Minutes of the Third COST 715 Meeting of Working Group 2, Antwerp, Belgium, 12 April 2000

WG 2 participants:

Alexander Baklanov
Koen De Ridder
Joao Ferreira
Sylvain Joffre
Ari Karppinen
Patrice Mestayer
Douglas Middleton
Martin Piringer, chair
Maria Tombrou-Tzella
Roland Vogt

Invited experts:

Mathias W. Rotach
Sue Grimmond
Valery Masson
Tim Oke
Emmanuel Guilloteau
Alberto Martilli

1. MP opened the meeting and welcomed the participants and the invited experts.

2. The draft agenda was adopted without change and is given in Annex 1.

3. Status of WG 2: Since the last meeting in Copenhagen, Roland Vogt from the University of Basle has become a new WG member. The working group comprises now 10 delegates from 9 European countries.

4. The revised list of attendants including full addresses is given in Annex 2. Annex 3 summarizes the lines of activities of WG 2 already fixed at the Hamburg meeting on 15 and 16 February 1999.

5. The main event during the WG meeting was the expert meeting on the surface energy balance in urban areas. The programme and a summary by DM is given in Annex 4. The STSM report by Alberto Martilli was submitted to the MC and will appear as an annex to the MCM minutes of Prague.

6. Decisions:

   Expert meeting: The WG decided to collect extended abstracts of the contributions and to ask the MC to publish them as an official COST 715 document with an ISBN number.

Final report: MP was asked to outline a first draft of possible chapters of a final report to focus future activities of the WG and to fix responsibilities. The latest version (SJ improved it considerably and added also a draft outline of a potential COST 715 final report) including tentative responsibilities is given in Annex 5. The WG is in favour of conducting an STSM or an expert meeting probably in the first half of 2002 to work extensively on the WG 2 final report and the contribution to the overall COST 715 report.

Study contract: The version launched by MP at Copenhagen was accepted by the WG and submitted to the MC chairman and vice-chairman for discussion at the next MCM at Prague. The title of the proposal is "Validation of net radiation and sensible heat flux time series calculated by pre-processors with measured data at three sites in Austria".

Next workshop: The WG, encouraged by the results of the expert meeting, strongly supports the idea of having a workshop on mixing height determination in urban areas preferably in connection with a MCM in autumn 2001 or spring 2002.

Co-operation: WG 2 welcomes intensified co-operations among the working groups of COST 715, especially with WG 1.

7. A date and place of a next WG 2 meeting was not fixed. Because of budgetary reasons and to enable co-operation among WGs, WG 2 would ask the MC to organize future WG meetings of all groups together with MCMs and to conduct joint meetings, if requested.

Annex 1: Agenda

1. Welcome of participants
2. Adoption of minutes and agenda
3. Status of activities of WG 2
4. Presentations of external and internal experts
5. Outputs and recommendations from the scientific discussion
6. Workplan and timetable of future activities of WG 2
7. Date and place of next meeting
8. AOB

Annex 2: List and addresses of participants

Name	Institution and Address	Tel./Fax/e-Mail
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Annex 3: Lines of activities of WG 2

a) To review theoretical concepts of the structure of the urban boundary layer.

b) To review and assess pre-processors, schemes and models for determining the mixing height, the surface energy budget and the stability that are available to the participants. Cases of strong stability and/or windless conditions are of special interest.

c) To review theoretical models together with available field measurements and LES for calculation of the minimum friction velocity and the heat transfer coefficient. Conditions of shear free convection over high roughness are of main importance

d) To identify and review suitable data sets within and outside the group that could be used to test and validate the pre-processors and models.

e) To carry out intercomparisons and to summarise comparisons of different schemes against each other and against data under specific conditions.

f) To assess the influence of the model outputs of certain specific effects such as complex topography, strong heterogeneity, slope effects and canopy trapping on radiative fluxes.

g) To assess the suitability of remote sensing tools to estimate canopy characteristics and surface fluxes.

h) To provide recommendations for the improvement of existing pre-processors and models and for the development of new schemes.

i) To provide recommendations for planning and conducting field campaigns in order to fill the important existing gaps for empirical data of key parameters for urban air pollution.

j) To promote co-ordination of related activities in Europe of presently scattered works, objectives, and responsibilities.

Annex 4: Expert meeting

Program

10:00 - 10:30 Registration and welcome of experts by WG 2
10:30 - 11:00 **M. Rotach**: The siting, choice, and operation of surface instrumentation in urban areas
11:00 - 11:30 **C.S.B. Grimmond**: Heat fluxes in cities
11:30 - 12:00 **K. De Ridder**: Remote sensing of the surface energy balance
12:00 - 12:30 **V. Masson**: Numerical study of urban effects on the atmospheric boundary layer

12:30 - 14:00 Lunch break

14:00 - 14:30 **T. Oke**: Urban - rural differences in the surface energy balance
14:30 - 15:00 **D. Middleton**: Field measurements and modelling of surface fluxes in Birmingham, UK
15:00 - 15:30 **E. Guilloteau**: A new modelling of heat exchanges between urban soil and atmosphere
15:30 - 16:00 **A. Martilli**: A parameterization of heat and momentum fluxes in urban areas for mesoscale models
16:00 - 16:30 Discussion

Report by Douglas R. Middleton

Introduction

The meeting was arranged under COST 715 to bring together experts to present reports on current understanding and discuss future research needs.

Presentations

M W Rotach discussed 'The siting, choice, and operation of surface instrumentation in urban areas'. Siting is difficult and controversial: the pupose of the measurements must be considered. Research measurements have different requirements from routine observing. The urban area exhibits huge complexity and measurements must match their intended purpose. For routine observation, the station needs to be representative. He suggested layers as follows, from ground up: canopy (between elements), roughness sub-layer (individual elements have local effects), inertial sub-layer (flow is representative of a larger area of elements), with urban mixed layer above. Their heights are of order h, $z_* \sim$ 2-5 h, $0.1 \times z_i$, z_i, respectively. Deciding on a representative site and erecting a mast to reach into the inertial sub-layer is not trivial. The layer may vary in height; it may differ for heat/momentum. Some understanding of turbulence profiles come from wind tunnel, but what of urban heat flux? Comparisons of urban winds and airport winds (as presented to COST 715 WG1 in Roskilde last year) from different cities are useful. At WMO stations, 10m for wind or 1.5-2.0 m screen height for temperatures are normal, but what is required in routine urban measurements? Spatial inhomogeneity must be taken into account. In discussion, Tim Oke (talk below) said as rapporteur for WMO on routine urban measurement specifications, due to report 2002, he was particularly interested to hear of relevant European work. What should an urban (routine) station comprise?

<u>Sue Grimmond</u> spoke on 'Heat Fluxes in Cities'. She described their measurement campaigns in North American cities from Vancouver to Mexico City. Energy fluxes are important model inputs. They use tall towers, $>2\times h$, with careful attention to fetch. Sites are characterised by GIS using maps/photos/aerial photos/surveys of the area after Grimmond and Souch (1994). The area flux model of Schmid (1994) serves to identify the footprint of influence on a sensor on a mast. Their studies include dry and moist areas, and irrigated cities; fraction building cover 0.2-0.5, fraction hard surface up to 0.4. Results are plotted on local solar time; water flux (latent heat) proves very important for the heat island. Irrigated cities in dry areas (Arizona) can be reversed vis a vis surroundings due to irrigation and extra vegetation. Measured Bowen ratio (ratio of latent and sensible fluxes) is used to compare cities. Variables include Q^* (net radiometer), Q_H (sonic), Q_E (krypton hygrometer), and heat storage term ΔQ_S from Q^*-Q_H-Q_E. Roughness terms zd and z0 via morphometric (geometric) methods, via plan area or frontal area indices; Raupach is preferred, see Grimmond and Oke (1999). Using these with kinematic heat flux they measure L, and plot z/L using measurement height z for different times of day (in local solar time). Heat storage term Q_S shows hysteresis in morning and evening; it may reach 100-250 W m^{-2}. Their objective hysteresis model of Grimmond and Oke (1999) describes this using independently derived parameters. Incoming solar radiation Q^* is a very important parameter and should be routinely measured, especially in cities. The extension of Priestley and Taylor model by De Bruin and Holtslag (1982) allows α to vary and $\beta \approx 20$ W m^{-2}. Radiation will be important for Q_E, Q_H, and Q_S.

<u>Koen De Ridder</u> described 'Remote Sensing of the Urban Surface Energy Balance', describing satellite methods and the additional local variables that are needed. Surface radiation temperature T_s can be measured from space; local air temperature T_a is also needed however. The net radiation R_N can be estimated and ground flux approximates 0.1 to 0.4 times R_N. Satellite measurements have a number of limitations to be considered, including

area of view, spatial resolution, return time between passes, and angle of view. Soil moisture can be derived by microwave measurements.

Valery Masson presented his model for 'Numerical study of Urban Effects on the Atmospheric Boundary Layer', being a summary of Masson (2000). The local energy terms in the urban area are modelled by TEB in considerable (if randomly arranged) detail: canyons serve as solar radiation traps absorbing up to ≈70 W m^{-2} from Q* with multiple reflections after Johnson and Oke (1981). The wind profile was logarithmic to roof level; exponential below. Data are from St Jacques tower, 40m tall, in Paris. Radiosondes from Trappes also used. The model also simulates heat transfer through the walls and roofs of buildings. His model creates a slightly neutral layer and stable above over the city on summer nights. He simulated the heat island with/without city; with/without orography. TEB is run within a mesoscale model MESO-NH; heat island and local changes to vertical profiles are modelled. Convergence at low level develops in the daytime.

Tim Oke reported on 'Urban-rural Differences in the Surface Energy Balance'. He described changes to the radiation budget with similar emissivity but aerosols in city air account for 10-15 W m^{-2}. Changes in fuel consumption are considered by Grimmond (1998). Urban-rural differences were reported by Cleugh and Oke (1986) and are summarised in Tim Oke's text book 'Boundary Layer Climates'. In line with Grimmond's presentation, Q* by radiometry; Q_H and Q_E by eddy correlation; Q_G via flux plate (rural) or difference ΔQ_S (city). A tower should reach above the top of the roughness sub-layer, in agreement with Rotach's talk. They used towers 26 to 29 metres. Urban-rural differences from a range of cities (cf Grimmond's talk) were consistent with published views, but the importance of latent heat flux according to local use of water is very important. Urban evaporation processes (including irrigation as in Tucson Arizona) can be large enough to materially alter the normal pattern which is a larger sensible heat flux in city by day and sustained flux into the night. Urban evaporation processes are discussed by Roth and Oke (1995); surfaces are not homogeneous, water vapour sources need not match or cover all urban sensible heat sources, and water can evaporate into cooler but drier descending air. Errors in modelling fluxes may arise unless account is made for the fact that the eddy diffusivities (averaged over an urban area) are not equal, i.e. $K_E \neq K_H$. Irrigation can change the Bowen ratio from say 1.1 to 2.7, as in Vancouver when there was an irrigation ban imposed. In considering urban and rural differences, take note of the character of the rural surroundings as much as the urban area … perhaps vegetated surroundings may diverge more from one another than do cities?

Doug Middleton in collaboration with Nicola Ellis (unable to attend) presented results from 'Field Measurements and Modelling of Surface Fluxes in Birmingham, UK'. The reasons behind interest in diagnosing the correct timing and sign of stability in urban areas was mentioned with regard to notable air pollution episodes (Wilkins, 1954; QUARG (1993), and the needs for air pollution modelling. Early work to parametrise Tim Oke's urban-rural differences for Q_H via the integral of Q* was described. This is used routinely in Boxurb for air quality forecasts, Middleton (1998). The urban measurements were then described, showing the Birmingham site. Synoptic data show the January/February 1999 data were largely neutral, with regular rain observed in the first two weeks. The SEB model by Best (1999) was used to analyse the results; the radiation model works well, given a good cloud observation. The surface temperature has significant impact on the heat flux calculated near the ground, and some difficulty arises in this part of the modelling. In this type of comparison it is important to have the sensors and model calculations at comparable heights. The problem of what to do when 1/L takes a default value was also discussed. Actions arising include: a sensitivity study of how the model behaves under different forcing, a test of model soil initialisation using an input or first measurement of deep soil temperature, role of leaf area index when modelling a 'concrete canopy', and exploration of coupling between soil surface and the canopy using other terms in addition to long wave radiation (Best having simplified Deardorff's work). There is also a need to try turbulence processing in line with the ideas of Mathias Rotach. He is attempting to match data from wind tunnels and urban studies.

Emmanuel Guilloteau gave 'A New Modelling of Heat Exchanges between Urban Soil and Atmosphere'. Using the French SUBMESO model which has a Force-Restore model of rural soil (Noilhan and Planton, 1989), he modelled urban soil-atmosphere interactions. The water parameters were modelled in considerable detail. Many different soil types are represented. The first simulations, without canopy parameterisations, demonstrate the need to model the influence of the canopy vertical surfaces through radiative trapping and sensible heat storage.

Alberto Martilli in collaboration with Clappier and Rotach gave 'A Parameterization of Heat and Momentum Fluxes in Urban Areas for Mesoscale Models'. Such fluxes are crucial for mesoscale models. Momentum exchange uses two roughness lengths, for canyon roofs and floors; a drag force approach applies at their walls. Energy budget is solved for differences between surface temperatures and air temperature. Radiative fluxes include multiple reflections within canyons. The result is a mesoscale model modified for urban effects.

Discussions

With regard to the drafting of a COST 715 WG2 report it was decided that:

1. There is a need for data sets on urban mixing heights.
2. The draft could consider measurements of surface fluxes over urban areas. It can cover mixing heights (simple schemes/measurement methods), urban meteorological stations (with input to WMO specification as mentioned by Tim Oke), fluxes and stability, with simple parameterization schemes. Appendices could list data sets, and urban meteorological pre-processors. A list of references should be included.
3. The draft will need to be integrated with other COST715 WG reports.

Conclusions

1. A number of European groups run mesoscale models with sub-models of fluxes for urban areas.
2. The influence of the urban canopy, building energy flows and thermal properties along with effective albedo reduction by radiative trapping between canyon walls may be important and should be modelled.
3. Water flux is a very important determinant of city heat island effects; the surrounding countryside must also be considered as it differs significantly from the remote ‘rural’ areas.
4. The behaviour of turbulent flux profiles in the thick roughness sub-layer due to high roughness elements requires more study, both in the field and with models.
5. Urban meteorological masts should go above the roughness sub-layer into the inertial sub-layer and above. The heights of these layers vary with conditions and fetch (2 to 5 times the building height).
6. Horizontal inhomogeneity of the canopy means diffusivities differ, $K_E \neq K_H$, since water transfers are surface processes while heat transfers are mediated by the canopy's own thermodynamics.
7. Sites should be characterised with the help of aerial photos, local surveys, maps, building dimensions, GIS, and urban data bases.
8. Satellites can measure some aspects of the urban environment, but are incomplete on their own and require skilled interpretation.

Annex 5

FINAL REPORT COST-715

COST-715 WG 2
Draft outline of structure of final report

Executive summary
List of figures
List of tables
List of acronyms and symbols
1. Introduction
2. Review of theoretical concepts of the structure of the urban boundary layer (PM)
3. Review and assessment of pre-processors, schemes and models for the surface energy budget (SJ, PM, AK)
    - 3.1 The surface energy budget
        - 3.1.1 Surface radiation budget
        - 3.1.2 Surface sensible flux
        - 3.1.3 Surface latent heat flux
        - 3.1.4 Storage term
        - 3.1.5 Anthropogenic flux
    - 3.2 Surface temperature
    - 3.3 Temperature roughness
    - 3.4 Input data requirement
4. Review and assessment of pre-processors, schemes and models for determining the mixing height (AB, SJ, MP, AK)
    - 4.1 Methods based on radiosoundings
    - 4.2 Methods based on parametrisation schemes
    - 4.3 Methods based on NWP model outputs
    - 4.4 Input data requirement
5. Review and assessment of available empirical data (AB, AK, MP)
    - 5.1 The urban surface energy budget and its components (RV)
    - 5.2 The mixing height
    - 5.3 Required ancillary data
6. Results of intercomparisons of different schemes against each other and against data (AB)
    - 6.1 The surface heat flux (SJ)
    - 6.2 The mixing height (MP)
7. Influence of specific disturbances on model outputs
    - 7.1 Effect of strong heterogeneity on radiative fluxes
    - 7.2 Effect of internal boundary layer development on the mixing height
    - 7.3 Effect of complex terrain features
8. Assessing the suitability of remote sensing tools to estimate canopy characteristics and surface fluxes (KR, RV)
9. Recommendations and needs (SJ, PM, AK)
    - 9.1 Improvement of existing pre-processors, schemes and models for the surface energy budget
    - 9.2 Improvement of existing pre-processors, schemes and models for the mixing height
    - 9.3 Outlook for development of new schemes
    - 9.4 Improvement of input data availability and quality for research and model validation
    - 9.5 Monitoring strategy for required parameters
    - 9.6 Need and planning of future field campaigns (RV)

List of references

Appendices:
- A1 Short description of pre-processors and models referred in this report
- A2 Documentation on data sets suitable for testing and validating pre-processors and models