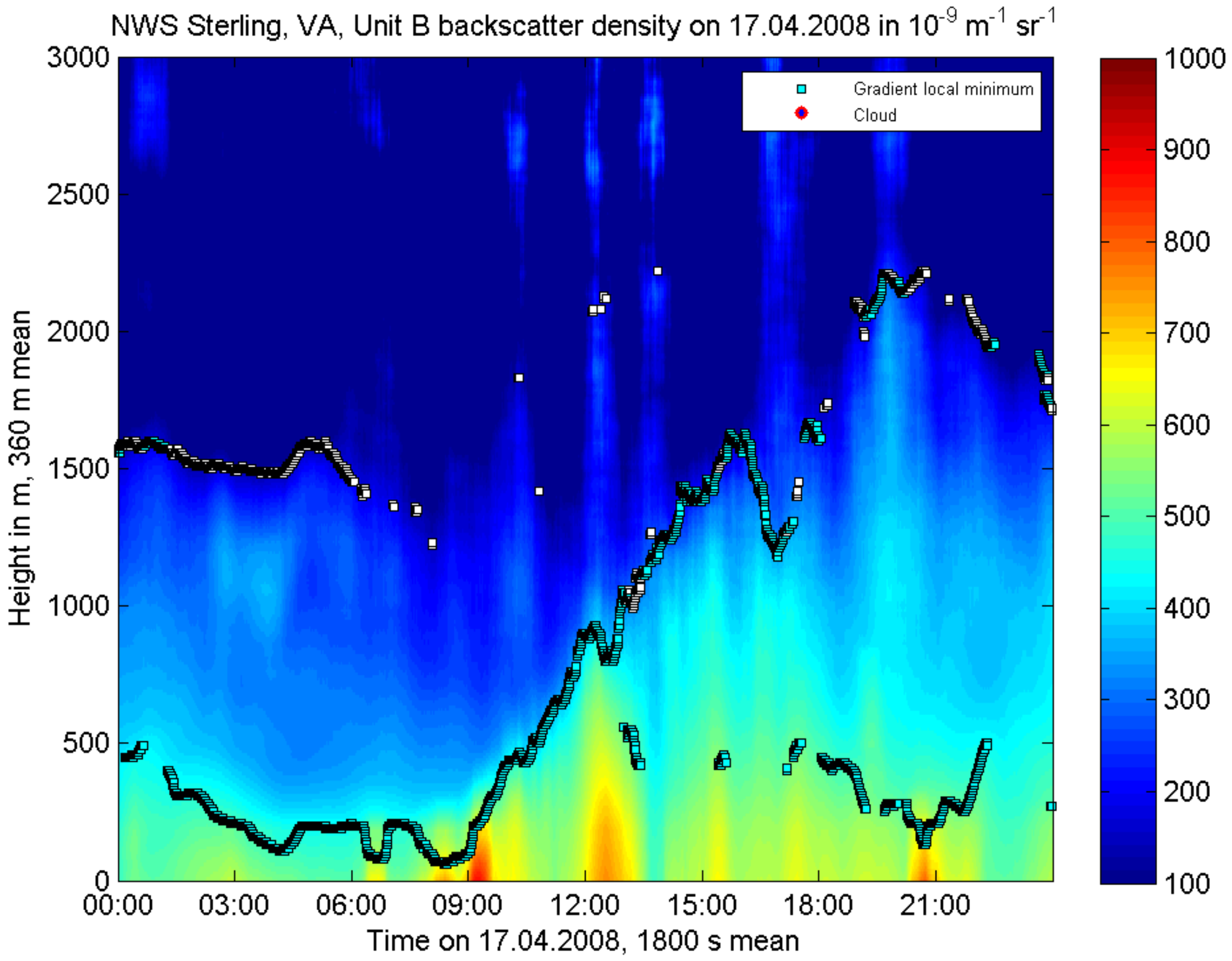
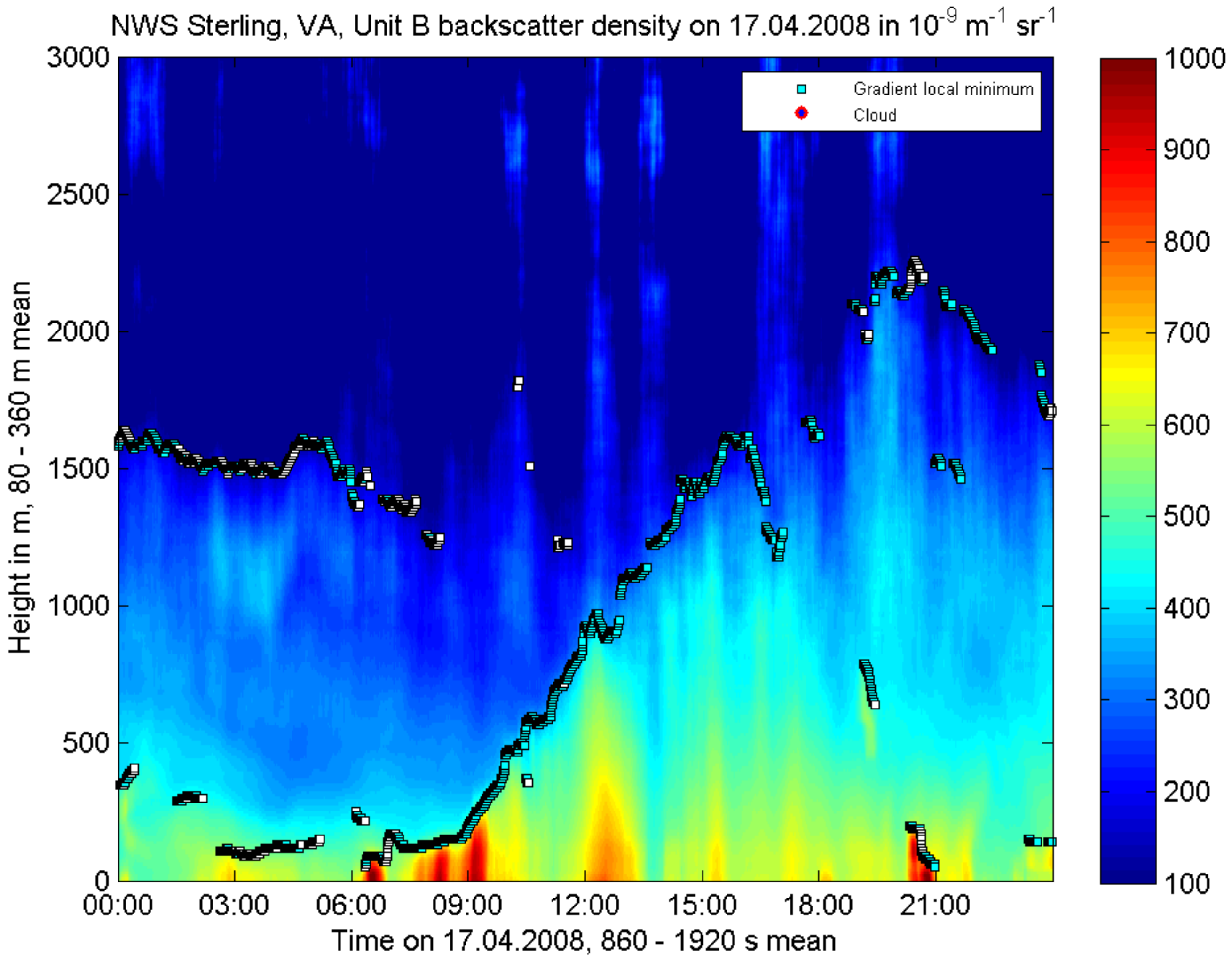
Boundary layer textbook - original

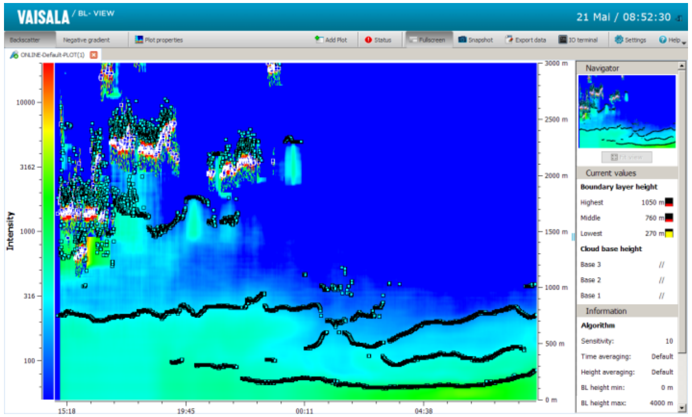


Boundary layer textbook - final



BL-VIEW
PBL Reporting and Analysis Tool

- BL-VIEW - Supportive PC-software package for Ceilometers
  - Ceilometer reports profile data
  - Supports CL31 and CL51
  - BL-View calculates PBL structure parameters and generates graphics and text output



- Main features
  - Automatic reporting of PBL structure with cost effective Ceilometer
  - Reporting of evolution of PBL
  - Quality index of reported PBL data

Thank You

Questions?

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Some aspects of Large Eddy Simulation (LES) and the potential for Helsinki

Antti Hellsten, Andreas Tack and

Sofia Mei-Kuei Tu

Contents

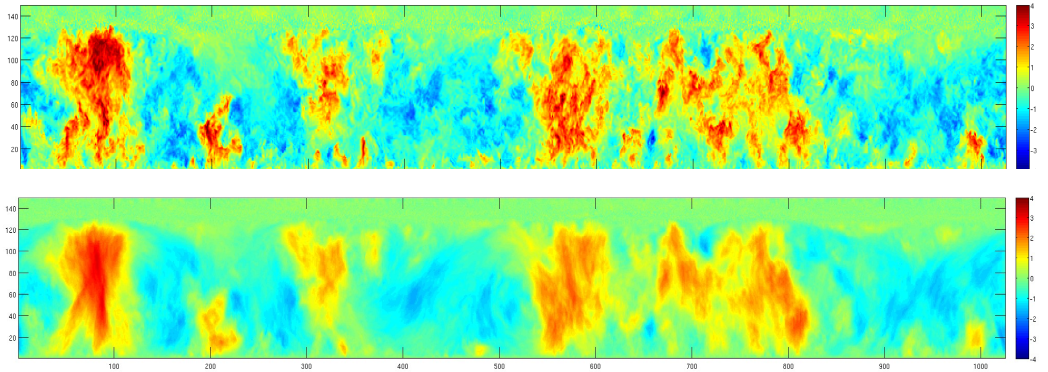
- **Some general information on LES**
- **Potential of LES in urban micro-meteorology**
- **Limitations of urban LES**
- **Urban-specific challenges in applying LES**
- **Helsinki**
- **Example: footprint estimation (idealized topography)**
- **Example: boundary-layer flow in central Paris**

LES equations

- **Filtering the Navier-Stokes equation yields the LES equations**
- **The sub-grid scale stress τ_{ij} arises from the nonlinear advection and needs to be modeled**
  - Smagorinski
  - Deardorff
  - Dynamic closures
  - Etc...

$$\frac{\partial \overline{u}_i}{\partial t} + \frac{\partial \overline{u}_j \overline{u}_i}{\partial x_j} + \frac{1}{\rho}\frac{\partial \overline{p}}{\partial x_i} = \frac{\partial}{\partial x_j}\left(\nu \frac{\partial \overline{u}_i}{\partial x_j}\right) - \frac{\partial \tau_{ij}}{\partial x_j}$$

$$\tau_{ij} = \overline{u_i u_j} - \overline{u}_i\ \overline{u}_j$$



Important facts about LES

- **Grid spacing has to be fine enough to properly resolve the large energy containing eddies**
- **At least about 80% of the TKE should be resolved**
- **Domain must be large enough to properly accommodate the largest flow structures**
- **Boundary conditions should not have any artificial effect on the turbulence**
  - Cyclic/periodic boundary conditions used often
- **Simulations have to be run for a long time to become independent of the initial conditions**
- **Heavy parallel computing capacity required**

The PALM model

(PA)rallelised (L)ES (M)odel

- Leibniz Universität Hannover, Institut für Meteorologie und Klimatologie (IMUK)

  http://palm.muk.uni-hannover.de/wiki

PALM is a large-eddy simulation (LES) model for atmospheric and oceanic flows which is especially designed for performing on massively parallel computer architectures. It can freely be used for scientific research.

Potential of LES in urban micro-meteorology

Urban LES with high sub-building resolution (SBR) and large domain could open valuable new possibilities and support to measurements as it would provide e.g.:

- **simultaneous data from all locations within the domain (including the upper ABL)**
- **new information about canopy and surface-layer dynamics**
- **estimation of footprints using LS particle tracking**
- **wind engineering and city planning studies**
- **possible post analyses of hazardous releases and contingency planning**

Limitations of urban LES

- **Simulations run slower than real time.**
- **Allowable simulation times are quite limited.**
- **Domain sizes are limited so that entire cities cannot be simulated with SBR.**
- **Domain sizes are limited so that deep convective ABLs cannot be properly fit into domains with SBR.**
- **Upwind boundary conditions remain a big challenge if periodicity cannot be assumed.**
- **Nesting in a larger-domain (lower resolution) simulation remains challenging.**
- **Unclear if any kind of assimilation to a real-life situation is possible at all.**

Some urban-specific challenges for LES

- **Huge ratios of smallest and largest spatial and temporal scales that need to be properly resolved.**
- **Modelling of surface fluxes (heat, moisture...) very complicated.**
- **Emission modelling.**

Helsinki

- **Central Helsinki is relatively small**
- **Surrounded by water from three directions**
- **Almost flat terrain**
- **No real high-rise buildings**
- **The central city has a fairly homogeneous lay-out**
- **Wealthy of morphology information available from different sources**
- **The urban measurement network and Testbed**

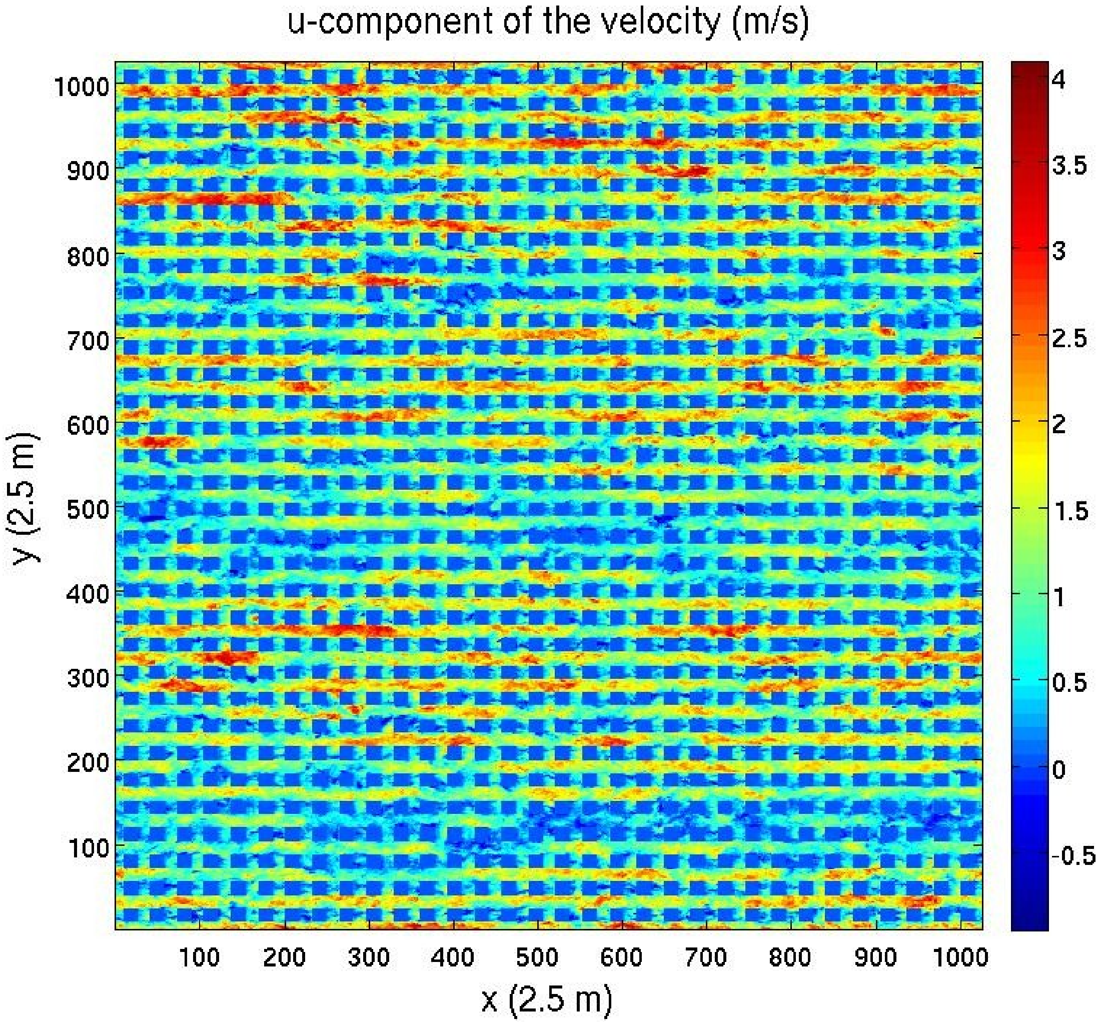
Example: flux footprint estimation

Estimation of footprints (or source are functions) using LES and Lagrangian Stochastic (LS) particle tracking would be very useful for interpretation of urban measurements such as for example CO_2 flux measurements.

We (Sofia Mei-Kuei Tu) are currently studying this problem. So far we have done this for a large regular array of identical cuboids with neutral ABL. This set up allows spatial averaging over multiple sensors.

Real urban topography does not allow spatial averaging and therefore it is much harder to achieve converged particle statistics.

Example: flux footprint estimation



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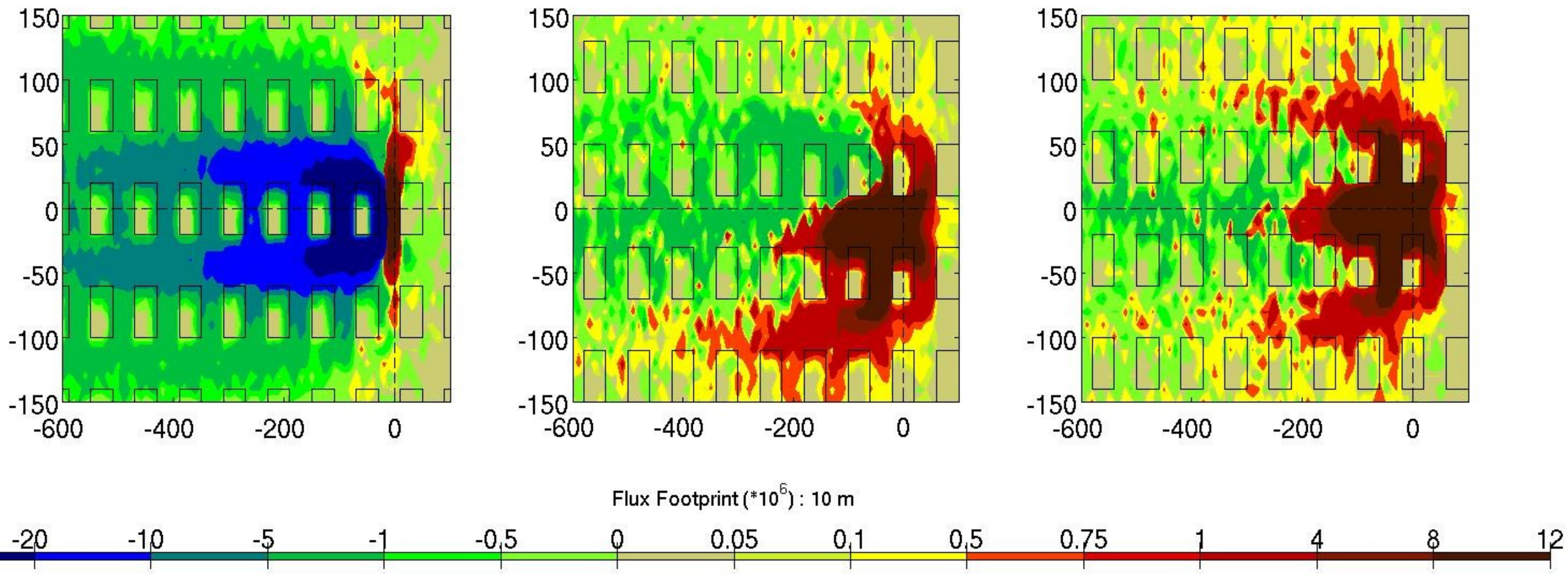
Example: flux footprint estimation



Example: Paris, Place d'Italie

- **Domain extent:**
  - 512m x 512m x 128m
- **Topopgraphy from BDTopo (IGN)**
- **Database sampled on 1m grid for high resolution LES**

Example: Paris, Place d'Italie

- **Simulation using PALM model**
- **Boundary conditions**
  - 2 m/s westerly geostrophic wind
  - Inversion at 90m
  - Cyclic boundaries
- **Color code**
  - Red = u-component
  - Green = v-component
  - Blue = w-component

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Example: Paris, Place d'Italie

- **Vertical slices at domain center**
- **Top:**
  - Visualization of velocity field
- **Bottom:**
  - Visualization of temperature field
- **Strong turbulence induced by urban structure**

Some additional material

Some of PALM's highlights are

- **excellent scaling, so far tested up to 10 000 cores (68.7 billion grid nodes)**
- **online data analysis (during model runs) in order to avoid I/O bottlenecks**
- **topography realized on Cartesian grid (allows for steep topography)**
- **non-cyclic horizontal boundary conditions including turbulent inflow**
- **code can be switched to ocean version with salinity equation and equation of state for seawater**

PALM's highlights continued

- **embedded parallelized Lagrangian particle model for various applications (footprint calculation, simulation of cloud droplet growth, visualization, etc.)**
- **interface which allows users to plug in their own code extensions without modifying the default code**
- **advanced shell scripts for installing and running the code in interactive and batch mode are available**
- **the code is permanently maintained and improved by the PALM group and other users; code management is based on subversion**

The PALM model – prognostic equations

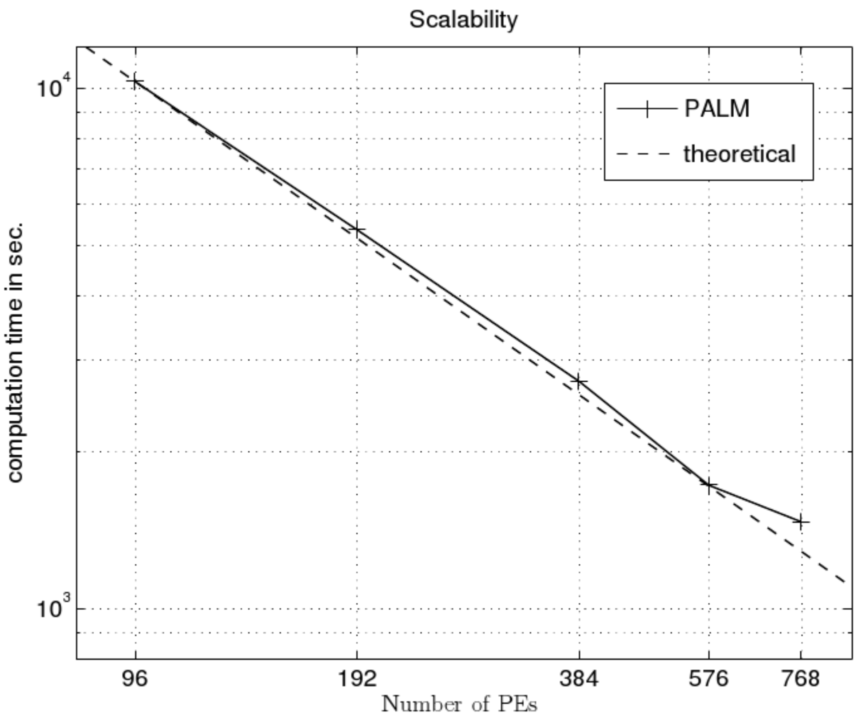
- **Prognostic equations:**
  - incompressible Navier-Stokes equations in Boussinesq form
  - potential temperature or liquid water potential temperature
  - total water content
  - sub-grid scale kinetic energy (Deardorff, 1980)
- **Diagnostic equations / parameterizations:**
  - long-wave radiation (Cox, 1976)
  - precipitation (Kessler, 1965; 1969)

The PALM model - numerics

- **finite difference discretization on orthogonal staggered grid**
- **advection terms in skew-symmetric form**
  - 2nd-order central scheme
  - 5th-order upwind biased scheme
- **explicit 4th-order Runge-Kutta time marching**
- **projection method for pressure (continuity) with the Poisson-equation solved using:**
  - Fourier-method (cyclic boundaries)
  - Multi-grid iteration (non-cyclic boundaries)

The PALM model - parallelisation

- **Parallelisation of PALM**
  - MPI and openMP parallelisation
  - 2D domain decomposition
  - good load balancing
  - small communication overhead
- **We have tested the MPI scalability on the CRAY XT5 of FMI using a constant problem size of about 430 million grid nodes**



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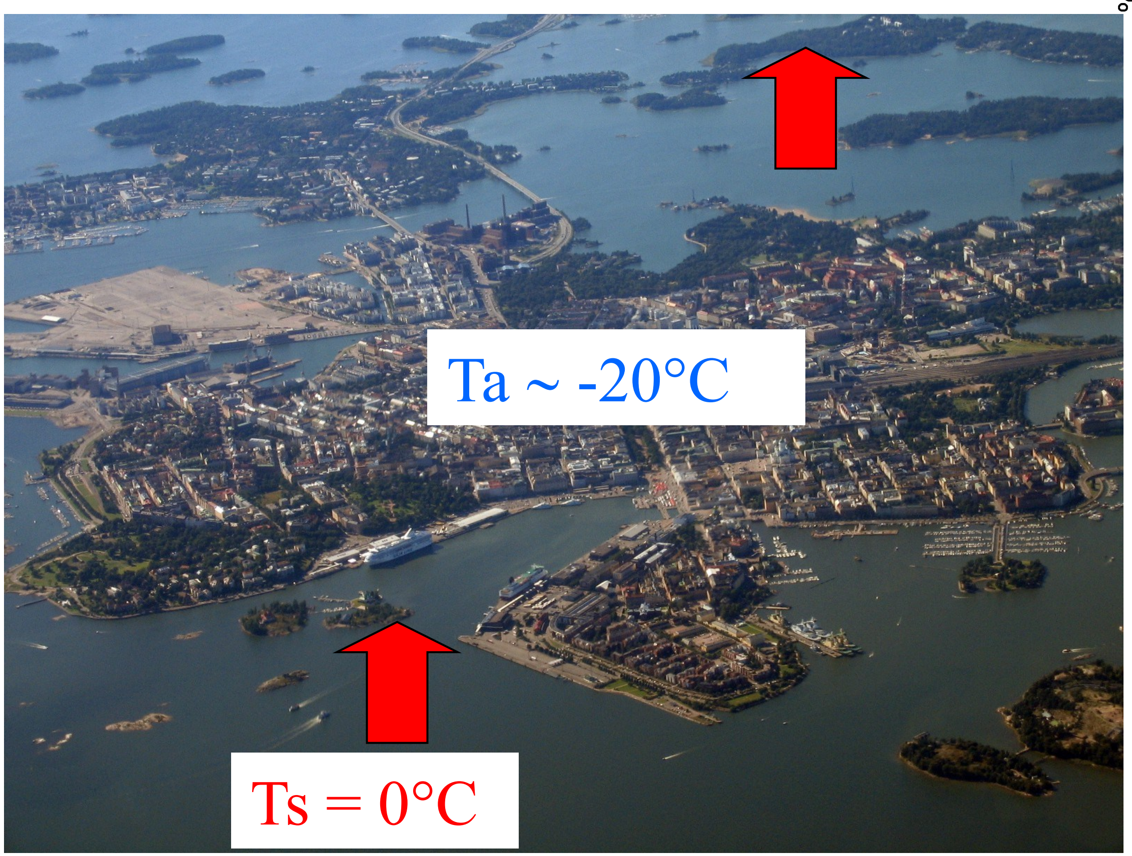
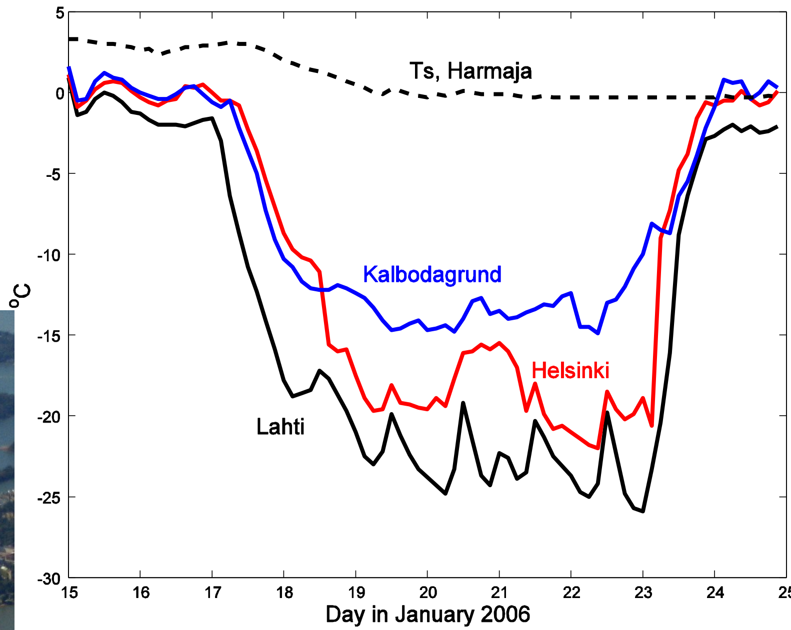
Atmosphere – sea-ice interactions and their relevance for wintertime UBL over Helsinki

Timo Vihma

Finnish Meteorological Institute

Helsinki during early-winter cold-air outbreaks





Characteristics of sea ice as a surface for the atmosphere

Consists of undeformed ice cover, rafted and ridged ice floes of variable thickness, in places separated by leads

Surface relatively homogeneous with respect to roughness, but often very heterogeneous with respect to Ts and albedo

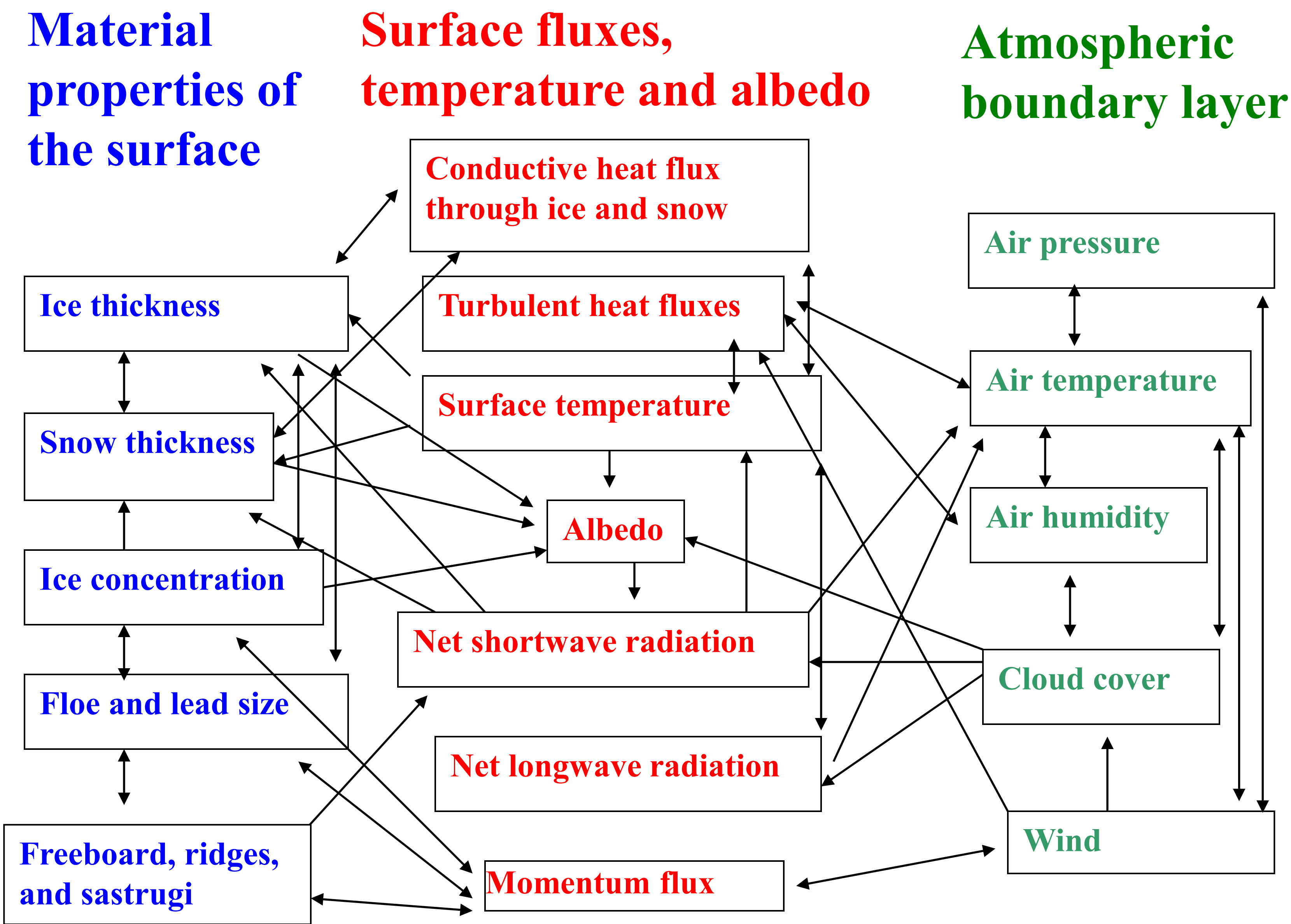
Interaction of dynamics and thermodynamics:

- surface type may change rapidly due to ice motion, slowly due to ice and snow thermodynamics

- due to the low heat conductivity of snow, Ts responds rapidly to radiative and turbulent forcing, and $\partial T/\partial z$ through snow/ice can be very large, up to 30 K/m

Over the marginal ice zone, the ABL often under modification

Interactive surface exchange and ABL processes



Vihma 2011

Heat fluxes over sea ice

Solar radiation: albedo is ~ 0.1 for open water and 0.4-0.9 for sea ice / snow.

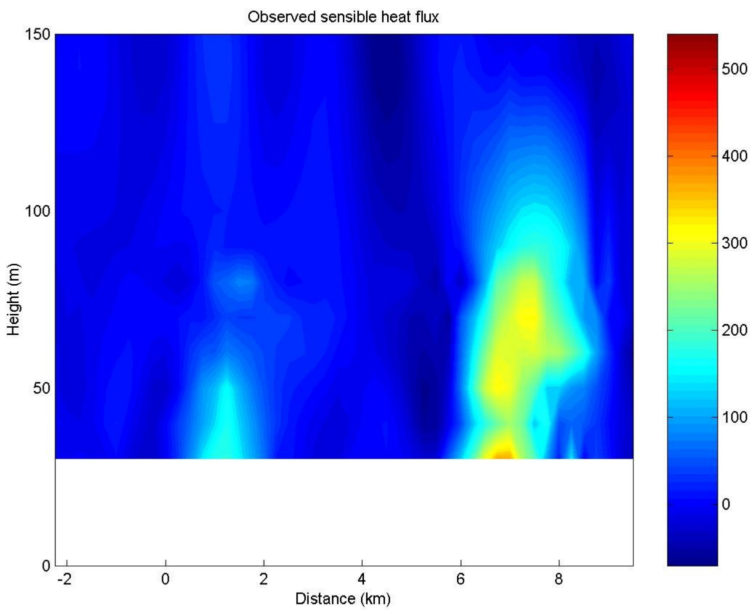
Longwave radiation: in winter, usually the dominating component in surface heat balance; net longwave radiation is usually negative (in winter some 20 Wm^{-2}**)**, but close to zero or slightly positive under a thick cloud cover in summer.

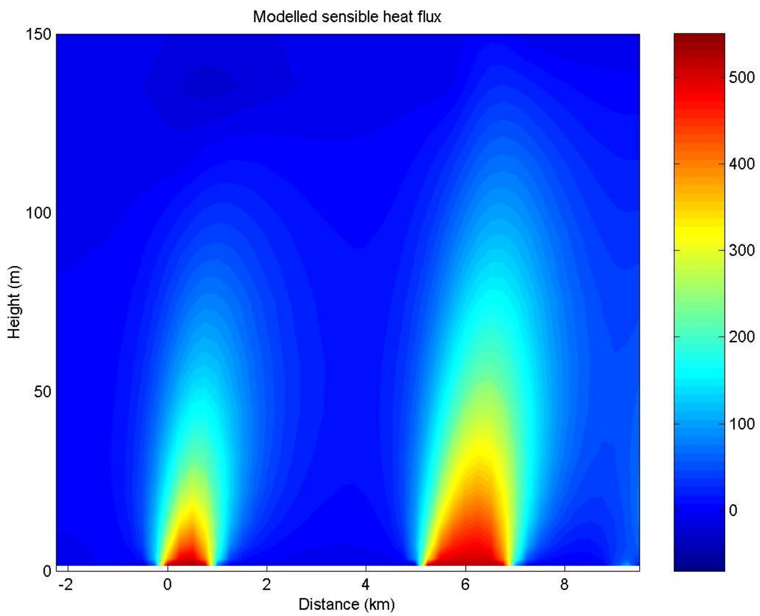
Conductive heat flux through ice and snow: typically ~ 5 Wm^{-2}, but much larger over new, thin ice

Sensible heat flux (H): typically from air to ice ~ 10-20 Wm^{-2}
Latent heat flux (LE): typically close to zero

Over leads in winter, H + LE can reach several hundreds of Wm^{-2}
→ Localized convection over leads; usually only reaches heights less than 100 m, but in rare cases can penetrate through the Arctic inversion.
→ parameterization of grid-averaged heat heat fluxes is a problem in models

Observed and modelled sensible heat flux over two leads in the Arctic (Lüpkes et al., 2012)





Sea ice roughness and air-ice momentum flux

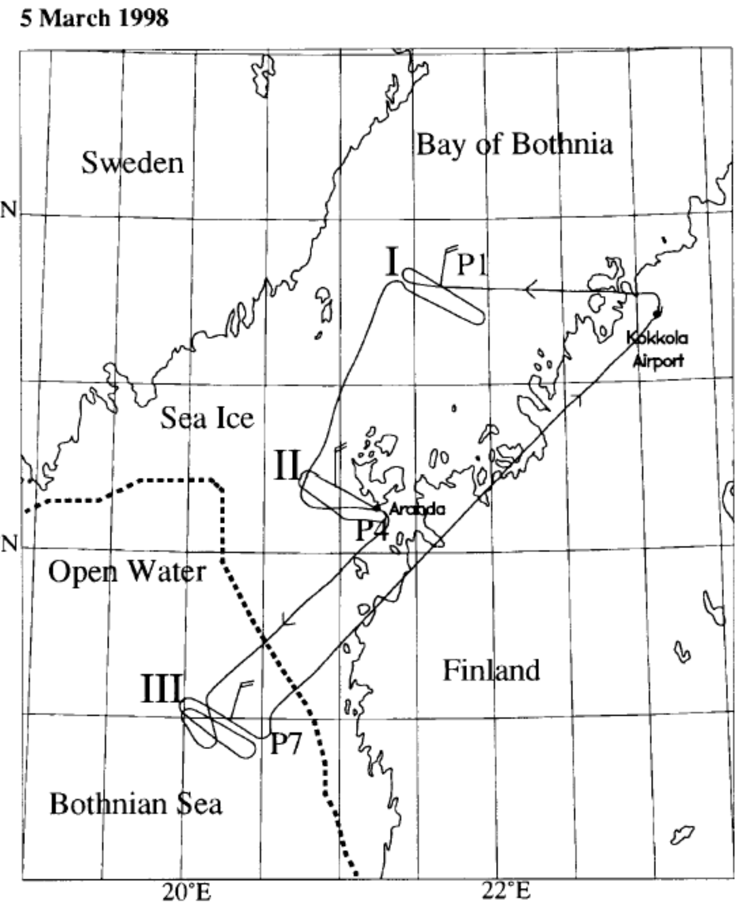
$$\tau = \rho C_{Dz} V_z^2 \qquad C_{Dz} = k^2 \left(\ln \frac{z}{z_0} - \Psi_M (z/L) \right)$$

- z_0 is affected by ice ridges, floe edges, and sastrugi

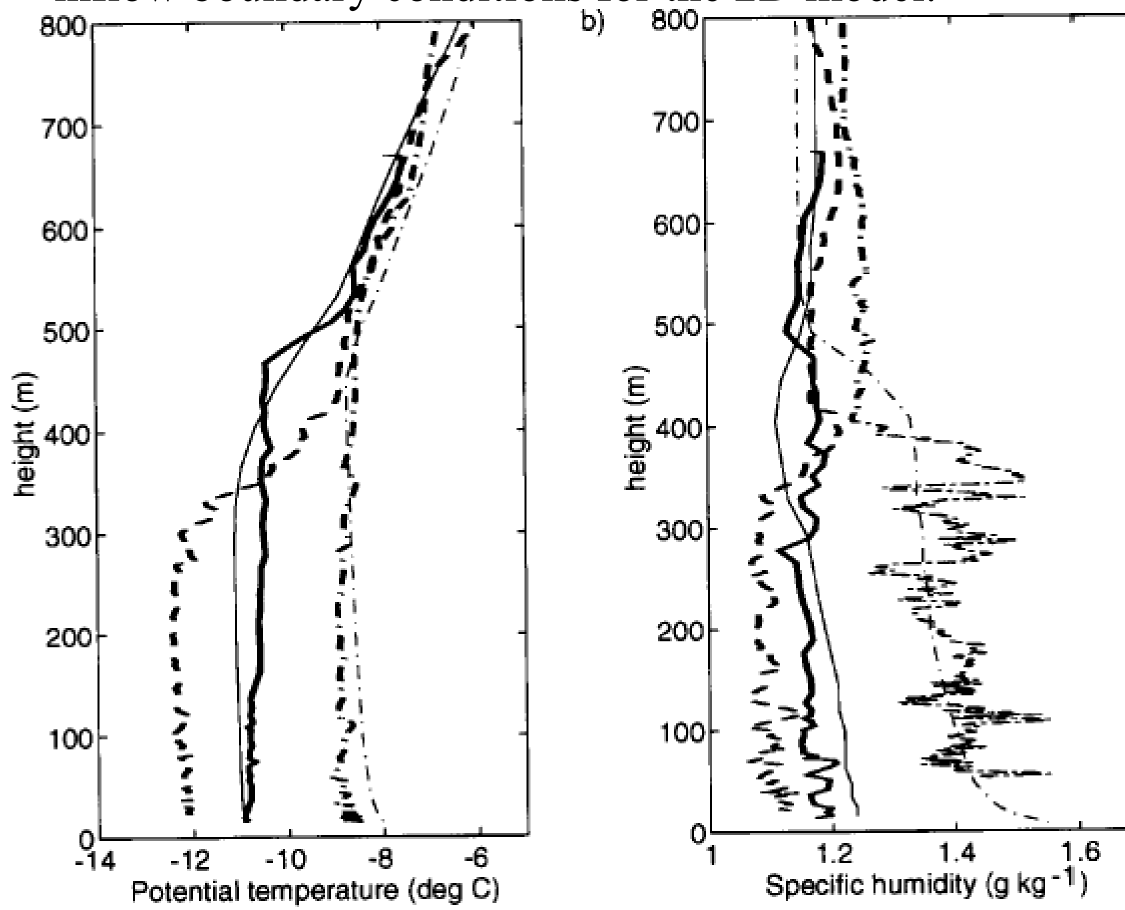
- observations over various ice types (Guest and Davidson, 1991):
  very smooth first-year ice: z_0 = 0.3 mm – very rough multiyear ice: z_0 = 30 mm
- sastrugi are often overlooked, but may be even more important than ridges (Andreas & Claffey, 1995), and sometimes even have a detectable effect on the ice drift (Vihma et al., 1996)
- various schemes presented for the aggregation of τ
- sea ice models are more sensitive to the stratification effect than to z_0 (Uotila, 2000)

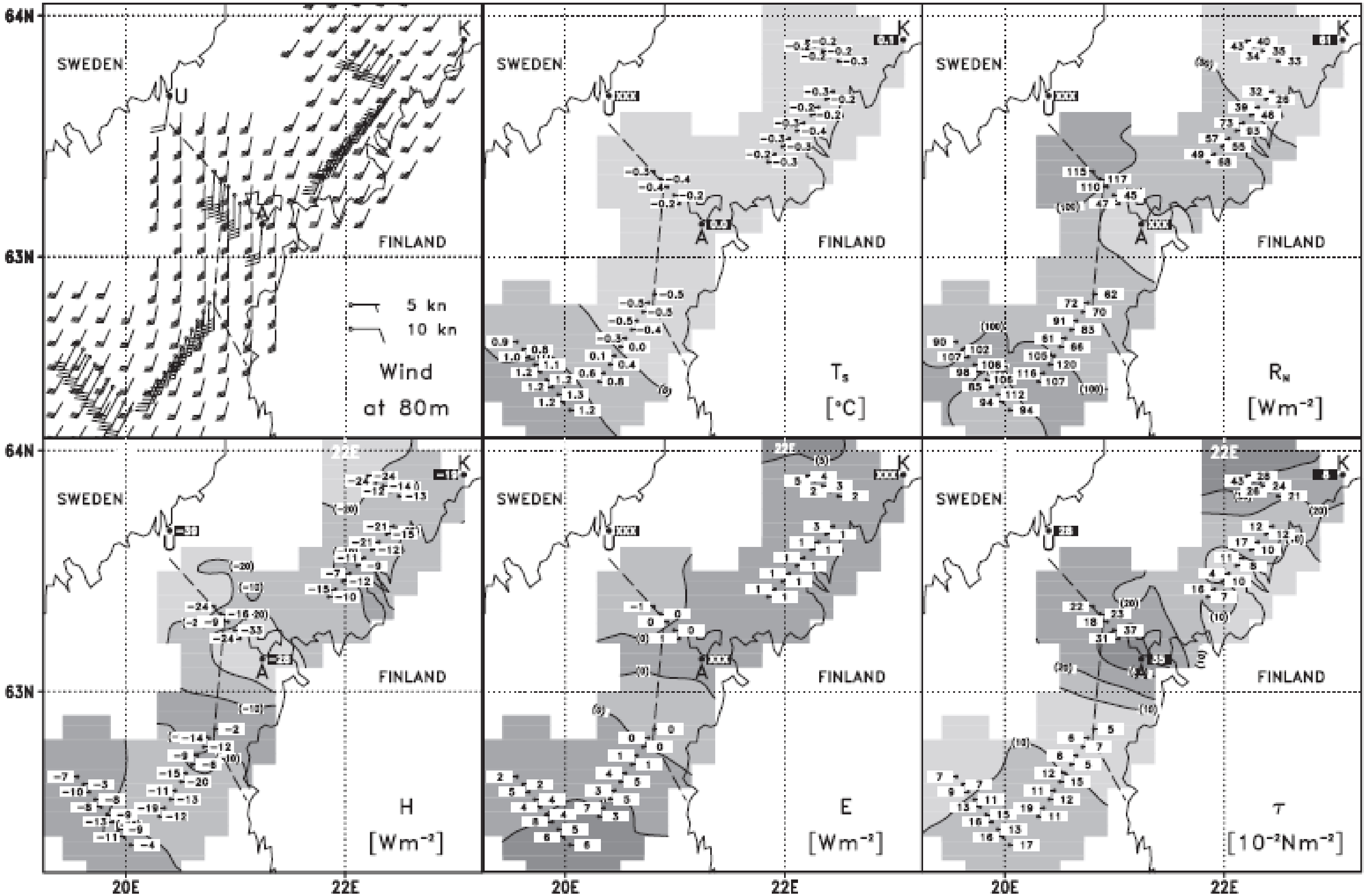
Combined effects of spatial variations in roughness and ice concentration (Vihma and Brümmer, BLM, 2002)

Flight pattern of research aircraft Falcon



Observed (thick lines) and modelled (thin lines) profiles of potential temperature and specific humidity. Observations at the upstream location (P1) were used as inflow boundary conditions for the 2D model.




64N
63N
20E
22E
SWEDEN
FINLAND
U
A
K
5 kn
10 kn
Wind at 80m
T_s [°C]
R_N [Wm^{-2}]
H [Wm^{-2}]
E [Wm^{-2}]
τ [$10^{-2}Nm^{-2}$]

New observation techniques

Small Unmanned Meteorological Observer (SUMO)



Quadrocopter


Conclusions

- In winter, sea ice conditions may have a large effect on the UBL over Helsinki
- Due to the operational Ice Service of FMI, we have good information on sea ice conditions in the vicinity of Helsinki: ice concentration and thickness, level of ridging.
- We have less good information on snow thickness on top of sea ice
- Modelling challenges include:
  - subgrid-scale surface fluxes; division to open water and ice is not enough
  - localized convection under a strong elevated inversion
  - fog arising from areas of open water; interaction or radiation and turbulence
  - response of the near-surface wind on large changes in stratification
  - sea ice dynamics in complex coastal / archipelago regions
  - processes in the scale of the Gulf of Finland: wind field, roll convection, precipitation
- Quadrocopters have a large potential for UBL studies in a town like Helsinki
- The state of the sea is also important in summer: coastal upwelling → SST may rapidly drop by 10 K

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Valuation of ecosystem services in urban areas:
a quick overview

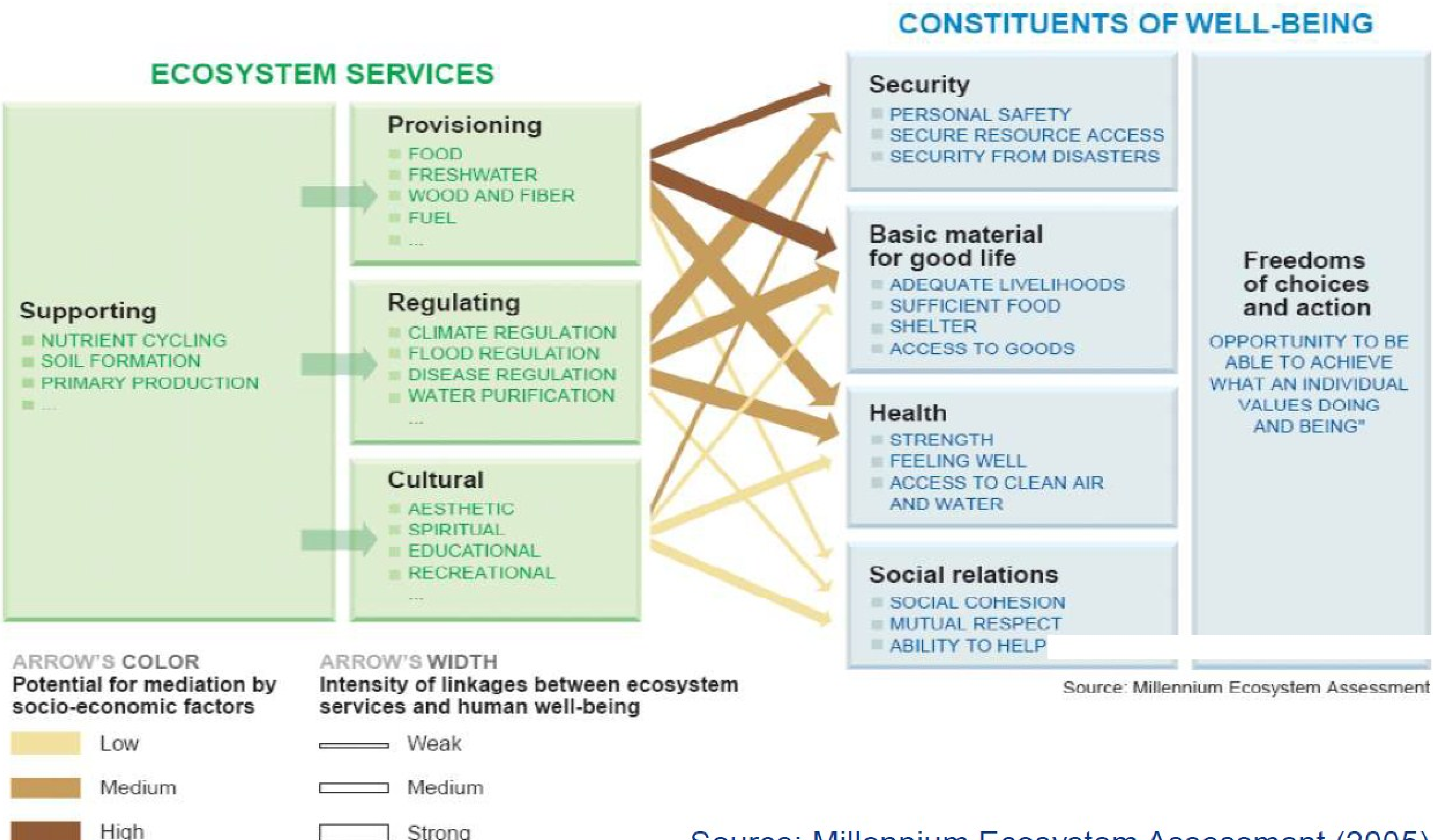
Adriaan Perrels (FMI)

Urban climate symposium
14.5.2012 – FMI, Helsinki

Topics

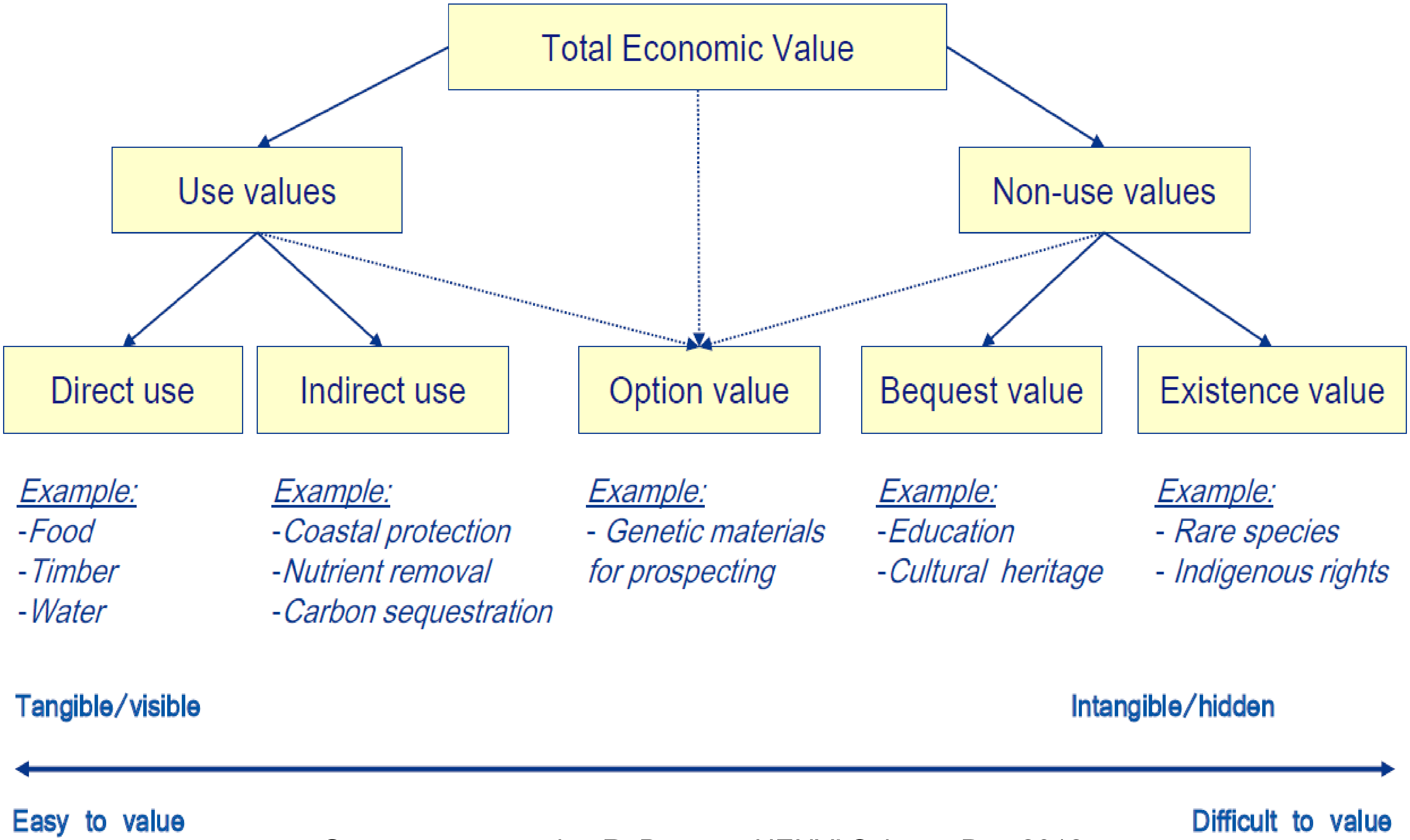
- Defining ecosystem services (ESS)
- Sustainable urban development and ESS
- ESS as part of economic system
- Some valuation examples
- Natural science – economics linkages

Defining Ecosystem services 1



Source: Millennium Ecosystem Assessment (2005)

Defining Ecosystem services 2



Source: presentation R. Brouwer HENVI Science Day 2012

Urban Sustainability

- **Agglomeration benefits** essential for existence and succeeding of cities, so …
  - Urban sustainability means sustaining agglomeration benefits (the composition of the benefits may evolve)
- Urban growth leads to **selective expulsion, density gradients** (spatial productivity / price gradient)
  - entails also **spatial substitution of ESS**
    - e.g. food production, recreation, nature reserves
  - entails also **technical substitution of ESS** (degradation)
    - e.g. sewer systems, air conditioning
  - unmanaged spatial and technical substitution may lead to negative agglomeration effects (megacities; sprawl)
- **NB!** sustainability (‘state’) and sustainable development are often mixed up

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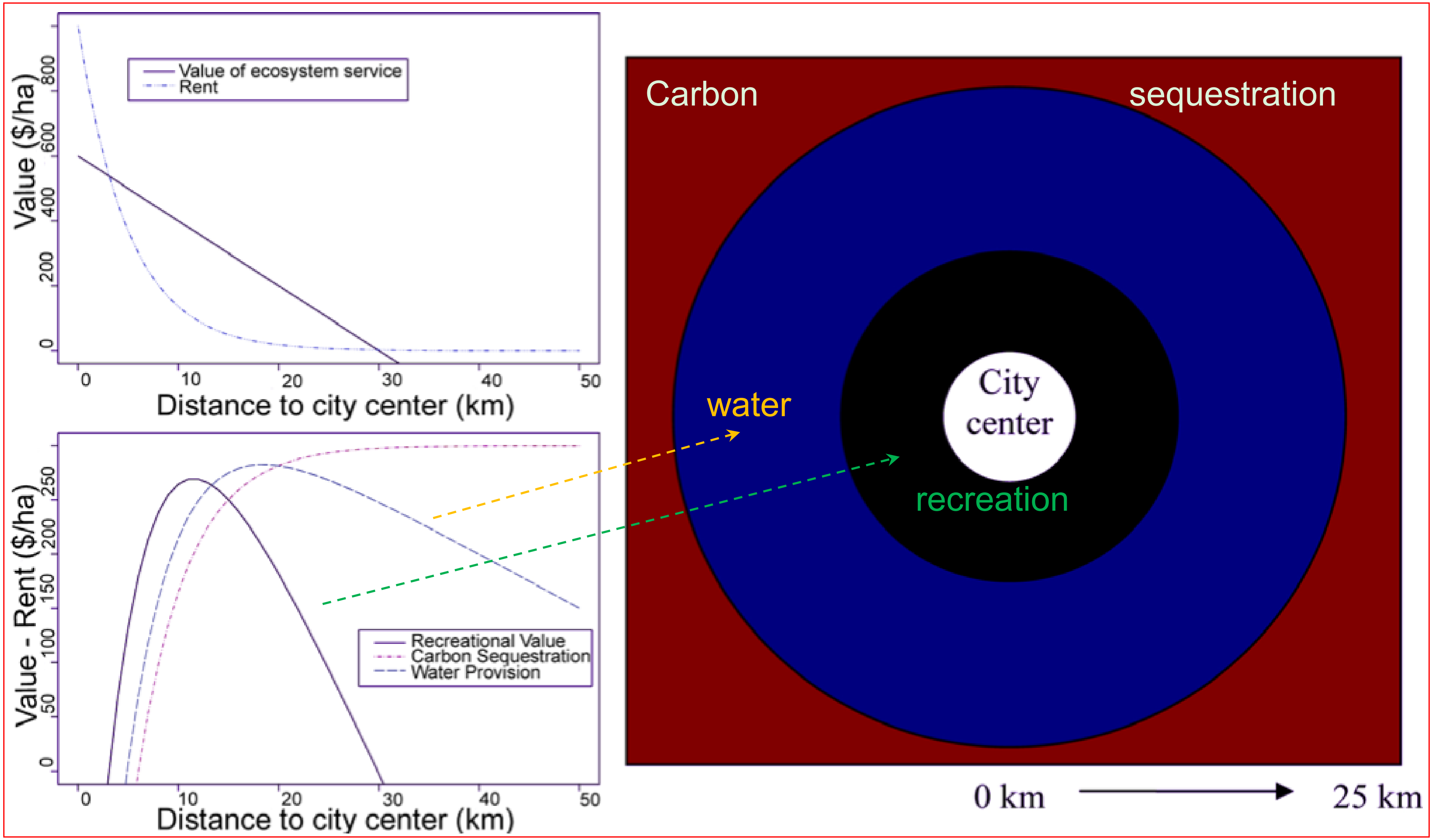
Urban density gradient and ESS of greenspace



Source: McDonald (2009), Ecosystem service demand and supply along the urban-to-rural gradient, *Journal of Conservation Planning,* Vol.5, pp. 1 — 14

…but urban green can be in **small and large** patches, denoting different levels of **integration** and thereby exploiting the **multiple use of space** to varying degrees

Ecosystem – engineering substitution effect

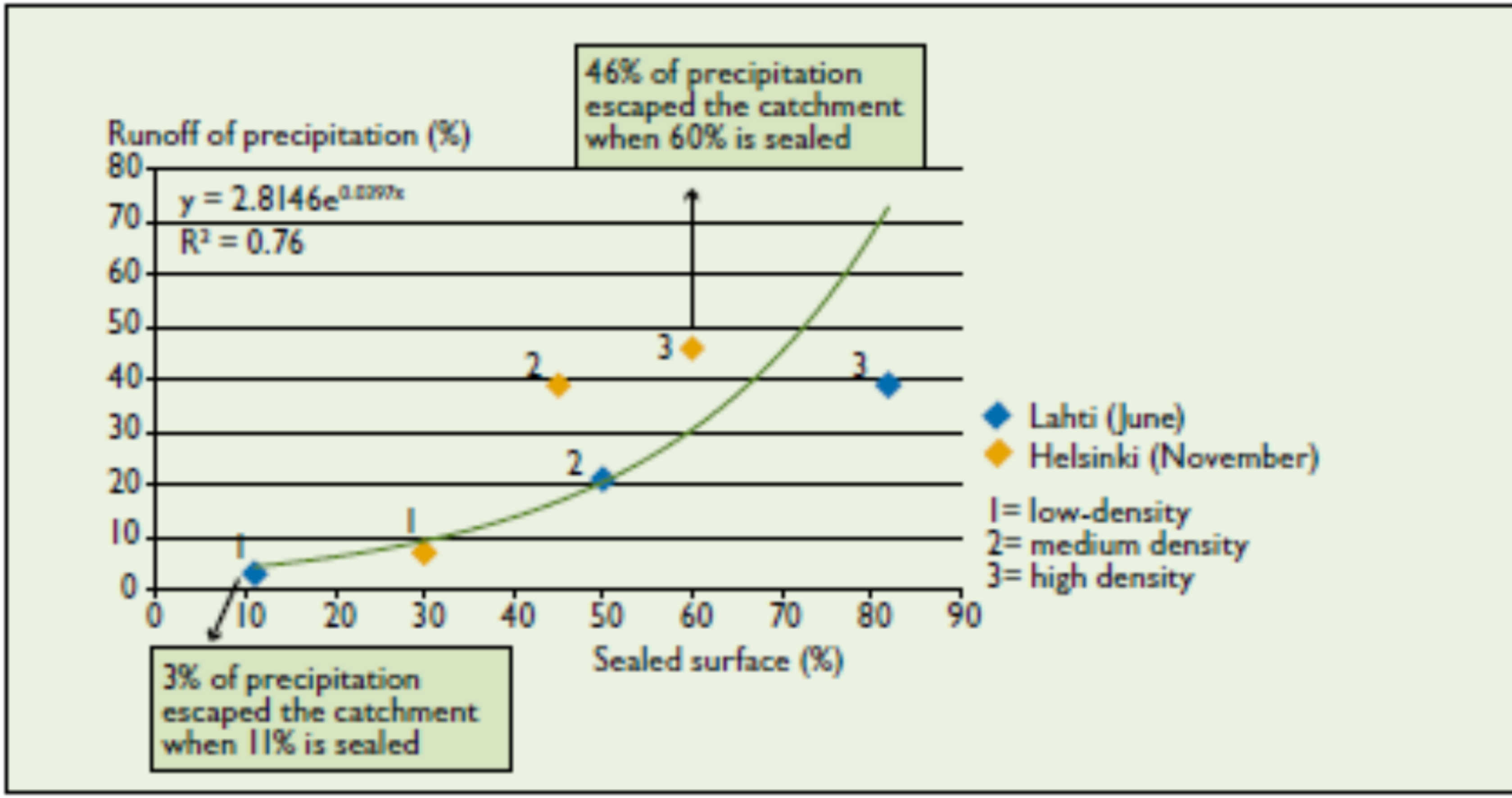
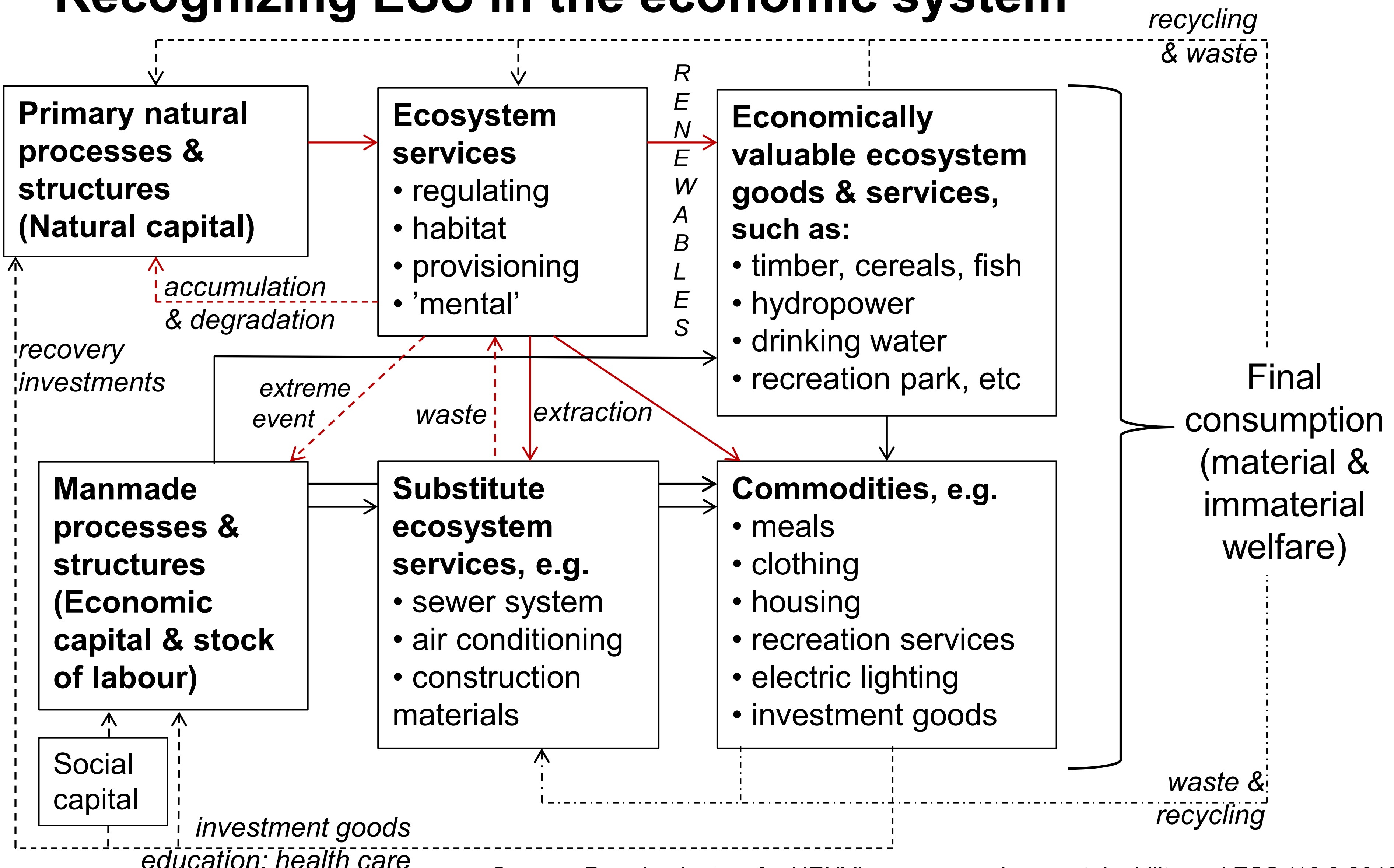


Figure 12. The amount of storm waters against the area of impermeable surfaces at the measurement points in Lahti and Helsinki. The fewer permeable surfaces there are, the less precipitation will soak in, with more running off as storm water.

Source: Ecosystem services and livelihoods – vulnerability and adaptation to a changing climate - VACCIA Synthesis Report, THE FINNISH ENVIRONMENT 26en | 2011, SYKE

Recognizing ESS in the economic system



Source: Perrels - lecture for HENVI course on urban sustainability and ESS (16.3.2012)

Valuating ESS

- The value attributed to a unit of ESS may be called a ‘price’, but should not be equated with the common notion of a transaction price
- **Valuating ESS: illustrative or instrumental (price)?**
- **Valuating ESS: reflective or prospective?**
  - **Reflective** (historic realizations & decomposition)
    - more certainty on answers thanks to data availability
    - review validity range with respect to input sensitivity
    - possibly limited prospective value (e.g. climate change impact assessments)
  - **Prospective**
    - Preferably based on validated simulation models
    - Scenarios should account for other relevant changes
    - How to handle discounting

Valuating ESS - approaches

- **Adjusted market prices**
  - Observed volumes & prices, corrected for tax, subsidy, etc.
- **Production function based**
  - Simulation models (+ measurements), separating ESS effect
- **Avoided damage**
  - observation based / natural experiment or
  - prospective – CBA of intervention on/involving ESS
- **Revealed preference**
  - consumer or company behaviour with implied values for ESS (e.g. certain tourism expenditures or insurances)
- **Stated preference**
  - Survey based tests eliciting conditional choices to review willingness to pay
- **Benefit transfer** – e.g. based on meta-analysis

Summary table from UK NEA - wetlands

Wetland type	UK Inland Wetlands		
No. of sites†	1,519		
Total area (hectares; ha)	601,550		
Ecosystem service-related goods	**Total value of service assuming it is present in all UK inland wetlands‡ (£ million/yr)**	**Average value of service where present (addition to default value)¶ (£/ha/yr)**	**Marginal value of service when provided by an additional hectare of new wetland§ (£/ha/yr)**
Biodiversity	273	454	304
Water quality improvement	263	436	292
Surface and groundwater supply	2	2	1
Flood control and storm buffering	366	608	407
Amenity and aesthetics	204	339	227

Source: UK NEA – Final report – Ch.22 Economic Values from Ecosystems

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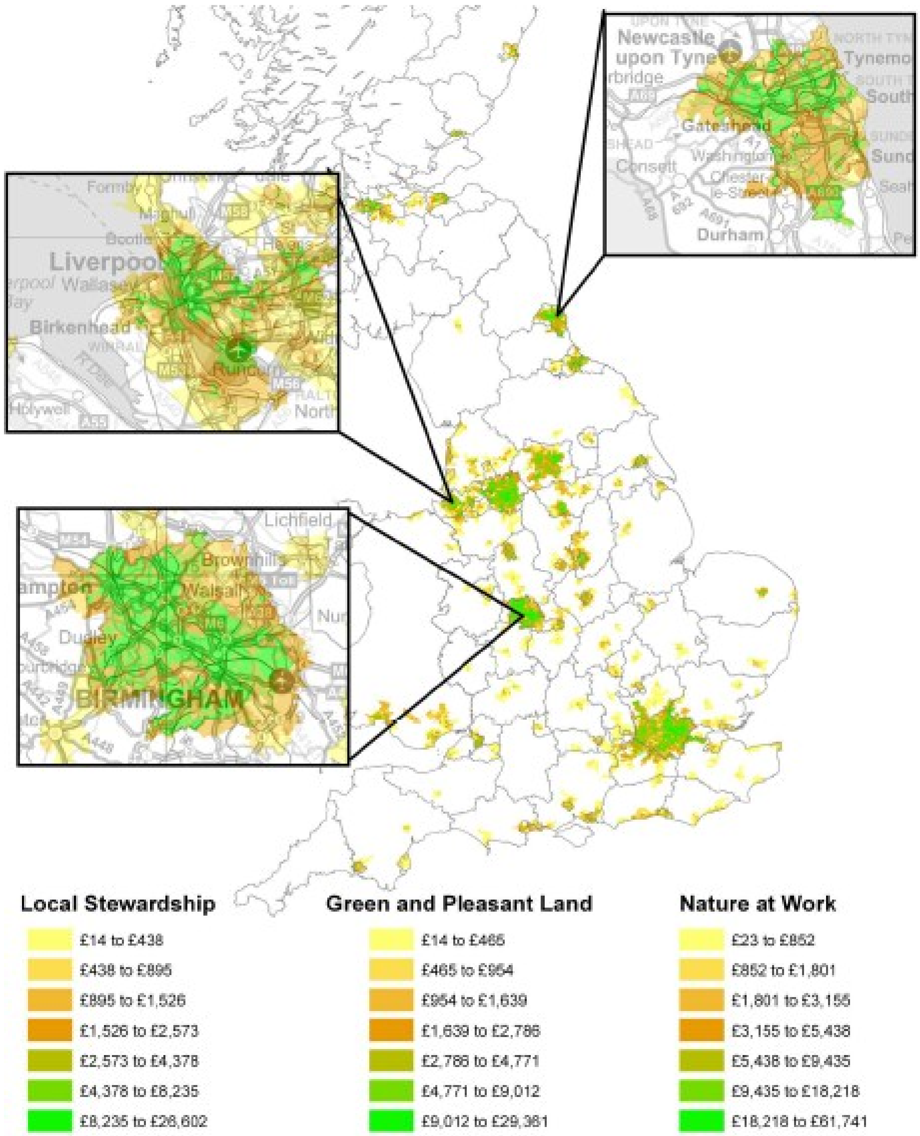
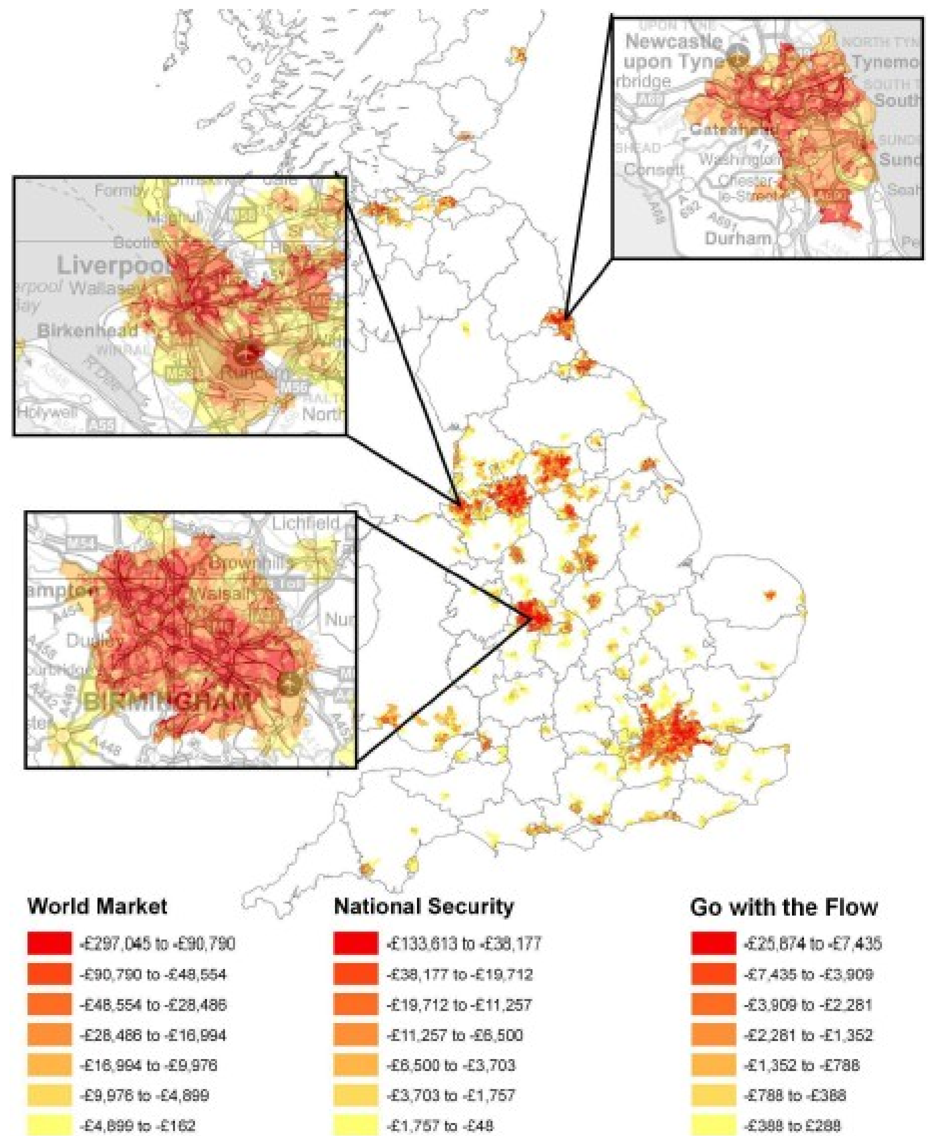
ESS trends in different scenarios in UK NEA





Evaluating green space availability in Finland

Logic: urban residents seek compensation in summerhouses

Basis:

- summerhouse ownership logit model including variables for living environment
- average expenditures allocated to summerhouse use or average travel expenditures for summerhouse travel

Results:

- Max. estimation: 74 mln.€
- Min. estimation: 20 mln. €
- Median value ~ 45 million euro/year
- This is an underestimation, e.g. it accounts only for summerhouse owners; if the valuation would be applied to the entire population, figures have to be multiplied by ~4
- In that case interval is 300 mln. ~ 80 mln.

Source: Perrels & Kangas, 2007; Perrels 2012 (HENVI lecture)

ENSURE / RECAST

- Urban sustainability and climate change resilience
- Implications of climate change induced changes in ESS for the value of real estate and urban prosperity (in Finland)
  - Hedonic pricing methods
  - (combined with) spatial correlation / spill-over effects
  - Urban simulation model(s)
- Investigate various green space solutions incl. green roofs
- Various weather / climate features can have both positive and negative effects
- Markets evolved; better risk information after 2000

Natural science – economics co-operation options in urban climate research

- Observation density / representation
- Spatial scales of natural and societal phenomena
- Impact propagation review – are we measuring the most relevant things from a societal / economic point of view?
- Observation & simulation system's investment appraisal
- Manmade feedbacks, e.g.
  - Anthropogenic emission sources
  - Anthropogenic intervention in natural processes
- Adding societal processes to scenario projections
- Urban planning; Environmental management
- Climate proofing of cities

Further reading / References

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Thank you

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