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Back cover: Cooling summer feelings in Rome

EDITORIAL

Dear EURASAP members,

In 2006 EURASAP has supported participation of young scientists in the ICUC6 in Göteborg, Sweden. Learn more about the meeting from "Past events".

Alberto Martilli has presented there a very well organised plenary talk on the urban aspects in mesoscale modelling. He was kind to share parts of it with the EURASAP community.

The Newsletter Editor

Scientists' Contributions

CURRENT RESEARCH AND FUTURE CHALLENGES IN URBAN MESOSCALE MODELLING

Alberto Martilli, CIEMAT, Spain

INTRODUCTION

The first mesoscale modeling studies date back to the seventies. Among these it is worth to mention the work of Bornstein (1975) that built his 2-D vorticity model URBMET to investigate the impact of urban heat island on wind field and boundary layer structure. However, it is only in the mid nineties that the interest in urban mesoscale started to increase very rapidly, as it can be seen from the number of publications on this subject in scientific journals (Fig. 1)

The reasons behind such increase of interest can be found in the interactions between several factors, as it is sketched in Fig. 2.

- First of all, the continuous increase of the urban population. In 1800, only 3 % of the world's population lived in urban areas. By 1900, almost 14 % were urbanites, and in 1950, 30 % of the world's population resided in urban centers. Nowadays about half of the world population lives in cities, and it is forecast that in 25 years from now, 75% of the world population will live in cities. Moreover, the size of the cities is also increasing. Just eight cities had populations of 5 million (megacities) or more in 1950. Megacities numbered 41 in 2000. By 2015, 59 megacities will exist, 48 in less developed countries. Such fast and very often chaotic growth entrained a number of environmental problems. The 'social' pressure to find tools to understand and manage such problems increased parallel to the increase of urban areas.

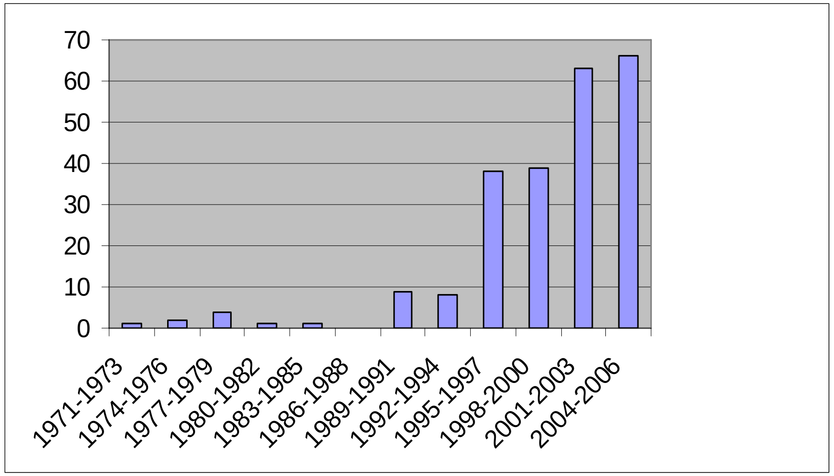

Figure 1. Number of publications on urban mesoscale from 1971 until now.

- Another very important factor that explains the popularity of urban mesoscale modeling studies in the last decade, was the increase in CPU power. The possibility to use fast and powerful computers modified the way people used models and the nature of the models themselves. People started to use larger domains, new and more sophisticated numerical and physical schemes, etc.
- The combination of the two factors mentioned above was the main motivation for a change in the use of the models. From research tools, used to investigate physical processes, they became tools that can be used for practical applications. For example, improve a weather forecast, evaluate an air pollution abatement strategy, or evaluate a countermeasure to reduce urban heat island. This was possible because with the new powerful computers we could apply models to real domains.
- This new way to use the models and the increase in confidence in their power had a consequence: the requirements to the models in terms of quality of the results became more and more stringent. Researchers started to look more and more carefully to model results, and outlined a series of deficiencies, mainly linked, in urban areas, with the difficulties to represent accurately the complexity of the urban surfaces.

- The model's deficiencies emerged in the previous point were the motivation for a series of new field campaigns in urban areas, aimed to improve our understanding of the behavior of the urban atmosphere.

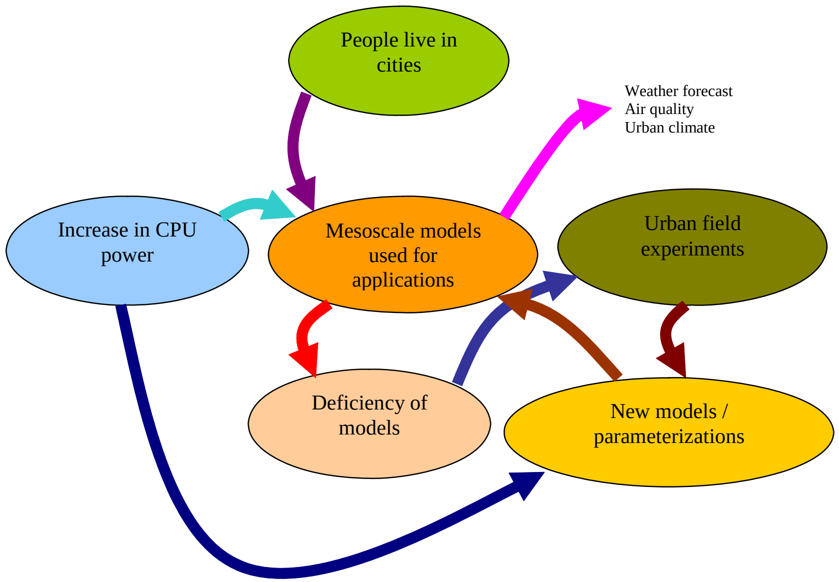

Figure 2. Scheme of the relations between the key factors behind the increase of interest on urban mesoscale modeling.

- The results of these experimental campaigns set the ground for the development of new models and parameterizations to represent urban areas. This, in turn, increased the performances of the mesoscale models, and increased the confidence in their results. The whole cycle described in the last four points above continued with a positive feed-back. Finally it must be mentioned that the increase of CPU power was a crucial point also in determining the nature of the urban parameterizations. The urban parameterizations that we use today, were impossible to be used ten years ago, because too sophisticated and expensive in CPU, and, likely, they will be obsolete in ten years from now.

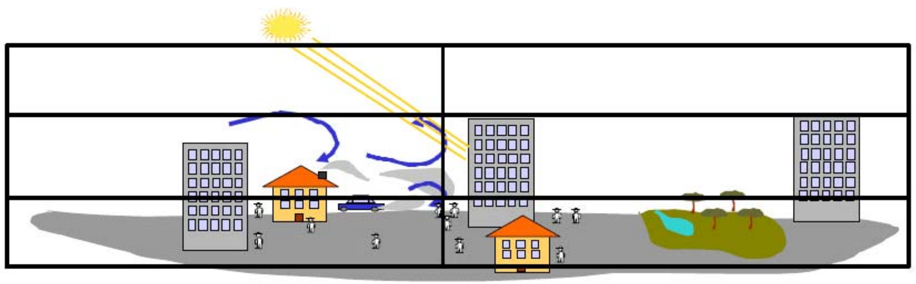

Figure 3. Urban heterogeneities and mesoscale resolution.

The main reason behind the difficulty in simulating the urban boundary layer lies in the complexity of the urban surfaces. A city, in fact, is a combination of urban elements as buildings, streets, gardens, etc. of a typical size of few tenths of meters or less. Each urban element has different dynamical and thermal properties. The presence of such urban elements generates atmospheric structures (both turbulent and not) at the same spatial scale of the urban heterogeneities. On the other hand, a mesoscale model needs a domain of several tenths of kilometers of horizontal extension in order to simulate mesoscale circulations. This limits, for computational reasons, the horizontal resolution to one kilometer or several hundreds of meters, at most. The urban heterogeneities, then, cannot be explicitly resolved with a mesoscale model (Fig. 3).

The question is: how to model the effects of the atmospheric features induced by the urban heterogeneities on the grid averaged variables computed by a mesoscale model? The best (and only) way is to parameterize such effects. The nature of this parameterization depends on the aim of the simulations (the degree of precision/sophistication we want), and the amount of CPU that we want to spend in this part of the modeling. In the following section a short review of the most common approaches proposed in the literature is presented (Fig. 4).

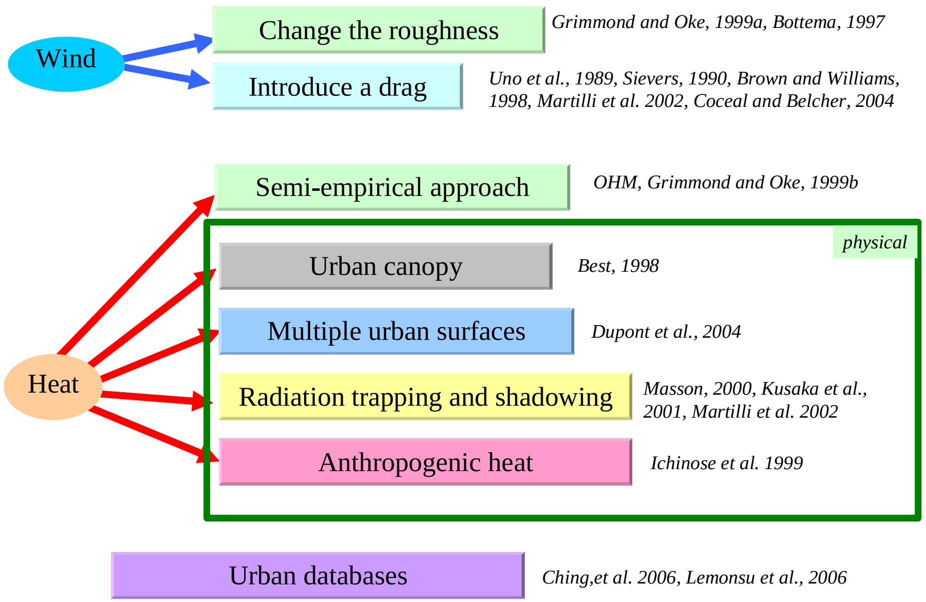

Figure 4. Different approaches to account for urban surfaces in mesoscale models.

CURRENT RESEARCH.

The presence of a city affects momentum (wind), and heat exchanges between the surfaces and the atmosphere. Historically the approaches proposed focus more on one or another of these two phenomena. Let analyze first the approaches proposed to simulate the impact on the wind, and then those proposed for the heat.

Wind

Change in roughness

The first approach proposed is to estimate the surface momentum flux using the classical Monin-Obukhov Similarity theory, with a roughness length z_0 adequate to the urban surfaces. Several approaches have been proposed to estimate such roughness length as function of the urban morphology, as it can be seen in the review by Grimmond and Oke (1999a). The main advantage of this approach is that it does not require big changes in the code, and it is not computationally expensive. On the other hand, it does not resolve any feature in the urban canopy and the Urban Roughness Sublayer. In such layer, in fact, the assumptions that the turbulent fluxes are constant with height, base of the MOST, is not fulfilled (Rotach, 1993). This approach can be used if the lowest model level is significantly deeper than the urban canopy, with the center of the grid cell within the inertial sublayer. Such characteristics make this approach good in particular for weather forecast models, since they are not very interested in the processes in the urban Roughness Sublayer, and they have strong CPU time constraints.

Drag force

Another approach that is becoming more and more popular in the last decade is to use a very high vertical resolution with several layers within the urban canopy. In such layers, a sink term is introduced in the momentum equation to represent the drag induced by the buildings. This drag term is proportional to the square of the mean velocity, and building density (Uno et al., 1989, Sievers, 1990, Brown and Williams, 1998, Martilli et al. 2002, Coceal and Belcher, 2004). This approach is similar to the one used in vegetation canopy modeling. Its main advantage is that it allows resolving some features of the urban canopy layer and the Urban Roughness Sublayer. The main disadvantage is that the high vertical resolution near the ground increases the CPU time. Such approach is in general used for air quality or climate studies, where it is crucial to have information on the atmospheric structure in the urban canopy (a very sensitive region for these studies, since it is where emissions are located and people live).

Heat

There are two groups of techniques. In the first (called semi-empirical), a relation is found between the storage and the net radiation, without attempting to solve the physics of the phenomena. In the second group below, instead, an attempt is made to resolve part of the physics of the problem.

Semi-empirical

A simple approach to estimate the storage of energy in the urban surfaces has been proposed by Grimmond and Oke (1999b). Such approach is based on the assumption that the energy stored in a material is a function of the net radiation, and its time derivative:

$$\Delta Q_s = \sum_{i=1,n} \left(a_{1i} R + a_{2i} \frac{\partial R}{\partial t} + a_{3i} \right)$$

The sum is done over the *n* urban surfaces, and the constants a_1, a_2, a_3 depend on the different materials and are derived experimentally. This technique, very cheap in CPU time, has been introduced by Taha (1999) in a mesoscale model, with good results.

Physical

A physical approach has been proposed by Best (1998), to account for the urban canopy. An intermediate layer is introduced to represent the canopy (Fig 5). Such layer exchanges radiation with the underlying surface, and exchanges heat with the atmosphere. It is a simple and not CPU expensive approach, useful for weather forecast models. It has been implemented in the UK forecast model, showing an improvement in temperature forecast.

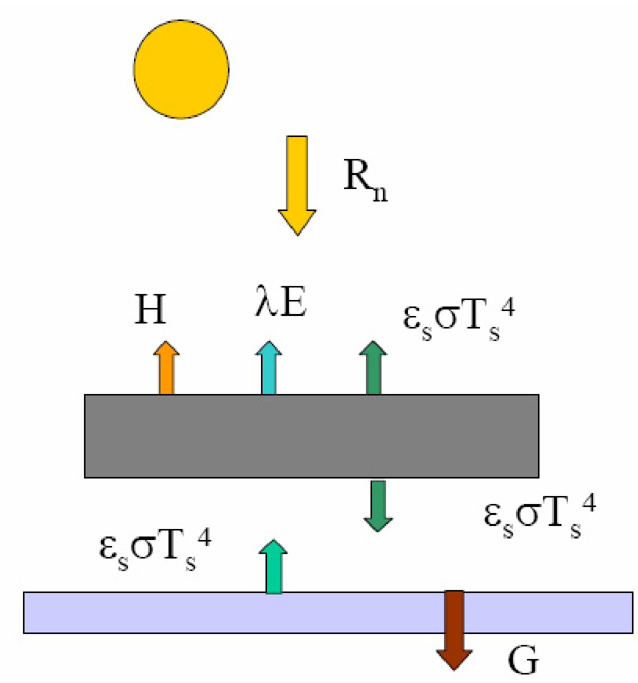

Figure 5. Representation of the Best (1998) approach.

Another physical approach has been proposed by Dupont et al. (2004, called SM2-U). This scheme aims to account for the different thermal and radiative properties of the urban surfaces (paved surfaces, natural surfaces, vegetated surfaces, roofs, canyons, etc.). It has been implemented in the French model Sub-MESO, and, in the Drag force form, in MM5, with good results.

The shadowing and radiation trapping effects in the urban canyons are also an important phenomena for the energy budget in urban areas. They reduce the total albedo, and the nocturnal radiation loss, acting to increase the Urban Heat Island (Fig. 6). With different degrees of details, three schemes have been proposed to account for these phenomenon (Masson (2000), Kusaka et al. (2001) and Martilli et al. (2002)).

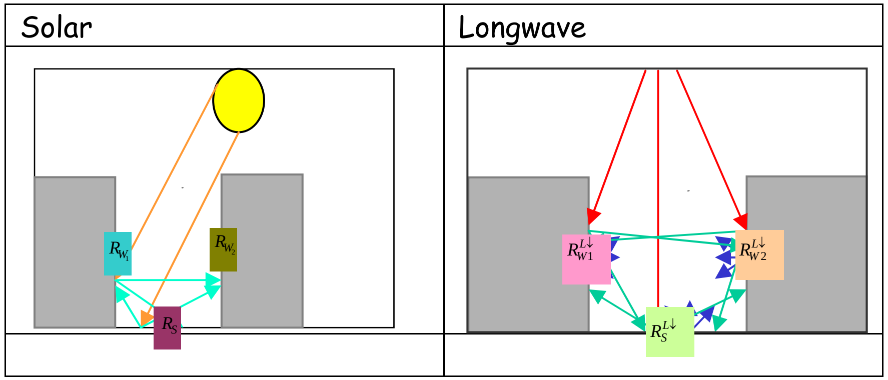

Figure 6. Trapping of solar and longwave radiation in the street canyon.

Another important factor in the determination of the sensible heat fluxes in urban areas is given by the anthropogenic heat sources. This can be determined from data about energy consumption. An example is given by the work of Ichinose et al. (1999). They found that for Tokyo, in limited areas, the anthropogenic heat flux can be of several hundreds of W m^{-2}, of the same order of maximum magnitude of the radiation fluxes. The anthropogenic heat flux, usually, does not enter in the surface energy balance, but it is injected directly in the atmosphere.

Urban data

The parameterizations mentioned above, need detailed information about the urban structure (morphology, materials, etc.), that are usually difficult to find. Several projects have been started in the last years in order to obtain these detailed data for urban areas. Among these projects, the most important are the one started by Ching et al. (2006) of the US EPA, and Lemonsu et al. (2006) at Environment Canada.

FUTURE CHALLENGES

The research in the next years in the field of urban mesoscale modeling will be driven by similar mechanisms as explained above. The challenge will be how to use the increased CPU power, and the better knowledge of the atmospheric behavior in urban areas obtained from the analysis of field campaign data, in order to improve model performances to be able to answer to the new problems linked with the increase of the urban population (Fig. 7). Moreover, it will be important also to investigate how much complexity it is necessary to model in order to have a satisfactory representation of urban areas (or, in other words, which are the most important urban parameters that define a city).

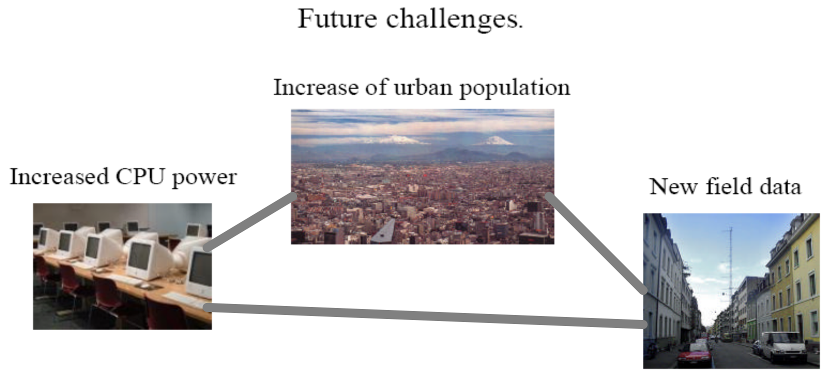

Figure 7. Interactions between CPU, Increase of urban population and field experiments.

In the following sections, a short description of the activities that will have a strong development in the future years is presented.

Link Mesoscale-CFD (RANS or LES).

CFD–RANS or LES models can run with a very high resolution, explicitly resolving buildings, but over a small domain (few city blocks, Fig. 8). Some research activities are starting with the aim to link such models with mesoscale models. Two approaches are proposed:

- Make a full coupling between CFD and mesoscale, initially one way (e. g. Mesoscale model gives the Boundary Conditions to the CFD model), but in the future also 2-way (Coirier et al. 2006). This approach will ensure the possibility to explicitly resolve the full complexity of a city. On the other hand, the limitations in CPU power, allowed, up to now, only small domains (1-2 km^2 size) for the CFD. Moreover, this approach will have to face the problem of a ratio of nearly two orders of magnitude between the resolution of the mesoscale model resolution and the CFD resolution.
- Use the CFD model as a tool to derive/test/improve urban parameterizations (Martilli and Santiago, 2006). This technique consists in performing a series of simulations over different urban configuration, and investigates the behavior of the spatially averaged results. From them, the turbulent and dispersive fluxes and the building drag can be deduced. Such variables must be then put in relation with some urban morphological parameters, in order to find general laws (and this is the most difficult part of the approach).

On the other hand the advantage is that the improved parameterizations derived with this method can be applied for the whole city with little CPU cost.

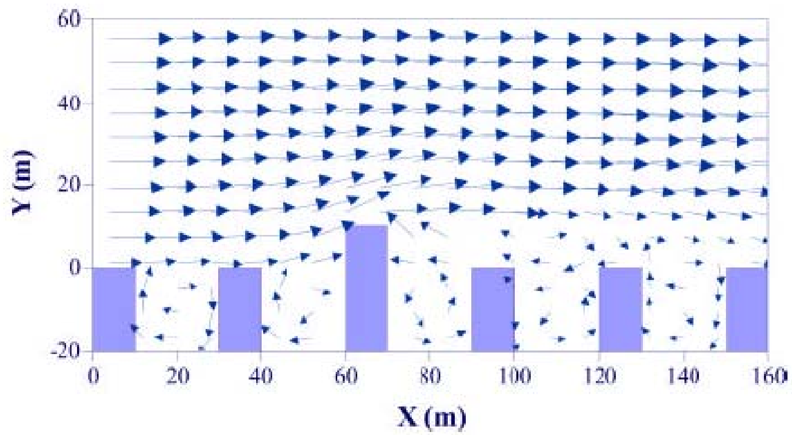

Figure 8. Example of CFD results over an array of buildings.

Better determination of anthropogenic heat fluxes

Work must be done in order to improve the estimation of anthropogenic heat fluxes. The future improvements will be based on better information about energy consumptions, but also on field measurements as those carried out, for example, in the CAPITUL experiment over the city of Toulouse (Pigeon et al. 2006).

Account for Building Energy

Linked with the previous point is the introduction of sub-modules to account for the sources and sinks of energy in the buildings and the mechanisms to exchange such energy with the exterior. For example, a pioneering approach has been proposed by Kikegawa et al. 2003, where a BEM (Building Energy Model) has been proposed, that accounts for heat generation due to equipments, and building occupants, solar radiation through windows, ventilation, heat conduction through walls and roofs, air conditioning (Fig. 9). This type of models can be implemented in urban parameterization. The main advantage, a part an improvement in the estimation of the sensible heat flux exchanged with the atmosphere, is in the possibility to estimate the impact on energy consumption due to an urban heat island mitigation strategy.

Feedbacks between the urban system and the environment

The urban climate - air quality - human response system is complex, replete with feedback mechanisms that are poorly understood. Mesoscale models can help to clarify the complex interactions between a change in the urban infrastructure, urban climate, air pollution and changes in human activities. With this aim, mesoscale models will need to be adapted to account, for example, for a variation in urban infrastructure, and also give in output the relevant variables that affect the human activities. A project oriented in this sense, is the one

carried out by Prof. Sailor (http://www.fuse.pdx.edu/index.htm).

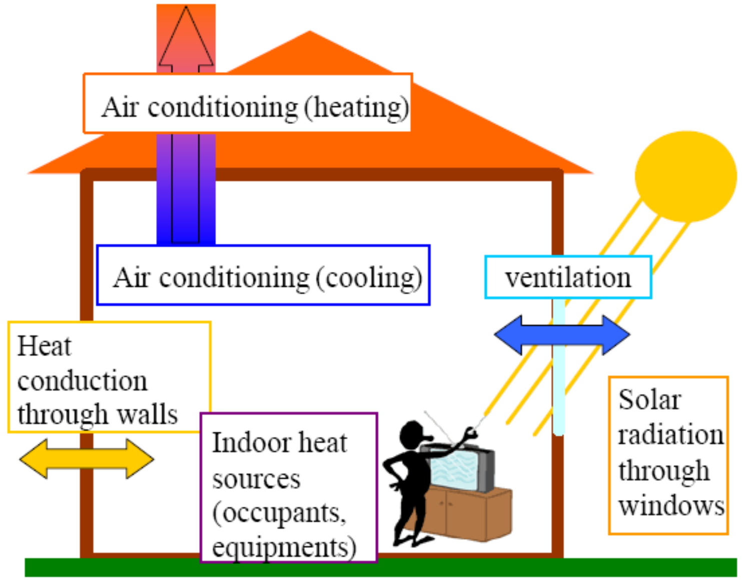

Figure 9. Scheme of the energy generation mechanisms in buildings and the exchanges with the exterior.

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Past Events

ICUC-6

The Sixth International Conference on Urban Climate (ICUC-6) was held in Göteborg Sweden, June 12-16 2006.

The Newsletter 18 of the International Association of Urban Climate (IAUC) is dedicated to the ICUC6. It is available from http://www.urban-climate.org/. The review is written by *Gerald Mills*, the IAUC Newsletter Editor.

"During these five days in June over 200 papers and over 90 posters were presented. A total of 338 registered for the event drawn from many countries. As at ICUC-5 in Lödz, the extraordinary participation of delegates from Japan was noticeable. Almost twice as many attended from Japan as from the host country, Sweden. This is a measure of the strength of urban climatology in Japan and their commitment to developing the field..."

The Papers and Posters were spread by subject area as follows:

- Turbulent exchange between the urban surface and its boundary, 7;
- Interactions between urban climate and emissions, 11;
- Observations of the urban surface energy balance and transfer coefficients, 6;
- Anthropogenic heat, 6;
- Air quality modeling, 6;
- Carbon exchanges in urban areas, 4;
- Urban human biometeorology, 13;
- Urban effects on mesoscale climate, 8;
- Turbulence within and above the urban surface layer, 6;
- Topoclimatology, 3;
- Flow & dispersion within street canyons, 7;
- Climatic performance of urban greenspace, 12;
- Novel radiative, thermal and air quality modeling, 7;
- Urban heat islands: nature, genesis and mitigation, 28;
- Modelling flow from the building scale to mesoscale, 5;
- Modelling the urban surface energy balance, 5;
-

- Urban sub-layer parameterizations in meteorological and climate models, 16;
- FUMAPEX, 4;
- Climate-sensitive urban design and planning, 15;
- Building climates and the climatic performance of built features, 6;
- Cities and global change, 4;
- Remote sensing of cities and urban climate, 8;
- Road climatology and paved surfaces, 5;
- Urban imacts on moisture, 8;
- Sessions in honour of T.R. Oke, 4.

There is a WMO's Expert Team closely connected to IAUC that focuses on Urban and Building Climatology, led by Sue Grimmond. Some of the planned actions of this group include:

- Updating the WMO Technical Notes 149 and 150 on Applications of Building Climatology and Urban Climatology and Urban Design, both originally written in 1976, under the leadership of Drs John Page and Gerald Mills;
- Initiation of a project to inter-compare urban models;
- Development of a web based urban climate bibliography which is a collaborative venture with the IAUC with the scientific community actively participating.

For details, please, read the IAUC Newsletter at http://www.urban-climate.org/.

Future events

Previously announced

CONFERENCE ON CLİMATE CHANGE AND THE MİDDLE EAST
20 - 23 november 2006, Suleyman Demirel conference hall, Istanbul Technical University, Istanbul, Turkey

http://www.climatechange_middleeast.itu.edu.tr

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GKSS SUMMER SCHOOL - "PERSISTENT POLLUTION: PAST, PRESENT AND FUTURE"
9–18 May 2007, Hunting castle Göhrde near Lüneburg, Germany

http://coast.gkss.de/events/5thschool/

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New announcements

AIR4EU FINAL CONFERENCE
Friday 10th November 2006, Prague

The Air4EU project, supported by the EU 6th Framework Programme, is developing solutions for a more efficient air quality assessment on the urban, regional and European scale. Since spring 2004 a close co-operation with stakeholders who are active in air quality assessment has been facilitated.

Information about the Air4EU project at www.air4eu.nl

Contact: Hermann Heich, email: heich@heich-consult.de

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ICAM 2007 - INTERN. CONFERENCE ON ALPINE METEOROLOGY
France, Chambery, 4-8 June 2007

Information at: http:// www.cnrm.meteo.fr ,
http:// www.cnrm.meteo.fr/ICAM2007

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FRAMING LAND USE DYNAMICS II
18-20 April 2007, Utrecht University, The Netherlands

In April 2003, the Framing Land Use Dynamics conference was held at Utrecht University, the Netherlands. It was considered an interesting and inspiring event, so the follow up conference, entitled Framing Land Use Dynamics II (FLUD-II) is organised on April 18-20 2007 by the Faculty of Geosciences of the University of Utrecht and the Environmental Assessment Agency (MNP).

For more information go to: www.geo.uu.nl/flud2007

The organising committee: Elisabeth Addink, Aat Barendregt, Dick Ettema, Derek Karssenberg and Ton de Nijs

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FIFTH INTERNATIONAL CONFERENCE "AIR'2007" QUALITY OF ENVIRONMENT,
St. Peterburg, June 507, 2007

The Conference is held by the Russian Association "Air Environment" (AE) and the International Society of the Built Environment (ISBE).

Contact: Prof. N. Z. Bitkolov, President of AE
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EUROPEAN ASSOCIATION FOR THE SCIENCE OF AIR POLLUTION

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